Particle Identification (PID) as a tool for the study of event-by-event fluctuations at MPD

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1) Abstract

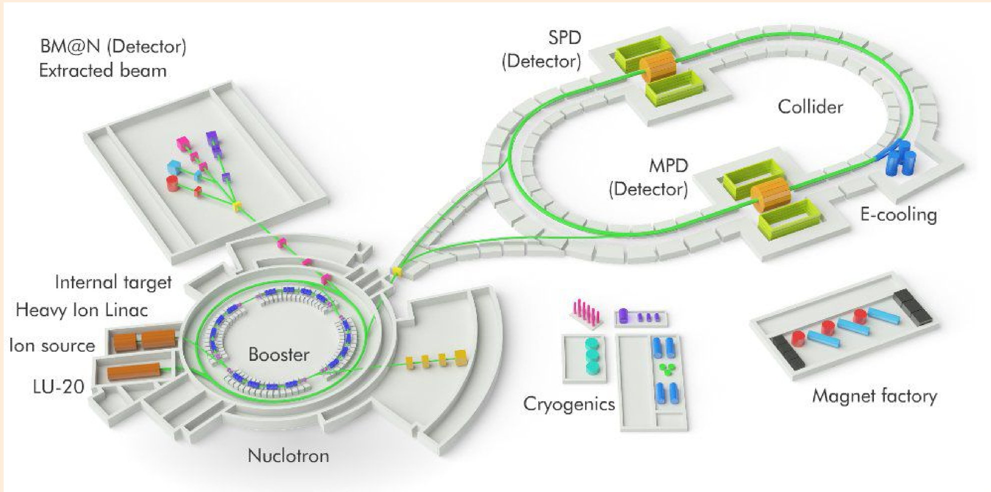

Figure 1: NICA complex scheme

The international mega-science project *NICA complex* (figure 1) is aimed at studying of the properties of nuclear matter in the region of the maximum baryonic density in laboratory [1]. Physics tasks of the NICA heavy-ion program are following:

- event-by-event fluctuation in hadron productions,
- femtoscopic correlation,
- directed and elliptic flows for various hadrons,
- multi-strange hyperon production (including hypernuclei): yield and spectra (the probes of nuclear media phases),
- photon and electron probes,
- charge asymmetry.

3) dE/dx identification

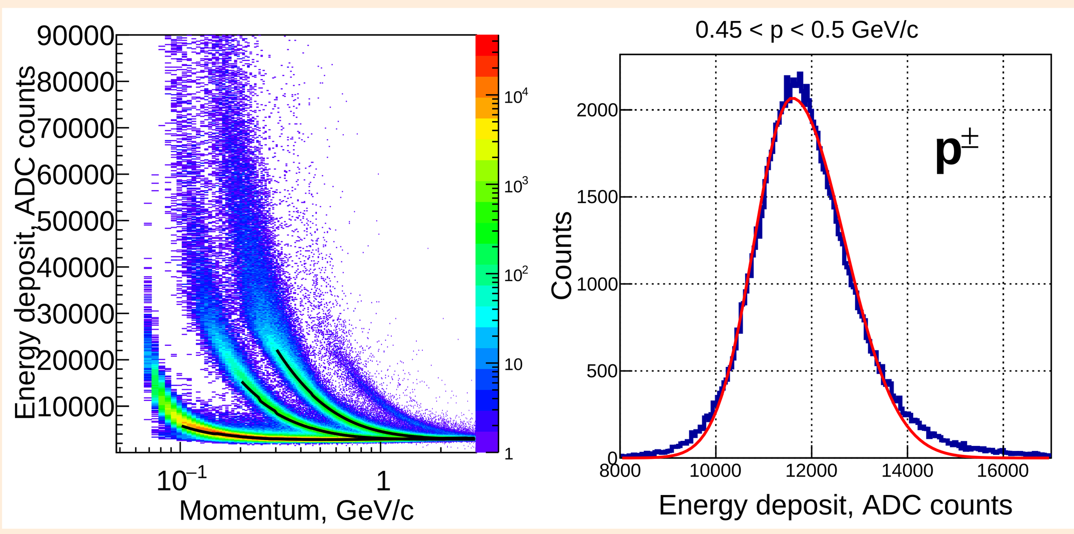

Figure 3: dE/dx vs p distribution (*left*) and dE/dx at the small momentum range (*right*)

Truncated energy deposit $(0 : 70)$ has an asymmetric gaussian shape (figure 3, right). This distribution can be described by the asymmetric gaussian function:

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

where A, $\bar{x}$, σ and δ – fit parameters.

