2015

JOINT INSTITUTE FOR NUCLEAR RESEARCH

Joint Institute for Nuclear Research

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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

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INTRODUCTION

The international community of JINR staff members achieved great success in most important trends of research in 2015. With the Seven-Year Plan of JINR Development for 2010–2016 having been completed, JINR was to work out and provide thorough discussions of the strategic plan of JINR development for the next period of seven years — 2017–2023. The administration of JINR and its advisory bodies state that the scientific community of the Institute has successfully accomplished this important task. The participants of the session of the Committee of Plenipotentiaries of the Governments of the JINR Member States, held in November 2015 in Minsk, approved the concept and parameters of the new seven-year programme. The CP session highly estimated the work of our staff members, marked great effort aimed at the achievement of bright scientific results and outspread of international cooperation in science.

Speaking about key results of the year, I would like in the first place to underline the utmost importance of the IUPAC decision to recognize the discoveries of elements 113, 115, 117 and 118 that were the result of many years of research held primarily at FLNR of JINR. The priority of the discovery of elements 115 and 117 has been given to the collaboration JINR – the Livermore National Laboratory (USA) – the Oak Ridge National Laboratory (USA). The priority of the discovery of element 118 has been given to the collaboration JINR – the Livermore National Laboratory.

The signing of the quadripartite protocol on 17 December in Beijing (China), during the 20th regular meeting of Heads of the Chinese and Russian Governments, among the RF Ministry of Education and Science, the Ministry of Science and Technology of China, the Academy of Sciences of China and the Joint Institute for Nuclear Research on joint development of the megaproject NICA in Dubna is also a significant event in the activities of the Institute that was so anticipated at JINR. Another important achievement of 2015 in timely implementation of the NICA project was the signing of contracts on the international level: with the company "Strabag" — to construct building for NICA, with the company ASG — to manufacture a magnet for MPD. These very important documents make it possible to schedule a detailed plan to put the collider into operation in 2019.

Over the past year, the complexity and speed of activities on the NICA project grew in various directions. A line was constructed for manufacture, assembling and testing of superconducting magnets; about 400 magnets will be produced and tested for the accelerator facilities NICA (JINR) and FAIR (Germany).

A good result of the year is definitely the output beam to check the main ion-optical parameters of the new fragment separator ACCULINNA-2 in the U400M cyclotron channel. The kinematic separator SHELS was launched into operation. The efficiency of this new setup was demonstrated in the first full-scale experiment at the U400 accelerator. The construction of the factory for superheavy elements was continued more actively, the project DRIBs-III was further developed with active participation of enterprises and organizations from the JINR Member States and other industrialized countries.

To secure a leading role for JINR in neutrino physics and astrophysics, which is the most fundamental and rapidly developing field of modern physics, unique tasks are solved at the Institute: a scientific-research infrastructure was established of the foremost level that

conducts studies in astrophysics of neutrino at the unique neutrino telescope Baikal-GVD and multifaceted fundamental and applied research at the antineutrino beams of the Kalinin atomic power station. In 2015, the cluster "Dubna" was deployed and put into operation in Lake Baikal. It is the first cluster of the neutrino telescope of the cubic km scale Baikal-GVD, which is one of the most powerful neutrino high-energy detectors in the Northern hemisphere.

The research pulsed reactor IBR-2 operated with full power after its refurbishment had been completed, strictly according to the project parameters. By all means, high scientific significance should be marked of the results obtained at IBR-2 spectrometers and their interdisciplinary features. The wide User Programme deployed at these spectrometers is implemented successfully. In 2015, 197 applications for experiments from 19 countries of the world were received within the framework of the User Programme.

An important part of upgrading of the setup IREN was finished: the mean energy of accelerated electrons was doubled that increases the power of the accelerated beam and, correspondingly, the neutron yield from the irradiated target by more than an order.

An important cycle of research was conducted with the application of nuclear physics methods that include gamma-spectroscopy and radioecology in global problems of the environment that produce effects on our planet. It should be mentioned that young researchers from various countries of the world took an active part in these studies.

Theoreticians of the Institute obtained valuable interesting results. The analysis of the vacuum stability in the Standard Model of elementary particle physics was conducted. Two-loop matching, three-loop renormalization group evolution, and pure QCD corrections through four loops were performed. An upper bound was derived on the pole mass of the top quark by requiring that the Standard Model be stable all the way up to the Planck mass scale. The obtained value of the top-quark mass conforms to the modern experimental one.

The JINR group presented the results of the two-antiproton correlation function with the data taken by the STAR experiment. The results provide fundamental information for understanding the structure of antinuclei and their properties.

New precision results on the measurement of the neutrino oscillation parameters were obtained by scientists from JINR for the Daya Bay (China) experiment on the basis of enlarged statistics. The result is the most accurate measurement of the oscillation amplitude in the world.

In 2015, new Borexino results on geo-neutrino flux measurement were published. For the first time in history of observation of geo-neutrinos it can be stated with probability of 98% that the geo-neutrino signal has non-null gain from the mantle. The second important result is the acquisition of the best restriction for the electron lifetime in relation to the decay with electric charge breaking.

In November 2015, it was announced that the collaborations Daya Bay, KamLAND, Super-Kamiokande, SNO and T2K/K2K were awarded the biggest Prize in science "Breakthrough Prize" in fundamental physics, for "the discovery and studies of neutrino oscillations". JINR staff members who took part in these experiments received the Prize.

Dubna scientists developed a device of a new construction — a laser detector of angular oscillations of the Earth surface where the resolution of $5 \cdot 10^{-9}$ rad was achieved. This result is of great importance as it gives new opportunities to precision studies of angular oscillations of surfaces. The detector can be the start to produce a new generation of instruments for research of fundamental tasks in science and technology.

The use of JINR accelerators solved the central task of radiobiology: key factors were established that determine various biological effectiveness of ionizing radiation with different physical characteristics. Mechanisms of radiation-induced mutagenesis were studied in cells with various levels of biological organization. Regularities and mechanisms of radiation damage formation were defined in the eye structures (cataractogenesis, retina damage) and different parts of the central nervous system of experimental animals at the action of radiation of different quality. Pioneer research was conducted in astrobiology. In collaboration with specialists from the Italian universities, unique data were obtained in modeling the synthesis of prebiotic compounds (the basis for generation of live systems) in space. Together with the Russian Academy of Sciences, large-scale research was conducted in nuclear planetology.

Much progress was achieved in the development of information technology and computer infrastructure of the Institute. A Centre of the Tier-1 level was put into operation for the CMS experiment at the Large Hadron Collider (LHC, CERN). The Centre is a basic JINR facility; it

provides for necessary conditions for the full-scale involvement of JINR physicists, the JINR Member States, the RDMS–CMS collaboration in processing and analysis of the data from the CMS experiment.

In 2015, 485 students and postgraduates took courses at the UC of JINR at basic chairs of MSU, MPhTI, "Dubna" University and universities of the JINR Member States. 134 students took part in the three-stage summer student practice in scientific trends of JINR. The development of a scientific engineer group was continued on the UC basis to use operating stands and physics simulators in order to train engineers-physicists and technical specialists.

The efforts undertaken by the JINR administration to widen cooperation, attract new countries to the JINR community and integrate the research programme and JINR facilities into the European and world scientific infrastructure can be considered quite fruitful; they make it possible to promote and enrich international cooperation.

While we are approaching the 60th anniversary of the Joint Institute, JINR Days were organized and held in the Member States on the occasion of the coming jubilee. Their agenda included topical events and fruitful meetings.

Another bright event within the framework of the JINR jubilee was held at the end of the year in Dubna — a photo gallery was ceremonially opened at the International University "Dubna". The portraits were displayed there of JINR physicists after whose names Dubna streets and alleys in the Institute sites were called — those scientists who represent the world of big science.

Today it is utterly important to create modern and comfortable conditions for young scientists who come to work at the Institute. In this connection, special attention is paid to the programme of development and improvement of social infrastructure, in particular, sports grounds were upgraded in the stadium "Nauka", the hostel for young staff members of JINR and the hotel for JINR personnel and participants of conferences and seminars were reconstructed.

All these achievements show that the Institute is on the upswing, developing intensively, due, to a large extent, to active integration with world scientific community. Together with our colleagues from the Member States, scientific partners from leading research centres and universities of the world, we are preparing to celebrate the 60th anniversary of the establishment of our Institute, our "common home on the bank of the Volga" and will do our best to make this milestone anniversary a motive to strengthen the prestige of JINR in the world scientific community, to solidate all staff members and their colleagues in the Member States and JINR Associate Members to achieve joint goals.

V. Matveev
Director
Joint Institute for Nuclear Research

2015

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 25–26 March. It was chaired by the Plenipotentiary of the Government of the Republic of Bulgaria, L. Kostov.

The Committee of Plenipotentiaries (CP) considered the report "Recommendations of the 117th Session of the JINR Scientific Council (February 2015). Results of JINR Activities in 2015" presented by JINR Director V. Matveev. The CP took note of the recommendations of the 117th session of the JINR Scientific Council, as well as of the information presented by the JINR Directorate on the implementation of the JINR Plan for Research and International Cooperation in 2014 and on the plans for JINR activities in 2015. The Committee recognized the large amount of high-quality physics results obtained last year by JINR scientists at the home facilities, as well as at external accelerators and reactors. In view of the complicated financial and economic situation, the CP commissioned the JINR Directorate to take the necessary measures to concentrate the available financial resources on the major projects of the seven-year plan.

The CP supported the Directorate's decisions and plans to preserve the engineering, social and sports infrastructure, and to develop it actively in the interests of JINR. The Institute is in a phase of active development. The opportunities afforded to JINR scientists and specialists by the experimental research base are expanding. With this in mind, the infrastructure of JINR should meet the modern requirements and have attractive environment for the staff and guests.

Given the current objective problems in the execution of the General Contractor Contract for the construction of FLNR's new experimental building (under the DRIBs-III project), resulting in an unacceptable delay in putting into operation a new basic facility of JINR, the CP endorsed the actions of the JINR Directorate to terminate the contractual relationship with the general contractor, in accordance with the current legislation of the Russian Federation; and commissioned the Directorate to organize a tender in order to select a new general contractor for the completion of the construction.

The CP asked the Plenipotentiaries to provide assistance to the JINR Directorate in carrying out events dedicated to the 60th anniversary of JINR in their respective countries.

Based on the report "Execution of the JINR Budget in 2014" presented by S. Dotsenko, Chief Accountant of JINR, the CP took note of the information presented, empowered the company "MS-Audit" to examine the Institute's financial activity for the year 2014, and approved the plan for auditing the financial activity as presented by the JINR Directorate.

Regarding the report "Results of the Meeting of the JINR Finance Committee Held on 23–24 March 2015" presented by S. Kulhánek, Chairman of the Finance Committee, the CP approved the Protocol of this meeting and JINR's report on the execution of the budget for the year 2014 in expenditure amounting to US$139 603.4 thousand and in income — to US$154 442.4 thousand.

The CP approved the plan of objectives of the Working Group for JINR Financial Issues under the CP Chairman for the years 2015–2016. It also endorsed the principles of the new method-

ology for calculating the scale of the Member States' contributions as formulated by the Working Group.

The CP postponed the approval of the final version of the new methodology for the scale of contributions, taking into account the principles and rules developed by the Working Group and the monitoring of their implementation, until the next session of the Committee of Plenipotentiaries in November 2015. Based on the decision of the Committee of Plenipotentiaries taken on 25–26 March 2014, it commissioned the JINR Directorate to submit to the Plenipotentiaries, until 1 May 2015, the rationale and amendments proposed for inclusion in the standard documents regulating the financial activities of JINR.

The CP extended, from 2017, the rule for the annual provision by the Member States of direct costs for the personnel sent to JINR by the Plenipotentiaries. It added a clarification to this rule stating that beginning from 2017 the minimum amount of money paid annually by each Member State to the JINR budget should be not less than the sum of direct costs for the personnel sent by the Plenipotentiaries over the calendar year preceding the year in which the Member States' contributions were calculated, plus 20% of this amount to compensate for JINR infrastructure costs, plus the grants of the respective Plenipotentiary and the cooperation programmes (up to 20%). In addition to its contribution, each Member State may fund individual projects of its interest.

The CP instituted a rule on the need to implement measures to ensure the industrial return in the contribution of a Member State in the amount of not less than 20% on the basis of the JINR tendering procedures.

The CP approved the "Regulation for the Intellectual Property Policy of JINR".

Due to the noncompliance of the Democratic People's Republic of Korea and of the Republic of Uzbekistan with the requirements of the Charter of JINR, the CP entrusted its Chairman to head a commission composed of the Plenipotentiaries of the Governments of the Republic of Azerbaijan, the Republic of Bulgaria, the Republic of Kazakhstan, the Republic of Poland, and of the Russian Federation to develop, by the CP next meeting, proposals concerning the future participation of the Democratic People's Republic of Korea and of the Republic of Uzbekistan in the activities of JINR.

Regarding the "Progress Report on the NICA Project" presented by JINR Vice-Director G. Trubnikov, the CP expressed satisfaction with the work accomplished by the JINR Directorate on the international tender to select the general contractor for the construction of the NICA complex, as well as with the results of the audit of the project, the analysis of its budget estimates, and of the adaptation of the project to modern world standards for preparing projects of similar facilities.

The CP agreed on the essential terms of a General Contractor Contract presented for the construction of the NICA complex: the cost estimate, the payment periods, and the work schedule for construction. It commissioned the JINR Directorate to conclude this contract with the consortium proposed by the Directorate (CJSC "Strabag" — the general contractor, Budostal-3 and PSJ — the potential contractors for NICA construction).

The CP endorsed the proposed plan to select a general contractor for the manufacture of the superconducting solenoid for the MPD detector, with an essential condition of the contract being for the general contractor to be fully responsible for the characteristics of the magnet, measured after its assembly and testing in the permanent location in the experimental hall. Only companies that have a positive experience of producing similar-sized superconducting solenoids should be considered as potential general contractors.

The CP welcomed the attraction of companies from the JINR Member States as subcontractors for the manufacture of the magnet yoke and associated equipment on the optimal competitive terms.

The CP expressed appreciation to the Plenipotentiaries of the Governments of the Republic of Bulgaria, Romania, the Slovak Republic, the Republic of Poland, and the Czech Republic for their active position in supporting the inclusion of the NICA project in the European Roadmap for Research Infrastructures.

The CP heard two invited reports: "CERN's Highlights in Research and Technology" presented by A. Zalewska, President of the CERN Council, and "CERN–JINR: 50 Years of Collaboration" presented by R. Voss, Head of CERN's International Relations Department, and thanked the speakers. The Committee also thanked LIT Director V. Korenkov for the report "Tier-1 Centre for the CMS Experiment at the Laboratory of Information Technologies" presented at the session.

A regular session of the Committee of Plenipotentiaries of the Governments of the JINR Member States was held on 20–21 November in Minsk (Belarus). It

was chaired by the Plenipotentiary of the Government of the Republic of Bulgaria, L. Kostov.

The Committee of Plenipotentiaries (CP) congratulated Academician I. Tighineanu (Republic of Moldova) on the award by the Scientific Council of the title "Honorary Doctor of JINR", in recognition of his outstanding contribution to the development of science and the education of young scientists.

The CP heard and discussed the report "Recommendations of the 118th Session of the JINR Scientific Council (September 2015). Brief Overview of the Results of JINR Activities in 2015 and Plans for 2016. Main Directions of the JINR Strategic Development for the Years 2017–2023" presented by JINR Director V. Matveev. The CP took note of the information presented by the JINR Directorate on the work towards attaining the goals of the current seven-year plan and towards implementing the recommendations of the Finance Committee and the decisions of the Committee of Plenipotentiaries, as well as the preliminary results of implementing the JINR Plan of Research and International Cooperation in 2015. The Committee approved the recommendations of the 117th and 118th sessions of the Scientific Council and the JINR Topical Plan of Research and International Cooperation for 2016.

The CP recognized the achievements of the JINR international staff of scientists and specialists in implementing the plans for research and international cooperation endorsed by the Scientific Council, the efforts of the JINR Directorate to ensure achieving the priority tasks of the Seven-Year Plan for the Development of JINR (2010–2016), as well as to provide financial resources for the ongoing research projects and the upgrade of experimental facilities in accordance with the priorities adopted by the CP.

The CP endorsed the Directorate's activities for the development and comprehensive discussion of the draft of the main directions of the strategic plan for the development of JINR for 2017–2023.

The CP supported the Directorate's activities aimed at expanding the horizons of cooperation with scientific research organizations of countries which are not members of JINR, at establishing strong scientific links with research centres in India, Brazil, China and other countries expressing their intention to join the Institute's scientific programme and to contribute to the development of the JINR research infrastructure. It also endorsed the efforts undertaken to deepen JINR's relations with major international scientific organizations and JINR's integration into the European and global research infrastructures.

The CP endorsed the activities of the Directorate aimed at improving the staff policy, the system of organization of scientific activities and the efficiency of governance, at strengthening the role of tendering procedures and control over the execution of decisions.

Regarding the report "Preparation of the Seven-Year Plan for the Development of JINR for 2017–2023" presented by JINR Chief Scientific Secretary N. Russakovich, the CP endorsed the main directions of the new plan noting that its scientific programme should be balanced with the financial strategy and staff policy.

The CP wished to consider the preliminary draft of the new seven-year plan based on the budget forecast for the forthcoming period at the session in April 2016 and expects submission of the Seven-Year Plan for the Development of JINR (2017–2023) for approval by the Committee of Plenipotentiaries in November 2016.

Based on the report "Draft Budget of JINR for the Year 2016" presented by S. Dotsenko, Chief Accountant of JINR, the Committee approved the JINR budget for the year 2016 with the total expenditure amounting to US$207.36 million and the contributions of the Member States for the year 2016. The Committee confirmed, as adopted at the CP session on 21–22 November 2014, the provisional volumes of the JINR budget in income and expenditure for the year 2017 amounting to US$212.58 million and for the year 2018 amounting to US$217.82 million, as well as the provisional sums of the Member States' contributions and of arrears payments, subject to adjustment in view of the financial strategy of the Institute for the years 2017–2023 and of the new methodology for calculating the scale of contributions.

Regarding the report "Results of the Meeting of the JINR Finance Committee Held on 17–18 November 2015" presented by S. Kulhánek, Chairman of the Finance Committee, the CP approved the Protocol of this meeting and the finalized Principles of the new methodology for calculating the Member States' contributions.

The CP instituted a rule on the need to implement measures to ensure the industrial return for a Member State in the amount of not less than 20% of its contribution on the basis of the JINR tendering procedures.

The CP took note of the report by the JINR Directorate on the work done to implement the decisions of the Working Group with respect to the standard documents regulating the financial activities of the Institute.

The CP commissioned the Working Group to submit a revised version of the "Financial Regulations of JINR" for approval by the Finance Committee and by the Committee of Plenipotentiaries in April 2016.

The CP took note of the proposal by the delegation of the Republic of Poland on the expedience of a possible improvement of the methodology for calculating the scale of the Member States' contributions, consisting of two components and based on an analysis of its application within five years. The first component takes into account Gross Domestic Product. The second component reflects the real participation in the activities of JINR. Measures of the real participation should be direct costs for the personnel sent by Plenipotentiaries, costs for their participation in the scientific activities at JINR and for international cooperation, cost of grants of the relevant Plenipotentiary and of cooperation programmes.

The CP commissioned the JINR Directorate to prepare an analysis of the current results of the Seven-Year Plan for the Development of JINR (2010–2016) and submit it for consideration to the Finance Committee and the CP in April 2016.

Based on the report "Results of the Audit of the JINR Financial and Economic Activities for the Year 2014" presented by A. Sedyshev, Director of the company "MS-Audit", and the recommendations of the Finance Committee, the CP approved the auditors' report for 2014 and commissioned the Working Group for JINR Financial Issues under the CP Chairman to include in its work plan the consideration of issues of improvement of financial and economic activities of the Institute, as marked by the auditors and being within the competence of the Finance Committee and the CP.

As proposed by CP Chairman L. Kostov — due to the expiration, on 31 December 2016, of the term of office of the present Director of JINR, the CP called the election of the JINR Director for the CP session to be held on 4–5 April 2016 and to be conducted in accordance with the JINR Charter and the Regulation for the Director of JINR. Written proposals for the nomination of candidates for the position of the JINR Director should be presented by the Plenipotentiaries of the JINR Member States to the CP Chairman not later than three months before the election date.

Based on the "Recommendations of the CP's Commission Concerning Further Participation of the Democratic People's Republic of Korea and the Republic of Uzbekistan in the Activities of JINR" presented by CP Chairman L. Kostov, the CP suspended the memberships of the Democratic People's Republic of Korea and of the Republic of Uzbekistan in the Joint Institute for Nuclear Research until the time when these states will again be able to implement fully their obligations to the Institute. The Committee commissioned the JINR Directorate to prepare, until 20 December 2015, a document clarifying the rules of practical implementation of this decision and the particularities of relationships between JINR and the countries whose memberships have been suspended. It requested the Plenipotentiaries to negotiate this document until 20 January 2016.

Regarding the information "Activities Dedicated to the 60th Anniversary of JINR" presented by D. Kamanin, Deputy Head of the JINR Science Organization and International Cooperation Department, the CP endorsed the efforts being undertaken by the JINR Directorate to organize conferences, round tables, and exhibitions commemorating the 60th anniversary of JINR in the Member States with a view to strengthening and further developing the scientific and technological contacts, and attracting young people.

A separate Ceremonial meeting dedicated to the 60th anniversary of JINR is to be held in Dubna on 5 April 2016. The CP invited all the Member States of JINR to send their national delegations to participate in this event at the level of senior representatives of governments, national academies of sciences and relevant ministries. The Committee commissioned the JINR Directorate to prepare the Programme of the Ceremonial meeting, envisaging in it the possibility for the heads of the national delegations to present welcoming speeches, awards of distinguished scientists and other staff members of JINR with orders and medals of the Member States, a gala concert of masters of art, and relevant protocol events.

The CP thanked A. Shumilin, Plenipotentiary of the Government of the Republic of Belarus to JINR, for the report "Results and Prospects for the Development of the Belarus–JINR Cooperation" presented at this session.

SESSIONS OF THE JINR SCIENTIFIC COUNCIL

The 117th session of the JINR Scientific Council took place on 19–20 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 2014), about the major results achieved by JINR in 2014 and about the activities planned for 2015.

FLNR Director S. Dmitriev reported the progress of construction of a Factory of Superheavy Elements, and VBLHEP Director V. Kekelidze made a progress report on the NICA project. The Scientific Council received a report from the Detector Advisory Committee (DAC) for the BM@N project presented by DAC member I. Tserruya.

The recommendations of the Programme Advisory Committees were reported by I. Tserruya (PAC for Particle Physics), W. Greiner (PAC for Nuclear Physics), and O. Belov (PAC for Condensed Matter Physics).

The Scientific Council heard the following scientific reports: "Astroparticle Physics: From ApPIC to ApPEC" presented by M. Spiro and "Scientific Heritage of F. Shapiro: From the 20th Century to the 21st Century" by V. Shvetsov. Also were presented the best reports by young scientists which had been recommended by the PACs.

The N. Bogoliubov Prize, the B. Pontecorvo Prize, and diplomas to the winners of JINR prizes for the year 2014 were awarded.

The endorsement of appointments of Deputy Directors of VBLHEP and LRB took place at the session.

Resolution. General Considerations. The Scientific Council took note of the comprehensive report presented by JINR Director V. Matveev. It welcomed the continuous support given by the JINR Member States despite the current difficult economic situation. The Scientific Council expressed its high appreciation of the efforts being taken by the Plenipotentiaries of the Governments of the Member States which guarantee not only the implementation of the current seven-year plan, but also the future development of JINR.

The Scientific Council was impressed by the wealth of high-quality physics results obtained last year by JINR scientists at the excellently operating home facilities, as well as at external accelerators, reactors and in other collaborations.

The Scientific Council took note of the decisions of the session of the Committee of Plenipotentiaries (CP) of the Governments of the JINR Member States held in November 2014. The Scientific Council was pleased with the decision to grant the European Organization for Nuclear Research the status of Observer at JINR, following a similar decision on the status of Observer of JINR at CERN taken earlier by the CERN Council. The Scientific Council regards this reciprocal arrangement as a strategic step towards intensifying the mutually beneficial partnership between these two international organizations, which have a long history of cooperation.

The Scientific Council noted the information on the ongoing interactions of JINR with major European science organizations, like NuPECC, ESFRI, ApPEC and others, which will definitely serve to promote effective international cooperation in the respective fields of research.

The Scientific Council welcomed the election of Professor A. Maggiora (INFN, Turin, Italy) as a new member of the JINR Scientific Council.

Recommendations on Reported Activities. The Scientific Council devoted particular attention to the accomplishment of the two main JINR strategic objectives, namely, the construction of the Factory of Superheavy Elements and of the NICA complex.

Concerning the report "Progress of Construction of a Factory of Superheavy Elements (SHE)" presented by FLNR Director S. Dmitriev, the Scientific Council noted that the construction of the DC-280 cyclotron and of the new experimental instruments was proceeding on schedule. Certain problems arose due to the delay in the civil construction of the SHE experimental hall; however, the necessary measures have been taken to resume this work. The Scientific Council recommended that the JINR and FLNR Directorates continue to work towards the successful achievement of this major project and to minimize any time delay. It concurred with the recommendation of the PAC for Nuclear Physics that the additional time due to the delay of the civil construction should be used to intensify the preparation of experiments, including the development of targets for high-intensity beams.

GOVERNING AND ADVISORY BODIES OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

COMMITTEE OF PLENIPOTENTIARIES OF THE GOVERNMENTS OF THE JINR MEMBER STATES

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Ukraine	– D. Soloviev
Republic of Uzbekistan	– A. Inoyatov
Socialist Republic of Vietnam	– Le Hong Khiem

Finance Committee

One representative of each JINR Member State

SCIENTIFIC COUNCIL

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Co-Chairman: M. Waligórski (Republic of Poland)
Scientific Secretary: N. Russakovich

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N. Tonchev	– Bulgaria
Tran Duc Thiep	– Vietnam
N. Tyurin	– Russia
M. Waligórski	– Poland
I. Wilhelm	– Czech Republic
A. Zagorodny	– Ukraine
G. Zinovjev	– Ukraine
Not appointed	– Uzbekistan

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

The Scientific Council noted with satisfaction the progress in implementing the NICA project as presented in the report by VBLHEP Director V. Kekelidze, in particular: the selection of a general contractor and the preparation of the construction site, the ongoing preparation of TDRs for the main subsystems of the MPD detector, the active work for the serial production of superconducting magnets for the NICA booster and collider, as well as for the FAIR SIS-100 accelerator, of mRPC TOF detectors for BM@N and MPD, of the TPC detector for MPD, of the electromagnetic calorimeter modules, and of the silicon vertex detector for BM@N, MPD and CBM. The Scientific Council understood the delays in signing the contracts for the construction of the collider building and the fabrication of the MPD magnet. Noting the importance of the NICA project for JINR, the Scientific Council encouraged the JINR Directorate to continue providing funds for the activities under this project.

The Scientific Council took note of the report from the Detector Advisory Committee (DAC) for the BM@N project presented by Professor I. Tserruya. The Scientific Council noted with satisfaction the ongoing interactions of the BM@N DAC and the BM@N team in defining the BM@N detector concept and the various detector components, as well as in evaluating the physics reach and performance of the detector. The Scientific Council fully supported the DAC's recommendation on a timely implementation of the experiment, thanked the members of the DAC for the detailed evaluation of the project, and recommended continuation of regular reviews.

Recommendations in Connection with the PACs. The Scientific Council supported the recommendations made by the PACs at their January 2015 meetings as reported at this session by I. Tserruya, Chairperson of the PAC for Particle Physics, by W. Greiner, Chairperson of the PAC for Nuclear Physics, and by O. Belov, Scientific Secretary of the PAC for Condensed Matter Physics. The Scientific Council suggested that the JINR Directorate should take into account these recommendations in preparing the JINR Topical Plan of Research and International Cooperation for 2016.

Particle Physics Issues. The Scientific Council appreciated the progress towards realization of the MPD project, sharing the PAC's concern on the two important milestones remaining on the critical path — the general contract for construction of the collider building and the contracts for the MPD magnet fabrication. It supported the recommendations on consolidation of all necessary efforts to avoid any further delay in approval of these contracts. The timetable of the entire project cannot be defined before these contracts are signed.

The Scientific Council recognized the important role of the Detector Advisory Committee (DAC) for the optimization of the BM@N experimental setup and looked forward to the results of the first test run scheduled on February–March 2015 aimed at assessing beam quality, test detector response, trigger, and integrated DAQ system of BM@N.

The Scientific Council noted the PAC's appreciation of the already well-developed consolidation plan of the JINR neutrino programme presented by the DLNP Directorate.

The Scientific Council supported the PAC's recommendations on the continuation of the ongoing projects in particle physics within the suggested time scales, as outlined in the PAC report. This is particularly true for the LHC project and experiments where the contribution to the upgrade should be well balanced with a strong involvement in the analysis.

Nuclear Physics Issues. The Scientific Council recognized the significant progress made in modernizing the infrastructure in the IREN accelerator building and the successful tests of the new klystron modulators delivered to JINR. It recommended that the FLNP Directorate provide assistance for the completion of the world-class neutron source with neutron intensities up to 10^{13} s^{-1} to make sure that the scientific programme can be achieved by 2016.

The Scientific Council appreciated the research work and developments carried out under the theme "Non-Accelerator Neutrino Physics and Astrophysics" which concerns studies of the weak interaction by looking for new or rare phenomena. The participation in the international projects of this theme provides a strong base and know-how for the development of home-based neutrino experiments at two basic facilities — the laboratories located at the Kalinin NPP and at Lake Baikal.

The Scientific Council appreciated the quality of the results obtained in the SuperNEMO, GERDA, and EDELWEISS projects, recognized the high quality of the preparatory work for the reactor antineutrino investigations within the GEMMA and DANSS projects, as well as the high scientific importance of the BAIKAL project with JINR's leading role in its implementation. It recommended extension of this theme and its projects for another three years.

The Scientific Council supported the recommendations on the continuation of the research programme of the FASA-3 project (investigations of very hot nuclei produced by relativistic light-ion projectiles and of thermal multifragmentation dynamics). It also supported the extension of the theme "Improvement of the JINR Phasotron and Design of Cyclotrons for Fundamental and Applied Research", which is focused on the development and improvement of accelerators for hadron therapy applications.

Condensed Matter Physics Issues. The Scientific Council highly appreciated the quality and interdisciplinary character of the main scientific results in the field of condensed matter research and instrumentation developments at the IBR-2 facility achieved in 2014. In particular, it welcomed the upgrade plans for the HRFD spectrometer. The new instrumentation developments will open new opportunities in the research programme and will be important for attracting more users of IBR-2 instruments. In this regard, the successful implementation of the FLNP User Programme at the IBR-2 spectrometers plays an important role. The Scientific Council concurred with the PAC that further development of the User Programme should be continued and that the scientific results achieved should be actively disseminated among research centres in the Member States.

The Scientific Council appreciated the new opportunities for high-performance computing opened by the HybriLIT heterogeneous computing cluster newly implemented at LIT, and supported the PAC's recommendation on further development of this facility in order to cover the wide range of user interests.

Common Issues. The Scientific Council welcomed the plans of the PACs to participate in the preparation of a new Seven-Year Plan for the Development of JINR (2017–2023) and to consider the proposals from the Laboratories expected to be presented at the next meetings in June 2015.

The Scientific Council encouraged the JINR Directorate to reconsider the possible gain in efficiency and synergy by organizing all neutrino research activities under the same umbrella programme.

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: "A Model of Sequential Electron Transport in the Graphene–Nucleotide–Graphene System. DNA Decoding", "Feasibility Study of $\Phi(1020)$ Production at NICA/MPD", "Analysis of Experimental Data from the Dynamic Albedo of Neutron (DAN) Instrument for NASA's Mars Science Laboratory", and thanked the speakers: V. Katkov (BLTP), L. Yordanova (VBLHEP), and P. Dubasov (FLNP). The Scientific Council welcomed similar reports in the future.

Memberships of the PACs. As proposed by the JINR Directorate, the Scientific Council appointed I. Štekl (IEAP CTU, Prague, Czech Republic) as a new member of the PAC for Nuclear Physics for a term of three years.

Scientific Reports. The Scientific Council highly appreciated the reports "Astroparticle Physics: From ApPIC to ApPEC" and "Scientific Heritage of F. Shapiro: From the 20th Century to the 21st Century", and thanked Professors M. Spiro and V. Shvetsov for their informative presentations.

Awards and Prizes. The Scientific Council congratulated Professors B. Sharkov (Russia) and Gh. Stratan (Romania) on the award of the diplomas "Honorary Doctor of JINR".

The Scientific Council approved the Jury's recommendations on the JINR prizes for 2014 in the annual scientific research competition in the fields of theoretical physics, experimental physics, physics instruments and methods, and applied physics.

The Scientific Council congratulated Professors M. Henneaux (ISIPC and ULB, Brussels, Belgium) and V. Rubakov (INR RAS, Moscow, Russia) on the award of the N. Bogoliubov Prize for their outstanding achievements in theoretical and mathematical physics, promoting international cooperation and educating young scientists. The Scientific Council thanked Professors M. Henneaux and V. Rubakov for their excellent presentations.

The Scientific Council congratulated Professor G. Domogatsky (INR RAS, Moscow, Russia) on the award of the B. Pontecorvo Prize for his outstanding contributions to high-energy neutrino astrophysics and neutrino astronomy, in particular, his pioneering development of a high-energy neutrino detection method by an underwater detector and construction of the detector at Lake Baikal. The Scientific Council thanked Professor G. Domogatsky for his excellent presentation.

Appointment of Deputy Directors of JINR Laboratories. The Scientific Council endorsed the appointment of H. Khodzhibagiyan, Yu. Potrebenikov, A. Sorin, and A. Vodopyanov as Deputy Directors of VBLHEP and the appointment of V. Lisý and G. Timoshenko as

Deputy Directors of LRB until the completion of the terms of office of the Directors of these Laboratories.

The Scientific Council agreed with the proposal of the VBLHEP Directorate to postpone the endorsement of appointment of the fifth Deputy Director until the next session of the Scientific Council.

The Scientific Council encouraged the JINR Directorate to look for outstanding candidates from all the Member States and to try to promote a gender balance.

The 118th session of the JINR Scientific Council took place on 24–25 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 the preliminary results of implementing the current Seven-Year Plan for the Development of JINR (2010–2016), the start of planning for the next seven-year period, the latest events in JINR's international cooperation, and the forthcoming celebration of the 60th anniversary of the Institute.

The Scientific Council heard proposals for the First Draft of the JINR Seven-Year Development Plan (2017–2023) presented by Vice-Directors G. Trubnikov, R. Lednický, and M. Itkis.

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: "Project SKA" presented by Professor R. Adam and "Report on the SQM 2015 Conference and on the South Africa–NICA Round-Table Workshop" presented by Professor J. Cleymans. The Scientific Council also heard the best reports by young scientists as recommended by the PACs.

V. Matveev presented the Directorate's proposals for the award of the title "Honorary Doctor of JINR". Diplomas to the winners of JINR prizes for the year 2014 were presented.

Endorsement of the appointment of a VBLHEP Deputy Director took place at the session.

Resolution. General Considerations. Based on the report presented by Director V. Matveev, the Scientific Council recognized that the main objectives of the current seven-year plan have been achieved by JINR. These include the timely commissioning of the modernized IBR-2 reactor, the fabrication of the main systems for the DC-280 cyclotron, the progress in upgrading the Nuclotron–NICA accelerator complex, the start-up of the Tier-1 centre at JINR, the commissioning of the Dubna cluster of the Baikal-GVD facility and the first data already collected from it. The Scientific Council congratulated the JINR staff on these important results.

The Scientific Council appreciated the recent signing of the contract on the NICA complex civil construction as a very significant step towards timely realization of the NICA facility and congratulated the JINR Directorate on this important event.

The Scientific Council took note of the situation with the construction of the SHE Factory building and urged the Directorate to take all possible measures for reducing the accumulated delay in starting experiments at this important facility.

The Scientific Council reiterated its recognition of the ongoing efforts aimed at the integration of JINR's research programme and facilities into the European and worldwide landscape, which allows the international cooperation in science to be intensified and enriched.

The Scientific Council noted the start of preparation of the next Seven-Year Plan for the Development of JINR for the years 2017–2023 in view of the progress of the current seven-year plan by the end of 2016.

Recommendations for the First Draft of the JINR Seven-Year Development Plan (2017–2023). The Scientific Council took note of the proposals for the First Draft of the JINR Seven-Year Development Plan (2017–2023) presented by Vice-Directors G. Trubnikov (Development of the JINR scientific infrastructure), R. Lednický (Particle physics and high-energy physics, Information technology), M. Itkis (Low- and intermediate-energy nuclear physics, Nuclear physics with neutrons, Condensed matter physics).

The Scientific Council noted that the main principles for elaborating this plan should be the continuity of the ongoing research programme with the new opportunities afforded by the novel technical developments, strengthening the personnel in quality and number, and optimizing the management and the corresponding regulations.

In view of these principles, the tasks to be addressed in the new seven-year plan should be as follows:

— focusing on the effective use of new and upgraded basic facilities built under the cur-

rent seven-year plan (modernized IBR-2, SHE Factory);

— constructing the first stage of the NICA complex (2019);

— promoting international cooperation around JINR's major facilities and further integrating these facilities into the European and worldwide research infrastructures;

— adapting the human resources to the requirements of the new basic facilities;

— attracting new countries to the JINR community;

— adjusting the general infrastructure and modus operandi of JINR in accord with the experience of international research centres of excellence.

The Scientific Council recommended that the Directorate continue its work towards completing the seven-year plan and looks forward to its further consideration at the next session.

Recommendations in Connection with the PACs. The Scientific Council took note of the recommendations made by the PACs at their June 2015 meetings 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 2016.

Particle Physics Issues. The Scientific Council noted the progress in upgrading the Nuclotron–NICA accelerator complex: development of the production line for manufacturing the superconducting magnets, diagnostic systems, ion source, commissioning of the new linear accelerators, and other NICA elements and systems.

The Scientific Council appreciated the successful collaboration work of the MPD Detector Advisory Committee and the MPD team, and the progress in implementing the MPD project — preparation of the TDR for the main detector subsystems, preparation of the structural elements of the facility, and development of the technological sites for detector series manufacturing which should proceed in accordance with a complete integration plan of the full MPD detector. The Scientific Council supported the PAC's recommendation to assign more manpower into this flagship project of JINR.

The Scientific Council noted the considerable progress achieved by the BM@N team, including simulation results and results of the first technical run. It supported the PAC's recommendations on further developments of the project and cooperation with the FAIR CBM team and negotiations with other external groups for possible collaborations.

The Scientific Council supported the PAC's decision on the approval of ongoing projects and new projects in particle physics only until the end of the current seven-year plan, with the exception of large projects where it is clear that the Institute commitments go beyond that date. Given the ongoing preparation of the next Seven-Year Development Plan, this recommendation will allow maximum flexibility to the Laboratories and Institute management in determining their priorities.

Nuclear Physics Issues. The Scientific Council took note of the PAC's recommendations concerning the concluding theme "Physics of Light Mesons" proposed for extension. The research programme of the theme related to investigation of production, decay and interaction of light mesons and muons is aimed at determining the symmetries and the interaction dynamics. The theme includes five projects (COMET, GDH&SPASCHARM, MEG-PEN, SPRING, TRITON) and two experiments (MUON, PAINUC) performed at various accelerators in the world. During the reported period of 2013–2015, numerous new results were obtained, published and reported at international conferences.

The Scientific Council appreciated the high quality of the investigations performed under the theme "Physics of Light Mesons" and supported its continuation in 2016. The theme and its projects will be re-examined within the framework of the new seven-year plan.

Condensed Matter Physics Issues. The Scientific Council highly appreciated the efforts being undertaken by the FLNP Directorate to develop the IBR-2 instruments. It noted, in particular, the implementation of the Real Time Diffractometer, a new instrument designed to study irreversible processes in solids *in situ* and in real time, which is already operational within the User Programme. Given the successful completion of the construction of this instrument, the Scientific Council concurred with the PAC's recommendation on the closure of the project "Diffractometer for Studies of Transient Processes in Real Time at the IBR-2 Reactor".

The Scientific Council endorsed the PAC's recommendations on extension of the theme "Medical and Biological Research with JINR Hadron Beams" for 2016. It noted the high

scientific and social importance of the results achieved for the last three years in the field of clinical research on proton radiotherapy applications in the treatment of different diseases, as well as in the fields of radiobiology and radiation genetics.

The Scientific Council appreciated the first scientific results achieved at LRB in the field of astrobiology. Using JINR accelerators and in collaboration with specialists from the Italian universities, new data were obtained on modeling the synthesis of prebiotic compounds in space. Recognizing the successful start of this activity, the Scientific Council supported the PAC's recommendation on extension of the theme "Research on Cosmic Matter on the Earth and in Nearby Space; Research on the Biological and Geochemical Specifics of the Early Earth" for 2016.

Common Issues. The Scientific Council took note of the PAC's recommendations on the first proposals from the Laboratories for the new Seven-Year Development Plan (2017–2023) in the respective areas of activity. Discussions of the First Draft of this plan are envisaged for the next meetings, with emphasis on the time scales for the various research programmes. The Scientific Council highly appreciated the willingness of the PACs to contribute to the preparation of this important document.

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: "Methods of Increasing the Efficiency of Registration of the Rare Decay $K_L^0 \to \pi^0\nu\overline{\nu}$ in the E391 Experiment", "Production of Straw Tubes for the COMET Experiment", "Study of Crystal and Magnetic Structures of Nanostructured Lanthanum–Strontium Manganites in a Wide Pressure and Temperature Range", and thanked the speakers: Yu. Stepanenko (DLNP), N. Tsverava (DLNP), and N. Belozerova (FLNP). The Scientific Council welcomed similar reports in the future.

Memberships of the PACs. As proposed by the JINR Directorate, the Scientific Council appointed E. Boos (SINP, Moscow, Russia) and P. Závada (IP, Prague, Czech Republic) as new members of the PAC for Particle Physics for a term of three years. The Scientific Council thanked the outgoing member V. Savrin for his successful work as a member of this PAC.

As proposed by the JINR Directorate, the Scientific Council appointed D. Sangaa (IPT, Ulaanbaatar, Mongolia) as a new member of the PAC for Condensed Matter Physics for a term of three years. The Scientific Council thanked the outgoing member L. Dubrovinsky for his successful work as a member of this PAC.

Scientific Reports. The Scientific Council highly appreciated the reports "Project SKA" and "Report on the SQM 2015 Conference and on the South Africa–NICA Round-Table Workshop", and thanked Professors R. Adam and J. Cleymans for their informative presentations.

Awards and Prizes. The Scientific Council endorsed the proposal of the JINR Directorate to award the title "Honorary Doctor of JINR" to Professors V. Fortov (Russia), P. Fré (Italy), R.-D. Heuer (Germany), J. Khubua (Georgia), Yu. Oganessian (Russia), H. Stöcker (Germany), I. Tighineanu (Moldova), and N.-V. Zamfir (Romania), in recognition of their outstanding contributions to the advancement of science and the education of young scientists.

The Scientific Council congratulated the laureates of the JINR prizes for 2014 — winners of the annual scientific research competition in the fields of theoretical physics, experimental physics, physics instruments and methods, and applied physics.

Appointment of a VBLHEP Deputy Director. The Scientific Council endorsed the appointment of R. Tsenov as Deputy Director of the Veksler and Baldin Laboratory of High Energy Physics (VBLHEP) until the completion of the term of office of the VBLHEP Director.

MEETINGS OF THE JINR FINANCE COMMITTEE

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

The Finance Committee considered the report "Recommendations of the 117th Session of the JINR Scientific Council (February 2015). Results of JINR Activities in 2014" presented by JINR Director V. Matveev, and highly appreciated the results produced by the JINR international staff in 2014. The Committee noted that despite the difficult economic and financial situation of 2014, the execution of the JINR budget complied adequately with the decisions

of the Committee of Plenipotentiaries (CP) concerning construction of basic facilities and implementation of the JINR research programme.

The Finance Committee supported the actions of the JINR Directorate towards optimizing the use of and yielding savings in financial, material and human resources, as well as the Directorate's decisions and plans to preserve the engineering, social and sports infrastructure, and to develop it actively in the interests of JINR.

The Finance Committee endorsed the actions of the JINR Directorate to terminate the contractual relationship with the general contractor for the construction of FLNR's new experimental building (under the DRIBs-III project) and commissioned it to organize a tender in order to select a new general contractor for the completion of the construction.

Regarding the report "Execution of the JINR Budget in 2014" 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 2014 in expenditure — US$139 603.4 thousand and in income — US$154 442.4 thousand. It also recommended that the CP empower the company "MS-Audit" to examine the Institute's financial activity for the year 2014 and approve the plan for auditing the financial activity as presented by the JINR Directorate.

Expressing deep concern that the suspension of the right to vote of the Democratic People's Republic of Korea and of the Republic of Uzbekistan in the Committee of Plenipotentiaries, due to the financial arrears of these Member States in contributing to the JINR budget within more than two years since this decision was taken, has not entailed the reduction of debt, the Finance Committee recommended that the CP consider overcoming this situation.

Based on the report "Results of the Meeting of the Working Group for JINR Financial Issues under the CP Chairman Held on 16–17 February 2015" presented by A. Khvedelidze, Chairman of the Working Group, the Finance Committee recommended that the CP approve the plan of objectives of the Working Group for JINR Financial Issues under the CP Chairman for the years 2015–2016 and endorse the principles of the new methodology for calculating the scale of the Member States' contributions as formulated by the Working Group. The Finance Committee recommended that the CP extend, from 2017, the rule for the annual provision by the Member States of direct costs for the personnel sent to JINR by the Plenipotentiaries, proposing that a clarification be added to this rule stating that beginning from 2017 the minimum amount of money paid annually by each Member State to the JINR budget should be not less than the sum of direct costs for the personnel sent by the Plenipotentiaries over the calendar year preceding the year in which the Member States' contributions were calculated, plus 20% of this amount to compensate for JINR infrastructure costs, plus the grants of the respective Plenipotentiary and the cooperation programmes (up to 20%). In addition to its contribution, each Member State may fund individual projects of its interest.

The Finance Committee recommended that the CP institute a rule on the need to implement measures to ensure the industrial return in the contribution of a Member State in the amount of not less than 20% on the basis of the JINR tendering procedures.

The Finance Committee recommended that the CP consider postponing the approval of the final version of the new methodology for the scale of contributions, taking into account the principles and rules developed by the Working Group and the monitoring of their implementation, until the next session of the Committee of Plenipotentiaries in November 2015. Based on the decision of the Committee of Plenipotentiaries taken on 25–26 March 2014, it was also recommended to commission the JINR Directorate to submit to the Plenipotentiaries, until 1 May 2015, the rationale and amendments proposed for inclusion in the standard documents regulating the financial activities of JINR.

The Finance Committee recommended that the CP approve the "Regulation for the Intellectual Property Policy of JINR", the draft of which was presented by A. Ruzaev, Assistant Director of JINR for Innovation Development.

Regarding the "Progress Report on the NICA Project" presented by JINR Vice-Director G. Trubnikov, the Finance Committee endorsed the work accomplished by the JINR Directorate on the international tender to select the general contractor for the construction of the NICA complex, as well as the results of the audit of the project, the analysis of its budget estimates, and of the adaptation of the project to modern world standards for preparing projects of similar facilities. It recommended that the CP agree on the essential terms of a General Contractor Contract presented for the construction of the object: the cost estimate, the payment periods, the work schedule for the construction of the NICA complex, commissioning the JINR Directorate to conclude this contract with the consortium pro-

posed by the Directorate (CJSC "Strabag" — the general contractor, Budostal-3 and PSJ — the potential contractors for NICA construction).

The Finance Committee supported the proposed plan to select a general contractor for the manufacture of the superconducting solenoid for the MPD detector, with an essential condition of the contract being for the general contractor to be fully responsible for the characteristics of the magnet, measured after its assembly and testing in the permanent location in the experimental hall. Only companies that have a positive experience of producing similar-sized superconducting solenoids should be considered as potential general contractors.

The Finance Committee endorsed the involvement of the Czech company Vitkovice as subcontractor for the manufacture of the magnet yoke and associated equipment, as well as the attraction of other companies from the JINR Member States on optimal competitive terms.

The Finance Committee heard a report "Precise Measurement of Charged Pion Polarizability in the COMPASS Experiment" presented by A. Guskov, Head of a DLNP Sector.

A meeting of the JINR Finance Committee was held on 17–18 November in Minsk (Belarus). It was chaired by S. Kulhánek, a representative of the Czech Republic.

The Finance Committee heard the report "Plans for Research Activities and Priorities of the Budget Policy of JINR in 2016. 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 118th session of the Scientific Council, the information presented by the JINR Directorate on the work towards attaining the goals of the current seven-year plan and towards implementing the recommendations of the Finance Committee and the decisions of the Committee of Plenipotentiaries taken in March 2015, as well as the preliminary results of implementing the JINR Plan of Research and International Cooperation in 2015.

The Finance Committee noted that the financial resources for the ongoing research projects and the upgrade of experimental facilities were being provided in accordance with the priorities adopted by the CP.

The Committee took note of the Directorate's activities for the development and comprehensive discussion of the draft of the main directions of the strategic plan for the development of JINR for 2017–2023 and of the financial strategy for these years.

The Finance Committee endorsed the activities of the Directorate aimed at improving the efficiency of governance, at strengthening the role of tendering procedures and control over the execution of decisions.

The Finance Committee recommended that the CP commission the Directorate to present a budget forecast for JINR for the period of 2017–2023 for approval by the CP in April 2016.

Regarding the report "Preparation of the Seven-Year Plan for the Development of JINR for 2017–2023" presented by JINR Chief Scientific Secretary N. Russakovich, the Finance Committee noted the importance and timeliness of drafting a new plan for the development of the Institute in view of the completion of the current seven-year plan (2010–2016).

The Finance Committee recommended that the CP commission the JINR Directorate to prepare an analysis of the current results of the Seven-Year Plan for the Development of JINR (2010–2016) and submit it for consideration to the Finance Committee and the CP in April 2016, as well as to submit the JINR Development Plan for 2017–2023 for approval by the CP in November 2016.

Based on the report "Draft Budget of JINR for the Year 2016" presented by S. Dotsenko, Chief Accountant of JINR, the Finance Committee recommended that the CP approve the JINR budget for the year 2016 with the total expenditure amounting to US$207.36 million and the contributions of the Member States for the year 2016.

The Finance Committee confirmed, as adopted at the CP session on 21–22 November 2014, the provisional volumes of the JINR budget in income and expenditure for the year 2017 amounting to US$212.58 million and for the year 2018 amounting to US$217.82 million, as well as the provisional sums of the Member States' contributions and of arrears payments, subject to adjustment in view of the financial strategy of the Institute for the years 2017–2023 and of the new methodology for calculating the scale of contributions.

The Finance Committee recommended that the Institute's Directorate address the issue of establishing the volume of commitments of the Russian Federation for the payment of its contribution to the JINR budget in the currency of the host country of JINR.

Regarding the report "Results of the Meeting of the Working Group for JINR Financial Issues under the CP Chairman Held on 1–7 July 2015" presented by JINR Vice-Director G. Trubnikov, the Finance Committee rec-

ommended that the CP approve the finalized Principles of the new methodology for calculating the Member States' contributions; institute a rule on the need to implement measures to ensure the industrial return for a Member State in the amount of not less than 20% of its contribution on the basis of the JINR tendering procedures; take note of the report by the JINR Directorate on the work done to implement the decisions of the Working Group with respect to the standard documents regulating the financial activities of the Institute; and commission the Working Group to submit a revised version of the "Financial Regulations of JINR" for approval by the Finance Committee and by the Committee of Plenipotentiaries in April 2016.

The Finance Committee took note of the proposal by the delegation of the Republic of Poland on the expedience of a possible improvement of the methodology for calculating the scale of the Member States' contributions, consisting of two components and based on an analysis of its application within five years. The first component takes into account Gross Domestic Product. The second component reflects the real participation in the activities of JINR. Measures of the real participation should be direct costs for the personnel sent by Plenipotentiaries, costs for their participation in the scientific activities at JINR and for international cooperation, cost of grants of the relevant Plenipotentiary and of cooperation programmes.

Based on the report "Results of the Audit of the JINR Financial and Economic Activities for the Year 2014" presented by A. Sedyshev, Director of the company "MS-Audit", the Finance Committee recommended that the CP approve the auditors' report for 2014 and commission the Working Group for JINR Financial Issues under the CP Chairman to include in its work plan the consideration of issues of improvement of financial and economic activities of the Institute, as marked by the auditors and being within the competence of the Finance Committee and the CP.

The Finance Committee commissioned the JINR Directorate to regularly provide to the Finance Committee and the CP a report on measures to implement the comments reflected in the acts of audits of the Institute's financial and economic activities.

The Finance Committee heard with interest the report "Educational Programmes of the JINR UC" presented by the Director of the University Centre, S. Pakuliak.

MEETINGS OF THE JINR PROGRAMME ADVISORY COMMITTEES

The 41st meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 22–23 January. It was chaired by Professor V. Kantser.

The Chairperson of the PAC welcomed two new members, Professors M. Dubničková and T. Perring, and presented a short overview of the PAC report delivered at the session of the JINR Scientific Council in September 2014 about the implementation of the recommendations taken at the previous PAC meeting. JINR Vice-Director M. Itkis informed the PAC about the Resolution of the 116th session of the Scientific Council (September 2014) and the decisions of the Committee of Plenipotentiaries (November 2014).

The PAC took note of the statistic results of the FLNP User Programme at the IBR-2 spectrometers and supported the work on the further development of this programme.

The PAC heard a report about the main scientific results in the field of condensed matter research and instrumentation developments at the IBR-2 facility achieved in 2014. Appreciating the high quality and interdisciplinary character of these results, the PAC recommended that FLNP consider the possibility of disseminating the results presented among research centres in the Member States. It also wished to hear the key results achieved worldwide in condensed matter research at neutron research facilities over the last few years. The PAC requested the FLNP Directorate to find a possibility to involve the Member States in using the IBR-2 instruments in the fields of nanoscience and nanotechnology.

The PAC noted the information presented on the status of the HRFD spectrometer, highly appreciating its upgrade plans. The PAC supported the efforts to develop high-resolution neutron techniques for pulsed neutron sources. To offer informed advice, it requested to be informed about the full upgrade programme for all FLNP instruments.

The PAC heard with interest a report on the new opportunities for high-performance computing opened by the newly implemented heterogeneous computing cluster HybriLIT at LIT. As an effective computational component of the Multi-

functional Centre for Data Storage, Processing and Analysis, HybriLIT is a highly needed facility for addressing intensive computing tasks to be faced by JINR research. In this regard, the PAC recommended further development of HybriLIT in order to cover a wide range of user interests.

The PAC considered the information presented about the international conference "Condensed Matter Research at IBR-2" (Dubna, 24–27 June 2014) and emphasized its importance for the neutron scientific community. The PAC recommended further organization of this conference every two years, with the next conference proposed to be held within the framework of the 2015 International Year of Light and Light-Based Technologies. It also suggested including neutron optical methods for matter characterization in the programme of this conference.

The PAC took note of the report about the V International Scientific School for Young Scientists and Students "Instruments and Methods of Experimental Nuclear Physics. Electronics and Automatics of Experimental Facilities" (Dubna, 10–15 November 2014). The PAC noted the high level and importance of the school for attracting young professionals to these activities and recommended further organization of this school annually.

The PAC heard information given about the round-table meeting "Topical Issues of General and Space Radiobiology and Astrobiology" (Dubna, 28–29 October 2014) which was held in memory of Academicians N. Sissakian and A. Sissakian.

The PAC heard with great interest the following scientific reports: "A Study of Hydrogen Bonding in Photo-Thermochromic and Fluorescent Colorants" (by A. Filarowski), "Latent Tracks of Swift Heavy Ions in Y–Al and Y–Ti Oxides" (by V. Skuratov), "Porous Sensors for Toxic Contaminant Analysis Based on Track Membranes with Surface-Enhanced Raman Spectroscopy Properties" (by A. Nechaev), "Induction and Repair of Clustered DNA Damage in Human Fibroblasts Exposed to Accelerated Boron Ions and Gamma Rays" (by L. Ježková), "Graphene-Based Tunnel Junction" (by V. Katkov), and "Testing Electronic Components at the FLNR Accelerator Complex" (by S. Mitrofanov). The PAC looks forward to hearing new scientific results at its future meetings.

The PAC reviewed the poster presentations by young scientists from BLTP and DLNP. It selected the poster "A model of Sequential Electron Transport in the Graphene–Nucleotide–Graphene System. DNA Decoding" (presented by O. Isaeva) as the best poster at this session and recommended it for presentation at the session of the Scientific Council in February 2015. The PAC also noted two other high-quality posters: "Positron Annihilation Spectroscopy at the LEPTA Facility" (by P. Horodek) and "X-Rays Microtomography on the MARS Scanner" (by D. Kozhevnikov).

The PAC was informed by the JINR Directorate on the start of preparation of a new Seven-Year Plan for the Development of JINR (2017–2023). The Directorate had requested the JINR Laboratories to elaborate their visions of scientific work to be accomplished during the next seven-year period and to present their first proposals in respective fields of research at the next meetings of the PACs in June 2015. The PAC emphasized the importance of this work for the future of JINR and expected to consider the proposals for this plan to be presented by the Laboratories in the field of condensed matter research at the next meeting.

As a general recommendation, the PAC suggested that, at its winter meetings, JINR Laboratories should report the results achieved in each previous year in implementing their themes and projects.

The 42nd session of the Programme Advisory Committee for Particle Physics took place on 26–27 January. It was chaired by Professor I. Tserruya.

The Chairperson presented a short 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 116th session of the Scientific Council (September 2014) and on the decisions of the Committee of Plenipotentiaries (November 2014).

The PAC was informed about the progress made in the NICA project. Note was taken that two important milestones remained on the critical path — the general contract for civil engineering and the contracts for the MPD magnet fabrication. The PAC appreciated the preparation work accomplished on these two issues since the previous report and recommended consolidation of all necessary efforts to avoid any further delay in approval of these contracts. The timetable of the entire project cannot be defined before these contracts are signed.

The PAC noted the progress achieved in the preparation of the BM@N project and supported the plan for realization of the experiment with beam extracted from the Nuclotron, awaiting

the results of the first test run scheduled for February–March 2015. The PAC appreciated the role played by the BM@N Detector Advisory Committee in optimizing the experimental setup. It also noted that the BM@N construction foresees a staging, taking into account the Nuclotron upgrade programme and subsystem developments.

The PAC was pleased to note a significant contribution made by the JINR team to the CBM project at FAIR. The PAC reckons that JINR's participation in the CBM project creates an important synergy between the FAIR and NICA projects and is important for the successful realization of the BM@N and MPD projects at Nuclotron–NICA. The Committee strongly supported continuation of the JINR group's participation in the CBM project until the end of 2020.

The PAC encouraged preparation of the HyperNIS detector for the first run with ^{7}Li beam during Nuclotron Run 50 and recommended continuation of the project until the end of 2018.

The PAC noted with interest the progress in preparing the DSS experiment with polarized deuteron beam at the Nuclotron internal target and further developments for the polarimetry at the Nuclotron with significant contribution from the Japanese collaborators. The PAC supported continuation of the DSS project until the end of 2018, requesting for its next meeting a detailed presentation of GEANT-simulation of the external beam experiment employing a 30-m-long time-of-flight system.

The PAC was pleased to recognize the achievements of the JINR group in developing the PANDA solenoid and muon subdetectors and recommended extension of the JINR group's participation in the PANDA project until the end of 2019.

The PAC appreciated the performance of the JINR group in the ATLAS experiment, the scientific significance and high quality of the results obtained during the LHC Run I, and recommended continuation of JINR's participation in the experiment until the end of 2019. The PAC also appreciated the significant contribution of the JINR groups both to the Phase-I detector upgrade and to the data analysis in the LHC experiments. It expects a reasonable visibility of the JINR groups at international conferences, a commensurate number of talks and scientific publications reflecting their major contributions.

The PAC discussed the written answers given by the proponents of the BAIKAL project and was satisfied with the information provided. It encouraged continuation of the already well-developed consolidation plan of the JINR neutrino programme.

The PAC took note of the information from the JINR Directorate on the start of preparation of a new Seven-Year Plan for the Development of JINR (2017–2023). The PAC looks forward to the proposals from the Laboratories to be considered at the next meetings.

The PAC heard the following scientific reports: "Ro-vibrational Spectroscopy of the Hydrogen Molecular Ion and Antiprotonic Helium" by V. Korobov and "Experiment DIRAC at CERN. Status and Prospects" by L. Afanasyev.

The PAC warmly encouraged the JINR Directorate to take necessary measures to increase the number of PhD students and young postdocs engaged in large projects in the Laboratories. The PAC noted with interest the poster presentations in particle physics by young scientists from DLNP and VBLHEP. It selected the poster "Feasibility Study of $\Phi(1020)$ Production at NICA/MPD" presented by L. Yordanova to be reported at the 117th session of the Scientific Council in February 2015.

The 41st meeting of the Programme Advisory Committee for Nuclear Physics was held on 29–30 January. It was chaired by Professor W. Greiner.

The Chairperson presented a short 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 116th session of the Scientific Council (September 2014) and the decisions of the Committee of Plenipotentiaries (November 2014).

The PAC heard a report about the status and further development of the IREN facility. It recommended that the FLNP Directorate provide assistance in completion of the world-class neutron source with neutron intensities up to 10^{13} s^{-1}.

The PAC took note of the report on the ongoing work to build a Factory of Superheavy Elements. It recommended that additional time due to the delay of the civil construction be used to intensify the preparation of experiments, including the development of targets for high-intensity beams.

The PAC heard a report on the theme "Non-Accelerator Neutrino Physics and Astrophysics", which is devoted to the studies of the weak interaction by looking for new or rare phenomena: neutrinoless double-beta decay, determination of the nature of the neutrinos and their

properties, interactions of neutrino with matter, and dark matter search. The PAC noted the high quality of investigations within the theme and recommended continuation of this theme and of the associated SuperNEMO, GERDA, EDELWEISS, GEMMA, and DANSS projects in 2016–2018.

The PAC heard a report and a proposal for extension of the project of deep-water investigations with the neutrino telescope at Lake Baikal (project BAIKAL). It appreciated JINR's leading role in the project implementation and recommended its continuation in 2016–2018.

The PAC heard a report on the results of numerous activities within the theme "Improvement of the JINR Phasotron and Design of Cyclotrons for Fundamental and Applied Research". It recommended continuation of the research programme under this theme in 2016–2018.

The PAC heard a report on the FASA-3 project under the theme "Research on Relativistic Heavy- and Light-Ion Physics. Experiments at the Nuclotron, SPS, and SIS18", supported the FASA-3 research programme and recommended its continuation in 2016–2017.

The PAC was informed by the JINR Directorate on the start of preparation of a new Seven-Year Plan for the Development of JINR (2017–2023). At its next session it intends to begin considering the research programmes in nuclear physics to be proposed by the Laboratories for this period and the development of associated experimental instruments.

The PAC heard with interest the following scientific reports: "Mass Distributions of Fission Fragments in the Mercury Region" by A. Andreev, "The Synthesis of Superheavy Nuclei in the $^{239,240}Pu + ^{48}Ca$ and $^{249-251}Cf + ^{48}Ca$ Reactions" by V. Utyonkov, and "Non-Stationary Quantum Phenomena in Ultracold Neutrons Optics" by A. Frank.

The PAC was pleased with the presentations of new results and proposals by FLNP young scientists. Two best posters were selected: "Analysis of Experimental Data from the Dynamic Albedo of Neutron (DAN) Instrument for NASA's Mars Science Laboratory" (presented by P. Dubasov) and "Nuclear and Related Analytical Techniques for Waste Water Bioremediation" (by I. Zinicovscaia). The report by P. Dubasov was recommended for presentation at the 117th session of the Scientific Council.

The 42nd meeting of the Programme Advisory Committee for Nuclear Physics was held on 4–5 June. It was chaired by Professor F. Piquemal.

The Chairperson presented a short 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 117th session of the Scientific Council (February 2015) and the decisions of the Committee of Plenipotentiaries (March 2015).

The PAC heard a report on the concluding theme "Physics of Light Mesons" presented by A. Kulikov with a proposal for its extension. The theme includes five projects (SPRING, GDH&SPASCHARM, COMET, TRITON, MEG-PEN) and two experiments (PAINUC, MUON). The PAC noted the high quality of all investigations performed under the theme and recommended its continuation in 2016. It will be re-examined within the framework of the new Seven-Year Development Plan (2017–2023).

A. Kulikov also reported on the SPRING project at the COSY facility. The PAC appreciated the high quality of the investigations performed in this project and recommended its extension for the next year.

The PAC heard a report on the MEG-PEN project presented by N. Khomutov. It invited the authors of the project to present a proposal for its extension at one of the next meetings of the PAC.

The PAC took note of the proposals by the Laboratories for the JINR Seven-Year Development Plan (2017–2023) in the field of nuclear physics research.

Proposals concerning the JINR Neutrino Programme at DLNP were presented by V. Bednyakov. The PAC noted the high quality and international visibility of the proposed neutrino investigations, together with the JINR leading role in a number of experiments of the highest scientific importance, such as the BAIKAL-GVD project and experiments with reactor antineutrinos at the Kalinin NPP.

FLNP proposals for the Seven-Year Development Plan were presented by V. Shvetsov. The PAC emphasized the importance of three research areas to be pursued in this period: investigations of the violation of fundamental symmetries in neutron-nuclear interactions and related data; investigations of the fundamental properties of neutron and UCN physics; applied and methodological research.

FLNR proposals for the Seven-Year Development Plan were presented by S. Dmitriev. The PAC stressed the importance of implementing the main FLNR projects: commissioning and further development of the SHE Factory; reconstruction of U400 and U400M cyclotrons and construction of a new experimental hall; and development of long-running experimental setups. The PAC supported the timeline suggested for the sequential activation of the above projects since it takes into account the continuity of the scientific experimental programme even during the stop of the accelerators.

BLTP proposals for the Seven-Year Development Plan were presented by V. Voronov. The PAC noted that the proposed programme appears to be complete, well balanced and justified.

A report on the LIT activities and proposals for the new seven-year plan were presented by T. Strizh. The PAC recognized the strategic role played by this Laboratory in providing excellent support for the information technologies and computational needs of a large and diverse scientific community.

Proposals for the development of the JINR educational programme for 2017–2023 were presented by S. Pakuliak. The PAC recognized the vital importance of this activity for the future of JINR.

The PAC took note of the directions of research for the JINR Seven-Year Development Plan proposed by the Laboratories. It looks forward to a more detailed elaboration of them.

The PAC heard two scientific reports: "Measurement of Angular Correlations of γ Rays in the Inelastic Scattering of 14 MeV Neutrons on Carbon Using the Tagged Neutron Method" presented by Yu. Kopatch and "Resonant Tunneling of Composite Systems through Repulsive Barriers" presented by S. Vinitsky.

The PAC was pleased with the presentations of new results and proposals by young scientists. Three best posters were selected: "Production of Straw Tubes for the COMET Experiment" presented by N. Tsverava, "Project EXPERT@SuperFRS" by V. Chudoba, and "Recent Experiment on Synthesizing Fl Isotopes in the $^{239}Pu + ^{48}Ca$ Reaction" presented by M. Shumeyko. The PAC recommended that the report by N. Tsverava be presented at the session of the Scientific Council in September 2015.

The 43rd session of the Programme Advisory Committee for Particle Physics took place on 15–16 June. It was chaired by Professor I. Tserruya.

JINR Vice-Director R. Lednický informed the PAC about the Resolution of the 117th session of the JINR Scientific Council (February 2015) and the decisions of the JINR Committee of Plenipotentiaries (March 2015).

Important preparation work for a new Seven-Year Development Plan of JINR (2017–2023) was launched. The PAC heard with great interest the proposals presented by directors of the Laboratories. The Committee noted that the development of a new seven-year plan is a formidable task of paramount importance for the near future of JINR. The PAC appreciated the ongoing work at the different Laboratories towards development of this plan, and expressed its readiness to contribute to, and help the Institute's management in this process as much as possible and needed.

The PAC was pleased to see the considerable progress in realization of the BM@N project, including simulation results and results of the first technical run. The Committee encouraged negotiations with the CBM team and other external groups for possible collaborations.

The PAC also appreciated the progress made in realization of the Nuclotron–NICA project and in the upgrade of the accelerator complex: development of the production line for manufacturing the superconducting magnets, diagnostic systems, ion source, commissioning of the new linear accelerators, and other NICA elements and systems. The PAC was pleased to learn that the contract for the NICA complex civil construction is expected to be signed in July 2015. The PAC recommended the extension of the Nuclotron–NICA project for five years.

The PAC and the Detector Advisory Committee for MPD appreciated the significant progress achieved by the MPD team in preparing the TDR for the main detector subsystems and the structural elements of the facility, and in developing the technological sites for detector series manufacturing. Construction of subsystems of the MPD Stage-1 detector should proceed in accordance with a complete integration plan of the full MPD detector. The PAC recommended adding more manpower into this flagship project of JINR. The PAC appreciated the progress of the negotiations towards signing the contract for the MPD magnet construction before its next meeting. It recommended the extension of the MPD project for five years.

The PAC noted the progress in upgrading the CMS and ATLAS detectors. The Committee was pleased by the development of a production area for Micromegas chambers. The PAC rec-

ommended extension of JINR's participation in CMS and ATLAS projects for three years.

Several other proposals on continuation of the projects previously approved for completion in 2015 and on two new projects were considered at this meeting. In particular, the PAC discussed the implementation of the ALPOM-2 project and appreciated the importance of measurement of the analyzing power planned under this project. The Committee heard with interest about JINR's participation in the STAR project at RHIC and noted the importance of the energy scan programme, its continuation and extension at NICA. The PAC noted the scientific significance of the NA62 experiment and appreciated the JINR contribution to the construction of the straw spectrometer for registration of secondary charged particles. The PAC recognized the progress in implementing the HADES programme under the CBM experiment at FAIR. The PAC took note of the activities in the SANC project aimed at participation in the LHC physics analyses and recommended to put some efforts in development of the NICA experimental programme. The Committee recognized the first direct solar *pp*-neutrino detection as an important achievement of the Phase II of the BOREXINO experiment. The PAC also discussed two new projects entitled "Design Work, Production, and Test of the Accelerators and Colliders Prototype Elements for Fundamental and Applied Purposes" and "Precision Laser Metrology for Accelerators and Detector Complexes".

Given the ongoing discussions on the preparation of the next JINR Seven-Year Development Plan and in order to allow maximum freedom to the Laboratories and Institute management in determining their priorities, the PAC decided to approve foregoing projects only until the end of the current seven-year plan. The exception was made for large projects (Nuclotron–NICA, MPD, CMS and ATLAS), where it was clear that the Institute commitments go beyond that date.

The PAC appreciated the reports "Evidence for Creation of Strong Electromagnetic Fields in Relativistic Heavy-Ion Collisions (a Proposal for the NICA Experiment)" presented by V. Toneev and "Project KOTO at J-PARC" presented by Yu. Stepanenko.

