Evidence of Multidimensional Void Scaling In Ring Like and Jet Like Events

Mitali Mondal[1], Arindam Mondal[2], Soma Biswas (Ghosh)[3], Dipak Ghosh[3] and Argha Deb[3]

[1] S. A. Jaipuria College, Kolkata – 700005

[2]RCC Institute of Information Technology, Beliaghata, Kolkata- 700 015

[3]Nuclear and Particle Physics Research Centre, Department of Physics, Jadavpur University, Kolkata – 700032

email: argha_deb@yahoo.com, mondal_arindam@yahoo.co.in

The fluctuation of local hadron density in multiparticle production processes implies the formation of spatial patterns that exhibit clusters of hadrons of varying sizes. There are clusters of hadrons separated by regions of no hadrons. The nonhadronic regions between the clusters are coined as the voids.

Various measures involving the fluctuations of the produced hadrons in bins of various sizes are examined with the aim of quantifying the clustering properties that are universal features of all critical phenomena.

A lot of studies have been carried out for the second order phase transition of high energy interactions [1]. However, the study of the fluctuation of voids in hadronisation may be useful for finding the observable critical behaviors related to quark-hadron phase transition [2]. Void, as its name implies, is defined as the probability of zero particles in a certain phase space regions. In two dimensional phase space there are regions of high particle density, low particle density or no particle.

This paper intends to study the signature of quark-hadron phase transition in high energy collisions following connecting void approach [2].

In order to find scaling behaviour of voids, binning is required. The bin number dependence provides information on critical behaviour of quark hadron phase transition.

The study is based on the ring like and jet like events of ^{16}O-AgBr interactions at 60 AGeV. The ring like and jet like events have been separated using a method adopted by Adamovich [3-4].

Void in multiparticle production have been defined and analysed following the suggestion of R. C. Hwa and Q. H. Zhang [2].

As proposed by Hwa if V_k be the sum of the empty bins that are connected to one another by at least one side, then one can define x_k to be the fraction of bins that the k^{th} void occupies as

$$x_k = V_k/M \quad \text{................(1)}$$

For every event thus have a set of void fractions that characterizes the spatial pattern. Since the pattern fluctuates from event-to-event, to perform the comparison of patterns, they first define the moments g_q for each event.

$$g_q = \frac{1}{m}\sum_{k=1}^{m} x_k^q \quad \text{............(2)}$$

where the sum is over all voids in the event, and m denotes the total number of voids. The normalized G moments can be define as

$$G_q = g_q \,/\, g_1^q \quad \text{...............(3)}$$

which depends not only on the order q, but also on the total number of bins M. Thus by definition $G_0 = G_1 = 1$. When q and M fixed, G_q fluctuates from event-to-event and is the quantitative measure of the void patterns, which in turn are the characteristic features of phase transition.

The M dependence of the average of G_q over all configurations is,

$$< G_q > = \frac{1}{N}\sum_{e=1}^{N} G_q^{(e)} \quad \text{.......(4)}$$

where the superscript e denotes the eth event and N is the total number of events.

If $<G_q>$ versus M in log-log plot shows very good linear behavior, one can write

$$< G_q > \propto M^{\tau_q} \quad \text{.............. (5)}$$

This scaling behavior implies that voids of all sizes occur at PT. Since the moments at different q are highly correlated, one can expect the scaling exponent, τ_q to depend on q as,

$$\tau_q = c_0 + cq \quad \text{..................(6)}$$

One would regard equation (6) only as a convenient parametrization of τ_q that allows focusing on c as a numerical description of the scaling behavior of the voids at PT. As suggested by Hwa the value of c ranging between 0.75 and 0.96 may be regarded as signature of quark-hadron phase transition [5].

