Beam energy and centrality dependence of the multiplicity fluctuations in heavy ion collisions

Maitreyee Mukherjee,* Sumit Basu, Subikash Choudhury, and Tapan K. Nayak
Variable Energy Cyclotron Centre, 1/AF, Bidhan Nagar, Kolkata-700064

Introduction

Event-by-event fluctuations of thermodynamic quantities have been proposed as the basic tools for understanding the particle production mechanisms and to probe the QCD phase transition. The fluctuations of experimentally accessible quantities, such as particle multiplicities, mean transverse momenta, temperature, particle ratios, and other global observables are related to the thermodynamic properties of the system, such as the entropy, specific heat, chemical potential and matter compressibility [1]. A non-monotonic behaviour of multiplicity fluctuations may signal the onset of deconfinement and can be effectively used to probe the critical point in the QCD phase diagram [2]. Measurements at the vanishing μ_B at LHC energies set the scale of all theoretical calculations, and one can accurately calculate several quantities and their fluctuations. Multiplicity fluctuations are normally characterized by the scaled variances of the multiplicity distributions, defined as,

$$\omega_{ch} = \frac{\sigma_n^2}{\langle n \rangle} \tag{1}$$

where $\langle n \rangle$ and σ_n^2 are the mean and variance of the multiplicity distribution, respectively [3].

Analysis strategy

Narrower centrality bins are important to choose to get rid of the inherent fluctuations within a centrality bin. For this analysis, centrality is selected from the minimum-bias distribution for the number of participants. It is desirable to choose wider centrality bins, such as 5% or 10% cross sections, because of lack of statistics. In these cases, we have centrality bin width effect (i.e, effect caused by non-uniformity of charged particle distributions), which needs to be corrected. These are done by dividing one centrality bin into smaller bins and weight the moments. Figure 1 shows the effect caused by the finite centrality bins and minimisation of this effect using weighted average of the scaled variance. Results for multiplicity fluctuations are shown here for Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV with the generated events from the default version of AMPT. Fluctuations for 5% cross section bins are seen to be very large compared to those of the 2% cross section and 1% cross section bins. This clearly shows the effect of the wide centrality bin. After making the correction of the bin width effect, the fluctuations for the 5% cross section bins and 2% cross section bins reduce by close to 34% and 11%, respectively, and almost coincide with that of

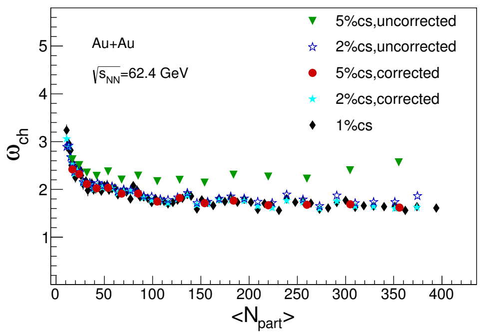

FIG. 1: (color online) Scaled variances (ω_{ch}) for Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV using the default mode of AMPT for 5% and 2% centrality bins before and after the centrality bin width corrections. The results for 1% centrality bins are also shown.

*Electronic address: maitreyee@vecc.gov.in

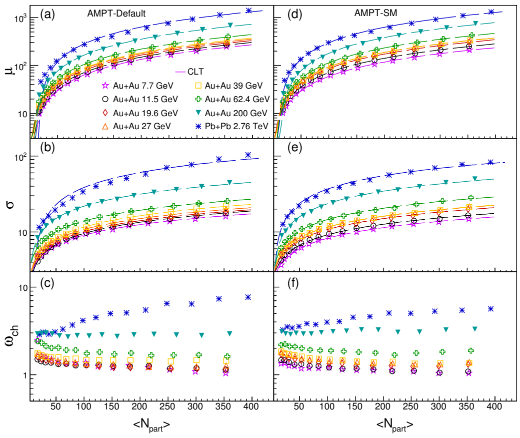

FIG. 2: (color online) Mean, sigma and ω_{ch} from the multiplicity distributions of charged particles, with generated events using the default (left panels) and SM (right panels) modes of the AMPT model for a wide range of collision energies. Dashed lines represents the expectations using the central limit theorem.

the 1% cross section bin. No centrality bin width dependence is observed after employing the correction.

Thus, it is possible to minimize the statistical fluctuations sufficiently and to evaluate the dynamical fluctuations.

Results from multiplicity fluctuations

The physics origin of the fluctuations in the multiplicity distributions are inherent in the width of the distributions. The analysis is performed with the generated events from AMPT-model in the default and the string-melting (SM) modes. For the analysis, transverse momentum considered is $p_T < 2.0$ GeV/c and the pseudorapidity range is $|\eta| < 0.5$.

The results from the multiplicity fluctuations are shown in figure 2. It has been observed that, Central Limit Theorem (CLT)-fits are better for μ and σ for lower energies. For energies from 7.7 GeV to 200 GeV, the scaled variance shows increasing trend for central to peripheral collisions. For 2.76 TeV, the trend for scaled variance is opposite.

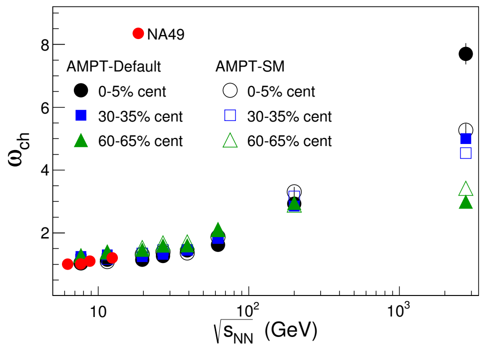

FIG. 3: (color online) Beam-energy dependence of scaled variance for three different centralities (0-5%, 30-35% and 60-65%) for a wide range of collision energies using two modes of AMPT model.

Beam-energy dependence of the multiplicity fluctuations is shown in figure 3. The fluctuations show an increasing trend from lower to higher energies. The fluctuations at low energies are close to each other for all centralities. Fluctuations increase for increasing beam energies for all RHIC energies. At 2.76 TeV and central collisions the fluctuations are larger for AMPT-default compared to the string melting mode. The results from AMPT matches with the results from NA49-experiment.

Acknowledgments

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References

[1] A. Adare *et al.*, Phys. Rev. **C 78**, 044902 (2008), arXiv: 0805.1521[nucl-ex] (2008)

[2] M. A. Stephanov, K. Rajagopal and E. V. Shuryak, Phys. Rev. Lett. **81**, 4816 (1998) [arXiv:hep-ph/9806219].

[3] M. M. Aggarwal *et al.*, Phys. Rev. **C 65**, 054912 (2002), arXiv:0108029v2 [nucl-ex] (2002).