Nuclear Effect in terms of Hurst Exponent in ^{28}Si-Emulsion Collisions at 14.6A GeV

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Introduction

The study of multiplicity correlations and fluctuations of produced charged particles in high energy ion collisions has been well known for few decades. This has never been more apparent than in recent years where these measurements helped to mark the discovery of new state of matter, so called Quark-Gluon Plasma (QGP) [1-5]. Various types of correlations and fluctuations present in heavy ion collisions at relativistic energies can provide us with valuable knowledge regarding the microscopic interactions inside the high density medium. In particular, the non-perturbative aspects of the strong interaction are difficult to study experimentally and probing the hot and dense QGP is one of the few avenues we have available.

The main aim of scaled factorial moments $F_q(M)$ is to look for the possible existence of the dynamical fluctuations so called "Intermittency" in high energy heavy ion collisions. While studying the behavior of factorial moments in h-h and A-A collisions, two different phenomenon have been observed.

(i) In one dimension (1D) phase space of pseudorapidity, the rise of $\ln < F_q >$ with the increasing phase space partition number M is much weaker for A-A collisions than for h-h collisions and the heavier the colliding nuclei are, the weaker is the rising of $\ln < F_q >$.

(ii) In 2d or 3D, the $\ln < F_q >$ vs. lnM plot for A-A collisions is bending upwards strongly, much stronger than for h-h collisions and the heavier the colliding nuclei are, the stronger is the upward bending of $\ln < F_q >$ vs. ln M plot.

Mathematical Tools

It has been found that the above two apparently contradictory observations are due to the superposition effect of the contribution from the large number of elementary collisions in a nuclear collision process.

To characterize the phase space partition in 2D, a quantity known as "Hurst exponent" is used and is defined such as: $H = \frac{\ln M_\eta}{\ln M_\phi}$ (1)

where M_η and M_ϕ are the number of partitions along the two perpendicular directions. The behavior of factorial moments F_q depends on the value of "H". Therefore, to study the possible abnormal behavior of F_q on the bin size, analysis should be performed with a suitable value of H. Otherwise, the observed trend of the calculated factorial moments will always be bending upwards, even if there is no fluctuation in the multi-particle production. The upward bending of the $F_q$moments can be weakened or totally removed if the exponents, H are given a proper value.

For the present investigations of nuclear effect in ^{28}Si-emulsion collision at total energy ≈ 409 GeV, we have used different values of Hurst exponent (H = 1.0, 1.5, 2.0, 2.5). The intervals $\Delta\eta$ and $\Delta\phi$ have been divided into sub-cells with the widths such as:

$$\left.\begin{aligned} \delta_\eta &= \Delta_\eta / M_\eta \\ \delta_\phi &= \Delta_\phi / M_\phi \end{aligned}\right\} \quad (2)$$

The scale factors of M_η and $M_\phi$are connected to each other by the relation: $M_\phi = \{M_\eta\}^{1/\eta}$ (3)

It is clear from eqn. (3) that M_η and M_ϕ cannot be integers simultaneously. Therefore the size of elementary phase space cell cannot take continuously varying values. This problem can be solved by applying the method of L. Lianshou et. al., such as given: $M_\phi = N + \alpha$ (4)

where N is the integer part and $0 \leq \alpha < 1$ represents the fractional part.

Results and Discussions

In the present work, we used $\Delta\eta = -2 \leq \eta_{max} \leq +2$ and $\Delta\phi = 0\text{-}2\pi$. The M_η was varied from 2-30. Further, to reduce the effect of non flat particle density distributions, the cumulative variables X_η and X_ϕ were used to make it in the corresponding regions 0-1. By using the above partition scheme, the values of $\ln < F_2 >$ were calculated with the help of general adaptation of Intermittency / scaled factorial moments $F_q(M)$.

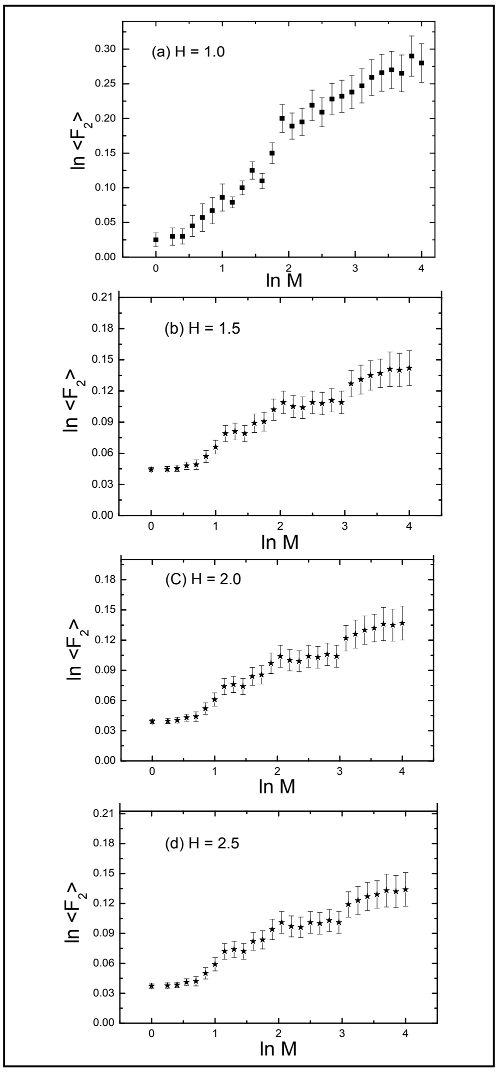

Fig. 1(a-d) The dependence of $\ln < F_2 >$ on ln M at an energy ≈ 409GeV.

The behavior of $\ln < F_2 >$ vs. ln M have been shown in Fig. 1(a-d) for the collisions of ^{28}Si with emulsion nuclei at an energy 409 GeV for different values of exponent H.

From this figure it has been observed that there is strong upward curve bend in Fig. 1 (a). However, when H increases, the upward bending is found weakened in Fig. 1(b-d).

We observe that the two dimensional second order factorial moment exhibits an upward bending as a function of partition of space, which is in turn means the superposition of contributions from the elementary collisions in the nucleus-nucleus collisions. This upward bending could, however, be removed by choosing proper partition along the longitudinal and perpendicular directions, that is, the right value of Hurst exponent "H". Moreover, it has been observed that heavier the colliding are, the strong the upward bending is. It is consistence with the fact that the number of elementary collisions is more for heavier nuclei.

Conclusions

It is worth mentioning that if QGP is formed, then there will be no elementary collisions. This in turn will lead to vanishing of the superposition effect due to the contribution of elementary collisions in nucleus- nucleus (A-A) collisions. Under such conditions, the upward bending in the two dimensional second factorial moment plots is not likely to be seen. Hence the study of the nuclear effect in nucleus- nucleus (A-A) collisions could be used as another indirect test of QGP formation.

References

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