JOINT INSTITUTE FOR NUCLEAR RESEARCH

International Intergovernmental Organization

Main themes and projects of the Seven-Year Plan for the Development of JINR For 2024–2030

Sergey Nedelko

58th meeting of the PAC for Nuclear Physics

January 29, 2024


Joint Institute for
Nuclear Research
SEVEN-YEAR
PLAN FOR THE
DEVELOPMENT
OF JINR
FOR 2024–2030


JOINT INSTITUTE FOR
NUCLEAR RESEARCH
TOPICAL PLAN
FOR JINR RESEARCH
AND INTERNATIONAL COOPERATION
2024

JINR's position among international intergovernmental scientific organizations (IISO)

2 in terms of the number of personnel among all IISO

5 in terms of budget size among IISO in the field of natural sciences

8 in terms of budget size among all IISO

Publications (Scopus)	JINR	CERN
2003-2022	**26066**	**31988**
2022	1335	1424
2021	1449	1392
2020	1595	1577
2019	1616	1689

No.	International intergovernmental scientific organization	Annual budget 2022, kUS$	Personnel 2022
1	European Space Agency	7 534 670	2 200
2/1	**CERN**	**1 472 685**	**12 200**
3	UNESCO	750 000	2 290
4	Joint Research Centre	603 617	2 750
5	European Molecular Biology Laboratory	336 162	1 980
6	European Southern Observatory	270 089	700
7	COMSTECH	225 865	
8/2	**JINR**	**221 600**	**5100**
9	Square Kilometer Array	184 350	
10	European Spallation Source	153 379	522
11	European Synchrotron Radiation Facility	149 296	717
12	Institut Laue-Langevin	129 537	563

7-YEAR JINR DEVELOPMENT PLAN FOR 2024–2030

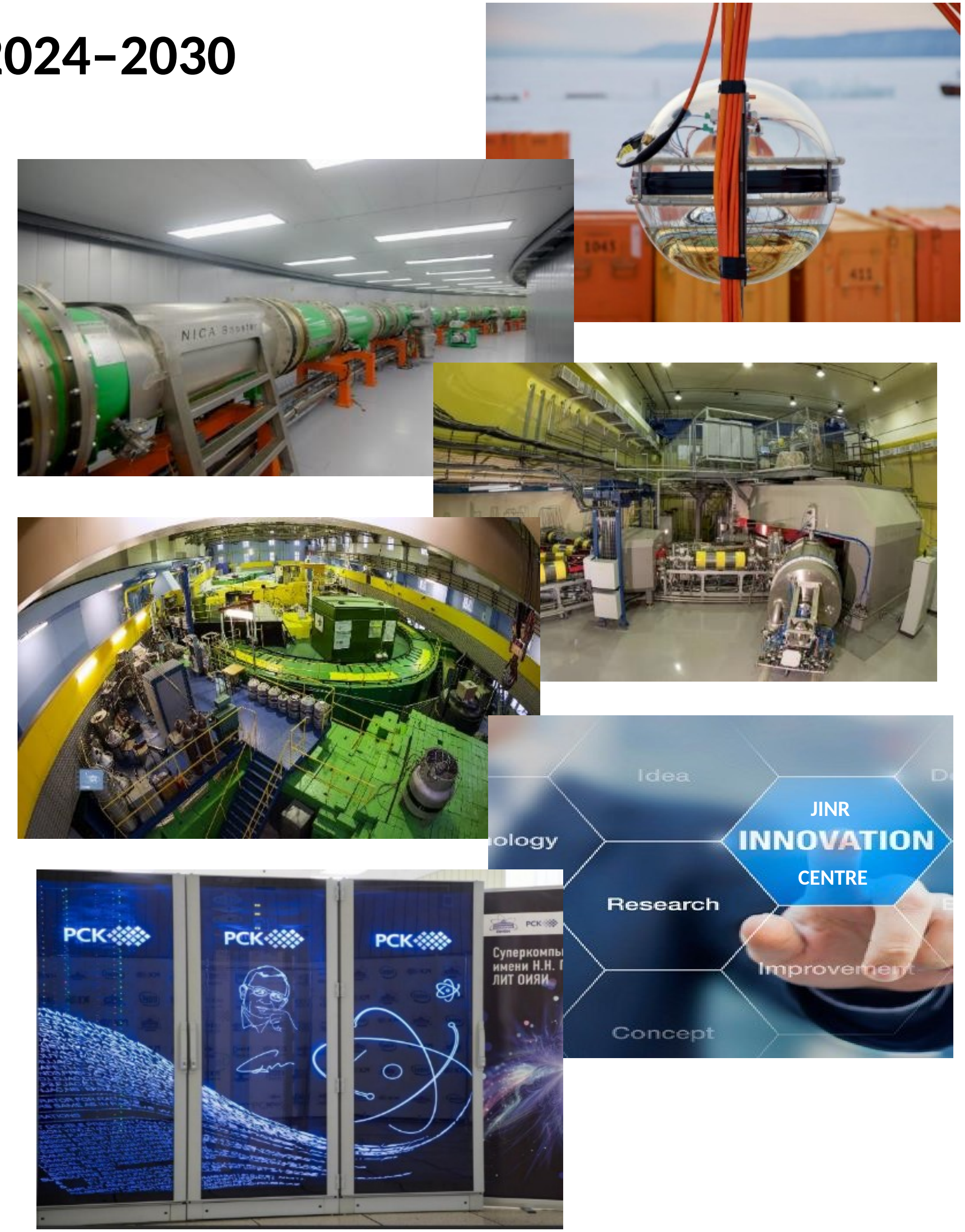
DEVELOPMENT OF LARGE RESEARCH INFRASTRUCTURE:

- NICA collider and experiments MPD, SPD, ARIADNA
- DRIBs-III (Factory STE, U-400R, DC-140, RHL-1 class)
- IBR-2M, New neutron source
- Telescope BAIKAL-GVD

WORK OF INTERNATIONAL COLLABORATIONS, NEW COUNTRIES

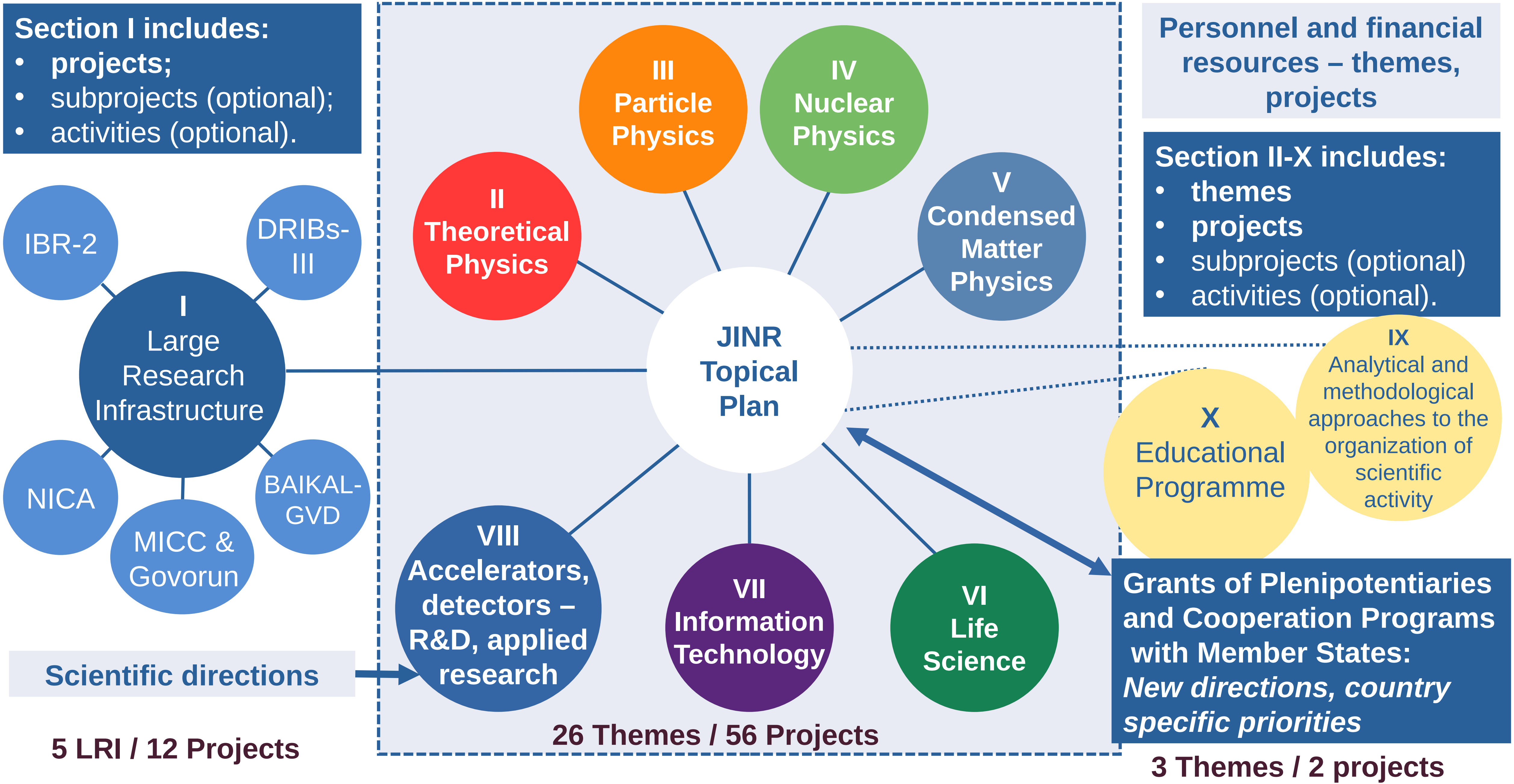
Completion of the creation of a large research infrastructure: megascience “NICA” (collaborations BM@N, MPD, SPD), neutrino observatory “Baikal-GVD”, new experimental complex U-400R, applied nuclear physics installations.

Large-scale international interdisciplinary research at existing large installations: SHE factory, IBR-2 reactor with a complex of spectrometers, a computing complex with a Govorun supercomputer, Laboratory of Radiation Biology - biomedicine and radiobiology, innovative research.