The PAC noted with interest the poster presentations in particle physics by young scientists from DLNP and VBLHEP. It selected the poster "Methods of Increasing the Efficiency of Registration of the Rare Decay $K_L^0 \to \pi^0\nu\overline{\nu}$ in the E391 Experiment" presented by Yu. Stepanenko to be reported at the session of the Scientific Council in September 2015.

The 42nd meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 22–23 June. It was chaired by Professor V. Kantser.

JINR Director V. Matveev presented the Honorary Diploma of JINR to Professor Emil Burzo, a member of the PAC, for his outstanding contributions to condensed matter physics and materials physics, and to the promotion of the scientific cooperation between Romania and the Joint Institute for Nuclear Research, and on the occasion of his 80th birthday.

The Chairperson of the PAC gave a short overview of the PAC report delivered at the session of the JINR Scientific Council in February 2015 concerning the implementation of the recommendations of the previous PAC meeting.

JINR Vice-Director M. Itkis informed the PAC about the Resolution of the 117th session of the JINR Scientific Council (February 2015) and the decisions of the JINR Committee of Plenipotentiaries (March 2015).

The PAC considered the reports on the themes "Medical and Biological Research with JINR Hadron Beams", "Research on Cosmic Matter on the Earth and in Nearby Space; Research on the Biological and Geochemical Specifics of the Early Earth" to be completed in 2015, and recommended their extension for 2016. Concerning the report on the concluding project "Diffractometer for Studies of Transient Processes in Real Time at IBR-2 Reactor", the PAC recommended its closure given the successful completion of this project.

The PAC heard the proposals presented by the Laboratories for the JINR Seven-Year Development Plan (2017–2023).

Concerning the FLNP draft proposals, the PAC recognized the relevance of the scientific tasks and their compliance with the technical, financial and human resources of the Laboratory. These include physics and chemistry of novel functional materials, physics of nanosystems and nanoscale phenomena, physics and chemistry of complex fluids and polymers, molecular biology and pharmacology, materials science and engineering. An important element of the next seven-year plan will be upgrade of the existing and construction of new spectrometers, as well as elaboration of the concept of the neutron source at JINR beyond the year 2033.

Concerning the LRB proposals, the PAC highly appreciated the research activities carried out by the Laboratory. The central problem

of radiobiology was solved: factors were identified determining the biological effectiveness of ionizing radiations of different quality. The mechanisms were studied of radiation-induced mutagenesis in different cells. Regularities were established of radiation damage formation in eye structures and central nervous system. Astrobiology and nuclear planetology research was conducted. The design and calculation of the biological shielding of the NICA complex are underway. The PAC supported the research planned at LRB and expansion of international cooperation in the scientific tasks to be addressed.

Taking note of the DLNP proposals, the PAC underlined the importance of the following areas of activity: design and development of semiconductor radiation-resistant detectors based on new materials and hybrid pixel detectors with high resolution; improvement of the existing and development of new instrumentation for characterization of detectors produced at JINR and the Member States; work in collaboration with other institutes in feasibility studies of application of the newly developed detectors in other areas of science and technology, in particular, applications for the MARS microCT scanner. However, the PAC recommended that the draft of the plans be radically modified in order to get a clear vision concerning opportunity and feasibility of condensed matter research in the Laboratory by elaborating a new concept of research, taking into account the specialization of DLNP and the general approaches of JINR for capacity development.

Concerning the FLNR proposals, the PAC supported the performance of the main projects of the Laboratory concurrently with the scientific programme on condensed matter physics and applied research, which includes detailed study of effects induced by heavy ions in matter, investigation of radiation resistance of materials under the influence of multicharged ions, development of next-generation track membranes with predetermined properties, synthesis of nanoobjects with unique properties, development of hybrid nanotechnologies, production of radioisotopes for nuclear medicine and radioecological studies. The PAC expects a significant enhancement of the experimental base at FLNR in the field of versatile applications of heavy-ion beams. It also underlined the possibility of involving the Member States in developing further plans.

Concerning the BLTP proposals, the PAC noted that the programme of investigations presented covers a broad spectrum of modern fundamental problems of statistical physics, condensed matter physics, and new materials. The programme appears to be complete, well balanced and justified.

With respect to the LIT proposals, the PAC emphasized the importance of creating a Multifunctional Information and Computing Complex at LIT as a vital JINR basic facility for addressing current and future challenges in the Institute's scientific research. The PAC also noted that the research planned is well founded and takes into account the fundamental interests of JINR and the Member States in the field of the development of IT and computing infrastructure. The PAC recommended the support of the programme proposed by LIT.

Regarding the UC proposals for the development of the JINR Educational Programme, the PAC supported the development of cooperation with universities of the Member States, the active participation of JINR employees in the educational process at JINR-based chairs of the leading Russian technical universities, the organization and running of annual International Student Practical Courses for students from the Member States and of scientific schools and excursions for physics teachers, school and university students at JINR and CERN. It endorsed the UC-based scientific-engineering group established to use the existing test benches and educational physical facilities for training engineering physicists and technicians. It also supported the new JINR Summer Student Programme.

The PAC was pleased with the following scientific reports: "Making Maps of Spin Dynamics" presented by T. Perring, "Quantum Models of Magnetism in Strongly Correlated Electron Systems with Strong Spin-Orbit Interaction" by V. Yushankhai, "Investigation of the Vesicular Systems via Neutron and X-Ray Small-Angle Scattering" by M. Kiselev, and "Biophotonics as a Base of Theranostics" by L. Avramov, as well as the poster presentations by FLNP young scientists.

The PAC selected the poster "Study of Crystal and Magnetic Structures of Nanostructured Lanthanum–Strontium Manganites in a Wide Pressure and Temperature Range" by N. Belozerova as the best poster at the session and recommended this poster to be reported at the session of the JINR Scientific Council in September 2015. The PAC also noted two other high-quality posters: "Research of the Coexistence of Ferromagnetism and Superconductivity in Layered Nanostructures" (V. Zhaketov) and "Detector ASTRA. New Detector Elements and Data Acquisition System" (V. Milkov).

PRIZES AND GRANTS

By the Resolution of the Scientific Council of the Institute for Nuclear Research of RAS, the **M. A. Markov Prize** was awarded to Viktor Anatolievich Matveev — JINR Director, Full Member of the Russian Academy of Sciences, for his contribution to the development of the strong interaction theory and the hadron quark model.

The **B. Pontecorvo Prize** was awarded to Professor Gianpaolo 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.

JINR PRIZES FOR 2015

I. Theoretical Physics Research

First Prizes

1. "Electromagnetic and Color Fields in Relativistic Heavy-Ion Collisions".
Authors: V. Voronyuk, G. Zinovjev, W. Cassing, S. Molodtsov, V. Toneev.

2. "Theoretical Studies of Synthesis Methods of Isotopes of New Superheavy Elements".
Authors: V. Zagrebaev, A. Karpov, W. Greiner.

Second Prize

"Lattice Studies of Landau Gauge Gluon and Ghost Propagators in Quantum Chromodynamics".
Authors: I. Bogolubsky, E.-M. Ilgenfritz, V. Mitrjushkin, V. Bornyakov, M. Müller-Preussker, A. Sternbeck.

II. Experimental Physics Research

First Prize

"Measurement of Charged-Pion Polarizability in the COMPASS Experiment".
Authors: A. Guskov, Z. Kroumchtein, A. Olshevskiy, I. Savin.

Second Prizes

1. "Effect of Compression of Charged Particle Bunches in a Trap with Electrostatic and Rotating Electric Fields".
Authors: E. Akhmanova, M. Eseev, A. Kobets, I. Meshkov, O. Orlov, A. Sidorin.

2. "Study of the ^{3}He and ^{3}H Spin Structure in the $dd \to {}^3\mathrm{He}n(\mathrm{H}p)$ Reactions at Intermediate Energies".
Authors: A. Isupov, A. Kurilkin, V. Ladygin, N. Ladygina, A. Malakhov, S. Reznikov, M. Janek, K. Suda, T. Uesaka.

III. Physics Instruments and Methods

First Prize

"Construction of the Kinematic Separator (Velocity Filter) SHELS".
Authors: A. Yeremin, A. Popeko, O. Malyshev, A. Lopez-Martens, K. Hauschild, O. Dorvaux, V. Chepigin, A. Svirikhin, A. Isaev, M. Chelnokov.

Second Prizes

1. "Problem-Oriented Complex of Programs for Solving Boundary Value Problems in the Dynamics of Few-Body Quantum Systems".
Authors: O. Chuluunbaatar, A. Gusev, S. Vinitsky, V. Gerdt, V. Rostovtsev, A. Abrashkevich, V. Debrov, A. Góźdź, P. Krassovitskiy, E. Kazaryan.

2. "Production of Intense Ion Beams from Metallic Compounds from ECR Ion Sources Using the MIVOC Method".

Authors: S. Bogomolov, A. Bondarchenko, A. Efremov, K. Kuzmenkov, A. Lebedev, V. Lebedev, V. Loginov, N. Vazvitsky, Z. Asfari, B. Gall.

IV. Applied Physics Research

First Prize

"Structure Diagnostics and Investigations of Powders and Liquid Suspensions of Detonation Nanodiamonds by Small-Angle Scattering of Thermal Neutrons".

Authors: M. Avdeev, V. Aksenov, I. Ivankov, A. Rogachev, O. Tomchuk, L. Bulavin, L. Rosta, V. Garamus, N. Rozhkova, E. Osawa.

Second Prize

"Multiphase Flow-Meters for Superconducting Accelerators, Cryogenics, and Oil Production".

Authors: A. Kakorin, A. Kovrizhnykh, V. Miklayev, Yu. Filippov.

Encouraging Prize

"Neutron Activation Analysis in Wastewater Treatment".

Authors: I. Zinicovscaia, M. Frontasyeva, O. Culicov, S. Pavlov, S. Gundorina, L. Cepoi, T. Chiriac, L. Rudi, A. Valuta, T. Mitina.

GRANTS

In 2015, 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.

The Russian Foundation for Basic Research financed JINR projects in the framework of the following competitions: "Competition of Projects of Fundamental Scientific Research" — 47 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" — 7 projects; "Regional Competition 'Central Russia'" — 2 projects; "Competition of Fundamental Oriented Research in Urgent Interdisciplinary Topics" — 11 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 Science of the Republic of Armenia — 1 project; together with the Belarussian Republican Foundation for Basic Research — 2 projects; together with the Vietnam Academy of Science and Technology — 1 project; together with the State Foundation of Natural Sciences of China — 3 projects; together with the Department of Science and Technology of the Government of India — 1 project; together with the German Scientific-Research Community — 2 projects; together with the National Centre for Scientific Research of France — 4 projects; together with the State Foundation for Basic Research of Ukraine — 1 project; together with the National Research Foundation of RSA — 1 project.

RFBR rendered financial support to JINR for organization of 11 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.

The Russian Scientific Foundation, in the framework of the competition "Fundamental Scientific Research and Scientific Research in Separate Scientific Groups", financed 3 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.

Thirteen projects were financed in the framework of the joint competition of research projects of the Belarussian Republican Foundation for Basic Research and the Joint Institute for Nuclear Research.

2015

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 2015 reflect the following data:

— joint research was conducted with scientific centres in the Member States, as well as international and national organizations in other countries, on 44 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 2991 specialists;

— for joint work and consultations, as well as for participation in meetings, conferences, and schools held at JINR, 1885 specialists were received;

— 76 international scientific conferences and schools, 20 workshops, and 13 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.

Chairman of the Egyptian Atomic Energy Authority Professor Atef A. Abdel-Fattah and Vice-Chairman of the Authority Professor Samy Sh. Soliman spent their workweek from **12** to **16 January** at JINR.

They visited IBR-2 and the IREN facility at FLNP, were shown cyclotrons MC-400 and IC-100, the microtron and the nanocentre at FLNR, were acquainted with the NICA project, detector laboratories and the factory of superconducting magnets at VBLHEP, and with the medical-technical complex, detectors for medicine, neutrino research at DLNP. The guests visited the Laboratory of Radiation Biology and the Laboratory of Information Technologies. Professor Atef A. Abdel-Fattah spoke about activities of the Egyptian Atomic Energy Authority at the seminar held at FLNR.

The visit finished with a meeting at the JINR Directorate which was attended by JINR Vice-Directors M. Itkis and R. Lednický, D. Kamanin, A. Popeko, and the Egyptian JINR staff member V. Badawi. The sides discussed prospects for further cooperation and outlined a number of new directions of cooperation, in particular, basic questions of nuclear physics, transmutation of nuclear and long-lived waste, design of detectors, and enlarging educational programmes of JINR.

On **26 January**, Ambassador Extraordinary and Plenipotentiary of the Federal Republic of Brazil to the Russian Federation Antonio José Vallim Guerreiro and his spouse came on their first official visit to the Joint Institute for Nuclear Research. They met with the JINR Directorate: JINR Director V. Matveev, JINR Vice-Director M. Itkis, JINR Chief Scientific Secretary N. Russakovich, and Head of the JINR International Cooperation Department D. Kamanin.

The guests visited the Veksler and Baldin Laboratory of High Energy Physics, where they were acquainted with the NICA project, the factory superconducting magnets, and the detector laboratories.

A regular meeting of the Joint Committee on the collaboration of the National Institute for Nuclear Physics and Particle Physics (IN2P3) (France) and JINR was held on **3 February** in Dubna.

On the French side, the meeting was attended by Director of IN2P3 J. Martineau, IN2P3 Deputy Directors for Research D. Guillemaud-Mueller, R. Gilbert Roger, U. Bassler, as well as a specialist in IN2P3 international collaboration S. Radegonde Sergent and Counsellor for Science and Technology of the French Embassy in Russia A. Michel.

JINR was represented by JINR Director V. Matveev, JINR Deputy Directors M. Itkis and R. Lednický, JINR Chief Scientific Secretary N. Russakovich, Head of the JINR International Cooperation Department D. Kamanin, Director of the Laboratory of Nuclear Problems V. Bednyakov, Director of the Laboratory of Theoretical Physics V. Voronov, and Deputy Director of the Laboratory of Nuclear Reactions A. Popeko.

After the meeting of the Coordination Committee at the JINR Directorate, the delegation members visited JINR Laboratories. They were acquainted with the work of the FLNR cyclotron complex. They visited VBLHEP, where they were told about the NICA project, the factory superconducting magnets, and the detector laboratories.

A delegation of the Embassy of the Federal Republic of Germany in Russia headed by Director of the Economics and Science Department Mr. Wolfgang Dik visited the Joint Institute for Nuclear Research on **4 February**. The delegation also included Director of the Economics and Science Department Holgar Karl Kolley, Head of the German Academic Exchange Service Office (DAAD) in Moscow, Director of the German Centre for Research and Innovation (GCRI) in Moscow Gregor Berghorn, Scientific researcher of the Science Devision of the German Embassy in Moscow Mikhail Rusakov, Head of the Department of Science, Education, Environment and Nuclear Energy, Counsellor of the German Embassy Uwe Meyer. On the JINR side, the meeting was attended by JINR Director V. Matveev, JINR Vice-Directors M. Itkis, R. Lednický, and G. Trubnikov, JINR Chief Scientific Secretary N. Russakovich, and Head of the JINR International Cooperation Department D. Kamanin.

The programme of the visit included several meetings and excursions to the JINR basic facilities. The guests visited the cyclotrons of the Flerov Laboratory of Nuclear Reactions and the MASHA facility; they were acquainted with one of the IBR-2 channels, where scientists from Germany are working, as well as with environmental research of the Frank Laboratory of Neutron Physics. In the Veksler and Baldin Laboratory of High Energy Physics, they visited the factory of superconducting magnets and the detector laboratories for the NICA accelerator complex. Development of JINR scientific relations, including relations with DAAD and GCRI, was discussed at separate meetings with JINR leaders. A special programme for Mr. G. Berghorn, who is the representative of these organizations in Moscow, was prepared; it included acquaintance with the University "Dubna" and the JINR University Centre, which were presented by UC Director S. Pakuliak.

The visit was finished with a meeting at the JINR Directorate, where both sides voiced wishes to maintain and increase scientific contacts, to move towards each other in solving financial and operational issues, as well as to attract young scientists.

On **24–25 February**, the 25th meeting of the Coordination Committee on implementation of the Agreement between the Ministry of Science and Education of Germany (BMBF) and JINR was held in Berlin on the issue of cooperation and use of JINR facilities. The German delegation was headed by Chief of the Department "Large Installations and Fundamental Research" of BMBF B. Firkorn-Rudolf; the JINR delegation was headed by JINR Vice-Director G. Trubnikov.

The meeting participants discussed the status of implementation of the Agreement, most urgent news on the development of scientific infrastructure and signed a regular JINR–BMBF Agreement on cooperation for the next three-year term. In distinction from the previous agreements, now the amount of the German contribution and the adopted topics of projects are secured for a three-year period, to use more efficiently the given resources. The annual contribution of BMBF to JINR will be 1.3 million euro, according to the new Agreement. It was also agreed to enlarge the cooperation format, especially in big projects of JINR: IBR-2, the factory of superheavy elements, and NICA.

In honour of the jubilee meeting, a festive dinner was organized where the participants spoke about the scientists, representatives of ministries and embassies owing to whom the cooperation of JINR with scientific centres of

Germany has been successfully developing for many years.

The Forum "JINR–Egypt. Five Years Together" devoted to the five-year fruitful cooperation between the Joint Institute for Nuclear Research and research centres of Egypt was held on **2–6 March** in Egypt. The JINR delegation of 33 people was headed by JINR Vice-Director R. Lednický. It included representatives of the Directorates of JINR Laboratories and UC, heads of joint research projects, young scientists, as well as four representatives of Romania, two from Tajikistan, by ones from Germany, Mongolia, Slovakia, Ukraine, the Czech Republic, and one invited expert from Norway.

Coordinator of the ARE–JINR cooperation Professor Tarek Hussein, JINR Vice-Director Professor Richard Lednický, Vice-Chairman of the Atomic Energy Authority of Egypt Professor Samy Ata-Allah, and President of the Academy of Scientific Research and Technology of Egypt Professor Mahmoud Sakr made their welcoming speeches at the opening of the Forum in the city named after 6 October near Cairo.

The plenary part of the Forum included 34 presentations and was held for two days. Review reports on the activities and development of priority research trends at JINR, the megaproject NICA and educational programmes of the JINR UC and the University "Dubna" were given on the first day. Egyptian participants made reviews on the cooperation of JINR with Egypt, the ARE–CERN cooperation programme, the SESAME project, the educational programmes and opportunities for Egypt to get involved in the NICA project. The second day was devoted to reports on joint projects in nuclear methods, distributed calculations, theory and modeling. A meeting of the Joint Committee on JINR–Egypt cooperation was held in the framework of the Forum where details of the announced competition in joint projects were discussed.

On 5 March, JINR representatives split into groups and took part in section meetings in Egyptian research and educational centres: Cairo University, the National Research Centre, the Egyptian Centre for Theoretical Physics, the Suez Canal University, the Egyptian Atomic Energy Authority (EAEA) where an advanced seminar was held on cooperation with JINR.

The social programme for the JINR delegation was organized on 6 March. It included a visit to the Silicon Valley of Cairo, a bus excursion, and a boat trip on the Nile.

On **26 March**, a meeting was held at the JINR Directorate with a Polish delegation headed by Ambassador of the Republic of Poland K. Pełczyński-Nałęcz. JINR Director V. Matveev informed the guests about the development of the cooperation of JINR with scientific centres of Poland and marked the fact that among all equal Member States of JINR Poland has always played an important role in scientific research at JINR Laboratories.

In her turn, K. Pełczyński-Nałęcz said that cooperation with JINR is of great importance for the development of physics in Poland. She also stressed that together with the annual increase of the Polish contribution to JINR, the initiative of the JINR Directorate to return a bigger part of the contribution to the country in the form of orders to Polish enterprises that are interested in this cooperation had played an important role in strengthening mutually beneficial partnership. It was decided at the meeting that JINR representatives would take part in the coming traditional "breakfast sessions of the Polish business" in the Embassy of Poland in Russia. The delegation from Poland took part in the celebration of the Day of JINR foundation; the guests also visited the basic facilities and got acquainted with the main trends of activities of the Flerov Laboratory of Nuclear Reactions and the Veksler and Baldin Laboratory of High Energy Physics.

On **26–27 March**, Ambassador Extraordinary and Plenipotentiary of the Czech Republic to RF V. Remek visited JINR. Vladimir Remek is the first cosmonaut of Czechoslovakia. On 27 March, the Ambassador visited the Flerov Laboratory of Nuclear Reactions, met with FLNR Director S. Dmitriev, was acquainted with the research programme of the Laboratory, and visited the basic facilities, as well as the Centre of Applied Physics.

The visit of the Ambassador to JINR finished with a meeting with JINR Director V. Matveev and leaders of the Institute. The meeting was attended by a delegation from the Czech Republic at the session of the Committee of Plenipotentiaries, consisting of Plenipotentiary Representative of the Czech Republic in JINR J. Dobeš, his Deputy I. Štekl, Senior Specialist of the Ministry of Finance of the Czech Republic S. Kulhánek, and Director General of the Czech company "Vacuum Prague" P. Hedvábný, as well as Head of the National Group of the Czech Republic A. Kovalík and his Deputy V. Chudoba. The parties discussed the status of cooperation between the Czech Republic and JINR in the fields of construction of new basic facilities, high-tech equipment

procurement in the Czech Republic, educational programmes, including not only the diploma and PhD work performed by Czech students at JINR, but also the work performed by students from the JINR Member States in the Czech Republic.

JINR Director V. Matveev handed to the Ambassador of the Czech Republic a letter of invitation for the President of the Czech Republic to visit JINR at his convenience; the letter was accepted with gratitude and the promise of assistance from the Embassy of the Czech Republic.

The first session of the Working Group under the JINR Directorate and the JINR Plenipotentiary of the Government of the Republic of Azerbaijan was held on **11–13 May** in Baku.

The main topics of the session were the educational programme of JINR and preparation of jubilee events on the 60th anniversary of JINR and the 70th anniversary of the Azerbaijan National Academy of Sciences (ANAS).

On the JINR side, the session of the Working Group was attended by JINR Chief Scientific Secretary N. Russakovich, Head of the JINR International Cooperation Department D. Kamanin, Director of the Laboratory of Information Technologies V. Korenkov, Director of the JINR University Centre S. Pakuliak, Head of the National Group of JINR employees of Azerbaijan N. Javadov. On the side of the Republic of Azerbaijan, the Working Group included representatives of the Azerbaijan National Academy of Sciences (ANAS): Plenipotentiary of the Government of the Republic of Azerbaijan to JINR Academician-Secretary of the ANAS Department of Physical, Mathematical and Technical Sciences, ANAS Corresponding Member N. Mamedov, Vice-President of the ANAS, Academician I. Guliyev, Head of the Laboratory "Physics of High Energy" of the Institute of Physics, Corresponding Member O. Abdinov, Director of the Institute of Radiation Problems, Academician A. Garibov. Leaders of a number of research institutes participated in the session of the Working Group as experts. Visits to the Institute of Physics of G. M. Abdullaev, the Institute of Radiation Problems and the Baku branch of the Moscow State University were organized.

The Working Group discussed a preliminary selection of young specialists who would soon be assigned to joint research and training at JINR and requirements for Azerbaijani students to participate in the second part of the Summer Student Practice in JINR research trends that is organized by the JINR UC. The Working Group also took a decision to announce a competition starting from 1 July of joint projects of JINR and scientific institutions of Azerbaijan, the results of which must have been tabulated on 1–15 October. The concluding meeting of the Working Group was held in the ANAS Presidium, under the chairmanship of Academy President A. Ali-Zade and finished with the signing of the Final Protocol. The next session of the Working Group will be held in Dubna.

From **28** to **30 May**, JINR Days were held in Tbilisi (Georgia) dedicated to the 60th anniversary of JINR. The delegation from the Institute included Academician V. Matveev, Vice-Directors R. Lednický and G. Trubnikov, VBLHEP Director V. Kekelidze, LIT Director V. Korenkov, representatives of the JINR Member States L. Kostov (Bulgaria), S. Arutyunyan and L. Mardoyan (Armenia).

The event started with a working meeting in the Ministry of Education and Science of Georgia that was attended by Georgian Minister of Education and Science T. Sanikidze, Deputy Minister G. Shervashidze, and Plenipotentiary of Georgia to JINR A. Khvedelidze. T. Sanikidze talked about the special place of JINR among international scientific organizations — collaborators of scientific and educational institutions of Georgia. The Minister reviewed the membership of Georgia to the Joint Institute for Nuclear Research and marked the establishment of a school of Georgian physics theoreticians and experimenters that was formed in Dubna and in many aspects monitors the present-day development of physics research in Georgia. She also stressed the necessity today to use the potential of JINR more effectively to train young Georgian physicists and engineers.

V. Matveev congratulated Georgian colleagues on the occasion of the Independence Day of Georgia celebrated on 26 May and on behalf of the international community of JINR gave greeting addresses to Prime Minister and Minister of Education and Science of Georgia. JINR Director spoke about the present situation at the Institute, organization of scientific research, prospects and opportunities to widen collaboration with Georgia in fundamental, applied and engineering research.

Issues of establishing attractive social and study conditions, professional and career growth for specialists from the JINR Member States were discussed at the meeting at the Ministry.

The same day the delegation from JINR took part in the meeting of the round-table discussion

"Georgia–JINR: Past, Present, Future" that was held at the Georgian Technical University under the chairmanship of the Georgian Minister of Education and Science T. Sanikidze and Rector of GTU Academician A. Prangishvili. Apart from the representatives of GTU, Vice-Rector of the I. Javakhishvili Tbilisi State University, Member of the JINR Scientific Council M. Eliashvili, Vice-Chancellor of the University of Georgia Professor S. Gogilidze, leading scientists, whose scientific work is connected with JINR, took part in the meeting. V. Kekelidze made a report about the flagship project of JINR NICA, and V. Korenkov made a report on modern trends in information research at the Laboratory of Information Technologies of JINR. In the discussion of the reports a number of suggestions were made about possible involvement of Georgian specialists in these projects.

An illustrative example of fruitful cooperation of Georgia with world-leading scientific centres through its membership to JINR was presented by the spokesperson of the COMET project Professor Y. Kuno. He spoke about fruitful and effective work of Georgian scientists, staff members of GTU and TSU, who worked at JINR on the theme of muon–electron conversion.

The participants of the round-table meeting were eager to see the exhibition about JINR on the achievements of the Institute and visited scientific and training laboratories of GTU, where teachers and students told them about methods and setups developed by the students.

After the round-table meeting Academician V. Matveev gave a public lecture and was awarded an Honorary Diploma of Doctor of the Georgian Technical University. The day finished with a concert given by GTU students.

On 29 May, the delegation from JINR visited the National Academy of Sciences of Georgia, where the guests had a meeting with its President Academician G. Kvesitadze, then an extended meeting of the NAS Presidium was held and V. Matveev was presented with a Diploma of a Foreign Member of the Academy.

In his speech, V. Matveev spoke about long-standing cooperation of JINR with Georgia, Georgian scientists, who worked in Dubna in different periods, and said special words about the outstanding contribution made by Academician A. Tavkhelidze in establishing the "Dubna" school of Georgian physicists and development of effective cooperation of scientific organizations of Georgia with JINR.

On 30 May, the delegation from JINR visited Tbilisi State University named after I. Javakhishvili. At the meeting with TSU Rector Academician V. Papava they discussed new issues connected with the extension of scientific departments of the University after the inclusion of NAS Institutes into them. It was stressed during the meeting how important it was to keep the ties between these Institutes and JINR. TSU Vice-Rector M. Eliashvili, Director of the Institute of High Energy Physics of TSU M. Nioradze and Plenipotentiary of Georgia to JINR A. Khvedelidze made proposals to add joint educational programmes to the existing scientific contacts.

The multidisciplinary Forum Brazil–JINR "Frontiers in Elementary Particle, Nuclear and Condensed Matter Physics" was held on **15–19 June** at ICH. The Brazilian delegation included 18 participants from 14 famous Brazilian universities and institutions, representing 6 states of Brazil. Among the honorary guests there were General Secretary of the Brazilian Physical Society Professor V. Bagnato and members of the Commission on Nuclear Physics and Applications T. Frederico, P. Gomes, and D. Menezes.

The programme of the Forum included plenary sessions with keynote reports, as well as local conferences in JINR Laboratories. Excursions to basic facilities of VBLHEP, FLNR, FLNP, and DLNP were organized for the guests.

JINR Director Academician V. Matveev noted in his welcoming speech that the aim of the Forum is to present the major fields of scientific and research activity of JINR, to explain the organization of functioning of the Institute, to share ambitious scientific plans that presuppose wide international cooperation.

The Organizing Committee of the Forum received the message from Ambassador Extraordinary and Plenipotentiary of Brazil A. Jose Vallim Guerreiro, who, in particular, said the following: "The Embassy of the Federal Republic of Brazil in Moscow cordially welcomes the participants of the Brazil–JINR Forum "Frontiers in Elementary Particle, Nuclear and Condensed Matter Physics" and wish the Forum to reach its goal, namely, to contribute to strengthening the cooperation between Brazilian researchers and the Joint Institute for Nuclear Research".

Directors of JINR Laboratories and interested scientists participated in the ceremonial opening of the Forum and plenary meetings of the first day. In the first half of the day, JINR Vice-Directors M. Itkis and R. Lednický presented overview reports on the major direc-

tions of JINR scientific research; and co-organizer of the Forum Professor of the Fluminense Federal University P. Gomes made a report on directions of research in the fields of nuclear physics and related areas in universities and research organizations of Brazil.

A round-table discussion was held on the last day of the Forum where the final declaration with proposals on cooperation and the possibility of associated membership of Brazil in JINR was signed.

On **18–20 June**, a delegation of the Institute of Plasma Physics of the Chinese Academy of Sciences headed by IPP Deputy Director Doctor Song Yuntao arrived to Dubna in the framework of a visit on development of cooperation between JINR and the IPP.

Excursions to basic facilities of VBLHEP, DLNP, and FLNR were organized for the guests. During the meeting between the JINR Directorate and the delegation of the IPP, the parties discussed the current state of the NICA scientific megaproject, which is being implemented at JINR. The meeting was attended by JINR Vice-Director R. Lednický, JINR Chief Engineer G. Shirkov, VBLHEP Director V. Kekelidze, and Head of the International Cooperation Department D. Kamanin. This visit expanded interests of cooperation in the field of superconductors. Special attention was focused on construction of new superconducting accelerators for medical purposes. Approval of a supplement to the memorandum of cooperation, which concerns joint developments in the fields of accelerators for proton therapy and other medical applications, was one of the results of the meeting. At the meeting at the JINR Directorate a possibility to organize the China–JINR Forum similar to the just-finished Forum with Brazil, and the India–JINR Forum, which was held last year, was discussed.

On **19 June**, at the invitation of CERN Director-General Professor R.-D. Heuer and President of the CERN Council Professor A. Zalewska, JINR Director V. Matveev and JINR Chief Scientific Secretary N. Russakovich attended the 176th open session of the CERN Council — the highest management body of this international scientific organization.

V. Matveev made a presentation on the history of JINR establishment, the scientific programme and development prospects. He expressed his gratitude to the CERN leaders and CERN Council for their decision on the mutual Observer Status for JINR and CERN as two largest international scientific organizations. Answering the questions from the audience, V. Matveev spoke about extending international cooperation in the framework of JINR, taking into account the interest shown by scientific community from a number of countries to their involvement in big science projects ("mega-science" class) in the Russian Federation, including a possibility even to join JINR. JINR Director took the opportunity to invite members of the CERN Council to JINR for the celebration events in March 2016 on the occasion of the 60th anniversary of JINR.

On **1–5 July**, by order of the CP of JINR, a meeting of the Working Group under the CP Chairman on financial issues was held in Kazimierz Dolny (the Republic of Poland). It was attended by representatives of the Republic of Armenia, the Republic of Azerbaijan, the Republic of Bulgaria, the Czech Republic, Georgia, the Republic of Kazakhstan, Mongolia, the Republic of Poland, the Russian Federation, and members of the JINR Directorate.

The Working Group discussed the following questions: accomplishment of recommendations and resolutions of the Finance Committee and CP by the JINR Directorate; elaboration of the final version of the method to calculate the contributions of the Member States; preparation of alterations in basic norm documents that regulate the financial activity of JINR.

The Working Group took note of the information presented by JINR Director V. Matveev on preparation of alterations in basic norm documents that regulate the financial activity of JINR, improvement of the administration system of the Institute and preparation of future plans of JINR development for the new seven-year period (2017–2023). The Working Group gave a more precise definition of the principles of the new calculation method of contributions of the Member States and recommended that they should be approved at the regular session of the Committee of Plenipotentiaries in November 2015. After the discussion of introducing alterations into the JINR Charter, the Financial Protocol of JINR and JINR Financial Norms, the Working Group took a decision to continue work in this issue, with an account of remarks and suggestions expressed by the representatives of the Member States.

The JINR Directorate expressed sincere gratitude to the representatives of the Republic of Poland for the organization of the meeting at the highest level.

On **5 July**, in the International Conference Hall the round-table meeting "Physics at NICA"

was held in the framework of the JINR–RSA cooperation. This event continued the series of meetings devoted to development and implementation of the NICA project. The participants, including representatives of the largest research centres of the Republic of South Africa, were informed about the preparation for experiments at the NICA accelerator complex and their theoretical justification. Excursions were organized to the NICA accelerator complex, the Department of Detector Manufacturing and the Superconducting Magnets Factory. The meeting finished with the signing of a memorandum of cooperation and an appeal to the Ministry of Education and Science and the Department of Science and Technology of South Africa on the establishment of an affiliate programme for the participation of South Africa in the NICA project.

E. Vivas, Minister-Counselor for Technology, Science and Education of the Embassy of the Bolivarian Republic of Venezuela in Moscow, visited JINR on **31 July**.

E. Vivas met with JINR Vice-Director Professor M. Itkis and Head of the JINR International Cooperation Department D. Kamanin, Scientific Secretary of the Flerov Laboratory of Nuclear Reactions A. Karpov and Scientific Secretary of the Veksler and Baldin Laboratory of High Energy Physics D. Peshekhonov who acquainted E. Vivas with their Laboratories and the main directions of scientific research. During the visit, several issues aimed at development of scientific cooperation between JINR and the Venezuelan research organizations and universities were discussed, first steps in development of cooperation with the support of the Venezuelan Embassy were laid out; in particular, information about JINR's research, conferences held by the Institute and educational opportunities in interested organizations of Venezuela.

Ambassador Extraordinary and Plenipotentiary of the Republic of Turkey in Moscow Ü. Yardim, and accompanying persons visited the Joint Institute for Nuclear Research on **7 August.** The guests visited the Frank Laboratory of Neutron Physics and the Flerov Laboratory of Nuclear Reactions. In the Directorate they had a meeting with JINR Director V. Matveev, JINR Vice-Director M. Itkis, and Head of the JINR International Cooperation Department D. Kamanin on prospects for bilateral and international scientific cooperation.

On **23 August**, the Minister of Higher Education of the Arab Republic of Egypt Alsaid Abdelkhalek, Rector of the Egyptian–Russian University in Cairo Cheriffe Helmi, Director of the Bureau of Culture of the Egyptian Embassy in Moscow Atef Mohamed visited JINR. At the JINR Directorate they were received by V. Matveev, R. Lednický, G. Trubnikov, and N. Russakovich. The Egyptian delegation was introduced to the history of the foundation of JINR along with the scope of its activities including its collaboration with the world scientific centres. The Egyptian Minister said that the change of Egypt's status from the associated member of JINR to its member state would promote further development of fruitful collaboration with JINR. It would allow extending the opportunities of training courses for Egyptian PhD students on the basis of JINR and promote direct contacts of ARE with largest world accelerator centres. After the meeting, the Egyptian delegation visited the cyclotron complex at the Flerov Laboratory of Nuclear Reactions. At the end of the visit the members of the Egyptian delegation made a sightseeing tour about Dubna.

On **10–11 September**, the Joint Institute for Nuclear Research welcomed a delegation from the city of Hefei, China. The delegation included leaders and representatives of the party and administration bodies, scientific research and medical institutes, and largest industrial companies.

The aim of the visit of the Chinese delegation was strengthening of mutually advantageous cooperation of scientific research and health care centres of China with JINR. The delegation was welcomed by JINR Vice-Directors G. Trubnikov and R. Lednický, JINR Chief Engineer G. Shirkov, and VBLHEP Director V. Kekelidze.

JINR Vice-Director G. Trubnikov made a presentation about JINR, describing the structure of the Institute, major directions of its scientific activity, development of the JINR experimental complex, in particular, the Nuclotron–NICA accelerator complex. G. Trubnikov also spoke about history of cooperation between JINR and research institutions of China. G. Shirkov made a report on applied scientific research that is conducted at accelerator complexes, about proton therapy at JINR, which aroused great interest of the guests.

During a conversation, the speakers focused on significance of international scientific cooperation, in particular, of uniting the efforts in the framework of the megascience project NICA, both in the fields of science and innovation. The Chinese guests were taken on excursions to VBLHEP and FLNR.

From **14** to **18 September**, in Dubna the Forum on Development of Cooperation between JINR and Czech Academic and Research Institutions was held.

The goal of the Forum was to engage more academic and scientific institutions of the Czech Republic in the joint current and new research projects.

At the opening of the Forum, JINR Chief Scientific Secretary N. Russakovich informed the participants about the main trends of research at JINR. Scientific secretary of the Forum L. Zavorka (DLNP) made a report on the contribution of specialists from Czechoslovakia and the Czech Republic to the activities of JINR and modern situation in cooperation. Director of the Institute of Experimental and Applied Physics of the Czech Technical University, Deputy Plenipotentiary of the Government of the Czech Republic to JINR I. Štekl spoke about conditions of work and life in Dubna. Excursions to all JINR Laboratories and SEZ "Dubna" were organized for the participants of the Forum.

From **14 September** to **13 October**, a regular training for young scientists and specialists from the CIS states was organized at the Joint Institute for Nuclear Research together with the International Innovative Nanotechnology Centre of the CIS countries under the support of the Intergovernmental Foundation for the Humanitarian Cooperation (IFHC) of the CIS Member States.

Twenty young people from Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Ukraine, and Uzbekistan attended this training, which was held at JINR Laboratories, the University "Dubna", and scientific and innovative enterprises of Dubna.

The training programme included lectures, practicums and guided tours at the JINR Laboratories and University Centre, as well as meetings at AYSS. At Dubna University, the young scientists met with Pro-rector of the University Yu. Kryukov, took part in the all-Russian conference "The Principles and Mechanisms of Formation of the National Innovation System" and in the seminar "JINR–Skolkovo" on the issues of commercialization of research and technology. They also visited the Special Economic Zone "Dubna" and innovative enterprises of Dubna.

All in all, 8 training courses were organized for 160 young scientists and specialists from the CIS Member States in 2009–2015 under the support of the IFHC.

On **12 October**, an agreement about cooperation in radiation medicine and accelerator technology with Chinese colleagues from the Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei was signed in Shanghai (China) by Corresponding Member of RAS G. Shirkov, JINR Chief Engineer.

Heads of the Institute of Plasma Physics, one of the key partners in the implementation of the NICA project, made a decision about the establishment of an oncology centre equipped with proton and carbon cyclotrons. As a result of negotiations with the Chinese colleagues, an agreement was concluded about the implementation, during the next year, of a technical project for the creation of two accelerators by staff members of the Scientific-Experimental Department of New Accelerators of the JINR Laboratory of Nuclear Problems. One of them will be designed for the medical centre in Hefei, while the major elements of the second specialized accelerator for proton therapy will be made for JINR, and this will allow taking Phasotron out of service. Signing this agreement was deemed as an important step in strengthening collaboration with China, also from the standpoint of preserving and developing proton and radiation medicine at the Institute.

On **18–20 October**, a regular meeting of the Machine Advisory Committee (MAC) on the NICA project was held at VBLHEP. The Committee included experts of largest scientific centres: CERN, GSI, FAIR, FNAL, BNL, Tokyo University, Russian centres NPI SB RAS, ITEP, NRC "Kurchatov Institute".

G. Trubnikov and I. Meshkov made reports on the status of the NICA complex; V. Kekelidze spoke about the experiment at the Nuclotron extracted beams BM@N, the detectors MPD and SPD, and the physics programme of the NICA project. The discussion of the main reports was held in the form of a lively panel session on a number of issues. The agenda of the meeting included nearly 20 reports on various trends of the accelerator complex: the collider, the booster, channels, the injection chain, sources, the cooling system, diagnostics, electronics, control systems, etc. Experts asked numerous specific questions, the leaders of research trends gave detailed explanations and answers.

On the first day of the meeting, the participants had an excursion to the sites of the complex construction. The second day was devoted to a general discussion, compilation of the report and recommendations for the NICA project. Besides, time was given for small

reports on the status of projects that are close to the topic, including FAIR. Tests of superconducting magnets, development of detectors, preparation of experiments at the Nuclotron are held at VBLHEP for FAIR and NICA.

On **21–24 October**, the Days of JINR devoted to the 60th jubilee of the Institute were held in Prague (Czech Republic). On the day before the opening ceremony, JINR Director V. Matveev, Vice-Director G. Trubnikov and Head of the International Cooperation Department D. Kamanin met with Plenipotentiary of the Government of the Czech Republic to JINR J. Dobeš, Director of the Institute of Experimental and Applied Physics I. Štekl, Rector emeritus of Charles University Professor I. Wilhelm, and representative of the Ministry for Education, Youth and Sports of the Czech Republic H. Dlouha. The participants of the meeting noted fruitfulness of the 60 years' collaboration between JINR and Czech research organizations, and exchanged current information on efforts made to increase international prestige of JINR in the European and worldwide scientific space and on resolution to strengthen collaboration in science and technology and develop joint educational programmes.

Timed to the JINR Days, a photo exhibition illustrating the past and the present of JINR was arranged at Charles University. The Czech high-technology industrial enterprises presented their information stands as well.

The opening ceremony of the Days of JINR in the Czech Republic took place at the conference hall of Charles University. It was attended by JINR representatives, staff members of Czech scientific organizations who worked in Dubna in different years, representatives of municipalities, ministries and authorities, commercial organizations. Among the guests were diplomats from the embassies in Prague of Moldova, Romania, Ukraine, Italy, and Russia. The RF trade representative in the Czech Republic S. Stupar gave a welcome speech, noting the importance and success of consolidation of efforts in scientific activities. The audience was welcomed by J. Dobeš, Plenipotentiary of the Government of the Czech Republic to JINR.

The working part of the JINR Days was opened by JINR Director V. Matveev with a report "JINR: Yesterday, Today, Tomorrow". Vice-Directors of the Institute G. Trubnikov and R. Lednický made talks about the development of the JINR infrastructure, scientific and research work, as well as plans for the future. Director of the Institute of Experimental and Applied Physics of the Czech Technical University I. Štekl marked in his report the successful cooperation between JINR and Czech scientific organizations, paying special attention to the educational activities and the problem of attracting students and postgraduates from the Czech Republic to JINR. Scientific Secretary of the IEAP CVUT Institute C. Granja presented a report on the fruitful cooperation with a few scientific groups at JINR in using multipixel detectors MEDIPIX. In the second half of the day, a special session devoted to the development of cooperation between JINR and industrial enterprises of the Czech Republic took place which was organized by Director of the firm "Vacuum Prague" P. Hedbávný.

On 23 October, the events within the framework of the Days of JINR were held not only at Charles University, were reports were presented to acquaint students, postgraduates, and young scientists with the main JINR activities, but also at one of the largest educational centre in the Czech Republic, Brno. Meetings and presentations dedicated to the 60th anniversary of the collaboration between JINR and the Czech Republic were held at Brno University of Technology and Masaryk University.

The JINR delegation was greeted by Vice-Dean of the Faculty of Electrical Engineering and Communication V. Aubrecht and Plenipotentiary of the Czech Republic to JINR J. Dobeš. Representatives of the municipal administration, professors, students, and young scientists took part in the meeting. Reports were presented by R. Lednický, N. Kucerka, S. Nedelko, V. Korenkov, and E. Krasavin. The audience were informed about the main directions of research at JINR, the leading projects NICA and DRIBs-III, and the upgrading of the IBR-2 reactor. In his concluding speech, J. Dobeš highlighted the main terms and conditions for practical work of Czech students at JINR.

The JINR delegation got acquainted with the COMTEST laboratory and the NETME centre, and visited the CERIT computer centre at Masaryk University, where discussions were held with the University management about the collaboration conditions and educational programmes for students and participation of young scientists and specialists in international scientific conferences at Dubna. Visits to the Faculty of Information Technology and Radiobiological Laboratory in Brno also took place.

On **22–24 October**, a delegation from the Leon Brillouin Laboratory (Saclay, France)

was on a visit to JINR. At the Directorate the guests were received by JINR Vice-Director M. Itkis, Chief Scientific Secretary N. Russakovich, FLNP Deputy Director O. Culicov, and A. Belushkin (FLNP).

On 23 October, a seminar was held at the Frank Laboratory of Neutron Physics where Director of the Leon Brillouin Laboratory (LBL) Ch. Alba-Simionesco acquainted the attendees with the activities of the LBL — a French national research centre specializing in neutron scattering. The guests from the LBL visited the experimental setups at the IBR-2 reactor.

The 19th meeting of the Russian–Chinese Sub-Commission on Scientific and Technical Cooperation of the Commission for arranging regular meetings of the Government Leaders was held on **26 October** at the International Conference Hall of JINR.

Addressing the participants, JINR Director V. Matveev marked the importance of the contribution to the establishment and development of the Institute made by Chinese scientists and specialists, and spoke about opportunities for further fruitful scientific and technical cooperation in the framework of the international project NICA.

Deputy Minister of Education and Science of the Russian Federation L. Ogorodova and Deputy Minister of Science and Technology of the People's Republic of China Cao Jianlin made reports on modern state policy of Russia and China in scientific, technical, and innovation spheres. L. Ogorodova spoke in particular about the adopted decision to keep the financing amounts of fundamental and research investigations and to increase the demand of applied elaborations in conditions of the RF budget reduction. She noted that out of six megascience projects approved for implementation in Russia, two are most actively developed. These are the heavy-ion collider NICA in Dubna and the high-flux reactor PIK in Gatchina.

Cao Jianlin spoke about the all-round support rendered by the Chinese government to the initiative of mass innovations and venture activity, use of the incubator effect, and gave statistical data that demonstrate high priority of scientific and technical activity in China.

At the meeting, information was given about the implementation of joint projects in scientific and technical fields, and a number of proposals were considered. The sides supported the proposal to prepare a quadruple agreement for the coming meeting of the government leaders of Russia and China — among the Ministry of Science and Technology of China, the Academy of Sciences of China, the Ministry of Education and Science of RF and the Joint Institute for Nuclear Research — on the participation of China in the NICA project.

It was decided to work out a protocol between the Ministry of Science and Technology of China and the Ministry of Education and Science of RF on bilateral scientific and technical cooperation in thermonuclear energy, and improve and sign the agreement on holding a contest to select joint projects in scientific and technical spheres.

In the second half of the day, the members of the Sub-Commission had excursions to the Veksler and Baldin Laboratory of High Energy Physics and the Flerov Laboratory of Nuclear Reactions. They were shown basic and experimental facilities of JINR. The meeting continued with a discussion of issues of the Russian–Chinese cooperation in fundamental and applied research in heavy-ion physics, plasma physics and nuclear energy. The meeting was concluded with the protocol of the Russian–Chinese Subcommission on Scientific and Technical Cooperation signed by the leaders of the delegations.

From **2** to **4 November**, the Days of JINR in Romania were held in Bucharest. On 2 November, the JINR delegation, represented by V. Matveev, N. Zamfir, M. Itkis, G. Trubnikov, G. Adam, and O. Culikov, was welcomed by Minister for Education and Scientific Research of Romania S. Cimpeanu. At the meeting dedicated to the 60th birthday of the Institute, JINR Director V. Matveev noted the significant contribution made by Romania to JINR and invited the Minister for Education and Scientific Research of Romania to take part in the 60th anniversary celebrations in March 2016. This invitation was accepted with gratitude.

The symposium dedicated to the 60-year history of successful cooperation between Romania and JINR was opened by Plenipotentiary of the Government of Romania to JINR Professor N. Zamfir. In his speech about the participation of Romania in JINR, N. Zamfir named Romanian scientists who took an active part in the formation and development of the Institute, stressed the importance of conducting collaborative research and usefulness of the educational programmes for students at Dubna. JINR Director V. Matveev made a review of the key projects at the Institute, including large-scale projects and refurbishment of the basic facilities. He also presented the diploma "Honorary Doctor

of JINR" to N. Zamfir, which was met with applause.

M. Costoiu, a member of the Romanian Parliament and Rector of the Polytechnic University of Bucharest, wished mutual success to the cooperation between Romania and JINR in future. C. Borcea, O. Culicov, G. Stratan, and G. Adam made talks about the contributions by Romanian colleagues to the scientific research activities at JINR Laboratories. The representatives of JINR were welcomed in Bucharest by the former Vice-Director of the Institute Professor A. Sandulescu, who worked in Dubna in the 1970s–1980s.

The JINR delegation visited the National Institute of Physics and Nuclear Engineering, as well as the building site of the international complex ELI — the project where Romania actively participates. At the Parliament of Romania a meeting took place with Head of the Commission for Education and Science E. Andronescu.

On 4 November, the JINR delegation accompanied by M. Costoiu, Vice-Rector G. Darie, and E. Andronescu, visited the Polytechnic University of Bucharest. M. Costoiu spoke about the major milestones in the University's history, its scientific and educational programme and modern status, as well as cited some statistics. For the representatives of JINR a guided tour at the National Institute for Research and Development in Electrical Engineering (ICPE-CA) was organized.

On **3–7 November**, the Days of NICA in Warsaw dedicated to the 60th anniversary of JINR were held. These events were organized at one of the largest universities of Poland — Warsaw University of Technology (WUT) — and were to attract young scientists and students to participate in the NICA project.

The Days of NICA in Warsaw were attended by students, postgraduates, and staff members of the University, as well as by young scientists from other centres engaged in scientific research for NICA. They were organized together with a meeting on the research perspectives of the STAR (BNL, USA), ALICE and NA-61 (CERN), FAIR (Germany) and NICA experiments.

On 6 November, JINR Director V. Matveev met with Vice-Rector of WUT for Science R. Bacewicz. In the course of the meeting, an agreement for cooperation between JINR and Warsaw University of Technology was signed which is to advance cooperation between JINR and WUT, including participation in the NICA project.

On **9 November**, a general meeting dedicated to the 70th jubilee of the Azerbaijan National Academy of Sciences (ANAS) was held in Baku (Azerbaijan).

President of the Republic of Azerbaijan I. Aliev took part in the meeting. Speaking at the ANAS general meeting, head of state marked the fact that sustainability of economic development of the country should be based on scientific research and internal resources.

ANAS President Academician A. Alizade, Laureate of the Nobel Prize American astrophysicist and cosmologist Professor J. Fitzgerald Smoot, and JINR Director V. Matveev took the floor at the meeting. JINR Director spoke about prospects for joint research.

From **17** to **21 November**, a series of important meetings were held in Minsk, the capital of Belarus, in the course of the visiting sessions of the Institute's governing bodies — the JINR Finance Committee and the Committee of Plenipotentiaries.

At the Presidium of NAS of Belarus, the delegation from JINR that included the Institute's leaders, directors of the Laboratories, and representatives of all JINR Member States took part in the discussion of the status and prospects of JINR–Belarus cooperation and had a meeting with RB NAS Presidium Chairman V. Gusakov and other members of the Presidium. The participants of the meeting were impressed by the poster exhibition dedicated to the 60th anniversary of JINR and to the long-standing successful cooperation between JINR and Belarus.

Fruitful negotiations were held at the State Committee for Science and Technology of Belarus, headed by Plenipotentiary of the Government of Belarus to JINR A. Shumilin, on development of innovation trends urgent for Belarussian economy and joint research in Dubna.

During the meeting with the first Pro-Rector of the Belarussian State University O. Ivashkevich, reports that covered all spheres of scientific and innovation activities of the University were made by leading Belarussian scientists and specialists. An extensive cultural programme was prepared for the JINR delegation.

On **4 December**, a meeting of the Council on Heavy-Ion Physics under the Presidium of the Russian Academy of Sciences was held at the International Conference Hall of JINR under the chairmanship of RAS Academician Yu. Oganessian. JINR Director RAS Academician V. Matveev took part in the meeting.

Council secretary I. Izosimov spoke about the accomplishment of the resolutions of the

previous Council meetings. JINR Vice-Director G. Trubnikov made a report on the status of the development of the NICA accelerator complex. VBLHEP Director V. Kekelidze spoke about the programme of experiments at the future collider.

FLNR Scientific Leader Yu. Oganessian talked about the most urgent tasks of the Laboratory in nuclear physics. FLNR programme on heavy-ion physics, including accelerators and detectors, was discussed in several reports. The following scientists took the floor at the meeting: G. Gulbekian, on status of construction of the superheavy elements factory; V. Utenkov, on the experiment of the synthesis of element 118 isotopes; A. Eremin, on rare channels of synthesis reactions; A. Fomichev, on a new fragment separator ACCULINNA-2; B. Gikal, on U400M cyclotron upgrading; and G. Ter-Akopyan, on studies of the structure of radioactive nuclei.

Ambassador Extraordinary and Plenipotentiary of Romania to the Russian Federation V. Soare visited JINR on **7 December**. He met with the JINR Directorate and visited JINR Laboratories. On the occasion of the National Day of Romania (1 December), a festive meeting was held at the cultural centre "Mir" with a concert of the Romanian ethno-rock-blues band "Nightlosers".

The Science Forum: South Africa-2015 was held on **8–9 December** in Pretoria, South Africa. The Forum brought together more than 1000 representatives of scientific research and educational organizations in the International Convention Centre.

JINR was represented by JINR Vice-Director G. Trubnikov, Head of the JINR International Cooperation Department D. Kamanin, Deputy Director of FLNP O. Culicov, Chief of the Scientific Department of FLNP S. Culicov, and the representative of the International Cooperation Department A. Sushchevich. G. Trubnikov made a presentation on prospects in particle physics, megaprojects in the fields of nuclear physics and neutrino physics, and study of nuclear matter under extreme conditions.

JINR was also represented with an information branded booth, demonstrating scientific and educational activities of JINR, the ten years' history of international cooperation with the Ministry of Science and Technology and scientific organizations of the Republic of South Africa, as well as the JINR major international projects.

On **17 December**, a number of important agreements and protocols on cooperation between Russia and China in the fields of science, industry and trade were signed in Beijing during the 20th Regular Meeting of Prime Ministers of Russia and China.

On behalf of JINR, RAS Corresponding Member G. Trubnikov, JINR Vice-Director, signed a Quadripartite Protocol among the Ministry of Education and Science of Russia, the Ministry of Science and Technology of China, the Chinese Academy of Sciences and the Joint Institute for Nuclear Research on the prospects of cooperation in the framework of the complex of superconducting rings with colliding beams of heavy ions NICA.

First Deputy Minister of Education and Science of the Russian Federation N. Tretyak signed the protocol on the part of the RF Ministry of Education and Science. The protocol was signed in the presence of Russian Prime Minister D. Medvedev and Chinese Prime Minister Li Keqiang.

This is a very important step in relations between JINR and China. The preparations for the signing of that agreement lasted for two years as directed by the instructions of the Governments of Russia and China, as well as of the JINR Committee of Plenipotentiaries.

CONFERENCES AND MEETINGS HELD BY JINR

Thirteen conferences were the largest among the scientific conferences and workshops held at JINR in 2015.

From 16 to 20 February, the ***XIX International Scientific Conference for Young Scientists*** was held at the Bogoliubov Laboratory of Theoretical Physics. It was dedicated to the centenary of the birth of the outstanding Soviet scientist Corresponding Member of the Academy of Sciences of USSR F. Shapiro. The Conference was organized by the Association of Young Scientists and Specialists of JINR (AYSS). It was attended by over 300 participants, including students, postgraduates, young scientists, and specialists from JINR and other Russian and foreign scientific centres who delivered oral and poster reports to the audience.

The programme of the Conference overlapped main fundamental and applied trends of research conducted at JINR; lectures were given on advanced theoretical and applied studies in neutron and nuclear physics and condensed matter physics. The Proceedings of the Conference must have been published as separate collections.

On the first day, FLNP Director V. Shvetsov made an introductory lecture about JINR and the Laboratory. A. Strelkov (FLNP) gave a report on the biography of F. Shapiro, Director of the Institute for Nuclear Physics (St. Petersburg) of NRC "Kurchatov Institute" V. Aksenov made a report "Neutron Research in Modern Science" speaking about the history and modern status of studies.

Traditionally, a competition for young JINR staff members and a competition for the best report in each of 9 sections were held. A special Prize after F. Shapiro was conferred on K. Mukhin (FLNP) for the work "A Complex of Cryogenic Neutron Moderators of the IBR-2 Reactor. R&D". In the "Theoretical Research" the First Prize was conferred on M. Kosič (Belgrade University, Serbia), two Third Prizes went to A. Tursunov (the Technical University, Prague, the Czech Republic) and A. Dumitrescu (the National Institute for Physics and Nuclear Technology, Bucharest, Romania). In "Experimental Research" the First Prize was given to E. Rukhadze (the Technical University, Prague, the Czech Republic), the Second to S. Rozov (DLNP), two Third Prizes to A. Tomchuk (FLNP) and M. Zadnepryanets (LRB).

An interesting social programme was offered to the participants. It included parties and sport events, like traditional volleyball and football, and archery, a climbing wall, and snooker. The Conference was concluded with an exhibition "From School Studies to Innovations" participated by the enterprise "Dedal", "Robotics School", and students from school 9 with devices they produced themselves.

On 25–29 May, the JINR International Conference Hall hosted the ***23rd International Seminar on Interaction of Neutrons with Nuclei: Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics*** (ISINN-23). The Seminar is organized by the Frank Laboratory of Neutron Physics annually at the end of May. This year it was dedicated to the 100th anniversary of the birth of the outstanding Soviet physicist, one of the founders of the LNP — Corresponding Member of the USSR Academy of Sciences F. L. Shapiro.

The Seminar was attended by about 70 staff members of different JINR Laboratories, 40 scientists from Russia and the CIS, and 20 representatives of a wide range of countries: Bulgaria, Great Britain, Vietnam, Germany, Iran, Romania, Serbia, Slovakia, France, and the United States. Within four working days, 60 oral reports and 50 poster presentations on the subject of the Seminar were given to the participants. The programme included traditional ISINN sessions: fundamental interactions and physics of UCN, physics of nuclear fission, nuclear analytical methods in biology and ecology, nuclear reactions with fast neutrons, issues of nuclear structure, methodical aspects of experiments with neutrons, as well as the traditional section concerning accelerator-driven subcritical systems. A distinctive feature of this year was an opening lecture dedicated to future experiments at PIK reactor being created in Gatchina.

The reports submitted by the guests from PNPI aroused a great interest among the participants. Currently, there is an agreement with the management of PNPI that the PIK reactor together with IBR-2 should form a joint user centre. Physicists from Dubna are taking an active part in developing a scientific programme for the PIK reactor. It is no coincidence that they offer their original version of the source of ultracold neutrons (UCN) for PIK (reported by E. Lychagin). Ultracold neutrons were discovered at LNP in 1968 under the guidance of F. Shapiro. In the following years, in the Soviet Union a powerful scientific school of physicists working in this field developed. Unfortunately, for more than 20 years there was no source of UCN in our country, the experimental results were obtained mainly at the Institute Laue–Langevin (ILL, France). Design and creation of the source at PIK will help to maintain the scientific school and implement an extended scientific programme with UCN. The scientific programme of PNPI in this field, which is a part of the research programme in the field of fundamental interactions, was presented by Professor A. Serebrov in his report.

One of the traditionally strong points of the Seminar was the fission section. It featured both theoretical and experimental work. In the theoretical part, the report by N. Karzhan from the Flerov Laboratory of Nuclear Reactions was devoted to new calculations of mass-energy distributions for the transactinides. A. Barabanov from the NRC "Kurchatov Institute" introduced

a new model to explain the recently discovered T-odd effects in ternary fission. The report by I. Guseva from PNPI presented a model to describe the angular anisotropy of prompt fission neutrons. In the experimental part of the report by A. Gagarskiy from PNPI, the data on the angular distributions of fission fragments under the influence of high-energy neutrons were presented, and the report by A. Vorobyov from PNPI was devoted to a thorough analysis of the data on angular correlations of prompt fission neutrons of different nuclei and the search for pre-bursting neutrons in fission. In the end, traditionally, the group from the Flerov Laboratory of Nuclear Reactions presented their methodical groundwork and the results obtained in experiments on the search for exotic modes of collinear cluster decay in fission (reports by D. Kamanin and Yu. Pyatkov).

The second day of the Seminar included two sections: "Fundamental Interactions and Physics of Ultracold Neutrons" and "Neutron Activation Analysis and Life Sciences". M. Musgrave (Great Britain) presented the latest results of the NPDGamma collaboration measuring parity violation in the reaction of neutron capture by proton. F. Dzhaparov (ITEP) considered the possibility of solving the fundamental problems of statistical physics using small-angle neutron scattering and beta nuclear magnetic resonance. P. Geltenbort (France), a regular participant of ISINN, made a remarkable review report on the recent results obtained at the source of ultracold neutrons in ILL. V. Ezhov from PNPI gave a detailed report on the experiment on measuring the neutron lifetime in a magnetic trap, including the latest results on the creation of the new facility. The latest news from the nEDM collaboration from PSI was brought by M. Musgrave. S. Doege (France) spoke about his work performed in order to obtain new data on the scattering cross section of ultracold neutrons on solid and liquid deuterium. A. Frank (JINR FLNP) considered the phenomenon of wave packet delay caused by the reflection of neutrons from multilayer resonant structures, and the issues of neutron diffraction on a moving grating. The colleagues from his group made presentations on the recent experiments with UCN conducted on a set of the TOF Fourier diffractometer and on the planned monitoring of the interaction of ultracold neutrons with matter moving with great acceleration.

From seminar to seminar contribution of participants in the section "Neutron Activation Analysis and Life Sciences" becomes more and more significant. This section attracts a large number of young people from different countries. Young scientists come to Dubna, talk about their achievements, and have the opportunity to socialize with the recognized leaders in this field, such as O. Duliu (Romania), M. Frontasyeva, S. Pavlov (JINR), V. Zaichik, B. Mankovska, M. Florek (Slovakia), S. Fränzle (Germany), and others. The reports and posters of this section reflect the research conducted in the field of environmental protection, biotechnology of water treatment, and development of new medicines based on the use of natural vegetation. The international team of the NAA sector and applied research of FLNP NPD once again demonstrated their enthusiasm and achievements in the field of application of nuclear-physical analytical methods in life and material sciences. It is worth stressing the fact of participation of students from Bulgaria, Vietnam, Albania, Kazakhstan, and Russian universities (Moscow, Ivanovo) in the section; it was their first performance at an international forum. Out of the session hours, intense discussion of cooperation plans with the Seminar participants from Romania (C. Stihi, C. Radulescu, O. Duliu), Kazakhstan (N. Omarova), and Russia (S. Gorelova) took place.

In the section devoted to accelerator-driven subcritical systems, which took place on the third day of the Seminar, the results obtained by a large international collaboration in the framework of the project "Energy and Transmutation" on the JINR accelerator base were presented. Zh. Hushvaktov, L. Zavorka (JINR DLNP) and P. Zhivkov (Bulgaria) made a report on the experimental results obtained at the VBLHEP nuclotron and DLNP phasotron with the target assembly QUINTA, and on the simulation results of the planned experiments with quasi-infinite target BURAN. The guests from Iran spoke about the advantages of using thorium fuel and the possibility of using radioisotopes for medical purposes on the accelerator-driven subcritical assemblies.

In the next section devoted to methodical issues, the experiments on the study of radiation damage in scintillators conducted at the IREN facility were reported. O. Shcherbakov (PNPI) gave a detailed report on the TOF spectrometer GNEIS of the PNPI proton synchrotron accelerator and on the installation created on it in order to test the electronic stability to the neutron component of natural radiation.

On the last day of the Seminar, the following sections took place: "Nuclear Structure, Photon Strength Function", "Reactions Induced by Fast Neutrons", and "Miscellaneous". Re-

ports by A. Voinov (University of Ohio, USA), A. Sukhovoy (JINR FLNP), and S. Kamerdzhiev (IPPE, Obninsk) were devoted to various approaches to the description of photon strength function. S. Sukhoruchkin (PNPI) presented the analysis of nonstatistical regularities in the excitation spectra of compound nuclei and the search for their correlations with fundamental constants.

Yu. Kopach (JINR FLNP) and V. Aleksakhin (JINR VBLHEP) reported on the results obtained by the method of tagged neutrons from a special $d{-}t$ generator, and M. Sedysheva (JINR FLNP) spoke about the new results of the study of reaction $^{144}\mathrm{Sm}(n,\alpha)^{141}\mathrm{Nd}$ achieved at the FLNP Van de Graaff accelerator.

Section "Miscellaneous" was remembered by the participants in connection with an interesting report by V. Ezhov (PNPI) on the study of Lake Vostok in Antarctica, as well as reports by V. Ignatovich (JINR FLNP) and Yu. Ratis (IPESA, Samara) dedicated to theoretical description of exotic nuclear reactions.

In conclusion, it should be noted that, as before, ISINN remains the site, where the participants can present their results that are not yet published, or preliminary, where in informal surroundings, during the breaks between the sessions or the traditional picnic one can discuss their work with colleagues, take advice, start a new collaboration.

The Seminar was organized with the support of RFBR (grant No.15-02-20255). ISINN-23 presentations and materials of the previous seminars are available on http://isinn.jinr.ru

From 29 June to 3 July, the LXV International Conference on Nuclear Physics ***"Nucleus 2015. New Horizons in Nuclear Physics, Nuclear Engineering, Femto- and Nanotechnologies"*** was held at St. Petersburg State University. It was attended by about 100 physicists from Russia, the USA, Switzerland, Kazakhstan, Ukraine. Not only fundamental issues of nuclear physics were discussed at the Conference, but also aspects of applied research related to nuclear energy and nuclear physics technologies.

On 30 June, a Big Plenary Meeting was held in the Assembly Hall of the building of 12 boards of SPSU dedicated to the 60th anniversary of JINR. Review reports on scientific research at JINR were presented there. Other meetings were held at the Physics Institute of SPSU in Peterhof.

Professor V. Aksenov spoke about PNPI in Gatchina, that is part of the NRC "Kurchatov Institute", and said that the largest reactor for neutron research in the world is under construction there. The reactor power start-up is planned for 2018. Its power will reach 100 MW, i.e., almost two times larger than in the biggest for today reactor of this type in the European Centre for Neutron Research — the Institute Laue–Langevin (ILL), Grenoble, France, whose power is 57 MW. Scientists of PNPI and SPSU have been closely cooperating with this centre for many years. To look inside the tiny atomic nucleus, one needs, as it turns out, tremendous energy and huge accelerators.

Professor Yu. Penionzhkevich (JINR) spoke about activities at JINR in different fields of fundamental science, applied research and education. He also presented results of the latest research of nuclear matter in extreme state (exotic nuclei). A new cyclotron complex of heavy ions DRIBs-III is developed in Dubna that will allow one to approach closely the borders of nuclei nucleon stability, including the region of superheavy elements.

Director of LIT Professor V. Korenkov made a report on the latest achievements of JINR in information technologies. The grid-system at JINR today allows high-accuracy communication with world centres and involvement in the analysis and processing of experimental data obtained in joint experiments at large accelerator complexes, including the LHC at CERN.

Professor V. Egorov spoke about nonaccelerator physics developed at JINR. He made an interesting report on the latest results of studies at nuclear reactors of neutrino properties.

Research at JINR was discussed in many reports at the Conference. Professor of Texas University A&M (USA) V. Goldberg presented results of studies of super-neutron-rich nuclei of lightest elements that were held jointly with scientists of JINR and the CIS.

The intense Conference programme was accompanied by interesting culture events. The place of the Conference itself cast creative atmosphere and fostered new scientific contacts among various groups from Russian and CIS centres and universities.

On 6–11 July, the International Conference ***"Strangeness in Quark Matter"*** (SQM-2015) was held at the Veksler and Baldin Laboratory of High Energy Physics of the Joint Institute for Nuclear Research. The first meeting of this series took place in 1991 in Denmark; later it was held in China, Brazil, Poland, Great Britain, and other countries. It has become now one of the most prestigious scientific forums on physics of

nuclear matter under extreme conditions of high temperatures and densities. About 250 scientists from more than 30 countries came to Dubna to participate in the Conference "Strangeness in Quark Matter".

At the ceremonial opening, JINR Director Academician V. Matveev spoke about the history and structure of JINR, scientific and educational programmes, cooperation with research centres and universities around the world. VBLHEP Director Professor V. Kekelidze spoke about implementation of the NICA project. Deputy Head of the city administration N. Smirnov made a presentation about Dubna.

More than 80 plenary and poster reports were presented during five days, more than a hundred plenary presentations in five sections were delivered. Among them were reports on the latest results of experiments carried out at CERN and RHIC (BNL, USA).

On 13–17 July, the 8th International Conference ***"Mathematical Modeling and Computational Physics"*** (MMCP'2015) was held in High Tatra Mountains, Stará Lesná, Slovakia. The Conference was devoted to the 60th anniversary of the foundation of the Joint Institute for Nuclear Research. It was organized by the Laboratory of Information Technologies (JINR, Dubna), the Institute of Experimental Physics of the Slovak Academy of Sciences (Košice), the Technical University of Košice, the Pavol Jozef Šafárik University (Košice), the Slovak Physical Society (Košice), and IFIN-HH (Bucharest, Romania).

The scientific subject of the Conference covered a wide spectrum of questions, including:

— mathematical methods and tools for modeling complex physical and technical systems, computational chemistry, biology, and biophysics;

— methods, software and computer complexes for experimental data processing;

— computer algebra and quantum computing methods, algorithms and software;

— distributed scientific computing and big data;

— parallel and hybrid calculations, extra massive parallelism.

Attending were more than 80 scientists and specialists from Belarus, Bulgaria, Germany, Canada, Russia, Romania, Slovakia, Ukraine, and a large number of Russian scientific centres and universities such as NRC "Kurchatov Institute", the Institute of Mathematical Problems of Biology of RAS (Pushchino, Russia), the Institute of Theoretical and Applied Mechanics of SB RAS, St.-Petersburg State University, Novosibirsk State University, PFUR, etc. In total, there were heard 18 plenary and more than 60 section reports.

From 14 to 18 July, an International Conference ***"Nuclear Structure and Related Topics"*** (NSRT-15) was held at the Bogoliubov Laboratory of Theoretical Physics. Co-Chairmen of the Organizing Committee of the Conference were V. Voronov and R. Jolos.

The Conference is held in Dubna every three years. In 2015, it was dedicated to the 90th anniversary of a prominent Soviet and Russian scientist, the founder of the Dubna school of atomic nucleus theory, Honoured Scientist of RF Professor V. G. Soloviev (1925–1998).

