Charged particle multiplicity fluctuations in high energy heavy-ion Collisions

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Introduction

One of the basic advantages studying heavy-ion collisions at relativistic energies is the production of large number of particles in each event, which helps the event-by-event study of several observables. The fluctuations of experimentally accessible quantities, such as particle multiplicity, mean transverse momentum, 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. In this article we estimate multiplicity fluctuations and access physical quantities accessible through it.

Multiplicity fluctuations have been characterised by the scaled variances of the multiplicity distributions, defined as, $\omega = \frac{\sigma^2}{\mu}$, where μ and σ^2 are the mean and variance of the multiplicity distribution, respectively. In the Grand Canonical Ensemble (GCE), the multiplicity fluctuations are related to the isothemal compressibility (κ_T) of the system,

$$\omega = k_{\rm B} T \frac{\mu}{V} \kappa_T, \tag{1}$$

where, $k_{\rm B}$ is the Boltzmann's constant, V is the volume and T is the temperature. The study of iso-thermal compressibility is important in order to understand the nature of the phase transition from the QGP system to hadronic system.In a continuous or second order transition, the power law scaling of compressibility is, $\kappa_T \propto (\frac{T-T_C}{T_C})^{-\gamma}$ where γ is the critical exponent and T_C is the critical temperature. Near the critical point, therefore, κ_T will diverge to infinity. Experimentally, its value should have a large increase close to critical point.

Here, a study of charged particle multiplicity fluctuations as a function of centrality and beam-energy for Au+Au collisions for the Beam Energy Scan (BES) energies at RHIC (from $\sqrt{s_{\rm NN}}$ = 7.7 GeV to 200 GeV) and Pb+Pb collisions at LHC-energy ($\sqrt{s_{\rm NN}}$ = 2.76 TeV) from the available experimental data as well as using different modes of the AMPT (A Multi-Phase Transport) model, have been presented, and κ_T are extracted.

Analysis methods and Results

Narrow bins in centrality are selected which helps to to get rid of inherent fluctuations within a centrality bin [1]. Multiplicity fluctuations as a function of collision centrality are shown in Fig. 1. It is observed from Fig. 1 that for all collision energies, μ and σ increase smoothly in going from peripheral to central collisions for all energies.

Fig. 2 shows the values of $\omega_{\rm ch}$ for central collisions for WA98, NA49 and PHENIX experiments (scaled to a common acceptance). A slow rise in $\omega_{\rm ch}$ has been observed from low to high collision energy and then remaining constant at higher energies.

Using the data plotted in Fig. 2, we have calculated the values of κ_T as a function of collision energy using:

$$\kappa_T = \omega_{ch} V / (T_{ch} \mu_{ch}) fm^3/MeV \tag{2}$$

The results for κ_T are plotted in Fig. 3. We see that iso-thermal compressibility of the produced system does not depend on collsion energy and its value is $\approx 56.02\ fm^3/GeV$.

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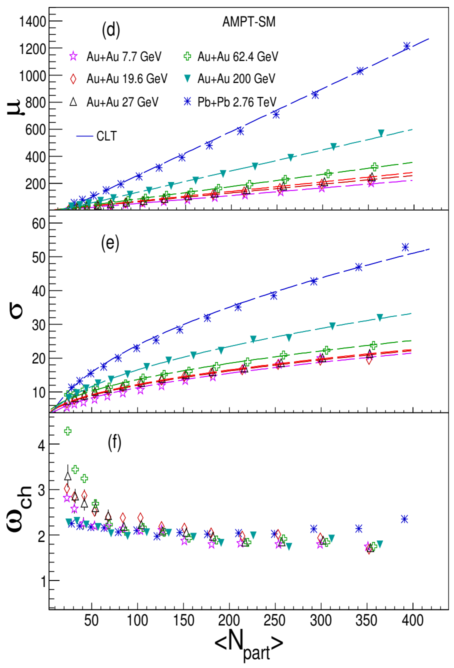

FIG. 1: (colour online) Mean, sigma and ω as a function of centrality for various collision energies. Dashed lines are fits using central limit theorem [1].

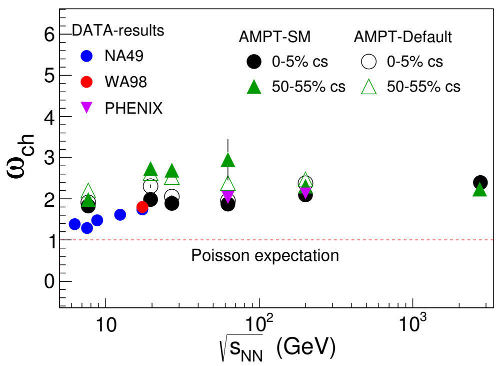

FIG. 2: (colour online) Beam-energy dependence ω_{ch}.

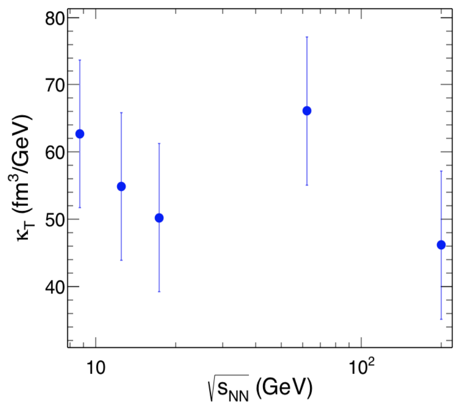

FIG. 3: Iso-thermal compressibility as a function of energy

Summary

We have presented a comprehensive study on the fluctuations of charged particle multiplity at mid-rapidity as a function of collision centrality and beam-energy. We have studied the multiplicity distributions of produced charged particles and their event-by-event fluctuations from available experimental data for heavy-ion collisions and using AMPT model calculations. Finally, we have extracted isothermal compressibility which is seen to remain constant at $\approx 56.02\ fm^3/GeV$, as a function of collision energy. Our study offers a novel way of calculating isothermal compressibility and will be useful for collisions at FAIR, RHIC and LHC energies.

References

[1] M. Mukherjee, S. Basu, S. Choudhury and T.K. Nayak; J. Phys. G: Nucl. Part. Phys. 43 085102 (2016), arXiv:1603.02083 [nucl-ex].