Project review

“Multi-Purpose Detector (MPD)”

The NICA accelerator complex and the MPD (“Multipurpose Detector”) experimental facility are in the final stages of construction, with the expectation of the first heavy-ion beams in late 2025. The main scientific goal of the MPD experiment is to study strongly interacting matter at extremely high baryon densities at collision energies $\sqrt{s_{NN}}$ = 4-11 GeV in the collider mode and/or $\sqrt{s_{NN}}$ = 2.4-3.5 GeV in the fixed-target configuration. The search for signals of onset of deconfinement, the first-order phase transition, and the critical end-point is the main content of the MPD physics program. The beam energy and the system-size scan programs will be implemented at NICA in order to achieve this goal. Model calculations indicate that the highest baryon densities are achieved in the NICA energy range, making MPD particularly well suited for such studies. This energy region is also important for modern astrophysics. Model calculations show that in neutron star mergers, nuclear matter reaches densities and temperatures similar to those observed in heavy-ion collisions at NICA energies. Thus, MPD offers a unique opportunity to complement the study of neutron star mergers by obtaining data from a ground-based laboratory experiment. The ability to study collisions of different nuclear systems at NICA is expected to significantly extend the results of the energy scan program for a single Au+Au system at the RHIC collider, which was finished in 2021.

In 2020-24, the main components of subsystems of the MPD Phase-I detector have been manufactured, which includes Time-Projection Chamber (TPC), Time-Of-Flight system (TOF), Electromagnetic Calorimeter (ECal), Fast Forward Detector (FFD) and Forward Hadron Calorimeter (FHCal). Their assembly, testing and calibration are currently underway. Extensive work has been done to assemble and commission the MPD solenoidal superconducting magnet. A test cooling of the magnet to liquid nitrogen temperature was performed in early 2024. In November, scheduled cooling of the magnet to liquid helium temperature began, and preparations for magnetic field measurements are underway. Multi-level platforms with clean rooms for power supplies, electronics and control systems of detector subsystems were designed and built, and the tracking of a huge number of cables and pipes of various diameters was optimized. The startup of the MPD with beams in 2025-2026 is expected to utilize Xe and Bi nuclei, which provide more reliable operation of the NICA accelerator complex during the commissioning phase. In Phase-I configuration, the MPD will be able to measure particle momenta and identify particles in the pseudorapidity range $|\eta| < 1.2$.

During the same period, a comprehensive program of physics feasibility studies for the MPD in Phase-I configuration was carried out. Using Monte Carlo simulations with full event reconstruction, the performance of measuring the yields of various particles species, including light mesons and hyperons, resonances, light nuclei and (hyper)nuclei, direct photons and dileptons, was investigated. The studies demonstrated that MPD would be capable of measuring collective flow and particle correlations as a function of collision centrality, transverse momentum, and particle momentum with high efficiency. MPD capabilities were also investigated for fixed-target operation, which will significantly extend the range of available energies and resolve the problem of decreasing event rate at lower collision energies, most relevant at startup. The results of these studies were presented at international conferences and published in refereed journals (more than 60 publications).

An important part of the project is devoted to discussion of the concept of a future upgrade of the MPD facility to Phase-II, which includes the installation of forward spectrometers consisting of the tracking stations and detectors for particle identification. The forward spectrometers will extend the pseudorapidity coverage of the MPD detector to $|\eta| < 2.0$. With the upgrade, the MPD will be able to study the QCD phase diagram in even more detail, for the first time using a three-dimensional scan in the collision energy, system size, and the particle pseudorapidity. The realization of the upgrade program will increase the sensitivity of measured signals to details of the QCD phase diagram.

At present time, more than 500 scientists and engineers from 39 institutes and universities from 12 different countries take part in the MPD project. For the first time, a functioning large international collaboration was created in JINR, which has passed the test of time for 6 years of its existence. The MPD project team undoubtedly possesses high scientific qualification in the creation of modern detector equipment, as well as vast experience in conducting heavy-ion experiments, physics analysis of experimental data and simulation of different processes gained at SIS, Nuclotron, SPS, RHIC and LHC accelerators.

The schedule for completing the basic configuration of the MPD and detector startup using the beams of the NICA collider looks quite realistic.

The resources requested for the Phase-II upgrade of the MPD, including the forward spectrometers, look adequate to the task and consistent with the experience in building and financing comparable experimental systems.

I support the project and propose to extend it for 5 years with the first priority.

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