The Conference programme is closely connected with studies in nuclear physics of low energy held at JINR. Both experimental and theoretical studies were reported there. The majority of the presentations were devoted to the properties of nonstable exotic nuclei that play an important role in various astrophysical processes.

From 27 July to 7 August, the 13th International School-Conference ***"Topical Problems of Physics of the Microworld"*** was held in Gomel (Belarus) at the health centre "Zolotye pesky". It was dedicated to the 60th anniversary of JINR and gathered more than 100 scientists, postgraduates and students from Belarus, Belgium, Germany, Italy, China, Russia, and Serbia.

The School-Conference was organized by the Joint Institute for Nuclear Research, the National Scientific-Educational Centre of Particle Physics and High-Energy Physics of the Belarussian State University, the B. Stepanov Physics Institute of NAS of Belarus, the Gomel Department of NAS of Belarus, the F. Skorina Gomel State University, and the Gomel P. Sukhoj State Technical University.

The first conference of this series was organized more than 40 years ago and gathered scientists who later became world-known. Co-Chairman of the Organizing Committee of JINR, Chief Scientific Secretary N. Russakovich noted at the opening ceremony: "Science is a special type of activity that survives in hardest times. Despite complexities in relations between our countries, science attracts many people, and it is very important…"

The scientific programme of the School-Conference provided the participants with a special accent on physics, technology of experiments at working and future accelerators, as well as on theory and experimental status of fundamental

interactions at high energy, especially in the context of new data (primarily, the discovery of the Higgs boson) obtained at the LHC in CERN. Scientists from JINR, Belarus, the world-known scientific centres CERN (Switzerland), DESY (Germany), INFN (Italy) and the scientific research institutions SRINP MSU, IHEP and INP (Russia), and the Bogoliubov ITP (Ukraine) delivered lectures and reports.

On 20–26 August, the ***17th International Lomonosov Conference on Elementary Particle Physics*** was held at the Physics Department of the Lomonosov Moscow State University. This year the Conference was devoted to the 60th anniversary of the Joint Institute for Nuclear Research. Its programme included the following groups of issues: theory of electroweak interactions, checking the Standard Model and its generalizations; neutrino physics, elementary particle astrophysics and cosmology, quantum gravitation effects; heavy quark physics, nonperturbative effects in QCD; and physics at future accelerators.

On 31 August – 5 September, the third annual International Conference ***"Physics at the LHC"*** (LHCP2015) was held in St. Petersburg. Co-organizers of the Conference were the Joint Institute for Nuclear Research, NRC "Kurchatov Institute", St.-Petersburg State University, and the Peter the Great St.-Petersburg Polytechnic University.

The Conference has been the result of joining two international conferences: "Physics at the Large Hadron Collider" and "Symposium on Hadron Collider Physics".

Over 350 scientists from more than 35 countries took part in LHCP2015. The Conference brought together not only representatives of four scientific collaborations at the LHC (CERN), but also physicists who conduct experiments at the proton–antiproton collider Tevatron (FNAL, USA) and physicists-theoreticians. It became a forum for active discussions in such topics as the physics of the Standard Model and beyond it, the Higgs boson, new particles and new interactions, supersymmetry, and physics of heavy-ion collisions.

The results of the first session of the Large Hadron Collider operation were discussed. One of the first of them was the measuring of the probability of production of a pair of top- and antitop-quarks obtained in the experiments ATLAS and CMS during the operation of the collider at the designed power of 13 TeV after the discovery of the Higgs boson and a two-year break for upgrading. Another animated discussion was held on the observing of a new pentaquark state which was proclaimed by the LHCb collaboration in June 2015.

Discussions were continued in the back rooms where physicists traditionally exchanged their ideas. They discussed not only the current experiments, but also prospects for their improvement, upgrading of the LHC that will allow higher luminosity and, correspondingly, more elementary collisions. The construction of new colliders was discussed separately. Such projects are ambitious enough, and they should be discussed dozens of years before their actual construction. In this context, LHCP2015 is an ideal place for such forums.

On 2–15 September, the regular ***23rd European School on High-Energy Physics*** was held in Bansko (Bulgaria). It is well known that this school keeps the traditions of the famous CERN–JINR schools that were held by turns in the Member States of these international nuclear centres.

The School of 2015 was jointly organized by CERN and JINR, with the support of the Bulgarian Nuclear Regulatory Agency, St. Kliment Ohridski Sofia University and the Institute of Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences. Professor R. Tsenov headed the Organizing Committee of the School in Bulgaria.

Ninety-two students from JINR and CERN Member States and other regions took part in the School.

World-leading specialists in various fields of high-energy physics gave 30 lectures that were accompanied every day by discussion sessions for students to learn the subjects better. Deputy Director of BLTP (JINR) A. Arbuzov read one of the basic courses of the School on quantum field theory and the Standard Model, A. Bednyakov (BLTP JINR) and S. Demidov (INP) headed two discussion groups.

Much interest was shown to traditional lectures on scientific programmes of CERN and JINR, which were presented by the leaders of these organizations Professor R. Hoeuer and Academician V. Matveev.

The agenda of the School also included a brief course of basic skill of presentation of scientific results to the public. This course was organized together with BBC professional journalists who work on scientific topics. They showed key aspects of their job and held a practical lesson interviewing students on selected themes.

An important feature of the School was students' presentations of their own scientific work and reports on the projects that were prepared in six discussion groups.

In addition to the ambitious scientific programme, the participants could do sports and in excursions get acquainted with nature and places of interest of the wonderful country — Bulgaria. That was a good motive to informal contacts among the participants.

It was mutually agreed that the School in Bulgaria was well organized and successfully accomplished. To a great extent it was due to the students who did their best and actively participated in all events.

On 7–11 September, the ***11th International Seminar on Problems of Charged Particle Accelerators*** was held at the health centre "Dubna" (Alushta, Crimea). It was dedicated to the memory of V. P. Sarantsev. The Seminar has been held in Alushta since 2005.

The purpose of this scientific forum was an exchange of news, results and plans in the accelerator topic, and traditionally it was attended by representatives of largest accelerator centres of Russia, such as the Lomonosov NAFU (Arkhangelsk), ITEP, IHEP, NRC "Kurchatov Institute", IPCEC RAS, INP RAS, the Lomonosov MSU, NRNU MEPI, JIHT RAS (Moscow), IAP RAS (Nizhni Novgorod), INP SD RAS (Novosibirsk), the companies "Tsiklotron" (Obninsk) and "Impulsnye tekhnologii" (Ryazan), SPSU, the company SRIEPE (St. Petersburg), NR TPU (Tomsk).

The organizers noted that the number of participants had considerably increased. 52 reports and 62 poster presentations were made. More than a half of the lecturers were young scientists. S. Tyutyunnikov (JINR) opened the Seminar with a report on scientific heritage of V. Sarantsev. Scientists from the Budker INP (Novosibirsk) made interesting presentations. E. Levichev made two reports: about the international project of a cyclic collider at superhigh energy FGG implemented at CERN, and about an interesting scientific programme at the electron–positron collider VEPP-4M. P. Shatunov continued to discuss this topic speaking about the development of the setup VEPP-2M and the work-out of an injector complex that will allow obtaining more intense positron beams and an increase in the luminosity of both colliders. V. Parkhomchuk made an informative report about the prospects of development of electron cooling systems at the energy of several MeV and about the electron cooling system of 2 MeV developed for the scientific research centre in Jülich (Germany).

One of the sessions was fully devoted to the NICA project. JINR Vice-Director G. Trubnikov spoke about the status of the project; A. Sidorin — about the start version of NICA; A. Dudarev — about the construction of buildings for the collider and detectors. The report by E. Donets on the status of development of the high-charged ion source was met with great interest. Many reports were made on the development of the accelerator techniques. A. Fateev spoke about the intake and exhaust systems at the accelerators of the NICA complex.

Papers on applied research were extensively presented at the Seminar. They were connected with the application of accelerators in related fields of science, for example, in solid matter physics. The report of ITEP Director A. Golubev "Intensive Ion Beams for Generation of Critical State of Matter" discussed interesting application that is important for understanding of the solid matter structure and even echoed the Big Bang theory — critical state of matter, astrophysics, etc.

One of the sessions dealt with accelerators of intermediate and low energy. B. Gikal spoke about the development of the cyclotron complex of FLNR, fundamental studies on the synthesis of superheavy elements and applied research. Among the reports presented at the session were the following: S. Rastigeev (Budker INP) presented a report "Accelerator Mass Spectrometer with Ion Selection in High-Voltage Terminal" about interesting work to develop a mass spectrometer for determination of the age of minerals, study of samples, and its application to tell the age of the Altai Princess; S. Sedykh and A. Kaminsky (JINR) made an interesting report about studies at the free electron maser and plans to establish a materials research centre on the basis of their elaborations.

At the session on applied research, M. Vorogushin (SRIEPE, St. Peterburg) made a report "SRIEPE Accelerators for Applied Studies", where he spoke about the development of medical accelerators. E. Shtarklev (Budker INP) made a report "Industrial Electron Accelerators ILU for Sterilization of Medical Equipment and Processing of Food Products" and discussed one of the topics actively developing in the world.

Beautiful scenery of the Crimea and excellent conditions at the health centre made the exchange of views and scientific discussions even more fruitful: there was a comfortable beach and a café "Dubok" at the participants' disposal. An excursion to the park "Paradiz"

(Aivazovskoe) on a ship was organized for the participants.

On 28 September – 2 October, a small town of Budva in the Republic of Montenegro hosted the ***XXV International Symposium on Nuclear Electronics and Computing*** (NEC'2015). The Symposium has been traditionally held by JINR since 1963 and for the eighth time JINR and CERN became its organizers.

In 2015, the Symposium was devoted to the 60th anniversary of the foundation of JINR. Co-chairmen of the Symposium were: LIT Director V. Korenkov from JINR, Dr. I. Bird from CERN. Attending were 120 leading specialists in modern computer and network technologies, distributed computing and nuclear electronics from 15 countries such as Belarus, Bulgaria, the Czech Republic, France, Germany, Great Britain, Russia, Switzerland, the USA, etc. The scientific programme of the Symposium covered a wide spectrum of questions and included the following sections: detector and nuclear electronics, computer applications for physical research, triggering and data acquisition, automation and control in scientific research, big data, grid-technologies and cloud computations, computing for experiments on large-scale accelerator installations (LHC, FAIR, NICA, etc.), problems of computations on hybrid platforms, as well as such traditional subjects as innovations in training with the use of information technologies.

In the framework of the Symposium the Third International School on Modern Information Technologies was organized for students, postgraduates and young scientists. It was attended by more than 40 students from the leading Russian universities. The young scientists heard lectures of the leading specialists on information technologies from JINR, CERN, University "Dubna" and attended a tutorial on the parallel programming technologies organized by the heterogeneous computations team HybriLIT (LIT JINR). The company "Innopraktika" provided a full financial and organizational support to the school participants. Also, within the Symposium, organized were a workshop "From Local File Catalog to Name Space Publisher + Meta-Catalog" and a round table devoted to the issues of consolidation of efforts of the Russian scientific and educational centres in the field of software development and computing for HEP megascience projects.

Also, the sponsors of the Symposium were the companies IBS, Niagara, Supermicro, Schneider Electric, Jet Infosystems and Jadran Group.

In total, the Symposium presented 96 reports, including 41 plenary and 55 sectional ones. During the closing ceremony, the best reports of young scientists were marked with diplomas. The best projects presented by the student school participants were also rewarded with diplomas.

The International Conference ***"Condensed Matter Research at the IBR-2"*** (CMR-2015) was held at the Frank Laboratory of Neutron Physics on 11–15 October. A series of these conferences was launched in 2014, aimed at providing a platform for discussion of the results of interdisciplinary studies of condensed matter using neutron scattering at the IBR-2 reactor, as well as for analysis of prospects of future research and improvement of instrumentation and methodological base. The CMR-2015 was dedicated to the 100th anniversary of the birth of the outstanding Soviet physicist Fyodor Shapiro, the event which was celebrated in JINR throughout 2015. F. Shapiro is recognized as one of the founders of the Frank Laboratory of Neutron Physics, who made a significant contribution to the development of scientific research areas and basic facilities of the Laboratory.

The Conference was attended by over 120 participants from scientific organizations and universities of the Russian Federation, Azerbaijan, Belarus, Bulgaria, Germany, Latvia, Moldova, Mongolia, Romania, Serbia, Slovakia, Ukraine, and Vietnam. Among the participants were renowned scientists and young researchers, students and postgraduates. A significant growth of interest to this series of conferences should also be noted, which manifested itself in the increase in the number of participants by nearly a quarter as compared to the previous conference.

The Conference programme, comprising more than 40 invited and oral reports and 60 poster presentations, included an introductory session and thematic sections covering topical research areas within which invited talks of well-known specialists and reports of participants selected on the basis of submitted abstracts were presented.

The round table concluded the work of the Conference, during which the participants were reported about the FLNP User Programme that makes it possible to employ the reactor facilities as a common use centre for conducting experiments by interested researchers on the basis of submitted proposals. The Conference participants exchanged their opinions concerning further improvement and development of the User Programme.

PARTICIPATION OF JINR IN INTERNATIONAL CONFERENCES

In 2015, scientists and specialists of the Joint Institute for Nuclear Research took part in 353 international conferences and meetings.

The largest delegations representing JINR attended the following events: the JUNO Collaboration Meeting (Guangzhou, China); the Daya Bay Collaboration Meeting (Hong Kong, China); the CLIC Workshop (CLIC 2015) (Geneva, Switzerland); the MEPhI-2015 Scientific Session (Moscow, Russia); the Conference "Neutron Diffraction-2015" (Gatchina, Russia); the 5th annual T1–T2 Workshop (Torino, Italy); the 49th PNPI Winter School (Roshchino, Russia); the PANDA Collaboration Meeting (Giessen, Germany); the 49th PNPI School on Condensed Matter Physics (Zelenograd, Russia); the 29th HADES Collaboration Meeting (Darmstadt, Germany); the 26th FCAL Collaboration Meeting (Geneva, Switzerland); the 25th CBM Collaboration Meeting (Darmstadt, Germany); the NOvA Collaboration Meeting (Batavia, USA); the Conference "Swift Heavy Ions in Matter" (SHIM 2015) (Darmstadt, Germany); the 22nd International Workshop "Nonlinear Phenomena in Complex Systems" (Minsk, Belarus); the 5th International Conference "Telecommunications, Electronics and Informatics" (ICTEI 2015) (Chişinău, Moldova); the 13th Pisa Meeting on Advanced Detectors "Frontier Detectors for Frontier Physics" (La Biodola, Italy); the PANDA Russia Workshop (Moscow, Russia); the 5th International Conference on Chemistry and Physics of the Transactinide Elements (TAN 15) (Fukushima, Japan); the 25th Daya Bay Reactor Neutrino Experiment Collaboration Meeting (Xi'an, China); the 5th Symposium "Neutrino and Dark Matter in Nuclear Physics" (NDM15) (Juväskylä, Finland); the Russian Scientific and Practical Conference "Medical and Biological Problems of Toxicology and Radiobiology" (St. Petersburg, Russia); the 4th European Radioactive Ion Beam Conference (EURORIB-2015) (Hohenroda, Germany); the 3rd International Conference on Radiation and Applications in Various Fields of Research (RAD2015) (Budva, Montenegro); the 10th Meeting "Matrix Elements for the Double-Beta-Decay Experiments" (MEDEX'15) (Prague, Czech Republic); the International Conference "Superstripes 2015: Quantum in Complex Matter" (Ischia, Italy); the 7th International Workshop on Biomonitoring of Atmospheric Pollution (BioMap 7) (Lisbon, Portugal); the 5th International Conference "High Energy Physics, Quantum Field Theory" (dedicated to the 85th anniversary of V. N. Gribov's birth) (Chernogolovka, Russia); the 12th International Conference on Nucleus–Nucleus Collisions (Katania, Italy); the 3rd Coordination Meeting of the IAEA Programme "Development of an Integrated Approach to Routine Automation of Neutron Activation Analysis" (Vienna, Austria); the International School of Subnuclear Physics, the 53rd Course: The Future of Our Physics Including New Frontier (Erice, Italy); the Workshop "Multifunctional Nanoparticles, Magnetically Controllable Fluids, Complex Flows, Engineering and Biomedical Applications" (Timişoara, Romania); the 17th GDRE Workshop "Heavy Ions at Relativistic Energies" (Nantes, France); the 12th International Conference "Advanced Carbon Nanostructures" (ACNS'2015) (St. Petersburg, Russia); the 15th International Balkan Workshop on Applied Physics and Material Science (IBWAP 2015) (Constanţa, Romania); the Workshop of Russian Users of Synchrotron Radiation and Neutrons (Moscow, Russia); the Workshop on Classical and Quantum Integrable Systems (CQIS 2015) (Protvino, Russia); the European Physical Society Conference on High Energy Physics (EPS HEP 2015) (Vienna, Austria); the 15th Schmidt Seminar on Superconductivity (Moscow, Russia); the 34th International Cosmic Ray Conference (ICRC 2015) (Hague, the Netherlands); the 24th International Congress of Refrigeration (ICR 2015) (Yokohama, Japan); the 22nd International Conference "Ion-Surface Interactions" (ISI-2015) (Moscow, Russia); the 4th International Conference on New Frontiers in Physics (ICNFP 2015) (Crete, Greece); the 6th European Conference on Neutron Scattering (ECNS 2015) (Zaragoza, Spain); the Euroschool on Exotic Beams 2015 (Dubrovnik, Croatia); the 3rd European Nuclear Physics Conference (EuNPC2015) (Groningen, the Netherlands); the Humboldt Kolleg "Interfacing Structure and Reaction Dynamics in the Synthesis of the Heaviest Nuclei" (Trento, Italy); the International Conference "Interaction of Superconductivity and Magnetism in Nanosystems" (Moscow, Russia); the 12th European Conference on Applied Superconductivity (EICAS 2015) (Lyon, France); the 54th PANDA Collaboration Meeting (Darmstadt, Germany); the 17th COMET International Collaboration Meeting (Paris, France); the Small Triangle Meeting on Theoretical Physics (Sveta Nedelja, Croatia);

the 13th International Conference on Heavy Ion Accelerator Technology (Yokohama, Japan); the 6th International Workshop on Supersymmetry on Integrable Systems (SIS'15) (Yerevan, Armenia); the 16th International Conference on Small-Angle Scattering (SAS 2015) (Berlin, Germany); the 59th IAEA General Conference and Forum "Atoms in Industry — Radiation Technology for Development" (Vienna, Austria); the 17th International Workshop in Computer Algebra and Scientific Computing (CASC 2015) (Aachen, Germany); the 16th International Workshop on Polarized Sources, Targets and Polarimetry (PSTP 2015) (Bochum, Germany); the 5th International Conference on Collective Motion in Nuclei under Extreme Conditions (COMEX5) (Cracow, Poland); the 26th CBM Collaboration Meeting (Prague, Czech Republic); the 5th International Conference "Models of Quantum Field Theory" (dedicated to A. N. Vassilyev) (St. Petersburg, Russia); the 22nd Nuclear Physics Workshop "Marie and Pierre Curie" (Kazimierz Dolny, Poland); the 39th European Cyclotron Progress Meeting (Louvain-la-Neuve, Belgium); the 3rd Workshop on Small-Angle Scattering (Gatchina, Russia); the 25th International Conference on Ultrarelativistic Nucleus–Nucleus Collisions (QUARK MATTER 2015) (Kobe, Japan); the 10th International Workshop on Beam Cooling and Related Topics (COOL'15) (Newport News, USA); the International Conference on Particle Physics and Astrophysics (Moscow, Russia); the 30th HADES Collaboration Meeting (Lisbon, Portugal); the Workshop on Dispersion Methods for Hadronic Contributions to QED Effects (Bratislava, Slovak Republic); the International Conference on Precision Physics and Fundamental Physical Constants (Budapest, Hungary); the 19th GANIL Colloqium (Colloque GANIL 2015) (Anglet, France); the Conference "National Instruments Days" (NIDays 2015) (Warsaw, Poland); the Mediterranean-Antarctic Neutrino Telescope Symposium (MANTS) (Amsterdam, the Netherlands); the International Symposium "Interaction of Governments and National Scientific Societies with International Organizations for the Purpose of Development and Application of Scientific Knowledge" (Kiev, Ukraine); the FCAL Workshop (Zeuthen, Germany); the 18th International Conference on Radiation Effects in Insulators (REI-18) (Jaipur, India); the 9th International Conference "Non-Euclidean Geometry in Modern Physics" (BGL-9) (Minsk, Belarus); the JUNO 3" PMT and Central Detector Electronics Workshop (Padova, Italy); the 12th International Topical Meeting on Nuclear Applications of Accelerators (AccApp'15) (Washington, USA); the Conference dedicated to the 35th anniversary of the High Energy Physics Institute of Tbilisi State University (Tbilisi, Georgia); the Science Forum: South Africa (SFSA 2015) (Pretoria, RSA).

DEVELOPMENT OF THE JINR INTERNATIONAL COLLABORATION AND RELATIONS OF THE YEAR 2015

1.	Number of short-term visits to JINR by specialists from the Member States (not counting Russian specialists)	1312
2.	Number of visits of specialists from other countries, including visits of specialists from the associated countries	912 490
3.	Number of visits by JINR specialists to the Member States (not counting Russian visits in Russia)	1292
4.	Number of visits by JINR specialists to other countries, including visits of specialists to the associated countries	1699
5.	Number of conferences, schools, and meetings held by JINR	109
6.	New cooperation agreements (memoranda of understanding), addenda to existing ones	11

LIST OF CONFERENCES, SCHOOLS, AND MEETINGS HELD BY JINR IN 2015 *

No.	Name	Place	Date	Number of participants
1.	Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	22–23 January	70
2.	Meeting of the Programme Advisory Committee for Particle Physics	Dubna	26–27 January	70
3.	Meeting with Representatives of the US Department of Energy	Dubna	26 January	16
4.	Joint Scientific Seminar "Big Data Processing and Analysis Challenges in Mega-Science Experiments"	Dubna	29–31 January	69
5.	Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	29–30 January	70
6.	Session of the Joint Committee on the JINR–IN2P3 Collaboration	Dubna	2–8 February	13
7.	International Workshop on Perspectives of Patricle Physics "Neutrino Physics and Astrophysics"	Valdai, Russia	2–7 February	30
8.	Meeting of the Working Group on JINR Financial Issues under the Chairman of the Committee of Plenipotentiaries	Dubna	16–17 February	30
9.	19th International Scientific Conference for Young Scientists and Specialists of JINR (AYSS-2015) dedicated to the centenary of the birth of F. L. Shapiro	Dubna	16–20 February	313
10.	117th Session of the JINR Scientific Council	Dubna	19–20 February	87
11.	Meeting of the Coordination Committee on Implementation of the BMBF–JINR Agreement	Berlin, Germany	25 February	9
12.	Workshop "Geant4 Looking for Applied Purposes"	Dubna	25–27 February	8
13.	ARE–JINR Forum "Five Years Together"	Cairo, Egypt	2–6 March	150
14.	Scientific School at CERN for Teachers of Physics from the JINR Member States	Geneva, Switzerland	22–29 March	23
15.	Meeting of the JINR Finance Committee	Dubna	23–24 March	85
16.	Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States	Dubna	25–26 March	114
17.	International Symposium on Super Heavy Nuclei (SHE 2015)	College Station, USA	31 March – 2 April	71
18.	19th Research Workshop "Nucleation Theory and Applications"	Dubna	1–20 April	48
19.	Memorial Seminar dedicated to the centenary of the birth of F. L. Shapiro	Dubna	6–7 April	86
20.	Seminar "Selected Problems in Quantum Field Theory" dedicated to the memory of E. A. Kuraev	Dubna	6–8 April	75
21.	Workshop on the Production of Enriched Isotope ND-150 for the SuperNEMO Experiment	Dubna	14–15 April	11

* A number of conferences were held jointly with other organizations; several conferences were dedicated to the 60th anniversary of JINR.

No.	Name	Place	Date	Number of participants
22.	GERDA Workshop	Dubna	15 May	20
23.	JUNO 3" PMT Group Workshop	Dubna	16–19 May	26
24.	8th Spring School on Nuclear Physics "JINR Days in Bulgaria"	Borovets, Bulgaria	16–20 May	70
25.	International Workshop on Hadron Structure and Spectroscopy (IWHSS 2015)	Suzdal, Russia	18–20 May	80
26.	Experiment TAIGA Collaboration Meeting	Dubna	19–21 May	35
27.	International Student Practice; 1st Stage — Practice for Students from ARE	Dubna	26 May – 11 June	28
28.	23rd International Seminar on Interaction of Neutrons with Nuclei (ISINN-23)	Dubna	25–29 May	120
29.	18th International Workshop on Computer Algebra	Dubna	26–27 May	35
30.	Scientific Practical Forum "Distributed Information and Computing Systems and Data Processing in the XXI Century"	Dubna	26–27 May	60
31.	JINR Days in Georgia	Tbilisi, Georgia	28–30 May	100
32.	Baikal Collaboration Workshop	Dubna	2–5 June	55
33.	4th International Conference "Modern Problems of Genetics, Radiobiology, Radioecology, and Evolution" dedicated to N. W. Timofeeff-Ressovsky and his scientific school	St. Peters-burg, Russia	2–6 June	207
34.	Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	4–5 June	51
35.	4th Scientific Conference of Young Scientists and Specialists (Alushta-2015)	Alushta, Russia	6–13 June	100
36.	Meeting of the Programme Advisory Committee for Particle Physics	Dubna	15–16 June	70
37.	Brasil–JINR Forum "Frontiers in Elementary Particle, Nuclear and Condensed Matter Physics"	Dubna	15–19 June	89
38.	Work Meeting "Silicon Tracking System for NICA–BMN Setup"	Dubna	18–19 June	28
39.	School for Teachers of Physics from the JINR Member States	Dubna	21–27 June	29
40.	Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	22–23 June	70
41.	23rd International Conference on Integrable Systems and Quantum Symmetries	Prague, Czech Republic	23–27 June	80
42.	7th International Student Summer School "Nuclear Physics — Science and Applications"	Poznan, Poland	24 June – 4 July	100
43.	9th APCTP–BLTP JINR Joint Workshop "Modern Problems in Nuclear and Elementary Particle Physics"	Almaty, Kazakhstan	27 June – 4 July	90
44.	School for Teachers of Physics from Moscow	Dubna	28 June – 4 July	56
45.	Summer School "Dense Matter"	Dubna	29 June – 11 July	87

No.	Name	Place	Date	Number of participants
46.	65th International Conference on Nuclear Physics "Nucleus 2015. New Horizons in Nuclear Physics, Nuclear Engineering, Femto- and Nanotechnologies"	Peterhof, Russia	29 June – 3 July	200
47.	International Conference "Hadron Structure 2015"	Horny Smokovec, Slovak Republic	29 June – 3 July	41
48.	Meeting of the Working Group on JINR Financial Issues under the Chairman of the Committee of Plenipotentiaries	Lublin, Poland	1–5 July	50
49.	Workshop on Condensed Matter Research with the Use of Neutron Scattering	Constanţa, Romania	4–7 July	57
50.	Round-Table Conference "Physics at NICA"	Dubna	5 July	90
51.	15th International Baikal School on Elementary Particle Physics and Astrophysics	Bolshie Koty, Russia	5–12 July	80
52.	International Student Practice; 2nd Stage — Practice for Students from the Member States and Other Countries	Dubna	5–26 July	73
53.	4th International School "Symmetry in Integrable Systems and Nuclear Physics"	Tsakhkadzor, Armenia	6–11 July	70
54.	International Conference "Strangeness in Quark Matter"	Dubna	6–11 July	225
55.	International Conference "New Photon Detectors 15"	Troitsk, Russia	6–9 July	180
56.	International Conference "Quantum Theory and Symmetries"	Yerevan, Armenia	13–18 July	100
57.	International Conference "Mathematical Modeling and Computational Physics" (MMCP'2015)	Stara Lesna, Slovak Republic	13–17 July	160
58.	International Conference "Nuclear Structure and Related Topics"	Dubna	14–18 July	118
59.	19th School for JINR Young Scientists and Specialists	Dubna (Lipnya)	17–19 July	60
60.	International School "Theory Challenges for LHC Physics" and CALC2015 Workshop	Dubna	20–30 July	80
61.	31st International Conference (Advanced Study Institute) "Symmetries and Spin"	Prague, Czech Republic	26–31 July	77
62.	International School-Conference "Actual Problems of Microworld Physics"	Novaya Guta ("Golden Sands"), Belarus	27 July – 7 August	120
63.	International Workshop "Supersymmetries and Quantum Symmetries"	Dubna	3–8 August	100
64.	International School "Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems"	Dubna	16–21 August	47
65.	17th Lomonosov Conference on Elementary Particle Physics	Moscow, Russia	20–26 August	250

No.	Name	Place	Date	Number of participants
66.	18th Annual RDMS CMS Collaboration Conference	Varna, Bulgaria	24–29 August	70
67.	Workshop "Computational Modeling in Complex Systems 2015"	Dubna	27–30 August	22
68.	6th International Pontecorvo Neutrino Physics School	Stary Smokovec, Slovak Republic	27 August – 4 September	91
69.	3rd International Conference "Physics at the LHC" (LHCP 2015)	St. Peters-burg, Russia	31 August – 5 September	300
70.	European School on High-Energy Physics (CERN–JINR School)	Bansko, Bulgaria	2–15 Sep-tember	130
71.	International Student Practice; 3rd Stage — Practice for Students from South Africa	Dubna	6–27 Sep-tember	53
72.	21st International School on Nuclear Physics and Its Applications & the International Symposium on Exotic Nuclei	Varna, Bulgaria	6–12 Sep-tember	105
73.	11th International Scientific Workshop in Memory of Professor V. P. Sarantsev "Problems of Charged Particle Accelerators"	Alushta, Russia	7–11 Sep-tember	210
74.	16th Workshop on High Energy Spin Physics (DSPIN-15)	Dubna	8–12 Sep-tember	87
75.	Internship Programme for Young Scientists from the CIS	Dubna	14 September – 13 October	50
76.	Forum on Development of Cooperation between JINR and the Czech Republic Academic and Scientific Institutions	Dubna	14–18 Sep-tember	24
77.	International Conference on Radiation Effects on Components and Systems	Moscow, Russia	14–18 Sep-tember	220
78.	Workshop "Modern Nuclear Physics Methods in Condensed Matter Physics"	Minsk, Belarus	15–16 Sep-tember	40
79.	4th South Africa–JINR Symposium "Few- to Many-Body Systems: Models, Methods and Applications"	Dubna	21–25 Sep-tember	92
80.	15th Session of the Coordination Committee on RSA–JINR Cooperation	Dubna	23 September	13
81.	5th Report Seminar of the National Group of Ukraine at JINR	Dubna	24–25 Sep-tember	30
82.	118th Session of the JINR Scientific Council	Dubna	24–25 Sep-tember	85
83.	25th International Symposium on Nuclear Electronics and Computing (NEC-2015)	Budva, Montenegro	28 September – 2 October	270
84.	14th International Seminar on Electromagnetic Interactions of Nuclei (EMIN 2015)	Moscow, Russia	5–8 October	68
85.	3rd International Workshop "Perspectives of Experimental Research at the Nuclotron Beams"	Dubna	8–9 October	63
86.	International Conference "Condensed Matter Research at the IBR-2"	Dubna	11–15 October	118
87.	JINR–INFN Steering Committee Meeting	Pisa, Italy	12–13 October	20
88.	Meeting of the NICA Machine Advisory Committee	Dubna	18–19 October	25

No.	Name	Place	Date	Number of participants
89.	JINR Days in the Czech Republic	Prague, Czech Republic	21–24 October	250
90.	Meeting of the Russian–Chinese Interdepartmental Commission for Science and Technology	Dubna	26 October	51
91.	International Conference “Modern Trends in Radiobiology and Astrobiology. Molecular, Genetic, Cell and Tissue Effects”	Dubna	27–30 October	93
92.	International Conference “Grid, Cloud and High Performance Computing in Science” (RO-LGG 2015)	Cluj Napoca, Romania	28–30 October	60
93.	International Conference devoted to the memory of Academician A. N. Tavkhelidze “Challenges in Contemporary Elementary Particle Physics and Quantum Field Theory”	Tbilisi, Georgia	29 October – 1 November	45
94.	Joint SKLTP–BLTP JINR Workshop on Physics of Strong Interactions	Guilin, China	30 October – 2 November	80
95.	Scientific School at CERN for Teachers of Physics from the JINR Member States	Geneva, Switzerland	1–7 November	42
96.	JINR–CERN School on Information Technologies “Grid and Advanced Information Systems”	Dubna	2–6 November	89
97.	JINR Days in Romania	Bucharest, Romania	2–5 November	500
98.	JINR–FAIR Workshop “SIS100 Superconducting Magnets Manufacturing Design Review”	Darmstadt, Germany	3–6 November	20
99.	Workshop on the NICA Project “Days of NICA in Poland”	Warsaw, Poland	4–7 November	90
100.	6th International School for Young Scientists and Students “Instruments and Methods of Experimental Nuclear Physics. Electronics and Automation of Experimental Facilities”	Dubna	9–14 November	104
101.	TUS Collaboration Workshop	Dubna	10–11 November	10
102.	18th Conference “Science. Philosophy. Religion”	Dubna	17–18 November	85
103.	Meeting of the JINR Finance Committee	Minsk, Belarus	17–18 November	97
104.	Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States	Minsk, Belarus	20–21 November	97
105.	Italy–Russia Round-Table Conference in Dubna “Hundred Years from GR’s Birth, SUGRA Gets into Its Forties“	Dubna	24–28 November	60
106.	Baikal Collaboration Workshop	Dubna	1–4 December	55
107.	Meeting of the Council on Heavy-Ion Physics under the RAS Presidium	Dubna	4 December	60
108.	Joint Scientific Seminar “Machine Learning for the LHC Distributed Data Placement and Track Finding”	Dubna	8–9 December	67
109.	Meeting of the Programme Advisory Committee for Particle Physics	Dubna	14–15 December	70

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

Dubna, 19–20 February. The 117th session of the JINR Scientific Council

Minsk (Belarus), 20–21 November. Visiting session of the JINR CP

Dubna, 15–16 June. The PAC for Particle Physics

Dubna, 22–23 January. A regular meeting of the PAC for Condensed Matter Physics.
Awarding of the authors of the best poster presentations

Dubna, 29–30 January. A regular meeting of the PAC for Nuclear Physics

Minsk (Belarus), 17–18 November. Visiting session of the JINR Finance Committee

Kazimierz Dolny (Poland), 1–5 July.
Participants of the meeting of the Working Group
under the Chairperson of the CP on financial issues

Berlin (Germany), 24–25 February. Participants of the 25th meeting of the Coordination Committee on the implementation of the BMBF–JINR Agreement on cooperation and use of JINR facilities

Dubna, 4 February. A delegation of the Embassy of the Federal Republic of Germany in Russia headed by Director of the Economics and Science Department W. Dik on a visit to JINR

Dubna, 26 March. A Polish delegation headed by Ambassador of the Republic of Poland K. Pełczyński-Nałęcz on a visit to JINR

Baku (Azerbaijan), 11–13 May. The first session of the Working Group under the JINR Directorate and the JINR Plenipotentiary of the Government of the Republic of Azerbaijan on cooperation

Dubna, 9–10 June. Chief of Department of Big Scientific Infrastructures of the Ministry of National Education, Higher Education and Science of France K. Chardonnay (left) on a visit to JINR

Tbilisi (Georgia), 28–30 May. JINR Days in Georgia

Dubna, 23 August.
Members of the JINR Directorate meet the delegation of the Arab Republic of Egypt

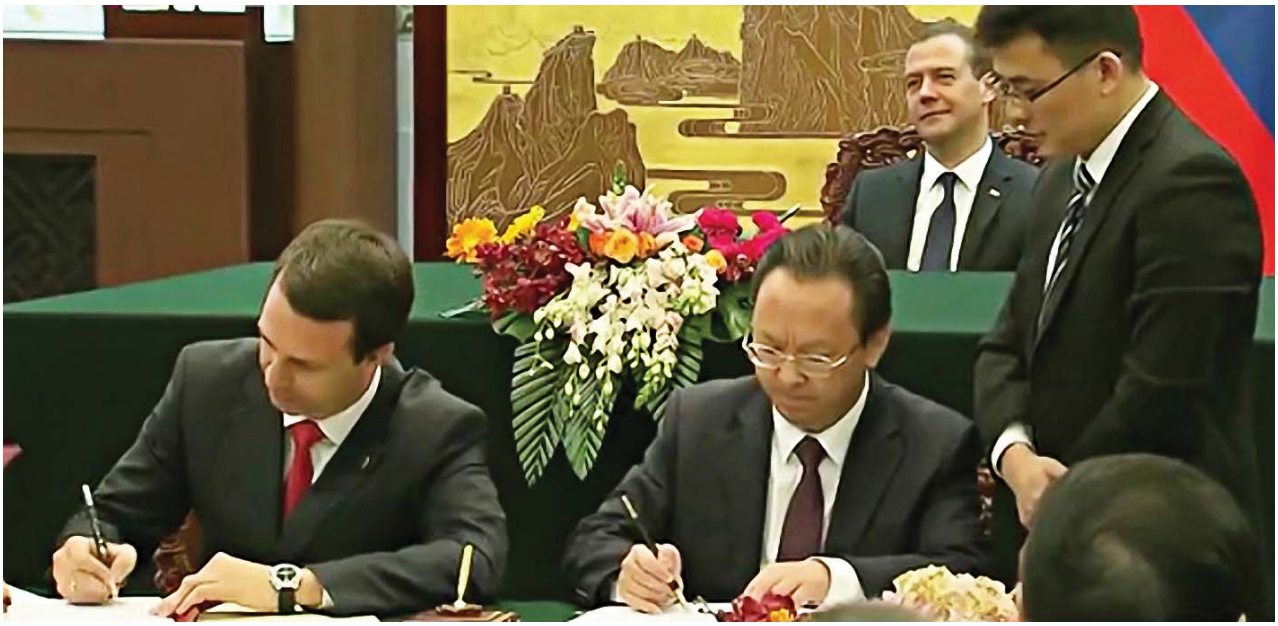
CERN (Geneva), 19 June. Signing of working protocols between CERN and JINR on cooperation in the LHC project and neutrino physics

Dubna, 24–28 November. The VII Round Table Italy–Russia@Dubna

Dubna, 18–20 June. A delegation from the Institute of Plasma Physics of the Chinese Academy of Sciences at JINR

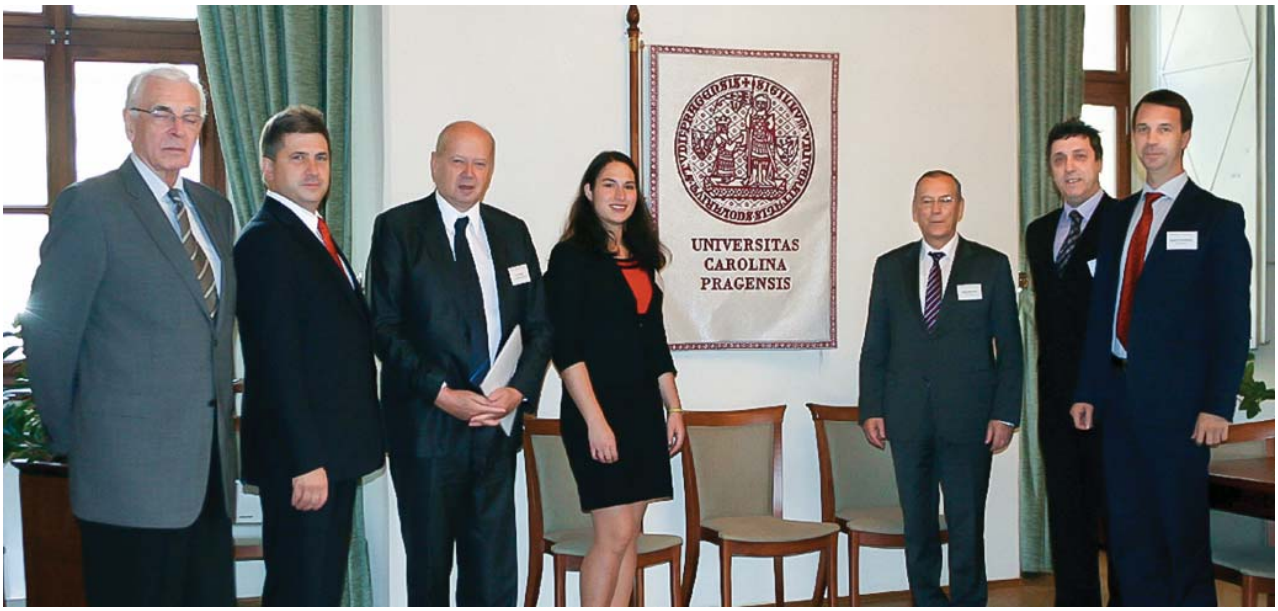
Shanghai (China), 12 October. Signing of an agreement with the leaders of the Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei

Beijing (China), 17 December. Signing of an agreement among the governments of the Russian Federation and the Chinese People's Republic, the Joint Institute for Nuclear Research and the Academy of Sciences of China on joint implementation of the international mega-science project NICA



Dubna, 15–19 June. The Forum Brazil–JINR “Frontiers in Elementary Particle, Nuclear and Condensed Matter Physics”

Minsk (Belarus), 19 November. JINR delegation at the Presidium of the National Academy of Sciences of Belarus



Prague (Czech Republic), 21–24 October. JINR Days on the occasion of the 60th anniversary of the Institute

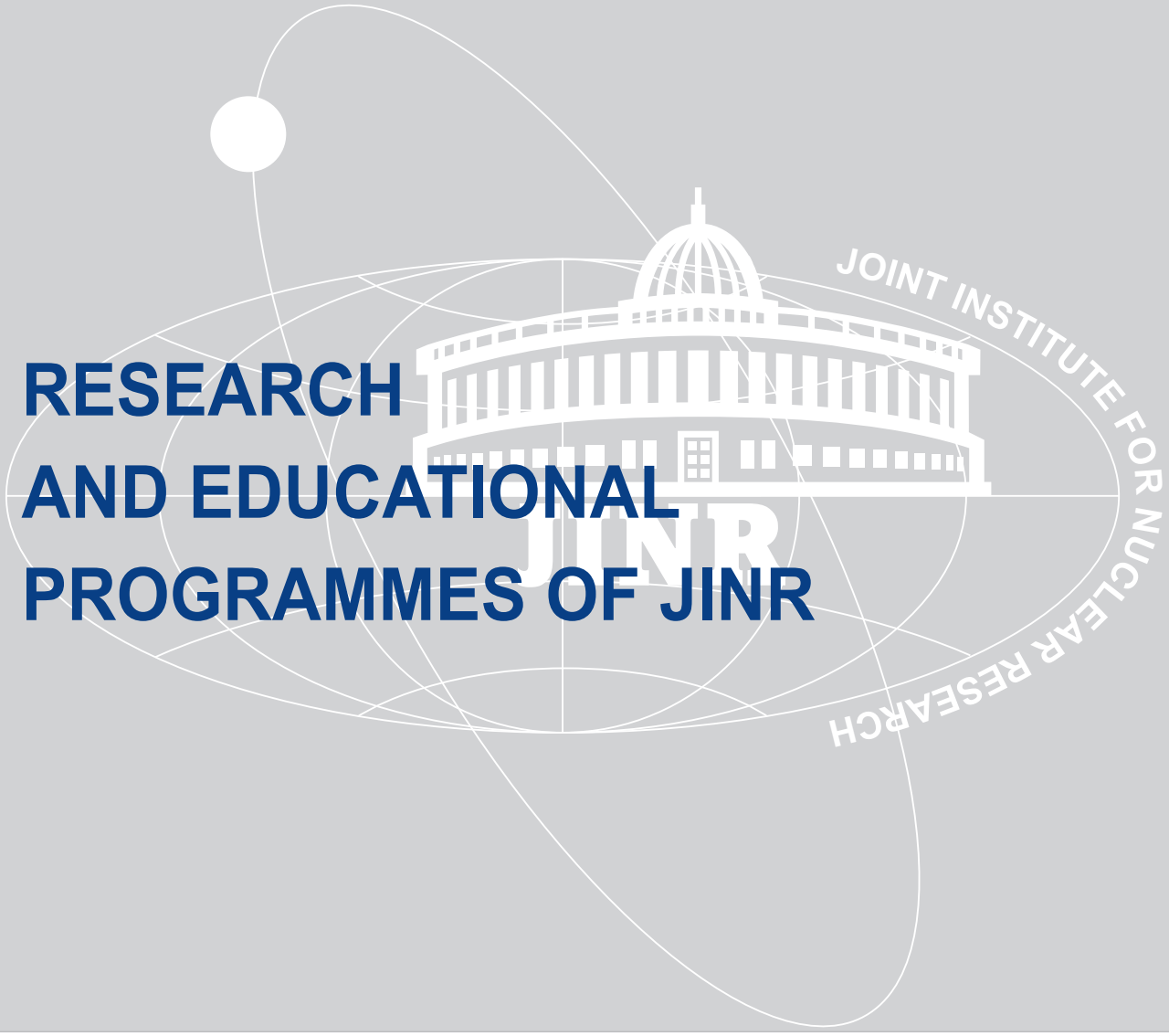
Dubna, 23 December. Ceremonial opening of the photo gallery of portraits of JINR scientists at the University "Dubna"

Alushta (Russia), 6–13 June. Participants of the IV International Conference of Young Scientists and Specialists "Neutron and Neutrino: Fundamental Properties, Experiments and Applied Research"

Bolshie Koty (Lake Baikal, Russia), 5–12 July.
The XV International Baikal Summer School on Elementary Particle Physics and Astrophysics

2015

RESEARCH AND EDUCATIONAL PROGRAMMES OF JINR



BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

At the Bogoliubov Laboratory of Theoretical Physics (BLTP), studies were carried out on the following four themes: Theory of Fundamental Interactions; Theory of Nuclear Structure and Nuclear Reactions; Theory of Condensed Matter; Modern Mathematical Physics: Strings and Gravity, Supersymmetry, Integrability. An important component of the BLTP activities is theoretical support of experimental research to be carried out within major international projects with the participation of JINR as well as Dubna based experimental programs of JINR Laboratories. The research resulted in about 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 2015, more than 1000 scientists participated in 19 international conferences, workshops and schools organized by the Laboratory mostly in Dubna and also in Member States. The international collaboration was supported by grants of the Plenipotentiaries of Bulgaria, the Czech Republic, Poland, the Slovak Republic, Hungary, Romania, and the JINR Directorate; the collaboration with German theorists was based on the Heisenberg–Landau Program; with Armenia, on the Smorodinsky–Ter-Martirosyan Program; with Polish theorists, on the Bogoliubov–Infeld Program; with Czech theorists, on the Blokhintsev–Votruba Program; and with Romanian theorists, on the Titeica–Markov Program. Collaboration with scientists from Western Europe was carried out in the framework of the JINR–INFN, JINR–IN2P3 agreements and was also supported by RFBR–CNSF, RFBR–DFG, RFBR–CNRS grants. The agreements for collaboration between the Bogoliubov Laboratory and CERN TH, KEK, APCTP (South Korea), ITP CAN (Beijing) are functioning. Twelve research projects and six conferences and schools were supported by the RFBR grants. One research group was supported within the RF state program of scientific schools, and one young scientist was sponsored by the grant of the President of RF. 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 70 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, more than one third of the scientific personnel are young scientists and PhD students. Within the JINR fellowship program for nonmember states, several young researchers from India, Japan, Mexico, South Korea, Tajikistan, and Turkey 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;
- Mixed Phase in Heavy-Ion Collisions.

In quantum gauge theories with maximal supersymmetry in six, eight, and ten dimensions the structure of the ultraviolet divergences for the elements of the S-matrix was studied. The leading divergence in the first few orders of perturbation theory (PT) was calculated, and recurrent relations, which allow one to get answers in any order by algebraic procedure without the calculations of the diagrams, were obtained. These relations are a generalization of the renormalization group equations for nonrenormalizable theories. For the sum of the total PT series, the differential equation was derived, the solutions of which were determined by the existence of a fixed point, where the theory is finite. In the case of six dimensions, a fixed point was found which is stable only at certain kinematics. For the full amplitude, the condition of finiteness is not satisfied [1].

A manifestly gauge-independent analysis of the vacuum stability in the Standard Model (SM) including two-loop matching, three-loop renormalization group evolution, and pure QCD corrections through four loops was performed. All these ingredients are exact, except that light-fermion masses are neglected. We in turn apply the criterion of nullifying the MS Higgs self-coupling and its beta function and the recently proposed consistent method for determining the true minimum of the effective Higgs potential that also avoids gauge dependence. Exploiting our knowledge of the Higgs-boson mass, an upper bound on the pole mass of the top quark was derived by requiring the SM to be stable all the way up to the Planck mass scale, and the theoretical uncertainty was estimated conservatively. This bound is compatible with the mass quoted by the Particle Data Group at the 1.3σ level [2].

For the first time, the contribution of orbital angular momenta of up, down, and strange quarks as well as gluon angular momenta to proton spin were computed using LQCD. It has been found that they contribute $\sim 47\%$ (sum of individual quark contribution) and $\sim 28\%$, respectively, thus accounting for all of missing proton spin. The other quantity, quark spin contribution, has been known for a long time to be $\sim 25\%$ both experimentally and in lattice QCD [3].

The hadronic vacuum polarization function obtained within the dispersive approach proved to be in good agreement with the relevant lattice simulation data. The hadronic contributions to electroweak observables (namely, to the muon anomalous magnetic moment and to the shift of the fine structure constant at the scale of Z-boson mass) evaluated within the dispersive approach agree with recent estimations of these quantities [4].

The universal structure of the integral conformal anomaly for the effective action of conformal field theories with boundaries in four dimensions was established. Two new additional functions (charges) related to boundary effects were calculated explicitly for a number of models and different boundary conditions [5].

Deep inelastic scattering data on the F2 structure function obtained by the BCDMS, SLAC, and NMC collaborations in fixed-target experiments were analyzed in the nonsinglet approximation with next-to-next-to-leading-order accuracy. The strong coupling constant was found to be $\alpha_s(M_Z) = 0.1157 \pm 0.0022$ (total exp. error), which is well compatible with the average world value [6].

Recently, there has been much interest in the tauonic semileptonic B-meson decays where one found larger rates than predicted by the Standard Model (SM). It is generally believed that the rare B-decay mode into a vector kaon and a lepton pair is one of the best modes to search for new physics beyond the SM. The LHCb collaboration reported on a measurement of formfactor independent angular observables where a local discrepancy, corresponding to 3.7 standard deviations, was observed. The above B decays were studied in the framework of the covariant quark model with built-in infrared confinement. The relevant form factors in the full kinematic momentum transfer region were computed. The calculated form factors were used to evaluate branching fractions and polarization observables of these transitions. Also, the corresponding semileptonic Λ_b baryon decays were analyzed with particular emphasis on the lepton helicity flip and scalar contributions, which vanish for zero lepton masses. The total rate, differential decay distributions, and the polarization observables were calculated. Large lepton mass effects in the dilepton spectra and polarization observables were found [7].

A new contribution to the hyperfine structure of the molecular ion H_2^+ resulting from relativistic corrections of the second order for vibrational excitations was obtained. This allowed one to solve a discrepancy with the data of a precision experiment by Jefferts (1969) and achieve the ultimate precision of 1 kHz in the spin-flip HFS transitions or of relative uncertainty 10^{-6} [8].

A combined analysis of all available data on the two-pion transitions of bottomonia was performed. The multichannel pion–pion scat-

tering was described in the model-independent approach based on analyticity and unitarity and using a uniformization procedure [9].

A class of models for relativistic covariant wave packets, which can be used as asymptotically free in and out states in the quantum field theoretical formalisms for description of the neutrino flavor oscillation phenomenon, was suggested. It was shown that the new "asymmetric" wave packet (AWP) was an appropriate alternative to more conventional "symmetric" wave packets, like the so-called relativistic Gaussian packet (RGP) widely used in the QFT-based approaches to the neutrino oscillation problem. It was proved that RGP was not a particular case of AWP, although many properties of these two models are almost identical in the quasistable regime. The features of AWP were studied in detail [10].

The influence of a neutrinoless electron to positron conversion on the cooling of strongly magnetized iron white dwarfs was studied. It was shown that they can be good candidates for soft gamma-ray repeaters and anomalous X-ray pulsars [11].

The extension of the Majorana neutrino mass mechanism of the neutrinoless double-beta decay ($0\nu\beta\beta$) with the inclusion of right-handed leptonic and hadronic currents was revised. The particular emphasis was on the reformulation of the decay rate and on the new and more general evaluation of the phase-space factors. The upper limits for effective neutrino mass and the parameters characterizing the right-handed current mechanism were deduced from data on the $0\nu\beta\beta$ decay of ^{76}Ge and ^{136}Xe. The differential decay rates, i.e., the angular correlations and the single-electron energy distributions for various combinations of the total lepton number violating parameters, which can help to disentangle the possible mechanism, were described and discussed [12].

The new mechanisms of the phase shift generation in quantum chromodynamics were investigated, their gauge invariance was proved, and the constraints for soft gluons matrix elements were obtained. The contributions to single-spin asymmetries of Drell–Yan and direct photon production processes were calculated [13].

The generalization of the Brodsky–Lepage–Mackenzie method for optimization of QCD perturbative series in the minimal subtraction scheme for renormalization group invariant quantities for an arbitrary order of coupling was completed. It was based on the β expansion suggested in [14].

By using QCD analysis of the COMPASS, HERMES, and recent very precise CLAS data on the proton and deuteron spin structure functions, it was confirmed that the polarized strange quark density was negative. This fact resolves the old problem of the differences in the results of analysis of the polarized DIS and SIDIS data [15].

The light-by-light hadronic corrections to the muon anomalous magnetic moments due to contributions of light pseudoscalar and scalar mesons and dynamical quark loop were calculated, and it was shown that this mechanism cannot explain the existing disagreement between experiment and prediction of the Standard Model [16].

A new mechanism for the pion production in high-energy reactions and for the energy loss of fast heavy quarks in quark–gluon plasma was proposed. This mechanism is based on pion production caused by the anomalous chromomagnetic quark–gluon–pion interaction. It was shown that this mechanism gives a larger contribution to the collisional energy loss of heavy quark in quark–gluon plasma than the perturbative contributions, which shows a nontrivial role of nonperturbative phenomena in strongly interacting quark–gluon plasma [17].

The detailed description of the processes $e^+e^- \to \eta(\eta')\pi\pi$ within the extended NJL model and in the τ decays into $\rho(770)$ and $\rho(1450)$ was given. In $\eta(\eta')\pi\pi\nu_T$, $\rho(770)(\rho(1450))\nu_T$ and $K^*(892)(K^{*\prime}(1410))\nu_T$ were performed using the extended NJL model [18].

Modern Mathematical Physics

The following topics of the theme were the focus of attention:

- Supersymmetry and Superstrings;
- Quantum Groups and Integrable Systems;
- Quantum Gravity and Cosmology.

Yang–Baxter R-operators, symmetric with respect to the orthogonal and symplectic algebras, are considered in a uniform way. Explicit forms for the spinorial and metaplectic R-operators are obtained. L-operators, obeying the RLL relation with the orthogonal or symplectic fundamental R-matrix, are considered in the interesting cases, where their expansion in inverse powers of the spectral parameter is truncated. Unlike the case of special linear algebra symmetry, the truncation results in additional conditions on the Lie algebra generators of which the L-operators are built and which can be fulfilled in distinguished representations only. Further, generalized L-operators, obeying the modified RLL relation with the fundamental

R-matrix replaced by the spinorial or metaplectic one, are considered in the particular case of linear dependence on the spectral parameter. It is shown how by fusion with respect to the spinorial or metaplectic representation these first order spinorial L-operators reproduce the ordinary L-operators with second order truncation [19].

Analytic shock wave and domain wall solutions were constructed in 5-dimensional backgrounds with broken scale invariance (Lifshitz metrics), we also built trapped surfaces formed in collisions of these shock waves and domain walls, which can be used for the description of the quark–gluon plasma formation in the holographic prescription. The multiplicity of the quark–gluon plasma was estimated in the framework of the holographic approach using calculations for the black hole entropy in dual gravity. We show that for certain Lifshitz metrics the value of the entropy is rather close to experimental data [20].

New component supersymmetric actions were constructed, for membrane in $D = 5$ and for 3-branes in $D = 6$ and $D = 8$; their invariance with respect to spontaneously broken and unbroken supersymmetries was studied. The construction was completed with the help of coset method, which allows one to algorithmically construct all necessary irreducibility conditions and the equations that allow excluding the auxiliary fields. When constructing the component actions, it is possible to construct an ansatz, invariant with respect to broken supersymmetry, which consists of generalization of bosonic action, and the Wess–Zumino term, that shifts by a constant under broken supersymmetry transformations [21].

For a certain class of the quantum integrable models with a particular dependence of the monodromy matrix on the spectral parameter, a new method of calculation of the form factors of the local operators was proposed [22].

Classical and quantum problems of harmonic oscillator on $SO(2,2)$ hyperboloid were considered. Orthonormalized wave functions were obtained through separation of variables. Hamilton–Jacobi equation was solved, and trajectories for different values of separation constant were constructed [23].

A new approach to the mirror symmetry conjecture, called special Bohr–Sommerfeld geometry, was proposed. In the framework of this new geometry, a duality "ample algebraic divisor — its Lagrangian shadow" was obtained [24].

The coset $Sp(2,R)/U(1)$ was parameterized by two real scalar fields. The formalism of auxiliary tensor (bispinor) fields in $U(1)$ self-dual nonlinear models of abelian gauge fields to the case of $Sp(2,R)$ self-duality was generalized. In this new formulation, $Sp(2,R)$ duality of the nonlinear scalar-gauge equations of motion is equivalent to an $Sp(2,R)$ invariance of the auxiliary interaction. This result was derived in two different ways, aiming at its further application to supersymmetric theories. Then extension to interactions with higher derivatives was also considered [25].

The issue of higher-dimensional counterterms for the $N = (1,1)$ supersymmetric Yang–Mills (SYM) theory in six dimensions was revised using the off-shell $N = (1,0)$ and on-shell $N = (1,1)$ harmonic superspace approaches. The second approach was developed in full generality and was used to solve, for the first time, the $N = (1,1)$ SYM constraints in terms of $N = (1,0)$ superfields. This provides a convenient tool to write explicit expressions for the candidate counterterms and other $N = (1,1)$ invariants and may be conducive to proving nonrenormalization theorems needed to explain the absence of certain logarithmic divergences in higher-loop contributions to scattering amplitudes in $N = (1,1)$ SYM [26].

A new model of inflation with Yang–Mills field is developed. Along with popular Higgs-inflation or supergravity inflation models, it can be regarded as compound inflation solving both initial conditions problem and describing the observational CMB data in a very natural and economic way. The observational data indicate that inflation corresponds to the energy scale, which is ten orders of magnitude lower than the Planck scale. The rising problem of initial conditions can be therefore resolved by assumption of preliminary inflation stage driven by the Yang–Mills field nonminimally coupled to gravity, while an observed inflation can be fitted by scalar field model with nonminimal coupling to gravity. The coupling to gravity via Horndeski prescription provides the unique generally and gauge covariant ghost-free theory [27].

Beltrami equation in three dimensions, that plays a key role in the hydrodynamics of incompressible fluids, has an unsuspected relation with minimal supergravity in seven dimensions. We show that only $D = 7$ supergravity and no other theory with the same field content but different coefficients in the Lagrangian admits exact two-brane solutions where Arnold–Beltrami fluxes in the transverse directions have been switched on. The rich variety of discrete groups

that classify the solutions of Beltrami equation are injected into the brane world by this newly discovered token. A new quite extensive area opens up for supergravity and for its dual gauge theories in three dimensions, where all classical fields and all quantum composite operators will be assigned to irreducible representations of discrete crystallographic groups [28].

Within the Dirac model for the electronic excitations of graphene, we calculate the full polarization tensor with finite mass and chemical potential. It has, besides the (00)-component, a second form factor, which must be accounted for. We obtain explicit formulas for both form factors and for the reflection coefficients. Using these, we discuss the regions in the momentum–frequency plane where plasmons may exist and give numeric solutions for the plasmon dispersion relations. It turns out that plasmons exist both for transverse electric and transverse magnetic polarizations over the whole range of the ratio of mass to chemical potential, except for zero chemical potential, where only a TE plasmon exists [29].

Theory of Nuclear Structure and Nuclear Reactions

In 2015, investigations within the area "Theory of Nuclear Structure and Nuclear Reactions" were carried out in accordance with four projects:

- Properties of Nuclei 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 correction term, which modifies the radial dependence of the nucleon effective mass, was added on top of several Skyrme energy–density functionals selected from their effective mass properties and predictions about the stability properties of ^{132}Sn. From the comparison of the effects induced by the surface-peaked effective mass in three doubly magic nuclei, it was found that ^{132}Sn was largely impacted by the correction, while ^{78}Ni and ^{100}Sn were only moderately affected. It was concluded that β-decay rates in these nuclei could be used as a test of different parts of the nuclear energy–density functional [30].

A new interpretation of the large number of low-lying states in ^{80}Ga was suggested. As shown, the coupling between one- and two-phonon terms in the wave functions and the tensor force are important for the description of this relatively weakly deformed nucleus [31].

The corrections induced by the correlations in the ground states of the even-even core result in a better description of the magnetic moments of the low-lying states in odd-A cadmium isotopes [32].

For the sample nuclei ^{56}Fe and ^{82}Ge, the thermal effects were studied [33] in the strength function of allowed Gamow–Teller transitions mainly contributing to the neutrino–nucleus reactions at low energies. New peaks were found in the Gamow–Teller strength functions at finite temperature owing to transitions from the excited states. The temperature rise shifts the Gamow–Teller centroid to lower energies because of the vanishing pairing correlations. As shown, the modification of the Gamow–Teller strength due to finite temperature leads to disappearance of the reaction threshold and significantly enhances the (anti)neutrino cross sections especially at neutrino energies < 10 MeV.

The excitation energies up to 1.2 MeV and the quasiparticle–phonon structure of the low-lying states of the odd-neutron nuclei $^{245-251}$Cm, $^{249-255}$Cf, $^{249-259}$Fm, $^{253-259}$No, and $^{257-261}$Rf were calculated [34]. As shown, the quasiparticle–phonon interaction is important for the description of experimental data.

The excitation spectra of superheavy nuclei belonging to the alpha-decay chain of ^{288}115 were calculated using two different single-particle potentials, modified two-center and Skyrme-based potentials. Besides $E1$ transitions, the strong $M1$ and $M2$ transitions are expected in ^{276}Mt in the Skyrme–Hartree–Fock and two-center shell model treatments, respectively [35].

The role of the spin–orbital potential, spin–spin forces, and hidden angular momenta in the description of spin and orbital scissor modes was investigated [36]. The generalization of the Wigner Function Moments method to include simultaneously spin degrees of freedom and pair correlations allowed one to improve agreement with experimental data.

The corresponding representation theory of proton–neutron symplectic model of collective motions was considered in the many-particle nuclear Hilbert space. The macroscopic (hydrodynamic) limit of the proton–neutron symplectic model was obtained through the group-theoretical contraction procedure [37].

The theoretical model was formulated to describe the recently identified collective proton pairing vibrational state in ^{208}Pb. As found,

the repulsion between the pair removal phonons is stronger than between the pair addition phonons. Quite generally, we conclude that in heavy nuclei the forces between protons and neutrons responsible for the pairing are quite similar [38].

The mass parameters for collective variables of dinuclear systems formed in cold fusion reactions were microscopically calculated with the linear response theory making use of the width of single-particle states and the fluctuation–dissipation theorem. The microscopical mass parameter in the neck was found to be much larger than the one obtained with the hydrodynamical model. Therefore, the dinuclear system lives rather long comparable to the fusion time [39].

The possibilities of production of yet-undiscovered neutron-rich isotopes of Ca, Gd, Dy, Er, Yb, Hf, W, Os, Hg, Pb, and Th were explored in various multinucleon transfer reactions with stable and radioactive beams. The probable projectile–target combinations and bombarding energies to produce these neutron-rich isotopes were suggested for future experiments [40].

The entrance channel effects on the yield of evaporation residues were studied in the fusion reactions leading to ^{220}Th. The largest value of the evaporation residue is observed in very mass asymmetric $^{16}O + ^{204}Pb$ reaction. The $^{40}Ar + ^{180}Hf$ reaction with large excitation energy of the compound nucleus produces less evaporation residues than almost mass symmetric $^{82}Se + ^{138}Ba$ reaction resulting in the lowest excitation value [41].

The basic principles of self-organization of a finite number of charged particles interacting via the Coulomb potential in disk geometry were found. As a result, a system of equations was derived, which allows us readily to determine with high accuracy equilibrium configurations of a few hundreds of charged particles. For $n \geqslant 200$, we predicted the formation of the hexagonal core and valence circular rings for the centered configurations [42].

Electron-impact single and double ionization of a helium atom in the presence of laser radiation with low frequency and intensity was studied theoretically. The kinematical regime of high impact energy and large momentum transfer, with two fast electrons in the final channel, was considered. The laser-assisted cross sections were found to be essentially more sensitive to the electron–electron correlations in helium than the field-free ones [43].

The quantitative theory of resonant processes in confined geometry of atomic traps was developed. In this approach, the widths and shifts of Feshbach resonances were calculated and resonant conditions for “dipolar confinement-induced resonances” were obtained. The quantitative theory of resonant processes in confined geometry of atomic traps was generalized to consider the p-wave Feshbach resonances [44].

The 2-flavor Polyakov-loop extended model was generalized [45] by taking into account the effective four-quark vector-type interaction with the coupling strengths, which are endowed with a dependence on the Polyakov field Φ. The effective vertex generates entanglement interaction between the Polyakov loop and the chiral condensate. It was shown that the finite value of the vector interaction strength Gv improves the model agreement with the lattice data.

It was proved [46] that the Tsallis statistics in the grand canonical ensemble satisfies the requirements of the equilibrium thermodynamics in the thermodynamic limit if the thermodynamic potential is a homogeneous function of the first order with respect to the extensive variables of state of the system and the entropic variable $z = 1/(q-1)$ is an extensive variable of state. The equivalence of canonical, microcanonical, and grand canonical ensembles for the nonrelativistic ideal gas of hadrons was demonstrated.

Based on the proposed model of the microscopic optical potential, the calculations of the pion and exotic nuclei scattering on protons and nuclei were performed. Suggesting the two-cluster structure of the ^{11}Be and ^{11}Li nuclei, the far periphery of these nuclei and mechanisms of their breakup were established [47].

Theory of Condensed Matter

Theoretical investigations within the theme “Theory of Condensed Matter and New Materials” were continued in the framework of the following projects:

- Physical Properties of Complex Materials and Nanostructures;
- Mathematical Problems of Many-Particle Systems.

A promising route to tailoring the electronic properties of quantum materials and devices rests on the idea of orbital engineering in multilayered oxide hetero-structures. It was shown that the interplay of interlayer charge imbalance and ligand distortions provides a knob for tuning the sequence of electronic levels even in intrinsically stacked oxides. In this regard, the d-orbital level structure of layered Sr_2IrO_4 was resolved by electron spin resonance and it was shown that the iridium d-levels are in-

verted with respect to their normal ordering. State-of-the-art electronic-structure calculations confirm the level switching in Sr_2IrO_4, whereas we found them in Ba_2IrO_4 to be instead normally ordered. Given the nonpolar character of the metal-oxygen layers, our findings highlight the tetravalent transition-metal 214 oxides as ideal platforms to explore *d*-orbital reconstruction in the context of oxide electronics [48].

New general properties of fractals were predicted. A particular important result is that a surface fractal can be realized as a sum of mass fractals, and thus the scattering amplitude of the surface fractal can be calculated as a sum of the mass fractal amplitudes [49].

The spin-wave excitation spectrum, magnetization, susceptibility, and the Néel temperature were calculated for the quasi-two-dimensional compass-Heisenberg model proposed for iridates in the antiferromagnetic and paramagnetic states [50].

The inverse Kibble–Zurek scenario for cold trapped Bose atoms was formulated. The accomplished numerical calculations confirmed the theoretical description [51].

The $t-J$ model of strongly correlated electrons was shown to be equivalent to a strongly coupled spin-fermion model, the spin sector being described by the nonlinear $(1+2)$ sigma model. Such a "hard-spin" model describes the Mott physics of almost localized conduction electrons. In contrast, the standard spin-fermion model is based on "soft-spin" collective excitations with large amplitude fluctuations. As a result, the energy window within which the essential non-Fermi liquid behavior sets in is in fact much larger than that predicted by the conventional spin-fermion approach, solely based on the itinerant fermion description [52].

It was shown that the quadrupole 5-7-5-7 defects have a marked influence on the thermal conductivity of graphene at low temperatures and are not relevant at room temperatures, which is important for practical use of graphene in thermionic devices [53].

It was shown that the uncompensated topological charge situated at the edges of zigzag graphene nanoribbons gives rise to a gap in the electronic spectrum thus initializing a metal–semiconductor transition. This finding offers the prospect of using these ribbons in nanoelectronic devices [54].

I-V characteristics of coupled Josephson junctions, which model the intrinsic Josephson junctions in high-temperature superconductors under external electromagnetic radiation, were investigated. A staircase structure of Shapiro steps is found in the branching region. Its origin is related to the coupling between junctions and their switching from rotating to oscillating states. This conclusion is tested by detailed analysis of the I-V characteristics as for total stack and for each junction in the stack. I-V curves of junctions in the stack are compared with the average of time derivative of phase difference. Experimental observation of this staircase structure would give us a prove of coupling between junctions and a way for precise measurement of its value. Such investigations would be also useful for the diagnostics of Josephson junctions in the stack [55].

It was demonstrated that the current-voltage (I-V) characteristics of resistively and capacitively shunted Josephson junctions (RCSJs), hosting localized subgap Majorana states, provide a phase-sensitive method for their detection. The I-V characteristics of such RCSJs, in contrast to their resistively shunted counterparts, exhibit subharmonic odd Shapiro steps. These steps, owing to their subharmonic nature, exhibit qualitatively different properties compared to harmonic odd steps of conventional junctions. In addition, the RCSJs hosting Majorana bound states also display an additional sequence of steps in the devil's staircase structure seen in their I-V characteristics; such a sequence of steps makes their I-V characteristics qualitatively distinct from that of their conventional counterparts [56].

A quantum field model that incorporates Bose-condensed systems near their phase transition into a superfluid phase and velocity fluctuations is proposed. The stochastic Navier–Stokes equation is used for a generation of the velocity fluctuations. The regime of equilibrium fluctuations is analyzed within perturbative renormalization group method. The main corollary gained from the analysis of the thermal equilibrium regime suggests that one-loop calculations of the presented models are not sufficient to make a definite conclusion about the stability of fixed points. We also show that critical exponents are drastically changed as a result of the turbulent background. The scaling exponent of effective viscosity is calculated and agrees with expected value $4/3$ [57].

An integrable generalization of ASEP with extra interaction that allows control of the particle clusterization was considered. The distribution of particle current depending on the value of the interaction strength, which shows two types of universal scaling behavior, was constructed. Either, when the density of particle clusters is finite, the distribution has the form

specific for the KPZ universality class, or all particles form a single cluster characterized by the Gauss distribution. The function unifying the two universal regimes and describing the transition between them was obtained [58].

