56th Meeting of the Programme Advisory Committee for Nuclear Physics

26 January 2023

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Programme Advisory Committee for Nuclear Physics, 56th. meeting, 26 January 2023

1. Opening of the meeting	*G. Trubnikov*
2. Structure and main directions of JINR research. Scientific results in recent years and the development of JINR for 2024–2030	***G. Trubnikov***
3. Information on the Resolution of the 132nd session of the JINR Scientific Council (September 2022) and on the decisions of the JINR Committee of Plenipotentiaries (November 2022) of the JINR Committee of Plenipotentiaries (November 2021)	*S. Dmitriev*
4. Draft Seven-Year Plan for the Development of JINR in nuclear physics for 2024–2030:	
4.1 FLNR main tasks: status and proposals for the Seven-Year Plan for the Development of JINR for 2024–2030	**S. Sidorchuk**
4.2 FLNP main tasks: status and proposals for the Seven-Year Plan for the Development of JINR for 2024–2030	**V. Shvetsov**
4.3 Research in non-accelerator neutrino physics and astrophysics and proposals for the Seven-Year Plan for the Development of JINR for 2024–2030	**E. Yakushev**
4.4 BLTP main tasks in the study of the theory of nuclear systems: status and proposals for the Seven-Year Plan for the Development of JINR for 2024–2030. Proposal for the extension of the theme «Theory of nuclear systems»	**N. Antonenko**
4.5 Status and prospects of the MLIT scientific programme	**V. Korenkov**

Closed session:

5. Meeting of the PAC members with the JINR Directorate
6. Preparation of the PAC recommendations
7. Adoption of the PAC recommendations
8. Closing of the meeting

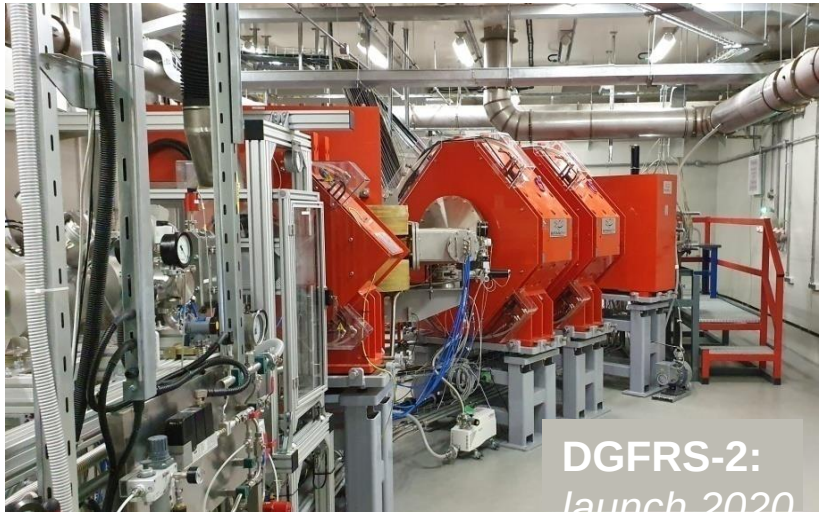
Flerov Laboratory of Nuclear Reactions:

Status and proposals in the 7-year plan of development for 2024 - 2030

The heavy-ion research in the FLNR is aimed at performing the tasks outlined in two themes:

- "Synthesis and properties of superheavy nuclei, structure of nuclei at the limits of nucleon stability"
- "Development of the FLNR accelerator complex and experimental setups (DRIBs-III)".

First experiments at SHE Factory (2020 - 2022)



Experiments:

$^{243}Am + {}^{48}Ca \rightarrow {}^{291}Mc^*$

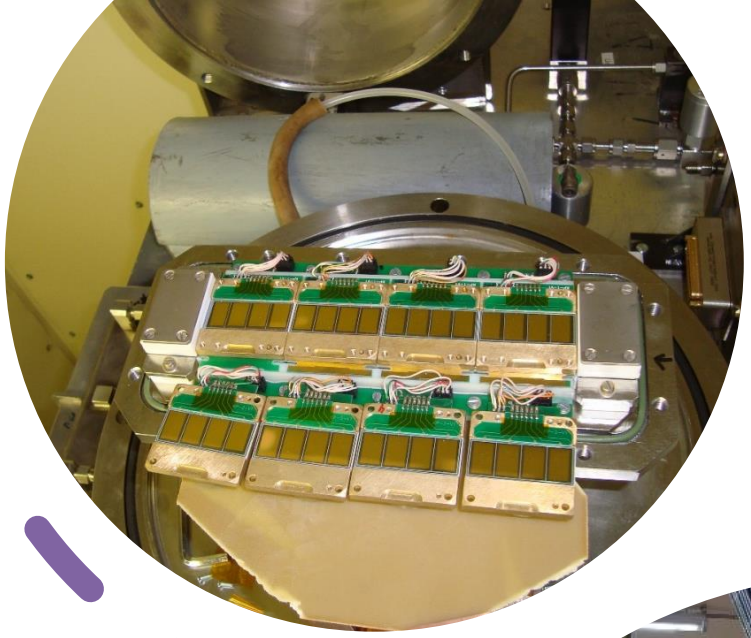
$^{242}Pu + {}^{48}Ca \rightarrow {}^{290}Fl^*$

