2016

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 978-5-9530-0470-1

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

The Joint Institute for Nuclear Research festively celebrated its 60th jubilee in the year 2016. Events dedicated to this remarkable date were held in JINR Member States. Besides, 2016 was an important year for JINR due to the accomplishment of the seven-year programme of JINR development for 2010–2016, summing up the results and switching to the implementation of the plan of JINR development for 2017–2023. The new ambitious programme, approved by the JINR CP, includes highly elaborate tasks that will demand concentration of all resources of our Institute.

The results of the previous seven-year programme demonstrate its successful accomplishment: a whole series of world-class results was obtained practically in all main scientific trends of research at JINR. The most important and brightest result of 2016 is the acknowledgement of the JINR priority in the synthesis of new superheavy elements at the border of the Mendeleev Periodic Table by the International Unions of Pure and Applied Chemistry and Physics (IUPAC and IUPAP) and confirmation of their names. Element 115 was named moscovium (Mc); element 118, oganesson (Og). Further research in this field is connected with the development of the world's first Factory of Superheavy Elements. In this context, the year 2016 was extremely important; in December the assembling of the main magnet of the basic facility of the SHE Factory — the new cyclotron DC-280 — was completed. The construction of the main technological systems is conducted according to the schedule. It is doubtless that launching of the SHE Factory will allow the Institute to maintain its leading role in the synthesis and studies of SHE properties, which is one of the key trends of modern nuclear physics.

JINR is entering a new era of its development as all the world is watching now how the unique project to construct the superconducting collider of heavy ions NICA is progressing for the research of fundamental properties of the superdense state of baryonic matter. It is an international project; it has been widely acknowledged by the world scientific community and included in the road map of development of the European scientific infrastructure. In 2016, a historic agreement was signed between JINR and the government of the Russian Federation on the implementation of the NICA project.

In November 2016, an official ceremony was held for the start-up of a high-technology line for assembling and testing of superconducting magnets. The Factory is located in the area of over 2500 square meters. It is equipped with the latest technological facilities, and qualified specialists are ready to assemble and test 350 magnets for the NICA project and 310 magnets for the FAIR project (Darmstadt, Germany).

Another important achievement of 2016 is the successful launching of the linear accelerator of heavy ions (HILAC) of the collider complex NICA, with the progress in the construction of the collider buildings and in the upgrade of the systems of electric and heat supply.

Experiments at the Nuclotron continued, including those in which our colleagues from universities and scientific centres of the USA and Europe participate. Considerable success was achieved in these experiments in the research of polarization phenomena and spin effects in nuclear interactions, nucleon correlations structure in reactions of deuteron–proton scattering, in search for hypernuclei, studies of the nuclear matter states, etc.

Theoreticians of JINR obtained new interesting results in 2016; they started the work-out of the programme "The Theory of Hadron Matter in Extreme Conditions" which is important for the support of the NICA project. Work continued to increase the accuracy of calculations that are necessary for the studies of the Standard Model (SM) at energy inaccessible at accelerators. A specific computer code was designed to find values that depend on the energy scale of the SM parameters. The key feature of the code is its openness. It allows immediate reproduction of results that refer to the issue of the SM vacuum stability

and upgrade them with an account of new experimental data. The code can be the starting point for studies of various new physics models.

Studies are started of superheavy nuclei whose structure fundamentally influences their production cross sections in reactions of full fusion with application of actinide targets. The strong shell effect at $Z = 120-126$ makes it possible to expect production of new nuclei with $Z = 120$ in the near future in fusion reactions of nuclei heavier than ^{48}Ca with actinides.

In the framework of the neutrino programme of JINR, work is actively in progress to develop a unique set-up in Lake Baikal — the deep water neutrino telescope of the cubic km scale (NT-1000) — the Baikal-GVD project. Since April 2016 the first full-scale cluster "Dubna" installed in Lake Baikal has been accumulating data. One of the big achievements of the year is the launching of a new control centre of the neutrino telescope in the lake, fabrication of electric supply systems, control, primary processing and storage of data.

The antineutrino detector DANSS was put into operation at the Kalinin NPS for remote measurement of the reactor parameters in real time.

Seven isotopes with simultaneous record of energy and tracks of double beta decay events were studied in the NEMO-3 experiment. Due to the big mass, results of ^{100}Mo and ^{82}Se stood out in the research.

JINR physicists took part in the ATLAS experiment where new physics was studied in high mass resonances in muon and electron decay channels, opportunities were studied to search for supersymmetric gluinos in their decay in the finite state that contained the electron and the muon, several hadron jets and large missing transverse momentum in proton–proton collisions at a centre-of-mass energy of 13 TeV. Search for new resonances with mass larger than 250 GeV decaying to a Z boson and a photon was performed.

In studies of femtoscopic correlations of kaon pairs produced in Pb–Pb collisions at an energy of 2.76 TeV at the ALICE facility (CERN), a group of scientists from JINR obtained new results for 1D femtoscopic correlations that showed good agreement with predictions of R. Lednický and V. Lyuboshits (JINR).

One of the important achievements of the JINR team in the COMPASS collaboration (CERN) is the accomplishment of the work to develop a new electromagnetic calorimeter. This detector was proposed and designed at JINR; it is a unique device — instead of traditional photomultipliers it uses the most modern photoreceivers — micro pixel avalanche photodiodes. The most precise measurements of charged kaon multiplicities were made and published with active participation of JINR.

A number of interesting studies of condensed matter were conducted at the IBR-2 reactor. In the conditions of combined action of high pressure and temperature, a new iron oxide was synthesized, Fe_4O_5, which is supposed to exist in the layers of the Earth Upper Mantle. Iron oxides play an important role in the formation of magnetic and other physical properties of the Earth, and find a wide range of technological applications.

Nowadays, the solution of scientific tasks is impossible without the latest achievements and work-out of new methods in computer and telecommunication technologies, high productive computer systems and programming. Simulation, processing, analysis and storage of petabytes of data, including those in the experiments at the NICA complex, demand the development of a distributed heterogeneous grid-cloud information-computing complex. During 2016, a unique centre of storage, processing and analysis of data from the global grid infrastructure developed actively — the Multifunctional Information and Computing Complex (MICC), which is one of the basic facilities of JINR.

JINR radiobiologists managed to obtain new bright results that are significant in various fields of medical biological sciences. These are, primarily, the studies of "cluster" DNA damages whose formation in cell genetic structures was predicted and theoretically founded at the Institute for the first time more than 20 years ago.

Multifaceted pluridisciplinary character of research at JINR makes our scientific centre different from other centres where studies are conducted in a narrow range of tasks. In this connection it is important to attract scientists from JINR Member States, talented young specialists and provide them with opportunities for studies in the widest field of modern science trends. The activities of JINR in education are systematically aimed at the implementation of this task.

In 2016, 440 students took courses at the University Centre of JINR at basic chairs of MSU, MPTI, MEPhI, "Dubna" University, and universities of Member States. Summer and work-practice courses were organized for 238 students of higher education institutions. Over 160 persons took part in the annual summer student practice in JINR research trends.

The engineer-physics tutorial for students, postgraduates and young scientists from JINR Member States continued to be held. A series of in-laboratory training courses is organized in its framework in various fields: from the basics of nuclear physics and radiation safety to the design of accelerators and elementary particle detectors, SHF- and vacuum hardware, beam diagnostics methods and automation of physics facilities.

In the context of science promotion and attraction of talented young people to the Institute, an important event took place — the JINR museum of History of Science and Technology opened a new renovated exposition. One of the halls of the museum was called "Experimentarium". It was equipped by young JINR scientists with interactive stands that can be used by school students to study laws of Nature on their own.

The science city of Dubna and the Joint Institute for Nuclear Research are equal in age. A ceremony of inauguration of the monument to the outstanding Russian scientist, the founder of the Periodic Table of Chemical Elements D. Mendeleev was held on the City Day, 24 July 2016, on the Volga embankment, which now bears the name of Mendeleev. Eleven out of 18 superheavy elements discovered in the last 60 years were synthesized exactly in Dubna. The monu-

ment reflects the outstanding contribution of the Institute and the city to the continuation of research started by Dmitrii Mendeleev.

Summing up the results of the past year, I would like to stress once more the fact that many successful achievements of our Institute are based on the international scientific cooperation that is one of the highest values of our civilization and modern world. We express our gratitude to all the Member States for their support. We can see how widely the Dubna new facilities may reflect the interests of physicists all over the world. The international character is also very important to the Institute to implement significant projects and ambitious plans of the new seven-year programme. In this context, active negotiations are held to broaden international cooperation. Thus, having crossed the latest landmark in the development of our scientific centre, we have every reason to face the future with optimism.

V. Matveev
Director
Joint Institute for Nuclear Research

2016

GOVERNING AND ADVISORY BODIES OF 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 4–5 April. It was chaired by the Plenipotentiary of the Government of the Republic of Bulgaria, L. Kostov.

The Committee of Plenipotentiaries (CP) considered the report "Results of JINR activities in 2015. Recommendations of the 119th session of the JINR Scientific Council (February 2016)" presented by JINR Director V. Matveev. The CP took note of the recommendations of the JINR Scientific Council, the information presented by the JINR Directorate on the implementation of the JINR Plan for Research and International Cooperation in 2015 and on the plans for JINR activities in 2016, the results of work accomplished for the development and comprehensive discussion of the draft of the strategic plan for JINR for 2017–2023, as well as of the JINR budget plan for 2017–2023 developed for the purpose of providing financial support to the Institute for the next seven-year period, taking into account the comments and suggestions made during the general discussion.

The CP welcomed the signature of contracts for the construction of the NICA scientific complex and for the production of the MPD superconducting magnet in accordance with international tenders, the beginning of active work for the assembly, testing and certification of serial samples of superconducting magnets for the NICA booster and collider and for the SIS-100 accelerator of the FAIR project in Darmstadt (Germany).

The CP appreciated the recognition, by decision of the International Union of Pure and Applied Chemistry (IUPAC), of the authorship of JINR, in collaboration with partners from the United States (Lawrence Livermore National Laboratory and Oak Ridge National Laboratory), in the discovery of new superheavy chemical elements with atomic numbers 115, 117, and 118; the commissioning, according to plan, of the first module of the gigaton deep underwater neutrino detector in Lake Baikal — the Dubna cluster; and the construction of a Tier-1 grid centre for the storage, processing and analysis of large data volumes from the CMS detector at CERN's LHC, in accordance with the JINR–CERN Agreement.

Based on the report "Execution of the JINR budget in 2015" presented by S. Dotsenko, Chief Accountant of JINR, the CP took note of the information presented; agreed with the proposals of the JINR Directorate for the improvement of methods and forms of reporting on the implementation of the JINR budget: adding a new form of the report on the execution of the JINR budget in income and expenditure and a cash flow form, reporting on the actual execution of the budget on cash basis; and recalculating the budget execution performance in US dollars.

The CP commissioned the JINR Directorate to continue work on the elaboration of proposals relating to issues of improving the structure of the JINR budget, the method of preparation of the balance sheet in US dollars, the development of automated systems for accounting and management accounting, and the analysis of the activities of JINR self-supporting subdivisions.

Due to the suspension of memberships of the Democratic People's Republic of Korea (DPRK) and of the Republic of Uzbekistan in JINR, the CP resolved, beginning in 2016 in the JINR budget income, to take into account the contributions of the DPRK and the Republic of Uzbekistan assessed in accordance with the method for calculating contributions approved by the CP, in order to preserve the current proportions of contributions from the Member States; to establish that in 2016 the contributions of the DPRK and of the Republic of Uzbekistan included in the JINR budget income shall not increase the arrears of these countries as recorded

on 31 December 2015; as well as to compensate JINR's budget deficit in 2016, arising from the unpaid contributions by the DPRK and by the Republic of Uzbekistan, at the expense of other incomes and revenues to the JINR budget.

The Committee recorded, as of 31 December 2015, the arrears of the DPRK in the payment of its contribution to the JINR budget as follows: current debt —- US$2 659.1 thousand, restructured debt —- US$679.2, debt for the years 2002–2003 —- US$102.8 thousand; and the arrears of the Republic of Uzbekistan in the payment of its contribution to the JINR budget as follows: current debt —- US$5 582.2 thousand, restructured debt —- US$1 081.8, debt for the years 2002–2003 —- US$1 051.7 thousand.

Regarding the report "Analysis of the current results of implementation of the Seven-Year Plan for the Development of JINR for 2010–2016" presented by N. Russakovich, Chief Scientific Secretary of JINR, the CP recognized that the funding of priority projects is being mainly carried out in accordance with the approved schedules. It commissioned the JINR Directorate to prepare the final version of the report on the implementation of the seven-year plan for publication by the CP session in March 2017, incorporating additional statistics on the Institute's publishing activities, staff dynamics, defense of dissertations, etc.

The CP took note of the inclusion of the NICA project in the new edition of the Roadmap of the European Strategy Forum on Research Infrastructures, and addressed the Plenipotentiaries of the Governments of the Member States which are also EU member states with a request to continue and intensify their efforts towards further integration of JINR's major projects into the European Union's scientific infrastructure.

Based on the report "Standard documents regulating the financial activities of JINR" presented by A. Ruzaev, Assistant Director of JINR for Innovation Development, the CP commissioned the JINR Directorate and the Working Group for JINR Financial Issues under the CP Chairman to finalize the "Financial Rules of JINR" in view of the comments and suggestions received from members of the Finance Committee, and to submit it for consideration to the Finance Committee and the CP in November 2016.

Based on the report "Results of the meeting of the JINR Finance Committee held on 1–2 April 2016" presented by A. Zarubin, representative of the Russian Federation in the JINR Finance Committee, the CP approved the protocol of this meeting. It agreed with the proposal of the JINR Directorate for restructuring the arrears of the Member States which occurred during 2002–2003 by analogy with the "Programme for restructuring the arrears and for reforming the system of calculation and payment of contributions of the JINR Member States for the years 2004–2010".

The CP commissioned the JINR Directorate to conduct consultations with Plenipotentiaries of the Governments of the Member States (Azerbaijan, Georgia, Mongolia, Ukraine) concerning restructuring of their arrears in the payment of contributions for 2002–2003 in accordance with the methodology proposed by the JINR Directorate by an individual schedule approved by the Finance Committee.

The Committee resolved to modify the amount of the contribution payable by the Republic of Cuba to the JINR budget in 2016, setting it for US$45.0 thousand; to compensate JINR's budget deficit in 2016, arising from the modified amount of the contribution of the Republic of Cuba, at the expense of other incomes and revenues to the JINR budget; to write off the arrears of the Republic of Cuba in the payment of its contribution to the JINR budget which accumulated up to the year 2015 inclusively, including in the period up to 2012 due to the absence of real participation of the Republic of Cuba in JINR activities; and in subsequent years to calculate the amount of the contribution of the Republic of Cuba to the JINR budget in accordance with the methodology adopted at the CP session in November 2015.

With a view to improving the efficiency of the Finance Committee, the CP asked the Plenipotentiaries of the Governments of the Member States to consider the issue of delegating permanent representatives to its membership. The Committee also commissioned the Directorate to intensify work for implementation of international standards of financial reporting at JINR.

Regarding the "Proposals of the Finance Committee for the selection of a company for auditing the financial activities of JINR for the year 2015" presented by A. Zarubin, representative of the Russian Federation in the JINR Finance Committee, the CP approved the LLC AC "Korsakov and Partners" (Moscow) as JINR's auditor for the year 2015 and authorized it to conduct an audit of the Institute's financial activities for the specified period. The Committee approved the plan for auditing the financial activities of JINR for 2015 as presented by the JINR Directorate and commissioned the Directorate to conclude a contract with this company.

Based on the report presented by L. Kostov, Chairman of the Committee of Plenipotentiaries, on the election of the Director of JINR, the CP approved Academician Victor Matveev as candidate for the position of the Director of JINR. In a secret ballot (unanimously 16 Plenipotentiaries of the Governments of the JINR Member States), the CP elected V. Matveev as Director of JINR for a term of five years taking office on 1 January 2017.

Regarding the report "Status of the NICA project" presented by JINR Vice-Director G. Trubnikov, the CP recognized the continuous progress in all the activities aimed at implementing the NICA complex: the accelerators, the detectors, and infrastructure development, and noted the recent achievements for the construction of the NICA building and for the fabrication of the MPD magnet. The Committee highly appreciated

the work of the MPD and the BM@N Detector Advisory Committees and the ongoing activities towards the preparation of TDRs for the main MPD detector subsystems, emphasizing the importance of making every effort possible to meet the construction schedule as well as to attract outside groups and to enhance international cooperation around the NICA project.

A regular session of the Committee of Plenipotentiaries of the Governments of the JINR Member States was held on 21–22 November in Kraków. It was chaired by the Plenipotentiary of the Government of the Republic of Bulgaria, L. Kostov.

The CP heard and discussed the report "Recommendations of the 120th session of the JINR Scientific Council (September 2016). Brief overview of the results of JINR activities in 2016 and plans for 2017. Main directions of the strategic development of JINR for 2017–2023" presented by JINR Director V. Matveev. The CP took note of the information presented, approved the recommendations of the 119th and 120th sessions of the Scientific Council, the JINR Topical Plan of Research and International Cooperation for 2017 as well as the Seven-Year Plan for the Development of JINR for 2017–2023 previously endorsed by the Scientific Council and by the Finance Committee.

The CP endorsed the efforts undertaken by the JINR Directorate towards the integration of JINR's new and upgraded facilities (NICA, SHE Factory, Baikal-GVD, IBR-2 and spectrometer complex, MICC) into the European and worldwide research infrastructures; the signature of the Agreement dated 2 June 2016 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; the work by the JINR Directorate for the organization of implementation of this Agreement as well as the "Regulation for the implementation of projects for the construction of large international research facilities of megascience class at JINR".

The CP endorsed the "Regulation for the Supervisory Board of the NICA complex project", the initial membership of the Supervisory Board and its decisions taken on 20 November 2016.

The CP took note of the information about current work to update the "Regulation for the JINR staff" and to commission the Directorate to forward the draft of this document to the Plenipotentiaries until 15 February 2017.

Regarding the report "Seven-year plan for the development of JINR for 2017–2023" presented by JINR Chief Scientific Secretary N. Russakovich, the CP recognized the large amount of work accomplished by the JINR Directorate to prepare the draft text of the seven-year plan and to organize its discussions at meetings of the Programme Advisory Committees and at sessions of the Scientific Council. In the opinion of the CP members, the draft budget plan of JINR for 2017–2023 ensures the implementation of the Institute's development plan for the next seven-year period, including the development of JINR's scientific and experimental base, engineering and social infrastructure, as well as a competitive level of staff salaries.

Based on the report "Draft budget of JINR for the year 2017, draft contributions of the Member States for the years 2018, 2019, and 2020" presented by S. Dotsenko, Chief Accountant of JINR, the Committee approved the JINR budget for the year 2017 with the total expenditure amounting to US$206.32 million and the scale of contributions of the Member States for 2017.

The CP approved the contributions of the Member States for the year 2017, the payment of contribution arrears of the Member States in 2017, determined the provisional volumes of the JINR budget in income and expenditure for the year 2018 amounting to US$205.98 million, for the year 2019 amounting to US$205.81 million, for the year 2020 amounting to US$208.76 million as well as the provisional sums of the Member States' contributions for the years 2018, 2019, and 2020.

Regarding the report "Results of the meeting of the JINR Finance Committee held on 18–19 November 2016" presented by S. Harizanova, Chief Accountant of the Nuclear Regulatory Agency of the Republic of Bulgaria, the CP approved the Protocol of this meeting and the "Financial Rules of JINR", taking into account the fact that the JINR draft budget for the next financial year is submitted to the JINR Member States not later than 1 October of the current financial year.

As decided by the CP, a working group was set up of representatives of the Republic of Bulgaria, the Czech Republic, the Republic of Poland, Ukraine, and of the JINR Directorate to develop proposals for the redemption of Ukraine's arrears in the payment of its contributions to the JINR budget. The Committee requested the Plenipotentiaries of the Governments of the Member States which have contribution arrears to take urgent measures for their repayment.

Regarding the report presented by D. Korsakov, Director of the audit company "Korsakov and Partners", the CP approved the auditors' report concerning the financial activities of JINR examined for the year 2015, approved the Accounting Report of JINR for 2015, took note of the plan of measures in connection with the audit accomplished, and commissioned the Directorate to prepare comments on the auditors' report by the next CP session.

Based on the report "Procedure for implementing the CP's decision on the suspension of memberships in JINR of the Democratic People's Republic of Korea and of the Republic of Uzbekistan" presented by JINR Chief Scientific Secretary N. Russakovich, the CP approved the proposed document. In the event that full participation of the Democratic People's Republic of Korea and of the Republic of Uzbekistan in JINR has

not been resumed until the year 2020, the CP will consider the issue of memberships of these states in JINR.

Regarding the report "Status of JINR's major research projects and their future prospects" presented by JINR Vice-Director G. Trubnikov, the CP recognized the strong prospects, uniqueness and feasibility of the presented development plan for the scientific programme and flagship projects of JINR, as well as its good integration into international programmes of fundamental and applied research.

The CP also heard with interest the report "Kraków synchrotron SOLARIS" presented by M. Stankiewicz, Director of the National Synchrotron Radiation Centre SOLARIS.

SESSIONS OF THE JINR SCIENTIFIC COUNCIL

The 119th session of the JINR Scientific Council took place on 18–19 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 informed the Scientific Council about the decisions of the session of the Committee of Plenipotentiaries of the Governments of the JINR Member States (November 2015), the major results achieved by JINR in 2015, and about the latest events in JINR's international cooperation.

JINR Chief Scientific Secretary N. Russakovich presented the second version of the Draft Seven-Year Plan for the Development of JINR for 2017–2023. VBLHEP Director V. Kekelidze presented a report on the status of the NICA project.

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

The Scientific Council heard two scientific reports: "Limits of atomic and nuclear masses" by Yu. Oganessian and "Neutrinos at Fermilab — international from the start" by N. Lockyer. It also heard the best reports by young scientists as recommended by the PACs.

Diplomas "Honorary Doctor of JINR" were awarded at the session. The B. Pontecorvo Prize and JINR Prizes for 2015 were also presented to the laureates.

Resolution. General Considerations. The Scientific Council took note of the comprehensive report presented by JINR Director V. Matveev. It wished to recognize that the objectives of the current seven-year plan in the area of major facilities have been achieved by JINR. These include the stable operation of the modernized IBR-2 reactor and the increased number of spectrometers now available for experiments at this facility, the ongoing construction of the Factory of Superheavy Elements with an expectation to put it into operation in 2017, the recent signature of important contracts which provide timely realization of the NICA project, the commissioning of the Dubna cluster of the Baikal-GVD facility, and the start-up of the CMS Tier-1 site. The Scientific Council congratulated the JINR staff on these important results.

The Scientific Council noted the intensified interactions with non-Member States such as China, India, Brazil and others aimed at establishing closer scientific cooperation and encouraged the JINR Directorate to continue efforts in this direction.

The Scientific Council was pleased to hear about the numerous meetings and conferences in Member States dedicated to the 60th anniversary of JINR, viewing these events as useful instruments for distributing information about JINR worldwide.

Recommendations on the Draft Seven-Year Plan for the Development of JINR for 2017–2023. The Scientific Council took note of the second version of the Draft Seven-Year Plan for the Development of JINR (2017–2023) presented by JINR Chief Scientific Secretary N. Russakovich.

Recalling the decision of the Committee of Plenipotentiaries taken at its meeting in November 2015 that the scientific programme of JINR's new development plan should be balanced with the financial strategy and staff policy, the Scientific Council recommended that appropriate milestones be introduced in the seven-year plan concerning the construction and installation steps of large facilities (such as NICA, SHE Factory, etc.) in order to better follow the evolution of the whole process and to help planning and prioritizing actions for the in-time accomplishment of the objectives.

The Scientific Council endorsed this version on the whole and requested the JINR Directorate to continue work on this plan and discussions at the meetings of the PACs, looking forward to being presented with the pre-final draft at the next session in September 2016.

Recommendations on the NICA Project. Concerning the report "Status of the NICA project" presented by VBLHEP Director V. Kekelidze, the Scientific Council was pleased with the continuous progress in all the activities aimed at implementing the NICA complex: the accelerators (including injection complex, booster, Nuclotron and collider), the detectors (BM@N, MPD and SPD) and infrastructure development (including the facilities needed for mass production of magnets and detector elements). The Scientific Council was extremely

pleased with the recent achievements related to the construction of the NICA building and to the fabrication of the MPD magnet.

The Scientific Council highly appreciated the work of the MPD and the BM@N Detector Advisory Committees and the ongoing activities aimed at the preparation of TDRs for the main MPD detector subsystems. It also noted the considerable progress achieved by the BM@N team in testing the various detector components.

Recognizing that considerably more manpower is needed for the timely completion of the NICA complex and its detectors, the Scientific Council encouraged the VBLHEP management to make every effort possible to attract outside groups and promote international cooperation around NICA. Good examples of this are the collaboration with FAIR concerning multipole magnets and the collaboration with CERN for the development of the EVM-ADB2 system which essentially contributes to the efficient management of the NICA project.

Recommendations in Connection with the PACs. The Scientific Council supported the recommendations made by the PACs at their meetings in December 2015 and January 2016 as reported at this session by Professors I. Tserruya (PAC for Particle Physics), F. Piquemal (PAC for Nuclear Physics), and P. Alekseev (PAC for Condensed Matter Physics). The Scientific Council suggested that the JINR Directorate should take these recommendations into account in preparing the JINR Topical Plan of Research and International Cooperation for 2017.

Particle Physics Issues. The Scientific Council joined the PAC for Particle Physics in congratulating the JINR Directorate and the VBLHEP management for signing the contracts for the construction of the NICA building and for the fabrication of the MPD magnet, and for the Mega Science state support by the Russian Government of the NICA project. The Scientific Council concurs with the PAC that these are very significant achievements that put the entire NICA project into a credible path and allow the establishment of a detailed time-line towards the goal of starting NICA operations in 2019.

The Scientific Council was very pleased to note that construction work for the Nuclotron–NICA project had already begun and that further progress had been achieved in commissioning the new RFQ system for LU-20, the first section of the new linear accelerator HILAC, and other NICA new elements and systems. The Council welcomed the successful collaboration of the NICA Machine Advisory Committee and the NICA team. It also recognized the progress in upgrading JINR infrastructure including the Nuclotron subsystems. The Scientific Council urged further development of the production line for the NICA superconducting magnets and its completion. The Council noted the importance of this programme for realizing the NICA and FAIR projects and strongly supported the plan to increase the manpower by approximately 30% to ensure the success of this programme.

The Scientific Council urged the MPD team to complete the Technical Design Reports for the Stage 1 MPD in order to start detector mass production after a proper evaluation by the MPD DAC. It welcomed the efforts being taken by the VBLHEP management to attract new students and to increase the personnel engaged in the realization of the NICA/MPD project.

The Scientific Council supported the steps taken by the VBLHEP management in prioritizing the allocation of manpower to ensure the timely completion of the MPD and BM@N detectors.

Nuclear Physics Issues. The Scientific Council appreciated the high quality of investigations in the physics of ultracold neutrons and reactions with cold polarized neutrons under the theme “Investigations in the Field of Nuclear Physics with Neutrons”. It recommended that FLNP provide a detailed report on the completion of the theme with further investigations to be proposed in the new seven-year plan with the inclusion of ongoing (TANGRA, REGATA) and new projects.

The Scientific Council recommended speeding up the commissioning of the IREN facility to make it possible to carry out world-class experiments in nuclear physics with neutrons at JINR.

Noting the significant progress in implementing the COMET experiment at the J-PARC accelerator in Japan, the Scientific Council supported JINR’s active participation in this project.

The Scientific Council noted the great importance of the IUPAC decision on the confirmation of the discovery of elements 113, 115, 117, and 118, and on the priority for the discovery of elements 115, 117 and 118, which had been given to the collaborations between JINR and Lawrence Livermore National Laboratory (USA) and Oak Ridge National Laboratory (USA). The Scientific Council congratulated JINR on this outstanding achievement.

The Scientific Council recommended that FLNR continue its highly topical investigations on the synthesis of superheavy elements and study of their nuclear and chemical properties, nuclear reaction mechanisms, and properties of nuclei at stability limits.

The Scientific Council supported the recommendations of the PAC for Nuclear Physics on the need to improve the detection system of the SHELS velocity filter in 2016 in order to ensure the effective operation of the set-up and to focus on the spectroscopy of the element with $Z = 115$, as well as to complete work towards the development and commissioning of the ACCULINNA-2 fragment separator with a view to conducting first experiments in 2016–2017.

Condensed Matter Physics Issues. The Scientific Council highly appreciated the new scientific results achieved at the IBR-2 instruments in the field of con-

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. Mamedov
Republic of Belarus	– A. Shumilin
Republic of Bulgaria	– L. Kostov
Republic of Cuba	– F. C. Diaz-Balart
Czech Republic	– J. Dobeš
Georgia	– A. Khvedelidze
Republic of Kazakhstan	– K. Kadyrzhanov
Democratic People's Republic of Korea	– Li Je Sen
Republic of Moldova	– I. Tighineanu
Mongolia	– S. Davaa
Republic of Poland	– M. Waligórski
Romania	– F.-D. Buzatu
Russian Federation	– D. Livanov
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: M. Waligórski (Republic of Poland)
Scientific Secretary: N. Russakovich

O. Abdinov	– Republic of Azerbaijan
Ts. Baatar	– Mongolia
C. Borcea	– Romania
M. Budzyński	– Republic of Poland
L. Cifarelli	– Italy
A. D. García	– Republic of Cuba
A. Dubničková	– Republic of Slovakia
M. Eliashvili	– Georgia
P. Fré	– Italy
S. Galès	– France
N. Giokaris	– Greece
B. Grynyov	– Ukraine
A. Harrison	– UK
M. Hnatič	– Republic of Slovakia
P. Jenni	– Switzerland
M. Jeźabek	– Republic of Poland
E. Kenzhin	– Republic of Kazakhstan
G. Khuukhenkhuu	– Mongolia
S. Kilin	– Republic of Belarus
M. Kovalchuk	– Russian Federation
G. Kulipanov	– Russian Federation
A. Maggiora	– Italy
S. Maksimenko	– Republic of Belarus
V. Matveev	– Russian Federation
J. Mnich	– Germany
D. Nagy	– Hungary
Nguyen Manh Shat	– Socialist Republic of Vietnam
G. Poghosyan	– Republic of Armenia
S. Pospišil	– Czech Republic
I. Povar	– Republic of Moldova
E. Rabinovici	– Israel
V. Rubakov	– Russian Federation
K. Rusek	– Republic of Poland
B. Sharkov	– Russian Federation
N. Shumeiko	– Republic of Belarus
A. Skrinsky	– Russian Federation
M. Spiro	– France
H. Stöcker	– Germany
Ch. Stoyanov	– Republic of Bulgaria
Gh. Stratan	– Romania
V. Strazhev	– Republic of Belarus
N. Tonchev	– Republic of Bulgaria
Tran Duc Thiep	– Socialist Republic of Vietnam
N. Tyurin	– Russian Federation
M. Waligórski	– Republic of Poland
I. Wilhelm	– Czech Republic
A. Zagorodny	– Ukraine
G. Zinovjev	– Ukraine

Programme Advisory Committee for Particle Physics

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

Programme Advisory Committee for Nuclear Physics

Chairperson: W. Greiner (Germany)
Scientific Secretary: N. Skobelev

Programme Advisory Committee for Condensed Matter Physics

Chairperson: V. Kantser (Moldova)
Scientific Secretary: O. Belov

INTERNAL ORGANIZATION OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

DIRECTORATE

Director V. Matveev
Vice-Director M. Itkis
Vice-Director R. Lednický
Vice-Director G. Trubnikov
Chief Scientific Secretary N. Russakovich
Chief Engineer G. Shirkov

Bogoliubov Laboratory of Theoretical Physics

Director V. Voronov

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 trends

Central Services

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

densed matter research. It was pleased to note the stable operation of the reactor at a power of 2 MW, providing the performance of experiments with extracted beams in accordance with the plan. The ongoing instrumentation developments at the reactor, including the construction of new cryogenic moderators, are important for extending the research programme, improving the quality of the experimental results and for attracting new users to the IBR-2 instruments.

The Scientific Council noted the successful implementation of the polarized CARS microscopy option at the multimodal platform for Raman and nonlinear optical microscopy and microspectroscopy at FLNP, as well as first results of the surface enhanced Raman spectroscopy experiments. It also welcomed using the JINR scientific and technological potential for addressing tasks in different fields of radiation biology.

The Scientific Council endorsed the recommendation of the PAC for Condensed Matter Physics on the approval of a new project entitled "LEPTA project: Development of experimental techniques and applied research with slow monochromatic positron beams" for implementation in 2016–2017 within the DLNP theme "Novel Semiconductor Detectors for Fundamental and Applied Research".

Common Issues Concerning the Seven-Year Plan for the Development of JINR (2017–2023). The Scientific Council supported the following general guidelines proposed by the PAC for Particle Physics for the elaboration of the new Seven-Year Plan for the Development of JINR in the area of particle physics:

— focus resources to ensure the timely completion of the NICA complex and the start of the physics programme with first stage configuration by 2019;

— upgrade the general infrastructure and modus operandi of JINR to make NICA an attractive facility for outside users, collaborators and visitors, like in major international research centres;

— intensify the inter-laboratory collaboration at JINR;

— promote international cooperation around JINR's major in-house projects, like BM@N, MPD, SPD, and BAIKAL;

— prioritize participation in outside projects focusing on the scientific merit of the ongoing research programmes and capitalizing on the success, visibility and impact of the JINR groups participating in these programmes.

The Scientific Council concurred with the PAC for Nuclear Physics that the programme of the new seven-year plan in the field of nuclear physics should be based on the following main directions:

— construction and operation of the SHE Factory;

— modernization of IREN;

— promotion of international cooperation in experiments carried out by JINR, in particular BAIKAL, SHELS, and ACCULINNA-2;

— contributions to the non-accelerator physics experiments and the COMET project.

Concerning the recommendations of the PAC for Condensed Matter Physics for the new seven-year plan, the Scientific Council was informed about the detailed written comments by PAC members delivered to the JINR Directorate. It appreciated the PAC initiative on including a special chapter with a concise SWOT (strengths–weaknesses–opportunities–threats) analysis of the new Seven-Year Development Plan based on the results of the previous Seven-Year Plan implementation. The Scientific Council also noted the PAC suggestion on adding information on the seven-year strategy of JINR for innovative and applied research. In relation to the IBR-2 instruments for condensed matter investigation, it supported the PAC recommendation on the need for elaborating of at least a general line of research planned to be realized after the modernization or construction of new instruments.

The Scientific Council welcomed the PAC proposals aimed at increasing the visibility and image of JINR on the international arena in the next seven-year period. In particular, it found useful the idea about the organization of visiting conferences in Europe related to the basic scientific topics of the Institute and underlined the importance of further strong support of international cooperation.

The Scientific Council recommended that the JINR Directorate define priorities, in particular, concerning participation in international projects, taking into account the contributions of JINR to the research programmes and their scientific merits.

Other Issues. The Scientific Council noted that medical and biological investigations using JINR basic facilities had been carried out in a number of JINR Laboratories over many years. These investigations concern fundamental issues in molecular biology, genetics, physiology, astrobiology, and the use of accelerated charged particles in the therapy of cancer. The progress of these studies and proposals of new projects so far had been mostly considered at meetings of the PAC for Condensed Matter Physics. Taking into account the high scientific and social importance of the medical and biological studies underway at JINR, with a view to their better coordination, planning and evaluation by international experts, the Scientific Council recommended that the JINR Directorate establish a Programme Advisory Committee for Nuclear Methods in Biology and Medicine at JINR.

Reports by Young Scientists. The Scientific Council appreciated the following reports by young scientists which were selected by the PACs for presentation at this session: "TPC MPD/NICA readout electronics", "Energy dependence of mass, charge, isotopic distributions and TKE in neutron-induced fission of ^{235}U and ^{239}Pu", "Positron beam studies of radiation damage induced by swift heavy ions in palladium", and thanked the speak-

ers: S. Vereshchagin (VBLHEP), H. Paşca (BLTP), and P. Horodek (DLNP). The Scientific Council will welcome similar reports in the future.

Memberships of the PACs. As proposed by the JINR Directorate, the Scientific Council re-appointed V. Kantser as Chairperson of the PAC for Condensed Matter and I. Tserruya as Chairperson of the PAC for Particle Physics, each for a term of three years.

The Scientific Council appointed M. Lewitowicz (GANIL, Caen, France) as a new member of the PAC for Nuclear Physics and S. Nagaitsev (FNAL, Batavia, USA) as a new member of the PAC for Particle Physics, each for a term of three years. The Scientific Council thanked the outgoing member O. Zimmer for his successful work as a member of the PAC for Nuclear Physics.

Recommendation for a Medium- and Long-Term Strategy. The Scientific Council recommended that the JINR Directorate consider a framework to elaborate a JINR road map for a medium- and long-term strategy embedded in the global international science context.

Scientific Reports. The Scientific Council highly appreciated the reports "Limits of atomic and nuclear masses" and "Neutrinos at Fermilab — international from the start", and thanked Professors Yu. Oganessian and N. Lockyer for their excellent presentations.

Awards and Prizes. The Scientific Council congratulated Professors J. Khubua (Georgia), Yu. Oganessian (Russia), and H. Stöcker (Germany) on the award of diplomas "Honorary Doctor of JINR", in recognition of their outstanding contributions to the advancement of science and the education of young scientists.

The Scientific Council congratulated JINR Director V. Matveev and Vice-Director M. Itkis on being awarded medals of the H. Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences (IFJ PAN) for their great contributions to and consistent support of the scientific collaboration between JINR and IFJ PAN. The awards were presented at the session by the Director of this Institute, M. Jezabek.

The Scientific Council approved the Jury's recommendations on the award of the B. Pontecorvo Prize to Professor G. Bellini (INFN and University of Milan, Italy) for his outstanding contributions to the development of low-energy neutrino detection methods, their realization in the Borexino detector, and the important solar and geo-neutrino results obtained in this experiment.

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.

Announcement of Vacancies in the Directorates of JINR Laboratories. The Scientific Council announced the vacancies of positions of the Director of the Bogoliubov Laboratory of Theoretical Physics and of the Director of the Flerov Laboratory of Nuclear Reactions. The elections for these positions will take place at the 121st session of the Scientific Council.

The 120th session of the JINR Scientific Council took place on 22–23 September. 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 comprehensive report covering such issues as the decisions of the latest session of the JINR Committee of Plenipotentiaries (April 2016), implementation of the recommendations of the 119th session of the Scientific Council (February 2016), the status of the JINR priority projects, recent results of JINR research activities, international cooperation, and some organizational issues.

JINR Chief Scientific Secretary N. Russakovich presented information about the preparation of the final Draft of the Seven-Year Plan for the Development of JINR for 2017–2023. The Scientific Council also heard reports: "Progress of the NICA project" presented by VBLHEP Director V. Kekelidze and "Status of the Factory of Superheavy Elements and its future prospects" presented by FLNR Director S. Dmitriev.

The recommendations of the Programme Advisory Committees were reported by A. Cheplakov (PAC for Particle Physics), F. Piquemal (PAC for Nuclear Physics), and O. Belov (PAC for Condensed Matter Physics).

The Scientific Council heard two invited scientific reports: "Latest results of the ALICE experiment and detector upgrade plans" presented by Professor P. Giubellino and "Nuclear planetology: Space experiments and recent results" presented by Professor I. Mitrofanov. The Scientific Council also heard the best reports by young scientists as recommended by the PACs.

V. Matveev presented the Directorate's proposal for the award of the title "Honorary Doctor of JINR". The award of the B. Pontecorvo Prize took place at the session, and diplomas to the winners of JINR prizes for the year 2015 were presented.

General Considerations of the Resolution. The Scientific Council congratulated the JINR Directorate for having signed the Agreement with the Government of the Russian Federation concerning a dedicated support of the Russian Federation for the construction and exploitation of the NICA complex as an international megaproject to be realized in the territory of Russia.

The Scientific Council congratulated the Institute for its international recognition in the discovery of new superheavy elements through the proposed naming of the elements moscovium and oganesson.

The Scientific Council congratulated Professor V. Matveev on his re-election as Director of the Joint Institute for Nuclear Research for another term of five

years and wished him much success in leading this international centre and developing an efficient strategy for its sustainable development in the long-term future.

Recommendations on the Draft Seven-Year Plan for the Development of JINR (2017–2023). The Scientific Council took note of the final Draft of the Seven-Year Plan for the Development of JINR for 2017–2023 presented by Chief Scientific Secretary N. Russakovich. Noting that the plan is well balanced and clearly reflects the uniqueness of JINR as a multidisciplinary research centre, the Scientific Council appreciated the efforts towards integration of JINR's new and updated facilities (NICA, SHE Factory, Baikal-GVD, IBR-2) into the European and worldwide research infrastructures. The Scientific Council recommended that the JINR Finance Committee and Committee of Plenipotentiaries approve the presented seven-year plan, with an understanding that it will be updated on a year-by-year basis with the actual situation taken into account.

The Scientific Council emphasized that attracting and educating young personnel, especially for running the SHE Factory and the NICA complex, is extremely important and encouraged the JINR Directorate to take all appropriate measures in this direction.

Recommendations on the NICA Project. Taking note of the report "Progress of the NICA project" presented by VBLHEP Director V. Kekelidze, the Scientific Council was pleased with the dynamic and comprehensive efforts being taken on this flagship project of JINR.

The Scientific Council appreciated the progress in developing the Nuclotron–NICA accelerator complex, including the commissioning of the new fore-injector of the LU-20 linear accelerator, the installation and testing of the linear accelerator HILAC, and the testing of the new polarized source. At the same time, the Scientific Council expressed concern about the delay in manufacturing the superconducting magnets and recommended intensified work to eliminate it.

The Scientific Council recognized the efforts of the BM@N collaboration towards testing and commissioning new detector subsystems, in particular, GEM-based tracking detectors for the development of a state-of-the-art apparatus, and welcomed the signing of the Memorandum of Understanding on the participation of the CBM STS group in construction of four wide-aperture silicon stations for the BM@N detector.

The Scientific Council also welcomed the signing of the agreement between the MPD collaboration and participants from China for placing an order to manufacture the electromagnetic calorimeter modules. The Scientific Council appreciated the implementation of contracts for manufacturing the MPD superconducting magnet and congratulated the collaboration management on ensuring good progress of work on this very important element.

Recommendations on the SHE Factory. Concerning the report "Status of the Factory of Superheavy Elements (SHE) and its future prospects" presented by FLNR Director S. Dmitriev, the Scientific Council appreciated the high pace of construction of the Factory's experimental building and the beginning of installation work for the DC-280 cyclotron in accordance with the schedule for the installation and commissioning of the cyclotron proposed by the FLNR Directorate. The Scientific Council supported the proposed programme of first experiments planned at the SHE Factory in 2018–2019.

The Scientific Council recommended that the JINR and FLNR Directorates give special attention to the timely completion of the construction of the SHE Factory, and to the installation and commissioning of the DC-280 accelerator and of instrumentation (gas-filled separator and pre-separator for chemical studies), which will allow first experiments at the Factory to begin.

Recommendations in Connection with the PACs. The Scientific Council supported the recommendations made by the PACs at their meetings in June–July and proposed that the JINR Directorate take these recommendations into account in preparing the JINR Topical Plan of Research and International Cooperation for 2017.

Particle Physics Issues. The Scientific Council shared the satisfaction of the PAC for Particle Physics with the above-mentioned Agreement between the Russian Government and JINR concerning dedicated support from Russia to the NICA megaproject and with the Protocol among the Russian Ministry of Education and Science, the Chinese Ministry of Science and Technology, the Chinese Academy of Sciences and JINR on prospects of cooperation within the framework of the NICA megaproject (superconducting systems, ECAL and TOF systems, and theory). These are important steps that will enhance the international status of the NICA project and further guarantee its timely completion in 2020.

The Scientific Council endorsed the progress towards realization of the Nuclotron–NICA project and the efforts taken towards modernization of the key infrastructure subsystems such as power supply, cryogenics, and water cooling. It welcomed the successful launch of the NICA cryogenic complex — the largest helium liquefier in Russia with a capacity of 1100 liters per hour. The Scientific Council also noted that the set-up of the facility for producing and testing of superconducting magnets for the NICA accelerator complex is nearing completion.

The Scientific Council appreciated the importance of the experimental programme using beams from the Nuclotron, in particular, the technical runs that serve for testing and commissioning of key subsystems of the BM@N detector.

The Scientific Council joined the PAC in reiterating again the need to attract young scientists and additional external groups for the realization of the MPD project.

The Scientific Council supported the PAC's recommendations on the approval of new projects and the continuation of ongoing projects in particle physics within the suggested time scales, as outlined in the PAC report.

Nuclear Physics Issues. The Scientific Council noted the importance of the development of the IREN facility and experiments carried out with it. The Scientific Council appreciated the various achievements of FLNP scientists in the investigations of fundamental symmetries using cold polarized neutrons, research on fundamental properties of the neutron using ultracold neutrons, and measurements of related nuclear data. The Scientific Council supported the opening of a new theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron" to continue research activities in nuclear physics using FLNP's neutron facilities (IREN, IBR-2, EG-5). The FLNP Directorate should concentrate on achieving the designed beam parameters of the IREN project in order to pursue the proposed research programmes of this Laboratory during 2017–2019.

Noting with satisfaction the results produced by FLNR in the synthesis of new elements and in the study of reactions with beams of stable and radioactive nuclides, the Scientific Council supported the opening of a new theme "Synthesis and Properties of Superheavy Elements, Structure of Nuclei at the Limits of Nucleon Stability" for the next five years with the following major objectives: synthesis of new superheavy elements; α-, β-, and γ-spectroscopy of heavy and superheavy nuclei and study of their chemical properties; study of reactions induced by stable and radioactive ion beams leading to the formation of exotic nuclei; investigation of the structure of exotic nuclei close to and beyond the nucleon stability.

The Scientific Council appreciated the high-quality results achieved by FLNR in improving its accelerator facilities and experimental research instruments, including the development and construction of a new high-current DC-280 accelerator, the construction of the experimental building of the SHE Factory and of new physics set-ups (DGFRS-II, SHELS, ACCULINNA-2). The Scientific Council supported the opening of a new theme "Development of the FLNR Accelerator Complex and Experimental Set-ups (DRIBs-III)" for the next five years with the following major objectives: completion of construction and commissioning of the SHE Factory, upgrade of the U400M cyclotron, development and construction of new long-running experimental set-ups.

Condensed Matter Physics Issues. The Scientific Council appreciated the progress achieved in constructing the complex of cryogenic moderators at the IBR-2 facility. This will significantly increase the flux of cold neutrons enabling the implementation of an advanced physics research at the level of the leading neutron sources. The Scientific Council shared the opinion of the PAC for Condensed Matter Physics on the necessity to manufacture a back-up movable reflector for the reactor prior to 2019 to ensure stable operation of the IBR-2 facility until the end of its service life. It also supported the steps being taken by FLNP towards ensuring safe operation of the reactor as well as its monitoring, diagnostics, and state prognosis.

The Scientific Council welcomed FLNP's intent to define the concept of the JINR neutron source beyond the year 2032 which may imply either the use of the existing facility or construction of a new one.

Taking note of the PAC's recommendations on the state of inelastic neutron scattering research at IBR-2, the Scientific Council was pleased to note a steadily rising interest in the use of the NERA spectrometer and urged the FLNP team to make greater efforts to attract users to the DIN-2PI instrument.

The Scientific Council recognized the new scientific results in the fields of medical and biological research with JINR hadron beams, radiation physics, radiochemistry, and nanotechnology investigations using accelerated heavy ions beams as well as in astrobiology.

The Scientific Council supported the PAC's recommendations on the continuation of ongoing themes and projects in condensed matter physics and the opening of new ones within the suggested time scales, as outlined in the PAC report.

Common Issues. The Scientific Council supported the recommendations taken by the PACs for Particle Physics and Nuclear Physics to extend the theme "Information and Computing Infrastructure of JINR" until the end of 2019 and to open a project under this theme for the development of a Multifunctional Information and Computing Complex (MICC) at JINR (including the Tier-1 centre in connection with CERN). The Scientific Council emphasized the importance of further developing Information Technology within the MICC project aimed at improving the telecommunication and network infrastructure of JINR. This will increase the performance of systems for storing, processing and data analysis as well as further develop heterogeneous and cloud components of the complex to support a broad spectrum of world-class research in various areas conducted at JINR and in Member States.

Issues Concerning the Draft Seven-Year Plan for the Development of JINR (2017–2023). The Scientific Council noted the general support given by the three PACs to the Second Draft of the Seven-Year Plan, which had been presented for the corresponding areas of research by Vice-Directors R. Lednický and M. Itkis, and quoted some of the statements.

- The PAC for Particle Physics was pleased to note that the procedures proposed by this PAC for the elaboration of the new seven-year plan in the area of particle physics had been adopted by the JINR Directorate as general guidelines.
- The PAC for Nuclear Physics congratulated the Directorate for the high quality of the document reflect-

ing the excellent science performed at this international centre.

• The PAC for Condensed Matter Physics welcomed the amendments in the chapter "Condensed Matter Physics" concerning radiobiological and astrobiological research and the inclusion of two new chapters: "Introduction" and "Development of the Engineering Infrastructure". For the seven-year plan in general, this PAC expressed an opinion that the Plan should allow for flexibility to include new projects.

The Scientific Council thanked the PACs for the comprehensive discussions of the Draft Seven-Year Plan for the Development of JINR and for their important remarks and suggestions.

Other Issues. The Scientific Council welcomed the current preparation by the JINR Directorate, with participation of the PACs, of an update of the Regulation for the JINR Programme Advisory Committees and of methods for the evaluation of projects submitted to the PACs, and looks forward to receiving the final version of the Regulation for approval at the next session.

Recalling its previous recommendation, the Scientific Council appreciated the preparatory steps being taken by the JINR Directorate in establishing a PAC for Nuclear Methods in Biology and Medicine.

Reports by Young Scientists. The Scientific Council appreciated the following reports by young scientists which were selected by the PACs for presentation at this session: "Matter effect in neutrino oscillations for the NOνA experiment", "Anthropogenic effects on the coastal phytoplankton studied by neutron activation analysis", "Analysis of small-angle synchrotron X-ray scattering experimental data from vesicular systems by means of the parallel asynchronous differential evolution method", and thanked the speakers L. Kolupaeva (DLNP), P. Nekhoroshkov (FLNP), and E. Zhabitskaya (LIT).

Memberships of the PACs. As proposed by the JINR Directorate, the Scientific Council appointed N. Kardjilov (HZB ME, Berlin, Germany) as a new member of the PAC for Condensed Matter Physics for a term of three years. The Scientific Council thanked the outgoing member E. Burzo for his successful work as a member of this PAC.

Scientific Reports. The Scientific Council highly appreciated the reports "Latest results of the ALICE experiment and detector upgrade plans" and "Nuclear planetology: Space experiments and recent results", and thanked Professors P. Giubellino and I. Mitrofanov for their excellent presentations.

Awards and Prizes. The Scientific Council endorsed the proposal of the JINR Directorate to award the title "Honorary Doctor of JINR" to Professor F. Dydak (Austria), in recognition of his outstanding contribution to the advancement of science and the education of young scientists.

The Scientific Council approved the Jury's recommendations on the award of the V. Dzhelepov Prize to Professor Ju. Budagov (JINR) for the development and construction of a unique laser metrology system for measuring the angular oscillation of the Earth's surface.

The Scientific Council congratulated Professor G. Bellini on the award of the B. Pontecorvo Prize for his outstanding contributions to the development of low-energy neutrino detection methods, their realization in the Borexino detector, and the important solar and geo-neutrino results obtained in this experiment. The Scientific Council thanks Professor G. Bellini for his excellent presentation "The impact of the Borexino results on neutrino and solar physics".

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 FLNR Director. 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 February 2017, by one and a half or two years. The final decision for a new election date will be taken at the 122nd session of the Scientific Council in September 2017.

In Memory of Scientists. The Scientific Council expressed deep regret over the sad loss of Professor N. Giokaris (Greece) and Professor N. Shumeiko (Belarus), who served as members of the JINR Scientific Council during 2008–2016 and 1992–2016, respectively, and made outstanding contributions to the development of JINR and its international cooperation.

MEETINGS OF THE JINR FINANCE COMMITTEE

A meeting of the JINR Finance Committee was held on 1–2 April. It was chaired by M. Alashkevich, a representative of the Russian Federation.

The Finance Committee considered the report "Results of JINR activities in 2015. Plans for scientific activities for 2016" presented by JINR Director V. Matveev, highly appreciating the results produced by the JINR international staff in 2015. The Committee noted that in executing the budget under the complicated financial and economic situation in 2015, the implementation of JINR research projects was carried out in accordance with the priorities established by the recommendations of the Scientific Council and the decisions of the Committee of Plenipotentiaries (CP).

Regarding the report "Execution of the JINR budget in 2015" presented by S. Dotsenko, Chief Accountant of JINR, the Finance Committee recommended that the CP take note of the information on the execution of the budget in 2015.

Due to the suspension of memberships of the Democratic People's Republic of Korea (DPRK) and of the Republic of Uzbekistan in JINR, the Finance Committee recommended that the CP resolve, beginning in 2016 in the JINR budget income, to take into account the contributions of the DPRK and the Republic of Uzbekistan assessed in accordance with the method for calculating contributions approved by the CP; to establish that in 2016 the contributions of the DPRK and of the Republic of Uzbekistan included in the JINR budget income shall not increase the arrears of these countries as recorded on 31 December 2015; as well as to compensate JINR's budget deficit in 2016 at the expense of other incomes and revenues to the JINR budget.

The Finance Committee recommended that the CP record, as of 31 December 2015, the arrears of the DPRK in the payment of its contribution to the JINR budget as follows: current debt — US$2 659.1 thousand, restructured debt — US$679.2, debt for the years 2002–2003 — US$102.8 thousand; and the arrears of the Republic of Uzbekistan in the payment of its contribution to the JINR budget as follows: current debt — US$5 582.2 thousand, restructured debt — US$1 081.8 thousand, debt for the years 2002–2003 — US$1 051.7 thousand.

Regarding the report "Selection of a company for auditing the financial activities of JINR for the year 2015" presented by JINR Vice-Director R. Lednický, the Finance Committee recommended that the CP approve the LLC AC "Korsakov and Partners" (Moscow) as JINR's auditor for the year 2015, authorize it to conduct an audit of the Institute's financial activities for the specified period, as well as approve the plan for auditing the financial activities of JINR for 2015 as presented by the JINR Directorate.

Regarding the report "Analysis of the current results of implementation of the Seven-Year Plan for the Development of JINR for 2010–2016" presented by N. Russakovich, Chief Scientific Secretary of JINR, the Finance Committee recognized that the funding of priority projects is being mainly carried out in accordance with the approved schedules. It was suggested that this summary report should be supplemented with information of statistical nature reflecting the major results of JINR's scientific activities over the seven-year period and be published as a separate brochure.

Based on the report "Standard documents regulating the financial activities of JINR" presented by A. Ruzaev, Assistant Director of JINR for Innovation Development, the Finance Committee recommended finalizing the text of the "Financial Rules of JINR" in view of the comments and suggestions received from members of the Finance Committee, and submitting it for consideration to the Finance Committee and the CP in November 2016.

Regarding the report "Issues of improvement of JINR financial and economic activities, as marked by the auditors and being within the competence of the FC and the CP" presented by S. Dotsenko, Chief Accountant of JINR, the Finance Committee recommended that the CP agree with the proposals of the JINR Directorate for the improvement of methods and forms of reporting on the implementation of the JINR budget: adding a new form of the report on the execution of the JINR budget in income and expenditure and a cash flow form, reporting on the actual execution of the budget on cash basis; and recalculating the budget execution performance in US dollars.

The Finance Committee recommended that the CP commission the JINR Directorate to continue work on the elaboration of proposals relating to issues of improving the structure of the JINR budget, the method of preparation of the balance sheet in US dollars, the development of automated systems for accounting and management accounting, and the analysis of the activities of JINR self-supporting subdivisions.

Based on the report "Settlement of the Member States' arrears which occurred in 2002–2003" presented by N. Russakovich, Chief Scientific Secretary of JINR, the Finance Committee recommended that the CP agree with the proposal of the JINR Directorate for restructuring the arrears of the Member States which occurred during 2002–2003 by analogy with the "Programme for restructuring the arrears and for reforming the system of calculation and payment of contributions of the JINR Member States for the years 2004–2010". It was also recommended that the CP commission the JINR Directorate to conduct consultations with Plenipotentiaries of the Governments of the Member States (Republic of Azerbaijan, Georgia, Mongolia, Ukraine) concerning restructuring of their arrears in the payment of contributions for 2002–2003 in accordance with the methodology proposed by the JINR Directorate by an individual schedule approved by the Finance Committee.

Based on the report "Making recommendations and proposals on the appeals of the Plenipotentiary of the Government of the Republic of Cuba concerning the arrears in the payment of contributions by the Republic of Cuba to the JINR budget" presented by N. Russakovich, Chief Scientific Secretary of JINR, the Finance Committee recommended that the CP set the amount of the contribution payable by the Republic of Cuba to the JINR budget in 2016 to be US$45.0 thousand; write off the arrears of the Republic of Cuba in the payment of its contribution to the JINR budget which accumulated up to the year 2015 inclusively, including in the period up to 2012 due to the absence of real participation of

the Republic of Cuba in JINR activities; and in subsequent years calculate the amount of the contribution of the Republic of Cuba to the JINR budget in accordance with the methodology adopted at the CP session in November 2015.

Regarding the report "Results of the meeting of the Working Group (WG) for JINR Financial Issues under the CP Chairman held on 10–11 March 2016" presented by S. Harizanova, Chairperson of the WG, the Finance Committee took note of the recommendations taken by the WG.

The Finance Committee thanked DLNP Deputy Director D. Naumov for his informative report "Experiment BAIKAL" presented at the meeting.

A meeting of the Finance Committee was held on 18–19 November in Kraków (Poland). It was chaired by A. Zarubin, a representative of the Russian Federation.

The Finance Committee heard the report "Plans for research activities and priorities of the budget policy of JINR in 2017. Main directions of the strategic development of JINR for the years 2017–2023" presented by JINR Director V. Matveev, took note of the recommendations of the 120th session of the Scientific Council, the information presented by the JINR Directorate on work towards attaining the goals of the seven-year plan and towards implementing the recommendations of the Finance Committee and the decisions of the Committee of Plenipotentiaries taken in March 2016, as well as the preliminary results of implementing the JINR Plan of Research and International Cooperation in 2016.

The Finance Committee endorsed the signature of the Agreement dated 2 June 2016 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; the work by the JINR Directorate for the organization of implementation of this Agreement as well as the related documents prepared: "Regulation for the implementation of projects for the construction of large international research facilities of megascience class at JINR" and the "Regulation for the Supervisory Board of the NICA complex project".

Regarding the report "Seven-year plan for the development of JINR for 2017–2023" presented by JINR Chief Scientific Secretary N. Russakovich, the Finance Committee endorsed the Plan and recommended it for approval by the CP. The Committee noted that the draft budget plan of JINR for 2017–2023 ensures the implementation of the Institute's development plan for the next seven-year period, including the development of JINR's scientific and experimental base, engineering and social infrastructure, as well as a competitive level of staff salaries.

Based on the report "Draft budget of JINR for the year 2017, draft contributions of the Member States for the years 2018, 2019, and 2020" presented by S. Dotsenko, Chief Accountant of JINR, the Finance Committee recommended that the CP approve the JINR budget for the year 2017 with the total expenditure amounting to US$206.32 million and the scale of contributions of the Member States for 2017.

The Finance Committee recommended that the CP approve the contributions of the Member States for the year 2017 and the repayment of contribution arrears of the Member States in 2017 to the JINR budget.

The Finance Committee recommended that the CP determine the provisional volumes of the JINR budget in income and expenditure for the year 2018 amounting to US$205.98 million, for the year 2019 amounting to US$205.81 million, for the year 2020 amounting to US$208.76 million as well as the provisional sums of the Member States' contributions for the years 2018, 2019, and 2020.

Regarding the report "Results of the meeting of the JINR Finance Committee held on 18–19 November 2016" presented by S. Harizanova, Chief Accountant of the Nuclear Regulatory Agency of the Republic of Bulgaria, the CP approved the Protocol of this meeting and the "Financial Rules of JINR", taking into account the fact that the JINR draft budget for the next financial year is submitted to the JINR Member States not later than 1 October of the current financial year. The Finance Committee also took a number of decisions on the improvement of financial reporting and reporting on the implementation of the JINR budget. The Finance Committee approved the schedules for the repayment of restructured debts of some Member States (Republic of Azerbaijan, Georgia, Mongolia) in the payment of contributions to the JINR budget for 2002–2003.

Based on the information presented by the JINR Directorate on the current situation with the payment of contributions by the Member States, the Finance Committee addressed a request to the Plenipotentiaries of the Governments of the Member States which have contribution arrears to take urgent measures for their payment.

Regarding the report "Results of the audit of the JINR financial activities for the year 2015" presented by D. Korsakov, Director of the audit company "Korsakov and Partners", the Finance Committee recommended that the CP approve the accounting report of JINR for 2015 and the auditors' report concerning the JINR financial activities for 2015, take note of the plan of measures in connection with the audit accomplished, and commission the Directorate to prepare comments on the auditors' report by the next CP session.

The Finance Committee heard with interest the reports "Development trends of distributed computing and Big Data analytics" presented by V. Korenkov, Director of LIT, and "Young scientists at JINR" presented by V. Chudoba, Senior Researcher of FLNR and Chairman of the JINR AYSS.

The 44th meeting of the Programme Advisory Committee for Particle Physics took place on 14–15 December 2015. It was chaired by Professor I. Tserruya.

JINR Vice-Director R. Lednický informed the PAC about the Resolution of the 118th session of the JINR Scientific Council (September 2015) and on the decisions of the JINR Committee of Plenipotentiaries (November 2015).

The PAC congratulated the JINR Directorate and the VBLHEP management for signing the contract with STRABAG for the construction of the NICA buildings and with ASG for the fabrication of the MPD magnet, as well as for the Mega Science Award of 4.9 Billion Roubles for the next three years by the Russian Federal Government to support the NICA project. In view of the fact that construction work has already begun, these very significant achievements put the entire NICA project into a credible path and allow the establishment of a detailed time-line towards the goal of starting NICA operations in 2019.

Further progress has been achieved in commissioning the new RFQ system for LU-20, the first section of the new linear accelerator HILAC and other NICA new elements and systems. The PAC supported further development of the production line for the NICA superconducting magnets and its completion. It noted the importance of this programme for realizing the NICA and FAIR projects and strongly supported the plan to increase the manpower by one third to ensure the success of this programme.

The Committee urged the MPD team to complete Technical Design Reports for the main subsystems of the Stage 1 detector in order to start detector mass production after a proper evaluation by the MPD Detector Advisory Committee. The PAC welcomed the efforts being taken by the VBLHEP management to attract new students and to increase the personnel engaged in the realization of the NICA–MPD project.

The PAC discussed the following general guidelines for the elaboration of the new Seven-Year Plan for the Development of JINR for 2017–2023 on the topics of relevance to the PAC for Particle Physics:

— focus resources to ensure the timely completion of the NICA complex and the start of the physics programme with first stage configuration by 2019;

— prioritize participation in outside projects focusing on the scientific merit of the ongoing research programmes and capitalizing on the success, visibility and impact of the JINR groups participating in these programmes;

— promote international cooperation around JINR's in-house major projects, like BM@N, MPD, SPD, and BAIKAL;

— upgrade the general infrastructure and modus operandi of JINR to make NICA an attractive facility for outside users, collaborators and visitors, like in major international research centres.

The PAC heard with interest a general overview on the Seven-Year Plan and corresponding plans of DLNP and VBLHEP. The Committee strongly supported the priorities in allocation of manpower within VBLHEP to ensure the timely completion of the MPD and BM@N detectors, in accordance with the guidelines listed above. The PAC encouraged increased inter-lab collaboration on the NICA complex and reiterated its recommendation to make every effort possible to attract outside collaborators to the in-house projects and expressed concern about the little progress achieved in this direction. It also encouraged the formation of an international SPD collaboration and the timely presentation of a Conceptual Design Report.

The PAC appreciated the reports "First results of the NOνA project" and "Precise measurement of charged-pion polarizability at COMPASS" presented by A. Olshevsky and A. Guskov.

The PAC was pleased to review 27 poster presentations in particle physics by young scientists from four laboratories — DLNP, BLTP, VBLHEP and LIT, and recognized the overall good quality of the results presented. It selected the poster "TPC MPD/NICA readout electronics" presented by S. Vereshchagin (VBLHEP) to be reported at the session of the Scientific Council in February 2016.

The 43rd meeting of the Programme Advisory Committee for Nuclear Physics was held on 20–22 January. It was chaired by Professor F. Piquemal.

The Chairperson of the meeting 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 118th session of the Scientific Council (Dubna, September 2015) and the decisions of the Committee of Plenipotentiaries (Minsk, Belarus, November 2015).

The PAC heard reports on the theme "Investigations in the Field of Nuclear Physics with Neutrons" and on the projects carried out under this theme as presented by V. Shvetsov, Yu. Kopach, and M. Frontasyeva. The PAC appreciated the high-quality investigations in the physics of ultracold neutrons and reactions with cold polarized neutrons, looking forward to further development of these investigations in collaborations with other leading laboratories. The PAC noted the high level of neutron activation analysis at the Frank Laboratory and its new developments, and appreciated the involvement of young people across the world in this work.

The PAC recommended that FLNP provide a detailed report on the completion of the theme with further investigations to be proposed in the new seven-year plan under a new theme with the inclusion of ongoing and new projects. The PAC recommended speeding up

the commissioning of the IREN facility to make it possible to carry out experiments in nuclear physics with neutrons at JINR.

The PAC heard a status report on the COMET experiment presented by A. Kulikov. COMET is one of the most fundamental investigations of lepton flavor violation by searching for muon-to-electron conversion. The PAC noted the significant progress in implementing the experiment and encouraged the JINR group to maintain the active participation in it.

The PAC heard a report on the theme "Synthesis and Properties of Nuclei at the Stability Limits" presented by the theme leader, M. Itkis, and by the leaders of the projects "Velocity filter SHELS" and "Fragment separator ACCULINNA-2", A. Eremin and A. Fomichev. The PAC noted the high-quality investigations pursued by FLNR, which allow this laboratory to keep leading positions in the field of heavy-ion physics.

In view of the current construction of the accelerator complex "Factory of Superheavy Elements (SHE)", the PAC received, with interest, a report presented by Yu. Oganessian on potential methods for the synthesis of new superheavy nuclei. The PAC noted that fusion reactions with charged particle emission and incomplete fusion of very heavy projectiles could be promising ways for the production of heaviest and neutron-rich isotopes at the SHE Factory.

The PAC emphasized the great importance of the IUPAC decision on the confirmation of the discovery of elements 113, 115, 117, and 118, which is a result of many-year research work accomplished, first of all, at FLNR. The PAC was informed that the priority for the discovery of elements 115 and 117 had been given to the collaboration JINR – Lawrence Livermore National Laboratory (USA) – Oak Ridge National Laboratory (USA). The priority for the discovery of element 118 had been given to the collaboration JINR–Lawrence Livermore National Laboratory (USA). The PAC congratulated JINR on this outstanding achievement.

The PAC emphasized the importance of experiments planned at FLNR on the synthesis of new isotopes of element 118.

The PAC was pleased with the results of first experiments with the SHELS velocity filter and with the progress in the development of a new fragment separator, ACCULINNA-2, expressing hope to see these efforts completed in 2016.

As recommended by the PAC at the previous meeting, S. Dmitriev presented a detailed timetable for the FLNR Seven-Year Development Plan for 2017–2023. The PAC recommended approval of the proposed timetable, with particular attention to be given to the development of new-generation set-ups for the SHE Factory.

The PAC heard a report "Main directions of research in the field of nuclear physics in 2017–2023" presented by M. Itkis, and supported the proposed programme based on the forefront directions of research included in the new seven-year plan:

— construction and operation of the SHE Factory;

— modernization of IREN;

— promotion of international cooperation in experiments carried out by JINR, in particular, BAIKAL, SHELS, and ACCULINNA-2;

— contributions in non-accelerator physics experiments and COMET project.

The PAC heard scientific reports "Investigation of the composition of celestial bodies by neutron and gamma spectroscopy" presented by V. Shvetsov and "Microscopic optical potential description of elastic scattering and breakup reactions of light exotic nuclei" presented by M. Gaidarov.

The PAC was pleased with the presentations of new results and proposals by young scientists. Three best posters were selected: "Energy dependence of mass, charge, isotopic distributions and TKE in neutron-induced fission of ^{235}U and ^{239}Pu" presented by H. Paşca, "Anisotropic quantum scattering in two dimensions" presented by E. Koval and O. Koval, and "Design studies of a compact superconducting cyclotron SC200 for proton therapy" presented by O. Karamyshev. The PAC recommended the report by H. Paşca for presentation at the session of the Scientific Council in February 2016.

The 43rd meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 28–29 January. It was chaired by Professor V. Kantser.

The Chairperson of the PAC introduced the new member of the Committee D. Sangaa and presented an overview of the report delivered at the session of the JINR Scientific Council in September 2015 concerning the implementation of recommendations of the previous PAC meeting.

JINR Vice-Director M. Itkis informed the PAC about the Resolution of the 118th session of the JINR Scientific Council (September 2015) and the decisions of the JINR Committee of Plenipotentiaries (November 2015).

The PAC considered reports on the progress with four ongoing themes. Noting the detailed report on the themes "Investigations of Condensed Matter by Modern Neutron Scattering Methods" and "Development of the IBR-2 Facility with a Complex of Cryogenic Neutron Moderators", the PAC appreciated the main scientific results in the field of condensed matter research and instrumentation developments at IBR-2 obtained in 2015. The PAC was pleased to note the stable operation of the IBR-2 facility at a power of 2 MW, providing the performance of experiments with extracted beams in accordance with the plan, and underlined the importance of further development of the cryogenic moderator complex to cover beams 1, 4–6, and 9 of IBR-2. It also appreciated the high scientific significance of the results

produced at IBR-2 instruments and their interdisciplinary character. The progress achieved in the instrumentation development is important for extending the research programme, improving the quality of the experiments performed and for attracting new users to the IBR-2 instruments. As for the User Programme at the IBR-2 spectrometer complex, the PAC recommended its further continuation and reiterated the importance of collecting the scientific reports, making them available for experts. It also encouraged the User Committee to select the most significant applications and present them at meetings of the PAC.

Concerning the report on the theme "Multimodal Platform for Raman and Nonlinear Optical Microscopy and Microspectroscopy for Condensed Matter Studies", the PAC was pleased to note the implementation of polarized CARS microscopy option at the platform and the first results of the surface-enhanced Raman spectroscopy experiments.

Considering the report on the implementation of the research programme within the theme "Research on the Biological Effect of Heavy Charged Particles with Different Energies", the PAC noted the many-sided character of the scientific directions presented and the high quality of the research being conducted at LRB. The PAC underlined the importance of using the JINR scientific and technological potential for addressing theoretical and applied tasks in the field of radiation biology, radiation genetics, space radiobiology as well as in application of nuclear and physical methods for studies of celestial bodies.

The PAC heard a proposal for a new project entitled "LEPTA project: Development of experimental techniques and applied research with slow monochromatic positron beams" and noted the importance of the development at JINR of the positron annihilation spectroscopy (PAS) method. Such activity is presently based on the positron injector with unique parameters at LEPTA facility constructed at DLNP. Further progress in the facility development will allow increasing significantly the PAS application opportunities in condensed matter studies. The PAC recommended approval of the LEPTA project for implementation in 2016–2017 and suggested that DLNP elaborate a concept of user policy regarding this research.

The PAC received proposals on the main directions of research in the field of condensed matter physics in 2017–2023 and presented its recommendations concerning preparation of the new Seven-Year Plan of the Development of JINR. In particular, the PAC encouraged the JINR Directorate to include a special chapter in the plan with a concise SWOT (strengths–weaknesses–opportunities–threats) analysis of the new plan based on the results of the previous one. It also suggested adding information on the seven-year strategy of JINR for innovative and applied research. The PAC recommended drawing special attention to the proposals by Member States to the Seven-Year Plan. It also presented its proposals on how to increase the visibility of JINR on the international arena in the next seven-year period. In particular, in order to raise the image of the Institute, it was suggested that the JINR Directorate organize visiting conferences in Europe related to the basic scientific topics of the Institute and invite official representatives of states' ministries to these events. The PAC also noted the importance of further strong support of international cooperation. In relation to the IBR-2 instruments for condensed matter investigation, the PAC encouraged elaborating of at least a general line of research work planned to be realized after the modernization or construction of new instruments. It also noted that the plan of modernization of the already existing IBR-2 instruments and construction of new ones should include well-defined research aims that could be realized as a result of the changes planned and more balanced proportion for allocation of the expenditure planned on the instruments for investigation of elastic and inelastic neutron scattering with regard to the perspective of development of neutron scattering landscape.

The PAC was pleased to note the results of the international conferences "Condensed Matter Research at IBR-2" (11–15 October 2015, Dubna), "Modern Trends in Radiobiology and Astrobiology. Molecular, Genetic, Cell, and Tissue Effects" (28–30 October 2015, Dubna), and the 6th International School for Young Scientists and Students "Instruments and Methods of Experimental Nuclear Physics" (9–14 November 2015, Dubna), and welcomed their further organization.

