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PARTICLE IDENTIFICATION (PID) AND PROSPECTS FOR THE STUDY OF EVENT-BY-EVENT FLUCTUATIONS IN MPD*

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Physics goals of the Multi-Purpose Detector (MPD) require excellent particle identification (PID) capability over as large as possible phase-space volume. The identification of charged hadrons is achieved at the momenta of 0.1–3 GeV/c. Results of hadron identification and preliminary possibility estimation of the study of event-by-event fluctuations at MPD are presented for the current PID phase-space coverage $|\eta| \leq 1.6$.

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1. Introduction

The main scientific goal of the NICA/MPD project is to explore the phase diagram of strongly interacting matter in the region of highly compressed and hot baryonic matter [1]. The search for the possible critical end point (CEP) [2] in the QGP diagram requires excellent particle identification capability over as large as possible phase-space volume. The identification of charged hadrons is achieved by the time-of-flight (TOF) measurements which are complemented by the energy loss (dE/dx) information from TPC.

TPC is the main MPD tracking detector. TPC is responsible for particle momentum measurements, vertex determination, two track separation, dE/dx measurements and particle identification in pseudorapidity region $|\eta| < 2$. A new approach based on the full simulation of the detector physics and response is required in order to get realistic estimations of the MPD performance instead of a simplified approach at the smeared hit production level. The recent development of the MPD PID is based on the proposed "realistic" tracking algorithm.

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Barrel TOF is designed to perform time-of-flight measurements for further m^2 calculations up to its pseudorapidity limit $|\eta| < 1.4$.

To obtain further results, the UrQMD generator (Au+Au collisions, $\sqrt{s} = 8$ GeV, an impact parameter $0 < b < 3$ fm) has been used.

2. Track selection criteria

In the case when some track is propagating close to the TPC sector boundary, charge collection and momentum reconstruction are difficult. In order to remove tracks with a notable difference between simulated and reconstructed momenta, the following new selection criterion (named the TPC edge cut) has been suggested: if at least 50% of track hits are closer then 1.5 cm to the sector boundary the track should be removed. The suggested criterion removes about 4% tracks from the data.

The following selection criteria have been applied to the tracks: $N_{\text{hits}} \geq 20$, $|\eta| < 1.6$ and the TPC edge cut.

3. PID parameterizations

3.1. dE/dx parameterization

The typical distribution of dE/dx on the full momentum is shown in Fig. 1. PID includes the Bethe–Bloch functions with 5 parameters to describe the most probable dE/dx value of each particle specie

$$\frac{\mathrm{d}E}{\mathrm{d}x} = \frac{a_0}{\left(\frac{p}{E}\right)^{a_3}} \left[a_1 - \left(\frac{p}{E}\right)^{a_3} - \ln\left(a_2 + \left(\frac{m}{p}\right)^{a_4}\right)\right]. \tag{1}$$

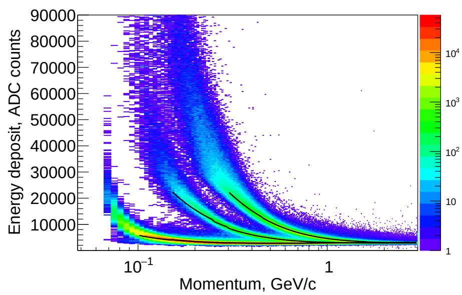

Fig. 1. dE/dx *versus* p.

The energy deposit has an asymmetric Gaussian shape even if the truncation procedure (0:70) is applied. It can be described by the asymmetric Gaussian function

$$f(x) = \begin{cases} A\,e^{-\frac{(x-\bar{x})^2}{2\sigma^2}}, & \text{for } x < \bar{x}\,, \\ A\,e^{-\frac{(x-\bar{x})^2}{2(\sigma(1+\delta))^2}}, & \text{for } x \geq \bar{x}\,, \end{cases}$$

where δ is an asymmetry parameter.

The ratio of $\mathrm{d}E/\mathrm{d}x$ value in asymmetric Gaussian peak over the $\mathrm{d}E/\mathrm{d}x$ value expected from the Bethe–Bloch function (Fig. 2) is used to estimate the parameterization quality. The closer the ratio to one, the better the Bethe–Bloch description is. Typical width values are 6% and 8%.

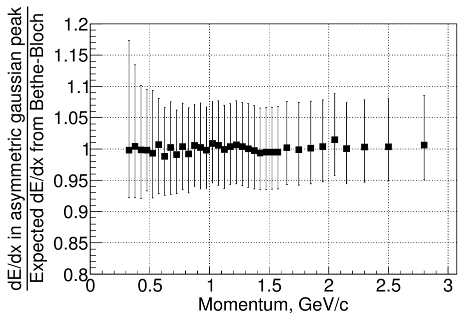

Fig. 2. $\mathrm{d}E/\mathrm{d}x$ quality criterion.

Typical $\mathrm{d}E/\mathrm{d}x$ distributions with small and big asymmetry are shown in Figs. 3 and 4, respectively. The asymmetry can stem from the strong $\mathrm{d}E/\mathrm{d}x$ dependence in the low momenta region. Truncation procedure cannot remove this effect. There can be other reasons of the asymmetry which we do not understand.

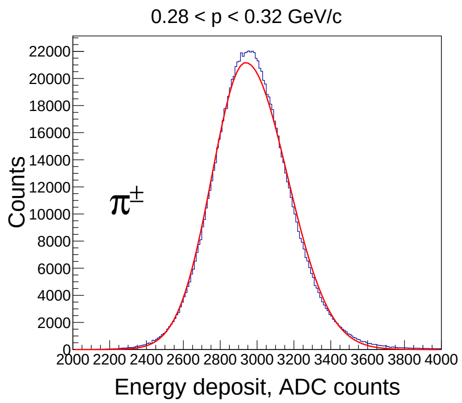

Fig. 3. $\mathrm{d}E/\mathrm{d}x$ with small value of asymmetry.

