World Applied Sciences Journal 3 (6): 913-915, 2008
ISSN 1818-4952

Geometrical and Dynamical Fluctuations in Pb-Pb, Pb-Nb Interactions

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Abstract: The fluctuations in pseudorapidity density are well described by Fritiof and IRIS, model for a bulk of the data at a few high multiplicity events remain unexplained. In these events, the estimated energy density is within the range of values predicated for the onset of the deconfinement phase transition. It is important to know whether fluctuations are, in fact, of statistical nature or geometrical ones or due to some physical process. A fluctuation is not just due to statistical origin if it exceeds five or six standard deviations. Different methods devised to understand the nature of these fluctuations are discussed.

Key words: Heavy ion interaction・dynamical fluctuations・Pb interaction

INTRODUCTION

For the last few years, the experimental efforts allow to study the nucleus-nucleus collisions in high energy range up to 200 AGeV. At CERN, they have induced to study the ultra-relativistic heavy-ion collision, which basically increased interest on such study due to possibility of producing Quark-Gluon Plasma (QGP) if the energy density in these collisions is sufficiently high.

The fluctuations which are in physical observable are a topic of interest for some years because they provide important signals regarding the formation of (QGP), as well as it help to address the question of thermalization. The nonstatistical fluctuations has been classified by Hwa [1-3] in to two categories; (first) geometrical fluctuations corresponding to a sample of events with different impact parameters in which charged particle multiplicity varies from one event to another and can be minimized by proper selection criteria for central events; and (second) dynamical fluctuations which arise from thermalization, hydrodynamical expansion, hadronization process and so on, is expected to contain new physics [1]. As suggested be Hwa, it is useful to separate these two contributions.

In this model, the normalized second (C_2) and third (C_3) moments of the experimental charged particle multiplicity distributions are

$$C_2 = \frac{\langle n^2 \rangle}{\langle n \rangle^2},\ C_3 = \frac{\langle n^3 \rangle}{\langle n \rangle^3} \tag{1}$$

Calculated in different η bins as a function of the charged particle multiplicity (n) η bins are centered around the mid rapidity and are increased symmetrically [1]. Let us write:

$$L_2 \equiv C_2 \langle n \rangle - 1 = S_2 \langle n \rangle,\ and$$
$$L_3 \equiv C_3 \langle n \rangle^2 - C_2 \langle n \rangle + 2 = S_3 \langle n^2 \rangle \tag{2}$$

Slops S_i contain contributions from both geometrical (μ_i) and dynamical (ν_i) fluctuations, i.e., $S_i = \mu_i + \nu_i$. Thus if slops S_i for a sample of events, corresponding to fixed impact parameter (for which contribution of μ_i is almost equal to 1), exceed unity it will imply that dynamical fluctuations are presents. The data have been analyzed as suggested by Hwa.

RESULTS AND DISCUSSION

To explore the non statistical fluctuations in data, we have analysed second and third moments defined by Hwa [2]. In Figure 1, plots of *L2* and *L3* are shown for experimental *Pb* and *Nb* events. *L2* and *L3* are defined in equation 2. The data has been analysed using the WA98 experiment data.

The points are for different window sizes i.e. $\Delta\eta$=1 to $\Delta\eta$=1.2 units. The observed slopes *S2* and *S3* for *Pb* and *Nb* are given in the figure itself. The similarity of slope values for *Pb* and *Nb* as well as their closeness to 1 in magnitude indicates that most of the fluctuations are non statistical.

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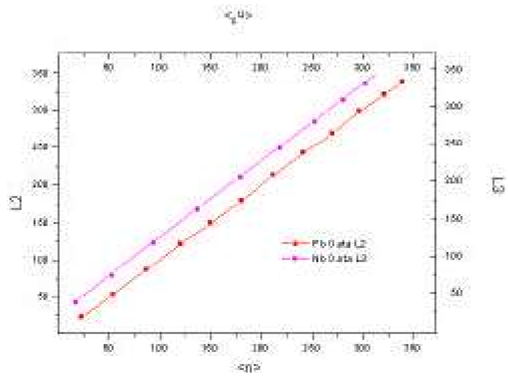

Fig. 1:

The plots of L_2 as function of <n> and L_3 as a function of <n^2>, respectively, are shown in Figure 1. Values of S_2 and S_3 are respectively, *1.00261±0.00303* for *Pb* induced interactions and *0.98623 ± 6.94911E-4* for *Nb* induced interactions, from the figure above we notes that we did not observe any large dynamical fluctuations. Thus, the Helios collaboration did not observe any large dynamical fluctuations [1]. In WA98 experiments, event sample were selected by a high transverse energy trigger using heavy target nuclei *Nb*. Sengupta *et al*. [4] reported smaller values of S_2 for *S-Em* interactions than those for *O-Em* interactions. Thus, the values of S_2 seem to reflect the geometrical fluctuations.

