JOINT INSTITUTE FOR NUCLEAR RESEARCH

TOPICAL PLAN
FOR JINR RESEARCH
AND INTERNATIONAL COOPERATION
2026

Dubna 2025

All the Themes or Activities in the Plan are listed by fields of research. Each Theme or Activity is coded according to the JINR system of classification and contains the following information:

the first number*	-	the field of research;
the second number **	-	the conventional number of laboratory;
the third number	-	the theme's or activity's ordinal number;
the fourth and the fifth numbers	-	the years of the theme's or activity's beginning and completion.

All the Projects (Subprojects) in the Plan are listed by Themes. Each Projects (Subproject) is coded according to the JINR system of classification and contains the following information:

the first number*	-	the field of research;
the second number **	-	the conventional number of laboratory;
the third number	-	the theme's ordinal number;
the fourth number	-	the project's (subroject's) ordinal number;
the fifth and the sixth numbers	-	the years of the project's (subroject's) beginning and completion.

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- 01 - Theoretical Physics
- 02 - Elementary Particle Physics and High-Enegry Heavy-Ion Physics
- 03 - Nuclear Physics
- 04 - Condensed Matter Physics
- 05 - Radiation Research in Life Sciences
- 06 - Information Technology
- 07 - Applied Innovation Activities
- 08 - Physics and Technology of Charged Particle Accelerators
- 09 - Organization of Scientific Activity and International Cooperation. Strengthening Human Resources. Educational Programme

**
- 0 - All-Institute topics
- 1 - VBLHEP
  Veksler and Baldin Laboratory of High Energy Physics
- 2 - DLNP
  Dzhelepov Laboratory of Nuclear Problems
- 3 - BLTP
  Bogoliubov Laboratory of Theoretical Physics
- 4 - FLNP
  Frank Laboratory of Neutron Physics
- 5 - FLNR
  Flerov Laboratory of Nuclear Reactions
- 6 - MLIT
  Meshcheryakov Laboratory of Information Technologies
- 7 - LRB
  Laboratory of Radiation Biology
- 8 - DSOA
  Department of Science Organization Activities
- 9 - UC
  University Centre

Prepared by
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D.S. Korobov
Ya.L. Martovskaya

Dubna 2025

Contents

List of projects and subprojects of the JINR Topical Plan for 2026

JINR Large Research Infrastructure

02-1-1065-2007/2026

NICA Complex
Design and Construction of the Complex of Accelerators, Collider and Physics Experimental Facilities at Extracted and Colliding Ion Beams Aimed at Studying Dense Baryonic Matter and the Spin Structure of Nucleons and Light Ions, and at Carrying out Applied and Innovation Projects

Leaders: V.D. Kekelidze
A.S. Sorin
G.V. Trubnikov

Deputies: A.V. Butenko
V.M. Golovatyuk
M.N. Kapishin

Participating countries and international organizations:
Armenia, Azerbaijan, Belarus, Bulgaria, Chile, China, Cuba, Egypt, Georgia, Germany, Japan, Kazakhstan, Mexico, Moldova, Mongolia, Russia, Serbia, Slovakia, Uzbekistan, South Africa.

The problem under study and the main purpose of the research:
Search and investigation of phase transitions in strongly interacting nuclear matter at extremely high baryon densities, study of the nucleon spin structure, of light nuclei and polarization phenomena in few nucleon systems. Development of theoretical models of the studied processes and theoretical support of the experiments. Development of the Nuclotron accelerator complex as a basic facility for studying relativistic nuclear collisions in the range of atomic masses A = 1÷197. Investigation of reaction dynamics and studing modifications of hadron properties in nuclear matter, near-threshold strange hyperons production and search for hyper nuclei in interactions of the Nuclotron extracted ion beams with fixed targets at the BM@N detector. Development and stage-by-stage creation of the NICA heavy ion collider accelerator complex, the multi-purpose detector (MPD/NICA) and spin physics detector (SPD/NICA) for experiments with colliding heavy ions beams. Modernization of extraction beam lines and Nuclotron magnetic system. Carrying out of experiments with ion beams and polarized proton and deuteron beams at the Nuclotron. Development of the infrastructure for applied research at NICA heavy ion beams.

Projects of the infrastructure:

	Name of the projects	Project leaders	Project code
1.	Nuclotron-NICA	A.V. Butenko E.M. Syresin *Scientific leader:* I.N. Meshkov	02-1-1065-1-2011/2027
2.	BM@N	M.N. Kapishin	02-1-1065-2-2012/2026
3.	MPD	V.M. Golovatyuk V.D. Kekelidze V.G. Riabov	02-1-1065-3-2011/2030
4.	SPD	A.V. Guskov *Deputy:* V.P. Ladygin	02-1-1065-4-2020/2029

Projects:

	Name of the project	Project leaders	Status
Laboratory	Responsible from laboratories		
1.	**Nuclotron-NICA**	**A.V. Butenko** **E.M. Syresin** *Scientific leader:* **I.N.Meshkov**	Realization
1.1.	**NICA injection complex: technical design preparation and construction of the NICA injection complex: (sources of heavy ions and polarized light nuclei, HILAC linear accelerators of heavy ions and light nuclei of beam transporting to the Nuclotron)**	**V.A. Lebedev** **V.A. Monchinsky** **E.M. Syresin** **A.V. Tuzikov**	Realization
1.1.a.	**Commissioning of the heavy ion source (KRION)**	**E.E. Donets**	Realization
1.1.b.	**Upgrade the polarized proton and deuteron source (SPI)**	**V.V. Fimushkin** **R.A. Kuzyakin**	Realization
1.1.c.	**Development and construction of the beam injection systems and beam transportation channels. Development of the beam control and diagnostics systems**	**D.E. Donets** **E.V. Gorbachev** **A.V. Tuzikov**	Realization
1.1.d.	**Design and start of construction the new proton and light ion injector LILAC**	**A.V. Butenko** **B.V. Golovensky** **E.M. Syresin**	Realization

VBLHEP V.P. Akimov, M.Yu. Averyanov, A.M. Bazanov, S.A. Besfamilniy, A.S. Bogatov, A.Yu. Boytsov, S.A. Burashnikov, A.M. Butenko, V.V. Chumakov, E.E. Donets, V.V. Fimushkin, A.R. Galimov, N.I. Garanzha, S.V. Gudkov, J. Guran, I.L. Guryleva, A.M. Ivanov, K.A. Ivshin, V.N. Karpinsky, A.E. Kirichenko, S.S. Kiselev, V.V. Kobets, S.Yu. Kolesnikov, A.B. Kolesov, O.S. Kozlov, A.A. Kozlovsky, A.N. Kublikov, M.V. Kulikov, N.A. Kulikov, V.N. Kulikov, O.A. Kunchenko, R.A. Kuziakin, S.M. Kuznetsov, D.Yu. Legontsev, D.S. Letkin, D.O. Leushin, D.A. Luosev, A.V. Lushin, N.A. Malyshev, A.A. Martynov, S.V. Mikhailov, V.V. Myalkovsky, A.V. Nesterov, V.V. Peshkov, A.A. Pogodin, D.O. Ponkin, R.G. Pushkar, A.Yu. Ramzdorf, D.N. Rassadov, Yu.V. Riazantsev, S.S. Romanenko, V.V. Salnikov, V.O. Shapovalov, I.V. Shirikov, A.M. Shumkov, V.B. Shutov, P.V. Sinuygin, A.A. Slivin, A.N. Soloviev, A.S. Spiridonov, A.N. Svidetelev, A.M. Tikhomirov, E.V. Tikhonov, S.B. Timofeev, V.I. Tiulkin, E.D. Tsyplakov, A.V. Vadeev, A.A. Voronin, A.Yu. Zakharov, I.N. Zhabin, L.V. Zinoviev

1.2.	**Development of the NICA Booster and its technological systems**	**A.V. Butenko** **V.A. Lebedev** **I.N. Meshkov** **E.M. Syresin** **A.O. Sidorin**	Realization
1.2.a.	**Magnet cryostat system, vacuum system, system of electron cooling**	**A.R. Galimov** **V.S. Shpakov** **V.A. Lebedev** **A.S. Sergeev**	Realization
1.2.b.	**Power supply and energy evacuation system**	**E.V. Ivanov** **V.N. Karpinsky**	Realization
1.2.c.	**RF accelerating system of the Booster**	**O.I. Brovko**	Realization
1.2.d.	**Diagnostics, injection, correction of optics, beam extraction and transport systems**	**A.V. Tuzikov** **E.V. Gorbachev**	Realization

VBLHEP A.V. Agapodchenko, N.N. Agapov, A.V. Alfeev, V.A. Andreev, A.S. Averichev, M.Yu. Averyanov, A.A. Baldin, A.M. Bazanov, A.V. Beloborodov, Yu.G. Bespalov, D. N. Bogoslovsky, D.S. Cherkunov, V.P. Chernyaev, D.E. Donets, V.M. Drobin, A.A. Fateev, S.A. Goncharov, I.L. Guryleva, N.V. Indykov, G.E. Ivanov, P.R. Kharyuzov, D.G. Kindyashov, A.E. Kirichenko, S.Yu. Kolesnikov, I.V. Kondrikov, A.V. Konstantinov, A.I. Korobkov, D.S. Korovkin, S.A. Korovkin, V.V. Kosachev, S.A. Kostromin, E.V. Kostyukhov, O.S. Kozlov, A.N. Kublikov, A.V. Kudashkin, E.A. Kulikov, O.A. Kunchenko, G.L. Kuznetsov, N.I. Lebedev, A.V. Lushin, R.N. Masalov, S.V. Mikhailov, V.V. Myalkovsky, A.V. Nesterov, D.N. Nikiforov, A.L. Osipenkov, K.G. Osipov, A.V. Pel'tikhin, M.V. Petrov, G.A. Petrovsky, A.V. Philippov, N.V. Pilyar, R.V. Pivin, O.V. Prozorov, S.V. Romanov, P.A. Rukoyatkin, T.V. Rukoyatkina, D.V. Ryzhov, G.S. Sedykh, V.Yu. Selivanov, N.V. Semin, A.S. Sergeev, A.V. Shabunov, M.M. Shandov, A.A. Shurygin, V.S. Shvetsov, A.I. Sidorov, S.A. Smirnov, Z.I. Smirnova, V.S. Stepanov, A.N. Svidetelev, V.V. Tarasov, A.M. Tikhomirov, N.D. Topilin, Yu.A. Tumanova, V.I. Tyulkin, B.V. Vasilishin, L.R. Vildanova, I.S. Volchenkov, A.I. Zagray, A.Yu. Zakharov

DLNP E.V. Akhmanova, V.I. Khilinov, O.S. Orlov, A.Yu. Rudakov, N.A. Rybakov, A.A. Sidorin, S.L. Yakovenko

1.3.	**Development and renovation of the Nuclotron**	**A.V. Butenko** **A.O. Sidorin** **E.M. Syresin** **V.A. Lebedev**	Projecting Realization
1.3.a.	**Magnet cryostat system, vacuum system**	**A.R. Galimov**	Projecting Realization
1.3.b.	**Power supply and energy evacuation system**	**E.V. Ivanov** **V.N. Karpinsky**	Projecting Realization
1.3.c.	**RF accelerating system of the Nuclotron**	**O.I. Brovko** **A.A. Volodin**	Projecting Realization
1.3.d.	**Diagnostics, injection, correction of optics, beam extraction and transportation systems**	**E.V. Gorbachev** **P.A. Rukoyatkin**	Projecting Realization

VBLHEP A.V. Agapodchenko, R.M. Akhmadrizyalov, A.S. Aksenov, A.V. Alfeev, V.A. Andreev, S.A. Arefiev, A.S. Averichev, A.M. Bazanov, E.S. Belyakov, S.A. Besfamilny, Yu.G. Bespalov, A.S. Bogatov, L.G. Bogdan, V.V. Borisov, A.Yu. Boytsov, A.P. Bulakh, A.M. Butenko, E.A. Butenko, P.S. Cherkasov, D.S. Cherkunov, A.Yu. Chmyrev, V.V. Chudakov, V.V. Chumakov, S.A. Dolgiy, D.E. Donets, E.E. Donets, I.I. Donguzov, A.M. Donyagin, G.L. Dorofeev, V.M. Drobin, A.V. Eliseev, V.G. Elkin, A.E. Emelianov, R.O. Esaulkov, A.A. Fateev, A.A. Feoktistov, G.A. Filatov, V.V. Fimushkin, A.V. Gaevsky, V.E. Galkin, F.N. Ganyushkin, N.I. Garanzha, B.V. Golovensky, I.I. Golubev, O.M. Golubitsky, S.A. Goncharov, S.P. Gorelikov, A.V. Grebennikov, D.M. Gribov, S.V. Gudkov, M.V. Gulina, K.N. Gurylev, I.L. Guryleva, S.A. Gusev, N.V. Indykov, G.E. Ivanov, S.A. Karetnik, A.N. Karpuk, V.A. Kashirin, D.G. Kindyashov, A.E. Kirichenko, S.V. Kirov, D.I. Klimansky, A.S. Klyagin, V.V. Kobets, A.B. Kolesov, I.V. Kondrikov, A.V. Konstantinov, A.V. Kopchenov, M.Yu. Korobitsyna, V.S. Korolev, G.E. Koroleva, S.A. Korovkin, V.V. Kosachev, V.A. Kosinov, I.K. Kovrizhina, A.P. Kozlov, O.S. Kozlov, A.N. Kublikov, A.V. Kudashkin, T.G. Kudinova, P.I. Kudryashov, T.A. Kulaeva, E.A. Kulikov, M.V. Kulikov, N.A. Kulikov, O.A. Kunchenko, L.V. Kutuzova, A.A. Kuznetsov, A.A. Kuznetsov, G.L. Kuznetsov, D.Yu. Kuznetsov, M.I. Kuznetsov, R.A. Kuzyakin, R.V. Lapin, I.N. Lebedev, N.I. Lebedev, V.A. Lebedev, I.G. Lebedeva, M.P. Lepkin, D.S. Letkin, D.O. Leushin, D.V. Lobanov, K.V. Loshmanova, V.O. Luchentsov, D.A. Luosev, A.V. Lushin, A.M. Malyshev, A.A. Martynov, R.N. Masalov, E.S. Matyukhanov, A.A. Merkuriev, A.V. Merkuryev, M.Yu. Meshenkov, E.A. Mikhailov, S.V. Mikhailov, Yu.A. Mitrofanova, D.V. Monakhov, V.A. Monchinsky, D.M. Morozov, V.V. Morozova, V.A. Mosalov, V.V. Myalkovsky, O.E. Naumov, S.I. Nefediev, O.A. Nefedov, E.A. Negey, A.V. Nesterov, N.A. Newgate, D.N. Nikiforov, A.M. Nikitin, I.Yu. Nikolaichuk, K.A. Nosov, M.S. Novikov, S.Yu. Novozhilov, Yu.M. Nozhenko, M.N. Omelianenko, A.L. Osipenkov, O.A. Parfenov, V.V. Pashinsky, V.V. Peshkov, L.A. Peshkova, I.M. Petrov, M.V. Petrov, V.D. Petrov, A.S. Petukhov, A.V. Philippov, M.N. Philippov, N.A. Philippov, E.Yu. Philippova, N.V. Pilyar, R.V. Pivin, A.A. Pogodin, V.K. Polyakova, D.O. Ponkin, A.A. Ponomarev, O.V. Prozorov, R.G. Pushkar, A.Yu. Ramsdorf, D.N. Rassadov, I.N. Repkin, S.V. Romanov, T.V. Rukoyatkina, S.A. Rumyantsev, D.V. Ryzhov, D.Yu. Saveliev, M.K. Savenkova, G.S. Sedykh, V.Yu. Selivanov, A.V. Sergeev, E.V. Sergeeva, V.G. Shabratov, M.M. Shandov, A.N. Scherbakov, A.V. Shemchuk, I.V. Shirikov, A.M. Shumkov, V.M. Shumkov, A.A. Shurygin, V.B. Shutov, D.S. Shvidky, T.V. Sidorenkov, A.I. Sidorov, P.A. Sidorov, V.O. Sidorova, A.V. Skrypnik, A.A. Slivin, S.A. Smirnov, V.L. Smirnov, Z.I. Smirnova, R.A. Smolkov, A.G. Sorokin, O.Yu. Stankov, L.E. Sveshnikova, A.L. Svetov, A.N. Svidetelev, M.I. Svideteleva, R.V. Talysin, V.V. Tarasov,

A.M. Tikhomirov, E.V. Tikhonov, A.B. Tischenko, N.V. Travin, A.A. Troitsky, A.V. Tsvetkov, Yu.A. Tsvetkova, V.I. Tyulkin, A.V. Vadeev, B.V. Vasilishin, L.R. Vildanova, I.S. Volchenkov, A.A. Volodin, A.A. Voronin, N.A. Voroshilov, M.I. Yablochkin, A.I. Zagray, A.Yu. Zakharov, I.N. Zhabin, V.M. Zhabitsky, A.S. Zhbankov, L.V. Zinoviev, D.A. Zolotykh, E.V. Zolotykh, A.G. Zorin

1.4.	**Technical design, R&D of technological systems and construction of the NICA heavy ion collider with an energy of E_{CM}= 4-11 GeV and an average luminosity of $1 \cdot 10^{27}$ см $^{-2}$с $^{-1}$ and light polarised nuclei with a luminosity of $1 \cdot 10^{32}$ см $^{-2}$с $^{-1}$ (by protons, at E_{CM}=27 GeV)**	**S.A. Kostromin V.A. Lebedev I.N. Meshkov A.O. Sidorin E.M. Syresin**	Projecting Realization
1.4.a.	**Magnet cryostat and vacuum systems**	**A.R. Galimov D.N. Nikiforov**	Realization
1.4.b.	**Power supply and energy evacuation system**	**E.V. Ivanov V.N. Karpinsky M.V. Petrov**	Realization
1.4.c.	**RF system of the Collider**	**O.I. Brovko A.M. Malyshev**	Realization
1.4.d.	**Beam diagnostics, injection and transportation systems**	**A.V. Tuzikov E.V. Gorbachev**	Projecting Realization
1.4.e.	**Cooling and feedback systems for charged particle beams**	**I.N. Meshkov A.O. Sidorin V.A. Lebedev**	Projecting Realization
1.4.f.	**Systems of proton and deuteron polarization monitoring and control**	**S.A. Kostromin V.V. Fimushkin**	Projecting Realization

VBLHEP A.V. Agapodchenko, R.M. Akhmadrizyalov, A.S. Aksenov, A.V. Alfeev, V.A. Andreev, S.A. Arefiev, A.S. Averichev, A.M. Bazanov, E.S. Belyakov, S.A. Besfamilny, Yu.G. Bespalov, A.S. Bogatov, L.G. Bogdan, V.V. Borisov, A.Yu. Boytsov, O.I. Brovko, A.P. Bulakh, A.M. Butenko, E.A. Butenko, P.S. Cherkasov, D.S. Cherkunov, A.A. Chernova, A.Yu. Chmyrev, V.V. Chudakov, V.V. Chumakov, S.A. Dolgiy, D.E. Donets, E.E. Donets, I.I. Donguzov, A.M. Donyagin, G.L. Dorofeev, V.M. Drobin, A.V. Eliseev, V.G. Elkin, A.E. Emelianov, R.O. Esaulkov, A.A. Fateev, A.A. Feoktistov, G.A. Filatov, A.V. Gaevsky, V.E. Galkin, F.N. Ganyushkin, N.I. Garanzha, B.V. Golovensky, I.I. Golubev, O.M. Golubitsky, S.A. Goncharov, E.V. Gorbachev, S.P. Gorelikov, A.V. Grebennikov, A.Yu. Grebentsov, D.M. Gribov, S.V. Gudkov, S.V. Gudkov, M.V. Gulina, K.N. Gurylev, I.L. Guryleva, S.A. Gusev, N.V. Indykov, E.V. Ivanov, G.E. Ivanov, A.N. Karpuk, V.A. Kashirin, D.G. Kindyashov, A.E. Kirichenko, S.V. Kirov, D.I. Klimansky, A.S. Klyagin, V.V. Kobets, A.B. Kolesov, I.V. Kondrikov, A.V. Konstantinov, A.V. Kopchenov, M.Yu. Korobitsyna, S.A. Korovkin, V.S. Korolev, G.E. Koroleva, V.V. Kosachev, V.A. Kosinov, I.K. Kovrizhina, A.P. Kozlov, O.S. Kozlov, A.V. Kudashkin, T.G. Kudinova, P.I. Kudryashov, R.I. Kukushkina, T.A. Kulaeva, E.A. Kulikov, M.V. Kulikov, N.A. Kulikov, O.A. Kunchenko, L.V. Kutuzova, A.A. Kuznetsov, A.A. Kuznetsov, G.L. Kuznetsov, D.Yu. Kuznetsov, M.I. Kuznetsov, R.A. Kuzyakin, R.V. Lapin, I.N. Lebedev, N.I. Lebedev, I.G. Lebedeva, M.P. Lepkin, D.S. Letkin, D.O. Leushin, D.V. Lobanov, K.V. Loshmanova, V.O. Luchentsov, D.A. Luosev, A.V. Lushin, A.M. Malyshev, A.A. Martynov, R.N. Masalov, E.S. Matyukhanov, A.A. Merkuriev, M.Yu. Meshenkov, E.A. Mikhailov, S.V. Mikhailov, Yu.A. Mitrofanova, D.V. Monakhov, V.A. Monchinsky, D.M. Morozov, V.V. Morozova, V.A. Mosalov, V.V. Myalkovsky, O.E. Naumov, D.V. Neapolitansky, S.I. Nefediev, O.A. Nefedov, E.A. Negey, A.V. Nesterov, N.A. Newgate, D.N. Nikiforov, A.M. Nikitin, I.Yu. Nikolaichuk, K.A. Nosov, M.S. Novikov, S.Yu. Novozhilov, Yu.M. Nozhenko, M.N. Omelianenko, A.L. Osipenkov, O.A. Parfenov, V.V. Pashinsky, V.V. Peshkov, L.A. Peshkova, I.M. Petrov, M.V. Petrov, V.D. Petrov, A.S. Petukhov, A.V. Philippov, M.N. Philippov, N.A. Philippov, E.Yu. Philippova, N.V. Pilyar, R.V. Pivin, A.A. Pogodin, V.K. Polyakova, D.O. Ponkin, A.A. Ponomarev, O.V. Prozorov, R.G. Pushkar, A.Yu. Ramsdorf, D.N. Rassadov, I.N. Repkin, S.V. Romanov, P.A. Rukoyatkin, T.V. Rukoyatkina, S.A. Rumyantsev, D.V. Ryzhov, D.Yu. Saveliev, M.K. Savenkova, A.N. Scherbakov, G.S. Sedykh, V.Yu. Selivanov, A.V. Sergeev, E.V. Sergeeva, V.G. Shabratov, M.M. Shandov, A.V. Shemchuk, I.V. Shirikov, A.M. Shumkov, A.A. Shurygin, V.B. Shutov, D.S. Shvidky, T.V. Sidorenkov, A.I. Sidorov, P.A. Sidorov, V.O. Sidorova, A.V. Skrypnik, A.A. Slivin, S.A. Smirnov, V.L. Smirnov, Z.I. Smirnova, R.A. Smolkov, A.G. Sorokin, O.Yu. Stankov, V.S. Stepanov, L.E. Sveshnikova,

A.L. Svetov, A.N. Svidetelev, M.I. Svideteleva, E.M. Syresin, R.V. Talysin, V.V. Tarasov, A.M. Tihomirov, E.V. Tikhonov, A.B. Tischenko, N.V. Travin, A.A. Troitsky, A.V. Tsvetkov, Yu.A. Tsvetkova. V.I. Tyulkin, A.V. Vadeev, B.V. Vasilishin, L.R. Vildanova, I.S. Volchenkov, A.A. Volodin, A.A. Voronin, N.A. Voroshilov, M.I. Yablochkin, M.V. Yurkov, A.I. Zagray, A.Yu. Zakharov, I.N. Zhabin, V.M. Zhabitsky, A.S. Zhbankov, L.V. Zinoviev, D.A. Zolotykh, A.G Zorin

DLNP E.V. Akhmanova, V.I. Khilinov, O.S. Orlov, A.Yu. Rudakov, A.A. Sidorin, S.L. Yakovenko

DRB V.Yu. Schegolev., S.G. Shirkov

1.5.	**R&D, construction and development of cryogenic systems**	**N.N. Agapov** **A.V. Konstantinov**	Projecting Realization

VBLHEP S.A. Arefiev, M.A. Basheva, D.M. Belov, V.M. Drobin, A.E. Emelyanov, E.F. Filippova, S.P. Gorelikov, S.V. Gudkov, E.V Ivanov, M.V. Kondratiev, V.A. Kosinov, E.A. Kulikov, D.V. Lobanov, Yu.A. Mitrofanova, L.P. Peshkov, I.M. Petrov, S.A. Smirnov, O.B. Yarovikova

Brief annotation and scientific rationale (NICA):
The development and carryout works on of the existing infrastructure of the VBLHEP accelerator complex: HILAC, Booster, Nuclotron, beam transport channels in bldg. 1, bldg. 205 and new building 17 and other systems and new equipment required for the NICA collider commissioning at project equipment configuration in 2027.

Expected results upon completion of the project:
Commissioning of the NICA complex objects at basic configuration of the collider equipment, prolongation of the experiments at fixed targets with heavy ion and light nuclei polarized beams, start the experiments at colliding beams, R&D, prototyping, testing, pre-serial magnet production for the "new" Nuclotron ring.

Expected results of the project in the current year:
Experiments with circulating in collider heavy ion beams at the kinetic energy up to 2 GeV/n with internal target and colliding beams.

2.	**BM@N**	**M.N. Kapishin**	Realization
2.1.	**Development of the operational area of the setup: increasing the radiation protection, improving detector subsystems and engineering infrastructure**	**S.Yu. Anisimov** **M.N. Kapishin** **S.M. Piyadin**	Realization
2.2.	**Construction of the basic detector complex of the BM@N setup**	**M.N. Kapishin** **S.M. Piyadin**	Realization
2.3.	**Development of the technological and engineering systems, control systems and test areas of the setup**	**S.Yu. Anisimov** **S.M. Piyadin** **N.D. Topilin**	Realization

VBLHEP S.V. Afanasiev, G.N. Agakishiev, K.A. Alishina, V.I. Astakhov, V.N. Azorskiy, V.A. Babkin, R. Barak, S.N. Bazylev, M.G. Buryakov, S.G. Buzin, A.I. Chebotov, D.D. Chemezov, D.V. Dementiev, A.V. Dmitriev, J.R. Drnoyan, D.K. Dryablov, B.V. Dubinchik, P.O. Dulov, A.S. Egorov, D.S. Egorov, V.V. Elsha, A.A. Fedyunin, I.A. Filippov, I.R. Gabdrakhmanov, O.P. Gavrischuk, K.V. Gertsenberger, V.M. Golovatyuk, P.N. Grigoriev, V.Yu. Karzhavin, R.R. Kattabekov, V.D. Kekelidze, S.V. Khabarov, Yu.T. Kiryushin, V.I. Kolesnikov, A.A. Kolozhvari, Yu.A. Kopylov, L.D. Kovachev, I.V. Kruglova, S.N. Kuklin, E.M. Kulish, V.V. Kutergina, A.S. Kuznetsov, E.A. Ladygin, N.A. Lashmanov, R. Lednický, V.V. Lenivenko, A.M. Makan'kin, A.I. Malakhov, S.P. Merts, Yu.A. Murin, R.V. Nagdasev, D.N. Nikitin, S.V. Novozhilov, I.S. Osokin, V.A. Plotnikov, I.Yu. Polev, N.E. Pukhaeva, S.V. Reshetova, V.Yu. Rogov, I.A. Romanov, I.A. Rufanov, P.A. Rukoyatkin, M.M. Rumyantsev, D.G. Sakulin, S.A. Sedykh, S.V. Sergeev, A.V. Shchipunov, A.D. Sheremetiev, A.I. Sheremetieva, M.O. Shitenkov, A.V. Shutov, V.B. Shutov, I.V. Slepnev, V.M. Slepnev, I.P. Slepov, A.V. Smirnov, A.S. Sorin, V.N. Spaskov, Yu.Yu. Stepanenko, E.A. Streletskaya, B.V. Sukhov, D.A. Suvarieva, N.A. Tarasov, O.G. Tarasov, A.V. Terletsky, O.V. Teryaev, V.V. Tikhomirov, A.A. Timoshenko, I.A. Tyapkin, V.V. Ustinov, V.A. Vasendina, V.K. Velichkov, A.A Voronin, V.I. Yurevich, N.I. Zamyatin, I.A. Zhavoronkova, A.I. Zinchenko, R.A. Zinchenko, E.V. Zubarev

MLIT E.I. Alexandrov, I.N. Alexandrov, N.A. Balashov, D.A. Baranov, I.A. Filozova, Zh.Zh. Musulmanbekov, V.V. Palichik, I.S. Pelevaniuk, D.V. Podgainy, O.I. Streltsova, N.N. Voytishin, M.I. Zuev

FLNP E.I. Litvinenko, I.S. Zhironkin

2.4. Analysis of BM@N experimental data and feasibility studies for BM@N program in heavy ion beams

M.N. Kapishin
A.I. Zinchenko

Realization

Abstract and scientific rationale (BM@N):
Investigation of reaction dynamics and studingmodifications of hadron properties in nuclear matter, near-threshold strange hyperons production and search for hyper nuclei in interactions of the Nuclotron extracted ion beams with fixed targets at the BM@N detector.

Expected results upon completion of the project:
Commissioning of BM@N and obtaining physics results on interactions of Nuclotron extracted ion beams with fixed targets to study reaction dynamics and the equation-of-state of nuclear matter, modifications of hadron properties in nuclear matter, near-threshold strange hyperons production and to search for hyper nuclei.

Expected results in the current year:
Preparing the BM@N set-up for the physics run with a heavy ion beam extracted from the Nuclotron. New data collection with a heavy ion beam at BM@N. Analysis of new experimental data collected at BM@N.

3. MPD

V.M. Golovatyuk
V.D. Kekelidze
V.G. Ryabov

Realization

VBLHEP R. Adhikari, S.V. Afanasiev, G. Agakishiev, E.I. Alexandrov, I.N. Alexandrov, A.R. Alvarez, S.V. Andreeva, T.V. Andreeva, A.A. Aparin, R.D. Arteche, V.I. Astakhov, S.P. Avdeev, G.S. Averichev, A.V. Averyanov, V.A. Babkin, I.A. Balashov, N.A. Baldin, R.V. Baratov, V.M. Baryshnikov, K.D. Basharina, A.G. Bazhazhin, S.N. Bazylev, A.V. Belyaev, E.V. Belyaeva, D.N. Bogoslovsky, I.V. Boguslavsky, M.G. Buryakov, A.V. Butenko, A.V. Butorin, S.G. Buzin, A.V. Bychkov, S.C. Ceballos, V.V. Chalyshev, V.A. Cheplakova, V.V. Chepurnov, Vl.V. Chepurnov, G.A. Cheremukhina, D.V. Dementiev, A.V. Dmitriev, E.V. Dolbilina, V.H. Dodokhov, A.G. Dolbilov, D.E. Donets, A.Yu. Dubrovin, P.O. Dulov, N.V. Dunin, V.B. Dunin, A.A. Efremov, D.S. Egorov, V.V. Elsha, N.E. Emelyanov, O.V. Fateev, Yu.I. Fedotov, A.A. Fedyunin, I.A. Filippov, M.A. Gaganova, O.P. Gavrishchuk, S.E. Gerasimov, K.V. Gertsenberger, V.M. Golovatyuk, A.O. Golunov, Yu.S. Goneim, N.V. Gorbunov, P.N. Grigoriev, Z.A. Igamkulov, A.Yu. Isupov, A.V. Ivanov, S.I. Kakurin, M.N. Kapishin, I.A. Kashunin, A.O. Kechechyan, G.D. Kekelidze, V.D. Kekelidze, A.S. Khvorostukhin, V.A. Kireev, Yu.T. Kiryushin, V.I. Kolesnikov, A.A. Kolozhvari, V.G. Komarov, A.I. Kostylev, M.E. Kozhevnikova, V.A. Kramarenko, Yu.F. Krechetov, I.V. Kruglova, V.A. Krylov, A.V. Krylov, S.N. Kuklin, N.A. Lashmanov, R. Lednický, V.I. Lobanov, Yu.Yu. Lobanov, S.P. Lobastov, Yu.R. Lukstinsh, D.T. Madigozhin, A.T. Makarov, A.I. Malakhov, I.A. Maldonado-Cervantes, I.V. Malikov, M.A. Medvedeva, D.G. Melnikov, S.P. Merts, I.N. Meshkov, I.I. Migulina, G.D. Milnov, Yu.I. Minaev, S.A. Mituksin, N.A. Molokanova, A.A. Moshkin, A.E. Moskovsky, S.A. Movchan, K.A. Mukhin, E.E. Muravkin, Yu.A. Murin, V.A. Nikitin, V.A. Novoselov, I.A. Oleks, O.E. Orlov, V.A. Pavlyukevich, V.A. Penkin, D.V. Peshekhonov, V.A. Petrov, A.V. Pilyar, S.M. Piyadin, N.O. Ridinger, O.V. Rogachevsky, V.Yu. Rogov, I.A. Rufanov, M.M. Rumyantsev, A.A. Rybakov, Z. Sadygov, V.A. Samsonov, A.A. Savenkov, S.A. Sedykh, A.Yu. Semenov, I.A. Semenova, S.V. Sergeev, E.V. Serochkin, Yu.V. Shafarevich, D.V. Shchegolev, A.V. Shcipunov, A.D. Sheremetyev, A.I. Sheremetyeva, M.O. Shitenkov, I.A. Shmyrev, A.A. Shunko, A.V. Shutov, V.B. Shutov, A.O. Sidorin, I.V. Slepnev, V.M. Slepnev, I.P. Slepov, I.A. Smelyansky, A.S. Sorin, G.G. Stiforov, L.Yu. Stolypina, E.A. Streletskaya, O.I. Streltsova, D.A. Tereshin, A.V. Terletsky, O.V. Teryaev, V.V. Tikhomirov, A.A. Timoshenko, N.D. Topilin, V.V. Trofimov, G.V. Trubnikov, I.A. Tyapkin, S.Yu. Udovenko, V.A. Vasendina, S.V. Vereshchagin, A.S. Vodopyanov, O.A. Volodina, A.L. Voronin, V. Voronyuk, V.I. Yurevich, N.I. Zamyatin, S.A. Zaporozhets, M.V. Zaytseva, A.I. Zinchenko, A.A. Zinchenko, D.A. Zinchenko, V.N. Zryuev, A.L. Zubarev

DLNP A.V. Guskov, N.V. Khomutov, N.P. Kravchuk, V.L. Malyshev, A.G. Olshevsky

MLIT V. Abgaryan, A.S. Airyan, E.I. Aleksandrov, I.N. Aleksandrov, A.I. Balandin, N.A. Balashov, D.A. Baranov, D.V. Belyakov, Ya. Busha, A.O. Golunov, O. Grigoryan, S. Hnatič, V.V. Ivanov, I.A. Kashunin, A.A. Kokorev, V.V. Korenkov, V.V. Mitsyn, A.N. Moibenko, Zh.Zh. Musulmanbekov, A.V. Nechaevskiy, V.V. Papoyan, S.S. Parzhitskiy, I.S. Pelevanyuk, D.V. Podgainyi, D.I. Pryakhina, R.N. Semenov, S.V. Shmatov, O.I. Streltsova, T.A. Strizh, V.V. Trofimov, A.S. Vorontsov, N.N. Voytishin, M.I. Zuev

LTP V.D. Toneev

FLNP E.I. Litvinenko

3.1.	**Design and construction of the superconducting solenoid and magnet yoke**	**K.A. Mukhin** **N.D. Topilin**	Realization

VBLHEP R.V. Baratov, S.E. Belyaev, E.V. Belyaeva, S.E. Gerasimov, Yu.Yu. Lobanov, V.A. Novoselov, I.A. Smelyansky, D.A. Tereshin, G.P. Tkachev

3.2.	**Construction of the detector complex of the start configuration of the MPD setup**	**V.M. Golovatyuk** **V.D. Kekelidze**	Realization

VBLHEP V.A. Babkin, C.N. Bazylev, A.P. Ivashkin, S.A. Movchan, Yu.A. Myrin, N.D. Topilin, I.A. Tyapkin, V.I. Yurevich

3.3.	**Design and creation of the data acquisition and control systems**	**S.N. Bazylev** **I.V. Slepnev**	Realization

VBLHEP A.A. Fedyunin, I.A. Filippov, S.N. Kuklin, A.V. Schipunov, A.B. Shutov, V.M. Slepnev, N.A. Tarasov, A.V. Terletsky

3.4.	**Development of MPD physical program**	**V.G. Ryabov** **V.I. Kolesnikov** **A.I. Zinchenko**	Realization

3.5.	**Development of MPD data processing and physics analysis system**	**O.V. Rogachevsky** **A.G. Dolbilov** **S.V. Shmatov**	Realization

VBLHEP A.A. Moshkin, I.P. Slepov

MLIT E.I. Aleksandrov, I.N. Aleksandrov, A.I. Balandin, N.A. Balashov, D.A. Baranov, D.V. Belyakov, A.G. Dolbilov, A.O. Golunov, S. Hnatič, I.A. Kashunin, V.V. Korenkov, V.V. Mitsyn, A.N. Moibenko, Zh.Zh. Musulmanbekov, S.S. Parzhitskiy, I.S. Pelevanyuk, D.V. Podgainy, D.I. Pryakhina, R.N. Semenov, O.I. Streltsova, T.A. Strizh, V.V. Trofimov, A.S. Vorontsov, N.N. Voytishin, M.I. Zuev

Abstract and scientific rationale (MPD):

The physical launch of the NICA collider with the beam is planned for 2026. By the middle of the forth quarter of 2026, the collider should provide collisions of the Xe beam with the fixed wire target installed in the collision area of the MPD experiment. Tungsten will be used as the wire material. In the second and third stages of the launch, interactions of Xe colliding beams should be implemented.

The timing of the construction and launch of the experimental facility is tightly linked to the collider launch schedule. By mid-summer 2026, the MPD experimental facility should be fully assembled and installed in its operation position with the beam. The detector subsystems should be integrated into a common data control and readout system. The first data collected by the MPD facility with the beam will be used to study the operation and characteristics of the detector subsystems, to tune the signal recovery algorithms in the detector subsystems, and to reconstruct charged particle tracks and their association with signals in external detectors.

Expected results upon completion of the project:
Creating and launching the first stage of the MPD experimental.
The configuration of the first stage includes: a magnet that creates a uniform field up to 0.57T, a track system based on the time projection chamber TPC, a time-of-flight detector FFD-TOF, an electromagnetic calorimeter ECal and a forward hadron calorimeter FHCal. Holding a technical run on the beams of the NICA collider to configure all subsystems of the MPD experimental setup, holding a physical run on the beam for a set of events corresponding to collisions of heavy ions in the required beam configuration in order to study the properties of baryonic matter.

Creation and commissioning of a centralized monitoring, control and operation system for detectors, magnets, gas system (DCS), as well as an emergency indication and emergency response system.

Development of the DAQ system for the detector subsystems.

Development of a system for continuous monitoring of the quality of data recorded from detectors (QA), calibration of detectors and primary processing of data obtained from the experimental facility to switch from the raw data format to tables of recovered tracks and hits in detector subsystems, processing of the tables of tracks and hits obtained at the previous stage in order to determine the operational characteristics of detectors and the entire facility, as well as obtaining the first physical results.

Expected results of the project in the current year:
Cooling of the Solenoid to the temperature of liquid nitrogen, start of the first collaboration shifts.

Current supply to superconducting and correction magnet windings, testing of magnet operation modes and energy evacuation systems.

Carrying out measurements of the magnetic field at different current values.

Completion of the construction of TOF, FHCal, FFD subsystems, assembly of the TPC housing, and first 40 half-sectors of the ECal.

Determination of optimal parameters and algorithms for the operation of the MPD trigger system, built on the basis of FFD, FHCal and TOF, for effective selection of events corresponding to collisions of nuclei with the fixed target and in the collision mode of colliding beams, determination of the coordinates of the primary vertex and the starting time T0. Implementation of the developed algorithms in hardware.

Simulation of the operation of the MPD experimental facility in Xe+W collisions using various event generators in order to study the possibilities of its use for studying collisions of an ion beam with a fixed target. Such a beam configuration is likely to provide the largest amount of experimental data available for study.

4.	**Construction of the SPD facility for studying spin effects in nuclear interactions**	**A.V. Guskov** *Deputy:* **V.P. Ladygin**	Project preparation

VBLHEP R.R. Akhunzyanov, V.Yu. Alexakhin, V.A. Anosov, V.I. Astakhov, N.I. Azorskiy, V.N. Azorskiy, D. Baigarashev, A.A. Baldin, E.G. Baldina, K.D. Basharina, V.V. Bautin, E.V. Belyaeva, Yu.G. Bespalov, Ver.V. Bleko, V.V. Bleko, D.N. Bogoslovskii, V.V. Borisov, D.V. Budkouski, E.A. Bushmina, D.D. Chemezov, S.A. Chetverikov, V.B. Chmill, V.B. Dunin, T.L. Enik, A.S. Galoyan, O.P. Gavrishchuk, S.E. Gerasimov, S.M. Golubykh, N.V. Gorbunov, D.A. Gubachev, Yu.V. Gurchin, A.Yu. Isupov, A.V. Ivanov, N.Ya. Ivanov, S.I. Kakurin, Y. Kambar, I.Yu. Kapitonov, V.Yu. Karjavin, G.D. Kekelidze, D. Kereibay, S.V. Khabarov, P.R. Kharyuzov, E.A. Klevtsova, E.S. Kokoulina, Yu.A. Kopylov, D.S. Korovkin, A. Korzenev, E.V. Kostyukhov, M.A. Kozhin, V.A. Kramarenko, V.A. Kukharev, O.M. Kuznetsov, E.A. Ladygin, V.P. Ladygin, R. Lednický, A.N. Livanov, K.V. Loshmanova, V.M. Lysan, D.T. Madigozhin, N.S. Markov, K.V. Mikhailov, O. Minko, S.A. Movchan, Y. Mukhamejanov, A. Mukhamejanova, D. Myktybekov, S.N. Nagorniy, D.N. Nikiforov, V.A. Nikitin, V.V. Pavlov, V.V. Perelygin, M.V. Petrov, V.A. Polyakov, A.A. Ponomarev, V.V. Popov, S.G. Reznikov, N.S. Rogacheva, S. Romakhov, A.B. Safonov, N. Sagimbaeva, K.M. Salamatin, A.A. Savenkov, V.V. Shalaev, A.I. Sheremeteva, S.S. Shimansky, S.N. Shkarovskiy, A.A. Shunko, S.E. Sinelshchikova, S.A. Smirnov, S.Yu. Starikova, E.A. Streletskaya, S.I. Sukhovarov, O.G. Tarasov, A.A. Terekhin, A.V. Tishevsky, N.D. Topilin, Yu.A. Troyan, E.A. Usenko, E.V. Vasilieva, S.V. Vizgalov, I.S. Volkov, P.V. Volkov, K.S. Volkova, Yu.V. Yershov, N.I. Zamiatin, E.V. Zemlyanichkina, I.A. Zhizhin, I.A. Zhukov, A.V. Zinin, D.A. Zolotykh, E.V. Zubarev

DLNP V.M. Abazov, L.G. Afanasyev, G.D. Alexeev, A.Eh. Allakhverdieva, N.B. Anfimov, A.M. Artikov, N.V. Atanov, V.Yu. Baranov, A.V. Boikov, A.E. Bolshakova, Z.A. Budtueva, V.V. Chalyshev, A.V. Chetverikov, D. Choheli, A.V. Chukanov, A. Datta, Yu.I. Davydov, D.V. Dedovich, M.A. Demichev, I.I. Denisenko, M. Dima, M.-T. Dima, M.-O. Dima, D.V. Fedoseev, V.N. Frolov, E. Ginya, L.K. Gladilin, A. Gongadze, A.O. Gridin, K.I. Gritsay, A.V. Guskov, N. Huseynov, A.V. Karpishkov, R.N. Korotkin, N.A. Kovyazina, V.A. Kozhukalov, I.E. Kreslo, V.G. Kruchonak, Yu.A. Kulchitsky, A.V. Kulikov, V.S. Kurbatov, S.A. Kutuzov, K.I. Kuznetsova, P.I. Lensky, I. Lyashko, A. Maltsev, V.D. Moskalenko, A.G. Olshevsky, A.A. Piskun, F.V. Prokoshin, D.I. Rusov, A.V. Rybnikov, O.B. Samoylov, A.S. Selyunin, S.S. Seryubin, V.I. Sharov, A.V. Shipilova, K. Shtejer, L.L. Simbiryatin, A.V. Simonenko, A.N. Skachkova, S.A. Sokolov, V.V. Tereshchenko, A.I. Tropina, Yu.N. Uzikov, I.I. Vasiliev, A.O. Vasyukov, A.Yu. Verkheev, L.S. Vertogradov, Yu.L. Vertogradova, I.V. Yeletskikh, V.V. Zel, A.S. Zhemchugov, N.I. Zhuravlev, I.Yu. Zimin

MLIT E.I. Alexandrov, I.N. Alexandrov, A.V. Didorenko, A.G. Dolbilov, N.V. Greben, Z.K. Khabaev, A.K. Kiryanov, O.L. Kodolova, A.S. Konak, P.A. Korshunova, B.F. Kostenko, M.A. Mineev, N.G. Monakov, D.A. Oleynik, S.S. Omelyanchuk, G.A. Ososkov, A.Sh. Petrosyan, D.I. Pryakhina, L.R. Romanychev, S.V. Shmatov, V.V. Uzhinsky, N.N. Voytishin

BLTP V.A. Saleev, O.V. Teryaev, A.S. Zhevlakov

Abstract and scientific rationale (SPD):

The Spin Physics Detector is a planned experimental setup at the NICA collider is intended to study the spin structure of the proton and deuteron and the other spin-related phenomena with polarized proton and deuteron beams at a collision energy up to 27 GeV and a luminosity up to 10^{32} cm^{-2} s^{-1}. In the polarized proton-proton collisions, the SPD experiment will cover the kinematic gap between the low-energy measurements at ANKE-COSY and SATURNE and the high-energy measurements at the Relativistic Heavy Ion Collider, as well as the planned fixed-target experiments at the LHC. As for the possibility for NICA to operate with polarized deuteron beams at such energies, it is unique. SPD is planned to operate as a universal facility for comprehensive study of the unpolarized and polarized gluon content of the nucleon at large and moderate x, using different complementary probes such as: charmonia, open charm, and prompt photon production processes. A priority of the experiment is the measurement of parton distributions depending on the transverse momentum of partons in the nucleon (TMD PDFs). The study of spin effects in the elastic scattering of protons and deuterons, and in the production of lambda-hyperons, search for dibaryon resonances, study of the charmed particles production near threshold, study of multiquark correlations, and other polarized and unpolarized physics will be available at the first stage of the collider operation with reduced luminosity and collision energy of proton and ion beams.

Expected results upon completion of the project:

The main result of the experiment should be new information on the gluon helicity, gluon Sivers, Boer-Mulders and other Transverse Momentum Dependent PDFs in the nucleon, as well as the gluon transversity distribution and tensor PDFs in the deuteron, via the measurement of specific single and double spin asymmetries. The results expected to be obtained by SPD will play an important role in the general understanding of the properties of strong interaction, specifically, of the nucleon gluon content and will serve as a complementary input to the ongoing and planned studies at RHIC, and future measurements at the EIC (BNL) and fixed-target facilities at the LHC (CERN). Simultaneous measurement of the same quantities using different processes at the same experimental setup is of key importance for minimization of possible systematic effects.

Expected results of the project in the current year:

Creation of subsystem components for the SPD setup for the first stage of the experiment: the central tracker based on Micromegas, the main tracker based on straw tubes, the beam-beam counter, the muon system, the cryogenic system, the data acquisition system, and the computing infrastructure.

Design, development, testing and optimization of prototypes of the detectors and other subsystems of the SPD setup.

Creation and development of infrastructure for testing prototypes of the SPD subsystems at the Nuclotron beams.

Activities of the infrastructure:

	Name of the activity	Leaders	Implementation period
Laboratory	Responsible from laboratories		Status
1.	**Theoretical investigations, calculations and development of models describing nuclear matter properties at high temperatures and compressions, dynamics of high energy nuclear interactions at extremely high baryonic densities, spin and P-odd effects**	**D. Blaschke** **A.S. Sorin** **O.V. Teryaev**	2024-2026 Realization
BLTP	V.V. Braguta, A. Frizen, Yu.B. Ivanov, A.S. Khvoroctukhin, Ya.N. Klopot, A.G. Oganesyan, A. Parvan, A.A. Roenko		
MLIT	Yu.L. Kalinovsky, Zh.Zh. Musulmanbekov, E.G. Nikonov		
DLNP	G.I. Lykasov		
VBLHEP	Kh.U. Abraamyan, D.A. Artemenkov, P.N. Batyuk, D.K. Dryablov, V.D. Kekelidze, M.A. Kozhin, R. Lednický, A.I. Malakhov, S.G. Reznikov, O.V. Rogachevsky, V. Voronyuk		
2.	**Computer infrastructure: online and offline clusters of the distributed computer complex, system of simulation, data transfer and analysis, information and technological computer systems**	**A.G. Dolbilov** **O.V. Rogachevsky**	2024-2026 Realization
VBLHEP	O.S. Fedoseev, D.G. Mel'nikov, Yu.I. Minaev, S.A. Mityukhin, D.V. Peshekhonov, B.G. Schinov, S.N. Shkarovsky, I.V. Slepnev, I.P. Slepov, V.L. Svalov		
MLIT	I.A. Kashunin, D.V. Kekelidze, V.V. Korenkov, V.V. Mitsyn, D.A. Oleynik, I.S. Pelevanyuk, A.Sh. Petrosayn, M.S. Plyashkevich, D.V. Podgainy, T.A. Strizh, V.V. Trofimov, P.V. Zrelov		
3.	**Construction and development of the test zone for detector R&D at the linear electron accelerator at DLNP**	**A.S. Zhemchugov** **A.A. Baldin**	2024-2026 Projecting Realization
VBLHEP	T. L. Enik, O. Gavrishchuk, V.V. Kobets, Yu.A. Murin, V.G. Shabratov		
DLNP	A.E. Brukva, D.L. Demin, M.I. Gostkin, V.G. Kruchonok, S.Yu. Porokhovoy, Ya.A. Samofalova, A.N. Trifonov, K.E. Yunenko		
4.	**Construction and development of infrastructure for applied and innovation research at the NICA complex**	**A.V. Butenko** **A.S. Sorin**	2024-2026 Projecting Realization
4.1	**Construction of beamlines for applied research, of stations for irradiation of electronic components and biological objects with long-range ions and stations for irradiation of electronic components with low-energy ions**	**A.V. Butenko** **E.M. Syresin**	Realization
4.2	**R&D for the development and exploitation of irradiation stations for applied research at the NICA complex; organization of international collaboration**	**O.V. Belov** **E.M. Syresin**	Projecting Realization
VBLHEP	A.A. Baldin, E.A. Klevtsova, A.V. Rogachev, V.N. Shalyapin, 3 pers.		

DLNP K.V. Belokopytova

FLNP M.V. Bulavin

5.	**Construction of the complex of buildings with engineering infrastructure for object placement, engineering systems and carrying out R&D for the NICA complex**	**N.N. Agapov** **V.D. Kekelidze** **N.D. Topilin** **A.V. Trubnikov**	2024-2026 Projecting Realization
5.1.	**Technical designing, coordination of the construction of the building complex and engineering infrastructure development**	**A.V. Dudarev** **I.N. Meshkov** **A.V. Trubnikov** **S.A. Kostromin**	Projecting Realization
5.2.	**R&D, production of prototypes and full-scale superconducting magnets for the NICA booster and collider, renovated Nuclotron**	**D.N. Nikiforov**	Projecting Realization

VBLHEP V.V. Agapova, A.S. Averichev, V.I. Batin, A.M. Bazanov, N.P. Bazylev, V.V. Borisov, A.A. Bortsova, A.V. Bychkov, S.A. Dolgy, A.M. Donyagin, V.M. Drobin, N.A. Filippov, E.Yu. Filippova, E. Fischer, A.R. Galimov, O.M. Golubitsky, Yu.V. Gusakov, E.Yu. Ivanenko, V.N. Karpinsky, I.E. Karpunina, S.Yu. Kolesnikov, A.V. Konstantinov, V.S. Korolev, S.A. Kostromin, A.V. Kudashkin, E.A. Kulikov, O.A. Kunchenko, G.L. Kuznetsov, V.I. Lipchenko, D.V. Lobanov, A.A. Makarov, A.Yu. Merkur'ev, Yu.A. Mitrofanova, A.V. Nesterov, M.S. Novikov, A.L. Osipenkov, R.V. Pivin, D.O. Ponkin, T.F. Prakhova, A.S. Sergeev, M.M. Shandov, A.V. Shemchuk, E.V. Shevtchenko, S.A. Smirnov, Yu.A. Tumanova, N.A. Zhil'tsova

MLIT P.G. Akishin

5.3.	**Upgrade and development of electric power and technological nets aimed at the increasing of economics and technical efficiency**	**N.N. Agapov** **N.V. Semin**	Projecting Realization

VBLHEP A.V. Alfeev, E. Fischer, A.M. Karetnik, A.A. Makarov, M.I. Migulin, M.S. Novikov, E.V. Serochkin, V.Yu. Shilov, A.N. Sotnikov, V.M. Stepanov, V.P. Tchernyaev, O.M. Timoshenko, N.D. Topilin

CCD Yu.N. Balandin, I.S. Frolov, L.I. Tikhomirov

OCE S.G. Shirkov, 2 pers.

LRB G.N. Timoshenko, 3 pers.

Collaboration 1065

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
Azerbaijan	Baku, BA	NNRC
Belarus	Minsk, MI	BSU
		IE NASB
		INP BSU
		IP NASB
		JIPNR-Sosny
		PTI NASB

Country or International Organization	City, region	Institute or laboratory
Bulgaria	Plovdiv	PU
Chile	Valparaiso, VS	USM
China	Beijing, BJ	CIAE
		IHEP CAS
		Tsinghua
		UCAS
	Hefei, AH	ASIPP CAS
		USTC
	Hengyang, HN	USC
	Huzhou, ZJ	HUTC
	Jinan, SD	SDU
	Lanzhou, GS	IMP CAS
	Qingdao, SD	SDU
	Shanghai, SH	Fudan
		SINAP CAS
	Wuhan, HB	CCNU
	Yichang, HB	CTGU
Cuba	Havana	InSTEC
Egypt	Giza, GZ	ECTP MTI NU
Georgia	Tbilisi, TB	GTU
Germany	Darmstadt, HE	GSI Helmholtz
	Julich, NRW	FZJ Helmholtz
Japan	Tokyo	Nihon Univ.
Kazakhstan	Almaty, ALA	INP
		PTI Satbaev Univ.
Mexico	Mexico City, CDMX	UNAM
	Puebla de Zaragoza, PUE	BUAP
Moldova	Chisinau, CU	IAP
Mongolia	Ulaanbaatar	IPT MAS
Russia	Belgorod, BEL	BelSU
	Dolgoprudny, MOS	MIPT
	Fryazino, MOS	Istok
	Gatchina, LEN	NRC KI PNPI
	Kazan, TA	Compressormash
		Spetshmash
	Moscow, MOW	Cryogenmash
		Geliymash
		HSE
		IBMP RAS
		ITEP
		LPI RAS
		MEPhI

Country or International Organization	City, region	Institute or laboratory
		MIREA
		MISIS
		MSU
		NRC KI
		PRUE
		SINP MSU
		VEI VNIITF
	Novocherkassk, ROS	SRSPU NPI
	Novosibirsk, NVS	BINP SB RAS
		STL "Zaryad"
	Protvino, MOS	IHEP
	Saint Petersburg, SPE	SPbSPU
		SPbSU
	Samara, SAM	SNRU
	Syktyvkar, KO	DM Komi SC
	Tomsk, TOM	TPU
		TSU
	Troitsk, MOW	INR RAS
	Vladikavkaz, SE	NOSU
	Zhukovsky, MOS	Technology
Serbia	Belgrade, BG	VINCA
Slovakia	Kosice, KI	UPJS
	Nova Dubnica, TC	EVPU
South Africa	Somerset West, WC	iThemba LABS
	Stellenbosch, WC	SU
Uzbekistan	Tashkent, TK	Physics-Sun

02-2-1148-2010/2028

Baikal-GVD
Baikal Deep Underwater Gigaton-Scale Neutrino Telescope

Leader: I.A. Belolaptikov

Deputy: S.V. Rozov

Participating countries and international organizations:
Czech Republic, Kazakhstan, Russia, Slovakia.

The problem under study and the main purpose of the research:
Implementation of the project that includes upgrade and development of the Baikal-GVD deep-underwater detector up to the detection volume of 1 km^3 in studies of fluxes of high-energy neutrinos of astrophysical origin.

Project of the infrastructure:

Name of the project	Project leader	Project code
Laboratory Responsible from laboratories		**Status**
1. Baikal-GVD	**I.A. Belolaptikov** *Deputy*: **S.V. Rozov**	02-2-1148-1-2010/2028 Realization

DLNP V.F. Allakhverdyan, P.I. Antonov, I.V. Borina, V. Dik, A.A. Doroshenko, I.S. Dotsenko, T.V. Elzhov, A.N. Emelianov, A. Golubev, K.V. Golubkov, N.A. Gorshkov, B. Kalinova, I. Kamnev, S.A. Katulin, S.L. Katyulina, E.V. Khramov, M.M. Kolbin, K.V. Konischev, A.V. Korobchenko, M.V. Kruglov, E. Kulkova, T. Lednicka, M.L. Minaev, T.A. Morozova, D.V. Naumov, D.A. Orlov, D.P. Petukhov, E.N. Pliskovski, G.B. Safronov, I. Scherbakova, B.A. Shaybonov, A.S. Sheshukov, K.I. Shevchenro, M. Shevchenko, A.E. Sirenko, M.N. Sorokovikov, N.I. Sosunov, I.A. Stepkin, A.P. Stromakov, B.B. Ulzutuev, V. Volnykh, Z. Wang, Yu.V. Yablokova, E. Yakushev, A.A. Zaikin, S.I. Zavialov, D.V. Zubchenko, D.Yu. Zvezdov

MLIT M.S. Katulin, A. Soloviev

Abstract and scientific rationale:
The Baikal-GVD project is aimed at the further development of the gigaton-scale neutrino telescope for research in multimessenger astronomy, study of fundamental properties of the most energetic cosmic neutrinos, indirect search for galactic dark matter, and applied research. The international Baikal-GVD collaboration is constructing the neutrino telescope in Lake Baikal. The arrays of light-sensitive elements, housed in optical modules, detect Cherenkov light produced by charged particles in the lake water while travelling with the speed exceeding the speed of light in water. These particles could originate from interactions of neutrinos in water or in the bedrock. The energy and direction of original neutrinos are reconstructed from the amount of Cherenkov photons and time of their detection by single light-sensitive elements. The telescope is capable of investigating cosmic neutrinos and identifying their sources, searching for neutrinos from dark matter annihilation, and other rare phenomena. The scientific programme of the project is focused on solving fundamental problems of astrophysics and elementary particle physics: identification of astrophysical sources of ultra-high-energy neutrinos, revelation of mechanisms of formation and evolution of galaxies, etc. In particular, one of the short-range goals is mapping the high-energy neutrino sky in the Southern Hemisphere, including the region of the Galactic Centre. Other topics include the indirect search for dark matter by detecting neutrinos produced in WIMP annihilations in the Sun or in the Earth's interior. The Baikal-GVD will also search for exotic particles, such as magnetic monopoles, supersymmetric Q-balls, or nuclearites. The Baikal-GVD, the unique neutrino telescope, is one of the JINR basic facilities.

Expected results upon completion of the project:
Construction of the deep-underwater neutrino telescope of a scale of 1 km^3 in Lake Baikal. Study of high-energy neutrino fluxes from space, search for hypothetical particles – magnetic monopoles, as well as particles-candidates for dark matter. A large detection volume, in combination with a high angular and energy resolution and also with moderate background conditions typical of fresh water, makes it possible to effectively study the diffusive neutrino flux and fluxes from individual astrophysical objects with constant and variable luminosity.

Expected results for the project in the current year:
Data taking by 14 already installed clusters of the Baikal-GVD neutrino telescope. Search for and study of high-energy neutrinos of astrophysical origin. Preparation for deployment of the next detector clusters. Design and testing of the new system of data acquisition and data transmission which ensures the reduction of the threshold of detectable energies.

Collaboration 1148

Country or International Organization	City, region	Institute or laboratory	
Czech Republic	Prague, PR	CTU	
Kazakhstan	Almaty, ALA	INP	
Russia	Irkutsk, IRK	ISU	
	Moscow, MOW	MEPhI	
		SINP MSU	
	Nizhny Novgorod, NIZ	NNSTU	
	Saint Petersburg, SPE	SMTU	
	Troitsk, MOW	INR RAS	
Slovakia	Bratislava, BL	CU	

06-6-1118-2014/2030

MICC
Multifunctional Information and Computing Complex

Leaders: V.V. Korenkov
S.V. Shmatov

Deputies: A.G. Dolbilov
D.V. Podgainy
T.A. Strizh

Participating countries and international organizations:
Armenia, Azerbaijan, Belarus, Bulgaria, CERN, China, Egypt, France, Georgia, Kazakhstan, Mexico, Mongolia, Russia, South Africa, Uzbekistan.

The problem under study and the main purpose of the research:
The main objective of the MICC is to meet the needs of the JINR scientific community to the maximum extent possible in order to solve urgent tasks, from theoretical research and experimental data processing, storage and analysis to the solution of applied tasks in the field of life sciences. The tasks of the NICA project, the neutrino programme, the tasks of processing data from the experiments at the LHC and other large-scale experiments, as well as support for users of the JINR Laboratories and its Member States will be the priorities.

The Theme presupposes the inclusion of two activities, which, like the project, are aimed at meeting the requirements of a large number of research and administrative personnel:
– development of the digital platform "JINR Digital EcoSystem", which integrates existing and future services to support scientific, administrative and social activities, as well as to maintain the engineering and IT infrastructures of the Institute, which in turn will provide reliable and secure access to different types of data and enable a comprehensive analysis of information using modern technologies of Big Data and artificial intelligence;

– creation of a multi-purpose hardware and software platform for Big Data analytics based on hybrid hardware accelerators; machine learning algorithms; tools for analytics, reports and visualization; support of user interfaces and tasks.

Project of the infrastructure:

Name of the project	Project leaders	Project code
Laboratory Responsible from laboratories		Status
1. MICC Multifunctional Information and Computing Complex	**V.V. Korenkov** **S.V. Shmatov** *Deputies:* **A.G. Dolbilov** **D.V. Podgainy** **T.A. Strizh**	06-6-1118-1-2014/2030 Realization

MLIT K.N. Angelov, A.I. Anikina, A.V. Anisenkov, O.A. Antonova, A.I. Balandin, N.A. Balashov, A.V. Baranov, D.V. Belyakov, T.Zh. Bezhanyan, S.V. Chashchin, A.I. Churin, O.Yu. Derenovskaia, V.P. Dergunov, A.T. Dzakhoev, A.V. Evlanov, V.Ya. Fariseev, M.Yu. Fetisov, S.V. Gavrilov, A.P. Gavrish, T.M. Goloskokova, A.O. Golunov, L.I. Gorodnicheva, E.A. Grafov, E.N. Grafova, N.I. Gromova, A.E. Gushchin, A.V. Ilyina, N.N. Karpenko, I.I. Kalagin, A.S. Kamensky, I.A. Kashunin, M.Kh. Kirakosyan, A.K. Kiryanov, A.A. Kokorev, G.A. Korobova, S.A. Kretova, N.A. Kutovsky, I.V. Kudasova, O.N. Kudryashova, E.Yu. Kulpin, A.E. Klochiev, A.V. Komkov, V.I. Kulakov, A.A. Lavrentiev, Yu.M. Legashchev, M.A. Lyubimova, M.A. Maksimov, V.N. Markov, S.V. Marchenko, M. A. Matveev, A.N. Makhalkin, Ye. Mazhitova, A.A. Medyantsev, V.V. Mitsyn, N.N. Mishchenko, A.N. Mityukhin, A.N. Moibenko, I.K. Nekrasova, V.N. Nekrasov, D.A. Oleinik, V.V. Ovechkin, S.S. Parzhitsky, I.S. Pelevanyuk, D.I. Pryakhina, A.Sh. Petrosyan, D.S. Polezhaev, L.A. Popov, T.V. Rozhkova, Ya.I. Rozenberg, D.V. Rogozin, R.N. Semenov, A.S. Smolnikova, I.A. Sokolov, E.V. Solovieva, I.G. Sorokin, I.N. Stamat, V.P. Sheiko, D.A. Shpotya, B.B. Stepanov, A.M. Shvalev, O.I. Streltsova, Sh.G. Torosyan, V.V. Trofimov, N.V. Trubchaninov, E.O. Tsamtsurov, V.Yu. Usachev, S.I. Vedrov, A.S. Vorontsov, N.N. Voytishin, A.Yu. Zakomoldin, S.E. Zhabkova, M.I. Zuev

VBLHEP	K.V. Gertsenberger, A.O. Golunov, Yu.I. Minaev, A.N. Moshkin, O.V. Rogachevsky, I.V. Slepnev, I.P. Slepov
BLTP	A.A. Sazonov
FLNP	G.A. Sukhomlinov
FLNR	A.S. Baginyan, A.G. Polyakov, V.V. Sorokoumov
DLNP	Yu.P. Ivanov, V.A. Kapitonov, A.S. Zhemchugov
LRB	V.N. Chausov
UC	I.N. Semenyushkin

Abstract and scientific rationale:
To attain the major goals of JINR's flagship projects, it will be required to process a huge amount of experimental data. According to a very rough estimate, these are tens of thousands of processor cores and hundreds of petabytes of experimental data. The experiments of the NICA project and the JINR neutrino programme (Baikal-GVD, JUNO, etc.) entail Tier0, Tier1 and Tier2 grid infrastructures. To achieve these goals, it is essential to develop distributed multi-layer heterogeneous computing environments, including on top of the resources of the participants of other projects and collaborations.

The concept of the development of information technology, scientific computing and Data Science in the JINR Seven-Year Plan provides for the creation of a scientific IT infrastructure that combines a multitude of various technological solutions, trends and methods. The IT infrastructure implies the coordinated development of interconnected IT technologies and computational methods aimed at maximizing the number of JINR strategic tasks to be solved that require intensive data computing. The large research infrastructure project "Multifunctional Information and Computing Complex" holds a special place in this concept.

The MICC main objective for 2024-2030 is to perform a set of actions aimed at the modernization and development of the major hardware and software components of the computing complex, the creation of a state-of-the-art software platform enabling the solution of a wide range of research and applied tasks in accordance with the JINR Seven-Year Plan. The rapid development of information technology and new user requirements stimulate the development of all MICC components and platforms. The MICC computing infrastructure encompasses four advanced software and hardware components, namely, the Tier1 and Tier2 grid sites, the hyperconverged "Govorun" supercomputer, the cloud infrastructure and the distributed multi-layer data storage system. This set of components ensures the uniqueness of the MICC on the world landscape and allows the scientific community of JINR and its Member States to use all progressive computing technologies within one computing complex that provides multifunctionality, scalability, high performance, reliability and availability in 24x7x365 mode with the multi-layer data storage system for different user groups.

Within the MICC, it is provided to support the operation of all MICC hardware and software components, i.e., the Tier1 and Tier2 grid sites, the cloud infrastructure, the hyperconverged "Govorun" supercomputer, the multi-layer data storage system, the network infrastructure, the power supply and climate control systems, as well as to modernize/reconstruct the above components in accordance with new trends in the development of IT technologies and user requirements. In addition, it is required to ensure high-speed telecommunications, a modern local area network infrastructure and a reliable engineering infrastructure that provides guaranteed power supply and air conditioning for the server equipment.

Expected results upon completion of the project:
Modernization of the JINR MICC engineering infrastructure (reconstruction in accordance with modern requirements of the machine hall of the 4th floor of MLIT).

Modernization and development of the distributed computing platform for the NICA project with the involvement of the computing centres of the NICA collaboration.

Creation of a Tier0 grid cluster for the experiments of the NICA megaproject to store experimental and simulated data. Expansion of the performance and storage capacity of the Tier1 and Tier2 grid clusters as data centres for the experiments of the NICA megaproject, the JINR neutrino programme and the experiments at the LHC.

Enlargement of the JINR cloud infrastructure to broaden the range of services provided to users on the basis of containerization technologies. Automation of the deployment of cloud technologies in the JINR Member States' organizations.

Expansion of the HybriLIT heterogeneous platform, including the "Govorun" supercomputer, as a hyperconverged software-defined environment with a hierarchical data storage and processing system.

Design and elaboration of a distributed software-defined high-performance computing platform that combines supercomputer (heterogeneous), grid and cloud technologies for the effective use of novel computing architectures.

Development of a computer infrastructure protection system based on fundamentally new paradigms, including quantum cryptography, neurocognitive principles of data organization and data object interaction, global integration of information systems, universal access to applications, new Internet protocols, virtualization, social networks, mobile device data and geolocation.

Expected results for the project in the current year:
Operation and provision of the reliable, safe and integral functioning of backbone external telecommunication channels (3x100 Gbps), the backbone network (2x100 Gbps), the transport network of the NICA megaproject (4x100 Gbps), the MLIT mesh network (100 Gbps), and the Wi-Fi network at the Institute's sites in 24x7x365 mode. Provision of standard network services (email, file sharing, security), maintenance, support and development of user databases, network elements, etc. Introduction of dual authorization and certification authorities in the JINR network. Elaboration of alternative routes for external telecommunication channels with Chinese centers and other organizations participating in the JUNO and NICA projects.

Creation and commissioning of a server hall on the 4th floor of the MLIT building.

Ensuring the uninterrupted operation of the MICC engineering complex in 24x7x365 mode, including guaranteed power supply systems (diesel generators, uninterruptible power supplies), climate control systems (chillers, dry coolers, inter-row air conditioners, etc.), and fire safety systems for the machine hall on the 2nd floor of the MLIT building. Comprehensive maintenance and optimization of all engineering equipment to ensure the ultimate efficiency of the computing infrastructure. Modernization of Tier2 Module 1 (installation of inter-row air conditioners and additional telecommunication cabinets) within the development of the MICC engineering infrastructure. Modernization of the power supply system of Tier1 Module 0. Organization of new Module 3 based on existing telecommunication cabinets.

Expansion of the performance and storage system of the MICC basic components, namely, the Tier1 center up to 25,000 CPU cores and 25,000 TB, Tier2/CICC up to 13,000 CPU cores, the EOS-based data lake up to 60 PB, including dedicated EOS systems for MPD and SPD. Maintenance of the unified storage and access system for common software (CVMFS). Commissioning of additional drives for the connection of CTA and Enstore with the TS4500 tape library. Support and maintenance of the operation of WLCG virtual organizations, the NICA experiments, etc., local user groups on the MICC CICC/Tier1 and Tier2 resources. Elaboration of a regional center for the JUNO experiment on top of the MICC resources.

Development of the prototype of a fully functional Tier0/Tier1 center for the experiments at the NICA accelerator complex.

Enhancement of the distributed information and computing environment (DICE) on the basis of the cloud resources of the JINR Member States' organizations and the neutrino platform at the expense of resources acquired by the Baikal-GVD, JUNO, and NOvA experiments.

Modernization of performance metrics visualization tools for the cloud infrastructure and the failure notification system. Implementation of Ceph Dashboard, a new web interface for the centralized management of Ceph-based cloud storage.

Implementation of automation tools for launching tasks in a distributed heterogeneous environment created on top of the DIRAC platform. Integration of the FTS3 system for managing data transfer within the existing distributed environment. Conducting BM@N mass data production sessions, technical support for launching MPD experiment tasks.

Enlargement of the CPU component of the "Govorun" supercomputer to meet current user needs, including within event modeling for the experiments at the NICA complex. Automation of the processes of OS network loading and cluster software configuration using XCAT, Puppet, etc. software packages on the compute nodes of the "Govorun" supercomputer.

Implementation of a system for collecting, visualizing and analyzing statistics on the utilization of computing resources and software by users of the HybriLIT platform and the "Govorun" supercomputer.

Testing and implementation of parallel and distributed data storage and processing systems, such as Apache Ignite, Deepseek 3FS (Fire-Flyer File System), etc., to enhance the efficiency of working with model and experimental data on the HybriLIT platform and the "Govorun" supercomputer.

Enhancement of the ML/DL/HPC ecosystem, including the quantum computing polygon, and implementation of work on integrating the computing resources of the "Govorun" supercomputer on top of the DASK software product to solve massively parallel tasks related to machine and deep learning algorithms.

Maintenance of the data storage and processing system for the SPD experiment using the MICC resources (cloud infrastructure for hosting middleware services, CICC computing infrastructure for performing tasks). Support for carrying out mass modeling within the preparation stage for SPD experiment data taking, processing, and analysis.

Development of a hardware and software platform for monitoring the MICC engineering and computing infrastructure. Enhancement of the LITmon monitoring system: elaboration of a monitoring system for the server infrastructure to store SPD experiment data; modernization of monitoring the engineering infrastructure of the MICC cooling system; modernization of the serial console monitoring system; creation of a platform for the automatic deployment of the monitoring system.

Activities of the infrastructure:

Name of the activity	Leaders	Implementation period
Laboratory Responsible from laboratories		Status
1. The digital ecosystem (Digital JINR)	**V.V. Korenkov** **S.D. Belov**	2024-2026 Realization

MLIT A.A. Artamonov, N.A. Balashov, N.E. Belyakova, O.V. Belyakova, A.S. Bondyakov, N.A. Davydova, I.A. Filozova, L.A. Kalmykova, E.N. Kapitonova, A.O. Kondratiev, E.S. Kuznetsova, E.K. Kuzmina, S.V. Kunyaev, L.D. Kuchugurnaya, D.V. Neapolitanskiy, I.K. Nekrasova, M.M. Pashkova, L.V. Popkova, Ya.I. Popova, A.V. Prikhodko, T.F. Sapozhnikova, V.S. Semashko, S.V. Semashko, E.V. Sheiko, I.A. Sokolov, G.V. Shestakova, L.A. Shiryaeva, T.S. Syresina, Yu.V. Trofimov, D.Yu. Usov, T.N. Zaikina

VBLHEP V.V. Morozov, I.V. Slepnev, A.V. Trubnikov

DLNP R.S. Kovalenko

DSDD A.V. Sheiko, M.P. Vasiliev

Abstract and scientific rationale:
The activity is related to the creation of an Institute-wide digital platform "JINR Digital EcoSystem". The main objective is the organization of a digital space with a single access and data exchange between electronic systems, as well as the transition of actions that previously required a personal or written request to a digital form. The platform is designed to ensure the integration of existing and future services to support scientific, administrative and social activities, as well as to maintain the engineering and IT infrastructures of the Institute.

Within the activity, two main directions of work are planned: the creation of the basic infrastructure of the digital platform (including the software-hardware and methodological support of its functioning) and different digital services. In addition to service support, digital services for scientific collaborations, whose activity is related to JINR's basic facilities, will be developed and maintained for use by the Institute's staff members.

Expected results upon completion of the activity:
Creation of a hardware-software and methodological basis for the functioning of the Institute-wide digital platform.

Development and implementation of digital services for distributed access to resources (information, computing, administrative, organizational ones) in a unified environment.

Transition of the processes of getting permits, approvals and applications of different types into a digital form.

Creation of a catalogue and a distributed storage of data related to the scientific and technical aspects of the Institute's activity, as well as of tools for their analysis, presentation and the construction of predictive models.

Expected results in the activity in the current year:
Use of the unified environment for storing and managing data of basic and applied DES services, integration with the Big Data infrastructure to analyze the specified data.

Development of the institutional repository of publications of JINR staff members: transition to a new version of the repository software, connection of additional sources of information on articles, development of algorithms to link staff member profiles with articles, refinement of user interfaces, uploading articles of JINR staff members published before 2021 to the system.

Commissioning of a digital service for the centralized remote testing of JINR staff members' knowledge on radiation safety.

Implementation of electronic user registration on CICC resources.

Organization of an electronic system for accounting work and receiving requests from staff members for MLIT technical services.

Implementation of additional capabilities in the geoinformation system to support the activities of JINR technology services and departments upon their request. Integration of the geoinformation system with other DES services.

Ongoing support and development of the Dubna EDMS. Provision of procurement data for the document management system created by the Development of Digital Services Department.

Implementation of uploading electronic originals and copies of documents in the service of expense reports on business trips, optimization of request review processes.

Transition of the functionality of the baza.jinr.ru document database to the Dubna EDMS.

Development of digital collaboration services (scientific documentation database, project management, secure file sharing and collaboration service for documents of various types, etc.).

Development of the user support system and the electronic request system for various DES services, preparation of knowledge bases and documentation for users.

2. The multi-purpose hardware and software platform for Big Data analytics **P.V. Zrelov** 2024-2026

Realization

MLIT	A.A. Artamonov, D.A. Baranov, S.D. Belov, I.A. Filozova, Yu.E. Gavrilenko, O.V. Ivantsova, A.V. Ilyina, M.S. Katulin, I.A. Kashunin, E.A. Kuznetsov, M.A. Matveev, D.V. Neapolitanskiy, I.S. Pelevanyuk, N.V. Ryabov, R.N. Semenov, T.M. Solovieva, E.V. Sheiko, Yu.B. Starchenko, V.A. Tarabrin, T.N. Zaikina, D.P. Zrelova, A.V. Yakovlev
Assosiated personnel	A.V. Bogdanov, A.B. Degtyarev, Zu.U. Kiyamov, V.V. Korkhov, V.V. Mareev, N.L. Shchegoleva

Abstract and scientific rationale:
The activity provides for the creation of a multi-purpose hardware and software platform for Big Data analytics, which implements a full cycle of continuous processing, from data acquisition to the visualization of processing and analysis results, forecasts, recommendations and instructions, within the JINR MICC. One of the tasks planned to be solved using the platform is the elaboration of an analytical system for managing the MICC resources and data flows to enhance the efficiency of using computing and storage resources and optimize experimental data processing, as well as the development of the intelligent monitoring of distributed computing systems and data centres. Another essential task is the creation and development of analytics tools for the services of the JINR Digital EcoSystem.

Expected results upon completion of the activity:
Creation of a universal core of a Big Data mining platform.

Development and implementation of a number of standard software solutions for different classes of tasks within the platform.

Elaboration and development of analytics tools for the JINR Digital EcoSystem.

Development of methods and creation of complex solutions for analysing the security of data and computer systems.

Development of artificial intelligence methods within the analytical platform and creation of a software environment for work with technical and scientific information.

Elaboration of common solutions based on Big Data analytics for expert and recommendation systems, including for the optimization of the processes of functioning of the MICC components.

Expected results of the activity in the current year:
Deployment, configuration and service of access to autonomous specialized generative AI models and tools for interacting with them to solve the tasks of developing information systems and analyzing data.

Development of a prototype of a system for collecting, analyzing and storing traffic data from the JINR local area network with implementation in the form of a Big Data processing pipeline to enhance the network's security.

Elaboration of a methodology for the intelligent processing of scientific and technical information (scientific publications, patents, program and database registration materials, texts of projects, educational programs, job offers, CVs, etc.). Examples of implementation on the Institute's topics.

Development of a prototype of a software data platform on top of a composition of Big Data analytics tools, namely, Apache Spark, Dask, and the ROOT package, using hardware computing accelerators (graphics processors).

Analytical tools, hardware and software infrastructure and methods for integrating and analyzing data from Digital EcoSystem services.

Elaboration of quantum-like analogues of classical data analysis methods, in particular, machine learning methods, including the application of quantum convolutional and quantum generative adversarial neural networks.

Analysis of the possibility of using Industrial Internet of Things (IIoT) technologies for the JINR MICC engineering infrastructure: a) analysis of requirements for the IIoT system (parameters of the environment, types of equipment, data exchange protocols, and security requirements), b) development of a prototype of the system architecture, including the logical and physical structure of interaction of diverse components.

Study of the possibility of creating multi-level decentralized storage and its optimization:
– comprehensive analysis of the existing architecture of storage and processing systems within the MICC infrastructure and determination of optimal strategies for the system's development:

– development of analytical methods and software tools for modeling the behavior of a distributed system based on the MICC infrastructure.

Collaboration 1118

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	IIAP NAS RA
		RAU
Azerbaijan	Baku, BA	ADA
		IP
Belarus	Minsk, MI	INP BSU
		IP NASB
		JIPNR-Sosny
		UIIP NASB
Bulgaria	Sofia	INRNE BAS
		SU
CERN	Geneva, CH	CERN
China	Beijing, BJ	IHEP CAS
Egypt	Cairo, C	ASRT
France	Marseille, PAC	CPPM
Georgia	Tbilisi, TB	GRENA
		GTU
		UG
Kazakhstan	Almaty, ALA	INP
	Astana, AST	AB INP
		AITU
Mexico	Mexico City, CDMX	UNAM

Country or International Organization	City, region	Institute or laboratory
Mongolia	Ulaanbaatar	IMDT MAS
Russia	Chelyabinsk, CHE	SUSU
	Chernogolovka, MOS	SCC IPCP RAS
	Dubna, MOS	SCC "Dubna"
		SEZ "Dubna"
		Uni Dubna
	Gatchina, LEN	NRC KI PNPI
	Moscow, MOW	BMSTU
		FRC CSC RAS
		HSE
		IITP RAS
		ISP RAS
		KIAM RAS
		MEPhI
		MISIS
		MPEI
		MSU
		NRC KI
		PFUR
		PRUE
		RCC MSU
		RSCC
		SINP MSU
	Novosibirsk, NVS	BINP SB RAS
		ICMMG SB RAS
		SKIF
	Protvino, MOS	IHEP
	Pushchino, MOS	IMPB RAS
	Saint Petersburg, SPE	FIP
		ITMO
		SPbSPU
		SPbSU
	Samara, SAM	SNRU
	Taganrog, ROS	SRI MCS SFU
	Troitsk, MOW	INR RAS
	Vladikavkaz, SE	NOSU
	Vladivostok, PRI	IACP FEB RAS
	Voronezh, VOR	VSU
South Africa	Cape Town, WC	UCT
Uzbekistan	Tashkent, TK	AS RUz
		INP AS RUz

03-5-1129-2017/2028

DRIBs-III
Development of the FLNR Accelerator Complex and Experimental Setups

Leaders: I.V. Kalagin
S.I. Sidorchuk

Deputies: V. A. Semin

Scientific leader: Yu.Ts. Oganessian

Participating countries and international organizations:
Armenia, China, Kazakhstan, Mexico, Russia, Serbia, South Africa, Vietnam.

The problem under study and the main purpose of the research:
The implementation of the DRIBs-III that includes the upgrade and development of the FLNR cyclotron complex, expansion of the experimental infrastructure of the Laboratory (construction of new physics setups), and the development of accelerator systems. The project is aimed at improving the operation stability of accelerators and at increasing the intensity and improving the quality of ion beams of both stable and radioactive nuclides, while at the same time reducing power consumption. The goal of the project is to significantly improve the efficiency of experiments on the synthesis of superheavy elements and study of their properties.

In addition, the construction of the DC-140 accelerator complex for applied research is planned to be completed and commissioning work will be proceeding. The work is carried out under "The project for the creation of the JINR Innovation Research Center" as a part of "The FLNR research complex for materials science" project.

Within the theme quite as important are the support of physics experiments and the development of existing accelerators and experimental setups.

Projects of the infrastructure:

	Name of the project	Project leaders	Project code
1.	Construction of the U-400R accelerator complex	I.V. Kalagin A.V. Karpov *Deputy:* V. A. Semin	03-5-1129-1-2024/2028
2.	Development of the experimental setups to study the chemical and physical properties of superheavy elements	S.I. Sidorchuk *Deputy:* A.M. Rodin	03-5-1129-2-2024/2028

Projects:

	Name of the project	Project leaders	Status
Laboratory	Responsible from laboratories		
1.	**Construction of the U-400R accelerator complex**	**I.V. Kalagin** **A.V. Karpov** *Deputy:* **V.A. Semin**	Manufacture

FLNR M.B. Barbashev, V. Bass, E. Batchuluun, A.A. Bogachev, Y.A. Bolatkazyyev, A.N. Bykov, O.A. Chernyshev, A.N. Dey, I. Franko, K.B. Gikal, A.T. Issatov, Yu.M. Itkis, I.A. Ivanenko, G.N. Ivanov, R.K. Kabytayeva, N.Yu. Kazarinov, S.A. Klygin, E.A. Klenov. G.N. Knyazheva, E.M. Kozulin, N.I. Kozulina, G.A. Kononenko, A.V. Kulikov, K.A. Kulkov, V.I. Lisov, M.I. Makarov, K.V. Novikov, N.F. Osipov, S.V. Pashchenko, I.V. Pchelintsev, N.N. Pchelkin, A.G. Popeko, E.O. Savelieva, S. Satian, Yu.M. Sereda, A.A. Sidorov, A.A. Suslov, A.V. Tikhomirov, R.S. Tikhomirov, R.E. Vaganov, V.A. Veryovochkin, V.A. Vorobyov, A.N. Vorontsov, A.S. Zabanov, S.I. Zagrebayeva, A.O. Zhukova, S.Yu. Zinchenko

VBLHEP A.F. Markelov, A.S. Petuhov, A.A. Fateev

Abstract and scientific rationale:
The goal of the project is the construction of the U-400R accelerator complex for the detailed study of the mechanisms of nuclear reactions with stable heavy-ion beams (fusion–fission, quasifission, multinucleon transfer, etc.), synthesis of new nuclides in these reactions, and decay spectroscopy of nuclei under investigation.

The project encompasses such tasks as the construction of a new experimental hall, the upgrade of the U-400 cyclotron (U-400R following the modernization), and the construction of new separators and ion-guide systems for beam transport.

The accelerator complex will be used for the detailed study of the properties of the isotopes of heavy and superheavy elements and in searches for novel methods of synthesizing heavy nuclides. The studies do not imply the use of radioactive target material in amounts exceeding 10^5Bq.

Expected results upon completion of the project:
Upgrade of the U-400 cyclotron → U-400R.

Construction of a new experimental hall of U-400R.

Construction of new experimental set-ups and beam transport channels from U-400R.

Commissioning of the DC-140 accelerator complex for complex applied research.

Expected results of the project in the current year:
Implementation of the experimental programme at the U-400 cyclotron.

Completion of the construction of the U-400R experimental hall.

Start of the reconstruction of the U-400 (U-400R) cyclotron.

Construction of a beamline transport system following from building No. 131 to the U-400R experimental hall.

Development of a design of the STAR kinematic separator of multinucleon transfer reaction products.

Development of a design of the SCIF-D set-up for studying nuclear reaction mechanisms.

Development of methods for beam diagnostics of stable and radioactive nuclides.

2. **Development of the experimental setups to study the chemical and physical properties of superheavy elements**

S.I. Sidorchuk
Deputy:
A.M. Rodin

Manufacture

FLNR N.V. Aksenov, A.A. Astakhov, A.Yu. Bodrov, Y.A. Bolatkazyyev, G.A. Bozhikov, E.V. Chernysheva, I. Chuprakov, A.V. Guljaev, A.V. Guljaeva, A.I. Holtzman, D. Ibadullayev, R.K. Kabytayeva, P. Kohout, A. Kohoutova, A.B. Komarov, N.D. Kovrizhnykh, V.D. Kulik, D.A. Kuznetsov, A.Sh. Madumarov, I.V. Muravyov, A.S. Novoselov, A. Opihal, O.V. Petrushkin, A.V. Podshibyakin, V.S. Salamatin, V.D. Shubin, M.V. Shumeiko, D.I. Solovyev, V.Yu. Vedeneev, S.A. Yuhkimchuk

Abstract and scientific rationale:
Nowadays acceleration of high-intensity beams at the DC-280 cyclotron (SHE Factory) provides sufficient statistics in experiments on the synthesis of superheavy nuclei in the vicinity of the island of stability (Z=114, N=184), thereby opening up new avenues for research. Among the new opportunities the SHE Factory offers are first and foremost studies of the chemical properties of short-lived ($T_{1/2}$<0.5 s) isotopes of superheavy elements and precise measurements of their masses.

To carry out experiments on the synthesis of element 119 in the ^{50}Ti+^{249}Bk reaction, the SHE Factory upgrade project has to be implemented, providing re-equipping of some areas in compliance with Class 1 radiation safety regulations.

The project aims to create novel state-of-the-art experimental instruments. Experimental set-ups to be installed at the DC-280 cyclotron will be used for synthesizing and studying the physical and chemical properties of the isotopes of heavy and superheavy elements as well as in studies of nuclear reaction mechanisms, in nuclear spectrometry and mass spectrometry. To attain these goals, we are planning to construct a new gas-filled GASSOL separator whose key elements are a superconducting solenoid and a multi-reflection time-of-flight mass spectrometer.

Based on a superconducting solenoid magnet, the magnetic gas-filled separator (GASSOL) is intended for studying the physical and chemical properties of superheavy elements, including their short-lived ($T_{1/2}$< 0.5 s) isotopes, thereby establishing a pathway to elements heavier than Fl. In addition to the efficient separation of reaction products, the separator will focus nuclei of interest into a sport not exceeding 1 cm in diameter.

The specialized high-resolution mass spectrometer is designed for measuring the masses of superheavy elements with Z=104–118 and A=266–294 and their radioactive decay products with an accuracy of <100 keV. Its principle of operation is based on the multi-reflection time-of-flight (MR-ToF) technique.

