Pseudo rapidity fluctuation study in forward and backward zone in heavy ion interactions on Event-by-Event basis

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Abstract

Event-by-Event pseudo rapidity fluctuation study has been carried out for the shower tracks of the ^{16}O–AgBr interactions at 60 AGeV and of ^{32}S–AgBr interactions at 200 AGeV in the forward & backward regions of the pseudo rapidity space in terms of ϕ measurements. The non-zero ϕ values signify the presence of dynamical fluctuation and correlation in our data. The ϕ values decrease in both the zones with increasing the gap between them in pseudo rapidity space.

I. Introduction

Extremely hot and dense nuclear matter, which existed just after Big-Bang, can be created at laboratory by colliding two nuclei moving at relativistic speed **[1]**. The fluctuation study of different observables of the particles coming out of the collision region may give important information about collision history, production mechanism and phase transition **[2-4]**. Fluctuations in multiplicity and density of the final state particles act as probe for the thermalization and statistical behaviour of the particles **[5-7]**. Drastic change in specific heat is expected when a system undergo phase transition. In case of first order phase transition fluctuation in energy density is observed **[8]**. In the context of fluctuation study Event-by-Event fluctuation study finds its own importance as study of each event separately may reveal some rare phenomena which may occur for any particular event where favourable condition was created. Event-by-Event transverse momenta fluctuation study was carried out by NA49 collaboration **[9]** for Pb+Pb collision at 158 AGeV. There are a few studies on Event-by-Event pseudo rapidity fluctuation. Such study was first time done by KLM collaboration **[10]** recently S. Bhattacharyya et al. studied Event-by-Event pseudo-rapidity fluctuation-its multiplicity and target dependence **[11]**. It will be further interesting if we carry out such an analysis in different zones of the pseudo rapidity space and find out if there is any dependence on space. Therefore such a study will be interesting and hope to give a clear insight to Event-by-Event physics. There is no such study in pseudo rapidity bins. We have carried out the measurements in the pseudo rapidity bins of the pions produced in collisions occurring at relativistic energy namely, ^{16}O-AgBr interactions at 60AGeV and ^{32}S-AgBr interactions at 200AGeV.

II. Experimental Section

The present analysis is based on the interactions of the ^{16}O beam and ^{32}S beam at energies of 60 and 200 AGeV, respectively, with AgBr being the target present in nuclear emulsion. The emulsion plates containing the interactions were obtained from EMU-08 experiments **[12-14]** performed at CERN using SPS to accelerate ^{16}O beams to energy 60 AGeV and ^{32}S beams to 200 AGeV energy. Small stacks of ILFORD G5 emulsion plates of dimensions 18X7.5 X 0.06 cm^3 and 18 X 7 X 0.06 cm^3 **[13]** were exposed horizontally to ^{16}O beams at energy 60 AGeV and ^{32}S beams at energy 200 AGeV respectively. Details regarding measuring instrument, measurement procedure: like scanning of each plate, selection of tracks etc. and event selection criteria can be found from our previous publications **[15, 16]**.The emission angle (θ) was measured for each track with respect to the beam direction by taking readings of the coordinates of the interaction point (X_0, Y_0, Z_0), coordinates (X_1, Y_1, Z_1) of a point at some distance away from the interaction point on each secondary track and coordinates (X_i, Y_i, Z_i) of a point on the incident beam. The pseudo-rapidity variable ($\eta = -\ln\tan\frac{\theta}{2}$), which may be treated as a convenient substitute of the rapidity variable of a particle when the rest mass of the particle can be neglected in comparison to its energy or momentum, has been determined for each pion track for further analysis.

III. Methodology

To determine the fluctuation of global kinematical variable a generous technique was developed by M. Gazdzicki and S. Mrowczynski in **[5]**. This technique was based upon the idea that in each basic collision all particles are emitted in correlated way and this should lead to large Event-by-Event fluctuation. The measurement procedure according to **[5]** is as follows: Let variable x be any kinematical variable (p, p_T, η……) of a single particle. Let us introduce two new variables: i) a single particle variable

$$z = x - \bar{x} \qquad \text{……(1)}$$

where $\bar{x}$ is the mean value of (inclusive) x-distribution,and ii) a corresponding sum-variable

$$Z_k = \sum_{i=1}^{N_k} x_i - \bar{x} \qquad \text{……...(2)}$$

with summation running over all particles of a given sort which are produced in a specified phase space region in a single A-A collision. The fluctuation measurement quantity ϕ is defined as

$$\varphi = \sqrt{\frac{\langle z^2 \rangle}{\langle N_{total} \rangle}} - \sqrt{\overline{z^2}} \qquad \text{……..(3)}$$

with N_{total} being the particle multiplicity in the event and< . . .> denoting the average over events, is sensitive to the correlation between multiplicity of particles and their momenta characteristic for particle sources constituting A-A collisions. In this work we study Event-by-Event pseudo rapidity fluctuation and the variable *z* is defined as

$$z = \eta_i - \bar{\eta} \qquad \text{……(4)}$$

IV. Results and Discussions

The ϕ values in full rapidity space of the shower tracks are calculated according to **equation 4** and have been presented in **table 1** for both concerned interactions.