$^{238}U + {}^{48}Ca \rightarrow {}^{286}Cn^*$

$^{232}Th + {}^{48}Ca \rightarrow {}^{280}Ds^*$

- **238 new events** of synthesis of superheavy nuclides (*3 times more than in the entire history of research*);
- Decay properties **33 isotopes**;
- **New isotopes**: ^{287}Mc, ^{264}Lr, ^{276}Ds, ^{272}Hs, ^{268}Sg;
- **New decay modes**: ^{268}Db (alpha-decay), ^{279}Rg (spontaneous fission);
- Indication of the 1st excited state in ^{286}Fl;
- Test of target stability up to 6.5 pμA of ^{48}Ca;

Chemistry of Cn&Fl:



- At the Superheavy Element Factory, preparations are underway for the first experiment to study the chemical properties of elements 114 (flerovium) and 112 (copernicium) in the reaction of $^{48}Ca + ^{242}Pu \rightarrow Fl^*$

- The first commissioning tests of the GRAND separator on a beam of ^{48}Ca have been successfully performed.

- A fairly compact image of recoil nuclei was obtained in the focal plane of the detector chamber: 5 x 5.5 cm, which allows proceeding to the next stages of the experiment preparation.

First run (Nov.-Dec. 2022) $^{48}Ca + ^{242}Pu \rightarrow Fl^*$

Second run is planned for 2023.

ACCELERATOR COMPLEX DRIBs-3

DC280

Main goals:

Experiments on extremely low (σ<100 fb) cross sections:

- Synthesis of new SHE in reactions with ^{50}Ti, ^{54}Cr ...;
- Synthesis of new isotopes of SHE;
- Search for rare decay modes of SHE;
- Study of excitation functions.

Experiments requiring high statistics:

- Nuclear spectroscopy of SHE;
- Precise mass measurements;
- Study of chemical properties of SHE.

U400 → U400R

Reconstruction:

- Reconstruction of the accelerator is scheduled for the beginning of the upcoming seven-year period

CONSTRUCTION of the NEW EXPERIMENTAL HALL (2023-2025)

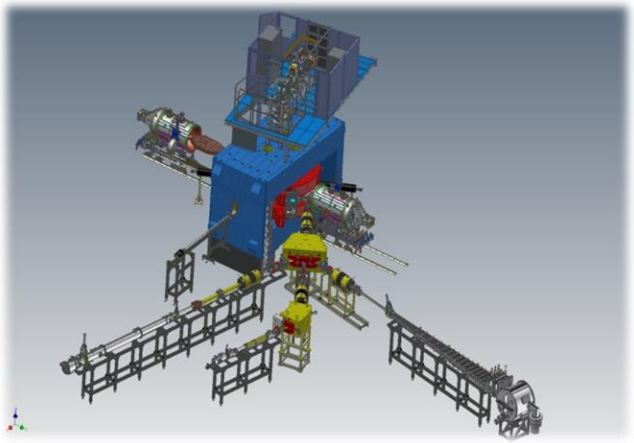
U400M

Modernization and launch in 2023

Expected results of the upgrade in 2023:

- Stable operation;
- Improved beam quality;
- Increase of beam intensities.
- Studies of the ^{7}He structure in the ^{6}He(d,p)^{7}He reaction are planned as the first experiment.

DC140



Development of a new facility for applied research:

- Main goals of the project include solid-state physics studies, surface modifications of materials, production of track membranes and testing electronic components for single radiation effects.
- Ion beams from O to Bi with energies 4.8 and 2.1 MeV/n for applied studies.

