Conference Paper

Performance of the MPD experiment for the anisotropic flow measurements

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Abstract

The main goal of the future MPD experiment at collider NICA(JINR,Dubna) is to explore the QCD phase diagram in the region corresponding to the highest baryon chemical potential. Properties of such dense matter can be studied using the azimuthal anisotropy of the produced particles. Performance of the detector response based on simulations with realistic reconstruction procedure is presented for centrality determination, reaction plane estimation, directed and elliptic flow coefficients.

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1. Introduction

Studies of the quark-gluon matter thermodynamical properties is one of the main priorities in the number of experiments specializing in the heavy-ion physics [1]. Transverse azimuthally anisotropic flow measurements are one of the key methods to study the time evolution of the strongly interacted medium formed in the nucleus collisions. In the non-central collisions, initial spatial anisotropy results in the azimuthally anisotropic particle emission. The magnitude of the anisotropic flow is defined using the the Fourier coefficients $v_k\{\Psi_n\}$ of azimuthal distribution of the emitted particles with respect to the reaction plane [2]:

$$\frac{dN}{d(\phi-\Psi_n)} = 1 + 2\sum_{k=1}^{\infty} v_k \cos\left[k(\phi-\Psi_n)\right], \tag{1}$$

where ϕ – is the azimuthal angle of particle, k – is the harmonic order and Ψ_n is the n-th order symmetry plane angle. v_1 is hence called directed flow, v_2 – elliptic flow.

In this work centrality determination based on the multiplicity from TPC and anisotropic flow analysis for $Au+Au$ collisions will be presented for the two energies corresponding the highest and lowest energies of the NICA collider.

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2. Simulation and analysis

The future MPD detector will be capable of a 4π-spectrometer, detecting charged hadrons, electrons and photons in heavy ion collisions at high luminosities in NICA energy range [3]. In order to achieve this goal the detector comprises precise tracking system and highly-effective particle identification system based on time-of-flight measurement and calorimetry.

Primary track selection based on the DCA distributions and implementation of the realistic tracking algorithm Cluster Finder (CF) will be shown compared to the previous results [4].

For the event generation the UrQMD (Ultra-relativistic Quantum Molecular Dynamics) [5] and LAQGSM (The Los Alamos version of the Quark-Gluon String Model) [6] were used. The UrQMD is used for performance study of the reaction plane determination and anisotropic flow measurements for the beam energy 5 and 11 GeV while the LAQGSMis used for the reaction plane determination for the 11 GeV only. Used statistics is 1M events for each of the energy point and model choice. Further simulations were carried out using GEANT4 framework using MPD detector geometry and Cluster Finder (CF) and Hit Producer (HP) tracking algorithms for 5 and 11 GeV correspondingly. Following cuts were used in the analysis:

- $|\eta| < 1.5$
- $0.2 < p_T < 3\ GeV/c$
- $N_{hits}^{TPC} > 32$
- 2σ DCA cut for primary particle selection
- particle identification (PID) – is the cuts from PDG codes (Monte Carlo information)

where DCA – is the distance of the closest approach between the reconstructed vertex and a charged particle track.

For the collective flow measurement event plane method was used [2]. Reaction plane was estimated from the energy deposition of the nuclear fragments in backward and forward rapidities in the forward hadron calorimeters (FHCal). Q-vector was calculated as follows:

$$q_x^m = \frac{\sum E_i \cos m\phi_i}{\sum E_i},\ q_y^m = \frac{\sum E_i \sin m\phi_i}{\sum E_i}. \quad (2)$$

The event plane angle was calculated as follows:

$$\Psi_m^{EP} = \text{TMath::ATan2}(q_y^m, q_x^m), \quad (3)$$

where E_i is the energy deposition in the i-th module of FHCal, ϕ_i – its azimuthal angle. For $m = 1$ weights had opposite signs for backward and forward rapidities due to the antisymmetry of the v_1 as a function of rapidity. The values of v_n itself could be calculated as follows:

$$v_n = \frac{\left\langle \cos\left[n(\phi - \Psi_m^{EP})\right]\right\rangle}{Res_n\{\Psi_m^{EP}\}}, \ Res_n\{\Psi_m^{EP}\} = \left\langle \cos\left[n(\Psi_m^{EP} - \Psi_m)\right]\right\rangle, \tag{4}$$

