DETECTION OF D^+-MESON DECAYS IN THE TRACKING SYSTEM OF NICA-MPD*

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(Received January 20, 2021)

The silicon vertex detector is a part of the NICA-MPD tracking system, designed for efficient detection of the short-lived products of nucleus–nucleus interactions. The paper presents the results of computer simulations of the identification capability of the MPD tracking system, when reconstructing the decays of D^+ produced in central Au+Au collisions at $\sqrt{S_{NN}} = 9$ GeV. Both, the time-projection chamber and the vertex detector based on monolithic active pixel sensors were taken into consideration.

DOI:10.5506/APhysPolBSupp.14.497

1. Introduction

One of the important physics tasks for future experiments at the MPD set-up is the measurement of inclusive cross sections for the formation of multi-strange particles in heavy-ion collisions at energies of the NICA collider ($\sqrt{S_{NN}} = 4 \div 11$ GeV). An enhancement in the yield of the multi-strange particles in relativistic nucleus–nucleus interactions is considered as one of possible signs of the phase transition of strongly interacting nuclear matter to the state of deconfinement [1]. The yield of heavy-flavour particles, including D-mesons, will also depend on the phase of the excited nuclear medium. This is because creation of a $D\bar{D}$ pair in hadronic phase requires 1.1 GeV more energy than creation of a quark–antiquark $c\bar{c}$ pair in phase of deconfinement. Therefore, by analogy with the strangeness, a change in the dependence of the average number of charmed mesons on the energy of colliding nuclei may be a sign of the onset of the deconfinement.

* Presented at NICA Days 2019 and IV MPD Collaboration Meeting, Warsaw, Poland, October 21–25, 2019.

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Detection of the short-lived D^0 and D^+ mesons, with an average path of 123 and 312 μm, respectively, is impossible with the MPD set-up without a vertex detector with high spatial resolution placed as close as possible to the particles creation point. The vertex detector for the MPD experiment will be composed of modern monolithic active pixel sensors (MAPS) with the best spatial resolution at high counting rate [2]. The particle identification capability of the MPD tracking system, including the Time Projection Chamber (TPC) and the vertex detector is studied in the present work for the reconstruction of decays of the D^+ created in the central Au+Au collisions at $\sqrt{S_{NN}} = 9$ GeV.

2. The vertex detector of MPD

The MPD-TPC will be the main tracking detector in the central rapidity region of the MPD [3]. Its performance will be further enhanced with a vertex inner tracking system (ITS) to provide reliable identification of short-lived hadrons. The ITS is expected to increase the accuracy for the reconstruction of the coordinates of the primary vertex of the interaction, and of the secondary vertices of decays of unstable particles near the interaction point.

The ITS will consist of five concentric layers of MAPS with an inner spatial resolution of 5 μm, assembled in ladders around the beam pipe [2]. The two outer layers (outer barrel) will be built with sensors of 100 μm thickness, whereas the three inner layers (inner barrel) will include a new generation of MAPS with decreased thickness of the epitaxial layer.

A general view and cross section of the ITS is shown in Fig. 1 for a beam pipe diameter of 40 mm. Its geometry parameters are reported in Table I. The effective silicon thickness of the five layers was calculated taking into account the radiation length of the materials composing the ladders, the cooling system, the pixel detectors themselves and the front-end electronics.

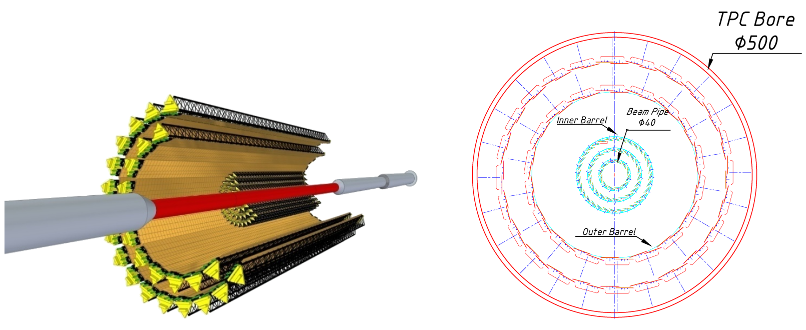

Fig. 1. The general view and cross section of the inner tracking system of the MPD for ∅40 mm beam pipe.

TABLE I

Geometry parameters of the MPD 5-layers inner tracking system for ∅40 mm beam pipe.

Layer	Number of ladders	$R_{\min}$ [mm]	$R_{\max}$ [mm]	Length [mm]	Effective thickness [μm]
1	12	22.4	26.7	750	50
2	22	40.7	45.9	750	50
3	32	59.8	65.1	750	50
4	36	144.5	147.9	1526	700
5	48	194.4	197.6	1526	700

3. Reconstruction of the D^+-mesons decays by the MVA method

The evaluation of the identification capability of the MPD tracking system in reconstruction of D^+ was performed in object-oriented software framework MpdROOT [4]. The TMVA [5] toolkit for multivariate data analysis was used, since it provides the classification algorithms for solution of the signal and background separation problem. The selection of D^+-meson signals in the spectrum by the invariant mass of their decay products was based on the classification by the boosted decision tree (BDT) method. The following variables defined by the kinematics of three-particle decay $D^+ \to \pi^+ + \pi^+ + K^-$ were used as an input for the BDT classifier:

1. D^+-meson path length till the decay: *path*;
2. The sum of the least distances between each pair of the daughter particles tracks in the D^+ decay point: *sum distance*;
3. The angle between a vector connecting the primary vertex to the D^+ decay vertex, and a vector of the D^+ reconstructed momentum: *pointing angle*.

