Correlations and Event-by-Event Pseudorapidity Fluctuations in p-p and Pb-Pb Collisions at LHC Energy

M. Mohsin Khan[1],* Shakeel Ahmad[2], Kushal Das[2], and M. Irfan[2]
[1] *Department of Applied Physics, A.M.U.,Aligarh - 202002, INDIA and*
[2] *Deptartment of Physics, AMU, Aligarh - 202002, INDIA*

Introduction

One of the main objectives of the ALICE experiment at the world's largest and most powerful accelerator, LHC, CERN is to study p-p, p-Pb and Pb-Pb collisions[1] at ultra-relativistic energies. The results so far are very encouraging regarding formation of a novel phase of matter, quark-gluon-plasma(QGP), predicted by the quantum chromodynamics (QCD)[2]. It is interesting to note that high energy density regime of the QCD is believed to be very sensitive to non-linear dynamics and non-perturbative effects, including parton saturation, onset of color deconfinement and chiral symmetry restoration[2]. In ultra-relativistic heavy-ion collisons, conditions of extreme temperature and high energy density are likely to be reached, which are required for producing QGP; a dense system of quarks and gluons is created which subsquently expands before partons hadronize and eventually decouple. It has also been proposed[3] that during such a phase transition, the underlying dynamics results in the fluctuations of some important observables. Furthermore, during hadronization, behaviour of fluctuations in the value of an observalble is envisaged to be more striking than those in the average value of the observable. Occurrence of fluctuations in measurable quantities in relativistic nuclear collisions is considered to be one of the vital signatures of QGP formation. Fluctuations measurements such as multiplicity fluctuations, rapidity density fluctuations, energy fluctuations, net charge fluctuations and mean transverse momentum fluctuations have been done in various studies [4, 5]. Observation of these fluctuations can reveal various interesting features of the underlying systems, e.g., multiplicty fluctuations may shed light whether a global thermalization has been reached[3, 5]. On the other hand, the energy fluctuations are related to the specific heat of the produced and hadronized system and hence can provide evidence regarding QGP formation[4]. Dynamical mean-p_t fluctuaions are considered to provide information about the existence of the critical point of the phase transition, whereas charge fluctuations are sensitive to the charge of the collective system. These fluctuations are capable of distingushing QGP and hadronic phases and hence deserve a well focussed and critical investigation.
Several analyses have provided clear evidences regarding occurrence of fluctuations in pseudorapidity distributions of particles produced in ultra-relativistic nuclear collisions. These fluctuations are also envisaged to yield vital information on the space-time evolution of the produced system. There has been spurt of interest in the study of multiplicity fluctuations in the recent years, whcih is linked to the availability of high multiplicity events in nuclear collisions at RHIC and LHC energies. In the present study an attempt is made to look at event-by-event fluctuations in pseudorapidty distributions of particles in p-p and Pb-Pb collisions at LHC energy.

Detail of the Data

The data used in the study are simulated using AMPT model[6]. Two samples of data comprising 100k p-p collisions at $\sqrt{s}$ = 2.76 TeV and 5k Pb-Pb collisions at $\sqrt{s_{NN}}$= 2.76 TeV are generated; both the data sets comprise of minimum bias events.

*Electronic address: mohsinkhan.ph@amu.ac.in

Method of analysis

It has been proposed[4] that event-by-event pseudorapidity(η) fluctuations can be studied in terms of a quantity Φ expressed as

$$\Phi = \sqrt{\frac{< Z^2 >}{< N_{ch} >}} - \sqrt{< z^2 >} \qquad (1)$$

where $< z^2 >$ is the second moment of the inclusive distribution of variable z= $\eta_i - \bar{\eta}$, η_i is the pseudorapidity of ith particle and $\bar{\eta}$ is the average value of pseudorapidity, which is defined below, $< N_{ch} >$ is the average multiplicity of the charged particles produced in all the interactions considered. The quantity $< Z >$ is defined as

$$< Z >= \frac{1}{N_{evt}} \sum_{k=1}^{N_{evt}} z_k \qquad (2)$$

where N_{evt} is the total number of events and $z_k = \sum_{i=1}^{N_k}(\eta_i - \bar{\eta})$;$\bar{\eta}$ is obtained by averaging over a single particle inclusive distribution using the following expression:

$$\bar{\eta} = \frac{1}{N_{ch}} \sum_{k=1}^{N_{evt}} \sum_{i=1}^{N_k} \eta_i \qquad (3)$$

where N_k is the multiplicity of kth event. A non-zero value of Φ, defined by Eq. 1, may be an indication for the existence of correlations amongst the produced particles.

Results and Discussion

The data samples are divided into various sets on the basis of the produced charged particle multiplicity, N_{ch}; $< N_{ch} >$ and ϕ are determined for each set. Fig.1 depicts the variation of Φ with $< N_{ch} >$ for the Pb-Pb collisions. The errors presented are the statistical one. It is observed from the figure that the value of Φ decreases with increasing $< N_{ch} >$, indicating thereby that the event-by-event pseudorapidity fluctuations decrease with increasing mean multiplicity of the produced charged particle. It might be a reflection of the fact that as the average multiplicity of charged particles produced in high energy hadronic and nuclear collisions increase, the secondary particles may be produced by several independent sources. A major contribution to independent emission of particles from several random sources leads to smearing out the fluctuations and correlation.

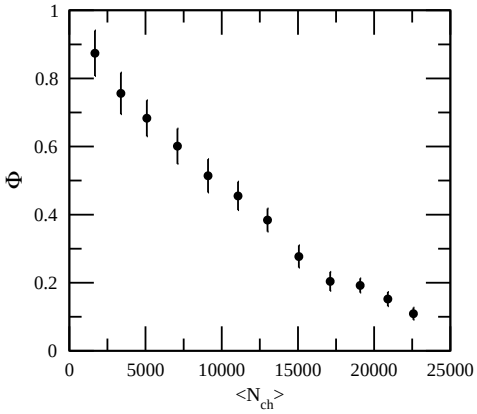

FIG. 1: Variation of ϕ with $< N_{ch} >$ for Pb-Pb Collisions at $\sqrt{s_{NN}} = 2.76TeV$

Conclusions

The results of the present study provide clear evidence regarding correlated production of particles. Furthermore, discernible event-by-event fluctuations in pseudorapidity distributions have also been observed. Results of a similar analysis for pp data will also be presented.

References

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