Expected results upon completion of the project:
Development of methods for producing intensive beams of ^{48}Ca, ^{50}Ti, ^{54}Cr, etc.

Construction of the GASSOL gas-filled separator based on a superconducting solenoid for radiochemical studies of superheavy elements.

Construction of a multi-reflection time-of-flight mass spectrometer.

Expected results of the project in the current year:
Enabling experiments on the synthesis of superheavy elements and study of their properties at the Superheavy Element Factory.

Testing novel methods for producing ions of refractory metals (Ti, Cr).

Implementing the SHE Factory upgrade project involving re-equipment of experimental areas to comply with Class 1 radiation safety regulations.

Launching experiments on synthesis of element 119.

Assembling and commissioning of the superconducting gas-filled GASSOL separator.

Installing the GASSOL engineering systems and a beamline transport system from DC-280 to the separator.

Designing and manufacturing a test bench of the multi-reflection time-of-fight mass spectrometer.

Collaboration 1129

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
China	Lanzhou, GS	IMP CAS
Kazakhstan	Astana, AST	AB INP
Mexico	Cuernavaca, MOR	UNAM
Russia	Nizhny Novgorod, NIZ	IAP RAS
	Saint Petersburg, SPE	IAI RAS
		Neva-Magnet
		NIIEFA ROSATOM
	Tomsk, TOM	TSU
Serbia	Belgrade, BG	VINCA
	Novi Sad, VO	UNS
South Africa	Gqeberha, EC	NMU
	Somerset West, WC	iThemba LABS
	Stellenbosch, WC	SU
	Vanderbijlpark, GT	VUT
Vietnam	Hanoi, HN	HUST
		IOP VAST

Pulsed Neutron Source and the Complex of Spectrometers

Leader: E.V. Lychagin

Participating countries and international organizations:
Argentina, Armenia, Azerbaijan, Belarus, Bulgaria, China, Cuba, Czech Republic, Egypt, France, Germany, Hungary, IAEA, India, Italy, Japan, Kazakhstan, Latvia, Mongolia, Poland, Romania, Russia, Serbia, Slovakia, South Africa, Spain, Sweden, Switzerland, Tajikistan, USA, Uzbekistan, Vietnam.

The problem under study and the main purpose of the research:
Revealing the relationships between the structural features of materials and their physical properties at the microscopic level is one of the fundamental tasks that determines the development of modern concepts in the field of condensed matter physics, materials science, chemistry, geophysics, engineering, biology and pharmacology. The unique advantages of using neutron research methods make their application the most optimal, and in some cases the only approach for solving a wide range of topical fundamental and applied problems. For the successful implementation of the neutron research program, it is of utmost importance to support and develop large infrastructures, encompassing the neutron source and the suite of spectrometers.

The main objective of the project for the development of the complex of spectrometers is the continuous improvement of experimental techniques available to scientists. This is achieved mainly by increasing the number of controlled parameters, number of detectors, and sample environment systems used in the experiment. Quality is also improved by upgrading them, increasing the requirements for the accuracy and operation speed of data acquisition equipment, and ensuring remote control over spectrometer subsystems and the experiment. The user policy implemented on IBR-2 spectrometers imposes additional requirements for the equipment of the spectrometers, control systems, and data acquisition systems, which should be easy to master and use, have a user-friendly graphical interface and provide access to measurement results via the Internet.

The development of a concept for the new advanced neutron source at JINR is an important task, the successful solution of which is of key importance for the continuation of the neutron research program after the expiration of the IBR-2 service life. As part of this task, work on the development and construction of the new pulsed fast neutron reactor was included in the Seven-Year Plan for the Development of JINR for 2017–2023 and has been being continued in the current Seven-Year Plan for the Development of JINR for 2024–2030. The main stages of developing the concept of the new source include: development of a preliminary scientific program and determination of the composition of the suite of scientific instruments for conducting neutron research, development of technical specifications for the draft and infrastructure projects, justification of the design of the new neutron source, and the implementation of the research and development program. Work on the reactor design also includes computational and experimental research into the dynamics of pulsed reactors, optimization of the design of the main reactor systems, development of fuel and fuel rods based on it, optimization of the configuration of the complex of moderators, and development of prototypes or special test stands.

Projects and subprojects of the infrastructure:

	Name of the project / subproject	Project / subproject leaders	Project / subproject code
1.	Investigations of functional materials and nanosystems using neutron scattering	D.P. Kozlenko V.L. Aksenov A.M. Balagurov	04-4-1149-2-2021/2028
1.1.	Study of structure and dynamics of functional materials and nanosystems at the IBR-2 spectrometer complex	D.P. Kozlenko *Deputies:* M.V. Avdeev G.D. Bokuchava	04-4-1149-2-1-2024/2028
1.2.	Development of an inelastic neutron scattering spectrometer in inverse geometry BJN (Bajorek-Janik-Natkaniec) at the IBR-2 reactor	E.V. Raksha E.A. Goremychkin	04-4-1149-2-2-2021/2028
2.	Scientific and methodological research and developments for condensed matter investigations with IBR-2 neutron beams	V.I. Bodnarchuk V.I. Prikhodko	04-4-1149-3-2021/2028

2.1. Construction of a wide-aperture backscattering detector (BSD-A) for the HRFD diffractometer	V.M. Milkov	04-4-1149-3-1-2021/2028
2.2. Vector magnet for investigations with polarized neutrons	A.N. Chernikov	04-4-1149-3-2-2024/2028
2.3. Design and development of infrastructure elements for spectrometers at the IBR-2 reactor	V.I. Bodnarchuk V.I. Prikhodko M.V. Bulavin	04-4-1149-3-3-2024/2028
3. New advanced neutron source at JINR	E.V. Lychagin V.N. Shvetsov M.V. Bulavin	04-4-1149-4-2021/2028
3.1. Research and development for the justification of the draft design of the new advanced neutron source at JINR – NEPTUN pulsed fast reactor	E.V. Lychagin V.N. Shvetsov M.V. Bulavin	04-4-1149-4-1-2024/2028

Projects / Subprojects:

Name of the project	**Project leaders**	**Status**
Laboratory	Responsible from laboratories	
1. Investigations of functional materials and nanosystems using neutron scattering	**D.P. Kozlenko** **V.L. Aksenov** **A.M. Balagurov**	Realization
FLNP, LIT, BLTP, VBLHEP, FLNR	see subprojects participants	

Abstract and scientific rationale:

Within the framework of the project, it is planned to study the structural features, magnetic ordering, dynamics, physicochemical properties of new promising materials and nanosystems that demonstrate important functional properties, the microscopic mechanisms of which are poorly understood. The list of objects of study includes multiferroic materials, alloys with giant magnetostriction and shape memory effects, low-dimensional and geometrically frustrated magnets exhibiting unusual magnetic states and properties, materials promising for use in compact electric current sources, magnetic layered nanostructures demonstrating various proximity effects, for example, the coexistence of superconducting and magnetically ordered states, organic functional materials with hydrogen bonds, complex fluids and polymers with a wide range of potential technological applications, the structural organization and properties of which can change significantly with changes in concentration and chemical composition, biological nanosystems, including lipid membranes, proteins and their complexes, the study of which makes it possible to understand the biophysical processes occurring in living organisms, the mechanisms of action and transfer of drugs, the causes of various diseases, biohybrid materials, structural materials that are widely used or planned to be used in various industrial and manufacturing sectors. In addition, it is planned to conduct applied studies of texture, residual stresses and internal organization of rocks and minerals, structural materials, objects of natural and cultural heritage, aimed at establishing mechanisms of geophysical processes, formation of defects and stressed areas in industrial products, reconstruction and analysis of ancient technologies, evolution and development of classification of fossil organisms.

Expected results upon completion of the project:

In the process of realization of the scientific program, new experimental results will be obtained in the study of the relationship between the structural features and dynamics of new functional materials and nanosystems and their physical properties at the microscopic level, which are of great importance for the development of modern concepts in the field of condensed matter physics, chemistry, materials science, biophysics, geophysics and the development of advanced technologies in the field of electronics, compact power sources, pharmacology and medicine. During the implementation of the scientific program, theoretical predictions and models will be experimentally tested, and new phenomena and regularities will be revealed.

The implementation of the methodological program will result in the modernization of the available spectrometers and the development and construction of new instruments at IBR-2, which will expand the scope of their application for interdisciplinary scientific research of new functional materials and nanosystems.

Development and construction of basic elements of the BJN spectrometer will be performed.

Expected results of the project in the current year:

Realization of scientific program

Determination of structural parameters and phase states of functional alloys demonstrating magnetostriction and shape memory effects.

Establishing of relationship between structural, dielectric, ferroelectric и photocatalytic properties of complex substituted silver niobate oxides.

Determination of parameters of the atomic and magnetic structure of low-dimensional magnetic materials in a wide range of thermodynamic parameters (temperature, pressure).

Determination of characteristics of structural and magnetic phase states of functional materials at high pressure and analysis of their modification.

Analysis of complex structural and microstructural states of solid electrolytes and electrodes for metal-ionic accumulators.

Analysis of structural organization of optical nanomaterials, evolution of structural parameters of luminescent nanoparticles in a glass matrix.

Determination of structural features and analysis of the dynamics of functional materials with molecular complexes and ionic liquids.

Establishing of phenomena and effects related to the coexistence of magnetism and superconductivity in layered nanostructures composed of transition, rare-earth and other metals.

Determination of structural characteristics of carbon nanomaterials, including those used as electrode components of Li-based electric current sources.

Analysis of structural properties of magnetic nanosystems, including colloids, composites with magnetic nanoparticles, aggregation effects in magnetic fluids and core-shell nanostructures.

Determination of structural characteristics of polymer systems on substrates, surfactant micelles in bulk and on the surface, complexes of polymers with surfactant micelles.

Analysis of structural features of nanocomposite thin films, including silicate thin films with nanoparticles.

Analysis of phase separation effects in liquids at solid interfaces.

Analysis of physical and biological properties of lipid and native membranes, protein interactions, structure and properties of protein and membrane-protein complexes, crystallization of proteins.

Determination of structural characteristics and study of properties of biohybrid complexes.

Determination of residual stresses and microstrains in constructional materials and bulk products, geological objects.

Texture analysis of biological and paleontological objects, construction materials and earth rocks, cultural heritage objects.

Analysis of internal organization and construction of 3D models of cultural and natural heritage objects, industrial materials and products using neutron radiography and tomography.

Realization of instrument development program for the IBR-2 spectrometers

Installation of elements of the neutron transport system and detector system of the radiography and tomography mode of the small-angle scattering and imaging spectrometer on beamline 10.

Modernization of the detector system for the DN-12 diffractometer for studies of microsamples, which is aimed at improving its technical parameters and expanding the available range of high pressures.

Reconstruction of the Epsilon diffractometer for realization of texture studies.

Modernization of the REMUR reflectometer aimed at increasing the luminosity, polarization efficiency and improving background conditions, and developing sample environment systems.

Improvement of technical parameters and expansion of experimental capabilities of the GRAINS multifunctional reflectometer (development of liquid cells for experiments).

Modernization of the available IBR-2 spectrometers aimed at improving their technical characteristics, replacing obsolete and failed units.

Upgrade of the FSS correlation spectrometer on beamline 13 and improvement of its technical parameters. Further development of the RTOF correlation method.

Purchase and testing of pyrolytic graphite crystals for the development of the focusing analyzer of the BJN spectrometer, conducting test measurements with a prototype of the focusing analyzer at the IBR-2 reactor, development of the concept of the neutron guide system.

Name of the subproject	Subproject leaders	Status
1.1. Study of structure and dynamics of functional materials and nanosystems at the IBR-2 spectrometer complex	**D.P. Kozlenko** *Deputies:* **M.V. Avdeev** **G.D. Bokuchava**	Realization

FLNP M.V. Avdeev, G.D. Bokuchava, S.E. Kichanov, A.I. Kuklin, E.V. Raksha, V.A. Turchenko

LIT A.G. Soloviev , E.V. Zemlyanaya

BLTP V.Yu. Yushankhai

VBLHEP M.Yu. Barabanov

FLNR P.Yu. Apel, V.A. Skuratov

Abstract and scientific rationale:
The subproject is aimed at studying the features of the structure, magnetic ordering, dynamics, physical and chemical properties of novel promising functional and structural materials, complex liquids and polymers, nanosystems, geophysical objects. The explanation of microscopic mechanisms of the formation of their properties is important both for the development of modern concepts in the field of condensed matter physics, materials science, biophysics, chemistry, geophysics, pharmacology, engineering sciences, and new technological applications in energy production, electronics, biology and medicine.

Neutron methods for studying matter (diffraction, small-angle scattering, reflectometry, inelastic scattering, radiography and tomography) provide detailed information about the atomic and magnetic structure and dynamics of materials at the atomic and nanoscale levels. Due to the peculiarities of the interaction of slow neutrons with matter, neutron scattering methods are highly effective in determining the positions of light atoms surrounded by heavy ones, studying the distribution of elements with close atomic numbers, studying isotopic substitution processes and magnetic structures. This provides great advantages when using neutron scattering methods in the study of a wide range of promising functional materials and nanosystems compared to other approaches.

To ensure the solution of the scientific tasks of the project, it is planned to carry out work to ensure the uninterrupted operation, modernization and reconstruction of the existing spectrometers of the IBR-2 reactor, as well as to complete the work on the creation of a new small-angle scattering and imaging spectrometer. Along with neutron methods, complementary methods of X-ray scattering, Raman, atomic force spectroscopy, etc. with the application of additional laboratory equipment, will be used to improve the efficiency of solving the tasks.

Expected results upon completion of the subproject:
The realization of the scientific program is expected to result in obtaining new experimental information, which will be of importance for studying the relationship between the structural features and dynamics of new functional materials and nanosystems and their physical properties at the microscopic level, as well as for developing modern concepts in the field of condensed matter physics, chemistry, materials science, biophysics and geophysics. The obtained results can later be used to develop scientific foundations for the development of advanced technologies in the field of electronics, compact current sources, pharmacology and medicine. During the implementation of the scientific program, theoretical predictions and models will be experimentally tested, and new phenomena and regularities will be revealed.

The implementation of the methodological program will result in the modernization of the available spectrometers and the development and construction of new instruments at IBR-2, which will expand the scope of their application for interdisciplinary scientific research of new functional materials and nanosystems.

Expected results of the subproject in the current year:

Realization of scientific program

Determination of structural parameters and phase states of functional alloys demonstrating magnetostriction and shape memory effects.

Establishing of relationship between structural, dielectric, ferroelectric и photocatalytic properties of complex substituted silver niobate oxides.

Determination of parameters of the atomic and magnetic structure of low-dimensional magnetic materials in a wide range of thermodynamic parameters (temperature, pressure).

Determination of characteristics of structural and magnetic phase states of functional materials at high pressure and analysis of their modification.

Analysis of complex structural and microstructural states of solid electrolytes and electrodes for metal-ionic accumulators.

Analysis of structural organization of optical nanomaterials, evolution of structural parameters of luminescent nanoparticles in a glass matrix.

Determination of structural features and analysis of the dynamics of functional materials with molecular complexes and ionic liquids.

Establishing of phenomena and effects related to the coexistence of magnetism and superconductivity in layered nanostructures composed of transition, rare-earth and other metals.

Determination of structural characteristics of carbon nanomaterials, including those used as electrode components of Li-based electric current sources.

Analysis of structural properties of magnetic nanosystems, including colloids, composites with magnetic nanoparticles, aggregation effects in magnetic fluids and core-shell nanostructures.

Determination of structural characteristics of polymer systems on substrates, surfactant micelles in bulk and on the surface, complexes of polymers with surfactant micelles.

Analysis of structural features of nanocomposite thin films, including silicate thin films with nanoparticles.

Analysis of phase separation effects in liquids at solid interfaces.

Analysis of physical and biological properties of lipid and native membranes, protein interactions, structure and properties of protein and membrane-protein complexes, crystallization of proteins.

Determination of structural characteristics and study of properties of biohybrid complexes.

Determination of residual stresses and microstrains in constructional materials and bulk products, geological objects.

Texture analysis of biological and paleontological objects, construction materials and earth rocks, cultural heritage objects.

Analysis of internal organization and construction of 3D models of cultural and natural heritage objects, industrial materials and products using neutron radiography and tomography.

Realization of instrument development program for the IBR-2 spectrometers

Installation of elements of the neutron transport system and detector system of the radiography and tomography mode of the small-angle scattering and imaging spectrometer on beamline 10.

Modernization of the detector system for the DN-12 diffractometer for studies of microsamples, which is aimed at improving its technical parameters and expanding the available range of high pressures.

Reconstruction of the Epsilon diffractometer for realization of texture studies.

Modernization of the REMUR reflectometer aimed at increasing the luminosity, polarization efficiency and improving background conditions, and developing sample environment systems.

Improvement of technical parameters and expansion of experimental capabilities of the GRAINS multifunctional reflectometer (development of liquid cells for experiments).

Modernization of the available IBR-2 spectrometers aimed at improving their technical characteristics, replacing obsolete and failed units.

Upgrade of the FSS correlation spectrometer on beamline 13 and improvement of its technical parameters. Further development of the RTOF correlation method.

1.2. Development of an inelastic neutron scattering spectrometer in inverse geometry BJN (Bajorek-Janik-Natkaniec) at the IBR-2 reactor	**E.V. Raksha** **E.A. Goremychkin**	Realization

FLNP A.B. Eresko, A.A. Kruglov

Abstract and scientific rationale:
An analysis of the state of research in the field of condensed matter dynamics using inelastic neutron scattering (INS) at FLNP has shown that the existing NERA inelastic neutron scattering spectrometer, which some time ago successfully competed with similar facilities in European neutron centers, is now significantly outdated and no longer meets the needs of the user community in the Eastern European region. Therefore, an extremely important task is to upgrade the INS spectrometer in the historically established research area in order to maintain the competitive position of FLNP JINR in the field of neutron spectroscopy among other world neutron centers.

A promising approach is the creation of a new high-luminosity INS spectrometer that will use modern neutron optics and new design solutions to obtain high-resolution results with a good signal-to-background ratio over a wide range of energy transfer and using the smallest possible mass of the sample under study. This approach is proposed to be used to develop and construct a universal inverse geometry INS spectrometer BJN (**B**ajorek-**J**anik-**N**atkaniec). The combination of the high flux of the IBR-2 pulsed neutron source, modern focusing neutron optics, energy analyzers with a very large surface (two analyzers with an area of ~3.3 m^2) will ensure the maximum possible luminosity of the spectrometer being developed, while the gain factor compared to the NERA spectrometer can be up to a factor of 400.

The main range of scientific problems for which the BJN spectrometer will be used, includes:
– investigations of structural phase transitions at the microscopic level;

– study of proton diffusion processes in systems with different types of hydrogen bonds;

– study of the dynamics of protons in molecular crystals in a wide energy-transfer range;

– investigations of associative interactions of chemical particles, including systems with the formation of hydrogen bonds of various types;

– investigations of magnetic dynamics in compounds with 4*f* and 3*d* transition metals.

List of research objects:
– molecular crystals and their phase derivatives;

– pharmaceutical preparations in the bulk form and in the form of "micronized" or "amorphous" powders;

– new biologically active compounds, including nanostructured ones;

– energy storage materials;

– intermetallic compounds of 4*f* and 3*d* transition metals;

– catalysts;

– photonic materials for industrial applications;

– nanocomposite materials.

Expected results upon completion of the subproject:
Development and construction of basic elements of the BJN spectrometer.

Expected results of the subproject in the current year:
Purchase of pyrolytic graphite crystals to develop a focusing analyzer.

Test measurements with the model prototype of the focusing analyzer of the BJN spectrometer at the IBR-2 reactor.

Development of the concept of the neutron guide of the spectrometer.

Collaboration 1149-2

Country or International Organization	City, region	Institute or laboratory	
Armenia	Yerevan, ER	AANL	
		SRCHCH	
Azerbaijan	Baku, BA	AzTU	
		IP	
Belarus	Minsk, MI	BSTU	
		RI PCP BSU	
		SPMRC NASB	

Country or International Organization	City, region	Institute or laboratory
Bulgaria	Sofia	IE BAS
		IEES BAS
		INRNE BAS
		ISSP BAS
		UCTM
China	Dongguan, GD	CSNS
	Harbin, HL	HEU
Cuba	Havana	InSTEC
Czech Republic	Prague, PR	CTU
		IG CAS
		IP CAS
Egypt	Alexandria, ALX	AU
	Cairo, C	ASU
		EAEA
	Giza, GZ	CU
France	Gif-sur-Yvette, IDF	LLB
	Grenoble, ARA	IBS
		ILL
Hungary	Budapest	EK-CER
		Wigner RCP
India	Chennai, TN	IIT Madras
	Patna, BR	NIT Patna
Italy	Messina, ME	UniMe
Japan	Tokyo	Keio Univ.
		Waseda Univ.
Kazakhstan	Almaty, ALA	INP
		KazNU
		RPC Microbiology
Latvia	Riga	ISSP UL
Mongolia	Ulaanbaatar	IPT MAS
Poland	Bialystok, PD	UwB
Romania	Baia Mare, MM	TUCN-NUCBM
	Bucharest, B	INCDIE ICPE-CA
		UB
	Cluj-Napoca, CJ	INCDTIM
		RA BC-N
		UBB
	Constanta, CT	MINAC
	Iasi, IS	NIRDTP
		TUIASI
		UAI
		UAIC

Country or International Organization	City, region	Institute or laboratory
	Pitesti, AG	UPIT
	Targoviste, DB	VUT
	Timisoara, TM	ICT
		UVT
Russia	Chelyabinsk, CHE	SUSU
	Chernogolovka, MOS	ISSP RAS
	Dolgoprudny, MOS	MIPT
	Dubna, MOS	Uni Dubna
	Gatchina, LEN	NRC KI PNPI
	Kaliningrad, KGD	IKBFU
	Kazan, TA	FRC KazSC RAS
		KFU
		KPhTI FRC KSC RAS
	Krasnoyarsk, KYA	FRC KSC SB RAS
		KIP SB RAS
		SibFU
	Moscow, MOW	CQMM MIEM HSE
		FRC CP RAS
		IA RAS
		IEPT RAS
		IGEM RAS
		IGIC RAS
		IMET RAS
		INMI RAS
		Inst. Immunology FMBA
		IPE RAS
		KC CaPh
		MEPhI
		MIET
		MISIS
		MSU
		NRC KI
		PIN RAS
		SINP MSU
		VIAM
	Nizhny Novgorod, NIZ	IPM RAS
		UNN
	Omsk, OMS	OSTU
	Perm, PER	ICMM UrB RAS
		ITCh UrB RAS
	Rostov-on-Don, ROS	RIP SFU
		SFedU

Country or International Organization	City, region	Institute or laboratory
	Saint Petersburg, SPE	CRISM "Prometey"
		IMC NRC KI PNPI
		Ioffe Institute
	Stavropol, STA	NCFU
	Sterlitamak, BA	SB UUST
	Tomsk, TOM	TPU
	Troitsk, MOW	HPPI RAS
		INR RAS
	Tula, TUL	TulSU
	Tyumen, TYU	UTMN
	Yekaterinburg, SVE	IMP UB RAS
		UrFU
Serbia	Belgrade, BG	VINCA
	Novi Sad, VO	UNS
Slovakia	Kosice, KI	IEP SAS
South Africa	Pretoria, GT	Necsa
		UP
Spain	Barcelona, CT	ICMAB-CSIC
	Leioa, PV	BCMaterials
	Madrid, MD	CENIM-CSIC
Switzerland	Villigen, AG	PSI
Tajikistan	Dushanbe, DU	NAST
		PHTI NAST
		TTU
USA	Berkeley, CA	UC
Uzbekistan	Tashkent, TK	INP AS RUz
Vietnam	Da Nang, DN	DTU
	Hanoi, HN	IOP VAST

Name of the project	Project leaders	Status
Laboratory	Responsible from laboratories	
2. Scientific and methodological research and developments for condensed matter investigations with IBR-2 neutron beams	**V.I. Bodnarchuk** **V.I. Prikhodko**	Realization
FLNP	see subprojects participants	

Abstract and scientific rationale:

Condensed matter research using neutron scattering is carried out using fairly complex experimental equipment that allows the implementation of various neutron techniques. To obtain results at the level of world standards, it is necessary to constantly improve measurement techniques to ensure control and monitoring of numerous experimental parameters, improve the operation speed and resolution of data acquisition equipment, and control various mechanisms and sample environment systems. The user policy carried out at the IBR-2 spectrometers imposes additional requirements for the equipment of the spectrometers, control systems, and data acquisition systems, which should be easy to master and easy to use, should have convenient graphic interface and provide access to measurement results via the Internet, etc.

Expected results upon completion of the project:
Commissioning of BSD detector at HRFD on beamline 5 of the IBR-2 reactor and obtaining the first experimental results.

Development of a vector magnet based on asymmetric Helmholtz coils, with a temperature control device for low (1.5 K) and ultra-low (down to 0.5 K) temperatures for the REMUR reflectometer.

Installation of a new chopper on beamline 8 of the IBR-2 reactor.

Development and manufacture of position-sensitive neutron counters of various diameters with resistive anodes.

Development of a test stand to test the characteristics of PSDs.

Development of a standard module of a PSD system based on resistive-wire tubes with a cathode diameter of 6 mm.

Development and commissioning of a new detector system for the REMUR spectrometer.

Development and fabrication of direct-beam monitor at the YuMO spectrometer.

Development of the architecture of a multi-gap ^{10}B-PPRC, manufacture of the prototype and study of its characteristics.

Development of a multi-counter system for the inelastic scattering instrument being designed on beamline 2 of IBR-2.

Adjustment and testing of the ASTRA-M detector at the FSD spectrometer.

Development of a technical design for the BSD-FSD backscattering detector for the FSD spectrometer.

Development of a new ±90°-detector with combined electronic and time focusing, similar to the ASTRA-M detector on the FSD spectrometer.

Development of detector electronics and data acquisition, pre-processing and accumulation systems for new detector systems. Introduction of multichannel digitizers into the measuring systems of IBR-2 spectrometers.

Introduction of PLCs into control systems of spectrometers. Equipping spectrometers with video surveillance systems. Introduction of new measuring devices and controllers at the request of instrument responsible persons. Automation of the vacuum control system on spectrometers NERA, SKAT, FSD, FSS. Automation of the control system of the magnet current source for the DN-12 cryostat. Unification of temperature control and regulation systems used on IBR-2 spectrometers.

Development of a new cryostat for cooling high-pressure chambers at the DN-12 diffractometer.

Development and implementation on the IBR-2 spectrometers of a new version of the Sonix+ software package and related systems adapted to work with the event list data format.

Continuous modernization (in cooperation with LIT) of the FLNP local area network segment.

Simulation of spectrometers or its elements for the purpose of modernization of operating spectrometers and for the development of the new one.

Commissioning of an automated storage of containers with irradiated samples and an automated sample positioning system at the irradiation facility.

Providing of uninterrupted operation of all spectrometers on IBR-2 beamlines.

Expected results of the project in the current year:
Commissioning of BSD detector at HRFD on beamline 5 of the IBR-2 reactor and obtaining the first experimental results.

Development and manufacture of position-sensitive neutron counters of various diameters with resistive anodes.

Development of a standard module of a PSD system based on resistive-wire tubes with a cathode diameter of 6 mm.

Development of a test stand to test the characteristics of PSDs.

Development and fabrication of direct-beam monitor at the YuMO spectrometer.

Development of a multi-counter system for the inelastic scattering instrument being designed on beamline 2 of IBR-2.

Adjustment, testing and commissioning of the ASTRA-M detector on the FSD spectrometer.

Development of a new ±90° detector with space and time focusing for the FSS diffractometer, which is similar to the ASTRA-M detector, along with detector electronics and data acquisition and accumulation electronics.

Development of a project of a detecting module and data acquisition system for the multi-detector system of the DN-12 spectrometer; testing of elements of the data acquisition system on a neutron beam.

Development of infrastructure for constructing neutron detectors.

Introduction of digitizers into the measuring systems of IBR-2 spectrometers (FSD, FSS and HRFD).

Assembly of a cryostat of the REMUR reflectometer. Assembly site: cryogenic stand, building 119.

Development, installation and commissioning of the control system of the CM-202 moderator in the direction of IBR-2 beamlines №№ 7, 8, 10, 11, as well as the dispatch system for automated control of the complex of cryogenic moderators. Implementation of the program and methodology for testing the system at power, commissioning.

Assembly of a test cryostat for studying current leads and magnet coils.

Production of sections of HTSC tape necessary for winding magnet coils by soldering its pieces.

Development of a system for high-precision movement of facility equipment towards the IBR-2 reactor; manufacturing of an automated storage facility for radioactive samples in accordance with the developed design documentation. Study of radiation resistance of materials at the radiation research facility of the IBR-2 reactor.

Development and implementation on the IBR-2 spectrometers of a new version of the Sonix+ software package and related systems adapted to work with the event list data format.

Development of the Sonix+ software package for connecting new systems, DAQ controllers and sample environment devices according to user requests.

Ongoing and timely support of the FLNP local area network segment and its modernization in accordance with the plans of the Laboratory of Information Technologies, as well as maintenance of the FLNP Central Computing Complex.

Name of the subproject	Subproject leader	Status
2.1. Construction of a wide-aperture backscattering detector (BSD-A) for the HRFD diffractometer	**V.M. Milkov**	Realization

FLNP A.M. Balagurov, A.A. Bogdzel, N.N. Bogobmolova, O.N. Bogomolova, O. Daulbaev, V.A. Drozdov, Hai Van, P.A. Kislitsyn, A.A. Kozlyakovskaya, A.K. Kurilkin, E.I. Litvinenko, G.E. Malkova, S.M. Murashkevich, M.M. Podlesny, V.V. Shvetsov, O.V. Volodin

Abstract and scientific rationale:
At present, the HRFD detector system consists of three detectors, two of which are located at scattering angles of ±152°, and the third one at 90°. The first two detectors are mVainly used to study the structure of polycrystals, and the third one is employed to measure internal stresses. The detecting element is Li-glass-based scintillators. From the present-day viewpoint, these detectors have two disadvantages: high sensitivity to γ-background and insufficiently large solid angle (~0.16 sr). Due to this, the resulting diffraction spectra have a rather high background and a low (by modern criteria) data acquisition rate, despite the fact that the neutron flux at the sample position is sufficiently high (10^7n/cm^2/s).

To eliminate these shortcomings, in 2017 it was proposed to replace the existing backscattering detectors with a new wide-aperture scintillation detector based on the ZnS(Ag)/^{6}LiF scintillator using combined electronic-geometric focusing. Its implementation will make it possible to radically improve the parameters of the HRFD diffractometer and bring it to the leading positions in the world. Estimates show that the use of the new wide-aperture detector will allow an approximately two- to three-fold increase in the number of experiments, along with a significant improvement in the accuracy of the obtained structural information, and the expansion of the capabilities of the diffractometer for performing experiments under various external conditions at the sample position.

Expected results upon completion of the subproject:
Commissioning of BSD-A detector at HRFD on beamline 5 of the IBR-2 reactor and obtaining the first experimental results.

Expected results of the subproject in the current year:
Commissioning of BSD-A detector at HRFD on beamline 5 of the IBR-2 reactor and obtaining the first experimental results.

2.2. Vector magnet for investigations with polarized neutrons	**A.N. Chernikov**	Realization

FLNP A.V. Altynov, V.I. Bodnarchuk, A.P. Buzdavin, F.A. Chervyakov, U.D. Lusina, I.A. Morkovnikov, T.B. Petukhova, V.V. Sadilov, N.D. Zernin, V.D. Zhaketov

Abstract and scientific rationale:
Reflectometry of polarized neutrons is an experimental method for studying low-dimensional metal heterostructures, polymer films, biological systems, the free surface of liquids, magnetic fluids, and requires experimental equipment that includes a special magnetic system. The developed magnetic system—a vector magnet—will allow changing the direction of the

magnetic field in two directions and will have an aperture that allows placing a temperature control device at low and ultra-low temperatures, as well as a neutron and gamma-ray detection system. The vector magnet will be installed on the REMUR reflectometer on beamline 8 of the IBR-2 reactor.

Expected results upon completion of the subproject:
Development of a vector magnet based on asymmetric Helmholtz coils, with a temperature control device for low (1.5 K) and ultra-low (down to 0.5 K) temperatures for the REMUR reflectometer.

Expected results of the subproject in the current year:
Assembly of a cryostat of the REMUR reflectometer.

Assembly of a test cryostat for studying current leads and magnet coils.

Production of sections of HTSC tape necessary for winding magnet coils by soldering its pieces.

2.3. Design and development of infrastructure elements for spectrometers at the IBR-2 reactor

V.I. Bodnarchuk
V.I. Prikhodko
M.V. Bulavin

Realization

FLNP Yu.A. Astakhov, V.V. Bulavina, A.V. Churakov, T.N. Dydyshko, V.Yu. Egorov, O.V. Ermolaeva, A.I. Ioffe, I.V. Kovalev, A.G. Kolesnikov, T.V. Milkova, A.S. Ovodov, M.O. Petrova, G.A. Sukhomlinov, N.V. Shvetsov, V.K. Shirokov, E.Yu. Voskanyan, K.B. Yakovlev, V.V. Zhuravlev

Abstract and scientific rationale:
The IBR-2 reactor is a unique neutron source, which is used to study the structure and physical properties of condensed matter. Information about objects under study is obtained using specialized neutron scattering instruments (spectrometers) by applying various research techniques. The quality of the obtained information is largely determined by the characteristics of the neutron source and the quality of experimental equipment. The IBR-2 pulsed reactor is a high-flux neutron source with a power of over 1 MW. The key requirements for the equipment of scientific instruments are the most efficient use of the thermal neutron flux within the framework of the implemented methodology. The equipment of any spectrometer is quite diverse and includes elements that form a neutron beam, systems for detecting neutron and other types of radiation, various systems for monitoring and controlling experiments, special equipment for creating the required conditions at the sample position during measurements, etc. At the same time, all elements and mechanisms must perform their functions under conditions of increased radiation load and ensure uninterrupted operation for long periods of time. Each spectrometer is a unique object even within the framework of the implementation of one and the same technique at the same source. Despite the fact that the equipment of IBR-2 instruments includes a number of standard elements, their configuration is always unique and requires special attention.

This sub-subproject is aimed at fulfilling the tasks of designing and developing reliable and efficient elements of spectrometers for comprehensive support of experimental work and obtaining high-level scientific results.

The high qualification of the personnel of the Department of the IBR-2 spectrometers' complex (SC) and their extensive experience in the development and operation of equipment and control systems for the IBR-2 spectrometers will undoubtedly make it possible to implement this sub-subproject aimed at further improving the experimental infrastructure of the IBR-2 reactor. The sub-subproject consists of 7 sections, each representing a separate element of the experimental infrastructure.

Expected results upon completion of the subproject:
Development of technical documentation for the equipment of control systems of the complex of cryogenic moderators of the IBR-2 reactor; commissioning of control systems for the collector unit and cooling pipelines, and cryogenic moderators CM-201 and CM-202; installation of a dispatch system with a server that integrates control over the entire complex of cryogenic moderators, commissioning of the dispatch system.

Installation of a new chopper on beamline 8 of the IBR-2 reactor.

Introduction of automatic PLC-based control systems to control the vacuum integrity in the channels.

Development and manufacture of position-sensitive neutron counters of various diameters with resistive anodes.

Development of a test stand to test the characteristics of PSDs.

Development of a data acquisition system based on multichannel digitizers.

Development of a standard module of a PSD system based on counters with resistive anodes and a cathode diameter of 6 mm.

Development and putting into operation of a new detector system for the REMUR spectrometer.

Development and fabrication of direct-beam monitor at the YuMO spectrometer.

Development of the architecture of a multi-gap ^{10}B-PPRC, manufacture of the prototype and study of its characteristics.

Development of a multi-counter system for the inelastic scattering instrument being designed on beamline 2 of IBR-2.

Adjustment and testing of the ASTRA-M detector at the FSD spectrometer.

Development of a technical design for the BSD-FSD backscattering detector for the FSD spectrometer.

Development of a new ±90°-detector with combined electronic and time focusing, similar to the ASTRA-M detector on the FSD spectrometer.

Introduction of multichannel digitizers into the measuring systems of IBR-2 spectrometers.

Introduction of PLCs into control systems of spectrometers. Equipping spectrometers with video surveillance systems. Introduction of new measuring devices and controllers at the request of instrument responsibles. Automation of the vacuum control system on spectrometers NERA, SKAT, FSD, FSS. Automation of the control system of the magnet current source for the DN-12 cryostat. Unification of temperature control and regulation systems used on IBR-2 spectrometers.

Development of a new cryostat for cooling high-pressure chambers at the DN-12 diffractometer.

Development and implementation on the IBR-2 spectrometers of a new version of the Sonix+ sotware package and related systems adapted to work with the event list data format.

Continuous modernization (in cooperation with LIT) of the FLNP local area network segment.

Simulation of spectrometers or its elements for the purpose of modernization of operating spectrometers and for the development of the new one.

Study of radiation resistance of materials at the radiation research facility of the IBR-2 reactor. Regular operation of a system for high-precision movement of facility equipment towards the IBR-2 reactor; manufacturing of an automated storage facility for radioactive samples in accordance with the developed design documentation.

Providing of uninterrupted operation of all spectrometers on IBR-2 beamlines.

Expected results of the subproject in the current year:
Development, installation and commissioning of the control system of the CM-202 moderator in the direction of IBR-2 beamlines 7, 8, 10, 11 , as well as the dispatch system for automated control of the complex of cryogenic moderators. Implementation of the program and methodology for testing the system at power, commissioning. Development of an automated high-performance device for the production of working material for the complex of IBR-2 cryogenic moderators.

Development and manufacture of position-sensitive neutron counters of various diameters with resistive anodes.

Development of a standard module of a PSD system based on counters with resistive anodes and a cathode diameter of 6 mm.

Development of a test stand to test the characteristics of PSDs.

Development and fabrication of a direct-beam monitor at the YuMO spectrometer.

Development of a multi-counter system for the inelastic scattering instrument being designed on IBR-2 beamline 2.

Adjustment and testing of the ASTRA-M detector at the FSD spectrometer.

Development of a new ±90°-detector with combined electronic and time focusing, similar to the ASTRA-M detector on the FSD spectrometer.

Development of a project of a detecting module and data acquisition system for the multi-detector system of the DN-12 spectrometer; testing of elements of the data acquisition system on a neutron beam.

Introduction of multichannel digitizers into the measuring systems of IBR-2 spectrometers.

Development and implementation on the IBR-2 spectrometers of a new version of the Sonix+ sotware package and related systems adapted to work with the event list data format.

Support and development of the SONIX+ software on requests of responsibles, based on USB-3 adaptation of SONIX+ software for the operation with DAQ controllers. Development of the new version of SONIX+ software adjusted for the operation in the list mode.

Ongoing and timely support of the FLNP local area network segment and its modernization in accordance with LIT plans, as well as maintenance of the FLNP Central Computing Complex.

Study of radiation resistance of different materials at the radiation research facility. Development of a system for high-precision movement of the radiation research facility as part of a robotic system for handling radioactive samples with a visual and dose monitoring system; manufacturing of an automated storage facility for radioactive samples in accordance with the developed design documentation.

Putting into operation of new measuring devices and controllers at the request of instrument-responsible scientists.

Collaboration 1149-3

Country or International Organization	City, region	Institute or laboratory
Belarus	Minsk, MI	INP BSU
Czech Republic	Rez, ST	UJV
Egypt	Cairo, C	EAEA
Hungary	Budapest	Wigner RCP
Kazakhstan	Almaty, ALA	INP
Romania	Bucharest, B	IFIN-HH
	Cluj-Napoca, CJ	INCDTIM
		UBB
		UTC-N
	Targoviste, DB	VUT
Russia	Dolgoprudny, MOS	MIPT
	Dubna, MOS	Uni Dubna
	Gatchina, LEN	NRC KI PNPI
	Kazan, TA	KFU
	Moscow, MOW	NRC KI
	Troitsk, MOW	INR RAS
	Yekaterinburg, SVE	IMP UB RAS
Sweden	Lund, M	ESS ERIC
Uzbekistan	Tashkent, TK	INP AS RUz

Name of the project	Project leaders	Status
Laboratory	Responsible from laboratories	
3. New advanced neutron source at JINR	**E.V. Lychagin** **V.N. Shvetsov** **M.V. Bulavin**	Realization
FLNP	see subproject participants	

Abstract and scientific rationale:
According to Article 4 of the JINR Charter, one of the main areas of research at the Institute is condensed matter physics using nuclear physics methods. The main instrument for this research at the Institute is the neutron beamlines of the IBR-2M reactor at FLNP.

Despite the rapid development in recent decades of various experimental methods for studying the condensed state of matter, neutrons remain in a number of cases the only research probe due to their high sensitivity to light elements, isotopic composition, sensitivity to magnetic fields and high penetrating power. In FLNP JINR, tremendous experience has been accumulated in using neutron beamline instruments of unique pulsed reactors of several generations: IBR, IBR-30, IBR-2,

IBR-2M. The state-of-the-art suite of instruments of the IBR-2M reactor makes it possible to conduct applied and fundamental research using almost all neutron scattering techniques. This suite and the user access policy in the form of the User Program are a center of attraction for a large number of researchers from JINR Member States and partner countries.

The main neutron source IBR-2M, currently operating at JINR, is a unique facility that has no analogues in the world, the development and construction of which is one of the most striking achievements of JINR. The expected service life of the reactor (taking into account the possibility of replacing the fuel, extending the license) ends in the early 1940s. Based on this, one of the most important tasks of the Institute is to develop a project for an advanced neutron source that should replace the IBR-2M reactor and could be constructed by the mid-1940s.

Today, the competitiveness of neutrons as a research tool is largely determined by the time required to perform measurements, the accuracy of determining the measured parameters (both spatial and energy), and the minimum and maximum sizes of samples available for research. These possibilities are determined by both the quality of the neutron source itself and the quality of the beamline instruments. Accordingly, one of the main parameters determining the prospects of the source is the achievable neutron flux on the samples under study. The project "New Advanced Neutron Source at JINR" is aimed at developing such a source. Within the framework of the project, the type and parameters of the source, the number and type of moderators, the schemes of optical systems for neutron beamlines, as well as the list of necessary instruments should be determined based on the areas of advanced research with neutrons.

Since 2016, the development of the project for a new advanced neutron source has been underway at FLNP JINR. Taking into account the development trends of high-intensity sources in the world, the current market situation and the extensive experience of the Frank Laboratory of Neutron Physics, it was decided that the new source at JINR should be a pulsed one. Various options were considered: a source based on a proton accelerator with a non-multiplying target, with a multiplying target and mechanical modulation of the multiplication factor (superbooster), various options for a pulsed reactor.

As a result, the work on the development of the new pulsed reactor NEPTUN was included in the seven-year plan for the long-term development of JINR for 2024-2030 as a subproject of the project for the development and construction of the new advanced neutron source at JINR. The concept of the NEPTUN pulsed fast reactor with neptunium nitride fuel was selected based on the results of work carried out in the previous seven-year period, and supported and approved at the 51st meeting of the PAC for CMR in January 2020 for further elaboration.

In 2025, based on the results obtained during the design, the General Designer, represented by JSC NIKIET, was tasked with developing an alternative concept for a pulsed reactor with high performance characteristics, the construction of which is possible in a relatively short (15 years) period of time.

Expected results upon completion of the project:
Development of the scientific program and the concept of the suite of instruments for conducting scientific and applied research at the new neutron source.

Determination of the type of the source and its parameters.

Obtaining the necessary initial data for developing a preliminary design of the source and a design of the necessary infrastructure.

Estimation of the cost of the project implementation.

Selection of optimal materials for use as cryogenic moderators at the new neutron source. Selection of technology for developing a complex of cryogenic moderators at the new neutron source depending on the choice of moderating material.

Expected results of the project in the current year:
Analysis of source types/variants for further design, taking into account the studied options.

Comparison of the efficiency of different hydrogen-containing moderators with different geometries.

Development of a prototype facility for the implementation of technology for continuous loading and unloading of frozen material into a moderator chamber.

Proposals for the layout of beamlines and the concept of the suite of instruments at the source.

Development of a software verification scheme for a pulsed reactor.

Name of the subproject	Subproject leaders	Status
3.1. Research and development for the justification of the draft design of the new advanced neutron source at JINR — NEPTUN pulsed fast reactor	**E.V. Lychagin V.N. Shvetsov M.V. Bulavin**	Realization

FLNP M.V. Avdeev, A.M. Balagurov, V.I. Bodnarchuk, G.D. Bokuchava, K.V. Bulatov, O.E. Chepurchenko, P.A. Dorofeev, V.V. Ermolaev, T.Yu. Fedorova, A.I. Frank, A.V. Galushko, E.A. Goremychkin, D.S. Grozdov, A.A. Khassan, K. Khramko, S.E. Kichanov, Yu.N. Kopach, D.P. Kozlenko, N. Kučerka, A.I. Kuklin, I.V. Kushnir, E.E. Perepelkin, M.M. Podlesnyy, M.V. Rzyanin, E.P. Shabalin, A.E. Verkhoglyadov, I. Zinicovscaia, 3 engineers, 3 researchers

VNIITF S.A. Andreev, D.V. Khmelnickii, 3 researchers

VNIINM A.V. Davydov, Yu.A. Ivanov, 7 engineers, 4 researchers

NIKIET A.B. Goryachikh, A.V. Lopatkin, I.T. Tretyakov, 4 engineers, 3 researchers

Abstract and scientific rationale:

The main stages of work on the development and construction of the new reactor include: justification of the design of the new neutron source, development of technical specifications for the draft and infrastructure projects, as well as the implementation of an R&D program that includes a computational and experimental study of the dynamics of pulsed reactors, optimization of the design of the main reactor systems, development of fuel and fuel rods based on it, optimization of the configuration of the complex of moderators, development of prototypes or special test stands (for example, an experimental test stand or a prototype of a reactivity modulator, a prototype of experimental fuel rods, test stand for a mesitylene-based cryogenic moderator with a system for fast change of the working material, etc.).

In accordance with the roadmap of the NEPTUN project, the next major stage after the completion of the stages of conceptual design and development of a technical proposal is a draft design. A draft design is developed to determine the principal (constructive, schematic, etc.) solutions for the product, giving a general idea of the working principle and (or) the design of the product. On the basis of the draft design, a justification for investments is developed, which is an obligatory document in the development of such a complex facility as a research reactor (Decree of the Government of the Russian Federation №306 of 14.03.1997).

At the draft design stage, the development and selection of the main technical solutions, the study of structural and functional schemes of the product, the selection of basic structural elements, etc. are carried out. As a rule, at this stage, one or two variants of the reactor are considered from among those recognized as feasible at the conceptual design stage.

The choice of a specific core configuration option is the most important moment and the key point of the entire project of construction of the NEPTUN reactor. This is due to the fact that the technical solutions fixed in the draft design, further at the next stages (technical design, preparation of working design documentation), being included in the voluminous design documentation, can only be changed with great difficulty. Therefore, already before the draft design stage, a thorough study of all controversial and ambiguous points is required, as well as R&D and calculations (kinematic, electrical, thermal, etc.) that confirm the operability and reliability of the product in all specified operating conditions.

The main objective of the subproject is to conduct research and development work to justify the development of the draft design of the NEPTUN reactor. These R&D include: development of neptunium-nitride fuel and neptunium-nitride-based fuel rods; study of dynamics of the pulsed reactor; optimization of the design of the reactivity modulator and the reactor vessel in terms of reducing thermal loads and shape changing; development and implementation of a list of R&D to justify the development of the draft design.

The work carried out jointly with JSC NIKIET from 2020 to 2023 represents a serious research and development and experimental design study of the concept of the NEPTUN reactor, however, the issues and problems that have arisen, primarily regarding the determination of the power threshold for reactor stability, concerning the layout of the core, technical solutions in the design of the reactor vessel and the reactivity modulator, do not yet allow us to proceed to the draft design stage.

The results of the work in 2021-2024 showed that, firstly, the configuration of the core has a stronger impact on the threshold of power stability of the pulsed reactor than previously thought, and secondly, the amount of R&D work required to implement the concept under consideration based on neptunium nitride fuel leads to a long period for the development and construction of the new reactor, significantly exceeding the potential service life of the existing IBR-2M reactor (early 1940s).

In this context, in 2025, the main efforts were focused on studying the mechanisms for the formation of power feedback in pulsed reactors, developing mathematical models describing the processes leading to pulse energy fluctuations, including taking into account the operating experience of the IBR-2 and IBR-2M reactors.

Expected results upon completion of the subproject:
Development of a computer model describing the phenomenon of vibrational instability of a pulsed reactor, including neutron-physical, thermohydraulic and thermomechanical calculation modules.

Determination of the reactor core configuration.

Justification of technical solutions for the design of the vessel and reactivity modulator with permissible thermal loading and temperature deformations.

Development of a list of R&D necessary to justify the design of the reactivity modulator, its components and the reactor vessel.

Determination of the maximum power of the NEPTUN reactor, taking into account the permissible fluctuations and temperature deformations of its components of the core, vessel and modulator.

Expected results of the subproject in the current year:
Experimental determination of parameters of model fuel rods or fuel assemblies for the NEPTUN reactor on the FLNP test stand when using various fastening schemes. Calculations of the dynamics of periodic pulsed reactors taking into account the obtained experimental data within the framework of the developed mathematical model.

Calculations of the dynamics of pulsed reactors of periodic operation, including the use of experimental data from the IBR-2/IBR-2M reactors within the framework of the developed mathematical model in order to identify the causes of oscillatory instability.

Collaboration 1149-4

Country or International Organization	City, region	Institute or laboratory
Argentina	San Carlos de Bariloche, RN	CAB CNEA
Belarus	Minsk, MI	BSTU
Czech Republic	Rez, ST	NPI CAS
France	Grenoble, ARA	ILL
Germany	Berlin, BE	HZB
	Julich, NRW	FZJ Helmholtz
Hungary	Budapest	Wigner RCP
IAEA	Vienna, AT	IAEA
Romania	Bucharest, B	INCDIE ICPE-CA
Russia	Gatchina, LEN	NRC KI PNPI
	Moscow, MOW	NIKIET ROSATOM
		NRC KI
		VNIINM ROSATOM
	Obninsk, KLU	IPPE ROSATOM
	Snezhinsk, CHE	RFNC-VNIITF
	Troitsk, MOW	INR RAS
South Africa	Pretoria, GT	UP
Sweden	Lund, M	ESS ERIC
Uzbekistan	Tashkent, TK	INP AS RUz

Theoretical Physics (01)

Fundamental Interactions of Fields and Particles

Theme leaders: D.I. Kazakov
O.V. Teryaev

Participating countries and international organizations:
Belarus, Bulgaria, Canada, Chile, China, Croatia, Finland, France, Germany, Hungary, India, Iran, Italy, Poland, Portugal, Russia, Serbia, Slovakia, Spain, Sweden, United Kingdom, USA, Vietnam.

The problem under study and the main purpose of the research:
The main current problems of the modern theory of fundamental interactions are the development ofmethods of quantum field theory, their application to the description of elementary particle physics within the Standard Model and beyond, theoretical support for existing and planned experiments. Within the framework of the Standard Model, efforts will be focused on the developmentof multiloop computing methods and their applications to processes at the Large Hadron Collider, the development of new approaches to hadron physics, including heavy quark physics. In physics beyond the Standard Model, the search for Dark matter, manifestations of supersymmetry and other possible new physical phenomena are of particular interest. Theoretical support for the search for new physics in accelerator experiments will be combined with research and analysis of astrophysical data.

Developments in neutrino physics, including the field-theoretic description of neutrino oscillations and the processes of neutrino-nucleon interactions with nuclear matter, in particular in connection with the Baikal-GVD experiment, will remain under constant concern. Special attention will be paid to the theoretical support of the key elements of the JINR experimental program. By studying QCD methods, various approaches to the description of the structure of hadrons and quark-gluon matter under the specific conditions of the NICA complex will be developed and applied.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	Quantum field theory and physics beyond the standard model	D.I. Kazakov A.V. Bednyakov	01-3-1135-1-2024/2028
2.	QCD and hadron structure	I.V. Anikin S.V. Mikhailov O.V. Teryaev	01-3-1135-2-2024/2028
3.	Phenomenology of strong interactions and precision physics	V.I. Korobov M.A. Ivanov	01-3-1135-3-2024/2028
4.	Theory of hadronic matter under extreme conditions	V.V. Braguta E.E. Kolomeitsev S.N. Nedelko	01-3-1135-4-2024/2028
5.	Theory of electroweak interactions and neutrino physics	A.B. Arbuzov V.A. Naumov	01-3-1135-5-2024/2028

Projects:

	Name of the project	Project leaders
Laboratory	Responsible from laboratories	
1.	**Quantum Field Theory and physics beyond the Standard Model**	**D.I. Kazakov** **A.V. Bednyakov**

BLTP A.N. Baushev, A.T. Borlakov, Ch.R. Das, D.A. Evdokimov, A.G. Golovin, N.A. Gramotkov, V.A. Filippov, Ha Thanh Hung, R.M. Iakhibbaev, A.V. Kotikov, G.A. Kozlov, A.I. Mukhaeva, A.V. Nesterenko, A.I. Onishchenko, M.V. Savina, O.P. Solovtsova, D.M. Tolkachev, A.V. Trenogin, D.A. Volkova

MLIT S.V. Shmatov

VBLHEP B.Yu. Alexakhin, B.G. Shaikhatdenov

Abstract and scientific rationale:

Quantum Field Theory (QFT) is a widely recognized "language" used to describe the properties of elementary particles and their interactions. It is well known that the triumph of the Standard Model (SM) of particle physics would have been impossible without comparing experimental data obtained from accelerators such as LEP (CERN), HERA (DESY), Tevatron (Fermilab), and LHC (CERN) with high-precision calculations performed using QFT methods. Many years have passed since the construction of the SM, and all these years scientists were searching for New Physics. The problem of dark matter in the Universe is an obvious argument for such searches. The main aim of the Project is to develop the quantum field formalism of gauge and supersymmetric theories, as well as to construct and study particle physics models beyond the Standard Model. In the context of the Project, it is planned to use existing experience and new ideas to investigate a wide range of problems related to high-precision calculations within and beyond perturbation theory as well as to the nature of possible New Physics. Special attention will also be paid to issues that arise at the intersection of particle physics, astrophysics, and cosmology.

Expected results upon completion of the project:

Improved estimate of the contribution from hadronic vacuum polarization to the anomalous magnetic moment of the muon.

Investigation of the shapes of higher twist contributions in deep inelastic scattering with the resummation of large threshold logarithms.

Calculation of two-loop diagrams that arise in non-relativistic QED using the effective mass method and investigation of the completeness of basis functions for elliptic polylogarithms.

Development of a new specialized computer package for the epsilon expansion of generalized hypergeometric functions with one or more variables, whose indices depend on the dimensional regularization parameter, as well as for the numerical calculation of the resulting functions.

Explicit analytical calculation of multi-point master integrals using differential equations.

Calculation of two-loop contributions to electron-muon scattering and quarkonia production.

Calculation of the double spectral density in the problem of sum rules for B-anti-B mixing, which is an important experimental quantity that imposes strict constraints on possible new physics.

Calculation of three-loop massive form factors and polarization operators in QCD.

Calculation of multi-loop amplitudes and form factors with a large number of kinematic invariants in theories with extended supersymmetry.

Derivation of systematic solutions to quantum spectral curve equations in the case of maximally supersymmetric Yang-Mills theory in four dimensions and ABJM theory in three dimensions, both in the weak and strong coupling limits.

Calculation of spectra, correlation functions, and amplitudes in a number of six-dimensional "fishnet" models.

Application of the large charge expansion method to gauge theories and analysis of the resulting implications in both particle physics and condensed matter theory.

Investigation of the scheme dependence of a previously proposed self-consistent subtraction procedure for non-renormalizable theories.

Calculation of effective potentials for a range of theories of modified gravity and their application to analyze various inflationary models.

Investigation of the theory and phenomenology of scalar and vector bosonic stars.

Detailed cosmological and astrophysical analysis of the properties of primary black holes and their connection to the dark matter problem and observable supermassive black holes.

Analysis of the prospects for experimental detection of additional Abelian gauge symmetries and an extended Higgs sector in a range of new physics models. Investigation of the so-called supersymmetric extensions of the Standard Model.

Physical analysis of LHC data aimed at detecting manifestations of the "dark sector" in events where either a Higgs boson or a Z boson is produced, accompanied by a significant fraction missing "transverse" energy (MET), presumably carried away by a messenger particle that ultimately decays into DM particles. The expected outcome is new anomalies in the experimental data (in the fortunate event – the discovery of New Physics), or, in the absence of such signals, new unique constraints on the model parameter space for the considered scenarios of dark matter and Higgs sector.

Development of new (using neural networks for global scanning) as well as optimization and improvement of existing software for modeling physical processes beyond the Standard Model.

Expected results of the project in the current year:
Study of the relationship between the behavior of the QCD running coupling in the non-perturbative region and higher-twist operator contributions using experimental constraints from Bjorken sum rules in deep inelastic scattering.

Deep inelastic scattering data analysis with the analytic strong coupling, comparison against conventional methods.

Investigation of the decay properties of twisted particles (muons and neutrons).

Derivation and analysis of analytical solutions to the renormalization group equations for a number of quantum field models using a novel algorithm for iterative summation of higher-order perturbative contributions.

Analysis of the low-energy effective action in four-dimensional massless supersymmetric models.

Calculation of loop-induced anomalous chiral contributions to the effective potential in the superfield formalism.

Calculation of subleading terms in the anomalous dimensions of fixed-hypercharge operators in the context of large-charge expansion applied to the SM. Comparison with perturbative results.

Development of an efficient computational algorithm for asymptotic expansions of Euler-Mellin integrals and analytic continuation of Gelfand-Kapranov-Zelevinsky hypergeometric functions.

Analytical calculation of next-to-next-to-leading order (NNLO) QED corrections to the total cross section of $e^+e^- \to \mu^+\mu^-$ annihilation process.

Study of the phenomenological manifestations of an additional heavy Z'-boson predicted in New Physics models with a 3-3-1 extended gauge group.

Derivation of relations between window quantities for hadronic vacuum polarization contributions to the muon anomalous magnetic moment in spacelike and timelike domains.

Derivation of an analytic expression for electromagnetic corrections to the anomalous magnetic moments of leptons that include contributions from the lepton-loop vacuum polarization and mixed-type diagrams. Estimation of the accuracy of the corresponding asymptotic expansions.

Detailed study of cosmological perturbations and evaluation of their potential role in explaining the rapid formation mechanisms of supermassive black holes in the early Universe.

Analysis of galaxy formation processes and velocity fields in the central region of the void, with a subsequent comparison of theoretical predictions against observational data.

Study of the mechanism of formation of scalar boson stars in the model of random fluctuation walk.

Construction of the field model for the vector (Proca-) star with minimal interactions with the scalar field under the impact of gravity.

Analysis of the influence of black hole parameters (mass, spin, charge), external fields, "hair", greybody factor, and memory burden effects on Hawking neutrino radiation from primordial and galactic black holes.

Estimation of the number of primordial black holes per Hubble volume with near-extremal color charge and non-Abelian hair, the analysis of potential phenomenological ramifications.

2. QCD and hadron structure

I.V. Anikin
S.V. Mikhailov
O.V. Teryaev

BLTP Yu.A. Anikin, V.V. Bytiev, S.V. Goloskokov, R.V. Khakimov, N.V. Krasnikov, A.G. Oganesian, A.V. Pimikov, A.A. Pivovarov, G.Yu. Prokhorov, V.A. Saleev, A.A. Sazonov, O.V. Selyugin, D.A. Shohonov, A.Ya. Silenko, D. Strozik-Kotlorz, N.I. Volchanskiy, V.I. Zakharov, A.S. Zhevlakov

Abstract and scientific rationale:

Lacking a complete theoretical understanding of the color confinement, the only method of applying QCD is based on the factorization of the short-distance (perturbative) and long-distance (nonperturbative) dynamics. The conventional systematic way of dealing with the long-distance part is to parametrize it in terms of matrix elements of quark and gluonoperators between hadronic states generating GPDs, DAs, TMDs, etc. These matrix elements have to be either extracted from experiment or determined on the lattice. In many phenomenological applications they are usually modeled in terms of various nonperturbative methods or models.The main objective of the project is to develop comprehensive theoretical frameworks to study the multi-dimensional partonic content of hadrons by combining various approaches based on the factorization theorem and starting from the first principles of QCD.

For many years, theoretical and experimental studies of the nucleon structure have been restricted to a one-dimensional picture along a light-cone direction. Within this one dimensional picture, quark and gluon contents of the nucleus are described by the parton distribution functions (PDFs) which depend on the longitiudinal momentum of the parton inside the hadron.

The last decade has witnessed a tremendous effort to go beyond this one-dimensional description of the nucleon. Recent improvements in experimental facilities such as increased electron beam luminosities and polarization degrees, detector resolution and coverage, and advanced theoretical computation frameworks, such as calculating radiative and power corrections to complementary sets of observables, provide a breakthrough for investigating the multi-dimensional partonic content of the nucleon, which is also referred to as hadron tomography. In this respect, the multi-dimensional parton distribution functions such as transverse-momentum-dependent distribution functions (TMDs) or generalized parton distribution functions (GPDs) have been the key subjects of both experimental and theoretical studies.

With the advent of new generation colliders such as the Electron Ion Collider (EIC) in the USA and the Large Hadron electron Collider (LHeC) at CERN, theoretical improvements of these distribution functions are mandatory for a precise comparison with experimental data. Motivated from this need, the main objective of the proposed project is to develop a comprehensive theoretical framework to study the multi-dimensional partonic content of the hadrons by combining various approaches starting from the first principles of QCD.

Expected results upon completion of the project:

Analytic evaluation of 3-loop 2-point Feynman master-integrals with composite external vertices for arbitrary indices of propagators.

Calculation of $\alpha^2_s(\alpha_s\beta_0)^{n-1}$ and $\alpha^3_s\beta_1(\alpha_s\beta_0)^{n-2}$ contributions in the nonsinglet ERBL evolution kernel and correlator of two vector composite quark currents in QCD.

Calculation of pion electromagnetic form factors in the framework of light-cone sum rules in the low and (or) moderate energy regime.

Revision of distribution amplitudes (leading twist) of (pseudo)scalar and (longitudinal and transverse) vector mesons within QCD sum rules taking into account new QCD corrections $O(\alpha^2_s)$ obtained by us for all of their components.

Derivation and analysis of the full differential equation system for Feynman integrals with multiple parameters of masses and impulses.

Study of tau lepton decays and processes of electron-positron annihilation into mesons including the processes with three pseudoscalar mesons in the final state.

Investigation of the inner structure and nature of the meson interaction at low energies by using the Nambu–Jona-Lasinio model.

Study of the Drell-Yan hadronic structure function within the perturbative QCD in α^2_s order of the coupling constant. Check of the Lam-Tung identity in α^2_s order of the strong coupling constant.

Study of dark axion portal and obtaining bounds for the model in fixed target experiments. The analysis of new physics for NA64 experiment. Study of the visible mode of axion or dark photon.

Study of the sum rules for hadron fragmentation functions in QCD with the use of the generalized truncated Mellin moments approach.

Investigation of analytical and numerical optimizations of perturbative series for observables using the renormalization group in QCD.

Study of anomalous transport phenomena in a relativistic quantum medium associated with the curvature of space-time.

Study of the influence of the hadron potential at large distances on the total cross sections, which determines the peculiarity of the scattering amplitude at small momentum transfer. Investigation of the energy dependence and crossing properties of the new anomalous terms of the elastic amplitude of proton-proton and proton-antiproton scattering at NICA energies.

Study of the new-found types of transverse momentum dependent parton distributions within the original frame that involves the newly-found additional contribution in the inverse Radon transforms.

Study of the phase diagram of the SU(2)-Higgs Electroweak theory. Study of Z(N) symmetry and thermodynamic properties of meta-stable states at very high temperature in the context of QCD and Electroweak theory.

The creation of a computational framework to analyze CMS Open Data.

Expected results of the project in the current year:
Study of tau lepton decays and processes of electron-positron annihilation with three mesons in the final state.

Analytical and numerical optimizations of perturbation series for observables using beta-expansion and renormalization group in QCD.

Calculation of the correlator of two vector composite quark currents and the nonsinglet ERBL evolution kernel of the orders $\alpha^2_s(\alpha_s\beta_0)^{n-1}$ and $\alpha^3_s\beta_1(\alpha_s\beta_0)^{n-2}$ in QCD.

Analysis of polarization effects in the elastic e+p to e+p processes in the one-photon exchange approximation in the case when the spin quantization axes of the target proton at rest and the incident or scattered electron are parallel.

Study of heavy meson leptoproduction in the Generalized Parton Distributions approach.

Study of the charge sum rules for hadron fragmentation functions in QCD.

Study of inclusive hadron production in proton-proton and heavy-ion collisions at the NICA collider kinematics.
Study of exclusive production of massive vector mesons within the QCD factorization approach.

Analytical and numerical optimization of perturbative series for observables using the renormalization group in QCD. Applications to the DIS sum rules.

Analytic evaluation of 3-loop 2-point Feynman master-integrals with composite external vertices for arbitrary indices of propagators.

Development of a method to directly obtain higher orders of ε-expansion of multivariate hypergeometric functions which are important for QCD applications.

Evaluation (making use of resurgent-analysis methods) of currently unavailable nonperturbative contributions to the QCD Adler function of the subleading order in large-n_f expansion (n_f indicates the number of quark flavors).

Study of T-even hadronic structure functions of the Drell-Yan process.

Study of the axion and vector portal between the Standard Model and dark matter, implementation to fixed target experiments to obtain bounds for the model.

Study of dark matter from rare meson decays.

Calculation of the electromagnetic pion form factor for moderate momentum transfers in the framework of the analytical perturbation theory of QCD and comparison with the latest JLab experimental data.

Investigation of the possibility of the existence of previously unknown phase transitions in a relativistic fluid of elementary particles in the region of ultra-low temperatures and extremely high accelerations and vorticities.

Comparative analysis of different approaches to formulation of axion electrodynamics based on the axion-photon coupling.

Investigation of the dissipative properties of the relativistic quantum medium in curved spaces with a horizon and search for dissipative transport coefficients for theories with different spins, and analysis of the connection with predictions based on string theory.

Deriving the energy dependence of the estimates of the contribution of the tenzor pomeron on spin-dependent amplitudes of nuclon-nuclon elastic scattering. Obtaining a quantitative description of all available experimental data on differential cross sections and spin-correllation parameters in elastic NN-scattering from sqrt(s)= 5 GeV up to sqrt(s)= 14 TeV.

Study of the contribution of the effects induced by the effective one-loop action of Heisenberg-Euler QED and its generalization to QCD to the transport coefficients of transport effects (CME, CSE, CESE, CMW, CEW, CVE) in heavy ion collisions.

Theoretical substantiation of producing particles with orbital angular momenta in strong interactions at heavy-ion collisions.

Original results are expected in the field of dissipative transport phenomena in non-inertial systems. Namely, shear and bulk viscosity in accelerated and/or rotating systems for massless and massive fields with different spins and at different temperatures will be calculated, and possible deviations from the membrane paradigm and string theory will be searched for. A connection between dissipative transport coefficients and conformal quantum anomaly is planned to be analyzed.
Study of T-even hadronic structure function of Drell-Yan process.

Study of vector and axion-like portals between Standard model and dark matter, implementation to fixed target experiments to obtain bounds for model.

Calculation of electric dipole moments of baryons.

3. Phenomenology of strong interactions and precision physics — **V.I. Korobov, M.A. Ivanov**

BLTP D. Aznabayev, G. Gurjav, A.N. Issadykov, D.I. Melikhov, Yu.S. Surovtsev, J. Tyulemissov, A. Tyulemissova

Abstract and scientific rationale:
The project is expected to develop low-energy effective field theories: non-relativistic quantum electrodynamics (NRQED) and covariant quark model of hadrons (Covariant Confined Quark Model, CCQM).

The Standard Model of particle physics, formulated about 50 years ago, forms the basis of our understanding of fundamental interactions. During this time, significant theoretical work has been carried out to improve the calculation technique and increase the accuracy of predictions in the SM. An effective field theory (EFT) is a quantum field theory which is not fundamental but is valid over a limited range of energies or distances. This makes it possible to successfully use EFT and renormalization group methods to calculate real physical quantities and processes observed in the experiment with high accuracy. The EFT approach provides not only a systematic approach to the analysis of experimental results, but is also a valuable tool for determining the correlation of various observables, which gives a deeper understanding of where to look for possible indicators of new physics beyond the SM.

Expected results upon completion of the project:
Exploration of the possibilities of using the combined approach in NRQED, when part of the contributions to the energy of the bound system is considered in the framework of QED, as the total sum over all terms in the powers of the electron binding parameter $v/c \sim Z\alpha$.

Introduction of new terms in the general NRQED scheme, which will make it possible to take into account the contributions of light scattering on light, nontrivial centipede diagrams for one- and two-loop self-energy diagrams, necessary for calculating corrections of the order $m\alpha^7$-$m\alpha^8$ and higher.

It is planned to study the spectra of pionic (π^-−He+) and kaonic (K^-−He+) helium atoms in order to refine the pion and kaon masses. The expected relative accuracy in mass measurements is ~10^{-8}.

Within the framework of CCQM, investigate the possibility of violation of lepton universality in lepton decays of charmonium and bottomonium and their radial excitations.

Obtain bounds on the values of the Wilson coefficients of the Standard Model Effective Theory (SMEFT) operators responsible for the violation of lepton universality in the tauon sector.

Calculate the partial widths of strong and electromagnetic decays of vector D-mesons with an open charm.

Calculate matrix elements and widths of nonleptonic two-particle decays of charmed baryons without changing the charm.

Perform an analysis of strong decays of the charmonium-like state Y(4230) in order to study the nature of its structure.

Perform a theoretical analysis of lepton decays of the B-meson with four leptons in the final state.

Expected results of the project in the current year:
Calculation of relativistic corrections in the orders $m(Z\alpha)^6$ and $m(Z\alpha)^6(m/M)$ in the formalism of the three-body problem.

Development of an effective theory for NRQED interactions of scale $< (\alpha r_0)$, where r_0 is the Bohr radius, for calculating corrections of orders $m\alpha^7$- $m\alpha^8$ and higher with a relative accuracy of an order of 10^{-12} for the energies of ro-vibrational transitions.

Obtaining improved values for the proton-to-electron ratio and the Rydberg constant with a relative accuracy of $\sim 10^{-12}$ from the comparison of theory and experiment on H_2^+ spectroscopy.

Study of the vector D-meson decay into a D-meson and an electron-positron pair in detail within the CCQM framework in the regard with the recent observation of anomalies in e^+e^- nuclear transitions by the ATOMKI collaboration which may hint at the existence of a vector boson with a mass around 17 MeV referred to as X17. Similar anomaly was also observed by the BESIII collaboration in the Dalitz decay of the vector D-meson into a D-meson and an electron-positron pair.

Study of hidden-charm strong decays of the spin-2 partner $X2(4014)$ of the charmonium-like state $X(3872)$ in the framework of the covariant confined quark model.

4. Theory of hadronic matter under extreme conditions

V.V. Braguta
E.E. Kolomeitsev
S.N. Nedelko

BLTP M. Bordag, M. Hasegawa, Y. Heo, Yu.B. Ivanov, A.S. Khvorostukhin, K.D. Montenegro, Nguyen Hoang Wu, A.V. Nikolsky, A.A. Roenko, A.M. Snigirev, D.A. Sychev, N.S. Tsegelnik, V.E. Voronin, D. Voskresensky

Abstract and scientific rationale:
Modern heavy ion accelerators make it possible to study the properties of strong interactions of elementary particles, which are described by quantum chromodynamics (QCD) under the influence of extreme external conditions. In particular, the quark-gluon matter that is created in such experiments is expected to have a temperature of several hundred MeV, the baryon chemical potential of about 100 MeV, external magnetic field $eB \sim 1$ GeV^2 and relativistic rotation with an angular velocity of ~ 10 MeV. Such conditions significantly change the properties of QCD. In the presented project, it is planned to study the properties of QCD at nonzero baryon density, high temperature, large external magnetic field and relativistic rotation using lattice simulation and other approaches.

Expected results upon completion of the project:
In the presented project, it is planned to study the properties of QCD at non-zero baryon density, non-zero temperature and non-zero magnetic field using lattice simulation with an imaginary chemical potential, dynamic u-, d-, and s- quarks and the physical mass of the pi-meson. To conduct such a study, a program written by our group will be used that implements advanced supercomputer technologies and algorithms.

It is expected that quark-gluon matter, which is produced in the process of collision of heavy ions, is not only highly heated and affected by a strong magnetic field but also has a non-zero angular velocity of rotation. Therefore, to interpret the results of heavy ion collision experiments, an important theoretical problem is the study of the properties of rotating quark-gluon matter. In the presented project, we are planning for the first time to study the properties of rotating quark-gluon matter in the framework of lattice simulation.

One of the aims of the project is to impose new constraints on the equation of state of the nuclear and hadronic matter under extreme conditions existing in heavy-ion collisions and the centers of compact stars. For this, the description of strongly interacting systems in and out of equilibrium will be developed. Such observables as the strange and charmed particle production, the directed and elliptic flows of particles, the global spin polarization of hyperons and their intercorrelations will

be analyzed within transport and hydrodynamic approaches and compared with existing and future experimental data. Various sources of the spin polarization such as local vorticity of the medium, axial vortex effect, and electromagnetic field will be quantitatively compared and their role in the formation of the observable polarization signal will be clarified.

The possibility of the thermodynamic description of light nuclei and hypernuclei production in heavy-ion collisions within the hydrodynamic approach will be theoretically explored. Formulation of the equations of the viscous hydrodynamics with the internal spin and rotation degrees of freedom as an effective field theory will be achieved. Possible phase transformation in nonequilibrium and equilibrium nuclear matter under the influence of compression, heating, magnetic field, and rotation will be classified and studied. New constraints on the equation of state from the description of the neutron star masses, radii, and the neutron star cooling should be obtained.

Elementary hadronic scattering amplitudes and the corresponding differential cross sections are important ingredients of transport models. The multichannel description of the meson-baryon scattering within the generalized potential approach based on the chiral SU(3) Lagrangian with the parameters tuned to the lattice QCD data and available experimental data on the hadron scattering will be developed.

Expected results of the project in the current year:
Calculation of the interquark potential and energy losses of high-energy quarks passing through the plasma in the presence of 1) electromagnetic fields and 2) acceleration within the framework of the holographic model of N = 4 SYM plasma.

Study of the scenario of breakdown of analytical confinement and chiral symmetry
restoration in QCD at finite hadron temperature. Estimation of the corresponding critical temperature.

Improvement of the "Nuclear medium cooling scenario" to describe the neutrino radiation of compact stars. A more realistic description of the pion degrees of freedom will be used.

Study of the instability of the boson vacuum at rotation. Consideration of vector bosons and the mutual influence of fields and rotation.

Study of the values of the baryon density achieved in heavy ion collisions in the energy range of NICA and FTX-STAR within the frame of the model of Three-Fluid Dynamics (3FD).

Systematic calculations of the baryon directed flow in energy range of NICA and FTX-STAR to predict the results of future experiments with a focus on signals of the onset of the transition to the quark-gluon phase.

Study of the effect of acceleration on the properties of QCD within the framework of lattice simulation. In particular, study of the influence of acceleration on the confinement/deconfinement phase transition in gluodynamics and the possibility of realizing a spatially inhomogeneous phase transition.

Study of spatially inhomogeneous confinement/deconfinement phase transitions and breaking/restoring chiral symmetry in rotating QCD within the framework of lattice QCD simulation with dynamic quarks with masses close to physical ones.

Study of the influence of the spin chemical potential on the properties of QCD, in particular, calculation of spin density, spin susceptibility and the possibility of transition of spin degrees of freedom into angular rotation.

5. Theory of electroweak interactions and neutrino physics — **A.B. Arbuzov, V.A. Naumov**

BLTP A. Ahmedov, Yu.M. Bystritskii, M. Deka, A.D. Dolgov, M.S. Dvornikov, S.B. Gerasimov, I.D. Kakorin, S.G. Kovalenko, K.S. Kuzmin, D.A. Kuznetsov, A.A. Nikitenko, N.N. Nikolaev, K. Nurlan, A.A. Osipov, N. Rajeev, D.S. Shkirmanov, V. Shmidt, M.K. Volkov, U.E. Voznaya, A.F. Zakharov, V.A. Zykunov

Abstract and scientific rationale:
The Standard Model of particle physics is the most successful theory of fundamental interactions. Despite numerous experiments on its verification and a deep theoretical study of its properties, there are still many problems in this model that need to be solved. The presence of such problems leads us to believe that the Standard Model is only an effective theory, i.e., a low-energy approximation of a more fundamental physical theory. To search for new physical phenomena, it is necessary to have high-precision predictions obtained within the framework of the Standard Model. Within this project, it is planned to obtain such predictions for the conditions of existing and future experiments at colliders, including LHC, FCCee, CEPC, ILC. Calculations will be carried out in order to carry out precise verification of the Standard Model (SM) and search for the limits of applicability of the latter.

Neutrinos are a unique source of information on physics beyond the Standard Model. In particular, reliably observed transitions between different types of neutrinos (neutrino flavors) indicate a violation of the conservation of the electron, muon and taon quantum numbers, which is present in the SM with massless neutrinos. The project is devoted to the study of physical processes involving neutrinos, including elementary exclusive interactions of neutrinos with nucleons and nuclei, neutrino transport in matter, taking into account coherent and inelastic interactions, study of astrophysical and cosmological effects, superhigh-energy neutrinos in cosmic rays, manifestation of neutrino oscillations in primary nucleosynthesis under extreme astrophysical conditions (in particular, in the vicinity of astrophysical black holes), as well as in accelerator and reactor experiments. In particular, the hypothesis about the possible existence of a sterile neutrino, its role in nucleosynthesis and the formation of the large-scale structure of the Universe will be considered. It is also planned to study a new mechanism for the production of ultra-high-energy neutrinos, up to 10^{21} eV (UHECR) in models of modified gravity in higher-dimensional space. Research carried out within the framework of this project will allow obtaining restrictions on models of compact objects, on the properties of particles (for example, on the mass of a graviton), as well as on alternative theories of gravity, which have been proposed recently. In recent years, reliable evidence has been obtained for the association of high-energy neutrinos with blazars, which are most likely supermassive black holes, and the construction of consistent models of these phenomena is also extremely important and timely. Cosmological and astrophysical phenomena predicted in modified gravity models will be investigated. First of all, scalar-tensor models of gravity will be considered and the manifestations of quantum field effects in them will be studied.

Expected results upon completion of the project:
Improvement of basic phenomenological models of electromagnetic nucleon forms-factors in the space-like and time-like domains of q^2 based on the global statistical analysis of elastic electron scattering data on hydrogen and deuterium. Implementation of the models in the form of software modules of the GENIE neutrino generator. Application of the results to calculations of the cross sections of neutrino-nucleon interactions in the models of the running axial mass (M_A^{run}) and SuSAM*.

Improvement of the superscaling model SuSAM* with a modified scaling function based on a global statistical analysis of quasielastic electron scattering data on various nuclear targets (from hydrogen to uranium). Model implementation in the GENIE generator. Predictions of the momentum distribution of nucleons in the nucleus within the superscaling approach.

Improvement of the RK model of resonance neutrinoproduction of pions with corrected contributions to the full amplitude based on the global statistical analysis of single pion production data in (anti)neutrino interactions with hydrogen and deuterium. Implementation of the model in the GENIE generator.

Development of a method for solving the quantum kinetic equations describing the transport of massive high-energy neutrinos in heterogeneous (astrophysical) media taking into account the neutrino mixing (including mixing with hypothetical sterile states) and their coherent and inelastic interactions with matter. Application of the theory to the calculation of the passage through the Sun of neutrinos generated by cosmic rays in the solar atmosphere (prediction of the flavor composition, energy and angular distributions). Evaluation of the corresponding background in the experiments on the detection of neutrinos generated by the annihilation of dark matter particles gravitationally bound in the Sun.

Study of the contribution of ultra-high-energy neutrinos arising in a multidimensional modification of gravity and comparison of theoretical expectations with observations with the Baikal-GVD and IceCube detectors.

Calculation of electroweak radiative corrections to electron-positron annihilation processes, which are planned to be studied at future colliders, including FCCee, CEPC and Super Charm-Tau Factory. Creation of computer programs that can be directly used to simulate and analyze data from experiments at these colliders.

Application of the method of parton distributions developed in QCD to describe electrodynamic corrections to processes studied in current and future experiments in the field of high energy physics.

Construction of high-precision theoretical predictions for Bhabha scattering processes at small and large angles used for luminosity monitoring at electron-positron colliders.

Analysis of semileptonic many-particle decay modes of tau leptons taking into account the excited states of mesons in intermediate states. Construction of a consistent scheme for describing such decays and creation of a computer program for simulating such processes.

Expected results of the project in the current year:
Calculation of the processes of bremsstrahlung and creation of electron-positron pairs for the purpose of using them to obtain a polarized positron beam.

Calculation of spin asymmetry in the processes of vector boson production in proton-proton collisions under the conditions of the STAR experiment.

Investigation of meson decays in the ground and excited states and meson production processes in tau lepton decays in the

quark-meson Nambu-Jona-Lasinio model.

Calculation of the contribution of virtual photons to the masses of pseudo-Goldstone states within the framework of 1/Nc chiral perturbation theory in order to reveal the role of the gluon anomaly in the mechanism of restoration of isospin symmetry broken by the masses of light quarks.

Calculation of 1/Nc corrections to the Wess-Zumino-Witten anomaly due to the contribution of virtual photons in order to study their role in the description of phenomenological data on two-photon decays of pion, eta, and eta-prime mesons.

Development of the method of structure functions in quantum electrodynamics and its application to the calculation of higher-order radiative corrections to the processes of interaction of elementary particles studied in modern and future experiments.

Calculation of the contributions of quantum effects to the processes of intense cosmological particle production in the early universe.

Establishing conditions for detecting neutrino bursts from distant supernovae (with source identification) on modern and future neutrino telescopes.

Taking into account resonance effects during refraction (forward-scattering) of neutrinos in the plasma of the early Universe, including the evolution of transitions between active and sterile neutrinos as well as CP violation effects.

Numerical modeling of the passage of a high-energy neutrino beam in the vicinity of a supermassive black hole (SMBH) at the JINR Govorun supercomputer. In this case, the direction of the flux of neutrinos incident on the SMBH relative to its spin will be considered arbitrarily.

Calculation of the characteristics of a superfluid neutrino condensate such as the phase transition temperature and correlation length and the characteristic cooling time of the cluster using methods of quantum field theory at a finite temperature.

Development of precision parameterizations of the electromagnetic form factors of the proton and neutron, based on data on elastic scattering of electrons on hydrogen and deuterium targets. Analysis of the influence of uncertainties in the adjustable parameters on the cross sections of quasi-elastic scattering of neutrinos on nuclei and on the polarization vector of the final lepton.

Improvement of modern models of quasielastic and resonant neutrino production of leptons on nucleons and nuclei taking into account accelerator data on electron and neutrino scattering. Checking the fulfillment of positivity constraints — a sensitive criterion for the correctness of the model. Implementation of the results in the Monte Carlo neutrino generator GENIE.

Obtaining refined constraints on the graviton mass taking into account new observational data on the motion of bright stars in the vicinity of the Galactic Center.

Consideration of gravitational lensing for the model of the Galactic Center from dark matter.

Calculation of parameters of gravitational shadows in the vicinity of galactic centers for naked singularities and wormholes.

Collaboration 1135

Country or International Organization	City, region	Institute or laboratory	
Belarus	Gomel, HO	GSTU	
		GSU	
	Minsk, MI	INP BSU	
		IP NASB	
		JIPNR-Sosny	
Bulgaria	Sofia	INRNE BAS	
Canada	Corner Brook, NL	MUN	

Country or International Organization	City, region	Institute or laboratory
Chile	Arica, AP	UTA
	Santiago, RM	UNAB CTEPP
China	Beijing, BJ	IHEP CAS
	Guangzhou, GD	SYSU
	Haikou, HI	HNU
	Lanzhou, GS	IMP CAS
Croatia	Zagreb	RBI
Finland	Helsinki	HIP
France	Gif-sur-Yvette, IDF	Irfu
	Paris, IDF	ENS
		IHP
Germany	Dusseldorf, NRW	HHU
	Hamburg, HH	UHH
	Regensburg, BY	UR
	Tubingen, BW	Univ.
	Zeuthen, BB	PITZ DESY
Hungary	Budapest	ELTE
India	Ettimadai, TN	Amrita Univ.
	Kolkata, WB	IACS
	Sunabeda, OD	CUO
Iran	Tehran	IPM
		UT
Italy	Naples, NA	INFN Naples
Poland	Katowice, SL	US
	Krakow, MA	IFJ PAN
	Otwock-Swierk, MZ	NCBJ
Portugal	Coimbra	UC
Russia	Chernogolovka, MOS	LITP RAS
	Dubna, MOS	Uni Dubna
	Irkutsk, IRK	ISDCT SB RAS
		ISU
	Moscow, MOW	ITEP
		SINP MSU
	Novosibirsk, NVS	BINP SB RAS
		NSU
	Protvino, MOS	IHEP
	Troitsk, MOW	INR RAS
	Vladivostok, PRI	FEFU
Serbia	Belgrade, BG	AOB
		VINCA
Slovakia	Bratislava, BL	CU
		IP SAS

Country or International Organization	City, region	Institute or laboratory
Spain	Granada, AN	UGR
Sweden	Stockholm, AB	KTH
United Kingdom	Liverpool, MSY	UOL
	London, LND	IMPERIAL
USA	Wako, TX	BU
Vietnam	Hanoi, HN	IOP VAST
	Ho Chi Minh City, SG	VNUHCM

Theory of Nuclear Systems

Theme leaders: N.V. Antonenko
A.A. Dzhioev
S.N. Ershov

Participating countries and international organizations:
Algeria, Armenia, Belarus, Belgium, Brazil, Bulgaria, China, Czech Republic, Egypt, France, Germany, Greece, Hungary, India, Iran, Italy, Japan, Kazakhstan, Lithuania, Mexico, Norway, Poland, Republic of Korea, Romania, Russia, Serbia, Slovakia, South Africa, Spain, Sweden, United Kingdom, USA, Uzbekistan.

The problem under study and the main purpose of the research:
The theme proposes to research and develop ways to solve current problems in nuclear physics, relativistic nuclear physics, nuclear astrophysics, in the field of quantum few-body systems, and nonlinear quantum processes. Researches will be closely coordinated with experimental programs at facilities that exploit high-intensity beams of stable and/or radioactive ions at JINR (SHE-factory, ACCULINA-2) and worldwide (FAIR, ISOL facilities, SPES, SPIRAL2, FRIB, RAON, HIAF, iThemba LABS, ELI-NP). Studies of collisions of high-energy heavy ions and the phenomenon of color transparency will be associated with the NICA project at JINR. Large-scale studies of the structure of exotic nuclei, the dynamics of nuclear reactions, properties and methods of obtaining superheavy nuclei are planned. The task is to include dissipation and diffusion in the dynamics of the nucleus-nuclear interaction and preserve the essence of the quantum multiparticle nature of colliding nuclei. The study of systems with a small number of particles is also necessary in order to describe resonant processes in nuclear physics and high-energy physics. Studies of nonlinear quantum processes in very strong polarized electromagnetic fields, which are achieved in short high-frequency laser pulses, are of interest.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	Microscopic models for exotic nuclei and nuclear astrophysics	A.A. Dzhioev	01-3-1136-1-2024/2028
2.	Low-energy nuclear dynamics and properties of nuclear systems	S.N. Ershov G.G. Adamian	01-3-1136-2-2024/2028
3.	Quantum few-body systems	A.K. Motovilov V.S. Melezhik	01-3-1136-3-2024/2028
4.	Relativistic nuclear dynamics and nonlinear quantum processes	S.G. Bondarenko A.B. Larionov	01-3-1136-4-2024/2028

Projects:

	Name of the project	Project leaders
Laboratory	Responsible from laboratories	
1.	**Microscopic models for exotic nuclei and nuclear astrophysics**	**A.A. Dzhioev**

BLTP N.N. Arsenyev, E.B. Balbutsev, I.N. Borzov, H.G. Ganev, M.S. Kosarev, V.A. Kuzmin, L.A. Malov, M.A. Mardyban, I.V. Molodtsova, V.O. Nesterenko, A.P. Severyukhin, D.Yu. Smolyannikov, G. Stratan, A.I. Vdovin, P.I. Vishnevskiy

Abstract and scientific rationale:
The scientific Project aims to solve a fundamental task of contemporary nuclear physics - development and improvement of a self-consistent microscopic approach to describe the structure of ground and excited states of exotic and superheavy atomic nuclei, as well as to predict their decay properties. On the one hand, such an approach is necessary for planning the research program of modern heavy ion accelerator facilities (SHE-Factory at JINR, SPIRAL2 at GANIL, FAIR at GSI, RIBF at RIKEN) and for interpretation of their results. On the other hand, the need for reliable theoretical nuclear data is also relevant for modeling various astrophysical processes.

The self-consistent microscopic approach used in the Project to describe ground and excited nuclear states is based on the combination of the energy density functional (EDF) method and the quasiparticle-phonon nuclear model (QPM). The EDF has proven itself in global calculations of nuclear characteristics and in astrophysics. The use of the coupling of simple and complex configurations in the framework of QPM is nowadays practically the only way allowing one to go beyond the harmonic approximation using large configuration space without violating the Pauli principle.

Expected results upon completion of the project:
The form and parameters of the EDF will be extrapolated far beyond the stability valley. Special attention will be paid to isovector properties, which play a crucial role in nuclei with large neutron-proton asymmetry.