The distributions of these variables are shown in Fig. 2. The thermal generator was tuned to the energy of NICA collider [6] to generate 10^6 signal events of D^+ decay, and 10^5 background events of the central Au+Au collisions at $\sqrt{S_{NN}} = 9$ GeV were generated by the QGSM generator [7]. The result of the input variables classification at training and testing of the BDT method is presented in Fig. 3.

According to the distribution from Fig. 3, the optimal selection parameter of the classifier was set to $\mathrm{BDTD}_{\mathrm{response}} > 0.34$, and it was applied to separate the signal and the background for 10^6 signal and 10^5 background

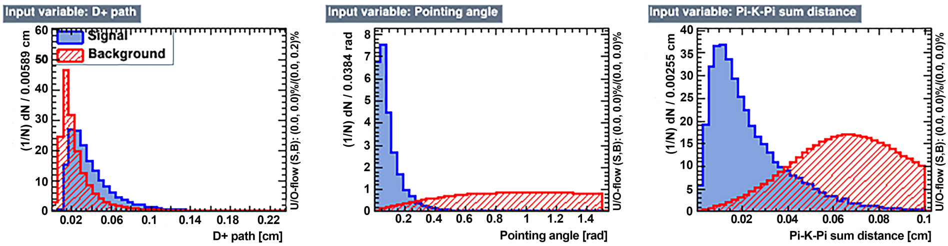

Fig. 2. Distribution of the BDT classifier input variables for the signal $D^+ \to \pi^+ + \pi^+ + K^-$ and background Au+Au events.

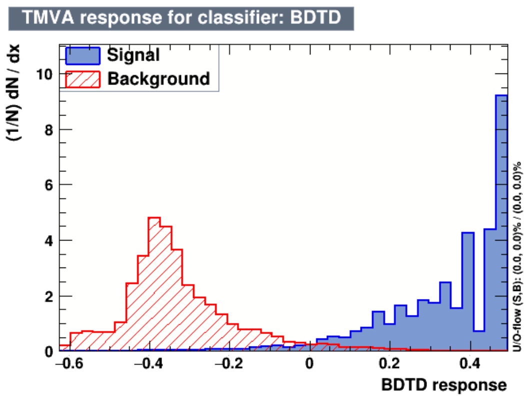

Fig. 3. Distribution of the BDT classifier responses to the background Au+Au and signal $D^+ \to \pi^+ + \pi^+ + K^-$ events.

events. The invariant mass $M(K^-\pi^+\pi^+)$ signal spectrum satisfying the chosen selection criterion was scaled to statistics of 10^8 central Au+Au collisions, accounting for the multiplicity of D^+ mesons and the probability of their decay to the channel $D^+ \to \pi^+ + \pi^+ + K^-$ (BR = 9.13%). The multiplicity of D^+ in the central Au+Au collisions was evaluated with the dynamic model of a hadron string [8], resulting in around 10^{-2} meson/event at energies of the NICA collider. After applying the selection criterion to the background events, the residual combinatorial background had a uniform invariant mass distribution in the chosen range of 1.7–2.1 GeV/c^2. After that, it was also scaled to statistics of 10^8 events with the addition of the statistical fluctuations. The sum of the signal and background spectra normalized to 10^8 central Au+Au collisions is depicted in Fig. 4. It can be seen that the extraction of the D^+ signal in such conditions may be done with 1% efficiency at the significance level of $\frac{S}{\sqrt{(S+B)}} = 10.5$.

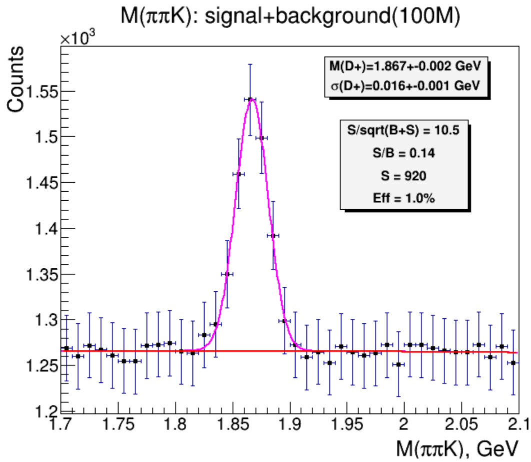

Fig. 4. D^+-mesons signal found by MVA method in the invariant mass spectrum in 10^8 central Au+Au collisions at $\sqrt{S_{NN}} = 9$ GeV.

4. Conclusion

The evaluation of the identification capability of the MPD tracking system in the central Au+Au collisions at the energy $\sqrt{S_{NN}} = 9$ GeV has shown that the D^+ signal extraction efficiency in the invariant mass spectrum of their decay products in the $D^+ \to \pi^+ + \pi^+ + K^-$ channel is 1%. This result opens a prospect for studies of the heavy-flavours physics in the heavy-ions collisions experiments at the NICA-MPD set-up.

The study was carried out with the financial support of the Russian Fund of Fundamental Research in the framework of the scientific project No. 18-02-40119.

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