The rotor–router model on a graph describes a discrete-time walk accompanied by the deterministic evolution of configurations of rotors randomly placed on the vertices of the graph. The following property was proved: if at some moment of time, the rotors form a closed clockwise contour on the planar graph, then the clockwise rotations of rotors generate a walk which enters into the contour at some vertex v, performs a number of steps inside the contour so that the contour formed by rotors becomes anticlockwise, and then leaves the contour at the same vertex v. This property generalizes the previously proved theorem for the case when the rotor configuration inside the contour is a cycle-rooted spanning tree, and all rotors inside the contour perform a full rotation. The proven property was used for an analysis of the subdiffusive behavior of the rotor–rotor walk [59].

The Totally Asymmetric Simple Exclusion Process (TASEP) was studied on open networks consisting of three consecutively coupled long chain segments, the inner one being shunted by a fourth chain of arbitrary length. The conditions for the occurrence of traffic jams and their properties were investigated within the effective rates approximation and by Monte Carlo simulations, when the external segments were in the maximum current phase. For any length of the shortcut and any values of the injection and ejection rates in the domain of the maximum current phase, there exists a position of the shortcut where the shunted segment is in a phase of coexistence with a completely delocalized domain wall. The main features of the coexistence phase and the particle density profiles in the whole network are well described by the domain wall theory. The model displays unexpected features: the one through the longer shunted segment is larger than the current through the shortcut, and the delocalized domain wall in the shunted segment induces a similar behavior even in shortcuts containing a small number of sites [60].

New solutions of the star-triangle relation and Yang–Baxter equation were found for the vertex and IRF-type models of statistical mechanics. They are described by q-special functions related to superconformal indices of three-dimensional supersymmetric field theories [61].

The structure of the spectrum of the Laplacian supported by a dilated honeycomb lattice with a delta-type coupling in the vertices was characterized. There was determined the number of spectral gaps in dependence on the strength of the potentials and the dilation parameter [62].

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

In 2015, the research and education project DIAS-TH was successfully continued. There were the following activities in the framework of DIAS-TH:

- XIX Research Workshop "Nucleation Theory and Applications", April 1–30, Dubna;
- Helmholtz–DIAS International Summer School "Dense Matter", June 29 – July 11, Dubna;
- Helmholtz–DIAS International Summer School "Theory Challenges for LHC Physics" and Workshop "Calculations for Modern and Future Colliders", July 20–30, Dubna;
- International School "Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems", August 16–21, 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

- Seminar dedicated to the memory of Prof. E. A. Kuraev "Selected Problems in Quantum Field Theory", April 6–8, Dubna;
- Brazil–JINR Forum "Frontiers in Nuclear, Elementary Particle and Condensed Matter Physics", June 15–19, Dubna;

• XXIII International Colloquium "Integrable Systems and Quantum Symmetries", June 23–27, Prague, Czech Republic;

• IX APCTP–BLTP JINR Joint Workshop "Modern Problems in Nuclear and Elementary Particle Physics", June 27 – July 4, Almaty, Kazakhstan;

• XV International Conference "Strangeness in Quark Matter" (SQM-2015), July 6–11, Dubna;

• IV International School "Symmetry in Integrable Systems & Nuclear Physics", July 6–11, Tsakhkadzor, Armenia;

• IX International Conference "Quantum Theory and Symmetries (QTS-9)", July 13–18, Yerevan, Armenia;

• International Conference "Nuclear Structure and Related Topics (NSRT15)", July 14–18, Dubna;

• Advanced Studies Institute "Symmetry and Spin", July 26 – August 1, Prague, Czech Republic;

• International Workshop "Supersymmetries and Quantum Symmetries (SQS'2015)", August 3–8, Dubna;

• VI International Pontecorvo "Neutrino Physics School", August 27 – September 4, Horny Smokovec, Slovakia;

• XVI International Workshop "High Energy Spin Physics (DSPIN-15)", September 8–12, Dubna;

• IV South Africa–JINR Symposium "Few to Many Body Systems: Models, Methods and Applications", September 21–25, Dubna;

• SKLTP–BLTP Joint Workshop "Physics of Strong Interaction", October 29 – November 3, Dubna;

• VII Italy–Russia@Dubna Round Table "Hundred Years from GR's Birth, SUGRA Gets into Its Forties", November 24–28, Dubna.

COMPUTER FACILITIES

In 2015, all services of the main BLTP server (WWW, e-mail, etc.) were moved to the tenfold more powerful equipment. A number of obsolete network switches were replaced by contemporary models. This made it possible to upgrade the local network connection speeds from 100 to 1000 Mbit/s for about 200 workplaces and increase the link bandwith between BLTP LAN and JINR backbone from 1 to 10 Gbit/s.

Sixteen high-performance desktop PCs were purchased. The most demanded packages of licensed software like Wolfram Mathematica and Intel Parallel Studio XE were updated to the latest versions.

REFERENCES

1. *Bork L. V. et al.* // JHEP. 2015. V. 1511. P. 059.
2. *Bednyakov A. V. et al.* // Phys. Rev. Lett. 2015. V. 115. P. 201802.
3. *Deka M. et al.* // Phys. Rev. D. 2015. V. 91. P. 014505.
4. *Nesterenko A. V.* // J. Phys. G. 2015. V. 42. P. 085004.
5. *Fursaev D.* // JHEP. 2015. V. 1512. P. 112.
6. *Kotikov A. V., Krivokhizhin V. G., Shaikhatdenov B. G.* // J. Phys. G. 2015. V. 42, No. 9. P. 095004;
   Kotikov A. V., Krivokhizhin V. G., Shaikhatdenov B. G. // JETP Lett. 2015. V. 101, No. 3. P. 141–145.
7. *Gutsche T. et al.* // Phys. Rev. D. 2015. V. 92. P. 114008;
   Ivanov M. A., Tran C. T. // Ibid. P. 074030;
   Dubnička S. et al. // Few Body Syst. 2015. V. 57. P. 1–23.
8. *Korobov V. I. et al.* // Phys. Rev. Lett. 2016. V. 116. P. 053003.
9. *Surovtsev Yu. S. et al.* // Phys. Rev. D. 2015. V. 91. P. 037901;
   Surovtsev Yu. S. et al. // Ibid. V. 92. P. 036002.
10. *Naumov V. A., Shkirmanov D. S.* // Mod. Phys. Lett. A. 2015. V. 30. P. 1550110.
11. *Belyaev V. B. et al.* // Nucl. Phys. A. 2015. V. 937. P. 17.
12. *Štefánik D. et al.* // Phys. Rev. C. 2015. V. 92. P. 055502.
13. *Anikin I. V., Teryaev O. V.* // Eur. Phys. J. C. 2015. V. 75. P. 184;

Anikin I. V., Teryaev O. V. // Phys. Lett. B. 2015. V. 751. P. 495.
14. *Kataev A. L., Mikhailov S. V.* // Phys. Rev. D. 2015. V. 91. P. 014007.
15. *Leader E., Sidorov A. V., Stamenov D. B.* // Ibid. P. 054017.
16. *Dorokhov A. E., Radzhabov A. E., Zhevlakov A. S.* // Eur. Phys. J. C. 2015. V. 75. P. 417.
17. *Kochelev N. et al.* // Phys. Rev. D. 2015. V. 92, No. 3. P. 034025;
Kochelev N. et al. arXiv:1510.00472 [hep-ph].
18. *Ahmadov A. I., Kalinovsky Yu. L., Volkov M. K.* // Intern. J. Mod. Phys. A. 2015. V. 30. P. 1550161.
19. *Isaev A. P., Karakhanyan D., Kirschner R.* // Nucl. Phys. B. 2016. V. 904. P. 124.
20. *Aref'eva Ya., Golubtsova A. A.* // JHEP. 2015. V. 1504. P. 011.
21. *Bellucci S. et al.* // Class. Quant. Grav. 2015. V. 32. P. 035025;
Bellucci S. et al. // Ibid. P. 115008.
22. *Pakuliak S., Ragoucy E., Slavnov N. A.* // Nucl. Phys. B. 2015. V. 893. P. 459.
23. *Petrosyan D. R., Pogosyan G. S.* // SIGMA. 2015. V. 11. P. 1.
24. *Tyurin N. A.* arXiv:1508.06804v1 [math.SG]. 2015.
25. *Ivanov E., Lechtenfeld O., Zupnik B.* // JHEP. 2015. V. 1503. P. 123.
26. *Bossard G., Ivanov E., Smilga A.* // Ibid. V. 1512. P. 085.
27. *Davydov E., Gal'tsov D.* arXiv: 1512.02164 [hep-th].
28. *Fre P., Sorin A. S.* // Fortsch. Phys. 2015. V. 63. P. 411.
29. *Bordag M., Pirozhenko I.* // Phys. Rev. D. 2015. V. 91. P. 085038.
30. *Severyukhin A. P. et al.* // Phys. Rev. C. 2015. V. 90. P. 034322.
31. *Etilé A. et al.* // Ibid. V. 91. P. 064317.
32. *Mishev S., Voronov V. V.* // Phys. Rev. C. 2015. V. 92. P. 044329.
33. *Dzhioev A. A., Vdovin A. I., Wambach J.* // Ibid. P. 045804.
34. *Shirikova N. Yu. et al.* // Eur. Phys. J. A. 2015. V. 51. P. 21.
35. *Bezbakh A. N. et al.* // Phys. Rev. C. 2015. V. 92. P. 014329.
36. *Balbutsev E. B., Molodtsova I. V., Schuck P.* // Ibid. V. 91. P. 064312.
37. *Ganev H. G.* // Intern. J. Mod. Phys. E. 2015. V. 24. P. 1550039;
Ganev H. G. // Eur. Phys. J. A. 2015. V. 51. P. 84.
38. *Jolos R. V., Heusler A., von Brentano P.* // Phys. Rev. C. 2015. V. 92. P. 014329.
39. *Adamian G. G., Antonenko N. V., Lenske H.* // Ibid. V. 91. P. 054602.
40. *Myeong-Hwan Mun et al.* // Ibid. V. 91. P. 054602.
41. *Kim K. et al.* // Ibid. P. 064608.
42. *Cerkaski M., Nazmitdinov R. G., Puente A.* // Phys. Rev. E. 2015. V. 91. P. 032312.
43. *Bulychev A. A., Kouzakov K. A.* // Phys. Rev. A. 2015. V. 91. P. 023413.
44. *Saeidian S., Melezhik V. S., Schmelcher P.* // J. Phys. B. 2015. V. 48. P. 155301.
45. *Friesen A. V., Kalinovsky Yu. L., Toneev V. D.* // Intern. J. Mod. Phys. A. 2015. V. 30. P. 1550089.
46. *Parvan A. S.* // Eur. Phys. J. A. 2015. V. 51. P. 108.
47. *Lukyanov V. K. et al.* // Phys. At. Nucl. 2015. V. 78. P. 147;
Lukyanov V. K. et al. // Phys. Rev. C. 2015. V. 91. P. 034606.
48. *Bogdanov N. et al.* // Nature Communications. 2015. V. 6. P. 7306.
49. *Cherny Yu. et al.* // Rom. J. Phys. 2015. V. 60. P. 658.
50. *Vladimirov A. A., Ihle D., Plakida N. M.* // Eur. Phys. J. B. 2015. V. 88. P. 148.
51. *Yukalov V. I., Novikov A. N., Bagnato V. S.* // Phys. Lett. A. 2015. V. 379. P. 1366;
Yukalov V. I., Novikov A. N., Bagnato V. S. // J. Low Temp. Phys. 2015. V. 180. P. 53.
52. *Ferraz A., Kochetov E.* // Eur. Phys. Lett. 2015. V. 109. P. 37003.
53. *Krasavin S. E., Osipov V. A.* // J. Phys.: Cond. Matter. 2015. V. 27. P. 425302.
54. *Pincak R., Smotlacha J., Osipov V. A.* // Physica B: Condensed Matter. 2015. V. 475. P. 61.
55. *Shukrinov Yu. M., Rahmonov I. R., Nashaat M.* // Pis'ma v ZhETF. 2015. V. 102. P. 919.
56. *Maiti M. et al.* // Phys. Rev. B. 2015. V. 92. P. 224501.
57. *Dančo M. et al.* // Phys. Rev. E. 2016. V. 93. P. 012109.
58. *Derbyshev A. E., Povolotsky A. M., Priezzhev V. B.* // Phys. Rev. E. 2015. V. 91. P. 022125.
59. *Papoyan Vl. V., Poghosyan V. S., Priezzhev V. B.* // J. Phys. A. 2015. V. 48. P. 285203.
60. *Bunzarova N., Pesheva N. C., Brankov J. G.* // Physica A. 2015. V. 438. P. 645.
61. *Gahramanov I., Spiridonov V. P.* // JHEP. 2015. V. 08. P. 040.
62. *Exner P., Turek O.* // Integral Equations and Operator Theory. 2015. V. 81. P. 535.

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 2015 was focused on the implementation and further development of the NICA project (the Nuclotron–NICA, MPD, and BM@N subprojects) and the 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 VBLHEP's accelerator complex in 2015 was aimed at the construction of systems and elements for the NICA complex.

During the acceleration 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 of the NICA complex — the Booster and Collider.

Nuclotron–NICA

Among the most significant achievements obtained in 2015, there are the following:

• The general contract with Strabag company on the complex construction has been prepared and signed on 18 September, 2015. Civil works have been started. The construction is scheduled to be completed within 43 months.

• Works were continued on the upgrade of the existing linac (LU-20) for light ions and the construction of a new linac for heavy ions. The RFQ and RF amplifiers for the LU-20 were shipped to JINR on 6 October, 2015. The equipment was mounted and assembled on the test bench on 16 October, 2015 and successfully passed all the tests.

All elements of a new heavy ion linac (HILac) ($z/A \geqslant 0.14$) were delivered to the Laboratory and assembled. The commissioning is in progress.

A new He Liquefier OG-1000 was installed and prepared for test in accordance with the plan of the cryogenic complex development. Two units of a helium screw compressor aggregate Kaskad-110/30 were delivered to the Laboratory and are ready for assembly.

• The development of technological line for SC magnet fabrication for the NICA and SIS-100 accelerators was continued in 2015. The line has to fabricate and test more than 250 SC magnets for the NICA facility. Assembly and test of one unit takes approximately three weeks. Now the line is close to completion. Mounting of the second and the third (the final) satellite refrigerator units was completed in 2015. The third and fourth test benches, out of six, have been mounted. The last two test benches will be installed in the first quarter of 2016. Serial production of the SC-magnet yokes has started. 26 out of 48 quadrupole magnet yokes have been delivered and tested for assembly with the cryostat and further test program.

MPD Project

R&D works on the MPD subsystems were 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.

Progress with the MPD Magnet

The schedule of the project realization strongly depends on the timely construction of the MPD superconducting solenoidal magnet. The contract on the magnet construction and delivering was signed between ASG Superconductors S.p.A., Italy, and JINR on 21 December, 2015. ASG will deliver the magnet basic elements, cryostat with cold mass within 34 months.

Progress with TPC

Works on the TPC are going in accordance with the schedule. The pad-plane printed circuit board of the TPC Read-Out-Chamber (ROC) is designed and manufactured. The pad connectivity test is completed.

The complete set of micromirrors for the TPC laser calibration system is manufactured and delivered to Dubna. All laser beam splitters are assembled, their calibration is in progress.

The gas system will be built in collaboration with PNPI, St. Petersburg, and industry. All gas system components and parts are delivered to the Laboratory.

Progress with TOF

In February 2015, two large MRPC prototypes having strip readout (strip 600 × 10 mm) of resistive electrodes with a width of 280 and 400 μm, were tested at the "MPD test channel" facility. A new symmetric three-stack design of the detector was used for the first time. Time resolution and efficiency at different discrimination thresholds of the amplifiers were evaluated. The time resolution of both detectors was better than 50 ps at efficiency above 98% (see Fig. 1).

The influence of the particle transit angle through the MRPC on its time resolution was studied using the precise positioning device (see Fig. 2). Time resolution is about 50 ps, even when transit angles are up to 70°.

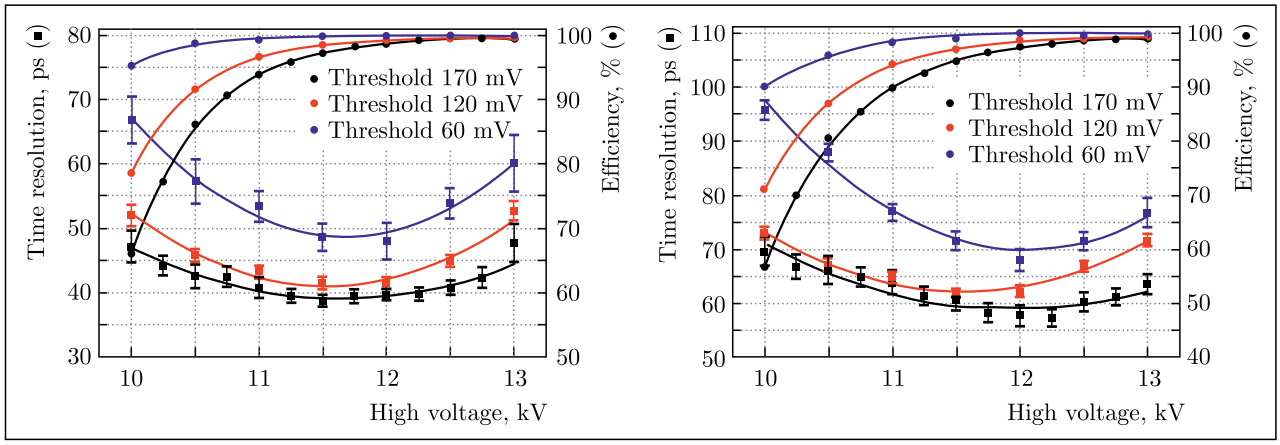


Fig. 1. Efficiency and time resolution of the MRPC. Width of electrodes of 280 μm (left); width of electrodes of 400 μm (right)

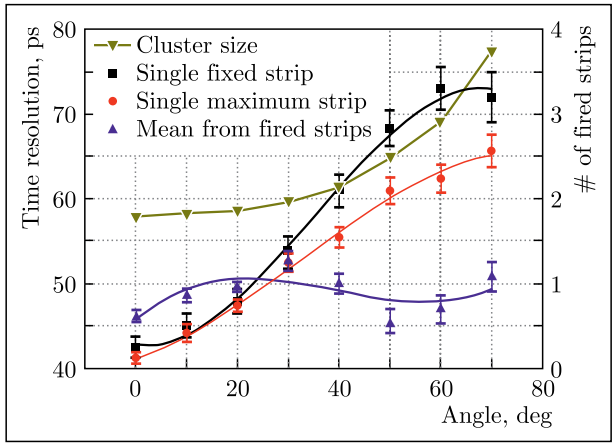


Fig. 2. Influence of the particle transit angle through the MRPC on time resolution

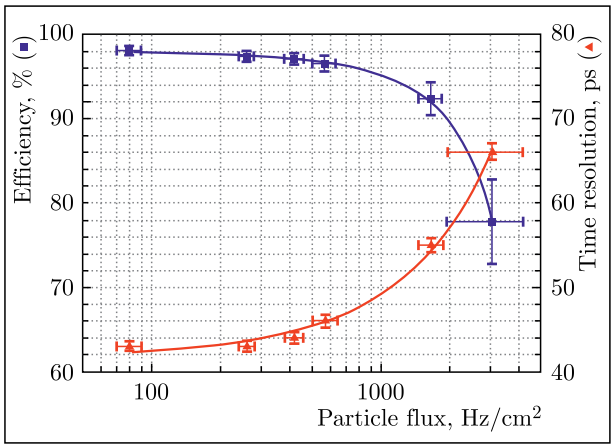


Fig. 3. Load capacity of the MRPC with resistive electrode with width of 280 μm

The MRPC load capacity with thin glass (280 μm) was also studied (see Fig. 3). With the particle flux up to 2 kHz/cm^2 time resolution of the detector is better than 60 ps at the recording efficiency above 90%.

An area with ultrasonic washing and drying devices, detector assembly room, and autopainting of the glass with semiconductor paint device are ready for using.

Progress with FFD

In 2015, 12 T0 detector modules (FFD module prototypes) based on MCP-PMTs XP85012/A1-Q were constructed and tested on the BM@N setup channel. L0 trigger electronics, software and Slow Control system were manufactured for the detector control.

Experimental research was carried out in the extracted beams of deuterons and carbon nuclei at the MPD and BM@N test areas.

Time resolution of the Cherenkov modules was estimated within the TOF dimensions in the deuteron beam with CD1 and CD2 pairs of modules and CAEN mod.N6742 digitizer. The example of test results is shown in Fig. 4.

Progress with MPD TDRs

Current status of TDRs for the MPD subsystems is presented in the following table:

Subsystem	Status
Time Projection Chamber (TPC)	Completed
TPC gas system	Completed
Time-Of-Flight system	Completed
Zero Degree calorimeter	Completed
Fast Forward detector	Completed
Data Acquisition system	Completed
Electromagnetic calorimeter	In preparation
Slow Control system	In preparation
MPD integration	In preparation
MPD magnet	Completed

BM@N Project

The BM@N technical run was carried out in the extracted deuteron and carbon beams of the Nuclotron in February–March 2015. The following elements of the BM@N detector were tested: Time-Of-Flight system (TOF), Trigger and Start Time detectors (T0), outer Drift chambers (DCH), hadron Zero Degree calorimeter (ZDC), beam monitors, beam profile detectors. The integrated Data Acquisition System (DAQ) was in operation.

Time and spatial structure of the beam were measured during the run. The nucleus contents of the carbon beam before and after interaction with the target are shown in Fig. 5. The momentum of the deuteron beam measured in the BM@N setup is presented in the left part of Fig. 6. The right part of Fig. 6 illustrates the TOF spectra obtained during the run with a carbon beam and a carbon target.

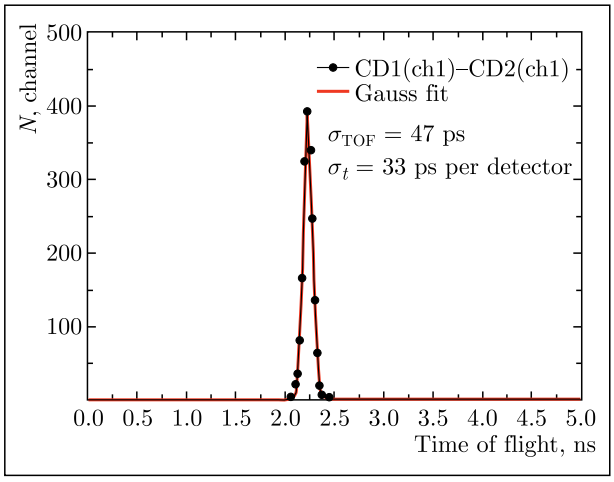


Fig. 4. Measurement of the Cherenkov module time resolution on the deuteron beam with energy of 3.5 GeV/nucleon

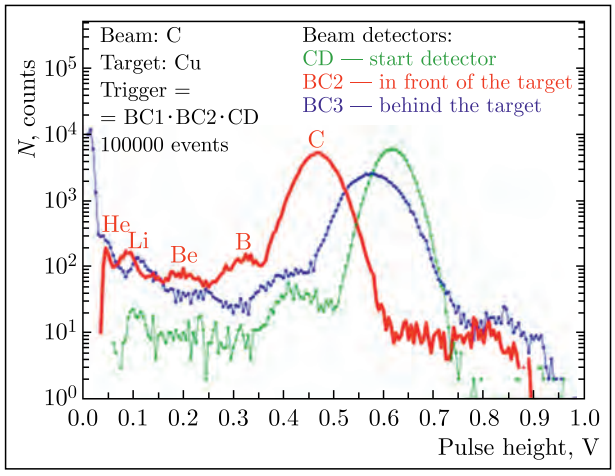


Fig. 5. Fractions of light nucleus in the carbon beam before interaction (red spectrum) and after interaction (blue spectrum) as visible in the amplitude distributions of the beam counters situated in front and behind the target. The green spectrum presents the amplitude response of Cherenkov time start detector situated in front of the target

Extension of International Cooperation

The Protocol has been signed in Beijing in December 2015 between the Ministry of Education and Science of the Russian Federation, Ministry of Science and Technology of People's Republic of China, Academy of Science of People's Republic of China, and Joint Institute for Nuclear Research on cooperation in the framework of the NICA complex.

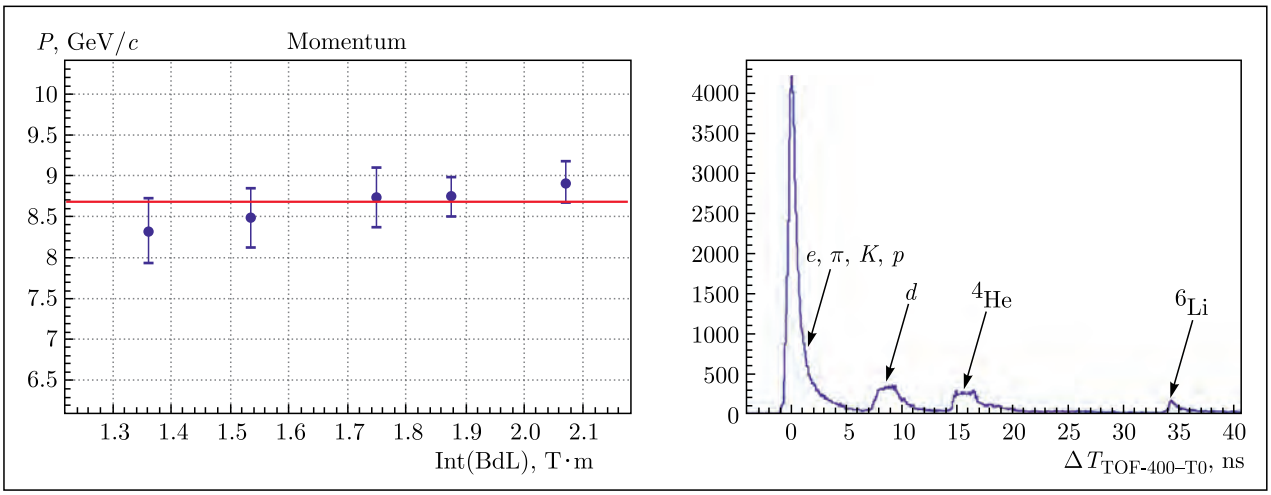


Fig. 6. Momentum of the deuteron beam (vertical scale) measured in the BM@N setup at different values of the magnetic field integral (horizontal scale). The red line presents the nominal value of the deuteron beam momentum of 8.68 GeV/c (left). The TOF spectra TOF-400–T0 are obtained in interaction of a carbon beam with momentum 3.5 A GeV with a carbon target (right)

EXPERIMENTS CARRIED OUT AT THE NUCLOTRON DURING THE 2015 RUNS

DSS

In the framework of the DSS project, the following results have been obtained in 2015:

• The experimental data on the angular dependence of the elastic deuteron–proton scattering cross section at the deuteron energies of 1600 and 1700 MeV using the setup at the internal target have been obtained in the Spring-2015 Nuclotron run. The preliminary results have been reported at the international conferences.

• During the same run, the unique data for deuteron–proton nonmesonic breakup in the so-called "space star" configuration at the energy of 400 MeV have been obtained using setup at the internal target.

• The theoretical calculations for the interpretation of the obtained experimental data on deuteron–proton elastic scattering and for the $dd \to {}^3\mathrm{H}p$ reaction at 2000 and 200 MeV, respectively, have been performed [1] in the framework of the relativistic multiple scattering model.

HyperNIS

In the framework of the HyperNIS project, the analog electronics part of the Front-End readout system for multiwire proportional chambers (MWPC) of the HyperNIS spectrometer was tested at one of the MWPCs at the extracted Nuclotron beam in March 2015.

The trigger for selection of hyper-hydrogen production events operated very stable during about 40 h. Tests of the pixel detector TimePix were performed at the extracted ^{7}Li and ^{12}C beams.

QUINTA

In 2015, the QUINTA experiment carried out on the proton beam with energies $E_p = 660$ MeV was aimed at measuring the spatial and energy distributions of the neutron field inside nuclear assemblies and on the surface. For this purpose, the channels of nuclear reactions in the Co target with different thresholds were used.

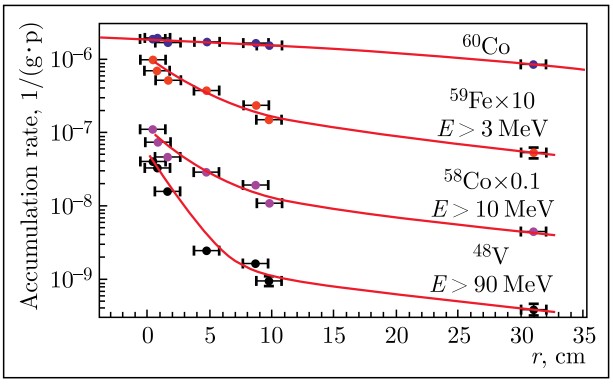


Fig. 7. Radial distribution of the accumulation rates after the fifth section for ^{60}Co, ^{59}Fe, ^{58}Co, and ^{48}V

Figure 7 shows the spatial distribution of the radial flux density of neutrons of different energies starting from $E \leqslant 0.1$ MeV up to the maximum. There is a strong anisotropy in the radial direction. Appearance of the high-torch with energy $E_n \geqslant 20$ MeV is detected as a consequence of the end of the target on $Z =$ 650 mm [2].

PARTICIPATION IN EXPERIMENTS AT EXTERNAL ACCELERATORS

Experiments at the LHC

ALICE

New results of the 3D femtoscopic correlation analysis for charged kaon pair production in Pb–Pb collisions at 2.76 TeV (per nucleon pair) were obtained by the JINR group and compared with the ones for charged pions and with the prediction of the Hydro-Kinetic Model (HKM). Figure 8 shows transverse mass (m_T) dependence of particle emission source radii (three components $R_{\rm out}$, $R_{\rm site}$, $R_{\rm long}$) for kaon and pion pair productions in central events. The HKM with rescatterings describes well kaon data and most results for pions. Deviation from ideal m_T scaling (radii for kaons are systematically higher than for pions) is explained in this theoretical model by essential transverse flow and rescattering phase. These results have been reported by the JINR group at QM-2015 Conference.

Results for the 1D femtoscopic correlation analysis of charged kaons, obtained by the JINR group, are compared with the ones for neutral kaons, charged pions, protons and antiprotons [3, 4]. The main results are the following:

- the femtoscopic invariant radius ($R_{\rm inv}$) for kaons and protons exhibits transverse mass scaling which is consistent with the hydrodynamic model predictions assuming collective flow;
- the deviation from the scailing for pions can be explained as a consequence of the increase of the Lorentz factor with decreasing particle mass during the transformation from Longitudinally Co-Moving System to the Pair Rest Frame;
- the predictions of the HKM for $R_{\rm inv}$ coincide well with the observations.

New results for the inclusive J/ψ and first results for the $\psi(2S)$ productions in Pb–Pb collisions at 2.76 TeV have been published with participation of the JINR group [5].

Figure 9 shows the ALICE result for the double ratio $([\psi(2S)/J/\psi]_{\rm Pb-Pb}/[\psi(2S)/J/\psi]_{pp})$ measured between $\psi(2S)$ and J/ψ production yields at $(s_{NN})^{1/2} = 2.76$ TeV in Pb–Pb and p–p collisions for two p_T intervals and depending on Pb–Pb collision centrality in terms of the mean number of participant nucleons ($N_{\rm part}$). Due to the small statistics of $\psi(2S)$, only the 95% confidence level limit is shown at higher p_T ($3 < p_T < 8$ GeV/c).

ATLAS

The JINR ATLAS group was working in several areas: analysis of the ATLAS experimental data, simulation of the liquid argon hadronic calorimeter degradation at high luminosity of LHC, irradiation tests at the IBR-2M reactor for the ATLAS Upgrade program.

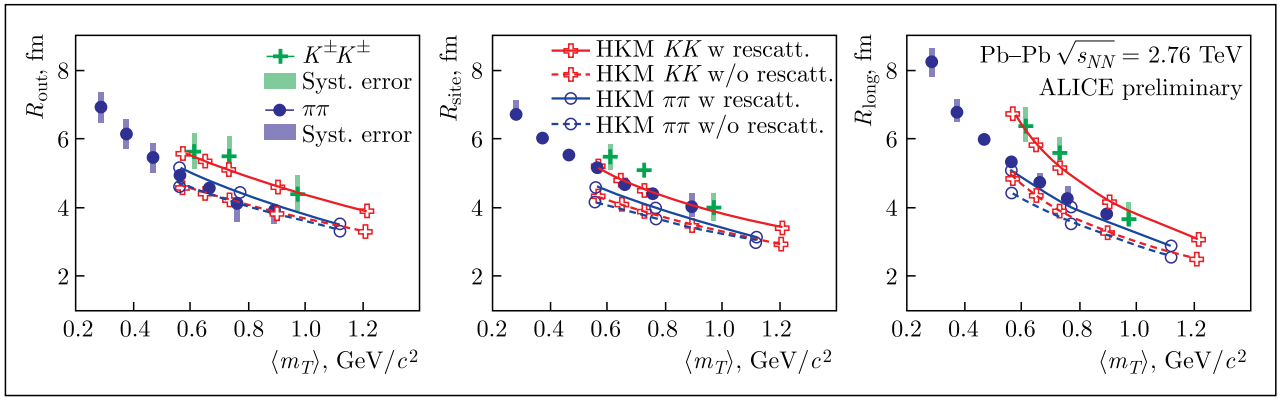


Fig. 8. Three components ($R_{\rm out}$, $R_{\rm site}$, $R_{\rm long}$) of kaon and pion emission source radius versus m_T obtained for Pb–Pb central events. The results of the HKM are presented for comparison

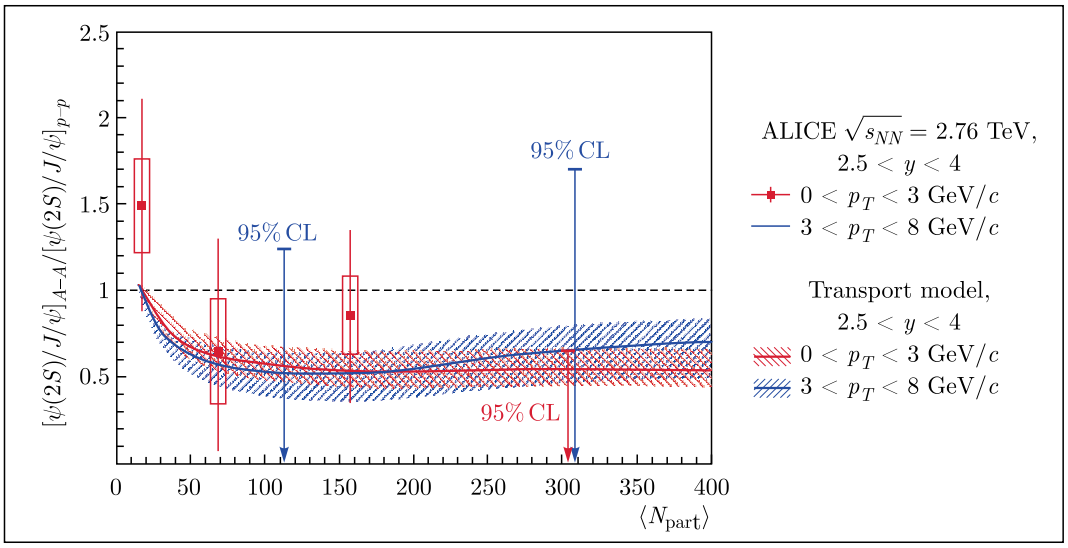


Fig. 9. Double ratio between $\psi(2S)$ and J/ψ vs $\langle N_{\rm part}\rangle$ for Pb–Pb and p–p collisions at 2.76 TeV

The analysis of the ATLAS experimental data aimed at the search for the process of the Higgs boson associative production with W/Z boson was continued. The ratio of the observed and expected in the Standard Model signal yields was found to be $0.74 \pm 0.09(\text{stat.}) \pm 0.14(\text{syst.})$.

CMS

During 2015, the JINR group in the framework of the CMS experiment participated in obtaining, processing and analyzing of the LHC session data on the colliding beams of protons at energy of 13 TeV in c.m.s. with luminosity up to $4 \cdot 10^{33}$ cm$^{-2} \cdot$ s^{-1}.

The measurements of the invariant mass spectrum of events with a pair of muons were carried out on the first data with the magnetic field on the statistics corresponding to the integral luminosity of ~ 2 fb^{-1}. A good agreement between the results of the measurements and SM predictions was obtained taking into account different background processes [6, 7].

Experiments at the CERN Super Proton Synchrotron

COMPASS

In 2015, the COMPASS experiment collected data on measurement of the Drell–Yan processes with the use of the pion 160 GeV beam and transversely polarized hydrogen target. The data analysis is in progress.

In 2015, the COMPASS collaboration published the result obtained in the measurement of the pion polarizability. The aim of this measurement was the verification of the Chiral Perturbation Theory (ChPT), which predicts the charged pion, electrical and magnetic polarizability values $\alpha_\pi = (2.9 \pm 0.5) \cdot 10^{-4}$ fm^3 and $\beta_\pi = (-2.8 \pm 0.5) \cdot 10^{-4}$ fm^3, respectively, [8].

The muon beam was used for study and control of various systematic effects. Figure 10 shows the ratio of the measured energy spectrum of the emitted photons to the expected spectrum for the point-like pion, based on the statistics of about 63 000 detected events (top) and muon (bottom). Quantity x_γ is the ratio of the emitted photon energy to the beam energy. Deviation of this ratio for the pion from a constant at high energies corresponds to the values of the pion polarizabilities $\alpha_\pi = -\beta_\pi = (2.0 \pm 0.6_{\rm stat} \pm 0.7_{\rm syst}) \cdot 10^{-4}$ fm^3 (under the assumption $\alpha_\pi + \beta_\pi = 0$) [9]. The result is in good agreement with the ChPT prediction.

The essential contribution was also made by the JINR group in receiving new results on spin asymmetry of A_1^p and structure function g_1^p. These results were obtained by the COMPASS collaboration using the polarized 200 GeV muons scattered off the longitudinally polarized NH^3 target. The data were collected in 2011 and complement those recorded in 2007 at 160 GeV, in particular at lower values of x. They improve the statistical precision of $g_1(x)$ by about a factor of two in the region $x \leqslant 0.02$. A next-to-leading order QCD fit to the g_1 world data is performed. It leads to a new determination of the quark spin contribution to the nucleon spin, $\Delta\Sigma$ ranging from 0.26 to 0.36, and to a re-evaluation of the first moment of g_1. The uncertainty of $\Delta\Sigma$ is mostly due to the large

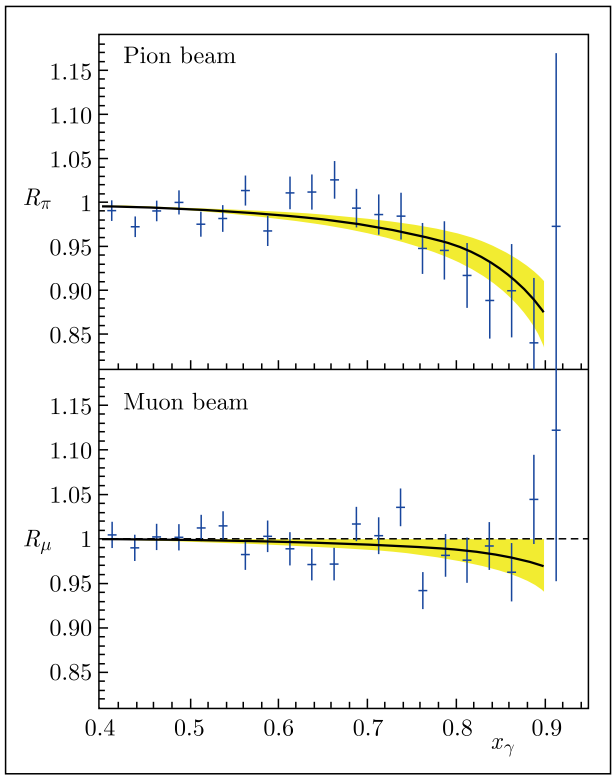


Fig. 10. The ratio of the measured energy spectrum of the emitted photons to that expected for a point particle versus x_γ

uncertainty in the present determinations of the gluon helicity distribution. A new evaluation of the Bjorken sum rule based on the COMPASS results for the nonsinglet structure function $g_1^{NS}(x, Q^2)$ yields as the ratio of the axial and vector coupling constants $|g_A/g_V| = 1.22 \pm \pm 0.05(\text{stat.}) \pm 0.10(\text{syst.})$, which validates the sum rule to an accuracy of about 9%.

NA62 and NA48/2

In 2015, the main activities of the JINR group in the NA48/2 and NA62 experiments were the following:

• A search for the hypothetical gauge boson (dark photon) has been performed on the basis of the NA48/2 data. The dark photon with a priory unknown mass and mixing parameter ε is appearing in the hidden sector of new physics models with an extra $U(1)$ gauge symmetry. A mixing parameter defines the interaction of the dark photon with the visible sector. The main decay mode of the dark photon is expected to be e^+e^-. But for the e^+e^- invariant mass between 10 and 125 MeV/c^2 no significant signal has been observed in the NA48/2 samples of $K^\pm \to \pi^\pm\pi^0$ decays with the consequent decays $\pi^0 \to \gamma e^+e^-$ final state. Upper limits at 90% CL for the dark photon production probability as

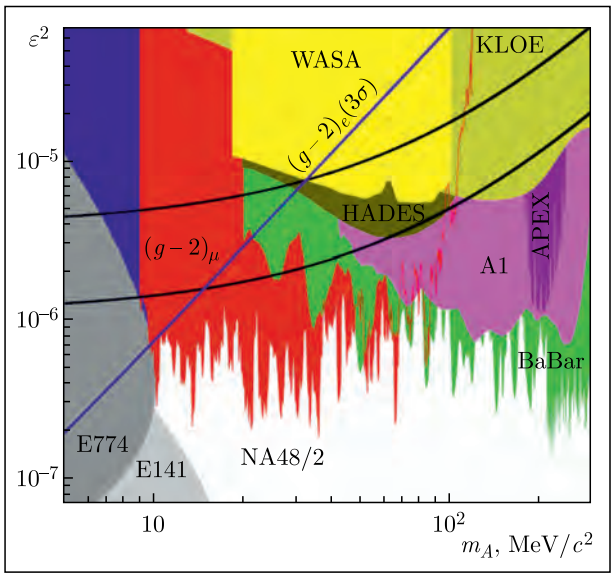


Fig. 11. Limits for a mixing parameter (ε^2) and mass (m_A) for the existing dark photon. Red region corresponds to the NA48/2 data

well as for the mixing parameter are calculated providing the considerable improvement over the existing data in the mass range of 10–60 MeV/c^2 (see Fig. 11) [10].

• The analysis of the rare decay $K^\pm \to$ $\to \pi^\pm\pi^0e^+e^-$, observed for the first time in the NA48/2 experiment, is now in the final cross check phase. The preliminary measured value of the branching ratio reported earlier is $\text{Br}(\pi^\pm\pi^0e^+e^-) = (4.06 \pm 0.17) \cdot 10^{-6}$.

• The NA62 experiment is devoted to the study of a very rare charged kaon decay into the charged pion, neutrino and antineutrino. The JINR group in collaboration with CERN is responsible for the R&D and straw detectors for the magnetic spectrometer with high spatial resolution, operating in vacuum, as well as for the software development for simulation and reconstruction of the events recorded in the spectrometer. During the 2015 experimental run, the JINR group took responsibility for the low and high voltage power supply control system.

NA61/SHINE

In 2015, the VBLHEP group took part in the TOF detector maintenance during data taking, software developments and data analysis of the NA61/49 experiment.

In February–April 2015, the data on Ar–Sc collisions at 13, 19, 30, 40, 75, and 150A GeV/c have been registered in the NA61/SHINE experiment. These data completed the energy scan with Ar–Sc collisions.

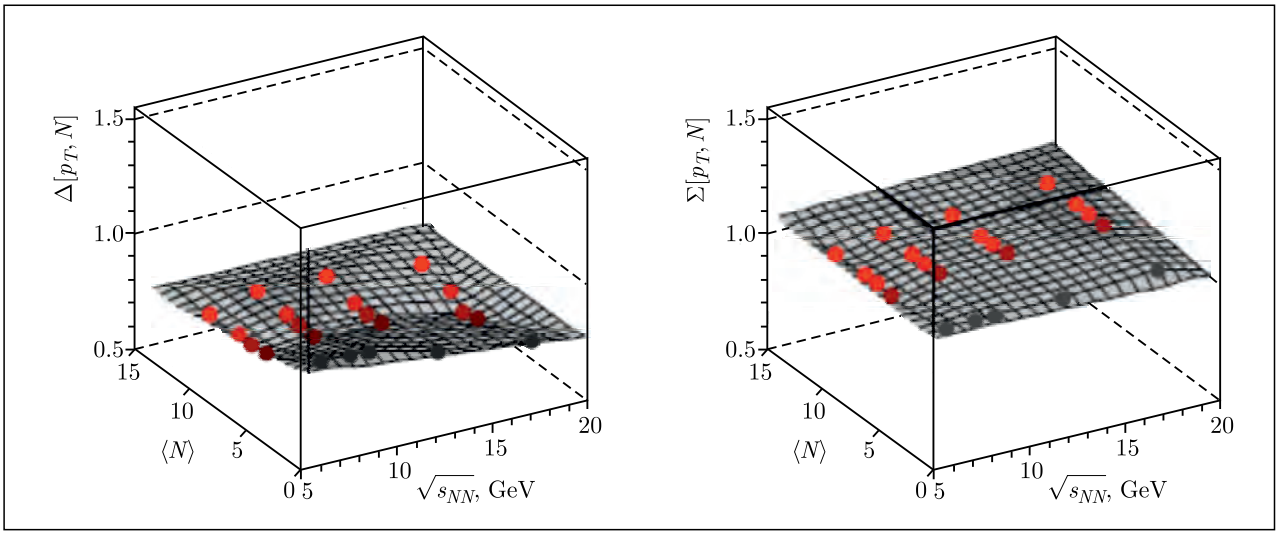


Fig. 12. The graphical presentation of current status of search for the critical point. Transverse momentum and multiplicity fluctuations show no CEP

The main goal of the new energy-system size scan at SPS has been performed by the NA61 experiment is the search for the Critical End Point (CEP) [11, 12].

The graphical presentation of the current status of search for the critical point in NA61/SHINE is presented in Fig. 12.

Transverse momentum fluctuations in Be–Be and p–p interactions show no structures which could be related to the critical point. Be–Be results are close to those from inelastic p–p reactions. The analysis of Ar–Sc data is ongoing.

Experiment at the Relativistic Heavy Ion Collider, BNL

STAR

The STAR collaboration performed the first high-statistics measurement of $\Lambda\Lambda$ correlation function in Au–Au collisions at $\sqrt{s_{NN}} = 200$ GeV [13]. The STAR measurement can provide precious data for the understanding of hyperon–hyperon interaction which is an important input to various baryon–baryon interaction potential model as well as for the study of equation of state for neutron stars. The $\Lambda\Lambda$ interaction is also closely related to the existence of the H dibaryon, one of the most searched for exotic hadrons in nuclear collisions.

The JINR group published [14] the result for the study of two-antiproton correlation function with data taken by the STAR experiment at RHIC. It shows the attracting nuclear force between two antiprotons and presents the measurement of the two key parameters that characterize the corresponding strong interaction, namely, the scattering length (f_0) and effective range (d_0). This result provides a fundamental ingredient for understanding the structure of more sophisticated antinuclei and their properties.

Experiment at FAIR

CBM

In 2015, in the framework of the CBM project the following results have been obtained:

• The work on the preparation of technical documentation for the manufacture of the superconducting dipole magnet CBM has been continued. The drawings of the major parts of the magnet in standards of GOST and ISO, necessary for holding tenders with Russian and foreign companies, have been prepared.

• Physical start of a site of assembly of modules and STS supermodules for the BM@N experiments (expected to be commissioned by 2019), CBM (2021) and MPD with all auxiliary rooms, the first phase of the first shift of technicians to assemble modules (the first stage of training of technicians of the first change for assembly of modules), development and production (manufacturing) of specialized equipment, assembly of the first prototypes by employees (staff) of VBLHEP.

EVENTS

International Conference on Strangeness in Quark Matter

The 15th International Conference on Strangeness in Quark Matter was held at the Laboratory on July 6–11, 2015. This topical conference was devoted to Strangeness and Heavy Flavor production in Heavy Ion Collisions. The conference was focused on new experimental and theoretical developments, on the role of strange and heavy-flavor quarks in proton–proton and heavy-ion collisions and in astrophysical phenomena. New results obtained at LHC, RHIC, and other experimental facilities were presented.

International Workshop on Hadron Structure and Spectroscopy

The annual International meeting on Hadron Structure and Spectroscopy took place in Suzdal on 18–20 May. COMPASS-II (CERN) and Joint Institute for Nuclear Research (JINR) were co-organizers of the event. 80 physicists from Russia, Europe, Asia and America took part in this workshop. Twenty-six review reports were presented within three days.

The extensive discussion of problems and tasks in the field of hadron structure was opened by several reports of the leading physicists-theorists: A. Deshpande (USA), A. Bachetta (Italy), Yu. Hatta (Kyoto, Japan), and M. Deka (JINR). Further, COMPASS provided the results of the research on a transverse nucleon spin structure and hadron spectroscopy.

Perspectives of Experimental Research at the Nuclotron Beams

The third Workshop of the Nuclotron Beam Users "Perspectives of Experimental Research at the Nuclotron Beams" was held at the Laboratory on 8–9 September, 2015. 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. Representatives of the JINR Directorate, Member States, the LHEP Directorate, and current experiment group leaders attending the Workshop signed the Protocol summarizing discussions on the Nuclotron user policy, requests and recommendations aimed at the realization of the scientific programme as well as at the effective usage of the beam time.

REFERENCES

1. *Terekhin A. A. et al.* Study of the *dp*-Elastic Scattering at 2 GeV // Phys. Part. Nucl. Lett. 2015. V. 12. P. 695.
2. *Asquith N. L. et al.* Study of $^{232}\mathrm{Th}\,(n,\gamma)$ and $^{232}\mathrm{Th}\,(n,f)$ Reaction Rates in a Graphite Moderated Spallation Neutron Field Produced by 1.6 GeV Deuterons on Lead Target // Nucl. Instr. Meth. B. 2015. V. 344. P. 51–58.
3. *Adam J. et al. (ALICE Collab.).* One-Dimensional Pion, Kaon, and Proton Femtoscopy in Pb–Pb Collisions at $(s_{NN})^{1/2} = 2.76$ TeV. arXiv:1506.07884. 2015.
4. *Rogochaya E.* Bose–Einstein Correlations of Charged and Neutral Kaons in $p-p$ and Pb–Pb Collisions with ALICE Experiment at the LHC // ICNFP2015, Crete, 2015.
5. *Adam J. et al. (ALICE Collab.).* Differential Studies of Inclusive J/ψ and $\psi(2S)$ Production at Forward Rapidity in Pb–Pb Collisions at $(s_{NN})^{1/2} = 2.76$ TeV. arXiv:1506.08804[nucl-ex]. 2015.
6. *CMS Collab.* Search Strategy for High-Mass Resonances Decaying to Muon Pairs at 13 TeV in Preparation of the Run2. CMS AN-2015/061. 2015.
7. *CMS Collab.* Search for High-Mass Resonances Decaying to Muon Pairs in pp Collisions at 13 TeV. CMS AN-2015/223. 2015.
8. *Gasser J., Ivanov M. A., Sainio M. E.* Revisiting $\gamma\gamma \to \pi^+\pi^-$ at Low Energies // Nucl. Phys. B. 2006. V. 745. P. 84.
9. *Adolph C. et al. (COMPASS Collab.)* // Phys. Rev. Lett. 2015. V. 114. P. 062002.
10. *Batley J. R. et al. (NA48/2 Collab.).* Search for the Dark Photon in π^0 Decays // Phys. Lett. B. 2015. V. 746. P. 178.
11. *Turko L. for the NA61 Collab.* Search for the Critical Point of the Strongly Interacting Matter at the CERN SPS NA61/SHINE Experiment // J. Phys. Conf. Ser. 2015. V. 623, No. 1. P. 012027.
12. *Anticic T. et al.* Measurement of Event-by-Event Transverse Momentum and Multiplicity Fluctuations Using Strongly Intensive Measure $\Delta[p_T, N]$ and $\Sigma[p_T, N]$ in Nucleus–Nucleus Collisions at the CERN Super Proton Synchrotron // Phys. Rev. C (in press).
13. *STAR Collab.* The First High Statistics Measurement of $\Lambda\Lambda$ Correlation // Phys. Rev. Lett. 2015. V. 114. P. 022301.
14. *STAR Collab.* Observation of Interaction between Anti-Nucleons // Nature (submitted). 2015.

DZHELEPOV LABORATORY OF NUCLEAR PROBLEMS

NEUTRINO PHYSICS AND RARE PHENOMENA, ASTROPHYSICS

The most important result of the **Baikal** experiment in 2015 was deployment of the first cluster (8 strings, 192 optical modules) of the cubic-kilometer-scale neutrino telescope (GVD project). Data acquisition and event statistics accumulation began. This first cluster, put into operation on 30 March, was named "DUBNA". The cluster assembly process confirmed the calculated mounting rate (one and later two clusters a year), which would allow the detector to be constructed on schedule. In 2015, production facilities were built at JINR for manufacturing 300–600 optical modules a year, which must be enough to meet all the needs of the experiment, namely, to construct one cluster (later two clusters) of elevated height during the expedition season. The manufactured modules will be tested in a section of 12 OMs (a minimum data acquisition unit) on specially designed test benches. Power supply, control, and data processing and storage systems, fitting the shipping containers, are made for a new control center of the Baikal neutrino telescope. They will be delivered to Lake Baikal and put into operation during the next expedition.

In 2015, within the **Daya Bay** project new oscillation parameter values $\sin^2 2\theta_{13} = 0.084 \pm \pm 0.005$, $\Delta m^2_{ee} = (2.44 \pm 0.11) \cdot 10^{-3}$ eV^2 [1] were obtained after updating the energy model of the experiment. The reactor antineutrino rate and spectrum shape were measured from the near detectors data. Like other reactor experiments, Daya Bay observes an overall $\sim 5\%$ antineutrino flux deficit and at the same time the excess of neutrinos with energies around 5–6 MeV [2]. The deficit and the excess are observed in comparison with the Huber–Mueller antineutrino flux mode. The Daya Bay collaboration with four other neutrino experiments won the Breakthrough Prize 2016 in the field of fundamental physics for the "fundamental discovery and exploration of neutrino oscillations". Among the winners are the scientists: M. O. Gonchar, Yu. A. Gornushkin, D. V. Naumov, I. B. Nemchenok, A. G. Olshevskiy, E. A. Yakushev, V. A. Matveev, and B. A. Popov.

Within the **JUNO** project, scanning station was created for measurement of differential PMT characteristics and dedicated software was developed. The system is under calibration and testing. The PMT lab magnetic field measurement and R&D of the magnetic field compensation system are continued. The system is assembled and installed in the PMT lab.

In 2015, the Dubna group in **Borexino** participated in the data-taking shifts and took an active part in the physical analysis of the accumulated data carried out by the "antineutrino", "rare physics", and "*pp* neutrino" working groups. In the current year, new Borexino results of the Earth antineutrino flux measurement were published [3]. Improved geoneutrino measurement is done with 2056 days of data taking which is two times higher in comparison with the previous publication. The obtained signal value is in agreement with the majority of predictions from geophysical models, but their discrimination is not possible due to uncertainties of the current measurement. The null observation of geoneutrinos with Borexino alone has a probability of $3.6 \cdot 10^{-9}$ (5.9σ). A geoneutrino

signal extracted for the mantle is at 98% CL. The second important result obtained in 2015 with Borexino is the improved electron lifetime limit with respect to the charge-violating decay $e \to \nu + \gamma$ [4]. Appearance of a monoenergetic (256 keV, half-mass of the electron) photon was considered as a signal of decay. The obtained lower limit of $\tau \geqslant 6.6 \cdot 10^{28}$ y is two orders of magnitude greater than the previous world's best constraint for this mode.

In 2015, after the year of operation, the first results on measurement of oscillation parameters were announced by the long baseline experiment **NOvA**. The following parameters were measured: $\sin^2\theta_{23} = 0.51 \pm 0.10$, $\Delta m^2_{32} = (2.37^{+0.16}_{-0.15}) \cdot 10^{-3}$ eV^2 (NH), and $\Delta m^2_{32} = (-2.40^{+0.14}_{-0.17}) \cdot 10^{-3}$ eV^2 (IH) [5]. In 2015, a special test bench was constructed at JINR to measure NOvA electronics parameters. Also, a Remote Operation Center (ROC-Dubna) was put into operation for monitoring and controlling the NOvA experiment from Dubna. Analysis of NOvA systematic uncertainties arising from the poor knowledge of the neutrino–nucleon cross sections, density of the Earth, and the use of different approximations in the oscillation analysis was performed at JINR. The software for the supernova signal analysis was also developed.

In 2015, within the **OPERA** experiment the search for the tau-neutrino interactions in the detector with a sample of two most probable target bricks per event yielded five events with 0.25 expected from all possible background sources. This means a discovery of the tau-neutrino appearance in the CNGS beam at a confidence level of 5.1 standard deviations [6]. Thus, the main goal of the experiment — to prove through direct observation of ν_τ appearance in the ν_μ beam that this type of oscillations is responsible for the deficit of the atmospheric muon neutrinos — was successfully achieved. The new restrictions on the sterile neutrino existence and their contribution to the $\nu_\mu \to \nu_\tau$ oscillation were obtained. With a leading participation of the JINR group, the analysis of the $\nu_\mu \to \nu_e$ oscillations continues with the full sample of the events found during five years of data taking (53 events by now) [7].

The **NEMO-3** detector, which had been operating in the Modane Underground Laboratory from 2003 to 2010, was designed to search for neutrinoless double-β ($0\nu\beta\beta$) decay. The final results of the search for $0\nu\beta\beta$ decays with 6.941 kg of ^{100}Mo using the entire NEMO-3 data set with a detector lifetime of 4.96 y, which corresponds to an exposure of 34.3 kg $\cdot$ y, were published. A lower limit on the half-life of $0\nu\beta\beta$ decays in ^{100}Mo was found to be $T_{1/2}\,(0\nu\beta\beta) > 1.1 \cdot 10^{24}$ y at 90% CL under the hypothesis of light Majorana neutrino exchange. Depending on the model used for calculating nuclear matrix elements, the corresponding limit for the effective Majorana neutrino mass lies in the range $\langle m_\nu \rangle < 0.33{-}0.62$ eV [8]. The NEMO-3 result is comparable with the best available experimental limits.

The Dubna team participating in the **EDELWEISS** experiment was mainly involved in the assembly and commissioning of the facility, low background study, development of new low-threshold detectors, detector simulations, and data analysis. The first preliminary results of the EDELWEISS-III were reported in 2015 at TAUP-2015. We performed a blinded dedicated low-threshold analysis to achieve better sensitivity to small nuclear and electronic recoils that might be induced by low-mass WIMP particles. The result has an improvement of a factor 40 at WIMP mass 7 GeV in comparison with the previous phase EDELWEISS-II. Positive results reported by some other experiments were directly verified. It is important that the sensitivity achieved by EDELWEISS-III completely covers the region of positive CoGeNT results for the same nucleus (Ge).

The **νGeN** experiment is aimed at detecting coherent neutrino-Ge nucleus elastic scattering with special HPGe detectors developed at DLNP, JINR (Dubna) in collaboration with BSI (Riga) [9]. To be sensitive to the coherent scattering signal, the νGeN setup will be placed near power generated unit #3 of 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}. Within 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 work is to construct detectors with an energy threshold of 200 eV and below for further detailed studies of the coherent scattering process.

During 2015, the project was focused on building and testing the νGeN cryostat with four HPGe detectors ($\sim$400 g each). Created after selection of radioactively-less materials, the νGeN cryostat was taken for tests to the underground laboratory LSM in August 2015. Performances of the HPGe detectors were studied and the cryostat background was measured.

During the test, the energy thresholds for the νGeN detectors were found to be at a level of ~ 350 eV. The energy resolutions (FWHM) for the 10.4 keV cosmogenic line were found to be at 220 ± 10 eV level. The experimental intensity ratio of the L (1.3 keV) and K (10.4 keV) cosmogenic lines 0.11 ± 0.01 is an important indicator of stability of the detection efficiency in the low-energy region. In December 2015, after the tests were accomplished, the νGeN cryostat with detectors was delivered to Dubna.

The **GERDA** experiment is aimed at searching for the neutrinoless double-beta decay ($0\nu\beta\beta$) of ^{76}Ge. In 2015, new limits were obtained for the ^{76}Ge lifetime against the neutrinoless double-beta decay to the excited states of the daughter nucleus ^{76}Se $T_{1/2}(0^+ \to 0_1^+) > 1.5 \cdot 10^{24}$ y and $T_{1/2}(0^+ \to 2_1^+) > 0.9 \cdot 10^{24}$ y (90% CL) [10] and against the two-neutrino double-beta decay $T_{1/2}(0^+ \to 0_1^+) > 3.7 \cdot 10^{23}$ y and $T_{1/2}(0^+ \to 2_1^+) > 1.6 \cdot 10^{23}$ y (90% CL) [11]. These results are almost 100 times higher than the earlier obtained limits and rule out a few theoretical models. An additional analysis of the GERDA Phase I data also yielded new limits on the parameters of the possible $\beta\beta$ decay with emission of a majoron, $T_{1/2}(0\nu\chi)$ (spectral index $n = 1) > 4.2 \cdot 10^{23}$ y, and for other majoron modes, which are currently the most rigorous limits [12]. Also, GERDA Phase II was prepared and launched in 2015. The goal is to increase the mass of the detectors by a factor of two and decrease the background by another order of magnitude.

Within the **TAIGA** project, the design and fabrication of the IACT telescope were mainly done in 2015. At the beginning of 2016 it will be first tested at JINR and then moved to the Tunka area for testing and data taking. Besides, the second IACT telescope production is supposed at JINR.

The **NUCLEON** satellite was launched on 26 December 2014. The mission is to take data on the energy spectrum and its composition of cosmic rays in the 10^{11}–10^{15} eV energy region, which is important for clarifying their origin.

The **TUS** experiment is planned for operation at the beginning of 2016 on the dedicated "Mikhail Lomonosov" satellite. TUS is designed to operate for 3–5 years.

PHYSICS OF ELEMENTARY PARTICLES

The **ATLAS** group at JINR was searching for the resonance in the muon decay channel. It was shown that the examined modes of the resonances were ruled out at their masses below 2.5–3 TeV. The possibility of the inclusive search for supersymmetric particles gluinos and squarks of the first and second generations was investigated. In order to separate the events with SUSY particle production from the Standard Model background, such selection criteria as high missing transverse energy due to the presence of neutrinos or LSP, a large number of high-energy hadron jets, and high transverse energy in the event were used. No deviations from the Standard Model were found [13].

The $\Lambda_b^0 \to \psi(2S)\Lambda^0$ decay was observed and the branching ratio of the $\Lambda_b^0 \to \psi(2S)\Lambda^0$ to $\Lambda_b^0 \to J/\psi\Lambda^0$ was measured. The $J/\psi X$ and $\psi(2S)X$ mesons were reconstructed in their decays to a muon pair, while the $\Lambda^0 \to p\pi^-$ decay was exploited for the Λ^0 baryon reconstruction. The branching ratio was measured to be $\Gamma(\Lambda_b^0 \to \psi(2S)\Lambda^0)/\Gamma(\Lambda_b^0 \to J/\psi\Lambda^0) = 0.501 \pm$ $\pm\, 0.033\,(\text{stat.}) \pm 0.016\,(\text{syst.}) \pm 0.011(B)$. The ratio falls into the range 0.5–0.8, in agreement with the branching ratios of analogous B meson decays. The only available theoretical expectation for the branching ratio (0.8 ± 0.1) exceeds the measured value [14].

The **SANC** project includes theoretical predictions for many three- and four-particle Standard Model (SM) processes at the one-loop precision level (QCD and EW NLO). The main result of 2015 is updating the integrator and generator MCSANC to version 1.30: implementation of processes with inverse photons and gluons into the existing one-loop modules and implementation of higher-order radiative correction. Implementation of new processes ZH, $ud \to WH$, $ud \to tb$ (s-channel), and $bd \to tu$ (t-channel) into the integrator and generator MCSANC at the one-loop approximation at the parton and hadron levels was started [15].

Within the **CDF** and **Mu2e** projects, the main results were finalization of the most precise CDF top quark mass measurement with $t\bar{t}$ dilepton events using the full CDF Run II data

set, tests of the LYSO and CsI(pure) crystals with electron beams at the Frascati, Erevan, and Dubna accelerators, and participation in the Muon g-2 experiment.

The dilepton channel features two main characteristics: a very low background and incomplete information on what exactly happened during the event due to the two undetected neutrinos present in W decays. The latter feature makes it impossible for scientists to fully reconstruct the event, meaning that we cannot accurately determine the jet energy. A new optimal method for measuring the top quark mass in the dilepton channel is developed. The method uses a "hybrid" variable sensitive to the true value of the top mass. The result obtained after all improvements is the top quark mass of 171.46 ± 3.15 GeV/c^2. This is the most precise CDF measurement in the dilepton channel. Our measurement is consistent with the current world average of 173.34 ± 0.76 GeV/c^2 [16].

We work on choosing the type of crystal (LYSO vs BaF2 vs CsI) for the Mu2e calorimeter. The LYSO type crystals are studied using gamma ray sources and electron beams. The measurements were performed using the e-beam of the Beam Test Facility (BTF) in Frascati, Italy, in the energy range from 100 to 400 MeV. A matrix of nine CsI crystals was irradiated with the electron beam of the Yerevan accelerator LEA-75. A good energy resolution $\sigma/E = 8.2\%$ was obtained.

The **BES-III** experiment at the Beijing electron–positron collider BEPC-II continued to take data in 2015. The main results were obtained in charm physics, light hadron physics, and study of charmonium-like states Z_c. A new neutral state $Z_c^0(3900)$ was discovered in $e^+e^- \to \pi^0\pi^0 J/\psi$. The state is presumably an isospin partner of $Z_c^{\pm}(3900)$. A new neutral structure $Z_c^0(3885)$ was observed near the DD^* production threshold in $e^+e^- \to (DD^*)\pi^0$. This structure is assumed to be an isospin partner of $Z_c^{\pm}(3885)$. Thus, the Z_c states established so far represent four isospin triplets with masses of 3885, 3900, 4020, and 4025 GeV [17, 18].

The absolute measurement of $\Lambda_c^+ \to \Lambda e^+ \nu_e$ decay branching ratio was performed for the first time at $\sqrt{s} = 4.599$ GeV just above the $\Lambda_c^+\Lambda_c^-$ production threshold, which provided a twofold improvement of the current precision. The measured value is $B(\Lambda_c^+ \to \Lambda e^+ \nu_e) = = (3.63 \pm 0.38\,(\text{stat.}) \pm 0.20\,(\text{syst.}))$ [19].

The $X(3823)$ resonance was observed in the process $e^+e^- \to \pi^+\pi^- X(3823) \to \pi^+\pi^-\gamma\chi_{c1}$ with a statistical significance of 6.2σ. The $X(3823)$ mass was measured to be $(3821.7 \pm 1.3 \pm 0.7)$ MeV, while its width was limited to less than 16 MeV (90% CL). These results are consistent with the BELLE measurements and confirm the interpretation of $X(3823)$ as a $\psi(1^3D_2)$ state [20].

During the 2008–2010 production runs, the **PEN** experiment accumulated about $2.3 \cdot 10^7$ $\pi^+ \to e^+\nu$ and $> 1.5 \cdot 10^8$ $\pi \to \mu \to e$ decays and a significant number of pion and muon radiative decays. A comprehensive blind maximum likelihood analysis is under way to extract a new experimental value of $R^{\pi}_{e/\mu}$. A series of calculations refined the SM description branching ratio to a precision $5 \cdot 10^{-4}$. The first results of the data processing will be available in 2016. Once completed, the analysis of the PEN $\pi^+ \to e^+\nu$ data is expected to yield improvements of the SD^- structure-dependent amplitude, which constrains $F_V - F_A$; the 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. We determined [21] the residual beam polarization in the thin stopping target by measuring the asymmetry of the angular distribution of the Michel decay positrons as a function of energy. The initial muon beam polarization is predicted to be $P_\mu = -1$ within the Standard Model (SM) with massless neutrinos. We estimated our residual muon polarization to be $P_\mu = -0.85 \pm 0.03\,(\text{stat.})^{+0.04}_{-0.05}\,(\text{syst.})$ in the stopping target, which is consistent with the SM predictions when the depolarizing effects occurring during the muon production, propagation, and moderation in the target are taken into account. The knowledge of beam polarization is of fundamental importance in order to model the background of our $\mu^+ \to e^+\gamma$ search.

The experiments were carried out with the **ANKE** setup at the COSY accelerator in Jülich in the field of intermediate-energy hadron physics using polarized beams and polarized jet targets. The vector and tensor analyzing powers A_y and A_{yy} were measured in the charge exchange reaction $pd \uparrow\to n\{pp\}s$ at the proton beam energy of 600 MeV and momentum transfer more than 160 MeV/c with use of a deuterium polarized jet target [22]. These data are in good agreement with the previous results obtained with a polarized deuteron beam and are

also consistent with the impulse approximation predictions.

The charge exchange interaction of vector polarized deuterons with a polarized hydrogen target, $d \uparrow p \uparrow \rightarrow \{pp\}sn$, was studied in a high-statistics experiment at a deuteron beam energy of 726 MeV [23]. The polarized jet target with a storage cell was used. The deuteron A_y^d and proton A_y^p vector analyzing powers as well as the spin correlations C_{yy} and C_{xx} were measured. The data are well described in the impulse approximation. Preparations of the JEDI experiment on the search for the electric dipole moment of charged particles began within the SPRING project.

Within the **NN-GDH** project, the first data on target and beam–target asymmetries for the $\gamma p \rightarrow \pi^0 \eta p$ reaction at photon energies from 1050 to 1450 MeV were obtained within the framework of the "complete experiment" in meson photoproduction. The measurements were performed by the A2 collaboration at the MAMI C accelerator using the Crystal Ball/TAPS detector setup and the Dubna–Mainz proton polarized target. The general assumption that the reaction is dominated by the $\Delta 3/2^-$ amplitude was confirmed. The data are sensitive to small contributions from other partial waves [24].

The Compton scattering asymmetries in the $\Delta(1232)$ resonance region were measured by the A2 collaboration at the MAMI C accelerator using circularly/linearly polarized photon beam and longitudinally/transversely polarized proton target. The first experimental values were extracted for all four proton spin polarizabilities, that describe the proton spin response to the incident polarized photon [25].

