2018

JOINT INSTITUTE FOR NUCLEAR RESEARCH

Joint Institute for Nuclear Research

Phone: (7-49621) 65-059
Fax: (7-495) 632-78-80
E-mail: post@jinr.ru
Address: JINR, 141980 Dubna, Moscow Region, Russia
Web http://www.jinr.ru

Online version: http://wwwinfo.jinr.ru/publish/Reports/Reports_index.html

ISBN 978-5-9530-0514-2

JINR MEMBER STATES

Republic of Armenia
Republic of Azerbaijan
Republic of Belarus
Republic of Bulgaria
Republic of Cuba
Czech Republic
Georgia
Republic of Kazakhstan
Democratic People's Republic of Korea
Republic of Moldova
Mongolia
Republic of Poland
Romania
Russian Federation
Slovak Republic
Ukraine
Republic of Uzbekistan
Socialist Republic of Vietnam

AGREEMENTS ON GOVERNMENTAL LEVEL ARE SIGNED WITH THE FOLLOWING STATES:

Arab Republic of Egypt
Federal Republic of Germany
Republic of Hungary
Italian Republic
Republic of Serbia
Republic of South Africa

CONTENTS

INTRODUCTION

In 2018, the Joint Institute for Nuclear Research accomplished actively and systematically tasks in all priority directions of the seven-year programme of JINR (2017–2023) that foresees implementation of large-scale and ambitious scientific projects included in it. At the same time, the keynote of the year was summing up the results of the 25-year period of modern development of the Institute that was marked by strengthening its international status, accounting for serious political and economic changes in some Member States. It was in these years that the phrase uniting us "Science Bringing Nations Together" became the motto of the Institute and new projects were started that should provide steady development of the Institute. A number of states concluded agreements with JINR on associate membership, demonstrating the growing international scientific prestige of Dubna.

The scientific and technical potential accumulated over these years laid the foundation for the work-out of a long-term strategic plan of JINR development up to 2030 that includes the construction of the superconducting accelerator complex NICA, the projects DRIBs-III and DERICA (Dubna Electron-Radioactive Ion Collider fAcility), superbooster "Neptun" — a future neutron source that could eventually replace the existing reactor IBR-2, the development of the deep water neutrino telescope Baikal-GVD in Lake Baikal, and a research complex for hadron therapy. A special international working group tackles the strategy of the Institute development, and the Directorate pays great attention to it.

In 2018, our main scientific projects were included in perspective international plans for development of particle physics, fundamental physics, and condensed matter physics. In particular, in September the ESFRI Strategy Report on Research Infrastructures was presented in Vienna that contains the NICA complex, the SHE factory and the IBR-2 reactor. Thus, the Institute plays an important role for all Member States, and primarily for Russia, as one of the efficient instruments for integration into the world science.

An important benchmark in implementation of the flagship project of JINR — the development of the NICA collider complex — was the official inauguration of the international collaborations MPD and BM@N and two big meetings on these experiments held in Dubna. Involvement of wide international scientific participation is a common world practice for efficient advancing and obtaining bright interesting results.

An accelerator run was conducted successfully at the basic element of the currently developed NICA complex — the superconducting synchrotron Nuclotron, at extracted beams of $^{12}C^{6+}$, $^{40}Ar^{16+}$ and $^{78}Kr^{26+}$ ions. For the first time in the world practice, a nonstructural mode of slow extraction of an accelerated beam from the superconducting synchrotron was realized using HF noise to improve the quality and uniformity of the bunch. Krypton ions with an energy of 3.1 GeV/nucleon were accelerated and extracted from the ring; the possibility of stable operation of the Nuclotron with a field of 18 kG level was demonstrated. At the BM@N facility, which is the first phase of the NICA complex, data acquisition was conducted in the physics programme on studies of short-range correlations. During the run, over 200 million events were recorded, including those obtained in testing new elements of the facility at beams of argon and krypton ions.

The goal of constructing at JINR the world's first Factory of Superheavy Elements is the synthesis of new superheavy elements with $Z = 119$ and 120 and further studies of the properties of SHE earlier discovered at JINR (^{114}Fl, ^{115}Mc, ^{116}Lv, ^{117}Ts, ^{118}Og). The implementation of this unique project will allow preserving the priority of JINR in the synthesis and study of properties of new elements — one of the most important fields of modern nuclear physics. In 2018, the first stage of the Factory of Superheavy Elements was constructed, including the experimental building, the new heavy-ion accelerator DC-280 (with a design ion intensity one order of magnitude higher than that of any existing accelerator in the world), and the high-efficiency gas-filled separator of reaction products.

The production of a test beam of accelerated ions at the DC-280 cyclotron became a bright demonstration of JINR capacity to solve successfully most complex scientific and technical tasks. We are also very glad that the UN General Assembly proclaimed 2019 the International Year of the Mendeleev Periodic Table of Chemical Elements.

Theoreticians of the Institute developed a new approach to the theory of nonrenormalized interactions. Generalizations of the renormalization group equations are obtained, which make it possible to sum up the leading asymptotics in all orders of the perturbation theory. The ultraviolet behavior of a number of supersymmetric gauge models of quantum field theory is found.

The third cluster of the deep underwater detector was installed in Lake Baikal as the next step towards full-scale Baikal-GVD detector. The detector consists of 864 optical modules assembled on 24 vertical strings (8 strings in each cluster) distributed from 750 to 1250 meters depth. On-line work is conducted for search and analysis of events that register neutrinos of superhigh energy coming from another galaxy. The world is surprised to see how vigorously JINR is developing this trend because our talented scientists demonstrate here a unique ability to proceed at a fast pace.

In 2018, the strictest model-independent restriction on the existence of sterile neutrino was obtained in the analysis of the first part of experimental data collected by the neutrino detector DANSS. The neutrino detector DANSS, developed by JINR's DLNP physicists in collaboration with ITEP collegues (Moscow) and installed at the Kalinin NPP, registers about 4000 reactor antineutrinos per day with a background less than 2–3% (both values are the worldwide best now).

Very important work was conducted at the Institute on upgrading and improving specifications of the spectrometer park at the pulsed reactor IBR-2. At present it is among the state-of-the-art facilities of this type. During the year, studies of condensed state of matter were continued and a new perovskite phase of the simple binary oxide Mn_2O_3 was synthesized at high pressures and temperatures. A study of structural, magnetic and ferroelectric properties of this material was performed. The existence of two modulated antiferromagnetic phases ($T_{N1} \approx 100$ K, $T_{N2} \approx 50$ K) was established, and their magnetic structure was determined. In the low-temperature antiferromagnetic phase, emergence of the spin-induced spontaneous ferroelectric polarization was detected.

A unique supercomputer "Govorun" was launched at JINR. It is named in honour of the talented scientist N. Govorun, who established the Laboratory of Information Technologies, together with M. Meshcheryakov. It is a heterogeneous computer platform that contains both CPU computing components and computation accelerators GPU NVIDIA V100 (DGX) for resource-intensive massive-parallel calculations. The supercomputer occupies the 9th place in the international rating. A lot of scientists from Russia and other countries already work at it, make calculations, and simulate nuclear processes that will be studied experimentally at the NICA collider.

Radiobiologists of JINR developed a fundamentally new technique of increasing the biological effectiveness of medical proton beams and γ-therapy facilities. The approach is based on the application of the officinal preparation which is used in oncological practice for the treatment of hematopoietic system cancer. When the preparation is introduced before human cell exposure to ionizing radiation, DNA single-strand breaks are transformed into lethal double-strand ones. The proposed approach provides a significant increase in the biological effectiveness of proton beams, thereby bringing the areas of the therapeutic use of proton and carbon ion accelerators much closer to each other.

Of course, one of the priority tasks that are still urgent at JINR as a large international scientific centre is work to extend the cooperation geography, attract other countries and big international organizations to participation in activities of the Institute. A roadmap of 10-year scheduled cooperation between Russia and Germany was signed. This important document opens opportunities for a wider cooperation of JINR with institutes and specialists of Germany. A roadmap for cooperation between Russia and France was also signed that foresees deeper interactions of scientists from French scientific centres with JINR.

One more important event of the year is the accomplishment of the RF Government's decision to provide the Institute with the right to independently establish the attestation system of scientific staff and to confer degrees of Candidates of Science and Doctors of Science. Due to the international status of JINR, it is the only possibility to establish an international system of attestation.

In light of the ambitious scientific projects being pursued by the Institute and scheduled for years to come, it is utterly important to attract intellectual resources to JINR — talented young people interested in science and to train young specialists who could even now master the most advanced technology. According to this task, a joint educational project of JINR and the Dubna State University was started — the International Engineer School (higher engineering and physics school) whose aim is training of specialists in design and operation of physical facilities that are used in solving scientific and applied tasks and in work-out of special science-intensive technologies.

In 2018, over 400 students of the JINR-based departments of MSU, MIPT, MEPhI, Dubna State University, and the universities of JINR Member States were trained at the University Centre. More than 200 students from higher education institutions of Azerbaijan, Belarus, Brazil, Bulgaria, China, Cuba, the Czech Republic, Egypt, Germany, Italy, Kazakhstan, Mongolia, Poland, Romania, RF, RSA, Serbia, Slovakia, Ukraine and Uzbekistan became participants of the summer student practice courses at JINR. These programmes allow students and postgraduates to become acquainted with research areas of the Institute and accomplish their training and scientific projects.

The annual joint JINR–CERN Schools for Physics Teachers from JINR Member States gathered more than 50 teachers of physics from Azerbaijan, Belarus, Bulgaria, India, Kazakhstan, Moldova, RF and Ukraine.

To attract talented youth to the Institute and our city, it is necessary to create decent conditions of life and work. That is why we are actively developing the social and sport basis of the Institute. In 2018, an upgraded race track, bicycle rental and renovated sport building were opened at the JINR stadium “Nauka”. It is encouraging that we have close creative contacts with the city administration and the Deputies Council.

Attention should be paid to one more outstanding and long-awaited event — the construction of the bridge across the Volga River has been at last completed. It is undoubtedly a great achievement. The bridge is constructed on the most advanced technological level; it opened not only an opportunity to connect the right and left bank parts of Dubna. It actually became a symbol of further development of the science city of Dubna.

We note with satisfaction that the tasks determined by the Seven-Year Plan of the Development of JINR to create an advanced basis for experimental research in fundamental physics, condensed matter physics, development and application of innovation ideas, in educational activities are successfully being solved, and this allows us to look in future with optimism.

Bright achievements and results obtained by the multinational community of the Institute in all research fields and the immense experience we accumulated show that the international scientific cooperation is one of the highest values in modern world. It is a unique association of efforts, intellectual potential and culture of many peoples. I would like to express our deep gratitude to the Government of the Russian Federation, Governments of JINR Member States and other countries that cooperate with JINR, to all our partners for the full support to the Institute. JINR will actively continue the all-round scientific technical cooperation, long-term planning, and development of ties with international and national scientific centres for the sake of progress and flourishing of science.

V. Matveev
Director
Joint Institute for Nuclear Research

2018

GOVERNING AND ADVISORY BODIES OF JINR

JOINT INSTITUTE FOR NUCLEAR RESEARCH

JINR

ACTIVITIES OF JINR GOVERNING AND ADVISORY BODIES

SESSIONS OF THE JINR COMMITTEE OF PLENIPOTENTIARIES

A regular session of the Committee of Plenipotentiaries of the Governments of the JINR Member States was held on 27 March. It was chaired by the Plenipotentiary of the Russian Federation, G. Trubnikov.

The Committee of Plenipotentiaries (CP) considered the report by JINR Director V. Matveev presenting a detailed overview of the progress in implementation of JINR's high-priority projects and their place in the long-term international programmes of fundamental physics research. The CP recognized the significant number of high-quality physics results obtained by JINR scientists in 2017 at home facilities of the Institute as well as at external accelerators, reactors and in various collaborations; commended the work done by the JINR Directorate and staff towards developing the Institute's research infrastructure including the NICA megaproject, the Factory of Superheavy Elements (SHE) and the IBR-2 spectrometer complex, as well as the efforts towards achieving important milestones of constructing and upgrading these facilities.

The CP noted the significant ramping up of the international visibility of JINR and its flagship projects: the NICA project has already been included in the ESFRI roadmap and in the NuPECC long-range plan; synthesis of superheavy elements by JINR is a world-leading programme, the SHE Factory has also been included in the NuPECC long-range plan; IBR-2 is part of the European neutron roadmap; the neutrino research projects at the Kalinin NPP and at Lake Baikal are also flagship programmes with prospects to be integrated into the APPEC roadmap.

The CP took note of the meeting of the Supervisory Board of the NICA complex project held on 2 February 2018 and of its recommendations on the research programme, on the structure of its management bodies, on its financial support, and on the civil construction of the NICA complex.

The CP welcomed the JINR Directorate's plans to hold a three-day meeting of stakeholders in April 2018 to officially launch the MPD and BM@N international collaborations.

The CP commended the efforts of the JINR Directorate towards completing the first phase envisaging construction of the SHE Factory in July 2018 and towards starting first experiments in late 2018.

The CP supported the work of the JINR Directorate and of the Republic of Poland for developing a Cooperation Agreement on the construction and operation of a Laboratory for Structural Research of Macromolecules and New Materials at the SOLARIS National Synchrotron Radiation Centre of the Jagiellonian University in Kraków, based on the results of consideration of this initiative at sessions of JINR's PAC for Condensed Matter Physics and Scientific Council.

The CP welcomed the Institute's plans for the participation in celebrations dedicated to the 2019 International Year of the Periodic Table of Chemical Elements, including in those planned by UNESCO.

The CP noted with satisfaction the holding, on 26 March 2018, of the festive meeting dedicated to the 25th anniversary of the accession to the Institute of a group of independent states.

The CP took note of the signing of the Letter of Intent between JINR and the Government of the French Republic, which creates conditions for the entry of the French Republic into the states participating in JINR on the basis of government-level cooperation agreements, and requested the Directorate to provide more detailed information on the agreements reached at the next session of the CP in November 2018.

The CP welcomed the efforts of the JINR Directorate aimed at training scientific and engineering personnel for large high-tech projects of JINR and in Member States, as well as towards the development and support of the Institute's educational activities in general.

Regarding the report "Execution of the JINR budget in 2017" presented by S. Dotsenko, Chief Accountant of JINR, the CP noted the balanced execution of the budget in income and expenditure in 2017.

Regarding the report "Draft of the revised budget of JINR for 2018" presented by M. Vasilyev, Deputy Head of the JINR Finance and Economy Office, the CP approved the revised budget for 2018 with the total income and expenditure amounting to US$268.79 million.

Regarding the report "Results of the meeting of the JINR Finance Committee held on 23–24 March 2018" presented by A. Khvedelidze, Plenipotentiary of the Government of Georgia to JINR, the CP approved the protocol of this meeting. The Committee resolved: with a view to ensuring the proper financing of JINR's activities, to complete the transition period stipulated in the Financial Protocol to the JINR Charter by 1 January 2020; to commission the JINR Directorate to prepare a Procedure for the offset of the cost of supplies of equipment, instruments, materials, services and individual work on the Institute's orders against payments of the Member States' contributions by 1 June 2018 for consideration at the next meeting of the Working Group for JINR Financial Issues under the CP Chairman; to commission the JINR Directorate to finalize and enact the Regulation for the programmes of cooperation between JINR and scientific organizations of the Member States by 1 June 2018.

The CP endorsed the programme for improving the procurement activities of JINR, taking into account the constant monitoring of the quality of provision for the Institute's needs, the effectiveness of contractual work at the level of the best practices and capabilities of suppliers from Member States; commissioned the JINR Directorate to continue the work in accordance with JINR's Order "On initiating the process of JINR's withdrawal from the founders (shareholders) of legal entities and of liquidation of non-profit organizations established with JINR's participation" as well as to prepare an updated draft Regulation for the introduction of adjustments to the JINR budget and to send it to the Member States as part of organizing the next meetings of the Finance Committee and of the CP in November 2018.

Regarding the "Proposals of the Finance Committee for the selection of an organization for auditing the financial activities of JINR for the year 2017" presented by A. Khvedelidze, the CP approved the LLC AC "Korsakov and Partners" as JINR's auditor for the year 2017 as well as the plan for auditing the financial activities of JINR for 2017 as presented by the JINR Directorate.

After hearing with interest the report "Supercomputer — a state-of-the-art project for the development of JINR basic facilities" presented by V. Korenkov, Director of the Laboratory of Information Technologies, and visiting LIT to participate in the presentation of the Supercomputer named after N. Govorun, the CP noted the significant progress in developing high-performance computing at JINR required for the radical acceleration of complex theoretical research in hadron matter physics underway at BLTP and for enabling the use of newest computing platforms in the NICA project; appreciated highly the work of the LIT team for commissioning the supercomputer "Govorun"; noted the active participation of BLTP in the justification of its parameters and future research programme; and welcomed the efforts of the LIT Directorate for the development of IT at JINR, amongst others to support the Laboratory's initiative to create a unified cloud infrastructure with JINR participating countries based on the Supercomputer.

Regarding the information "Current work for the development of the JINR strategic long-range plan" presented by B. Sharkov, Deputy Director of JINR, the CP took note of the information about the activity of the International Working Group for JINR Strategic Long-Range Planning and commissioned the JINR Directorate to regularly inform the CP about the progress in this work.

Regarding the information "Election to the membership of the JINR Scientific Council" presented by JINR Chief Scientific Secretary A. Sorin, the CP thanked the members of the Scientific Council for the successful work accomplished during 2013–2018; for the next five-year period, established the maximum composition of the Scientific Council comprising 50 members; and approved the membership of the Scientific Council for a new term of five years based on the results of open ballot.

Based on the duly discussed report "Endorsement of the appointment to positions of JINR Vice-Directors" presented by JINR Director V. Matveev, the CP endorsed the appointment of R. Lednický as Vice-Director of JINR until the end of 2021, entrusted the Leader of the NICA Project, V. Kekelidze, to execute partially the powers of JINR's Vice-Director until the end of 2021 with the continuation of his work as Director of VBLHEP, whose term of office expires in September 2019, as well as prolonged for one year the right granted to the JINR Director to extend the term of office or to assign temporary duties of JINR Vice-Directors, including to other persons, until their official approval by the CP.

A regular session of the Committee of Plenipotentiaries of the Governments of the JINR Member States was held in Bucharest on 19–20 November. It was chaired by G. Trubnikov, a representative of the Russian Federation.

Based on the report presented by JINR Director V. Matveev, the Committee of Plenipotentiaries (CP) appreciated highly the efforts of the JINR Directorate to develop JINR's flagship research programmes, in particular:

— noted the progress towards construction of the NICA collider complex as well as the official opening of the MPD and BM@N international collaborations and the holding of two collaboration meetings of the MPD and BM@N experiments, which is a significant step in the advancement of these experiments and which contributes to attracting a wide international community to the realization of the NICA project;

— commended the efforts being taken towards the timely completion of the construction, licensing, and commissioning of the Factory of Superheavy Elements (SHE Factory) as well as the plans of first test experiments;

— welcomed the steps being taken towards a better coordination of the neutrino physics programme and towards implementation of priorities in this area in a more concerted and efficient manner;

— noted with satisfaction the progress of the research programme in the field of condensed matter physics, which includes, among other things, the development of the concept for a new source of neutrons at JINR replacing the IBR-2 reactor after completion of its exploitation, as well as the signing of the Letter of Intent concerning the establishment of a Laboratory for Structural Research of Macromolecules and New Materials at the SOLARIS synchrotron of the Jagiellonian University in Kraków;

— welcomed the launching of the Supercomputer "Govorun", which has taken a prominent place in the international ratings of computing systems;

— highlighted the progress achieved by JINR in integrating its basic facilities into the global research infrastructure programmes, in particular, the inclusion of the NICA complex, the SHE Factory and IBR-2 reactor in the ESFRI Strategy Report on Research Infrastructures presented on 11 September 2018 in Vienna.

The CP commissioned the JINR Directorate to present, at the CP's session in March 2019, an analysis of implementation of the schedules of the NICA megaproject, the SHE Factory and of the Baikal project, also to continue the ongoing work to attract new partners, in particular, GSI (Germany), to the implementation of JINR projects and scientific programmes, and to report on the results at the CP's next session.

Noting with satisfaction the JINR Directorate's attention to the analysis of implementing the Seven-Year Plan for the Development of JINR for 2017–2023, the CP stressed the importance of consolidating JINR's research programme within the major objectives of the seven-year plan and of concentrating efforts on the in-house experiments.

The CP commissioned the JINR Directorate to prepare a plan of activities dedicated to the 2019 International Year of the Periodic Table of Chemical Elements, especially in the JINR Member States and in states participating in JINR under agreements on science and technology cooperation.

The CP commended the efforts of the JINR Directorate aimed at popularizing the achievements of JINR and at implementing its educational programme, with special attention drawn to the need to further enhance the awareness of the scientific community of the Member States about JINR's flagship programmes and opportunities to participate in collaborations around its major projects.

The CP supported the JINR Directorate's proposal to establish a Science and Engineering Council for Innovations with the participation of representatives of JINR Member States, requesting suggestions for the concept of JINR's innovation policy at the CP's next session in March 2019.

The CP took note that the Republic of Bulgaria, when updating the National Road Map on Research Infrastructure, had included JINR in this document. It recommended that the JINR Directorate support the efforts of the Government of the Republic of Bulgaria towards increasing the effectiveness of the participation of Bulgarian scientists in the research carried out at JINR Laboratories.

Based on the report "Draft budget of JINR for the year 2019, draft contributions of the Member States for the years 2020, 2021, and 2022" presented by M. Vasilyev, Deputy Head of the JINR Finance and Economy Office, the CP approved the JINR budget for the year 2019 with the total income and expenditure amounting to US$232 112.4 thousand and allowed the JINR Director to introduce adjustments to the JINR budget in 2019, including adjustments to the expenditure items "Salaries" and "International cooperation", within the approved budget in accordance with the Regulation for the introduction of adjustments to the JINR budget. The CP also approved the scale of contributions of the JINR Member States for the year 2019.

The CP determined the provisional volumes of the JINR budget in income and expenditure for the year 2020 amounting to US$208.53 million, for the year 2021 amounting to US$212.50 million, for the year 2022 amounting to US$217.65 million, as well as the provisional amounts of the Member States' contributions for the years 2020, 2021, and 2022.

Regarding the report "Draft budget for the use of the special-purpose funds of the Russian Federation, provided in accordance with the Agreement between the Government of the Russian Federation and JINR on the construction and exploitation of the NICA complex of superconducting rings for heavy-ion colliding beams, for the year 2019" presented by VBLHEP Director V. Kekelidze and JINR Vice-Director R. Lednický, the CP approved the budget for the use of the special-purpose funds of the Russian Federation allocated in accordance with this Agreement for the year 2019 in the amount of 2 311 471.1 thousand rubles.

The CP took note of the information from the JINR Directorate and the NICA megaproject management on measures aimed at ensuring the effective use of the budget funds of JINR and of the special-purpose funds of the Russian Federation allocated for the construction of the NICA complex as well as at reducing the delay

GOVERNING AND ADVISORY BODIES OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

COMMITTEE OF PLENIPOTENTIARIES OF THE GOVERNMENTS OF THE JINR MEMBER STATES

Republic of Armenia	– S. Harutyunyan
Republic of Azerbaijan	– N. Timur oglu Mamedov
Republic of Belarus	– A. Shumilin
Republic of Bulgaria	– L. Kostov
Republic of Cuba	– F. C. Diaz-Balart
Czech Republic	– R. Plaga
Georgia	– A. Khvedelidze
Republic of Kazakhstan	– E. Kenzhin
Democratic People's Republic of Korea	– Li Je Sen
Republic of Moldova	– V. Ursachi
Mongolia	– S. Davaa
Republic of Poland	– M. Waligórski
Romania	– F.-D. Buzatu
Russian Federation	– M. Kotyukov
Slovak Republic	– S. Dubnička
Ukraine	– B. Grynyov
Republic of Uzbekistan	– Not appointed
Socialist Republic of Vietnam	– Le Hong Khiem

Finance Committee

One representative
of each JINR Member State

SCIENTIFIC COUNCIL

Chairman: V. Matveev
Co-Chairman: C. Borcea (Romania)
Scientific Secretary: A. Sorin

F. Azaiez	– Republic of South Africa
Ts. Baatar	– Mongolia
C. Borcea	– Romania
M. Budzyński	– Republic of Poland
Bum-Hoon Lee	– Republic of Korea
L. Cifarelli	– Italian Republic
A. Dubničková	– Slovak Republic
P. Fré	– Italian Republic
S. Galès	– French Republic
A. D. García	– Republic of Cuba
P. Giubellino	– Federal Republic of Germany
B. Grynyov	– Ukraine
M. Hnatič	– Slovak Republic
M. Jeźabek	– Republic of Poland
Jiangang Li	– People's Republic of China
G. Khuukhenkhuu	– Mongolia
S. Kilin	– Republic of Belarus
M. Kovalchuk	– Russian Federation
G. Lavrelashvili	– Georgia
P. Logatchov	– Russian Federation
A. Maggiora	– Italian Republic
S. Maksimenko	– Republic of Belarus
S. Maskevich	– Republic of Belarus
V. Matveev	– Russian Federation
J. Mnich	– Federal Republic of Germany
Sh. Nagiyev	– Republic of Azerbaijan
D. L. Nagy	– Republic of Hungary
N. Nešković	– Republic of Serbia
G. Poghosyan	– Republic of Armenia
S. Pospišil	– Czech Republic
I. Povar	– Republic of Moldova
E. Rabinovici	– State of Israel
V. Rubakov	– Russian Federation
K. Rusek	– Republic of Poland
V. Sadovnichy	– Russian Federation
A. Sergeev	– Russian Federation
M. Spiro	– French Republic
H. Stöcker	– Federal Republic of Germany
Ch. Stoyanov	– Republic of Bulgaria
Gh. Stratan	– Romania
Tran Duc Thiep	– Socialist Republic of Vietnam
R. Tsenov	– Republic of Bulgaria
M. Waligórski	– Republic of Poland
I. Wilhelm	– Czech Republic
M. Zdorovets	– Republic of Kazakhstan
G. Zinovjev	– Ukraine
Not appointed	– Democratic People's Republic of Korea
Not appointed	– Republic of Uzbekistan

Programme Advisory Committee for Particle Physics

Chairperson: I. Tserruya (Israel)
Scientific Secretary: A. Cheplakov

Programme Advisory Committee for Nuclear Physics

Chairperson: M. Lewitowicz (France)
Scientific Secretary: N. Skobelev

Programme Advisory Committee for Condensed Matter Physics

Chairperson: D. L. Nagy (Hungary)
Scientific Secretary: O. Belov

INTERNAL ORGANIZATION OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

DIRECTORATE

Director V. Matveev
Vice-Director M. Itkis
Vice-Director V. Kekelidze
Vice-Director R. Lednický
Vice-Director B. Sharkov
Chief Scientific Secretary A. Sorin
Chief Engineer B. Gikal

Bogoliubov Laboratory of Theoretical Physics

Director D. Kazakov

Research in
- symmetry properties of elementary particles
- field theory structures
- interactions of elementary particles
- theory of atomic nuclei
- theory of condensed matter

Frank Laboratory of Neutron Physics

Director V. Shvetsov

Research in
- nuclei by neutron spectroscopy methods
- fundamental properties of neutrons
- atomic structure and dynamics of solids and liquids
- high-temperature superconductivity
- reactions on light nuclei
- materials by neutron scattering, neutron activation analysis and neutron radiography methods
- dynamic characteristics of the pulsed reactor IBR-2

Veksler and Baldin Laboratory of High Energy Physics

Director V. Kekelidze

Research in
- structure of nucleons
- strong interactions of particles
- resonance phenomena in particle interactions
- electromagnetic interactions
- relativistic nuclear physics
- particle acceleration techniques
- interactions of multicharged ions in a wide energy range

Laboratory of Information Technologies

Director V. Korenkov

Research in
- provision of operation and development of the JINR computing and networking infrastructure
- optimal usage of international computer networks and information systems
- modern methods of computer physics, development of standard software

Dzhelepov Laboratory of Nuclear Problems

Director V. Bednyakov

Research in
- strong, weak and electromagnetic interactions of particles, particle structure
- nuclear structure
- nuclear spectroscopy
- mesoatomic and mesomolecular processes
- particle acceleration techniques
- radiobiology

Laboratory of Radiation Biology

Director E. Krasavin

Research in
- radiation genetics and radiobiology
- photo radiobiology
- astrobiology
- radiation protection physics
- mathematical simulation of radiation-induced effects

Flerov Laboratory of Nuclear Reactions

Director S. Dmitriev

Research in
- properties of heavy elements, fusion and fission of complex nuclei, cluster radioactivity, reactions on an isomer hafnium target
- reactions with beams of radioactive nuclei, structure of neutron-rich light nuclei, nonequilibrium processes
- interactions of heavy ions with condensed matter
- particle acceleration techniques

University Centre

Director S. Pakuliak

Directions of activities:
- senior students' education
- JINR postgraduate courses
- school students' education
- staff training and retraining
- organization of schools and practice courses in JINR research fields

Central Services

- central scientific and information departments
- administrative and economic units
- manufacturing units

emerging over the past year in the planned construction of the NICA complex facilities.

Regarding the report "Results of the meeting of the JINR Finance Committee held on 16–17 November 2018" presented by S. Harizanova, Chairperson of the Finance Committee, the CP approved the Protocol of this meeting and the Regulation for the introduction of adjustments to the JINR budget. The Committee commissioned the JINR Directorate to finalize the draft Procedure for the offset of costs of supplies of equipment, instruments, materials, services and individual work on the Institute's orders against payments of JINR Member States' contributions, taking into account the comments and suggestions made by members of the Working Group for JINR Financial Issues under the CP Chairman and by the Plenipotentiaries, and to send it to the Member States as part of the organization of the next meeting of the Finance Committee and session of the CP in March 2019.

The CP commissioned the JINR Directorate to prepare a new version of the draft Regulation for research and educational programmes of JINR's cooperation with scientific organizations and universities of JINR Member States, taking into account the comments made by members of the Working Group, and to enact this Regulation from 1 January 2020.

The CP resolved to retain the current practice of withholding personal income tax (PIT) from JINR employees who are citizens of Member States, as well as to set off PIT withheld from JINR employees, who are citizens of Member States for which the CP had decided to suspend membership in JINR, accountable against reducing the arrears of the corresponding state in order to apply a unified approach.

The CP commissioned the JINR Directorate to prepare drafts of the updated documents regulating JINR purchasing activities and to send them to the Plenipotentiaries by 1 March 2019.

Based on the report "Results of the audit of the financial activities of JINR performed for the year 2017 and analysis of implementation by the JINR Directorate of the Plan of activities resulting from the audit of the financial activities of JINR performed for the year 2016" presented by D. Korsakov, Director of the audit company "Korsakov and Partners", the CP took note of the auditors' report concerning the financial activities of JINR examined for 2017, approved the Accounting Report of the Joint Institute for Nuclear Research for 2017 and the form of the Act concerning the funds received towards payment of the contribution to the JINR budget from a Member State of JINR.

Based on the information "Changes in the membership of the JINR Scientific Council" presented by A. Sorin, Chief Scientific Secretary of JINR, the CP took note of the inclusion in the membership of the Scientific Council of B. Grynyov (State Fund for Fundamental Research of Ukraine, Kiev, Ukraine) appointed by the Plenipotentiary of the Government of Ukraine, and G. Lavrelashvili (A. Razmadze Mathematical Institute, TSU, Tbilisi, Georgia) appointed by the Plenipotentiary of the Government of Georgia.

Based on the report "Status of the agreements with Associate States, preparation of agreements with France and other states" presented by D. Kamanin, Deputy Head of the JINR Science Organization and International Cooperation Office, the CP commended the efforts of the JINR Directorate to elevate the status of the Arab Republic of Egypt, the Republic of Serbia, and of the Republic of South Africa to full Member States of JINR, as well as the current work to prepare a cooperation agreement with the Government of the French Republic. The CP took note of the delay in extending the cooperation agreement with the Government of the Federal Republic of Germany, of the success of the JINR Directorate in developing cooperation with the Italian Republic, and of the methodological work towards restoring the status of Hungary in JINR, and of the efforts made to attract India, Brazil and other states to JINR.

The CP heard with interest the report "Main trends, challenges and future development of information technology" presented by LIT Director V. Korenkov.

The CP supported the proposal by the Plenipotentiary of the Government of the Republic of Poland, M. Waligórski, to name one of the alleys on the site of the Laboratory of Nuclear Problems in honour of Academician A. Hrynkiewicz.

SESSIONS OF THE JINR SCIENTIFIC COUNCIL

The 123rd session of the JINR Scientific Council took place on 22–23 February. It was chaired by JINR Director V. Matveev and Professor M. Waligórski of the H. Niewodniczański Institute of Nuclear Physics and Oncology Centre (Kraków, Poland).

V. Matveev presented a detailed report which concerned the highlights in the recent activities of JINR in the context of the world's fundamental nuclear physics science, the decisions of the session of the JINR Committee of Plenipotentiaries (November 2017), the results of implementation of the JINR scientific programme in the first year of the new seven-year plan, major events in JINR international cooperation, and some organizational issues.

The Scientific Council heard the reports "SOLCRYS — new laboratory for structural research at the Polish synchrotron SOLARIS: Proposed concept” and “Complementarity between neutron and synchrotron X-ray scattering, the potential of the synergy between IBR-2 and SOLARIS” presented by SOLARIS Director M. Stankiewicz and FLNP Director V. Shvetsov.

The Scientific Council also heard the report “Status and future development of the Laboratory of Information Technologies” presented by LIT Director V. Korenkov.

The recommendations of the Programme Advisory Committees were reported by I. Tserruya (PAC for Particle Physics), M. Lewitowicz (PAC for Nuclear Physics), and P. Alekseev (PAC for Condensed Matter Physics).

The Scientific Council heard two reports concerning the activities of the Nuclear Physics European Collaboration Committee (NuPECC) and its long-range plan “Perspectives in nuclear physics” presented by the former and current Chairpersons of this Committee, A. Bracco (Italy) and M. Lewitowicz (France), as well as the best reports by young scientists recommended by the PACs.

The recommendations of the juries for the award of the B. Pontecorvo Prize and of JINR annual prizes for best papers in the fields of scientific research, instruments and methods, and applied research were approved.

Elections for the positions of the FLNP and LIT Directors were held, and vacancies of positions in the Directorates of JINR Laboratories were announced.

Resolution. General Considerations. Based on the report presented by JINR Director V. Matveev, the Scientific Council appreciated highly the significant number of high-quality physics results obtained by JINR scientists in 2017 at home facilities of the Institute as well as at external accelerators, reactors and in various collaborations.

The Scientific Council was pleased to note the successful development of the JINR research infrastructure, including the NICA megaproject, the Factory of Superheavy Elements (SHE) and the IBR-2 spectrometer complex, and commended the efforts undertaken by the JINR Directorate and staff towards achieving the important milestones of constructing and upgrading these facilities.

The Scientific Council was also pleased to note the ramping up of the international visibility of JINR and its flagship projects. The NICA project has already been included in the ESFRI roadmap and in the NuPECC long-range plan, and every effort should be made in order for it to become also part of the European Strategy for Particle Physics. Synthesis of superheavy elements by JINR is a world-leading programme. IBR-2 is recognized as part of the European neutron roadmap. The neutrino research projects at the Kalinin NPP and at Lake Baikal are also flagship programmes and should be on the APPEC roadmap. The Scientific Council supported this trend and appreciated highly the JINR Directorate’s attention to the advice given by the Scientific Council on the integration of these facilities into the European and global research infrastructure landscapes.

The Scientific Council took note of the meeting of the Supervisory Board of the NICA complex project held on 2 February 2018 and its recommendations on the NICA development programme for the next several years, on the structure of its management bodies, on its financial support, on its research programme, and on the civil construction of the NICA complex.

The Scientific Council expects that the first phase envisaging construction of the SHE Factory will be completed in July 2018 and that the first experiments will begin in October – November 2018, according to the timeline of commissioning this important complex as presented at the previous session of the Scientific Council.

The Scientific Council took note of the 10th Meeting of the Group of Senior Officials on Global Research Infrastructures, which was held at JINR on 9–12 October 2017, and underlined the importance of acquainting its participants with the largest facilities of the JINR research infrastructure.

The Scientific Council noted with great satisfaction the decision of the UN General Assembly to proclaim 2019 as the International Year of the Periodic Table of Chemical Elements and looks forward to the active participation of JINR, which made outstanding contributions to the discovery of new superheavy elements, in these celebrations, including those planned by UNESCO.

The Scientific Council welcomed the work carried out by the JINR Directorate for developing a Code of professional ethics of the JINR staff and a Regulation on the implementation of JINR’s right to independently confer academic degrees and to issue the relevant diplomas.

Cooperation with the National Synchrotron Radiation Centre SOLARIS of the Jagiellonian University in Kraków (Poland). The Scientific Council took note of the reports “SOLCRYS — new laboratory for structural research at the Polish synchrotron SOLARIS: Proposed concept” and “Complementarity between neutron and synchrotron X-ray scattering, the potential of the synergy between IBR-2 and SOLARIS” presented by SOLARIS Director M. Stankiewicz and FLNP Director V. Shvetsov. It supported the idea of building a Laboratory for Structural Research of Macromolecules and New Materials belonging to JINR in one of its Member States — Poland. Noting that the realization of this plan would strengthen the experimental capabilities of JINR and of the Jagiellonian University in solid-state physics and biology, the Scientific Council encouraged them to develop a detailed project encompassing a planned research programme, which should take into account world’s cooperation in the use of synchrotron radiation.

At its next session, the Scientific Council wished to hear a detailed concept report for the new laboratory agreed upon by the two sides.

Status and Future Development of LIT. The Scientific Council took note of the report "Status and future development of the Laboratory of Information Technologies" presented by LIT Director V. Korenkov. The Scientific Council welcomed the activities on the project of the Multifunctional Information and Computing Complex aimed at further development of the network and computing infrastructure for scientific research underway at JINR and its Member States on the basis of advanced information technologies in accordance with the Seven-Year Plan for the Development of JINR for 2017–2023.

The Scientific Council welcomed the development of high-performance computing (HPC), new architectures and principles of the organization of computations leading to innovative changes in the research strategy and noted the key basis of the scientific IT ecosystem which is a distributed software-configured HPC platform combining supercomputer (heterogeneous), grid and cloud technologies.

The Scientific Council also welcomed the active participation of LIT in implementing the priority tasks of JINR and its Member States, in particular, those related to the NICA megaproject.

Activities of NuPECC and Its Long-Range Plan in Nuclear Physics. The Scientific Council took note of the reports concerning the activities of the Nuclear Physics European Collaboration Committee (NuPECC) and its long-range plan "Perspectives in nuclear physics" presented by the former and current Chairpersons of this Committee, A. Bracco (Italy) and M. Lewitowicz (France).

The future of facilities is well presented in the plan, with particular focus on FAIR, ISOL facilities (SPIRAL2, ISOLDE, SPES), ELI-NP, NICA and the SHE Factory, as well as the recommendations concerning the nuclear physics science to be addressed at these facilities. In particular, the plan highlights the importance of the NICA and SHE Factory projects on the European roadmap for nuclear physics. In addition, the role of theory, applications, R&D for future projects, and of the education of young scientists is emphasized.

As a member of NuPECC, JINR actively participated in the elaboration of the long-range plan and will be one of the major driving forces in its implementation phase. Realization of this plan on the European and international levels proposed by NuPECC is coherent with the Seven-Year Plan for the Development of JINR (2017–2023) and should tighten the links between JINR and the entire nuclear physics community in Europe.

Recommendations in Connection with the PACs. The Scientific Council supported the recommendations made by the PACs at their meetings in January – February 2018 and proposed that the JINR Directorate should take these recommendations into account while preparing the JINR Topical Plan of Research and International Cooperation for 2019.

Particle Physics Issues. The Scientific Council appreciated the significant progress achieved in the successful preparation of the KRION-6T heavy-ion source for operation in the Nuclotron run, welcomed the regular commissioning of new equipment and supported the programme of timely modernization of existing elements of the accelerator complex, in particular, the upgrade of the LU-20 linac and the associated substantial increase in beam intensity.

The Scientific Council took note of the forced interruption of Run 55 of the Nuclotron due to a failure of the cooling system of the superconducting magnets and of the measures taken to prevent recurrence of similar accidents in the future.

The Scientific Council recognized the steady progress in developing key infrastructure elements including the upgrade of the power supply system of beam channels, the launch of the new Nuclotron control system, the commissioning of the new helium liquifier, the progress in upgrading the existing cryogenic complex, the preparation for the installation of the booster synchrotron, and the work carried out for the preparation of the collider magnet system, as well as the progress with the roadmap for the construction of the NICA Centre building.

The Scientific Council welcomed the plans to hold a three-day meeting at JINR in April 2018 to officially launch the MPD and BM@N international collaborations and strongly encouraged the initiative to establish a grant programme to attract and support research conducted at the NICA facility.

The Scientific Council acknowledged the efforts undertaken by the JINR and VBLHEP Directorates to strengthen the participation of China's groups in the construction of the MPD electromagnetic calorimeter and recommended that the international team focus on the optimization of the detector specifications and design in view of finalizing the ECAL TDR. The Scientific Council appreciated the recent advance in the MPD magnet construction, but shared the PAC's concern about the delay in the magnet delivery to JINR. The contract should be successfully completed with no additional slippage.

The Scientific Council welcomed the commissioning of new equipment of the BM@N experiment and the first use of the large-area GEM tracking detectors, but reiterated its concern about the lack of manpower for an in-depth analysis of the data collected in recent runs. It looks forward to the detector operation during Run 55 with the new heavy-ion source, KRION-6T, and to the forthcoming study of short-range correlations.

The Scientific Council supported the recommendations on the approval of new projects and on the continuation of ongoing projects in particle physics within the suggested time scales as outlined in the PAC recommendations. It endorsed, in particular, the proposed plan for the formal establishment of the SPD collaboration and preparation of the Conceptual Design Report of the SPD detector, backed by local theoretical support, by January 2019. The Scientific Council supported the continuation of JINR's participation in the upgrade of the ATLAS and CMS detectors until the end of 2020. It also supported the PAC's approach in the evaluation of the Borexino/SOX/DarkSide project where three distinct experiments with rather diversified physics goals and timelines were put into one proposal. The Scientific Council recommended that the proponents should carry on the data analysis of the Borexino experiment until the end of 2019. With respect to SOX, due to the potential delays mentioned, the proponents should present a detailed status report to the PAC in order to decide on a possible recommendation. Concerning DarkSide-20k, the proponents were asked to present to the JINR Directorate an overall strategy to be considered by the PAC in order to allow for a thorough evaluation of all aspects of the project related to science, contributions and consistency of the group, investments and timeline.

Nuclear Physics Issues. The Scientific Council highly appreciated the results of scientific research carried out within the theme "Non-Accelerator Neutrino Physics and Astrophysics" consisting of six distinct projects. The rare processes under study include search for neutrinoless double beta decay (GERDA (G&M) and SuperNEMO projects), experiments with reactor antineutrinos (DANSS and GEMMA-III projects), direct search for dark matter particles (EDELWEISS-LT project), and investigations of high-energy neutrinos from space with the deep-water neutrino telescope at Lake Baikal (Baikal-GVD project). Recognizing the world-leading results obtained in all these projects, the Scientific Council supported the general direction in which the theme was developing, when the participation in highly prestigious international projects provides an access to know-how for the development of home-based neutrino experiments at two basic facilities — the laboratories located at the Kalinin NPP and at Lake Baikal.

The Scientific Council recommended continuation of the rigorous support of these projects and research programmes for 2019–2021, and of the Baikal project for a longer period until the end of 2023, underlining the necessity to continue the efforts to improve the local infrastructures at JINR and at Lake Baikal and to ensure the sufficient human resource for the timely data analysis.

The Scientific Council noted the progress in the construction of the SHE Factory. The installation work for the DC-280 cyclotron is well advanced and is now planned to reach an end in the first half of 2018. The start-up and adjustment are to be accomplished by mid-2018. The commissioning of the DC-280 accelerator should start by September 2018.

Significant progress was also made in the construction of the experimental set-ups including the target system, separators and detection systems. In particular, a new gas-filled recoil separator was manufactured and delivered to Dubna; its assembly was scheduled for January – March 2018. First test experiments are planned for October – November 2018.

In addition to the technical work, an important effort of FLNR and JINR concentrates on the licensing process, which should be accomplished to begin experiments on the synthesis and studies of superheavy elements.

The Scientific Council supported the well-considered decision of the FLNR Directorate concerning the continuation of the operation of U-400 for several years in parallel to the operation of experiments at GFS-1. Both experiments, spectroscopy and reaction studies at SHELS and new elements at GFS-1, will be complementary.

In 2016, a new fragment separator ACCULINNA-2 was constructed on the beam line of the U-400M cyclotron. With the ^{15}N primary beam, it was tested to produce various secondary beams of radioactive isotopes. Intensities of the obtained secondary beams were 25 times higher than those obtained with the previous facility ACCULINNA-1. The Scientific Council supported the plan according to which ACCULINNA-2 would become the major facility to study exotic nuclei at JINR's FLNR.

The Scientific Council highly appreciated the results obtained in the main research directions of the concluding theme "Theory of Nuclear Structure and Nuclear Reactions": structure of nuclei far from stability, nucleus–nucleus collisions at low energies, fusion dynamics, few-body systems, nuclear dynamics at relativistic energies, properties of hot and dense nuclear matter. The Scientific Council noted that these topics were strongly connected with the main experimental activities in the main facilities at JINR and other centres. It supported the smooth transition of nuclear theory activities under the new theme "Theory of Nuclear Systems" for 2019–2023 that should continue incorporating complex and broad views on the various aspects of nuclear structure and reactions in close synergy with the experimental programme of JINR and in other facilities, operating or in the construction phase, such as FAIR, SPES, HIE-ISOLDE, SPIRAL2, and ELI-NP.

Neutrino Physics Issues. After the presentations of the various neutrino experiments reported by the Chairmen of the PAC for Nuclear Physics and of the PAC for Particle Physics, the Scientific Council reiterated its recommendation that all these ongoing and recently planned neutrino experiments be presented and discussed within a joint meeting of the two PACs leading to a more coordinated neutrino physics programme and therefore allowing implementation of priorities in a more concerted and efficient way.

Condensed Matter Physics Issues. The Scientific Council noted the progress in the discussion of the scientific case for a new JINR neutron source replacing the IBR-2 reactor after its shut-down and welcomed the continuation of this programme in close connection with FLNP's scientific plans.

The Scientific Council took note, with interest, of the principles of construction and the parameters of one of the possible concepts of a new source, presented at the meeting of the PAC for Condensed Matter Physics, where the subcritical assembly of ^{237}Np with a mechanic reactivity modulation controlled by a pulsed proton accelerator (superbooster) is considered as an option of the future facility. If successfully implemented, such a source can take one of the world's leading positions among the high-flux pulsed sources of the middle of the current century. The Scientific Council, however, shared the PAC's opinion that taking a univocal position in the matter of the physical scheme of the new neutron source would be premature at this stage.

The Scientific Council endorsed the timeline for the preparation of JINR's new neutron source which was proposed by the PAC for Condensed Matter Physics. It recommended continuation of work to study other options for the facility with a clear analysis of the parameters of the new source in terms of strengths, weaknesses, opportunities and threats with respect to the envisaged long-term user programme.

The Scientific Council highly appreciated the ongoing upgrades of the existing IBR-2 spectrometers and development of new ones, which results in improvement of their parameters and extension of research areas, as well as making them more attractive for potential users. It supported the plans towards the further development of the IBR-2 spectrometer complex, which take into account the reactor's specific features (high flux, long pulse, availability of cryogenic moderator) and will assure the maintenance of the instruments at the level comparable with other leading research centres in the world, as well as the extension of research areas and improvement of research quality. The Scientific Council especially noted the progress in upgrading the DN-6 high-pressure neutron diffractometer for investigations of microsamples under extreme conditions, sharing the PAC opinion that the ongoing improvement of this instrument should remain one of the priority activities towards development of the whole IBR-2 spectrometer complex at the moment.

The Scientific Council highly appreciated FLNP's efforts to run the User Programme at an internationally recognized level. Considering the User Programme to be the key instrument for securing the position of IBR-2 as one of the leading neutron sources in the world, the Scientific Council encouraged the FLNP Directorate to further support this highly important activity, taking into account the PAC's recommendations on the need to upgrade the proposal assessment web applications being utilized within a professional system supporting the work of proposers, reviewers and the FLNP management, as well as on a strict need of submitting experimental reports by all successful proposers as the necessary feedback.

Reports by Young Scientists. The Scientific Council appreciated the reports by young scientists which were selected by the PACs for presentation at this session: "Sensitive neutron detection method using iodine-containing scintillators" and "Limit on the effective magnetic moment of solar neutrinos using Borexino data", and thanked the respective speakers: D. Ponomarev (DLNP) and A. Vishneva (DLNP).

Memberships of the PACs. As proposed by the JINR Directorate, the Scientific Council appointed A. Maj (INP, Kraków, Poland) and V. Nesvizhevsky (ILL, Grenoble, France) as new members of the PAC for Nuclear Physics, each for a term of three years.

Awards and Prizes. The Scientific Council approved the Jury's recommendations on the award of the B. Pontecorvo Prize to Professors G. Fogli (University and INFN, Bari, Italy) and E. Lisi (INFN, Bari, Italy), for their pioneering contribution to the development of global analysis of neutrino oscillation data from different experiments.

The Scientific Council approved the Jury's recommendations on the award of JINR annual prizes for best papers in the fields of scientific research, instruments and methods, and applied research.

Elections and Announcement of Vacancies in the Directorates of JINR Laboratories. The Scientific Council elected V. Shvetsov as Director of the Frank Laboratory of Neutron Physics (FLNP) and V. Korenkov as Director of the Laboratory of Information Technologies (LIT), each for a second term of five years. The Scientific Council announced the vacancies of positions of Deputy Directors of FLNP and LIT. The endorsement of appointments will take place at the next session of the Scientific Council in September 2018.

The Scientific Council endorsed the appointment of N. Antonenko, M. Hnatič, and A. Isaev as Deputy Directors of BLTP, until the completion of the term of office of BLTP Director D. Kazakov.

The 124th session of the JINR Scientific Council took place on 20–21 September. It was chaired by JINR Director V. Matveev and Professor C. Borcea of the H. Hulubei National Institute of Physics and Nuclear Engineering (Bucharest, Romania).

V. Matveev delivered a comprehensive report, covering the priorities of the JINR development within the current seven-year period (2017–2023), the main goals of the JINR research programme, the decisions of the recent session of the JINR Committee of Plenipotentiaries (March 2018), and events in JINR's international cooperation.

The Scientific Council heard reports concerning progress in implementing the Seven-Year Plan for the Development of JINR (2017–2023) in its major sections, presented by JINR Vice-Director R. Lednický (particle physics and information technology), by JINR Vice-Director and VBLHEP Director V. Kekelidze (NICA project), by JINR Vice-Director M. Itkis (nuclear physics), by JINR Vice-Director B. Sharkov (condensed matter physics and radiation biology), by JINR Chief Engineer B. Gikal (development of the engineering infrastructure), and by UC Director S. Pakuliak (education).

The recommendations of the Programme Advisory Committees were reported by I. Tserruya (PAC for Particle Physics), M. Lewitowicz (PAC for Nuclear Physics), and D. L. Nagy (PAC for Condensed Matter Physics).

The awarding of the B. Pontecorvo Prize took place at the session, and diplomas to the winners of JINR prizes for the year 2017 were presented. The Jury's recommendation to award the V. Dzhelepov Prize was approved. The Scientific Council heard the best reports by young scientists as recommended by the PACs.

The election of the Director of DLNP was held, and the appointments of Deputy Directors of FLNP and LIT were endorsed. Vacancies of positions in the Directorates of JINR Laboratories were announced.

General Considerations of the Resolution. The Scientific Council took note of the comprehensive report by JINR Director V. Matveev and recognized the efforts being taken by the JINR Directorate towards achieving the priority goals of scientific research in the fields of particle physics, nuclear physics, condensed matter physics, and radiation biology. The Scientific Council emphasized the importance of consolidating the scope of in-house experiments and of experiments within the framework of international partnership programmes, with essential contribution being made by the JINR staff.

The Scientific Council approved the adopted order of priorities in the development of JINR facilities to provide JINR with the necessary basis for maintaining its unique position among the leading physics research centres and for further integrating JINR into the European and global research programmes. It was appreciated that the NICA complex and the Factory of Superheavy Elements (SHE Factory) had been included in the ESFRI roadmap and in the NuPECC long-range plan, and that IBR-2 had become a part of the European neutron roadmap. The neutrino research projects at the Kalinin NPP and at Lake Baikal, other JINR's flagship programmes, should also be integrated into the global research infrastructure. Every effort should be made to insert JINR as an element of the European Strategy of Particle Physics in partnership with CERN.

The Scientific Council welcomed the JINR Directorate's work to develop the Institute's engineering infrastructure as well as the measures being taken to support the educational activity and to implement the human resources and social policy, considering these activities to be vitally important for achieving JINR's strategic goals.

The Scientific Council welcomed JINR's increasing international cooperation, in particular, strengthening ties with European partners, establishing new partnerships with China, and expanding cooperation horizons in Latin America and Africa, as well as the training programme "JINR Expertise for Member States and Partner Countries" and the cooperation with research and educational organizations of Israel.

The Scientific Council expects active participation of JINR and its partners in events to be held within the International Year of the Periodic Table of Chemical Elements in 2019.

Implementation of the Seven-Year Plan for the Development of JINR for 2017–2023. The Scientific Council noted with high appreciation the reports concerning progress in implementing the Seven-Year Plan for the Development of JINR (2017–2023) in its major sections. On the whole, the Scientific Council highly appreciated the ongoing efforts to implement the seven-year plan. However, considering the increasing number of new scientific themes and projects reported, it stressed that JINR needed to consolidate its research programme within the major objectives of the seven-year development plan. At its future sessions, the Scientific Council expects to be informed about further progress in implementing the seven-year plan, especially with respect to the NICA and SHE Factory projects.

Recommendations in Connection with the PACs. The Scientific Council supported the recommendations made by the PACs at their meetings in June 2018 and requested the JINR Directorate to consider these recommendations while preparing the JINR Topical Plan of Research and International Cooperation for 2019.

Particle Physics Issues. The Scientific Council appreciated the progress towards realization of the Nuclotron–NICA project, noting the successful operation of the KRION-6T heavy-ion source and significant improvements in the quality of the beam structure, while encouraging the accelerator team to further improve the emittance of the extracted beam. The Scientific Council welcomed the progress achieved in the civil construction of the NICA collider complex, the efforts of the VBLHEP and JINR Directorates towards its timely completion, and the continuous progress in various other areas of this flagship project.

The Scientific Council congratulated the NICA management for organizing the First Collaboration Meeting of the MPD and BM@N experiments, which took place at JINR on 11–13 April 2018, considering it to be a significant milestone in the realization of these experiments and in opening the NICA project to international collaboration. The Scientific Council noted with satisfaction the great interest of the international scientific community in the MPD and BM@N experiments, as reflected by the attendance of some 200 participants at the meeting and by the large number of new groups that are joining the collaborations. The Scientific Council endorsed the clear road map developed at this meeting for the establishment of the structure and management teams of the MPD and BM@N collaborations and supported the management's efforts to secure funding for NICA collaborators.

The Scientific Council appreciated the ongoing collaborative efforts to prepare the technical design reports for the MPD subsystems, urging the MPD team to finalize the ECAL TDR, including results of simulation for the recently adopted projective geometry, and to develop a detailed scenario for the timely construction and commissioning of ECAL as soon as possible.

The Scientific Council appreciated the successful commissioning of the large-area GEM detectors and of the first silicon stations of the vertex detector of the BM@N set-up, and seconded the recommendations of the PAC for Particle Physics, encouraging the team to concentrate on the analysis of the large sample of experimental data collected in the recent Nuclotron run with argon and krypton beams and on the completion of the detector configuration, including the installation of a vacuum pipe through the experimental set-up. The Scientific Council also congratulated the collaboration for the prompt completion of the first measurements of short-range correlations in carbon nuclei using reverse kinematics in the BM@N set-up, and looks forward to the completion of the physical analysis of these results.

The Scientific Council supported the PAC's recommendations on the approval of new projects and on the continuation of ongoing projects in particle physics within the suggested time scales, as outlined in the PAC's recommendations. In particular, continuation of the HyperNIS, ALPOM-2 and DSS projects, as well as JINR's participation in the NA62 and STAR experiments, was approved until the end of 2021 with first priority.

The Scientific Council endorsed the PAC's recommendations for the continuation of JINR's participation in the NA61 and HADES experiments until the end of 2021 with second priority. In particular, it supported the PAC's suggestion to reduce the NA61 travel budget since there will be no run in 2019 and 2020, and the suggestion to the JINR HADES team to shift its focus to the performance of similar dilepton measurements at NICA.

The Scientific Council recognized with appreciation the important results achieved by the JINR group in collaboration with CERN within the project "Precision laser metrology for accelerators and detector complexes". It agreed with the PAC that the group should implement its expertise in the NICA project and supported the recommendation on the continuation of this project until the end of 2021 with second priority.

The Scientific Council supported the PAC's recommendation to approve the new project "ARIeL: Physics at future e^+e^- colliders" until the end of 2021 with third priority. Although theoretical calculations performed within the project could be useful for a future electron–positron collider, the Scientific Council shared the PAC's concern about the harsh international competition in the area of the proposed studies and other uncertainties which could affect the expected impact of this research.

Nuclear Physics Issues. The Scientific Council was pleased to note that the autonomous tuning work for the DC-280 cyclotron, which is the central part of the SHE Factory, is approaching its final phase. The commissioning of DC-280 and first test experiments are planned for the end of 2018. In addition to constructing the experimental set-ups, a great deal of effort is also focused on licensing which must be completed prior to the first experiments.

The Scientific Council recommended that the JINR and FLNR Directorates put all necessary efforts to allow for the timely completion of the construction, licensing, and commissioning of the SHE Factory in 2018. The FLNR Directorate was recommended to provide thorough monitoring during the commissioning of the main systems and set-ups of the SHE Factory in order to guarantee reliable performance of the facility within the design parameters, and to focus on the preparation of Day-1 experiments.

The Scientific Council endorsed the first experiment using the ACCULINNA-2 fragment separator, aimed at studying the properties of ^{7}H in the ^{8}He(d, ^{3}He)^{7}H reaction and recommended the allocation of the requested beam time at the U-400M accelerator.

The Scientific Council appreciated the scientific goals and the current progress with the MAVR analyzer; recommended completing the integration of all its mechanical and electrical systems and performing the in-beam commissioning experiment as soon as possible in order to verify whether the projected performance is achieved.

The Scientific Council expressed concern about the slow progress in the development of the new SC202 cyclotrons and recommended that closer collaboration be established with the Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei. The Scientific Council supported the recommendation of the PAC for Nuclear Physics for extending the theme "Improvement of the JINR Phasotron and Design of Cyclotrons for Fundamental and Applied Research" until the end of 2019, noting however the lack of fundamental research aspects of this theme. The Scientific Council expects the new design to be fully completed by the next year, and a detailed schedule of the construction of the SC202 compact cyclotron to be submitted to the PAC for consideration.

Neutrino Physics Issues. The Scientific Council welcomed the decision taken by the PACs for Particle Physics and Nuclear Physics to hold a joint session on neutrino physics and dark matter research on 22 January 2019. This will lead to a better coordination of the neutrino physics programme, therefore allowing implementation of priorities in a more concerted and efficient manner.

Condensed Matter Physics Issues. The Scientific Council took note of an alternative option for the development of a new source of neutrons at JINR, submitted to the PAC for Condensed Matter Physics, and recommended that the suggested physical scheme based on a subcritical booster with a plutonium dioxide core and a non-multiplying tungsten target be thoroughly considered while elaborating the general concept of a new neutron source. The Scientific Council welcomed the initiation of a discussion concerning the relevant scientific programme for a new source and, in particular, the development of a scientific rationale for the use of the moderators of ultracold and very cold neutrons at this facility. The Scientific Council expressed its intention to continue, together with this PAC, to follow up on the development of the general concept of a new neutron source and its scientific programme.

The Scientific Council took note of the activities of the team coordinated by the FLNP Directorate concerning the development of the concept of a new Laboratory for Structural Research of Macromolecules and New Materials at the National Synchrotron Radiation Centre SOLARIS of the Jagiellonian University in Kraków (Poland). Acknowledging that such a laboratory would contribute to extending the JINR research tools, which is of considerable importance in terms of complementarity between existing neutron-based techniques and future X-ray methods, at the same time the Scientific Council concurred with the PAC's recommendation to continue the analysis of the feasibility of the technical design and parameters required by future experiments in such a laboratory.

The Scientific Council supported the PAC's recommendations on the reviewed themes and projects. In particular, it welcomed the successful completion of the project "Isotope identifying reflectometry at the IBR-2 reactor", which resulted in implementing a principally new method to study diffuse processes in layered nanostructures at the IBR-2 facility, and concurred with the closure of this completed project.

The Scientific Council expects that the revised proposal of the project "Development of a facility for measurements with test electron beams at DLNP. LINAC-200" be reconsidered, assuming that the authors of the project will elaborate a detailed scientific proposal within the scope of the PAC for Condensed Matter Physics or, alternatively, will submit this proposal to another PAC.

Appreciating the recent achievements within the concluding theme "Theory of Condensed Matter", the Scientific Council agreed that a new theme "Theory of Complex Systems and Advanced Materials" be opened for the period 2019–2023. It especially appreciated the opportunity to achieve closer correlation between the ongoing theoretical studies and experimental programmes at the JINR.

Other Issues. With regard to the considered conceptual project of a research centre for proton therapy at JINR, the Scientific Council recognized the importance of further development of instruments and methods for proton therapy at JINR and supported the idea of assuming a leading role in disseminating the culture of proton therapy in JINR Member States. Considering the discussed ongoing work on the construction, together with the Chinese colleagues, of the SC202 therapeutic cyclotron, and the current state of the Phasotron, the Scientific Council recommended that the JINR Directorate develop the possibility of implementing a project of a compact research infrastructure for proton therapy at JINR.

Common Issues. The Scientific Council noted the efforts by the University Centre (UC) in coordination and support of the educational and human resource development programmes at JINR within the concluding theme "Organization, Support, and Development of JINR Educational Programmes". As part of this theme, one of the main issues and functions of JINR is being implemented — attracting talented young people and partner scientific research organizations of the Member States to JINR. In order to accomplish this, conditions are being created at JINR to assign Bachelor, Master, and PhD students from Member-State universities to work on their theses. Together with JINR Laboratories, the UC organizes and runs student programmes of various levels, which may attract talented young people and ensure the continuity of JINR's scientific schools. The Scientific Council recommended that these activities be continued within the framework of the new theme "Organization, Support and Development of the JINR Human Resources Programme" proposed for 2019–2023, enhancing the cooperation with leading universities of the Member States to attract young people to work on JINR's flagship projects.

Reports by Young Scientists. The Scientific Council appreciated the following reports by young scientists, selected by the PACs for presentation at this session: "How robust is a third family of compact stars against pasta phase effects?", "Fusion–fission and quasi-fission in the near-barrier reaction $^{32}S + ^{197}Au$", and "Analysis of the working ability of a planar graphene tunnel field-effect transistor in the presence of edge vacancies", and thanked the respective speakers: A. Ayriyan (LIT), I. Harca (FLNR), and A. Glebov (BLTP). The Scientific Council welcomed such selected reports in the future.

Awards and Prizes. The Scientific Council congratulated Professors G. Fogli (University and INFN, Bari, Italy) and E. Lisi (INFN, Bari, Italy) on the award of the B. Pontecorvo Prize for their pioneering contribution to the development of global analysis of neutrino oscillation data from different experiments, and thanked them for their excellent presentations.

The Scientific Council approved the Jury's recommendations on the award of the V. Dzhelepov Prize to Professor V. Komarov (JINR) for his pioneering work on the construction of the first channel for proton therapy at the JINR synchrocyclotron.

The Scientific Council congratulated the winners of JINR annual prizes for best papers in the fields of scientific research, instruments and methods, and applied research.

Election of the Co-Chairman of the Scientific Council. The Scientific Council elected Professor C. Borcea as Co-Chairman of the Scientific Council for a term of three years.

Elections and Announcement of Vacancies in the Directorates of JINR Laboratories. The Scientific Council agreed with the proposal made by JINR Director V. Matveev to postpone the election of the Director of the Flerov Laboratory of Nuclear Reactions, previously announced for September 2018, by one and a half years, until the 127th session of the Scientific Council in February 2020. According to the Regulation, a new election date will be announced at the next session of the Scientific Council in February 2019.

The Scientific Council elected V. Bednyakov as Director of the Dzhelepov Laboratory of Nuclear Problems (DLNP) for a second term of five years.

The Scientific Council announced the vacancies of positions of DLNP Deputy Directors. The endorsement of appointments will take place at the next session of the Scientific Council in February 2019.

The Scientific Council endorsed the appointment of O. Culicov, N. Kučerka, and E. Lychagin as Deputy Directors of the Frank Laboratory of Neutron Physics (FLNP), until the completion of the term of office of FLNP Director V. Shvetsov.

The Scientific Council endorsed the appointment of J. Buša and T. Strizh as Deputy Directors of the Laboratory of Information Technologies (LIT) until the completion of the term of office of LIT Director V. Korenkov. The Scientific Council announced the vacancy of a third Deputy Director position at LIT. The endorsement of appointment will take place at the next session of the Scientific Council in February 2019.

The Scientific Council announced the vacancies of positions of the Directors of the Veksler and Baldin Laboratory of High Energy Physics and of the Laboratory of Radiation Biology. The elections will take place at the 126th session of the Scientific Council in September 2019.

MEETINGS OF THE JINR FINANCE COMMITTEE

A meeting of the JINR Finance Committee was held on 23–24 March. It was chaired by S. Harizanova, a representative of the Republic of Bulgaria.

The Finance Committee heard the report presented by JINR Director V. Matveev on implementation of the JINR Plan of Research and International Cooperation in 2017 and on plans for activities for 2018. The Committee commended the work done by the JINR Directorate and staff aimed at developing the Institute's research infrastructure, in particular, at realizing the NICA megaproject, at commissioning the Factory of Superheavy Elements, at developing the neutrino programme, and at improving the IBR-2 spectrometer complex, as well as the efforts towards achieving important milestones of constructing and upgrading these facilities. The Committee recognized the significant number of high-quality physics results obtained by JINR scientists in 2017 at home facilities of the Institute as well as at external accelerators, reactors and in various collaborations.

The Finance Committee supported the work of the JINR Directorate for developing a Cooperation Agreement on the construction and operation of a Laboratory for Structural Research of Macromolecules and New Materials at the SOLARIS National Synchrotron Radiation Centre of the Jagiellonian University in Kraków, based on the results of consideration of this initiative at sessions of JINR's PAC for Condensed Matter Physics and Scientific Council.

The Finance Committee took note of the signing of the Letter of Intent between JINR and the Government of the French Republic, which creates conditions for the entry of the French Republic into the states participating in JINR on the basis of government-level cooperation agreements.

The Finance Committee welcomed the efforts of the JINR Directorate aimed at training scientific and engineering personnel for large high-tech projects of JINR and in Member States, as well as at developing and supporting the Institute's educational activities in general.

Based on the report “Execution of the JINR budget in 2017” presented by S. Dotsenko, Chief Accountant of JINR, the Finance Committee recommended that the CP note the balanced execution of the budget in income and expenditure in 2017.

The Finance Committee heard the report “Draft of the revised budget of JINR for 2018” presented by M. Vasilyev, Deputy Head of the JINR Finance and Economy Office, and recommended that the CP approve the revised budget of JINR for the year 2018 with the total income and expenditure amounting to US$268.79 million.

Regarding the report “Results of the meeting of the Working Group (WG) for JINR Financial Issues under the CP Chairman held on 22 March 2018” presented by A. Khvedelidze, Chairman of the WG, the Finance Committee recommended that the CP take note of the JINR Directorate’s information about implementation of the plan of measures on the follow-up of the audit of the financial activities of JINR for 2016.

With a view to ensuring the proper financing of JINR’s activities, the Finance Committee recommended putting for consideration by the CP the issue of completing the transition period stipulated in the Financial Protocol to the JINR Charter by 1 January 2020.

The Finance Committee recommended that the CP commission the JINR Directorate to prepare a draft Procedure for the offset of the cost of supplies of equipment, instruments, materials, services and individual work on the Institute’s orders against payments of the Member States’ contributions, by 1 June 2018 for consideration at the next meeting of the Working Group, as well as to finalize and enact the Regulation for the programmes of cooperation between JINR and scientific organizations of the Member States by 1 June 2018.

The Finance Committee recommended that the CP endorse the programme for improving the procurement activities of JINR and commission the JINR Directorate to continue the work in accordance with JINR’s Order “On initiating the process of JINR’s withdrawal from the founders (shareholders) of legal entities and of liquidation of non-profit organizations established with JINR’s participation”, to prepare an updated draft Regulation for the introduction of adjustments to the JINR budget and to send it to the Member States as part of organizing the next meetings of the Finance Committee and of the CP in November 2018.

Regarding the report “Selection of an organization for auditing the financial activities of JINR for the year 2017” presented by JINR Vice-Director R. Lednický, the Finance Committee recommended that the CP approve the LLC AC “Korsakov and Partners” as JINR’s auditor for the year 2017 as well as the plan for auditing the financial activities of JINR for 2017 proposed by the JINR Directorate.

The Finance Committee heard with interest the report “JINR accelerators and radiation risk problems in manned space flights” presented by Director of the Laboratory of Radiation Biology E. Krasavin.

A meeting of the JINR Finance Committee was held in Bucharest (Romania) on 16–17 November. It was chaired by S. Harizanova, a representative of the Republic of Bulgaria.

The Finance Committee heard a report presented by JINR Director V. Matveev on implementation of the plan of research and international cooperation in 2018 and on plans of JINR activities for the year 2019. The Committee commended the work being done by the JINR Directorate and staff which is aimed at consolidating the efforts of scientists and specialists on the priority projects of the Seven-Year Plan for the Development of JINR (2017–2023) as well as at integrating JINR’s leading projects into international and first of all European strategy programmes in order to create favourable conditions to participate in experimental research at the advanced basic facilities and research complexes being constructed at JINR. The Finance Committee appreciated highly the progress in implementing JINR’s flagship programmes, noting the achievement in 2018 of important stages in developing the research infrastructure and of a significant number of important physics results produced by JINR scientists at JINR facilities and in experiments carried out within international partnership programmes.

The Finance Committee praised the actions being taken by the Directorate towards elaborating JINR’s long-term development strategy for a period until the year 2030.

The Committee members welcomed the efforts of the Institute’s Directorate to create conditions for the training of highly qualified scientific and engineering staff for JINR, in particular, the planned start in 2019 of the International School of Engineering — a joint project of JINR and the Dubna State University, as well as the elaboration and detailed discussion of the implementation of JINR’s right to independently confer academic degrees.

Based on the report “Draft budget of JINR for the year 2019, draft contributions of the Member States for the years 2020, 2021, and 2022” presented by M. Vasilyev, Deputy Head of JINR’s Finance and Economy Office, the Finance Committee recommended that the CP approve the JINR budget for the year 2019 with the total income and expenditure amounting to US$232 112.4 thousand and allow the JINR Director to introduce adjustments to the JINR budget in 2019, including adjustments to the expenditure items “Salaries” and “International cooperation”, within the approved budget in accordance with the Regulation for the introduction of adjustments to the JINR budget. The Finance Committee also recommended that the CP approve the scale of contributions of the JINR Member States for the year 2019.

The Finance Committee recommended that the CP determine the provisional volumes of the JINR budget in income and expenditure for the year 2020 amounting to US$208.53 million, for the year 2021 amounting to US$212.50 million, for the year 2022 amounting to US$217.65 million, as well as the provisional amounts of the Member States' contributions for the years 2020, 2021, and 2022.

Regarding the report "Draft budget for the use of the special-purpose funds of the Russian Federation, provided in accordance with the Agreement between the Government of the Russian Federation and JINR on the construction and exploitation of the NICA complex of superconducting rings for heavy-ion colliding beams, for the year 2019" presented by VBLHEP Director V. Kekelidze and JINR Vice-Director R. Lednický, the Finance Committee recommended that the CP approve the budget for the use of the special-purpose funds of the Russian Federation, allocated in accordance with this Agreement, for the year 2019 in the amount of 2 311 471.1 thousand rubles.

Regarding the report "Results of the meeting of the Working Group for JINR Financial Issues under the CP Chairman held on 19 November 2018" presented by A. Khvedelidze, Chairman of the Working Group, the Finance Committee recommended that the CP approve the Regulation for the introduction of adjustments to the JINR budget and that the CP commission the JINR Directorate to finalize the draft Procedure for the offset of costs of supplies of equipment, instruments, materials, services and individual work on the Institute's orders against payments of JINR Member States' contributions and to send the updated draft of this Procedure to the Member States as part of the organization of the next meeting of the Finance Committee and session of the CP in March 2019.

The Finance Committee recommended that the CP commission the JINR Directorate to prepare a new version of the draft Regulation for research and educational programmes of JINR's cooperation with scientific organizations and universities of JINR Member States, taking into account the comments made by members of the Working Group, and to enact this Regulation from 1 January 2020; also to prepare drafts of the updated documents regulating JINR purchasing activities and to send them to the Plenipotentiaries by 1 March 2019. The Finance Committee recommended that the CP resolve to retain the current practice of withholding personal income tax from JINR employees who are citizens of JINR Member States.

Based on the report "Results of the audit of the financial activities of JINR performed for the year 2017 and analysis of implementation by the JINR Directorate of the plan of activities resulting from the audit of the financial activities of JINR performed for the year 2016" presented by D. Korsakov, Director of the audit company "Korsakov and Partners", the Finance Committee recommended that the CP approve the auditors' report and the accounting report of JINR for 2017.

The Finance Committee heard with interest the report "Development of the engineering infrastructure for implementing JINR's research programme" presented by JINR Chief Engineer B. Gikal.

MEETINGS OF THE JINR PROGRAMME ADVISORY COMMITTEES

The 47th meeting of the Programme Advisory Committee for Nuclear Physics was held on 17–18 January. It was chaired by Professor M. Lewitowicz.

The Chairman of the PAC presented an overview of the implementation of the recommendations taken at the previous meeting. JINR Vice-Director M. Itkis informed the PAC about the Resolution of the 122nd session of the Scientific Council (September 2017) and about the decisions of the Committee of Plenipotentiaries (November 2017).

The PAC heard reports on the projects implemented within the theme "Non-Accelerator Neutrino Physics and Astrophysics" and proposals for their extension. The theme consists of six projects which are devoted to the studies of rare phenomena associated with the weak interaction by methods of modern nuclear spectroscopy.

The GERDA (G&M) project is dedicated to search for the neutrinoless double beta decay of ^{76}Ge with open Ge detectors directly immersed in liquid argon. The analysis of data allowed setting a new half-life limit on the neutrinoless double beta decay of $^{76}\mathrm{Ge} > 8.0 \cdot 10^{25}$ y. The new-generation ton-scale ^{76}Ge experiment LEGEND has recently been started. In this experiment, it is planned to achieve an ultimate sensitivity of 10^{28} y.

The long-term successful participation of JINR in the NEMO experiment has led to the obtaining of fundamental world-level results for the two-neutrino and neutrinoless double beta decay of enriched isotopes ^{48}Ca, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{116}Cd, ^{130}Te and ^{150}Nd. The new-generation SuperNEMO detector will have a modular design with the ability to simultaneously measure several isotopes at a sensitivity level to the half-life $T_{1/2}(2\beta_0\nu) \geqslant 10^{26}$ y. JINR plays a key role in the project, especially in constructing the calorimeter, the VETO system, modeling and data processing programmes, and in developing methods for the purification of isotopes.

The PAC heard a report and a proposal for extension of the project of deep-water investigations with the neutrino telescope at Lake Baikal (project Baikal-GVD). The second stage of the Baikal-GVD will be a new research infrastructure aimed primarily at studying astrophysical neutrino fluxes. During 2016–2017, the Baikal collaboration deployed two full-scale clusters with 576 optical modules. At the end of 2021, the collaboration is planning to put into operation 10 clusters with 2880 optical modules. This will allow about 30 extraterrestrial events with energies above 100 TeV to be accumulated for detailed investigations of IceCube signal.

The aim of the DANSS project is to construct a relatively compact neutrino detector which is located close to an industrial power reactor at the Kalinin NPP and, in addition to the reactor monitoring, is used for searching for short-range neutrino oscillation to a sterile state. Based on other scintillator elements, it is planned to develop and construct two new neutrino detectors S^3 (S-cube) with improved parameters. They would have better energy resolution. The first of them will be constructed by IEAP CTU (Prague) and installed at the Temelin NPP (Czech Republic). The second one will operate parallel to DANSS at the Kalinin NPP.

The PAC heard a report on the progress in the GEMMA-III project experiments with reactor neutrinos conducted by JINR staff at the Kalinin NPP. The aim of the GEMMA project is to investigate reactor neutrino properties using high-purity low-threshold germanium detectors. In particular, the experiments search for the magnetic moment of neutrino (MMN) and coherent elastic neutrino–nucleus scattering (CENNS). The experimental set-up will be located under reactor core No. 3 at the Kalinin NPP, where the distance from the centre of the core is only 10 m, on a special lifting mechanism.

The PAC heard a report on the recent results of the EDELWEISS experiment. In the experiment, innovative cryogenic HPGe bolometers installed in a low-background set-up are used for the direct search of weakly interacting massive particles (WIMP) from the galactic halo considered to be the main candidates for the role of dark matter. The main objective of the new phase of the experiment named EDELWEISS-LT is to search for spin-independent scattering on nucleons of the so-called light WIMPs. The relevance of this is rising from new theoretical approaches favoring WIMPs with a mass below 10 GeV/c^2.

Recognizing the world-leading results obtained in all these projects, the PAC recommended supporting these experiments rigorously until the end of 2021 and of the Baikal project — until the end of 2023, as well as extending international contacts with the KM3NET collaboration to develop common synergies to become part of the ESFRI and APPEC roadmaps.

The PAC heard a report on the progress in construction of the Factory of Superheavy Elements (SHE). The commissioning of the DC-280 accelerator should start by September 2018. The construction of the experimental set-ups including the target system, separators and detection systems has made a very important progress. First test experiments are planned for October–November 2018. In addition to the technical work, an important effort of FLNR and JINR concentrates on the licensing process, which should be accomplished to begin experiments on the synthesis and studies of superheavy elements.

The PAC supported the FLNR team for the well-thought-out decisions concerning the continuation of the operation of U-400 for several years in parallel with the operation of experiments at GFS-1 and at SHELS.

The PAC heard a report on preparing day-one experiments at the new fragment-separator ACCULINNA-2. With the ^{15}N primary beam, the new fragment separator was tested to produce various secondary beams of radioactive isotopes. Intensities of the obtained secondary beams were 25 times higher than those obtained with the previous ACCULINNA facility. Thus, ACCULINNA-2 becomes the basic facility to study exotic nuclei at FLNR.

The PAC took note of the report on the concluding theme “Theory of Nuclear Structure and Nuclear Reactions” and of the proposal for a new theme entitled “Theory of Nuclear Systems”. The PAC noted the results obtained in the main research areas and a smooth transition to the new theme “Theory of Nuclear Systems” which should be solidly connected with the physics items of strong interest for the SHE Factory and ACCULINNA-2 facilities at JINR and for other facilities operating or in the commissioning phase such as FAIR, SPES, HIE-ISOLDE, SPIRAL2, and ELI-NP. The PAC recommended closure of the theme “Theory of Nuclear Structure and Nuclear Reactions” after its completion in 2018 and approval of the new theme “Theory of Nuclear Systems” for 2019–2023.

The PAC heard the following scientific reports: “Study of vorticity and hyperon polarization in heavy-ion collisions within the NICA energy range”, “Application of multinucleon transfer reactions to the synthesis of neutron-rich nuclei” and “Neutron activation analysis of arsenic and mercury content in human remains of the XVI–XVII centuries from the Moscow Kremlin necropoleis” presented by V. Toneev, A. Karpov and A. Dmitriev, respectively.

The PAC recommended that the results obtained with the “Quinta” assembly and the future programme with the BURT target within E&T&RM project be assessed at a dedicated review meeting to be organized by the JINR Directorate.

