PROCEEDINGS OF SCIENCE

Feasibility study of heavy ion collision physics at NICA JINR

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The Nuclotron-based Ion Collider fAcility (NICA) project is under active realization at the Joint Institute for Nuclear Research (JINR, Dubna). The main goal of the project is experimental study of baryon rich QCD matter in heavy ion (up to Au) collisions at centre-of-mass energies up to 11 GeV per nucleon. Two modes of the operation is foreseen, collider mode and extracted beams, with the two detectors, MPD and BM@N. In the collider mode the average luminosity is $L = 10^{27} cm^{-2} s^{-1}$ for Au(79+). Extracted beams of various nuclei species with maximum momenta 13 GeV/c (for protons) will be available. The NICA project also foresees a study of spin physics with the detector SPD with extracted and colliding beams of polarized deuterons and protons at centre-of-mass energies up to 27 GeV (for protons). The NICA experimental program allows to search for possible signs of the phase transitions and critical phenomena as well as to shed light on the problem of nucleon spin structure. Hereafter, feasibility studies of the observables, which are most sensitive to such phenomena, are presented.

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1. Introduction

The main goal of physics program at the Nuclotron-based Ion Collider fAcility (NICA) accelerator complex is a search for the mixed phase of quark matter and baryon rich hadronic matter as a consequence of the first order phase transition. Hereafter, we collect the most promising observables which are sensitive to the initial state of the created matter. Full detail of the Monte Carlo analysis of detectors at NICA can be found in publication [1].

2. Anisotropic flow

Anisotropic flow is formed at the early stage of collision and is sensitive to the system properties at the very early stage of fireball evolution.

The event plane resolution was estimated from forward hadron calorimeters using a sub-event technique and is shown in Fig.1(left). Good resolution allows to reconstruct direct flow with the high accuracy (Fig.1(middle)). The slope of v_1 for the identified (by energy loss in the TPC volume)

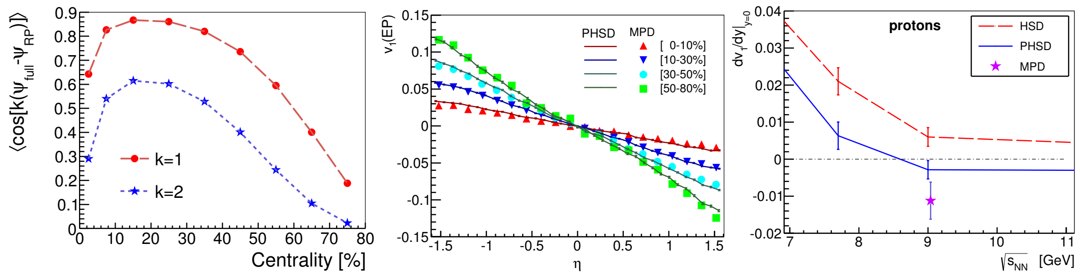

Figure 1: The event plane resolution (left) for the 1st and the 2nd harmonics from the forward hadron calorimeters. The reconstructed direct flow (middle) for charged particles as a function of pseudorapidity and slope (right) of direct flow for protons at mid-rapidity for Au+Au collisions at $\sqrt{s_{NN}}$ =9 GeV.

protons from mid-central collisions is shown in Fig.1(right). Also, predictions from the hadronic (HSD) and partonic (PHSD) models are presented there. The observed difference between the reconstructed slope and the model one appears to be due to efficiency of proton identification.

Mixed harmonic technique allows to reconstruct elliptic flow in wide centrality range. Fig.2(left) shows the integrated elliptic flow. The differential distributions of v_2 for all charged particles for

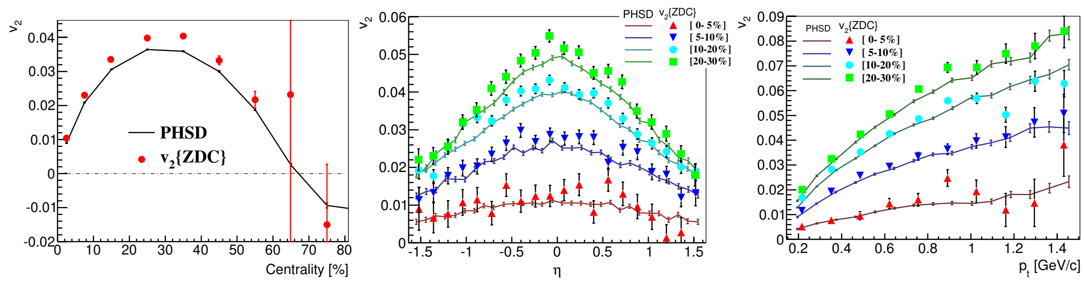

Figure 2: The reconstructed elliptic flow v_2 for charged particles for Au+Au collisions at $\sqrt{s_{NN}}$ =9 GeV.

several centrality intervals are presented in Fig.2(middle) and Fig.2(right). The reconstructed flow for central and mid-central events reproduces the model distributions slightly overestimating them. In the case of peripheral collisions the obtained error bars are essentially big and increasing of the statistics is required.

3. Charged azimuthal correlations

Charged azimuthal correlations are sensitive to a possible effect of local parity violation (Chiral Magnetic Effect) in the QCD.