These parameters have been parameterized as functions of the full momentum up to 3 GeV/c. Obtained functions have been implemented in MPD PID.

For instance, the most probable dE/dx value $\bar{x}$ as a function of full momentum (figure 3, left) is described by Bethe-Bloch function with 5 free parameters:

$$-\frac{dE}{dx} = a_0 \left(\frac{p}{\sqrt{p^2+m^2}}\right)^{-a_3} \Bigg\{a_1 - \frac{p}{\sqrt{p^2+m^2}}^{a_3} - \ln\left(a_2 + \left(\frac{m}{p}\right)^{a_4}\right)\Bigg\},$$

where p – full momentum, a_i – fit parameters.

2) MPD detector and general idea of PID

The MPD detector (figure 2) is a large acceptance spectrometer for heavy-ion collisions study at NICA [2]. Physics goals of MPD require excellent particle identification capability over as large as possible phase space volume. Identification of charged hadrons at momenta $0.1 - 3$ GeV/c is achieved by the time-of-flight (TOF) measurements which are complemented by the energy loss (dE/dx) information from the TPC.

PID provides vector of probabilities for each identified particle. It can be based on dE/dx and m^2 values information (combined probability vector) or just on dE/dx value.

LAQGSM generator ($Au + Au$ collision, $\sqrt{s_{NN}} = 11$ GeV, minimum bias events) has been used for further obtained results (excluding box 6).

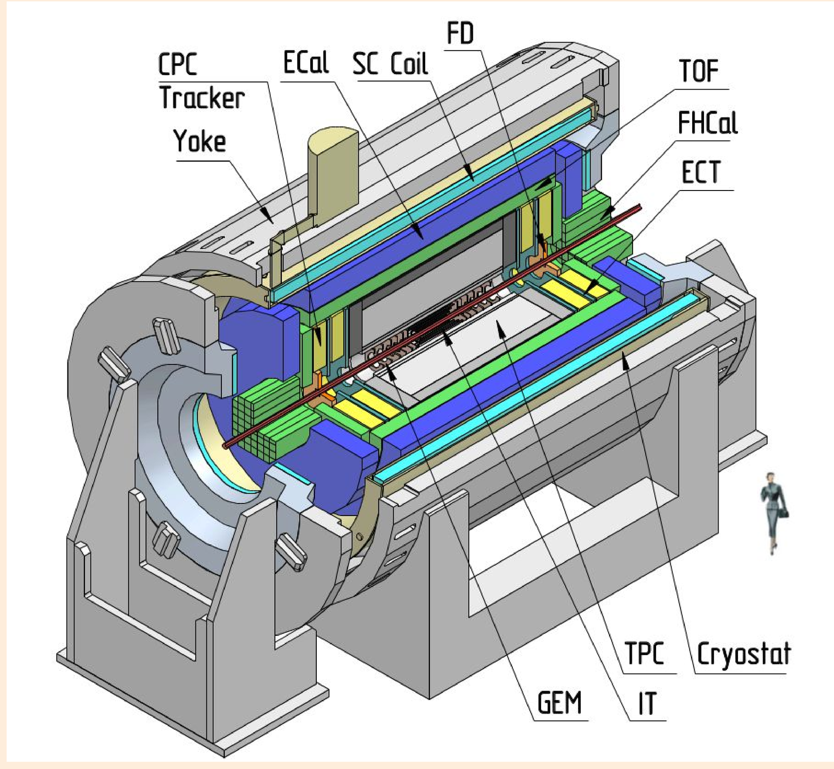

Figure 2: MPD scheme

Analysis has been carried out for primary (from Geant) particles with the number of hits per track ≥ 20 and $|\eta| < 1.6$. Tracks with 50% hits closer than 1.5 cm to TPC boundaries (in the XY-plane) have been removed.