The PAC reviewed the presentations of new results and proposals by young scientists in the field of nuclear physics research. The best posters selected were “Sensitive neutron detection method using iodine-containing scintillators” presented by D. Ponomarev, “Utilization of the $(p, 4n)$ reaction potential for the production of medical isotopes with medium-energy protons: Radionuclide generator ^{90}Mo$\rightarrow^{90}$Nb” presented by A. Marinova and “Active background suppression using argon scintillation for the GERDA Phase II and the LEGEND experiment" presented by E. Shevchik. The poster "Sensitive neutron detection method using iodine-containing scintillators" was recommended for presentation at the session of the Scientific Council in February 2018.

The 47th meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 22–23 January. It was chaired by Professor D. L. Nagy.

The Chairman of the PAC presented an overview of the implementation of the recommendations of the previous PAC meeting. JINR Vice-Director M. Itkis informed the PAC about the Resolution of the 122nd session of the JINR Scientific Council (September 2017) and about the decisions of the JINR Committee of Plenipotentiaries (November 2017).

The PAC heard with interest a report on the development of the scientific case for a new source of neutrons at JINR, presented by N. Kučerka. The PAC supported the activities of FLNP in this direction, appreciating the attention being paid to the requirements of the scientific community in the context of modern science, as well as the ongoing discussions on the scientific case of the new source, and recommended their continuation.

The PAC appreciated the report "A 20-year forward look at JINR's high-flux pulsed neutron source" presented by V. Aksenov and took note of the principles of construction and the parameters of a neutron source — a superbooster. The PAC considered the subcritical assembly of ^{237}Np with a mechanic reactivity modulation controlled by a proton accelerator to be a possible conception of the future neutron source. If successfully implemented, such a source will take one of the world's leading positions among the high-flux pulsed sources. At the same time, the PAC recommended continuing the work to study other options with a clear analysis of the parameters of the new source in terms of strengths, weaknesses, opportunities and threats with respect to the envisaged long-term user programme. The PAC suggested a timeline for the preparatory phase of JINR's new neutron source with estimated deadlines.

The PAC took note of the report presented by D. Kozlenko on the current state of the IBR-2 spectrometer complex and plans of its development. It appreciated the significant upgrade of the IBR-2 spectrometers and development of new instruments, resulting in improvement of their parameters and extension of research areas, as well as making them more attractive for potential users. The PAC recommended further development of IBR-2 instruments taking into account the current trends in the progress of neutron scattering techniques.

The PAC heard a report on the activities at the high-pressure neutron diffractometer DN-6 for investigation of microsamples under extreme conditions, presented by E. Lukin. Taking into account that the DN-6 diffractometer becomes one of the world-leading instruments for neutron scattering studies of matter under extreme conditions, the PAC recommended further development of DN-6 and its introduction to the FLNP User Programme.

The PAC took note of the comprehensive report presented by D. Chudoba on the progress in implementing the FLNP User Programme and highly appreciated FLNP's efforts to run the User Programme at an internationally recognized level. The PAC underlined that the User Programme is the key instrument for securing the position of IBR-2 as one of the leading neutron sources in the world and encouraged the FLNP Directorate to upgrade the proposal assessment web applications being utilized within a professional system supporting the work of proposers, reviewers and the FLNP management, as well as to require experimental reports to be submitted by all successful proposers.

The PAC heard with interest a report on the concept of JINR's synchrotron radiation laboratory at the SOLARIS synchrotron of the Jagiellonian University in Kraków, presented by V. Shvetsov. The PAC considered fruitful the idea of establishing such a laboratory in one of the Member States. It invited the Directorates of JINR Laboratories to elaborate the details of envisaged cooperation based on a more detailed scientific case and in terms of well-established user demands and the existing synchrotron radiation landscape. In this regard, the PAC recommended that the JINR Directorate, together with the Jagiellonian University, form a working group of representatives of both organizations with the participation of interested representatives of scientific centres of JINR Member States in order to develop the concept of the laboratory and a forward-looking scientific programme.

The PAC heard with interest the scientific reports "Cultural heritage research using neutron imaging at the IBR-2 reactor" and "Planar graphene tunnel field-effect transistor: Effect of edge vacancies on performance" presented by I. Saprykina and V. Katkov, respectively.

The PAC took note of the information about the international conference "Condensed Matter Research at the IBR-2" (Dubna, 9–12 October 2017) presented by T. Ivankina and recommended that the holding of similar international meetings be continued in future.

The PAC selected the poster "Fullerene-based complexes in solutions for anticancer therapy and neurodegenerative diseases" by O. Kyzyma as the best poster at the session. The PAC also noted two other high-quality posters: "Investigation of the crystal and magnetic structure of nanostructured complex oxides of transition metals in a wide pressure and temperature range" by N. Belozerova and "Clusterization aspects of fullerenes C_{60} and C_{70} in toluene/N-methyl-2-pyrrolidone mixture according to SANS, SAXS and DLS data" by T. Nagorna.

The 48th meeting of the Programme Advisory Committee for Particle Physics took place on 31 January – 1 February 2018. It was chaired by Professor I. Tserruya.

The Chairman of the PAC presented an overview of the implementation of the recommendations taken at the previous meeting. JINR Vice-Director R. Lednický informed the PAC about the Resolution of the 122nd session of the Scientific Council (September 2017) and about the decisions of the Committee of Plenipotentiaries (November 2017).

The PAC took note of the progress in developing the Nuclotron–NICA accelerator complex and congratulated the VBLHEP staff on the successful preparation of the KRION-6T heavy-ion source for operation in Run 55 of the Nuclotron. The PAC appreciated the regular commissioning of new equipment and supported the programme of timely modernization of existing elements of the accelerator complex, in particular, the upgrade of LU-20 and the subsequent substantial increase in beam intensity. The PAC recognized the progress in the development of the key infrastructure elements including the upgrade of the power supply system of beam channels, the launch of the new Nuclotron control system, the commissioning of the new helium liquifier, the progress in upgrading the existing cryogenic complex, the preparation for the installation of the booster synchrotron, and the work carried out for the preparation of the collider magnet system. The PAC was pleased with the progress achieved in the civil construction of the collider complex and with the roadmap for the construction of the NICA Centre building.

The PAC was concerned about the problems encountered with the operation of the cooling system of the superconducting magnets, which caused the forced interruption of Run 55 of the Nuclotron. It noted with satisfaction the efforts undertaken by the Laboratory for the rapid restoration work at the cryogenic helium facility and its successful completion. The PAC appreciated the information provided by the project management on the measures taken to prevent recurrence of similar accidents in the future.

The PAC was very pleased to know about the recent initiatives to attract new non-JINR collaborators to the MPD and BM@N experiments. The PAC welcomed the plans to hold a three-day meeting at JINR in April 2018 to officially launch the MPD and BM@N international collaborations and strongly encouraged the initiative to establish a grant programme to attract and support research conducted at the NICA facility.

The PAC appreciated the recent advance in the MPD magnet construction but was concerned about the delay in the magnet delivery to JINR. The Committee urged the team to ensure timely and successful completion of the contract, avoiding any further delay. It acknowledged the efforts undertaken by the JINR and VBLHEP managements to strengthen the participation of groups from China in the construction of the MPD electromagnetic calorimeter. The PAC welcomed the commissioning of new equipment and the first use of the large-area GEM tracking detectors in the BM@N experiment. The PAC reiterated its concern about the lack of manpower for an in-depth analysis of the data collected in recent runs. The Committee looks forward to a report on the detector operation during Run 55 with the new heavy-ion source, KRION-6T, and on the study of short-range correlations.

The PAC took note of the progress towards realization of the SPD project and endorsed the proposed plan for the preparation of the Conceptual Design Report of the SPD detector, backed by local theoretical support, which will be submitted to this PAC in January 2019, and for the formal establishment of the SPD collaboration.

Concerning JINR's participation in the upgrade of detectors at the LHC, the Committee was pleased to hear about the commissioning of the Micromegas chamber production site at JINR for the ATLAS Muon Spectrometer and appreciated the realization of a second workshop dedicated to the production of smaller-size muon chambers for domestic projects. The PAC appreciated the progress achieved by the JINR group in the CMS Phase-I detector upgrade and R&D work for the HL-LHC, and recommended continuation of JINR's participation in these two projects until the end of 2020.

The PAC took note of the realization of the Borexino/SOX/DarkSide project and appreciated the broad spectrum of important results obtained in the Borexino experiment. However, it also noted that Borexino, SOX and DarkSide are three distinct experiments with rather diversified physics goals and timelines. Given the interest in the continuation of the Borexino programme on pp, geo- and CNO neutrinos, it was recommended that the group carry on the data analysis until the end of 2019. Concerning SOX, due to the issues admitted by the proponents about potential delays, the PAC proposed that a detailed status report be presented at the next PAC meeting in order to decide on a possible recommendation. Finally, the PAC noted the scientific interest of the dark matter DarkSide-20k project. However, considering the different scientific scope with respect to Borexino, and given the scale and the complexity of the experiment, the PAC recommended that the proponents and the JINR management first establish a global strategy to be presented to the PAC at the next meeting in order to allow a thorough evaluation of all aspects of the project related to science, contributions and consistency of the group, investments and timeline.

The PAC heard with interest the reports on the scientific results obtained by the JINR groups in the LHC experiments: it noted the progress in the study of the kaon femtoscopy, ultraperipheral $\mathrm{Pb}+\mathrm{Pb}$ collisions and the test results of the ALICE electromagnetic calorimeter PHOS with new electronics modules TQDC-16E made by the JINR group; appreciated the new results on searches for physics beyond the Standard Model in the $Z\gamma$ final states, measurements of the differential cross section of the $W/Z+$ heavy flavour production, searches for pentaquark states in decays of Λ_b baryons, and studies of $B_c(2S)$ mesons in the ATLAS experiment; and also appreciated the significant contribution of the JINR group in the CMS experiment to the study of di-muon production and multijet states in the Standard Model and in the context of BSM searches.

The PAC took note of the scientific report "Factorization theorem and duality: From low-energy to high-energy regimes" presented by I. Anikin.

The PAC reviewed 30 poster presentations in particle physics by young scientists from DLNP, LIT and VBLHEP, and selected the poster "Limit on the effective magnetic moment of solar neutrinos using Borexino data" presented by A. Vishneva to be reported at the session of the Scientific Council in February 2018. The PAC reiterated its recommendation that the posters should focus on the actual work of the young scientists.

The PAC took note of the actions taken by the COMPASS group in response to the Committee's recommendations given at the previous session. In particular, the size of the group was decreased by 25% and the travel expenses were lowered by 10%. The PAC considered that these are very modest steps but was pleased to know that further reductions will be implemented after completion of the 2018 run at the CERN SPS. The PAC was pleased that these changes will enable a stronger participation of the group members in the SPD project.

The 48th meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 14–15 June. It was chaired by Professor D. L. Nagy.

D. L. Nagy presented an overview of the implementation of the recommendations of the previous PAC meeting. JINR Vice-Director B. Sharkov informed the PAC about the Resolution of the 123rd session of the Scientific Council (February 2018) and the decisions of the Committee of Plenipotentiaries of the JINR Member States (March 2018).

The PAC heard a report on an alternative option for the development of a new source of neutrons at JINR. The physical scheme presented is based on a subcritical booster with a plutonium dioxide core, giving a criticality level of no more than 0.98, and a non-multiplying tungsten target. The PAC recommended that the work on the development of the general concept of a new neutron source on the basis of the presented approaches be continued.

The PAC took note of the report on a scientific programme in nuclear physics being proposed for a new JINR's neutron source. Noting that very cold and ultracold neutrons are of great interest for fundamental physics research, the PAC recommended starting the development of a scientific case for the moderators of ultracold and very cold neutrons at a new JINR neutron source.

The PAC took note of the activities concerning the development of the concept for a new Laboratory for Structural Research of Macromolecules and New Materials at the National Synchrotron Radiation Centre SOLARIS of the Jagiellonian University in Kraków, presented by N. Kučerka. The PAC acknowledged that the new capability to be provided by the new laboratory would become a part of the JINR research tools, especially in terms of complementarity between existing neutron-based techniques and future X-ray methods. The PAC recommended continuing the analysis of the feasibility of the technical design and parameters required by future experiments.

The PAC was informed about the progress in the development of JINR's strategic long-range plan up to 2030 and beyond. The PAC endorsed the steps towards formation of the memberships of the subgroups for condensed matter physics and neutron physics, as well as for radiobiology and astrobiology and the work plans for 2018–2019, recommending that the subgroups provide regular information on their work at its future meetings.

The PAC took note of the report on the concluding project "Isotope identifying reflectometry at the IBR-2 reactor". It was pleased to note that Isotope Identifying Reflectometry (IIR), a principally new method designed to study diffuse processes in layered nanostructures, had been successfully implemented at the IBR-2 reactor. Given the successful completion of these activities, the PAC recommended closure of the project.

The PAC considered a proposal for opening a new project "Development of a facility for measurements with test electron beams at DLNP. LINAC-200". The PAC appreciated DLNP's efforts to develop new types of elementary particle detectors required for experiments at future accelerators. Nevertheless, it missed a scientific case of the project within the competency of this PAC. The PAC encouraged the authors of the proposal to elaborate a scientific case within the scope of the PAC for Condensed Matter Physics or to consider submitting their proposal to another PAC.

The PAC took note of the report on the concluding theme "Theory of Condensed Matter" and considered a proposal for the opening of a new theme "Theory of Complex Systems and Advanced Materials". The PAC highly appreciated the results obtained in the main research areas and also welcomed the interrelation between the ongoing theoretical studies and the JINR experimental programmes. The PAC supported continuation of this research under a new theme and the deepening of cooperation with the experimental groups of JINR and its Member States in order to raise it to a higher level. The PAC recommended closure of the concluding theme and opening a new one for the period 2019–2023.

The PAC took note of the report on the concluding theme "Organization, Support, and Development of JINR Educational Programmes" and considered a proposal for opening a new theme "Organization, Support and Development of the JINR Human Resources Programme". Within the current theme, the University Centre has been performing the overall coordination and support of the educational and human resource development programmes at JINR. As part of the theme, one of the main issues and functions of JINR is being implemented — attracting talented young people and partner scientific research organizations of the Member States to the Institute. The PAC recommended closure of the concluding theme and opening a new one for the period 2019–2023.

The PAC took note of the conceptual project of a Research Centre for Proton Therapy at JINR. Taking into account the real state of the Phasotron and the ongoing work on the construction, together with Chinese colleagues, of the SC202 therapeutic cyclotron, the PAC invited the JINR Directorate to elaborate the project of a new research infrastructure for therapy with proton beams which could also serve as a pilot facility for future use in the JINR Member States as well as an educational tool for training specialists in proton therapy.

The PAC heard with interest the scientific reports: "90 years of Raman effect: Surface-enhanced micro-CARS mapping of organic molecules", "Solitons and autowaves in biopolymers", and "Investigations of structural and dynamic features of lipid membranes using neutron and X-ray scattering methods", presented by G. Arzumanyan, A. Bugay, and D. Soloviov, respectively.

The poster "Analysis of the working ability of a planar graphene tunnel field-effect transistor in the presence of edge vacancies" by A. Glebov was selected as the best poster at the PAC session. The PAC also noted two other high-quality posters: "Recrystallization role in ion track formation in dielectrics" by R. Rymzhanov and "Studies of Wigner quasiprobability distributions" by V. Abgaryan.

The 49th meeting of the Programme Advisory Committee for Particle Physics took place on 18–19 June 2018. It was chaired by Professor I. Tserruya.

JINR Vice-Director R. Lednický informed the PAC about the Resolution of the 123rd session of the Scientific Council and the decisions of the Committee of Plenipotentiaries of the JINR Member States.

The PAC heard with interest reports concerning the long-range plans of JINR's development in the area of particle physics and in the area of relativistic heavy-ion and spin physics. It highly appreciated the JINR Directorate's efforts towards establishing priorities and shaping up the strategic plans for the future of JINR.

The PAC congratulated the VBLHEP staff for the successful completion of Run 55 of the Nuclotron. It particularly noted the successful operation of the KRION-6T heavy-ion source and the significant improvements in the quality of the beam structure, encouraging the accelerator team to improve on the emittance of the extracted beam. The PAC acknowledged the progress achieved in the civil construction of the NICA collider complex, the efforts of the VBLHEP and JINR managements towards its timely completion, and welcomed the steady progress in various other areas of this flagship project.

The PAC appreciated the presentation by VBLHEP Director V. Kekelidze about the First Collaboration Meeting of the MPD and BM@N experiments, which took place at JINR on 11–13 April 2018. The PAC was pleased to note the great interest of the international scientific community in the MPD and BM@N experiments as reflected by the attendance of about 200 participants at the meeting and by the large number of new groups that are joining the collaborations. The PAC endorsed the roadmap for the establishment of the structure and management teams of the MPD and BM@N collaborations.

The PAC appreciated the ongoing efforts for the preparation of the technical design reports for the MPD subsystems, in particular for the FHCAL detector, and urged the MPD team to finalize the ECAL TDR, including results of simulation for the recently adopted projective geometry. The PAC acknowledged the improved BM@N detector performance and large statistics of experimental data collected in the recent Nuclotron run with argon and krypton beams, and in the first run with carbon beam for the short-range correlations studies. The PAC recommended that the team concentrate on the analysis of the collected data, on the completion of the detector configuration, and on the installation of the vacuum pipe through the experimental set-up. The PAC heard with interest the report on the first measurement of short-range correlations in a carbon nucleus using reverse kinematics in the BM@N set-up and congratulated the collaboration for the rapid realization of this project, looking forward to the results of the physics analysis.

The PAC congratulated the JINR NA61 team for the three PhD theses and two doctoral dissertations successfully defended. However, the PAC considered that the travel budget, which represents most of the requested fund of the proposal, is relatively high, in particular, keeping in mind that there will be no runs in 2019 and 2020. Assuming that the travel request will be significantly reduced, the PAC recommended continuation of JINR's participation in the NA61 experiment until the end of 2021 with second priority.

The PAC took note of the results of the NA62 experiment aimed at measuring the very rare kaon decay $K^+ \to \pi^+\nu\nu$. The PAC appreciated the observation of the first candidate event of $\pi^+\nu\nu$ decay and the publication of the first results on searches for heavy neutral leptons. However, beam properties (background and intensity) could affect the experiment sensitivity. To mitigate the impact, the collaboration is taking corrective measures that are expected to still keep this unique experiment at the forefront of its research field. Therefore, the PAC recommended continuation of JINR's participation in the NA62 experiment until the end of 2021 with first priority.

The PAC took note of the report on the HyperNIS project for the study of the lightest neutron-rich hypernuclei and recommended continuation of the project until the end of 2021 with first priority.

The PAC took note that for the first time a collection of data has been obtained in the ALPOM-2 experiment on the azimuthal asymmetries for the polarized-neutron charge-exchange reactions $n + \mathrm{CH}_2 \rightarrow n + X$, as well as for C, CH (scintillator) and Cu polarimeter analyzers. The PAC considered these results to be very important for JLab experiments and recommended continuation of the ALPOM-2 project until the end of 2021 with first priority.

The PAC took note of the report on the DSS experiment at the Nuclotron's internal target. The Committee encouraged the collaboration to find funding for an appropriate upgrade of their experimental set-up in order to increase the available phase space, and recommended continuation of the DSS project until the end of 2021 with first priority.

The PAC appreciated the results obtained by the JINR group in the STAR experiment on the study of antiproton–antiproton and lambda–lambda correlations performed with high statistics, the analysis of scaling properties of the charged hadrons spectra, and the team's participation in the event plane detector upgrade. The Committee also noted the preparations for the "Beam Energy Scan Phase II". It encouraged the team to share its experience with the MPD team and recommended continuation of JINR's participation in the STAR experiment until the end of 2021 with first priority.

The PAC took note of the report on the HADES experiment at GSI/FAIR focused on the precise spectroscopy of e^+e^- pairs produced in proton-, pion- and heavy-ion-induced reactions in the beam kinetic energy range of 1–3.5 GeV. The PAC encouraged the JINR team to shift its focus to the investigation of dileptons at NICA and recommended continuation of JINR's participation in the HADES experiment until the end of 2021 with second priority.

The PAC took note of the report on implementation of the project "Precision laser metrology for accelerators and detector complexes" and considered that the group should implement its expertise in the NICA project. The PAC recommended continuation of this project until the end of 2021 with second priority.

The PAC heard with interest the proposal of a new project entitled "ARIeL: Physics at future e^+e^- colliders". Although theoretical calculations performed within the project could be useful for any future electron–positron collider, there are serious points of concern: uncertainties on the choice of the future machine(s) beyond the HL-LHC; limited capacity of the CLIC to address Higgs studies; a harsh international competition on the proposed studies which would affect the expected impact of this research. The PAC recommended approval of this project until the end of 2021 with third priority.

The PAC took note of the proposal to continue the theme "Dubna International Advanced School of Theoretical Physics" (DIAS-TH). The PAC appreciated the activities focused on the education of young scientists and students and the regular organization of dedicated training courses, lectures, workshops and schools, and recommended continuation of the DIAS-TH activities within this theme until the end of 2023 with first priority.

The PAC took note of the proposals to open two new themes: "Fundamental Interactions of Fields and Particles" and "Modern Mathematical Physics: Gravity, Supersymmetry and Strings" until the end of 2023. Given the high quality of the scientific productivity of the groups and the sound plans for future research, the PAC recommended approval of the themes with first priority.

The PAC reviewed the poster presentations in particle physics by young scientists from DLNP, LIT, BLTP and VBLHEP. It selected the poster "How robust is a third family of compact stars against pasta phase effects?" presented by A. Ayriyan to be reported at the session of the Scientific Council in September 2018.

The 48th meeting of the Programme Advisory Committee for Nuclear Physics was held on 20–21 June. It was chaired by Professor M. Lewitowicz.

M. Lewitowicz introduced the new members of the PAC, Adam Maj and Valery Nesvizhevsky, and presented an overview of the implementation of the recommendations taken at the previous meeting. JINR Vice-Director M. Itkis informed the PAC about the Resolution of the 123rd session of the Scientific Council (February 2018) and the decisions of the Committee of Plenipotentiaries of the Governments of the JINR Member States (March 2018).

The PAC for Particle Physics and the PAC for Nuclear Physics suggested organizing a joint session on neutrino physics and dark matter research, which is scheduled for 22 January 2019. The agenda will be prepared by the Chairmen of both PACs in close collaboration with the JINR Directorate.

The PAC took note of the report on the results of activities within the theme "Improvement of the JINR Phasotron and Design of Cyclotrons for Fundamental and Applied Research" focused on the development and improvement of accelerators for hadron therapy applications. Now the Phasotron is still operating mainly for medical research, but should be phased out and replaced within a few years due to its enormous cost in manpower and resources. The plan is to replace it by a superconducting isochronous cyclotron SC202 that has been jointly developed by JINR and the Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei. The PAC recommended extension of the theme "Improvement of the JINR Phasotron and Design of Cyclotrons for Fundamental and Applied Research" until the end of 2019 and expects a new complete project to be ready next year, focused on the timely realization of the SC202 compact cyclotron.

The PAC took note of the information on the concluding theme "Organization, Support, and Development of the JINR Educational Programme" and on the opening of a new theme "Organization, Support, and Development of the JINR Human Resources Programme". The PAC appreciated the results achieved by the UC in addressing issues of training scientific and engineering personnel in order to realize large-scale projects both on the basis of the JINR Laboratories and in research centres of the Member States. The PAC recognized the successful implementation of the JINR Summer Student Programme, which ensures a stable number of interested young people coming to the summer practical courses at JINR. The PAC supported the recommendations of the 48th meeting of the PAC for Condensed Matter Physics (14–15 June 2018) on the opening of the new theme "Organization, Support, and Development of the JINR Human Resources Programme".

The PAC heard a report on the status and quality assurance of the DC-280 cyclotron which is the central part of the Factory of Superheavy Elements (SHE). The start of the complex launching of the DC-280 accelerator with ion beams is scheduled for September 2018. The commissioning of DC-280 and first test experiments are planned for the end of 2018. The PAC recommended that the JINR and FLNR Directorates put all necessary efforts to allow for the timely completion of the construction, licensing, and commissioning of the SHE Factory in 2018. The PAC recommended that the quality assurance system devised at FLNR be used during launching and tuning work and the commissioning of the main systems of the SHE Factory, and that the FLNR Directorate focus on the preparation of Day-1 experiments and make a presentation on the planned scientific programme at the next PAC meeting.

The PAC heard a report on first experiments carried out at the new ACCULINNA-2 fragment separator and endorsed the first experiment on the ACCULINNA-2 fragment separator aimed at studying the properties of ^{7}H in the ^{8}He(d, ^{3}He)^{7}H reaction.

The PAC heard a report on the construction of the MAVR high-resolution magnetic analyzer based on the MSP-144 magnet with stepped poles. To increase the solid angle of the MAVR magnetic-optical system, a doublet of quadrupole lenses is installed in front of the MSP-144 magnet. Now the installation work for the analyzer and ion beam tracing systems is being completed in the U-400 experimental hall. MAVR will allow FLNR physicists to detect products of nuclear reactions with stable and radioactivity beams with better energy resolution, in order to study the structure of exotic nuclei in different mass regions. The PAC recommended completing integration of all its systems and suggests performing the in-beam commissioning experiment to verify whether the projected performance is achieved.

The PAC heard with interest the report "Supercomputer "Govorun" — new prospects for heterogeneous computations in nuclear physics" and noted the substantial progress in developing the high-performance computing component of the Multifunctional Information and Computing Complex at JINR. The PAC supported LIT's efforts to develop the supercomputer "Govorun" as one of the essential tools for a further fast development of experimental and theoretical physics at JINR and in its Member States.

The PAC heard the following scientific reports: "State-of-the-art and future prospects of neutron activation analysis at the IBR-2 reactor", "Investigation of subsurface layers of solids with the help of charged particle beams accelerated at the EG-5 electrostatic generator" and "Appearance of quasi-fission in reactions of heavy-ion collisions" presented by M. Frontasyeva, A. Kobzev and A. Nasirov, respectively.

The PAC reviewed the presentations of new results and proposals by young scientists in the field of nuclear physics research. The best posters selected were "The fusion–fission and quasi-fission in the near-barrier reaction $^{32}S + ^{197}Au$" presented by I. Harca, "Spectroscopy of the isotopes of transfermium elements in Dubna: Present status and perspectives" presented by A. Kuznetsova and "Orientation of statically deformed heavy nuclei in multinucleon transfer reactions" presented by V. Saiko. The poster "The fusion–fission and quasi-fission in the near barrier reaction $^{32}S + ^{197}Au$" was recommended for presentation at the session of the Scientific Council in September 2018.

PRIZES AND GRANTS

The ***V. Dzhelepov Prize*** was awarded to Professor V. Komarov (DLNP, JINR) for his pioneering work on the construction of the first channel for proton therapy at the JINR synchrocyclotron.

The ***B. Pontecorvo Prize*** was awarded to Professor F. Halzen (University of Wisconsin, Madison, USA) for his leading role in the construction of the IceCube detector and experimental discovery of very-high-energy cosmological neutrinos.

The ***Lomonosov Gold Medal*** was awarded to Professor Yu. Oganessian (FLNR, JINR) for fundamental research in the field of interaction of complex nuclei and experimental evidence of existence of an "island of stability" for superheavy elements.

JINR PRIZES FOR 2018

I. Theoretical Physics Research

First Prizes

1. "Multidimensional supersymmetric mechanics, Witten–Dijkgraaf–Verlinde–Verlinde equation and its generalization".
Authors: S. Krivonos, O. Lechtenfeld, O. Sutulin.

2. "Vortical excitations in nuclei".
Authors: J. Kvasil, W. Kleinig, V. Nesterenko, P.-G. Reinhard, A. Repko.

Second Prize

"Description of low-energy meson production at colliding e^+e^- beams and in decays of tau leptons within the extended Nambu–Jona-Lasinio model".
Authors: M. Volkov, A. Arbuzov, A. Pivovarov, K. Nurlan.

II. Experimental Physics Research

First Prizes

1. "Study of pp-chain solar neutrino properties with the Borexino detector".
Authors: A. Vishneva, O. Smirnov, A. Sotnikov.

2. "Correlation of structure and physical properties in ordered iron-based alloys".
Authors: A. Balagurov, I. Bobrikov, S. Sumnikov, I. Golovin, V. Palacheva.

Second Prize

"Manifestation of the cluster structure of ^{9}Be nuclei in the mechanism of their interaction".
Authors: S. Lukyanov, A. Denikin, V. Maslov, M. Naumenko, Yu. Penionzhkevich, J. Mrazek, W. Trzaska, K. Mendibaev, N. Skobelev, Yu. Sobolev.

III. Physics Instruments and Methods

First Prize

"ACCULINNA-2 project: The physics case and technical challenges".
Authors: A. Bezbakh, L. Grigorenko, M. Golovkov, A. Gorshkov, S. Krupko, S. Sidorchuk, S. Stepantsov, G. Ter-Akopian, F. Fomichev, P. Sharov.

IV. Applied Physics Research

First Prize

"Structure and properties of aqueous solutions of C_{60} and C_{70} fullerenes for biological applications".
Authors: E. Kyzyma, V. Petrenko, O. Ivankov, M. Avdeev, V. Aksenov, L. Bulavin, Yu. Prylutskyy.

Second Prize

"Determination of the elemental content of Moldavian wines and soils by neutron activation analysis".
Authors: I. Zinicovscaia, O. Culicov, M. Frontasyeva, S. Gundorina, O. Duliu, R. Sturza.

Encouraging Prizes

1. "Symmetry effects in quantum dots".

Authors: R. Nazmitdinov, M. Dineykhan, N. Simonović, A. Puente.

2. "Study of the structure of a proton in hard $p{-}p$ processes of production of prompt photons or vector bosons accompanied by heavy jets".

Authors: V. Bednyakov, S. Brodsky, G. Lykasov, A. Lipatov, J. Smiesko, S. Tokar.

3. "Discovery and prospects of investigation of transitional dynamics in three-body decays of exotic nuclei".

Authors: T. Golubkova, L. Grigorenko, M. Zhukov, P. Sharov.

4. "Position-sensitive twin ionization chamber for nuclear fission investigations".

Authors: Sh. Zeynalov, P. Sedyshev, O. Sidorova, V. Shvetsov, L. Svetov.

GRANTS

In 2018, for the implementation of a number of scientific projects, the staff members of the Joint Institute for Nuclear Research received financial support of the Russian Foundation for Basic Research (RFBR), the Russian Scientific Foundation (RSF), the Belarussian Republican Foundation for Basic Research (BRFBR), and the Foundation for the Advancement of Theoretical Physics and Mathematics "BASIS".

RFBR financed JINR projects in the framework of the following competitions: "Competition of Projects of Fundamental Scientific Research" (23 projects); "Competition of Projects Accomplished by Young Scientists (My First Grant)" (8 projects); "Competition of the Best Projects of Interdisciplinary Fundamental Research" (2 projects); "Competition of Fundamental Oriented Research in Urgent Interdisciplinary Topics" (1 project).

RFBR financed a number of JINR scientific projects in the framework of international contests: together with the State Committee of Science of the Ministry of Education and Science of the Republic of Armenia (1 project); together with the Belarussian Republican Foundation for Basic Research (1 project); together with the National Scientific Foundation of Bulgaria (2 projects); together with the Department of Science and Technology of the Government of India (3 projects); together with the State Foundation of Natural Sciences of China (1 project); together with the Ministry of Science, Technology and Environment of the Republic of Cuba (1 project); together with the Ministry of Education, Culture, Science and Sport of Mongolia (1 project); together with the German Scientific-Research Community (2 projects); together with the National Centre of Scientific Research of France (3 projects).

RFBR rendered financial support to JINR for organization of 7 scientific conferences in the framework of the competitions "Organization and Holding of Conferences and Scientific Events in the Territory of Russia" and "Organization of Russian and International Scientific Events for Young Researchers".

RSF financed JINR scientific projects in the framework of the competitions: "Holding of Fundamental Scientific Research and Scientific Research in Separate Scientific Groups" (7 projects); "Holding of Initiative Research by Young Scientists" (2 projects); "Holding of Research by Scientific Groups under the Guidance of Young Scientists" (1 project).

Fifteen projects were financed in 2018 in the framework of the joint competition of research projects of BRFBR and JINR.

The Foundation for the Advancement of Theoretical Physics and Mathematics "BASIS", under the programme "Scientific Mobility" financed 1 project for the competition "Visitor".

2018

INTERNATIONAL RELATIONS AND SCIENTIFIC COLLABORATION

COLLABORATION IN SCIENCE AND TECHNOLOGY

The main results of the international cooperation in science and technology of the Joint Institute for Nuclear Research in 2018 are reflected by the following data:

— joint research was conducted with scientific centres in the Member States, as well as with international and national organizations in other countries, on 42 topics of first priority and one topic of second priority;

— to solve cooperation issues and questions of participation in scientific meetings and conferences, the Joint Institute sent 3277 specialists;

— for joint work and consultations, as well as for participation in meetings, conferences, and schools held at JINR, 2010 specialists were received;

— 59 international scientific conferences and schools, 18 workshops, and 13 meetings were organized and held.

The international cooperation of JINR is presented in agreements and treaties. Its development comprises joint experiments at basic facilities of physics centres, the acquisition of research data, the preparation of joint publications of the research results, the supply of equipment and techniques for the interested sides, etc.

On 19 January, President of the New Mongol Academy J. Galbadrakh and Head of the Department of Natural Sciences of the New Mongol Institute of Technology O. Nyamsuren visited JINR. Head of the Mongolian national group of JINR O. Chuluunbaatar accompanied the Mongolian guests.

The guests had a meeting at the JINR Directorate with M. Itkis, A. Sorin, D. Kamanin, E. Krasavin, A. Belushkin and D. Sangaa. In particular, the sides discussed further steps on development of contacts on the sidelines of the upcoming international conference "Modern Trends in Natural Sciences and Advanced Technologies in Science Education" that will be held on 20–24 August 2018 in Ulaanbaatar, Mongolia.

In the JINR Visit Centre, the guests were given an introductory lecture on activities of the JINR University Centre and its educational programmes. Acquaintance with the Joint Institute for Nuclear Research was continued at the Laboratory of Information Technologies, the Laboratory of Radiation Biology and the Bogoliubov Laboratory of Theoretical Physics.

The Supervisory Board on the NICA Megascience Project gathered in Dubna **on 2 February** at the Joint Institute for Nuclear Research. The Board members are representatives of JINR and the Russian Federation — the Ministry of Finance, the Ministry of Education and Science, the Russian Academy of Sciences and the Government of the Moscow Region.

This meeting of the Board was the second one; the first took place on 20 November 2016 in Krakow, in the framework of the JINR CP session. It was attended by RAS President A. Sergeev, Deputy Minister of Education and Science G. Trubnikov, JINR Director V. Matveev, representatives of the Government of the Russian Federation, Plenipotentiary of the Bulgarian Government to JINR L. Kostov, JINR Vice-Director R. Lednický, VBLHEP Director and Head of the project V. Kekelidze, and JINR Chief Scientific Secretary A. Sorin.

The decisions adopted at the meeting of the Supervisory Board were related to the programme of the project development for the nearest several years, to the structure of the administration bodies, financial grounds, scientific programme details and the schedule of the building construction. The members of the Board visited the factory of superconducting magnets and the construction site of NICA, the building of the synchrophasotron where the development of the booster had been started; they visited the BM@N facility where experiments are under way on Nuclotron extracted beams. The experts were informed about the work to construct the multipurpose detector MPD and about the development of the SPD detector.

On 14 February, a Round Table was held in the UNESCO Headquarters in Paris on the occasion of the 20th anniversary of JINR–UNESCO cooperation and the discovery of new superheavy elements of the Periodic Table of Chemical Elements. It was attended by a representative delegation of JINR. Welcoming speeches were made by Director of the UNESCO Division of Science Policy and Capacity Building D. Nakashima, JINR Vice-Director M. Itkis, Deputy Minister of Education and Science G. Trubnikov and IUPAC ex-president N. Tarasova. JINR Vice-Director M. Itkis delivered the report on history, present and future projects of JINR, Academician Yu. Oganessian told the audience about JINR research on discovery of superheavy elements, and Director of the JINR University Centre S. Pakuliak presented international student programmes implemented at JINR.

The Round Table concluded with the engaging discussion of modern trends of the world fundamental science development, including ways and means of increasing interest in science among the youth.

In February, the workshop "JINR Day in France" was held in Paris on the occasion of the 60th anniversary of establishment of scientific contacts between JINR and France that had been initiated after the visit of the outstanding French physicist Frèdèric Joliot-Curie to Dubna. The meeting, organized by the National Centre for Scientific Research (CNRS) of France, was aimed at the extension of cooperation of JINR with French scientific organizations.

The delegation included the JINR Directorate members, Directors of the JINR Laboratories, representatives of the JINR University Centre and the JINR International Cooperation Department, as well as experts in relevant scientific fields. The Rissian side and the JINR CP were represented by Deputy Minister of Education and Science of the Russian Federation G. Trubnikov.

More than 90 participants representing French scientific centres, universities and diplomatic missions of a number of the JINR Member States took part in the event. The scientific programme of the "JINR Day in France" covered a wide range of scientific issues, including theoretical physics, heavy ion physics, neutron research, and radiobiology. The workshop was concluded by the round table on educational issues during which means of attracting the youth to science and the JINR role in this process were discussed.

A Letter of Intent was signed in the ceremonial atmosphere to conclude a Memorandum of Understanding between the French Government and the Joint Institute for Nuclear Research; prolongation of the JINR–IN2P3 45-year collaboration was ratified; documents on prolongation of collaboration agreements on the GDRI EUREA and LIA JoULE were signed as well.

On 16 February, at CNRS a regular meeting of the Joint Committee on the Collaboration IN2P3–JINR was held, where the plan on joint projects for 2018 was approved.

On 20 February, a delegation from the Moscow Centre of Industry of the Republic of Bulgaria visited JINR. It was headed by Deputy Chairman of the Centre Ts. Genchev.

In the conference hall of the Flerov Laboratory of Nuclear Reactions, the guests met with leading specialists of JINR, including their compatriots working at Dubna, learned about research at JINR and current projects, and informed the participants about activities of their organization. The participants discussed issues of arranging delivery and purchase activities of JINR, involvement of enterprises of Member States in tenders held at JINR. The guests from Bulgaria talked about opportunities to arrange direct communications with the JINR Directorate to promote Bulgarian companies and enhance the participation of Bulgarian enterprises in future tenders announced by JINR, in particular, concerning the construction of the NICA collider and development of the infrastructure.

On 21 February, an Agreement between JINR and the Academy of Sciences and Humanities of Israel was signed. The Agreement provides development of cooperation in experimental and theoretical physics, astrophysics and related technology.

Before the signing, exchange of opinions was held involving Chairman of the Committee on High Energy Physics of Israel Professor E. Rabinovici, Chairman of the Committee on Nuclear Physics Professor I. Tserruya, JINR Director Academician V. Matveev, JINR Vice-Directors M. Itkis and R. Lednický, V. Kekelidze, A. Sorin, and D. Kamanin. The sides noted fruitful cooperation and successful results of the previous agreement of 2013–2017 between JINR and the Academy of Sciences and Humanities of Israel. In particular, under that agreement a meeting on high energy physics was held in Israel jointly with the Weizmann Institute of Science. Now Israeli scientists take part in activities on the NICA project.

On 28 February, a representative delegation of the Republic of Cuba visited JINR. The delegation was represented by Deputy Minister of Science, Technology and Environment of Cuba D. Alonso Mederoz, Extraordinary and Plenipotentiary Ambassador of Cuba to the Russian Federation G. Peñalver Portal, President of the Nuclear Energy and Advanced Technology Agency (AENTA), Director of the Centre of Applied Technologies and Nuclear Development (CEADEN) A. Diaz Garcia, AENTA Assistant Chairman on Economic and Financial Affairs J. Luis Dona, International Cooperation Expert of the Ministry of Science, Technology and Environment of Cuba C. Mendez, and Minister Counsellor of the Embassy of Cuba in Moscow R. Zayas Bu. At JINR, the delegation was accompanied by DLNP researcher Professor A. Leyva Fabelo.

JINR Director V. Matveev, JINR Chief Scientific Secretary A. Sorin, Deputy Head of the International Cooperation Department A. Kotova and International Cooperation Department Expert O. Belova welcomed the delegation in the JINR Directorate. On behalf of JINR, V. Matveev expressed deep and sincere condolences on the tragic death of Plenipotentiary of the Government of the Republic of Cuba to JINR F. C. Diaz-Balart.

A. Sorin delivered a short presentation on basic fields of JINR research and applied investigations as well as on the JINR basic facilities. Issues of further development of JINR–Cuba cooperation were discussed, including plans to train engineer staff and increase the number of young Cuban scientists sent to JINR to study and participate in research.

The delegation from Cuba visited several laboratories of the Institute and had a meeting with JINR staff members from Cuba, where they were informed about their work and life in Dubna.

On 20 March, on the invitation of the Hungarian Atomic Energy Authority (HAEA), a JINR delegation took part in the seminar organized by the Hungarian Nuclear Society (MNT) with the aim of developing business contacts and giving an additional pulse to cooperation of JINR with Hungarian research organizations.

On the JINR side, Head of the International Cooperation Department D. Kamanin, Chairman of the Programme Advisory Committee for Condensed Matter Physics D. L. Nagy and Head of the Division of Condensed Matter Physics of JINR FLNP A. Belushkin participated in the seminar.

The seminar was opened by HAEA Director General D. Fichtinger. The Dubna delegation members presented in their reports potentials of JINR as a basis for development of international cooperation in science and technology, history of scientific contacts between JINR and Hungary, as well as scientific research conducted at the spectrometer complex of the IBR-2 reactor.

The host party presented the research infrastructure of the Institute for Nuclear Research ATOMKI of the Hungarian Academy of Sciences. New developing areas of cooperation were specified in the report on participation of the Wigner Research Centre in the NICA project. President of the Hungarian Nuclear Society M. Ördögh spoke about major areas of activity of his organization. The event was concluded with a round table that brought together all interested participants of the seminar for the vivid discussion of the ways to support cooperation between Hungary and JINR and attract young scientists from Hungary to joint projects.

On 11–13 April, the First Collaboration Meeting of the MPD and BM@N Experiments at the NICA Facility was held at JINR. Representatives of more than 40 scientific centres from 19 countries participated in the event. The participants were acquainted with progress and plans on implementation of the NICA megascience project, and discussed possibilities of joining efforts and resources.

The meeting was opened by JINR Director Academician V. Matveev, who marked tremendous interest in new ideas and new approaches to implement the NICA project. JINR Vice-Director, VBLHEP Director V. Kekelidze also stressed the importance of intellectual resources in tackling the tasks. Two experiments, BM@N and MPD, which are already being implemented with the participation of the international community, provide a widest range of research opportunities. The event showed once more growing interest of the international scientific community in the research at the NICA complex, as evidenced by about 200 participants attending the meeting and a large number of new groups joining the collaboration.

In addition to the plenary meetings, excursions were organized to the NICA construction site, to the factory of superconducting magnets and detector laboratories. Discussion resulted in the elaboration of the Charters of the MPD and BM@N collaborations that were supported by 29 organizations from 14 countries. A special committee was elected for selection of candidates for the positions of spokespersons of the collaborations. Elections were scheduled for autumn 2018, at the next meetings of the MPD and BM@N collaborations.

On 14 May, the 11th internship for young scientists and specialists from the CIS countries organized by the International Innovative Nanotechnology Centre of the CIS countries (IINC CIS) with the support of the Intergovernmental Foundation for Educational, Scientific and Cultural Cooperation (IFESCCO) was launched in the Green Hall of the JINR International Conference Hall.

This year, researchers, teachers, engineers, postgraduate students and students from Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Ukraine and Uzbekistan arrived at Dubna to participate in the internship programme. The programme of the internship comprised excursions to the JINR Laboratories, lectures on particle physics, high energy physics, and condensed matter physics with an outlook of methods used for study of materials, in chemistry and radiobiology. One of the days of the internship was fully dedicated to acquaintance with the JINR structure and with the work of departments and various services.

Participants built research teams to unite young scientists keen on similar topics. This provided not only the exchange of research and scientific-organizational experience but development of new approaches and ideas as well. Particularly for this task, the programme provided special team training and business games.

During the internship, topical issues were discussed in the round-table format related to scientific activities, scientific-organizational events that are held in CIS, and support of innovation projects. A meeting was held of the participants with representatives of JINR Association of Young Scientists and Specialists (AYSS) and the Council of Young Scientists of the Moscow Region.

The participants of the meeting visited the Centre of Prototyping and the Engineering Centre at the Dubna State University, got acquainted with innovation management and commercializing of elaborations at the Special Economic Zone, the nanotechnological centre

"Dubna" and the innovation territorial cluster "Nuclear-Physics and Nano Technologies". The internship concluded with defense of projects and presentation of certificates.

On 16 May, FLNR Scientific Leader Academician Yu. Oganessian, Head of the FLNR Sector Professor Yu. Penionzhkevich, Director of the JINR University Centre S. Pakuliak and Rector of the Dubna State University D. Fursaev visited the NRNU MEPhI.

Topical issues concerning training of technical personnel for JINR mega-projects were discussed. In particular, the need to strengthen training of the Dubna State University graduates in engineering sciences and to establish of a school of engineering at the university was highlighted. The parties agreed to work on expanding the traditional cooperation between MEPhI, JINR and the Dubna State University in the field of engineering training of students.

In conclusion, MEPhI Rector M. Strikhanov presented the order "For Merit for MEPhI" to the outstanding graduate of his Alma Mater Academician Yu. Oganessian.

On 18 May, members of the General Assembly of the Astroparticle Physics European Consortium (APPEC) S. Leray (CEA Saclay, IRFU, France) and F. Moglia (DESY, Hamburg, Germany) visited the Joint Institute for Nuclear Research.

The guests from APPEC got acquainted with the main projects of JINR, visited the Frank Laboratory of Neutron Physics, the Flerov Laboratory of Nuclear Reactions and the Veksler and Baldin Laboratory of High Energy Physics. A presentation on "Applications and societal benefits of nuclear physics" was made by S. Leray at FLNR. She presented in her report the latest advances, particularly, in the fields of nuclear energy, health care, nuclear safety, space, environment and materials science.

At the JINR Directorate, the guests were welcomed by JINR Vice-Director B. Sharkov, Deputy Head of the JINR Finance and Economy Office M. Vasiliev, Head of the JINR International Cooperation Department D. Kamanin and Deputy Head of the Department A. Kotova. The participants of the meeting discussed possible ways of further cooperation development, in particular, the possibility of including one of the JINR flagship projects, Baikal-GVD, in the roadmap of the European Strategy Forum on Research Infrastructures (ESFRI). The guests noted that the Baikal-GVD project had already attracted attention of APPEC. According to the participants of the meeting, planned joint steps will serve for wider spread of information about research and opportunities of JINR in European countries.

On 18 May, a delegation from the Philippine Nuclear Research Institute (PNRI) came for a one-day visit to Dubna to get acquainted with JINR and establish scientific contacts with the aim of further cooperation. The delegation was represented by PNRI Director Carlo A. Arcilla, Chief of the PNRI Atomic Research Division Lucille V. Abad, Chief of the PNRI Technology Diffusion Division Ana Elena L. Conjares, as well as by President of the Mardas Corporation Dave Ranile. The delegation was accompanied by representatives of the State Atomic Energy Corporation Rosatom.

At the JINR Directorate, the guests were welcomed by JINR Vice-Director M. Itkis, Head of the JINR International Cooperation Department D. Kamanin and Deputy Head of the Department A. Kotova. The guests were informed about JINR, major objects of its scientific infrastructure, and fields of research.

The head of the Philippine delegation noted in his turn that the main field of PNRI activities is applied research. Nowadays, the Republic of the Philippines is committed to active development of nuclear power in the country as well as to development of its own scientific base. In this respect, the Philippine party expressed great interest in JINR educational programmes aimed at training of highly qualified specialists.

The Philippine delegation visited the Frank Laboratory of Neutron Physics, where the guests were shown the IBR-2 reactor and the IREN facility. The delegation also visited the Flerov Laboratory of Nuclear Reactions, where the guests were acquainted with research carried out at the Laboratory and its accelerator complex. The visit to the JINR Laboratories was concluded at the Veksler and Baldin Laboratory of High Energy Physics where the Synchrophasotron, the Nuclotron superconducting accelerator as well as the factory of superconducting magnets were shown to the guests.

On 8 June, the 7th international training programme for decision-makers in science and international scientific cooperation "JINR Expertise for Member States and Partner Countries" (JEMS-7) was finished. Representatives of ministries, universities and scientific organizations of China, the Czech Republic, Russia, RSA, and Vietnam participated in JEMS-7.

The milestones of the rich programme of acquaintance with JINR were summed up at a round table with representatives of the JINR Directorate, at the end of which JINR Director Academician V. Matveev awarded diplomas to the participants. The participants of the training programme noted in their speeches its significant benefits in professional terms and their vivid impression of the Institute at large. It was also noted that JEMS provides a comfortable environment for establishing business ties, generation of new ideas and organization of joint projects.

On 15 June, a JINR delegation headed by JINR Director Academician V. Matveev visited the Republic of Uzbekistan at the invitation of President of the Academy of Sciences of Uzbekistan Academician B. Juldashev.

During the meeting with State Counsellor of the President of the Republic of Uzbekistan R. Kasymov, issues of cooperation with scientific and educational centres of Uzbekistan, as well as of restoration of full membership of Uzbekistan in JINR, were discussed. The ways of joint actions on the discussed issues were outlined. The delegation from JINR visited the Academy of Sciences of the Republic of Uzbekistan (ASRU), the Institute of Nuclear Physics of ASRU where meetings and fruitful discussions were held on cooperation of scientists from JINR and Uzbekistan. In particular, under discussion were preparations for the 20th international conference of the CMS RDMS collaboration to be held in Tashkent and Samarkand in September. The conference is jointly organized by JINR, CERN and the Academy of Sciences of the Republic of Uzbekistan. At the end of the visit, the sides exchanged opinions and outlined plans for deepening and updating programmes of scientific, technical and educational cooperation between JINR and Uzbekistan.

The JINR delegation visited the unique scientific complex "Solntse" ("The Sun") placed in the Tian Shan mountains at a height of 1050 m. Thanks to solar energy obtained during the day, controlled temperature up to 3000°C can be achieved for research in the fields of applied sciences and for the needs of industry and social spheres.

On 17 July, Ambassador of the Italian Republic to the Russian Federation P. Q. Terracciano, Scientific Attaché A. Spallone, First Counsellor of the Department of the promotion of Italian culture, science and language and coordination of the consular network W. Ferrara and a delegation of the National Centre for Nuclear Physics of Italy (INFN) headed by President F. Ferroni and INFN Vice-President A. Masiero visited JINR.

At the press conference for the city media, the Italian Ambassador expressed his confidence that "history will continue bearing fruit, and our cooperation will be stronger and stronger". The INFN President mentioned in particular that the superconducting magnet for the NICA project is produced by INFN specialists in Genoa and stressed their intention to develop cooperation.

On 26–27 July, a famous scientist A. Misaki, Professor of the Saitama University (Japan), Visiting Professor of SINP MSU and the Altai State University, visited the Joint Institute for Nuclear Research.

Professor A. Misaki got acquainted with JINR, starting with the Dzhelepov Laboratory of Nuclear Problems. He inspected the test site of the gamma-ray telescope for the TAIGA experiment, in which he is an external expert. He also visited the photodetector laboratory for the Baikal experiment and the memorial study of B. Pontecorvo. Then Professor Misaki visited the Bogoliubov Laboratory of Theoretical Physics and the Laboratory of Information Technologies. At LIT, he was shown the advanced supercomputer "Govorun" and delivered a seminar on the problem of diversity of LPM showers at extremely high energies.

Professor A. Misaki passed the LIT Directorate the signed protocol on holding joint scientific and research activities of the Joint Institute for Nuclear Research and the Saitama University (Japan), which presupposes establishing theoretical, mathematical and computing base for modelling LMP showers of superhigh energies, computational investigation of their characteristics and structure in order to solve problems emerging in analysis of results obtained in such experiments as IceCube, Antares, Baikal, and TAIGA.

On 8 August, Ambassador Extraordinary and Plenipotentiary of the Republic of Chile to the Russian Federation R. J. N. Maturana paid a working visit to the Joint Institute for Nuclear Research for information purposes and opportunities of scientific cooperation. He was accompanied by the engineer E. Rosas and Professor of the Federico Santa Maria Technical University (Valparaiso, Chile) S. Kovalenko.

R. Maturana visited the Flerov Laboratory of Nuclear Reactions, the Veksler and Baldin Laboratory of High Energy Physics and the Laboratory of Information Technologies. At the meeting in the Directorate of the Institute, JINR Vice-Director M. Itkis and Head of the JINR International Cooperation Department D. Kamanin spoke to the guests about flagship projects of the Institute, forms of cooperation in education, applied research and relations with scientific centres of the world. Professor S. Kovalenko, who previously worked at the Dzhelepov Laboratory of Nuclear Problems of JINR, mentioned a number of fields where cooperation had already been started between the scientific centre of the Federico Santa Maria Technical University and JINR, particularly on the NICA project. A Memorandum of Understanding was signed.

On 28 August, representatives of the Bauman Moscow State Technical University headed by Dean of the Power Engineering Department A. Zherdev visited JINR. The aim of the visit was to facilitate cooperation between the Bauman University and JINR in the field of training highly skilled engineers for flagship projects of the Institute. The guests visited the Flerov Laboratory of Nuclear Reaction, where they were acquainted with the Factory of Superheavy Elements, and had an excursion to the Veksler and Baldin Laboratory of High Energy Physics, where they visited the NICA construction site and saw the line for assembly and cryogenic tests of superconducting magnets.

On 5 September, a meeting of JINR Director V. Matveev with Plenipotentiary of the Government of the Socialist Republic of Vietnam to JINR, Director of the Institute of Physics of the Vietnam Academy of Science and Technology (VAST) Le Hong Khiem was held. The Vietnamese Plenipotentiary was accompanied by Deputy Secretary of the Party Committee of VAST Nguyen Quang Liem and Officer of the Department of Social & Natural Science of VAST Vu Van Dat. The Vietnamese delegation arrived in Dubna to take part in the 8th international training programme for decision-makers in science and international scientific cooperation "JINR Expertise for Member States and Partner Countries" (JEMS-8).

The major aim of the meeting at the JINR Directorate was to discuss an offer of the Vietnamese party to hold the session of the Committee of Plenipotentiaries of the Governments of the JINR Member States and the meeting of the JINR Finance Committee of November 2019 in Vietnam. The idea of holding an international scientific conference after the session of the Committee of Plenipotentiaries was also discussed. During the meeting in the JINR Directorate, the parties discussed steps to develop and strengthen cooperation, paying special attention to issues of professional training of young Vietnamese scientists at JINR. The JINR party was represented by JINR Vice-Director R. Lednický, Advisor to the JINR Directorate M. Tumanova, Head of the JINR International Cooperation Department D. Kamanin, and Head of the national group of the Socialist Republic of Vietnam in JINR Nguen Van Tiep. A memorandum was issued as a result of the meeting in the Directorate.

In early September, the 8th international training programme for decision-makers in science and international scientific cooperation "JINR Expertise for Member States and Partner Countries" (JEMS-8) started at JINR. Specialists from Bulgaria, Egypt, Italy, South Africa and Vietnam came to Dubna to participate in JEMS-8. They visited JINR laboratories where they were shown basic facilities, learned about fundamental and applied research conducted there, and about international cooperation and educational opportunities. The participants of the event were much impressed by the lecture on the history of Russia and the Soviet atomic project, as well as by a sightseeing excursion around Dubna.

The results of the training course were summed at the round-table discussion. JEMS-8 participants shared their impressions and expressed their gratitude to the organizers. Representatives of Botswana signed an agreement on cooperation with JINR. All participants of the event received certificates and souvenirs.

On 26 September, a Chinese delegation headed by Director-General of the National Agency of China on the project ITER of the Ministry of Science and Technology Delong Luo and representatives of Rosatom visited the Joint Institute for Nuclear Research.

The guests visited the Veksler and Baldin Laboratory of High Energy Physics, where they were acquainted with the NICA complex that is under construction and the site of superconducting magnets. They also visited the Multifunctional Information and Computing Complex and saw the supercomputer "Govorun" at the Laboratory of Information Technologies. Issues of cooperation were discussed with leaders of JINR laboratories.

On 2 October, the ceremonial opening of Days of Slovakia at JINR was held at the Scientists' Club of JINR, on the occasion of the 25th anniversary of establishing the Slovak Republic and its participation in the Joint Institute. Among the participants there were representatives of the Directorate and Laboratories of the Institute, the Group of Slovak JINR staff members, the Chamber of Commerce and Industry of Dubna, a number of city-forming enterprises and companies. A delegation from Slovakia took part in the ceremony; it included representatives of the Embassy of Slovakia in Russia, the companies Cryomont, Sylex, Cryosoft, TRENS SK, NUVIA, SITEL and other firms related to cryogenics, optic fiber, super modern devices for fire fighting, engineering, monitoring of radiation safety and systems for quality control. Representatives of each firm made brief introductory presentations. JINR Vice-Director R. Lednický talked to the guests about the history, structure and main areas of research of JINR.

The Slovak delegation, accompanied by JINR and city enterprises leaders, visited VBLHEP, FLNR, DLNP, and LIT.

Issues of developing cooperation were considered in detail at a round-table meeting: the participants discussed actual opportunities for Slovak companies in design and manufacturing of equipment for physical and experimental facilities of JINR.

The Joint Institute for Nuclear Research took part in the XIII Moscow Festival NAUKA0+ **on 12–14 October**. The main topic of the event was "Megascience: Russia in the world and Russia for the world". The exhibit of JINR included mock-up models of the existing and future facilities of JINR and exposition interactive stands. It was displayed in the Fundamental Library of MSU and in Expocentre in Krasnaya Presnya, where JINR staff members held master classes in physics, chemistry, and robotics for school students. In the framework of the "Golden Lecture Course" in the Fundamental Library of MSU, Academician Yu. Oganessian gave a lecture on the discovery of new superheavy elements of the Mendeleev Table, and Professor V. Kekelidze presented a lecture on megascience challenges of the NICA project. V. Shvetsov, D. Naumov, N. Anfimov, and M. Shirchenko gave lectures in the "Shuvalovsky" Residential Complex of MSU.

On 16–18 October, Director of the National Centre for Research and Development of Poland (NCBR) M. Chorowski, Plenipotentiary of the Government of Poland to JINR M. Waligórski, and Chairman of the Commission under the Plenipotentiary of the Government of Poland on cooperation with JINR M. Budzyński visited JINR.

Major fields of NCBR activities are management and implementation of strategic research programmes and elaborations in innovations, support and transfer of scientific research results into economics, and management of applied research and projects in national defence and safety. According to M. Chorowski, an important sphere of the centre's activities is to encourage students and postgraduates in scientific research and work in innovation companies.

At the Directorate, the meeting was held with JINR Director Academician V. Matveev, JINR Vice-Directors M. Itkis and V. Kekelidze, and Head of the International Cooperation Department D. Kamanin. The guests were acquainted with the history and structure of JINR, trends of research, flagship projects and educational activities.

The Polish delegation visited the Flerov Laboratory of Nuclear Reactions, the Frank Laboratory of Neutron Physics, and the Veksler and Baldin Laboratory of High Energy Physics, where the guests were acquainted with the projects and facilities involving Polish staff members work and had a sightseeing excursion around Dubna.

On 18 October, a delegation of the Parliamentary Committee on science, education, culture, youth and sport of the Czech Republic headed by Chairman of the Committee V. Klaus and a delegation of the Embassy of the Czech Republic in RF headed by Ambassador Extraordinary and Plenipotentiary V. Pivoňka paid an introductory visit to JINR. The meeting was also attended by Deputy Plenipotentiary of the Czech Government to JINR I. Štekl.

In the JINR Scientists' Club, the delegation was received by the leaders of the Joint Institute. The guests listened to an overview presentation about JINR of R. Lednický and a presentation of I. Štekl devoted to the forms and results of participation of the Czech Republic in JINR.

The Czech delegation was particularly interested in the work of the Czech company ASARCO on the reconstruction of the JINR hotel on Moskovskaya street 2, where a large number of young scientists from the JINR Member States live. The acquaintance of the delegation with the JINR scientific infrastructure started at the Veksler and Baldin Laboratory of High Energy Physics. The visit was continued at the Flerov Laboratory of Nuclear Reactions, where the delegation had an informal meeting with the Czech staff members of JINR. At the concluding meeting with the Directorate, results of the visit were summed up and plans for further cooperation were made.

On 24–26 October, the delegation of the Helmholtz Centre for Heavy Ion Research (GSI, Darmstadt) visited JINR. The delegation consisted of Technical Director of GSI and project FAIR J. Blaurock, SIS100/SIS18 Leader P. Spiller, Head of the Department of Superconducting Magnets and Testing Ch. Roux, as well as of staff members of this department A. Bleile and E. Fischer. The main goal of the visit was to finalize and sign agreements on joint work in the field of superconducting magnets. The previous JINR–GSI cooperation agreement expired on 1 August 2018, and the parties expressed their intention to continue and develop their successful cooperation.

The guests visited the Flerov Laboratory of Nuclear Reactions, the Laboratory of Information Technologies, and the Veksler and Baldin Laboratory of High Energy Physics. At VBLHEP, J. Blaurock provided an introductory lecture on the management system of the FAIR project, progress in the project's implementation, and participation of JINR in it. Meetings of the delegation with the JINR Directorate and leaders of the JINR laboratories were held during the working visit.

On 26 October, as a result of the visit, a framework Agreement on cooperation between GSI (FAIR) and JINR was signed. As part of implementation of the Agreement, the parties signed a contract on carrying out cryogenic testing of superconducting magnets for the SIS100 accelerator at JINR.

On 31 October, the Open Doors Day at the NICA complex was held at the Veksler and Baldin Laboratory of High Energy Physics. It was organized by the Council of Young Scientists and Specialists of VBLHEP. The programme included topical lectures in English and excursions around the laboratory and to the NICA construction site. This event was the first attempt of such type at JINR. Participants were divided into 6 groups of 13 persons each; there were many more applications sent to the event, but the organizers had to select participants from other cities and students from such universities as MEPhI and MSU.

Chairman of the Council of Young Scientists and Specialists of VBLHEP K. Roslon opened the course of lectures. A. Aparin made an introductory lecture about VBLHEP, and M. Shandov delivered a lecture about the accelerator complex and the magnet factory. A set of reports about main experiments at NICA were presented by A. Ramsdorf (ion sources), P. Batyuk (BM@N experiment), N. Geraksiev (MPD experiment) and A. Gribovsky (SPD experiment). Certificates of acknowledgement were presented to the lecturers.

The guests, accompanied by young laboratory members, were then acquainted with the Synchrophasotron, the NICA construction site, the factory of superconducting magnets, and the BM@N experimental facility with a fixed target.

Summing up the results of the Open Doors Day, the organizers and participants noted that such a manner of science popularization is in high demand and will continue to be used.

On 30 November, a festive ceremony of awarding the title of Doctor Honoris Causa of the National Research Centre "Kurchatov Institute" was held in Moscow, in the House of Scientists named after A. P. Alexandrov. This honorary title was awarded to JINR Director Academician V. Matveev, President of the Russian Academy of Sciences (RAS) A. Sergeev and Rector of the Moscow State University V. Sadovnichy.

Diplomas, medals, and robes of honorary doctors were awarded by President of the NRC "Kurchatov Institute", RAS Corresponding Member M. Kovalchuk.

He highlighted that this year the honorary title was awarded to the brilliant scientists who lead organizations that work closely with the NRC KI. In his acceptance speech, V. Matveev noted that the inclusion among the Honorary Doctors of the NRC "Kurchatov Institute" is an honour for any scientist.

On 3–7 December, the 9th international training programme for decision-makers in science and international scientific cooperation "JINR Expertise for Member States and Partner Countries" (JEMS-9) was held. Staff members of relevant ministries, research and educational organizations of Chile, Cuba, Iraq, Rwanda, and Vietnam came to Dubna.

Following the tradition, the JINR Directorate welcomed JEMS participants at the JINR Scientists' Club on the first day of the programme. The JINR Directorate was represented by JINR Vice-Directors B. Sharkov and R. Lednický, and JINR Chief Scientific Secretary A. Sorin. Participants of the training programme described the tasks set by their organizations and opportunities for cooperation with JINR; exchange of opinions on a range of topical issues was held.

According to the programme, participants were acquainted with various aspects of JINR activities, listened to lectures by leading specialists of the Institute and visited basic facilities. Due to the active attitude of the participants, additional elements were added to the programme, in particular, a lecture on particle physics and JINR involvement in largest world projects.

A traditional round-table discussion summed up the week of the training course. The participants exchanged their impressions about the course, its results and plans. Among the practical outcomes of the training course are the programme of actions and other documents, which were symbolically given to representatives of Iraq and Rwanda. The training course also contributed to the planning of events in Cuba, Chile and Vietnam in the near future.

On 7 December, the joint delegation of the National Aeronautics and Space Administration (NASA) and the RAS Institute of Medico-Biological Problems (IMBP) visited JINR.

The NASA delegation was represented by Director of the NASA Human Research Program (NASA HRP) W. Paloski, NASA HRP Chief Scientist J. Fogarty, Associate Chief Scientist on International Collaborations of NASA HRP L. Vega, Element Scientist for the Human Factors and Behavioral Performance Element of NASA HRP T. Williams, Director for Medical Policy and Ethics of NASA M. Weyland, and NASA HRP International Science Manager I. Kofman. IMBP Director Academician O. Orlov, as well as IMBP staff members T. Agaptseva, M. Belakovsky, B. Meshcheryakov, and A. Shurshakov, represented the IMBP.

For several years, IMBP and JINR, in cooperation with MSU and the RAMS Research Institute of Medical Primatology, have been carrying out studies of the effects of space types of radiation on various animals, including primates, which is one of the scientific interests of NASA. Representatives of the NASA came to Dubna in order to determine possible interests and fields of cooperation in research into effects of heavy charged particles on animals.

The guests made a tour around JINR laboratories. At LRB, special attention was given to fields of research of radiation safety in deep space missions. At VBLHEP, the delegation was acquainted with the flagship megascience project NICA and the factory of superconducting magnets. At FLNR, the guests learned about the results of the synthesis of superheavy elements and achievements of JINR in this field. The NASA delegation also visited the Factory of Superheavy Elements.

During the final meeting with the JINR Directorate, a proposal was made to join JINR to the already existing NASA–IMBP RAS collaboration. Development of cooperation in this area was discussed at the wrap-up extended meeting at IMBP on 13–14 December in Moscow.

On 8 December, a festive meeting was held at the Cultural Centre "Mir" on the occasion of the 100th anniversary of establishing the unitary state of Romania on 1 December 1918. Transylvania joined the Romanian Kingdom to become a single state. The celebration organized by the Ambassador of Romania to the Russian Federation and by the Joint Institute for Nuclear Research was enriched with a performance of the Romanian folklore ensemble "Ţara Vrancei" (Focşani, Romania).

Ambassador Extraordinary and Plenipotentiary of Romania to the Russian Federation V. Soare opened the event. He started his speech with an introduction to historical events that preceded the great unification of Romanians. "This was made not by one politician, government or a party, but by all nation," V. Soare noted. "During the last 100 years, Romania has been supporting the principles of international law and neighbourliness as well as advocated strengthening of close ties among the states of the European Union".

R. Lednický passed the greetings to Romanian people on behalf of the JINR Directorate and read out a welcoming speech which, in particular, said: "The Embassy of Romania in the Russian Federation plays a big role in extending cooperation of Romania with JINR. We are happy to welcome the Romanian folklore ensemble "Ţara Vrancei" at the JINR Cultural Centre "Mir". Romanian artists have visited Dubna several times. In 2010, a Week of Romanian Cinema was organized with the support of the Embassy. We are happy that Dubna is the first city after Moscow in the tour of this ensemble. We hope to continue successful development of cultural links and wish people of Romania peace, welfare and prosperity!"

During the concert, videos acquainting the audience with natural and architectural sites of Romania, its folk-crafts, scientific achievements, industry and sports were demonstrated on the screen of the big concert hall of the Cultural Centre "Mir".

On 10 December, during of a working visit of Federal Minister of Education and Research of Germany A. Karliczek, bilateral negotiations were held in the House of the Government of the Russian Federation. The Russian delegation was represented by Deputy Prime Minister of the Russian Federation T. Golikova, Aide to the RF President A. Fursenko, Minister of Science and Higher Education of the Russian Federation M. Kotyukov, and First Deputy Minister of Science and Higher Education of the Russian Federation G. Trubnikov.

During the discussions, Russia and Germany outlined plans for scientific and technological cooperation for the next decade having signed a Roadmap for cooperation of the two countries. The parties agreed to make considerable efforts to support young talented scientists. German partners confirmed their readiness to take part in projects on the basis of the research reactor PIC and the complex of superconducting rings with colliding heavy ion beams NICA.

The meeting was also attended by President of the NRC "Kurchatov Institute" M. Kovalchuk, Director of the Joint Institute for Nuclear Research V. Matveev, Member of the Board of the Jülich Research Centre S. Schmidt and Scientific Leader of the Centre for Antiproton and Ion Research and the Helmholtz Centre for Heavy Ion Research P. Giubellino. Representatives of both delegations greeted the joint manifest of Ministers of Foreign Affairs of Russia and Germany adopted on 6 December 2018 on holding a year of Russian–German scientific and educational partnership in 2019–2020.

On 12–14 December, a visit to JINR of a delegation from the Republic of Korea was held. Representatives of the Ministry of Science, ICT and Future Planning visited JINR: Hyohee Lee, Director of the Planning and Coordination Division, and Seog Hyung Kim, Senior Researcher of the Division. The Korean delegation was also represented by Seung Woo Hong, Head of the RAON Liaison Centre, Professor of the Department of Physics of the Sungkyunkwan University, and Chang-bum Moon, President of the RAON User Association, Professor of the Display Engineering of the Hoseo University.

At the Flerov Laboratory of Nuclear Reactions, the guests learned about the Factory of Superheavy Elements, the ACCULINNA-2 separator of radioactive nuclei and the nanocentre. Professor Seung Woo Hong held the seminar "The RAON project status" devoted to the construction of a new Korean accelerator of radioactive ions and preparation of first experiments.

Acquaintance of the delegation with the JINR scientific infrastructure was continued at the Veksler and Baldin Laboratory of High Energy Physics, where the guests visited the NICA construction site, the BM@N detector as well as the factory of superconducting magnets. The guests had meetings with representatives of the Bogoliubov Laboratory of Theoretical Physics and Frank Laboratory of Neutron Physics, and leaders of the JINR University Centre and the MSU SRINP department.

At the JINR Directorate, the representatives of the Republic of Korea were greeted by JINR Vice-Directors M. Itkis and R. Lednický. The guests expressed their interest in establishing cooperation not only in scientific fields but also in the sphere of training young Korean scientists on JINR basis.

On 15 December, in Cairo in the Egyptian Academy of Science and Technology the 8th session of the Joint Committee on the ARE–JINR Cooperation was held, in which the JINR delegation led by JINR Vice-Director R. Lednický took part.

R. Lednický opened the working programme of the session with a presentation on the main events in the life of JINR. The Deputy Director of FLNP, E. Lychagin, and the Deputy Director of LIT, T. Strizh, presented an overview of the development directions of their laboratories. Director of the UC S. Pakuliak and head of the group of Egyptian staff at JINR V. Badawi reported on the joint work on the training of young scientific staff. A member of the Egyptian Nuclear Science Commission, Professor at the Zagazig University M. Shair presented an analysis of the organizational issues of the student practices and proposals for the further development of this cooperation format. Head of the JINR International Cooperation Department D. Kamanin made a presentation of the roadmap for developing cooperation between JINR and Egypt. The session participants outlined a number of joint activities for the next two years. The final event of the session was the signing of a roadmap, which, according to the common opinion of the two parties, is the starting point of a new stage of cooperation.

On 26 December, the regular meeting of JINR STC was opened with the information of FLNR Director S. Dmitriev about the first beam of accelerated heavy ions obtained at the DC-280 cyclotron, a basic facility of the Factory of Superheavy Elements. Head of the JINR International Cooperation Department D. Kamanin made a report on broadening the horizons of international cooperation of JINR.

JINR Vice-Director B. Sharkov informed members of STC about a special competition for young scientists. An expert consultative body under the JINR Directorate was established, with Chairman V. Matveev and Deputy Chairman B. Sharkov. Leading scientists of JINR, representing major fields of the Institute's activities, were included in the committee. The body will accept and consider applications from JINR laboratories.

STC Chairman R. Jolos introduced to participants of the meeting a draft solution for the issue of innovative activities. The STC recommended that the JINR Directorate continue development of the concept of innovative activity; in particular, it proposed to establish a council on innovations under JINR Chief Engineer for consideration of developments with innovation prospects, presented by the laboratories, as well as a group in the JINR Directorate, the major aim of which would be support and promotion of innovative projects of the Institute to the technology markets of the JINR Member States.

JINR Director V. Matveev made a new-year eve report on the milestones of the expiring year.

CONFERENCES AND MEETINGS HELD BY JINR

Twelve conferences were the largest among the scientific conferences and workshops held at JINR in 2018.

From 29 January to 3 February, the Dubna State University hosted the 25th jubilee international interdisciplinary conference ***"Mathematics. Computer. Education"***. From the outset, the Joint Institute for Nuclear Research has been a co-organizer of this series of conferences, aimed at integrating the efforts of specialists working in science and higher education, preserving the traditions of Russian science and education, improving the skills of scientific and pedagogical personnel in the field of mathematical simulations and information technologies, attracting young people to science and education. In 2018, the conference was attended by more than 200 representatives of universities and research organizations. The conference included plenary presentations delivered by leading scientists, poster sessions, round tables, workshops on modern information technologies and mathematical modeling in biology, teaching methods and mathematics. A traditional symposium with international participation "Biophysics of Complex Systems: Computational and Systems Biology, Molecular Modeling, Medical Biophysics" was held under the support of the Russian Foundation for Basic Research. Thematic round-table sessions "Big Data and cloud technologies, artificial intelligence and quantum computing", "Digital economy" and "Electronic educational resources and technologies" were organized in addition to the traditional conference sections.

On 29 January, the plenary session was opened with an overview report of D. Fursaev (rector of Dubna State University) "Gravitational waves: Our knowledge of the Universe at a threshold of changes." The report discussed modern ideas about the processes in the Universe and prospects for the further study of these processes. The session was continued by JINR Director Academician of RAS V. Matveev, who spoke about strategic directions of JINR development and interdisciplinary research combining present-day promising research fields in physics and biology. On 30–31 January, plenary sessions included presentations on Big Data analysis. In the report "The structure of algorithms — a challenge for computing sciences", V. Voevodin (MSU) considered the problems that arise when creating new algorithms for Big Data analysis. V. Korenkov (Director of JINR LIT, Head of department at Dubna State University) made an overview report on trends in the development of distributed computing and Big Data analytics. The issues of Big Data analysis were discussed by P. Zrelov (JINR, LIT) in his report "Big Data technology and analytics". R. Dushkin (Moscow) delivered a striking report "Quantum supremacy. What awaits us after appearing a universal quantum computer" that raised a lot of questions and discussions. On 1 February, at the session devoted to modeling complex biological systems, A. Bugay (JINR) reported on new approaches to simulation of radiation-induced disorders in the nervous system. On 2 February, reports of the plenary session were devoted to the memory of Academician N. Moiseev.

The all-Russian seminar "The Russian Scientific Language" was held as part the conference under the support of the Russkiy Mir Foundation. The seminar focused on the problem of preserving and reviving the role of the Russian language in the development of science. Among the participants of the seminar were professional philologists and linguists as well as representatives of various scientific specialties, such as mathematics, physics and biology, from different Russian cities. Scientists shared their own experience of scientific research, teaching, and writing articles. At the conference it was decided to organize a working group on the Russian language in science. The development of recommendations aimed at popularizing science in the Russian language has already begun. This work is expected to be carried out in close contacts with scientists, publishers of scientific literature, scientific foundations and authorities.

It is important to highlight the hospitality and organizational efforts of Dubna State University and the Joint Institute for Nuclear Research to receive the conference attendees, support in the reports presentation, organization of video-broadcast of the conference sessions and presentation of video materials on the YouTube portal of Dubna State University.

From 27 May to 2 June the ***20th international seminar on high energy physics "Quarks" (Quarks-2018)*** was held in Roshchino, Valdai (Russia). It was organized by the Institute for Nuclear Research of RAS (Troitsk) and the Joint Institute for Nuclear Research. The international seminar "Quarks" is one of the largest Russian platforms for presentation and discussion of the latest results of studies in theoretical particle physics and cosmology. The seminar has been held every two years since 1980. The present event gathered about 180 scientists, including about 40 foreign scientists from Switzerland, France, Germany, Italy, the USA, Canada, Japan and other countries. Each of them presented results of scientific studies in plenary or section reports.

The extensive programme of the seminar contained such topical trends as physics beyond the Standard Model (rare processes, phenomenology of the Higgs boson, exotics); cosmology and particle astrophysics; gravitation theory and its modifications; neutrino physics; quantum chromodynamics, strong interactions; selected issues of mathematical physics; and recent results of selected experiments.

At the seminar, special attention was paid to most topical issues, such as axion-analogue and ultralight dark matter, astrophysics of gravitational waves, AdS/CFT phenomenology, anomalies in the data from the LHC, the breaking of Lorentz invariance and conditions of energy dominance, ghost instabilities, etc. In the framework of the seminar, some Russian and international experimental groups whose research was connected with the topics of the seminar presented their latest results, promoting close and efficient interaction between theoreticians and experimenters.

Consequently, most topical theoretical and experimental results are presented at the international seminar "Quarks-2018", and their discussion determines and coordinates further development of all related fields of physics both in the country and at the international level. During the event, young scientists had opportunities not only to present their work to the scientific community but also to learn about current trends of research and their status. Some young scientists obtained full or partial financial support to take part in the seminar, which will allow their involvement in the active scientific work.

The annual ***International Seminar on Interactions of Neutrons with Nuclei (ISINN-26)*** was held from 28 May to 1 June in Xi'an (China). In 2018, for the first time ISINN-26 was jointly organized by its founder and long-term organizer — the Frank Laboratory of Neutron Physics of JINR, the Northwest Institute of Nuclear Technology (NINT), Xi'an Jiaotong University (XJTU) and the Chinese Radiation Physics Society (CRPS). The seminar drew the attention of specialists from the major nuclear centres of China: the Institute of Nuclear Physics and Chemistry (INPC) of the Chinese Academy of Engineering Physics, the Chinese Institute for Radiation Protection (CIRP), the Chinese Institute of Atomic Energy (CIAE), the Institute of High Energy Physics (IHEP), universities of Lanzhou, Beijing, Sichuan and others. The seminar brought together a large group of researchers from the JINR Member States, as well as from Egypt, France, Japan, Italy, the Republic of Korea, Pakistan, and the United States. The scientific programme of the seminar included 23 invited talks, 47 oral presentations and 64 posters.

Opening the seminar, the Co-Chairman of the Organizing Committee, NINT Director Professor Hei Dongwei, pointed out that he was very pleased to see the participants of ISINN-26 in Xi'an, the capital of ancient China, which played an important role in history as a link between the West and the East. FLNP Director V. Shvetsov thanked his colleagues from China for the work done to organize ISINN-26, a conference that each year for 26 years now has been gathering scientists from around the world. The participants of the seminar were greeted by Head of the Department of International Cooperation and Exchange of XJTU Professor Liang Li and Honorary Chairman of ISINN-26 W. Furman (JINR), who expressed the hope that the traditional exchange of knowledge between experienced and young researchers would continue. And the fact that the conference attracted a large number of young people means that neutron research has a future.

The first plenary sessions were opened with invited talks by W. Furman ("Experimental and theoretical aspects of nuclear fission induced by resonance neutrons"), V. Shvetsov ("Nuclear planetology"), Tang Jingyu ("Status of CSNS and Back-n White Neutron facility"), G. Tagliente ("The n_TOF facility at CERN"), P. Geltenbort ("Fundamental neutron physics at the ILL"), Ruan Xichao ("Progress of neutron reaction data measurements at CIAE"), and Gong Jian ("Prospects for studying neutron scattering in China").

The plenary sessions and invited talks on the second day of the seminar were devoted both to problems of fundamental nuclear physics and to purely practical problems. Great interest was aroused by the reports devoted to the study of collinear cluster fission. Unusual properties of this exotic nuclear fission mode still trigger heated discussions and criticisms, which, in turn, initiate new experiments. Lively discussions were triggered by the reports on research using neutron-activation analysis, development of neutron detectors and an original cold moderator at the IBR-2M reactor of JINR FLNP.

