Study of non-thermal phase transition in the emission spectra of projectile fragments

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Introduction

The power law behaviour of the scaled factorial moments(SFM) known as intermittency proposed by Bialas and Peschanski[1], which was initially developed to study turbulent flows, is a statistical tool for the extraction of non-statistical fluctuation without the spurious influence of statistical fluctuations. Intermittency of distribution of a physical obserable which is now applied in many different fields is believed to probe criticality. This technique was applied to the multifragmenting systems at low energy which indicated that fragmentation processes are scale invariant. Płoszajczak and Tucholski [2] first introduced the SFM analysis for the study of dynamical fluctuations in fragment size distributions in the break up of high energy nuclei in the nuclear emulsion. They studied the break-up of 197Au nuclei at around 1 GeV/nucleon, and showed that the factorial moments of the charge distribution of the fragments increased like a power law with increasing charge resolution, thus exhibiting the property of self similarity or otherwise the intermittency and concluded that the intermitteny in nuclear fragmentation is relevant in the search for critical phenomena. Thus it has been believed that the cluster size distributions are intermittent at the critical point.

Here an attempt has been made to study the possible signature of non-thermal phase transition in one dimensional pseudorapidity space in the light of intermittency for projectile fragmenation data obtained from NIKFI-BR2 emulsion stacks exposed to ^{24}Mg 4.5 AGeV (JINR) beam.

Mathematical formalism

It should be pointed out that the single particle density distribution spectrum is non flat. The non-uniformity of the particle spectra influences the scaling behaviour of the factorial moments. In order to reduce the distortion of intermittency due to single particle density distribution, we have converted the single particle density distribution spectrum from η (cos θ) space to a distribution in $\chi(\eta)$, where $\chi(\eta)$ is a new cumulative variable defined as,

$$\chi(\eta) = \frac{\int_{\eta_{min}}^{\eta} \rho(\eta) d\eta}{\int_{\eta_{min}}^{\eta_{max}} \rho(\eta) d\eta}$$

where η_{min} and η_{max} are the minimum and maximum values of the pseudorapidity distribution $\rho(\eta)$ between which the variable $\chi(\eta)$ corresponding to single particle density distribution is uniformly distributed from 0 to 1 in χ space.

Following the technique of Bialas and Peschanski [1], the horizontally averaged normalized or SFMs is expressed by the following relation,

$$< F >_q = \frac{1}{< n >^q} < \frac{1}{M} \sum_{m=1}^{M} n_m(n_m - 1) - - - (n_m - q + 1) >$$

where $$n = \frac{1}{M} \sum_{m=1}^{M} n_m$$

Here, n_m is the number of fragments in the m^{th} bin in the ith event. M is the total number of bins in which the $\chi(\eta)$ is divided into. It has been shown by Bialas and Peshanski that for the presence of any dynamical contribution to the fluctuation, the SFM should follow a power law of the form $F_q \propto M^{\varphi_q}$.

Results: Variation of $\ln < F_q >$ with ln M

Fig. 1 exhibit a plot of $\ln < F_q >$ against ln M for different order of moments q = 2–5 for all the projectile fragments with $Z_{pf} \geq 1$ in $\chi(\eta)$ space. The straight lines drawn are the least square fit to experimental data points. The SFM is observed to increase linearly with decreasing bin widths, indicating thereby the presence of intermittent behavior in the emission spectrum.

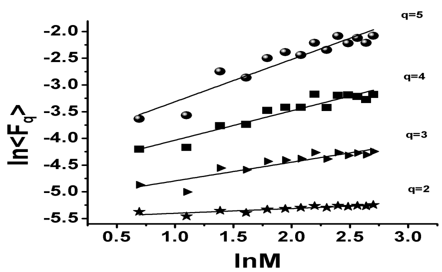

Fig. 1 Variation of $\ln < F_q >$ with q

Lipa and Buschbeck [3], for the first time had correlated the scaling behavior of factorial moments to the physics of fractal and multifractal objects. They pointed out that the

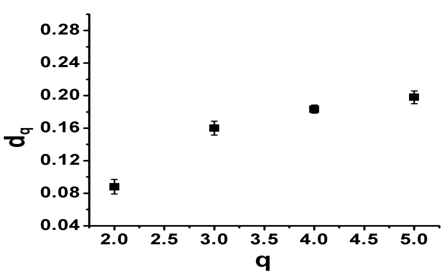

Fig. 2 Variation of d_q with q

anomalous dimension, d_q, which is used for the description of the fractal objects, can be directly computed from the intermittency index φ_q using therelation, $d_q = \varphi_q/(q\text{-}1)$. The order independence of d_q is associated with the monofractal behavior of multiparticle spectra whereas an increase will indicate multifractality. In Fig. 2, variations of anomalous dimension d_q with the orders of the moment q. The figure shows that d_q increases linearly with q, indicating multifractal pattern of the emission spectra of the projectile fragments.

Variation of λ_q with q

It is already shown that [4] the intermittent behavior in the final state of multiparticle production in a heavy-ion collision may be a projection of non-thermal phase transition believed to occur during the evolution of the collision which in turn would be responsible for the occurrence of anomalous events. The intermittency exponent φ_q is related to a parameter λ_q which provides the signature of non-thermal phase transition, with the help of the parameter $\lambda_q = (\varphi_q + 1)/q$,

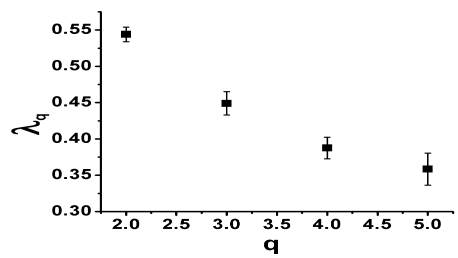

Fig. 3 Variation of λ_q with q

The condition that such non-thermal phase transition may occur is that the function λ_q, is predicted to have a minimum value at q= q_c, where q_c need not necessarily be an integer. It is clear from Fig.3 is that there is no observed minimum at q= q_c indicating no evidences of non thermal phase transition in the spatial distribution of projectile fragments.

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