Using a unified set of EDF parameters, the effect of interaction between simple and complex configurations on the properties of charge-neutral and charge-exchange nuclear excitations will be investigated with respect to their resonance structure as well as on the decay characteristics of nuclei at the driplines.

The developed self-consistent EDF+QPM framework will be applied to study β-decay in the context of astrophysical r-process and weak nuclear reactions with hot nuclei in various astrophysical scenarios (supernova explosions, stellar nucleosynthesis, neutrino emission).

Prediction of α spectra of superheavy nuclei for planning future experiments. α-decays from isomeric states as well as fission from these states will be considered.

In order to determine the competition between different modes of radioactive decay of superheavy nuclei, lifetime calculations concerning orbital electron capture and β^+-decay will be carried out.

Analysis of the evolution of magic numbers as a function of the ratio of neutron to proton numbers in the nucleus and prediction of new nuclei with closed (sub)shells near the proton and neutron driplines.

Study of the role of tensor interaction in the fragmentation of the Gamow-Teller resonance and beta-decay of exotic nuclei.

Investigation of neutrino interaction with matter that is important in various astrophysical phenomena, e.g., supernovae, neutron star mergers, etc. The role of inelastic neutrino scattering on nuclei and the magnetic field in the neutrino thermalization process must be elucidated.

Calculations of charge and matter distribution radii for long isotopic chains, including deformed nuclei. Theoretical analysis of isotopic behavior of radii and observed anomalies.

Expected results of the project in the current year:
Microscopic study of cluster states within the symplectic symmetry approach to clustering.

Analysis of the γγ-decay width of a low-energy 3^- state.

Study of the fine structure of isoscalar monopole and quadrupole resonances in spherical nuclei.

Study of the giant dipole resonance, electric spin dipole resonance, and collective spin-M2 states in heavy even-even spherical and axially-deformed nuclei within the Wigner function moments method.

Investigation of K-isomers in nobelium isotopes using the Lipkin-Nogami prescription and pairing blocking effect.

Wavelet analysis of isoscalar monopole excitations in the ^{24}Mg nucleus.

Analysis of the recently observed scissor M1 resonance in ^{254}No.

Isoenergetic description of induced fission within energy-density functional theory.

Calculations with modified Fayans energy density functional of charge radii and beta-decay rates of neutron-rich nuclei in the region of the 3rd peak of the r-process.

2. Low-energy nuclear dynamics and properties of nuclear systems — **S.N. Ershov, G.G. Adamian**

BLTP E.Kh. Alpomishev, A.V. Andreev, N.V. Antonenko, A.S. Bazhin, A.N. Bezbakh, R.V. Jolos, Sh.A. Kalandarov, E.V. Mardyban, N.S. Moiseev, A.B. Mukhammadsoliev, R.G. Nazmitdinov, A.K. Nasirov, D.T. Nguyen, F.O. Otakhonov, H. Paşca, A. Rahmatinejad, I.S. Rogov, V.V. Sargsyan, H.V.M. Seif, T.M. Shneidman, N.B. Shulgina

MLIT J. Busa, E.G. Nikonov

FLNR Yu.V. Pyatkov

Abstract and scientific rationale:
The purpose of the project is to study the important dynamical nuclear processes such as fusion, quasifission, multinucleon transfers, capture and breakup. Investigations of the near threshold effects demand uniform description of the nuclear structure and reactions. Priority will be a development of cluster models that allow us to reveal peculiarities of the nuclear structure at extreme excitatios. A further development of the completely quantum models for decays of weakly bound nuclei is planned. The transport coefficients and nucleus-nucleus potentials calculated microscopically would be used in the double-folding model for a description of the fusion dynamics.

It is necessary to study in detail the influence of the environment on the rate of astrophysical reactions. This demands further development of the theory of the quantum systems. Thus, it is necessary to consider low-energy dipole excitations that play presumably a noticeable role in stellar nucleosynthesis.

Study of the nuclear properties depending on an energy is necessary to reveal effects outside the mean field description. In heated nuclei, the potential energy surface changes in such a way that the height of the fission barrier for superheavy nuclei decreases. Therefore, investigations of the shell effects damping with increasing energy are important for estimation of the stability of excited heavy nuclei.

Exploring the formation of superheavies with Z=119 and 120 in fusion reactions must be continued within a microscopic approach. Also, the peculiarities of the quasifission competing with the complete fusion will be considered. There are plans to compare the calculated mass distributions and TKE of the quasi-fission products with distributions of the fission products. New heavy ion isotopes, which cannot be obtained in the complete fusion reactions, can be formed by transfer reactions. Therefore, further theoretical analysis of these reactions by including a cluster transfer into the description is required. Investigations of the synthesis of new isotopes of superheavy nuclei must be continued in the evaporation channels of charged particles in order to search for the most suitable reactions for future experiments.

The advantage of the cluster approach is the simultaneous description of α-decay and spontaneous fission from the ground state of both even-even and even-odd nuclei with the same set of parameters. The main model assumption is that charge asymmetry as a collective coordinate is responsible for these processes. In the same approach, it is necessary to investigate fission from isomeric states and induced fission. Success in describing experimental data will lead to a new insight into fission process.

Expected results upon completion of the project:
Creation of new theoretical approaches and models for description and prediction of the properties of unstable nuclei and exotic nuclear systems and their application to astrophysical problems.

Explanation of the reaction mechanism with particles and nuclei within the broad energy interval.

Exploring the limits of nuclear stability, positions of proton and neutron drip-lines, detection of proton shell closure beyond Pb, and the best way to produce a certain isotope.

Study of fusion and fission dynamics providing benchmarks for confirming certain ways of fusion and fission.

Investigation of the influence of the environment on astrophysical reactions.

Study of the nuclear structure change with temperature and angular momentum, the role of cluster degrees of freedom in nuclear excitations, and the properties of superheavies.

Exploration of the properties of nuclear systems beyond the nucleon stability, the multineutron radioactive decay existence.

Expected results of the project in the current year:
Study of the manifestation of the alpha-particle excitation mode in the properties of superheavy and N=Z medium mass nuclei.

Investigation of the properties of the first excited 1^- state in heavy nuclei.

Study of the properties of semimagic nuclei with a closed proton shell and neutrons at the beginning of filling shell.

Study of the possibility of formation of new neutron-rich isotopes in multi-nucleon transfer reactions at intermediate energies.

Prediction of cross-sections for formation of new neutron-deficient isotopes in neutron emission channels of complete fusion reactions on lead and bismuth targets.

Prediction of cross-sections for formation of new superheavy nuclei in complete fusion reactions with incident nuclei of ^{49}Sc, ^{50}Ti, ^{51}V, ^{54}Cr. Study of the isotopic dependence of the cross-section.

Study of the role of cluster degrees of freedom in spontaneous and induced binary and ternary fission.

Derivation of a semi-empirical formula for calculating half-lives of spontaneous fission of heavy and superheavy nuclei.

Study of the role of deformation degrees of freedom in spontaneous ternary fission of ^{252}Cf within the microscopic-macroscopic approach.

Study of the possibility of synthesis of neutron rich isotopes of superheavy nuclei in the framework of dinuclear system model.

Calculation of the yields of various ternary decay channels in spontaneous and induced ternary fission of heavy nuclei in the framework of TNS model.

3. Quantum few-body systems

A.K. Motovilov
V.S. Melezhik

BLTP	K.A. Bornikov, M.V. Egorov, D.S. Grudko, M. Ilias, E.A. Kolganova, V.N. Kondratyev, E.A. Koval, M.V. Kremenetskiy, A.V. Malykh, A. Mukhametkaliuly, Yu.V. Popov, S.A. Rakityansky, A.A. Saimukha, P.A. Selishchev, D. Sen, D.I. Shalapinin, E.A. Solov'ev, D. Valiolda, S.S. Vetrov, S.I. Vinitsky, V.Yu. Yushankhai
DLNP	O.I. Kartavtsev
MLIT	O. Chulunbaatar, A.A. Gusev, L.A. Syurakshina
VBLHEP	A.A. Korobitsin

Abstract and scientific rationale:
The project is aimed at studying systems formed by a small set of constituents of nuclear, subnuclear or atomic-molecular origin. The smallness of the number of constituents in a system allows one to develop and use mathematically rigorous, precise and consistent approaches to its investigation, the approaches that do not require further simplifying physical assumptions and approximations. The goal of the project consists in developing and improving the methods of numerical solving of few-body problems in nuclear, atomic and molecular physics, and astrophysics. The developed approaches and methods will be employed in the numerical study of various concrete few-body quantum systems.

Expected results upon completion of the project:
Development of methods and approaches of the theory of few-body systems, settling some still remaining mathematical questions and issues. A contribution to Efimov physics with establishing new universal features in the behavior of ultracold few-body systems including the lattice few-body systems. Numerical calculations of ultracold three-atom systems in Efimov or pre-Efimov states by employing Faddeev equations. Theoretical study of non-stationary systems, in particular, the study of

few-particle systems in varying external fields. Analysis of bound-state problems and scattering processes in low-dimensional few-particle systems. Development of the dynamical adiabatic theory and theory of hidden crossings of the potential-energy levels. Application of these theories to inelastic transitions in atom-atom collisions.

Expected results of the project in the current year:
Construction of a phenomenological model for the fusion of light nuclei in the presence of negatively charged leptons within the interaction region.

First-principles study of the adsorption of elemental Hg, Cn, Pb and Fl on the trigonal Selenium surface with the inclusion of relativistic effects.

Investigation of the Wan der Waals clusters of He and Ne atoms and possible Efimov states within the Faddeev approach.

Study of magnetorotational supernova neutrino spectra vs mass ordering.

Investigation of the alignment and orientation of symmetric top molecules by two color laser pulses.

Obtaining exact analytical results for a system of three particles with point interactions.

Obtaining bounds for the unitary invariant norms of the tangent of the operator angle between perturbed and unperturbed spectral subspaces under additive perturbation of Hamiltonian.

Study of resonant scattering of muons on atomic nuclei.

Single ionization of helium atom by 75 keV protons near the cusp region.

Studying the threshold irregularities of the multi-channel Jost matrices.

Study of the kinetics of growth of the chromium silicide layer in silicon-chrome binary plates.

Study of the total reflection and "canal" states phenomena occurring during scattering of neutrons on single and double graphene layers.

Calculation of the total breakup cross sections of the halo nucleus of ^{11}Be in collisions with targets in different mass ranges.

4. Relativistic nuclear dynamics and nonlinear quantum processes — **S.G. Bondarenko, A.B. Larionov**

BLTP	U.A. Dmitrienko, A.V. Frizen, K.S. Kalinin, L.P. Kaptar, V.K. Lukyanov, A. Parvan, K.M. Sulyukova, A.I. Titov, V.D. Toneev, S.A. Yuriev
MLIT	Yu.L. Kalinovskiy, A.V. Khmelev
VBLHEP	A.A. Aparin, E.V. Nedorezov

Abstract and scientific rationale:
The aim of the project is to study the universal laws in relativistic collisions of heavy ions accompanied by various particles production; determination of the most important observables to test the equation of state of the nucleus; theoretical support for experiments at the NICA complex. The large nuclear transparency compared to the predictions of Glauber-like models may indicate the presence of color transparency and should be carefully considered. Based on the generalized eikonal approximation, nuclear transparencies in *dd* collisions will be calculated, which are available at NICA SPD. It is planned to study three/four-nucleon bound (^{3}He,T,^{4}He) and scattering systems (elastic proton-deuteron) in the Bethe-Salpeter-Faddeev relativistic formalism. Study the properties of heated and compressed nuclear matter in the collision of heavy ions is based on the Nambu-Iona-Lasinio Polyakov loop model.

Our theoretical efforts are aimed at solving the following problems:
– improving transport approaches for describing the dynamics of relativistic collisions of heavy ions;

– identification of the most important observables in relativistic collisions of heavy ions to test the equation of state of the nucleus;

– study of the time of evolution of rapidly colliding systems to a local isotropic state in momentum space;

– study of the features of the interaction of high-energy gamma quanta with a strong laser field;

– consideration of relativistic effects in low-nucleon systems.

Expected results upon completion of the project:
Development of theoretical models and methods in the theory of nonlinear quantum processes of interaction of charged particles with intense electromagnetic fields. In this case, in addition to the dependence of observables on the field intensity, it is planned to study the polarization effects and the role of the shape and the carrier phase of the pulse.

Extension of the relativistic consideration of three-nucleon (^{3}He,T) systems in the formalism of the Bethe-Salpeter-Faddeev equation with separable interaction to four-nucleon systems in the Yakubovsky formalism (calculation of the ^{4}He binding energy, electromagnetic form factor of the system). Investigation of elastic proton-deuteron backscattering using the relativistic three-nucleon Bethe-Salpeter-Faddeev equation with a separable interaction kernel (taking into account nucleon rescattering diagrams). Consideration of the elastic electromagnetic form factor of the pion taking into account the anomalous magnetic moment of the quark in the framework of the covariant separable quark-quark interaction.

Study of the properties of heated and compressed nuclear matter in the collision of heavy ions. Of particular interest is the study of possible phase transitions that occur during the cooling of the system, as well as the problem of violation of CP invariance in strong interactions, which may be a consequence of the influence of the chiral anomaly on the topological structure of QCD vacuum in strong magnetic fields arising during the collision of heavy ions. The purpose of the study is to consider how the scattering cross section changes depending on the properties of the medium. Study of two-photon and Dalitz decays of light mesons within the NJL model at finite temperature and density. The production spectrum of dilepton pairs is directly related to various intermediate states of quark-hadron matter, and its study can provide information on phase transitions.

Investigations of the phenomenon of color transparency (CT), short-range nucleon-nucleon correlations and cumulative effect. Predictions for planned CPU search experiments at FAIR PANDA and NICA SPD. Based on the generalized eikonal approximation, taking into account the CT effects, we will calculate the nuclear transparency in the hard processes $d(d,2p)nn$ and $A(p,2p)$ with heavier nuclear targets (A >2) , for which the CT effects should be stronger.

Development of a solid theoretical basis for describing the interaction of a proton with a SRC pair in the nucleus, taking into account the NLS/VKD. Nucleon-nucleon short-range correlations (SRC) manifest themselves in interactions of high-energy particles with nuclei with sufficiently large momentum transfers (Q > 1 GeV).

Investigation of the influence of the nuclear medium on such fundamental characteristics of the elementary NN amplitude as the total cross section for scattering of a nucleon by a bound nucleon of the nuclear medium, the energy dependence of the ratio of its real part to the imaginary part, as well as its slope parameter depending on the momentum transferred to the nucleon bound in the nucleus.

Calculation of exact hadronic distributions in transverse momentum and rapidity by new methods within the framework of Tsallis-1, Tsallis-3 and q-dual statistics and their application to describe experimental data for hadrons produced in collisions of heavy ions and protons with protons at LHC, RHIC, NICA and FAIR energies. Generalization of the quantum-statistical hadron model with exactly conserved strangeness of the system to the case of exact conservation of the baryon and electric charges of the system and finding recursive equations for the exact solution of the partition function and ensemble averages. The use of this model to calculate the multiplicity of identified hadrons produced in heavy ion collisions at LHC, RHIC, NICA and FAIR energies.

Investigations of the behavior of ghost and gluon propagators at finite temperature in an approach based on the Dyson-Schwinger equation in the Landau gauge in the truncated rainbow approximation. It is planned to investigate possible phase transitions from a bound state of a glueball to a free gluon plasma for the problem of phase transitions to a quark-gluon plasma in a hot nuclear medium (in processes in experiments at the NICA facility).

Expected results of the project in the current year:
Calculation of quark-antiquark condensates and meson masses at finite temperature in the extended linear sigma model.

Calculation of hadronic decays of light and heavy mesons in the framework of the quark model with a separable kernel of interaction.

Investigation of three-particle systems including bound states and scattering states in the regions of medium and high energies using the previously constructed and tested Bethe-Salpeter-Faddeev approach. Consideration of both nucleon systems and systems including hyperons.

Inclusion of the intermediate Δ(1232) resonance in the calculation of the amplitude of the pd→ppn process using the generalized eikonal approximation method. Verification of the constructed model by comparison with experimental data on the spectra of cumulative protons and the tensor analyzing power T_{20} of the deuteron. Obtaining predictions on the cumulative proton spectra and T_{20} for the pd→ppn process in the deuteron beam mode of the Nuclotron with a fixed proton target ($\sqrt{s_{NN}}\approx$3 GeV) and in the dd collision mode at the first phase of NICA SPD ($\sqrt{s_{NN}}\approx$5-6 GeV).

Development of a hadronic blast-wave model grounded in the principle of local equilibrium, employing Tsallis non-extensive statistics to calculate the transverse momentum distributions of hadrons. Application of these distributions within the proposed model, alongside with a model employing the standard Tsallis statistics, to analyze experimental data on hadrons produced in proton-proton and heavy-ion collisions at LHC, RHIC, and NICA energies.

Further investigations of QED corrections to the lepton anomaly g−2. Analytical calculations of the sixth and higher order contributions due to bubble-like and mixed types of lepton loops in the vacuum polarization operator within the Mellin-Barnes representation.

Investigation of the influence of the nuclear environment on the nucleon-nucleon scattering amplitude parameters based on the analysis of nucleon-nucleon collision cross sections at energies up to 100 MeV/nucleon.

Investigation of the off-shell electromagnetic pion form factors in the Bethe-Salpeter formalism with a separable kernel of interaction. Calculation of the half-mass pion form factors F_1 and F_2 related to each other by the Ward-Takahashi identity.

Development of models and methods for the study of nonlinear quantum processes in the interaction of photons and charged particles with intense laser fields taking into account polarization.

Collaboration 1136

Country or International Organization	City, region	Institute or laboratory
Algeria	Setif	UFAS1
Armenia	Yerevan, ER	RAU
		YSU
Belarus	Gomel, HO	GSTU
	Minsk, MI	IP NASB
Belgium	Brussels, BRU	ULB
	Louvain-la-Neuve, WBR	UCL
Brazil	Florianopolis, SC	UFSC
	Niteroi, RJ	UFF
	Sao Jose dos Campos, SP	ITA
	Sao Paulo, SP	UEP
Bulgaria	Sofia	INRNE BAS
		NBU
China	Beijing, BJ	CIAE
		ITP CAS

Country or International Organization	City, region	Institute or laboratory
		PKU
	Lanzhou, GS	IMP CAS
		LZU
	Shanghai, SH	SHNU
		SHU
Czech Republic	Prague, PR	CU
Egypt	Cairo, C	FUE
	Giza, GZ	CU
France	Caen, PAC	GANIL
	Orsay, IDF	IJCLab
Germany	Berlin, BE	HZB
	Bielefeld, NRW	Univ.
	Bonn, NRW	UniBonn
	Cologne, NRW	Univ.
	Darmstadt, HE	GSI Helmholtz
		TU Darmstadt
	Dresden, SN	HZDR
		TU Dresden
	Erlangen, BY	FAU
	Frankfurt am Main, HE	GU
	Giessen, HE	JLU
	Hamburg, HH	UHH
	Leipzig, SN	Univ.
	Mainz, RP	JGU
	Rostock, MV	Univ.
	Siegen, NRW	Univ.
Greece	Athens	NCSR Demokritos
Hungary	Budapest	Wigner RCP
	Debrecen	ATOMKI
India	Chandigarh, CH	PU
	Kasaragod, KL	CUK
	New Delhi, DL	IUAC
Iran	Zanjan	IASBS
Italy	Catania, CT	INFN LNS
	Messina, ME	UniMe
	Naples, NA	INFN Naples
	Turin, TO	UniTo
Japan	Kobe	Kobe Univ.
	Morioka	Iwate Univ.
	Osaka	RCNP
		UOsaka
	Sendai	IMRAM

Country or International Organization	City, region	Institute or laboratory
Kazakhstan	Almaty, ALA	INP
		KazNU
Lithuania	Kaunas	VMU
Mexico	Mexico City, CDMX	UNAM
Norway	Bergen	UiB
	Oslo	UiO
Poland	Krakow, MA	IFJ PAN
	Lublin, LU	UMCS
	Otwock-Swierk, MZ	NCBJ
	Warsaw, MZ	UW
Republic of Korea	Daejeon	IBS
	Jeonju	JBNU
	Seoul	SNU
		Yonsei Univ.
Romania	Bucharest, B	IFIN-HH
		UB
	Cluj-Napoca, CJ	UBB
Russia	Dolgoprudny, MOS	MIPT
	Gatchina, LEN	NRC KI PNPI
	Khabarovsk, KHA	PNU
	Moscow, MOW	MEPhI
		MSU
		NRC KI
		PFUR
		SINP MSU
	Omsk, OMS	OmSU
	Saint Petersburg, SPE	SPbSU
		VNIIM
	Saratov, SAR	SGU
	Tomsk, TOM	TPU
	Troitsk, MOW	INR RAS
	Vladivostok, PRI	FEFU
Serbia	Belgrade, BG	IPB
Slovakia	Bratislava, BL	CU
		IP SAS
South Africa	Johannesburg, GT	WITS
	Pretoria, GT	UP
	Somerset West, WC	iThemba LABS
	Stellenbosch, WC	SU
Spain	Palma, IB	UIB
Sweden	Gothenburg, O	Chalmers
	Lund, M	LU

Country or International Organization	City, region	Institute or laboratory	
United Kingdom	Guildford, SRY	Univ.	
USA	Notre Dame, IN	ND	
	University Park, PA	Penn State	
Uzbekistan	Namangan, NG	NamMTI	
	Samarkand, SA	SamSU	
	Tashkent, TK	IAP NUU	
		INP AS RUz	
		Physics-Sun	

Theory of Complex Systems and Advanced Materials

Theme leaders: V.A. Osipov
A.M. Povolotsky

Participating countries and international organizations:
Armenia, Australia, Belarus, Brazil, Bulgaria, Canada, China, Egypt, Finland, France, Germany, India, Iran, Japan, Mongolia, Poland, Romania, Russia, Serbia, Slovakia, South Africa, United Kingdom, USA, Vietnam.

The problem under study and the main purpose of the research:
The most important directions of fundamental research will be theoretical studies of physical phenomena and processes in condensed matter, studies of the properties of new advanced materials, constructing and analysis of theoretical models and the development of analytical and computational methods for their solution. Complex materials such as high-temperature superconductors, magnetic materials, smart composite materials, fractal and layered structures are supposed to be studied and a wide class of systems with strong electronic correlations will be analyzed. Theoretical research in this area will be aimed at supporting the experimental study of these materials carried out at the Frank Laboratory of Neutron Physics, JINR. It is planned to conduct research in the field of physics of nanostructures and nanomaterials, in particular, using the software packages for modeling physical and chemical processes and for analysis of physical characteristics. First of all, these are modern two-dimensional materials such as graphene, transition metal dichalcogenides, etc., including their modification and chemical functionalization for a subsequent use in the design of new devices for nanoelectronics, spintronics, etc. Partly, these studies are focused on experiments held at the FLNR Center for Applied Physics JINR, Nanobiophotonics Centre at FLNP JINR, the Institute of Semiconductor Physics SB RAS and a number of other laboratories of the JINR Member States. The physical properties of stacks of Josephson junctions and various Josephson nanostructures will be studied in detail. Much attention will be paid to the analysis of both lattice and field models of equilibrium and nonequilibrium systems of statistical mechanics. The concepts of scaling and universality allow one to go beyond the model approach and apply the results obtained to broad classes of phenomena studied in the physics of condensed matter. Studies of a wide range of universal phenomena in complex systems – phase transitions in condensed matter and high-energy physics, scaling in (magneto)hydrodynamic turbulence, chemical reactions, percolation, etc. by the methods of quantum field theory including the functional renormalization group are supposed to be carried out.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	Complex materials	E.M. Anitsash	01-3-1137-1-2024/2028
2.	Mathematical models of statistical physics of complex systems	A.M. Povolotsky	01-3-1137-2-2024/2028
3.	Nanostructures and nanomaterials	V.A. Osipov V.L. Katkov	01-3-1137-3-2024/2028
4.	Quantum field theory methods in complex systems	M. Hnatič	01-3-1137-4-2024/2028

Projects:

	Name of the project	Project leaders
Laboratory	Responsible from laboratories	
1.	**Complex materials**	**E.M. Anitsash**
BLTP	N.N. Bogoliubov, A.Yu. Cherny, A.A. Donkov, N.K. Hoang, P.A. Maksimov, A.A. Vladimirov, V.I. Yukalov, V.Yu. Yushankhai	
FLNP	V.L. Aksenov, A.M. Balagurov, A.S. Doroshkevich, A. Islamov, D.P. Kozlenko, A.I. Kuklin, E.P. Popov	
MLIT	A. Khvedelidze, L.A. Syurakshina, Ya. Talochka, E.P. Yukalova	

FLNR M. Mirzaev

DLNP D.V. Karaivanov, Nguyen Trung, A.I. Velichkov

Abstract and scientific rationale:
Enormous recent progress in both the art of sample preparation and the measurement techniques has produced a wealth of high quality data on thermodynamic, transport, structural and spectroscopic properties for new complex materials that exhibit unconventional forms of magnetism, showing evidence for strong electronic and magnetic correlations, or having fractal properties at nano and microscales. These materials attract now considerable attention for various applications, e.g., in quantum computing or in describing the physical and chemical properties of colloids, biological systems, granular materials etc.

Expected results upon completion of the project:
Estimation of the exchange parameters of Kitaev materials based on transition and rare-earth metals and calculation of their spin-wave spectrum.

Magnetic phase diagrams in strongly-correlated electronic systems within the t-J model for electron doping.

Explaining the structure of systems of dense random packings in nano- and micro-materials.

Development and application of quantum algorithms for computational problems in condensed matter physics and quantum chemistry.

Development of a theory of stability for mixtures of quantum fluids.

Understanding the irradiation resistance of various compounds.

Expected results of the project in the current year:
Identification of magnetic excitations of $CoGeO_3$ pyroxene.

Study of the magnetic structure and excitations of a novel spin ladder material.

Analysis of the correlation properties of dense packing systems with a power-law particle size distribution depending on the packaging protocol: study of spatial correlations between particles of different sizes and the characteristic parameters of these correlations.

Investigation of dynamical transitions in the internal bosonic Josephson effect.

Development of the approach for summation of virial expansions by means of self-similar factor approximants.

Study of methods for the regulation of dynamics in probabilistic complex networks.

Derivation of molecular dynamics potentials for the titanium-hydrogen system using ab-initio numerical data.

Numerical investigation by ab-initio codes of model two dimensional systems, as well as some silicon-nitrogen compound systems.

Investigation of 2D excitons in a magnetic field.

Development and application of quantum algorithms and tensor networks for computational problems in condensed matter physics and quantum chemistry.

Computing the dynamics of quantum entanglement using tensor networks in low-dimensional spin models with long-range interactions.

2. Mathematical models of statistical physics of complex systems — A.M. Povolotsky

BLTP G.Y. Chitov, V.I. Inozemtsev, V.V. Papoyan, P.N. Pyatov, V.P. Spiridonov

Abstract and scientific rationale:
Non-perturbative studies of large-scale systems with many interacting degrees of freedom constitute an important part of modern theoretical physics that has been experiencing a growing interest of researchers during the last decade. Recent

advances in this direction are based on the construction and investigation of exactly solvable models of equilibrium and non-equilibrium statistical physics, quantum mechanics and related quantum field theories. Then, with the use of the concepts of scaling and universality the results obtained from the exact solutions can be extended to vast classes of physical phenomena far beyond the realm of such systems. The exact solvability of models of physical systems is provided by their special mathematical structure coined by the term integrability. The models with such a structure is the major subject of studies within the current project.

The project is aimed at further exploration of the field of exactly solvable models of statistical physics, quantum mechanics and quantum field theories, which requires a development of new theoretical tools based on the theory of integrable systems and discovery of new mathematical structures standing behind the exact solvability. The main objectives of the project consist in obtaining exact results about universal laws in interacting particle systems with stochastic dynamics and models of random interface growth, models of equilibrium statistical physics including percolation, polymers and other two-dimensional lattice models and quantum spin chains, studies of known and construction of new types of special functions playing the role of building blocks in the theory of integrable systems and computations of partition functions (superconformal indices), studies of known and construction of new algebraic structures standing behind the integrability concept.

Expected results upon completion of the project:
Construction and complete classification of one-dimensional stochastic models of interacting particles based on representations of Hecke algebras and related two-dimensional lattice models of interacting paths, as well as obtaining their exact solutions using the Markov duality methods.

Calculation of exact cluster densities and their asymptotic expansions in percolation models, as well as loop densities in associated densely packed loop models on lattices with different boundary conditions, construction of asymptotic expansions of thermodynamic quantities characterizing the behavior of free-fermionic models on lattices of finite size, such as dimers, Ising model and spanning tree models with different geometry under various boundary conditions. It is also planned to study the boundary behavior of nonlocal correlation functions in models of dense polymers and spanning trees, as well as to describe the limiting forms and universal fluctuations of polymer configurations in these models.

Application of the studied models of polymers and quantum spin chains to problems from related fields of quantum mechanics and biophysics. Among them are the studies of "entangled states" and magnetic properties of complex quantum spin systems related to the problems of quantum computing, the use of a rotor-router model (Eulerian walks) to study the dynamics of double-stranded DNA breaks.

Development of mathematical structures behind the integrability. In particular, further study of the properties of elliptic beta integrals and elliptic hypergeometric functions and their various limiting forms, new applications of these functions to quantum field theory, quantum and statistical mechanics and soliton theory, construction of complex hypergeometric functions on root systems in the Mellin-Barnes representation and study of their connections to the two-dimensional conformal field theories. Finding generalized modular transformations for elliptic hypergeometric integrals and description of their consequences for superconformal indices (statistical sums) of four-dimensional supersymmetric field theories. It is also planned to generalize the obtained results to the cases of rarefied hypergeometric functions of various types and describe the relevant physical systems, as well as to investigate connections between soliton solutions of integrable equations, lattice Coulomb gases, non-local Ising chains and ensembles of random matrices.

Construction and study of new algebraic structures underlying integrability and their use for constructing new integrable systems that could be useful in various applications. Generalization of the Hamilton-Cayley theorem to the case of orthogonal type quantum matrix algebras and study of the subalgebra of spectral values of orthogonal quantum matrices. Construction of an analogue of the Gauss expansion in the reflection equation algebras, and development of the representation theory of these algebras.

It is also planned to study a series of R-matrix solutions of the braid relation, which make it possible to model stochastic reaction-diffusion processes and study the possibility of constructing new link/knot invariants using new series of R-matrices.

Expected results of the project in the current year:
Construction of systems of Markov duality functions and their application to the calculation of correlation functions in a stochastic eight-vertex model.

Calculation of correlation functions in diffusion limited annihilation and coagulation of particles on a ring.

Investigation of quantum entanglement in the magnetic properties in clusters containing Cu, Ni, and Co with spins of 1/2, 1, and 3/2, respectively.

Application of the rotor-router model, also known as the Eulerian walk, to describe the dynamics of recovery of double-stranded polymer breaks.

Explanation of the cascades of percolation transitions in models of the type of cellular automata from the analysis of Lee-Yang zeros of the generalized partition functions of stationary (non-equilibrium) states and the transfer-matrix spectra. Development of applications of the neural networks (AI) for an analysis of these transitions.

Investigation of limiting transitions in the hyperbolic many-body Ruijsenaars model in two singular limits leading to different complex models of the Calogero-Sutherland type.

Construction of R-matrices associated with a series of 4n-dimensional (n=1,2…) representations of the quantum supergroup U_q gl(2|1) and investigation of related knot invariants, presumably being colored versions of the Gould-Links invariant.

Investigation of the product in characteristic subalgebras of the Quantum Matrix algebras associated with the R-matrix representations of Birman-Murakami-Wenzl algebras, in particular, construction of an analogue of the Pieri's formula for these algebras.

3. Nanostructures and nanomaterials

V.A. Osipov
V.L. Katkov

BLTP M. Abdelghani, D. Anghel, K.K. Kesharpu, E.A. Kochetov, S.E. Krasavin, K.V. Kulikov, N.L. Matsko, I.R. Rahmonov, M.A.A.M. Salem, N.M. Shchelkachev, I.K. Sobolev, Yu.M. Shukrinov

MLIT I. Sarhadov, E.B. Zemlianaya

FLNP G.M. Arzumanyan

FLNR V.A. Skuratov

LRB A.N. Bugay

Abstract and scientific rationale:
It is planned to conduct research in the field of physics of nanostructures and nanomaterials, in particular, using the software packages for modeling physical and chemical processes and for analysis of physical characteristics. First of all, these are modern two-dimensional materials such as graphene, transition metal dichalcogenides, etc., including their modification and chemical functionalization for a subsequent use in the design of new devices for nanoelectronics, spintronics, etc. Partly, these studies are focused on experiments held at the FLNR Center for Applied Physics JINR, Nanobiophotonics Center at FLNP JINR, the Institute of Semiconductor Physics SB RAS and a number of other laboratories of the JINR Member States. It is planned to analyze topological superconductivity in strongly correlated electronic systems in order to find possible applications for the transmission and storage of quantum information. The physical properties of stacks of Josephson junctions and various Josephson nanostructures will be studied in detail.

The main goal of the project is a theoretical study of the properties of new promising materials, primarily nanostructures and nanomaterials. This is explained not only by the fundamental nature of the physical properties of these materials but also by their practical importance for designing new electronic devices, as well as devices for storing, processing and transmitting information, sensors and biosensors, and others.

Expected results upon completion of the project:
The project is aimed at solving tasks in the following areas:
– in order to identify materials with promising properties for use as a component base for a new generation of electronics, it is planned to study thermal and electron transport in low-dimensional materials of various configurations and chemical composition. An analysis will be made of the role of functionalization, structural modification, the influence of thin layers, polycrystalline, structural defects, and other factors. Experimental studies are carried out in cooperation with the Educational and Scientific Technological Laboratory "Graphene Nanotechnologies" NEFU in Yakutsk (synthesis), the Institute of Semiconductor Physics SB RAS (synthesis, characterization, functionalization), FLNP JINR (chracterization, functionalization, irradiation) and FLNR JINR (ion irradiation to create nanopores);

– analysis of topological superconductivity in strongly correlated electronic systems in order to search for possible applications for the transmission and storage of quantum information and for the study of non-standard quantum transport that is insensitive to local noise sources;

– study of dynamic, transport and chaotic phenomena in hybrid Josephson nanostructures with magnetic materials for the purposes of superconducting spintronics. Modeling of quantum phenomena in Josephson qubits (memory elements);

– study of the properties of polarons in low-dimensional materials and nanostructured objects. Analysis of plasmon-phonon interaction and plasmons in nanoscale and massive objects.

Expected results of the project in the current year:
Study of the temperature dependence of the band gap and electron mobility in various two-dimensional crystals due to interaction with phonons.

Analysis of topological properties of Moiré materials resulting from strongly correlated electronic states.

Study of the magnetic phase diagram in a hexagonal lattice taking into account quantum corrections.

Study of the behavior of electrical conductivity in a field-effect transistor based on polycrystalline graphene. Identification of the role of contact resistance.

Investigation of unusual superconducting states occurring in altermagnets.

Analysis of "optical modes" in a one-dimensional Josephson metamaterial consisting of Josephson junctions with two types of capacitances.

Investigation of the possibility of using an array of nanomagnets to observe a quantum phase transition.

Demonstration of the possibility of controlling dynamic states of magnetization in superconducting hybrid structures with a magnet in the presence of external electromagnetic radiation.

Carrying out first-principles calculations of the formation, migration and clustering of vacancies in a silicon crystal under the influence of ionizing radiation. Calculation of hydrogen adsorption by the resulting microcavities in silicon.

4. Quantum field theory methods in complex systems **M. Hnatič**

BLTP L.Ts. Adzemyan, N.V. Antonov, N.M. Gulitskiy, G.A. Kalagov, M. Ketser, M.V. Kompaniets, N.M. Lebedev, L. Mižišin, Yu.M. Molotkov, M.Yu. Nalimov, A.V. Ovsyannikov

MLIT J. Buša

Abstract and scientific rationale:
Complex physical phenomena such as developed turbulence, transport phenomena, non-equilibrium phase transitions, percolation, chemical reactions and surface growth in random media are difficult to study theoretically and experimentally; however, in the light of their wide distribution in nature such studies prove themselves to be very valuable.

The main task of the project will be the formulation of the corresponding theoretical models, which can be investigated using the methods of quantum field theory and non-equilibrium statistical physics. The main goal is to study the statistical characteristics of fluctuating fields in the region of large spatial scales, identify phase transitions and to calculate universal critical exponents and non-universal amplitudes.

Dynamic nonlinear systems in which non-equilibrium (stochastic) fluctuations of physical quantities play a decisive role, is one of the most important research topics by leading scientific teams in the world. They cover a wide range phenomena, which we observe in the world around us.

Notable examples of stochastic processes include: hydrodynamic and magneto-hydrodynamic turbulence, describing, in particular, turbulent movements in the Earth's atmosphere and oceans, the spread of pollutants in them (including chemically active), as well as chaotic motions of plasma on the surface of the sun and in space. One of the important consequences of the existence of mechanical instabilities in electrically conducting turbulent media is an exponential growth of magnetic fluctuations leading to the formation of observed nonzero averaged magnetic fields only due to the kinetic energy of the turbulent medium.

Another important example of stochastic systems is percolation processes. They describe phenomena such as seepage in porous media, filtration, spread of infectious diseases, forest fires and others. Their universal feature is the existence of a non-equilibrium phase transition to an inactive (absorbing) state that extinguishes all activity of the observed system. Obviously, the study of transitions between a stationary active and the inactive phase is of great practical importance.

The main object of the study is physical quantities that depend on space-time coordinates and therefore are fluctuating fields, and the measured quantities are their statistical averages. The most important of them are non-zero average field values, response functions, multipoint correlation functions, two-point simultaneous correlations (structural functions), including composite fields (operators). In the region of large spatial and temporal scales, their scaling behavior with universal critical exponents is observed. The analysis of stability regions of scaling regimes and the calculation of indices is a priority goal in the study of stochastic nonlinear systems.

The main goal of the project is to study stochastic nonlinear dynamic systems such as developed (magneto)hydrodynamic turbulence, non-equilibrium phase transitions, phase transitions in systems with high spins, kinetics of chemical reactions, percolation processes, surface growth in random media and self-organized criticality.

Expected results upon completion of the project:
Investigation of the crossover in systems of multicomponent fermions within the BEC-BCS functional renormalization group: analysis of phase diagrams and calculation of transition temperatures to the ordered state. Approbation and adaptation of computational methods for solving non-perturbative equations of the functional renormalization group.

Development of computational methods for calculating the contributions of multi-loop diagrams to the renormalization group functions of dynamical models. Investigation of the dynamics of the superconducting phase transition in low-temperature superconductors.

Study of the effects associated with the violation of mirror symmetry in magneto-hydrodynamic developed turbulence. Calculation of two-loop Feynman diagrams generated by the Lorentz force and two-loop diagrams of the response function leading to an exponential growth of magnetic field fluctuations in the region of large scales. Study of the phenomenon of turbulent dynamo.

Construction of effective field-theoretical models of chemical reactions of various types of particles occurring in random media. Study of the infrared scaling behavior of statistical correlations of particle densities by renormalization group methods.

Study of isotropic and directed percolation. Calculation of multi-loop Feynman diagrams generating ultraviolet divergences. Finding fixed points of the renormalization group equations and calculating critical exponents for physically significant and experimentally observable quantities - response functions, density of active nodes (agents), effective radius and mass of active zones.

Study of the effect of isotropic motion of a medium with different statistical characteristics on the possibility of anisotropic scaling in the Hua-Kardar self-organized criticality model. Investigation by the functional renormalization group method of possible asymptotic regimes corresponding to the non-universal scaling behavior of a surface growing in a random environment and described by a model that includes an infinite number of types of interactions.

Expected results of the project in the current year:
Study of a field-theoretic model of stochastic magnetohydrodynamics with broken mirror symmetry: a study of the "cross" composite operators of velocity and magnetic field required to calculate the parameters of the α-effect responsible for the occurrence of the electromotive force.

Calculation of correlators and critical indices in a model of a passive scalar field carried by developed turbulent flows in the Kraichnan ensemble using the equations of the non-perturbative renormalization group.

Study of directed percolation in the presence of hydrodynamic fluctuations: two-loop calculations of control parameters and critical exponents.

Calculations in the A-model of critical dynamics with φ3 interaction in the three-loop approximation.

Study of the problem of random walks of particles on a randomly inhomogeneous ("rough") surface under the action of gravity: calculation of exponents in the laws of spreading a spot of wandering particles.

Investigation of a random walk (diffusion) model in a randomly inhomogeneous (fluctuating) medium: study of the influence of correlation time and medium compressibility, calculation of exponents in sub- and superdiffusion laws.

Investigation of surface growth models in a moving random medium (for example, in a turbulent fluid): study of the inverse influence of growth nonlinearity on the medium motion.

Investigation of the anisotropy of scaling solutions in the Hua-Kardar model of random surface growth under the action of anisotropic mass transfer by isotropic motion of the external medium.

Investigation of the influence of dipole-dipole interaction on the critical behavior of Ising-type magnets by the functional renormalization group method.

Calculation of high-order asymptotics of expansions and resummation of multi-loop results of scaling exponent calculations in the IR-effective theory of quantum gravity.

Collaboration 1137

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
		YSU
Australia	Canberra, ACT	ANU
	Sydney, NSW	USYD
Belarus	Minsk, MI	IM NASB
		IP NASB
		SPMRC NASB
Brazil	Natal, RN	IIP UFRN
	Sao Paulo, SP	USP
Bulgaria	Sofia	IMech BAS
		ISSP BAS
Canada	Montreal, QC	UdeM
	Sherbrooke, QC	UdeS
China	Beijing, BJ	Tsinghua
Egypt	Giza, GZ	CU
Finland	Helsinki	UH
France	Marseille, PAC	CPT
Germany	Leipzig, SN	Univ.
India	Kolkata, WB	IACS
Iran	Zanjan	IASBS
Japan	Utsunomiya	UU
Mongolia	Ulaanbaatar	IPT MAS
Poland	Wroclaw, DS	WUST
Romania	Bucharest, B	UB
	Timisoara, TM	UVT
Russia	Moscow, MOW	HSE
		MSU
		PFUR
	Novosibirsk, NVS	ISP SB RAS
		NIIC SB RAS
	Protvino, MOS	IHEP
	Saint Petersburg, SPE	PDMI RAS

Country or International Organization	City, region	Institute or laboratory	
		SPbSU	
	Saratov, SAR	SGU	
	Tomsk, TOM	TPU	
	Vladivostok, PRI	FEFU	
Serbia	Belgrade, BG	VINCA	
Slovakia	Bratislava, BL	CU	
	Kosice, KI	IEP SAS	
		UPJS	
South Africa	Pretoria, GT	UNISA	
United Kingdom	Coventry, WMD	Warwick	
USA	Pasadena, CA	Caltech	
Vietnam	Hanoi, HN	IOP VAST	
	Ho Chi Minh City, SG	VLU	

01-3-1138-2019

Modern Mathematical Physics: Integrability, Gravity and Supersymmetry

Theme leaders: A.P. Isaev
S.O. Krivonos

Participating countries and international organizations:

Armenia, Australia, Brazil, Bulgaria, CERN, China, Czech Republic, France, Germany, Greece, Egypt, Iran, Ireland, Israel, Italy, Japan, Kazakhstan, Kyrgyzstan, Poland, Portugal, Republic of Korea, Russia, Serbia, Spain, United Kingdom, USA.

The problem under study and the main purpose of the research:
The main task of the Theme is the development of mathematical methods for solving the most important problems of modern theoretical physics, namely: development of new mathematical methods for studying and describing a wide class of classical and quantum integrable systems and their exact solutions; analyzing and searching for solutions to a wide range of problems of supersymmetric theories, including models of strings and other extended objects; study of nonperturbative regimes in supersymmetric gauge theories; development of cosmological models of the early Universe, gravitational waves and black holes.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	Integrable systems and symmetries	A.P. Isaev S.O. Krivonos N.A. Tyurin	01-3-1138-1-2024/2028
2.	Supersymmetry, higher spins, gravity	E.A. Ivanov S.A. Fedoruk	01-3-1138-2-2024/2028
3.	Quantum gravity, cosmology and strings	I.G. Pirozhenko D.V. Fursaev	01-3-1138-3-2024/2028

Projects:

	Name of the project	Project leaders
Laboratory	Responsible from laboratories	
1.	**Integrable systems and symmetries**	**A.P. Isaev** **S.O. Krivonos** **N.A. Tyurin**
BLTP	H.D. Dimov, A.A. Golubtsova, N.Yu. Kozyrev, M.A. Podoinicin, A.A. Provorov	

Abstract and scientific rationale:
Our project is devoted to important problems of modern mathematical physics. The three most important investigation directions of the project are the study of holographic duality, construction of supersymmetric theories and description of unitary irreducible representations of Poincare groups in higher dimensions. Each of these directions can be regarded separately but in our project we concentrate our attention on the problems which lie on the borders of these major directions. As byproducts, we study certain applied problems, including those that arise in connection with booster thematic.

Expected results upon completion of the project:
The first problem of the project is the study of algebraic and differential structures in holographical systems, which belongs to the subject of modern mathematical physics considered in the context of holographic duality. This part of the project is focused on the study of properties of integrable systems appearing in holographical models.

The second problem is devoted to the construction of an action of the non-Abelian N=(1,0), d=6 tensor multiplet possessing as many as possible numbers of properties of six dimensional superconformal theories. This problem is related to the first one since it is devoted to field theories with extended supersymmetry which are very important in the mathematical physics studies since they help to describe common properties of quantum fields theories and many aspects of the string theory.

The third problem of our project arises in the context of studies of the models with higher spin fields requiring a certain description of unitary irreducible representations of Poincare groups and symmetry groups of AdS spaces. According to Wigner, each irreducible representation of the four-dimensional Poincare group is assotiated with an elementary particle (field). This conception is generalized to the case of arbitrary dimension and to the case of other groups including supergroups. Therefore, when studying different field models, one first of all asks the question of classification and explicit construction of unitary irreducible representations of the symmetry group of the studied theory.

Expected results of the project in the current year:
Study of integrable models on doubly deformed background geometries of the type of three-dimensional deformed AdS multiplied by compact deformed Einstein manifolds and obtaining string solutions from the class of pulsating strings and the class of spikes and magnons. Obtaining dispersion relations between conserved charges with the help of quasiclassical quantization. Study of the information content of these theories and their complexity.

Construction of superconformal mechanics with N=3 and N=6 extended supersymmetry which include interactions with bosonic currents forming so(3), su(3), so(6) Lie algebras.

Construction of N=(1,0) supergravity action in six-dimensional spacetime by modifying the action of the tensor multiplet constructed in JHEP 03 (2023) 223.

Calculation of colour factors in an infinite series of Feynman diagrams arising in non-Abelian gauge theories with spinor gauge groups based on the properties of the split Casimir operator.

Search for universal expressions for the 6-j symbols arising in the associativity conditions for the tensor product of three adjoint representations of simple Lie algebras.

Construction of representations with continuous spin in the AdS_d space, where dimension d>=4. Investigation of the unitarity of these representations and their relation to classification within the framework of the light cone formalism.

Construction and investigation of thermal flows in 3-dimensional gauge supergravity with the target space of the sigma model S^2 associated with irrelevant deformations in the context of holographic duality.

Construction of a field realization of a continuous (infinite) spin representation for the symmetry group of an anti-de Sitter space of arbitrary dimension.
Search for new examples of lagrangian submanifolds in Grassmannian Gr(r, n).

2. Supersymmetry, higher spins, gravity **E.A. Ivanov**
S.A. Fedoruk

BLTP A.A. Averiyanov, I.L. Buchbinder, A.S. Budekhina, E.T. Musaev, A.P. Nersessian, G.A. Sarkissian, Ya.M. Shnir, S.S. Sidorov, A.O. Sutulin, N.M. Zaigraev

Abstract and scientific rationale:
The project is aimed at solving fundamental problems of modern theoretical physics associated with the development of superfield methods in gauge theories with extended supersymmetry in various dimensions, including extended supersymmetric mechanics. The implementation of the project includes the construction of new field and quantum-mechanical models with global and gauge symmetries, the development of new, including geometric, methods for studying the structure of these models at the classical and quantum levels, the study of the structure of the corresponding quantum effective actions and classical solutions of these models, including black holes. All tasks of the project are set by the modern development of theoretical physics and are organically joined by the unity of methods and approaches.

Expected results upon completion of the project:
Calculating all leading and subleading in the dimensional regularization parameter two-loop counterterms in 6D, N=(1,0) and N=(1,1) supersymmetric gauge theories.

Constructing a one-loop induced effective action in the theory of hypermultiplet interacting with N=2 supergravity in the harmonic superspace approach.

Development of the methods of calculation of the one-loop induced effective action in the theory of hypermultiplet coupled to external fields of N=2 harmonic gauge superfields.

Derivation of 4D, N=2 harmonic superfield formulation for N=2 supersymmetric gauge fermionic higher spin fields.

Working out 4D, N=2 superfield gauge theory of higher spin fields in the AdS space.

Development of effective methods for describing gauge fields and superfields of an infinite spin in an arbitrary space-time dimension.

Finding Lagrangians describing the interactions of infinite spin fields and higher spin fields with fields of a fixed spin.

Finding out superfield harmonic Lagrangians of sigma models obtained by T-duality from 2D, N=(4,4) supersymmetric hyperkahler and quaternion-kahler sigma models.

Building a superfield matrix formulation of new N=4 and N=8 supersymmetric extensions of integrable many-particle systems and their quantization.

Construction of new models of N-extended supersymmetric quantum mechanics by using the superfield gauging method, which describe the interaction of dynamic and semidynamic multiplets of various types.

Construction and study of N=4 models of supersymmetric mechanics based on the interaction of linear and nonlinear supermultiplets with the component content (4,4,0), (3,4,1) and (2,4,2).

Constructing the Hamiltonian formulation and performing quantization of the generalizations of systems with the nonlinear (2,4,2) supermultiplet.

Constructing an extension of N=4 supersymmetric mechanics with (3,4,1) supermultiplet to the class of systems parametrized by an arbitrary holomorphic function.

Construction and study of many-particle systems with nonlinear supermultiplets.

Construction of a superfield description of Calogero-type models with extended N≥4 supersymmetries.

Analysis of the integrability of N-extended supersymmetric systems of the Euler–Calogero–Moser and Calogero–Moser–Sutherland types for the A(n-1) series of the Coxeter group.

Finding an explicit form of the functionally independent conserved Liouville currents in N=2 supersymmetric Calogero models for all root systems of Coxeter groups.

Construction of two new exactly calculated rarefied elliptic beta integrals associated with special lens spaces and a special subgroup of the modular transformations group SL(2,Z).

Computation of a matrix of modular transformations of one-point conformal blocks on a torus in the Neveu-Schwarz sector of the N=1 superconformal Liouville field theory, based on the expression of this matrix as an integral of the product of certain elements of the fusion matrix.

Obtaining the difference equations for the fusion matrix in the Neveu-Schwarz sector of the N=1 superconformal Liouville field theory.

Finding a new class of solutions of GR with gauge multicomponent matter fields in models with spontaneous symmetry breaking.

Constructing and exploring a new class of solutions of extenged Einstein gravity with the Chern-Simons term that represents stationary rotating black holes.

Expected results of the project in the current year:

Calculation of all leading and subleading in dimensional regularization parameter two-loop counterterms in 6D, N=(1,1) supersymmeteric gauge theories.

Calculation of three-loop on-shell divergences of the effective action in 6D, N=(1,1) supersymmetric Yang-Mills theory in the harmonic superspace approach.

Calculation of one-loop divergences in 6D, N=(1,0) supergauge theory with non-minimal coupling of a hypermultiplet with a vector multiplet.

Quantization and calculation of the effective action in the theory of totally antisymmetric tensor-spinor field in the AdS space.

Development of BRST-construction for partially massless higher spin fields in the AdS space.

Construction of a one-loop induced effective action in the hypermultiplet theory interacting with N=2 supergravity in the harmonic superspace approach.

Derivation of the 4D, N=2 harmonic superfield formulation for N=2 supersymmetric gauge fermionic higher spin fields.

Working out 4D, N=2 superfield gauge theory of higher spin fields in the AdS space.

Classification of dimension 8 Drinfeld doubles and the corresponding families of dual solutions to 10-dim supergravity. Construction of a class of tri-vector deformations analogous to almost-abelian bi-vector Yang-Baxter deformations.

Developing a framework for generating full extremal brane solutions from their near-horizon limits by abelian tri-vector deformations. Search and analysis of a connection of such transformations with the non-relativistic 11-dimensional Newton-Cartan supergravity. Analysis of necessary and sufficient conditions for polyvector deformations to generate solutions to 10- and 11-dimensional supergravity.

Construction of matrix supersymmetric mechanics using indecomposable N=8 supermultiplet nonlinearly combining the multiplet (1,8,7) and two multiplets (8,8,0). Gauging the constructed superfield matrix model.

Construction of supersymmetric extensions of integrable Calogero models with trigonimetric and elliptic potentials. Analysis of the integrability of these systems based on the construction of the corresponding Lax pair.

Study of the semiclassical limit of the difference equation for the parafermionic hyperbolic gamma functions. Constructing solutions of the parafermionic quantum mechanic arising in this limit and in particular of the supersymmetric Calogero-Sutherland model.

Construction and study of non-Abelian generalizations of the MICZ-Kepler system.

Construction and study of the quantum Landau problem on the second-order surfaces of revolution.

Study of systems with Lagrangians depending on external curvatures and their applications.

Construction and study of new solutions of the generalized theory of gravity with scalar matter fields describing charged and stationary rotating black holes.

Study of self-gravitating vortons and Hopfions in the presence of an event horizon.

3. Quantum gravity, cosmology and strings

I.G. Pirozhenko
D.V. Fursaev

BLTP A. Afsal, E.A. Davydov, B.N. Latosh, A.B. Pestov, A.S. Sorin, V.A. Tainov, P.V. Tretyakov

Abstract and scientific rationale:
The project is aimed at solving the fundamental problems of classical and quantum gravity and conducting advanced theoretical research at the national and world level in this area at BLTP JINR. In classical gravity, the project is focused on studying all kinds of gravitational wave phenomena, including shock waves in General Relativity, as well as various sources of gravitational wave background such as cosmic strings. One of the directions of the project is the elaboration of cosmological models that explain the properties of the observable Universe based on field theory methods and modified gravity. In the field of quantum gravity, it is planned to develop an apparatus of quantum field theory in an external classical gravitational background and new methods for an approximate estimation of the effective gravitational action in various regimes. Asymptotic symmetries in gravity, the relationship between gravity, thermodynamics and quantum entanglement, the holographic properties of gravity, and the AdS/CFT correspondence will also be explored.

Expected results upon completion of the project:
Development of field theory methods against the background of shock gravitational waves using the method of

supertranslations at the wave front; study of classical field effects induced by shock waves, including the astrophysical applications.

Study of classical effects in the gravitational field of shock gravitational waves, including the case of the gravitational field induced by null cosmic strings (cosmic strings moving at the speed of light); study of gravitational (electromagnetic) radiation induced by the motion of null cosmic strings near massive (charged) sources, estimation of the parameters of these objects corresponding to the observed characteristics of induced radiation.

Study of physical effects associated with the formation of caustics and other defects on the world sheet of the null cosmic string as possible sources of gravitational bursts; development of the holonomy method proposed for describing free classical fields against the background of a gravitational shock wave.

Quantization and study of quantum effects in the gravitational field of shock gravitational waves, calculation of the expectation value of the renormalized energy-momentum tensor.

Derivation and study of the properties of exact solutions of the Einstein equations related to the subject of this project, for example, the search for non-trivial solutions that have global hyperbolic isometry and allow the introduction of holonomy associated with these transformations.

Study of the gravitational entropy associated with various surfaces in Riemannian geometry, in particular, study of the entropy formed when the light cones of the past and future (causal diamonds) intersect, as well as study of quantum corrections and renormalization of this quantity.

Further development of spectral geometry methods applied to nonlinear spectral problems; using these methods to study the finite-temperature QFT on stationary manifolds of a general form, as well as the application of this theory to calculate the effects of quark-gluon matter taking into account rotation and acceleration.

Study of cosmological models of modified gravity, an attempt to explain on their basis the key characteristics of the observed cosmology such as the accelerated expansion of the Universe; the study of cosmological perturbations in a teleparallel theory with a non-minimal scalar-tensor coupling, where the main object is the torsion scalar, in contrast to general relativity, where the main object is the Ricci scalar.

Construction of integrable cosmological potentials for spatially flat cosmologies with one scalar field for searching and constructing realistic completely integrable inflationary models with a phase transition; study of phase transitions in quantum theory, including gravity, and the formation dynamics of walls separating regions with different field values, the development of the thick-wall approximation method taking into account gravity, as well as the construction and study of exactly solvable inflationary models with phase transitions.

Development of methods in the framework of the Picard-Lefschetz theory and their application for calculating Lorentz path integrals in problems of quantum field theory, gravity and cosmology, and, in particular, in problems of describing the lensing of gravitational waves.

Expected results of the project in the current year:
Study of the properties of gravitational waves in Einstein-Gauss-Bonnet gravity.

Study of perturbations of classical electromagnetic fields caused by the action of general type gravitational shock waves: analysis of secondary electromagnetic shock waves.

Formulation of the Cauchy problem for perturbations of the gravitational field caused by gravitational shock waves, setting initial data at the shock wave front, search for explicit asymptotics of gravitational perturbations in the case of fields created by point gravitational sources.

Defining gravitational shock waves propagating on a general gravitational background, determination of canonical variables at the shock wave front, determination of the canonical momenta variation under supertranslations, study of the mechanism of spontaneous diffeomorphism covariance breaking at the shock wave front.

Study of inflationary scenarios emerging in the context of calculating the one-loop effective action for various scalar-tensor gravity models. Estimation of the observable characteristics of such inflationary scenarios such as the tilt of the scalar perturbation spectrum and the ratio of the amplitudes of tensor and scalar perturbations.

Development of the FeynGrav computational package by means of implementing Feynman rules constructed with making use of the BRST formalism in order to improve the package performance.

Collaboration 1138

Country or International Organization	City, region	Institute or laboratory
Armenia	Ashtarak, AG	IPR NAS RA
		IRE NAS RA
	Yerevan, ER	AANL
		YSU
Australia	Perth, WA	UWA
	Sydney, NSW	USYD
Brazil	Juiz de Fora, MG	UFJF
	Santo Andre, SP	UFABC
	Sao Paulo, SP	USP
Bulgaria	Sofia	INRNE BAS
		SU
CERN	Geneva, CH	CERN
China	Beijing, BJ	UCAS
	Guangzhou, GD	SYSU
	Hengyang, HN	USC
	Nanchang, JX	NCU
	Shanghai, SH	SHU
Czech Republic	Prague, PR	CTU
Egypt	El Shorouk, C	BUE
France	Lyon, ARA	LPENSL
	Marseille, PAC	CPT
	Nantes, PDL	Subatech
	Paris, IDF	ENS
		LUTH
	Tours, CVL	UT
Germany	Bonn, NRW	UniBonn
	Hannover, NI	LUH
	Leipzig, SN	Univ.
	Munich, BY	LMU
	Oldenburg, NI	IPO
	Potsdam, BB	AEI
Greece	Athens	NKUA
Iran	Isfahan	UI
	Tehran	FU
		IPM
Ireland	Dublin, L	DIAS
Israel	Jerusalem, JM	HUJI
	Tel Aviv, TA	TAU
Italy	Frascati, RM	INFN LNF
	Padua, PD	UniPd

Country or International Organization	City, region	Institute or laboratory
	Trieste, TS	SISSA
	Turin, TO	UniTo
Japan	Okinawa	OIST
	Tokyo	Keio Univ.
		TUS
		UTokyo
Kazakhstan	Almaty, ALA	KazNU
Kyrgyzstan	Bishkek, GB	BSU
Poland	Bialystok, PD	UwB
	Krakow, MA	JU
	Wroclaw, DS	UWr
Portugal	Aveiro	UA
Republic of Korea	Daejeon	IBS
Russia	Chernogolovka, MOS	LITP RAS
	Dolgoprudny, MOS	MIPT
	Kazan, TA	KFU
	Moscow, MOW	HSE
		IPMech RAS
		ITEP
		LPI RAS
		MI RAS
		MSU
		SAI MSU
		Skoltech
	Novosibirsk, NVS	NSU
	Protvino, MOS	IHEP
	Saint Petersburg, SPE	PDMI RAS
	Tomsk, TOM	TPU
		TSPU
	Troitsk, MOW	INR RAS
	Voronezh, VOR	VSU
Serbia	Belgrade, BG	MI SANU
		UB
	Nis, NI	Univ.
Spain	Barcelona, CT	IEEC-CSIC
	Bilbao, PV	UPV/EHU
	Santiago de Compostela, GA	USC
	Valencia, V	IFIC-CSIC
	Valladolid, CL	UVa
United Kingdom	Cambridge, CAM	Univ.
	Canterbury, KEN	UKC
	Durham, DUR	Univ.

Country or International Organization	City, region	Institute or laboratory
	Glasgow, GLG	U of G
	London, LND	IMPERIAL
USA	College Park, MD	UMD
	Coral Gables, FL	UM
	New York, NY	CUNY
		SUNY
	Philadelphia, PA	Penn

Elementary Particle Physics and High-Energy Heavy-Ion Physics (02)

Participation in international experiments

02-1-1066-2007

Investigation of the Properties of Nuclear Matter and Particle Structure at the Collider of Relativistic Nuclei and Polarized Protons

Theme leaders: R. Lednický
Yu.A. Panebrattsev

Participating countries and international organizations:
Armenia, Azerbaijan, Bulgaria, China, Cuba, Egypt, France, India, Kazakhstan, Mexico, Mongolia, Russia, Serbia, Slovakia, USA, Vietnam.

The problem under study and the main purpose of the research:
Investigation of the properties of nuclear matter with extremely high density and temperature, search for the signatures of the quark deconfinement and possible phase transitions at the collisions of heavy nuclei at the energies of the Relativistic Heavy Ion Collider (RHIC). Measurement of spin dependent structure functions of nucleons and nuclei using polarized proton beams at RHIC.

Project in the theme:

Name of the project	Project leaders	Project code
Laboratory	Responsible from laboratories	Status
1. STAR	**Yu.A. Panebrattsev** **R. Lednický**	02-1-1066-1-2010/2026
		Realization
VBLHEP, MLIT, BLTP, UC	the list of participants is given in Activities	

Abstract and scientific rationale:
The goal of the STAR project (JINR participation) is to study the properties of nuclear matter at extreme densities and temperatures, to search for signatures of quark deconfinement and possible phase transitions in heavy ion collisions over a wide energy range at the Relativistic Heavy Ion Collider (RHIC). The research program also includes the study of the structure functions of quarks and gluons in collisions of transversely and longitudinally polarized protons.

Expected results upon completion of the project:
Obtaining information about the properties of excited nuclear matter. Participation in experiments with nuclei and polarized protons at the STAR facility at the RHIC nuclear collider at BNL.

Measurement at the STAR facility of spin effects in experiments with polarized protons. Obtaining new information about the spin – dependent distribution functions of quarks and gluons in the proton.

Research of femtoscopic correlations, structure of events and scaling properties of nuclear interactions, global polarization, events with wide transverse momenta.

Conducting experiments on the Beam Energy Scan program BESII in the collider mode and in the fixed target mode. Search for signatures of phase transitions and critical points of QCD.

Development of the STAR detector software and creation of corresponding infrastructure at JINR for processing and analysis of experimental data of the STAR facility at JINR.

Development of a System for Precision Polarization Degree Measurements Based on Silicon Detectors for the SPI facility (Source of Polarized Ions).

Creation of the joint educational programs in relativistic nuclear physics and physics of the microworld together with BNL and JINR member states universities.

Expected results of the project this year:
Analysis of experimental data using the BESII energy scan program in collider experiments in the energy range 7.7–200 GeV and experiments with a fixed target in the energy range 3.0–7.7 GeV. Search for signatures of phase transitions and the QCD critical point.

The study of spectra of K_s^0 meson production in AuAu collisions at the energy 19.6 GeV using high-precision, high-statistics datasets from the STAR Beam Energy Scan (BESII) over a wide range of transverse momentum (0.0–6.0) GeV/c and for seven centralities.

Collection of statistics in experiments with gold nuclei and proton-nucleus collisions with epy energy of 200 GeV and the maximum luminosity of the collider in the central region ($-1.5 < \eta < 1.5$) and in the region of small angles ($2.5 < \eta < 4.2$).

The study of event structure, collective variables, correlation characteristics, femtosopic correlation functions and high-p_T processes. Study of femtoscopic correlations in the energy range from 3 to 7.7 GeV. Study of the nuclear modification factor in collisions of gold nuclei at energies of 7.7, 11.5, 14.6, 19.6 and 27 GeV.

The study of residual third-body Coulomb and isospin effects of colliding nuclei on identical charged pion femtoscopic correlations at high baryon density region.

The study of femtoscopic correlations of K_s^0 meson pairs taking into account Quantum Statistics and Final State Interactions. Determination of the femtoscopic parameters as a function of the average transverse momentum meson pair and collision centrality.

Software development and creation of infrastructure for processing STAR data at JINR using GRID technologies. Using machine learning methods for data processing.

Creation of media resources and laboratory works with the BNL and universities of the participating countries for training personnel to work at colliders of relativistic nuclei and polarized protons.

Development of proposals for the creation of detectors for studying polarization phenomena at colliders, including the NICA collider.

Calculation of kinematic parameters of experiments on the study of the nucleus structure functions and the spin structure of the proton in e-p and e-A, with respect to the collision energy. Development of a physics program for experiments at small (Nuclotron range) and high energies (EIC range).

Participation in the preparation of long-term archiving system and access to data recorded by the STAR experiment during data collection.

Activities of the theme:

Name of the activity	Leaders	Implementation period
Laboratory Responsible from laboratories		Status
1. Participation in experiments and data analysis according to the BESII energy scan program. Search for signatures of phase transitions and the QCD critical point	**Yu.A. Panebrattsev**	2024-2026 Data taking Data analysis

VBLHEP A. Aitbayev, A.A. Aparin, G.S. Averichev, T.G. Dedovich, V.B. Dunin, A.O. Kechechyan, A.A. Korobitsyn, S.S. Panyushkina, Oris Suarez Eng, V.V. Tikhomirov, A.A. Timofeev, M.V. Tokarev, Vinh Ba Luong, G.A. Yarygin

Abstract and scientific rationale:
Data processing using the BESII energy scan program in collider mode and in fixed-target mode.

Expected results upon completion of the activity:
Drawing conclusions about phase transition signatures and the QCD critical point based on data analysis of the BESII program.

Expected results of the activity this year:
Study of event structure, collective variables, correlation characteristics, femtosopic correlation functions and high-p_T processes. Study of femtoscopic correlations in the energy range from 3 to 7.7 GeV. Study of the nuclear modification factor in collisions of gold nuclei at energies of 14.6, 19.6 and 27 GeV.

The study of femtoscopic correlations of K_s^0 meson pairs taking into account Quantum Statistics and Final State Interactions.

2. Study of spin effects in collisions of transversely polarized protons with protons and nuclei. Measurement of inclusive transverse spin asymmetries and fragmentation functions	**M.V. Tokarev**	2024-2026 Realization

VBLHEP A.A. Aparin, T.G. Dedovich, E.I. Schakhaliev, Oris Suarez Eng, O.V. Teryaev

MLIT Zh.Zh. Musulmanbekov

BLTP S.V. Goloskokov

Abstract and scientific rationale:
Study of the structure functions of quarks and gluons in collisions of transversely and longitudinally polarized protons at an energy of 510 GeV and in collisions of polarized protons with nuclei at an energy of 200 GeV. Analysis of experimental data using the Cold QCD program.

Expected results upon completion of the activity:
Conducting experiments with longitudinally and transversely polarized protons at a maximum energy of 510 GeV.

Analysis of experimental data using the Cold QCD program. This allowed us to study the distributions of Sievers, transversity, Collins fragmentation functions in previously inaccessible regions and expand the program for the analysis of asymmetries of the production of $W^{\pm}$ and Z^0 bosons.

Expected results of the activity this year:
Execution of an experimental program with transversely polarized protons at an energy of 200 GeV.

Performing measurements in a wide range of pseudo-rapidities of $-1.5 < \eta < 1.5$ (central region) and $2.8 < \eta < 4.2$ (forward rapidity), corresponding to the range of Bjorken variable $0.005 < x < 0.5$.

3. The study of event structure, collective effects, femtoscopic correlations and high-p_T processes

R. Lednický
Yu.A. Panebrattsev

2024-2026

Realization

VBLHEP G.N. Agakishiev, A.A. Aparin, T.G. Dedovich, A.O. Kechechyan, A.A. Korobitsyn, Vinh Ba Luong, S.S. Panyushkina, E.I. Schakhaliev, A.A. Timofeev, M.V. Tokarev

MLIT G.A. Ososkov

Abstract and scientific rationale:
Further development and application of correlation femtoscopy methods developed at JINR for the analysis of experimental data.

Expected results upon completion of the activity:
Study of the space-temporal parameters of the production processes, using correlations of identical and non-identical particles, including hyperons, considering the interaction in the final state and spin correlations, to clarify the equation of state of dense and super dense nuclear matter similar to that in neutron stars.

Expected results of the activity this year:
Study of the fractal structure of events depending on the transverse momentum. The study of manifestations of nuclear effects in fractal analysis of Monte Carlo AuAu events at collision energy 200 GeV and different centrality using A Multi-Phase Transport generator. Nuclear effects such as final state interactions, nuclear shadowing, production of high transverse momentum minijets and quark-antiquark pairs can significantly affect the shape of p_T spectra of fractal and non-fractal events.

Determination of femtoscopic parameters for pairs of identical particles on the fixed-target mode data in the energy region 3–6.5 GeV.

Study of residual third-body Coulomb and isospin effects of colliding nuclei on identical charged pion femtoscopic correlations at high baryon density region.

Study of the production of neutral kaons in the region of small transverse momenta.

The study of fractal structure of nuclei in the cumulative hadron production in the framework of z-scaling approach.

Investigation of subtle effects in relativistic heavy-ion collisions from STAR data using high-order Q-cumulants.

4. Modernization of the STAR facility for measurements in the rapidity region of 2.5 < η < 4.2. Collection of statistics on collisions of gold nuclei at an energy of 200 GeV and the maximum luminosity of the RHIC collider

Yu.A. Panebrattsev

2024-2026

Data taking
Data processing
Data analysis

VBLHEP A.A. Aitbaev, G.N. Agakishiev, A.A. Aparin, G.S. Averichev, T.G. Dedovich, A.O. Kechechyan, Vinh Ba Luong, O.V. Rogachevsky, E.I. Schakhaliev, M.V. Tokarev

MLIT N.I. Gromova, V.V. Mitsyn

Abstract and scientific rationale:
Implementation of an experimental program with heavy nuclei using the Hot QCD Physics program in the extended acceptance of the STAR facility in the region of high rapidity and increased luminosity of the RHIC collider.

Expected results upon completion of the activity:
Investigation, within the framework of the Hot QCD Physics program, the microstructure of QGP in gold-gold collisions at the energy of 200 GeV to refine the QCD phase diagram and determine the properties of QGP at small scales.

Expected results of the activity this year:
Obtaining an experimental data of the Hot QCD program for collisions of gold nuclei at a maximum energy of 200 GeV and maximum luminosity of the collider.

5. Development of the software and formation of the infrastructure for the STAR data processing at JINR. Application of machine learning methods for data processing

Yu.A. Panebrattsev
V.V. Korenkov (MLIT)

2024-2026

Realization

VBLHEP G.N. Agakishiev, A.A. Aparin, A.A. Korobitsyn, P.D. Semchukov

MLIT N. Balashov, V.V. Mitsyn, G.A. Ososkov, T.A. Strizh

Abstract and scientific rationale:
Using distributed computing capabilities (JINR GRID structure) to process data from the STAR experiment. Development of machine learning methods for analyzing experimental data from the STAR facility.

Expected results upon completion of the activity:
Preparation of experimental data from runs 2022–2024 in the formats for data processing at JINR.

Development of new data processing methods.

Expected results of the activity this year:
Preparation and adaptation of developed method for particle identification based on machine learning methods for the MPD and SPD experiments.

6. Creation of media resources and laboratory works with the BNL and universities of the participating countries for training personnel to work at colliders of relativistic nuclei and polarized protons

N.E. Sidorov
K.V. Klygina

2024-2026

Realization

VBLHEP E.I. Golubeva, N.A. Lashmanov, M.P. Osmachko, D.O. Ponkin, P.D. Semchukov, V.K. Velichkov, N.I. Vorontsova

UC S.N. Balalykin, Hoang Bao Han Nguyen, L.V. Platonova, O.A. Smirnov, T.G. Stroganova

Abstract and scientific rationale:
Development of media resources and laboratory works for training personnel to work at colliders of relativistic nuclei and polarized protons.

Expected results upon completion of the activity:
Preparation of educational and presentation materials on studying the structure of matter and nucleus-nucleus interactions in experiments at colliders (RHIC, NICA).

Expected results of the activity this year:
Creation of a new exhibition about the NICA/MPD accelerator complex using elements of virtual, extended and augmented reality. Creation of remote laboratory works for studying nuclear physics. Preparation for re-publication of the textbook "Nuclear Physics" for a specialized school (grades 10–11).

7. Development of proposals on creating detectors for study of polarization phenomena at colliders — **V.B. Dunin** — 2024-2026

Project development

VBLHEP N.V. Dunin, V.V. Fimushkin, K.A. Ivshin, A.N. Solovev

Abstract and scientific rationale:
Development of proposals for the creation of detectors for polarimetry at the NICA collider.

Expected results upon completion of the activity:
Creation of a polarimeter that will provide an accuracy of about 2 % in 300 seconds at a current of 10 mA.

Expected results of the activity this year:
Production of a prototype of a universal proton polarimeter, where it is planned to place 4 clusters of silicon detectors placed at angles of 110 and 130 degrees, allowing to measure the asymmetry in the ^{6}Li(p, ^{3}He)^{4}He reaction.

Creation of a hardware platform for precision polarization degree measurements at the SPI source to expand its functional capabilities for experiments within the SPD NICA program.

8. Study the possibility of future expansion of the investigation of nuclear structure and proton spin structure in *e-p* and *e*-A collisions at the NICA complex, as well as study the possibility of participating in the development of the Electron-Ion Collider (EIC) project — **A.A. Aparin** — 2024-2026

Project development

VBLHEP V.B. Dunin, A.A. Korobitsyn, N.A. Lashmanov, S.S. Panyushkina, V.Yu. Rogov, Oris Suarez Eng

BLTP A.S. Zhevlakov

DLNP A.S. Zhemchugov

Abstract and scientific rationale:
Further prospects for research in the field of relativistic nuclear physics are associated with the creating and conducting experiments at electron-ion colliders. Studies of spin effects at the EIC appear to complement the physics program of the SPD experiment at the NICA collider.

Expected results upon completion of the activity:
Together with JINR Member States, participation in the preparation of the EIC physics program. Preparation of proposals for the participation of the JINR group in the development of the technical design of one of the detectors for studying electron-ion collisions.

Expected results of the activity this year:
Calculation of kinematic characteristics of p-A and e-A collision experiments and search for optimal observables. Calculation of the necessary accelerator luminosity parameters and interaction rate for conducting experiments with the specified setup.

Collaboration 1066

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
Azerbaijan	Baku, BA	IRP
Bulgaria	Sofia	INRNE BAS
		SU
China	Lanzhou, GS	IMP CAS
	Wuhan, HB	CCNU
Cuba	Havana	InSTEC
Egypt	Cairo, C	AUC
	Giza, GZ	NILES CU
France	Nantes, PDL	Subatech
India	Chandigarh, CH	PU
	Jammu, JK	JU
	Tirupati, AP	IISER
Kazakhstan	Almaty, ALA	INP
Mexico	Mexico City, CDMX	UNAM
Mongolia	Ulaanbaatar	MNUE
Russia	Dolgoprudny, MOS	MIPT
	Moscow, MOW	ITEP
		MEPhI
	Protvino, MOS	IHEP
	Saint Petersburg, SPE	SPbSU
Serbia	Belgrade, BG	VINCA
	Novi Sad, VO	UNS
Slovakia	Bratislava, BL	IP SAS
	Kosice, KI	UPJS
USA	Berkeley, CA	Berkeley Lab
	Bloomington, IN	IU
	Chicago, IL	UIC
	Lemont, IL	ANL
	New Haven, CT	Yale Univ.
	Stony Brook, NY	SUNY
	University Park, PA	Penn State
	Upton, NY	BNL
Vietnam	Da Lat, LD	DNRI

02-2-1081-2009

ATLAS
Upgrade of the ATLAS Detector and Physics Research at the LHC

Theme leader: V.A. Bednyakov

Deputies: A.P. Cheplakov
I.V. Yeletskikh

Participating countries and international organizations:
Armenia, Azerbaijan, Belarus, Bulgaria, Canada, CERN, France, Georgia, Germany, Israel, Italy, Netherlands, Russia, Slovakia, Spain, USA.

The problem under study and the main purpose of the research:
Studies of the proton-proton interactions at unprecedented collision energies (up to 14 TeV), in particular, investigation of the nucleon structure, measurements of the Higgs-boson properties, searches for new phenomena beyond the Standard Model, studies of the heavy quarks and multiquark states, precision Standard Model tests, participation in software support of the ATLAS experiment, modelling of the physical processes and upgrade of the detector systems. Development and production of detecting systems of the ATLAS facility, participation in operation of the facility.

Project in the theme:

	Name of the project	**Project leader**	**Project code**
Laboratory	Responsible from laboratories		**Status**
1.	**ATLAS** **Detector upgrade and physics at the LHC**	**V.A. Bednyakov** *Deputies:* **A.P. Cheplakov** (VBLHEP) **I.V. Yeletskikh**	02-2-1081-1-2010/2030 Technical proposal

DLNP A.M. Artikov, N.V. Atanov, O.S. Atanova, V.Yu. Baranov, V.Yu. Batusov, V.A. Bednyakov, I.R. Boyko, A.V. Boykov, M.V. Chizhov, Yu.I. Davydov, D.V. Dedovich, M.A. Demichev, A.R. Didenko, O.A. Dolovova, E.V. Dydyshka, A.V. Ershova, I.V. Fomichev, V.V. Glagolev, A. Gongadze, I. Gongadze, L. Gongadze, M.I. Gostkin, K.I. Gritsay, A.V. Guskov, N. Huseinov, Yu.P. Ivanov, L.V. Kalinovskaja, S.N. Karpov, Z.M. Karpova, N.N. Kaurtsev, D.V. Kharchenko, N.V. Kirichkov, N.A. Kovyazina, D.A. Kozhevnikov, V.G. Kruchonok, Yu.A. Kultchitsky, A.V. Lapkin, M.V. Lyablin, I. Lyashko, G.I. Lykasov, V.V. Lyubushkin, T.V. Lyubushkina, S.N. Malyukov, I. Minashvili, I. Minashvili (jr.), S.P. Mokrenko, V.D. Moskalenko, Yu.A. Nefedov, A.A. Nozdrin, E.M. Plontikova, S.Yu. Porokhovoy, I.N. Potrap, A.A. Prokhorov, E.N. Ramakoti, V.A. Rogozin, T.O. Rudenko, A.A. Sapronov, M.V. Serochkin, A.V. Shaikovskii, A.G. Shutov, A.V. Simonenko, R.V. Sotenskii, M.M. Shiyakova, A.N. Shalyugin, V.V. Tereschenko, I.N. Troeglazov, P.V. Tereshko, A.D. Tropina, Yu.A. Usov, A.O. Vasyukov, V.I. Yermolchik, A.S. Zhemchugov

VBLHEP F.N. Ahmadov, Yu.A. Fillipov, A.V. Ivanov, E.A. Ladygin, M. Manashova, S.N. Nagorny, N.I. Ponomarenko, B.G. Shaykhatdenov, A.A. Snesarev, A.A. Soloshenko, T. Turtuvshin, N.I. Zimin

MLIT E.I. Alexandrov, I.N. Aleksandrov, N.I. Gromova, A.V. Iakovlev, V.V. Korenkov, M.A. Mineev

BLTP A.B. Arbuzov, A.V. Bednyakov, S.G. Bondarenko, D.I. Kazakov, O.V. Teryaev

FLNP M.V. Bulavin

Abstract and scientific rationale:
The main purpose of the international ATLAS experiment is investigation of proton-proton interactions at unprecedented energies at the LHC collider (from 7 to 14 TeV center-of-mass energy). These interactions are the source of different (including unknown) physical processes between elementary particles. Study of such processes and their description within a common framework represent the main problem of the modern physical science.

The ATLAS multipurpose facility is unique and unprecedented regarding its performance and complexity. It combines the most up-to-date advances of science, technology and communication. Participation in such a large-scale international project gives access to the cutting-edge technologies of the physical experiment, allows gaining experience in real data analysis, precision modelling of the physical processes, software and theoretical support of experiment and looks absolutely necessary for such an international organization as JINR.

The second phase of the ATLAS detector upgrade is aimed at preparing the facility for operation in the conditions of high luminosity of the LHC. During the first phase, which was successfully completed in 2022, the main contribution of the JINR group was participation in the implementation of the project to create a new muon wheel, an important element of the muon spectrometer. The modernization of the muon spectrometer continues in terms of creating RPC cameras. The development, testing and manufacturing of a system for reading signals from a liquid-argon calorimeter (LAr) based on fiber optic technology is underway. With the participation of JINR, a new high-granularity timing detector (HGTD) is being developed.

The ATLAS experiment is currently performing a number of precision tests of the Standard Model, probing the limits of its validity and searching for the answers to the key questions of the modern physics like the nature of dark matter, existence of additional spacial dimensions, etc.

Expected results upon completion of the project:
Analysis of pp-collisions data at 13.6 TeV as well as High-Luminosity LHC (HL-LHC) data are going to provide the new and unique experimental results. The most important among them are investigation of the proton structure, in particular, the transverse momentum density of gluons in proton; studies of the heavy hadron spectra, including beauty mesons and exotic tetraquark and pentaquark states; precision SM tests at LHC energies and searches beyond the SM. The High Luminosity regime of the LHC will allow studies of the processes, e.g., Higgs-boson production in association with a single top-quark.

Achieving these goals is impossible without developing new methods of data analysis. The active participation of JINR physicists is planned in the trigger software support, development of new methods of detector simulation, application of the machine learning techniques in physics analysis.

The implementation of this Project aimed at solving highly significant scientific problems will yield unique applied results. Among these 'byproduct' results are the experience in operation of remote monitoring systems for technically complicated devices, big data processing and development and practical use of distributed comtputing systems (GRID) and database monitoring applications in long-term large-scale experiments. Applications of this experience if possible in other JINR projects.

Completion of the modernization of the detector systems will ensure stable and efficient operation of the ATLAS facility with the LHC luminosity at a level 5-7 times higher than the design value of about 10^{34} cm^{-2} s^{-1}, and reaching the integrated luminosity at the level of 3000 fb^{-1} .

Expected results of the project this year:
Study of the resonant J/psi pair production, probing of the fully-charmed tetraquark models describing these processes. Studies of the hidden-charm tetraquark states in B-hardron decays to J/psi + light hardons. Analysis of the Higgs boson production in association with a single top quark. Measurements of the heavy beauty meson properties, in particular, Bc-meson excited states. Predictions and measurements of the gluon transverse momentum density in a proton. Search for quantum black holes in the lepton+jet channel at 13 TeV. Higgs boson production in association with vector W, Z bozon studies. Development and support of the ATLAS software. Development of database monitoring applications. Simulation studies of the ATLAS calorimeter response. Participation in the Phase-2 ATLAS Upgrade Project of the muon spectrometer and calorimeters: development and prototyping of the RPC cameras, creation of fiber optic cables for the LAr test bench. Creation of a tooling prototype for HGTD assembly.

Collaboration 1081

Country or International Organization	City, region	Institute or laboratory	
Armenia	Yerevan, ER	AANL	
Azerbaijan	Baku, BA	IP	
Belarus	Gomel, HO	GSTU	

Country or International Organization	City, region	Institute or laboratory
		GSU
	Minsk, MI	IAP NASB
		INP BSU
		IP NASB
Bulgaria	Sofia	SU
Canada	Vancouver, BC	TRIUMF
CERN	Geneva, CH	CERN
France	Aubiere, ARA	LPCA
	Orsay, IDF	IJCLab
Georgia	Tbilisi, TB	HEPI-TSU
Germany	Zeuthen, BB	PITZ DESY
Israel	Rehovot, M	WIS
Italy	Pisa, PI	INFN Pisa
Netherlands	Amsterdam, NH	NIKHEF
Russia	Moscow, MOW	ITEP
		MSU
	Protvino, MOS	IHEP
	Vladikavkaz, SE	NOSU
Slovakia	Bratislava, BL	CU
		IP SAS
Spain	Barcelona, CT	IFAE
USA	Lemont, IL	ANL

02-1-1083-2009

CMS
Compact Muon Solenoid at the LHC

Theme leader: V.Yu. Karjavin

Deputy: S.V. Shmatov

Scientific leader: V.A. Matveev

Participating countries and international organizations:
Armenia, Austria, Belarus, Belgium, Brazil, Bulgaria, CERN, China, Croatia, Cyprus, Finland, France, Georgia, Germany, Greece, Hungary, India, Iran, Ireland, Italy, Mexico, Montenegro, Netherlands, New Zealand, Pakistan, Republic of Korea, Russia, Serbia, Spain, Switzerland, Taiwan, Turkey, United Kingdom, USA, Uzbekistan.

The problem under study and the main purpose of the research:
Development and implementation of a research program at the LHC accelerator complex to study phenomena within the standard model and beyond; modernization, commissioning and operation of the CMS experimental complex. Upgrade, commissioning and operation of the CMS experimental complex.

Project in the theme:

	Name of the project	Project leader	Project code
Laboratory	Responsible from laboratories		**Status**
1.	**CMS. Physics studies at the CMS experiment and the second phase of detector upgrade for operation in high luminosity conditions**	**V.Yu. Karjavin**	02-1-1083-1-2010/2030 Realization
1.1.	**Research physics programme with the CMS detector**	**S.V. Shmatov** (MLIT)	Realization
VBLHEP	V.Yu. Alexakhin, D.V. Budkovsky, S.N. Gninenko, I.N. Gorbunov, A.Yu. Kamenev, A.V. Lanev, V.V. Shalaev, S.G. Shulga, A.V. Zarubin, I.A. Zhizhin		
BLTP	D.I. Kazakov, G.A. Kozlov, M.V. Savina, O.V. Teryaev, V.A. Zykunov		
MLIT	T.A. Aushev, O.L. Kodolova, V.Yu. Korsakov, A.N. Nikitenko, G.A. Ososkov, V.V. Palchik, I. Satyshev, K.V. Slizhevsky, E.N. Tolchko, N.N. Voytishin		
1.2.	**CMS endcap detectors**	**V.Yu. Karjavin**	Maintenance Data taking Upgrade
1.2.1	**Construction of the Highly Granularity Calorimeter (HGCal)**	**V.Yu. Karjavin** **S.V. Afanasev**	
1.2.2	**First forward muon station ME1/1**	**V.Yu. Karjavin** **V.V. Perelygin**	
VBLHEP	V.Yu. Alexakhin, D. Bunin, B.V. Dubinchik, Yu.V. Ershov, S.N. Gninenko, N.S. Golova, A.O. Golunov, N.V. Gorbunov, A.Yu. Kamenev, S.V. Kilchakovskaya, S.V. Kondratieva, D.N. Kozlov, A.M. Kurenkov, O.V. Kutinova, A.M. Makankin, A.I. Malakhov, G.D. Milnov, V.V. Perelygin, V.A. Smirnov, E.V. Sukhov, I.V. Tlisova, V.V. Ustinov, A.A. Zaitsev, A.V. Zarubin		
MLIT	A. Khvedelidze, O.L. Kodolova, V.V. Palchik, I. Satyshev, S.V. Shmatov, N.N. Voytishin		

1.3. **Development of software for distributed computation, data processing and analysis based on GRID-technology**

V.V. Korenkov (MLIT)
S.V. Shmatov (MLIT)

Realization

MLIT A.G. Dolbilov, I.A. Filozova, A.O. Golunov, I.A. Kashunin, O.L. Kodolova, V.V. Mitsyn, A.N. Moybenko, D.A. Oleynik, G.A. Ososkov, V.V. Palichik, A.Sh. Petrosyan, R.N. Semenov, T.A. Strizh, E.N. Tolchko, V.V. Trofimov, N.N. Voytishin

VBLHEP A.O. Golunov, A.V. Lanev, A.Yu. Kamenev

Abstract and scientific rationale:
The project aims to extensive research in the field of elementary particle physics with the CMS experimental facility at the LHC. The priority goal is to study fundamental laws of nature.

The project involves an analysis of the physics processes in proton-proton colisions with a collision energy up to 13.6 TeV in the c.m.s. By the end of the LHC RUN3 the CMS experiment will collect experimental data with statistics corresponding to an integrated luminosity of up L_{int} = 500 fb^{-1}. Processing and analysis of this data will help to obtain new physics results in the following areas:

– searches for new physics in dilepton final states and interpretation of the results within beyond-Standard-Model scenarios (TeV–scale gravity, extended gauge models, dark matter models, theories with lepton number violation, etc.);

– searches for new physics in channels with two leptons/two b-quarks and missing transverse energy in the final state, testing beyond-SM predictions (searches for extended Higgs sector and dark matter candidates);

– exploration of Higgs boson properties and searches for new scalar bosons beyond the SM in decay channels to leptons and b-quark pairs;

– studies of Drell–Yan muon pair production processes to test SM predictions at the new energy scale, to measure the weak mixing angle, and to verify quark and gluon structure distribution functions;

– studies of QCD jet properties and refinement of fragmentation functions.