The PAC heard with interest the scientific reports "First evidence on the role of ^{11}B-irradiation of meteorites and formamide in the origin of biomolecules" by R. Saladino and "On the impact of nanoparticles on the structural stability of bio-macromolecules" by V. Petrenko, and looks forward to hearing new scientific results at its future meetings.

The PAC selected the poster "Positron beam studies of radiation damage induced by swift heavy ions in palladium" by P. Horodek as the best poster at the meeting. It also noted two other high-quality posters: "Spontaneous DNA damage in mouse retina and adaptive response of the retina to low doses of proton radiation" by Yu. Vinogradova and "Mathematical modeling of the radiation-induced DNA double-strand break repair in mammalian and human cells" by M. Panina.

The 45th session of the Programme Advisory Committee for Particle Physics took place on 20–21 June. It was chaired by Professor I. Tserruya.

JINR Vice-Director R. Lednický informed the PAC about the Resolution of the 119th session of the JINR Scientific Council (February 2016) and the decisions of the JINR Committee of Plenipotentiaries (April 2016). The PAC thanked R. Lednický for his comprehensive report about the status of JINR's new Seven-Year Plan for the Development of JINR (2017–2023) and noted

with satisfaction that the procedures proposed by the PAC for Particle Physics for the elaboration of the new seven-year plan in the area of particle physics had been adopted as general guidelines.

The PAC congratulated the JINR Directorate and the VBLHEP management for signing the Agreement between the Russian Government and JINR on a dedicated contribution from Russia to the NICA megaproject that guarantees its realization. The PAC welcomed the signing of the Protocol among the Russian Ministry of Education and Science, the Chinese Ministry of Science and Technology, the Chinese Academy of Sciences and JINR on the prospects of cooperation within the framework of the NICA megaproject (superconducting systems, ECAL and TOF systems, and theory). The PAC regards these as important steps that will enhance the international status of the NICA project and provide additional guarantee for its timely completion in 2019.

The PAC was very pleased with the successful commissioning of the new fore-injector of the LU-20 linear accelerator based on the RFQ system and with the steady progress in infrastructure developments at JINR. The Committee welcomed the successful launch of the NICA cryogenic complex — the largest helium liquefier in Russia with a capacity of 1100 liters per hour. It also noted that the set-up of the facility for producing and testing superconducting magnets for the NICA accelerator complex is nearing completion.

The PAC encouraged further efforts towards completion of the technical design reports for the main subsystems of the MPD detector. At the same time, the PAC emphasized again the need to attract young professionals and additional external groups for the realization of the MPD project. The PAC considered it important to provide BM@N with the requested test beam time at the Nuclotron to ensure the timely start of the experiment. The PAC requested the BM@N team to establish clear milestones to allow appropriate monitoring of the project.

The PAC took note of the new project "Development of a precision magnetic spectrometer, SCAN-3, and research of non-nucleon degrees of freedom in nuclei, nucleon correlations and nuclear fragmentation at the internal target of the Nuclotron". The PAC recognized the scientific importance and uniqueness of the proposed research, and the high interest of JINR Member States. The Committee recommended approval of the project until the end of 2019.

The PAC reviewed with interest the project for the development of a Multifunctional Information and Computing Complex (MICC) of JINR. The PAC noted that the project covers all components of the Complex from the engineering and network infrastructure to the computing components with different architectures and data storage systems, and takes into account the prospects for the development of present-day IT and computing techniques. The experience gained by LIT will be used to develop the computing infrastructure of the NICA megaproject. The PAC recommended approval of the project until the end of 2019.

At a closed session with the JINR Directorate, the PAC discussed the drafts of updates proposed for the governing regulations of the PACs and the evaluation procedures of projects. The PAC was very pleased with significant developments that follow previous discussions of the PAC with the Directorate and recent proposals made by the chairpersons of the PAC for Particle Physics and the PAC for Condensed Matter Physics. The PAC thanked the JINR Directorate for the opportunity to comment on the drafts before they are finalized.

The PAC heard the scientific reports "Internal spin structure of the nucleon" by A. Sidorov and "NA64 experiment at CERN SPS. Search for dark sector in missing energy events" by N. Krasnikov.

The PAC reviewed poster presentations in particle physics by young scientists from DLNP and VBLHEP. Recognizing the overall good quality of the results presented, the PAC selected the poster "Matter effect in neutrino oscillations for the NOνA experiment" by L. Kolupaeva to be reported at the session of the Scientific Council in September 2016.

The 44th meeting of the Programme Advisory Committee for Nuclear Physics was held on 23–24 June. It was chaired by Professor F. Piquemal.

The Chairperson of the meeting 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 119th session of the JINR Scientific Council and the decisions of the JINR Committee of Plenipotentiaries.

The PAC heard a report on the theme "Investigations in the Field of Nuclear Physics with Neutrons" and a proposal for opening a new theme presented by V. Shvetsov. The PAC appreciated the results obtained under this theme. It noted, in particular, the importance of the development of the IREN accelerator facility and of the experiments accomplished; the achievements in the investigations of fundamental symmetries and properties of the neutron using ultracold neutrons and in the measurements of related nuclear data.

The PAC recommended approval of the new theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron" until the end of 2019. The FLNP Directorate should concentrate on achieving the designed beam parameters of the IREN project in order to pursue the research programmes of the Laboratory proposed for the new theme.

The PAC heard a report on the theme "Physics of Light Mesons", which includes 3 projects (COMET, GDH&SPASCHARM, SPRING) and 4 activities (MEG-PEN, TRITON, MUON, PAINUC).

Due to the termination of the COSY work for hadron physics, it was suggested that the status of

SPRING be changed from "project" to "activity" within the above theme.

A successful run was performed at the DLNP Phasotron (experiment TRITON), observing for the first time two additional output channels (e^+e^- and very likely 2γ) which had escaped observation in previous experiments. To conclude this experiment, a final run of about 200 h at the Phasotron should be allocated.

The PAC invited the participants of the PEN and PAINUC experiments to present final reports on the results produced; it also recommended that JINR's collaboration in the MEG-II experiment be continued.

The goal of the GDH&SPASCHARM project is an investigation of the nucleon spin structure with the MAMI microtron in Mainz (GDH) and with the U70 synchrotron in Protvino (SPASCHARM). In both experimental programmes, polarized targets are used. The PAC appreciated the quality of preparations for the experiments as part of the GDH&SPASCHARM project and recommended its continuation until the end of 2019.

On the whole, the PAC recommended approval of the report on the theme "Physics of Light Mesons". However, the extension of this theme was postponed until its detailed evaluation at the next PAC meeting.

The PAC heard a report on the scientific results of the concluding theme "Synthesis and Properties of Nuclei at the Stability Limits" and a proposal for opening a new theme "Synthesis and Properties of Superheavy Elements, Structure of Nuclei at the Limits of Nucleon Stability". The PAC recommended approval for opening the new theme until the end of 2021.

The PAC heard a report on the theme "Accelerator Complex of Ion Beams of Stable and Radioactive Nuclides (DRIBs-III)" and a proposal for opening a new theme "Development of the FLNR Accelerator Complex and Experimental Set-ups (DRIBs-III)" for a term of five years, up to the end of 2021. The PAC supported the proposed upgrade of the U400M cyclotron and preparation for the upgrade of the U400 cyclotron, and recommended that the JINR Directorate draw particular attention to the timely completion of the construction of the SHE Factory, the installation and commissioning of the DC280 accelerator and physics set-ups with a view to conducting first experiments at the SHE Factory.

The PAC heard a report on the theme "Information and Computing Infrastructure of JINR" and a proposal for its extension and opening, within this theme, of a project for the development of a Multifunctional Information and Computing Complex (MICC). The PAC recommended extension of the theme "Information and Computing Infrastructure of JINR" until the end of 2019 and opening of the project for the development of MICC at JINR under the theme. The PAC emphasized the necessity to provide information about the articles prepared under support of the LIT team and its infrastructure. It would also like to see more visible evidence of support for JINR laboratories and JINR Member States by LIT.

The PAC supported the proposed directions of the Seven-Year Plan for the Development of JINR in the field of nuclear physics and recommended that the JINR Directorate present this plan for final consideration by the Scientific Council at its next session in September 2016.

The PAC was informed about the proposals on methods for the evaluation of JINR projects and themes by the Programme Advisory Committees and about the current preparation of an update of the Regulation for the JINR PACs.

The PAC heard the scientific reports "UCN source at external beam of thermal neutrons" by A. Muzychka and "Population of ground-state rotational bands of heavy nuclei produced in complete fusion reactions" by V. Sargsyan.

The PAC was pleased with the presentations of new results and proposals by young scientists and selected three best posters: "Anthropogenic effects on the coastal phytoplankton studied by neutron activation analysis" (by P. Nekhoroshkov), "On the possibility of determining the moisture content in coke (fuel) with a BGO scintillation gamma detector and a ^{239}Pu–Be neutron source" (by D. Grozdanov), and "The experimental set-up Kolkhida" (by D. Berikov). The PAC recommended that the report by P. Nekhoroshkov be presented at the session of the Scientific Council in September 2016.

The members of the PAC thanked the Directorate of FLNP for the organization of the visit to this Laboratory and for the explanations about its main basic facilities and experiments.

The 44th meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 30 June – 1 July. It was chaired by Professor V. Kantser.

The Chairperson of the PAC presented an overview of his report delivered at the session of the JINR Scientific Council in February 2016 concerning the implementation of the recommendations of the previous PAC meeting. JINR Vice-Director M. Itkis informed the PAC about the Resolution of the 119th session of the JINR Scientific Council and the decisions of the JINR Committee of Plenipotentiaries.

The PAC took note of the report on the concluding theme "Development of the IBR-2 Facility with a Complex of Cryogenic Neutron Moderators" and project "Construction of a complex of cryogenic moderators at the IBR-2 facility" and recommended their extension until the end of 2019. It was emphasized that construction of the cryogenic moderator complex would increase the flux of slow neutrons up to 20 times for 8 out of 14 FLNP spectrometers, enabling the implementation of an advanced physics research programme

at the level of the leading neutron sources (ISIS, SNS, JSNS).

The PAC noted that by mid-2016 the available movable reflector of the IBR-2 facility had used 40% of its design service life. To ensure a guaranteed operation of the reactor until the end of its service life, the PAC recommended manufacturing a reserve movable reflector of the same design until 2019.

The PAC supported the activity towards ensuring the safe operation of the reactor as well as monitoring, diagnostics, and prognosis of its state. The PAC appreciated FLNP's intent to prepare the grounds for using the IBR-2 facility beyond the year 2032, endorsing the possibility, within the next three years, to develop a concept of the corresponding research programme implying the use of the existing facility or the design of a new neutron source at JINR. The PAC also suggested performing an analysis of similar set-ups available or planned to be developed in Russia and in the world.

The PAC heard a report on the current state of the inelastic neutron scattering facilities operating at IBR-2 and acknowledged the steady interest in the use of the NERA spectrometer that provides significant results and publications. It supported further development of the spectrometer and recommended preparing an upgrade plan within the framework of a new project. With regard to the DIN-2PI spectrometer, the PAC recommended that greater efforts be made to attract users to this facility.

The PAC considered a report on the concluding theme and project "Research on Cosmic Matter on the Earth and in Nearby Space; Research on the Biological and Geochemical Specifics of the Early Earth" and a proposal for their extension. It recognized the scientific merit of the project which is focused on astrobiology, addressing its fundamental and applied topics by a multidisciplinary approach. To determine the elemental and structural composition of cosmic matter samples, the authors suggested using a number of analytical methods actively applied at FLNP at a high scientific and technical level. Noting that this project is a large and multidisciplinary collaboration of JINR (FLNP and LRB), the Russian Academy of Sciences and various institutions, the PAC recommended extension of the theme and project until the end of 2019.

The PAC heard a report on the concluding theme "Medical and Biological Research with JINR Hadron Beams" and a proposal for opening two new projects "Further development of methods, technologies, schedule modes and delivery of radiotherapy" and "Project RADIOGENE: Experimental justification of radiation genetic risk estimation according to the frequency of heritable DNA changes in human and animal structural genes". The PAC emphasized the importance of the results achieved both in the field of clinical research on proton radiotherapy and in radiobiology. The JINR Medical and Technical Complex is currently the only centre for proton therapy in Russia, which is in operation and at the same time has acquired considerable expertise in this field. Noting the significance of the proposed scientific programme, the PAC recommended opening the proposed projects within a new theme "Biomedical and Radiation-Genetic Studies Using Different Types of Ionizing Radiation" until the end of 2019.

The PAC appreciated the broad spectrum of R&D studies accomplished within the concluding theme "Radiation Effects and Physical Basis of Nanotechnology, Radioanalytical and Radioisotope Investigations at the FLNR Accelerators" and heard a proposal for opening a new theme "Radiation Physics, Radiochemistry, and Nanotechnology Investigations Using Beams of Accelerated Heavy Ions" until the end of 2021. The activities under the proposed theme are expected to be integrated with the scientific programme of the FLNR Nanotechnology Centre, which will be of great interest for other JINR laboratories and researchers from cooperating centres. Given the successful completion of the concluding theme, the PAC recommended its closure and opening the newly proposed theme for the requested period.

The PAC adopted the recent add-ons to the Draft Seven-Year Plan for the Development of JINR with respect to the version of September 2015. It recommended acceptance of the proposed revisions to the chapter "Condensed Matter Physics" concerning sections addressing radiobiological and astrobiological research as well as study of nanosystems by the positron annihilation spectroscopy method. At the same time, the PAC found this chapter to be slightly imbalanced between neutron scattering research and optical methods. The PAC expressed an opinion that the Plan should pose signs of flexibility to have a possibility to include new projects.

The PAC heard the following scientific reports: "Neutron texture investigations of metallic and biological materials" by D. Nikolaev, "Energy dispersive EXAFS spectrometer in the NRC "Kurchatov Institute": Status and experimental results" by S. Tyutyunnikov, and "Novel features of Josephson nanostructures under external electromagnetic radiation. Results of collaboration with Germany, Slovakia, South Africa, Egypt, Japan, India, and Tajikistan" by Yu. Shukrinov.

The PAC selected the poster "Analysis of small-angle synchrotron X-ray scattering experimental data from vesicular systems by means of the parallel asynchronous differential evolution method" by E. Zhabitskaya as the best poster at the session. It also noted two other high-quality posters: "Parallel implementations of image reconstruction algorithms for X-ray microtomography" by M. Zuev and "Application of cloud technologies at JINR" by N. Kutovsky.

The PAC delivered a number of recommendations on methods for the evaluation of projects and themes by the PACs and appreciated the progress in developments of the methodology previously submitted by PAC

for Condensed Matter Physics to the JINR Directorate. Regarding the principle of the proposal expertise, the Committee noted that evaluation in the form of written reports delivered by PAC members and based on the suggested criteria is a promising method to provide estimation of the project's quality. In order to raise the effectiveness of evaluation, the PAC recommended appointing one or two of its members to provide monitoring of the progress within each project and theme, and suggested providing a crosscheck for personnel included in several different proposals. The PAC made a number of recommendations concerning the additional sections to the proposal form to be considered for the next draft of the proposals on evaluation methods. It found the elaboration of new evaluation methods to be useful in view of the current preparation of an update of the Regulation for the JINR PACs to be approved by the Scientific Council.

PRIZES AND GRANTS

The ***V. Dzhelepov Prize*** was awarded to Professor Ju. Budagov (JINR) for the development and construction of a unique laser metrology system for measuring the angular oscillation of the Earth's surface.

The ***B. Pontecorvo Prize*** was awarded to a group of authors including Professor Yifang Wang (IHEP, Beijing, China), Professor Soo-Bong Kim (Seoul National University, South Korea) and Professor Koichiro Nishikawa (KEK, Tsukuba, Japan), for their outstanding contributions to the study of the neutrino oscillation phenomenon and to the measurement of the θ_{13} mixing angle in the Daya Bay, RENO and T2K experiments.

JINR PRIZES FOR 2016

I. Theoretical Physics Research

First Prize

"Cluster Approach for Describing Nuclear Fission".
Authors: H. Paşca, G. Adamian, A. Andreev, N. Antonenko, R. Jolos, A. Nasirov, T. Shneidman.

Second Prizes

1. "Conformal Anomalies, Quantum Entanglement, Boundaries, and Distributional Geometry".
Author: D. Fursaev.

2. "Is It Possible to Discover a Dark Matter Particle with an Accelerator?"
Author: V. Bednyakov.

II. Experimental Physics Research

First Prizes

1. "Magnetic Phenomena in Intermetallic Compounds RCo_2: Studies of the Limits of the Itinerant Electron Metamagnetism Concept".
Authors: D. Kozlenko, E. Lukin, S. Kichanov, A. Rutkauskas, B. Savenko, E. Burzo, P. Vlaic, Dang Ngoac Toan.

2. "Investigation of the Spontaneous Fission Properties of Short-Lived Isotopes of Transfermium Elements".
Authors: A. Svirikhin, A. Yeremin, A. Popeko, O. Malyshev, V. Chepigin, A. Isaev, M. Chelnokov, E. Sokol, A. Andreev, Yu. Popov.

Second Prize

"Investigations of Hadronic Hydrogen-Like Atoms in the DIRAC Experiment".
Authors: L. Afanasiev, O. Gorchakov, K. Gritsai, M. Zhabitsky, V. Kruglov, L. Kruglova, A. Kulikov, R. Lednický, L. Nemenov, M. Nikitin.

III. Physics Instruments and Methods

First Prize

"Investigation of Exotic Radioactive Decays Using Vertex Method: Project EXPERT".
Authors: A. Bezbakh, A. Gorshkov, L. Grigorenko, G. Kaminski, S. Krupko, I. Mukha, M. Pfutzner, R. Slepnev, A. Fomichev, V. Chudoba.

Second Prize

"Construction and Commissioning of the Heavy-Ion Linear Accelerator of the NICA Injection Complex".
Authors: P. Butenko, P. Govorov, D. Donets, V. Kobets, K. Levterov, V. Monchinsky, A. Sidorin, U. Ratzinger, G. Trubnikov, H. Höltermann.

IV. Applied Physics Research

First Prize

"Reduction of Radiation Damage in Biological Objects by Means of Laser Radiation".
Authors: K. Voskanyan, G. Mitsyn, V. Gaevsky.

Second Prize

"Neutron Activation Analysis for Ecological State Assessment of Coastal Ecosystems of the Black Sea".

Authors: A. Kravtsova, P. Nekhoroshkov, M. Frontasyeva, I. Zinicovscaia, N. Yushin, O. Bunkova, I. Stukolova, A. Yakovlev, A. Kamnev.

Encouraging Prizes

1. "Physics Research of the JINR Group in the ATLAS Experiment at the Large Hadron Collider".

Authors: V. Bednyakov, I. Eletskikh, M. Chizhov, E. Khramov, L. Gladilin, V. Lyubushkin, Yu. Kulchitsky, E. Plotnikova, P. Tereshko.

2. "Peculiarity of Nuclear Reaction Mechanism by Weakly Bound Light Nuclei".

Authors: S. Lukyanov, Yu. Sobolev, A. Denikin, V. Maslov, M. Naumenko, Yu. Penionzhkevich, V. Samarin, N. Skobelev, A. Kugler, J. Mrazek.

3. "Investigation of the Deeply Subcritical Target Assembly QUINTA Consisting of 512 kg Natural Uranium Irradiated by Deuterons in an Energy Range from 1 to 8 GeV at the JINR Nuclotron".

Authors: V. Furman, N. Gundorin, J. Adam, A. Baldin, A. Berlev, A. Solnyshkin, S. Tyutyunnikov, V. Voronko, L. Zavorka, V. Chilap.

GRANTS

In 2016, to implement 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 Foundations of the RF Ministry of Education and Science.

RFBR financed JINR projects in the framework of the following competitions: "Competition of projects of fundamental scientific research" (32 projects); "Competition of projects accomplished by young scientists (My first grant)" (3 projects); "Competition of projects accomplished by leading young groups" (1 project); "Competition of projects accomplished by young scientists under the guidance of candidates and doctors of science in RF scientific institutions" (3 projects); "Regional competition 'Central Russia' " (2 projects); "Competition of fundamental oriented research in urgent interdisciplinary topics" (6 projects).

RFBR financed a number of JINR scientific projects in the framework of international contests: together with the State Committee on Science of the Ministry of Education and Science of the Republic of Armenia (1 project); together with BRFBR (1 project); together with the Vietnamese Academy of Sciences and Technology (1 project); together with the Foundation of Development of Science and Technology of Egypt (1 project); together with the State Foundation of Natural Sciences of China (1 project); together with the Department of Science and Technology of the Government of India (3 projects); together with the German Scientific-Research Community (4 projects); together with the National Centre of Scientific Research of France (4 projects); together with the State Foundation of Fundamental Research of Ukraine (1 project).

RFBR rendered financial support to JINR for organization of 7 scientific conferences in the framework of the competitions "Organization of conferences and scientific events in the territory of Russia" and "Organization of Russian and international scientific events for young researchers in the territory of Russia".

Financial support was rendered in the framework of the RFBR programme "Scientific Electronic Library" in the competition to obtain the access to electronic scientific information resources of foreign publishing houses.

RSF, in the framework of the competition "Fundamental scientific research and scientific research in separate scientific groups", financed 4 projects.

The RF Ministry of Education and Science, in the framework of the Federal Target Programme "R&D in Priority Trends of the Development of the Scientific-Technological Complex of Russia for 2014–2020", financed 1 project.

Nineteen projects were financed in 2016 in the framework of the joint competition of research projects of BRFBR and JINR.

2016

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 2016 reflect 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 41 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 2850 specialists;

— for joint work and consultations, as well as for participation in meetings, conferences, and schools held at JINR, 2007 specialists were received;

— 51 international scientific conferences and schools, 17 workshops, and 22 meetings were organized and held;

— 16 scholarship holders worked at JINR laboratories.

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 joint research results, the supply of equipment and techniques for the interested sides, etc.

The JINR Days in Latin America were held **on 1–5 February** in Havana (Cuba) in the framework of the celebration of the 60th anniversary of JINR. A representative delegation from JINR came to the capital of Cuba to participate in the festive events.

The celebration of JINR's 60th anniversary coincided with the 40th anniversary of membership of the Republic of Cuba in JINR. This fact was reflected in a special issue of a brochure about JINR and the participation of the Republic of Cuba, as well as in materials of a permanent commemorative exhibition whose ceremonial opening was held on 1 February in the Higher Institute of Technologies and Applied Sciences (InSTEC). The exhibition was opened by JINR Director V. Matveev, InSTEC Rector B. G. Moreda and Plenipotentiary of the Government of the Republic of Cuba to JINR F. C. Diaz-Balart.

The JINR delegation visited the Centre for Advanced Studies of Cuba (CEAEC) being developed in Havana. During a conversation with leaders of CEAEC, prospects of cooperation were outlined. The JINR delegation also visited the University of Information Science (UCI).

On 2 February, in the University of San Jeronimo, one of the oldest universities in Latin America, the ceremony of conferring the title "Honorary Doctor of InSTEC" on JINR Director V. Matveev, as well as of conferring the title "Distinguished Professor of InSTEC" on JINR Vice-Director M. Itkis, was held in a festive atmosphere. The ceremony was attended by representatives of the diplomatic corps of JINR Member States accredited in Havana. The JINR Director presented JINR anniversary honorary diplomas to Cuban colleagues who worked in Dubna in different years and to students who were trained at JINR. Minister of Education and Science of Russia, Plenipotentiary of the Government of the Russian Federation to JINR D. Livanov delivered a welcoming speech at the ceremonial meeting.

On 3 February, the JINR delegation visited the Institute of Molecular Immunology (CIM) and the Centre for Applied Technology and Nuclear Development (CEADEN), where FLNR staff member A. Nechaev and JINR Vice-Director G. Trubnikov gave lectures on scientific research and educational opportunities at JINR. JINR Director V. Matveev invited a Cuban delegation to take part in festive events in Dubna dedicated to the jubilee of JINR.

On 17 February, Prime Minister of the Russian Federation D. Medvedev signed an order on the celebration of the 60th anniversary of the Joint Institute for Nuclear Research. It assigns, in particular:

"The RF Ministry of Education and Science should work out and validate, in concurrence with the RF Ministry of Foreign Affairs and JINR, the plan of the major events of preparation and holding the celebration of the 60th anniversary of the Institute.

The RF Ministry of Foreign Affairs should inform the secretariats of the UN and UNESCO about the

preparation for the celebration of the 60th anniversary of the Institute; make provision for the events to mark the 60th anniversary of the Institute in preparation of intergovernmental programmes of the Russian Federation and foreign states, in concurrence with the RF Ministry of Education and Science.

The RF Ministry of Communications and Mass Media should render assistance in reporting the process of preparation and organization of the events on the celebration of the 60th anniversary of the Institute in the state mass media".

The JINR Days in Slovakia dedicated to the 60th anniversary of JINR were held **on 22–25 February.**

On 22 February, a full-scale poster and multimedia exhibition was opened in the Slovak Technical Museum in Košice. Placed in two halls, it presented the history and the present of JINR with animated representation of the operating JINR basic facilities. The exhibition was open until 13 March.

The opening of the exhibition was preceded by a big press conference where Director General of the Museum E. Lobanič, as well as M. Hnatič, G. Martinska, and Yu. Panebrattsev made reports and answered questions. At the opening of the exhibition S. Vocal, L. Sándor, and G. Martinska spoke about their work at JINR, and V. Voronov and B. Starchenko spoke about JINR nowadays.

On 24 February, in the building of the Ministry of Education, Science, Research and Sport of the Slovak Republic, where the second exhibition of the Institute was laid out, a memorial scientific seminar was held. The seminar was opened by JINR Vice-Director M. Itkis and Plenipotentiary of the Government of the Slovak Republic to JINR S. Dubnička. Greetings from the Ministry were announced by Deputy Minister P. Plavchan.

Slovak scientists, who continue their cooperation with JINR, L. Sándor, J. Růžička, P. Balgavy, M. Hnatič, F. Šimkovic, and N. Kucherka made reports at the seminar. The words "Dubna is needed" sounded in every speech.

On 9 March, a working meeting of the Moscow Region Governor A. Vorobiev and JINR Director V. Matveev was held in the Government of the Moscow Region. They discussed issues of cooperation between the Institute and the Government of the Moscow Region, and the agenda of events to mark the 60th anniversary of JINR.

A high-level governmental delegation from Ethiopia headed by Deputy Prime Minister Mr. Demeke Mekonnen visited JINR **on 19 March**. The delegation also included Minister of Science and Technology A. Ahmed, Minister of Education Sh. Wolassa, and Ambassador Extraordinary and Plenipotentiary of Ethiopia to Russia G. A. Teshome.

At the JINR Directorate, JINR leaders told the guests about the history, structure, main trends of research at JINR, the permanent and associate membership to JINR, and opportunities for university education and scientific specialists' training.

During the visit, excursions to JINR laboratories were organized for the Ethiopian delegation. The guests were acquainted with the FLNR accelerator complex and the construction of the megaproject NICA.

On 25 March, on the eve of the JINR Establishment Day, the official ceremony of laying the first stone for the project "Complex of Superconducting Rings for Heavy Ion Colliding Beams NICA" was held at the Veksler and Baldin Laboratory of High Energy Physics. It was attended by Assistant to RF President A. Fursenko, Governor of the Moscow Region A. Vorobiev, Deputy Minister of Education and Science of RF L. Ogorodova, member of the Council on Physical Culture and Sports under the RF President I. Rodnina, as well as by famous scientists: RAS President Academician V. Fortov and Nobel Prize winner in physics of 2004 American theoretical physicist D. Gross. JINR was represented by Director of the Institute Academician V. Matveev, JINR Vice-Director G. Trubnikov, VBLHEP Director V. Kekelidze, and Chairman of the Committee of Plenipotentiaries of the Governments of JINR Member States L. Kostov.

After the inauguration of the start of construction, guests had an excursion around the Laboratory departments where the NICA project is under construction. Then, in the conference hall of VBLHEP, the Moscow Region Governor A. Vorobiev and JINR Director V. Matveev signed an Agreement on cooperation between the Government of the Moscow Region and JINR. Academician V. Fortov was presented the Diploma and the gown of the Honorary Doctor of JINR. D. Gross was awarded with the medal "For the Services to JINR". The Nobel Laureate gave a lecture "Quantum chromodynamics — a true and beautiful theory".

A festive event dedicated to the 60th anniversary of the Joint Institute for Nuclear Research was held in the culture centre "Mir" **on 26 March**. Members of the JINR Directorate and JINR staff members, Dubna City Mayor V. Mukhin, the Head and representatives of the City Administration of Dubna, leaders of enterprises and organizations of Dubna, deputies of Dubna City Council, and representatives of public associations attended the festive event.

JINR Director RAS Academician V. Matveev noted in his speech the main phases of establishment of the Institute and activities of JINR; he spoke about each laboratory individually, as well as about the people who became the JINR history and contributed to the establishment of key basic facilities of JINR.

At the end of his speech, on behalf of the JINR Directorate and the JINR Scientific Council, V. Matveev congratulated staff members and veterans of JINR and all those who attended the anniversary ceremony.

After congratulatory speeches and awarding, the "Moscow Virtuosi" orchestra and Maestro V. Spivakov presented their musical gift to the audience.

On 5 April, festive events on the celebration of the 60th anniversary of JINR were continued in Dubna. Sixty balloons — white doves — were let into the sky to mark elevated scientific endeavours in search for new discoveries for the benefit of the mankind. A jubilee reception and a festive meeting were organized at the culture centre "Mir" for representatives of Embassies, scientific centres, governmental delegations from different countries. The holiday was finished with a grand firework show in the evening in the Molodezhnaya grassy clearing for Dubna citizens and guests.

On 7–9 April, JINR Days were held in Bulgaria on the occasion of the 60th anniversary of the JINR foundation. The opening ceremony was held on 7 April in the Museum of Man and Nature, with greeting words of Plenipotentiary of the Government of the Republic of Bulgaria to JINR L. Kostov. A full-scale poster exhibition was displayed for guests on the history and development of JINR–Bulgaria cooperation since JINR establishment, joint achievements and research projects. The exhibition was meant to attract young Bulgarian scientists and specialists to JINR projects. A film produced by the Bulgarian journalist M. Cherneva on the order of the first national television channel of Bulgaria was shown to the audience.

On 8 April the festive events were held in the Sofia Central Military Club. Among those present were Ambassadors of Egypt, Kazakhstan, Poland, Slovakia, representatives of the Embassies of Azerbaijan, Belarus, Vietnam and France. JINR Director Academician V. Matveev spoke to the guests about new scientific achievements of the Institute and plans for the future. Professor Ch. Stoyanov made a report on the research in nuclear physics in Bulgaria.

Bulgarian scientists L. Kostov, N. Angelov, I. Brankov, and P. Fiziev were awarded badges of honour for their big contribution to the development of Bulgaria–JINR cooperation. Bulgarian teachers T. Teodosiev, T. Ivanova, M. Jijova, R. Kostadinova, and K. Perfanova were awarded honorary diplomas for achievements in teaching physics.

The scientific session included the following reports: "Properties of superheavy nuclei on the stability border" by M. Itkis, "Present and future projects of the INRNE BAS–JINR cooperation" by D. Tonev, "Neutrino at Dubna" by S. Bilenky, "Cooperation of the Bogoliubov Laboratory of Theoretical Physics with institutes of Bulgaria" by V. Voronov, and "JINR and high energy physics in Bulgaria" by L. Litov. Directors of JINR laboratories V. Kekelidze, V. Korenkov and V. Shvetsov spoke about priority directions of JINR activities. The representative of the Institute of Electrochemistry and Energy Systems of BAS D. Vladikova made a report on innovation subject.

On the same date, a meeting of the leaders of the Joint Institute with Director of the Agency "Nauka" at the Ministry of Education and Science of Bulgaria Z. Karova and head of department G. Zhicheva was held. The JINR representatives were accompanied by Plenipotentiary of the Government of the Republic of Bulgaria to JINR L. Kostov. They discussed issues of cooperation and further plans, and the establishment of a special Bulgarian trust for the NICA project.

On 9 April, President of BAS Academician S. Vodenicharov received the JINR delegation. From the Bulgarian side Professor D. Tonev and Director of INRNE BAS Ch. Stoyanov were present. S. Vodenicharov handed the Marin Drinov Award to M. Itkis for his contribution to the studies of the mechanism of the superheavy elements synthesis and development of cooperation between the Academy of Sciences of Bulgaria and JINR. Professor V. Voronov was awarded the Badge of Honour "For the Services for the Bulgarian Academy of Sciences" and his contribution to development of cooperation between BAS and JINR.

On 13 April, an Agreement was signed in Moscow on cooperation between JINR and IAEA in the framework of the international forum "Integrated Solutions in Knowledge Management for Communities of Scientists, Engineers, Operators" organized by the State Corporation on Atomic Energy ROSATOM. The document was signed from the JINR side by JINR Director Academician V. Matveev and from the IAEA side by IAEA Deputy Director General M. Chudakov. As V. Matveev stressed, the signing of this Agreement can be regarded as a new stage of development of JINR relations with ROSATOM and IAEA.

This framework agreement provides the basis for organization of mutually beneficial and systematic exchange of information about scientific research opportunities at JINR and partner scientific organizations of IAEA. One of the important elements of this Agreement is the appointment of coordinators — Director of IAEA Department of Physics and Chemistry Sciences M. Venkatesh (India) and Deputy Director of the JINR Frank Laboratory of Neutron Physics O. Culicov.

The Agreement envisages training of staff and development of the infrastructure in the field of safe operation and disposal of nuclear research reactors, accelerators, and in applied spheres, i. e., application of radiation and isotopes in medicine, neutron activation analysis, neutron spectroscopy, studies in materials science. The cooperation will be continued in the international system of nuclear information INIS Collection that includes now over 3.4 million documents in 63 languages.

On 19 May, a working visit to JINR was paid by Dr. Chao-Ming Fu, Director of the Department of Science and Technology of the representative office of the Taipei–Moscow Coordination Commission on Economic and Cultural Cooperation under the Ministry of Science and Technology of Taiwan.

During a discussion with JINR Vice-Director M. Itkis, Dr. Chao-Ming Fu noted his special interest in issues of materials science and educational projects of JINR. The parties agreed to promote contacts more actively and, in particular, to organize the next visit for wider and more detailed acquaintance with the activities of JINR and elaboration of proposals on development of cooperation. The guest visited the cyclotron complex and the nanotechnological centre of the Flerov Laboratory of Nuclear Reactions.

On 24 May, members of the Programme and Organizing Committees of the 26th international Crimea conference "Microwave Technology and Telecommunication Techniques" (KryMiKo-2016) visited JINR. These were scientists and specialists in microwave technology from industrial and academic organizations of Moscow, Fryazino, Sevastopol, Ekaterinburg, Kharkov, Kiev, Saratov, St. Petersburg. The guests visited VBLHEP and FLNR.

On 26 May, an exhibition devoted to the 60th anniversary of JINR was opened in the Physics Department of Kiev National University after T. Shevchenko, in the framework of the JINR Days in Ukraine.

The JINR CP Chairman L. Kostov, Plenipotentiary of the Ukranian Government to JINR B. Grynyov, the Dean of the Physics Department N. Makaretsy, the Head of the Chair of Molecular Physics L. Bulavin, and JINR UC Director S. Pakuliak opened the event. Students and teachers of the Physics Department of KNU attended the ceremony.

On 2 June, a JINR delegation headed by Vice-Director R. Lednický took part in the scientific conference "Days of the Joint Institute for Nuclear Research in Moldova" in Chisinau, at the Presidium of the Academy of Sciences of Moldova (ASM), in the framework of the 60th anniversary of JINR and the 55th jubilee of ASM.

The conference was opened and chaired by ASM First Vice-President, Plenipotentiary of the Government of Moldova to JINR Academician I. Tighineanu. The opening was attended by diplomatic representatives from Embassies of Belarus, Georgia, Kazakhstan, and Russia. Chairman of the Parliamentary Committee of Culture, Education, Research, Youth, Sports and Media V. Hotineanu delivered a welcoming address. JINR Vice-Director R. Lednický presented honorary diplomas to Moldovan scientists and staff of organizations cooperating with JINR. Special attention was paid to the personal contribution of ASM Academician V. Moskalenko to the successful development of cooperation of Moldovan scientists with JINR.

The scientific programme of the conference included an overview of theoretical and experimental collaborative work, achievements of scientific research in Moldova and the major JINR projects. As part of the celebration, a poster exhibition demonstrating the present-day JINR and participation of Moldova in JINR activities was opened in one of the halls of the ASM administrative building.

Durring the visit of the delegation to Chisinau, JINR representatives were welcomed in the Government of Moldova by Vice-Premier G. Brega. The participants of the meeting informed the Vice-Premier about the present status of the Institute, opportunities for Moldovan scientists and engineers, and educational projects.

On 3 June, the JINR delegation met with Rector of the Technical University of Moldova (TUM) Professor V. Bostan and Dean of the Faculty of Computers, Informatics and Microelectronics of TUM I. Balmuş. During the meeting, the guests paid special attention to prospects for educating students and the summer student programme. The delegation visited scientific and educational laboratories of the University. LIT Deputy Director Professor Gh. Adam and UC Director Professor S. Pakuliak gave lectures to students of the Faculty.

In early June, a representative delegation of JINR, headed by Director Academician V. Matveev, visited Ulaanbaatar (Mongolia). Visitors from JINR took part in festive events on the 60th anniversary of JINR. As part of the JINR Days in Mongolia, official meetings were held and the 6th International Conference on Contemporary Physics, ICCP-VI, was organized in the National University of Mongolia (NUM) from 7 to 10 June. Scientists from the majority of JINR laboratories took part in it.

The JINR delegation was received by Plenipotentiary of the Government of Mongolia to JINR Professor S. Davaa, and Secretary and Head of the Executive Office of the Nuclear Energy Board B. Tuyatsehtsehg.

On 6 June, the ceremonial opening of the JINR Days was held at the National University of Mongolia. It was attended by representatives of the Embassies of Belarus, Laos and France.

A poster exhibition about JINR today and involvement of Mongolia in JINR research was displayed in the University exhibition hall. JINR Director V. Matveev handed Honorary Diplomas and Medals to 33 distinguished Mongolian scientists who worked at JINR and contributed to the development of scientific cooperation.

On 7 June, the JINR delegation was received by Senior Vice-President of the Academy of Sciences of Mongolia Academician D. Rehdgehl and AS General Secretary Professor T. Galbaatar. The sides discussed prospects of cooperation, participation of Mongolia in new scientific projects of JINR and current educational programmes.

Before the start of the International Conference on Contemporary Physics, the JINR delegation had a meeting with NUM President Doctor R. Bat-Ehrdehneh, and the title of Honorary Doctor of the National University of Mongolia was ceremonially conferred on JINR Director V. Matveev.

On 8 June, JINR representatives were received by Mongolian Minister of Education, Culture and Science L. Gantumur in the Government of Mongolia.

During the stay of the JINR delegation in Mongolia, a bilateral committee was established on the development of cooperation to improve, in particular, information awareness of the Mongolian scientific community about today's JINR activities, and promote the attraction of young scientists to work at JINR. For instance, a visit of the NUM delegation headed by NUM President to JINR was planned, along with organization of a school for young scientists in selected fields of JINR research in Mongolia in 2017.

On 14–18 June, festive events were held in Astana (Kazakhstan) on the 60th anniversary of JINR and the 10th anniversary of the start-up of the DC-60 heavy ion accelerator developed with participain of staff members of the Flerov Laboratory of Nuclear Reactions of JINR.

On 15 June, the international meeting "JINR Days in Kazakhstan" was ceremonially opened in the conference hall of the hotel "Astana Mariott". Vice-Minister of Energy of the Republic of Kazakhstan B. Jaksaliev greeted the delegation from JINR. Representatives of the Embassies of Armenia, the Czech Republic, Georgia, Poland, Romania, Russia, Slovakia, Ukraine, and the Directorate of the "Rosatom Central Asia" company were among the guests of honour.

V. Matveev, M. Itkis, S. Dmitriev and D. Kamanin were awarded Badges of Honour "Honoured Worker of Atomic Industry of the Republic of Kazakhstan" of various degrees, for active participation in the development of cooperation in nuclear physics. In their turn, Kazakh colleagues K. Kadyrzhanov, N. Burtebaev, F. Penkov and T. Zhantikin were awarded Honorary Service Medals "For the Service for Science and JINR". Kazakh school students — winners of the republican and international competitions — also received Prizes. They were awarded Honorary Diplomas by the General Director of RSE INP S. Sakhiev and JINR Director V. Matveev.

On the first day of the meeting, a number of participants were awarded commemorative medals "The 20th Anniversary of the Gumilev ENU" during the talks of the JINR delegation with leaders of the Eurasian National University after L. Gumilev. JINR representatives visited the branch of the Institute of Nuclear Physics — the interdisciplinary scientific research complex in Astana and had an excursion to the heavy ion accelerator DC-60.

On the second day of the meeting, a Memorandum on cooperation with JINR was signed in the Nazarbaev University. The JINR delegation also visited the hospital of the medical centre of the Department of Presidential Affairs of the Republic of Kazakhstan and the department of the corporate foundation "University Medical Centre" of the Republican Diagnostic Centre. The majority of the staff who operate facilities that produce radionuclide pharmaceuticals were trained at JINR.

To conclude JINR Days in Kazakhstan, the participants of the meeting visited the Republican training-health improving centre "Baldauren" on the shore of Lake Borovoe. There, Diplomas were handed to winners of school competitions, and school students listened to a report about JINR educational programmes.

On 15–16 June, a delegation from the Republic of Botswana headed by Minister of Education and Skills Development U. Dow and Ambassador Extraordinary and Plenipotentiary of the Republic of Botswana to Russia L. Nthekela visited the Joint Institute for Nuclear Research.

During the visit, a meeting with JINR Vice-Director G. Trubnikov, Director of the JINR University Centre S. Pakuliak, FLNR Deputy Director A. Popeko and Deputy Director of the Centre of Applied Physics of FLNR P. Apel was held; actual steps to enhance scientific and educational cooperation, especially between young researchers, were discussed at the meeting. Issues of cooperation with FLNR on nanotechnological applications, in particular on track membranes, were also discussed. The delegation visited VBLHEP and FLNR.

On 5 July, a delegation from the Second University of Naples headed by the world-known astronomer Professor M. Capaccioli visited JINR. The delegation consisted of the University academic staff.

The guests visited the cyclotron complex and the nanotechnological centre at the Flerov Laboratory of Nuclear Reactions, and had an excursion to the Dzhelepov Laboratory of Nuclear Problems where they showed a special interest in neutrino physics research and astrophysics. The Italian visitors marked the importance of the Medical and Technical Complex that operates on the basis of the Phasotron. Professor M. Capaccioli expressed interest in development of cooperation in the sphere of education.

On 12–14 October, a representative delegation from JINR visited Baku (Azerbaijan). On 12 October, a meeting of the Working Group of the JINR Finance Committee was held in the Presidium of the Academy of Sciences of Azerbaijan. Plenipotentiary of the Government of Bulgaria Professor L. Kostov presided over the meeting. Issues of financing that had to be discussed before the sessions of the JINR Finance Committee and the JINR Committee of Plenipotentiaries were discussed.

On 13 October, JINR Days in Azerbaijan were inaugurated. Ceremonial meetings in the framework of the JINR Days were held under the guidance of the President of the National Academy of Sciences of Azerbaijan Academician A. Alizade, in the Scientists' Club in the Academy campus. Among guests of honour were

the Ambassador of the Russian Federation, the Ambassador of Poland, first secretaries of the Embassies of the Czech Republic, the Republic of Kazakhstan and the Republic of Belarus, member of the JINR Scientific Council O. Abdinov and members of the Academy of Sciences of Azerbaijan taking an active part in the development and growth of cooperation with JINR. A poster exhibition was organized for the participants. It was dedicated to the jubilee of JINR, priority trends of research at its laboratories and the history of JINR–Azerbaijan cooperation.

JINR Director V. Matveev, VBLHEP Director V. Kekelidze and other speakers made reports at the meetings. In respect and acknowledgement of the contribution to the development of cooperation, the following members of the delegation from JINR were awarded medals issued to commemorate the 70th anniversary of NASA: N. Russakovich, S. Pakuliak, L. Kostov, M. Budzyński and I. Shtekl. JINR Director was awarded the Medal named after Nasreddin Tusi. After the official ceremony, the guests visited the Institute of the National Academy, the National Centre of Nuclear Research and Baku State University.

From 16 to 25 October, a delegation of JINR's FLNP visited the Arab Republic of Egypt. Among the issues of the visit was the participation in the 7th International Conference on Optic Spectroscopy, Lasers and Their Application organized by the National Scientific Research Centre of Egypt. M. Frontasyeva, Kh. Kholmurodov, V. Badavi and invited scientists spoke in their reports about results of their studies in the framework of the joint protocol of the Academy of Scientific Research and Technology of Egypt and JINR, and according to the topics of their scientific research.

On 24 October, members of the JINR delegation visited the Atomic Energy Agency of Egypt and were received by the Agency Director Professor A. Abdel Fattah and Deputy Director on international cooperation Professor S. Atalla. A seminar was held where scientists from Dubna and their Egyptian colleagues made reports to the audience of the Agency staff members and invited professors from leading universities of Egypt. After the seminar, a meeting was organized with the Agency leaders where prospects for further interaction between JINR and Egypt were discussed, as well as extension of cooperation of JINR with the Atomic Energy Agency and the development of scientific and educational contacts.

From 19 to 22 October, Days of JINR in Armenia were held in Yerevan. The event was dedicated to the 60th anniversary of the Joint Institute for Nuclear Research and the 25th anniversary of Armenia's membership in JINR. JINR Director V. Matveev headed the delegation of the Institute that included leading specialists, leaders of JINR, laboratories and the UC.

The ceremonial opening of the JINR Days in Armenia was held in the Mesrop Mashtots Institute of Ancient Manuscripts, and it gathered representatives of the State Committee of Science of Armenia, the Ministry of Education and Science of Armenia, Yerevan State University (YeSU), the Yerevan Physics Institute (YePI) and other scientific organizations. Welcoming adrresses were delivered by Minister Counselor of the RF Embassy in Armenia A. Ivanov, Senior Counselor of the Embassy of Belarus in Armenia D. Semenovich, and Ambassador Extraordinary and Plenipotentiary of Kazakhstan to Armenia T. Urazaev.

Reports were made on cooperation as well as on implementation, results and plans for joint research projects.

A meeting of the JINR Directorate with President of the Republic of Armenia S. Sargsyan took place on 19 October, and meetings with Yerevan Mayor T. Margaryan and RA NAS President R. Martirosyan were held in the following days.

On 20 October, the JINR delegation visited the Yerevan State University, where University Rector A. Simonyan awarded the title of "YeSU Honorary Doctor" and YeSU Gold Medal to V. Matveev for his contribution to the development of science and strengthening of scientific relations between Russia and Armenia.

On 21 October, the JINR delegation visited the CANDLE Synchrotron Research Institute and the Alikhanyan National Laboratory (Yerevan Physics Institute), where they got acquainted with the diagnostic centre with the 18/18 CICLON cyclotron of the IBA company for radioisotopes production for PET tomography.

On 16 November, a representative delegation of JINR headed by the Institute Director V. Matveev took part in the workshop "Perspectives for Joint Science and Academic Training at FAIR and NICA" that was held in the GSI Helmholtz Centre for Heavy Ion Research (Darmstadt, Germany). At the workshop, the German side was represented by Deputy Director-General of BMBF B. Vierkorn-Rudolf, FAIR Scientific Director B. Sharkov, GSI Scientific Director K. Langanke and other members of the FAIR project. Both parties made reports on the main areas of fruitful cooperation in NICA and FAIR projects and on prospects of the cooperation. Following the workshop, a joint Declaration on further development of cooperation between NICA and FAIR projects was signed.

From 28 November to 1 December, the forum "RSA–JINR: 10 Years Together" was held in the International Conference Centre in Pretoria (RSA). It was dedicated to the 60th anniversary of JINR and 10 years of cooperation of JINR with the Republic of South Africa. Leaders and senior specialists of JINR took part in it. The agenda of the forum included discussions of cooperation results for the past decade and prospects for further development. Representatives of the diplomatic corps of the countries that participate in the activities of JINR, delegations from the RSA Department on Science

and Technology (DST), the National Research Foundation (NRF), the National Cyclotron Laboratory of RSA iThemba LABS, the leading state company of RSA in atomic energy NECSA and a number of universities attended the forum.

At the opening ceremony, the following persons addressed the audience: General Director of DST Ph. Mdjwara, Deputy Director of NRF G. Pillay and Minister-Counselor of the RF Embassy in RSA A. Litvinov. JINR Director V. Matveev spoke to the participants about modern achievements and plans for development at JINR. He handed commemorative diplomas and medals to the representatives of South African organizations and universities for their large contribution to RSA–JINR cooperation. A poster exhibition was opened during the forum, which showed JINR cooperation with RSA and important joint projects.

In conclusion, the JINR delegation visited RSA scientific research centres in Johannesburg, Cape Town and Stellenbosch.

On 28 November, the official launching ceremony of a high-tech line for assembling and testing of superconducting magnets was held at the Veksler and Baldin Laboratory of High Energy Physics of JINR. Leaders of the projects NICA and FAIR (Darmstadt, Germany), Dubna Administration, and representatives of scientific groups took part in it.

The shop where the line is set occupies an area of 2500 square meters. New technological equipment is installed here, a group of qualified specialists is established who will assemble and test 350 magnets for the NICA project and 310 magnets for the FAIR project. The magnets are tested in special high-tech areas designed by laboratory specialists and equipped with high-precision devices.

The ceremonial pressing of the button launched the line; the stand for control of the processes and the information display switched on. VBLHEP Deputy Director Professor G. Khodzhibagiyan conducted an excursion for the participants of the ceremony and journalists. A technical meeting was held within the event, where reports on magnet development were given. A Protocol of launching the test bench was signed.

On 1 December, the 16th meeting of the Joint Coordinating Committee on RSA–JINR cooperation was held in Pretoria. The meeting was in an extended format. JINR was represented by all laboratories and the UC. The RSA participants represented the Department on Science and Technology, the National Research Foundation and coordinators of different subject trends.

During the meeting, the results of the first year of the three-year cycle of joint projects approved at the previous meeting were considered. Preparation was started for several new projects aimed at widening of JINR cooperation with iThemba LABS in accelerator and experimental technology for heavy ion physics of high and medium energy, and in radiobiology. A special mention was given to high effectiveness of educational projects of JINR. The participants discussed issues of improvement of interactions and management of projects, further steps to widen cooperation and strengthen ties in the NICA project.

A press conference on naming the new elements of the Mendeleev Periodic Table of Elements was held **on 12 December** in the conference hall of JINR's Flerov Laboratory of Nuclear Reactions. JINR Director Academician V. Matveev, Scientific Leader of the Flerov Laboratory of Nuclear Reactions Academician Yu. Oganessian, and Director of the Flerov Laboratory of Nuclear Reactions Professor S. Dmitriev answered questions of journalists from seven central Russian TV channels and other mass media representatives.

Academician V. Matveev opened the press conference. He emphasized outstanding achievements of the scientific community of the Flerov Laboratory of Nuclear Reactions, founder of the laboratory Academician G. Flerov, the Scientific Leader of FLNR Academician Yu. Oganessian and FLNR Director Professor S. Dmitriev. V. Matveev also mentioned the jubilee of JINR and the new Seven-Year Plan of the Development of JINR with one of the important tasks being the construction of the Factory for Superheavy Elements.

Answering the questions of journalists, Yu. Oganessian said that on 2 March the inauguration ceremony of new names of the elements would be held in Moscow in the RAS Central House of Scientists, with the participation of scientists from JINR Member States, the USA and other countries. On behalf of the JINR Directorate and FLNR Directorate, Academician V. Matveev invited all in attendance to take part in the ceremony of the international inauguration of the new elements' names.

CONFERENCES AND MEETINGS HELD BY JINR

Nine conferences were the largest among the scientific conferences and workshops held at JINR in 2016.

On 25–30 January, LIT hosted the 23rd International conference ***"Mathematics. Computer. Education"***. The conference has been held since 1993 and manifested itself as a productive form of exchanging experience among specialists in various research areas including mathematicians, biologists, economists, and teachers.

The conference was attended by 250 scientists from the JINR Member States and 32 cities of Russia, Ukraine, Belarus, and Kazakhstan. A symposium "Biophysics of Complex Systems. Molecular Modeling. System Biology" was organized in the framework of

the conference. Some sessions on mathematics, mathematical simulation and computing methods, biology, economics and pedagogy included oral and poster reports. Alongside with the traditional round tables "Debatable problems of natural sciences" and "Cultural space of Russia", new round tables "Architecture and biophysics", "Experimental economics", and "Mathematical problems in biology" were organized.

The participants of plenary sessions heard the lectures of prominent Russian scientists on topical problems in different scientific fields.

At the opening and during the conference, the leading specialists from JINR presented their reviews of the large-scale scientific programmes and projects such as NICA (G. Trubnikov, JINR Vice-Director), DRIBs — the construction of the Factory of Superheavy Elements (S. Dmitriev, FLNR Director), BAIKAL — the neutrino programme on using Lake Baikal for neutrino detection (D. Naumov, DLNP Deputy Director). The JINR leading experts determined trends of the reports in the field of physics and computational mathematics. The tendencies of the modern development of distributed computations necessary for big data processing were considered in the report delivered by V. Korenkov, LIT Director. E. Krasavin, LRB Director, Corresponding Member of RAS, spoke about a radiation barrier during manned flights in deep space. V. Natiaganov (Faculty of Mechanics and Mathematics, MSU) acquainted the conference participants with critical parallels of the planet, an astronomical chronograph of seismicity and discussed dangerous geophysical experiments.

The biological direction of the plenary reports was presented by a number of outstanding specialists in biophysics, molecular biology and mathematical simulations of biological systems. A. Rubin (Head of Biophysics Department, Faculty of Biology, MSU, Corresponding Member of RAS) reported on the modern problems of the development in biophysics. O. Chernavskaya and D. Chernavsky (Lebedev Physics Institute, RAS) spoke about applications of mathematical modeling in cognitive science (knowledge engineering). A concept of perception of a masterpiece mentioned in the report caused a lively discussion which continued at the round-table session "Debatable problems of natural sciences". R. Efremov (Shemyakin and Ovchinnikov Institute of Bio-Organic Chemistry, RAS) presented cellular membranes as stochastic dynamic systems and discussed the opportunities of designing new membrane materials. D. Logofet (MSU Institute of Physics of Atmosphere, RAS) emphasized modeling as a tool for studying biological systems and spoke about applications of matrices and graphs for these purposes. The application of the new mathematical method which has led to the discovery of a new phenomenon in small reed ontogeny (a perennial plant (cereal) occupying open spaces) was an interesting and instructive example. A. Tsaturjan (MSU Institute of Mechanics) reported on the mechanisms of work of the actin-myosin motor of cross-striped muscles. A. Medvinsky (Institute of Theoretical and Experimental Biophysics, RAS) raised an interesting and important question of conformity of the reality model using an example of chaotic modes in the models of the population dynamics.

The JINR educational programmes and the innovative principles of IT education at the University "Dubna" were presented by S. Pakuliak, Director of the JINR University Centre, and E. Cheremisina, Director of the Institute of System Analysis and Management (University "Dubna"). V. Tikhomirov (Faculty of Mechanics and Mathematics, MSU) discussed the purposes and concepts of mathematical education. A. Degtyarev (St. Petersburg State University), as an expert in computing sciences, reported about specificity of physical and mathematical training in the institutes of higher education. G. Polotovsky (Nizhni Novgorod State University) in his report discussed a question of the mutual understanding among mathematicians and specialists in nonmathematical areas.

Hot social and economic issues were covered in the reports delivered by prominent specialists in the field of social economy and mathematical simulation. A. Warshawsky (Central Economics and Mathematics Institute, RAS) discussed some social, economic and political challenges due to excessive inequality. In their joint report V. Livshyts (Central Economics and Mathematics Institute, RAS) and S. Panov (University "Dubna") also touched on the theme of inequality in Russia and stressed its consequences. A lively debate was caused by G. Malinetsky's report (Keldysh Institute of Applied Mathematics, RAS) that discussed and united the topics of science, war of the future and arms race in Russia.

In total, the plenary sessions included 20 reports considering the urgent problems of physics and mathematics, economics and sociology, biology and education. This reflects in full the interdisciplinary character of the conference and a problem of searching the ways of overcoming the language barriers among specialists in different fields of science.

The thematic symposium "Molecular Modeling" (chairpersons M. Khrenova and I. Kovalenko) was devoted to application of the methods of quantum chemistry, molecular and Brown dynamics to solving the problems arising in chemistry and biology. A competition for the best poster report was won by D. Khomich with her work "Research in molecular mechanisms of ion adsorption on lipidic membranes".

The thematic symposium "System Biology" (chairpersons T. Pliusnina and A. Sorokin) was devoted to the problems generating at the interface of molecular biology, computational mathematics, bioinformatics and the theory of complex systems. A. Sorokin's report "Rule-based modeling of systems of the intracellular signality" reviewed a situation in the modeling of signality pathways. E. Metelkin reported on the use of mathematical simulation for solving urgent problems of mod-

ern pharmacology. G. Lebedeva spoke about a global analysis of sensitivity in the application to the models of system pharmacology. P. Ermachenko presented a promising method of creating photobiological architectural shells — the generative planning.

Alongside with the sectional sessions and round tables, 11 master classes were held to acquaint the conference participants with the bases of modern high-level programming languages and their application for simulations when solving some research tasks.

A master class "Parallel programming technologies for computing systems with hybrid architecture" provoked particular interest. For four days, representatives of the team on heterogeneous computations HybriLIT (LIT JINR) headed by O. Streltsova held the tutorial. The questions of designing effective applications to perform calculations on the heterogeneous computing systems containing multi-core CPU, graphic processors (GPUs) and co-processors Intel Xeon Phi were considered during the lectures and practical training.

The international conference "Mathematics. Computer. Education" was organized at a high scientific level. It is pleasant to note that the list of the conference attendees has been appreciably changed towards increasing the number of young people. The conference was traditionally brought to an end with a discussion of the work of the sections and awarding young participants with certificates for the best reports.

A bus tour to the accelerator complex NICA and a concert of the popular singer of Russian romance Yulia Ziganshina were organized within the conference.

From 14 to 18 March ***the 20th International Scientific Conference of Young Scientists and Specialists*** was held at the Bogoliubov Laboratory of Theoretical Physics. Being a jubilee event, it was devoted to the 60th anniversary of JINR. The highly topical programme of the conference was meant, according to its organizers, to reveal maximum peculiarities of each laboratory of JINR, show scientific achievements in fundamental and applied research.

Young JINR staff members were almost a half of the total number of attendees, while the other half was represented by students and postgraduates of universities of Belarus, Cuba, the Czech Republic, Egypt, Finland, Germany, India, Kazakhstan, Poland, RSA, Russia, Serbia, Slovakia, Sweden, and Ukraine.

Directors and leading specialists of all JINR laboratories gave review lectures at the conference. Participants presented their own scientific results in posters or oral presentations at the meetings of nine topical sections. Traditionally, a competition for the JINR Prize was held among young scientists and specialists. In the evenings a sports entertaining programme was organized for the conference attendants.

On 12–15 April, a regular international session-conference ***"Physics of Fundamental Interactions"*** of the Section of Nuclear Physics of the Physical Sciences Division of the Russian Academy of Sciences (SNP PSD RAS) was held in Dubna. This time it was dedicated to the 60th anniversary of the establishment of the Joint Institute for Nuclear Research. Over 450 scientists from many scientific centres, universities of Russia, representatives of big international collaborations of the USA and Europe gathered in Dubna. The participants of the session-conference discussed many topical important issues in view of determination of the direction of modern and future development of science in elementary particle physics, nuclear physics, new heavy transuranium elements physics, condensed matter physics and matter states in extreme conditions defined by high temperature and matter density.

For four days, 35 plenary invited reports and over 300 presentations were made at ten parallel sections on physics at colliders, theory of fundamental interactions, physics of flavours, hadrons and exotics, nuclear physics at low and intermediate energy, nuclear physics at high energy, neutrino physics, astrophysics of particles, gravitation and cosmology, detectors, experimental procedure and nuclear physics methods, physics and technology of accelerators.

The scientific programme of the session-conference opened with a plenary report on the search and discovery (September 2015) of gravitational waves (the gravitational wave observatory LIGO, USA), where Russian research groups were actively involved. The results of the research are undoubtedly an outstanding event in the life of modern scientific world community.

Much attention was paid to the development of home scientific experimental base in studies of the microworld conducted by young Russian scientists, engineers and specialists from JINR Member States. Invited reports and unconventional presentations related to the development of the RF-supported project of the accelerator complex with a heavy-ion collider of the superconducting type, NICA, implemented at JINR in the framework of an international collaboration of many Member States of the Institute and other countries raised particular interest and many questions. In several years fundamental research will be held in Dubna at this complex to study super dense state of matter at high temperature and huge values of baryon density of nuclear matter, spin structure of strongly interacting particles and hadrons, and a wide range of applied research and innovative studies will be conducted. A unique ring accelerator Nuclotron is already operating successfully in Dubna. Launched in 1993, it is one of the main elements of the NICA complex.

Experiments on the synthesis and studies of nuclear physical and chemical properties of superheavy elements were in the spotlight in discussions of issues in low energy physics. Joint research of heavy ions held at JINR accelerators brings bright results in discoveries of new chemical elements, filling the remaining "vacancies" in the Mendeleev Periodic Table of Elements.

Representatives of large international collaborations, such as CDF and D0 at the proton–proton collider Tevatron in the Fermi National Accelerator Laboratory (USA), detectors ATLAS, CMS and ALICE at the Large Hadron Collider, and COMPASS at the superproton synchrotron at CERN (Switzerland), spoke in their reports about the considerable contribution of Russian and JINR scientists to experimental programmes in elementary particle physics.

The Dubna SNP PSD RAS session-conference summed up the results of the studies of fundamental properties of matter, accounting for the 60-year experience and development of JINR in collaboration with scientific and educational centres of Russia, JINR Member States, and many other countries, and outlined principal directions in search of new physics.

The 24th International Seminar on Interaction of Neutrons with Nuclei: Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics (ISINN-24) took place in Dubna from 24 to 27 May. The seminar is organized every year at the end of May by the Frank Laboratory of Neutron Physics. This year it was dedicated to the 60th anniversary of JINR.

The seminar was attended by about 70 researchers from different JINR laboratories, about 30 scientists from Russia and CIS, as well as by around 30 representatives from a wide variety of countries, including Bulgaria, Belgium, Vietnam, Germany, Egypt, Italy, China, Poland, Romania, France, the USA and South Africa. During the four working days, the participants presented a total of 50 oral and 50 poster reports on the themes of the seminar. The scientific programme included sessions traditional for ISINN: fundamental interactions and UCN physics, physics of nuclear fission, nuclear analytical techniques in biology and ecology, nuclear reactions with fast neutrons, nuclear structure, methodological aspects of experiments with neutrons, accelerator-driven subcritical systems. The section devoted to the review of the available neutron sources, sources currently under construction and those that are planned, as well as to the research programmes for them, became a distinctive feature of this seminar.

The scientific programme of the conference was opened by a report of Liang Tianjiao (China) on the current status of the Chinese Spallation Neutron Source (CSNS). The main objective of designing the new CSNS source is the creation of a large installation for investigations in the field of materials science, life sciences, neutron radiography, i. e., all research areas that are associated with the neutron scattering techniques. The installation is being built in Guangdong province, an hour's journey from the Hong Kong Airport. Its startup is scheduled for 2018. The report presented by V. Aksenov was devoted to the review of European neutron sources and prospects for completion of the construction of the high-flux reactor PIK in Gatchina. G. Tagliente (Italy) spoke about the experimental programme being implemented at CERN's pulsed fast neutron source nTOF and new experimental possibilities of the facility due to the commissioning of a new short flight path. O. Shcherbakov (Russia) spoke in detail about the programme of research carried out at the pulsed neutron source GNEIS, which has been successfully operating for many years at PNPI. The report of FLNP Director V. Shvetsov was focused on the current status of the source of resonance neutrons IREN of JINR's FLNP and plans for the development of the facility. V. Khryachkov (Russia) presented a report on investigations with fast neutrons produced by the accelerator complex at IPPE in Obninsk.

The section dedicated to the physics of ultracold neutrons was opened by P. Geltenbort (ILL, France) with a review of the recent achievements in this area made in different research centres and, first of all, at the Institut Laue–Langevin that he represented. Precision measurement of the neutron lifetime is one of the most topical problems for UCN physics. The existing situation with the difference in the measurement results from beam and storage experiments only "adds fuel to the fire". Hydrogen-free oils remain to be good candidates for creating UCN traps with low losses. The results of the studies of the properties of these oils were covered in two reports presented by FLNP researchers Yu. Pokotilovski and E. Lychagin. A young FLNP researcher M. Zakharov reported on the methodological developments of a group of physicists from FLNP who are concerned with the verification of the weak equivalence principle for the neutron. The Fourier UCN spectrometry method realized by the group will make it possible to improve the accuracy of measurements by a factor of 10. In his report, V. Ignatovich proposed a specific experimental layout to test the concept of wave packets, which, in his opinion, can and should be implemented in practice to verify the fundamental principles of quantum mechanics.

The second day of the seminar started with two plenary reports. Then the participants took part in two parallel sessions: one was focused on the use of nuclear-physical analytical methods, mainly neutron activation analysis (NAA), to solve applied problems of ecology, biology and materials science; and the other, on the problems of electro-nuclear systems and nuclear structure.

The first plenary report was delivered by the former NASA employee R. Hoover (USA), who is now working at Athens State University (Alabama, USA) and the University of Buckingham (UK). For many years he has been involved in astrobiology research, trying to answer the main question — whether life is restricted to the planet Earth or more widely distributed across the Cosmos. The objects of research are the planets of the Solar System, comets visiting it and meteorites that fell on Earth at different times. By demonstrating electron microscope images of microscopic fossils found

in meteorites and considering the recent data on the distribution of water, oxygen and other chemical compounds on the planets, Professor R. Hoover comes to the conclusion that life might be distributed throughout the Solar System much more widely than we believe and it is quite possible that life on Earth was seeded from space.

M. Frontasyeva made a detailed report on the current state of affairs in the FLNP's NAA sector. She spoke about the history of the development of the sector, the construction of the neutron-activation complex REGATA, its development and current possibilities, as well as about the recent achievement — automation of the process of obtaining spectra of irradiated samples. It was demonstrated that there had been a steady growth of interest from the JINR Member States in the studies conducted in the sector. The speaker also outlined an extensive scientific programme implemented at the REGATA facility.

The relevance of investigations at the REGATA facility was confirmed in the reports of the participants of the section "Neutron activation analysis and life sciences". This section attracts a large number of young scientists. R. Hoover (USA) said that while studying meteorites scientists started to apply the NAA method used at FLNP to determine the degree of the difference of meteorites from terrestrial rocks. The results of investigations of materials of extraterrestrial origin were reported by M. Frontasyeva. O. Duliu (Romania) presented the results of the use of various analytical techniques, including NAA, in a comparative study of nine orthodox icons. A guest from Egypt W. Badawy and his colleague M. Ibrahim reported on the results of the study of sources of pollution in the delta of the Nile, which plays an important role in the country. A. Ene (Romania) spoke about the studies on the extent of pollution with metals in Romania and in the Danube region. P. Nekhoroshkov (FLNP) reported on how he uses the NAA to study phytoplankton of the Black Sea. The report of D. Vu (Vietnam) was devoted to the study of air pollution in Vietnam using the moss biomonitoring technique. I. Zinicovscaia, on behalf of a broad collaboration of scientists from Dubna, Egypt and Romania, talked about the investigation of the Red Sea corals. V. Zaichick (Obninsk) presented new results of the study of changes in the composition of trace elements in inflamed bones.

The session devoted to the properties of electronuclear systems (ENS) being designed was opened by an invited talk given by A. Stankovskiy (Mol, Belgium) on the status of the first (approved for implementation in 2010) ENS project MYRRHA. This large international project with an estimated cost of about one billion euros was funded up to 30% by the Belgian Government with the expectation of further support being provided by interested countries and institutions. However, difficulties with the licensing of already developed technical solutions for the project forced them to reconsider the original plan-schedule. The corrected plan-schedule of the project provides for the construction and testing of various operating modes of the proton linear accelerator with the simultaneous work on the improvement and licensing of the whole installation. Naturally, the commissioning date for ENS MYRRHA is shifted well beyond 2020. The report triggered a lively discussion since the investigations carried out at JINR with a model of ENS QUINTA, as well as planned experiments with a large uranium target, might be useful in overcoming the difficulties with the licensing of ENS MYRRHA.

The reports made by J. Adam and J. Khushvaktov (DLNP), as well as by M. Bielewicz (VBLHEP), were devoted to the discussion of the results obtained in the experiments with the model of ENS QUINTA at JINR Nuclotron and Phasotron accelerators. The speakers presented new and more accurate data on the spectra of secondary neutrons generated inside and on the surface of the uranium target assembly QUINTA under the action of bombarding deuterons and protons. In this hard neutron field the reactions on the sample of metallic thorium were studied at the energy of incident deuterons of 6 GeV. The report of P. Zhivkov (INRNE BAS, Sofia) dealt with the uncertainties in the calculations of properties of ENS with a quasi-infinite (having low leakage of secondary neutrons) core, which are the result of using different nuclear databases. The discussion that followed the report has shown that a careful approach should be taken when using standard transport codes in the calculations of ENS.

The final session of the second day of the seminar was focused on the problems of gamma decay of excited states of heavy nuclei produced in a thermal neutron capture process (A. Sukhovoj, FLNP), nonstatistical regularities in the properties of neutron resonances and their possible relation to the mass spectrum of elementary particles (S. Sukhoruchkin, NRC KI PNPI). The discussion of these results demonstrated the usefulness of neutron physics methods for the investigation of fundamental problems of nuclear structure and the Standard Model.

The third day was entirely devoted to methodological issues. M. Qiu from the Northwest Institute of Nuclear Technology (China) presented the design of a fission chamber based on helium scintillation for detection of fission neutrons. The report of his colleague X. Weng was focused on the development of z-pinch imaging technique using the penumbral method from plasma neutron radiation, as well as on the design of a special diaphragm for this method. L. Zavorka (DLNP JINR and PTB, Germany) reported on the successful use of the technique of digital signal processing for different detectors of intense neutron fluxes. This technique is gaining increasingly wide acceptance and is of considerable interest for experimenters. G. Ahmadov (FLNP) presented the results of tests of an alpha-particle position-sensitive detector based on LYSO scintillator and micropixel avalanche photodiodes. The presented

results look promising, and the work to improve the resolution of the detector will be continued. A. Gagarski (NRC KI PNPI) presented the results of the successful use of a low-pressure gaseous multiwire fission chamber designed at PNPI. The chamber made it possible to obtain interesting physical and methodological results for studies of angular distributions of fission fragments as well as for monitoring neutron beams. Yu. Rogov (Diamant LLC, Skolkovo) spoke about the successful application of the tagged neutron method for detecting diamonds in kimberlite ore. D. Hliustin (INR RAS) presented methodological results obtained with the time-of-flight spectrometer RADEX of the linear proton accelerator of the Moscow Meson Factory. D. Berikov (DLNP) reported on the current status of the KOLKHIDA facility, which had undergone a thorough modernization and is ready for the implementation of the scientific programme aimed at studying interactions of polarized neutrons with polarized nuclei.

As was the case in the previous seminars, the fission section, which was held on the final day, turned out to be quite eventful. F. Goennenwein from the University of Tübingen (Germany) gave a review on the problem that has almost escaped the attention of the researchers recently — the appearance of effects in fission caused by not only the known shells and magic numbers, but also the so-called anti-shells. In particular, he drew attention to the experiments conducted in the 1990s by the group from IPPE under the supervision of A. Goverdovskii, and pointed out that there had been no intelligible theoretical explanation of those results yet. Two reports were devoted to T-odd effects in fission. S. Kadmensky proposed a new version of the theoretical description of the effects, and G. Danilyan presented an overview of the experimental results obtained in the framework of the international collaboration on the FRM-2 reactor in Garching. A. Vorobyev from Gatchina reported on the results of the studies performed at the GNEIS facility to determine the angular anisotropy of fission fragments of heavy nuclei from neutron-induced fission in the neutron energy range of up to 200 MeV. A theoretical approach to the description of the anisotropy of this kind has been suggested by A. Barabanov from the Kurchatov Institute. I. Guseva (Russia) presented a report on the study of neutron–neutron correlations in the neutron-induced fission. The report of Sh. Zeynalov (FLNP) was devoted to the description of the technique of measuring prompt fission neutrons using digital technology. Lastly, in the final report of the seminar, P. Egelhof from Darmstadt (Germany) discussed a unique setup currently used at the reactor of the ILL in Grenoble for precise measurements of fission fragments. The principle of operation of the setup is based on the accurate measurement of the temperature of heating of a sapphire crystal hit by fission fragments. This makes it possible to avoid a lot of systematic errors inherent in the majority of other methods.

As before, ISINN continues to be a platform where participants can present their as-yet-unpublished and sometimes preliminary results, where in an informal and enjoyable atmosphere in the breaks between sessions and during the traditional picnic one has a chance to discuss one's work with colleagues, get advice, and establish new scientific contacts and cooperation.

