PROCEEDINGS OF SCIENCE

Event-by-event multiplicity fluctuations in heavy ion collisions

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Multiplicity distributions of produced particles and their event-by-event fluctuations are studied using the AMPT model in the default and string melting modes. In addition to being sensitive to the QCD phase transition, these fluctuations provide baselines for other event-by-event measurements. The collision energy and centrality dependence of fluctuations are estimated for heavy-ion collisions from = 7.7 GeV to 2.76 TeV. The choice of narrow centrality bins and the corrections of centrality bin width effect helps to avoid inherent volume fluctuations within a given centrality window. The mean and width of the multiplicity distributions monotonically increase as a function of increasing centrality. The multiplicity fluctuations expressed in terms of scaled variances, decrease from peripheral to central collisions for all energies, except for that of the Pb+Pb collisions at = 2.76 TeV. The beam energy dependence shows an increase of multiplicity fluctuations with increasing beam energy.

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1. Introduction

Multiplicity, i.e, the number of the produced particles after the collision, is an important quantity to know about the characteristics of the evolving system. It helps to understand the mechanisms of particle production and put constraints on many models which are used to describe the collisions [1]. The presence of phase transition can manifest itself by characteristic behavior of several observables. But we do most of the studies in collection of events. Few observables may change very dramatically from one event to another. Fluctuation in multiplicity from event to event is one of them and it may provide a distinct signal of the phase transition from hadronic gas to QGP phase [2, 3]. Multiplicity fluctuation is expressed in terms of the scaled variance, i.e, variance of the multiplicity distribution scaled over the mean of the distribution.

$$\omega_{ch} = \frac{\langle N_{ch}^2 \rangle - \langle N_{ch} \rangle^2}{\langle N_{ch} \rangle} = \frac{\sigma^2}{\mu} \tag{1.1}$$

Fig. 1 shows the multiplicity distribution for a particular centrality, with ~ 1000 events generated

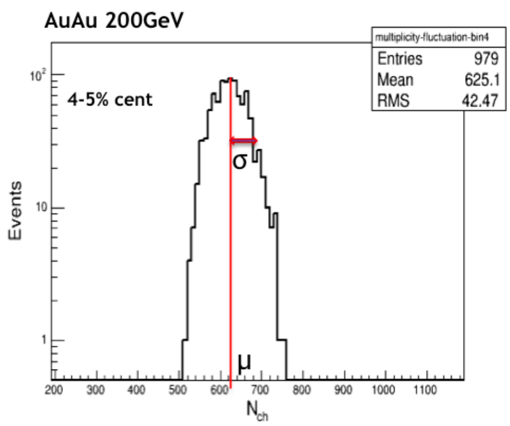

Figure 1: Multiplicity distribution of 4-5% centrality for Au-Au collisions at $\sqrt{s}_{NN} = 200$ *GeV* showing mean (μ) and sigma(σ)

with AMPT model with default settings for $p_{\mathrm{T}} < 2.0$ GeV/c and $|\eta| < 0.5$. 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 [4]. Variance is directly related to isothermal compressibility (k_T) of the system formed in heavy ion collisions [3],i.e,

$$\sigma^2 = \frac{k_B T \mu^2}{V} k_T \tag{1.2}$$

where, k_B is Boltzmann's constant, T is the temperature and V is the volume of the system. Clear signature of the critical behaviour is possible to observe by looking for the expected power law scaling of k_T as,

$$k_T \propto \left(\frac{T - T_c}{T_c}\right)^{-\gamma} \propto \varepsilon^{-\gamma} \tag{1.3}$$

where, γ is the critical exponent for k_T. k_T is expected to increase by at least an order of magnitude close to the QCD critical point. Additionally, determination of critical exponent helps to determine the universality class in which QCD is grouped, providing essential constraints for the models [3]. Another important thing are the parameters characterizing the multiplicity distributions. Charged particle multiplicity distributions can be described by the negative binomial distributions [3] and the parameters of the distributions, i.e, mean (μ) and k_{NBD} are related to the multiplicity fluctuations as,

$$\omega_{ch} = 1 + \frac{\mu}{k_{NBD}} \tag{1.4}$$

Parameters characterizing multiplicity distributions contain good physics messages. ALICE experiment probes a continuous range of Bjorken-x below 10^{-4} with the central Detectors. Thus, ALICE experiment will be able to access a novel regime where initial state effects can be studied very well [5]. Event by event multiplicity fluctuation has been studied earlier in SPS (WA98 experiment) and RHIC (PHENIX experiment) energies. Here the study of centrality dependence and beam-energy (from RHIC and LHC energies) dependence of charged particle multiplicity fluctuation has been presented and discussed.