Table 1.ϕ values measured in whole rapidity space for considered interactions

Interactions	Calculated ϕ values for	
	Experimental Events	Randomly generated events
^{16}O-AgBr	4.27±0.53	-0.06
^{32}S-AgBr	4.31±0.43	-0.03

From **table 1** it is observed that the ϕ values are significantly greater than zero for both interactions which in turn signify the presence of strong correlation among the produced pion.

A large number of events (5 times the experimental events) have been generated using the Monte Carlo simulation process of independent emission. In order to find out whether the source of present pseudo rapidity fluctuation and correlation is the dynamics of the pion production process we have calculated the ϕ values for randomly generated events also. These values are given in **table 1**. In this case the nearly zero ϕ values confirm the fact that the source of fluctuation and correlation present in our data is the dynamics of the multi-particle production process and not a result of the mere statistics.

In order to study the fluctuations in different pseudo rapidity windows we have divided the full pseudo rapidity space in two non-overlapping zones of equal width around the central rapidity value (η_c) with a gap η_{gap} between them. The zone which has pseudo rapidity values greater than η_c is termed as the Forward zone whereas the zone having pseudo rapidity values less than η_c is termed as backward zone. For a clear understanding we have demonstrated the division of the pseudo rapidity zones in **figure 1**.

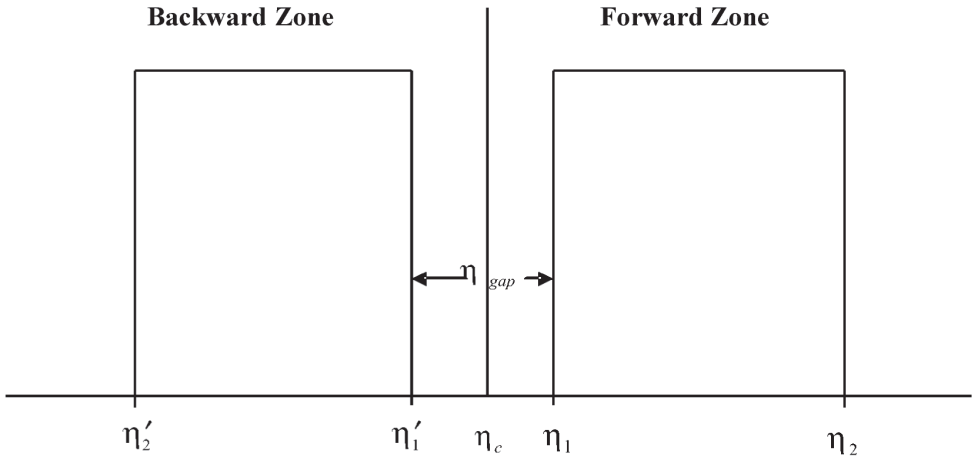

Figure 1. Schematic diagram of the measurement of forward and backward rapidity zone.

Three sets of such zones are selected for three different value of η_{gap}, in doing so width of forward and backward zones were kept same for all the sets. The concerning values are tabulated in **table 2**.

Table 2.Different rapidity values for selecting the zones for the experimental data

Interactions	η_c	η_{gap}	η_2'	η_1'	η_1	η_2	Width of each zone
^{16}O-AgBr	2.7	0.2	-0.4	2.6	2.8	5.8	3.0
		0.4	-0.5	2.5	2.9	5.9	
		0.6	-0.6	2.4	3.0	6.0	
^{32}S-AgBr	3.7	0.2	0.6	3.6	3.8	6.8	
		0.4	0.5	3.5	3.9	6.9	
		0.6	0.4	3.4	4.0	7.0	

Now ϕ values are calculated separately in both zones for the two interactions for a particular value of η_{gap}. The calculated values have been presented in **table 3**.

