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## NEW JINR PROJECTS AND COOPERATION WITH BELARUSIAN SCIENTISTS

**Abstract.** The issues of the international cooperation of Belarusian organizations with the Joint Institute for Nuclear Research within the framework of international projects with the participation of scientists and specialists of Belarus are considered.

**Keywords:** JINR, scientific cooperation, international project, experiments

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## НОВЫЕ ПРОЕКТЫ ОИЯИ И СОТРУДНИЧЕСТВО С БЕЛОРУССКИМИ УЧЕНЫМИ

**Аннотация.** Рассматриваются вопросы международного сотрудничества белорусских организаций с Объединенным институтом ядерных исследований в рамках международных проектов с участием белорусских ученых и специалистов.

**Ключевые слова:** ОИЯИ, научное сотрудничество, международный проект, эксперименты

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The Joint Institute for Nuclear Research (JINR) is situated in the Dubna town on the right bank of the Volga river, 120 km north from Moscow. JINR is an International Intergovernmental Scientific Research Organization, established in 1956 by 12 countries to unite scientific and material potential of its member states in order to study fundamental properties of matter. Originally, Belarus joined JINR as a Republic of the Soviet Union. At present, there are 18 JINR Member States: Armenia, Azerbaijan, Belarus, Bulgaria, Cuba, Czech Republic, Georgia, Kazakhstan, D. P. Republic of Korea, Moldova, Mongolia, Poland, Romania, Russian Federation, Slovakia, Ukraine, Uzbekistan and Vietnam. Participation of Egypt, Germany, Hungary, Italy, the Republic of South Africa and Serbia in JINR activities is based on bilateral agreements signed on the governmental level. The agreement on the membership of Belarus to JINR was signed on December 10, 1991. It was facilitated by close ties of the scientific centres and universities of Belarus with the international centre in Dubna. The ratification of the admission act and the appointment of the Plenipotentiary Representative of Belarus at JINR was carried out in March, 1992, by the corresponding official decree of the Belarus Republic Government.

The supreme governing body of JINR is the Committee of Plenipotentiaries (CP) of the Governments of the JINR Member States since March 26, 2014. The Plenipotentiary representative of the Belarus Government is Shumilin Alexander Gennadyevich, the chairman of the State Committee for Science and Technology of Belarus. In November 2015, the meeting of the JINR Finance Committee and the session of the Committee of Plenipotentiaries of the Governments of the JINR Member States were held in Minsk.

In JINR, the most advanced scientific research is implemented with the help of so-called basic facilities of the Institute. In recent years, almost all of them have been substantially modernised.

The basic facility, to carry out investigations in the field of high-energy physics, is the Nuclotron – a superconducting ion accelerator (accelerating ions up to gold nuclei with the maximum kinetic energy

of 4.5 GeV/nucleon and, longitudinally and transversally polarized particles with the maximum kinetic energy of 12.5 GeV per proton). An accelerator-experimental collider complex NICA (Nuclotron based Ion Collider fAcility), aimed at studying new states and properties of matter with the use of ultra relativistic heavy ions and polarized light ions is under construction. Also, the capabilities of the operating individual elements of the NICA complex are already used in applied research.

The basic facility in the field of heavy-ion physics at low and intermediate energies is the complex of isochronous cyclotrons U400M and U400MR. It allows one to accelerate heavy ions up to energies of 50 MeV/nucleon with the intensity sufficient to produce new super heavy elements and carry out an advanced applied research. Their modernisation allowed implementing the 2nd stage of the DRIBs (Dubna Radioactive Ion Beams), project which goal is to create beams of exotic nuclei with a shortage or excess of neutrons. The third stage, a heavy-ion plant, involves the construction of a new high-current cyclotron dedicated to the detailed study of super heavy elements in the island of stability.

The main basic installation for the condensed matter physics and nuclear physics with neutrons is the modernized pulsed IBR-2M reactor. The pulsation frequency of the reactor is 5 Hz, the energy in the pulse is 1.5 GW and the neutron flux is  $10^{16}$  per second per  $\text{cm}^2$ . In addition, an electron accelerator driven pulsed neutron source IREN (Intense REsonance Neutron Source) functions at JINR since 2009 at energies of hundreds of keV.

Another basic facility of JINR is the Phasotron (modernized synchrocyclotron), used mainly for hadron therapy and applied research.

As a basic JINR facility, its Central Information and Computer Complex can also be considered. Currently, it includes Tier 1 for CMS, Tier 2, a heterogeneous cluster for parallel computing and branched network structure. In the frame of this complex an element of the computing infrastructure of the NICA project is being created.

