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SHORT-LIVED RESONANCES AND NEUTRAL MESONS IN THE PHYSICAL PROGRAM OF THE NICA-MPD*

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Short-lived hadronic resonances such as $K^*(892)$, $\rho(770)$, $\phi(1020)$, $\Sigma(1385)$, $\Lambda(1520)$ and $\Xi(1530)$ are used to study different aspects of particle production and collision dynamics in pp, $p+A$ and $A+A$ collisions. The yields of resonances are sensitive to the competing processes of hadron rescattering and regeneration, thus making these particles unique probes of the properties of the late hadronic phase. Measurements of resonances with different masses and quantum numbers also provide insight into strangeness production and processes that determine the shapes of particle momentum spectra. We discuss results of the model-based studies of the influence of the hadronic phase on the measured properties of resonances in heavy-ion collisions at NICA energies. Moreover, we discuss prospects for resonance measurements in the MPD experimental setup and results of the feasibility studies obtained using Monte Carlo simulation of the detector performance.

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1. Introduction

The study of short-lived resonances has always played an important role in the physical programs of heavy-ion experiments. The most often measured resonances include $K^*(892)$, $\rho(770)$, $\phi(1020)$, $\Sigma(1385)$, $\Lambda(1520)$ and $\Xi(1530)$ [1]. These particles are copiously produced in heavy-ion collisions

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and hence can be reconstructed in the hadronic decay channels. Being particles with different masses, lifetimes and quark contents, the resonances probe many important aspects of heavy-ion collisions. They carry information about hadron chemistry and strangeness production, reaction dynamics and processes that shape the particle transverse momentum (p_{T}) spectra, about density and lifetime of the hadronic phase.

2. Properties of short-lived resonances

In the absence of experimental data, the resonance properties in Au+Au collisions at $\sqrt{s_{NN}} = 11$ GeV were evaluated using the general-purpose event generators: UrQMD [2], AMPT [3], PHSD [4], and EPOS [5].

The UrQMD, PHSD, EPOS generators predict an enhanced production of particles containing valence s-quarks in high multiplicity Au+Au collisions. Enhanced yields are also predicted for $\phi(1020)$ meson, which has hidden strangeness. The AMPT model predicts noticeable enhancement only for baryons, which contain at least two s-quarks. The predicted strangeness enhancement is not consistent with the statistical canonical suppression of strangeness in low-multiplicity systems and is driven by the evolution of the interacting system, presence of a phase transition, and/or recombination of hadrons in the hadron gas. It suggests that the $\phi(1020)$ measurements will play a key role in the evaluation of the dominant strangeness production mechanisms in heavy-ion collisions at NICA.

The UrQMD, PHSD, EPOS and AMPT generators predict a significant evolution of the proton-to-meson ratios with multiplicity in Au+Au collisions. It may suggest both the development of the collective radial flow and the essential role of the parton recombination in hadronization. Particles with similar masses are expected to be equally sensitive to the development of collective radial flow, while the effect of recombination depends on the number of valence quarks in the particle. The calculations show that measurement of $p/K^*(892)$ and $p/\phi(1020)$ ratios as a function of transverse momentum and collision centrality will be crucial for the study of hadronization mechanisms at intermediate momentum.

The UrQMD, AMPT and PHSD event generators were used to estimate the influence of the late hadronic phase of nuclear collisions on the resonance properties measured in hadronic decay channels. Calculations showed that the integrated yields of the shortest-lived $\rho(770)$ and $K^*(892)^0$ resonances are significantly suppressed in central Au+Au collisions in comparison with peripheral collisions, see Fig. 1. The suppression is explained by the loss of the measured signals due to the rescattering of daughter particles in the hadron gas. Predictions for the longest-lived $\phi(1020)$ meson are model-dependent. UrQMD and PHSD predict moderate enhancement of the resonance yield in central Au+Au collisions, while AMPT predicts a suppression. The calculations demonstrate the opposite effect of the hadronic phase on the measured yields of the short-lived resonances ($\tau < 5$ fm/c) and somewhat longer-lived ($\tau > 10$ fm/c) resonances. The calculations also indicate that the lifetime and the density of the hadronic phase in heavy-ion collisions at NICA will be sufficient to effectively modify final-state properties of the produced particles. Such modifications will have to be accounted for when the measured particle yields, flow, fluctuations *etc.* are compared to model predictions.