Table 3.calculated ϕ values

Interactions	η_{gap}	Calculated ϕ values in forward zone for		Calculated ϕ values in backward zone for	
		Experimental events	Randomly generated events	Experimental events	Randomly generated events
^{16}O-AgBr	0.2	0.70±0.03	0.03	2.54±0.13	-0.01
	0.4	0.63±0.03	0.03	2.51±0.12	-0.002
	0.6	0.53±0.03	0.02	2.45±0.12	-0.01
^{32}S-AgBr	0.2	0.72±0.04	0.01	1.25±0.06	-0.02
	0.4	0.64±0.03	-0.02	1.12±0.05	0.03
	0.6	0.61±0.03	-0.002	1.03±0.05	-0.02

The non-zero ϕ values for all selected zones signify the presence of Event-by-Event pseudo rapidity fluctuation and presence of strong correlation among the produced pions for the considered interactions. Again as it is clear

from **table 3** backward zone of each interaction have greater ϕ values than corresponding value in forward zone for a particular η_{gap}. From **table 3** it is also clear that for both interactions ϕ values are slowly varying function of η_{gap}, particularly ϕ decreases slowly with increasing η_{gap}. This trend is observed for both zones of the considered interactions. This signifies that as we move away from the incident beam direction fluctuation decreases. Forward and backward zones for randomly generated events are chosen similarly as for experimental data. Here also we have considered three sets for different values of η_{gap}. While width of the zones were kept identical for chosen three sets. The calculated values of ϕ for randomized events in all selected zones are given in **table 3**. As it can be observed from table 3 here also ϕ values for randomized data set are negligibly small with respect to experimental one for both zones. The variation of ϕ values with η_{gap} for experimental and randomized data set have been plotted for forward and backward zone separately in **figure 2** for ^{16}O-AgBr interactions and in **figure 3** for ^{32}S-AgBr interactions. The error bars shown in the figure are purely statistical.

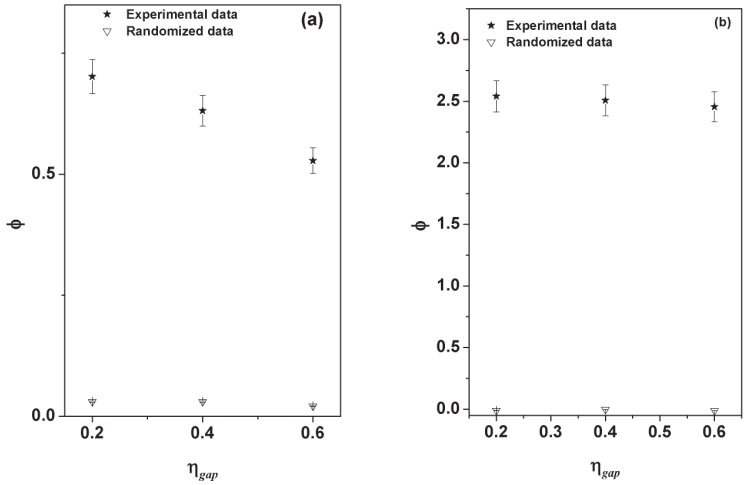

Figure 2.ϕ vs. η_{gap} plots for ^{16}O-AgBr interactions. (a) in forward zone, (b) in backward zone.

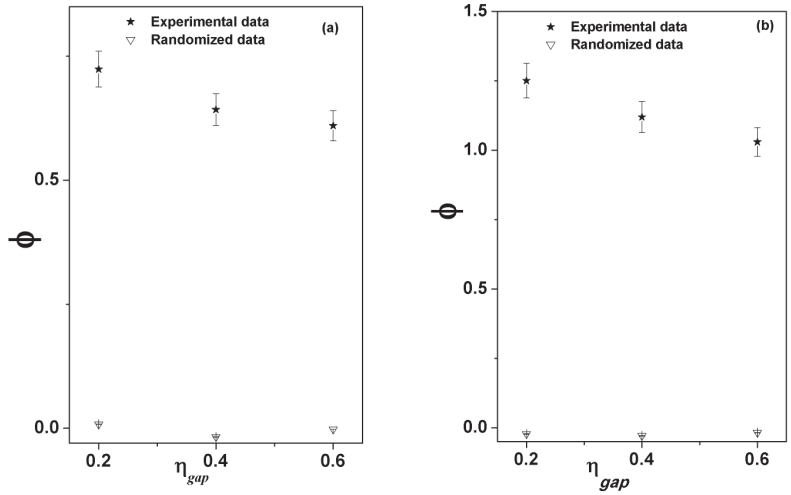

Figure 3.ϕ vs. η_{gap} plots for ^{32}S-AgBr interactions. (a) in forward zone, (b) in backward zone.

V. Conclusions

We have successfully carried out the Event-by-Event pseudo-rapidity fluctuation study in terms of ϕ measurement. Non-zero ϕ values for the experimental events signify the presence of fluctuation and correlation in our data. Negligible ϕ values for randomized data set confirms that source of this fluctuation and correlation is the dynamics of the pion production mechanism. Decrease in ϕ values with η_{gap} signifies that as one go away from incident beam direction fluctuation decreases.

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