2. Centrality selection

Centrality selection for this work has been done using minimum bias distribution of the number of participants (N_{part}). Fig. 2 shows an example for Au-Au collisions at $\sqrt{s}_{NN} = 7.7\ GeV$. Now,

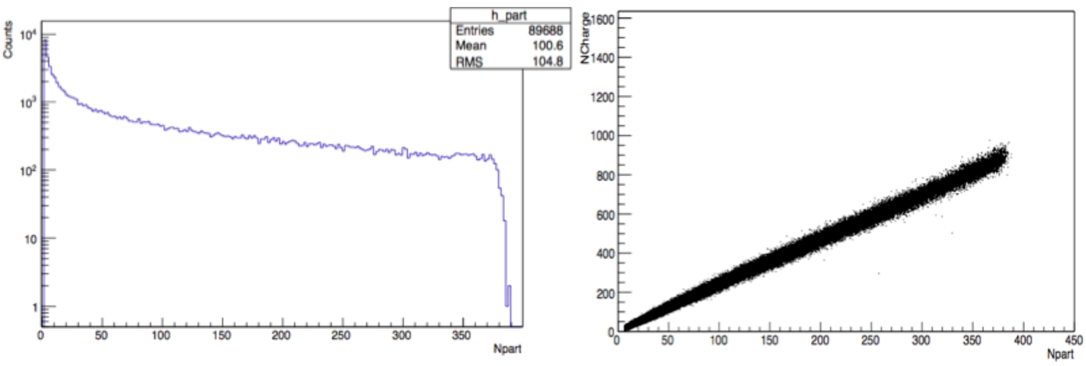

Figure 2: Au-Au collisions at $\sqrt{s}_{NN} = 7.7\ GeV$, events generated with default-AMPT. Left : Minimum-bias distribution of N_{part}. Right : Correlation between N_{part} and N_{charge}.

from the correlation plot, it is evident that N_{part} is directly proportional to some quantities that are experimentally observed, such as number of produced charged particles, i.e, N_{ch}. So, centrality selection from N_{part} is quite justified. Fig. 3 shows an example for centrality selection and from the right-side plot, it is observed that N_{ch}-minimum bias distribution is the convolution of N_{ch}-distributions in different centralities. Fluctuation increases as we increase the centrality width. In Fig. 4, it has been shown that finer bin in centrality needs to be selected for fluctuation studies. This will avoid inherent fluctuations in N_{part} within a given centrality. In this analysis, we select 0-1%, $1-2\%, 2-3\%, 3-4\%$ centrality bins and also check with centrality binwidth corrections. Centrality bin-width effect arises due to the impact parameter(or volume) variations due to the finite centrality bin. Prescription is to divide one centrality bin into smaller bins and weight the moments [6]. The results with bin width correction has been shown in the right side plot of Fig. 4.