Fig.3(left) shows the reconstructed two-particle angular correlation $\gamma_{ab} = \langle \cos[\phi_a + \phi_b - 2\Psi_{RP}] \rangle$ for the same and opposite charged particles with respect to the reaction plane angle Ψ_{RP}. It is of in-

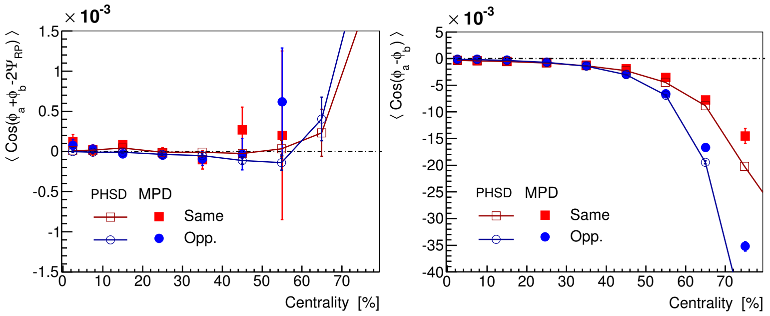

Figure 3: Correlations of the same and opposite charged particles with respect to reaction plane for Au+Au collisions at $\sqrt{s_{NN}}$ =9 GeV.

terest to consider the average $\langle \cos[\phi_a - \phi_b] \rangle$ that is supposed to be independent of the reaction plane and can be used in order to estimate systematic errors (Fig.3(right)). The azimuthal correlations and their projections are well reconstructed for central and mid-central collisions.

4. Baryon stopping power

Stopping power describes the conversion of the initial collision energy into hot and dense nuclear matter.

The 3-fluid dynamic model (3FD) associates the “wiggle”-behavior of rapidity distribution with a first-order phase transition [2]. To estimate this effect at the NICA energies we use the 3FD model with particlization procedure used for the UrQMD3.4 model [3]. The result of this

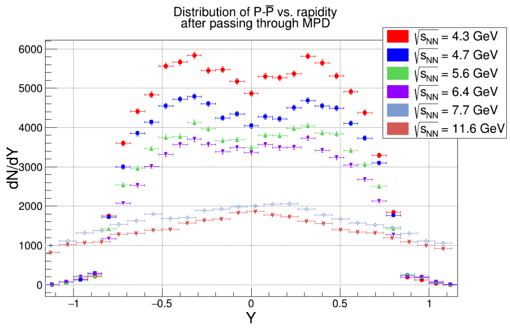

Figure 4: Dependence of the net-proton distribution on rapidity for AuAu-collisions at the NICA energy scan.

simulation shown in Fig.4 clearly indicates such peak-deep-peak behavior at mid-rapidity even with the simulation response for the MPD detector.

5. Dilepton production

The correlated lepton production is sensitive to the in-medium properties of hadrons.

The obtained results for the background-subtracted invariant mass distributions of electron-positron pairs and the signal-to-background ratio are shown in Fig 5. The overall signal-to-background ratio was found to be close to 10% [4].

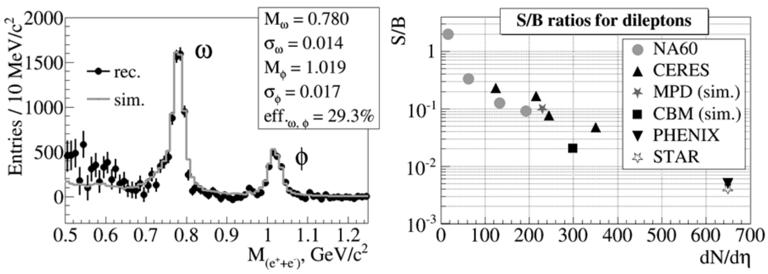

Figure 5: Background-subtracted invariant mass distributions (left) of electron-positron pairs from central Au+Au collisions at the MPD. Signal-to-Background (S/B) ratio (right) from heavy-ion experiments as a function of total charged multiplicity.

6. Hyperon and hypernuclei production

It is of further interest to consider strangeness production at high baryon densities as well as the mechanism and dynamics of hypernuclei formation.

In Fig.6 the invariant mass distributions of Λ-π^- and Λ-K$^-$ pairs from central Au+Au collisions at the center-of-mass energy $\sqrt{s} = 9$ GeV are shown. We have estimated the expected yields of particle species under interest for 10 weeks of the data taking at the nominal NICA collider luminosity [5].

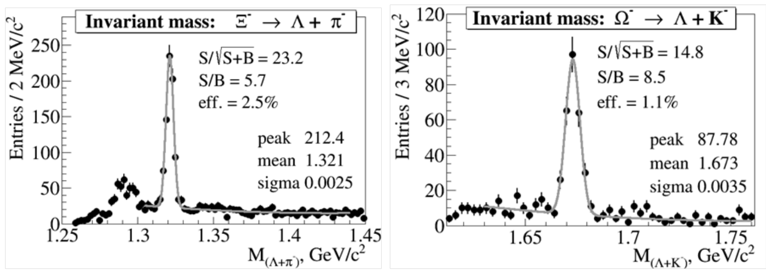

Figure 6: The reconstructed invariant mass of Λ and π^- candidates (left) as well as of Λ and K$^-$ pairs (right) from central Au+Au collision at $\sqrt{s_{NN}} = 9$GeV.

7. Summary

The NICA experiments are well suited to provide a variety of experimental data for the critical assessments of the QCD matter phase transitions in the low-temperature and high baryonic density domain of the QCD phase diagram. The sophisticated theoretical models accompanied by results of a realistic Monte Carlo Geant simulation of the proposed experimental setups at NICA support the ability of finding new phenomena in heavy ion collisions.

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