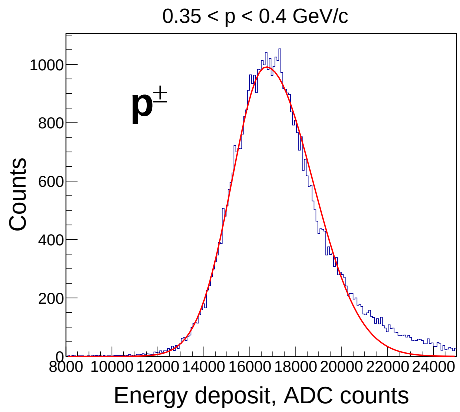

Fig. 4. $\mathrm{d}E/\mathrm{d}x$ with typical value of asymmetry.

3.2. m^2 parameterization

m^2 resolution growth in momenta should be known in order to use the combined PID. Gray/red lines on the m^2 *versus* p plot (Fig. 5) depict 3σ bands for protons, kaons and pions.

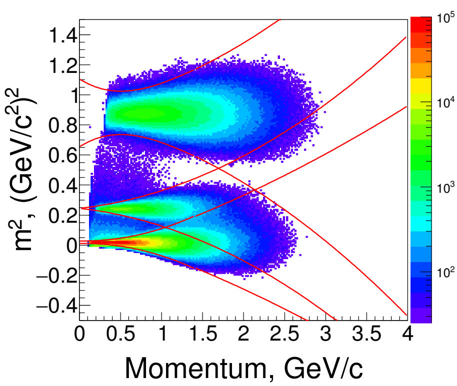

Fig. 5. (Color online) m^2 *versus* p.

There is a TPC-TOF mismatch effect which is significant in the low momenta region. Typical example of the TPC-TOF mismatch is shown in Fig. 6. PDG-kaon's m^2 value has been incorrectly reconstructed for 10% of the tracks with $0.3 < p < 0.4$ GeV/c. For these tracks, $\mathrm{d}E/\mathrm{d}x$ is reconstructed correctly but m^2 is far from the expected value. The fraction of mismatched tracks decreases to 2% in the high momenta region. To reduce the PID inefficiency due to the mismatch effect, the TOF information may be ignored and particles may be identified by $\mathrm{d}E/\mathrm{d}x$ value, but only in low momenta region ($p < 0.8$ GeV/c).

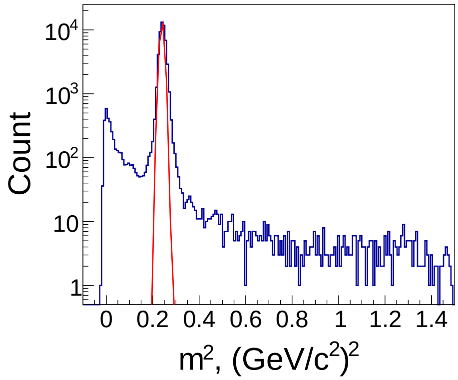

Fig. 6. PDG-kaons, $0.3 < p < 0.4$ GeV/c.

4. Results

PID results are presented as an efficiency and contamination dependencies on the full momentum (Fig. 7). Here, efficiency is defined as the ratio of correctly identified tracks to all reconstructed ones. Contamination is defined as the ratio of falsely identified tracks to all identified ones.

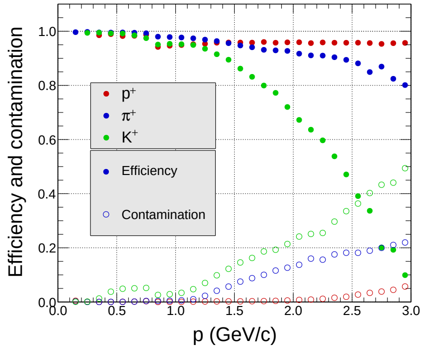

Fig. 7. PID efficiency and contamination.

The MPD PID has been used to obtain very preliminary results for the study of event-by-event fluctuations at NICA. The plots in Fig. 8 are the ratios of two cumulants (k_3/k_2 top and k_4/k_2 bottom) calculated at the different collision energies for net-baryons distributions. Circled markers are calculated from the reconstructed net-proton distribution, triangles are from the MC simulation. The observed difference is due to the fact that there are no corrections for pseudorapidity limitation, the PID efficiency, *etc.*

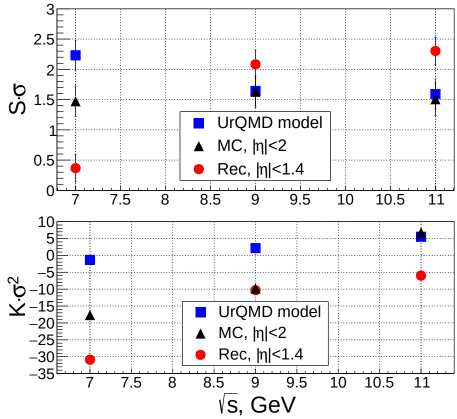

Fig. 8. Ratios of net-proton cumulants.

5. Conclusions

The suggested method of particle identification allows distinguishing π/K up to 1.5 GeV$/c$ and π/p up to 3 GeV$/c$. An extension to the endcaps is crucially important for the further event-by-event fluctuation study.

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