The presentations of ISINN-24 and materials of the previous seminars are available at the web page: http://isinn.jinr.ru

III International Conference on Small-Angle Neutron Scattering (YuMO2016) took place at the Frank Laboratory of Neutron Physics on 6–9 June. The meeting was dedicated to the 80th anniversary of Yuri Mechislavovich Ostanevich (1936–1992), who made a crucial contribution to the construction of spectrometers at the pulsed reactor IBR. He was one of the originators of the development of the time-of-flight SANS technique and the selection of advanced scientific areas for its application. His leadership and outstanding scientific achievements in SANS studies of polyelectrolytes, small molecules, fractals, metallic glasses, macromolecules, polymers, etc. were recognized by a number of awards including the State Prize of the Russian Federation in 2000. The small-angle neutron scattering (SANS) instrument successfully operating at the IBR-2 reactor is called YuMO in his honour.

YuMO is a successor of the first-ever SANS instrument built on a "white" neutron pulsed beam (named CsOK after Cser, Ostanevich, and Kozlov), which together with its two-detector system allows now performing rapid measurements in a wide q-range. Nowadays the SANS technique is applied to a wide range of scientific problems in condensed matter, soft matter, biology and nanotechnology. Despite the fact that there are currently over 30 SANS instruments in operation worldwide (both at reactors and at spallation sources), the demand for beam-time is considerably higher than the time available.

The YuMO2016 conference focused on providing opportunities to discuss various possibilities of exploiting the SANS technique in many aspects of condensed matter research. It also provided ground for the scientific and technical development requests from the YuMO spectrometer users, as organized in the previous user meetings, the first of which was held in 2006. At that meeting research groups from different neutron centres, universities and research institutes across Europe presented over 35 oral and poster contributions describing scientific and methodological results. Most of them were obtained using the SANS-YuMO instrument before the high-flux pulsed reactor IBR-2 shutdown in 2006. The second event was organized in June 2011 after the IBR-2 refurbishment and accomplishment of modernization works and the start-up of scientific experiments. It brought together leading scientists in SANS and soft condensed matter re-

search from 12 countries (including the Czech Republic, Egypt, France, Germany, Hungary, Moldova, Mongolia, Poland, Romania, the Russian Federation, the Slovak Republic, and Ukraine) who gave 27 oral talks and presented 32 posters. The third meeting of this successful series has been expanded to a full conference format due to the ever increasing interest in the YuMO instrument. This time FLNP had an opportunity to welcome more than 110 participants from 14 different countries and three continents (Europe, North America and Australia). The scientific programme included 43 oral presentations and more than 60 posters presented during the poster sessions and breaks.

The conference introductory session was opened by FLNP Director V. Shvetsov and was followed by Ostanevich's former close collaborator and co-founder of the YuMO instrument Dr. L. Cser, who shared his memories about his friend. The overall picture of the JINR activities was delivered by JINR Vice-Director R. Lednický, while more details on FLNP, its user programme, and current status of the YuMO spectrometer were provided by the laboratory personnel. Professor H. Stuhrmann started the first topical session dedicated to the SANS methods and instrumentation by describing the role of polarized neutrons in the localization of free radicals in the structural biology. The poster session, comprising more than 30 posters, concluded the first day of the conference.

The topic of the second day focused on bio-related SANS studies. It was opened by Dr. N. Zaccai from Cambridge University, who presented his results concerning the membrane protein biogenesis obtained from neutron analysis. The programme continued with more talks regarding the utilization possibilities for neutrons, and SANS in particular, in the studies of drug delivery systems, neurodegenerative diseases, and other aspects of biomembranes. The closely related topic of complex system investigations by means of SANS including soft matter research continued to be the focus of the next day agenda. Dr. A. Ozerin discussed the questions of the current status and future outlook for polymer-nanoparticles composites. The theme of nanoparticles, some of which can be loaded with magnetic material and those that have some relation to biological applications, was discussed throughout this session and also further during the day.

Professor A. Michels opened another part of the complex system session, the one that focused more on the magnetic aspect of matter and methodology. The session later changed topic, presenting atomic force microscopy, NMR, Raman spectroscopy, and molecular dynamics simulations as complementary methods for condensed matter research, which was followed by another poster session displaying again more than 30 posters at the end of the day. The specific role of SANS in condensed matter research became the topic of the last day of the meeting. Dr. J. Teixeira presented this aspect in the case of physical studies of liquid water, while Academician E. Burzo surveyed exchange interactions in heavy rare-earth compounds. Much more condensed matter studies, either utilizing SANS or other complementary techniques, were presented during this session that included but was not limited to the talks concerning the structures of nanoparticles and nanocomposites for advanced and industrial applications.

The final presentation of the conference took the participants overseas to the Oak Ridge National Laboratory, out of which Dr. J. Katsaras presented the approaches of his group in the search of nanoscopic lipid domains in real biological membranes. The presentation was delivered via video recording followed by the live discussion over internet.

The conference chairs Dr. A. Kuklin, Dr. M. Balasoiu, and Dr. N. Kucerka concluded the event by expressing their gratitude to the Organizing Committee and participants. Finally, and perhaps most importantly, it was more than intriguing to listen to the role of neutrons and/or small-angle scattering methods utilized in the presented studies and across various scientific fields.

On 15–28 June, ***the European School on High Energy Physics*** was held in Skeikampen (Norway). It is traditionally organized by JINR with CERN and JINR Member States, each in its turn. Professor H. Sandaker from Oslo University headed the Organizing Committee in Norway, her colleagues and the permanent Organizing Committee from CERN and JINR assisted her in holding the event.

As is known, this series of schools is especially popular for its high level of modern lectures, discussion sessions, student projects and other events whose programme is constantly upgraded.

This time, 102 students of 34 nationalities, mainly from CERN and JINR Member States, and other places attended the school.

Thirty-two lectures were given by leading world specialists in various fields of high energy physics in the framework of the school; they were accompanied by special discussion sessions for better mastery of the information. I. Tkachev (INR RAS) gave a basic course on cosmology, JINR staff members A. Sapronov and R. Sadykov were leaders of two discussion groups.

Eight students from JINR attended the school, 4 other students came from Russian institutes and 9 students from institutes of Member States: Bulgaria, Poland, Romania, Slovakia, the Czech Republic, and Hungary. They had additional support from JINR.

Participants showed much interest in lectures on scientific programmes and plans of further development of CERN and JINR which were traditionally presented by the leaders of these scientific centres Professor F. Gianotti and Academician V. Matveev.

A brief course of methods to present scientific results to the public has been included in the agenda of the school for several recent years. This time, after the lectures by BBC journalists a competition of stu-

dent projects was held as practice classes, where each discussion group spoke on a selected topic. Professor E. Lillestol, who had been a successful organizer of these schools for many years before, headed the competition jury.

The participants of the school will also remember wonderful landscapes and tourist excursions where they had to demonstrate skills of mountain climbing. But the main pleasure was in contacts that resulted in better understanding among young scientists.

On 4–9 July, the Laboratory of Information Technologies hosted the 7th international conference ***"Distributed Computing and Grid Technologies in Science and Education" (GRID'2016)***. The conference is held every two years and is traditional for the laboratory. This year the conference was dedicated to the 60th anniversary of JINR and the 50th anniversary of LCTA (now LIT).

The GRID conference is a unique platform for discussing a wide range of issues related to the use and development of distributed grid technology, heterogeneous and cloud computing in various fields of science, education, industry and business. The conference attracted a large community of Russian and foreign specialists ready to discuss emerging challenges and prospects of the development of advanced information technology. The conference was attended by more than 250 scientists from the research centres of Azerbaijan, Belarus, Bulgaria, Chile, China, Czech Republic, France, Georgia, Germany, Moldova, Mongolia, Romania, Slovakia, Sweden, and other countries. Russia was represented by participants from more than 30 universities and scientific research centres. The conference was organized in ten sections which discussed the issues related to the development of grid technologies, heterogeneous computing, volunteer computing, cloud computing, big data analytics. Also, in the framework of the conference a school for young scientists, postgraduates and students was organized, where tutorials were conducted on heterogeneous and cloud computing.

Financial support for the conference was provided by the JINR Directorate. The sponsors and partners of the conference were IBS Platformix, Supermicro Computer, NIAGARA, Brocade, INSPUR, Innopractika, Jet infosystems, Schneider Electric, NVIDIA, I-Teko, Intel, PARALLEL.RU, as well as the Open Systems publishing house.

The conference was opened by JINR Director V. Matveev. He delivered a report devoted to the history, current status and perspectives of the development of the Institute and emphasized that the information infrastructure of JINR is one of its basic facilities.

The plenary session was opened by the Chairman of the conference LIT Director V. Korenkov who reported on the current status and prospects of the development of the Laboratory of Information Technologies. Special attention was focused on the grid infrastructure, including the creation of the Tier-1 centre, the development of computing for the NICA megaproject and the creation of a heterogeneous computing system and other projects actively developing at LIT.

In his plenary report, Li Weidong (Institute of High Energy Physics, Beijing, China) presented an overview dedicated to the development of grid technologies in China. Li Weidong highlighted fruitful cooperation between JINR and China, within which software for projects JUNO and BESIII had been developed.

A report on the current status and plans for implementation of the NICA megaproject was made by JINR Vice-Director G. Trubnikov.

The plenary talk given by V. Voevodin (MSU SRCC) overviewed the development of computing at Moscow State University and discussed some prospects of designing new parallel algorithms due to the rapid development of new computing architectures and parallel programming technologies.

A number of plenary reports were made by the representatives of the IT industry which sponsored the conference. These reports analyzed the development of information technologies and the development trends in storage systems, computer communications, new computing architectures as well as designing large computing centres.

Dr. T. Strizh (LIT JINR) gave an overview of the status and perspectives of the development of Tier-1 centre at LIT for the CMS experiment which was commissioned at LIT in early 2015. The report noted that during the work on the creation and operation of Tier-1, invaluable experience was accumulated which would be demanded in the design, construction and operation of the future information and computing centre for the NICA megaproject.

A plenary lecture given by V. Velikhov (NRC "Kurchatov Institute") was devoted to the current status and development prospects of the centre Tier-1 at NRC "Kurchatov Institute" in connection with the second session at the Large Hadron Collider (LHC).

Great interest of the conference attendees was aroused by the report delivered by O. Smirnova (Lund University, Sweden) devoted to the current trends in distributed computing and data storage systems using an example of NorduGrid, covering different aspects, from technological to political ones.

M. Borodin (MEPhI) reported on the main component of the ProdSys2 system for the ATLAS experiment. ProdSys2 is used by thousands of physicists for remote data analysis, the volume of processed data being beyond the EXABYTE scale. The report also presented important design solutions ProdSys2 as well as lessons learned from the experience during the second LHC session.

L. Mascetti (CERN) delivered a report on the development of storage systems at CERN using a distributed file system EOS for a cloud-based infrastructure CERNBox which allows effective use of data for sci-

entific and engineering research. The success of the solution EOS/CERNBox is confirmed by its high popularity — the number of users of this cloud storage has recently crossed a threshold of 5000.

In his report, D. Oleynik (LIT JINR) gave an overview of the PanDA (Production and Distributed Analysis System) project, its run on supercomputing platforms as a portal independent of a particular computing infrastructure and opportunities for the use of this system not only for tasks of high energy physics and nuclear physics, but also for intensive tasks in bioinformatics and astrophysics.

Gh. Adam (LIT JINR) analyzed the development of heterogeneous computing at JINR on the basis of HybriLIT cluster. The report gave a description of the software environment of the cluster for developing parallel applications and carrying out massive parallel computations using various computational architectures. Some examples of using the cluster to solve various problems underway at JINR were given, too.

The report delivered by S. Polyakov (IPM RAS) was devoted to supercomputer process simulations in microelectronics taking into account the atomic and molecular structure of some electronic elements. The report presents an approach to the numerical solving of problems for the calculation of electronic elements with the use of the models of the grid at a macro-level and to solving the equations of molecular dynamics at a micro-level. Since the overall algorithm is quite intensive, its implementation is initially focused on using parallel computing.

A memorial plenary session was dedicated to the 50th anniversary of the Laboratory of Information Technologies. LIT Director V. Korenkov gave a historical overview of the development of computers and IT technologies at LIT and the major achievements. He emphasized a particular role of the founders of the Laboratory M. Meshcheryakov who had made a huge contribution to the creation of the Laboratory, the Institute and the town of Dubna, and N. Govorun who made enormous contribution to the development of automation of scientific researches in the USSR and at JINR. N. Govorun had organized a strong like-minded team consisting of the Laboratory staff with the participation of leading specialists from other Soviet cities and different countries. As important moments in the history of LCTA/LIT, V. Korenkov noted the creation of translator from the FORTRAN language, monitoring system "Dubna", operating system "Dubna", as well as the creation of a terminal network on the basis of the Intercom dialogue system, which finally led to the construction of the local area network JINET integrating practically all the computing machines of JINR, and other important achievements of the Laboratory. V. Korenkov also spoke about JINR–CERN cooperation in the field of computing and about LIT cooperation with leading research centres.

V. Gerdt reported on the development of analytical and quantum computing at the Laboratory. The initiative of introducing analytical (symbolic) computing at JINR belongs to D. Shirkov. The initiative was supported by M. Meshcheryakov and N. Govorun. This work is still successfully progressing at LIT.

The lecture delivered by V. Ilyin (SINP MSU) was dedicated to the history of the development of grid technologies in Russia.

A total of 35 plenary, more than 120 oral and 43 poster reports were presented at the conference. Forty students and young scientists from Mongolia, Romania and the Russian universities (MEPhI, St. Petersburg State University and University "Dubna") attended the school.

During the conference the participants were involved in fruitful discussions and arguing; new IT projects aimed at the development of distributed and high-performance computing were proposed. New areas of LIT cooperation with organizations, universities of Russia and JINR Member States were found.

Presentations of the delivered reports, electronic version of the Book of Abstracts as well as conference photos are available on the official site of the conference at http://grid2016.jinr.ru.

From 5 to 10 September Kazan (Russia) hosted ***EXON 2016,*** an international symposium on one of the most important and the most 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 GANIL National Centre (France), the RIKEN Research Center (Japan), the GSI Helmholtz Centre for Heavy Ion Research (Germany), and the National Superconducting Cyclotron Laboratory (Michigan, USA). That is why the heads of these five world leading scientific centres became co-chairmen of the Organizing Committee of the symposium: Yu. Oganessian (JINR), M. Lewitowicz (GANIL), H. En'yo (RIKEN), H. Stöcker (GSI), and B. Sherrill (USA). The symposium was held with the active participation of Kazan (Volga Region) Federal University (KFU). This is the eighth symposium on Exotic Nuclei held in Russia.

The EXON 2016 was attended by about 160 scientists from 20 countries, most of whom are leading experts in the field of nuclear physics. The most representative delegations were from Germany, France, Japan, and the USA. 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 exotic nuclei physics and new projects of the largest accelerator complexes and experimental facilities. In addition, discussions with 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.

At the opening of the symposium, which was held in the old assembly hall, the representatives of the managements of KFU and JINR spoke.

During the symposium, the results of recent experiments on the synthesis and study of properties of nuclei of new superheavy elements were discussed: the discovery of new superheavy elements shows high efficiency of international cooperation. Interesting results were obtained in joint experiments on chemical identification of elements 112 and 114, performed at the Flerov Laboratory of Nuclear Reactions of JINR, the GSI (Germany), and the Paul Scherrer Institute (Switzerland). A vivid example of cooperation with US scientists is an experiment on the synthesis of element 117 held at the cyclotron of JINR FLNR under the leadership of Yu. Oganessian, Academician of RAS. In 2014 Moscow hosted the inauguration of element 114 (flerovium) and element 116 (livermorium) discovered in Dubna.

In June 2016, the International Union of Pure and Applied Chemistry and the International Union of Pure and Applied Physics approved the discovery of new chemical elements of the Mendeleev Periodic Table with atomic numbers 113, 115, 117, and 118.

For the element with atomic number 113 the discoverers at RIKEN Nishina Centre for Accelerator-Based Science (Japan) proposed the name nihonium and the symbol Nh. Nihon is one of the ways to say "Japan" in Japanese, and literally means "the Land of Rising Sun". For the element with atomic number 115 the name proposed is moscovium with the symbol Mc, and for the element with atomic number 117 the name proposed is tennessine with the symbol Ts. For the element with atomic number 118, the collaborating teams of discoverers at the Joint Institute for Nuclear Research and Lawrence Livermore National Laboratory (USA) proposed the name oganesson and the symbol Og. The proposal is in line with the tradition of honoring a scientist and recognizes Professor Yuri Oganessian for his pioneering contributions to transactinoid elements research. His many achievements include the discovery of superheavy elements and significant advances in the nuclear physics of superheavy nuclei, including experimental evidence for the "island of stability".

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 enable significant progress towards the synthesis and study of properties of new exotic nuclei. Projects SPIRAL2, RIKEN RI Beam Factory, FAIR, DRIBs, NICA, FRIB were presented by the heads of these projects H. En'yo, Ch. Scheidenberger, S. Dmitriev, G. Trubnikov, G. Bollen, A. Jokinen, R. Bark, and F. Ibrahim.

Before the start of the symposium, a satellite school "Contemporary Physics and Nuclear Medicine" was held for two days. The leading JINR Professors A. Karpov, G. Trubnikov, Yu. Penionzhkevich, V. Egorov, A. Belushkin, P. Apel, and E. Syresin delivered lectures on modern problems of nuclear physics and nuclear medicine to students, postgraduates and Professors of KFU.

A total of about 80 oral reports and 40 poster presentations were delivered during the symposium. All of them will be published as a special issue of the World Scientific Publishing.

While in Kazan, the JINR Directorate held a meeting with the rector and vice-rectors of Kazan Federal University. They agreed to sign a framework agreement on cooperation between JINR and KFU on training highly qualified specialists and scientific cooperation.

The XXIII Baldin international seminar on high energy physics problems ***"Relativistic Nuclear Physics and Quantum Chromodynamics"*** named ***"Baldin autumn"*** was held on 19–24 September in the Big Conference Hall of the Veksler and Baldin Laboratory of High Energy Physics. The seminar continued the traditional conferences established by Academicians A. Baldin and M. Markov in 1969. This year is the 90th anniversary of Alexander Baldin, so the seminar was dedicated to his memory.

Greeting the participants, V. Matveev emphasized the scientific and organizational contribution of A. Baldin and wished successful holding of the seminar. V. Kekelidze spoke about the importance of the seminar and the support of the International Union of Pure and Applied Physics. Deputy Head of the City Administration N. Smirnov addressed the participants.

The seminar gathered a record number of participants — 250 physicists from 22 countries. There were presented 157 reports, 57 of which were delivered at plenary sessions and 100 at parallel sections. The reports covered the research results of most of the world leading physics centres, such as CERN, GSI (Germany), BNL (USA) and many others. The seminar was supported by the RFBR grant and the grant of JINR Director. There were a lot of young scientists: more than a quarter of participants were under the age of 35.

On the first day of the seminar the reports were devoted to activities of A. Baldin. Professors A. Malakhov, V. Burov, A. Kovalenko, and S. Gerasimov made reports. VBLHEP Head of Sector Anton Baldin described some methodological and philosophical ideas of Academician A. Baldin; P. Zarubin spoke about results obtained at nuclear beams of the Synchrophasotron and the Nuclotron. Professor L. Pondrom (USA) and Professor N. Konopleva (Moscow) made interesting reports. At the first day plenary session, reports of the major collaborations of the Large Hadron Collider were also heard, in particular, of the CMS (I. Gorbunov, JINR) and ATLAS (M. Przybycień, Poland) collabora-

tions. A. Kovalenko (JINR) gave a presentation on the preparation of experiments with polarized protons and deuterons. E. Tomasi-Gustafsson (France) reported on the advances in the study of the hadron electromagnetic structure. V. Kuvshinov (Minsk, Belarus) made a theoretical report about the color states evolution in vacuum at large distances.

The most significant, both theoretical and experimental, results were heard at plenary sessions. Presentations were made by participants from JINR, Russian cities St. Petersburg, Moscow, and Gatchina, as well as from Kazakhstan, Sweden, Germany, France, the USA, Brazil, South Africa, the Czech Republic, South Korea, Poland, Slovakia, and Belarus.

On the second day of the seminar, theoretical reviews were delivered by D. Blaschke (Recent theory developments for NICA), S. Kulagin (Nuclear parton distributions), A. Andrianov (Chiral imbalance in QCD), O. Teryaev (Hyperons polarization in heavy-ion collisions), and A. Zakharov (Graviton mass bounds from an analysis of bright star trajectories at the Galactic Centre). New experimental data were presented by V. Nedorezov (GRAAL) and J. Ritman (FAIR/PANDA).

On the third day, interesting reports devoted to experiments were made by A. Kupsc and A. Dbeyssi (BESIII), D. Marchand (PRAE) and C. Baessler (Nab). The Bethe–Salpeter approach was discussed in theoretical reviews of V. Burov and L. Tomio; J. Cleymans presented the thermal model for small systems, and A. Kataev discussed the new renormalization-group representation.

On the fourth day, P. Federic, M. Tokarev, A. Taranenko, and P. Federicova discussed the latest data from experiments at RHIC/STAR and LHC. S. Olsen made an interesting report on the probing of the $X(3872)$ meson structure with near-threshold pp and pA collisions. E. Golovach introduced, on behalf of the CLAS/CLAS12 collaboration, a report about new states of hadronic matter. Theoretical reports of S. Gerasimov, V. Lukyanov and B. Slowinski were devoted to various aspects of photon– and pion–nucleus scattering.

On the fifth day, V. Ladygin presented a review on investigations of compressed baryonic matter at GSI, R. Schicker and S. Kiselev presented the latest results of the ALICE/LHC collaboration. Wang Ying spoke about polarization measurements for np scattering. I. Savin discussed the azimuthal asymmetries in the COMPASS experiment. H. Machner devoted his report to η mesons bound states, and Yu. Surovtsev spoke about the effect of the η–η channel of charmonia and bottomonia.

On the final day of the seminar, the status and prospects of experimental studies were discussed. So, W. Barth in his report presented a superconducting CW-LINAC for heavy ion acceleration at GSI. V. Kekelidze devoted his detailed report to the NICA project which is virtually the future of VBLHEP. M. Janek spoke about research at the Nuclotron using polarized and unpolarized deuteron beams. M. Pasyuk made an overview of the GlueX experiment at JLab. An overview report of S. Shimanskiy was dedicated to the 45th anniversary of the research of the cumulative effect.

P. Zarubin presented the results of the BECQUEREL experiment for studying nuclear clustering in light nucleus. In a report on the development of the Baldin approach for the relativistic nuclear interactions, A. Malakhov demonstrated a good coherence of predictions with the LHC experimental data.

The parallel sessions were grouped under the following topics: relativistic heavy ion collisions, dynamics of multiparticle production, applied use of relativistic beams, quantum chromodynamics at large distances, hadron spectroscopy and multiquarks, cumulative and subthreshold processes, polarization phenomena and spin physics, studies of exotic nuclei in relativistic beams, accelerator facilities (status and perspectives), structure functions of hadrons and nuclei, and the NICA/MPD project at JINR. The parallel sessions were attended by scientists from JINR, Russian cities Moscow, St. Petersburg, Gatchina, Saratov, Nizhni Novgorod, Samara, Yoshkar-Ola, a number of countries such as Serbia, Kazakhstan, the Czech Republic, Poland, Ukraine, Iran, China, Belarus, Mongolia, and Romania. Almost all reports raised great interest and useful scientific discussions.

One can get acquainted with the reports, which are published in EPJ Web of Conferences, on the website of the seminar: http://relnp.jinr.ru/ishepp/index.html.

PARTICIPATION OF JINR IN INTERNATIONAL CONFERENCES

In 2016, scientists and specialists of the Joint Institute for Nuclear Research took part in 386 international conferences and meetings.

The largest delegations representing JINR attended the following events: the NEMO/SuperNEMO Collaboration Meeting (Bardonecchia, Italy); the 7th JUNO Collaboration Meeting (Xiamen, China); the CLIC Workshop 2016 (Geneva, Switzerland); the NOνA Collaboration Meeting (Dallas, USA); the 52nd Winter School on Theoretical Physics (Ladek Zdroj, Poland); the workshop "Neutron Diffraction – 2016" (Gatchina, Russia); the IAEA Research Coordination

Meeting on Advanced Moderators (Vienna, Austria); the NUSTAR Annual Meeting (Darmstadt, Germany); the 50th Annual Winter School of PNPI NRC KI (St. Petersburg, Russia); the 31st HADES Collaboration Meeting (Darmstadt, Germany); the 50th PNPI School on Condensed Matter Physics (Zelenogorsk, Russia); the 20th International Symposium on "Nanophysics and Nanoelectronics" (Nizhni Novgorod, Russia); the international scientific and practical conference "Radiation Oncology – 2016" (Moscow, Russia); the 26th Daya Bay Reactor Neutrino Experiment Collaboration Meeting (Beijing, China); the 23rd Scientific and Practical Conference of Students, Postgraduates and Young Scientists (University "Dubna") (Dubna, Russia); the 5th conference "Problems of Mathematical and Theoretical Physics and Mathematical Modeling" (Moscow, Russia); the JUNO Monte Carlo and Analysis Workshop (Jülich, Germany); the 1st International Conference on Radioanalytical and Nuclear Chemistry (RANC-2016) (Budapest, Hungary); the 27th CBM Collaboration Meeting (Darmstadt, Germany); the International Workshop on Probing Fundamental Symmetries and Interactions with UCN (Mainz, Germany); the Seminar on Superconducting Detectors and Quantum Technologies (Moscow, Russia); the 6th All-Russian conference "Information and Telecommunication Technologies and Mathematical Modeling of High-Tech Systems" (Moscow, Russia); the 8th annual conference "Polynomial Computer Algebra" (PCA'2016) (St. Petersburg, Russia); the 2nd Conference of the International Humanitarian Project "Minsk Initiative": "Chernobyl: Overcoming. The Contribution of Scientific and Creative Intelligentsia of Belarus, Russia and Ukraine" (Minsk, Belarus); the 22nd All-Russian Scientific Conference of Physics Students (Rostov on Don, Taganrog, Russia); the 10th Central European Training School on Neutron Techniques (Budapest, Hungary); the 7th International Particle Accelerator Conference (IPAC-2016) (Busan, Republic of Korea); the 18th International Seminar on Neutron Scattering Investigation in Condensed Matter (Poznan, Poland); the All-Russian Conference on Problems in Dynamics, Particle Physics, Plasma Physics and Optoelectronics (Moscow, Russia); the 55th Annual Conference of the Particle Therapy Co-operative Group (PTCOG 55) (Prague, Czech Republic); the 11th International Conference on Clustering Aspects of Nuclear Structure and Dynamics (Naples, Italy); the International Conference on Physics of Liquid Matter: Modern Problems (PLMMP-2016) (Kyiv, Ukraine); the Nobel Symposium NS160 "Chemistry and Physics of Heavy and Superheavy Elements" (Scania (Bäckaskog Castle), Sweden); the international conference "Critical Point and Onset of Deconfinement" (CPOD 2016) (Wroclaw, Poland); the PANDA Meeting 2016 II at GSI (Darmstadt, Germany); the Intel Xeon Phi Users Group International Conference (St. Petersburg, Russia); the 15th European Powder Diffraction Conference (EPDIC15) (Bari, Italy); the International School on Subnuclear Physics — the 54th Course: The New Physics Frontiers in the LHC-2 Era (Erice, Italy); the 5th International Workshop on Numerical Modelling of High Temperature Superconductors (Bologna, Italy); the CMS Week (Geneva, Switzerland); the 1st International Conference of Cryogenics and Refrigeration Technology (Bucharest, Romania); the Workshop on Inelastic Neutron Scattering (Spectrina-2016) (Gatchina, Russia); the 35th International Workshop on Nuclear Theory (Govedartzi, Bulgaria); the 27th Carpathian Summer School of Physics (CSSP16) (Sinaia, Romania); the 27th International Conference on Neutrino Physics and Astrophysics (NEUTRINO 2016) (London, UK); the 14th International Conference on Magnetic Liquids (Yekaterinburg, Russia); the 18th GDRE workshop "Heavy Ions at Relativistic Energies" (Nantes, France); the 16th International Balkan Workshop on Applied Physics and Materials Science (Constanta, Romania); the conference "Classical and Quantum Integrable Systems" (St. Petersburg, Russia); the JUNO Collaboration Meeting (Beijing, China); the international conference "Quantum Field Theory and Gravity" (QFTG 2016) (Tomsk, Russia); the 38th International Conference on High Energy Physics (ICHEP 2016) (Chicago, USA); the conference "Recent Advances in Quantum Integrable Systems" (RAQIS'16) (Geneva, Switzerland); the Euroschool on Exotic Beams 2016 (Mainz, Germany); the Zakopane Conference on Nuclear Physics (Zakopane, Poland); the 12th Quark Confinement and the Hadron Spectrum Conference (Thessaloniki, Greece); the 9th International Conference on Nuclear and Radiochemistry (Helsinki, Finland); the 42nd Conference of the European Radiation Research Society (Amsterdam, Netherlands); the International Workshop on Hadron Structure and Spectroscopy (IWHSS 2016) and COMPASS Collaboration Meeting (Seeon, Germany); the 12th European Conference on Atoms, Molecules and Photons (ECAMP 12) (Frankfurt am Main, Germany); the 11th International Conference on Physics of Advanced Materials (ICPAM-11) and the 2nd Autumn School on Physics of Advanced Materials (PAMS-2) (Cluj-Napoca, Romania); the 26th International Nuclear Physics Conference (INPC2016) (Adelaide, Australia); the International Conference on Nuclear Data for Science and Technology (ND 2016) (Bruges, Belgium); the 7th Russian Youth School on Radiochemistry and Nuclear Technologies (Ozyorsk, Russia); the 21st International Conference on Cyclotrons and Their Applications (Zürich, Switzerland); the International School of Astroparticle Physics (ISAPP2016) (Milan, Italy); the international conference and school of young scientists "Superconducting Hybrid Nanostructures: Physics and Application" (Dolgoprudny, Russia); the 18th Workshop on Computer Algebra in Scientific Computing (CASC 2016) (Bucharest, Romania); the 22nd International Symposium on Spin Physics (SPIN'16) (Urbana, USA);

the 28th CBM Collaboration Meeting (Tübingen, Germany); the international conference "Biomembranes 2016: Mechanisms of Aging and Age-Related Diseases" (Dolgoprudny, Russia); the 17th international conference "Physicochemical and Petrophysical Studies in Earth Sciences" (Moscow, Borok, Russia); the international conference "Russian Supercomputing Days" (Moscow, Russia); the 23rd nuclear physics workshop "Marie and Pierre Curie" (Kazimierz Dolny, Poland); the 4th Workshop on Small-Angle Neutron Scattering (Gatchina, Russia); the 2nd International Conference on Particle Physics and Astrophysics (ICPPA-2016) (Moscow, Russia); the All-Russian scientific conference "Membranes-2016" (Nizhni Novgorod, Russia); the 18th international conference "Data Analytics and Management in Data Intensive Domains" (DAMDID/RCDL 2016) (Ershovo, Moscow, Russia); the International Conference on Nuclear Spectroscopy and Nuclear Structure "Nucleus-2016" (Sarov, Russia); the Small Triangle Meeting on Theoretical Physics (Košice, Slovakia); the 11th conference "New Opportunities for Better User Group Software" (NOBUGS 2016) (Copenhagen, Denmark); the 32nd HADES Collaboration Meeting (Paris, France); the 7th International Conference on Optical Spectroscopy, Laser and Their Applications (Cairo, Egypt); the NOνA Collaboration Meeting (Batavia, USA); the 6th International Meeting of Union for Compact Accelerator-Driven Neutron Sources (UCANS-VI) (Xi'an, China); the 6th International Conference on Fission and Properties of Neutron-Rich Nuclei (Sanibel, USA); the conference "Slow Control – Warsaw 2016" (Warsaw, Poland); the 1st Russian crystallographic congress "From the Convergence of Sciences to Nature-Like Technologies" (Moscow, Russia); the 25th Russian Particle Accelerator Conference (RuPAC 2016) (St. Petersburg, Russia); the 59th PANDA Collaboration Meeting (Darmstadt, Germany); the 27th Daya Bay Reactor Neutrino Experiment Collaboration Meeting (Taipei, China (Taiwan)); the International Workshop on Supersymmetry in Integrable Systems (SIS'16) (Hannover, Germany).

DEVELOPMENT OF THE JINR INTERNATIONAL COLLABORATION AND RELATIONS OF THE YEAR 2016

1.	Number of short-term visits to JINR by specialists from the Member States (not counting Russian specialists)	1175
2.	Number of visits of specialists from other countries, including visits of specialists from the associated countries	832 351
3.	Number of visits by JINR specialists to the Member States (not counting Russian visits in Russia)	1133
4.	Number of visits by JINR specialists to other countries, including visits of specialists to the associated countries	1717 224
5.	Number of conferences, schools, and meetings held by JINR	101
6.	New cooperation agreements (memoranda of understanding), addenda to existing ones	16

CONFERENCES, SCHOOLS, AND MEETINGS HELD BY JINR IN 2016*

No.	Name	Place	Date	Number of participants
1.	26th meeting of the Joint Committee on IN2P3–JINR Collaboration	Paris, France	18–19 January	10
2.	Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	20–22 January	60
3.	23rd international conference "Mathematics. Computer. Education"	Dubna	25–30 January	254
4.	Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	28–29 January	64

*A number of conferences were held jointly with other organizations; many events were dedicated to the 60th anniversary of JINR. There were also held meetings of the JINR Science and Technology Council (8) and the JINR Technology Council (3). Besides, JINR assisted in organization of the 25th Russian Conference on Particle Accelerators (RuPAC 2016), the Lake Baikal Three Messenger Conference and some other events.

No.	Name	Place	Date	Number of participants
5.	JINR Days in Latin America	Havana, Cuba	1–5 February	120
6.	119th session of the JINR Scientific Council	Dubna	18–19 February	66
7.	Extended xFitter Workshop	Dubna	18–20 February	33
8.	JINR Days in Slovakia. Ceremonial opening of the exhibition dedicated to the 60th anniversary of JINR	Košice, Bratislava, Slovakia	22–25 February	95
9.	29th Task Force Meeting of UNECE ICP Vegetation	Dubna	29 February–3 March	93
10.	Meeting of the Working Group on the JINR Financial Matters under the CP Chairman	Dubna	10–11 March	28
11.	20th International Scientific Conference of Young Scientists and Specialists of JINR (AYSS-2016)	Dubna	14–18 March	202
12.	29th FCAL Collaboration Workshop	Dubna	21–22 March	32
13.	Physics Days in Dubna	Dubna	27–29 March	200
14.	Czech Days at JINR	Dubna	29–31 March	95
15.	Meeting of the JINR Finance Committee	Dubna	1–2 April	110
16.	Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States	Dubna	4–5 April	131
17.	JINR Days in Bulgaria. Round-table meeting. Ceremonial opening of the exhibition dedicated to the 60th anniversary of JINR	Sofia, Bulgaria	7–9 April	100
18.	20th research workshop “Nucleation Theory and Applications”	Dubna	9–24 April	54
19.	Scientific session of the Physical Sciences Division of the Russian Academy of Sciences (PSD RAS)	Dubna	11 April	115
20.	International session-conference of the Section of Nuclear Physics of PSD RAS “Physics of Fundamental Interactions”	Dubna	12–15 April	431
21.	JINR Day in Hungary	Dubna	14 April	35
22.	JUNO PMT and Electronics Workshop / European JUNO Meeting	Dubna	16–19 April	76
23.	Working Meeting on ESFRI Policy and Related Issues	Dubna	20 April	23
24.	COMET International Collaboration Meeting (CM19)	Minsk, Belarus	16–20 May	82
25.	9th spring school on nuclear physics “JINR Days in Bulgaria”	Borovets, Bulgaria	16–20 May	60
26.	10th international workshop “Application of Lasers and Storage Devices in Atomic Nuclei Research” (LASER 2016)	Poznan, Poland	16–19 May	95
27.	First stage of the International Student Practice (for students from ARE)	Dubna	23 May – 11 June	32
28.	24th International Seminar on Interaction of Neutrons with Nuclei (ISINN-24)	Dubna	23–27 May	126
29.	19th International Workshop on Computer Algebra	Dubna	24–25 May	50
30.	19th International Seminar on High Energy Physics (QUARKS-2016)	Pushkin, Russia	29 May – 4 June	242
31.	International conference “Modern Trends in Radiobiology and Physiology”	Dubna	1–2 June	26
32.	JINR Days in Moldova	Chisinau, Moldova	1–3 June	40
33.	III International Conference on Small-Angle Neutron Scattering (YuMO 2016) dedicated to the 80th anniversary of Yu. Ostanevich	Dubna	6–9 June	123

No.	Name	Place	Date	Number of participants
34.	JINR Days in Mongolia	Ulaanbaatar, Mongolia	6–9 June	60
35.	6th International Conference on Contemporary Physics (ICCP-VI)	Ulaanbaatar, Mongolia	7–10 June	60
36.	5th School-Conference of Young Scientists and Specialists (Alushta-2016)	Alushta, Russia	6–12 June	89
37.	BAIKAL Collaboration Workshop	Dubna	7–10 June	57
38.	24th International Conference on Integrable Systems and Quantum Symmetries (ISQS-24)	Prague, Czech Republic	14–18 June	80
39.	JINR Days in Kazakhstan. Workshop on Achievements and Perspectives of DC-60 Heavy-Ion Accelerator	Astana, Kazakhstan	14–18 June	40
40.	European School on High Energy Physics (a CERN–JINR school)	Skeikampen, Norway	15–28 June	130
41.	School for Teachers of Physics from JINR Member States	Dubna	19–25 June	34
42.	Meeting of the Programme Advisory Committee for Particle Physics	Dubna	20–21 June	70
43.	Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	23–24 June	66
44.	School for Teachers of Physics from Moscow	Dubna	26 June – 1 July	19
45.	Meeting of the Technical Advisory Board of Baikal-GVD Project	Dubna	27–30 June	20
46.	JINR/BLTP – SKLTP/CAS Joint Workshop on Physics of Strong Interacting Systems	Dubna	28 June – 3 July	56
47.	Meeting of the Programme Advisory Committee on Condensed Matter Physics	Dubna	30 June – 1 July	70
48.	Summer school “Sociocultural Morthology of a Small Town: Authors, Practices, Institutions (Dubna)”	Dubna	3–12 July	60
49.	Second stage of the International Student Practice	Dubna	4–25 July	89
50.	International Workshop on Few-Body Systems (FBS-Dubna-2016)	Dubna	4–7 July	43
51.	7th international conference “Distributed Computing and Grid Technologies in Science and Education”	Dubna	4–9 July	248
52.	16th International Baikal Summer School on Physics of Elementary Particles and Astrophysics	Bolshiye Koty, Russia	8–15 July	74
53.	20th School of Young Scientists and Specialists	Dubna	15–17 July	50
54.	Helmholtz international summer school “Quantum Field Theory at the Limits: From Strong Fields to Heavy Quarks”	Dubna	18–30 July	81
55.	School for Polish Teachers of Physics	Dubna	24–30 July	15
56.	International school “Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems”	Dubna	31 July – 6 August	48
57.	34th Russian Cosmic Rays Conference (RCRC-2016)	Dubna	15–19 August	150
58.	10th APCTP–BLTP/JINR–RCNP–RIKEN Joint Workshop on Nuclear and Hadronic Physics	Wako, Japan	17–21 August	80
59.	NA62 Collaboration Meeting	Dubna	22–27 August	80
60.	School at CERN for High School Students from the Russian Federation	Geneva, Switzerland	22–27 August	19
61.	Student training course “Advanced Materials Investigation by Means of Neutron Scattering Methods”	Dubna	27 August – 4 September	35

No.	Name	Place	Date	Number of participants
62.	Helmholtz international summer school "Cosmology, Strings and New Physics"	Dubna	29 August – 10 September	75
63.	8th International Symposium on Exotic Nuclei (EXON 2016)	Kazan, Russia	5–10 September	140
64.	Third stage of the International Student Practice (for students from Belarus, Cuba, Serbia and South Africa)	Dubna	5–23 September	32
65.	19th Annual RDMS CMS Collaboration Conference	Varna, Bulgaria	6–11 September	60
66.	International workshop "NICA Accelerator Complex: Problems and Solutions – 2016"	Sozopol, Bulgaria	10–17 September	40
67.	International workshop "Classical and Quantum Integrable Systems and Supersymmetry"	Tianjin, China	19–24 September	56
68.	23rd Baldin international seminar on high energy physics problems "Relativistic Nuclear Physics and Quantum Chromodynamics" (Baldin ISHEPP 23)	Dubna	19–24 September	204
69.	120th session of the JINR Scientific Council	Dubna	22–23 September	61
70.	72nd Nuclear Physics Division Board Meeting of the European Physical Society	Dubna	26–30 September	26
71.	International conference "New Trends in High Energy Physics"	Budva, Montenegro	3–8 October	90
72.	4th international workshop "Perspectives of Experimental Research at the Nuclotron Beams"	Dubna	6–7 October	55
73.	Meeting of the Working Group on Financial Matters under CP Chairman	Baku, Azerbaijan	11–15 October	37
74.	JINR Days in Azerbaijan	Baku, Azerbaijan	12–14 October	37
75.	JINR Days in Armenia	Yerevan, Armenia	18–22 October	30
76.	7th JINR–CERN school on information technology "GRID and Advanced Information Systems at CERN"	Dubna	24–28 October	94
77.	School for Teachers of Physics from JINR Member States at CERN	Geneva, Switzerland	30 October – 6 November	49
78.	Meeting of the Working Group on Theory of Hadronic Matter under Extreme Conditions	Dubna	31 October – 3 November	79
79.	International scientific school for young scientists and students "Instruments and Methods of Experimental Nuclear Physics, Electronics and Automatics of Experimental Facilities"	Dubna	7–11 November	80
80.	Round table meeting "Topical Issues of General and Space Radiobiology and Astrobiology"	Dubna	9–11 November	62
81.	Workshop "Perspectives for Joint Research and Academic Training at FAIR and NICA"	Darmstadt, Germany	16 November	44
82.	Meeting of the JINR Finance Committee	Kraków, Poland	18–19 November	86
83.	Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States	Kraków, Poland	21–22 November	86
84.	BAIKAL Collaboration Workshop	Dubna	28 November – 4 December	61
85.	Forum "RSA–JINR: 10 Years Together"	Pretoria, RSA	28–29 November	85

No.	Name	Place	Date	Number of participants
86.	16th meeting of the Joint Coordinating Committee on RSA–JINR Cooperation	Pretoria, RSA	1 December	85
87.	iThemba LABS–JINR Joint Workshop	Cape Town, RSA	2 December	85
88.	19th annual conference “Science. Philosophy. Religion”	Dubna	5–6 December	52
89.	Meeting on the TANGRA Project	Dubna	8–9 December	26
90.	International seminar “Biology and Materials” (BIOMAT)	Dubna	12–13 December	49

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.


JOINT INSTITUTE FOR NUCLEAR RESEARCH
1956 • 2016
ДУБНА

Dubna, 18–19 February. The 119th session of the JINR Scientific Council

Dubna, 26 March. The ceremonial meeting devoted to the 60th anniversary of the Joint Institute for Nuclear Research

Dubna, 5 April.
Festive events on the 60th
anniversary of JINR

Kraków (Poland),
21–22 November.
JINR CP session

Havana (Cuba),
1–5 February. JINR Days
in Latin America

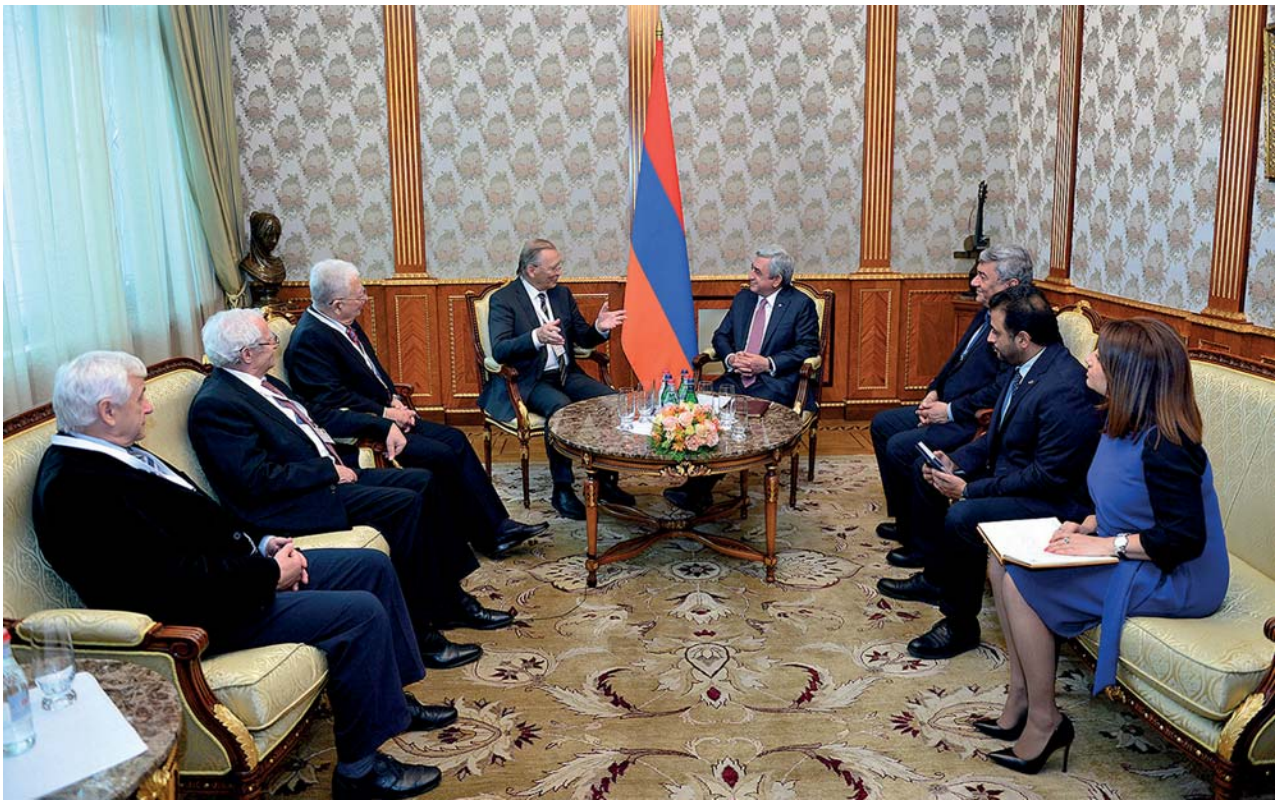
Slovakia, 22–25 February. JINR Days in Slovakia dedicated to the 60th anniversary of JINR

Sofia (Bulgaria), 7–9 April. JINR Days in Bulgaria dedicated to the 60th anniversary of JINR

Ulaanbaatar (Mongolia), 6–9 June. Participants of JINR Days in Mongolia

Astana (Kazakhstan), 14–18 June. Participants of festive events on the 60th anniversary of JINR

Baku (Azerbaijan), 12–14 October. Participants of JINR Days in Azerbaijan



Yerevan (Armenia), 18–22 October. JINR Days in Armenia dedicated to the 60th anniversary of JINR

Pretoria (RSA), 1 December.
Participants of the 16th meeting of the Joint Coordinating Committee on RSA–JINR cooperation
in the framework of the forum “RSA–JINR: 10 Years Together” dedicated to the 60th anniversary of JINR

Dubna, 25 March. The first-stone laying ceremony for the NICA project

Dubna, 1–2 April. A regular meeting of the JINR Finance Committee

Dubna, 20–22 January. A regular meeting of the Programme Advisory Committee for Nuclear Physics

Dubna, 30 June – 1 July. The meeting of the PAC for Condensed Matter Physics. The PAC Chairman V. Kantser acquaints himself with poster reports by young scientists

Dubna, 28–29 January. A regular meeting of the Programme Advisory Committee for Condensed Matter Physics. Left: member of the PAC R. Saladino (Italy) discusses the poster presentation with a young scientist. Right: member of the PAC E. Burzo (Romania) presented the Diploma of the Academy of Sciences of Romania to D. Kozlenko (FLNP)

Dubna, 26–30 September. The 72nd Nuclear Physics Division Board Meeting of the European Physical Society, dedicated to the 60th anniversary of JINR

Moscow, 13 April. Signing of an agreement on JINR–IAEA cooperation

Budva (Montenegro), 3–8 October. The international conference “New Trends in High Energy Physics”

Darmstadt (Germany), 16 November. Participants of the workshop
“Perspectives for Joint Science and Academic Training at FAIR and NICA”

Skeikampen (Norway), 15–28 June. Organizers and attendees of the European School on High Energy Physics dedicated to the 60th anniversary of JINR

Kazan (Russia), 5–10 September.
Participants of the International Symposium on Exotic Nuclei (EXON 2016)

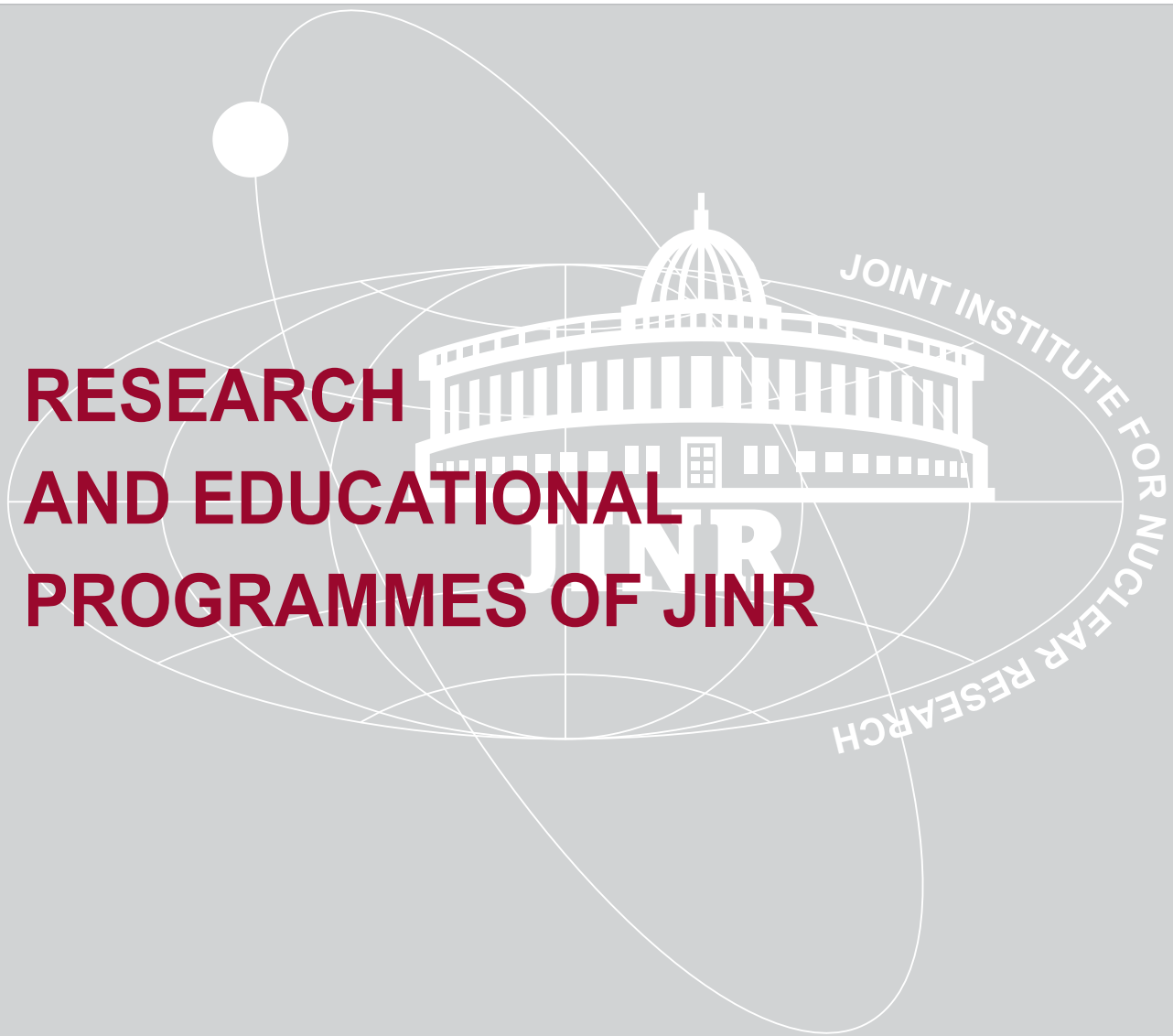
Dubna, 1 November. Presentation of the JINR Museum of Science and Technology History (*photo by G. Myalkovskaya*)

Dubna, 30 August. An excursion to JINR laboratories for journalists of ARS Press and a press conference

Dubna, 24 July. Inauguration of the monument to D. Mendeleev on the city's embankment

2016

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. Two new sectors were organized at BLTP for enhancement of theoretical research in neutrino physics and phenomenology of relativistic heavy ion physics. 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 500 publications in peer-reviewed journals and proceedings of international conferences. 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 2016, more than 600 scientists participated in 11 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 German theorists was based on the Heisenberg–Landau Program; with Armenia, on 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 CAN (Beijing) are functioning, as well as the active cooperation with theorists from CERN. 19 research projects and 4 conferences and schools were supported by the RFBR grants. Much attention was paid to recruiting young researchers, students, and post-graduate students to the Laboratory within the research and education project "Dubna International Advanced School of Theoretical Physics" (DIAS-TH), in particular. More than 130 PhD students and young scientists from the JINR Member States participated in the DIAS-TH schools. The Laboratory plays the role of the training center 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 nonmember states, several researchers from Argentina, India, Japan, Mexico, and Tajikistan 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 systematic study of the leading ultraviolet divergences for the on-shell scattering amplitudes in gauge field theories with maximal supersymmetry in dimensions $D = 6$, 8, and 10 is carried out. The all loop summation of the leading divergences is performed with the help of the differential equations which are the generalization of the renormalization group (RG) equations for nonrenormalizable theories. Numerical solutions of these equations in the general case are obtained in

$D = 6$, 8, and 10 dimensions. The key issue is that the summation of infinite series for the leading and the subleading divergences does not improve the situation and does not allow one to remove the regularization and obtain the finite answer. This means that despite numerous cancellations of divergent diagrams these theories remain nonrenormalizable [1].

Dynamical chiral symmetry breaking is studied within $(2 + 1)$-dimensional QED with N four-component fermions. The leading and next-to-leading orders of the $1/N$ expansion are computed exactly. The analysis is carried out in arbitrary nonlocal gauge. Resummation of the wave-function renormalization constant at the level of the gap equation yields a strong suppression of the gauge dependence of the critical fermion flavor number, $Nc(\xi)$. Here ξ is the gauge fixing parameter, which is such that chiral symmetry breaking takes place for $N < Nc(\xi)$. The results show that chiral symmetry breaking should take place for integer values $N \leqslant 3$. A correspondence between reduced QED4,3 and QED3 allows us to derive also the corresponding results in graphene at the infrared Lorentz-invariant fixed point where the system is described by an effective relativistic-like field theory. The results are in good agreement with the ones found in models with instantaneous Coulomb interaction [2].

A Grassmannian integral representation is obtained for tree-level gauge invariant off-shell amplitudes (reggeon amplitudes) with an arbitrary number of external legs, one of which is off-shell both for the case of maximally supersymmetric Yang–Mills theory and pure gluodynamics. A further generalization of this result to the case of arbitrary number of off-shell legs was obtained. It is shown that the (deformed) off-shell amplitude expressions could be also obtained using quantum inverse scattering method for auxiliary $gl(4|4)$ super spin chain [3].

Finite size corrections are obtained for ground and excited states of generalized Dicke model [4].

Leading SM contribution to the strong coupling beta function is obtained at the four-loop level. In addition to the well-known pure QCD corrections, the Yukawa interactions of top quarks are taken into account together with self-interactions of the Higgs boson. Numeric analysis of the new contribution shows that above the electroweak scale it turns out to be an order of magnitude larger than recent five-loop pure QCD result obtained by other authors [5].

The four-quark structure of the recently discovered charged $Z_c(3900)$, $Z(4430)$, and $X_b(5568)$ exotic states has been examined within a covariant quark model. It was found that the tetraquark-type current widely used in the literature for the $Z_c(3900)$ leads to a significant suppression of the DD^* modes. Contrary to this, a molecular-type current provides an enhancement by a factor of 6–7 for the DD^* modes compared with the $J/\psi\pi$ and $\eta_c\rho$ modes in agreement with recent experimental data from the BESIII Collaboration [6].

The possible new physics (NP) effects in the exclusive decays $B \to D(D^*) + \tau^- + \nu_\tau$ have been studied in some extension of the Standard Model by taking into account right-handed vector (axial), left- and right-handed (pseudo)scalar, and tensor current contributions. We provide constraints on NP operators based on measurements of the ratios of branching fractions of the tau and muon modes and consider the effects of these operators on physical observables in different NP scenarios [7].

For hydrogen molecular ions contributions to the energy in orders $m\alpha^6$ and $m\alpha^7$ are obtained, which take into consideration vibrational motion of nuclei [8].

Energies of ionization of H_2^+, HD^+, and D_2^+, which are required for determination of masses of light nuclei from precision spectroscopy of H_2, HD, etc., were calculated. Improved values for fundamental transitions in the hydrogen ions, which allow one to determine with a significant precision such fundamental physical quantity as the Rydberg constant, proton charge radius, and proton-to-electron mass ratio, were calculated [9].

A thorough statistical analysis of all available reactor data was performed in order to test one of the predictions of the quantum-field theoretical approach to neutrino oscillations — violation of the classical inverse square law (ISL) for the antineutrino count rate as a function of distance. The value of the ISL violation L_0 is found to be 1.5–3.5 m that corresponds to the spectrum-weighted value of the mean momentum spread of the external in and out wave packets of the order of 0.5–0.8 eV [10].

A theoretical approach is proposed to calculate the nucleon axial form factor for large virtualities in the $Q^2 = 1{-}10$ GeV^2 range using the next-to-leading order light-cone sum rules, which is important due to emerging possibilities to study threshold pion electroproduction at large momentum transfers [11].

The specific toroidal structures of vorticity field in heavy-ion collisions were found, named as femto-vortex sheets. Their relation to polarization of hyperons, recently discovered experimentally, is established [12].

By using QCD analysis of the HERMES data on the multiplicity production of the positively and negatively charged pions in the semi-inclusive unpolarized processes, the fragmentation functions of the u and anti-u quarks into the pions are determined. It is shown that the HERMES data presented in different representations, (x, z) and (Q^2, z), are probably inconsistent [13].

The width of the decay $\tau \to K^-\pi^0\nu_\tau$ is calculated in the framework of the Nambu–Jona-Lasinio model, taking into account the contributions of the intermediate vector $K^*(892)$ and scalar $K_0^*(800)$ mesons. It is shown that the main contribution to the width of this decay is given by the subprocesses with the intermediate W boson and vector $K^*(892)$ meson. The scalar channel with the intermediate $K_0^*(800)$ meson gives an

insignificant contribution. It is shown that the contribution of the subprocess with the intermediate $K^{*\prime}(1410)$ meson is negligible as well [14].

The glueball contribution to the equation of state (EoS) of hot gluon matter below and above T_c is investigated. It is shown that the strong changing of the masses of the scalar and pseudoscalar glueballs near T_c is determining the thermodynamics of the $SU(3)$ gauge theory. The arguments are provided to justify that these glueballs become massless at $T_G \approx 1.1T_c$, which is crucial to understand the behavior of the trace anomaly found in lattice calculations [15].

Radiative mechanism of spontaneous conformal symmetry breaking in a conformal-invariant version of the Standard Model (SM) is suggested. The Coleman–Weinberg mechanism of dimensional transmutation in the SM gives rise to finite vacuum expectation values and, consequently, masses of scalar and spinor fields. A natural bootstrap between the energy scales of the top quark and Higgs boson is suggested. The Coleman–Weinberg mechanism was also studied for the case of a supersymmetric system of scalar and fermion fields [16].

The Three-fluid Hydrodynamics-based Event Simulator Extended by UrQMD final State interactions (THESEUS) has been constructed, and its performance with basic results is described in a collaborative publication. The program is the first and only (so far) that can provide event simulation in the energy range of NICA and FAIR with the equation of state of matter as an input, so that, in particular, the question of typical signatures for a first-order phase transition, as opposed to a crossover transition, can be investigated with it. As examples are given: the proton rapidity distribution and flow observables [17].

Results for the topological susceptibility at nonzero temperature obtained from lattice QCD with four dynamical quark flavors are presented. Different smoothing methods, including gradient Wilson flow and over-improved cooling, are applied before calculating the susceptibility. It is shown that the considered smoothing techniques basically agree with each other, and that there are simple scaling relations between flow time and the number of cooling/smearing steps. The topological susceptibility exhibits a surprisingly slow decrease at high temperature [18].

An approach to QCD vacuum as a medium describable in terms of a statistical ensemble of almost everywhere homogeneous Abelian (anti-)self-dual gluon fields was refined. These fields play the role of the confining medium for color charged fields as well as underline the mechanism of realization of chiral $SU_L(N_f) \times SU_R(N_f)$ and $U_A(1)$ symmetries. Hadronization formalism based on this ensemble leads to manifestly defined quantum effective meson action. Strong, electromagnetic, and weak interactions of mesons are represented in the action in terms of nonlocal n-point interaction vertices given by the quark–gluon loops averaged over the background ensemble. New systematic results for the mass spectrum and decay constants of radially excited light, heavy-light mesons, and heavy quarkonia were presented. Transition form factors $F_{P\gamma^*\gamma^{(*)}}$ of pseudoscalar mesons were studied consistently with mass spectra. It is found that $Q^2F_{\pi\gamma^*\gamma}(Q^2)$ approaches a constant value at asymptotically large Q^2, which complies with Belle data more likely than with BaBar ones. At the same time, the generally accepted factorization bound is shown to be satisfied for the case of the symmetric kinematics, $Q^2F_{P\gamma^*\gamma^*}(Q^2)$ [19].

Theory of Nuclear Structure and Nuclear Reactions

In 2016, 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 g-factors for the $2^+_{1,2}$ states of ^{132,134,136}Te are studied by performing self-consistent calculations with the Skyrme force f_- and taking into account the coupling between one- and two-phonon configurations. Available experimental data are well described. It is shown that the negative g-factor (-0.18) predicted for the 2^+_1 state in ^{136}Te indicates significant neutron character of this state. In contrast, a large positive g-factor $(+0.64)$ is predicted for the 2^+_2 state in ^{136}Te, which reveals a dominant proton character, corresponding to a mixed-symmetry state with severe breaking of F-spin symmetry [20].

The random phase approximation with Skyrme forces is extended to finite temperatures to obtain the strength function of Gamow–Teller transitions in neutral channel for nuclei embedded in a hot supernova medium. Different Skyrme parameterizations are used to analyze thermal effects on the strength distribution of charge-neutral Gamow–Teller (GT) transitions in ^{56}Fe and ^{82}Ge. It is shown that cross sections and rates for weak-interaction processes involving hot nuclei demonstrate robustness against the variation of the Skyrme force parameters. However, due to a larger strength of thermally unblocked low- and negative-energy GT transitions, the calculated low-energy cross sections for inelastic neutrino scattering off hot nuclei are larger than those obtained within other approaches [21].

A two-dimensional collective Hamiltonian on both azimuthal and polar motions in triaxial nuclei is proposed to investigate chiral and wobbling modes. The broken chiral and signature splittings in the mean field approximation are restored by this Hamiltonian. This newly developed model is applied to a triaxial rotor coupled with one proton particle and one neutron hole on $h_{11/2}$ orbital. By diagonalizing the Hamiltonian, the angular momenta and energy spectra are obtained.

The results agree with the exact solutions of the particle rotor model at high rotational frequencies [22].

Using the improved scission-point model, the isotopic trends of the charge distribution of fission fragments are studied in induced fission of even-even Th isotopes. The calculated results are in good agreement with available experimental data. With increasing neutron number the transition from symmetric to asymmetric fission mode is shown to be related to the change of the potential energy surface. The change of the shape of mass distribution with increasing excitation energy is discussed for fissioning ^{A}Th nuclei. At high excitation energies, there are unexpected large asymmetric modes in the fission of neutron-deficient Th isotopes considered [23].

The possibilities of direct production of the isotopes of transfermium nuclides ^{259,260}Md, ^{260,261}No, $^{261-264}$Lr, ^{264,265}Rf, $^{264-268}$Db, $^{266-269}$Sg, $^{266-271}$Bh, $^{267-274}$Hs, and $^{270-274}$Mt in various asymmetric hot fusion-evaporation reactions are studied. The excitation functions of the formation of these isotopes in the αxn and pxn evaporation channels are predicted for the first time [24].

A new method is suggested to extract pure transfer probabilities $P_{\rm tr}$ and $P_{1n,2n}$ from the transfer and capture (fusion) experimental data. The almost exponential dependence of the extracted pure one- and two-neutron transfer probabilities at backward angle on the minimal distance of approach is shown for the $^{40}\mathrm{Ca}+{}^{96}\mathrm{Zr}$ system. As found, at energy slightly below the Coulomb barrier the ratio $P_{1n,2n}$ becomes close to unity [25].

The probability of the formation and decay of a dinuclear system is investigated for a wide range of relative orbital angular momentum values. The mass and angular distributions of the quasifission fragments are studied for the collision $^{78}\mathrm{Kr}\,(10A\ \mathrm{MeV})+{}^{40}\mathrm{Ca}$ within dinuclear system model. The analysis shows the possibility of the 180° rotation of the system, so that projectile-like products can be observed in the forward hemisphere with large cross sections, which can explain the phenomenon observed recently in the ISODEC experiment [26].

A three-body system consisting of two identical fermions of mass m and a distinct particle of mass m_1, with zero-range interactions between different particles, was studied in the universal limit of low energies. It was shown that for an unambiguous definition of the (Hermitian) three-body Hamiltonian in the interval $8.619 < m/m_1 \leqslant 13.607$ one needs to introduce an additional parameter constraining the wave function near the triple-collision point. The dependence of the three-body bound-state energies on m/m_1 and the three-body parameter for the most important case $L^P = 1^-$ was calculated and analyzed with the aid of a simple model. The same problem was discussed for different L^P. The states of odd L and P for two identical fermions and states of even L and P for two identical bosons were considered. It is established that an additional three-body parameter is needed for the definition of the (Hermitian) three-body Hamiltonian for m/m_1 above a critical value specific for each L^P sector [27].

Geometric (confinement-induced) resonances were predicted in atom-ion systems, dependence of their positions on the atomic mass and the colliding energy was calculated, analytic and semianalytic formulae for the position of the geometric resonance were obtained in the "long-wavelength and zero-energy limit". Possible applications of the phenomenon were discussed, e.g., determination of the atom-ion scattering length and the temperature of the atomic ensemble in the presence of an ion impurity, etc. It was found that a slight anisotropy of the confining trap considerably enhances the reactive rate constants in the scattering of cold atoms [28].

Assuming the Hamiltonian H reads as a J-self-adjoint 2×2 block-operator matrix, conditions are established ensuring the analytic continuability of one of the Schur complements of the operator 2×2-matrix H-E to the unphysical sheets of the energy E plane. Theorems on factorization of the continued complement in the sense of Markus and Matsaev are proven. In the Feshbach spectral case, it is established that the operator root of the Schur complement, analytically continued to the respective unphysical sheet, generates for H a pair of J-orthogonal invariant subspaces [29].

The nature of phase transition in hot and dense nuclear matter is discussed in the framework of the effective $SU(2)$ Nambu–Jona-Lasinio (PNJL) model with a Polyakov loop with two quark flavors — one of the few models describing the properties of chiral and confinement–deconfinement phase transitions. The parameters of the models are considered and the additional interactions are examined that influence the structure of phase diagram and the positions of critical points in it. The effect of meson correlations of the thermodynamic properties of the quark–meson system is examined. The evolution of the model with changes in the understanding of the phase diagram structure is discussed [30].

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.

Iridium oxides with a honeycomb lattice have been identified as platforms for the much anticipated Kitaev topological spin liquid. A new type of magnetic ground state that was called "the structure of triplet dimers on an effective triangle lattice" has been predicted. The prediction can be verified by means of neutron diffraction and neutron magnetic spectroscopy [31].

A new theoretical model is developed to describe the structural properties of low-viscosity sodium alginate from small-angle neutron scattering data. It is found

that addition of salt accelerates the gelation process, induces a collapse which shortens sodium alginate chains, and a transition from a rough surface fractal-like structure to a mass fractal structure occurs [32].

A distribution function of relaxation times was investigated in a new group of materials $Sr_{14-x}Ca_xCu_{24}O_{41}$. It has been found that a commonly used description based on the relaxation rate does not give the proper distribution function even in the case of a broad distribution. For this reason, our original data processing procedure was developed. It was revealed that the observed thermal relaxation at $x = 12$ clearly indicates the formation of the spin density wave (SDW) ground state at low temperatures [33].

The microscopic theory of high-temperature superconductivity in cuprates was formulated within the extended Hubbard model in the limit of strong correlations [34]. The spin-wave excitation spectrum, magnetization, susceptibility, and the Neel temperature were calculated for the quasi-two-dimensional compass-Heisenberg model for iridates, for the Kitaev–Heisenberg model on the honeycomb lattice [35].

The suppression of the long-range antiferromagnetic order in the strongly correlated systems has been studied in the framework of the Kondo–Heisenberg model. The spin–spin correlation functions at different doping levels and Kondo-coupling λ have been calculated within the quantum Monte Carlo method. The critical doping level has been found. The restoration of the long-range order with decreasing λ has been shown [36].

The influence of both the concentration and different location of edge vacancy defects on the stability of edge states in zigzag-type semi-infinite graphene sheet was studied. Three types of distributions have been considered: normal, uniform, and periodic. When vacancies are located at a distance of one or two atoms, their mutual influence leads to the appearance of subpeaks in the local density of electronic states. The edge state turns out to be destroyed most effectively when vacancies are located at a distance not exceeding the characteristic range of mutual influence [37].

It is shown that the experimentally observed increase of Young's modulus in single-layer graphene with low density of point defects leads to a noticeable enhancement of the thermal conductivity in a wide temperature range [38].

The phase dynamics of SQUID consisting of Josephson junctions with topologically nontrivial barriers is investigated, and its comparative analysis with simple SQUID is performed. It is shown that in case of SQUID with nontrivial barrier the branch of I-V characteristics corresponding to the resonance frequency shifts in $\sqrt{2}$ along the voltage [39].

The von Neumann entanglement entropy and Schmidt gap in the vortex free ground state of the Kitaev model considering different geometries for the subsystem were investigated. It was found that for square/rectangular and cylindrical geometries of the subsystems the entanglement entropy shows signature of phase transition from gapless to gapped phase. The results show that though the gapless and gapped phases of the Kitaev model are topologically distinct, exact nature of entanglement entropy and Schmidt gap depends on the geometry of the subsystem with respect to the full system [40].

Statistical systems composed of atoms interacting with each other through nonintegrable interaction potentials are considered. A novel iterative procedure for describing such systems is developed, starting from a correlated mean field approximation, allowing for a systematic derivation of higher orders [41].

A unifying picture that extends the semiclassical perspective of Heller, which relates the localization measure to the probability of return, is introduced. The dependence of the localization measure on the initial state and the strength of the many-body interactions is explored using a novel recursive projection method [42].

A matrix-product representation for the stationary states of the totally asymmetric simple exclusion process (TASEP) on a finite ring in the case of a generalized discrete-time dynamics with two hopping probabilities was constructed. Exact finite-size expressions for the probability normalization factor, the current of particles, and the correlation function were obtained and analyzed in the regimes of dynamic attraction and repulsion. An explicit analytic expression for the pair correlation function in the limit of irreversible aggregation was derived [43].

The quantum Yang–Baxter equation (YBE) and star-triangle relation define exactly solvable models in statistical mechanics. The most complicated solution of YBE (R-matrix) is defined by an integral operator with an elliptic hypergeometric kernel and it defines models with the continuous values of spins. A principally new class of finite-dimensional R-matrices has been found, which is built from elliptic theta functions with two different modular parameters. It is connected to finite-dimensional representations of the elliptic modular double and determined by two-dimensional lattices of discrete values of the spins. This yields new discrete integrable systems in statistical mechanics whose physical properties have not been determined yet, except the cases of Baxter's 8-vertex model and its higher spin generalization due to Sklyanin. These YBE solutions were obtained with the help of the operator intertwining equivalent representations of the relevant symmetry algebra. For special spin values, this operator has finite-dimensional invariant spaces which were described explicitly [44].

The internal structure of rotor-router walk on a semi-infinite cylinder and growth of the cluster of visited sites by rotors are considered. It is shown that the average width of the surface region of the cluster evolves to the stationary value by a scaling law whose parameters are close to the standard Kardar–

Parisi–Zhang (KPZ) exponents. The sequence of characteristic labels corresponding to closed clockwise contours formed by rotors is in average an ordered helix structure [45].

Modern Mathematical Physics: Strings and Gravity, Supersymmetry, Integrability

The topics of the main focus in the theme were:
- Supersymmetry and Superstrings;
- Quantum Groups and Integrable Systems;
- Supersymmetry;
- Quantum Gravity, Cosmology and Strings.

