Vol. 14 (2021) *Acta Physica Polonica B Proceedings Supplement* No 3

CENTRALITY DETERMINATION IN HEAVY-ION COLLISIONS WITH MPD DETECTOR AT NICA*

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(Received February 1, 2021)

Centrality is a key parameter for defining the collision system size in relativistic heavy-ion collisions. The centrality determination provides a tool for comparing the anticipated measurements with Multi-Purpose Detector (MPD) at NICA with those of other experiments and with theoretical calculations. The performance for collision centrality determination in MPD experiment using the multiplicity of produced particles is presented.

DOI:10.5506/APhysPolBSupp.14.503

1. Introduction

Investigations of properties of the strongly interacting matter at high net-baryon densities are the main scientific mission of the MPD (Multi-Purpose Detector) at the accelerator facility Nuclotron-NICA (JINR, Dubna) [1]. Collisions of relativistic heavy-ions at energies in the range of 4 to 11 GeV per nucleon in the center-of-mass system which are planned at the NICA collider allow for experimental investigation of the matter in the region of high net-baryon densities exceeding that of the normal nuclear matter by 5–10 times. The size and evolution of the matter created in a relativistic heavy-ion collision depend on collision geometry. Experimentally, collisions can be characterized by the measured particle multiplicities around midrapidity or by the energy measured in the forward rapidity region, which is sensitive to the spectator fragments. In the present work, we use multiplicity of the produced particles for centrality determination. In order to extract collision geometry-related quantities, such as the average impact parameter or number of participating nucleons, a Glauber Model Monte Carlo approach (MC-Glauber) is employed [2].

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

2. Centrality determination procedure and performance

A sample of 1 M minimum-bias Au+Au collisions for each value of the collision energy $\sqrt{s_{NN}} = 5$, 7.7 and 11.5 GeV simulated with UrQMD event generator [5] was used for the analysis. MPDRoot framework is used to simulate the detector response to particles transported with Geant4 through the MPD setup. Charge particles tracks are reconstructed in the Time Projection Chamber (TPC) of MPD. Event multiplicity (N_{ch}) calculated from charged tracks within pseudorapidity cut $|\eta| < 0.5$ [4]. Figure 1 (left) shows the multiplicity distribution for Au+Au collisions at $\sqrt{s_{NN}} = 11.5$ GeV and full MPD simulation (black line).

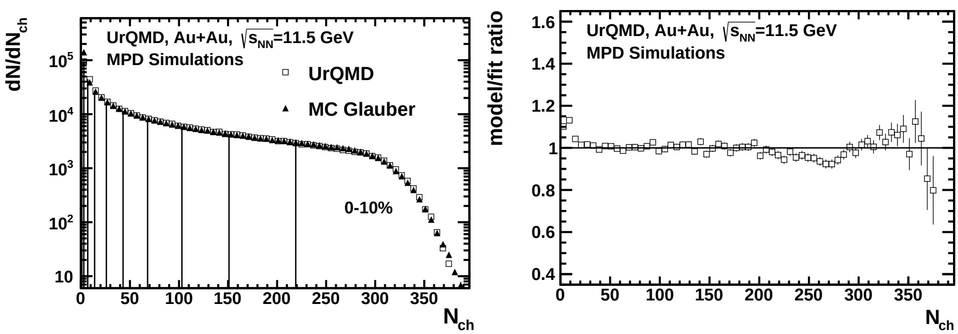

Fig. 1. (Color online) Left: Track multiplicity distribution from the reconstructed UrQMD events (black line) for Au+Au collisions at $\sqrt{s_{NN}} = 11.5$ GeV compared to the fitted distribution using the MC-Glauber approach (gray/red line). Right: Ratio of the track multiplicity distribution to the results of MC-Glauber fit.

In the MC-Glauber approach, the multiplicity of particles in a heavy-ion collision is modeled as a sum of particles produced from a set of N_{a} independent emitting sources (ancestors). Each ancestor produces particles according to negative binomial distribution (NBD) with mean value μ and width k

$$M_{\mathrm{MC-Gl}}(N_{\mathrm{a}}, \mu, k) = P_{\mu,k} \times N_{\mathrm{a}}\,, \qquad N_{\mathrm{a}}(f) = [f N_{\mathrm{part}} + (1-f) N_{\mathrm{coll}}]\,, \quad (1)$$

where N_{part} and N_{coll} are the number of participants and the number of binary collisions simulated with MC-Glauber corresponding to contributions from soft and hard processes. The track multiplicity distribution for the charged particles in TPC is then parametrised with a distribution of $M_{\mathrm{MC-Gl}}$ simulated according to equation (1). The result of the procedure is shown in Fig. 1 (left) by the gray/red line. The MC-Glauber fit was done for multiplicities above 20. Vertical lines represent event classification for the 10% centrality bins. The right part of Fig. 1 shows the ratio of the track multiplicity distribution to the MC-Glauber fit [3]. A value of the multiplicity at which MC-Glauber fit starts to deviate from the multiplicity distribution defines the so-called anchor point below which centrality determination is not reliable. This allows extracting the collision geometry-related quantities, such as the average impact parameter $\langle b \rangle$ or number of participating nucleons $\langle N_{\rm part} \rangle$ for a given class of centrality.

