Study of Deconfinement Phase Transition in Heavy Ion Collisions at BNL Energies

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***Abstract*—The Scaled factorial moments (SFMs) of multiplicity distribution are used to study the deconfinement phase transition in high energy heavy-ion collisions. In the present article we studied the Renyi dimensions and multifractal spectrum in the interaction of ^{28}S-emulsion collisions at 14.6A GeV to investigate non thermal phase transitions during such collisions.**

***Index Terms*—Novel state of matter, quark-gluon plasma (QGP), scaled factorial moments (SFMs).**

I. Introduction

During last couple of years, different nuclei have been accelerated to relativistic energies and brought to collisions with a great variety of target nuclei. An ultimate aim of studying nucleus – nucleus (A-A) collisions is to investigate for a phenomena connecting with large densities obtained in such nuclear collisions.

So due to this one can obtained an opportunity to explore strongly interacting matter at energy densities unprecedented in a laboratory, which eventually gives an evidence for the existence of quark-gluon plasma (QGP). The QGP is a novel state of matter in which quarks and gluons are no longer confined to volumes of hadronic dimensions. In deep inelastic scattering experiments, it has already been revealed that quarks at very short distances move freely, which is referred to as the asymptotic freedom. Quantum Chromo-dynamics (QCD) describes the strong interactions of quarks and gluons [1]. The experimental observation of large rapidity fluctuations in relativistic heavy ion collisions by R. C. Hwa and J. C. Pan [2], [3] using the method of multifractal moments method, G_q, has provided keen interest and excitement in about their nature and origin. Bialas and Peschanski [4], [5] suggested a power law scaling behavior in terms of normalized scaled factorial moments, SFMs ($< F_q > \propto M^{\alpha_q}$) on the bin size and described the phenomenon as "intermittency". The SFMs method cannot only predicts the existence of large non-statistical fluctuations but it could also investigate the pattern of fluctuations and their origin.

The main emphasis of the present experimental / statistical work is to explore the second order phase transition, which take place during the relativistic heavy ion collisions, with the help of Renyi dimension, D_q, and multifractal spectrum, $f(\alpha_q)$.

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II. Experimental Details and Data Collection

In the present experiment, FUJI nuclear emulsion pellicles were irradiated horizontally with a beam of ^{28}Si nuclei at 14.6A GeV at Alternating Gradient Synchrophasotron (AGS) of Brookhaven National Laboratory (BNL), NewYork, USA have been used for data collection. The method of line scanning has been adopted to scan the stacks, which was carried out carefully using Japan made NIKON (LABOPHOT and Tc-BIOPHOT) high-resolution microscopes with 8 cm movable stage using 40X objectives and 10X eyepieces by two independent observers, so that the bias in the detection, counting and measurements can be minimized. The interactions due to beam tracks making an angle < 2° to the mean direction and lying in emulsion at depths > 35 μm from either surface of the pellicles were included in the final statistics. The other relevant details about the present experiments and target identifications may be seen in our previous work [6]-[8].

In the present analysis, the pseudorapidity (η) and azimuthal angle (ϕ) have been used as the two variables representing phase space. For the study of dynamical fluctuations, the pseudorapidity interval $\Delta\eta$ is taken as -1.25 to 6.75, while the azimuthal angle varies from $\Delta\phi$ = 0 - 2π and it is divided into M_ϕ bins of size, $\delta\phi = 2\pi/M_\phi$.

Only events with $N_S \geq 8$ were considered to maximize the contribution of dynamical fluctuations [3]. We have total 951 data events of relativistic shower charged particle (N_S) with mean multiplicity $\langle N_S \rangle = 21.34 \pm 0.16$. For this purpose we have divided it into three subsets of data with different N_S-intervals: 1) in $8 \leq N_S \leq 15$ with $\langle N_S \rangle = 11.45 \pm 0.19$, 2) $16 \leq N_S \leq 23$ with $\langle N_S \rangle = 19.15 \pm 0.25$ and $N_S \geq 24$ with $\langle N_S \rangle = 34.32 \pm 0.33$ in the collisions ^{28}Si-Em at 14.6A GeV.

III. Mathematical Tools

In order to perform a meaningful analysis of intermittency, normalized "cumulative" variables, $X(\eta)$ and $X(\phi)$ were used to reduce the effect of non-uniformity in single charged particle distributions. In terms of new scaled variables, $X(\eta)$ and $X(\phi)$, the single particle density distribution is always uniform in between X = 0 and 1 and both "vertical" and "horizontal" averaging of scaled factorial moments should produce the same result.

The cumulative variable in the phase space (say η) is defined as [9]:

$$X(\eta) = \int_{\eta_{\min}}^{\eta} \rho(\eta')d\eta' \Big/ \int_{\eta_{\min}}^{\eta_{\max}} \rho(\eta')d\eta' \tag{1}$$

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