Actions of $N = 4$ superparticles in the AdS3 space were constructed, including ones with higher derivatives. It was proved that the idea of using the method of nonlinear realizations is applicable to the construction of actions in curved spaces, provided that one can choose coordinates and fields in such a way that fermionic coordinates of superspace transform homogeneously under broken supersymmetry. Nonrelativistic limit of these systems was also considered [46].

A new generalization of the special Lagrangian geometry on Calabi–Yau manifolds, which has been exploited in SYZ-construction for the explanation of Mirror Symmetry, to the case of arbitrary algebraic varieties is proposed. It is proven that the moduli space of our Special Bohr–Sommerfeld Lagrangian submanifolds is finite; certain examples of the moduli spaces are presented [47].

The six-dimensional $N = (1, 0)$ supersymmetric model of the Abelian gauge multiplet coupled to a hypermultiplet is considered in the harmonic superspace approach. The divergent part of the one-loop effective action is computed. It is shown that the corresponding counterterms contain the purely gauge multiplet contribution together with the mixed contributions of the gauge multiplet and hypermultiplet. The theory is on-shell one-loop finite in the gauge multiplet sector and contains unremovable divergences in the mixed sector [48].

A new kind of nonrelativistic $N = 8$ supersymmetric mechanics is introduced, associated with worldline realizations of the supergroup $SU(2|2)$ treated as a deformation of flat $N = 8$, $d = 1$ supersymmetry. Various worldline $SU(2|2)$ superspaces are constructed and the corresponding superfield techniques are developed. For the off-shell $SU(2|2)$ multiplets $(3, 8, 5)$, $(4, 8, 4)$, and $(5, 8, 3)$, the most general superfield and component actions are constructed and analyzed. For the simplest $(5, 8, 3)$ model the quantization is performed [49].

The existence of hairy black holes is studied in the generalized Einstein–Skyrme model. It is proven that in the BPS model limit there are no hairy black hole solutions, although the model admits gravitating (and flat space) solitons. As an example, it is shown that there are no hairy black holes in the $L_2+L_6+L_0$ model [50].

The Schrödinger eigenvalue problems for the Whittaker–Hill potential and the periodic complex potential Q_i are studied using their realizations in two-dimensional conformal field theory. It is shown that the Hamiltonian H_1 is PT-symmetric for some special choice of parameters and has a real spectrum in the weak coupling region. Thus, H_1 can serve as another new model for testing postulates of PT-symmetric quantum mechanics [51].

New models of the $SU(2|1)$ supersymmetric mechanics based on gauging the systems with dynamical $(1, 4, 3)$ and semidynamical $(4, 4, 0)$ supermultiplets are presented. A new $N = 4$ extension of $d = 1$ Calogero–Moser multiparticle system is obtained by gauging the $U(n)$ isometry of matrix $SU(2|1)$ harmonic superfield model [52].

A new mechanism for inflation is proposed, which uses the Horndeski prescription to couple gravity with classical homogeneous and isotropic $SU(2)$ Yang–Mills field. This generally and gauge covariant YM theory with a curvature-dependent action is ghost-free. It is shown that the action leads to second-order gravity and Yang–Mills field equations. The respective solution space contains the de Sitter boundary, which after some finite time attracts trajectories, thus a robust inflation with a graceful exit is ensured. A two-step inflationary scenario is obtained when the Higgs field is included in the theory. In this case, the Planck-scale YM-generated inflation naturally prepares the desired initial conditions for the GUT-scale Higgs inflation [53].

Modified teleparallel gravity with a function $f(T, T_G)$ in action is investigated. The function depends on a torsion scalar T and an analogue of Gauss–Bonnet invariant T_G. As distinct from the usual teleparallel gravity with $f(T)$ in the action, this theory contains higher derivative terms, which may produce different instabilities. It is explicitly demonstrated that the Minkowski stability in such kind of theories demands that $f_T(0, 0) < 0$, $f_{T_G T_G}(0, 0) > 0$. It is checked whether these restrictions are fulfilled for various types of functions discussed by other authors [54].

Explicit compact formulae for the ponderomotive forces in the macroscopic electrodynamics of moving media are derived in the Minkowski and Abraham approaches. The expression for the Abraham force is obtained for arbitrary dependence of the medium velocity on spatial coordinates and time and for nonstationary external electromagnetic field. The Lorentz force is found, which is exerted by external electromagnetic field on the conduction current in a medium [55].

The influence of temperature on the surface plasmons in graphene was investigated using the recently developed polarization tensor for the electronic excitations in $(2 + 1)$ dimensions. A model with nonzero mass gap but zero chemical potential was considered. It is shown that the plasmons may exist for both polarizations of the electromagnetic field, transverse electric (TE) and transverse magnetic (TM). For TE, the momentum region, where the dispersion function is real, appears bounded from below, whereas for TM it is

bounded from above. The influence of the temperature on plasmons is compared with the respective effect of the chemical potential [56].

It is demonstrated that solutions to the Beltrami 3-dimensional hydrodynamics equation can be viewed as instantons of an $N = 2$ supersymmetric nonlinear sigma model on 4-dimensional locally Hyper–Kähler worldvolume with a 4-dimensional Hyper–Kähler target space, so that they are triholomophic maps between the worldvolume and the target space. Consequently, the classification of the solutions to the 3-dimensional Beltrami equation is reduced to enumeration of the triholomorphic maps, which is represented in terms of a topological sigma model [57].

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

In 2016, the research and education project DIAS-TH was successfully continued. There were the following activities in the framework of DIAS-TH:

- XX Research Workshop "Nucleation Theory and Applications", April 1–30, Dubna;
- Helmholtz International Summer School "Quantum Field Theory at the Limits: From Strong Fields to Heavy Quarks", July 18–30, Dubna;
- International School "Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems", July 30 – August 6, Dubna;
- Helmholtz International Summer School "Cosmology, Strings and New Physics", August 28 – September 10, Dubna;
- Regular seminars for students and postgraduates were organized;
- Computer processing of video records of lectures was continued;
- Web-site of DIAS-TH was supported.

CONFERENCES AND MEETINGS

11 conferences, workshops, and schools were organized in 2016:

- XX Research Workshop "Nucleation Theory and Applications", April 1–30, Dubna;
- International Session-Conference SNP PSD RAS "Physics of Fundamental Interactions", April 12–15, Dubna;
- XXIV International Colloquium "Integrable Systems and Quantum Symmetries", June 14–18, Dubna;
- BLTP/JINR–KLTP/CAS Joint Workshop "Physics of Strong Interaction", June 28 – July 3, Dubna;
- International Workshop "Few-Body Systems", July 4–7, Dubna;
- Helmholtz International Summer School "Quantum Field Theory at the Limits: from Strong Fields to Heavy Quarks", July 18–30, Dubna;
- International School "Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems", July 30 – August 6, Dubna;
- Helmholtz International Summer School "Cosmology, Strings and New Physics", August 28 – September 10, Dubna;
- International Workshop "Classical and Quantum Integrable Systems and Supersymmetry", September 19–24, Tianjin, China;
- XXIII International Baldin Seminar "Relativistic Nuclear Physics and Quantum Chromodynamics", September 19–24, Dubna;
- Meeting of the working group "Theory of Hadronic Matter under Extreme Conditions", October 31 – November 3, Dubna.

COMPUTER FACILITIES

In 2016, new faster processors were installed and the memory on the main computational server theor2.jinr.ru was extended to 512 GB. The upgrade of network links to the speed of 1 Gbit/s for all PCs at BLTP has been completed with the installation of several high-performance switches. Main BLTP switches and servers now communicate via 10 Gbit/s lines. The video-broadcast server in conference hall has been moved to

more powerful equipment. This allows for better quality of video-broadcasts and better service of more watchers. To improve video-broadcasts from the fourth floor auditorium, new Full HD PTZ camera has been installed. Software packages like Mathematica, Maple, Intel Parallel Studio, Origin Pro running on BLTP servers and used on PCs via network licenses have been upgraded to the latest releases. Additional network licenses were purchased for Maple and Origin Pro.

REFERENCES

1. *Borlakov A. T., Kazakov D. I., Tolkachev D. M., Vlasenko D. E.* // JHEP. 2016. V. 12. P. 154. arXiv:1610.05549 (2016).
2. *Kotikov A. V., Shilin V. I., Teber S.* // Phys. Rev. D. 2016. V. 94. P. 056009;
   Kotikov A. V., Teber S. // Phys. Rev. D. 2016. V. 94. P. 114010; 114011.
3. *Bork L. V., Onishchenko A. I.* arXiv:1607.02320 [hep-th]; 1610.09693 [hep-th].
4. *Pogosov W. V., Bork L. V., Onishchenko A. I., Shapiro D. S.* arXiv: 1612.01774 [cond-mat.stat-mech].
5. *Bednyakov A. V., Pikelner A. F.* // Phys. Lett. B. 2016. V. 762. P. 151.
6. *Goerke F., Gutsche T., Ivanov M. A., Korner J. G., Lyubovitskij V. E., Santorelli P.* // Phys. Rev. D. 2016. V. 94. P. 094017.
7. *Ivanov M. A., Korner J. G., Tran C. T.* // Phys. Rev. D. 2016. V. 94. P. 094028.
8. *Korobov V. I., Koelemeij J. C. J., Karr J.-Ph., Hilico L.* // Phys. Rev. Lett. 2016. V. 116. P. 053003.
9. *Karr J.-Ph., Hilico L., Koelemeij J. C. J., Korobov V. I.* // Phys. Rev. A. 2016. V. 94. P. 050501(R).
10. *Naumov D. V., Naumov V. A., Shkirmanov D. S.* // Part. Nucl. 2016. V. 47. P. 1884.
11. *Anikin I. V., Braun V. M., Offen N.* // Phys. Rev. D. 2016. V. 94. P. 034011.
12. *Baznat M. I., Gudima K. K., Sorin A. S., Teryaev O. V.* // Phys. Rev. C. 2016. V. 93. P. 031902.
13. *Leader E., Sidorov A. V., Stamenov D. B.* // Phys. Rev. D. 2016. V. 93. P. 074026.
14. *Volkov M. K., Pivovarov A. A.* // Mod. Phys. Lett. A. 2016. V. 31. P. 1650043.
15. *Kochelev N.* // Eur. Phys. J. A. 2016. V. 52. P. 186.
16. *Arbuzov A. B., Nazmitdinov R. G., Pavlov A. E., Pervushin V. N., Zakharov A. F.* // Europhys. Lett. 2016. V. 113. P. 31001;
    Arbuzov A. B., Cirilo-Lombardo D. J. // Phys. Lett. B. 2016. V. 758. P. 125.
17. *Batyuk P., Blaschke D., Bleicher M., Ivanov Yu., Karpenko Iu., Merts S., Nahrgang M., Petersen H., Rogachevsky O.* // Phys. Rev. C. 2016. V. 94. P. 044917.
18. *Trunin A., Burger F., Ilgenfritz E.M., Lombardo M. P., Müller-Preussker M.* // J. Phys. Conf. Ser. 2016. V. 668. P. 012123.
19. *Nedelko S. N., Voronin V. E.* // Phys. Rev. D. 2016. V. 93. P. 094010; arXiv:1612.02621 [hep-ph].
20. *Severyukhin A. P., Arsenyev N. N., Pietralla N., Werner V.* // Phys. At. Nucl. 2016. V. 79. P. 469.
21. *Dzhioev A. A., Vdovin A. I., Marinez-Pinedo G., Wambach J., Stoyanov Ch.* // Phys. Rev. C. 2016. V. 94. P. 015805(13).
22. *Chen Q. B., Zhang S. Q., Zhao P. W., Jolos R. V., Meng J.* // Phys. Rev. C. 2016. V. 94. P. 044301.
23. *Paşca H., Andreev A. V., Adamian G. G., Antonenko N. V.* // Phys. Rev. C. 2016. V. 94. P. 064614.
24. *Hong J., Adamian G. G., Antonenko N. V.* // Phys. Rev. C. 2016. V. 94. P. 044606.
25. *Scamps G., Sargsyan V. V., Adamian G. G., Antonenko N. V., Lacroix D.* // Phys. Rev. C. 2016. V. 94. P. 064606.
26. *Nasirov A., Kayumov B., Oh Y.* // Nucl. Phys. A. 2016. V. 946. P. 89.
27. *Kartavtsev O. I., Malykh A. V.* // Europhys. Lett. 2016. V. 115. P. 36005.
28. *Melezhik V. S., Negretti A.* // Phys. Rev. A. 2016. V. 94. P. 022704;
    Shadmehri S., Melezhik V. S., Saeidian S. // Phys. Rev. A. 2016. V. 93. P. 063616.
29. *Albeverio S., Motovilov A. K.* // Math. Notes. 2016. V. 100. P. 761.
30. *Kalinovsky Yu. L., Toneev V. D., Friesen A. V.* // Phys. Usp. 2016. V. 59. P. 367.
31. *Nishimoto S., Katukuri V., Yushankhai V., Stoll H., Roessler U., Hozoi L., Rousochatzakis I., van den Brink J.* // Nature Commun. 2016. V. 7. P. 10273.
32. *Badita C.R., Aranghel D., Radulescu A., Anitas E. M.* // Rom. Rep. Phys. 2016. V. 68. P. 1115.
33. *Sahling S., Remenyi G., Lorenzo J. E., Monceau P., Katkov V. L., Osipov V. A.* // Phys. Rev. B. 2016. V. 94. P. 144107.
34. *Plakida N. M.* // Physica C. 2016. V. 531. P. 39.
35. *Vladimirov A. A., Ihle D., Plakida N.* // JETP. 2016. V. 149. P. 1232.
36. *Ivantsov I., Ferraz A., Kochetov E.* // Phys. Rev. B. 2016. V. 94. P. 235118.
37. *Glebov A. A., Katkov V. L., Osipov V. A.* // JETP. Lett. 2016. V. 104. P. 860.
38. *Krasavin S. E., Osipov V. A.* // Europhys. Lett. 2016. V. 113. P. 66002.
39. *Rahmonov I. R., Shukrinov Yu. M., Dawood R.* // Pis'ma ZhETF. 2016. V. 103. P. 444.
40. *Mandal S., Maiti M., Varma V. K.* // Phys. Rev. B. 2016. V. 94. P. 045421.

41. *Yukalov V. I.* // Phys. Rev. E. 2016. V. 94. P. 012106.
42. *Kohen D., Yukalov V. I., Ziegler K.* // Phys. Rev. A. 2016. V. 93. P. 042101.
43. *Aneva B. L., Brankov J. G.* // Phys. Rev. E. 2016. V. 94. P. 022138.
44. *Chicherin D., Derkachov S. E., Spiridonov V. P.* // Commun. Math. Phys. 2016. V. 345. P. 507.
45. *Papoyan Vl. V., Poghosyan V. S., Priezzhev V. B.* // J. Stat. Mech.: Theory and Experiment. 2016. V. 073209.
46. *Kozyrev N., Krivonos S., Lechtenfeld O.* // Phys. Rev. D. 2016. V. 93. P. 065024.
47. *Tyurin N. A.* // Izvestiya: Mathematics. 2016. V. 80, No. 6. P. 1257.
48. *Buchbinder I. L., Ivanov E. A., Merzlikin B. S., Stepanyantz K. V.* // Phys. Lett. B. 2016. V. 763. P. 375.
49. *Ivanov E., Lechtenfeld O., Sidorov S.* // JHEP. 2016. V. 1611. P. 031.
50. *Kichakova O., Shnir Ya., Wereszczynski A.* // Phys. Rev. D. 2016. V. 94. P. 024060.
51. *Piatek M., Pietrykowski A. R.* // JHEP. 2016. V. 1607. P. 131.
52. *Fedoruk S., Ivanov E.* // JHEP. 2016. V. 1611. P. 103.
53. *Gal'tsov D. V., Davydov E. A.* // Phys. Lett. B. 2016. V. 753. P. 622.
54. *Tretyakov P. V.* // Mod. Phys. Lett. A. 2016. V. 31. P. 1650085.
55. *Nesterenko V. V., Nesterenko A. V.* // J. Math. Phys. 2016. V. 57. P. 092902.
56. *Bordag M., Pirozhenko I. G.* // Intern. J. Mod. Phys. B. 2016. V. 30. P. 1650120.
57. *Fre P., Grassi P. A., Sorin A. S.* // Fortsch. Phys. 2016. V. 64. P. 151.

VEKSLER AND BALDIN LABORATORY OF HIGH ENERGY PHYSICS

The activity of the V. I. Veksler and A. M. Baldin Laboratory of High Energy Physics in 2016 was focused on the implementation and further development of the NICA project (the Nuclotron–NICA, MPD, and BM@N subprojects) and participation in current research at the Nuclotron and in various experiments at world-class accelerator centers.

THE MOST IMPORTANT RESULTS IN THE DEVELOPMENT OF THE NICA COMPLEX

Development of the VBLHEP's accelerator complex in 2016 was aimed at the further construction of systems and elements for the NICA complex.

During the two Nuclotron runs, there were carried out the works aimed both to enhance the capabilities of the accelerator complex for the current research programme and to test the equipment and operation modes of the constructed facilities for the NICA complex parts — the Booster and Collider.

Very important step was taken in 2016 in realization of the NICA as a megascience project of the Russian Federation: an agreement between the Government of the Russian Federation and the Joint Institute for Nuclear Research on the establishment and operation of the Complex of Superconducting Rings for Heavy Ion Colliding Beams NICA was signed on 27 April, 2016.

Nuclotron–NICA

Civil Construction

In the framework of the civil works carried out by the Strabag company, all preparatory works were finished, and construction of the collider ring and MPD experimental building was started.

Injection Complex for Light Ions and Polarized Beams

Substantial progress was achieved in 2016 in the modernization and development of the light ion and polarized particle injection complex:

• New RFQ pre-injector for the linear accelerator LU-20 was designed in co-operation with ITEP and MEPhI and fabricated at VNIITF (Snezhinsk). Its control and diagnostic systems were provided with participation of the specialists from INR RAS. In 2016, new pre-accelerator was put in operation and used during the Nuclotron runs [1, 2].

• Work on the commissioning of the new source of polarized ions (SPI) was finished and the source was also put in operation. During 2016 Nuclotron runs, SPI was used for production of nonpolarized and polarized deuterons. Obtained beam polarization was $\sim 70\%$ in the vector mode, and the beam intensity reached $\sim 10^9$ d/cycle [3, 4].

• The beam polarimetry system was installed, tested, and debugged in the operating mode during the 52nd and 53rd Nuclotron runs.

Heavy Ion Injection Complex

Heavy ion linear accelerator (HILac) of the NICA collider injection complex, which had been developed and constructed in co-operation with German company Bevatech OHG, was fully commissioned and tested in October 2016 and now is ready for operation. HILac is the first heavy ion accelerator of new generation at the JINR Member States institutions, in particular, the high-frequency power supply system of HILac based on the solid-state transistor amplifiers of ~ 1 MW level power. Such technical solution is used for the first time in the world. The test of the HILac properties was done with C^{2+} ion beam obtained from the laser source (charge-to-mass ratio corresponds to ions of gold in the

charge state of 32^{+}). The design energy and transmission coefficient close to the projected have been obtained [5, 6].

Construction of the ESIS heavy ion source "KRION-6T" was going according to the plan. New superconducting solenoid designed to operate at the magnetic field of 6.2 T was created and successfully tested. First operation of the source in the heavy ion injection chain is planned at the end of 2017.

Superconducting Magnet Fabrication and Test Workshop

An official ceremony of launching of the high-technology line for assembling, test, and certification of superconducting magnets for the NICA Booster, Collider, and SIS100 accelerator was held on 28 November. 360 magnets for the NICA complex and 310 magnets for FAIR accelerator SIS100 will be prepared at the factory. The mass production of the Booster magnets was started. 100% of the yokes for the Booster magnets were produced and delivered, 13 magnets were already tested. Work is going on.

Mobile Cryogenic Target

New mobile cryogenic target which can be filled with liquid hydrogen, deuterium, or helium-4 was fabricated. It can be used in different experiments at the Nuclotron beams.

MPD Setup

R&D works on the MPD subsystems have been almost completed. The TDR for most of the basic subdetectors has been prepared and now is under evaluation by the DAC. The preparation for the detector element mass production is going on.

Status of the MPD Magnet Construction

Work is going on under the contract signed between ASG Superconductors S.p.A., Italy, and JINR. The status of the subsystems readiness is presented in the Table.

TPC Status

The clean room for TPC assembly was commissioned on 30 October. The design of assembly tooling for the TPC has been prepared and the manufacture is going on. Mass production of Read Out Chambers is going on, 4 chambers out of 24 were produced, 1 was tested. FE electronics development and works aimed at the preparation of the gas, cooling, and laser systems are in progress.

TOF Status

The workshop for the TOF mass production has been prepared. All 28 TOF module housing was made in close collaboration with NC PHEP BSU and "Artmash" (Minsk, Belarus) and delivered. Mass production of full-scale modules for MPD TOF has been started. It is planned to assemble 40 mRPC for four modules till the end of the year. The total amount of modules for TOF barrel is 28.

ECAL Status

Significant success concerning the realization of the ECAL subsystem was obtained in 2016. In particular:

- New modification of the module was developed.
- The entities capable to produce the main ECAL elements were found.
- An Agreement between JINR and Tsinghua University was signed on the participation of Tsinghua physics group in the MPD experiment, preparation of workshop in China for the mass production of the ECAL modules for MPD, and production of the first 10 test modules.
- New methods of data analysis — clusterization, reconstruction of an event, and particle identification — have been developed and included in the analysis software.

Progress with STS

The following results aimed at the development of the silicon tracker workshop were achieved during 2016:

- Serial deliveries of silicon sensors from CIS (Germany) and Hamamatsu (Japan) for the second stage of BM@N were started.
- 40 "Igolkin-type" carbon fiber noncentral frames for the BM@N were produced at CERN.
- First test stand for the in-beam tests of the assembled demonstrator boards with silicon sensors was launched.

Type of work	Contractor	Duration	Status
Cryostat production and common supervising	JINR – ASG Superconductors S.p.A., Genova, Italy	2015–2018	In progress
Consultations for cryostat production	JINR – Neva-Magnet, St. Petersburg, Russia	2015–2018	In progress
MPD yoke production and control assembly	JINR – Vitcovice Heavy Machinery, Ostrava, Czech Republic	2016–2017	In progress
Forging production for MPD yoke	JINR – SPETSMASH, Kazan, Russia	2015–2016	Completed
Transport system design	JINR – TSU, Tbilisi, Georgia	2016	Completed

• The developing and production of jigs for module assembly were finished. Three technicians were trained for the module assembly.

• Memorandum of Understanding about participation of CBM STS group in creation of four wide-aperture silicon stations for BM@N was signed.

• Active negotiations on the possible collaboration aimed at the creation of systems based on the innovative MAPS sensors for the ALICE and NICA/MPD were conducted with the CERN colleagues.

BM@N Setup

BM@N setup — the first stage of the NICA project — is now under preparation to data taking in 2019. Two technical runs were carried out on the extracted deuteron beams of the Nuclotron in July and December of 2016. The first configuration of the BM@N central tracking system which includes six GEM stations and one silicon strip plane was put in operation and successfully tested during these runs. Five GEM detectors have a size of 66×41 cm and one detector is 163×45 cm in size; it is the largest ever produced GEM detector. It is planned to equip BM@N with 6–8 more such detectors in 2017. Large drift chambers, small-angle calorimeter, elements of TOF system for the hadron identification, detectors for beam profile and structure measurement, as well as the triggering system and integrated DAQ system were commissioned during 2016.

EXPERIMENTS CARRIED OUT AT THE NUCLOTRON DURING THE 2016 RUNS

DSS

In the scope of the DSS experiment, the following results were obtained in 2016:

• The upgraded version of the polarimeter was put in operation at the internal target. Determination of the beam polarization based on the measuring of the asymmetry in the deuteron–proton elastic scattering was commissioned during the 52nd (June 2016) run at the Nuclotron.

• The analysis of the experimental data on the angular dependence of the cross sections of elastic deuteron–proton scattering at deuteron energies of 1300 and 1400 MeV obtained at internal target was performed. Preliminary results were reported at international conferences.

• Data for the deuteron–proton nonmesonic breakup in coplanar geometry at an energy of 400 MeV obtained at internal target were proceeded. Preliminary results were reported at international conferences.

• The theoretical calculations for the interpretation of the obtained experimental data on deuteron–proton elastic scattering were performed within the relativistic multiple scattering model taking into account the excitation of delta-isobar in the intermediate state.

Alpom-2

The measurements of analyzing powers in the reaction $p + CH_2$ and $n + CH_2$ in the energy range up to 7.5 and 4.5 GeV/c, respectively, were performed during the Nuclotron runs. Results on the neutron asymmetry were obtained for the first time (see Fig. 1).

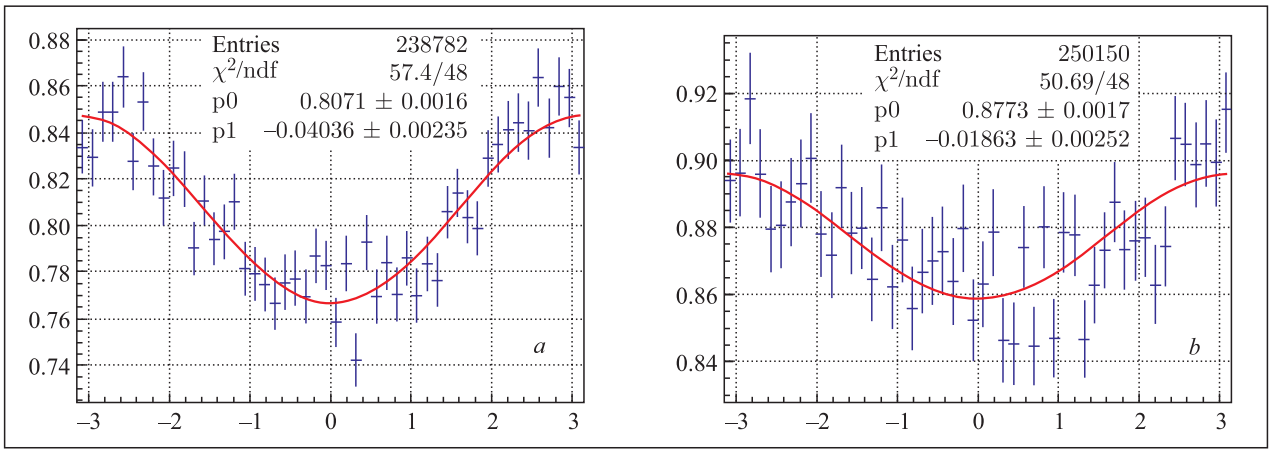


Fig. 1. Proton (a) and neutron (b) asymmetry

Experiments at the Large Hadron Collider

ALICE

New results of the 1D femtoscopic correlation analysis for K^+K^- pair production in Pb–Pb collisions at 2.76 TeV (per nucleon pair) were obtained and compared with the prediction of Lednický R. and Luboshitz V. (Sov. J. Nucl. Phys. 1982. V. 35). Figure 2, *a* shows the typical correlation function for K^+K^- pair productions. The curve is the fit with Lednický–Luboshitz formula and describes well the data including ϕ meson peak. Figure 2, *b* shows the source radii of K^+K^- pairs and of identical kaons ones versus pair transverse momentum, k_T. Identical pairs were analyzed with the help of quantum statistical method, as well as K^+K^- pairs analysis takes into account only interaction in the final state. The good agreement between two different methods is seen [7, 8].

New results were obtained with the JINR team participation for the J/ψ and ρ^0 production in ultraperipheral Pb–Pb collisions (UPC) at 5.02 TeV. The J/ψ resonance peak was studied and cross section was obtained taking into account the background [9, 10].

The tests of the modules of the PHOS ALICE electromagnetic calorimeter were performed in beams of electrons at PS and SPS CERN accelerators in the energy range of 1–160 GeV. This study aimed at making the optimal choice for the upgrade of photodetectors and readout electronics. The goal of the upgrade is to provide the calorimeter functioning at the room temperature without the worsening of the energy resolution and the improvement of the time resolution. Currently, PHOS is running at the temperature $-28\,^\circ$C and has the time resolution $\sigma_t = 4{-}5$ ns.

Silicon photomultipliers area of 6×6 mm (four parallel connected 3×3 mm in size SiPM) showed some energy resolution worse than APD of 10×10 mm, but significantly better than APD of 5×5 mm. SiPM area increased twice would get the same resolution as 10×10 mm.

The time resolution for SiPM is $\sigma_t = 0.15$ ns to energy of 1 GeV. It is possible to use two SiPM as photodetectors, one for the range of 0–10 GeV, the other for the range of 10–160 GeV.

CMS

In 2016, the JINR group took part in data taking, processing, and physics analysis of data collected during the LHC run with the proton beams at energy of 13 TeV and the luminosity up to 1.52×10^{34} sm$^{-2} \cdot$ s^{-1}. The new limits on the masses of new dilepton resonances were obtained from 2015 data, 95% CL lower limit on the masses of spin-1 Z' of sequential standard model (SSM) is 3.37 TeV. The preliminary results of 2016 in the dimuon channel with an integrated luminosity of 13 fb^{-1} extend this limit up to 3.75 TeV.

Experiments at the CERN Super Proton Synchrotron

COMPASS

With considerable participation of the JINR group, the multiplicities of charged pions and unidentified hadrons produced in deep-inelastic scattering were measured by the COMPASS. Data were obtained with 160 GeV muon beam and an isoscalar target (^{6}LiD).

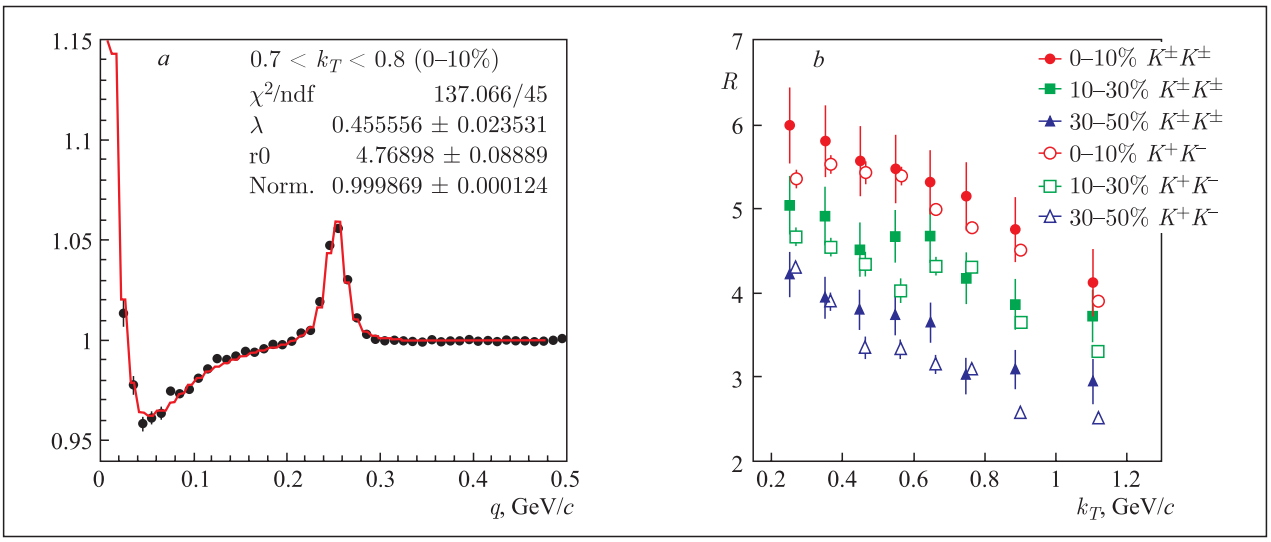


Fig. 2. *a*) Correlation function of K^+K^- pairs. The curve is Lednický–Luboshitz prediction; *b*) the source radii versus k_T

Precise measurements of charged kaon multiplicities in deep inelastic scattering were performed and published [11]. These data cover the kinematic domain $1 < Q^2 < 60$ (GeV/c)^2 in the photon virtuality, $0.004 < x < 0.4$, $0.1 < y < 0.7$, $0.20 < z < 0.85$, and $W^2 > 5$ (GeV/c)^2 in the invariant mass of the hadronic system. The results from the sum of the z-integrated K^+ and K^- multiplicities at high x point to a value of the nonstrange quark fragmentation function are larger than those obtained by the earlier DSS fit (see Fig. 3).

One of the main achievements of the JINR group in 2016 is a completion of works on assembly and installation of a new electromagnetic calorimeter (ECAL0) into the COMPASS setup (see Fig. 4). This calorimeter, suggested and developed at JINR, is a unique device of the "shashlyk"-type (scintillator, lead), in which the most advanced photodetectors — Micro-pixel Avalanche Photo Diodes (MAPD) with ultrahigh pixel density (up to 15 thousand pixels/mm^2) were used, instead of the traditional photomultiplier tubes.

NA61/SHINE

A group of the VBLHEP of JINR was responsible for processing and analysis of the experimental data on light nuclei production in central Pb + Pb interactions. During the data taking, transverse momentum spectra, rapidity distributions, and particle ratios were measured. Result of data analysis has shown that the obtained yields are compared to predictions of statistical models. Obtained phase–space distributions of light nuclei were compared to those of protons in the context of a coalescence approach. The coalescence parameters

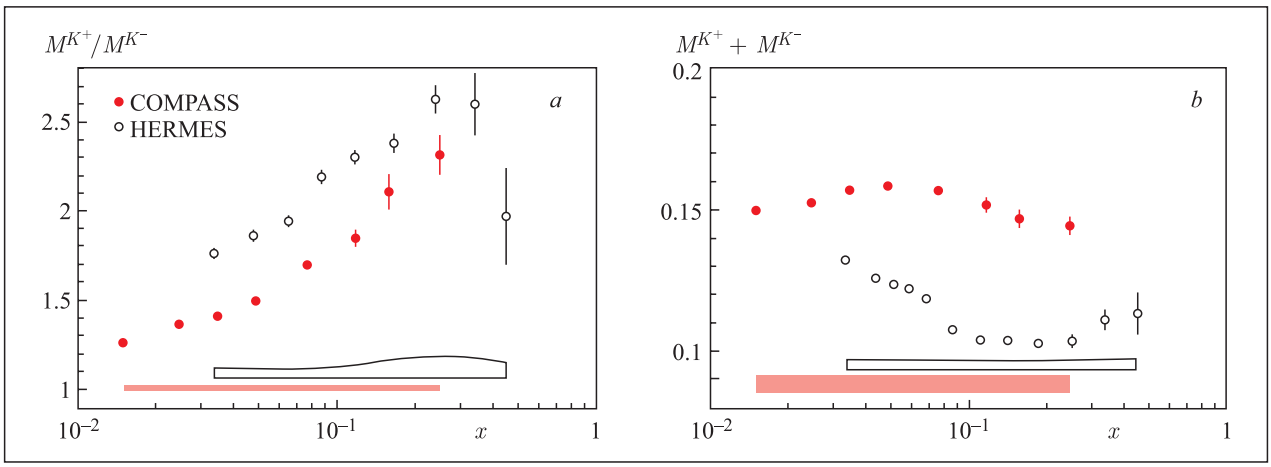


Fig. 3. *a*) Ratio of z-integrated multiplicities, M^{K^+}/M^{K^-}. *b*) Sum of z-integrated multiplicities, $M^{K^+} + M^{K^-}$. COMPASS data (full points) are compared to HERMES data (open points)

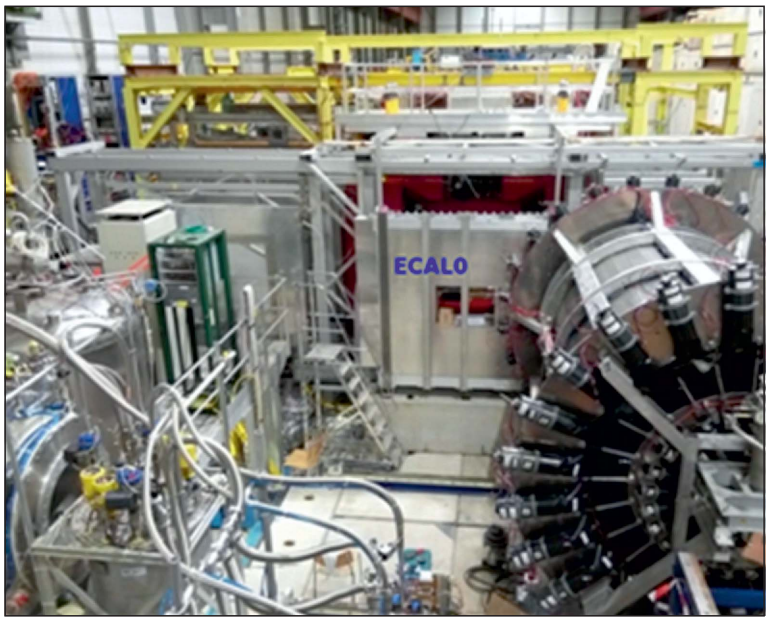


Fig. 4. ECAL0 in the COMPASS setup

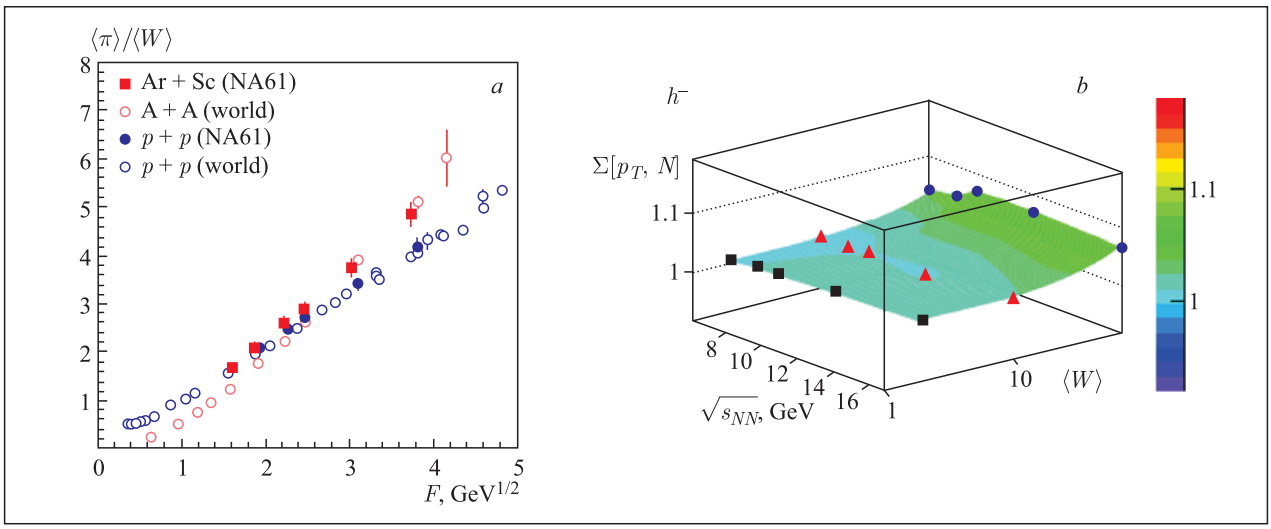


Fig. 5. *a*) Kink plot: mean pion multiplicity divided by mean number of wounded nucleons as a function of Fermi collision energy measure F. *b*) $\Sigma[p_T, N]$ in inelastic $p+p$ (grey squares), 0–5% Be + Be (red triangles), and 0–5% Ar + Sc (blue circles) collisions obtained by NA61/SHINE at forward rapidity, $0 < y_\pi < y_{\rm beam}$, and in $p_T < 1.5$ GeV/c

B_2 and B_3, as well as coalescence radii for d and ^{3}He were determined as a function of transverse mass at all energies [12].

Detailed study of fluctuations in $p + p$, Be + Be, and Ar + Sc collisions for critical end-point search is in progress (see Fig. 5). Transverse momentum fluctuations in the observed interactions show no structures which could be related to the critical point [13].

Experiments at the Relativistic Heavy Ion Collider, BNL

STAR

The JINR team of the STAR collaboration takes part in the analysis of the BES-I data. The original method of data analysis has been suggested and exploited for search for new phenomena in nuclear matter created in heavy ion collisions. The preliminary STAR data, which are shown in Fig. 6, cover a wide kinematical and dynamical range of particle production, collision energy $\sqrt{s_{NN}} = 7-200$ GeV, centrality of collisions 5–80%, and momentum range $p_T = 0.2-12$ GeV/c.

As seen from Fig. 6, the data demonstrate strong energy and centrality dependence of spectra, exponential behavior of the spectra at low p_T and energy $\sqrt{s_{NN}}$, a power behavior of spectra at high p_T and energy $\sqrt{s_{NN}}$. One observes that difference of yields at various energies strongly increases with transverse momentum.

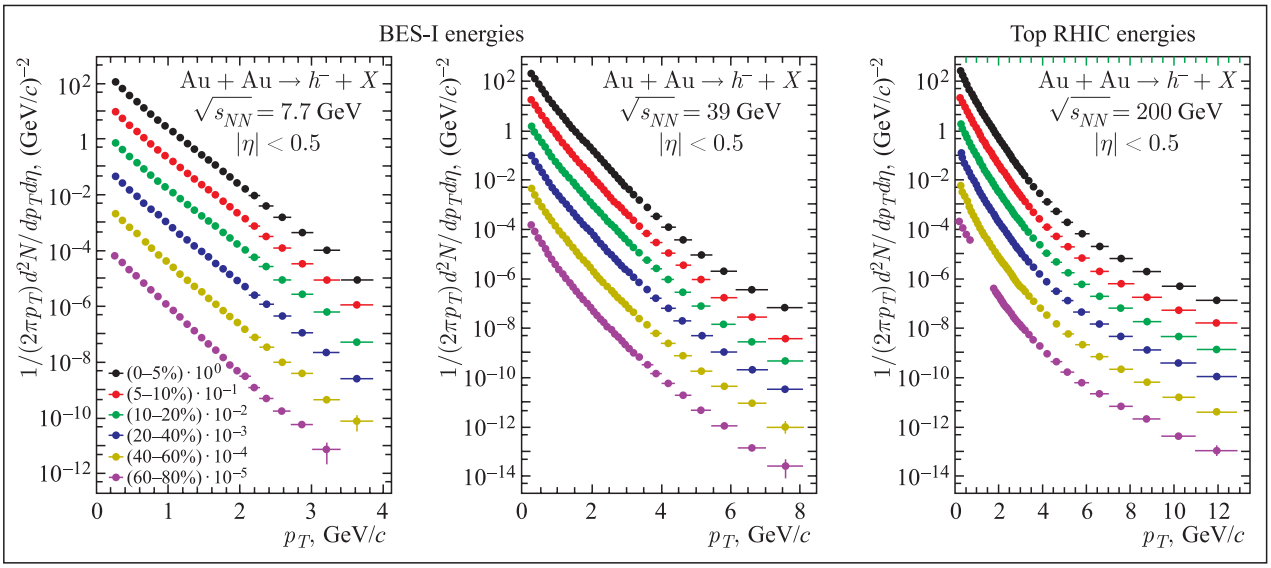


Fig. 6. Transverse momentum distribution of negative charged particle production at BES-I energies of 7.7 and 39 GeV, and RHIC energy of 200 GeV as a function of centrality

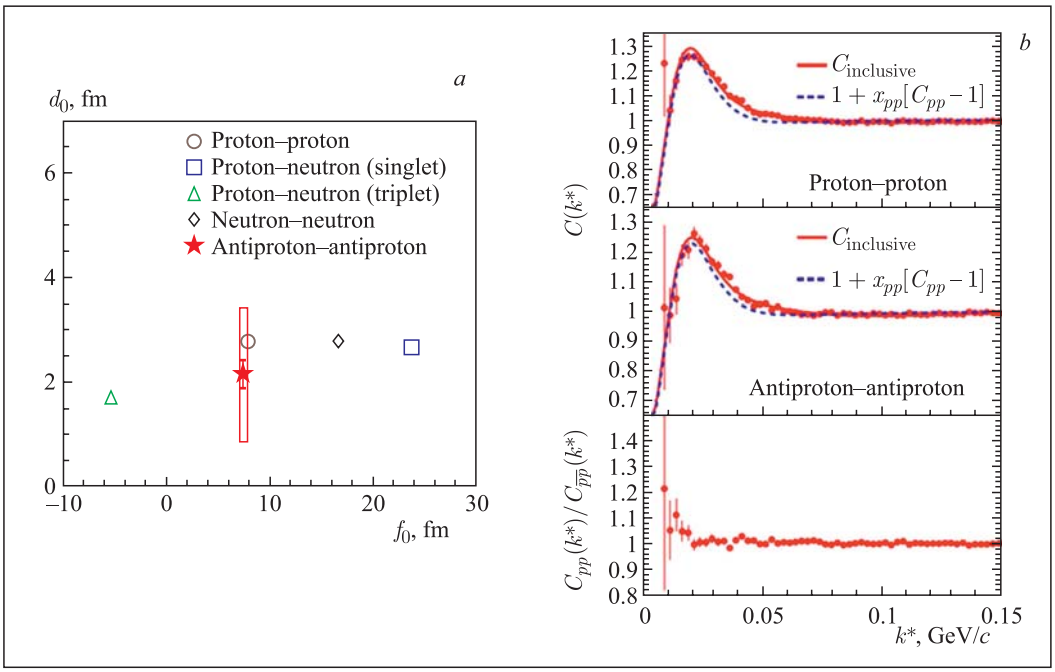


Fig. 7. *a*) Effective range d_0 dependence on scattering length f_0. *b*) Correlation functions of $N-N$ and $\bar{N}-\bar{N}$ pairs

New very important results have been obtained with an active participation of the JINR group in the measurement of interaction between antiprotons. Antiproton pair correlations obtained by the STAR experiment with gold ions at 200 GeV per nucleon were analyzed [14]. Results show the attracting nuclear force between two antiprotons. The measurement of the two key parameters that characterize the corresponding strong interaction, namely, the scattering length (f_0) and effective range (d_0) are presented in Fig. 7, *a*. As direct knowledge from the interaction between two antiprotons, the simplest system of antinucleons (nuclei), this result provides a fundamental ingredient for understanding the structure of more sophisticated antinuclei and their properties (see Fig. 7, *b*).

Experiments at FAIR

CBM

In the framework of the CBM project preparation, the following results were obtained in 2016:

• The simulation for the central and peripheral Au + Au interactions at the energy of 4A GeV aimed at the study of the light nuclear fragments (deuterons, tritium, etc.) coalescence was performed.

• The simulation for the vector meson decays using "vector-finding" approach to reconstruct the tracks of muons in the MUCH CBM was continued.

• The radiation tests of silicon photodetectors from various manufacturers (Ketek, Zecotek, Hamamatsu) and registering electronics for the centrality and reaction plane determination the CBM detectors were performed.

EVENTS

Signing of the Agreement between the Moscow Region and JINR and the First Stone Laying Ceremony for the Mega-Science NICA Project

An agreement on cooperation between the Government of the Moscow Region and the Joint Institute for Nuclear Research was signed on 25 March at VBLHEP. The agreement was signed by the Governor of the Moscow Region A. Yu. Vorobiev and JINR Director Academician V. A. Matveev.

International Session-Conference of SNP PSD RAS "Physics of Fundamental Interactions"

From 12 to 15 April 2016, the Section of Nuclear Physics of the Physical Sciences Division of the Russian Academy of Sciences (SNP PSD RAS) and the Joint Institute for Nuclear Research (JINR) was held at JINR, an International Session-Conference of the SNP PSD RAS "Physics of Fundamental Interactions".

The Programme of the Session-Conference covered basic theoretical and experimental aspects of particle physics and related problems in nuclear physics, astrophysics, and cosmology.

The NA62 International Collaboration Meeting

The NA62 International Collaboration Meeting was held at VBLHEP on 22–27 August 2016. The meeting is held annually in one of 32 institutions, representing 12 countries participating in the collaboration. More than 60 experts visited the meeting in Dubna; they discussed the most pressing issues faced by the collaboration and made outline plans for its activities in the short and medium term. One day of the workshop was

set for the meeting of the Steering Committee of the collaboration.

Baldin Seminar

The XXIII International Baldin Seminar on High Energy Physics Problems "Relativistic Nuclear Physics and Quantum Chromodynamics", named "Baldin Autumn", was held on 19–24 September 2016 in the Big Conference Hall of the Laboratory of High Energy Physics of JINR. Since this year is the 90th anniversary of Alexander Mikhailovich Baldin, the Seminar was dedicated to his memory.

The Seminar gathered a record number of participants — 250 physicists from 22 countries. There were presented 157 reports, 57 at the plenary sessions and 100 at parallel sections. The reports covered the research results of the most of the world leading physics centers, such as CERN (Switzerland), GSI (Germany), BNL (USA), and many others. The Seminar was also supported by the RFBR grant and the grant of the JINR Director. There were a lot of young scientists. More than a quarter of participants were aged less than 35.

Perspectives of Experimental Research at the Nuclotron Beams

The fourth International Workshop of the Nuclotron Beam Users "Perspectives of Experimental Research at the Nuclotron Beams" was held on 6 October 2016 at VBLHEP.

The present status and prospect of the Nuclotron facility, which provides unique possibilities for investigations at relativistic ion beams in the kinetic energy range from hundreds of MeV to several GeV per nucleon, were discussed.

After reports, on the milestones of the general discussion, representatives of the JINR Member States and consumers of the Nuclotron beams approved the resulting document of the Workshop, determining the development of the user policy and development of the accelerator complex in the nearest future.

BIOMAT

The International Workshop on Biophysics and Materials at NICA "BIOMAT" was held on 12–13 December 2016 at VBLHEP for the first time. It was dedicated to applied research at the NICA complex. This was initially pertinent to radiobiology, ion beam interactions with materials, and exposure of electronic components, testing of electronic components for space applications. The Workshop gathered 60 participants from Russia, Belarus, Germany, Egypt, Italy, Poland, the Czech Republic. Opportunities for joint research were discussed in the round table format.

REFERENCES

1. *Trubnikov G., Butenko A. et al.* Commissioning of New Proton and Light Ion Injector for Nuclotron–NICA // Proc. of IPAC2016, Busan, Korea, 2016.
2. *Trubnikov G., Butenko A. et al.* Commissioning of New Light Ion RFQ Linac and First Nuclotron Run with New Injector // RuPAC2016, St. Petersburg, Russia, 2016.
3. *Kovalenko A. D. et al.* Current Results on Implementation of the Nuclotron/NICA R&D Program with Polarized Beams. Presented at SPIN2016, Urbana/Champagne, IL, USA, Sept. 2016.
4. *Krivenkov D. O. et al.* Polarimetry at Nuclotron. Presented at SNP School 2016, Tohoku Univ., Sendai, Japan, Nov. 2016.
5. *Butenko A. V., Trubnikov G. V. et al.* The Heavy Ion Linac at the NICA Project // Proc. of LINAC2014, Geneva, Switzerland, 2014.
6. *Butenko A. V., Trubnikov G. V. et al.* Commissioning of Heavy Ion Linear Accelerator (HILAC) of the NICA Project // Proc. of RuPAC2016, St. Petersburg, 2016.
7. *Adam J. et al. (ALICE Collab.).* Centrality Dependence of Pion Freeze-Out Radii in Pb–Pb Collisions at $(s_{NN})^{1/2} = 2.76$ TeV // Phys. Rev. C. 2016. V. 93. P. 024905.
8. *Adam J. et al. (ALICE Collab.).* Multipion Bose–Einstein Correlations in *pp*, *p*–Pb and Pb–Pb Collisions at LHC // Phys. Rev. C. 2016. V. 93. P. 054908.
9. *Adam J. et al. (ALICE Collab.).* Differential Studies of J/ψ and $\psi(2S)$ Production at Forward Rapidity in Pb–Pb Collisions at $(s_{NN})^{1/2} = 5.02$ TeV // JHEP. 2016. V. 1605. P. 179.
10. *Adam J. et al. (ALICE Collab.).* J/ψ Suppression at Forward Rapidity in Pb–Pb Collisions at $(s_{NN})^{1/2} = 5.02$ TeV. arXiv:1606.08197. 2016.
11. *COMPASS Collab.* Multiplicities of Charged Kaons from Deep-Inelastic Muon Scattering Off an Isoscalar Target. CERN-EP/2016-206; hep-ex/1608.06760; Phys. Lett. B (submitted).
12. *Anticic A., Baatar B., Kolesnikov V. I., Malakhov A. I., Melkumov G. L. et al.* Production of Deuterium, Tritium, and ^{3}He in Central Pb + Pb Collisions at 20A, 30A, 40A, 80A, and 158A GeV at the CERN Super Proton Synchrotron // Phys. Rev. C. 2016. V. 94. P. 044906.
13. *Aduszkiewicz A., Baatar B., Kolesnikov V. I., Malakhov A. I., Matveev V., Melkumov G. L. et al.* Multiplicity and Transverse Momentum Fluctuations in Inelastic Proton–Proton Interactions at the CERN Super Proton Synchrotron. arXiv:1510.00163v4[hep-ex]. 2016.
14. *ALICE Collab.* // Nature. 2015. V. 527. P. 345.

DZHELEPOV LABORATORY OF NUCLEAR PROBLEMS

NEUTRINO PHYSICS AND RARE PHENOMENA, ASTROPHYSICS

In 2016, the **Baikal** collaboration made one more step to reach its goal of constructing a cubic-kilometer-scale neutrino detector (NT-1000 project). The first full-scale cluster of standard design (8 strings of 3 sections each, radius 60 m, 288 optical modules in total) was deployed during the winter expedition from February to March 2016. It was proved that the extended sections of 525 m length were constructible and operable. Data acquisition is proceeding now.

Since the plan for the next-year expedition is to deploy the second full-scale cluster of the standard design, it is important to produce 288 new optical modules. That is why we made the production line at JINR in 2016, which is capable of making 300–600 optical modules per year. That should be enough to meet the needs of the experiment even when we deploy two clusters per year. At present, 233 optical modules are assembled and 144 of them have passed the test procedures. Assembling and testing of the other optical modules are in progress. Moreover, the procedure of testing 12 optical modules as a single section, which is a minimal unit of the data-acquisition system of the detector, began at specially designed test benches.

One of the most important achievements of the last year is the construction of a new control station on the shore of Lake Baikal, which includes new power-supply detector control system, data-processing and data storage systems. Preliminary data processing consists of aggregating event data from different sections, making the time and amplitude calibrations of the detector, and obtaining the coordinates of the optical modules via the acoustic-positioning system data corresponding to the event time. All these tasks were accomplished in 2016.

In 2016, within the **Daya Bay** project the doubling of the acquired statistics (1230 days of DAQ) and the improvement of the uncorrelated detection efficiency uncertainty from 0.2 to 0.13% allowed refining the neutrino oscillation parameters: $\sin^2 2\theta_{13} = 0.0841 \pm 0.0033$, $\Delta m^2_{ee} = (2.45 \pm 0.08) \cdot 10^{-3}$ eV^2 [1]. It is the most precise measurement of both oscillation parameters.

A theory of neutrino oscillations based on wave packets was developed. It predicts the loss of coherence of wave packets and suppression of neutrino oscillations. The first limits on the coherence parameters are obtained. The upper limit on the relative neutrino energy spread is $\sigma_{\rm rel} < 0.20$ (95% CL) [2], which is equivalent to the lower limit on the spatial size $\sigma_x < 10^{-11}$ cm (95% CL). The measurement is based on the Daya Bay data acquired during the period of 621 days.

Within the **JUNO** project, a scanning station for large 50″ photomultiplier tubes (PMTs) was designed and manufactured. Its purpose is to measure differential (zonal) characteristics: photodetection efficiency, amplification, etc. Scanning station software is developed and is at the debugging stage. Several new scanning stations are being manufactured and prepared to be shipped to China. A prototype of the Top Tracker support was designed and produced. An algorithm to control the performance of the plastic scintillator by using the signal of cosmogenic muons is developed. We have developed a method and software for optimal veto volume determination in order to cut off long-lived isotopes of ^{8}He/^{9}Li produced in the interactions of cosmogenic muons. This optimization is needed to maximize the fiducial volume of the detector.

In 2016, limits on the neutrino fluxes associated with the gamma-ray bursts are obtained by the **Borexino** collaboration [3]. The analysis of the seasonal signal variations in Borexino is completed confirming the solar origin of the observed neutrino signal.

Limits on the spin-independent WIMP-nucleon cross section have been obtained using (1422 ± 67) kg $\cdot$ d of data acquired with the prototype of the DarkSide detector. These cross sections for the WIMP particles with a mass of 100 GeV (100 GeV, 10 TeV) are $2 \cdot 10^{-44}$ ($8.6 \cdot 10^{-44}$, $8.0 \cdot 10^{-43}$) cm^2 at 90% CL, respectively [4].

During 2016, within the **NOνA** experiment the analysis based on exposure of $6.05 \cdot 10^{20}$ POT (Protons On Target) was performed, and new results were obtained [5–7] for the muon neutrino oscillation parameters. In particular, an interesting hint for the non-maximal θ_{23} mixing was obtained for the first time at the $> 2.5\sigma$ significance level.

Moreover, the new results establish oscillation in the electron neutrino appearance mode, $\nu_\mu \to \nu_e$, with the $> 8\sigma$ level. This signal slightly prefers Normal Hierarchy (NH) of the neutrino mass, while Inverted Hierarchy (IH) with the lepton CP violation value $\delta_{\rm CP} = \pi/2$ is ruled out at the level of $> 3\sigma$.

The present NOνA statistics corresponds to about one project year (from six years expected in total). The new data (especially with antineutrino beam planned also for 2017) will help to resolve degeneracies in the effects of mass hierarchy, $\delta_{\rm CP}$, and θ_{23} octant.

Physicists from JINR DLNP take an active part in the **NA61/SHINE** experiment at CERN. In 2016, the analysis of the experimental data was completed, and new important results about the precision measurements of hadron production in interactions of 31 GeV/c protons with a thin carbon target and with a T2K replica target were published [8, 9]. These results are crucial for predictions of neutrino and antineutrino fluxes at the J-PARC accelerator complex and thus will allow further reduction of systematic uncertainties in determination of neutrino oscillation parameters by the T2K experiment.

The **NEMO-3** detector, which had been operating at the Modane Underground Laboratory from 2003 to 2010, was designed to search for neutrinoless double-β ($0\nu\beta\beta$) decay. Seven isotopes (^{100}Mo, ^{82}Se, ^{130}Te, ^{116}Cd, ^{150}Nd, ^{96}Zr, ^{48}Ca) were studied by the simultaneous recording of the energy and track of the event, ^{100}Mo and ^{82}Se with standing out since they were the most massive ones [10, 11]. No evidence for neutrinoless double-beta decay was observed, which led to obtaining limits on the effective neutrino mass that are among the best to date, especially for the ^{100}Mo and ^{82}Se isotopes.

As evolution of NEMO-3, the **SuperNEMO** experiment (new generation experiment to search for neutrinoless double-beta decay) is being performed. As the first phase, its first module called Demonstrator is under construction. It will contain 7 kg of ^{82}Se and will be able to reach the NEMO-3 sensitivity for the $0\nu\beta\beta$ decay in only five months. If no background events in the $0\nu\beta\beta$ region are detected after 2.5 y of data taking, which implies an exposure of 17.5 kg $\cdot$ y, the half-life sensitivity will be increased to $T(0\nu) > 6.5 \cdot 10^{24}$ y (90% CL), leading to a mass sensitivity of $\langle m\beta\beta \rangle < 200{-}400$ meV. The SuperNEMO Demonstrator module is currently under assembly at the LSM, the last part will be assembled at the beginning of 2017. Data taking will start in the second half of the year to measure the level of background achieved.

The **EDELWEISS** program searches for evidence of direct WIMPs from the Milky Way galaxy scattering off Ge nuclei within cryogenic Ge crystals. The EDELWEISS detectors are cryogenic (working temperature $\sim$ 20 mK) Ge bolometers allowing simultaneous measurement of phonon and ionization signals. A comparison of the two signals provides highly efficient event-by-event discrimination between nuclear recoils and electrons. In 2016, the main objective of the EDELWEISS collaboration was to accumulate WIMP data from 800 g FID detectors with an active rejection of the surface background. EDELWEISS continues testing new approaches to extending the investigated WIMP masses to the low-mass region.

In 2016, the results of the search for low-mass WIMPs at EDELWEISS-III were published. The 90% CL exclusion limit set for the WIMPs with $m_\chi = 4$ GeV/c^2 is $1.6 \cdot 10^{-39}$ cm^2 [12, 13]. Positive results reported by some other experiments were directly verified. It is important that the achieved EDELWEISS-III sensitivity completely covers the region of positive CoGeNT results obtained with the same nucleus (Ge).

The **νGeN** experiment is intended for detection of coherent neutrino — Ge nucleus elastic scattering using special HPGe detectors developed by DLNP (JINR, Dubna) in collaboration with BSI (Riga). To be sensitive to the coherent scattering signal, the νGeN experiment is performed under reactor of power #3 at the Kalinin Nuclear Power Plant (KNPP) at the point where the neutrino flux is greater than $5.4 \cdot 10^{13}$ cm$^{-2} \cdot$ s^{-1} (minimal distance 10 m). In the scope of the project, we work on creation and investigation of new low-threshold semiconductor detectors made from different materials (HPGe, CZT, SiC). The aim of this R&D is to build detectors with an energy threshold of 200 eV and below for further detailed study of the coherent scattering process.

In 2016, after some additional tests in Dubna the setup was delivered to the KNPP and assembled in the room located just under the reactor of power unit #3. Now the spectrometer is under commissioning. Integration of all parts of the setup (passive and active veto systems, data acquisition, moving platform that will change the distance between the detectors and the neutrino source) is in progress. The neutrino data acquisition begins in 2017.

In June 2016, the **GERDA** collaboration meeting released the first set of data accumulated during six months. The expected background of

0.001 counts/(keV · kg · y) was achieved. The first Phase II and previous Phase I data were analyzed together (total exposure 34.4 kg · y). A new half-life limit for neutrinoless double-beta decay was set to be $T_{1/2}(0\nu) > 5.3 \cdot 10^{25}$ y (90% CL). The sensitivity was $4.0 \cdot 10^{25}$ y [14]. Due to the unprecedented background level, no background count in the region of interest is expected until we get the design exposure of 100 kg · y in 2018. Thus, GERDA Phase II is the first background-free experiment aimed at searching for $0\nu\beta\beta$. Consequently, our sensitivity will increase linearly, unlike the case in other projects where it is proportional to the square root of exposure. At the end of the data taking, the GERDA Phase II sensitivity of 10^{26} y will be achieved.

At the end of 2016, a new international collaboration (preliminary name is NG-Ge76, Next Generation Ge-76) was formed. The goal of this new effort is to build a next-generation ton-scale experiment to search for the neutrinoless double-beta decay of ^{76}Ge. The first phase of this project with 200 kg of germanium detectors will be performed at the modified GERDA setup.

The IACT telescopes with $\sim$ 10 m^2 mirror and $\pm 5^\circ$ FoV are added to the **TAIGA** experiment to improve the detector sensitivity and decrease the energy threshold down to ~ 1.5 TeV for energy spectrum measurements of the known gamma sources and more efficient discrimination between gamma and hadron EAS. The JINR responsibility is to design, produce, and test the IACT telescope mechanics. After the combined mechanical tests the IACT was delivered to the Tunka area [15].

The **NUCLEON** device is placed as an additional payload on board the Resurs-P No. 2 satellite that was launched on 26 December 2014. Preliminary results are obtained from the charge distribution measurements of cosmic ray nuclei from lithium to iron and from the spectrum measurements of CR protons and He nuclei. They are in the reasonable agreement with other experimental data, in particular, with the ATIC, SOCOL, CREAM, TRACER, and AMS-2 results [16].

The **TUS** mission was launched at the end of April 2016 aboard the dedicated Mikhailo Lomonosov satellite and is expected to operate for 3–5 years. Now the TUS detector is working in the flight test regime. Unexpectedly, new background events were discovered which were not found before in the Tatiana and Tatiana-2 space flights. Short and powerful UV pulses arise in the UV filter due to interactions of CR hadrons that generate a trigger signal. The program of the TUS event visualization was developed at JINR. It allows the conclusion that at the $\sim$ 200th time step the CR particle interacted inside the UV-filter and produced secondary charged particles that generated light pulses. These light pulses along the path of secondary particles were registered by photodetector and produced a trigger [17].

PHYSICS OF ELEMENTARY PARTICLES

In the **ATLAS** experiment, a search is conducted for resonant high-mass new phenomena in dielectron and dimuon final states. The search uses 13.3 fb^{-1} of proton–proton collision data, collected at $\sqrt{s} = 13$ TeV by the ATLAS experiment at the LHC in 2015 and 2016. The dilepton invariant mass is used as the discriminating variable. No significant deviation from the Standard Model prediction is observed. Upper limits at 95% CL are set on the cross section times branching ratio for resonances decaying to dileptons, which are converted into lower limits on the resonance mass, ranging between 3.36 and 4.05 TeV, depending on the model.

Search for gluinos in final states with an isolated electron or muon, multiple jets and large missing transverse momentum are performed using proton–proton collision data at a centre-of-mass energy $\sqrt{s} = 13$ TeV. The dataset used was recorded in 2015 by the ATLAS experiment at the Large Hadron Collider and corresponds to an integrated luminosity of 3.2 fb^{-1}. Six signal selections are defined that best exploit the signal characteristics. The data agree with the Standard Model background expectation in all six signal selections, and the largest deviation is 2.1 standard deviation excess [18].

Search for new resonances with mass larger than 250 GeV decaying to a Z boson and a photon was performed. The Z bosons are identified through their decays either to charged, light, lepton pairs (e^+e^-, $\mu^+\mu^-$) or to hadrons. The data are found to be consistent with the expected background in the whole mass range investigated, and upper limits are set on the production cross section times decay branching ratio to $Z\gamma$ of a narrow scalar boson with mass between 250 GeV and 2.75 TeV [19].

Within the **Mu2e** project, the calorimetry R&D was performed: a matrix of CsI crystals was tested in electron beams at YERPHI (Yerevan, Armenia) and INFN (Frascati, Italy), and an energy resolution of 6.4% was obtained from the tests within at 35 MeV electron beam of LUE-75 at YERPHI. The photodetectors R&D for BaF_2 crystals is also under way, and development of a photodetector sensitive to the fast component of the spectrum of the crystal in the range up to 260 nm and in-

sensitive to the slow component peaking at 310 nm is in progress. Photocathodes with upper p-emitter layer of AlGaN : Mg are used as photodetectors suitable for discrimination of only fast emission components of BaF_2 crystals applied. An AlGaN photocathode with the Al mass fraction $x = 0.3$ was combined with a microchannel plate within one device. The Co-60 tests showed FWHM $\sim 10\%$ [20–22].

Within the Cosmic Ray Veto system, light collection from extruded scintillation plates with holes around the fibers filled with various fillers was investigated. An original solution to fill the holes with optical resin or rubber was found. The light collection from the strips filled with CKTN-MED(E) with 1.2 mm fibers is 1.8 times higher than in the "dry" case [23].

The analysis of the $D^+ \to K^-\pi^+e^+\nu_e$ decay channel based on the data collected in the **BES-III** experiment in 2010 and 2011 at the $\psi(3770)$ resonance is completed. Using a nearly background-free sample of 18262 decays, we measured the branching fraction $B(D^+ \to K^-\pi^+e^+\nu_e) = (3.71 \pm 0.03 \pm 0.08)\%$. For $0.8 < m_{K\pi} < 1.0$ GeV/c^2 the branching fraction is $B(D^+ \to K^-\pi^+e^+\nu_e) = (3.33 \pm 0.03 \pm 0.07)\%$. A partial wave analysis showed that in addition to the dominant $K^{-*}(892)^0$ process, there is the S-wave contribution of $(6.05 \pm 0.22 \pm 0.18)\%$, and all other components are negligible. The parameters of the $K^*(892)^0$ resonance and the form factors based on the spectroscopic pole were also measured. $K^*(892)^0$ helicity basis form factors were measured in a model-independent way [24].

In 2016, within **COMPASS** experiment the DLNP JINR group observed photoproduction of the exotic charmonium $X(3872)$ in the reaction $\gamma^*N \to X(3873)N'\pi^\pm$. The result is important for the understanding of the nature of exotic XYZ states studied before at electron–positron and hadron colliders. The group actively participated in the quality analysis of physics data collected in 2016. The possibility of their use for the study of the exotic charmonium was investigated.

Within the **PANDA** project, in addition to the approval of the Technical Design Report for the PANDA Muon System, the DLNP group constructed a big prototype of the system. This prototype comprises a laminated steel absorber (range system) with the total weight of around 10 t, which represents all substructures of the Muon System, and 272 eight-wire Mini Drift Tubes (MDT detector) 1 m long. Strip boards with 1-cm-wide strips are positioned on top of MDT layers. The strips run perpendicularly to the wires. The total number of the readout channels is about 4000 (2000 for wires and 2000 for strips). The DAQ and trigger system of the COMPASS/CERN experiment is adapted for the purpose of the beam test. The prototype passes tests with the T9/PS/CERN test beam. Three tuning/debugging runs were conducted at CERN to the moment. In 2017, the DLNP JINR group plans to perform runs for direct calibration of different prototype structures for muons, pions, and protons.

During the 2008–2010 production runs, the **PEN** experiment accumulated some $2.3 \cdot 10^7$ $\pi^+ \to e^+\nu$ and $> 1.5 \cdot 10^8$ $\pi \to \mu \to e$ decays as well as significant numbers of pion and muon radiative decays [25]. A comprehensive blind maximum likelihood analysis is under way to extract a new experimental value of $R^\pi_{e/\mu}$. The PEN goal is $\Delta R/R \approx 5 \cdot 10^{-4}$. The first results of the data processing will be available in 2017. Once completed, analysis of the PEN $\pi^+ \to e^+\nu\gamma$ data is expected to yield improvements in the SD-structure-dependent amplitude, which constrains F_V–F_A; analysis of the PEN $\mu \to e\nu\nu\gamma$ data is expected to improve the present value of the parameter η.

The international **MEG** collaboration is conducting an experiment to search for the $\mu^+ \to e^+\gamma$ decay using the accelerator muon beam at PSI, Switzerland. The final result is based on the full dataset collected by the MEG experiment: $7.5 \cdot 10^{14}$ stopped muons on the target. No significant excess of events is observed in the dataset with respect to the expected background, and a new upper limit on the branching ratio of this decay $B(\mu^+ \to e^+\gamma) < 4.2 \cdot 10^{13}$ (90% CL) is established, which represents the most stringent limit on the existence of this decay to date [26]. We identified $\sim 13\,000$ decays $\mu^+ \to e^+\nu_\mu\nu_e\gamma$ in a total sample of $1 : 8 \cdot 10^{14}$ positive muon decays and measured the branching ratio $(6.03 \pm 0.14(\text{stat.}) \pm 0.53(\text{syst.})) \cdot 10^{-8}$ for $E_e > 45$ MeV and $E_\gamma > 40$ MeV, consistent with the Standard Model prediction [27]. The precise measurement of this decay mode provides a basic tool for the timing calibration, a normalization channel, and a strong quality check of the MEG experiment in the search for the $\mu^+ \to e^+\gamma$ process.

Within the **GDH&SPASCHARM** project, the first ever successful experiment with the active polarized target was implemented. High efficiency and a low threshold for the detection of the recoil protons in the target open up new prospect for the study of the proton spin structure and extraction of the model-independent data. The proton polarization was $\approx 65\%$, the relaxation time amounted to 100 h at the temperature of 45 mK in the magnetic field of 0.4 T. The experiment was performed in the beam of circularly polarized tagged photons of the MAMI accelerator (Mainz). Polarization observables for π^0 and π^+ photoproduction as well as the Compton scattering asymmetries allowing extraction of model-independent data on the proton spin polarizabilities were measured.

The $\gamma p \to p\pi^0$ reaction was studied at laboratory photon energies from 425 to 1445 MeV with a transversely polarized target and a longitudinally polarized beam. The beam–target asymmetry was measured for the first time and new high-precision data for the target asymmetry were obtained. The experiment was performed at the photon tagging facility of

the Mainz Microtron (MAMI) using the Crystal Ball and TAPS photon spectrometers. The polarized cross sections were expanded in terms of associated Legendre functions and compared to recent predictions from several partial-wave analyses. The information about the contributions of various baryon resonances was obtained [28].

The double polarization observable and the helicity-dependent cross sections $\sigma_{1/2}$ and $\sigma_{3/2}$ were measured for η photoproduction from quasifree protons and neutrons. The circularly polarized tagged photon beam of the MAMI accelerator was used in combination with a longitudinally polarized deuterated butanol target. The results show that the narrow structure previously observed in η photoproduction from the neutron is only apparent in $\sigma_{1/2}$ and is hence related to a spin-1/2 amplitude corresponding to contributions of nucleon resonances $N^{-}_{1/2}$ (S_{11}) and $N^{+}_{1/2}$ (P_{11}). The results are in good agreement with recent reaction model predictions [29].

High-statistics measurements of the photon asymmetry Σ for the $\gamma p \to \pi^0 p$ reaction were made in the energy range of 320–650 MeV. The data were measured with the MAMI A2 real photon beam and the Crystal Ball/TAPS detector systems in Mainz, Germany. The results significantly improve the existing world data and are shown to be in good agreement with previous measurements and with the MAID, SAID, and Bonn–Gatchina predictions. An indication of interference between the very small F-waves and the $N(1520)^{-}_{3/2}$ and $N(1535)^{-}_{1/2}$ resonances was found [30].

