Multiplicity and Transverse Momentum Fluctuations using Strongly Intensive measure in Heavy-Ion Collisions at FAIR Energies

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Introduction

The CBM experiment at FAIR is expected to provide an opportunity to explore high μ_B region of the phase diagram and to locate the critical point. Non-monotonic behavior of various fluctuation measures is regarded as a signal of critical point because the magnitude of fluctuations and correlations may significantly change during phase transition, particularly for nucleus-nucleus (AA) collisions which are passing close to critical point. An attempt is, therefore, made to undertake a systematic study of event-by-event (ebe) fluctuations in Au-Au collision at future FAIR energies. Monte Carlo (MC) event samples corresponding to beam energies 10A, 20A 30A and 40A GeV/c are simulated in the framework of relativistic transport model, UrQMD. The simulated data are analyzed in terms of strongly intensive variables so that the contributions from the trivial fluctuations may be reduced.

Results and Discussion

The strongly intensive measure Σ is defined as[1,2]
$\Sigma[A,B] = \frac{1}{C_\Sigma}[\langle B\rangle w(A) + \langle A\rangle w(B) - 2(\langle AB\rangle - \langle A\rangle\langle B\rangle)]$, where A and B are two extensive variables which are independent of source number distribution, $\omega(x)$ is the scaled variance of x. The present work is based on the study of the joint fluctuations of multiplicities and sum of event transverse momenta in two separated η windows using the variable $\Sigma[A,B]$. The quantities [A,B] are taken as [N_F,N_B], [N_F,p_{T_B}] and [p_{T_F},p_{T_B}]. In order to examine the centrality dependence of $\Sigma[A,B]$, values of $\Sigma[A,B]$ for these sets of variable are calculated for 2%, 5% and 10% centrality bins at four beam energies. The two η windows, each of width $\Delta\eta = 0.5$ are considered and placed adjacent to each other such that they are symmetric with respect to η_c. It is observed that Σ[N_F,N_B] values are independent of centrality bin width. The variable acquires value $\sim$ 1 from 0–60% centrality. It increases to its maximum at $\sim$ 80% centrality and then decreases. The observed maxima in the region of very peripheral collisions may be related to the transition into a region of diffusive edges of the nuclei. But this centrality range is hardly accessible in experiments[3]. Variations of Σ[N_F,p_{T_B}] and Σ[p_{T_F},p_{T_B}] with centrality for the centrality bin width 2%, 5% and 10% for 40A GeV/c data are plotted in Fig.1. It may be noted from the figure that the values of Σ are $\sim$ 0.7 (for Σ[N_F,p_{T_B}]) and $\sim$ 0.6 (for Σ[p_{T_F},p_{T_B}]) upto $\sim$ 70% centrality and then gradually increase. It may also be noted in the figure that Σ[N_F,p_{T_B}] and Σ[p_{T_F},p_{T_B}] values depend on the centrality bin width such that the values are higher for narrow bins. This dependence is observed to become stronger for more central collisions. In AA collisions, volume of the system changes from event to event which causes the fluctuations in particle multiplicities. Such fluctuations can be minimized by proper selection of centrality bin widths. Selection of very narrow centrality bins would reduce the geometrical fluctuations to minimum but may not be possible due to centrality resolution of the detector. Also the very narrow centrality bins would give rise to fluctuations due to finite particle multiplicity. Hence one has to compromise with somewhat wider centrality bins, e.g., 5% or 10% of the total cross section and then apply the corrections to the inherent fluctuations taking the weighted mean of the observable X as: $X = \Sigma_i n_i X_i / \Sigma_i n_i$; where X_i is