4) TOF identification

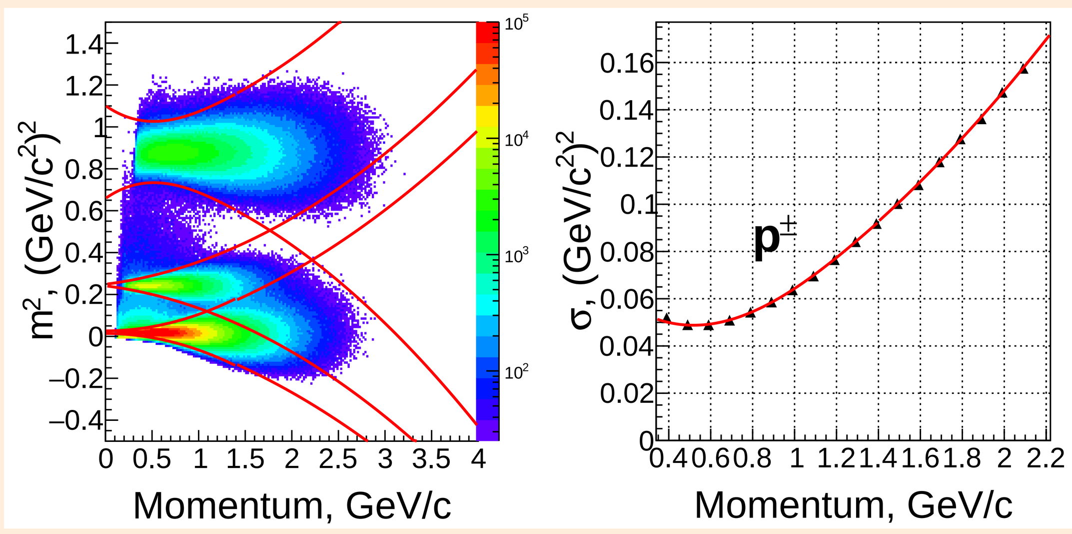

Figure 4: TOF PID: m^2 vs full momentum (*left*) and m^2-resolution of protons (*right*)

TOF identification significantly improves PID results in the high momenta region ($p > 1$ GeV/c).

It is based on the separation by the m^2 values (figure 4). Red lines on this figure show 3σ bands for pions, kaons and protons. m^2 can be calculated by the set of equations:

$$m^2 = \frac{p^2}{\gamma^2\beta^2} \qquad \beta = \frac{L}{ct} \qquad \gamma = \frac{1}{1-\beta^2}$$

where L – track length, t – time of particle flight, p – full momentum and c – speed of light.

6) Application of MPD PID

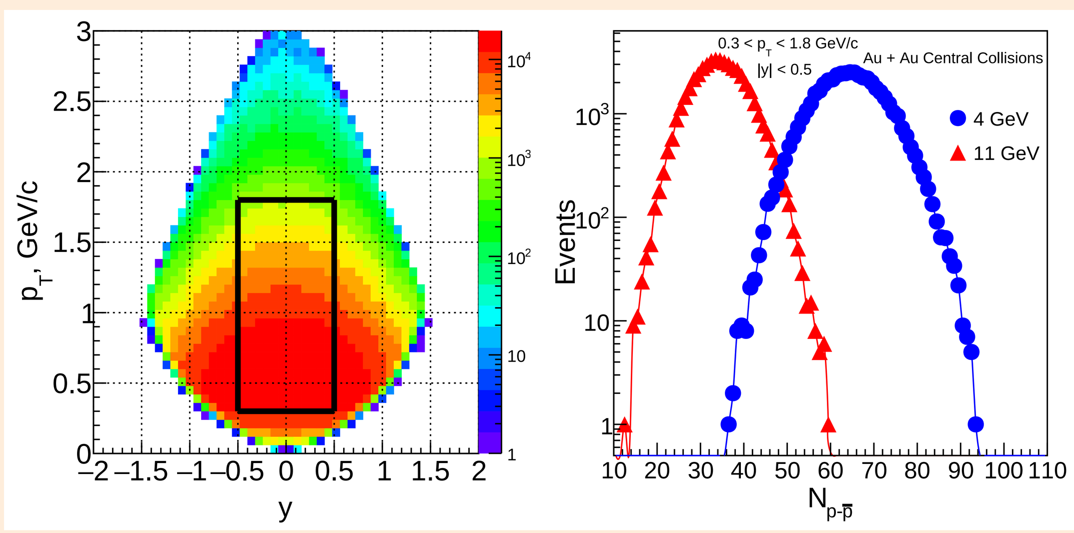

Figure 6: MPD phase-space for protons (*left*) and net-proton distribution at midrapidity (*right*)

UrQMD generator data (Au + Au, 0-5% centrality, 4 GeV and 11 GeV) have been passed through the whole MPD reconstruction chain including PID. As a result, net-proton distributions (figure 6, right) are carried out at midrapidity ($|y| < 0.5$) and within the transverse momentum range $0.3 < p_T < 1.8$ GeV/c. There are ~60 identified protons per one central Au+Au collision. By adding endcaps, the identified protons yield will be increased by 20%.