In the **COMET** project, the preparation of the experiment at the J-PARC accelerator (Japan) on the search for neutrinoless conversion of a muon to an electron is under way. A combine test with the participation of the COMET DLNP group was conducted with the 1.3 GeV electron beam of Tohoku University in 2016. Both the electromagnetic calorimeter (EMC) prototype and the straw-tracker (ST) prototype were used in the test beam. The EMC prototype consisted of 64 LYSO crystals delivered from JINR and divided into 16 modules of 2×2 crystals. Before the beam test all the crystals were studied and certified at JINR, and the most optimal (giving maximum of light) wrapping material consisting of Teflon + ESR was chosen. Also, the study of 20-μm straw tubes continues at JINR.

APPLIED RESEARCH AND ACCELERATORS PHYSICS

In 2016, the **Precision Laser Inclinometer** (PLI) application technique was significantly improved using the previously developed vacuumized prototype. The 2015 measurements had shown the necessity of compensating for the inclinometer noise induced by angular motion of the laser beam. This noise limits the frequency range and does not allow monitoring microseismic oscillations with a frequency below 10^{-3} Hz. In 2016, we proposed an innovative technique of compensation for angular motion of the laser beam using the reference laser beam. Based on this idea, a two-dimensional online compensation system was developed and showed its efficiency: the system compensates for the laser beam noise in a frequency range of $5 \cdot 10^{-6}$–0.1 Hz; the PLI sensitivity in the low-frequency range rises by a factor of more than 30 and reaches the spectral density of 10^{-8} rad/Hz$^{1/2}$ at the frequency of $5 \cdot 10^{-5}$ Hz. It allowed us to reach the fundamentally significant result: angular oscillations of the Earth's surface in two orthogonally related directions caused by the gravity influence of the Moon and the Sun were detected.

According to the agreement between the Institute of Plasma Physics of the Chinese Academy of Sciences (ASIPP) in Hefei, China, and the Joint Institute for Nuclear Research, Dubna, Russia, the project of a superconducting isochronous cyclotron for proton therapy **SC202** is developed at JINR. The cyclotron will accelerate protons up to 200 MeV with maximum beam current of 1 μA. We plan to manufacture two cyclotrons in China: one will operate at the Hefei Cyclotron Medical Center, and the other will replace the Phasotron at the DLNP Medico-Technical Complex and will be used for further research and development of proton therapy for cancer treatment.

Now the physical design of the SC202 cyclotron is developed. Simulations of all systems of the SC202 cyclotron are performed, parameters of the accelerator are chosen, and the beam dynamics from the ion source to the exit from the cyclotron is calculated [31–33]. The SC202 project developed at DLNP was approved by the experts commission in Hefei in October 2016. The SC202 systems and elements will be manufactured in 2017, and the cyclotron will be assembled, tuned, and tested in 2018. The results of the SC202 tests will be used by ASIPP for commercial production of cyclotrons.

The magnetic system of the specialized monochromatic positron channel (SMPC) for **positron annihilation spectroscopy** (**PAS**) is constructed at the sec-

tor of electron cooling. A new version of the cryogenic source of slow monochromatic positrons with closed-loop cooling based on a helium cryocooler was developed and commissioned. The working temperature of 6 K on the surface of the foil covering the ^{22}Na tablet was achieved. The flux of slow monochromatic positrons is $1.6 \cdot 10^6$ s^{-1}. The source was used to transfer positrons through cryogenic source of slow monochromatic positrons. Six PAS runs with the positron beam were performed in 2016. The investigated materials were Zr, Cu, Ag, graphite irradiated with heavy ions, and samples of sandblasted stainless steel.

In 2016, R&D of **novel semiconductor detectors** was mainly concentrated on the research of pixel detectors GaAs : Cr-based and Medipix readout chips and on the study of spectral computed tomography using the MARS CT scanner. Four assemblies of a Timepix readout chip and a GaAs : Cr sensor with very good bump-bond connection (99.8% active pixels) were produced by the JINR group together with the colleagues from IEAP CTU in Prague, Tomsk State University, and CERN. The detectors were carefully calibrated and installed in the ATLAS detector cavern under the ATLAS–GaAsPix project.

The energy resolution of the GaAs : Cr-based Timepix detector in the Medipix mode of a single pixel using collimated monoenergetic photons from the synchrotron radiation source VEPP-3M of the Budker Institute of Nuclear Physics in Novosibirsk was measured. The energy resolution reached 1% at 18 keV. Also, the geometrical mapping of the pixel sensitivity was obtained by scanning the detector with a pencil photon beam along the pixel column. The development of the readout electronics for Timepix detectors was started using the Altera Cyclone 5 SoC FPGA. Now debugging of the data transfer from the detector to PC and the chip DAC setting procedure is in progress.

The software for managing the MARS CT Scanner and preprocessing raw data was upgraded. As a result, errors were eliminated that caused scan interrupting. The gantry stopping procedure was improved, which decreased the gantry oscillation amplitude and time to a complete stop. Scanner management software was developed. The start–stop scanning mode was implemented. Now the program allows receiving images for multiple energy thresholds. To increase the dynamic range of projections, a series of shots can be made in each detector position. This combination allowed spectral tomography scanning. A software for simulating spectral tomography scan was developed using the GEANT4 package and adapted to running on a computer cluster. The method and software for identification of materials in the image domain are under development.

The main goals of the research at the **Medico-Technical Complex** (**MTC**) are 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 2016.

Regular sessions of proton therapy aimed to investigate its efficiency to treat different kinds of neoplasm were performed in collaboration with the Medical Radiological Research Centre (Obninsk) and the Radiological Department of the Dubna hospital. Seven treatment sessions with a total duration of 30 weeks were carried out. Sixty-one new patients were fractionally treated with the medical proton beam. The total number of the single proton irradiations (fields) was more than 4000. Other 33 patients were irradiated using the Co-60 gamma-therapy unit "Rokus-M".

The development of the software–hardware complex for the multileaf proton beam collimator prototype with four pairs of leaves was continued. The full-scale collimator will consist of 33 pairs of leaves and will be used in the so-called dynamic proton beam treatment technique. The design of the main components of the 3D treatment planning software for the proton conformal radiotherapy was continued. The elaborated variant of the software was successfully experimentally verified using the heterogeneous "Alderson phantom" and the radiochromic films and is now under clinical tests.

Together with the Division of Radiation Dosimetry of the Institute of Nuclear Physics (Prague, Czech Republic) and Proton Therapy Center in Prague, the comparison studies of the dose distributions outside the target volume using thermoluminescent detectors and radiochromic films at the JINR Phasotron radiotherapy proton beam and in the PTC scanning proton beam were continued. These studies are important for estimation of the secondary cancer risk during the proton therapy. The measurements showed that the absorbed doses outside the primary beam in Dubna were slightly higher than the scattering PTC proton beam due to scattering of the proton beam on the beam formation elements in the treatment room. Together with the Institute of Biomedical Problems RAS and LRB, JINR, influence of protons with different LET on biological objects was studied [34].

A new device for radiation protection of biological objects was developed on the basis of the laser module with a wavelength of 532 nm (green spectrum range). The device was used to test the assumption that primary photoacceptors under the radioprotective action of small doses of 633-nm laser radiation are cytochrome c-oxidases. Experiments performed on mouse fibroblast cells showed that the radioprotective effect was observed in the laser irradiation dose interval from about 0.4 to 0.85 mJ/cm^2. The maximum radioprotecting effect was observed at the laser radiation energy density of approximately 0.56 mJ/cm^2 [35].

REFERENCES

1. *An F. P. et al.* Measurement of Electron Antineutrino Oscillation Based on 1230 Days of Operation of the Daya Bay Experiment. arXiv:1610.04802 [hep-ex]; Phys. Rev. D (submitted).
2. *An F. P. et al.* Study of the Wave Packet Treatment of Neutrino Oscillation at Daya Bay. arXiv:1608.01661 [hep-ex]; Eur. Phys. J. C (submitted).
3. *Agostini M. et al.* A Search for Low-Energy Neutrino and Antineutrino Signals Correlated with Gamma-Ray Bursts with Borexino // Astropart. Phys. 2017. V. 86. P. 11–17.
4. *Agnes P. et al.* Results from the First Use of Low Radioactivity Argon in a Dark Matter Search // Phys. Rev. D. 2016. V. 93. P. 081101.
5. *Adamson P. et al. (NOvA Collab.).* First Measurement of Electron Neutrino Appearance in NOνA // Phys. Rev. Lett. 2016. V. 116, No. 15. P. 151806
6. *Adamson P. et al. (NOvA Collab.).* First Measurement of Muon-Neutrino Disappearance in NOνA // Phys. Rev. D. 2016. V. 93, No. 5. P. 051104.
7. *Vahle P. (on behalf of the NOvA Collab.).* New Results from NOνA // XXVII Intern. Conf. on Neutrino Physics and Astrophysics, London, July 4–9, 2016.
8. *Abgrall N. et al. (NA61/SHINE Collab.).* Measurements of $\pi^{\pm}$, $K^{\pm}$, K^S_0, Λ and Proton Production in Proton–Carbon Interactions at 31 GeV/c with the NA61/SHINE Spectrometer at the CERN SPS // Eur. Phys. J. C. 2016. V. 76. P. 84.
9. *Abgrall N. et al. (NA61/SHINE Collab.).* Measurements of $\pi^{\pm}$ Differential Yields from the Surface of the T2K Replica Target for Incoming 31 GeV/c Protons with the NA61/SHINE Spectrometer at the CERN SPS // Eur. Phys. J. C. 2016. V. 76. P. 617.
10. *Arnold R. et al.* Measurement of the Double-Beta Decay Half-Life and Search for the Neutrinoless Double-Beta Decay of ^{48}Ca with the NEMO-3 Detector // Phys. Rev. D. 2016. V. 93. P. 112008.
11. *Arnold R. et al.* Measurement of the $2\nu\beta\beta$ Decay Half-Life of ^{150}Nd and a Search for $0\nu\beta\beta$ Decay Processes with the Full Exposure from the NEMO-3 Detector // Phys. Rev. D. 2016. V. 94. P 072003.
12. *Armengaud E. et al. (EDELWEISS Collab.).* Constraints on Low-Mass WIMPs from the EDELWEISS-III Dark Matter Search // J. Cosmol. Astropart. Phys. 2016. V. 05. P. 019.
13. *Hehn L. et al. (EDELWEISS Collab.).* Improved EDELWEISS-III Sensitivity for Low-Mass WIMPs Using a Profile Likelihood Approach // Eur. Phys. J. C. 2016. V. 76. P. 548.
14. *GERDAQ Collab.* Search of Neutrinoless Double Beta Decay with the GERDA Experiment // Nucl. Part. Phys. Proc. 2016. V. 273–275. P. 1876.
15. *Gress O. et al.* // Nucl. Instr. Meth. A. 2016 (in press); http://dx.doi.org/10.1016/j.nima.2016.08.031.
16. *Tkachev L. et al.* Preliminary Results of the Cosmic Ray Study in the NUCLEON Space Experiment // PoS (ICHEP2016). 2016. P. 792.
17. *Grinyuk A. et al.* The TUS Orbital Detector Simulation // Nucl. Instr. Meth. A. (submitted).
18. *ATLAS Collab.* Search for Gluinos in Events with an Isolated Lepton, Jets, and Missing Transverse Momentum at $\sqrt{s} = 13$ TeV with the ATLAS Detector // Phys. J. C. 2016. V. 76. P. 565.
19. *ATLAS Collab.* Search for Heavy Resonances Decaying to a Z Boson and a Photon in pp Collision at $\sqrt{s} = 13$ TeV with the ATLAS Detector // Phys. Lett. B. 2017. V. 764. P. 11.
20. *Atanov N. et al.* Design and Status of the Mu2e Electromagnetic Calorimeter // Nucl. Instr. Meth. A. 2016. V. 824. P. 695.
21. *Atanov N. et al.* Measurement of Time Resolution of the Mu2e LYSO Calorimeter Prototype // Nucl. Instr. Meth. A. 2016. V. 812. P. 104.
22. *Atanov N. et al.* Energy and Time Resolution of a LYSO Matrix Prototype for the Mu2e Experiment // Nucl. Instr. Meth. A. 2016. V. 824. P. 684.
23. *Artikov A. et al.* Optimization of the Light Yield by Injecting an Optical Filler into the Co-Extruded Hole of the Plastic Scintillation Bar // J. Instr. 2016. V. 11. P. T05003.
24. *Ablikim M. et al.* // Phys. Rev. D. 2016. V. 94, No. 3. P. 032001.
25. *Pocanic D. et al.* arXiv: 1403.7416.
26. *The MEG Collab.* Search for the Lepton Flavour Violating Decay $\mu^+ \to e^+\gamma$ with the Full Dataset of the MEG Experiment // Eur. Phys. J. C. 2016. V. 76. P. 434.
27. *The MEG Collab.* Measurement of the Radiative Decay of Polarized Muons in the MEG Experiment // Eur. Phys. J. C. 2016. V. 76. P. 108.
28. *Annand J. R. M. et al.* T and F Asymmetries in π^0 Photoproduction on the Proton // Phys. Rev. C. 2016. V. 93, No. 5. P. 055209.
29. *Witthauer L. et al.* Insight into the Narrow Structure in η Photoproduction on the Neutron from Helicity-Dependent Cross Sections // Phys. Rev. Lett. 2016. V. 117. P. 132502.
30. *Gardner S. et al.* Photon Asymmetry Measurements of $\gamma p \to \pi^0 p$ for $E_\gamma = 320-650$ MeV // Eur. Phys. J. A. 2016. V. 52. P. 333.
31. *Shirkov G. et al.* Hadron Therapy Research and Application at JINR // XXV Rus. Part. Accel. Conf., St. Petersburg, Russia, 2016.
32. *Gurskiy S. V. et al.* Research and Development of a Compact Superconducting Cyclotron SC200 for Proton Therapy // IPAC'16, the Seventh Intern. Part. Accel. Conf., Pohang Accel. Lab., Korea, 2016.
33. *Karamysheva G. et al.* Compact Superconducting Cyclotron SC200 for Proton Therapy // The 21st Intern. Conf. on Cyclotrons and Their Applications, Zürich, Switzerland, 2016.
34. *Sahoo G. S. et al.* Measurement of LET (Linear Energy Transfer) Spectra Using CR-39 at Different Depths of Water Irradiated by 171 MeV Protons: A Comparison with Monte Carlo Simulation // Nucl. Instr. Meth. 2016. V. 18. P. 14.
35. *Voskanyan K. Sh. et al.* Effects of Hypofractionated and Standard Fractionated Irradiation of Mice Heads with Gamma-Rays and Protons on Their Peripheral Blood Parameters and Behavior // J. Phys. Science and Application. 2016. V. 6, No. 3. P. 30–36.

FLEROV LABORATORY OF NUCLEAR REACTIONS

In 2016, a wide range of scientific and applied research in heavy ion physics was conducted at the existing cyclotrons of the Flerov Laboratory of Nuclear Reactions — U400, U400M, and IC-100. In 2016, the total time of the cyclotrons operation has amounted to 15 724 h. In the reporting year, the main research areas were:

- development of the Laboratory accelerator complex, including the construction of the "Factory of Superheavy Elements";
- synthesis and study of the properties of nuclei at the drip lines;
- study of the interaction of heavy ions with condensed matter;
- applied research.

These fields of research are presented in three Laboratory themes that were completed in the reporting year.

DRIBs-III. ACCELERATOR COMPLEX OF ION BEAMS OF STABLE AND RADIOACTIVE NUCLIDES

Construction of the Accelerator Complex "Factory of Superheavy Elements" Based on the DC-280 Cyclotron. The new experimental building of the SHE Factory was prepared for the accelerator equipment installation works. In accordance with the schedule of installation and commissioning works, on September 15, 2016 the assembly of the DC-280 cyclotron was started. In December, the assembling of the cyclotron magnet was completed and the adjustment of the magnetic structure was carried out. The works on the preparation of the system of magnetic measurements scheduled for early 2017 were performed. The engineering equipment of the cyclotron was prepared for installation in the new building. The installation of the water cooling system was almost fully completed. The ion source was fully bench-tested. The complex commissioning works are scheduled to be started at the end of 2017 [1].

Development of the Existing FLNR Accelerator Complex. Most of the time of the U400 cyclotron operation was used to implement the research program on the synthesis and studies of the properties of a number of new isotopes of superheavy elements using ^{48}Ca beams. The studies on obtaining ^{50}Ti ion beams from the ion source by MIVOC (Metal Ions from the VOlatile Compounds) were carried out. The developed method has allowed obtaining a stable accelerated $^{50}Ti^{5+}$ beam at the U400 cyclotron with an energy of 5.3 MeV/nucleon, an intensity of approximately 10 $e\mu$A (see Fig. 1), as well as conducting two long-run physics experiments using a ^{50}Ti ion beam. The same method was used to obtain an intense Cr beam from the ion source (see Fig. 2).

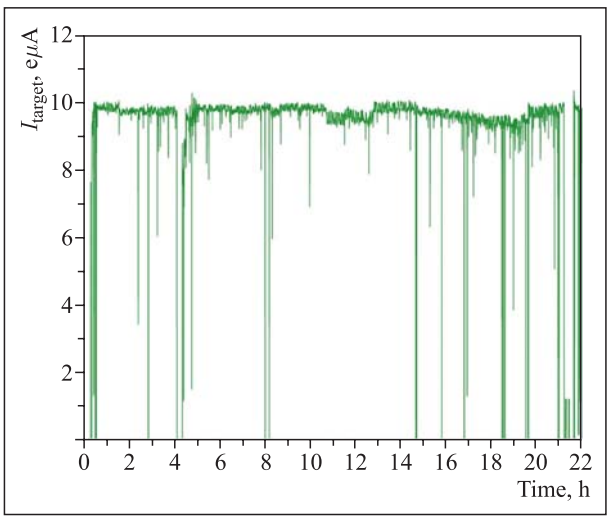


Fig. 1. Intensity of the beam of accelerated ^{50}Ti ions extracted from the U400 cyclotron

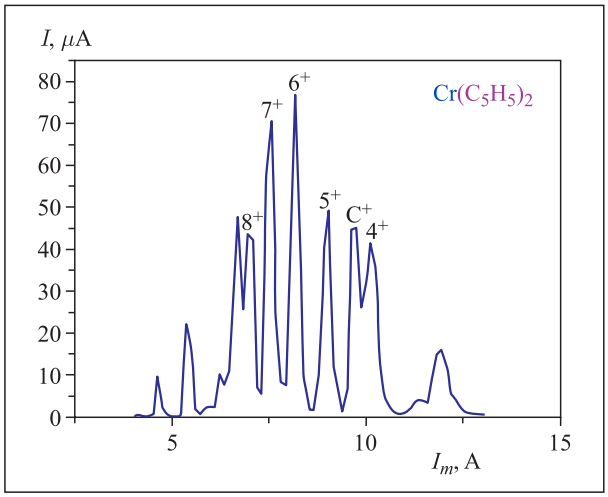


Fig. 2. Charge spectrum of chromium ions produced by the ECR4M source at the U400 cyclotron

A second electron-cyclotron resonance ion source with superconducting coils, which operates at a frequency of 18 GHz, was installed at the U400M cyclotron. It allowed obtaining Fe^{17+}, Xe^{30+}, Bi^{37+} ions with an energy of 15–30 MeV/nucleon. Accelerated beams were used to bring about the program of physics experiments, and, in particular, to test radiation resistance of the electronic components.

The modernized cyclic implanter IC-100 was used to implement the program of applied research using intensive ions from C to W with an energy of 1.0–1.2 MeV/nucleon. The ions accelerated in the IC-100 were also used for the calibration of detectors in the preparation of experiments at the U400 and U400M of FLNR, as well as for experimental setups of the other laboratories.

Designing of Experimental Setups for the Complex "Factory of Superheavy Elements". A new gas-filled recoil separator (DGFRS-II) is being manufactured. The contract with SigmaPhi company for the manufacturing of the separator was signed in 2015. The contract stipulates the delivery of the separator in the middle of 2017.

The works on the designing of a pre-separator intended for the studies of chemical properties of superheavy elements with lifetimes longer than 1 s were started. The possibility of designing a separator using superconducting magnets is being investigated.

Fragment Separator ACCULINNA-2. The works on the construction of a new fragment separator ACCULINNA-2 were continued. Earlier in 2015, the separator was fully assembled, vacuum tests and magnetic measurements were run. In December 2015, a test run of the setup with the primary ^{32}S beam was conducted. In 2016, the construction of an experimental cabin in the focal plane of the separator was completed. Works on the preparation for the construction of a biological shield in the area of the production target of the setup were performed. The necessary concrete blocks were purchased and delivered to FLNR.

Construction of a Separator Based on Resonance Laser Ionization (GaLS Setup). Works on the construction of the GaLS setup designed for the separation of transfer reaction products by selective laser ionization were continued [2]. In 2016, the assembly of the GaLS setup laser subsystem was completed. Its installation is expected to be finished at the beginning of 2017. The necessary vacuum equipment was purchased and delivered to FLNR. The designing of the mass separator was completed. The manufacturing of the separator magnet was started. The vacuum chamber of the separator was manufactured, tested and delivered to FLNR. The first version of the arrangement of the GaLS setup gas cell was designed and manufactured at the pilot plant of FLNR. In collaboration with iThemba Labs (RSA), the transport system for reaction products was designed and the manufacturing of its prototype was started.

Mass Spectrometer MASHA. The designing of a new version of the ECR ion source and the "Hot Catcher" was started. The upgrade was done to increase the total separation efficiency of mercury-like elements. The main feature of this version is the possibility to work at a temperature of up to 300 °C. The inner surfaces will be covered with a chemically inert glass-enamel layer. The technical requirements specification for the new version was prepared and a model of the new chamber of the ECR ion source was manufactured.

A setup for measuring the absolute cross sections of fusion reactions with heavy ion beams was designed. The model calculations were carried out, the necessary equipment was purchased, and the drawings were prepared. The main results obtained by the MASHA separator team are published in [3, 4].

SYNTHESIS AND PROPERTIES OF NUCLEI AT THE DRIP LINES

Synthesis of New Elements. On November 28, 2016, the International Union of Pure and Applied Chemistry (IUPAC) formally approved [5] the names and symbols for the new elements of D. I. Mendeleev's Periodic Table with atomic numbers 115, 117, and 118. At the end of 2015, the priority for these discoveries was assigned to JINR in collaboration with the USA scientific centers. The following names were approved:

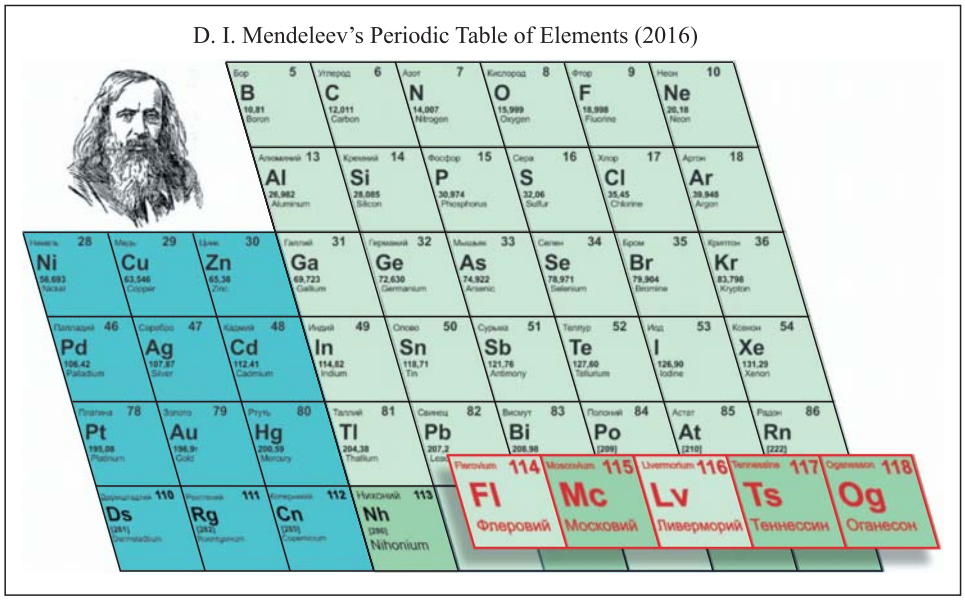


Fig. 3. Part of D. I. Mendeleev's Periodic Table highlighting the elements synthesized at JINR over the past 16 years

— Moscovium and symbol Mc for element 115;

— Tennessine and symbol Ts for element 117;

— Oganesson and symbol Og for element 118.

Thus, all the five chemical elements discovered in recent years completing the seventh period of D. I. Mendeleev's Periodic Table received their final names (see Fig. 3).

In 2016, we resumed and went further with the experiments aimed at the synthesis of the isotopes of Og with mass numbers 293–296 and study of their radioactive properties. The experiments were carried out using the Dubna Gas-Filled Recoil Separator (GFRS) of FLNR, JINR, in collaboration with the laboratories of Oak Ridge (ORNL), Knoxville (UT), Livermore (LLNL), and Nashville (VU). The target with a thickness of 0.35 mg/cm^2 was produced at ORNL and consists of a mix of Cf isotopes: ^{249}Cf (50.7%), ^{250}Cf (12.9%), and ^{251}Cf (36.4%). The energy of ^{48}Ca ions in the middle of the target layer was increased by 6 MeV compared to the experiment of 2015 and came up to 258 MeV, which corresponds to the expected cross-section maximum of the complete-fusion reactions $^{249-251}\mathrm{Cf} + {}^{48}\mathrm{Ca}$ with evaporation of four neutrons.

The total beam dose of ^{48}Ca ions accumulated at this energy value was $1.1 \cdot 10^{18}$. The experiment was stopped, as the target surface got covered with ballast admixture used in the process of target manufacturing. In the experiment, at the 252-MeV energy of ^{48}Ca we detected one decay chain of ^{294}Og — a product of the $3n$ channel of the $^{249}\mathrm{Cf} + {}^{48}\mathrm{Ca}$ reaction [6]. In the same reaction we synthesized four nuclei of this isotope in 2002, 2005, and 2012 [7]. The decay properties of all the nuclei of ^{294}Og, ^{290}Lv, and ^{286}Fl are in good agreement with the results obtained both in the reaction with ^{249}Cf and in the cross reactions $^{245}\mathrm{Cm}(^{48}\mathrm{Ca}, 3n)^{290}\mathrm{Lv}$ and $^{242}\mathrm{Pu}(^{48}\mathrm{Ca}, 4n)^{286}\mathrm{Fl}$ [6, 7].

The experiments will be resumed in 2017, as soon as a new target is manufactured.

Chemistry of Transactinides. The influence of the relativistic effects on the chemical properties of superheavy elements Cn and Fl using gas thermochromatography on the surface of selenium was investigated. Thermochemical calculations and tests on a ^{48}Ca beam were conducted. The results showed formation of stable selenides of light homologues of Cn and Fl in groups 12 and 14 of D. I. Mendeleev's Periodic Table with the opposite stability trends. It will allow separating the deposition zones of these elements in the thermochromatographic column for the first time [8]. In October 2016, in the framework of cooperation between FLNR and PSI (Switzerland) a joint experiment at the U400 of FLNR was carried out to study the adsorption of Cn and Fl on the surfaces of selenium and gold. To synthesize Cn and Fl isotopes, the reaction $^{48}\mathrm{Ca} + {}^{242}\mathrm{Pu}$ was used, which made it possible to investigate the adsorption of these elements in a single experiment. The reaction products were retained in the recoil nuclei collecting chamber filled with argon and helium. Further on, using a gas jet, they were transported through the capillary to the thermochromatographic column. The column consisted of an isothermal part including 16 Si-PIN detectors coated with selenium and 16 Si-PIN detectors coated with gold at a temperature gradient from $+20$ to $-165\,^{\circ}$C. The analysis of the accumulated data is in progress.

Spectroscopy of Heavy and Superheavy Nuclei. The experiment aimed at the spectroscopy studies of the ^{255}Lr isotope synthesized in the complete-fusion reaction $^{48}\mathrm{Ca}(^{209}\mathrm{Bi}, 2n)^{255}\mathrm{Lr}$ was performed using the

modernized recoil separator SHELS and a new detector chamber including a clover-type detector and four single-crystal Ge gamma detectors. The experiment showed that the modernization of the ion-optical system of the separator together with the increase in the gamma detection efficiency for the new design of the detector system (at least by a factor of 3) resulted in a 10-fold increase of statistics on the detected decays collected for the same integral flux of incident ions.

The experiments aimed at the study of the decay properties of ^{257}Db synthesized in the complete-fusion reaction ^{50}Ti(^{209}Bi, $2n$)^{257}Db were carried out. More than 1000 events of the ^{257}Db isotope decay were detected (see Fig. 4). The experimental data are under analysis.

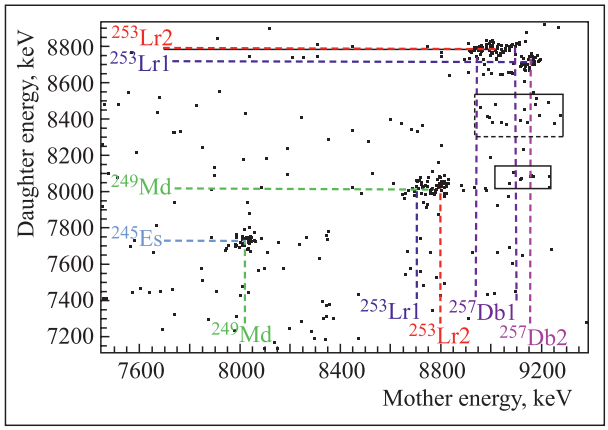


Fig. 4. Alpha–alpha correlations for ^{257}Db decay

Using ^{50}Ti, rare reaction channels with evaporation of a proton and several neutrons in the complete-fusion reaction ^{209}Bi(^{50}Ti, pxn)$^{258-x}$Rf were investigated. A number of decay events were detected at two beam energies. These events can be attributed to the $p0n$ channel. A cross-section limit for the $p1n$ channel was obtained. In October–November, 2016 the experiment was continued at a higher ^{50}Ti beam energy corresponding to a theoretically estimated maximum of the $p2n$ evaporation channel. Several spontaneous fission events of ^{256}Rf were detected.

The current status of the SHELS separator and certain results of the experimental campaigns are presented in [9, 10].

Dynamics of Heavy-Ion Interaction, Fission of Heavy and Superheavy Nuclei. In 2016, a series of experiments was carried out at the CORSET setup (U400 accelerator). The experiments were aimed at the estimation of contribution of quasifission, which hinders the complete fusion channel, when one uses heavy-ion beams of Ti, Cr, etc., instead of Ca. These investigations are particularly important for the planning of experiments on the synthesis of new superheavy nuclei with $Z > 118$. In 2016, the mass and energy distributions of binary fragments produced in the ^{52}Cr + ^{232}Th, ^{248}Cm reactions at energies near the Coulomb barrier were measured. The analysis of the mass–energy distributions of fission and quasifission fragments produced in the reaction ^{48}Ti + ^{238}U was completed [11, 12]. It was found that at energies below the Coulomb barrier the contributions of the symmetric fragments are virtually the same within the error bars for the ^{48}Ca + ^{244}Pu, ^{48}Ti + ^{238}U, and ^{52}Cr + ^{232}Th reactions leading to formation of a composite system with $Z = 114$. However, at energies above the barrier, the contribution of the symmetric fragments increases monotonously in the case of the ^{48}Ca-ions-induced reaction, whereas for the reactions with ^{48}Ti and ^{52}Cr ions it does not change and constitutes about 8–9%. It may indicate a considerable increase of the quasifission contribution at the transition from Ca to Ti and Cr ions. In addition, in 2016 the mass–energy and angular distributions of binary products formed in the ^{86}Kr + ^{198}Pt reaction, also leading to the $Z = 114$ composite system, were measured at the U400M cyclotron of FLNR. For this reaction, a deep inelastic process is the main exit channel.

In June 2016, in the framework of the collaboration between JINR (Dubna) and IN2P3 (France) a joint experiment to study the ^{32}S + ^{197}Au reaction dynamics was performed in Orsay. The measurements were carried out at the ALTO facility of IPN (Orsay, France) at the energy of incident ions of 5.2 MeV/u [13]. The energies and the multiplicities of γ rays were measured using the γ-ray spectrometers ORGAM and PARIS. The binary reaction fragments were measured by the double-arm time-of-flight spectrometer CORSET. The multiplicities and the energies of the prompt γ rays are related to the angular momentum and the excitation energy of fragments, respectively, while the shape of the giant dipole resonance spectrum depends on the deformation of the composite system. All these properties play an important role in the evolution of the dinuclear system. The analysis of the obtained experimental data is in progress.

The yields of radon isotopes in multinucleon transfer reactions ^{48}Ca + ^{242}Pu and ^{48}Ca + ^{208}Pb were measured at the MASHA separator. The results were presented at the EXON-2016 conference.

Structure of Exotic Nuclei. In 2016, an experiment aimed at searching for a $2p$ decay branch of the first excited $3/2^-$ state of ^{17}Ne populated in the p(^{18}Ne, d)^{17}Ne transfer reaction was conducted [14]. The population of the low-energy states up to 3 MeV of excitation in the ^{17}Ne nucleus was studied. As a result, a new upper limit $\Gamma_{2p}/\Gamma_\gamma \leqslant 2.5 \cdot 10^{-4}$ was established for the ratio of partial widths of the first excited $3/2^-$ state of ^{17}Ne in respect to the $2p$ and gamma decay. This significantly (about a factor of 30) reduces the value of the limit defined in the previous work by Chromik M. J. et al. (Phys. Rev. C. 2002. V. 66. P. 024313). Such a strong improvement of the $\Gamma_{2p}/\Gamma_\gamma$ limit over the previous data was achieved due

to the choice of reaction and due to the novel "combined mass" method applied in the reconstruction of the ^{17}Ne excitation spectrum. The latter allowed us to significantly increase the instrumental resolution in the measurements done with a thick target. Such improvements open a way to a direct experimental observation of the true radioactive $2p$-decay of the ^{17}Ne $3/2^-$ state. The theoretically predicted value is $\Gamma_{2p}/\Gamma_\gamma \sim 2.5{\cdot}10^{-6}$. A possibility of direct observation of such weak partial decay branches in one experiment makes this approach perspective for solving the problems of nuclear astrophysics.

The data analysis of the experiment aimed at the study of beta-delayed proton emission from ^{26}P and ^{27}S isotopes was completed [15]. The study was carried out at the ACCULINNA setup, together with the team from Warsaw University. The crucial feature of this experiment based on the use of the Optical Time Projection Chamber (OTPC) was direct observation of decay events in the absence of background. The results obtained for the decay of ^{26}P were found to be consistent with the previous study of Thomas J.-C. et al. (Eur. Phys. J. A. 2004. V. 21. P. 419). The measured half-life of ^{27}S agrees with the value determined in the previous work by Canchel G. et al. (Eur. Phys. J. A. 2001. V. 12. P. 377), where a stack of silicon detectors was used to perform proton measurements only with $E_p > 1.5$ MeV. In contrast, the OTPC detector provided low-background results for energies $E_p > 0.15$ MeV, and in this region the strongest emissions at 320 and 710 keV were detected. As a result, the new values of the branching ratios for βp and $\beta 2p$ channels were found to be much greater than the previous ones (by a factor of 3 or more). The studies showed that the technique based on the optical time projection chamber is preferable for the identification of decay channels and precise determination of their absolute branching ratios.

Reactions with Beams of Light Stable and Radioactive Nuclei. At the cyclotron U400M, using the ACCULINNA separator, a series of experiments was conducted to measure the energy dependence of the cross sections for the nuclei ^{6}He, ^{6,9}Li in a wide range of energies (10–50 MeV/nucleon). In these experiments, the so-called transmission method supplemented by registration of gamma rays was applied. A significant increase of the cross section in the form of a broad peak in the energy range 10–30 MeV/nucleon was noticed (see Fig. 5). This effect was not observed in the excitation functions of the reactions with the beams of ^{3}He, ^{4}He, ^{7,8}Li [16]. This was explained by the influence of cluster degrees of freedom, including the neutron ones, on the enhancement of the cross sections in this energy range [17].

A set of experiments was conducted at the fragment separator COMBAS to study the cross sections of light neutron-rich nuclei interaction (isotopes of helium ^{6,8}He and lithium ^{8,9,11}Li). Optimal reactions for the synthesis of these nuclei were selected and their beams were obtained in the focal plane of the separator. Experiments have shown that in the interaction of these nuclei at high energies certain peculiarities in the characteristics of the reactions associated with their cluster structure may also be manifested. Information on the cluster structure of ^{9}Be nucleus was obtained. For example, the values of the form factors were identified for two configurations of ^{9}Be: $^8\mathrm{Be}+n$ and $^5\mathrm{He}+\alpha$. The experiments were carried out at the cyclotron at the University of Jyväskylä (Finland). Angular distributions of the reaction products were measured for the channels ^{9}Be(^{3}He, ^{4}He)^{8}Be and ^{9}Be(^{3}He, ^{7}Be)^{5}He. It follows from the analysis that the contribution of the cluster configurations $n+{}^8$Be and $\alpha+{}^5$He constitutes 69 and 25% of the total cross section, respectively. Experiments were conducted to study the possible existence of the ^{5}He cluster. For this purpose, the angular distribution of inelastic scattering d on ^{9}Be nuclei was measured for the $\alpha+{}^7$Li exit channel. The studied reaction may proceed in two different ways: with the transfer of d or of ^{5}He from the target to the projectile. Calculations of the transfer cross sections made within the DWBA method yielded a sufficiently large value of

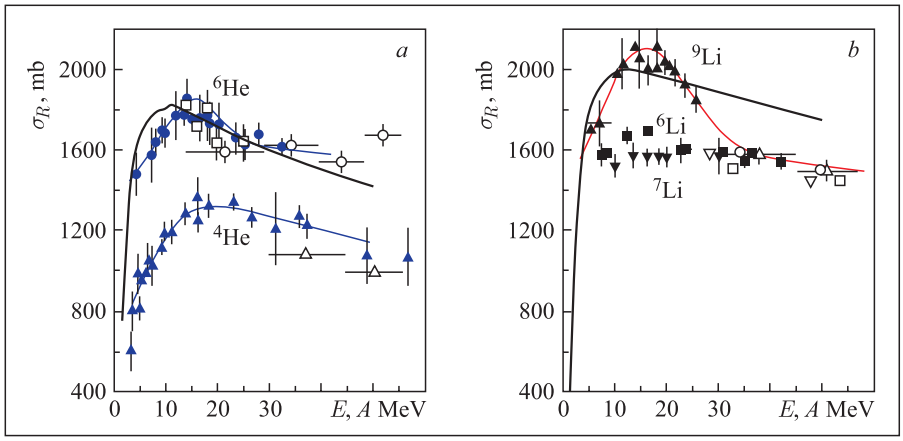


Fig. 5. Excitation functions of the total cross sections of nuclear reactions $^{4,6}\mathrm{He}+\mathrm{Si}$ (*a*) and $^{6,7,9}\mathrm{Li}+\mathrm{Si}$ (*b*)

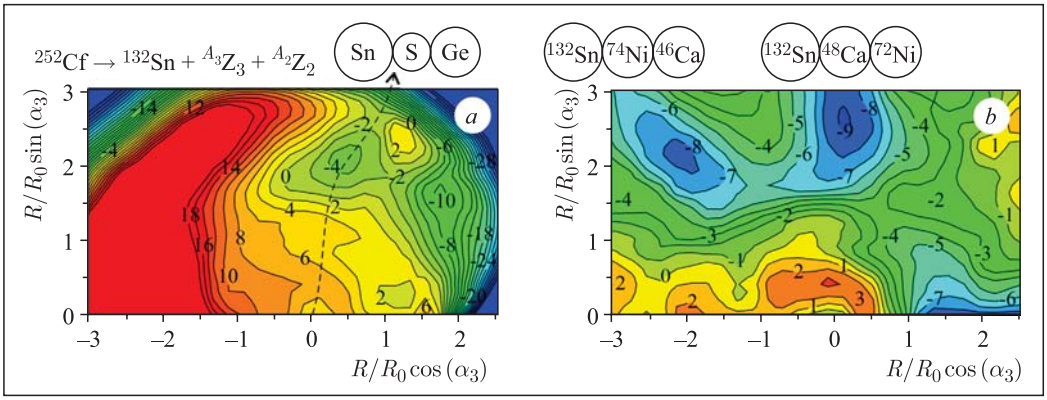


Fig. 6. Potential energy (*a*) and shell corrections (*b*) for ternary fission of the ^{252}Cf nucleus as a function of elongation, R, and mass of the third fragment, $\alpha_3 = \pi A_3/100$

the spectroscopic factor for the system $^9\text{Be} = \alpha + {}^5\text{He}$. It confirms the $\alpha + {}^5$He cluster structure of the ^{9}Be nucleus and a high probability of transfer of ^{5}He as a cluster [18].

Theoretical and Computational Physics. A three-center shell model, which allows calculating the potential energy of the deformed nucleus both for binary and ternary fission, was proposed [19]. The features of the potential energy landscape in the ternary fission of the ^{252}Cf nucleus were studied. It was shown that the macroscopic properties of the potential energy suppress the process of ternary fission. At the same time, the suppression factor increases with an increasing mass of the third (middle) fragment. True ternary fission of heavy nuclei with the formation of fragments of comparable masses is possible only due to the shell effects lowering the ternary fission barrier for certain combinations of fragment masses. Well-defined potential valleys, which make possible the ^{252}Cf ternary fission with the formation of a magic tin-like cluster as one of the fragments, were observed (see Fig. 6).

With partial support of RFBR and JINR–RSA cooperation program, the knowledge base on NRV low-energy nuclear physics (http://nrv.jinr.ru) was extended [20]. In particular, the databases containing experimental data on the properties of atomic nuclei were updated, and the interface of the NRV sections dedicated to working with the experimental data was improved. The functionality of a number of the knowledge base resources was extended: the possibility to analyze the multiplicities of particles accompanying the decay of a compound nucleus formed in heavy-ion fusion reactions was added; the possibility to simulate reactions of few-nucleon transfer under the FRESCO code was implemented, etc.

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

The morphology of bismuth (700 MeV, 1 GeV) and xenon (167 MeV) induced latent tracks in TiO_2 single crystalline was studied using high-resolution transmission electron microscopy [21]. The radiation hardening of EP450 and KP4 ODS steels irradiated with krypton and xenon ions of fission fragment energy was studied using the nanoindentation technique [22]. It was shown that the hardening level is about 20% for radiation damage doses of 0.1–1 dpa.

Using scanning electron microscopy of high resolution, detailed studies of the structure of track-etched membranes in the nanometer range were performed. Special attention was paid to the investigations of the features of asymmetrical nanopores. For the first time, the contribution of osmotic effects to the asymmetrical chemical etching of heavy ion tracks was revealed and analyzed [23].

The surface and electro-transport properties of composite track-etched membranes with a polymeric hydrophobic layer were studied. Composite track-etched membranes with a photocatalytic layer of titanium dioxide were synthesized and their structure and phase composition were investigated in detail [24]. The results obtained can be employed when designing self-cleaning filters for water purification to separate organic pollution.

New methods for separation and concentration of radioactive isotopes ^{99}Mo(^{99}Tc), ^{210}Po, ^{225}Ac, ^{237}U, ^{236}Pu, ^{236}Np for nuclear medicine and environmental research were developed.

The investigations carried out at FLNR in 2016 were supported by 7 grants of the Russian Foundation for Basic Research.

REFERENCES

1. *Dmitriev S., Itkis M., Oganessian Yu.* Status and Perspectives of the Dubna Superheavy Element Factory // Proc. of the Nobel Symp. "NS 160"; EPJ Web of Conf. 2016. V. 131. P. 08001.
2. *Zemlyanoy S., Zagrebaev V., Kozulin E., Kudryavtsev Yu., Fedosseev V., Bark R., Janas Z.* GALS — Setup for Production and Study of Multi-Nucleon Transfer Reaction Products: Present Status // J. Phys.: Conf. Ser. 2016. V. 724. P. 012057. doi:10.1088/1742-6596/724/1/012057.
3. *Novoselov A. S., Rodin A. M., Motycak S., Podshibyakin A. V., Krupa L., Belozerov A. V., Vedeneyev V. Yu., Gulyaev A. V., Gulyaeva A. V., Kliman J., Salamatin V. S., Stepantsov S. V., Chernysheva E. V., Yukhimchuk S. A., Komarov A. B., Kamas D.* Data Acquisition System for the Focal Plane Detector of the Mass Separator MASHA // Phys. Part. Nucl. Lett. 2016. V. 13, No. 5. P. 595.
4. *Motycak S., Rodin A. M., Novoselov A. S., Podshibyakin A. V., Krupa L., Belozerov A. V., Vedeneyev V. Yu., Gulyaev A. V., Gulyaeva A. V., Kliman J., Salamatin V. S., Stepantsov S. V., Chernysheva E. V., Yukhimchuk S. A., Komarov A. B., Kamas D.* A New Beam Diagnostic System for the MASHA Setup // Phys. Part. Nucl. Lett. 2016. V. 13, No. 5. P. 586.
5. IUPAC Press Release. https://iupac.org/iupac-announces-the-names-of-the-elements-113-115-117-and-118/.
6. *Rykaczewski K. P., Roberto J. B., Brewer N. T., Utyonkov V. K.* ORNL Actinide Materials and a New Detection System for Superheavy Nuclei // EPJ Web of Conf. 2016. V. 131. P. 05005.
7. *Utyonkov V., Oganessian Yu., Dmitriev S., Itkis M., Moody K., Stoyer M., Shaughnessy D., Roberto J., Rykaczewski K., Hamilton J.* The Discovery of Elements 113 to 118 // Proc. of the Nobel Symp. "NS 160"; EPJ Web of Conf. // 2016. V. 131. P. 06003.
8. *Chiera N. M., Aksenov N. V., Albin Y. V., Bozhikov G. A., Chepigin V. I., Dmitriev S. N., Dressler R., Eichler R., Lebedev V. Ya., Madumarov A., Malyshev O. N., Piguet D., Popov Y. A., Sabelnikov A. V., Steinegger P., Svirikhin A. I., Turle A., Vostokin G. K., Vogele A., Yeremin A. V.* Interaction of Elemental Mercury with Selenium Surfaces: Model Experiments for Investigations of Superheavy Elements Copernicium and Flerovium // J. Radioanal. Nucl. Chem. 2017. V. 311. P. 99–108.
9. *Popeko A. G. et al.* Separator for Heavy Element Spectroscopy — Velocity Filter SHELS // Nucl. Instr. Meth. B. 2016. V. 376. P. 140. doi:10.1016/j.nimb.2016.03.045.
10. *Svirikhin A. I. et al.* Spontaneous Fission of ^{256}Rf — New Data // Phys. Part. Nucl. Lett. 2016. V. 13. P. 480.
11. *Kozulin E. M., Knyazheva G. N., Novikov K. V., Itkis I. M., Itkis M. G., Dmitriev S. N., Oganessian Yu. Ts., Bogachev A. A., Kozulina N. I., Harca I., Trzaska W. H., Ghosh T. K.* Fission and Quasifission of Composite Systems with $Z = 108-120$: Transition from the Reactions with S and Ca Ions to Ti and Ni // Phys. Rev. C. 2016. V. 94. P. 054613.
12. *Itkis I. M., Itkis M. G., Knyazheva G. N., Kozulin E. M.* Fusion Probabilities in the Reactions with Actinide Nuclei Leading to the Formation of SHE // The VIII Intern. Symp. on Exotic Nuclei (EXON-2016), Kazan, Russia, 4–10 Sept., 2016 / Eds.: Yu. E. Penionzhkevich, Yu. G. Sobolev. World Sci. Publ., 2017. 8 p.
13. *Harca I. M., Kozulin E., Ashaduzzaman M., Borcea C., Brambilla S., Calinescu S., Ciemala M., DeCanditiis B., Dorvaux O., Itkis I., Kirakosyan V., Knyazheva G., Kozulina N., Kolesov I., La Rana G., Maj A., Matea I., Novikov K., Petrone C., Pulcini A., Quero D., Rath P., Saveleva E., Schmitt C., Sposito G., Stezowski O., Trzaska W. H., Vardaci E., Wilson J.* The Reaction ^{32}S + ^{197}Au near the Interaction Barrier // The VIII Intern. Symp. on Exotic Nuclei (EXON-2016), Kazan, Russia, 4–10 Sept., 2016 / Eds.: Yu. E. Penionzhkevich, Yu. G. Sobolev. World Sci. Publ., 2017. 9 p.
14. *Grigorenko L. V. et al.* Studies of Light Exotic Nuclei in the Vicinity of Neutron and Proton Drip Lines at FLNR JINR // Phys. Usp. 2016. V. 59. P. 321.
15. *Janiak L., Sokolowska N., Bezbakh A. A., Ciemny A. A., Czyrkowski H., Dąbrowski R., Dominik W., Fomichev A. S., Golovkov M. S., Gorshkov A. V., Janas Z., Kamiński G., Knyazev A. G., Krupko S. A., Kuich M., Mazzocchi C., Mentel M., Pfützner M., Pluciński P., Pomorski M., Slepniev R. S., Zalewski B.* Beta-Delayed Proton Emission from ^{26}P and ^{27}S // Phys. Rev. C. 2017. V. 95. P. 034315.
16. *Penionzhkevich Yu. E.* Nuclear Exoticism // Phys. At. Nucl. 2016. V. 79. P. 549.
17. *Sobolev Yu. G., Penionzhkevich Yu. E., Aznabaev D., Ivanov M. P., Kabdrakhimova G. D., Kabyshev A. M., Knyazev A. G., Kugler A., Lashmanov N. A., Lukyanov K. V., Maj A., Maslov V. A., Mendibayev K., Skobelev N. K., Slepnev R. S., Smirnov V. V., Testov D., Zemlyanaya E. V.* Experimental Research of Total Reaction Cross Section Energy Dependence for ^{6}He + $^{\mathrm{nat}}$Si and ^{9}Li + $^{\mathrm{nat}}$Si // Phys. Part. Nucl. Lett. (submitted).
18. *Lukyanov S. M., Harakeh M. N., Naumenko M. A., Yi Xu, Trzaska W. H., Burjan V., Kroha V., Mrázek J., Glagolev V., Piskoř Š., Voskoboynik E. I., Khlebnikov S. V., Penionzhkevich Yu. E., Skobelev N. K., Sobolev Yu. G., Tyurin G. P., Kuterbekov K., Tuleushev Yu.* Cluster Structure of ^{9}Be from ^{3}He + ^{9}Be Reaction // J. Phys. G. 2016. V. 724. P. 012031.
19. *Karpov A. V.* Ternary Fission of a Heavy Nuclear System within a Three-Center Shell Model // Phys. Rev. C. 2016. V. 94. P. 064615.
20. *Karpov A. V., Denikin A. S., Alekseev A. P., Zagrebaev V. I., Rachkov V. A., Naumenko M. A., Saiko V. V.* NRV Web Knowledge Base on Low-Energy Nuclear Physics // Phys. At. Nucl. 2016. V. 79. P. 749.

21. *O'Connell J., Skuratov V., van Vuuren A. J., Saifulin M., Akilbekov A.* Near Surface Latent Track Morphology of SHI Irradiated TiO_2 // Phys. Status Solidi. B. 2016. V. 253. P. 2144–2149.

22. *Kornieieva K., Skuratov V., Sohatsky A., O'Connell J. H., Golovin Yu., Korenkov V., Henoch Neethling J.* Nanomechanical Testing of ODS Steels Irradiated with 1 MeV/amu Heavy Ions // Philos. Mag. 2016. V. 96. P. 3430–3441.

23. *Apel P. Y., Bashevoy V. V., Blonskaya I. V., Lizunov N. E., Orelovitch O. L., Trautmann C.* Shedding Light on the Mechanism of Asymmetric Track Etching: An Interplay between Latent Track Structure, Etchant Diffusion and Osmotic Flow // Phys. Chem. Chem. Phys. 2016. V. 8. P. 25421–25433.

24. *Artoshina O. V., Milovich F. O., Rossouw A., Gorberg B. L., Iskhakova L. D., Ermakov R. P., Semina V. K., Kochnev Yu. K., Nechaev A. N., Apel P. Yu.* Structure and Phase Composition of Thin TiO_2 Films Grown on the Surface of Metallized Track-Etched Polyethylene Terephthalate Membranes by Reactive Magnetron Sputtering // Inorganic Materials. 2016. V. 52. P. 945–954; JINR Preprint P14-2016-26. Dubna, 2016.

FRANK LABORATORY OF NEUTRON PHYSICS

In 2016, scientific programme of the Frank Laboratory of Neutron Physics was aimed at obtaining new results under four 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", 04-4-1121-2015/2017, 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", 04-4-1111-2013/2017 headed by G. M. Arzumanyan); in neutron nuclear physics ("Investigations in the Field of Nuclear Physics with Neutrons", 03-4-1104-2011/2016, 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", 04-4-1105-2011/2016, 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", 04-4-1122-2015/2017, headed by S. A. Kulikov and V. I. Prikhodko).

CONDENSED MATTER PHYSICS

The greater part of experimental research was carried out on the spectrometers of the modernized IBR-2 reactor.

In 2016, within the framework of the User Programme, 238 proposals for conducting experiments were received from 19 different countries. The received proposals covered a broad spectrum of neutron research in physics (30%), materials science (35%), chemistry, geosciences, biology and applied sciences (constituting the rest 35%). Of the received proposals, 208 were admitted for implementation.

Scientific Results

1. Iron oxides play an important role in the formation of magnetic and other physical properties of the Earth and find a wide range of technological applications. Recently, a new iron oxide, Fe_4O_5, which can presumably exist in the layers of the Earth's upper mantle, has been synthesized under the combined effect of high pressures and temperatures. A comprehensive study of its physical properties, as well as atomic and magnetic structure using neutron diffraction techniques at the IBR-2 reactor, has revealed a new type of the charge-ordering state with the formation of dimeric and trimeric electronic states in this compound. The phase transition into this state is accompanied by a sharp increase in the electrical resistance and a subsequent change in the symmetry of the magnetic order, namely, from a collinear antiferromagnetic (AFM) order to a canting AFM order with a ferromagnetic (FM) component, as well as by a change in the nature of the modulation of the atomic structure, Fig. 1 [1].

The search for new multiferroics and magnetoelectrics is of current interest in modern condensed matter physics and materials science. A promising system is $BaMn_{1-x}Ti_xO_3$, whose end members are a classical ferroelectric $BaTiO_3$ with a high Curie temperature ($T_C = 395$ K) and $BaMnO_3$ — a compound exhibiting a giant magnetoelectric effect and having a relatively high temperature of magnetic ordering ($T_N = 230$ K). The studies of $BaMn_{1-x}Ti_xO_3$ over the entire concentration range $0 < x < 1$ have revealed a very rich structural polymorphism. An increase in the titanium concentration was followed by a sequence of phase transitions between different rhombohedral and hexagonal phases differing by the ratio of oxygen octahedra connected through the corners and edges,

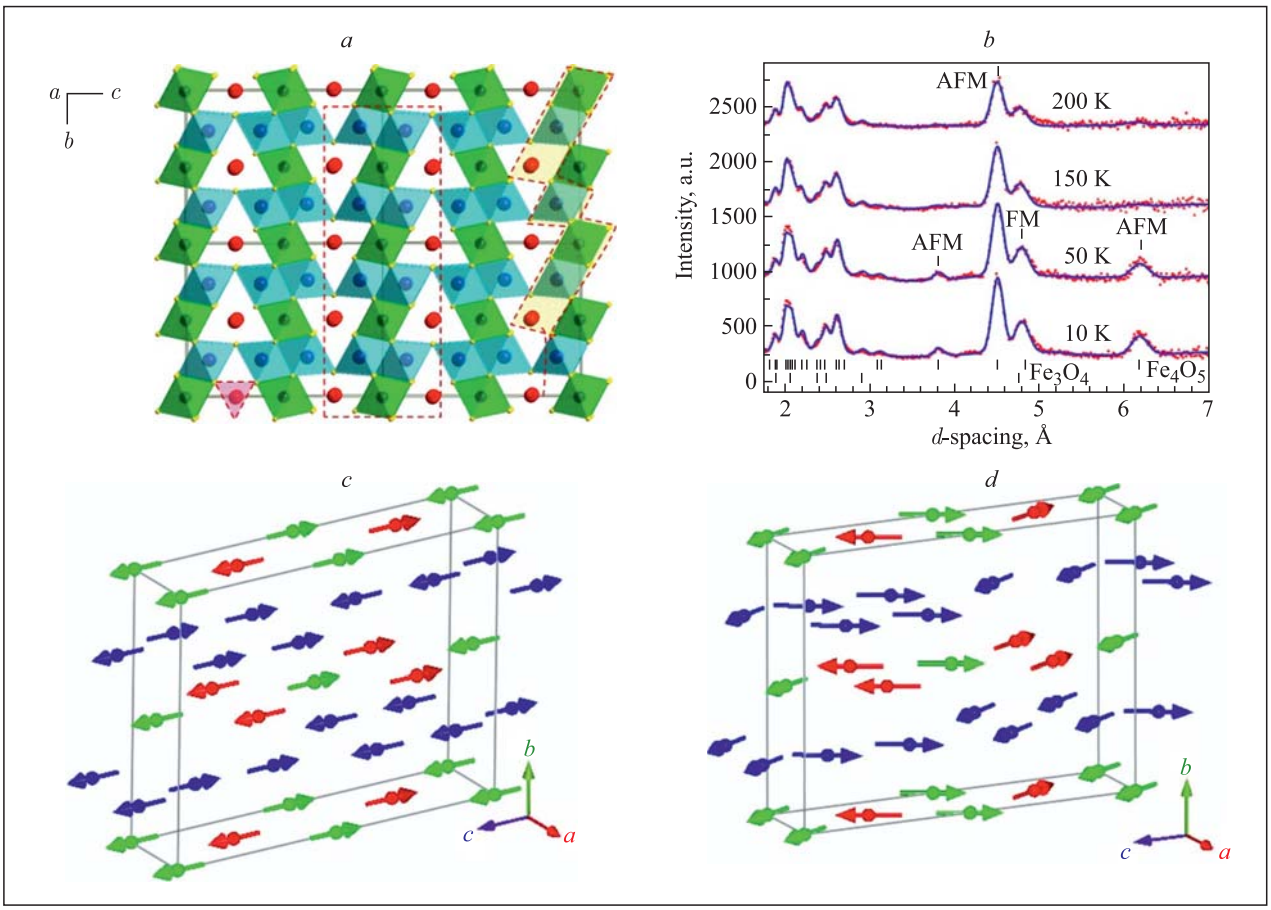


Fig. 1. Crystal structure of Fe_4O_5 (*a*), neutron diffraction spectra obtained at different temperatures and treated by the Rietveld method (*b*), magnetic structure at $T = 150$ K (*c*) and $T = 10$ K (*d*)

15R–8H–9R–10H–12R, Fig. 2 [2, 3]. It has been found that the formation of a long-range magnetic order is possible only in structures 9R, 8H, 15R and at concentrations of $Ti_x < 0.25$, and the Neel temperature has a very sharp concentration dependence and drops from 230 to 100 K in the given x-range.

Neutron diffraction studies of the $Fe_{0.735}Al_{0.265}$ compound were carried out in a wide temperature range (20–900 °C) to determine its structural states and atomic ordering mechanism [4]. The combination of high-resolution diffraction and real-time one made it possible to establish that, in contrast to traditional approaches, the structure of this compound at room temperature is a phase with only partially ordered arrangement (B2) of Fe and Al in a unit cell. A completely ordered phase (Fe_3Al–DO_3 type) is present as clusters of mesoscopic size (~ 200 Å) coherently incorporated into the matrix of the main phase. After the transition to a disordered state ($T > 740$ °C) and slow cooling to room temperature, the dimensions of the structurally ordered clusters increased to ~ 900 Å. A high contrast between the coherent neutron scattering lengths of iron and aluminum made it possible to determine with a good accuracy the temperature dependence of the occupancy factors of sites by Fe and Al atoms up to a phase transition to the disordered state. The obtained results call for further analysis of the equilibrium phase diagram for the Fe–Al system.

2. A number of experiments on small-angle neutron scattering (SANS) and neutron reflectometry with a horizontal sample plane for the interface of magnetic fluids with silicon (GRAINS) have been carried out in the framework of investigations of the structure and stability of magnetic nanoparticles in bulk and at interfaces, Fig. 3 [5]. It has been found that in the bulk of aqueous ferrofluids stabilized by sodium oleate there are comparatively small (size ~ 30 nm) and compact aggregates of magnetic particles. When magnetic fluids are modified by biocompatible polymer polyethylene glycol (PEG), cluster reorganization in the bulk of magnetic fluids is observed, namely, large and branched clusters (size > 130 nm, fractal dimension of 2.7) appear. The observed in-bulk reorganization of the magnetic fluids is correlated with the neutron reflectometry data, which is indicative of the formation of a single adsorption layer of magnetic particles on the surface of oxidized silicon in the initial magnetic fluid and the absence of any layer at the ferrofluid/silicon interface after the polymer modification.

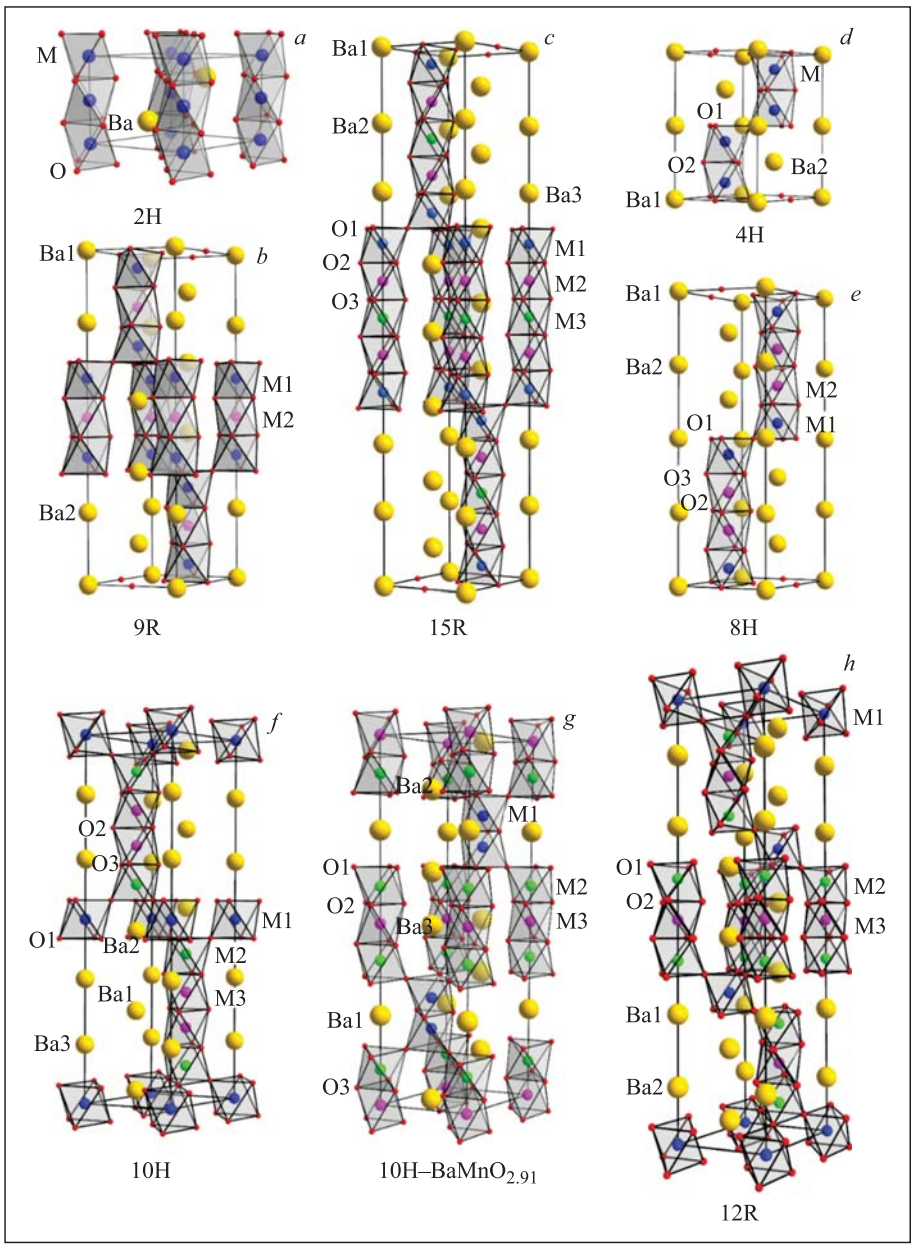


Fig. 2. Structure of polymorphic phases in the system $BaMn_{1-x}Ti_xO_3$

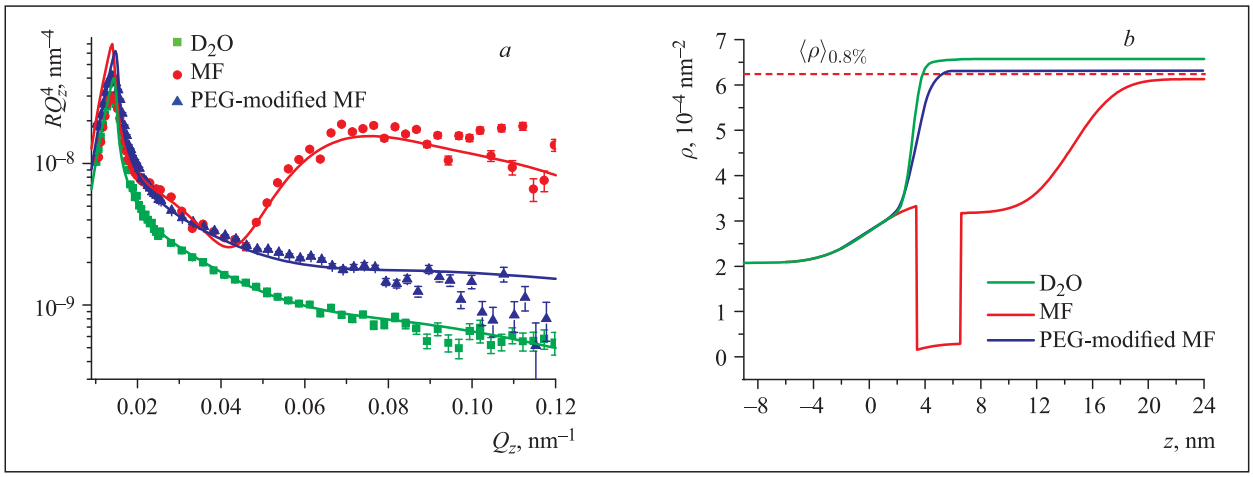


Fig. 3. *a*) Experimental reflectivity curves for heavy water and magnetic fluids; *b*) resulting scattering length density profiles

3. The biophysical research of fullerene solutions, in particular, aqueous solutions of C60 and C70, has been continued. It included the analysis of the cluster structure when placing fullerenes in physiological environment and the study of the interaction of C60 fullerene with antitumor antibiotics [6, 7]. Using SANS and tests on mutagenic activity of doxorubicin and C60 admixture with doxorubicin on *Salmonella Typhimurium* TA98 cells, it has been shown that fullerene C60 can act as an interceptor of the antitumor antibiotic doxorubicin and form hetero-complexes with this drug. The research on the interaction of C60 with doxorubicin, including SANS, scanning electron (SEM) and atomic force (AFM) microscopy, calorimetry, dynamic light scattering (DLS), and UV-Vis spectroscopy, has been extended to include other aromatic drugs with a similar to doxorubicin spatial structure such as landomycin and cisplatin. New effects of the biological interaction of fullerene C60 in combination with various anticancer drugs have been discovered and described.

4. In the framework of the studies on improving the performance of lithium batteries, a series of experiments on neutron reflectometry (GRAINS reflectometer) to study electrochemical interfaces of liquid electrolyte/solid electrode have been carried out (Fig. 3). From the specular reflectivity analysis, the formation of a solid-electrolyte interphase (SEI) on the surface of the electrode (Cu) has been concluded, as well as the lithium electrodeposition and growth of parasitic dendritic structures during the operation of an electrochemical cell have been tracked. The obtained profiles of the scattering length density perpendicular to the electrode surface have made it possible to analyze different modes of SEI formation, as well as the formation and growth of nanometer lithium layers of different roughness on the initially formed SEI. It has been shown that neutron reflectometry can be effectively used for *in situ* characterization of lithium plating on metal electrodes [8].

5. The passive transport of particles through lipid membranes in different lipid phase states has been investigated by inelastic X-ray scattering. It is known that the passive transport of molecules through a cell membrane depends on thermal motions of lipids. However, the nature of transmembrane transport and its precise mechanism are not fully understood. The phonon excitations in a lipid bilayer of 1,2-dipalmitoyl-sn-glycero-3-phosphocholine above and below the main phase transition temperature have been measured. In the gel phase, for the first time the presence of transverse high-frequency modes has been shown. The modes are terminated when the lipids change into the liquid phase. This termination is apparently due to the formation of short-lived nanometer lipid clusters and transient pores which facilitate the passive molecular transport through the lipid bilayer. The obtained data suggest that the phononic motion of the lipid hydrocarbon tails provides an effective mechanism of passive transport [9].

6. In collaboration with the Adam Mickiewicz University (Poznan, Poland), atomic and molecular dynamics of lovastatin has been studied by 1H NMR and inelastic neutron scattering complemented by theoretical *ab initio* calculations using the PW-DFT method. A consistent molecular dynamics model has been obtained, which can be later used to describe the dynamics of other alternative drug forms and tendencies to amorphization. It has been found that the molecular dynamics of lovastatin is determined by the motions of methyl groups and the conformational disorder in the methylbutanoate fragment. The vibrational dynamics of lovastatin was analyzed focusing on the energy transfer range with low wave numbers, which was experimentally studied by neutron (INS) and terahertz (THz-TDS) spectroscopy. The theoretical calculations made it possible for the first time to describe with high accuracy the phonon spectrum of lovastatin in this region (Fig. 4). It should be noted that the main contribution to the inelastic neutron scattering spectra is from vibrations of hydrogen-containing molecular groups, which are the most mobile ones for the movable mbt fragment contributing to the most intense vibrational mode. At the same time, the primary contribution to the terahertz spectra is from the most polar molecular groups containing oxygen and included in the lct fragment. The corresponding normal vibrational modes are shown in Fig. 4. The most intensive spectral features for THz-TDS are due to the modes related to the vibrations of hydrogen bridges O$\cdots$O in a range of above 65 cm^{-1}, while the modes in a range of below 65 cm^{-1} are determined by the vibrations of the whole lct fragment. This set of modes is of general nature without intending to be bound to a particular LOV compound and can be used in further studies of statins.