Differential cross sections for the $\gamma p \rightarrow \rightarrow \pi^0 p$ reaction were measured with the A2 tagged-photon facility at the Mainz Microtron, MAMI C, up to the center-of-mass energy $W = 1.9$ GeV. The new results, obtained with a fine energy and angular binning, increase the existing quantity of π^0 photoproduction data by $\sim 47\%$. Due to the unprecedented statistical accuracy and the full angular coverage, the results are sensitive to high partial-wave amplitudes [26].

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. Observation of this lepton flavor violating process in the charged sector would imply manifestation of "new physics" beyond the Standard Model. For phase-1 of the experiment a complete set of 2800 straw tubes was produced by ultrasonic welding. The tubes were 9.8 mm in diameter and up to 1.6 m long with walls 20 μm thick. Thin-wall tubes are required for reduction of multiple scattering, such thin tubes were produced for the first time. To this end, the production technology (originally designed at VBLHEP) was modified, and new procedures and standards for the tube pressure and elongation tests were developed. After the tests the tubes were sent to Japan for the assembling of the tracker with our participation. In creation of the calorimeter the JINR group took a responsibility to test and certify all the crystals. The crystal type LYSO was selected after the beam tests and subsequent analysis of the results, both fulfilled with the JINR participation. In 2015, a new test bench with a precise mechanical device for moving crystals, necessary electronics, and computing equipment was constructed for test of crystals.

In 2015, within the **COMPASS** project the results of the charged pion polarizability measurement in the reaction of electromagnetic scattering off the nickel nucleus with the hard photon emission were prepared for publication. That was the most precise dedicated measurement of this value, and it is especially important for testing applicability limits of the chiral perturbation theory [27]. The contribution of the DLNP group to this result is decisive. Also, the results of the search for exclusive photoproduction of the exotic hadron $Z_c(3900)$, discovered two years ago by the BES-III and BELLE collaborations, were prepared for publication [28]. It is the first attempt to discover the direct production of this particle, and all previous observations were performed for decays of the higher mass states.

APPLIED RESEARCH AND ACCELERATORS PHYSICS

According to the agreement between the Institute of Plasma Physics (IPP) of the Chinese Academy of Sciences in Hefei, China, and Joint Institute for Nuclear Research, Dubna, Russia, the project of a superconducting isochronous cyclotron SC200 for proton therapy is developed at JINR. The cyclotron will accelerate protons up to 200 MeV with a 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 Medicotechnical Complex of JINR and will be used for further research and development of proton therapy of tumors. The results of testing will be used by ASIPP for mass production of SC200. By now the simulation of the magnetic and accelerating systems and the beam dynamics have been performed, and the main parameters of the cyclotron have been chosen.

In 2015, JINR became an official member of the international **Medipix** collaboration that opens up new prospects for the R&D of semiconductor detectors using a unique pixel chip of the Medipix and Timepix types. The JINR group together with colleagues from CTU-Prague and CERN submitted a project of extending the existing luminosity and background monitoring system in the ATLAS cavern by additional pixel GaAs detectors, which was approved in the summer 2015. The first four detectors are produced and will be calibrated and installed in the ATLAS cavern in early 2016.

Three GaAs:Cr pad sensors (4×4 mm^2, 300 μm thick) were irradiated by a neutron beam of high intensity from the JINR IBR-2 neutron source. The characteristics of the sensors were measured before and after the irradiation. One of them was irradiated with a fluence of $2.3 \cdot 10^{14}$ neutrons and the others with a fluence of $8.8 \cdot 10^{15}$ neutrons. The former (fluence $2.3 \cdot 10^{14}$ CCE) was measured using an alpha-particle source. The CCE decreased by a factor of ~ 33.

In 2015, one of the first assemblies of the Timepix readout chip and the GaAs:Cr sensor 1000 μm thick with very good bump-bond connection (99.9% active pixels) was produced by the JINR group. This detector was calibrated on a pixel-by basis using the procedure developed by the JINR group. The energy resolution of the Timepix detector with the 1000 μm-thick GaAs:Cr sensor was about 12% at 20 keV and about 7% at 60 keV with the accuracy of the energy scale better than 1% (for photons below 100 keV).

The main goals of the research at the **Medicotechnical complex (MTC)** are to carry out medicobiological and clinical investigations on tumor 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 2015.

In collaboration with the Medical Radiological Research Centre (Obninsk) and the Radiological Department of the Dubna hospital, the regular sessions of proton therapy aimed to investigate its efficiency to treat different kinds of neoplasm were performed. Seven treatment sessions, total duration of 26 weeks, were carried out. Fifty-three new patients were fractionally treated with the medical proton beam. The total number of the single proton irradiations (fields) was more than 4000. Other 27 patients were irradiated using the "Rokus-M" Co-60 gamma-therapy unit.

Development of the software–hardware complex for the four-leaf-pair model prototype of a multileaf proton beam collimator was continued. The full-scale collimator will consist of 33 such pairs of leaves and will be used for the so-called dynamic proton beam treatment technique. Development of a computerized adjustable-energy decelerator of a proton beam was continued for this purpose as well [29].

Together with the Division of Radiation Dosimetry of the Institute of Nuclear Physics (Prague, Czech Republic), measurements of the background conditions in the proton therapy treatment room of the MTC and at the clinical scanning proton beam at Proton Therapy Center in Prague (PTC) were carried out using thermoluminescent detectors and radiochromic films. The measurements showed that the absorbed doses outside the primary beam in Dubna were slightly higher than at the PTC due to the proton scattering from the beam forming elements in the treatment room.

Experiments were performed to study the effect of fractionated γ-ray and proton irradiation of heads of mice on their peripheral blood and behavior by the "open field" test. Fractionated irradiation was used in two variants: conventional fractionation of 2 Gy once a day, 5 times a week, with the total radiation dose of 20 Gy; "extreme" hypofractionation of 10 Gy once a week, with the total radiation dose of 20 Gy. The results of the study showed that irradiation of mouse heads had no effect on their peripheral blood parameters in both variants of the fractionated irradiation, and the behavior of the mice did not depend on the type of ionizing radiation and the variant of the fractionated exposure we used [30]. On the basis of these results it can be concluded that extreme hypofractionation can successfully replace conventional fractionation, which in some cases is used for radiotherapy of brain tumors. The use of this type of fractionation decreases the duration of radiotherapy and increases throughput of medical centers that give radiotherapy.

REFERENCES

1. *An F. P. et al. (Daya Bay Collab.).* New Measurement of Antineutrino Oscillation with the Full Detector Configuration at Daya Bay // Phys. Rev. Lett. 2015. V. 115, No. 11. P. 111802; arXiv:1505.03456 [hep-ex].
2. *An F. P. et al. (Daya Bay Collab.).* Measurement of the Reactor Antineutrino Flux and Spectrum at Daya Bay. arXiv:1508.04233 [hep-ex]; Phys. Rev. Lett. (in press).
3. *Agostini M. et al. (Borexino Collab.).* Spectroscopy of Geoneutrinos from 2056 Days of Borexino Data // Phys. Rev. D. 2015. V. 92. P. 031101.
4. *Agostini M. et al. (Borexino Collab.).* A Test of Electric Charge Conservation with Borexino // Phys. Rev. Lett. 2015. V. 115. P. 231802.
5. *Adamson P. et al.* First Measurement of Muon-Neutrino Disappearance in NOvA. Fermilab-pub-16-007-ND, arXiv: 1601.05037v1 [hep-ex]. 2016.
6. *Agafonova N. et al.* Discovery of τ Neutrino Appearance in the CNGS Neutrino Beam with the OPERA Experiment // Phys. Rev. Lett. 2015. V. 115, No. 12. P. 121802.
7. *Agafonova N. et al.* Limits on Muon-Neutrino to Tau-Neutrino Oscillations Induced by a Sterile Neutrino State Obtained by OPERA at the CNGS Beam // JHEP. 2015. V. 1506. P. 069.
8. *Arnold R. et al. (NEMO-3 Collab.).* Results of the Search for Neutrinoless Double-Beta Decay in ^{100}Mo with the NEMO-3 Experiment // Phys. Rev. D. 2015. V. 92. P. 072022.
9. *Belov V. et al.* The νGeN Experiment at the Kalinin Nuclear Power Plant // J. Instrum. (JINST). 2015. V. 10. P. P12011.
10. *Agostini M. et al.* New Limits on $0\nu\beta\beta$ Decay of ^{76}Ge to Excited States of ^{76}Se // Phys. Rev. Lett. 2016 (in press).
11. *Agostini M. et al.* $2\nu\beta\beta$ Decay of ^{76}Ge into Excited States with GERDA Phase I // J. Phys. G: Nucl. Part. Phys. 2015. V. 42. P. 115201.
12. *Agostini M. et al.* Results on $\beta\beta$ Decay with Emission of Two Neutrinos or Majorons in ^{76}Ge from GERDA Phase I // Eur. Phys. J. C. 2015. V. 75. P. 416.
13. *Khramov E. (ATLAS Collab.).* Summary of the Searches for Squarks and Gluinos Using $\sqrt{s} = 8$ TeV pp Collisions with the ATLAS Experiment at the LHC // JHEP. 2015. V. 10. P. 054.
14. *Gladilin L., Lyubushkin V. (ATLAS Collab.).* Measurement of the Branching Ratio $\Gamma(\Lambda^0 \to \psi(2S)\Lambda^0)/\Gamma(\Lambda_b^0 \to J/\psi\Lambda^0)$ with the ATLAS Detector // Phys. Lett. B. 2015. V. 751. P. 63–80.
15. *Bardin D. et al.* J Functions for the Process $ud \to WA$ // JETP Lett. 2015. V. 103, No. 2.
16. *Aaltonen T. et al. (CDF Collab.).* Measurement of the Top-Quark Mass in the $t\bar{t}$ Dilepton Channel Using the Full CDF Run II Data Set // Phys. Rev. D. 2015. V. 92. P. 032003.
17. *Ablikim M. et al.* // Phys. Rev. Lett. 2015. V. 115, No. 11. P. 112003.
18. *Ablikim M. et al.* // Ibid. No. 18. P. 182002.
19. *Ablikim M. et al.* arXiv:1510.02610.
20. *Ablikim M. et al.* // Phys. Rev. Lett. 2015. V. 115. P. 011803.
21. *Baldini A. M. et al.* Muon Polarization in the MEG Experiment: Predictions and Measurements. arXiv:1510.04743. 2015; Eur. Phys. J (submitted).
22. *Gou B. et al.* Study of the $p\bar{d} \to n\{pp\}$ Charge-Exchange Reaction Using a Polarized Deuterium Target // Phys. Lett. B. 2015. V. 741. P. 305.
23. *Dymov S. et al.* Analyzing Powers and Spin Correlations in Deuteron–Proton Charge Exchange at 726 MeV // Ibid. V. 744. P. 391.
24. *Annand J. R. M. et al.* First Measurement of Target and Beam–Target Asymmetries in the $\gamma p \to \pi^0 \eta p$ Reaction // Phys. Rev. C. 2015. V. 91. P. 055208.
25. *Martel P. P. et al.* Measurements of Double-Polarized Compton Scattering Asymmetries and Extraction of the Proton Spin Polarizabilities // Phys. Rev. Lett. 2015. V. 114. P. 112501.
26. *Adlarson P. et al.* Measurement of π^0 Photoproduction on the Proton at MAMI C // Phys. Rev. C. 2015. V. 92, No. 2. P. 024617.
27. *Adolph C. et al.* Measurement of the Charged-Pion Polarizability // Phys. Rev. Lett. 2015. V. 114. P. 062002.
28. *Adolph C. et al.* Search for Exclusive Photoproduction of $Z_c^{\pm}(3900)$ at COMPASS // Phys. Lett. B. 2015. V. 742. P. 330.
29. *Shipulin K. N., Mitsyn G. V., Agapov A. V.* Technology for Bolus Verification in Proton Therapy // Phys. Part. Nucl. Lett. 2015. V. 12, No. 1. P. 190–194.
30. *Voskanyan K. et al.* The Effectiveness of Radiation Damage Reduction in Mice by Laser Light in Dependence of the Time Interval between Exposures // J. Phys. Sci. Appl. 2015. V. 5, No. 4.

FLEROV LABORATORY OF NUCLEAR REACTIONS

In 2015, the FLNR scientific programme on heavy ion physics included experiments on the synthesis and study of the properties of heavy, superheavy, and exotic nuclei using ion beams of stable and radioactive isotopes, studies of nuclear reaction mechanisms, development of acceleration technology, heavy ion interaction with condensed matter, and applied research. These areas of research were represented in three laboratory topics:

- Synthesis and properties of nuclei at the stability limits (nine subtopics);
- Radiation effects and physical bases of nanotechnology, radioanalytical and radioisotope investigations at FLNR accelerators (five subtopics);
- Accelerator complex of ion beams of stable and radioactive nuclides (DRIBs-III project) (nine subtopics).

In 2015, the operation time of the U400 and U400M FLNR cyclotrons amounted to 11 140 h.

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

DRIBs-III (Dubna Radioactive Ion Beams) is one of the core JINR projects. The following project tasks approved by JINR's Scientific Council and Programme Advisory Committee (PAC) for Nuclear Physics were fulfilled in 2015:

1. DC-280 cyclotron:

Manufacture of the accelerator units and systems was completed. Over 90% of the accelerator equipment is stored at the FLNR warehouse sites and is ready for assembling.

2. Experimental hall of the Factory of Superheavy Elements:

The construction is 50% complete. The construction is due and commissioning will be in 2016.

3. Development of experimental setups for the Superheavy Element Factory complex:

The contract was concluded with SigmaPhi company to have a gas-filled separator of recoil nuclei manufactured and delivered to JINR by mid-2017.

4. Fragment separator ACCULINNA-2:

The new ACCULINNA-2 fragment separator, which consists of primary and secondary beam lines, was fully assembled. Vacuum and magnetic measurement tests were carried out. In December 2015, first beam tests with the delivery of the ^{32}S primary beam were conducted. Thus, SigmaPhi completely fulfilled its obligations under the contract. The first experiment with the ACCULINNA-2 setup is awaited in 2016. Several institutes in Poland and the Czech Republic are involved in the project, in particular, in the development of a zero-angle spectrometer as well as vacuum and beam monitoring systems.

5. Development of a separator based on resonance laser ionization (GaLS setup):

Work on the development of the GaLS setup in collaboration with scientists from South Africa, Poland, Slovakia, Egypt, Belgium, and CERN continued. The setup is designed for separation of nuclear reaction products by selective laser ionization. The development of the complete optical arrangement of GaLS was finalized in 2015. The first four lasers (two Nd:YAG pump lasers and two dye lasers) were tested and prepared for installation. The laser laboratory room and control rooms were equipped and prepared. The order to manufacture a reaction chamber and a gas cell was placed. Target system variants were simulated. The main units of the gas and vacuum systems were equipped and prepared for installation.

SYNTHESIS AND PROPERTIES OF NUCLEI AT STABILITY LIMITS

Synthesis of New Elements. On 30 December 2015, IUPAC officially claimed the discovery of elements with atomic numbers 113, 115, 117, and 118. The priority for discovering elements 115 and 117 went to the JINR–Lawrence Livermore National Laboratory (LLNL)–Oak Ridge (ORNL) collaboration. The priority for discovery of element 118 was assigned to the JINR–LLNL collaboration. Elements with atomic numbers 113–118 were first synthesized at the U400 acceleration complex of the Flerov Laboratory of Nuclear Reactions, JINR. Element 118 completes the seventh row of the Periodic Table of Elements and is the heaviest element known today.

In 2015, we launched experiments on the synthesis of isotopes of element 118 with the mass numbers 293–296 and began to study their radioactive properties. The experiments were conducted at the FLNR JINR gas-filled recoil separator in collaboration with the laboratories at Oak Ridge (ORNL), Knoxville (UT), Livermore (LLNL), and Nashville (VU). A 0.35-mg/cm^2-thick target was produced at ORNL and consisted of a mix of ^{249}Cf (50.7%), ^{250}Cf (12.9%), and ^{251}Cf (36.4%) isotopes. The energy of ^{48}Ca ions in the middle of the target layer was 252 MeV, which is consistent with the expected cross section maximum of the complete fusion reactions $^{249-251}\mathrm{Cf} + {}^{48}\mathrm{Ca}$ with evaporation of three neutrons.

To this day, we have detected one decay chain of ^{294}118 presumably produced in the $3n$ channel of the $^{249}\mathrm{Cf} + {}^{48}\mathrm{Ca}$ reaction at a beam dose of $^{48}\mathrm{Ca}$ $1.4 \cdot 10^{19}$. In the same reac-

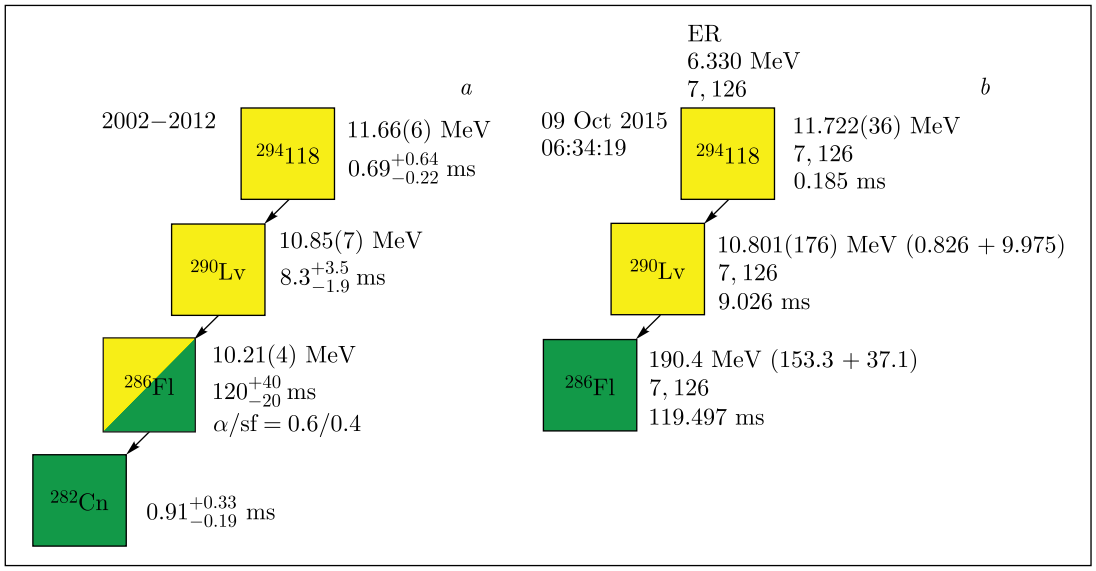


Fig. 1. *a*) The decay properties of the ^{294}118, ^{290}Lv, ^{286}Fl, and ^{282}Cn nuclei. The α-particle energies (uncertainty values are given in parentheses), half-lives, α decay and spontaneous fission branches for ^{286}Fl are given. *b*) The decay chain of ^{294}118 detected in these experiments. The energies of evaporation residue (ER), α particles, and spontaneous fission (α particle of ^{290}Lv and fission fragments of ^{286}Fl were registered by the focal plane and side detectors), numbers of front and back strips, and decay times of nuclei are given

tion, we synthesized four nuclei of this isotope in 2002, 2005, and 2012 [1]. The data on the decay properties of the $^{294}118$, ^{290}Lv, and ^{286}Fl nuclei are in fair agreement with the results obtained both in the reaction with ^{249}Cf and in the $^{245}\mathrm{Cm}\,(^{48}\mathrm{Ca}, 3n)^{290}\mathrm{Lv}$ and $^{242}\mathrm{Pu}\,(^{48}\mathrm{Ca}, 4n)^{286}\mathrm{Fl}$ cross reactions [1] (see Fig. 1). The cross section for the $^{249}\mathrm{Cf}\,(^{48}\mathrm{Ca}, 3n)^{294}118$ reaction also corresponds to the value measured in 2005 at a similar energy of ^{48}Ca (about 0.5 pb). The experiments are in progress.

Chemistry of Transactinides. The experiments aimed at studying the chemical properties of superheavy elements Cn, 113, and Fl continued. An experimental setup, combining physical and chemical separation of nuclear reaction products, was developed for the FLNR gas-filled recoil separator. The setup was designed to study the impact of relativistic effects on the chemical properties of element 113. The two isotopes, $^{284}113$ and $^{285}113$, with the lifetimes of about 1.0 and 6.0 s, respectively, were synthesized in the $^{48}\mathrm{Ca} + ^{243}\mathrm{Am}$ fusion reaction. Superheavy nuclei originating from the $2n$ and $3n$ evaporation channels were first separated, which substantially reduced the background from transfer reaction products (mainly actinides), aerosols of the target material, and nuclear reactions on the impurities in the target material. The apparatus for chemical separation was set in the focal plane of the separator. In the experiment, the formation of 113OH hydroxide was prevented. This allowed pioneer measurements of volatility of element 113 in the atomic state by a gas chromatography technique through interactions with a gold surface in inert gases.

Thermochemical calculations showed the formation of stable selenides of Cn and Fl with the opposite trend stability. This allowed first-time separation of deposition zones of these elements in a thermochromatographic column. Test experiments aimed at studying chemical interaction of Cn radioisotopes with selenium as compared to its homologue, Hg, were carried out at the U400 accelerator in 2015.

Research was continued on the manufacture of high-power targets of enriched actinide isotopes for experiments at the DC-280 accelerator with beam intensities up to 10 pμA. The results of previous studies were published in [2].

SHELS Separator. The development of a new vacuum chamber and BGO anti-Compton shields for the detector system in the focal plane of SHELS was finalized. The vacuum chamber parts were delivered in spring 2015. A call to tender was issued for the production of the BGO shields. The SCIONIX company (France) won the tender. The shields are currently being manufactured.

In May 2015, we ran a commissioning test to remeasure transmission efficiency of SHELS in case of asymmetric reactions with the ^{22}Ne beam and the ^{198}Pt target. A value of 12% was obtained for slow evaporation residues.

Using the fusion of the ^{48}Ca beam and the ^{204}Pb target, spontaneous fission of ^{250}No was studied. The neutron detector with 62 ^{3}He counters allowed measurements of neutron multiplicity for spontaneous fission of two activities: a short-lived (5 μs) and a long-lived (presumably an isomeric state of ^{250}No, 50 μs). The prompt neutron multiplicities for the two activities are $\nu = 4.48 \pm 0.21$ and $\nu = 3.93 \pm 0.26$ (for short- and long-lived activities, respectively).

In November 2015, first test experiments with the new detector chamber were performed. The decay properties of ^{207}Rn, ^{216}Th, and ^{254}No were studied in detail using the ^{48}Ca beam and the ^{164}Dy, ^{174}Yb, and ^{208}Pb targets. New low-lying levels in the ^{207}Rn nucleus were detected. The total efficiency of gamma quanta detection fell within 34–12%, depending on the energy (100 to 600 keV). The current status of SHELS and the new focal plane detector setup are presented in [3, 4].

Mass Spectrometer MASHA. In 2015, the following main activities were carried out by the working group of the mass spectrometer MASHA:

1. The work on upgrading the data acquisition system for the focal plane multistrip detector continued. The system is based on the state-of-the-art PXI and PXIe platforms introduced by National Instruments, which comprise high-speed multichannel analog-to-digital converters (ADCs: 250 MHz, 12 bits, 16 channels) developed by XIA. These ADCs allow digitizing of signal waveform. To date, the system has 704 spectrometric channels. In addition, new software for experimental data acquisition and processing was developed. On the whole, the upgrade enhances the capabilities of the setup to detect α decays and/or spontaneous fission of nuclei and provides better efficiency in measuring rare decay events.

2. High-speed ADCs (4GHz, 10 bits, 2 channels) and a time-to-digital converter (with a time resolution of 5 ps) based on the PXI and PXIe standards and provided by Agilent were

implemented for the beam energy measurement system. This upgrade significantly enhanced consistency of operation of the whole system and allowed the energy resolution $\Delta E/E \approx 0.6\%$.

3. The upgrade of the MASHA facility control system has begun. We examined WAGO-I/O-SYSTEM. The equipment required for the new control system was purchased and tested. The work on the development and implementation of the system has started. At the same time, we began working on gradual transition of the control system to a cutting-edge modular system based on CompactRIO. Several CompactRIO modules were purchased for subsequent examination and testing.

4. We conducted an experiment aimed at measuring the mass of ^{283}Cn, a daughter product of the α decay of the ^{287}Fl nucleus produced in the $^{48}\mathrm{Ca} + ^{242}\mathrm{Pu}$ reaction. From 1 April to 5 June, two experimental runs were conducted. The total irradiation time was 1 170 h. The number of ^{48}Ca ions that passed through the target was $3 \cdot 10^{18}$. No events of ^{283}Cn decay were observed. This means that separation efficiency of element 112 does not exceed 8%. The results were analyzed. A plan aimed to improve separation efficiency was proposed.

Dynamics of Heavy Ion Interaction, Fission of Heavy and Superheavy Nuclei. In 2015, the main attention was focused on studying the dynamics of complete fusion–fission and quasifission processes [5]. In February 2015, the mass–energy distributions of binary reaction products formed in the $^{48}\mathrm{Ti} + ^{238}\mathrm{U}$ reaction were measured with the CORSET setup using beams extracted from the U400 cyclotron. The results were compared with those obtained earlier for the $^{48}\mathrm{Ca} + ^{244}\mathrm{Pu}$ reaction. The contribution of symmetric fragments with masses $A/2 \pm 20$ u to the capture cross section was found to be 8.5% and 4.5% for Ca and Ti ions, respectively. At the Coulomb barrier energy, the estimated fusion–fission cross section for the $^{48}\mathrm{Ti} + ^{238}\mathrm{U}$ reaction was established to drop by one order of magnitude compared to the one for the $^{48}\mathrm{Ca} + ^{244}\mathrm{Pu}$ reaction.

The investigation of the role of shell effects in the formation of neutron-rich binary fragments in damped collisions has continued. The analysis of the mass, energy, and angular distributions of binary fragments formed in the $^{156,160}\mathrm{Gd} + ^{186}\mathrm{W}$ reactions at energies near the Coulomb barrier was completed. The cross sections for the formation of lead-like fragments in these reactions were around 10–100 μb. The maximum yields of lead-like nuclei were observed at angles close to those of the grazing collisions (28° for ^{160}Gd and 30° for ^{156}Gd). The obtained results confirm that multinucleon transfer reactions at energies close to the Coulomb barrier can be a possible pathway for producing new neutron-rich isotopes of heavy and superheavy nuclei.

A joint test experiment was carried out in GANIL (France) in May 2015 through a collaborative effort between JINR (Dubna) and IN2P3 (France). The experiment was devoted to the investigation of shell effects and clusterization in the giant nuclear system $^{238}\mathrm{U} + ^{238}\mathrm{U}$ at a projectile energy of 6.2 MeV/A. The obtained experimental data are being analyzed.

Furthermore, a joint experiment on the study of mass–energy distributions of fission fragments formed in the $^{232}\mathrm{Th}\,(p, f)$ reaction at energies below the Coulomb barrier was carried out in May 2015 under the protocol on scientific cooperation between JINR and INP (Almaty, Kazakhstan). The experiment is aimed at studying the properties of multimodal fission of actinide nuclei caused by shell effects in nuclear masses.

Exotic Decay Modes. The correlated mass distributions of fission fragments from the $^{235}\mathrm{U}\,(n_{\mathrm{th}}, f)$ reaction were analyzed. The obtained experimental data include the events that apparently result from delayed fission of shape isomers after light charged particle emission (ternary fission). The results of model calculations performed under such hypothesis agree with the bulk of the experimental points. The lifetimes of the observed fission isomers lie within the nanosecond range.

Structure of Exotic Nuclei. In 2015, the main efforts of the group were put into assembling and commissioning of a new-generation ACCULINNA-2 fragment separator. Experimental investigations on β-delayed particle emission from the proton-drip-line ^{27}S nucleus were at the same time carried out in collaboration with the University of Warsaw using the ACCULINNA fragment separator. The objective of collaborative work was to search for as-yet-unobserved decay channels ($\beta{-}3p$, $\beta{-}^{3}$He, etc.) of ^{27}S using the Optical Time Projection Chamber (OTPC). Figure 2 shows the examples of direct observation of β-delayed proton and two-proton emission from ^{27}S. The wealth of statistics on $\beta{-}2p$ decay will help clarify the branching ratio and define angular correlations between the emitted protons. Furthermore, several candidate events for $\beta{-}3p$

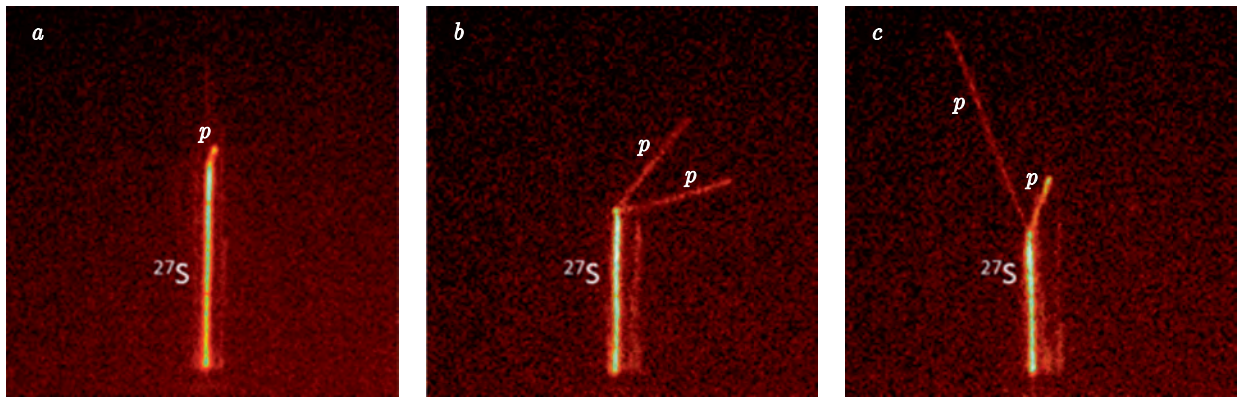


Fig. 2. Examples of rare β-delayed particle emission from ^{27}S: *a*) $\beta-p$ decay with low-proton energy; *b*) and *c*) $\beta-2p$ decays

decay were observed. The experimental data are being analyzed. Throughout the year, experimental data on exotic nuclei ^{6}He, ^{59}Ge, and ^{31}Ar obtained in earlier joint experiments with OTPC at CERN, MSU, and GSI were analyzed and published in [6], [7], and [8], respectively.

With the participation of the FLNR ACCULINNA group, a joint experiment aimed at studying the decay modes of the ^{30}Ar and ^{29}Cl nuclei at the proton drip-line was carried out using the FRS setup at GSI (Darmstadt, Germany). The two-proton decay of ^{30}Ar from its ground state was observed. This decay is an interplay of true and sequential decays [9]. The energies of the ground states of ^{30}Ar and ^{29}Cl located at 2.5 and 1.8 MeV above the two- and one-proton thresholds, respectively, were for the first time determined.

Reactions with Beams of Light Stable and Radioactive Nuclei. A series of experiments was conducted at the ACCULINNA and COMBAS fragment separators. The experiments aimed at studying light neutron-rich nuclei (isotopes of helium ^{6,8}He and lithium ^{8,9,11}Li). The differential cross sections for elastic and inelastic scattering and total reaction cross sections were measured. The nuclear potential, density distribution, and effective radius parameters were obtained. The values were found to vary immensely for halo nuclei as compared to normal nuclei and for nuclei at excited and ground states. The total reaction cross sections were measured by registering neutron and gamma rays with 4π spectrometers. The new $LaBr_3$ scintillation detectors, manufactured by a Dubna–Krakow collaboration, were for the first time used.

As part of the project for the development and testing of new detectors of the high-resolution magnetic analyzer MAVR, test experiments were conducted to measure the yields of neutron-rich oxygen isotopes in two reactions: a pure neutron pickup reaction with a beam of ^{18}O ions as compared to a multinucleon transfer reaction with a ^{22}Ne ion beam. The production cross sections for the $^{20-24}$O isotopes were measured and analyzed with the Q_{gg} systematics. The multinucleon transfer reaction with the ^{22}Ne beam was found to lead to the $^{20-24}$O isotopes with a greater cross section (10 mb for ^{24}O) than that for the reactions with the ^{18}O ion beam. The most important results obtained in 2015 were published in [10, 11].

Theoretical and Computational Physics. In 2015, a new model was proposed for the description of complete fusion cross sections and the corresponding barrier distribution functions. The model combines the quantum coupled-channels approach and the semiclassical method with a consideration of neutron rearrangement [12]. The proposed model was successfully tested using the ^{40}Ca, ^{32}S + ^{90,94,96}Zr, and ^{60,64}Ni + ^{100}Mo reactions. The calculated data are in fair agreement with the experimental ones. A more reliable microscopic consideration for coupling of relative motion to collective degrees of freedom allowed one to reproduce the structure of the barrier distribution function in detail. This is a step forward to a solution to an important problem of accounting for neutron transfer channels within the quantum coupled-channels model.

As part of the JINR–SAR cooperation programme, the breakup channels of light nuclei in the nucleus–nucleus collisions were in-

vestigated. The calculations were performed within the continuum-discretized coupled-channels approach for the $^{8}B + ^{58}Ni$, $^{8}B + ^{208}Pb$, and $^{19}C + ^{208}Pb$ reactions at 29.3, 170.3, and 1273 MeV incident energies, respectively [13]. The impact of diagonal and off-diagonal continuum–continuum couplings on the differential breakup cross section was studied in detail.

The knowledge base on low-energy nuclear physics (http://nrv.jinr.ru) was updated with the partial support from RFBR and the JINR–SAR collaboration. In particular, new models were added to the knowledge base, including the FRESCO code, which allows calculations of cross sections of various direct processes occurring in collisions of atomic nuclei within the coupled-channels approach.

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

Track Membranes

1. Methods were developed for surface modification of track membranes by low-temperature plasma, magnetron sputtering of titanium dioxide, and chemical adsorption of nanoparticles of chitosan and silver [14].

2. A comprehensive study of nanostructured and composite track-etched membranes was initiated using the equipment put into operation at the Nanocenter. The high-resolution SEM and X-ray photoelectron spectroscopy methods were used [15].

Nanostructures in Materials

1. The morphology of latent tracks induced by Kr and Xe ions with fission fragment energy was studied in $Y_2Ti_2O_7$ nanoparticles in EP450 ODS steel using high-resolution transmission electron microscopy. A threshold value was determined for specific ionization energy losses during amorphous latent track formation in nanoparticles. The diameter of tracks changes as the electronic stopping powers vary from 10 to 24 keV/nm [16].

2. The formation of microstructures with fission and synthesis of elements in dense gases — hydrogen, deuterium, helium, and xenon — was studied under bremsstrahlung with threshold energies from 10 to 23 MeV [17].

3. The impact of high-temperature plasma at the Plasma Focus PF-4 setup was studied on assemblies of heterogeneous metal foils containing hydrogen and deuterium in various states [18].

4. The effect of suppressing the formation of helium blisters on the surface of helium ion-doped silicon as a result of irradiation with high-energy bismuth ions was studied [19].

Radioanalytical Investigations

New methods were developed for separating and concentrating radioactive isotopes $^{99}Mo(^{99}Tc)$, ^{117}mSn, ^{225}Ac, ^{237}U, ^{236}Pu, ^{236}Np used in nuclear medicine and environmental research [20].

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REFERENCES

1. *Oganessian Yu. Ts., Utyonkov V. K.* Superheavy Element Research // Rep. Prog. Phys. 2015. V. 78. P. 036301.
2. *Dmitriev S. N., Popeko A. G.* High-Power Radioactive Targets as One of the Key Problems in Further Development of the Research Program on Synthesis of New Superheavy Elements // J. Radioanal. Nucl. Chem. 2015. V. 305. P. 927.
3. *Yeremin A. et al.* First Experimental Tests of the SHELS Separator // Part. Nucl., Lett. 2015. V. 12, No. 1. P. 35.
4. *Yeremin A. et al.* Experimental Tests of the Acceleration of ^{50}Ti Ions and Study of ^{50}Ti Induced Complete Fusion Reactions with SHELS Separator // Ibid. P. 43.

5. *Itkis M. G. et al.* Fusion and Fission of Heavy and Superheavy Nuclei (Experiment) // Nucl. Phys. A. 2015. V. 944. P. 204.
6. *Pfützner M. et al.* β Decay of ^{6}He into the $\alpha + d$ Continuum // Phys. Rev. C. 2015. V. 92. P. 014316.
7. *Ciemny A. A. et al.* First Observation of ^{59}Ge // Ibid. P. 014622.
8. *Lis A. A. et al.* β-Delayed Three-Proton Decay of ^{31}Ar // Ibid. V. 91. P. 064309.
9. *Mukha I. et al.* Observation and Spectroscopy of New Proton-Unbound Isotopes ^{30}Ar and ^{29}Cl: An Interplay of Prompt Two-Proton and Sequential Decay // Phys. Rev. Lett. 2015. V. 115. P. 202501.
10. *Denikin A. et al.* Inelastic Scattering and Clusters Transfer in ^{3,4}He + ^{9}Be Reactions // Phys. Part. Nucl. Lett. 2015. V. 12. P. 703.
11. *Sobolev Yu. G. et al.* Total Reaction Cross Section Excitation Function Studies for ^{6}He Interaction with ^{181}Ta, ^{59}Co, ^{nat}Si, ^{9}Be Nuclei // Proc. of the Intern. Symp. on Exotic Nuclei / Eds.: Yu. Penionzhkevich, Yu. Sobolev. World Sci., 2015. P. 147.
12. *Karpov A. V., Rachkov V. A., Samarin V. V.* Quantum Coupled-Channel Model of Nuclear Fusion with Semiclassical Consideration of Neutron Rearrangement // Phys. Rev. C. 2015. V. 92. P. 064603.
13. *Mukeru B., Lekala M. L., Denikin A. S.* Role of the Diagonal and Off-Diagonal Continuum–Continuum Couplings in the Breakup of ^{8}B and ^{19}C on ^{58}Ni and ^{208}Pb Targets // Nucl. Phys. A. 2015. V. 935. P. 18.
14. *Kravets L. I., Gilman A. B., Dinescu G.* Modification of Polymer Membrane Properties by Low-Temperature Plasma // Rus. J. General Chem. 2015. V. 85. P. 1284.
15. *Apel P. Yu. et al.* Production of Multi-, Oligo- and Single-Pore Membranes Using a Continuous Ion Beam // Nucl. Instr. Meth. B. 2015. V. 365. P. 641.
16. *Skuratov V. A. et al.* Swift Heavy Ion Tracks in $Y_2Ti_2O_7$ Nanoparticles in EP450 ODS Steel // J. Nucl. Mater. 2015. V. 456. P. 111.
17. *Didyk A. Yu., Wisniewski R., Wilczynska-Kitowska T.* The Carbon-Based Structures Synthesized through Nuclear Reactions in Helium at 1.1 kbar Pressure under Irradiation with Braking γ-Rays of 10 MeV Threshold Energy // Eur. Phys. Lett. 2015. V. 109. P. 22001.
18. *Didyk A. Yu. et al.* Hydrogen and Deuterium Distribution in Tungsten Foils Irradiated with High Temperature Deuterium Plasma in H_2O or D_2O Filled Hermetic Chambers // J. Surface Investigation. X-ray, Synchrotron and Neutron Techniques. 2015. V. 9. P. 859.
19. *Reutov V. F. et al.* Influence of the Ionization Energy Losses of High Energy Bismuth Ions on the Development of Helium Blisters in Silicon // Semiconductors. 2015. V. 49. P. 1290.
20. *Tran Duc Thiep et al.* Study of the Isomeric Ratios in Photonuclear Reactions of Natural Platinum Induced by End-Point Bremsstrahlung Energies in the Giant Dipole Resonance Region // J. Radioanal. Nucl. Chem. 2015. V. 303. P. 477.

FRANK LABORATORY OF NEUTRON PHYSICS

In 2015, the Frank Laboratory of Neutron Physics' scientific programme 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); 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 2015, within the framework of the User Programme, 197 proposals for conducting experiments were received from 19 different countries. The received proposals covered a broad spectrum of neutron research in physics (40%), materials science (26%), chemistry, geosciences, biology and applied sciences (constituting the rest 34%). Of the received proposals, 174 were admitted for realization.

Scientific Results

The magnetic, structural, and vibrational properties of YMn_2O_5 multiferroic with a strong magnetoelectric coupling have been studied by means of neutron, X-ray diffraction, and Raman spectroscopy at pressures up to 30 GPa in a temperature range from 10 to 300 K [1] (Fig. 1). The application of high pressure ($P > 1$ GPa) resulted in a suppression of commensurate and incommensurate antiferromagnetic (AFM) phases with a propagation vector $q = (\sim 1/2, 0, \sim 1/4)$ and appearance of a new commensurate AFM phase with $q_p = (1/2, 0, 1/2)$. This observation is in sharp contrast to a general trend towards the stabilization of the commensurate AFM phase with the propagation vector $q = (1/2, 0, 1/4)$ found in other RMn_2O_5 compounds under pressure. At higher pressures, $P > 16$ GPa, a structural phase transition accompanied by anomalies in the pressure behavior of some unit cell parameters and vibrational modes was observed. The obtained data allowed us to analyze the role of competing magnetic interactions in the formation of the magnetic ground state of RMn_2O_5 multiferroics.

A study of the evolution of the crystalline structure of the cathode material $LiNi_{0.8}Co_{0.1}Al_{0.1}O_2$ in the process of electrochemical cycling has been carried out using neutron diffraction (Fig. 2). The experiments were performed on the RTD (Real-Time-Diffractometer) diffractometer. Compositions of

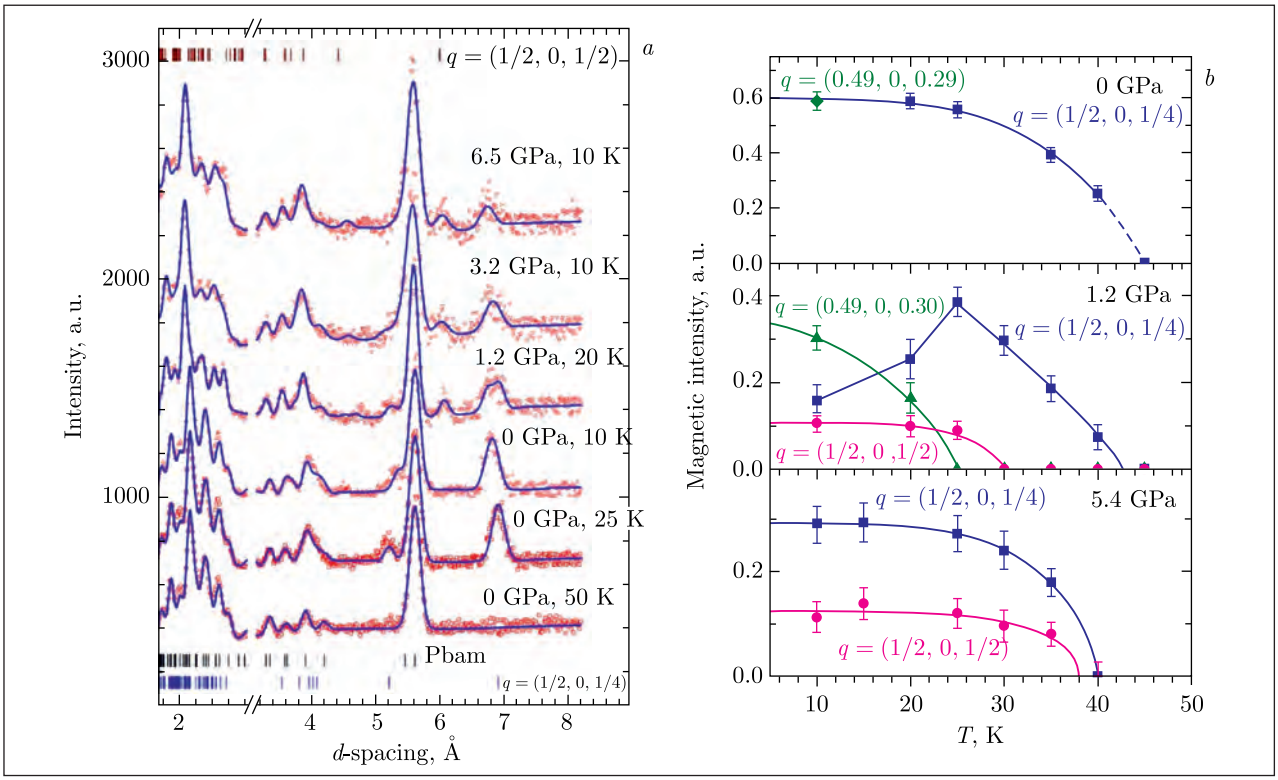


Fig. 1. *a*) Neutron diffraction spectra of YMn_2O_5 obtained at different pressures and temperatures with the DN-12 diffractometer and treated with the Rietveld method. *b*) Temperature dependences of integrated intensity of peaks $(1-q_x,-1,-q_z)/(1-q_x,1,-q_z)/(\pm q_x,1,\pm q_z)$ of commensurate and incommensurate AFM phases with a propagation vector $q=(\sim 1/2,0,\sim 1/4)$ and a peak $(-q_x,1,1-q_z)$ of commensurate AFM phase with a propagation vector $q_p=(1/2\ 0\ 1/2)$ under various pressures

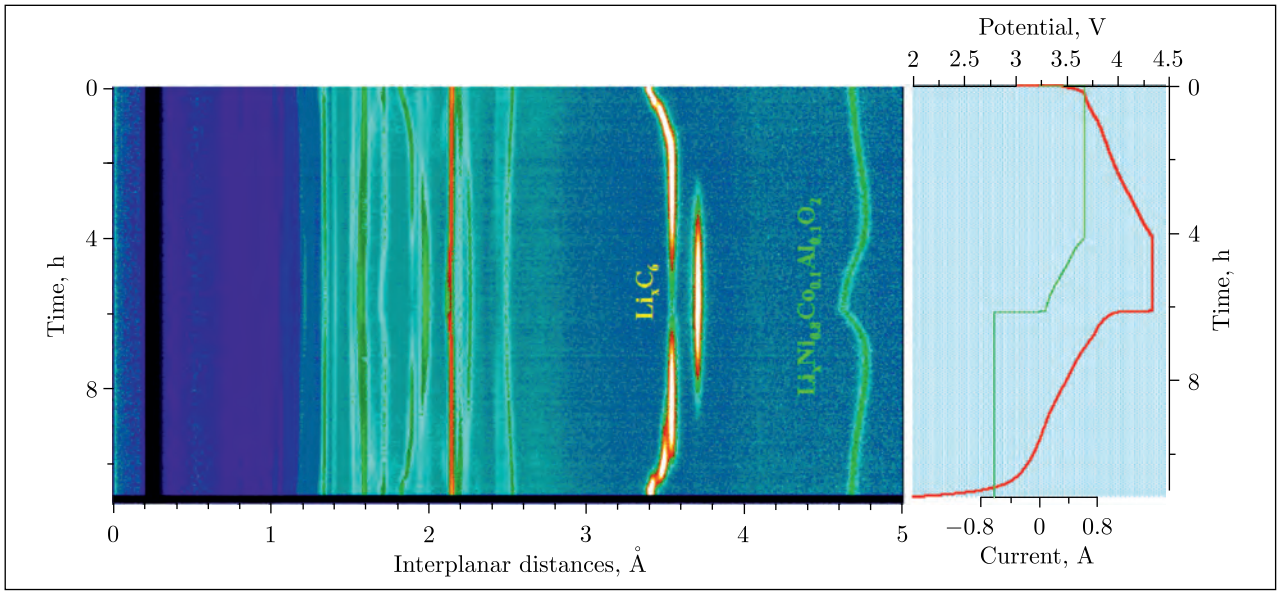


Fig. 2. The evolution of neutron diffraction spectra obtained in the real-time (operando) study of $LiNi_{0.8}Co_{0.1}Al_{0.1}O_2$ cathode material using high-intensity neutron diffraction. At the right: charge-discharge curve of the power source during the experiment

$LiNi_xCo_yAl_{1-x-y}O_2$ type are just starting to be introduced in mass production of lithium-ion batteries as a positive electrode (cathode), gradually replacing the widespread lithium cobaltate. Earlier such compounds were studied in real time during electrochemical cycling only in model cells by X-ray diffraction. Neutron diffraction makes it possible to study struc-

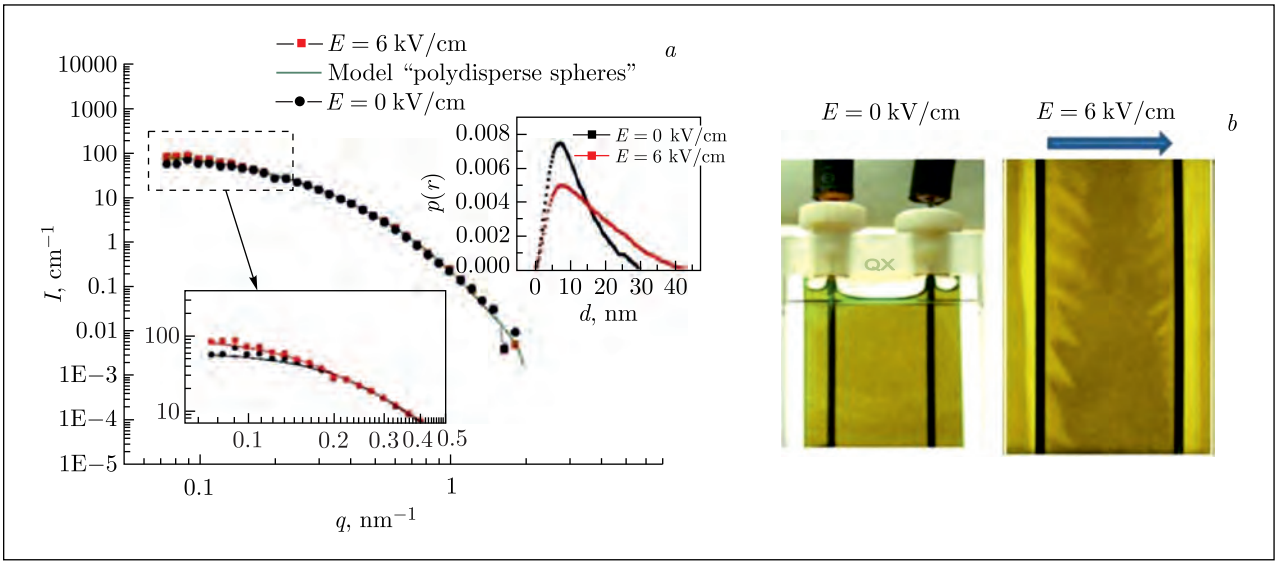


Fig. 3. The effect of an external electric field on the structure of the magnetic fluid magnetite/oleic acid/transformer oil for (*a*) nanoscale: small-angle neutron scattering (YuMO, IBR-2), magnetite concentration of 1%, and (*b*) macrolevel: visual observation of phase separation in a quartz cell (1 mm thick), magnetite concentration of 0.05%. The inset in the panel *a* shows the correlation functions reconstructed from the scattering curves (in the form of pair distance distribution functions) for a fluid in two states: "without a field" and "in a field", which point to an increase in the characteristic size as a result of aggregate formation under the applied field, as well as to the presence of anisotropy in the aggregate shape

tural changes in the electrode materials both in specialized electrochemical cells and immediately in finished products. This study investigated a Li-Ion 18650 cylindrical rechargeable battery, where graphite is used as a negative electrode and $LiNi_xCo_yAl_{1-x-y}O_2$ with $x \approx 0.8$ and $y \approx 0.1$ (the values were specified during the treatment of the obtained diffraction data) as a positive electrode. The crystal structure of $LiNi_xCo_yAl_{1-x-y}O_2$ in a completely discharged battery corresponds to a space group $R\text{-}3m$ with unit cell parameters $a = 2.8453(1)$ and $c = 14.1878(2)$ Å. On the basis of the analysis of experimental data obtained in the course of several charge-discharge cycles performed at different rates ($C/3$ and $C/10$, where C is the full capacity), it has been shown that the intercalation of lithium into graphite proceeds with the successive formation of several LiC_n phases. The formation of final LiC_6 phase during charging is easily detected by a step-like appearance of a diffraction peak at $d \approx 3.67$ Å. The phase separation in the cathode material $LiNi_{0.8}Co_{0.1}Al_{0.1}O_2$, which can be observed, for example, in $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$, has not been found. At the same time, the unit cell parameters of the two materials change during charging in a similar manner, and the expansion and subsequent contraction of the unit cell proceed anisotropically. When charging, at first the cell expands along the hexagonal c axis and slightly contracts in the basal plane (a and b axes). Towards the end of charging, there occur an abrupt contraction along the c axis and some expansion along the a and b axes.

Using small-angle neutron scattering, changes in the structural organization of transformer-oil-based magnetic fluids have been observed under the action of an external DC and AC electric field (Fig. 3) [2]. The investigations have been carried out to clarify the effect of the voltage breakdown enhancement in liquid transformers when adding nanoparticles, specifically magnetite nanoparticles stabilized by oleic acid, to a liquid carrier. It has been shown that after the application of a DC electric field along with a macroscopic phase separation the aggregation at the size level of 100 nm takes place strongly depending on the field strength. After the electric field is switched off, after a time (of the order of a few hours) the system returns to its original structural state. In the case of an AC electric field, the aggregates also appear at sufficiently low frequencies, and the process terminates when the frequency exceeds a certain critical value. Thus, in addition to the effects of aggregation in an external magnetic field, which is typical for magnetic fluids, a similar sensitivity to the electric field for magnetic fluids based on dielectric carriers has been detected, which opens up new potential possibilities for regulating the properties of

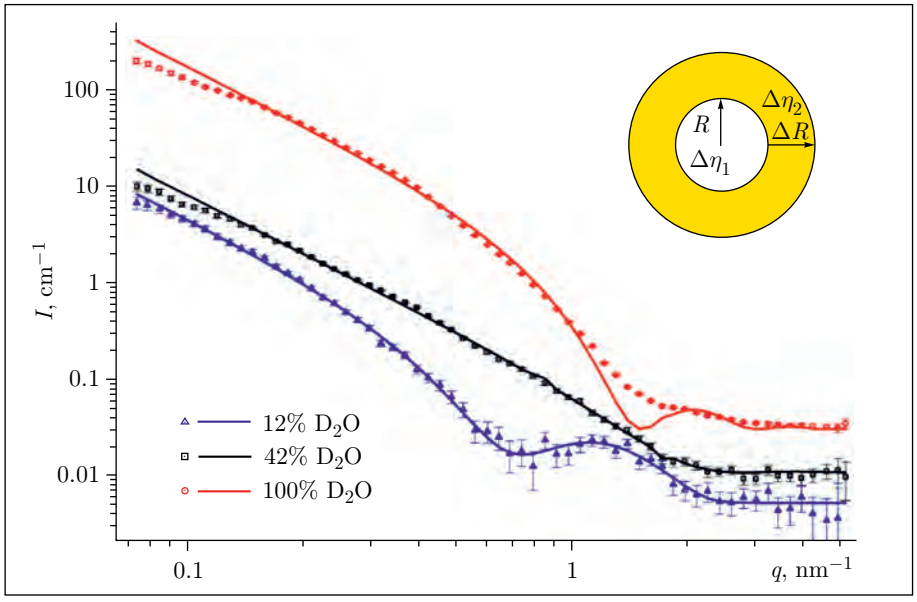


Fig. 4. Small-angle neutron scattering curves from a photoreceptor membrane measured with the contrast variation

these complex systems using external control parameters. The study has been carried out in collaboration with the Institute of Experimental Physics, Slovak Academy of Sciences (Košice, Slovakia), Faculty of Physics of the Taras Shevchenko National University of Kiev (Kiev, Ukraine), and the Research Centre of Jülich — Department of Neutron Research (Munich, Germany).

The visual pigment rhodopsin is a typical representative of the vast family of receptors coupled to G-proteins (GPCR). GPCR in membranes function in dimeric or oligomeric states. However, for rhodopsin and for the whole A class of rhodopsin-like GPCR the functional role of the dimeric state has not yet been established. A supramolecular organization of rhodopsin in photoreceptor membranes is currently much debated. The structural organization of the photoreceptor membranes has been investigated by small-angle neutron scattering with the contrast variation (Fig. 4). It has been found that rhodopsin has an unusually high packing density in the photoreceptor membrane with the distance between protein molecules of about 56 Å [3]. With a high probability the data obtained assume a monomeric character of rhodopsin molecules in the photoreceptor membrane.

In recent years, much interest has been shown in the study of hydrogen-bonded, donor-acceptor type supramolecular co-crystals for their potential use as functional materials with semiconducting and/or ferroelectric properties arising due to the electron- and proton-transfer phenomena. A comprehensive study of the crystal structure and molecular dynamics of co-crystals of bromanilic acid with 2,6-dimethylpyrazine (BrA: 2,6-DMP) 1:1 has been carried out using the methods of single-crystal X-ray diffraction, neutron spectroscopy (NERA spectrometer) and complementary spectroscopic methods (Fig. 5) [4]. To interpret the experimental results, theoretical calculations have been performed as well. The structural analysis has revealed that the system under study crystallizes in the monoclinic P21/c space group, with four molecular units per unit cell. The crystal structure can be described as an infinite net of antiparallelly oriented hydrogen-bonded molecular chains (see Fig. 5). The intermolecular analysis has revealed the nonequivalency of the moderate strength hydrogen-bonding interactions and the presence of multiple specific intermolecular forces. The theoretical calculations using Hirschfeld surface approximation and reduced density gradient approaches have exposed the role of stacking interactions and weak van der Waals forces in the stabilization of the crystal structure. The analysis of vibrational properties was performed using the methods of neutron and optical spectroscopy (mid-, far- and terahertz ranges).

The theoretical analysis of the vibrational spectra was made in the framework of DFT in the semilocal approximation taking into account semiempirical van der Waals corrections. Despite the quasi-harmonic approximation, good agreement between the theoretical and experimental spectra was achieved. In particluar, the

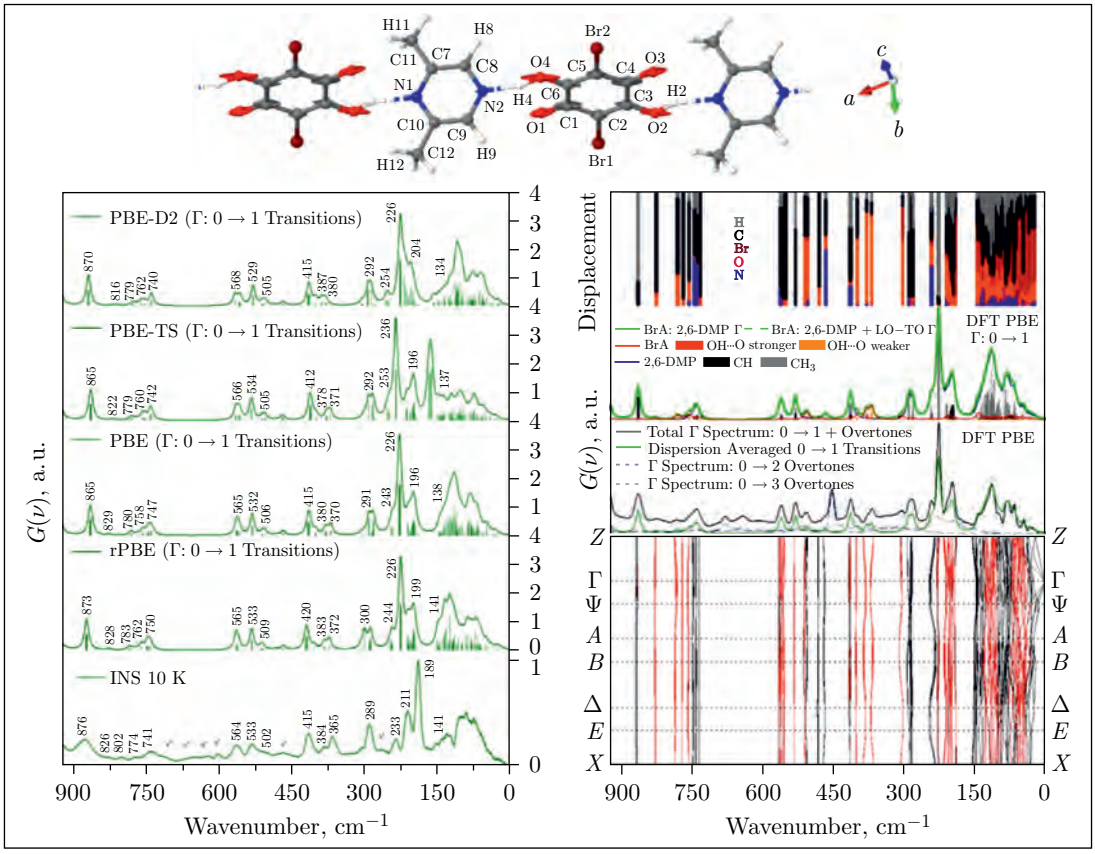


Fig. 5. Molecular structure, inelastic neutron scattering spectra (NERA 10 K) and theoretical calculated vibrational spectra (for $0 \rightarrow 1$ transitions) of BrA:2,6-DMP (1:1) in the frequency range below 925 cm^{-1}. The theoretical spectra are given for both constrained (rPBE; PBE) and fully (PBE-TS; PBE-D) optimized crystal structures. Also, calculated phonon dispersion curves along with the vibrational density of states decomposed into partial density contributions of each molecular fragment are selectively presented. In addition, the dispersion averaged spectrum is given along with the total Γ-point spectrum including the overtone contributions

significant influence of the long-range dipole coupling on the IR spectrum and the effect of the structure on the vibrations with small wave numbers have been revealed.

Instrument Development

Work to develop the final configuration of the new DN-6 diffractometer was continued. In cooperation with the Department of Spectrometers Complex, a second ring detector consisting of 96 independent helium counters has been manufactured. The detector consists of 16 sections with 6 independent detector elements each (helium proportional counters) with background shielding and collimation. Charge-sensitive preamplifiers (96 channels), three modules of 32-channel amplitude discriminators and a 192-channel digital data acquisition and accumulation module (MPD) were developed and manufactured specially for this detector. The electronics was adjusted and all the equipment with the software of the diffractometer was tested. The first successful methodological and scientific experiments with a new two-detector system have been carried out (Fig. 6).

The realization of the project aimed at creating a basic configuration of the diffractometer on beamline 6a for neutron diffraction studies of transition processes in real time (RTD diffractometer) has been completed. The diffractometer (Fig. 7) is designed to study irreversible transition processes with characteristic times ranging from fractions of a second to tens of minutes. In favorable cases, the time resolution of RTD will be fractions of a millisecond. The developed detector system (small-angle detector, detectors at medium scattering angles of 30°–90° and a detector at large scattering angles in combination with the available wavelength range of 0.5–20 Å) makes it possible to obtain diffraction spectra over a wide range of interplanar spacings $(d_{\min}, d_{\max}) = 0.5–300$ Å.

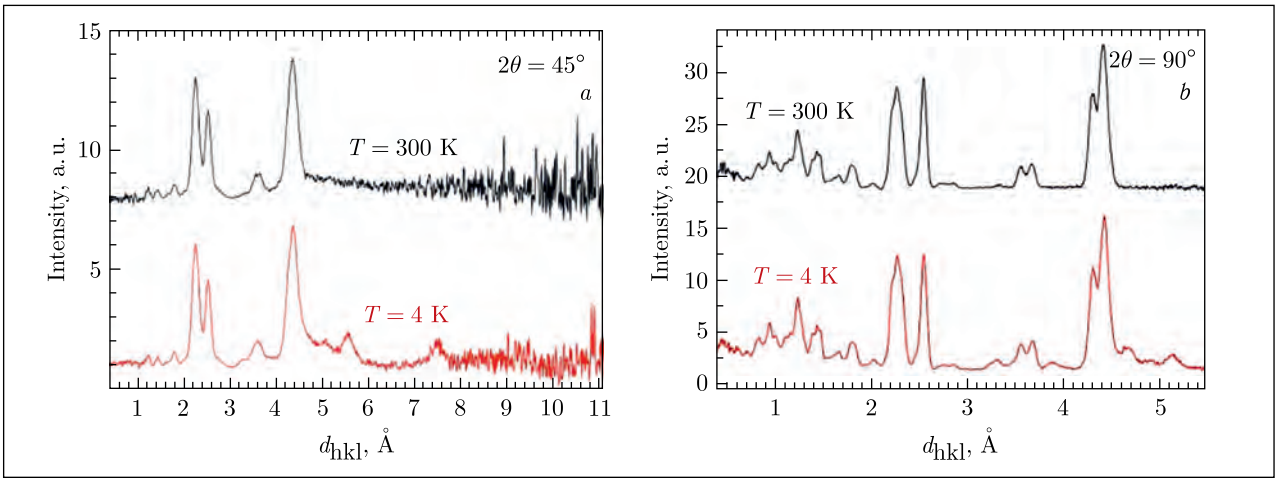


Fig. 6. Neutron diffraction spectra of $LiMn_2TeO_6$ obtained at scattering angles $2\theta = 45°$ (a) and 90° (b)

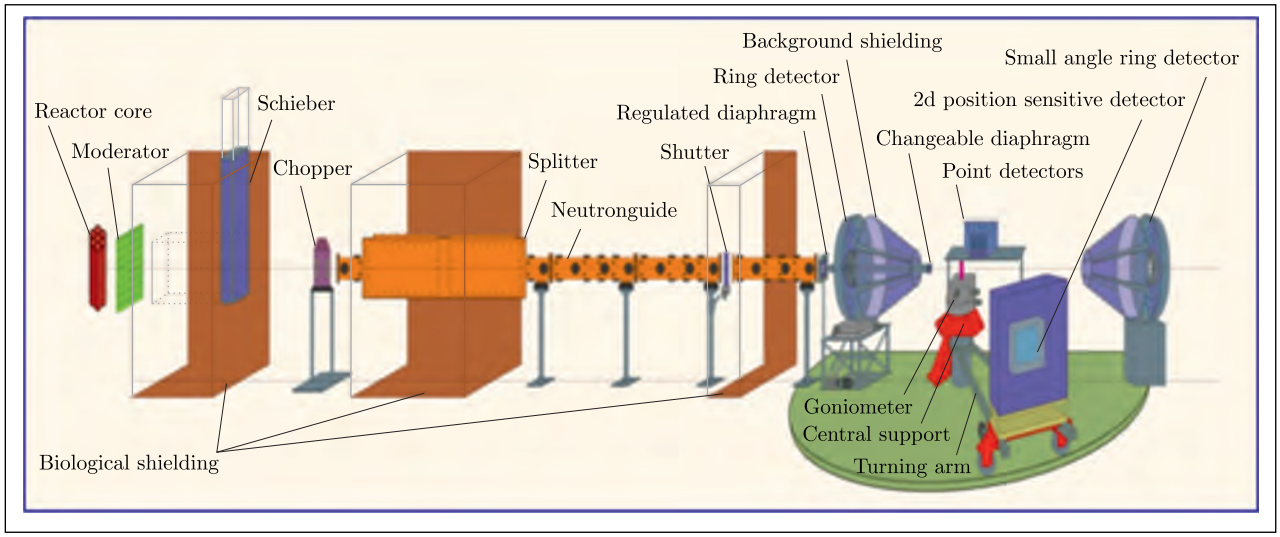


Fig. 7. Basic components of the RTD refractometer at the IBR-2 reactor. Shown from left to right are: reactor core and moderator, biological shielding, chopper to reduce the background between the reactor pulses, "splitter" to split the neutron beam into two beams, mirror neutronguide with a shutter to shut the beam, adjustable diaphragm at the exit of the neutronguide, central platform with a sample position and detectors. Four detector units are used: 2D PSD on a rotating platform, two ring detectors at small and large scattering angles, and a battery of ^{3}He counters near $2\theta = 90°$

A triaxial goniometer and two-coordinate PSD with an active area of 225 × 225 mm and a spatial resolution of 2 × 2 mm are used for investigations with single crystals and multilayer structures.

Multimodal Platform for Raman and Nonlinear Optical Microscopy and Microspectroscopy for Condensed Matter Studies

In 2015, the activities of the Sector of Raman Spectroscopy (Centre "Nanobiophotonics") were focused on the further development and enlarging of the spectral and microscopic possibilities of the optical platform CARS microscope. This was done with the aim to implement the state-of-the-art optical options for highly spectrally selective imaging and high-sensitivity enhanced Raman spectroscopy:

— Polarized Coherent Anti-Stokes Raman Scattering (P-CARS);

— Surface Enhanced Raman Scattering (SERS);

— Raman scattering using laser excitation at 532 nm.

Using this optical platform, a sample can be imaged by utilizing vibration frequencies in the spectral range of 1000–3580 cm^{-1}, which covers all most important vibrational modes of bio-molecules. A diode-pumped green laser

at 532 nm with an adjustable output power of up to 20 mW and more than 50 m coherence length (model SLM-417-20) was also incorporated into the optical system in 2015.

P-CARS imaging of membrane protein crystals. During the reporting period in cooperation with the Institute for the Physics of Complex Systems (Germany), the Institute of Structural Biology (France), Moscow Institute of Physics and Technology, and Orbeli Institute of Physiology (Armenia), research activities on membrane protein (MP) structural studies using nonlinear optical microscopy were initiated. For the first time CARS images of MP crystals with submicron resolution and high contrast were obtained.

Figure 8 compares Raman and CARS images of a sizable BR crystal.

SERS: First experiments. In cooperation with partners from the Republic of Belarus (BSUIR and Scientific-Practical Materials Research Centre of RB NAS), the spectra of spontaneous Raman scattering and SERS for rhodamine 6G dye (R6G) and protein lysozyme were obtained using a substrate based on porous crystalline silicon.

In 2015 the main research directions goals on SERS were the following:

— definition of the concentration sensitivity limit on the SERS active substrates based on silver/porous silicon (Ag/PS);

— definition of the maximum enhancement factor (EF) on the SERS active substrates based on plasmonic structures $Si/SiO_2/(Ag)$.

Plasmonic structures of $Si/SiO_2/(Ag)$. The second type of substrates exploited in the SERS studies were so-called plasmonic structures of $Si/SiO_2(Ag)$ composition, produced by ion-track technology. Monocrystalline silicon plates served as a surface to develop Si/SiO_2 structures. The obtained results are shown in Fig. 9. The results indicate that the best plasmon structures are the substrates with an etching time of 35 min, resulting in the SERS enhancement factor of as high as 10^7–10^8 (Fig. 9, *b*). The optimal laser power is of the order of 5 μW.

