Status of the NICA/MPD project

Kolesnikov V.I.\textsuperscript{1} and Zinchenko A.I.\textsuperscript{1} for the MPD Collaboration

\textsuperscript{1} \textit{Joint Institute for Nuclear Research (JINR)}

Abstract

A general-purpose detector for studying heavy-ion collisions at the NICA facility is under construction at JINR. The NICA/MPD physics program, basic design requirements, and the MPD experimental setup will be described. Results of detector simulation and the expected performance for selected observables will be presented.

1. Introduction

Experimental studies of QCD matter at high baryon densities provides new perspectives to resolve the most fundamental problems of the underlying theory - confinement and chiral symmetry breaking. Our knowledge about the QCD phase structure at intermediate $\mu_B$ is poor: theory suggests a first-order transition at large $\mu_B$ and its turn into a crossover at small baryon densities (and high $T$), hence, for consistency, the critical endpoint (CEP) is expected to exist. However a rigorous proof on such a QCD structure is not yet available and new reliable experimental data on the nature and properties of the phase transition are needed.

The goal of the NICA research program at JINR is to investigate a wide range of physics phenomena in heavy-ion collisions including phases of nuclear matter and EoS at high baryon density, properties of the hadron spectral function and features of hyperon-nucleon interaction in the medium, critical behavior of the QCD matter and the spin structure of the nucleon \textsuperscript{1}. The new NICA facility \textsuperscript{2} will be capable to provide ion beams with the design luminosity of $10^{37}$ cm$^{-2}$s$^{-1}$ (for gold ions) in the energy range from $\sqrt{s} = 4$ to 11A GeV. In
2018, we will start a detailed energy and system size scan focusing on hadroproduction and dilepton studies, event-by-event fluctuations and correlations. Production of composite objects with strangeness (hypernuclei) are of particular interest, since they are a unique tool to probe new nuclear structures or unknown properties of the baryonic interaction, which cannot be seen from the study of ordinary nuclei.

2. MPD detector

The MultiPurpose Detector (MPD) is designed to fully exploit the NICA physics potential. It is a spectrometer with a large uniform acceptance (full azimuth) capable of detecting and identifying hadrons, electrons and gammas at the very high event rate achieved at NICA [3]. All the elements of the detector (see Fig.1) are ordered inside a superconducting solenoid generating a magnetic field of up to 0.6 T. Tracking will be performed with a cylindrical Time Projection Chamber (TPC) with a MWPC-based readout. The TPC is required to have a high efficiency and momentum resolution over the pseudorapidity range $|\eta| < 2$. Having of about 65 measured space points per a track, TPC will enable particle identification via the specific energy loss ($dE/dx$) measurement with a precision better than 8%. At large pseudorapidities TPC tracking will be supplemented by a multi-layer straw tube tracker (ECT) located just after the TPC end plates. The Inner Tracker (IT) will consist of four layers of double-
sided silicon microstrip detectors serving mainly for determination of the position of the primary interaction vertex and secondary decay vertices. The Time-Of-Flight (TOF) system made by RPC (Resistive Plate Chambers) is intended for charged hadron identification. The TOF detector covers $|\eta| < 3$ and its performance should allow the separation of kaons from protons up to a total momentum of 3 GeV/c. Behind the TOF detector, a high segmented electromagnetic calorimeter (ECAL) for electron and gamma identification will be located. Arrays of quartz counters (FD) are meant for fast timing and triggering, and two sets of hadron calorimeters (ZDC), covering the pseudorapidity region $2.5 < |\eta| < 4$, will measure the forward going energy for centrality selection and event plane analysis. A more detailed description of the detector components can be found elsewhere [4].

3. MPD performance studies and R&D

MPD tracking and PID performance. The MPD performance studies were performed within the MPDRoot framework [11], which provides an interface to external event generators (like UrQMD), transport codes (Geant3,4), and implements MPD detector response simulations and event reconstruction algorithms. Tracking and vertexing performance of MPD are shown in Fig.2 for single track efficiency and spatial resolution along the beam axis $\sigma_z$. As one can see, the detector is able to provide highly efficient tracking up to $\eta = 2$, 

Fig. 2: (Left panel) Tracking efficiency in TPC versus $\eta$ for an ideal and realistic TPC response. (Right) Primary vertex reconstruction resolution ($\sigma_z$) as a function of charged track multiplicity.
and a resolution better than 40 microns can be achieved in central collisions.

**Progress in MPD prototyping**  During the years 2012-13, the main MPD R&D activities were aimed at developing of novel techniques in construction of TPC, TOF, IT and ECT detectors, as well as at production and tests of the first detector prototypes (see Fig. 3). For example, to ensure lightweight and mechanical stability of the TPC, its supporting elements will be made from composite materials in collaboration with industry. Also, to ensure accurate tracking at large-η, a new construction technology for ECT modules was developed allowing the alignment of straw tubes with a 100 micron precision within an object of 2 meters in diameter.

**MPD potential for hypernuclei measurements.** The feasibility of precise hypernuclei measurements at NICA has been investigated with the event generator DCM. The model implements a coalescence-based algorithm for (hyper)nuclei formation and calculated yields of fragments are in a good agreement with experimental data [5]. Roughly $5 \cdot 10^5$ central Au+Au collisions at $\sqrt{s} = 5A$ GeV were analyzed including full event reconstruction, particle iden-
tification by means of combined dE/dx (Fig. 4) and TOF measurements, and search for secondary vertices. To improve the signal-to-background ratio, a set of quality and topological cuts were applied on the number of TPC space points and the distance between the daughers at the decay vertex. The results for $^3\Lambda He \to ^3He + \pi^-$ are shown in Fig. 4 (right panel). With the overall reconstruction efficiency of about 1\% and design NICA luminosity we expect roughly 500 reconstructed $^3\Lambda He$ candidates per day of data taking. Such high event rates provide a good opportunity to gain further insights into production mechanism and properties of hypernuclei.

1. A.N. Sissakian and A.S. Sorin, J. Phys. G: Nucl. Part. Phys. 36, 064069 (2009); A. Sissakian, O. Shevchenko, A. Nagaytsev and O. Ivanov, arXiv:hep-ph/0807.2480v4
2. NICA Conceptual Design Report. Dubna, 2008. [http://nica.jinr.ru/files/NICA_CDR.pdf](http://nica.jinr.ru/files/NICA_CDR.pdf)
3. Kh.A. Abraamyan et al, Nucl. Instrum. Methods A 628, 99 (2011)
4. MPD Conceptual Design Report. Dubna, 2011. [http://nica.jinr.ru/files/MPD_CDR_en.pdf](http://nica.jinr.ru/files/MPD_CDR_en.pdf)
5. J. Steinheimer, K. Gudima, A. Botvina, I. Mishustin, M. Bleicher, H. Stocker, Phys. Lett. B 714 (2012), pp. 85-91