Planned research areas for 2024 – 2030

New elements

DGFRS II

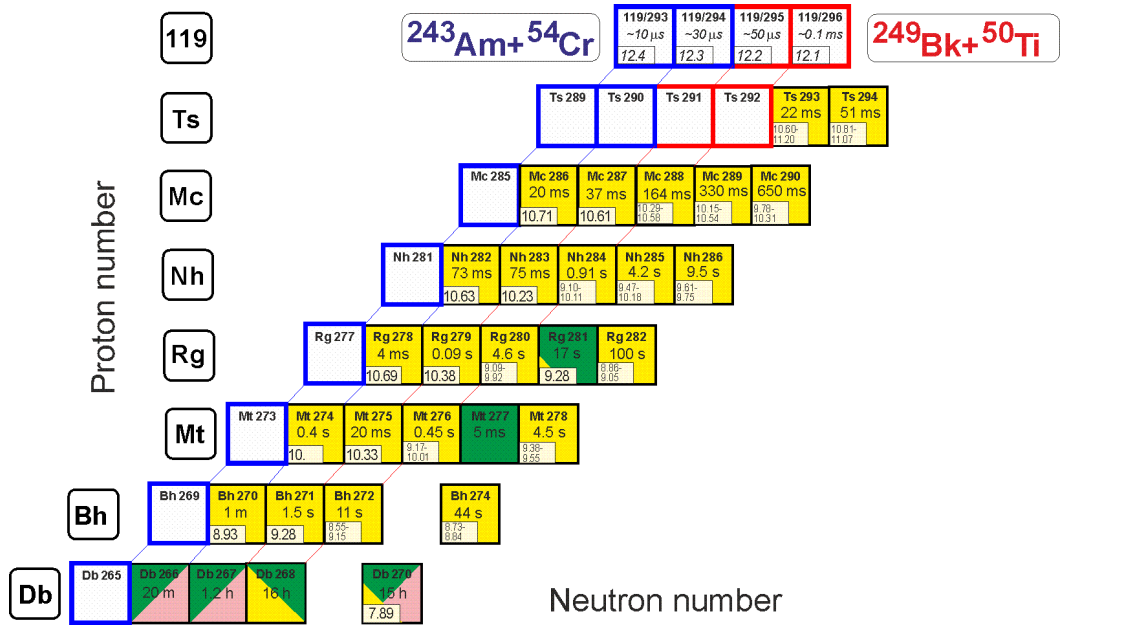
^{243}Am(^{54}Cr,3-4n)^{293,294}119 ($\sigma \sim 0.01$ pb)
^{249}Bk(^{50}Ti,3-4n)^{295,296}119 ($\sigma \sim 0.1$ pb)

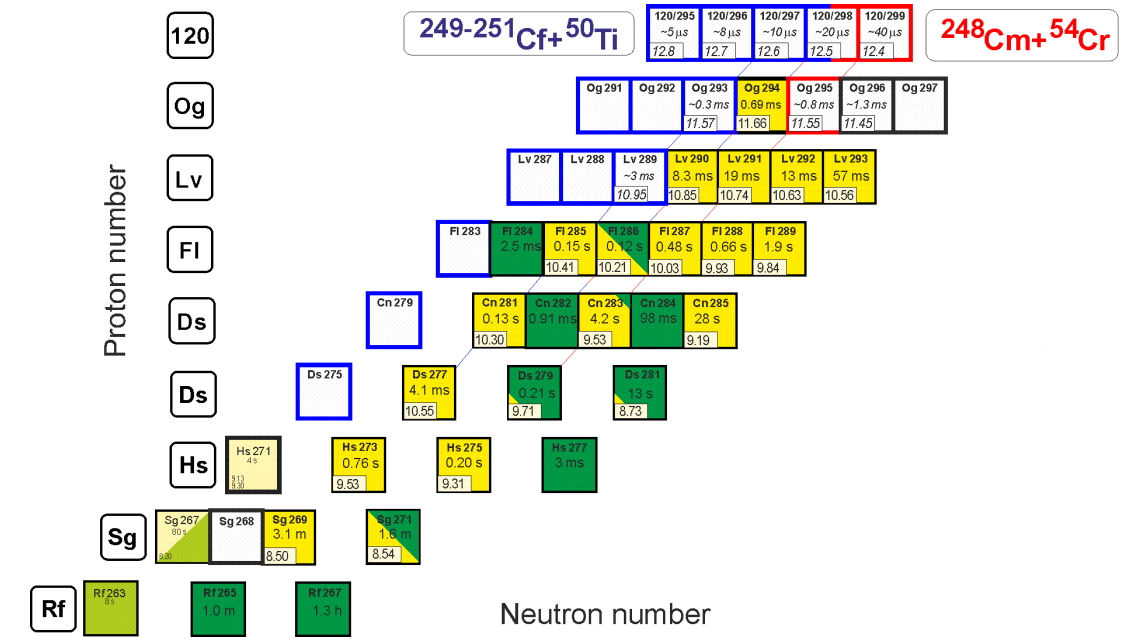
I_{beam}=3 pμA,
h_t=0.4 mg/cm^2,
ε_{coll}=0.6,
σ=0.05 pb $\rightarrow$ ≈1 event per month

^{245,246,248}Cm(^{54}Cr,3-4n)$^{295-299}$120
$^{249-251}$Cf(^{50}Ti,3-4n)$^{295-298}$120

Tasks:

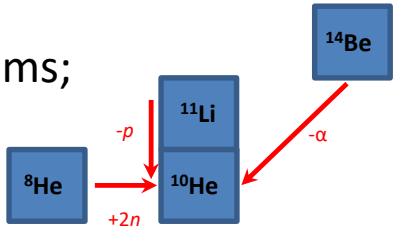
- Beam intensity increase (^{50}Ti,^{54}Cr);
- License to work with RM;
- I class RCL at the SHE Factory (Bk, Cf).





