Evidences of non-thermal phase transition in the charge distribution of projectile fragments

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Introduction

In heavy ion physics, one of the most important challenges is the identification and characterization of nuclear liquid-gas phase transition believed to be the underlying mechanism of nuclear multifragmentation process. The striking characteristics of the systems undergoing continuous phase transition that might have taken place in the final stage of fragmentation of heavy ion collisions are believed to be the occurrences of fluctuations of the fragments charge (mass) distribution. Such fluctuation may diverse or even tend to vanish near some critical value of the control parameter. In the study of heavy ion collision, numerous techniques have been developed to analyze the fluctuations and the correlations for various physical quantities. In particular, one of the most powerful and promising possibilities seems to be the analysis of event-by-event data in terms of intermittency which is a statistical concept initially developed to study turbulent flows. To examine the intermittent pattern of fluctuations Bialas and Peschanski [1] have proposed the method of scaled factorial moments which has the advantage of quantifying dynamical fluctuations without the spurious influence of statistical fluctuations. Later 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 ^{197}Au 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 the increasing charge resolution, thus exhibiting the property of self similarity or otherwise the intermittency and concluded that the study of intermittency in nuclear fragmentation is relevant in the search for critical phenomena. Here the method of scale factorial moment is applied to the study of non thermal phase transition in projectile fragmentation.

Mathematical formalism

Following the technique of Bialas and Peschanski [1], the averaged scaled factorial moments of order q is expressed by the following relation,

$$\langle F \rangle_q = \frac{1}{\langle n \rangle^q} \langle \frac{1}{M} \sum_{m=1}^{M} n_m (n_m - 1) --- (n_m - q + 1) \rangle$$

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. Here M is the total number of bins as the fragment charge interval Δs (1-12) is divided into bins of equal width δs = Δs / M. n is the fragment multiplicity in the interval Δs. For non flat fragment multiplicity distribution varying within a finite bin of width Δs introduces an extra M-dependent correction factor R_q which is given by:

$$R_q = \frac{1}{M} \sum_{m=1}^{M} \frac{M^q \langle n_m \rangle}{\langle n \rangle^q}$$

Thus, $\langle F_q \rangle / R_q = \langle F_q \rangle_c$ measures the contribution of dynamical fluctuations. If self similar fluctuations exist at all scales δs, the corrected factor factorial moment of the order q is given by $\langle F_q \rangle_c = (\Delta s/\delta s)^{\phi_q}$. The exponent φ_q is the slope characterizing a linear rise of $\ln \langle F_q \rangle_c$

with -ln δs for all bins of δs, which increases with the increasing order q of the moment.

Results: Variation of ln $<F_q>_c$ with -ln δs

Plots of ln$<F_q>_c$ against -ln δs for different orders of moments are shown in Fig. 1. It can be readily seen from this plot that the moment for the fragment multiplicity distribution continue to increase according to power law with the decreasing bin width δs variable, thereby indicating the intermittent pattern.

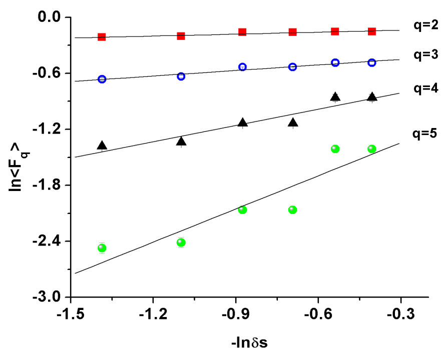

Fig. 1 Variation of ln $<F_q>$ with -lnδs

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

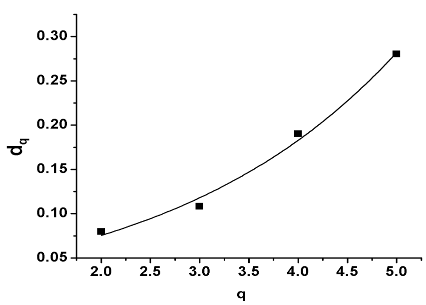

Fig. 2 Variation of d_q with q

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 the relation, $d_q = \varphi_q/(q-1)$. The order independence of d_q is associated with the monofractal behavior of multiparticle spectra whereas an increase will indicate multifractality. In Fig. 2, shows that d_q increases linearly with q, indicating multifractal pattern in the charge distribution of the projectile fragments.

Variation of λ_q with q

It is already shown that 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 $\lambda_q = (\varphi_q + 1)/q$,

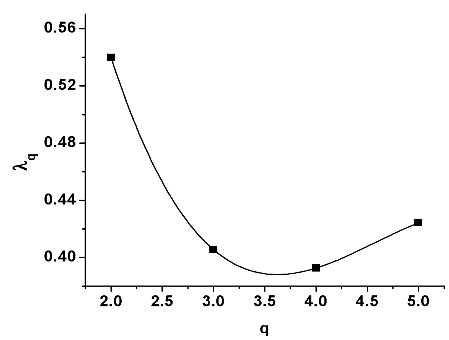

Fig. 3 Variation of λ_q with q

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 that a minimum at q= q_c indicates, evidences of non thermal phase transition in the charge distribution of the projectile fragments.

Referenceses

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