Transverse momentum fluctuations for Au-Au collisions at $\mathrm{E_{lab}}$ = 30A GeV using UrQMD model

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Introduction

One of the main goals of high energy heavy-ion collisons is to investigate the properties of strongly interacting matter under extreme conditions of temperature and/or pressure and to locate the critical point in the phase diagram. It has been suggested theoretically that there should be a smooth cross-over transition between the hadronic matter and a state of quasi-free quarks and gluons i.e., quark-gluon plasma (QGP) at zero baryon-chemical potential (μ_B) and high temperature (T). The RHIC and LHC, with the availability of very high collision energies, focus on this region of phase diagram and study the deconfined QCD matter. A first-order phase transition is expected at large μ_B and small T. The critical point is when the first-order phase transition line ends and has properties of second order phase transition. The beam energy scan (BES) at RHIC and CERN-SPS focus on this region of phase diagram and try to locate the critical point. To complement these, the upcoming experiments like CBM at FAIR and NICA at JINR will operate with similar goals.

In the nucleus-nucleus collisions, the volume varies on event-by-event basis and cannot be controlled. Thus, there is a need of quantities which can measure properties of the strongly interacting system independent of volume fluctuations. The strongly intensive quantities are such quantities which are independent of volume as well as volume flucuations. For example, the ratio of mean multiplicities of two different particle species is a strongly intensive quantity. The scaled variance (ω) is intensive but not the strongly intensive quantity.

In Ref. [1, 2], two families (Δ and Σ) of strongly intensive quantities were introduced. The $\phi-$measure [3], which has been used widely to quantify the fluctuations, belongs to the Σ family.

Formalism

The two extensive variables which have been used to get the strongly intensive quantities are summed transverse momentum ($P_T = \sum_{i=1}^{N_{ch}} p_T^{(i)}$) and charged-particle multiplicity (N_{ch}) within the chosen kinematic cuts [1, 2]:

$$\Delta[P_T, N_{ch}] = \frac{< N_{ch} > \omega[P_T] - < P_T > \omega[N_{ch}]}{< N_{ch} > \omega(p_T)}, \quad (1)$$

$$\Sigma[P_T, N_{ch}] = \frac{< N_{ch} > \omega[P_T] + < P_T > \omega[N_{ch}] - 2cov(P_T, N_{ch})}{< N_{ch} > \omega(p_T)}, \quad (2)$$

where

$$cov(P_T, N_{ch}) = < P_T N_{ch} > - < P_T >< N_{ch} >, \quad (3)$$

$$\omega[P_T] = \frac{< P_T^2 > - < P_T >^2}{< P_T >}, \quad (4)$$

$$\omega[Nv] = \frac{< N_{ch}^2 > - < N_{ch} >^2}{< N_{ch} >}, \quad (5)$$

The Φ_{p_T} has been expressed in terms of $\Sigma[P_T, N_{ch}]$ as following [1, 2]:

$$\Phi_{p_T} = \sqrt{\overline{p_T}\omega(p_T)} \left[\sqrt{\Sigma[P_T, N_{ch}]} - 1\right], \quad (6)$$

where $\omega(p_T)$ and $\overline{p_T}$ denote the scaled variance and average of inclusive p_T distribution.

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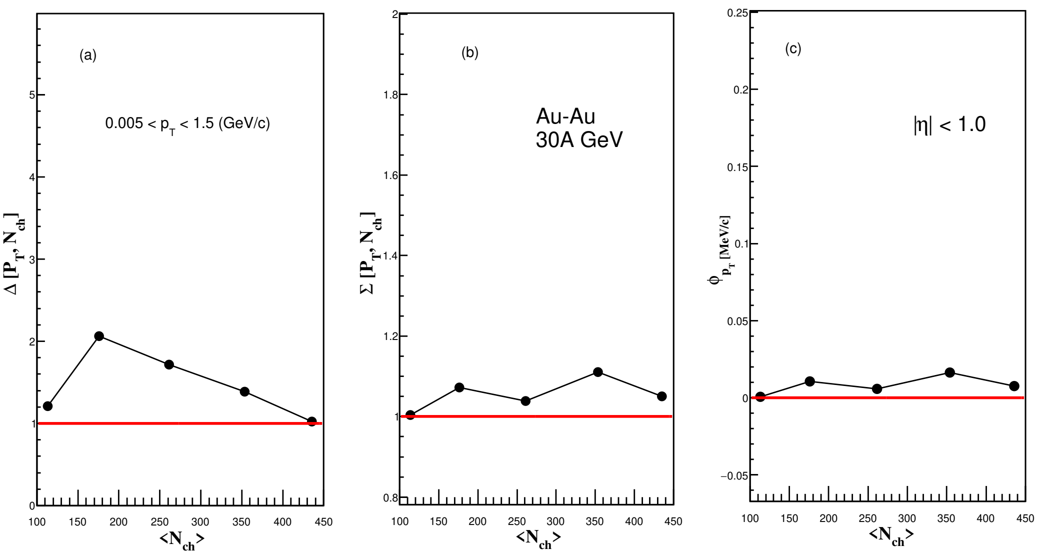

FIG. 1:
Variation of (a) $\Delta[P_T, N_{ch}]$, (b) $\Sigma[P_T, N_{ch}]$ and (c) ϕ_{p_T} as a function of $< N_{ch} >$ for Au-Au collisions at E_{lab} = 30A GeV.

Results and Discussion

The Au-Au collisions have been generated at $E_{\rm lab}$ = 30A GeV using the Ultra Relativistic Quantum Molecular Dynamics (UrQMD) model. The variation of $\Delta[P_T, N_{ch}]$, $\Sigma[P_T, Nv]$ and Φ_{p_T} has been shown in Fig. 1 (a,b,c) as a function of average charged particle multiplcity ($< N_{ch} >$).

In the independent particle production model (IPM), where inter-particle correlations are absent, these quantities (Δ and Σ) are normalized in such a manner that they attain the value of unity. In the absence of any event-by-event fluctuations, the Δ and Σ are equal to zero. The $\phi-$measure is equal to zero in case of IPM.

The value of $\Delta[P_T, N_{ch}]$ increases as we move from higher to lower values of $< N_{ch} >$ i.e., from central towards peripheral collisions and it again decreases for the lowest considered value of $< N_{ch} >$. A peak can be seen around $< N_{ch} > \approx 176$. The value of $\Delta[P_T, N_{ch}]$ is greater than unity for all values of $< N_{ch} >$, except for the most central case. The value of $\Sigma[P_T, N_{ch}]$ is nearly unity for almost all values of $< N_{ch} >$ and only a little deviation from the IPM reference values can be seen. The Φ_{p_T} shows almost same behaviour as that of $\Sigma[P_T, N_{ch}]$; as Φ belongs to the Σ family.

The $\Delta[P_T, N_{ch}]$, $\Sigma[P_T, N_{ch}]$ and Φ_{p_T} have also been investigated separately for positively and negatively charged particles. Also, the pseudorapidity dependence has been studied for these observables.

References

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[3] Gaździcki, Marek, and Stanisław Mrówczyński, Zeitschrift für Physik C Particles and Fields 54.1 (1992): 127-132.