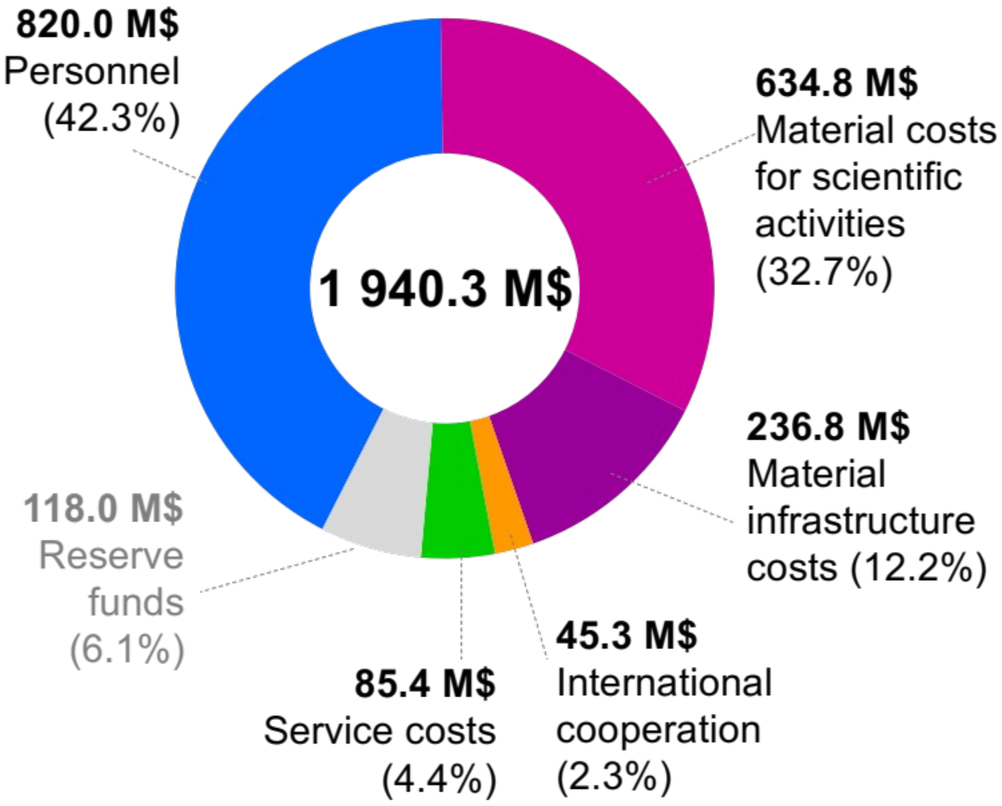


The Topical Plan for JINR Research and International Cooperation

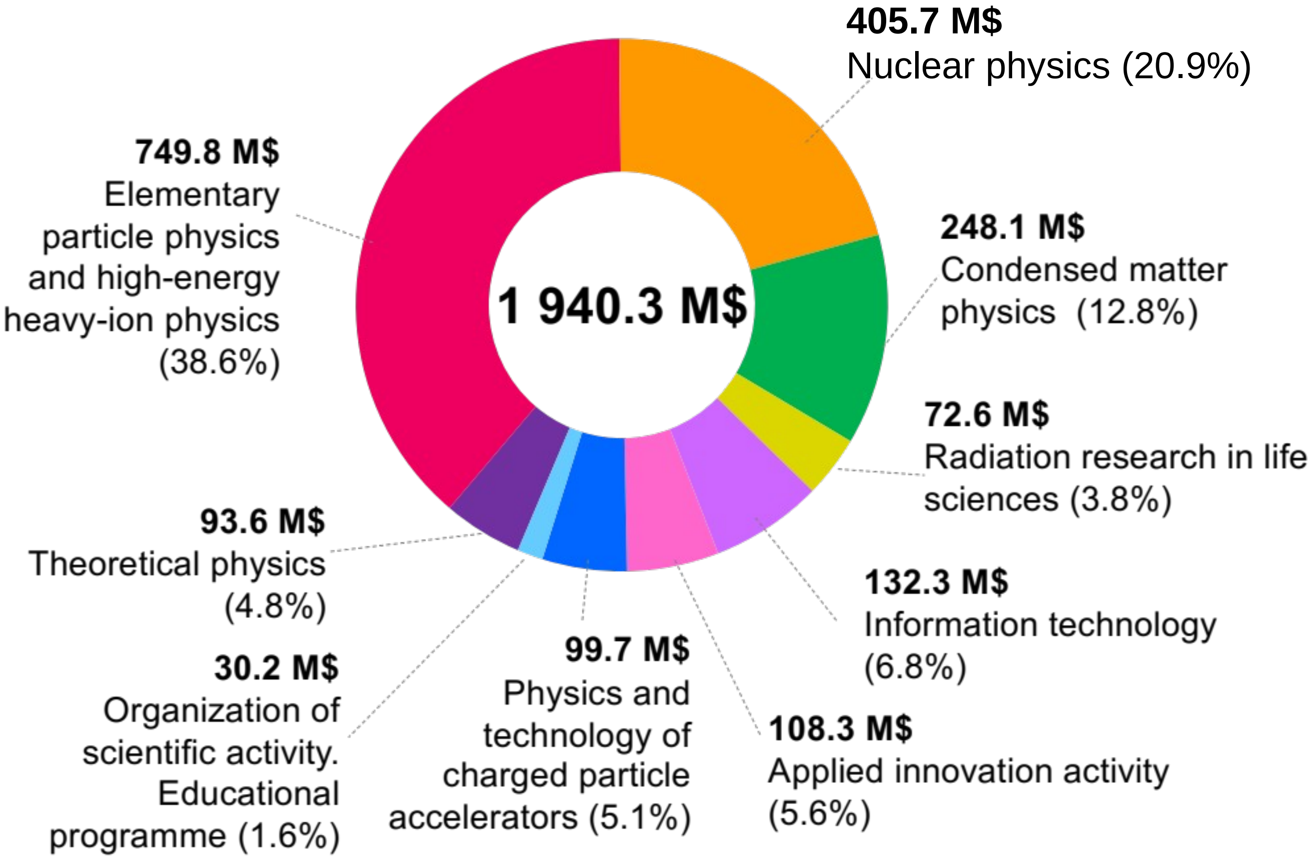
To be proved by the JINR SC and CP annually



Draft expenses of the Seven-Year Plan for 2024-2030 by types of expenses



Draft expenses of the Seven-Year Plan for 2024-2030 by fields of research (including overheads)



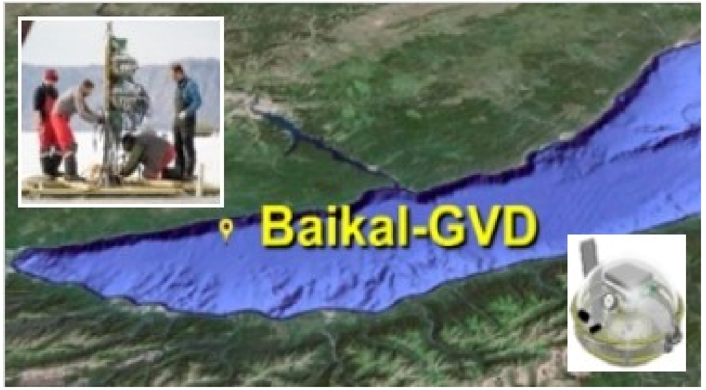
LRI IN THE 7-YEAR PLAN FOR THE DEVELOPMENT OF JINR (2024-2030)

Relativistic Heavy Ion & Spin Physics
NICA complex

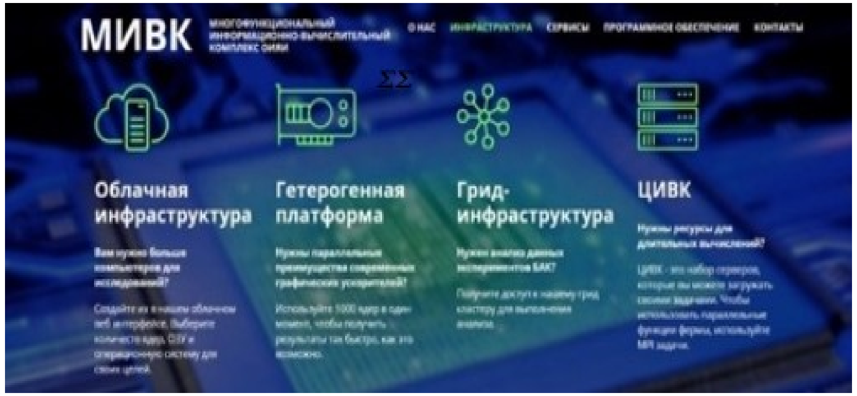
Low Energy Nuclear Physics
SHEF& DRIBS-III project

Condensed matter research
and Neutron physics (IBR-2)

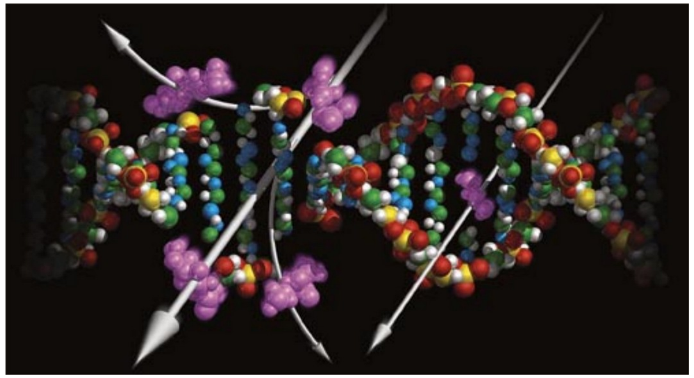
Neutrino & Astroparticle physics
Baikal-GVD



IT and High Power Computing
MIC complex



Life Sciences
RadioBiology, AstroBio, BioMed



THEORETICAL PHYSICS – 5 themes with 16 projects

Theory of Fundamental Interactions

Theory of Atomic Nucleus

Theory of Condensed Matter

Modern Mathematical Physics

Interlaboratory cooperation

VBLHEP Hot and dense nuclear matter in heavy-ion collisions

DLNP
Neutrino physics

MLIT
Lattice QCD calculations

FLNR
Superheavy and exotic nuclei

DLNP *Few-body systems, Exotic nuclei*

FLNP
Condensed Matter, New materials

FLNR
Nanoporous 2D membranes,
Ion irradiation

MLIT Computational methods for nuclear physics and quantum chemistry

Research and educational theme

DIAS-TH

“Dubna International Advanced School of Theoretical Physics”

Human strategy:
- ❑ Attraction of leading scientists
- ❑ Attraction of young researchers
- ❑ Stimulation of scientific activity