Starting in 2030, the LHC will operate in its high-luminosity phase (High Luminosity LHC, HL–LHC), reaching peak luminosities up to 5-7 $\times 10^{34}$ $cm^{-2}s^{-1}$. This upgrade will increase the accumulated statistics by more than an order of magnitude, with a projected integrated luminosity of ~3000 fb^{-1}. During the third long shutdown (LS3, 2026–2029), the upgrade of the CMS detector is planned to ensure efficient operation of all CMS subsystems under HL–LHC conditions. The current project includes JINR obligations in participation in the construction of the High–Granularity Calorimeter (HGCal) and upgrades of the Cathode Strip Chambers (CSCs) of the ME1/1 forward muon station of the CMS endcap muon system. During CMS operation period JINR obligation includes also maintenance and physical characteristics study of the CMS endcap detectors.

Expected results upon completion of the project:
Implementation of the physics research program at the CMS experimental setup with the design energy of proton beam interactions and integrated luminosity up to 500 fb^{-1}.

CMS detectors upgrade (in the framework of obligations) for operation under HL–LHC conditions.

Operations with the CMS Detector at the LHC, including commissioning and maintance of the CMS hadron calorimetry and the forward muon station during data taking at high luminosity.

Expected results of the project this year:
Tests of the Standard Model predictions and search for new physics signals in the channel with a pair of muons or a pair of b-quarks with missing transverse energy in the final state based on processing and analysis of experimental data from RUN2 and RUN3 with total statistics corresponding to an integrated luminosity of up to 400 fb^{-1}, development of high-energy muon reconstruction algorithms and jet reconstruction algorithms.

Technical support for CMS detector systems, participation in the data taking and quality control of experimental data.

Development of software for a distributed system for data processing and analysis based on GRID technologies and ensuring data transfer between the JINR Tier-1/Tier-2 centers and CMS.

Modernization of the ME1/1 muon station detectors and study of the characteristics of the CSC chambers when operating under high-luminosity conditions of the LHC.

Development of a hardware and software complex for testing the HGCal calorimeter detectors. Participation in tests of the HGCal sensitive elements and assembling the calorimeter.

Collaboration 1083

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
Austria	Vienna, W	HEPHY
Belgium	Antwerp, VAN	UAntwerp
	Brussels, BRU	ULB
		VUB
	Ghent, VOV	UGENT
	Leuven, VBR	KU Leuven
	Louvain-la-Neuve, WBR	UCL
	Mons, WHT	UMONS
Brazil	Rio de Janeiro, RJ	CBPF
		UERJ
	Sao Paulo, SP	Unesp
Bulgaria	Sofia	INRNE BAS
		SU
CERN	Geneva, CH	CERN
China	Beijing, BJ	IHEP CAS
		PKU
		Tsinghua
	Hangzhou, ZJ	ZJU
Croatia	Split	UNIST
	Zagreb	RBI
Cyprus	Nicosia	UCY
Finland	Helsinki	HIP
		UH
	Lappeenranta	LUT
France	Gif-sur-Yvette, IDF	Irfu
	Lyon, ARA	UL
	Paris, IDF	IN2P3
	Strasbourg, GES	IPHC
Georgia	Tbilisi, TB	GTU
		HEPI-TSU
Germany	Aachen, NRW	RWTH
	Hamburg, HH	DESY Helmholtz
		UHH
	Karlsruhe, BW	KIT Helmholtz
Greece	Athens	NCSR Demokritos
		NKUA
		NTU
	Ioannina	UoI
Hungary	Budapest	Wigner RCP

Country or International Organization	City, region	Institute or laboratory
	Debrecen	ATOMKI
		UD
India	Chandigarh, CH	PU
	Jatani, OD	NISER
	Kolkata, WB	SINP
	Mumbai, MH	BARC
		TIFR
Iran	Tehran	IPM
Ireland	Dublin, L	UCD
Italy	Bari, BA	INFN Bari
	Bologna, BO	INFN Bologna
	Catania, CT	INFN LNS
	Florence, FI	INFN Florence
	Frascati, RM	INFN LNF
	Genoa, GE	INFN Genoa
	Milan, MI	INFN Milan
	Naples, NA	INFN Naples
	Padua, PD	INFN Padua
	Pavia, PV	INFN Pavia
	Perugia, PG	INFN Perugia
	Pisa, PI	INFN Pisa
	Rome, RM	INFN Rome
	Trieste, TS	INFN Trieste
	Turin, TO	INFN Turin
Mexico	Mexico City, CDMX	Cinvestav
	Puebla de Zaragoza, PUE	BUAP
Montenegro	Podgorica	UCG
Netherlands	Eindhoven, NB	TU/e
New Zealand	Auckland, AUK	UoA
	Christchurch, CAN	UC
Pakistan	Islamabad, IS	QAU
Republic of Korea	Daejeon	KIST
	Gwangju	CNU
	Seoul	KU
		SJU
		SKKU
		SNU
		Yonsei Univ.
Serbia	Belgrade, BG	VINCA
Spain	Madrid, MD	CIEMAT
		UAM
	Oviedo, AS	UO

Country or International Organization	City, region	Institute or laboratory
	Santander, CB	IFCA-CSIC
Switzerland	Villigen, AG	PSI
	Zurich, ZH	ETH
		UZH
Taiwan	Taipei, TPE	NTU
	Taoyuan City, TAO	NCU
Turkey	Adana	CU
	Ankara	METU
	Istanbul, IDF	BU
		YTU
United Kingdom	Bristol, BST	Univ.
	Didcot, OXF	RAL
	London, LND	IMPERIAL
USA	Baltimore, MD	JHU
	Batavia, IL	Fermilab
	Boston, MA	BU
		NU
	Boulder, CO	CU
	Buffalo, NY	UB
	Cambridge, MA	MIT
	Charlottesville, VA	UVa
	Chicago, IL	UIC
	College Park, MD	UMD
	College Station, TX	Texas A&M
	Columbus, OH	OSU
	Davis, CA	UC Davis
	Detroit, MI	WSU
	Evanston, IL	NU
	Gainesville, FL	UF
	Houston, TX	Rice Univ.
	Iowa City, IA	UIowa
	Ithaca, NY	Cornell Univ.
	Knoxville, TN	UTK
	Lawrence, KS	KU
	Lincoln, NE	UNL
	Livermore, CA	LLNL
	Los Angeles, CA	UCLA
	Lubbock, TX	TTU
	Madison, WI	UW-Madison
	Manhattan, KS	KSU
	Minneapolis, MN	U of M
	Nashville, TN	VU

Country or International Organization	City, region	Institute or laboratory	
	New Brunswick, NJ	RU NB	
	New York, NY	RU	
	Notre Dame, IN	ND	
	Oxford, MS	UM	
	Pasadena, CA	Caltech	
	Pittsburgh, PA	CMU	
	Princeton, NJ	PU	
	Providence, RI	Brown	
	Riverside, CA	UCR	
	Rochester, NY	UR	
	San Diego, CA	SDSU	
	Santa Barbara, CA	UCSB	
	Tallahassee, FL	FSU	
	Tuscaloosa, AL	UA	
	Wako, TX	BU	
	West Lafayette, IN	Purdue Univ.	

02-2-1085-2009

Experimental Tests of the Fundamentals of QCD

Theme leader: A.V. Guskov

Deputy: A.S. Zhemchugov

Participating countries and international organizations:
Belarus, CERN, China, Czech Republic, Germany, Israel, Italy, Japan, Poland, Portugal, Russia, United Kingdom, USA.

The problem under study and the main purpose of the research:
Quantum chromodynamics is a true theory of strong interaction. However, despite its considerable success in describing the interaction of quarks and gluons within the perturbative approach, the question of why hadrons and nuclei are as we see them remains open. Description of fundamental properties of hadrons, such as their masses, spins, parton distributions, form factors, spectra, etc., on the basis of fundamental principles of QCD is one of the main unsolved problems of quantum chromodynamics. Confinement of quarks and gluons in hadrons, as well as the growth of the running constant of strong interaction with decreasing characteristic scale of interaction energy does not allow direct use of the perturbative approach, which has proved itself at high energies. At present, various phenomenological models are used to quantitatively describe the hadron spectrum, static properties of hadrons, and their interactions at low energies. Certain success has been achieved in lattice calculations. A comparison of model predictions and theoretical calculations for observables with measurement results is an important test of the consistency and applicability limits of the approaches used. The ultimate goal of the research in this direction, both theoretical and experimental, is to obtain a description of the spectra, structure, and properties of hadrons from first principles of QCD.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	BESIII	I.I. Denisenko *Deputy:* A.S. Zhemchugov	02-2-1085-1-2007/2028
2.	NA66 / AMBER Study of the fundamental properties of hadrons	A.V. Guskov	02-2-1085-2-2024/2026

Projects:

	Name of the project	Project leaders	Status
Laboratory	Responsible from laboratories		
1.	**BESIII**	**I.I. Denisenko** *Deputy:* **A.S. Zhemchugov**	Implementation

DLNP O.V. Bakina, I.P. Boyko, D.V. Dedovich, P. A. Egorov, A.V. Guskov, Yu.A. Nefedov

BLTP V.V. Bytyev

MLIT G.A. Ososkov, I.P. Pelevanyuk, V.V. Korenkov

Abstract and scientific rationale:
The goals of the JINR group in the BESIII project are to study hadronic QCD spectra and search for exotic states, study the production and decays of Charmonium states, search for exotic Charmonium states and charmonium-like structures, and determine c-quark fragmentation functions. The JINR group's participation in the project involves data analysis and development of algorithms for event reconstruction in the BESIII detector using machine learning methods.

Expected results upon completion of the project:
The project will produce new knowledge about the properties of strong interactions on the $Q^2 \sim M^2_{Jpsi}$ scale. In particular, information will be obtained on the spectrum of exotic light and charmonium-like states and their properties, as well as on the details of inclusive c-quark production.

Expected results of the project this year:
BESIII data analysis. Development of offline software and analysis tools. Participation in the data taking.

2. NA66 / AMBER **A.V. Guskov** Implementation
Study of the fundamental properties of hadrons

DLNP V.M. Abazov, G.D. Alexeev, N.V. Anfimov, A.I. Antoshkin, I.I. Denisenko, V.N. Frolov, A. Gongadze, A.O. Gridin, N.A. Koviazina, A. Maltsev, A.A. Piskun, A.S. Selyunin, S.S. Seryubin, N.I. Zhuravlev

VBLHEP V.A. Anosov, O.P. Gavrischuk, R. Gushterski, A.Yu. Korzenev, O.M. Kuznetsov, D.V. Peshekhonov, A.A. Shunko, E.V. Zemlyanichkina

MLIT A.Sh. Petrosyan

Abstract and scientific rationale:
AMBER (Apparatus for Meson and Baryon Experimental Research) is a new experimental facility with a fixed target on the M2 beam line of the CERN SPS. The facility is designed to perform a variety of measurements aimed at addressing fundamental questions of quantum chromodynamics, which are expected to lead to a significant improvement in the understanding of QCD as a modern theory of strong interactions. The proposed measurements cover physics ranging from the smallest Q^2 values, such as determining the charge radius of a proton in elastic muon-proton scattering, reactions with moderate Q^2 values for hadronic spectroscopy, and studies of hadronic structure with high Q^2 using rigid Drell-Yan, Charmonium, and fast photon production processes. The JINR group is responsible for the modernization and operation of the HCAL1 hadron calorimeter and MW1 (Muon Wall 1) high-angle muon identification system. It is also involved, along with a group from the University of Turin, in the production and support of the Bulk Micromegas track detectors that will replace the obsolete multi-wire chambers (MWPCs) in the SAS behind the SM2 magnet.

Expected results upon completion of the project:
Solving the proton radius puzzle.

New knowledge of the quark and gluon structure of mesons.

Accurate knowledge of the yield of antiprotons in p-p and p-He processes, essential for the search for dark matter in astrophysical experiments.

Expected results of the project this year:
Participation in R&D for Micromegas detectors.

Analysis of the data on the antiproton production in p-He interaction. Data taking for the Proton Radius Measurement programme.

Preparation of the front-end electronics upgrade to be able to operate in the triggerless mode.

Upgrade of the MW1 muon system.

Collaboration 1085

Country or International Organization	City, region	Institute or laboratory	
Belarus	Minsk, MI	INP BSU	
CERN	Geneva, CH	CERN	
China	Beijing, BJ	IHEP CAS	
Czech Republic	Prague, PR	CTU	
		CU	
Germany	Bonn, NRW	UniBonn	
	Darmstadt, HE	GSI Helmholtz	
	Freiberg, SN	TUBAF	

Country or International Organization	City, region	Institute or laboratory	
	Munich, BY	TUM	
Israel	Tel Aviv, TA	TAU	
Italy	Trento, TN	UniTrento	
	Trieste, TS	INFN Trieste	
	Turin, TO	INFN Turin	
Japan	Yamagata	YU	
Poland	Otwock-Swierk, MZ	NCBJ	
	Warsaw, MZ	IEP WU	
		WUT	
Portugal	Aveiro	UA	
	Lisbon	LIP	
Russia	Gatchina, LEN	NRC KI PNPI	
	Novosibirsk, NVS	BINP SB RAS	
	Protvino, MOS	IHEP	
United Kingdom	Glasgow, GLG	U of G	
USA	Los Alamos, NM	LANSCE LANL	

02-1-1087-2009

Research on Relativistic Heavy and Light Ion Physics Experiments at the Accelerator Complex Nuclotron-M/NICA at JINR and CERN SPS

Theme leaders: A.I. Malakhov
S.V. Afanasiev

Participating countries and international organizations:
Armenia, Belarus, Bulgaria, CERN, China, India, Kazakhstan, Mongolia, Romania, Russia, Slovakia, Uzbekistan.

The problem under study and the main purpose of the research:
Study of new phenomena in multiple particle productions associated with the manifestation of the quark and gluon degrees of freedom in the interaction of relativistic nuclei. Study of nucleon and nuclear interactions at the VBLHEP accelerator complex, CERN SPS. Energy scan of interactions of nuclei at 20-158 GeV/nucleon energies and the study of their dependence on the atomic number of nuclei. The search for the critical point on the phase diagram of nuclear matter at the NA61/SHINE (SPS, CERN). Study of hadron production in hadron-nucleus interactions. Use of the obtained data for the precision calculations of neutrino spectra and fluxes in the accelerator experiments to study the neutrino oscillations. Investigation of nucleon clustering and the contribution of unstable nuclear-molecular States to the dissociation of light stable and radioactive isotopes, as well as the properties of rarefied baryonic matter in the dissociation of heavy nuclei. Experimental and theoretical study of deep subthreshold, cumulative processes, the formation of hadrons and antimatter in the transition energy region. Investigation of processes in the region of large P_T ($P_T \geq 1$ GeV/c) in non-cumulative and cumulative kinematic regions at SPIN and FODS setups. Study of the behavior of elementary particles, nucleon resonances and nucleon fluctuations in nuclear matter on the SCAN spectrometer. Preparation of proposals of the experiments at the VBLHEP accelerator complex on the Nuclotron extracted beams and NICA Collider. Study of the short-range nucleon-nucleon correlations and the cluster structure of the nuclei using the beams of ions, polarized protons and deuterons at the internal target of the Nuclotron.

Projects in the theme:

Name of the project	Project leaders	Project code
1. NA61/SHINE	A.I. Malakhov *Deputies:* A.V. Dmitriev A.A. Zaitsev	02-1-1087-1-2012/2026
2. SCAN-3	S.V. Afanasiev *Deputy:* D.K. Dryablov	02-1-1087-2-2017/2027

Projects:

Name of the project	Project leaders	Status
Laboratory Responsible from laboratories		
1. NA61/SHINE	**A.I. Malakhov** *Deputies:* **A.V. Dmitriev** **A.A. Zaitsev**	Upgrade Preparation Data analysis

VBLHEP V.A. Babkin, M.G. Buryakov, V.M. Golovatyuk, V.A. Kireev, R.Yu. Kolesnikov, V.A. Matveev, G.L. Melkumov, M.M. Rumyantsev

DLNP G.I. Lykasov, V.V. Lyubushkin, B.A. Popov, V.V. Tereschenko

Abstract and scientific rationale:
The main physics goals include: search for the second-order critical end-point in the temperature versus baryon-chemical potential phase diagram (looking for nonmonotonic behavior of critical point signatures, such as transverse momentum and multiplicity fluctuations, intermittency signal, etc., when system freezes out close to the critical point),

study the properties of the onset of deconfinement (search for the onset of the horn, kink, step, and dale structures in collisions of light nuclei). In recent years, the program has been extended by Pb+Pb collisions where the open charm production, as well as collective effects are studied. Based on the obtained results, few years ago NA61/SHINE introduced a concept of two onsets in nucleus-nucleus collisions at the CERN SPS energies: onset of deconfinement (beginning of QGP formation – collision energy threshold for deconfinement) and onset of fireball (beginning of formation of a large cluster which decays statistically – system-size threshold for creation of statistical system). The strong interactions program is based on beam momentum scans (13A-158A·GeV/c) with light and intermediate mass nuclei (from p+p to Xe+La).

Expected results upon completion of the project:
Data analysis of the NA61/SHINE experiment (SPS, CERN).

Studies of the birth of hadrons in hadron-nuclear interactions.

The study of the formation of charmed hadrons (mainly D-mesons) during the interaction of heavy ions in order to obtain new data on the average number of charmed quark-antiquark pairs and to understand the mechanism of the birth of open charm.

Obtaining data for precision calculation of neutrino spectra and fluxes in accelerator experiments for the study of neutrino oscillations.

Completion of the modernization of the TOF system.

Expected results of the project this year:
Processing and analysis of experimental data obtained at the NA61/SHINE installation on p+p, Be+Be, Ar+Sc, O+O, Pb+Pb collisions.

Conducting experimental studies on a beam of relativistic lead nuclei.

Investigation of anti-core formation in Ar+Ca and Xe+La collisions.

The study of the formation of enchanted hadrons in the interaction of heavy ions in order to understand the mechanism of the birth of an open charm.

2. SCAN-3 — **S.V. Afanasiev**, *Deputy:* **D.K. Dryablov** — Upgrade / Preparation / Data analysis

VBLHEP Yu.S. Anisimov, A.A. Baldin, B.V. Dubinchik, P.R. Kharyuzov, S.V. Kilchakovskaia, Yu.F. Krechetov, O.V. Kutinova, M. Paraypan, D.G. Sakulin, V.A. Smirnov, E.V. Sukhov, V.V. Ustinov, D.V. Ustinov, V. Vartik

Abstract and scientific rationale:
The project is aimed at studying highly excited nuclear matter formed in dA interactions. This state of matter is studied by observing the decay of the excited nucleus into a pair of energetic particles emitted at an angle close to 180^0 and with an energy resolution of 4–5 MeV. The physics programme includes the study of the η- and Δ–nuclei formation and the determination of binding energies and widths of quasi-bound states.

Expected results upon completion of the project:
Upgrade of the SCAN setup.

Analysis of the experimental data on the behavior of nucleon resonances and nucleon fluctuations in nuclei, on the search and study of properties of the bound state-meson in nuclear matter.

Expected results of the project this year:
Testing of a three-beam magnetic spectrometer SCAN.

Conducting a technical session on the internal beam of the nuclotron to adjust the detectors and debug the data collection program.

Analysis of experimental data.

Activities of the theme:

Name of the activity	Leader	Implementation period
Laboratory Responsible from laboratories		Status
1. BECQUEREL2023	**P.I. Zarubin**, *Deputy:* **A.A. Zaitsev**	2024-2026 — Upgrade / Preparation / Data analysis

VBLHEP D.A. Artemenkov, N.K. Kornegrutsa, M. Natarjan, P.A. Rukoyatkin, V.V. Rusakova

Abstract and scientific rationale:
The BECQUEREL experiment is aimed at solving topical problems in nuclear clustering physics. The used method of nuclear track emulsion (NTE) makes it possible, due to its unique sensitivity and spatial resolution, to study in a unified approach multiple final states arising in dissociation of relativistic nuclei. Progress in this direction relies on computerized microscopy.

Expected results upon completion of the activity:
Search and study of the Hoyle state and more complex nuclear-molecular States in the dissociation of light nuclei.

Analysis of the isotopic composition of the fragmentation of heavy nuclei.

Use of automated microscopes, as well as improvement of the NE technology.

Expected results of the activity this year:
Analysis of exposures to Xe (NICA/Nuclotron) and Kr (GSI) nuclei to study ^{8}Be decays and the Hoyle state and accompanying α-ensembles and search for the 4α-condensate.

Estimation of the parameters of accompanying neutrons.

Mastering identification by multiple scattering of *He* and *H* isotopes on a motorized microscope.

Search for ^{8}Be and ^{9}B isobar-analogue states in the ^{9}Be and ^{10}C exposures.

Mastering the identification of ensembles of stopped α-particles in the fragmentation of nuclei from the composition of the emulsion under the action of relativistic particles.

2. Experiment FASA-3 for registration of nuclear fragments — **S.P. Avdeev** — 2024-2026

Upgrade Preparation Data analysis

DLNP V.I. Stegaylov

FLNR V.V. Kirakosyan, E.M.Kozulin, G.V. Mushinsky, O.V. Strekalovsky

VBLHEP H.U. Abraamian, Z.A. Igamkulov, V. Karach, L.V. Kornyushina, P.A. Rukoyatkin, Z.A. Sadygov

Expected results upon completion of the activity:
Analysis of the experimental data on the processes of the multiple emission of intermediate mass fragments on the beams of relativistic light ions using a 4-π FASA-3 setup for the registration of nuclear fragments.

Performing data analysis to determine the mechanism of multifragmentation and to obtain new information about the nuclear phase transitions "liquid-fog" and "liquid-gas".

Investigation of properties of hot nuclei formed in the collisions of light relativistic ions with heavy targets.

Production of the detector system for the registration of the decay of hypernuclei.

Expected results of the activity this year:
Debugging of the QUARTUS CAEN program at the FASA spectrometer for registration of nuclear fragments.

Analysis of experimental data in the framework of statistical and dynamic models.

Preparation of a new project.

3. Investigation with light and heavy ions for applied research — **A.I. Malakhov** — 2024-2026

Realization Preparation Data taking

VBLHEP N.N. Agapov, Yu.S. Anisimov, A.A. Baldin, E.G. Baldina, D.K. Dryablov, M. Paraypan

Expected results upon completion of the activity:
Use of heavy and light ions for applied research.

Expected results of the activity this year:
Analysis of the results of irradiation of biological objects in accordance with Agreement of the JINR-BAS cooperation.

4. Upgrade of equipment the station of internal target of the Nuclotron — **S.V. Afanasiev, R.Yu. Kolesnikov** — 2024-2026

Upgrade
Data taking

VBLHEP Yu.S. Anisimov, D.K. Dryablov, B.V. Dubinchik, A.S. Kuznetsov, S.N. Kuznetsov, D.G. Sakulin, V. Vartik

Expected results upon completion of the activity:
Replacement of target operation control electronics from the KAMAK system to modern industrial standards.

Creating software for new electronics. Production of a target based on the carbon isotope ^{13}C.

Expected results of the activity this year:
Preparing the station for operation in the spring Nuclotron Run.

5. Test of the detectors for measurements and control the luminosity at the collider NICA — **G.D. Milnov** — 2024-2026

R&D
Technical Proposal

VBLHEP K.U. Abraamyan, R.A. Akbarov, T.Y. Bokova, Z.A. Igamkulov, L.V. Kornyushina, I.I. Migulina, A.Z. Sadygov, Z.Y. Sadygov, V.I. Shokin

FLNP E.I. Litvinenko

Expected results upon completion of the activity:
Creation of a detector and development of algorithms for configuring beam reduction in the NICA collider.

Expected results of the activity this year:
Preparation of a technical project for luminosity measurement at the NICA collider.

Production of two planes for the luminosity measurement detector.

6. Study of the multiparticle correlations at modernized internal target station at Nuclotron — **V.P. Ladygin** — 2024-2026

Preparation
Data taking

VBLHEP Yu.V. Gurchin, A.Yu. Isupov, V.A. Kireev, N.B. Ladygina, K.S. Legostaeva, A.I. Malakhov, S.G. Reznikov, A.A. Terekhin, A.V. Tishevsky, I.S. Volkov

Abstract and scientific rationale:
The study of multiparticle correlations is one of the ways to study the dynamics of nuclear-nuclear collisions. One of the goals of research on the internal target of the Nuclotron is to evaluate the contribution of short-range 2-nucleon correlations for C+A and Xe+A collisions.

Expected results upon completion of the project:
Experimental and theoretical research on the project program.

Expected results of the project this year:
Processing of experimental data obtained with a ^{124}Xe beam with an energy of 3 GeV/nucleon 3.8 GeV/nucleon.

7. Search and investigation of a new charged particle in the 2-120 MeV mass range — **V.A. Nikitin** — 2024-2026

Data analysis

VBLHEP M.Kh. Anikina, A.V. Beloborodov, V.S. Rikhvitsky, A.Yu. Troyan, A.A. Zaitsev

Expected results upon completion of the activity:
Search and investigation of a charged particle in the 2-120 MeV mass range.

Expected results of the activity this year:
Addition of existing results with new data.

8. Acquisition, processing and digitation of information from bubble chamber and other fixed target experiments in the conditions of registration of multiple particle production in an energy range of 1-300 GeV

A.A. Baldin

2024-2026

Data analysis

VBLHEP S.G. Arakelyan, E.G. Baldina, A.V. Beloborodov, A.V. Belyaev, Ver.V. Bleko, Vit.V. Bleko, D.N. Bogoslovsky, S.A. Chetverikov, A.P. Ierusalimov, V.V. Ilyushchenko, P.R. Kharyuzov, E.A. Klevcov, D.S. Korovkin, N.E. Kukharev, V.A. Pukhaeva, O.V. Rogachevsky, A.B. Safonov, A.Yu. Troyan, Yu.A. Troyan

Expected results upon completion of the activity:
Collection, processing and digitization of the film information obtained using bubble chambers and in electronic experiments with fixed targets under the conditions of registration of multiple birth of particles in the energy range of 1-300 GeV.

Preparation of an education programme for highly qualified students for the NICA project.

Expected results of the activity this year:
Analysis of bubble chamber data, search and research of new phenomena based on the JINR LIT supercomputer.

Replenishment of the experimental data base in the field of relativistic nuclear physics.

Refinement of the results obtained on a propane two-meter chamber, and analysis of data on the results of the NA61/SHINE experiment.

9. High p_T physics with Nuclotron extracted beams

G.B. Sharkov
(NRNU"MEPhI")
Deputies:
S.S. Shimanskiy
A.V. Stavinskiy

2025-2026

Project preparation

VBLHEP P.N. Alekseev, A.A. Baldin, V.V. Bleko, M.A. Patsyuk

MLIT V.V. Uzhinskiy

Abstract and scientific rationale:
The project aims to provide an experimental search for manifestations and study the properties of the multi-quark (multi-nucleon) states with extracted from the nuclotron polarized and unpolarized beams of light nuclei. The use of cryogenic and polarized targets will allow for unique exclusive and correlation studies of rare processes in NN, dd, NA and AA interactions in the region of $p_T > 0.5$ GeV/c.

In order to realize the unique physics program, an experimental setup with the acceptance close to 4π must be created in order to work with extracted beams of polarized and unpolarized light nuclei from the nuclotron of maximal intensity.

Expected results upon completion of the activity:
Development of the experimental program and its physical justification for opening the project to create Conceptual (CDR) and, subsequently, Technical (TDR) projects.

Expected results of the activity this year:
Preparation of the first version of the Conceptual Design Report (CDR) and to approve the Project at the JINR PAC.

10. Neutron-rich nuclei on the NICA complex

A.V. Butenko
Y. Ts. Oganessian
S.V. Afanasiev

2025-2026

Project preparation

VBLHEP A.A. Baldin, D.K. Dryablov, S.V. Kilchakovskaia, R.Yu. Kolesnikov, O.V. Kutinova, A.S. Kuznetsov, A.I. Malakhov, D.G. Sakulin, V.A. Smirnov, E.V. Sukhov, V.V. Ustinov, D.V. Ustinov, V. Vartik

FLNR A.A. Bezbakh

Abstract and scientific rationale:
This project is a proposal to search for the formation of light neutron-rich nuclei, including ^{12}He, on beams of short-lived nuclei produced at the NICA accelerator complex. The identification of synthesized isotopes will be carried out by the decay products into a residual nucleus and secondary neutrons. The primary beam is planned to be formed on the internal target of the Booster, with further transfer to the nuclotron and output to the measuring pavilion at the experimental facility **FORTUNE** – (**F**acility f**O**r the **R**esearch **T**otally **U**nusual **N**eutron-rich **E**lements).

Expected results upon completion of the activity:
Development of an experimental program for the formation of neutron-rich at the NICA accelerator complex and its physical motivation. Determination of the yield of ^{12}Be isotopes in the reaction $^{12}C+^{124}Sn=^{12}Be+X$ on the internal target of the booster. The project preparation.

Expected results of the activity this year:
Determination of the yield of ^{12}Be isotopes in the reaction $^{12}C+^{124}Sn=^{12}Be+X$ on the internal target of the Nuclotron booster. The project preparation.

Collaboration 1087

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
		YSU
Belarus	Minsk, MI	INP BSU
Bulgaria	Blagoevgrad	AUBG
	Sofia	INRNE BAS
		Inst. Microbiology
		SU
CERN	Geneva, CH	CERN
China	Beijing, BJ	CIAE
		IHEP CAS
	Wuhan, HB	CCNU
India	Jaipur, RJ	UoR
	Mumbai, MH	BARC
Kazakhstan	Astana, AST	ENU
	Karaganda, KAR	KTU
Mongolia	Ulaanbaatar	IPT MAS
Romania	Bucharest, B	IFIN-HH
		UB
	Magurele, IF	ISS
Russia	Belgorod, BEL	BelSU
	Chernogolovka, MOS	ISMAN RAS
	Gatchina, LEN	NRC KI PNPI
	Moscow, MOW	ITEP
		LPI RAS
		MEPhI
		MSU
		NRC KI
	Protvino, MOS	IHEP

Country or International Organization	City, region	Institute or laboratory
	Saint Petersburg, SPE	FIP
	Smolensk, SMO	SmolGU
	Tomsk, TOM	TPU
	Troitsk, MOW	INR RAS
	Vladikavkaz, SE	Baspik
		NOSU
Slovakia	Bratislava, BL	IP SAS
	Kosice, KI	UPJS
Uzbekistan	Jizzakh, JI	JDPU
	Samarkand, SA	SamSU
	Tashkent, TK	Physics-Sun

02-1-1088-2009

ALICE
Study of Interactions of Heavy Ion and Proton Beams at the LHC

Theme leader: A.S. Vodopyanov

Participating countries and international organizations:
Armenia, Austria, Azerbaijan, Bangladesh, Brazil, Bulgaria, CERN, China, Croatia, Cuba, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Italy, Japan, Malta, Mexico, Netherlands, Norway, Pakistan, Peru, Republic of Korea, Romania, Russia, Slovakia, South Africa, Sri Lanka, Sweden, Thailand, Turkey, United Kingdom, USA.

The problem under study and the main purpose of the research:
Experimental study of heavy ion interactions at relativistic and ultrarelativistic energies.

Project in the theme:

	Name of the project	Project leader	Project code
Laboratory	Responsible from laboratories		Status
1.	**ALICE**	**A.S. Vodopyanov**	02-1-1088-1-2010/2030
			Realization

VBLHEP V.A. Arefiev, V.I. Astakhov, N.A. Baldin, D.N. Bogoslovski, A.V. Borisov, N.A. Burmasov, M.G. Buryakov, S.G. Buzin, S.C. Ceballos, R.A. Diaz, V.H. Dodokhov, A.A. Efremov, N.V. Gorbunov, E.L. Kryshen, V.I. Lobanov, P.V. Nomokonov, I.A. Oleks, I.A. Rufanov

Abstract and scientific rationale:
Participation in the data analysis of the experimental data on femtoscopy of the charged kaons, ultraperipheral interactions, including the measurements of exclusive dimuon production and coherent J/ψ and $\psi(2S)$ photoproduction in ultraperipheral collisions of lead nuclei, production of hyperons, the preparation of publications and presentations on conferences. Participation in the maintenance and operation of the detector ALICE. Preparation of proposals for the modernization of the ALICE detector: electromagnetic calorimeter.

Expected results upon completion of the project:
Participation in the data analysis, preparation of scientific publications and talks on the conferences. Participation in the maintenance, operation and upgrade of the ALICE detector. Preparation of the techical proposal for the construction of the electromagnetic calorimeter.

Expected results of the project this year:
Participation in the data analysis. Preparation of the scientific publications and talks on the conferences. Participation in the maintenance and operation of the ALICE detector.

Physics simulation of the electromagnetic calorimeter.

Activities of the theme:

	Name of the activity	Leader	Implementation period
Laboratory	Responsible from laboratories		Status
1.	**Physical process simulation and data analysis**	**B.V. Batyunya**	2026-2030
			Realization

VBLHEP A.V. Borisov, M.G. Burmasov, S.S. Grigoryan, E.L. Kryshen, A.V. Kuznetsov, K.P. Mikhaylov, E.P. Rogochaya, A.S. Vodopyanov

DLNP G.I. Lykasov

BLTP D. Blaschke, S.N. Nedelko

Abstract and scientific rationale:
Participation in the development of the ALICE scientific program and the processing and analysis of experimental data.

Expected results upon completion of the project:
Processing and analysis of experimental data on femtoscopy of charged kaons and ultraperipheral interactions in collisions of protons, nuclei and nuclei with protons.

Preparation of publications, reports at international conferences.

Expected results of the project this year:
Processing and analysis of experimental data on femtoscopy of charged kaons and ultraperipheral interactions in collisions of protons, nuclei and nuclei with protons.

Preparation of publications and reports at international conferences.

2. ALICE. Computing in the distributed environment-GRID — **A.S. Vodopyanov** — 2026-2030

Realization

VBLHEP B.V. Batyunya, E.P. Rogochaya, G.G. Stiforov

MLIT A.O. Kondratiev, V.V. Mitsyn

Abstract and scientific rationale:
Processing and analysis of experimental data are carried out within the framework of the distributed computer network GRID of the ALICE collaboration. Modernization of equipment and software is carried out on a permanent basis. The LIT JINR Complex is part of the ALICE GRID.

Expected results upon completion of the project:
Maintaining the working state of the ALICE GRID part at JINR.

Expected results of the project this year:
Maintaining the working state of the ALICE GRID part at JINR.

3. Electromagnetic calorimeter — **A.S. Vodopyanov, V.Kh. Dodokhov, P.V. Nomokonov** — 2026-2030

Projection

VBLHEP V.A. Arefiev, V.I. Astakhov, N.A. Baldin, D.N. Bogoslovski, M.G. Buryakov, S.G. Buzin, S.C. Ceballos, R.A. Diaz, A.A. Efremov, N.V. Gorbunov, E.L. Kryshen, A.V. Kuznetsov, V.I. Lobanov, I.A. Olex, I.A. Rufanov

Abstract and scientific rationale:
In connection with the need to improve forward detectors it is necessary to upgrade a system for reading signals from scintillating and quartz units of the forward subdetectors.

Expected results upon completion of the project:
Preparation of the technical proposal for the construction of the electromagnetic calorimeter.

Expected results of the project this year:
Physics simulation of the electromagnetic calorimeter.

Collaboration 1088

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
Austria	Vienna, W	SMI
Azerbaijan	Baku, BA	NNRC
Bangladesh	Dhaka, Dh	DU
Brazil	Campinas, SP	UNICAMP
	Porto Alegre, RS	UFRGS
	Santo Andre, SP	UFABC
	Sao Paulo, SP	USP
Bulgaria	Sofia	IAPS
		SU
CERN	Geneva, CH	CERN
China	Beijing, BJ	CIAE
	Hefei, AH	USTC
	Shanghai, SH	SINAP CAS
	Wuhan, HB	CCNU
		HBUT
Croatia	Split	UNIST
	Zagreb	RBI
		UNIZIG
Cuba	Havana	CEADEN
Denmark	Copenhagen	NBI
Finland	Helsinki	HIP
	Jyvaskyla	UJ
France	Aubiere, ARA	LPCA
	Gif-sur-Yvette, IDF	Irfu
	Grenoble, ARA	LPSC
	Lyon, ARA	UL
	Nantes, PDL	Subatech
	Orsay, IDF	IJCLab
	Strasbourg, GES	IPHC
	Villeurbanne, ARA	CC IN2P3
Germany	Bonn, NRW	UniBonn
	Darmstadt, HE	GSI Helmholtz
		TU Darmstadt
	Frankfurt am Main, HE	FIAS
		GU
	Heidelberg, BW	Univ.
	Munich, BY	TUM
	Munster, NRW	Univ.
	Tubingen, BW	Univ.

Country or International Organization	City, region	Institute or laboratory
	Worms, RP	ZTT
Greece	Athens	NKUA
Hungary	Budapest	Wigner RCP
India	Aligarh, UP	AMU
	Bhubaneswar, OD	IOPB
	Chandigarh, CH	PU
	Guwahati, AS	GU
	Indore, MP	IIT Indore
	Jaipur, RJ	UoR
	Jammu, JK	JU
	Jatani, OD	NISER
	Kolkata, WB	BNC
		SINP
		UC
		VECC
	Mumbai, MH	BARC
		IIT Bombay
Indonesia	Jakarta, JK	BRIN
Italy	Alessandria, AL	DiSIT UPO
	Bari, BA	DIF
		INFN Bari
		Poliba
	Bologna, BO	INFN Bologna
		UniBo
	Brescia, BS	UNIBS
	Cagliari, CA	INFN Cagliari
		UniCa
	Catania, CT	INFN Catania
		UniCT
	Erice, TP	EMFCSC
	Foggia, FG	UNIFG
	Frascati, RM	INFN LNF
	Legnaro, PD	INFN LNL
	Messina, ME	UniMe
	Padua, PD	INFN Padua
		UniPd
	Pavia, PV	UniPv
	Rome, RM	CREF
		INFN Rome
		Sapienza
	Salerno, SA	INFN Salerno
	Trieste, TS	INFN Trieste

Country or International Organization	City, region	Institute or laboratory
		UniTS
	Turin, TO	INFN Turin
		PoliTO
		UniTo
	Vercelli, VC	UPO
Japan	Hiroshima	HU
	Nagasaki	NIAS
	Nara	NWU
	Osaka	RCNP
	Saga	Saga Univ.
	Tokai	JAEA
	Tokyo	UTokyo CNS
	Tsukuba	Univ.
	Wako	RIKEN
Malta	Msida	UM
Mexico	Culiacan, SIN	UAS
	Mexico City, CDMX	Cinvestav
		UNAM
	Puebla de Zaragoza, PUE	BUAP
Netherlands	Amsterdam, NH	AUAS
		NIKHEF
	Utrecht, UT	UU
Norway	Bergen	HVL
		UiB
	Borre	USN
	Oslo	UiO
Pakistan	Islamabad, IS	COMSATS
		PINSTECH
Peru	Lima, LMA	PUCP
Republic of Korea	Busan	PNU
	Cheongju	CBNU
	Daejeon	KIST
	Gangneung	GWNU
	Incheon	Inha
	Jeonju	JBNU
	Seoul	Konkuk Univ.
		SJU
		Yonsei Univ.
Romania	Bucharest, B	IFIN-HH
		UPB
	Magurele, IF	ISS
Russia	Troitsk, MOW	INR RAS

Country or International Organization	City, region	Institute or laboratory
Slovakia	Bratislava, BL	CU
	Kosice, KI	IEP SAS
		TUKE
		UPJS
South Africa	Cape Town, WC	UCT
	Johannesburg, GT	WITS
	Somerset West, WC	iThemba LABS
Sri Lanka	Moratuwa	UOM
Sweden	Lund, M	LU
Thailand	Bangkok	KMUTT
	Chachoengsao	TMEC
	Nakhon Ratchasima	SLRI
		SUT
Turkey	Istanbul, IDF	IU
		YTU
	Konya	Karatay Univ.
United Kingdom	Birmingham, BIR	Univ.
	Daresbury, CHS	DL
	Derby, DBY	Univ.
	Liverpool, MSY	UOL
USA	Austin, TX	UT
	Berkeley, CA	Berkeley Lab
		UC
	Chicago, IL	CSU
	Columbus, OH	OSU
	Detroit, MI	WSU
	Houston, TX	UH
	Knoxville, TN	UTK
	Los Alamos, NM	LANSCE LANL
	New Haven, CT	Yale Univ.
	Oak Ridge, TN	ORNL
	Omaha, NE	Creighton Univ.
	San Luis Obispo, CA	Cal Poly
	West Lafayette, IN	Purdue Univ.

02-1-1096-2010

Study of Rare Charged Kaon Decays and Search for Dark Sector in Experiments at the CERN SPS

Theme leader: V.D. Kekelidze

Deputies: D.V. Peshekhonov
D.T. Madigozhin

Participating countries and international organizations:
Belgium, Bulgaria, Canada, CERN, Chile, France, Germany, Italy, Kazakhstan, Mexico, Romania, Slovakia, Spain, Switzerland, United Kingdom, USA.

The problem under study and the main purpose of the research:
Search for and study of rare kaon decays and CP violation processes. Search for rare events using beam-dump and missing energy techniques with CERN SPS secondary beams. Search for phenomena beyond the Standard Model. Construction and maintenance of detectors.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	NA62	V.D. Kekelidze *Deputy:* D.T. Madigozhin	02-1-1096-1-2010/2027
2.	NA64	V.A. Matveev D.V. Peshekhonov	02-1-1096-2-2017/2026

Projects:

Name of the project	Project leaders	Status
Laboratory Responsible from laboratories		
1. NA62	**V.D. Kekelidze** *Deputy:* **D.T. Madigozhin**	Data taking Data analysis

VBLHEP A.N. Baeva, D. Baigarashev, V.V. Bautin, D.D. Emelyanov, T.L. Enik, V.P. Falaleev, S.R. Gevorgyan, V.N. Gorbunova, E.A. Gudzovsky, I. Kambar, D. Kereibay, A.M. Korotkova, N.A. Molokanova, I.A. Polenkevich, K.M. Salamatin, S.N. Shkarovsky

Abstract and scientific rationale:
Implementation of the NA62 Project allows to clarify the CP-violation problem, to measure precisely very rare charged kaon decay to charged pions and two neutrinos, to carry out a search for supersymmetric particles and their partners to observe physics beyond the Standard Model. In addition, the characteristics of rare kaon and hyperon decays will be improved. Straw-detectors of the NA62 high resolution magnetic spectrometer working in vacuum will be supported during experimental runs. Development of a new detector prototype based on straws with a smaller diameter will be started to use it at higher intensity of the beams. Software for simulation, data analysis and processing will be developed.

Expected results upon completion of the project:
Measurement of the rare decay of a charged kaon into a pion and two neutrinos with an accuracy of about 10%, which will make it possible to refine the parameters of the Cabibbo-Kobayashi-Maskawa matrix and will be a decisive test of the Standard Model.

In addition, the probabilities and other parameters of a number of rare decays of charged kaons will be measured, which will make it possible to refine the parameters of the Chiral Perturbation Theory, which describes strong interactions at low energies.

Expected results of the project this year:
NA62 data analysis will be carried out.

Software for the simulation of the magnetic spectrometer and full set-up will be developed; system for detector calibration and event reconstruction will be upgraded; general software of the experiment will be developed.

Participation in the maintenance of the NA62 spectrometer, as well as in the development and maintenance of the control system for all detectors of the experiment.

Participation in the development of a straw detector for high intensity beams.

Participation in the NA62 experimental run at the CERN SPS.

2. NA64 **V.A. Matveev**
D.V. Peshekhonov

Preparation
Data taking
Data analysis

VBLHEP S.V. Gertsenberger, S.N. Gninenko, A.V. Ivanov, I. Kambar, G.D. Kekelidze, M.M. Kirsanov, V.A. Kramarenko, V.A. Polyakov, K.M. Salamatin, D.A. Shchukin, E.V. Vasilieva, P.V. Volkov, I.A. Zhukov

DLNP V.N. Frolov

BLTP N.V. Krasnikov, A.S. Zhevlakov

Abstract and scientific rationale:
Despite active searches for dark matter (DM) manifestations carried out at the LHC and in non-accelerator experiments, it still remains a great mystery. Another possibility is that in addition to gravity, the interaction between the dark sector and visible matter could occur via a new vector boson A' (dark photon). This has spurred theoretical and experimental efforts to search for manifestations and interaction portals between the visible and dark sectors, shifting the strategy from high-energy to high-intensity approaches.

The NA64 experiment is a fixed-target experiment at the CERN SPS. The NA64 setup is a hermetic detector designed to search for dark sector (DS) manifestations by detecting missing energy events in the scattering of electrons/positrons, hadrons, and muons on nuclei.

Expected results upon completion of the project:
The main aim of the NA64 project is the search for the new physics beyond the SM, namely the search on the secondary CERN SPS electron and muon beams of the dark photon (A') and hypotetical 16,7 MeV boson as well as other dark sector manifestations.

Expected results of the project this year:
NA64, analysis of the experimental data.

Operation and support of the detectors.

Participation in NA64 experimental runs in the experimental zone on the H4 SPS channels, CERN.

Online and offline software development, for the straw chambers analysis and for the DAQ experiment in particular.

Collaboration 1096

Country or International Organization	City, region	Institute or laboratory
Belgium	Louvain-la-Neuve, WBR	UCL
Bulgaria	Blagoevgrad	SWU
	Plovdiv	PU
	Sofia	SU
Canada	Toronto, ON	YU
	Vancouver, BC	TRIUMF
		UBC

Country or International Organization	City, region	Institute or laboratory
CERN	Geneva, CH	CERN
Chile	Valparaiso, VS	USM
France	Marseille, PAC	CPPM
Germany	Bonn, NRW	UniBonn
	Mainz, RP	JGU
Italy	Ferrara, FE	INFN Ferrara
	Florence, FI	INFN Florence
	Frascati, RM	INFN LNF
	Genoa, GE	INFN Genoa
	Naples, NA	INFN Naples
	Perugia, PG	INFN Perugia
	Pisa, PI	INFN Pisa
	Rome, RM	INFN Rome
		Tor Vergata
	Turin, TO	INFN Turin
Kazakhstan	Almaty, ALA	INP
Mexico	San Luis Potosi, SLP	UASLP
Romania	Bucharest, B	IFIN-HH
Slovakia	Bratislava, BL	CU
Spain	Valencia, V	IFIC-CSIC
Switzerland	Lausanne, VD	EPFL
	Zurich, ZH	ETH
United Kingdom	Birmingham, BIR	Univ.
	Bristol, BST	Univ.
	Glasgow, GLG	U of G
	Lancaster, LAN	LU
USA	Boston, MA	BU
	Fairfax, VA	GMU
	Menlo Park, CA	SLAC
	Merced, CA	UCMerced
	Upton, NY	BNL

02-2-1151-2025

Development of Advanced Detectors and Analysis Methods, Hadronic and Rare Leptonic Processes

Theme leader: Yu.I. Davydov

Participating countries and international organizations:
Azerbaijan, Belarus, China, Italy, Japan, Russia, Switzerland, Uzbekistan.

The problem under study and the main purpose of the research:
Precise determination of the Higgs boson properties and search for new physics phenomena beyond the Standard Model using Monte Carlo generators with full simulation of the detector's signal and background events at the CEPC.
Development of new detectors for use in the CEPC conditions and methods for their calibration.

Project in the theme:

	Name of the project	**Project leaders**	**Project code**
Laboratory	Responsible from laboratories		**Status**
1.	**Development of a physics program and detectors for experiments at CEPC**	**Yu.I. Davydov** **A.S. Zhemchugov** *Deputies:* **Yu.A. Kulchitsky** **A.B. Arbuzov**	02-2-1151-1-2025/2027 R&D Realization

DLNP A.M. Artikov, N.V. Atanov, O.S. Atanova, V.Yu. Baranov, A.V. Boikov, I.R. Boyko, D. Chokheli, A.E. Dadashova, D.V. Dedovich, O.A. Dolovova, Ye.V. Dydyshka, I.V. Eletskikh, E. Ginya, L.K. Gladilin, A. Gongadze, A.V. Guskov, N.A. Huseynov, L.N. Kalinovskaya, A.A. Kampf, V.I. Kiseeva, R. Lee, G.I. Lykasov, V.V. Lyubushkin, T.V. Lyubushkina, V.L. Malyshev, V.D. Moskalenko, E.M. Plotnikova, A.A. Prokhorov, V.A. Rogozin, L.A. Rumyantsev, R.R. Sadykov, A.A. Sapronov, A.N. Shalyugin, A.V. Simonenko, I.A. Suslov, P.V. Tereshko, A.D. Tropina, I.I. Vasilyev, V.L. Yermolchyk, I.Yu. Zimin

BLTP S.G. Bondarenko, V.V. Bytev, M.V. Savina, U.E. Voznaya, V.A. Zykunov

VBLHEP F.N. Ahmadov, D.V. Budkovsky, V.B. Chmill, Yu.V. Ershov, A.O. Golunov, V.Yu. Karzhavin, D.N. Kozlov, A.V. Lanyov, V.V. Perelygin, V.V. Shalaev, I.A. Zhizhin

MLIT O.L. Kodolova, Yu.V. Korsakov, A.N. Nikitenko, D.A. Oleynik, I.S. Pelevanyuk, A.Sh. Petrosyan, S.V. Shmatov, K.V. Slizhevsky, N.N. Voytishin

Abstract and scientific rationale:
The discovery of the Higgs boson at the LHC marked the beginning of a new era in high-energy physics. The proposed 100 km-circumference Circular Electron-Positron Collider (CEPC) program in China aims to make unprecedentedly precise measurements of the Higgs boson, test the predictions of electroweak theory, flavor physics, QCD, and explore new physics beyond the Standard Model (BSM).

The objectives of this project are to prepare proposals for a programme of research into the properties of Higgs bosons, study their exotic decays and search for new BSM physics phenomena, participate in software development, and perform a series of studies of new detectors for further use in experiments at the CEPC.

Expected results upon completion of the project:
Study of $e^+e^- \to ZX$ processes for precise determination of properties of the Higgs bosons, study of their exotic decays and search for new BSM physics phenomena using Monte Carlo generators. Theoretical support in the development of a physics programme, creation of modern Monte Carlo simulation tools, assessment of the collider luminosity.
Creation and research of prototypes of detector systems, development of methods for their calibration based on the particle flow algorithm.

Expected results of the project this year:
Evaluation of exotic Higgs boson decays and selection of individual decay modes for their detailed study.

Development of software and mathematical support for Monte Carlo simulation, precision theoretical calculations of electroweak interactions.

Bench studies of individual elements of the electromagnetic and hadron calorimeters, muon detector and their prototypes. Development of the concept of calibration of detector systems for experiments at the CEPC.

Activities of the theme:

Name of the activity	Leader	Implementation period
Laboratory Responsible from laboratories		Status
1. Mu2e	**Yu.I. Davydov**	2024-2027
		R&D Realization

DLNP A.M. Artikov, N.V. Atanov, O.S. Atanova, V.Yu. Baranov, A.V. Boikov, V.V. Glagolev, A.N. Shalyugin, I.A. Suslov, I.I. Vasilyev, I.Yu. Zimin

BLTP G.A. Kozlov

Abstract and scientific rationale:
The Mu2e experiment is aimed at searching for a process with lepton number violation for charged leptons $\mu^- N \rightarrow e^- N$, which is a coherent conversion of a muon into an electron in the field of a nucleus. At the non-zero neutrino mass this process is possible but remains unobservable, since the probability is proportional to $(\Delta m^2_{ij}/M^2_W)^2$, where Δm^2_{ij} is the difference between the squares of the masses of the eigenstates of the ith and jth neutrinos, and M_W is the mass of the W boson. The predicted probability for the process $\mu^- N \rightarrow e^- N$ is $\sim 10^{-50}$. This process is a theoretically perfect target for new physics searches. In many new physics models that include massive neutrinos, the probabilities of these processes significantly increase and become observable.

Expected results upon completion of the activity:
The data collection will be carried out in two runs with a two-year interval. In the first run it is planned to collect 6×10^{16} stopped muons. In the absence of $\mu^- \rightarrow e^-$ conversion events, a new limit on this process will be set at $R_{\mu e} < 6.2\times10^{-16}$ (90% CL), which is three orders of magnitude lower than the current limit $R_{\mu e} < 7\times10^{-13}$ (90% CL) set by the SINDRUM II experiment.

In the second stage of the data collection, it is planned to lower the limit on $\mu^- \rightarrow e^-$ conversion by another order of magnitude.

Expected results of the activity this year:
Participation in the preparation of a research programme on the muon beam of the accelerator and software for data analysis with cosmic muons.

Conducting radiation hardness studies of BaF_2 crystals (pure and doped with the rare earth element yttrium) and LYSO for use in the second phase of the experiment.

2. MEG II	**N.V. Khomutov**	2024-2027
		Realization Data taking Data processing

DLNP N.P. Kravchuk, V.L. Malyshev, A.M. Rozhdestvensky

VBLHEP A.O. Kolesnikov, V.A. Krylov

Abstract and scientific rationale:
The Standard Model (SM) of particle physics predicts a vanishingly small probability ($< 10^{-50}$) of processes violating the conservation of the lepton number for charged leptons. Therefore, the detection of such processes is an absolute indication of the presence of new physics beyond the SM, and their absence imposes a limitation on theories beyond the SM. The decay $\mu^+ \rightarrow e^+ \gamma$ is especially sensitive to such new physics. The MEG II experiment is the second phase of the MEG experiment to search for the decay $\mu^+ \rightarrow e^+ \gamma$ on the high-intensity (7×10^7 muons/s) beam of the HIPA accelerator at PSI (Switzerland). Thanks to a deep modernization of the facility, it is planned to improve the record upper bound for the decay probability obtained earlier in the first phase of the experiment by approximately an order of magnitude.

Expected results upon completion of the activity:
Processing of the full data set collected in 2021–2026. If the $\mu^+ \to e^+ \gamma$ decay is not detected, the existing constraint on the decay probability $B(\mu^+ \to e^+ \gamma) < 4{,}2 \times 10^{-13}$ (90% C. L.) will be improved to a level of $\sim 6.0 \times 10^{-14}$.

Expected results of the activity this year:
Continuation of new data collection.

Processing of experimental data collected in 2024–2025 and publication of intermediate results.

Collaboration 1151

Country or International Organization	City, region	Institute or laboratory
Azerbaijan	Baku, BA	IP
		IRP
Belarus	Minsk, MI	IE NASB
		INP BSU
		IP NASB
China	Beijing, BJ	IHEP CAS
	Jinan, SD	SDU
	Shanghai, SH	Fudan
Italy	Frascati, RM	INFN LNF
	Pisa, PI	INFN Pisa
Japan	Tokyo	UTokyo ICEPP
Russia	Dolgoprudny, MOS	MIPT
	Gatchina, LEN	NRC KI PNPI
	Moscow, MOW	HSE
	Novosibirsk, NVS	BINP SB RAS
Switzerland	Villigen, AG	PSI
Uzbekistan	Samarkand, SA	SamSU

Experiments at the NICA accelerator complex

02-1-1086-2009

Strangeness in Hadronic Matter and Study of Inelastic Reactions Near Kinematical Borders

Theme leaders: E.A. Strokovsky
E.S. Kokoulina
D.O. Krivenkov

Participating countries and international organizations:
Belarus, Cuba, Egypt, India, Israel, Russia, Slovakia, USA.

The problem under study and the main purpose of the research:
Strangeness in hadronic matter and study of boundary effects:
study of stabilizing effects of strangeness in nuclear matter and properties of the lightest hypernuclei; study of multi-particle dynamics in the inelastic proton-proton and proton-nucleus interactions with extremally high multiplicity; study of spectra and yields of soft photons in the deuteron-nucleus and nucleus-nucleus interactions; determination of hadronization parameters at NICA energy at the SPD facility; study of Short-Range Correlated (SRC) pairs of nucleons.

Project in the theme:

Name of the project	Project leaders	Project code / Status
Laboratory Responsible from laboratories		**Status**
1. HyperNIS-SRC **HyperNuclear intrinsic strangeness and short-range correlations**	**D.O. Krivenkov** **J. Lukstins** *Deputy:* **M.A. Patsyuk**	02-1-1086-1-2025/2029 **Status** Data taking
1.1. HyperNIS experiment	**D.O. Krivenkov** **J. Lukstins**	Realization Data taking

VBLHEP V.D. Aksinenko, M.H. Anikina, T. Atovullaev, A. Atovullaeva, A.V. Averyanov, S.N. Bazylev, S.S. Cherepanov, D.V. Dementiev, A.A. Fedyunin, A.A. Feschenko, A.I. Filippov, S.V. Gertsenberger, D.N. Grishchenko, A.S. Khvorostukhin, A.M. Korotkova, Yu.A. Murin, O.V. Okhrimenko, N.G. Parfenova, S.N. Plyashkevich, P.A. Rukoyatkin, A.V. Salamatin, A.D. Sheremetiev, A.V. Shipunov, M.O. Shitenkov, I.V. Slepnev, V.M. Slepnev, N.A. Tarasov, A.V. Terleskiy, A.L. Voronin

DLNP B.A. Popov, S.V. Tereschenko, V.V. Tereschenko

OCE A.N. Parfenov

Abstract and scientific rationale:
The study of properties of the lightest hypernuclei is relevant, has high significance and the Nuclotron beam is suitable place to investigate these tasks. The study of properties of light neutron-rich hypernuclei is of great interest, first of all, to clarify the theory of the intranuclear nucleon-nucleon interactions: the neutron halo, ΛN interaction including ΛN – ΣN conversion and the spin-dependent ΛN interaction etc. The special interest to this investigation is because of absence of reliable data on ${}^{6}_{\Lambda}$H properties and theoretical predictions that are strongly depend on model and controversial. Simultaneously, the lifetimes and production cross sections of ${}^{4}_{\Lambda}$H and ${}^{3}_{\Lambda}$H will be studied in the same experiment. The end measurements can be used as “reference points” to confirm the production and decay of ${}^{6}_{\Lambda}$H**.**

Expected results upon completion of the project:
Experimental conclusion about the existence of the hypernucleus ${}^{6}_{\Lambda}$H.

New experimental data on the properties of the lightest hypernuclei and experimental verification of corresponding theoretical models for these hypernuclei.

New experimental data on the drip-line location for loosely bound light hypernuclei with high neutron excess, necessary for the development of the theory of neutron-rich hypernuclei and models of their production in non-central nucleus-nucleus interactions.

New experimental data on the production of strangeness and vector mesons (including those, containing strange quarks) by polarized photons (close to the relevant thresholds).

Universal spectrometer for users of the Nuclotron beams.

Expected results of the project this year:
Restoration of overall operability of the 4B channel in building 205 VBLHEP.

Data taking for $^{6}_{\Lambda}$H search using beam of ^{7}Li nuclei. Analysis of the first experimental data for the $^{6}_{\Lambda}$H search and for the measurements of hyperhydrogen isotopes $^{6}_{\Lambda}$H and $^{4}_{\Lambda}$H lifetimes.

Upgrade of the HyperNIS magnetic spectrometer (tracking system) by adding the planes of GEM detectors. These detectors, which have already been (partially) purchased and are being tested at the HyperNIS setup by staff, will be integrated into this setup to improve accuracy of the hypernucleus decay vertex determination. Preparation of a project for joint experiments with SRC, integration of detectors, development of a technical design for a spectrometer with two magnets (installations of a second magnet, supply of communications, supports for detectors), common data acquisition systems (design and tests), MC for the optimal geometry of joint (HyperNIS and SRC experiments) detectors.

Within the collaboration with Japan: data taking at LEPS/LEPS2 setups on the production of strangeness and vector mesons (including those, containing strange quarks) by polarized photons (close to the relevant thresholds); analysis of data on such reactions, taken before.

1.2. SRC experiment

M. Patsyuk

Realization
Data taking

VBLHEP V.D. Aksinenko, M.Kh. Anikina, T. Atovullaev, A. Atovullaeva, A.V. Averyanov, A.G. Bochkova, A.A. Feschenko, S.V. Gertsenberger, D.N. Grishchenko., A.M. Korotkova, M. Miloi, O.V. Okhrimenko, N.G. Parfenova, S.N. Plyashkevich, P.A. Rukoyatkin, A.V. Salamatin

DLNP V.V. Tereschenko, Y.N. Usikov

BLTP A.B. Larionov

Abstract and scientific rationale:
The properties of nuclei are defined by interaction of their constituents: nucleons on the level of lower resolution and quarks and gluons at high resolution. The relation between these two descriptions remains a challenge. Short-Range Correlated (SRC) pairs of nucleons, which are temporary fluctuations of strongly interacting nucleons at a distance of around nucleon radius and individual momenta larger than that of mean-field nucleons, are coupled to both nuclear scales. Electron scattering experiments have shown the far-reaching impacts SRCs have on the many-body systems, the nucleon-nucleon interaction, and nucleon substructure.

Expected results upon completion of the project:
The next experiment being planned right now will involve the use of a tensor polarized deuteron beam from Nuclotron and existing detection equipment at LHEP JINR. Specifically, we will explore polarized deuteron hard scattering off a liquid hydrogen target, with a focus on SRC kinematics. With a polarized deuteron beam of 6 GeV/c/nucleon momentum we will select interactions with $|t, u| > 1$ (GeV/c)², and a center-of-mass scattering angle around 90 degrees. A coincidence between the two arms of a dedicated spectrometer will identify two protons resulting from the p(d,2p)n reaction. Simultaneous detection of the recoil partner neutron arising from the deuteron's hard breakup will also be possible. The two-arm spectrometer will be akin to the one used in the 2022 SRC/BM@N measurement. Detection of the recoil neutron will necessitate the incorporation of a neutron detector along the beam. It is important to note that the installation of the required detection systems for planned measurements in the HyperNIS experimental area will not disrupt the existing HyperNIS experimental setup. However, a larger band by the magnetic field is needed to obtain the required resolution. For that a second magnet needs to be installed. Another solution is creating a new analyzing magnet instead of the installed one.

Expected results of the project this year:
SRC at BM@N data analysis.

Estimation of the momentum resolution of the HyperNIS magnetic spectrometer in the perspective of solving the problems of the SRC experiment.

Development of the TDR for SRC setup at the HyperNIS experimental area.

Activity of the theme:

	Name of the activity	**Leaders**	**Implementation period**
Laboratory	Responsible from laboratories		**Status**
1.	**NEMAN**	**E.S. Kokoulina** **V.A. Nikitin**	2025-2026 Project preparation Data taking
VBLHEP	V.B. Dunin, O.P. Gavrischuk, V.V. Popov, S. Y. Sinelschikova, M.V. Tokarev		
BLTP	A.B. Arbuzov, Yu.A. Bystritsky, V.F. Zykunov		

Abstract and scientific rationale:
In high energy physics, events are usually analyzed for which the deviation from the average multiplicity does not exceed two average values. Events with a higher multiplicity occur extremely rarely, so it is difficult to collect large statistics for them, in addition, there are difficulties in processing them. When planning any experiment, simulations are performed, but despite the fact that the number of Monte Carlo generators increases every year, their predictions deviate significantly in the region of high multiplicity. Setting their parameters at the given energy stops working when moving to a higher energy. All this indicates a significant misunderstanding of the mechanism of multiple production. The study of events with the production of a large number of secondary particles will allow a deeper understanding of strong interactions, including the hadronization stage.

In the region of high multiplicity, a series of collective phenomena with a quantum nature are predicted, such as the formation of a pion (Bose- Einstein) condensate, an excess soft photon (less than 50 MeV) yield, Cherenkov radiation of gluons by quarks, and others. In this region, the longitudinal component of the momentum approaches the transverse component, reaching it. This indicates the disappearance of the leading effect, and in the same region, apparently, the formation of a condensate begins. These and other collective manifestations in the behavior of secondary particles can be studied at the future NICA collider in the SPD project, since it is planned to register events in the absence of any trigger. This project is aimed at studying the gluon component of the nucleon. The study of processes with high multiplicity in the model of gluon dominance developed at JINR will provide additional knowledge about the gluon component of the nucleon and its contribution to hadronization.

Expected results upon completion of the activity:
Preparation of a physics program for the study of collective phenomena in the region of high multiplicity in proton and deuterium interactions at the SPD facility at the NICA collider.

Development of the gluon dominance model for the collective behavior study of secondary particles in high multiplicity events at the energies of the future NICA collider at the SPD facility. Estimates of the contribution of gluon bremsstrahlung by quarks and gluon fission as dominant elementary QCD processes in this region. Estimates of hadronization parameters for different kinds of hadrons.

Determination of the critical region of multiplicity, at which the longitudinal and transverse components of the momentum become the same (the disappearance of the leading particle) and the establishment of its connection with the region of the pionic condensate formation.

Optimization of the SpdRoot simulation program.

Expected results of the activity this year:
Designing of electronics for reading and controlling silicon photomultipliers (SiPM) of a stand-alone multichannel spectrometer-calorimeter for detecting soft photons and using it to measure the polarization of the SPILER polarimeter at the output of a spin polarization source (SPI).

Participation in the development of a physics program at the future SPD facility with unpolarized and polarized beams of light nuclei and protons to study the behavior of multiplicity. Simulation of pp (dd, pd) interactions at energies up to 27 GeV.

Preparation of a physics program aimed at searching for collective phenomena in events with high (exceeding average) multiplicity, in particular, the pion (Bose-Einstein) condensate discovered at the U-70 accelerator, studying the excess yield of soft photons, Cherenkov radiation from quarks of gluons, the effect of disappearance of the leading particle, based on the results of the project "Thermalization", carried out at the U-70 accelerator at IHEP (Protvino). Fulfill Monte Carlo simulations with unpolarized and polarized proton beams and light nuclei to study the behavior of multiplicity. Perform a comparison with model predictions at energies up to 10 GeV for charged and neutral particles (mesons and baryons) in the gluon dominance model. Execute this simulation in the SPDRoot package.

Using the data from the project "Thermalization", obtain multiplicity distributions of neutral pions as a function of total multiplicity and confirm their approximation to the Poisson distribution predicted in the works of R. Lednický and colleagues. Construct a scheme for hadron annihilation in the gluon dominance model, explain the discovered feature of multiplicity behavior at the Novosibirsk collider experiment in e^+e^--annihilation in the threshold region of proton-antiproton pair production.

Develop a physics program on a future SPD facility with unpolarized and polarized proton beams and light nuclei to study multiplicity behavior. Simulation of pp (dd, pp) interactions at energies up to 27 GeV and preparation for a detailed study of the parameters of the hadronization stage of charged and neutral particles (mesons and baryons) in the gluon dominance model.

Development and modernization of an algorithm for setting the initial parameters of tracks in the Kalman filter to increase the efficiency of track reconstruction, the accuracy of pulse reconstruction, and finding interaction vertices in the SpdRoot software.

Investigate the influence of the substance in the endcap of the SPD installation on the reconstruction of tracks and the selection of optimal parameters for the reconstruction of tracks.

Develop a software package SpdRoot for working on simulated events close to experimental ones. Preparation of the NEMAN project.

Collaboration 1086

Country or International Organization	City, region	Institute or laboratory
Belarus	Gomel, HO	GSTU
		GSU
	Minsk, MI	BSUIR
		IAP NASB
		IP NASB
Cuba	Havana	InSTEC
Egypt	Alexandria, ALX	AU
India	Kolkata, WB	UC
Israel	Tel Aviv, TA	TAU
Russia	Chernogolovka, MOS	ISSP RAS
	Moscow, MOW	Azimuth Photonics
		Fomos-Materials
		SINP MSU
	Protvino, MOS	IHEP
	Saint Petersburg, SPE	SPbSPU
	Zelenograd, MOW	RIMST
Slovakia	Banska Bistrica, BC	UMB
USA	Cambridge, MA	MIT

02-1-1097-2010

Study of Polarization Phenomena and Spin Effects at the JINR Nuclotron-M/NICA Facility

Theme leader: V.P. Ladygin

Deputies: N.M. Piskunov
E.A. Strokovsky

Participating countries and international organizations:
Bulgaria, France, Japan, Romania, Russia, Slovakia, Sweden, United Kingdom, USA.

The problem under study and the main purpose of the research:
Polarization studies are undoubtedly relevant now. They combine the efforts of JINR Laboratories and many foreign laboratories, both participating and non-participating countries, in the design and conduct of experiments using unique beams of polarized deuterons with energies ranging from 5 MeV per nucleon to 5.6 GeV/n, secondary beams of polarized protons and neutrons, as well as beams of polarized protons directly accelerated in the Nuclotron. The possibility of obtaining beams of accelerated polarized protons in the Nuclotron without significant investment, demonstrated in 2017, became the basis for intensifying work on the spin program of the NICA project and, in particular, for the development of polarimetry techniques, the creation of new methods for precise control of the direction of the spin of protons, deuterons and other particles. This part of the work on the topic is directly related to the creation of the NICA complex and the testing of a new approach to controlling the polarization in the spin transparency mode. Of undoubted interest is also the study of the possibility of setting up experiments at the upgraded Nuclotron and the collider to measure EDM and parity violation. Within the framework of the theme, two projects are being carried out: ALPOM-2 and DSS. Preparation of the project on the systematic study of spin effects in the processes of production of strange baryons and vector mesons in elementary reactions and in cold dense nuclear matter at Nuclotron energies using beams of polarized and unpolarized particles on a fixed target and a wide-aperture magnetic spectrometer. Taking into account the presence of polarized beams, new experimental data will be obtained on the study of charge-exchange processes, on the study of the structure of 2- and 3-nucleon correlations in the reactions of deuteron-proton elastic scattering and deuteron breakup, by measuring of the vector and tensor analyzing powers in the deuteron core region, as well as other processes that are important for the development of the theoretical models describing the interactions of the simplest nuclear systems with allowance for relativism and the contribution of the meson and quark-gluon components of the internal motion of constituents in nucleons.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	ALPOM-2	N.M. Piskunov *Deputies:* E. Tomasi-Gustafsson V. Punjabi R.A. Shindin	02-1-1097-1-2010/2027
2.	DSS	V.P. Ladygin	02-1-1097-2-2010/2027

Projects:

Laboratory	Name of the project / Responsible from laboratories	Project leaders	Status
	1. ALPOM-2	**N.M. Piskunov** *Deputies:* **E. Tomasi-Gustafsson** **V. Punjabi** **R.A. Shindin**	Preparation Data taking
VBLHEP	S.N. Bazylev, A.A. Druzhinin, O.P. Gavrishchuk, L.V. Karnyushina, D.A. Kirillov, A.N. Livanov, P.A. Rukoyatkin, I.M. Sitnik, E.A. Strokovsky, K.S. Volkova		

Abstract and scientific rationale:
At present, it is necessary to measure the analyzing powers of protons and neutrons in scattering on CH_2, CH and other targets. Such data are necessary for experiments requiring measurements of the polarization of protons and neutrons in nuclear reactions. It is also necessary to optimize hadronic polarimetry and expand the database on analyzing powers both for

protons, the same for neutrons. This is possible only in Dubna, where polarized proton beams and neutrons obtained by fragmentation of accelerated polarized deuterons.

Expected results upon completion of the project:
Investigation of the analyzing powers in the scattering of polarized protons (at momenta up to 7.5 GeV) and neutrons (at momenta up to 6 GeV) on polyethylene at the ALPOM-2 installation.

Expected results of the project this year:
Testing of the installation's detectors on a nucleon beam, providing the first measurements on beams of polarized nucleons.

2. DSS **V.P. Ladygin**

Preparation Data taking

VBLHEP E.V. Chernykh, Yu.V. Gurchin, A.Yu. Isupov, N.B. Ladygina, A.N. Livanov, S.G. Reznikov, A.A. Terekhin, A.V. Tishevsky, I.S. Volkov, K.S. Volkova

DLNP G.I. Lykasov

Abstract and scientific rationale:
Study of the structure of 2- and 3-nucleon correlations in the reactions of deuteron-proton elastic scattering and deuteron breakup by measuring of the vector and tensor analyzing powers in the region of the deuteron core, as well as other processes important for the development of theoretical models describing the interactions of the simplest nuclear systems, taking into account relativism and the contribution of the meson and quark-gluon components of the internal motion of constituents in nucleons.

Expected results upon completion of the project:
Measurement of the structure of 2- and 3-nucleon correlations in deuteron-proton elastic scattering and nonmeson deuteron breakup in the experiments at the Nuclotron internal target.

Measurement of cross sections and analyzing powers of these reactions. Performing experiments on the deuteron and proton spins manipulation, development of the polarimetry at the Nuclotron internal target.

Obtaining of the experimental data on many-particle correlations in nucleus-nucleus interactions.

Expected results of the project this year:
Completion of the analysis of data on the analyzing powers A_y, A_{yy} and A_{xx} of the deuteron-proton scattering up to 1800 MeV. Continuation of the analysis on the many-particle correlations in the Xe+W interaction.

Upgrade of the deuteron and proton polarimeter at the Nuclotron internal target.

Publication of the results obtained on the polarimetry, on the deuteron analyzing powers in deuteron-proton elastic scattering and many-particle correlations in nucleus-nucleus interactions.

Activities of the theme:

Laboratory	**Name of the activity** Responsible from laboratories	**Leader**	**Implementation period** **Status**
1.	**Development of spin physics research infrastructure and technologies at the Nuclotron and other facilities. Design, construction and development of the spin control and polarimetry systems. Consideration of new experiments with polarized beams at the NICA complex**	**A.V. Butenko**	2026-2027 Realization

VBLHEP A.V. Averyanov, A.A. Druzhinin, Yu.N. Filatov, V.V. Fimushkin, A.S. Galoyan, D.O. Krivenkov, M.V. Kulikov, R.A. Kuzyakin, V.P. Ladygin, A.N. Livanov, N.M. Piskunov, S.G. Reznikov, R.A. Shindin, E.A. Strokovsky, K.S. Volkova

DLNP Yu.N. Uzikov

MLIT V.V. Uzhinsky

Abstract and scientific rationale:
The possibility of obtaining beams of accelerated polarized protons in the Nuclotron without significant investment, demonstrated in 2017, became the basis for the intensification of work on the spin program of the NICA project and, in particular, for the development of polarimetry methods, the creation of new methods of precise control of the direction of the rotation of protons, deuterons and other particles. This part of the work topic is directly related to the creation of the NICA complex and the development of a new approach to operate the polarization in the spin transparency regime. Of undoubted interest is also the study the possibility of setting up the experiments at the upgraded Nuclotron and collider to measure the EDM and parity violation.

Expected results upon completion of the activity:
Development of infrastructure for spin research at the Nuclotron-M/NICA complex and other installations. Preparation of technical projects for spin control systems and polarimetry. Analysis of the possibility of setting up new experiments with polarized proton beams and deuterons at the NICA complex, in particular on the search for EDM.

Expected results of the activity this year:
Creation of a project for the placement of elements of polarimetry for beam diagnostics and polarization control in the SPD section of the NICA collider ring.

Testing of polarimeter detectors at the F3 focus on a beam of polarized nucleons.

2. Preparation of a project to study the spin properties of strange baryons and mesons in a cold dense nuclear medium — **V.P. Ladygin** — 2026-2027

Proposal preparation

VBLHEP A.A. Aparin, D.I. Klimansky, A.N. Livanov, B.V. Lyong, E.V. Nedorezov, S.S. Panyushkina, M.M. Shandov, R.A. Shindin, O. Suarez Eng

DLNP N.A. Bazhanov, Yu. A. Usov

MLIT O.V. Derenovskaya, O. Suarez Eng, N.N. Voytishin

BLTP A.N. Isadykov, G.Yu. Prokhorov, O.V. Teryaev, A.S. Zhevlakov

Abstract and scientific rationale:
Data on the production of vector mesons obtained in different reactions at BNL, KEK and GSI show strong absorption of mesons in the nuclear medium, as well as changes in their masses and widths. A new important observable is the spin alignment of vector mesons and the dependence of its magnitude on the properties of dense matter. The increase in global polarization values of hyperons measured at BNL with decreasing energy of colliding nuclei also requires further experiments at Nuclotron energies. The goal of the new project is the systematic study of the spin effects in the processes of production of strange baryons and vector mesons in elementary reactions and in cold dense nuclear matter at Nuclotron energies using beams of polarized and unpolarized particles at a fixed target and a wide-aperture magnetic spectrometer.

Expected results upon completion of the activity:
Monte Carlo simulations will be performed using different event generators for the main physical processes in the Nuclotron energy range in fixed target kinematics for various colliding systems.

A plan for setting up the experiment with detector systems will be prepared, the required accuracy of signal recording and the possibility of the physical signal selection from the background will be assessed.

Test work will be carried out to develop and to manufacture promising detectors and readout electronics systems for them.

A letter of intent, conceptual and technical designs for a fixed target experiment with extracted and secondary beams of the Nuclotron, aimed at studying the properties of cold baryonic matter, including spin and polarization effects, will be prepared.

Expected results of the activity this year:
Monte Carlo simulation of nucleon-nucleon and nucleon-nucleus collisions at Nuclotron energies, comparison with existing experimental results obtained previously at BNL, CERN and GSI.

Development of the detector concept for the implementation of the proposed experimental program.

3. Experiments on the program STRELA at polarized deuteron beam **N.M. Piskunov** 2026-2027

Data taking

VBLHEP S.N. Bazylev, A.A. Druzhinin, L.V. Karnyushina, D.A. Kirillov, R.A. Shindin, I.M. Sitnik

Abstract and scientific rationale:
Performance of the experimental works on the charge exchange reaction measurements using polarized deuteron beam in the Nuclotron energy range.

Expected results upon completion of the activity:
Carrying out measurements on beams of polarized and unpolarized deuterons in the range from 3 to 6 GeV/c.

Expected results of the activity this year:
Preparation of the STRELA detectors for the first measurements in experimental zone in the focus of F5 of the VP-1 beamline of building 205.

4. Theoretical calculations of polarized processes V.K. Lukyanov (BLTP) 2026-2027

Data analysis

VBLHEP A.P. Ierusalimov, N.B. Ladygina

Abstract and scientific rationale:
Development of theoretical models describing the structure of light nuclei and the interactions of the simplest nuclear systems, taking into account relativism and the contribution of the nucleon-meson and quark-gluon components to the internal motion of constituents in nucleons.

Expected results upon completion of the activity:
Description of experimental data on cross sections and polarization observables in reactions involving light nuclei, including those obtained at the Nuclotron/NICA accelerator complex.

Expected results of the activity this year:
Description of experimental data on deuteron analyzing powers of deuteron-proton elastic scattering at intermediate energies. Analysis of the energy behavior of the cross section, tensor analyzing power and vector polarization transfer coefficient from deuteron to proton in deuteron-proton backward scattering at Nuclotron energies.

Collaboration 1097

Country or International Organization	City, region	Institute or laboratory
Belarus	Minsk, MI	INP BSU
Bulgaria	Sofia	UCTM
France	Gif-sur-Yvette, IDF	Irfu
	Orsay, IDF	IJCLab
Japan	Wako	RIKEN
Romania	Bucharest, B	INCDIE ICPE-CA
Russia	Belgorod, BEL	BelSU
	Dolgoprudny, MOS	MIPT
	Moscow, MOW	LPI RAS
		NRC KI
	Novosibirsk, NVS	STL "Zaryad"
	Troitsk, MOW	INR RAS

Country or International Organization	City, region	Institute or laboratory
		LPP LPI RAS
Slovakia	Bratislava, BL	IP SAS
	Kosice, KI	IEP SAS
		UPJS
	Zilina, ZI	UNIZA
Sweden	Uppsala, C	TSL
United Kingdom	Glasgow, GLG	U of G
USA	Newport News, VA	JLab
	Norfolk, VA	NSU
	Upton, NY	BNL
	Williamsburg, VA	W&M

02-1-1150-2025

Fundamental and Applied Physics Research with Relativistic Particle Beams

Theme leader: A.A. Baldin

Participating countries and international organizations:
Armenia, Belarus, Chile, Russia, United Kingdom.

The problem under study and the main purpose of the research:
It is planned to develop fundamental and applied fields of experimental research with beams of relativistic particles, including the acceleration complex NICA at the Test Zone of the SPD experiment (experimental facility MARUSYA), experiments at the front part of the extraction channel of the Nuclotron to the F3 focus, as well as with beams of the LINAC-200 (800) electron accelerator in the framework of the new collaboration FLAP (Fundamental&applied Linear Accelerator Physics collaboration), namely, investigation of the mechanisms of electromagnetic interactions and new applications involving the creation of neutron sources, controllable generation of various types of electromagnetic radiation using relativistic electrons, development of new methods of charged particle beam diagnostics, testing and calibration of detectors of particles and radiations for collider and other accelerator experiments.

Project in the theme:

Name of the project	Project leader	Project code
Laboratory Responsible from laboratories		**Status**
1. FLAP	**A.A. Baldin**	02-1-1150-1-2025/2029
Fundamental&applied research with beams of relativistic accelerated electrons	*Deputy:* **Vit.V. Bleko**	Development and testing of diagnostic systems Data acquisition and analysis

VBLHEP V.A. Alexandrov, E.V. Arkhipov, V.I. Astakhov, E.G. Baldina, A.V. Beloborodov, Ver.V. Bleko, D.N. Bogoslovskiy, E.A. Bushmina, A.V. Butenko, S.A. Chetverikov, P.R. Khar'yuzov, E.A. Klevtsova, V.V. Kobets, D.S. Korovkin, V.A. Kukharev, A.B. Safonov, V.G. Shabratov, A.V. Skrypnik, S.Yu. Starikova, A.P. Sumbaev, Yu.A. Troyan

DLNP D.L. Demin, A.N. Fedorov, V.V. Glagolev, M.I. Gostkin, M.A. Nozdrin, A.S. Zhemchugov

MLIT E.K. Kuz'mina, M.M. Pashkova, S.V. Semashko, V.S. Semashko, Yu.V. Trofimov

Abstract and scientific rationale:
It is planned to develop the fields of research at which the new collaboration FLAP (Fundamental & applied Linear Accelerator Physics collaboration) is focused, namely, investigation of the mechanisms of electromagnetic interactions and new applications, including the creation of neutron sources, controllable generation of various types of electromagnetic radition, such as diffraction Cherenkov and THz radiation in a range from 1 to 10 THz by relativistic electrons. Development of the new methods of charged particle beam diagnostics, testing and calibration of particle and radiation detectors for collider and other accelerator experimetns, including teh creation of time-of-flight calibrated beams of secondary neutrons with energies from thermal to 20 MeV.

Expected results upon completion of the project:
The main global results of the project will be:
– creation of a unique scientific-research installation for investigation of the mechanisms of generation of electromagnetic radiation in a wavelength range from 1 mm (microwave range) to 1 pm (g radiation) at interaction of relativistic electron beams wtih matter and external electromagnetic fields;

– development of fundamentally novel approaches to generation of electromagnetic radiation with controllable parameters based on the application of targets from functional materials;

– development of new nondestructive methods of charged particle beam diagnostics;

– development, testing and calibration of charged particle detectors and radiations for NICA SPD and MPD experiments;

– radiobiological studies with acclerated electron beams and secondary g quanta and neutrons;

– development of a pulsed neutron source with known parameters for investigations in the field of extreme states of matter;

– experiments on the search of hypothetic particles beyond the Standard Model.

Expected results of the project this year:
Creation and beam testing of particle detectors based on fast scintillator.

Registration of GHz and THz radiation from active targets irradiated by relativistic electron beams.

Creation of the time of flight test bench for registration of secondary neutrons.

Testing of stilbene-based scintillators for n - γ separation.

Testing of new neutron detectors based on microchannel plates and nanosized boron-10 samples for high spatial resolution neutronography.

Activities of the theme:

	Name of the activity	Leaders	Implementation period
Laboratory	Responsible from laboratories		Status
1.	**Processing, digitizing, and analysis of primary experimental information (films) obtained using bubble chambers**	**A.A. Baldin** **E.A. Klevtsova**	2025-2027 Data analysis

VBLHEP S.G. Arakelyan, E.G. Baldina, A.V. Beloborodov, A.V. Belyaev, Ver.V. Bleko, Vit.V. Bleko, D.N. Bogoslovsky, E.A. Bushmina, S.A. Chetverikov, D.S. Korovkin, N.E. Kukharev, V.A. Pukhaeva, O.V. Rogachevsky, A.B. Safonov, A.Yu. Troyan, Yu.A. Troyan

MLIT E.K. Kuz'mina, M.M. Pashkova, V.S. Rikhvitsky, V.S. Semashko, S.V. Semashko, Yu.V. Trofimov

Abstract and scientific rationale:
Continuation of filling in the experimental data base on multiple particle production in an energy range from 1 to 300 GeV obtained in experiments with bubble chambers.

Analysis of experimental data in the internediate energy range in relativistic physics based on the self-similarity approach and application of the properties of Lobachevsky geometry for description of multiple particle production.

Search and study of new phenomena in the conditions of registration of «soft processes» of particle production with high spatial and momentum resolution which is inavailable in modern electronic experiments.

Expected results at the end of the activity:
Creation of the required equipment for digitizing of experimental film information obtained using bubble chambers and in fixed-target electronic experiments in the conditions of registration of multiple particle production in an energy range of 1-300 GeV.

Preparation of the educational program for students qualifying for the NICA project.

Comparison of the results obtained using the bubble chambers and the simulations with modern models. Development of recommendations for the strategy of experimental research at the accelerator complex NICA.

Publication of the results of analysis of bubble chamber data.

Expected major results in the current year:
Creation of the electronic data base from scanned photofilms and processes stereo images.

Organization of the procedure of storage and processing of the obtained images using the JINR MLIT capacities.

More precise determination of the results obtained using the 2-m and 1-m hydrogen bubble chambers.

2. Investigation of deep subthreshold processes applied and educational programs at MARUSYA facility

A.A. Baldin
D.S. Korovkin

2025-2027

Preparation
Data taking

VBLHEP S.V. Afanasiev, V.A. Arefiev, E.V. Arkhipov, V.I. Astakhov, E.G. Baldina, S.N. Bazylev, A.V. Beloborodov, A.I. Berlev, Ver.V. Bleko, Vit.V. Bleko, D.N. Bogoslavsky, E.A. Bushmina, S.A. Chetverikov, P.R. Kharyuzov, E.A. Klevtsova, V.A. Kukharev, A.B. Safonov, S.Yu. Starikova, A.P. Sumbaev, A.Yu. Troyan, Yu.A. Troyan

BLTP S.G. Bondarenko

MLIT V.V. Korenkov, E.K. Kuz'mina, M.M. Pashkova, S.V. Semashko, V.S. Semashko

DLNP A.N. Fedorov

Abstract and scientific rationale:
Experimental studies of deep subthreshold and cumulative reations at extracted beams of Nucltron-N (SPD Test Zone, MARUSYA facility).

Performing correlation experiments with registration of groups of particles in the final state with one cumulative particle. Studies in the pre-cumulative and cumulative regtions with extracted polarized beams.

Expected results at the end of the activity:
New experimental data on A-dependences of rare subthreshold and cumulative processes of pion, kaon, and light nuclei production depending on the type and energy of projectile nuclei, momentum and angle of registered particles.

New upgraded facility supplemented with detectors for correlation experiments: multichannel gamma spectrometer, multiplicity detector, neutron detector.

Expected major results in the current year:
Putting in operation the upgraded magnetooptical channel of the MARUSYA facility.
Reconstruction of the experimental zone of the spectrometer channel at F4.

Creation of the new data acquisition system of the facility.

Putting in operation track detectors.

Development and creation of the neutron detector.

Testing of the Cherenkov detector.

Testing of the prototype detectors for the SPD experiment.

Continuation of experiments at extracted beams of Nuclotron-N wtih maximum available intensity.

Development of the software for simulation and processing of experimental data.

3. Neutron resonance spectroscopy

A.A. Baldin
V.N. Shvetsov

2025-2027

Preparation
Data taking

VBLHEP V.I. Astakhov, E.G. Baldina, A.V. Beloborodov, Ver.V. Bleko, Vit.V. Bleko, D.N. Bogoslavskiy, E.A. Bushmina, S.A. Chetverikov, P.R. Kharyuzov, E.A. Klevtsova, V.A. Kukharev, A.B. Safonov, S.Yu. Starikova, A.P. Sumbaev, Yu.A. Troyan

MLIT S.V. Semashko, Yu.V. Trofimov

FLNP N.V. Rebrova

Abstract and scientific rationale:
Experimental study of the methods for registration and measurement of neutron resonances upon passage of radiation generated by a neutron source through various materials. Neutron resonance spectroscopy and radiography for investigation of the properties of materials in extreme states.

Development and study of the methods of nondestructive inspection of samples and materials using thermal and epithermal neutrons.

A neutron image detector with high spatial (20-50 mkm) and time (50-100 ns) resolution will be developed in the framework of development of methods of real-time neutron tomography with thermal and resonance neutrons. This study is aimed at a broad range of fast processes in the field of the physics of extreme states of matter and material research. This method will allow one to study the physical and chemical composition of machine-building materials, gaseous cavities inside structural materials with high atomic mass. Another important advantage of neutron radiography is the possibility of visualization of hydrogen-containing substances in a metal matrix.

Expected results at the end of the activity:
Practical implementation of the method of nondestructive measurement of parameters of materials in extreme states. Practical implementation of the method of nondestructive study of composite materials.

Study of the feasibility of development of low-current power supply elements based on decay of unstable isotopes produced using a neutron source.

Expected major results in the current year:
Numerical and experimental determination of optimal characteristics of the neutron source.

Experimental determination of an optimal configuration of the experiment design to achieve the required measurement precision.

Improvement of methods for registration of parameters of neutron resonances.

Measurement of experimental spectra of neutrons from various materials irradiated by accelerated electron beams.