where $Res_n\{\Psi_m^{EP}\}$ is the event plane resolution, Ψ_m is the n-th order collision symmetry plane, which cannot be measured experimentally. So, in order to estimate event plane resolution, the two-subevent method with extrapolation algorithm was used [2]:

$$Res_n^2\{\Psi_m^{EP,A}, \Psi_m^{EP,B}\} = \left\langle \cos\left[n(\Psi_m^{EP,A} - \Psi_m^{EP,B})\right]\right\rangle, \ Res_n\{\Psi_m^{EP}\} = Res_n(\sqrt{2}\chi_{A,B}), \tag{5}$$

where $\chi_{A,B}$ – is the parameter proportional to the v_n and $\sum E_i$, A and B represent two subevents - left(backward rapidity) and right(forward rapidity) FHCal detectors. In this work v_1 and v_2 was measured with respect to 1-st order event plane ($m = 1$).

3. Results and conclusions

3.1. Centrality determination

On the Figure 1 (left) multiplicity of the primary charged particles produced in the $Au + Au$ collisions calculated using TPC detector is shown. This distribution was used to introduce the centrality classes with equal number of particles in each class. Centrality resolution of used classification is shown on the Figure 1 (right). In the $10 - 80\%$ centrality range resolution $\frac{\sigma_b}{\langle b\rangle} \sim 5 - 10\%$ for both CF and HP tracking algorithms.

3.2. Azimuthal anisotropic flow

On the Figure 2 resolution correction factor for v_1 and v_2 is shown. Since the LAQGSM simulates nuclear fragments, one can see the deterioration of the resolution factor because more particles goes through the beam hole in the center of FHCal unregistered. Other than that, results shows good performance in the wide centrality range $0 - 80\%$ for all energies and tracking algorithms.

On the Figure 3 one can see the directed v_1 and elliptic v_2 flow as a function of p_T. Signal after GEANT4 simulation (true) is compared with one after reconstruction procedure (reco) which is how future experimental data will be analyzed. One can see that the difference between true and reco values is negligible.

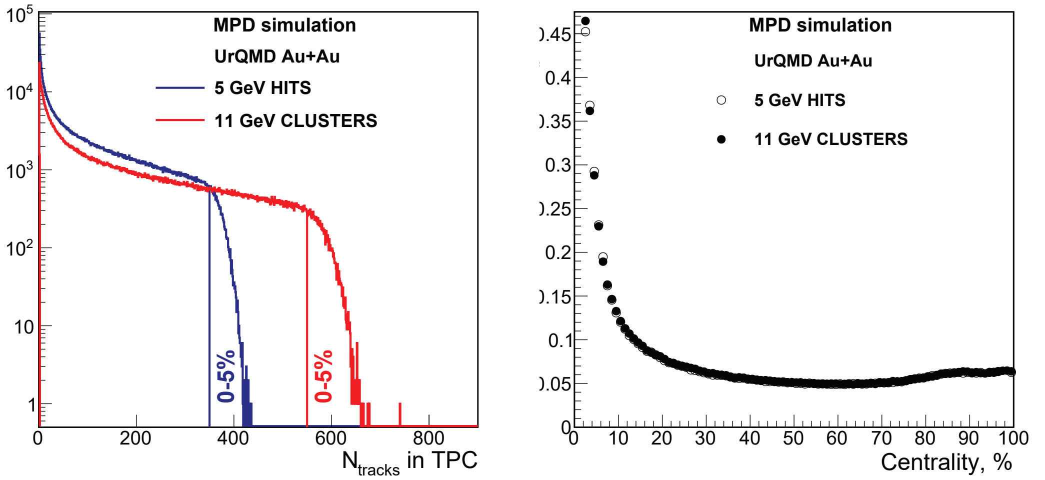

Figure 1: (left) Multiplicity distribution of the produced particles in TPC for 5 and 11 GeV. Vertical lines indicate $0-5\%$ centrality range. (right) Relative width $\frac{\sigma_b}{\langle b\rangle}$ of the impact parameter b distribution in the given centrality classes.

