Simulation of electromagnetic and strange probes of dense nuclear matter at NICA/MPD

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Abstract. The main task of the NICA/MPD physics program is a study of the properties of nuclear matter under extreme conditions achieved in collisions of heavy ions. These properties can reveal themselves through different probes, the most promising among those being the lepton-antilepton pairs and strange hadrons. In this paper the MPD performance for measuring the electron-positron pairs and strange hyperons in central Au+Au collisions at NICA energies is presented.

1. MPD detector performance

The main goal of studying heavy-ion collisions is to explore the properties of nuclear matter under extreme density and temperature conditions in order to resolve the most fundamental problems of the underlying theory - confinement and chiral symmetry breaking. To reach this goal, the MPD detector is designed as a 4π spectrometer capable of detecting charged hadrons, electrons and photons in heavy-ion collisions in the energy range of the NICA collider. The detailed description of the MPD geometry can be found in Ref. [1].

The present analysis is based on the detectors covering the mid-rapidity region (|η| < 1.3): the main tracker Time Projection Chamber (TPC) and barrel Time-Of-Flight system (TOF). For dilepton simulations the barrel ElectroMagnetic Calorimeter (EMC) is also used.

The track reconstruction method is based on the Kalman filtering technique and the number of TPC points per track is required to be greater than 10 to ensure a good precision of momentum and dE/dx measurements. In addition, we have restricted our study to the mid-rapidity region with |η| < 1.3. The track finding efficiency in TPC for primary and secondary tracks is above 95% for momentum p > 100 MeV/c. The momentum resolution ∆p/p ≈ 2% at pT < 1.5 GeV/c. The primary vertex resolution in transverse and longitudinal directions σx and σz < 0.15 mm in central collisions at track multiplicity in TPC > 500.

Particle identification (PID) in the MPD experiment will be achieved by combining specific energy loss (dE/dx) and time-of-flight measurements. The basic detector parameters, namely, dE/dx and TOF resolutions σdE/dx ≈ 6% and σTOF ≈ 100 ps will provide a high degree of selectivity for hadrons at momenta below 2 GeV/c.

An identified hadron candidate is assumed to lie within the boundaries of the PID ellipse (3σ around the nominal position for a given particle specie) in the dE/dx − M^2 space, where M^2 is the reconstructed particle mass squared. In addition, the probability for a given particle to belong to each of the species can be calculated knowing the widths of the corresponding distributions (along the dE/dx and M^2 axes) and the difference from the predicted position for
the specie. It was found that by requiring this probability to be greater than 0.75 one can obtain high PID efficiency and low contamination.

2. Simulations: event generators, data sets and results

The software framework for the MPD experiment MpdRoot[2] is based on FairRoot and provides a powerful tool for detector performance studies, development of algorithms for reconstruction and physics analysis of the data.

The event sample used for the study of hyperons was produced with the UrQMD generator at $\sqrt{s} = 9A$ GeV. The analyzed statistics of $4 \cdot 10^4$ central events ($0 - 3$ fm) corresponds to about 2 minutes of running time at the NICA collision rate of 6 kHz [1]. For dilepton simulations the Pluto generator was used at $\sqrt{s} = 7A$ GeV with accumulated statistics of $2 \cdot 10^7$ central events, corresponding to about 17 hours of NICA running time. Produced by the event generators particles have been transported through the detector using the GEANT3 transport package (describing particle decays, secondary interactions, etc.).

Multistrange hyperons were reconstructed using their decay modes into a charged particle and a Λ hyperon followed by Λ decay into a proton and a pion. The result for $\Xi^-$ hyperon simulations is presented in Fig. 1.

The measurement of the dilepton yield is rather complicated. Huge combinatorial background is the experimental challenge. Already the start version of MPD (TPC, TOF and EMC) allows to select electrons with a hadron supression factor up to $10^5$. Since the particle identification suppresses the hadron contamination, the main source of the remaining background is photon conversion in the detector material. The conversion pairs are rejected by a special topological cut. If only one lepton from a conversion pair is reconstructed, it can survive the cut. Such single tracks are rejected by a low-momentum cut $p_T > 200$ MeV/c and the requirement to satisfy the primary track selection criteria.

Figure 2 shows the invariant mass spectrum of reconstructed low-mass dielectrons after background subtraction (dots) and the one for true dielectrons from the Pluto generator (line). The obtained $S/B$ ratio in the mass region $0.2 < M_{e^+e^-} < 1.2$ GeV/$c^2$ is about 10%.

From the results presented (see also [3, 4]) one can conclude that MPD offers good opportunities for studies of strange and electromagnetic probes at the NICA collider.

References

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