7. On FSD, a series of TRIP-composites with austenitic matrix and different content of reinforcing ceramic phase of zirconium dioxide ZrO_2 partially stabilized by magnesium (Mg-PSZ) have been investigated at various degrees of plastic deformation (uniaxial compressive load). The study has been done in collaboration with the Freiberg University of Mining and Technology (Freiberg, Germany). At the load values above 650 MPa, the formation of two phases in the austenitic matrix was observed: cubic α'-martensite and hexagonal ε-martensite. The content of ε-martensite reached $\sim 15\%$ for all samples under deformation up to $\sigma = 1100$ MPa and then remained almost unchanged until the maximum load values of $\sigma = 1580$ MPa. In contrast, the α'-martensite phase exhibited a monotonic increase in the load range from 950 to 1580 MPa. In the ceramic sample of pure zirconium dioxide (100% ZrO_2), two phases were observed: cubic ($f \approx 55\%$) and tetragonal ($f \approx 45\%$). The residual deformation of the crystal lattice of the austenitic matrix is of compressive character and increases up to $\sim 10^{-3}$. In this case, the crystal lattice deformation in α'- and ε-martensites is more complex and reflects

the redistribution of the load between the phases. Furthermore, under the deformation in the range from 650 to 1580 MPa a noticeable broadening of the diffraction peaks with increasing plastic deformation was observed, which was caused by the variation in the contrast factor of dislocations. For the austenitic matrix, the dislocation densities were evaluated from the peak broadening. They reached the values in the range of

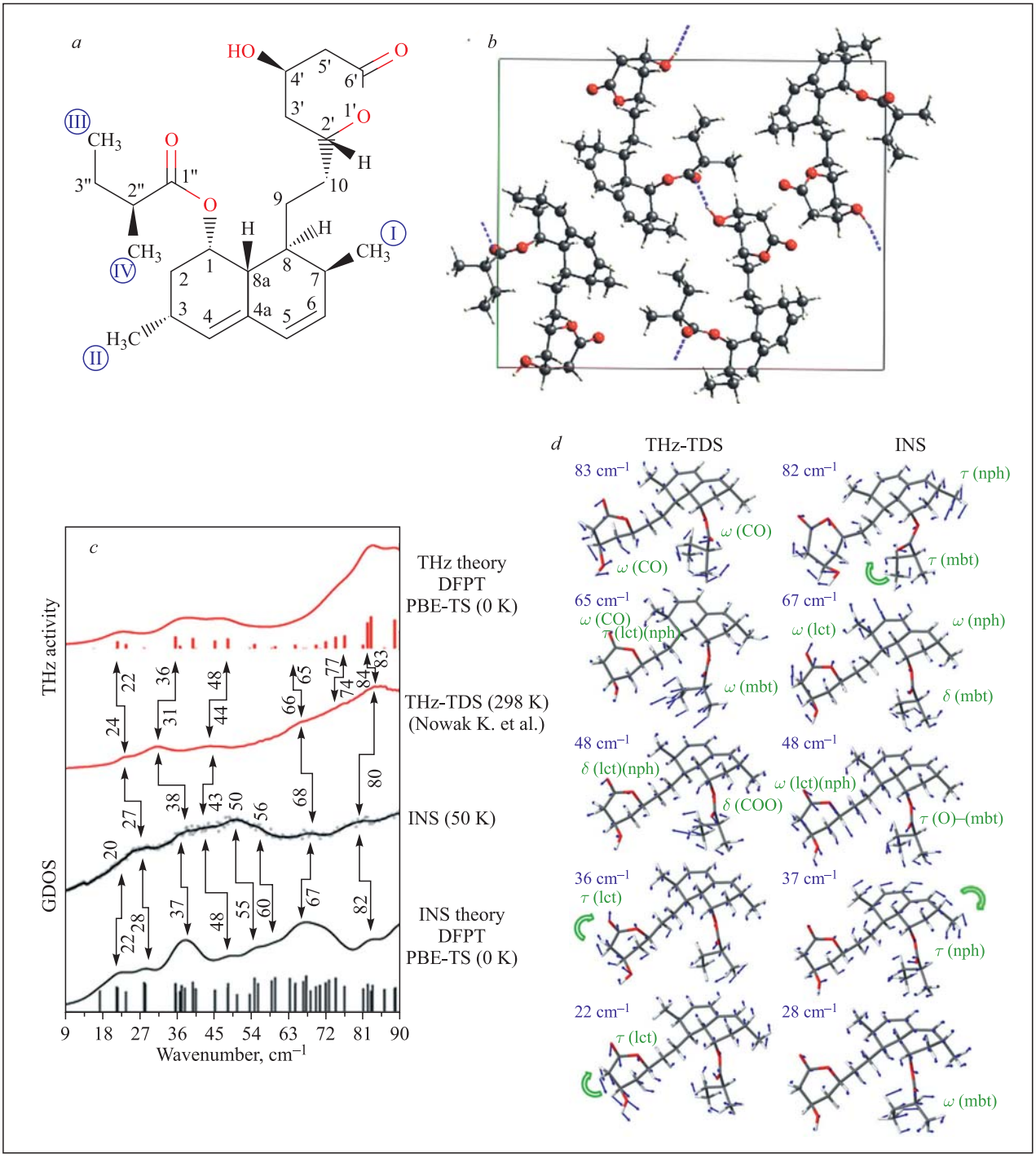


Fig. 4. *a*) Molecular formula of lovastatin (LOV; (1S,3R,7S,8S,8aR)-8-{2-[(2R,4R)-4-Hydroxy-6-oxooxan-2-yl]ethyl}-3,7-dimethyl-1,2,3,7,8,8a-hexahydronaphthalen-1-yl (2S)-2-methylbutanoate) with marked methyl groups (I–IV). *b*) Crystal structure of lovastatin (space group $P2_12_12_1$) optimized using PW-DFT (PBE-TS). *c*) Comparison of theoretically calculated (harmonic approximation DFPT PBE-TS) and experimental vibrational spectra of lovastatin according to the data of neutron (INS) and optical terahertz spectroscopy (data by Nowak K. et al. (Acta Poloniae Pharmaceutica in Drug Research. 2015. V. 72, No. 5. P. 851–866)). *d*) The most important vibrational modes of lovastatin contributing to the INS and THz-TDS spectra. The eigenvectors obtained from the harmonic PBE-TS calculations are shown in the projection of one molecule

$(12-20) \cdot 10^{14}$ m^{-2} depending on the content of zirconium dioxide in the composite.

8. The texture and microstructure of the pristine and retrogressed samples of eclogite and surrounding metasediments have been investigated to gain insights into the deformation processes in the palaeo-subduction channel of the Tauern region (Austria) [10]. The texture features and deformation processes in omphacite and glaucophane have been analyzed. The presence of a plastic deformation cycle in the metamorphism of eclogite and blueschist facies associated with the subduction and exhumation of rocks has been established.

Multimodal Platform for Raman and Nonlinear Optical Microscopy and Microspectroscopy for Condensed Matter Studies. In 2016, the research activities of the Raman Spectroscopy Sector were focused mainly on accomplishing the following objectives:

– highly sensitive, contrast, and, most notably, noninvasive imaging of biological samples using Raman scattering microscopy and nonlinear optics methods (CARS, SHG);

– further increase in the concentration sensitivity limit of sample measurements by the SERS method at a level no worse than 10^{-10} M;

– acquisition of new data on photo- and upconversion luminescence in glass-ceramics based on nanosized ZnO crystals doped with rare-earth elements.

1. In the reporting period, the work (started in 2015) on highly sensitive and high-speed visualization of protein crystals using the polarized coherent anti-Stokes Raman scattering (P-CARS) and the second harmonic generation (SHG) was completed. Thus, CARS, especially P-CARS, can be successfully applied for fast, high-resolution, high-contrast, and very informative imaging of protein crystals. The CARS and SHG images are composed of 500×500 pixels taken by raster scanning the sample. Signal integration time was 3 μs/pixel.

2. During the period under review, considerable advances have been made in SERS research. In particular, the concentration sensitivity limit at a level of 10^{-10} M has been obtained for DNA molecules. It is 2–3 orders of magnitude better than in 2015. The results of these studies suggest that the classical spectra of DNA molecules can be found by the SERS substrate mapping. Moreover, the prospects for the DNA detection by the SERS spectroscopy with lasers of 473, 633, and 785 nm wavelengths are very encouraging. To our knowledge, the detection of such a small amount of DNA has not been reported previously.

3. In transparent glass-ceramics from the potassium–zinc–aluminum–silicate system co-doped with rare-earth ions (europium, ytterbium) and containing ZnO nanocrystals, strong red ($\sim$ 612 nm) luminescence in the visible region from intracenter transitions on Eu^{3+} ions and ultraviolet exciton luminescence ($\sim$ 380 nm) from ZnO crystals have been simultaneously observed for the first time. Luminescence from triply charged europium ions has never been studied for this type of glass-ceramics.

NEUTRON NUCLEAR PHYSICS

In 2016, at FLNP the scientific activity in the field of neutron nuclear physics was carried out in the following traditional areas: 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 and applied research.

Modernization of the IREN Facility. In the late 2015, the second accelerating section was installed instead of the drift gap at the LUE-200 accelerator. In the early 2016, the connection of technical systems for the second accelerating section was made and a complex check of all systems of the accelerator was done. The existing accelerator configuration is as follows: The first section is powered by an E3730A Toshiba klystron, the second one, by a 2129 Thomson klystron. The power supply of klystrons is provided by Dawonsys modulators (Fig. 5). During 2016, the training of the accelerating systems with the gradual achievement of nominal operating parameters was carried out. In December the facility operated within nominal parameters at a frequency of 50 Hz without any failures during one week. Preliminary measurements of the neutron flux were carried out. The estimation showed an increase of the neutron yield by at least 3 times in comparison with the operation with one section.

Experimental and Methodological Investigations

1. A setup has been designed to study the prompt neutron emission and gamma-ray cascades for the fragments with defined masses in coincidence with PFN in the resonance neutron induced fission of ^{235}U. It consists of a double ionization chamber with Frisch grids, an NE-213-scintillator-based fast neutron detector, a pair of gamma-ray NaI-based scintillation detectors. The data acquisition system was implemented on the basis of an eight-channel system of synchronized pulse digitizers with a sampling rate of 250 MHz and amplitude resolution of 12 bits. The calibration experiments were carried out in the period from December 2015 to March 2016 on the IBR-2 thermal neutron beamline. At present, the data analysis and the setup upgrade involving the replacement of two NaI detectors with high-purity germanium detectors are in progress.

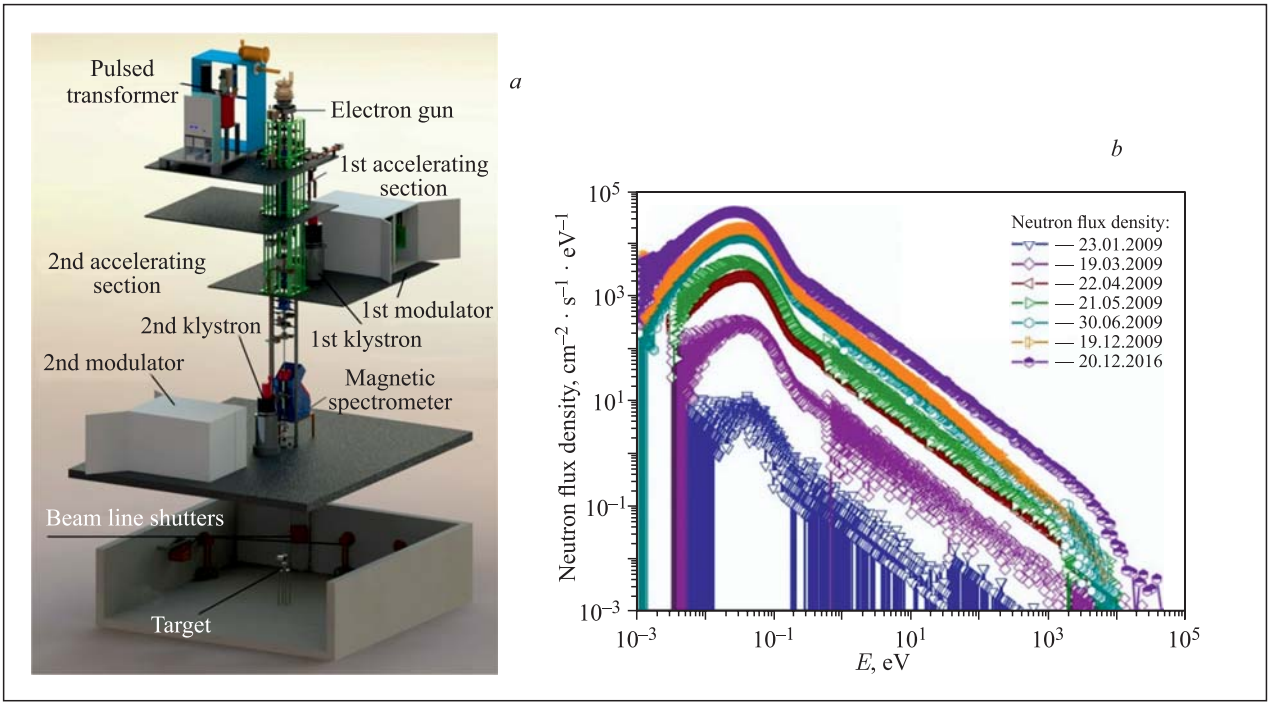


Fig. 5. *a*) Scheme of new accelerator configuration. *b*) Spectra of neutron flux density from IREN obtained during development of the facility

2. In the framework of the TANGRA project, the angular correlations of γ rays and neutrons, as well as gamma spectra produced in the inelastic scattering of 14.1 MeV neutrons by various nuclei, have been measured. These measurements are aimed at determining the partial cross sections of the formation of nucleus excitation levels with the corresponding gamma lines in inelastic neutron scattering reactions, as well as spin characteristics of these levels in the given reaction. This information is important for further development of the method of elemental analysis using tagged neutrons, in particular, to create a local database of characteristic gamma rays for a broad set of elements, and for a detailed study of inelastic scattering reactions of fast neutrons by these nuclei.

3. In the framework of the FLNP–ITEP–FRM2 collaboration, a series of experiments were continued to measure the ROT-effect in the emission of prompt γ rays and neutrons in the binary fission of ^{235}U and ^{233}U induced by polarized cold neutrons. The experiments with 0.3-eV neutrons were carried out on the POLI instrument at the FRM2 reactor (Garching, Germany). Fragments were detected by fast multiwire detectors and could be separated into light and heavy ones by the time of flight. Gamma rays and neutrons were detected by scintillation counters placed at specific angles to the direction of emission of the fragments. The effect of rotation of the fissioning system in or against the direction of the angular momentum transferred by a polarized neutron for gamma rays and neutrons was measured. The effect was measured for 9 days. As a result, the effect values (averaged over all detector position angles) were obtained: for gamma rays — $(-4.6 \pm 2.7) \cdot 10^{-5}$; for neutrons — $(2.7 \pm 2.9) \cdot 10^{-5}$. A new experiment is planned, in which we expect to observe the effect or determine its upper limit with the accuracy comparable to that obtained on the cold neutron beam.

4. The measurement of P-odd asymmetry in the emission of α particles in the $^{10}\mathrm{B}(n,\alpha)^{7}\mathrm{Li}$ reaction was carried out on the cold polarized neutron beam of the PF1B instrument at the ILL reactor (Grenoble, France). A 24-section ionization chamber with insensitive gas gaps was used as a detector of α particles. The P-odd asymmetry value was found to be $\alpha_{\mathrm{P-odd}}^{^{10}\mathrm{B},\alpha} = -(11.2 \pm 3.4) \cdot 10^{-8}$. The result has been obtained for the first time in the world. This is only the second nucleus after ^{6}Li for which the P-odd effect was discovered.

5. Ultracold neutrons (UCN) and very cold neutrons (VCN) intensively interact with nanoparticles due to the fact that the neutron wavelength and the particle size are of the same order of magnitude. One of the practical applications of nanoparticle reflectors can be a sharp increase in the VCN yield from the source, if we manage to form a narrow beam from the isotropic distribution and direct it to a neutron guide. In order to determine the possibility of the formation of such beams, a specialized experiment was carried out. A beam of very cold neutrons passes through a velocity selector and comes to the bottom of the trap through the inlet opening. The trap is a thick-walled tube with its walls consisting of nanodiamond powder. Neutrons confined in a trap can be detected by a position-sensitive detector mounted on

its exit end. The preliminary results have shown that the number of escaping neutrons is $\sim 1-2\%$ of the number of neutrons entering the trap, with the yield increasing as the neutron energy decreases. The beam formed has an angular divergence of $10^{-2}-10^{-3}$ rad. These results indicate that the covering of a VCN source with a nanoparticle reflector can result in an increase in the number of VCN in the neutron guide by a factor of tens.

6. For cold neutrons falling on the surface of a nanopowder a quasi-specular reflection can also be observed. We experimentally measured the parameters of this phenomenon using the reflection of neutrons from a nanodiamond powder. For this purpose, we measured the dependence of the angular distribution of reflected neutrons for different wavelengths of incident neutrons and different angles of incidence (1, 2, 3 and 4°) of the neutron beam on the surface. The measurements were performed for a powder of nanoparticles of different sizes. From the data it can be seen that for neutrons with longer wavelengths a more efficient reflector is that with large nanoparticles, for neutrons with shorter wavelengths — with small nanoparticles. The findings can help in the construction of primary sections of mirror neutron guides for VCN and CN placed near a reactor core, which can significantly increase the neutron emission of the sources into the neutron guides.

7. In 2016, the REGATA facility was used for multielement instrumental neutron activation analysis of about 3000 environmental samples (vegetation, soil, air filters), a number of technological, biological, and archaeological samples, as well as samples of extraterrestrial origin. Investigations of test samples were performed for an interlaboratory comparison of the results under the IAEA program.

THE IBR-2 PULSED REACTOR

In 2016, the IBR-2 research nuclear facility was operated in a nominal on-power mode under Rostekhnadzor license valid until 30.09.2022.

Statistical data on the IBR-2 operation for physics experiments are presented in the Table.

Data on the IBR-2 operation for physics experiments

No. cycle	Period	Moderator type	Reactor operation for physics experiments, h
1	18.01–29.01	Water	262
2	08.02–19.02	Water	262
3	14.03–28.03	Water	328
4	04.04–18.04	Water	328
5	16.05–27.05	Water	120
6	26.09–07.10	Canceled due to technical reasons	
7	17.10–03.11	Water	408
8	15.11–25.11	Cryogenic	237
9	05.12–26.12	Water	502
		Total:	2447

NOVEL DEVELOPMENT AND CONSTRUCTION OF EQUIPMENT FOR THE SPECTROMETER COMPLEX OF THE IBR-2 FACILITY

The following major activities were carried out in 2016 in the framework of the project “Development of PTH Sample Environment System for the DN-12 Diffractometer at the IBR-2 Facility”:

— a cryostat for a superconducting magnet with HTSC current leads and a cryostat for a high-pressure cell were manufactured;

— a machine for HTSC tape winding was manufactured;

— magnet windings were produced;

— thermal measurements were carried out for both cryostats with a prototype of the magnet in a vertical position with a zero current;

— equipment and materials required for final assembling and commissioning of the PTH system were purchased.

The achieved terminal temperatures of the magnet prototype (13 K), warm ends of HTSC current leads (55–57 K), and sample (2.8 K) correspond to the design values.

CONFERENCES AND MEETINGS

1. The 29th Task Force Meeting of the ICP Vegetation organized by the Frank Laboratory of Neutron Physics, Dubna, Russia, together with the ICP Vegetation Programme Coordination Centre for Ecology & Hydrology, Bangor, UK, 29.02–05.03.2016 (http://indico-new.jinr.ru/conferenceDisplay.py?confId =72).

2. The 24th International Seminar on Interaction of Neutrons with Nuclei: Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics (ISINN-24) dedicated to the 60th anniversary of JINR, Dubna, 23–27.05.2016 (http://isinn.jinr.ru).

3. The III International Conference on Small-Angle Neutron Scattering (YuMO2016) dedicated to the 80th anniversary of Yuriy Mechislavovich Ostanevich, Dubna, 6–9.06.2016 (http://yumo.jinr.ru/2016).

4. The Student Training Course "Advanced Materials Investigation by Means of Neutron Scattering Methods" organized by the Joint Institute for Nuclear Research together with the West University of Timisoara and University Ovidius from Constanta (Romania), Dubna, 27.08–04.09.2016.

5. Workshop on Small-Angle Neutron Scattering MURomets 2016, Gatchina, 28–30.09.2016; with the financial and organizational support of FLNP JINR (https://oiks.pnpi.spb.ru/events/muromets2016).

6. The VII International School for Young Scientists and Students "Instruments and Methods of Experimental Nuclear Physics. Electronics and Automatics of Experimental Facilities", Dubna, 07–11.11.2016 (http://d-instruments.ru/).

7. Meetings of TANGRA project organized by FLNP JINR and LLC "Diamant", Dubna, 20.10.2016, 8–9.12.2016.

REFERENCES

1. *Ovsyannikov S. V., Bykov M., Bykova E., Kozlenko D. P., Tsirlin A. A., Karkin A. E., Shchennikov V. V., Kichanov S. E., Gou H., Abakumov A. M., Egoavil R., Verbeeck J., McCammon C., Dyadkin V., Chernyshov D., van Smaalen S., Dubrovinsky L. S.* Charge Ordering Transition in Iron Oxide Fe_4O_5, Involving Competing Dimer and Trimer Formation // Nature Chem. 2016. V. 8. P. 501.
2. *Dang N. T., Kozlenko D. P., Phan T. L., Kichanov S. E., Khiem L. H., Jabarov S. H., Tran T. A., Dang N. V., Thanh T. D., Vo D. B., Savenko B. N.* Structural Polymorphism of Mn-Doped $BaTiO_3$ // J. Electron. Materials. 2016. V. 45. P. 2477–2483.
3. *Kozlenko D. P., Dang N. T., Phan T. L., Kichanov S. E., Dang N. V., Thanh T. D., Khiem L. H., Jabarov S. H., Tran T. A., Manh T. V., Le A. T., Savenko B. N.* The Structural, Magnetic and Vibrational Properties of Ti-Doped $BaMnO_3$ // J. Alloys Compd. (submitted).
4. *Balagurov A. M., Bobrikov I. A., Mukhametuly B., Sumnikov S. V., Golovin I. S.* Coherent Cluster Atomic Ordering in the Fe–27Al Intermetallic Compound // JETP Lett. 2016. V. 104. P. 539–545.
5. *Kubovcikova M., Gapon I. V., Zavisova V., Koneracka M., Petrenko V. I., Soltwedel O., Almasy L., Avdeev M. V., Kopcansky P.* On the Adsorption Properties of Magnetic Fluids: Impact of Bulk Structure // J. Magn. Magn. Mater. 2017. V. 427. P. 67–70.
6. *Prylutskyy Yu. I., Cherepanov V. V., Kostjukov V. V., Evstigneev M. P., Kyzyma O. A., Bulavin L. A., Ivankov O., Davidenko N. A., Ritter U.* Study of the Complexation between Landomycin A and C60 Fullerene in Aqueous Solution // RSC Adv. 2016. V. 6. P. 81231–81236.
7. *Prylutska S., Panchuk R., Goluński G., Skivka L., Prylutskyy Yu., Hurmach V., Skorokhyd N., Borowik A., Woziwodzka A., Piosik J., Kyzyma O., Haramus V., Bulavin L., Evstigneev M., Buchelnikov A., Stoika R., Berger W., Ritter U., Scharff P.* C60 Fullerene Enhances Cisplatin Anticancer Activity and Overcomes Tumor Cells Drug Resistance // Nano Res. 2017. V. 10, No. 2. P. 652–671.
8. *Avdeev M. V., Rulev A. A., Bodnarchuk V. I., Ushakova E. E., Petrenko V. I., Gapon I. V., Tomchuk O. V., Matveev V. A., Pleshanov N. K., Kataev E. Yu., Yashina L. V., Itkis D. M.* Monitoring of Lithium Plating by Neutron Reflectometry // Appl. Surface Science. 2017 (in press).
9. *Zhernenkov M., Bolmatov D., Soloviov D., Zhernenkov K., Toperverg B. P., Cunsolo A., Bosak A., Cai Y. Q.* Revealing the Mechanism of Passive Transport in Lipid Bilayers via Phonon-Mediated Nanometre-Scale Density Fluctuations // Nature Commun. 2016. V. 7. P. 1–9.
10. *Keppler R., Stipp M., Behrmann J. H., Ullemeyer K., Heidelbach F.* Deformation inside a Paleosubduction Channel — Insights from Microstructures and Crystallographic Preferred Orientations of Eclogites and Metasediments from the Tauern Window, Austria // J. Struct. Geol. 2016. V. 82. P. 60–79.

LABORATORY OF INFORMATION TECHNOLOGIES

The investigations performed at the Laboratory of Information Technologies during 2016 in the scope of the JINR research field "Networks, Computing, and Computational Physics" were focused on two first-priority themes, namely, "Information and Computing Infrastructure of JINR" and "Methods, Algorithms and Software for Modeling Physical Systems, Mathematical Processing and Analysis of Experimental Data". The cooperation with other JINR laboratories involved the participation of the LIT staff in research work within 30 themes of the JINR Topical Plan for JINR research and international cooperation. The LIT activity is intended to provide a further development of the JINR network and information infrastructure, mathematical and software provision for research and production activity under way at JINR and its Member States on the base of advanced information and computer technologies.

For more than a decade, the development of the information and computing infrastructure of JINR created at LIT was done within the Central Information and Computing Complex (CICC) of JINR. In the last few years, in connection with work on the organization of the computing project for NICA, the commissioning of the grid center Tier-1 for the CMS experiment, the implementation of a cloud computing structure and a cluster for hybrid computing, the information-computing environment of JINR evolved in a set of stand-alone structures that have a common engineering infrastructure. Thus, it is possible to identify this structure as a Multifunctional Information and Computing Complex (MICC) of JINR, which currently has the following basic components:

- the Central Information and Computing Complex (CICC) of JINR with home built up compute elements (CE) and mass storage elements (SE);
- the grid center Tier-1 for CMS experiment;
- the grid center Tier-2 site for experiments at the Large Hadron Collider (LHC) and other virtual organizations (VOs) in the grid environment;
- the heterogeneous cluster "HybriLIT" for parallel computing;
- the cloud-based grid infrastructure;
- the training and research grid-cloud infrastructure.

The JINR MICC provides resources needed for different tasks, implied by many projects the JINR researchers take part in, namely: COMPASS, BES-III, DIRAC, HARP, CMS, ALICE, ATLAS, H1, NEMO, OPERA, PANDA, NOνA, STAR, LHCb, etc. The JINR Tier-1 and Tier-2 are elements of the Russian Grid Segment used for LHC computing and other applications. The grid infrastructure at JINR is represented by CMS Tier-1 center and Tier-2 center for ALICE, ATLAS, LHCb, and CMS.

In 2016, 193 scientific papers were published by LIT researchers in referred journals, and 47 reports were presented at international and Russian conferences.

INFORMATION AND COMPUTING INFRASTRUCTURE OF JINR

During 2016, the work related to the reliable operation and development of the JINR networking, informational and computing infrastructure was in progress. The key components of this infrastructure are telecommunication data links, the JINR local area network (LAN), the CICC and the primary software, including the one on the basis of cloud, grid, and hybrid technologies. They integrate information resources of the Institute into a unified environment accessible to all users.

JINR Telecommunication Data Links. In 2016, the reliable work of the high-speed computer communication channel Dubna–Moscow was secured. The connection with scientific networks and Internet used the following telecommunication links: LHCOPN/CERN (10 Gbps), RBnet (10 Gbps), E-arena and Russian scientific networks (10 Gbps), RUNNet and international scientific networks (10 Gbps).

The throughput of the reserve data link was raised up to 10 Gbps and its reliability was improved at the expense of the addition of a supplementary router Cisco7606-S. The possibility of the gradual modernization of the external data link up to 100 Gbps has been

studied and this work was finished at the end of 2016. The new Transmode equipment for this modernization was purchased and put into operation.

Table 1 shows the distribution of the incoming (more than 3 TB) and outgoing traffics over JINR subdivisions in 2016.

Table 1

Subdivision	Incoming, TB	Outgoing, TB
DLNP	125.98	154.99
VBLHEP	102.43	90.68
General access servers	90.99	17.72
LIT	62.13	34.79
FLNP	49.2	63.15
University "Dubna"	48.98	38.43
FLNR	37.6	18.18
JINR Management	26.82	58.2
JINR Hotel & Restaurant Complex	25.47	4.4
Remote access node	24.05	5.74
BLTP	19.71	16.73
Joint-Stock Company "Dedal"	10.78	5.97
Medical-Sanitary Unit 9	10.65	0.82
LRB	8.76	5.26
Resort Hotel "Ratmino"	7.77	2.08
Joint-Stock Company "Atom"	5.13	0.65
Procurement and Logistics Service	4.23	3.07
Chief Engineer's Department	3.83	0.68

In 2016, the overall incoming JINR traffic, including the general access servers, Tier-1, Tier-2, and CICC, amounted to 14.2 PB (4.26 PB in 2015). The weights of the various incoming traffic categories are shown in Table 2.

Table 2

Scientific and educational networks, %	File exchange (p2p), %	Web resources, %	Social networks, %	Software, %
96.75	2.32	0.53	0.11	0.29

JINR Local Area Network. In 2016, work was in progress on the further development and improvement of the JINR network IT elements intended to increase the working efficiency of the JINR staff. The construction of the 10 GB network inside the laboratories was finished.

In the framework of the user's computer environment support, the scheduled work has been done on enhancement of the IPDB, mail, webmail, proxy, e-lib, and authorization services. For instance, work is carried out on the transition of the JINR subdivisions to the unified JINR mail service user@jinr.ru. An authorized WiFi has begun its operation on the JINR territory as well as services eduroam and VPN for remote work outside the JINR limits.

The JINR LAN includes 8222 network elements and 13364 IP addresses; 4301 users are registered at present within the network. There are 2341 users of mail.jinr.ru service as well as 1500 users of digital libraries and 371 remote VPN users.

JINR Grid Environment. The Tier-1 center for CMS at JINR was put into a full-operation mode in March 2015. By the end of 2016, the JINR Tier-1 resources comprise: computing power of 55.16 kHS06, 3600 cores/slots (11 Supermicro Twin Blades), disk capacity of 4037 TB (30 Disk servers with hardware RAID6) and 521.88 TB used as a buffer for tape storage (8 Disk servers with hardware RAID6), tape space of 5478.32 TB (IBM TS3500 tape library with $8 \times$ FC8 links to 8 Disk servers). The network is configured as two redundant triangles shared with the NRC "Kurchatov Institute" with 10 Gbit/s LHCOPN connection.

The mass storage systems are built on dCache and Enstore as a tape backend for dCache. Totally, two installations have now 4 PB of effective disk space, and the tape robot has a 5.4 PB of data storage capacity. To support the storage and access to data, 8 physical and 14 virtual machines have been installed.

Torque/Maui is used as a scheduler. The standard WLCG software stack was used for computing: $2 \times$ 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 JINR CMS Tier-1 has shown its stable state for the whole period after putting it into the full-operation mode [1]. During 2016, this center performed 8 257 163 tasks, using a normalized CPU time of 237 346 520 h in HEPSpec06 units. Figure 1 gives the contribution of the Tier-1 global centers to the CMS experimental data processing (in MEvents) for the year of 2016. The JINR Site takes one of the leading ranks in the world as to its productivity.

Figure 2 shows the number of events processed at the JINR CMS Tier-1 in June 2016 by the CMS activities (production, reprocessing, analysis, etc.).

One of the main functions of the Tier-1 centres is the archival storage of raw experimental and simulated data. Figure 3 shows the load of our tape robot during 2016. Figure 4 illustrates the requests from the Tier-1 and Tier-2 centres worldwide to the JINR CMS Tier-1 for data in June 2016. The average rate for RAW data transfers to the JINR CMS Tier-1 site is 250–300 MB/s, more than 1 TB/h was transferred.

The JINR Tier-2 center supports a number of virtual organizations (VOs), in particular, ALICE, ATLAS, BES, BIOMED, CMS, HONE, FUSION, LHCb, MPD, NOνA, STAR. The JINR Tier-2 computing resources comprise 2470 cores/slots, 46.72 kHS06; disk capacity:

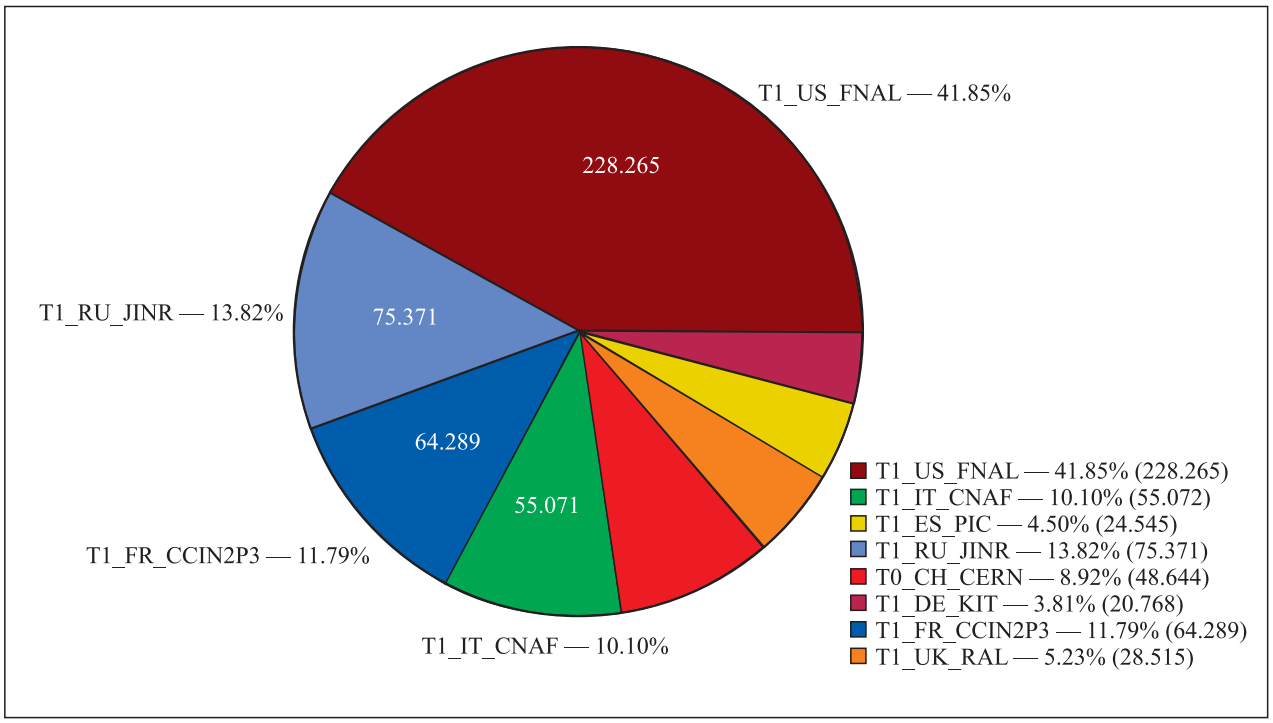


Fig. 1. Number of events processed for all CMS Tier-1 in MEvents in 2016 (sum: 545.470)

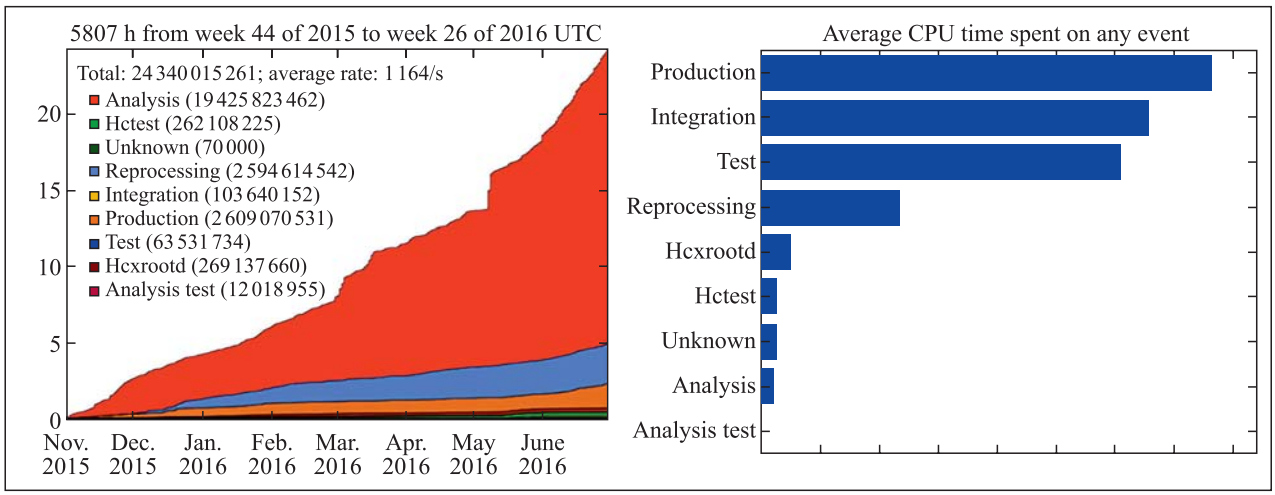


Fig. 2. Number of events processed at the JINR CMS Tier-1 in June 2016 by the CMS activities (production, integration, reprocessing, analysis, etc.)

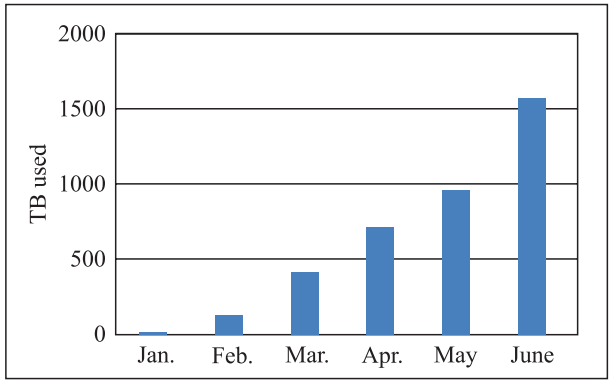


Fig. 3. JINR Tier-1 CMS tape robot load

587.46 TB for ALICE, 641.87 TB for ATLAS, 659.31 TB for CMS.

We are working on integration of OSG type Computing Element — HT-CONDOR in our WLCG Tier-2 infrastructure. At the moment, it is for STAR VO mainly but can be extended for supporting other VOs in the future.

The main users of the JINR grid resources are virtual organizations of all LHC experiments [2]. In 2016, this site executed 4 185 956 tasks (3 912 779 for LHC), CPU time being 186 711 011 h in HEPSpec06 units. Figure 5 summarizes data on using the grid site JINR-LCG2 by the virtual organizations within the RDIG/WLCG/EGI community in 2016.

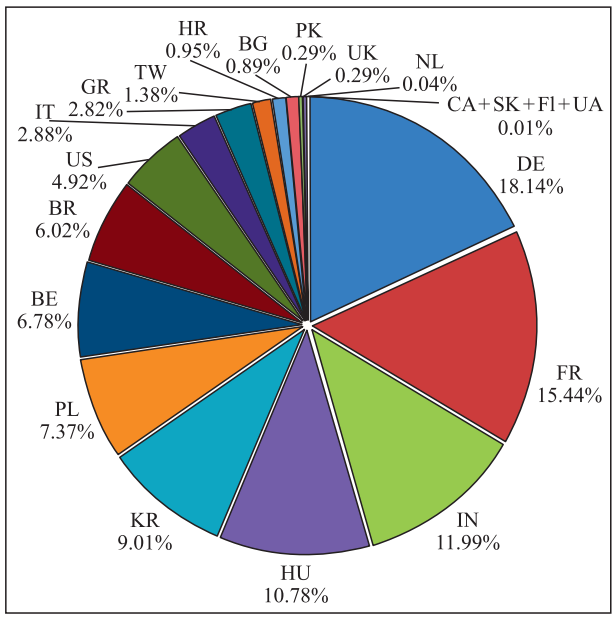


Fig. 4. The requests from the Tier-1 and Tier-2 centres to the JINR CMS Tier-1 for data in June 2016

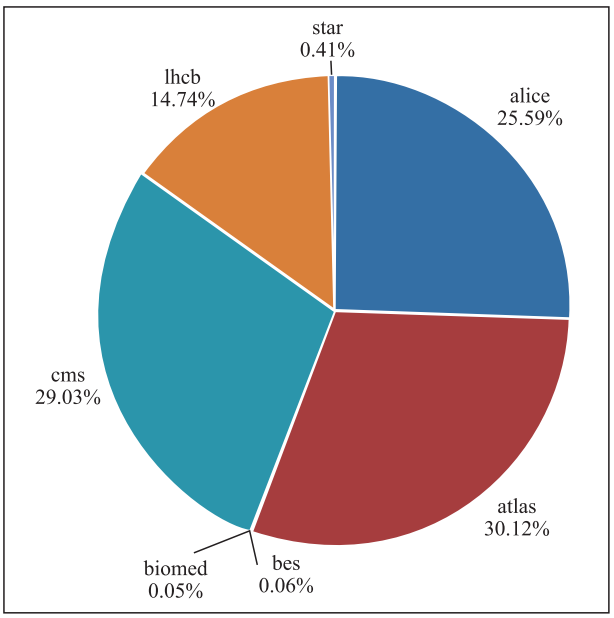


Fig. 5. Using the JINR-LCG2 grid site by virtual organizations within RDIG/WLCG/EGI

PanDA, production and distributed analysis system, manages tasks for ATLAS since 2005. Since that time the system has grown, and in 2013 the BigPanDA project started, aiming to prepare packets of PanDA which can be used outside the LHC. One of the experiments to which production management PanDA is being applied is COMPASS at CERN. The workflow of the experiment has to be changed to enable grid for production and user jobs. This year JINR as a computing site for COMPASS was connected through PanDA, i.e., the task was to allocate the space and define PanDA queue at JINR's computing infrastructure; define PanDA queues in other institutes participating in COMPASS and make their data analysis distributed [3].

The JINR MICC monitoring system provides real-time information about: work nodes, disk servers, network equipment, uninterruptable power supply elements, and cooling system. It can also be used for creating network maps and network equipment load maps, for drawing state tables and different plots. Special Control Room was equipped for operators of the MICC (see Fig. 6).

HappyFace monitoring system was installed and configured for the purposes of JINR Tier-1. It is a product developed in KIT for monitoring grid sites of CMS and ATLAS experiments. Currently, it is one of the key elements of JINR Tier-1 services monitoring (http://happyface.jinr.ru).

Development of the new service monitoring system for CMS Tier-1 at JINR was initiated. The system has a modular structure. The following modules were developed: Job Status — to determine the number of executed and aborted jobs; SSB Status — to collect monitoring results performed by WLCG Dash-

Fig. 6. Video Wall with HappyFace monitoring system at Control Room

board; PhedexQuality — to determine transfers quality from other grid sites and T1_RU_JINR; PhedexErrors — to determine Phedex errors connected to T1_RU_JINR. The test version of the service monitoring system was launched at lcgsens01o.jinr.ru. Now it aggregates and displays on the web page the data related to Phedex, dCache, and WLCG monitoring [4]. The system is developing as a general-purpose tool which can be adapted for other Tier-1 centers and experiments.

High-Performance Computer System. The multipurpose information complex at LIT provides carrying out computations, including the parallel ones, outside the grid environment. They are asked both by the experiments NOνA, PANDA, BES, NICA/MPD, etc., and the local users of the JINR laboratories. The JINR users and the grid users have an access to all the computer facilities via a unified batch processing system. Figure 7 gives the time distribution of the tasks executed on the computing cluster by the JINR subdivisions and the user groups. The main user of these resources is NICA/MPD (61.07% of astronomic time and 55.53% of processor time).

Systems of storage and access to data dCache and XROOTD ensure work with the data both for local JINR users and for the WLCG users and collaborations. Two dCache installations are supported: dCache-1 for experiments CMS and ATLAS; dCache-2 for local users, groups of users and international projects NICA/MPD, HONE, FUSION, BIOMED, COMPASS. Two installations of the XROOTD data access arrangement maintain work with the data of three international collaborations: ALICE, PANDA, and CBM. All the storage systems are constructed under the hardware data protection mechanism RAID6.

A system for grid and cloud services simulation of contemporary HENP experiments of the Big Data scale was developed. This simulation system is focused on improving the efficiency of the grid/cloud structures development by using the work quality indicators of some real system to design and predict its evolution. For these purposes the simulation program is combined with a real monitoring system of the grid-cloud service through a special database (DB). The DB accomplishes acquisition and analysis of monitoring data to carry out dynamical corrections of the simulation. Such an approach allows us to construct a general model pattern which should not depend on a specific simulated object, while the parameters describing this object can be used as input to run the pattern. The development of such kind software is very important for making a new grid/cloud infrastructure for such big scientific experiments as the NICA/MPD/SPD Tier-0/Tier-1 distributed computing [5, 6]. The NICA includes the BM@N experiment the first run of which is planned to be performed in 2017. Therefore, it is necessary to develop a computing system for distributed data storing and processing for the experiment. The simulation program SyMSim is used to choose a proper architecture of the BM@N computing system infrastructure. SyMSim facilitates making a decision regarding a required equipment [7].

Heterogeneous Computing Cluster HybriLIT. During 2016, the total performance of the HybriLIT cluster increased 1.8 times. At the moment, the computing component of the cluster contains four nodes with NVIDIA Tesla K80 graphical processors and four nodes with NVIDIA Tesla K40 accelerators, a node with Intel Xeon Phi 7120P co-processors, and a node with two

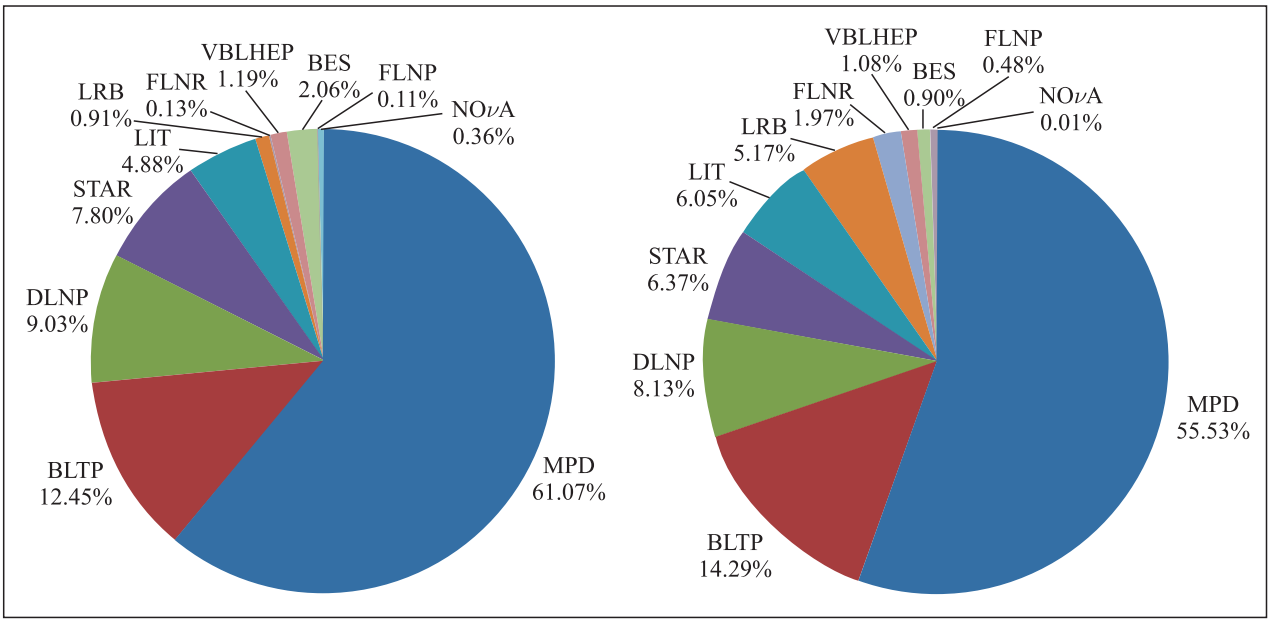


Fig. 7. Statistics of using astronomic (left) and processor time (right) of the computing cluster by the subdivisions and experiments of JINR without grid users

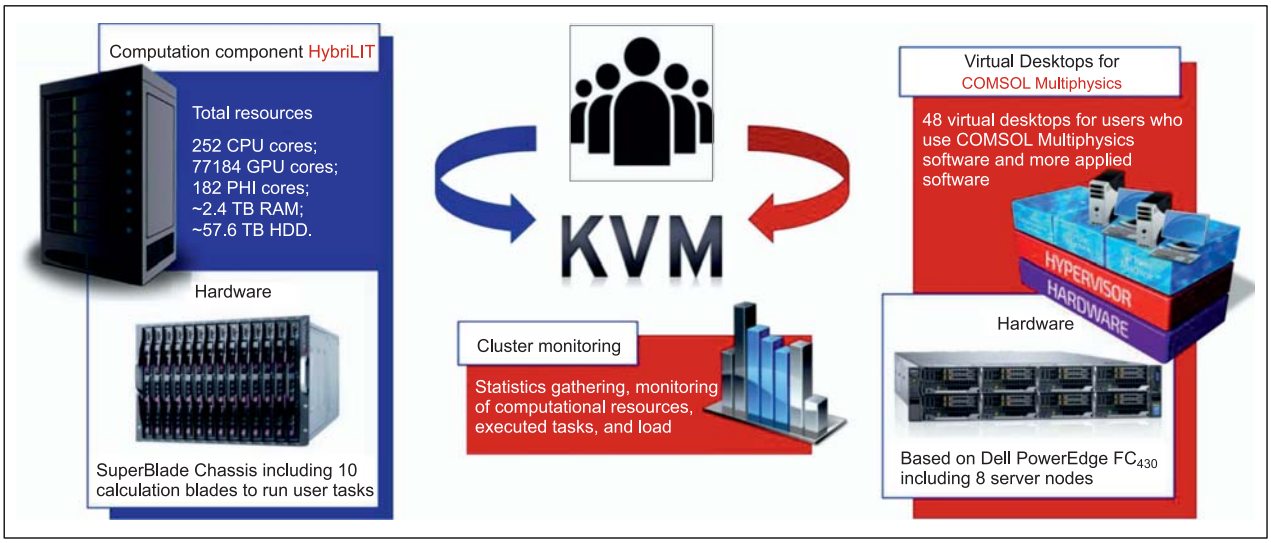


Fig. 8. The new component of the cluster to work with applied packages

types of computing accelerators NVIDIA Tesla K20x and Intel Xeon Phi 5110P. All the nodes have two multicore processors Intel Xeon. Overall, the cluster contains 252 CPU cores, 77184 GPU cores, 182 PHI cores; it has 2.4 TB RAM and 57.6 TB HDD, and its total capacity is 142 TFLOPS for operations with single precision and 50 TFLOPS for double precision.

In 2016, a new component was included in the cluster structure — a virtual desktop system to support users work with applied packages. Deployed was a polygon of eight servers where on the basis of KVM (Kernel-based Virtual Machine) virtual desktops with remote access to the package COMSOL Multiphysics for user groups have been designed. The developed new cluster's component allows the users to effectively utilize the cluster's resources conducting intensive calculations from the applied software packages on the computing nodes of the cluster (Fig. 8).

In 2016, the software and information environment of the cluster was actively maintained and developed allowing its users to develop software applications, to perform calculations with the help of the latest computational architectures. The total number of its users is 450 people from the JINR laboratories and the JINR Member States. In particular, the cluster resources are used for calculations in the field of quantum chromodynamics, quantum mechanics, and molecular dynamics. In addition, software PandaRoot, MpdRoot installed on the cluster allows one to perform calculations in high energy physics.

The heterogeneous cluster HybriLIT is used both to perform massively parallel computations and to learn how to use applied software packages and parallel programming technologies. During 2016, over 20 training courses were held, which were attended by over 200 specialists from various departments of the Institute, young scientists from the JINR Member States and Russian universities. The tutorials were dedicated to using applied packages MCTDHB-Lab, LAMMPS (Large-scale Atomic/Molecular Massively Parallel Simulator), VMD (Visual Molecular Dynamics), and parallel programming technologies CUDA, OpenMP, OpenCL, and MPI. Tutorials and master classes were held during the 7th International Conference "Distributed Computing and Grid Technologies in Science and Education" (GRID'2016) and the JINR–CERN School "Grid and Advanced Information Systems".

Cloud Environment. In 2016, the JINR cloud infrastructure [8] has been developing in the following directions: increasing the number of resources its users have access to; increasing the number of tasks it is used for; reimplementing an aggregation and visualization statistics on the cloud resources utilization using InfluxDB and Grafana software. The amount of the resources available for the JINR cloud users has been increased due to 1) maintaining additional servers as cloud nodes and 2) integration of part of computing resources of partner organizations clouds.

At present, the total number of CPU cores available for users in the JINR cloud is 330 (200 in 2015) and the total RAM is 840 GB (400 GB in 2015). The spectrum of tasks solved with the help of JINR increases. For this purpose, the following components have been installed on this infrastructure:

- PanDA testbed was deployed for PanDA software validation and extensions development for ATLAS and COMPASS experiments;
- DIRAC-based testbed (it is used for monitoring tools development for BES-III experiment distributed computing infrastructure as well as its computing facility);
- a set of VMs of NOνA experiment users for analysis and software development;
- NICA testbed for grid middleware evaluation for NICA computing model development;

• EOS testbed for research on heterogeneous cyber-infrastructures, computing federation prototype creation and development based on high-performance computing, cloud computing and supercomputing for Big Data storage, processing, and analysis;

• a standalone Spark instance for Machine Learning and Big Data analysis.

At present, one of the most important trends in the cloud technologies is the development of method of integrating various cloud infrastructures [9]. In order to join the cloud resources of partner organizations from JINR Member States for solving common tasks as well as to distribute a peak load across them, a cloud bursting driver has been designed by the JINR cloud team. It allows one to integrate the JINR cloud with the partner clouds either OpenNebula-based one (and in this case it is possible to enable real time external cloud resources monitoring) or any other cloud platform which supports Open Cloud Computing Interface (OCCI). The clouds of the following partner organizations from JINR Member States are integrated into the JINR cloud: Institute of Physics of Azerbaijan National Academy of Sciences (Baku, Azerbaijan); Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine (Kiev, Ukraine); Plekhanov Russian University of Economics — PRUE (Moscow, Russia). The geographical location of the partner organizations from JINR Member States whose cloud resources are integrated into the JINR cloud following the so-called "cloud bursting" model are shown in Fig. 9.

Besides, the JINR cloud is integrated into EGI Federated cloud thus enabling a possibility to use part of the JINR computing resources by EGI FedCloud Virtual Organizations.

Currently, one of the most important directions of the JINR cloud development is a reimplementation of an aggregation and visualization statistics on resources utilization. Initially it was done by JINR cloud team as an additional item in a menu of OpenNebula graphical web-interface (which is called "Sunstone"). However, a drawback of the implementation was a necessity to check the compatibility of that aggregation and visualization add-on against each new release of OpenNebula because its web-interface might be changed. It was needed to adopt the code of visualization module for the new Sunstone in case of its incompatibility. So in order to avoid such extra steps before software update on the JINR cloud as well as to store a collecting metrics in a database for further analysis against their changes over time and to obtain the dynamics for the selected period, it was decided to implement aggregation and visualization statistics on JINR cloud resources utilization using such tools as InfluxDB and Grafana software [10].

Information and Software Support. A traditional direction of the LIT activity in 2016 is the development and support of the program library JINRLIB as well as support of the program libraries (CERNLIB, CPC Program Library) developed by other research centres and organizations. The JINRLIB Web-site was renovated. A special section for parallel programs was added together with educational programs on parallel programming (MPI). The H-Utils package that is being developed at LIT for the HybriLIT users was included in the JINRLIB (http://wwwinfo.jinr.ru/programs/jinrlib/h-utils/index.html). This package contains a number of libraries and is aimed at help in solving general difficulties that the developers often face while creating software complexes for solving problems in the field of physics, chemistry, biology, etc. on high-performance computational platforms.

In the scope of the development of the JINR corporate information systems (CIS) [11], a subsystem of electronic coordination of orders on the basic activity has been developed and put into operation in the struc-

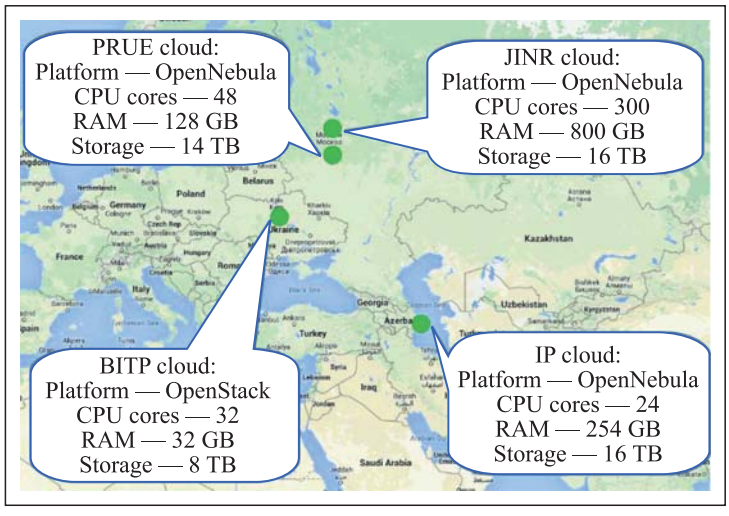


Fig. 9. Geographical locations of the partner cloud infrastructures from JINR Member States which provide part of their computational resources being integrated into the JINR cloud

ture of the system "Base of JINR documents"; a universal gateway for data exchange between different CIS subsystems 1C, EDH "Dubna", ADB2, ISS, PIN was implemented in 2016; work was in progress on enhancing the functionality of the information system of the NICA project management based on ADB system, implementation of functionality on the formation of Cost Book for the NICA project, realization of functionality on the formation of various consolidated reports on the project [12]; the development of the unified system 1C 8.2 UPP was in progress, a regular support of the end-users of the system also continued in 2016.

In 2016, the improvement of the software for the JINR Document Server (JDS) was in progress, namely, tools have been developed to speed up data entry, the quality of the content and efficient data reuse was improved. The work is carried out on the test server jds-test3 (http://jds-test3.jinr.ru), deployed in the cloud infrastructures of LIT JINR.

METHODS, ALGORITHMS AND SOFTWARE SUPPORT FOR MODELING PHYSICAL SYSTEMS, MATHEMATICAL PROCESSING, AND ANALYSIS OF EXPERIMENTAL DATA

One of the main directions of the research activity at LIT is to provide mathematical, algorithmic, and software support of the experimental and theoretical research underway at JINR. Below there is a brief report on some results.

A new algorithm of searching for tracks — candidates for event reconstruction in the experiment BM@N (Baryonic Matter at Nuclotron) — has been proposed. The event reconstruction is one of the most important tasks for experimental data processing in high energy physics. It consists of the tracks and their parameters evaluation in the tracking detectors of the experiment, which requires a huge number of searches of all the hits (reconstructed responses of the detector) to find those belonging to one track (see Fig. 1). The authors propose a new coordinate transformation that maps experimental data to the normalized coordinate space in which the hits corresponding to one track are grouped into compact horizontal segments. In order to estimate the parameters, the found tracks — the candidates — are approximated by Archimedes spirals. Due to the compactness of data in the space of normalized coordinates, the proposed algorithm can be effectively parallelized on modern computing architectures [13].

A computer program of the Glauber calculations for the NICA experiments has been proposed. It should be noted that all contemporary experiments with relativistic nuclear beams (RHIC, LHC, NICA, CBM) use and will use various methods of determining the geometrical properties of interactions, especially collision impact parameter. No impact parameter can be measured directly. That is why the experimental observable quantities are connected, in one or another manner, with the geometrical properties calculated within the Glauber approach. However, the existing methods of the Glauber calculations do not meet modern requirements. The proposed approach allows one to calculate the geometrical properties of interactions of gold nuclei with gold nuclei at RHIC and NICA energies (5–10 GeV in the center of mass of NN collisions) and to improve the result by 5–7% as compared to the currently used software. The changes of the physical characteristics of the NICA collisions can be related to changing the interaction physics [14].

A new segment building algorithm for the cathode-strip chambers has been developed. Results of comparison of the standard and new algorithm for various types of simulated data were obtained. Track segments are reconstructed with higher precision and efficiency using the new algorithm, especially for high luminosity on the LHC and high transverse momentum of particles passing through the muon endcap system. In July 2016, the algorithm was implemented in the official CMS reconstruction software package [15].

Effects of vector interaction in Nambu–Jona-Lasinio model with Polyakov loop have been studied in combination with entanglement interaction between quark and pure gauge sector. The QCD phase diagram was investigated. It has been found that the first-order chiral phase transition at the finite baryon chemical potentials and its critical point disappear at sufficiently large values of the vector interaction constant G_v. The presence of entanglement interaction between the quark and pure gauge sector leads to the increasing of value G_v when the first-order phase transition in the thermodynamic system disappears. The influence of nonzero G_v on the curvature of the crossover boundary in the $T-\mu$ plane nearby $\mu = 0$ is also examined for the cases of additional quark–gluon interaction and without it [16].

The Asynchronous Differential Evolution (ADE) method is applied to research on the drug delivery Phospholipid Transport Nano System (PTNS) in the scope of the Separated Form Factor model. Basic parameters of PTNS unilamellar vesicles are fitted to experimental data of the small-angle synchrotron X-ray scattering. The structure of PTNS nanoparticles has been analyzed depending on the maltose concentration in water. Numerical results confirm the efficiency of parallel MPI-implementation and the preference of the ADE-based global minimization in comparison to other popular optimizing procedures [17].

A new approach to the higher-order polynomial approximation (smoothing) based on the basic elements method (BEM) is proposed. The design of the BEM-polynomial is built on a three-point grid and depends on the control parameters x_0, $\alpha = x_\alpha - x_0$, $\beta = x_\beta - x_0$ related to the independent variable $\tau = x - x_0$ by a cross-ratio rule. The BEM polynomial of degree n is expressed using four basic elements given on the three-point grid: $x_0 + \alpha < x_0 < x_0 + \beta$, $\alpha\beta < 0$. Formulas for calculating the coefficients of the polynomial model of order 12 were obtained, depending on the interval length, the parameters α, β, and the derivatives $f^{(m)}(x_0 + \nu)$, $\nu = \alpha, \beta, 0$, $m = \overline{0,3}$. Application of the higher-degree BEM polynomials for piecewise polynomial approximation of functions and data smoothing enhances the stability and accuracy of calculations when increasing the grid step and reduces the computing complexity as well [18].

Two conceptual developments in the Bayesian automatic adaptive quadrature approach to the numerical solution of one-dimensional Riemann integrals (*Adam Gh., Adam S.* // Springer LNCS. 2012. V. 7125. P. 1–16) are reported. First, it is shown that the numerical quadrature, which avoids the overcomputing and minimizes the hidden floating point loss of precision, asks for the consideration of three classes of integration domain lengths endowed with specific quadrature sums: microscopic (trapezoidal rule), mesoscopic (Simpson rule), and macroscopic (quadrature sums of high algebraic degrees of precision). Second, sensitive diagnostic tools for the Bayesian inference on macroscopic ranges, coming from the use of Clenshaw–Curtis quadrature, are derived [19].

A research was in progress at LIT on the problem of mathematical description of quantum correlations in composite systems. A problem of classification and correlations in systems being in the so-called X-states was studied within the mathematical framework of the classical theory of invariants by means of advanced methods of computer algebra. Quantum entanglement properties of a mixed two-qubit system in mixed X-states were analyzed in terms of local unitary invariant polynomials in the elements of the density matrix [20]. The structure of the ring of invariant polynomials was studied, and it is shown that for the X-states there is an injective ring homomorphism of the quotient ring of $SU(2) \times SU(2)$-invariant polynomials modulo its syzygy ideal and $SO(2) \times SO(2)$-invariant ring freely generated by five homogeneous polynomials of degrees 1, 1, 1, 2, 2. The separable mixed 2-qubit X-states are classified in accordance with degeneracies in the spectrum of density matrices [21].

APPLIED RESEARCH

LIT researchers, in cooperation with VBLHEP scientists, conduct the investigation on the behavior of the solution to the nonlinear boundary-value magnetostatic problem in the vicinity of the "corner point" (the intersection of two environments — vacuum/iron) of ferromagnet. The upper estimate for the acceptable growth of the magnetic field in the vacuum region near the corner point of the ferromagnet has been obtained. It is shown that under certain conditions imposed on the magnetic permeability the magnetic field within the vacuum region in the vicinity of the corner points is limited. An algorithm of thickening differential grid near the corner point has been developed. It allows one to significantly reduce the computation time and simultaneously increase the accuracy of the solution of the boundary value problem. The results of modeling the magnetic system containing corner points are presented. The problems of creating a homogeneous map of the field of possible solenoid-type magnetic systems of the NICA installation are analyzed. The computations were performed with the help of two software products, i.e., TOSCA and MFC (Magnetic Field Calculation), developed by the authors [22].

INTERNATIONAL COOPERATION

In cooperation with scientists from South Africa, the inclusive reaction $^{59}\mathrm{Co}(p,\alpha)$ at an incident energy of 100 MeV has been studied. A theoretical analysis based on a statistical multistep mechanism indicates that the terminal step leading to emission of an α particle can be a pickup or knockout process, in which both are very prominent. This is a conclusion which is in agreement with an earlier study of the $^{93}\mathrm{Nb}(p,\alpha)$ reaction. This inspires an investigation of the reason why a mixture of knockout and pickup is present at incident energy of 100 MeV, whereas at both higher and lower incident energies the knockout appears to dominate for the target nucleus ^{93}Nb. It has been found that the different dynamics of the two competing reaction mechanisms provides explanation for the observed phenomenon. It is speculated that for ^{59}Co at both lower and higher

incident energies the trend is likely to be similar to that of ^{93}Nb [23].

In collaboration with scientists from research centers of the USA, the development of the workflows management system PanDA (Production and Data Analysis) has been proposed, which allows one to send tasks to HPC platforms. This development was tested on the Titan supercomputer (Oak Ridge Leadership Computing Facility, USA), supercomputer of the National Research Center "Kurchatov Institute", supercomputer IT4 (Ostrava, Czech Republic), and others. The testing has shown the possibility of using the modified PanDA WMS as a portal, independent of a computing infrastructure which can be used not only for solving intensive tasks of high energy physics and nuclear physics but also in other fields such as bioinformatics and astrophysics [24].

In 2016, in collaboration with colleagues from China and France work was in progress on the creation of a distributed computing environment for the experiment BES-III, which currently joins 12 resource centers from China, USA, Italy, JINR, and providing access to more than 3000 CPU cores and 0.5 PB disk space. In the current year, more than half a million tasks were executed in this distributed system. To date, the distributed data processing system of the BES-III experiment is reliable, it is a significant part of the computing power for experimental data processing [25].

CONFERENCES, WORKSHOPS

On 25–30 January, LIT hosted the 23rd International conference "Mathematics. Computer. Education". The conference has been held since 1993 and manifested itself as a productive form of exchanging experience between specialists in various scientific areas including mathematicians, biologists, economists, and teachers. 250 scientists from the JINR Member States and 32 cities of Russia, Ukraine, Belarus, and Kazakhstan attended the conference. A symposium "Biophysics of Complex Systems. Molecular Modeling. System Biology" was organized in the framework of the conference. Some sessions on mathematics, mathematical simulation and computing methods, biology, economy and pedagogy included oral and poster reports. Alongside with the traditional round tables, 11 master classes were organized to acquaint the conference participants with the bases of the modern high-level programming languages and their applications to modeling in solving research problems. The conference was traditionally brought to an end with a discussion of the work of the sections and awarding young participants with certificates for the best reports.

A traditional 19th two-day Workshop on Computer Algebra was held at LIT on 24–25 May. More than 40 scientists from universities and scientific institutes of Bucharest (Romania), St. George (Grenada), Tbilisi (Georgia), Turku (Finland), Moscow, Petrozavodsk, St. Petersburg, Saratov, Tambov, and Dubna took part in this workshop. Twenty-four reports were presented. The main goal of these workshops is to provide a forum for researchers on computer algebra methods, algorithms and software and for those who use this tool in theoretical, mathematical, and experimental physics. A number of new promising results on the development of algorithms for investigating and solving systems of algebraic, differential and difference equations, on symbolic-numeric simulation of quantum-mechanical systems, as well as on computation of multiloop Feynman integrals by computer algebra methods and on various computer algebra applications to physics and mathematics, were presented.

On 4–9 July, LIT hosted the 7th international conference "Distributed Computing and Grid Technologies in Science and Education" (GRID'2016). The conference is held every two years and is traditional for the Laboratory. This year the conference was dedicated to the 60th anniversary of JINR and the 50th anniversary of LCTA/LIT. Note that the GRID'2016 conference is a unique platform for discussing a wide range of issues related to the use and development of distributed grid technology, heterogeneous and cloud computing in various fields of science, education, industry, and business. The conference attracted a large community of Russian and foreign specialists ready to discuss emerging challenges and prospects of the development of advanced information technology. The conference was attended by more than 250 scientists from the research centers of Azerbaijan, Belarus, Bulgaria, Germany, Georgia, China, Moldova, Mongolia, Romania, Slovakia, Czech Republic, Chile, France, Sweden, etc. Russia was represented by participants from more than 30 universities and scientific research centers. The conference was organized in ten sections which discussed the issues related to the development of grid technologies, heterogeneous computing, volunteer computing, cloud computing, big data analytics. Also, during the conference a school for young scientists, postgraduates and students was organized, where tutorials on heterogeneous and cloud computing were conducted. In total, the conference participants heard 35 plenary, more than 120 oral, and 43 poster reports. Forty students and young scientists from Mongolia, Romania, and the Russian universities (MEPhI, St. Petersburg State University, and University "Dubna") attended the school.

On 24–28 October, the 7th school on information technologies "Grid and Advanced Information Systems

at CERN" organized by the Joint Institute for Nuclear Research and the European Organization for Nuclear Research (CERN) and supported by the National Research Nuclear University "MEPhI" and the Plekhanov Russian University of Economics was held at LIT. The School was attended by over 90 students as well as masters and post-graduates from Russia and Kazakhstan. The students attended lectures on modern information technologies delivered by the leading specialists of CERN and JINR. On the basis of the materials of the lectures, trainings and competitions were organized, the winners were awarded with prizes.

REFERENCES

1. *Astakhov N. S., Baginyan A. S., Belov S. D. et al.* JINR Tier-1 Centre for the CMS Experiment at LHC // Part. Nucl., Lett. 2016. V. 13, No. 5. P. 1103–1107.
2. *Gavrilov V., Golutvin I., Kodolova O. et al.* Status of RDMS CMS Computing // Part. Nucl., Lett. 2016. V. 13, No. 5. P. 1108–1111.
3. *Petrosyan A. Sh.* PanDA for COMPASS at JINR // Part. Nucl., Lett. 2016. V. 13, No. 5. P. 1095–1098.
4. *Kadochnikov I., Pelevanyuk I.* JINR Tier-1 Service Monitoring System: Ideas and Design // CEUR Workshop Proc. 2016. V. 1787. P. 281–284.
5. *Korenkov V., Nechaevskiy A., Ososkov G., Pryahina D., Trofimov V., Uzhinskiy A., Voytishin N.* The JINR Tier-1 Site Simulation for Research and Development Purposes // Eur. Phys. J. Web Conf. 2016. V. 108. P. 02033;
DOI: 10.1051/epjconf/201610802033.
6. *Korenkov V. V., Nechaevskiy A. V., Ososkov G. A., Pryahina D. I., Trofimov V. V., Uzhinskiy A. V.* Simulation Concept of NICA–MPD–SPD Tier-0–Tier-1 Computing Facilities // Part. Nucl., Lett. 2016. V. 13, No. 5. P. 1074–1083.
7. *Korenkov V., Nechaevskiy A., Ososkov G., Potrebenikov Yu., Pryahina D., Trofimov V., Uzhinskiy A.* Optimization of Distributed Data Processing System for NICA BM@N Experiment by Using Simulation // Procedia Comp. Sci. 2016. V. 101. P. 333–340.
8. *Baranov A. V., Balashov N. A., Kutovskiy N. A., Semenov R. N.* JINR Cloud Infrastructure Evolution // Phys. Part. Nucl. Lett. 2016. V. 13, No. 5. P. 672–675; DOI: 10.1134/S1547477116050071.
9. *Baranov A. V. et al.* Approaches to Cloud Infrastructures Integration // Comp. Res. Modeling. 2016. V. 8, No. 3. P. 583–590 (in Russian).
10. *Balashov N., Baranov A., Korenkov V.* Optimization of Over-Provisioned Clouds // Part. Nucl., Lett. 2016. V. 13, No. 5. P. 957–961.
11. *Filozova I. A., Bashashin M. V., Korenkov V. V., Kuniaev S. V., Musulmanbekov G., Semenov R. N., Shestakova G. V., Strizh T. A., Ustenko P. V., Zaikina T. N.* Concept of JINR Corporate Information System // Part. Nucl., Lett. 2016. V. 13, No. 5. P. 980–985.
12. *Bashashin M. V., Kekelidze D. V., Kostromin S. A., Korenkov V. V., Kuniaev S. V., Morozov V. V., Potrebenikov Yu. K., Trubnikov G. V., Philippov A. V.* NICA Project Management Information System // Part. Nucl., Lett. 2016. V. 13, No. 5. P. 969–973.
13. *Baranov D. et al.* // Eur. Phys. J. Web Conf. 2016. V. 108. P. 02012.
14. *Galoyan A. S., Uzhinsky V. V.* // Bull. Russ. Acad. Sci. Phys. 2016. V. 80. P. 333.
15. *Voytishin N. et al.* // Eur. Phys. J. Web Conf. 2016. V. 108. P. 02023.
16. *Friesen A., Kalinovsky Yu., Toneev V.* // J. Phys. Conf. Ser. 2016. V. 668, No. 1. P. 012128.
17. *Zemlyanaya E. et al.* // J. Phys. Comp. Simulations. 2016. V. 724. P. 012056.
18. *Dikusar N. D.* // Math. Models and Comp. Simulations. 2016. V. 8, No. 2. P. 183–200.
19. *Adam Gh., Adam S.* http://dx.doi.org/10.1051/epjconf/201610802002. 2016.
20. *Gerdt V., Khvedelidze A., Palii Yu.* On the Ring of Local Unitary Invariants for Mixed X-States of Two Qubits // Zap. Nauchn. Sem. POMI. 2016. V. 448. P. 107–123.
21. *Khvedelidze A., Torosyan A.* Spectrum and Separability of Mixed 2-Qubit X-States // Zap. Nauchn. Sem. POMI. 2016. V. 448. P. 270–285.
22. *Perepelkin E. E. et al.* // Part. Nucl., Lett. 2016. V. 13, No. 6(204). P. 1168–1174.
23. *Cowley A. et al.* // Phys. Rev. C. 2016. V. 93. P. 034624.
24. *De K., Jha S., Klimentov A. A., Maeno T., Mashinistov R. Yu., Nilsson P., Novikov A. M., Oleynik D. A., Panitkin S. Yu., Poyda A. A., Read K. F., Ryabinkin E. A., Teslyuk A. B., Velikhov V. E., Wells J. C., Wenaus T.* Integration of PanDA Workload Management System with Supercomputers // Part. Nucl., Lett. 2016. V. 13, No. 5. P. 1010–1019.
25. *Belov S. D., Deng Z. Y., Korenkov V. V., Li W. D., Lin T., Ma Z. T., Nicholson C., Pelevanyuk I. S., Suo B., Trofimov V. V., Tsaregorodtsev A. U., Uzhinskiy A. V., Yan T., Yan X. F., Zhang X. M., Zhemchugov A. S.* BES-III Distributed Computing Status // Part. Nucl., Lett. 2016. V. 13, No. 5. P. 1084–1088.