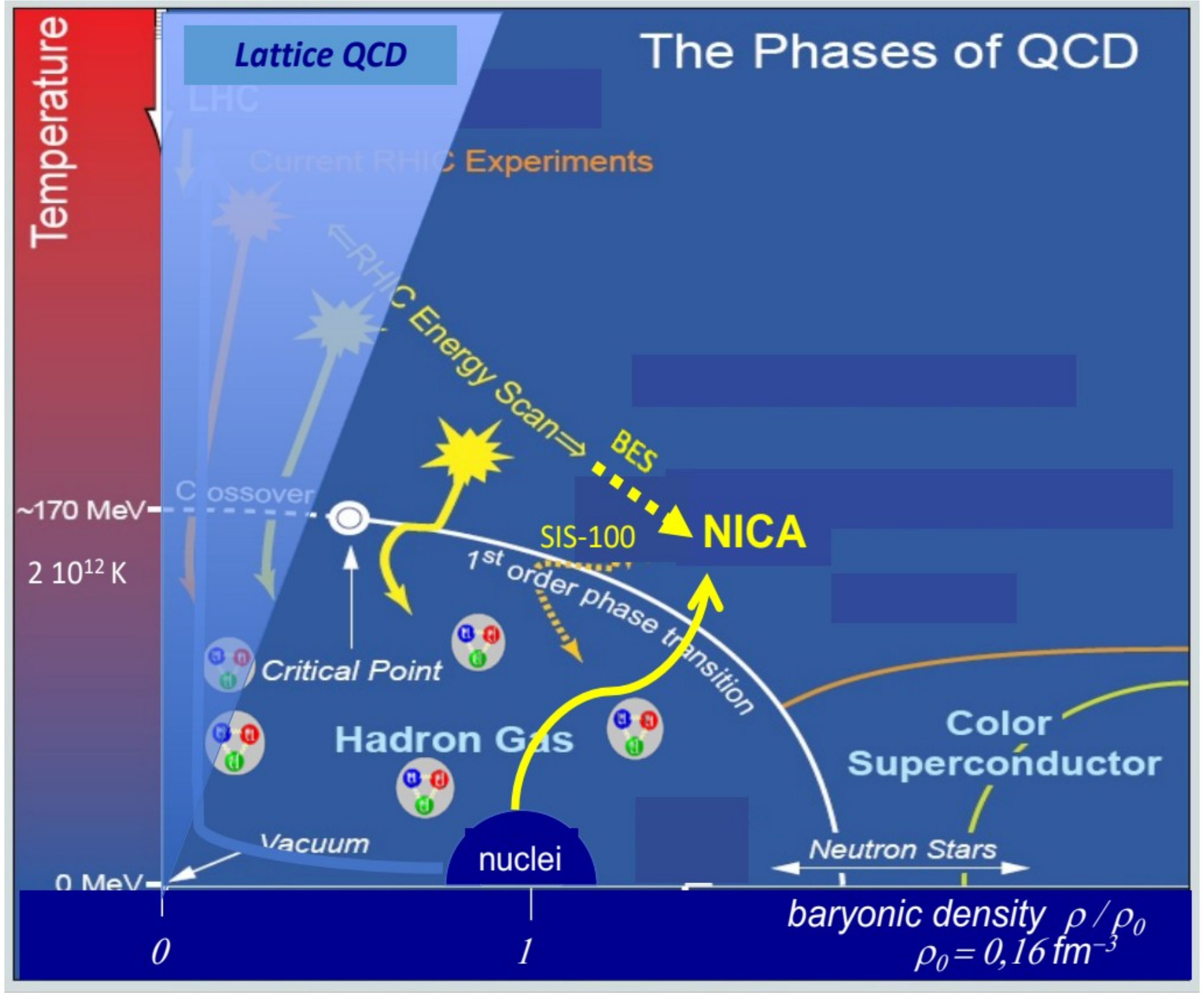
Scientific strategy:
- ❑ Extension of international collaboration
- ❑ Keeping up with current scientific trends
- ❑ Interplay of research and education

In **Relativistic Heavy Ion Physics**, a promising experimental program at JINR is associated with the NICA megaproject, the task of which is to study hot and dense strongly interacting QCD matter, searching for a mixed phase and a critical point in the QCD phase diagram in order to shed light on a poorly studied region of the phase diagram and test the predictions of non-perturbative QCD and other theoretical models describing strongly interacting matter.

After the commissioning of the basic configuration of the NICA collider complex at the BM@N and MPD experimental installations, the implementation of a physical program to study hot and dense baryonic matter and phase transformations in it will begin. The energy region of the NICA collider is of particular interest because it corresponds to the maximum possible density of baryons at the moment of their “freezing out.” In this energy range, the system occupies the maximum volume of space-time in the state of a mixed phase of quark-gluon matter (coexistence of hadrons with quarks and gluons).

In **perturbative and non-perturbative QCD**, the main tasks is to study properties of strong interactions by measuring the proton and deuteron spin structures at NICA-SPD project, as well as within the framework of JINR’s participation in the most important international collaborations (e.g., COMPASS/AMBER, BESIII).

NICA



BM@N & MPD

MPD covers this interesting region providing powerful combination of **large luminosity, collision energy and system size scan** (including isobars), large and consistent **acceptance,** full **centrality** range.

NICA is complementary to existing and planned world facilities (FAIR, SPS), and will be a natural and necessary continuation and significant expansion of studies at RHIC BES.

SPD

The SPD experiment is aimed at studying the properties of strong interactions in the nonperturbative region, at measuring the proton and deuteron spin structures, and at the development of a three-dimensional model of the nucleon. It is unique in its methodology, breadth of coverage and variety of tasks.

NICA Project Development in 2017-2023

2017

HILac commissioning

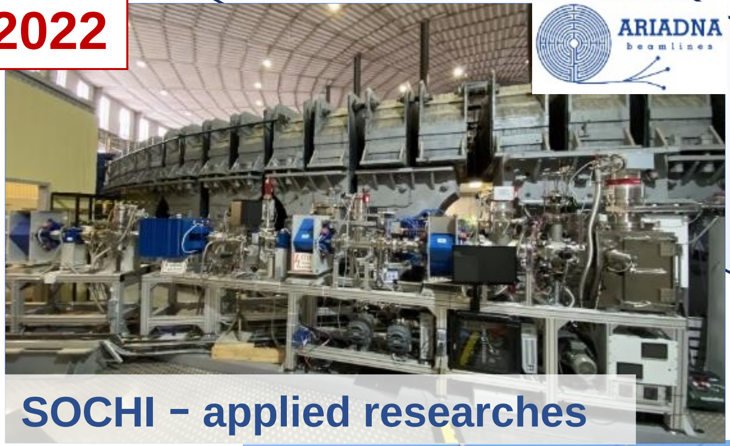
2018

Booster commissioning with beam

2020

2021-2022

NICA collider tunnel



SOCHI – applied researches

4th Technical Run (2022-2023): HILac + Booster + Nuclotron

Commissioning of the NICA injector complex!

2023

40MW – now available

2023

Succesfull 5th commissioning run at NICA in 2023 (4 months)

In this period staff members of the Accelerator Division have published 490 Scientific papers and presented 240 reports at various conferences + students practice (online/in-person).

International collaborations have been formed and necessary conditions for their effective functioning at JINR have been created

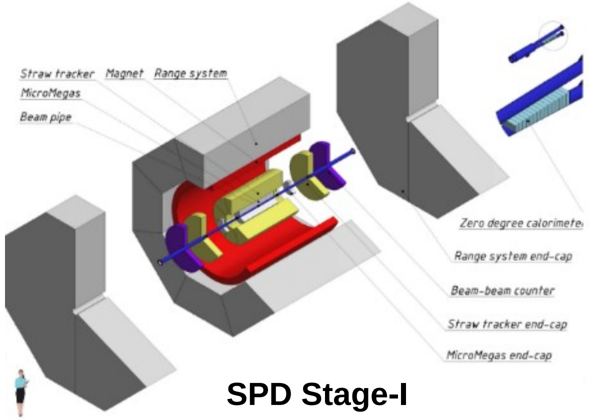
MPD: 11 countries, 35 institutes, >500 participants

	Year 2023	
12	Jan 15 - April 15th	Preparation for Vacuum test of Solenoid with Cryostat
13	April 20 - May 20th	Vacuum tests
14	May 25 - June 15th	Solenoid cooling down to Liquid Nitrogen temperature (-80K)
15	April 20 June 15th	Electronic Platform construction
16	June 15 – September 15	Activities in the MPD Hall will be stopped
17	October – December	Cooling down to the He temperature
	Year 2024	
18	January. - February 15	Supplying the current to the solenoid and Correction coils
19	March - May 15	Magnetic Field measurements
20	June 1 - June 10	Support Frame installation
21	June 20 – August 30th	Installation ECal sectors, Insertion devices mounting
22	Sept 1 – September 20th	Installation TOF modules, FHCal into poles
23	Sept 15 - Nov 20	TPC installation
24	Sept 18 - Nov 20	Cabling
25	Oct 20 - Nov 25	Installation of beam pipe
26	Nov 30 - Dec 10th	Move the MPD on Collider beam line, Commissioning

116 conference papers
65 publications

SPD: 14 countries, 32 institutes, ~300 participants

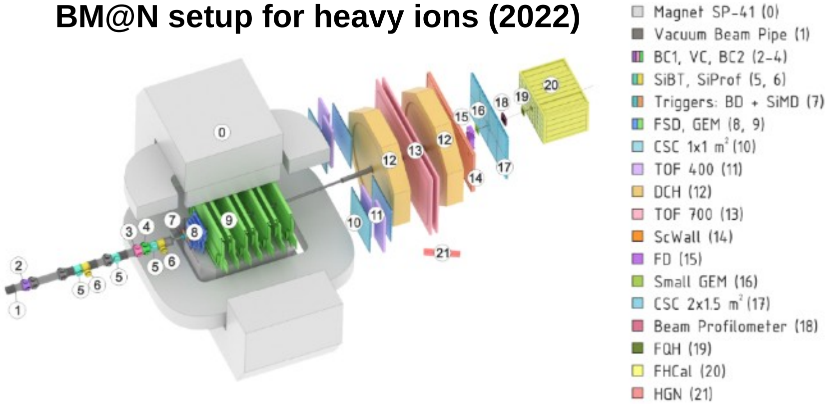
- SPD CDR was approved in Jan'2022;
- detectors prototyping/tests are ongoing;
- new version of **TDR** – Jan'2024;
- start of operation (Stage-I) – **2028**;
- **50** papers and **70** conference reports.



SPD Stage-I

BM@N: 5 countries, 13 institutes, >200 participants

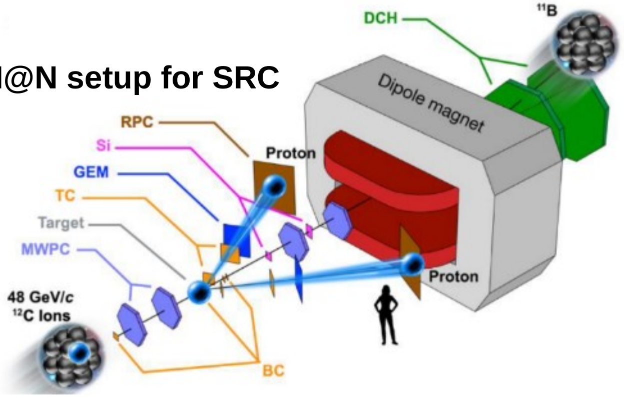
BM@N setup for heavy ions (2022)



4th NICA run (2022-2023):

- **550M events Xe+CsI at 3.0A, 3.8A GeV;**
- **analysis is ongoing;**
- **so far: 80 publications and 80 reports, including "Quark Matter", "Strangeness in Quark Matter", etc.**

BM@N setup for SRC



First observation of the Short-Range Correlations in inverse kinematics:

$^{12}C + p \rightarrow 2p + {}^{10}B\ /\ {}^{10}Be + (n\ /\ p)$

26 ^{10}B **events**

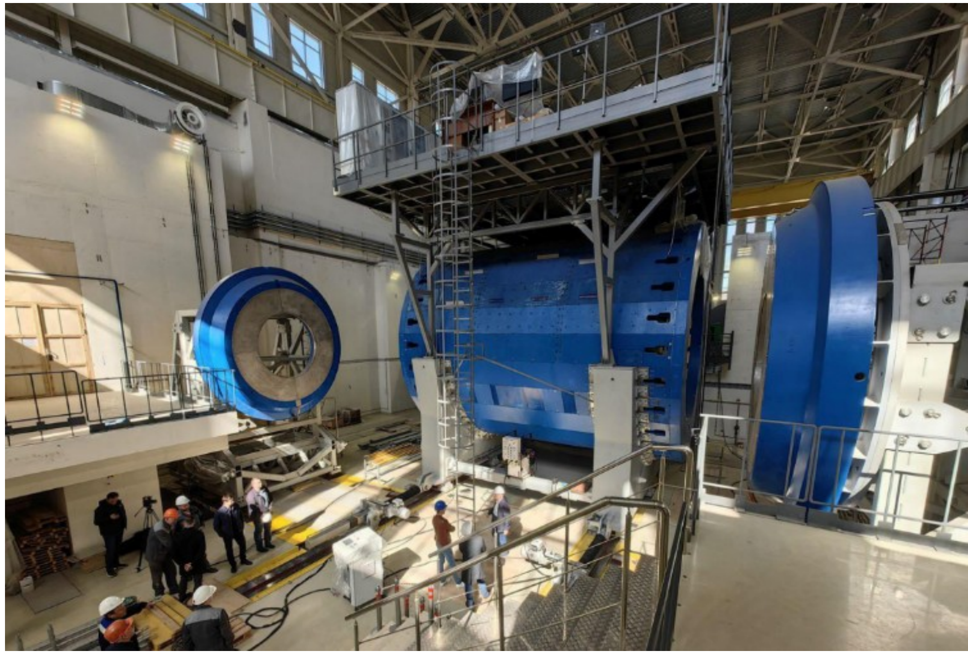
3 ^{10}Be **events** → ***np* pair dominance**

Paper was published in Nature Physics, 17 (2021)

Relativistic Heavy Ion Physics and Study of nucleon structure. Near and Long-Term Future

- The timely completion of the NICA project, its commissioning and steady and efficient operation.
- Completion of the detectors: **BM@N**, **MPD** and **SPD** at NICA and successful data taking over the decades to come. JINR will make significant contribution to the basic configuration of the SPD detector.
- After several years of running of MPD, an Upgrade is foreseen, responding to an increase in luminosity of NICA. Adding detectors in the forward region as planned.
- Studies of possible future extension of NICA for acceleration of electrons, opening new physics potential via e-p and e-A collisions.