The JINR includes seven laboratories, each of them is in fact comparable by size and scope of the research with major institutes in the respective field of research. These are Bogoliubov Laboratory of Theoretical Physics, Dzhelapov Laboratory of Nuclear Problems, Flerov Laboratory of Nuclear Reactions, Veksler and Baldin Laboratory of High Energy Physics, Frank Laboratory of Neutron Physics, Laboratory of Information Technologies and Laboratory of Radiation Biology. In addition, there is the University Centre (UC) aimed at training of high-quality young specialists for research at JINR and scientific centers of the Member States.

Since 2010, the Institute work has been organised according to seven-year plans for its development. Last such plan for the years 2017–2023 was approved by the CP at its session in Krakow on 21–22 November, 2016. The main objectives of the plan are:

- the effective use of new and modernized basic facilities (Nuclotron-M, IBR-2M, SHE factory);
- the construction and operation of a new fixed target facility at Nuclotron-BM@N;
- the realization of the first stage of the NICA collider and its detectors MPD and SPD;
- the realization of the full scale neutrino Gigaton Volume Detector at the Baikal lake;
- the extension of the international cooperation around basic facilities of JINR, further integration of these facilities into European and worldwide research infrastructures;
- attracting new countries to the JINR family;
- adjusting the general infrastructure and operation of JINR according to experience of best international research centers.

About 4500 employees work at JINR. Among them, there are 1200 scientists, about 400 from which are from the JINR Member States but Russia; about 1000 are doctors and candidates of science. About 350 students and post-graduate students study at the JINR UC.

The following three main areas can be distinguished from a wide range of JINR studies:

- (i) Particle and relativistic nuclear physics – the most direct way to study the structure of matter and its fundamental interactions. The scientists of the Institute conduct research in this field not only on accelerators in Dubna, but also at CERN, IHEP (Protvino, Russia), FNAL (Batavia, USA), BNL (Brookhaven, USA), DESY (Hamburg, Germany) and other scientific centres. An important partner of JINR is the GSI centre in Darmstadt, Germany, in close cooperation with which NICA and the FAIR accelerator complexes are being built.

- (ii) Nuclear physics at low and intermediate energies aimed at studying of nuclear properties, nuclear reactions, new elements, including super-heavy ones. The JINR is one of the world leaders in this field.
- (iii) Condensed matter physics including radiobiology. This is a rapidly developing area of the fundamental and applied research. Experimental methods of nuclear physics are used to study physical phenomena in solids and liquids, new properties of materials, and so on.

All the activities in these areas are supported by theoretical research, advanced computing, work in the field of constructing accelerators, detectors, electronics, etc. A special attention is paid to the training of young specialists and researches.

It should be emphasized that specialists and institutions of the Republic of Belarus are involved in practically all aspects of JINR activities.

At present, 21 research centres and the university of Belarus cooperate with JINR in the framework of 27 JINR scientific themes and projects – 4 in theoretical physics; 12 in elementary particle physics and relativistic nuclear physics; 2 in nuclear physics; 6 in condensed matter physics, radiation and radiobiological studies; 2 in networks, computing, computational physics and 1 in educational program. Belarus participation in works on the mega-project NICA has substantially expanded in accordance with the signed agreement between JINR and the State Committee for Science and Technology of the Republic of Belarus on May 31, 2013.

At present, 24 Belarusian specialists and members of their families work in Dubna. More than 150 Belorussian experts carry out investigations in Belarus institutions using JINR methods and technologies, with the participation of Dubna colleagues, as well as, visiting Dubna for short-term trips.

Several agreements between JINR and Belarusian organizations were signed during last ten years. The signed agreement on scientific and technical cooperation between the National Academy of Sciences of Belarus and JINR coordinates the development of current and future joint work plans, participation in the creation of joint industry, state and international programs of mutual interest, coordination of their implementation and practical use of the results obtained, including a rapid exchange of information.

Thanks to cooperation with JINR, the scientists of Belarus have real opportunities to access the world largest scientific accelerator centers. The Agreement between the State Committee for Science and Technologies of the Republic of Belarus, CERN and JINR on coordination of efforts to participate in the project for the creation of a Compact Muon Solenoid (CMS) is important and to date. Belarus plays an important role in the cooperation of Russia – Dubna Member States (RDMS) in CMS, periodically organising meetings of this collaboration. At present, scientists from Belarus, as specialists of the JINR Member State, participate in the ATLAS experiment at the LHC in daily contact with JINR experts.