The third and fourth days of the seminar were held in the form of two parallel sessions and a joint three-hour poster session. The reports of the participants from JINR, Russia, China and other countries covered a wide range of issues ranging from the violation of fundamental symmetries in nuclear fission to discussions of parameters of neutron sources on high-current proton accelerators operating in Russia and just recently put into operation in China, as well as experiments on them.

Lively discussions were sparked by the reports devoted to the development of promising experimental techniques. The wide geography of the speakers of the session dedicated to the application of neutron activation analysis in ecology and archeology inspired an active discussion of the presented results.

During a three-hour poster session, there was an opportunity to discuss in detail a lot of interesting experiments performed by numerous young Chinese participants of the seminar, as well as by researchers from other countries.

Summing up the results of the conference at the final plenary session, NINT Director Hei Dongwei and FLNP Director V. Shvetsov noted the success of the first experience of hosting the International Seminar on Interaction of Neutrons with Nuclei ISINN-26 in China and expressed the hope that plans for further joint organization and holding of future meetings of this series would be implemented. It should be emphasized that the serious financial support provided by Chinese sponsors largely contributed to the successful holding of ISINN-26, making it possible, in particular, to significantly reduce the costs for the participants from JINR.

From 20 June to 3 July the 26th annual ***European School on High Energy Physics (ESHEP-2018)*** was held in Maratea near Naples (Italy).

This cycle of schools, well-known in the past as CERN–JINR schools, traditionally attracts big attention of young scientists due to serious scientific programme, well-arranged agenda and detailed selection of lecturers and discussion leaders.

The audience is also important in the programme. The participants present posters on their research and after special training and making several groups prepare student projects on presenting scientific results to general public. Their active participation defines in the end the success of discussion sessions that are held daily after lectures.

In total, 105 attendants took part in the school'2018 who were chosen from over 200 candidates on the grounds of their scientific potential and participation in urgent research.

The scientific programme of the school included basic lectures in the main areas of modern high energy physics, especially those that were interesting from the point of the main JINR research trends — heavy ion physics and neutrino physics.

This time the lecturer in the basic course "Quantum Field Theory and the Standard Model" was A. Bednyakov, and discussion leaders were A. Pikelner and R. Sadykov.

CERN Director General F. Gianotti and JINR Director V. Matveev made traditional lectures on scientific programmes and prospects in research.

Thus, all the cycle of the European Schools on High Energy Physics, jointly organized by CERN and JINR, continue to be at high scientific and cultural level by improving constantly the programme and forms of communication with participants and public. The school'2019 will be held in Saint-Petersburg on 4–17 September.

From 3 to 5 July, the international conference ***"Biomonitoring of Atmospheric Pollution" (BioMAP-8)*** was held in Dubna. The conferences of this series have been held since 1997, every three years in various countries of the world: Portugal, Slovenia, Greece, Argentine, Turkey. In 2018, the conference was held for the first time in Russia; it was organized by the Neutron Activation Analysis and Applied Research Sector of JINR FLNP. Biomonitoring is a sensitive, selective and suitable method for air quality control. The purpose of these scientific meetings is to disseminate knowledge about methods and strategies of air monitoring. Leading scientists and experts in ecology and biomonitoring from Austria, Great Britain, Norway, Russia and the USA were invited to make reports.

JINR Vice-Director M. Itkis greeted the participants of BioMAP-8. Chairperson of the BioMAP-8 Organizing Committee M. Frontasieva (FLNP) spoke about the history of these conferences and gave a general picture of global air pollution. FLNP young staff members made poster presentations at the conference.

From 9 to 13 July, the ***32nd International Colloquium on Group Theoretical Methods in Physics (Group32)*** was held in Prague (Czech Republic) at the Faculty of Nuclear Physics and Engineering of the Czech Technical University. JINR was among its organizers. The colloquium is interdisciplinary and is aimed at joining the efforts of experts and young researchers in various fields.

The first colloquium was held in 1972 in Marseille and since then it has become regular. Today group theoretical methods are widely applied in physics — from research on particle physics to gravitation physics. That is why such colloquiums can be compared with Rochester conferences in high energy physics in their importance for the development of science. One more tradition of these colloquiums goes back to 1978, when the medal for outstanding contribution to the development of theoretical group methods instituted for the first time was awarded to the American theoretical physicist E. Wigner. Since then this medal has been called after him and awarded in recognition of "the outstanding contribution to understanding of physics via group theory".

The opening ceremony was held in the concert hall of the Prague conservatory. A series of colloquiums on group theoretical methods was traditionally dedicated to their application in physics, mathematics and other sciences, as well as to work-out of mathematical instruments and theories to develop group theory and symmetries. For the past years this theory has been considerably extended and diversified due to successful application of group theoretical, geometrical and algebraic methods in life sciences and other fields.

In the framework of the colloquium, the Prize after H. Weyl, one of the greatest mathematicians of the 20th century, was awarded. It is presented to young scientists who have accomplished specific tasks of considerable scientific quality in understanding of physics via symmetries theory. The awarding ceremony was held on 12 July in the Bethlehem Chapel of Prague, a most significant cultural and religious site of the city.

The 8th international conference ***"Distributed Computing and Grid Technologies in Science and Education" (GRID 2018)*** was held at the Laboratory of Information Technologies on 10–14 September. The conference, held every two years, is a unique platform for discussion of a wide spectrum of issues related to the use and development of distributed grid technology, heterogeneous and cloud calculations in various fields of science, education, industry and business. It traditionally attracted many Russian and foreign specialists who were eager to discuss arising tasks and prospects for the development of modern information technology. The conference was attended by 250 scientists from Belarus, Bulgaria, China, Czech Republic, France, Georgia, Germany, Moldova, Romania, Slovakia, Sweden, and other countries. Participants from Russia were specialists from more than 30 universities and research centres. Eleven sections on development of distributed computing, cloud and heterogeneous technologies, volunteer computing and Big Data analysis were organized during the conference.

Financial support was provided by the JINR Directorate; sponsors and partners of the conference were Huawei, IBS Platformix, Niagara Computers, Supermicro, Jet Infosystems, Schneider Electric, NVIDIA, Dell EMC, RSC Group, Intel, Cisco, Extreme Networks, and Softline. Information support was provided by PARALLEL.RU, Open Systems and international scientific journal "Modern Information Technologies and IT Education".

JINR Director V. Matveev opened the conference with a report dedicated to the current status and perspectives of the development of the Institute. In his speech, he made a special emphasis on the information infrastructure of JINR — one of the dynamically developing facilities of the Institute, and also mentioned the newly launched supercomputer "Govorun".

LIT Director V. Korenkov presented a report on the current status and perspectives of development of the Multifunctional Information and Computing Complex of JINR (MICC JINR). He made a special focus on distributed computing carried out in collaboration with CERN, BNL, FNAL, FAIR, China and JINR Member States, as well as on the development of MICC as a centre for scientific computing and multidisciplinary research carried out at JINR and in its Member States, including the NICA megaproject.

A total of 33 plenary talks, more than 120 sectional talks and 26 poster reports by students were presented in the course of the conference. The participants had fruitful discussions; new IT projects, directions of development of distributed and high-performance computing, and LIT collaboration aims were also discussed. Presentations, theses and photos are available at http://grid2018.jinr.ru.

The international school "Scientific Computing, Big Data Analytics and Machine Learning Technology for Megascience Projects" was held in the framework of the conference. The goal of the school was to attract young scientists, students and postgraduates to solve IT tasks and challenges related to various aspects of megaprojects in the field of high-energy physics and to familiarize participants with modern methods of Big Data analytics, machine learning and high-performance computing systems and to use this knowledge to solve IT tasks in the field of high-energy physics. The main topics of the school were Big Data using the example of the NICA megaproject and experiments at the Large Hadron Collider as the main source of Big Data in high-energy physics; distributed systems for collecting, processing, managing and storing information; use of high-performance systems (supercomputers, computing clusters) for data processing and modeling of physical experiments; and machine learning. Participants of the school had a possibility to attend plenary talks presented at the GRID 2018 by the leading specialists in the field of Grid technologies and distributed computing.

Forty-six students specializing in IT from leading universities of JINR Member States and Suez University (Egypt) took part in the school. All the students received attendance certificates.

From 10 to 15 September, Petrozavodsk (the capital of the Republic of Karelia, Russia) hosted the ***International Symposium on Exotic Nuclei (EXON 2018)*** covering one of the most important and rapidly developing areas of nuclear physics — the physics of exotic states of nuclei. The organizers of the symposium were five largest scientific centres where this area is being successfully developed: the Joint Institute for Nuclear Research in Dubna, the RIKEN Research Centre (Japan), the GANIL National Centre (France), the GSI Helmholtz Centre for Heavy Ion Research (Germany), and the National Superconducting Cyclotron Laboratory (Michigan, USA).

The symposium was held with the active participation of Petrozavodsk State University (PetrSU). Petrozavodsk University was founded in 1940 as a Karelian–Finnish University and was renamed in 1956.

Currently, the most complex physical experiments conducted with the use of large accelerator facilities and requiring huge financial investments cannot be performed by a single, even highly developed, country. Therefore, these studies are carried out in close cooperation of research centres of several countries, each of which makes its financial and intellectual contribution to the construction of largest facilities. The fundamental studies and methods used in them are also of great importance for the related areas of science and technology, such as nanotechnology, medicine, and microelectronics. Examples of this might be the Large Hadron Collider at the European Organization for Nuclear Research (CERN) and the NICA collider at JINR.

In these centres, scientists are producing and studying nuclei under extreme conditions — nuclei at high excitation energy (“hot” nuclei), strongly deformed (super- and hyperdeformed nuclei with an unusual configuration form), superheavy nuclei with the number of protons $Z > 110$, nuclei with abnormally high number of neutrons (neutron-rich nuclei) or protons (proton-rich nuclei). The study of the properties of nuclear matter under extreme conditions provides important information about the properties of the microcosm and the opportunity to simulate various processes occurring in the Universe.

EXON 2018 was attended by about 140 scientists from 20 countries, most of whom are leading experts in the field of nuclear physics. The most representative delegations were from Japan and China. Research centres of these countries are interested in developing cooperation with JINR and scientific centres of Russia.

The scientific programme included invited talks on important areas of the physics of exotic and superheavy nuclei and on new projects of the largest experimental facilities and accelerator complexes. In addition, discussions with the participation of leading scientists from various research centres in the world were organized. They discussed issues of cooperation in the field of fundamental physics of heavy ions and applied research.

A special day of the symposium was devoted to the present and future accelerator complexes for heavy ions and radioactive nuclei in the leading scientific centres of the world. Five laboratories, which are the co-founders of the symposium, are now creating a new generation of accelerators, which will promote significant progress towards the synthesis and study of properties of new exotic nuclei.

Before the beginning of the symposium, a satellite school “Contemporary Physics and Nuclear Medicine” was held for two days. At the school, the leading JINR professors delivered lectures to students, postgraduates, and professors of PetrSU.

During the symposium, a total of about 80 oral reports and 30 poster presentations were delivered. All of them were published as a special issue of the World Scientific Publishing.

The XXIV International Baldin Seminar on High Energy Physics Problems ***“Relativistic Nuclear Physics and Quantum Chromodynamics”***, organized by the Vekster and Baldin Laboratory of High Energy Physics and the Bogoluibov Laboratory of Theoretical Physics of JINR, was held from 17 to 22 September in Dubna. The seminar was supported by the International Union of Pure and Applied Physics (IUPAP) and the Russian Foundation for Basic Research (RFBR).

In 2018, the record number of participants, 259, came to Dubna, 73 of them being young physicists. The total number of reports was 183, including 47 plenary reports. Scientists from Armenia, Azerbaijan, Belarus, Brazil, Bulgaria, the Czech Republic, Estonia, France, Germany, Iran, Italy, Japan, Kazakhstan, Moldova, Mongolia, Poland, Russia, Slovakia, Switzerland, Ukraine, the USA and Uzbekistan took part in the event.

JINR Director Academician V. Matveev opened the seminar. He reminded the audience that this seminar had been organized by Academicians M. A. Markov and A. M. Baldin in 1969 and is held every two years in Dubna under the unofficial title “the Baldin Autumn”. V. Matveev stressed the role of A. M. Baldin in establishing relativistic nuclear physics at JINR, marked the importance of these seminars for the development of science at JINR and support of such projects as NICA, and wished every success to the participants of the seminar.

Director of the Veksler and Baldin Laboratory of High Energy Physics V. Kekelidze stressed the IUPAP’s appreciation of the seminar and wished the participants success, interesting reports and useful discussions.

Before the meetings started, co-chairman of the Seminar Organizing Committee Professor A. Malakhov, on behalf of the President of the Russian Engineer Academy and the International Engineer Academy B. Gusev, handed the Diploma of the full member of the International Engineer Academy to Bulgarian scientist I. Tsakov, for his active participation in engineer projects of JINR and other world scientific centres.

Traditionally, reports of almost all well-known collaborations of the world were presented at the seminar. The section on tasks related to implementation of the NICA project at JINR worked successfully.

A huge number of reports were dedicated to methodological developments, which are performed under the NICA programme. The topic of the special section at the seminar was the study of exotic nuclei in relativistic beams. The reports at the section on polarization phenomena and spin physics were heard and discussed with particular interest. This interest was caused by a series of messages that were connected with a session on a beam of polarized deuterons, which was successfully conducted last year at the Nuclotron.

The reports of many young scientists were made at a high scientific level. This concerns a large number of the results on the simulation of experiments at the NICA collider and on the analysis of data that were obtained at the Nuclotron and in international collaborations.

At one of the seminar sessions, A. Zarubin made a presentation of the book “The Discovery of the Higgs Boson at the Large Hadron Collider” by Italian physicists A. Nisati and G. Tonelli, published at JINR in Russian.

Traditionally, at the last plenary session, reviews were made of the status of current issues not only in high energy physics.

The reports can be viewed on the seminar website http://relnp.jinr.ru/ishepp/index.html.

As part of the cultural programme, a wonderful concert of laureates of international and Russian competitions led by Professor of the Moscow Tchaikovsky

Conservatory M. Grishina and an excursion to New Jerusalem Monastery (Istra, Russia) were organized for the seminar participants by the JINR Scientists' Club.

From 2 to 4 October, for the first time the ***International Workshop on Very Large Volume Neutrino Telescopes (VLVnT-2018)*** worked in Dubna. This is a regular, the 8th meeting of specialists in the field of neutrino and multichannel astronomy, equipment for current and future large-scale detectors in water and in ice. More than 120 specialists from scientific centres of Belgium, China, the Czech Republic, France, Germany, Holland, Japan, Italy, New Zealand, Russia, Sweden, the USA and JINR met in Dubna. Conversation topics were high-energy neutrino astrophysics, methodological aspects and equipment of the Antares, Baikal-GVD, IceCube and Km3NeT neutrino telescopes, neutrino oscillations, environmental studies using neutrinos, etc.

The presentation of all the participants of the meeting was accompanied by active discussion. During the meeting, a number of reports on the Baikal-GVD project were presented: on the progress in creating the detector and plans for the coming year, as well as on the results of the first experiments on it. An overview of the Baikal project at the meeting was made in the report of V. Aynutdinov (INR RAS), and the first results were presented by J.-A. Dzhilkibaev (INR RAS).

On 23 October, the ***international scientific-memorial seminar dedicated to the 110th anniversary of the birth of the Nobel and State Prizes winner, organizer and long-term Director of the Laboratory of Neutron Physics Academician I. M. Frank*** was held at the JINR Scientists' Club. The employees of FLNP, as well as the friends of Ilya Mikhailovich and the members of the Franks' large family, from several countries of the world took part in the seminar.

At the opening of the seminar, JINR Director Academician V. Matveev briefly introduced I. M. Frank's role in the organization of the Laboratory of Neutron Physics and formation of JINR, as well as presented the long way the Laboratory had passed over the years headed by I. M. Frank. FLNP Director V. Shvetsov spoke about his personal impressions on the meetings with I. M. Frank and the great atmosphere he was met with when he came to the Laboratory of Neutron Physics as a young scientist.

The scientific part of the seminar started with a report of Professor J. M. Carpenter (Argonne National Laboratory), one of the pioneers that have developed the pulsed neutron source. A. I. Frank devoted his report to the problems of neutron optics, highlighting particularly the unsolved problems in this field of science, quite close to I. M. Frank's scientific interests.

A vivid and emotional report devoted to the problems of symmetry in molecular biology was made by Professor of Moscow State University V. Tverdislov. Director of SINP MSU Professor M. Panasyuk dedicated his report to the problems of cosmic neutrons and their radiation impact on spacecraft and human body under conditions of cosmic neutrons.

The second part of the seminar was memorial. Dr. M. Sulman, Chair of the Swedish Institute of International Affairs, having been Executive Director of the Nobel Foundation for many years, made a very interesting report on the system of awarding Nobel prizes and peculiarities of the Nobel Committees' activities. He focused in his report on the history of awarding Nobel Prize in Physics in 1958 to I. E. Tamm, I. M. Frank and P. A. Cherenkov.

Reports of P. Scorer and A. G. Frank were devoted to the history of Frank family, forcibly divided in 1922. The employees of the FLNP and guests of the seminar, who knew Ilya Mikhailovich well enough, made a brief summary of memories in the concluding part of the seminar.

On 24 October, the participants of the seminar visited the Laboratory of Neutron Physics named after I. M. Frank, the renovated study of Iliya Mikhailovich, and saw photos from his archive. In Vvedenskoe cemetery in Moscow the participants laid flowers to the tomb of the scientist.

On 29–30 October the ***2nd Collaboration Meeting on the MPD and BM@N Experiments at the Accelerator Complex NICA*** was held at the Veksler and Baldin Laboratory of High Energy Physics. About 180 participants from Azerbaijan, Belarus, Bulgaria, China, the Czech Republic, France, Georgia, Germany, Israel, Korea, Mexico, Poland, Russia, Slovakia, Uzbekistan, representing scientific centres interested in these experiments, attended the event. At the first meeting (April 2018), the charter was approved and a special committee was elected under the guidance of Professor I. Tserruya to select candidates for leading positions of the collaborations. At the present meeting, elections were held, the status and plans for experiments were considered and discussed.

JINR Vice-Director R. Lednický addressed the meeting with greetings at the opening ceremony. Three detailed reviews were presented: on the NICA project (V. Kekelidze), the MPD experiment (V. Golovatyuk) and the BM@N experiment (M. Kapishin). The same day elections were held. The spokesman of the MPD experiment became Professor of the Warsaw Polytechnic University A. Kissel; Head of sector of the MPD Scientific-Experimental Department M. Kapishin became the spokesman of the BM@N collaboration.

Meetings of the collaborations were held the next day separately. Discussions were held on the status, plans, technical and working details.

At present, several countries take part in the MPD collaboration. The most important are Russia, China, Poland, Mexico, Bulgaria and Georgia. The BM@N collaboration includes Russia (ITEP, the Kurchatov Institute, MSU, INP SB RAS, MEPhI). Among the other countries' centres are the Czech Technical University in Prague (Czech Republic), the Warsaw Technological Institute (Poland), Tübingen University (Germany), three universities of China and institutes of Moldova and Bulgaria, in total 17 participating organizations.

The next stage, as stated by V. Kekelidze, will be agreements with exact institutions that will join the collaborations, indicating the contribution of a particular institute or scientific group: intellectual (data analysis, development of IT technologies) or material (the development of the detector or its maintenance).

PARTICIPATION OF JINR IN INTERNATIONAL CONFERENCES

In 2018, scientists and specialists of the Joint Institute for Nuclear Research took part in 462 international conferences and meetings.

The largest delegations representing JINR attended the following events: Workshop on Active Targets and Time Projection Chambers for High-Intensity and Heavy-Ion Beams in Nuclear Physics (Santiago de Compostela, Spain); Summer School on Bayesian Inference: Foundations and Applications (Bettys Bay, RSA); 11th JUNO Collaboration Meeting (Nanjing, China); NuSPRASEN Workshop on Nuclear Reactions (Theory and Experiment) (Warsaw, Poland); PARIS Collaboration Meeting (Warsaw, Poland); workshop "QED and QCD Effects in Atomic and Hadron Physics" (Lanzhou, China); 35th HADES Collaboration Meeting (Darmstadt, Germany); scientific seminar "Archaeology in the Moscow Region" (Moscow, Russia); NOvA Collaboration Meeting (Austin, USA); workshop "LHC Days in Belarus 2018" (Minsk, Belarus); 52nd Annual Winter School of St. Petersburg Nuclear Physics Institute NRC KI on Theoretical Physics (Roshchino, Russia); PANDA-Meeting 2018 I at GSI (Darmstadt, Germany); 31st Task Force Meeting of the UNECE ICP Vegetation (Dessau-Rosslau, Germany); 11th International Conference on Air Quality — Science and Application (Barcelona, Spain); 52nd School of St. Petersburg Nuclear Physics Institute NRC KI on Condensed Matter Physics (Sestroretsk, Russia); International Workshop on Hadron Structure and Spectroscopy (IWHSS 2018) (Bonn, Germany); 31st CBM Collaboration Meeting (Darmstadt, Germany); school-conference of young scientists "Ilyin Readings" (to the 90th birthday of RAS Academician L. A. Ilyin) (Moscow, Russia); 24th All-Russian Scientific Conference of Physics Students and Young Scientists (Tomsk, Russia); workshop "Spontaneous and Induced Fission of Very Heavy and Superheavy Nuclei" (Trento, Italy); international scientific conference of students, postgraduates and young scientists "Lomonosov 2018" (Moscow, Russia); NICA Workshop (Frankfurt, Germany); 8th All-Russian conference "Information and Telecommunication Technologies and Mathematical Modeling of High-Tech Systems" (Moscow, Russia); 11th annual conference "Polynomial Computer Algebra" (PCA'2018) (St. Petersburg, Russia); SuperNEMO Collaboration Meeting (Orsay, France); Daya Bay Analysis Workshop (Beijing, China); Workshop on Inelastic Neutron Scattering (Spectrina 2018) (Gatchina, Russia); WE-Heraeus-Seminar on Baryon Form Factors: Where Do We Stand? (Bad Honnef, Germany); 9th International Particle Accelerator Conference (IPAC 2018) (Vancouver, Canada); 6th International Conference on Superconductivity and Magnetism (ICSM 2018) (Antaliya, Turkey); CREMLIN WP4 Workshop "Engineering for Advanced Neutron Instrumentation and Sample Environment" (Peterhof, Russia); 18th Radiochemical Conference (RADCHEM) (Marianske Lazne, Czech Repablic); 27th International Conference on Ultrarelativistic Nucleus–Nucleus Collisions (Venice, Italy); All-Russian Conference on Problems of Dynamics, Particle Physics, Plasma Physics and Optoelectronics (Moscow, Russia); Meeting of the Detectors and Monitors Subcommittee of the Neutron Science Advisory Committee (Jülich, Germany); European JUNO Meeting (Strasbourg, France); international conference "Physics of Liquid Matter: Modern Problems" (Kiev, Ukraine); 25th international seminar "Nonlinear Phenomena in Complex Systems. Fractals, Chaos, Phase Transitions, Self-organization" (Minsk, Belarus); COMET Meeting (Tokai, Japan); 5th International Conference on Analytical and Nanoanalytical Methods for Biomedical and Environmental Sciences (IC-ANMBES 2018) (Brasov, Romania); International Workshop on Particle Physics at Neutron Sources 2018 (Grenoble, France); 16th All-Russian school-seminar "Wave Phenomena in Inhomogeneous Medium" named after A. P. Sukhorukov (Waves-2018) (Krasnovidovo, Russia); European conference "Radioactive Ion Beams" (EURORIB 2018) (Giens, France); 2nd International Workshop on Nuclear Emulsions for Neutrino Studies and WIMP Search (Anacapri, Italy); 28th International Conference on Neutrino Physics and Astrophysics (NEUTRINO 2018) (Heidelberg, Germany); CREMLIN Closing Conference (Hamburg, Germany); 11th International Conference on Chaotic Modeling, Simulation and Applications (CHAOS 2018) (Rome, Italy); 15th International Workshop on Meson Physics (MESON 2018) (Cracow, Poland); DarkSide Collaboration Meeting in Sardinia (Cagliari, Italy); International School of Subnuclear Physics (56th Course: From Gravitational Waves to QED, QFD and QCD) (Erice, Italy); 61st ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams (HB2018) (Daejeon, Republic of Korea); 6th International Conference on Radiation and Applications in Various Fields of Research (RAD 2018) (Ohrid, Macedonia); 12th International Conference on Ion Implantation and Other Applications of Ions and Electrons (Kazimierz Dolny, Poland); 37th International Workshop on Nuclear Theory (IWNT37-2018) (Borovets, Bulgaria); international conference “Nucleus-2018” (68th Conference on Nuclear Spectroscopy and Atomic Nucleus Structure) (Voronezh, Russia); 10th International Symposium on Swift Heavy Ions in Matter and 28th International Conference on Atomic Collisions in Solids (SHIM-ICACS 2018) (Caen, France); international conference “Polarized Neutrons for Condensed Matter Investigations” (PNCMI 2018) (Abingdon, UK); 7th International Conference on New Frontiers in Physics (ICNFP-2018) (Kolymbari, Greece); 39th International Conference on High Energy Physics (ICHEP 2018) (Seoul, Republic of Korea); 26th Extended European Cosmic Ray Symposium and 35th Russian Cosmic Ray Conference (26th E+CRS / 35th RCRC) (Barnaul – Belokurikha, Russia); Workshop on Classical and Quantum Integrable Systems (Protvino, Russia); 23rd International Conference on Computing in High Energy and Nuclear Physics (CHEP 2018) (Sofia, Bulgaria); 22nd International Conference on Few-Body Problems in Physics (FB22) (Caen, France); 18th International Balkan Workshop on Applied Physics and Materials Science (IBWAP 2018) (Constanta, Romania); 12th JUNO Collaboration Meeting (Beijing, China); EXPERT Workshop 2018 (Ostrava, Czech Republic); international conference “Quantum Field Theory and Gravity” (QFTG18) (Tomsk, Russia); international conference “Hadron Structure and QCD: From Low to High Energies” dedicated to the memory of Lev N. Lipatov (HSQCD 2018) (Gatchina, Russia); JOIN2 Developers Workshop (Hamburg, Germany); 53rd Zakopane Conference on Nuclear Physics (Zakopane, Poland); 2018 European Nuclear Physics Conference (Bologna, Italy); 27th International Cryogenic Engineering Conference and International Cryogenic Materials Conference 2018 (ICEC27-ICMC 2018) (Oxford, UK); conference “History of the Neutrino” (Paris, France); 23rd International Workshop on ECR Ion Sources (Catania, Italy); 23rd International Spin Symposium (SPIN 2018) (Ferrara, Italy); 29th Linear Accelerator Conference (LINAC 2018) (Beijing, China); 9th Russian Conference on Radiochemistry (Radiochemistry 2018) (St. Petersburg, Russia); Conference on the Use of Neutron Scattering in Condensed Matter (Peterhof, Russia); NOvA Collaboration Meeting (Batavia, USA); 12th International Conference on Physics of Advanced Materials (ICPAM-12) (Heraklion, Greece); international conference and school “Modern Trends in Condenced Matter Physics” dedicated to the 100th anniversary of G. B. Abdullayev (Baku, Azerbaijan); Critical Point and Onset of Deconfinement Conference (CPOD 2018) (Corfu, Greece); 25th nuclear physics workshop “Structure and Dynamics of Atomic Nuclei” (Kazimierz Dolny, Poland); 32nd CBM Collaboration Meeting (Darmstadt, Germany); international conference “Biomembranes 2018” (Dolgoprudny, Russia); 26th Russian Particle Accelerator Conference (RuPAC-2018) (Protvino, Russia); Small Triangle Meeting on Theoretical Physics 2018 (Pticie, Slovak Republic); Moscow Science Festival (in the framework of the 8th All-Russian Festival NAUKA0+) (Moscow, Russia); 14th International Conference on Heavy Ion Accelerator Technology (HIAT 2018) (Lanzhou, China); 13th International Symposium on Electron Beam Ion Sources and Traps (EBIST 2018) (Shanghai, China); WE-Heraeus-Seminar on Particle Physics with Cold and Ultra-Cold Neutrons (Bad Honnef, Germany); 6th Conference on Collective Motion in Nuclei under Extreme Conditions (COMEX6) (Cape Town, RSA); conference “Slow Control 2018” (Warsaw, Poland); 2018 IEEE Nuclear Science Symposium and Medical Imaging Conference (IEEE NSS-MIC 2018) (Sydney, Australia); GERDA General Meeting (Catania, Italy); 8th International Conference on Quarks and Nuclear Physics (QNP 2018) (Tsukuba, Japan); UNESCO – JINR Round Table Meeting (Paris, France); JINR Day in France (Paris, France); Meeting of the Joint Committee on the Collaboration JINR–IN2P3 (Paris, France); International School on Nuclear Methods for Environmental and Life Science (Becici (Budva), Montenegro); Meeting of the Coordination Committee on the Collaboration INFN–JINR (Padova, Italy); International School on Nuclear Physics “JINR Days in Bulgaria” (Borovets, Bulgaria); 20th International Seminar on High Energy Physics (Quarks-2018) (Valday, Russia); 26th International Seminar on Interaction of Neutrons with Nuclei (ISINN-26) (Xi’an, China); international conference “Nuclear Structure and Related Topics” (NSRT 18) (Burgas, Bulgaria); 7th Scientific Conference for Young Scientists and Specialists of JINR (Alushta-2018) (Alushta, Russia); 2018 CERN–JINR European School of High-Energy Physics (ESHEP) (Maratea, Italy); 32nd International Colloquium on Group Theoretical Methods in Physics (Group32) (Prague, Czech Republic); International Workshop on Spin Physics at NICA (SPIN-Praha-2018) (Prague, Czech Republic); 18th International Baikal School on Physics of Elementary Particles and Astrophysics “Exploring the Universe through Multiple Messengers” (Bolshiye Koty, Russia); 14th international school-conference “Actual Problems of Microworld Physics” (Aziory, Belarus); 12th APCTP–BLTP JINR joint workshop “Modern Problems in Nuclear and Elementary Particle Physics” (Bussan, Republic of Korea); international conference “Modern Trends in Natural Sciences and Advanced Technologies in Science Education” (Ulaanbaatar, Mongolia); 6th international conference “Models in Quantum Field Theory” dedicated to the memory of Professor A. N. Vasiliev (MQFT-2018) (Peterhof, Russia); joint BLTP JINR – KLTP CAS workshop “Physics of Strong Interacting Systems” (St. Petersburg, Russia); international workshop “NICA Accelerating Complex: Problems and Solutions — 2018” (Sozopol, Bulgaria); EXON 2018 Satellite School (Petrozavodsk, Russia); 9th International Symposium on Exotic Nuclei (EXON 2018) (Petrozavodsk, Russia); 20th Annual RDMS CMS Collaboration Conference (Tashkent – Samarkand, Uzbekistan); School on the Use of Neutron Scattering in Condensed Matter (Peterhof, Russia); conference “New Trends in High-Energy Physics” (Becici (Budva), Montenegro); 26th Collaboration Meeting of the COMET (Tbilisi, Georgia); 15th International Seminar on Electromagnetic Interactions of Nuclei (EMIN-2018) (Moscow, Russia); 6th international conference “Engineering of Scintillation Materials and Radiation Technologies” (ISMART 2018) (Minsk, Belarus); school for young scientists and seminar “JINR Information Centres: Tasks and Prospects” and ceremonial opening of “JINR Information Centre in the South of Russia” at the North Ossetian State University (Vladikavkaz, Russia); 11th Scientific School for Physics Teachers from JINR Member States (Geneva, Swetzerland); 5th South Africa–JINR symposium “Advances and Challenges in Physics by JINR and South Africa” (Somerset West, RSA); Meeting of the JINR Finance Committee and Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States (Bucharest, Romania); Meeting of the Joint Committee on the ARE–JINR Cooperation (Cairo, Egypt).

DEVELOPMENT OF THE JINR INTERNATIONAL COLLABORATION AND RELATIONS OF THE YEAR 2018

1.	Number of short-term visits to JINR by specialists from the Member States (not counting Russian specialists)	1151
2.	Number of visits of specialists from other countries,	859
	including visits from the Associate Members	406
3.	Number of visits by JINR specialists to the Member States (not counting Russian visits in Russia)	1338
4.	Number of visits by JINR specialists to other countries,	1939
	including visits of specialists to the Associate Members	640
5.	Number of conferences, schools, and meetings held by JINR	90
6.	New cooperation agreements (memoranda of understanding), addenda to existing ones	37

CONFERENCES, SCHOOLS, AND MEETINGS HELD BY JINR IN 2018*

No.	Name	Place	Date	Number of participants
1.	Seminar dedicated to the 110th anniversary of the birth of D. I. Blokhintsev	Dubna	11 January	70
2.	Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	17–18 January	70
3.	Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	22–23 January	67
4.	Winter school “Partition Functions and Automorphic Forms”	Dubna	29 January – 2 February	74
5.	25th international conference “Mathematics. Computer. Education”	Dubna	29 January – 3 February	257
6.	Meeting of the Programme Advisory Committee for Particle Physics	Dubna	31 January – 1 February	62
7.	UNESCO – JINR Round Table Meeting	Paris, France	14 February	50
8.	28th meeting of the Joint Committee on the Collaboration IN2P3 – JINR	Paris, France	14–16 February	16
9.	JINR Day in France	Paris, France	15 February	87

*A number of conferences were held jointly with other organizations.

No.	Name	Place	Date	Number of participants
10.	123rd session of the JINR Scientific Council	Dubna	22–23 February	98
11.	Meeting of the Working Group for JINR Financial Issues under the CP Chairman	Dubna	22 March	27
12.	Meeting of the JINR Finance Committee	Dubna	23–24 March	73
13.	International conference “JINR: 25 Years of a New Era” devoted to the JINR Foundation Day	Dubna	26 March	115
14.	Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States	Dubna	27 March	85
15.	Physics Days in Dubna	Dubna	30 March – 1 April	300
16.	1st Collaboration Meeting of the MPD and BM@N Experiments at the NICA Facility	Dubna	11–13 April	218
17.	2nd international workshop “Simulations of HIC for NICA Energies”	Dubna	16–19 April	69
18.	Extended Meeting of the JINR–FMBA Working Group on Nuclear Medicine	Dubna	17 April	50
19.	Colloquium on Nonequilibrium Phenomena in Strongly Correlated Systems	Dubna	18–19 April	69
20.	Meeting on the Top Tracker Detector of the JUNO Experiment	Dubna	19–21 April	15
21.	International School on Nuclear Methods for Environmental and Life Science	Becici (Budva), Montenegro	22–29 April	65
22.	22nd International Scientific Conference for Young Scientists and Specialists of JINR (AYSS-2018)	Dubna	23–27 April	187
23.	Meeting of the Coordination Committee on the Collaboration INFN–JINR	Padova, Italy	10–11 May	16
24.	International School on Nuclear Physics “JINR Days in Bulgaria”	Borovets, Bulgaria	15–18 May	80
25.	20th International Workshop on Computer Algebra	Dubna	21–22 May	48
26.	Baikal Collaboration Workshop	Dubna	22–25 May	59
27.	20th International Seminar on High Energy Physics (Quarks-2018)	Roshchino (Valday), Russia	27 May – 2 June	150
28.	26th International Seminar on Interaction of Neutrons with Nuclei “Fundamental Interactions and Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics” (ISINN-26)	Xi’an, China	28 May – 1 June	110
29.	Visiting session of the RAS Scientific Council on Radiobiology	Dubna	30 May	60
30.	International conference “Radiation Exposure-Related Problems of Chemical Protection and Repair”	Dubna	30–31 May	100
31.	International conference “Nuclear Structure and Related Topics” (NSRT’18)	Burgas, Bulgaria	3–9 June	59
32.	TAIGA Collaboration Meeting	Dubna	5–8 June	30
33.	Meeting of the Machine Advisory Committee for NICA Project at JINR (NICA MAC)	Dubna	7–8 June	29

No.	Name	Place	Date	Number of participants
34.	7th School-Conference of Young Scientists and Specialists of JINR (Alushta-2018)	JINR Resort Hotel "Dubna", Alushta, Russia	11–18 June	71
35.	Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	14–15 June	64
36.	Meeting of the Programme Advisory Committee for Particle Physics	Dubna	18–19 June	63
37.	Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	20–21 June	72
38.	2018 CERN–JINR European School of High-Energy Physics (ESHEP)	Maratea, Italy	20 June – 3 July	130
39.	International Scientific School for Physics Teachers from JINR Member States	Dubna	24–30 June	33
40.	JINR–IMP CAS Workshop on NICA and HIAF Projects	Dubna	2–3 July	33
41.	International conference "Biomonitoring of Atmospheric Polution" (BioMAP-8)	Dubna	3–5 July	150
42.	3rd mini-work meeting "Making up a Work Plan for Building the BMN DSSD-GEM Hybrid Tracking System for the BM@N-2"	Dubna	5–6 July	32
43.	International workshop "Low-Dimensional Materials: Theory, Modeling, Experiment"	Dubna	9–12 July	51
44.	32nd International Colloquium on Group Theoretical Methods in Physics (ISQS-25)	Prague, Czech Republic	9–13 July	300
45.	International Workshop on Spin Physics Experiments at NICA	Prague, Czech Republic	9–13 July	60
46.	18th International Baikal Summer School on Physics of Elementary Particles and Astrophysics "Exploring the Universe through Multiple Messengers"	Bolshiye Koty, Russia	12–21 July	76
47.	Helmholtz international school-workshop "Calculations for Modern and Future Colliders"	Dubna	22 July – 1 August	87
48.	30th Summer International Computer School	Dubna	1–19 August	62
49.	International school "Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems"	Dubna	5–10 August	65
50.	14th international school-conference "Actual Problems of Microworld Physics"	Aziory (Grodno Region), Belarus	13–23 August	130
51.	International workshop "Supersymmetry in Integrable Systems — SIS'18"	Dubna	13–15 August	46
52.	Helmholtz international summer school "Matter under Extreme Conditions in Heavy-Ion Colisions and Astrophysics"	Dubna	20–31 August	75
53.	12th APCTP–BLTP JINR joint workshop "Modern Problems in Nuclear and Elementary Particle Physics"	Busan, Republic of Korea	20–24 August	75

No.	Name	Place	Date	Number of participants
54.	International conference "Modern Trends in Natural Sciences and Advanced Technologies in Science Education"	Ulaanbaatar, Mongolia	20–23 August	89
55.	6th international conference "Models in Quantum Field Theory" dedicated to the memory of Professor A. N. Vasiliev (MQFT-2018)	Peterhof, Russia	27–31 August	86
56.	Joint BLTP JINR–KLTP CAS workshop "Physics of Strong Interacting Systems"	St. Petersburg, Russia	2–7 September	65
57.	41st European Cyclotron Progress Meeting (ECPM 2018)	Dubna	3–5 September	57
58.	2nd international workshop "Lattice and Functional Techniques for Exploration of Phase Structure and Transport Properties in Quantum Chromodynamics"	Dubna	4–6 September	31
59.	International workshop "NICA Accelerating Complex: Problems and Solutions — 2018"	Sozopol, Bulgaria	8–15 September	46
60.	Satellite school of the symposium "EXON 2018"	Petrozavodsk, Russia	8–9 September	120
61.	8th international conference "Distributed Computing and Grid Technologies in Science and Education"	Dubna	10–14 September	242
62.	9th International Symposium on Exotic Nuclei (EXON 2018)	Petrozavodsk, Russia	10–15 September	140
63.	20th Annual RDMS CMS Collaboration Conference	Tashkent–Samarkand, Uzbekistan	12–15 September	70
64.	School on Neutron Scattering for Condensed Matter Investigations (in the framework of the conference of the same name)	Peterhof, Russia	15–21 September	38
65.	XXIV International Baldin Seminar on High Energy Physics Problems "Relativistic Nuclear Physics and Quantum Chromodynamics"	Dubna	17–22 September	178
66.	124th session of the JINR Scientific Council	Dubna	20–21 September	113
67.	8th Report Seminar of the Ukraine National Group at JINR	Dubna	21 September	20
68.	Conference "New Trends in High-Energy Physics"	Becici (Budva), Montenegro	24–30 September	65
69.	Seminar "Specific Features of the Safety Conrol at the Radiation Sources Operation"	Dubna	25–26 September	12
70.	26th Collaboration Meeting of the COMET	Tbilisi, Georgia	1–5 October	69
71.	Days of Slovakia at JINR	Dubna	1–3 October	45
72.	Workshop on Very Large Volume Neutrino Telescopes	Dubna	2–4 October	130
73.	15th International Seminar on Electromagnetic Interactions of Nuclei (EMIN-2018)	Moscow, Russia	8–11 October	71
74.	6th international conference "Engineering of Scintillation Materials and Radiation Technologies"	Minsk, Belarus	9–12 October	117

No.	Name	Place	Date	Number of participants
75.	School for young scientists and seminar "JINR Information Centres: Tasks and Prospects" and ceremonial opening of "JINR Information Centre in the South of Russia at the North Ossetian State University"	Vladikavkaz, Russia	10–14 October	70
76.	International conference "Modern Problems in Space Radiobiology and Astrobiology"	Dubna	17–19 October	80
77.	Meeting of the Working Group for JINR Financial Issues under the CP Chairman	Dubna	19 October	28
78.	Memorial seminar dedicated to the 110th anniversary of the birth of I. M. Frank	Dubna	23 October	120
79.	Meeting of the RAS Council on Heavy Ion Physics	Dubna	26–27 October	40
80.	2nd Collaboration Meeting of the MPD and BM@N Experiments at the Accelerator Complex NICA	Dubna	29–30 October	157
81.	International Scientific School for Physics Teachers from JINR Member States	Geneva, Switzerland	4–11 November	24
82.	5th South Africa–JINR symposium "Advances and Challenges in Physics by JINR and South Africa"	Somerset West, RSA	4–9 November	80
83.	Workshop "Computational Modelling of Complex Systems"	Dubna	15 November	23
84.	Meeting of the JINR Finance Committee	Bucharest, Romania	16–17 November	56
85.	Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States	Bucharest, Romania	19–20 November	75
86.	Forum for Czech Talented Students	Dubna	19–24 November	24
87.	International scientific seminar "Physics and Humanities: World Experinece and Reality of Science and Humanities in CIS Countries"	Dubna	22–23 November	50
88.	Baikal Collaboration Meeting	Dubna	27–30 November	58
89.	Workshop "Advanced Ideas and Experiments for the New Dubna Neutron Source (DNS-IV). The Related Moderators and Infrastructure"	Dubna	6–8 December	40
90.	Meeting of the Joint Committee on the ARE–JINR Cooperation	Cairo, Egypt	15 December	12

There were also held meetings of the JINR Science and Technology Council, training courses "JINR Expertise for Member States and Partner Countries" (JEMS-6, 7,8,9), International Student Practice (3 stages — for 3 groups), and 11th Internship for Young Scientists and Specialists of the CIS Countries. Besides, JINR assisted in organizing and conducting the international conference "Nucleus-2018" (68th Conference on Nuclear Spectroscopy and Nuclear Structure), the international conference and school "Modern Trends in Condensed Matter Physics" dedicated to the 100th anniversary of Academician G. B. Abdullayev, the Conference on Neutron Scattering for Condensed Matter Investigations, the 4th International Conference on Particle Physics and Astrophysics (ICPPA 2018), the 26th Russian Conference on Particle Accelerators (RuPAC 2018), and some other events held in 2018.

**The Joint Institute
for Nuclear Research
is an international
intergovernmental
scientific
research
organization,
the activities
of which
are based on
principles
of openness
for participation
to all interested
states
and of their equal,
mutually beneficial collaboration.**

Dubna, 26 March.
Celebration of the JINR
Foundation Day

Dubna, 20–21 September.
The 124th session of the JINR
Scientific Council

Dubna, 27 March.
JINR CP session

Bucharest (Romania), 19–20 November. A regular session of the JINR CP (*courtesy of the CP Organizing Committee*)

Bucharest (Romania), 16–17 November. A regular meeting of the JINR Finance Committee

Dubna, 18–19 June. The 49th meeting of the Programme Advisory Committee for Particle Physics

Dubna, 22–23 January. The 47th meeting of the Programme Advisory Committee for Condensed Matter Physics

Sergiev Posad (Russia), 21 June. The participants of the 48th meeting of the JINR Programme Advisory Committee for Nuclear Physics on an excursion to the Holy Trinity – St. Sergius Lavra

Paris (France), 15 February. The signing of the Letter of Intent by representatives of the Government of France and JINR during the workshop “JINR Day in France”

Dubna, 21 February. The signing of the Agreement between JINR and the Academy of Sciences and Humanities of Israel

Cairo (Egypt), 15 December. The signing of a roadmap for the JINR–Egypt cooperation development in the framework of the 8th session of the Joint Committee on ARE–JINR Cooperation

Dubna, 26 October. The signing of the framework Agreement on cooperation between JINR and GSI (FAIR)

Bucharest (Romania), 20 November. The signing of a memorandum of cooperation on projects ELI-NP, IFIN-HH and JINR NICA following the results of the scientific symposium on JINR–Romania cooperation, within the framework of the JINR CP retreat

Dubna, 28 February. A representative delegation of the Republic of Cuba visited JINR

Dubna, 18 May. Members of the General Assembly of the Astroparticle Physics European Consortium S. Leray (CEA Saclay, IRFU, France) and F. Moglia (DESY, Hamburg, Germany) on a visit to JINR

Dubna, 16–18 October. A delegation from Poland, consisting of Director of the National Centre for Research and Development M. Chorowski (second from left), Plenipotentiary of the Government of the Republic of Poland to JINR M. Waligórski (first from left) and Chairman of the Commission under the Plenipotentiary of the Government of Poland on cooperation with JINR Professor M. Budzyński (third from left), at a meeting with the JINR Directorate

Dubna, 12–14 December. The representatives of the Ministry of Science, ICT and Future Planning of the Republic of Korea visited JINR

Dubna, 16 April. Participants of the 6th international training programme
“JINR Expertise for the Member States and Partner Countries”

Dubna, September. The participants of the 8th international training programme
for decision-makers in science and international scientific cooperation “JINR Expertise
for Member States and Partner Countries” (JEMS-8) at the Flerov Laboratory of Nuclear Reactions

Dubna, 2 October. Days of Slovakia at JINR dedicated to the 25th anniversary of establishing the Slovak Republic and its participation in the Joint Institute

Dubna, 25 May. The festive event on the occasion of the Day of Slavic Writing and Culture in the Cultural Centre “Mir”

Dubna, 8 December. The ceremonial meeting on the occasion of the 100th anniversary of establishing the unitary state of Romania

Moscow, the Kremlin, 27 June. The Russian President V. Putin presented the Order
“For Merit to the Fatherland”, III class, to Academician V. Matveev

Moscow, 30 November. The title of Doctor Honoris Causa
of the National Research Centre “Kurchatov Institute” was awarded to JINR Director Academician
V. Matveev, President of the Russian Academy of Sciences A. Sergeev and Rector of the Moscow State University V. Sadovnichy

2018

RESEARCH AND EDUCATIONAL PROGRAMMES OF JINR

BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

At the Bogoliubov Laboratory of Theoretical Physics (BLTP), studies were carried out on the following four themes: Theory of Fundamental Interactions; Theory of Nuclear Structure and Nuclear Reactions; Theory of Condensed Matter; Modern Mathematical Physics: Strings and Gravity, Supersymmetry, Integrability. An important component of the BLTP activities is theoretical support of experimental research to be carried out within major international projects with the participation of JINR as well as Dubna-based experimental programs of JINR Laboratories. The research resulted in about 520 publications in peer-reviewed journals and proceedings of international conferences, two monographs, and one utility model patent. Most of the results were obtained in cooperation with scientists from the JINR Member States, Brazil, China, Egypt, Germany, India, Italy, France, South Africa, and other countries. The Laboratory has become a site for organization of international conferences, workshops, schools for young scientists in various fields of theoretical physics. In 2018, more than 900 scientists participated in 18 international conferences, workshops and schools organized by the Laboratory. The international collaboration was supported by grants of the Plenipotentiaries of Bulgaria, the Czech Republic, Hungary, Poland, the Slovak Republic, Romania, and the JINR Directorate; the collaboration with Armenia was based on the Smorodinsky–Ter-Martirosyan Program; with Polish theorists, on the Bogoliubov–Infeld Program; with Czech theorists, on the Blokhintsev–Votruba Program; and with Romanian theorists, on the Titeica–Markov Program. Collaboration with scientists from Western Europe was carried out in the framework of the JINR–INFN, JINR–IN2P3 agreements. The agreements for collaboration between the Bogoliubov Laboratory and APCTP (South Korea), ITP CAS (Beijing) are functioning, as well as the active cooperation with theorists from CERN. Sixteen research projects and 6 conferences were supported by the RFBR grants, and 3 research projects by the RSF. Much attention was paid to recruiting young researchers, students, and postgraduate students to the Laboratory within the research and education project “Dubna International Advanced School of Theoretical Physics” (DIAS-TH). More than 150 PhD students and young scientists from the JINR Member States participated in the DIAS-TH schools. The Laboratory plays the role of the training centre for young scientists and students from many countries. Currently, about one third of the scientific personnel are young scientists and PhD students. Within the JINR fellowship program for non-member states, several researchers from India, Iran, Japan, Mexico, Tajikistan, and Vietnam have been working at BLTP on the long-term basis.

SCIENTIFIC RESEARCH

Theory of Fundamental Interactions

Theoretical investigations were continued in the framework of the following projects:

- Standard Model and Its Extensions;
- QCD Parton Distributions for Modern and Future Colliders;
- Physics of Heavy and Exotic Hadrons;
- Hadron Matter under Extreme Conditions.

A new approach to the theory of nonrenormalized interactions was developed. Generalizations of the renormalization group equations were obtained, which made it possible to sum up the leading asymptotics in all orders of perturbation theory. The ultraviolet behavior of a number of supersymmetric gauge models of quantum field theory was found [1].

Certain three-loop contributions to the self-coupling beta functions in the general two-Higgs-doublet extension (2HDM) of the Standard Model (SM) were found. As a by-product of the study the inconsistency in the implementation of the well-known two-loop result in modern computer codes was pointed out. In addition, a phenomenological study of certain 2HDM scenarios demonstrates that there are regions in the parameter space that survive experimental constraints and predict the enhancement of the decay of heavy Higgs bosons into a τ–μ pair [2].

The full set of integrals describing the fully inclusive phase space of a decay of a particle into five massless ones was calculated. The three-loop effective potential in a general renormalizable scalar theory with spontaneous symmetry breaking was evaluated. All necessary vacuum bubble diagrams with one and two masses were calculated. An algorithm and a computer code for effective reduction of four-loop massive vacuum integrals necessary for four-loop calculations in the SM were suggested [3].

A possibility of the Bose condensation in two dimensions was analyzed. It was shown that in contrast to the case of a perfect Bose gas, where Bose condensation is not possible in two dimensions due to logarithmic divergences of the system's density as the chemical potential goes to zero, in a real system of interacting particles this situation is drastically altered by higher loop correction containing infrared divergences. The proper analysis requires the summation of all leading singularities, which can be grouped into finite expressions by means of the quantum field renormalization group approach. The value of the critical exponent was estimated on the basis of the Borel summation of ε expansion. Two possible types of the new phase density were considered: uniform and vortex backgrounds. Having performed an analysis of the Goldstone singularities in both cases, one obtains that the mean value of the bosonic field, which is usually considered as an order parameter of the superfluid phase transition in three dimensions, is always equal to zero; therefore, only two-point correlation functions could give an indication of the phase transition. In order to establish which of the backgrounds actually occurs, the values of the corresponding free energies were compared resulting in a conclusion that the constant density of the system in the new phase was more energetically advantageous [4].

Inspired by recent improved measurements of charm semileptonic decays at BESIII, a large set of $D(D_s)$-meson semileptonic decays was studied. The required hadronic form factors were computed in the full kinematic range of momentum transfer by employing the covariant confined quark model. The decay branching fractions and their ratios were calculated, which show good agreement with available experimental data. Predictions were given for the forward–backward asymmetry and the longitudinal and transverse polarizations of the charged lepton in the final state [5].

The problem of distinguishing between the dominant mechanisms of $0\nu\beta\beta$ decay was investigated. It was shown that light and heavy Majorana neutrino mass mechanisms were in general indistinguishable in the measurements of the $0\nu\beta\beta$ half-life with different isotopes. An interpolating formula was proposed, which allows one to calculate the $0\nu\beta\beta$-decay half-life for arbitrary neutrino mass. A seesaw-type 6×6 neutrino mixing matrix was suggested, which implies that the 3×3 mixing matrix of heavy neutrinos is the Hermitian conjugate of the 3×3 PMNS mixing matrix of light neutrinos. The region of dominance of heavy over light neutrino exchange mechanisms for the considered scenarios within left–right symmetric models was identified [6].

The hadron tensors related to the pion–nucleon and photon-induced Drell–Yan process with incoming nucleon being transversally polarized were calculated. The new single-spin asymmetries were predicted which directly probe gluon poles and which were expressed in terms of photon (both chiral-odd and chiral-even) or pion distribution amplitudes and chiral-odd nucleon function stemming from the nucleon transverse polarization. In connection with new COMPASS results, the proposed single-spin asymmetries probing gluon poles together with chiral-odd and time-odd functions were discussed [7].

The method was proposed for determination of the linear polarization of gluons inside an unpolarized proton by using deep inelastic scattering processes with heavy-quark pair leptoproduction. Such measurements can be carried out with the COMPASS facility [8].

The lightcone sum-rule description of the pion–photon transition form factor was investigated, based on dispersion relations in combination with the renormalization group of QCD in terms of the formal solution of the Efremov–Radyushkin–Brodsky–Lepage evolution equation. It was shown that the emerging scheme amounts to a certain version of Fractional Analytic Perturbation Theory (FAPT). In order to ensure a correct asymptotic behavior of the considered physical quantity, this modified FAPT version has to be supplemented with process-specific boundary conditions in contrast to the standard ones. However, it provides the advantage of significantly improving the inclusion of radiative corrections in the low-momentum regime of QCD perturbation theory using renormalization-group summation [9].

The internal composition of compact stars around the phase transition was studied. The possibility of the existence of a geometric structure at such conditions was considered. It is shown that first-order phase transitions, like the liquid-gas transition, proceed via formation of structures such as bubbles and droplets. In strongly interacting compact star matter, at the crust–core transition, as well as at the hadron–quark transition in the core, these structures form different shapes called "pasta phases". Taking into account these phases, various compact star observables, including their moment of inertia and baryon mass, were calculated [10].

In the framework of the quasipotential method in quantum electrodynamics, the contribution of light pseudoscalar, axial vector, and scalar mesons to the interaction operator of a muon and a proton in muonic hydrogen atom was calculated. The parameterization of the transition form factor of a meson into two photons, based on the experimental data and QCD asymptotics, was used. Numerical estimates of the contributions to the hyperfine structure of the spectrum of the S and P levels were presented. This is relevant, in particular, to determination of the proton charge radius. Using the obtained result for the hyperfine interaction of a muon and a proton due to meson exchanges, a similar contribution in the case of muonic ions of lithium, beryllium, and boron was estimated [11].

Recent STAR data on transverse-momentum spectra and midrapidity rapidity densities of various hadrons, in the energy range of RHIC-BES, c.m. energies $\sqrt{s_{NN}} = 7.7-39$ GeV, were analyzed within the model of three-fluid dynamics (3FD). The purely hadronic equation of state (EoS) fails to reproduce the data. A good overall reproduction of the data is found within the deconfinement scenarios. The success of the deconfinement scenarios confirms that the deconfinement indeed occurs in nucleus–nucleus collisions in the RHIC-BES energy range. This analysis indicated also a high degree of stopping of the baryon matter in the central region of colliding nuclei even at the collision energy of $\sqrt{s_{NN}} = 39$ GeV. In order to clarify this finding, the baryon and energy densities attained in central Au + Au collisions in the RHIC-BES energy range were estimated. It was shown that a considerable part of the baryon charge is stopped in the central fireball. The highest initial baryon densities of the equilibrated matter, $n_B/n_0 \approx 10$, are reached in the central region of colliding nuclei at $\sqrt{s_{NN}} = 20-40$ GeV. Consequences of these high initial baryon densities can only be observed in the fragmentation regions of colliding nuclei in AFTER@LHC experiments in the fixed-target mode. The highest midrapidity baryon density at the freeze-out is achieved at $\sqrt{s_{NN}} \approx 8$ GeV and is experimentally accessible at the NICA facility [12].

Vorticity of nuclear matter generated in heavy-ion collisions at energy of $\sqrt{s_{NN}} = 39$ GeV was studied within the model of three-fluid dynamics. A peculiar structure consisting of two vortex rings was found: one ring in the target fragmentation region and the other one in the projectile fragmentation region. These rings are formed even in central collisions. The matter rotation is opposite in these two rings. In semi-central collisions, the average vorticity in the midrapidity region turns out to be more than an order of magnitude lower than the total one, which is dominated by the contributions of the fragmentation regions and is produced because of asymmetry of the vortex rings in noncentral collisions. This suggests that in semi-central collisions the global polarization in the fragmentation regions should be at least an order of magnitude higher than that observed by the STAR collaboration in the midrapidity. However, it can be observed only in AFTER@LHC experiments in the fixed-target mode. This polarization should be asymmetrical in the reaction plain and correlate with the corresponding directed flow [13].

The formation of vorticity of the nuclear fluid formed in heavy-ion collisions at energies available at the NICA accelerator and the related to this polarization of hyperons were studied. Calculations were performed in the framework of the parton–hadron–string dynamics (PHSD) model, which takes into account both hadronic and quark–gluonic degrees of freedom. The formation of vorticity in peripheral Au + Au collisions at $\sqrt{s_{NN}} = 7.7$ GeV is demonstrated. The obtained results for the Λ polarization are in agreement with the experimental data of the STAR collaboration, whereas the model is not able to explain the observed high values of the anti-Λ polarization [14].

A detailed low-temperature scan of the phase diagram of dense two-color QCD with $N_f = 2$ quarks and interactions of a static quark–antiquark pair were carried out using lattice simulation. At small chemical potential μ, the hadronic phase with broken chiral symmetry, very low baryon density and without diquark condensate was observed. At the critical point $\mu = m_\pi/2$, the second-order transition occurs with condensation of scalar diquarks, confinement, nonzero baryon density, and restored chiral symmetry. For larger values of the chemical potential, the system turns into another phase, where the relevant degrees of freedom are fermions residing inside the Fermi sphere, and the diquark condensation takes place on the Fermi surface. This phase is very similar to the quarkyonic state. At higher chemical potential, the deconfinement phase transition occurs. The screening for the Polyakov line is well described by the Debye formula parameterized by screening length decreasing with growing baryon density and an effective coupling constant. The latter is of order of unity, which indicates that even at large density two-color quark matter is a strongly correlated system [15].

Theory of Nuclear Structure and Nuclear Reactions

In 2018, investigations were carried out in accordance with four projects:

• Nuclear Properties at the Border of Stability;

• Low-Energy Dynamics and Nuclear System Properties;

• Quantum Few-Body Systems;

• Processes with Nuclei at Relativistic Energies and Extreme States of Matter.

The existence of individual vortical toroidal $E1$-excitations was predicted in light deformed nuclei. In ^{24}Mg this excitation acquires the lowest energy, which simplifies its experimental identification. It was shown that the vortical toroidal state becomes the lowest only in nuclei with a strong axial prolate deformation [16].

The low-lying collective states of the ground, β and γ bands in ^{154}Sm and ^{238}U were described within the microscopic proton–neutron symplectic model with $Sp(12, R)$ dynamical algebra. A simple geometrical multiphonon interpretation was given to the obtained results, based on the algebraic realization of the coupled two-rotor model [17].

It was found that the solution of time-dependent Hartree–Fock (TDHF) equations by the Wigner function method with the isovector–isoscalar coupling taken into account leads to the prediction of two different types of nuclear spin scissors mode. Calculations show that the spin scissors mode is localized at lower energies than the orbital scissors, while the B($M1$) transition probabilities for the spin mode is larger. This prediction is confirmed in the actinides, in particular, in ^{232}Th [18].

The relation between the $E0$ transition rate and more easily measurable B($E2$) transition probabilities was derived by applying the Q-phonon scheme. The available data partly support this relation except the ^{152}Gd case. In the new experiment the transition probabilities were remeasured, and the new data agree with the relation derived [19].

The comparative analysis of the hot fusion reactions $^{50}\mathrm{Ti} + {}^{247-249}\mathrm{Bk}$ and $^{51}\mathrm{V} + {}^{246-248}\mathrm{Cm}$ for synthesis of element 119 was made with the dinuclear system model and the prediction of nuclear properties of the microscopic–macroscopic approach, where the closed proton shell at $Z \geqslant 120$ was expected. The quasiparticle structures of nuclei in the alpha-decay chain of ^{295}119 and a possible spread of alpha energies were studied. The calculated values of alpha particle Q were compared with the available experimental data. The termination of the alpha-decay chain of ^{295}119 was revealed [20].

The entrance channel effect on the deexcitation cascade of the excited compound nucleus was revealed by calculating the evaporation residue cross sections for the reactions with different mass and charge asymmetries but leading to the same compound nucleus ^{220}Th having the same excitation energy. The strong difference between the observed cross sections of the evaporation residues was explained by the formation of the compound nucleus with different orbital angular momentum which is related to the dependence of the partial fusion cross section on the entrance channel characteristics [21].

The statistical properties of 1^- states in the region of the isovector giant dipole resonance, calculated for ^{206}Hg, ^{204,206,208}Pb, and ^{210}Po nuclei were analyzed within the microscopic model based on the Skyrme interaction. It was shown that employing the random distribution for the coupling between microscopic one-phonon and two-phonon states, generated by the Gaussian orthogonal ensemble (GOE) distribution, good agreement was obtained with the microscopic description of the decay widths [22].

Two limiting models, reproducing the ^{22}C nuclear structure within the three-body cluster approach, which describe all existing experimental data, were presented. The ^{22}C ground state properties, geometry and continuum structure were studied. The prediction for the soft dipole mode in ^{22}C, which is accesible in the process of the Coulomb fragmentation, was made [23].

Atom-molecular collisions were studied using the Faddeev differential equations. The results of calculation of the scattering length for collision of a ^{4}He atom with ^{4}He^{6}Li and ^{4}He^{7}Li dimer were presented. Also, the binding energies of $\mathrm{He_2}\,{}^6\mathrm{Li}$ and $\mathrm{He_2}\,{}^7\mathrm{Li}$ three-atom systems were computed. The numerical results show that the modern potential models support two bound states in both the trimers. In both cases, the energy of the excited state is very close to the one of the lowest two-body threshold. The large values of the scattering length indicate that these systems are of the Efimov type [24].

Ultramagnetized atomic nuclei arising at supernova explosions, neutron star mergers, in magnetar crusts and heavy-ion collisions were considered. It was shown that for field strengths of 0.1–10 TT the linear magnetic response dominated and the Zeeman effect led to an increase in the binding energy of atomic nuclei with open shells. A considerable increase in a yield of corresponding products of explosive nucleosynthesis is consistent with the results of observations. For iron group nuclei, such a magnetic enhancement of ^{44}Ti yield also implies a significant increase in the fraction of the main titanium isotope ^{48}Ti in a chemical composition of galaxies [25].

For the first time the dynamical approach was developed for calculation of charge exchange in $\mathrm{H}^+ + \mathrm{He}^+$ ($1s$) collisions in a wide range of energies up to the maximum cross section. At low energies our 4-state results correctly reproduce the shoulder in the energy dependence of the cross section around $E_{cm} = 6$ keV. The 2-state results correctly predict the position of the maximum of the cross section at $E_{cm} = 40$ keV [26].

The effect of composite pions on the behavior of the chiral condensate at finite temperature within the Polyakov-loop improved Nambu–Jona-Lasinio (PNJL) model was investigated. At low temperatures, the model reproduces the chiral perturbation theory result for the chiral condensate, while at high temperatures the PNJL model result is recovered. The new aspect is a consistent treatment of the chiral restoration transition region within the Beth–Uhlenbeck approach on the basis of mesonic phase shifts for the treatment of correlations [27].

Using the relativistic Bethe–Salpeter formalism, the potential of nucleon–nucleon interaction with Yamaguchi-type form factors and scalar propagators for nucleons was constructed [28].

Utilizing the quark propagator for the fermion Matsubara frequencies, obtained within the Dyson–Schwinger formalism, the Bethe–Salpeter vertex function in the pseudo-scalar $q\bar{q}$ channel for the lowest boson Matsubara frequencies was evaluated and a competition of $q\bar{q}$ bound states and quasi-free two-quark states at $T \sim 100$ MeV was found. This indicates the pseudo-scalar meson dissociation below the QCD deconfinement [29].

The exact analytical lattice results for the partition function of the free neutral scalar field in one spatial dimension in both the configuration and the momentum space were obtained in the framework of the path integral method. The thermodynamic properties and the finite volume corrections to the thermodynamic quantities of the free real scalar field were studied. It was found that on the finite lattice the exact lattice results for the free massive neutral scalar field agree with the continuum limit only in the region of small values of temperature and volume. However, at these temperatures and volumes the continuum physical quantities for both massive and massless scalar field deviate essentially from their thermodynamic limit values and recover them only at high temperatures or/and large volumes in the thermodynamic limit [30].

A theory of nonlinear quantum processes in the strong electromagnetic fields was developed. On its basis, a significant enhancement of the cross sections of multiphoton (subthreshold) processes in the interaction of photons and electrons with short electromagnetic (laser) pulses was predicted [31].

Theory of Condensed Matter

Theoretical investigations within the theme "Theory of Condensed Matter" were continued in the framework of the following projects:

- Complex Materials and Nanostructures;
- Contemporary Problems of Statistical Physics.

Theoretical investigations are performed on small-angle scattering (SAS). The emergence of surface fractals in several classes of cellular automata (CA) was demonstrated. Based on these results, it was shown that SAS can provide a route towards experimental testing of randomness in CA-based structures at nano- and microscales [32].

The frictional force exerted on the trapped 1D Bose gas under the influence of a moving random potential was studied. It was shown that repulsive interactions between bosons lead to a superfluid response and suppression of frictional force, which can inhibit the onset of Anderson localization. A quantitative analysis of the Landau instability for the integrable Lieb–Liniger model was performed, and the existence of effective mobility edges was demonstrated [33].

A spin-rotation-invariant Green-function theory for the dynamic spin susceptibility in the spin-1/2 antiferromagnetic $t-J$ Heisenberg model on the honeycomb lattice was presented. Employing a generalized mean-field approximation for arbitrary temperatures and hole dopings, the electronic spectrum of excitations, the spin-excitation spectrum and thermodynamic quantities (two-spin correlation functions, staggered magnetization, magnetic susceptibility, correlation length) were calculated by solving a coupled system of self-consistency equations for the correlation functions. The temperature and doping dependence of the magnetic (uniform static) susceptibility is ascribed to antiferromagnetic short-range order. Our results on the doping dependences of the magnetization and susceptibility were analyzed in comparison with the previous results for the $t-J$ model on the square lattice [34].

A mechanism was proposed suggesting the resolution of the dichotomy of long-lived spin polarization storage versus fast spin reversal at the required time. A system of atoms or molecules interacting through magnetic dipolar forces was considered. The constituents were assumed to possess internal structure allowing for the generation of the alternating-current quadratic Zeeman effect, whose characteristics can be efficiently regulated by quasiresonant dressing. The sample was connected to an electric circuit producing a feedback field acting on spins. By switching on and off the alternating-current quadratic Zeeman effect it is possible to realize spin reversals with a required delay time. The suggested technique of regulated spin reversal can be used in quantum information processing and spintronics [35].

The dynamics of the integrable stochastic raise and peel model of fluctuating interface, evolving via nonlocal avalanche dynamics, was investigated for the first time. The statistics of avalanche flows in this model was described. Large deviation functions characterizing the flow dynamics in the large time limit were constructed. The cumulants of the flow, such as mean and variance, etc., were explicitly evaluated. The phase transition, which takes place when the time-averaged flow deviates from its most probable value, was characterized [36].

A wide class of four-dimensional quiver field theories was constructed which are dual to Seiberg's supersymmetric quantum chromodynamics used for a description of the electromagnetic dualities in non-Abelian field theories. It was deduced from sequences of symmetry transformations for superconformal indices of the corresponding theories built with the help of the elliptic Fourier transformation and elliptic Bailey lemma for elliptic hypergeometric integrals on the A_n root system [37].

The spectral properties of the underdoped $t-J$ model for cuprates were calculated using the cluster perturbation theory method. The appearance of quantum oscillations phase was explained by the effective closure of electron orbits in momentum space due to the Bragg reflection of electrons on the charge density wave. This scenario describes well how quantum oscillations occur in the presence of a strong electron correlation within the pseudogap phase [38].

The effect of coupling between the superconducting current and magnetization in the superconductor/ferromagnet/superconductor Josephson junction under an applied circularly polarized magnetic field was studied. Manifestation of ferromagnetic resonance in the frequency dependence of the amplitude of the magnetization and the average critical current density was demonstrated. The IV-characteristics show subharmonic steps that form devil's staircases, following a continued fraction algorithm. The origin of the found steps relates to the effect of the magnetization dynamics on the phase difference in the Josephson junction [39].

Using Bardeen's approach and orbital wave functions obtained by the algorithm of Herman and Skillman, we calculated interatomic matrix elements for tunnel interaction between the atoms from the set of B, C, N, Si, P, S, Ti, V, Se, Mo, Te and W, which constitute many 2D materials. In a wide range of interatomic distances, these values were approximated by simple functions with a small set of parameters. The results are presented in reference tables. These results will be useful for describing different tunnel phenomena in low-dimensional materials using the tight-binding approach [40].

Modern Mathematical Physics: Strings and Gravity, Supersymmetry, Integrability

The topics of main focus in the theme were:

- Quantum Groups and Integrable Systems;
- Supersymmetry;
- Quantum Gravity, Cosmology and Strings.

Spin-tensor wave functions of free massive particles with arbitrary spin were obtained on the basis of the Wigner unitary representations of the covering group $\mathrm{ISL}(2, \mathrm{C})$ of the Poincaré group. The wave functions automatically satisfy the Dirac–Pauli–Fierz equations. In the framework of the two-spinor formalism, spin-vectors of polarizations were constructed and conditions that fix the corresponding relativistic spin projection operators (Behrends–Fronsdal projection operators) were obtained. With the help of these conditions explicit expressions for relativistic spin projection operators for integer spins (Behrends–Fronsdal projection operators) were found, and then relativistic spin projection operators for half integer spins were obtained. These projection operators determine the nominators in the propagators of fields of relativistic particles. Generalizations of the Behrends–Fronsdal projection operators for arbitrary space–time dimensions $D > 2$ were deduced [41].

In the framework of the Hamiltonian formalism, $N = 4$ supersymmetric particle mechanics on curved spaces described by several $N = 4$, $d = 1$ linear multiplets was studied. It is shown that the existence condition for the supersymmetry is given by a generalization of the celebrated Witten–Dijkgraaf–Verlinde–Verlinde equation, which is called "curved WDVV equation". Solutions to this new equation on isotropical spaces were found, generalizations of potentials and solutions of WDVV, known in the flat case, were constructed to these spaces [42].

Special Bohr–Sommerfeld Lagrangian submanifolds were studied in the case when the ambient symplectic manifold admits a compatible integrable complex structure, which means that the last one is algebraic. For this case, it is shown how the special Bohr–Sommerfeld geometry is reduced to the Morse theory on the complements to ample divisors. It implies the construction of a Lagrangian shadow of an ample divisor in algebraic variety, which gives an example of the correspondence "algebraic vs. symplectic". The existence condition for the Lagrangian shadow was presented, and several examples of Lagrangian shadows for ample divisors in the projective plane, complex quadric, and the flag variety were given [43].

A new world-line Lagrangian model of the $D = 4$ massless relativistic particle with continuous spin was proposed and its twistorial formulation was developed. The description uses two Penrose twistors subjected to four first-class constraints. After the first quantization of the world-line twistorial model, the wave function is defined by an unconstrained function on the two-dimensional complex affine plane. The twistor transform is found which determines the space–time field of the continuous spin particle through the corresponding twistor one, which plays the role of a prepotential. It is shown that this space–time field is an exact solution of the space–time constraints defining the irreducible massless representation of the Poincaré group with continuous spin [44].

The $6D$, $N = (1, 1)$ supersymmetric Yang–Mills theory was considered in $N = (1, 0)$ harmonic superspace, and the structure of the two-loop divergences in the hypermultiplet sector was analyzed. Using the $N = (1, 0)$ superfield background field method, the two-point supergraphs with the hypermultiplet legs were studied, and it was proved that their total contribution to the divergent part of effective action vanishes off shell [45].

Solutions of the Einstein–Skyrme model were studied. Firstly, test Skyrmions on the Kerr background were considered. In the sector with nonzero baryon charge, these Skerrmions are akin to the known Skyrme solutions on the Schwarzschild background. In the nontopological sector, on the other hand, Skerrmions have no analogue on the Schwarzschild background. Nontopological Skerrmions carry no baryon charge and bifurcate from a subset of Kerr solutions defining the existence line. Nontopological Skerrmions trivialize in the vanishing BH mass limit. The back reaction of these Skerrmions was discussed which yields rotating BHs with synchronized Skyrme hair continuously converting to the Kerr solution (self-gravitating Skyrmions) in the nontopological (topological) sector [46].

$SU(2|1)$ supersymmetric multiparticle quantum mechanics with additional semidynamical spin degrees of freedom was considered. In particular, an $N = 4$ supersymmetrization of the quantum $U(2)$ spin Calogero–Moser model was provided, with an intrinsic mass parameter coming from the centrally extended superalgebra $\widehat{su}(2|1)$. The full system admits an $SU(2|1)$ covariant separation into the centre-of-mass sector and the quotient. Explicit expressions for the classical and quantum $SU(2|1)$ generators in both sectors as well as for the total system were derived, and the relevant energy spectra, degeneracies, and the sets of physical states were determined [47].

The rarefied elliptic beta integral in various limiting forms was considered. In particular, an integral identity for parafermionic hyperbolic gamma functions was obtained, which describes the star-triangle relation for parafermionic Liouville theory [48].

The Casimir force between two half spaces separated by a gap L, in which a scalar field is confined by the Dirichlet boundary conditions, was calculated. The field interacts via the Yukawa coupling with another scalar field residing in the whole space. The reflection coefficients of the half spaces were computed in terms of one-loop polarization operators derived in the considered QFT model. These reflection coefficients completely define the separation dependent finite part of the vacuum energy. There is an upcoming interest in this type of calculations caused by high precision measurement of dispersion forces (up to femtonewton) and the need to account for internal dynamical properties of the interacting bodies [49].

Modification of $f(R,T)$-gravity (where T is a trace of energy-momentum tensor) was proposed by introducing higher derivatives of matter fields. Stability conditions in the proposed theory were discussed and restrictions for parameters were found to prevent appearance of the main type of instabilities, such as ghost-like and tachyon-like instabilities. Cosmological equations were derived for a few representations of theory, and the main differences with convenient $f(R,T)$-gravity without higher derivatives were discussed. It was demonstrated that in the presented theory inflationary scenarios appear quite naturally even in the dust-filled Universe without any additional matter sources. The inflationary model was constructed in one of the simplest representations of the theory, the main inflationary parameters were calculated, and it was found that they may be in good agreement with observations [50].

Many black-hole-type solutions acquire undesirable properties due to the phenomenon of mass inflation, when the inner horizon becomes singular. This phenomenon is universal and arises due to scattering of the falling matter on the inner horizon (which always happens in the real world). According to the present study, the phenomenon of mass inflation does not occur for a whole class of solutions: if in the effective phase space the corresponding solutions do not allow energy transfer between the degrees of freedom. A distinctive feature of these solutions is a kind of “quantization” of the measured parameters of the model [51].

DUBNA INTERNATIONAL ADVANCED SCHOOL OF THEORETICAL PHYSICS (DIAS-TH)

In 2018, the research and educational project DIAS-TH was successfully continued. There were the following activities in the framework of DIAS-TH:

• XIV Winter School on Theoretical Physics “Partition Functions and Automorphic Forms”, 29 January – 2 February, Dubna;

• Helmholtz International Summer School “Modern Colliders — Theory and Experiment 2018” and Workshop “Calculations for Modern and Future Colliders”, 22 July – 1 August, Dubna;

• International School “Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems”, 5–10 August, Dubna;

• Helmholtz International Summer School “Matter under Extreme Conditions in Heavy-Ion Collisions and Astrophysics”, 20–31 August, Dubna;

• Regular seminars for students and postgraduates were organized;

• Computer processing of video records of lectures was continued;

• Website of DIAS-TH was supported.

CONFERENCES AND MEETINGS

In addition to the activities within DIAS-TH mentioned above, fourteen conferences, workshops and schools were organized in 2018:

• XIV Winter School on Theoretical Physics “Partition Functions and Automorphic Forms”, 29 January – 2 February, Dubna;

• II International Workshop “Simulations of HIC for NICA Energies”, 16–18 April, Dubna;

• Colloquium “Nonequilibrium Phenomena in Strongly Correlated Systems”, 18–19 April, Dubna;

• XX International Seminar on High Energy Physics “Quarks-2018”, 27 May – 2 June, Roshchino, Valdai District, Russia;

• International Conference “Nuclear Structure and Related Topics” (NSRT18), 3–9 June, Bourgas, Bulgaria;

• International Workshop "Low-Dimensional Materials: Theory, Modeling and Experiment", 9–12 July, Dubna;

• XXXII International Colloquium "Group Theoretical Methods in Physics", 9–13 July, Prague, Czech Republic;

• International Workshop "Supersymmetry in Integrable Systems" (SIS'18), 13–16 August, Dubna;

• VI International Conference "Models in Quantum Field Theory" (MQFT-2018) in memory of Prof. A. N. Vasiliev, 27–31 August, Peterhof, Russia;

• BLTP/JINR–SKLTP/CAS Joint Workshop "Physics of Strong Interacting Systems", 2–7 September, St. Petersburg, Russia;

• II International Workshop "Lattice and Functional Techniques for Exploration of Phase Structure and Transport Properties in Quantum Chromodynamics", 4–6 September, Dubna;

• XXIV International Baldin Seminar on High Energy Physics Problems "Relativistic Nuclear Physics and Quantum Chromodynamics", 17–22 September, Dubna;

• XV International Seminar "Electromagnetic Interactions of Nuclei" (EMIN-2018), 8–11 October, Moscow, Russia;

• V South Africa – JINR Symposium "Advances and Challenges in Physics within JINR and South Africa", 4–9 November, Somerset West, South Africa.

COMPUTER FACILITIES

In 2018, the most powerful server at BLTP theor3.jinr.ru was brought into operation. The server is equipped with a total of 24 CPU cores, 768 GB of RAM and GPU Tesla P100. The seminar auditorium of the 2nd floor was equipped with a high-resolution stationary projector and motorized retractable screen. In order to fully update the audio and video equipment of the BLTP conference hall, high-resolution projector with a laser source of light, advanced sound reinforcement system and control equipment were purchased. To increase computing power in individual work places, 14 PCs and notebooks were acquired. The technical support was extended and updated versions were installed for Mathematica, Maple, Origin Pro, and Intel Parallel Studio. Three additional network licenses were purchased for Mathematica and Origin Pro.