	2022	2023	2024	2025	2026	2027	2028	2029
NICA Collider commissioning		Commissioning runs						
MPD extended config. construction and opration			System design and production		Detector extended mode operation			
Consruction of NICA collider extended config.								
Prep. and start of polarized beam operation	SC-solenoids production and tests				Spin transparency mode operation			
SPD construction and commissioning	R & D, prototyping, testing			SPD systems production and assembly			SPD operation	
Nuclotron modernization	R & D, prototyping, testing			Magnets production, ring assembly			New Nuclotron operation	



Flerov Laboratory of Nuclear Reactions Program for the next decade:

Searching for the boundaries of the existence of nuclear matter by focusing on the boundaries of the island of stability of superheavy elements (SHE) – an area of the nuclide map where long-lived isotopes can be detected, studying their properties using nuclear spectroscopy methods (α-, β- , γ-spectroscopy), as well as their chemical properties, the study of the mechanisms of various nuclear reactions leading to the formation of new unknown nuclei. A significant increase (20 times) in the efficiency of experiments is necessary for the synthesis of even heavier elements 119 and 120.

Study of multinucleon transfer reactions during collisions of actinides with energy near the barrier, which are promising for the synthesis of new neutron-rich isotopes of heavy and superheavy elements up to the beta stability line. The modernized U-400R accelerator complex will create the necessary conditions for an in-depth study of these and other low-energy nuclear reactions with heavy ions.

Continuation of experimental research in the field of **light exotic nuclei located on the boundaries of nuclear stability, including the study of the nuclear halo, neutron coat, cluster states, exotic multineutron decays** (two-nucleon virtual states, 2n- and 4n-radioactivity), two-proton radioactivity, **search for new magic numbers, spectroscopy of exotic nuclei and reactions with halonuclei.**

Synthesis of new elements @ SHE Factory

TARGETS:

- Rosatom and ORNL (USA): *Isotopically enriched heavy actinide materials;*
- Radiochemical Lab of class 1

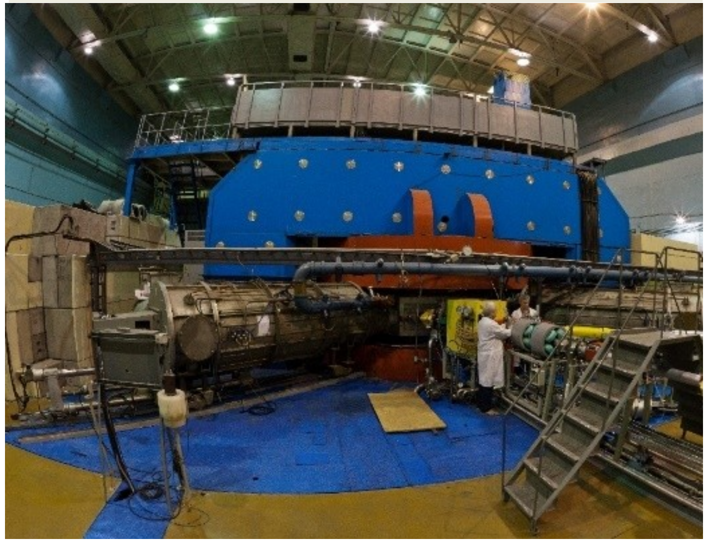
BEAMS:

- Production of high-intensity beams of ^{50}Ti, ^{54}Cr and others
- New ECR-28 GHz (2024)

Radioactive Ion-Beam research

Basic facility: U-400M

Ambitions: E up to 80AMeV, I x 2



Operation from end of 2023

- Nucleon halo, neutron skin;
- Exotic decays: b-delayed, 2p,2n radioactivity;
- Soft excitation mode;
- New magic numbers;
- Spectroscopy of exotic nuclei;
- Cluster states;
- Reactions with RIBs;
- Astrophysical applications.

Nuclear reaction studies @ U-400R

Ambitions: up to 2.6 mA (U-beam)
10^{10-11}, smooth energy variation

Upgrade in 2023-25. Operation from 2026

- **Multinucleon transfer reactions:** *Production of new isotopes of heavy,SH nuclei; Study of properties of new nuclei.*
- **Decay spectroscopy of heavy nuclei:** *actinides and light transactinides*
- **Study of fusion-fission and quasifission reactions leading to heaviest nuclei**
- **Low-energy and spontaneous fission of heaviest nuclei**
- **Study of nuclei at high excitation energies (several hundred of MeV)**

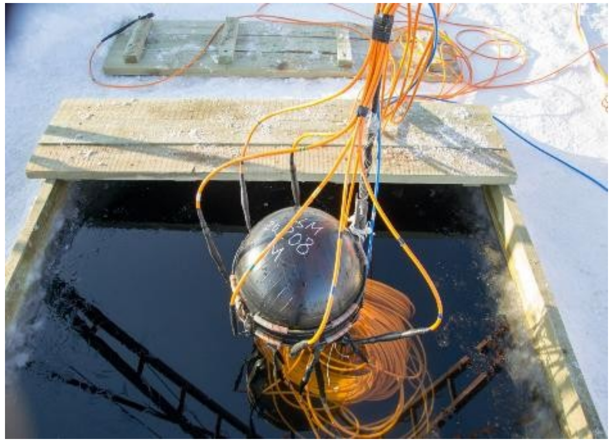
The main directions in **Particle Physics** for JINR for the medium and long term are related to:

- precision study of strongly interacting states, including structure, phase QCD states, new hadronic states, including exotic multiquark states;
- study of the physics of electroweak interaction and flavor physics;
- further progress in understanding the evolution of the Universe in collider experiments, including the search for dark matter;
- astrophysical and cosmological observations and gravitational wave studies, multi-channel astronomy and the dark sector in non-accelerator experiments;
- experimental and theoretical definition of a model that goes beyond the Standard Model;

The JINR research program in the field of **neutrino physics and astrophysics** is aimed at fundamental problems: identification of astrophysical sources of ultra-high energy neutrinos, mechanisms of formation and evolution of galaxies, determination of the neutrino mass hierarchy, origin of neutrino mass, restrictions on the CP violation phase, direct search dark matter, precision study of coherent elastic scattering of neutrinos on nuclei, etc.

Currently, it is believed that phenomena occurring in the Universe should be studied by simultaneously observing different signals. The **Baikal-GVD project** is one of the cornerstones of this approach. The TAIGA installation, a set of gamma-ray and muon telescopes located in Siberia, in the Tunka Valley, south of Lake Baikal, can be considered as an additional instrument from the point of view of multichannel astronomy.

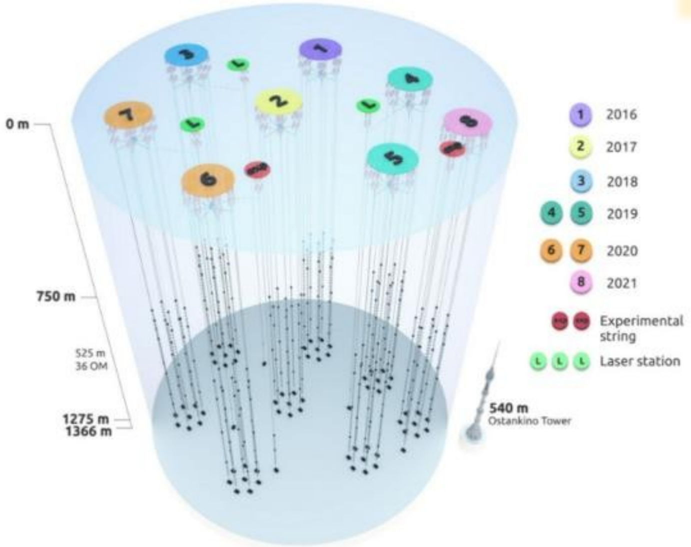
NEUTRINO AND ASTROPARTICLE PHYSICS



Baikal-GVD: Identification of astrophysical sources of ultra-high energy (exceeding tens of TeV) neutrinos. Actuality: their sources are still unknown. The identification of sources will help to elucidate mechanisms of galaxies creation and evolution.

Main advantage of Baikal-GVD: pure and t-stable water. Angular resolution of muon tracks 0.3-0.5 grad (IceCube: 0.5-1), angular resolution of shower direction 2-3 grad (IceCube: 15),

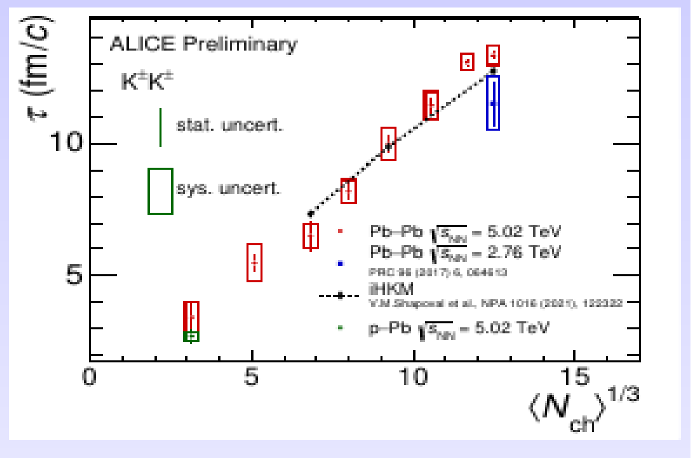
Year	Number of clusters	Number of OMs
2016	1	288
2017	2	576
2018	3	864
2019	5	1440
2020	7	2016
2021	8	2304
2022	10	2880
2023	12	3456
2024	14	4032
2025	16	4600



The second phase of the Baikal-GVD neutrino telescope will begin at the turn of 2025 and is scheduled for completion in 2030, when the facility will have more than 20 clusters (approximately 6000-7000 optical modules) with an effective volume of about or above 1 km3.