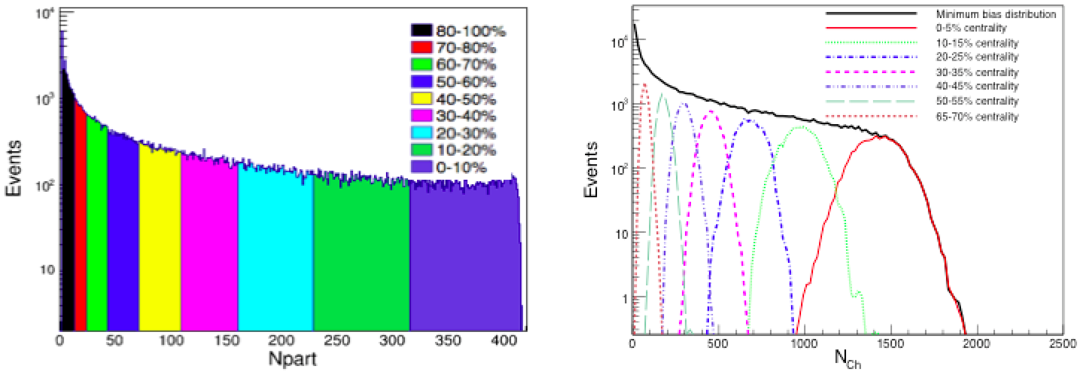

Figure 3: Au-Au collisions at $\sqrt{s_{NN}} = 7.7\ GeV$, events generated with AMPT-String Melting model. Left : Centrality selection using N_{part} minimum-bias distribution. Right : Charged particle multiplicity distributions in different centralities.

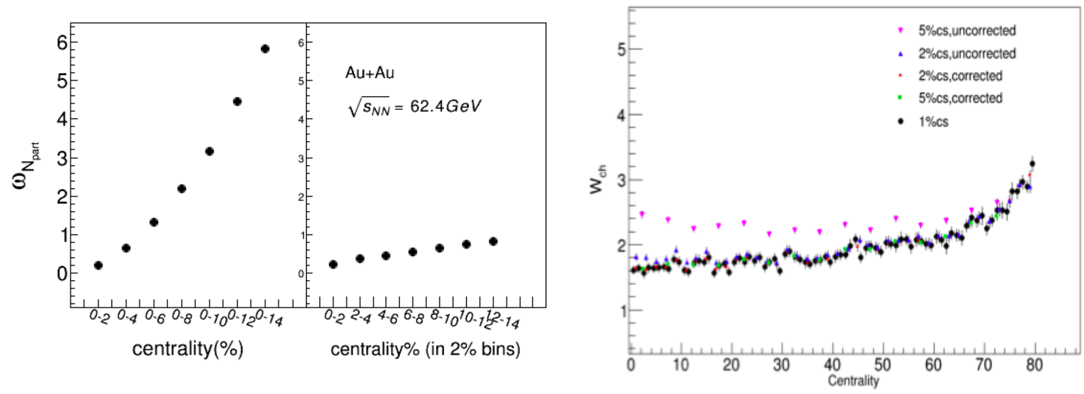

Figure 4: Left : Fluctuations in N_{part} as a function of different centrality bins for Au-Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV using the default mode of AMPT. The left panel shows the fluctuations for continuous increase of centrality and the right panel shows the results for narrow centrality bins. Right : Binwidth-correction effect on the multiplicity fluctuation for Au-Au collisions at $\sqrt{s_{NN}} = 62.4\ GeV$, events generated with AMPT-default model.

Binwidth correction changes result for 5% centrality by $\sim 3.6\%$ and for 2% centrality by $\sim 1\%$. So, doing analysis using narrower centrality bins(here, 1% centrality) is quite justified. Doing analysis with say, 5% or 2% bins need binwidth correction.

3. Results

Fig. 5 shows the final results. We observe an opposite trend of scaled variance from central to peripheral collisions for Pb-Pb compared to Au-Au at lower energies, both in AMPT-Default and AMPT-String Melting. Values for ω_{ch} are a bit larger with AMPT-default than AMPT-String Melting for Pb-Pb. In the results, statistical errors are within the data points. In Fig. 6, results have been shown for three different centralities, i.e, 0-2%, 30-32% and 70-72%. Scaled variance