REFERENCES

1. *Kazakov D. I., Borlakov A. T., Tolkachev D. M., Vlasenko D. E.* // Phys. Rev. D. 2018. V. 97. P. 125008; *Kazakov D. I.* // Phys. Lett. B. 2018. V. 786. P. 327.
2. *Bednyakov A. V.* // JHEP. 2018. V. 1811. P. 154; *Bednyakov A. V., Rutberg V.* // Mod. Phys. Lett. A. 2018. V. 33. P. 1850152.
3. *Gituliar O., Magerya V., Pikelner A.* // JHEP. 2018. V. 1806. P. 099; *Kniehl B., Pikelner A., Veretin O.* // Nucl. Phys. B. 2018. V. 937. P. 533; *Pikelner A.* // Comp. Phys. Commun. 2018. V. 224. P. 282.
4. *Hnatic M., Kalagov G. A., Nalimov M. Yu.* // Nucl. Phys. B. 2018. V. 936. P. 206.
5. *Soni N. R., Ivanov M. A., Korner J. G., Pandya J. N., Santorelli P., Tran C. T.* // Phys. Rev. D. 2018. V. 98. P. 114031.
6. *Babič A., Kovalenko S., Krivoruchenko M. I., Šimkovic F.* // Phys. Rev. D. 2018. V. 98. P. 015003.
7. *Anikin I. V., Szymanowski L.* // Eur. Phys. J. A. 2018. V. 54. P. 130.
8. *Efremov A. V., Ivanov N. Ya., Teryaev O. V.* // Phys. Lett. B. 2018. V. 780. P. 303.
9. *Ayala C., Mikhailov S. V., Stefanis N. G.* // Phys. Rev. D. 2018. V. 98. P. 096017.
10. *Abgaryan V., Alvarez-Castillo D. E., Ayriyan A., Blaschke D. B., Grigorian H.* // Universe. 2018. V. 4, No. 9. P. 94.
11. *Dorokhov A. E., Kochelev N. I., Martynenko A. P., Martynenko F. A., Radzhabov A. E.* // Phys. Lett. B. 2018. V. 776. P. 105; *Dorokhov A. E., Krutov A. A., Martynenko A. P., Martynenko F. A., Sukhorukova O. S.* // Phys. Rev. A. 2018. V. 98. P. 042501.
12. *Ivanov Yu. B., Soldatov A. A.* // Phys. Rev. C. 2018. V. 97. P. 024908; Phys. Rev. C. V. 98. P. 014906; Phys. Rev. C. V. 97. P. 021901.
13. *Ivanov Yu. B., Soldatov A. A.* // Phys. Rev. C. 2018. V. 97. P. 044915.
14. *Kolomeitsev E. E., Toneev V. D., Voronyuk V.* // Phys. Rev. C. 2018. V. 97. P. 064902.
15. *Braguta V. V., Ilgenfritz E.-M., Kotov A. Yu., Molochkov A. V., Nikolaev A. A.* // Phys. Rev. D. 2018. V. 94. P. 114510; *Astrakhantsev N. Y., Bornyakov V. G., Braguta V. V., Ilgenfritz E.-M., Kotov A. Y., Molochkov A. V., Nikolaev A. A., Rothkopf A.* arXiv:1808.06466 [hep-lat].
16. *Nesterenko V. O., Repko A., Kvasil J., Reinhard P.-G.* // Phys. Rev. Lett. 2018. V. 120. P. 182501.
17. *Ganev H.* // Phys. Rev. C. 2018. V. 98. P. 034314.

18. *Balbutsev E. B., Molodtsova I. V., Schuck P.* // Phys. Rev. C. 2018. V. 97. P. 044316.
19. *Wiederhold J., Kern R., Lizarazo C., Pietralla N., Werner V., Jolos R. V. et al.* // J. Phys. C. 2018. V. 1023. P. 012024.
20. *Adamian G. G., Antonenko N. V., Lenske H.* // Nucl. Phys. A. 2018. V. 970. P. 22.
21. *Mandaglio G., Anastasi A., Curciarello F., Fazio G., Giardina G., Nasirov A. K.* // Phys. Rev. C. 2018. V. 98. P. 044616.
22. *Severyukhin A. P., Aberg S., Arsenyev N. N., Nazmitdinov R. G.* // Phys. Rev. C. 2018. V. 98. P. 044319.
23. *Shulgina N. B., Ershov S. N., Vaagen J. S., Zhukov M. V.* // Phys. Rev. C. 2018. V. 97. P. 064307.
24. *Kolganova E. A.* // Few-Body Syst. 2018. V. 59. P. 28.
25. *Kondratyev V. N.* // Phys. Lett. B. 2018. V. 782. P. 167.
26. *Grozdanov T. P., Solov'ev E. A.* // Eur. Phys. J. D. 2018. V. 72. P. 64.
27. *Blaschke D., Dubinin A., Ebert D., Friesen A. V.* // Phys. Part. Nucl. Lett. 2018. V. 15. P. 230.
28. *Bondarenko S. G., Burov V. V., Yurev S. A.* // Phys. Part. Nucl. Lett. 2018. V. 15. P. 442.
29. *Dorkin S., Kaptari L., Kaempfer B.* // Phys. Part. Nucl. Lett. 2018. V. 15. P. 411.
30. *Parvan A. S.* // Physica A. 2018. V. 496. P. 410.
31. *Titov A. I., Takabe H., Kämpfer B.* // Phys. Rev. D. 2018. V. 98. P. 036022.
32. *Anitas E. M., Sliamov A.* // Ann. Physik. 2018. V. 530. P. 1800187.
33. *Cherny A. Yu., Caux J.-S., Brand J.* // J. Phys. B. 2018. V. 51. P. 015301.
34. *Vladimirov A. A., Ihle D., Plakida N. M.* // Eur. Phys. J. B. 2018. V. 91. P. 195.
35. *Yukalov V. I., Yukalova E. P.* // Phys. Rev. B. 2018. V. 98. P. 144438.
36. *Povolotsky A. M., Pyatov P. N., Rittenberg V.* // J. Stat. Mech. Theory Exp. 2018. P. 053107.
37. *Brunner F., Spiridonov V.* // JHEP. 2018. V. 2018. P. 105.
38. *Ivantsov I., Ferraz A., Kochetov E.* // Phys. Rev. B. 2018. V. 98. P. 214511.
39. *Nashaat M., Botha A. E., Shukrinov Yu. M.* // Phys. Rev. B. 2018. V. 97. P. 224514.
40. *Katkov V. L., Lobanov D. A.* // J. Comput. Electron. 2018; https://doi.org/10.1007/s10825-018-1281-y.
41. *Isaev A. P., Podoynitsyn M. A.* // Theor. Math. Phys. 2018. V. 195, No. 3. P. 779.
42. *Kozyrev N., Krivonos S., Lechtenfeld O., Nersessian A., Sutulin A.* // Phys. Rev. D. 2018. V. 97. P. 085015; arXiv:1711.08734.
43. *Tyurin N. A.* // Izv. Math. 2018. V. 82, No. 3. P. 612.
44. *Fedoruk S., Isaev A. P., Rusnak A.* // JHEP. 2018. V. 1807. P. 031; arXiv:1805.09706 [hep-th].
45. *Buchbinder I. L., Ivanov E. A., Merzlikin B. S., Stepanyantz K. V.* // Phys. Lett. B. 2018. V. 778. P. 252; arXiv:1711.11514 [hep-th].
46. *Herdeiro C., Perapechka I., Radu E., Shnir Ya.* // JHEP. 2018. V. 10. P. 119; arXiv:1808.05388 [hep-th].
47. *Fedoruk S., Ivanov E., Lechtenfeld O., Sidorov S.* // JHEP. 2018. V. 1804. P. 043; arXiv:1801.00206 [hep-th].
48. *Sarkissian G., Spiridonov V. P.* // JHEP. 2018. V. 1810. P. 097; arXiv:1809.00493 [hep-th].
49. *Bordag M., Pirozhenko I. G.* // Symmetry. 2018. V. 10. P. 74.
50. *Tretyakov P. V.* // Eur. Phys. J. C. 2018. V. 78. P. 896.
51. *Davydov E. A.* // Theor. Math. Phys. 2018. V. 197, No. 2. P. 1663.

VEKSLER AND BALDIN LABORATORY OF HIGH ENERGY PHYSICS

The activity of the Veksler and Baldin Laboratory of High Energy Physics in 2018 was focused on the implementation and further development of the NICA facility (the Nuclotron–NICA, MPD, BM@N and SPD projects) and participation in the current research at the Nuclotron as well as in various experiments at world-class accelerator centers.

MOST IMPORTANT RESULTS IN THE DEVELOPMENT OF THE NICA COMPLEX

Development of the VBLHEP accelerator complex in 2018 was aimed at further construction of the NICA complex systems and elements.

From February to April, the 55th accelerator run at the basic element of the currently developing NICA Complex — the superconducting synchrotron Nuclotron — was performed at extracted ion beams $^{12}C^{6+}$, $^{40}Ar^{16+}$ and $^{78}Kr^{26+}$ [1].

Some important results were achieved during the Nuclotron run, in particular:

• For the first time, a nonstructural mode of slow extraction of an accelerated beam from the superconducting synchrotron was implemented using HF noise to improve the quality and uniformity of the bunch (Fig. 1).

• A new source of multicharged ions Krion-6T, which is essential for the heavy-ion program of the NICA complex, has worked extremely stably and reliably.

• For the first time in Russia, krypton ions with the energy of 3.1 GeV/nucleon were accelerated and extracted from the ring, the possibility of stable operation of the Nuclotron with the field of 18 kG level was demonstrated.

Nuclotron–NICA Project

Civil Construction

The western semi-ring of the collider and the electron cooling system placement were prepared for the equipment installation. The construction of the eastern semi-ring is in progress. Status of the MPD Hall preparation complies with the scheduled delivering and positioning the MPD magnet at the end of 2019. The SPD Hall reinforced concrete structure is under

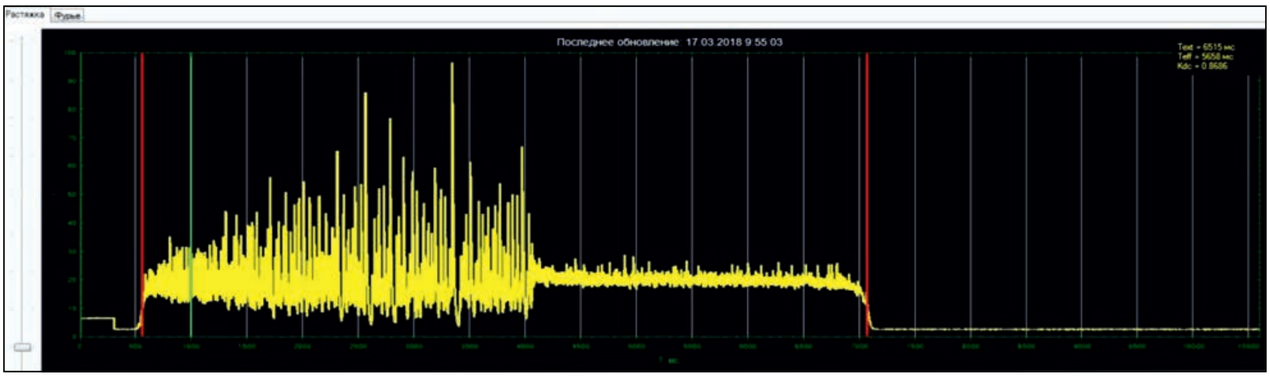


Fig. 1. Left part of the spectrum before kicker switching on; right part — after it

development (80% is ready). The total amount of the mounted reinforced concrete structures is about 500 t.

Booster

All magnets for the Booster synchrotron were produced and certified. The assembly of the Booster magnetic system was started in September 2018. Two quadrants out of four were equipped with dipole magnets at the end of 2018. Work goes on according to the schedule. Booster commissioning with a beam is expected to be carried out at the end of 2019.

Construction of the beam transport channel from the heavy ion linac (HILac) to the Booster was almost finished. The design of the Booster–Nuclotron beam transporting channel was performed during 2018 in close cooperation with the Budker INP and is in the final stage now. Equipment manufacturing was started.

Collider

During 2018, work on the design of the beam transporting channels from the Nuclotron to the NICA collider rings was performed under the contract with SigmaPhi Group (France), equipment manufacturing was started.

Fabrication of two RF stations of the system responsible for the injection to the collider is in the final stage. The manufacturing of the collider electron cooling equipment and collider RF stations was also started in 2018. Five dipole collider magnets were produced and successfully tested, 20 yokes for the collider dipole magnets were produced. Pre-serial structural collider magnet was successfully tested, serial production was begun. The production of the high-vacuum beam chambers for the collider magnets was started.

NICA Computing Infrastructure

The work on the NICA computing infrastructure goes on in close cooperation with JINR LIT. In the scope of this activity, a high-speed network (400 Gb/s) between LIT and VBLHEP was developed and is under commissioning now; a new computer cluster with 4 PB disc space and 4000 CPU cores was put into operation at VBLHEP.

MPD Setup

MPD Magnet

Work on the construction of the superconducting (SC) magnet for the Multi-Purpose Detector (MPD) goes on according to the schedule under the contract signed with ASG Superconductors S. p. A. (Italy) and Vitkovice HM (the Czech Republic). In particular, in 2018 magnet yoke control assembly was successfully performed at Vitkovice HM; magnet cryostat was manufactured and tested; all three modules of the SC coils were produced; the coil is under assembly now; nitrogen screen was manufactured and now is ready for installation; SC magnet power supply system was produced and is ready for the delivery to JINR.

Under cooperation with CERN, a machine for the precise measurement of the magnetic field map in the TPC location area (design parameters: $8 \cdot 10^3$ points through the area of 814 mm in diameter with the length of 3400 mm along the magnet axes) was produced and will be delivered from CERN to JINR in 2019.

Time Projection Chamber

Time projection chamber (TPC) is the main element of the MPD tracking and particle identification systems. The following works were performed on the TPC in 2018: the clean room for TPC assembly and corresponding equipment were established; all main elements of the detector body were delivered to JINR and are ready for assembly; the TPC HV electrode was manufactured; the pilot system including 512 channels for the TPC front-end (FE) electronics based on the SAMPA chips was produced and successfully tested; the geometry of the TPC read-out chamber frame boxes was tested; the development of the LV power supply was going on in collaboration with BSU (Minsk); two lasers for the TPC alignment were put into operation; commissioning of the TPC gas system was started and is in progress now.

Time of Flight (TOF) System

In 2018, mass production of the MPD TOF system was started, frame boxes for the detectors and electronics for the TOF are ready; manufacturing of the detectors goes on. Base components of the TOF gas system were produced by the team from the Warsaw University of Technology.

Fast Forward Detector (FFD)

In 2018, the following results on the FFD system were achieved:

• The design of the detector and FE electronics installation around the beam pipe was prepared.

• HV power supply system based on the modules of Wiener and Iseg was designed.

• Electronics of FFD and trigger were developed and prototyped.

• The test bench for FFD modules with cosmic muons was assembled.

• Laser alignment system project was finalized; system tests were started.

Electromagnetic Calorimeter

One of the unique high-tech subsystems of the MPD experiment is the large-scale shashlyk-type electromagnetic calorimeter with projection geometry. It is required to produce more than 40 thousand modules and assemble them into a single cylindrical system, calibrate them and put into operation. This is a joint project with Tsinghua University (Beijing). The following results were achieved:

• The production of all components of the electromagnetic calorimeter was established. Almost 50% of scintillation plates (out of 10^7) and bearing plates (out of $3 \cdot 10^4$) were produced at two plants. The order on the manufacturing of the lead plates (10^7 units) was placed on two plants.

• Two sections of the calorimeter module assembly were organized at IHEP and Tensor plant (Russia). They cover the JINR share (25%). The site for the modules assembly of the China share (75%) was organized in Beijing as well. The issue of funding is still open.

• First produced modules were successfully tested.

• Works on the design of the MPD power structure were performed in Khotkovo (Moscow Region), the first samples are expected to be ready at the end of 2019.

BM@N Setup

BM@N setup is under permanent extending. In 2018, the central tracker was equipped with three forward Si strip detectors and six GEM detectors 163×45 cm. During the data taking, two types of TOF detectors, electromagnetic and hadron calorimeters, outer tracker, including drift tube planes and cathode strip chamber, detector for the neutron registration, beam monitoring and trigger detectors were used.

Last year, the BM@N physics program was extended by "Probing Short-Range Correlations" (SRC). An international team, which includes physicists from JINR, Russia, USA, Germany, France and Israel, prepared the setup and provided the first data taking on this program during the 55th Nuclotron run. Almost 20 TB (8M events) of data with 4-GeV carbon ion beam and liquid hydrogen target were obtained. Data analysis is in progress.

After the SRC run, the equipment was rearranged for the BM@N heavy ion program, and the run was continued with argon and krypton beams with kinetic energy of 3.2 and 2.3 (2.9) GeV, respectively. The measurements were aimed at the detection of inelastic interactions of ion beams with nuclear targets (Al, Cu, Sn, Pb) to study production of hyperons, strange mesons, light nucleus fragments, and multigamma states. Obtained statistics composes 200M events. Data analysis is in progress [2].

MPD and BM@N Common Issues

Two "kick off" meetings were organized in April and October 2018 to form the BM@N and MPD collaborations.

The discussions and presentations at the first meeting were centered around three main topics:

• current status and plans for the MPD and BM@N experiments, including all subsystems, simulations, expected performance of the detectors and preparedness for data analysis;

• current status and schedule of the NICA facility including the expected machine parameters;

• procedures to establish and adopt the by-laws of the collaborations, including the formation of the governing bodies of the collaborations.

The major aim of the second meeting was to discuss the present state and work plans for the MPD and BM@N experiments and elections of governing bodies of the collaborations. M. Kapishin was elected a BM@N spokesman and A. Maksimchuk — a BM@N technical coordinator; A. Kisel was elected a spokesman of the MPD, and V. Golovatiuk becomes an MPD technical coordinator. The BM@N collaboration was formed by 216 participants from 17 institutions presented by 10 countries; MPD, by 436 participants from 26 institutions and 10 countries.

The Protocol to the Cooperation Agreement between the European Organization for Nuclear Research (CERN) and the Joint Institute for Nuclear Research (JINR) concerning the development and provision by CERN of monolithic pixel detectors, TPC front-end electronics, and other items for the MPD experiment at the NICA facility at JINR was signed in 2018.

Silicon Vertex Detector

In 2018, the works on a wide-aperture silicon tracking system (STS) of the BM@N facility were continued. Production line for the STS modules assembly on layouts was fully debugged, and the works on the assembly of working modules were started.

In December 2018, a test run on the extracted electron beam with the energy of 100 MeV at the Linac-200 (JINR) was held. During the run, the operation of the electronics for the STS of the experiment was tested. The setup consisted of two test stations based on double-sided micro-strip silicon sensors measuring 1.5×1.5 cm. The thickness of the sensors is 300 μm, the width of the strips is 58 μm, the angle between the strips is 90°. The signal was read out and processed using STSXYTER v.2.0 and subsequent AFCK and FLIB blocks based on FPGA modules. As a result of the run, $\sim$200 GB of data for electron energies from 50 to 100 MeV were collected. Based on the data obtained, the following parameters are to be investigated: cluster sizes that depend on energy, charge collection efficiency, and signal-to-noise ratio.

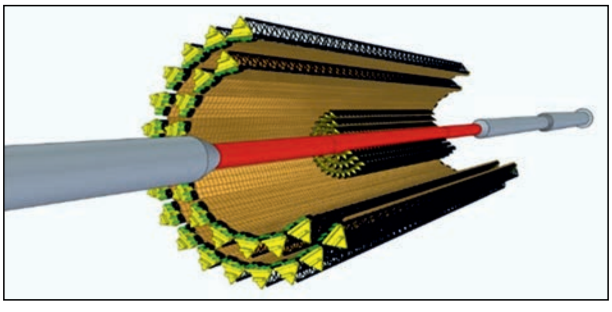


Fig. 2. 3D image of a five-layer tracker for MPD of the "optimal" variant

The run was performed in cooperation with a group from St. Petersburg State University (under the leadership of V. Zherebchevsky), which performed the study of monolithic active pixel sensors ALPIDE. These sensors will be used to develop the internal tracker of the NICA-MPD facility.

Within the project on the development of an internal tracking system of MPD-ITS, the preliminary design of the tracker was carried out (Fig. 2). A design of the facility with a thin-walled beryllium ion pipeline and related devices in the TPC zone was developed.

SPD Setup

The proposed SPD detector is aimed at implementation of the scientific program presented in LOI, supported by the PAC for Particle Physics in 2014, and should meet the following requirements:

- close to 4π geometrical acceptance;
- high-precision (~ 50 μm) and fast vertex detector;
- high-precision (~ 100 μm) and fast tracker;
- good particle ID capabilities;
- efficient muon range system;
- good electromagnetic calorimeter;
- low material budget over the track paths;
- trigger and DAQ system able to cope with event rates at luminosity of 10^{32} $(\mathrm{cm}\cdot\mathrm{s})^{-1}$;
- modularity and easy access to the detector elements, that makes further reconfiguration and upgrade of the facility possible.

In 2018, an official project "Conceptual and Technical Design of the Spin Physics Detector (SPD) at the NICA Collider" [3] was prepared to be presented for the approval at the 50th PAC for Particle Physics.

EXPERIMENTS CARRIED OUT AT THE NUCLOTRON

FASA

The kinetic energy spectra of intermediate mass fragments ($2 < Z < 20$) have been studied for the data obtained by the group in 4.4 GeV $d+$ Au collisions [4]. An example of kinetic energy spectra for boron and neon fragments is shown in Fig. 3. The strong difference between the experimental data and calculated ones in the framework of the intranuclear cascade (INC) and statistical multifragmentation model (SMM), which includes no flow, is seen. It was suggested that this enhancement is caused by the expansion of the system, which is assumed to be radial. SMM gives the coordinates R_Z and momenta of the fragments with charge Z in the freeze out volume with radius R_{sys}. To describe the experimental data, the radial velocity for each particle in freeze out volume was added. A homogeneous radial expansion was assumed, in which the flow velocity is a linear function of the particle from the center of mass. The velocity $V_{\mathrm{flow}}(Z)$ of a particle with

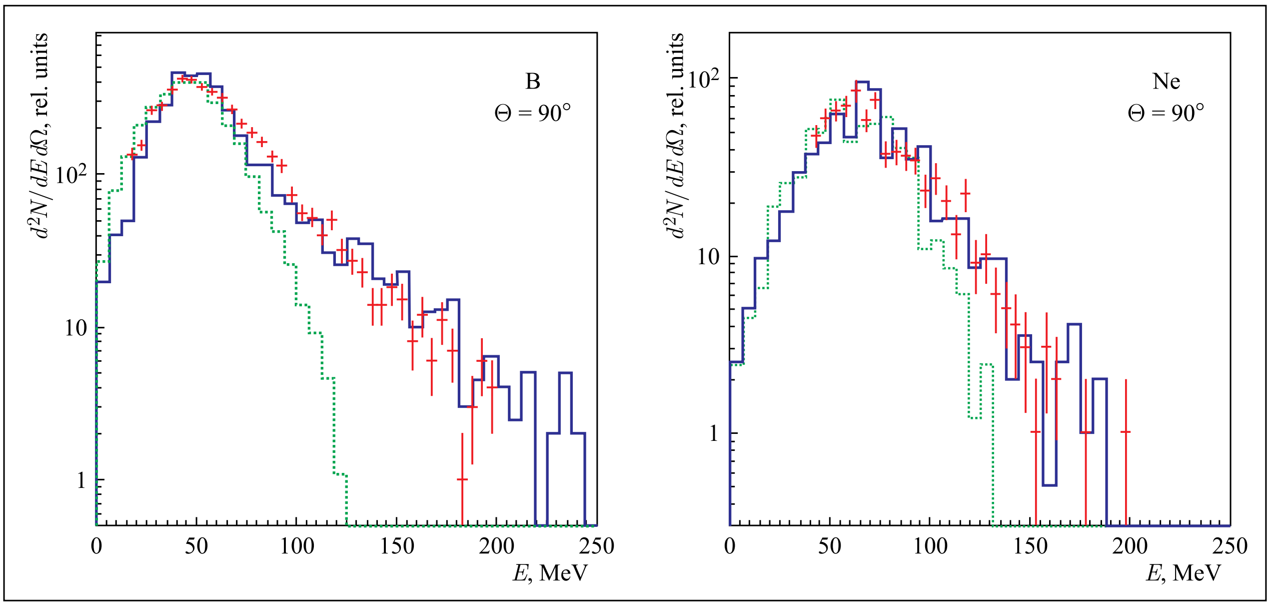


Fig. 3. Kinetic energy distributions of boron and neon fragments obtained for d (4.4 GeV) + Au collisions at polar angle $\Theta = 90^\circ$. Points are experimental data. Solid lines (blue): INC + SMM calculations with radial flow $V^0_{\mathrm{flow}} = 0.15c$ (c — light speed) for boron distribution and $V^0_{\mathrm{flow}} = 0.08c$ for neon distribution. Dotted lines (green): INC + SMM calculations without radial flow

a charge Z located on a radius R_Z was taken as follows:

$$V_{\text{flow}}(Z) = V^0_{\text{flow}} \frac{R_Z}{R_{\text{sys}}},$$

where V^0_{flow} is the radial velocity at the surface of the system. The value of V^0_{flow} has been adjusted to describe the measured kinetic energy of fragments. A good agreement of measured and calculated kinetic energy spectra including a radial flow was found.

DSS

Within the DSS project, the following important results were obtained in 2018:

• An upgraded version of the experimental facility on the internal beam for measuring short-range nucleon–nucleon correlations in the interaction of light nuclei was fully put into operation during the 55th run of the Nuclotron.

• Analysis of experimental data on the angular dependence of the elastic $d{-}p$ scattering cross section at the deuteron energies of 1000, 1300 and 1800 MeV obtained at the internal target was performed.

• Analysis of experimental data on the angular dependences of the deuteron analyzing powers A_x, A_y and A_{xx} of elastic $d{-}p$ scattering at the deuteron energies of 400, 700, 800 and 1000 MeV obtained at the internal target was performed [5].

PARTICIPATION IN EXPERIMENTS AT EXTERNAL ACCELERATORS

Experiments at the Large Hadron Collider

ALICE

New results of femtoscopic correlation functions for K^+K^- pair production in Pb–Pb collisions at 2.76 TeV per nucleon pair are presented in Fig. 4. One can see the new Dubna fit (Fig. 4, *a*) within the FSI model using traditional parameters of $a_0(980)$ (Martin, Achasov) and free ones for $f_0(980)$ with small coupling constant [6]. The data and model agreement is visibly better than for the fit with all traditional parameters (Fig. 4, *b*). The new value of f_0 width ((7.0 ± 2.2) MeV) was obtained from Dubna fit which corresponds to the one of BESIII collaboration ((9.5 ± 1.1) MeV).

New results were obtained for comparison of the ALICE femtoscopic data with the EPOS-3 model for p–Pb collisions at 5.02 TeV [7]. Figure 5, *a* shows that the data and model femtoscopic emission source radii are compatible well at the same centralities but only with including hadronic cascade rescattering mechanism.

New results were obtained with the JINR team participation for the J/ψ production in ultraperiferal Pb–Pb collisions at 5.02 TeV. The differential cross section is shown in Fig. 5, *b* with the theoretical predictions at different gluon shadowing contributions in nuclei.

The tests of the modules of the PHOS ALICE electromagnetic calorimeter were performed on the beams of electrons at PS and SPS CERN accelerators in the energy range of 1–160 GeV. This study was aimed at making the optimal choice for the upgrade of photodetectors and readout electronics. The goal of the upgrade

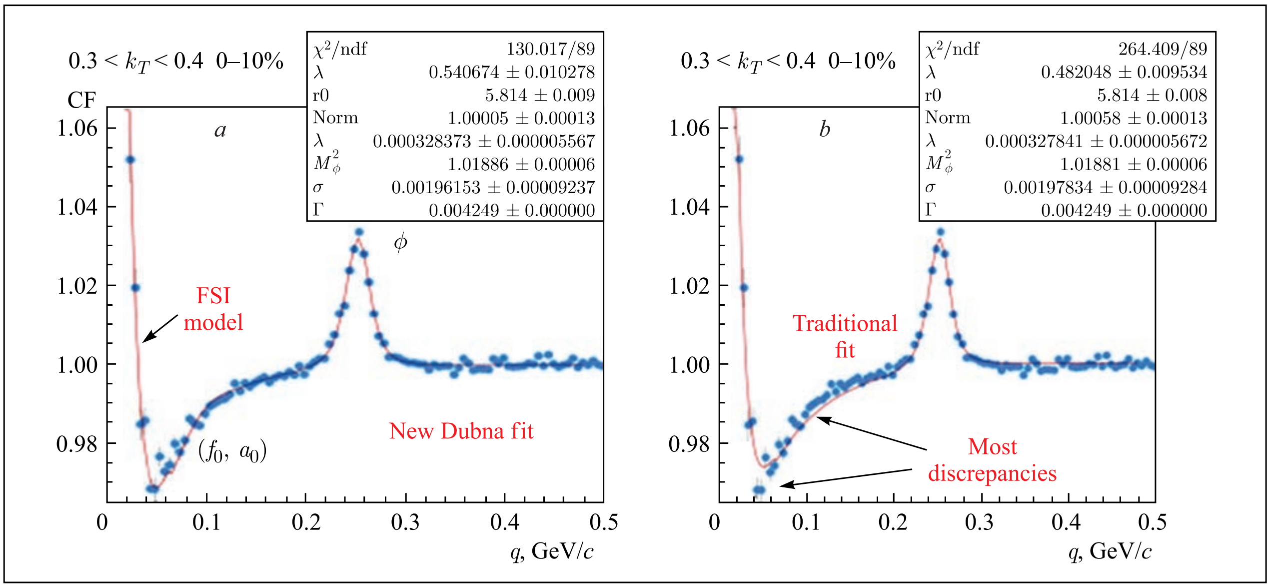


Fig. 4. The femtoscopic correlation functions for K^+K^- pairs production in Pb–Pb collisions at 2.76 TeV

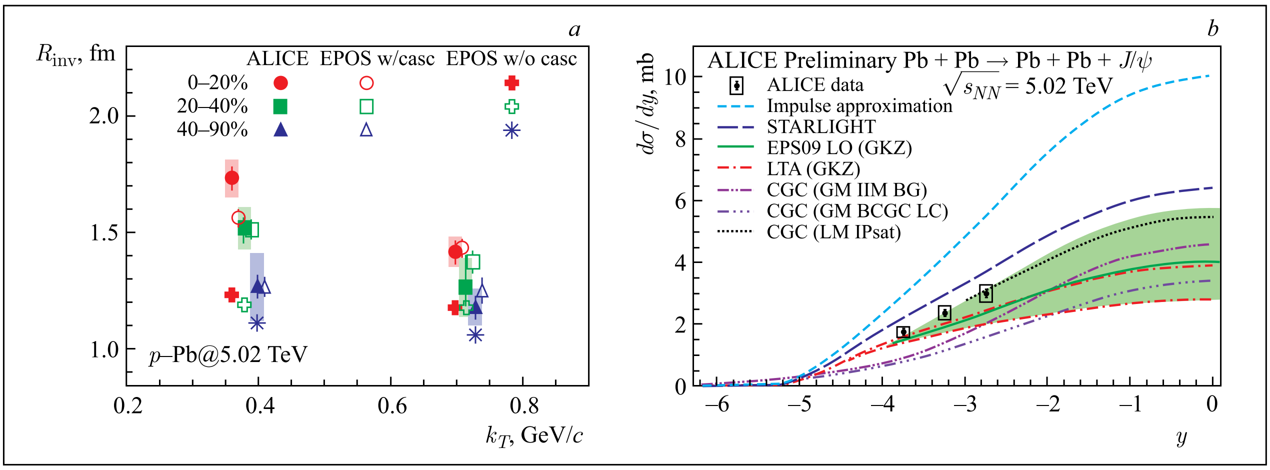


Fig. 5. *a*) Emission source radii of $K^{ch}K^{ch}$ pairs versus pair transverse momentum. *b*) Differential cross section versus rapidity of J/ψ production in comparison with different model predictions

is to provide the calorimeter functioning at the room temperature without worsening of the energy resolution and with the improvement of the time resolution. Currently, PHOS is running at the temperature of $-25\,°C$ and has the time resolution of $\sigma_t = 3{-}4$ ns. A number of tests performed on the electron beams at CERN with different SiPMs have shown that it is possible to reach the time resolution better 500 ps at working temperature $T = +18\,°C$.

ATLAS

In 2018, the ATLAS group members were engaged in the following activities: experimental data analysis, simulation of the new process including SUSY particles, participation in the ATLAS detector upgrade program for high-luminosity environment at HL-LHC as well as QCD analysis of the DIS data.

Observation of the Higgs boson decay into a pair of b quarks, reported at the major international conference ICHEP2018 in Seoul, was announced in CERN press-release, in communications from the ATLAS collaboration, and in many publications at the scientific centers (including Dubna), as the most significant result of the ATLAS experiment in 2018 [8].

The ATLAS data corresponding to an integrated luminosity of 79.8 fb^{-1} of proton–proton collisions collected at a centre-of-mass energy of $\sqrt{s} = 13$ TeV in Run-2 in 2015–2017 were analyzed. An excess over the expected background was observed, with a significance of 4.9 standard deviations compared with an expectation of 4.3σ. The measured signal strength relative to the SM prediction for $m_H = 125$ GeV was found to be $\mu = 1.06 \pm 0.16(\text{stat.}) + 0.21 - 0.19(\text{syst.})$. The invariant mass spectrum of two b jets is presented in Fig. 6.

ATLAS has already observed all four main production modes of the Higgs boson, two of which this year. These observations mark a new milestone in the study

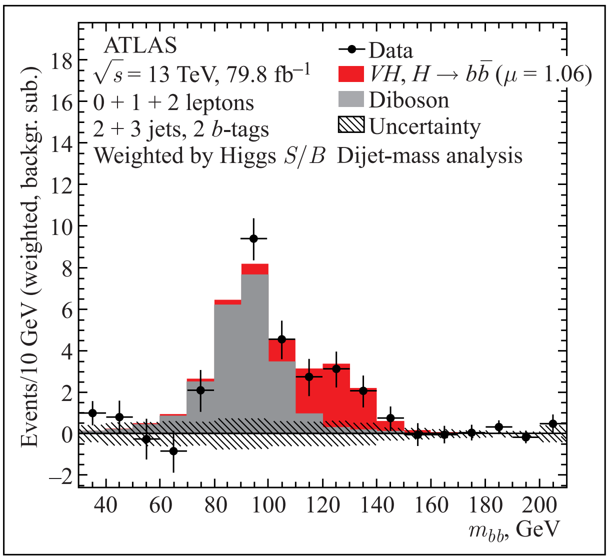


Fig. 6. The distribution of m_{bb} in data after subtraction of all backgrounds except for the WZ and ZZ diboson processes, as obtained with the dijet-mass analysis. The contributions from all lepton channels, p_T^V regions and number-of-jets categories are summed and weighted by their respective S/B, with S being the total fitted signal and B the total fitted background in each region. The expected contribution of the associated WH and ZH production of a SM Higgs boson with $m_H = 125$ GeV is shown scaled by the measured signal strength ($\mu = 1.06$). The size of the combined statistical and systematic uncertainties for the fitted background is indicated by the hatched band

of the Higgs boson, as ATLAS transitions from observations to precise measurements of its properties. Precision analysis of the $H \to bb$ decay for the Higgs boson produced in association with the vector boson W/Z is also promising for searches for the new physics beyond the Standard Model.

CMS

In 2018, the JINR group took part in data taking, processing and physics analysis of data collected during the LHC Run-2 with the proton beams at energy of 13 TeV and luminosity up to $2.32 \cdot 10^{34}$ $\mathrm{sm}^{-2} \cdot \mathrm{s}^{-1}$. Figure 7 shows the result on the search for new neutral resonances (both with spin 1 and spin 2) in expected decays to muon pairs. The model-independent 95% CL upper limits on cross sections of these processes were measured, as well as the 95% CL mass limits for these resonance states were set (Fig. 8). The new mass limits are 4.5 and 3.7 TeV for the sequential standard model (SSM) and the ψ model of E_6 GUT, respectively; for the Randall–Sundrum model with the coupling $c = 0.01-0.1$, masses less than $2.00-4.01$ TeV are excluded; for a simplified dark matter model with the exchange of a mediator particle in the s-channel, the mediator mass is excluded for less than 1.8 and 4 TeV, for vector and axial-vector coupling constants, respectively [9]. Moreover, the results on the dependence of the muon momentum resolution on the momentum using two muon tracks produced by cosmic muons were obtained [10].

In 2018, the analysis of the high-multiplicity events (leptons, photons, and jets with $p_T > 50$ GeV/c) was completed with the first Run-2 data ($L_{\mathrm{int}} = 35.9\ \mathrm{fb}^{-1}$). The model-independent 95% CL limits on the product of the cross section and the acceptance of a new physics signal in these final states are set for the different categories of events with multiplicity $N \geqslant 11$ and for the S_T value of $1.5-8.0$ TeV. Semiclassical black holes and string balls with masses as high as $7.2-10.2$ TeV are excluded for the value of the fundamental Planck mass M_D of 7.5–10 TeV/c^2.

Experiments at the CERN Super Proton Synchrotron

COMPASS

In 2018, the COMPASS collaboration performed an additional data taking on the Drell–Yan measurements program using a polarized hydrogen target and a pion beam with energy 160 GeV.

The K^- over K^+ multiplicity ratio was measured in deep-inelastic scattering, for the first time for kaons carrying a large z fraction of the virtual-photon energy [11]. The data were obtained by the COMPASS collaboration using a 160 GeV muon beam and an isoscalar ^{6}LiD target. Kaons are identified in the momentum range from 12 to 40 GeV/c, thereby restricting the range in Bjorken-x to $0.01 < x < 0.40$. The z-dependence of the multiplicity ratio is studied for $z > 0.75$ (Figs. 9 and 10). For large z values, $z > 0.8$, the results contradict expectations obtained using the formalism of (next-to-) leading order perturbative quantum chromodynamics. This may imply that cross-section factorization or/and universality of (kaon) fragmenta-

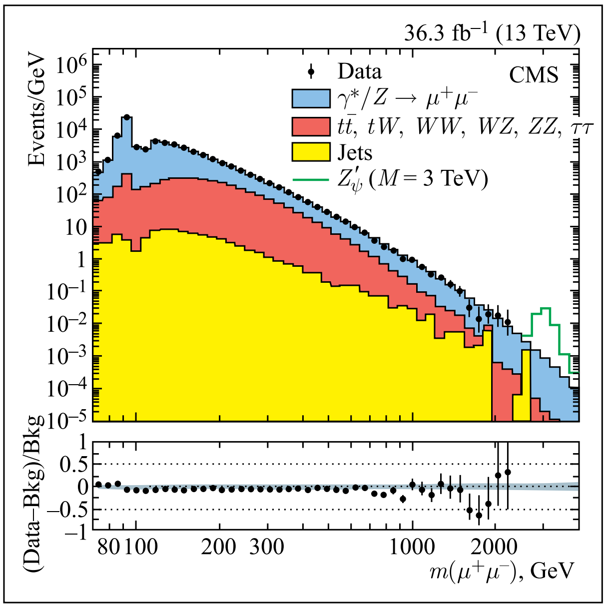


Fig. 7. The invariant mass spectrum of dimuon events. The data of 2016 at 13 TeV are used. The points with error bars represent the observed yield. The histograms represent the expectations from the SM processes

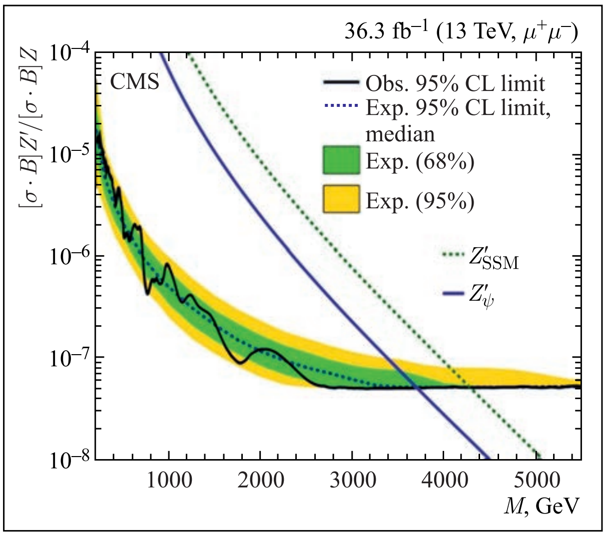


Fig. 8. The upper limits at 95% CL on the product of production cross section and branching fraction for a spin 1 resonance, relative to the product of production cross section and branching fraction of a Z boson, for the dimuon channel. The shaded bands correspond to the 68 and 95% quantiles for the expected limits. Theoretical predictions for the spin 1 Z'_{SSM} and Z'_ψ resonances are shown for comparison

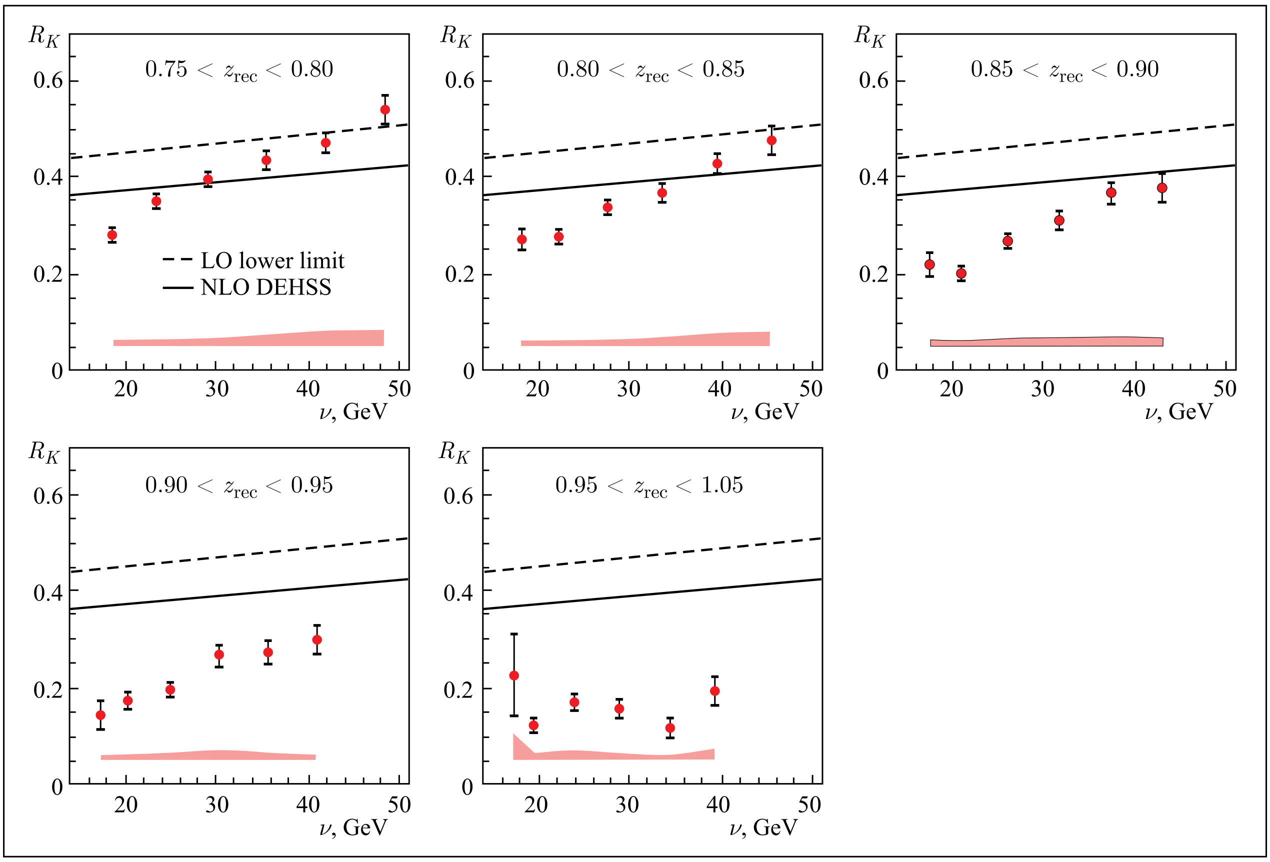


Fig. 9. The K^-/K^+ multiplicity ratio as a function of ν in bins of z, shown for the first bin in x. QCD predictions are given in solid and dashed lines

tion functions do not hold. Our studies suggest that within this formalism an additional correction may be required, which takes into account the phase space available for hadronization.

For the first time, COMPASS has performed the measurements of exclusive single-photon muoproduction on the proton using 160 GeV/c polarized μ^+ and μ^- beams of the CERN SPS impinging on a liquid hydrogen target. One has determined the dependence of the average of the measured μ^+ and μ^- cross sections for deeply virtual Compton scattering on the squared four-momentum transfer t from the initial to the final proton. The slope B of the t-dependence is fitted with a single exponential function for range $0.1-2$ (GeV/c)^2. This result can be converted into an average transverse extension of partons in the proton, for the average virtuality of the photon $\langle Q^2 \rangle = 1.8$ (GeV/c)^2 and the average value of the Bjorken variable equal to $x_{\rm Bj} = 0.056$ [12].

NA61/SHINE

In 2018, NA61/SHINE detected the first preliminary indication of critical point observation (Fig. 11). Intermittency signal in protons is expected to increase close to the critical point. At the critical point, a local power law dependence of fluctuations is expected. Preliminary results from the data analysis of Be + Be and Ar + Sc collisions could be the first possible evidence of critical point at Ar + Sc, while there is no signal in Be + Be data.

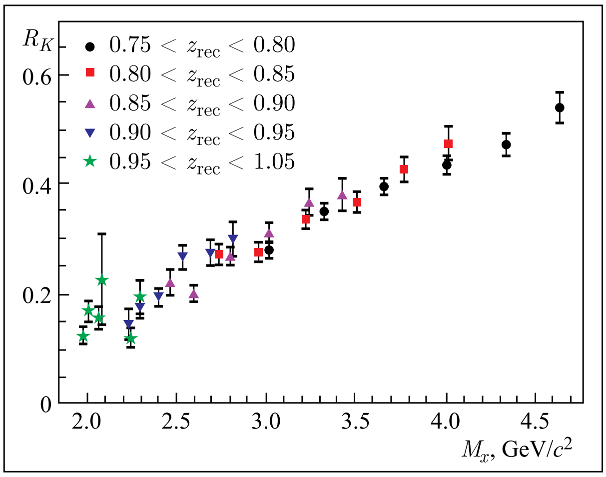


Fig. 10. The K^-/K^+ multiplicity ratio presented as a function of x

NA62

The search for heavy neutral lepton production in K^+ decays has been performed on the basis of NA62 data collected in 2015 [13]. Upper limits in the range from 10^{-7} to 10^{-6} have been set on the squared mixing matrix element $|U_{e4}|^2$ and $|U_{\mu 4}|^2$ for heavy neutrino masses in the ranges 170–448 MeV/c^2 and 250–373 MeV/c^2, respectively.

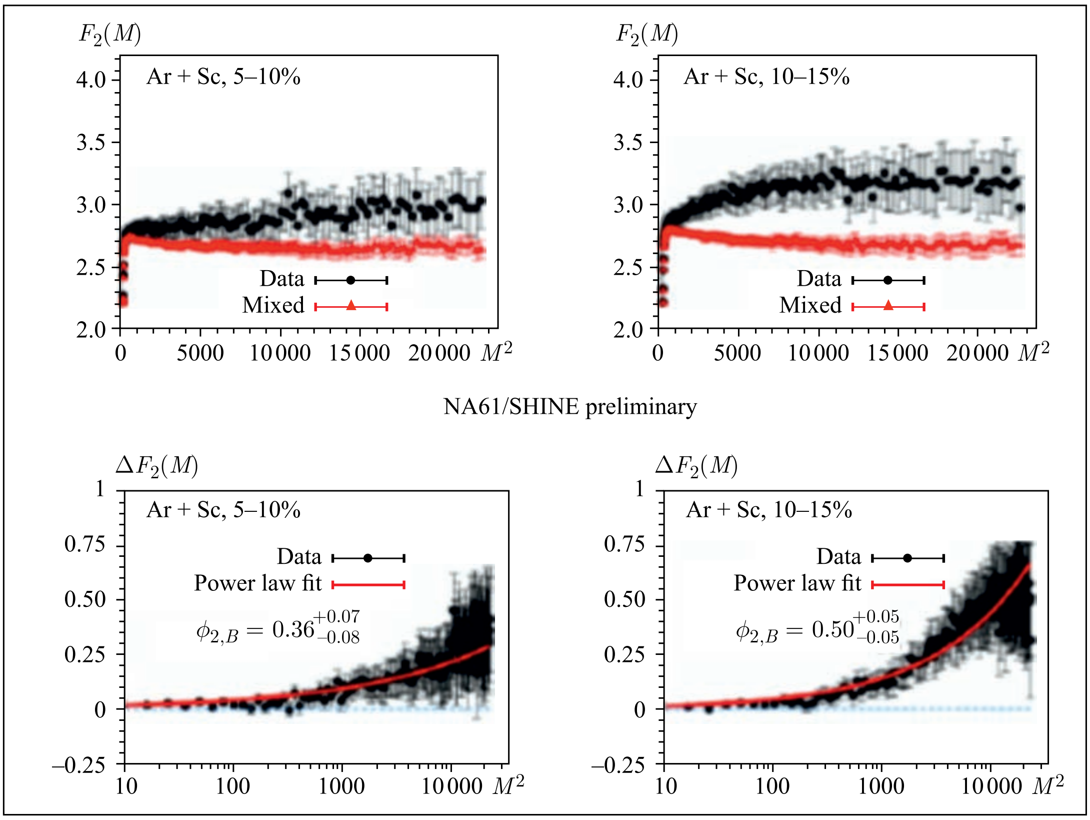


Fig. 11. Top: factorial moments $F_2(M)$ of identified protons in Ar + Sc collisions at 150A GeV/c for data (black) and mixed events (red). Bottom: background subtracted factorial moment $\Delta F_2(M)$ exhibits a power law behavior predicted for the systems being in the vicinity to the critical point. This could be the first evidence of critical point signal in the NA61/SHINE

The final paper on the K_{e3} and $K_{\mu 3}$ semileptonic decays form factors based on the NA48/2 data is published [14]. A measurement of the form factors of charged kaon semileptonic decays is presented, based on $4.4 \cdot 10^6$ K_{e3} and $2.3 \cdot 10^6$ $K_{\mu 3}$ decays collected in 2004 by the NA48/2 experiment. The results are obtained with the improved precision in comparison to earlier measurements. The combination of measurements in both semileptonic modes is also presented.

The final paper on the results of the NA48/2 analysis of the rare decay $K^\pm \to \pi^\pm \pi^0 e^+ e^-$, which had not been observed earlier, was published [15]. Results are based on $1.7 \cdot 10^{11}$ $K_{\rm ch}$ decays recorded in 2003–2004. A sample of 4919 candidates with 4.9% background contamination allows determining the branching ratio BR $= (4.24 \pm 0.14) \cdot 10^{-6}$. The study of the kinematic space shows the evidence for a structure-dependent contribution in agreement with predictions based on chiral perturbation theory (ChPT). Several P- and CP-violating asymmetries are also evaluated.

The first NA62 result on the search for $K^+ \to \pi^+ \nu\bar{\nu}$ decay based on small subsample of the data collected in 2016 (corresponding to $1.21 \cdot 10^{11}$ K^+ decays) has been published [16] (Fig. 12). The single event sensitivity is $3.15 \cdot 10^{-10}$ which corresponds to 0.267 Standard Model events. One signal candidate is observed, while the expected background is 0.152 events.

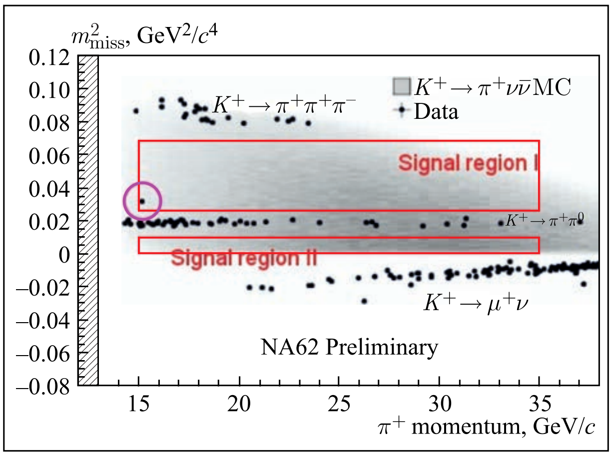


Fig. 12. The first NA62 result on the search for $K^+ \to \pi^+ \nu\bar{\nu}$ decay based on small subsample of the data collected in 2016 (corresponding to $1.21 \cdot 10^{11}$ K^+ decays)

The analysis of NA48/2 data in order to investigate the rare decay $K^{00}_{\mu 4}$, which has never been observed earlier, is in progress. The events selection for background suppression is developed, the first estimation of branching fraction is in agreement with the available theoretical ChPT prediction.

NA64

The main objective of the NA64 experiment is the search for physics beyond the SM, namely, the search for a light dark photon (A') and other signs of the dark sector.

In 2018, during two runs at the SPS CERN channel, a test run (April 2018) and a data taking one (May–June 2018), six stations of straw detectors (12 double-layer cameras with the size of 200×200 mm) were tested and functioned successfully. JINR staff took part in the installation and dismantling of the equipment, maintenance of straw detectors as experts, work in data taking shifts and on-line analysis of the collected data. During the run, $2 \cdot 10^{11}$ events were collected in the invisible mode and $3 \cdot 10^{10}$ in the visible one, data analysis goes on.

In 2018, the collaboration completed the analysis, and the data of 2016 and 2017 on the search for a signal of the dark photon in the invisible decay mode were published. Summary statistics of them amounted to $\sim 10^{11}$, but no candidate signal that corresponds to the signature of a dark photon was detected [17].

In 2017 the run was partially devoted to the search for a new hypothetical X boson with the mass of 16.7 MeV, the existence of which could explain the result on the anomalous production of e^+e^- pairs in the decay of the excited state of ^{8}Be* obtained in the ATOMKI experiment, $5.4 \cdot 10^{10}$ events were taken. The hypothetical boson was not detected, the data obtained allowed to significantly increase the constraint on the probability of its production, complementing the results of other research groups [18] (Fig. 13).

In 2018, the experiment got a permanent experimental zone at CERN on the H4 channel, preparatory works on its arrangement were started.

Experiments at the Relativistic Heavy Ion Collider, BNL

STAR

In 2018, the STAR collaboration reported a new physics phenomenon which had been predicted by the JINR group.

• To study the chiral magnetic effect, a run was conducted and statistics was collected on the isobar nuclei Zr-96 and Ru-96 at the energy of 200 GeV.

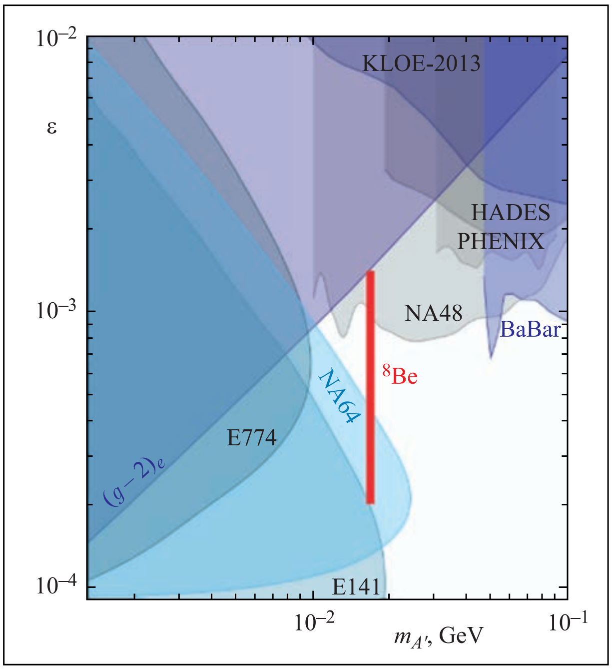


Fig. 13. The 90% CL exclusion areas in the $(m_{A'}; \varepsilon)$ plane from the NA64 (blue area). For the mass of 16.7 MeV, the region excluded by NA64 is $1.3 \cdot 10^{-4} < \varepsilon < 4.2 \cdot 10^{-4}$. The allowed range of ε explaining the ^{8}Be* anomaly (red area) and constraints from other experiments are shown

• Earlier (in 2017), the global polarization of lambda in the energy range of 10–60 GeV had been detected. In 2018, new data on the presence of global polarization of Λ and $\bar{\Lambda}$ at maximum RHIC energy of 200 GeV were published. A special area of research interests of the Dubna group in the STAR experiment is the study of global polarization in the range of NICA energies in the collider mode and the corresponding measurements with a fixed target in the STAR experiment.

• One of the new results is the study of the antiproton correlation function. These are direct measurements of antinucleon interactions. New results on pp and $\bar{p}\bar{p}$ at 39 GeV were presented at the international conference "Quark Matter 2018" (Venice, Italy).

REFERENCES

1. *Sidorin A. et al.* Status of the Nuclotron // Proc. of RuPAC2018, Protvino, Russia, 2018. P. 49–51.
2. *Baranov D. et al.* First Results from BM@N Technical Run with Deuteron Beam // Phys. Part. Nucl. Lett. 2018. V. 15, No. 2. P. 148–156.
3. *SPD Team.* Conceptual and Technical Design of the Spin Physics Detector (SPD) at the NICA Collider, October 2018; http://indico.jinr.ru/conferenceDisplay.py?confId=665.
4. *Avdeyev S. P., Karcz W., Kirakosyan V. V., Rukoyatkin P. A., Stegaylov V. I., Oeschler H., Botvina A. S.* Time Scale of the Thermal Multifragmentation in ^{4}He(4 GeV) + Au Collisions // Bull. Russ. Acad. Sci.: Phys. 2018. V. 82, No. 6. P. 711.
5. *Janek M. et al.* Calibration Procedure of the $\Delta E - E$ Detectors for *dp* Breakup Investigation at Nuclotron // Phys. Part. Nucl. Lett. 2018. V. 15. P. 76.
6. *Acharya S. et al. (ALICE Collab.).* Azimuthally Differential Pion Femtoscopy Relative to the Third Harmonic Event Plane in Pb–Pb Collisions at $(s_{NN})^{1/2} = 2.78$ TeV // Phys. Lett. B. 2018. V. 785. P. 320–331.
7. *Acharya S. et al. (ALICE Collab.).* Inclusive J/ψ Production in Xe–Xe Collisions at $(s_{NN})^{1/2} =$

5.02 TeV // Phys. Lett. B. 2018. V. 785. P. 419–428.

8. *The ATLAS Collab.* Observation of $H \to bb$ Decays and VH Production with the ATLAS Detector // Phys. Lett. B. 2018. V. 786. P. 59; DOI:10.1016/j. physletb.2018.09.013; ATLAS CONF Note: ATLAS-CONF-2018-036; https://cds.cern.ch/record/2630338/files/ATLAS-CONF-2018-036.pdf.
9. *Sirunyan A. M. et al. (CMS Collab.).* Search for High-Mass Resonances in Dilepton Final States in Proton–Proton Collisions at 13 TeV // JHEP. 2018. V. 1806. P. 120; arXiv:1803.06292.
10. *Abbiendi G. et al.* Performance of High-p_t Muons Collected with CMS at 13 TeV during Proton–Proton Collisions. CMS AN-2018/008.
11. *COMPASS Collab.* K^- over K^+ Multiplicity Ratio for Kaons Produced in DIS with a Large Fraction of the Virtual-Photon Energy // Phys. Lett. B. 2018. V. 786. P. 390.
12. *COMPASS Collab.* Transverse Extension of Partons in the Proton Probed by Deeply Virtual Compton Scattering. CERN-EP/2018-016; Phys. Lett. B (submitted).
13. *Cortina Gil E. et al. (NA62 Collab.).* Search for Heavy Neutral Lepton Production in K^+ Decays // Phys. Lett. B. 2018. V. 778. P. 137.
14. *Batley J. R. et al. (NA48/2 Collab.).* Measurement of the Form Factors of Charged Kaon Semileptonic Decays // JHEP. 2018. V. 1810. P. 150.
15. *Batley J. R. et al. (NA48/2 Collab.).* First Observation and Study of the $K^\pm \to \pi^\pm\pi^0e^+e^-$ Decay. arXiv:1809.02873 [hep-ex]; Phys. Lett. B (submitted).
16. *Cortina Gil E. et al. (NA62 Collab.).* First Search for $K^+ \to \pi^+\nu\nu$ Using the Decay-in-Flight Technique. CERN-EP-2018-314.
17. *Banerjee D. et al. (NA64 Collab.).* Search for Vector Mediator of Dark Matter Production in Invisible Decay Mode // Phys. Rev. D. 2018. V. 97. P. 072002.
18. *Banerjee D. et al. (NA64 Collab.).* Search for a New $X(16.7)$ Boson and Dark Photons in the NA64 Experiment at CERN // Phys. Rev. Lett. 2018. V. 120. P. 231802.

DZHELEPOV LABORATORY OF NUCLEAR PROBLEMS

NEUTRINO PHYSICS AND RARE PHENOMENA, ASTROPHYSICS

The Baikal neutrino telescope is one of the three largest operating detectors in terms of effective volume and effective area for natural neutrino flux observation and the largest in the North Hemisphere. The most important achievement in 2018 is the construction of the third cluster of the deep underwater detector in Lake Baikal as the next step to the full-scale **Baikal-GVD** detector. The detector-2018 consists of 864 optical modules (OMs) assembled on 24 vertical strings (8 strings in each cluster) distributed at the depth of 750–1250 m. The deep underwater detector GVD-2018 has the effective volume of about 0.16 km^3 for cascade registration, which allows looking into the astrophysical neutrino flux of ultra-high energy detected in IceCube experiment [1]. During 2018, the detector was run in the regular data-taking mode and in special test regimes. Also, the assembling and testing of more than 600 OMs for next-stage clusters (4 and 5) of the Baikal-GVD were conducted in Dubna (JINR) and Moscow (INR). The analysis of the 2016–2017 experimental data also proceeded during this year. A limit on the neutrino flux from the event GW170817 was obtained [2].

The **Daya Bay** experiment has collected the largest statistics of electron antineutrino interactions, almost 4.5 million events. With the background contribution below 2%, the total statistical uncertainty does not exceed 0.3%. The most precise measurement of the neutrino mixing angle θ_{13} and the second precise measurement Δm^2_{23} [3] were obtained. Based on the previous dataset of 2.5 million events, the measurement of the reactor electron antineutrino flux was updated. It confirmed the 5% discrepancy between the experimental data and the Huber–Mueller model prediction [4].

Within the **JUNO** project, the support structure for the Top Tracker (TT) of the muon detector was developed. Several prototypes were built and tested. The contract for fabrication is under preparation. The TT modules are stored at the JUNO site until 2020. In order to monitor the TT stability, the modules are now operating as a cosmic muon detection system. Brand new High Voltage Units (HVU) were designed in collaboration with dedicated companies for both large and small photomultipliers of the JUNO experiment. Testing facilities for quality control and long-term tests of the HVUs were developed. The JINR group is fully responsible for mass production and test of the JUNO HVUs.

In 2018, within the **Borexino** project, the results of the most complete and precise analysis of neutrino fluxes accompanying solar thermonuclear processes were published [5], which were obtained with an active participation of the JINR group. The project of the 20-t two-phase time-projection chamber based on liquid argon intended for Dark Matter (DM) search (DarkSide-20k experiment) was published. The results of the DM search in the DarkSide-50 detector were published, namely, limits on spin-independent DM-nucleon scattering for WIMP particles with masses of 100 GeV, 1 TeV and 10 TeV; limits on spin-independent DM-nucleon scattering for WIMPs starting from 1.8 GeV with the strongest limits in the 1.8–6 GeV range [6]; and limits on the DM-electron scattering for the DM particle energy up to 1 GeV.

During 2018, within the **NOνA** experiment, new oscillation results from measurement of electron neutrino appearance and muon neutrino disappearance modes were published [7]. Also, the first analysis of the data collected in both neutrino and antineutrino beams was performed. Analysis of the antineutrino beam statistics corresponding to $6.91 \cdot 10^{20}$ protons-on-target (POT) added to the neutrino beam dataset corresponding to $8.85 \cdot 10^{20}$ POT allowed obtaining 58 candidate events of ν_e, 18 of anti-ν_e, 113 of ν_μ, and 65 of anti-ν_μ with the background level of 15.1, 5.3, 5.0, and 1.4 events, respectively. From the combined fit of these data, the normal hierarchy of neutrino masses is preferred at the

1.8σ level, the value of δCP $= \pi/2$ is excluded at 3σ, and lower octant and maximal mixing for θ_{23} is excluded at 1.8σ. Further increase in statistics allows the NOνA experiment to reach sensitivity of 3σ for the mass hierarchy by 2020 and significantly improve δCP determination by 2024. The NOνA remote operation center and computing infrastructure at JINR are routinely operating. Members of the NOνA group at JINR are actively involved in the experiment with the tasks of physics analysis coordination, management of the online and offline software, and expert duties during the detector operation.

Within the **SuperNEMO** project at the Modane Underground Laboratory, the Demonstrator Module has been finally closed. This was preceded by the installation of foil sources and a calibration system made during 2018. An important article of NEMO-3 with the final results on ^{82}Se was published [8]. The 2$\nu\beta\beta$-decay half-life of ^{82}Se is $T_{1/2}(2\nu) = (9.39 \pm 0.17(\text{stat.}) \pm 0.58(\text{syst.})) \cdot 10^{19}$ y under the single-state dominance hypothesis for this nuclear transition. The corresponding nuclear matrix element is $|M^{2\nu}| = 0.0498 \pm 0.0016$. In addition, a search for 0$\nu\beta\beta$ decay using 0.93 kg of ^{82}Se was continued and no evidence for a signal was found. The resulting half-life limit is $T_{1/2}(0\nu) > 2.5 \cdot 10^{23}$ y (90% CL), which corresponds to the Majorana neutrino mass $\langle m_\nu \rangle < (1.2{-}3.0)$ eV.

In 2018, on the basis of the accumulated experimental data on the WIMP search, the **EDELWEISS** collaboration derived limits (Figs. 1 and 2) on several hypothetical processes beyond the Standard Model: emission of axions or Axion Like Particles (ALPs) from the Sun, absorption of bosonic keV-scale DM particles from our galactic halo, etc. These limits are a significant im-

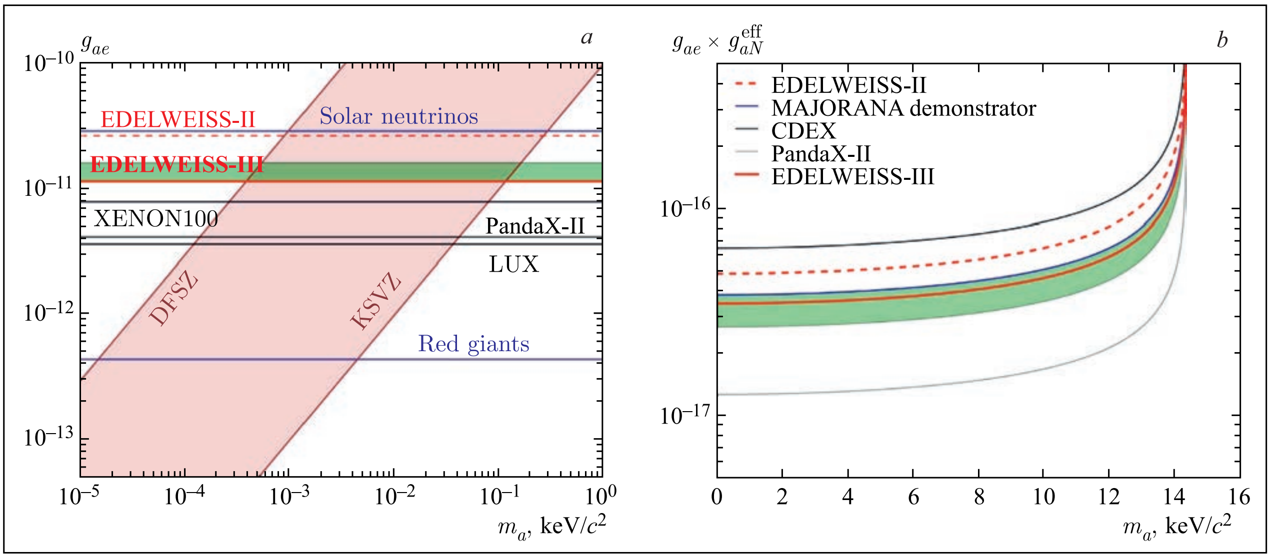


Fig. 1. EDELWEISS 2018 limits on the solar axion–electron coupling: obtained from the lack of observation of a CBRD signal (*a*) and derived from the absence of observation of the 14.4 keV line (*b*)

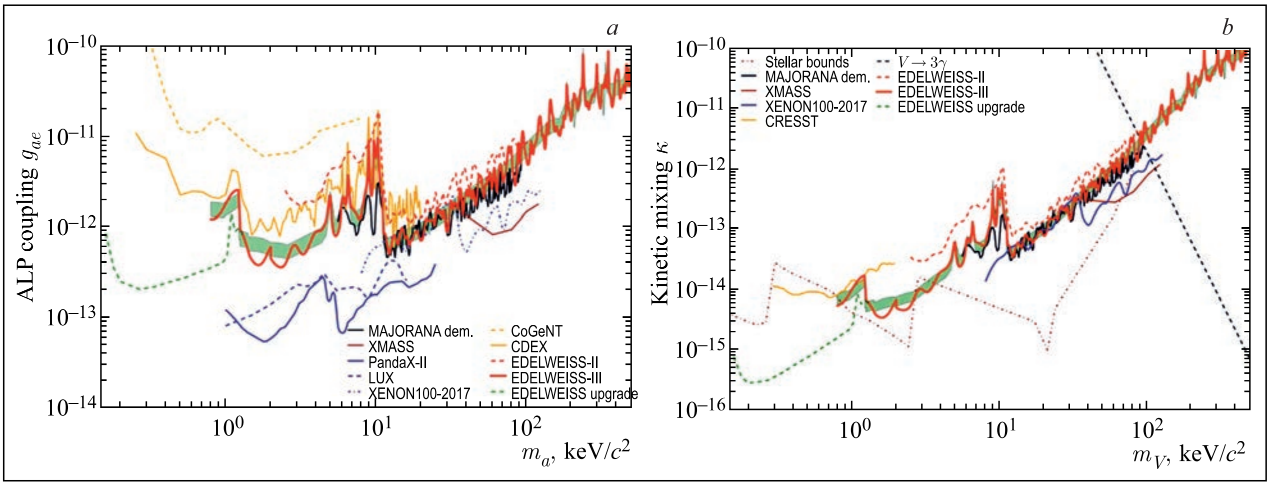


Fig. 2. *a*) Limits on the ALP dark matter coupling to electrons from EDELWEISS and other direct search experiments. *b*) Limits on the hidden photon DM kinetic mixing from direct searches (bosonic DM). The green dashed lines are sensitivity projections for upgraded EDELWEISS detectors

provement with respect to the previous results. For processes with an associated electron recoil energy below 6 keV, EDELWEISS provided the best limits from the spectroscopic Germanium-based experiment and started to explore new parameter space for bosonic DM scenarios with a mass below 1 keV [9, 10]. A significant progress was made in the ongoing R&D of new lower-energy threshold detectors. New bolometer detectors capable of detecting recoil nuclei with unprecedented low energies from ~ 20 eV were developed. The data obtained during the R&D phase are being processed. The first results are planned to be published in the first half of 2019. It should be mentioned that participation in the EDELWEISS project gives JINR an important access to the low-background infrastructure for development and test of low-radioactive low-energy threshold setups for neutrino experiments at the Kalinin Nuclear Power Plant (KNPP).

Within the **GERDA** experiment, about 60 $\mathrm{kg \cdot y}$ of data were accumulated in Phase II by April 2018. The total amount of data collected in both phases of the GERDA experiment exceeded 80 $\mathrm{kg \cdot y}$. The background index is improved by almost a factor of two compared to the 2017 release, $\sim 6 \cdot 10^{-4}$ counts/(keV $\cdot$ kg $\cdot$ y), being the best result amongst all double-beta decay experiments when normalized to the energy resolution. No event close to $Q\beta\beta$ was found, and a 90% CL lower limit of $T_{1/2}^{0\nu} > 0.9 \cdot 10^{26}$ y was set for the frequentist analysis. The median sensitivity overpassed 10^{26} y for the first time ever, which is a very important milestone for the $0\nu\beta\beta$ search [11]. In 2018, the GERDA collaboration also performed the upgrade aimed at testing the novel Ge detectors and increasing the mass of ^{76}Ge, as well as showing the possibility of improving the background index and proving the robustness and reproducibility of the GERDA approach, which is very important for the future Ge experiments. GERDA will take data until the design exposure of 100 $\mathrm{kg \cdot y}$ is reached (at the end of 2019) [12]. At that time the sensitivity should be well above 10^{26} y. However, this sensitivity will not allow getting information about the neutrino mass hierarchy. In order to address this issue, the new-generation experiment LEGEND is under preparation. It is supposed to have at least two phases. The first phase (LEGEND-200) will operate with ~ 200 kg of enriched isotope, and the expected sensitivity will be 10^{27} y. LEGEND-200 will be carried out in the modified GERDA infrastructure at Laboratori Nazionali del Gran Sasso (LNGS). The goal is to start data taking in the first phase of LEGEND in 2021.

The **GEMMA-III** project is a new experiment constructed under reactor #3 of the Kalinin Nuclear Power Plant (KNPP). It is an evolution of the GEMMA and νGEN experiments. GEMMA-I set the world's best upper limit on the magnetic moment of the neutrino $< 2.9 \cdot 10^{-11} \mu_{\mathrm{B}}$ (90% CL). The new experimental setup will be located at about of 10 m-distance from the 3 GW reactor core. It allows working with an enormous neutrino flux of more than $5 \cdot 10^{13}$ $\mathrm{cm^{-2} \cdot s^{-1}}$ (the best conditions in the world among the experimental facilities). Moreover, the experimental setup is located under the reactor, which gives about 50 m w.e. of overburden, reducing the background caused by cosmic radiation. Signals from neutrino scattering will be detected by low-energy HPGe detectors of a new type, which allows reaching 200-eV threshold. The detectors are produced in collaboration with Canberra company (Mirion, Lingosheim). In August 2018, the detector was moved to JINR for further investigations with new electronics, in a configuration identical to the one to be used at KNPP. The energy resolution obtained with pulsed generation was 78.0(3) eV (FWHM). The demonstrated energy threshold is about 200 eV. It will allow signals from CEvNS to be detected. Assembly of the GEMMA-III experimental setup at KNPP started at the end of 2018.

The **DANSS** detector has started to operate at unit 4 of KNPP in 2016. It registers about 4000 neutrinos per day with a background less than 2–3% (both values are the world's best now). Due to a lifting gear, the detector is on-line movable by 2 m, thus measuring the neutrino energy spectrum as a function of the distance. In addition to the reactor diagnostics, this feature allows investigating short-range neutrino oscillations (i.e., periodic variation in the neutrino flux with distance) in the way independent of any questionable assumptions about the theoretical neutrino spectrum. In 2018, the first portion of the data (approximately one year of measurement) was analyzed and the strictest model-independent limit [13] of the sterile neutrino existence was obtained. The data acquisition and the detailed analysis are in progress.

The gamma-ray observatory **TAIGA** targets the energy range above 30 TeV. The observatory combines several IACTs (Imaging Atmospheric Cherenkov Telescope) with a net of comparatively cheap wide-angle non-imaging optical detectors — HiSCORE detectors. The combination of two complementary methods of gamma-ray separation allows building a device with a large area at a relatively low price. TAIGA will include a network of 500 HiSCORE detectors and up to 16 IACTs covering an area of 5 $\mathrm{km^2}$ and muon detectors with a total sensitive area of 2000 $\mathrm{m^2}$ distributed over an area of 1 $\mathrm{km^2}$. Since TAIGA will be the northernmost gamma observatory, its location provides some advantages for observing the sources with large declinations. Within the TAIGA project, JINR is responsible for the mechanical platform of the IACT. In addition, JINR participates in the data taking in the Tunka area, MC simulation, and physical analysis [14]. The first IACT has been taking data since 2016, and the second IACT was produced in 2018.

In 2018, within the **OPERA** experiment, a new advanced approach was applied to the data selection, which allowed increasing the number of the tau-neutrino events up to 10 (with 2 expected background events) and increasing the statistical significance of the discovery up to 6 sigmas [15]. The paper on new restrictions for the contribution of non-standard oscillations in the ν_μ to ν_e channel (of the LSND type) was published [16].

PHYSICS OF ELEMENTARY PARTICLES

Within the **ATLAS** project, a search for the decay of the Standard Model (SM) Higgs boson into a bb pair when produced in association with a W or Z boson is performed. The data corresponding to an integrated luminosity of 79.8 fb^{-1} were collected in proton–proton collisions during Run 2 of the Large Hadron Collider (LHC) at a centre-of-mass energy of 13 TeV. For a Higgs boson mass of 125 GeV, an excess of events over the expected background from other SM processes is found with an observed (expected) significance of 4.9 (4.3) σ. A combination with the results from other searches in Run 1 and Run 2 for the Higgs boson in the bb decay mode is performed, which yields an observed (expected) significance of 5.4 (5.5) σ, thus providing direct observation of the Higgs boson decay into b quarks. The ratio of the measured event yield for a Higgs boson decaying into $b\bar{b}$ to the SM expectation is $\mu = 1.01 \pm 0.12(\mathrm{stat.})^{+0.16}_{-0.15}(\mathrm{syst.})$ (Fig. 3, *a*). Additionally, a combination of the Run 2 results of searching for the Higgs boson produced in association with a vector boson yields an observed (expected) significance of 5.3 (4.8) σ [17].

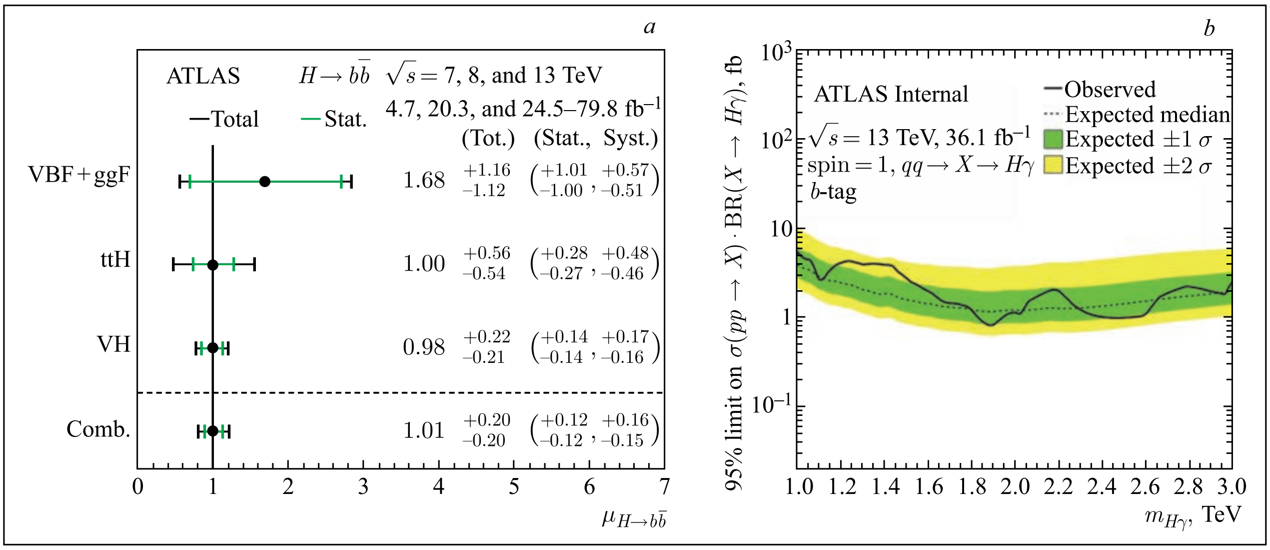


Fig. 3. *a*) The fitted values of the Higgs boson signal strength parameter μ for $m_H = 125$ GeV based on the 7, 8, and 13 TeV data. *b*) Production cross-section limits for the $H\gamma$ resonance as a function of its mass

A search for new resonances with a mass larger than 1 TeV decaying to a W, Z, or Higgs boson and a photon is performed. The dataset consists of an integrated luminosity of 36.1 fb^{-1} of pp collisions collected at $\sqrt{s} = 13$ TeV with the ATLAS detector at the LHC. The $W/Z/H$ bosons are identified through their decays to hadrons. The data are found to be consistent with the expected background in the entire mass range investigated, and upper limits are set on the production cross-section times decay branching ratio to $W/Z/H + \gamma$ of a narrow scalar boson with a mass between 1 and 6.8 TeV (Fig. 3, *b*) [18].

Within the **COMPASS** project, the search for the photoproduction of the charmonium-like resonance $X(3872)$ in the reaction $\gamma^* N \to X(3872)\pi^\pm N' \to (J/\psi\pi^+\pi^-)\pi^\pm N'$ revealed a signal with the statistical significance of 4.1σ in the spectrum of invariant masses of the $J/\psi\pi^+\pi^-$ subsystem of the final state (Fig. 4, *a*). The mass and the width of the observed particle are fully consistent with the expected ones for $X(3872)$, while a detailed analysis of the decay kinematics of the observed particle showed complete disparity with the well-known decay kinematics of $X(3872)$. The invariant mass distributions for two pions produced in the decay of $X(3872)$ observed in the ATLAS experiment, where the ρ^0-meson signal is visible, and at COMPASS (Fig. 4, *b*) allow an assumption that the discovered signal may belong to a new particle that was called $\tilde{X}(3872)$, which is a partner particle of $X(3872)$.

