Referee's report on the prolongation of the Project
« Studies of Baryonic Matter at the Nuclotron (BM@N)» for 2022-2026 years

The main goal of the presented Project is the study of dense nuclear matter at low collision energies of nuclei (2-4 GeV / nucleon) up to gold nuclei.

In the Introduction and Chapter 2, the proposed studies are substantiated in sufficient detail from the point of view of the currently available experimental and theoretical results obtained in the energy range under consideration. In particular, it is planned to study the characteristics of the resulting strange mesons and hyperons, hypernuclei and elliptical particle fluxes. It should be noted that in these traditional studies, the presented experiment can complement a number of available results in the energy range of 2-4 GeV / nucleon. In addition, an important factor is the expected achievement of the interaction rate of 50 kHz, which is twice the value obtained in this energy range in the STAR F.t. experiment. A much higher value can only be achieved with the future SIS100 accelerator. In the presented project, an important aspect is the comparison with theoretical models and, in particular, the possible study of the equation of state. There are still many unclear points in this issue from the point of view of the phase diagram in the region of low temperatures and high baryon densities, where the dualism of dense baryonic and quark matter (quarkyonic matter) can manifest itself. The production of hypernuclei and hyperons with increased strangeness is traditionally studied here, while the statistics of the latter will noticeably increase in comparison with the previously obtained one due to an increase in the Nuclotron energy and an increased frequency of recorded interactions. The connection of these results with theoretical concepts of the state of matter of neutron stars is specially discussed, where the choice of the equation of state with the inclusion of hyperon matter plays a decisive role, and some theoretical contradictions are designated as the "hyperon puzzle". It can be noted here that in recent years, studies of femtoscopic correlations of pairs of different hyperons have been very popular in this direction, which make it possible to determine the nature of the forces of their interaction (attraction or repulsion). But such studies, carried out at RHIC and especially LHC energies, most likely cannot be carried out at low energies of the Nuclotron.

In the 3rd chapter, all the components of the experimental setup are considered in detail, the characteristics of which should ensure the possibility of obtaining the planned results. These characteristics are discussed in Section 3.1 and are selected based on the experience obtained in various experiments in the study of collisions of relativistic heavy ions. By the same principle, a set of different detectors is determined in combination with the optimal value of the magnetic field of the analyzing magnet. It should be noted that in addition to the already proven and widely used technologies, the most modern ones are also used, for example, GEM detectors for the central tracking system. In combination of these detectors with silicone microstrip detectors and cathode strip chambers, the entire track system, according to the results of MC simulation, allows achieving a momentum resolution (Δp / p) (1.6 - 1.2)% in the momentum range (0.5 - 4, 0) GeV / c and with an optimal magnetic field of 0.4 T, which is sufficient to solve the planned research. One of the main characteristics of the facility - the ability to identify charged particles and light nuclei, is provided by a time-of-flight (TOF) detector based on chambers with a set of resistive plates (multi-gap resistive plate chambers). This technology is currently the most popular, since at moderate costs it allows obtaining a good time resolution of $85 \div 120$ ps (in the configuration of the BM @ N setup together with the T0 detector), which, in turn, will ensure the identification of pions, kaons, and protons at the level for the most part 3 sigma time resolution. The setup is complemented by an electromagnetic and a hadronic (with a quartz hodoscope) calorimeters, respectively, for studying processes involving electrons and photons, and for determining the centrality of nuclear collisions (taking into account the loss of heavy fragments). The set of trigger detectors assumes an effective “on-line” selection of the required events.

An important aspect of the experiment is preliminary runs of the setup with an incomplete set of detectors on beams of light and medium nuclei, during which the characteristics of a number of detectors were verified. The first physical studies of the production of Λ hyperons showed the capabilities of the setup close to the calculated ones and also good results of detector calibrations.

In the considered BM@N project, the planned physical studies seem to be relevant, and the configuration of the experimental setup is adequate to the tasks set. The requested funding is in line with the stated costs.

The uncertainties and possible reasons for the delay in the start of the experiment in full, indicated in Chapter 4, can be considered as objective conditions that apply to the full NICA project, which will certainly use the experience of the BM@N experiment.

I recommend approving the extension of “the Baryonic Matter Research at the Nuclotron (BM@N)” Project with the first priority for 2022 – 2026 years within the requested resources.

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