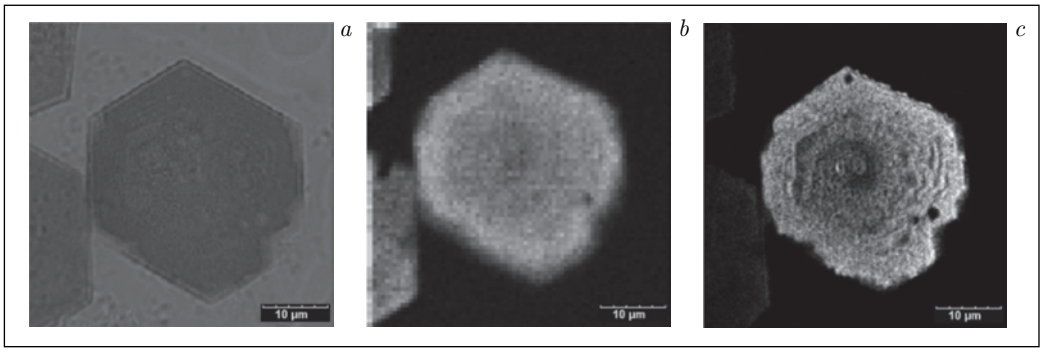


Fig. 8. *a*) Microphotograph, *b*) Raman ($\lambda_{ex} = 785$ nm) and *c*) P-CARS ($\lambda_p = 915.5$ nm, $\lambda_{St} = 1064$ nm) images at vibration 1529 cm^{-1} of bacteriorhodopsin crystal. Scan area — 48×48 μm

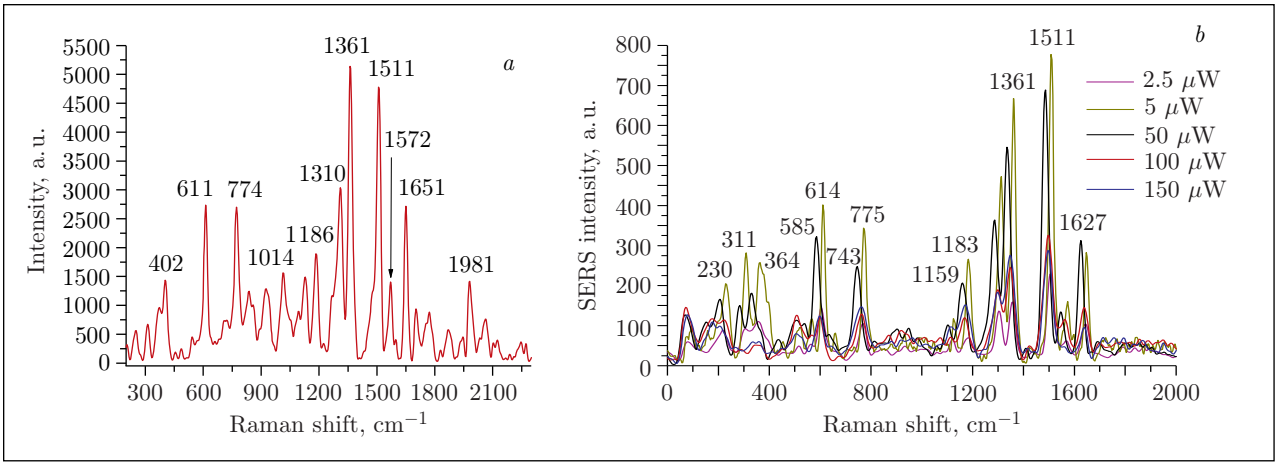


Fig. 9. *a*) Raman spectrum of 10^{-2}M solution of R6G (control); *b*) SERS spectrum of 10^{-6} M solution of R6G on plasmonic structures of $Si/SiO_2/(Ag)$ with an etching time of 35 min

Photo- and up-conversion luminescence (UCL) of oxyfluoride nanoglassceramics doped with rare earth elements (REE). In 2015, an international collaboration was established with the Institute of Solid State Physics of the University of Latvia (Riga), with the Belarussian State Technological University (Minsk), and the Institute of Solid State Physics and Semiconductors (Minsk). The structural and spectral characteristics of oxyfluoride glasses co-doped by europium and ytterbium ions with different molar concentrations were studied.

Luminescent characteristics. Photoluminescence spectra of precursor and heat-treated samples were measured under the laser excitations of 325, 405, 456 nm, and a xenon lamp at the wavelength of 440 nm. At all the excitation wavelengths a pronounced red photon emission was observed, typical for $4f-4f$ transition of Eu^{3+}.

The spectra of up-conversion luminescence of the precursor and heat-treatment samples were detected at the CARS microscope using laser excitation at 976 nm corresponding to the maximal value of absorption coefficient of Yb^{3+} ion.

NEUTRON NUCLEAR PHYSICS

In 2015, in 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 for nuclear astrophysics; experiments with ultracold neutrons; applied research using NAA. The scientific program to study the inelastic scattering of fast neutrons made into a separate project TANGRA was successfully implemented. A number of investigations in the field of fundamental physics and ultracold neutron physics were performed on the neutron beams of nuclear research centres in China, France, Germany, Switzerland, and USA.

Of particular note is the accurate implementation of the planned activities on the modernization of the IREN facility aimed to ensure that in 2016 two accelerating sections of the accelerator will operate.

Modernization of the IREN Facility

In April–May 2015, at the IREN facility, a group of staff members of VBLHEP and FLNP, together with the specialists from DAWONSYS (Republic of Korea), carried out the final stage of assembling and adjustment of two sets of new modulators to power pulsed klystrons — SHF sources of power of the LUE-200 accelerating system, which is a driver of the pulsed source of resonance neutrons. Commissioning of the modulators capable of generating electrical load pulses with a pulse power of up to 180 MW and an average power of 180 kW will allow doubling the average energy of accelerated electrons and providing operation of the accelerating system with a cycle frequency of up to 120 Hz, which will increase the power of the accelerated beam and correspondingly the neutron yield from the irradiated target of the IREN source by more than one order.

Experiments have been conducted to compare the neutron yield from tungsten and uranium nonmultiplying targets. The accelerator operated with one accelerating section, DAWONSYS modulator and TH2129 Thomson klystron of 17 MW. At the same operating modes of the accelerator the gain in the case of the uranium-238 target was 2.6.

At present, the second section of the accelerator has been installed; the work on its connection is in progress.

Experimental and Methodological Investigations

Measurement of the angular distribution of γ rays with an energy of 4.43 MeV produced in the inelastic scattering of neutrons with an energy of 14.1 MeV by carbon. One of the first experiments planned in the framework of the project TANGRA (TAgged Neutrons and Gamma RAys) is the measurement of angular correlations of γ rays and neutrons produced in the reaction of inelastic scattering of neutrons with an energy of 14.1 MeV by carbon nuclei:

$$^{12}\mathrm{C}\,(n,n')^{12}\mathrm{C}^{*} \xrightarrow{\gamma} {}^{12}\mathrm{C}.$$

The result of this experiment will make it possible not only to make a correct comparison with the experimental data obtained earlier in the experiments studying the characteristics of

the reaction and significantly differing among themselves, but also to obtain information on the mechanism of inelastic scattering of fast neutrons by carbon nuclei. It should be noted that in the framework of the TANGRA project it is planned to carry out a series of experiments for a detailed study of the inelastic scattering of fast neutrons by ^{12}C, ^{14}N, ^{16}O, ^{27}Al, ^{56}Fe, ^{37}Cl, ^{32}P and other nuclei using the tagged neutron method (TNM). In addition, the interest in the study of these reactions is dictated by the need to address many applied problems basing on the use of TNM and connected with mineralogy and geology of the Earth, determination of the elemental composition of rocks, as well as with the creation of algorithms and devices for detection of hidden dangerous substances (explosives, narcotic and highly toxic substances).

A schematic of the experimental setup is presented in Fig. 10, *a*, and its general view is given in Fig. 10, *b*.

A portable neutron generator ING-27 developed and manufactured at the N. L. Dukhov All-Russia Research Institute of Automatics (VNIIA) was used as a source of neutrons with an energy of 14.1 MeV. To form a tagged neutron flux, the generator comprises a built-in silicon double-sided strip detector that consists of 8 mutually perpendicular strips on each side forming an 8×8 matrix of 4×4 mm pixels. The total active area of the 64-element α detector is 32×32 mm. The α detector is located 62 mm away from the tritium target of the neutron generator and intended to detect α particles with an energy of 3.5 MeV produced in the reaction $d + t \to \alpha(3.5\ \text{MeV}) + n(14.1\ \text{MeV})$.

Twenty two detectors of γ rays on the basis of NaI(Tl) crystals shaped as hexahedrons (distance between the crystal faces — 85 mm, the crystal height — 200 mm) were used as detectors of characteristic nuclear γ radiation with an energy of 4.43 MeV from carbon. The γ ray detectors were arranged perpendicularly to the horizontal plane in a circle of 370 mm radius with a carbon target placed in its centre. The angle between the axes of two adjacent NaI(Tl) crystals in the horizontal plane was 15°.

In the experiment, for each detector the number of detected events corresponding to the total absorption peaks for gamma rays with an energy of 4.43 MeV (detected in coincidence with the central pixel of alpha detector) was determined. Then, the obtained number of events was averaged for each pair of γ detectors located symmetrically at a specified polar angle relative to the axis of the central tagged neutron beam.

To describe quantitatively the anisotropy of the angular distribution for γ rays generated in the inelastic scattering reaction, the anisotropy parameter W is used. It is defined as the ratio of the number of events detected by the detector positioned at an angle θ to the number of events detected by the detector positioned at an angle of 90°:

$$W(\theta) = 1 + a\cos^2\theta - b\cos^4\theta.$$

Figure 11 shows the anisotropy parameter for γ rays generated in the course of the reaction of inelastic neutron scattering from carbon as a function of the polar angle obtained from the experimental data processing. The errors in the angle (angular resolution of the detector) were obtained by the Monte Carlo simulations

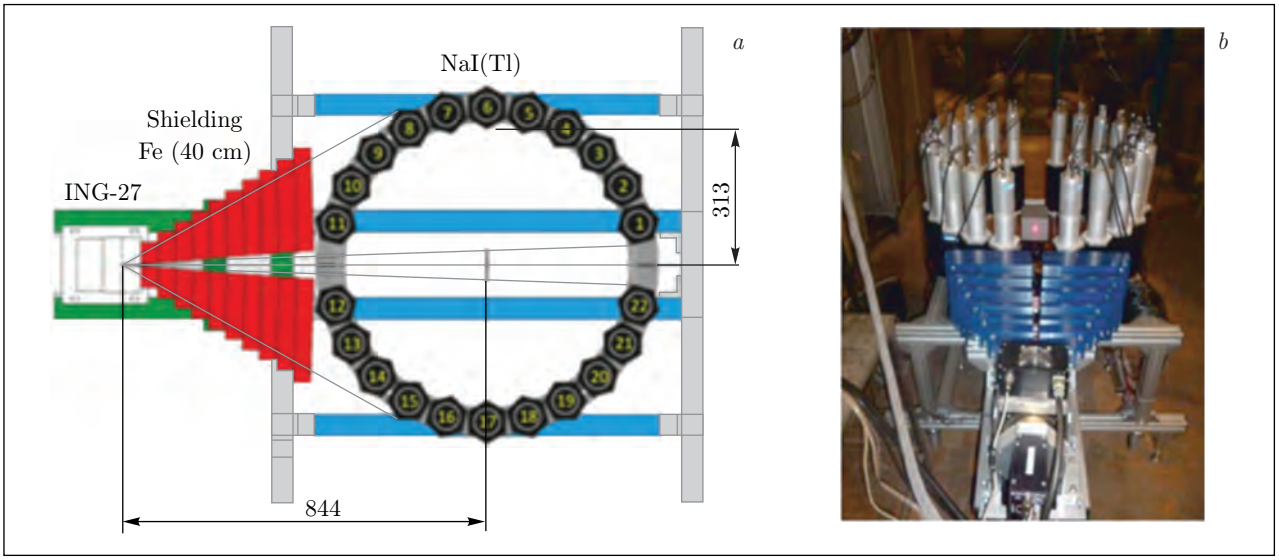


Fig. 10. *a*) A schematic of the experimental setup; *b*) a general view of the setup

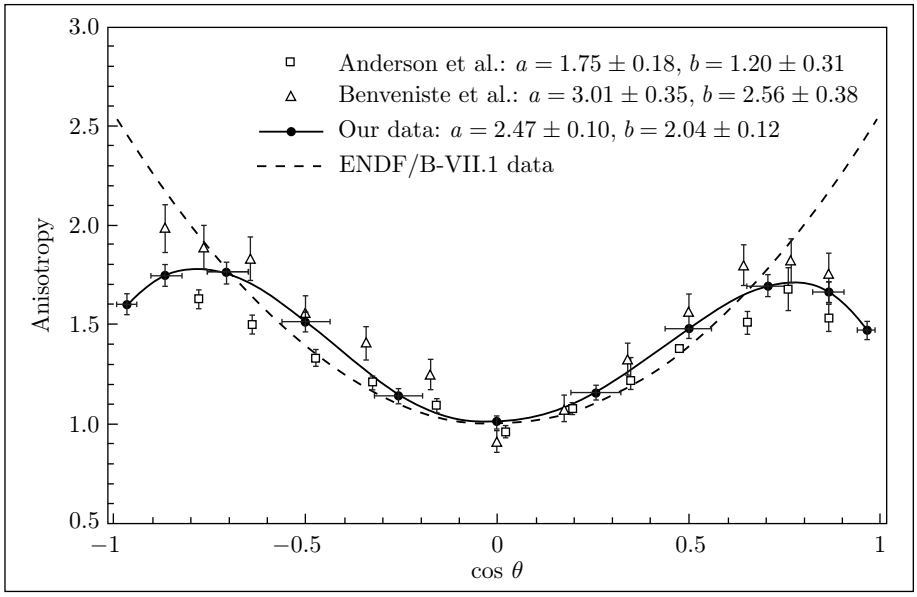


Fig. 11. Angular dependence obtained from the experimental data in comparison with the evaluated and other experimental data

using the Geant4 package. The obtained angular dependence can be described using the above formula with the parameters $a = 2.47 \pm 0.10$ and $b = 2.04 \pm 0.12$. The figure also shows a comparison with the experimental data obtained in other studies and a theoretical curve from the ENDF/B-VII.1 library.

Calculations of a UCN source of a new type at an external beam of thermal neutrons. A detailed calculation of the parameters of a UCN source of a new type has been conducted, which is based on a new method for production of ultracold neutrons in a helium source. The principal idea of the method presented for the first time in [5] consists in installing a helium UCN source into a thermal neutron beam and in surrounding it with a reflector moderator, which is a source of cold neutrons needed to produce UCN. At the same time, the flux of cold neutrons in the source could be several times greater than the flux of incident neutrons due to their numerous reflections from the reflector moderator.

The source of this type should be installed close to the reactor biological shielding. Figure 12 presents the layout of the source on one of the beamlines of the PIK reactor.

Calculations of the parameters of the source with a reflector moderator of solid methane and liquid deuterium have been performed. These calculations have shown that the installation of such a UCN source with a methane moderator on a thermal neutron beamline of the

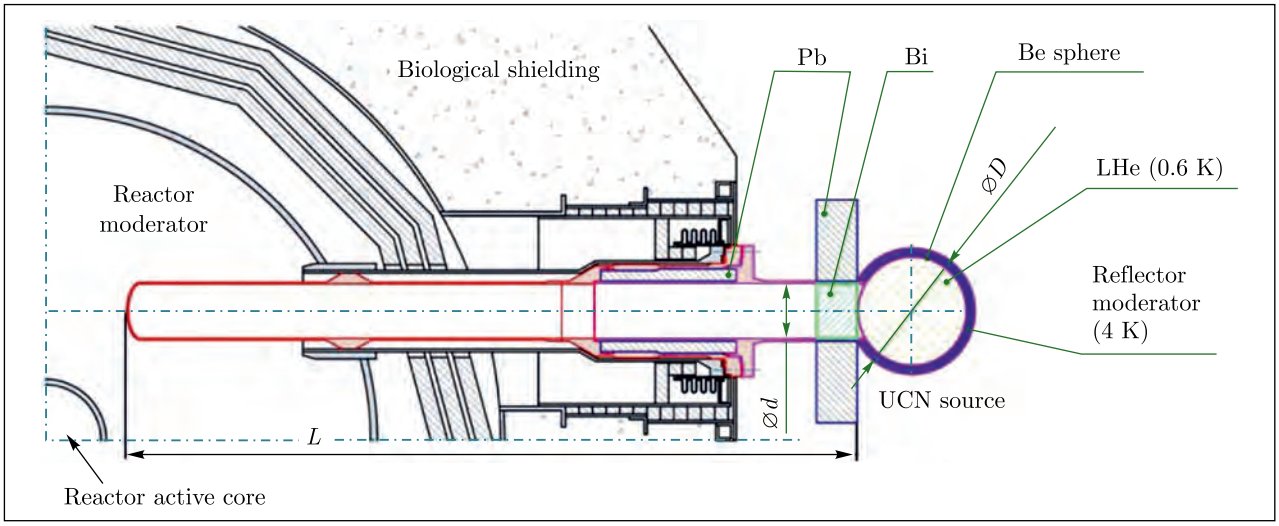


Fig. 12. A possible layout of the UCN source on one of the thermal neutron beamlines of the PIK reactor

PIK reactor allows achieving a UCN density of $\sim 1 \cdot 10^5$ cm^{-3} in the source with a production rate of $\sim 2 \cdot 10^7$ s^{-1}, which is, respectively, a factor of 1000 and 20 higher than those that can be provided by the most intensive UCN source available today. At the same time, the UCN density in the source with a deuterium moderator can be $\sim 2 \cdot 10^5$ cm^{-3} with a production rate of the source of $\sim 8 \cdot 10^7$ s^{-1}.

Calculations of the heat release in the UCN source have also been performed demonstrating that, with achieving the above parameters, the heat release power will be in the range of 1–2 W, which makes it possible to realize the proposed concept of the source in practice.

Analytical investigations at the IBR-2 reactor. *Development of the NAA&AR Sector experimental base.* In the reporting period in the NAA&AR Sector the development of a software package for complex automation of multielement neutron activation analysis (NAA) at the IBR-2 reactor [6] was continued; three automatic sample changers (SC) were installed and successfully operated to automate mass measurements of spectra of irradiated samples on three detectors.

Analysis of materials of extraterrestrial origin. In 2015, a study aimed at searching for cosmic dust in peat columns collected in Siberia in the area of the Tunguska meteorite fall was performed in cooperation with the Adam Mickiewicz University in Poznan (Poland). The age determination of peat column layers was carried out in Poland. The data treatment has been completed; a paper is being prepared for publication. Using scanning electron microscopy and energy-dispersive X-ray spectroscopy, moss samples collected in the Arctic (Northern Norway) and Antarctic (King George Island) have been analyzed. The particles detected by means of electron microscopy along with the results of the neutron activation analysis of samples allow one to make a conclusion about their origin, which will contribute to the development of criteria for identification of particles of extraterrestrial origin. A multielement analysis of meteorites of unknown nature received from Italy has been performed. The NAA results and the use of statistical methods of multielement analysis for their processing have made it possible to determine the type of the meteorite material: ferrous chondrites and carbonaceous chondrites. The results of the research were presented and discussed at the International Conference "Modern Trends in Radiobiology and Astrobiology", organized by JINR LRB on October 28–30, 2015 [7] in Dubna.

THE IBR-2 PULSED REACTOR

The IBR-2 research nuclear facility is operated under Rostekhnadzor license No. GN-03-108-2614 of 27.04.2012 and Rostekhnadzor license No. GN-03-108-2871 of 30.04.2014.

Since January 2015 regular IBR-2 cycles of scientific experiments have been carried out at a power of 2 MW with the CM 202 moderator operating either in the water or cryogenic mode in accordance with the schedule of the physical start-up of the cold moderator.

The table presents data on the IBR-2 operation for physics experiments.

Data on the IBR-2 operation for physics experiments

No. cycle	Period	Moderator type	Reactor operation for physics experiments, h
1	19.01–02.02	Water	326
2	11.02–21.02	Cryogenic	230
3	11.03–21.03	Cryogenic	240
4	30.03–16.04	Water	330
5	13.05–27.05	Water	336
6	28.09–09.10	Water	264
7	19.10–02.11	Water	267
8	09.11–23.11	Water	326
9	07.12–21.12	Water	327
		Total:	2646

NOVEL DEVELOPMENT AND CONSTRUCTION OF EQUIPMENT FOR THE SPECTROMETER COMPLEX OF THE IBR-2 FACILITY

Cryogenic Moderators

In 2015, work and research continued on a special stand of a cryogenic pelletized moderator with an inclined section at an angle of elevation of 40° in the direction of experimental beamlines Nos. 4–6. Hardware and software of the stand have demonstrated stable and trouble-free operation during all experiments and will be used in a real moderator CM 202 in the future.

Detectors and Electronics

For experimental studies with fast neutrons, a new spectrometer based on a proton telescope (PT), has been designed, manufactured and tested (detailed description of PT can be found in the Annual Report 2012 and JINR Patent http://www.freepatent.ru/images/patents/13/2445649/patent-2445649.pdf). The measurement of energy distributions of neutron fluxes

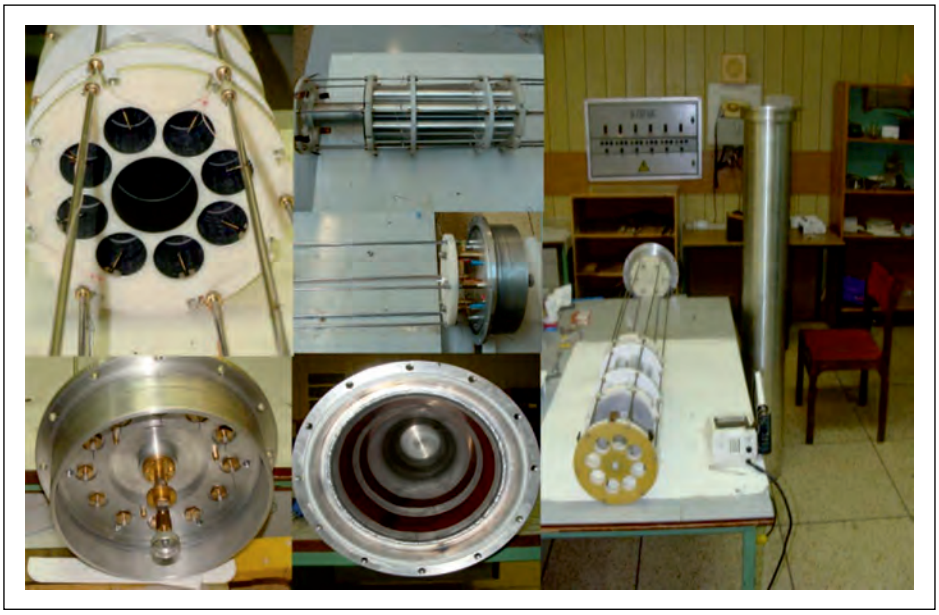


Fig. 13. Electrode system of the new proton telescope

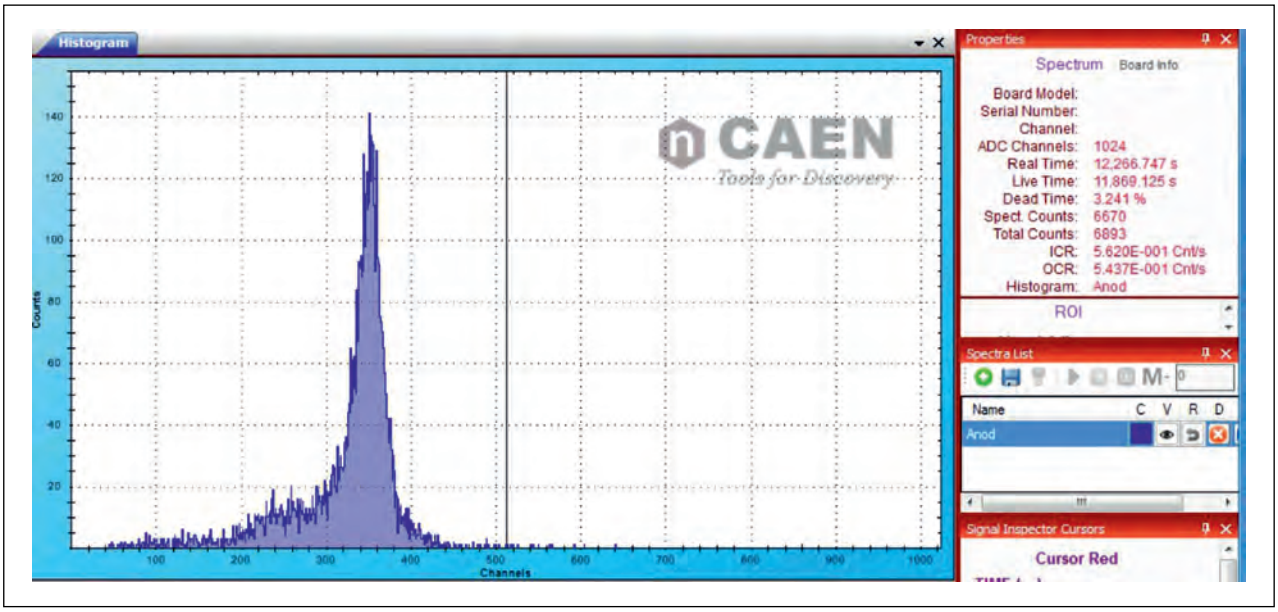


Fig. 14. Beam spectrum from a neutron generator ING-07 obtained using PT (neutron energy 2.5 MeV, gas mixture composition: 500 mbar CH_4)

in the spectrometer is performed by measuring the kinetic energy of recoil protons elastically scattered at small angles as a result of (n, p) interaction in a gas hydrogen-containing medium. New versions of PT, electronics and software have been designed in accordance with protocol No. 4519-4-15/17 of 15.06.2015 between JINR and the National Fusion Research Institute (Daejeon, Republic of Korea), where the spectrometer is planned to be used for the diagnostics of a nuclear fusion reactor (KSTAR). At FLNP it will be used to obtain spectra of fast and resonance neutrons of neutron-producing targets of IREN and EG-5. Figures 13 and 14 show the electrode system of PT and beam spectrum from a neutron generator ING-07.

CONFERENCES AND MEETINGS

On May 25–29, the JINR International Conference Centre hosted the **23rd International Seminar on Interaction of Neutrons with Nuclei:** Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics (**ISINN- 23**). The Seminar is organized by the Laboratory of Neutron Physics annually at the end of May. This year it was dedicated to the 100th anniversary of the birth of the outstanding Soviet physicist, one of the founders of the LNP — Corresponding Member of the USSR Academy of Sciences F. L. Shapiro.

The Seminar was attended by about 70 staff members from different laboratories of JINR, about 40 scientists from Russia and the CIS, and about 20 representatives of a wide range of countries: Bulgaria, France, Great Britain, Germany, Iran, Romania, Serbia, Slovakia, Vietnam, and the United States. Within four working days, 60 oral reports and 50 poster presentations on the subject of the Seminar were given to the participants.

The 6th European Conference on Neutron Scattering (ECNS-2015) was held in Zaragoza, Spain, from August 30 to September 4. The Conference is organized every four years since 1996 under the auspices of the European Neutron Scattering Association (ENSA). ECNS-2015 brought together over 600 representatives of the European neutron scattering community to discuss recent developments and advances in all branches of science in which neutron scattering is used. The Conference's topics covered a wide range of relevant interdisciplinary problems of physics of condensed and soft matter, biology and medicine, chemical design, magnetism and spintronics, fundamental neutron physics, diagnostics of functional materials and objects of cultural heritage, geology and investigations of matter under extreme conditions. The Conference provided a platform for discussion of the current status and prospects of the available and future European neutron sources (nuclear research reactors and accelerator-based spallation sources), development of specialized neutron moderators and instruments on neutron sources, as well as proposals for the implementation of new methods and approaches for investigations of matter using neutron scattering.

JINR was represented at ECNS-2015 by a delegation of twenty FLNP scientists who reported their results of the investigations conducted at the Laboratory neutron sources — IBR-2 and IREN. An important part of the ECNS programme was an exhibition of the world's leading neutron centres, in which JINR participated with great success. The FLNP stand provided the Conference participants with an opportunity to become acquainted with the operation and plans of development for the neutron sources at JINR. The presentation was primarily focused on the implementation of the user policy at the IBR-2 pulsed reactor after its recent modernization. Numerous visitors of the stand could get the most comprehensive information about the possibilities of the existing spectrometers and find out the details of obtaining experimental beamtime at the IBR-2.

The International Conference "Condensed Matter Research at the IBR-2" (CMR-2015) was held at the Frank Laboratory of Neutron Physics on October 11–15. A series of these conferences was launched in 2014, aimed at providing a platform for discussion of the results of interdisciplinary studies of condensed matter using neutron scattering at the IBR-2 reactor, as well as for analysis of prospects of future research and improvement of instrumentation and methodological base. The CMR-2015 was dedicated to the 100th anniversary of the birth of the outstanding Soviet physicist F. L. Shapiro, the event which was celebrated in JINR throughout 2015. F. L. Shapiro

is recognized as one of the founders of the Frank Laboratory of Neutron Physics, who made a significant contribution to the development of scientific research areas and basic facilities of the Laboratory.

The Conference was attended by over 120 participants from scientific organizations and universities of the Russian Federation, Azerbaijan, Belarus, Bulgaria, Germany, Latvia, Moldova, Mongolia, Romania, Serbia, Slovakia, Ukraine, and Vietnam.

The VI International School for Young Scientists and Students "Instruments and Methods of Experimental Nuclear Physics. Electronics and Automatics of Experimental Facilities" was held on November 9–14 at FLNP. The School was organized by the Frank Laboratory of Neutron Physics with the support of the JINR Directorate and Plenipotentiary of Kazakhstan. Seventy two attendees from the JINR Member States (Belarus, Kazakhstan, Russia, Ukraine) took part in the School. The most representative group of participants came from Dubna, Obninsk, Kharkov, Astana, Moscow, Almaty, Tomsk, and Dimitrovgrad. Among them were 4th year students (28 participants), 5th and 6th year students (27 participants), 3rd year students (7 participants), 2nd year students (3 participants), 4 postgraduates and 3 researchers.

REFERENCES

1. *Kozlenko D. P. et al.* Competing Magnetic States in Multiferroic YMn_2O_5 at High Pressure // Phys. Rev. B. 2015. V. 92. P. 134409 (1–7).
2. *Rajnak M. et al.* Direct Observation of Electric Field Induced Pattern Formation and Particle Aggregation in Ferrofluids // Appl. Phys. Lett. 2015. V. 107. P. 073108.
3. *Feldman T. B. et al.* Study of Visual Pigment Rhodopsin Supramolecular Organization in Photoreceptor Membrane by Small-Angle Neutron Scattering Method with Contrast Variation // Dokl. Ross. Akad. Nauk. 2015. V. 465, No. 5. P. 1–5 (in Russian).
4. *Łuczyńska K. et al.* Experimental (X-Ray, ^{13}C CP/MAS NMR, IR, RS, INS, THz) and Solid-State DFT Study on (1:1) Co-Crystal of Bromanilic Acid and 2,6-Dimethylpyrazine // J. Phys. Chem. B. 2015. V. 119. P. 6852–6872.
5. *Lychagin E. V. et al.* http://www.hindawi.com/journals/ahep/2015/547620/. 2015.
6. *Pavlov S. S., Frontasyeva M. V., Dmitriev A. Yu.* Automation of Reactor Neutron Activation Analysis // The International Atomic Energy Agency's Third Research Coordination Meeting on Development of an Integrated Approach to Routine Automation of NAA (CRP 1888), June 22–26, 2015, Vienna, Austria.
7. *Frontasyeva M. V.* Neutron Activation Analysis and Microscopy of Extraterrestrial Materials // Intern. Conf. "Modern Trends in Radiobiology and Astrobiology", Dubna, October 28–30, 2015.

LABORATORY OF INFORMATION TECHNOLOGIES

The investigations performed at the Laboratory of Information Technologies during 2015 in the framework 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.

A presentation of the Tier-1 level centre for the CMS experiment at the Large Hadron Collider (LHC) took place at LIT on March 26. This centre is a basic JINR facility, it provides the physicists of the Institute, JINR-participating countries and RDMS-CMS collaboration with the opportunity of a full-scale participation in processing and analysis of data coming from the CMS experiment. When creating the centre, the engineering infrastructure (uninterrupted power supply, climate control, etc.), a high-speed reliable network infrastructure with a dedicated reserved channel to CERN (LHCOPN), a computing system (2400 computing nodes) as well as a storage on the basis of disk arrays (2.4 PB) and tape libraries of big capacity (5 PB) have been developed. These systems provide a 100% reliability and availability of the centre.

The multifunctional centre for storing, processing and analysis of data launched on the base of the JINR Central Information and Computer Complex (CICC) provides a wide spectrum of possibilities for its users on the basis of its components: a grid-infrastructure of levels Tier-1 and Tier-2 to support experiments at the LHC (ATLAS, ALICE, CMS, LHCb), FAIR (CBM, PANDA) and other large-scale experiments (NICA); a general-purpose computing cluster; a cloud computing infrastructure; a computing cluster with heterogeneous architecture HybriLIT; an educational and research infrastructure for distributed and parallel computations.

In 2015, LIT researchers published 155 scientific papers in peer-reviwed journals and presented 30 reports at international and Russian conferences.

INFORMATION AND COMPUTING INFRASTRUCTURE OF JINR

During 2015, work related to the reliable operation and development of the JINR networking and information 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 that on the basis of cloud, grid and hybrid technologies, integrating information resources of the Institute into a unified environment accessible to all users.

JINR Telecommunication Data Links. In 2015, the reliable operation of the high-speed computer communication channel Dubna–Moscow was ensured. The connection with scientific networks and Internet was provided using the following telecommunication links: LHCOPN/CERN (10 Gbps), RBnet (10 Gbps), E-arena (10 Gbps) and Russian scientific networks (10 Gbps), RUNNet and international scientific networks (10 Gbps). The throughput of the reserve data link was increased up to 10 Gbps and was improved at the expense of the additional router Cisco7606-S. The opportunity of modernization of the external data link up to 100 Gbps has been studied. Table 1 shows the distribution of the incoming (more than 3 TB) and outgoing traffics in 2015 over JINR subdivisions.

Table 1

Subdivision	Incoming, TB	Outgoing, TB
DLNP	107.45	48.49
VBLHEP	74.46	66.31
General access servers	60.29	11.11
LIT	52.08	27.19
FLNP	42.98	57.24
JINR Hotel & Restaurant Complex	25.47	4.4
FLNR	23.61	4.12
BLTP	23.22	16.35
JINR Management	20.92	61.44
Node of remote access	19.65	5.09
University “Dubna”	12.12	8.38
VG Computers	11.9	1.64
Joint Stock Company “Dedal”	10.98	4.46
Medical-Sanitary Unit 9	9.84	1.02
LRB	7.01	2.86
Joint-Stock Company “Atom”	3.76	0.33

In 2015, the overall incoming JINR traffic, including the general access servers, Tier-1, Tier-2 and CICC, amounted to 4.3 PB (3.3 PB in 2014). The weights of the various incoming traffic categories are shown in Table 2.

The creation of the Tier-1 centre at JINR required a high-speed reliable network infrastructure with a dedicated reserved channel to CERN (LHCOPN). The LHCOPN throughput between Tier-0 and Tier-1 and between Tier-1 and Tier-1 is 10 Gbps.

JINR Local Area Network. In 2015, 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 continued. The work on introduction of the 10 GB network has covered approximately 80% of the networking equipment of the Laboratories.

In the framework of the user’s computer environment support, the scheduled work has been done on enhancement of the mail, webmail, proxy, e-lib and authorization services. Work has been started 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. New rules of work in the network have been prepared and approved for the JINR users. At present, preparation is in progress on transition of the JINR network to a new standard of network addressing 1Pv6.

In 2015, the JINR LAN included 7806 network elements and 12555 IP addresses; 4129 users were registered within the network. There were more than 1500 users of mail.jinr.ru service as well as 1480 users of digital libraries and 641 remote VPN users.

Multifunctional Centre for Data Storage, Processing and Analysis. In 2015, work was progressing on launching a multifunctional information-computer complex at JINR. Its main task is to expand the set of computing services provided for the user. It involves the following elements:

- automated data processing system for the CMS experiment at the LHC of the Tier-1 level;
- grid infrastructure of the Tier-2 level to support LHC experiments (ATLAS, ALICE, CMS, LHCb), FAIR (CBM, PANDA) and other large-scale experiments and projects within the global grid infrastructure;

Table 2

Scientific and educational networks, %	File exchange (p2p), %	Web-resources, %	Social networks, %	Software, %	Multimedia, %
91.33	4.86	2.77	0.67	0.36	0.01

• high-performance computing system (including the parallel ones) outside the limits of heterogeneous and grid systems;
• heterogeneous computer complex;
• cloud environment.

JINR Grid Environment. In 2015, a Tier-1 centre for the CMS experiment at the LHC was launched [1]. It is one of the eight such centres worldwide. It provides the physicists of the Institute, its participating countries, RDMS-CMS collaboration, and the whole CMS collaboration with the opportunity of a full-scale participation in the processing and analysis of data coming from the CMS experiment. The experience gained in LIT at the creation of the Tier-1 centre will be used in the development and introduction of the information environment of storage and data processing of the NICA megaproject and other large-scale projects of the JINR Member States. During 2015, this centre performed 1 362 474 tasks, using a normalized CPU time of 141 753 061 h in HEPSpec06 units. Figure 1 gives the contribution of the Tier-1 global centres to the CMS experimental data processing for the last months of 2015. The JINR Site takes one of the leading ranks in the world as to its productivity.

In 2015, active work was in progress within the global large-scale grid projects "Worldwide LHC Computing Grid" (WLCG, http://lcg.web.cern.ch/LCG/) and "European Grid Infrastructure" (EGI-InSPIRE — Integrated Sustainable Pan-European Infrastructure for Researchers in Europe, http://www.egi.eu/projects/egi-inspire/). The JINR computer cluster, as a grid site JINR-LCG2 of the global grid infrastructure, supports computations of eight virtual organizations (alice, atlas, biomed, cms, dteam, fusion, hone, and lhcb) and provides possibilities for using grid resources for the experiments BES and PANDA as well. At the moment, the cluster comprises 2560 64-bit processors and 1800 TB disk data storage. The central CICC network router is connected to the main border router of the JINR network at the Ethernet rate of 10 GB. The main users of the JINR grid resources are virtual organizations of all LHC experiments. In 2015 this site executed 4 666 405 tasks, CPU time being 171 418 826 h in HEPSpec06 units. Figure 2 summarizes data on using the grid site JINR-LCG2 by the virtual organizations within the RDIG/WLCG/EGI in 2015.

During 2015, the data storage systems of the JINR grid centre comprising two grid sites (JINR-LCG2 and JINR-T1 in terms of the WLCG project) of the global WLCG infrastructure performed in the following way: data volume transferred from the JINR to all world grid sites (USA, France, Switzerland, Canada, etc.) is 3215 TB for the CMS experiment and 308 TB for the ATLAS experiment, while the data volume received by the JINR is 3052 TB for the CMS experiment and 351 TB for the ATLAS experiment.

Throughout 2015, JINR grid centre data storage systems were in active use by the users from JINR member and associated states in the framework of their participation in the ALICE, ATLAS and CMS projects. For CMS, 815 TB of data were transferred from the JINR and 654 TB were transferred to the JINR, including Italy — 330 and 348 TB, respectively, Germany — 408 and 286 TB, Russian Federation — 37 and 5 TB, Ukraine — 23 and 3 TB, Hungary — 14 and 9 TB. For ATLAS, 72.5 TB of data were trans-

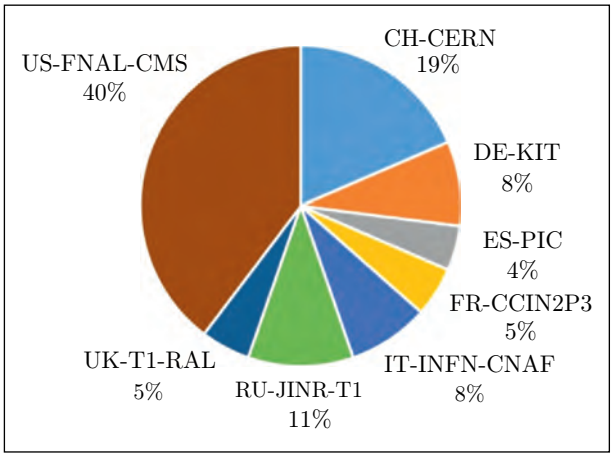


Fig. 1. Usage of the Tier-1 centres by the CMS experiment

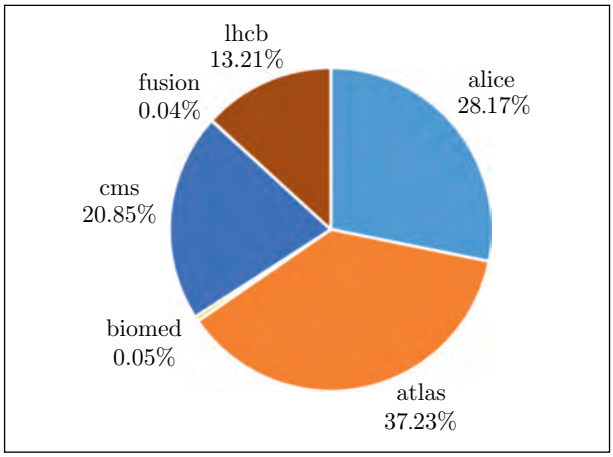


Fig. 2. Using the JINR-LCG2 grid site by virtual organizations within RDIG/WLCG/EGI

ferred from the JINR and 66 TB were transferred to the JINR, including Germany — 24 and 28 TB, respectively, Russia — 32 and 20 TB, Italy — 13 and 14 TB, Czechia — 0.5 and 2 TB, Romania — 1 and 1 TB, Slovakia — 1.5 and about 0.5 TB; also there was data exchange with grid sites from Armenia and South Africa. Data of the ALICE experiment (more than 300 TB) were transferred from the JINR and 2 TB were transferred to the JINR, including Russia — about 300 and 2 TB, respectively; 2 TB were transferred to Italy and 2 TB to Romania, also there was data exchange with grid-sites from Czechia, Germany, South Africa, Slovakia, and the Ukraine.

A new monitoring system of the JINR computer complex has been put into operation, and a centre of control and management over its operation has been launched. For the reliable functioning of the whole computer complex, it is necessary to trace in real time the status of all its units, stating with the power supply and ending the robotized tape library. At present, 690 elements of the computer complex are monitored and 3497 checks are performed in real time. The monitoring allows exhaustive control over the functioning of the system, visualization of the state of the computer complex and sends notifications about failures in the form of e-mail message, SMS, etc. [2]. Figure 3 represents one of the screens of monitoring which shows the functioning of the elements of the computing cluster.

Work on the support and development of services of the PanDA platform includes investigations on using network metrics for decision making (the dynamic clouds mechanism) due to services responsible for the network metrics delivery. The update of services which deliver those metrics to PanDA's information system was performed. The transfer of COMPASS' workflow to PanDA was in progress. In collaboration with Nizhny Novgorod University, works were undertaken on the PanDA server installation at JINR and on running a PanDA queue for job submission to the cluster of this university [3].

High-Performance Computer System. The Multipurpose Information Complex at LIT provides carrying out computations, including the parallel ones, outside the grid environment. These are asked both by the experiments NOVA, PANDA, BES, NICA/MPD, etc. and the local users of the JINR Laboratories. The JINR users and the grid users have access to all the computer facilities via a unified batch processing

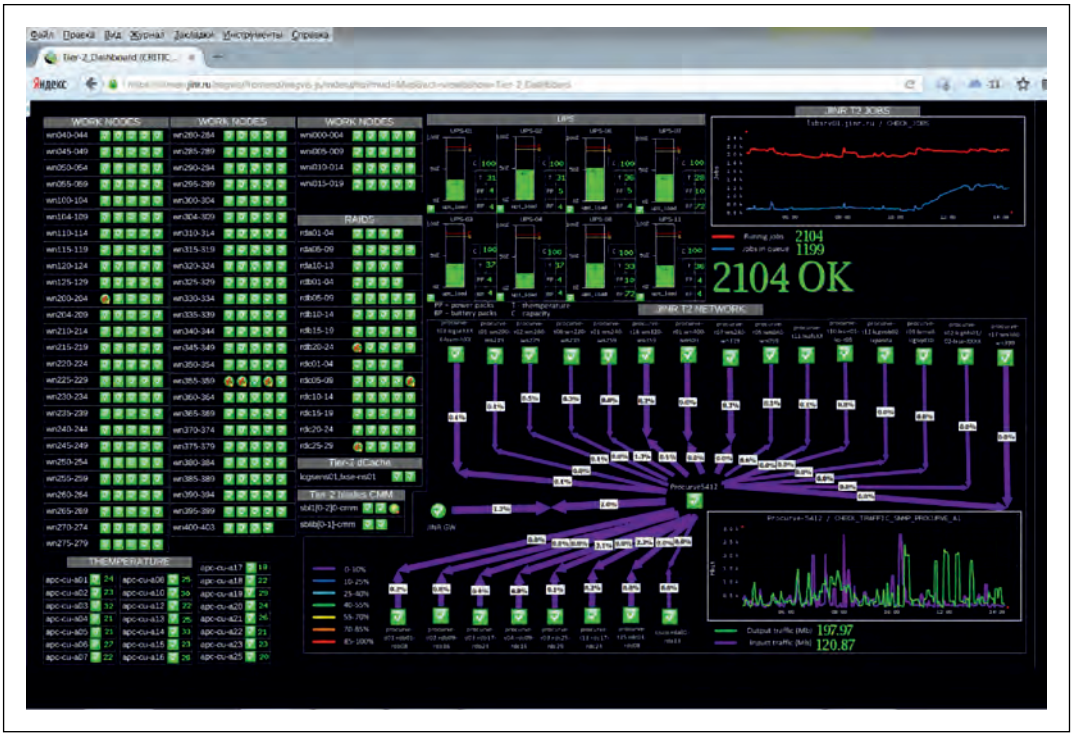


Fig. 3. The cluster component monitoring screen that shows in real time the current state and provides check-up of the computing servers (WN), disc arrays (RD), cooling panels (APC) switches and routers as well as the load of the network of the computing complex and the load of the uninterrupted power supply (UPS), a number of tasks executed by the complex (2104) and a job queue (1199)

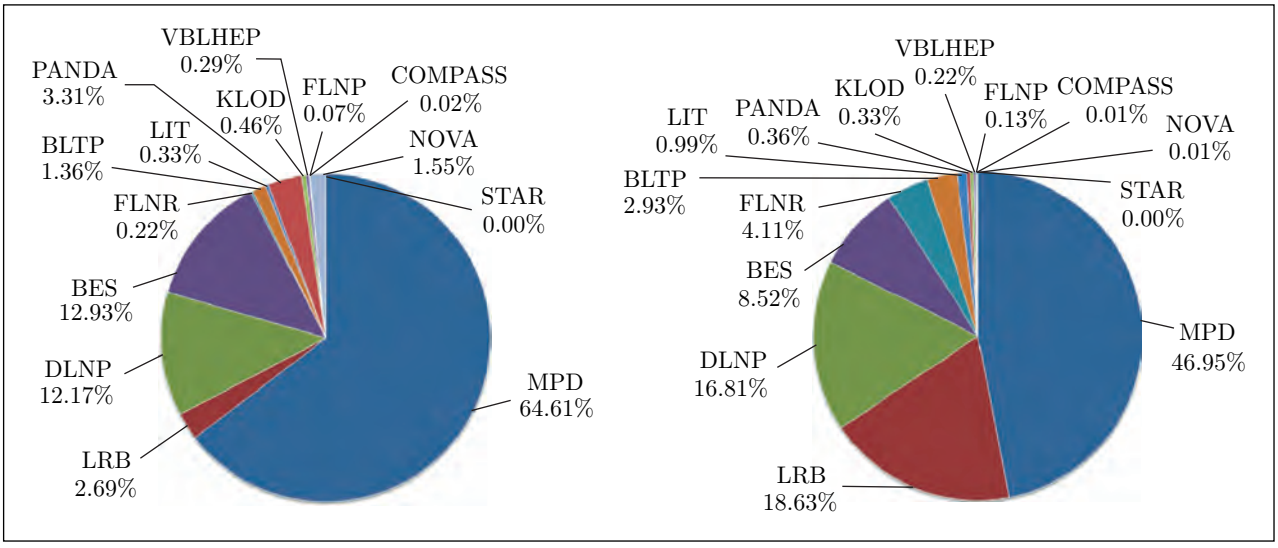


Fig. 4. Statistics of using astronomic (left) and processor time (right) of the computing cluster by the subdivisions and experiments of JINR without grid users

system — batch. In 2015, 903 staff members were registered as users of the computing cluster (apart from the grid users). Figure 4 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 (64.6% of astronomic time and 46.9% 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 the experiments CMS and ATLAS; dCache-2 for local users, groups of users and the international projects NICA/MPD, HONE, FUSION, BIOMED, COMPASS. Two installations of the XROOTD data access arrangement maintain work with data of three international collaborations: ALICE, PANDA and CBM. All the storage systems are constructed under the hardware data protection mechanism RAID6.

Computing Cluster with a Heterogeneous Architecture HybriLIT. In 2015, the heterogeneous structure of the computer complex was actively developed. Its computing capacity was increased to enable parallel applications for solving a wide range of mathematical resource-intensive tasks with the use of all possibilities of multicore components and computation accelerators. For instance, in 2015 the performance of the cluster increased 1.5 times at the expense of including two computing nodes with graphic accelerators of the last generation NVIDIA K80. Figure 5 shows the current configuration of the cluster which consists of two computing nodes with two graphic processors NVIDIA Tesla K80, four units with three GPU NVIDIA Tesla K40 (Atlas) in each, a unit with two co-processors Intel Xeon Phi 7120P as well as a unit containing NVIDIA Tesla K20x and a co-processor Intel Xeon Phi 5110P. Each computing node contains two 12-core processors Intel Xeon E5-2695v2. In total the

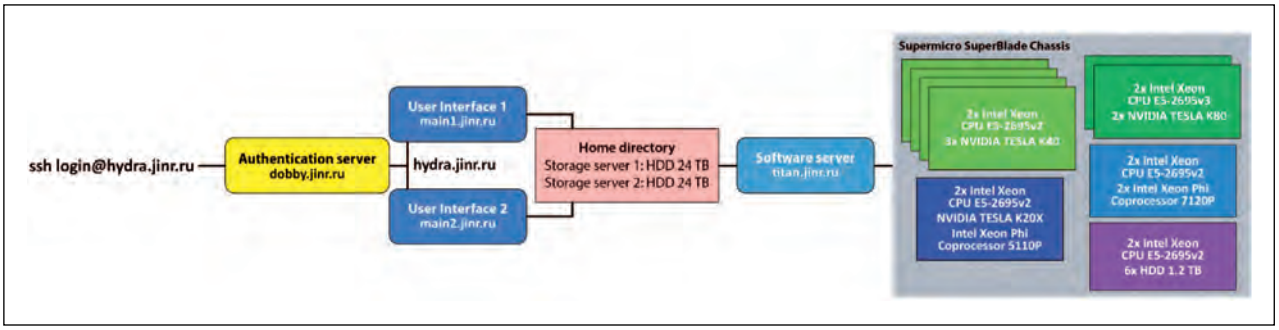


Fig. 5. The structure of the HybriLIT heterogeneous computing cluster

cluster contains 216 CPU cores, 57 216 GPU cores, 182 PHI cores; 896 GB RAM; 57.6 TB HDD. The cluster's full productivity is 111 TFLOPS for single-precision computation and 240 TFLOPS for double-precision computation. During 2015, the number of users doubled to reach 120 researchers from JINR and its Member States as well as from Russian universities. The HybriLIT cluster was intensively used for computations using computational accelerators for dedicated software development as well as for performing resource-demanding computations with the use of the packages of applied software and mathematical libraries already adapted to hybrid architectures.

Now HybriLIT is used not only for parallel calculations but also as a polygon for training students, postgraduate students and young scientists in the field of parallel programming technologies. During 2015, on the basis of the cluster, training courses were carried out in the framework of conferences and schools held by LIT (MMCP'2015, NEC'2015, AIS GRID'2015) within programs on international cooperation at Sofia University and the Mongolian State University. On its basis, regular training courses and tutorials for the JINR employees are held. As part of the regular training courses on parallel computing technologies organized at LIT for the JINR employees, students and postgraduates of the University "Dubna", the heterogeneous computations team HybriLIT held tutorials on C/C++ program languages, ROOT/PROOF program packages parallel programming technologies CUDA, OpenMP, OpenCL, MPI as well as on the user-friendly GitLab web-interface for mutual parallel development of applications.

Cloud Environment. In 2015 the modernization and upgrade of the JINR cloud infrastructure was continued (http://cloud.jinr.ru). The LIT JINR cloud infrastructure is based on OpenNebula software. In order to minimize the service downtime by increasing its reliability and availability, the JINR cloud was built in a highly available (HA) configuration (Fig. 6).

Currently the JINR cloud has 40 servers running 200 cores, 400 GB RAM and 16 TB disk space. The JINR cloud usage [4] is developed in three main areas:

- for testing, educational and research tasks as part of participation in various projects;
- systems and services deployment with high reliability and availability requirements; and
- extension of computing capacities of the grid infrastructures.

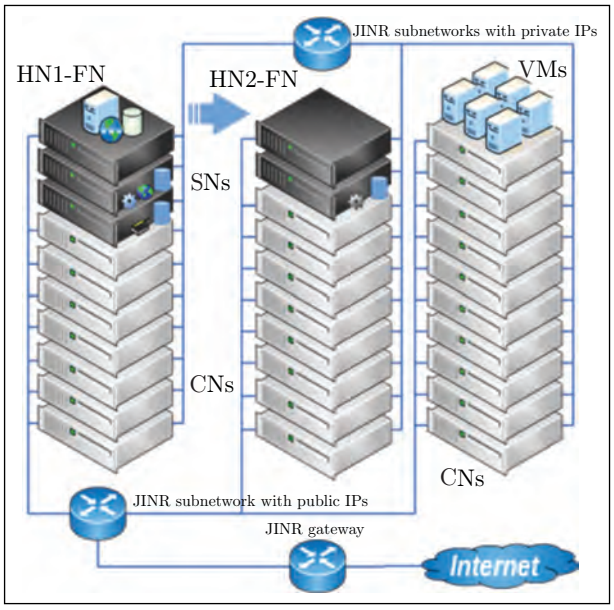


Fig. 6. The scheme of the JINR cloud in configuration of high reliability and availability: HN1-FN, HN2-FN — physical servers with components of the cloud front-end machine (FN), CNs are cloud working nodes on which the virtual machines (VMs) are placed; SNs — datastore units

The services and testbeds currently deployed in the JINR cloud are the following: EMI-based testbed (it is used for trainings, testing, development and research tasks related to grid technologies as well as for fulfilling the JINR obligations in local, national and international grid projects such as, e.g., WLCG); PanDA testbed which is used for PanDA software validation and extensions, developments for the ATLAS and COMPASS experiments; DIRAC-based testbed (it is used for monitoring tools development for BESIII experiment distributed computing infrastructure and also as its computing facility); a set of VMs of NOvA experiment users for analysis and software development; NICA testbed for grid middleware evaluation for the 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; HybriLIT services (Indico — a service for event organization, archival and collaboration; FreeIPA — an integrated identity and authentication service used for user accounts management in HybriLIT; Git — local Git repository (well-known distributed revision control system) for HybriLIT team); Helpdesk (a web application for the day to day operations of an

IT environment including user technical support of JINR IT services); DesktopGrid testbed based on BOINC software (to estimate the volunteers' computing technology for possible use in solving JINR users' tasks); web-service HepWep (provides opportunities to use different tools for Monte-Carlo simulation in high-energy physics); test instances of the JINR document server (JDS) and JINR Project Management Service (JPMS); CT for web-sites development including new JINR web-portal; JINR GitLab — local GitLab installation for all JINR users; Hadoop testbed; a set of users' VMs and CTs which are used for their own needs; a set of CTs for evaluation of various monitoring software to be used for the JINR Tier-1 grid site monitoring system development.

In order to join resources in the framework of cooperation on joint projects, integration of the JINR cloud with the cloud of the Plekhanov Russian University of Economics, the Institute of Physics of Azerbaijan National Academy of Sciences (Baku) and the Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine (Kiev) has been done, and the work is in progress with the European cloud infrastructure EGI Federated Cloud.

Information and Software Support. Within the NICA project the information control system of the NICA project, (ADB2-EVM) is actively developed at LIT. A flexible instrument was created for expansion of the existing system ADB2-EVM for the NICA project, it was elaborated during the work on the APT EVM system. In the framework of the development of an IS of the NICA project management, functional opportunities have been implemented: control over a hierarchical structure of the project (WBS), planning and re-planning activities on the project; work with baselines; tracing the process of the project realization on indices of actual costs (AC), on input of parameters of the budgeted cost of work performed (EV — the earned value or the volume of the work fulfilled); regular notification of users by e-mail (for timely reporting the progress of the work); account forms (graphics) according to ADB2-EVM (earned value management) procedure; financial statements on the project due to the "annual window" as a basic structure of the JINR budget and schedules of payments on the project activities, a hierarchical structure of users access rights, Web-interface. Also, in 2015 work was in progress on the expansion of the functional opportunities of the scheduling unit by way of integrating the ADB2 and MS Project Prof. The possibility of selecting alternative variants of profiles of the work schedule has been added.

Another direction of the project NICA support at LIT is related to the dynamic simulations of all the processes included in the store, transfer and analysis of data for the computer infrastructure of this project. The SyMSim (Synthesis of Monitoring and SIMulation) program has been designed for modeling a grid-cloud environment. The originality of this approach consists in integration of the process of modeling the information computing environment with real data monitoring of grid-cloud environments (example — the Tier-1 centre at JINR) in the framework of one program. The results of modeling the computer system for NICA experiments consisting of Teir-0 and Tier-1 centres allow one to draw conclusions about the optimal relationship between the number of processors and the storage systems for data processing. Solutions are aimed at modeling problems and subsequent development of data storages [5]. Within the project, a new system of modeling grid and cloud services has been created which integrates monitoring, analysis of its results and simulation itself. The objects of the simulations are the computing facilities intended for processing information of tens of petabytes per year [6].

The main work within the development of the unified information platform 1C 8.3 UPP was directed toward the inclusion into the system of the self-supporting subdivisions of JINR. In 2015 the following subdivisions were added to 1C 8.3 UPP: Department of Chief Power Engineer (DCPE), Motor Transport Service (MTS), Repair-Building Management (RBM), Social Infrastructure Management, Hotel-Restaurant Complex Management (HRCM), and the boarding house "Dubna". The primary book-keeping, time-keeping and human resources records management have been started simultaneously. Automatic calculation of the cost price of release in RBM, MTS and DCPE was adjusted. During 2015 the calculation of the wages was centralized which in turn allowed one to increase the rate of preparing the reporting in various funds (Pension Fund of Russia, Social Insurance Fund). In the HRCM a module of accounting the available housing facilities of the Institute was started. The human resources management was provided with a module on accounting cards of special estimation of working condition (SEWC); a unified electronic database of cards was generated. There were modernized all personnel documents and documents of the

Department of Labor Protection and Wages for accounting the results of SEWC cards.

In 2015, a subsystem of the electronic coordination of orders on the basic activity was developed and put into operation as part of the system "Base of JINR Documents". Besides, in 2015, a first run of the high-grade system of electronic document circulation (EDC) "Dubna" was developed and put in trial operation. In the development of the EDC "Dubna" applied were technologies and tools earlier developed in cooperation with CERN and successfully used for the creation of the systems of automating administrative activity in CERN and JINR. These tools allow one to create, in a short period of time, complex and flexible web-applications with friendly user interfaces. A document "Application for purchase of production" has been started in the system.

The support and development of the software for the automation of information and JINR library activities was continued in 2015. This includes filling and support of digital collections of JINR STL newsletters, support of digital catalogs, support of the on-line service "Electronic Mailing STL Weekly Newsletters". In 2015 the support of Open Access repository JINR Document Server was in progress: filling and verification of collections, output format settings, Authority Records module setting and testing.

During 2015, work was in progress to update the software environment, databases and contents of the LIT and JINR information sites http://lit.jinr.ru, http://www.jinr.ru, http:/wwwinfo.jinr.ru, faxe.jinr.ru, ptp.jinr.ru, and pkp.jinr.ru. In cooperation with JINR STD AMS, work continued on modernization of software related to scientific and administrative activity. Also, within theme 05-8-1037-2001/2019 work was in progress to update the 2015 database for "The System of the Interactive Formation of a Topical Plan for Research in Scientific Organizations" (with reference to JINR): the site ptp.jinr.ru. Maintenance and modernization of the web-portal of journals "Physics of Elementary Particles and Atomic Nuclei" and "Particles and Nuclei, Letters" continued in 2015 (http://pepan.jinr.ru/). Regular work was traditionally conducted on the design and support of various information websites, sites of conferences, workshops, and symposia organized by JINR Laboratories as well as organization of a website hosting (upon request). Among them are web-portals for FLNP (ISINN), FLNR (EXON-2016), LRB (MPGRRE-2015), etc.

Since May 2015, works have been underway (in cooperation with the JINR International Department) on launching a specialized information system User Office that provides online support of the process of receiving visitors to 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 program code widely applied at RHIC and LHC for calculations of geometrical properties of nucleus–nucleus interactions has been adapted for the experiments NICA/MPD and CBM. A parameterization of *pp* elastic scattering amplitude proposed earlier is used for setting the nucleon–nucleon collision profile. An approach well known in physics of low and intermediate energies is used for determination of nuclear parameters. The code is enlarged by a possibility to account for Gribov inelastic screening [7].

A new algorithm of the track-segment reconstruction in the cathode-strip chambers of the CMS experiment has been developed and tested. As seen from Fig. 7, on the Monte Carlo data with TeV muons the efficiency of the track-segment reconstruction of the suggested algorithm is 4–7% higher. It practically does not decrease with the growth of the pseudorapidity in contrast to the standard algorithm [8].

Estimations of the spatial resolution in the CMS cathode-strip chambers have been obtained using the LHC experimental data of 2015, in agreement with the results obtained in 2012. The resolution (from 64 down to 50 μм) in the bottom part of the chamber ME1/1 after separating the coupled signals from the strips has been significantly improved. The computations performed based on Monte Carlo data for the future collider HL-LHC have shown that the trigger loadings in ME1/1 chambers due to hadron penetrating radiation will increase 30 times as compared to the experimental data of 2012. This will demand additional technical

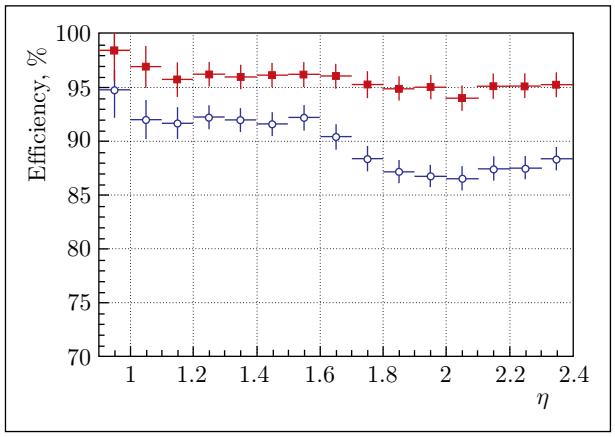


Fig. 7. Efficiency of the track-segment reconstruction in cathode-strip chambers depending on the pseudorapidity for simulated TeV muons: the results of reconstruction with a standard algorithm (blue), with a new algorithm (red)

solutions, for instance, increase in the thickness of the calorimeter absorber [8].

An algorithm of the particle trajectories reconstruction in drift chambers has been developed and implemented for the BM@N experiment so the "noisy" channels were eliminated. Besides, the geometrical alignment of the chambers was achieved (at the software level). Estimations of the spatial resolution and efficiency of the drift chambers, as well as of the Nuclotron beam pulse, were given.

An algorithm of the charged particle track reconstruction based on Kalman filter has been proposed. This algorithm is used for solving one of the key tasks of the CBM (Condensed Baryon Matter) experiment, i.e., recognition of the charged particle trajectories and their parameters. Since within the CBM experiment the full reconstruction of signal events in real-time experiments is planned, the developed algorithms should be fast and they have to maximize the capabilities of present-day multi-core processors and GPU architectures. Computations were performed with a high-performance server with two processors Intel Xeon X5660 and a graphic card Nvidia GTX 480 [9].

A model of microscopic optical potential (OP) has been applied to construct the pion-nucleus differential cross sections of elastic and inelastic scattering on the nuclei ^{28}Si, ^{58}Ni, ^{208}Pb at $T_{\rm lab} = 291$ MeV. The density distributions of ^{10}Be and ^{11}Be nuclei obtained within the quantum Monte Carlo model and the generator coordinate method are used to calculate the microscopic optical potentials (OPs) and cross sections of elastic scattering of these nuclei on protons and ^{12}C. To analyze the inelastic scattering cross sections, the parameters of the πN amplitude in a nuclear medium obtained earlier from the analysis of data of elastic scattering on the same nuclei have been used. The well-known energy dependence of the volume integrals is used as a physical constraint to resolve the ambiguities of the parameter values. The potentials can be used in further calculations of cross section of the reactions with these participating nuclei [10].

A new Bayesian analysis was suggested using independent mass and radius constraints for extracting probability measures for realistic models of cold dense nuclear matter equations of state. One of the key issues of such an analysis is whether a deconfinement transition in core of compact stars proceeds as a crossover or rather first-order transition. The latter is relevant for the possible existence of a critical endpoint in the QCD phase diagram under scrutiny in present and upcoming heavy-ion collision experiments such as MPD (NICA) and CBM (FAIR). Due to this problem, the question of the existence of mass twins (the third-family stars) — two stars with the same mass but different structures — is getting interesting. Using the constructed hybrid EoS based on APR-type hadronic models (without and with baryonic excluded volume effect) and bag model for the quark phase, a probabilistic estimation has been made on the basis of observational constraints. For the analysis used were the constraints for the mass of configuration taken from observation of one of the massive pulsar PSR J0348+0432 and for radius of PSR J0437-4715. Calculations show that the high-mass twin stars configurations have the highest probability measure [11].

A theoretical approach earlier used to calculate double photoionization of a binuclear nitrogen molecule N_2 was extended to grasp the processes of photoionization of the three-centered molecule CO_2 in which a dissociation dication $CO_{22}+$ is generated. The electron bound states are described in terms of Dyson orbitals, and the emitted electrons are simulated by a parametrized correlated three-center function of continuum. Differential scattering cross sections are studied when detecting emitted electrons on concurrence. Orientation of the internuclear axis of CO_2 molecule is left arbitrary. A comparison of the obtained results with a Gaussian parametrized model demonstrates similarities and distinctions between monoatomic targets and molecule CO_2 [12].

Nonrelativistic quantum mechanics considers the motion of a charged particle with spin

in a weak field of a monochromatic electromagnetic wave in the framework of the dipole approximation and predicts the particle's spin precession. However, with increasing intensity of electromagnetic radiation the relativistic effects come into force and violate the adiabatic spin dynamics. For their quantitative calculation a model of spin-laser interaction beyond the dipole approximation has been formulated. The evolution of state of the spin-1/2 particle was described in a quasi-classical approach based on the Pauli equation and modified by relativistic corrections taking into account the effect of the interaction delay, the influence of the magnetic component of the Lorentz force, and the Thomas precession. When computing transitions in an elliptically polarized laser field, the Pauli equation was reduced to the Riccati equation. Its numerical analysis allowed one to establish the resonant character of the spin-flip probability depending on the intensity, polarization and the gyromagnetic ratio of the charged particle [13].

APPLIED RESEARCH

Algorithms of numerical simulations of the evolution of the heat conductivity processes with a time-periodic source have been developed at LIT in cooperation with VBLHEP (JINR) and realized in the OpenCL language to calculate with the help of graphic processor devices. A model of the multilayered cylindrical device with a nontrivial computational domain and nonlinear thermodynamic properties of materials at cryogenic temperatures is considered. This model describes the so-called cryogenic cell designed for pulsing working gases into the multiply charged ion source chamber. The surface is heated by passing a pulsed electrical current through one of the conductive layers of the cell. The algorithm makes possible the further optimization of the design of the cryogenic cell [14].

Scientists of LIT and FLNP performed investigation on the structure of a polydispersed population of the unilamellar DMPC vesicles in sucrose solutions by methods of small-angle neutron scattering (SANS) and X-ray scattering (SAXS). The calculations based on a unified approach in the framework of the separated form factors model (SFF) show that the structure of the vesicle system essentially depends on the sucrose concentration [15].

Research on the physical processes in porous materials is in progress at LIT. Penetration and moisture transfer leads to chemical and physical damages of materials. A new system of equations has been proposed in which three physical processes are included: transfer of heat, liquid and vapor in porous materials. The proposed equations are solved with a splitting scheme. The results of numerical experiments are in good agreement with observable data [16].

A method of forecasting the passenger traffic in Moscow metro with the help of artificial neural networks has been developed at LIT and FTI "Rostransmodernizatsiya", Moscow. The analysis and the selection of those factors that have a major impact on the passenger traffic in the subway were done. The data corresponding to the daily volumes of the passenger traffic on weekdays demonstrated the fundamental possibility of a short-term forecasting with acceptable accuracy. It is shown that the use of the wavelet filtering for the realized values of daily traffic allows one to improve significantly the prediction accuracy and to expand the time horizon [17].

INTERNATIONAL COOPERATION

The work performed by specialists of LIT and the National Institute for Research and Development of Isotopic and Molecular Technologies (INCDTIM, Cluj-Napoca, Romania) analyzes an approach to the efficient satellite image processing which involves two steps. The first step assumes the distribution of the steadily increasing volume of satellite collected data through a Grid infrastructure. The second step assumes the acceleration of the solution of the individual tasks related to image processing by implementing execution codes which make heavy use of spatial and temporal parallelism. An instance of such an execution code is the image processing by means of the iterative Perona–Malik filter within FPGA application specific hardware architecture [18].

In the framework of collaboration between a heterogeneous computations HybriLIT cluster team and a group of the theory of multiparticle boson systems of the Centre for Quantum Dynamics of Heidelberg University, work was in progress on the software development for research in the dynamic properties of quantum systems, including those realized on the basis of super-cold atoms and the molecules in external magnetic-optical potentials (traps). In 2015, a software package MCTDHB-Lab (http://qdlab.org) was presented which is based on solving a nonstationary Schrödinger equation by the MCTDHB (MultiConfigurational Time-Dependent Hartree for Bosons) method. This is a cross-platform package (i.e., it works under operating systems Windows, Linux, OS X), a freely distributed and convenient graphic interface (see Fig. 5). On the basis of this package, systematic studies of the dynamic properties of multiparticle quantum systems have been conducted [19].

CONFERENCES AND MEETINGS

The workshop "Big Data Processing and Analysis Challenges in Mega-Science Experiments" was held at the NRC "Kurchatov Institute" and LIT on 29–30 February. The main objective of the workshop was to discuss big data challenges in mega-science experiments. The workshop was attended by well-known specialists from Russia, USA, CERN, European centres and Taiwan. Much attention was given to the modeling of cloud infrastructures and the discussion of the further development of modern computer infrastructures for solving tasks on processing data from LHC experiments and other mega-projects as well as problems in the field of biology, chemistry, climate, and social problems. There were also presented reports on the development of Tier-1 centres in Taiwan, Kurchatov Institute and LIT. The workshop was concluded with a discussion on the development of the global computer infrastructure that is used in the current and future mega-projects.

