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Prospects of studying the production of hypernuclei in heavy-ion interactions at the NICA collider at JINR

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New acceleration complex NICA (Nuclotron-based Ion Collider fAcility) as well as MultiPurpose Detector (MPD) is underway at Joint Institute for Nuclear Research (Dubna, Russia) for the study of heavy-ion collisions. Strangeness and hypernuclei production is presently under active experimental and theoretical investigation and is of particular interest of the NICA/MPD program. We combine several dynamical transport models and the MST cluster finding procedure to calculate the production of light nuclei and hypernuclei in heavy-ion collisions at NICA energies. The emphasis will be put on the NICA prospects for the study of the production of hypernuclei and detector performance in the reconstruction of hypernuclei species.

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1. Introduction

A new accelerator complex NICA (Nuclotron-based Ion Collider facility) [1] for the study of the collisions of heavy ions and polarized particles is under construction at JINR (Dubna, Russia). The main goal of the NICA physics program is the experimental investigation of the strongly interacting matter phase diagram in the less explored region of the maximal baryon density. One of the main goals of the NICA project is to study the nucleon-hyperon and hyperon-hyperon interactions by the measurement of the production of hypernuclei. In order to better understand the dynamics of hot and dense hadronic matter, in particular, the strangeness production mechanism, the Multipurpose Detector (MPD) [2] experiment at the NICA collider will provide new precise experimental data on the total yields, rapidity, transverse momentum and azimuthal angle distributions of strange particles, including (anti)-hyperons and hypernuclei.

2. Parton-Hadron-Quantum-Molecular Dynamics

For our study of the hypernuclei production we employ the Parton-Hadron-Quantum-Molecular Dynamics (PHQMD) [3] transport approach. The PHQMD approach extends the established PHSD [5, 6] transport approach by replacing the mean-field propagation by density dependent two body interactions in a similar way as in the Quantum Molecular Dynamics [4, 7] models – this allows for a dynamical description of cluster and hypernuclei formation. The clusters are identified with the Minimum Spanning Tree [7] or the Simulated Annealing Clusterization Algorithm [8] which finds the most bound configuration of nucleons and clusters. The PHQMD approach can be used in different modes for the hadron propagation: the mean-field based PHSD mode and the QMD mode with different equations-of-state (EoS). This allows to study the sensitivity of observables on the different descriptions of the potential interactions among nucleons. The rapidity distribution of ^3He from Pb+Pb central collisions at $\sqrt{s_{NN}} = 8.8$ GeV is shown on the left pane of the Fig.1: the dots indicate the experimental data from the NA49 Collaboration [9], the red squares show the PHQMD results [4] taken at the physical time $t = t_0 cosh(y)$ for $t_0 = 67$ fm/c. The PHQMD approach shows a good agreement with the experimental data over the whole rapidity range. On the right plot of the Fig.1 the PHQMD models predictions [4] for the yields of $^3_\Lambda H$, $^4_\Lambda H$ and $^4_\Lambda He$ are presented.

3. Reconstruction of hypernuclei for the MPD detector

Hypernuclei analysis was performed using the PHQMD model with the MST cluster recognition algorithm. All the produced particles from the model were propagated through the detector material using the GEANT3 transport package and then all Monte-Carlo particles "hits" were converted to signals using the realistic detector response simulation. Charged particle trajectories and momenta were reconstructed utilizing the Kalman filter tracking algorithm [10]. All tracks, reconstructed in the TPC, were extrapolated to the TOF detector and matched with simulated TOF hits. The PID was achieved by using both time-of-flight measurements from the TOF subsystem and the energy loss (dE/dx) by TPC.

In order to reconstruct hypertritons, secondary vertices were reconstructed for identified helium and π^- pairs by applying a set of additional topological and kinematic cuts.