Collaboration 1150

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	IAPP NAS RA
		YSU
Belarus	Minsk, MI	INP BSU
Chile	Santiago, RM	UNAB CTEPP
Russia	Belgorod, BEL	BelSU
		Erendi Vakuum
	Dubna, MOS	Horocycle
		IAS "Omega"
		IPTP ROSATOM
	Gatchina, LEN	NRC KI PNPI
	Moscow, MOW	LPI RAS
		Marafon
		MIREA
	Saint Petersburg, SPE	SPbSPU
	Sarov, NIZ	VNIIEF ROSATOM
	Tomsk, TOM	TPU
	Vladikavkaz, SE	Baspik
United Kingdom	Egham, SRY	Royal Holloway

Neutrino physics and astrophysics

02-2-1099-2010

Study of Neutrino Oscillations and Astrophysical Research

Theme leaders: D.V. Naumov
A.G. Olshevskiy

Participating countries and international organizations:
CERN, China, Czech Republic, France, Germany, Italy, Japan, Romania, Russia, Slovakia, Switzerland, Turkey, United Kingdom, USA.

The problem under study and the main purpose of the research:
Measurement of the parameters of neutrino oscillations and other properties of neutrinos in experiments of various types, as well as astrophysical research in ground-based and space experiments. Global analysis of data from neutrino experiments, development of experiments and creation of new-type facilities.

Projects in the theme:

Name of the project	Project leaders	Project code
1. JUNO	D.V. Naumov *Deputies:* N.V. Anfimov M.O. Gonchar	02-2-1099-1-2009/2026
2. Studying neutrino properties in accelerator experiments	L.D. Kolupaeva A.G. Olshevskiy *Deputies:* Yu.A. Gornushkin O.B. Samoylov	02-2-1099-4-2026/2028
3. TAIGA	A.N. Borodin	02-2-1099-3-2015/2026

Projects:

Name of the project	Project leaders	Status
Laboratory Responsible from laboratories		
1. JUNO	**D.V. Naumov** *Deputies:* **N.V. Anfimov** **M.O. Gonchar**	Realization

DLNP A.I. Antoshkin, T.A. Antoshkina, N.S. Bessonov, S.V. Biktemerova, A.E. Bolshakova, V.V. Chalyshev, A.V. Chetverikov, A.V. Chukanov, S.G. Dmitrievskiy, D.A. Dolzhikov, D.V. Fedoseev, Yu.A. Gornushkin, M.B. Gromov, V.O. Gromov, D.E. Korablev, A.V. Krasnoperov, K.I. Kuznetsova, P.I. Lenskii, E.A. Naumova, I.B. Nemchenok, A.G. Olshevskiy, A.V. Rybnikov, A.S. Selyunin, V.I. Sharov, O.Yu. Smirnov, S.A. Sokolov, A.P. Sotnikov, V. Zavadskiy, I.N. Zhutikov

MLIT N.A. Balashov, A.V. Baranov, A.N. Makhalkin, R.N. Semenov, E.O. Tsamtsurov

BLTP N.S. Tsegelnik

VBLHEP V.I. Astakhov, V.B. Shutov

Abstract and scientific rationale:
Measurement of the neutrino mass hierarchy in the long-f reactor experiment. Precise determination of the parameters of neutrino oscillations. Study of neutrino fluxes from various sources: the Sun, the Earth and others.

Expected results upon completion of the project:
Determination of the ordering of neutrino masses with an accuracy of > ~3σ, precision measurement of the spectrum of reactor antineutrinos, search for sterile neutrino states, measurement of solar and geoneutrino fluxes.

Expected results of the project this year:
Publication of a paper on the JUNO detector performance. Publication of the results of first measurement of neutrino oscillation parameters in JUNO. Start of data taking in the TAO detector. Estimation of the sensitivity of the JUNO experiment to neutrino mass ordering via atmospheric neutrinos.

2. Studying neutrino properties in accelerator experiments NOvA, T2K, NA65/DsTau, FASER

L.D. Kolupaeva
A.G. Olshevskiy
Deputies:
Yu.A. Gornushkin
O.B. Samoylov

Realization

DLNP N.V. Anfimov, A.I. Antoshkin, O.S. Atanova, V. Yu. Baranov, A.E. Bolshakova, V.V. Chalyshev, A.V. Chetverikov, I.E. Chirikov-Zorin, A.V. Chukanov, Yu.I. Davydov, S.G. Dmitrievsky, D.V. Fedoseev, O.V. Geytota, V.V. Glagolev, A.D. Gridina, V.O. Gromov, A.D. Ivanova, A.I. Kalitkina, N.V. Khomutov, V.I. Kiseeva, O.L. Klimov, D.E. Korablev, V.A. Kozhukalov, K.I. Kuznetsova, V.V. Lyubushkin, A.V. Pavlov, B.A. Popov, A.V. Rybnikov, A.S. Selyunin, V.I. Sharov, A.S. Sheshukov, S.A. Sokolov, A.P. Sotnikov, I.A. Suslov, S.V. Tereschenko, V.V. Tereschenko, I.I. Vasilyev, S.G. Vasina, I.Yu. Zimin

BLTP I.D. Kakorin, G.A. Kozlov, K.S. Kuzmin, V.A. Matveev, V.A. Naumov, D.S. Shkirmanov

MLIT N.A. Balashov

Abstract and scientific rationale:
Measurement of the neutrino mass hierarchy, CP violation and other parameters of neutrino oscillations in the NOvA and T2K long baseline accelerator experiments. Study of tau leptons production via D_S meson production and decay in proton-nucleus collisions at 400 GeV/c (the NA65/DsTau experiment). Study of high-energy neutrino properties in the range of ~100 GeV — 3 TeV at the LHC collider in CERN (the FASER experiment). Search for new particles and exotic reactions. Estimation of neutrino interaction cross-sections.

Expected results upon completion of the project:
Determination of the neutrino mass ordering and the lepton CP-parity violation parameter in long baseline accelerator experiments at a significance level of ~3σ, precise measurement of the Δm^2_{32} and $\sin^2\theta_{23}$ oscillation parameters. Joint analysis of neutrino experiment data. Search for new particles and exotic reactions. Measurement of neutrino interaction cross sections of all types for the energy range of 100–3000 GeV. Measurement of the D_S meson production cross-section in proton-nucleus collisions with subsequent decay to a tau lepton at 400 GeV/c. Refinement of the measurement of the tau neutrino flux from accelerators.

Expected results of the project this year:
Continuing to collect statistics in the experiment detectors and data processing. Search for magnetic monopoles in the far detector of the NOvA experiment. Preparing publications on measuring the parameters of neutrino oscillations in the NOvA and T2K experiments. Estimating the cross section of charmed particle production based on the data from the pilot run of the NA65/DsTau experiment. Conducting methodological research and developing the detector readout electronics. Developing a new program for track reconstruction and vertex search.

3. TAIGA

A.N. Borodin

Realization

DLNP P.A. Bezyazykov, A.V. Blinov, M.I. Dzhakupov, V.M. Grebenyuk, A.A. Grinyuk, H. Karatash, A. Pan, S.Yu. Porokhovoy, A.V. Shaikovsky

MLIT I. Satyshev

Abstract and scientific rationale:
Investigation of gamma radiation and charged cosmic rays (CRs) in the energy range of 10^{13}–10^{18} eV by detecting Cherenkov radiation from extensive air showers: studying the high-energy edge of the spectrum of the brightest galactic and extragalactic sources of gamma radiation, searching for galactic PeVatrons, applying a new hybrid approach to study mass composition of CRs in the range of 10^{14} –10^{17} eV, studying of CR anisotropy in the energy range of 100–3000 TeV.

Expected results upon completion of the project:
Investigation of the energy spectrum of gamma quanta from galactic sources and the search for new sources of gamma quanta. Monitoring of the flux of gamma rays from nearby extragalactic sources. Search for TeV gamma rays from gamma-ray bursts and gamma rays correlated with high-energy neutrinos. Search for cosmic accelerators in which protons are accelerated to energies of 100–3000 TeV. Investigation of the mass composition of cosmic rays in the region of transition from galactic to extragalactic rays.

Expected results of the project this year:
Further collection and analysis of data to reconstruct the spectrum of gamma rays from galactic sources. Modernization of the 5th Cherenkov telescope, development and preparation for operation of new Cherenkov detectors.

Activities of the theme:

Name of the activity	Leaders	Implementation period
Laboratory Responsible from laboratories		Status
1. Experiment SHiP	**A.G. Olshevskiy**	2026-2028
		R&D Project preparation

DLNP N.V. Anfimov, A.V. Chukanov, S.G. Dmitrievsky, Yu.A. Gornushkin, L.D. Kolupaeva, O.B. Samoilov, A.S. Selyunin, S.A. Sokolov

BLTP N.V. Krasnikov, G.A. Kozlov, V.A. Matveev

VBLHEP N.I. Azorsky, V.V. Bautin, S.A. Movchan, E. Mukhamedzhanov, A. Mukhamedzhanova, D. Myktybekov, S. Romakhov, K.M. Salamatin, T.L. Yenik, A.A. Zaitsev, N.I. Zimin

Abstract and scientific rationale:
Study of neutrino properties. Search for new vector and scalar light particles-candidates for dark matter. Methodical studies on SHiP detectors.

Expected results upon completion of the activity:
Evaluation of the SHiP experiment sensitivity and its consideration while forming requirements for detectors. Preparation of a project for JINR participation in the SHiP experiment, taking into account the methodological studies carried out for detector systems based on scintillators and straw tubes.

Expected results of the activity this year:
Formulation of proposals for the SND detector subsystem using tile calorimetry, as well as the UBT detector for precise determination of the time stamp of events. Methodological studies with straw tubes for HSDS.

2. Experiment Borexino/DarkSide	**O.Yu. Smirnov**	2024-2026
		Data analysis

DLNP M.V. Gromov, D.V. Korablev, O.E. Lychagina, O.B. Samoylov, A.S. Sheshukov, A.P. Sotnikov, A.V. Vishneva

Abstract and scientific rationale:
Completion of analysis of unique data from the Borexino detector. Search for dark matter particles and rare processes in the DarkSide-50 and DarkSide-20k experiments.

Expected results upon completion of the activity:
Refinement of solar neutrino flux measurements based on the largest and best-quality Borexino dataset. Obtaining new constraints on rare processes and non-standard neutrino interactions from Borexino data. Searching for light dark matter particles with sensitivity two orders of magnitude greater than current limits. Searching for rare processes in the DarkSide-50 and DarkSide-20k experiments and obtaining corresponding constraints on reaction parameters.

Expected results of the activity this year:
Publication of the results of the analysis of the full Borexino data set, including a new data processing technique. Expected results include refinement of solar neutrino fluxes and constraints on non-standard neutrino properties. Publication of constraints on the lifetime of argon-36 with respect to two-neutrino double electron capture.

Collaboration 1099

Country or International Organization	City, region	Institute or laboratory
Belgium	Ghent, VOV	UGENT
CERN	Geneva, CH	CERN
China	Beijing, BJ	IHEP CAS
		Tsinghua
	Guangzhou, GD	SYSU
	Shanghai, SH	SJTU
Czech Republic	Prague, PR	CU
France	Paris, IDF	LPTHE
	Strasbourg, GES	IPHC
Germany	Aachen, NRW	RWTH
	Hamburg, HH	UHH
Italy	Milan, MI	UNIMI
	Naples, NA	Unina
	Padua, PD	INFN Padua
	Salerno, SA	INFN Salerno
Japan	Fukuoka	Kyushu U
	Nagoya	Nagoya Univ.
	Tokai	JAEA
	Tokyo	Toho Univ.
Romania	Magurele, IF	ISS
Russia	Dubna, MOS	Uni Dubna
	Irkutsk, IRK	ISU
	Moscow, MOW	LPI RAS
		SINP MSU
	Troitsk, MOW	INR RAS
Slovakia	Bratislava, BL	CU
Switzerland	Bern, BE	UNIBE
	Lausanne, VD	EPFL
Turkey	Ankara	METU
United Kingdom	London, LND	IMPERIAL
		QMUL
		UCL
USA	Batavia, IL	Fermilab
	Duluth, MN	UMD
	Minneapolis, MN	U of M
	Mobile, AL	USA
	Pasadena, CA	Caltech
	Williamsburg, VA	W&M

02-2-1144-2021

Search for New Physics in the Lepton Sector

Theme leader: Z. Tsamalaidze

Participating countries and international organizations:
Australia, Belarus, China, Czech Republic, France, Georgia, Germany, India, Japan, Kazakhstan, Malaysia, Republic of Korea, Russia, United Kingdom.

The problem under study and the main purpose of the research:
Search for evidence of new physics beyond the Standard Model by measuring the neutrinoless coherent transition of a muon to an electron (μ → e conversion) in the field of an aluminium nucleus.

Project in the theme:

Name of the project	Project leader	Project code
Laboratory Responsible from laboratories		Status
1. COMET	**Z. Tsamalaidze**	02-2-1144-1-2025/2029
		R&D Realization

DLNP D.Sh. Chokheli, I.L. Evtukhovich, P.G. Evtukhovich, A. Hassan, V.A. Kalinnikov, E.S. Kaneva, Kh. Khubashvili, A.V. Pavlov, B.M. Sabirov, A.V. Simonenko, V.V. Tereschenko, N. Tsverava, I.I. Vasilyev, E.P. Velicheva, V.P. Volnykh

BLTP D. Aznabaev, A. Issadykov, G.A. Kozlov

MLIT D. Goderidze, A. Khvedelidze

VBLHEP D. Baigarashev, T.L. Enik

Abstract and scientific rationale:
Charged-lepton flavour-violating (CLFV) processes offer deep probes for new physics with discovery sensitivity to a wide range of new physics models — SUSY, Higgs Doublets, Extra Dimensions, and, particularly, models explaining the neutrino mass hierarchy. The most sensitive exploration of CLFV processes is ensured by experiments that utilize high intensity muon beams to search for CLFV μ→e transitions, such as: $\mu^+ \to e^+\gamma$ (MEG at PSI, Switzerland); $\mu^+ \to e^+e^-e^+$ (Mu3e at PSI, Switzerland) and the coherent neutrinoless conversion of a muon into an electron in the field of a nucleus $\mu^-N \to e^-N$ (COMET at J-PARC, Japan; Mu2e at Fermilab, USA).

The COMET experiment seeks to measure the neutrinoless coherent transition of a muon to an electron in the field of an aluminium nucleus. The event signature of coherent neutrinoless $\mu^- \to e^-$ conversion in a muonic atom is the emission of a monoenergetic single electron in a certain time interval. The energy of the signal electron for aluminium is 104.97 MeV, and the lifetime of the muonic atom is 864 ns.

This makes neutrinoless $\mu^- \to e^-$ conversion very attractive experimentally. Firstly, the e^- energy of about 105 MeV is well above the end-point energy of the muon decay spectrum (~52.8 MeV). Secondly, since the event signature is a monoenergetic electron, no coincidence measurement is required. Thirdly, the long lifetime means that backgrounds associated with the beam flash can be eliminated. Thus, the search for this process has the potential to improve sensitivity by using a high muon rate without suffering from accidental background events.

There exist various theoretical models which predict sizable charged lepton mixing branching ratios. Among them, the best motivated models are the supersymmetric (SUSY) extensions of the SM, such as SUSY-GUT or SUSY-Seesaw models. Modern theoretical motivations for lepton flavor violation, data on current experimental bounds and expected improvements are reviewed by Marciano, Mori and Roney.

The COMET experiment will be carried out in two stages: Phase-I and Phase-II. The experimental sensitivity goal for this process in Phase-I is 3.1×10^{-15}, or the 90% upper limit of the branching ratio of 7×10^{-15}, which is a factor of 100 improvement of the existing limit $B(\mu^- + \mathrm{Au} \to e^- + \mathrm{Au}) \leq 7\times10^{-13}$ from SINDRUM II at PSI. The goal of Phase-II is a SES of 2.6×10^{-17}, which is a factor of about 10 000 better than the current experimental limit. The expected number of background events is 0.032, with a proton beam inter-bunch extinction factor of 3×10^{-11}. To achieve the target sensitivity and background

level, the 3.2 kW 8 GeV proton beam from J-PARC (Japan) will be used. Two types of detectors - CyDet (cylindrical detector system) and StrECAL (straw tracker and electron calorimeter) - will be used for detecting the $\mu^- \rightarrow e^-$ conversion events and for measuring beam-related background events.

Scientists from DLNP JINR successfully participate in the preparation stage of the COMET experiment. For Phase-I, JINR specialists manufactured and tested the entire set of straw tubes with a diameter of 9.8 mm and a length of 1.6 m (more than 2700 pieces), and for Phase-II, they will produce a full set of straw tubes with a diameter of 5 mm. The JINR specialists actively participate in the creation of the straw tracker, the electromagnetic calorimeter and the cosmic ray veto system (CRV) at the stages of modelling and scientific and technical activities. They will also continue to be actively involved in the assembly and maintenance of these detectors. The JINR specialists participate in the analysis of the test measurement data and will participate in the analysis of the COMET experiment data.

Expected results upon completion of the project:
Completion of assembly, testing, calibration, installation, cosmic test and maintenance of the straw detector for Phase-I.

Development and optimization of the crystal calibration method for the calorimeter with allowance for the features of the experiment: the presence of the magnetic field and the high-resolution calorimeter.

Simulation of a complex detector system (tracker, calorimeter, etc.).

Participation in the preparation, engineering and physics run, acquisition and analysis of data of Phase-I.

Research and development for production of straw tubes with a wall thickness of 12 μm and a diameter of 5 mm. Measurement of all mechanical properties and development of quality control standards for manufactured new straw tubes 5 mm in diameter.

Production of straw tubes (about 1000 pcs) for a full-scale prototype.

Production of a full-scale straw station with new tubes (12 μm, 5 mm) at JINR, and measurements on the beam.

Preparation, mass-production and testing of straw tubes for Phase-II.

Full participation in the design, assembly, installation, cosmic test and maintenance of the calorimeter.

Participation in the assembly and maintenance of the CRV for Phase-I and Phase-II.

Participation in the beam tests of the detector components for Phase-II.

Participation in the assembly, testing, installation and maintenance of the entire detector system for Phase-II.

Expected results of the project this year:
Completion of assembly, testing, calibration, installation and cosmic test of the straw detector for Phase-I.

Development and optimization of the crystal calibration method for the calorimeter with allowance for the features of the experiment: the presence of the magnetic field and the high-resolution calorimeter.

Simulation of the complex detector system (tracker, calorimeter, etc.).

Participation in the preparation of the engineering and physics run of Phase-I.

Research and development for production of straw tubes with a wall thickness of 12 μm and a diameter of 5 mm. Measurement of all mechanical properties and development of quality control standards for manufactured new straw tubes 5 mm in diameter.

Participation in the design and assembly of the calorimeter.

Participation in the assembly of the CRV for Phase-I.

Collaboration 1144

Country or International Organization	City, region	Institute or laboratory	
Australia	Melbourne, VIC	Monash	
Belarus	Minsk, MI	BSU	
		INP BSU	
		IP NASB	
China	Beijing, BJ	IHEP CAS	
Czech Republic	Prague, PR	CU	

Country or International Organization	City, region	Institute or laboratory	
France	Paris, IDF	IN2P3	
Georgia	Tbilisi, TB	GTU	
		HEPI-TSU	
		UG	
Germany	Dresden, SN	TU Dresden	
India	Mumbai, MH	IIT Bombay	
Japan	Fukuoka	Kyushu U	
	Osaka	UOsaka	
	Tsukuba	KEK	
Kazakhstan	Almaty, ALA	INP	
Malaysia	Bangi, SL	UKM	
Republic of Korea	Seoul	SKKU	
Russia	Novosibirsk, NVS	BINP SB RAS	
		NSU	
United Kingdom	London, LND	IMPERIAL	

Nuclear Physics (03)

03-4-1146-2024

Neutron Nuclear Physics

Theme leaders: Yu.N. Kopatch
P.V. Sedyshev
V.N. Shvetsov

Participating countries and international organizations:
Albania, Armenia, Azerbaijan, Bangladesh, Belarus, Brazil, Bulgaria, CERN, China, Croatia, Cuba, Czech Republic, Egypt, Finland, France, Georgia, Germany, Hungary, IAEA, India, Italy, Japan, Kazakhstan, Moldova, Mongolia, North Macedonia, Poland, Republic of Korea, Romania, Russia, Serbia, Slovakia, Slovenia, South Africa, Switzerland, Thailand, Turkey, USA, Uzbekistan, Vietnam.

The problem under study and the main purpose of the research:
Nuclear physics research with neutrons is traditionally one of the priority areas developed at JINR. These studies are carried out within the framework of the scientific theme "Nuetron Nuclear Physics" (03-4-1146-2024). The integrated use of the FLNP basic facilities (IREN pulsed source of resonance neutrons, IBR-2 pulsed reactor, EG-5 electrostatic generator, as well as TANGRA facility) makes it possible to conduct nuclear physics research in a wide range of neutron energies from cold neutrons to ~20 MeV, and the use of external neutron sources, such as the n_TOF neutron time-of-flight facility at CERN, allows expanding the energy range to several hundreds of MeV.

The research and development activities within the framework of the theme are aimed at implementing the tasks formulated in the Seven-Year Plan for the Development of JINR for 2024–2030 in the field of "Nuclear Physics".

The physics investigations can be grouped into three research areas:
– study of violations of fundamental symmetries in the interactions of neutrons with nuclei, obtaining nuclear data;

– study of fundamental properties of the neutron, physics of ultracold and very cold neutrons;

– applied and methodological research.

The scientific program of the theme "Neutron Nuclear Physics" will be implemented within the framework of four projects: two scientific ("Investigations of neutron nuclear interactions and properties of the neutron" and "TANGRA") and two scientific and technical projects ("Modernization of the EG-5 accelerator and its experimental infrastructure" and "Development of the concept of an ultracold neutron source at the IBR-2 pulsed reactor").

Work on the development of the neutron radiography technique with resonance neutrons is planned to be singled out as a separate activity.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	Development and elaboration of the tagged neutron method for determining the elemental structure of matter and studying nuclear reactions (TANGRA - Tagged Neutrons and Gamma Rays)	Yu.N. Kopatch	03-4-1146-1-2014/2028
2.	Modernization of the EG-5 accelerator and its experimental infrastructure	A.S. Doroshkevich	03-4-1146-2-2022/2026
3.	Investigations of neutron nuclear interactions and properties of the neutron	V.N Shvetsov P.V. Sedyshev	03-4-1146-3-2024/2028
4.	Development of the concept of an ultracold neutron source at the IBR-2 pulsed reactor	V.N. Shvetsov G.V. Kulin *Deputy:* A.I. Frank	03-4-1146-4-2026/2027

Projects:

Name of the project	Project leaders	Status
Laboratory Responsible from laboratories		
1. Development and elaboration of the tagged neutron method for determining the elementalstructure of matter and studying nuclear reactions (TANGRA - Tagged Neutrons and Gamma Rays)	**Yu.N. Kopatch**	Upgrade Data acquisition Data analysis

FLNP N.A. Fedorov, D. Grozdanov, C. Hramco, P.I. Kharlamov, P.S. Prusachenko, V.R. Skoy, V.N. Shvetsov, T.Yu. Tretiakova

VBLHEP V.Yu. Aleksakhin, S.V. Khabarov, Yu.N. Rogov, M.G. Sapozhnikov, V.M. Slepnev, N.I. Zamiatin, E.V. Zubarev

DLNP A.V. Krasnoperov, A.V. Salamatin

Abstract and scientific rationale:

Information about neutron-nuclear interactions is extremely important for both fundamental and applied physics. The fact that the neutron has no electric charge makes it a unique probe for studying nuclear forces. Due to electrical neutrality, the high penetrating power of neutron radiation makes it promising for studying the structure of matter at both the nuclear and molecular levels. Neutrons are also widely used for applied purposes: in inspection systems, non-destructive elemental analysis facilities, in instruments for studying the immediate environment of boreholes (logging), as well as in the creation of neutron and gamma radiation detectors used on board orbital and descent spacecraft for analysis of soil and atmosphere of celestial bodies. Information about neutron-nuclear reactions is also necessary for the design of promising nuclear power facilities, as well as for modeling various devices and objects that interact with neutron radiation in one way or another. An indicator of the relevance of studying the characteristics of neutron-nuclear interactions can be the fact that the list of the most requested nuclear data for the most part consists of queries directly related to neutron-nuclear reactions.

The TANGRA (TAgged Neutrons and Gamma Rays) project is aimed at studying neutron-nuclear reactions using the tagged neutron method, finding new ways to use neutron methods in fundamental and applied research, improving existing and creating new approaches to processing the results of nuclear physics experiments. One of the tasks to be solved within the framework of the project is the interpretation of existing experimental data on the reactions of interaction of fast neutrons with atomic nuclei, their systematization and validation. The priority area of work is the acquisition of nuclear data.

Expected results upon completion of the project:

Performing experiments to study the angular distributions of scattered neutrons.

Experimental study of (n,γ) and (n’,γ)-correlations.

Theoretical description of the studied reactions.

Conducting experiments to study the reaction (n,2n).

Conclusion on the applicability of the tagged neutron method for elemental analysis of soils. In case of a positive result, the creation of prototypes of stationary and mobile facilities, as well as methodological recommendations for their use for agricultural and environmental monitoring.

The results obtained during the implementation of this project will be valuable for both fundamental and applied science. The obtained experimental data on the yields and angular distributions of γ-rays can be used to increase the accuracy of Monte Carlo simulations of various physics facilities. Another planned application of the obtained experimental results is fast elemental analysis. Optimized model parameters can be used to theoretically describe previously unstudied reactions. The developed prototypes of facilities for elemental analysis of soils can become the basis for creating devices useful for intensifying agriculture and monitoring the state of the environment.

Expected results of the project in the current year:

Development of a database of γ-ray emission cross-sections in reactions induced by fast neutrons.

Preparation of measurements of differential cross-sections of neutron and γ-radiation emission in elastic and inelastic neutron scattering on a number of elements in a wide energy range (from the detector registration threshold to 10–15 MeV).

Theoretical description of (n,γ) and (n,n'γ) angular correlations in reactions with fast neutrons.

Development of a method for determining carbon content in soil using a mobile device that utilizes the tagged neutron method for analysis. Determination of sensitivity limits to other elements.

2. Modernization of the EG-5 accelerator and its experimental infrastructure

A.S. Doroshkevich

Upgrade
Data acquisition
Data analysis

FLNP I.A. Chepurchenko, R.Sh. Issaev, Yu.N. Kopach, A.N. Likhachev, V.N. Semenov, K.E. Studnev, S.N. Tkachenko, K.N. Udovichenko, I.A. Zaitsev, T.Yu. Zeleniak

Abstract and scientific rationale:
The project is aimed at modernizing the main systems of the electrostatic charged particle accelerator EG-5, developing ion-beam and complementary methods for studying the elemental composition and physical properties of near-surface layers of solids.

***Goals of the project**:* to provide technical feasibility for the implementation of the scientific program of the JINR Topical Plan in studying reactions with fast quasi-monoenergetic neutrons; development of nuclear physics methods for studying the elemental composition; solution of problems of neutron-radiation materials science; implementation of practical applications of neutron physics; ensuring technical feasibility for the implementation of the unique options of the microbeam spectrometer.

Objectives of the project. The main technical task of the project is to restore the energy range of accelerated particles of 900 keV - 4.1 MeV and increase the ion beam current to 100-250 μA while maintaining the energy stability of the ion beam at a level no worse than 500 eV, ensuring the spatial stability of the ion beam, sufficient to implement the option of the microbeam spectrometer / nuclear microprobe.

The main organizational task is the formation and development of human resources potential to ensure the full implementation of the project for at least 3 seven-year periods.

The objectives of the project also include upgrading and replenishing the experimental infrastructure of the accelerator complex with new techniques, in particular, the development of new methods for studying the physical properties of the surface of materials that can complement and improve the quality of the resulting scientific products, the intensification of international scientific and technical cooperation, the organization of user policy, the formation of an interlaboratory accelerator center on the basis of FLNP JINR to solve a wide range of unique scientific and technological problems.

The main criteria for the successful implementation of the project are providing a neutron flux sufficient to conduct nuclear physics experiments with fast neutrons, and an energy stability of the ion beam sufficient to create a microbeam spectrometer/nuclear microprobe.

Expected results upon completion of the project:
As a result of the implementation of the project, the technical parameters of the accelerator will be restored (energy of accelerated particles of 4.1 MeV at a maximum current of at least 100 μA), which will make it possible to conduct studies of reactions with fast neutrons at JINR, as well as provide technical conditions for the installation of a microbeam spectrometer. A neutron generator based on a solid-state lithium target with a moderator will be added to the existing neutron generator with a gas target, and the chamber for irradiating samples with ion beams will be modified.

A new specialized laboratory will be created for the preparation of objects of study, which will be equipped with complementary methods for studying the optical and electronic properties of the surface, such as ellipsometry, optical and electron microscopy, methods for studying electrical properties at direct and alternating current (voltammetry, impedancemetry).

In addition to modernization and expansion of the instrumental base of the accelerator complex, the formation of personnel potential for the next 20-30 years will be carried out. The available methods of elemental analysis will be supplemented by methods of analysis based on prompt gamma rays from inelastic neutron scattering and neutron activation analysis.

Modernization of EG-5 at JINR, where there are highly qualified specialists, good detecting equipment and valuable developments in the field of neutron investigations of atomic nuclei, will make it possible in the short term to conduct a number of new, unique experiments on obtaining the energy spectra and angular distributions of charged particles from (n, α) and (n, p) / (α, n) and (p, n) reactions and integral and differential cross sections of the latter in the neutron energy range up to ~6 MeV, on processes of fission of atomic nuclei by fast neutrons, activation analysis, experiments in the field of neutron materials science and etc.

Technical projects in materials science will be carried out for JSC Mikron, ROSATOM State Corporation, and the NICA complex.

Expected results of the project in the current year:
Conducting physics experiments with the old ion source and accelerator tube.

Developing a control system for the new ion source.

Developing a project for automation and control of the accelerator.

Receiving a new accelerator tube and installing it together with the new ion source.

3.	**Investigations of neutron nuclear interactions and properties of the neutron**	**V.N. Shvetsov** **P.V. Sedyshev**	Upgrade Data acquisition Data analysis

FLNP Yu.V. Aleksiayenak, A. Asylova, G.S. Ahmedov, W. Badawy, D. Berikov, S.B. Borzakov, O. Chaligava, I. Chuprakov, O.-A. Culicov, A.Yu. Dmitriev, A.S. Doroshkevich, S. Enkhbold, Fan Lyong Tuan, N.A. Fedorov, O.S. Filippova, A.I. Frank, M.V. Frontasyeva, V.I. Furman, Yu.M. Gledenov, E.A. Golubkov, D.N. Grozdanov, D.S. Grozdov, C. Hramco, A.S. Kayukov, A.K. Kirillov, V.L. Kuznetsov, G.V. Kulin, H.K. Le, Le Ch.M. Nyat, A.I. Madadzadia, S. Mazhen, A.G. Malinin, Zh.V. Mezentseva, L.V. Mitsyna, A.Yu. Muzychka, T.B. Mi Nguyen, A.Yu. Nezvanov, P.S. Nekhoroshkov, S.S. Pavlov, Phan Luong Tuan, Yu.N. Pokotilovski, N.V. Rebrova, A.D. Rogov, I.A. Saprykina, O.V. Sidorova, E.I. Sharapov, M.S. Shvetsova, V.R. Skoy, Z.D. Slavkova, A.V. Strelkov, S.Yu. Taskaev, T.Yu. Tretyakova, K. Turlybekuly, K.V. Udovichenko, K.N. Vergel, D.C. Vu, A. Yergashov, N.S. Yushin, K.N. Zhernenkov, M.A. Zakharov, Sh.S. Zeinalov, T.Yu. Zeleniak, I.I. Zinicovscaia. A.O. Zontikov, 60 engineers, 2 workers

VBLHEP A.P. Sumbaev, T.L. Enik, 3 engineers

Abstract and scientific rationale:
Nuclear processes and structural changes in materials induced by slow, resonance and fast neutrons and accelerated charged particles are traditionally in the focus of research attention at FLNP JINR. The interaction of neutrons with atomic nuclei is of interest for both fundamental and applied research. The integrated use of the FLNP basic facilities (IREN pulsed source of resonance neutrons, IBR-2 pulsed reactor, EG-5 electrostatic generator) makes it possible to conduct nuclear physics research in a wide range of neutron energies from cold neutrons to ~20 MeV, and the use of external neutron sources, such as the n_TOF neutron time-of-flight facility at CERN, allows expanding the energy range to several hundreds of MeV. Fundamental research carried out at the FLNP Department of Nuclear Physics includes studies on the violation of space and time symmetry, the mechanism of nuclear reactions, the structure of atomic nuclei, fission processes induced by neutrons, neutron-induced reactions with the emission of light particles, the properties of the neutron as an elementary particle, the properties of ultracold and very cold neutrons, quantum mechanical effects involving neutrons.

Also, in FLNP, a variety of research programs has been developed for applied investigations, such as obtaining nuclear data and information on the radiation resistance of materials for nuclear technologies, power engineering and transmutation, radiation mutagenesis on fast neutrons, neutron activation analysis using thermal and epithermal neutrons, neutron activation analysis using prompt gamma-rays, elemental analysis using neutron resonances, elemental analysis using fast neutrons, analysis of the elemental composition of thin films, investigation of the radiation resistance of materials to the effects of accelerated charged particles on electrostatic accelerator beams, development of radiation-resistant nanostructured materials using accelerated ion beams.

Expected results upon completion of the project:
Refinement of characteristics of known resonances and detection of previously unknown ones.

Measurement of reaction cross sections and product correlations in the resonance region with an accuracy sufficient to study P- and T-odd effects. Performing experiments to study TRI and ROT effects in fission, measuring the mass-energy and angular distributions of fragments, prompt neutrons and gamma-rays; searching for rare and exotic fission modes, using both IBR-2 and third-party sources.

Conducting experimental and theoretical studies of neutron-nuclear reactions in a wide range of energies of incident particles.

Study of the neutron dispersion law in a refractive medium, including in the case of high accelerations.

Development of models for calculating the transport of UCN and CN in the material of nanodiamond reflectors and the extension of their applicability to the range of thermal neutrons.
Study of the structure of graphites after their intercalation and measurement of cross sections for cold neutron scattering by intercalated graphites.

Obtaining data for nuclear power engineering and astrophysics: measurement of integral and differential neutron cross sections, angular correlations in the energy range from cold neutrons to hundreds of MeV.

Study of radiation resistance of various materials, including those promising for use as neutron reflectors and moderators. Development and study of radiation resistance of electronic components, including those operating on new physical principles.

Development of energy and electronics devices using powder nanotechnology and ion beams.

Obtaining new data and monitoring the environmental situation in certain regions of the JINR Member States with the help of NAA.

Study of the influence of neutron irradiation on the properties of biological objects and tissues.

Investigation of layered structures, including high-temperature superconductors using RBS, ERD and PIXE techniques.

Performing elemental analysis of various objects of cultural heritage.

Expected methodological results:
Determination of optimal technologies for the synthesis and modification of substances for use as UCN and CN reflectors.

Development of methods for cleaning water and soil, and assessing the quality of food products.

Study of the processes of accumulation of nanoparticles in the organs of animals and plants, assessment of their impact on the health of living objects under study.

Development of a technique for non-destructive elemental analysis using prompt gamma-rays. Improvement of existing methods of activation analysis using thermal and resonance neutrons.

Development of methods for analyzing the electrical properties of developed electronic devices, power engineering devices, and ionizing radiation sensors based on new physical principles.

The fundamental results obtained during the implementation of the project will be of great importance for understanding the mechanisms of neutron-nuclear reactions and the development of theoretical ideas about these processes. The study of P- and T-odd effects will provide information on the contribution of the weak interaction to nuclear forces and can serve as an alternative method for determining the mixing coefficient Vud of a CKM matrix. Obtaining new information about ROT and TRI effects, as well as exotic fission modes, will make it possible to clarify the features of one of the stages of this process – the scission of a fissile nucleus into fragments. The data obtained during the implementation of the neutron-optical part of the project will be needed to create new neutron moderators and reflectors. In addition, they will allow significant progress in the development of neutron microscopy methods and studies of the magnetic structure of various objects. The implementation of the applied research program of the project will be of great social importance and contribute to the progress of environmental, materials science, archaeological, and nanotechnological investigations, as well as promising developments in the field of modern electronics and energy. The techniques of elemental and structural analysis being created and modernized will be in demand in many branches of human activity.

Expected results of the project in the current year:
Measurement of angular distributions of γ-rays emitted in the ^{35}Cl(n,γ) and ^{56}Fe(n,γ) reactions on the IREN facility and extraction of partial neutron widths of p-wave resonances.

Design and construction of an instrument on a 16-meter flight path of channel 4 of the IREN facility and development of a methodology for determining the parameters of p-wave neutron resonances using complex (radiation capture, transmission, self-indication) measurements.

Conducting methodological work on channel 1 of the IREN facility to prepare experiments on measuring spectra of charged particles emitted from reactions involving heavy nuclei on the Back-n beamline at the China Spallation Neutron Source (CSNS).

Design and construction of a prototype of a neuron polarizer based on ^{3}He.

Measurement of yields, angular and energy distributions of particles in the quaternary fission of ^{252}Cf.

Measurement of yields, angular and energy distributions of particles in neutron-induced ternary fission of ^{239}Pu.

Study of primary gamma-ray transitions in ^{176}Lu and ^{177}Lu after capture of resonance neutrons in the 1–100 eV range, aimed at investigating the structure of rotational bands of this deformed nucleus and possible K-mixing effects.

Conducting measurements of fast-neutron-induced (n,α) reaction on ^{19}F, ^{20}Ne, ^{50,52,53}Cr, ^{171}Yb nuclei using solid and gas samples.

Continuation of work on determining the elemental composition of archaeological finds, as well as a number of industrial samples, using neutron resonance analysis methods (radiation capture, transmission) on channel 3 of the IREN facility.

Conducting elemental analysis of various cultural heritage objects, solving current problems of art history, restoration and archeology.

Assessment of atmospheric deposition of heavy metals in the JINR Member States using passive and active biomonitoring.

Development of environmentally friendly methods for wastewater and soil treatment.

Achievement of new results in studying the influence of metal nanoparticles and neutron radiation on living organisms.

Preparation of an experiment to measure the speed of a neutron in matter.

Measurement of the Goos-Haenchen shift in an experiment on the total reflection of a neutron wave from a resonant structure (in case of availability of modern high-resolution neutron reflectometer).

Measurement of neutron scattering cross sections on DND powder depending on its density.

Obtaining mutants for breeding drought- and salt-resistant varieties of agricultural plants.

4. Development of the concept of an ultracold neutron source at the IBR-2 pulsed reactor

V.N. Shvetsov
G.V. Kulin
Deputy:
A.I. Frank

Realization

FLNP V.I. Bodnarchuk, M.V. Bulavin, A.V. Galushko, M.A. Zakharov, V.M. Milkov, A.Yu. Muzychka, A.Yu. Nezvanov, A.A. Popov, A.D. Rogov, A.N. Chernikov, Pham Khac Tuyen, 6 engineers, 3 workers

Abstract and scientific rationale:
The aim of the project is to develop a concept for a world-class ultracold neutron (UCN) source at the IBR-2 pulsed reactor. The development and construction of a UCN source at JINR is a highly relevant task. The research program at the future source will be based on the development of results obtained in previous years by JINR physicists in collaboration with other research centers. It is assumed that the priority areas will be a precision test of the weak equivalence principle using gravitational quantum spectrometry and the study of the universal acceleration law in the quantum sector.

The creation of an intensive UCN source at the IBR-2 pulse reactor is a rather complex task, since, despite the record high value of the neutron flux density in a pulse, this reactor is characterized by a relatively low value of the average neutron flux density. Due to the uniqueness of the IBR-2 reactor, the solution to this problem is associated with the search for fundamentally new technical solutions. At present, the design scheme of the source has been developed. It is proposed to use a thin chamber with liquid hydrogen as a converter. It is planned to implement the principle of pulsed neutron accumulation (PNA), which will allow for a significant gain in the density of neutron gas in a material trap. In order to preserve the pulsed structure of the neutron flux during transportation, which is absolutely necessary for the implementation of the PNA principle, it is proposed to obtain UCN by slowing down faster very cold neutrons (VCN) directly before the trap in a superconducting magnetic resonance system.

During the implementation of the project, a prototype source (PS) will be built at the site of the future source on beamline 3 of the IBR-2 reactor. It will differ from the designed source by the absence of a slowing-down superconducting magnetic resonance system and a cryogenic converter based on mesitylene, which does not require complex safety measures. The internal surface of the PS neutron guide will not be subject to the same strict requirements as the neutron guide of the designed source. At the same time, the design of PS will have much in common in its main features with the design of the future source. The construction of PS will allow us to verify the correctness of the technical solutions adopted for the creation of the projected source, as well as to conduct experimental studies necessary for developing a full-fledged concept of the projected source. In addition, the creation of such a source will allow the young researchers of the group, which will build the UCN source and begin physical research on it, to gain their first practical experience of working with neutrons.

Expected results upon completion of the project:
Development of a concept for a world-class ultracold neutron source at the IBR-2 pulsed reactor.

Development and construction of a prototype source to test the correctness of the proposed technical solutions and conduct experimental studies necessary for developing a full-fledged concept of the projected source.

Expected results of the project in the current year:
Development of the design and selection of materials for the head section of the channel with a converter for the prototype source.

Design of the engineering infrastructure of the source on beamline 3, which provides the possibility of moving the prototype source from the working position to the standby position with a closed shutter.

Commencement of work on safety justification related to the proposed use of a small-volume cryogenic liquid-hydrogen converter.

Design of scientific equipment for experiments with a prototype source.

Activity of the theme:

Name of activity	Leaders	Implementation period
Laboratory Responsible from laboratories		Status
1. Neutron resonance spectroscopy	**A.A. Baldin** **V.N. Shvetsov**	2025-2026
		Realization Data acquisition

VBLHEP V.I. Astakhov, E.G. Baldina, A.V. Beloborodov, Ver. V. Bleko, Vit.V. Bleko, D.N. Bogoslavsky, E.A. Bushmina, S.A. Chetverikov, P.R. Kharyuzov, E.A. Klevtsova, D.S. Korovkin, V.A. Kukharev, A.B. Safonov, S.V. Semashko, S.S. Shimansky, S.Yu. Starikova, Yu.A. Troyan, A.Yu. Troyan

FLNP N.V. Rebrova, P.V. Sedyshev

Abstract and scientific rationale:
Experimental study of methods for detecting and measuring neutron resonances upon passage of radiation generated by a neutron source through various materials. Neutron resonance spectroscopy and radiography for studying the properties of materials in extreme states.

Development and study of methods of nondestructive testing of samples and materials using thermal and epithermal neutrons.

Within the framework of development of methods of real-time neutron tomography with thermal and resonance neutrons, a neutron image detector with high spatial (20–50 μm) and time (50–100 ns) resolution will be developed. This study is aimed at a broad range of fast processes in the field of the physics of extreme states of matter and materials research. The method will make it possible to study the physical and chemical composition of machine-building materials, gas cavities inside structural materials with high atomic mass. Another important advantage of neutron radiography is the possibility of visualization of hydrogen-containing substances in a metal matrix.

Expected results at the end of the activity:
Practical implementation of the method of nondestructive measurement of parameters of materials in extreme states. Practical implementation of the method of nondestructive study of composite materials.

Study of the feasibility of development of low-current batteries based on the decay of unstable isotopes produced using a neutron source.

Expected major results in the current year:
Preparation of IREN channel 1a for testing neutron and gamma-ray detectors.

Conducting test experiments with gas, scintillation and microchannel neutron detectors.

Determination of neutron resonance parameters.

Collaboration 1146

Country or International Organization	City, region	Institute or laboratory
Albania	Tirana, TR	UT
Armenia	Yerevan, ER	SRCHCH
Azerbaijan	Baku, BA	BSU
		IGG
		IRP
Bangladesh	Pabna, Ra	PUST
Belarus	Gomel, HO	IRB NASB
	Khoiniki, HO	PSRER

Country or International Organization	City, region	Institute or laboratory
	Minsk, MI	BSU
		HMTI NASB
		IEB NASB
		IGIC NASB
		INP BSU
		RI PCP BSU
		SPMRC NASB
Brazil	Itabuna, BA	UFSB
Bulgaria	Plovdiv	PU
		UFT
	Sofia	IE BAS
		INRNE BAS
CERN	Geneva, CH	CERN
China	Beijing, BJ	PKU
	Dongguan, GD	CSNS
	Xi'an, SN	NINT
		XJTU
Croatia	Zagreb	OIKON
		RBI
Cuba	Havana	UH
Czech Republic	Prague, PR	CTU
	Rez, ST	CVR
Egypt	Alexandria, ALX	AU
	Giza, GZ	CU
		NRC
	Mansoura, DK	MU
	Shibin El Kom, MNF	MU
Finland	Oulu	UO MRU
France	Gif-sur-Yvette, IDF	LLB
	Grenoble, ARA	ILL
		LPSC
	Saint-Paul-les-Durance, PAC	CEA Cadarache
Georgia	Tbilisi, TB	AIP TSU
		TSU
Germany	Mainz, RP	JGU
Hungary	Budapest	RKK OU
IAEA	Vienna, AT	IAEA
India	Aizawl, MZ	MZU
	Varanasi, UP	BHU
Italy	Rome, RM	ENEA
	Siena, SI	UNISI
Japan	Kyoto	KSU

Country or International Organization	City, region	Institute or laboratory
	Tsukuba	KEK
Kazakhstan	Almaty, ALA	INP
	Astana, AST	ENU
	Kyzylorda, KZY	KazSRIRG
		KU
Mexico	Mexico City, CDMX	UNAM
	Morelia, MIC	UMSNH
Moldova	Chisinau, CU	IChem
		IMB ASM
Mongolia	Ulaanbaatar	GCRA
		MUST
		NRC NUM
North Macedonia	Skopje	UKiM
Poland	Gdansk, PM	GUT
	Krakow, MA	IFJ PAN
	Lodz, LD	UL
	Lublin, LU	UMCS
	Opole, OP	UO
	Otwock-Swierk, MZ	NCBJ
	Poznan, WP	AMU
Republic of Korea	Daejeon	KAERI
Romania	Baia Mare, MM	TUCN-NUCBM
	Bucharest, B	IFIN-HH
		IGR
		INCDIE ICPE-CA
		UB
	Cluj-Napoca, CJ	INCDTIM
	Constanta, CT	UOC
	Galati, GL	DJUG
	Iasi, IS	NIRDTP
		UAIC
	Magurele, IF	ISS
	Oradea, BH	UO
	Pitesti, AG	ICN
	Ramnicu Valcea, VL	ICSI
	Sibiu, SB	ULBS
	Targoviste, DB	VUT
	Timisoara, TM	UVT
Russia	Arkhangelsk, ARK	NArFU
	Borok, YAR	IBIW RAS
	Dolgoprudny, MOS	MIPT
	Donetsk	DonIPE

Country or International Organization	City, region	Institute or laboratory
	Dubna, MOS	Diamant
		Uni Dubna
	Elykaevo, KEM	Sirius. Kuzbass
	Gatchina, LEN	NRC KI PNPI
	Grozny, CE	CSPU
	Irkutsk, IRK	LI SB RAS
	Ivanovo, IVA	ISUCT
	Izhevsk, UD	UdSU
	Kaliningrad, KGD	IKBFU
	Kemerovo, KEM	KemSU
	Moscow, MOW	DSSI
		GPI RAS
		IA RAS
		IKI RAS
		IMET RAS
		IPCE RAS
		ITEP
		LPI RAS
		MISIS
		MNRHU
		MSU
		NRC KI
		Sechenov Univ.
		SIAS
		SINP MSU
		SM "MK"
		SNIIP ROSATOM
		VNIIA ROSATOM
		VNIIKR
	Nizhny Novgorod, NIZ	IPM RAS
	Novosibirsk, NVS	ISP SB RAS
	Obninsk, KLU	IPPE ROSATOM
	Perm, PER	PSNRU
	Saint Petersburg, SPE	Botanic garden
		FIP
		Ioffe Institute
		Radium Inst.
		SPMU
		SPSFTU
	Sevastopol	IBSS RAS
	Staraya Ladoga, LEN	SL Museum
	Troitsk, MOW	INR RAS

Country or International Organization	City, region	Institute or laboratory
	Tula, TUL	TulSU
	Vladikavkaz, SE	NOSU
	Voronezh, VOR	VNIILGISbiotech
		VSU
	Yekaterinburg, SVE	IPAE
		UrFU
	Zelenograd, MOW	Angstrem
		Mikron
Serbia	Belgrade, BG	IPB
		UB
		VINCA
	Novi Sad, VO	UNS
Slovakia	Bratislava, BL	CU
		IEE SAS
Slovenia	Ljubljana	GeoSS
South Africa	Bellville, WC	UWC
	Pretoria, GT	UNISA
	Stellenbosch, WC	SU
Switzerland	Villigen, AG	PSI
Thailand	Hat Yai	PSU
Turkey	Bandirma, IDF	BANU
	Canakkale, IDF	COMU
USA	Durham, NC	Duke
	Los Alamos, NM	LANSCE LANL
	Oak Ridge, TN	ORNL
Uzbekistan	Tashkent, TK	INP AS RUz
		Physics-Sun
Vietnam	Da Lat, LD	DNRI
	Hanoi, HN	IOP VAST
		VNU

03-5-1130-2017

Synthesis and Properties of Superheavy Elements, Structure of Nuclei at the Limits of Nucleon Stability

Theme leader: S.I. Sidorchuk

Deputy: A.V. Karpov

Scientific leader: Yu. Ts. Oganessian

Participating countries and international organizations:
Belarus, Brazil, China, France, Germany, India, Italy, Kazakhstan, Republic of Korea, Russia, South Africa, Vietnam.

The problem under study and the main purpose of the research:
Synthesis of nuclei at stability limits and the investigation of their properties. Investigation of the mechanisms of heavy-ion-induced reactions. Study of the physical and chemical properties of heavy and superheavy elements.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	Investigation of heavy and superheavy elements	M.G. Itkis A.V. Karpov	03-5-1130-1-2024/2028
2.	Light exotic nuclei at the borders of nucleon stability	G. Kaminski S.I. Sidorchuk *Deputies:* A.A. Bezbakh A.S. Fomichev	03-5-1130-2-2024/2028

Projects:

Laboratory	Name of the project	Project leaders	Status
Responsible from laboratories			
1.	**Investigation of heavy and superheavy elements**	**M.G. Itkis** **A.V. Karpov**	Implementation

FLNR A.M. Abakumov, F.Sh. Abdullin, D. Abdusamadzoda, N.V. Aksenov, Yu.V. Albin, A.A. Astakhov, E. Batchuluun, A.Yu. Bodrov, A.A. Bogachev, G.A. Bozhikov, M.L. Chelnokov, V.I. Chepigin, E.V. Chernysheva, I. Chuprakov, V.D. Danilkin, H.M. Devaraja, A. Dey, A.V. Guljaev, A.V. Guljaeva, A.I. Holtzman, D. Ibadullayev, A.V. Isaev, Yu.M. Itkis, I.N. Izosimov,D.E. Katrasev, S.A. Klygin, G.N. Knyazheva, P. Kohout, A. Kohoutova, A.B. Komarov, G.A. Kononenko, N.D. Kovrizhnykh, E.M. Kozulin, N.I. Kozulina, K.A. Kulkov, N.Yu. Kurkova, D.A. Kuznetsov, A.A. Kuznetsova, A.Sh. Madumarov, A.Yu. Malokost, O.N. Malyshev, R. Mukhin, I.V. Muravyov, I. V. Novikov, A.S. Novoselov, I.V. Pchelintsev, O.V. Petrushkin, A.V. Podshibyakin, A.N. Polyakov, A.G. Popeko, Yu. A. Popov, L.S. Porobanyuk, V.A. Rachkov, A.M. Rodin, A.V. Sabelnikov, R.N. Sagaidak, V. Saiko, V.S. Salamatin, S. Sathayan, E.O. Savelieva, B. Saylaubekov, Yu.M. Sereda, V.D. Shubin, M.V. Shumeiko, E.A. Sokol, D.I. Soloviev, A.I. Svirikhin, M. Tezekbayeva, R.S. Tikhomirov, Yu.S. Tsyganov, V.K. Utenkov, V. Yu. Vedeneev, A.A. Voinov, I.V. Vorobyov, A.N. Vorontsov, M.G. Voronyuk, G.K. Vostokin, S.A. Yuhkimchuk

BLTP M. Iliaš, D. Sen

Abstract and scientific rationale:
The Project aims to study the heaviest nuclei and atoms in a comprehensive way: conducting experiments on the synthesis of elements with Z=119 and 120; synthesizing new isotopes of superheavy elements; studying nuclear (spectroscopy) and chemical properties of superheavy elements; and investigating nuclear reaction dynamics, including multi-nucleon transfer, leading to the formation of neutron-rich heavy nuclei.

The project will be implemented mainly at the Superheavy Element Factory of JINR commissioned in 2020. The studies on nuclear reaction dynamics will be carried out at the U-400 accelerator complex before it is shut off for upgrade and will be pursued at U-400R after the facility if back in business. During the upgrade, studies on reaction dynamics and mechanisms will be carried out at the U-400M accelerator.

Expected results upon project completion:
Synthesis of new superheavy elements 119 and 120.

Synthesis of superheavy nuclei and study of their decay properties.

Study of the chemical properties of superheavy elements.

Spectroscopy of the radioactive decay of heavy and superheavy nuclei.

First experiments aimed to measure the masses of superheavy nuclei.

Study of the dynamics of heavy-ion nuclear reactions.

Expected results of the project in the current year:
First experiments using the DGFRS-2 separator of the SHE Factory for synthesizing element 119.

Test experiments for synthesizing elements with Z>118.

Experiments aimed at studying the properties of the radioactive decay (α-, β-decay, spontaneous fission) of short-lived isotopes with Z=102–106 at the SHELS separator using the GABRIELA and SFiNX detecting systems and those of the isotopes of element 114 and its decay products at the GRAND separator (DGFRS-3).

Experimental and theoretical studies of the chemical properties of Cn and Fl at the SHE Factory.

Development of target and beam material production techniques for experiments on the synthesis of superheavy elements and study of their properties at the SHE Factory.

Investigation of mass–energy and angular distributions of fragments formed in multinucleon transfer reactions and in fusion–fission and quasi-fission reactions.

2. Light exotic nuclei at the borders of nucleon stability

G. Kaminski
S.I. Sidorchuk
Deputies:
A.A. Bezbakh
A.S. Fomichev

Implementation

FLNR E. Almanbetova, A. Amer, A. Azhibekov, D. Aznabaev, E. Batchuluun, S.G. Belogurov, A.A. Bezbakh, A.A. Bogachev, I.V. Butusov, D. Ertaeva, E.M. Gazeeva,M.S. Golovkov, A.V. Gorshkov, L.V. Grirogenko, T. Isataev, A. Ismailova, Yu.M. Itkis, B.R. Khamidullin, M. Khirk, S.A. Klygin, A.G. Knyazev, G.N. Knyazheva, G.A. Kononenko, E.M. Kozulin, N.I. Kozulina, S.A. Krupko, K.A. Kulkov, S.M. Lukyanov, V.A. Maslov, B. Mauey, K.A. May, K. Mendibaev, K.D. Molotorenko, I.A. Muzalevskiy, E.Yu. Nikolskii, K.V. Novikov, Yu.L. Parfenova, N.H. Phan, S.A. Rimzhanova, E.O. Savelieva, Yu.M. Sereda, A.V. Shakhov, P.G. Sharov, N.K. Skobelev, R.S. Slepnev, V.I. Smirnov, Yu.G. Sobolev, S.V. Stepantsov, S.S. Stukalov, R.S. Tikhomirov, I.V. Vorobyov, A.N. Vorontsov, R. Wolski

Abstract and scientific rationale:
The investigations aim to study the structure of light nuclei and nuclear systems near and beyond the borders of nuclear stability using direct nuclear reactions (charge–exchange, one- or two-nucleon transfer), to investigate rare decay channels and the influence of reaction mechanisms on the observed properties of the studied nuclei. Direct reactions employed for studying the structure of isotopes near the borders of nuclear stability allow for more reliable data acquisition and the revision of existing knowledge. The experimental programme will be mainly implemented at the ACCULINNA-1,2 and MAVR setups using the upgraded U-400M accelerator complex of FLNR JINR that allow a wide range of experimental studies of light exotic nuclei using secondary beams in the energy range of 5–50 MeV/nucleon.

The ACCULINNA-2 separator will be equipped with a radio frequency filter for additional purification of secondary beams, a magnetic spectrometer for reaction product separation, a cryogenic target complex of hydrogen (including tritium) and helium isotopes, an array of neutron detectors based on stilbene crystals and BC-404 plastic, and systems for the registration of charged particles.

Expected results upon project completion:
Study of the properties of the drip-line isotopes of light nuclei.

First experiments using the tritium target.

Study of the structure of the drip-line isotopes of light nuclei in (d,p) and (d,n), (t,p), (t,a), (p,d), etc. reactions.

Studies of exotic decays, including 2n and 4n emission.

Investigation of nucleon and cluster transfer (2*n*, *d*, *t*, ^{3}He, etc.) in reactions involving light nuclei.

Expected results of the project in the current year:
Study of nuclei near the boundaries of nucleon stability.

Conduct of the ^{6,8}He+^{4}He experiments at the ACCULINNA-1,2 setups.

Preparation for and conduct of experiments at the ACCULINNA-1,2 fragment separators using radioactive beams and the cryogenic targets D_2, ^{4}He.

Running of experiments on measuring the cross sections of individual reaction channels at ACCULINNA-1 employing the MULTI spectrometer.

Development of the infrastructure of the ACCULINNA-2 fragment separator (RF kicker, tritium target complex).

Collaboration 1130

Country or International Organization	City, region	Institute or laboratory
Belarus	Minsk, MI	IE NASB
		OELT NASB
Brazil	Niteroi, RJ	UFF
China	Beijing, BJ	PKU
		UCAS
	Lanzhou, GS	IMP CAS
France	Orsay, IDF	IJCLab
	Strasbourg, GES	IPHC
Germany	Darmstadt, HE	GSI Helmholtz
India	Kolkata, WB	VECC
	Manipal, KA	MU
	Roorkee, UK	IIT Roorkee
	Rupnagar, PB	IIT Ropar
	Santiniketan, WB	Visva-Bharati
Italy	Naples, NA	Unina
Kazakhstan	Almaty, ALA	INP
	Astana, AST	ENU
		NU
Republic of Korea	Daejeon	IBS
Russia	Dimitrovgrad, ULY	RIAR ROSATOM
	Moscow, MOW	INEOS RAS
		MSU
		NRC KI
		SINP MSU
	Saint Petersburg, SPE	Ioffe Institute
		Radium Inst.
		SPbSU
	Sarov, NIZ	VNIIEF ROSATOM

Country or International Organization	City, region	Institute or laboratory	
	Sosnovy Bor, LEN	SPII "VNIPIET"	
	Troitsk, MOW	INR RAS	
	Voronezh, VOR	VSU	
South Africa	Pretoria, GT	UNISA	
	Richards Bay, NL	UNIZULU	
	Somerset West, WC	iThemba LABS	
	Thohoyandou, LP	UNIVEN	
Vietnam	Hanoi, HN	IOP VAST	

03-2-1100-2010

Non-Accelerator Neutrino Physics and Astrophysics

Theme leaders: E.A. Yakushev
S.V. Rozov

Participating countries and international organizations:
Azerbaijan, Belgium, Bulgaria, Czech Republic, France, Germany, Italy, Japan, Kazakhstan, Russia, Slovakia, Switzerland, United Kingdom, USA, Uzbekistan, Vietnam.

The problem under study and the main purpose of the research:
Search for neutrinoless and two-neutrino modes of double beta decay and their investigation, revelation of the neutrino nature, Majorana or Dirac, determination of the absolute neutrino mass scale and hierarchy, search for the magnetic moment of electron neutrinos, and search for possible manifestations of dark matter. Investigations of nuclear reactor in-core processes at the Kalinin Nuclear Power Plant. Search for signals from coherent reactor antineutrino scattering and their investigation. Precision study of the coherent scattering spectrum to search for manifestations of New Physics. Search for sterile neutrinos. Spectroscopy of nuclei far from the line of beta stability. Study of interactions between intermediate-energy pions and helium nuclei. Development of new methods for detection of charged and neutral particles. Development of methods for producing and purifying radionuclide preparations for synthesis of radiopharmaceuticals. Application of hyperfine interaction methods to studying radiopharmaceuticals and their precursors. Development and application of methods and techniques to manufacture and analyze low-background materials with an exceptional ultra-low content of radioactive impurities.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	Radiochemistry and spectroscopy for astrophysics and nuclear medicine	D.V. Filosofov *Deputies:* Yu.B. Gurov A.Kh. Inoyatov D.V. Karaivanov	03-2-1100-1-2024/2028
2.	Investigations of reactor neutrinos on a short baseline	I.V. Zhitnikov *Deputies:* A.V. Lubashevskiy S.V. Rozov M.V. Shirchenko	03-2-1100-2-2024/2028
3.	Nuclear spectrometry for the search and investigation of rare phenomena	D.R. Zinatulina *Deputies:* K.N. Gusev D.V. Ponomarev S.V. Rozov	03-2-1100-3-2024/2028

Projects:

	Name of the project	Project leaders	Status
Laboratory	Responsible from laboratories		
1.	**Radiochemistry and spectroscopy for astrophysics and nuclear medicine**	**D.V. Filosofov** *Deputies:* **Yu.B. Gurov** **A.Kh. Inoyatov** **D.V. Karaivanov**	Implementation R&D Production Data taking

DLNP A.M. Abd, I.V. Alekseesv, K.M. Alshubaki, K.V. Antokhina, A. Baimukhanova, J.A. Dadakhanov, K.S. Dadakhanova, E. Denisova, A.N. Emeliyanov, S.A. Evseev, V.V. Fariseeva, S.V. Fateev, Yu.B. Gurov, A.Kh. Inoyatov, B.E. Kalinova, I.I. Kamnev, D.V. Karaivanov, O.I. Kartvtsev, S.A. Katulin, S.L. Katulina, Yu.K. Khusenova, Zh.Kh. Khushvaktov, E.Yu. Kulkova, E.S. Kurakina, V.H. Le, T.V. Le, T. Lednicka, N.V. Mazarskaya, N.A. Mirzaev, N.D. Mokhine, V.A. Morozov, N.V. Morozova, T.A. Morozova, M.V. Mukhina, I.B. Nemchenok, T. N.A. Nguyen, T.T. Pham , D.V. Ponomarev, A.V. Rakhimov, S.V. Rozov, I.E. Rozova, A.V. Salamatin, D.A. Salamatin, J.K. Samatov, K.V. Shakhov, I.S. Sherbakova, M.Yu. Shevchenko, A.A. Solnyshkin, V.I. Stegailov, I.A. Suslov, N. Temerbulatova, V.V. Timkin, V.N. Trofimov, Yu.A. Vaganov, O.V. Vagina, A.I. Velichkov, N.A. Vinokurov, V.P. Volnykh, M.Yu. Vorobyeva, E.A. Yakushev, A.A. Zaikin

Abstract and scientific rationale:
The project is aimed at developing methods for nuclear spectroscopy and radiochemistry to use in nuclear medicine, astrophysics, and neutrino physics. The project involves novel techniques for particle detection, calibration of experimental facilities, determination of background, and also design of exceptionally pure materials, etc., as well as development of methods for nuclear medicine, such as production and purification of radioisotopes, design and synthesis of radiopharmaceuticals, study of mechanisms affecting the tissues at radionuclide decay locations, etc.

Specific area:
– novel detectors (semiconductor detectors, liquid and plastic organic scintillators, composite scintillation detection systems, neutron and radon detectors, etc.);

– post-decay spectroscopy of electrons and other emissions with the focus on extremely low energies;

– standard gamma-spectroscopy based on semiconductor particle detectors (SPDs) with the focus on precision measurements of emission energy and source activity (of both point-like and volume sources) in order to study decay modes and to determine cross sections of nuclear reactions;

– methods of hyperfine interactions using radioactive tracers, namely the Method of Perturbed Angular Correlations (PAC) and Emission Mössbauer Spectroscopy to study radiopharmaceuticals and their precursors in aqueous systems and other matrices;

– methods for production and purification of radionuclide preparations to synthesize radiopharmaceuticals, including their production with generators, physicochemical methods for evaluating properties of radionuclides and radiopharmaceuticals (their precursors) in homogeneous and heterogeneous systems;

– methods and techniques for production and analysis of low-background materials with a uniquely low content of radioactive impurities, in particular, using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), as well as other analytical techniques and nuclear spectroscopy.

Methods of nuclear spectroscopy and radiochemistry for studying neutrino properties, searching for dark matter particles and investigating rare physical processes have long and deservedly proved effective in numerous experiments in fundamental physics and nuclear medicine. The relevance of this topic is certain. The focus on the development of methods and techniques, expanding the horizon of the experiments being performed at DLNP JINR, guarantees the scientific novelty of the project.

Expected results upon completion of the project:
New detectors:
– detectors based on silicon carbide (SiC) will be designed and then applied to register nuclear radiation; SiC detectors with a high radiation hardness and good operability at high temperatures (> 400°C) are intended to be used for monitoring the operation of high-current accelerators, nuclear reactors, as well as for diagnostics of hot plasma;

– liquid tellurium-loaded scintillators are expected to be designed and applied to search for the neutrinoless double β-decay, as well as other types of liquid and plastic scintillators;

– composite scintillation detection systems will be developed for neutrino experiments;

– ^{3}He counters will be developed and applied to the detection of low neutron fluxes (below 10^{-6} n×cm^{-2}×s); a compact sensitive radon detector will be designed, as well as the technology to produce low-level radioactive components using 3D printing.

It is planned to experimentally study the spectra of low-energy electrons (0–50 keV) with the ESA-50 spectrometer and also the spectra of gamma and X-ray radiation with SPDs during radioactive decay in order to obtain new data on low-excited states of nuclei and post-decay relaxation of atomic systems, as well as to search for ways to perform the spectrometry of post-decay photons (from the edge of infrared radiation up to soft X-rays) in the energy range of 1–200 eV.

The method for using the codes (Geant4, MCNP, and FLUKA) to simulate parameters of HPGe spectrometers both at the LINAC-200 Electron Accelerator intended to determine yields of photonuclear reactions, and also at other JINR basic facilities will be developed; decay modes of a wide range of radionuclides will be studied, and also their content in samples (^{96}Zr, ^{40}K, ^{138}La, etc.) will be determined in order to investigate rare processes.

It is expected that the methods of Perturbed Angular Correlations (PAC) and also Emission Mössbauer Spectroscopy using radioactive tracers ^{111}In, ^{152}Eu, ^{154}Eu, ^{119}Sb, ^{119m}Sn, ^{57}Co, ^{161}Tb, etc. will be mastered in order to study radiopharmaceuticals and their precursors (components) in aqueous systems and other matrices; physicochemical methods for evaluating properties of radionuclides and radiopharmaceuticals in homogeneous and heterogeneous systems will be improved.

Radiochemistry and nuclear medicine:
– sorption processes in various solution–sorbent systems as a chemical basis of methods for purifying radiopharmaceuticals (also low-background materials) are planned to be studied, and radionuclide generators for production of radiopharmaceuticals to be designed;

– methods for production of radionuclides and their separation (including mass separation) from targets irradiated with protons, neutrons and gammas for production of radiopharmaceuticals (^{103}Pd, ^{119}Sb, ^{161}Tb, some alpha emitters, etc.) will be developed;

– on the basis of reverse-tandem schemes, the development of a wide range of radionuclide generators will be continued in order to expand the possibilities of producing medical radionuclides; the possibility of producing 1–2 generators of significant activity for external users will be considered;

– methods for radiolabelling with radionuclides the radiopharmaceuticals based on chelators with "slow" kinetics will be developed; radium chelation will be investigated.

Methods for producing samples (^{82}Se, ^{96}Zr, shielding materials, solder, etc.) with a new ultra-low content of impurities (from mBq/kg to μmBq/kg of Th and U) will be developed and employed to solve problems in astrophysics and neutrino physics will be developed and employed; reverse chromatography will be used, low-boiling and other reagents, prepared or selected, will be utilized, as well as reactor materials, selected and prepared;

– it is planned that the method for analysing samples at an ultra-low level of sensitivity (mBq/kg – μmBq/kg of Th and U) using ICP-MS, the neutron activation analysis (NAA) and other techniques will be developed and employed; that the methods for precise determination of the chemical and isotopic composition of materials used in astrophysical and neutrino experiments will be designed.

Expected results of the project this year:
New detectors:
– characteristics of the detectors based on ultra-high purity silicon carbide (SiC) will be determined for the use in spectroscopy of nuclear radiation;

– techniques for manufacturing plastic scintillators applicable to separation of n/γ-radiation by the pulse shape will be tested;

– results of designing of composite scintillation detection systems for next-generation neutrino experiments will be obtained; a prototype auxiliary detector for large reactor experiments will be developed;

– a novel ^{3}He counter with a low internal background will be tested;

– technology for manufacturing components of low-level radioactive plastics using 3D printing will be developed.

Schemes of post-decay photon spectrometers (from the edge of infrared radiation up to soft X-rays) in the energy range of 1–200 eV will be proposed. The prototype will be tested with radionuclide sources in the range of 1–5 eV.

Experimental data on low-energy electron spectra from the decay of radioisotopes of ^{56}Co, ^{57}Co, ^{83}Rb, ^{155}Eu with the ESA-50 beta spectrometer are planned to be obtained in order to test the available computer codes for evaluating dose components of Auger and conversion electrons in radiation hygiene and radionuclide therapy. Within the project “Novel method for evaluating detection efficiency in gamma spectroscopy and activity of radioactive sources used in real experiments” and in collaboration with the Republic of Serbia, instrumental spectra of gamma radiation of radioisotopes ^{139}Ce and ^{207}Bi will be measured.

Photonuclear reaction yields, namely using ^{165}Ho and ^{181}Ta nuclei, will be determined; decay modes of a wide range of radionuclides, their content in samples will be specified to study rare processes.

PAC spectrometers are planned to be upgraded; new emission Mössbauer spectrometers using radioactive tracers ^{111}In, ^{152}Eu, ^{154}Eu, ^{119}Sb, ^{119m}Sn, ^{57}Co, ^{161}Tb, etc. will be launched.

Radiochemistry and nuclear medicine: the results of studying sorption processes of various solution–sorbent systems, as well as novel schemes of radionuclide separation are expected.

Methods for obtaining samples (^{96}Zr, ^{57}Fe) with a new ultra-low content of impurities to solve problems in astrophysics and neutrino physics will be developed and utilized; new experimental data will be acquired.

The methodology for precisely evaluating elemental composition of materials and samples used when performing experiments with the mass spectrometer (ICP-MS) in radiochemistry, astrophysics and neutrino physics.

The new DLNP JINR basic facility, Spectrometry Cluster, will be created. It will be commissioned in its basic configuration (7 spectrometers based on high-purity germanium, a scintillation detector and a PAC spectrometer).

2. Investigation of reactor neutrinos on a short baseline DANSS, Ricochet, vGeN	**I.V. Zhitnikov** *Deputies:* **A.V. Lubashevskiy** **S.V. Rozov** **M.V. Shirchenko**	Realization R&D Upgrade Data taking

DLNP A.M. Abd, Yu.V. Aksenova, I.V. Alekseesv, V.V. Belov, A. Bystryakov, I.S. Dotsenko, M.S. Dovbnenko, A.N. Emeliyanov, S.A. Evseev, V.V. Fariseeva, S.V. Fateev, D.V. Filosofov, M.V. Fomina, Yu.B. Gurov, K.N. Gusev, D.A. Ilyushkin, A.K. Inoyatov, B.E. Kalinova, I.I. Kamnev, D.V. Karaivanov, S.A. Katulin, S.L. Katulina, S.V. Kazarcev, J.K. Khushvaktov, S.P. Kiyanov, E.Yu. Kulkova, A.S. Kuznetsov, T. Lednicka, A.V. Lubashevskiy, N.V. Mazarskaya, D.V. Medvedev, N.A. Mirzaev, V.A. Morozov, T.A. Morozova, I.B. Nemchenok, D.V. Ponomarev, D.S. Pushkov, S.V. Rozov, I.E. Rozova, A.V. Salamatin, D.A. Salamatin, K.V. Shakhov, M.V. Shirchenko, I.S. Sherbakova, M.Yu. Shevchenko, E.A. Shevchik, I.A. Suslov, N. Temerbulatova, V.V. Timkin, Yu.A. Vaganov, O.V. Vagina, S.I. Vasiliev, V.P. Volnykh, M.Yu. Vorobyeva, E.A. Yakushev, A.A. Zaikin, I.V. Zhitnikov

Abstract and scientific rationale:

The project combines the experiments DANSS, Ricochet, and νGeN, studying antineutrino fluxes from nuclear reactors at distances of less than 20 m. The experiments have a common research area, with scientific problems overlapping and coinciding in many respects and also by the ways to solve them. In addition, the same JINR staff and JINR infrastructure resources are involved in this research.

DANSS is an experiment using an antineutrino spectrometer based on plastic scintillators with a sensitive volume of 1 m^3 located at Power Unit 4 at the Kalinin NPP. The lifting mechanism moves the spectrometer in the online mode 2 m vertically, enabling measurements at the distance of 11–13 m from the reactor. A high-segmented detector and combined active and passive shielding suppress the background down to several percentages relative to ~5000 neutrino-like events recorded per day.

The νGeN experiment is aimed at studying fundamental properties of neutrinos, in particular, at searching for the neutrino magnetic moment, coherent elastic neutrino scattering (CEνNS), and other rare processes. The νGeN spectrometer is placed under the reactor core of Power Unit 3 at the Kalinin NPP. Neutrino scattering is detected with a specialized low-threshold, low-background germanium detector. Active and passive shielding from background radiation guarantees a low level of background in the region of the search for rare events. The detection of events of interest ensures the search for New Physics beyond the Standard Model, and, in addition, can also be applied to practical tasks, for example, to developing new-generation detectors to monitor the operation of the nuclear reactor using the antineutrino flux.

Ricochet is a new-generation reactor neutrino experiment aimed at the one-percent-precision measurement of coherent elastic neutrino-nucleus scattering (CEνNS) in the sub-100-eV recoil nucleus energy region, which could reveal New Physics in the electroweak sector. It was planned to install the facility near the research nuclear reactor at the Laue-Langevin Institute (ILL) until the end of 2024. Ricochet will host two cryogenic detector arrays: CRYOCUBE (Ge bolometers based on those developed by the EDELWEISS experiment) and Q-ARRAY (superconducting Zn).

Expected results upon completion of the project:

The main goals of the DANSS experiment are to test the hypothesis of oscillations of reactor antineutrinos into the sterile state and to precisely monitor the operation of the nuclear reactor by measuring the antineutrino flux for a long time. Over the next few years, it is planned to create a new upgraded facility DANSS-2, with the improved energy resolution and the increased detection volume. Thus, the sensitivity to sterile neutrinos will be significantly higher. The search for oscillations into the light sterile neutrino ($\Delta m_{14}^2 \sim 0.1$–10 eV) is one of the current trends in fundamental neutrino physics. The existence of sterile neutrinos could explain several contradictory observations, first of all, the reactor and gallium (anti)neutrino anomalies, and at the same time become a revolutionary discovery of New Physics. Reactor experiments with a short baseline (<30 m) have several competitive advantages in this research area: a huge antineutrino flux from the most intense available artificial sources of (anti)neutrinos on Earth and a small distance from the radiation source where the hypothesized oscillation pattern is not smeared yet. It should be noted that the DANSS spectrometer is the leader among the facilities of this type.

It is expected that the νGeN project will check and specify the parameters of coherent scattering of reactor antineutrinos off germanium nuclei and also, following several years of measurements, increase the sensitivity to the electron (anti)neutrino magnetic moment to $\sim 1\times10^{-11}$ m_B, which will greatly improve the present-day best limit.

In the Ricochet experiment, according to the elaborated and experimentally proven background model, the statistical significance of the CEνNS detection after only one reactor cycle will be between 7.5 and 13.6 σ, depending on the muon veto efficiency. The targeted ~1%-precision measurement is expected to be reached over about ten reactor cycles (3–5 years onsite). It will increase the probability of discovering New Physics by an order of magnitude compared to that of the ongoing experiments.

Expected results of the project this year:

DANSS – Processing of the entire DANSS dataset. It is intended to prepare the launch of data acquisition with the DANSS-II detector at the Kalinin NPP. The results of reconstruction of reactor antineutrino spectra using the DANSS dataset are expected, as well as those of the study of spectra of high-energy reactor antineutrinos.

νGeN – It is planned to proceed with data taking to increase statistics. Moreover, the upgrade of the experimental setup is intended, namely the installation of a new, already tested internal veto, as well as the upgrade of passive and active shielding and the start of a new data-taking system that analyses signals using the pulse shape. The data analysis and modelling will be continued. New results considering backgrounds, the neutrino magnetic moment, CEvNS, and other phenomena will be obtained.

Ricochet – As the installation and commissioning phases had been completed, the first science run with the full Ricochet payload (18 detectors: 7 planar detectors and 11 FID detectors) started in July 2025. It will be continued, with the first physics results expected in 2026. An improved Monte Carlo model is planned to be developed on the basis of experimental data.

3. Nuclear spectrometry for the search and investigation of rare phenomena LEGEND, TGV, SuperNEMO, MONUMENT, Zr-BNO, Se-LSM

D.R. Zinatulina
Deputies:
K.N. Gusev
D.V. Ponomarev
S.V. Rozov

Implementation
Upgrade
Data taking

DLNP A.M. Abd, Yu.V. Aksenova, I.V. Alekseesv, V.V. Belov, I.S. Dotsenko, A.N. Emeliyanov, V.V. Fariseeva, S.V. Fateev, D.V. Filosofov, M.V. Fomina, Yu.B. Gurov, K.N. Gusev, D.A. Ilyushkin, A.K. Inoyatov, S.V. Kazarcev, B.E. Kalinova, I.I. Kamnev, D.V. Karaivanov, O.I. Kartvtsev, S.A. Katulin, S.L. Katulina, T. Khusainov, A.A. Klimenko, O.I. Kochetov, A.S. Kuznetsov, E.Yu. Kulkova, T. Lednicka, A.V. Lybashevsky, N.V. Mazarskaya, N.A. Mirzaev, V.A. Morozov, T.A. Morozova, I.B. Nemchenok, D.V. Ponomarev, A.V. Rakhimov, S.V. Rozov, N.S. Rumyantseva, A.V. Salamatin, D.A. Salamatin, E.O. Sushenok, K.V. Shakhov, M.Yu. Shevchenko, E.A. Shevchik, M.V. Shirchenko, A.M. Shihada, I.S. Sherbakova, N. Temerbulatova, V.V. Timkin, V.I. Tretyak, V.N. Trofimov, Yu.A. Vaganov, O.V. Vagina, S.I. Vasiliev, V.P. Volnykh, M.Yu. Vorobyeva, E.A. Yakushev, A.A. Zaikin, D.R. Zinatulina, I.V. Zhitnikov

Abstract and scientific rationale:
The project comprises six main experiments: LEGEND (Large Enriched Germanium Experiment for Neutrinoless double beta Decay), TGV (Telescope Germanium Vertical), SuperNEMO (Neutrino Ettore Majorana Observatory), MONUMENT (Muon Ordinary capture for the NUclear Matrix elemENTs), Zr-BNO, and Se-LSM. The experiments solve the problems of searching for different modes of double beta decay and studying them (two-neutrino ($2\nu\beta\beta$) and neutrinoless ($0\nu\beta\beta$)) using nuclear-spectroscopy methods. The detection of double beta decay will allow us to answer the question about the neutrino nature (the process is possible only for Majorana particles) and will undoubtedly indicate the New Physics beyond the Standard Model.

Development of a compact spherical modular muon detector DSTAR (Detection System for Tracking Angular Radiation) based on plastic scintillators and silicon photomultipliers. The detector is designed for the precision measurement of the flux of cosmic muons and their angular distribution, as well as for the development of muography techniques for solving applied problems.

Expected results upon completion of the project:
The LEGEND experiment, the successor of the GERDA and Majorana projects, is designed to search for the neutrinoless double beta decay of ^{76}Ge ($0\nu\beta\beta$). LEGEND is based on bare detectors of isotopically enriched ^{76}Ge immersed in liquid argon. The experiment is performed in two stages. At the first stage – LEGEND-200 – it is intended to use about 200 kg of ^{76}Ge, with the aim to reach the sensitivity of 10^{27} years over five years of accumulating data. At the second stage – LEGEND-1000 – the measurement will be conducted using 1 tonne of enriched germanium for 10 years. A low background level, high-energy resolution, and efficient discrimination using the event topology will ensure the possibility of unambiguous detection of $0\nu\beta\beta$ with T1/2 = 1028 years.

The programme of the SuperNEMO Demonstrator includes precision measurements of the two-neutrino double beta decay ($2\nu\beta\beta$) and is aimed at reaching the best limits on $0\nu\beta\beta$ for the isotope ^{82}Se.

The purpose of the MONUMENT experiment is to measure muon capture by several daughter nuclei, the candidates for the $0\nu\beta\beta$ decay.

Within the project, rare double beta decays of several isotopes are investigated. At present, two experiments, Zr-BNO and Se-LSM, are being performed.

The Zr-BNO experiment is aimed at the search for the double beta decay of ^{96}Zr into exited states of ^{96}Mo and at the search for the beta decay of ^{96}Zr into ^{96}Nb using a unique sample of enriched zirconium, produced for the first time in Russia by the centrifuge method.

The Se-LSM experiment is aimed at the search for double beta decay of ^{82}Se into exited states of ^{82}Kr with the OBELIX, a low-background spectrometer at the underground laboratory LSM in Modane, using a sample of enriched selenium weighing 6.5 kg.

The TGV spectrometer will be used for further investigations of the ECEC decay of ^{106}Cd and ^{130}Ba. According to estimations and theoretical predictions considering these rare processes, we hope to detect these decays for the first time in the direct experiment.

A muon detector DSTAR comprising 64 scintillator modules, with a unified time synchronization and coincidence event triggering system, will be created and tested. The project plans to establish a reference dataset from terrestrial, underground, and deep-underwater measurements; to develop algorithms for the inverse problem of muon tomography to reconstruct matter density distributions; to create the necessary software; and to prepare methodological documentation. First, muon fluxes at different depths in Lake Baikal will be measured, as well underground measurements at the Baksan Neutrino Observatory will be conducted; the muon background at the Kalinin NPP will be monitored; atmospheric muons at northern latitudes will be investigated (subject to agreement with Rosatomflot).

Expected results of the project this year:
The LEGEND-200 facility will be further optimized at the underground laboratory Gran Sasso, including the additional installation of recently produced detectors of enriched ^{76}Ge and the restart of data taking.

Simultaneously, R&D of hardware components of LEGEND-1000 will be conducted, such as detector holders, ASICs, detector immersion system, argon veto. New germanium detectors will be manufactured and tested; the start of the assembly of the LEGEND-1000 facility will be prepared.

Taking of calibration data with the spectrometer SuperNEMO Demonstrator. Taking of data of $0\nu\beta\beta$ and $2\nu\beta\beta$ decays in the ^{82}Se nucleus.

The MONUMENT activities will be continued. A series of new experiments at the PSI site will be prepared and performed (including R&D at JINR – purchase of stripped silicon detectors and electronics, calibrating and simulating). Data accumulation, processing, and analysis. Measuring muon capture with solid targets ^{12,13}C (investigation of light nuclei in terms of validating theoretical models applicable to double beta decay). R&D of application of muon capture to other areas interfaced with physics, such as radiobiology and mesochemistry.

The upgrade of the TGV spectrometer (both detectors and electronics). Measurements of enriched ^{106}Cd with the TGV setup.

Zr-BNO – Results of measurements of the enriched ^{96}Zr sample with the low-background facilities at JINR and BNO.

Se-LSM – Results of measurements of the enriched ^{82}Se sample with the low-background facility OBELIX at the underground laboratory LSM in Modane.

Assembly and testing of the DSTAR detector in the base configuration (64 modules); start of data taking; conducting muon flux measurements at different depths in Lake Baikal.

Activities of the theme:

Name of the activity	Leaders	Implementation period
Laboratory Responsible from laboratories		Status
1. Nuclear bolometer of SATURNE project	**V.N. Trofimov**	2025-2027
		R&D

DLNP A.N. Fedorov, V.G. Kolomiec, A.B. Neganov, A.A. Priladyshev

Abstract and scientific rationale:
This activity is part of the programme "Study of coherent elastic neutrino scattering off atoms, nuclei and electrons and measurements of electromagnetic neutrino characteristics with the intense antineutrino tritium source" (SATURNE project: SArov TritiUm neutRiNo Experiment) funded by the Federal Budget of RF and Rosatom. Within this activity, DLNP JINR is involved in developing low-temperature detection systems, namely in manufacturing prototype low-temperature helium and silicon detectors based on the ^{3}He/^{4}He dilution cryostat and also in studying different ways of generation and detection of elementary excitation pulses in superfluid helium.

Expected results of the activity upon completion:
Data on different ways of generation and detection of elementary excitation pulses in superfluid helium.

Expected results of the activity in the current year:
Development and commissioning of the JINR-designed cryogenic system based on the dry ^{3}He/^{4}He dilution cryostat.

Data processing

DLNP I.A. Belolaptikov, V.M. Grebenyuk, S.A. Gustov, A.G. Molokanov, V.A. Panyushkin, A.M. Rozhdestvensky, S.V. Rozov, I.E. Rozova, B.M. Sabirov, S.V. Shvydky

FLNR V.N. Frolov, M.A. Naumenko

Abstract and scientific rationale:
This activity is a follow-up of the projects DUBTO and PAINUC, it means it will be a collaborative experiment of JINR and INFN, Italy, focused on the studies of pion–helium interactions at energies below the Δ-resonance. In this experiment, the data will be used previously obtained at the JINR Phasotron with the technique of self-shunted streamer chambers developed at JINR. The goal is to get additional experimental data on the $\pi^{\pm}$^{4}He interaction at 106 and 68 MeV which is of great value for theorizing and developing models of nuclear matter.

Expected results of the activity upon completion:
The kinematics of the $\pi^{\pm}$^{4}He interaction, such as outgoing momentum of secondary particles and their exit angles, invariant masses of two and three particles, will be obtained. In particular, the probabilities of different channels of the $\pi^{\pm}$^{4}He interaction will be specified.

Expected results of the activity in the current year:
In 2026, the already measured images of $\pi^{\pm}$^{4}He interactions will be analysed in view of a novel approach to identification of secondary charged particles, and also the processing of raw experimental data (about half of the available statistics) will be prepared and launched.

Collaboration 1100

Country or International Organization	City, region	Institute or laboratory
Azerbaijan	Baku, BA	IRP
Belgium	Leuven, VBR	KU Leuven
Bulgaria	Plovdiv	PU
	Sofia	INRNE BAS
Czech Republic	Prague, PR	CTU
		CU
France	Bordeaux, NAQ	LP2i
	Grenoble, ARA	CNRS
		ILL
	Lyon, ARA	UL
	Modane, ARA	LSM LPSC
	Orsay, IDF	IJCLab
Germany	Heidelberg, BW	MPIK
	Munich, BY	TUM
	Tubingen, BW	Univ.
Italy	Assergi, AQ	INFN LNGS
	Turin, TO	INFN Turin
Japan	Osaka	UOsaka
	Tsuruga	WERC
Kazakhstan	Almaty, ALA	INP
Russia	Dubna, MOS	Uni Dubna
	Gatchina, LEN	NRC KI PNPI

Country or International Organization	City, region	Institute or laboratory
	Moscow, MOW	ITEP
		LPI RAS
		MEPhI
		MSU
	Neutrino, KB	BNO INR RAS
	Nizhny Novgorod, NIZ	IPM RAS
		NNSTU
	Sarov, NIZ	VNIIEF ROSATOM
	Voronezh, VOR	VSU
Slovakia	Bratislava, BL	CU
Switzerland	Villigen, AG	PSI
	Zurich, ZH	UZH
United Kingdom	London, LND	IMPERIAL
USA	Amherst, MA	UMass
	Austin, TX	UT
	Cambridge, MA	MIT
	Chapel Hill, NC	UNC
	Evanston, IL	NU
	Idaho-Falls, ID	INEEL
	Tuscaloosa, AL	UA
Uzbekistan	Tashkent, TK	INP AS RUz
Vietnam	Hanoi, HN	IOP VAST

Condensed Matter Physics (04)

04-4-1147-2024

Optical Methods in Condensed Matter Studies

Theme leaders: G.M. Arzumanyan
N. Kučerka

Deputy: K.Z. Mamatkulov

Participating countries and international organizations:
Armenia, Belarus, Egypt, Kazakhstan, Russia, Serbia, Uzbekistan, Vietnam.

The problem under study and the main purpose of the research:
Fundamental and applied studies of low-dimensional materials (2D-materials and van der Waals heterostructures) using Raman spectroscopy and upconversion luminescence. Fluorescence microscopy and vibrational spectroscopy in studies of photoactivated programmed cell death (netosis and apaptosis). Spectroscopy of lipid-protein interactions and secondary structure of proteins. Mastering low-frequency Raman spectroscopy.

Project in the theme:

Name of the project	Project leaders	Project code
Laboratory Responsible from laboratories		Status
1. NANOBIOPHOTONICS	**G.M. Arzumanyan** **K.Z. Mamatkulov**	04-4-1147-1-2024/2028 Data taking Realization

FLNP	K. Abdeljawaad, Y. Arynbek, N.A. Bykova, A. Damir, M.N. Eshonqulova, H.D. Le, I.A. Morkovnikov, Tri N.B. Pham
BLTP	V.A. Osipov
VBLHEP	V. Vartic
MLIT	O.I. Streltsova
LRB	E.B. Dushanov

Abstract and scientific rationale:
Since the first successful isolation of single-layer graphene by mechanical exfoliation of graphite in 2004, two-dimensional materials (2DMs) have attracted much attention owing to qualitative changes in their physical and chemical properties due to the quantum size effect associated with their nanoscale thicknesses. Atomically thin two-dimensional transition metal dichalcogenides (TMDCs), such as MoS_2, WSe_2, and others, exhibit strong light-matter coupling, making them potentially interesting candidates for various applications in electronics, optics, and optoelectronics. They can be assembled into heterostructures, combining the unique properties of their constituent monolayers. Raman spectroscopy is one of the most non-destructive and relatively fast techniques for characterizing such materials, providing high spectral resolution. Vibrational frequencies in the Raman spectrum of low-dimensional materials exhibit characteristic features of the sample, including line shape, peak position, spectral width, and intensity. These parameters provide useful information about physical, chemical, electronic, and transport properties of such materials.

