Intermittency in hybrid UrQMD-hydro data

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Introduction

One of the prime objective of heavy-ion collisions is to understand the particle production mechanism [1]. Different physical processes such as cascading particle production, Bose-Einstein correlation, collective flow, chaotic hydrodynamic processes, binary decays etc. give correlation among varying number of particles [2–5]. Studying fluctuation is expected to give information about particle production mechanism. Fluctuations in the multi-particle final state of heavy-ion collisions could be statistical and non-statistical or dynamical. Out of several methods, the method of scaled factorial moments (SFM) proposed by Bialas and Peschanski [4] is considered to be the most significant one for extracting the dynamical contribution to the fluctuation in multiplicity distribution in high energy collisions. A power law growth of the scaled factorial moments with decreasing phase-space bin size, referred to as intermittency, thereby indicates the presence of dynamical fluctuation. The power law behavior of SFM is related with the self similarity and fractal properties of the underlying production processes.

In the present work an attempt has been made to analyze UrQMD hydro generated data using scaled factorial moment technique to realize the presence of intermittency.

Results and Discussions

In this work, the analysis was done by generating UrQMD (default), UrQMD-hydro(default) Monte Carlo (MC) events for central ($b = 0-3$ fm) Au-Au collisions at $E_{lab} = 10AGeV$. Initial shape dependence of the single particle density distribution spectrum of UrQMD-hydro (default) data is removed by converting pseudorapidity(η) and azimuthal angle(ϕ) variables to new cummulative variables $\chi(\eta)$ and $\chi(\phi)$ respectively defined in ref [6].

Horizontally averaged scaled factorial moments $< F_q >$ of order q, for two-dimensional $\chi(\eta,\phi)$ spaces, described in details in ref [6], are then estimated for hybrid UrQMD-hydro, UrQMD transport and MC-RAND (generated by random number generater) generated data using the formula-

$$< F_q >= \frac{1}{N}\sum_{i=1}^{N} M^{q-1}\sum_{m=1}^{M} n_m(n_m-1)... ..(n_m-q+1)/<n>^q \quad (1)$$

where, M is the total number of bins, n_m is the number of particles in m^{th} bin, N is the sample size for a particular type of events. Bialas and Peschanski have shown that for any dynamical cntribution to the fluctuation, the scaled factorial moments should follow a power law of the form $< F_q >\propto M^{\alpha_q}$, α_q is known as intermittency index. It confirms the existence of intermittency in the emitted particles in high energy collisions. A clear signature of power law behavior of the form $< F_q >\propto M^{\alpha_q}$ for the estimated values of $< F_q >$ with the increasing number of phase-space bin M^2 of two dimensional $\chi(\eta,\phi)$ space could be observed from ln $< F_q >$ vs. lnM^2 plots of fig. 1 for q=2-6 confirming the presence of intermittency in UrQMD-hydro generated data. The solid lines shown in the plots are the best-fitted lines drawn with correlation coefficient $R^2 = 0.99$.

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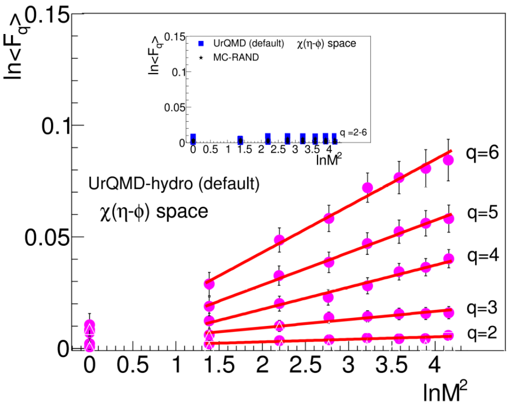

FIG. 1: ln< F_q > vs lnM^2 plot for UrQMD-hydro (default), UrQMD(default) and MC-RAND data

The observation of such power law behaviour confirmes the presence of intermittency in hybrid UrQMD-hydro generated data. It may be noted that no significant values of intermittency could be observed with UrQMD (transport) or MC-RAND generated data.

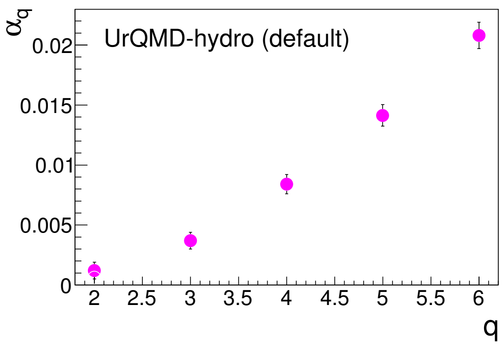

FIG. 2: ln< F_q > vs lnM^2 plot for UrQMD-hydro (default), UrQMD(default) and MC-RAND data

Intermittency is also related to the anomalous fractal dimension through the equation $d_q = \frac{\alpha_q}{q-1}$. It is claimed that an increase in d_q with q is associated with particle production via some branching mechanism and order independence of d_q, on the other hand, is indicative of particle production via a phase-transition. In fig. 3 it could be readily seen that the d_q increases with order of moment q.

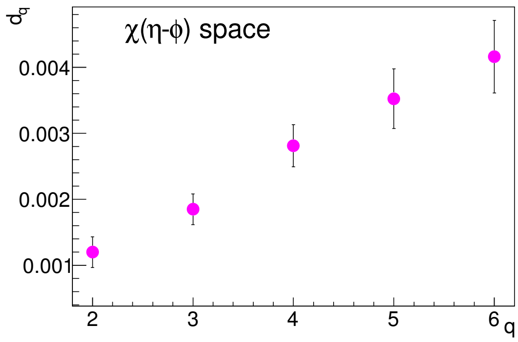

FIG. 3: ln< F_q > vs lnM^2 plot for UrQMD-hydro (default), UrQMD(default) and MC-RAND data

From the present two dimensional scaled factorial moment analysis on $\chi(\eta, \phi)$ space, it is found that the data generated with UrQMD transport model does not exhibit any signature of intermittency while the hybrid UrQMD-hydro model, which is a mixture of transport and hydrodynamic model, does exhibit intermittency. Thus, the hydrodynamic evolution of produced particles of heavy-ion collision, that takes place in the intermediate stage of the space-time evolution of such collision, could be one of the important contributors of intermittent type of particle emission in heavy-ion collision.

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