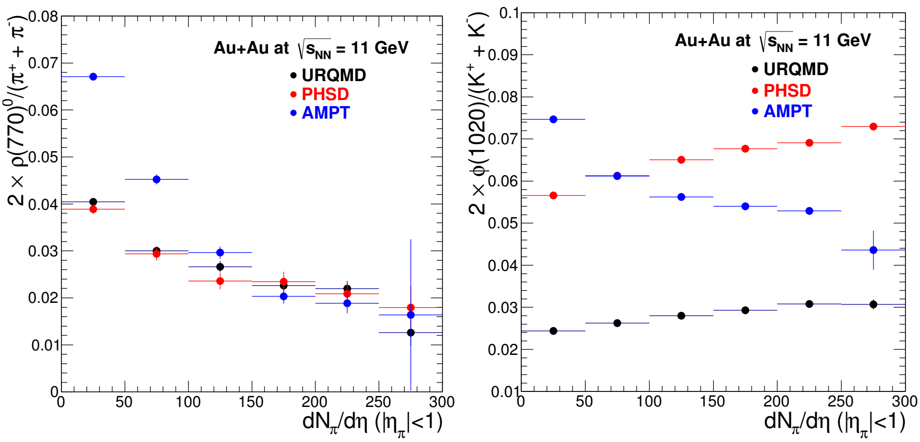

Fig. 1. $\rho(770)/\pi$ (left) and $\phi(1020)/K$ (right) ratios as a function of multiplicity in Au+Au collisions predicted by the UrQMD, AMPT and PHSD event generators.

3. Reconstruction of short-lived resonances

Capabilities of the MPD experiment at NICA for the reconstruction of the resonances were studied using the realistic simulations of the MPD detector [6]. The UrQMD event generator was used to simulate 10^7 Au+Au collisions, and the Geant-based MpdRoot was used to track particles through the detector materials and to simulate a response of different detector subsystems. The simulated events were used to develop and optimize the reconstruction techniques for the resonance decays, see Fig. 2. The corresponding resonance reconstruction efficiencies, and their dependence on the particle transverse momentum and rapidity were also evaluated, see Fig. 3. The reconstructed resonance yields were found to be in agreement with the generated ones that confirm that the developed reconstruction chain is valid and robust.

The feasibility studies showed that the $\rho(770)$, $K^*(892)^0$, $\phi(1020)$ and $\Lambda(1520)$ resonances can be measured in the range of transverse momenta from 0 to 3 GeV/c with 10^7 sampled Au+Au collisions. Such a number of events can be collected in one week of operation during the first run of NICA. Centrality-dependent studies or reconstruction of other resonances would require significantly larger statistics, which is a subject of further studies.

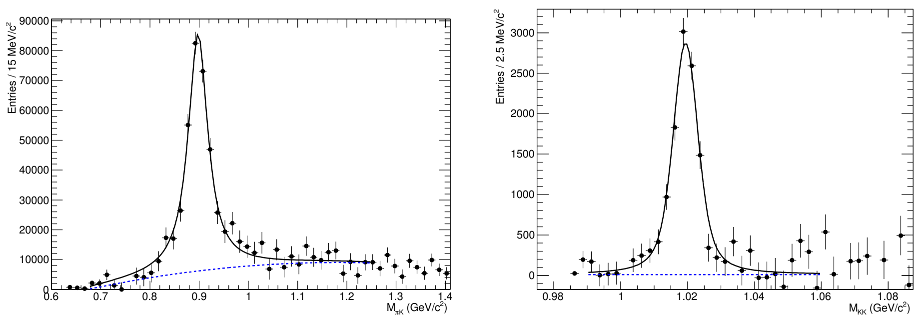

Fig. 2. Examples of invariant mass distributions for the opposite-sign πK (left) and KK (right) pairs after subtraction of the mixed-event background in the p_{T} range of 0.1–0.3 GeV/c. Peaks from decays of $K^*(892)^0$ and $\phi(1020)$ mesons are fit to a combination of the Voightian function and polynomial.

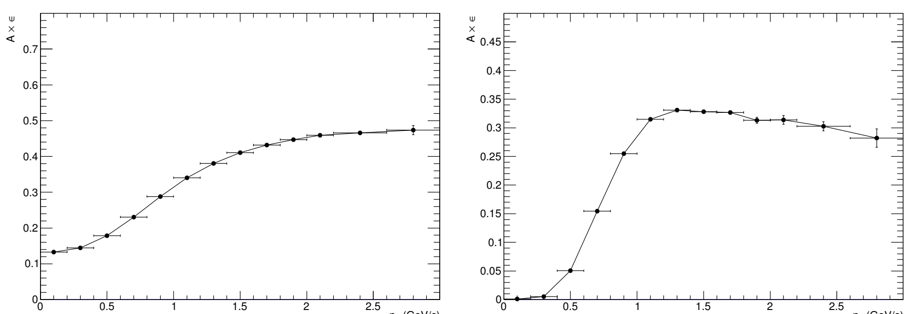

Fig. 3. Reconstruction efficiencies evaluated for $K^*(892)^0$ (left) and $\phi(1020)$ (right) mesons as a function of transverse momentum at $|y| < 0.5$.

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