Figure 2 shows the centrality dependence of the average impact parameter $\langle b \rangle$ (left panel) and average number of participating nucleons $\langle N_{\rm part} \rangle$ (right panel) for Au+Au collisions at $\sqrt{s_{NN}} = 11.5$ GeV. The results for the $\langle b \rangle$ and $\langle N_{\rm part} \rangle$ estimated with the MC-Glauber approach (closed boxes) are consistent with the values used in the UrQMD generator within 5–10%. The

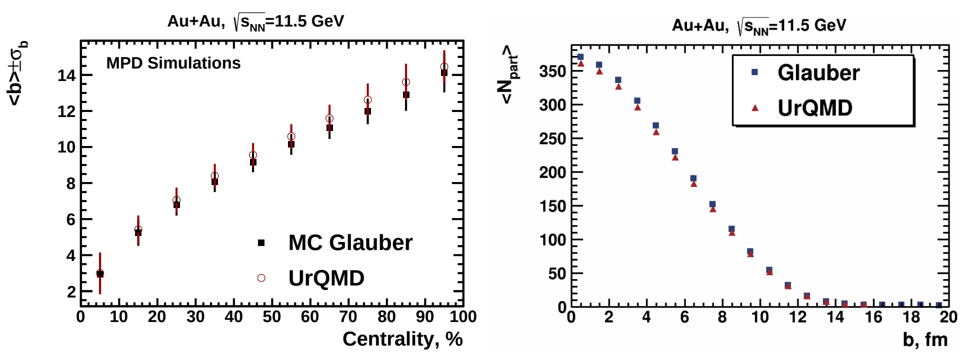

Fig. 2. Centrality dependence of the average impact parameter $\langle b \rangle$ (left panel) and average number of participating nucleons $\langle N_{\rm part} \rangle$ (right panel) for Au+Au collisions at $\sqrt{s_{NN}} = 11.5$ GeV. The resulting values of $\langle b \rangle$ and $\langle N_{\rm part} \rangle$ extracted from the MC-Glauber model (closed boxes) are compared with the values used in UrQMD generator.

average number of participating nucleons $\langle N_{\rm part} \rangle$ from the UrQMD generator was estimated at the passage time of the two colliding nuclei. Figure 3 (left) shows the centrality dependence of the average impact parameter $\langle b \rangle$ for Au+Au collisions at $\sqrt{s_{NN}} = 11.5$ GeV extracted by the same procedure for events generated using transport models: PHSD [6] and SMASH [7, 8]. The resulting $\langle b \rangle$ values are in a good agreement for presented models: UrQMD, PHSD and SMASH, and results estimated with the MC-Glauber approach. The right part of Fig. 3 shows the centrality dependence of $\langle b \rangle$ for Au+Au collisions at energies of $\sqrt{s_{NN}} = 5$, 7.7 and 11.5 GeV. The good agreement between results indicates that the geometrical properties of the collision are not changing in the NICA energy range of $\sqrt{s_{NN}} = 4$–11 GeV.

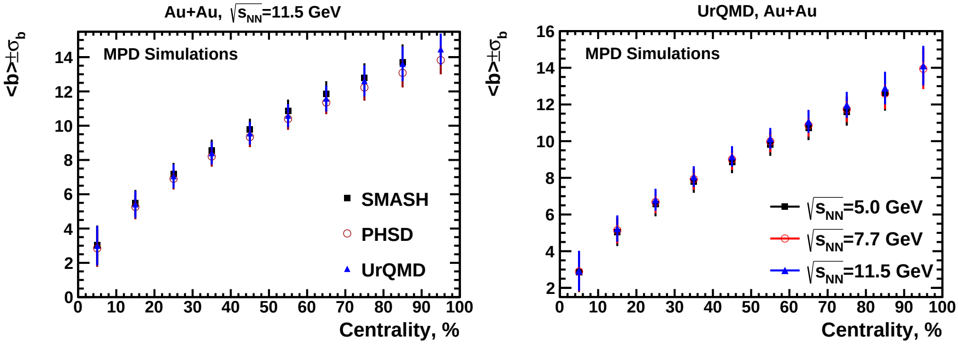

Fig. 3. Centrality dependence of $\langle b \rangle$ for Au+Au collisions at $\sqrt{s_{NN}} = 11.5$ GeV (left panel). Different symbols correspond to the results obtained using transport models: UrQMD, PHSD and SMASH. The right panel shows the centrality dependence of $\langle b \rangle$ for Au+Au collisions at $\sqrt{s_{NN}} = 5$, 7.7 and 11.5 GeV for UrQMD model.

3. Summary

The centrality determination procedure based on multiplicity of the produced particles has been tested for the full MPD simulation chain using the UrQMD model events for Au+Au collisions at $\sqrt{s_{NN}} = 5$, 7.7 and 11.5 GeV. This provides a tool to compare the anticipated MPD measurements with those of other experiments and with theoretical calculations.

The reported study was funded by the Russian Foundation for Basic Research (RFBR) according to the research project No. 18-02-40086 and was supported by the Ministry of Science and Higher Education of the Russian Federation, Project "Fundamental properties of elementary particles and cosmology" No. 0723-2020-0041.

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