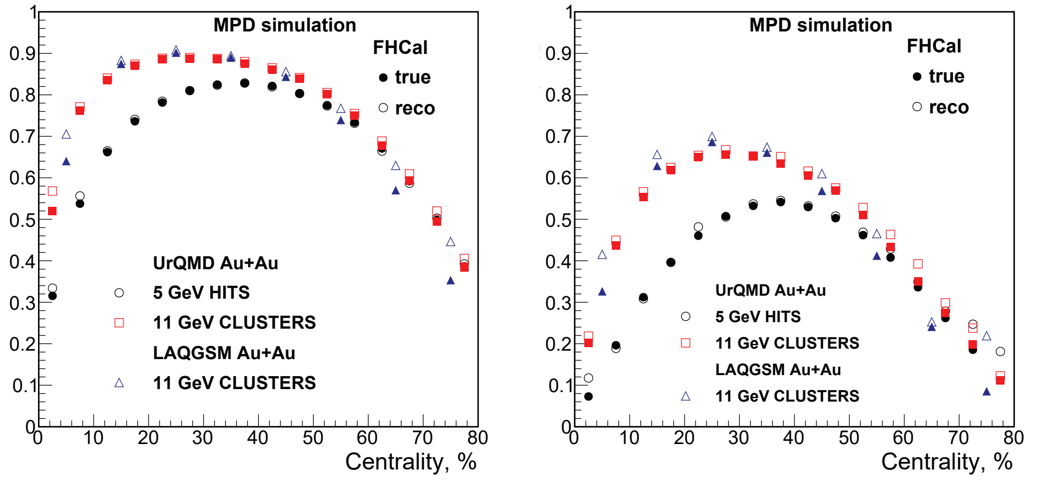

Figure 2: Resolution correction factor as a function of centrality for v_1 (left) and v_2 (right) for the UrQMD and LAQGSM event generators. Results from the GEANT4 simulation marked as true and one from the reconstruction procedure is marked as reco.

4. Summary

Track multiplicity of the emitted charged particles in TPC can be used for centrality determination with resolution $5-10\%$ in a wide centrality range $10-80\%$. Event plane orientation can be estimated using energy deposition in FHCal with high resolution factor ($Res_1\{\Psi_1^{EP}\} \sim 0.9$, $Res_2\{\Psi_1^{EP}\} \sim 0.7$ for centrality $20-40\%$). Directed (v_1) and elliptic (v_2) flow were extracted in simulations using event plane method. Results for the reconstructed (reco) and generated (true) values are in good agreement.

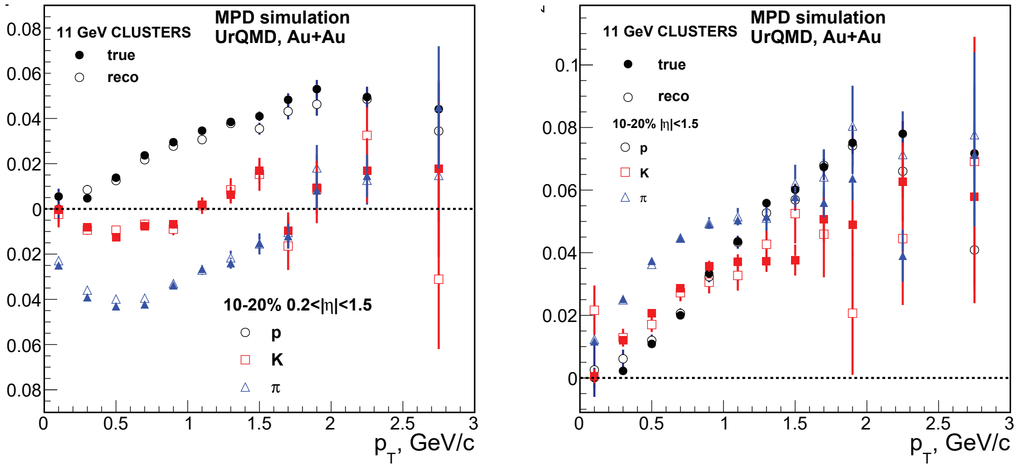

Figure 3: Directed flow v_1 (left) and elliptic flow (right) as a function of p_T. Signal from the GEANT4 simulation marked as true and one from the reconstruction procedure is marked as reco.

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