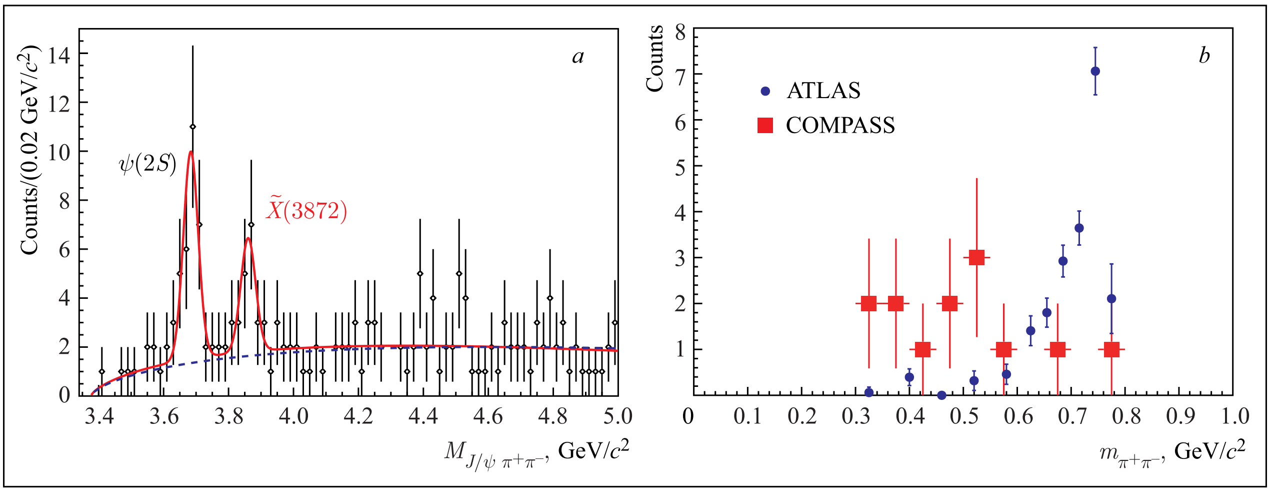


Fig. 4. *a*) Invariant mass spectrum of the subsystem $J/\psi\pi^+\pi^-$. *b*) Invariant mass spectra for $\pi^+\pi^-$ observed in the decay of $X(3872)$ in the ATLAS experiment and in the decay of $\tilde{X}(3872)$ at COMPASS

It has almost the same mass but a different set of quantum numbers. Existence of such a partner particle is predicted by some theoretical models describing $X(3872)$ as a state of two quarks and two antiquarks closely bounded by strong interaction (tetraquark). The mass of the new state $\tilde{X}(3872)$ is (3860.1 ± 10.0) MeV/c^2, while its Breit–Wigner width is below 51 MeV/c^2 with the 90% probability [19]. This result obtained with the decisive contribution of the DLNP group is important for understanding the nature of exotic charmonia.

The main task of the **BESIII** experiment is the studies in charmonium physics, physics of charmed mesons and tau leptons, and light hadron spectroscopy in the electron–positron collisions in the energy range of 2–4.6 GeV. A new charged charmonium-like structure with the mass around 4030 MeV was observed by BESIII in the mass spectrum of $(\pi \pm \psi(3686))$ for the data at $\sqrt{s} = 4.416$ GeV. In 2018, a neutral analog with a mass around 4040 was established at this energy point in the system of $(\pi 0\pi 0\psi(3686))$ [20]. It is still not clear whether these are the same states as the ones observed earlier by Belle in $Y(4360)$ decay.

A large data sample collected by BESIII at $\sqrt{s} =$ 4574.5, 4580.0, 4590.0, and 4599.5 MeV gave an opportunity to measure the cross section of the $e^+e^- \to \Lambda_c^+\Lambda_c^-$ process with unprecedented precision. The nonzero cross section near the $\Lambda_c^+\Lambda_c^-$ production threshold was confirmed. At center-of-mass energies $\sqrt{s} =$ 4574.5 and 4599.5 MeV, the higher statistics data made it possible to measure the Λ_c polar angle distributions. From these, the Λ_c electric-to-magnetic form factor ratios ($|G_E/G_M|$) are measured for the first time. They are found to be $1.14\pm0.14\pm0.07$ and $1.23\pm0.05\pm0.03$, respectively [21].

The ability of BEPCII to operate near the $\Lambda\Lambda$ mass threshold allowed studying the process $e^+e^- \to \Lambda\Lambda$ using data samples at $\sqrt{s} = 2.2324$, 2.400, 2.800, and 3.080 GeV. The Born cross section is measured to be $305\pm45^{+66}_{-36}$ pb at $\sqrt{s} = 2.2324$ GeV, which is 1.0 MeV above the threshold. The substantial cross section near the threshold is significantly larger than that expected from theory, which predicts the cross section to vanish at the threshold [22]. In order to have an overall consistent picture of these unexpectedly observed phenomena, more data, in particular, close to the relative thresholds, are needed.

In 2018, within the **Mu2e** project, about 50 crystals were prepared for the calorimeter assembly and tested on the special testbed. All of them met the quality control demands. The preamps of the electromagnetic calorimeter were adjusted to obtain a linear response to electrons. A method was developed and measurements were made to determine the cause of the significant nonlinearity of the preamplifiers, and a number of changes were made to the preamplifier circuit. In June 2018, a session on measuring the resistance of front-end electronics to gamma irradiation was held at the Calliope setup, ENEA, Italy, with the DLNP group participation. The result showed a drop in the output signal level with an increase in the dose of radiation with a steepness of $\sim$ 6%/krad, caused by damage to digital chips in the digital feedback loop of the linear regulator. The 16-channel profilometer made from scintillating fibers Kuraray SCSF 81J was tested at the beam of the electron accelerator Linac-200. The possibility of using the profilometer as a trigger was shown. In 2018, studies of the Mu2e electromagnetic calorimeter performance was carried out. Using Mu2e MC, some points important for the detector calibration with the electrons originated from muon decay in orbit (DIO) were investigated. The goal is to develop a method for precise, independent crystal-by-crystal calibration, and the precision of the calibration should satisfy the requirements documented by the Mu2e collaboration [23, 24].

In 2018, **the Muon g-2** experiment had a first physics data-taking run, during which a dataset twice as large as that accumulated by E821 was collected. The MIDAS data acquisition system recorded data at up to 250 Mb/s and was live for 90% of the beam-on time. The online software developed and supported by JINR (MIDAS alarm system, MIDAS custom web pages for controling DAQ electronics, Event Display application) was successfully used during the run.

Within the **COMET** project, a special laboratory aimed at developing and studying a special type of welded straw tubes based on the ultrasonic technology has been created. The objective of this laboratory is to make and test straws with a wall thickness of 12 μm and with a diameter of 5 mm for the COMET experiment. At the first stage of the study, full length 1400-mm straw tubes with a thickness of 12 μm and various diameters of 5–10 mm were welded. After being prepared for the tests, the tubes were pumped with argon up to 3 bar overpressure to check for gas leakages. Stress testing showed that the 12-μm tube and the quality of the seam fully satisfied all the requirements for working in vacuum conditions. In order to ensure a high coordinate accuracy of the straw detector, the material from which straws are made is required to have stable physical characteristics. Therefore, for a purpose of quality control, a bench with a termostabilization system for measuring properties of straws was developed and built. The characteristics of the 9.8-mm straws measured on the bench were the range of elastic deformation, the influence of temperature on the elastic properties of the tubes and their dependence on the thickness, the effect of the drop in the internal pressure of the straws on their tension [25], and stress relaxation of the straw. In 2018, the prototype calorimeter was tested at Tohoku University (Japan) on an electron (1.3 GeV) beam with the participation of members of the COMET collaboration from the DLNP. The prototype of the electromagnetic calorimeter was tested on the 105-MeV electron beam. The energy resolution varied from 3.8 to 4.4% depending on the beam hit, and the spatial resolution was 5.8 mm.

Within the **GDH&SPASCHARM** project, the reaction $\gamma p \to \eta p$ was measured with high statistics at the MAMI accelerator. The currently most precise data on the $\eta \to 3\pi^0$ decay were obtained from these measurements, which allowed the detailed study of its dynamics. The present data were compared to recent theoretical calculations. Also, the reaction $\gamma p \to \pi^0 \eta p$ was investigated with the world's best statistical accuracy in the energy range from the threshold to $E_\gamma = 1.45$ GeV [26], allowing precision data on the observables needed for understanding the reaction dynamics to be extracted and compared with existing models. The A2 collaboration performed the world's first precision measurements of the total cross sections and angular distributions for π^0 photoproduction off quasi-free nucleons bound in the deuteron. Significant difference was found between the cross sections for free and bound protons due to the effects from final state interactions. This difference was used to estimate the photoproduction cross section of neutral pions on free neutrons.

The η' meson and its decay modes play an important role in understanding quantum chromodynamics and related theoretical models. An experimental study of the $\eta' \to \pi^0\pi^0\eta \to 6\gamma$ decay was conducted with the best up-to-date statistical accuracy by measuring η' mesons produced in the $\gamma p \to \eta' p$ reaction with the A2 tagged-photon facility at the Mainz Microtron, MAMI [27]. The available statistics and experimental resolution allowed, for the first time, an observation of a structure below the $\pi^+\pi^-$ mass threshold.

Within the **PANDA** Muon System project, the most important achievement of 2018 is calibration of the full-scale prototype. The calibration was performed at the T9 test beam of CERN's Proton Synchrotron. Though the data obtained are preliminary, they clearly indicate the excellent abilities of the apparatus with respect to muons and hadrons, which is the main task of the Muon System. The prototype response was studied for muons and hadrons — pions and protons of both signs (including antiprotons) — in the full PANDA momentum range of 1–10 GeV/c. For the first time the neutron signal was observed. The JINR group plans to continue precise calibration since 2021 at CERN. It is worth mentioning that all already conducted and planned R&D on PANDA make a basis for the Muon System of the Spin Physics Detector (SPD) proposed for NICA.

APPLIED RESEARCH AND ACCELERATORS PHYSICS

The professional **Precision Laser Inclinometers** (PLIs) developed and manufactured by JINR are commissioned at CERN (Switzerland) and at the Garni Geophysical Observatory (Armenia) for the complex testing of the instrument. During the periods of minimal oscillations (≈ 50 nrad) of the microseismic peak, a minimal spectral density of oscillations of $2.4 \cdot 10^{11}$ rad/Hz$^{1/2}$ in the frequency range of 0.01–4 Hz was recorded by the professional PLI installed in the CERN tunnel [28].

According to the results of the three-month monitoring of microseismic activity in the Armenian Highland region, microseisms in the angular representation caused by distant earthquakes, deformation of the Earth's surface by the Moon and the Sun, and industrial noise were registered. For the first time, the JINR inclinometer detected angular oscillations of the microseismic peak from the Black and Caspian Seas. The effect of angular oscillations of the Earth's surface on the spatial divergence of the focuses of collider beams in the collision area was investigated. It was found that such displacements could be quite significant in colliders of the CLIC type with a beam preparation zone length of several kilometers.

The main goal of the research at the **Medico-Technical Complex (MTC)** is to carry out medico-biological and clinical investigations into tumour treatment, upgrade equipment and instrumentation, and develop new techniques for treatment of malignant tumours and for associated diagnostics with medical hadron beams of the JINR Phasotron. The following main results were obtained in 2018.

Regular sessions aimed at investigating proton therapy efficiency to treat different kinds of neoplasm were performed in collaboration with the Russian Medical Academy for Postgraduate Education (Moscow) and the Radiological Department of the Dubna hospital. During the year seven treatment sessions, total duration of 28 weeks, were carried out. Fifty new patients were fractionally treated with the medical proton beam. The total number of the single proton irradiations (fields) was about 4000. Other 23 patients were irradiated using the ^{60}Co gamma-therapy unit "Rokus-M" (2000 fields) [29, 30].

Clinical trial activity of radioprotecting device with a wavelength of 532 nm on the face, neck, nasopharynx, and hypopharynx of radiosensitive patients undergoing a course of radiation therapy at the MTC was conducted. Laser radiation provided effective radioprotecting effect both in the preliminary and subsequent laser irradiations [31].

Within the **Radiogene** project, the sequencing of the black point mutations induced by different doses of ^{60}Co γ rays and 0.85-MeV fission neutrons in the mature germ cells of Drosophila melanogaster was completed. From these results, the frequency of base substitution changes on a per Gy per nucleotide basis was determined for γ rays and neutrons as 1.2 and $3.9 \cdot 10^{-9}$, respectively. On the basis of these results and the literature data on the spontaneous frequency of base substitutions in Drosophila germ cells, the doubling doses as the measure of radiation genetic risk in induction of these DNA changes was computed as 2.9 and 1.1 Gy for γ rays and neutrons, respectively. The sequence analysis of the Drosophila vg gene from two wild-type laboratory lines, seven spontaneous, and nine γ-ray-induced mutants was carried out. The single nucleotide polymorphism (SNP) in the wild-type lines and spontaneous mutants was determined. Small deletions as the main mutational damage in exon 4 for γ-ray-induced vg mutants were found. The PCR assay of spontaneous and γ- and neutron-induced mutations at the white gene of Drosophila melanogaster was completed, and the main DNA changes underlying the white mutations were detected. The DNA samples were prepared for sequence analysis [32, 33].

The physical design of the compact superconducting cyclotron **SC230** was performed at DLNP. The cyclotron will deliver > 230 MeV beam for proton therapy and medico-biological research. The proposed design combines advantages of two most successful accelerators on the market of equipment for proton therapy: the C235 cyclotron (has resistive coils), IBA, Belgium, with a low magnetic field level and the fourth harmonic of acceleration and the Varian Proscan, PSI, with 4 accelerating cavities and superconducting coils. The technical design of the cyclotron can be finished in 2019.

In 2018, within the **R&D of new semiconductor detectors**, a stacked detector based on three Timepix chips and three different sensor layers made of silicon, gallium arsenide, and cadmium telluride for color micro-CT was developed. Research and development were carried out for the first GaAs:Cr-Timepix3 detector as the detector for transition radiation (production, preliminary tests, and calibration) [34]. The high-voltage bias sources for semiconductor pixel detectors up to 1000 V and software for this bias source were developed.

Positron annihilation spectroscopy (PAS) runs were carried out on the beam of monochromatic positrons at the LEPTA facility. The stability of the system of gammas-ray quantum energy measurement was significantly improved. The vacuum and magnetic systems were constructed for the **PALS** spectrometer. In 2019, it is planned to conduct regular studies of materials using the PAS method. An ion source will be installed in the experimental chamber, which will allow one to investigate multilayer thin film coatings.

REFERENCES

1. *Avrorin A. et al. (Baikal Collab.).* Baikal-GVD — Neutrino Telescope of the Next Generation // Bull. Russ. Acad. Sci. 2018 (in press).
2. *Avrorin A. et al. (Baikal Collab.)* Search for High-Energy Neutrinos from GW170817 with Baikal-GVD Neutrino Telescope // Pis'ma Zh. Eksp. Teor. Fiz. 2018. V. 108, No. 12. P. 803–804.
3. *Adey D. et al. (Daya Bay Collab.).* Measurement of Electron Antineutrino Oscillation with 1958 Days of Operation at Daya Bay // Phys. Rev. Lett. 2018. V. 121. P. 241805.
4. *Adey D. et al. (Daya Bay Collab.).* Improved Measurement of the Reactor Antineutrino Flux at Daya Bay. arXiv:1808.10836.

5. *Agostini M. et al. (Borexino Collab.).* Comprehensive Measurement of pp-Chain Solar Neutrinos // Nature. 2018. V. 562. P. 505.
6. *Agnes P. et al. (DarkSide Collab.).* Low-Mass Dark Matter Search with the DarkSide-50 Experiment // Phys. Rev. Lett. 2018. V. 121. P. 081307.
7. *Acero M. A. et al. (NOνA Collab.).* New Constraints on Oscillation Parameters from ν_e Appearance and ν_μ Disappearance in the NOνA Experiment // Phys. Rev. D. 2018. V. 98. P. 032012.
8. *Arnold R. et al. (NEMO Collab.).* Final Results on Se-82 Double Beta Decay to the Ground State of Kr-82 from the NEMO-3 Experiment // Eur. Phys. J. C. 2018. V. 78. P. 821.
9. *Armengaud E. et al. (EDELWEISS Collab.).* Searches for Electron Interactions Induced by New Physics in the EDELWEISS-III Germanium Bolometers // Phys. Rev. D. 2018. V. 98, No. 8. P. 082004.
10. *Arnaud Q. et al. (EDELWEISS Collab.).* Optimizing EDELWEISS Detectors for Low-Mass WIMP Searches // Phys. Rev. D. 2018. V. 97, No. 2. P. 022003.
11. *Agostini M. et al. (GERDA Collab.).* Improved Limit on Neutrinoless Double-β Decay of ^{76}Ge from GERDA Phase II // Phys. Rev. Lett. 2018. V. 120. P. 132503.
12. *Agostini M. et al. (GERDA Collab.).* Upgrade for Phase II of the GERDA Experiment // Eur. Phys. J. C. 2018. V. 78. P. 388.
13. *Alekseev I. et al. (DANSS Collab.).* Search for Sterile Neutrinos at the DANSS Experiment // Phys. Lett. B. 2018. V. 787. P. 56–63.
14. *Kuzmichev L. A. et al.* TAIGA Gamma Observatory: Status and Prospects // Phys. At. Nucl. 2018. V. 81, No. 4. P. 497–507.
15. *Agafonova N. et al. (OPERA Collab.).* Final Results of the OPERA Experiment on ν_τ Appearance in the CNGS Neutrino Beam // Phys. Rev. Lett. 2018. V. 120, No. 21. P. 211801.
16. *Agafonova N. et al. (OPERA Collab.).* Final Results of the Search for $\nu_\mu \to \nu_e$ Oscillations with the OPERA Detector in the CNGS Beam // JHEP. 2018. V. 1806. P. 151.
17. *ATLAS Collab.* Observation of $H \to bb$ Decays and VH Production with the ATLAS Detector // Phys. Lett. B. 2018. V. 786. P. 59.
18. *Aaboud M. et al. (ATLAS Collab.).* Search for Heavy Resonances Decaying to a Photon and a Hadronically Decaying $Z/W/H$ Boson in pp Collisions at $\sqrt{s} = 13$ TeV with the ATLAS Detector // Phys. Rev. D. 2018. V. 98. P. 032015.
19. *Aghasyan M. et. al.* Search for Muoproduction of $X(3872)$ at COMPASS and Indication of a New State $\tilde{X}(3872)$ // Phys. Lett. B. 2018. V. 783. P. 334.
20. *Ablikim M. et al. (BESIII Collab.).* Measurement of $e^+e^- \to \pi^0\pi^0\psi(3686)$ at $\sqrt{s}$ from 4.009 to 4.600 GeV and Observation of a Neutral Charmonium-like Structure // Phys. Rev. D. 2018. V. 97. P. 052001.
21. *Ablikim M. et al. (BESIII Collab.).* Precision Measurement of the $e^+e^- \to \Lambda_c^+\Lambda_c^-$ Cross Section near Threshold // Phys. Rev. Lett. 2018. V. 120. P. 132001.
22. *Ablikim M. et al. (BESIII Collab.).* Observation of a Cross Section Enhancement near Mass Threshold in $e^+e^- \to \Lambda\Lambda$ // Phys. Rev. D. 2018. V. 97. P. 032013.
23. *Atanov N. et al.* Design and Status of the Mu2e Crystal Calorimeter // IEEE Trans. Nucl. Sci. 2018. V. 65, No. 8. P. 2073–2080.
24. *Baranov V. A. et al.* A Tracker Prototype Based on Cathode Straw Tubes // Instrum. Exp. Tech. 2018. V. 61, Iss. 5. P. 645.
25. *Volkov A. D. et al.* Influence of Internal Pressure on Stress of Welded Straws of Track Detectors // Adv. Appl. Phys. 2018. V. 6, No. 1. P. 83–90 (in Russian).
26. *Sokhoyan V. et al.* Experimental Study of the $\gamma p \to \pi^0\eta p$ Reaction with the A2 Setup at the Mainz Microtron // Phys. Rev. C. 2018. V. 97, No. 5. P. 055212.
27. *Adlarson P. et al.* Measurement of the Decay $\eta' \to \pi^0\pi^0\eta$ at MAMI // Phys. Rev. D. 2018. V. 98, Iss. 1. P. 012001.
28. *Azaryan N. et al.* The Minimization of the Long Term Noises of the 24-Bit ADC for the Precision Laser Inclinometer. JINR Preprint P13-2018-47. Dubna, 2018.
29. *Oancea C. et al.* LET Spectra behind High-Density Titanium and Stainless Steel Hip Implants Irradiated with a Therapeutic Proton Beam // Radiat. Meas. 2018. V. 110. P. 7–13; https://doi.org/10.1016/j.radmeas.2018.01.003.
30. *Oancea C. et al.* Perturbations of Radiation Field Caused by Titanium Dental Implants in Pencil Proton Beam Therapy // Phys. Med. Biol. V. 63. P. 215020; https://doi.org/10.1088/1361-6560/aae656.
31. *Voskanyan K. et al.* Radioprotective Effect of Laser Radiation with a Wavelength of 532 nm on Fibroblast Cells // J. Phys. Sci. Appl. 2018. V. 8, No. 2. P. 17–21.
32. *Alexandrova M. V., Alexandrov I. D.* Radiation Biology of Structurally Different Drosophila Genes. Report 6. The Cinnabar Gene: Sequence Analysis of γ- and Neutron-Induced Gene/Point Mutations // Radiats. Biol. Radioekologiya. 2018. V. 58, No. 1. P. 15–25 (in Russian).
33. *Kravchenko E. V. et al.* Radiation Biology of Structurally Different Drosophila Genes. Report 7. The Yellow Gene. General Characteristics of Radiomutability and PCR Assay of Gene “Point” Mutations // Radiats. Biol. Radioekologiya. 2018. V. 58, No. 4. P. 341–351 (in Russian).
34. *Smolyanskiy P. et al.* Properties of GaAs:Cr-Based Timepix Detectors // J. Instrum. 2018. V. 13. P. T02005.

FLEROV LABORATORY OF NUCLEAR REACTIONS

CONSTRUCTION OF THE ACCELERATOR COMPLEX "FACTORY OF SUPERHEAVY ELEMENTS" BASED ON THE DC-280 CYCLOTRON

The FLNR crucial task is the construction of the Factory of Superheavy Elements (SHE Factory) whose key element is the DC-280 cyclotron [1]. The construction of the building of the SHE Factory was completed. The act of acceptance of the SHE Factory building was signed by OOO YAVA Stroy and JINR. The Rostechnadzor statement of the facility compliance with the requirements of the technical regulations was received. Integrated commissioning of the DC-280 cyclotron was completed. On 26 December 2018, the first beam of accelerated Kr ions was produced. In the first quarter of 2019, we are planning to continue the work at DC-280 on the production of heavy-ion beams with design parameters.

Construction of Experimental Setups of the Factory of Superheavy Elements. The first experimental setup for the ongoing studies of superheavy nuclei at the SHE Factory is a new gas-filled recoil separator (DGFRS-II). The separator was designed at FLNR and manufactured by SigmaPhi Group (France). The main separator units were assembled during 2018. The first quadrupole lens Q_1 focuses vertically the nuclei knocked out of the target to increase the efficiency of their transport through the gap of the magnet D_1, where products of complete-fusion reactions (ERs) are separated from the bulk of beam particles and the products of background reactions. ERs are then focused by two quadrupole lenses Q_2 and Q_3. The magnet D_2 is installed for the additional separation of ERs from background particles.

Other essential components of DGFRS-II were designed and manufactured: a system for the differential pumping of gas to provide a pressure gradient from 1 Torr in the separator to 10^{-7} Torr in the beam line, a rotating entrance window, and target modules. By the end of 2018, we expect the delivery of a detection system module and a support for beam line components and for the detector module. Power and signal cables for magnets and vacuum system of DGFRS-II were installed; water cooling pipes and compressed air piping were mounted. A trial run to test magnets and components of the differential pumping system was successfully completed. An electronic system for the registration of synthesized nuclei was developed.

In the first quarter of 2019, commissioning work and experiments with beams of accelerated heavy ions aimed at determining the optimal parameters of the separator will continue. These activities will allow the implementation of the experimental program at the SHE Factory in the second quarter of 2019. The synthesis of the isotopes of moscovium in the $^{48}Ca + {}^{243}Am$ reaction will be the first test experiment.

The construction of a pre-separator for the chemical investigation of SHE continues. The delivery and assembly of the pre-separator are planned for 2019.

SYNTHESIS OF NUCLEI AT STABILITY LIMITS AND THEIR PROPERTIES

According to the decisions taken by PAC and the Scientific Council of JINR, SHE Project was implemented concurrently with the FLNR scientific program. A wide variety of scientific and applied investigations in heavy-ion physics were conducted at FLNR at the existing U-400, U-400M, and IC-100 cyclotrons. The total operation time of the cyclotrons in 2018 was 16 900 h. Most of the operation time was spent on the implementation of the research program investigating ^{50}Ti beams (U-400 cyclotron, SHELS setup) and ^{15}N beams (U-400M cyclotron, ACCULINNA-1, 2 and COMBAS setups). In addition, applied studies (NIIKP) were conducted at the U-400 and U-400M cyclotrons.

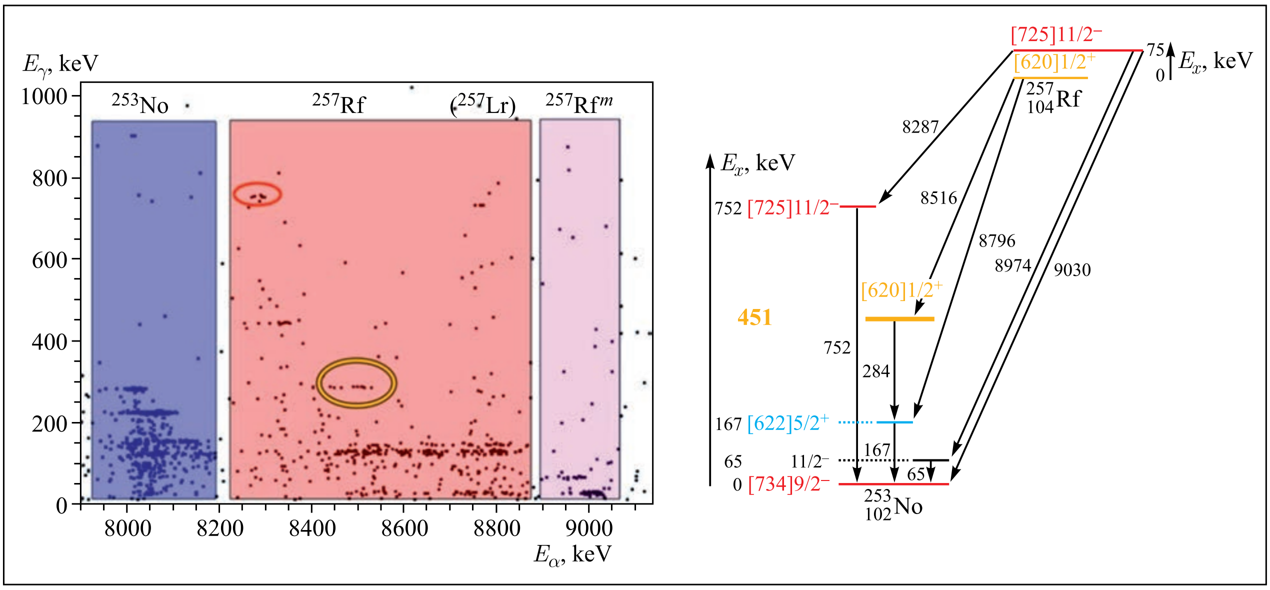


Fig. 1. Fine structure of the α decay of the ^{257}Rf mother nucleus

Spectroscopy of Heavy and Superheavy Nuclei. Following the upgrade of the SHELS separator, which involved the installation of large electrostatic deflector plates, a test experiment with accelerated ^{22}Ne ions was conducted at the U-400 cyclotron in January 2018. The experiment showed that the upgrade allowed a more efficient use of the cyclotron, thus increasing the transmission efficiency of slow evaporation residues formed in asymmetric fusion reactions by 30% (from 3 to 10%, depending on the reaction mass asymmetry (from ^{22}Ne + ^{238}U to ^{22}Ne + ^{198}Pt)).

In February 2018, the ^{50}Ti + ^{208}Pb reaction was used for the study of the radioactive decay properties of the ^{256,257}Rf isotopes. An integral flux of $4.6 \cdot 10^{18}$ was collected, about 6 750 nuclei of ^{256}Rf and 5 400 those of ^{257}Rf were registered. The experiment continued in November 2018. In June 2018, experiments devoted to studying the properties of the radioactive decay of ^{254}Rf undergoing in the ^{50}Ti + ^{206}Pb reaction were completed. An integral flux of $3.8 \cdot 10^{18}$ was collected; about 1500 nuclei of ^{254}Rf were detected.

The integrated detection system GABRIELA (α, β, and γ spectrometry) was employed in the investigations. The experimental evidence is under analysis. Several isomeric states in the isotopes ^{254,256,257}Rf with the half-lives ranging from 5 to 200 μs were detected. Figure 1 gives the data on the fine structure of the α decay of the ^{257}Rf mother nucleus to the ^{253}No daughter nucleus. The $11/2^-$ state of the ^{253}No nucleus was for the first time observed, and the $1/2^+$ state (451-keV level) detected earlier was confirmed.

The information on the current status of SHELS and some experimental results are presented in [2].

Chemistry of Transactinides. Experiments for the study of the chemical properties of volatile species of nihonium ($Z = 113$) [3] were continued. The chemical behavior of its lighter homologue — thallium — was studied on-line employing the U-400 accelerator facility. A short-lived radionuclide ^{184}Tl ($T_{1/2} = 10.1$ s) was synthesized in the ^{141}Pr(^{46}Ti, $3n$)^{184}Tl reaction. Following separation at SHELS, evaporation residues were collected in a chamber isolated from the separator by a thin Mylar foil and further transported in a gas to the chemical setup. Formed chemical species of thallium were studied simultaneously by the isothermal adsorption chromatography method and γ spectroscopy. Thallium volatile chemical species having low adsorption interaction with quartz surfaces were observed. The results are analyzed and prepared for publication [4]. Subsequent experiments at SHELS for the on-line identification and study of the registered species using the cryodetector setup are scheduled for 2019.

The adsorption interaction of elemental Cn ($Z = 112$) with trigonal selenium was studied in joint experiments with a group from the Paul Scherrer Institute (Switzerland) at the chemical channel of U-400 in May 2018. The ^{283}Cn radionuclide was synthesized in the ^{242}Pu(^{48}Ca, $3n$)^{287}Fl reaction owing to the ^{287}Fl decay. Nuclear reaction products were thermalized behind a stationary target filled with argon and helium and subsequently transported through a capillary to the COLD detector. The first eight out of 32 Si-PIN detectors were covered with trigonal selenium and kept at room temperature. The rest of the detectors were covered with gold and operated at a negative temperature gradient (from room temperature to a maximum at $-150\,°$C). Several Cn-related spontaneous fission events were observed. The chemical evidence and the experimental data are still under analysis.

Dynamics of Heavy-Ion Interaction, Fission of Heavy and Superheavy Nuclei. With the participation of specialists from VECC (Kolkata, India), the treat-

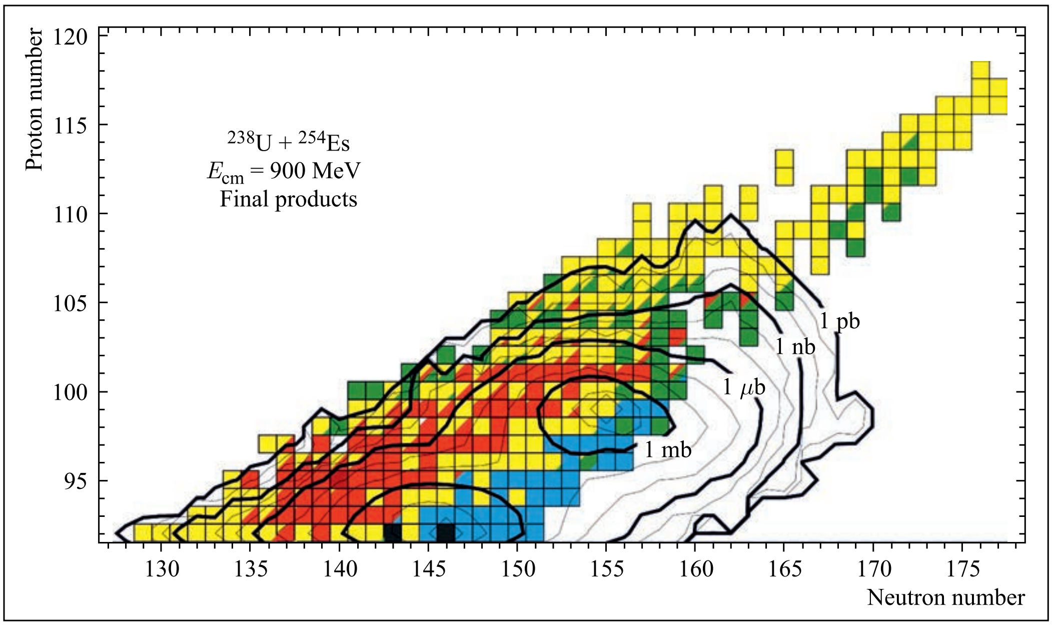


Fig. 2. Cross sections for the synthesis of nuclei in the $^{238}U + ^{254}Es$ reaction at the energy $E_{cm} = 900$ MeV

ment of the experimental data from the U-400 and U-400M cyclotrons (FLNR, JINR) was completed. The experiments were aimed at measuring mass and energy distributions of binary fragments formed in the $^{48}Ti + ^{238}U$, $^{52}Cr + ^{232}Th$, and $^{84,86}Kr + ^{198}Pt$ reactions leading to the formation of a composite system with $Z = 114$ [5]. The experiments were conducted using the double-arm time-of-flight spectrometer CORSET at energies near the Coulomb barrier: ^{48}Ti ions at 246, 258, and 271 MeV; ^{52}Cr ions at 264, 288, 302, and 320 MeV; ^{84}Kr ions at 420 and 470 MeV; and ^{86}Kr ions at 400 and 465 MeV. The studies showed a significant increase in the contribution of the quasi-fission process when passing through a transition from Ca to Ti and Cr ions. The fusion probability was found to drop by a factor of 4 and 25 during the transition from the $^{48}Ca + ^{244}Pu$ reaction to the $^{48}Ti + ^{238}U$ and $^{52}Cr + ^{232}Th$ reactions, respectively.

In December 2018, we performed measurements of mass and energy distributions of fission fragments of the $^{254,\,256}Fm^*$ compound nuclei produced in the $^{22}Ne + ^{232}Th$ and $^{18}O + ^{238}U$ reactions at energies near and above the Coulomb barrier. The studies are a continuation of a series of experiments aimed at searching for a super asymmetric mode in the fission of actinide nuclei [6, 7]. Enhanced fragment yields were observed in the mass region ~ 70 u in all the reactions under consideration, which is due to the influence of proton and neutron shells with $Z = 28$ and $N = 50$.

In collaboration with IN2P3 (France), the analysis of the results of the joint experiment dedicated to studying the dynamics of the $^{32}S + ^{197}Au$ reaction at the energy of incident ions of 5.2 MeV/nucleon was finalized in 2018. The measurements were performed at ALTO (IPN, Orsay, France). The energies and multiplicities of γ quanta were measured using the ORGAM and PARIS spectrometers. Binary reaction fragments were registered by the CORSET spectrometer. Substantial efforts of collaborators were directed towards studying the properties of fission- and quasi-fission processes by investigating the properties of neutron and gamma-quanta emission from fission-like fragments. A non-equilibrium process was detected in the incomplete relaxation of the collective spin modes of fission-like fragments [8].

Low-energy multinucleon transfer reactions in collisions of two actinide nuclei were modeled within a theoretical approach based on the Langevin equation [9]. Yields of nuclei heavier than the target were measured. The cross sections for the synthesis of such nuclei were shown to decrease rapidly as the number of transferred nucleons increased. This makes the region of superheavy nuclei hardly accessible via multinucleon transfer reactions. Quite high cross sections (those exceeding 1 μb) nevertheless allow the synthesis of numerous as-yet-undiscovered isotopes of heavy actinides (Fig. 2). The contour lines in the figure are drawn over each order of magnitude up to 1 pb.

Structure of Exotic Nuclei. In 2018, first experiments were conducted with radioactive beams produced at the commissioned ACCULINNA-2 fragment separator [10]. The separator was manufactured in cooperation with SigmaPhi Group (France) and installed at the primary beam line of the U-400M accelerator. In spring experiments were performed with the ^{6}He and ^{9}Li beams produced in the fragmentation reaction of the primary ^{15}N beam on a 2-mm-thick beryllium target at the energy of 49.7 MeV/nucleon. The ^{6}He beam with the energy of 25 MeV/nucleon and the intensity of 10^5 s^{-1}, 90% purified from other ions and focused on a spot 17 mm in diameter at the deuterated polyethylene (CD_2) target, was used to study the $^6\mathrm{He} + d$ elastic and inelastic scattering in a wide angular range (from 25 to 130 degrees according to the center-of-mass system). The measurements lasted for two weeks and for the first time provided unique high-statistics data. In another one-week experiment with ^{6}He, the one-proton transfer ^{6}He(d, ^{3}He) reaction was studied in order to populate the ground and excited states of the heavy hydrogen isotope ^{5}H. These results were necessary for planning an experiment to make searches for the superheavy hydrogen isotope ^{7}H when it is synthesized in one-proton transfer (d, ^{3}He) from the ^{8}He projectile nucleus. The third experiment was aimed at studying low-lying states of the ^{10}Li isotope populated in the $^9\mathrm{Li}(d,p)^{10}\mathrm{Li} \rightarrow n + {}^9\mathrm{Li}$ reaction. The detection of protons in coincidence with neutrons [11] moving backwards and forward, respectively, was a key issue in the study. The measurements with the ^{9}Li ($I \sim 8 \cdot 10^4$ s^{-1}) beam that lasted for several days allowed us to obtain the data needed for the evaluation of the method efficiency and for the planning of similar measurements in 2019.

In November 2018, the first experimental search for ^{7}H was undertaken using the $^8\mathrm{He}(d, {}^3\mathrm{He})^7\mathrm{H} \rightarrow t + 4n$ reaction (25 MeV/nucleon), with ^{3}He and tritons being detected. To accumulate sufficient data on the population of the ^{7}H resonance state at the rate several events per day, we had to meet the following conditions: 1) ^{8}He beam intensity on the target not less than $6 \cdot 10^4$ s^{-1}; 2) D_2 thickness in a cryogenic target cell at $3 \cdot 10^{20}$ at/cm^2; 3) registration efficiency of $^3\mathrm{He} - t$ coincidences not less than 75%; and 4) energy resolution of charged-particle telescopes at 100 keV, needed for the identification of low-energy ^{3}He nuclei. All of these requirements were fulfilled during two runs: one run was completed with the D_2 target (took about 10 d) and the other one involved an empty target (1.5 d). Based on data processing, a decision will be made on further development of the method and on conducting a long-term experiment with the detection of all products of the $^8\mathrm{He} + d$ reaction, including neutrons.

Reactions with Beams of Light Stable and Radioactive Nuclei. In 2018, a series of experiments studying nuclear reaction mechanisms leading to the formation of neutron-rich nuclei was initiated. Reaction products were separated from primary beam nuclei using magnetic spectrometers and separators — ACCULINNA, MAVR, COMBAS, VAMOS, and LISE — specially designed for such experiments. Optimal reactions for the production of new nuclei with a maximum number of neutrons were determined.

A significant increase in the cross section for the production of exotic nuclei was found in the reaction with the ^{18}O nuclei accelerated to 8.5 MeV/nucleon and directed at the ^{238}U target. The increase was on account of transfer of a large number of neutrons from a target nucleus to the nucleus of a bombarding particle [12]. The comparison of experimental evidence and calculated data revealed that transfer reactions could be used for the production of exotic nuclei with high cross sections. These studies have become increasingly relevant due to the construction of new-generation zero-angle magnetic spectrometers (MAVR at JINR and S3 at GANIL) [13].

In December 2018, first experiment with a heavy-ion beam was conducted at U-400 employing a new high-resolution magnetic analyzer MAVR. The spectrometer allows the investigation of nuclear reactions with stable and radioactive beams. During the first run at the accelerator's beam, spectrometer parameters — its efficiency, impulse resolution, position sensitivity, and purification coefficient of reaction products from the primary beam — were measured. All of the parameters corresponded to the estimated values and allowed the measurements of the properties of reaction products with a high resolution and efficiency in a wide range of angles, including 0 degrees with respect to the beam. In the first experiment, the $^{18}\mathrm{O} + {}^{\mathrm{nat}}\mathrm{Ta}$ reaction at 179 MeV was studied, which allowed the measurement of the energy spectrum of the exotic nucleus ^{16}C (consisting of three alpha particles and a presumable halo of four neutrons) using the method of missing masses, thus making it possible to draw conclusions regarding the structure of the nucleus. The spectrometer was manufactured in cooperation with the scientific centers of Armenia, Bulgaria, Vietnam, Poland, the Czech Republic, and Finland.

Precision experiments devoted to investigating the interaction of the ^{6,8}He and ^{9,11}Li beams with other nuclei were performed. The exotic structure of the beam nuclei — ^{6,8}He consist of an alpha-particle core and a halo of 2 and 4 neutrons, respectively, whereas ^{9,11}Li can also be represented in the form of an alpha-particle core and a "halo" of deuteron and neutron clusters — determines the features of the mechanism of their interaction with other nuclei. The energy dependence of total cross sections was measured, from sub-barrier energy up to 50 MeV/nucleon [14, 15]. The results indicated that the probability of reactions involving these nuclei at energies below the Coulomb barrier was high. In addition, a maximum significantly exceeding a smooth dependence described by conventional formulas for typical bound nuclei was observed in the energy dependence of cross sections for the interaction of exotic nuclei at energies about 20–30 MeV/nucleon.

On the basis of the time-dependent Schrödinger equation solution, together with calculations performed using the statistical model of compound nucleus decay, an analysis of the main cross sections of the experimental interaction (i.e., angular distributions of differential cross sections and total reaction cross sections) was completed for weakly bound helium and lithium nuclei (^{6,8}He and ^{6,9,11}Li). Neutrons and neutron clusters in exotic nuclei were shown to influence the reaction probability. Neutrons in the sub-barrier region help nuclei overcome the Coulomb barrier and act as "nuclear glue" in the fusion of two nuclei. Nucleon transfer reactions involving nucleon transfer from a projectile to a target nucleus are observed with a higher probability at the energies from 20 to 30 MeV/nucleon (Fermi energy). These results are of great importance not only for a deeper understanding of the properties of nuclear matter (microworld) but are key in understanding process modeling in space (macroworld). For example, the cross sections obtained for the interaction of neutron-rich nuclei can change the scenario for the formation of light elements in astrophysical nucleosynthesis.

All of the studies were conducted in collaboration with the GANIL National Center (France), the University of Texas (USA), INP (France), L. N. Gumilyov Eurasian National University (Kazakhstan), the Institute of Nuclear Physics (Czech Republic), and the Henryk Niewodniczański Institute of Nuclear Physics (Poland).

RADIATION EFFECTS AND PHYSICAL BASES OF NANOTECHNOLOGY, RADIOANALYTICAL AND RADIOISOTOPE INVESTIGATIONS AT FLNR ACCELERATORS

Temperature dependences of nanoscale defects on the surface of single crystalline TiO_2 irradiated with 220-MeV xenon ions were studied [16]. The average height of hillock-like structures and the depth of the disordered region in the sub-surface layer were found to increase as the irradiation temperature was raised in the range 80–1000 K. "Hillocks" have a crystalline structure and are epitaxial to the original crystal surface.

Osmotic flows through track membranes with a pore radius of 10–50 nm in the water/membrane/salt solution system were measured [17]. The intensive transport of water through the pores was found to occur only in the case of a dissolved substance dissociating into ions. The electric double layer proved to be of utmost importance in the mechanism of osmotic transport. Transport through the pores under the osmotic pressure was shown to be a flow of a viscous liquid through a cylindrical capillary.

Nanosized polytetrafluoroethylene films deposited on the surface of track-etched polyethylene terephthalate membranes by high-frequency magnetron sputtering and electron beam dispersion of polymers in vacuum were synthesized and studied [18]. The morphology and chemical composition of films deposited by the two methods were shown to differ substantially.

The elemental composition of wastes of the Mizur tailing pond (Republic of North Ossetia) was studied by neutron activation and the X-ray fluorescence analysis. The tailing pond was found to be a zone of geochemical anomalies where tailings contained high amounts of Zn, As, S, Cu, Sb, Se, Ag, In, Pb, and Cd [19].

DEVELOPMENT OF CURRENTLY OPERATING FLNR ACCELERATOR COMPLEX

In the course of preparation for the upgrade of the U-400R cyclotron, design data are being prepared for the construction of a new experimental hall. The following sections of the design documentation are being negotiated: Technology Solutions, Radiation Safety, and Environmental Protection Activities.

A ^{54}Cr beam with an intensity of about 0.5 pμA was produced at the U-400 accelerator (SHELS target). The Metal Ions from VOlatile Compounds (MIVOC) method was employed.

As part of the U-400M upgrade program, new main magnet coils fabricated and delivered to Dubna are under preparation for assembly.

CONSTRUCTION OF NEW AND DEVELOPMENT OF EXISTING EXPERIMENTAL SETUPS

Construction of a Separator Based on Resonance Laser Ionization (GaLS Setup). Additional laser equipment (TiSa laser system, a frequency doubling cavity, a beam forming and propagating system, etc.) were delivered to FLNR and are currently being installed. Software for monitoring EdgeWave lasers was developed. Thus, test experiments on selective resonance laser ionization using reference cells should be possible in 2019.

The first draft of the tape station design was developed at iThemba LABS in South Africa. Test measurements were conducted, and an on-line experiment on gamma spectroscopy of Yb isotopes was performed with a view to determine the deformation and triaxiality of these nuclei. A model of a sextupole ion guide was made in order to estimate possible losses of ions coming out of a gas cell. The modeling predicted transport efficiency close to 100% during the first 65 mm of the path and its subsequent decrease when transporting ions over longer distances. To increase transport efficiency and decrease ion time of flight, a segmented quadrupole ion guide is being developed [20, 21]. A three-dimensional model was created for observing beam dynamics at GALS. A separator magnet and a vacuum chamber were manufactured. The yoke and coils of the separator were assembled and tested at the manufacturer's construction site [20, 21].

Joint experiments with colleagues from the Catholic University of Leuven (Belgium) and CERN were continued. In the experiments, the RILIS laser ion source at ISOLDE, CERN, was employed. Laser spectroscopy measurements aimed at determining the nuclear properties of the neutron-deficient Au and Tl isotopes were performed [22].

Mass Spectrometer MASHA. The upgrade of the MASHA control and data acquisition systems based on WAGO-I/O-SYSTEM, compactRIO, and PXI/PXIe was continued in collaboration with the Palacký University Olomouc (Czech Republic) and the Institute of Experimental and Applied Physics of the Czech Technical University in Prague (Czech Republic). The systems were successfully tested in experiments carried out this year. A PXI/PXIe based system for current measurement was developed for testing several types of ECR ion sources (those with inner glass-enamel coating, TiN coating, etc.) by using an impulse valve (a minimum time impulse being 2 ms).

Experiments aimed at measuring the separation time of short-lived reaction products produced in the $^{40}Ar + ^{144}Sm$ and $^{40}Ar + ^{166}Er$ fusion reactions were performed. A new design of a hot solid catcher (thin carbon nanotube paper employed) was used in the experiments. In addition, longevity tests of the hot catcher were carried out at the temperature of $1800\,^{\circ}C$ and the beam current $\leqslant 0.5$ pμA. Separation time was shown not to exceed 1 s, which is about half as high as the other one obtained when using a thick carbon absorber. The separation efficiency was unaffected for 85 h at the ^{40}Ar beam current $\leqslant 0.5$ pμA, while it was one sixth as high under a given set of conditions when the thick carbon absorber was employed.

We continue our efforts devoted to developing a new ECR ion source and a hot catcher. The new design will incorporate the features that enable the entire complex to withstand temperatures up to $300\,^{\circ}C$. The inner surfaces of vacuum pipelines and the chamber will be coated with chemically non-reactive glass enamel. Measurements of efficiency and time separation are currently performed for inert gases and mercury by using a quick-opening impulse valve, which allows gas and steam to be fed into the ECR source at a minimum impulse length not exceeding 2 ms.

The studies performed at FLNR in 2018 were supported by five grants from the Russian Foundation for Basic Research (RFBR) and by two grants from the Russian Science Foundation (RSF).

REFERENCES

1. *Kalagin I., Dmitriev S., Oganessian Yu., Gulbekian G., Gikal B., Bogomolov S., Ivanenko I., Ivanov G., Kazarinov N., Osipov N., Semin V.* The New DC-280 Cyclotron. Status and Road Map // Phys. Part. Nucl. Lett. 2018. V. 15, No. 7. P. 813.
2. *Rezynkina K. et al.* The Influence of Octupole Vibration on the Low-Lying Structure of ^{251}Fm and Other Heavy $N = 151$ Isotones // Phys. Rev. C. 2018. V. 97. P. 054332.
3. *Svirikhin A. I. et al.* Short-Lived Isotopes of Transfermium Elements: Studying Characteristics of Spontaneous Fissioning // Bull. Russ. Acad. Sci.: Phys. 2018. V. 82, No. 6. P. 632.
4. *Steinegger P., Aksenov N. V., Albin Y. V. et al.* // Book of Abstr. of the IX Intern. Symp. on Exotic Nuclei (EXON-2018), Petrozavodsk, Russia, 10–15 Sept. 2018.
5. *Kozulin E. M., Knyazheva G. N., Ghosh T. K., Sen A., Itkis I. M., Itkis M. G., Novikov K. V., Diatlov I. N., Pchelintsev I. V., Bhattacharya C., Bhattacharya S., Banerjee K., Saveleva E. O., Vorobiev I. V.* Fission and Quasifission of the Composite System $Z = 114$ Formed in Heavy-Ion Reactions at Energies near the Coulomb Barrier // Phys. Rev. C (submitted).
6. *Pan A. N., Kozulin E. M., Itkis I. M., Itkis M. G., Knyazheva G. N., Gikal K. B., Novikov K. V., Kvochkina T. N., Burtebayev N. T., Covalchuk K. V.* Proton Induced Fission of ^{232}Th at Low and Intermediate Energies // Bull. Russ. Acad. Sci.: Phys. 2018. V. 82, No. 6. P. 721–724; Izv. Akad. Nauk, Ser. Fiz. 2018. V. 82, No. 6. P. 800–803 (in Russian).
7. *Gikal K. B., Kozulin E. M., Itkis I. M., Itkis M. G., Knyazheva G. N., Novikov K. V., Pan A. N.* Searching for the Superasymmetric Fission Mode of ^{248}Cf, ^{254}Fm, and ^{260}No in Reactions $^{22}Ne + ^{232}Th$, ^{238}U; $^{16}O + ^{232}Th$, ^{238}U // Bull. Russ. Acad. Sci.: Phys. 2018. V. 82, No. 6. P. 716–720; Izv. Akad. Nauk, Ser. Fiz. 2018. V. 82, No. 6. P. 795–799 (in Russian).
8. *Harca I. M., Kozulin E. M. et al.* The Spin of Fragments Following the Heavy Ion Induced Fission in the $^{32}S + ^{197}Au$ Reaction near the Interaction Barrier // Eur. Phys. J. A (submitted).
9. *Saiko V. V., Karpov A. V.* Analysis of Multinucleon Transfer Reactions with Spherical and Statically Deformed Nuclei by Using a Langevin-Type Approach // Phys. Rev. C (submitted).
10. *Fomichev A. S. et al.* The ACCULINNA-2 Project: The Physics Case and Technical Challenges // Eur. Phys. J. A. 2018. V. 54. P. 97.
11. *Bezbakh A. A. et al.* A Neutron Spectrometer for Experiments with Radioactive Beams on the ACCULINNA-2

Fragment-Separator // Instrum. Exp. Tech. 2018. V. 61, No. 5. P. 631.
12. *Stefan I. et al.* Neutron-Rich Nuclei Produced at Zero Degrees in Damped Collisions Induced by a Beam of ^{18}O on a ^{238}U Target // Phys. Lett. B. 2018. V. 779. P. 456–459.
13. *Zernyshkin V. A. et al.* Charged Particle Trajectories in the MAVR High-Resolution Magnetic Spectrometer // Phys. Part. Nucl. Lett. 2018. V. 15, Iss. 5. P. 531–536.
14. *Kabyshev A. M. et al.* Some Peculiarities of Interactions of Weakly Bound Lithium Nuclei at Near-Barrier Energies // J. Phys. G: Nucl. Part. Phys. 2018. V. 45, No. 2. P. 025103.
15. *Naumenko M. A., Penionzhkevich Yu. E. et al.* // J. Phys. Conf. Ser. 2018. V. 1023. P. 012018.
16. *O'Connell J. H., Aralbayeva G., Skuratov V. A., Saifulin M., Janse van Vuuren A., Akilbekov A., Zdorovets M.* Temperature Dependence of Swift Heavy Ion Irradiation Induced Hillocks in TiO_2 // Mater. Res. Express. 2018. V. 5, No. 5. P. 1–10.
17. *Apel P. Y., Blonskaya I. V., Lizunov N. E., Olejniczak K., Orelovitch O. L., Toimil-Molares M. E., Trautmann C.* Osmotic Effects in Track-Etched Nanopores // Small. 2018. V. 14. P. 1703327.
18. *Kravets L. I., Altynov V. A., Yablokov M. Yu., Gilman A. B., Satulu V., Mitu B., Dinescu G.* Investigation of Morphology and Chemical Structure of Nanosized Polytetrafluoroethylene Films Deposited on the Surface of Track-Etched Membranes by Plasma Processing // High Energy Chem. 2018. V. 52, Iss. 4. P. 318–325.
19. *Kamanina I. Z., Pukhaeva N. E., Gustova M. V., Frontasyeva M. V., Chigoeva D. N., Kaplina S. P.* The Use of Nuclear Physics Methods for the Analysis of Wastes from the Mining and Processing Industry by the Example of the Unal Tailing Pond // Adv. Current Nat. Sci. 2018. No. 7. P. 142–150.
20. *Zemlyanoy S., Avvakumov K., Kazarinov N., Fedosseev V., Bark R., Blazczak Z., Janas Z.* Heavy Neutron Rich Nuclei: Production and Investigation // J. Phys.: Conf. Ser. 2018. V. 1023. P. 012004.
21. *Zemlyanoy S. G., Zagrebaev V. I., Avvakumov K. A., Kazarinov N. Yu., Kudryavtsev Yu., Fedosseev V., Bark R., Janas Z.* GALS — Setup for Production and Study of Heavy Neutron Rich Nuclei at Dubna // IGLIS-NET Newslet. 2018. No. 6. P. 18–21.
22. *Cubiss J. G., Barzakh A. E., Andreyev A. N., Al Monthery M., Althubiti N., Andel B., Antalic S., Atanasov D., Blaum K., Cocolios T. E., ..., Fedosseev V. N., Zemlyanoy S. G., Zuber K.* Change in Structure between the $I = 1/2$ States in ^{181}Tl and ^{177,179}Au // Phys. Lett. B. 2018. V. 786. P. 355.

FRANK LABORATORY OF NEUTRON PHYSICS

In 2018, the scientific programme of the Frank Laboratory of Neutron Physics was aimed at obtaining new results within five research themes of the JINR Plan for Scientific Research and International Scientific and Technical Cooperation: in condensed matter physics ("Investigations of Condensed Matter by Modern Neutron Scattering Methods", 04-4-1121-2015/2020, headed by D. P. Kozlenko, V. L. Aksenov, and A. M. Balagurov; "Multimodal Platform for Raman and Nonlinear Optical Microscopy and Microspectroscopy for Condensed Matter Studies", 04-4-1133-2018/2020, headed by G. M. Arzumanyan and N. Kučerka); in neutron nuclear physics ("Investigations in the Field of Nuclear Physics with Neutrons", 03-4-1128-2017/2019, headed by V. N. Shvetsov, Yu. N. Kopatch, E. V. Lychagin, and P. V. Sedyshev); in development of the FLNP basic facilities ("Development of the IBR-2 Facility with a Complex of Cryogenic Neutron Moderators", 04-4-1105-2011/2019, headed by A. V. Belushkin and A. V. Vinogradov); in development of the IBR-2 spectrometers and computation complex ("Development of Experimental Facilities for Condensed Matter Investigations with Beams of the IBR-2 Facility", 04-4-1122-2015/2020, headed by S. A. Kulikov and V. I. Prikhodko).

CONDENSED MATTER PHYSICS

In 2018, the IBR-2 reactor operated for physics experiments within FLNP User Programme only for 41 days. 131 proposals for experiments were received from 13 different countries. The submitted proposals covered a broad spectrum of neutron research in physics (25%), materials science (39%), chemistry, geosciences, biology and applied sciences (36%). 116 proposals were selected for realization.

Structure Investigations of Novel Oxide, Intermetallic and Nanostructured Materials. Recently, a new binary perovskite oxide Mn_2O_3 was synthesized under high-pressure and high-temperature conditions. The uniqueness of this material lies in the fact that the A and B positions of the perovskite structure (ABO_3) are occupied by the same manganese ions. A comprehensive study of the structural, magnetic, and ferroelectric properties of this material in the low-temperature region was carried out (Fig. 1). The existence of two complex modulated antiferromagnetic (AFM) phases ($T_{N1} \approx 100$ K, $T_{N2} \approx 50$ K) was established. In the AFM phase arising at T_{N1}, a longitudinal spin density wave with the propagation vector $k_1 = (0\ 0\ 1/8)$ arises. At temperatures $T < T_{N2}$, an incommensurate AFM phase is formed with helicoidally and cycloidally modulated components described by a combination of wave vectors $k_{2-0} = (0\ 0\ 1.244)$, $k_{2-1+} = (0\ 0\ 1.006)$, $k_{2-1-} = (0\ 0\ 0.494)$, $k_{2-2+} = k_{2-2-} = (0\ 0\ 0.256)$. The spin-induced spontaneous ferroelectric polarization and the magnetoelectric effect were observed in the region $T < T_{N2}$ [1].

Steels and iron alloys have been so far the main construction materials, demonstrating an impressive diversity of useful properties. Correspondingly, they have been actively studied for centuries. At the same time, at least some fundamental properties of iron as their main component still do not have a generally accepted explanation. In particular, this concerns a mechanism of phase transitions between its allotropic modifications, α- and γ-phases. The most commonly used Bain model in the theoretical analysis of the rearrangement of atoms during the $\alpha \rightarrow \gamma$ transition in iron and steels implies the expansion of the *bcc* cell along one of the fourth-order axes by $\sim 21\%$ and compression in the perpendicular plane by $\sim 12\%$. As a result, a body-centered

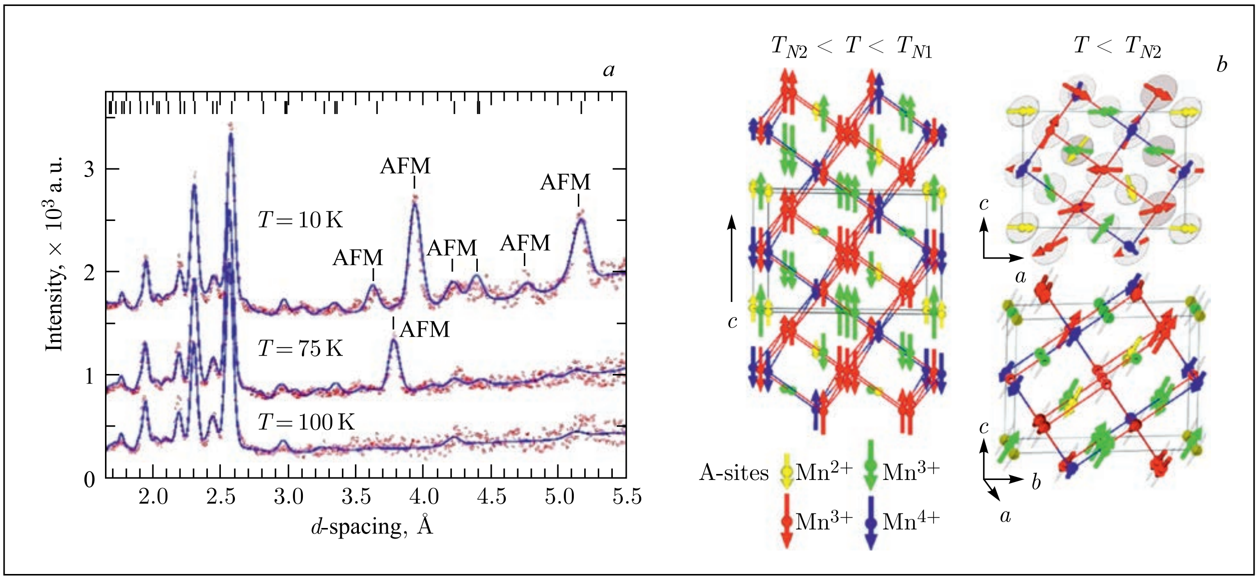


Fig. 1. Neutron diffraction spectra (*a*) and symmetry of modulated magnetic structures of Mn_2O_3 oxide (*b*)

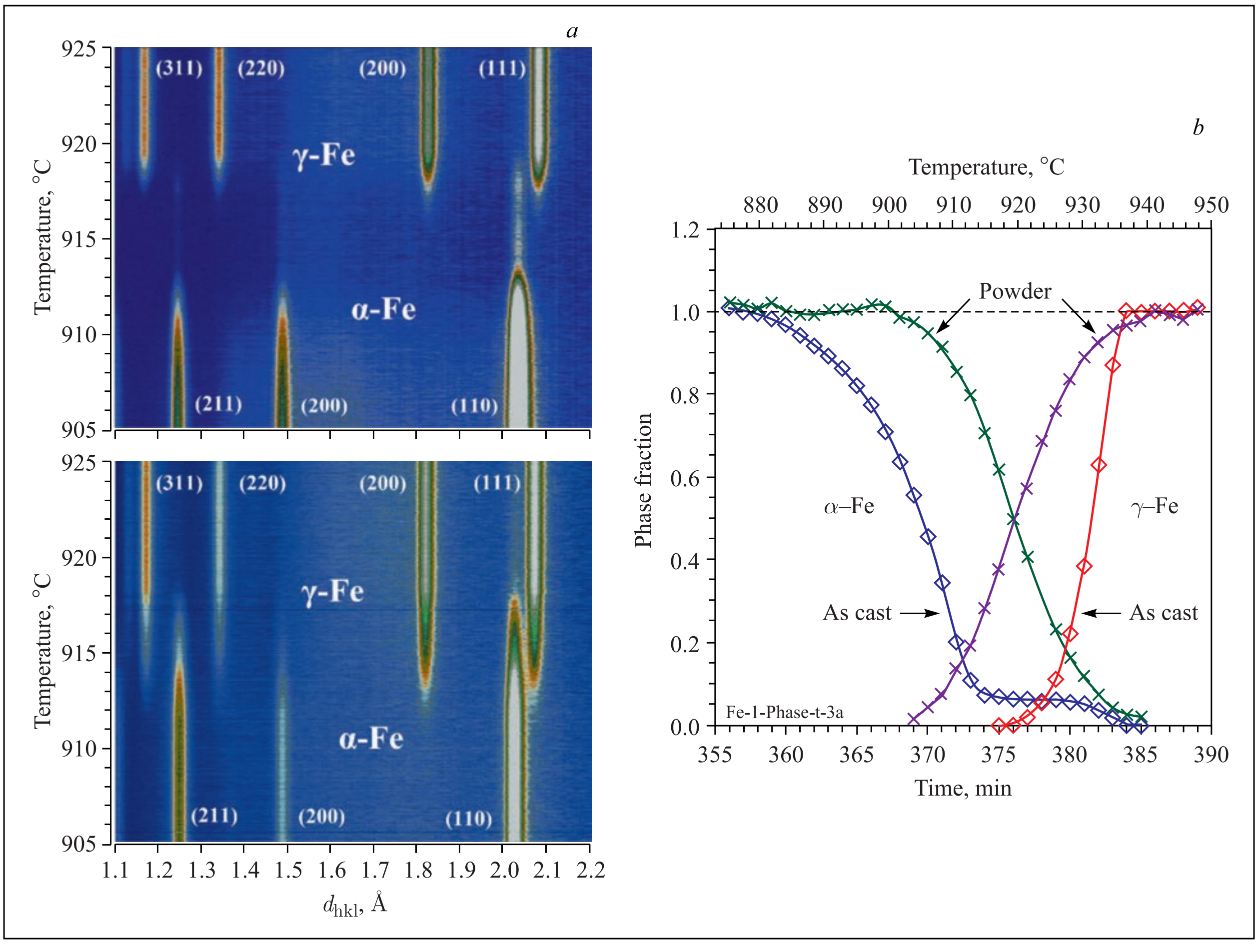


Fig. 2. *a*) 2D representation of diffraction patterns from iron samples of Fe-1 (top) and Fe-2 (bottom) upon heating. The region of $\alpha \to \gamma$ transition corresponding to a temperature of 911 °C is shown. The vertical axis corresponds to the temperature (and time), whereas the horizontal axis corresponds to the interplanar distance. The initial state is α–Fe with indicated (110), (200) and (211) peaks. The final state is γ–Fe with indicated (111), (200), (220) and (311) peaks. In both cases, the temperature increased linearly at a rate of $\Delta T/\Delta t \approx 0.5$ °C/min. Diffraction patterns were recorded every second. *b*) Time dependences of α- and γ-phases in iron samples of Fe-1 (as cast, diamonds) and Fe-2 (powder, triangles) upon heating at a rate of 2.2 °C/min. The scales of time (below) and temperature (above) are indicated

tetragonal cell is formed, where a change in the axes transforms it into an *fcc* cell. Such a rearrangement of atoms does not imply their coordinated displacements in contrast to the rearrangement accompanying a cooperative (martensitic) phase transition. However, the rate of transformation is so high that despite large deformations, the long-range order, in fact, holds at all stages of the rearrangement of the structure.

To obtain information on microscopic mechanisms of the rearrangement of the atomic structure in technically pure Fe, for the first time, *in situ* neutron diffraction was applied [2]. The experiments were carried out on the HRFD diffractometer with three types of samples: a fine-crystalline iron powder, as-cast iron produced by casting in a template, and as-cast iron which passed a cycle of slow heating to the complete transition to the γ-phase and slowly cooling to return to the α-phase. The heating–cooling cycle in the temperature range of up to 960 °C was repeated three times. In Fig. 2, the $\alpha \to \gamma$ transition is shown as 2D distributions of the intensities of peaks in the interplanar distance vs. temperature/time coordinates for Fe-1 (as-cast) and Fe-2 (powder) samples measured when heated at a constant rate of $\Delta T/\Delta t \approx 0.5$ °C/min. In the Fe-1 sample, γ-phase appears only after almost complete disappearance of α-phase (Fig. 2). The gap between the disappearance of α-phase and the appearence of γ-phase was confirmed on heating all studied as-cast samples within the accuracy of the content of the α-phase in the middle of the gap region and its temperature width, which both depend to some extent on the heating rate. The situation for the powder Fe-2 is completely different: a change in the content of the phases occurs synchronously and with the intersection of a level of 0.5 in the middle of the time interval corresponding to the appearance of γ-phase and the disappearance of α-phase. The time interval from the beginning of a decrease in α-phase to its complete disappearance in the powder is about 18 min, whereas this time interval for the as-cast sample and the corresponding temperature interval are almost twice as large.

Investigation of Magnetic Fluids and Nanoparticles. On the GRAINS reflectometer, neutron reflectometry experiments were carried out to study the effect of an external non-uniform magnetic field on the adsorption of magnetic nanoparticles from ferrofluids on a flat interface (magnetic fluid based on transformer oil/silicon single crystal). It was shown that the specular reflectivity curves are sensitive to the applied external magnetic field (Fig. 3). Thus, at low fields (< 35 mT), this system is described by a simple model with a sharp boundary between two semi-infinite media. However, there is a slight increase in the concentration of magnetic particles in the near-boundary layer. With a further increase in the external magnetic field (35−75 mT), the experimental curves can be described only by a model of several layers at the interface between the media. In this case, the formation of two adsorption layers with different content of the magnetic material in each layer is observed [3].

Investigation of Carbon Nanomaterials. Over the past few decades, colloidal systems based on nematic liquid crystals and nanoparticles have been actively investigated. The studies are related to potential

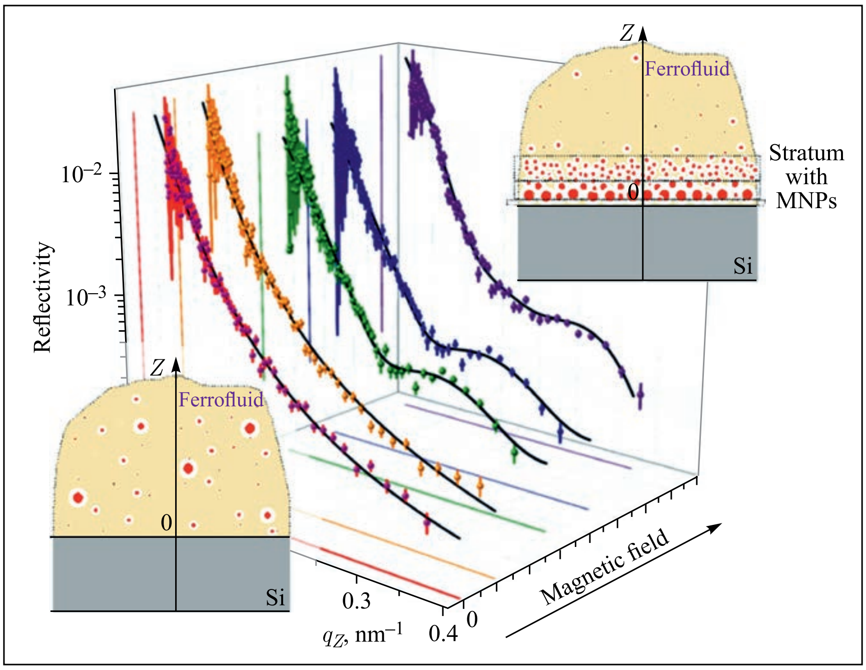


Fig. 3. Neutron reflectometry data and the proposed model of adsorption of magnetic particles of the ferrofluid at the interface with a solid with increasing external magnetic field strength

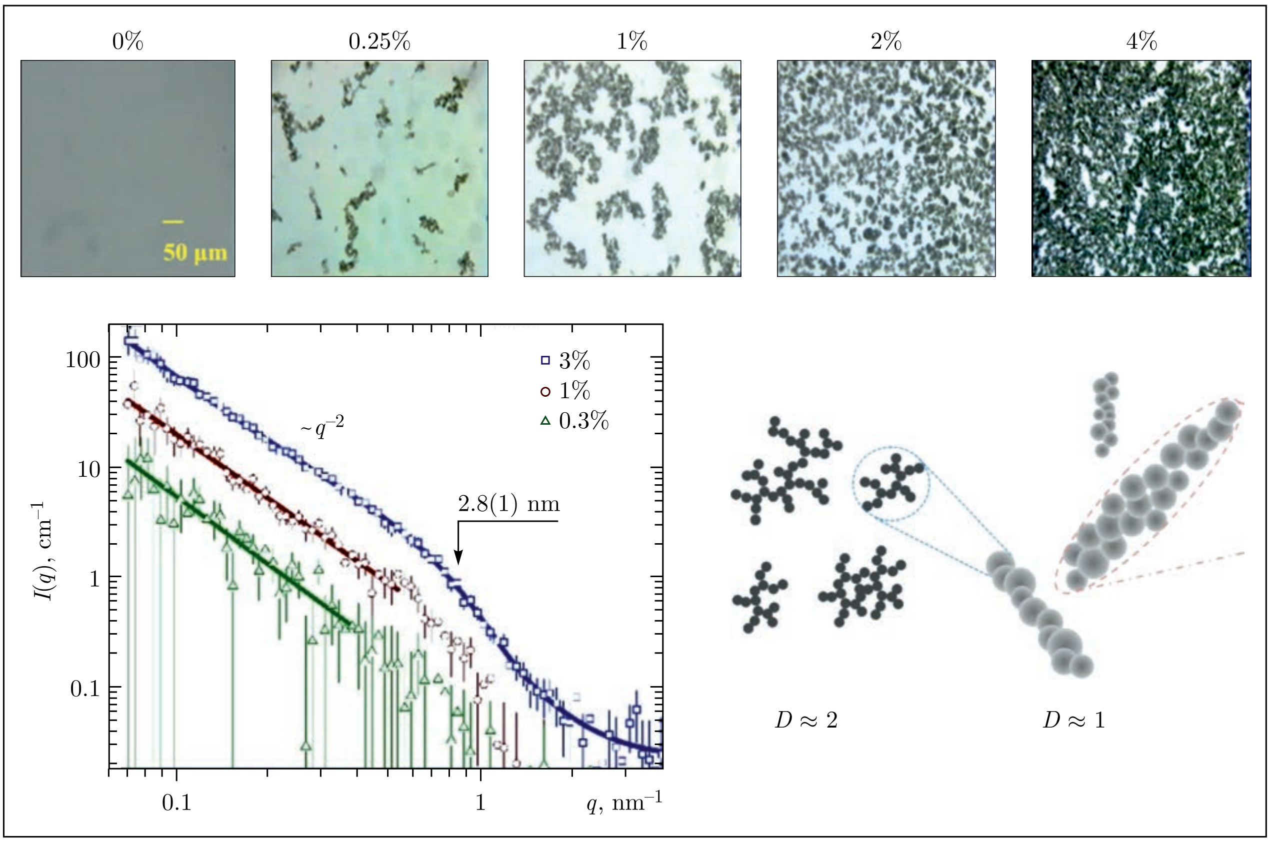


Fig. 4. Structural organization of liquid crystal suspension with nanodiamonds

possibilities of varying physicochemical properties of liquid crystal layers for practical applications in data storage and visualization. The features of the aggregation of diamond nanoparticles in composites based on nematic liquid crystals were investigated with small-angle neutron scattering and polarization microscopy [4]. It was shown that similar to the initial aqueous dispersions of nanodiamonds used in the synthesis, the composite system has a multi-level structure (Fig. 4). Nanodiamonds are assembled into fractal clusters with a dimension of 2, significantly smaller than in the original dispersions (dimension of 2.3). At the next level, clusters enter into the composition of quasilinear aggregates capable of forming a continuous network at concentrations of above 1 wt. %. Additionally, the effect of the thickness of the liquid crystal suspension layer on the aggregation process was considered.

Investigation of Layered Nanostructures and Electrochemical Interfaces. In the framework of the study of the ways to prevent parasitic structures on electrode surfaces in lithium batteries, a series of neutron reflectometry experiments on model electrochemical interfaces "liquid electrolyte/solid electrode" were performed on the GRAINS reflectometer. The effect of a non-electroactive additive (tetrabutyl ammonium perchlorate, TBAP) in a lithium-containing electrolyte was studied [5]. From the analysis of specular reflectivity curves obtained in the operando mode, it was shown that the formation of a solid-electrolyte interphase (SEI) on the electrode surface as well as the lithium electrodeposition and growth of parasitic structures are significantly suppressed by adding a non-electroactive component to the electrolyte. The obtained scattering length density profiles perpendicular to the electrode surface made it possible to analyze in more detail different modes of SEI formation as well as the formation and growth of nano-sized lithium layers in different conditions.

Instrument Development. In collaboration with the Institute of Nuclear Physics of the Ministry of Energy of the Republic of Kazakhstan (Almaty, Kazakhstan), the work on the design of a new instrument of radiography and tomography at the VVR-K stationary research reactor as well as on the ordering and purchasing of special equipment and materials was conducted. The basic configuration of the instrument and biological shield were installed on beamline 1 in the experimental hall of the reactor. The thermal neutron flux measured at the exit of beamline 1 is $\sim 4.5 \cdot 10^8$ n/cm^2/s. First test experiments were performed, which demonstrated good prospects for using the neutron radiography and tomography facility at the VVR-K reactor for neutron research in various fundamental and applied research areas.

MULTIMODAL PLATFORM FOR RAMAN AND NONLINEAR OPTICAL MICROSCOPY AND MICROSPECTROSCOPY FOR CONDENSED MATTER STUDIES

The main goal of the theme is aimed at developing modern methods for highly sensitive (single molecules), chemically selective nonlinear Raman microspectroscopic ways of detection — primarily, Coherent Anti-Stokes Raman Scattering (CARS) spectroscopy of organic molecules adsorbed on nanostructured surfaces.

The studies in 2018 were focused on achieving the following major results:

— testing SERS-active substrates of various configurations to select the most optimal one for effective SECARS spectroscopy;

— obtaining and analysis of SERS and SECARS spectra as well as intensity maps of light scattered by organic molecules attached to Au-nanoparticles;

— upgrade of the CARS microspectrometer software NanoSP to adapt it to the ultrasensitive modality of SECARS;

— obtaining data on structural and spectroscopic/luminescent properties of the core–shell nanostructure SrF_2:Yb, Er@SrF_2.

Obtaining and Analysis of SERS and SECARS Spectra and Intensity Maps of Light Scattered by Organic Molecules Attached to Au-Nanoparticles. The obtained experimental results demonstrated for the first time the possibility of recording high-contrast SECARS signals from reporter molecules of thionitrobenzoic acid, TNB, attached to gold nanoparticles deposited on the surface of new SERS-active metamaterials based on the nanostructured faceted surface of a CeO_2 dielectric film deposited on an Al sublayer. The investigations showed that at Raman resonant laser excitation of the molecules/Au-NP conjugates immobilized on the surface, strong SECARS signals can be generated using laser powers that do not destroy the conjugates.

Coupling CARS with the plasmonic metamaterial structures under investigation provided excellent chemical imaging contrast (up to 400) for biochemically relevant 5-thio(2-nitrobenzoic acid) reporter molecules. Taking into account relatively easy handling and long-term stability of the investigated metamaterial junction at ambient conditions, it might be considered as a promising candidate for a single-molecule sensitivity surface-enhanced Raman scattering SECARS-biosensor.

Results of SECARS Measurements. In order to more accurately evaluate the SECARS signal intensity, a number of prior measurements were performed using the above-mentioned substrates with unmodified analyte molecules immobilized on the surface of gold nanoparticles. The spatial distribution of epi-CARS signals from an area of the sample surface was recorded at two pump wavelengths $\lambda_p = 932$ nm and $\lambda_p = 900$ nm. The selected values for λ_p correspond to the Raman shifts of 1.333 cm^{-1} (resonant with one of Raman-active transitions of TNB) and 1.714 cm^{-1} (non-resonant transition).

NEUTRON NUCLEAR PHYSICS

In 2018, at FLNP the scientific activity in the field of neutron nuclear physics was carried out in the following traditional directions: investigations of time and space parity violation processes in neutron–nuclear interactions; studies of the fission process; experimental and theoretical investigations of fundamental properties of the neutron; gamma-spectroscopy of neutron–nuclear interactions; atomic nuclear structure, obtaining of new data for reactor applications and nuclear astrophysics; experiments with ultracold neutrons, applied research using neutron activation analysis (NAA). The scientific program to study the inelastic scattering of fast neutrons (TANGRA project) is being successfully implemented. A number of experiments in the field of fundamental physics and ultracold neutron physics were performed at the facilities of nuclear research centers in Germany, China, France, and Switzerland.

Development of the IREN Facility. In 2018, a complete replacement of the cooling system for the LUE-200 accelerator of the IREN facility was performed. In parallel with this work, the reconstruction of the premises for the pneumatic transport setup REGATA-2 and radiochemical laboratory was conducted.

The construction and bench tests of a unique electron injector were completed. The electron injector is a three-electrode electron gun with a barium-oxide cathode from a GS-34 triode. A special feature of this injector is the ability to control the pulse duration of an electron beam in the range from 40 to 400 ns [6].

Main Scientific Results. ***Position-Sensitive Ionization Chamber for Studying Prompt Fission Neutrons in Resonance Neutron-Induced Fission.*** A position-sensitive twin ionization chamber (TIC) for experimental studies of correlations between the emission of prompt fission neutrons (PFN) and the characteristics of fission fragments (FF) was developed and designed at FLNP [7]. TIC is intended for measurement of kinetic energies, masses and orientation in the 3D space of the fission axis of correlated FF. TIC will be used as a part of a PFN detector consisting of 32 fast neutron detectors (FND) with BC-501 liquid scintillator, which are located on a sphere 1.4 m in diameter and concentrated around the axis of the resonance neutron beam of IREN.

