Study of Quark-Hadron Phase Transition using Connecting Void Approach

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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. This paper intend to study the signature of quark-hadron phase transition in high energy collisions following connecting void approach proposed by R. C. Hwa and Q. H. Zhang [1].

The two-dimensional pseudorapidity ($X\eta$) – azimuthal angle space ($X\varphi$) can be divided into M equal bins. Bins with very low hadron density are then regarded as empty. A void is a contiguous collection of empty bins.

Let V_k be the sum of the empty bins that are connected to one another by at least one side; k simply labels a particular void. We can then define x_k to be the fraction of bins on the lattice that the k_{th} void occupies

$$x_k = V_k/M \quad \ldots\ldots\ldots\ldots\ldots(1)$$

For every event we thus have a set $S_e = \{x_1, x_2 x_3 \ldots\ldots\ldots\}$ of void fractions that characterizes the spatial pattern. Since the pattern fluctuates from event-to-event, S_e cannot be used to compare patterns in an efficient way. For a good measure to facilitate the comparison, let us first define the moments g_q for each event.

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

where the sum is over all voids in the event, and m denotes the total number of voids. We then define the normalized G moments

$$G_q = g_q / g_1^q \quad \ldots\ldots\ldots\ldots(3)$$

which depends not only on the order q, but also on the total number of bins M. Thus by definition $G_0 = G_1 = 1$. This G_q is defined in the same spirit as that in Ref. [2] for rapidity gaps, but they are not identical because the x_k here for voids do not satisfy any sum rule. Now, Gq as defined in Eq. (3) is a number for every event for chosen values of q and M. With 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.

Our first step in that search is to study the M dependence of the average of G_q over all configurations, i.e.,

$$\langle G_q \rangle = \frac{1}{N}\sum_{e=1}^{N} G_q^{(e)} \quad \ldots\ldots\ldots\ldots..(4)$$

where the superscript e denotes the eth event or configuration! And N is the total number of events.

If $\langle G_q \rangle$ versus M in log-log plot shows very good linear behavior; consequently, we may write

$$\langle G_q \rangle \propto M^{\gamma_q} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

This scaling behavior implies that voids of all sizes occur at PT. Since the moments at different q are highly correlated, we expect the scaling exponent, γ_q to depend on q in some simple way as,

$$\gamma_q = c_0 + cq \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(6)$$

There is no obvious reason why the q dependence of γ_q should be so simple. We would regard Eq.(6) only as a convenient parametrization of γ_q that allows us to focus on c as a numerical description of the scaling behavior of the voids at PT. The value of c ranging between 0.75 and 0.96 may be regarded as signature of quark-hadron phase transition [3].

We also define $S_q = \langle G_q \ln G_q \rangle$ …(7)
Here S_q is not define as entropy but is a measurement of the fluctuation of G_q. S_q versus M in log-log plot shows very good linear behavior; consequently, we may write

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

Here also we expect the scaling exponent, σ_q depend on q in some simple way as,

$$\sigma_q = s_0 + sq \quad \text{..................(9)}$$

The value of *s* ranging between 0.7 and 0.9 may be regarded as signature of quark-hadron phase transition [3]

We choose to work on ^{32}S–AgBr interactions at 200 AGeV and ^{16}O-AgBr interactions at 60 AGeV. We divide the phase space region into a number of bins and then calculate the number of voids using connecting bin approach.

For both data we calculate the average G_q or $\langle G_q \rangle$ and then ploted $\ln \langle G_q \rangle$ versus $\ln M$ in Fig 1 and Fig 2 for ^{32}S–AgBr interactions at 200 AGeV and ^{16}O-AgBr interactions at 60 AGeV data respectively. The plots show a good linear behavior.