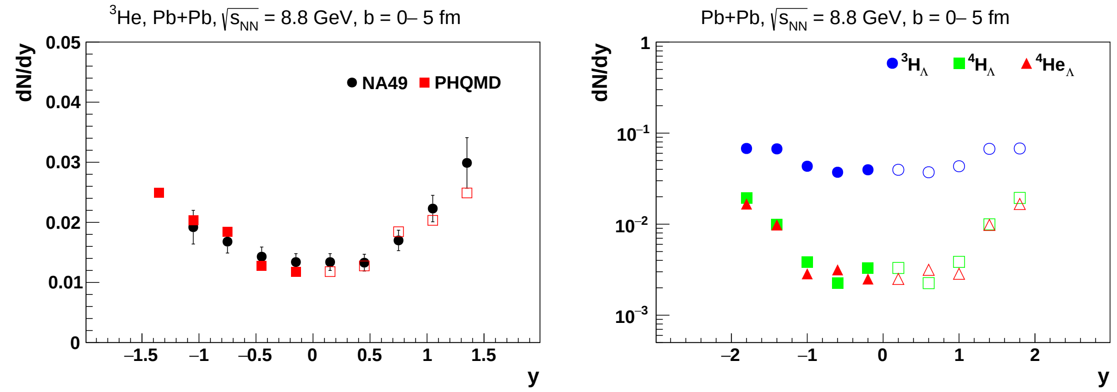

Figure 1: Left: the rapidity distribution of ^3He from Pb+Pb central collisions at $\sqrt{s_{NN}}$ = 8.8 GeV. The dots indicate the experimental data from the NA49 Collaboration [9], the red squares show the PHQMD results [4] taken at the physical time $t = t_0 cosh(y)$ for t_0 = 67 fm/c. Right: the rapidity distributions of $^3_\Lambda H$, $^4_\Lambda H$ and $^4_\Lambda He$ from central Pb+Pb collisions at $\sqrt{s_{NN}}$ = 8.8 GeV calculated at the physical time $t = t_0 cosh(y)$ for t_0 = 53 fm/c [4].

The results on light hypernuclei reconstruction are presented in Fig. 2: left panel shows the obtained invariant mass distributions for $^3_\Lambda H \longrightarrow {}^3He + \pi^-$ decay mode, right panel demonstrates the reconstructed invariant mass spectra for the $^4_\Lambda H \longrightarrow {}^4He + \pi^-$ decay mode. The results have been obtained for $40 \cdot 10^6$ minimum bias $Bi + Bi$ collisions at the energy of $\sqrt{s_{NN}}$ = 9.2 GeV. Blue dots represent the reconstructed data points, while the red curve is the sum of a polynomial used to evaluate the combinatorial background and a Gaussian function for the signal.

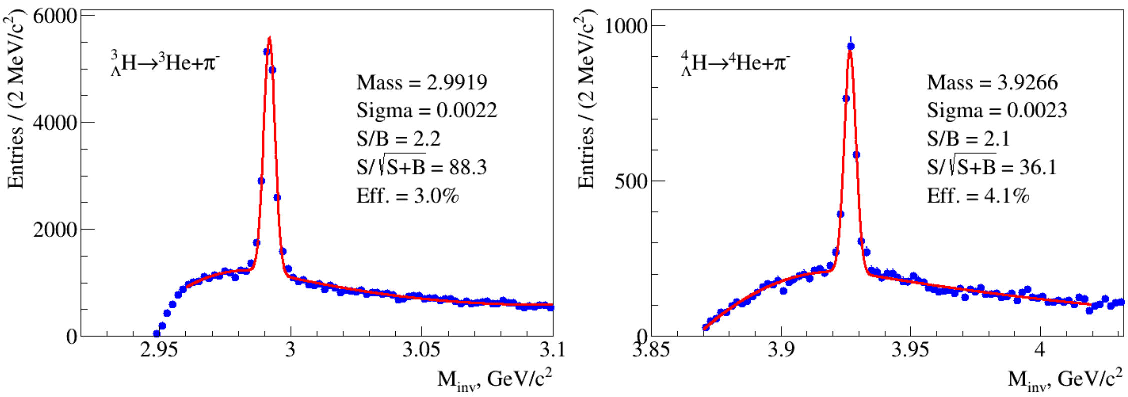

Figure 2: Reconstructed invariant mass spectra of light hypernuclei: $^3_\Lambda H \longrightarrow {}^3He + \pi^-$ decay mode (left) and $^4_\Lambda H \longrightarrow {}^4He + \pi^-$ decay mode (right).

4. Conclusions

The MPD experiment at NICA is designed for the study of the less explored region of the QCD phase diagram. The MPD setup offers good opportunities for the study of the production of hypernuclei in heavy-ion collisions at NICA energies. The PHQMD model is a microscopic n-body transport approach for the description of heavy-ion dynamics and cluster formation which

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may provide the theoretical description for the origin of the hypernuclei formation process in the hot and dense matter.

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