On 26–27 May, LIT hosted the scientific practical forum "Distributed Information and Computing Systems and Data Processing in the 21st Century" (DICS-XXI) which was organized by the JINR Laboratory of Information technologies and the Skobeltsyn Scientific Research Institute of Nuclear Physics of MSU (SRINP MSU). The DICS-XXI forum was dedicated to the present-day tendencies in the field of design, creation and application of modern and promising distributed information and computing systems and the technologies of big data processing on their basis. Reports of leading specialists in the field of distributed computer systems, including supercomputer and grid technologies, were presented to the forum participants. The forum was attended by more than 50 representatives from the following institutions and companies: Joint Institute for Nuclear Research, SRINP MSU, National Research Centre "Kurchatov Institute", state budgetary educational institution of the Moscow Region "International University of Nature, Society and Man 'Dubna'", state educational institution of the higher professional education "St. Petersburg State University of Information Technologies, Mechanics and Optics", joint-stock company "Niagara Computers", Russian agency of corporation "American Power Conversion", and Russian branch of IBM. A round-table session "The Future of Distributed Technologies for Big Data Processing" was held when the forum was over.

A traditional two-day Workshop on Computer Algebra was held at LIT on 26–27 May. More than 30 scientists from universities and scientific institutes of Bucharest (Romania), Minsk (Belarus), Tbilisi (Georgia), Moscow, St. Petersburg, Rostov-on-Don, Saratov, and Dubna took part in this workshop. Twenty-eight reports were presented. A number of new promising results on developments of algorithms for investigating and solving systems of algebraic and differential equations, symbolic-numeric simulation of quantum-mechanical systems, computation of the multiloop Feynman integrals by computer algebra methods and various computer algebra applications to physics and mathematics were presented.

On 13–17 July, the eighth international conference "Mathematical Modeling and Computational Physics" (MMCP'2015) was held in High Tatra Mountains, Stará Lesná, Slovakia. The conference was devoted to the 60th anniversary of the Joint Institute for Nuclear Research. It was organized by LIT, IFIN-HH (Bucharest, Romania), the Institute of Experimental Physics of the Slovak Academy of Sciences (Košice), the Technical University of Košice, the Pavol Jozef Šafárik University (Košice), and the Slovak Physical Society (Košice). The scientific

area of the conference covered a wide spectrum of questions including: mathematical methods and tools for modeling complex physical and technical systems, computational chemistry, biology, and biophysics; methods, software and computer complexes for experimental data processing; computer algebra and quantum computing methods, algorithms and software; distributed scientific computing and big data; parallel and hybrid calculations, extra massive parallelism. Attending were 90 scientists and specialists from Belarus, Bulgaria, Germany, Canada, Russia, Romania, Slovakia, Ukraine, USA, Taiwan, etc. A large number of Russian scientific centres and universities such as NRC "Kurchatov Institute", Institute of Mathematical Problems of Biology of RAS (Pushchino, Russia), Institute of Theoretical and Applied Mechanics of SB RUS, St. Petersburg State University, Novosibirsk State University, PFUR, etc., were presented. In total, there were heard 17 plenary and 62 oral reports. The young conference attendees were especially interested in the training course on parallel programming technologies CUDA and OpenCL, conducted on the basis of the HybriLIT heterogeneous computing cluster.

On 27–30 August, LIT hosted the workshop "Computational Modeling in Complex Systems". Twenty-two scientists from JINR, Russia, Slovakia, China and Taiwan attended the meeting. The participants heard 16 reports on computational methods, algorithms and tools of modeling complex physical phenomena and technical systems. The reports presented the results of investigations obtained with simulations of biophysical and astrophysical systems, processes of stochastic dynamics, optics and accelerator techniques.

On 28 September – 2 October, the XXV International Symposium on Nuclear Electronics and Computing (NEC'2015) was held in Budva, Montenegro. The symposium has been traditionally held by JINR since 1963, and for the eighth time JINR and CERN became its organizers. The scientific programme of the symposium covered a wide spectrum of questions and included the following sections: detector and nuclear electronics, computer applications for physical research, triggering and data acquisition, automation and control in scientific research, big data, grid technologies and cloud computations, computing for experiments on large-scale accelerator installations (LHC, FAIR, NICA, etc.), problems of computations on hybrid platforms as well as such traditional subjects as innovations in training with the use of information technologies. This year the symposium is devoted to the 60th anniversary of JINR. Attending were 120 leading specialists in modern computer and network technologies, distributed computing and nuclear electronics from 15 countries. In the framework of the symposium, a workshop, a round-table session and an international students school on modern information technologies were organized. The school was attended by more than 40 students from leading Russian universities.

On 2–6 November, the sixth school on information technologies "Grid and Advanced Information Systems" was held under the auspices of the Joint Institute for Nuclear Research, the European Organization for Nuclear Research (CERN) and the National Research Nuclear University "MEPhI". It was devoted to the management of scientific complexes and information systems in reference to the technologies developed at JINR and CERN. The school was attended by over 60 students from leading universities of Moscow, Moscow Region, Tver and St. Petersburg (National Research Nuclear University "MEPhI", Lomonosov Moscow State University, Saint Petersburg State University, University "Dubna", the Plekhanov Russian University of Economics, and Tver State University). A tutorial on the parallel programming technologies on hybrid architectures was organized on the basis of the HybriLIT cluster.

REFERENCES

1. *Astakhov N. S. et al.* // Comp. Res. Modeling. 2015. V. 7, No. 3.
2. *Kashunin I. et al.* // ROLCG 2015 Conf. Cluj-Napoca. http://www.itim-cj.ro/rolcg/contributions/s7_1.pdf
3. *Petrosyan A. Sh.* // Comp. Res. Modeling. 2015. V. 7, No. 6.
4. *Kutovskiy N. et al.* // Procedia Comp. Sci. 2015. V. 66. P. 574–583.
5. *Korenkov V. V. et al.* // Systems and Tools of Informatics. 2015. V. 25, No. 1. P. 3–19.
6. *Korenkov V. et al.* // Procedia Comp. Sci. 2015. V. 66. P. 533–539.

7. *Galoyan A., Uzhinsky V.* // Part. Nucl., Lett. 2015. V. 12, No. 1(192). P. 231–236.

8. *Voytishin N., Palichik V.* // Proc. of MMCP2015. 2015 (in press); 2015 RDMS CMS Conference. 2015;
Golutvin I. et al. // EJP (in press).

9. *Ablyazimov T. O. et al.* // Phys. Part. Nucl. Lett. 2015. V. 12, No. 3. P. 423–427.

10. *Zemlyanaya E. V. et al.* // Phys. Rev. C. 2015. V. 91. P. 034606;
Lukyanov V. K. et al. // Intern. J. Mod. Phys. E. 2015. V. 24. P. 1550035;
Lukyanov V. K. Zemlyanaya E. V., Lukyanov K. V. // Nucl. Phys. 2015. V. 78, No. 1. P. 147–155.

11. *Ayrian A. et al.* // Part. Nucl. 2015. V. 46, No. 5. P. 854–857.

12. *Alwan O. et al.* // J. Phys. B. 2015. V. 48. P. 185203-1–7.

13. *Khvedelidze A. M., Rogozhin I. A.* // Math. Modeling. 2015. V. 27, No. 7. P. 118–125.

14. *Ayrian A. et al.* Appl. Therm. Eng. 2016. V. 94. P. 151–158.

15. *Kiselev M. A. et al.* // Crystallogr. 2015. V. 60, No. 1. P. 144–149.

16. *Amirkhanov I. V. et al.* // Part. Nucl., Lett. 2015. V. 12, No. 3(194). P. 584–589.

17. *Ivanov V. V., Osetrov E. S.* // Nat. Res. Nucl. Univ. MEPhI Bull. 2016. V. 5, No. 1. P. 65–74.

18. *Belcan B. et al.* // Comp. Res. Modeling. 2015. V. 7, No. 3. P. 399–403.

19. *Klaiman S. et al.* // High Performance Computing in Science and Engineering'14: Transactions of the High Performance Computing Center / Ed. by W. E. Nagel, D. H. Kröner, M. M. Resch. Heidelberg: Springer, 2015. http://qdlab.org.

LABORATORY OF RADIATION BIOLOGY

In 2015, 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 04-9-1112-2013/2015 "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

A comparative study was continued of the induction and repair of clustered DNA double-strand breaks (DSBs) formed in human skin fibroblasts under exposure to ^{60}Co γ rays and accelerated heavy ions with different characteristics. The technique of immunocytochemical staining of DNA DSB marker proteins γ-H2AX and 53BP1 was used.

It was shown that accelerated ^{20}Ne ions (linear energy transfer (LET): 129 keV/μm; energy $E = 47.5$ MeV/nucleon) and ^{11}B ions (LET = 135 keV/μm; $E = 8.4$ MeV/nucleon) induce DNA DSBs whose repair is much slower than in the case of γ rays (Fig. 1). The damage induced by ^{20}Ne ions with higher energy is the slowest to repair. Within 24 hours after irradia-

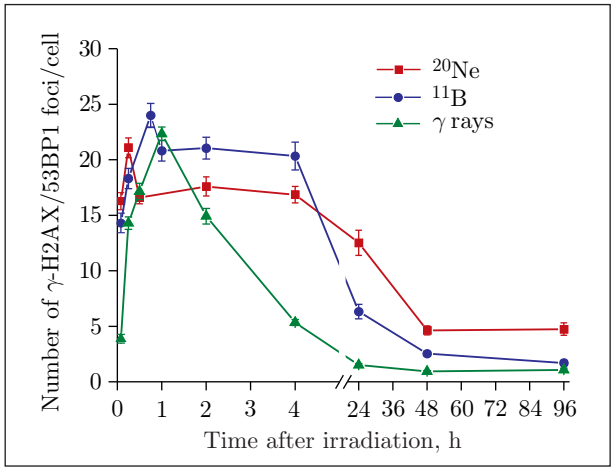


Fig. 1. Kinetics of γ-H2AX/53BP1 foci formation and elimination for exposure to 1 Gy of ^{60}Co γ rays and accelerated ^{20}Ne and ^{11}B ions (vertical irradiation)

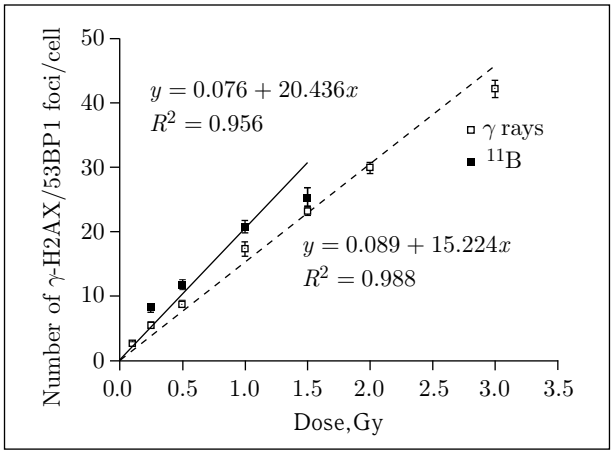


Fig. 2. A dose dependence of γ-H2AX/53BP1 foci induction within 1 h after vertical irradiation with ^{60}Co γ rays and accelerated ^{11}B ions

tion with ^{20}Ne ions, 13 γ-H2AX/53BP1 foci per cell remain on average (60% of their maximal yield), while for exposure to ^{11}B ions and γ rays this level is 6 (26%) and 1 (5%), respectively.

A dose dependence of γ-H2AX/53BP1 foci induction was obtained for exposure to γ rays and accelerated ^{11}B ions. The number of γ-H2AX/53BP1 foci changes linearly with increasing the dose (Fig. 2) for both γ rays ($y = 15.224x + 0.089$, $R^2 = 0.988$) and ^{11}B ions ($y = 20.436x + 0.076$, $R^2 = 0.956$).

An analysis of the structure of the γ-H2AX/53BP1 foci induced by accelerated ^{11}B ions with the horizontal irradiation geometry shows that the area of the foci increases during the 24 h post-irradiation period (Fig. 3, *a*, *b*). An increase in the area of the foci correlates with an increase in the proportion of the complex γ-H2AX/53BP1 foci consisting of several separate foci that are located in immediate proximity to each other (Fig. 3, *b*). The obtained data point to the formation of accelerated heavy ion-induced hardly repairable clustered DNA DSBs [1–3].

Experiments were conducted to study *in vivo* the specifics of the induction and repair of DNA DSBs in mammalian brain cells (Purkinje and hippocampus cells) formed under exposure to ^{60}Co γ rays. A comparative analysis of DNA DSB repair kinetics was performed for irradiation *in vivo* and *in vitro*. Unlike irradiation *in vitro* where an exponential DNA DSB repair kinetics is observed, for irradiation *in vivo*, repair kinetics is complicated: first, the DNA DSB yield increases, peaking 4 hours after irradiation; then, it decreases (Fig. 4). Possible

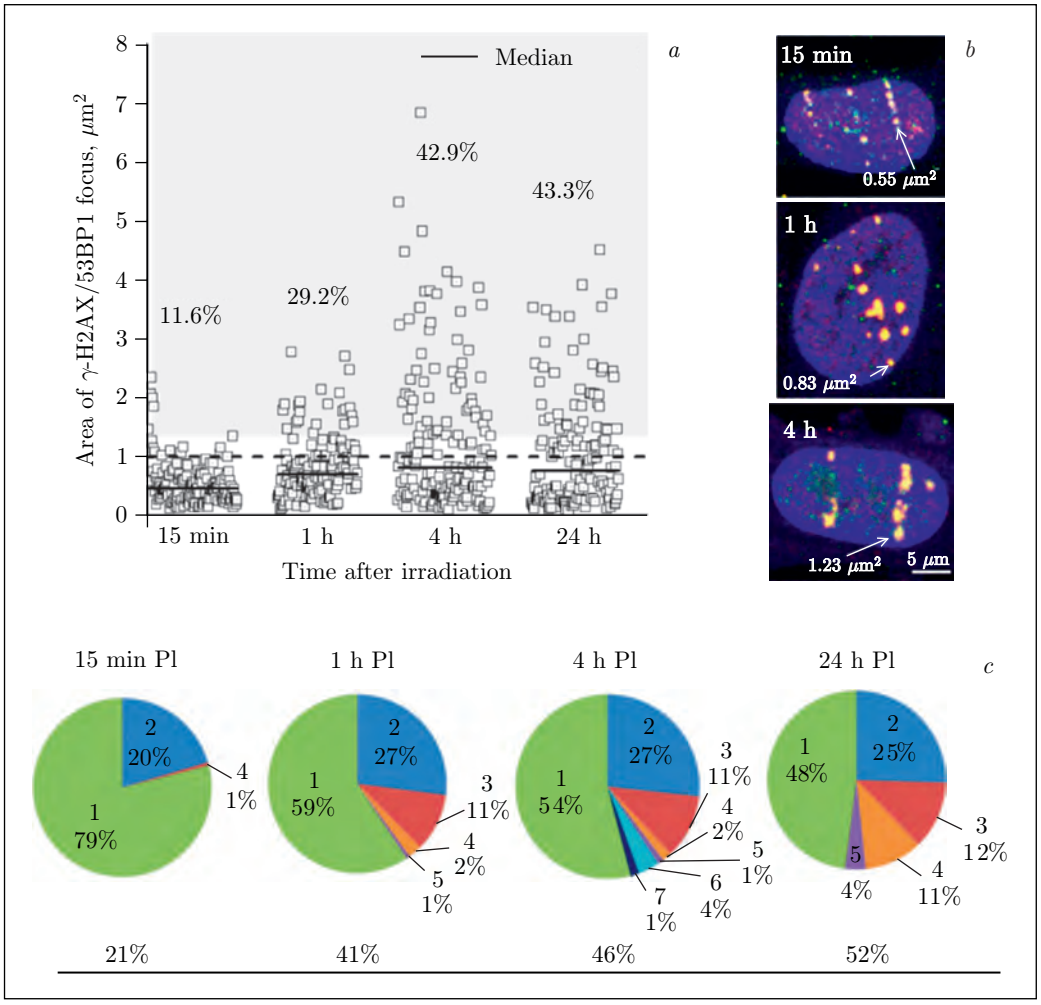


Fig. 3. A detailed analysis of the γ-H2AX/53BP1 foci structure for the horizontal geometry of ^{11}B ion irradiation. *a*) The γ-H2AX/53BP1 foci area at different times after irradiation. The proportion of large γ-H2AX/53BP1 foci with an area of more than 1 μm^2 is shown. *b*) DNA DSB visualization in fibroblast nuclei by immunocytochemical staining. Marked are the γ-H2AX/53BP1 foci with the most typical area for the specified time interval. *c*) The percentage of separate foci that are part of complex γ-H2AX/53BP1 foci

specifics of *in vivo* DNA DSB repair processes in nervous cells are discussed.

For ^{60}Co γ irradiation, the modifying effect was studied of different forms of lipid A (diphosphoryl lipid A (DLA) and monophosphoryl lipid A (MLA)) on apoptosis induction and formation of DNA structure damage (single- and double-strand breaks) in human peripheral blood lymphocytes. It was shown that in the samples irradiated in the presence of DLA, the apoptotic cell and DNA break yield significantly increases with increasing the γ-irradiation dose (Fig. 5) [4].

A series of experiments were conducted to study HPRT-mutagenesis induced by accelerated ions of different linear energy transfer (LET) (50, 116, 138, and 153 keV/μm) and γ rays in V79 Chinese hamster cells. It was found that its manifestation depends on the duration of irradiated cell seeding (mutation expression time) in a selective nutrient medium with 6-thioguanine and on radiation LET. With increasing expression time, the mutagenesis level rose up to a maximum and then decreased to the spontaneous level. The location of this maximum depended on accelerated ion LET (Fig. 6). With increasing LET, the maximum shifted to longer expression times. For γ rays, the highest mutagenesis level was observed on the 3rd–4th day after irradiation, while for accelerated ^{18}O ions (LET~116 keV/μm), 11 d after exposure, and 23 d after exposure to accel-

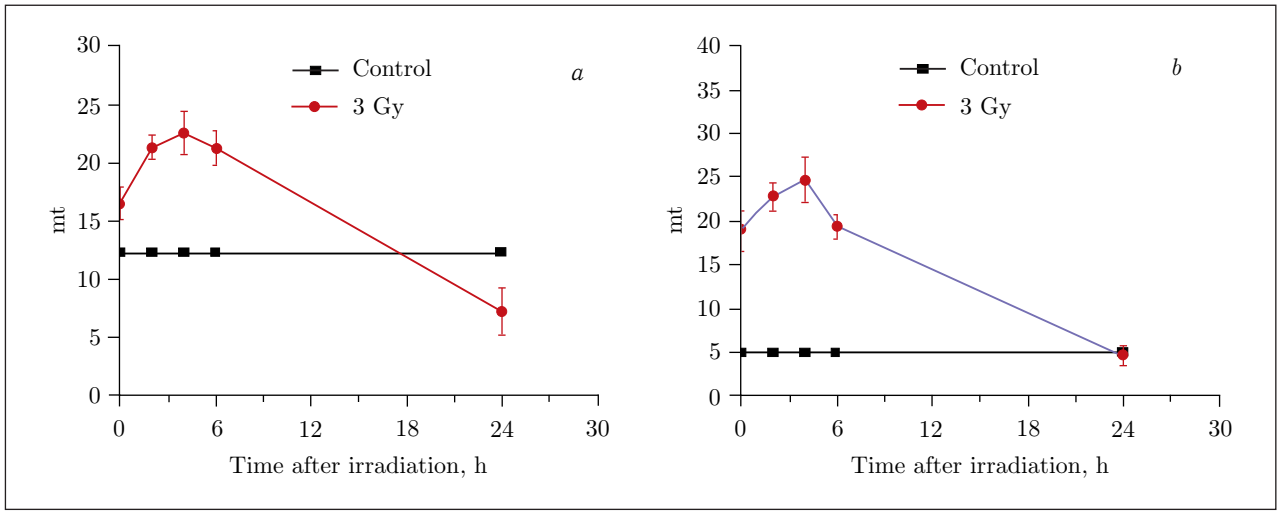


Fig. 4. DNA DSB repair kinetics in cerebellum Purkinje cells (*a*) and in mouse hippocampus cells (*b*) for γ irradiation

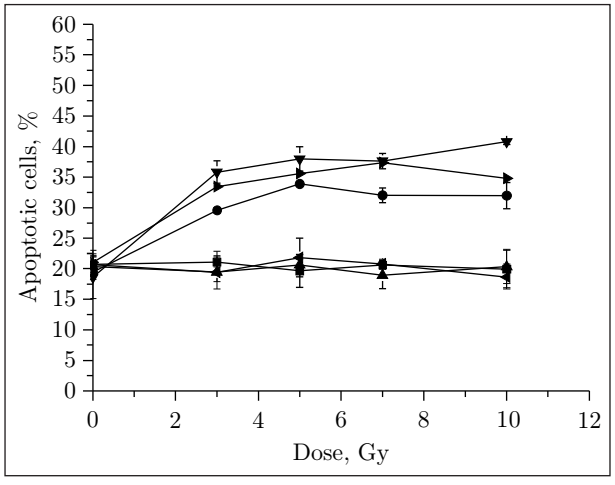


Fig. 5. The effect of the MLA and DLA modifying agents on the apoptotic death of blood lymphocytes for ^{60}Co γ irradiation: ■ control 0 h, ● control 24 h, ▲ DLA 0 h, ▼ DLA 24 h, ◄ MLA 0 h, ► MLA 24 h

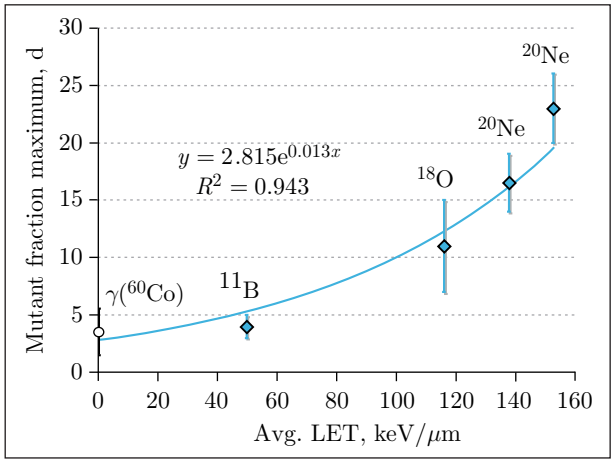


Fig. 6. The maximal level of radiation-induced mutagenesis in Chinese hamster cells depending on expression time and accelerated ion LET

erated ^{20}Ne ions (LET~153 keV/μm). Based on this research, it is possible to assume that an increased level of radiation-induced mutagenesis is determined by higher chromosome instability of the irradiated cell population, and its manifestation at different expression times depends on initial damage severity [5].

PHOTORADIOBIOLOGICAL RESEARCH

Research was performed on the action of accelerated protons and the chemical agent methylnitrosourea (MNU) on the mouse retina. It was shown that the dose dependence is nonlinear for these exposures. In particular, the radiation dose–effect curve has a radioresistance plateau near 15 Gy, above which structural and functional changes are apparent in the retina in response to exposure, indicating the presence of recovery mechanisms in retina elements (Fig. 7).

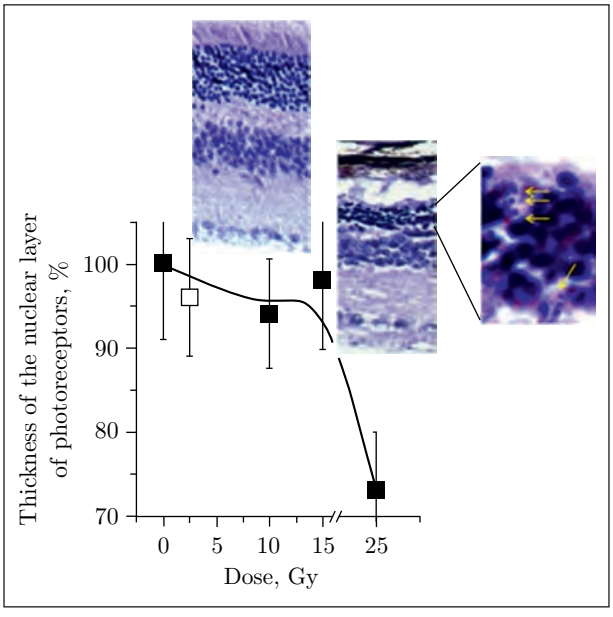


Fig. 7. Changes in the thickness of the nuclear layer of mouse photoreceptors (expressed as percent of control) in response to a local proton irradiation of a mouse head 3 d (■) and 30 d (□) after irradiation

Regularities were studied in the formation of DNA double-strand breaks under exposure of the retina to accelerated protons and MNU (Fig. 8). It was found that a pre-irradiation *in vivo* decreases apoptotic photoreceptor death in the retina caused by MNU action. It was shown that induced retinal resistance to MNU's retinotoxic effect is associated with increased DNA repairability, which was probably a result of a proton pre-irradiation of the retina at a dose of 1 Gy.

In retinal damage repair, an important role is played by Müller glial cells, which are the only retinal cells that are capable of division. Also, the participation of these cells in mouse retinal adaptive response was evaluated at the phenomenological level. A technique was developed of the visualization of these cells on retinal sections with the use of the proliferative marker bromodeoxyuridine (BrUdR).

The results of this research are important for solving the fundamental problems of the damage and repair of terminally differentiated cells and tissues made up of them. They can be used to forecast the danger of the retinotoxic exposure and evaluate its consequences; to optimize the radiation and chemical therapy of head, brain, neck, and eye tumors; and to perform a primary evaluation of the efficiency of pharmaceuticals interfering with retinal degradation. These data can also be a prognostic indicator of the effect of the space conditions on the human organism during long-term manned space flights [6–8].

RADIATION PHYSIOLOGY AND NEUROCHEMISTRY

The action of accelerated heavy charged particles was studied on the neurochemical mechanisms involved in providing the behavior and memory functions and formation of emotional and motivational states. With the use of the high-performance liquid chromatography technique, changes were evaluated of the levels of the key brain neuromediators (noradrenaline, dopamine, and serotonin) and their metabolites in rats of different age categories exposed to 1 Gy of 500 MeV/nucleon ^{12}C ions. It was shown that 30 and 90 d after irradiation with heavy charged particles, changes are induced in the functioning of the noradrenaline, dopamine,

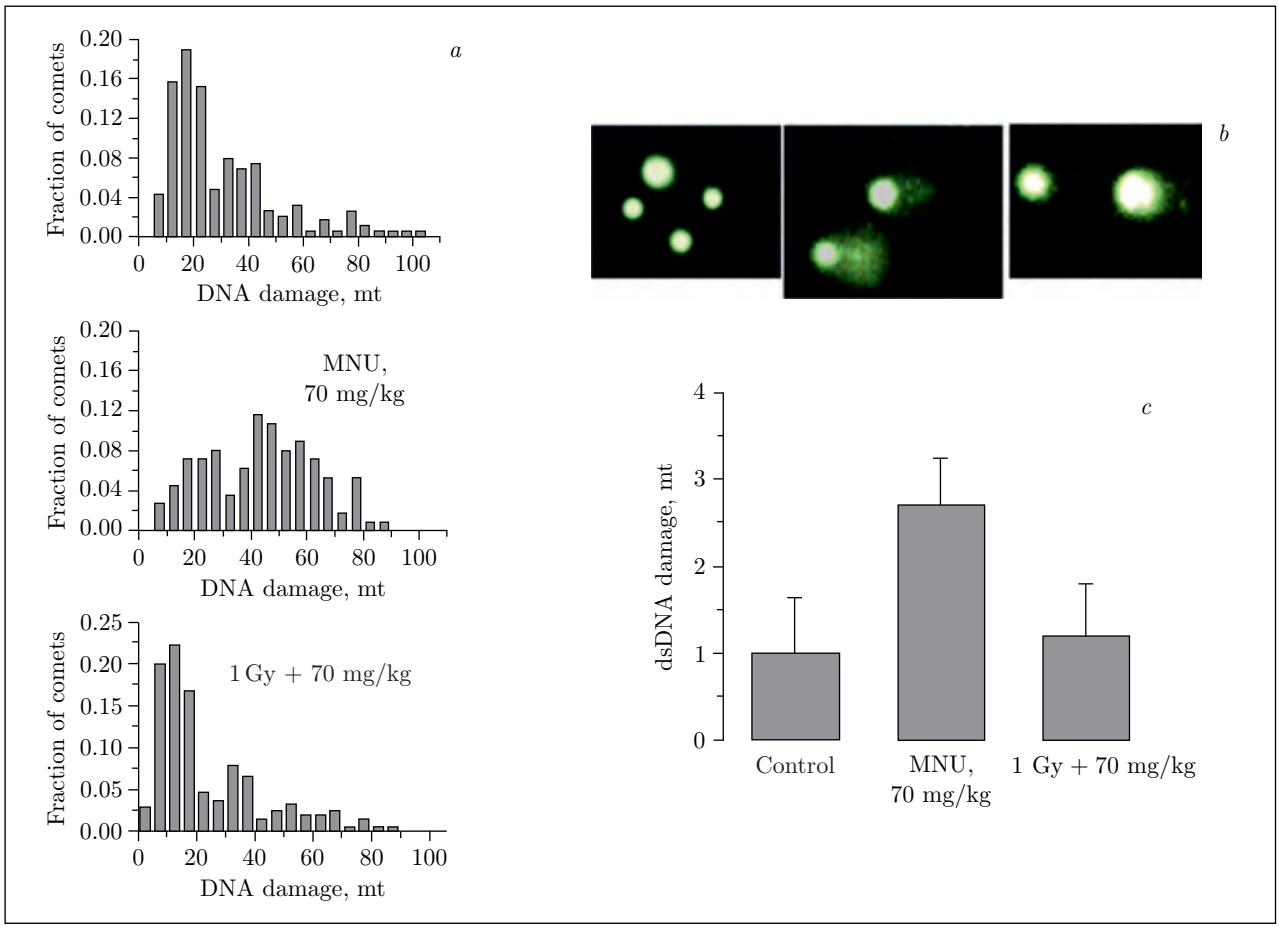


Fig. 8. Double-stranded DNA (dsDNA) breaks in the mouse retina 48 h after irradiation with an adapting dose of accelerated protons (1 Gy) and single introduction of MNU (70 mg/kg): *a*) cell distributions by the degree of dsDNA damage; *b*) microphotographs of dsDNA comets; *c*) average DNA damage yield found from damage degree distributions

and serotoninergic system. The most evident differences between the irradiated and control animals were observed in the prefrontal cortex and hypothalamus, which points to an important role of these structures in the realization of the delayed effects of radiation exposure on the central nervous system functions (Fig. 9). For a number of indicators of the content of monoamines and their metabolites in the brain, a decrease was noted in the intensity of time-related changes in the irradiated rats' prefrontal cortex, hypothalamus, and hippocampus. On the basis of the obtained results, a hypothesis was put forward that the compensatory and recovery mechanisms are actively realized in the late post-irradiation period, and, for relatively low linear energy transfer (of the order of 10 keV/μm), they can lead to the partial recovery of the brain's radiation-damaged functions. For higher LET, the compensatory and recovery mechanisms are realized to a lesser extent, and functional disorders get stronger with time.

Data were obtained on the action of ^{60}Co γ rays on neuromediator exchange in rats of different age categories. Concentrations of noradrenaline, dopamine, serotonin, and their metabolites were measured in the prefrontal cortex, hypothalamus, hippocampus, and striatum 30 and 90 d after irradiation at the age of 3 and 5 months, respectively. After exposure to 1 Gy of γ rays, exchange dynamics was most affected in the prefrontal cortex, hypothalamus, and hippocampus, which points to the sensitivity of these structures to relatively low doses of γ radiation (Fig. 10). It was found that in these brain parts γ rays have little effect on the general trend of the post-irradiation changes; however, as regards the age aspect, the metabolism character changed in many parameters. A comparison of the obtained results with data on the action of accelerated ^{12}C ions showed that γ radiation has a weaker effect on the time dynamics of neuromediator exchange than heavy nuclei. Based on the conducted research, it was

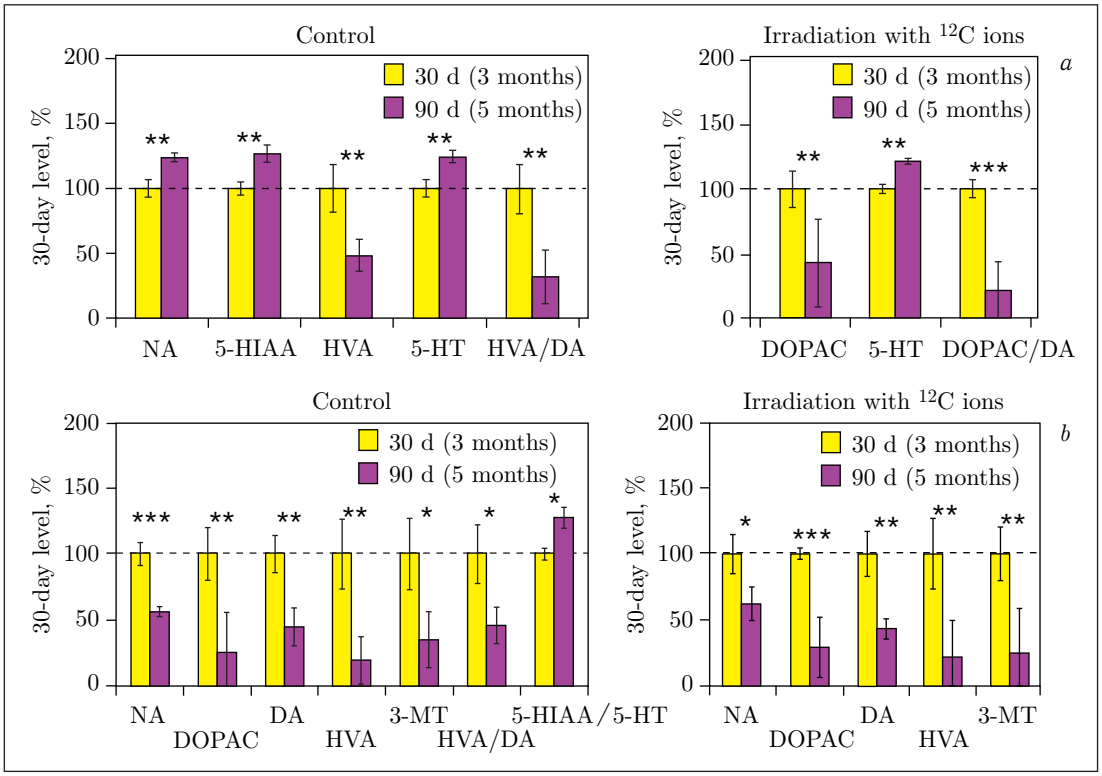


Fig. 9. The distribution of monoamines and their metabolites in the prefrontal cortex (*a*) and hypothalamus (*b*) of the brain of rats of different age categories 30 and 90 d after irradiation with 1 Gy of 500 MeV/nucleon ^{12}C ions ($\pm$SD; $* - p \leqslant 0.1$; $** - p \leqslant 0.05$; $*** - p \leqslant 0.01$). The age of the animals at the study moment is shown in parentheses. Monoamines and their metabolites are denoted as follows: NA — noradrenaline; DA — dopamine; DOPAC — 3,4-dihydroxyphenylacetic acid; HVA — homovanilic acid; 3-MT — 3-methoxythyramine; 5-HT — 5-hydroxytriptamine; 5-HIAA — 5-hydroxyindoleacetic acid

suggested that for heavy-ion exposure, more significant changes in the functioning of the mediatory systems lead to a more intense realization of the compensatory and recovery processes, which can underlie the modification of the normal dynamics of neuromediator exchange in the studied post-irradiation period [9, 10].

Neurocytological effects were studied that are induced in the rat cerebellum by accelerated ^{12}C ions and γ rays. Rats were irradiated at the Nuclotron-M accelerator of JINR's Laboratory of High Energy Physics with ^{12}C ions with a linear energy transfer of ~ 11 keV/μm and at the Rocus-M facility of JINR's Medical Technical Complex with ^{60}Co γ rays. The amount and dynamics of structure damage formation in the Purkinje cell layer of the cerebellum significantly differed between the specified groups. On the 30th day after exposure, the number of neurons with dystrophic changes was reliably higher in the groups of rats irradiated with ^{12}C ions than in the intact animals. Differences in the structure damage yield were also found between the groups of rats irradiated with γ rays and ^{12}C ions. The analysis of the obtained materials performed on the 90th day after irradiation showed that the number of neurocytes with dystrophic changes is reliably higher in the groups of rats irradiated with ^{12}C ions compared with γ rays (Table 1). Nevertheless, the proportion of cells with dystrophic disorders in the total number of the changed neurons decreased. For γ irradiation, the formation dynamics of degenerative cell reactions on the 90th day after exposure consists in a decrease of their number to the intact animal level. Based on the above, one can conclude that irradiation with 500 MeV/nucleon ^{12}C ions at a dose of 1 Gy results in a significant increase in the proportion of the Purkinje cells with dystrophic disorders. The identified cell reactions point to the development of degenerative processes in the rat cerebellum cortex. The dynamics of the formation of changes and their character indicate that an unbiased evaluation of the radiation danger of accelerated heavy charged particles for the central nervous system is needed, and detailed experiments have to be conducted to determine cytomorphological changes in different structures of the brain.

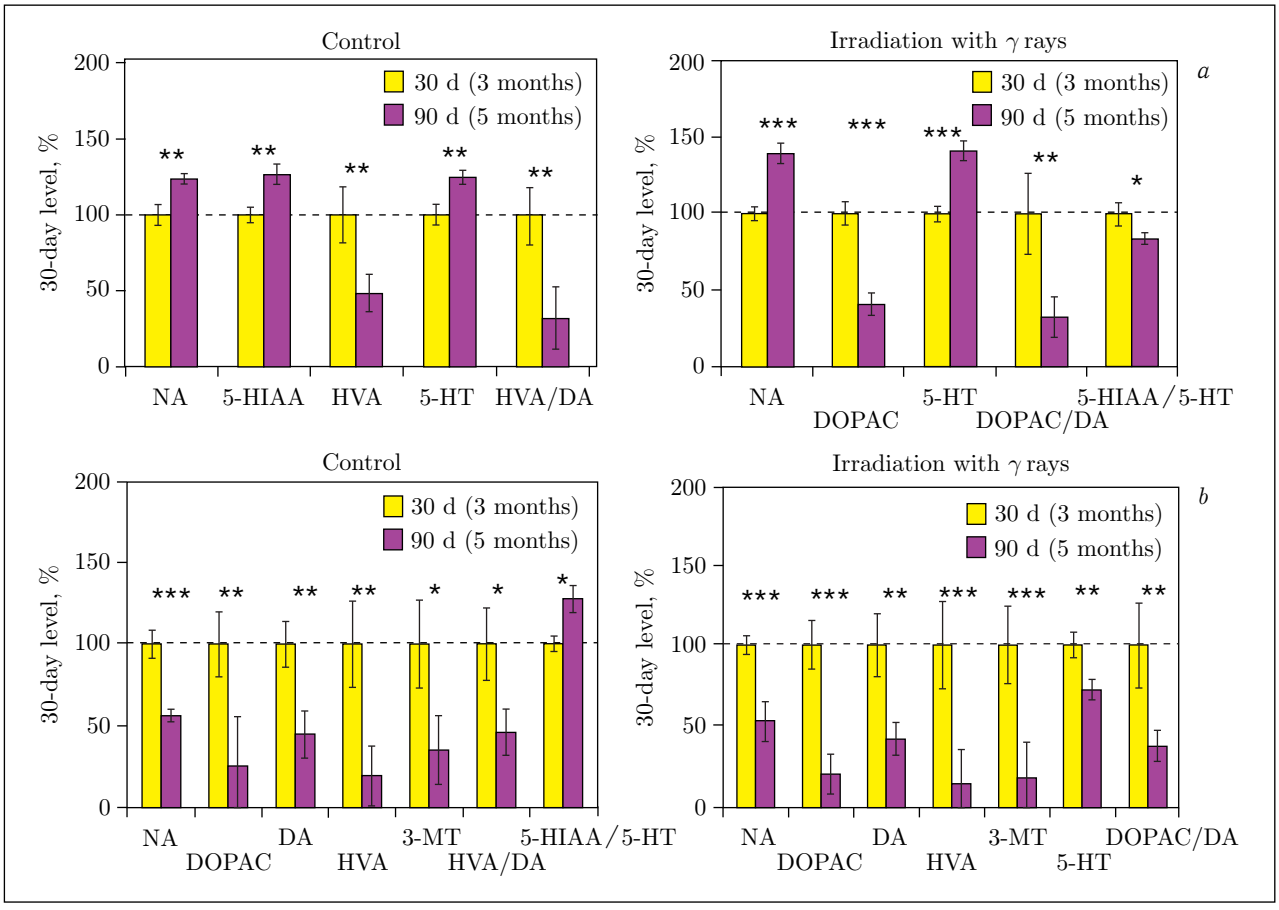


Fig. 10. The distribution of monoamines and their metabolites in the prefrontal cortex (*a*) and hypothalamus (*b*) of the brain of rats of different age categories 30 and 90 d after irradiation with 1 Gy of ^{60}Co γ rays ($\pm$SD; $*$ — $p \leqslant 0.1$; $**$ — $p \leqslant 0.05$; $***$ — $p \leqslant 0.01$). The age of the animals at the study moment is shown in parentheses

Table 1. The number of Purkinje cells in the rat cerebellum cortex at different times after exposure

Group	Type of morphological changes					
	30 d			90 d		
	No. 1, %	No. 2, %	No. 3, %	No. 1, %	No. 2, %	No. 3, %
Control	67.7 $\pm$ 2.6	28.1 $\pm$ 2.7	4.2 $\pm$ 1.4	75.5 $\pm$ 1	20 $\pm$ 2	4.5 $\pm$ 1.6
γ-irradiated	54.3 $\pm$ 6.3	35.8 $\pm$ 6.1	9.9 $\pm$ 0.4	71 $\pm$ 3.2	24.1 $\pm$ 3.2	4.9 $\pm$ 0.8
^{12}C-irradiated	49.2 $\pm$ 3.1	34.6 $\pm$ 2.8	16.2 $\pm$ 2.3	61.8 $\pm$ 2.3	30.3 $\pm$ 1.5	7.9 $\pm$ 1
Groups: 1 — neurons without apparent changes; 2 — neurons with morpho-functional and compensatory adaptive changes; 3 — neurons with dystrophic changes.						

The action was studied of high-energy protons and accelerated ^{12}C ions on the cognitive functions and the content of monoamines and their metabolites in rhesus macaque *(Macaca mulatta)* peripheral blood. It was shown that macaque head irradiation with 3 Gy of 170 MeV protons (LET: 0.53 keV/μm) does not lead to significant changes in cognitive functions and concentrations of the studied neuromediators in blood at late times after exposure. However, after irradiation with 1 Gy of 500 MeV/nucleon ^{12}C ions (LET: 10.6 keV/μm), a reliable decrease was observed in cognitive functions and serotonin metabolite concentrations in the blood of macaques of the excitable unbalanced type of higher nervous activity (Figs. 11 and 12). Macaques of the strong balanced type of higher nervous activity were found to be resistant to both radiations, which agrees with ample literature data. Based on the obtained results, one can conclude that disorders caused by heavy-ion exposure even at relatively low doses develop

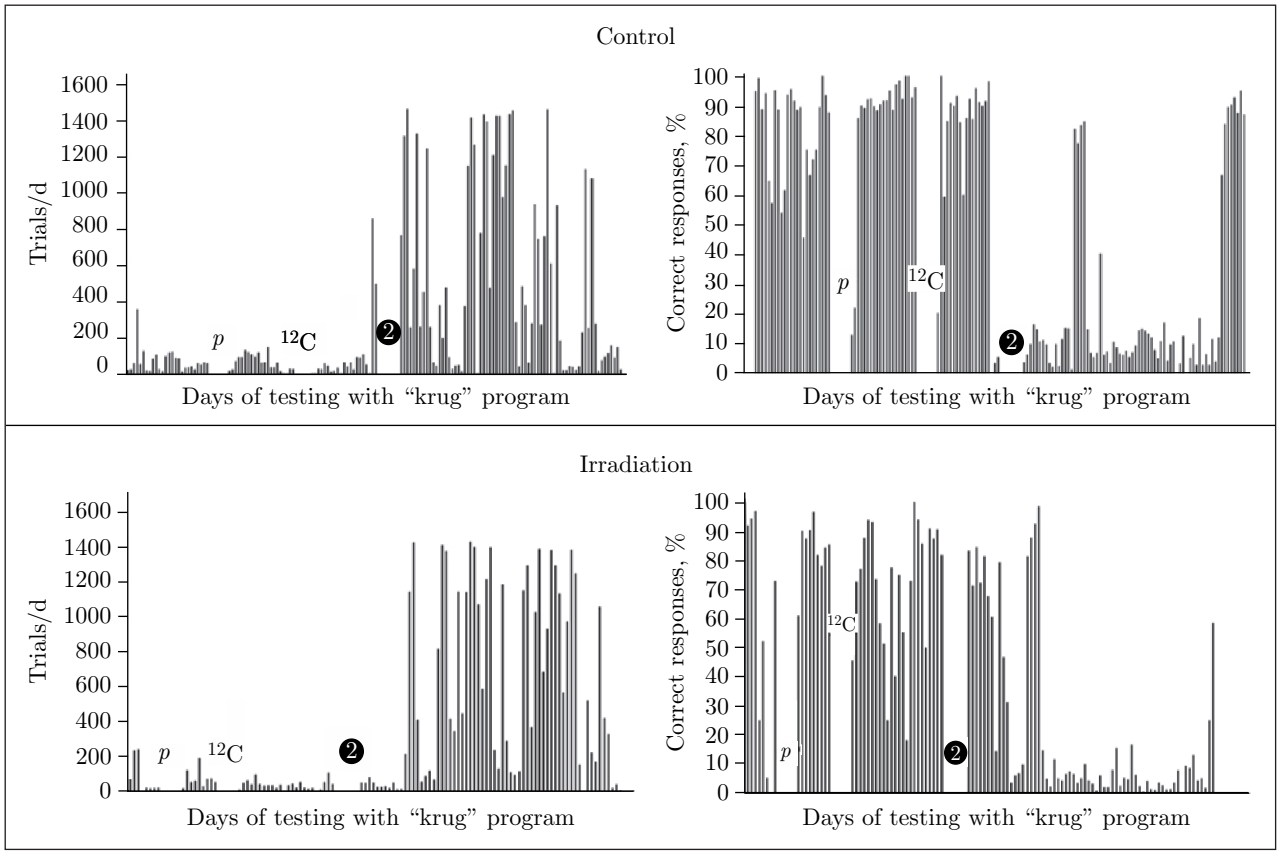


Fig. 11. Cognitive function indicators of the control and irradiated monkey groups. p — proton irradiation day; ^{12}C — carbon ion irradiation day; FI — false irradiation (the same procedures without irradiation); 2 — a new complexity level of the game program

and increase with time. Moreover, it may be suggested that this exposure is so intense and affects so many processes in the brain that a decrease in the concentration of monoamine metabolites in blood liquor can correspond to a decrease in the concentration of monoamines and their metabolites in the monkey brain [11].

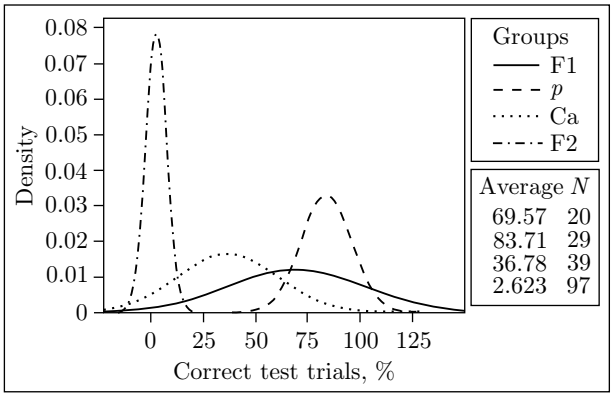


Fig. 12. The density distribution of monkeys' cognitive functions. F1 — training before experimental exposures; p — proton irradiation; Ca — carbon ion exposure; F2 — training at a new complexity level

MATHEMATICAL MODELING OF RADIATION-INDUCED EFFECTS

Modeling was continued of the systems of heavy charged particle–induced genetic damage repair.

A mathematical model was developed [12, 13] that describes the main mechanisms of radiation-induced DNA double-strand break (DSB) repair in mammalian and human cells. The mechanisms include non-homologous end joining (NHEJ), homologous recombination (HR), single-strand annealing by direct repeats (SSA) and microhomologous sequences (micro-SSA), and alternative non-homologous end joining (Alt-NHEJ). The model represents the time characteristics of the main DNA repair

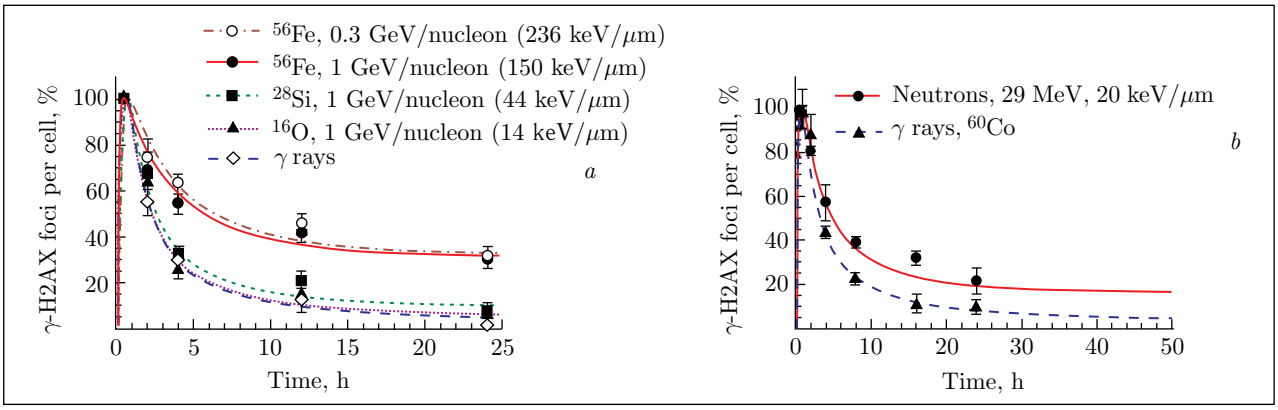


Fig. 13. *a*) Dynamics of the yield of γ-H2AX foci in human skin fibroblasts induced by 1 Gy of ionizing radiations with different physical characteristics; *b*) a comparison of γ-H2AX foci kinetics in human blood lymphocytes. The curves are the calculated results; the dots are experimental data (Asaithamby et al., 2008 (*a*); van der Sickel et al., 2014 (*b*))

stages for ionizing radiations in a wide LET range (0.2–236 keV/μm), including a broad spectrum of heavy ions — up to ^{56}Fe nuclei (Fig. 13, *a*). The enzymatic interaction rate parameters of the kinetic equations were determined by fitting the theoretical curves to the experimental data on certain repair stages and were chosen taking into account the specifics of DNA DSB repair after exposure to radiations of different quality. Along with modeling the interactions of the main regulatory proteins and protein complexes, taken into account was the presence of DNA metastable states forming at different repair stages.

The proposed model allows for different repair mechanism activity levels depending on cell cycle phases and takes into consideration damage complexity, in particular, the presence of clustered DSBs, which can be induced by high-LET radiation. It was also shown that the model correctly reproduces the dynamics of the repair of cell damage induced by neutrons with LET of 20 keV/μm at a dose of 0.5 Gy (Fig. 13, *b*). The proposed calculation approach can thus be used for a deeper analysis of the present and future experimental data, which is important for the development of a generalized theory of DNA DSB repair.

A detailed analysis was performed of a mathematical model of DNA repair systems in *E. coli* bacterial cells [14, 15]. Regularities were analyzed of the influence of defects in different damage repair genes on the ultraviolet (UV) mutagenesis level. Nucleotide excision repair (NER) efficiency was evaluated depending on UV radiation energy fluence; the concentrations of the key proteins were calculated (Fig. 14, *a*). It was shown that with an increase in the yield of UV lesions, the characteristic time of their NER increases (Fig. 14, *b*). The calculated results on the time dynamics of regulatory protein concentrations (Fig. 14, *a*), replication kinetics, and mutation frequency (Fig. 14, *c*) agree well with the known experimental data. A comparative analysis was performed of the efficiencies of postreplicative repair systems (Fig. 14, *d*) depending on the damage level and defect presence in the NER system. As an example, considered are wild-type cells and *uvrA* and *polA* gene-deficient mutant strains. It was found that the maximal efficiency of translesion synthesis is four times higher than the efficiency of errorless repair by homologous recombination. These results can be used for predicting bacterial cell response to radiations with different characteristics and other exposures.

Modeling was continued of the molecular mechanisms of disorders in structures and functions of the nervous system caused by exposure to accelerated heavy charged particles. In collaboration with scientists of the National University of Mongolia, a cycle of research was carried out on Monte Carlo modeling of radiation-induced damage with the GEANT4 software toolkit. A computational method was proposed which allows evaluation of the character of dose and energy distributions in specific neurons of the brain for irradiation with heavy charged particles. With the use of the developed approach, it was shown [16] that cell morphology is an important factor determining the specifics of energy deposition in isolated neuron components (Fig. 15). The obtained data point to a possibility of the radiation damage of the synaptic contact area, which can cause behavioral and cognitive disorders observed in laboratory animals after exposure to heavy charged particles.

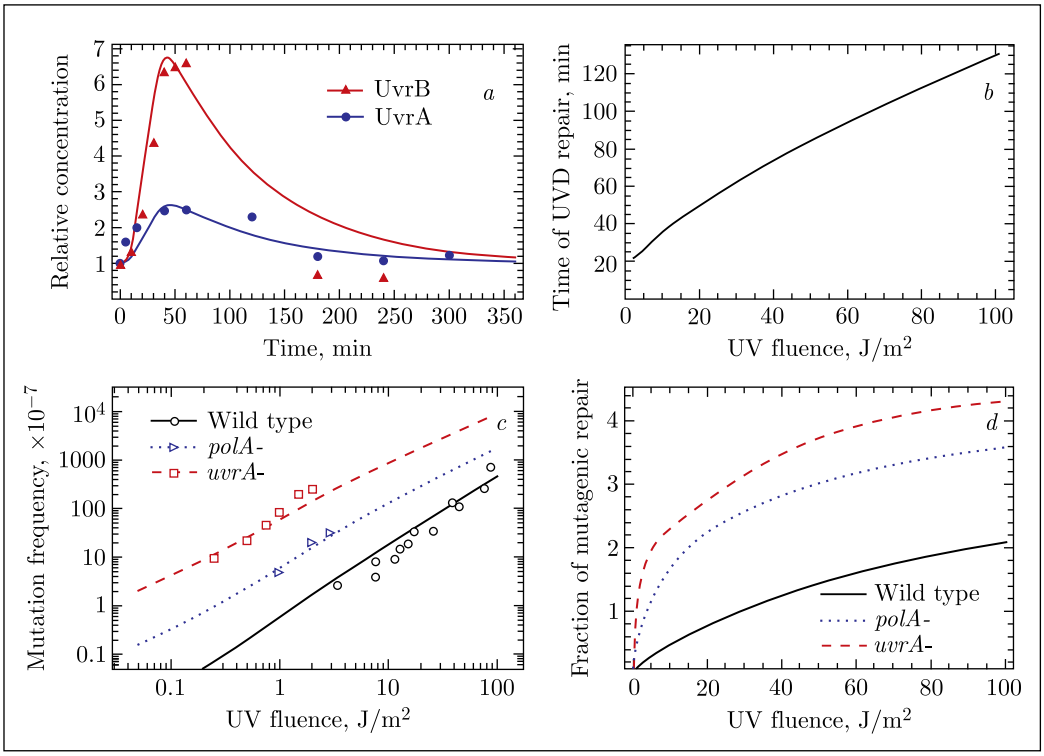


Fig. 14. *a*) Concentration dynamics of the NER system's key proteins during SOS response at an UV fluence of 10 J/m^2. *b*) Characteristic time of UV damage repair by NER in wild-type cells. *c*) Induced mutation frequency for different genotypes. *d*) The amount of ssDNA repaired by translesion synthesis with respect to that of ssDNA repaired by homologous recombination. The curves are the calculated results; the dots are experimental data (Lin et al., 1997, Pruteanu et al., 2009 (*a*); Kato et al., 1974, Bates et al., 1989 (*c*))

This method was extended to evaluating the yield of water radiolysis products in brain neurons (in particular, in synapses). The chemical reactions and processes of the diffusion of the main radiolysis products were modeled in synaptosomes and a detailed neuron structure in general [17]. The developed method is applicable to the description of the action of proton, carbon ion, and iron ion beams with physical characteristics that are close to those of the galactic cosmic ray spectrum.

An approach to the calculation of radiation-induced disorders in synaptosomes and synaptic receptors was developed based on a small-voxel model [18]. Charged particle track calculation for a voxel model of receptors was performed using the GEANT4 toolkit. As the result, a distribution was obtained of the stochastic events of energy deposition in GluN1a/GluN1b subunits of the NMDA receptor for irradiation with ^{1}H, ^{4}He, ^{12}C, ^{28}Si, and ^{56}Fe particles. A high value of heavy charged particles' energy deposition in small volumes can lead to disorders in the synaptic active zone and, in particular, cause synaptic receptor damage. Although the mechanism of radiation action on the synapses' sensitive structures is not known precisely, this research can contribute to a better understanding of the early stages of lesion appearance during the primary interaction between a charged particle and biological structures.

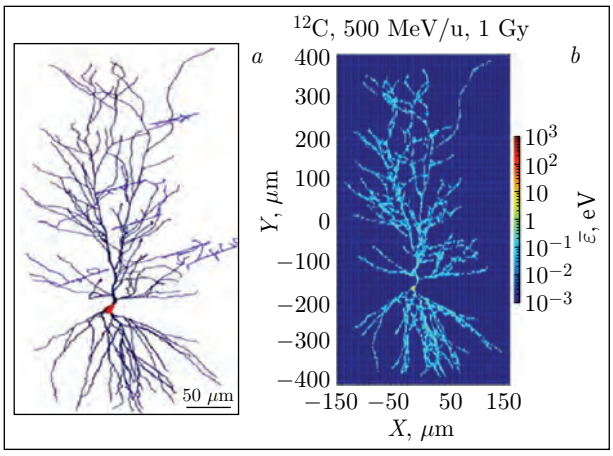


Fig. 15. *a*) A 3D model of a pyramidal neuron of the CA1 region of the rat hippocampus matched with calculated tracks of 500 MeV/nucleon ^{12}C ions. The soma is shown in red; dendrites, in blue. *b*) A spatial distribution of energy ($\bar{\varepsilon}$) deposited in the neuron body after ^{12}C ion passage for a dose of 1 Gy

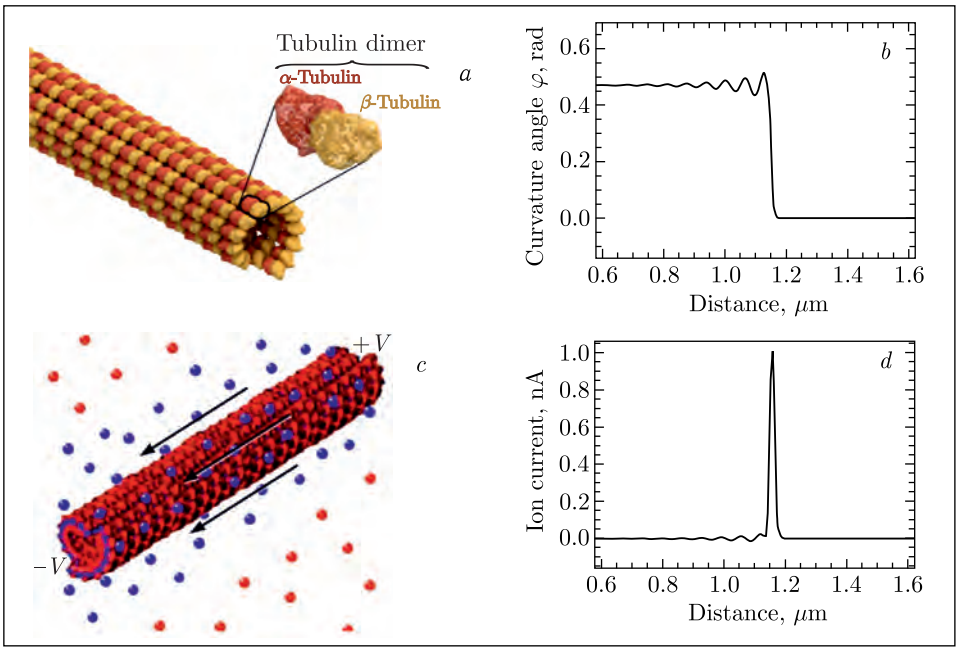


Fig. 16. Signal transport in a microtube. During propagation, the α and β forms of tubulin (*a*) locally change their conformation, which is expressed as the bending angle (*b*). A deformation is accompanied by an ion current pulse along the microtube surface (*c*, *d*)

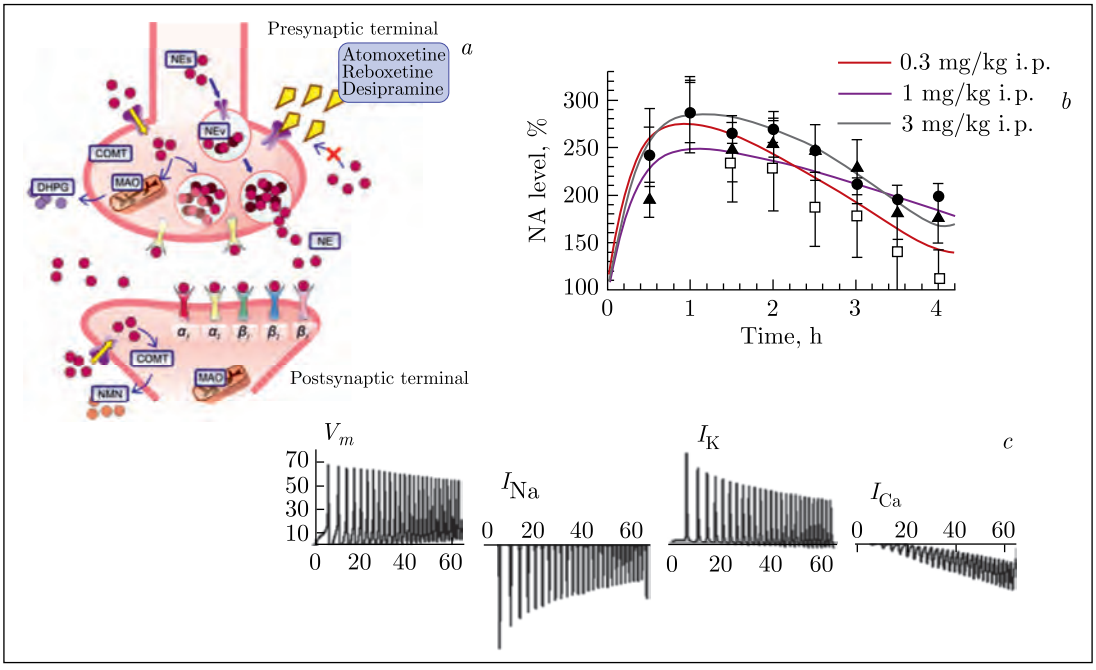


Fig. 17. *a*) A scheme of the action of noradrenaline inverse capture inhibitors. *b*) Noradrenaline dynamics in the prefrontal cortex of the rat brain after introduction of atomoxetine at 0.3–3 mg/kg i.p. ($\pm$SEM) (Bymaster et al., 2002). *c*) Estimation of the membrane's nonsynaptic characteristics. V_m is the membrane potential (mV); I_{Na}, I_K, and I_{Ca} are the sodium, potassium, and calcium currents, respectively

A research was conducted on intracellular signal transmission along cytoskeleton microtubes [19]. Microtubes, being a metastable formation that depends on the level of metabolism and expression of stabilizing proteins, and participating in synapse functioning regulation, can be a potentially sensitive target for radiation action. It is known that tubulin has two possible spatial configurations with different energy that differ by the mutual orientation of the α and β subunits (Fig. 16, *a*). On the other hand, in a solution, the microtube has polyelectrolyte

properties. Taking into account these specifics, a theoretical model was developed of a nonlinear interaction between an ion layer and polymer's structure deformation. It was shown that the structure deformation energy accumulated through guanosine triphosphate hydrolysis can be used for the conduction of ion current pulses. Calculations based on this model showed that a stable nonlinear deformation wave can propagate in the microtube (Fig. 16, *b*), accompanied by an ion current, in particular, by Ca^{2+} ions condensed on the polymer surface (Fig. 16, *c*, *d*). The results of this study clear up the pattern of intracellular Ca^{2+} ion transport. It follows from the evaluation of the stability of the obtained solutions that cytoskeleton degradation caused by radiation or chemical exposure can lead to disorders of intracellular signaling and synaptic plasticity.

An approach was proposed to the mathematical modeling of monoamine concentration dynamics after exposure to chemical agents, including some medicines [20]. The developed mathematical model allows description of the processes taking place in synapses after introduction of chemical agents influencing the functioning of monoamine transporters (Fig. 17). It also presents dopamine, noradrenaline, and serotonin level dynamics in different structures of the rat brain after an injection of monoamine inverse capture inhibitors. With the use of the proposed computational techniques, the action of atomoxetine, reboxetine, fluoxetine, desipramine, and GBR 12909 was studied. The developed model approach is valuable for getting a better understanding of the mechanisms of the action of pharmacological preparations on monoaminergic systems in the treatment of different cognitive disorders.

RADIATION PROTECTION PHYSICS AND RADIATION RESEARCH

In 2015, LRB staff participated in designing the Nuclotron booster. The booster is a component of the NICA accelerator complex; its function is the preliminary acceleration of ^{197}Au ions to an energy of 578 MeV/nucleon. It is planned to place the booster inside the existing yoke of the Synchrophasotron at the Laboratory of High Energy Physics (LHEP). Radiation protection design requirements for the Nuclotron booster were prepared and approved. Based on the universal Monte Carlo code MCNPX for calculating radiation transport in matter, a detailed mathematical model was constructed of LHEP's Building 1 and the booster inside the Synchrophasotron ring; biological shielding and non-purpose-charged ion beam stopper options were proposed; and radiation environment was predicted inside and around Building 1 for routine booster operation at the NICA complex (Fig. 18). It was shown that if all proposed measures are implemented, the booster's contribution to the annual effective neutron dose at the LHEP's protection zone will not exceed its quota. The ultimate result of this work was a booster project as regards radiation protection. The project covers the radiation zoning of the booster rooms and the area adjacent to Building 1; booster functioning with an internal target; activation of the booster equipment, materials, and cooling agents; booster radiation monitoring and entrance blocking systems; and emergencies at the booster.

An experimental stand was commissioned to test and calibrate nuclear planetary science instruments equipped with fast neutron generators. The stand was created in a collaboration of JINR's LRB and FLNP and Space Research Institute of the Russian Academy of Sciences (SRI RAS) observing all the radiation safety measures. The building hosting the stand provides a low background of scattered neutrons and allows testing instruments with different planetary soil models. The simulation of planetary regoliths is based on using a silicate glass pack with a total weight of up to 35 t, which is a model of an absolutely dry soil (Fig. 19). Water presence in a soil is modeled by polyethylene layers at different depths. For the best possible approximation of the chemical composition of the Martian regolith for Fe, Al, and Cl, thin layers of steel, aluminum, and polyvinyl chloride were included in the glass pack. Overall, the chemical composition of the models agrees well with the average chemical composition of the Martian and Lunar regolith. In 2015, a great amount of work was accomplished at the LRB experimental stand to test the following SRI RAS instruments: DAN (Dynamic Albedo of Neutrons), MGNS (the Mercurian Gamma and Neutron Spectrometer for ESA's future Bepi-Colombo mission to Mercury), ADRON-LR (the

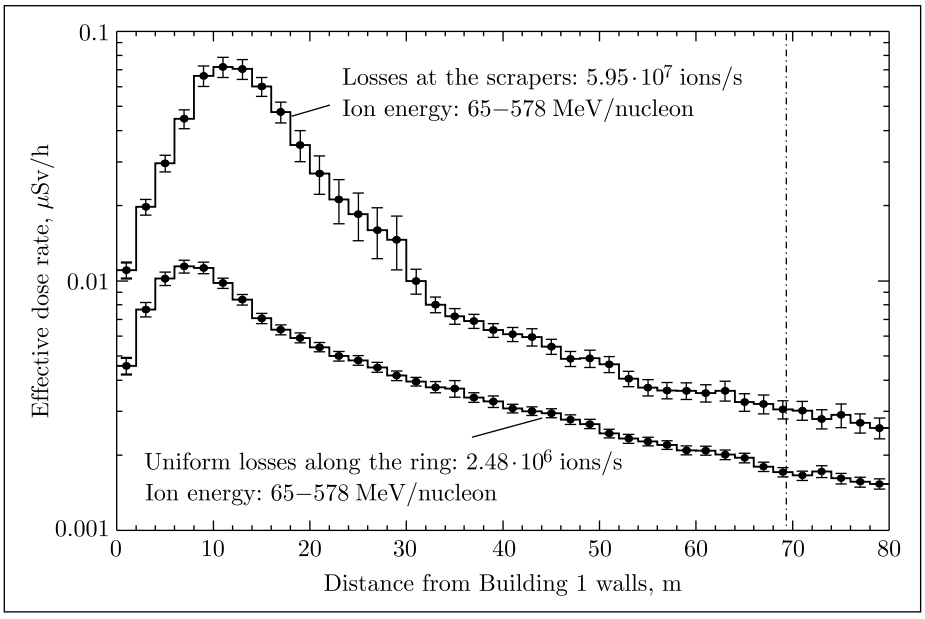


Fig. 18. Radial distributions of the effective neutron dose rate from different sources of ion losses on the booster. The dotted line is the nearest border of the LHEP territory. The slits and gaps in the Synchrophasotron yoke are filled with concrete

Active Neutron and Gamma-Ray Detector for Roscosmos's Luna-Glob mission), ADRON-RM, and FREND (the two latter are, respectively, the Neutron Detector and High-Resolution Epithermal Neutron Detector for ESA's and Roscosmos's future ExoMars mission). After a neutron generator pulse, measured for a number of soil models were time distributions of albedo neutron detection by DAN instruments and γ-ray spectra at different time intervals. The results of the experiments allowed evaluation of the sensitivity of the techniques used to determine the elemental composition of the near-surface layers of planetary soils, in particular, to measure their water ice (permafrost) content [21].

Broad energy range neutron spectrometry using a multisphere spectrometer was continued. Spectra were measured at channels 3 and 11 of the IBR-2 reactor to verify the correctness of neutron dose measurement by personal albedo neutron dosimeters (Fig. 20).