Hwa also define $S_q = \langle G_q \ln G_q \rangle$……(7)
Here S_q is a measurement of the fluctuation of G_q. If S_q versus M in log-log plot shows good linear behavior, consequently, one may write

$$S_q = M^{\sigma_q} \ldots\ldots (8)$$

Here also one expects the scaling exponent, σ_q depend on q as,

$$\sigma_q = s_0 + sq \ldots\ldots (9)$$

Again Hwa proposed the value of s ranging between 0.7 and 0.9 may be regarded as signature of quark-hadron phase transition [5].

We divide the phase space region into a number of bins for ring like and jet like events of ^{16}O-AgBr interactions and calculate the number of voids using connecting bin approach.

For both the data we calculate the average G_q and then plotted $\ln \langle G_q \rangle$ versus $\ln M$ in Fig 1 for ^{16}O-AgBr interactions at 60 AGeV ring like and jet like events respectively. The plots show a linear behavior.

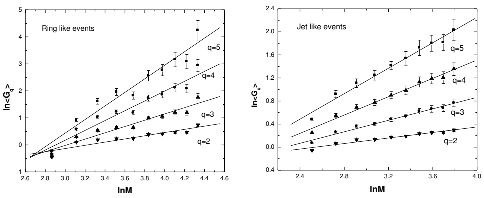

Fig 1: The variation of the *ln < Gq>* on the *ln M* for Ring like and jet like events

We also calculate the S_q and then plotted $\ln S_q$ versus $\ln M$ in Fig 2 for ring like and jet like events respectively. The plots again show a linear behavior.

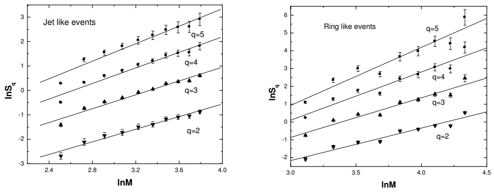

Fig 2: The variation of the $\ln S_q$ on the $\ln M$ for Ring like and jet like events

From the linear fits of Fig 1 we calculated the value of τ_q from equation (5) and from the linear fit of Fig 2 we calculate σ_q from equation (8). Then we plot τ_q vs q and σ_q vs q in Fig 3. Fig 3 shows the dependence of scaling exponent τ_q on q and σ_q on q which also indicate a good linear behavior.

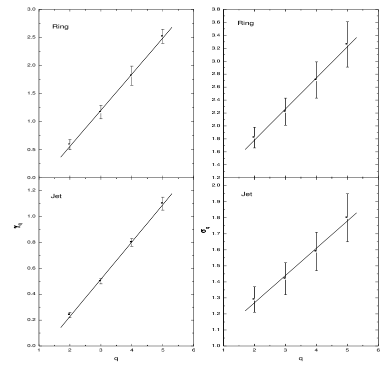

Fig 3: τ_q and σ_q vesus q for Ring like and jet like events

From the linear fit of the graphs we have obtained the value of c as 0.643 ± 0.019 and 0.228 ± 0.007 and the value of s as 0.478 ± 0.023 and 0.170 ± 0.012 for ^{16}O-AgBr interactions ring and jet data respectively. It is observed that c and s values are much greater in case of ring like events than that of jet like events.

As per the prediction of Hwa and Zhang our experimental values suggest that no quark-hadron phase transition of second order have been taken place for both jet like and ring like events of ^{16}O-AgBr interactions at 60 AGeV. However, it is interesting to note that different void pattern fluctuation is exhibited by ring like and jet like events, which hints towards different mechanism in their production process.

References

[1] Hwa and Nazirov, Phys. Rev. Lett. 69 , (1992); M. Stephanov, K. Rajagopal, E. Shuryak, Physical Review D, 60, 114028 (1999)
[2] R. C. Hwa, Q. H. Zhang, Phys. Rev. C 62, 054902 (2000)
[3] M Adamovich et al. J. Phys. G 19 2035 (1993)
[4] D Ghosh, A Deb, P K Halder, S GuptaRoy Astroparticle Physics, 27, 127 (2007)
[5] R. C. Hwa; Phys. Rev. C 64, 054904 (2001)