LABORATORY OF RADIATION BIOLOGY

In 2016, the Laboratory of Radiation Biology (LRB) continued the realization of Theme 04-9-1077-2009/2017 "Research on the Biological Effect of Heavy Charged Particles with Different Energies" in the following fields: fundamental radiobiological and radiation genetics research with heavy charged particles; research on the action of accelerated charged particles on the central nervous system and eye structures; 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

Research was continued on the regularities of the induction and repair of DNA double-strand breaks (DSBs) in normal human fibroblast cells after exposure to ionizing radiations with different physical characteristics [1–4]. Experiments were repeated on cell irradiation with ^{60}Co γ rays to refine the dose dependences of DNA DSB induction and to analyze the complexity of clustered γH2AX/53BP1 foci and kinetics of their morphology change. At the U400M accelerator (the Laboratory of Nuclear Reactions, JINR), normal human fibroblasts were irradiated with ^{11}B ions with energies of 32.3 and 13.5 MeV/nucleon and the respective linear energy transfer (LET) values of 44.6 and 91.5 keV/μm and ^{20}Ne ions with an energy of 46.6 MeV/nucleon and LET of 132.1 keV/μm. Cells were irradiated in two geometries: normally to the beam to study the dose dependence and kinetics of DNA DSB repair and tangentially (at an angle of 10°) to study the tracks formed by γH2AX/53BP1 foci in cell nuclei, their clustering degree, and their morphology change. The irradiated cells were fixed at different times after exposure and immunofluorescent staining was performed to detect the γH2AX and 53BP1 proteins — DNA DSB repair markers. A comparative analysis was performed between the

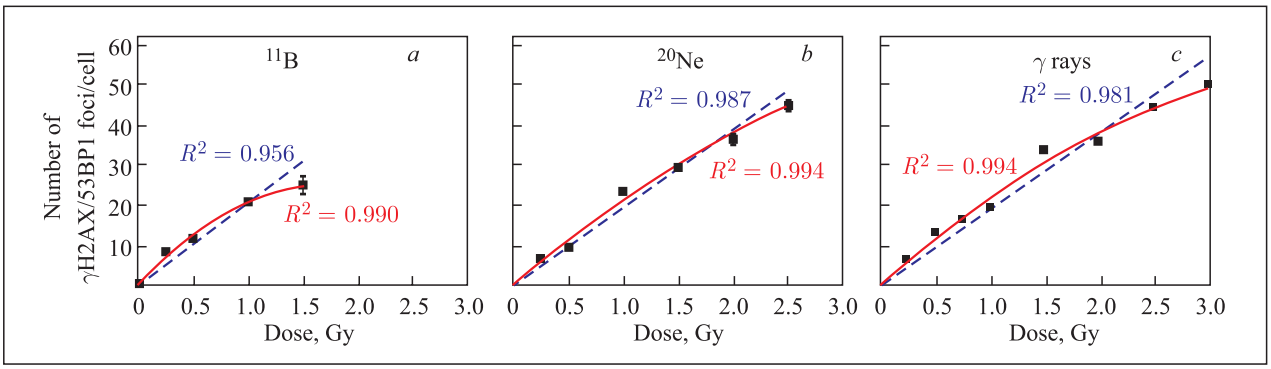


Fig. 1. Dose dependences of γH2AX/53BP1 foci induction in human fibroblast nuclei 1 h after irradiation with accelerated ^{11}B (*a*) and ^{20}Ne (*b*) ions and ^{60}Co γ rays (*c*) in the normal geometry. The solid and dashed lines are a linear quadratic and linear approximation, respectively

obtained data and the results of earlier experiments on the irradiation of fibroblasts with ^{11}B ions with an energy of 8.1 MeV/nucleon and LET of 138.1 keV/μm. It was shown that the kinetics of the formation and elimination of γH2AX/53BP1 foci is different and depends on the physical characteristics of a specific ionizing radiation.

A dose dependence was obtained of γH2AX/53BP1 foci induction in human fibroblasts 1 h after irradiation with ^{60}Co γ rays and accelerated ^{11}B and ^{20}Ne ions. For all types of radiation used in the study, a linear dependence is observed at low doses, which is characteristic of the dose dependence of DNA DSB formation. However, with increasing the dose, a deviation from linearity takes place, which can be accounted for by the experimental techniques (Fig. 1).

For both types of accelerated heavy ions, a delay of the kinetics of γH2AX/53BP1 foci elimination — i.e., DNA DSB repair — was observed compared with γ rays. It was shown that 4 h after heavy ion irradiation, 85% of the maximal γH2AX/53BP1 foci level remains in cells, while for γ irradiation, 41%. It was also found that in the case of ^{20}Ne ion exposure, γH2AX/53BP1 foci elimination proceeds much slower than for ^{11}B ions, which is probably connected with a higher complexity of the foci and, therefore, with more difficult repair of DNA DSBs induced by neon ions. 24 h after γ exposure, radiation-induced foci yield decreases to a minimum of 6%; for boron ion exposure, to 26%; while for neon ion irradiation, 45% of the γH2AX/53BP1 foci remains (Fig. 2). These conclusions agree with the results obtained on the cells irradiated tangentially at an angle of 10°. It was established that the size (area) and complexity (the shape and number of the individual foci in a cluster) of the γH2AX/53BP1 foci are much greater for neon ion exposure (Fig. 3).

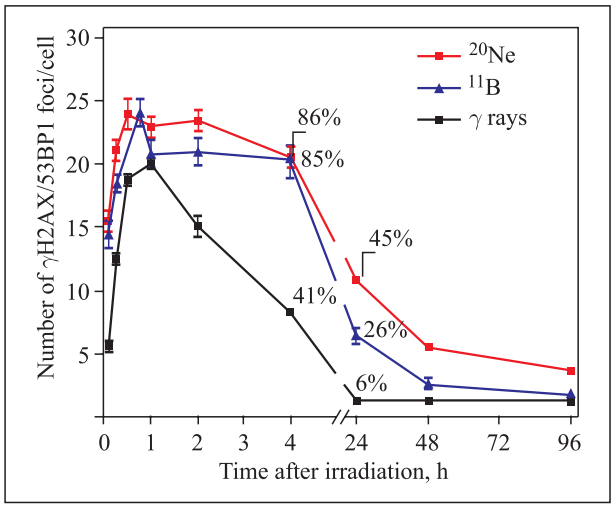


Fig. 2. Kinetics of the formation and elimination of γH2AX/53BP1 foci in human fibroblast nuclei after irradiation with accelerated ^{11}B and ^{20}Ne ions and ^{60}Co γ rays

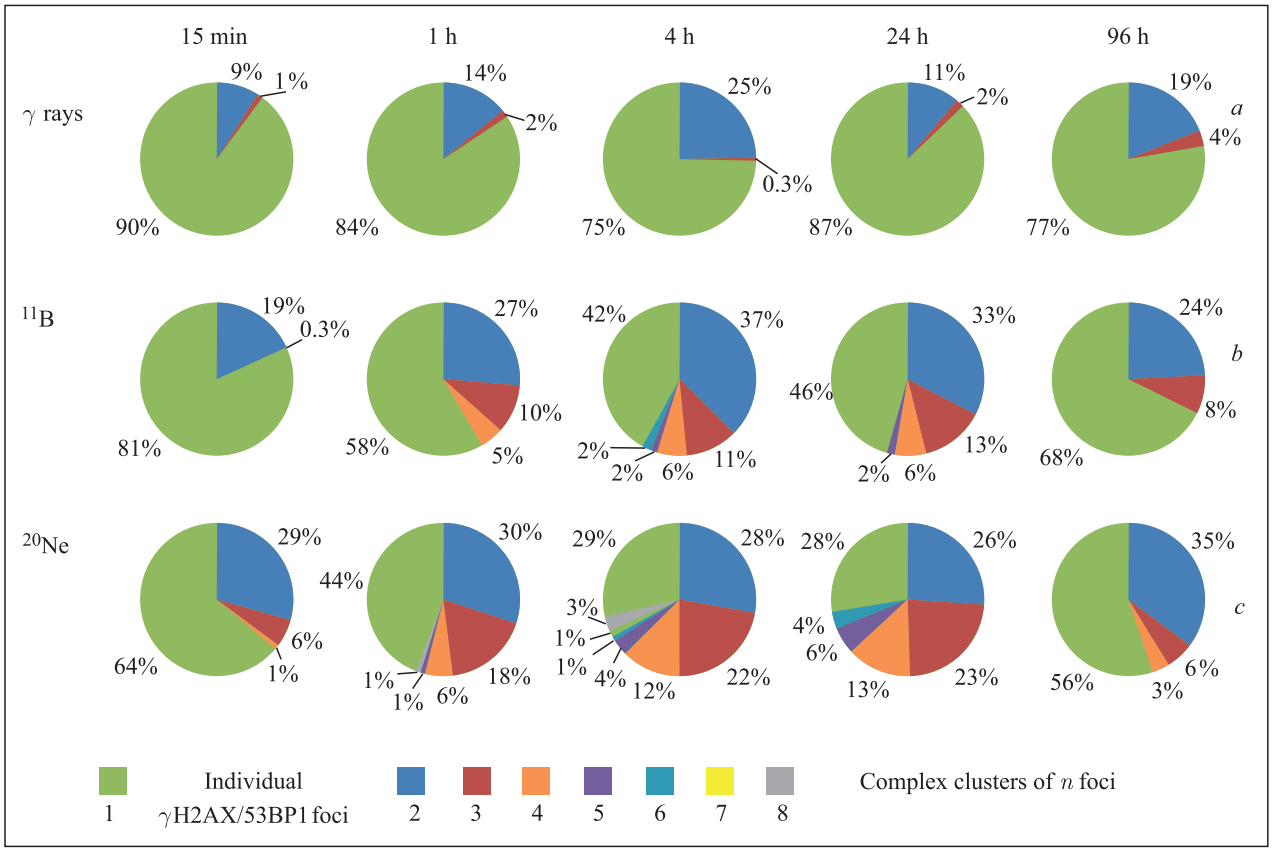


Fig. 3. Histograms of the kinetics of complex clustered γH2AX/53BP1 foci structure change for irradiation with ^{60}Co γ rays (*a*) and accelerated ^{11}B (*b*) and ^{20}Ne (*c*) ions

A study was started of the regularities in the formation and repair of DNA DSBs in rat brain neurons after exposure to ionizing radiations of different quality. An immunohistochemical analysis-based technique was developed and refined of detecting γH2AX/53BP1 foci in paraffin sections of rat brain tissues prepared with the help of an electronic rotary microtome (HM 340E, Thermo Fisher Scientific). To study the dose dependence and kinetics of the induction and elimination of γH2AX/53BP1 foci after exposure to ^{60}Co γ rays, female Sprague–Dawley rats (11 weeks old, weighing 220 g) were cranially irradiated at doses of 1, 3, and 5 Gy; 1, 4, and 24 h afterwards, they were decapitated and subsequent analysis was performed.

Research was continued on the regularities in the formation and repair of DNA DSBs of different genesis — direct and enzymatic — after exposure to ionizing radiations with different LET in the presence of repair inhibitors cytosine arabinoside (AraC) and hydroxyurea (HU) in human peripheral blood lymphocytes. Dose dependences were obtained for DSB induction by ^{60}Co γ rays and accelerated ^{11}B ions with LET of 44, 89, and 127 keV/μm; they have a linear character both in normal conditions and in the presence of DNA repair inhibitors (Fig. 4).

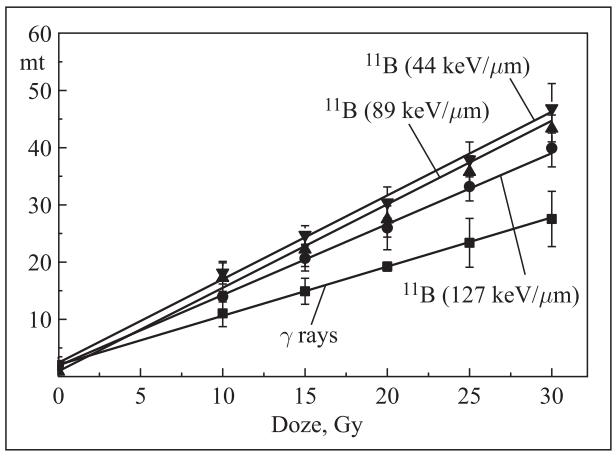


Fig. 4. Dose dependences of DNA DSB induction by accelerated ^{11}B ions with LET of 44, 89, and 127 keV/μm and ^{60}Co γ rays

It was shown that both for γ and accelerated ^{11}B ion exposure, DNA DSB yield decreases exponentially in the course of repair and practically ends after 6 h of postirradiation incubation. In the presence of inhibitors, an increase in DNA DSB yield is observed for exposure to γ rays and ^{11}B ions with LET of 44 keV/μm; and a slight decrease in DNA DSB yield is observed for irradiation with ions with LET of 89 keV/μm. With increasing LET to 127 keV/μm, a decrease in DNA DSB yield with exponential kinetics is observed — like in the absence of repair inhibitors (Fig. 5).

With the use of the fluorescent immunocytochemical staining method, specifics were studied of the formation of direct and enzymatic DNA DSBs in human fibroblasts exposed to ^{60}Co γ rays at a dose of 1 Gy — in normal conditions and in presence of the repair inhibitors AraC and HU. It was shown that in normal conditions, the maximal yield of radiation-induced γH2AX/53BP1 foci takes place 1 h after exposure; 4 h afterwards, most of the foci — about 80% — are eliminated. In presence of inhibitors, γH2AX/53BP1 foci yield grows linearly, which indicates a pronounced modifying effect of DNA repair inhibitors on the formation of enzymatic DNA DSBs after exposure to ^{60}Co γ rays (Fig. 6).

A qualitative analysis was performed of morphological changes in Purkinje neurons of the rat cerebellar cortex, which are easily identified without using specific morphological markers thanks to a unique anatomical organization of the cerebellar cortex [5]. It was established that the maximal yield of γH2AX/53BP1 foci in Purkinje neurons is formed 1 h after exposure (12 γH2AX/53BP1 foci/nucleus); 4 h later, it decreases by 50%. 24 h after irradiation, only 2.5 foci/nucleus

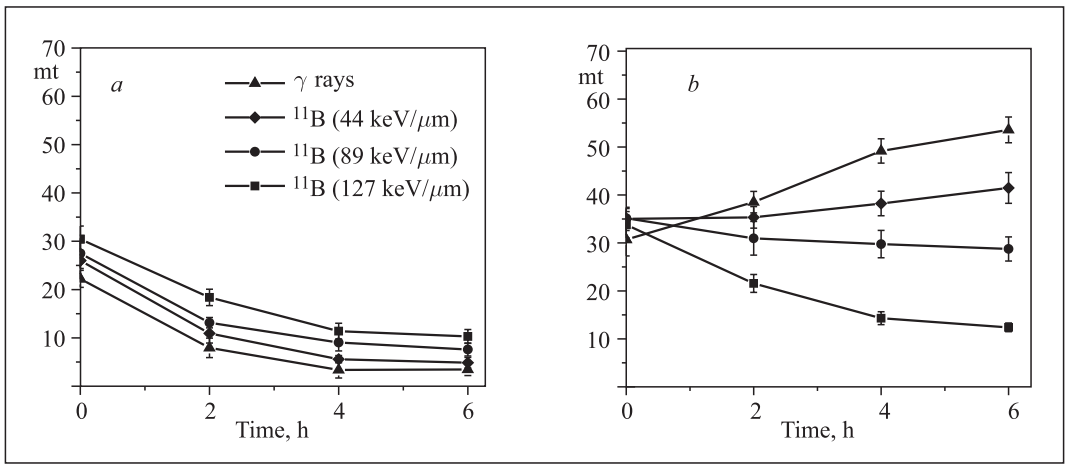


Fig. 5. Kinetics of DNA DSB repair after exposure to γ rays and ^{11}B ions with different LET at a dose of 20 Gy in normal conditions (*a*) and in the presence of AraC+HU (*b*)

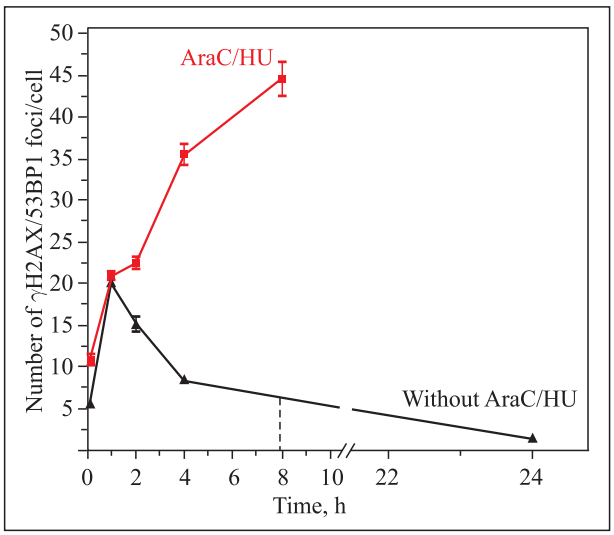


Fig. 6. Kinetics of γH2AX/53BP1 foci yield in human fibroblasts in presence of AraC and HU after the exposure to ^{60}Co γ rays

remain in nuclei, which points to effective DNA DSB repair. It was shown that the dose dependence of the frequency of γH2AX/53BP1 foci formation 1 h after exposure to ^{60}Co γ rays is linear (Fig. 7).

The role of radiation-induced reactive oxygen species (ROS) and reactive nitrogen species (RNS) in the induction of chromosomal aberrations in CAL51 cells of human breast carcinoma at high and low γ-radiation doses was studied. It is generally thought that oxidative and nitrosative stress induced in cells by ionizing radiation causes DNA damage and cell death. Use of antioxidants significantly moderates these adverse consequences. However, these compounds perform the key regulatory role at the physiological level. In particular, ROS and RNS activate quite a number of cytoprotective mechanisms aimed at cell homeostasis recovery and thus prevent oxidative and nitrosative stress development. It allows assuming that at high and low doses of ionizing radiation, the ROS and RNS effect on chromosome aberration yield can significantly

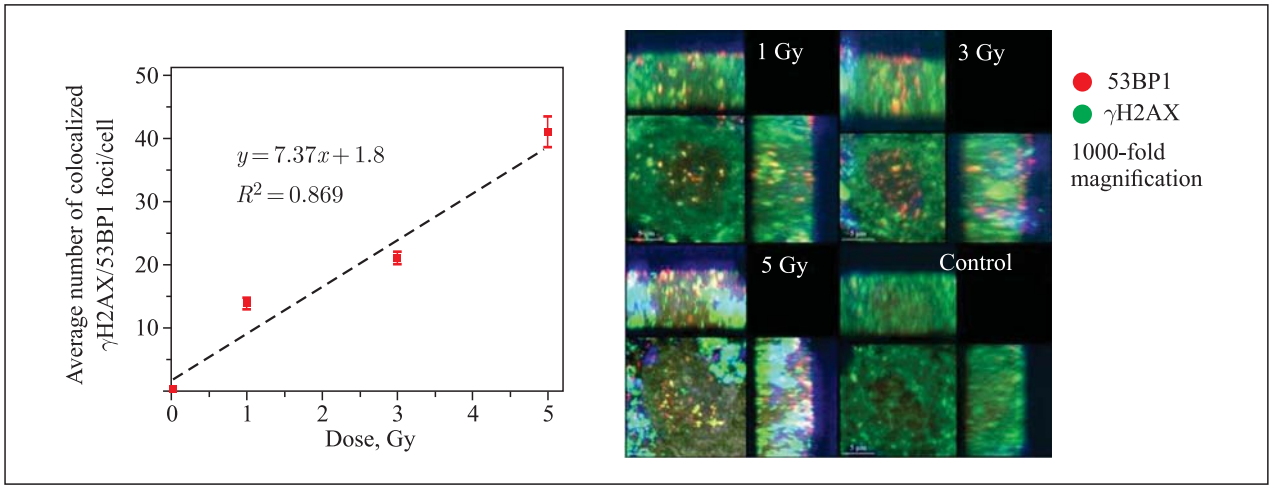


Fig. 7. Dose dependence of the number of radiation-induced γH2AX/53BP1 foci in Purkinje cell nuclei 1 h after the exposure

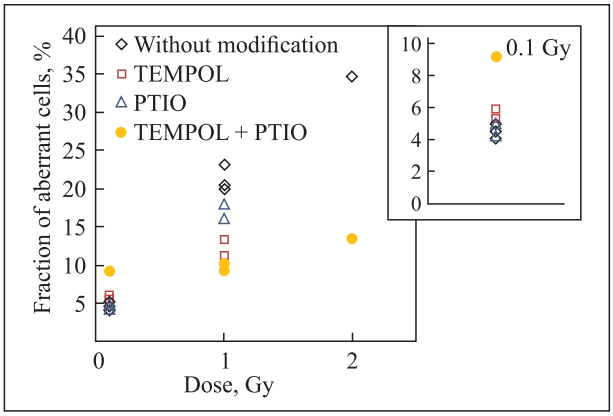


Fig. 8. The effect of ROS and RNS yield suppression (TEMPOL and PTIO, respectively) on the frequency of chromosomal aberrations induced by ^{60}Co γ radiation

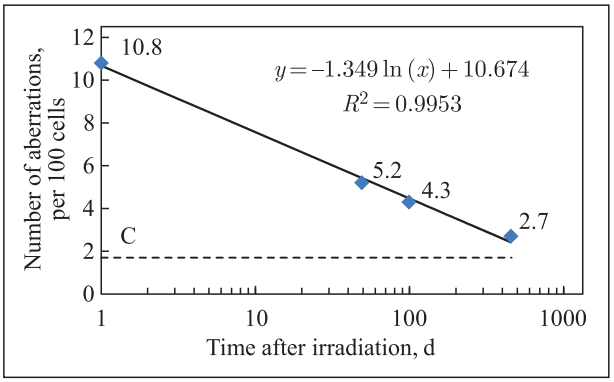


Fig. 9. The dynamics of the total number of chromosomal aberrations in blood lymphocytes of *Macaca mulatta* monkeys after head irradiation with 170 MeV protons (3 Gy) + ^{12}C ions (1 Gy)

differ. To check this suggestion, chromosome aberration yield after γ exposure was studied in CAL51 cells in presence of the antioxidant TEMPOL and nitrogen oxide interceptor PTIO. The aberrations were detected with the anaphase technique. An analysis of the data shown in Fig. 8 allowed concluding that at high doses oxygen and nitrogen radicals make a great contribution to chromosome aberration induction because radical neutralization in presence of TEMPOL and PTIO leads to a decrease in aberrant cell yield, the modifiers' joint action having a synergetic effect. A different pattern is observed at a dose of 0.1 Gy. Nitrogen oxide neutralization has no influence on chromosome aberration yield; ROS yield suppression causes an insignificant increase in chromosome aberration yield, and the modifiers' joint action causes a sharp DNA damage increase. So, it was established that ROS and RNS perform a protective function at low doses, and use of antioxidants can have negative consequences for the cell in this case.

Analysis of chromosomal aberrations in peripheral blood lymphocytes of *Macaca mulatta* monkeys was conducted after head irradiation with 170 MeV protons (3 Gy, LET $\sim$ 0.53 keV/μm) and, 48 d later, with accelerated 500 MeV/nucleon ^{12}C ions (1 Gy, LET $\sim$ 10.6 keV/μm) [6]. It was found that the number of chromosomal aberrations was monotonically decreasing during the whole study (454 d); this decline is well described by a logarithmic function (Fig. 9). After a chromosomal aberration elimination-based extrapolation of the obtained logarithmic curve to later times, it can be assumed that the control sample's level of chromosomal aberrations would be reached approximately 2 yr after the exposure. Besides, a dose dependence was obtained of chromosomal aberration yield in monkeys' peripheral blood lymphocytes after *in vitro* exposure of blood samples to 170 MeV protons.

PHOTORADIOBIOLOGICAL RESEARCH

Research was continued on the role of Müller glial cells (MGC) in the mouse retina recovery mechanism. It was shown that retinal resistance that formed after a pre-exposure to 170 MeV protons at a dose of 1 Gy followed by a cytotoxic injection of methylnitrosourea correlates with a decrease in the photoreceptor apoptosis frequency (Fig. 10), DNA double-strand break yield, Caspase-3 expression, and MGC gliosis, which indicates a decrease in the level of cell damage and death in the retina.

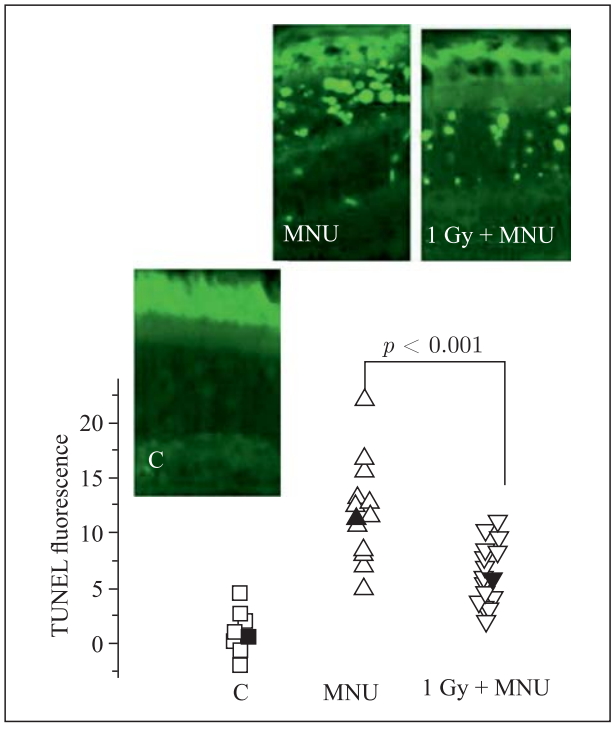


Fig. 10. The fluorescence intensity of the nuclear layer of the mouse retina photoreceptor cells in the control (C), 48 h after a single 70 mg/kg methylnitrosourea injection (MNU), and after a combined action of 1 Gy of accelerated protons and a 70 mg/kg MNU injection

A series of experiments was conducted jointly by LRB JINR and Sofia University "St. Kliment Ohridski". It was shown that when a mouse electroretinogram (ERG) is fully rectified after a visible light exposure, retinal functional activity recovers in 1–2 h. It was also shown that a total mouse irradiation with 170 MeV protons and γ rays at a dose of 5 Gy causes an irreversible decrease of the ERG amplitudes 8–9 months after the exposure (Fig. 11).

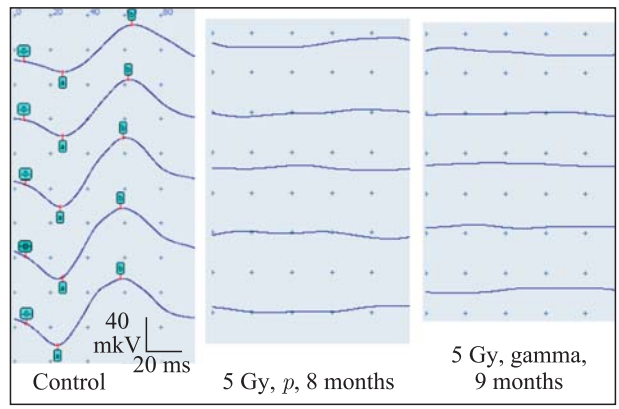


Fig. 11. Changes in a mouse ERG after a whole body irradiation with protons and γ rays at a dose of 5 Gy

A cycle of research on the neurochemical indices of the rat brain after exposure to ionizing radiations of different quality was performed. With the highly efficient liquid chromatography technique, changes were evaluated in the levels of the key brain neuromediators (noradrenaline, dopamine, serotonin, and their metabolites) in rats of different age cohorts irradiated with 500 MeV/nucleon ^{12}C ions at a dose of 1 Gy. It was shown that accelerated heavy charged particles induce changes in the functioning of the noradrenaline, dopamine, and serotonergic systems 30 and 90 d after the exposure. The most pronounced differences between the irradiated and control animals were observed in the prefrontal cortex, nucleus accumbens, and hypothalamus, which points to an important role of these structures in the realization of the long-term effects of radiation exposure on the central nervous system functions. For a number of indicators of the content of monoamines and their metabolites in the brain, a decrease was observed in the intensity of the temporal changes in the prefrontal cortex, hypothalamus, and hippocampus of the irradiated rats. On the basis of these results, it was assumed that in the late postirradiation period an active realization of the compensatory and recovery mechanisms takes place. At relatively low linear energy transfer (LET) of the particles — about 10 keV/μm — these mechanisms can lead to a partial recovery of the brain's functions damaged by radiation (Fig. 12). At higher LET, the compensatory and recovery mechanisms are less pronounced, and functional disorders increase with time [7].

Neurochemical research results were compared with animal behavior indices after irradiation. It was found that along with changes in monoamine metabolism, exposure to accelerated ^{12}C ions leads to modifications of animals' motion and exploratory activity and changes in irradiated rats' anxiety indices (Fig. 13) [8].

A comparative study of the effect of 500 MeV/nucleon ^{12}C ions and γ rays at a dose of 1 Gy on the dynamics of age-related changes in monoamine exchange was conducted. It was shown that γ radiation has a weaker effect on the age-related dynamics of neuromediator exchange than ^{12}C ions. Based on this research, it was assumed that in the case of heavy ion exposure, more serious disorders in the functioning of the neuromediator systems lead to a higher intensity of the compensatory and recovery processes, which can cause a modification of the normal dynamics of the age-related changes during the studied postirradiation period.

Modeling was done of a combined effect of the radiation and nonradiation space flight factors on rats' behavior and cognitive abilities, as well as on monoamine and acetylcholine metabolism in the key structures of the rat brain [9–11]. With this purpose, a combined exposure to weightlessness, simulated by antiorthostatic suspension, and radiation, represented by γ rays and Bragg peak protons, was studied. An integrated evaluation of animals' behavior indices included the following tests: open field, Morris water maze, elevated plus maze, and passive avoidance. It was found that both with and without antiorthostatic suspension, radiation caused rats' thigmotaxis attenuation (Fig. 14). A decrease in the learning ability related to working (but not spatial) memory damage was observed in response to antiorthostatic suspension and combined exposure. An analysis of monoamine metabolism showed that the serotonergic system is the most sensitive to the space flight factors modeled in the experiment. Compared with the animals that underwent only antiorthostatic suspension, the irradiated rats and the rats that

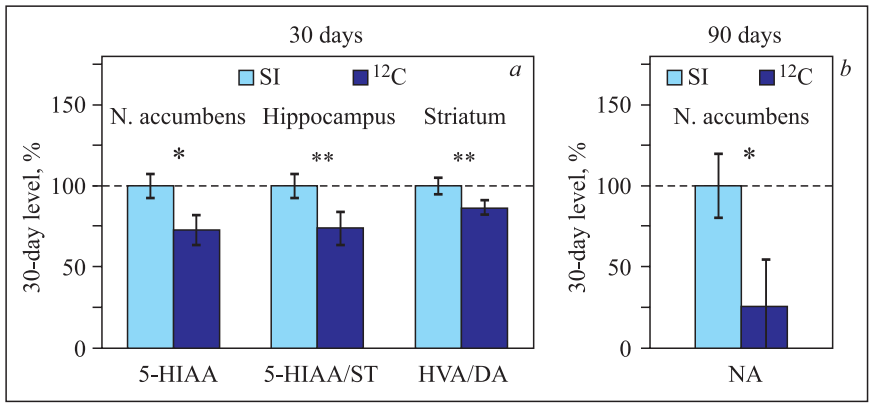


Fig. 12. Monoamine metabolism dynamics in rat brain structures after exposure to accelerated carbon ions (^{12}C, 500 MeV/nucleon, 1 Gy; $\pm$ SEM; * — $p < 0.05$; ** — $p < 0.1$; single-factor analysis of variance). The evaluation was obtained by comparing the respective data 30 (a) and 90 (b) days after irradiation. Monoamines and their metabolites are denoted as follows: DA — dopamine, ST — serotonin, NA — noradrenaline, 5-HIAA — 5-hydroxyindoleacetic acid, HVA — homovanilic acid, SI — sham irradiation (keeping the control rats in the same conditions as the irradiated ones but without radiation exposure)

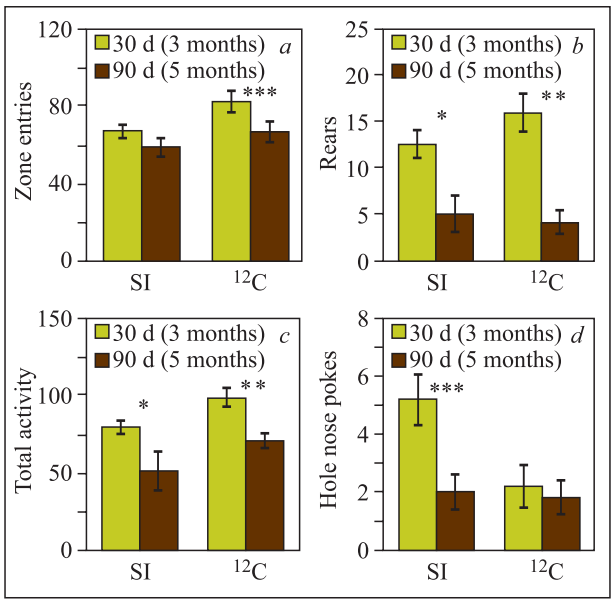


Fig. 13. The effect of accelerated carbon ions (^{12}C, 500 MeV/nucleon, 1 Gy) on the temporal dynamics of the open field test indices: *a*) the number of the crossed zones; *b*) the number of elevations; *c*) total motion activity as a sum of zone crossings and elevations, and *d*) the number of the acts of studying holes in the floor (± SEM; * — $p < 0.05$; ** — $p < 0.01$; *** — $p < 0.1$ between 30 and 90-day indices; single-factor analysis of variance). In parentheses, the animals' age at the time of research is specified. SI — sham irradiation (keeping the control rats in the same conditions as the irradiated ones but without radiation exposure)

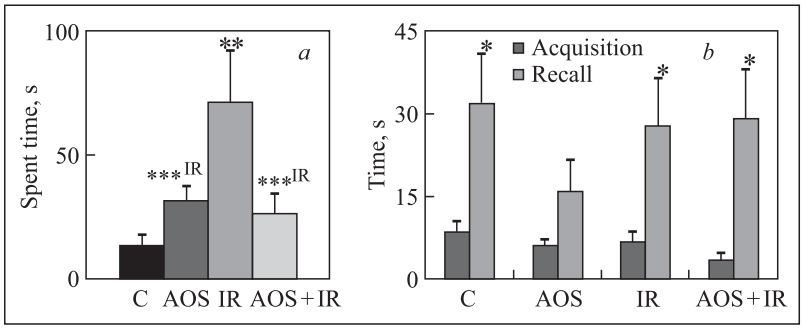


Fig. 14. *a*) The combined effect of space flight factors on total spent time in the elevated plus maze test (± SEM; ** — $p < 0.01$; *** — $p < 0.05$ by Duncan's test); *b*) the passive avoidance test indices (± SEM; * — $p < 0.05$ by a t-test). C — control animals; AOS — animals that were subjected to antiorthostatic suspension modeling weightlessness; IR — animals exposed to ionizing radiation; AOS + IR — animals subjected to a combination of antiorthostatic suspension and radiation exposure

were subjected to a combined exposure showed a much higher acetylcholine concentration in their hippocampus. In general, the results of this research point to an antagonistic effect of antiorthostatic suspension and radiation exposure on the animals' cognitive functions and psycho-emotional condition.

MATHEMATICAL MODELING OF RADIATION-INDUCED EFFECTS

Modeling of heavy charged particle-induced genetic damage repair systems was continued. Results were published of the mathematical analysis of the regulation mechanisms of the functioning of the repair systems in bacterial cells and a comparative analysis of their efficiency [12], as well as modeling systems of repair of DNA double-strand breaks (DSBs) induced by γ rays, neutrons, and charged particles in a wide linear energy transfer (LET) range [13].

Modeling was continued of the molecular mechanisms of heavy charged particle-induced disorders of central nervous system (CNS) structures and functions. Studying the early stages of nervous cell damage induced by high-energy heavy charged particles is of

particular importance for explaining later CNS functional disorders. With the use of Monte Carlo technique realized in the Geant4-DNA software tool, a computer simulation was done of physicochemical acts of charged particle interaction with separate cerebral neurons and a small neural network made up of 10 neurons (Fig. 15) [14–16]. Calculations were performed for ^{12}C and ^{56}Fe ions and protons of different energies in a relatively wide LET range — from several to hundreds of keV/μm. The topologies of the neurons and neural network in the CA1 region of the hippocampus were taken from the known data available at the NeuroMorpho.org database. The spatial distributions of the local dose and energy transferred by charged particles to the sensitive structures of the neuron were calculated; radiolysis product yield was estimated. Special attention was paid to the processes of energy deposition in synaptic contacts (Fig. 16). The average number of energy deposition events in small volumes (359.9 and 429.8 nm^3) corresponding to the NMDA and AMPA receptors was calculated (Fig. 17, *a*). An estimation of radiolysis product yield in neurons (Fig. 17, *b*) allows assuming that the observed increase in the reactive oxygen species level can be one of the causes of the oxidative damage to synaptic structures, which violates the normal transmission of a nerve impulse between cells. The results of this study suggest that neuron morphology is an important factor determining the accumulation of the local exposure dose and radiolysis products in cells.

To calculate the disfunctions of the synaptic receptors, it is necessary to know both the spatial distribution of damage emerging after charged particle passing and the temporal dynamics of the closure and opening of the ion channel of the formed structure during functional activity. To this end, molecular dynamics methods were used [17]. A model of the NMDA glutamate receptor was taken from the PDB base (structure 4TLM). Some parts of the system were reconstructed

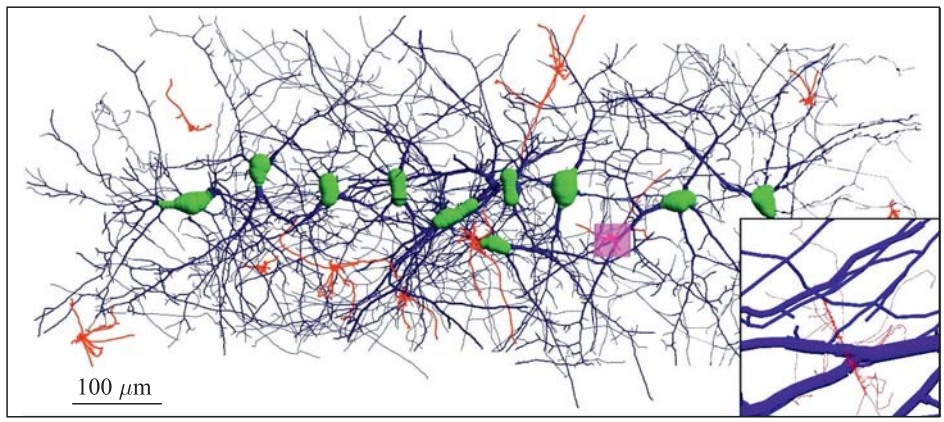


Fig. 15. A spatial model of a 10-cell neural network in the CA1 region of the hippocampus crossed by 10 tracks of 1000 MeV/nucleon ^{56}Fe ions. The inset shows a zoom into the area marked purple. The ^{56}Fe tracks are red

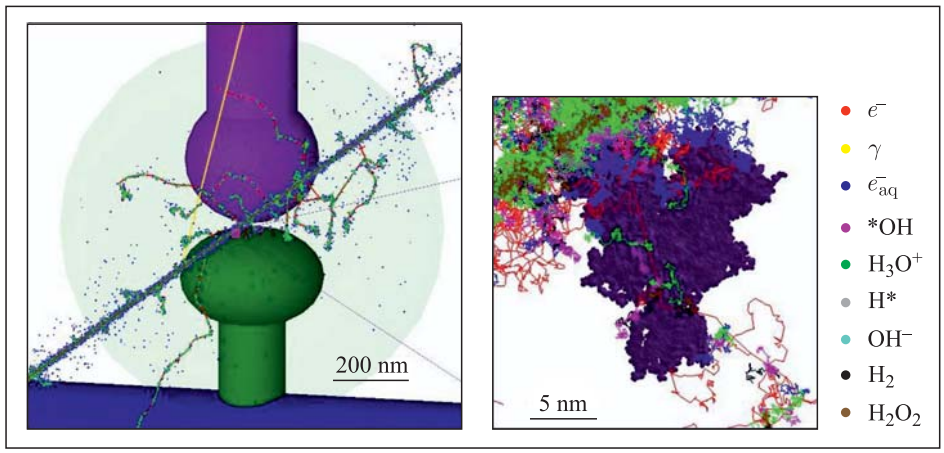


Fig. 16. Physicochemical processes in the structure of a 100 MeV/nucleon ^{56}Fe ion track crossing a synaptic contact zone. Shown are a presynaptic axon (purple) and a postsynaptic dendrite spine (green) with the NMDA and AMPA receptors (purple and maroon, respectively). The inset on the right shows a zoom into a fragment of a model of the NMDA receptor with segments of secondary particle tracks and water radiolysis products. The dots of different colors denote the spatial localization of the radiolysis products

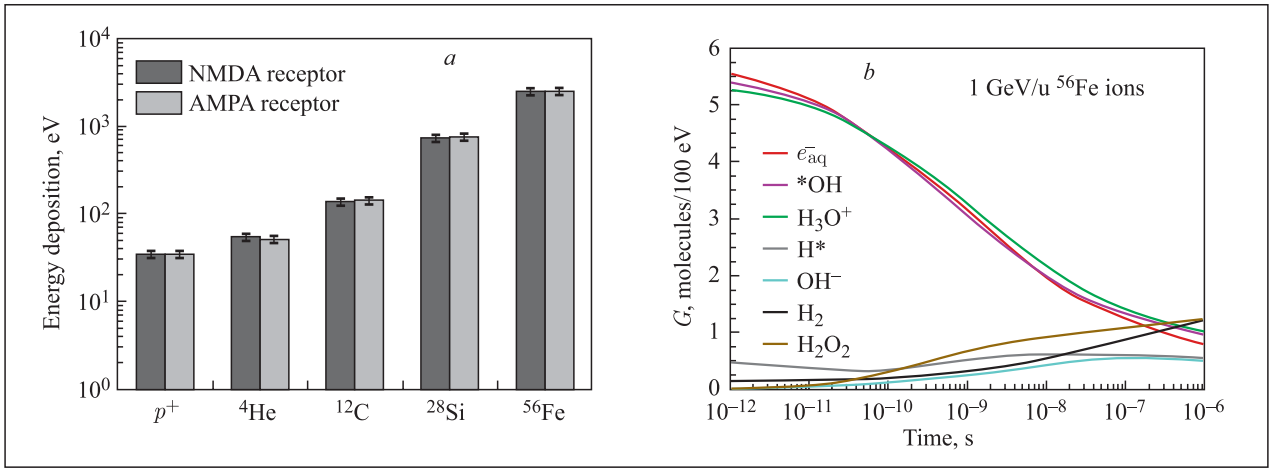


Fig. 17. *a*) Average energy deposition in NMDA and AMPA synaptic receptor structures for the following 1000 particles with an energy of 1 GeV/nucleon: p^+, ^{4}He, ^{12}C, ^{28}Si, and ^{56}Fe. *b*) Water radiolysis product yield (G) per 1 neuron for a 1 GeV/nucleon ^{56}Fe ion crossing it. The chosen time interval corresponds to the chemical stage of particle track evolution

by the MODELLER program and refined by the VMD software package. The ion channel radius changes were calculated with the HOLE program. The obtained results make it possible to calculate theoretically the radiation damage to the receptors and the corresponding synaptic transmission change, which is necessary for the analysis of the disorders of neural networks' neurophysiological activity.

A model of intracellular signal transport along the microtubes of the nervous cell axons was proposed (Fig. 18) [18–20]. The framework's dynamics description is based on a quasi-one-dimensional nonlinear chain model; for the oscillations of the microtube surface-located ends consisting of carboxylic groups (C-termini), an analogy with smectic liquid crystals is used. For the considered degrees of freedom, nonlinear solutions of the kink and breather types were obtained and analyzed; the characteristic parameters and propagation velocity were determined. The stability of the found solutions was calculated. The influence was analyzed of the microtube-associated proteins — in particular, τ protein — and modification of C-termini on signal

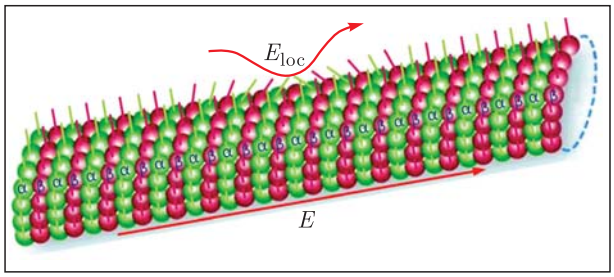


Fig. 18. A schematic of a ferroelectric model of a microtube as a liquid crystal layer rolled into a cylinder. The C-termini are shown as rods. The microtube forms a giant dipole with the internal electric field E. The localized signal wave is denoted as the corresponding associated field E_{loc}

propagation. The obtained results clear up the possible mechanisms of cytoskeleton degradation and disorders of intracellular signaling induced by a radiation or chemical exposure.

The development of mathematical modes of neural networks and structures is an extremely important task in the analysis of the radiobiological effects of accelerated charged particles. The dynamics was studied of the time-space structure of prefrontal cortex neurons during working memory functioning [21]. The proposed biophysical model is a neural network of 36 interneurons and 144 pyramidal neurons, which are interconnected by excitatory and inhibitory synapses. Each neuron's morphology is taken into account, consisting of the soma and dendrite structure with the corresponding distribution of ion channels. When information on some object is received, spatially ordered structures with high cell activity emerge in the modeled brain's region (Fig. 19). The model includes the radiation-induced changes in the synaptic receptor number and ion channel conductivities evaluated on the basis of experimental data. In the course of calculations, an absorbed dose threshold was found, above which the stability of the time-space structures specific for the given network is lost.

A model was developed of the neuron population of the CA3 region of the hippocampus taking into account the membrane properties and spatial geometry of the synaptic contacts [22]. A special feature of the model is a detailed record of each single neuron's spatial structure, which holds up to 19 segments. Prospects are thus opened for the further development of the model's radiobiological aspects with the use of microdosimetry methods with a view to the evaluation of energy deposition in tracks of charged particles of different energies. Both in isolated neurons and in their population, the operation potential is generated

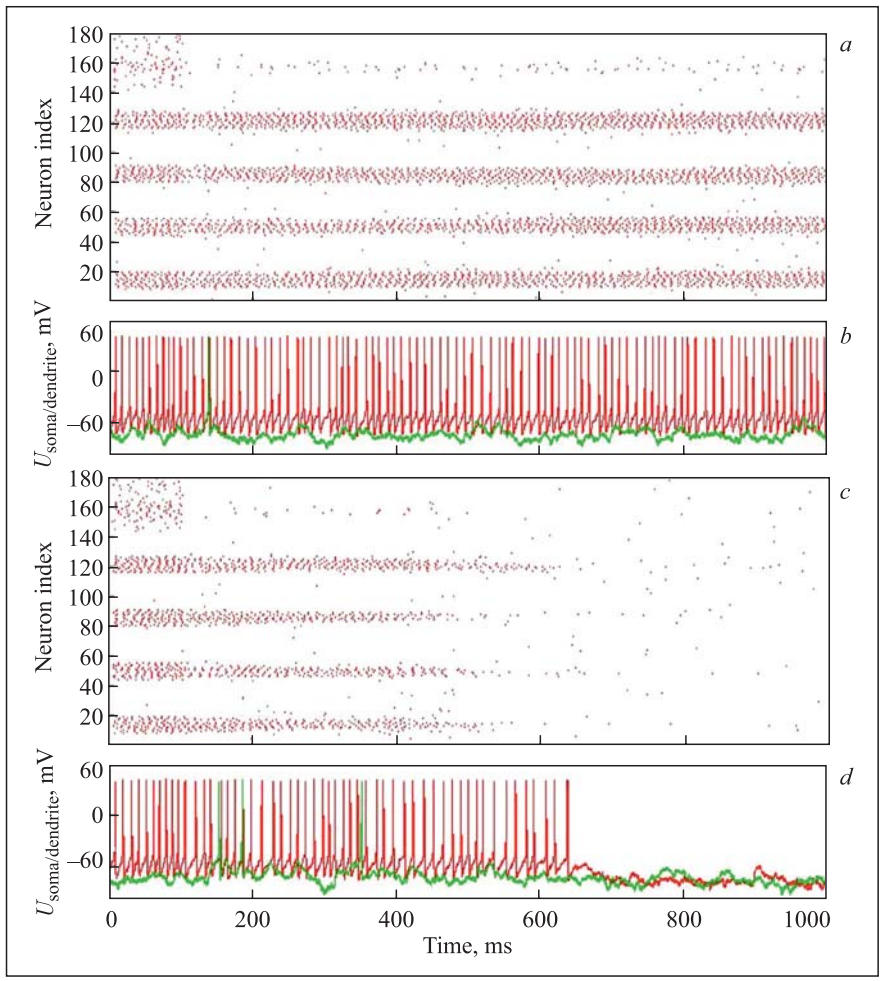


Fig. 19. Calculation of pattern generation from operation potential pulses during the functioning of working memory: *a*) a rasterogram showing the coordinate and time of pulse generation (dots); *b*) the temporal dynamics of the operation potential U on the soma (red curve) and dendrites (green curve) of an isolated neuron. *c, d*) Changes in neural network parameters after exposure to 600 MeV/nucleon ^{56}Fe ions at 0.3 Gy

in a burst mode, the frequency of which increases with external stimulus enhancement. Later, this model is going to be the basis of a more detailed analysis of the electrophysiological activity of the hippocampus neurons and radiation-induced damage to spatial memory.

RADIATION PROTECTION PHYSICS AND RADIATION RESEARCH

Two radiobiological research sessions were conducted at the MC400 cyclotron, the Laboratory of Nuclear Reactions: with 36 MeV/nucleon ^{11}B nuclei (23–24 January 2016) and with 50 MeV/nucleon ^{20}Ne nuclei (30 March 2016). A $\Delta E{-}E$ spectrometer for monitoring the charge composition of an ion beam was tested at the LRB facility Genome-M.

Work was continued on the prediction of the radiation conditions during the NICA complex operation. A number of specific tasks were performed, including the evaluation of the stripping target activation, dose rates near the Booster–Nuclotron transport channel, exposure of the electronics mounted near the arches of the external wall of the collider canyon, exposure and activation of the system's high-frequency (HF) resonators, the possibility of using an iron–cobalt alloy for making the HF cores, etc. The next important stages of solving the radiation safety issues at the NICA complex are the calculation of the upper shielding of the Nuclotron tunnel and estimation of the contribution of the BM@N experiment (Building 205) to the radiation conditions at the adjacent territory.

In a joint effort with specialists of the Medico-Technical Complex (MTC), the Laboratory of Nuclear

Problems, a reference field of secondary neutrons from the MTC carbon absorber was generated for long-term fractioned (quasi-chronic) irradiation of laboratory animals, and first exposures of mice were performed. The component and spectral composition of the field was calculated with the Monte Carlo software package MCNPX for simulating radiation transport in matter.

In 2016, in cooperation with specialists from the Space Research Institute of the Russian Academy of Sciences, a great amount of equipment testing for future missions Luna-Glob, Luna-Resource, BepiColombo, and ExoMars was performed at the planetary soil model of the DAN (Dynamic Albedo of Neutrons) experimental stand.

STUDYING COSMIC MATTER ON THE EARTH AND IN NEARBY SPACE

Research was continued on the synthesis of prebiotic compounds from formamide with meteorites as catalysts under exposure to radiation. Materials were published on irradiation with boron ions [23]. 170 MeV proton irradiation of mixtures of formamide and different meteorite samples was repeated. Another type of sample analysis was performed — Raman spectroscopy. Eighteen samples of meteorite matter and terrestrial minerals were used in the experiment (the meteorites: Campo del Sielo, Canyon Diablo, Sikhote-Alin, Seymchan, NWA4482, NWA2828, Gold Basin, Dhofar959, NWA1465, NWA5357, Al Haggounia, and Chelyabinsk; the minerals: covellite CuS, chalcopyrite $CuFeS_2$, montmorillonite KSF, and Al-pillared montmorrilonite KP-30) in a mixture with formamide. This research was done in collaboration with the Biophotonics Laboratory of the Institute of Electronics, the Bulgarian Academy of Sciences. The study was based on using a state-of-the-art inVia Qontor Raman microscope (the Renishaw company) at the Faculty of Nano- and Biomedical Technologies, Saratov Chernyshevsky State University, with which the LRB's Bulgarian colleagues are cooperating. The acquired spectra are being analyzed. Preliminary results indicate that nucleic bases and nucleosides were present in the reaction mixtures (see the Table).

Experiments were conducted on the synthesis of DNA and RNA component nucleosides by irradiating "nucleic base + sugar" mixtures with a 170 MeV proton beam. As sugars, ribose and 2-deoxyribose were used. A "nucleoside + phosphate group" mixture was exposed to the same radiation in search of a possible synthesis of nucleotides that are DNA and RNA building blocks. The results were analyzed in Viterbo, Italy. Based on the preliminary results, it can be confidently said that irradiation of an "adenine + deoxyribose" mixture (Fig. 20) yielded, in addition to other molecules, deoxyadenosine and polyribosylated adenosine (Fig. 21).

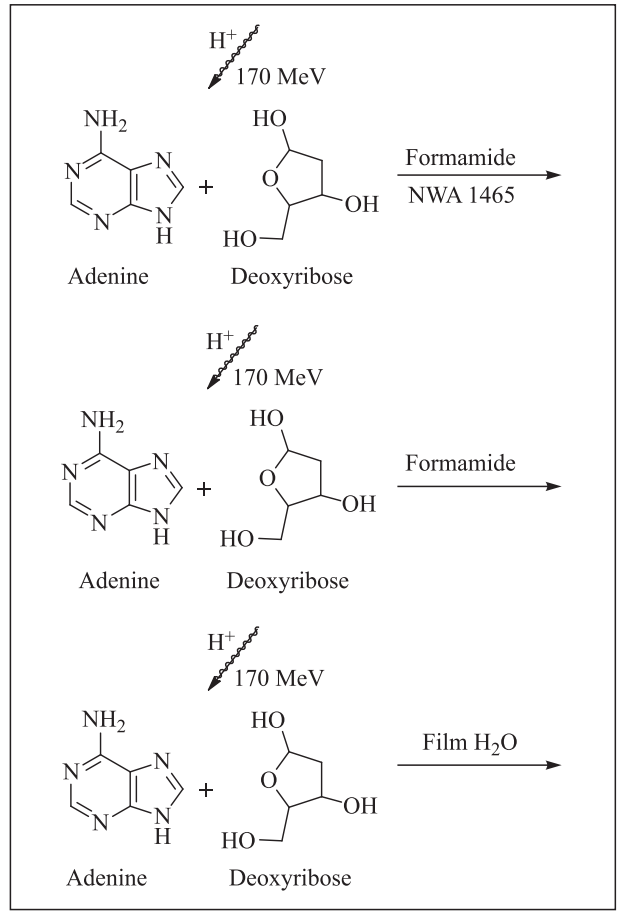


Fig. 20. Scheme of the irradiation of an adenine–deoxyribose mixture

Results of the irradiation of "formamide + meteorite/mineral" mixtures obtained by Raman spectroscopy

The observed nucleic bases and nucleosides				
Uracil	Cytosin	Hypoxanthine	Adenine	Guanine
4,6-DHP	Mannose	2,6-Diaminopurine	Orotic acid	Isocytosine
Thymine	Yhymidine	2′-Deoxyribose	Ribose	Adenosine
Glucose	Galactose	3(OH)pyridine	Uridine	Cytidine

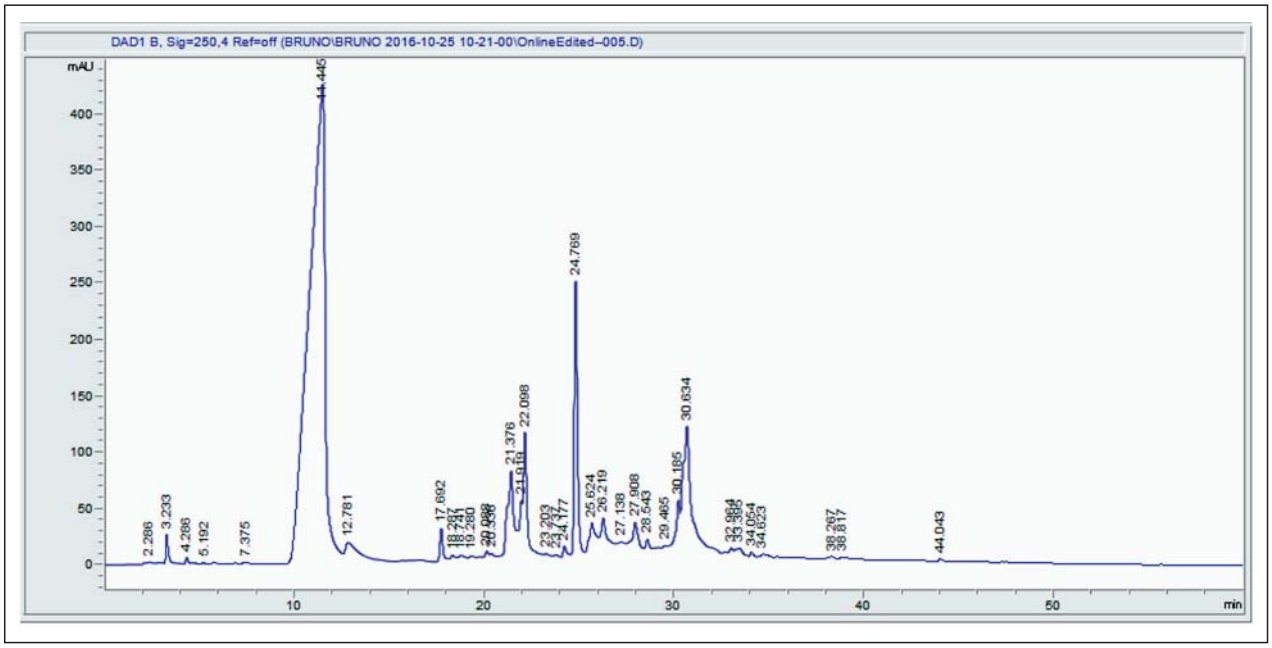


Fig. 21. High-pressure liquid chromatography spectrum of an irradiated mixture "adenine + deoxyribose + formamide + NWA1465"

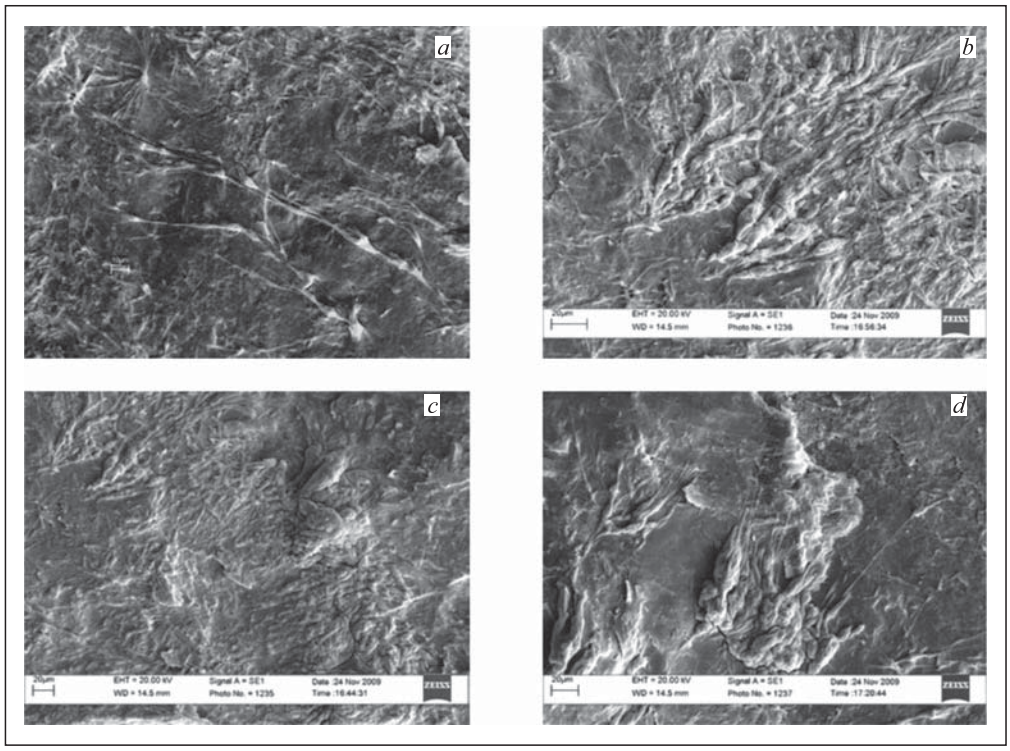


Fig. 22. Highly organized fossilized algoids *Gazavarzinia antiqua Rozanov et Astafyeva*, 2013 (Imandra-Varzuga, PR_1, 2.45 billion years): *a–c*) amply ramified main stems (about 10 μm in diameter) and ramified side branches (about 5 μm in diameter) are seen; *d*) flattened rounded bases, or patches (more than 50 μm in size), by means of which algae stuck to the substrate

A micropaleontological study of early Precambrian rocks was done at Borisyak Paleontological Institute of the Russian Academy of Sciences. All bacterial paleontology analyses were made using the following scanning electron microscopes: CamScan-4 with a Link-60 microanalyzer; Zeiss EVO 50 with an Inca Oxford (350) X-ray microanalyzer; and TESCAN VEGA II ZMU with an X-ray energy dispersive microanalysis system INCA ENERGY 450. Only fresh cleavages of rocks (both ancient and modern) were studied — sometimes

slightly acid-etched. It should be noted that pseudomorphs, not microorganisms themselves, were the subject of research in all cases.

Research on the most ancient residual as well as Archean and early Proterozoic ferruginous quartzites of Karelia, the Kola Peninsula, and the Kursk Magnetic Anomaly was continued (Fig. 22) [24–27]. New data were obtained on the biogenic origin of minerals. The role of life was evaluated in relation to the concentration of minerals on the Earth. Issues of the settlement of lava flows [28] and land colonization by microorganisms [29, 30] were examined.

In early Proterozoic ferruginous quartzites of the Kursk Magnetic Anomaly (the Lebedinsky mine; limonite-martite ores and striated ferruginous quartzites of the Korobkovsky ore deposit), fossilized cyanobacteria were found, represented by trichomes merged into a single cover [24]. The minerals are deposited *in situ*. Morphologically, they are close to the modern representatives of the genus *Microcoleus*.

In striated ferruginous quartzites aged 2.7–2.8 billion years (the Archean Eon) from deposits in Karelia and the Kola Peninsula, microfossils of an apparently bacterial origin were found [27]. On the basis of an evaluation of organic carbon content and balance calculations, it was established that the formation of the studied Archean ferruginous quartzites took place in a medium enriched with organic matter. A comparative analysis of the morphology of modern and Neoarchean microorganisms suggests a bacterial origin of some amount of magnetite in the studied quartzites.

The results of microfossil research indicate that the biogenic factor played an important role in the formation of sedimentary early Proterozoic ferruginous quartzites of the Kursk Magnetic Anomaly. It was confirmed by the finds of cyanobacteria and abundant glycocalyx in fossil samples. It follows from here that sedimentary ferruginous quartzites were being deposited in the photic zone conditions — that is, in shallow water — and O_2 content in the atmosphere was quite high.

In early Precambrian Kejv proto-schists (the Kola Peninsula), nanobacteria deposited *in situ* were found. It is suggested that the presence of nanobacteria points to the involvement of the biological factor in the formation of host rocks; also, the presence of biofilms and nanobacteria suggests that the conditions of the external medium were unfavorable for bacterial life.

CONFERENCES AND EDUCATION

In 2016, the Laboratory's researchers participated in 14 scientific conferences in Russia and 10 conferences in different countries of the world. Jointly with the Scientific Council on Radiobiology of the Russian Academy of Sciences, a three-day conference was held entitled "Urgent Problems of Radiobiology and Astrobiology. Genetic and Epigenetic Effects of Ionizing Radiations". Its participants were about 100 scientists of institutes and research organizations of Russia, Italy, and the USA. Discussed were urgent issues of space radiobiology, astrobiology, radiation genetics, molecular and cell radiobiology, and data on the mechanisms of the formation of genetic and epigenetic changes in the genome.

The education process continued at the Department of Biophysics of University "Dubna". The Department's current total enrolment includes 34 students and 7 postgraduates. Bachelor's education is given in the field of Nuclear Physics and Technology represented by the program "Human and Environmental Radiation Safety"; Master's education is given in the field of Physics represented by the program "Radiation Biophysics and Astrobiology", and postgraduate education is given in the specialty of Radiobiology. In 2016, eight students were enrolled in the Bachelor's program; five students continued their Master's program. Six students successfully completed education and received their Master's diplomas in the field of Physics (the program "Radiation Biophysics and Astrobiology").

In 2016, Yulia Vinogradova, a Junior Scientist at LRB, defended her Candidate's thesis "Research on Mouse Retina Damage and Recovery after Exposure to Accelerated Protons and Methylnitrosourea" and was awarded with Moscow Oblast Governor's Prize in Science and Innovation for Young Scientists and Specialists for her work "Research on the Structural and Functional Recovery of the Mouse Retina after Retinotoxic Exposure to Ionizing Radiation and Alkylating Agents."

REFERENCES

1. *Zadneprianetc M., Boreyko A. V., Bulanova T., Falk M., Falková I., Davídkova M., Ježková L., Kozubek S., Krasavin E. A., Kruglyakova E., Smirnova E., Valentová O.* Spatiotemporal Analysis of γH2AX/53BP1 Foci after High- and Low-LET Irradiation // Book of Abstracts of the 42nd Annual Meeting of the Eur. Radiation Research Society (ERRS 2016), Amsterdam, Netherlands, Sept. 4–8, 2016. P. 107.

2. *Kruglyakova E. A., Boreyko A. V., Bulanova T. S., Zadnepryanets M. G., Ježková L., Smirnova E. V.* The Effect of Radiation Quality on the Formation of DNA Damage and Cell Reactions in Human Fibroblasts // The 5th Annual Conf. of Young Scientists and Specialists, Alushta, Russia, 2016 (in Russian); http://indico.jinr.ru/contributionDisplay.py?contribId=54&sessionId=10&confId=89.
3. *Zadnepryanets M. G., Boreyko A. V., Bulanova T. S., Ježková L., Krasavin E. A., Kruglyakova E. A., Smirnova E. V.* Space and Time Analysis of γH2AX/53BP1 Foci in Accelerated Ion Tracks // Book of Theses of the 7th Intern. School on Molecular Genetics for Young Scientists "Genomics and Biology of Living Systems", Zvenigorod, Russia, Nov. 14–18, 2016. P. 31 (in Russian).
4. *Dubničková M., Kuzmina E. A., Chausov V. N., Ravnachka I., Boreyko A. V., Krasavin E. A.* The Effects of Lipid A on Gamma-Irradiated Human Peripheral Blood Lymphocytes *In Vitro* // Phys. Part. Nucl. Lett. 2016. V. 13. P. 274.
5. *Bulanova T. S., Jezkova L., Kruglyakova E. A, Zadneprianetc M. G., Smirnova E. V., Boreyko A. V.* Formation and Repair of DNA Double-Strand Breaks in Brain Cells of Sprague–Dawley Rats after ^{60}Co γ-Ray Irradiation // Phys. Part. Nucl. Lett. 2017. Special Issue (submitted).
6. *Blaha P., Koshlan I. V., Koshlan N. A., Govorun R. D., Elsha D.V., Bogdanova J. V., Krasavin E. A.* HPRT Mutant Induction and Analysis in V79 Cells after Exposure to Ionizing Radiation with Different Qualities // Book of Abstracts of the 62nd Radiation Research Society Meeting, Kona, Hawaii, USA, 16–19 Oct. 2016. P. 258.
7. *Belov O., Belokopytova K., Bazyan A., Kudrin V., Narkevich V., Ivanov A., Severiukhin Yu., Timoshenko G., Krasavin E.* Exposure to ^{12}C Particles Alters the Normal Dynamics of Brain Monoamine Metabolism and Behaviour in Rats // Physica Medica, Eur. J. Med. Phys. 2016. V. 32, No. 9. P. 1088–1094.
8. *Belokopytova K. V., Belov O. V., Kudrin V. S., Narkevich V. B., Krasavin E. A., Timoshenko G. N., Bazyan A. S.* Monoamine Exchange Dynamics in the Rat Brain Structures at Late Times after Accelerated Carbon Ion Exposure // Neurochem. J. 2016. V. 33, No. 2. P. 147–155 (in Russian).
9. *Kokhan V. S., Matveeva M. I., Bazyan A. S., Kudrin V. S., Mukhametov A., Shtemberg A. S.* Combined Effects of Antiorthostatic Suspension and Ionizing Radiation on the Behaviour and Neurotransmitters Changes in Different Brain Structures of Rats // Behavioural Brain Research. V. 320. P. 473–483. http://dx.doi.org/ 10.1016/j.bbr.2016.10.032.
10. *Kokhan V. S., Matveeva M. I., Mukhametov A., Shtemberg A. S.* Risk of Defeats in the Central Nervous System during Deep Space Missions // Neurosci. Biobehav. Rev. 2016. V. 71. P. 621–632.
11. *Bazyan A. S.* Motivational and Emotional Conditions: Structural, System, Neurochemical, Molecular, and Cellular Mechanisms // Physiol. Usp. 2016. V. 47, No. 1. P. 15–33 (in Russian).
12. *Bugay A. N., Vasilyeva M. A., Parkhomenko A. Yu., Krasavin E. A.* Mathematical Analysis of Regulatory Networks and Damage Repair Efficiency in Bacterial Cells // Genetics, Evolution and Radiation (Crossing Borders, The Interdisciplinary Legacy of Nikolay W. Timofeeff-Ressovsky) / Eds.: V. L. Korogodina, C. E. Mothersill, S. G. Inge-Vechtomov, C. B. Seymour. Springer Intern. Publ. AG, 2016. P. 175–186.
13. *Fourie H., Slabbert J. P., Belov O. V., Newman R., Panina M. S., Rossouw N.* Estimating the Effectiveness of High LET Radiations to Induce Damage to DNA in Human Lymphocytes and Modelling the Repair Thereof // Physica Medica. 2016. V. 32. P. 155. http://dx.doi.org/10.1016/j.ejmp.2016.07.051.
14. *Bayarchimeg L., Belov O. V., Batmunkh M., Lkhagva O.* Modeling of Synaptic Receptors under Irradiation with Charged Particles // Mongol. J. Phys. 2016 (in press); http://mnglps.mn/index.php/en/.
15. *Belov O. V., Batmunkh M., Incerti S., Lkhagva O.* Radiation Damage to Neuronal Cells: Simulating the Energy Deposition and Water Radiolysis in a Small Neural Network // Physica Medica. 2016. V. 32. P. 1510–1520.
16. *Batmunkh M., Belov O. V., Bayarchimeg L., Lkhagva O.* Radiation Effects in the Central Nervous System: Simulation Technique and Practical Applications // Mongol. J. Phys. 2016 (in press); http://mnglps.mn/index.php/en/.
17. *Dushanov E.* Ion Channel Dynamics of Glutamate Ionotropic Receptors in Synaptic Transmission Processes // Book of Theses of the 23rd Intern. Conf. "Mathematics. Computer. Education", Dubna, Jan. 25–30, 2016. V. 23. P. 69 (in Russian).
18. *Sekulic D. L., Sataric B. M., Zdravkovic S., Bugay A. N., Sataric M. V.* Nonlinear Dynamics of C-Terminal Tails in Cellular Microtubules // Chaos. 2016. V. 26. P. 073119.
19. *Zdravkovic S., Zekovic S., Bugay A. N., Sataric M. V.* Localized Modulated Waves and Longitudinal Model of Microtubules // Appl. Math. Comput. 2016. V. 285. P. 248–259.
20. *Zdravkovic S., Bugay A. N.* Why Are Biological Systems Nonlinear? // Nonlin. Phenomena in Complex Systems. 2016. V. 19, No. 1. P. 71–79.
21. *Bugay A. N.* Radiation Induced Disfunction in the Working Memory Performance Studied by Neural Network Modeling // Book of Abstracts of Belgrade BioInform. Conf. 2016, June 20–24, 2016. P. 50.
22. *Batova A. S., Bugay A. N., Parkhomenko A. Yu.* Approaches to the Mathematical Modeling of Hippocampus Neurons' Electrophysiological Activity // JINR News. 2016. No. 3. P. 26–29.
23. *Saladino R., Carota E., Botta G., Kapralov M. I., Timoshenko G. N., Rozanov A. Yu., Krasavin E. A., Di Mauro E.* First Evidence on the Role of Heavy Ion Irradiation of Meteorites and Formamide in the Origin of Biomolecules // Origins of Life and Evolution of Biospheres. 2016. P. 1–7.
24. *Rozanov A. Yu., Astafyeva M. M., Zaytseva L. V., Alfimova N. A., Felitsyn S. B.* Cyanobacteria (?) in Ferruginous Quartzites of the Kursk Magnetic Anomaly // Dokl. Akad. Nauk. 2016. V. 470, No. 3. P. 1–3 (in Russian).
25. *Astafyeva M. M.* The Most Ancient Weathering Rinds and the Problem of the Bacterial Colonization of

Land // Paleontology. Stratigraphy. Astrobiology. Marking the 80th Birthday of A. Yu. Rozanov. Borisyak Paleontol. Inst. of the Russ. Acad. of Sciences, Moscow, 2016. P. 31–43 (in Russian).
26. *Astafyeva M. M.* New Results of Bacterial Paleontology Research // The 100th Anniversary of the Russian Paleontological Society. Problems and Prospects of Paleontological Research: Proc. of the 62nd Session of the Paleontol. Soc. St. Petersburg, 2016. P. 17–18 (in Russian).
27. *Astafyeva M. M.* First Results of a Bacterial Paleontology Study of Early Precambrian Ferruginous Quartzites of Karelia and the Kola Peninsula // Proc. of the Round-Table Meeting "Topical Issues of Radiobiology and Astrobiology. Genetic and Epigenetic Effects of Ionizing Radiation", Dubna, Nov. 9–11, 2016. P. 91–93 (in Russian).
28. *Astafyeva M. M.* The Early Earth: Lava Flows and the Possibility of Life // Colloquium "Earth at the Early Stages of Solar Planetary System Development", Sternberg Astron. Inst. at Moscow State Univ., Nov. 28–30, 2016 (in Russian).
29. *Astafyeva M. M.* Colonization of Land // The 2nd All-Russia Conf. on Astrobiology (Life in the Universe: Physical, Chemical, and Biological Aspects), Pushchino, Russia, June 5–9, 2016. P. 39–40 (in Russian).
30. *Astafyeva M. M.* Early Colonization of Land by Microorganisms // Proc. of the 2nd All-Russia Paleontol. Conf. "Algae in Biosphere Evolution". 2016. P. 19–22 (in Russian).