Fig. 19. A planetary soil model with the DAN instrument and neutron generator (NG) above it

RESEARCH ON COSMIC MATTER ON EARTH AND IN NEARBY SPACE

Research was continued on the synthesis of chemical compounds from formamide NH_2COH (an HCN hydrolysis product) under exposure to radiations with different linear energy transfer. Synthesis reactions occurred under irradiation with accelerated protons and ^{11}B and ^{12}C ions in the presence of catalysts obtained from meteorites of different classes (Fig. 21). To continue studying the synthesis of prebiotic compounds, experiments were performed on the possibility of the synthesis of nucleosides — DNA and RNA components — by 170 MeV proton beam irradi-

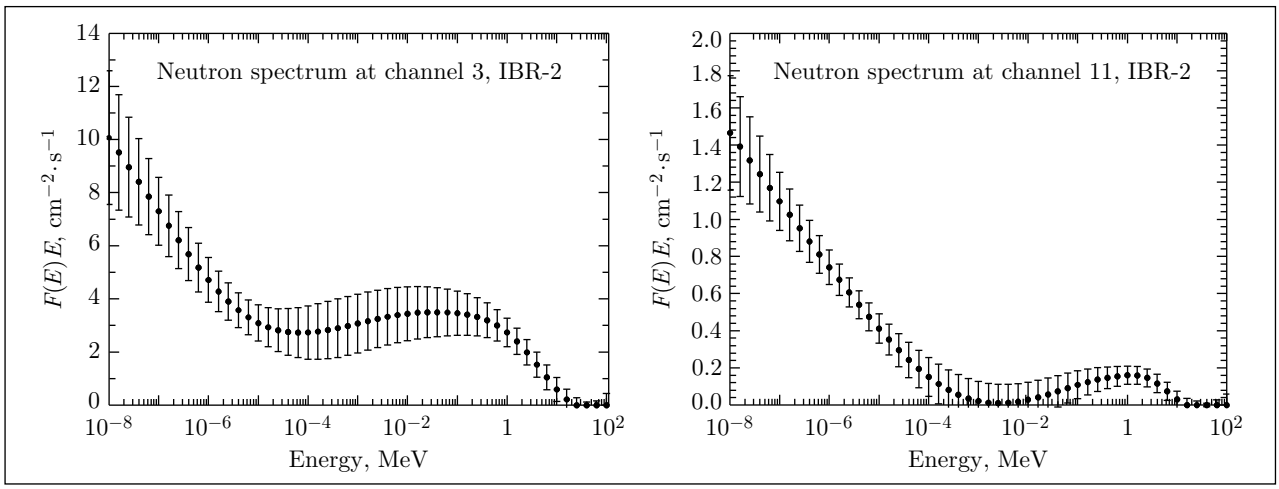


Fig. 20. Neutron spectra at IBR-2 experimental halls

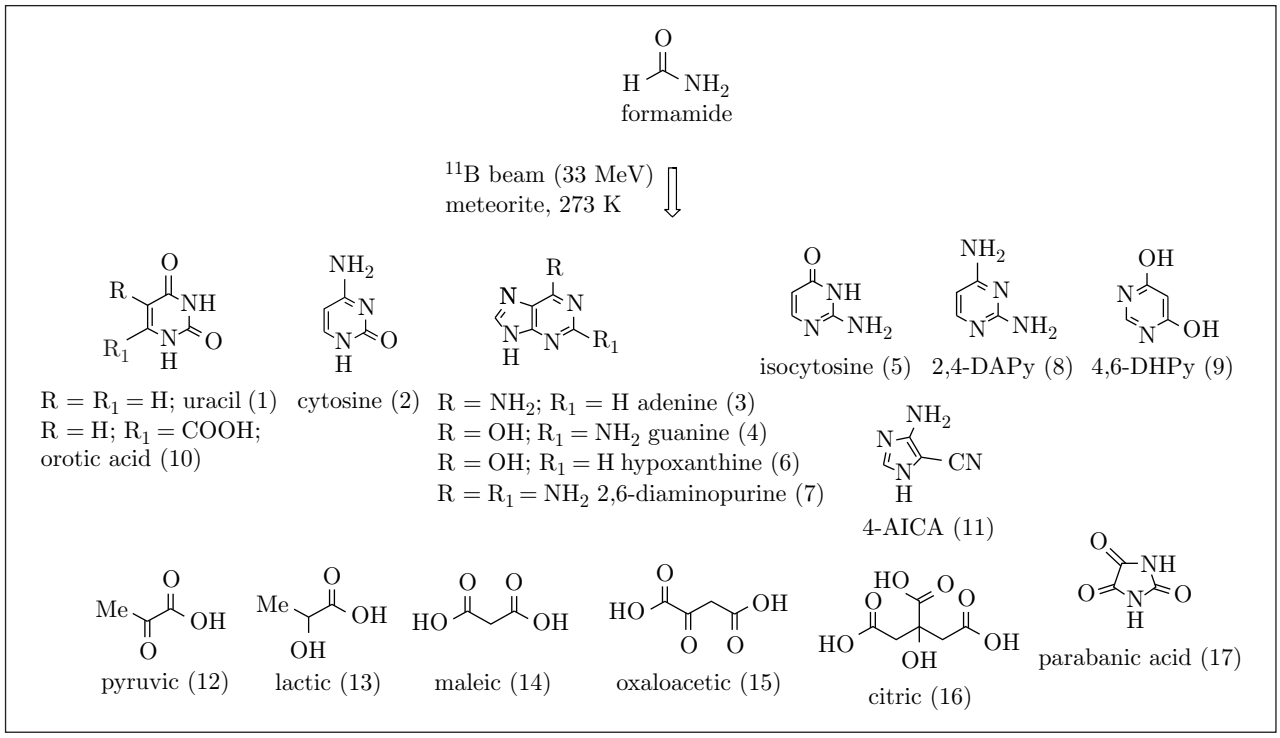


Fig. 21. Compounds formed from formamide under irradiation with ^{11}B ions in the presence of meteorite matter

ation of a mixture of a nucleic base and sugar. As sugars, ribose and 2-deoxyribose were used. A mixture of a nucleoside and phosphate group was exposed to the same radiation to study the possibility of the synthesis of nucleotides that are DNA and RNA building blocks. Results of these experiments can shed light on the problem of the synthesis of the first prebiotic compounds on the early Earth [22].

As there is no detailed data on the elemental composition of the meteorite samples in the experiment with formamide, a neutron activation analysis of the samples was made jointly with JINR's Laboratory of Neutron Physics staff. The results on some of the meteorites are presented in Table 2. The contents of the main elements agree with literature data. The contents of other elements were calculated for the first time.

Ample and unique material was obtained on the biogenic structures found in the most ancient rocks studied. The early Precambrian (Archean and early Proterozoic) terrestrial sediments are the nearest in age to the meteorite rocks. For this reason, studying early Precambrian fossilized microorganisms in different sedimentary and volcanogenic rocks and in different

Table 2. NAA results on iron meteorites

Elements	Concentration, mg/kg		
	Canyon Diablo	Campo de Cielo	Sikhote Alin
Na	126 ± 5	193 ± 8	69 ± 3
Al	129 ± 4	807 ± 17	232 ± 6
Cl	132 ± 13	347 ± 28	107 ± 2
Ca	160 ± 49	662 ± 108	—
V	0.30 ± 0.05	27.0 ± 0.9	0.40 ± 0.05
Cr	405 ± 26	361 ± 24	377 ± 27
Mn	35 ± 2	79 ± 5	35 ± 3
Fe	828 000 ± 42 808	868 000 ± 44 876	915 000 ± 47 306
Co	4000 ± 76	4350 ± 83	4540 ± 86
Ni	48 800 ± 4089	46 400 ± 3888	46 800 ± 3922
Cu	145 ± 38	212 ± 55	176 ± 45
Zn	244 ± 19	168 ± 17	—
As	19.0 ± 0.4	12.0 ± 0.3	11.0 ± 0.3
Br	1.2 ± 0.4	0.4 ± 0.1	—
Mo	11 ± 3.2	8.4 ± 2.5	7 ± 2
Sb	0.60 ± 0.02	0.20 ± 0.01	0.10 ± 0.01
Ba	537 ± 35	—	—
La	1.30 ± 0.09	1.30 ± 0.08	0.60 ± 0.07
Sm	0.20 ± 0.06	0.20 ± 0.06	0.10 ± 0.03
W	1.6 ± 0.5	1.2 ± 0.4	0.8 ± 0.3
Au	1.7 ± 0.5	1.5 ± 0.5	1.4 ± 0.4
U	0.20 ± 0.03	—	—

minerals — pillow lavas, residual soils, phosphorites, bauxites, etc. — is the key to studying biomorphic and biogenic structures in materials of an extraterrestrial origin. The obtained data allowed clearing up the conditions and processes of the formation of a number of rocks and ores. The biomorphic structures found in meteorites are arguments in favor of the theory of panspermia.

Pseudomorphoses of filamentous and coccoid forms were found in all carbonaceous chondrites. Orgueil, Murchison, Efremovka, and other meteorites contain fossilized remains of filamentous and coccoid forms that are similar in morphology and size to modern Earth's bacterial forms and their ancient analogs. Among the microfossils found in meteorites, there were coccoid-like forms, some of which have a distinctive pylome making them closer to the amoeba-like species (i.e., eukaryotes). The most interesting are large saccular forms, which can be thought of as fossilized eukaryotic organisms. The age of all known carbonaceous chondrites is comparable with that of Earth (4.5–4.6 billion years). Since the meteorites (first of all, carbonaceous chondrites) are so ancient, and the fossilized remains are yet older, there are grounds to suggest that these organisms existed before Earth's formation.

CONFERENCES AND EDUCATION

In 2015, the Laboratory's researchers participated in 12 scientific conferences in Russia and 9 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 "Modern Trends in Radiobiology and Astrobiology. Molecular, Genetic, Cell, and Tissue

Effects". Its participants were about 100 scientists of institutes and research organizations of Russia, Italy, and the U.S. The conference topics included urgent issues of space radiobiology, astrobiology, radiation genetics, radiation therapy, and molecular and cell radiobiology.

The education process continued at the Department of Biophysics of Dubna University. Total enrollment in the Human and Environmental Radiation Safety specialty is 39 students and four postgraduates attend the Radiobiology specialty program. In 2015, eight new students were accepted to the Department. Eight students successfully completed their education and received diplomas in engineering physics.

REFERENCES

1. *Zadneprianetc M. et al.* IRIF Cluster Formation and Structure in Human Fibroblasts after Irradiation with Boron Ions and γ-Rays // Third Intern. Conf. on Radiation and Applications in Various Fields of Research (RAD 2015), Budva, Montenegro, June 8–12, 2015. Book of Abstracts. Niš: RAD Association, 2015. P. 451.
2. *Falk M. et al.* DSB Repair in Normal and Radioresistant Tumor Cells Exposed to γ-Rays, Protons of Different Energies, and High-LET Ions // The 15th Intern. Congress of Radiation Research (ICRR 2015), Kyoto, Japan, May 25–29, 2015. Book of Abstracts, Poster No. 3-PS2E-20.
3. *Ježková L. et al.* Analysis of DSB Repair and Structure of IRIF Clusters Induced by High- and Low-LET Radiations // Ibid. Poster No. 2-PS3D-25.
4. *Dubničková M. et al.* The Effects of Lipid A on Gamma-Irradiated Human Peripheral Blood Lymphocytes *In Vitro* // Phys. Part. Nucl. Lett. 2016. V. 13, No. 2. P. 274–278.
5. *Blaha P. et al.* Comparison of the Influence of Densely and Sparsely Ionizing Radiation on the Induction of HPRT Mutants in V79 Cells // 61st Annual Meeting of Radiation Research Society, Weston, Florida, USA, September 18–22, 2015. Book of Abstracts.
6. *Tronov V. A. et al.* Research on Retinal Adaptive Response to Proton Irradiation in Mice: Connection with DNA Repair and Photoreceptor Cell Death // Part. Nucl., Lett. 2015. V. 12, No. 1(192). P. 241–255 (in Russian).
7. *Tronov V. A. et al.* Radiation Preconditioning of the Mouse Retina *In Vivo* Increases Its Resistance to Subsequent Genotoxic Exposure and Stimulates Its Recovery // Cytology. 2015. V. 56, No. 2. P. 119–128 (in Russian).
8. *Vinogradova Yu. V.* Research on Retinal Damage and Recovery in Mice after Irradiation with Accelerated Protons and Exposure to Methylnitrosourea // Extended Abstract of Cand. Sci. Dissertation. Moscow, 2015. 24 p. (in Russian).
9. *Belokopytova K. V. et al.* Distribution of Monoamines and Their Metabolites in Rat Brain Structures at Late Times after ^{12}C Ion Irradiation // Neurochem. J. 2015. V. 32, No. 3. P. 243–251 (in Russian).
10. *Belokopytova K. V. et al.* Dynamics of the Age-Related Changes in the Exchange of Monoamines and Their Metabolites in Rat Brain Structures after ^{12}C Ion Irradiation // Russ. Sci. Conf. with Intern. Participation "Medical and Biological Problems of Toxicology and Radiobiology", 4–6 June 2015, St. Petersburg, Russia. Theses. St. Petersburg, 2015. P. 50–51 (in Russian).
11. *Belyaeva A. G. et al.* Action of High-Energy Protons and ^{12}C Ions on Monkeys' Cognitive Functions and Content of Monoamines and Their Metabolites in Peripheral Blood // Human and Animal Physiology. 2015 (in press) (in Russian).
12. *Belov O. V. et al.* A Quantitative Model of the Major Pathways for Radiation-Induced DNA Double-Strand Break Repair // J. Theor. Biol. 2015. V. 366. P. 115–130.
13. *Fourie H. et al.* Theoretical Modelling of γ-H2AX Foci Kinetics in Human Lymphocytes after Exposure to Fast Neutrons // PhysicaMedica. 2015. V. 31. P. S4.
14. *Bugay A. N. et al.* Modeling Nucleotide Excision Repair and Its Impact on UV-Induced Mutagenesis during SOS-Response in Bacterial Cells // J. Theor. Biol. 2015. V. 364, No. 1. P. 7–20.
15. *Bugay A. N. et al.* Modeling the Induced Mutation Process in Bacterial Cells with Defects in Excision Repair System // Phys. Part. Nucl. Lett. 2015. V. 12, No. 7. P. 850–862.
16. *Batmunkh M. et al.* Estimation of the Spatial Energy Deposition in CA1 Pyramidal Neurons under Exposure to ^{12}C and ^{56}Fe Ion Beams // J. Rad. Res. Appl. Sci. (Elsevier). 2015. V. 8, No. 4, P. 498–507.
17. *Batmunkh M. et al.* Time-Dependent Yields of Water Radiolysis Products in CA1 Hippocampal Neurons Exposed to High-Energy Ions // IV Intern. Conf. "Modern Problems of Genetics, Radiobiology, Radioecology, and Evolution", St. Petersburg, Russia, 2–6 June 2015. St. Petersburg, 2015. P. 80.

18. *Bayarchimeg L., Belov O. V., Lhagva O.* Modeling of Energy Deposition in GluN1a/GluN2B NMDA Receptor of Synapses Exposed to Charged Particles // Proc. Nat. Res. Conf. (Mongol. Phys. Soc.), Ulaanbaatar, Mongolia, October 2–3, 2015. P. 64–66.
19. *Bugay A. N.* Nonlinear Waves As Signals in Microtubules // Nonlin. Phenom. Compl. Syst. 2015. V. 18, No. 2. P. 236–242.
20. *Aksenova S. V., Belov O. V., Sokol O. E.* Mathematical Modeling of Postsynaptic Processes in the CA3 Region of the Hippocampus // Proc. Intern. Conf. "Modern Trends in Radiobiology and Astrobiology. Molecular, Genetic, Cell, and Tissue Effects", 28–30 October 2015, Dubna, Russia. Dubna, 2015. P. 104–106.
21. *Litvak M. L. et al.* Ground Tests with Active Neutron Instrumentation for the Planetary Science Missions // Nucl. Instr. Meth. Phys. Res. A. 2015. V. 788. P.194–202.
22. *Saladino R. et al.* Meteorite-Catalyzed Syntheses of Nucleosides and of Other Compounds of Prebiotic Relevance from Formamide under Proton Irradiation // PNAS. 2015. V. 112, No. 21. P. E2746–E2755.

UNIVERSITY CENTRE

International Student Practice. In 2015, the International Student Practice in JINR Fields of Research, held in three stages, was attended by 134 representatives of Azerbaijan, Belarus, Bulgaria, Cuba, the Czech Republic, Egypt, Poland, Romania, Serbia, Slovakia, and South Africa (Figs. 1 and 2). In 2004, 34 students came from the Member States to participate in the very first Practice. Since 2004 and up to now, the event has been attended by 1145 students and postgraduates.

On 26 May – 11 June, the first stage of the Practice was held for 26 Egyptian students. On 5–26 July, 73 students from Azerbaijan, Bulgaria, the Czech Republic, Poland, Romania, and Slovakia took part in the second stage of the event. The participants in the final, third, stage, held on 7–25 September, were 33 students from South Africa, Belarus, Cuba, and Serbia.

The number of students willing to participate in the Practice grows every year. For example, in 2015, 26 out of 127 applications submitted in Egypt were selected in the national competition. As for South Africa, it was 25 selected students out of 60 applicants having submitted the documents for participation.

The Practice programme included lectures on the fields of research conducted at JINR, visits to the basic facilities of the Institute, and work on the research projects in JINR laboratories. The UC website (http://uc.jinr.ru) has a constantly updated database of research projects (currently, there are 59 projects). Due to the fact that the participants are under supervision of the laboratory staff members who must perform their main duties at the same time, the number of projects is different for each stage of the Practice. The last day of the event is

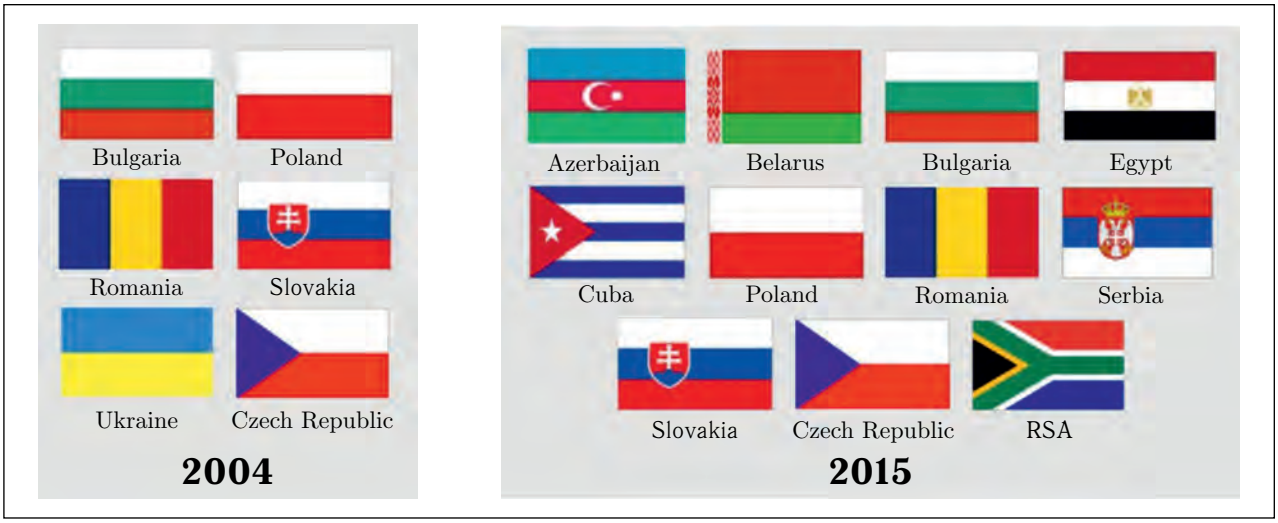


Fig. 1. Practice participating countries, 2004 vs. 2015

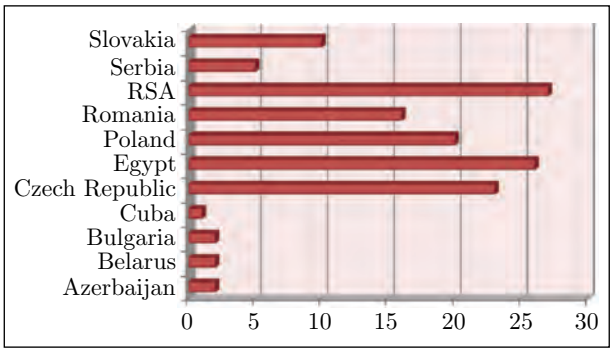


Fig. 2. Number of participants in the Practice 2015 by countries

dedicated to the presentation of students' reports on the implementation of their projects.

JINR-Based Educational Process. In 2015, 485 undergraduate and postgraduate students of the JINR-based departments of MSU, MIPT, University "Dubna", and the universities of the Member States were trained at the JINR UC. Eighteen students attended the postgraduate programme of JINR; seven of them specialized in "Theoretical Physics".

In February 2015, due to the rearrangement of the JINR postgraduate programme, new rules of attachment of JINR employees with higher professional education to the Institute to prepare their PhD theses without mastering the training programmes of the teaching staff came into force. The attachment has been performed in accordance with the specialties supervised by the JINR Dissertation Councils. Currently, 13 degree-seekers from Russia, Georgia, and Kazakhstan are attached to JINR, eight of them have chosen "Nuclear and Elementary Particle Physics".

The summer training programme 2015 was organized at FLNP, VBLHEP, FLNR, and LIT for 21 senior students of the Belarussian State University of Informatics and Radio Engineering, Gomel State Technical University, Tver State Technical University, Tomsk Polytechnic University, Ural State Technical University, Karazin Kharkiv National University, and South Ural State University.

The UC website (http://uc.jinr.ru/) has a regularly updated database of the training courses taught at the JINR-based departments of MSU, MIPT, and University "Dubna". The available subjects, currently being 107 in total, include: Particle Physics and Quantum Field Theory; Nuclear Physics; Condensed Matter, Nanostructure and Neutron Physics; Physical Facilities; Information Technologies; Mathematical and Statistical Physics.

New Student Programmes. The Summer Student Programme 2015 was attended by 33 undergraduate and postgraduate students from MSU, MIPT, MEPhI, St. Petersburg and Omsk State Universities, universities of Armenia, Belarus, Bulgaria, Cuba, Egypt, Georgia, Poland, Romania, Slovakia, South Africa, Ukraine, and Uzbekistan. The competition rate for the participation in the Programme 2015 was 4:1. The Summer Student Programme allows participants to do their research projects in the Institute laboratories for 6–8 weeks (June–October).

Seventh International Student Summer School on Nuclear Physics — Science and Applications. On 24 June – 4 July, Poznan (Poland) hosted the Seventh International Student Summer School on Nuclear Physics — Science and Applications (NUCPHYS-SC&APPL). The School was organized by the JINR UC, Department of Physics of the A. Mickiewicz University in Poznan, Czech Technical University in Prague, and Comenius University in Bratislava (Slovakia). The School participants were the young scientists of JINR and the students of the universities of Armenia, the Czech Republic, Poland, Romania, Russia, and Uzbekistan.

The School programme included lectures and presentations of the participants on modern trends in the following fields of physics: nuclear physics of heavy ions at high and low energies; experimental facilities — reactors, accelerators, and detectors; nuclear techniques in condensed matter physics; neutron physics, application of nuclear techniques in life sciences and technology.

International School-Conference "Integrable Structures in Quantum Field Theory". On 27 February – 1 March, the JINR UC and the Faculty of Mathematics of the National Research University "Higher School of Economics" ran the International School-Conference "Integrable Structures in Quantum Field Theory". Eighteen students and young scientists from the Bogolyubov Institute of Theoretical Physics of the Ukrainian AS, Higher School of Economics, and Moscow Institute of Physics and Technology attended the lectures delivered by the leading research workers of the Lebedev Physical Institute of RAS, Institute of Theoretical and Experimental Physics and National Research University "Higher School of Economics". The school was held in the framework of the JINR–Ukraine Bogolyubov Programme on Theoretical Physics.

Scientific Schools for Teachers of Physics at JINR and CERN. The JINR UC in collaboration with CERN continues organizing international scientific schools for teachers of physics from JINR Member States at JINR and CERN (http://teachers.jinr.ru/).

On 22–29 March, the school at CERN was attended by 23 physics teachers from Astana and Almaty, Kharkov, Alushta, Moscow and St. Petersburg, as well as from the Arkhangelsk, Bryansk, Ivanovo, Kostroma, Nizhny Novgorod, Sverdlovsk, and Smolensk regions.

The school in Dubna was held on 21–27 June. The feature of the schools held at JINR is the fact that not only teachers, but also their students can participate in the event. In 2015, the school was attended by 25 teachers and 11 students from Belarus, Bulgaria, Kazakhstan, Russia, and Ukraine. The Russian Federation was represented by teachers and students from Moscow and the Moscow Region, St. Petersburg, Crimea, Karelia, Krasnoyarsk Territory, the Novgorod, Omsk, Tambov and Volgograd regions, Tatarstan, and Khakassia.

On 28 June – 3 July, on the proposal and with direct financial support of the Moscow City Teacher's House the school for 16 Moscow teachers was held at JINR for the second time.

On 1–8 November, the school at CERN was attended by 43 physics teachers from RF, Belarus, Ukraine, and Switzerland. Russia was represented by teachers from Moscow, the Moscow Region, St. Petersburg, as well as from the Voronezh, Irkutsk, Kirov, Novosibirsk, Nizhny Novgorod, Samara, Smolensk, Tomsk, and Chelyabinsk regions, and from Bashkortostan, Tatarstan, Chuvashia, Krasnodar Krai, and Primorsky Krai.

Physics Days. On 27–29 March, Dubna hosted Physics Days. The organizers were the JINR UC, the Interschool Mathematics and Physics Optional Course, and University "Dubna". For physics amateurs of all ages, entertaining demonstrations of physical and chemical experiments and their discussion, mathematical games, competitions, workshops, lectures, and a meeting with the representatives of a scientific magazine for school students "Kvantik" were organized.

Video Conferences. The JINR UC continues organizing and providing assistance in the running of video conferences, as well as in the broadcasting through the JINR system of video-conference management. In 2015, the following video conferences were held:

- a video conference between CERN and the teachers of physics from the Republic of Karelia;
- meetings of the joint seminar "Physics at the LHC";
- a video conference "Research in High Energy Physics" in the framework of the 5th All-Russia Science Festival held at the Palace of Pioneers in Moscow;
- a virtual tour of the CMS experiment at the Large Hadron Collider for the participants of the International Experimental Physics Olympiad (IEPhO-2015) at the Educational Centre "Sirius" (Sochi) and students of the European Gymnasium (Moscow).

School for Tour Guides On 24–26 February, JINR together with the Administration of Dubna ran the School for Tour Guides. Twenty-seven participants became familiar with the history of Dubna and JINR, work of the well-known scientists, and JINR fields of research. They also visited the basic facilities of the Institute.

Visits. In 2015, the UC organized visits to JINR for school and university students from Dolgoprudny (38 people), Dubna (34), Moscow (132), and Dmitrov District (20). The programmes of the visits included lectures about JINR, excursions to the basic facilities of the Institute, hands-on activities in the UC physics lab, an excursion to the educational centre named after A. N. Sissakian, and maths competitions. Seventeen chemistry teachers from Dmitrov district visited FLNP.

One-week introductory training programmes were developed for 19 high school students from Arkhangelsk, 28 students from Veliky Novgorod, and 14 German school students, members of the J. Kennedy Physics Club (Berlin, Germany).

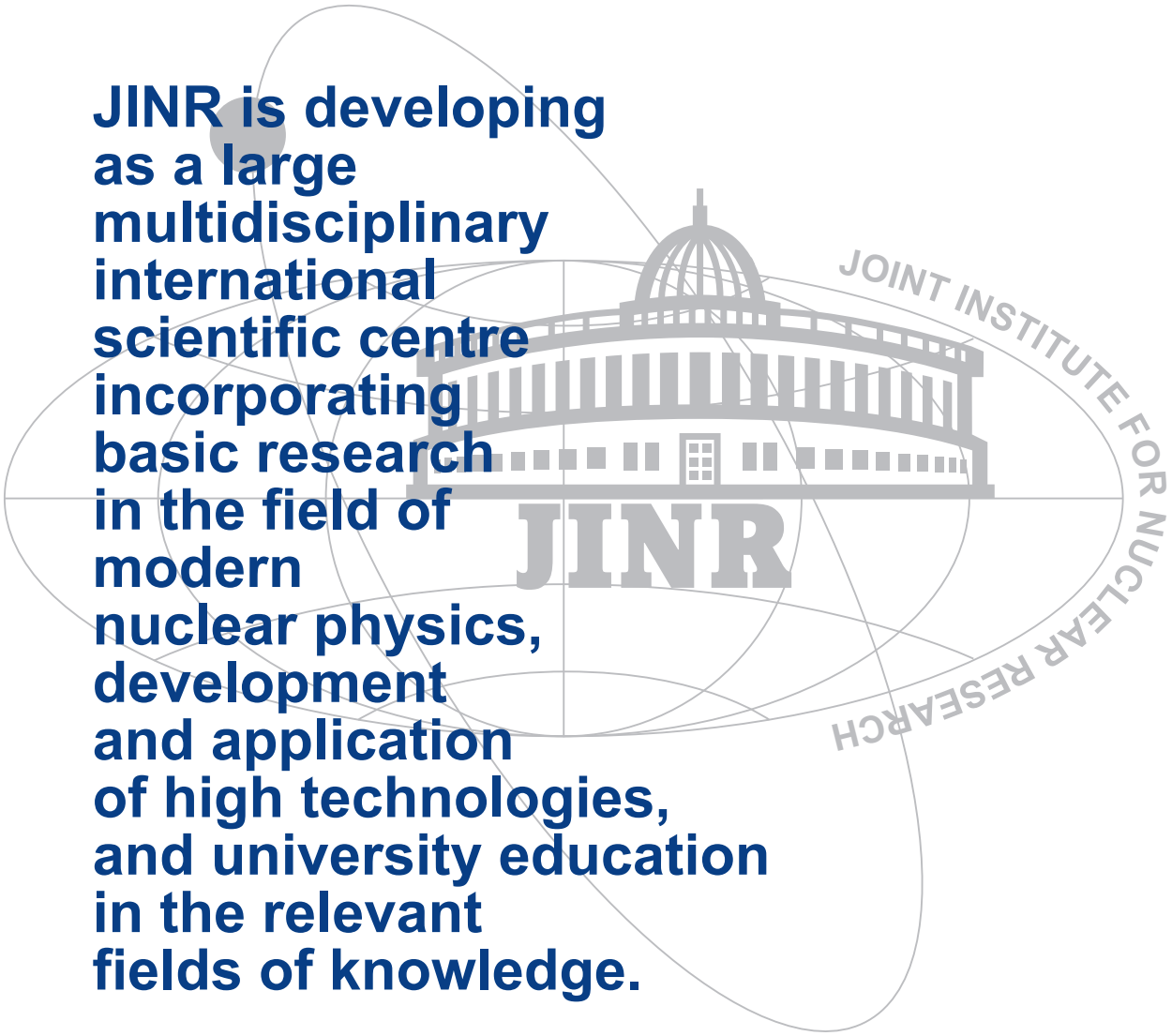
Work with School Students. Twice a week during the academic year, 38 high school students from Dubna attend physics classes, including workshops and experimental demonstrations in the UC physics lab, as well as classes dedicated to training for the Unified State Examination.

Advanced Training and Skill Improvement of Workmen, Engineers, Technicians, and Staff Members. Sixty-three workmen were trained at the courses for the personnel maintaining the facilities subordinate to Rostechnadzor. In 2015, eight staff members of the Institute improved their skills at various seminars organized by Moscow educational institu-

tions. Eighty-seven JINR staff members were trained at the courses organized at JINR and certified by the Central Attestation Commission of JINR. In 2015, certification of 24 Institute top executives and specialists in the normative legal acts and normative-technical documents stating requirements for industrial safety in various sectors of supervision was done by the Territory Certification Commission of Rostechnadzor. One hundred and ten employees were trained at JINR and certified by the Central Attestation Commission of JINR in the new rules on labour protection when working at heights. The JINR UC trained 24 employees of Dubna organizations in the occupations subordinate to Rostechnadzor of RF. In 2015, eight students from the Moscow Region Industrial Economic and Agrarian-Technological Colleges were trained at JINR.

In 2015, the English language course at the JINR UC was attended by 69 JINR employees; the German language course, by 27; the French course, by 17. Fifteen foreign specialists studied Russian.

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, 2 December.
Seminar in memory of V. Kadyshevsky

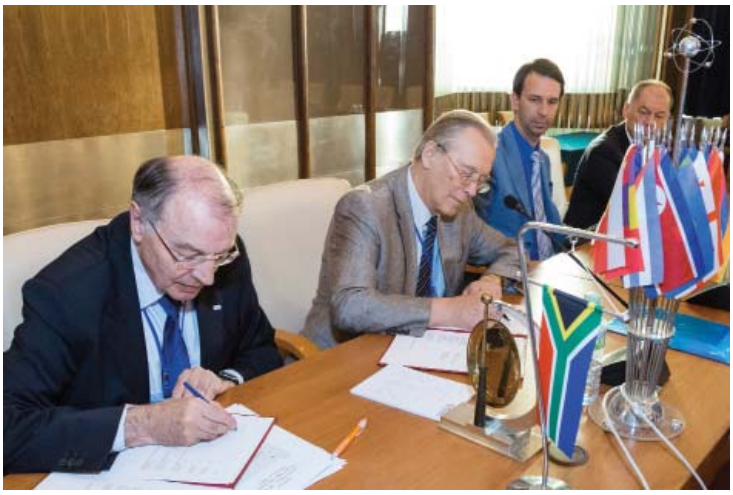
The Bogoliubov Laboratory of Theoretical Physics, 16–20 February.
The XIX International Scientific Conference for Young Scientists dedicated
to the centenary of the birth of Corresponding Member of the USSR Academy of Sciences F. Shapiro

Dubna, 21–25 September. The IV RSA–JINR Symposium "Few- to Many-Body Systems: Models, Methods and Applications"

The Bogoliubov Laboratory of Theoretical Physics, 14–18 July.
The International Conference "Nuclear Structure and Related Topics" (NSRT-15)

The Veksler and Baldin Laboratory of High Energy Physics,
18–20 October. Meeting of the MAC board on NICA

The Veksler and Baldin Laboratory of High Energy Physics, 6–11 July.
Participants of the International Conference “Strangeness in Quark Matter” (SQM-2015)



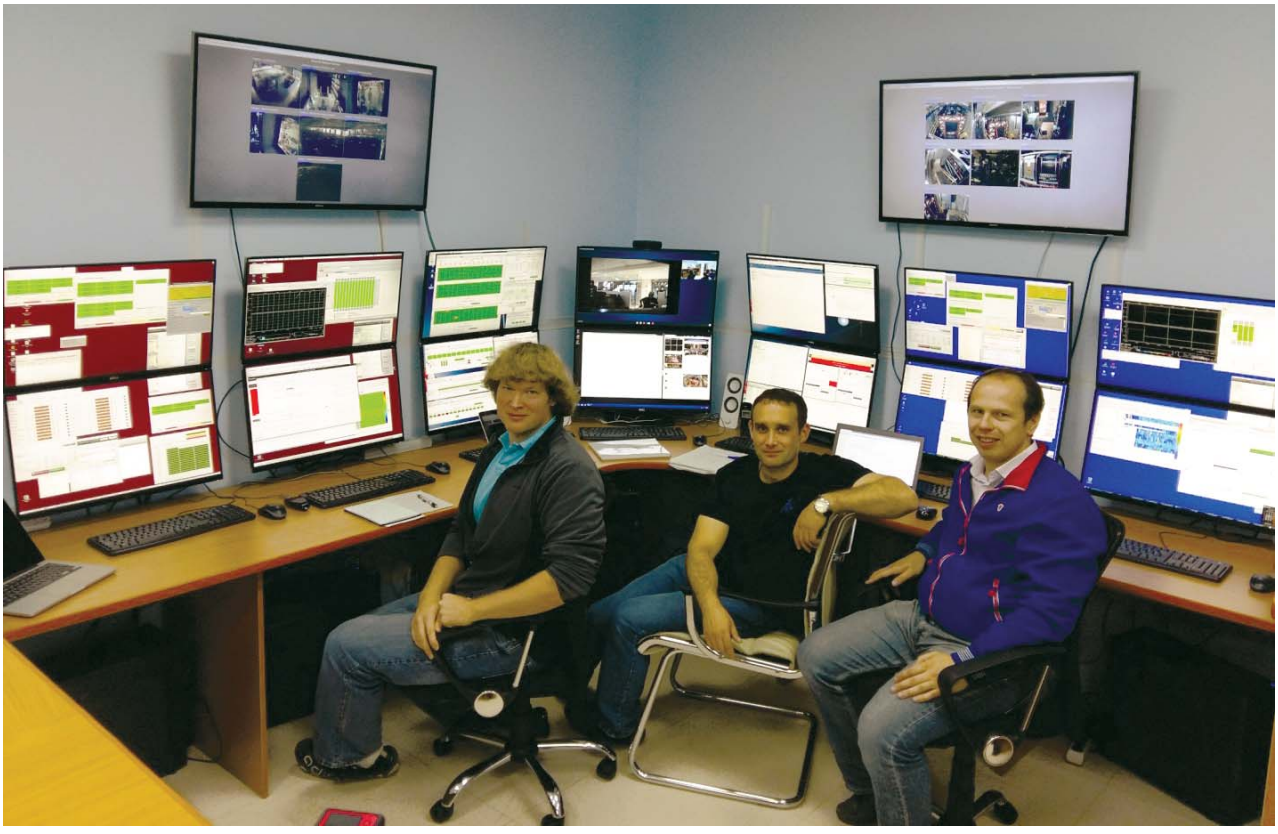
Dubna, 5 July.
Round-Table Discussion
“Physics at NICA”. Signing of a memorandum on JINR–RSA cooperation

Dubna, 3 February.
Guests from France — participants of the Joint Committee on JINR–IN2P3 (France) cooperation on an excursion at the Veksler and Baldin Laboratory of High Energy Physics

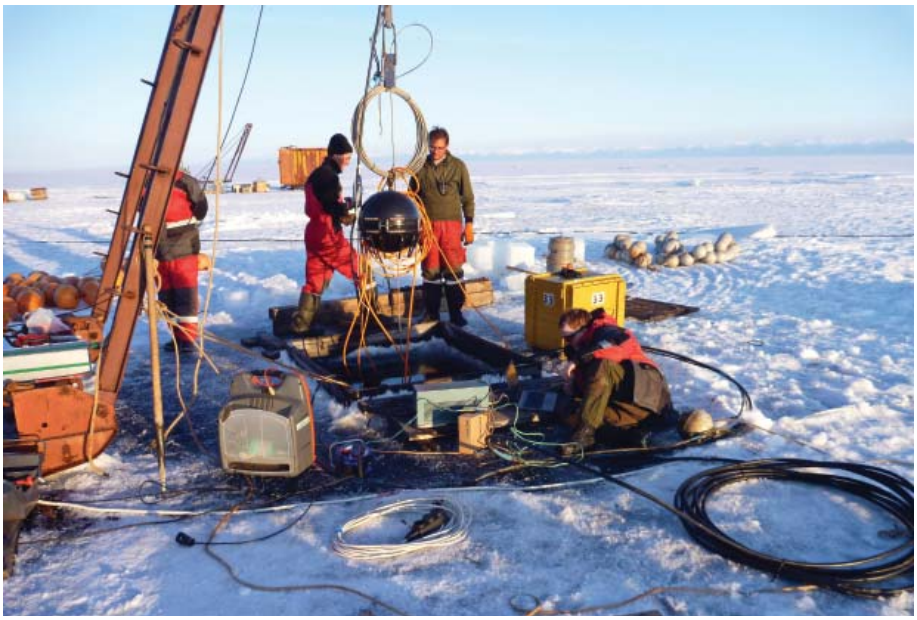
The Veksler and Baldin Laboratory of High Energy Physics, 14–18 September.
Participants of the Forum on Development of JINR–Czech Republic Cooperation on an excursion

The Dzhelepov Laboratory of Nuclear Problems. From left to right: Laboratory Director V. Bednyakov and the authors of the invention “A Device for Measurement of the Inclination Angle” Professor Ju. Budagov and Candidate of Physics and Mathematics M. Lyablin

Remote Operations Control Centre for the NOvA experiment at JINR (ROC–Dubna)



The Dzhelepov Laboratory of Nuclear Problems. JINR staff members who made a principle contribution to the development of the experiment on measuring the polarized pion and analysis of the results Z. Krumshtein, A. Olshevsky, and A. Guskov



Assembling a string of optical modules of the Baikal-GVD neutrino telescope

A team of participants to launch the deep underwater neutrino telescope of the multi-megaton scale “Dubna” at Lake Baikal

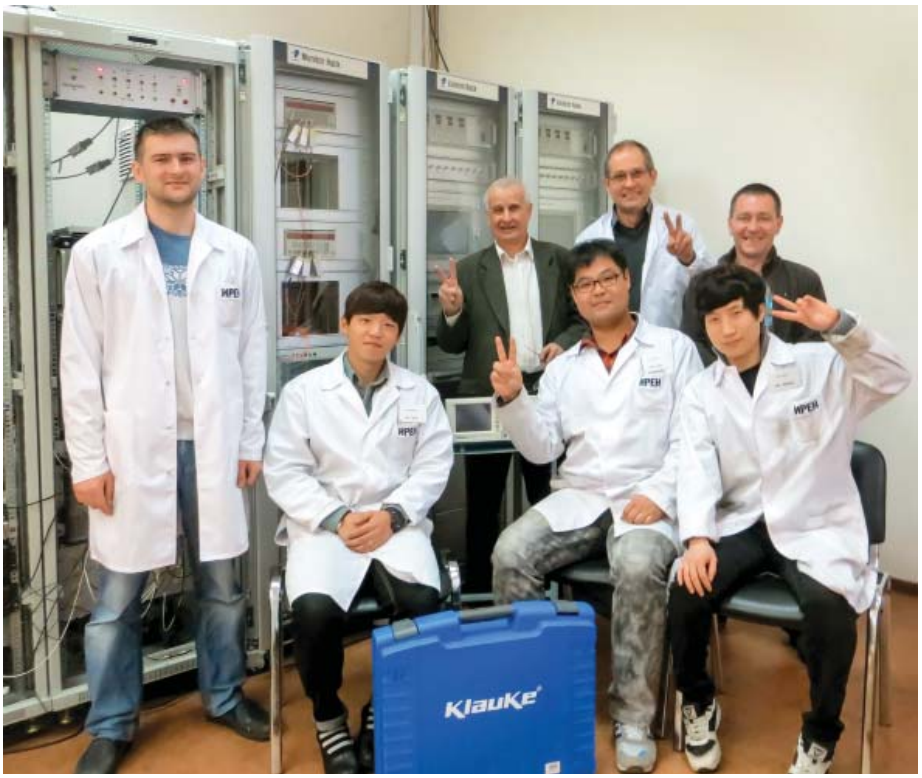
The Flerov Laboratory of Nuclear Reactions, 31 July. Minister-Counselor for technology, science and education of the Embassy of the Bolivarian Republic of Venezuela E. Vivas (centre) on an excursion

Dubna, 30–31 May. Director of the Atomic Energy Authority of Arab countries A. Mahdjub on a visit to JINR: at the Flerov Laboratory of Nuclear Reactions

Dubna, 4 December. Meeting of the Council on Heavy-Ion Physics under the RAS Presidium chaired by RAS Academician Yu. Oganessian

Varna (Bulgaria), 6–12 September. Participants of the International Symposium on Exotic Nuclei

The Frank Laboratory of Neutron Physics, 9–14 November.
The 6th International Scientific School “Instruments and Methods of Experimental Nuclear Physics. Electronics and Automation of Experimental Facilities”



The Frank Laboratory of Neutron Physics. The team LHEP–LNP–Dawonsys after the first launch of the modulator

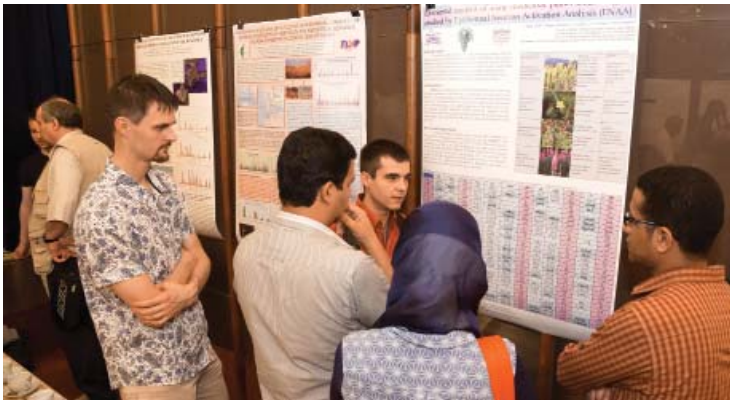
The Frank Laboratory of Neutron Physics. Assembling of new modulators for the IREN facility

The Frank Laboratory of Neutron Physics. Researchers of the Sector of Neutron Optics adjusting the GRAINS reflectometer. The reflectometric cell of the solid–liquid type where single crystal silicon is used as a substrate is being mounted *(Photo by M.Avdeev)*

Dubna, 23 October. Director of the Leon Brillouin Laboratory (Saclay, France) Ch. Alba-Simionesco speaking at a seminar at the Frank Laboratory of Neutron Physics

The Frank Laboratory of Neutron Physics, 7 August. Ambassador Extraordinary and Plenipotentiary of the Republic of Turkey in Moscow Ü. Yardim (third right) and accompanying persons on an excursion

Dubna, 24 March. Opening of the exhibition dedicated to the centenary of the birth of one of the founders of the Laboratory of Neutron Physics, Corresponding Member of the USSR Academy of Sciences F. Shapiro (1915–1973)



Dubna, 25–29 May. The 23rd International Seminar on Interaction of Neutrons with Nuclei (ISINN)

The Laboratory of Information Technologies, 5 February.
A Seminar on the Heterogeneous Cluster HybriLIT

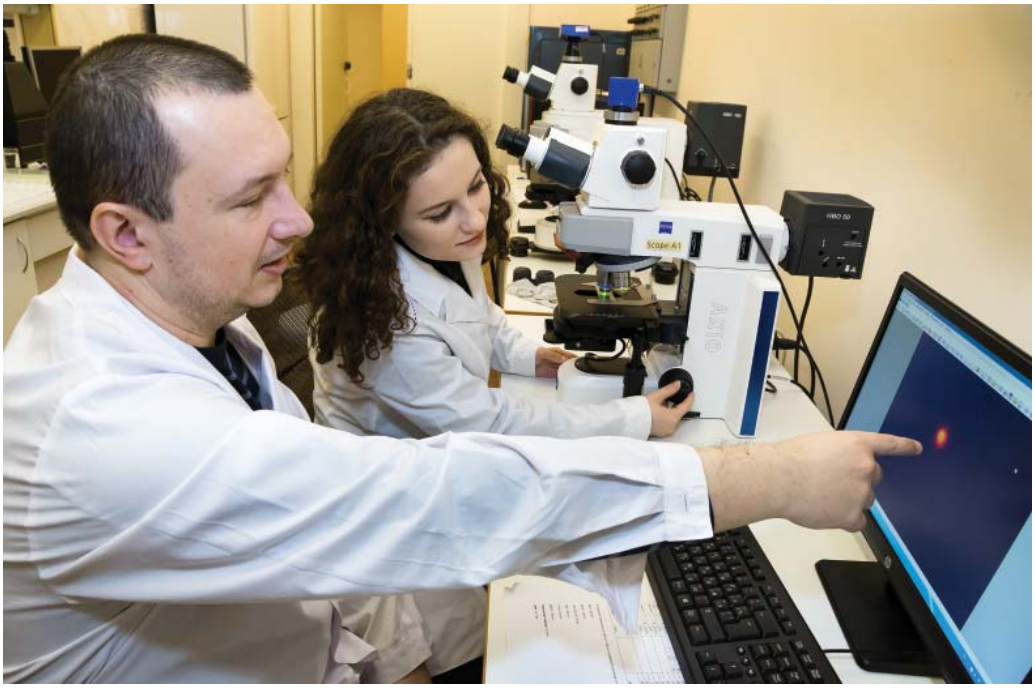
Dubna, 2–6 November. Participants of the International JINR–CERN School on Information Technologies "Grid and Advanced Information Systems"

Laboratory of Radiation Biology. From left to right: Academicians of RAS V. Matveev, M. Ostrovsky, A. Rozanov, and Corresponding Member of RAS E. Krasavin

Dubna, 28–30 October. Participants of the Conference
"Modern Trends in Radiobiology and Astrobiology. Molecular, Genetic, Cell and Tissue Effects"

Laboratory of Radiation Biology. Participants
of the JINR International Student Practice

Laboratory of Radiation Biology.
Experiments in the group of molecular biology



High Tatra Mountains (Stará Lesná, Slovakia), 13–17 July. Participants of the 8th International Conference "Mathematical Modeling and Computational Physics" (MMCP'2015)

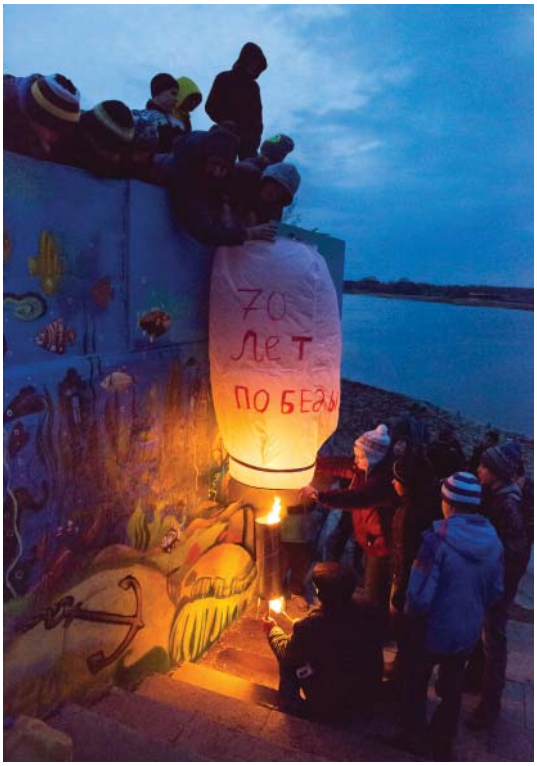
Moscow, 10 November. The laureates of the annual award of the Moscow Region Governor in science and innovations for young scientists and specialists, including young staff members of LIT, JINR (row one): D. Pryakhina (first left), A. Nechaevsky (second left) and O. Derenovskaya (fifth left)

Dubna, 26 May – 11 June. Students from ARE — participants of the first stage of the International Student Practice, at the Veksler and Baldin Laboratory of High Energy Physics

Dubna, 7–25 September. International practice courses for RSA students

Dubna, 21–27 June. Physics teachers from the JINR Member States at a lecture at the Flerov Laboratory of Nuclear Reactions

Dubna, 27–29 March. Days of Physics organized by the JINR UC, the interschool additional course of physics and mathematics and the University “Dubna”



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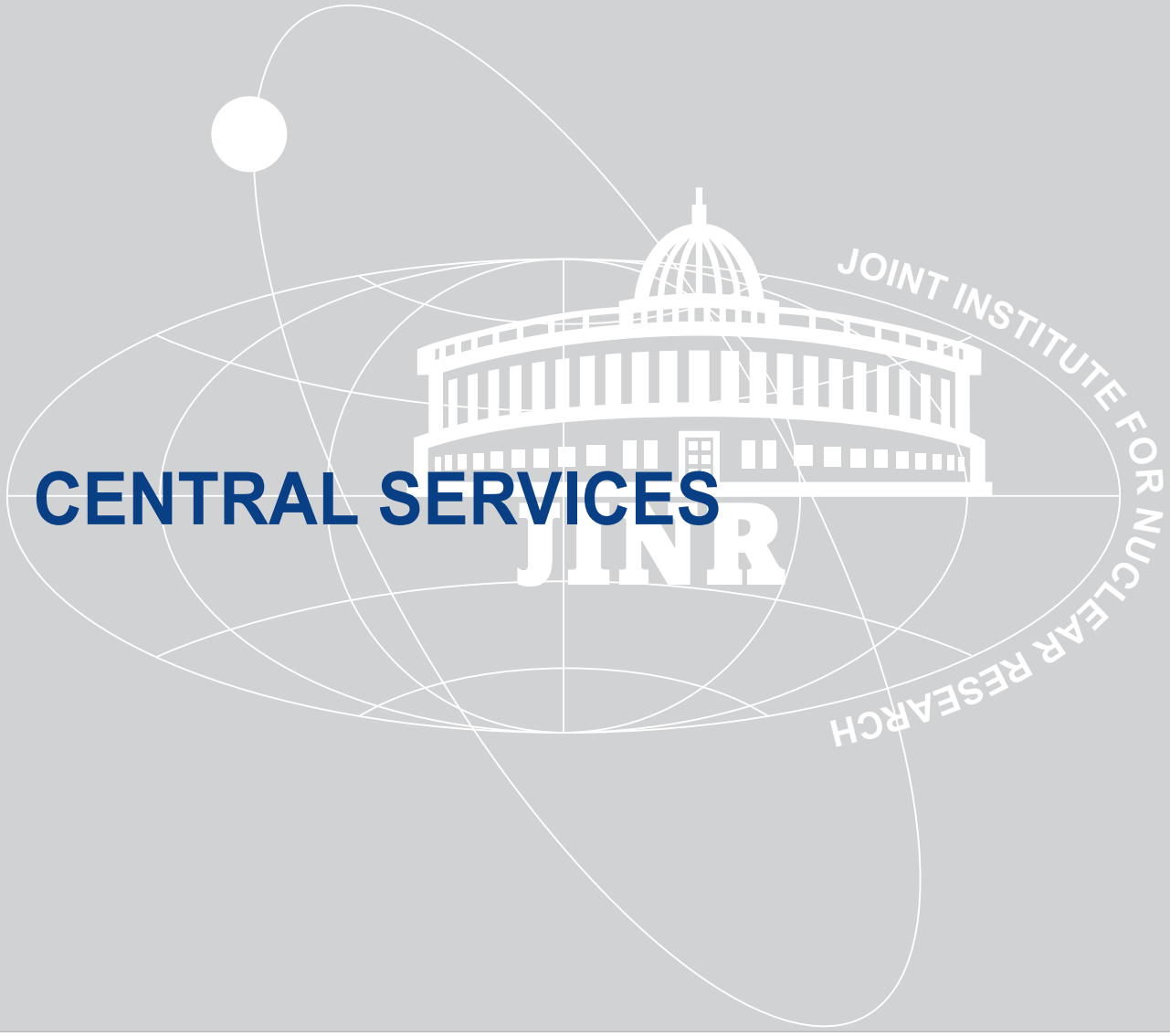

CENTRAL SERVICES

PUBLISHING DEPARTMENT

In 2015, the Publishing Department issued 106 titles of publications and 58 titles of official documents.

Among published in 2015 books of abstracts and proceedings of various conferences, schools and workshops, organized by JINR, are the following ones: the Book of Abstracts of the International Conference "Condensed Matter Research at the IBR-2" (Dubna, 11–15 October 2015), the Book of Abstracts of the International Conference dedicated to the 90th anniversary of Professor V. Soloviev "Nuclear Structure and Related Topics" (Dubna, 14–18 July 2015), the Proceedings of the XII International School-Seminar "Actual Problems of Microworld Physics" (Gomel, Belarus, 22 July – 2 August 2013), the Proceedings of the International Workshop "Status and Prospects of Creating of Resonators for New Generation of e^+e^- Linear Accelerators and Colliders" (Minsk, 22–25 April 2014), the Proceedings of the XXII International Seminar on Interaction of Neutrons with Nuclei (ISINN-22) (Dubna, 27–30 May 2014), the Proceedings of the Conference "Modern Trends in Radiobiology and Astrobiology. Molecular, Genetic, Cell, and Tissue Effects" (Dubna, 28–30 October 2015), and others.

The JINR Annual Report for the year 2014 (Russian and English versions) and the Annual Report of the Frank Laboratory of Neutron Physics of JINR for the year 2014 were published.

In 2015, the monograph by E. Syresin "Proton and Ion Therapy", which discusses ionizing effect of charged particles on the tumour, technology, results of treatment, as well as accelerating technique for proton and ion therapy, was published. For the preparation and publication of this book, the Publishing Department of JINR was awarded the Diploma of the Winner of the international competition for the best science-and-publishing project "Scientific Book" in nomination "Natural Science".

To the jubilee of the Laboratory of Radiation Biology the book "Radiobiological Research at JINR" was published, where the history of the Laboratory establishment and modern directions of research are considered. The book is presented to the reader in the Russian and English languages.

Among other publications of the year 2015 are "Technical Project of Accelerating Complex NICA" in four volumes, "History of JINR Establishment in Decisions of the Central Committee of the Communist Party of the Soviet Union. 1955–1958", book by M. Smondyrev "Self-Portrait in Five Dimensions".

In the series of the JINR UC study guides, the manual "Technologies of Intellectual Computing. Quantum Computing and Programming in Self-Organizing Intellectual Control Systems" by S. Ulyanov, A. Reshetnikov, and G. Reshetnikov was issued.

In 2015, six issues of the journal "Physics of Elementary Particles and Atomic Nuclei" that included 69 reports, as well as seven issues of the journal "Physics of Elementary Particles and Atomic Nuclei, Letters" that included 118 papers, were published.

The information bulletin "JINR News" was continued to be published in Russian and English. Fifty issues of the JINR weekly newspaper "Dubna: Science, Cooperation, Progress" were published in 2015.

In the framework of exchange of scientific publications, the organizations that cooperate with JINR (in above 40 countries of the world) received JINR publications: JINR preprints and communications, the information bulletin "JINR News", JINR Annual Reports, the journals "Par-

ticles and Nuclei" and "Particles and Nuclei, Letters".

The Publishing Department forwarded over 180 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 Modeling", 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 2014" was issued. Publication of express bulletins of the Licensing and Intellectual Property Department was continued.

The Publishing Department fulfilled numerous orders of the Laboratories to produce posters, Xerox copies and book binding. Over 175 thousand various forms were printed.

SCIENCE AND TECHNOLOGY LIBRARY

In 2015, the JINR Science and Technology Library (STL) rendered services to 2740 readers. 9400 copies of publications were given out. As of 1 January 2016, the Library stock amounted to 438 183 copies, 192 275 of them being in foreign languages. 358 publications ordered by readers were received via the interlibrary loan system. On the whole, the Library received 3071 copies of books, periodicals, preprints, and theses from all compiling sources, including 1345 publications in foreign languages. All the new publications were registered in the central catalogues, branch catalogues, and in the Absotheque information system.

The weekly express bulletins "Books", "Articles", and "Preprints" (156 issues) were published, including 8085 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. They displayed 2380 publications. Five 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 our users.

"The Bibliographic Index of Papers Published by JINR Staff Members in 2014" (1510 titles) was prepared by the JINR Science and Technology Library and published by the JINR Publishing Department. The Index is available on the STL website in the section "Services". The database of papers of JINR scientists is Internet accessible.

927 JINR preprints and communications have been scanned and added to the electronic catalogue.

The STL received 150 titles of periodicals. Due to the Library subscription to the foreign journals, JINR scientists have access to the full-text online versions of these journals.

The Scientific Electronic Library is used by our 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 Consortia, JINR scientists are provided with the electronic access to the full-text versions of journals of the publishing houses Elsevier, Springer, of the American Physical Society, American Institute of Physics, and Nature Publishing Group, as well as to journal "Science" and information retrieval databases "Web of Science" and "MathSciNet".

Within the framework of the project "History of JINR and Dubna in Books, Journals, and Central Newspapers", 42 new bibliographic records have been introduced.

In 2015, in exchange for JINR publications printed by the JINR Publishing Department, the Library received 502 publications from 17 countries. Of them 118 issues were from Russia, 12 from Romania, 5 from Ukraine, 202 from Germany, 9 from France, 36 from Japan, and 33 from CERN.

In 2015, within the framework of the Absotheque information system, the input of documents to electronic catalogue was for: books — 1390 titles, journals — 2438 numbers, preprints — 1910 titles, theses and authors' abstracts — 126 titles, book articles — 872 titles, and journal articles — 7393 titles.

As of 1.01.2016, the total number of records in the Absotheque information system was 253 407.

LICENSING AND INTELLECTUAL PROPERTY DEPARTMENT

In 2015, the activities of the Licensing and Intellectual Property Department (LIPD) were conducted in the following areas:

Industrial Intellectual Property Protection. Work was done on applications for JINR patents that had undergone the formal FIIP (Federal Institute of Industrial Property) expertise of Rospatent in 2014–2015.

Arrangements were done, changes, alterations, and clarifications were agreed upon and included into 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; analogues and prototypes were searched. Reports on patent studies were prepared.

For seven elaborations, together with the authors, descriptions and invention formulae were compiled; application packets were prepared and sent to the RF Rospatent to obtain the patents for:

— "Coordinate gas-filled detector";
— "A method to measure the neutron transmitted pulse spectrum";
— "A method and device to measure the neutron beam profile";
— "A method of synchronized acceleration of charged particles in the permanent magnetic field";
— "A method of adjustment of the high-frequency resonator to resonance frequencies with given ratio";
— "Induction synchrotron with permanent magnetic field";
— "A method to produce carrier-free Ag radioisotopes".

In 2015, work was completed on applications sent earlier, and 10 RF patents for invention were obtained:

— "A device to measure the tube stretch in STRAW detectors" by A. Volkov;
— "A method to manufacture an adapter to connect resonator with case of the collider cryomodule" by B. Sabirov, G. Shirkov, Yu. Budagov, G. Trubnikov, E. Pekar, L. Dobrushin, S. Illarionov, and A. Bryzgalin;
— "A method to produce mono- and oligopore membranes" by P. Apel, S. Dmitriev, O. Ivanov, and A. Nechaev;
— "A graphene-based tunnel field transistor" by V. Katkov and V. Osipov;
— "A method of axial beam injection into a compact cyclotron with superhigh magnetic field" by S. Vorozhtsov and V. Smirnov;
— "A method to measure fast neutron fluence with a semiconductor detector" by N. Zamyatin, A. Cheremukhin, and A. Shafranovskaya;
— "A device to produce cylinder tubes for gas-filled drift detectors of ionizing radiation" by S. Movchan, V. Elshi, Yu. Ershov, S. Shkarovsky, Yu. Potrebenikov, V. Kekelidze, E. Kislov, T. Enik, N. Azorsky, and A. Kolesnikov;
— "A method to accelerate a body" by S. Dolya;
— "A method to determine density space distribution in nanolayer" by Yu. Nikitenko;
— "An analyzer of substance composition" by V. Shalyapin ans S. Tyutyunnikov.

As of 1 January 2016, JINR possesses 60 RF patents in force for invention.

Patents and Information. In 2015, 36 issues of the Rospatent official gazette "Inventions. Utility Models" were received at JINR. 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 Department stock is 3235 Rospatent bulletins.

Standardization. Standard library was supplemented with: 35 new intergovernmental and state RF standard documents (GOSTs), 12 GOST directories and standard information directories for 2015, directories of national standards and technical conditions, guidelines, recommendations, and regulations issued in 2015. Over 308 alterations were introduced into relevant documents of the standard library files and subscribers' copies on the basis of these norm documents (ND).

Forty-two GOST official copies were distributed in departments for permanent use. Departments regularly obtained information on new ND and alteration in GOSTs.

Database and automatic search for norm documentation were enriched on the basis of the LIPD archives. The access to the database (about 12 000 positions) was organized on the internet page of LIPD.

"The Catalogue of Normative Legal Acts and Norm Documentation Used at the Joint Institute for Nuclear Research" was regularly updated in the database, with urgent references to the legal reference system KONSULTANT PLUS as of the end of 2015. Over 3000 references were added to the electronic index.

Data on intergovernmental standards (GOST), national standards of the Russian Federation (GOST R), and other normative-technical documentation applied at the Joint Institute for Nuclear Research were updated, as of 2015.

Together with the Department of Labour Protection, the organization standard STO 08626319-010-2015 "Provisions on labour protection organization, responsibilities, rights, and charges of administrative technical personnel for provision requirements of labour protection at the Joint Institute for Nuclear Research (P1)" was developed and introduced.

Alterations were introduced into the index of licenses received from the RF federal bodies for authorization for business connected with accomplishment of JINR Charter functions.

2015

ADMINISTRATIVE ACTIVITIES

FINANCIAL ACTIVITIES

Budget Implementation. In total, in 2015, resources of 132.4 M$ arrived at JINR, that makes 73% of the scheduled budget incomes.

Comparing to 2014, the contribution payment was more regular. Practically all Member States paid a half of the contribution in the first part of the year; that is in accordance with the Principles of contribution payment established in the Financial Protocol of JINR.

Three priority directions of expenses were indicated in the 2015 budget:

— financing of scientific projects of the Institute in development and refurbishment of basic facilities, expenses for their maintenance in accordance with the scheduled amounts;
— provision for wages growth not lower than those in the region of JINR location;
— provision for operation of engineering and social infrastructure.

The main part of material expenses in 2015 was directed to the implementation of scientific projects of JINR, such as:

— development of the accelerator complex NICA;
— development of the cyclotron complex DRIBs-III;
— neutrino programme;
— upgrading of the nuclear research facility IBR-2 and research spectrometers;
— information, computer, and network support of JINR activities.

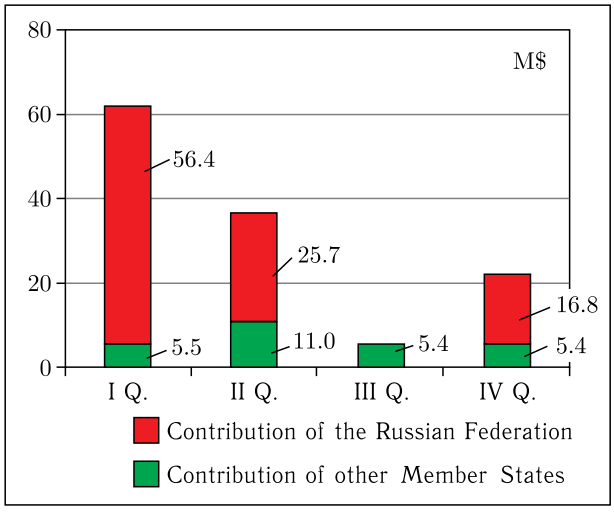

Fig. 1. Quarterly arrival of contributions by the Member States in 2015

According to the accounting report, the actual expenses of resources in 2015 totaled to 168.7 M$, at 182.6 M$ scheduled, i.e., are executed in 92%.

The main budget expenses are concentrated on two consolidated items: "Personnel" and "Material Expenses, Research&Development, Construction" that are about 80% of all budget expenses.

The expenses on "Personnel" are one of the largest parts of the budget expenses. Their fraction in the actual amount of 2015 is 40.5%. In total, 68.3 M$ were spent for personnel in 2015.

Chapter 1		Chapter 2		Chapter 3		Chapter 4		Total on chapters 1–4	
Scientific research		Basic facilities		Laboratory infrastructure		JINR infrastructure			
Schedule	De facto	Schedule	De facto	Schedule	De facto	Schedule	De facto	Schedule	De facto
122 481.3	107 096.4	10 753.2	9 241.2	24 437.7	22 890.8	26 467.0	29 479.1	184 139.2	168 707.5

The actual expenses for international cooperation were 9.9 M$. About a third of these expenses were executed at the expense of the means from the countries that concluded agreements on cooperation with JINR, as well as at the expense of financing cooperation programmes with scientific organizations from the Member States.

The consolidated item "Material Expenses, Research&Development, Construction" that included expenses to finance development and upgrading of the experimental base of JINR was 65.6 M$.

10.1 M$ were spent in 2015 on basic repair and maintenance. 5.6 M$ in it were used by Laboratories for buildings repair in the sites of the Institute.

4.5 M$ were used for repair of buildings and constructions of the all-Institute infrastructure. In particular, social constructions outside the Institute territory were also repaired.

The choice of infrastructure sites for repair was mainly related to the preparation of the celebration of the 60th jubilee of the Institute. They were primarily "User-Office", the "Dubna" Hotel, the Culture Centre "Mir", the JINR International Conference Hall, and the JINR Museum.

To improve housing conditions of JINR staff members and students, large-scale repair work was conducted in premises of the JINR hostel in Leningradskaya street, building 10, and of the front of the hostel in Mokhovaya street, building 6.

Much repair work was done in sports grounds of the stadium "Nauka". A football pitch with artificial turf and illumination was opened, and a hockey pitch was reconstructed.

The year 2016 will crown the Seven-Year Plan of the Institute Development (2010–2016); the results of the programme will much depend on the activities in this year, especially in upgrading of the JINR experimental base.

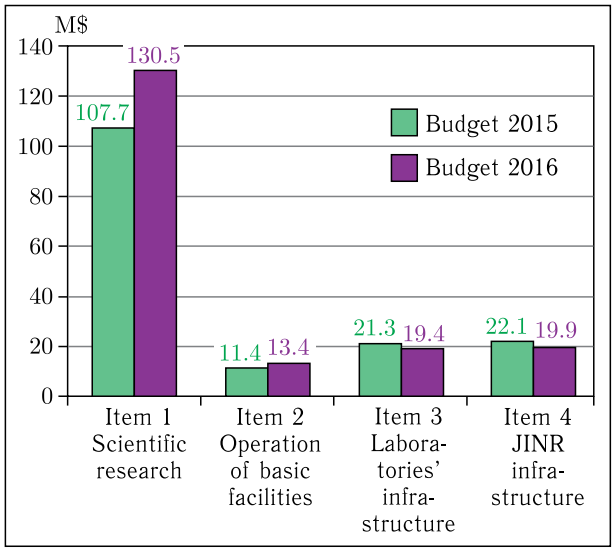

Fig. 2. Comparison of scheduled expenses in budget items of 2015 and 2016

In 2016, the expenses are greatly increased in the consolidated item "Material Expenses, 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.

STAFF

As of 1 January 2016, the total number of the staff members at the Joint Institute for Nuclear Research was 4801.

Working at JINR are: RAS Academicians V. Matveev, Yu. Oganessian, M. Ostrovsky, D. Shirkov; RAS Corresponding Members V. Aksenov, E. Krasavin, I. Meshkov, A. Starobinsky, G. Trubnikov, G. Shirkov; Members of other state Academies of Sciences I. Zvara, R. Mir-Kasimov, A. Hrynkiewicz, B. Yuldashev; 248 Doctors of Science, 599 Candidates of Science, including 68 Professors and 22 Assistant Professors.

In 2015, 521 people were employed and 418 people discharged because of engagement period expiry and for other reasons.

AWARDS

By the Decree of the RF President, S. Mazurenko was awarded ***the Order of Friendship*** for effective work at JINR.

The title ***"Honorary Doctor of JINR"*** was conferred on N.-V. Zamfir (Romania), Yu. Oganessian (Russia), I. Tiginyanu (Moldova), V. Fortov (Russia), P. Fré (Italy), R.-D. Heuer (Germany), Dzh. Hubua (Georgia), and H. Stöcker (Germany), for outstanding services to JINR in development of priority trends in science and technology, and training scientific staff.

The title ***"Honorary JINR Staff Member"*** was conferred on three JINR staff members, for the services to JINR and long-standing fruitful work. In 2015, one JINR staff member was awarded the departmental badge of Honour in Labour ***"Veteran of Atomic Energy Industry"***. A number of staff members of the Institute were presented other departmental, city, and Institute awards.

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