The WA98 collaboration [5] investigated the normalized variance

$$\Omega = \frac{\langle n^2 \rangle - \langle n \rangle^2}{\langle n \rangle^2} = C_2 - 1 \quad (3)$$

$$\Omega(\eta, \Delta\eta) - [\Delta\eta\, \rho(\eta)]^{-1} = const \quad (4)$$

Equation (4) shows the normalized variance is related to the average multiplicity density.

Looking to the histograms [6] in Fig. 2a and 2b correspond to the calculations from equation (4) using normalization at $\Delta\eta$=1.0. The excess is neglecting in the data at small values of $\Delta\eta$ as compared to that of statistical formula.

The variation of Ω as a function of $\Delta\eta$ for central *Pb-Pb* interactions at 158 AGeV for (a) data and (b) the Fritiof.

Figure 3c σ_2 versus $\langle n_s \rangle$ for various rapidity windows for *Pb* induced interactions at 158 energy; The dashed line represents the asymptotic behavior.

Equation (4) can be written as:

$$\frac{\sigma^2}{\langle n \rangle^2} - \frac{1}{\langle n \rangle} = const \quad (5)$$

Also $F_2 = 1 + \frac{\sigma^2}{\langle n \rangle^2} - \frac{1}{\langle n \rangle}$, so that Eq. (5) lead to the expectation $F_2 = const$

Rewriting the above equation as [7,8]

$$\sigma = \langle n \rangle \sqrt{F_2 - 1} \sqrt{1 + \frac{1}{\langle n \rangle (F_2 - 1)}} \quad (6)$$

And for large $\langle n \rangle$,σ can be written as:

$$\sigma \cong \langle n \rangle \sqrt{(F_2 - 1)} + \frac{1}{2\sqrt{(F_2 - 1)}} \quad (7)$$

Since F_2 = const., A linear relationship between σ and $\langle n \rangle$ for different $\Delta\eta$windows. Figure 3 shows the

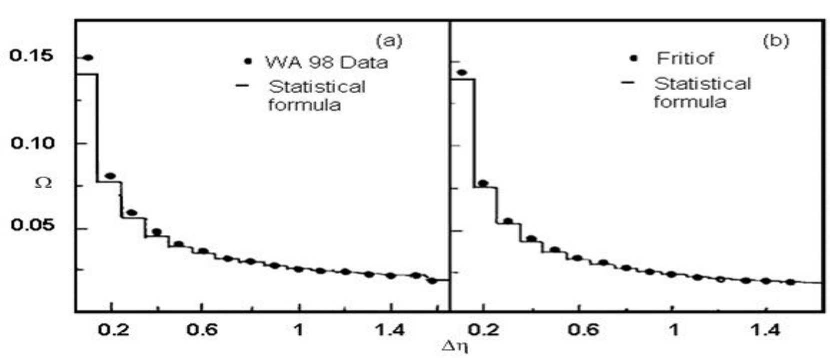

Fig. 2:

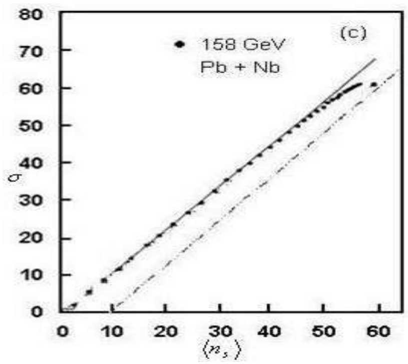

Fig. 3:

variations of σ with ⟨n_s⟩ for *Pb - Nb* interactions for the energy 158 A GeV. It is seen that the relationship between σ and ⟨n⟩ is indeed linear for smaller Δη windows. This linear relationship is broken for large Δηwindows.

CONCLUSION

We do not see any evidence of statistical fluctuations, multiplicity density are studied, as well the fluctuations in pseudorapidity densities are described by Fritiof, Venus, IRIS, etc., for the bulk of the data, but a few high multiplicity events remain unexplained.

ACKNOWLEDGMENTS

The suggestions are valuable from Prof. K. B. Bhalla, Dr. Ashish Agnihotri which helped greatly to improve the paper are gratefully acknowledged

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