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the observable in ith bin[4]. Since the quantity $\Sigma[A, B]$ for the sets [N$_F$,p$_{T_B}$] and [p$_{T_F}$,p$_{T_B}$] exhibit centrality dependence, corrections are applied by estimating the values of Σ[A,B] in 1% centrality bins. Centrality dependence of Σ[N$_F$,p$_{T_B}$] and Σ[p$_{T_F}$,p$_{T_B}$], after applying the corrections, are shown in the right panels of Fig.1. It is observed that after bin width corrections data for various centrality classes overlap showing no centrality bin width dependence. It is also observed that the values of Σ[A,B] for the three sets of variables are independent of the beam energy for all the centrality classes. Similar centrality dependence of Σ[A,B] has been observed in MC studies in the framework of model with string fusion for Pb-Pb collisions at $\sqrt{s}_{NN} = 2.76$ TeV[5].Values of Σ[A,B] for the three sets of variables are calculated for 7.2% central Au-Au collisions at 10A, 20A, 30A and 40A GeV/c. The widths of the two windows $\Delta\eta$ is taken to be 0.2 and their separation with respect to η_c is varied from 0 to 1.2 in steps of 0.4. The selection of the window widths and their positions in η space is important for capturing the hadrons resulted from the resonance decays and accounting for the effect of global charge conservations. Variations of Σ[A,B] with η_{sep} for the various data sets are displayed in Fig.2. It is observed that Σ[N$_F$,N$_B$] acquire a value ∼ 1 for small and large η-separations and independent of beam energy. Values of Σ[N$_F$,p$_{T_B}$] and Σ[p$_{T_F}$,p$_{T_B}$] are noticed to increase with increasing η_{sep} in almost identical fashion. However, values of Σ[N$_F$,p$_{T_B}$] are somewhat larger as compared to those for Σ[p$_{T_F}$,p$_{T_B}$]. Joint fluctuations of multiplicity in two η windows have also been addressed in terms of event-wise observable $C = (N_F - N_B)/\sqrt{N_F N_B}$. The variance, σ_c^2 would have the properties similar to that of Σ[N$_F$,N$_B$]. The values of σ_c^2 have been observed to be ∼ 1 for $\eta_{sep} = 0$ and somewhat higher for large η_{sep} for Au-Au collisions at $\sqrt{s_{NN}} = 100$ GeV. The findings of the present work are in fine agreement with those observed for 0-8% central Be-Be collisions at 150A GeV/c by NA61/SHINE collaboration. The observed trend of variations of $\Sigma[A, B]$ with η_{sep} is similar to the prediction of quark-gluon string model for LHC energies.

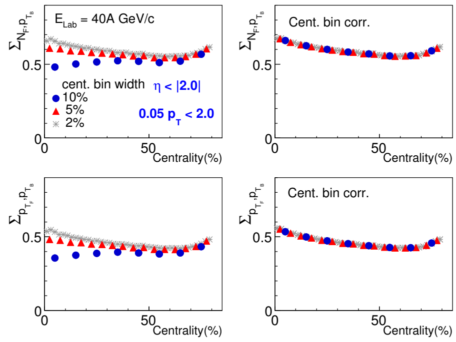

FIG. 1: Variations of Σ[N$_F$,N$_B$] with respect to centrality for different bin width in Au-Au collisions at 10 and 40 A GeV/c.

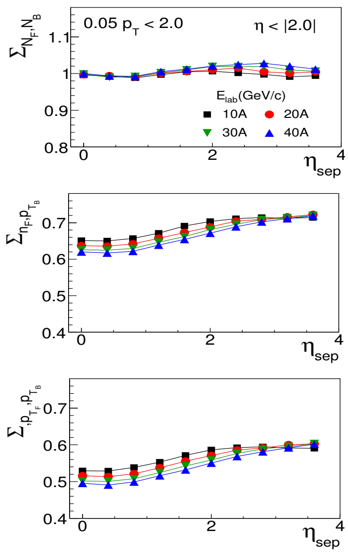

FIG. 2: Variations of Σ measure with η_{sep} in Au-Au collisions at 10A, 20A 30A and 40A GeV/c.

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