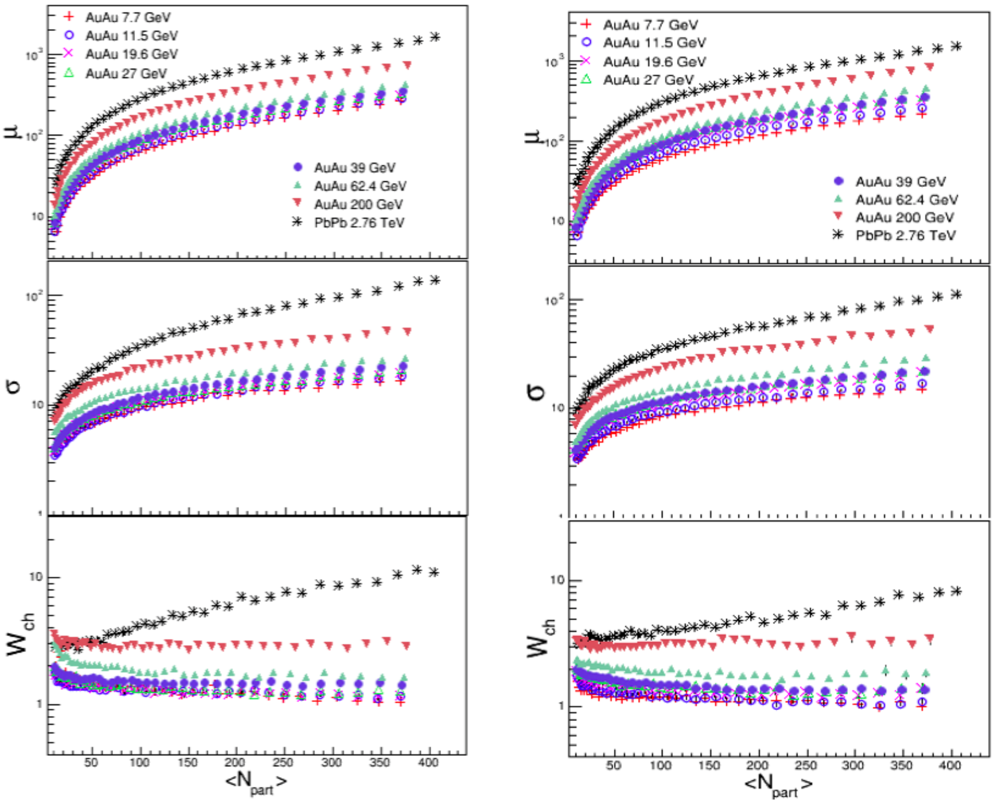

Figure 5: Binwidth corrected results : Centrality dependence of the Scaled Variance. Left : AMPT-Default. Right : AMPT String-Melting

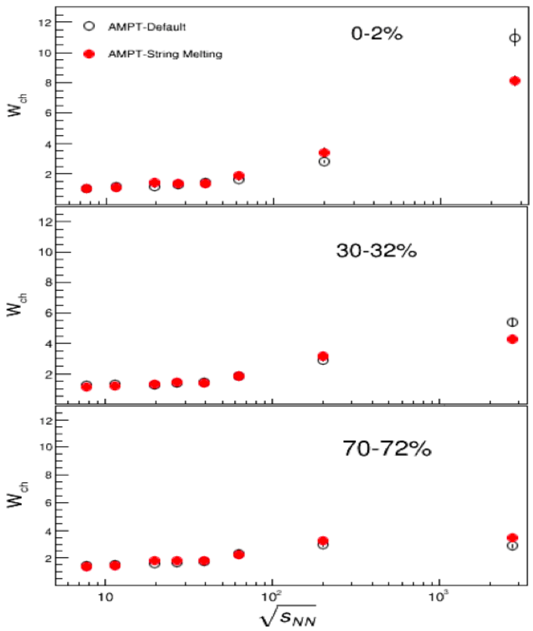

Figure 6: Beam-energy dependence of the Scaled Variance

increases from lower to higher energies. In higher energies, AMPT-String Melting gives lower value for scaled variance than AMPT with default settings.

4. Summary

Centrality and beam-energy dependence of multiplicity fluctuation has been studied for energies ranging from $\sqrt{s_{NN}} = 7.7$ GeV to $\sqrt{s_{NN}} = 2.76$ TeV with the help of AMPT-Default and AMPT-String melting models. Centrality selection is done from minimum bias distribution of N_{part}. Narrower centrality bins are selected for the analysis and centrality bin width correction has been done properly. The trend for scaled variance is opposite in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV in compared to its trend in lower energies. We are looking at the data from ALICE experiment. We expect the results soon.

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