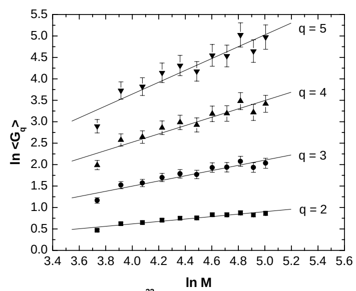

Fig 1: $\ln\langle G_q\rangle$ vs ln M for ^{32}S-AgBr interactions at 200 AGeV

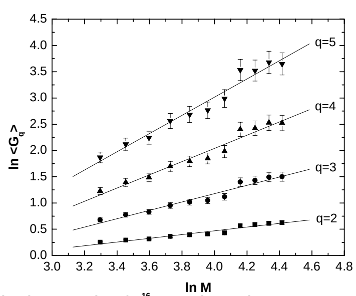

Fig 2 $\ln\langle G_q\rangle$ vs ln M for ^{16}O-AgBr interactions at 60 AGeV

We also calculate the S_q and then ploted *ln S* versus *ln M* in Fig 3 and Fig 4 for ^{32}S–AgBr data and ^{16}O-AgBr data respectively. The plots again show a good linear behavior.

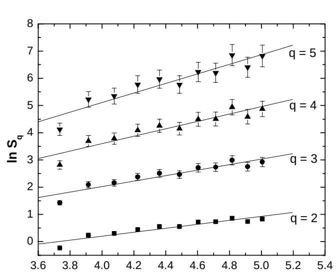

Fig 3: ln S vs ln M for ^{32}S-AgBr interactions at 200 AGeV

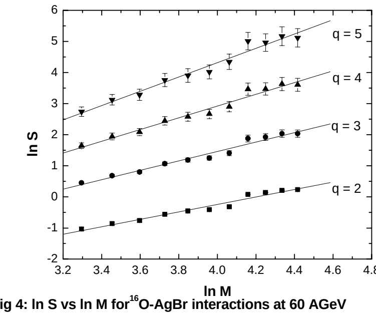

Fig 4: ln S vs ln M for ^{16}O-AgBr interactions at 60 AGeV

From the linear fit of Fig 1 & Fig 2 we calculated the value of τ_q from equation (5) and from the linear fit of Fig 3 & Fig 4 we calculate σ_q from equation (9). Then plot τ_q vs q and σ_q vs q in Fig 5. Fig 5 shows the dependence of scaling exponent τ_q on q and σ_q on q which also indicate a good linear behavior.

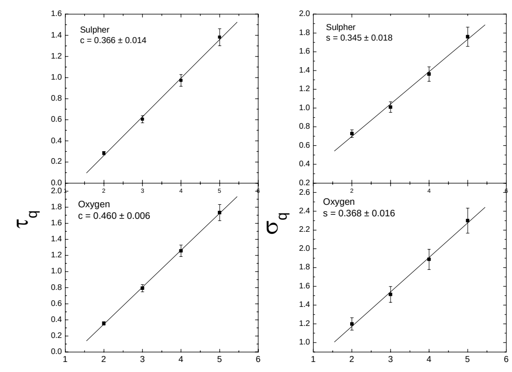

Fig 5: τ_q and σ_q

From the linear fit of the graphs we are getting the value of *c* as 0.366 ± 0.014 and 0.460 ± 0.006 and the value of *s* as 0.345 ± 0.018 and 0.368 ± 0.016 for ^{32}S-AgBr data and ^{16}O-AgBr data respectively.

The values suggest that no quark-hadron phase transition has taken place in case of ^{32}S–AgBr interactions at 200 AGeV and ^{16}O-AgBr interactions at 60 AGeV according to the criteria suggested in Ref. [1]. However, the result will be useful for comparing the value of c and s with other high energy data.

References

[1] R. C. Hwa, Q. H. Zhang, Phys. Rev. C 62 (2000) 054902

[2] R. C. Hwa and Q. Zhang; Phys. Rev. D 62 (2000) 014003.

[3] R. C. Hwa; Phys. Rev. C 64(2001) 054904