Planned research topics for 2024 – 2030

- Beyond the nucleon stability line with 2n-transfer
  ^{10}He, ^{13}Li,^{16}Be. Lighter neutron-rich isotopes like ^{6,8}He, ^{11}Li, $^{11\text{-}14}$Be are also of interest;
- Structure of neutron-rich isotopes in (d,p) reactions;
- Impact of the reaction mechanism on population of low energy spectra of exotic nuclear systems;
- Exotic radioactivity
  (formation of 2-p radioactive nuclei in (^{3}He,n) reactions, ^{26}S);
- Isotopic symmetry of nuclear reactions
  (^{3}H,^{3}He) and (^{3}He,^{3}H);
- Total reaction cross-sections;
- β-decays of neutron-rich nuclei, β-delayed decays.



Instrumentation Development

- In-beam detectors;
- Neutron detector array (increase in number of modules);
- Charged particles detector arrays (angular and energy acceptance);
- RF-kicker (operational run with ion beam);
- Zero-angle spectrometer hodoscope;
- Cryogenic tritium target.

Recommendation:
The PAC heard with interest the report on the main achievements of FLNR for the period 2017–2023.
The PAC supports the proposed strategy for the development of heavy-ion physics research in FLNR for 2024–2030.
The PAC expects that its research areas will be presented in the form of themes and projects at the next meeting of the PAC for Nuclear Physics in June 2023.

FLNP main tasks: status and proposals for the Seven-Year Plan for the Development of JINR for 2024–2030

Research directions and activities:

- Investigation of fundamental symmetries violation in neutron-nuclei interactions and collecting respective nuclear data:
  - TRI and ROT effects in nuclear fission;
  - prompt neutron emission in fission (the **ENGRIN** project, since 2022);
  - Parameters of (n,p) and (n,α) reactions in astrophysics and engineering;
  - angular distribution of γ-ray emission in (n,n') reactions (the **TANGRA** project, since 2014).
- Investigation of neutron fundamental properties, ultracold and very cold neutron physics:
  - quantum-mechanical effects with slow neutrons;
  - developing new UCN and VCN sources;
  - interaction of slow neutrons with nanoparticles.
- Nuclear data.
- Exploitation and development of the IREN facility.

Applied and methodological research:

- Ecology;
- Archeology;
- Nanotoxicology;
- Analysis of Extraterrestrial objects;
- Developing new technologies for electronics and applications;
- etc.

- Neutron Activation Analysis at IBR-2 and IREN;
- Prompt γ-Activation Analysis at IBR-2;
- Neutron Resonance Capture Analysis at IREN;
- Ion Beam Analysis at EG-5;
- Other analytical techniques (IR, ICP-MS, X-ray);
- Project “Modernization of EG-5”

Plans for 2024-2030

IREN neutron source. It allows us to perform the research program on fundamental nuclear physics with neutrons and nuclear data measurements, similar to the programs at neutron sources like GELINA (IRMM, Geel).

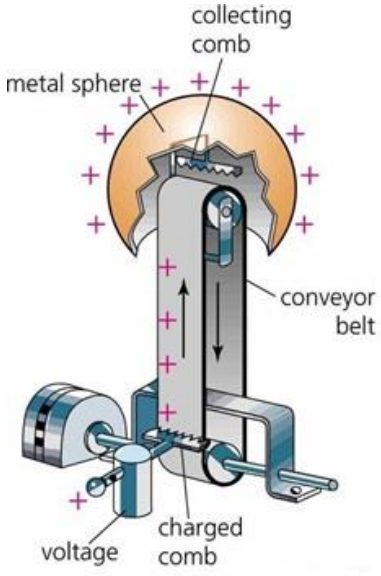
Scientific program for IREN

- Nuclear fission in resonances.
- Search and study of P- and T- violating effects.
- Nuclear data for nuclear engineering and astrophysics.
- Neutron activation analysis and prompt-γ analysis.
- Experimental study of isotopes production in photonuclear reactions

Tasks for the next 7 years:

- Increase neutron yield up to $3 \cdot 10^{12}$ n/sec
  - ✓ Electron energy up to 150 MeV;
  - ✓ Peak current 2,5 A;
  - ✓ Pulse length 150-200 ns'
- modernization of experimental halls of the facility
- Increase operation time up to 3000 hours/year