Optical methods of research are also very promising in Life Sciences. In particular, the combination of vibrational spectroscopy with fluorescence microscopy will allow a detailed study of the mechanisms and signalling pathways of photoactivated programmed cell death – NETosis. Raman spectroscopy is also a fine and highly informative tool in revealing the secondary structure of proteins and is sensitive to lipid-protein interactions.

Expected results upon completion of the project:
Spectral and structural properties of 2DMs synthesized by plasmon-enhanced CVD method.

Mechanism of Raman enhancement effects from analyte molecules adsorbed on two-dimensional materials. Study of their protective properties as applied to biomolecules.

Upconversion luminescence on a low-dimensional platform: studies depending on the sample, temperature and excitation wavelength.

Spectroscopic analysis of conformational transformations in the secondary structure of proteins present in various membrane mimetics, including pH and temperature.

Simulation of lipid-protein interaction by MD and DFT.

Identification of mechanisms and signaling pathways of photoinduced NETosis by UV, visible and IR radiation. Identification of primary acceptors of photoinduced NETosis.

Characterization of the effects of simultaneous and sequential exposure to laser radiation on intact neutrophil cells at two different wavelengths.

Raman spectroscopy of ultra-low frequencies ~ 10 cm^{-1} at different wavelengths of excitation of the Raman signal.

Expected results of the project in the current year:
Exploring interaction of 2DMs with peptides: towards photoinhibiting of amyloid beta–42 aggregation.

Photoinduced modulation of immune response: a new approach to reduce harmful effects of excessive NETs formation.

Temperature-dependent SERS activity of 3D-substrate of G/CuAg Alloy NPs.

Low-frequency Raman spectroscopy in Materials Science and Life Sciences – refinement of the technique on selected samples.

Collaboration 1147

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	YSU
Belarus	Minsk, MI	BSUIR
		IBCE NASB
		SOL instruments
Egypt	Minya, MN	MU
Kazakhstan	Almaty, ALA	INP
Russia	Moscow, MOW	MSU
	Saint Petersburg, SPE	PFSPSMU
Serbia	Belgrade, BG	UB
Uzbekistan	Jizzakh, JI	JBNUU
Vietnam	Hanoi, HN	IMS VAST
		IOP VAST

Radiation Research in Life Sciences (05)

05-7-1077-2009

Research on the Biological Effects of Ionizing Radiations with Different Physical Characteristics

Theme leader: A.N. Bugay

Participating countries and international organizations:
Armenia, Azerbaijan, Belarus, Bulgaria, Cuba, Egypt, Italy, Mongolia, Russia, Serbia, Slovakia, South Africa, Uzbekistan, Vietnam.

The problem under study and the main purpose of the research:
Theoretical and experimental research on the biological effects of heavy charged particles of different energies at JINR's basic facilities.

Projects in the theme:

Name of the project	Project leaders	Project code
1. Molecular, genetic and organism effects of ionizing radiations with different physical characteristics	A.V. Boreyko P.N. Lobachevsky	05-7-1077-1-2024/2028
2. Radiation-biophysical and astrobiological research	I. Padrón Díaz A.Yu. Rozanov	05-7-1077-2-2024/2028

Projects:

Name of the project	Project leaders	Status
Laboratory Responsible from laboratories		
1. Molecular, genetic, and organismal effects of ionizing radiations with different physical characteristics	**A.V. Boreyko** **P.N. Lobachevsky**	Data taking Realization Modeling

LRB T.N. Bazlova, N.N. Budionnaya, V.N. Chausov, K. Erzhan, A.V. Frolova, T. Fam, K.N. Golikova, E.V. Golubeva, I. Hernández González, M.D. Isakova, N.A. Koltovaya, O.V. Komova, V.L. Korogodina, I.V. Koshlan, N.A. Koshlan, M.A. Kovalenko, P.A. Kozhina, A.N. Kokoreva, I.A. Kolesnikova, O. Kotb, T.S. Khramko, M.E. Krupnova, P.V. Kutsalo, E.A. Kuzmina, M. Lal, P.O. Lkhasuren, O.N. Matchuk, Yu.V. Melnikova, L.A. Melnikova, E.A. Nasonova, A. Nurkasova, B. Nguen, T. Nguen, N.V. Pakhomova, D.V. Petrova, E.V. Pronskih, S.K. Sakharova, Yu.S. Severiukhin, D.V. Shamina, N.V. Shvaneva, E.A. Shipilova, I.V. Smekina, T.V. Smirnov, E.V. Smirnova, E.V. Steshina, S.I. Tiunchik, G.T. Tilavova, D.M. Utina, O.O. Vinogradova, Yu.V. Vinogradova, V.C. Vinogradova, I.A. Zamulaeva, N.I. Zhuchkina

Abstract and scientific rationale:
The aim of the project is to study the molecular, genetic and organismal effects of ionizing radiation with different physical characteristics. The use of ionizing radiation of a wide range of linear energy transfer in radiobiological experiments allows obtaining unique information on the nature of the damage to the DNA structure of cells after irradiation, the mechanisms of the induction of gene and structural mutations in cells with different levels of genome organization, and the action of particle radiation on tumor during radiation therapy.

Within the framework of the project, fundamental and applied problems of modern radiation biology will be addressed: the formation and repair of cluster DNA damage in normal and tumor cells following exposure to accelerated charged particles; the study of the radiosensitizing effect of the DNA repair modifier AraC in combination with various molecular biological complexes during irradiation of tumor cells and tissues; the study of the induction of gene and structural mutations in normal and tumor cells following exposure to charged particles; investigation of acute and long-term morphological and functional changes in the mammalian central nervous system following exposure to radiation with different physical characteristics.

Expected results upon completion of the project:
To study clustered DNA DSB formation after exposure to accelerated charged particles of different energies in the nuclei of human skin fibroblasts, tumor cells, and neurons of different parts of the central nervous system of irradiated animals.

To study the repair kinetics of clustered DNA DSB in the post-irradiation period in the nuclei of human skin fibroblasts and radioresistant tumor cells.

To study mechanisms of the radiosensitizing effect of cytosine arabinoside in combination with various molecular biological complexes on normal and tumor cells after exposure to radiation with different LET.

To study quantitatively the survival of normal and tumor cells after radiation exposure in the presence of a combination of DNA repair modifiers.

To continue investigation of point and structural mutation induction in *Saccharomyces cerevisiae* yeast cells by radiation with different LET.

To study the influence of heterogeneity of cell population in haploid yeast on the radiation-induced mutagenesis; estimate mutagenesis in different phases of cell cycle.

To study the influence of respiratory impairment as the result of mitochondrial DNA damage on the sensitivity to the mutagenic effect of radiation.

To study the mechanism of radioresistance and its effect on radiation-induced mutagenesis in yeast mutants.

To continue the study of radiation-induced mutagenesis and to compare the yield of chromosomal aberrations in Chinese hamster cells at the highest and lowest mutagenesis levels depending on the time of expression and LET of accelerated ions.

To analyse structural disorders in the *hprt* gene and their projection on disorders in the chromosome machinery of cells.

To finalise the mFISH study of the biological effectiveness of proton beams.

To study the biological effectiveness of low-energy X-rays following *in vitro* irradiation of human blood lymphocytes using the mFISH method.

To evaluate the contribution of complex chromosome aberrations to the biological effectiveness of densely ionizing radiations following irradiation of human normal and tumour cells *in vitro.*

To study the induction and kinetics of chromatin break repair by premature chromatin condensation in normal and tumour human cells exposed to sparsely and densely ionizing radiation.

To continue the study of primary and late morphological and functional changes in the central nervous system of rats following exposure to ionizing radiation with different physical characteristics.

To conduct studies of pharmacological protection agents' action under ionizing radiation exposure.

To continue the investigation of the activation of microglial cells in cell culture and inflammatory markers in the brain of mice following exposure to ionizing radiation of different quality.

To investigate the possibility to modulate the activation of microglial cells in irradiated culture and neuroinflammation in the brain of irradiated mice by using inhibitors to the receptors of signalling pathways involved in these processes.

To study *in vivo* the radiosensitizing effect of cytosine arabinoside in combination with other molecular biological complexes on melanoma tumor growth in mice following the combined exposure to these agents and proton radiation.

To evaluate the influence of the combined action of AraC and other molecular biological complexes on the survival of different normal and tumor cell lines based on clonogenic survival criterion upon X-ray and proton irradiation.

To study the kinetics of the formation and elimination of DNA damage in U87 glioblastoma and other radioresistant cell cultures after proton and X-ray exposure in the presence of AraC and other molecular biological complexes.

To study DNA DSB formation in different components of the central nervous system after *in vivo* irradiation with protons and X-rays in the presence of a combination of radiomodifiers.

Expected results of the project in the current year:

To continue the analysis of the formation, repair, and structure of complex clustered DNA damage by immunocytochemical staining of the repair proteins γH2AX, 53BP1, OGG1, and XRCC1 after exposure to accelerated charged particles and X-rays in normal and tumor cells (human fibroblasts, U87 glioblastoma cells, B16 mouse melanoma cells, Ehrlich ascites carcinoma cells, and BxPC-3/PANC-1 pancreatic cells) and neurons of various parts of the central nervous system of animals.

To continue the selection of molecular biological complexes that increase the radiosensitivity of tumor cells in combination with cytosine arabinoside, and to study the mechanisms of their radiosensitizing effect on the survival of, and apoptosis induction and DNA damage formation and elimination in, normal and tumor cells *in vitro* and *in vivo* after exposure to ionizing radiations with different physical characteristics.

To complete the mFISH analysis of chromosomal aberrations induced in peripheral blood lymphocytes of *Macaca mulatta* monkeys after exposure to accelerated carbon ions

To continue the mFISH study of karyotypes and genetic stability of normal and tumor human cell lines used at the LRB, depending on their origin and duration of cultivation.

To continue the mFISH study of the biological effectiveness and induced spectrum of chromosomal aberrations in normal and tumor cells of mammals and humans after exposure to ionizing radiations with different physical characteristics.

To continue the analysis of impairments in behavioral responses, cognitive functions, and cortical electrical activity and their correlation with pathomorphological changes in CNS tissues after whole-body and local exposure of rats to ionizing radiations with different physical characteristics.

To evaluate AraC pharmacokinetics by high-performance liquid chromatography in a tumor focus of small laboratory animals in order to optimize the use of a radiomodifier for simulating radiation therapy.

To investigate the radioprotective effects of natural and synthetic compounds using new methodologies involving models of normal tissues of small laboratory animals.

Using microplate approaches, to screen potential radiomodifiers, including metal complexes of protoporphyrins, boron nitride quantum dots, and various plant-derived compounds, in order to determine their cytotoxicity and effect on radiosensitivity of normal and tumor cells.

To conduct a comparative analysis of the induction of various types of DNA damage (base damage, and single- and double-strand breaks) at the molecular level in a plasmid model by accelerated charged particles with different physical characteristics.

Using a plasmid model, to investigate the effect of the concentration of radiation-induced radical scavengers on the DNA damage yield after X-ray exposure.

To conduct an analysis of morphological, physiological, and genetic changes in microorganisms exposed to the orbital flight factors on board the BION-M No. 2 biosatellite.

2. Radiation-biophysical and astrobiological research

I. Padrón Díaz
A.Yu. Rozanov

Data taking
Realization
Modeling

LRB A.N. Afanaseva, S.V. Aksenova, A.S. Batova, L.G. Beskrovnaya, S.A. Budyonny, A.V. Chizhov, D.V. Davydov, E.B. Dushanov, I.M. Enyagina, A.A. Glebov, I.S. Gordeev, M.I. Kapralov, E.A. Kolesnikova, A. Yu. Kostyukhov, E.N. Lesovaya, Yu.K. Legoshin, B. Lhagwaa, N.V. Lomakin, B. Munkhbaatar, M.S. Panina, E.E. Pavlik, A.Yu. Parkhomenko, A.K. Ryumin, O.G. Sadykova, E.A. Saprykin, T. Tudevdorzh, N.V. Ustinov, M.A. Vasilyeva

FLNR G. Kaminski, S.V. Mitrofanov, L.A. Pavlov, Yu.G. Teterev, K.D. Timoshenko

FLNP A.V. Churakov, M.V. Frontasyeva, N. Kučerka, V.G. Pyataev, V.N. Shvetsov, K.V. Udovichenko, N.S. Yushin, I. Zinkovskaya

MLIT A. Khvedelidze, A.V. Nechaevsky, Yu. Palii, O.I. Streltsova, M.I. Zuev

DLNP V.V. Glagolev, A.Kh. Inoyatov, G.A. Karamysheva, G.V. Mitsyn, V.A. Rozhkov, G.A. Shelkov, R. Sotensky

VBLHEP A.A. Baldin, E.M. Syresin

Abstract and scientific rationale:
A wide range of JINR's ionizing radiation sources, especially heavy ion beams of various energies, offer a unique opportunity to solve a number of fundamental problems of radiobiology and astrobiology, as well as practical problems related to space exploration and the development of radiation medicine.

Due to the high complexity and cost of performing biological experiments at accelerator complexes, it is of paramount importance to improve experimental methods, ensure dosimetry and radiation safety, and perform relevant computer simulations. The most pressing issues here are the need for experimental reproduction of the energy and spectral composition of cosmic and other types of ionizing radiation, the search for methods for non-destructive analysis of unique samples and automated processing of biological experiment data, as well as the high complexity and resource intensity of computer simulation of processes in living systems.

This project is aimed at solving a complex of the above problems arising in radiobiological and astrobiological research. In the course of its implementation, it is planned to develop new stations for irradiation and dosimetry systems; introduce methods for non-destructive analysis of unique samples; develop and test systems for automated computer processing of biological data; formulate new mathematical models and computational approaches for radiobiology, bioinformatics, and

radiation medicine; and identify mechanisms and pathways of the catalytic synthesis of prebiotic compounds under radiation exposure.

Expected results upon completion of the project:
Provision of dosimetry and irradiation of biological samples at JINR accelerators.

Upgrade and commissioning of the GENOME-3 facility.

Development of a multimodal tomography system for small laboratory animals.

Equipping a room for radiobiological experiments using radionuclides.

Creation of a prototype space radiation simulator.

Development and testing of instruments for neutron dosimetry and spectrometry.

Development of an information system for working with experimental data in the form of two-dimensional images, computed tomography data, and video recordings.

Development of protocols for labeling two-dimensional images and video materials, formation of a labeled database.

Testing the implemented analysis algorithms; development and registration of software designed for automated data processing.

Development of mathematical models of the formation and repair of various types of DNA damage and models of the formation of mutations and chromosomal aberrations.

Molecular dynamics modeling of structural and functional disorders in mutant and oxidized forms of proteins.

Development of mathematical models of radiation-induced death of tumor cells and prediction of tumor growth for promising radiation therapy methods.

Theoretical evaluation of radiation-induced disorders of the CNS on the basis of mathematical models of brain neural networks, taking into account damage to synaptic receptors, oxidative stress, and impaired neurogenesis and gliogenesis.

Study of possible pathways of, and conditions for, the formation of prebiotic compounds by irradiation of cosmic matter or terrestrial rocks in combination with the simplest organic molecules.

To conducting structural and elemental analysis of microfossils and organic compounds in various meteorites by nuclear physics methods.

Expected results of the project in the current year:
To continue developing mathematical models of induction and repair of clustered DNA damage of various complexity in normal and tumor cells of mammals and humans in different phases of the cell cycle after exposure to accelerated charged particles with different characteristics.

To continue developing a mathematical model of the effect of ionizing radiation in the presence of radiosensitizers on the growth of transplanted tumors in laboratory mice.

To continue developing mathematical models of survival and population dynamics of neuronal and tumor stem cells after exposure to ionizing radiations with different physical characteristics.

To continue developing a mathematical model of the induction of chromosomal aberrations in mammalian and human cells after exposure to ionizing radiations with different characteristics.

To perform a molecular dynamics study of the interaction of molecules of promising radiomodifiers with cellular structures such as DNA, membranes, and target proteins.

To investigate the relative contribution of local and distributed decay mechanisms of a DNA-associated radionuclide – Auger electron emitter – to DNA damage induction.

To prepare permitting documentation and ensure the commissioning the KUBTEC's X-ray unit XCELL 320.

To ensure scheduled and service maintenance of the SARRP facility.

To continue developing software packages to improve calculation methods for determining the physical characteristics of the radiation fields and precision dosimetry for the existing X-ray units.

To continue improving the methods of computed tomography of small laboratory animals at the SARRP facility.

To commission the GENOME-3 facility and ensure the conduction of radiobiological experiments at U-400M cyclotron beams.

To conduct modeling radiation fields generated during the operation of applied research stations (ISKRA and SIMBO) in the Measurement Hall of the NICA complex and the MSC-230 accelerator.

To take part in studying radiation fields during the commissioning and routine operation of the IREN facility using the Bonner sphere method and to continue calculating and designing a model of a new neutron dosimeter based on helium and boron counters of a wide energy range.

To study the processes of fossilization of microorganisms and provide a morphological description of microfossil remains found in meteorites.

To conduct experiments on the synthesis of prebiotic compounds from formamide after its irradiation with accelerated charged particles in the presence of terrestrial mineral and meteorite material.

To analyze the results of the experiment on the synthesis of prebiotic compounds in space conditions conducted under the BION-M No. 2 program.

Activities of the theme:

	Name of the Activity	Leaders	Implementation period
Laboratory	Responsible from laboratories		Status
1.	**Training specialists in radiation safety and radiobiology**	**A.N. Bugay** **A.V. Boreyko**	2024-2026 Realization

LRB L.G. Beskrovnaya, N.N. Budionnaya, V.N. Chausov, E.B. Dushanov, E.B. Enyagina, I.S. Gordeev, A.K. Grishanin, I.V. Koshlan, T.S. Khramko, E.N. Lesovaya, P.N. Lobachevsky, Yu.V. Mokrov, A.Yu. Rozanov, O.G. Sadykova, Yu.S. Severyukhin, O.O. Vinogradova, Yu.V. Vinogradova

Collaboration 1077

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
		RAU
		YSU
Azerbaijan	Baku, BA	Khazar Univ.
Belarus	Gomel, HO	IRB NASB
	Minsk, MI	IBCE NASB
		INP BSU
		Inst. Physiology NASB
		SPMRC NASB
Bulgaria	Sofia	IE BAS
		IMech BAS
		Inst. Microbiology
		NCRRP
Cuba	Havana	CEA
		CNEURO
		CPHR
		UH
	San Jose de las Lajas	CENTIS
Egypt	Sadat City, BH	USC
Italy	Viterbo, VT	UNITUS
Mongolia	Ulaanbaatar	NUM

Country or International Organization	City, region	Institute or laboratory
Russia	Borok, YAR	Borok GO IPE RAS
	Chelyabinsk, CHE	SUSU
	Kazan, TA	FRC KazSC RAS
	Moscow, MOW	FCBN FMBA
		FMBC FMBA
		IBMC
		IBMP RAS
		IGEM RAS
		IHNA & NPh
		IKI RAS
		MSU
		NRC KI
		PIN RAS
		SAI MSU
	Novosibirsk, NVS	BIC SB RAS
	Obninsk, KLU	MRRC NMRRC
	Pushchino, MOS	IPKhiBPP RAS
	Sochi, KDA	SRI MP
	Troitsk, MOW	ISAN
	Vladivostok, PRI	FEFU
		PIBOC
Serbia	Belgrade, BG	IBISS
		IORS
		UB
		VINCA
	Kragujevac, KG	UniKg
Slovakia	Bratislava, BL	CU
South Africa	Bellville, WC	UWC
	Somerset West, WC	iThemba LABS
Uzbekistan	Parkent, TO	IMS Physics-Sun
	Tashkent, TK	INP AS RUz
Vietnam	Hanoi, HN	INPC VAST
		ITT VAST
		VINATOM

05-2-1132-2017

Study of Molecular Genetic Mechanisms of Adaptations of Extremophilic Organisms

Theme leader: E.V. Kravchenko

Participating countries and international organizations:
Egypt, Moldova, Russia, USA.

The problem under study and the main purpose of the research:
Study of the mechanisms of adaptation of extremophilic organisms to physical and chemical stresses and their use for protection of other organisms.

Project in the theme:

	Name of the project	Project leader	Project code
Laboratory	Responsible from laboratories		Status
1.	**TARDISS** **Protection against physical and chemical stresses with tardigrade proteins**	**E.V. Kravchenko**	05-2-1132-1-2021/2028 Realization

DLNP S.V. Apraksina, A.V. Korobeinikova, A.V. Rzyanina, K.A. Tarasov, A.S. Yakhnenko, M.P. Zarubin

FLNP O.I. Ivankov, T.N. Murugova

CAP (FLNR) E.V. Andreev, P.Y. Apel, A.N. Nechaev

Abstract and scientific rationale:
Mechanisms of adaptation of living organisms to existence in extreme conditions are of great interest for applied and fundamental research, in particular, mechanisms of resistance to ionizing radiation, high mineralization of the environment, effects of heavy metals, high and low temperatures and high pressure. Under the conditions of an increasing level of radiation background due to various man-made components, the problem of cosmic radiation, which prevents the long stay of living organisms in space, the need to protect healthy tissues from radiation during radiation therapy of tumours, and a number of general mechanisms underlying cell aging and their damage by ionizing radiation, the study of new mechanisms for increasing radioresistance is one of the most important areas of molecular biology and radiobiology.

Representatives of Tardigrada (tardigrades) belong to the group of animals most resistant to various types of stress on Earth. Tardigrades are able to survive after exposure to both rare and dense ionizing radiation at doses of about 5 kGy.

The Dsup protein is a new protein discovered in 2016 in the tardigrade *Ramazzottius varieornatus*, one of the most radioresistant species of multicellular organisms. Previously, we created the *D. melanogaster* lines and the HEK293 human cell culture expressing this protein, for which a significant increase in radioresistance was shown when exposed to various types of ionizing radiation. For the *D. melanogaster* lines expressing Dsup, the transcriptomic analysis was performed, which revealed the effect of the Dsup protein on a number of processes at the cellular and organism levels. Our results were published in 2023 in iScience (Q1) (https://doi.org/10.1016/j.isci.2023.106998). In the course of the experiments to determine the structure of the Dsup protein, the physical dimensions of the Dsup protein molecule were estimated for the first time, some parameters of the DNA-Dsup complex were established, and the existence of a possible secondary structure of the Dsup protein was shown.

The problems to be solved during the implementation of the project are new and important not only for fundamental molecular biology and radiobiology but also for applied areas of biotechnology, space research and other disciplines that require an increase in the level of radioresistance of organisms.

Expected results upon completion of the project:
Creation of a regulated scheme for the expression of the gene encoding the Dsup protein in the *melanogaster* model object to develop a controlled system for the temporary increase in radioresistance of the whole organism.

Evaluation of the effect of the Dsup protein on chromatin compaction in cells to establish the fundamental characteristics of the Dsup protein and map new regulatory elements in the *D. melanogaster genome*.

Obtaining data on the stability and properties of the Dsup protein during exposure to high temperatures and ionizing radiation to evaluate the use of this protein in pharmacology and medicine as a cryoprotectant, preservative and stabilizer for vaccines and other DNA/RNA-containing drugs, and as a protective agent for radio- and chemotherapy.

Development of a technique and a material for purification of nucleic acids from solutions and concentrating DNA and RNA from various biological fluids using the Dsup protein.

Obtaining hybrid molecules of Dsup-antitumor drug and development of a system for the effective delivery of hybrid molecules to the cell nucleus.

Expected results of the project this year:
Development of an effective method for isolating exosomes from human mesenchymal stem cells and loading them with gold nanoparticles. Study of the characteristics and loading efficiency of the obtained exosomes using small-angle scattering methods and assessment of the effect of the obtained exosomes on the death of irradiated cancer cells. Ultrastructural analysis of cells treated with nanoparticle-loaded exosomes.

Synthesis and purification of hybrid molecules Dsup-antitumor drug.

Assessment of the efficiency of delivery of control protein Dsup into the culture of normal human cells using exosomes and changes in cell radioresistance.

Collaboration 1132

Country or International Organization	City, region	Institute or laboratory
Egypt	Aswan, ASN	ASWU
	New Borg El-Arab, ALX	GEBRI
Moldova	Chisinau, CU	IMB ASM
Russia	Moscow, MOW	MSU
		NMRC RB
	Novosibirsk, NVS	RICEL
USA	Tampa, FL	USF

Information Technology (06)

06-6-1119-2014

Methods, Algorithms and Software for Modeling Physical Systems, Mathematical Processing and Analysis of Experimental Data

Theme leaders: S.V. Shmatov
O. Chuluunbaatar

Deputies: N.N. Voytishin
P.V. Zrelov

Participating countries and international organizations:
Armenia, Belarus, Bulgaria, CERN, China, Egypt, France, Georgia, Italy, Japan, Kazakhstan, Mexico, Mongolia, Russia, Serbia, Slovakia, South Africa, Tajikistan, Vietnam, United Kingdom, USA, Uzbekistan.

The problem under study and the main purpose of the research:
The theme is aimed at organizing and providing computational, algorithmic and software support for the preparation and implementation of experimental and theoretical research conducted with JINR's participation, at elaborating, developing and using computational methods for modelling complex physical systems studied within the projects of the JINR Topical Plan. Within the theme, mathematical methods and software, including those based on machine and deep learning algorithms using recurrent and convolutional neural networks, will be developed for modelling physical processes and experimental facilities, processing and analysing experimental data in the field of elementary particle physics, nuclear physics, neutrino physics, radiobiology, etc. Particular attention will be paid to the creation of systems for the distributed processing and analysis of experimental data, as well as information and computing platforms to support research conducted at JINR and other research centres.

The main directions of work are mathematical and computational physics to support JINR's large research infrastructure projects, primarily, the NICA flagship project in the fixed target mode (BM@N) and in the collider mode for relativistic heavy ion collisions (MPD) and polarized beams (SPD), the Baikal-GVD neutrino telescope. Cooperation with experiments at the world's accelerator centres (CERN, BNL, etc.), experiments in the field of neutrino physics and astrophysics, radiobiological research programmes will also be continued. The possibility of using the developed methods and algorithms within other projects is being considered.

The major direction in modelling complex physical systems, including the states of dense nuclear matter and quantum systems, will be the development of methods, software packages and numerical research based on the solution of the corresponding systems of nonlinear, spatially multidimensional integral, integro-differential or differential equations in partial derivatives with a large number of parameters characterized by the presence of critical modes, bifurcations and phase transitions with the complex application of methods of computational physics, quantum information theory and hybrid quantum-classical programming methods, quantum computing in quantum chemistry and physics.

In addition, the training of specialists in the field of computational physics and information technology within the IT School will be continued.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	Mathematical methods, algorithms and software for modeling physical processes and experimental facilities, processing and analyzing experimental data	S.V. Shmatov *Deputies:* A.S. Ayriyan N.N. Voytishin	06-6-1119-1-2024/2026
2.	Methods of computational physics for the study of complex systems	E.V. Zemlyanaya O. Chuluunbaatar *Deputies:* Yu.L. Kalinovsky A. Khvedelidze	06-6-1119-2-2024/2026

Projects:

Name of the project	Project leaders	Status
Laboratory Responsible from laboratories		
1. Mathematical methods, algorithms and software for modeling physical processes and experimental facilities, processing and analyzing experimental data	**S.V. Shmatov** *Deputies:* **A.S. Ayriyan** **N.N. Voytishin**	Realization

MLIT	P.G. Akishin, E.P. Akishina, A.I. Anikina, A.V. Anisenkov, E.I. Alexandrov, I.N. Alexandrov, T.A. Aushev, D.A. Baranov, T.Zh. Bezhanyan, J. Busa, M.V. Chadeeva, R.N. Chistov, K.A. Chizhov, N.V. Greben, H. Grigorian, S. Hnatič, O.Yu. Derenovskaya, A.V. Didorenko, N.D. Dikusar, V.V. Ivanov, A.A. Kazakov, A.K. Kiryanov, O.L. Kodolova, A.S. Konak, Yu.V. Korsakov, P.A. Korshunova, B.F. Kostenko, Z.K. Khabaev, M.A. Mineev, N.G. Monakov, Zh.Zh. Musulmanbekov, A.V. Nechaevsky, A.N. Nikitenko, E.G. Nikonov, D.A. Oleynik, S.S. Omelyanchuk, E.S. Osetrov, G.A. Ososkov, V.V. Palichik, V.V. Papoyan, I.S. Pelevanyuk, N.K. Petrov, A.Sh. Petrosyan, D.V. Podgainy, S.M. Polikarpov, D.I. Pryahina, A.G. Reshetnikov, L.R. Romanychev, A.R. Ryabov, I. Satyshev, A.S. Sedelnikov, K.V. Slizhevsky, A.G. Soloviev, T.M. Solovjeva, O.I. Streltsova, S.A. Shadmehri, Z.A. Sharipov, S.K. Slepnev, E.N. Talochka, Z.K. Tuhliev, A.V. Uzhinsky, V.V. Uzhinsky, S.V. Ulyanov, A.V. Yakovlev, V.B. Zlokazov, M.I. Zuev
VBLHEP	V. Yu. Aleksakhin, A.A. Aparin, Yu.V. Bespalov, O.I. Brovko, D.V. Budkovski, A.V. Bychkov, D.K. Dryablov, I.R. Gabdrakhmanov, A.S. Galoyan, K.V. Gertsenberger, V.M. Golovatyuk, M.N. Kapishin, V.Yu. Karzhavin, A.A. Korobitsyn, A.V. Krylov, A.V. Lanev, V.V. Lenivenko, S.P. Lobastov, S.P. Merts, A.A. Moshkin, Yu.A. Murin, D.N. Nikiforov, M. Patsyuk, O.V. Rogachevsky, V.G. Riabov, V.V. Shalaev, S.G. Shulga, A.V. Taranenko, E.V. Zemlyanichkina, I.A. Zhizhin, A.I. Zinchenko, D.A. Zinchenko
BLTP	D.I. Kazakov, M.V. Savina, O.V. Teryaev, V.D. Toneev, V.A. Zykunov
FLNP	M. Balasoiu, M.V. Frontasyeva, A.I. Ivankov, A.H. Islamov, Yu.S. Kovalev, A.I. Kuklin, Yu.N. Pepelishev, Yu.L. Ryzhikov, A.V. Rogachev, V.V. Skoy, K.N. Vergel
DLNP	V.A. Bednyakov, I.A. Belolaptikov, I.V. Borina, A.N. Borodin, A. Datta, V. Dik, I.I. Denisenko, T.V. Elzhov, A.A. Grinyuk, A.V. Guskov, V.A. Krylov, V.S. Kurbatov, D.V. Naumov, A.E. Pan, F.V. Prokoshin, A.E. Sirenko, L.L. Simbiryatin, M.N. Sorokovikov, B.A. Shaibonov, A.C. Zhemchugov, D.Yu. Zvezdov
LRB	I.A. Kolesnikova, Yu.S. Severyukhin, D.M. Utina
Assosiated personnel	A.N. Amirkhanov, E.V. Alpatov, A.V. Baskakov, A.R. Buzykaev, S.A. Bulanova, O.V. Bulekov, N.A. Burmasov, M.A. Bykovsky, S.A. Doronin, F.A. Dubinin, A.I. Durov, D.V Ermak, O.L. Fedin, D.A. Ivanishchev, Yu.D. Karpova, V.T. Kim, V.N. Kovalenko, M.A. Kondratyev, E.V. Kuznetsova, A.S. Kurova, A.V. Lazareva, A.A. Levkov, V.V. Makarenko, M.V. Malaev, V.P. Maleev, T.E. Mokoena, V.A. Mosolov, A.N. Morozikhin, P.V. Nekrasov, G.A. Nigmatkulov, G.E.Petrov, A.S. Povarov, Yu.G. Ryabov, D.R. Sharikova, S.Yu. Smirnov, E.Yu. Soldatov, D.E. Sosnov, K.A. Tertyshnaya, P.E. Teterin, M.V. Zhalov, E.N. Zavidov, A.M. Zakharov, A.V. Zelenov

Abstract and scientific rationale:

The project is aimed at organizing and providing computational support for physics research programmes implemented with JINR's participation, at developing mathematical methods and software for modelling physical processes and experimental facilities, processing and analysing experimental data in the field of elementary particle physics, nuclear physics, neutrino physics, condensed matter, radiobiology, etc. The particular attention will be paid to the creation of systems for the distributed processing and analysis of experimental data, as well as information and computing platforms to support research at JINR and other world centres.

The main areas of work are mathematical and computational physics to support JINR's large research infrastructure projects, first of all, the experiments at the NICA accelerator complex and the Baikal-GVD neutrino telescope. Further cooperation with experiments at the largest world accelerator centres (CERN, BNL, etc.), experiments in the field of neutrino physics and astrophysics, radiobiological research programmes will also be continued. The possibility of using the developed methods and algorithms within other megascience projects is being considered.

Expected results upon completion of the project:
Revision of interaction generators and their development for modelling the processes of interactions of light and heavy nuclei, including those at NICA energies (FTF, QGSM, DCM-QGSM-SMM, etc.), and processes beyond the Standard Model, such as the production of candidate particles for the role of dark matter, additional Higgs bosons and processes that violate the lepton number, etc. (QBH, Pythia, MadGraph, etc.) for LHC conditions at a nominal energy and a total integrated luminosity up to 450 fb^{-1}.

Development of algorithms for the reconstruction of charged particle tracks for experimental facilities, including those at NICA and the LHC, creation of appropriate software and its application for data processing and analysis, the study of the physical and technical characteristics of detector systems.

Development of scalable algorithms and software for processing multi-parameter, multi-dimensional, hierarchical data sets of exabyte volume, including those based on recurrent and convolutional neural networks, for machine and deep learning tasks, designed primarily for solving various problems in particle physics experiments, including for the NICA megaproject and neutrino experiments.

Creation and development of data processing and analysis systems and modern research tools for international collaborations (NICA, JINR neutrino programme, experiments at the LHC).

Development of algorithms and software for JINR's research projects in the field of neutron physics.

Development of algorithms, software and computing platforms for radiobiological research, applied research in the field of proton therapy and ecology.

Expected results of the project current year:
Completion of the revision of the Geant4 FTF model, more accurate specification of the functions of fragmentation of quarks and diquarks into strange particles in the Geant4 QGS model. Optimization of the DCM and UrQMD 3.4 models. Attempt to develop a quark-gluon string model for nucleus-nucleus interactions.

Physics analysis of data obtained in the NICA MPD, NICA BM@N and NA61/SHINE experiments within the Geant4 FTF and UrQMD 3.4 models. Mass computing for the given models at the request of the experiments.

Considering various effects of the DCM-QGSM-SMM generator: dependences of the lifetime of resonances on the density of the nuclear medium, suppression of the production cross section of pseudoscalar mesons, enhancement of the production of hyperons in a dense nuclear medium, nucleus deformations. Elaboration of a lattice model of the nucleus and a percolation model of multifragmentation.

Algorithms, software, Monte Carlo modeling and data analysis within the CMS experiment to investigate the 28 GeV resonance in the muon pair spectrum using the LHC Run 3 statistics. Search for a resonance at 28 GeV in the e+e- and tau+tau- decay channel using LHC Run 2 and Run 3 data.

Algorithms, software, Monte Carlo modeling and data analysis within the CMS experiment to search for dark matter particles in Run 3 data in the final state with two muons of different signs and the missing momentum. Interpretation of the results within the Inert Doublet Model and 2HDM+a models.

Debugging of the procedure for testing sensitive elements of the high-granularity calorimeter of the CMS experiment, including track reconstruction and the evaluation of the efficiency of each detector cell. Working out the possibility of monitoring calorimeter cells using physics processes.

Development and adjustment of algorithms and methods for reconstructing muon trajectories in the Cathode-Strip Chambers (CSCs) of the muon system of the CMS experiment to compare the continuous wavelet analysis approach for separating overlapping signals with the neural network approach based on a KAN network, to estimate the CSC spatial resolution and the aging effect on data obtained in 2025 at the GIF++ facility at CERN and in proton-proton beam collisions at the LHC.

Participation in the modernization of the ATLAS Athena IOVDbSvc package for CREST, adaptation of the EventIndexPicking service to the requirements of the Production System Group, modification of the TDAQ Resource manager in accordance with the tasks of the ATLAS JIRA system.

Study of the efficiency and speed of various machine learning methods for particle identification in the BM@N experiment.

Finding a full set of correction parameters for the STS and GEM detectors of the BM@N experiment (with and without magnetic fields) and their software implementation for current detector configurations in 2025-2026.

Preparation of the detailed geometry of track detectors for the current configuration of the facility within BM@N Run 9. Preparation of algorithms for simulating realistic responses for the gas and semiconductor detectors of the hybrid tracking system, as well as algorithms for reconstructing coordinates from the microstrip planes of the detectors to process experimental data collected in 2025 within BM@N Run 9.

Algorithms for modeling responses of the track detectors of the BM@N experiment on top of generative adversarial networks (GANs). Algorithms for spatial coordinate reconstruction in the track detectors using a hybrid approach based on classical and quantum neural networks.

Monte Carlo modeling investigation of multi-particle correlations in pp interactions at the NICA beam energy of 13 GeV, comparison with theoretical models.

Implementation of the gradient boosting-based charged particle identification program in MPDroot.

Modernization of clustering algorithms and completion of the ACTS tracker integration into global reconstruction within the MPDroot software shell. ACTS testing by users in mass production conditions.

Update of the external dependencies of MPDRoot and its adaptation to changes in the packages used (GCC 15.x, GEANT4 11.4+, ROOT 6.38+, C++23). End of support for CentOS 7 and start of support for Alma Linux 10.x. Assessment of the possibility of distributing the MPDRoot package using CVMFS on the macOS platform.

Elaboration and implementation of neural network algorithms for event reconstruction tasks in the SPD experiment at the NICA accelerator complex.

Elaboration and implementation of neural network methods based on Kolmogorov-Arnold networks (KANs) for the deconvolution of multicomponent signals obtained in a physics experiment.

Development of algorithms on top of tensor networks for the charged particle track reconstruction task in TPC MPD at the NICA accelerator complex.

Application of classical tracking methods for constructing and extrapolating tracks from TPC to the ToF system of the MPD experiment.

Development and support of the functioning of information systems of the BM@N and MPD experiments to describe the facility geometry, detector configuration, and management process. Creation of a prototype of the BM@N Data Quality Assurance system. Creation and implementation of an MPD e-log system. Participation in the development of an MPD DAQ online system.

Investigation of the properties of hadron jet/cluster reconstruction algorithms under SPD conditions. Study of the possibility of observing particle clusters in the inclusive case. Determination of the kinematics of partons of a hard process using machine learning algorithms.

Implementation of a model for processing and storing simulated data from the SPD experiment, relevant for 2025-2026. Integration of the SPD middleware and application software being created on the Sampo software platform.

Functional testing and debugging of the components and interfaces of the middleware complex for the data preprocessing system of the SPD experiment on the hardware-software prototype of a primary data processing cluster, SPD Online Filter.

Provision of the required level of functioning that meets the needs for the mass modeling of physics processes of the SPD experiment in a distributed computing environment based on the PanDA load management system and a data management system on top of the RUCIO DDM package.

Development of processing management systems, addition of new processes and a system for accounting data processing requests. Elaboration of security issues, in particular, user authentication and authorization, experimental data access policies. Enhancement of monitoring tools for the infrastructure, services, and data processing processes. Development of systems for the semi- and automatic testing of services of the created distributed computing environment.

Optimization of Baikal-GVD automated data processing graphs for the efficient use of multithreading in processing programs.

Development of software for data processing on the YuMO small-angle neutron scattering spectrometer.

Construction of a machine learning model for the hadron and gamma quantum classification task in the TAIGA experiment.

Modeling of an upgraded version of the OLVE-HERO prototype for accelerator beam tests.

Development of mathematical methods and algorithms for trajectory reconstruction in the proton digital calorimeter simulation task.

Further optimization of the web application for experimental data fitting: selection of the best LLM model, elaboration of an additional user interface, increasing the number of accepted data formats.

Application of high-order BEM polynomials to enhance the methodology of processing reactor data and neutron noise from the IBR-2M reactor.

Development of an algorithmic module on top of deep learning models and explainable artificial intelligence models for the tasks of analyzing data obtained using the Morris Water Maze test system in experiments aimed at studying the behavioral reactions of laboratory animals exposed to various factors.

Elaboration of algorithms based on deep learning and computer vision methods and creation of a web application for analyzing data obtained using the Open Field test system in experiments aimed at studying the effects of ionizing radiation and other factors on biological objects.

Research in the field of enhancing the accuracy of plant disease classification and detection models. Assessment of the efficiency and applicability of various methods for generating synthetic images of plant diseases.

Investigations in the field of soil pollution prediction using remote sensing data and various machine learning methods. Development of neural network methods for calibrating mobile platforms to evaluate air purity.

Development of new computational methods on the basis of the universal inverse Radon transform and creation of software for the enhanced analysis of computed tomography data.

Elaboration of algorithms for neutron spectrum reconstruction based on Bonner spectrometer readings using deep neural networks with input feature transformation. Creation of a web application prototype.

Testing and refinement of the prototype of a quantum fuzzy PID controller and the demonstration model of a robot with the built-in prototype of a self-organizing controller. Testing in operational mode of the prototype of an intelligent system for controlling cryogenic systems for superconducting magnets of the NICA accelerator complex in normal and abnormal situations on the basis of a quantum coordination self-organizing PID controller. Enhancement of the methodology of the developed structure of the intelligent RF station control system.

2. Methods of computational physics for the study of complex systems

E.V. Zemlyanaya
O. Chuluunbaatar
Deputies:
Yu.L. Kalinovsky
A. Khvedelidze

Realization

MLIT V. Abgaryan, G. Adam, S. Adam, P.G. Akishin, A.S. Ayriyan, E.A. Ayrjan, D.R. Badreeva, I.V. Barashenkov, M.V. Bashashin, A.A. Bogolubskaya, L. Bordag, M. Bureš, J. Buša, Jr.J. Buša, A.M. Chervyakov, G. Chuluunbaatar, Kh. Chuluunbaatar, D. Goderidze, H. Grigorian, A.A. Gusev, T.V. Karamysheva, A.V. Khmelev, V.V. Kornyak, O.O. Kovalev, D.S. Kulyabov, K.V. Lukyanov, N.V. Makhaldiani, S.D. Mavlonberdieva, T.I. Mikhailova, A.V. Nechaevsky, E.G. Nikonov, Yu. Palii, V.V. Papoyan, D.V. Podgainy, R.V. Polyakova, A.R. Rakhmonova, V.S. Rikhvitsky, I.A. Rogojin , B. Saha, I. Sarkhadov, Z.A. Sharipov, O.I. Streltsova, L.A. Syurakshina, Yu.N. Talochka, O.V. Tarasov, A.G. Torosyan, Z.K. Tukhliev, K.D. Verkhovtseva, A.V. Volokhova, O.O. Voskresenskaya, R.M. Yamaleev, E.P. Yukalova, O.I. Yuldashev, M.B. Yuldasheva, M.I. Zuev

BLTP M.A. Abdelghani, A.A. Donkov, A.V. Friesen, M. Hnatič, K.V. Kulikov, V.K. Lukyanov, E.V. Mardyban, R.G. Nazmitdinov, Yu.V. Popov, I.R. Rahmonov, Yu.M. Shukrinov, S.I. Vinitsky, D.N. Voskresensky, V.I. Yukalov, V.Yu. Yushankhai

FLNR E. Batchuluun, A.V. Karpov, M.N. Mirzayev, V.V. Samarin, Yu.M. Sereda

FLNP M.A. Kiselev, N. Kučerka, E.E. Perepelkin

DLNP O.V. Karamyshev, G.A. Karamysheva, I.D. Lyapin, E.P. Popov

VBLHEP A.V. Bychkov, D.N. Nikiforov

LRB A.N. Bugay, A.V. Chizhov

Abstract and scientific rationale:
The project is aimed at the development and application of mathematical and computational methods for modelling complex physical systems studied within the JINR Topical Plan and described by systems of dynamic nonlinear, spatially multidimensional integral, integro-differential or differential equations that depend on the parameters of models. The evolution of solutions to such systems can be characterized by the occurrence of critical modes, bifurcations and phase transitions. Mathematical modelling is an inseparable part of modern scientific research.

It entails an adequate mathematical formulation of problems within the models under study, the adaptation of known numerical approaches or elaboration of new ones to effectively take into account the features of the studied physical processes, the development of algorithms and software packages for high-performance simulation on modern computer systems, including the resources of the JINR Multifunctional Information and Computing Complex.

Expected results upon completion of the project:
Development of methods, algorithms and software packages for conducting the numerical research of interactions of various types in complex systems of nuclear physics and quantum mechanics.

Methods for modelling multifactorial processes in materials and condensed matter under external actions.

Methods for solving simulation tasks in the design of experimental facilities and the optimization of their operating modes.

Methods for modelling complex processes in dense nuclear matter based on the equation of state.

Methods for modelling quantum systems using quantum information theory methods and hybrid quantum-classical programming methods.

Expected results of the project current year:
Development of methods for solving multidimensional initial-boundary value problems for quantum tunneling in subbarrier heavy-ion fusion reactions and methods for calculating the characteristics of the inelastic scattering of fast electrons on atoms at large transferred momenta, taking into account the Migdal effect.

Elaboration of finite element methods for solving multidimensional boundary value problems, including a computational scheme for solving six-dimensional boundary value problems to study quadrupole-octupole collective models of the atomic nucleus.

Simulation of nucleon transfer and nuclear fragmentation processes in heavy ion interactions in the medium energy range within the transport-statistical approach. Microscopic models-based analysis of the optical potential of experimental data on proton-nucleus scattering and nucleus-nucleus interactions to obtain information on the structure of interacting nuclei and to investigate the influence of the nuclear environment on the mechanisms of these reactions.

Development of high-precision algorithms and methods of their parallel implementation for the numerical study of equations of motion that describe models of few-particle systems.

Numerical solution of many-particle quantum mechanics problems in applications of condensed matter physics by tensor network methods, including hybrid ones, with the introduction of neural network technologies. Study on this basis of quantum magnetism in low-dimensional spin systems, nonequilibrium quantum dynamics of isolated and open electron and magnetic quantum systems. Quantum-chemical computation of the electronic structure and spin states of organometallic molecular magnets based on transition and rare-earth metals.

Investigation of coherent dynamic phenomena in the Rabi-Josephson boson transition. Simulation of probabilistic dynamic networks with various memory types.

Modeling of complex processes in materials under the influence of high-energy heavy ion irradiation, nanoclusters and laser irradiation within a combined approach that integrates molecular dynamics methods and a thermal peak model.

Development of methods for the high-performance numerical study of dynamic processes in Josephson structures of various types. Simulation of the dynamics of a chain of parallel superconductor–ferromagnet–superconductor j0 transitions, including the study of resonance properties and the emergence of magnons in such systems. Investigation of intertype superconductors and superconductors with impurities.

Numerical analysis of small-angle scattering data on small-radius vesicular systems within various approaches to obtain new information on the structure and properties of such systems depending on external factors.

Study of localized structures in systems described by nonlinear dynamic equations in one- and multidimensional field theory models, including moving oscillons, as well as the periodic solutions of the Ablowitz-Ladik equation with a nonlinear phase.

Optimization of the method and the software package for calculating the motion trajectories of a particle beam in the isochronous cyclotron to speed up the computation of the beam transmission coefficient.

Comparative analysis of various scenarios of the finite-element modeling of the magnetization phenomenon of a massive MgB_2 superconductor using the COMSOL package in order to select the optimal numerical approach.

Development, parallel implementation, and theoretical justification of a matrix-free h-p semi-adaptive three-level iterative loop method to solve large-scale finite-element systems on multi-core computers. Computations for optimizing the characteristics of superconducting magnets on the basis of 3D computer modeling and the volume integral equation method.

Optimization of computational methods and modernization of a software package for the parallel computer modeling of neutron star cooling, as well as for the validation of equation-of-state models of superconducting strongly interacting nuclear matter on the basis of observational data for compact objects. Study of the role of the spinor field in the accelerated expansion of the Universe based on the solution of a self-consistent system of Einstein–Dirac equations and comparison of the obtained numerical results with observational data and known theoretical models.

Investigation of nonlocal interaction models to describe meson spectra and development of numerical solution methods for the corresponding systems of equations, calculation on this basis of the physical characteristics of the systems under study. Description of the processes of production and dissociation of heavy quarkonia.

Implementation of a quantum circuit of the QAOA algorithm for 2- and 3-dimensional variants of the Ising model with a transverse electric field in the Quda-Q environment. Implementation of a quantum circuit of a nonlocal gate to create a two-qubit state with specified entanglement characteristics in the Cirq environment on the basis of the factorization of SU(4) transformations, which enables the construction of a double coset $SU(2)xSU(2)\backslash SU(4)/U(1)^4$.

Study of the manifestations of deviation of a quantum system from the classical version based on a joint analysis of the negativity of the Wigner function for the qutrit and the characteristics of entanglement in a system of two qubits.

Construction of a model of a finite-dimensional quantum system on top of the Weyl-Heisenberg and Clifford groups with a description of quantum states by means of discrete Wigner functions defined over Galois fields.

Construction of chains of functional relation reduction for multi-loop Feynman integrals using a software package in the Maple system.

Elaboration of an algorithm for minimizing the influence of environmental interference and systematic experimental errors on single-qubit logic gates by implementing a specific sequence of unitary operations.

Implementation of quantum particle tracking algorithms using the qbsolv, neal libraries, and Google OR-Tools for efficient parallel processing in QUBO tasks. Solution of the tracking task in the QUBO formulation using the quantum-inspired QIOPT optimizer, designed for solving combinatorial, integer, and mixed optimization problems.

Model building speed-up and introduction of enhanced false segment filtering in tracking algorithms to reduce the impact of noise interference when using SPD datasets.

Analysis of the band structure and modeling of nonequilibrium carrier relaxation in mixed scintillation crystals promising for use in ionizing radiation detectors using the Quantum Espresso DFT package and the computing resources of the “Govorun” supercomputer.

Activity of the theme:

Name of the activity	**Leaders**	**Implementation period**
Laboratory Responsible from laboratories		**Status**
1. Training of specialists in the field of computational physics and information technology	**V.V. Korenkov** **A.V. Nechaevsky** **D.I. Pryahina** **O.I. Streltsov**	2024-2026 Realization

MLIT	T.Zh. Bezhanyan, O.Yu. Derenovskaya, E. Mazhitova, I.S. Pelevanyuk, A.S. Vorontsov, E.N. Voytishina, M.I. Zuev
UC	D.V. Kamanin, A.Yu. Verkheev
Assosiated personnel	A.V. Bogdanov, V.V. Korkhov, Zh.U. Kiyamov, A.N. Nikolskaya

Abstract and scientific rationale:

The training and retraining of specialists in computational physics and information technology on the basis of the Multifunctional Information and Computing Complex (MICC) of the Joint Institute for Nuclear Research (JINR) and its educational components are performed for:

- upskilling JINR staff members in order to develop scientific projects, including megascience ones, which are implemented at JINR or with its participation, as well as to create and support the JINR Digital EcoSystem (DES);

- disseminating competencies in computational physics and information technology to the regions of Russia and the JINR Member States to enhance the personnel potential of JINR and organizations cooperating with the Institute;

- the main prerequisite for the creation of the activity is the necessity to form a research environment in order to ensure the professional growth of IT specialists, the creation and development of scientific groups, and the engagement of new specialists in JINR projects. The additional training of the personnel, mainly on request of the JINR Laboratories, should be aimed at developing special competencies, in-depth knowledge and practical skills in computational physics and information technology.

Expected results upon completion of the activity:
Holding events for JINR staff members to study state-of-the-art information technologies and opportunities to work on the MICC components and in the DES.

Forming a set of JINR projects in which students can participate.

Forming a list of competencies and required courses for the implementation of projects.

Elaboration of training courses and educational programmes that will provide personnel training for solving a variety of tasks within projects.

Creation of an ecosystem for the implementation of educational programmes on the basis of the JINR MICC, including the cloud infrastructure, the HybriLIT heterogeneous computing platform, which comprises the education and testing polygon and the “Govorun” supercomputer.

Creation of a software and information environment and a platform for organizing and holding events, lectures, workshops, hackathons, etc.

Involvement of specialists from JINR and JINR Information Centres, researchers from the JINR Member States’ organizations, lecturers from leading educational organizations that cooperate with JINR in order to hold educational and scientific events.

Forming event programmes and organizing interaction with universities and JINR Information Centres.

Expected results of the activity in the current year:
Elaboration of training courses and implementation of the educational master’s program entitled “Data Processing Methods and Technologies in Heterogeneous Computing Environments” in direction 01.04.02 Applied Mathematics and Computer Science at the branch of Lomonosov Moscow State University.

Holding the Lomonosov Universiade for students from universities of the Russian Federation and the JINR Member States in order to discover and support talented youth, as well as to attract students to enroll for the master’s course at the MSU branch in Dubna.

Holding JINR Schools of Information Technologies.

Training of highly qualified specialists for scientific projects implemented at JINR in collaboration with scientific and educational organizations of the Russian Federation and the JINR Member States.

Conducting educational practices and scientific seminars on information technologies for students from the Russian Federation and the JINR Member States.

Development of the components of the ecosystem on top of the JINR MICC, including the cloud infrastructure and the HybriLIT heterogeneous computing platform, for the implementation of educational programs and the information support of the activity.

Collaboration 1119

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
		YSU
Belarus	Gomel, HO	GSU
	Minsk, MI	IM NASB
		INP BSU
		IP NASB
Bulgaria	Sofia	SU
CERN	Geneva, CH	CERN

Country or International Organization	City, region	Institute or laboratory
China	Beijing, BJ	CIAE
Egypt	Giza, GZ	CU
France	Gif-sur-Yvette, IDF	Irfu
Georgia	Tbilisi, TB	GTU
		TSU
		UG
Italy	Genoa, GE	INFN Genoa
Japan	Sendai	IMRAM
Kazakhstan	Almaty, ALA	IETP KazNU
		INP
	Astana, AST	ENU
Mexico	Mexico City, CDMX	UNAM
Mongolia	Ulaanbaatar	IMDT MAS
		MUST
Russia	Chelyabinsk, CHE	SUSU
	Dubna, MOS	MSU Branch
		Uni Dubna
	Gatchina, LEN	NRC KI PNPI
	Moscow, MOW	HSE
		ITEP
		LPI RAS
		MEPhI
		MISIS
		MPEI
		MSU
		PFUR
		RCC MSU
		SINP MSU
	Petropavlovsk-Kamchatsky, KAM	KamGU
	Pushchino, MOS	IMPB RAS
	Saint Petersburg, SPE	SPbSU
	Samara, SAM	SNRU
	Saratov, SAR	SGU
	Sarov, NIZ	MSU Branch
	Tomsk, TOM	TPU
		TSU
	Troitsk, MOW	INR RAS
	Tula, TUL	TulSU
	Tver, TVE	TverSU
	Vladikavkaz, SE	NOSU
	Vladivostok, PRI	FEFU
	Voronezh, VOR	VSU

Country or International Organization	City, region	Institute or laboratory
Serbia	Belgrade, BG	UB
Slovakia	Kosice, KI	UPJS
South Africa	Cape Town, WC	UCT
	Somerset West, WC	iThemba LABS
Tajikistan	Khujand, SU	KSU
United Kingdom	Oxford, OXF	Univ.
USA	Arlington, TX	UTA
Uzbekistan	Tashkent, TK	AS RUz
		INP AS RUz
		Physics-Sun
Vietnam	Ho Chi Minh City, SG	HCMUE

Applied Innovation Activities (07)

07-1-1107-2011

Applied Research at NICA in Radiation Materials Sciences, Life Sciences and New Methods of Energy Production

Theme leaders: O.V. Belov
E.M. Syresin

Participating countries and international organizations:
Armenia, Belarus, Bulgaria, Mexico, Moldova, Russia, South Africa, Uzbekistan.

The problem under study and the main purpose of the research:
Obtaining applied research and technology results within the activity areas of the ARIADNA collaboration, including life sciences, biomedical technologies, space research, radiation materials science, radiation hardeness of electronics, development of new technologies for ADS using NICA beams.

Project in the theme:

	Name of the Project	Projects leader	Project code
Laboratory		Responsible from laboratories	**Status**
1.	**ADSR** **Accelerator driven subcritical reactor**	**M. Paraipan**	07-1-1107-1-2011/2027 Realization

VBLHEP, FLNP, BLTB, LRB, MLIT, FLNR, DLNP see list of activities

Abstract and scientific rationale:
The project is aimed to determine the optimum beam-converter combination meant to optimize the efficiency of an accelerator driven subcritical reactor. The planned research will proceed in two directions. The first involves the comparative study of the fission distribution and the energy released in enriched fuel blanket, irradiated with proton beams with energy 0.2–2 GeV and ion beams with masses until ^{20}Ne and energies in the interval 0.2–1 AGeV. The second includes measurements of the neutron yield from various converters, irradiated with proton and ion beams.

The possibility of implementing a nuclear system with increased burning capabilities lies in the use of an accelerator driven subcritical reactor (ADSR). It consists of a particle accelerator coupled with a nuclear reactor. The particle beam striking a converter placed in the central part of the reactor provides a supplementary source of neutrons which allows functioning of the reactor in subcritical regime (with criticality coefficient k_{eff} below 0.99), ensuring safer exploitation of nuclear plants. The harder neutron spectrum obtained ensures better incineration of the actinides.

Despite almost generalized opinion that the optimal beam for ADS is a proton beam with an energy around 1–1.5 GeV we have shown in a series of works that ion beams have a superior energetic efficiency than protons. The activities within the project are oriented towards searching for conditions which maximize the energy efficiency of ADSR and ensure high burnup. Within the previous years, aspects related with the core geometry, the material used for the converter, the fuel composition, the working value of k_{eff}, the enrichment and power density distribution were investigated. The influence of the beam characteristics (particle type, energy, beam intensity), and of the accelerator type were also studied. The main conclusions obtained constitute the bases for extending the project in accordance with the stated objectives.

The proposed graphite target "GAMMA4" with fuel rods inserted inside and a central hole for the placement of different converters allows a correct comparison between the number of fissions and the energy released realized with proton and ion beams. The use of a graphite block instead of Pb gives the possibility to diminish the necessary amount of fissile material due to the softer neutron spectrum. Such target is easier to manipulate (due to its lower weight) and cheaper. The proposed graphite target "GAMMA4" is suitable for a comparative study of the efficiency of various beams in terms of the possibility of their use in ADS.

Expected results upon completion of the project:
Selection of an optimal design of a target of the ADS.

Verification of a principally new concept of a system based on the use of ion beams instead of protons.

Implementation of the first stage of experimental programme focused on the measurement of neutron yields with different converter combinations.

Expected results of the project this year:
The development of technical project for the lead target (block with dimensions of 110x110x150 cm, with central hole for the converters and vertical and horizontal holes for the placement of the fission detectors).

The design of the system for the measurement of the beam intensity (ionization chamber and two plastic scintillators for the absolute calibration of the ionization chamber).

The analysis of the experimental method and the determination of the maximal beam intensities depending on the radiation shielding of the experimental room.

Activities of the theme:

	Name of the activity	Leaders	Implementation period
Laboratory	Responsible from laboratories		Status
1.	**R&D within the research topics of the ARIADNA collaboration: experiments in space research, life sciences, biomedical technologies, materials sciences and structure of matter, radiation hardening of electronics and advanced nuclear physics technologies**	**O.V. Belov**	2024-2026 Data taking Data analysis

VBLHEP	K.P. Afanasyeva, V.A. Artyukh, S. Ceballos, V.B. Dunin, V. Dzhavadova, Yu.S. Kovalev, I.A. Kryachko, I.I. Maryin, Yu.A. Murin, M.S. Novikov, A.N. Osipov, V.A. Pavliukevich, N.E. Pukhaeva, A.V. Rogachev, Z. Sadygov, V.N. Shalyapin, S.E. Sinelshikova, A.A. Slivin, G.I. Smirnov, E.M. Syresin
DLNP	A.V. Agapov, G.V. Mitsyn, A.G. Molokanov, A.V. Rzyanina, S.V. Shvidkiy, V.I. Stegailov
FLNR	P.Yu. Apel, A.N. Nechaev
FLNP	M.V. Bulavin
BLTP	V.A. Osipov

Abstract and scientific rationale:
In 2026, beamtimes are expected to be conducted for the main facilities of the NICA complex. The ARIADNA infrastructure, including beamlines, areas for applied research and zones of user infrastructure, will allow for a number of relevant studies aimed at using accelerated ion beams in space research, life sciences and biomedical technologies, as well as in radiation materials science, radiation resistance of electronics, and modern nuclear physics technologies.

Expected results upon completion of the activity:
Obtaining new data on the interaction of heavy ion beams with various types of materials and biological objects in order to create advanced developments based on modern radiation technologies. Obtaining results on specific structural and functional modifications in the studied samples having different nature after exposure to ions with energies from 3.2 MeV/nucleon to 3.5–4.0 GeV/nucleon.

Expected results of the activity this year:
Conducting the planned beamtimes in 2026 will allow:
– simulate the impact of individual components of cosmic radiation with the use of beams of NICA facility and radiation facilities of collaborating organizations. Study the combined effects of radiation and other physical and biological factors in experiments on laboratory animals, tissues and cell cultures;

– obtain information on the relative biological effectiveness of heavy nuclei with energies of up to 4.5 GeV/nucleon. To assess the impact of high-energy charged particles on the physicochemical characteristics, redox properties and biological activity (in vitro and in vivo) of rare earth metal nanoparticles in various modifications;

– implement highly sensitive methods for detecting radiation-induced biological damage at the molecular and cellular levels based on the ARIADNA user infrastructure. Conduct a series of experiments to identify specific time profiles of proteins and protein complexes for the repair of double-strand breaks in nuclear (nDNA) and mitochondrial (mtDNA) DNA associated with various types of cancer, and formulate approaches to developing a diagnostic method based on DNA repair markers;

– evaluate the radiation-protective properties of materials in radiation fields generated by the NICA complex for subsequent use as additional and local protection against ionizing cosmic radiation on board space complexes;

– perform the second stage of developing the method of high-temperature radiation modification of various types of polymer compounds using polytetrafluoroethylene (PTFE) as an example using high-energy ion beams. Study the mechanisms of radiation defect formation and release of volatile compounds – suboxides during irradiation of synthetic sapphire and corundum;

– obtain new information on the radiation stability of ultralight highly porous materials based on aerogels and ferrites with different crystal structures in terms of the impact of accelerated ions in a wide energy range. Obtain model estimates for the effect of heavy-ion components of cosmic radiation on ultra-high-temperature ceramics HfB2(ZrB2)-SiC;

– obtain new data on the possibility of creating structural and morphological nanosingularities during irradiation of oxide model catalysts with heavy ions in order to tune the activity and selectivity of catalysis;

– perform R&D on the development of analytical devices used for collecting experimental data from biological objects and materials exposed to ionizing radiation.

2. R&D on optimization of methods for irradiating samples of various types; development of the supporting equipment for ARIADNA target stations. Development of laboratory areas for deployment of the user equipment

O.V. Belov

2024-2026

Realization

VBLHEP V.B. Dunin, E.S. Matyukhanov, M.S. Novikov, V.A. Pavliukevich, A.V. Shemchuk, S.E. Sinelshikova

DLNP A.V. Agapov, G.V. Mitsyn, A.G. Molokanov

Abstract and scientific rationale:
A necessary pre-condition for conducting research using modern radiation technologies is the constant improvement of methodological approaches to conducting irradiation sessions and the development of appropriate sample environment systems. In particular, the development of irradiation stands and the development of the necessary equipment in accordance with the tasks of the proposed experiments is of great importance. Carrying out research within the framework of the ARIADNA collaboration, which implies a multi-user mode of operation, requires the creation of sites for the deployment of users' own equipment in order to carry out the process of sample preparation and analytical studies in a short time after irradiation.

Expected results upon completion of the activity:
Creation and development of sample preparation and analytical research areas within the framework of the ARIADNA scientific work program. Manufacture and commissioning of stands and test chambers for studying the combined effect of accelerated ions and other physical factors on material samples and biological objects.

Expected results of the activity this year:
Working out irradiation modes for different samples at ARIADNA applied research stations. Completing the second stage of work on developing the stands and testing the chambers for studying the combined effect of accelerated ions and other physical factors on material samples and biological objects. Studying the effect of ionizing radiation on the main parameters of the resistive-emission layer of the MCP in experiments on heavy ions. Developing a methodology for assessing the integral indicators of the beam intensity and profile for various types of samples studied in the ARIADNA experiments. Developing and testing a detector system for ARIADNA long-term irradiation station. Developing and testing detectors based on fluorescent screens for applied research.

3. Upgrade of spectrum-analitical complex for activation measurements

V.N. Shalyapin

2024-2026

Realization

VBLHEP D.R. Drnoyan, I.A. Kryachko, E.V. Strekalovskaya, Toan Tran Ngor

DLNP V.I. Stegaylov

Abstract and scientific rationale:
Activation of irradiated materials and structural elements of heavy ion accelerators is an important aspect of conducting experiments on irradiation of various types of targets. The spectrum analysis complex of VBLHEP Division No 5 allows for a wide range of gamma spectra measurements, including in flow mode. Gamma spectra analysis using the available spectrum analysis complex will be used as a routine technique in most ARIADNA applied research experiments involving irradiation of samples with accelerated ion beams.

Expected results upon completion of the activity:
Updating the set of detectors of the spectrum analysis complex, the corresponding software and the necessary equipment for carrying out measurements using different types of samples. Extending of works on the development of the database of gamma spectra for ARIADNA experiments.

Expected results of the activity this year:
Updating the detector software; updating the power supplies and the detector central control system. Conducting routine changes to the gamma spectra for applied research at the NICA complex in 2026 beamtime sessions.

4. Software development and dosimetric calculations for ARIADNA experiments. Simulation of radiation conditions at the NICA complex

M. Paraipan

2024-2026

R&D

VBLHEP O.V. Belov, T. Chan Ngoc, V. Javadova, M. Paraipan, A.A. Slivin

LRB A.V. Chizhov

Abstract and scientific rationale:
Software development and dosimetric calculations are an integral part of the preparation of experiments under the ARIADNA scientific program at the NICA complex, as well as an important element of the analysis of dose loads in sessions on irradiation of targets of various types. The use of modern program codes for the interaction of accelerated ions with matter allows planning irradiation sessions using various materials in order to select optimal irradiation parameters and subsequent reconstruction of energy release events in the target material. The data obtained during dosimetric calculations are important input parameters for further studies in terms of structural and functional changes in irradiated samples. An important paretic aspect of this activity is obtaining modeling of radiation conditions in various parts of the NICA complex using the developed modeling approaches and program codes.

Expected results upon completion of the activity:
Obtaining dosimetric data on irradiation of various types of samples with accelerated ion beams in a wide energy range, including composite materials, as well as other objects with a complex structure and elemental composition. Obtaining estimates of radiation fields for various sections of the NICA complex; calculating the necessary elements of biological protection.

Expected results of the activity this year:
Obtaining estimates of dose loads for samples of composite materials, biological objects and electronic elements when irradiated with heavy ion beams with energies in the range from 3.2 MeV/nucleon to 4 GeV/nucleon. Modeling the interaction of accelerated ion beams with materials in sessions planned for 2026 at the NICA complex. Development of algorithms based on deep learning and computer vision methods, creation of web applications for analyzing data obtained in ARIADNA collaboration experiments to study the effects of ionizing radiation and other factors on biological objects. Calculation of radiation fields in the areas of applied research facilities taking into account the placement of additional user equipment.

5. Studying the mechanisms of radiation modification of superconducting properties in 2nd generation HTSC tapes

M.S. Novikov

2024-2026

R&D

VBLHEP Yu.P. Filippov, E.S. Matyukhanov, M.S. Novikov, A.V. Shemchuk

FLNP A.N. Chernikov

Abstract and scientific rationale:
The aim of the research is to develop methods for increasing the critical current of second-generation HTSC tapes using radiation modification technologies. In recent years, results have been obtained at VBLHEP indicating an increase in the critical current of second-generation HTSC tapes after irradiation with accelerated ions and protons. The discovered effects require further study from the standpoint of creating prototypes of equipment based on radiation-modified HTSC tapes and testing their application in various scientific and practical tasks, including accelerator technology.

Expected results upon completion of the activity:
Obtaining information on the patterns of change in the critical current of second-generation HTSC tapes by radiation modification and mechanical deformation. Obtaining results on the stability of the effect of radiation-induced increase in the critical current of HTSC tapes over time under the influence of various physical factors. Second-generation HTSC tapes. Determining the possibilities of practical application of radiation-modified second-generation HTSC tapes.

Expected results of the activity this year:
Study of radiation-stimulated change of critical current of HTSC composites under special conditions of radiation exposure (presence of background magnetic field and low temperature). Study of properties of irradiated second-generation HTSC tapes during subsequent operation in ionizing radiation fields. Continuation of data taking on structural modifications of HTSC tapes after radiation exposure and mechanical treatment. Calculation of defect formation in HTSC tapes under the influence of charged particles; optimization of radiation defects as magnetic flux pinning centers; calculation of radiation and thermal conditions for a station for rewinding HTSC tapes through a beam of charged particles to create pinning centers.

6. Organization and maintenance of the user program ARIADNA. Development of ARIADNA collaboration — **O.V. Belov** — 2024-2026

Realization

VBLHEP M.S. Novikov, M. Paraipan, Yu.A. Tsaplina

Abstract and scientific rationale:
Applied research at the NICA complex is carried out in the form of the ARIADNA collaboration, which includes more than 30 organizations from the JINR member countries. The multi-user mode of operation at the NICA complex applied research facilities implies the presence of a coordinated user program that unites the efforts of the ARIADNA collaboration member organizations in obtaining advanced scientific and scientific-practical results. The main task in this area is to coordinate the user program, as well as to create conditions for the coordinated work of user groups during sessions at the NICA complex.

Expected results upon completion of the activity:
Development of a user program for applied research at the NICA complex, ensuring coordinated work of scientific groups from various organizations.

Expected results of the activity this year:
Development of the ARIADNA web portal, including a system for electronic submission of applications for experiments using the NICA complex applied research infrastructure. Testing the multi-user mode of operation on elements of the ARIADNA infrastructure. Maintenance of programs to support the work of scientific collaborations on the NICA complex. Development of scientific programs for organizations joining the ARIADNA collaboration. Ensuring the representation of the ARIADNA collaboration at scientific and scientific-organizational events related to applied research and innovation.

Collaboration 1107

Country or International Organization	City, region	Institute or laboratory	
Armenia	Yerevan, ER	AANL	
		CANDLE	
		YSU	
Belarus	Minsk, MI	BSU	
		INP BSU	
		JIPNR-Sosny	
Bulgaria	Plovdiv	MUP	
Mexico	Mexico City, CDMX	INCan	
Moldova	Chisinau, CU	MSU	
Russia	Dolgoprudny, MOS	MIPT	
	Dubna, MOS	IAS "Omega"	
		IPTP ROSATOM	

Country or International Organization	City, region	Institute or laboratory
		MSU Branch
	Moscow, MOW	FMBC FMBA
		FRC CP RAS
		IBMP RAS
		IGIC RAS
		ITEP
		JIHT RAS
		Kvant-R
		MEPhI
		PFUR
		SINP MSU
	Obninsk, KLU	MRRC NMRRC
	Pushchino, MOS	ITEB RAS
	Saint Petersburg, SPE	SPbSU
	Tomsk, TOM	TPU
	Vladikavkaz, SE	NOSU
South Africa	Somerset West, WC	iThemba LABS
	Stellenbosch, WC	SU
Uzbekistan	Tashkent, TK	INP AS RUz

07-5-1131-2017

Radiation Materials Science, Nanotechnological and Biomedical Investigations with Heavy-Ion Beams

Theme leader: P.Yu. Apel

Deputy: V.A. Skuratov

Participating countries and international organizations:
Armenia, Australia, Belarus, Kazakhstan, Russia, Serbia, South Africa, Vietnam.

The problem under study and the main purpose of the research:
Experimental and theoretical studies of radiation tolerance of solids to heavy-ion impact, materials testing, controlled modification of materials properties, and the development of new functional structures.

Projects in the theme:

	Name of the project	Project leaders	Project code
1.	Radiation tolerance of materials to high-intensity beams of heavy ions	V.A. Skuratov *Deputy:* R.A. Rymzhanov	07-5-1131-1-2024/2028
2.	Nanocomposite and functional track etched membranes	P.Yu. Apel *Deputy:* A.N. Nechaev	07-5-1131-2-2024/2028
3.	High-sensitivity sensor based on molecular recognition for viruses detection	A.N. Nechaev E.G. Zavyalova	07-5-1131-3-2025/2029

Projects:

	Name of the project	Project leaders	Status
Laboratory	Responsible from laboratories		
1.	**Radiation tolerance of materials to high-intensity beams of heavy ions**	**V.A. Skuratov** *Deputy:* **R.A. Rymzhanov**	Manufacturing

FLNR V.A. Altynov, P.Yu. Apel, I.V. Dukach, N.S. Kirilkin, D.A. Komarova, E.A. Korneeva, V.A. Kuzmin, N.G. Kuzmina, N.V. Kurylev, Le Thi Phuong Thao, N.E. Lizunov, M. Mamatova, A.Yu. Markin, M. Mirzaev, A. Mutali, Nguyen Van Tiep, O.L. Orelovich, E.A. Piyadina, V.K. Semina, A.S. Sokhatsky, V.G. Shmarovoz

Abstract and scientific rationale:
The aim of the project is to accumulate a database for a better understanding of the fundamental laws of high-intensity ionization in model and structural materials. The knowledge of fundamental mechanisms is of paramount importance for nuclear power engineering, nanotechnology applications and for the testing of target materials for nuclear physics experiments. As an innovative approach, it is proposed to study the effects of dense ionization on a previously created defect structure formed by exposure to "conventional" radiation (hundreds of keV and units of MeV, ion irradiation), which is the most reliable way to simulate damage produced by fission products. The main approach to achieving the goals of the project will be the use of modern structural analysis techniques – high-resolution transmission electron microscopy in combination with molecular dynamics methods for modeling track formation processes. Structural changes will be also investigated using scanning electron microscopy, X-ray diffraction, confocal Raman and luminescence microscopy, and the real-time optical spectroscopy under ion irradiation. The radiation resistance of promising reactor materials and target materials for nuclear physics experiments will be investigated by micro- and nanomechanical testing methods.

Expected results upon completion of the project:
Advanced understanding of the fundamental physical laws of high-density ionization in solids based on the studied dependencies of the kinetics of swift structural changes in the tracks of fast heavy ions in the near-surface areas of nanostructured dielectrics – nanoparticles, interfacial layers, and layered structures.

Results of modeling by molecular dynamics methods of lattice relaxation processes and the formation of regions with a modified structure in the near-surface and interphase regions of composite materials exposed to energetic ions – nanoclusters in matrices and layered materials.

Data on the combined effect of dense ionization and helium on the transport properties of fission fragments in protective layers and inert matrices.

Accumulation of a database on the parameters of ion tracks in conventional and nanostructured ceramics promising for nuclear physics applications.

Data on the long-term stability of target materials during prolonged irradiation with intense heavy-ion beams.

Expected results of the project in the current year:
Investigation of the relation between the ion track morphology and the optical properties of single Al2O3 and MgAl2O4 crystals irradiated with swift heavy ions.

Structural studies and micromechanical testing by nanoindentation of the Fe-Cr-Ni and Fe-Cr-Ni-Co alloys uniformly doped with helium ions.

Atomistic modeling of defects induced by swift heavy ions on the surface and the interfaces of nanostructured materials.

2. Nanocomposite and functional track etched membranes

P.Yu. Apel
Deputy:
A.N. Nechaev

Manufacturing

FLNR N.V. Aksenov, V.A. Altynov, E.V. Andreev, I.V. Blonskaya, M.V. Gustova, N.A. Drozhzhin, I.V. Dukach, I.N. Fadeikina, E.L. Filatova, L.I. Kravets, O.V. Kristavchuk, M.A. Kuvaytseva, N.G. Kuzmina, N.E. Lizunov, A.V. Lundup, A.A. Markin, S.V. Mitrofanov, S.A. Mityukhin, L.G. Molokanova, D.A. Murashko, I.F. Myatleva, E.B. Nesterova, D.V. Nikolskaya, O.L. Orelovich, U.V. Pinaeva, O.A. Polezhaeva, R.K. Ragimova, A. Russou, G.V. Serpionov, I.N. Shamshiddinova, V.V. Shirkova, D.V. Schegolev, I.I. Vinogradov, G.N. Volnukhina

DLNP E.V. Kravchenko, M.P. Zarubin

FLNP Yu. E. Gorshkova, O.Yu. Ivanshina , I. Zinkovskaya

LRB I.V. Koshlan

Abstract and scientific rationale:
The project's goal is to develop nanocomposite and functional track-etched membranes (TMs) for applications in nanotechnology, biomedicine, sensor technologies, and novel membrane separation processes. TMs are an example of the industrial application of ion-track technology. They have a number of significant advantages over conventional membranes due to their precisely determined structure. Their pore size, shape, and density can be varied in a controllable manner so that a membrane with the required transport and retention properties can be produced. The modern trends in biology, medicine, environmental research, green energy harvesting, and other areas formulate the demands for membranes with novel specific functionalities. These functionalities can be provided by setting (tuning) the geometry, morphology, and chemical properties of TMs. The present project will focus on the development of various functional track-etched membranes using the following approaches:
– setting the pore architecture;

– composite structures;

– hybrid structures;

– targeted chemical and biochemical modification;

– selection of bulk material.

Special attention will be focused on biomedical applications of track-etched membranes.

The main result of the project will be the creation of scientific and technical foundations for the development of new membranes with specific functions. The applicability of the developed membranes in practically important membrane separation processes, biomedical procedures and analytical tasks will be investigated.

Expected results upon completion of the project:
Functionalized TMs obtained from ion-irradiated polymer films using soft photolysis and liquid extraction of degradation products from tracks for electrodialysis and the electro-baromembrane process:
– determination of ion-selective properties of membranes;

– investigation of the possibility of mono- and multivalent-ion separation on nanoporous TMs using electrodialysis and the electro-baromembrane process.

Experimental verification of the possibility of manufacturing nanocomposite, functionalized, and hybrid TMs:
– TMs with asymmetric and modified nanopores for the separation of racemic mixtures;

– microfiltration TMs with immobilized proteins for the detection of free RNA and DNA and their use in biosensors;

– functionalized nanoporous membranes made of polyvinylidene fluoride (PVDF) for selective preconcentration of toxic metals and their quantitative determination;

– TMs functionalized with silver nanoparticles and bioactive substances for the creation of bactericidal and viricidal filtration materials;

– modified TMs with improved cell adhesion for cell culture systems;

– affinity ultra- and microfiltration TMs for exosome separation;

– nanocomposite TMs with immobilized silver and gold nanoconjugates and aptamers for the diagnosis of viral diseases using SERS and fluorescence spectroscopy;

– hybrid TMs with surface polymer nanofiber structures and modified selective complex compounds, ligands and metal-organic frameworks for selective removal of toxic metals from water.

Data on ion-selective, electrokinetic, and osmotic properties of modified nanopores, including asymmetric nanopores, depending on their geometry and functional groups on the surface.

Expected results of the project in the current year:
Acquisition of experimental data on the selectivity of polyimide ion-exchange membranes produced by the ion-track method for binary solutions containing magnesium ions and alkali metal ions.

Development and production of anisotropic microporous membranes for the use in medical diagnostic equipment.

Electrochemical determination of heavy metal ions in water using nanoporous polyvinylidene fluoride track membranes modified with 4-vinylpyridine and N-vinylimidazole. Study of the impact of matrix effects on the analytical characteristics of sensors.

Hybrid membranes based on metallized track-etched membranes and polyvinylidene fluoride nanofibers, copolymers of tetrafluoroethylene and vinylidene fluoride (Fluoroplastic-42). Study of the relaxation and piezoelectric properties of hybrid membranes.

Development and production of aptasensors based on track-etched membranes coated with silver and gold nanoparticles, exhibiting the surface enhanced Raman scattering (SERS) effect, for rapid and selective analysis of exosomes.

Creation of track-etched membranes modified by homo- and hetero-metal-organic frameworks of transition metals (Co, Ni, Cu, and Zn) and tryptophan. Investigation of structural, selective, and bactericidal properties.

3. High-sensitivity sensor based on molecular recognition for viruses detection

A.N. Nechaev
E.G. Zavyalova

Implementation

FLNR V.A. Altynov, E.V. Andreev, P.Yu. Apel, I.V. Blonskaya, N.A. Drozhzhin, I.N. Fadeikina, E.L. Filatova, M.A. Kuvaytseva, A.V. Lundup, A.A. Markin, S.V. Mitrofanov, S.A. Mityukhin, L.G. Molokanova, D.A. Murashko, O.L. Orelovich, U.V. Pinaeva, O.A. Polezhaeva, G.V. Serpionov, D.V. Schegolev, I.I. Vinogradov

DLNP E.V. Kravchenko, M.P. Zarubin

Abstract and scientific rationale:
The purpose of the project is to develop a fundamentally new diagnostic technology characterized by rapid analysis, high sensitivity and specificity, and the ability to adapt for detecting various types of virus-containing analytes. Viruses will be detected using next-generation specialized medical equipment – the Raman luminescent diagnostic complexes. The method is based on the use of nanocomposite track-etched membranes providing surface enhanced Raman spectroscopy (SERS). SERS active track-etched membranes will ensure the selectivity of virus retention in the studied samples and high detection sensitivity. The use of bio-affinity interactions with functional analogues of antibody aptamers labeled by SERS reporters will

be an additional factor in the specificity of marker detection. The project will result in the development and experimental justification of a novel biosensor technology for the diagnosics of animal infectious diseases, in particular the African swine fever (ASF) virus. The experimental justification of the hypotheses and the choice of optimal technical solutions will be based on DNA sequencing of ASF and an artificially synthesized enzyme immunoassay reagent – an aptamer capable of immobilizing onto the surface of silver and gold nanoparticles. At the final stages of the work, an experimental test system will be designed for rapid detection of antigens of one of the ASF viruses in clinical material. The project implementation should ensure the achievement of world-class results through the synergistic interaction of specialists in applied nuclear physics, radiation processing of materials, colloidal chemistry, modern biomedical technologies, and microelectronics.

Expected results upon completion of the project:
The result of the project is theoretical and experimental research for the development and production of new functionalized TMs and highly sensitive biosensors for monitoring viruses of various etiologies posing epidemic risks. The main results of the project are the following.

Experimental results related to the analysis of the properties of components for upcoming viral sensors and the possibility of their manufacture:
– TMs functionalized with plasmonic nanoparticles of silver and gold, as well as their alloys;

– synthesis and characterization of aptamers with the highest affinity to the ASF virus and gold and silver nanoparticles;

– nanocomposite TMs with SERS-active ensembles of nanoparticles, with immobilized aptamers for rapid and sensitive detection of viruses (using the ASF virus as an example);

– proof of the efficacy of the developed algorithms for virus monitoring using ASF as an example.

Development and assembly of sensors based on Raman spectroscopy for TM-based viral detection:
– development of an ASF virus analysis protocol using sensors;

– development of diagnostic kits for rapid analysis of ASF;

– development and fabrication of TM-based test strips for selective ASF detection;

– assessment of the possibility of using sensors and test strips with immobilized aptamers for monitoring and diagnozing diseases having social consequences (influenza, coronavirus, hepatitis, oncology).

Expected results of the project in the current year:
Evaluation of the antiviral properties of non-genotoxic aptamers against the ASF virus in vitro before and after exposure using the comet assay.

Selection of aptamers with virucidal effects for further development of TMs with immobilized aptamers.

Modification of gold and silver nanolayers by the ASFV specific aptamers (microfiltration track-etched membranes) and the analysis of the ASF virus using Raman spectroscopy

Evaluation of the antiviral properties of TMs with immobilized aptamers targeting the ASF virus.

Collaboration 1131

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	ICP NAS RA
		IMB NAS RA
		YSU
Australia	Canberra, ACT	ANU
Belarus	Gomel, HO	GSU
	Minsk, MI	BSU
Kazakhstan	Astana, AST	AB INP
		ENU
		NU
Russia	Chernogolovka, MOS	ISSP RAS
	Dolgoprudny, MOS	MIPT

Country or International Organization	City, region	Institute or laboratory
	Ivanovo, IVA	ISUCT
	Krasnodar, KDA	KubSU
	Moscow, MOW	FMBC FMBA
		IGIC RAS
		ISPM RAS
		ITEP
		MPGU
		MSU
		PFUR
		RIVS
		RSMU
		TIPS RAS
	Novosibirsk, NVS	ISP SB RAS
Serbia	Belgrade, BG	VINCA
South Africa	Bellville, WC	UWC
	Durban, NL	UKZN
	Gqeberha, EC	NMU
	Mthatha, EC	WSU
	Pretoria, GT	TUT
		UNISA
		UP
	Somerset West, WC	iThemba LABS
	Stellenbosch, WC	SU
	Vanderbijlpark, GT	VUT
Vietnam	Hanoi, HN	IMS VAST

07-1-A001-2025/2027

Creation of a Line of High-Voltage Power Supplies and Voltage Switches for Experimental Facilities

Activity leader: D.O. Ponkin

The problem under study and the main purpose of the research:
Development and production of a group of high-voltage power supplies and voltage switches for experimental facilities. The experimental testing sites will be VBLHEP facilities: the NICA injector, BM@N, MPD.

Activity:

Name of the activity	Leader	Implementation period
Laboratory Resposible from laboratories		Status
1. Creation of a line of high-voltage power supplies and voltage switches for experimental facilities	**D.O. Ponkin**	2025-2027
		Development Creation Testing

VBLHEP E.A. Butenko, M.G. Dzugaev, N.A. Malyshev, E.S. Matyukhanov

Abstract and scientific rationale:
It is planned to create a group of programmable electronic modules - high-voltage power supplies and voltage switches for a wide range of technical tasks. The R&D activity is based on the use of the accumulated experience in the development of high-voltage power supplies for the KRION ion sources at the NICA injector. A line of precision DC high-voltage power supplies will be created with an amplitude of 1/3/6/15 kV of both positive and negative polarities, and output currents ranging from a few to tens of mA. It is planned to create high-voltage modules in various designs to expand the spectrum of application areas: a mini-module for internal installation into units, a rack-mount version for a 19' rack (industrial option), and a desktop unit for stand-alone operation.

Expected results upon completion of the activity:
The created line of high-voltage modules and the initial phase of equipment testing conducted under experimental conditions at the operating JINR and partner facilities. Confirmation of the technical specifications for the created devices through bench and experimental tests. Technical documentation developed for the entire line of devices. An approved main test programme and a test protocol for partner facilities.

Expected results of the activity this year:
Development of a group of high-voltage modules:
– controlled mini-module;

– desktop power supply with display;

– industrial unit in a 19’ rack;

– high-voltage switch.

Ensuring the specifications of the developed devices meet the technical requirements.

07-2-A002-2025/2028

Development of Deep Tissue Oxygenation Measurement Systems Using Time-Domain Diffuse Optics (TD-DO) Technique

Activity leader: A.S. Selyunin

Participating countries and international organizations:
Russia.

The problem under study and the main purpose of the research:
Modern optical methods, such as time-domain diffuse optics (TD-DO), enable probing of biological tissues in the near-infrared range at depths of 3–5 cm; however, their accessibility is limited by high costs.

The goal of this research is to develop an affordable, compact single-channel TD-DO system for monitoring oxygenation in biological tissues, including the brain.

As part of the project, it is planned to create a source of ultrashort light pulses based on the original generator. Development of a high-precision time measurement system based on an affordable high-speed time-to-digital converter (TDC). Conducting methodical studies of silicon photomultipliers (SiPMs) for efficient single-photon detection in the picosecond time range. Development of a control, data acquisition, processing, and visualization module. Development of control and reconstruction algorithms. Conducting pre-clinical and in-vivo tests to validate the proposed solution.

Activity:

Name of the activity	Leader	Implementation period Status
Laboratory Resposible from laboratories		
1. Development of deep tissue oxygenation measurement systems using time-domain diffuse optics (TD-DO) technique	**A.S. Selyunin**	2025-2028 Realization

DNLP N.V. Anfimov, D.V. Fedoseev, Kh. Karatash, A.V. Rybnikov, V.I. Sharov, S.A. Sokolov

Abstract and scientific rationale:
Development of a cost-effective system for non-invasive diagnostics using picosecond pulses of near-infrared and infrared light. This system enables the detection of photons that penetrate biological tissues to a depth of 3–5 cm, opening new possibilities for monitoring oxygenation in deep tissues and the brain, as well as for stroke diagnostics. The proposed method may also find applications in other fields, such as environmental studies, food quality control, and more.

Expected results upon completion of the activity:
Development of a portable single-channel system for brain oxygenation monitoring. Preclinical and in-vivo tests have been conducted. The feasibility of scaling up for mass production has been explored. Initiated the transition to the development of multi-channel functional near-infrared spectroscopy (fNIRS) system.