Activities in the Framework of the TANGRA Project. ***Measurement of Angular Anisotropy of Gamma-Ray Emission in Reactions of Inelastic Scattering of Neutrons with an Energy of 14.1 MeV on Different Nuclei.*** In the framework of the TANGRA project, the angular distributions of gamma rays in the $(n, n'\gamma)$ reaction on different nuclei were measured. The measurements were carried out using two multidetector systems: "Romashka" consisting of 22 NaI(Tl) scintillation detectors and "Romasha" comprising 18 BGO detectors. A general view of the experimental setups is shown in Fig. 5.

Measurements were made for the following elements: C, Si, O, Bi, Al, Pb, Fe, Ti, Sn, Zn, Mn, Mg, K, Ca, Na, Cl, N, Ni, and P. An example of the angular distribution of gamma rays for the 6.13-MeV oxygen line is shown in Fig. 6.

Analytical Investigations at the IBR-2 Reactor. At the REGATA facility, a multielement neutron activation analysis of about 2000 environmental samples (vegetation, soil, air filters), a number of technological, biological and archaeological samples, as well as samples of extraterrestrial origin was carried out in the frame-

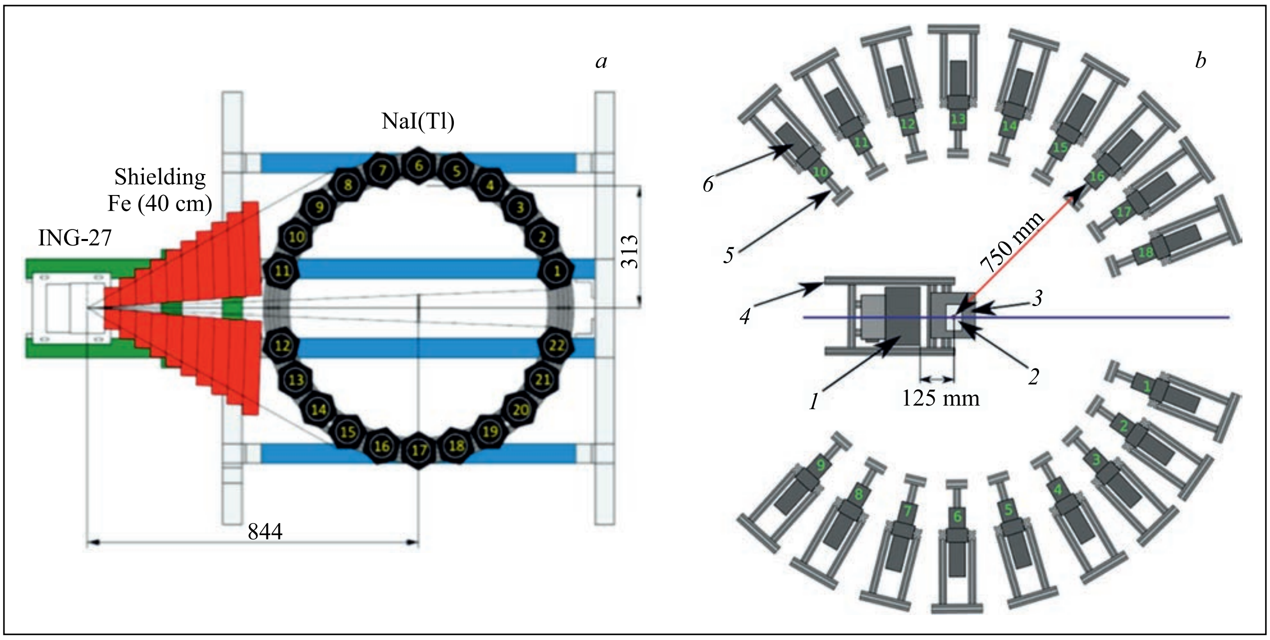


Fig. 5. General view of the experimental setups. *a*) "Romashka" detector system consisting of 22 NaI(Tl) scintillators; *b*) "Romasha" detector system consisting of 18 BGO scintillators: *1* — ING-27 generator; *2* — target; *3* — target holder; *4* — aluminium frame; *5* — support stand for γ-ray detector; *6* — γ-ray detector

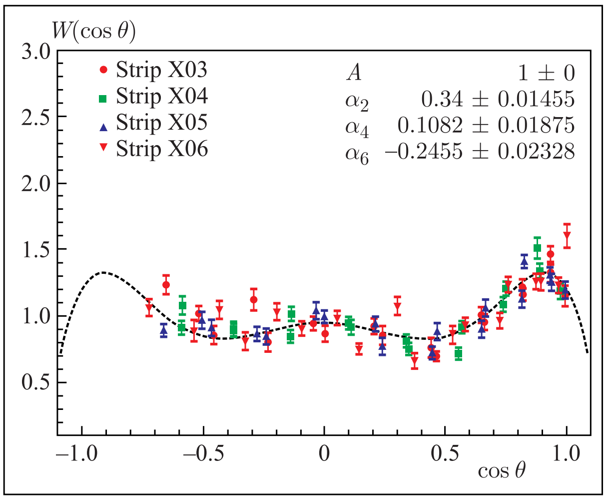


Fig. 6. Angular distribution of gamma rays with an energy of 6.13 MeV from the reaction $^{16}O(n, n'\gamma)^{16}O$. The probability of gamma-ray emission as a function of the cosine of the angle of emission relative to the direction of incident neutrons is described by the expression $W(\theta) = A \sum_{i=0}^{2J} a_i P_i(\theta)$

work of the programs and grants of the JINR Member States and Protocols on scientific and technical cooperation with research and educational institutions from different countries. Test samples for interlaboratory comparison under the IAEA program were studied. An elemental analysis of $\sim$ 1000 samples was performed using Thermo Scientific iCE3500 atomic absorption spectrometer.

IBR-2 PULSED REACTOR AND COMPLEX OF CRYOGENIC NEUTRON MODERATORS

In 2018, the IBR-2 research nuclear facility was operated in a nominal on-power mode under Rostechnadzor license valid until 30.09.2022. Statistical data on the IBR-2 operation are presented in the table.

No. of cycle	Period	Moderator type	Reactor operation for physics experiments, h
1	15.01–28.01	Water	262
2	06.02–18.02	Cryogenic	272
3	14.03–17.03	Water	56
4	09.04–21.04	Water	283
5	14.05–16.05	Water	45
6	—	—	Canceled
7	—	—	Canceled
8	19.11–04.12	Water	247
9	10.12–28.12	Water	422
		Total:	1587

In 2018, the CM-202 moderator operated for two cycles in a cryogenic moderator mode. CM-202 was cooled using a new cryogenic system. After having upgraded the pipeline system, thermal bridges and having optimized the operating parameters of the equipment, the temperature in the CM-202 chamber was reduced by 10 K. As a result, the minimum temperature in the CM-202 chamber is 20–22 K. The experiments conducted on the REMUR (beamline 8) and NERA (beamline 7c) spectrometers at new temperatures have shown an increase in the flux of cold neutrons of up to 22%.

In 2018, in accordance with contract No. 170-154126/400/683 of 24.08.2015 in the course of manufacturing a standby movable reflector MR-3R at the Votkinsk Machine-Building Plant, the specialists from the FLNP Mechanical and Technological Department performed inspection and supervision of manufacturing of units and component parts of the movable reflector, as well as acceptance testing of the reflector units at intermediate stages and assembly checks of IRM2M.110.000SB and IRM2M.50.000SB. At present, at the Votkinsk Machine-Building Plant the assembling of MR-3R is in progress before trials in accordance with the agreed program.

NOVEL DEVELOPMENT AND CONSTRUCTION OF EQUIPMENT FOR THE SPECTROMETER COMPLEX OF THE IBR-2 FACILITY

In 2018, the activities on the creation of a clean room (CR) for assembling neutron detectors were completed. The CR is located in FLNP bldg 119 and comprises two clean zones: an anteroom and a working area. The working area serves for winding and washing detector electrodes as well as for assembling detectors. The clean room maintains a constant temperature and humidity, and the air is filtered to remove aerosol and suspended particles. The air purity in the anteroom corresponds to ISO 7 class, in the working area — to ISO 6 class in accordance with GOST ISO 14644-1-2002. The creation of CR allows us to significantly reduce the time required for assembling neutron detectors, and, most importantly, improve the quality of performed work.

EVENTS

1. The annual International Seminar on Interaction of Neutrons with Nuclei (ISINN-26) was held in Xi'an (China) from 28 May to 1 June. In 2018, for the first time, the Northwest Institute of Nuclear Technology (NINT) and Xi'an Jiaotong University (XJTU), as well as the Chinese Radiation Physics Society (CRPS) became co-organizers of ISINN, along with its founder and long-term organizer — Frank Laboratory of Neutron Physics.

2. The international conference "Biomonitoring of Atmospheric Pollution BioMAP-8" was held in Dubna on 2–7 July. Its aim was to share knowledge about methods and strategies for monitoring ambient air quality.

3. The 24th Russian Conference on Neutron Scattering in Condensed Matter (NSCM-2018) was held on 17–21 September in Peterhof, St. Petersburg, and continued its more than half-a-century tradition of holding these meetings, which gather scientists to discuss current problems related to the use of neutron scattering techniques. The Joint Institute for Nuclear Research was a co-organizer of this Conference along with the National Research Center "Kurchatov Institute", Petersburg Nuclear Physics Institute and St. Petersburg State University.

4. The International Scientific and Memorial Seminar dedicated to the 110th anniversary of the birth of the Nobel and State Prize laureate, organizer and long-term Director of the Laboratory of Neutron Physics of the Joint Institute for Nuclear Research Academician Ilya Mikhailovich Frank was held in the JINR Scientists' Club on 23 October 2018.

5. The international conference "Biomembranes 2018" organized with the participation of the Joint Institute for Nuclear Research was held at the Moscow Institute of Physics and Technology in Dolgoprudny on 1–5 October 2018. A major goal of the conference was to provide up-to-date information about research on biomembranes and to discuss cutting-edge problems of modern integrative structural biology of biomembranes and membrane proteins, theoretical biophysics of membrane systems and computer modelling.

6. The workshop "Advanced Ideas and Experiments for the New Dubna Neutron Source (DNS-IV). Related Moderators and Infrastructure" was held on 6–8 December in the JINR International Conference Hall. This meeting summarized the results of three-year work on the concept of DNS-IV and outlined areas for further activities.

REFERENCES

1. *Cong J., Zhai K., Chai Y., Shang D., Khalyavin D. D., Thompson R. D., Kozlenko D. P. et al.* Spin-Induced Multiferroicity in the Binary Perovskite Manganite Mn_2O_3 // Nature Commun. 2018. V. 9. P. 2996.
2. *Balagurov A. M., Bobrikov I. A., Golovin I. S.* Anomalous Behavior of an $\alpha \rightarrow \gamma$ Phase Transition in Iron: Results of *In Situ* Neutron Diffraction Experiment // JETP Lett. 2018. V. 107. P. 558–563.
3. *Nagornyi A. V., Petrenko V. I., Rajnak M., Gapon I. V., Avdeev M. V., Dolnik B., Bulavin L. A., Kopcansky P., Timko M.* Particle Assembling Induced by Nonhomogeneous Magnetic Field at Transformer Oil-Based Ferrofluid/Silicon Crystal Interface by Neutron Reflectometry // Appl. Surf. Sci. 2019 (in press).
4. *Tomylko S. V., Tomchuk O. V., Ivankov O. I., Ryukhtin V., Bulavin L. A., Avdeev M. V.* Multilevel Structure of Diamond Nanoparticles — Liquid Crystal Composites // Mater. Today: Proc. 2018 (submitted).
5. *Avdeev M. V., Bobrikov I. A., Petrenko V. I.* Neutron Methods for Tracking Lithium in Operating Electrodes and Interfaces // Phys. Sci. Rev. 2018. P. 20170157.
6. *Golubkov E. A., Lebedev N. I., Minashkin V. F., Pokrovsky S. V., Repkin A. N., Chepurchenko R. A., Shabratov V. G., Shvetz V. A.* A Triode Electron Gun of Linear Accelerator LUE-200, IREN Facility. JINR Preprint P9-2018-42. Dubna, 2018 (in Russian).
7. *Zeynalov Sh. S., Sedyshev P. V., Sidorova O. V., Shvetsov V. N.* Position Sensitive Detector for Prompt Fission Neutron Investigations // Intern. J. Mod. Phys.: Conf. Ser. 2018. V. 48. P. 1860123.

LABORATORY OF INFORMATION TECHNOLOGIES

In 2018, research on two topics of first priority, namely, “Information and Computing Infrastructure of JINR” and “Methods, Algorithms and Software for Modeling Physical Systems, Mathematical Processing and Analysis of Experimental Data”, was conducted by the Laboratory of Information Technologies (LIT) in the scope of the JINR research field “Networks, Computing, Computational Physics”. The LIT staff participated in research on 25 topics of the JINR Topical Plan within cooperation with other JINR Laboratories.

In 2018, the Multifunctional Information and Computing Complex (MICC) of JINR was replenished with a new high-performance component. The “Govorun” supercomputer, representing a heterogeneous computing platform containing computing components with nodes based on the processors Intel® Xeon® Scalable and Intel® XeonPhi™ 7290 as well as a component with computing accelerators GPU NVIDIA V100 (DGX-1), was successfully installed and put into operation, which would enable conducting resource-intensive, massively parallel calculations that require different types of computing architectures. The processor component of the “Govorun” supercomputer was implemented by the Russian JSC “RSC Technologies”, a developer and integrator of the “full cycle” supercomputer solutions of new generation based on advanced liquid cooling as well as a number of its own innovative solutions.

The JINR MICC consisting of four key components — the grid infrastructure, the central computing complex, the computing cloud, and the HybriLIT high-performance platform, which includes the “Govorun” supercomputer, ensures the implementation of a whole range of competitive research conducted at the world level at JINR in experiments: MPD, BM@N, ALICE, ATLAS, CMS, NOνA, BESIII, STAR, COMPASS and others. The MICC includes the Tier-1 grid center which is the only one in the JINR Member States and one of the seven world data storage and processing centers of the CMS experiment (CERN) of such a high level. The JINR Tier-1 and Tier-2 grid centers are elements of the global grid infrastructure used in the WLCG project for processing data from the LHC experiments and other grid applications.

In 2018, employees of the Laboratory of Information Technologies published 251 scientific papers in refereed scientific journals, presented 103 reports at international and Russian conferences.

JINR INFORMATION AND COMPUTING INFRASTRUCTURE

In 2018, work related to the development and maintenance of the reliable operation of the JINR network and information and computing infrastructure was continued. The main elements of this infrastructure are telecommunication channels, the JINR local area network (LAN), a multifunctional information and computing complex, and basic software including those based on cloud, grid and hybrid technologies combining the Institute information and computing resources into one environment available for all users.

In 2018, works on the creation of new tools to support MICC users’ work in terms of developing and simplifying data access, providing users with convenient tools to access their home directories, remote access to shared data storages and software, convenient and unified authentication method and authorization, began. The systems common to all the MICC components, such as CVMFS for organizing access to shared software of user groups, EOS for distributed storage and access to data, were installed and put into operation. The volume of the system based on EOS is 3.74 PB. These systems will be used to store, process, analyze data, simulate the NICA experiments using the MICC resources, and to create a single EOS space at two JINR sites.

JINR Telecommunication Data Links. In 2018, reliable operation of the Dubna–Moscow high-speed communication channel was ensured. The external JINR channel was built on the DWDM (Dense Wave Division Multiplexing) technology and used one 100 Gbit/s lambda and two lambdas (two frequencies) of 10 Gbit/s each. According to the development plans, the modernization of the network infrastructure and external communication channels (data link) began. The configured DWDM equipment for the organization of an additional fiber-optic channel Dubna–Moscow with a capacity of 100 Gbit/s was installed at the MMTS-9 site in Moscow which would give a new direct channel to CERN. Thus, the external distributed network of JINR will be represented by the JINR–CERN direct channel (data link) and a backup channel passing through MMTS-9 in Moscow and Amsterdam ensuring the operation of LHCOPN (JINR–CERN) for connection between Tier-0 (CERN) and Tier-1 (JINR) and the external superimposed network LHCONE intended for the JINR Tier-2 center, direct channels for connection using RU-VRF technology with the collaboration of RUHEP research centers and networks Runnet, RASnet.

The distribution of incoming and outgoing traffics over JINR subdivisions in 2018 (exceeding 10 TB by incoming traffic) is presented in the table.

Subdivision	Incoming, TB	Outgoing, TB
DLNP	197.8	67.84
VBLHEP	161.99	77.77
LIT	87.55	22.91
FLNP	76.84	39.77
Hotel and Restaurant Complex	67.72	8.11
FLNR	67.09	11.49
Remote access node	50.01	5.21
JINR Directorate	41.33	28.24
BLTP	29.08	7.91
Medical-Sanitary Unit 9	19.92	1.12
Dubna State University	17.69	20.02
JSC “NPK Dedal”	16.89	1.25
Social Infrastructure Management Office	11.99	1.06
Procurement and Logistics Service	11.63	10.35
LRB	10.65	3.47

In 2018, the total incoming traffic of JINR including general-purpose servers, Tier-1, Tier-2 and computing complex amounted to 18.62 PB. Traffic with scientific and educational networks accounting for 96.6% of the total is the main one.

JINR Local Computing Network. In 2018, work on the development and improvement of network components of the JINR IT-structure designed to increase its efficiency was continued. A new 4×100 Gbit/s connection project is being implemented between the DLNP and VBLHEP sites with double redundancy in order to improve the reliability of the optical backbone. The 100 Gbit/s equipment for the optical backbone of the JINR network and the MICC network infrastructure is at the testing and configuration stage. The Internet exchange node IX-GW of the JINR network, the VPN service, and the computing cluster of the network service were modernized. The Institute mail cluster mail.jinr.ru was transferred to the new hardware, new software, and new type of data storage. The basis of this platform is a disk cluster based on CEPH and a virtual cluster based on Proxmox (KVM). At present mail service mail.jinr.ru contains 2621 actual mailboxes. A plugin which would enable working from mobile devices was installed on webmail.jinr.ru. The SSO-login system (single authentication login) simplifying the user access to applications integrated into the system was put into operation. To date, services such as PIN, JINR Document Database, ADB2, SED have been integrated into the SSO system. More than 400 network infrastructure elements, 150 services, 20 000 counters are being continuously monitored. Approximately 48 thousand events indicating attacks on the JINR network were recorded. Each month about 250 notifications are sent to external providers about attacks on the network.

The JINR LAN contains 7629 network elements and 13 897 IP-addresses, 6910 network users, 2465 mail.jinr.ru service users, 1489 electronic library users, and 344 remote access service users.

JINR Grid Environment. The JINR grid infrastructure is represented by the Tier-1 center for the CMS experiment at the LHC and the Tier-2 center which supports a whole number of virtual organizations (VO), particularly, ALICE, ATLAS, CMS, LHCb, BES, BIOMED, COMPASS, MPD, NOνA, STAR and others.

The data processing system at the JINR CMS Tier-1 consists of 332 64-bit machines: $2 \times$ CPU, 6–16 cores/CPU forming altogether 6512 cores for batch processing and provides a performance of 96.43 kHS06. The storage system consists of disk arrays and long-term data storage on tapes and is supported by the dCache-3.2 and Enstore 4.2.2 software. The total usable capacity of disk servers is 8.3 PB, the IBM TS3500 tape robot is 11 PB. The Torque 4.2.10/Maui 3.3.2 software (custom build) is used as a resource manager and task scheduler. The PhEDEx software is used as a tool for management of the CMS data placement. The standard WLCG program stack is used for data processing: $2 \times$ CREAM, $4 \times$ ARGUS, BDII top, BDII site, APEL parsers, APEL publisher, EMI-UI, $220 \times$ EMI-WN + gLExec-wn, $4 \times$ FTS3, LFC, WMS, L&B, glite-proxyrenewal. The service support system provides the operation of a computing service, a data storage service, a grid service, a data transfer service (FTS — File Transfer System), a distributed computing management system (PBS — Portable Batch System), an information service (monitoring of services, servers, storage, data transmission, information sites).

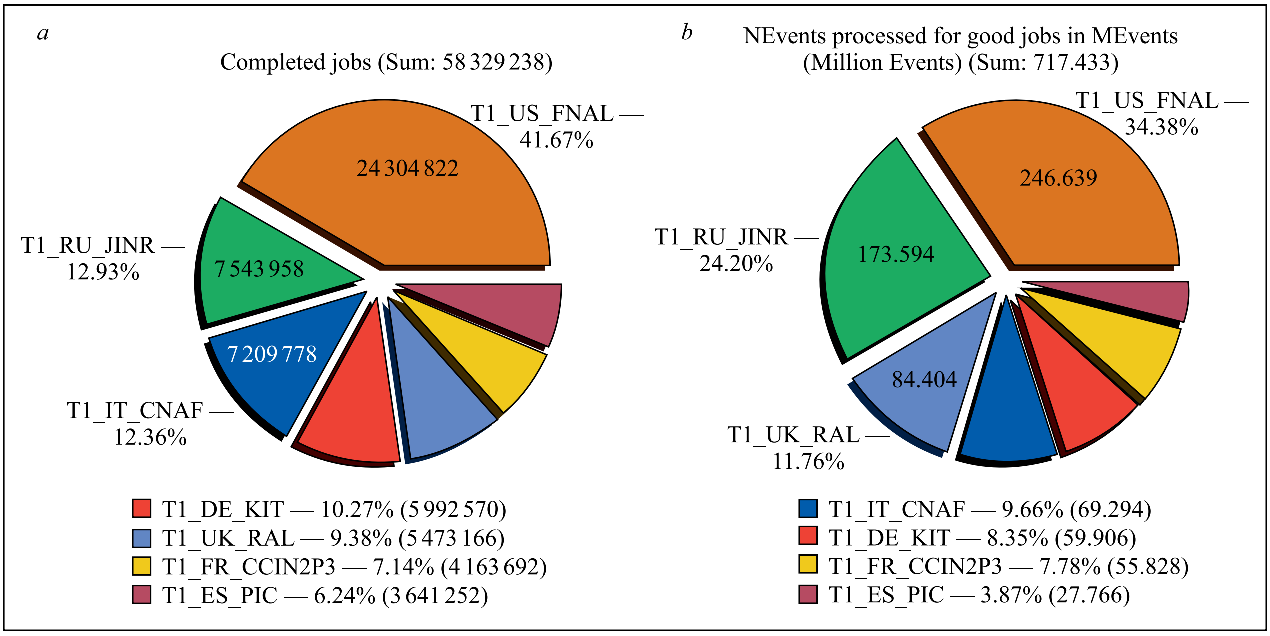


Fig. 1. The number of jobs (*a*) and events (*b*) processed for CMS by Tier-1 centers during 2018

The CMS Tier-1 center at JINR has demonstrated stable work through the entire period since its launch into full operation [1]. In 2018, 7 543 958 tasks were completed, 173 594 million events were processed which accounted for 24.2% of the total number of the CMS experiment events processed by all Tier-1 sites. Figure 1 demonstrates the contribution of the world first-level centers to the processing of CMS experimental data during 2018. The JINR site takes the second place in its performance among world CMS Tier-1 centers.

Figure 2 shows the number of events processed at the JINR CMS Tier-1 center in 2018 by different types of stream processing (reconstruction, modeling, reprocessing, analysis, etc.).

One of the main functions of the Tier-1 centers is to provide data exchange with all global sites operating on the CMS experiment and storage of raw experimental and simulated data. In 2018, the total data exchange with the tape robot was 12.3 PB (5.6 PB of new data). The disk storage was used more actively: the total amount of transferred data was 60.2 PB, of which 19.5 PB of new data. Figure 3 shows the statistics of the JINR CMS Tier-1 data exchange with other grid centers during 2018. The average data transfer rate for the JINR CMS Tier-1 is 400–520 MB/s.

The Tier-2 center at JINR provides data processing for all four experiments at the LHC (ALICE, ATLAS, CMS, LHCb) and apart from that supports a number of virtual organizations (VO) that are not members of the LHC (BES, BIOMED, COMPASS, MPD, NOνA STAR, ILC). The computing resources of the Tier-2 center consist of 4128 cores. The data storage system is installed in two versions of the software: two dCache

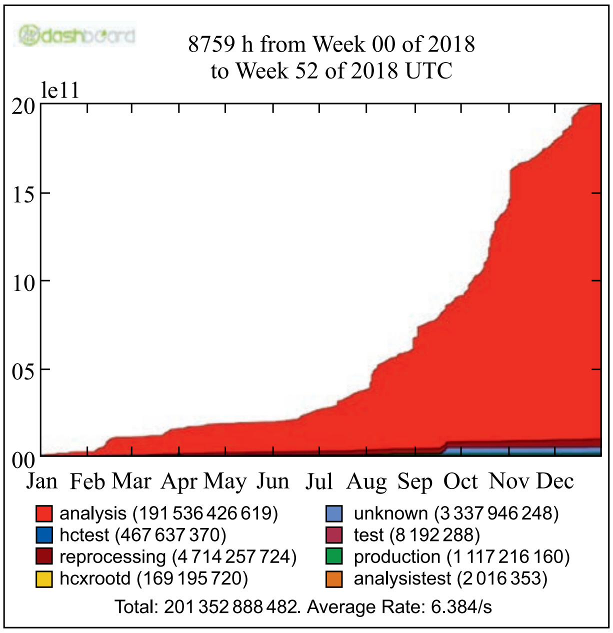


Fig. 2. Distribution of events processed at the JINR CMS Tier-1 center in 2018 by type of processing (reconstruction, simulation, reprocessing, analysis, etc.)

installations and two XROOTD installations. Figure 4 shows data on the use of the JINR Tier-2 site (JINR-LCG2) by VOs in the framework of grid projects in 2018.

High-Performance Computing System. The MICC allows users to perform calculations including parallel ones outside the grid environment. It is necessary for experiments such as NOνA, PANDA, BES, NICA/MPD and others, as well as for local users from

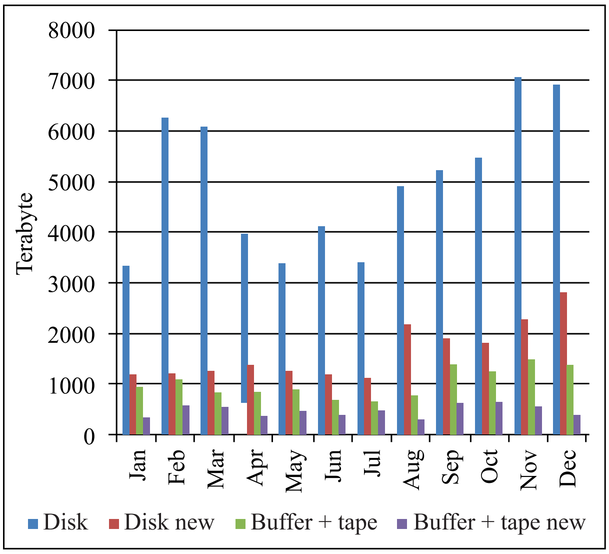


Fig. 3. Statistics of the JINR CMS Tier-1 data exchange with other grid centers during 2018: disk — all exchanges with the disk array (reading and recording); disk new — new data from the total volume (recording); buffer + tape — all exchanges with the tape robot (reading and recording); buffer + tape new — new data from the total volume transferred to the tape robot (recording)

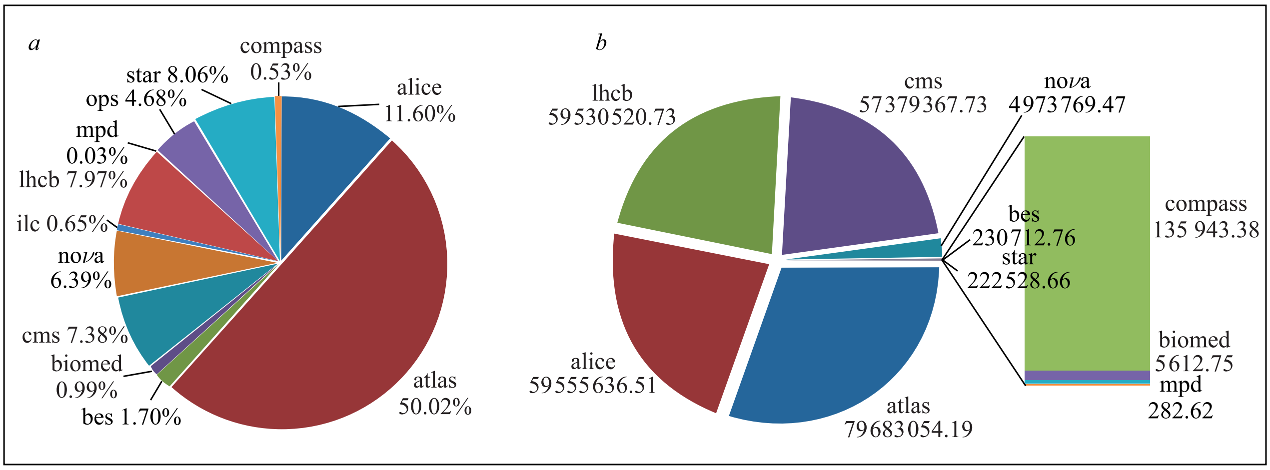


Fig. 4. The use of the JINR-LCG2 grid site at JINR by the virtual organizations of the global grid infrastructures: *a*) distribution by the number of jobs; *b*) distribution by the normalized CPU time in HS06 hours

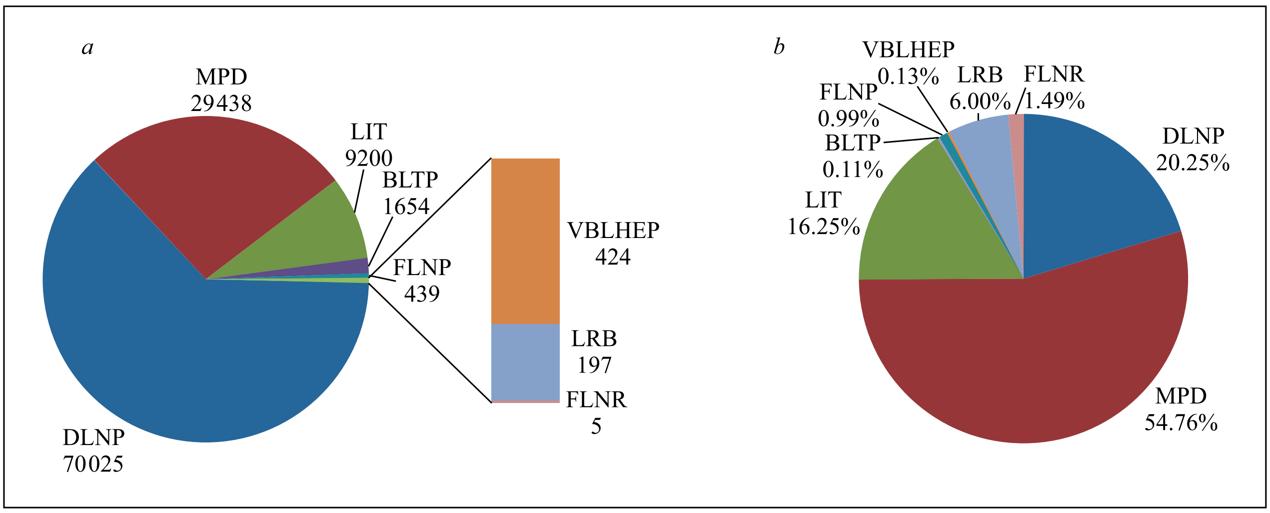


Fig. 5. Statistics of the use of the computing cluster by the JINR subdivisions and experiments without taking into account the users of the grid environment: *a*) distribution by the number of jobs; *b*) distribution by the normalized CPU time in HS06 hours

the JINR Laboratories. All computing resources are available to JINR users and users of the grid environment through a single system of batch processing of jobs. Figure 5 shows the time distribution of jobs performed on the computing cluster by the JINR Laboratories and user groups.

Cloud Environment. JINR takes part in a large number of research projects, in many of which computing resources are an important means for obtaining significant scientific results. In this connection the integration of the computing resources of the Institute Member States into a united information and computing environment is an important and urgent task, the solution of which would significantly speed up the research process. For effective use of local computing resources cloud infrastructures were or are being created in each of the organizations participating in their unification. In 2018, work on integrating the clouds of each of the partner organizations of the JINR Member States into a distributed platform based on the DIRAC software (Distributed Infrastructure with Remote Agent Control) was carried out [2]. Clouds of organizations integrated into the JINR distributed information and computing environment are shown in Fig. 6.

In 2018, the JINR cloud infrastructure resources were increased from 728 CPU cores and 3 TB of total RAM to 1572 CPU cores and 8 TB of total RAM. The main users of cloud infrastructure are DLNP, LIT and the NOνA experiment.

A service has been developed that provided JINR cloud users with the opportunity to gain access to computing resources through a problem-oriented web interface adapted to form a computing job using a specific application package or a set of them for work in a narrow area of research. The user of this service should only input the values for the parameters of his job and the address for downloading the results in the web interface [3]. The entire computing part will be performed on virtual machines (VM) of the JINR cloud infrastructure. The scheme and interrelations of the service components are presented in Fig. 7.

A method of increasing the efficiency of using cloud resources was developed [4], which was based on the idea of dynamic redistribution of VMs on physical equipment. A two-rank strategy of VM distribution through cloud infrastructure nodes was implemented, that would allow minimizing the amount of idle resources of cloud infrastructure and the impact of congestion at the same time.

Heterogeneous Infrastructure. In 2018, the JINR MICC was replenished with a new high-performance component — the “Govorun” supercomputer [5]. It is a natural development of the HybriLIT heterogeneous platform and has led to a significant increase in the performance of both the CPU and GPU components of the platform. The supercomputer GPU component includes 5 NVIDIA DGX-1 servers. Each server has 8 GPU NVIDIA Tesla V100 based on the latest NVIDIA Volta architecture. In addition, one NVIDIA DGX-1 server has 40 960 CUDA cores which are equivalent to 800 high-performance CPUs in their computing power. DGX-1 uses a whole number of new technologies including NVLink 2.0 bus with a capacity of up to 300 Gbit/s.

The new supercomputer includes a high-density and energy-efficient solution “RSC Tornado” with direct liquid cooling developed by specialists of the Russian group of RSC companies. New universal computing cabinets “RSC Tornado” with a record energy density and a system of precision liquid cooling balanced for

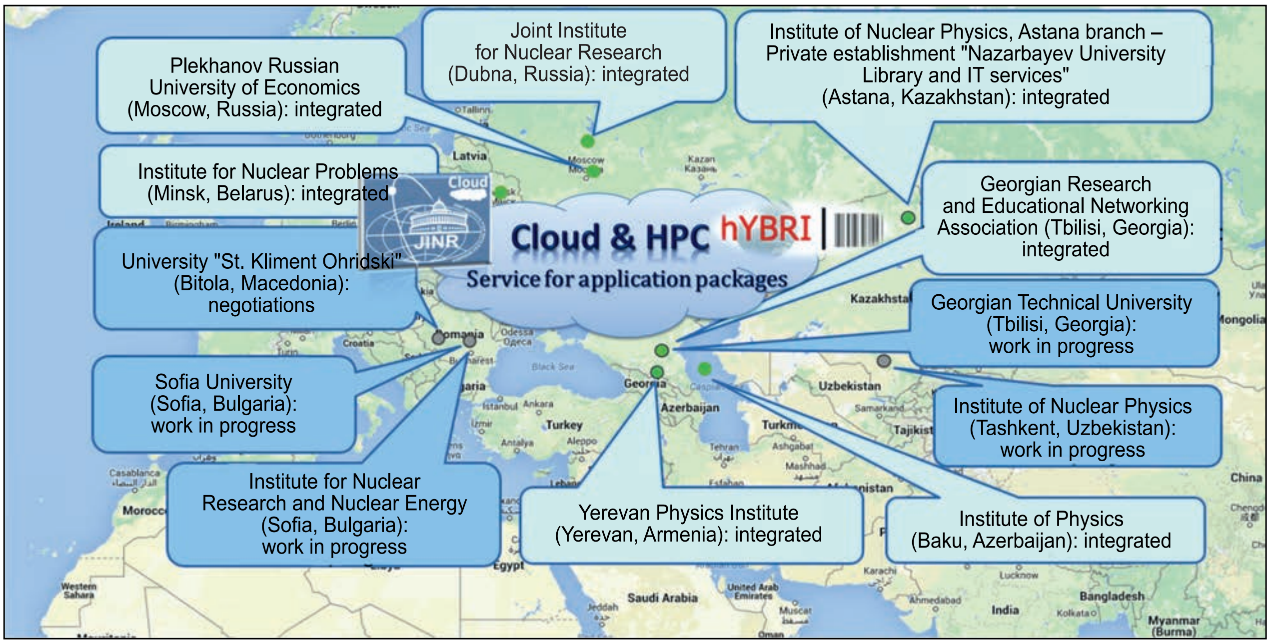


Fig. 6. Clouds of organizations integrated into the JINR distributed information and computing environment

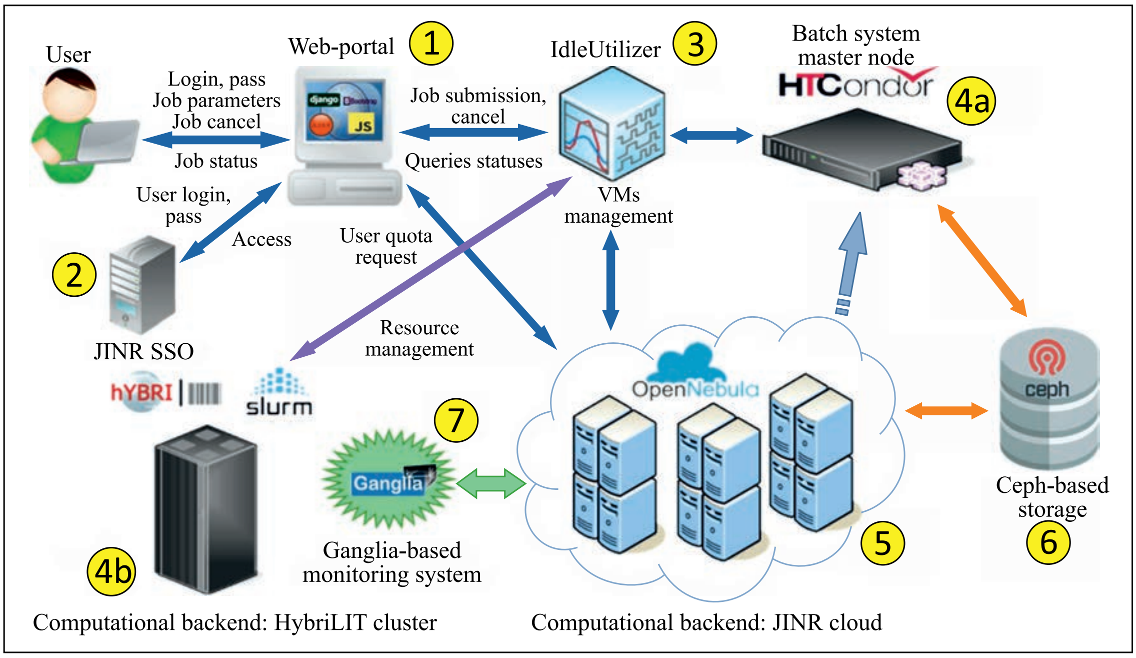


Fig. 7. The scheme of the service for providing users with access to computing resources through a problem-oriented web interface

constant work with a high-temperature coolant (up to $+63\,^\circ$C at the entrance to the computer cabinet) were installed at LIT. The work in the "hot water" mode for the given solution allowed one to apply the year-round free-cooling mode ($24 \times 7 \times 365$) using only dry-cooling towers operating at an ambient temperature of up to $+50\,^\circ$C and also completely get rid of the freon circuit and chillers. As a result, the average annual PUE of the system reflecting the level of energy efficiency is less than 1.03. Thus, cooling consumes less than 3% of all consumed electricity which is an outstanding result for the HPC industry.

The computing nodes were based on Intel server products: the most powerful 72-core server processors Intel® XeonPhi™7290, processors of Intel® Xeon® Scalable (models Intel® Xeon® Gold 6154 and the latest high-speed solid-state disks Intel® SSD DC P4511 with NVMe interface and a capacity of 1 TB). For high-speed data transfer between computing nodes, the supercomputer uses an advanced switching technology Intel® Omni-Path providing the speed of non-blocking switching up to 100 Gbit/s based on 48-port switches Intel® Omni-Path Edge Switch 100 Series with 100% liquid cooling that ensures a high efficiency of the cooling system in the "hot water" mode and the lowest total cost of ownership of the system. The use of Intel® Omni-Path Architecture allows not only matching the current needs of resource-intensive user applications but also providing the necessary network bandwidth for the future.

Peak supercomputer performance is 1 PFlops for single-precision operations and 500 TFlops for double-precision operations.

At present, the supercomputer is used to solve problems that require massively parallel calculations in various fields of nuclear physics and high energy physics, particularly, in lattice quantum chromodynamics to study the properties of hadronic matter at high-energy density and baryon charge and in the presence of supramaximal electromagnetic fields. It is also applied for mathematical modeling of interactions of antiprotons with protons and nuclei using DPM, FTF and UrQMD + SMM generators developed at JINR and being of interest for the NICA/MPD experiment, for modeling the dynamics of collisions of relativistic heavy ions, as well as for solving applied problems such as calculating Josephson junctions, modeling the dynamics of many-particle Boson systems in magnetic optical traps, calculating corrections for the matrix element in the first Born approximation in case of a direct ionization of a helium atom by a fast proton taking into account different models of the final state and others.

The average load on computing components is the following: the component based on Intel® Xeon® Scalable is 80.58% (maximum 89%); the component based on Intel® XeonPhi™ is 38.41% (maximum 74%); the component with GPU computing accelerators is 73.58% (maximum 100%). In total, over the period of operation all the groups performing calculations on the supercomputer completed over 66 000 tasks on all computing components.

Monitoring System. To ensure reliable operability of the MICC in the 24/7 mode, it is extremely important to monitor all components at three levels: hardware, network and service. Different components of the MICC require a different approach to monitoring, and one can hardly find a single monitoring system capable of satisfying all the requirements and at the same time remaining flexible for changes. A multilevel monitoring system of the MICC was created, and at present it is being expanded using different technologies such as Nagios, Icinga2, Grafana as well as systems developed at LIT. Grafana as a visualization tool is currently used only in the JINR computing cloud, but can be accepted for other components. The monitoring of the Tier-1 services, monitoring of the HybriLIT heterogeneous cluster and the "Govorun" supercomputer were specially developed at LIT.

In 2018, work on refining the software package for modeling distributed data storage and processing systems (SyMSim) with the aim of using it to improve the topology of the computer network and the performance of the data center of the Institute of High Energy Physics of the Chinese Academy of Sciences was carried out. Parameters from the database of the computing infrastructure of the Institute as well as some data from the BESIII experiment were used as input data for simulation. The first simulation results showed that the proposed approach allowed making an optimal choice of the network topology increasing its performance and saving resources [6].

In the framework of the creation of a system for storing and processing data from the BM@N and MPD experiments included in the NICA complex, a new macro-modeling scheme was developed and implemented. This program uses a probabilistic approach to assess various equipment configurations which would determine the probabilities of loss of information arriving from the detectors for each of these configurations. This probability would not exceed the specified limit and the price would be minimal, selected taking into account economic factors. The program was tested on the calculations of the efficiency of the data acquisition and storage system of the BM@N experiment from price investments in the system of the disk memory of the intermediate data storage [7].

A set of interconnected cloud services and tools for managing and processing data of biomonitoring were developed; these tools allow one to simplify and automate the stages of monitoring starting from selecting sites for collecting samples and ending with generating maps of pollution distribution and predicting environmental changes. This is the first solution in Russia and Europe that allows all specialists involved in the biological monitoring network to get access to the data on environmental pollution. In 2018, the development of the architecture and technologies of the portal moss.jinr.ru was continued (Fig. 8). The ability to compare the concentrations of heavy metals in samples of different years in the form of diagrams as well as statistical calculations was added. The module for comparison of concentrations in countries and regions was optimized. The module for calculating geo-indexes was improved — now it is possible to set the level of background pollution. The possibility of creating pollution maps by users of the platform was expanded and the ability to import data into Google Earth was added. Maps and statistical calculations for the atlas 2015–2016 were formed. An alpha-version of a mobile application for

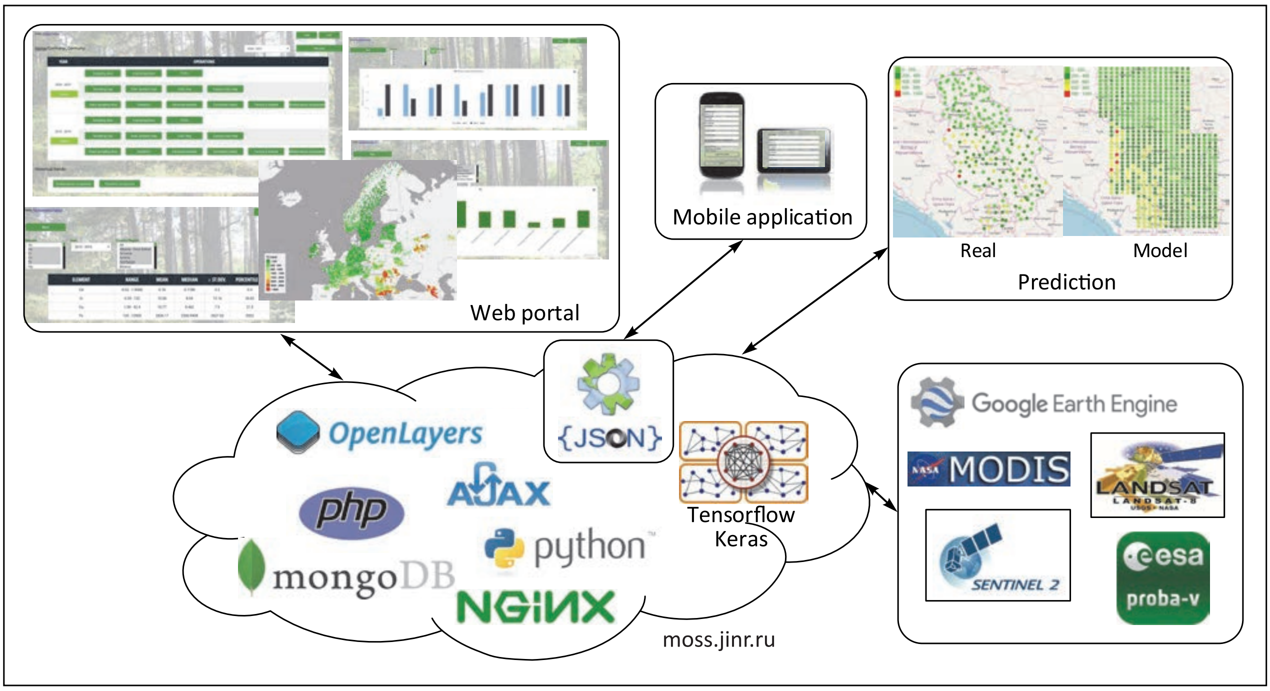


Fig. 8. Architecture and technologies of the portal moss.jinr.ru

registering data on sampling sites and uploading them to the platform was developed. The application will reduce the number of errors when filling out forms and provide the potential to verify the correctness of the definition of moss type by the participants through the use of machine learning methods.

In the framework of the project with RFBR, methods and tools for using high-performance computing infrastructures and software applications for processing textual and graphical information about plant diseases to minimize losses in agriculture were developed [8]. A platform architecture (Fig. 9) for identifying plant diseases using modern software and organizational technologies was proposed. A web site of the project (http://pdd.jinr.ru/) was implemented. A special model of a deep convolutional network with a Siamese architecture allowing one to evade the problem of a small sample was developed. The recognition accuracy on the test sample of images was more than 95%.

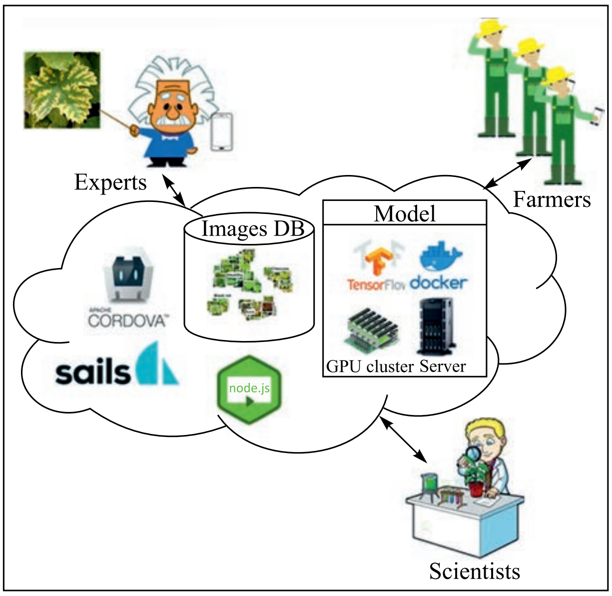


Fig. 9. Platform architecture

Works on the further development of the APT EVM project management system for NICA were completed: a consolidated report "NICA — Disbursement of Funds" with the possibility of detailing was developed. It would allow quickly controlling the information on project financing as well as forecasting expenses for the current year based on expert estimation. A module for accounting payments under contracts was developed, other current works for forming references and reports were completed, the system was maintained.

As part of the task for the further development of "1C Manufacturing Enterprise Management", a module for the purchase of computer equipment was created. The module for forming regulated reports of self-supporting units was improved. In the first half of 2018, the programs "1C: ERP Enterprise Management 2" and "1C: SPM Salary and Personnel Management" were purchased, now they are being set up, and employees of the 1C group are being trained to use the given products. On the basis of the program "1C: Retail" cash registers were launched at the "Nauka" stadium and the Athlete's House.

In the framework of the development of the "Dubna" electronic document system (EDS), ten new documents were developed and put into operation and eight were prepared for commissioning. Three specialized reports on monitoring the status and timing of documents' passage in the system were developed (Fig. 10). A version of the "Dubna" EDS adapted for mobile devices was developed and put into operation. The following works on the improvement of the system part of the "Dubna" EDS were carried out: user authentication through the JINR SSO unified authentication system was implemented and put into operation; complete refactoring of the means of assigning and verifying user access rights to documents for more flexible management of access rights was carried out; tools for automating the creation of a new type of document, its form and patterns of agreement routes were developed. When developing the "Dubna" EDS, open technologies and software, such as Java Servlet, Apache Tomcat, WALT, MySQL, JQuery, Linux, were used. Rapid and effective development of the system was achieved because of the use of the Agile software development principles.

The development of the JINR Document Server information services is being carried out under the JOIN2 project (Just anOther INvenio INstance) aimed at bringing together the partner organizations for the development of the Invenio software platform taking into account their specifics. The project partners are libraries of research centers and universities in Germany. To date, a collection of authoritative records of the Organization, Division and Personnel was deployed on the test server jds-join2. Data for forming a directory of grants with the participation of JINR were collected. Web forms with extended functionality were introduced into the data entry module which would allow automatic metadata import into publications from external bibliographic databases by a number of identifiers such as DOI, arXiv, InsWoS.

In 2018, the state registration certificate of the computer program "Software Complex of Intellectual Scheduling and Adaptive Self-Organization of Virtual Computing Resources" was received. N. A. Balashov, A. V. Baranov, I. S. Kadochnikov, V. V. Korenkov, N. A. Kutovsky, I. S. Pelevanyuk are the authors. The software complex is designed to optimize the consumption of computing resources in cloud infrastructures and can be used by cloud providers in infrastructures built on the IaaS model on the OpenNebula platform. The complex includes the VM strategy of planning based on VM and server rankings, API for interacting with the

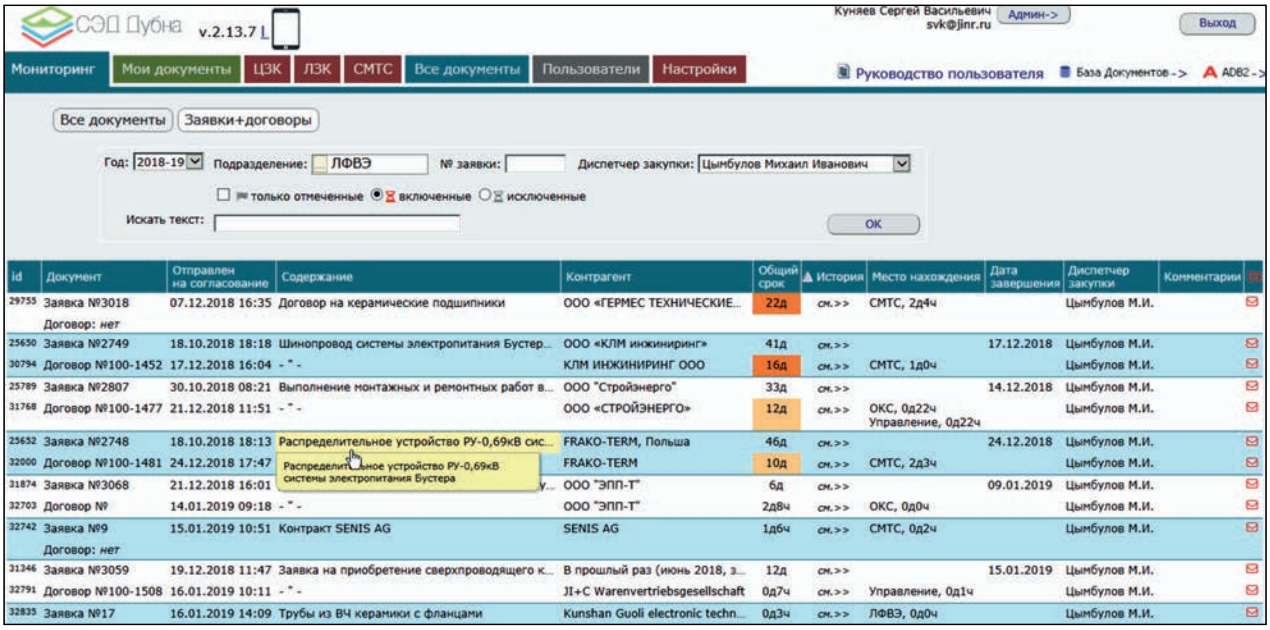


Fig. 10. Specialized report of monitoring the status of purchase requisitions and supply contracts

OpenNebula platform, an administrative web interface, net-snmp extensions and corresponding polling modules for Icinga 2 which allow collecting information on the current use of VM resources based on KVM as well as OpenVZ containers.

Traditional work on the maintenance and development of the JINRLIB program library continued. The library included the DFM-POTM/DFM-POTM_MPI software package which implemented the construction of a nucleus–nucleus optical potential of elastic scattering based on the double folding model and included the DFM-POTM sequential version and the DFM-POTM_MPI parallel version written in C++ and developed with the use of MPI technology (authors are K. V. Lukyanov, E. V. Zemlyanaya, M. V. Bashashin; http://wwwfofo.jinr.ru/programs/jinrlib/dfm-potm/index.html).

In 2018, works on maintenance and development of the functionality of the services rendered to the users of the "Visit Center" portal providing online support for the implementation of the JINR visitors reception process (https://visitcentre.jinr.ru/) and the modernization of the JINR journals' web portal "Physics of Elementary Particles and Atomic Nuclei" (PEPAN) and "Letters to PEPAN" (http://pepan.jinr.ru/) were carried out. Traditionally the development, creation and maintenance of websites of conferences, symposia at the request of Laboratories and other JINR departments were carried out (ECPM-2018, http://ecpm2018.jinr.ru; EXON-2018, http://exon2018.jinr.ru). Hosting with the transfer of all the information of past conferences (from 2006 to 2017) to create the site of the international conference "Mathematical Modeling and Computational Physics" (MMCP-2019) (http://mmcp.jinr.ru) was organized.

METHODS, ALGORITHMS AND SOFTWARE FOR MODELING PHYSICAL SYSTEMS, MATHEMATICAL PROCESSING, AND ANALYSIS OF EXPERIMENTAL DATA

One of the main activities of LIT is to provide mathematical, algorithmic and software support for experimental and theoretical studies conducted at JINR. Below there is a breif report on some results.

Two different algorithms based on deep neural networks for the reconstruction of elementary particle tracks in the processing of experimental information from the GEM tracking detector in the BM@N experiment at the NICA collider were developed and implemented. The first algorithm using deep recurrent networks showed an efficiency of 98% on the carbon–carbon collisions modeled by the Geant4 program. The second algorithm based on the original generalization of the convolutional neural network showed high efficiency and speed of work on model events without a magnetic field [9].

New probabilities of the birth of strange quark–antiquark and diquark–antiquark pairs were proposed and introduced into the FTF model of the Geant4 package. A good agreement between calculations using the improved version of the FTF model and experimental data from the NA61/SHINE collaboration on the production of K-mesons, antiprotons and Lambda-hyperons into proton–proton, proton–carbon and pi-meson–carbon interactions at different initial energies was obtained. In the framework of the improved FTF model, the kinematic characteristics of Lambda-hyperons and K-mesons produced in antiproton–proton interactions were calculated and compared with experimental data at different momentum values of incident antiprotons. A good agreement between experimental data and calculations using the FTF model with new probabilities and rotating quark–gluon strings was achieved. The applicability of the FTF model for the development of the physical program of the Panda Phase0 and Panda Phase1 experiments was shown [10].

The reactions p, d, He, $\mathrm{C}+\mathrm{C}$, Ta, and $\mathrm{C}+\mathrm{Ne}$, Cu at momentum of 4.2, 4.5, and 10 GeV/s per nucleon were modeled using the UrQMD model supplemented by the Statistical Multifragmentation Model (SMM). Azimuthal correlations of pions and protons produced in the listed reactions were calculated and compared with the experimental data obtained at VBLHEP on the SKM-200-GIBS and Propane Bubble Chamber installations. A good agreement between calculations using $\mathrm{UrQMD}+\mathrm{SMM}$ and experimental data was achieved [11].

For the NICA/SPD experiment elastic pp and $\bar{p}p$ interactions were simulated in the scope of a unified systematization of experimental data (USESD) in a wide range of initial energies from 100 MeV to several TeV. Inelastic proton–proton interactions were simulated using FTF at different incident proton energies, and the applicability of the USESD and FTF models for the NICA/SPD experiment was justified [12].

The method of separated form factors (SFF) is an effective method for studying the structure of polydisperse systems of phospholipid vesicles based on the analysis of small-angle scattering data. In this approach the basic parameters of the vesicular system are determined by minimizing the discrepancy between the experimental data of the small-angle scattering intensity and the results of SFF calculations. The minimization procedure is based on the generalized method of the least squares implemented in the FUMILI program of the JINRLIB library. The efficiency of parallel implementation was tested on the HybriLIT cluster using the parallel MPI version of this program — PFUMILI. It was shown that the acceleration of calculations was 6–9 times depending on the number of experimental points. The assessment of the structural parameters of the vesicles of the phospholipid transport system was made on the basis of the numerical analysis of small-angle neutron scattering data obtained on the YuMO small-angle spectrometer at the Frank Laboratory of Neutron Physics [13].

Based on the hybrid model of a microscopic optical potential using three models of $^{12,14}\mathrm{Be}$ nuclei density, calculations of the observed physical characteristics of the scattering of these nuclei during the interaction of these nuclei with a carbon and proton target were carried out. A good agreement with the experimental data on the scattering of $^{12,14}\mathrm{Be}+p$ at an energy of 700 MeV was obtained. It was shown that adequate reproduction of the differential scattering cross sections of $^{12,14}\mathrm{Be}+{}^{12}\mathrm{C}$ at an energy of 56 MeV/nucleon required consideration of the contribution of inelastic channels. The momentum distributions of $^{8}\mathrm{B}$ breakup fragments in the reactions of this nucleus with other nuclei and the total cross sections for the reactions of $^{6}\mathrm{He}$ and $^{8,9}\mathrm{Li}$ with other nuclei in a wide range of atomic masses and energies were calculated on the basis of the microscopic approach [14].

A parallel version of the program for calculating the nucleus–nucleus potential of double folding based on the OpenMP technology was developed. The calculations performed on the HybriLIT cluster confirm the efficiency of the developed parallel program comparable to the previously developed MPI implementation [15].

The stability of solutions of the third family for hybrid compact stars with a quark core corresponding to the emergence of high-mass twins with respect to the softening of the phase transition using a design imitating the effects of "pasta" structures in the mixed phase was investigated. A parameterized class of hybrid models of the equation of state based on the relativistic mean-field model was considered for both hadronic and quark phases of matter. The effect of the construction of phase transition with a mixed phase consists in the appearance of additional pressure near the critical point belonging to the coexistence of the hadronic and quark phases of matter. The value of the relative additional pressure of about 6%, at which the solution corresponding to the third family of compact stars disappeared, was found. It was shown that at least the heavier star from the registered merger of a pair of neutron stars GW170817 could be a member of the third family of hybrid stars [16].

Within the framework of the continuous atomistic model which consisted of a combination of the thermal peak model and the molecular dynamics method, an approach was developed on the basis of which processes in a nickel target were irradiated with uranium ions of a 700-MeV energy. To solve the equations of the continuous-atomistic model, a software package was developed, the calculations were carried out on the HybriLIT heterogeneous platform [17].

A new method for constructing fully symmetric multidimensional Gaussian quadratures on a simplex was developed. The main idea of the method is to replace the coordinates of nodes with their symmetric combinations obtained by the Vieta theorem, which simplifies the system of nonlinear algebraic equations. The construction of the required systems of equations is performed analytically using the original author's algorithm implemented in the Maple system. Up to the sixth order the given systems are solved using the built-in Polynomial System procedure that implements the Gröbner basis technique, while the systems of higher order are solved using the developed symbolic-numerical algorithm based on numerical methods for solving a system of nonlinear algebraic equations implemented in the Maple–Fortran environment. The obtained quadrature formulas are used to solve self-adjoint elliptic boundary-value problems in the d-dimensional polyhedral finite region by the finite element method of high order of accuracy [18].

The problem of describing an N-level quantum system in terms of quasiprobability distributions was considered. The classification of the Wigner quasiprobability distributions on the phase space realized in the form of a symplectic flag manifold was studied. The Wigner quasiprobability distribution is constructed in the form of a dual convolution of the density matrix and the Stratonovich–Weyl kernels [19]. It was shown that the moduli space of the Stratonovich–Weyl nucleus was given by the intersection of the orbit space of the connected action of the $SU(N)$ group and a single $(N-2)$-dimensional sphere. The general approach is illustrated by a detailed description of the module space of 2-, 3-, and 4-dimensional systems.

A new algorithm for decomposing the irreducible components of the permutation representations of finite groups over zero characteristic fields was proposed. The algorithm is based on the fact that the components of an invariant scalar product in invariant subspaces are projection operators into these subspaces which makes it possible to reduce the problem to solving systems of quadratic equations. In the zero characteristic the proposed algorithm significantly exceeds the most well-known algorithm in the computing group theory called MeatAxe. The current implementation of the algorithm allows splitting representations of dimensions to hundreds of thousands [20].

The TDDS software package (Thomas Decomposition of Differential Systems) in the Maple symbolic computation language intended for algebraic analysis of systems of nonlinear partial differential equations is included in the Computer Physics Communications program library and the latest version of Maple (Maple 2018) [21].

A Bayesian automatic adaptive quadrature solution for numerical integration was proposed which took into account three main factors: refining the automatic adaptive m-panel scheme by using quadrature sums adapted to the scales of the length of the integration domain; quick assessment of the problem complexity; the use of a weaker accuracy of the two possible ones (specifications of input accuracy and internal properties of the integral function). Consideration of the above factors allows one to achieve the highest possible accuracy of the solution with the minimum possible computation time [22].

APPLIED RESEARCH

In the course of research conducted together with FLNP in the framework of the international program on monitoring and forecasting air pollution in Europe and Asia (UNECE International Cooperative Program (ICP) Vegetation), a cloud platform was developed in the JINR cloud service for managing monitoring data. To ensure reliable storage, analysis, processing and collective use of monitoring data, modern methods of program management, statistics and machine learning were used, which also allowed using satellite imagery data to predict air pollution with heavy metals in some European regions. With the help of the developed models, the air pollution by Sb in Norway and by Mn in Serbia was successfully predicted [23]. At present the system contains information on more than 6000 sampling sites in 40 regions of various countries in Europe and Asia.

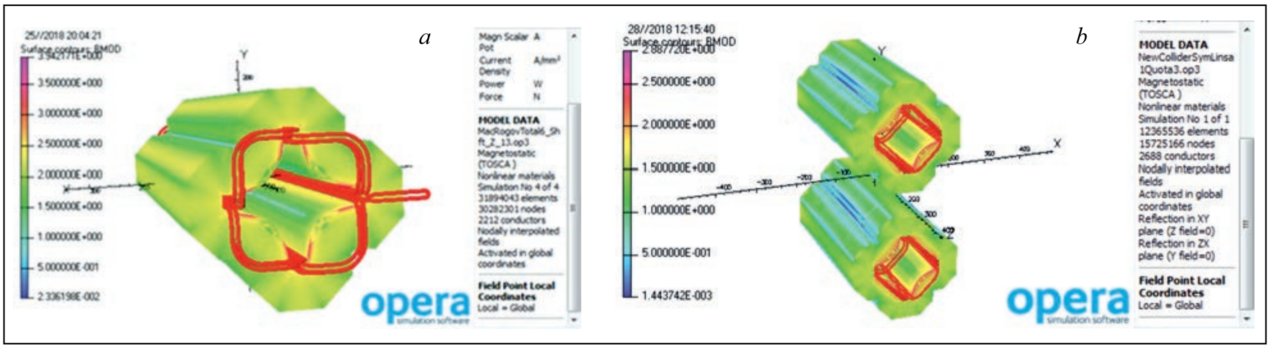


Fig. 11. *a*) 3D model of quadrupole magnet of the SIS100 (FAIR, GSI); *b*) 3D model of quadrupole magnet of the NICA collider

The method of volume integral equations of magnetostatics with a linear approximation of magnetization was applied for three-dimensional modeling of the magnet system of the CBM experiment (FAIR, GSI, Darmstadt) and the quadrupole magnet of the NICA collider. This method allows narrowing the solution of the problem of finding unknowns to the region filled with magnetic material. During simulation the symmetry of the magnetic field, which reduced the number of unknowns by eight times in the case of the SIS100 magnet of the CBM experiment and by sixteen times for the quadrupole magnet of the NICA collider, was taken into account. The influence of the deviation of magnet parameters on the quality of the field distribution in the working area of the magnet was also studied. The simulation results are presented in Fig. 11 [24].

The method of medium-term forecasting of daily passenger traffic volumes in the Moscow Metro was developed. It includes three prediction options: 1) based on artificial neural networks (ANN); 2) using a singular-spectral analysis implemented in the "Gusenica"-SSA package; 3) when using both ANN and the "Gusenica"-SSA approach. The developed methods and algorithms allow the medium-term forecasting of passenger traffic in the Moscow Metro with acceptable accuracy [25].

INTERNATIONAL COOPERATION

In collaboration with colleagues from Bulgaria, Slovakia and Japan, a numerical analysis of the phase dynamics of the stack of long Josephson junctions was carried out taking into account inductive and capacitive coupling between neighboring Josephson junctions. The influence of the model parameters on the structure of the current–voltage characteristic, the radiation power and the dynamics of the fluxons in individual Josephson junctions inside the stack was studied. The coexistence of a charge traveling wave with fluxon states was demonstrated. The given state can be considered as a new collective excitation in the system of coupled Josephson junctions. It was shown that the observed collective excitation led to a decrease in the radiation power from the system [26].

In collaboration with University of Prešov, Slovakia, algorithms and software for the numerical simulation of the interaction of water and porous materials were developed and implemented. The relevance of these studies is due to the fact that the physical characteristics of porous materials significantly depend on water saturation and affect the strength, protective and other properties of these materials. One of the most common types of pores in natural and artificial building materials are the so-called blind half-closed pores, or pores of the bag type. A three-dimensional model of this type of pores was developed. This model was used to simulate the interaction of water vapor and individual pores using a hybrid method that combined the molecular dynamics method and the method based on the use of the diffusion equation. Special studies to determine the dependences between different implementations of thermostats and the preservation of thermodynamic and statistical characteristics of the water vapor – pore system were carried out. Two types of evolution of the water vapor – pore system, pore drying and wetting, were investigated. A complete study of the properties of the diffusion coefficient, diffusion velocity, and other diffusion parameters of the water vapor – pore system was also carried out [27].

REFERENCES

1. *Baginyan A., Balandin A., Belov S., Dolbilov A., Golunov A., Gromova N., Kadochnikov I., Kashunin I., Korenkov V., Mitsyn V., Pelevanyuk I., Shmatov S., Strizh T., Trofimov V., Voytishin N., Zhiltsov V.* // CEUR Workshop Proc. 2018. V. 2267. P. 1–10; http://ceur-ws.org/Vol-2267/1-10-paper-1.pdf.
2. *Baranov A. V. et al.* // CEUR Workshop Proc. 2018. V. 2267. P. 257–261.
3. *Balashov N. A., Bashashin M. V., Kuchumov R. I., Kutovskiy N. A., Sokolov I. A.* // Mod. Informat. Technol. IT-Education. 2018. V. 14, No. 1. P. 61–72; https://doi.org/10.25559/SITITO.14.201801.061-072.
4. *Balashov N. A., Baranov A. V., Kadochnikov I. S., Korenkov V. V., Kutovskiy N. A., Pelevanyuk I. S.* // Mod. Informat. Technol. IT-Education. 2018. V. 14, No. 1, P. 101–110; https://doi.org/10.25559/SITITO.14.201801.101-110.
5. *Adam Gh., Bashashin M., Belyakov D., Kirakosyan M., Matveev M., Podgainy D., Sapozhnikova T., Streltsova O., Torosyan Sh., Vala M., Valova L., Vorontsov A., Zaikina T., Zemlyanaya E., Zuev M.* // CEUR Workshop Proc. 2018. V. 2267. P. 638–644; http://ceur-ws.org/Vol-2267/638-644-paper-122.pdf.
6. *Nechaevskiy A., Ososkov G., Pryahina D., Trofimov V., Weidong Li* // Eur. Phys. J. Web Conf. 2018. http://www.epj-conferences.org/.
7. *Trofimov V., Nechaevskiy A., Ososkov G., Pryahina D.* // CEUR Workshop Proc. 2018. V. 2267. P. 393–399; http://ceur-ws.org/Vol-2267/393-399-paper-75.pdf/.

8. *Uzhinskiy A., Goncharov P., Ososkov G., Nechaevskiy A.* // CEUR Workshop Proc. 2018. V. 2267. P. 200–206;
Goncharov P., Ososkov G., Nechaevskiy A., Uzhinskiy A., Nestsiarenia I. // Advances in Neural Computation, Machine Learning, and Cognitive Research II. Springer, 2018. P. 151–159.
9. *Baranov D., Mitsyn S., Goncharov P., Ososkov G.* The Particle Track Reconstruction Based on Deep Learning Neural Networks. https://arxiv.org/abs/1812.03859.
10. *Galoyan A., Ribon A., Uzhinsky V.* // Contributions to Proc. of IWNT-37. Rila, Bulgaria, 2018. arXiv:1810.09973 [hep-ph].
11. *Chkhaidze L., Chlachidze G., Djobava T., Galoyan A., Kharkhelauri L., Togoo R., Uzhinsky V.* FERMILAB-PUB-18-497-TD. arXiv:1808.02661 [nucl-ex]; Eur. Phys. J. C. 2018 (in press).
12. *Uzhinsky V., Galoyan A.* arXiv:1806.01534 [hep-ph].
13. *Bashashin M. V. et al.* // Eur. Phys. J. Web Conf. 2018. V. 173. P. 05003.
14. *Lukyanov K. V., Sobolev Yu. G., Penionzhkevich Yu. E., Zemlyanaya E. V.* // J. Phys. Conf. Ser. 2018. V. 1023. P. 012026.
15. *Bashashin M. V., Zemlyanaya E. V., Lukyanov K. V.* // Proc. of All-Russian Conf. with Intern. Participation “Information and Telecommunication Technologies and Mathematical Modeling of High-Tech Systems”. M.: PFUR, 2018. P. 148–251.
16. *Ayriyan A. et al.* // Phys. Rev. C. 2018. V. 97. P. 045802.
17. *Batgerel B. et al.* // Eur. Phys. J. Web Conf. 2018. V. 173. P. 03005.
18. *Gusev A. A. et al.* // Lect. Notes Comput. Sci. 2018. V. 11077. P. 197–213.
19. *Khvedelidze A., Abgaryan V.* On the Family of Wigner Functions for N-Level Quantum System. 2018. arXiv: https://arxiv.org/abs/1708.05981.
20. *Kornyak V. V.* // Zap. Nauchn. Semin. POMI. 2018. V. 468. P. 228–248.
21. *Gerdt V., Lange-Hegermann M., Robertz D.* // Comput. Phys. Commun. 2019. V. 234. P. 202–215; https://doi.org/10.1016/j.cpc.2018.07.025.
22. *Adam Gh., Adam S.* // Eur. Phys. J. Web Conf. 2018. V. 173. P. 01001; https://doi.org/10.1051/epjconf/201817301001.
23. *Uzhinskiy A. V., Ososkov G. A., Goncharov P. V., Frontasyeva M. V.* Perspectives of Using a Satellite Imagery Data for Prediction of Heavy Metals Contamination // Comput. Res. Modeling. 2018. V. 10, No. 4. P. 535–544.
24. *Akishin P., Sapozhnikov A.* // Eur. Phys. J. Web Conf. 2018. V. 173. P. 03001.
25. *Ivanov V. V., Osetrov E. S.* // Phys. Part. Nucl. Lett. 2018. V. 15, No. 1(213). P. 88–108.
26. *Rahmonov I. et al.* // Eur. Phys. J. Web Conf. 2018. V. 173. P. 06011.
27. *Nikonov E., Pavlus M., Popovicova M.* // Eur. Phys. J. Web Conf. 2018. V. 173. P. 06009.

LABORATORY OF RADIATION BIOLOGY

In 2018, the Laboratory of Radiation Biology continued research within Theme 04-9-1077-2009/2020 “Research on the Biological Effect of Heavy Charged Particles with Different Energies” in the following fields: fundamental radiobiological and radiation genetics research; research on the action of accelerated charged particles on the central nervous system; mathematical modeling of radiation-induced effects; and radiation research at JINR’s basic facilities and in the environment. Work was continued on Theme 04-9-1112-2013/2019 “Research on Cosmic Matter on the Earth and in Nearby Space; Research on the Biological and Geochemical Specifics of the Early Earth”.

RADIATION GENETICS AND RADIOBIOLOGY

Analysis of the Structure of Clustered DNA Double-Strand Breaks Induced by Accelerated Heavy Ions and γ Rays. With the use of heavy-ion accelerator beams, research was continued on the regularities and mechanisms of the formation of DNA double-strand breaks (DSBs) in human and mammalian cells after exposure *in vitro* and *in vivo.* As is known, DNA DSBs are the most severe damage to the genetic material and are the molecular substrate of the development of lethal events for cells and different types of structural

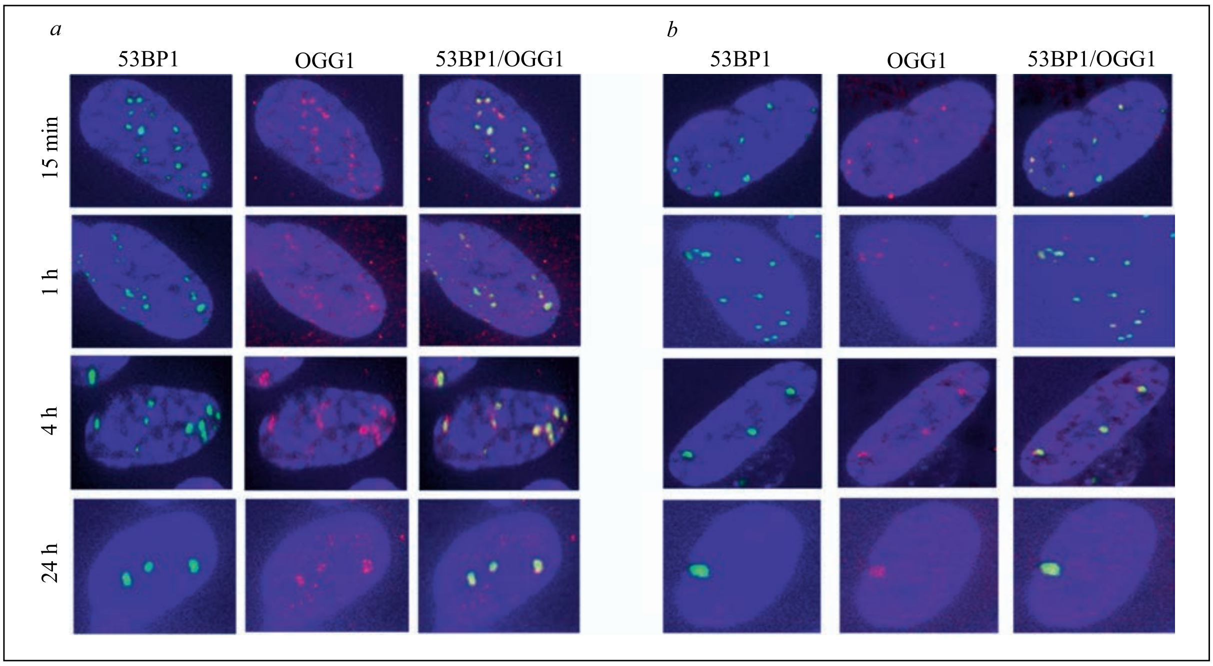


Fig. 1. Formation of clustered DNA DSBs in fibroblast nuclei after exposure to high- and low-LET radiation: accelerated ^{15}N ions (*a*) and ^{60}Co γ rays (*b*), respectively

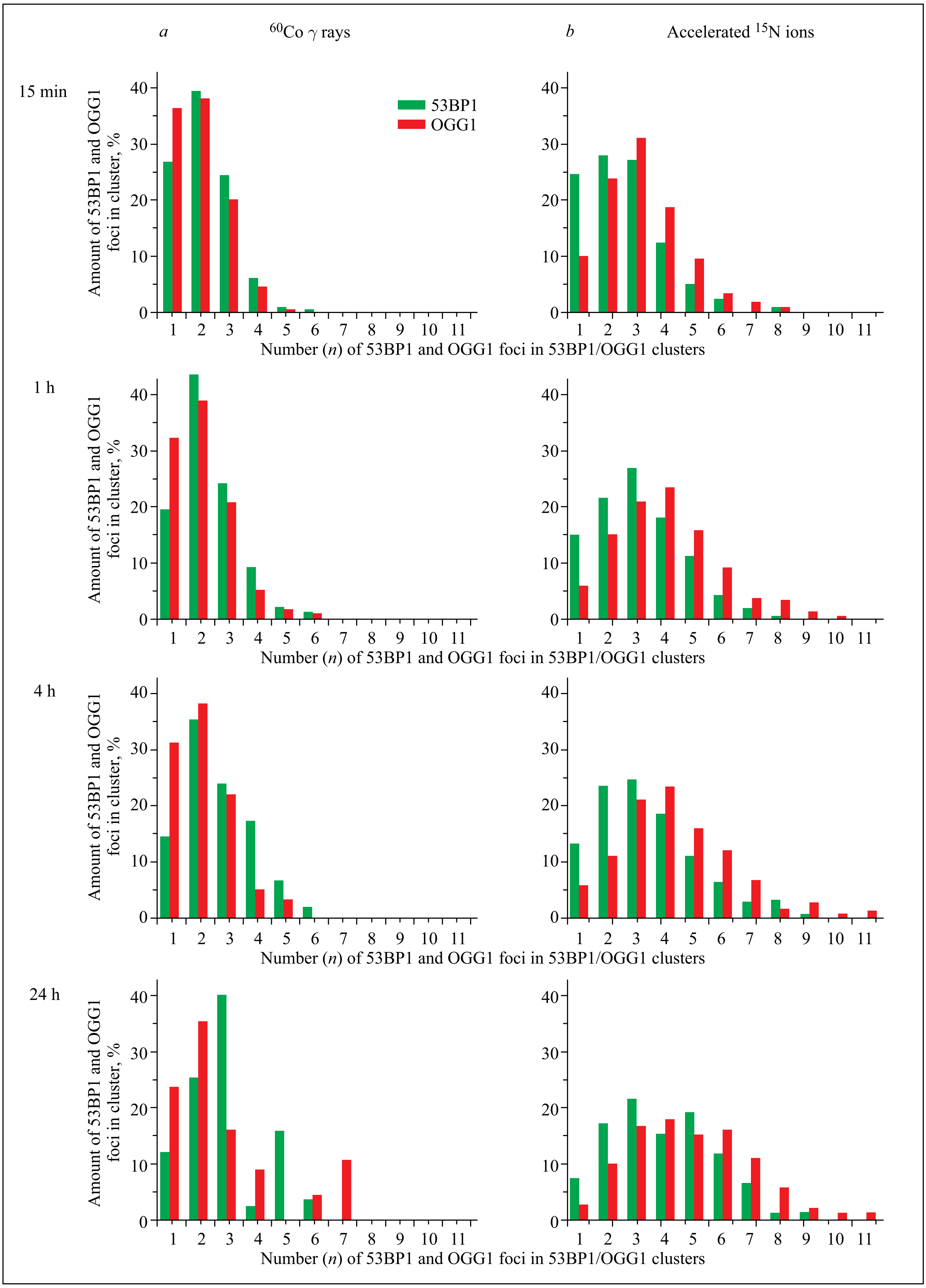


Fig. 2. The distribution of the 53BP1 and OGG1 foci over the 53BP1/OGG1 clusters in fibroblast nuclei after exposure to ^{60}Co γ rays (*a*) and accelerated ^{15}N ions (*b*)

mutations of genes underlying many radiation-induced effects. A distinguishing feature of heavy charged particles' action on cell genetic structures is the formation of clustered DNA damage, including closely spaced DSBs, which is not typical of electromagnetic ionizing radiation. Single clustered DSBs include not only breaks of the sugar-phosphate backbone — the main valence chain, but also modified bases. The detailed study of the fine structure of such a damage is an important task because the repairability of DSBs with different composition is rather different. It should be noted that no data on the structure of single clustered DSBs, which include modified bases, has been published yet. Using specific fluorescent antibodies allows visualization of the marker proteins of DNA DSB repair (53BP1) and proteins participating in damaged base repair (OGG1). The colocalization places of these marker proteins are the sites of clustered DNA DSB formation. In experiments on human skin fibroblasts in culture, using immunocytochemical techniques, regularities in the formation of clustered DNA damage of this type induced by accelerated ^{15}N ions and ^{60}Co γ rays were studied.