In accordance with the Agreement between JINR and the Belarusian State Committee for Science and Technology, signed in Minsk on May 31, 2013, the cooperation on the mega-project NICA is expanding. The following is already under way in the different areas:

- development of the power supply system of the Nuclotron and transfer lines of the extracted beams;
- development of the NICA collider stochastic cooling elements (beam test was performed in December, 2016, at Nuclotron);
- simulation and optimization of operating characteristics of superconducting resonators for a linear proton accelerator;
- development of electronics – low voltage distribution board and read-out chambers for the TPC/MPD detector;
- development of the box prototype and mass production for TOF/MPD detector;
- assembly and metrology devices production for silicon tracker system of BM@N set-up;
- development of MPD mock-up etc.

In total, 14 contracts have been signed in 2016–2017 and 14 are planned to be signed in 2017–2018.

Among the Belarusian scientific organizations cooperating with JINR, the Belarusian State University and its research institutes should be distinguished in terms of their close connections with JINR. In addition, JINR most active partners are:

- State Scientific Institution “United Institute of Energy and Nuclear Research – Pine Nans” (OIEHP-Sosny NASB) – on 7 topics;
- State Scientific Institution “Institute of Physics. B. I. Stepanov NASB (IF NASB) – on 6 topics;
- Scientific Research Institution “Institute of Nuclear Problems” of BSU (Research Institute of Nuclear Physics of BSU) – on 16 topics;
- Belarusian State University of Informatics and Radioelectronics (BSUIR) – on 4 topics;
- Belarusian State University (BSU) – on 4 topics;
- Gomel State University named after Frantsisk Skorina (GSU) – on 7 topics;
- Sukhoi State Technical University of Gomel (GSTU) – on 6 topics.

Other 16 institutes and organizations of Belarus are participating in this cooperation, including Belarusian State Academy of Aviation (BSAA) in Minsk.

The Agreement on Cooperation between JINR and the Sukhoi State Technical University of Gomel, has been devoted to the training of highly qualified specialists in the most promising fields of science and applications. In March 2002, the General Agreement on Cooperation of the Gomel State University with JINR was signed. It involves the search for, development and implementation of new forms of integration of higher education and science in the fields of physics, new technologies, applied mathematics, electronics and computer technology.

The development of science in Belarus is facilitated by international conferences, symposiums, meetings and schools held on its territory. Among them, so-called Gomel schools can be considered as traditional ones. The first of them was held on the Gomel land in 1971. Then, with the interval of one year, there were three more schools. Since 1997, the tradition of holding Gomel schools has been renewed. At the origins of the school stood such prominent scientists as N. N. Bogolyubov, F. I. Fedorov, V. G. Kadyshevsky, V. A. White, B. V. Bokut and others. The most recent (twelfth) school-seminar “Actual problems of physics of the microworld” was held in the summer of 2015. JINR plays an important role in organizing and conducting these schools.

In 2014, the JINR-organized International Meeting “Status and Prospects for the Creation of Resonators for a New Generation of  $e^+e^-$  Linear Accelerators and Colliders” was held in Minsk in cooperation with Belarus. In 2015, the joint conference “Modern Nuclear Physics Research in Condensed Matter Physics” and in 2016 a working meeting of the COMET collaboration, were held in Minsk.

Every year, on the basis of the JINR UC and the JINR Laboratories, scientific and training practice of students is organized. The table below reflects the number of students from various universities and institutes of Belarus, who took part in it. Four Laboratories accepted Belarus students, conducting their training on the most modern installations and equipment. It should be noted that JINR invests about \$ 1000 per student. We consider this activity as very important and hope for more active cooperation with universities and institutes of Belarus in this important task of training highly qualified specialists.

#### Research-and-training student practice at JINR

Belarusian universities	Year					
	2012	2013	2014	2015	2016	2017
GSU	2	3	2	2	2	1
BSUIR		3	8	5	3	5
GSTU				3	10	3
BSAA					1	1
BSU						2
In total:	2	6	10	10	16	12

Since 2006, the Memorandum of Cooperation between JINR and the Belarusian Republican Foundation for Basic Research (BRFFR) has been in force. On the basis of the Memorandum, the Agreement between the BRFFR and JINR on the joint thematic competition of research projects is signed annually, which results in the financing of winning projects. Ten projects were supported by this fund in 2016 and 2017.

Though some of the issues of JINR – Belarus cooperation have not been fully resolved, the cooperation between JINR and Belarus is currently at a fairly high level and is constantly expanding.

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