Expected results of the activity this year:
Development and creation of a demonstrator probe with implementation of a full measurement chain: light source – detector – data analysis system. Conducting studies on homogeneous phantoms simulating the optical properties of biological tissues: measurement of optical properties; studies of photon time distributions. Conducting studies on heterogeneous phantoms: detection of localized absorbing regions at depths of 1–3 cm; analysis of temporal characteristics of transmitted radiation. Verification of experimental data with Monte Carlo simulation results.

Collaboration A002

Country or International Organization	City, region	Institute or laboratory	
Russia	Moscow, MOW	MSU	

07-2-A003-2025/2028

Development of Micro-SPECT Systems for Precision Imaging in Model Biological Experiments

Activity leader: V.A. Rozhkov

Participating countries and international organizations:
Cuba, Egypt, Russia.

The problem under study and the main purpose of the research:
Single-photon emission computed tomography (SPECT) is one of the key methods of molecular imaging in medicine, widely used in oncology, cardiology, and neurodegenerative disease diagnostics. However, existing SPECT systems have a number of significant limitations, including low spatial resolution (5–10 mm), which hinders the visualization of small anatomical structures and molecular processes; a considerable level of background noise and artifacts caused by the use of conventional collimators; limited detector sensitivity, resulting in prolonged scan times and, consequently, increased radiation dose; as well as insufficient system flexibility, which restricts the ability to adapt the equipment to different types of radiopharmaceuticals and the specific requirements of various studies.

Activity:

Name of the activity	Leader	Implementation period
Laboratory Resposible from laboratories		Status
1. Development of micro-SPECT system for precision imaging in model biological experiments	**V.A. Rozhkov**	2025-2028
		Realization

DNLP A. Hassan, R.V. Sotensky

LRB G.I. Hernandez

Abstract and scientific rationale:
The project is aimed at developing a micro-SPECT (single-photon emission computed tomography) system for high-precision imaging of radiopharmaceutical distribution in biological specimens under conditions approximating preclinical research. The primary goal is to create a sensitive and compact system based on Timepix detectors utilizing coded aperture collimators. One of the key features of the proposed system is its cost — an order of magnitude lower than existing commercial alternatives. This technology enables submillimeter spatial resolution, improved gamma photon detection efficiency, and a significant reduction in image artifacts compared to traditional collimation schemes.

The system under development will be adapted for use with a wide range of radiopharmaceuticals commonly applied in nuclear medicine, radiation biology, and related fields. The project includes the creation of a working prototype, its testing in a laboratory environment, and a series of experiments simulating real-world application scenarios. As part of the project, image reconstruction algorithms will also be developed and optimized to enhance contrast and improve the accuracy of small target visualization.

The anticipated results are expected to find application in applied biomedical research, radiopharmaceutical development, evaluation of new diagnostic and therapeutic methods, as well as in fundamental research in radiation biophysics.

Expected results upon completion of the activity:
The final outcome of the project will be a fully functional micro-SPECT system comprising a Timepix-based detector module, a coded aperture system, a mechanical framework for precise positioning of the sample and detector, radiation shielding for personnel, and dedicated software for data acquisition and image reconstruction. The main objective of the development is to create a compact and high-precision device for laboratory studies on small rodents, enabling a breakthrough in the visualization of radiopharmaceutical distribution and facilitating research at an entirely new level.

Unlike conventional SPECT systems, the use of a coded aperture will enable spatial resolution below 1 mm, which is particularly important for studying small animals and complex biological structures.

Expected results of the activity this year:
Development of design documentation for electrical and mechanical components of the micro-SPECT system has been developed.

Collaboration A003

Country or International Organization	City, region	Institute or laboratory	
Cuba	Havana	CEADEN	
Egypt	Alexandria, ALX	AU	
Russia	Moscow, MOW	MEPhI	
	Vladivostok, PRI	FEFU	

07-4-A004-2025/2028

Testing of Neurotoxicity and Assessment of Contrast Agents, Nanoparticles and Other Compounds Accumulation in Animal Models in TaaS Format

Activity leader: I. Zinicovscaia

Participating countries and international organizations:
Belarus, Russia.

The problem under study and the main purpose of the research:
A key stage in the development of new drugs and a condition for their successful registration and commercialization is to conduct high-quality preclinical studies of efficacy, metabolism and toxicity in accordance with current standards. Such studies can be conducted on the basis of preclinical departments of pharmaceutical companies, and in the event of inexpediency of creating such - in specialized organizations providing the relevant services. Within the framework of this activity, it is proposed to organize testing of neurotoxicity and assessment of the accumulation of contrast agents, nanoparticles and other compounds on animal models in the TaaS format within the framework of interlaboratory cooperation.

Activity:

Name of the activity	Leader	Implementation period
Laboratory Resposible from laboratories		Status
1. Testing of neurotoxicity and assessment of accumulation of contrast agents, nanoparticles and other compounds in animal models in TaaS format	**I. Zinicovscaia**	2025-2028
		Data acquisition and analysis

FLNP O. Chaligava, D.S. Grozdov, N.S. Yushin

LRB K.N. Golikova, G.I. Hernandez, I.A. Kolesnikova, I.S. Severiukhin, D.M. Utina

DLNP V.A. Rozhkov

Abstract and scientific rationale:
The declared activity envisages the creation of an experimental system for assessing the toxicity and accumulation of contrast agents, nanoparticles and other compounds used for medical diagnostics within the framework of interlaboratory cooperation between FLNP, LRB and DLNP. The system will include a set of methods and protocols, experimental equipment and competencies necessary to conduct studies of promising diagnostic and therapeutic compounds on small laboratory animals and develop new technological approaches for nuclear medicine tasks. In particular, a number of ethology and pathophysiology methods will be used to assess the neurotoxicity of new drugs. The neutron activation analysis at the IBR-2 reactor will be used to determine the accumulation of elements in different organs, which will determine their selectivity in relation to tissue structures, as well as conduct a correlation analysis of the dependence of the degree of pathological processes and the metal content in the organ. Tomographic studies will be carried out at the "Kalan" stand located in DLNP.

Expected results upon completion of the activity:
Interlaboratory testing of neurotoxicity and assessment of accumulation of contrast agents, nanoparticles and other compounds, developed in JINR Member States, will be organized on animal models in the TaaS format. The system will include stages of assessment of drug efficacy, metabolism and toxicity.

Expected results of the activity this year:
Interlaboratory testing of neurotoxicity and assessment of iodine-containing drugs accumulation will be organized on animal models in the TaaS format. The system will include stages of assessment of drug efficacy, metabolism and toxicity.

Collaboration A004

Country or International Organization	City, region	Institute or Laboratory	
Belarus	Minsk, MI	INP BSU	
Russia	Moscow, MOW	MSU	

07-5-A005-2025/2028

Multifunctional Preparative Tangential Flow Filtration System

Activity leader: I.I. Vinogradov

Participating countries and international organizations: Russia.

The problem under study and the main purpose of the research:
The development of a multifunctional preparative tangential flow filtration system and the optimization of tangential filtration for micro-, ultra-, and diafiltration of liquids.

Activity:

Name of the activity	Leader	Implementation period
Laboratory Resposible from laboratories		Status
1. Multifunctional preparative tangential flow filtration system	**I.I. Vinogradov**	2025-2028
		Realization
FLNR E.V. Andreev, N.A. Drozhzhin, U.V. Pinaeva		

Abstract and scientific rationale:
The research is aimed at developing a multifunctional preparative tangential flow filtration system for micro-, ultra-, and diafiltration of liquids, such as culture media, blood plasma, buffers, and other solutions using flat sheet membranes. Tangential flow filtration systems are widely used in laboratories, industry, and medicine. A multifunctional preparative tangential flow filtration system can be used for various applications, including pharmaceutics (for the concentration and purification of proteins, vaccines, and antibodies), biotechnology (production of biopharmaceuticals, such as antibiotics and enzymes, and for the removal of endotoxins), food industry (clarification of juices, beer, and other beverages, as well as for purification and stabilization of liquids), winemaking (clarification of wine and other fermented beverages), medicine (purification of infusion and perfusion fluids and drugs), and many other fields.

Expected results upon completion of the activity:
The main result of the research will be the development of a multifunctional preparative tangential flow filtration system that will be used for optimizing tangential flow filtration and for studying physical and chemical interactions between the components of filtered liquids and track-etched membranes, hybrid membranes, and ultrafiltration membranes. Furthermore, the system will be used for investigating the membrane, physical, and chemical processes on the new types of flat sheet membranes; for filtering liquid media in small volumes (filtration process being already optimized) to develop a final product; for concentrating substances in small volumes; and for testing theoretical models of membrane modules for mass production. As a result of the collaborative effort, a single-use module will be developed with the pre-determined filtration parameters, a form factor, materials, and other specific features.

Expected results of the activity in the current year:
A prototype of a multifunctional preparative tangential flow filtration system with a unified connection system for PEEK chromatography tubes, sterile silicone tubes with Luer-lock connectors, and silicone tubes without connectors.

Real-world testing:
– sterilization of water using track-etched membranes and concentration of a radiopharmaceutical based on sterile aqueous suspension of technetium labeled with human albumin particles;

– closed-loop filtration of the ascitic fluid of cancer patients using track-etched membranes for maintaining the electrolyte balance and nutrition while removing circulating cancer cells from the abdominal cavity;

– concentration and purification of silver, gold, silicon oxide nanoparticles, etc.

Lab testing of a single-use module (concentration–filtration of a hemoglobin solution using ultrafiltration and filtration of model solutions of latex beads using microfiltration).

Collaboration A005

Country or International Organization	City, region	Institute or laboratory	
Russia	Moscow, MOW	NMRCO	
		Sechenov Univ.	

Physics and Technology of Charged Particle Accelerators (08)

08-2-1126-2015

Development of Scientific DLNP Infrastructure for Research Using Semiconductor Detectors, Laser Metrology, Electrons, Positrons and Cryogenic Technology

Theme leaders: V.V. Glagolev
G.A. Shelkov

Deputy: V.V. Tereschenko

Participating countries and international organizations:
Armenia, Azerbaijan, Belarus, Bulgaria, Czech Republic, Germany, Russia, Serbia, Uzbekistan, Vietnam.

The problem under study and the main purpose of the research:
In addition to the Projects highlighted below, the task of particular importance is the complete of commissioning of the basis facility of DLNP – the linear electron accelerator LINAC-200.
The main objectives of the research at the LINAC-200 linear electron accelerator for the upcoming 7-year period are:
– providing electron beams with energies of up to 200 MeV (with a possible increase in energy up to 800 MeV) for research and scientific and methodological work on the creation of detectors of elementary particles at JINR and in scientific centres of the member states for experiments at the NICA collider and other facilities, including those outside JINR;

– study of controlled generation of electromagnetic radiation by relativistic electrons based on the use of functional materials, search for new methods and creation of equipment for beam diagnostics in accelerators;

– carrying out research work on the creation of beams of relativistic electrons with a large orbital momentum;

– implementation of educational programmes of the JINR University Centre;

– conducting research, including applied studies in the field of radiation materials science, radiobiology, radiochemistry.

The expected operating time of the accelerator within the framework of the open user programme will be at least 2000 hours per year.

The goal of the project "Design and development of a test zone for methodological studies of detectors at the linear electron accelerator at DLNP" is to create an infrastructure based on the LINAC-200 for methodological studies using electron beams with energies from 20 MeV to 200 MeV.

Within the project "Precision laser metrology for accelerators and detector complexes", the main objectives are to carry out scientific research and methodological studies on the development of Precision Laser Inclinometers for their application to scientific and applied tasks (monitoring the position of collider elements, improving the accuracy of measurements of Gravity antennas, earthquake forecasting); improvement of methods of metrological measurements; creation of a seismically isolated platform.

The goal of the project "Development of experimental techniques and applied research on monochromatic positron beams (PAS)" is to create a facility to study the structure of various materials and defects arising under various physical influences (aging, external loads, radiation exposure). One of the methods is positron annihilation spectroscopy (PAS). This method is sensitive to the detection of various (so-called "open-volume") defects ranging in size from 0.1 to 1 nm with a minimum concentration of up to 10^{-7} cm^{-3}. The PAS method has four orders of magnitude better spatial resolution compared to the transmission electron microscope.

The main goal of the project "New semiconductor detectors for fundamental and applied research" is the development and methodological study of a new class of physical devices - hybrid pixel semiconductor detectors operating in the mode of counting individual particles. These devices first appeared at the turn of the 2000s and differ from other pixel detectors by the ability to process and digitize the signal directly in the pixel, which makes it possible to obtain data on the energy of each particle falling into an individual pixel in addition to coordinate information.

The goals the project "GDH&SPASCHARM" are the introduction equipment operating at ultra-low temperatures and polarized targets into the practice of physical experiment and conduct of polarization studies and participation in innovative projects using cryogenic, magnetic and polarization technologies.

Projects in the theme:

	Name of the project	Project leader	Project code
1.	Design and development of a test zone for methodological studies of detectors at a linear electron accelerator LINAC-200 in the DLNP	M.I.Gostkin *Deputy:* E.S. Abdelshakur	08-2-1126-1-2024/2028
2.	Precision laser metrology for accelerators and detector complexes	V.V. Glagolev M.V. Lyablin	08-2-1126-2-2016/2028
3.	Development of experimental techniques and applied research with slow monochromatic positron beams (PAS)	A.A. Sidorin *Scientific leader:* I.N. Meshkov	08-2-1126-3-2016/2028
4.	Novel semiconductor detectors for fundamental and applied research	G.A. Shelkov *Deputies:* V.A. Rozhkov V.V. Tereschenko	08-2-1126-4-2015/2028
5.	GDH&SPASCHARM	Yu.A. Usov	08-2-1126-5-2011/2028

Projects:

	Name of the project	Project leader	Status
Laboratory	Responsible from laboratories		
1.	**Design and development of a test zone for methodological studies of detectors at a linear electron accelerator LINAC-200 in the DLNP**	**M.I. Gostkin** *Deputy:* **E.S. Abdelshakur**	Implementation

DLNP M.A. Demichev, D.L. Demin, Amer Hassan, D.V. Kharchenko, V.G. Kruchonok, A.A. Nozdrin, M.A. Nozdrin, S.Yu. Porokhovoy, A.N. Trifonov, A.A. Ulankin, K.E. Unenko, A.S. Zhemchugov

FLNR S.V. Mitrofanov, Yu.G. Teterev

VBLHEP V.V. Kobets

Abstract and scientific rationale:

Scientific and methodological studies of elementary particle detectors are a necessary condition for the progress of nuclear physics and high energy physics. Preparation of experiments at future accelerators requires new types of detectors capable of coping with large loads and providing the required accuracy and reliability of particle detection. Development of new detectors is also important for applied research based on the use of synchrotron radiation sources and intense X-ray facilities. In particular, creation of new SR sources and super-powerful lasers in the JINR Member States leads to the creation of experimental stations based on detectors with high spatial and energy resolution.

The lack of facilities with test electron beams at JINR significantly slows down progress in development of new types of electromagnetic calorimeters and coordinate detectors for future MPD and SPD experiments at the NICA collider, photon imaging detectors, radiation-resistant detectors and dosimetric instruments. The purpose of the presented project is to create an infrastructure based on the linear electron accelerator LINAC-200 for methodological research on electron beams with an energy of 20 MeV and 200 MeV. It is planned to use a test area based on LINAC-200 and for conducting experiments on the study of photonuclear reactions, for applied research (radiation materials science, radiation genetics, etc.).

Expected results upon completion of the project:

As a result of the implementation of the project, an equipped test zone will appear at the LINAC-200 accelerator of DLNP JINR for carrying out scientific methodological and scientific experimental work by JINR groups and institutes of the JINR Member States.

Expected results of the project this year:

Design and construction of the user extraction point for the 60 MeV electrons.

Development of the dosimetry equipment for the accelerator extraction points.

Start of the accelerator operation according to the chosen user applications.

2. Precision laser metrology for accelerators and detector complexes — **V.V. Glagolev, M.V. Lyablin** — Implementation

DLNP I.V. Bednyakov, S.A. Bednyakov, K.S. Bunyatov, Yu.I. Davydov, Yu.V. Klemeshov, S.M. Kolomoets, A.V. Krasnoperov, A.M. Kuzkin, R.V. Ni, A.A. Pluzhnikov, K.D. Polyakov, S.N. Shilov, G.D. Shirkov, G.T. Torosyan

BLTP A.N. Baushev

GA&C G.V. Trubnikov

Abstract and scientific rationale:
The implementation of the project is aimed at long-term monitoring of the behaviour of the base of the collider (NICA) to track critical design changes that can cause beam deviations from the calculated orbits. Also, monitoring will make it possible to control angular vibrations of the collider elements from microseismic noise of industrial and natural origin in order to identify sources of noise and frequencies that coincide with the resonant frequencies of the collider elements, which can lead to a decrease in luminosity.

An equally important component of the project is development of a compact inclinometer capable of measuring changes in the angles of inclination of the surface with an accuracy of about 10^{-8} radians throughout the year, and further, building of a network of such inclinometers in seismic regions to determine energy accumulation zones and potentially seismic areas.

Expected results upon completion of the project:
Creation of a network of small-sized precision laser inclinometers (MPLIs) for monitoring the behaviour of the base of the collider NICA to track critical design changes that can cause beam deviations from the calculated orbits. Creation of a hardware-software complex for synchronization and processing of MPLI data. Creation of software for visualization of changes in the position of the Earth's surface under the NICA collider.

Modification of the current MPLI version for long-term stable operation for 6-12 months with angular measurements accuracy of 10^{-7} rad at remote geodetic points, powered by solar panels.

R&D on a new version of the MPLI - an interferometric PLI (IPLI), which has a weak temperature dependence and less expensive production based on available components.

Based on the sets of modified MPLIs and IPLIs, carry out deployment of networks to determine the regions of seismic energy accumulation and monitor objects on the territory of Kamchatka, Armenia, Belarus and Uzbekistan.

Create the necessary software for receiving data from the PLI network, online control, visualization of the Earth's surface by a controlled network, algorithms (including machine learning, neural networks) for determining zones of increased accumulation of seismic energy.

Creation of a prototype of an amplitude interferometric length meter for a length of 16 m, creation of a prototype of a laser reference line for a length of 128 m, creation of a prototype of a seismically stabilized research platform, use of compact MPLIs to improve the frequency parameters of the gravitational antennas of the VIRGO detector.

Expected results of the project this year:
Take measurements of the SPD hall tilt using several IPLI.

Perform joint measurements of microseismic vibrations using IPLI and geophysical instruments at the "Naroch" Geophysical Observatory in Belarus.

Develop a prototype of an inclinometer with data acquisition using a photomatrix.

3. Development of experimental techniques and applied research with slow monochromatic positron beams (PAS) — **A.A. Sidorin**, *Scientific leader:* **I.N. Meshkov** (VBLHEP) — Implementation

DLNP E.V. Akhmanova, V.I. Hilinov, Nguyen Vu Minh Trung, O.S. Orlov, E.P. Popov, A.Yu. Rudakov, S.F. Samedov

VBLHEP V.V. Kobets

Abstract and scientific rationale:
Applied research in the field of solids by PAS methods and the development of experimental techniques using these methods are among the goals of the project. To study defects in materials, the annihilation line Doppler broadening (DBAL) method is used, which is implemented on a flow of slow monochromatic positrons. The DBAL spectrometer is made according to the standard scheme. The Positron Annihilation Lifetime Spectroscopy (PALS) method implemented on an autonomous ^{22}Na source is also used. To develop the experimental base, the PALS method is being introduced on a flow of slow monochromatic positrons. The group proposed an original version of this method based on the formation of an ordered stream of slow positrons.

Expected results upon completion of the project:
Improvement of the DBAL spectrometer by adding to the measurement scheme the possibility of registering the coincidence of two annihilation gamma quanta.

Completion of the positron ordering system and commissioning of the PALS spectrometer on a monochromatic positron beam.

Development of the ion etching technique using the created etching system and its application to the study of thin-film multilayer materials.

There is a problem of high-temperature vacuum heating, which can be solved by heating samples with an electron beam. The available technical capabilities make it possible to implement this heating method.

Expected results of the project this year:
Continuation of applied research together with TPU (Zr/Nb layered materials), SAFU (synthetic diamonds).

Research of polymeric materials and thin films (BiVO) by the DUAL method using the coincidence scheme together with colleagues from Vietnam.

Research of various materials (semiconductors, metals, alloys) by the DUAL and PALS methods.

Implementation of the ordering system for the PALS method on the positron beam.

Development of the automatic control system for the PAS installation.

4. Novel semiconductor detectors for fundamental and applied research

G.A. Shelkov
Deputies:
V.A. Rozhkov
V.V. Tereschenko

Implementation

DLNP S. Abdelshakur, N.N. Kaurtsev, V. Kruchonok, A.V. Lapkin, G.K. Lavrov, S.A. Malinin, V. Makarova, R.V. Sotensky, Phi Truong Hoai Bao

FLNR A.T. Isatov, S. Mitrofanov, Yu.G. Teterev

FLNP A.A. Ahmedov, D. Berikov, Yu.N. Kopach

LRB A.N. Bugay, A.V. Chizhov

Abstract and scientific rationale:
In 2015, theme 1126 was opened. The main goal of the work is the development and methodological research of a new class of physical devices - hybrid pixel semiconductor detectors operating in the single-particle counting mode. These devices first appeared at the turn of the 2000s. and differ from other pixel detectors by the ability to process and digitize the signal directly in the pixel, which makes it possible to obtain data on the energy of each particle falling into an individual pixel in addition to coordinate information.

The ability to measure the energy of an X-ray gamma ray opens up new possibilities that were previously unavailable. Having such information, you can determine not only the absorption capacity of individual elements of the object under study, but also determine the material of this element. Thus, in medical X-ray tomographs, the identification of substances in individual

parts of a living organism provides vital information about metabolic pathways, tissue components and delivery mechanisms of these substances. This task is of particular importance when studying drug delivery. Carrying out such studies using X-ray computed tomography (CT) is currently difficult due to the lack of available detection systems with high spatial resolution and capable of measuring the energy of gamma rays. The goal of this project is to create a hardware and software basis for the development of detection systems with hybrid pixel detectors and radiographic medical and industrial equipment based on them. As a result of the project, prototypes of new energy-sensitive pixel detectors will be developed and manufactured in industry.

Expected results upon completion of the project:
The main direction of further work will be the development of our own ASIC and the production of new energy-sensitive semiconductor X-ray image detectors and equipment for:
- creating a hardware and software basis for the development of new types of X-ray devices for medical and industrial diagnostics, including computed tomography;

- improving methods for identifying substances in x-ray studies using data on the measured energy of gamma quanta.

Expected results of the project this year:
Manufacturing and testing of the first elements of the developed ASIC.

Creation of a prototype system for read-out data for pixel detectors.

Continuation of joint work with chemists from Moscow State University on the MARS microtomograph.

5. GDH&SPASCHARM **Yu.A. Usov** Implementation

DLNP N.A. Bazhanov, D.V. Belov, A.S. Dolzhikov, A.N. Fedorov, I.V. Gapienko, I.S. Gorodnov, V.L. Kashevarov, A. Kovalik, E.S. Kuzmin, A.B. Neganov, A.A. Priladyshev, Yu.N. Uzikov, V.P. Volnykh

BLTP S.B. Gerasimov

VBLHEP V.V. Fimushkin, M.V. Kulikov, L.V. Kutuzova

Abstract and scientific rationale:
Experimental study of one-spin asymmetries in the production of various light particles using a pion beam with an energy of 28 GeV at the first stage, and the study of one-spin and two-spin asymmetries in dozens of reactions, including those with the formation of charmonium, using a polarized proton beam (SPASCHARM project).

The ultimate goal of the SPASCHARM project is to study the spin structure of the proton, starting with determining the contribution of gluons to the spin of the proton at large values of the Björken variable x by studying the spin effects in the formation of charmonium. This will make it possible to understand the hadronic mechanism of charmonium production and to isolate the gluon polarization $\Delta g(x)$ at large values of x.

Experiments with a real photon beam: photoproduction of mesons on nucleons and nuclei and Compton scattering on nucleons. Main objectives: experimental confirmation of the Gerasimov-Drell-Hearn (GDH) sum rule, investigation of the helicity structure of partial reaction channels, resolution of the excitation spectrum of baryons from light quarks, search for missing baryon resonances and exotic states (dibaryons, narrow nucleon resonances), study of the structure of hadrons.

Measurement of $\Delta\sigma T$ and $\Delta\sigma L$ in an experiment on the transmission of polarized neutrons through a polarized deuteron target at neutron energies <16 MeV, where there are limited experimental data and where theory predicts a significant effect of three-nucleon forces (3NF). This part of the project (NN) is a continuation of measurements of the same quantities in the scattering of neutrons by protons, which were carried out earlier.

Research and development of polarization equipment for MESA.

To date, there is no theory that gives a complete and consistent description of all the observed polarization effects in the hadronic sector. Therefore, a systematic experimental study of polarization effects in a wide variety of reactions using polarized beams and polarized targets is of great importance for the development of a theory that consistently describes all the observed spin phenomena.

The observed polarizations are the paramount characteristics of the interactions of elementary particles and nuclear reactions. Formally, the measurement of spin-dependent parameters imposes additional restrictions on the proposed reaction mechanism, the structure of the microobject under study, and the very nature of the fundamental interaction. It should be noted that

modern experiments aimed at searching for the effects of CP violation and T invariance violation outside the Standard Model, as well as CPT violation, are based on polarization measurements.

Expected results upon completion of the project:
Development and construction of a new cryostat for a polarized "frozen" target of the SPASCHARM installation.

Development and construction of the main components of a powerful $^{3}He/^{4}He$ dilution refrigerator for the MESA facility.

Completion of work on the creation of a cryostat for a polarized target at the University of Bonn.

Return transport and full launch of the polarized target in Mainz for the GDH project.

Carrying out polarization studies using a polarized "frozen" target at the MAMI-C accelerator.

Carrying out polarization studies on a new polarized target at the Bonn University accelerator ELSA.

Assembly, installation and testing of a powerful 3He/4He dilution refrigerator on the beam channel of the MESA setup.

Launch of the modified polarized target of the SPASCHARM facility and the beginning of the collection of physical statistics on the accelerator.

According to the NN-interaction program, channeling experiments will be carried out after the upgrade of the stand for the source of polarized deuterons – 2024-2025.

Carrying out precise measurements of vector and tensor polarizations of the deuteron beam at the VdG accelerator.

Preparation of a special device for using a new target material based on trityl-doped butanol.

Manufacture and installation of equipment for measuring polarization of neutrons using scattering on a 4He target.

Depreservation of the polarized deuteron target and the beginning of measuring the difference between the cross sections $\Delta\sigma T$ and $\Delta\sigma L$ in the experiment on transmission of at neutron energies <16 MeV.

Expected results of the project this year:
Complete creation of a new cryostat for a polarized target at the University of Bonn.

Participation in the physical data taking at the ELSA accelerator.

Collaboration 1126

Country or International Organization	City, region	Institute or laboratory	
Armenia	Gyumri, SH	IGES NAS RA	
Azerbaijan	Baku, BA	IRP	
Belarus	Minsk, MI	CGM NASB	
		INP BSU	
Bulgaria	Sofia	INRNE BAS	
Czech Republic	Prague, PR	CTU	
Germany	Bonn, NRW	UniBonn	
	Mainz, RP	JGU	
Russia	Arkhangelsk, ARK	NArFU	
	Moscow, MOW	Kristal	
		MEPhI	
	Novosibirsk, NVS	ISP SB RAS	
	Petropavlovsk-Kamchatsky, KAM	FRC GC RAS	
	Protvino, MOS	IHEP	
	Saint Petersburg, SPE	ETU "LETI"	

Country or International Organization	City, region	Institute or laboratory
		NWRSCC FMBA
	Tomsk, TOM	TSPU
		TSU
Serbia	Novi Sad, VO	UNS
Uzbekistan	Tashkent, TK	IS AS RUz
Vietnam	Ho Chi Minh City, SG	CNT VINATOM

08-2-1127-2016

Advanced Studies of Systems of New-Generation Accelerators and Colliders for Fundamental and Applied Research

Theme leaders: G.V. Trubnikov
G.D. Shirkov
B.N. Gikal

Participating countries and international organizations:
Azerbaijan, China, Egypt, Russia, South Africa, Uzbekistan

The problem under study and the main purpose of the research:
Development of the systems and elements of new generation accelerators at JINR, applied research on accelerators. Participation in the development of the international accelerator complex projects. Participation in the development of the concept of establishment a pilot scientific and clinical center for proton therapy.

Project in the theme:

	Name of the project	Project leaders	Project code
Laboratory	Responsible from laboratories		**Status**
1.	**Creation of test benches for testing subsystems of the MSC-230 cyclotron**	**G.A. Karamysheva** **S.L. Yakovenko**	08-2-1127-1-2024/2027 Technical project

DLNP A.V. Agapov, V.A. Akatov, N.D. Belov, I.V. Chernetskaya, A.F. Chesnov, S.N. Dolya, I.V. Evseeva, S.B. Fedorenko, A.N. Fedorov, D.A. Fedorov, R.V. Galkin, V.A. Gerasimov, A.L. Gonshior, S.V. Gursky, O.V. Karamyshev, N.V. Kirichkov, I.N. Kiyan, M.R. Kudrinsky, O.E. Lepkina, O.V. Lomakina, I.D. Lyapin, V.A. Malinin, D.A. Malysh, A.B. Maslennikov, G.V. Mitsyn, Ya.B. Musina, I.M. Palnikov, A.A. Pavlova, D.S. Petrov, D.V. Popov, N.S. Potapova, D.V. Rogozin, V.M. Romanov, M.A. Rumyantsev, N.A. Rybakov, L.D. Sedov, S.G. Shirkov, S.V. Shustrov, A.A. Sinitsa, G.M. Skripka, N.V. Slesarenko, A.S. Stankus, V.P. Timofey, V.A. Vesenkov, A.I. Vlasov, S.L. Yakovenko

VBLHEP V.V. Borisov, A.V. Merkuryev, D.N. Nikiforov, M.S. Novikov, M.V. Petrov, R.V. Pivin, A.A. Ponomarev, R.V. Talyzin

MLIT P.G. Akishin, T.V. Karamysheva

FLNP A.N. Chernikov

Abstract and scientific rationale:
The project is aimed at creating the medical superconducting cyclotron MSC-230 and the infrastructure for radiobiological studies. The project implementation will allow continuing at a new level the research in proton-beam therapy, conducted with proton beams of the Phasotron at DLNP JINR over decades. The planned high intensity of the proton beam — with the maximum current of 1 μA in the continuous mode and of 10 μA in the pulsed mode — will allow to research the new FLASH therapy method.

It is necessary to simulate and test prototypes elements of the cyclotron, such as the superconducting coils, the proton source, and the deflector for successful commissioning of the MSC-230.

The development of MSC-230 superconducting proton cyclotron will create a source of intensive proton beam, opening up possibilities for modernization of equipment for precise control and high dose rate for FLASH therapy method studies. The research in the field of proton radiation therapy, which was carried out for many years on proton beams of Phasotron at DLNP JINR will continue. Due to the planned high intensity of proton beam on the new accelerator it is possible to implement a transition to the so-called FLASH therapy. FLASH radiation is performed at a high dose rate (40 Gy/s) for a very short time (10-50 ms). This radiation method significantly reduces the damage to the healthy tissue surrounding the radiated tumor. There are no proton beam therapy centres in the world that can implement this radiation technique currently.

The proton cyclotron MSC-230 will implement: the conduction of the broad-spectrum radiobiological studies; improvement of the efficiency of irradiation by protons using the heavy metal nanoparticles; practical challenges of space radiobiology; enhancing radiation protection systems of spacecraft for near-Earth pilot flights; development and calibration of new detectors

for the space industry; study of effects of ionizing radiation on animal behavior (monkeys, rodents).

The proton cyclotron MSC-230 will implement of the breakthrough R&D in the field of superconducting magnetic technologies for accelerators of the future, including technologies based on high-temperature superconductors (HTSC), ultracompact cryogenic supply systems, use artificial intelligence (AI) technologies in the modeling of cyclotrons for applied purposes, irradiation planning and radiobiology. To implement artificial intelligence (AI) technologies in the simulation of cyclotrons for applied purposes, irradiation planning and radiobiology.

Expected results upon completion of the project:
Creation of the medical superconducting cyclotron MSC-230 and infrastructure for radiobiological research. Radiobiological studies, medical certification of the proton beam and dosimetry equipment.

Expected results of the project this year:
The study of the operability of individual cyclotron systems: deflector, proton source. Development of the magnetic field measurement system including the calibration magnet. Determination of medical and technical conditions for the proton therapy center projecting.

Activities of the theme:

	Name of the activity	Leaders	Implementation period
Laboratory	Responsible from laboratories		Status
1.	**Further development of methods, technologies, schedule modes and provision of radiotherapy**	**G.V. Mitsyn**	2024-2026 R&D

DLNP A.V. Agapov, K.V. Belokopytova, S.N. Dima, G.V. Donskaya, V.N. Gaevsky, S.A. Gustov, M.D. Indiukova, I.I. Klochkov, A.G. Molokanov, S.A. Pisareva., A.V. Rzyanina, S.V. Shvidkiy, S.S. Uglova

Abstract and scientific rationale:
This project is a continuation of the medical and biological research started at the JINR Laboratory of Nuclear Problems in 1967 using proton beams. The project includes the following works: participation in the determination of medical and technical conditions for the project to create a proton therapy center, calculation of beam transportation channels to the irradiation units, development and manufacture of the detectors for dosimetric support of FLASH therapy, development and testing of all technological stages of planning and conducting proton therapy. It is planned to conduct medical and biological research at the DLNP linear electron accelerator (LINAC-200), which is supposed to form an electron beam with an energy of 20-25 MeV for irradiating cell cultures and small laboratory animals (mice, rats).

Expected results of the activity upon completion:
The manufacturing and testing of proton beam Bragg peak modifiers (comb filters) using 3D-printing for the future radiological center based on the MSC-230 accelerator. Manufacturing and testing of thin-walled multi-wire and strip ionization chambers. Formation of an electron beam with an energy of 20-25 MeV on the LINAC-200 accelerator for medical and biological research.

Expected results of the activity in the current year:
Creation of the test benches for the single cyclotron elements test and the MSC-230 assembling, the beam transport channel and treatment room design. The MSC-230 commissioning. Manufacturing of the transport channel and treatment room with a control panel.

2.	**R&D of Photoinjecting systems**	**M.A. Nozdrin**	2024-2026 Technical Proposal Realization

DLNP A.V. Afanasiev, A.S. Dyatlov, D.S. Shokin, K.E. Yunenko, P.P. Zhuravlev

VBLHEP V.V. Bleco, N.I. Garanzha, J. Huran, V.G. Shabratov, A.V. Skrypnik

Abstract and scientific rationale:
The most modern free electron lasers, as well as other facilities which require high quality electron beam, the photocathode injectors are being used. Such injectors allow to obtain higher beam quality than thermoemission ones. Replacement of the thermoinjector of the LINAC-200 accelerator to the photoinjector is being considered. This will result in the beam emittance reduction, will give more flexibility in beam temporary profile and eventually will allow to construct LINAC-200-based FEL in the range from far IR to UV and soft X-rays.

Expected results of the activity upon completion:
The photoinjector testbench with the electron energy of up to 6 MeV based on S band RF gun construction.

The possibility of replacing the thermoinjector of the LINAC-200 accelerator with a photoinjector to improve beam quality and variability of its parameters conclusion.

Research of the quantum efficiency of various "transparent" photocathodes based on ultra-thin carbon films: depending on deposition method, carbon phases and structures, doping elements and their concentration, cathode shape etc.

Expected results of the activity in the current year:
Modernization of the testbench RF system. Preparation of the proposal on the new laser driver and system of the laser-RF synchronization. Start of the testbench commissioning.

Further development of the safety systems.

3. Participation in the development of the concept and joint project with FMBA of Russia for the creation of a pilot scientific and clinical center for proton therapy — **G.D. Shirkov** — 2024-2026

Preparation of project

DLNP S.G. Shirkov, S.L. Yakovenko

VBLHEP L.Yu. Stolypina

Abstract and scientific rationale:
The Federal Medical and Biological Agency (FMBA) of Russia expressed its intention to take part together with JINR in the development of a joint concept (and in the future, a project) for the establishment of a pilot scientific and clinical center for proton therapy on the basis of the existing medical center №9 of the FMBA in Dubna and based on the MSC-230 accelerator being created at JINR. The objectives of the center will be development of modern methods and technologies of radiation therapy, medical technologies and diagnostics for the use of radiation therapy, advanced scientific research in the field of radiobiology, experimental irradiation and further treatment of patients.

Expected results of the activity upon completion:
Preparation of the project for establishment a proton therapy center.

Expected results of the activity in the current year:
Development of medical and technical conditions for the project of establishment a proton therapy center.

Collaboration 1127

Country or International Organization	City, region	Institute or laboratory	
Azerbaijan	Baku, BA	MOM	
China	Hefei, AH	ASIPP CAS	
Egypt	Cairo, C	ASRT	
Russia	Dimitrovgrad, ULY	FNKCRIO FMBA	
	Moscow, MOW	FCBN FMBA	
		FMBC FMBA	
		IBMP RAS	
		IKI RAS	
		MSU	
	Novocherkassk, ROS	SRSPU NPI	
	Pushchino, MOS	ITEB RAS	
	Saint Petersburg, SPE	NIIEFA ROSATOM	
South Africa	Somerset West, WC	iThemba LABS	
Uzbekistan	Tashkent, TK	INP AS RUz	

Organization of Scientific Activities and International Cooperation Strengthening Human Resources Educational Programme (09)

09-8-1037-2001

Analytical and Methodological Developments for the Organization of Scientific Research and International Cooperation in the Main Directions of JINR Development

Theme leaders: V. A. Matveev
S.N. Nedelko
O.-A. Culicov

Participating countries and international organizations:
Armenia, Bulgaria, Egypt, Kazakhstan, Russia, South Africa, Tunisia.

The problem under study and the main purpose of the research:
Development of analytical materials concerning prospects of scientific research.

Preparation of scientific research plans. Development of science-organization and methodological materials for the special-purpose financing of research areas, themes and projects.

Development and application of information systems for the analysis of results of theoretical and experimental research.

Organization of international cooperation with the Member States of JINR, with states participating in JINR activities on the basis of bilateral agreements, and with scientific research institutions with which JINR has collaboration agreements.

Expected results upon completion of the theme:
Recommendations on the main areas of activity and development of JINR.

Analysis of scientific and technical cooperation and scientific and organizational activities of the laboratories and divisions of the Institute.

Scientific and organizational support for the process of developing plans and reports for research and international cooperation at JINR.

Ensuring operational interaction with representatives of JINR Member States and states participating in JINR activities on the basis of bilateral agreements in the field of scientific research.

Expected results of the theme in the current year:
Improvement of the organization and coordination of JINR scientific research work.

Analysis of the results of JINR activities for 2025 in the main research areas.

Preparation for the publication of the Topical Plan for the year 2027. Identification of JINR's priority research directions for 2027. Update, administration and support of the electronic system for maintaining the Topical Plan for JINR Research and International Cooperation (Topical Plan).

Development of JINR's grantmaking activities and participation in special-purpose programmes for financing scientific research in 2026.

Preparation of analytical materials for ministries and agencies of Member States.

Development and promotion of JINR's information resources on the Internet. Ensuring the operation of the official JINR website.

The publication of the JINR weekly newspaper "Dubna: Science, Cooperation, Progress" and the quarterly publication of the bulletin "JINR News".

Support for the system of concluding and recording agreements on scientific and technical cooperation.

Promotion of realization of JINR's right to independently confer academic degrees of Russian Federation. Support of the operation of JINR's dissertational councils.

Preparation for the publication of the JINR Annual Report for 2025. Preparation of materials for the INIS system.

Scientific and organizational support and preparation of materials of JINR's governing and advisory bodies.

Prompt interaction with representatives of Member States and states participating in the activities of JINR on the basis of bilateral agreements in the fields of scientific research. Organization and holding of meetings of joint cooperation committees. Interaction with international organizations.

Organization and holding of contests for JINR Prizes, preparation of materials for nominating candidates for memberships in academies of sciences, for conferring honorary titles, for awarding medals and other decorations.

Study of the history of the development of JINR as an international intergovernmental scientific organization. Expert and analytical support for the JINR Museum of Science and Technology, including the historical archive.

	Area of activity	**Leaders**
Laboratory (Subdivision)	Responsible from laboratory	
1.	**Preparation for the publication of the Topical Plan**	**S.N. Nedelko** **A.S. Zhemchugov**
DSOA	N.A. Boklagova, D.S. Korobov, N. Kučerka, Ya.L. Martovskaya	
2.	**Support and improvement of the operation of JINR's governing and advisory bodies**	**S.N. Nedelko** **O.-A. Culicov**
DSOA	T.V. Bogdanova, N.A. Boklagova, T.B. Ivashkevich, E.V. Kesharpu, D.S. Korobov, N. Kučerka, Ya.L. Martovskaya, N.I. Sissakian	
ICD	D.O. Al-Maaitah, O.N. Belova, N.M. Dokalenko, O.M. Korotchik, A.A. Kotova, Yu.N. Polykova	
3.	**Preparation of analytical materials for ministries and agencies**	**S.N. Nedelko** **O.-A. Culicov** **A.S. Zhemchugov**
DSOA	T.V. Bogdanova, N.A. Boklagova, N.V. Doroshkevich, D.S. Korobov, O.V. Krupa, N. Kučerka, Ya.L. Martovskaya	
ICD	E.A. Badawy, T.V. Keselis, M.A. Khvedelidze, A.A. Kotova, D. Marković	
UC	D.V. Kamanin	
STL	E.V. Ivanova, V.V. Litsitis	
4.	**Development of JINR's grantmaking activities and participation in special-purpose programmes for financing scientific research**	**S.N. Nedelko** **O.-A. Culicov**
DSOA	N.A. Boklagova, D.S. Korobov, Ya.L. Martovskaya, N.I. Sissakian	
5.	**Support for the operation of JINR's dissertation councils**	**S.N. Nedelko** **A.S. Zhemchugov**
DSOA	T.B. Ivashkevich, N.I. Sissakian	
VBLHEP	O.V. Belov	

6.	**Organizational support for JINR's activities under protocols and agreements**	**S.N. Nedelko** **O.-A. Culicov**
DSOA	N.V. Doroshkevich, O.V. Krupa, N. Kučerka, N.I. Sissakian	
ICD	E.A. Badawy, T.V. Keselis, A.A. Kotova, I.T. Suleymanov	
UC	D.V. Kamanin	
7.	**Provision for the operation and development of JINR's Internet resources**	**S.N. Nedelko** **O.-A. Culicov**
DSOA	N.A. Boklagova, V.E. Fufaeva, D.S. Korobov, A.G. Nanev, N.I. Sissakian, B.M. Starchenko	
CSS Office	N.V. Borozna, D.R. Bulatova, N.V. Zaikina	
UC	D.V. Kamanin, A.A. Suschevich	
Editorial office of the weekly newspaper "Dubna: Science, Cooperation, Progress"	G.I. Myalkovskaya	
8.	**Preparation for the publication of the quarterly bulletin "JINR News" and the JINR Annual Report**	**S.N. Nedelko** **A.S. Zhemchugov**
DSOA	E.S. Asanova, I.V. Kronshtadtova, B.M. Starchenko, Yu.G. Shimanskaya, I.Yu. Shcherbakova	
9.	**Preparation of materials for the INIS system**	**S.N. Kruglova**
DSOA	B.M. Starchenko	
10.	**International cooperation**	**O.-A. Culicov**
ICD	E.A. Badawy, T.V. Keselis, A.A. Kotova, I.T. Suleymanov	
DSOA	T.V. Bogdanova, N.A. Boklagova, D.S. Korobov, N. Kučerka, A.S. Zhemchugov	
11.	**Support for the development and implementation of the services of the JINR digital ecosystem in the part relevant to the profile of DSOA activities**	**N. Kučerka** **O.-A. Culicov**
MLIT	S.D. Belov, D.V. Neopolitansky, A.V. Prihodko	
12.	**Study of the history of the development of JINR as an international intergovernmental scientific organization**	**S.N. Nedelko** **A.S. Zhemchugov**
DSOA	V.E. Fufaeva	
ICD	E.A. Badawy	
Director Office	M.A. Khvedelidze	
Museum	E.K. Malaya, A.A. Rastorguyev, A.E. Zlotnikova	

Collaboration 1037

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
		YSU
Bulgaria	Sofia	SU
Egypt	Cairo, C	ASRT
Kazakhstan	Almaty, ALA	INP
Russia	Moscow, MOW	HSE
		IMEMO RAS
		IOS RAS
		MGIMO
		PFUR
		RIEPL
	Saint Petersburg, SPE	ITMO
South Africa	Somerset West, WC	iThemba LABS
Tunisia	Tunis	AAEA

09-9-1139-2019

Scientific and Educational Programmes for the Training of Highly Qualified Personnel

Theme leaders: G.V. Trubnikov
D.V. Kamanin
W. Badawy

Participating countries and international organizations:
Armenia, Azerbaijan, Belarus, Bulgaria, Cuba, Egypt, Kazakhstan, Mongolia, Russia, Serbia, South Africa, Tunisia, Uzbekistan, Vietnam.

The problem under study and the main purpose of the research:
Development and implementation of human capacity-building programmes in JINR to meet the demands of the Member States in highly-qualified specialists, as well as to provide for supply of scientific and engineering staff for the needs of the Institute is a key task, which includes work with various target audiences, counting schoolchildren and school teachers.

For these purposes, the UC, together with universities of JINR Member States, creates conditions for students and PhD students from universities in the Member States to enable them to work on their qualification theses based on research conducted in the laboratories of the Institute, supports activities of JINR-based university departments in the hosting country, participates in creation and development of network training programmes, trains students, PhD students, and interns on the basis of cooperation agreements with universities of JINR Member States, as well as international organizations. An important component of human capacity-building activities is organization and running of international student practices and schools for young people from the Member States of the Institute; building and maintenance of educational and laboratory infrastructure intended for hands-on training in scientific and engineering disciplines; support and further development of the system of training courses aimed at gaining or improving professional skills and qualifications of JINR technical and engineering personnel.

Development of JINR outreach programme aimed at promotion of modern science achievements among school students and teachers, organization of excursions and online tours of JINR main facilities; participation in science festivals, exhibitions, and forums promoting JINR; development of cooperation and interaction with school educational centres; design and production of information materials for JINR information centres, administration of the UC groups in social media.

Expected results upon completion of the theme stages or projects:
Participation in the development of lecture courses and seminars for students and PhD students of the JINR-based departments of Russian universities.

Training of students and PhD students in JINR on the basis of cooperation agreements with universities from JINR Member States and other countries.

Support and further development of the Engineering and Physics Training Workshop for students and PhD students from JINR Member States and partner countries.

Support of the system of assigning Institute employees to JINR for preparation of their PhD theses without completing the academic programme of the PhD course. Participation in the Institute system of attestation of scientific personnel.

Organization and running of JINR student programme "START", online programme "INTEREST", international student schools and practices.

Launch of the short-term Advanced Science Programme for Young Researchers and Engineers ("ASPYRE") in JINR.

Creation of organizational prerequisites to ensure JINR contribution to national human capacity-building programmes for large-scale infrastructure projects in JINR Member States and other partner countries.

Further development of the licensed system of training courses aimed at acquiring or improving professional skills and qualifications of technical and engineering personnel of the Institute.

Implementation of the advanced training programmes for school teachers from JINR Member States.

Support of Dubna Interschool Physics and Mathematics Open Classroom and science programmes for school children, interaction with educational institutions and natural science programmes for school children.

Further development of the network of JINR Information centres.

Supply of JINR-based departments in partner universities and JINR information centers in the Member States with electronic and printed materials, information resources.

Organization and running of the JEMS programme to further promote and expand contacts with universities and educational centres in JINR Member States, Associated Members and partner countries.

Development of printed and electronic popular science information materials promoting the Institute and modern scientific achievements for use in educational processes.

Provision of JINR partner universities and information centres in the Member States with electronic and printed informational materials.

Extension of JINR partner network through further development of educational programmes.

Expected results in the current year:
Support and supervision of the educational process at JINR-based departments of Russian universities, explore possibilities for extended stay in Dubna for senior course students.

Support of the system of assigning young researchers to JINR laboratories for preparation of their PhD theses.

Organization and running of the International Student Practices in JINR fields of research for university students from JINR Member States. Synchronization of practices for South Africa and ARE and the preceding science schools. Attraction of new countries for participation in the programme.

Organization and running of JINR student programme "START" (summer and winter sessions) and online programme "INTEREST" (spring and autumn waves). Attraction of new leaders of educational programmes from among young scientists.

Development of organizational prerequisites for JINR human capacity-building programmes for national large-scale infrastructure projects at the requests of Member States and interested partners.

Launch of a regular student school for future teachers.

Organization and running of joint scientific events and schools with partner universities at JINR, targeting junior course students.

Support and further development of an information system on preparation of qualification theses by students and PhD students from universities of the JINR Member States in the Institute laboratories.

Increased load of the Engineering and Physics Training Workshop for students and PhD students from JINR Member States, as well as young JINR staff members, further development of existing laboratory training workshops, development of training workshops at LINAC-200. Further development of educational programmes on accelerator arrangement and beam diagnostics, on electronics based on chip programmed logics.

Regular work of the language courses programme aimed at teaching Russian as a foreign language and English to JINR personnel in a club format. Extension of the range of studied languages.

Running of skill development and refresher courses for JINR technical and engineering staff. Organization of training in labour safety.

Organization of scientific schools for physics teachers from JINR Member States, including those run in English.

Extension of educational programmes for high school students from JINR partner countries.

Further development of virtual tours of JINR main facilities and video conferences with educational institutions in JINR Member States. Organization and support of science schools for school children and group visits to JINR for JINR-based university departments and information centres.

Expansion of the user community of the “Engineers of the Future” educational and methodology complex in JINR hosting country, adaption of parts of its materials for use in other JINR Member States.

Provide for presence of the human capacity-building component in the programme of events planned to celebrate JINR 70th Anniversary.

Organization of JINR participation in science festivals, run by universities in JINR hosting country within the framework of celebrating JINR 70th Anniversary. Trial participation in science festivals in other JINR Member States.

Opening of JINR Information Centres in new locations in the hosting country and other Member States.

Organization and running of the JEMS programmes in accordance with the international cooperation plan.

Area of activity	Leaders
Laboratory (Subdivision)	
Leaders from laboratories	Responsible from laboratories
1. Organization of the educational process at JINR	**D.V. Kamanin W. Badawy**
DLNP Ye. A. Yakushev D.V. Naumov	A. Baimukhanova, A.G. Olshevskiy, A.S. Zhemchugov
BLTP D.I. Kazakov	N.V. Antonenko, V.V. Braguta
FLNP E.V. Lychagin V.N. Shvetsov	M.V. Avdeev, A.V. Belushkin, S.A. Kulikov
VBLHEP A.V. Butenko N.A. Strokovsky O.V. Belov	A.I. Malakhov, A.O. Sidorin, D.V. Peshekhonov
FLNR S.I. Sidorchuk	A.V. Karpov, V.A. Rachkov
MLIT S.V. Shmatov V.V. Korenkov T.A. Strizh	O.Yu. Derenovskaya, I.S. Pelevanyuk, O.I. Streltsova
LRB A.N. Bugay	I.V. Koshlan, A.V. Boreiko, R.A. Kozhina
Directorate V.D. Kekelidze L. Kostov B.N. Gikal	V.A. Matveev, B.Yu. Sharkov
ICD O.-A. Culicov	E.A. Badawy
2. Outreach and JINR promotion	**A.A. Suschevich**
DLNP	N.V. Anfimov, M.V. Shirchenko
BLTP	A.V. Andreev, A.V. Frizen
FLNP	C. Khramko
VBLHEP	D.K. Dryablov
FLNR	K.B. Gikal, A.V. Karpov
MLIT	I.S. Pelevanyuk
LRB	T.S. Khramko, I.A. Kolesnikova, Yu.S. Severyukhin
JINR Universal Library	O.V. Gaponova

3. Engineering and physics training **M.A. Nozdrin**

VBLHEP	K.G. Osipov, R.V. Pivin
DLNP	A.N. Trifonov, A.S. Zhemchugov
FLNR	D.S. Belozerov, A.Yu. Bodrov, V.A. Buzmakov, K.B. Gikal, A.M. Kapitonov, A.V. Khalkin, E.V. Pishchalnikova, A.V. Sabelnikov, K.A. Verlamov, V.Yu. Zhegolev, D.A. Zlydenny

4. JINR information centres **D.V. Kamanin**
JEMS programme

DLNP D.V. Naumov	E.N. Dubovik
BLTP N.V. Antonenko	A.V. Andreev
FLNP V.N. Shvetsov	A.Yu. Nezvanov
VBLHEP R. Lednický	A.O. Sidorin
FLNR S.I. Sidorchuk	G. Kaminski, A.V. Karpov
MLIT O.Yu. Derenovskaya O.I. Streltsova	I.S. Pelevanyuk
LRB A.N. Bugay	I.V. Koshlan
DSOA S.N. Nedelko	A.S. Zhemchugov
ISD O.-A. Culicov	E.A. Badawy, Yu.N. Polyakova

Project in the theme:

Name of the project	**Project leader**	**Project code**
Laboratory Responsible from laboratories		**Status**
1. Open information and educational environment for supporting fundamental and applied multidisciplinary research at JINR	**Yu.A. Panebrattsev** **K.V. Klygina** **N.E. Sidorov**	09-9-1139-1-2021/2028 Realization

VBLHEP A.P. Cheplakov	A.S. Averichev, A.A. Aparin, O.V. Belov, E.I. Golubeva, P.N. Grigoriev, A.A. Korobitsyn, N.A. Lashmanov, V.Yu. Rogov, Vinh Ba Luong, Yu.D. Orlova, M.P. Osmachko, N.E. Pukhaeva, P.D. Semchukov, N.I. Vorontsova, G.A. Yarygin
FLNR A.V. Karpov A.S. Denikin	D. Aznabayev, T. Isatayev, S.M. Lukianov, K. Mendibayev, M.A. Naumenko, V.A. Rachkov
LRB A.N. Bugai I.V. Koshlan	A.V. Chizhov, D.V. Davydov, I.S. Gordeev, M.I. Kapralov, V.A. Krylov, E.A. Nasonova, E.E. Pavlik, A.Yu. Rosanov, A.K. Ryumin

Abstract and scientific rationale:
The integration of science, education and the achievements of modern technologies is becoming especially important as one of the most important factors for the development of the economy and the social structure of a society based on knowledge-intensive technologies. To solve these tasks, it is necessary to combine the efforts of various universities and research centers to create new training courses and research practices.

The Joint Institute for Nuclear Research, as an international organization, which unites member states, associate members and dozens of collaborating universities from around the world, offers its solution to this problem in the form of the implementation of the project "Open information and educational environment for supporting fundamental and applied multidisciplinary research at JINR".

Project purposes:
– use of modern educational technologies for the preparation of university students and improving the qualifications of specialists for work at JINR;

– attracting talented young people from the participating countries and countries cooperating with JINR to participate in research projects of the Institute;

– implementation of the results in the field of fundamental and applied research obtained at JINR into the educational process in the member countries and associate members of JINR, expanding the geography of cooperation;

– cooperation with the world's leading scientific centers and universities in the field of creating educational resources for physics teachers and high school students;

– increasing the awareness of fundamental and applied multidisciplinary research conducted at JINR and the JINR brand among a wide audience, publishing of courses prepared by leading JINR specialists on international platforms of open education;

– creation of educational and exhibition content on JINR topics at the level of leading scientific centers.

Expected results upon completion of the project:
Information support of the main areas of fundamental and applied research at JINR.

Creation of online courses and new educational programs on the subject of the Institute's activities for modern educational platforms.

Development of a project in creation of virtual, remote and hands-on practicums for the study of nuclear physics and applied research.

Development of exhibition activities devoted to the achievements of JINR and modern science in the Russian Federation and JINR partner countries.

Creation of multimedia resources and web solutions to support JINR information centres.

Creation of digital educational materials and research practicums for schoolchildren to study physics and biology at an advanced level in schools of the Russian Federation and partner countries.

Creation and implementation in the educational process in Russian schools of an educational and methodological complex for studying physics at an advanced level "Physics 7-9. Engineers of the Future".

Expected results of the project in the year:
Creation and development of an information system for supporting applied research at the NICA accelerator complex.

Cooperation with NRNU MEPhI in the field of creating online courses in nuclear physics, engineering, atomic and related technologies and their further publishing at the educational portals of JINR (edu.jinr.ru) and NRNU MEPhI (online.mephi.ru), and website physics-engineers.ru.

Using augmented, extended and virtual reality to prepare exhibition stands dedicated to the main facilities and experimental research at JINR.

Development of a virtual practicum on radiobiology for working with an electron microscope using the example of the study of microfossils and organic compounds in meteorites and in ancient terrestrial rocks.

Development of a platform for remote practicums together with iThemba LABS.

Development of hands-on practicums and new virtual laboratory works on nuclear electronics and the basics of ionizing particle detection.

Organizing practices and workshops for university students and teachers as part of the development of the Virtual Laboratory project.

Creation of a series of videos on the use of carbon-free energy sources and the basics of experimental nuclear physics for schoolchildren for educational institutions in South Africa.

Creation of electronic educational materials for the support site of the educational and methodological complex for studying physics at an advanced level in Russian schools "Physics 7-9. Engineers of the Future".

Creation of electronic educational materials for the elective course "Nuclear Physics" and the course "Introduction to Nuclear Physics and Nuclear Electronics" for university students and senior students of specialized schools, including research practicums in nuclear physics (hands-on, virtual and remote).

Activity of the theme:

Name of the activity	Leaders	Implementation period Status
Laboratory Responsible from laboratories		
1. Creation of educational and methodological complexes for studying physics at the basic and advanced levels for basic and secondary general education	**G.V. Trubnikov** **Yu.A. Panebrattsev**	2026-2028 Realization

UC	S.N. Balalykin, I.A. Lomachenkov, Hoang Bao Hanh Nguyen, L.V. Platonova, O.A. Smirnov, T.G. Stroganova, T.E. Strokovskaya, D.V. Zhuravleva
VBLHEP	E.I. Golubeva, K.V. Klygina, N.A. Lashmanov, Ba Vinh Luong, S.P. Merts, Yu.D. Orlova, M.P. Osmachko, D.O. Ponkin, P.D. Semchukov, A.O. Sidorin, N.E. Sidorov, N.I. Vorontsova, G.A. Yarygin
BLTP	M. Hnatič, D.I. Kazakov
LRB	A.N. Bugai, I.V. Koshlan, E.A. Nasonova
DLNP	D.V. Naumov, V.A. Rozhkov, M.V. Shirchenko
FLNP	N.A. Fedorov

Abstract and scientific rationale:

The problem of training engineering personnel is common not only for Russia, but also for other JINR partner countries. To solve this problem, it is proposed to update the curricula and develop educational and methodological complexes.

Improving the level of physical and engineering education is impossible without including in physics courses information about the modern picture of the world, examples of the development of new technologies at the intersection of physics, chemistry, biology, radiobiology and astrophysics. JINR as an international multydisciplinary scientific center has all the capabilities for this.

Within the framework of the project (activity), it is planned to create new curricula and textbooks for studying physics at the basic and advanced (aimed at training future engineers) levels of basic general (7-9 grades) and secondary general (10-11 grades) education.

Considering that physics is an experimental science, within the framework of the proposed project (activity), a modern practical course will be developed with a large number of laboratory and practical works aimed at developing students' research and engineering skills. The key component included in the teaching and methodological complex is a support site with an electronic format of textbooks, a media library of digital educational resources for schoolchildren, as well as various methodological materials for the teacher.

Goals of the activity:
– to increase interest in studying physics and engineering activities among schoolchildren, and as a result – to increase the level of knowledge of physics for further education in technical universities and colleges;

– to develop materials for methodological support of physics teachers in the implementation of new teaching and methodological complexes in the educational process;

– to participate jointly with the Russian Academy of Sciences in the development and implementation of a unified state textbook in schools;

– to conduct an examination of the created teaching and methodological complexes within the framework of expert procedures of the Russian Academy of Sciences and the teaching community;

– to implement the project results in educational programs for the study of physics in schools and universities of the JINR partner countries.

Expected results at the end of the activity:
Creation of four teaching and methodological complexes for studying physics at the basic and advanced (aimed at training future engineers) levels of basic general (7-9 grades) and secondary general (10-11 grades) education:
• "Physics 7–9. Basic Level";
• "Physics 7–9. Engineers of the Future";
• "Physics 10–11. Basic Level";
• "Physics 10–11. Engineers of the Future".

Development of a modern laboratory practical course for Russian schools, including the use of ICT, and publication of a corresponding teachers' guide.

Implementation of the project results in the Russian Federation and interested countries. Creation of an information environment for the teaching community to use the project results.

Expected major results in the current year:
Development of the concept of educational and methodological complexes for studying physics at the basic level of basic general and secondary general education.

Preparation of the manuscript of the unified state textbook on physics for basic general education at the basic level (grades 7– 9).

Preparation of the unified state textbook on physics for secondary general education at the basic level (grades 10–11).

Conducting an expertise of textbooks in the expert council of the Russian Academy of Sciences and the educational community. Preparing textbooks for publication by the Prosveshcheniye Publishing house.

Development of a support website for the educational and methodological complex "Physics 7–9. Engineers of the Future".

Development of laboratory, research and practical works for a physics practicum using information and communication technologies and "smartphonics".

Development of media resources in English or other languages for studying physics in schools in JINR partner countries.

Collaboration 1139

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	YSU
Azerbaijan	Baku, BA	IP
Belarus	Gomel, HO	GSU
	Minsk, MI	BSTU
		INP BSU
Bulgaria	Sofia	INRNE BAS
		SU
Cuba	Havana	ASC
Egypt	Cairo, C	ASRT
		EAEA
Kazakhstan	Almaty, ALA	KazNU
	Astana, AST	ENU
	Oskemen (Ust-Kamenogorsk), VOS	EKU
Mongolia	Ulaanbaatar	MNUE
		NUM
Russia	Arkhangelsk, ARK	NArFU
		NSMU
	Belgorod, BEL	BelSU

Country or International Organization	City, region	Institute or laboratory
	Dolgoprudny, MOS	MIPT
	Dubna, MOS	Uni Dubna
	Grozny, CE	CheSU
	Irkutsk, IRK	ISU
	Ivanovo, IVA	IvSU
	Kazan, TA	KFU
	Kostroma, KOS	KSU
	Krasnodar, KDA	KubSU
	Moscow, MOW	BMSTU
		HSE
		MEPhI
		MPEI
		MSU
		PFUR
	Novocherkassk, ROS	SRSPU NPI
	Petropavlovsk-Kamchatsky, KAM	KamGU
	Saint Petersburg, SPE	SPbSPU
		SPbSU
	Samara, SAM	SNRU
	Smolensk, SMO	SmolGU
	Tomsk, TOM	TPU
		TSU
	Tula, TUL	TulSU
	Vladikavkaz, SE	NOSU
	Vladivostok, PRI	FEFU
	Voronezh, VOR	VSU
	Yakutsk, SA	NEFU
	Yaroslavl, YAR	YSU
	Yekaterinburg, SVE	UrFU
Serbia	Novi Sad, VO	UNS
	Sremska Kamenica, VO	Educons Univ.
South Africa	Bellville, WC	UWC
	Pretoria, GT	UNISA
	Somerset West, WC	iThemba LABS
	Stellenbosch, WC	SU
Tunisia	Tunis	AAEA
Uzbekistan	Samarkand, SA	SamSU
	Tashkent, TK	AS RUz
		TashSTU
Vietnam	Hanoi, HN	IOP VAST
		VINATOM

09-3-1117-2014

DIAS-TH
Dubna International Advanced School of Theoretical Physics

Theme leader: I.G. Pirozhenko
Rector of DIAS-TH: E.A. Kolganova

Participating countries and international organizations:
Armenia, Czech Republic, Russia, Serbia.

The problem under study and the main purpose of the reserch:
The Dubna International Advanced School of Theoretical Physics (DIAS-TH) is a scientific and educational project aimed, firstly, at training senior students, post-graduate students and young scientists on research topics of the Laboratory of Theoretical Physics, priority scientific areas of JINR research and modern areas of physics. The second goal of the project is to expand international cooperation and attract young scientists from Russia and the participating countries to JINR.

Project in the theme:

	Name of the project	Project leaders	Project code
Laboratory	Responsible from laboratories		
1.	**DIAS-TH** **Dubna International Advanced School of Theoretical Physics**	**I.G. Pirozhenko** **E.A. Kolganova**	09-3-1117-1-2024/2028

BLTP N.V. Antonenko, A.N. Baushev, E.A. Davydov, M. Hnatič, A.P. Isaev, M.A. Ivanov, R.V. Jolos, G.V. Kalagov, O.P. Klimenko, E.A. Kolganova, N.M. Lebedev, L. Mižišin, V.A. Osipov, M.V. Savina, S.S. Sidorov, A.S. Sorin, O.V. Teryaev, P.V. Tretyakov, V.I. Zhuravlev, 4 students

MLIT Yu.L. Kalinovsky, V.V. Korenkov, S.V. Shmatov

FLNP V.L. Aksenov

VBLHEP V.D. Kekelidze

DLNP V.A. Bednyakov, D.V. Naumov

FLNR A.S. Denikin, Yu.Ts. Oganessian

Brief annotation and scientific rationale:
The Dubna International Advanced School of Theoretical Physics (DIAS-TH) is a scientific and educational project that has successfully been developing at the N.N. Bogolyubov Laboratory of Theoretical Physics since 2003.

The project is aimed, firstly, at training senior students, post-graduate students and young scientists on research topics of the Laboratory of Theoretical Physics, priority scientific areas of JINR research and modern areas of physics. For this purpose, schools of various levels are regularly held for students, postgraduates and young scientists from the JINR Member States and other countries, and lectures are published. In addition, review lectures on problems of modern physics are organized for JINR staff. Both researchers of JINR Laboratories and internationally recognized scientists from scientific centers of the Russian Federation and foreign scientific centers are involved in giving lectures. Lectures given by the world's leading experts at DIAS schools stimulate the emergence of new areas of research at BLTP. The project provides in-depth training in the field of modern theoretical and mathematical physics. To this end, the project participants cooperate with the JINR University Center, as well as with the JINR-based Departments at Dubna State University, Moscow Institute of Physics and Technology, Moscow State University.

Secondly, the project is aimed at dissemination of scientific knowledge, namely, informing schoolchildren and people who are not professionally engaged in science about the achievements of modern theoretical physics, in particular, about current research at BLTP. In addition, one of the objectives of the project is to encourage young scientists to cooperate with BLTP JINR.

Expected results upon completion of the project:
Within the framework of the project "Dubna International School of Modern Theoretical Physics", in educational activities it is supposed to organize regular schools on JINR priority topics and modern scientific areas for schoolchildren, students, post-

graduate students and young scientists from the JINR Member States and other countries; to carry out review lectures on problems of modern physics for JINR staff; to continue/renew cooperation with scientific organizations of the Russian Federation and foreign scientific organizations, higher educational institutions in educational activities; to participate in the educational activities at the JINR-based departments of Moscow State University, MEPhI, MIPT, Dubna State University together with the JINR University Center; to organize schools for students, graduate students and young scientists in cooperation with the Moscow Institute of Physics and Technology, Yerevan Institute of Physics, etc.; to take part in international scientific and educational projects.

In the dissemination of physical knowledge it is planned to collabotate with other projects promoting popular science, such as Post Nauka, with foundations of the Russian Federation (Science Foundation of the Russian Federation, Federal Target Programs) and international foundations in organizing and conducting international schools for students, graduate students and young scientists.

It is also planned to support the DIAS-TH website, to provide video broadcasting of lectures, to record the video of lectures, and to support the digital archive of DIAS-TH.

Expected results of the project in the current year:
Organization at BLTP of three schools on theoretical physics for students, post-graduates and young scientists:
– DIAS-TH Winter school on quantum effects in gravity (Chairman of the Organizing Committee I.G. Pirozhenko);
– School of fundamental interactions (Chairmen of the Organizing Committee N.V. Antonenko, E.A. Kolganova, O.V. Teryaev);
– International Summer School "Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems" (Chairman of the Organizing Committee M. Hnatič).

Organization of one-day lectures/discussions and regular seminars for students and post-graduates and JINR researchers.

Computer processing of video records of lectures, support of digital archive of video records.

Support of Web-site of DIAS-TH.

Collaboration 1117

Country or International Organization	City, region	Institute or laboratory
Armenia	Yerevan, ER	AANL
Czech Republic	Prague, PR	CTU
Russia	Chernogolovka, MOS	LITP RAS
	Dolgoprudny, MOS	MIPT
	Kazan, TA	KFU
	Moscow, MOW	HSE
		ITEP
		LPI RAS
		MI RAS
		MSU
		SAI MSU
		SINP MSU
		Skoltech
	Novosibirsk, NVS	NSU
	Protvino, MOS	IHEP
	Saint Petersburg, SPE	SPbSU
	Saratov, SAR	SGU
	Troitsk, MOW	INR RAS
Serbia	Nis, NI	Univ.

Alphabetical index: International Cooperation

Pabna, Ra

PUST | Pabna University of Science and Technology | https://pust.ac.bd/, 1146

Belarus

Gomel, HO

GSTU | Educational Institution "Pavel Sukhoi State Technical University of Gomel" | http://www.gstu.by/, 1135, 1136, 1081, 1086

GSU | Educational Institution "Francisk Skorina Gomel State University" | http://gsu.by/, 1135, 1081, 1086, 1119, 1131, 1139

IRB NASB | State Scientific Institution "Institute of Radiobiology of the National Academy of Sciences of Belarus" | http://www.irb.basnet.by/, 1146, 1077

Khoiniki, HO

PSRER | State Nature Conservation Research Institution "Polesie State Radiation and Ecological Reserve" | https://zapovednik.by/, 1146

Minsk, MI

BSTU | Educational Institution "Belarusian State Technological University" | http://www.belstu.by/, 1149-2, 1149-4, 1139

BSU | Educational Institution "Belarusian State University" | http://www.bsu.by/, 1065, 1144, 1146, 1107, 1131

BSUIR | Educational Institution "Belarusian State University of Informatics and Radioelectronics" | http://www.bsuir.by/, 1086, 1147

CGM NASB | Government Agency "Center for geophysical monitoring of National Academy of Sciences of Belarus" | https://cgm.by/, 1126

HMTI NASB | State Scientific Institution "A.V. Luikov Heat and Mass Transfer Institute of the National Academy of Sciences of Belarus" | http://www.itmo.by/, 1146

IAP NASB | State Scientific Institution "Institute of Applied Physics of the National Academy of Sciences of Belarus" | http://iaph.bas-net.by/, 1081, 1086

IBCE NASB | State Scientific Institution "Institute of Biophysics and Cell Engineering NAS of Belarus" | https://ibce.by/, 1147, 1077

IE NASB | Republican Research and Production Unitary Enterprise "Institute of Power Engineering of the National Academy of Sciences of Belarus" | http://ipe.by, 1065, 1151, 1130

IEB NASB | State Scientific Institution "V.F. Kuprevich Institute of Experimental Botany of the National Academy of Sciences of Belarus" | https://botany.by/, 1146

IGIC NASB | State Scientific Institution "Institute of General and Inorganic Chemistry of National Academy of Sciences of Belarus" | https://www.igic.bas-net.by/, 1146

IM NASB | State Scientific Institution "Institute of Mathematics of the National Academy of Sciences of Belarus" | http://im.bas-net.by/, 1137, 1119

INP BSU | Institute for Nuclear Problems of Belarusian State University | http://www.inp.bsu.by/, 1065, 1118, 1149-3, 1135, 1081, 1085, 1087, 1151, 1097, 1150, 1144, 1146, 1077, 1119, 1107, A004, 1126, 1139

Inst. Physiology NASB | State Scientific Institution "Institute of Physiology of the National Academy of Sciences of Belarus" | http://physiology.by/, 1077

IP NASB | State Scientific Institution "B.I. Stepanov Institute of Physics of the National Academy of Sciences of Belarus" | http://ifan.basnet.by/, 1065, 1118, 1135, 1136, 1137, 1081, 1151, 1086, 1144, 1119

JIPNR-Sosny NASB | State Scientific Institution "Joint Institute for Power and Nuclear Research - Sosny" of the National Academy of Sciences of Belarus | http://sosny.bas-net.by/, 1065, 1118, 1135, 1107

OELT NASB | State Scientific and Production Association "Optics, Optoelectronics and Laser Technology" | https://oelt.basnet.by/, 1130

PTI NASB | State Scientific Institution "Physical-Technical Institute of the National Academy of Sciences of Belarus" | http://www.phti.by/, 1065

RI PCP BSU | Research Institute for Physical Chemical Problems of the Belarusian State University | http://fhp.bsu.by/, 1149-2, 1146

SOL instruments | Limited Liability Company "SOL instruments" | https://solinstruments.by/, 1147

SPMRC NASB | State Scientific and Production Association "Scientific and Practical Center of the National Academy of Sciences of Belarus for Materials Science" | https://physics.by/, 1149-2, 1137, 1146, 1077

UIIP NASB | State Scientific Institution "The United Institute of Informatics Problems of the National Academy of Sciences of Belarus" | http://www.uiip.bas-net.by/, 1118

Belgium

Antwerp, VAN

UAntwerp | University of Antwerp | http://www.uantwerpen.be/, 1083

Brussels, BRU

ULB | Université Libre de Bruxelles | http://www.ulb.ac.be/ VUB | Vrije Universiteit Brussel | http://www.ulb.be/, 1136, 1083

VUB | Vrije Universiteit Brussel | http://www.vub.ac.be/, 1083

Ghent, VOV

UGENT | Ghent University | http://www.ugent.be/, 1083, 1099

Leuven, VBR

KU Leuven | Catholic University of Leuven | http://www.kuleuven.be/, 1083, 1100

Louvain-la-Neuve, WBR

UCL | Catholic University of Louvain | http://uclouvain.be/, 1136, 1083, 1096

Mons, WHT

UMONS | University of Mons | http://web.umons.ac.be/, 1083

Brazil

Campinas, SP

UNICAMP | State University at Campinas | http://www.unicamp.br/, 1088

Florianopolis, SC
UFSC | Federal University of Santa Catarina | http://ufsc.br/, 1136

Itabuna, BA
UFSB | Federal University of Southern Bahia | https://ufsb.edu.br/, 1146

Juiz de Fora, MG
UFJF | Federal University of Juiz de Fora | http://www2.ufjf.br/, 1138

Natal, RN
IIP UFRN | International Institute of Physics of the Federal University of Rio Grande do Norte | http://www.iip.ufrn.br/, 1137

Niteroi, RJ
UFF | Federal Fluminense University | http://www.uff.br/, 1136, 1130

Porto Alegre, RS
UFRGS | Federal University of Rio Grande de Sul | http://www.ufrgs.br/, 1088

Rio de Janeiro, RJ
CBPF | Brazilian Center for Physics Research | https://www.gov.br/cbpf/pt-br, 1083
UERJ | State University of Rio de Janeiro | https://www.uerj.br/, 1083

Santo Andre, SP
UFABC | Federal University of ABC | http://www.ufabc.edu.br/, 1138, 1088

Sao Jose dos Campos, SP
ITA | Technological Institute of Aeronautics | http://www.ita.br, 1136

Sao Paulo, SP
UEP | Unit of Professional Education Santa Casa de São Paulo | http://www.santacasasp.org.br/), 1136
Unesp | São Paulo State University | https://www.international.unesp.br/, 1083
USP | University of São Paulo | http://www5.usp.br/, 1137, 1138, 1088

Bulgaria*

Blagoevgrad
AUBG | American University in Bulgaria | http://www.aubg.edu/, 1087
SWU | South-West University "Neofit Rilski" | http://www.swu.bg/, 1096

Plovdiv
MUP | Medical University of Plovdiv | https://mu-plovdiv.bg/, 1107
PU | Plovdiv University "Paisii Hilendarski" | https://uni-plovdiv.bg/, 1065, 1096, 1146, 1100
UFT | University of Food Technologies Plovdiv | http://uft-plovdiv.bg/, 1146

Sofia
IAPS | Institute for Advanced Physics Studies | http://iaps.institute/, 1088
IE BAS | Academician Emil Djakov Institute of Electronics of the Bulgarian Academy of Sciences | https://www.ie-bas.org/, 1149-2, 1146, 1077
IEES BAS | Institute of Electrochemistry and Energy Systems "Academic Evgeni Budevski" of the Bulgarian Academy of Sciences | http://iees.bas.bg/, 1149-2
IMech BAS | Institute of Mechanics of the Bulgarian Academy of Sciences | http://www.imbm.bas.bg/, 1137, 1077
INRNE BAS | Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences | http://www.inrne.bas.bg/, 1118, 1149-2, 1135, 1136, 1138, 1066, 1083, 1087, 1146, 1100, 1126, 1139
Inst. Microbiology | Stephan Angeloff Institute of Microbiology of the Bulgarian Academy of Sciences | http://microbio.bas.bg/, 1087, 1077
ISSP BAS | Georgi Nadjakov Institute of Solid State Physics of the Bulgarian Academy of Sciences | http://www.issp.bas.bg/, 1149-2, 1137
NBU | New Bulgarian University | http://www.nbu.bg/, 1136
NCRRP | National Centre of Radiobiology and Radiation Protection | http://ncrrp.org/, 1077
SU | Sofia University "St. Kliment Ohridski" | http://www.uni-sofia.bg/, 1118, 1138, 1066, 1081, 1083, 1087, 1088, 1096, 1119, 1037, 1139
UCTM | University of Chemical Technology and Metallurgy | https://uctm.edu/en/, 1149-2, 1097

Canada

Corner Brook, NL
MUN | Memorial University of Newfoundland - Grenfell Campus | http://www.grenfell.mun.ca/, 1135

Montreal, QC
UdeM | University of Montreal | http://www.umontreal.ca/, 1137

Sherbrooke, QC
UdeS | University of Sherbrooke | https://www.usherbrooke.ca/, 1137

Toronto, ON
YU | York University | https://www.yorku.ca/, 1096

Vancouver, BC
TRIUMF | Canada's particle accelerator centre | http://www.triumf.ca/, 1081, 1096
UBC | University of British Columbia | http://www.ubc.ca/, 1096

CERN

Geneva, CH
CERN | European Organization for Nuclear Research | http://home.cern/), 1118, 1138, 1081, 1083, 1085, 1087, 1088, 1096, 1099, 1146, 1119

* The cooperation may be limited by the conditions adopted unilaterally by the State.

Chile

Arica, AP

UTA | University of Tarapacá | https://www.uta.cl, 1135

Santiago, RM

UNAB CTEPP | Theoretical and Experimental Center for Particle Physics of Andrés Bello National University | https://www.unab.cl/en/, 1135, 1150

Valparaiso, VS

USM | Federico Santa María Technical University | http://www.usm.cl/, 1065, 1096

China

Beijing, BJ

CIAE | China Institute of Atomic Energy | http://www.ciae.ac.cn/, 1065, 1136, 1087, 1088, 1119

IHEP CAS | Institute of High Energy Physics of the Chinese Academy of Sciences | http://www.ihep.ac.cn/, 1065, 1118, 1135, 1083, 1085, 1087, 1151, 1099, 1144

ITP CAS | Institute of Theoretical Physics of the Chinese Academy of Sciences | http://english.itp.cas.cn/, 1136

PKU | Peking University | https://english.pku.edu.cn/, 1136, 1083, 1146, 1130

Tsinghua | Tsinghua University | https://www.tsinghua.edu.cn/en/, 1065, 1137, 1083, 1099

UCAS | University of Chinese Academy of Sciences | https://english.ucas.edu.cn/, 1065, 1138, 1130

Dongguan, GD

CSNS | China Spallation Neutron Source | https://english.ihep.cas.cn/csns/, 1149-2, 1146

Guangzhou, GD

SYSU | Sun Yat-Sen University | https://www.sysu.edu.cn/sysuen, 1135, 1138, 1099

Haikou, HI

HNU | Hainan University | http://en.hainanu.edu.cn, 1135

Hangzhou, ZJ

ZJU | Zhejiang University | http://www.zju.edu.cn/english/, 1083

Harbin, HL

HEU | Harbin Engineering University | https://english.hrbeu.edu.cn/, 1149-2

Hefei, AH

ASIPP CAS | Institute of Plasma Physics of the Chinese Academy of Sciences | http://english.ipp.cas.cn/, 1065, 1127

USTC | University of Science and Technology of China | http://www.ustc.edu.cn/, 1065, 1088

Hengyang, HN

USC | University of South China | http://english.usc.edu.cn/, 1065, 1138

Huzhou, ZJ

HUTC | Huzhou University | https://www.cuesc.com/school/HUTC, 1065

Jinan, SD

SDU | Shandong University, Jinan Campus | http://en.sdu.edu.cn/, 1065, 1151

Lanzhou, GS

IMP CAS | Institute of Modern Physics of the Chinese Academy of Sciences | https://english.imp.cas.cn/, 1065, 1129, 1135, 1136, 1066, 1130

LZU | Lanzhou University | https://en.lzu.edu.cn/, 1136

Nanchang, JX

NCU | Nanchang University | https://english.ncu.edu.cn/, 1138

Qingdao, SD

SDU | Shandong University, Qingdao Campus | https://www.en.qd.sdu.edu.cn/, 1065

Shanghai, SH

Fudan | Fudan University | http://www.fudan.edu.cn/, 1065, 1151

SHNU | Shanghai Normal University | https://english.shnu.edu.cn/, 1136

SHU | Shanghai University | https://en.shu.edu.cn, 1136, 1138

SINAP CAS | Shanghai Institute of Applied Physics of the Chinese Academy of Sciences | http://english.sinap.cas.cn/, 1065, 1088

SJTU | Shanghai Jiao Tong University | https://www.icrr.u-tokyo.ac.jp/en/, 1099

Wuhan, HB

CCNU | Central China Normal University; Institute of Particle Physics | http://physics.ccnu.edu.cn/English.htm, 1065, 1066, 1087, 1088

HBUT | Hubei University of Technology | https://en.hbut.edu.cn/, 1088

Xi'an, SN

NINT | Northwest Institute of Nuclear Technology, 1146

XJTU | Xi'an Jiaotong University | https://en.xjtu.edu.cn/, 1146

Yichang, HB

CTGU | China Three Gorges University | https://www.en-ctgu.com/, 1065

Croatia

Split

UNIST | University of Split | http://www.unist.hr/, 1083, 1088

Zagreb

OIKON | Oikon Ltd. Institute for Applied Ecology | http://www.oikon.hr/, 1146

RBI | Rudjer Boskovic Institute | http://www.irb.hr/, 1135, 1083, 1088, 1146

UNIZIG | University of Zagreb | https://www.unizg.hr/homepage/, 1088

Cuba

Havana

ASC | Academy of Sciences of Cuba | http://www.academiaciencias.cu/, 1139

CEA | Center for Advanced Studies of Cuba | https://www.cea.cu/, 1077

CEADEN | Center of Technological Applications and Nuclear Development, 1088, A003
CNEURO | Cuban Neuroscience Center | https://www.biocubafarma.cu/node/6, 1077
CPHR | Center for Radiation Protection and Hygiene | https://www.cphr.edu.cu/, 1077
InSTEC | Higher Institute of Technologies and Applied Sciences | http://www.instec.cu/, 1065, 1149-2, 1066, 1086
UH | University of Havana | http://www.uh.cu/, 1146, 1077

San Jose de las Lajas

CENTIS | Center of Isotopes "CENTIS" | http://www.centis.cu/, 1077

Cyprus

Nicosia

UCY | University of Cyprus | http://www.ucy.ac.cy/, 1083

Czech Republic*

Prague, PR

CTU | Czech Technical University in Prague | http://www.cvut.cz/, 1148, 1149-2, 1138, 1085, 1146, 1100, 1126, 1117
CU | Charles University in Prague | http://www.cuni.cz/, 1136, 1085, 1099, 1144, 1100
IG CAS | Institute of Geology of the Czech Academy of Sciences | http://www.gli.cas.cz/, 1149-2
IP CAS | Institute of Physics of the Czech Academy of Sciences | http://www.fzu.cz/, 1149-2

Rez, ST

CVR | Centrum výzkumu Řež - Research centre Řež | http://cvrez.cz/, 1146
NPI CAS | Nuclear Physics Institute of the Czech Academy of Sciences | http://www.ujf.cas.cz/, 1149-4
ÚJV Řež | Joint-Stock Company "Nuclear Research Institute Řež" | https://www.ujv.cz/en, 1149-3

Denmark

Copenhagen

NBI | Niles Bohr Institute of the University of Copenhagen | http://www.nbi.ku.dk/, 1088

Egypt

Alexandria, ALX

AU | Alexandria University | https://alexu.edu.eg/, 1149-2, 1086, 1146, A003

Aswan, ASN

ASWU | Aswan University | http://www.aswu.edu.eg/, 1132

Cairo, C

ASRT | Academy of Scientific Research and Technology | http://www.asrt.sci.eg/, 1118, 1127, 1037, 1139
ASU | Ain Shams University | http://www.asu.edu.eg/, 1149-2
AUC | American University in Cairo | https://www.aucegypt.edu/, 1066
EAEA | Egyptian Atomic Energy Authority | http://www.eaea.org.eg/, 1149-2, 1149-3, 1139
FUE | Future University in Egypt | https://www.fue.edu.eg/, 1136

El Shorouk, C

BUE | The British University in Egypt | https://www.bue.edu.eg/, 1138

Giza, GZ

CU | Cairo University | http://cu.edu.eg/, 1149-2, 1136, 1137, 1146, 1119
ECTP MTI NU | Egyptian Center for Theoretical Physics of Modern University for Technology and Information (MTI) at Nile University Campus | https://ippog.org/node/1008/, 1065
NILES CU | National Institute of Laser Enhanced Sciences of Cairo University | https://laser.cu.edu.eg/, 1066
NRC | National Research Centre | http://www.nrc.sci.eg/, 1146

Mansoura, DK

MU | Mansoura University | http://www.mans.edu.eg/en/, 1146

Minya, MN

MU | Minia University | https://www.minia.edu.eg/Minia/home.aspx, 1147

New Borg El-Arab, ALX

GEBRI | Genetic Engineering & Biotechnology Research Institute of the SRTA-City | http://srtacity.sci.eg/institutions/gebri/, 1132

Sadat City, BH

USC | University of Sadat City | https://usc.edu.eg, 1077

Shibin El Kom, MNF

MU | Menoufia University | https://www.menofia.edu.eg/Home/en, 1146

Finland

Helsinki

HIP | Helsinki Institute of Physics | http://www.hip.fi/, 1135, 1083, 1088
UH | University of Helsinki | http://www.helsinki.fi/, 1137, 1083

Jyvaskyla

UJ | University of Jyväskylä | http://www.jyu.fi/, 1088

Lappeenranta

LUT | Lappeenranta-Lahti University of Technology | https://www.lut.fi/, 1083

Oulu

UO MRU | Microelectronics Research Unit (MIC) of the Faculty of Information Technology of the University of Oulu | http://www.oulu.fi/en/, 1146

* The cooperation may be limited by the conditions adopted unilaterally by the State.

France

Aubiere, ARA

LPCA | Laboratoire de Physique de Clermont Auvergne | https://lpca.in2p3.fr/?lang=en, 1081, 1088

Bordeaux, NAQ

LP2i | Laboratoire de Physique des Deux Infinis de Bordeaux | https://www.lp2ib.in2p3.fr/, 1100

Caen, PAC

GANIL | Grand National Heavy Ion Accelerator | http://www.ganil-spiral2.eu/, 1136

Gif-sur-Yvette, IDF

Irfu | Institute of Research into the Fundamental Laws of the Universe of French Alternative Energies and Atomic Energy Commission | http://irfu.cea.fr/, 1135, 1083, 1088, 1097, 1119

LLB | Léon Brillouin Laboratory CEA-CNRS | http://www-llb.cea.fr/, 1149-2, 1146

Grenoble, ARA

CNRS | National Centre for Scientific Research | http://www.cnrs.fr/, 1100

IBS | Institute of Structural Biology | http://www.ibs.fr/, 1149-2

ILL | Institute Laue-Langevin | http://www.ill.eu/, 1149-2, 1149-4, 1146, 1100

LPSC | Laboratory of Subatomic Physics and Cosmology | http://lpsc.in2p3.fr/, 1088, 1146

Lyon, ARA

LPENSL | Physics Laboratory of Ecole Normale Supérieure de Lyon | https://www.ens-lyon.fr/PHYSIQUE/, 1138

UL | Universite de Lyon | http://www.universite-lyon.fr/, 1083, 1088, 1100

Marseille, PAC

CPPM | Centre of Particle Physics Marseille | https://www.cppm.in2p3.fr, 1118, 1096

CPT | Centre of Theoretical Physics | http://www.cpt.univ-mrs.fr/, 1137, 1138

Modane, ARA

LSM LPSC | Modane Underground Laboratory of Laboratory of Subatomic Physics and Cosmology | http://www-lsm.in2p3.fr/, 1100

Nantes, PDL

Subatech | Subatomic Physics Laboratory and Associated Technologies | http://www-subatech.in2p3.fr/, 1138, 1066, 1088

Orsay, IDF

IJCLab | Laboratory of the Physics of the two infinities Irène Joliot-Curie | https://www.ijclab.in2p3.fr/, 1136, 1081, 1088, 1097, 1130, 1100

Paris, IDF

ENS | École Normale Supérieure Paris | http://www.ens.fr/, 1135, 1138

IHP | Institute Henri Poincaré | https://www.ihp.fr/en, 1135

IN2P3 | National Institute of Nuclear Physics and Physics Particles | http://www.in2p3.cnrs.fr/, 1083, 1144

LPTHE | Laboratory of Theoretical Physics and High Energy of Sorbonne University | http://lpthe.jussieu.fr/, 1099

LUTH | Laboratory Universe and Theories of Paris Observatory and Université de Paris Cité | https://luth.obspm.fr/?lang=en, 1138

Saint-Paul-les-Durance, PAC

CEA Cadarache | Energy Transition Research Center Cadarache of French Alternative Energies and Atomic Energy Commission | http://cadarache.cea.fr/cad, 1146

Strasbourg, GES

IPHC - IN2P3/CNRS | Hubert Curien Multidisciplinary Institute of the University of Strasburg - IN2P3/CNRS | http://www.iphc.cnrs.fr/, 1083, 1088, 1099, 1130

Tours, CVL

UT | University of Tours | http://www.univ-tours.fr/, 1138

Villeurbanne, ARA

CC IN2P3 | IN2P3 Computing Center | https://cc.in2p3.fr/, 1088

Georgia

Tbilisi, TB

AIP TSU | Elevter Andronikashvili Institute of Physics of the Ivane Javakhishvili Tbilisi State University | https://www.aiphysics.tsu.ge/index-e.html, 1146

GRENA | Georgian Research and Educational Networking Association | http://www.grena.ge/, 1118

GTU | Georgia Technical University | http://gtu.ge/, 1065, 1118, 1083, 1144, 1119

HEPI-TSU | High Energy Physics Institute of Ivane Javakhishvili Tbilisi State University | http://www.hepi.tsu.ge/, 1081, 1083, 1144

TSU | Ivane Javakhishvili Tbilisi State University | http://www.tsu.ge/, 1146, 1119

UG | University of Georgia | http://www.ug.edu.ge/, 1118, 1144, 1119

Germany*

Aachen, NRW

RWTH | Rheinisch-Westfaelische Technische Aachen University | http://www.rwth-aachen.de/, 1083, 1099

Berlin, BE

HZB | Helmholtz Berlin Centre for Materials and Energy of the Helmholtz Association | https://www.helmholtz-berlin.de/index_en.html, 1149-4, 1136

Bielefeld, NRW

Univ. | Bielefeld University | http://www.uni-bielefeld.de/, 1136

* The cooperation may be limited by the conditions adopted unilaterally by the State.