Baikal-GVD: flagship experiment of JINR with a leading role in the collaboration.
Gain new experience in the detector design, construction, deployment, maintenance, simulation and data analysis. Expected breakthrough discoveries.
SAC: light sensors, data transmission, radio-antennas + optics => New Quality and Efficiency

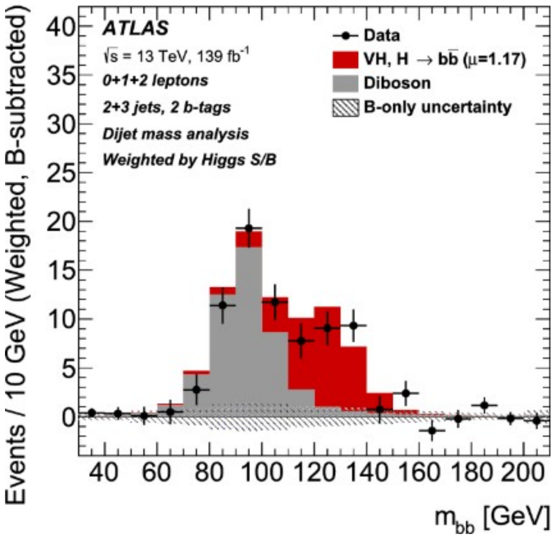
Selected Results from CERN and BNL in 2017-2023



ALICE:

- Comprehensive study of the femtoscopic correlations;
- Kaon emission time (τ) is obtained in 3D femtoscopic analysis of $K^{\pm}K^{\pm}$ pair roduction (EPS-HEP 2023, Hamburg).

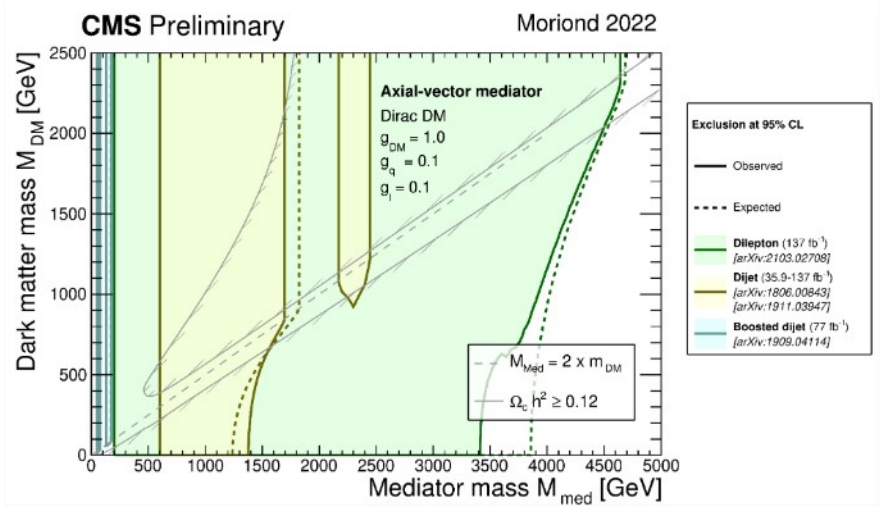
- 29 publications;
- 28 conference reports.



ATLAS:

- First observation of the Higgs boson decay into a pair of b-quarks;
- Limits on chiral W*/Z* bosons in Drell-Yan and two-jet processes;
- Study of B_c state properties, Penta/Tetraquark states;
- Measurements of BEC parameters.

- 50 publications;
- 36 conference reports.



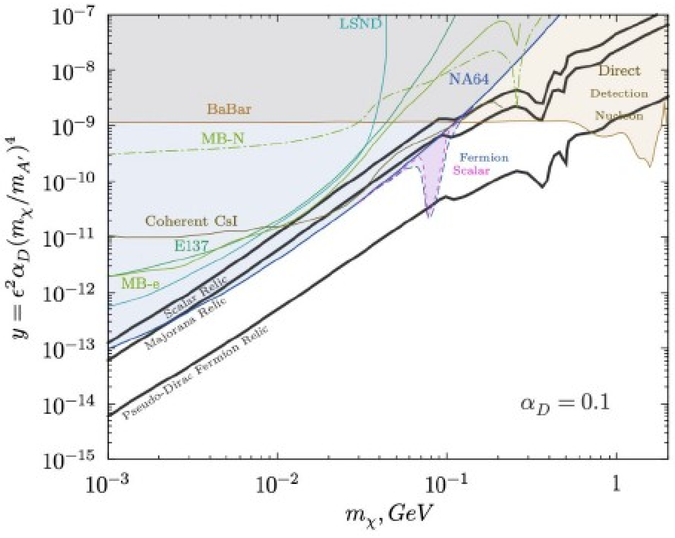
CMS:

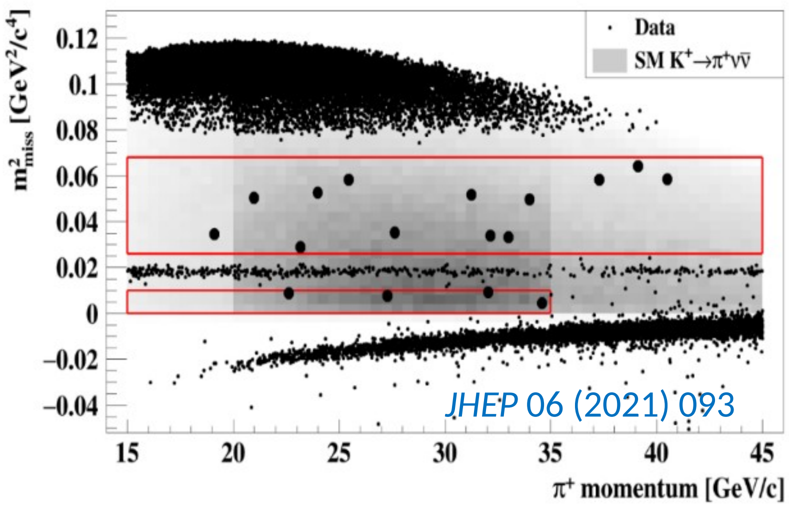
- Searches for the Physics BSM including extra Higgs bosons, new gauge bosons, extra dimensions, etc. with dilepton/bbar + missing transverse energy signatures;
- Search for Dark Matter;
- SM tests with Drell-Yan processes and jets.

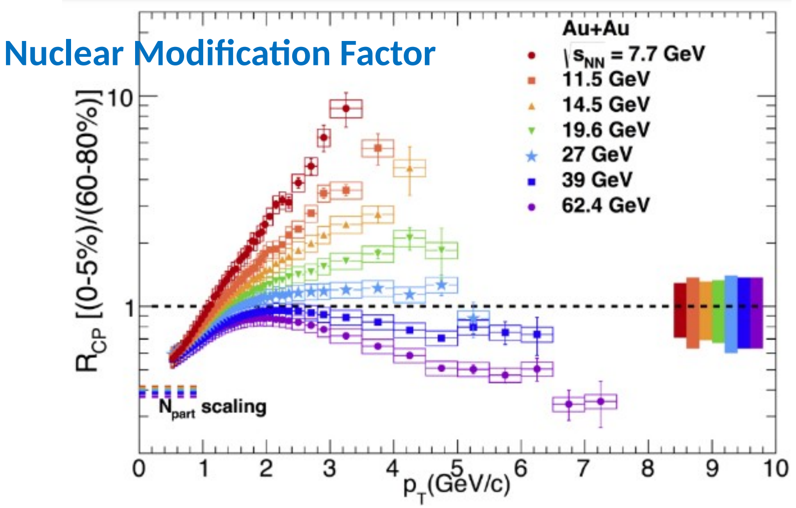
- >100 publications;
- 140 talks at conferences and workshops;

Both, ATLAS and CMS teams made significant contribution to their detector's Upgrade in Phase-I, now moving to Phase-2 Upgrade

Selected Results from CERN and BNL in 2017-2023







NA64:

- Detector has been built;
- 10^{12} eot collected by 2022;
- the most stringent limits are established for light DM.

- 22 publications, 25 reports;
- JINR award in 2020.

NA62:

- the most precise measurement of rare decay BR($K^+ \to \pi^+\nu\nu$) = ($10.6^{+4.0}_{-3.4} \pm$ 0.9syst) $\times 10^{-11}$ 20 candidates were found (7 expected in SM), now aiming at 10% accuracy;
- limits improved in searches for dark heavy photon in π^o decays.

- 30 publications;
- 38 conference reports.

STAR:

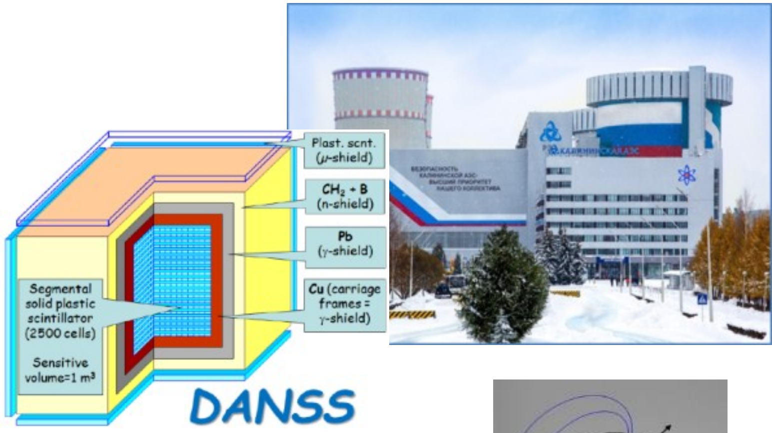
- Beam Energy Scan at RHIC;
- gluon spin contribution to the proton spin is positive;
- asymmetry of sea-quarks.

- 17 publications;
- 27 conference reports.

Non-accelerator neutrino physics and astrophysics

Scientific directions :

– Double beta decay, neutrino nature (Majorana or Dirac), Nuclear matrix elements
– Fundamental neutrino properties (magnetic moment, mixture with a sterile state, etc)
– Monitoring of nuclear reactors with neutrino detectors
– Direct and indirect search for Dark Matter
– Investigation of galactic and extragalactic neutrino sources
– Atomic processes accompanying radioactive decay
– Applied directions of research



The major aims:

– BAIKAL-GVD: Observation of ultra-high energy astrophysical neutrinos; identification of their sources and nature

– DANSS: precision measurement of the spectrum of reactor antineutrinos

– RICOCHET: New physics with precision measurements at reactors.