UNIVERSITY CENTRE

In 2016, JINR University Centre celebrated its anniversary: 25 years ago it was established in order to implement the educational programme of the Institute.

International Student Practice. In 2016, 161 representatives of Azerbaijan, Belarus, Egypt, Cuba, Poland, Romania, Serbia, Slovakia, the Czech Republic, and South Africa participated in the three stages of the Practice (Figs. 1 and 2).

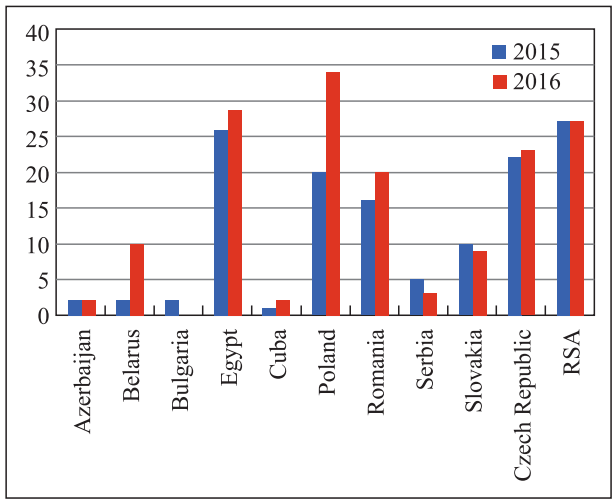


Fig. 1. Number of ISP participants distributed by countries, 2015–2016

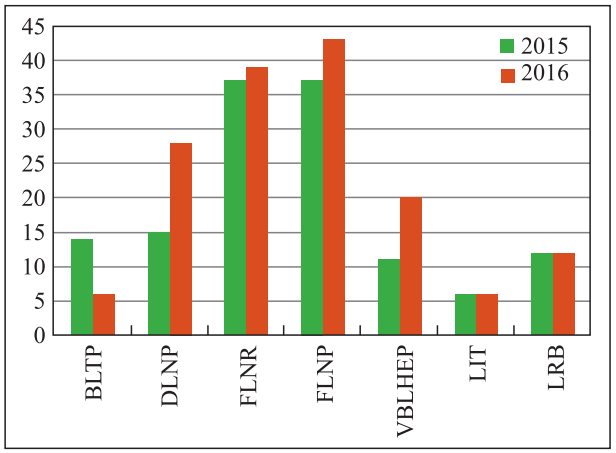


Fig. 2. Number of ISP participants distributed by JINR laboratories, 2015–2016

The 1st stage of the Practice 2016 started on 23 May. Traditionally, this stage is attended by representatives of Egypt. Twenty-eight undergraduate and postgraduate students and young scientists from 16 universities and research centres of Egypt were selected by the authorized national representatives (out of 100 applicants) to participate in the Practice.

The 2nd stage of the Practice 2016 began on 4 July. Thirty-four students from Poland, 23 students from the Czech Republic, 20 students from Romania, 9 students from Slovakia, and 2 students from Azerbaijan came to JINR to take part in the event. This stage is always noted for a large number of participants. However, in 2016 the number of people willing to participate in the Practice was a record-breaking — 88 students won selective competitions in their countries.

On 5–23 September, 27 students from South Africa, 10 students from Belarus, 3 students from Serbia, and 2 students from Cuba became participants in the final 3rd stage of the Practice.

The Practice programme traditionally included lectures on the research conducted at JINR and visits to the main experimental facilities, but most of the time was devoted to research projects. The database of research projects at the UC website (http://uc.jinr.ru) has 61 projects. At the 1st stage of the Practice, the staff-members of the laboratories supervised 32 projects; at the 2nd stage — 42 projects; at the 3rd stage — 39 projects. The final day of the Practice was dedicated to the participants' presentation of reports on the work performed.

Egyptian students took part in a social event at University "Dubna". For the participants of the 2nd stage a picnic on Lipnya Island was organized. The participants of the 3rd stage visited Moscow and Tver and took part in a new social event "International Morning" organized at the JINR Visit Centre. It included a lecture on the history of Russia and Dubna, as well as reports of the participants on the history and traditions of their countries, demonstration of national costumes and tasting of national cuisine.

JINR-Based Education. In 2016, 440 students from the JINR-based departments of MSU, MIPT, MEPhI,

University "Dubna", and universities of the Member States were trained at the JINR University Centre.

Summer training was organized for 238 students from the universities of Armenia, Belarus, Georgia, Mongolia, and the Russian Federation. Among the universities of RF were: MSU, MIPT, MEPhI, MISA, Voronezh State University, St. Petersburg State Electrotechnical University, Tver State Technical University, Tomsk Polytechnic University, South-Russian State Polytechnic University. Students of the JINR-based departments of University "Dubna" constituted the major part of trainees. To do the training, the students were attached to the JINR laboratories. The largest number of students was at VBLHEP — 81 people; LIT and LRB welcomed 44 and 35 students, respectively.

In 2016, 19 degree-seekers from the Russian Federation, Georgia, and Kazakhstan were attached to JINR in order to prepare their PhD theses without mastering the training programmes of the teaching staff at the PhD courses. Eleven of them chose "Physics of Atomic Nucleus and Elementary Particles" as their major subject.

The UC website (http://uc.jinr.ru/) database of training courses intended for students from the JINR-based departments of MSU, MIPT, and University "Dubna" presents 124 lecture courses in the following fields: Particle Physics and Quantum Field Theory; Nuclear Physics; Condensed Matter Physics; Nanostructure and Neutron Physics; Physics Setups; Information Technologies; Mathematical and Statistical Physics.

Engineering and Physics Training intended for accelerator engineers and experimental physicists is a new activity offered by the JINR UC. Currently, it includes hands-on courses on vacuum and RF technology, electronics and precision laser metrology. Courses on nuclear physics, automation and particle detectors are being elaborated. After commissioning the electron accelerator LINAC-800, a part of these courses can be performed using the accelerator beams.

New Student Programmes. The Summer Student Programme 2016 was attended by 39 undergraduate and postgraduate students from MSU, MIPT, MEPhI, universities of St. Petersburg (St. Petersburg State University, St. Petersburg Electrotechnical University "LETI", ITMO University), University "Dubna", universities of Belarus, Egypt, Kazakhstan, Cuba, Poland, Romania, South Africa. Over 6–8 weeks, from June to October, students and postgraduates fulfilled their research projects at the Institute laboratories.

International Scientific Schools for Physics Teachers at JINR and CERN. On 19–25 June, JINR hosted a regular School for Physics Teachers from JINR Member States. The event was attended by 26 teachers and 8 school students from Bulgaria, Russia, and Ukraine. Russian teachers and students came from the Vologda, Moscow, Rostov, Samara, Sverdlovsk, Tambov, and Chelyabinsk regions, the Crimea, the Nenets AR, Tatarstan, and Chuvashia. On 26 June – 1 July, the Third School for 20 teachers from Moscow and Moscow Region was held with the financial support of the Moscow City Teachers' House.

With regard to the feedback from the former participants, the programmes of the Schools included popular science lectures by the leading JINR specialists, visits to the main experimental facilities of JINR, and hands-on activities in the UC Physics Lab. High-school students presented their reports at the scientific seminar. For the teachers, a round table "Modern Physics Issues and Methods of Teaching Physics at School" was organized.

On 30 October – 6 November, CERN hosted the 9th Scientific School for Physics Teachers from JINR Member States. The School was organized by CERN and JINR, with the financial support of the Centre of National Intellectual Reserve, Moscow State University. The School was attended by 46 physics teachers from Armenia, Kazakhstan, Moldova, Russia, and Ukraine. The Russian Federation was represented by teachers from Moscow and Moscow Region; St. Petersburg; Arkhangelsk, Vologda, Irkutsk, Kirov, Kurgan, Kursk, Lipetsk, Novosibirsk, Pskov, Samara, Sverdlovsk, Tambov, Tomsk, and Chelyabinsk regions; Bashkortostan, Tatarstan, and Chuvashia. The programme of the event included lectures, visits to experimental facilities, meetings with scientists both in the working and informal environment, and excursions.

Physics Days. On 27–29 March, Dubna hosted Physics Days held in the framework of the JINR 60th anniversary celebration. The event was organized by the JINR University Centre and the Interschool Mathematics and Physics Open Classroom. For the third time amateurs in physics of different ages had the opportunity to see exciting scientific demonstrations, including those with liquid nitrogen, and independently perform physics experiments. Those who are fond of mathematics solved tasks and puzzles, participated in mathematical battles. The event was attended by school students from Dubna, Dmitrov district, Moscow, St. Petersburg, and Otto Wichterle gymnasium of Ostrava-Poruba (Czech Republic).

During the Physics Days, the 5th Robotics Tournament of the Open Upper-Volga Educational Cyber Network was held. The tournament was organized by JINR, the Interregional Computer School, Keldysh Institute of Applied Mathematics, and Open Upper-Volga Educational Cyber Network (OUVECN).

Video Conferences. JINR UC continues organizing and assisting in the running of video conferences, as well as in the broadcasting through the JINR system of video-conference management. In 2016, the following video conferences were held:

— video broadcasting of the joint workshop sessions "Physics at the LHC";

— video conference for pupils of the 5, 7, 8, 9, and 11 grades of Moscow school No. 1386;

— video conference "Joint Institute for Nuclear Research: NICA Collider, the Most Important Discoveries

of the Recent Years" for students from Troitsk and Novomoskovsky administrative district of Moscow;

— video lectures "Elements of Relativistic Quantum Field Theory" by A. Khvedelidze for students of the National Research University "Moscow Engineering Physics Institute";

— virtual tour of the CMS experiment (CERN) in the JINR Library;

— video conference on the new JINR accelerator complex NICA and the work of the DLNP Medico-Technical Complex organized for students from Moscow school No.185.

All-Russian Science Festival NAUKA 0+. At the VI All-Russian Science Festival NAUKA 0+, held on 7–9 October in Moscow, JINR was represented at two sites, where exhibitions dedicated to the main fields of research and pioneer projects of the JINR laboratories were installed. Visitors of all ages had the opportunity to participate in physics and chemistry experiments, competitions and master-classes in robotics, as well as to acquire new knowledge about science using interactive technologies, educating programmes and games.

Visits. The programme of introductory visits for students from Balashikha, Veliky Novgorod, Dubna, Moscow, Michurinsk, Smolensk, St. Petersburg, Tver, John F. Kennedy Physics School (Berlin) included lectures about JINR, visits to the main experimental facilities, hands-on activities at the UC Physics Lab, popular science demonstrations, and a visit to the A. N. Sissakian Education Centre. Students of the Bauman State Technical University made a tour of the IBR-2 reactor. For children from the summer camp "Leto" demonstration of experiments with liquid nitrogen was organized.

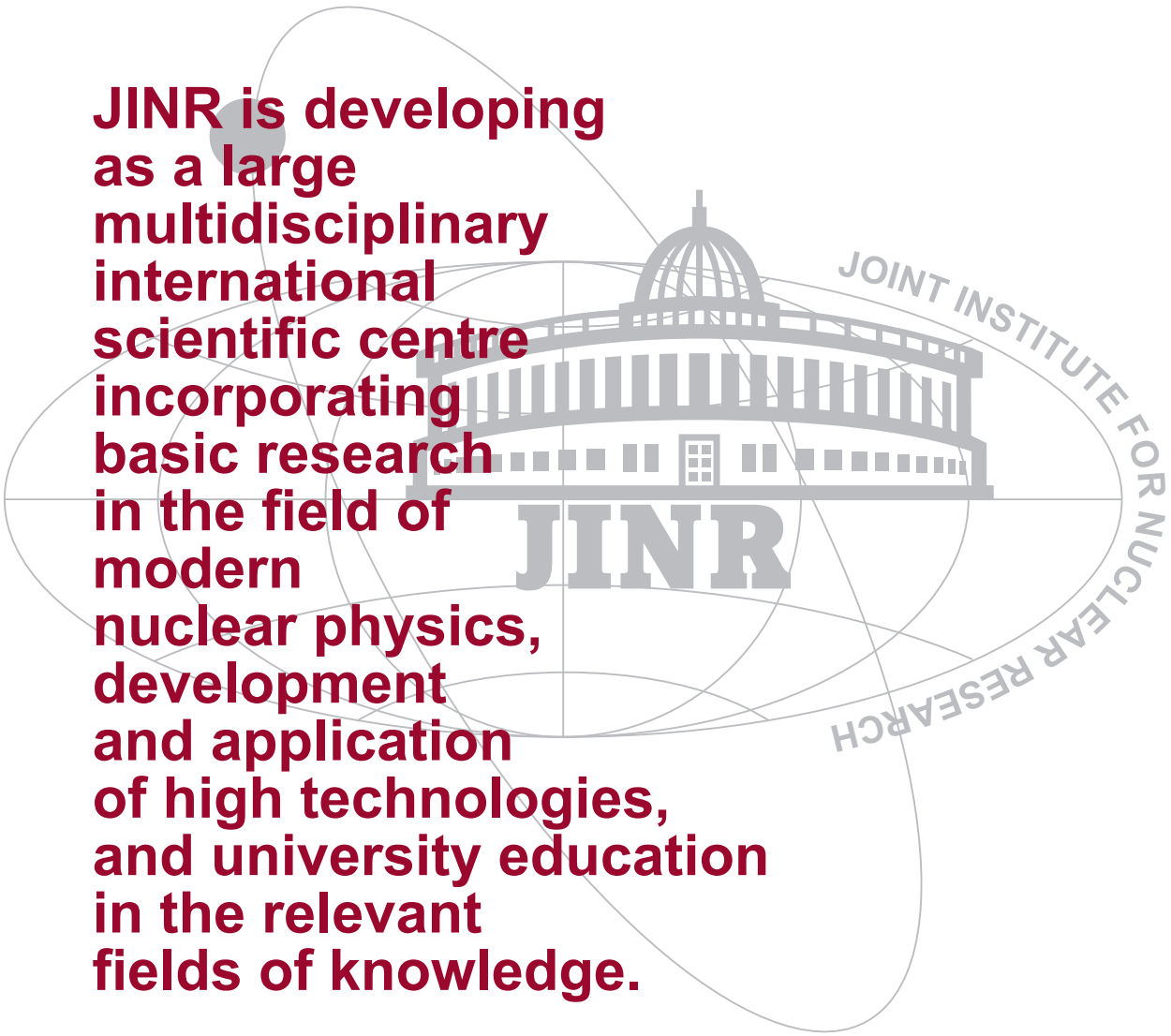
Work with School Students. During the academic year, twice a week, 33 high-school students from Dubna attended physics classes that included hands-on activities at the UC Physics Lab, as well as classes training pupils for the Unified State Exam.

For pupils of all ages, the center for additional education PRIMER started its work with the support of the University Centre, thus enhancing and complementing the JINR Interschool Open Classroom programme. The Centre will organize clubs, projects, and tutorials in mathematics, informatics, robotics, and science, as well as provide assistance in the preparation for the final attestation.

Advanced Training and Skill Improvement of Workmen, Engineers, Technicians, and Staff-Members. Eighty-nine JINR staff-members and twenty representatives of Dubna organizations were trained at the courses intended for the personnel maintaining the facilities subordinate to Rostechnadzor. Ninety-one JINR staff-members were trained at the courses organized at JINR and certified by the Central Attestation Commission of JINR. In 2016, the Territory Certification Commission of Rostechnadzor certified 22 JINR top executives and specialists in the normative legal acts and normative-technical documents stating requirements for industrial safety in various spheres of supervision. Four hundred and thirty JINR staff-members were trained and certified by the Central Attestation Commission of JINR in the new rules on labour protection related to working at heights. One hundred and sixty people were trained in labour protection, and the knowledgeability of the heads and committee members of the structural divisions of the Institute was tested. Thirty-three top executives and specialists of the Institute were trained in fire safety. Ten students from MRICC and MRATT were trained at JINR.

151 JINR staff-members attend language courses organized by the University Centre: English — 105 people, French — 22, German — 15, Russian as a foreign language — 9 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.



The Bogoliubov Laboratory of Theoretical Physics, 25 May.
The jubilee seminar on the 60th anniversary of the Laboratory

The Bogoliubov Laboratory of Theoretical Physics, 25 May.
Participants of the jubilee seminar on the 60th anniversary of the Laboratory

The Bogoliubov Laboratory of Theoretical Physics, 3 March. A seminar in memory of Academician D. Shirkov

The Bogoliubov Laboratory of Theoretical Physics, 18–30 July. Participants of the summer school “Quantum Field Theory at the Limits: From Strong Fields to Heavy Quarks” (SFHQ-2016)

The Bogoliubov Laboratory of Theoretical Physics, 9–24 April. Participants of the 20th research workshop “Nucleation Theory and Applications”

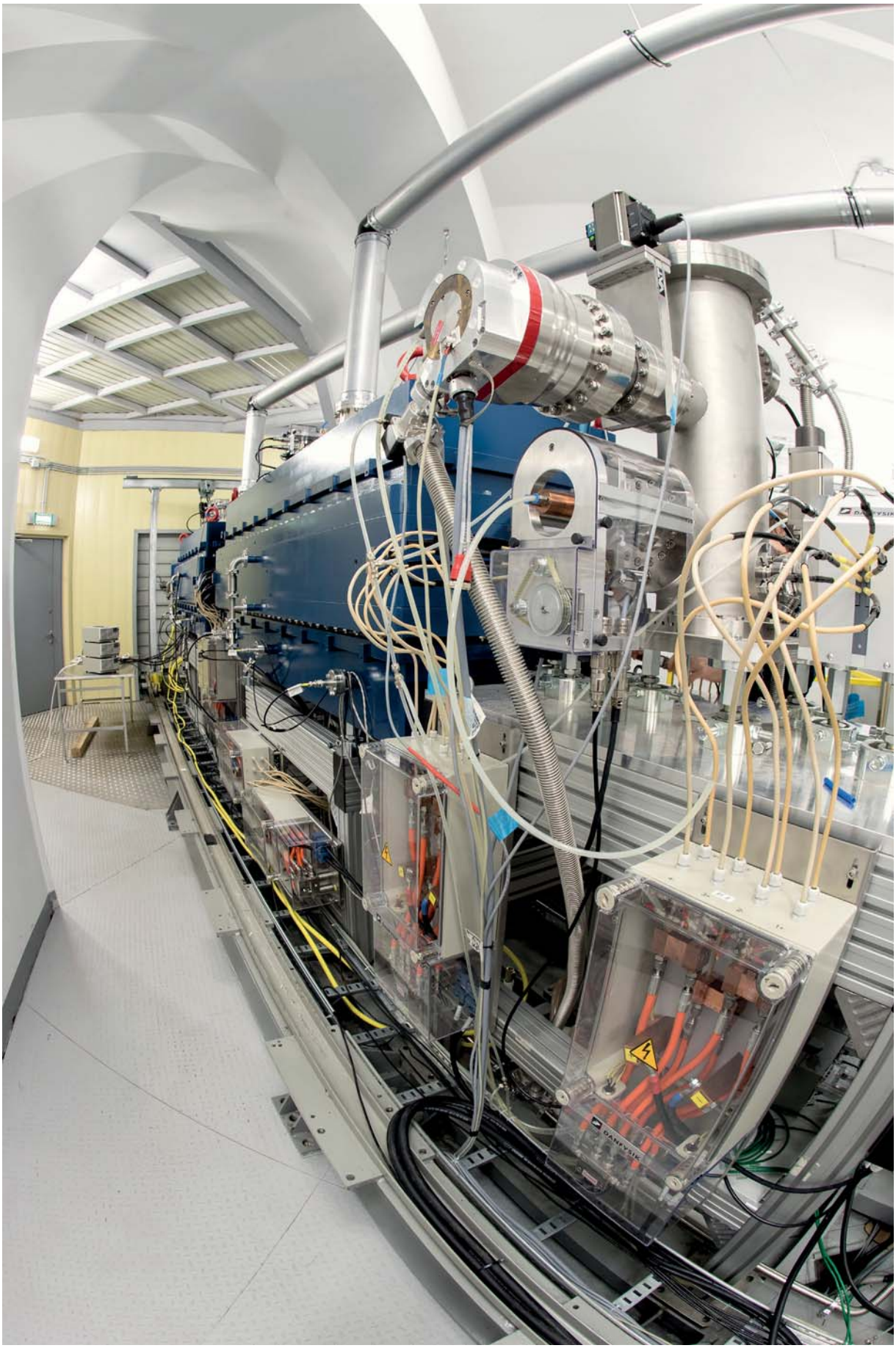
The Bogoliubov Laboratory of Theoretical Physics, 29 August – 10 September. The Helmholtz international summer school “Cosmology, Strings, and New Physics”

Dubna, 16 February. Signing of a contract between JINR and ASG Superconductors (Genoa, Italy), to manufacture a superconducting solenoid for the NICA/MPD magnet

The Veksler and Baldin Laboratory of High Energy Physics, 26 February.
A ceremonial meeting and laying of the flowers to the memorial plaque of Academician A. Baldin

The Veksler and Baldin Laboratory of High Energy Physics, May. Participants of the process of launching the new linear accelerator of deuterons and light nuclei for the NICA collider

The Veksler and Baldin Laboratory of High Energy Physics, 20 April.
A group of foreign journalists visiting JINR in the framework of the international project CREMLIN



The Veksler and Baldin Laboratory of High Energy Physics.
The heavy ion linear accelerator of the NICA collider

The Veksler and Baldin Laboratory of High Energy Physics, 19–24 September. Participants of the 23rd Baldin international seminar “Relativistic Nuclear Physics and Quantum Chromodynamics”

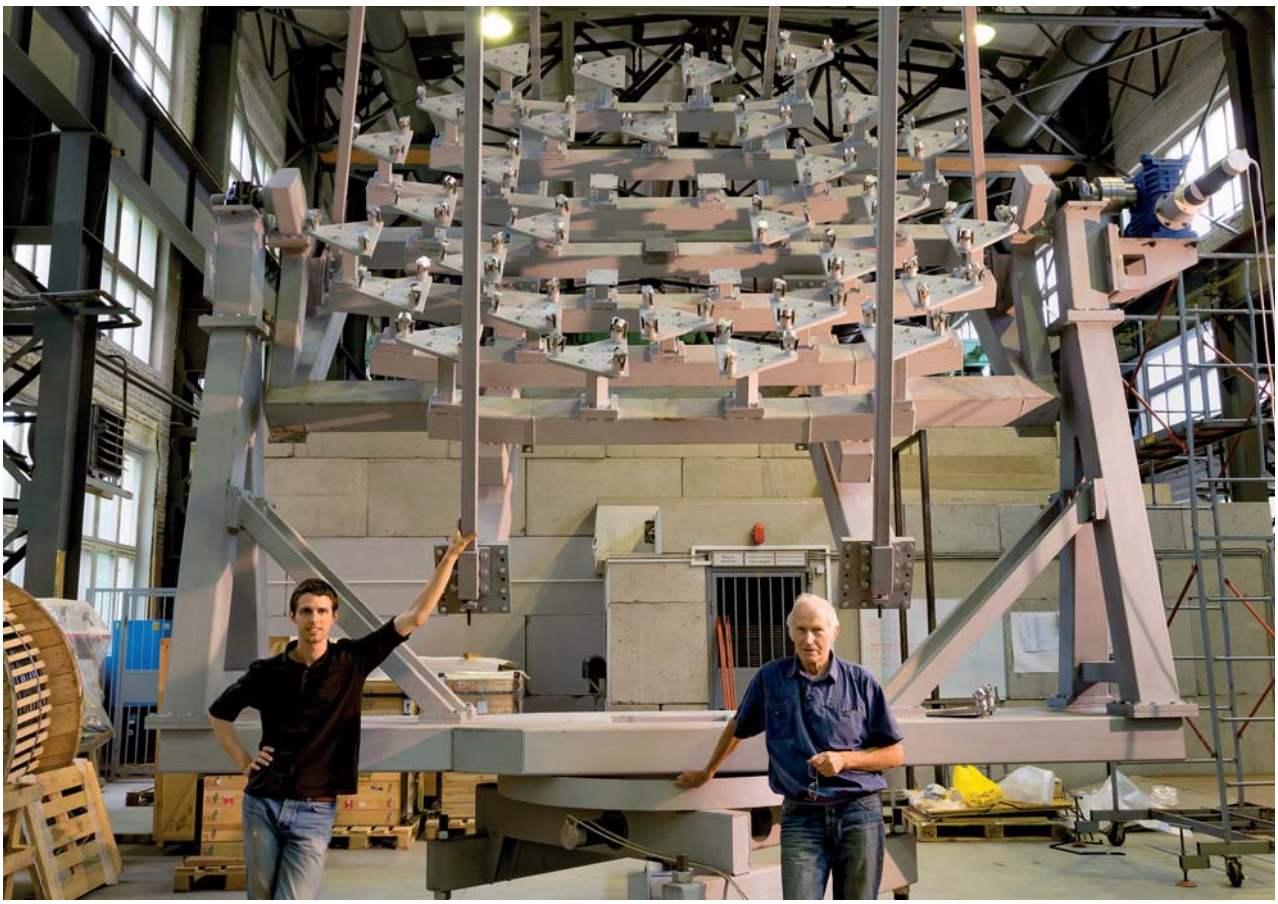
The Veksler and Baldin Laboratory
of High Energy Physics. The construction site for the NICA complex

The Veksler and Baldin Laboratory of High Energy Physics, 28 November. The official ceremony of launching of a high-technology line for assembling and testing of superconducting magnets

The Veksler and Baldin Laboratory of High Energy Physics.
The technological site of the manufacture of superconducting magnets for the NICA project

The Dzhelepov Laboratory of Nuclear Problems, 18–20 February.
Participants of the extended xFitter Workshop

The Dzhelepov Laboratory of Nuclear Problems, July. JINR Leader of the TAIGA experiment L. Tkachev (right) and the diploma student of the University “Dubna” Ya. Sagan



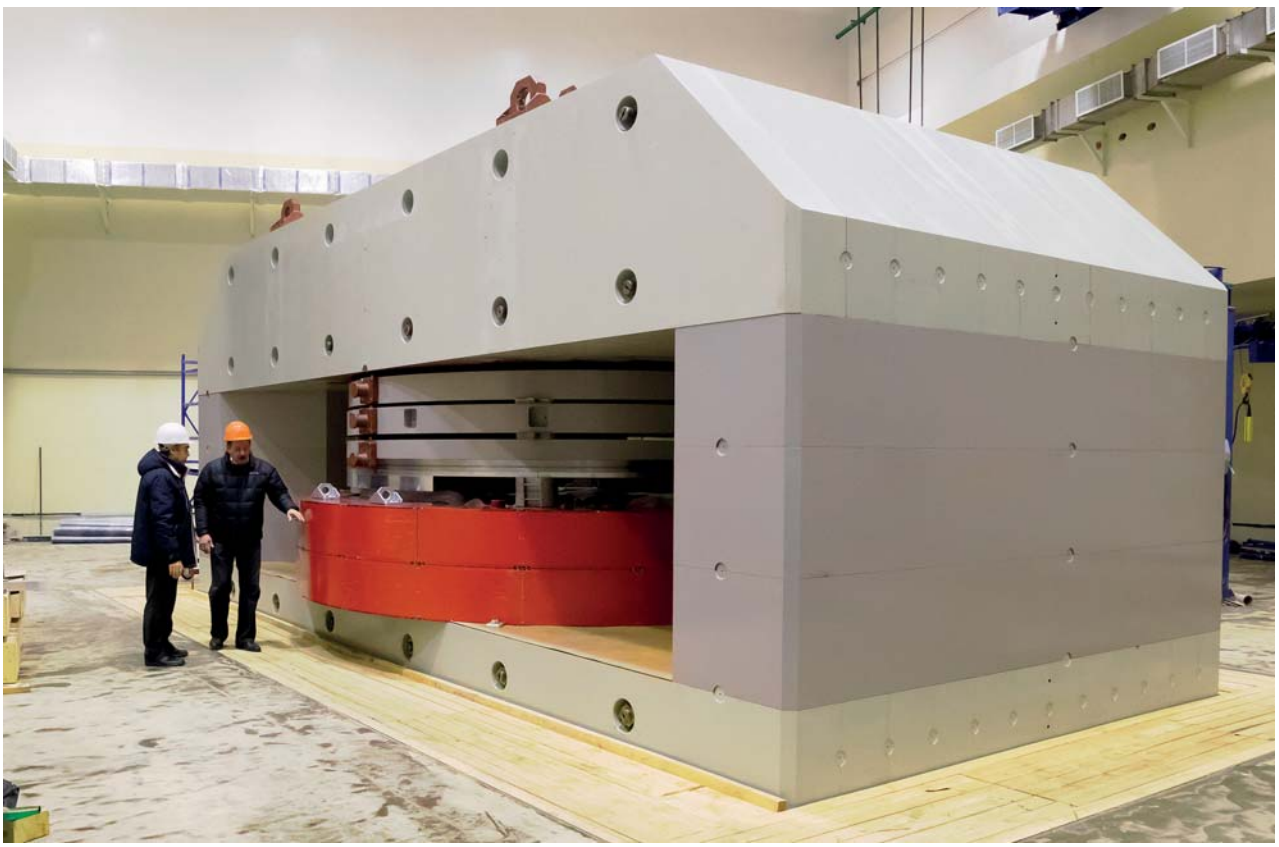
The Dzhelepov Laboratory of Nuclear Problems.
The JINR Medical and Technical Complex for proton therapy sessions

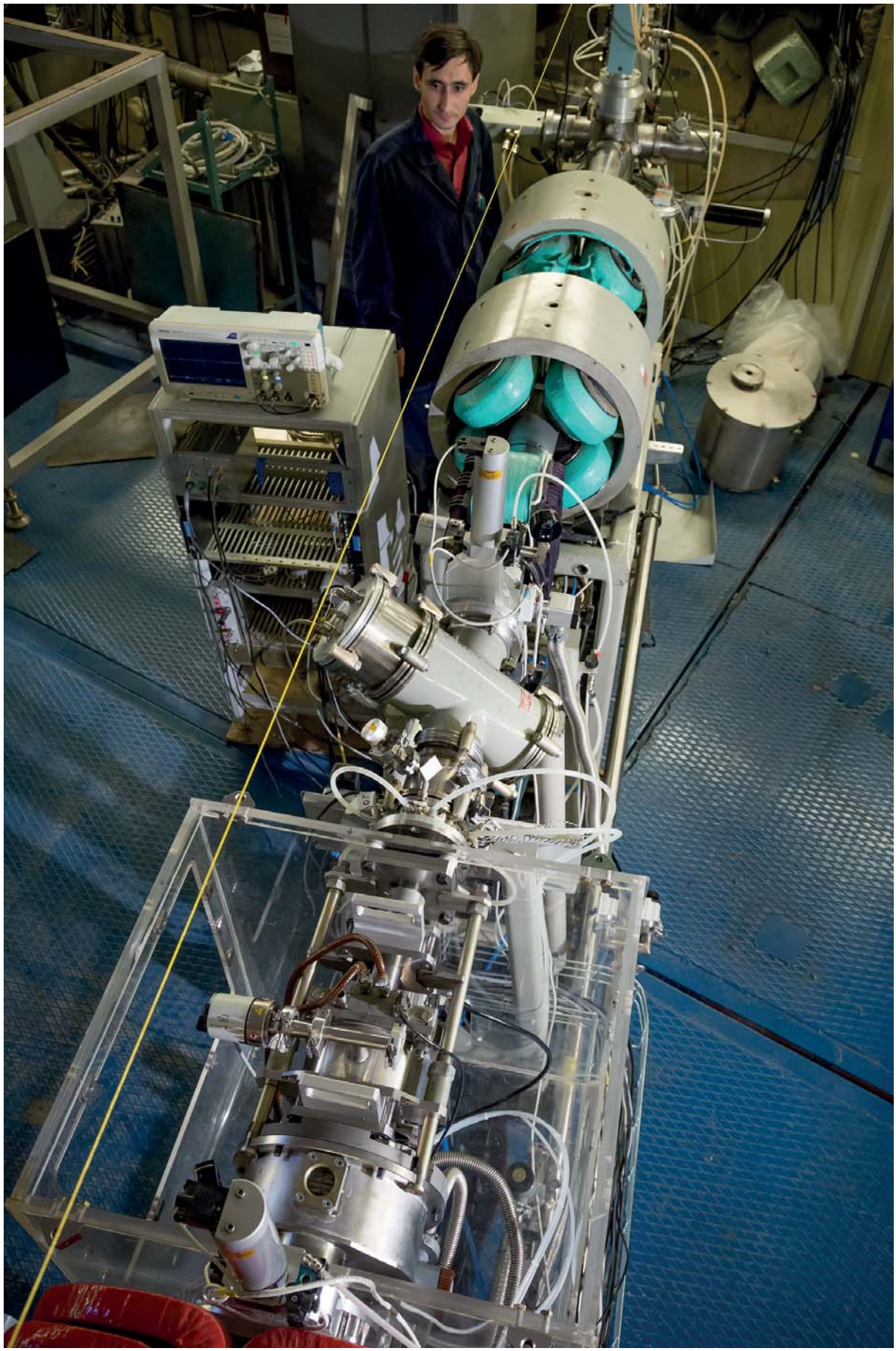
Dubna, 4–25 July. Participants of the 2nd stage of the JINR International Student Practice

The laboratory for photodetector testing

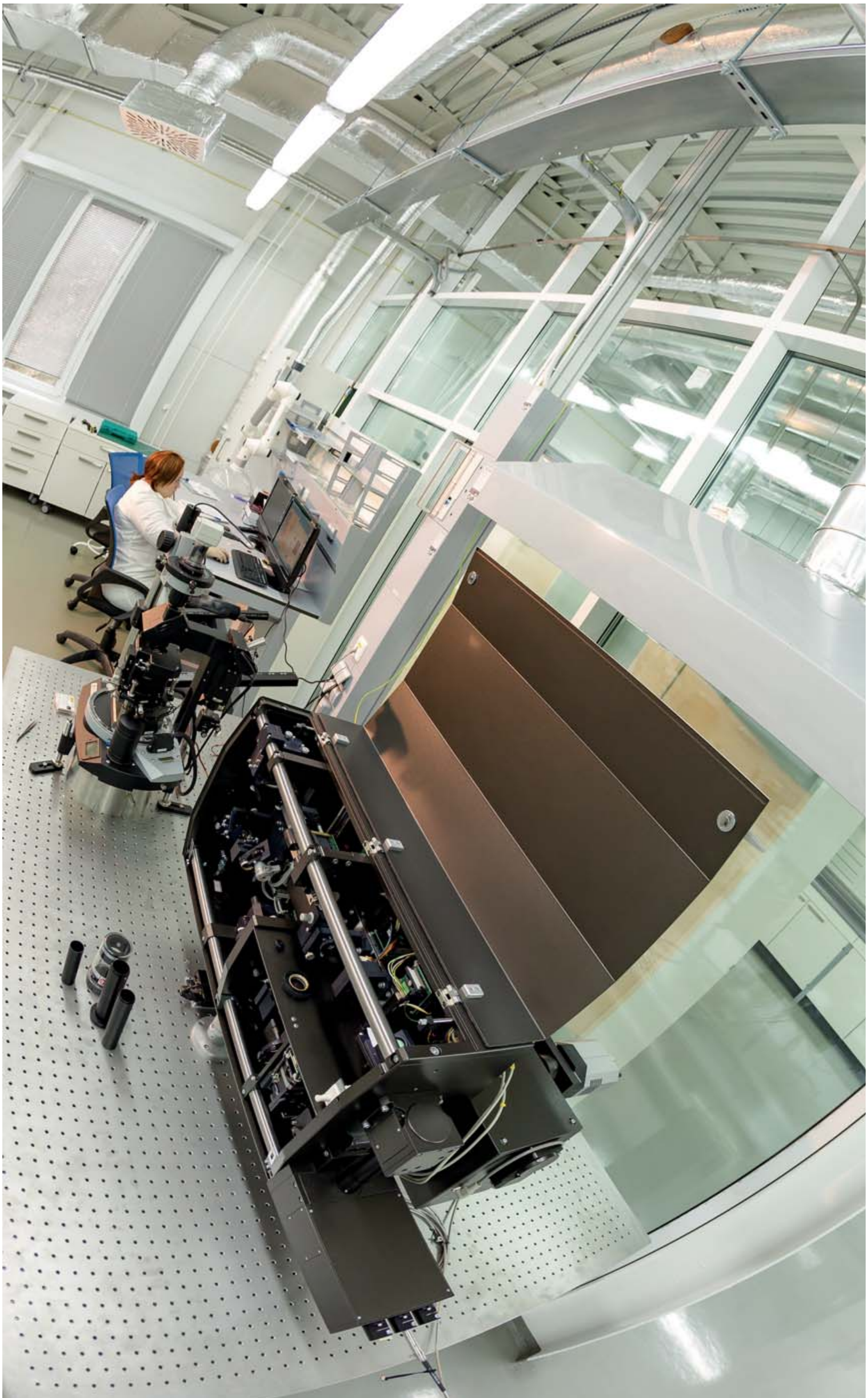
The Flerov Laboratory of Nuclear Reactions. The construction of the Factory of Superheavy Elements

The Flerov Laboratory of Nuclear Reactions, 15 September.
The assembling of the DC-280 cyclotron magnet in the building of the SHE Factory





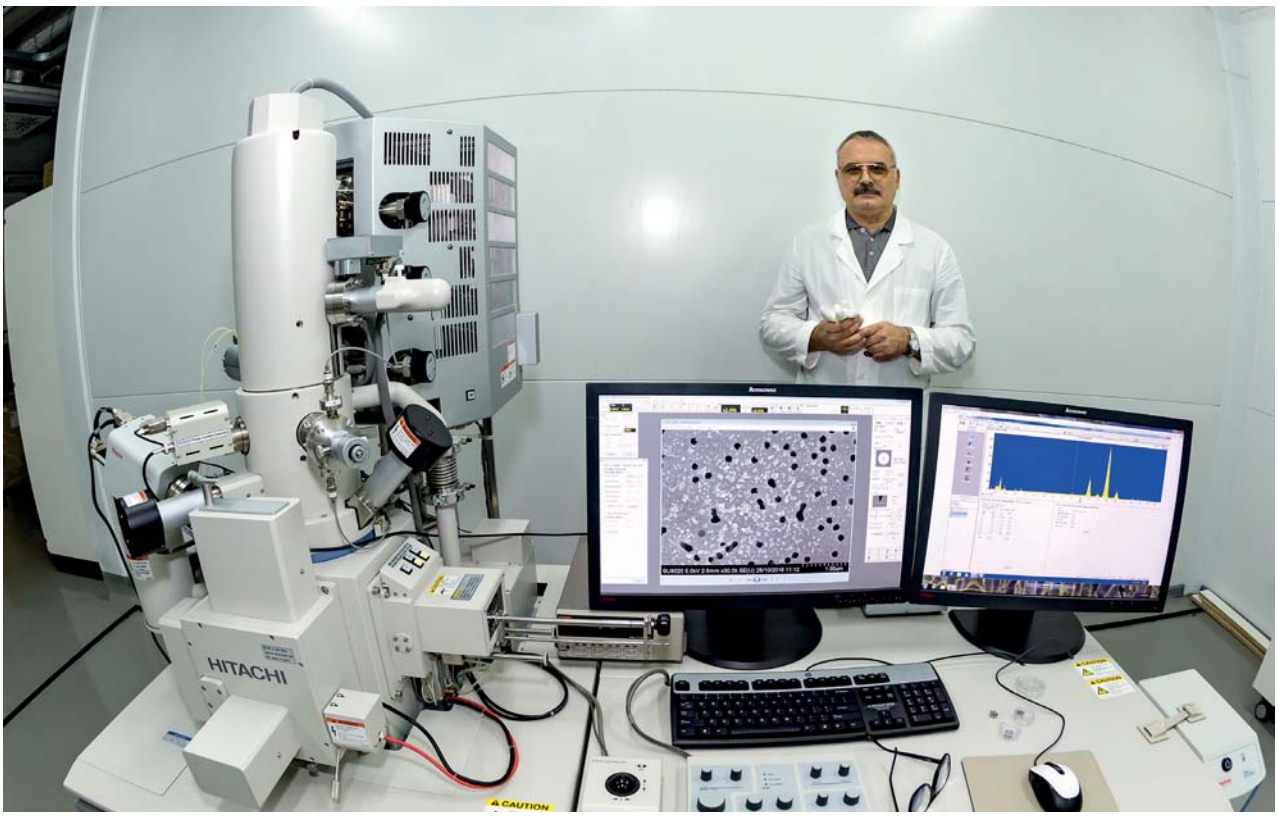
The Flerov Laboratory of Nuclear Reactions. The Dubna gas-filled separator of recoil nuclei



The Flerov Laboratory of Nuclear Reactions. The scanning probe microscope for profiler measurements NTEGRA Spectra

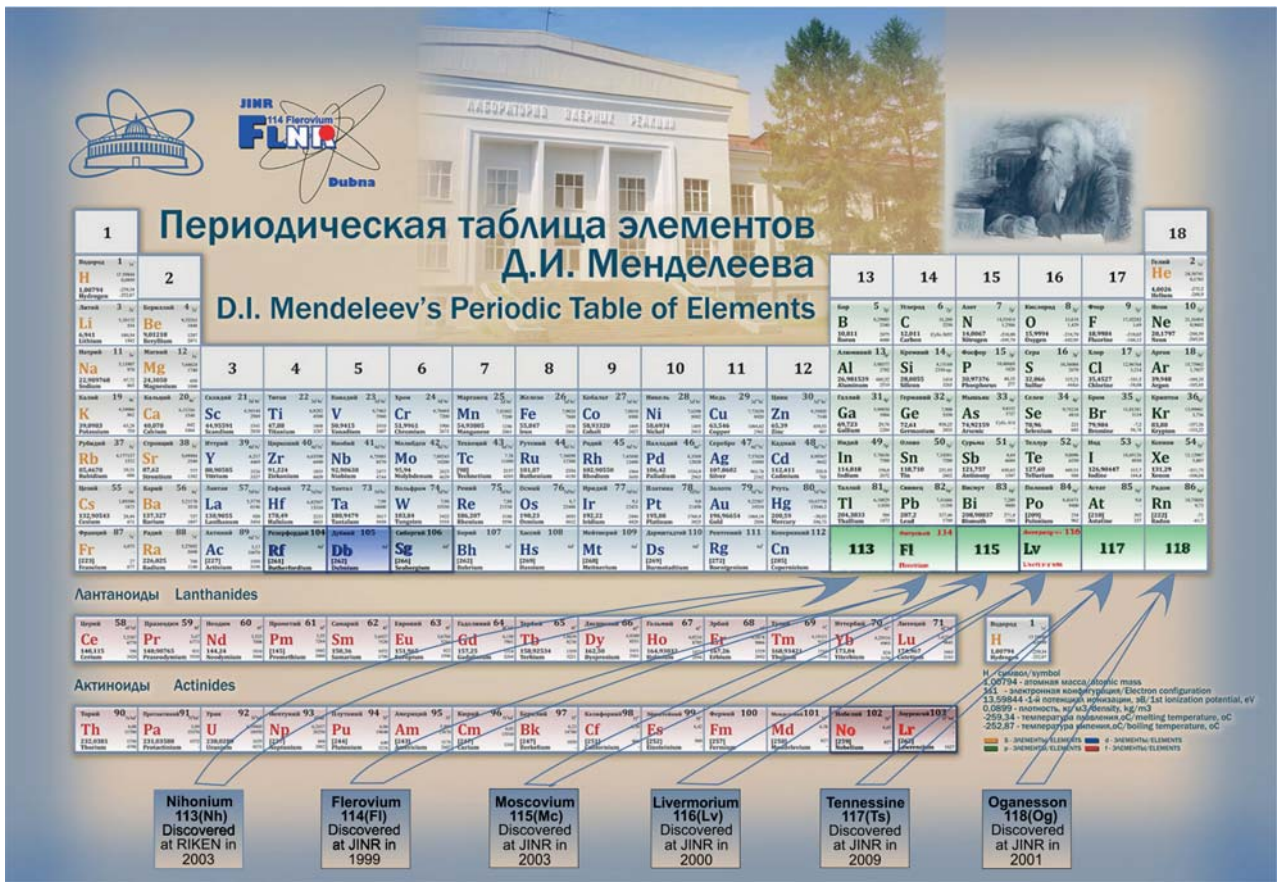
Kazan (Russia), 5–10 September. Leaders of the Kazan Federal University and JINR representatives during EXON 2016

The Flerov Laboratory of Nuclear Reactions.
The focused-beam electronic microscope Hitachi SU8020



The Flerov Laboratory of Nuclear Reactions, 12 December. A press conference on naming the new elements of the Mendeleev Periodic Table

A new table of chemical elements



The Frank Laboratory of Neutron Physics, 17 October.
The seminar dedicated to the 80th birthday of E. Shabalin

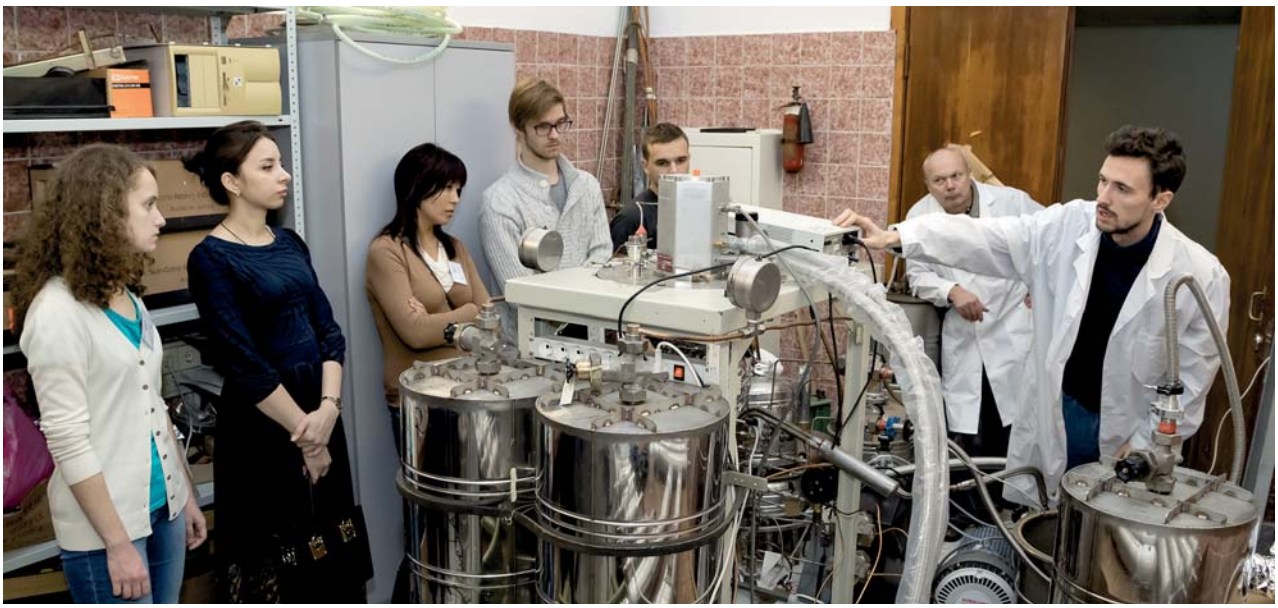
The Frank Laboratory of Neutron Physics, 6–9 June.
Participants of III International Conference on Small-Angle Neutron Scattering (YuMO2016)

The Frank Laboratory of Neutron Physics. The inelastic neutron scattering spectrometer NERA

The Frank Laboratory of Neutron Physics. The CARS microspectrometer

The Frank Laboratory of Neutron Physics, 23 June.
Participants of a meeting of the PAC for Nuclear Physics. An excursion around the Laboratory

The Frank Laboratory of Neutron Physics, 7–11 November.
The international scientific school for young scientists and students "Instruments and Methods of Experimental Nuclear Physics. Electronics and Automatics of Experimental Facilities"



Dubna, 16 September. A ceremonial meeting dedicated to the 50th anniversary of the establishment of JINR's Laboratory of Information Technologies. Presentation of a birthday cake

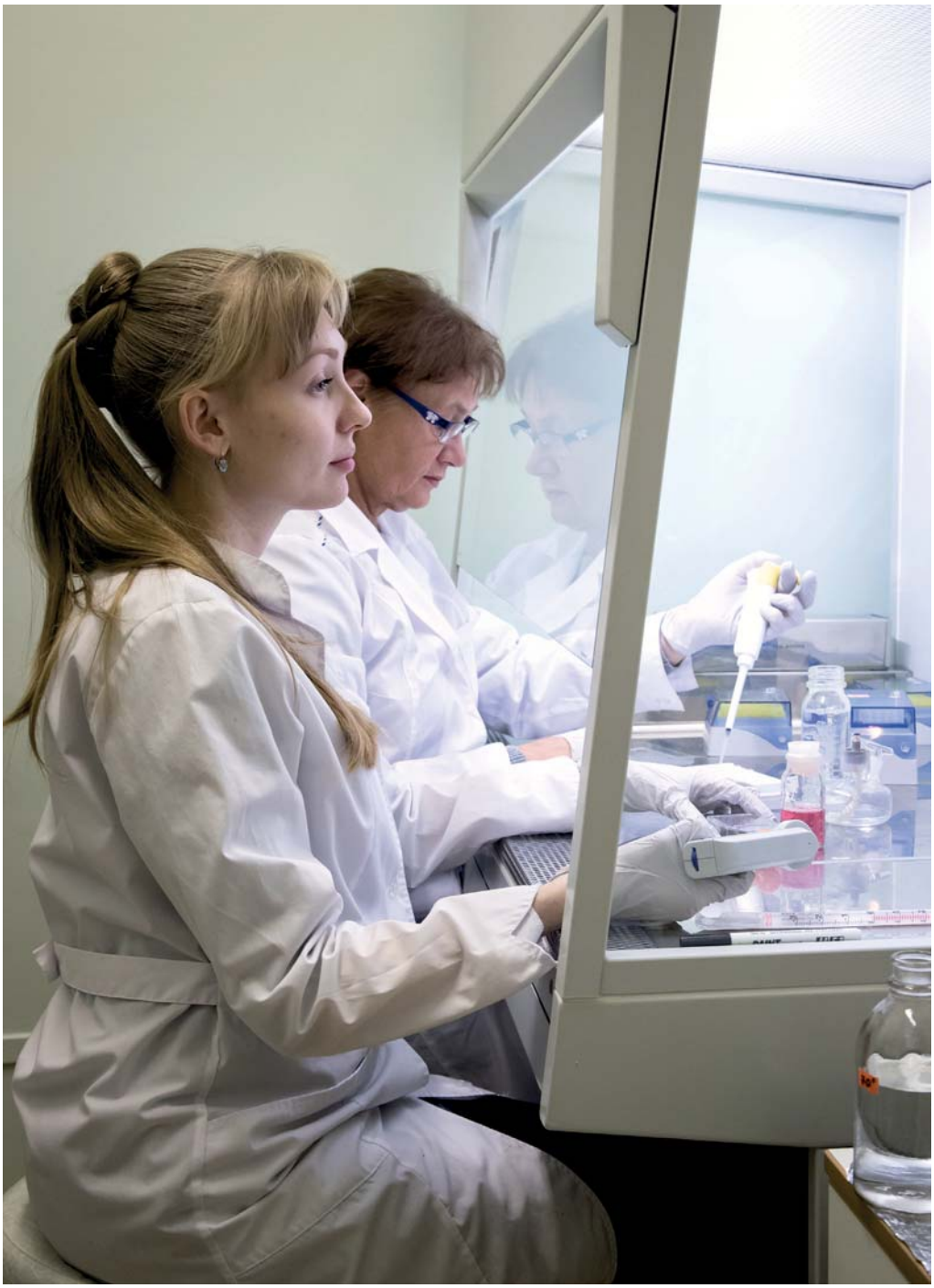
The Laboratory of Information Technologies, 4–9 July.
The 7th international conference "Distributed Computing and Grid Technologies in Science and Education"

The Laboratory of Information Technologies. The control room of the JINR Multifunctional Information and Computing Complex

Dubna, 24–28 October. The 7th JINR–CERN school on information technology “Grid and Advanced Information Systems at CERN”

Dubna, 1–2 June. Participants of the international conference “Modern Trends in Radiobiology and Physiology”

The Veksler and Baldin Laboratory of High Energy Physics, 12–13 December.
The round table in the framework of the international seminar “Biology and Materials” (*photo by E. Goryachkin*)



The Laboratory of Radiation Biology. Investigation of radiation effects

Dubna, 23 May – 11 June. The international practice for students from ARE.
Doing class research projects

Dubna, 19–25 June. School for Teachers of Physics from JINR Member States

Dubna, 5–23 September. The 3rd stage of the JINR International Student Practice

Dubna, 27–29 March. Physics Days on the occasion of the 60th anniversary of JINR

2016

CENTRAL SERVICES

PUBLISHING DEPARTMENT

In 2016, the Publishing Department issued 92 titles of publications and 45 titles of official documents.

Among the books of abstracts and proceedings of various conferences, schools and workshops organized by JINR that appeared in 2016 are the following ones: the Book of Abstracts of the III International Conference on Small-Angle Neutron Scattering dedicated to the 80th anniversary of Yu. Ostanevich, the Book of Abstracts of the 7th international conference "Distributed Computing and Grid Technologies in Science and Education", the Book of Abstracts of the VIII International Symposium on Exotic Nuclei (EXON 2016), the Proceedings of the 4th South Africa–JINR Symposium "Few to Many Body Systems: Models, Methods and Applications", the Proceedings of the XXIII International Seminar on Interaction of Neutrons with Nuclei (ISINN-23), the 4th issue of the Proceedings of the joint scientific seminar of the RDMS CMS collaboration "Physics on the Large Hadron Collider", the Proceedings of the conference "Urgent Problems of Radiobiology and Astrobiology. Genetic and Epigenetic Effects of Ionizing Radiations" and others.

The JINR Annual Report for the year 2015 (Russian and English versions) and the Annual Report of the Frank Laboratory of Neutron Physics of JINR for the year 2015 were published.

The most important publications issued in 2016 are a monograph by Yu. Penionzhkevich and R. Kalpakchieva "Light Nuclei at the Border of Neutron Stability", a handbook by V. Zagrebaev "Nuclear Reactions with Heavy Ions", a book of memoirs about Academician A. Baldin "He Was Always Confident in His Ideas".

Two books dedicated to the jubilee of the Laboratory of Information Technologies were published: a volume of memoirs of LIT staff members "It Hasn't Been a While, It Was So Long Ago. . . " and a collection "That Very 'Impulse' " compiled based on the materials of the popular wall newspaper "Impulse" at JINR, which was issued by the staff of the Laboratory in 1963–1989.

In the series of the JINR UC study guides, three manuals were issued.

In 2016, six issues of the journal "Physics of Elementary Particles and Atomic Nuclei" (brief name "Particles and Nuclei") that included 53 reports, as well as 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-one issues of the JINR weekly newspaper "Dubna: Science, Cooperation, Progress" were published in 2016.

In the framework of exchange of scientific publications, the organizations that cooperate with JINR (in over 40 countries of the world) received 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 146 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 published in the journals "Nuclear Physics", "Theoretical and Mathematical Physics", "Instruments and Experimental Techniques", "Radiation Biology. Radioecology", "Biochemistry", "Crystallography", "Journal of Surface Investigation. X-Ray, Synchrotron and Neutron Techniques", "Mathematical Models and Computer Simulations", and other periodicals.

To keep readers of the 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 2015" 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, various posters, including those for photo exhibitious organized at JINR and other world scientific centres on the occasion of the 60th auniversary of JINR.

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. A new service for large-format (A0) document scanning was offered. Over 116 thousand various forms were printed.

SCIENCE AND TECHNOLOGY LIBRARY

In 2016, the JINR Science and Technology Library (STL) rendered services to 2424 readers. 8880 copies of publications were given out. As of 1 January 2017, the Library stock amounted to 436 014 copies, 192 160 of them being in foreign languages. 168 publications ordered by readers were received via the inter-library loan system. 296 requests from other libraries were completed. On the whole, the Library received 2694 copies of books, periodicals, preprints and theses from all compiling sources, including 1149 publications in foreign languages. All the new publications were registered in the central catalogues, branch catalogues and in the automated library information system "Absotheque".

The weekly express bulletins "Books", "Articles", "Preprints" (156 issues) were published, including 8044 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". The exhibitions of new acquisitions of books, preprints, periodicals and theses were arranged weekly. 2444 publications were displayed on them. Four topical exhibitions were organized.

The electronic catalogues of books, journals, articles, preprints and theses are available online at http://lib.jinr.ru/cat.htm. The total number of requests to the electronic catalogues was 14 000. The service of online ordering of literature via OPAC (Online Public Access Catalogue) continues to be available for users.

"The Bibliographic Index of Papers Published by JINR Staff Members in 2015" (1425 titles) was prepared by the JINR Science and Technology Library and published by the JINR Publishing Department. The Index is available on the Library website, in the section "Services". The database of papers of JINR scientists is Internet accessible. The bibliographic index "Books and Monographs Published by JINR Staff Members in 1956–2016" was prepared for the 60th anniversary of JINR.

3064 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 online versions of these journals.

The Scientific Electronic Library is used by readers very actively. The total number of requests to the journal online versions through the Scientific Electronic Library and sites of foreign publishing houses was 150 000.

Due to the Library participation in the RFBR and NEICON Consortium, JINR scientists are provided with the electronic access to the full-text versions of journals of the publishing houses Elsevier and Springer, of the American Physical Society, as well as to the journal "Nature" and information retrieval databases Web of Science, MathSciNet and Scopus. The electronic books of Cambridge University Press were purchased.

Within the framework of the project "History of JINR and Dubna in Books, Journals and Central Newspapers", 120 new bibliographic records have been introduced.

In 2016, in exchange for JINR publications printed by the JINR Publishing Department, the Library received 420 publications from 13 countries. Of them 69 issues were from Russia, 8 from Romania, 6 from Ukraine, 230 from Germany, 7 from France, 26 from Japan, and 33 from CERN.

In 2016, within the framework of the automated library information system "Absotheque", the input of documents to electronic catalogue was for: books — 684 titles, journals — 1744 numbers, preprints — 3645 titles, theses and authors' abstracts — 175 titles, book articles — 770 titles, and journal articles — 7738 titles.

As of 1 January 2017, the total number of records in the automated library information system "Absotheque" was 272 735.

LICENSING AND INTELLECTUAL PROPERTY DEPARTMENT

In 2016, 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 2015–2016. Arrangements were done; changes, alterations and clarifications were agreed upon and included in the application documents according to the comments rendered by FIIP experts. In order to define the technical level of new elaborations made by JINR staff members for the purpose of patentability, a number of elaborations by JINR staff members were inspected: objects of legal protection were defined and classified according to the International Patent Classification (IPC); analogues and prototypes were searched. Reports on patent studies were prepared; for eight elaborations, in collaboration with the authors, packages of submission documents were prepared and forwarded to RF Rospatent to obtain patents for inventions:

— "A device for emission and mass spectral analysis of organic substances";
— "An experimental method of prevention of neurological disorder status and muscle tonus in acute disease";
— "A method of charged particle beams focusing";
— "A method of slow extraction of charged particle beam";
— "A method of multiturn injection of charged particles into circumferential accelerator";
— "A method of changing reactivity in nuclear facilities on fast neutrons with threshold-fission isotopes";
— "A cryogenic flanged two-part linkage for ball-type cold neutron moderator";
— "A semiconductor pixel detector of charged ionizing particles".

In 2016, work was completed on applications sent earlier and five RF patents were obtained for the inventions:

— "A device to measure angle of plane" by A. Volkov;
— "A method to measure the spectrum of transferred neutron pulse" by Yu. Nikitenko;
— "A method and device to measure the profile of neutron beam (beams)" by V. Bystritsky, V. Slepnev, N. Zamyatin;
— "A method to adjust high-frequency resonator to resonance frequencies with scheduled rate" by S. Prokhorov;
— "A device to measure location of wires in gaseous wire chambers" by L. Glonti, V. Kekelidze, Yu. Potrebennikov, V. Samsonov, T. Jenik, A. Kolesnikov, S. Movchan, A. Sotnikov.

As of 1 January 2017, JINR possesses 60 RF patents for invention in force.

Patents and Information. In 2016, 36 issues of the Federal state institution "Federal Institute of Industrial Property" of the bulletin "Inventions. Utility Models" were received at JINR. Since 2014 this bulletin has been received at JINR in electronic version based on the information search system "Mimoza". It contains full descriptions of patents for inventions, English abstracts for inventions, formulae of useful models and announcements about changes in the legal status.

The information published in the bulletins was processed with respect to the JINR topics. The processing results were presented in 12 issues of the LIPD bulletins "Patents" distributed in departments of JINR. The LIPD stock is 3271 Rospatent bulletins.

The LIPD page on the JINR website is regularly updated.

Standardization. Standard library was supplemented with: 45 new intergovernmental and state RF standard documents (GOSTs), 12 GOST directories

and standard information directories for 2016, directories of national standards and technical conditions, guidelines, recommendations and regulations issued in 2016. Over 399 alterations were introduced to relevant documents of the standard library files and subscribers' copies on the basis of these norm documents (NDs). Eighty GOST official copies and other norm documents were distributed in departments for permanent use. 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 2016, the database contains over 6000 references of standards and NDs with hyper reference to these documents located on the sites of the Federal Agency of Technical Regulation and Metrology (ROSSTANDART) and the legal reference system KONSULTANT PLUS.

"The Index of Standard Regulations and Norm Documents Used by the Joint Institute for Nuclear Research for Its Activities in the Use of Atomic Energy" (JINR Index AE-2016) was issued and distributed.

The electronic version of the Index contains direct references to official documents located on sites of the RF Government and in the legal reference system KONSULTANT PLUS.

Amendments were introduced to the index of licenses received from the RF federal bodies for authorization for business connected with accomplishment of JINR Charter functions.

2016

ADMINISTRATIVE ACTIVITIES

FINANCIAL ACTIVITIES

In 2016, a total of 120.04 M$ arrived in JINR, which makes 58% of the scheduled budget incomes.

Compared to 2015, the contribution payment was less regular. Many Member States paid their contributions only at the end of the year, even more aggravating the situation in financing of the Institute activities in 2016, which was already complicated by the scarcity of funds.

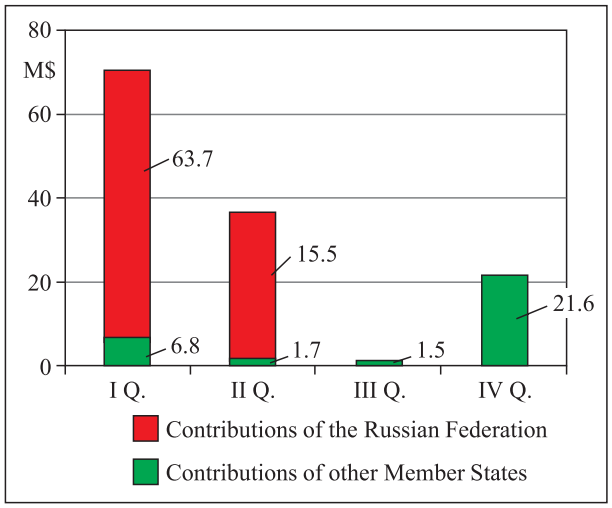


Fig. 1. Quarterly arrival of contributions by Member States in 2016

The main issues of expenses were meant for payment of wages of the Institute staff and provision for material expenses in implementation of the main scientific projects, such as:

— development of the accelerator complex NICA;

— development of the cyclotron complex DRIBs-III;

— neutrino programme;

— development of the nuclear research facility IBR-2 and research spectrometers;

— information, computer and network support of JINR activities.

According to the accounting report, the total actual expenses in 2016 amounted to 150.3 M$, at 210.6 M$ scheduled; i.e., 71% of budget expenditures were executed.

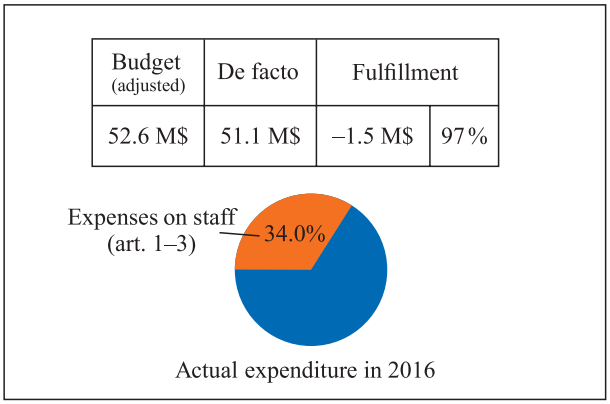


Fig. 2. Actual expenses on staff in 2016

The expenses on staff in 2016 were 51.1 M$. This fraction of the total actual expenditure is 34.0%.

The actual material expenses in 2016 were about 72.0 M$. Due to considerable underfunding, they were 39 M$ lower than those scheduled in the budget. Their fraction in actual expenditure in 2016 was 48%.

Chapter 1 Scientific research		Chapter 2 Basic facilities		Chapter 3 Laboratory infrastructure		Chapter 4 JINR infrastructure		Total on Chapters 1–4	
Schedule, k$	De facto, k$	Schedule, k$	De facto, k$	Schedule, k$	De facto, k$	Schedule, k$	De facto, k$	Schedule, k$	De facto, k$
156 339.9	105 705.0	11 450.3	6 803.9	21 212.7	18 817.6	21 615.0	18 958.3	210 617.9	150 284.8

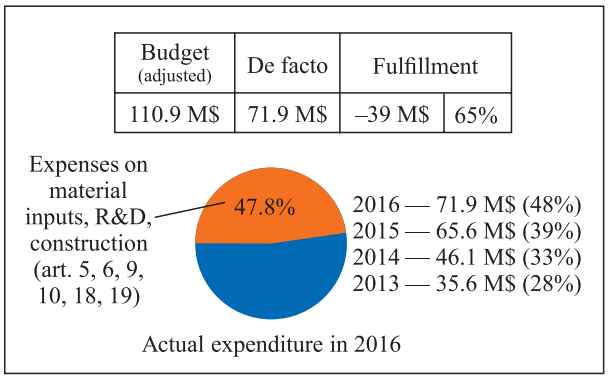


Fig. 3. Actual expenses on material inputs, R&D and construction in 2016

The actual expenses for international cooperation were 8.1 M$, which is 62% of the total sum. A big part of these costs includes business trips of JINR staff members to CERN and other large scientific centres and states that concluded agreements on cooperation with JINR, being not JINR Members.

The actual expenses on electricity, heat energy and water supplies in 2016 were 4.3 M$.

Other expenses in 2016 were mainly connected to the infrastructure. At year-end, they totaled to 14.9 M$.

In 2016, 7.3 M$ were used for capital and current repair works. 5.1 M$ of them were used by Laboratories for building repair in the sites of the Institute.

2.2 M$ were used for repair of buildings and constructions of the all-Institute infrastructure.

In 2016, the expenses are greatly increased in the consolidated item "Material Inputs, Research & Development, Construction". In total, they are 110.6 M$. More than a half of this sum is scheduled for the NICA project. Over 85% of all material expenses will be forwarded to scientific projects.

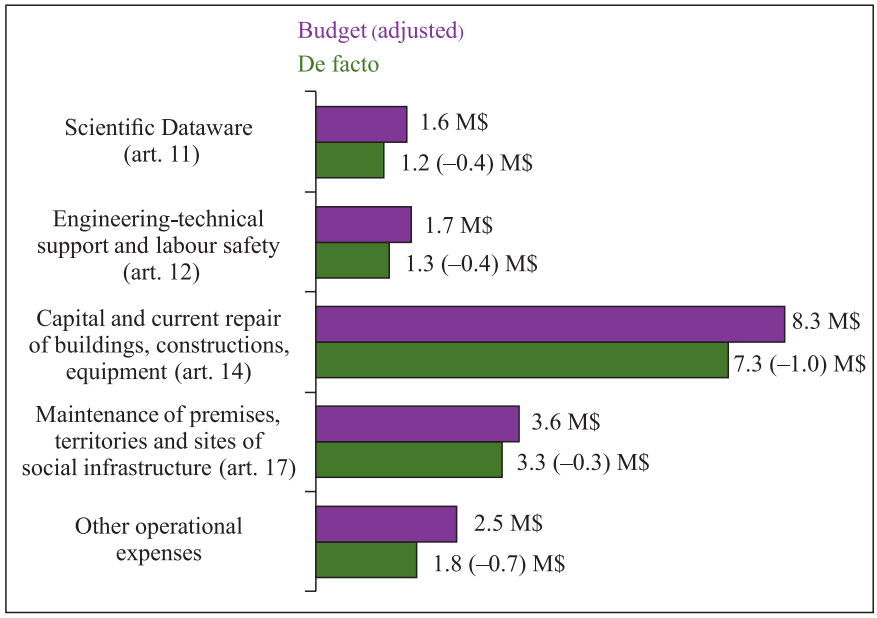


Fig. 4. Fulfillment of operational expenses in 2016

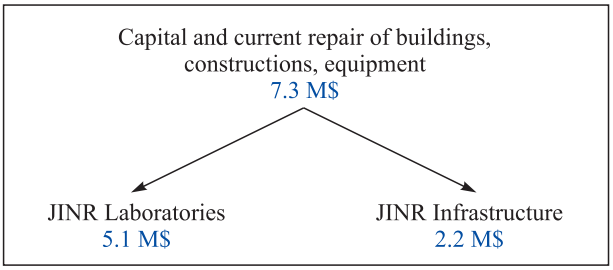


Fig. 5. Capital and current repair in 2016

STAFF

As of 1 January 2017, the total number of staff members at the Joint Institute for Nuclear Research was 4913.

Working at JINR are: RAS Academicians V. Matveev, Yu. Oganessian, M. Ostrovsky, G. Trubnikov; 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, T. Ravdandorzh, B. Yuldashev; 236 Doctors of Science, 578 Candidates of Science, including 66 Professors and 25 Assistant Professors.

In 2016, 573 persons were employed and 461 persons discharged because of engagement period expiry and for other reasons.

AWARDS

For the services for JINR, long-standing and fruitful work, 968 staff members of JINR were honored, including 3 staff members awarded the title ***"Honorary Worker of RF Science and Technology"***; 4 staff members awarded the title ***"Honorary Worker of Science of the Moscow Region"***, and 71 staff members awarded the title ***"Honorary JINR Staff Member"***. One staff member was presented ***the Award of the Governor of the Moscow Region in Science and Innovations for Young Scientists.*** A number of staff members of the Institute 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
D. Chudoba
S. Dotsenko
N. Golovkov
E. Ivanova
I. Koshlan
S. Pakuliak
D. Peshekhonov
D. Podgainyj
A. Shabashova
I. Shcherbakova
Yu. Shimanskaya
S. Sidorchuk
I. Titkova
L. Tyutyunnikova
A. Vasiliev

Translation by
M. Aristarkhova
T. Avdeeva
S. Chubakova
L. Galimardanova
O. Kronshtadtov
I. Kronshtadtova
S. Negovelov
M. Potapov
G. Sandukovskaya
S. Savinykh

Design by
Yu. Meshenkov

Photography by
I. Lapenko
E. Puzynina

Joint Institute for Nuclear Research. 2016

Annual Report

2017-10

Редакторы *Е. И. Кравченко, Е. И. Крупко*
Корректор *Т. Е. Попеко*
Компьютерная верстка *И. Г. Андреевой, Е. М. Граменицкой,*
Е. В. Дергуновой, Л. В. Пахомовой, Т. А. Савельевой

Подписано в печать 24.05.2017.
Формат 60×84/8. Печать цифровая.
Усл. печ. л. 22,6. Уч.-изд. л. 30,1. Тираж 170 экз. Заказ № 59120.

Издательский отдел Объединенного института ядерных исследований
141980, г. Дубна, Московская обл., ул. Жолио-Кюри, 6.
E-mail: publish@jinr.ru
www.jinr.ru/publish/