5) PID results

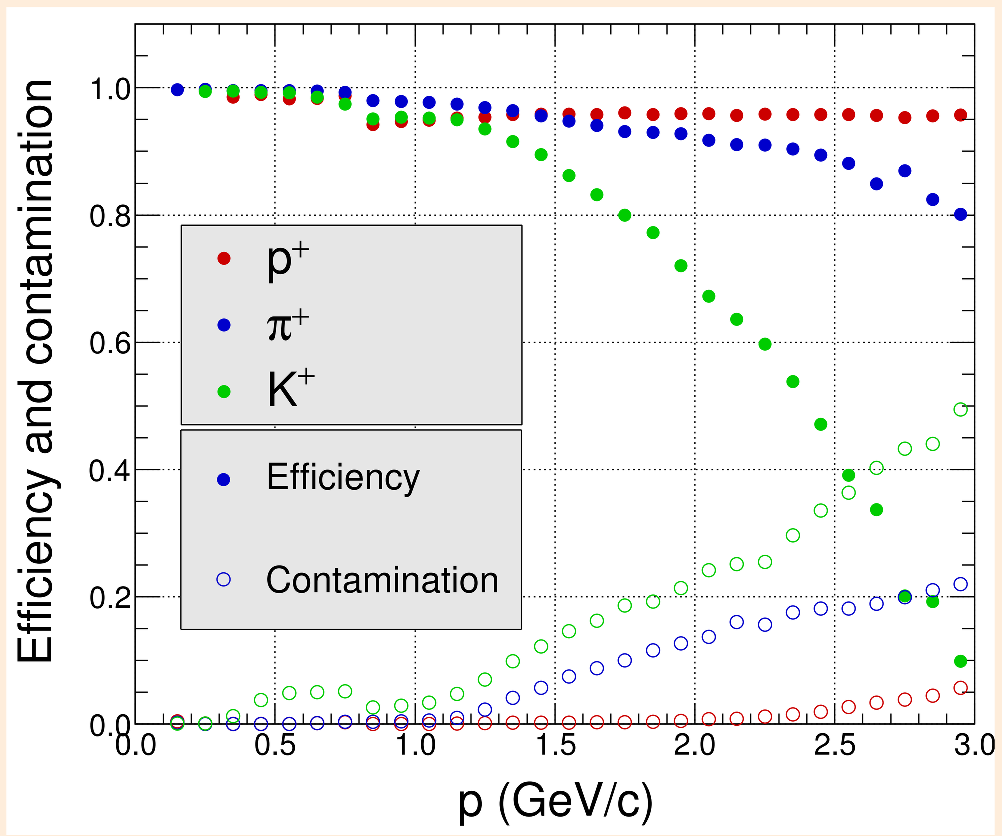

Figure 5: Combined PID efficiency and contamination

PID performance can be characterized by PID efficiency and contamination (figure 5), which are defined as follows:

$$\textbf{efficiency} = \frac{\textbf{right identified tracks}}{\textbf{all tracks}}$$

$$\textbf{contamination} = \frac{\textbf{wrong identified tracks}}{\textbf{identified tracks}}$$

Only tracks with TOF hit have been taken into account when combined PID efficiency and contamination are calculated.

The particle specie is defined as maximum probability (without any probability threshold).

7) Conclusions

Suggested method of particle identification allows to distinguish π and K up to 1.5 GeV/c and π and p up to 3 GeV/c;

MPD PID can identify 60 protons per one central collision. By adding endcaps, this number will be increased by 20%.

References

[1] V. D. Kekelidze, R. Lednicky, V. A. Matveev, I. N. Meshkov, A. S. Sorin and G. V. Trubnikov, 2016 *Eur. Phys. J.* A **52** 211.

[2] Abraamyan K U *et al.*, 2011 *Nucl. Instrum. Meth* A **628**, 99.