EG-5 electrostatic generator as neutron source and source for ion beam analysis



Scientific program for EG-5 in nuclear physics

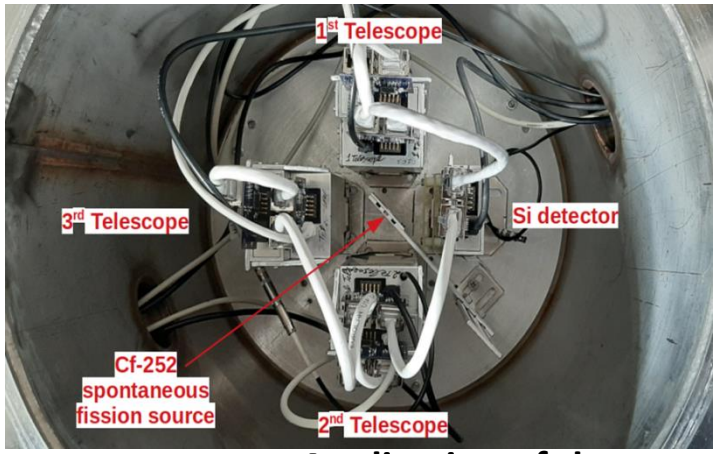
Obtaining data for nuclear engineering and astrophysics: integral and differential neutron cross sections, angular correlations in the relevant energy range.

Tasks for the next 7years:

- increase current up to 50 μA;
- increase energy up to 4.1 MeV;
- modernization of experimental infrastructure;
- development of ion microbeams.

Plans for 2024-2030

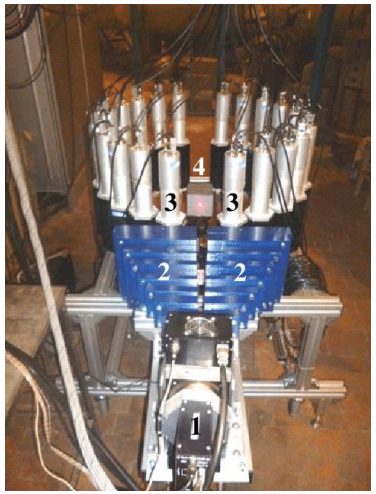
NEUTRON NUCLEAR PHYSICS AT the NEUTRON GENERATOR, IBR-2 AND OTHER NEUTRON SOURSES



Nuclear fission process:

- measurement of mass-energy and angular distributions of fragments;
- prompt and delayed neutrons and γ-quanta;
- search for rare and exotic fission modes – quaternary and quinary fission, etc;
- Study of T-odd effects in fission.

TANGRA Project



Application of the tagged neutron method for measuring angular and energy distributions of emitted γ-rays and neutrons in (n,n') reactions with neutrons at the energy of 14 MeV.

Tasks for the next 7years:

- Development of an original method for measuring neutron lifetime in a beam of a pulsed neutron source.
- Development and application of neutron and nuclear methods: instrumental activation analysis; prompt-γ neutron activation; elemental analysis of surface layers of solids.
- Development of experimental infrastructure (development of neutron polarizer, new detector systems, etc.)
- Nuclear data

RESEARCH WITH ULTRACOLD NEUTRONS

Scientific program for an UCN source in Dubna:

- **Plan for the next seven years** is to build an UCN source at the IBR-2 reactor with world-class parameters, based on the time focusing method;
- Neutron lifetime measurement (with the accuracy of <1 sec);
- Investigation of abnormal UCN losses;
- Non-stationary quantum effects and neutron optics

Recommendation:

The PAC heard with interest the report on the main achievements of FLNP during the seven-year period 2017–2023.