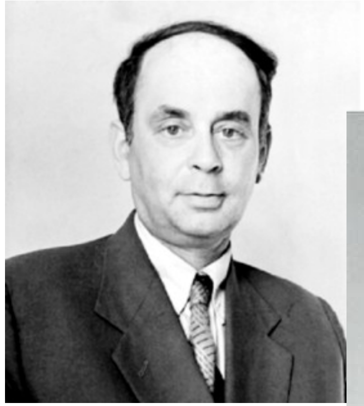
– νGeN: search for magnetic moment of neutrino

– LEGEND: neutrinoless double-beta decay at 10^{28} years

– Radiochemistry plus spectroscopy for astrophysics and nuclear medicine

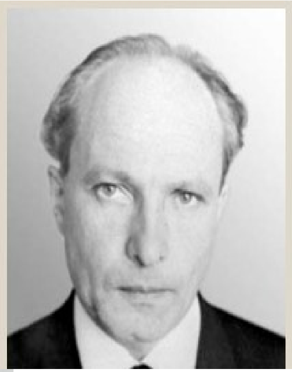
Neutron Nuclear Physics and Condensed Matter Research @ JINR

- **UCN physics;**
  - Neutron lifetime;
  - Weak equivalence principle check. EDM?
  - Neutron quantum states in gravitational field;
- **Neutron scattering for condensed matter studies @ IBR-2;**
  - Diffraction at high pressure;
  - Soft matter;
  - Nanostructurized magnetic materials;
  - Energy selective neutron radiography and tomography;
- **Nuclear physics with neutrons @ IREN, IBR-2 & external sources;**
  - Nuclear data for engineering and astrophysics;
  - Fundamental symmetries violation in neutron-nucleus interaction;
  - Applied research;



I.M. Frank

D.I. Blokhintsev



F.L. Shapiro

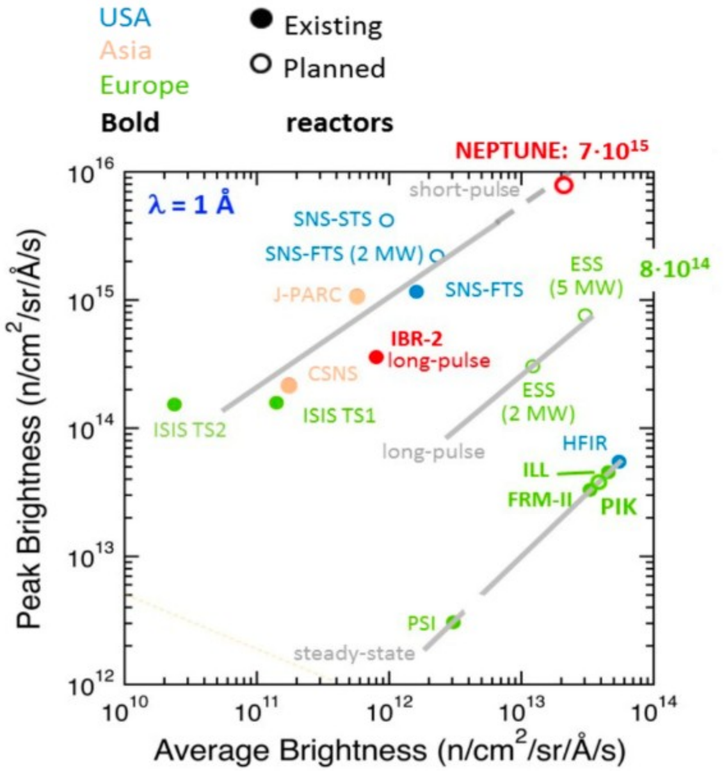
Frank Laboratory of Neutron Physics

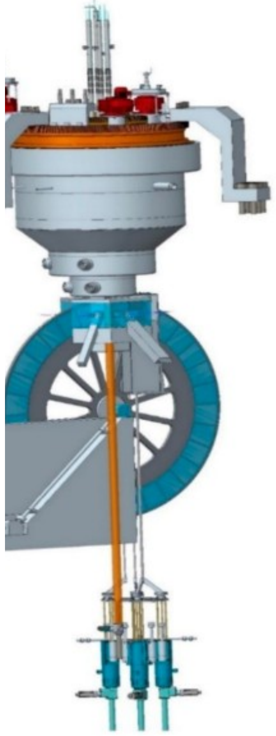
THE IBR-2 FACILITY

The service life of the core IBR-2 reactor is expected to end in 2032-35. **The possibility to extend the operation of the IBR-2 until 2040 is being studied.** To extend the reactor core campaign new fuel (manufacture of FA with FR) around 2026.

Considering the present-day tendency, **after 2030 only five sources will be available in Europe**: ISIS (Didcot, UK), SINQ (PSI, Villige), FRM II (TU Munich), and two new sources: ESS (Lund, Sweden) and reactor PIK (NRC KI, Gatchina, Russia), both under construction with the start of operations planned for 2023-2024. Oak Ridge (STS SNS) – **is planned in 2037**.

JINR provides Feasibility Studies for new neutron source **IBR-3** (“**NEPTUNE**” as one of scenarios-using Np fuel). The goal is to have the **best** pulsed neutron source in the world by end of 2030-s: with brightness of 7*10^15 (for TN), and 9*10^14 (for CN)

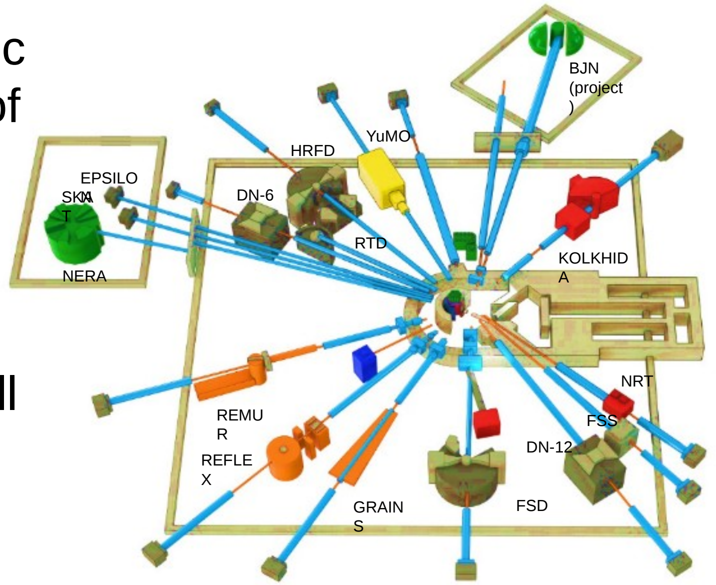




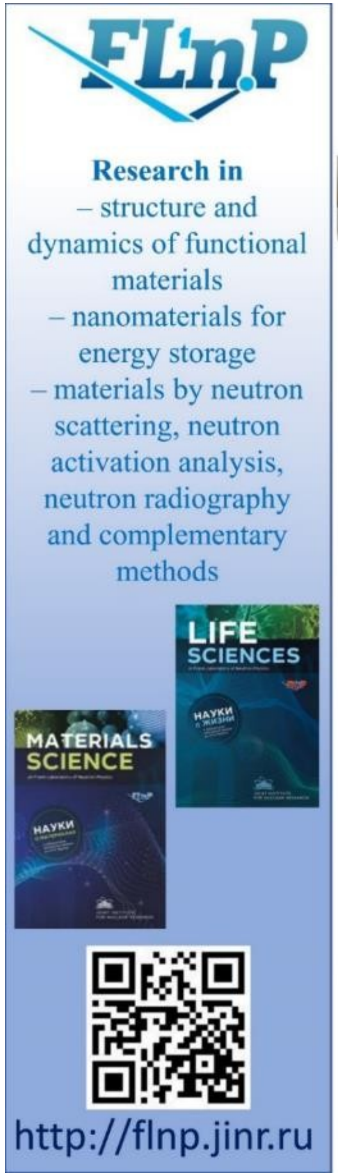
Condensed Matter Physics, Neutron Physics. Priority research in 2024-2030

SPECTROMETER COMPLEX

- Development of the basic configuration elements of the inverse geometry inelastic n-scattering spectrometer BJN.
- Completion of basic configuration of the small angle n-scattering and imaging spectrometer.



- Modernization and reconstruction of spectrometers HRFD, YuMO, RTD, DN-6, DN-12, FSD, NERA, REMUR, REFLEX, SKAT, EPSILON, FSS, NRT, focused on improvement of technical parameters and extension of research capabilities.
- Development of laboratory equipment for samples characterization and physical properties measurements.
- **Support and modernization of the complex of cryogenic moderators. New operating reliable Ultra Cold Neutrons (UCN) channel.**



X-RAYS

SAXS/WAXS/USAXS

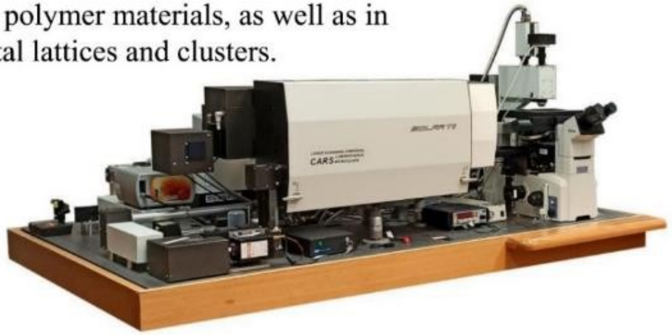
Analysis of particle size distribution, crystallization rates and lamellar structure of semi crystalline polymers. Size and shape analysis of surfactants or proteins in solutions. In situ studies of nanostructure transitions and others.

DIFFRACTOMETER

Analysis of phase composition and type of crystal structure and microstructural parameters of polycrystalline materials (films, nanomaterials and solid objects).

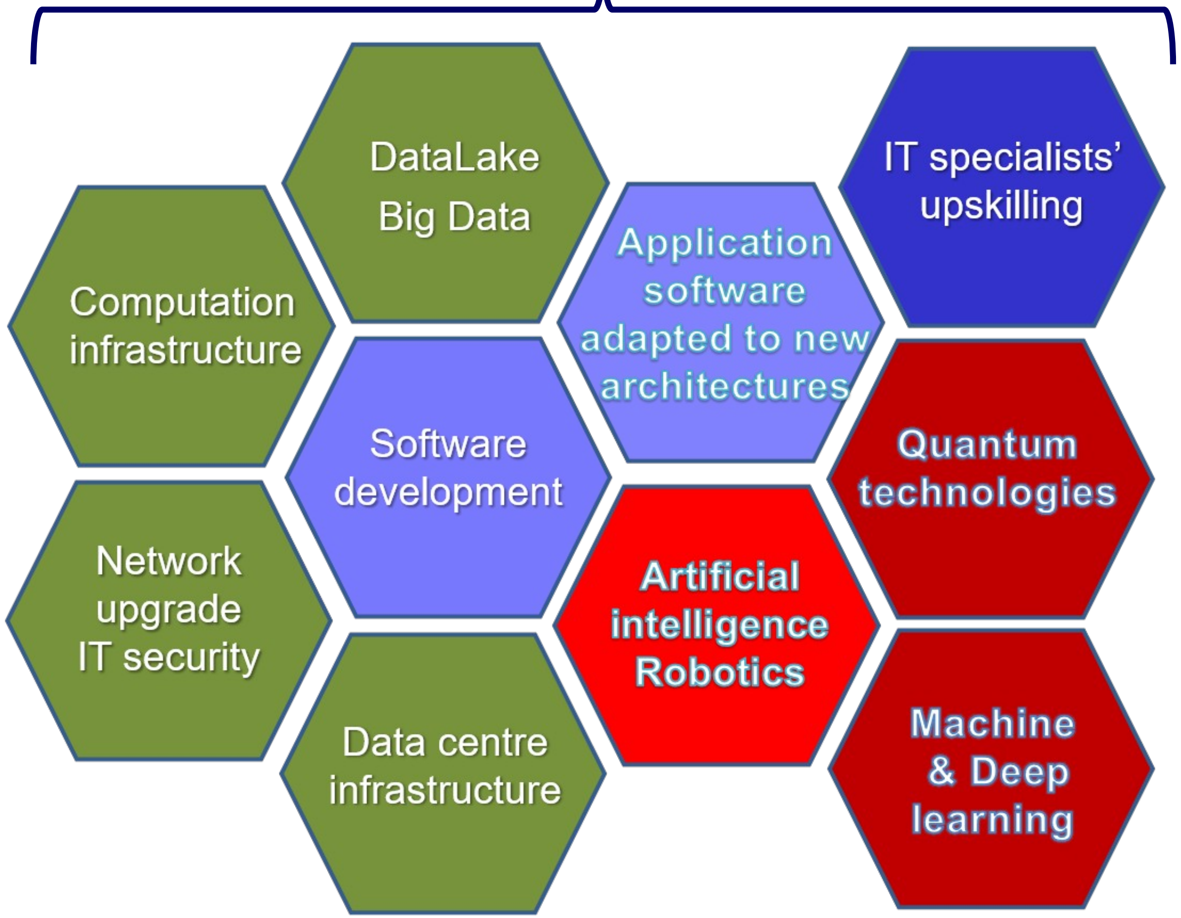
RAMAN SPECTROSCOPY

Analysis of nature of chemical bonds in organic molecules and polymer materials, as well as in inorganic crystal lattices and clusters.