Bonn, NRW
UniBonn | University of Bonn | http://www.uni-bonn.de/, 1136, 1138, 1085, 1088, 1096, 1126

Cologne, NRW
Univ. | University of Cologne | http://www.uni-koeln.de/, 1136

Darmstadt, HE
GSI Helmholtz | Helmholtz-Centre for the Study of Heavy Ions of the Helmholtz Association | http://www.gsi.de/, 1065, 1136, 1085, 1088, 1130
TU Darmstadt | Technical University Darmstadt | http://www.tu-darmstadt.de/, 1136, 1088

Dresden, SN
HZDR | Helmholtz-Zentrum Dresden-Rossendorf of the Helmholtz Association | http://www.hzdr.de/, 1136
TU Dresden | Technical University of Dresden | http://tu-dresden.de/, 1136, 1144

Dusseldorf, NRW
HHU | Heinrich Heine University Dusseldorf | https://www.hhu.de/, 1135

Erlangen, BY
FAU | Friedrich Alexander University of Erlangen-Nuremberg | http://www.fau.eu/, 1136

Frankfurt am Main, HE
FIAS | Frankfurt Institute for Advanced Studies | https://fias.institute./en/, 1088
GU | Goethe University of Frankfurt on Main | https://www.goethe-university-frankfurt.de/, 1136, 1088

Freiberg, SN
TUBAF | Technical University Bergakademie of Freiberg | http://tu-freiberg.de/, 1085

Giessen, HE
JLU | Justus Liebig University Giessen | http://www.uni-giessen.de/, 1136

Hamburg, HH
DESY Helmholtz | Deutsches Elektronen-Synchrotron DESY of the Helmholtz Association | http://www.desy.de/), 1083
UHH | University of Hamburg | http://www.uni-hamburg.de/, 1135, 1136, 1083, 1099

Hannover, NI
LUH | Gottfried Wilhelm Leibniz University of Hannover | http://www.uni-hannover.de/, 1138

Heidelberg, BW
MPIK | Max Planck Institute for Nuclear Physics | http://www.mpi-hd.mpg.de/, 1100
Univ. | University of Heidelberg | http://www.uni-heidelberg.de/, 1088

Julich, NRW
FZJ Helmholtz | Research Centre Jülich of the Helmholtz Association | http://www.fz-juelich.de/, 1065, 1149-4

Karlsruhe, BW
KIT Helmholtz | Karlsruhe Institute of Technology of the Helmholtz Association | http://www.kit.edu/, 1083

Leipzig, SN
Univ. | University of Leipzig | http://www.uni-leipzig.de/, 1136, 1137, 1138

Mainz, RP
JGU | Johannes Gutenberg University of Mainz | http://www.uni-mainz.de/, 1136, 1096, 1146, 1126

Munich, BY
LMU | Ludwig-Maximilians University of Munich | https://www.lmu.de/en/, 1138
TUM | Technical University of Munich | https://www.tum.de/, 1085, 1088, 1100

Munster, NRW
Univ. | University of Münster | http://www.uni-muenster.de/, 1088

Oldenburg, NI
IPO | Institute of Physics of the Cari von Ossietzky University of Oldenburg | http://www.uol.de/en/physics/, 1138

Potsdam, BB
AEI | Max Planck Institute for Gravitational Physics Albert Einstein Institute | http://www.aei.mpg.de/, 1138

Regensburg, BY
UR | University of Regensburg | http://www.uni-regensburg.de/, 1135

Rostock, MV
Univ. | University of Rostock | http://www.uni-rostock.de/, 1136

Siegen, NRW
Univ. | University of Siegen | http://www.uni-siegen.de/, 1136

Tubingen, BW
Univ. | Eberhard Karls University of Tübingen | http://uni-tuebingen.de/, 1135, 1088, 1100

Worms, RP
ZTT | Centre for Technology and Transfer of Worms University of Applied Sciences | https://www.hs-worms.de/, 1088

Zeuthen, BB
PITZ DESY | Photo Injector Test Facility of Deutsches Elektronen-Synchrotron of the Helmholtz Association (Zeuthen) | https://pitz.desy.de/, 1135, 1081

Greece

Athens
INPP NCSR Demokritos | Institute of Nuclear and Particle Physics of the National Centre for Scientific Research "Demokritos" | http://www.inp.demokritos.gr/, 1136, 1083
NKUA | National and Kapodistrian University of Athens | http://www.uoa.gr/, 1138, 1083, 1088
NTU | National Technical University of Athens | http://www.ntua.gr/, 1083

Ioannina
UoI | University of Ioannina | https://uoi.gr/, 1083

Hungary

Budapest

EK-CER | Center for Energy Research of HUN-REN | https://www.ek.hun-ren.hu, 1149-2

ELTE | Eötvös Loránd University | http://www.elte.hu/, 1135

RKK OU | Rejto Sándor Faculty of Light Industry and Environmental Engineering of the Obuda University | http://rkk.uni-obuda.hu/, 1146

Wigner RCP RMI | Institute for Particle and Nuclear Physics of Wigner Research Centre for Physics of HUN-REN | https://wigner.hu/en/, 1149-2, 1149-3, 1149-4, 1136, 1083, 1088

Debrecen

ATOMKI | Institute for Nuclear Research of HUN-REN | http://www.atomki.hu/, 1136, 1083

UD | University of Debrecen | https://unideb.hu/en, 1083

IAEA

Vienna, AT

IAEA | International Atomic Energy Agency | http://www.iaea.org/, 1149-4, 1146

India

Aizawl, MZ

MZU | Mizoram University | https://www.mzuonline.in/, 1146

Aligarh, UP

AMU | Aligarh Muslim University | http://www.amu.ac.in/, 1088

Bhubaneswar, OD

IOPB | Autonomous Research Institution of the Department of Atomic Energy Institute of Physics, Bhubaneswar | http://www.iopb.res.in/, 1088

Chandigarh, CH

PU | Panjab University | http://puchd.ac.in/, 1136, 1066, 1083, 1088

Chennai, TN

IIT Madras | Indian Institute of Technology Madras | http://www.iitm.ac.in/, 1149-2

Ettimadai, TN

Amrita Univ. | Amrita Vishwa Vidyapeetham (Amrita University) | https://www.amrita.edu/, 1135

Guwahati, AS

GU | Gauhati University | https://gauhati.ac.in/, 1088

Indore, MP

IIT Indore | Indian Institute of Technology Indore | https://www.iiti.ac.in/, 1088

Jaipur, RJ

UoR | University of Rajasthan | http://www.uniraj.ac.in/, 1087, 1088

Jammu, JK

JU | University of Jammu | http://www.jammuuniversity.ac.in/, 1066, 1088

Jatani, OD

NISER | National Institute of Science Education and Research of the Department of Atomic Energy | http://www.niser.ac.in/, 1083, 1088

Kasaragod, KL

CUK | Central University of Kerala of the Department of Atomic Energy | http://cukerala.ac.in/, 1136

Kolkata, WB

BNC | Autonomous Research Institute S.N.Bose National Centre for Basic Sciences under Department of Science and Technology | http://www.bose.res.in/, 1088

IACS | Indian Association for the Cultivation of Science | http://www.iacs.res.in/, 1135, 1137

SINP | Saha Institute of Nuclear Physics of the Department of Atomic Energy | http://www.saha.ac.in/, 1083, 1088

UC | University of Calcutta | http://www.caluniv.ac.in/, 1088, 1086

VECC | Variable Energy Cyclotron Centre of the Department of Atomic Energy | https://www.vecc.gov.in/, 1088, 1130

Manipal, KA

MU | Manipal University | http://www.manipal.edu/, 1130

Mumbai, MH

BARC | Bhabha Atomic Research Centre of the Department of Atomic Energy | http://www.barc.gov.in/, 1083, 1087, 1088

IIT Bombay | Indian Institute of Technology Bombay | https://www.iitb.ac.in/, 1088, 1144

TIFR | Tata Institute of Fundamental Research of the Department of Atomic Energy | http://www.tifr.res.in/, 1083

New Delhi, DL

IUAC | Inter-University Accelerator Center | http://www.iuac.res.in/, 1136

Patna, BR

NIT Patna | National Institute of Technology Patna | http://www.nitp.ac.in/, 1149-2

Roorkee, UK

IIT Roorkee | Indian Institute of Technology Roorkee | https://www.iitr.ac.in/, 1130

Rupnagar, PB

IIT Ropar | Indian Institute of Technology Ropar | http://www.iitrpr.ac.in/, 1130

Santiniketan, WB

Visva-Bharati | Visva-Bharati University | https://visvabharati.ac.in/, 1130

Sunabeda, OD

CUO | Central University of Odisha | https://cuo.ac.in/, 1135

Tirupati, AP

IISER | Indian Institute of Science Education and Research, Tirupati | https://www.iisertirupati.ac.in/, 1066

Varanasi, UP

BHU | Banaras Hindu University | http://www.bhu.ac.in/, 1146

Indonesia

Jakarta, JK

BRIN (LIPI) | The National Research and Innovation Agency | https://www.brin.go.id/en |, 1088

Iran

Isfahan

UI | University of Isfahan | https://ui.ac.ir, 1138

Tehran

FU | Farhangian University | https://cfu.ac.ir/en/, 1138

IPM | Institute for Studies in Theoretical Physics and Mathematics of the Institute for Research Fundamental Sciences | http://www.ipm.ac.ir/, 1135, 1138, 1083

UT | University of Tehran | https://ut.ac.ir/en, 1135

Zanjan

IASBS | Institute for Advanced Studies in Basic Sciences | http://iasbs.ac.ir/, 1136, 1137

Ireland

Dublin, L

DIAS | Dublin Institute for Advanced Studies | http://www.dias.ie/, 1138

UCD | University College Dublin | https://www.ucd.ie/, 1083

Israel

Jerusalem, JM

HUJI | Hebrew University of Jerusaliem | http://www.huji.ac.il/, 1138

Rehovot, M

WIS | Weizmann Institute of Science | http://www.weizmann.ac.il/, 1081

Tel Aviv, TA

TAU | Tel Aviv University | http://www.tau.ac.il/, 1138, 1085, 1086

Italy

Alessandria, AL

DiSIT UPO | Department of Science and Technological Innovation of the University of Eastern Piedmont "Amedeo Avogadro" | https://www.disit.uniupo.it/en, 1088

Assergi, AQ

INFN LNGS | Gran Sasso National Laboratory of National Institute for Nuclear Physics | https://www.lngs.infn.it), 1100

Bari, BA

DIF | Interuniversity Department of Physics University of Bari and Polytechnic University of Bari | https://www.uniba.it/it/ricerca/dipartimenti/fisica, 1088

INFN | National Institute for Nuclear Physics, Section of Bari | http://www.ba.infn.it/, 1083, 1088

Poliba | Polytechnic University of Bari | http://www.en.poliba.it/, 1088

Bologna, BO

INFN | National Institute for Nuclear Physics, Section of Bologna | http://www.bo.infn.it/, 1083, 1088

UniBo | University of Bologna | http://www.unibo.it/, 1088

Brescia, BS

UNIBS | University of Brescia | https://en.unibs.it/, 1088

Cagliari, CA

INFN | National Institute for Nuclear Physics, Section of Cagliari | http://www.ca.infn.it/, 1088

UniCa | University of Cagliari | http://www.unica.it/, 1088

Catania, CT

INFN | National Institute for Nuclear Physics, Section of Catania | https://www.ct.infn.it/it/, 1088

INFN LNS | National Institute for Nuclear Physics, National Laboratory of the South | http://www.lns.infn.it/, 1136, 1083

UniCT | University of Catania | http://www.unict.it/, 1088

Erice, TP

EMFCSC | Ettore Majorana Foundation and Centre for Scientific Culture | http://www.ccsem.infn.it/, 1088

Ferrara, FE

INFN | National Institute for Nuclear Physics, Section of Ferrara | http://www.fe.infn.it/, 1096

Florence, FI

INFN | National Institute for Nuclear Physics, Section of Florence | http://www.fi.infn.it/, 1083, 1096

Foggia, FG

UNIFG | University of Foggia | https://www.unifg.it/en, 1088

Frascati, RM

INFN LNF | National Institute for Nuclear Physics, National Laboratory of Frascati | http://www.lnf.infn.it/, 1138, 1083, 1088, 1096, 1151

Genoa, GE

INFN | National Institute for Nuclear Physics, Section of Genoa | http://www.ge.infn.it/, 1083, 1096, 1119

Legnaro, PD

INFN LNL | National Institute for Nuclear Physics, Legnaro National Laboratories | http://www.lnl.infn.it/, 1088

Messina, ME

UniMe | University of Messina | http://www.unime.it/, 1149-2, 1136, 1088

Milan, MI

INFN | National Institute for Nuclear Physics, Section of Milan | http://www.mi.infn.it/, 1083

UNIMI | University of Milan | http://www.unimi.it/, 1099

Naples, NA

INFN | National Institute for Nuclear Physics, Section of Naples | http://www.na.infn.it/, 1135, 1136, 1083, 1096

Unina II | University of Naples Federico II | http://www.unina.it/, 1099, 1130

Padua, PD

INFN | National Institute for Nuclear Physics, Section of Padua | http://www.pd.infn.it/, 1083, 1088, 1099

UniPd | University of Padua | http://www.unipd.it/, 1138, 1088

Pavia, PV

INFN | National Institute for Nuclear Physics, Section of Pavia | http://www.pv.infn.it/, 1083

UniPv | University of Pavia | http://www.unipv.it/, 1088

Perugia, PG

INFN | National Institute for Nuclear Physics, Section of Perugia | http://www.pg.infn.it/, 1083, 1096

Pisa, PI

INFN | National Institute for Nuclear Physics, Section of Pisa | http://www.pi.infn.it/, 1081, 1083, 1096, 1151

Rome, RM

CREF | Enrico Fermi Historical Physics Museum and Study and Research Centre | https://www.cref.it/en/hp-english/, 1088

ENEA | Italian National Agency for New Technologies, Energy and Sustainable Economic Development | https://www.enea.it/en/, 1146

INFN | National Institute for Nuclear Physics, Section of Rome | http://www.roma1.infn.it/, 1083, 1088, 1096

Sapienza | Sapienza University of Rome | https://www.uniroma1.it/en, 1088

Tor Vergata | Tor Vergata University of Rome | https://web.uniroma2.it/en, 1096

Salerno, SA

INFN | National Institute for Nuclear Physics, Section of Salerno | http://www.sa.infn.it/, 1088, 1099

Siena, SI

UNISI | University of Siena | https://en.unisi.it/, 1146

Trento, TN

UniTrento | University of Trento | https://www.unitn.it/en, 1085

Trieste, TS

INFN | National Institute for Nuclear Physics, Section of Trieste | http://www.ts.infn.it/, 1083, 1085, 1088

SISSA | International School for Advanced Studies | http://www.sissa.it/, 1138

UniTS | University of Trieste | https://portale.units.it/en, 1088

Turin, TO

INFN | National Institute for Nuclear Physics, Section of Turin | http://www.to.infn.it/, 1083, 1085, 1088, 1096, 1100

PoliTO | Polytechnic University of Turin | https://www.polito.it/en, 1088

UniTo | University of Turin | http://www.unito.it/, 1136, 1138, 1088

Vercelli, VC

UPO | University of Eastern Piedmont "Amedeo Avogadro" | http://www.unipmn.it/, 1088

Viterbo, VT

UNITUS | University of Tuscia | https://www.unitus.it/en/, 1077

Japan

Fukuoka

Kyushu U | Kyushu University | http://www.kyushu-u.ac.jp/, 1099, 1144

Hiroshima

HU | Hiroshima University | http://www.hiroshima-u.ac.jp/, 1088

Kobe

Kobe Univ. | Kobe University | http://www.kobe-u.ac.jp/, 1136

Kyoto

KSU | Kyoto Sangyo University | http://www.kyoto-su.ac.jp/, 1146

Morioka

Iwate Univ. | Iwate University | http://www.iwate-u.ac.jp/, 1136

Nagasaki

NIAS | Nagasaki Institute of Applied Sciences | https://nias.ac.jp/, 1088

Nagoya

Nagoya Univ. | Nagoya University | http://www.nagoya-u.ac.jp/, 1099

Nara

NWU | Nara Women's University | https://www.nara-wu.ac.jp/nwu/en/, 1088

Okinawa

OIST | Okinawa Institute of Science and Technology | https://www.oist.jp, 1138

Osaka

RCNP | Research Center for Nuclear Physics of Osaka University | http://www.rcnp.osaka-u.ac.jp/, 1136, 1088

UOsaka | Osaka University | http://www.osaka-u.ac.jp/, 1136, 1144, 1100

Saga

Saga Univ. | Saga University | http://www.saga-u.ac.jp/, 1088

Sendai

IMRAM | Institute of Multidisciplinary Research for Advanced Materials, Tohoku University | https://www2.tagen.tohoku.ac.jp/en/, 1136, 1119

Tokai

JAEA | Japan Atomic Energy Agency | http://www.jaea.go.jp/, 1088, 1099

Tokyo

Keio Univ. | Keio University in Minato (Mita Campus) | http://www.keio.ac.jp/, 1149-2, 1138

Nihon Univ. | Nihon University | http://www.nihon-u.ac.jp/, 1065

Toho Univ. | Toho University | http://www.toho-u.ac.jp/, 1099

TUS | Tokyo University of Science | https://www.tus.ac.jp/en/, 1138

UTokyo | University of Tokyo | http://www.u-tokyo.ac.jp/, 1138

UTokyo CNS | Center for Nuclear Study, University of Tokyo | https://www.cns.s.u-tokyo.ac.jp/en/, 1088

UTokyo ICEPP | International Center for Elementary Particle Physics, University of Tokyo | https://icepp.s.u-tokyo.ac.jp/en/, 1151
Waseda Univ. | Waseda University | http://www.waseda.jp/, 1149-2

Tsukuba

KEK | High Energy Accelerator Research Organization | http://legacy.kek.jp/, 1144, 1146
Univ. | University of Tsukuba | http://www.tsukuba.ac.jp/, 1088

Tsuruga

WERC | Wakasa Wan Energy Research Centre | https://www.werc.or.jp/, 1100

Utsunomiya

UU | Utsunomiya University | http://www.utsunomiya-u.ac.jp/, 1137

Wako

RIKEN | RIKEN Institute of Physical and Chemical Research | https://www.riken.jp/, 1088, 1097

Yamagata

YU | Yamagata University | http://www.yamagata-u.ac.jp/, 1085

Kazakhstan

Almaty, ALA

IETP KazNU | Research Institute of Experimental and Theoretical Physics of Al-Farabi Kazakh National University Scientific | https://farabi.university/science/nii/34, 1119
INP | Republic State Enterprise "Institute of Nuclear Physics" of the Ministry of Energy of the Republic of Kazakhstan | https://inp.kz/en, 1065, 1148, 1118, 1149-2, 1149-3, 1136, 1066, 1096, 1144, 1146, 1130, 1100, 1147, 1119, 1037
KazNU | Al-Farabi Kazakh National University | https://farabi.university/, 1149-2, 1136, 1138, 1139
PTI Satbaev Univ. | LLP Physical-Technical Institute of Kazakh National Research Technical University named after K. I. Satbayev | https://sci.kz/, 1065
RPC Microbiology and Virology | Limited Liability Partnership "Research and Production Center of Microbiology and Virology" | http://imv-kaz.kz/, 1149-2

Astana, AST

AB INP | The Astana branch of the Institute of Nuclear Physics of the Ministry of Energy of the Republic of Kazakhstan | https://inp.kz/ru/structure/astaninskij-filial/, 1118, 1129, 1131
AITU | Astana IT University | https://astanait.edu.kz/en, 1118
ENU | L.N. Gumilyov Eurasian National University | https://enu.kz/en, 1087, 1146, 1130, 1119, 1131, 1139
NU | Nazarbayev University | https://nu.edu.kz/en, 1130, 1131

Karaganda, KAR

KTU | Abylkas Saginov Karaganda Technical University | https://www.kstu.kz/, 1087

Kyzylorda, KZY

KazSRIRG | Limited Liability Partnership "Kazakh Scientific Research Institute of Rice Cultivation named after Ibray Zhakhaev" | https://kazniirice.kz/en/, 1146
KU | Korkyt Ata Kyzylorda University | https://korkyt.edu.kz/en/, 1146

Oskemen (Ust-Kamenogorsk), VOS

EKU | Sarsen Amanzholov East Kazakhstan State University | https://vku.edu.kz/en/, 1141

Kyrgyzstan

Bishkek, GB

BSU | Bishkek State University named after K. Karasaev | https://bhu.kg/en/, 1138

Latvia

Riga

ISSP UL | Institute of Solid State Physics of the University of Latvia | http://www.cfi.lu.lv/, 1149-2

Lithuania

Kaunas

VMU | Vytautas Magnus University | http://www.vdu.lt/, 1136

Malaysia

Bangi, SL

UKM | National University of Malaysia | https://www.ukm.my, 1144

Malta

Msida

UM | University of Malta | https://www.um.edu.mt/, 1088

Mexico

Cuernavaca, MOR

UNAM | National Autonomous University of Mexico Campus Morelos | http://www.unam.mx/, 1129

Culiacan, SIN

UAS | Autonomous University of Sinaloa | https://www.uas.edu.mx/, 1088

Mexico City, CDMX

Cinvestav | Center for Research and Advanced Studies of the National Polytechnic Institute | http://www.cinvestav.mx/, 1083, 1088
INCan | National Cancer Institute | http://www.incan.salud.gob.mx, 1107
UNAM | National Autonomous University of Mexico (Mexico City) | http://www.unam.mx/, 1065, 1118, 1136, 1066, 1088, 1146, 1119

Morelia, MIC

UMSNH | Michoacana University of San Nicolás de Hidalgo | https://umich.mx/, 1146

Puebla de Zaragoza, PUE

BUAP | Meritorious Autonomous University of Puebla | http://www.buap.mx/, 1065, 1083, 1088

San Luis Potosi, SLP

UASLP | Autonomous University of San Luis Potosi | http://www.uaslp.mx/, 1096

Moldova

Chisinau, CU

IAP | Institute of Applied Physics of the Ministry of Education and Research of the Republic of Moldova | http://www.phys.asm.md/, 1065

IChem | Institute of Chemistry | http://ichem.md/, 1146

IMB ASM | Institute of Microbiology and Biotechnology of the Academy of Sciences of Moldova | http://www.imb.asm.md/, 1146, 1132

MSU | Moldova State University | http://usm.md/, 1107

Mongolia

Ulaanbaatar

GCRA | Geological Center for Research and Analysis | https://gcra.gov.mn/, 1146

IMDT MAS | Institute of Mathematics and Digital Technology of the Mongolian Academy | https://imdt.ac.mn/, 1118, 1119

IPT MAS | Institute of Physics and Technology of the Mongolian Academy of Sciences | https://ipt.ac.mn, 1065, 1149-2, 1137, 1087

MNUE | Mongolian National University of Education | https://msue.edu.mn/, 1066, 1139

MUST | Mongolian University of Science and Technology | http://www.must.edu.mn/, 1146, 1119

NRC NUM | Nuclear Research Center of the National University of Mongolia | http://nrc.num.edu.mn/, 1146

NUM | National University of Mongolia | http://www.num.edu.mn/, 1077, 1139

Montenegro

Podgorica

UCG | University of Montenegro | http://www.ucg.ac.me/, 1083

Netherlands

Amsterdam, NH

AUAS | Amsterdam University of Applied Sciences | https://www.amsterdamuas.com/, 1088

NIKHEF | National Institute for Subatomic Physics | http://www.nikhef.nl/, 1081, 1088

Eindhoven, NB

TU/e | Eindhoven University of Technology | https://www.tue.nl/en/, 1083

Utrecht, UT

UU | Utrecht University | http://www.uu.nl/, 1088

New Zealand

Auckland, AUK

UoA | University of Auckland | http://www.auckland.ac.nz/, 1083

Christchurch, CAN

UC | University of Canterbury | http://www.canterbury.ac.nz/, 1083

North Macedonia

Skopje

UKiM | Ss. Cyril and Methodius University in Skopje | http://www.ukim.edu.mk/, 1146

Norway

Bergen

HVL | Western Norway University of Applied Sciences | https://www.hvl.no/en/, 1088

UiB | University of Bergen | http://www.uib.no/, 1136, 1088

Borre

USN | University of South-Eastern Norway, Vestfold Campus | https://www.usn.no/english/, 1088

Oslo

UiO | University of Oslo | http://www.uio.no/, 1136, 1088

Pakistan

Islamabad, IS

COMSATS | COMSATS University Islamabad | https://www.comsats.edu.pk/, 1088

PINSTECH | Pakistan Institute of Nuclear Science and Technology, 1088

QAU | Quaid-i-Azam University | http://www.qau.edu.pk/, 1083

Peru

Lima, LMA

PUCP | Pontifical Catholic University of Peru | https://www.pucp.edu.pe/, 1088

Poland*

Bialystok, PD

UwB | University of Bialystok | http://www.uwb.edu.pl/, 1149-2, 1138

Gdansk, PM

GUT | Gdańsk University of Technology | http://pg.edu.pl/, 1146

Katowice, SL

US | University of Silesia in Katowice | http://www.us.edu.pl/, 1135

Krakow, MA

IFJ PAN | Henryk Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences | http://www.ifj.edu.pl/, 1135, 1136, 1146

JU | Jagiellonian University in Kraków | http://www.uj.edu.pl/, 1138

Lodz, LD

UL | University of Lódź | http://www.uni.lodz.pl/, 1146

Lublin, LU

UMCS | Marie Curie-Sklodowska University in Lublin | http://www.umcs.pl/, 1136, 1146

Opole, OP

UO | University of Opole | http://www.uni.opole.pl/, 1146

* The cooperation may be limited by the conditions adopted unilaterally by the State.

Otwock-Swierk, MZ

NCBJ | National Centre for Nuclear Research | http://www.ncbj.gov.pl/, 1135, 1136, 1085, 1146

Poznan, WP

AMU | Adam Mickiewicz University in Poznań | http://www.amu.edu.pl/, 1146

Warsaw, MZ

IEP WU | Institute of Experimental Physics of Warsaw University | http://en.ifd.fuw.edu.pl/, 1085

UW | University of Warsaw | http://www.uw.edu.pl/, 1136

WUT | Warsaw University of Technology | http://www.pw.edu.pl/, 1085

Wroclaw, DS

UWr | University of Wroclaw | https://uwr.edu.pl/, 1138

WUST | Wroclaw University of Science and Technology | http://www.pwr.edu.pl/, 1137

Portugal

Aveiro

UA | University of Aveiro | http://www.ua.pt/, 1138, 1085

Coimbra

UC | University of Coimbra | http://www.uc.pt/, 1135

Lisbon

LIP | Laboratory of Instrumentation and Experimental Particle Physics | http://www.lip.pt/, 1085

Republic of Korea

Busan

PNU | Pusan National University | http://www.pusan.ac.kr/, 1088

Cheongju

CBNU | Chungbuk National University | https://www.cbnu.ac.kr/english/index.do, 1088

Daejeon

IBS | Institute for Basic Science | http://www.ibs.re.kr, 1136, 1138, 1130

KAERI | Korea Atomic Energy Research Institute | http://www.kaeri.re.kr/, 1146

KIST | Korea Institute of Science and Technology | https://www.kist.re.kr/eng/index.do, 1083, 1088

Gangneung

GWNU | Gangneung-Wonju National University | http://www.gwnu.ac.kr/, 1088

Gwangju

CNU | Chonnam National University | http://www.jnu.ac.kr/, 1083

Incheon

Inha | Inha University | https://eng.inha.ac.kr/, 1088

Jeonju

JBNU | Jeonbuk National University | https://www.jbnu.ac.kr/en, 1136, 1088

Seoul

Konkuk Univ. | Konkuk University | http://www.konkuk.ac.kr/, 1088

KU | Korea University | http://www.korea.edu/, 1083

SJU | University of Sejong | https://eng.sejong.ac.kr/index.do/, 1083, 1088

SKKU | Sungkyunkwan University | http://www.skku.edu/, 1083, 1144

SNU | Seoul National University | http://www.en.snu.ac.kr/, 1136, 1083

Yonsei Univ. | Yonsei University | https://www.yonsei.ac.kr/, 1136, 1083, 1088

Romania*

Baia Mare, MM

TUCN-NUCBM | Technical University of Cluj-Napoca, North University Center of Baia Mare | http://www.utcluj.ro/, 1149-2, 1146

Bucharest, B

IFIN-HH | Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering | http://www.ifin.ro/, 1149-3, 1136, 1087, 1088, 1096, 1146

IGR | Geological Institute of Romania | https://igr.ro, 1146

INCDIE ICPE-CA | National Institute of Research and Development in Electrical Engineering ICPE-CA | http://www.icpe-ca.ro/, 1149-2, 1149-4, 1097, 1146

UB | University of Bucharest | http://www.unibuc.ro/, 1149-2, 1136, 1137, 1087, 1146

UPB | University Politehnica of Bucharest | http://www.upb.ro/, 1088

Cluj-Napoca, CJ

INCDTIM | National Institute for Research and Development of Isotopic and Molecular Technologies | http://www.itim-cj.ro/, 1149-2, 1149-3, 1146

RA BC-N | Romanian Academy Cluj-Napoca Branch | https://acad-cj.ro/, 1149-2

UBB | Babeş-Bolyai University | http://www.ubbcluj.ro/, 1149-2, 1149-3, 1136

UTC-N | Technical University of Cluj-Napoca | http://utcluj.ro/, 1149-3

Constanta, CT

MINAC | Museum of National History and Archeology in Constanța | https://www.minac.ro/, 1149-2

UOC | "Ovidius" University of Constanta | http://www.univ-ovidius.ro/, 1146

Galati, GL

DJUG | "Dunarea de Jos" University of Galaţi | http://www.ugal.ro/, 1146

Iasi, IS

NIRDTP | National Institute of Research and Development for Technical Physics | http://www.phys-iasi.ro/, 1149-2, 1146

TUIASI | "Gheorghe Asachi" Technical University of Iaşi | http://www.tuiasi.ro/, 1149-2

* The cooperation may be limited by the conditions adopted unilaterally by the State.

UAI | University "Apollonia" of Iaşi | http://univapollonia.ro/, 1149-2
UAIC | "Alexandru Ioan Cuza" University of Iaşi | http://www.uaic.ro/, 1149-2, 1146

Magurele, IF

ISS | Institute of Space Science | https://www.spacescience.ro/, 1087, 1088, 1099, 1146

Oradea, BH

UO | University of Oradea | http://www.uoradea.ro/, 1146

Pitesti, AG

ICN | Institute for Nuclear Research - Piteşti | http://www.nuclear.ro/, 1146
UPIT | University of Piteşti | http://www.upit.ro/, 1149-2

Ramnicu Valcea, VL

ICSI | National Research and Development Institute for Cryogenic and Isotopic Technologies | http://www.icsi.ro/, 1146

Sibiu, SB

ULBS | "Lucian Blaga" University of Sibiu | https://www.ulbsibiu.ro/ro/, 1146

Targoviste, DB

VUT | "VALAHIA" University of Târgovişte | http://www.valahia.ro/, 1149-2, 1149-3, 1146

Timisoara, TM

ICT | "Coriolan Drăgulescu" Institute of Chemistry | http://acad-icht.tm.edu.ro/, 1149-2
UVT | West University of Timişoara | http://www.uvt.ro/, 1149-2, 1137, 1146

Russia

Arkhangelsk, ARK

NArFU | Northern (Arctic) Federal University named after M.B Lomonosov | http://narfu.ru/, 1146, 1126, 1139
NSMU | Northern State Medical University | http://www.nsmu.ru/, 1139

Belgorod, BEL

BelSU | Belgorod National Research State University | https://bsuedu.ru/bsu/, 1065, 1087, 1097, 1150, 1139
Erendi Vakuum | Limited Liability Company "Erendi Vakuum", 1150

Borok, YAR

IBIW RAS | Federal State Budgetary Institution of Science "I.D. Papanin Institute for the Biology of Inland Waters of the Russian Academy of Sciences" | http://ibiw.ru/, 1146
IPE RAS | Borok Geophysical Observatory branch of Federal State Budgetary Institution of Science "Schmidt Institute of the Physics of the Earth of the Russian Academy of Sciences" | http://wwwbrk.adm.yar.ru/, 1077

Chelyabinsk, CHE

SUSU | South Ural State University | https://www.susu.ru/ru/, 1118, 1149-2, 1077, 1119

Chernogolovka, MOS

ISMAN RAS | Federal State Budgetary Institution of Science "Merzhanov Institute of Structural Macrokinetics and Materials Science of the Russian Academy of Sciences" | http://www.ism.ac.ru/, 1087
ISSP RAS | Federal State Budgetary Institution of Science "Osipyan Institute of Solid State Physics of the Russian Academy of Sciences" | http://issp.ac.ru/, 1149-2, 1086, 1131
LITP RAS | Federal State Budgetary Institution of Science "L.D. Landau Institute for Theoretical Physics of the Russian Academy of Sciences" | http://www.itp.ac.ru/, 1135, 1138, 1117
SCC IPCP RAS | Federal State Budgetary Institution of Science "Supercomputer Centre of the Institute of Problems of Chemical Physics of the Russian Academy of Sciences" | https://icp-ras.ru/, 1118

Dimitrovgrad, ULY

FNKCRIO FMBA | Federal Scientific and Clinical Center for Medical Radiology and Oncology of the Federal Medical and Biological Agency | https://fnkcrio.ru, 1134
RIAR ROSATOM | Joint-Stock Company "State Scientific Center Research Institute of Atomic Reactors" State Atomic Energy Corporation Rosatom | http://www.niiar.ru/, 1130

Dolgoprudny, MOS

MIPT | Moscow Institute of Physics and Technology (National Research University) | http://mipt.ru/, 1065, 1149-2, 1149-3, 1136, 1138, 1066, 1151, 1097, 1146, 1107, 1131, 1139, 1117

Donetsk

DonIPE | Galkin Donetsk Institute for Physics and Engineering | http://www.donfti.ru/, 1146

Dubna, MOS

Diamant | Limited Liability Company "Diamant" | https://diamant-sk.com/, 1146
Horocycle | Limited Liability Company "Horocycle", 1150
IAS "Omega" | Limited Liability Company "Institute for Advanced Studies "Omega" | http://dubna-oez.ru/, 1150, 1107
IPTP ROSATOM | Joint-Stock Company "Institute of Physical and Technical Problems" State Atomic Energy Corporation Rosatom | https://iftp.ru/, 1150, 1107
MSU Branch | Federal State Budget Educational Institution of Higher Education M.V. Lomonosov Moscow State University MSU Branch in Dubna | https://dubna.msu.ru/filial, 1119, 1107
SCC "Dubna" | "Dubna" Satellite Communication Centre, Branch of the Federal State Unitary Enterprise "Russian Satellite Communication Company" | http://www.rscc.ru/, 1118
SEZ "Dubna" | Special Economic Zone of Technical-Innovative type "Dubna" | http://oezdubna.ru/, 1118
Uni Dubna | Dubna State University | http://www.uni-dubna.ru/, 1118, 1149-2, 1149-3, 1135, 1099, 1146, 1100, 1119, 1139

Elykaevo, KEM

Sirius. Kuzbass | State Autonomous Institution of Additional Education "Sirius. Kuzbass" | https://kemsirius.kemobl.ru/, 1146

Fryazino, MOS

Istok | Joint-Stock Company "Research and Production Corporation "Istok" named after A.I. Shokin" | https://istokmw.ru/, 1065

Gatchina, LEN

NRC KI PNPI | Federal State Budgetary Institution "B.P. Konstantinov Petersburg Nuclear Physics Institute" of the National Research Centre "Kurchatov Institute" | https://www.pnpi.nrcki.ru/, 1065, 1118, 1149-2, 1149-3, 1149-4, 1136, 1085, 1087, 1151, 1150, 1146, 1100, 1119

Grozny, CE

CheSU | Kadyrov Chechen State University | https://chesu.ru/, 1143

CSPU | Chechen State Pedagogical University | https://chspu.ru/, 1146

Irkutsk, IRK

ISDCT SB RAS | Federal State Budgetary Institution of Science "Matrosov Institute for System Dynamics and Control Theory of the Siberian Branch of the Russian Academy of Sciences" | http://www.idstu.irk.ru/, 1135

ISU | Irkutsk State University | https://isu.ru/, 1148, 1135, 1099, 1139

LI SB RAS | Federal State Budgetary Institution of Science "Limnological Institute of the Siberian Branch of the Russian Academy of Sciences" | http://www.lin.irk.ru/, 1146

Ivanovo, IVA

ISUCT | Ivanovo State University of Chemistry and Technology | http://isuct.ru/, 1146, 1131

IvSU | Ivanovo State University | http://ivanovo.ac.ru/, 1144

Izhevsk, UD

UdSU | Udmurt State University | http://udsu.ru/, 1146

Kaliningrad, KGD

IKBFU | Immanuel Kant Baltic Federal University | http://www.kantiana.ru/, 1149-2, 1146

Kazan, TA

Compressormash | Joint-Stock Company "Kazancompressormash" | http://compressormash.ru/, 1065

FRC KazSC RAS | Federal Research Center "Kazan Scientific Center of the Russian Academy of Sciences" | https://knc.ru, 1149-2, 1077

KFU | Kazan Volga Region Federal University | http://kpfu.ru/, 1149-2, 1149-3, 1138, 1139, 1117

KPhTI FRC KSC RAS | Zavoisky Physical-Technical Institute, Subdivision of Federal State Budgetary Institution of Science "Federal Research Center "Kazan Scientific Center of the Russian Academy of Sciences" | https://www.kfti.knc.ru/, 1149-2

Spetshmash | Ltd. "Research and Production Enterprise "Spetshmash" | http://spmsh.ru/, 1065

Kemerovo, KEM

KemSU | Kemerovo State University | https://kemsu.ru/, 1146

Khabarovsk, KHA

PNU | Pacific National University | http://pnu.edu.ru/, 1136

Kostroma, KOS

KSU | Kostroma State University | https://kosgos.ru/, 1145

Krasnodar, KDA

KubSU | Kuban State University | http://kubsu.ru/, 1131, 1139

Krasnoyarsk, KYA

FRC KSC SB RAS | Federal Research Center "Krasnoyarsk Science Center of the Siberian Branch of the Russian Academy of Sciences" | https://ksc.krasn.ru, 1149-2

KIP SB RAS | Federal State Budgetary Institution of Science "Kirensky Institute of Physics, Siberian Branch of the Russian Academy of Sciences" | http://www.kirensky.ru/, 1149-2

SibFU | Siberian Federal University | https://sfu.ru, 1149-2

Moscow, MOW

"Fomos-Materials" | Joint-Stock Company "Fomos-Materials" | http://newpiezo.com/, 1086

Azimuth Photonics | LLC "Company "AZIMUTH PHOTONICS" | http://www.azimp.ru/, 1086

BMSTU | Bauman Moscow State Technical University | https://www.bmstu.ru/, 1118, 1139

CQMM MIEM HSE | Centre for Quantum Metamaterials of A.N. Tikohonov Moscow Institute of Electronics and Mathematics of National Research University Higher School of Economics | https://cqmm.hse.ru/, 1149-2

Cryogenmash | Joint-Stock Company of Cryogenic Engineering "Cryogenmash" | http://cryogenmash.ru/, 1065

Crystal | Joint-Stock Company "Design Centre "Kristal" | https://dckristal.ru/, 1127

DSSI | V.V. Dokuchaev Soil Science Institute | http://www.esoil.ru/, 1146

FCBN FMBA | Federal State Budgetary Institution "Federal Center for Brain and Neurotechnologies" Federal Medical-Biological Agency | https://фцмн.рф/, 1077, 1127

FMBC FMBA | Federal State Budgetary Institution "Russian State Research Center − A.I. Burnazyan Federal Medical Biophysical Center" Federal Medical-Biological Agency | http://fmbafmbc.ru/, 1077, 1107, 1131, 1127

FRC CP RAS | N.N. Semenov Federal Research Center for Chemical Physics Russian Academy of Sciences | http://chph.ras.ru/, 1149-2, 1107

FRC CSC RAS | Federal Research Center "Computer Science and Control" of the Russian Academy of Sciences" | https://www.frccsc.ru/, 1118

GPI RAS | Federal State Budgetary Institution of Science Federal Research Center "General Physics Institute of the Russian Academy of Sciences" | http://www.gpi.ru/, 1146

Geliymash | Joint-Stock Company "Scientific and Production Association "Geliymash" | http://geliymash.ru/, 1065

HSE | National Research University Higher School of Economics | http://www.hse.ru/, 1065, 1118, 1137, 1138, 1151, 1119, 1037, 1139, 1117

IA RAS | Federal State Budgetary Institution of Science "Institute of Archaeology of the Russian Academy of Sciences" | http://archaeolog.ru/, 1149-2, 1146

IASRWA | Joint-Stock Company "Interregional Agency for Scientific Restoration of Works of Art" | http://mnrhu.ru/, 1146

IBMC | Federal State Budgetary Institution of Science Institute of Biomedical Chemistry | http://www.ibmc.msk.ru/, 1077

IBMP RAS | Federal State Budgetary Institution of Science "State Scientific Centre of the Russian Federation - Institute for Biomedical Problems of the Russian Academy of Sciences" | http://www.imbp.ru/, 1065, 1077, 1107, 1127

IEPT RAS | Federal State Budgetary Institution of Science "Institute of Earthquake Prediction Theory and Mathematical Geophysics of the Russian Academy of Sciences" | https://www.itpz-ran.ru, 1149-2

IGEM RAS | Federal State Budgetary Institution of Science "Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry of the Russian Academy of Sciences" | http://www.igem.ru/, 1149-2, 1077

IGIC RAS | Federal State Budgetary Institution of Science "Kurnakov Institute of General and Inorganic Chemistry of the Russian Academy of Sciences" | http://www.igic.ras.ru/, 1149-2, 1107, 1131

IHNA & NPh | Federal State Budgetary Institution of Science "Institute of Higher Nervous Activity and Neurophysiology of the Russian Academy of Sciences" | http://www.ihna.ru/), 1077

IITP RAS | Federal State Budgetary Institute of Science "Institute for Information Transmission Problems (Kharkevich Institute) of the Russian Academy of Sciences" | http://iitp.ru/, 1118

IKI RAS | Federal State Budgetary Institution of Science "Space Research Institute of the Russian Academy of Sciences" | https://iki.cosmos.ru/, 1146, 1077, 1127

IMEMO RAS | Federal State Budgetary Scientific Institution "Primakov National Research Institute of World Economy and International Relations of the Russian Academy of Science" | http://imemo.ru/, 1135

IMET RAS | Federal State Budgetary Institution of Science "A.A. Baikov Institute of Metallurgy and Materials Science of the Russian Academy of Sciences" | http://www.imet.ac.ru/, 1149-2, 1146

INEOS RAS | A.N. Nesmeyanov Institute of Organoelement Compounds of Russian Academy of Sciences| https://ineos.ac.ru/, 1130

INMI RAS | Vinogradsky Institute of Microbiology of Federal State Budgetary Institution of Science "Federal Research Centre "Fundamentals of Biotechnology" of the Russian Academy of Sciences" | https://www.fbras.ru/, 1149-2

Inst. Immunology FMBA | National Research Center – Institute of Immunology Federal Medical-Biological Agency of Russia | http://nrcii.ru/, 1149-2

IOS RAS | Institute of Oriental Studies of the Russian Academy of Sciences | https://www.ivran.ru/, 1136

IPCE RAS | Federal State Budgetary Institution of Science "A.N. Frumkin Institute of Physical Chemistry and Electrochemistry of the Russian Academy of Sciences" | http://www.phyche.ac.ru/, 1146

IPE RAS | Federal State Budgetary Institution of Science "Schmidt Institute of Physics of the Earth of the Russian Academy of Sciences" | http://www.ifz.ru/, 1149-2

IPMech RAS | Federal State Budgetary Institution of Science "Ishlinsky Institute for Problems in Mechanics of the Russian Academy of Sciences" | http://www.ipmnet.ru/, 1138

ISP RAS | Federal State Budgetary Institution of Science "Ivannikov Institute for System Programming of the Russian Academy of Sciences" | http://www.ispras.ru/, 1118

ISPM RAS | Federal State Budgetary Institution of Science "Enikolopov Institute of Synthetic Polymeric Materials of the Russian Academy of Sciences" | http://www.ispm.ru/, 1131

ITEP | Federal State Budgetary Institution "Russian Federation State Scientific Centre - Alikhanov Institute for Theoretical and Experimental Physics" of the National Research Centre "Kurchatov Institute" | http://www.itep.ru/, 1065, 1135, 1138, 1066, 1081, 1087, 1146, 1100, 1119, 1107, 1131, 1117

JIHT RAS | Joint Institute for High Temperatures of the Russian Academy of Sciences | https://jiht.ru/, 1107

KC CaPh | Kurchatov Complex of Crystallography and Photonics of National Research Centre Kurchatov Institute | https://kif.ras.ru/, 1149-2

KIAM RAS | Federal State Budgetary Institution of Science "Federal Research Center Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences" | http://www.keldysh.ru/, 1118

Kvant-R | Limited Liability Company "Kvant-R", 1107

LPI RAS | Federal State Budgetary Institution of Science "P.N. Lebedev Physical Institute of the Russian Academy of Sciences" | http://www.lebedev.ru/, 1065, 1138, 1087, 1097, 1150, 1099, 1146, 1100, 1119, 1117

Marafon | Limited Liability Company "Marafon" | http://www.marathon.ru/, 1150

MEPhI | National Research Nuclear University MEPhI (Moscow Engineering Physics Institute) | http://www.mephi.ru/, 1065, 1148, 1118, 1149-2, 1136, 1066, 1087, 1100, 1119, 1107, A003, 1126, 1139

MGIMO | Moscow State Institute of International Relations | https://mgimo.ru/, 1137

MI RAS | Federal State Budgetary Institution of Science "Steklov Mathematical Institute of the Russian Academy of Sciences" | http://www.mi.ras.ru/, 1138, 1117

MIET | National Research University of Electronic Technology | http://www.miet.ru/, 1149-2

MIREA | MIREA - Russian Technological University | http://www.mirea.ru/, 1065, 1150

MISIS | National University of Science and Technology "MISIS" | http://www.misis.ru/, 1065, 1118, 1149-2, 1146, 1119

MPEI | National Research University "Moscow Power Engineering Institute" | http://mpei.ru/, 1118, 1119, 1139
MPGU | Moscow State Pedagogical University | https://mpgu.su/homempgu/, 1131
MSU | Lomonosov Moscow State University | http://www.msu.ru/, 1065, 1118, 1149-2, 1136, 1137, 1138, 1081, 1087, 1146, 1130, 1100, 1147, 1077, 1132, 1119, 1131, A002, A004, 1127, 1139, 1117
NIKIET ROSATOM | Joint-Stock Company "N.A. Dollezhal Research and Development Institute of Power Engineering" State Atomic Energy Corporation Rosatom | http://www.nikiet.ru/, 1149-4
NMRC RB | National Medical Research Center for Rehabilitation and Balneology of the Ministry of Health of the Russian Federation | https://www.nmicrk.ru/, 1132
NMRCO | Federal State Budgetary Institution "N.N. Blokhin National Medical Research Center of Oncology" of the Ministry of Health of the Russian Federation | https://www.ronc.ru/, A005
NRC KI | National Research Centre "Kurchatov Institute" | https://nrcki.ru/, 1065, 1118, 1149-2, 1149-3, 1149-4, 1136, 1087, 1097, 1146, 1130, 1077
PFUR | Peoples' Friendship University of Russia named after Patrice Lumumba | http://www.rudn.ru/, 1118, 1136, 1137, 1119, 1107, 1131, 1037, 1139
PIN RAS | Borissiak Paleontological Institute of the Russian Academy of Sciences | https://www.paleo.ru/, 1149-2, 1077
PRUE | Federal State Budgetary Educational Institution of Higher Education "Russian University of Economics named after G.V. Plekhanov" | https://www.rea.ru/, 1065, 1118
RCC MSU | Research Computing Center Lomonosov Moscow State University | https://rcc.msu.ru/, 1118, 1119
RIEPL | Russian Research Institute of Economics, Politics and Law in Science and Technology | https://riep.ru/, 1138
RIVS | Federal State Budgetary Scientific Institution "I.I. Mechnikov Research Institute of Vaccines and Serums" | https://instmech.ru/, 1131
RSCC | Federal State Unitary Enterprise "Russian Satellite Communications Company" | http://www.rscc.ru/, 1118
RSMU | N.I. Pirogov Russian National Research Medical University | https://rsmu.ru/, 1131
SAI MSU | Sternberg Astronomical Institute of the M.V. Lomonosov Moscow State University | http://www.sai.msu.ru/, 1138, 1077, 1117
Sechenov Univ. | I.M. Sechenov First Moscow State Medical University | https://www.sechenov.ru/, 1146, A005
SIAS | State Institute for Art Studies | http://sias.ru/, 1146
SINP MSU | Skobeltsyn Institute of Nuclear Physics of the M.V. Lomonosov Moscow State University | http://www.sinp.msu.ru/, 1065, 1148, 1118, 1149-2, 1135, 1136, 1086, 1099, 1146, 1130, 1119, 1107, 1117
Skoltech | Skolkovo Institute of Science and Technology | https://www.skoltech.ru/, 1138, 1117
SM "MK" | Federal State Institution "State Museum Moscow Kremlin" | http://www.kreml.ru/, 1146
SNIIP | Joint-Stock Company "Specialized Scientific Research Institute for Instrumentation Engineering" State Atomic Energy Corporation Rosatom | https://www.sniip.ru/, 1146
TIPS RAS | A.V. Topchiev Institute of Petrochemical Synthesis of the Russian Academy of Sciences | http://www.ips.ac.ru/, 1131
VEI VNIITF ROSATOM | Federal State Unitary Enterprise "All-Russian Electrotechnical Institute" branch of Russian Federal Nuclear Center Zababakhin All-Russia Research Institute of Technical Physics State Atomic Energy Corporation Rosatom | http://www.vei.ru/, 1065
VIAM | Federal State Unitary Enterprise "All-russian Scientific Research Institute of Aviation Materials" of the National Research Center "Kurchatov Institute" | https://viam.ru/, 1149-2
VNIIA ROSATOM | Federal State Unitary Enterprise "Dukhov Automatics Research Institute" State Atomic Energy Corporation Rosatom | http://www.vniia.ru/, 1146
VNIIKR | Federal State Budgetary Institution "All-Russian Plant Quarantine Center" | https://vniikr.ru/, 1146
VNIINM ROSATOM | Joint-Stock Company "Advanced Research Institute of Inorganic Materials named after Academician A. A. Bochvar" State Atomic Energy Corporation Rosatom | http://www.bochvar.ru/, 1149-4

Neutrino, KB

BNO INR RAS | Baksan Neutrino Observatory Federal State Budgetary Institution of Science "Institute for Nuclear Research of the Russian Academy of Sciences" | http://www.inr.ru/bno/, 1100

Nizhny Novgorod, NIZ

IAP RAS | Federal Research Center A.V. Gaponov-Grekhov Institute of Applied Physics of the Russian Academy of Sciences | https://www.ipfran.ru/, 1129
IPM RAS | Federal State Budgetary Institution of Science "Institute for Physics of Microstructures of the Russian Academy of Sciences" - branch of IPM RAS | http://ipmras.ru/, 1149-2, 1146, 1100
NNSTU | Nizhny Novgorod State Technical University named after R.E. Alekseev | https://nntu.ru/, 1148, 1100
UNN | National Research Lobachevsky State University of Nizhny Novgorod | http://www.unn.ru/, 1149-2

Novocherkassk, ROS

SRSPU NPI | M.I. Platov South-Russian State Polytechnic University (NPI) | https://www.npi-tu.ru/, 1065, 1127, 1139

Novosibirsk, NVS

BIC SB RAS | Federal State Budgetary Institution of Science "Federal Research Center "Boreskov Institute of Catalysis of the Siberian Branch of the Russian Academy of Sciences" | http://www.catalysis.ru/, 1077
BINP SB RAS | Federal State Budgetary Institution of Science "Budker Institute of Nuclear Physics of the Siberian Branch of the Russian Academy of

Sciences" | http://www.inp.nsk.su/, 1065, 1118, 1135, 1085, 1151, 1144
ICMMG SB RAS | Institute of Computational Mathematics and Mathematical Geophysics of Siberian Branch of the Russian Academy of Sciences | https://icmmg.nsc.ru, 1118
ISP SB RAS | Federal State Budgetary Institution of Science "Rzhanov Institute of Semiconductor Physics of the Siberian Branch of the Russian Academy of Sciences" | http://www.isp.nsc.ru/, 1137, 1146, 1131, 1126
NIIC SB RAS | Nikolaev Institute of Inorganic Chemistry of Siberian Branch of the Russian Academy of Sciences | http://www.niic.nsc.ru/, 1137
NSU | Novosibirsk State University | http://www.nsu.ru/, 1135, 1138, 1144, 1117
RICEL | Research Institute of Clinical and Experimental Lymphology – Branch of the Institute of Cytology and Genetics, Siberian Branch of Russian Academy of Sciences | https://www.niikel.ru/, 1132
SKIF | Synchrotron Radiation Facility - Siberian Circular Photon Source "SKIF" Boreskov Institute of Catalysis of Siberian Branch of the Russian Academy of Sciences | https://srf-skif.ru , 1118
STL "Zaryad" | STL "Zaryad", 1065, 1097

Obninsk, KLU

IPPE ROSATOM| Joint-Stock Company "State Scientific Centre of the Russian Federation - Institute of Physics and Power Engineering" State Atomic Energy Corporation Rosatom | https://www.ippe.ru/, 1149-4, 1146
MRRC NMRRC | A.Tsyb Medical Radiological Research Center – branch of the Federal State Budgetary Institution "National Medical Research Radiological Centre" of the Ministry of Health of the Russian Federation | https://new.nmicr.ru/mrrc/, 1077, 1107

Omsk, OMS

OmSU | Dostoevsky Omsk State University | http://www.omsu.ru/, 1136
OSTU | Omsk State Transport University | https://www.omgups.ru/, 1149-2

Perm, PER

ICMM UrB RAS | Federal State Budgetary Institution of Science "Institute of Continuous Media Mechanics of the Russian Academy of Sciences Ural Branch" | https://www.icmm.ru/, 1149-2
ITCh UrB RAS | Federal State Budgetary Institution of Science "Institute of Technical Chemistry of the Russian Academy of Sciences Ural Branch" | http://www.itcras.ru/, 1149-2
PSNRU | Perm State National Research University | http://www.psu.ru/, 1146

Petropavlovsk-Kamchatsky, KAM

FRC GC RAS | Kamchatka branch of the Federal Research Center "Geophysical Service of Russian Academy of Sciences" | https://www.emsd.ru/, 1128
KamGU | Vitus Bering Kamchatka State University | https://www.kamgu.ru/, 1119, 1139

Protvino, MOS

IHEP | Federal State Budgetary Institution "Russian Federation State Scientific Centre - Institute for High Energy Physics" of the National Research Centre "Kurchatov Institute" | http://www.ihep.su/, 1065, 1118, 1135, 1137, 1138, 1066, 1081, 1085, 1087, 1086, 1126, 1117

Pushchino, MOS

IMPB RAS | Federal State Budgetary Institution of Science "Institute of Mathematical Problems of Biology of the Russian Academy of Sciences" | http://www.impb.ru/, 1118, 1119
IPKhiBPP RAS | Institute of Physico-Chemical and Biological Problems of Soil Science of the Russian Academy of Sciences | https://issp.pbcras.ru, 1077
ITEB RAS | Federal State Budgetary Institution of Science "Institute of Theoretical and Experimental Biophysics of the Russian Academy of Sciences" | https://iteb.ru/, 1107, 1127

Rostov-on-Don, ROS

RIP SFU | Research Institute of Physics of the Southern Federal University | http://ip.sfedu.ru/, 1149-2
SFedU | Southern Federal University | http://www.sfedu.ru/, 1149-2

Saint Petersburg, SPE

Botanic garden BIN RAS | Federal State Budgetary Institution of Science "Botanic Garden of the V.L. Komarov Botanic Institute of the Russian Academy of Sciences" | http://botsad-spb.com/, 1146
CRISM "Prometey" | Central Research Institute of Structural Materials "Prometey" named after I.V. Gorynin of National Research Center "Kurchatov Institute" | http://www.crism-prometey.ru/en/, 1149-2
ETU "LETI" | Saint Petersburg State Electrotechnical University "LETI" | http://www.eltech.ru/, 1129
FIP | V.A. Fock Institute of Physics of the Saint Petersburg State University | https://spbu.ru/, 1118, 1087, 1146
IAI RAS | Institute for Analytical Instrumentation of the Russian Academy of Sciences | http://iairas.ru/, 1129
IMC NRC KI PNPI | Federal State Budgetary Institution of Science "Institute of Macromolecular Compounds" branch of Petersburg Nuclear Physics Institute named by B.P. Konstantinov of NRC "Kurchatov Institute" | http://macro.ru/, 1149-2
Ioffe Institute | Federal State Budgetary Institution of Science "Ioffe Physical Technical Institute of the Russian Academy of Sciences" | http://www.ioffe.ru/, 1149-2, 1146, 1130
ITMO University | ITMO University | http://www.itmo.ru/, 1118, 1037
Neva-Magnet | Neva-Magnet S&E, Ltd | http://www.magnet.spb.su/, 1129
NIIEFA ROSATOM | Joint-Stock Company "D.V. Efremov Scientific Research Institute of Electrophysical Apparatus" | http://www.niiefa.spb.su/, 1129, 1127
NWRSCC FMBA | North-West Regional Scientific and Clinical Center named after L.G. Sokolov Federal Medical and Biological Agency | https://med122.com/, 1130

PDMI RAS | Federal State Budgetary Institution of Science "St. Petersburg Department of V.A. Steklov Institute of Mathematics of the Russian Academy of Sciences" | http://www.pdmi.ras.ru/pdmi/, 1137, 1138

PFSPSMU | Pavlov First Saint Petersburg State Medical University | https://www.1spbgmu.ru/, 1147

Radium Institute ROSATOM | Joint-Stock Company "V.G. Khlopin Radium Institute" State Atomic Energy Corporation Rosatom | http://www.khlopin.ru/, 1146, 1130

SMTU | Saint-Petersburg State Marine Technical University | https://www.smtu.ru/, 1148

SPbSPU | Peter the Great St.Petersburg Polytechnic University | http://www.spbstu.ru/, 1065, 1118, 1086, 1150, 1139

SPbSU | Saint Petersburg State University | http://spbu.ru/, 1065, 1118, 1136, 1137, 1066, 1130, 1119, 1107, 1139, 1117

SPMU | Saint Petersburg Mining University | https://www.spmi.ru/, 1146

SPSFTU | Saint Petersburg State Forest Technical University | http://spbftu.ru/, 1146

VNIIM | D.I. Mendeleyev All-Russian Institute for Metrology | https://www.vniim.ru/, 1136

Samara, SAM

SNRU | Samara National Research University | http://www.ssau.ru/, 1065, 1118, 1119, 1139

Saratov, SAR

SGU | N.G. Chernyshevsky Saratov State University | http://www.sgu.ru/, 1136, 1137, 1119, 1117

Sarov, NIZ

MSU Branch | Branch of Lomonosov Moscow State University in Sarov | https://sarov.msu.ru/, 1119

VNIIEF ROSATOM | "Russian Federal Nuclear Centre" – All-Russian Scientific Research Institute of Experimental Physics State Atomic Energy Corporation Rosatom | http://www.vniief.ru/, 1150, 1130, 1100

Sevastopol

IBSS RAS | Federal Research Center "A.O. Kovalevsky Institute of Biology of the Southern Seas of RAS" | https://ibss-ras.ru/, 1146

Smolensk, SMO

SSU | Smolensk State University | http://www.smolgu.ru/, 1087, 1139

Snezhinsk, CHE

RFNC-VNIITF ROSATOM | Federal State Unitary Enterprise "Russian Federal Nuclear Center Zababakhin All-Russia Research Institute of Technical Physics" State Atomic Energy Corporation Rosatom | http://www.vniitf.ru/, 1149-4

Sochi, KDA

SRI MP | Federal State Budgetary Scientific Institution "Scientific Research Institute of Medical Primatology" | http://www.primatologia.ru/, 1077

Sosnovy Bor, LEN

SPII "VNIPIET" | Joint-Stock Company "Sosnovoborsky Design and Survey Institute "All-Russian Scientific Research and Design Institute of Energy Technology" | http://ru.vnipiet.ru/, 1130

Staraya Ladoga, LEN

SL Museum | Staraya Ladoga Historical, Architectural and Archaeological Museum-Reserve | https://ladogamuseum.com/, 1146

Stavropol, STA

NCFU | North-Caucasus Federal University | https://ncfu.ru/, 1149-2

Sterlitamak, BA

SB UUST | Sterlitamak Branch of Ufa University of Science and Technology | https://str.uust.ru/, 1149-2

Syktyvkar, KO

DM Komi SC UrB RAS | Federal State Budgetary Institution of Science "Department of Mathematics Komi Sciences Centre of the Russian Academy of Sciences Ural Branch" | http://www.komisc.ru/, 1065

Taganrog, ROS

SRI MCS SFU | Scientific Research Institute of Multiprocessor Computing Systems of the Southern Federal University | https://mvs.sfedu.ru/, 1118

Tomsk, TOM

TPU | National Research Tomsk Polytechnic University | http://tpu.ru/, 1065, 1149-2, 1136, 1137, 1138, 1087, 1150, 1119, 1107, 1139

TSPU | Tomsk State Pedagogical University | http://www.tspu.edu.ru/, 1138, 1126

TSU | National Research Tomsk State University | http://www.tsu.ru/, 1065, 1129, 1119, 1126, 1139

Troitsk, MOW

HPPI RAS | Federal State Budgetary Institution of Science "Institute for High Pressure Physics of the Russian Academy of Sciences" | http://www.hppi.troitsk.ru/, 1149-2

INR RAS | Federal State Budgetary Institution of Science "Institute for Nuclear Research of the Russian Academy of Sciences" | http://www.inr.ru/, 1065, 1148, 1118, 1149-2, 1149-3, 1149-4, 1135, 1136, 1138, 1087, 1088, 1097, 1099, 1146, 1130, 1119, 1117

ISAN | Federal State Budgetary Institution of Science "Institute of Spectroscopy of the Russian Academy of Sciences" | http://isan.troitsk.ru/, 1077

LPP LPI RAS | Laboratory of Photomeson Processes Department of High-Energy Physics of Federal State Budgetary Institution of Science "P.N. Lebedev Physical Institute of the Russian Academy of Sciences" | http://www.lebedev.ru/, 1097

Tula, TUL

TulSU | Tula State University | https://tulsu.ru/, 1149-2, 1146, 1119, 1139

Tver, TVE

TverSU | Tver State University | http://tversu.ru/, 1119

Tyumen, TYU

UTMN | University of Tyumen | https://www.utmn.ru/, 1149-2

Vladikavkaz, SE

NOSU | North-Ossetian State University named after K.L. Khetagurov | http://www.nosu.ru/, 1065, 1118, 1081, 1087, 1146, 1119, 1107, 1139

VTC "Baspik" | Limited Liability Company "Vladikavkaz Technological Center "Baspik" | https://baspik.com/, 1087, 1150

Vladivostok, PRI

FEFU | Far Eastern Federal University | http://dvfu.ru/, 1135, 1136, 1137, 1077, 1119, A003, 1139
IACP FEB RAS | Institute of Automation and Control Processes FEB RAS | https://www.iacp.dvo.ru/, 1118
PIBOC | G.B. Elyakov Pacific Institute of Bioorganic Chemistry | http://www.piboc.dvo.ru/, 1077

Voronezh, VOR

VNIILGISbiotech | Federal State Budgetary Institution "Research Institute of Forest Genetics, Breeding and Biotechnology" | https://vniilgisbiotech.ru/, 1146
VSU | Voronezh State University | http://www.vsu.ru/, 1118, 1138, 1146, 1130, 1100, 1119, 1139

Yakutsk, SA

NEFU | North-Eastern Federal University in Yakutsk | http://www.s-vfu.ru/, 1146

Yaroslavl, YAR

YSU | P.G. Demidov Yaroslavl State University | https://www.uniyar.ac.ru, 1147

Yekaterinburg, SVE

IMP UB RAS | Federal State Budgetary Institution of Science "M.N.Mikheev Institute of Metal Physics of Ural Branch of the Russian Academy of Sciences" | http://www.imp.uran.ru/, 1149-2, 1149-3
IPAE | Institute of Plant and Animal Ecology of Ural Branch of the Russian Academy of Sciences | https://ipae.uran.ru/, 1146
UrFU | Ural Federal University named after the First President of Russia B.N. Yeltsin | http://urfu.ru/, 1149-2, 1146, 1139

Zelenograd, MOW

Angstrem | Joint-Stock Company "Angstrem" | https://www.angstrem.ru/, 1146
Mikron | Joint-Stock Company "Mikron" | https://www.mikron.ru/, 1146
RIMST | Joint-Stock Company "Research Institute of Material Science and Technology" | http://www.niimv.ru/, 1086

Zhukovsky, MOS

Technology | Limited Liability Company "Technology" | https://geliy24.ru/, 1065

Serbia

Belgrade, BG

AOB | Astronomical Observatory of Belgrade | https://www.aob.rs/, 1135
IBISS | Institute for Biological Research "Siniša Stanković" | https://www.ibiss.bg.ac.rs, 1077
IORS | Institute of Oncology and Radiology of Serbia | https://www.ncrc.ac.rs/, 1077
IPB | Institute of Physics Belgrade of the University of Belgrade | https://www.ipb.ac.rs/en, 1136, 1146
MI SANU | Mathematical Institute of the Serbian Academy of Sciences and Arts | https://www.mi.sanu.ac.rs/, 1138
UB | University of Belgrade | http://www.bg.ac.rs/, 1138, 1146, 1147, 1077, 1119
VINCA | "Vinca" Institute of Nuclear Sciences | http://www.vin.bg.ac.rs/, 1065, 1129, 1149-2, 1135, 1137, 1066, 1083, 1146, 1077, 1131

Kragujevac, KG

UniKg | University of Kragujevac | https://en.kg.ac.rs/, 1077

Nis, NI

Univ. | University of Niš | https://www.ni.ac.rs/en, 1138, 1117

Novi Sad, VO

UNS | University of Novi Sad | http://www.uns.ac.rs/, 1129, 1149-2, 1066, 1146, 1126, 1139

Sremska Kamenica, VO

Educons Univ. | Educons University | https://educons.edu.rs/, 1148

Slovakia*

Banska Bistrica, BC

UMB | Matej Bel University | http://www.umb.sk/, 1086

Bratislava, BL

CU | Comenius University in Bratislava | http://uniba.sk/, 1148, 1135, 1136, 1137, 1081, 1088, 1096, 1099, 1146, 1100, 1077
IEE SAS | Institute of Electrical Engineering of the Slovak Academy of Sciences | http://www.elu.sav.sk/, 1146
IP SAS | Institute of Physics of the Slovak Academy of Sciences | http://www.fu.sav.sk/, 1135, 1136, 1066, 1081, 1087, 1097

Kosice, KI

IEP SAS | Institute of Experimental Physics of the Slovak Academy of Sciences | https://websrv.saske.sk/uef/en/, 1149-2, 1137, 1088, 1097
TUKE | Technical University of Košice | http://www.tuke.sk/, 1088
UPJS | Pavol Jozef Šafárik University in Košice | http://www.upjs.sk/, 1065, 1137, 1066, 1087, 1088, 1097, 1119

Nova Dubnica, TC

EVPU | Electrotechnical Research and Projecting Company Nová Dubnica, j.s.c. | http://www.evpu.sk/, 1065

Zilina, ZI

UNIZA | University of Žilina | http://www.uniza.sk/, 1097

Slovenia

Ljubljana

GeoSS | Geological Survey of Slovenia | http://www.geo-zs.si/, 1146

* The cooperation may be limited by the conditions adopted unilaterally by the State.

South Africa

Bellville, WC
UWC | University of the Western Cape | http://www.uwc.ac.za/, 1146, 1077, 1131, 1139

Cape Town, WC
UCT | University of Cape Town | http://www.uct.ac.za/, 1118, 1088, 1119

Durban, NL
UKZN | University of KwaZulu-Natal | https://www.ukzn.ac.za/, 1131

Gqeberha (Port Elizabeth), EC
NMU | Nelson Mandela University | http://www.mandela.ac.za/, 1129, 1131

Johannesburg, GT
WITS | University of the Witwatersrand | http://www.wits.ac.za/, 1136, 1088

Mthatha, EC
WSU | Walter Sisulu University | https://www.wsu.ac.za/, 1131

Pretoria, GT
Necsa | South African Nuclear Energy Corporation | http://www.necsa.co.za/, 1149-2

TUT | Tshwane University of Technology | https://www.tut.ac.za/, 1131

UNISA | University of South Africa | http://www.unisa.ac.za/, 1137, 1146, 1130, 1131, 1139

UP | University of Pretoria | http://up.ac.za/, 1149-2, 1149-4, 1136, 1131

Richards Bay, NL
UNIZULU | University of Zululand | https://www.unizulu.ac.za/, 1130

Somerset West, WC
iThemba LABS | iThemba Laboratory for Accelerator Based Sciences | http://www.tlabs.ac.za/, 1065, 1129, 1136, 1088, 1130, 1077, 1119, 1107, 1131, 1127, 1037, 1139

Stellenbosch, WC
SU | Stellenbosch University | http://www.sun.ac.za/, 1065, 1129, 1136, 1146, 1107, 1131, 1139

Thohoyandou, LP
UNIVEN | University of Venda | https://www.univen.ac.za/, 1130

Vanderbijlpark, GT
VUT | Vaal University of Technology | https://www.vut.ac.za, 1129, 1131

Spain

Barcelona, CT
ICMAB-CSIC | Institute of Materials Science of Barcelona of Spanish National Research Council | https://icmab.es/, 1149-2

IEEC-CSIC | Institute of Space Science of Spanish National Research Council | http://www.ice.csic.es/, 1138

IFAE | Institute for High Energy Physics | http://www.ifae.es/, 1081

Bilbao, PV
UPV/EHU | University of the Basque Country | http://www.ehu.eus/, 1138

Granada, AN
UGR | University of Granada | https://www.ugr.es/en, 1135

Leioa, PV
BCMaterials | Basque Center for Materials, Applications and Nanostructures | https://www.bcmaterials.net/, 1149-2

Madrid, MD
CENIM-CSIC | National Center for Metallurgical Research of Spanish National Research Council | http://www.cenim.csic.es/, 1149-2

CIEMAT | Centre for Energy, Environment and Technological Research | http://www.ciemat.es/, 1083

UAM | Autonomous University of Madrid | http://www.uam.es/, 1083

Oviedo, AS
UO | University of Oviedo | http://www.uniovi.es/, 1083

Palma, IB
UIB | University of the Balearic Islands | http://www.uib.cat/, 1136

Santander, CB
IFCA-CSIC | Institute of Physics of Cantabria of the University of Cantabria and Spanish National Research Council | https://ifca.unican.es/en-us, 1083

Santiago de Compostela, GA
USC | University of Santiago de Compostela | https://www.usc.gal/en, 1138

Valencia, V
IFIC-CSIC | Institute for Particle Physics of the University of Valencia and Spanish National Research Council | https://webific.ific.uv.es/web/en, 1138, 1096

Valladolid, CL
UVa | University of Valladolid | https://universityofvalladolid.uva.es/, 1138

Sri Lanka

Moratuwa
UOM | University of Moratuwa | https://uom.lk/, 1088

Sweden

Gothenburg, O
Chalmers | Willam Chalmers University of Technology | http://www.chalmers.se/, 1136

Lund, M
ESS ERIC | European Spallation Source of European Research Infrastructure Consortium | https://ess.eu/, 1149-3, 1149-4

LU | Lund University | http://www.lu.se/, 1136, 1088

Stockholm, AB
KTH | Royal Institute of Technology | http://www.kth.se/, 1135

Uppsala, C
TSL | Svedberg Laboratory of the Uppsala University | http://www.tsl.uu.se/, 1097

Switzerland

Bern, BE
UNIBE | University of Bern | http://www.unibe.ch/, 1099

Lausanne, VD
EPFL | Ecole Polytechnique Fédérale de Lausanne | http://www.epfl.ch/, 1096, 1099

Villigen, AG
PSI | Paul Scherrer Institute | http://www.psi.ch/, 1149-2, 1083, 1151, 1146, 1100

Zurich, ZH
ETH | Swiss Federal Institute of Technology Zurich | http://www.ethz.ch/, 1083, 1096
UZH | University of Zurich | http://www.uzh.ch/, 1083, 1100

Taiwan

Taipei, TPE
NTU | National Taiwan University | http://www.ntu.edu.tw/, 1083

Taoyuan City, TAO
NCU | National Central University | http://www.ncu.edu.tw/, 1083

Tajikistan

Dushanbe, DU
NAST | National Academy of Sciences of the Republic of Tajikistan | https://amit.tj/en, 1149-2
PHTI NAST | S.U. Umarov Physical-Technical Institute of the National Academy of Sciences of the Republic of Tajikistan | http://www.phti.tj/, 1149-2
TTU | Tajik Technical University named after academician M.S. Osimi | https://web.ttu.tj/en, 1149-2

Khujand, SU
KSU | Khujand State University | http://www.hgu.tj/, 1119

Thailand

Bangkok
KMUTT | King Mogkut's University of Technology Thonburi | https://global.kmutt.ac.th/, 1088

Chachoengsao
TMEC | Thai Microelectronics Center | http://tmec.nectec.or.th/, 1088

Hat Yai
PSU | Prince of Songkla University | http://www.psu.ac.th/, 1146

Nakhon Ratchasima
SLRI | Synchrotron Light Research Institute Synchrotron Light Research Institute of the Ministry of Science and Technology | https://www.slri.or.th/en/, 1088
SUT | Suranaree University of Technology | http://www.sut.ac.th/, 1088

Tunisia

Tunis
AAEA | Arab Atomic Energy Agency | http://www.aaea.org.tn/, 1139

Turkey

Adana
CU | Çukurova University | http://www.cu.edu.tr/, 1083

Ankara
METU | Middle East Technical University | http://www.metu.edu.tr/, 1083, 1099

Bandirma, IDF
BANÜ | Bandırma Onyedi Eylül Üniversites | https://www.bandirma.edu.tr/, 1146

Canakkale, IDF
ÇOMU | Çanakkale Onsekiz Mart University | http://www.comu.edu.tr/, 1146

Istanbul, IDF
BU | Boğaziçi University | http://www.boun.edu.tr/, 1083
IU | Istanbul University | http://www.istanbul.edu.tr/, 1088
YTU | Yuldiz Technical University | http://www.yildiz.edu.tr/en/, 1083, 1088

Konya
Karatay Univ. | KTO Karatay University | https://www.karatay.edu.tr/, 1088

United Kingdom

England

Birmingham, BIR
Univ. | University of Birmingham | http://www.birmingham.ac.uk/, 1088, 1096

Bristol, BST
Univ. | University of Bristol | https://www.bristol.ac.uk/, 1083, 1096

Cambridge, CAM
Univ. | University of Cambridge | http://www.cam.ac.uk/, 1138

Canterbury, KEN
UKC | University of Kent | http://www.kent.ac.uk/, 1138

Coventry, WMD
Warwick | University of Warwick | https://warwick.ac.uk/, 1137

Daresbury, CHS
DL | Daresbury Laboratory of Science and Technology Facilities Council | https://www.ukri.org/who-we-are/stfc/facilities/daresbury-laboratory/ , 1088

Derby, DBY
Univ. | University of Derby | https://www.derby.ac.uk/, 1088

Didcot, OXF
RAL | Rutherford Appleton Laboratory of Science and Technology Facilities Council | https://www.ukri.org/who-we-are/stfc/facilities/rutherford-appleton-laboratory/, 1083

Durham, DUR
Univ. | Durham University | http://www.dur.ac.uk/, 1138

Egham, SRY
Royal Holloway | Wilson Laboratory of the Physics Department of Royal Holloway, University of London; John Adams Institute for Accelerator Science | https://www.royalholloway.ac.uk/, 1150

Guildford, SRY
Univ. | University of Surrey | http://www.surrey.ac.uk/, 1136

Lancaster, LAN
LU | Lancaster University | http://www.lancaster.ac.uk/, 1096

Liverpool, MSY
UOL | University of Liverpool | http://www.liv.ac.uk/, 1135, 1088

London, LND
IMPERIAL | Imperial College London | http://www.imperial.ac.uk/, 1135, 1138, 1083, 1099, 1144, 1100
QMUL | Queen Mary of the University of London | http://www.qmul.ac.uk/), 1099
UCL | University College London | http://www.ucl.ac.uk/, 1099

Oxford, OXF
Univ. | University of Oxford | http://www.ox.ac.uk/, 1119

Scotland

Glasgow, GLG
U of G | University of Glasgow | http://www.gla.ac.uk/, 1138, 1085, 1096, 1097

USA

Amherst, MA
UMass | University of Massachusetts Amherst | https://www.umass.edu/, 1100

Arlington, TX
UTA | University of Texas Arlington | http://www.uta.edu/, 1119

Austin, TX
UT | University of Texas at Austin | http://www.utexas.edu/, 1088, 1100

Baltimore, MD
JHU | Johns Hopkins University | http://www.jhu.edu/, 1083

Batavia, IL
Fermilab | Fermi National Accelerator Laboratory | http://www.fnal.gov/, 1083, 1099

Berkeley, CA
Berkeley Lab | Lawrence Berkeley National Laboratory of the University of California | http://www.lbl.gov/, 1066, 1088
UC | University of California | http://www.universityofcalifornia.edu/, 1149-2, 1088

Bloomington, IN
IU | Indiana University Bloomington | http://www.iub.edu/, 1066

Boston, MA
BU | Boston University | http://www.bu.edu/, 1083, 1096
NU | Northeastern University | http://www.northeastern.edu/, 1083

Boulder, CO
CU | University of Colorado at Boulder | http://www.colorado.edu/, 1083

Buffalo, NY
UB | University at Buffalo of the State University of New York | http://www.buffalo.edu/, 1083

Cambridge, MA
MIT | Massachusetts Institute of Technology | http://www.mit.edu/, 1083, 1086, 1100

Chapel Hill, NC
UNC | University of North Carolina at Chapel Hill | https://www.unc.edu/, 1100

Charlottesville, VA
UVa | University of Virginia | http://www.virginia.edu/, 1083

Chicago, IL
CSU | Chicago State University | https://www.csu.edu/, 1088
UIC | University of Illinois at Chicago | http://www.uic.edu/, 1066, 1083

College Park, MD
UMD | University of Maryland | http://www.umd.edu/, 1138, 1083

College Station, TX
Texas A&M | Texas A&M University | http://www.tamu.edu/, 1083

Columbus, OH
OSU | Ohio State University | http://www.osu.edu/, 1083, 1088

Coral Gables, FL
UM | University of Miami | http://welcome.miami.edu/, 1138

Davis, CA
UC Davis | University of California, Davis | http://ucdavis.edu/, 1083

Detroit, MI
WSU | Wayne State University | http://wayne.edu/, 1083, 1088

Duluth, MN
UMD | University of Minnesota Duluth | https://d.umn.edu/, 1099

Durham, NC
Duke | Duke University | http://www.duke.edu/, 1146

Evanston, IL
NU | Northwestern University | http://www.northwestern.edu/, 1083, 1100

Fairfax, VA
GMU | George Mason University | http://www.gmu.edu/, 1096

Gainesville, FL

UF | University of Florida | http://www.ufl.edu/, 1083

Houston, TX

Rice Univ. | William Marsh Rice University | http://www.rice.edu/, 1083

UH | University of Houston | http://www.uh.edu/, 1088

Idaho-Falls, ID

INEEL | Idaho National Engineering and Environmental Laboratory | http://www.inl.gov/, 1100

Iowa City, IA

UIowa | University of Iowa | https://uiowa.edu/, 1083

Ithaca, NY

Cornell Univ. | Cornell University | http://www.cornell.edu/, 1083

Knoxville, TN

UTK | University of Tennessee of Knoxville | http://www.utk.edu/, 1083, 1088

Lawrence, KS

KU | University of Kansas | http://www.ku.edu/, 1083

Lemont, IL

ANL | Argonne National Laboratory of the Department of Energy | http://www.anl.gov/, 1066, 1081

Lincoln, NE

UNL | University of Nebraska-Lincoln | http://www.unl.edu/, 1083

Livermore, CA

LLNL| Lawrence Livermore National Laboratory | http://www.llnl.gov/, 1083

Los Alamos, NM

LANSCE LANL | Los Alamos Neutron Science Center of Los Alamos National Laboratory of the Department of Energy | http://www.lanl.gov/, 1085, 1088, 1146

Los Angeles, CA

UCLA | University of California, Los Angeles | http://www.ucla.edu/, 1083

Lubbock, TX

TTU | Texas Tech University | http://www.ttu.edu/, 1083

Madison, WI

UW-Madison | University of Wisconsin-Madison | http://www.wisc.edu/, 1083

Manhattan, KS

KSU | Kansas State University | https://www.k-state.edu/, 1083

Menlo Park, CA

SLAC | Stanford Linear Accelerator Center of National Accelerator Laboratory | http://www6.slac.stanford.edu/, 1096

Merced, CA

UCMerced | University of California, Mered Madison | http://www.ucmerced.edu/, 1096

Minneapolis, MN

U of M | University of Minnesota Twin Cities Campus | http://twin-cities.umn.edu/, 1083, 1099

Mobile, AL

USA | University of South Alabama | https://www.southalabama.edu/, 1099

Nashville, TN

VU | Vanderbilt University | http://www.vanderbilt.edu/, 1083

New Brunswick, NJ

RU NB | Rutgers University New Brunswick | https://newbrunswick.rutgers.edu/, 1083

New Haven, CT

Yale Univ. | Yale University | http://www.yale.edu/, 1066, 1088

New York, NY

CUNY | City University of New York | https://www.cuny.edu/, 1138

RU | Rockefeller University | http://www.rockefeller.edu/, 1083

SUNY | State University of New York | http://www.suny.edu/, 1138, 1066

Newport News, VA

JLab | Thomas Jefferson National Accelerator Facility (Jefferson Lab) | http://www.jlab.org/, 1097

Norfolk, VA

NSU | Norfolk State University | http://www.nsu.edu/, 1097

Notre Dame, IN

ND | University of Notre Dame | http://www.nd.edu/, 1136, 1083

Oak Ridge, TN

ORNL | Oak Ridge National Laboratory | http://www.ornl.gov/, 1088, 1146

Omaha, NE

Creighton Univ. | Creighton University | https://www.creighton.edu/, 1088

Oxford, MS

UM | University of Mississippi | http://www.olemiss.edu/, 1083

Pasadena, CA

Caltech | California Institute of Technology | http://www.caltech.edu/, 1137, 1083, 1099

Philadelphia, PA

Penn | University of Pennsylvania | http://www.upenn.edu/, 1138

Pittsburgh, PA

CMU | Carnegie Mellon University http://www.cmu.edu/, 1083

Princeton, NJ

PU | Princeton University; Joseph Henry Laboratories of Physics | http://www.princeton.edu/, 1083

Providence, RI

Brown | Brown University | https://www.brown.edu/, 1083

Riverside, CA

UCR | University of California, Riverside | http://www.ucr.edu/, 1083

Rochester, NY
UR | University of Rochester | http://www.rochester.edu/, 1083

San Diego, CA
SDSU | San Diego State University | http://www.sdsu.edu/, 1083

San Luis Obispo, CA
Cal Poly | California Polytechnic State University | California Polytechnic State University | https://www.calpoly.edu/, 1088

Santa Barbara, CA
UCSB | University of California, Santa Barbara | https://www.universityofcalifornia.edu/, 1083

Tallahassee, FL
FSU | Florida State University | http://www.fsu.edu/, 1083

Tampa, FL
USF | University of South Florida | https://www.usf.edu/, 1132

Tuscaloosa, AL
UA | University of Alabama | http://www.ua.edu/, 1083, 1100

University Park, PA
Penn State | Pennsylvania State University | http://www.psu.edu/, 1136, 1066

Upton, NY
BNL | Brookhaven National Laboratory | http://www.bnl.gov/, 1066, 1096, 1097

Wako, TX
BU | Baylor University | http://www.baylor.edu/, 1135, 1083

West Lafayette, IN
Purdue Univ. | Purdue University | http://www.purdue.edu/, 1083, 1088

Williamsburg, VA
W&M | College of William & Mary | http://www.wm.edu/, 1097, 1099

Uzbekistan

Jizzakh, JI
JBNUU | Jizzakh Branch of the National University of Uzbekistan named after Mirzo Ulugbek | http://nuu.uz/, 1147

JDPU | Jizzakh State Pedagogical University | https://jdpu.uz, 1087

Namangan, NG
NamMTI | Namangan Institute of Engineering and Technology | http://nammti.uz/, 1136

Parkent, TO
IMS PTI "Physics-Sun" | Institute of Materials Science of the Physical Technical Institute of the Scientific and Production Association "Physics-Sun" of the Academy of Sciences of the Republic of Uzbekistan | https://imssolar.uz/, 1077

Samarkand, SA
SamSU | Samarkand State University named after Sharof Rashidov | https://www.samdu.uz/, 1136, 1087, 1151, 1139

Tashkent, TK
AS RUz | Academy of Sciences of the Republic of Uzbekistan | http://www.academy.uz/, 1118, 1119, 1139

IAP NUU | Institute of Applied Physics of the National University of Uzbekistan named after Mirzo Ulugbek | http://nuu.uz/, 1136

INP AS RUz | Institute of Nuclear Physics of the Academy of Sciences of the Republic of Uzbekistan | http://www.inp.uz/, 1118, 1149-2, 1149-3, 1149-4, 1136, 1146, 1100, 1077, 1119, 1107, 1127

IS AS RUz | Institute of Seismology named after G. A. Mavlyanov of the Academy of Sciences of the Republic of Uzbekistan | https://www.seismos.uz/, 1131

PTI "Physics-Sun" | Physical Technical Institute of the Scientific and Production Association "Physics-Sun" named after S.A. Azimov of the Academy of Sciences of the Republic of Uzbekistan | http://www.fti.uz/, 1065, 1136, 1087, 1146, 1119

TashSTU | Tashkent State Technical University | http://tdtu.uz, 1139

Vietnam

Da Lat, LD
DNRI | Dalat Nuclear Research Institute | https://nri.gov.vn/en, 1066, 1146

Da Nang, DN
DTU | Duy Tan University | https://duytan.edu.vn/, 1149-2

Hanoi, HN
HUST | Hanoi University of Science and Technology | https://hust.edu.vn/en/, 1129

IMS VAST | Institute of Material Science of the Vietnam Academy of Science and Technology | https://ims.ac.vn/, 1147, 1131

INPC VAST | Institute of Natural Products Chemistry of the Vietnam Academy of Science and Technology | https://inpc.ac.vn/, 1077

IOP VAST | Institute of Physics of the Vietnam Academy of Science and Technology | https://iop.vast.vn/?lang=en, 1129, 1149-2, 1135, 1137, 1146, 1130, 1100, 1147, 1139

ITT VAST | Institute for Tropical Technology of the Vietnam Academy of Science and Technology | http://itt.vast.vn/, 1077

VINATOM | Vietnam Atomic Energy Institute of the Ministry of Science and Technology | https://vinatom.gov.vn/en/, 1077, 1139

VNU | Vietnam National University Hanoi | http://www.vnu.edu.vn/, 1146

Ho Chi Minh City, SG
CNT VINATOM | Center for Nuclear Techniques, VINATOM | https://vinatom.gov.vn/en/, 1132

HCMUE | Ho Chi Minh City University of Education | https://hcmue.edu.vn/en/, 1119

VLU | Văn Lang University | https://www.vlu.edu.vn/en/, 1137

VNUHCM | Vietnam National University Ho Chi Minh City | https://vnuhcm.edu.vn/, 1135