A qualitative analysis of the obtained images of stained fibroblast nuclei showed that most of the radiation-induced 53BP1 foci colocalize with OGG1 foci, forming 53BP1/OGG1 clusters — both after accelerated ^{15}N ion and ^{60}Co γ-ray exposure. Figure 1 shows the kinetics of 53BP1/OGG1 cluster formation and elimination after irradiation with accelerated ^{15}N ions and ^{60}Co γ rays. After exposure, the number of the 53BP1/OGG1 clusters decreases with time for radiations of both high and low linear energy transfer (LET). But the elimination rate of the foci induced by accelerated ions is slower than that of the foci induced by γ rays, which is clearly seen 4 h after the exposure. 24 h after the exposure, the number of noneliminated 53BP1/OGG1 clusters in fibroblast nuclei is higher for accelerated ion than for γ-ray exposure. These data indicate that the repair of clustered DNA DSBs induced by accelerated ^{15}N ions is complicated [1–6].

To study possible causes of the repair slowdown of clustered DNA DSBs induced by accelerated ^{15}N ions, a comparative analysis of the structure of 53BP1/OGG1 clusters induced by accelerated ^{15}N ions and ^{60}Co γ rays was performed (Fig. 2). It was found that the clusters induced by γ rays contain up to 6 53BP1 foci and up to 7 OGG1 foci, the vast majority of the clusters containing 1–5 53BP1 foci and 1–4 OGG1 foci (Fig. 2, *a*). Unlike this, the clusters induced by accelerated ^{15}N ions contain up to 9 53BP1 foci and up to 11 OGG1 foci, the vast majority of them containing 1–6 53BP1 foci and 2–8 OGG1 foci (Fig. 2, *b*).

The obtained data clearly indicate that the structure of the 53BP1/OGG1 clusters and, respectively, clustered DNA DSBs is more complicated in the case of high-LET radiation exposure due to an increase in the number of single lesions of different types in a cluster. The histograms show that complicated structure survives up to 24 h after the exposure to radiation of both types, which points to the obstruction of the repair of lesions of all types in a cluster. The structure of the foci clusters detected after accelerated ^{15}N ion and ^{60}Co γ-ray exposure was analyzed. Three cluster groups were identified: the first one included the clusters where the OGG1 foci outnumbered 53BP1; in the second, the clusters had the same number of the OGG1 and 53BP1 foci; and in the third, there were fewer OGG1 foci than 53BP1.

Figure 3 shows that after γ-ray and accelerated ion exposure a large number of clusters with the same number of foci is observed (40–50% and 30–40%, respectively). But the number of clusters in the first and third groups is significantly different for radiations of different LET. It can indicate that in the case of accelerated ion exposure, most of the clusters (over 50%) have several base lesions per one DNA DSB; for γ-ray exposure, there is less than one base lesion per one DNA DSB.

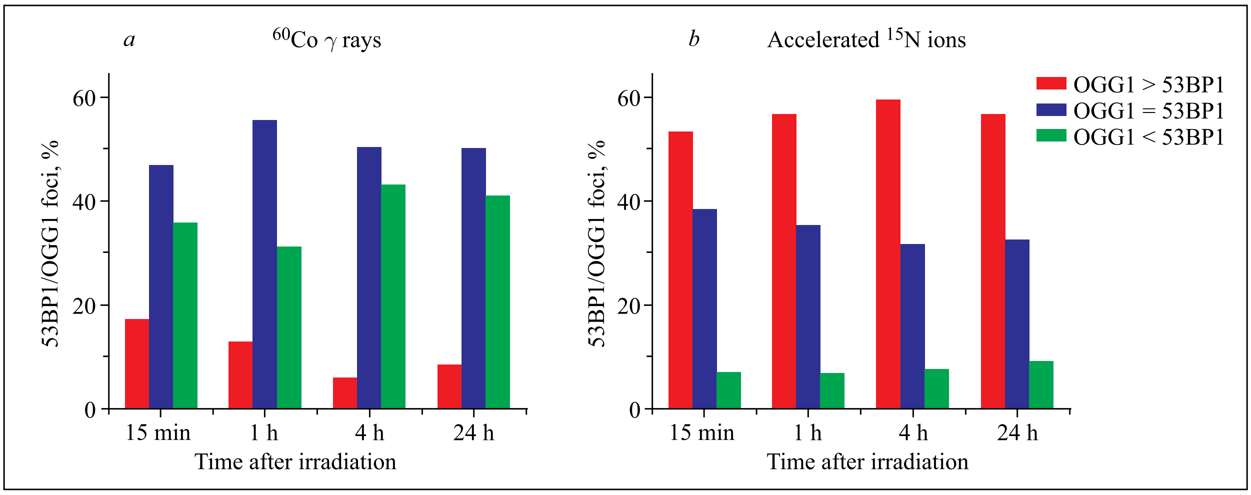


Fig. 3. Distribution of the OGG1 and 53BP1 foci in clusters induced by ^{60}Co γ rays (*a*) and accelerated ^{15}N ions (*b*)

The obtained data show that low- and high-LET radiations induce clustered DNA DSBs of fundamentally different composition.

Formation of DNA Double-Strand Breaks in Mammalian Central Nervous System Cells. With the use of the DNA comet assay, regularities were studied in DNA DSB formation in rodent central nervous system (CNS) structures. In homogenates of mouse hippocampal tissues, the dependence of DNA DSB induction on the dose of exposure to ionizing radiations of different LET was studied. Accelerated nitrogen ions of different energies and γ rays were used in experiments. Figure 4 shows the dose dependence of the comet

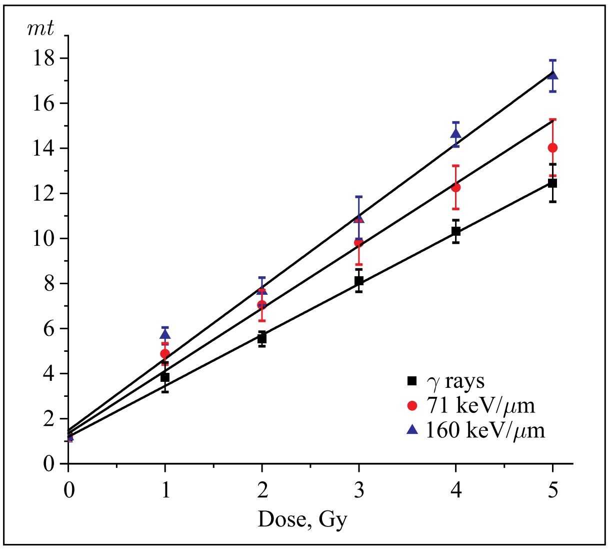


Fig. 4. The dose dependence of DNA DSB induction in mouse hippocampal cells after *in vitro* exposure to ^{60}Co γ rays and accelerated ^{15}N ions with LET of 71 and 160 keV/μm

tail moment for cell irradiation with nitrogen ions of different LET and γ rays. A linear character of DNA damage yield is observed for all types of radiation used. With increasing radiation's LET, an increase is observed in the efficiency of DNA DSB induction. On the basis of the obtained data, accelerated ions' relative biological effectiveness (RBE) values were evaluated determined as the ratio of the accelerated heavy ion and γ-ray exposure doses inducing the same effects. For ^{15}N ions with LET of 71 and 160 keV/μm, RBE was found to be 1.2 and 1.5, respectively.

A comparative analysis of DNA DSB repair kinetics in mouse hippocampal cells for γ-ray and accelerated nitrogen ion exposure *in vitro* was performed. As is seen in Fig. 5, it is exponential for all radiation types used. The yield of the damage induced by accelerated nitrogen ions with LET of 160 keV/μm is higher than that in the case of exposure to γ rays and nitrogen ions with lower LET. 24 h after irradiation with nitrogen ions with LET of 160 keV/μm, remaining damage yield was twice as high as the control level. These results reflect the fast (about 2 h) and slow (up to 24 h and more) phases of DNA DSB repair.

In a special series of experiments, DNA DSB induction in hippocampal cells of mice of different ages exposed to ^{60}Co γ rays *in vivo* was studied. The results (Fig. 6) indicate that the experimental animals' age has an effect on the formation of damage in the genetic structures of the CNS neurons. In young animals (8 weeks), damage yield was found to be much higher than in adults, which can be explained by the fact that the number of immature and proliferating neurons in young animals' hippocampus is about 10 times higher than in adults' one. DNA damage yield in 17- and 24-week old animals was practically the same for each

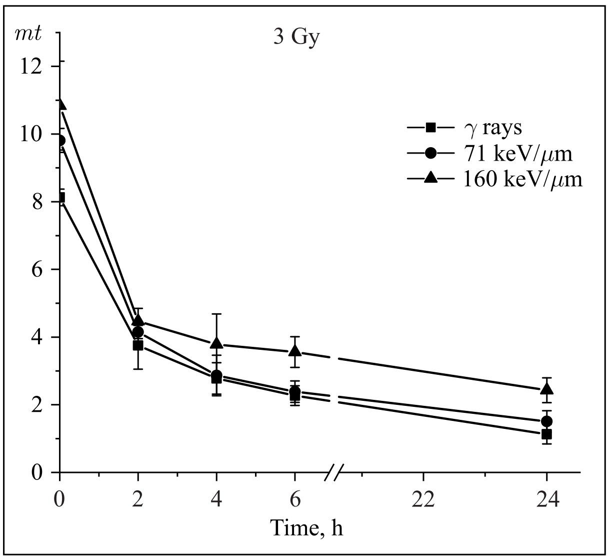


Fig. 5. DNA DSB repair kinetics in mouse hippocampal cells after *in vitro* exposure to ^{60}Co γ rays and accelerated ^{15}N ions with LET of 71 and 160 keV/μm at a dose of 3 Gy

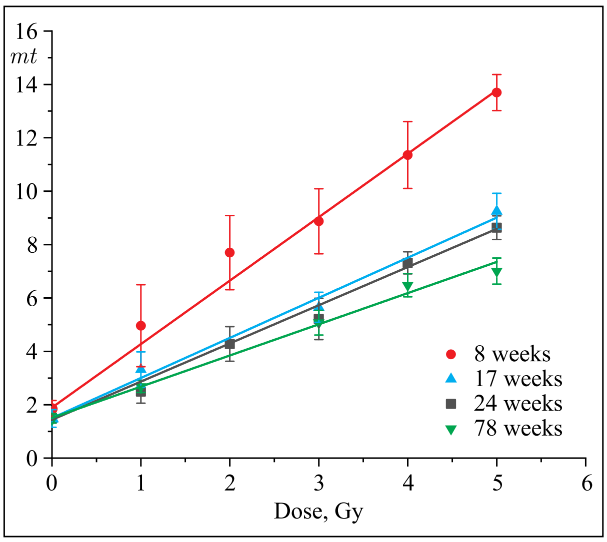


Fig. 6. The dose dependence of DNA DSB induction in mouse hippocampal cells after total exposure of mice of different ages (8, 17, 24, and 78 weeks) *in vivo* to ^{60}Co γ rays

irradiation dose. In 78-week old mice, the number of DNA DSBs was half of that in 8-week olds in the case of γ-ray exposure at a dose of 5 Gy. The *in vivo* results thus indicate that the experimental animals' age affects the radiosensitivity of neuronal elements.

Radiation-induced effects in young neuronal elements were also studied in experiments on a primary rat hippocampal culture. To obtain a hippocampal neuron culture, 1-β-D-arabinofuranosylcytosine (AraC) — an efficient DNA synthesis inhibitor — was used at a concentration of 3 mM. It was established that a 24-h incubation of a primary culture in the presence of AraC causes the death of a huge part of the astrocyte population (over 90%). The action of ^{60}Co γ rays on a primary rat hippocampal culture was studied both in the presence and absence of AraC. In hippocampal neurons, the highest yield of γH2AX/53BP1 foci was observed 1 h after the exposure (Fig. 7). DNA DSB formation in astrocytes was detected by the phosphorylated H2AX (γH2AX) histone. In cells of this type, the highest γH2AX foci yield was observed 1 h after the exposure. 24 h after the exposure, effective foci elimination was observed both in neurons and in hippocampal astrocytes. At the same time, single unrepaired γH2AX/53BP1 foci were observed in neurons. DAPI nuclei staining revealed an increased yield of pyknotic nuclei, which points to a high rate of apoptotic cell death in the post-irradiation period [7, 8].

DNA DSB Formation in Rat Brain Neurons after Accelerated ^{36}Kr Ion Exposure. The induction and repair of DNA DSBs in the rat hippocampal formation after exposure to accelerated 2.46-GeV/nucleon ^{36}Kr ions was studied by the immunohistochemical staining of paraffin sections of the rat brain using antibodies specific to the γH2AX and 53BP1 proteins. It was observed that complex clustered DNA DSBs form in different structures of this formation of the central nervous system at different times after exposure to heavy nuclei (Fig. 8). It was established that most of the γH2AX/53BP1 foci ($\sim$80%) are part of complex clusters and are localized on visualized repair proteins' sites ($\sim$75%) along the charged particle tracks. It was shown that after 24 h of post-irradiation incubation, effective elimination of radiation-induced γH2AX/53BP1 foci takes place in cells of the dentate gyrus and CA1 subregion of the hippocampal formation (Fig. 9). In dentate gyrus cells, the γH2AX/53BP1 foci formation peak was observed 4 h after the exposure [9–11].

Development of a Method for Increasing the Efficiency of the Biological Action of Ionizing Radiations in the Presence of Radiomodifiers. The LRB's earlier research showed that in the post-irradiation period in cells exposed to γ rays and high-LET particles DNA DSB yield is modified to a different degree in the presence of the DNA synthesis inhibitors — 1-β-D-arabinofuranosylcytosine (AraC) and hydroxyurea (HU). For γ-ray exposure, DNA DSB yield significantly increased in the presence of modifying agents during the post-irradiation incubation of human cells in culture and lymphocytes. In the case of accelerated heavy ions, however, the modifiers' effect was weaker. Their influence on DNA DSB formation is determined by the fact that AraC is an efficient inhibitor of DNA polymerase α and, to a lower degree, β, which do DNA repair synthesis. HU, being ribonucleotide reductase inhibitor, has an effect on the intracellular nucleotide pool — in particular, cytosine — and diminishes it. It results in the prolonged fixation of the emerging direct DNA single-strand breaks (SSBs) which form during excision repair. Such lesions can become sites of

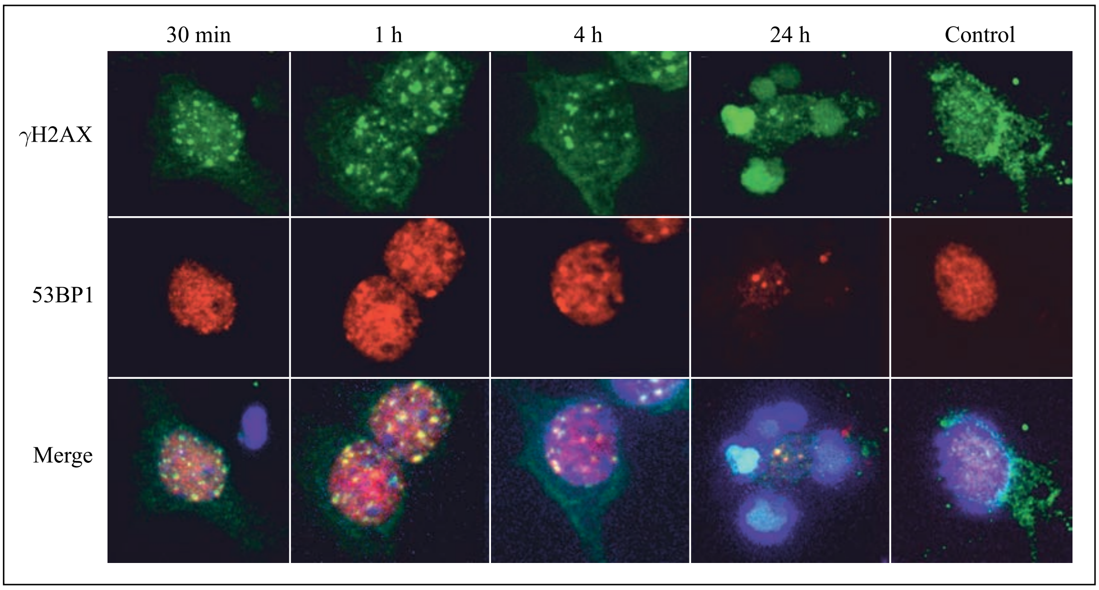


Fig. 7. γH2AX/53BP1 foci formation kinetics in neurons of a rat hippocampal culture *in vitro* in the presence of AraC after exposure to ^{60}Co γ rays at a dose of 3 Gy (1000-fold magnification)

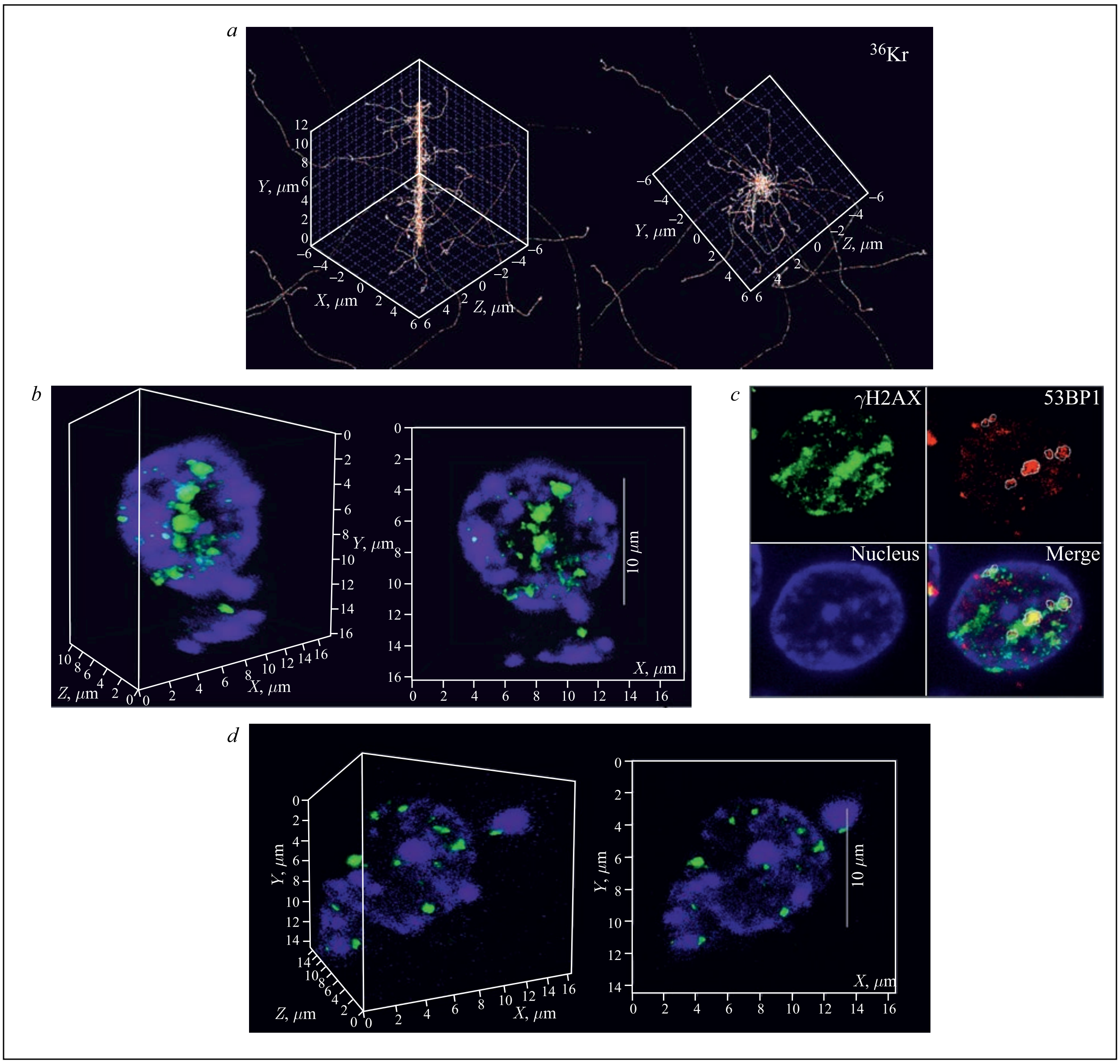


Fig. 8. An immunohistochemical staining visualization of a ^{36}Kr ion track in the nucleus of a dentate gyrus cell. *a*) Structure simulation of a ^{36}Kr ion track ($E = 2.58$ GeV/nucleon and LET 250 keV/μm) (NASA's RITRACKS 3.1 code). *b*) A track of γH2AX foci formed by a krypton ion (green); the nucleus and stained chromatin (blue). *c*) A visualization of a krypton ion track in a cell of the CA1 subregion 1 h after exposure. *d*) An immunohistochemical staining visualization of a proton track in the nucleus of a dentate gyrus cell

enzymatic DNA DSB formation as a result of S_1-endonucleases' attack on the thread opposite the damaged part. Considering that AraC and HU are officinal preparations and are used in oncological practice, it seems extremely important to study their effect on the formation of molecular disorders in human cells after exposure to ionizing radiations of different quality — first of all, Bragg peak protons. The current clinical use of these preparations is based on the inhibition of the cell cycle's S phase. In the light of LRB's earlier results on the modifying effect of these agents on DNA DSB yield after exposure to ionizing radiations of different quality, as well as the possible prospects for their practical use, the action of these agents on the biological effectiveness of a modified Bragg peak proton beam was studied.

With the use of the immunocytochemical and immunohistochemical methods of detecting γH2AX/53BP1 foci, the frequency of DNA DSB induction in cells by accelerated protons under normal conditions and in the presence of modifying agents and by boron ions under normal conditions was studied. Along with these techniques, the DNA comet assay was used. When cells were irradiated with protons without modifiers, the radiation-induced foci (RIF) yield increased and then decreased in the post-irradiation period. The

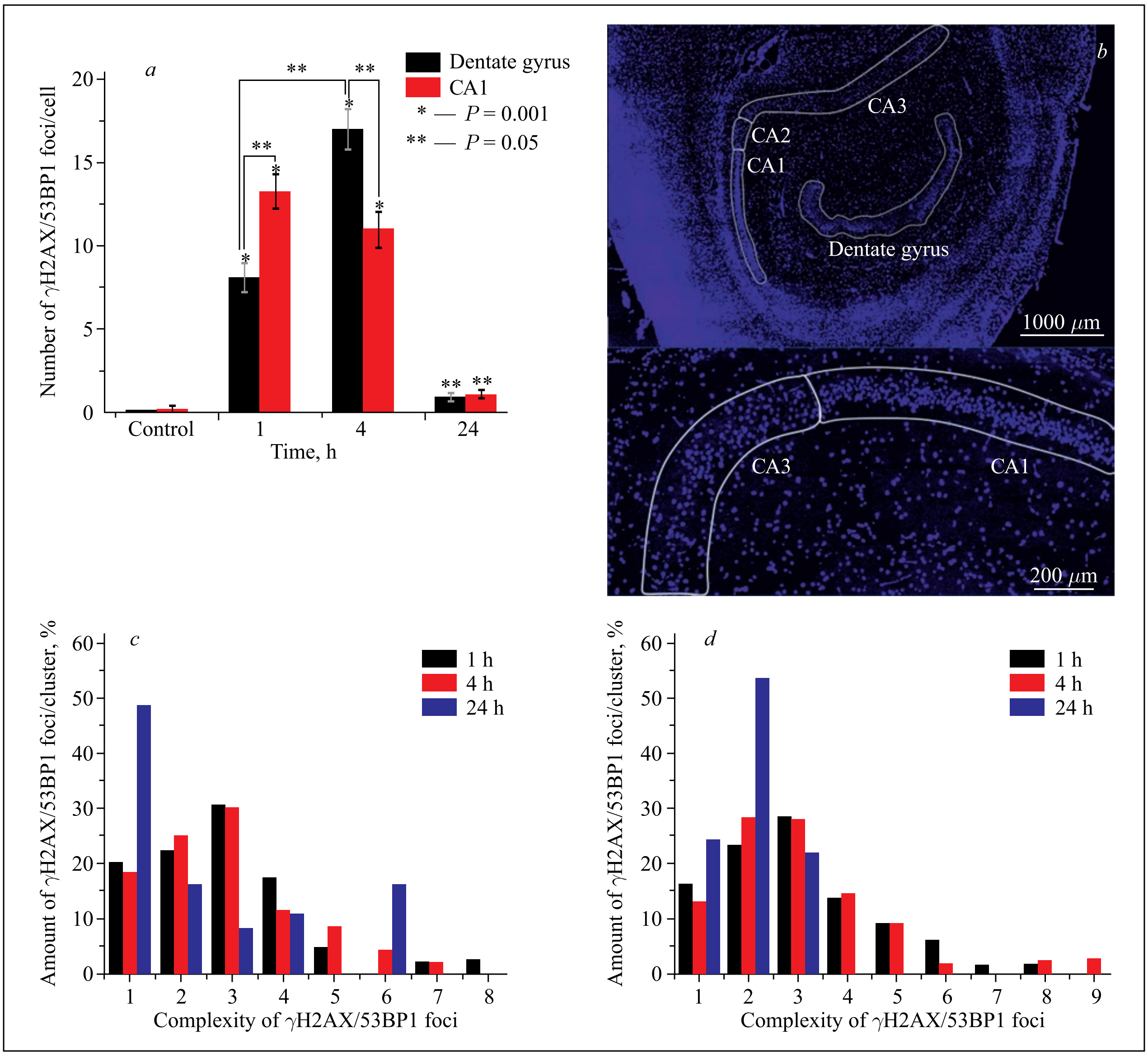


Fig. 9. Kinetics of the formation and elimination of γH2AX/53BP1 foci in cells of the dentate gyrus and CA1 subregion of the hippocampal formation after irradiation with accelerated ^{36}Kr ions. Shown is the mean value ± the standard error of the mean. *a*) A statistically significant difference between the number of γH2AX/53BP1 foci in the CA1 subregion and dentate gyrus of the hippocampal formation is observed 1 and 4 h after exposure, $P = 0.05$. A statistically significant difference in the number of γH2AX foci is observed between 1 and 4 h after dentate gyrus exposure. Statistically significant differences from the nonirradiated control are observed at 1 and 4 h, $P = 0.001$, and 24 h, $P = 0.05$. *b*) Hippocampal formation anatomy. *c, d*) The complexity of the γH2AX/53BP1 foci clusters formed after accelerated ^{36}Kr ion exposure in cells of the dentate gyrus (*c*) and CA1 subregion (*d*) of the hippocampal formation. Shown is the mean value of the different compositions of the γH2AX/53BP1 clusters. Plotted on the abscissa is the number of subfoci in a single γH2AX/53BP1 cluster; on the ordinate, the percent proportion of the clusters of a specified composition to all the examined γH2AX/53BP1 foci

highest and lowest foci yields were observed 1 and 24 h after the exposure, respectively. A completely different kinetics of γH2AX/53BP1 foci formation was observed for proton irradiation of cells in the presence of modifiers. Due to AraC and HU influence, a sharp increase in the number of RIF instead of a decrease took place during the post-irradiation incubation of cells. This effect persisted up to 24 h of observation (Fig. 10).

Taking into account the obtained results, which point to the high biological effectiveness of Bragg peak protons in the presence of DNA repair synthesis inhibitors, a comparison of the biological effectiveness of accelerated protons and boron ions was made (physical characteristics of the latter are close to those of carbon ions). One can see that for heavy ion irradiation, like for proton irradiation, the maximum number of γH2AX/53BP1 foci in human fibroblast nuclei

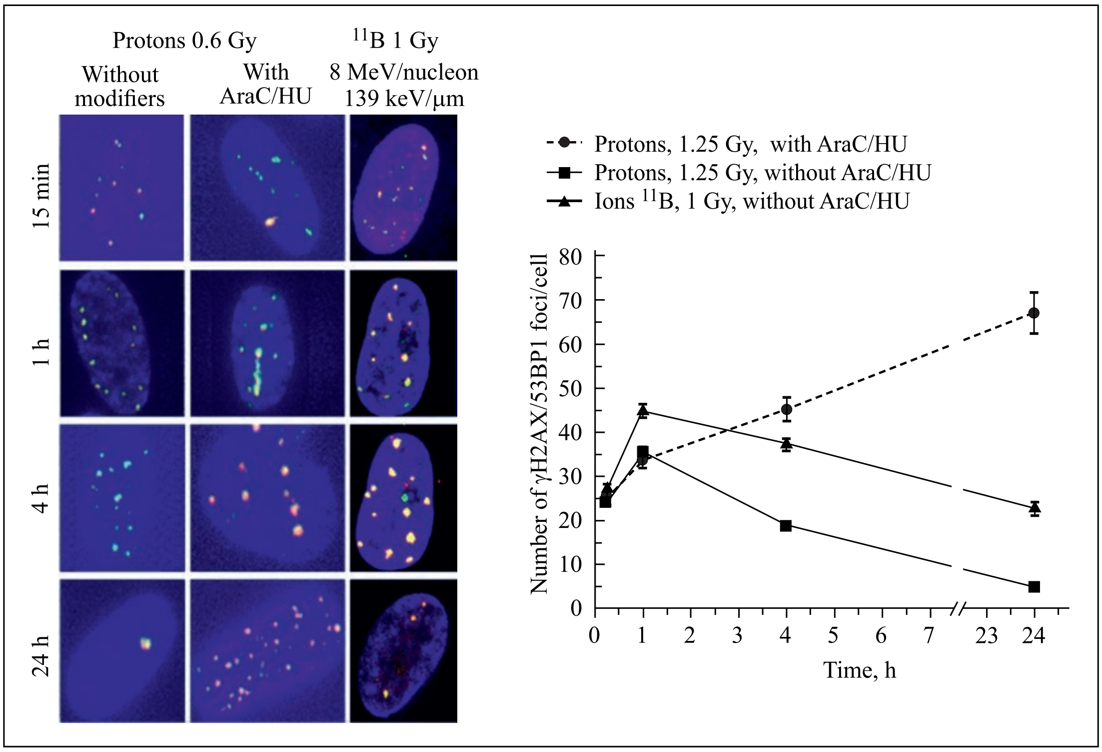


Fig. 10. Images of single γH2AX/53BP1 foci and kinetics of their formation and elimination in human cell nuclei after exposure to Bragg peak protons and 8 MeV/nucleon boron ions — for irradiation under normal conditions and in the presence of AraC and HU

is observed about 1 h after the exposure. For boron ions, the RIF yield is about twice as high as for proton exposure under normal conditions during the whole post-irradiation period.

RIF repair kinetics is similar to that observed for proton exposure under normal conditions. But in the case of cell irradiation with protons in the presence of AraC and HU, 1 h and especially 24 h after the exposure, the RIF yield is much higher than in the case of accelerated boron ion exposure. These differences in the number of foci are determined, on the one hand, by enzymatic DNA DSB formation in the presence of modifiers and, on the other, by DSB repair in the post-irradiation period after cell exposure to accelerated heavy ions.

Of special interest are the results of the irradiation of a human glioblastoma cell culture (U87) with extended Bragg peak protons in the presence of AraC. The obtained data indicate an effective modification of DNA DSB formation in tumor cells. After 24 h of post-irradiation incubation, the number of γH2AX/53BP1 foci in the nuclei of glioblastoma cells exposed in the presence of AraC was about 3.5 times higher than in the case of exposure under normal conditions (Fig. 11).

With the use of the DNA comet assay, the kinetics was studied of DNA DSB formation and repair in hippocampal cells of rats (Sprague Dawley males) after a cranial exposure to accelerated protons *in vivo* at a dose of 3 Gy in the presence of a modifier — the DNA repair inhibitor AraC (Fig. 12). As can be seen, for the proton irradiation of cells both under normal conditions and in the presence of a modifier, an increase is observed in the number of DNA DSBs, followed by a decrease in the post-irradiation period. A comparative analysis showed that after 24 h of post-irradiation incubation, the number of γH2AX/53BP1 foci in the nuclei of rat hippocampal cells exposed *in vitro* in the presence of AraC was about 4.5 times higher than in the case of irradiation under normal conditions.

These data, obtained both *in vivo* and *in vitro,* indicate that the damaging action of extended Bragg peak protons on the cells' genetic structures is sharply enhanced in the presence of cytosine arabinoside — an agent that blocks DNA repair and replication synthesis. The radiation-induced DNA SSBs are not repaired for a long time and transform into enzymatic DSBs during the processing of sites opposite SSBs by endonucleases, which increases the effectiveness of radiation exposure. This finding suggests that the combined use of the officinal preparations involved in this study can be promising for radiation therapy as it would bring the areas of the therapeutic use of proton and carbon ion accelerators much closer to each other [12–14].

Research on the Influence of Oxidative and Nitrosative Stress Modulators on Chromosomal Aberration Induction in CAL51 Human Breast Carcinoma Cells by Different Doses of γ Radiation. Ionizing radiation exposure causes an increase in the yield of reactive oxygen and nitrogen species (ROS and RNS,

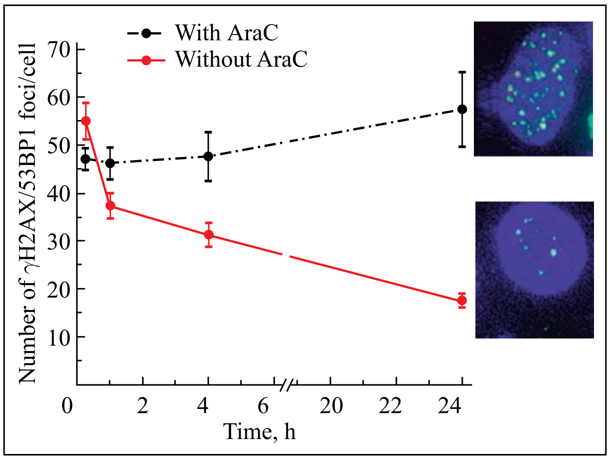


Fig. 11. Kinetics of the formation and elimination of γH2AX/53BP1 foci in the nuclei of human glioblastoma cells (U87) exposed to extended Bragg peak protons at a dose of 1.25 Gy

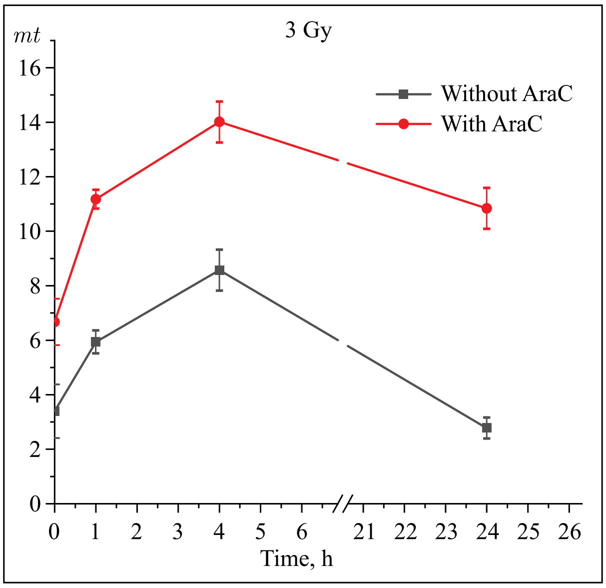


Fig. 12. Kinetics of the formation and elimination of γH2AX/53BP1 foci in rat hippocampal cells for cranial *in vivo* exposure to modified Bragg peak protons at a dose of 3 Gy under the modifying effect of cytosine arabinoside (AraC)

respectively) in cells. The effect of these radicals on cell fate depends largely on the dose of exposure. When their yield is moderate, they can trigger protective mechanisms because, through redox-sensitive signal pathways, they regulate many metabolic processes and can also activate proteins participating in the DNA repair. But overproduction of these radicals leads to the development of the so-called oxidative and nitrosative stresses, which are accompanied by a significant increase in the damage to DNA, lipids, proteins, and other intracellular structures. To eliminate the oxidative and nitrosative stresses, a number of compounds were developed, like free radical scavengers and antioxidants with different mechanisms of action, which neutralize ROS and RNS and have a pronounced protective effect both *in vitro* and *in vivo*. However, the effect of these compounds on cells exposed to low doses of ionizing radiation has not been studied yet.

In this research, the influence was studied of the superoxide anion scavenger TEMPOL and nitrogen oxide scavenger carboxy-PTIO (cPTIO) on the induction of chromosomal aberrations in CAL51 human breast carcinoma cells by different doses of γ radiation. The aberrant cells were counted by the anaphase method 8 h after the exposure. A total of six experiments were performed. The significance of the difference between aberrant cell yields, when unobvious, was verified by Fisher's inverse χ^2 test of the global null hypothesis for the whole series of six experiments.

It was found that for high doses of γ radiation (50, 100, and 200 cGy) the ROS scavenger TEMPOL decreases the chromosomal aberration yield, which is in full agreement with its ability to neutralize oxidant action (Fig. 13, *a*). However, no significant influence of the RNS scavenger cPTIO on the aberrant cell yield was observed (Fig. 13, *b*), which contradicts some of the data published earlier indicating that an increased nitrogen oxide level can cause DNA damage. This conclusion is confirmed by the fact that in the case of the combined use of both modifiers sharp effect of TEMPOL did not change in the presence of cPTIO (Fig. 13, *c*).

A different picture was seen at a dose of 10 cGy, where an inverse effect of these modifiers was observed: in the presence of TEMPOL and cPTIO, the aberrant cell proportion increased (inserts in Fig. 13). For their joint use, the effect was maximal and, on average, was twice as high as the control yield of aberrant cells. A statistical analysis showed that differences were reliable at the level of $\alpha = 0.05$.

A measurement of the ROS yield in cells irradiated at a dose of 10 cGy showed that TEMPOL enhanced, rather than suppressed, ROS production (Fig. 14, *a*), which might explain an increase in the aberration yield in its presence at this dose. But in cells exposed at 1 Gy a comparable effect was observed (Fig. 14, *b*).

It is known that nitroxides, including TEMPOL, are stable radicals in water, but in the cell they undergo a set of chemical transformations. They can be reduced to hydroxylamine or oxidized to oxoammonium depending on the cell's redox status. Oxoammonium is quite a strong oxidant that can damage biomolecules. In a number of earlier works, it had been reported that TEMPOL enhanced ROS production but attenuated the oxidative stress inductors' effect. It suggests that there

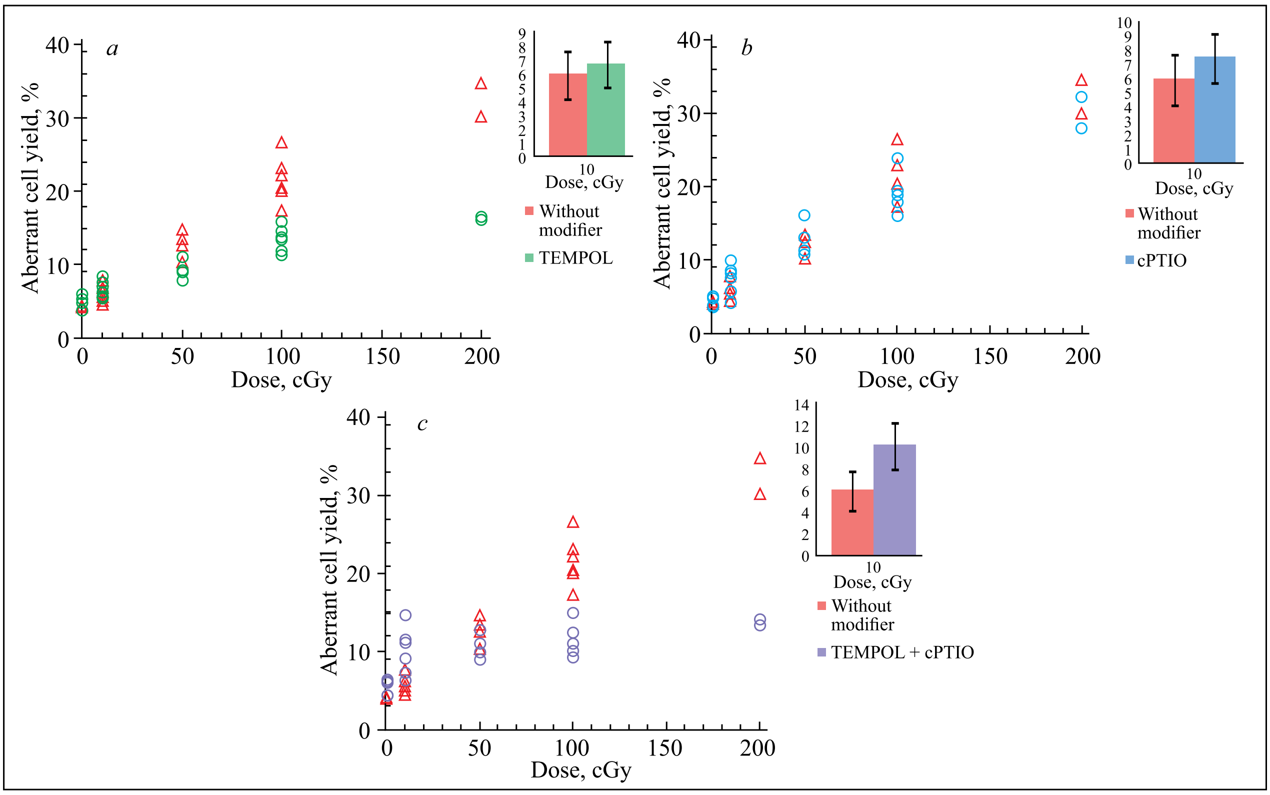


Fig. 13. The effect of the antioxidant TEMPOL and nitrogen oxide scavenger cPTIO on the CAL51 aberrant cell yield after exposure to γ radiation: *a*) TEMPOL 2 mM; *b*) cPTIO 30 μM; *c*) TEMPOL + cPTIO. The error bars denote 95% confidence intervals

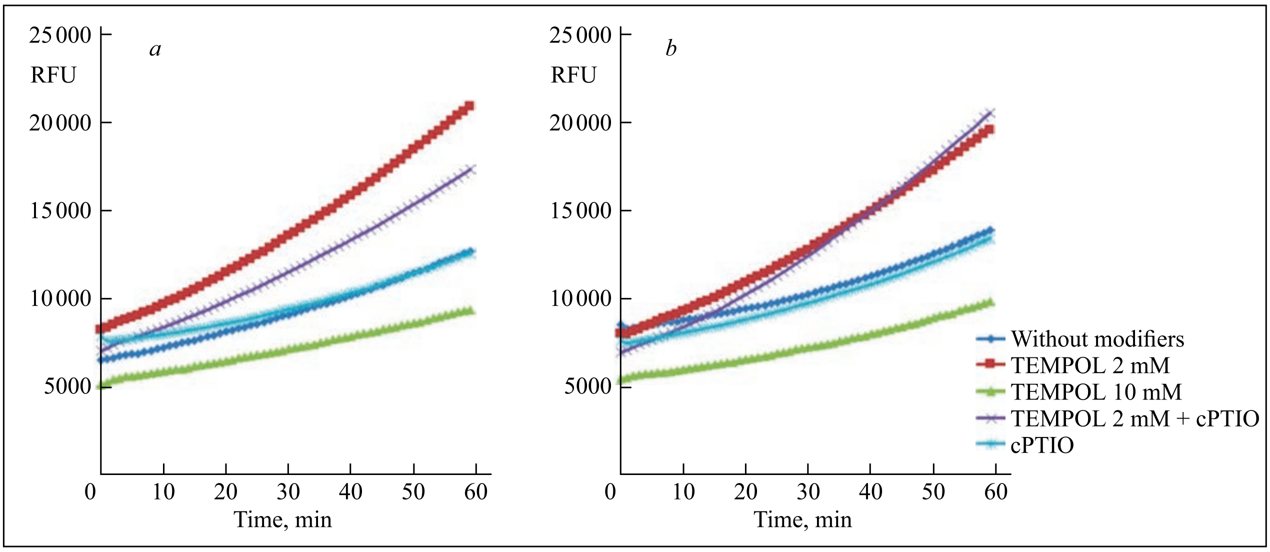


Fig. 14. The effect of the antioxidant TEMPOL and nitrogen oxide scavenger cPTIO on the ROS level (in relative fluorescence units (RFU)) in CAL51 human breast carcinoma cells. One hour-long measurements were performed 8 h after exposure at doses of 10 cGy (*a*) and 1 Gy (*b*)

is an alternative mechanism of this antioxidant's action, which is not connected with its ability to neutralize the superoxide anion. It is supposed that this mechanism might consist in the activation of cytoprotective redox-sensitive signal pathways under exposure to an elevated ROS level in the presence of TEMPOL. For example, in ultraviolet-irradiated human keratinocytes, this nitroxide enhanced ROS production, but, at the same time, activated the protective Keap1–Nrf2–ARE pathway. Considered as another possible mechanism is oxoammonium's ability to reduce to the initial nitroxide when interacting with the superoxide anion under high concentration of the latter, functioning as a superoxide dismutase mimetic.

Cytogenetic Analysis of Chromosomal Damage in Human and Mammalian Cells. In 2018, acquisition was completed of the equipment and software required by a new method of human and animal chromosome analysis, multicolor fluorescent *in situ* hybridization (mFISH). This technique allows identification of each chromosome pair in human (22, X, Y), mouse (20, X, Y), rat, and other animal cells by using a cocktail of chromosome-specific probes labeled with unique combinations of five fluorochromes. Fluorochrome combinations are interpreted by an analysis software tool (MetaSystems, Germany) (Fig. 15). The mFISH method allows evaluating the frequency of heritable symmetric aberrations (translocations) and complex chromosomal aberrations (three and more breaks in two and more chromosomes) (Fig. 15, *b*). The latter are the marker of densely ionizing radiation, reflecting the cluster character of DNA damage formation along the particle tracks. The action of accelerated protons on normal and tumor human cells has not been studied with mFISH yet; the primary task is thus to check the conclusions made by K. George et al. (2015) based on a 2–3-color FISH analysis that the relative biological effectiveness of all the protons used in their study (with energies of 5–2500 MeV), measured by complex chromosomal aberration yield, is >1. As 2–3-color FISH detects only some part of a complex aberration due to a limited number of painted chromosomes, and normalization of the aberrations observed with 2–3-color FISH by the whole genome leads to data distortion and the loss of a significant amount of information, an adequate and full evaluation of complex aberrations is possible only with mFISH.

An mFISH analysis (Fig. 16) of chromosomal aberrations induced in human blood lymphocytes with 150 MeV and extended Bragg peak protons at a dose of 3 Gy showed that extended Bragg peak protons are more effective than 150 MeV ones as the aberration yield per 100 cells was 253 and 200, respectively. The analysis followed the mPAINT system: counted were the acentric fragments (one DNA DSB in one chromosome) that were not connected with exchanges; simple exchanges developing from two DNA DSBs in two chromosomes and containing translocations; dicentrics; rings (centric and acentric rings and pericentric inversions); and complex aberrations with three and more breaks in two and more chromosomes, which were described by the C/A/B (chromosome/arm/breaks) formula. Figure 16 shows that irradiation with extended Bragg peak protons induces more aberrations of all types than 150-MeV protons at the same dose, the ring chromosome and complex aberration yield showing the sharpest increase (1.8- and 1.6-fold, respectively).

The contribution of complex aberrations to the total number of chromosome breaks was evaluated. As is seen in Fig. 17, the proportion of the breaks originating from complex aberrations was 25, 33, and 43% for γ rays, 150-MeV protons, and extended Bragg peak protons, respectively. The data obtained with the mFISH method thus show that biological effectiveness of corpuscular radiation is higher than that of photon radiation as it is based on more complex chromosomal aberrations.

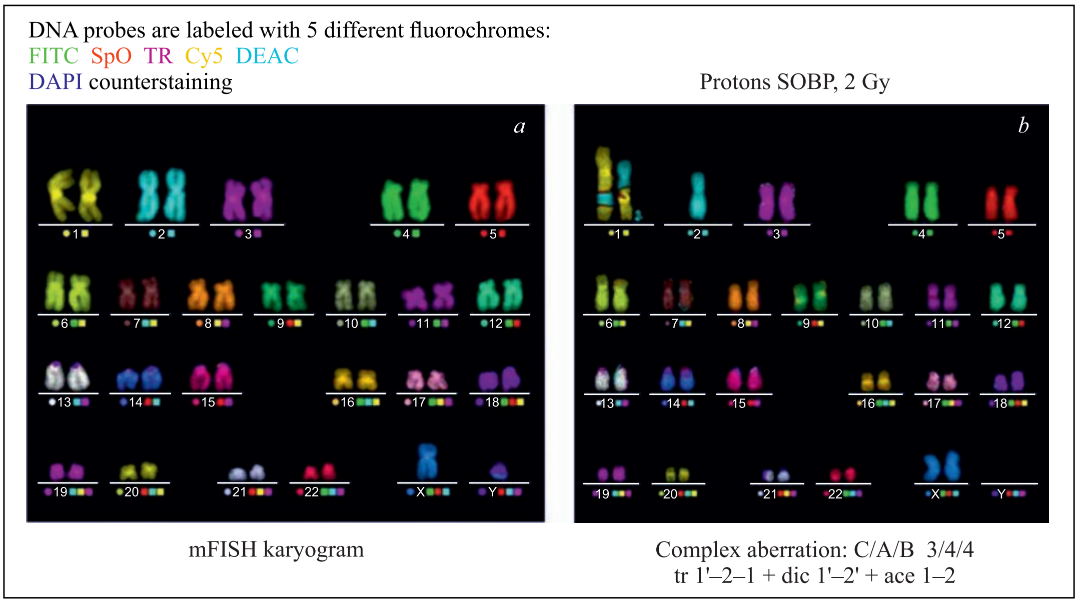


Fig. 15. The mFISH principle and human lymphocyte karyograms. *a*) A normal human karyotype (46, XY). *b*) A complex aberration induced by extended Bragg peak protons, 2 Gy, consisting of four breaks in three chromosomes. With standard painting (using the Giemsa dye), it is identified as a dicentric with a fragment (two breaks in two chromosomes)

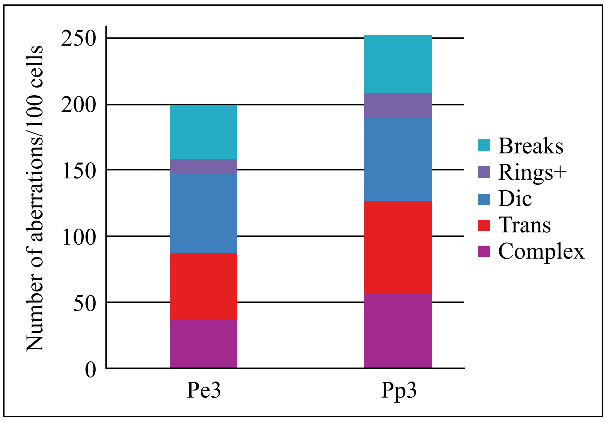


Fig. 16. The mFISH-measured frequency of different types of chromosomal aberrations induced in human blood lymphocytes by 150-MeV protons (Pe3) and extended Bragg peak protons (Pp3) at a dose of 3 Gy. Shown are the yields of acentric fragments (breaks), centric and acentric rings (rings+), dicentrics (dic), translocations (trans), and complex aberrations (complex)

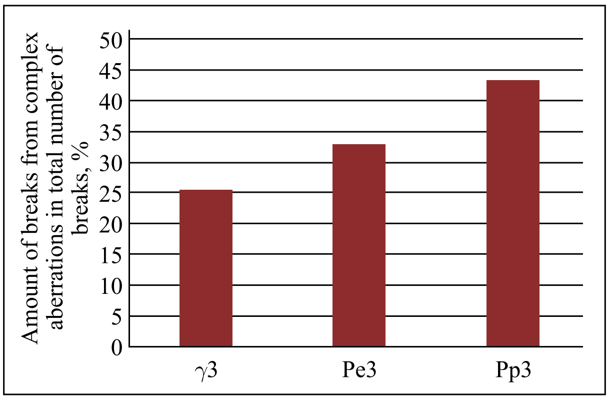


Fig. 17. The contribution of complex aberrations to the total yield of the chromosome breaks induced in human blood lymphocytes by irradiation with ^{60}Co γ rays (γ3), 150-MeV protons (Pe3), and extended Bragg peak protons (Pp3) at a dose of 3 Gy evaluated with the mFISH method

A cycle of research was completed on the analysis and modeling of data on chromosomal aberration induction in human lymphocytes by different types of radiation obtained with classical metaphase techniques [15–17]. In 2018, an evaluation of the sensitivity of different cytogenetic methods was performed. Classical cytogenetic (metaphase) analysis is based on examining chromosomes in dividing cells — in mitosis. The main disadvantage of the method is that the cell has to enter the mitosis phase, but radiation exposure effectively induces division delay, G2 arrest (which is necessary for damage repair), and interphase cell death (apoptosis); the strength of these effects depends on the radiation LET and dose. This fact often influences the results and leads to damage underestimation. In this case, chosen as an alternative analysis technique can be chemically induced premature chromatin condensation (PCC) using Calyculin A — a specific 1 and 2A phosphatase inhibitor, which causes instantaneous chromatin condensation in the interphase cells without a need for the cells to enter mitosis. The PCC method thus eliminates the cell cycle perturbations' influence on the measured chromosomal aberration yield.

The aberrations detected by metaphase analysis are the final result of a completed repair. But it would be interesting to assess the initial damage. Figure 18 shows dose dependences of the amount of chromosome breaks induced in human blood lymphocytes by ^{60}Co γ rays measured with different cytogenetic methods. The damage yield detected with the PCC technique with an immediate post-irradiation introduction of Calyculin A depends linearly on the dose. Its value is about 15 chromatid breaks in G2 cells per 1 Gy of γ exposure per cell (PCC t0) — compared with 0.4 aberrations/cell as determined by classical metaphase analysis, where

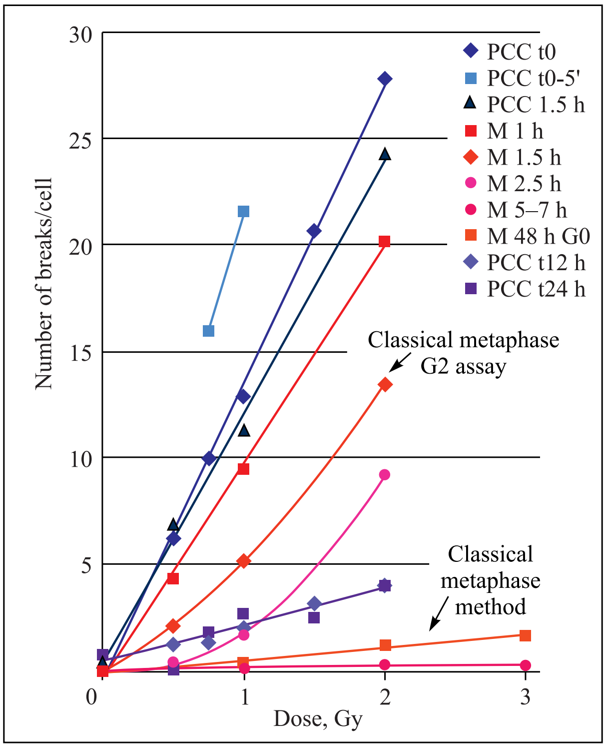


Fig. 18. Dose dependences of the number of chromosome breaks induced in human blood lymphocytes by γ radiation obtained with different cytogenetic techniques — metaphase (M) and PCC analyses — at different times after exposure

nonstimulated lymphocytes are exposed in the G0 phase (M 48 h G0). All other data were obtained by the irradiation of an asynchronous population of stimulated lymphocytes. Introduction of Calyculin A 5 min before irradiation increased the break yield up to 22/Gy/cell (PCC t0-5′), but conducting experiments under such conditions is risky because a short delay in exposure can result in the absence of observed breaks due to the onset of chromatin condensation. Damage repair is completed 12 h after the exposure; the residual break yield was about two chromatid breaks in G2 cells per 1 Gy of γ exposure per cell (PCC t12 h and PCC t24 h), which is approximately 5 times as high as the level measured in mitotic cells (M 48 h G0). Among the classical metaphase techniques, the most sensitive is G2 assay with fixation 1.5 h after the exposure. It is considered that only the cells that were irradiated at the end of the G2 phase beyond the G2/M checkpoint are counted in this analysis — that is, the cells that can enter mitosis with numerous lesions without any delay for repair. In these mitotic cells, the yield of about 5 breaks/Gy/cell is observed. For fixation 1 h after the exposure, the break yield increases up to 10, but in this case analysis is complicated by the fact that at the moment of irradiation pre-mitotic chromatin condensation has already begun; so, the breaks are expressed less clearly. The most interesting is a comparison of the G2 assay (the damage detected in G2 cells — PCC 1.5 h) and PCC data: the difference is more than twofold (5 and 12/Gy/cell, respectively). It is seen that by no means all damaged G2 cells can reach mitosis: they are arrested at the G2/M border for damage repair. It is confirmed by a metaphase analysis done 2.5 and 5–7 h after exposure (M 2.5 h and M 5–7 h), which showed a low mitotic index and a low number of detected lesions.

A combination of different cytogenetic techniques thus provides the most comprehensive insight into DNA damage induction and repair and cell fate. These results are going to be used in modeling radiation-induced chromosome damage taking into account the particle track structure [18].

Genetic Effects Induced by Ionizing Radiation in a Model Unicellular Eukaryotic Organism (the Yeast *Saccharomyces cerevisiae*). In studying point lesions in eukaryote cells, it is expedient to use the unicellular yeast *Saccharomyces cerevisiae*. For testing different point lesions — namely, all types of base pair sub-

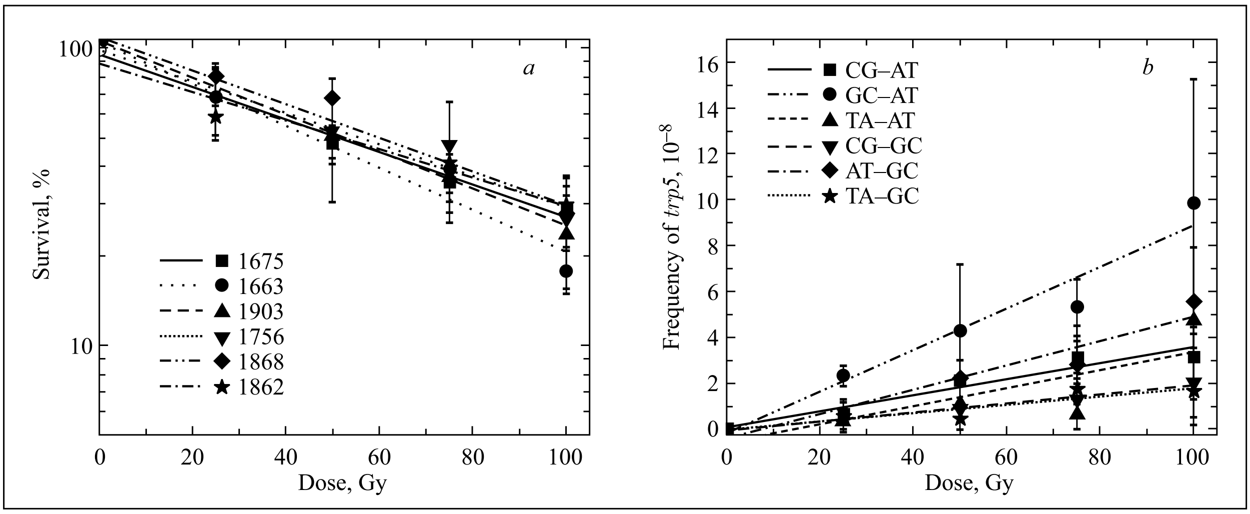


Fig. 19. Survival (*a*) and mutagenesis (*b*) curves for haploid *trp5* strains after ^{60}Co γ exposure

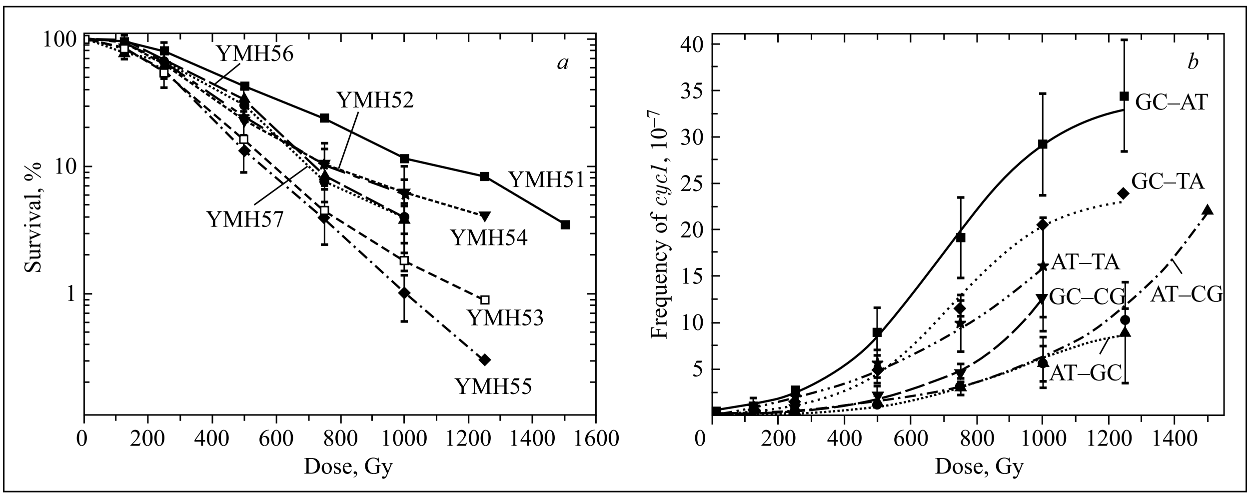


Fig. 20. Survival (*a*) and mutagenesis (*b*) curves for diploid *cyc1* strains after ^{60}Co γ exposure

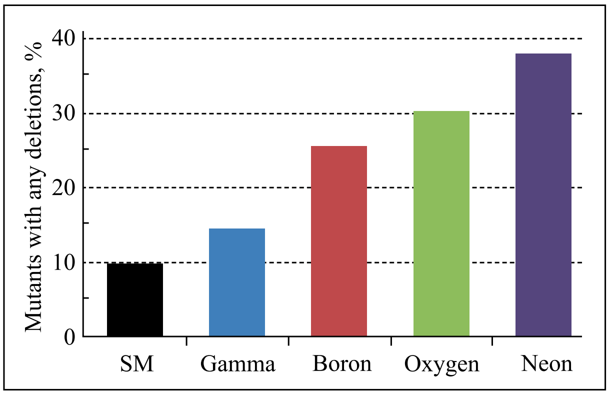


Fig. 21. Proportion of mutants with a complete or partial deletion of the *HPRT* gene. Shown are spontaneous mutants (SM), γ-radiation-induced mutants (gamma), and mutants induced by accelerated ^{11}B, ^{18}O, and ^{20}Ne ions (boron, oxygen, and neon, respectively)

stitution — two genetic systems were used: collections of six isogenic haploid *trp5* strains and 14 isogenic haploid and diploid *cyc1* strains. These strains differ in the only substitution in codon 50 of the *TRP5* gene and in codon 22 of the *CYC1* gene. Dose dependences of point mutagenesis were obtained for haploid and diploid strains [19, 20]. For ^{60}Co γ-ray exposure, a linear dose dependence was observed in haploid strains of both test systems (Fig. 19) and a power dependence in diploid strains (Fig. 20). Although the mutation spectra of different test systems' haploid strains were different, GC–AT transitions prevailed in both test systems. For diploid *cyc1* strains, the mutation spectrum, in general, was the same as that of haploid *cyc1* strains; the GC–AT transitions prevailed in both. It can be suggested that the mutation spectra depend on the nucleotide context, and the mutagenesis mechanisms differ for haploid and diploid strains.

Radiation-Induced Mutagenesis in Mammalian Cells. Research was continued on mutagenesis in V79 Chinese hamster cells induced by accelerated heavy charged particles of different LET (50, 116, 138, and 153 keV/μm) and ^{60}Co γ rays. A correlation was found between induced mutagenesis in the *HPRT* gene and expression time after heavy-ion exposure. A molecular analysis was performed of HPRT mutants induced by radiation of different LET. More than 1200 HPRT-mutant clones were isolated and analyzed in experiments. Essential changes in the mutation spectra were found at the exon level. A significant rise was observed in the yield of structure mutations (deletions) in the cell genome with increasing particles' LET (Fig. 21), which is connected with the growth of the frequency of clustered DNA damage formation after cell irradiation with heavy charged particles.

RADIATION PHYSIOLOGY

A fluorescent and chromatographic analyses of *bis*-retinoids of the mouse retina and retinal pigment epithelium before and after Bragg peak proton exposure were made [21]. It was shown that ionizing radiation exposure at doses of 1–4 Gy causes a shift to shorter wavelengths of the maximum of the fluorescence spectrum of chlorophorm extracts obtained from retinal pigment epithelium and the retina. A chromatographic analysis of these extracts revealed changes in the relative content of specific *bis*-retinoids. The obtained spectral and chromatographic data show that mouse exposure to Bragg peak protons at 1–4 Gy results in the radiation oxidation of *bis*-retinoids in eye tissues.

An evaluation of the optomotor reflex and visual behavior in rats irradiated with protons of an energy of 170 MeV at a dose of 5 Gy was performed. For visual function evaluation, the equipment included a platform and a display with visual stimulation. Some behavioral changes were observed in rats after cranial exposure. Cranial proton irradiation did not cause a statistically

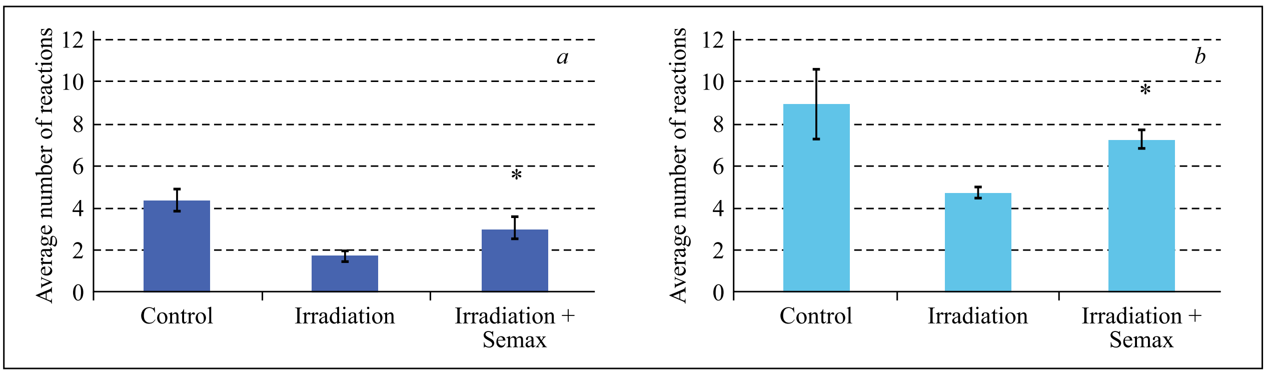


Fig. 22. The mouse emotional status indicator on the 7th day after proton exposure at a dose of 2.3 Gy (*a*) and 3 Gy (*b*). * — statistically significant difference from the irradiated control group (the Mann–Whitney test, $P < 0.05$)

significant decrease in the rats' optomotor response (the ratio of correct to incorrect head turns) on the 30th and 90th days after the exposure. However, in the remote post-irradiation period, statistically significant changes were observed in the animals' visual behavior. It was found that on the 90th day after the exposure, the total time of the head's location in the area where the animal can focus on the visual stimulus is shorter in the irradiated animals.

An evaluation was made of the Semax preparation effect on accelerated proton-irradiated mice's behavioral reactions, skeletal muscle strength, bone marrow syndrome manifestations, and morphological changes in brain neurons [22]. It was established that the preparation, introduced intranasally, normalizes the emotional status indicator on the 7th day after accelerated proton exposure at doses of 2.3 and 3 Gy (Fig. 22). The preparation also restores the irradiated animals' skeletal muscle strength indicator to the control values. The morphology of the sensorimotor cortex in the Semax-treated irradiated animals is close to normal (see the table).

The number of sensorimotor cortex neurons in different animal groups on the 7th day after proton exposure at 2.3 Gy, $(\mu \pm m)$ %

Group	Intact neurons, %	Reversible morphofunctional and compensatory adaptive neurons, %	Dystrophic neurons, %
1. Unexposed control	84.5 ± 0.86	14.8 ± 0.81	0.76 ± 0.33
2. Exposed control, no Semax	$74.5 \pm 0.78^{*,**}$	$21.5 \pm 0.75^{*}$	$3.87 \pm 0.33^{*,**}$
3. Exposed, with Semax	86.0 ± 1.31	11.9 ± 1.16	1.80 ± 0.41

* Statistically significant difference from group 1 ($P < 0.05$).
** Statistically significant difference from group 3 ($P < 0.05$).

An approach was proposed to a more precise evaluation of histological changes in the nervous tissue after irradiation. Brain neurons' morphometric indicators were registered using image analysis capabilities of the ImageJ program. Also, the possibility of using convolution neural networks for the neuromorphological analysis of the brain tissue was considered.

The task is being solved with the help of the Anaconda distribution kit. The first results of neural network training were obtained: identification of a brain structure (the hippocampus) and counting the number of nerve cells in a picture. In addition to conducting morphological research with a routine histological technique [23], a methodology of staining rat brain preparations involving the labeling of degenerative neurons with the Fluero Jade B fluorochrome was mastered (Fig. 23).

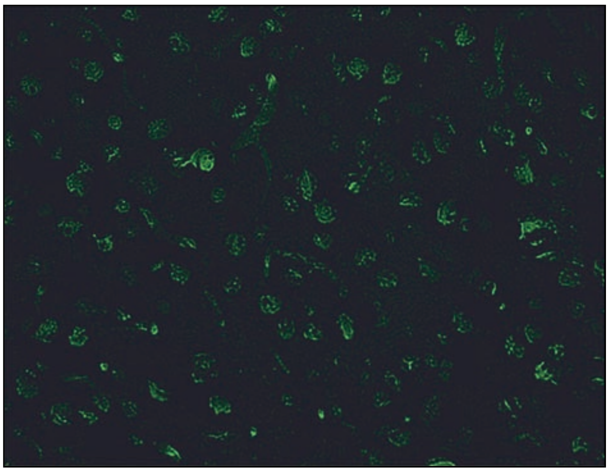


Fig. 23. Neurons of the rat brain cortex after proton exposure at a dose of 1 Gy (200-fold magnification). Staining: Fluero Jade B

MATHEMATICAL MODELING OF RADIATION-INDUCED EFFECTS

Modeling tracks of accelerated particles with different characteristics and processes of primary molecular damage induction was continued [24–26]. To overcome the computational difficulties in modeling radiation-induced effects in hippocampal neural networks, simplified neuron models were developed in which the neurons' geometrical properties are equivalent to those of neurons of real morphology. The three-dimensional structure and parameters of simplified neuron models and models with the realistic morphology of the dendrite tree were developed using experimental data. This approach allowed simulating a random distribution of dendritic spines in the proposed neuron models. Monte Carlo modeling with the Geant4-DNA software toolkit showed that after proton, carbon ion, and iron ion exposure with fluences and energies corresponding

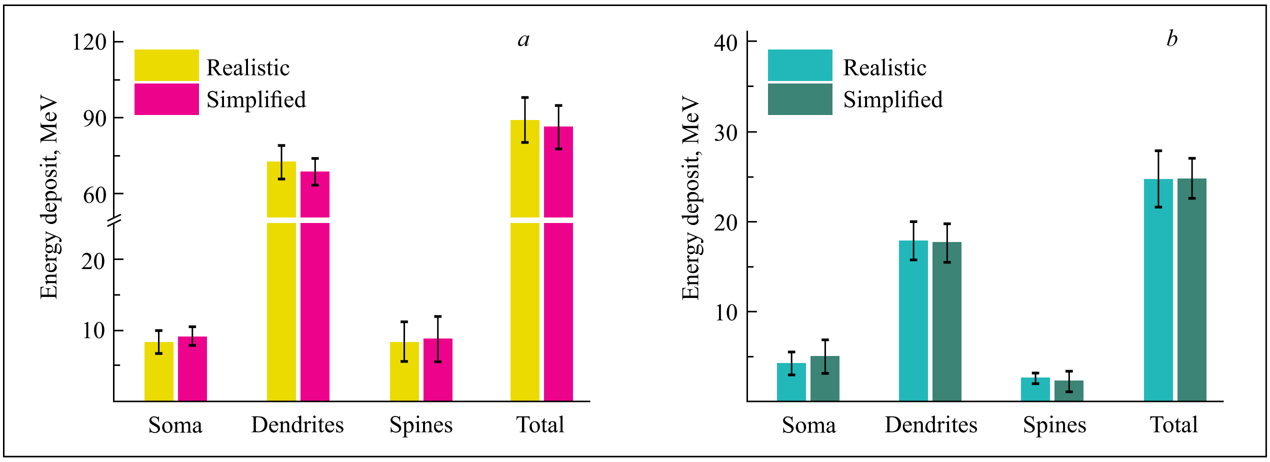


Fig. 24. Total energy deposition in a realistic and simplified models of a pyramidal (*a*) and granular (*b*) neurons under exposure to 600 MeV/u ^{56}Fe ions with a fluence of $3.2 \cdot 10^5$ particles/cm^2

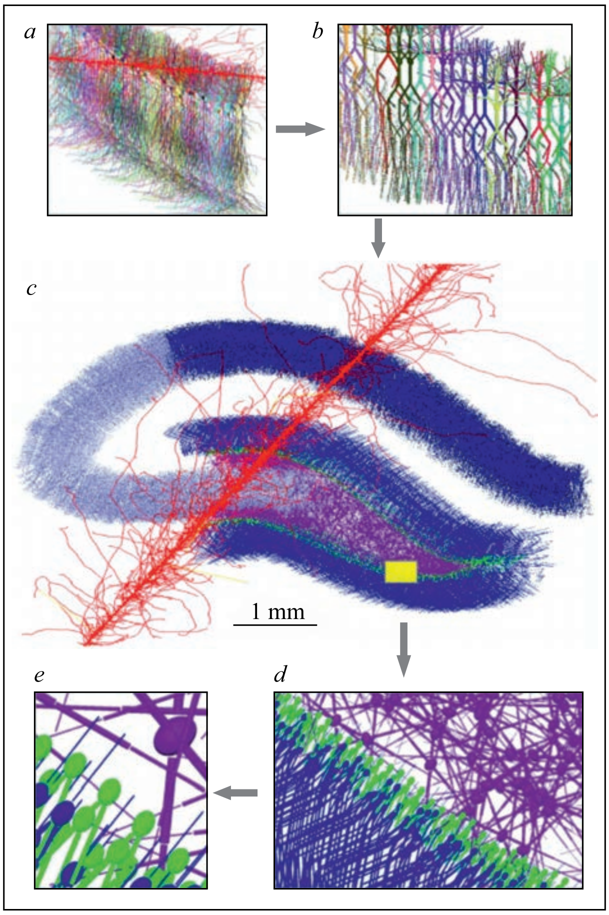


Fig. 25. A sample three-dimensional representation of neurons of different morphology in the rat hippocampus traversed by a single ^{56}Fe ion track. An example of a realistic (*a*) and simplified (*b*) models of networks of pyramidal neurons in the CA1 region. The central panel (*c*) shows a 3D model of the rat hippocampus; the inserted panels (*d, e*) depict a close-up view of the selected region (the yellow square). The dentate gyrus granular cells are highlighted in blue; neurons in the subgranular zone, green; mossy fibers in the hilus, purple; CA1 pyramidal neurons, dark blue; and CA3/CA2 pyramidal neurons, light blue. A 600-MeV/u ^{56}Fe ion track structure is shown in red

to real galactic cosmic rays the distribution of the energy deposition events and radiolysis products is the same for simplified and realistic models of granular and pyramidal neurons of the rat hippocampus (Fig. 24). To perform this task, the simplified models require several times less computation time and hardware resources [24], which allows studying neural networks of thousands of cells. Simplified models were used to simulate a distribution of the absorbed dose and forming DNA damage in a three-dimensional rat hippocampus model that included pyramidal cells, mature and immature granular cells, mossy fiber cells, and nerve stem cells (Fig. 25). It was predicted that most of radiation-induced DNA damage would form in the dentate gyrus. Also, energy deposition and radiolysis processes were studied in other critical components of nerve cells: membrane ion channels (K^+, Na^+, and Ca^{2+}) and synaptic receptors (NMDA, AMPA, and GABA(A)).

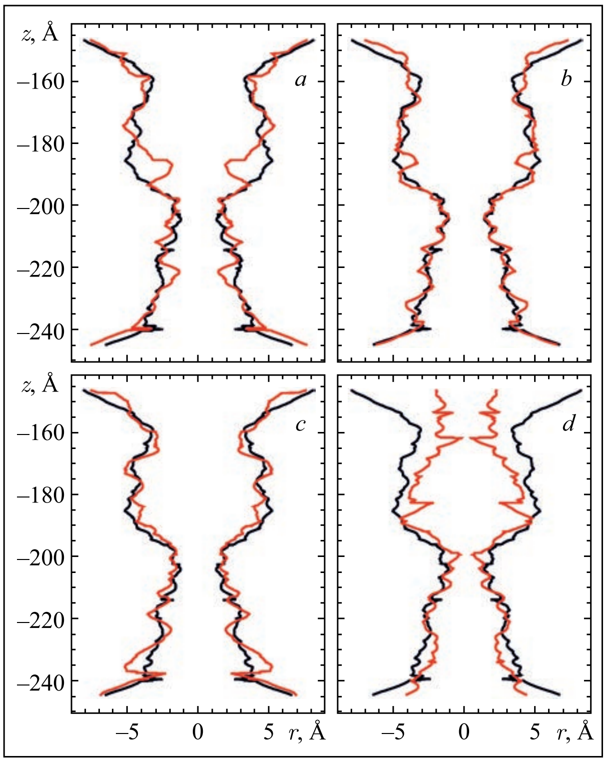


Fig. 26. Activated (open) NMDA ion channel geometry (the pore radius *r* versus coordinate *z* along the vertical symmetry axis). Four mutant forms (red) — p.Arg540His (*a*), p.Asn615Leu (*b*), p.Val618Gly (*c*), and p.Phe671_Gln672del (*d*) — are compared with the native variant (black)

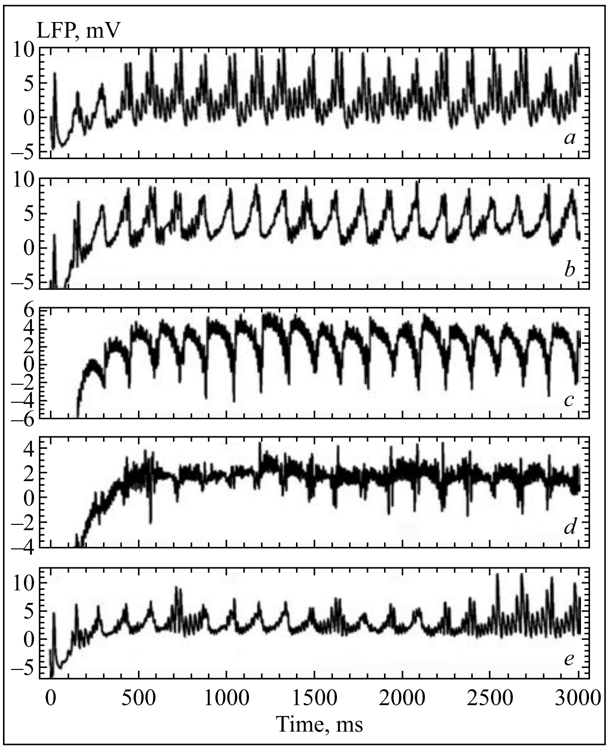


Fig. 27. A local field potential (LFP) generated by a hippocampal neural network with various forms of NMDA receptors: the native form (*a*), p.Arg540His mutation (*b*), p.Asn615Leu mutation (*c*), p.Val618Gly mutation (*d*), and p.Phe671_Gln672del mutation (*e*)

Modeling shows that the most probable targets of radiation damage are the GABA and NMDA synaptic receptors rather than ion channels on the membrane. It was shown that the indirect lesions caused by chemical interaction with free radicals dominate over the direct molecule ionization events. Efficiency of damage induction by particle exposure at different doses and for different linear energy transfer values was evaluated.