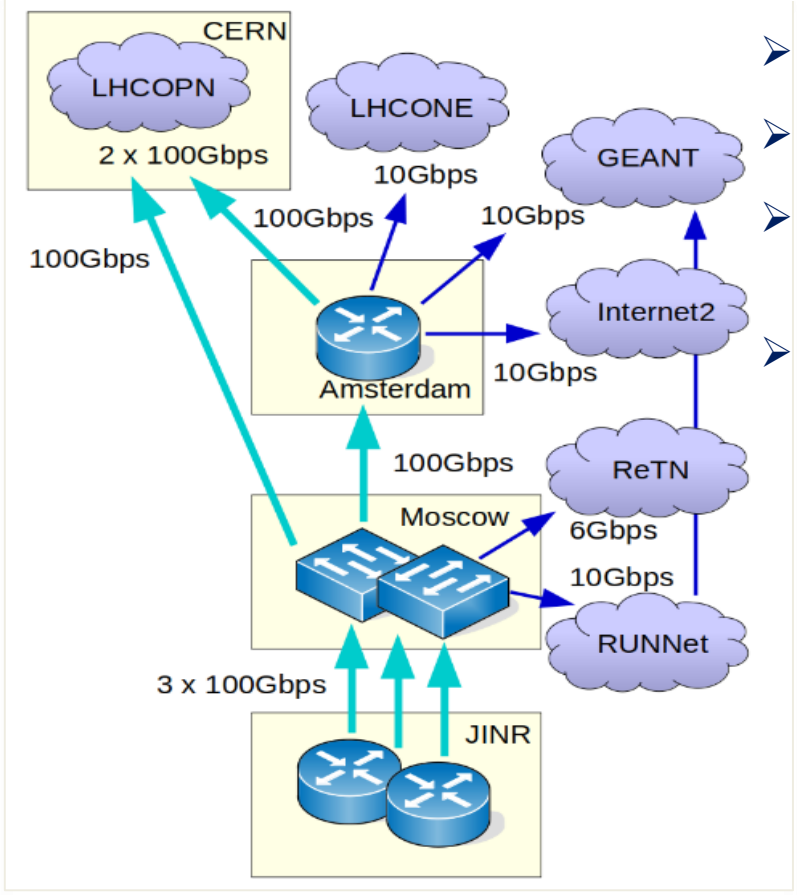
The PAC recommends continuing scientific research in the field of nuclear physics with neutrons using the FLNP facilities, in particular the IREN pulsed source of resonance neutrons, the IBR-2 pulsed reactor, and the EG-5 electrostatic generator, by opening several new projects.

The PAC recommends to consider singling out the development of IREN as an infrastructure project, given the fact that the research in nuclear physics at FLNP should become based on this facility.

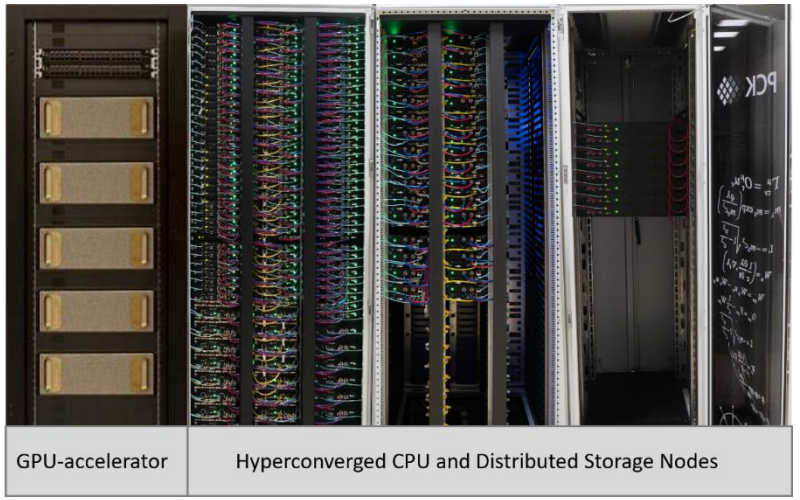
The PAC recommends to present the extension of the theme with proposals to open new projects, in the framework of the theme, at the next meeting in June 2023.

Status and prospects of the Meshcheryakov Laboratory of Information Technologies scientific program

The network infrastructure is a fundamental component of the IT infrastructure of JINR and the MICC. It provides access to Internet, computing resources and data storage systems, as well as enables experimental data processing and computing. MLIT ensures the reliable and fault-tolerant operation of all components of the network infrastructure:

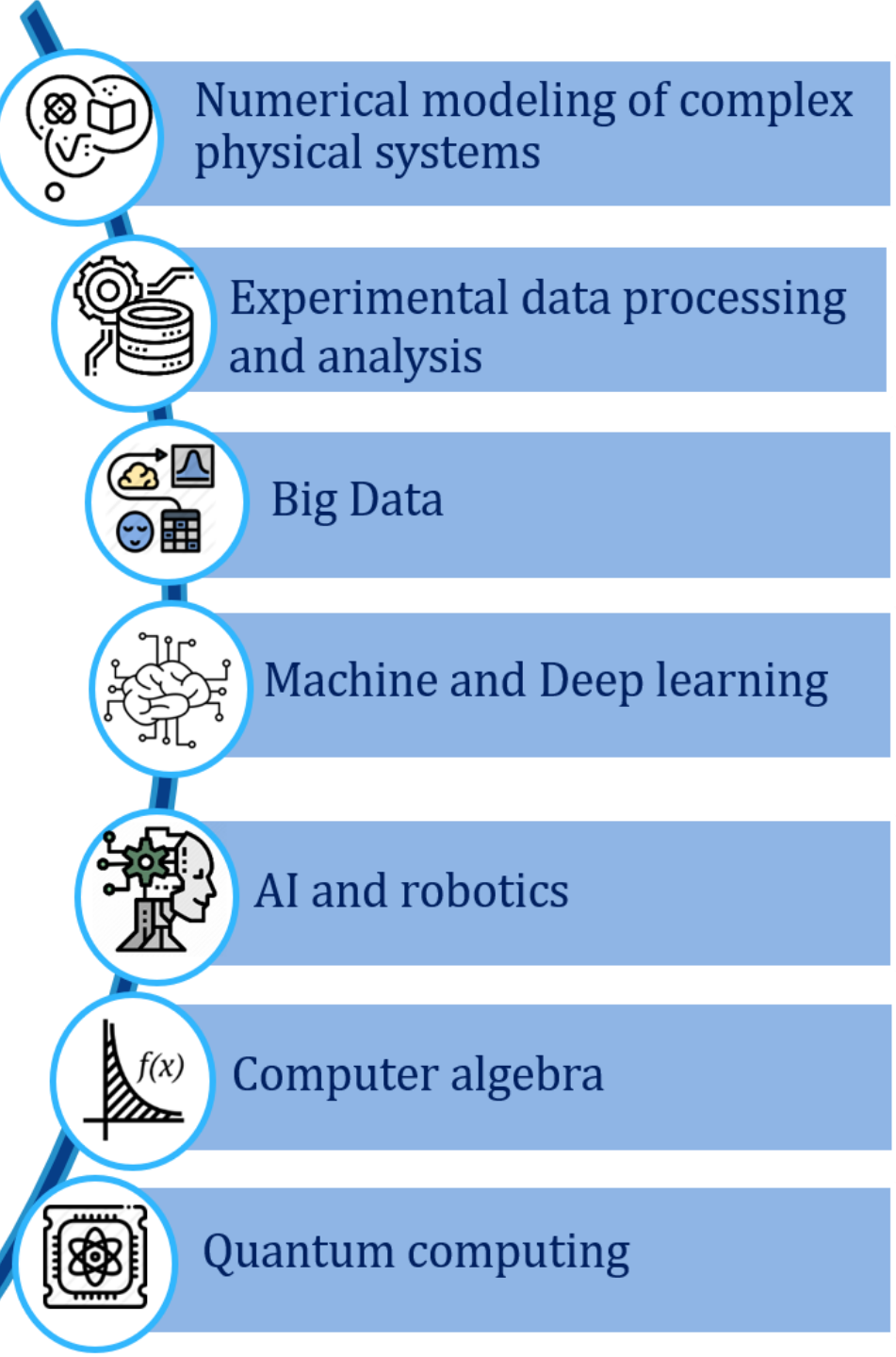


- JINR-Moscow 3x100 Gbit/s
- JINR-CERN 100 Gbit/s and JINR-Amsterdam 100 Gbit/s
- multi-site cluster network with a bandwidth of 4x100 Gbit/s for the NICA megaproject
- local area network with a bandwidth of 2x100 Gb/s



"Govorun" Supercomputer

The resources of the "Govorun" supercomputer are used by scientific groups from all the Laboratories of the Institute for solving a wide range of tasks in the field of theoretical physics, as well as for physics modeling and experimental data processing.



Methods, Algorithms and Software

- Other activities of MLIT are related to the development and implementation of effective methods, algorithms and software for physical systems modeling, mathematical processing and experimental data analysis using the MICC resources for the successful achievement of the scientific program by scientists of JINR and its Member States.

- The most important tasks are the development of new data processing and analysis algorithms based on deep and machine learning, including artificial intelligence, and the development of modern Big Data methods and algorithms for solving applied problems.

Recommendation:

The PAC heard with interest the report on the main achievements of MLIT for the seven-year period 2017–2023.

The PAC fully supports the MLIT scientific programme related to the development of the themes "Information and computing infrastructure of JINR" and "Methods, algorithms and software for modeling physical systems, mathematical processing and analysis of experimental data".

The PAC recommends to present the extension of the theme with proposals to open new projects, in the framework of the theme, at the next meeting in June 2023.

Research in Non-accelerator neutrino physics and astrophysics and proposals for the Seven-Year Plan

The research theme: Non-accelerator neutrino physics and astrophysics

Research directions:

- investigation of double beta-decay by different calorimetric and track calorimetric methods;
- search for the neutrino magnetic moment, neutrino-nucleus coherent scattering (CEvNS);
- investigation of galactic and extragalactic neutrino sources, diffusive neutrino cosmic background, search for exotic particles, search for sterile neutrinos;
- distant investigation of processes inside a nuclear reactor core using neutrinos;
- development of new methods for the detection of charged and neutral particles;
- development of modern radiochemistry for astrophysics and nuclear medicine.