Strategy for Information Technology and Scientific Computing at JINR

Scientific IT ecosystem:



The coordinated development of interconnected IT technologies and computational methods

Steady implementation/upgrades of

- Networking (**Tb/s** range)
- Computing infrastructure within the Multifunctional Information & Computing Complex (MICC) and
- "Govorun" Supercomputer,
- NICA Tier0-Tier1-number of Tier2;
- Baykal, NOvA, JUNO – all types of resources
- LHC@HL-LHC: Tier1 for CMS, Tier 2 for ATLAC, ALICE
- Data center infrastructure,
- Data Lake & long-term storage for all experiments.

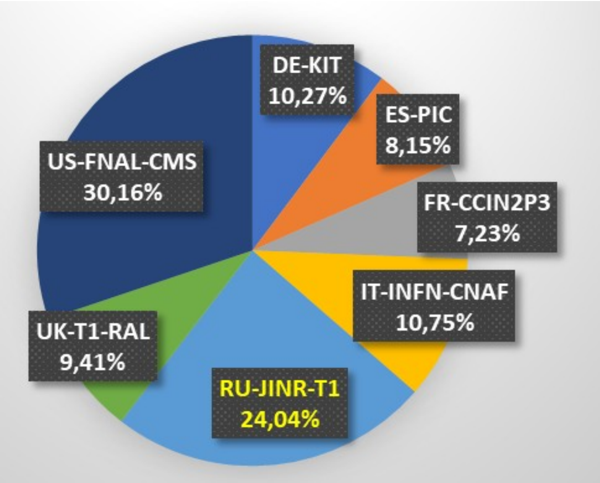
The **development of new data processing and analysis algorithms** based on

- ML/DL,
- artificial intelligence,
- Big Data
- Quantum technologies.

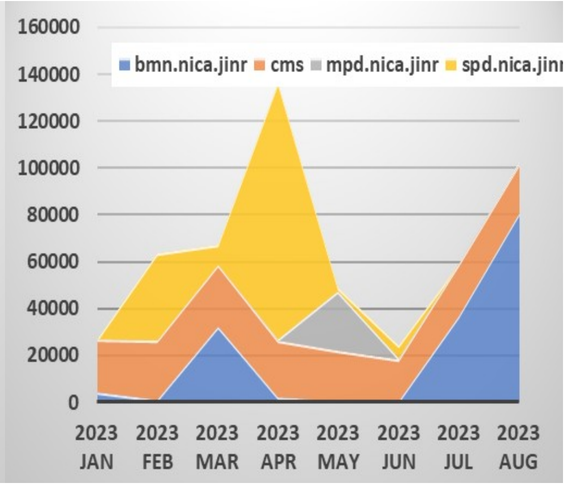
A variety of means will be used for IT specialists upskilling.

MICC – Grid Infrastructure and DIRAC

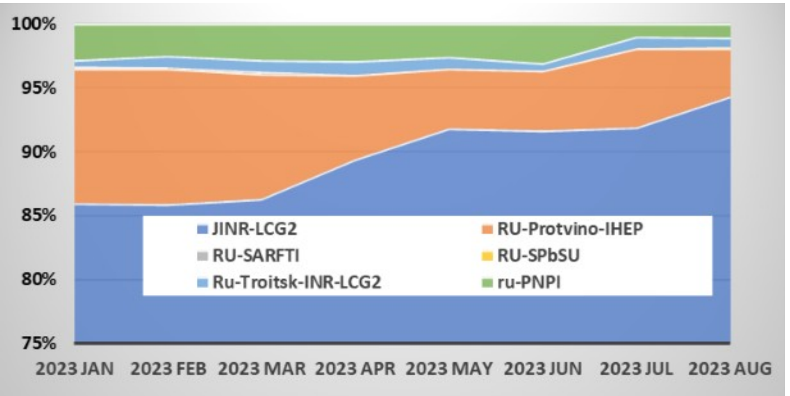
In 2023, the JINR Tier1 site for CMS is ranked second (24%) among Tier1 world centres for CMS. JINR Tier1 is also used for the MPD, BM@N and SPD experiments.



Distribution by CPU Work (HS23 hours) among CMS Tier1 worldwide



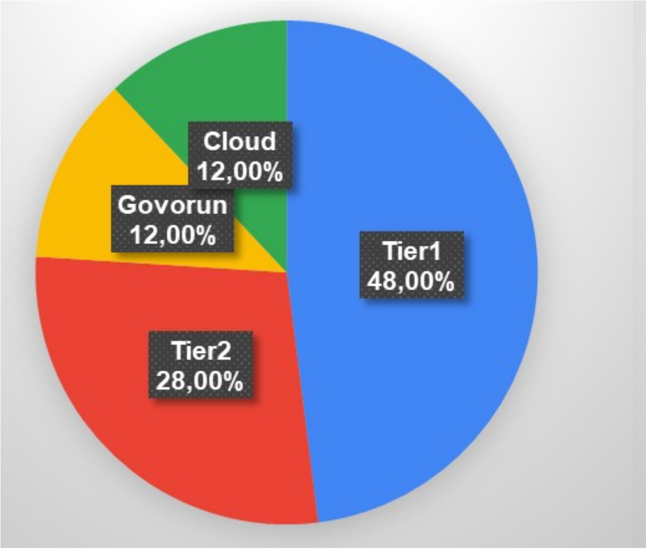
Distribution by the number of jobs completed on Tier1 by CMS, BM@N, MPD and SPD



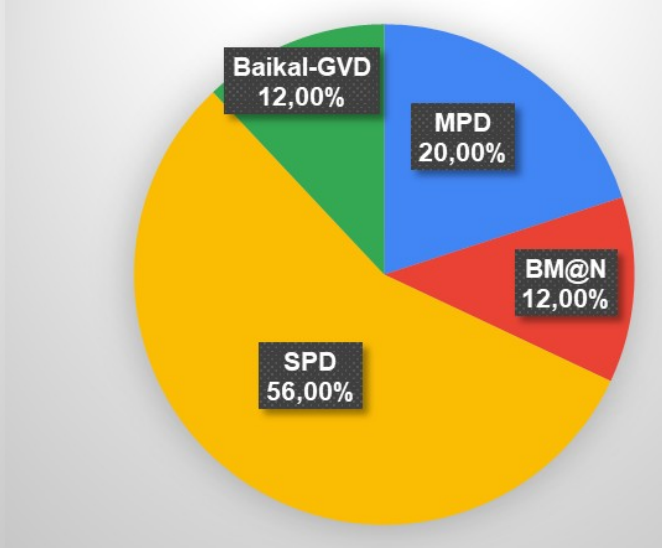
The JINR Tier2 output is the highest (89.3%) in the Russian Data Intensive Grid.

In 2023, DIRAC is the only system that includes all key MICC components. DIRAC serves as an intermediate layer between users and various computing resources, ensuring their efficient, transparent and reliable use, providing a common interface to heterogeneous resources.

At the moment, DIRAC is used to support the collaborations of the NICA experiments: MPD, BM@N and SPD, as well as the Baikal-GVD neutrino telescope.



Distribution by the normalized CPU time among the MICC components: Tier1, Tier2, Cloud and Govorun for jobs sent via DIRAC in 2023

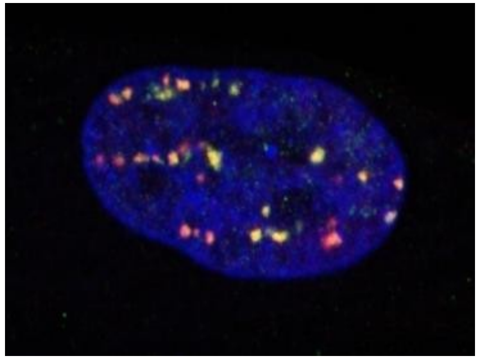


Distribution by the normalized CPU time among MPD, BM@N, SPD and Baikal-GVD for jobs sent via DIRAC in 2023

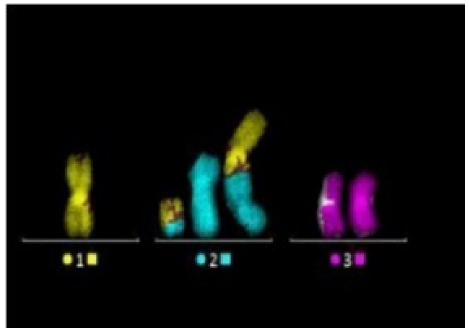
RADIATION RESEARCH IN LIFE SCIENCES

MAIN RESEARCH FIELDS:

Molecular Radiobiology

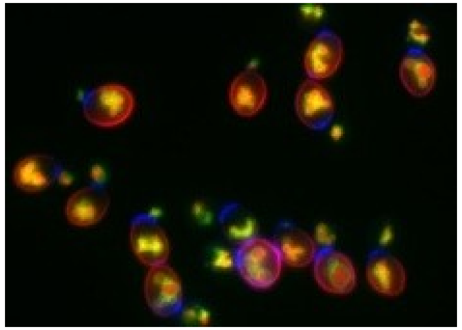


Radiation Cytogenetics

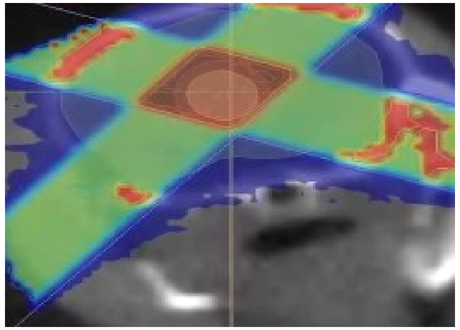


Radiation Physiology

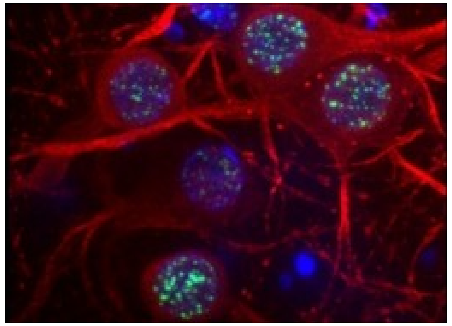
Radiation Genetics



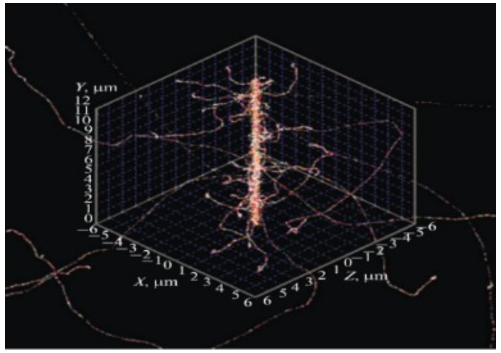
Clinical Radiobiology



Radiation Neuroscience

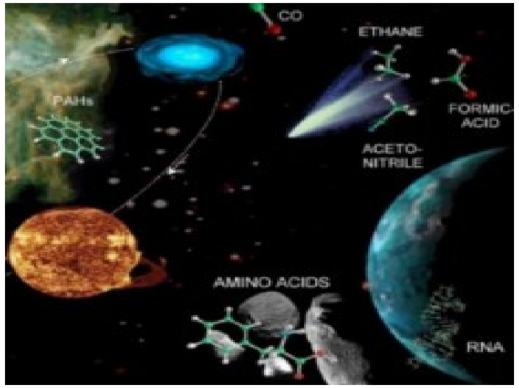


Mathematical Modeling



Radiation Research

Astrobiology

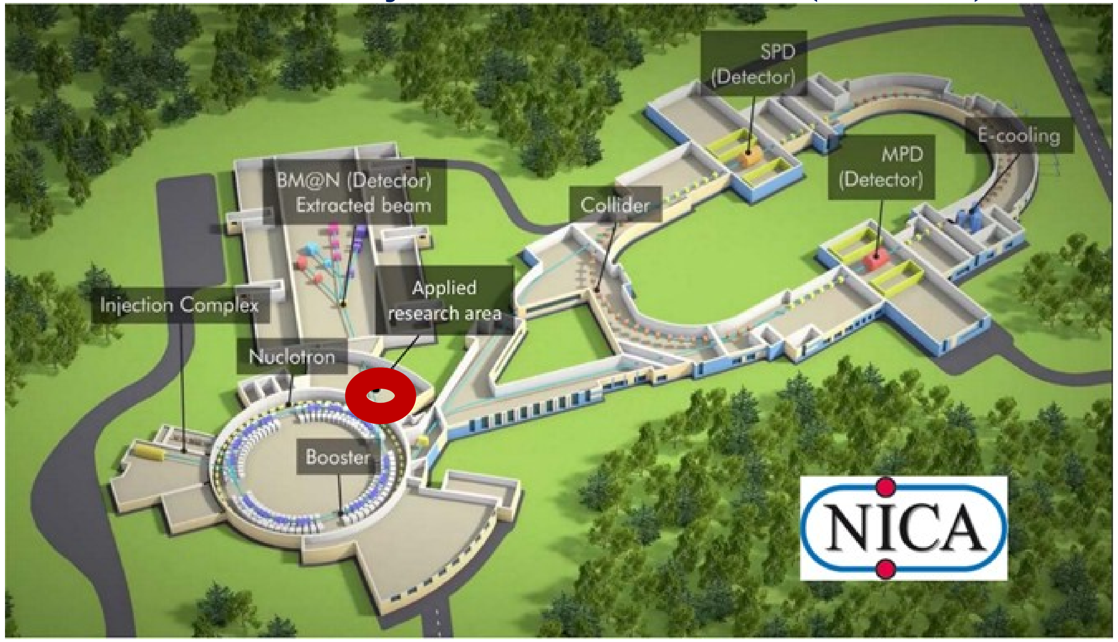


JINR's radiation sources for radiobiological studies

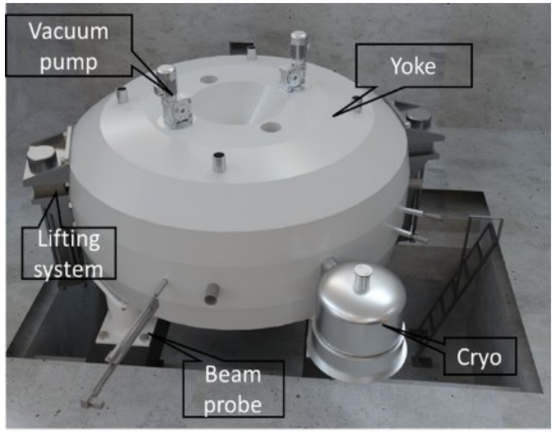
Phasotron:
protons 170 MeV

U-400M cyclotron:
heavy ions 50 MeV/u (Li-Ne)

Nuclotron: heavy ions 0.3-1 GeV/u (H – Kr)



cyclotron MSC230
(since 2024):
protons up to 230 MeV



IBR-2, IREN: neutrons

SARRP: X-ray

Linac200:
electrons 20-200 MeV

BEAM PHYSICS AND ACCELERATOR TECHNOLOGIES

Researchers of JINR are active participants of the of state-of-the-art international accelerator projects: LHC, XFEL, FAIR, RHIC, GANIL, INFN, IMP CAS, HIAF, EIC, ILC, CLIC, FCC, etc. **We will focus on R&D in the following areas:**

– highly charged intense ion sources for generating heavy-ion beams (Z > 40+);

– superconducting magnetic technologies: high-field magnets with fields up to 14–20 T, fast-cycling high-field magnets (B > 4 T, ramp 4-10 T/s), high-current cables and windings (I_{cr} > 30 kA);

– studies in the field of high-temperature superconductivity, R&D of ”Dubna SC” cable technologies;

– efficient fast cooling systems for intense hadron beams (~ 10 - 100 ms);

– superconducting RF structures (RFQ and DTL) and cryomodules for intense p- and i- beams;

– research in the field of colliding beam accelerators. Problems of future colliders (FCC, ILC, CpeC, etc.);

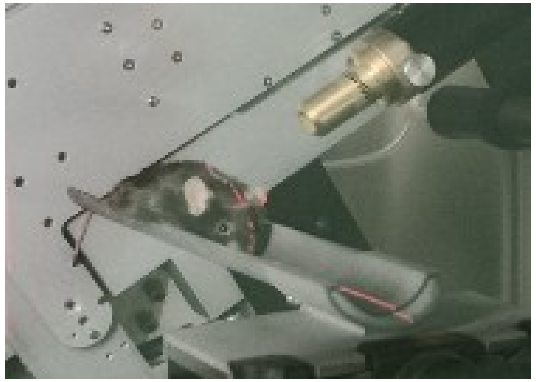
– R&D on beam therapy (flash, pencil beam, light ions, neutrons);

– development of modeling methods (including using AI methods) of beam dynamics with the real electromagnetic fields in accelerator structures and in-flight beam parameters, deep machine learning for operation.

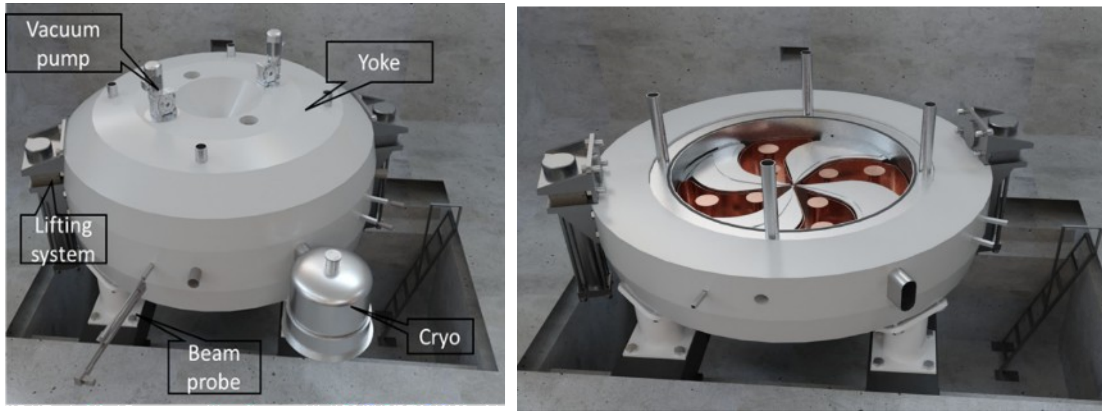
Progress for the implementation depends on the coordination of priorities/resources, which must be carried out in close Interlaboratory JINR cooperation and involving centers from Member States.
It is feasible within the framework of the dedicated All-Institute theme for the period 2024–2030.

INNOVATIONS: INTERNATIONAL CENTRE FOR NUCLEAR TECHNOLOGIES RESEARCH

- **Radiation Biology @ LRB**, OMICS, neuro-RB studies, radiation neuroscience. Approaches to increase radiosensitivity: pharmaceuticals, transgene systems, targeted delivery and radionuclide;
- **ARIADNA.** Applied beams@NICA: radiobiological studies (400-800 MeV/n); irradiation of electronics and material science (3; 150-350 MeV/n); nuclear physics (1-4.5 GeV/n);
- **DC140 cyclotron:** Space electronics testing, radiation material science, new generation of track membranes;
- **MSC230 cyclotron:** research and beam therapy: treatment planning; radiomodificators for g- and p-therapy, flash-therapy, pencil beam (10 µA, >5 Gr/l @ 50 ms pulse).
- **Radiochemical Laboratory Class-I** for production of radioisotopes (Ac^{225}, ^{99m}Tc), nuclear medicine R&D in photonuclear reactions @ 40MeV e-accelerator.



DC-140 (construction phase)



MSC-230 (general view)

LRIs as a base of International Training Programmes

3 stages of international student practice take place every year

About 100 project topics in the main areas of JINR research are offered to students

Over 150 students participate in international introductory practices annually

Students from **23 countries** come to JINR for internships and practices

Over 30 participants in long-term student programmes and internships annually

Students from **8 countries** have been on excursions to JINR over the past 5 years

Programmes for students and young scientists

- Bachelor's, Master's and PhD theses;
- INTEREST – INTErnational REmote Student Training at JINR; Student Online Practice; **interest.jinr.ru**
- International student practices; **uc.jinr.ru/ru/isp**
- Summer Student Programme; **students.jinr.ru**
- Conferences and schools for young scientists and specialists. **ayss.jinr.ru**


JOINT INSTITUTE FOR NUCLEAR RESEARCH
TOPICAL PLAN
FOR JINR RESEARCH
AND INTERNATIONAL COOPERATION
2024

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RISKS and MITIGATION

Subject to the principle of reciprocity, the Institute will continue to fulfill all its obligations, will consistently pursue a policy of Open Access to its research infrastructure and scientific data, strictly follow internationally recognized standards of scientific expertise and legal support of intellectual property.

The main financial risk for the development of JINR for 2024-2030, associated with the geopolitical situation, is the incomplete and/or untimely fulfillment of the Member-country contributions, the reduction of member states and non-payment of contributions by states where membership was suspended for an indefinite period. Such factors, first of all, will affect the reduction of JINR's human capital, a decrease in the value of its assets and competitiveness, and a significant shift in the timing of achieving scientific results that directly affect the scientific visibility of the Institute's member countries.

Attracting new states with strong and dynamically developing economies to orbit of JINR is the most important area of work to prevent the development of negative scenarios for realization of financial risks.

The Sum of Contributions are to be increased by 5% annually to fully cover the $1,944.6 million cost. In case of insignificant indexation of the amount of contributions, we have: underfunding of certain stages of work on large scientific projects (NICA-SPD in the first place, about $ 45 million, DRIBs-III Radiochemical Laboratory - class 1 - about 8.5 M$), Life Science and external cooperation up to 10 M$, reduction of experimental time (10-20 M$, as well as cancellation of the involvement of about 200 highly qualified scientists and specialists (36 M$).Even after these cardinal cuts for the JINR Development Program, the budget will have a deficit of about 100 M$.


Thank you!