The distinguishing features of the transcription process and its dependence on the structure and energy parameters of a DNS chain part were studied [27]. This analysis allowed finding the parameter range where transcription is impossible, which can disorder the synthesis of proteins.

The connection between the functional properties of the NMDA synaptic receptors and mutations in the *GRIN1* and *GRIN2* genes encoding the proteins of these structures was studied. It is important for the analysis of the neurodegenerative disorders caused by different diseases and radiation exposure. With the use of computer molecular dynamics modeling, the process of NMDA receptor activation and the structure of the receptor's ion channel were studied (Fig. 26). The open channel's ion conductances determined by its geometry and by bonding magnesium ions, which block the penetration of other ions of the electrolyte into the intracellular space, were also calculated in this research. The receptors' calculated characteristics were in agreement with experimental data for the known point mutations identified in a number of epileptic disorders. The influence of the mutant receptors' properties on the hippocampal neural networks' functioning was studied by analyzing the simulated electroencephalograms (Fig. 27) and their spectra. For the double point mutations and deletions in the *GRIN2* gene, a decrease in the ion channel conductance was observed, which leads to the attenuation of the theta and gamma rhythm amplitudes in the hippocampus. It can indicate that after exposure to accelerated heavy charged particles the formation of hard-to-repair DNA damage like clustered double-strand breaks and the structural mutations induced by the latter have a negative effect on the synthesized proteins' structure [10] and thus on hippocampal activity [28].

Two radiobiological experiment sessions were conducted at the MC-400 cyclotron (FLNR JINR). At 46 MeV/nucleon ^{15}N nuclei beams, a large number of different biological samples were irradiated at doses of 0.6–80 Gy in the linear energy transfer (LET) range of 70–200 keV/μm. At the medical beam of the Phasotron (DLNP JINR), many different biological samples, including animal and human cells, laboratory animals, and formamide, were irradiated with 160-MeV Bragg peak protons.

At the Nuclotron (VBLHEP JINR), a radiobiological experiment session was conducted, in which primates and small laboratory animals were irradiated with 2.58 GeV/nucleon ^{84}Kr nuclei, in order to study morphological changes in rat brain structures and to model the action of galactic cosmic radiation's heavy nuclei on animals' cognitive functions. The exposed animals were six *Macaca mulatta* male monkeys: four from the Institute of Medical Primatology (Adler, Russia) and two from the Institute of Biomedical Problems of RAS (Moscow). The absorbed dose averaged over the whole brain volume is estimated at about 0.15 Gy, but in a small volume of the brain hit by the beam the local dose was higher — up to 3 Gy. Also, exposure of the brain of three laboratory rats was performed at an average absorbed dose of about 0.74 Gy.

The krypton nuclei beam was practically clear, as the impurity of lower charge nuclei was less than 10%. Due to the beam's low intensity at the F3 focus (not more than $2 \cdot 10^5$ nuclei/s), no beam defocusing providing a uniform exposure field was done. The monkey brain was irradiated with a narrow nuclear beam with an average LET of 282 keV/μm in the brain tissue. Measurements with Gafchromic EBT-03 radiochromic film showed that the beam cross section was close to an ellipse with the half-height X and Y widths of about 0.34 and 0.86 cm, respectively. The nuclear beam intensity was measured with a specially designed ionization drift chamber in which the electrodes were inclined to suppress columnar ion recombination. The chamber had been pre-calibrated based on the readings of a scintillation counter installed in the beam. The chamber's sensitivity to 2.3 GeV/nucleon ^{84}Kr nuclei was 14.0 nuclei per one chamber pulse.

As part of the VBLHEP's project of constructing beams for applied research at the Nuclotron, specifications were prepared for a channel and irradiation facility for radiobiological research at beams of heavy ions, $^{12}C - ^{56}Fe$, with energies of 500–800 MeV/nucleon. Necessary preliminary calculations were performed.

To provide zoned neutron radiation monitoring at the NICA facility, a method was proposed based on a linear combination of readings of slow neutron dosimeters in two polyethylene moderators $3''$ and $10''$ in diameter containing a lead converter [29]. Another possible design of a dosimeter with an extended energy range for operational and zoned radiation monitoring near high-energy accelerators is proposed in [30]. Both these designs were developed by modeling energy sensitivity of the dosimeters using MCNPX — a software package for Monte Carlo simulation of radiation transport in matter.

As further research on the realistic evaluation of radiation risk to the crews on long-term flights beyond Earth's magnetosphere, fluence-to-effective dose conversion coefficients were calculated for single- and multi-charged particles, neutrons, and γ rays on the basis of radiation quality factor dependences on LET, linear energy, and the Z^{*2}/β^2 dependence proposed by NASA. The coefficients were calculated for the cohort of adult non-smoking men, which is close to the astronaut cohort.

With the participation of the Institute of Space Research (ISR) of RAS, space equipment tests were continued at the DAN (dynamic albedo of neutrons) experimental stand. Besides, as part of the fulfillment of the ISR grant for the creation of the Space Gamma Spectrometer with Tagged Charged Particles, a layout of an experiment at a proton beam of the Phasotron (DLNP), was designed; scintillator counter telescope was fabricated; a complex of electronic instruments in the NIM standard was adjusted; and five runs at a 160-MeV proton beam were conducted with the ISR gamma spectrometer and "proton event tags", which allow making time samplings of the general flow of events coinciding with the beam's protons hitting different targets (reactor graphite, silicate glass, and sodium chloride).

STUDYING COSMIC MATTER ON THE EARTH AND IN NEARBY SPACE

A number of experiments on abiotic phosphorylation of nucleosides were conducted. This subject is a serious obstacle to research on the formation of the first living organisms. An optimal pathway was deduced of the synthesis of adenosine nucleotides from adenosine ($C_{10}H_{13}N_5O_4$) and sodium dihydrogen phosphate (NaH_2PO_4) under exposure to 170-MeV protons in the presence of the matter of the NWA 2828 carbonaceous chondrite meteorite as a catalyst. As a result, besides the target nucleoside, found in the mixture were its derivatives, adenosine polyphosphates and inorganic polyphosphates, which underscores the system's

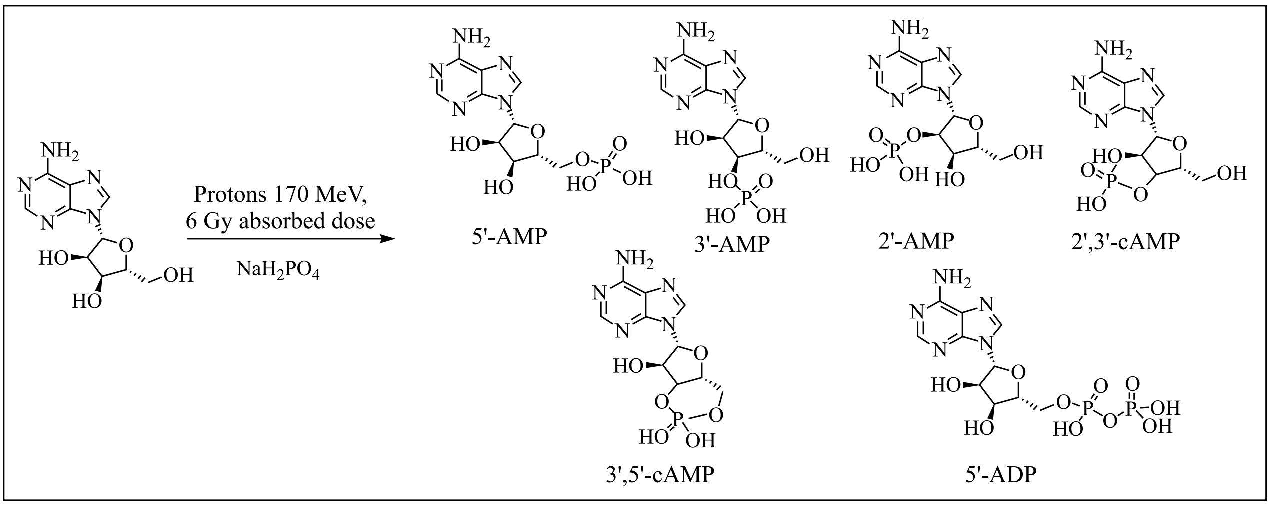


Fig. 28. Adenosine nucleotides obtained by irradiation of adenosine and NaH_2PO_4 by 170-MeV protons under four experiment conditions

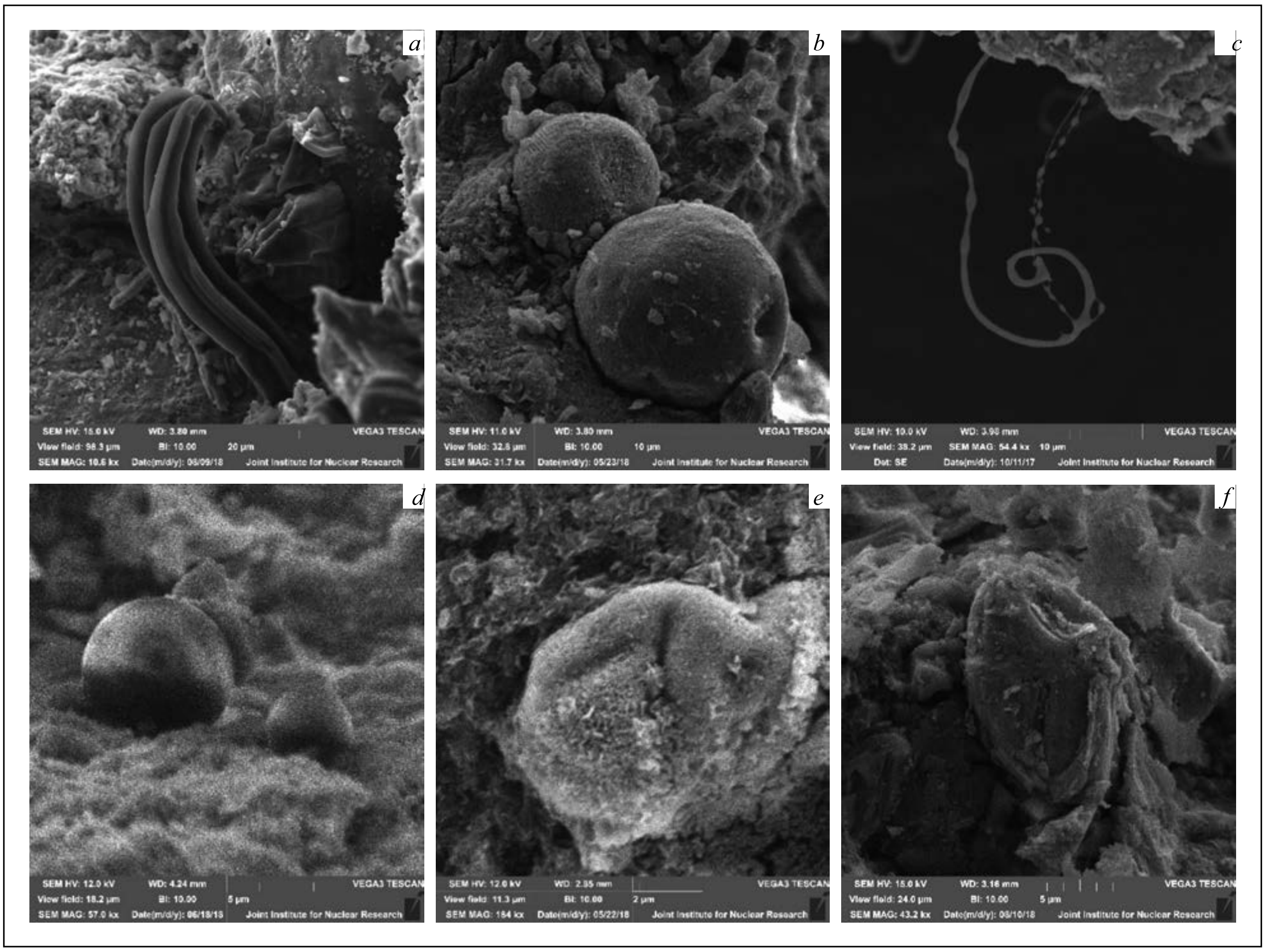


Fig. 29. Microfossils of the Orgueil (*a–e*) and Murchison (*f*) meteorites: a cyanobacterial filament (*a*); prasinophyte cells (*b*) (pores are seen); ray fungi filaments (*c*); testate amoebas (*d*); a pollen-like form (*e*); and an alveolate (*f*)

high reactivity. These experiments reproduce, to some extent, the conditions in space or on the early Earth, when solar wind protons not only passed through interplanetary space but also reached the Earth's surface. The experiments thus allow modeling a prebiotic phosphorylation scenario. Adenosine1 phosphorylation was performed under four different experiment conditions: 1) dry powder mixture of adenosine and NaH_2PO_4; 2) dry powder mixture of adenosine, NaH_2PO_4, and NWA 2828; 3) adenosine and NaH_2PO_4 in a liquid

NH_2CHO solution; 4) adenosine powder, NaH_2PO_4, and NWA 2828 in a liquid NH_2CHO solution.

In all four reaction mixtures, formation of alicyclic and cyclic adenosine nucleotides was observed (Fig. 28): 5′-adenosine monophosphate (5′-AMP), 3′-adenosine monophosphate (3′-AMP), 2′-adenosine monophosphate (2′-AMP), and 2′, 3′-cyclo-adenosine monophosphate (2′, 3′-cAMP). In addition, a significant yield of adenine was observed, which formed due to a partial break of the β-glycosidic bond. Also, 3′, 5′-cyclo-adenosine monophosphate (3′, 5′-cAMP) and 5′-adenosine diphosphate (5′-ADP) were obtained. It was established in the experiments that the total yield of adenosine nucleotides significantly increased when the reaction mixture contained formamide (NH_2CHO) and meteorite matter.

Bacterial paleontology studies of meteorites and terrestrial rocks were continued. More than 20 samples of meteorites — first of all, of the carbonaceous chondrites Orgueil and Murchison — and terrestrial rocks were studied with a Tescan Vega 3 scanning microscope at the Astrobiology Sector. Analyzed were several hundred images of fossil microorganisms, including cyanobacteria, ray fungi, prasinophytes, testate amoebas, alveolates, and more (Fig. 29).

As part of the cooperation with Borisyak Paleontological Institute of the Russian Academy of Sciences, a series of bacterial paleontology studies of Precambrian rocks were conducted [31–33]. In particular, in early Precambrian Keiv paraschists (the Kola Peninsula), *in situ* buried nanobacteria were discovered. It is suggested that the presence of nanobacteria indicates the participation of biological factor in the formation of enclosing strata [31].

Volcanogenic and sedimentary rocks (early Proterozoic pillow lavas of Karelia and South Africa) were studied and found to contain different fossilized bacteria and, possibly, even eukaryotes. It was shown that at that early time the conditions for the development of life and colonization of cooling lava flows and volcanogenic rocks were favorable [32]. The current knowledge of the Archean microorganisms was assessed [33].

Using archaeocyathan evolution as an example, Acad. A. Yu. Rozanov showed the importance of the ideas on evolution proposed by N. I. Vavilov, L. S. Berg, D. N. Sobolev, etc. and questioned the creative role of natural selection [34].

CONFERENCES AND EDUCATION

In 2018, the Laboratory's researchers participated in nine scientific conferences in Russia and six conferences worldwide.

Jointly with the RAS Councils on Radiobiology and Astrobiology, the following two conferences were held: "Problems of Radiation Exposure-Related Chemical Protection and Repair" and "Modern Problems of Space Radiobiology and Astrobiology". More than 150 scientists representing research institutes and scientific organizations of the Czech Republic, Italy, Mongolia, Slovakia, Russia, and the USA took part in the conferences. The scope of the conferences included discussions on topical issues in space radiobiology, molecular and cell radiobiology, and astrobiology. The main tasks for further research in these fields were formulated.

The education process continued at the Department of Biophysics of Dubna University. The Department's current total enrolment includes 35 students and eight postgraduates. Bachelor's education is given in nuclear physics and technology represented by the program "Human and Environmental Radiation Safety"; Master's education is given in physics represented by the program "Radiation Biophysics and Astrobiology"; and postgraduate education is given in the specialty of Radiobiology. In 2018, eight students were enrolled in Bachelor's program; nine students continued their Master's program. Six students successfully completed education and received their Master's diplomas in physics (the program "Radiation Biophysics and Astrobiology"). In 2018, two Candidate's theses were successfully defended.

Two patents for inventions were obtained in 2018: "A Method for Increasing the Frequency of DNA Double-Strand Break Formation in Human Cells under Exposure to Ionizing Radiation in the Presence of Radiomodifiers" (E. A. Krasavin, A. V. Boreyko, T. S. Bulanova, V. N. Chausov, E. A. Kulikova, G. N. Timoshenko) and "A Method for the Prophylaxis of a Decrease in Muscle Strength during the Acute Radiation Syndrome in an Experiment" (A. A. Ivanov, E. A. Krasavin, K. N. Lyakhova, Yu. S. Severyukhin, A. G. Molokanov). The first proposes an approach that provides a significant increase in the biological effectiveness of proton beams, thereby bringing the areas of the therapeutic use of proton and carbon ion accelerators much closer to each other. The latter relates to experimental medicine and may find application in the rehabilitation of patients after the proton therapy of tumors of different types.

REFERENCES

1. *Kulikova E., Boreyko A., Bulanova T., Ježková L., Zadneprianetc M., Smirnova E.* Visualization of Clustered DNA Damage along Accelerated Ions Tracks // Eur. Phys. J. Web Conf. 2018. V. 177. P. 06002; https://doi.org/10.1051/epjconf/201817706002.
2. *Depes D., Lee Jin-Ho, Bobkova E., Ježková L., Falkova I., Bestvater F., Pagacova E., Kopecna O., Zadneprianetc M., Bacikova A., Kulikova E., Smirnova E., Bulanova T., Boreyko A., Krasavin E., Hausmann M., Falk M.* Single-Molecule Localization Microscopy as a Promising Tool for H2AX/53BP1 Foci Exploration // Eur. Phys. J. D. 2018. V. 72. P. 158; https://doi.org/10.1140/epjd/e2018-90148-1.
3. *Bobkova E., Depes D., Lee Jin-Ho, Ježková L., Falkova I., Pagacova E., Kopecna O., Zadneprianetc M., Bacikova A., Kulikova E., Smirnova E., Bulanova T., Boreyko A., Krasavin E., Wenz F., Bestvater F., Hildenbrand G., Hausmann M., Falk M.* Recruitment of 53BP1 Proteins for DNA Repair and Persistence of Repair Clusters Differ for Cell Types as Detected by Single Molecule Localization Microscopy // Intern. J. Mol. Sci. 2018. V. 19. P. 3713; https://www.mdpi.com/1422-0067/19/12/3713.
4. *Zadneprianetc M. G., Boreyko A. V., Bulanova T. S., Ježková L., Krasavin E. A., Kulikova E. A., Smirnova E. V., Falk M., Falkova I.* Regularities in the Formation and Elimination of γH2AX/53BP1 Foci Induced by γ-Rays and Accelerated Heavy Ions // Radiats. Biol. Radioekologiya. 2018. V. 58, No. 2. P. 146–156 (in Russian).
5. *Zadneprianetc M. G., Boreyko A. V., Bulanova T. S., Ježková L., Krasavin E. A., Kulikova E. A., Smirnova E. V., Falk M., Falkova I.* Structure Analysis of Complex Damage to DNA Caused by Accelerated ^{11}B Ions and ^{60}Co γ-Rays // Radiats. Biol. Radioekologiya. 2018. V. 58, No. 3. P. 229–237 (in Russian).
6. *Zadneprianetc M. G., Boreyko A. V., Bulanova T. S., Ježková L., Krasavin E. A., Kulikova E. A., Smirnova E. V.* The Influence of Physical Characteristics of Accelerated Heavy Ions on the Formation and Repair of DNA Double-Strand Breaks // Phys. Part. Nucl. Lett. 2018. V. 15, No. 6. P. 693–699.
7. *Kuzmina E. A., Boreyko A. V., Dubnickova M., Ilina E. V., Kozhina R. A., Tiunchik S. I., Chausov V. N.* The Modifying Influences of Lipid A Derivatives of Gamma-Irradiation-Induced DNA Double-Strand Breaks // Abstr. of the Intern. Conf. "Problems of Radiation Exposure-Related Chemical Protection and Repair", Dubna, 2018. P. 87–89 (in Russian).
8. *Kozhina R. A., Ilyina E. V., Kuzmina E. A., Tiounchik S. I.* Lipid A Influence on the Induction of DNA Double-Strand Breaks by ^{60}Co γ-Rays *In Vivo* and *In Vitro* // Abstr. of Conf. "Lomonosov 2018", Moscow, 2018 (in Russian).
9. *Bulanova T. S., Zadneprianetc M. G., Ježková L., Kruglyakova E. A., Smirnova E. V., Boreyko A. V.* Induction and Repair of DNA Double-Strand Breaks in Rat Cerebellar Cortex Exposed to ^{60}Co γ-Rays // Phys. Part. Nucl. Lett. 2018. V. 15, No. 1. P. 121–126; doi: 10.1134/S1547477118010041.
10. *Boreyko A. V., Bugay A. N., Bulanova T. S., Dushanov E. B., Ježková L., Kulikova E. A., Smirnova E. V., Zadneprianetc M. G., Krasavin E. A.* Clustered DNA Double-Strand Breaks and Neuroradiobiological Effects of Accelerated Charged Particles // Phys. Part. Nucl. Lett. 2018. V. 15, No. 5. P. 551–561.
11. *Bulanova T. S., Boreyko A. V., Krasavin E. A., Kulikova E. A., Severyukhin Yu. S., Smirnova E. V., Timoshenko G. N., Zadnepryanets M. G.* Formation of DNA Double-Strand Breaks in Rat Brain Neurons after Exposure to Accelerated ^{78}Kr Ions // Part. Nucl., Lett. (in press) (in Russian).
12. *Chausov V. N., Boreyko A. V., Bulanova T. S., Zadneprianetc M. G., Ilyina E. V., Ježková L., Krasavin E. A., Kozhina R. A., Kuzmina E. A., Kulikova E. A., Smirnova E. V., Tiounchik S. I.* Formation of Direct and Enzymatic DNA Double-Strand Breaks in the Presence of Repair Inhibitors after Exposure to Radiations of Different Quality // Phys. Part. Nucl. Lett. 2018. V. 15, No. 6. P. 700–710.
13. *Krasavin E. A., Boreyko A. V., Chausov V. N., Ilyina E. V., Kozhina R. A., Kulikova E. A., Kuzmina E. A., Smirnova E. V., Timoshenko G. N., Tiounchik S. I., Zadnepryanets M. G.* DNA Synthesis Inhibitors' Effect on the Biological Effectiveness of a Modified Bragg Peak Proton Beam. JINR Preprint P19-2018-48. Dubna, 2018 (in Russian).
14. *Chausov V. N., Boreyko A. V., Bulanova T. S., Ilyina E. V., Ježková L., Krasavin E. A., Kozhina R. A., Kulikova E. A., Kuzmina E. A., Smirnova E. V., Tiounchik S. I., Zadnepryanets M. G.* Induction of Direct and Enzymatic DNA Double-Strand Breaks by Radiation of Different Quality in the Presence of Repair Inhibitors // Part. Nucl., Lett. 2018. V. 15, No. 6(218). P. 573–588 (in Russian).
15. *Kowalska A., Pereira W., Czersrki K., Nasonova E., Kutsalo P.* Fano Factor of Chromosome Aberrations and Assessment of Repair Efficiency // Acta Phys. Pol. A. 2018. V. 133. P. 225–227.
16. *Kowalska A., Nasonova E., Czerski K., Kutsalo P., Pereira W., Krasavin E.* Production and Distribution of Chromosome Aberrations in Human Lymphocytes by Particle Beams with Different LET: Part I // Radiat. Environ. Biophys. 2018 (submitted).
17. *Kowalska A., Czerski K., Nasonova E., Kutsalo P., Krasavin E.* Production and Distribution of Chromosome Aberrations in Human Lymphocytes by Particle Beams with Different LET: Part II // Radiat. Environ. Biophys. 2018 (submitted).
18. *Kowalska A., Czerski K., Nasonova E., Kutsalo P., Krasavin E.* Initial Radiation DNA Damage Observed in Prematurely Condensed G2 Chromosomes of Human Lymphocytes and Analytical Model of Ion Tracks // The 5th Intern. Conf. "Dynamics of Systems on the Nanoscale" (DySoN 2018), Potsdam, Germany, Oct. 8–12, 2018.
19. *Koltovaya N., Lyubimova K., Zhuchkina N.* Genetic Effects after Irradiation of Heavy Ions in Haploid and Diploid Yeast Cells // Book of Abstr. of the 6th In-

tern. Conf. on Radiation and Applications in Various Fields of Research (RAD 2018), Ohrid, Macedonia, June 18–22, 2018. P. 24.

20. *Koltovaya N., Zhuchkina N., Lyubimova K.* All Types of Base Pair Substitutions Induced by γ-Rays in Haploid and Diploid Yeast Cells // J. Bioeng. Life Sci. 2018. V. 12. No. 9.
21. *Yakovleva M. A., Feldman T. B., Lyakhova K. N., Utina D. M., Vinogradova Yu. V., Kolesnikova I. A., Ostrovsky M. A.* Changes in the Composition of Bisretinoids in the Mouse Eye Retina and Retinal Pigment Epithelium after Exposure to Ionizing Radiation // Abstr. Intern. Conf. "Problems of Radiation Exposure-Related Chemical Protection and Repair", Dubna, 2018. P. 179 (in Russian).
22. *Lyakhova K. N., Ivanov A. A., Molokanov A. G., Severyukhin Yu. S., Utina D. M., Krasavin E. A.* The Effect of the Semax Neuropeptide on Proton-Irradiated Mice's Cognitive Behavioral Activity Indicators and Skeletal Muscle Strength // Aerospace Environ. Med. 2018. V. 52, No. 4. P. 71–76 (in Russian).
23. *Kolesnikova I. A., Budennaya N. N., Severyukhin Yu. S., Lyakhova K. N., Utina D. M.* Analysis of the Morphofunctional Condition of Experimental Animals' Brain Structures in a Long-Term Period after Proton Irradiation // Bull. New Med. Technol. 2018. V. 25, No. 3. P. 177–181 (in Russian).
24. *Batmunkh M., Aksenova S. V., Bayarchimeg L., Bugay A. N., Lkhagva O.* Optimized Neuron Models for Estimation of Charged Particle Energy Deposition in Hippocampus // Phys. Med. 2019. V. 57. P. 88–94.
25. *Bayarchimeg L., Bugay A., Batmunkh M., Lkhagva O.* Evaluation of Radiation-Induced Damage in Membrane Ion Channels and Synaptic Receptors // Phys. Part. Nucl. Lett. 2019. V. 16. P. 54–62.
26. *Batmunkh M., Bugay A. N., Bayarchimeg L., Lkhagva O.* Radiation Damage to Nervous System: Designing of Optimal Models for Realistic Neuron Morphology // Eur. Phys. J. Web Conf. 2018. V. 173. P. 05004.
27. *Zdravković S., Satarić M. V., Parkhomenko A. Yu., Bugay A. N.* Demodulated Standing Solitary Wave and DNA–RNA Transcription // Chaos. 2018. V. 28. P. 113103.
28. *Batova A. S., Bugay A. N., Dushanov E. B.* Effect of Mutant NMDA Receptors on Oscillations in a Model of Hippocampus // J. Bioinform. Comput. Biol. 2019 (in press); https://doi.org/10.1142/S0219720019400031.
29. *Beskrovnaia L. G., Guseva S. V., Timoshenko G.N.* Method for Monitoring of Neutron Fields near High-Energy Accelerators // Phys. Part. Nucl. Lett. 2018. V. 15, No. 3. P. 336–341.
30. *Toan C. N., Beskrovnaia L. G., Latysheva L. N., Sobolevsky N. M., Timoshenko G. N.* Dosimeter for Measuring the Ambient Dose of Neutrons with Energy from 10^{-4} MeV to 1 GeV Based on a Cylindrical Polyethylene Moderator // Phys. Part. Nucl. Lett. 2019. V. 16, No. 1. P. 63–69.
31. *Astafyeva M. M., Balagansky V. V.* Keivy Paraschists (Archean-Early Proterozoic): Nanobacteria and Life // Stratigr. Geol. Correl. 2018. V. 26, No. 3. P. 117–126; doi: 10.7868/S0869592X18030080 (in Russian).
32. *Astafieva M. M.* Life in Ancient Cooling Lava // Paleontol. J. 2018. V. 52, No. 10. P. 45–61; doi: 10.1134/S0031030118100052.
33. *Rozanov A. Yu., Astafyeva M. M.* A New Take on the Archean Eukaryotes // Proc. Russ. Acad. Sci. (in press) (in Russian).
34. *Rozanov A. Yu.* Biologization in Paleontology // Fundamental and Applied Paleontology. Proc. of the 64th Session of the Paleontol. Soc. with the Russ. Acad. Sci., St. Petersburg, 2–6 April 2018. P. 3–7 (in Russian).

UNIVERSITY CENTRE

At the meetings of the 48th session of the Programme Advisory Committee on Condensed Matter Physics and Nuclear Physics, the recommendation on the opening of the UC "Organization, Support and Development of the JINR Human Resources Programme" for the period 2019–2023 was supported. The results of UC work on the topic "Organization, Support, and Development of JINR Educational Programmes" that came to its end in 2018 were highly appreciated. The new Programme is aimed at training scientific and engineering personnel to enable them to implement large-scale projects at the Institute Laboratories and in the research centres of the JINR Member States.

International Student Practice. International Student Practices (ISP) in JINR Fields of Research are of consistently high interest among young people — almost 1600 representatives of the JINR Member States and Associate Members have taken part in the event. Since 2004, the majority of participants have been students from Poland — their number has come up to 315 people, the Czech Republic — 250, Romania — 177. Since 2007, groups of 20–30 students from the universities of South Africa have been coming annually to participate in the Practice, and since 2009 JINR has been visited by students from Egypt. This year the number of South African participants has reached 287; as for Egyptian students, the number has come up to 224.

Stage 1 of ISP began on 3 June. Seventeen students from South Africa became its participants. On 9 July, 75 students from Azerbaijan, Bulgaria, Czech Republic, Poland, Romania, and Slovakia arrived to take part in Stage 2. On 9 September, 48 students from Belarus, Egypt, Cuba, Mongolia, and Serbia participated in Stage 3 of the event.

Traditionally, the ISP programmes included introductory lectures on the research conducted at the JINR Laboratories, as well as visits to the basic facilities of the Institute. Most of the time was devoted to working on the research projects. The social programme included excursions to Dmitrov and Moscow and lectures on the history of Russia.

JINR-Based Education. In 2018, over 400 students of the JINR-based departments of MSU, MIPT, MEPhI, Dubna State University, and the universities of the JINR Member States were trained at the University Centre and the laboratories of the Institute. The JINR Laboratories welcomed more than 300 students from the universities of Belarus, Kazakhstan, Russia, and Ukraine for summer internship.

Twenty-eight degree-seekers from Belarus, Georgia, Kazakhstan, Mongolia, Russia, Ukraine, and the USA were assigned to JINR to prepare their PhD theses without mastering the doctoral programme.

In the 2018/2019 academic year, students of the JINR-based departments of MIPT, MSU, and Dubna State University were offered 89 lecture courses. The programmes of the courses are available at uc.jinr.ru.

In 2018, a new JINR-based department of the Kazan Federal University — Department of Nuclear Materials Science — was established to join the other 12 JINR-based departments of MSU, MEPhI, MIPT, and Dubna State University.

MEPhI and JINR have announced the first enrollment for a new network Master Degree programme aimed at training students to work at JINR, and in particular, in the NICA project.

JINR Summer Student Programme. Sixty-three participants of the Summer Student Programme from Belarus, Brazil, Bulgaria, China, Cuba, Egypt, Germany, Italy, Kazakhstan, Poland, Romania, Russia, Serbia, Ukraine, and Uzbekistan spent 4–8 weeks doing their research projects at the JINR Laboratories.

The Programme was attended by Bachelor students of their third and fourth year of studies, Master students, and first-year PhD students.

International School on Nuclear Methods for Environmental and Life Science (NMELS'18). On 22–28 April, Montenegro hosted the International School on Nuclear Methods for Environmental and Life Science (NMELS'18) organized by UC, FLNP, and DLNP. The School was devoted to studying nuclear and related methods for ecological studies of various ecosystems:

air, water, and soil pollution; water purification technologies; radioecology; nuclear medicine (radioisotopes and hadron therapy); and nuclear detectors in medicine. The event was attended by 50 undergraduate and postgraduate students from Albania, Bosnia, Bulgaria, Croatia, Greece, Hungary, Macedonia, Montenegro, Romania, and Serbia.

Satellite School in Petrozavodsk. On 8–9 September 2018, the Petrozavodsk State University (PetrSU) hosted the Satellite School for undergraduate and postgraduate students, as well as for young scientists of the Institute of Physics and Technology and the Institute of Medicine of PetrSU. The School preceded the IX International Symposium on Exotic Nuclei (EXON-2018).

International Scientific Schools for Physics Teachers at JINR and CERN. On 24–30 June, a regular School for Physics Teachers from the JINR Member States was held in Dubna. The event was organized in cooperation with the European Organization for Nuclear Research (CERN). The School was attended by 23 teachers and 13 school students from Belarus, India, Moldova, Russia, and Ukraine. The guests got acquainted with the fields of scientific research conducted at JINR: the leading specialists of the Institute gave lectures and guided tours of the JINR Laboratories and experimental facilities. A special programme was prepared for the school students: they attended a physics workshop and had a chance to give a talk at a scientific seminar.

On 4–11 November, the XI Scientific School for Physics Teachers from the JINR Member States was held at CERN. Twenty-four teachers from Belarus, Russia, and Ukraine came to CERN to attend the programme that included lectures, excursions, and meetings with scientists. The staff members of CERN, JINR and other Russian scientific organizations, who work at CERN, delivered lectures introducing the participants to particle physics, cosmology, radiation biology, and computing. The participants got acquainted with the scientific programme and experimental facilities of the Large Hadron Collider, as well as with the CERN Control Centre, the SM-18 testing facility, and the Antimatter Factory. In addition, the teachers visited the Microcosm Museum, the S'Cool Lab, and the Globe media centre.

VIII All-Russia Science Festival NAUKA0+. At the VIII All-Russia Science Festival NAUKA0+ "Megascience: Russia in the World — Russia for the World", JINR presented its exhibition stands at two of the most prestigious sites of Moscow. In the Fundamental Library of Moscow State University, JINR specialists delivered lectures on the up-to-date research and presented the models of the existing and future JINR facilities, such as the Multi-Purpose Detector, the U-400 cyclotron, the deep-water neutrino telescope used in the Baikal experiment (including a real optical module), and the Medico-Technical Complex of JINR DLNP. In the Expocentre, JINR staff members ran a programme for younger school students, which included master classes, lectures, experimental demonstrations in physics, chemistry, and robotics.

For the first time Dubna State University took part in the Festival and presented the project "Dubna School of Engineering". Also, for the first time this year the University became a regional site of the Festival.

Work with School Students. In the 2018/2019 academic year, the Interschool Physics and Mathematics Open Classroom of UC attended by school students of 6–11 grades organized classes that included workshops and preparation for the Unified State Exam. In the spring and autumn, open olympiads in Physics and Mathematics were held.

The students attending the Interschool Physics and Mathematics Open Classroom became the prizewinners of the olympiads in Mathematics, Physics, and Computer Science at the XXVI International Space Olympiad for school students held in Korolyov.

Physics Days. On 31 March – 1 April, Dubna hosted the 5th Physics Days organized and run by the JINR UC and the Interschool Physics and Mathematics Open Classroom. The event was attended by school students from Bryansk, Dubna, and Moscow. The programme included physics demonstrations, scientific quest "In the Realm of Liquid Nitrogen", astronomical observations prepared by the club "AstroDubna", mathematical tasks and contests.

The 7th Tournament of Cyber Dubna-2018. On 10–11 February, the 7th tournament of the Open Upper Volga Cybernetics Network, called Cyber Dubna-2018, organized by the JINR UC and the Interregional Computer School was held in Dubna. The CROC system integrator, Keldysh Institute of Applied Mathematics of RAS, Bauman MSTU, and LLC "Citadel" also took part in the organization of the event. The tournament was attended by 120 school students from Vladimir, Moscow, and Tver Regions. The participants competed in the ability to build and program robots, took part in robot races, were engaged in a creative workshop, listened to the lecture "Robots and Space", and got acquainted with the activities of JINR at the Museum of the History of Science and Technology.

International Computer School 2018 in Ratmino. On 4–18 August, the Resort Hotel "Ratmino" hosted the 30th Interregional Computer School (ICS) named after V. Volokitin and E. Shirkova organized with the support of the JINR University Centre. Sixty participants aged 7–16 from Belarus, Russia, Switzerland, the USA, and Uzbekistan worked on the scientific projects in Physics, Chemistry, Mathematics, Biology, Robotics, etc. Special courses (aimed at advancement and updating of school knowledge), lectures of the leading scientists and specialists, sports, extensive cultural and intellectual events were also included in the programme of the School.

Visits to JINR. In 2018, introductory visits were organized for 967 school and university students, as well as teachers from France, Germany, Israel, Japan, Mongolia, Russia, and Slovenia. The guests got acquainted with the exhibition of the JINR Museum of Science and Technology, the history of the research conducted at the Laboratories up to the present day, and visited the basic facilities.

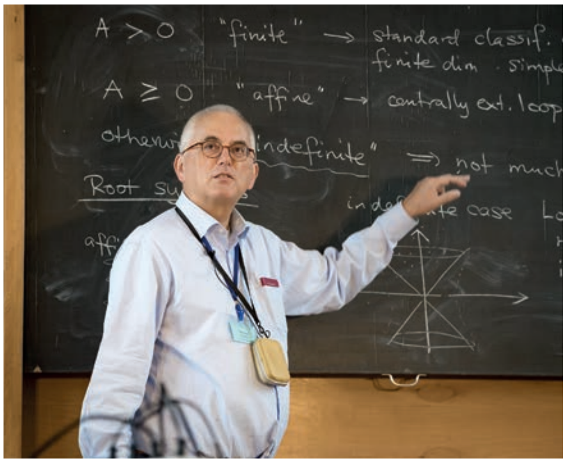
Skill Improvement at JINR. One hundred and two JINR staff members and four representatives of Dubna organizations were trained at the courses intended for the personnel maintaining the facilities subordinate to Rostechnadzor. One hundred and forty-two JINR staff members, including top executives, engineers, technicians, and specialists, were trained in the normative legal acts and normative-technical documents stating requirements for industrial safety in various industries of supervision and certified by the Central Attestation Commission of the Institute and the Territorial Attestation Commission of the Central Department of Rostechnadzor. The training in the basics of fire safety was organized for 66 JINR staff members, and nine staff members were sent to the Education Centre “Dubna” to be trained in the basics of fire safety and labour protection. Fourteen students of the Dubna State University College and Moscow Region Agrotechnology College were trained at JINR.

In 2018, 164 JINR staff members signed up for the language courses organized by JINR UC: English — 118 people, French — 17 people, German — 17 people, Russian — 12 foreign specialists.

JINR is developing as a large multidisciplinary international scientific centre incorporating basic research in the field of modern nuclear physics, development and application of high technologies, and university education in the relevant fields of knowledge.

Dubna, 6 March. Inauguration of the memorial plaque to mark the 90th anniversary of the birth of Dmitry Vasilievich Shirkov

The Bogoliubov Laboratory of Theoretical Physics, 11 January. The all-Institute seminar on the occasion of the 110th anniversary of the birth of Dmitry Ivanovich Blokhintsev



The Bogoliubov Laboratory of Theoretical Physics, 29 January – 2 February. The international winter school for undergraduate and postgraduate students and young scientists “Partition Functions and Automorphic Forms”

Dubna, 20–31 August. The participants of the Helmholtz international summer school “Matter under Extreme Conditions in Heavy-Ion Collisions and Astrophysics”

The Veksler and Baldin Laboratory of High Energy Physics, 2 February. Members of the Supervisory Council on the NICA mega-science project on an excursion at the laboratory

The construction site of the NICA complex

The Veksler and Baldin Laboratory of High Energy Physics, 7–8 June. The meeting
of the Machine Advisory Committee for the NICA project at JINR

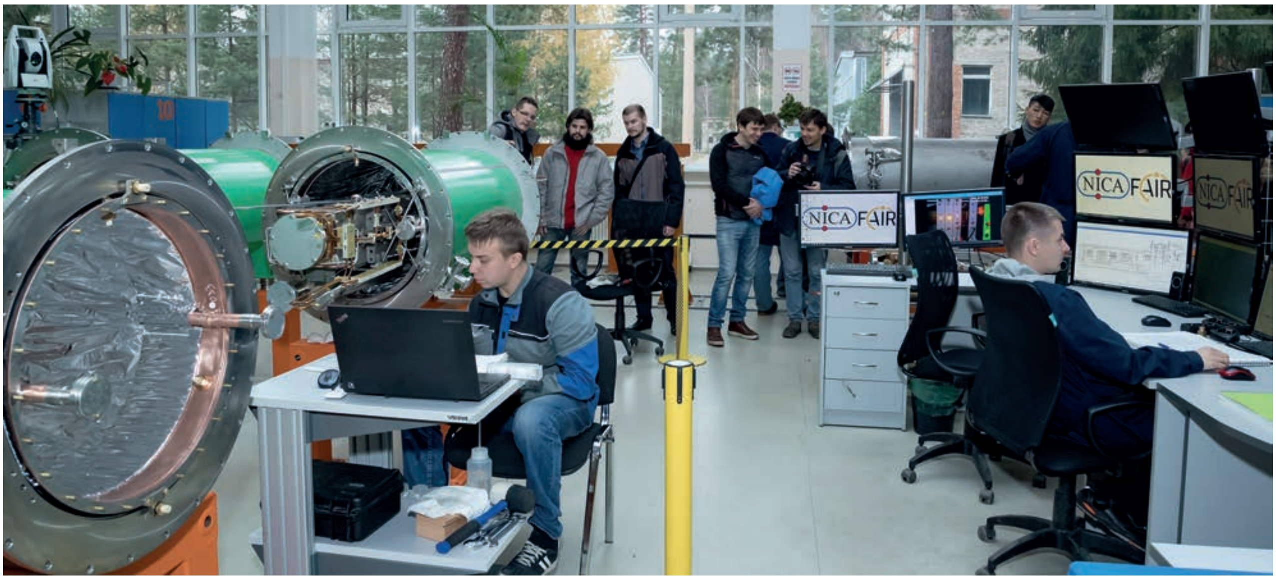
The Veksler and Baldin Laboratory of High Energy Physics, 12 April. Participants of the first
Collaboration Meeting of the MPD and BM@N Experiments at the NICA Facility on an excursion around the laboratory

Dubna, 17 September. The opening of the XXIV International Baldin Seminar on High Energy Physics Problems “Relativistic Nuclear Physics and Quantum Chromodynamics”

The Veksler and Baldin Laboratory of High Energy Physics, 4 May.
Participants of the seminar devoted to the 10th anniversary of the VBLHEP establishment

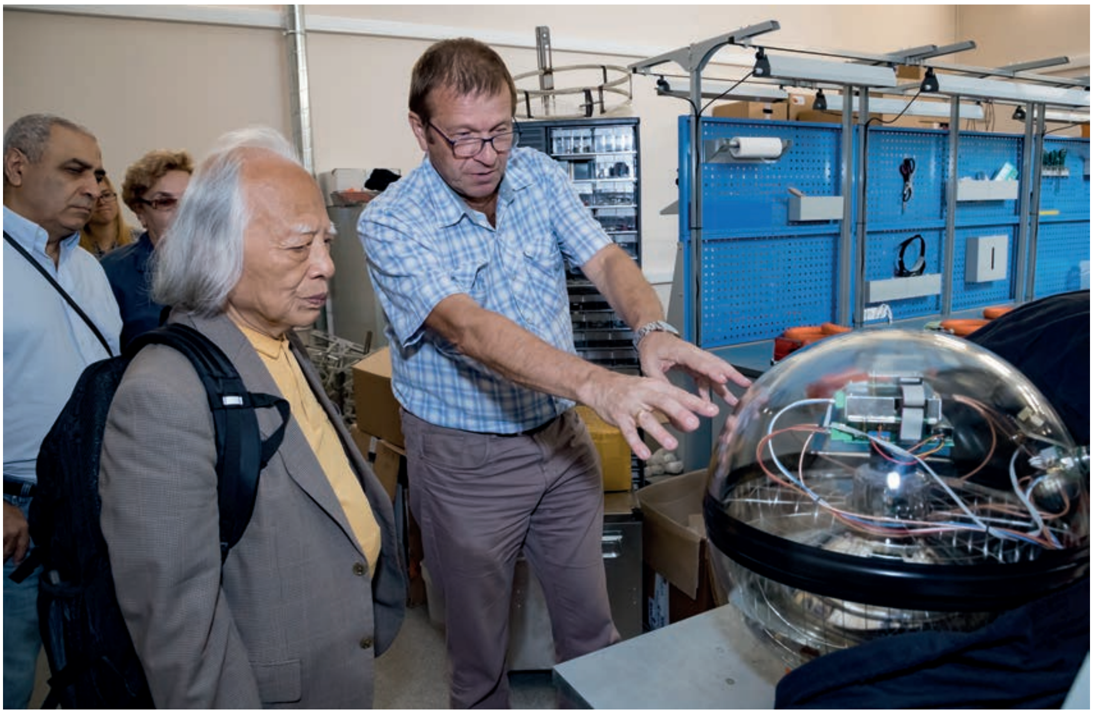
Dubna, 17 July. JINR is visited by an Italian delegation. At the Veksler
and Baldin Laboratory of High Energy Physics

Dubna, 10 August. The delegation of the China National
Nuclear Corporation and the China Institute of Atomic Energy visits the NICA construction site



The Veksler and Baldin Laboratory of High Energy Physics, 31 October.
The Open Doors Day to acquaint visitors with the NICA project

The Dzhelepov Laboratory of Nuclear Problems. Participants of the gamma-telescope development for astrophysical research in the experiment TAIGA



The Dzhelepov Laboratory of Nuclear Problems, 26 July. A. Misaki, Professor of the Saitama University (Japan), on an excursion around the laboratory

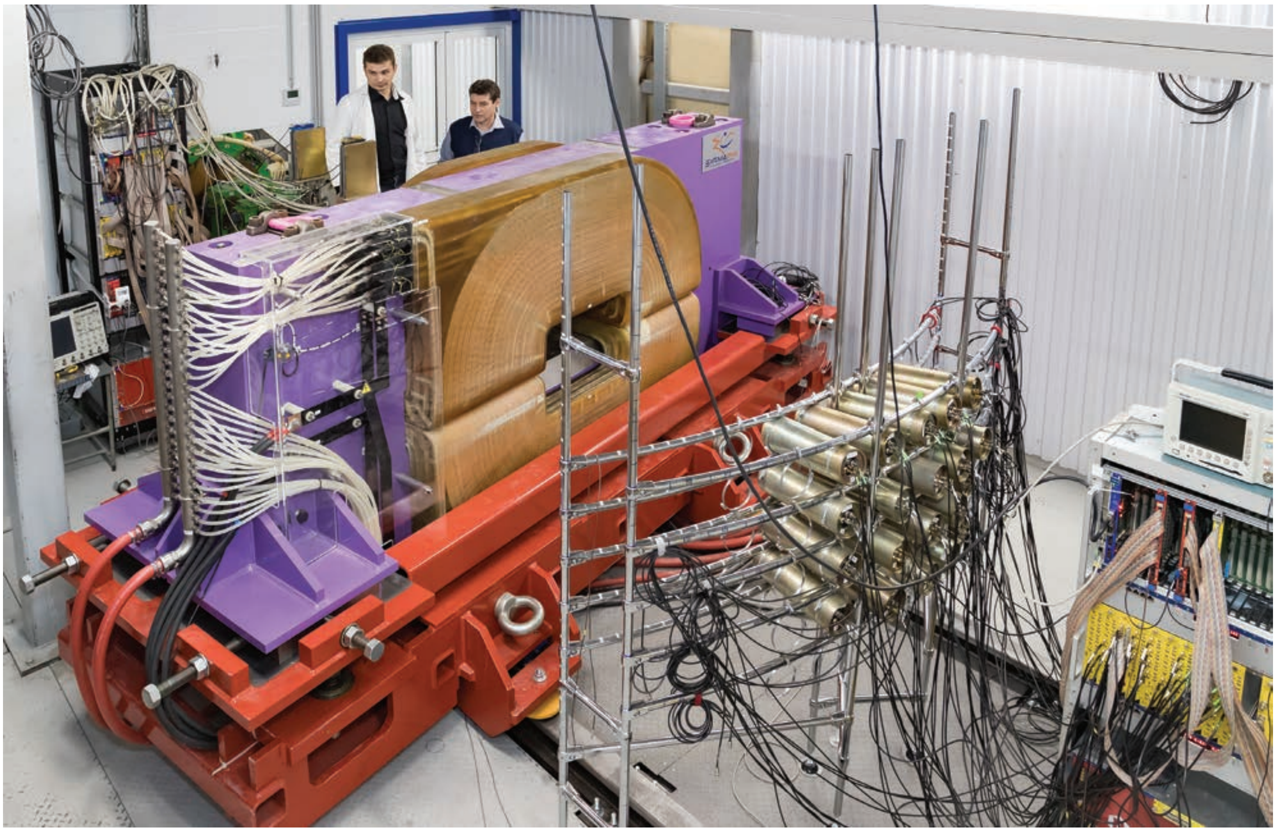
Dubna, 2–4 October. The International Workshop on Very Large Volume Neutrino Telescopes (VLVnT-2018)

Moscow, 30 March. Academician Yu. Oganessian and Professor B. Jonson at the annual General Meeting of the Russian Academy of Sciences after being awarded the RAS Lomonosov Gold Medals

The Flerov Laboratory of Nuclear Reactions. The development of the DC-280 accelerator, the basic facility of the Factory of Superheavy Elements, has been completed

The Flerov Laboratory of Nuclear Reactions, June. The participants of the final assembling of the GNS-2 magnetic system of the Factory of Superheavy Elements

The Flerov Laboratory of Nuclear Reactions. The array of neutron detectors installed behind the dipole magnet and used to arrange coincidences with protons from the ^{9}Li + *d* reaction



Dubna, 3–5 September. The participants of the 41st European Cyclotron Progress Meeting

Petrozavodsk (Russia), 10–15 September. The participants of the 9th International Symposium on Exotic Nuclei (EXON 2018)

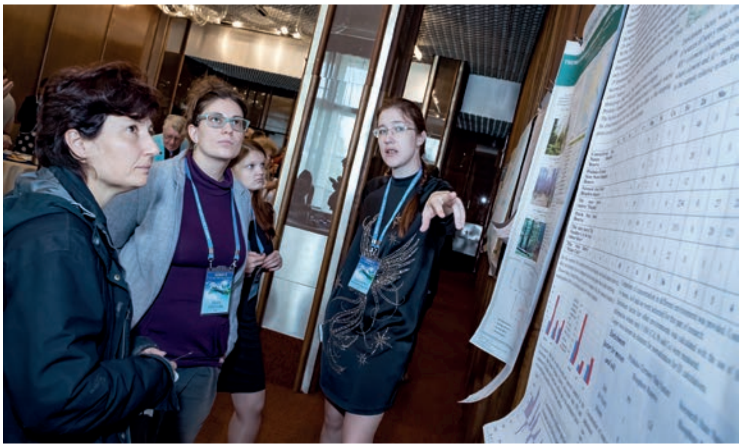

INTERNATIONAL SEMINAR
DEDICATED TO THE 110TH ANNIVERSARY
OF THE BIRTH OF NOBEL PRIZE WINNER,
ACADEMICIAN ILYA MIKHAILOVICH FRANK
JINR
DUBNA
Joint Institute for Nuclear Research
Division of Physical Sciences of RAS
Faculty of Physics, Moscow State University
D.V.Skobeltsin Institute of Nuclear Physics
НИИЯФ МГУ
РОССИЙСКАЯ АКАДЕМИЯ НАУК
October 23-24
JINR Scientists' Club, Dubna, Joliot-Curie St., 6
Organizing Committee:
Co-chairmen: V.A. Matveev, V.L. Aksenov, V.N. Shvetsov
Members:
A.M. Balagurov (JINR), A.V. Vinogradov (JINR),
T.S. Donskova (JINR), S.V. Kozenkov (JINR), D.P. Kozlenko (JINR),
O. Culicov (JINR), S.A. Kulikov (JINR), N. Kučerka (JINR),
E.V. Lychagin (JINR), M.I. Panasyuk (SINP),
V.A. Rubakov (INR RAS), N.N. Sysoev (MSU), D. Chudoba (JINR),
A.I. Frank (JINR), I.A. Scherbakov (IGP RAS)
The program of the Seminar will include reports covering the research areas of I.M.Frank's interest:
Neutron optics and ultracold neutrons
Biophysics and condensed matter physics
Physics of reactors, neutron sources
Cherenkov and transition radiation
Physics of cosmic rays
Contact us:
Scientific_Secretary@nf.jinr.ru
t.: +7(496)216-50-96

Dubna, 23 October. The scientific-memorial seminar dedicated to the 110th anniversary of the birth of Academician I. M. Frank, winner of the Nobel Prize in Physics

The Frank Laboratory of Neutron Physics. Equipment for production of new ceramic and special alloys at high temperature and high pressure

Dubna, 6–8 December. The workshop “Advanced Ideas and Experiments for New Dubna Neutron Source (DNS-IV)”

Xi'an (China), 28 May. Participants of the 26th International Seminar on Interaction of Neutrons with Nuclei (ISINN-26)



Dubna, 3–5 July. The 8th international workshop "Biomonitoring of Atmospheric Pollution" (BioMAP-8)

Dubna, 3 December. The conference of young scientists and specialists of FLNP

The Laboratory of Information Technologies, 27 March. Presentation of the supercomputer “Govorun”

Dubna, 26 September. The visit to JINR of the representatives of the Ministry
of Science and Technology of China. A tour of the Laboratory of Information Technologies

Laboratory of Information Technologies, 10 September. The participants of the 8th international conference "Distributed Computing and Grid Technologies in Science and Education" (GRID 2018)

Dubna, Resort Hotel "Ratmino", 4–18 August. The 30th jubilee Interregional Computer School named after V. Volokitin and E. Shirkova organized with the support of the JINR UC

Dubna, 31 May. The winners of the young scientist report contest held during the international conference "Problems of Radiation Exposure-Related Chemical Protection and Repair"

Dubna, 17 October. The international conference "Modern Problems in Space Radiobiology and Astrobiology"

Dubna, 7 December. JINR is visited by a joint delegation of the National Aeronautics and Space Administration and the RAS Institute of Medico-Biological Problems

The Laboratory of Radiation Biology.
Studies of the effect of types of space radiation on living organisms

Dubna, 4 June. Stage 1 of the International Student Practice at JINR for participants from the Republic of South Africa. On an excursion at the Dzhelepov Laboratory of Nuclear Problems

Dubna, 12 April. Israeli high-school students and teachers from the Centre for Science Education HEMDA (Tel Aviv, Israel) on a visit to JINR

Alushta (Crimea, Russia), 11–18 June. The participants of the 7th School-Conference of Young Scientists and Specialists of JINR

Dubna, 31 March – 1 April. Physics Days


Moscow, 12–14 October.
JINR's participation
in the XIII Moscow
Festival NAUKA0+


2018

CENTRAL SERVICES

PUBLISHING DEPARTMENT

In 2018, the Publishing Department issued 72 titles of publications and 39 titles of official documents.

Among the books of abstracts and proceedings of various conferences, schools and workshops organized by JINR that appeared in 2018 are the following ones: the Proceedings of the conference “New Trends in High-Energy Physics” (Budva, 2–8 October 2016), the Proceedings of the Student Poster Session of the VII International Pontecorvo Neutrino Physics School (Prague, 20 August – 1 September 2017), the Proceedings of the XXV International Seminar on Interaction of Neutrons with Nuclei (ISINN-25) (Dubna, 22–26 May 2017), the Book of Abstracts of the 8th International Workshop on Biomonitoring of Atmospheric Pollution (BioMAP-8) (Dubna, 2–7 July 2018).

The JINR Annual Report for the year 2017 (Russian and English versions) was published.

A book “The Joint Institute for Nuclear Research in the ATLAS Experiment. 1992–2015” by V. A. Bednyakov, Yu. A. Budagov, V. V. Kukhtin, N. A. Russakovich, A. P. Cheplakov, G. A. Shelkov, and E. V. Khramov was published. The book provides an account of contributions made by JINR staff members to the development, design, assembly, commissioning and successful operation of all major units of the ATLAS facility, as well as to physics results of fundamental importance obtained using this facility.

A book by famous Italian physicists A. Nisati and G. Tonelli titled “The Discovery of the Higgs Boson at the Large Hadron Collider” was published. This is a translation into Russian of the paper published earlier in the journal “La Rivista del Nuovo Cimento”.

In 2018, six issues of the journal “Physics of Elementary Particles and Atomic Nuclei” (brief name “Particles and Nuclei”) that included 145 reports came out. Seven issues of the journal “Physics of Elementary Particles and Atomic Nuclei, Letters” (brief name “Particles and Nuclei, Letters”) that included 171 papers were published.

The information bulletin “JINR News” was continued to be published in Russian and English.

Fifty-two issues of the JINR weekly newspaper “Dubna: Science, Cooperation, Progress” were published in 2018.

In the framework of exchange of scientific publications, the organizations in over 40 countries of the world that cooperate with JINR received the following JINR publications: JINR preprints and communications, the information bulletin “JINR News”, JINR Annual Reports, the journals “Particles and Nuclei” and “Particles and Nuclei, Letters”.

The Publishing Department forwarded over 114 papers and reports on the results of research conducted by JINR scientists to the editorial boards of journals, to various conferences, symposia, meetings and schools held both in the JINR Member States and in other countries. Papers by JINR staff members were submitted to the journals “Nuclear Physics”, “Theoretical and Mathematical Physics”, “Atomic Energy”, “Instruments and Experimental Techniques”, “Radiation Biology. Radioecology”, “Radiochemistry”, “Crystallography”, “Journal of Surface Investigation. X-Ray, Synchrotron and Neutron Techniques”, “Physics of the Solid State”, and other periodicals.

To keep readers of the JINR Science and Technology Library (STL) timely informed about new publications received, express bulletins of STL are issued by the Publishing Department. “The Bibliographic Index of Papers Published by JINR Staff Members in 2017” was issued. Publication of express bulletins of the Licensing and Intellectual Property Department was continued.

The Publishing Department fulfilled numerous orders of JINR laboratories to produce poster presentations of the Institute’s staff members for submission to conferences and workshops.

At the request of the laboratories and other departments of JINR, the Publishing Department performed binding services and photocopying of scientific-technical and engineering-design documentation. Over 135 thousand various forms were printed.

New printing equipment was installed in the Publishing Department in 2018. These are a digital printing machine Konica Minolta AccurioPress C3080P and a one-knife paper cutter Guowang with a cutting width of 115 cm.

SCIENCE AND TECHNOLOGY LIBRARY

In 2018, the JINR Science and Technology Library (STL) rendered services to 2000 readers. An electronic loan system has been implemented. 7780 copies of publications were given out. As of 1 January 2019, the library stock amounted to 437 454 copies, 194 365 of them being in foreign languages. 133 publications ordered by readers were received via the interlibrary loan system. 56 requests from other libraries were completed. On the whole, the library received 2398 copies of books, periodicals, preprints and theses from all acquisition sources, including 1047 publications in foreign languages. All the new publications were registered in the central catalogues, branch catalogues and in the information system "Absotheque".

The weekly express bulletins "Books", "Articles", and "Preprints" (156 issues) were published including 8006 titles. Electronic versions of the bulletins are distributed among 100 addresses via e-mail. Subscription is available via the STL website in the section "Services" http://lib.jinr.ru/ntb_mail/newslist.html. The exhibitions of new acquisitions of books, preprints, periodicals and theses were arranged weekly. 1955 publications were displayed on them. Five topical exhibitions were organized.

The electronic catalogues of books, journals, articles, preprints and theses are accessible in Internet at the address http://lib.jinr.ru:80 http://lib.jinr.ru:8080/OpacUnicode/80/OpacUnicode. The total number of requests to the electronic catalogues was 15 000. In the electronic catalogue, in the personal account the readers can order requested literature and look through their reader's register forms.

"The Bibliographic Index of Papers Published by JINR Staff Members in 2017" (1463 titles) was prepared by the JINR STL and published by the JINR Publishing Department. The Index is available on the library website, in the section "Services": http://lib.jinr.ru/buk/2016/bibl_uk.php. One biobibliographic index has been prepared. The database of papers of JINR scientists is Internet accessible.

2229 JINR preprints and communications have been scanned and added to the electronic catalogue.

The STL received 113 titles of periodicals. Due to the library subscription to the foreign journals, JINR scientists have access to full-text electronic versions of these journals.

The Scientific Electronic Library is used by the readers very actively. The total number of requests to the electronic journal versions through the Scientific Electronic Library and sites of foreign publishing houses was 150 000. Due to the library participation in the RFBR and the Ministry of Science and High Education Consortiums, JINR scientists are provided with the electronic access to the full-text versions of journals of the following publishing houses: Elsevier, Springer, Wiley, IEEE Digital Library, as well as journal "Nature" and information retrieval databases Web of Science, MathSciNet and Scopus.

Within the framework of the project "History of JINR and Dubna in Books, Journals and Central Newspapers", 51 new bibliographic records have been introduced. The information system "Literature about JINR Scientists" is available on the page of the website of JINR STL "Publications about JINR": http://who-is-who.jinr.ru/catalog3/main.html.

In 2018, in exchange for JINR publications printed by the JINR Publishing Department, the library received 476 publications from 14 countries. Among them 67 issues were from Russia, 25 from Romania, 5 from Ukraine, 262 from Germany, 10 from France, 42 from Japan, and 26 from CERN.

In 2018, within the framework of the information system "Absotheque", the input of documents to electronic catalogue was for: books — 876 titles, journals — 1804 numbers, preprints — 2713 titles, theses and author's abstracts — 452 titles, book articles — 665 titles and journal articles — 8124 titles.

As of 1 January 2019, the total number of records in the information system "Absotheque" was 299 682.

Bibliometric Factors of Publication Activity of JINR Staff Members (by Web of Science Database on 31.01.2019)

JINR publication statistics in 2018 was as follows:

- Total number of publications — 1 406;
- Total number of citations — 1 619;
- Excluding self-citations — 1 229;
- Average citations per article — 1.15;
- h-index — 16.

Joint publications of JINR authors and authors from different countries are presented in Tables 1–3.

Table 1. Joint publications with authors from JINR Member States

State *	Number of publications
Armenia	313
Azerbaijan	168
Belarus	320
Bulgaria	251
Cuba	33
Czech Republic	398
Georgia	265
Kazakhstan	36
Moldova	17
Mongolia	55
Poland	445
Romania	232
Slovakia	219
Ukraine	253
Uzbekistan	32
Vietnam	18

* The states are arranged in alphabetical order.

Table 2. Joint publications with authors from Associate Members

State *	Number of publications
Egypt	162
Germany	584
Hungary	295
Italy	446
Serbia	271
South Africa	160

* The states are arranged in alphabetical order.

Table 3. Joint publications with authors from other states and regions

State / region *	Number of publications	State / region *	Number of publications
USA	486	Denmark	147
France	418	Lithuania	147
China	407	New Zealand	147
Switzerland	364	Estonia	145
England	347	Latvia	145
Turkey	328	Qatar	142
Brazil	324	Scotland	140
Spain	314	Chile	136
Greece	303	Israel	133
Austria	297	Sri Lanka	118
Taiwan	291	Argentina	115
Portugal	286	Slovenia	114
South Korea	264	Morocco	110
Colombia	262	Saudi Arabia	83
India	253	Palestine	56
Japan	238	U Arab Emirates	42
Malaysia	234	Indonesia	31
Sweden	216	Peru	31
Pakistan	212	Tajikistan	7
Australia	210	Jordan	5
Mexico	198	Algeria	3
Croatia	197	Wales	3
Netherlands	196	Albania	2
Finland	195	Botswana	2
Belgium	179	Macedonia	2
Thailand	178	Montenegro	2
Cyprus	162	Costa Rica	1
Norway	156	Luxembourg	1
Iran	153	Nigeria	1
Ireland	152	Uganda	1
Canada	150	Uruguay	1
Ecuador	149	Venezuela	1

* States / regions are arranged as the number of publications decreases.

LICENSING AND INTELLECTUAL PROPERTY DEPARTMENT

In 2018, the activities of the Licensing and Intellectual Property Department (LIPD) were conducted in the following areas:

Industrial Intellectual Property Protection. In this area, work was done on applications for JINR patents that had undergone the formal Federal Institute of Industrial Property (FIIP) expertise of Rospatent in 2016–2018. Arrangements were done; changes, alterations and clarifications were agreed upon and included in the application documents according to the comments rendered by FIIP experts. Expert evaluation was conducted of a number of project elaborations of JINR staff members for the purpose of patentability, which included objects of legal protection and their classification according to the International Patent Classification (IPC); analogues and prototypes were searched. Reports on patent studies were prepared; for seven elaborations, in collaboration with the authors, packages of submission documents were prepared and forwarded to RF Rospatent for patents on inventions:

— "A device for extraction of charged particles from a cyclic accelerator";

— "A gas-filled detector to measure small-angle scattering of thermal neutrons";

— "A device to watch heliosphere";

— "A method to simulate chemical behaviour of atoms of superheavy elements";

— "A hybrid pixel detector of ionizing radiation";

— "A Device to study properties of straw tubes of particle coordinate detector";

— "A method to increase the frequency of production of double-stranded DNA breaks in human cells by the action of ionizing radiation under the influence of radiomodificators".

In 2018, work was finished on applications submitted earlier and 11 RF patents were obtained for the inventions:

— "A method of slow extraction of charged particles beam" by G. Dolbilov;

— "A method of multi-turn injection of charged particles into cyclic accelerator" by G. Dolbilov;

— "A cryogenic flange connector for ball cold neutrons moderator" by K. Mukhin and A. Kustov;

— "A method of determining Poisson ratio of sealed thin-walled polymer tube material" by A. Volkov and Z. Tsamalaidze;

— "A semiconductor pixel detector of charged strongly ionized particles (multicharged ions)" by G. Shelkov, D. Kozhevnikov, P. Smolyanskij, M. Demichev, S. Kotov, V. Kruchonok, A. Zhemchugov, and Abdelshakur El Said Mokhammed Abu Elazm;

— "A method of slow removal of a beam of charged particles from a ring accelerator" by G. Dolbilov;

— "A method for preventing reduction of muscular force in acute radiation injury in experiment" by A. Ivanov, E. Krasavin, K. Lyakhova, Yu. Severyukhin, and A. Molokanov;

— "Electrically independent safety valve vacuum-operating drift chamber" by L. Glonti, V. Kekelidze, Yu. Potrebenikov, V. Samsonov, and V. Chepurnov;

— "A method for changing reactivity in pulsed nuclear power plants of periodic action on fast neutrons with threshold-fissionable isotopes" by E. Shabalin and G. Komyshev;

— "A method to determine space profiles of nuclear and magnetic potentials of interaction of polarized neutrons with layered structure" by Yu. Nikitenko and V. Zhaketov;

— "A planar semiconductor detector" by G. Shelkov, D. Kozhevnikov, P. Smolyansky, S. Kotov, V. Kruchonok, A. Zhemchugov, and Lejva Fabelo Antonio.

The computer program "Program complex for intellectual simulation and adapted self organization of virtual computer resources" by the authors N. Balashov, A. Baranov, I. Kadochnikov, V. Korenkov, N. Kutovsky, and I. Pelevanyuk was registered in Rospatent.

As of 1 January 2019, JINR possesses 69 RF patents for invention in force.

Patents and Information. In 2018, 36 issues of the federal state institution "Federal Institute of Industrial Property" of the bulletin "Inventions. Utility Models" were received at JINR. The information published in the bulletin was processed according to JINR topics. The processing results were presented in 12 issues of the LIPD bulletins “Patents”. The LIPD stock is 3343 Rospatent bulletins.

On a regular basis, the information list of LIPD is updated on obtaining a new patent by the JINR staff members, and regular contact is maintained with the JINR website on inclusion of this information in the page “JINR News”.

The LIPD page on the JINR website is regularly updated.

Standardization. Standard library was supplemented: 35 new intergovernmental and state RF standard documents, 12 GOST directories and standard information directories for 2018; directories of national standards and technical conditions, guidelines, recommendations and regulations issued in 2018. 170 alterations were introduced into relevant documents of the standard library files and subscribers’ copies on the basis of these norm documents (NDs). Eleven GOST official copies and other norm documents were distributed in departments for permanent use. The access to the database was supported of the standards library that contains about 11 700 positions on the LIPD internet page.

Information about new accessions and changes in NDs is regularly forwarded to departments.

“The Catalogue of Normative Legal Acts and Norm Documentation Used at the Joint Institute for Nuclear Research” was regularly updated in the database. As of the end of 2018, the database contains over 8600 normative standards and NDs with hypertext references to these documents published on the sites: the official Internet portal of RF legislative information (pravo.gov.ru), the Federal Agency for Technical Regulation and Metrology (Rosstandart), and the legal reference system “Consultant Plus”. In 2018, the base was replenished with RF standards (GOSTs RISO, GOSTs), guiding documents, methodology notes, recommendations and references to the above-mentioned sites of normative documents that are available in the library of LIPD and JINR departments.

Work was continued on updating information on interstate standards in force in Russia (GOST), national standards of RF (GOST R) and other normative and technical documentation that refers to the activities of the Joint Institute for Nuclear Research.

2018

ADMINISTRATIVE ACTIVITIES

FINANCIAL ACTIVITIES

To implement the resolutions of the Finance Committee and the Committee of Plenipotentiaries (Protocols of 18–19 and 21–22 November 2016), starting in 2017, recording of management accounts has been set up on cash basis, whereas actual revenue and expenditure are recounted in the record currency (US dollars), at the exchange rate of the date of the operation.

In total in 2018, resources of 209.3 M$ arrived in JINR, which makes 101% of the scheduled budget incomes. Over 94% of all actual revenue was contributions of JINR Member States.

More than 67% of the amount of the assessed contributions paid by Member States and the payment of arrears of Member States was received in the first half of 2018.

The main budget expenditure was stipulated for wages payment for the JINR staff members and provision of material expenditure to implement the main scientific projects: the project for the NICA accelerator complex development; the project for the DRIBs-III cyclotron complex development; the neutrino programme; development of the research nuclear facility IBR-2 and spectrometers; information, computer and network services for the JINR activities.

According to the accounting report, actual expenditure of 2018 totaled up to 211.6 M$ with 268.8 M$ scheduled; i.e., the budget expenditure was executed to 79%.

The main budget expenditure was focused on two consolidated chapters: “Personnel” and “Material Expenditure, R&D and Construction”.

The staff costs in 2018 amounted to US$73.1 million. Their share of the total amount of actual budget expenditures is 34.5% (Fig. 1).

The consolidated chapter “Material Expenditure, R&D and Construction” is the biggest in the budget expenditure, whose means were forwarded to construction, upgrading and development of basic experimental facilities.

In 2018, US$103.7 million was actually used, which amounted to 83% of the budgeted funds for material expenditures.

In general, the share of material costs amounted to 49% of all actual expenses. For comparison, in 2013 the share of actual material expenses amounted to 28% of the total amount of expenses, in 2014 — 33%, in 2015 — 39%, and in 2016 — 48% (Fig. 2).

Of 103.7 M$ of actual material expenditures, almost 90% was used to accomplish scientific projects of JINR, which is the main priority in spending budget means (Fig. 3).

The actual expenditure for international cooperation was 8.7 M$. It was forwarded to finance business trips of staff members to JINR Member States.

Budget (updated)	Actual	Execution
75.1 M$	73.1 M$	97%

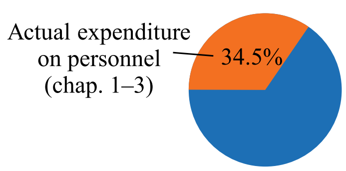


Fig. 1. Actual expenditure on personnel in 2018

Budget (updated)	Actual	Execution	
125 M$	103.7 M$	–21.3 M$	83%

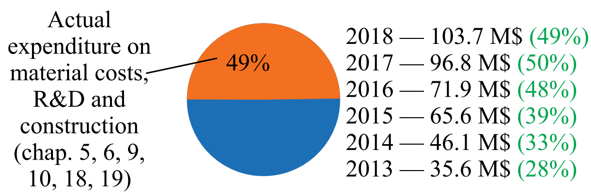


Fig. 2. Actual expenditure on material costs, R&D and construction in 2018

A big part of expenditure was spent for trips of JINR staff members to CERN and other large scientific centres and to non-member countries of JINR, due to concluded agreements on cooperation.

Expenditure on electric energy, heating and water supply in 2018 was 4.9 M$.

The expenditure for repair work was necessary to maintain buildings, constructions and equipment for operation, both at JINR sites and beyond them. In 2018, 10.9 M$ was spent on repairs (Fig. 4).

Other expenditure of 2018 was mainly related to the infrastructure and included that for social sphere, transport service payment, communication, sites protection and others. As of 2018, it totaled up to 10.3 M$ (Fig. 5).

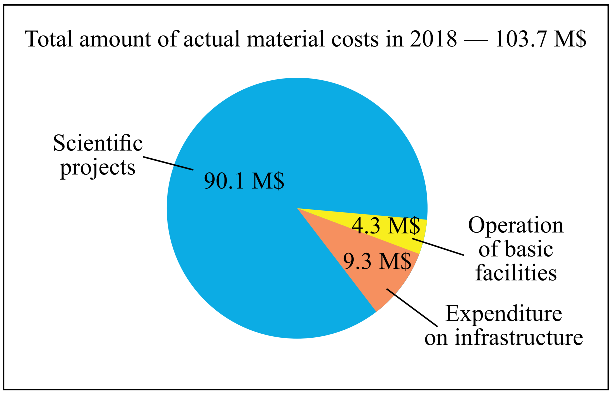


Fig. 3. Actual expenditure on material costs, R&D and construction in 2018

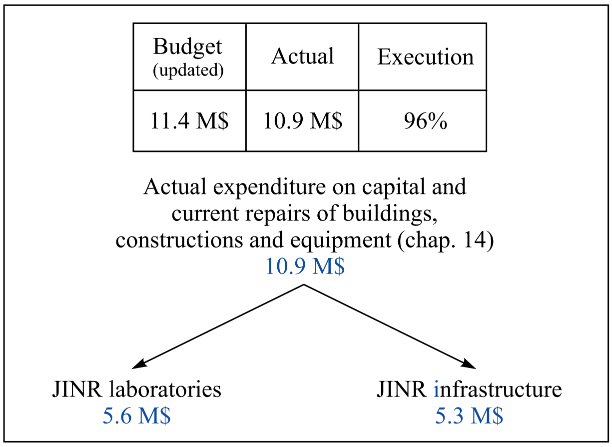


Fig. 4. Actual expenditure on repair in 2018

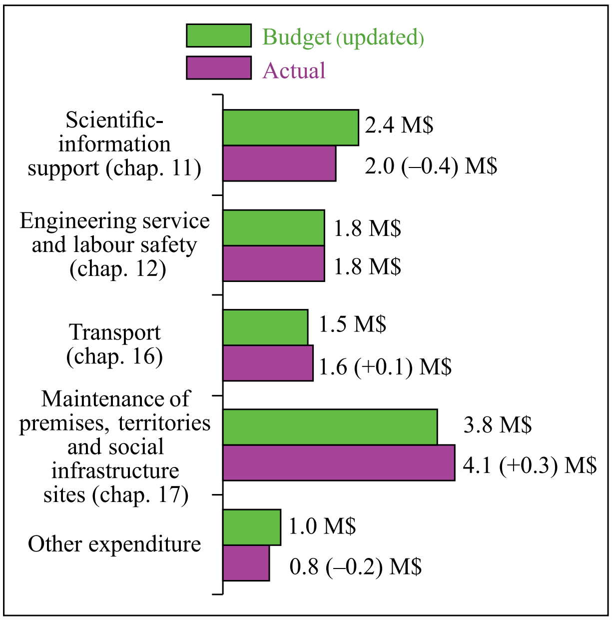


Fig. 5. Actual operating costs in 2018

STAFF

As of 1 January 2019, the total number of staff members at the Joint Institute for Nuclear Research was 5065.

Working at JINR are: RAS Academicians V. Matveev, Yu. Oganessian, M. Ostrovsky, G. Trubnikov, B. Sharkov; RAS Corresponding Members V. Aksenov, L. Grigorenko, D. Kazakov, E. Krasavin, I. Meshkov, A. Starobinsky, G. Shirkov; Members of other state Academies of Sciences I. Zvara, G. Zinoviev, B. Yuldashev, O. Chuluunbaatar; 239 Doctors of Science, 602 Candidates of Science, 57 Professors and 24 Assistant Professors.

In 2018, 556 people were employed and 478 people were discharged because of engagement period expiry and for other reasons.

AWARDS

For the services for JINR and international cooperation, the Order ***“For Merit to the Fatherland”, II class,*** was awarded to 3 staff members; the Order ***“For Merit to the Fatherland”, I class,*** was awarded to 4 staff members; the ***Lomonosov Gold Medal*** of the RAS was awarded to 1 staff member; the title of ***Doctor Honoris Causa of the NRC “Kurchatov Institute”*** was conferred on 1 staff member; the title ***“Honorary JINR Staff Member”*** was conferred on 6 staff members. A number of JINR staff members received other departmental, city and Institute awards.

Responsible for the preparation of the Annual Report: B. Starchenko

The Annual Report was prepared by
A. Andreev
N. Boklagova
D. Chudoba
S. Dotsenko
N. Golovkov
E. Ivanova
A. Karpov
I. Koshlan
O. Kronshtadtov
S. Pakuliak
D. Peshekhonov
D. Podgainyj
A. Shabashova
I. Shcherbakova
I. Titkova
L. Tyutyunnikova
A. Vasiliev

Translation by
T. Avdeeva
S. Chubakova
I. Kronshtadtova
S. Negovelov
M. Potapov
Yu. Rybachuk
G. Sandukovskaya
S. Savinykh
E. Voitishina

Design by
Yu. Meshenkov

Photography by
I. Lapenko
E. Puzynina

Joint Institute for Nuclear Research. 2018
Annual Report

2019-12

Редакторы: *Е. И. Кравченко, Е. И. Крупко*
Корректор *Т. Е. Попеко*

Подписано в печать 6.05.2019.
Формат 60×84/8. Печать цифровая.
Усл. печ. л. 23,0. Уч.-изд. л. 30,5. Тираж 155 экз. Заказ № 59693.

Издательский отдел Объединенного института ядерных исследований
141980, г. Дубна, Московская обл., ул. Жолио-Кюри, 6.
E-mail: publish@jinr.ru
www.jinr.ru/publish/