7 main projects:

Neutrinoless double beta-decay

SuperNEMO,
GERDA (Legend),
Monument,

Experiments with the reactor anti-neutrino

EDELWEISS/Ricochet,
vGeN,
DANSS,

Dedicated to deep-water investigations with the neutrino telescope on Lake Baikal

BAIKAL-GVD

In addition to the scientific personal involved in the theme, the following resources are available to carry out the scientific projects:

- the laboratory for the production and repair of semiconductor detectors,
- laboratory for development and production of scintillation materials for detectors,
- radiochemical sector (development of calibration radioactive sources, purification of materials designated for low-background measurements from their contamination by natural radioactivity, etc),
- mechanical workshops,
- a group of computer support,
- a group of mass separators.

North hemisphere biggest neutrino detector BAIKAL-GVD

Neutrino telescopes bring important information complementary to the traditional optic and radio telescopes.

Main principle : determination of direction and energy of charged particles (appearing as a result of neutrino interaction) using the Cherenkov radiation

Baikal project: From 1980 tests and R&D, started in 1993.

Now – building BAIKAL-GVD (**Gigaton Volume Detector)** has huge progress and will continue

Physics:

- Investigate Galactic and extragalactic neutrino “point sources”;
- Diffuse neutrino flux – energy spectrum, local and global anisotropy, flavor content;
- Indirect search for Dark Matter;
- Exotic particles – monopoles, Q-balls, nuclearites, …

Propose to reorganize the structure of the theme

The new structure will have 4 main projects:

- **BAIKAL-GVD**
- **A short baseline reactor neutrino investigation (Ricochet, DANSS-2, and νGeN experiments)**
- **Nuclear spectrometry for search and investigation of rare phenomena (all double beta decay related experiments and activities, search for Dark Matter by nuclear spectrometry methods, etc)**
- **Radiochemistry plus spectroscopy for astrophysics and nuclear medicine**

Recommendation:

The PAC heard with interest the report on the main work performed and achievements of DLNP for the seven-year period 2017–2023.

The PAC recommends reorganizing the structure of the theme and presenting larger projects in neutrino physics and astrophysics at the next PAC meeting.

The PAC underlines the importance of the efforts of DLNP to further improve the local infrastructure at JINR and on Lake Baikal.

BLTP: Theory of Nuclear Systems

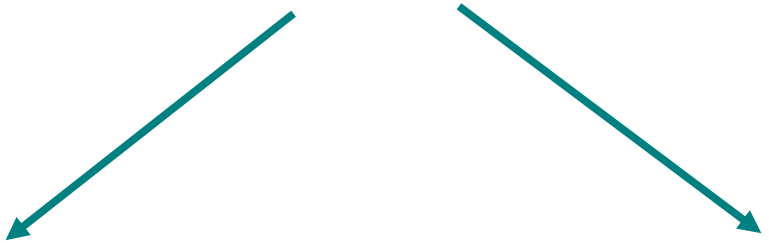
The works present the main research directions:

- structure of nuclei far from stability,
- structure of superheavy nuclei,
- nucleus-nucleus collisions at low energies,
- fusion and fission dynamics, reactions of astrophysical interest,
- few-body systems,
- nuclear dynamics at relativistic energies,
- properties of hot and dense nuclear matter,
- nonlinear quantum processes in strong polarized electromagnetic fields.

For better organization of research, the theme should consist of four projects:

- “Microscopic models for exotic nuclei and nuclear astrophysics”,
- “Low-energy nuclear dynamics and properties of nuclear systems”,
- “Quantum few-body systems”,
- “Relativistic nuclear dynamics and nonlinear quantum processes”.

Concept of the Theme «Theory of Nuclear Systems»



Development of theoretical ⟺ Applications for experiments methods

Multidisciplinar nature

Attraction of young researchers in nuclear theory

The future theoretical studies will be closely related to the programs of operating and commissioning facilities at JINR (SHE-factory, ACCULINA-2) and in the world (FAIR, ISOL facilities HIE-ISOLDE, SPES, SPIRAL2, FRIB, RAON, HIAF). The studies of heavy-ion collisions at high energies will be related to the NICA project at JINR.

Recommendation:

The PAC supports the continuation of the nuclear theory research under the ongoing theme, which should reflect a complex and broad approach to various aspects of nuclear structure and nuclear reactions and correspond to the experimental programme of JINR.

The PAC also appreciates the BLTP educational activities and the connection between theoretical studies and the JINR experimental programme.

The PAC appreciates the results obtained in the main areas of research and recommends the extension of the theme “Theory of nuclear systems” until 2030.

The next meeting of the PAC for Nuclear Physics will be held on **29–30 June 2023.**

THANK YOU FOR YOUR ATTENTION!