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Maximum fluctuations of pion density in relativistic heavy-ion interactions

Dipak Ghosh*, Argha Deb, Jayita Ghosh, Swarnapratim Bhattacharyya and Kanchan Kumar Patra
High Energy Physics Division,
Jadavpur University, Calcutta-700 032, India
E-mail : dipakghosh-in@yahoo com

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Abstract : Maximum density fluctuation of charged pions in narrow pseudo-rapidity intervals in a Monte-carlo background has been studied using ^{16}O-AgBr interactions data at 2.1 AGeV. The study indicates correlated pion emission in pseudo-rapidity intervals $\delta\eta$ = 0.1 to 1. Further analysis suggests that a maximum charged particle density in a given pseudo-rapidity interval rises linearly with pion multiplicity

Keywords : Pion density fluctuation, pseudo-rapidity interval, relativistic heavy-ion interactions

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For the past few years, various experiments [1] were performed with hadron-hadron, hadron-nucleus and nucleus-nucleus interactions at relativistic and ultra-relativistic energies [2-6] in order to reveal the underlying dynamics of multiparticle production process. The experiments showed that the produced particles are emitted in a correlated fashion [7]. Different scientists suggested that the production of resonance, creation of hot multinucleon fireballs or the formation of quark gluon plasma to be the reason behind such effect. Several theoretical models [8] were put in support of the above. But whatever may be the reason behind such phenomena, it has been felt strongly by the physicists to carry out detailed study on correlation to reveal the inner dynamics of the collision process.

Here in this note, we will study the correlation and clusterisation using pionisation data of ^{16}O-AgBr interactions at 2.1 AGeV. The data were obtained from Illford G5 emulsion stacks exposed to ^{16}O beam of energy 2.1 AGeV at BEVALAC BERKELEY. To identify the primary events, two independent observer scanned the plates separately with the help of two Leitz Metalloplan microscopes, using a 10X objective in conjunction with a 25X ocular, to increase the efficiency to 98%. The final measurements were done using an oil immersion 100X objective. The measuring system fitted with it, has 1 μm resolution along the X and Y axes and 0.5 μm along the Z axis.

*Corresponding Author.
60/7/1, M. T. Road, Calcutta-700 031, India

After scanning, the events that are chosen for the above analysis have the following criteria :

i) the beam track should not be at an angle greater than 3° to the mean beam direction of the pellicle.

ii) the interaction should not lie within 20 μm from the top or bottom pellicle.

iii) All the incident beam are traced back in order to ensure the event to be a primary one.

According to emulsion technology, the particles produced after interactions are classified as

i) black particles with ionisation $\geq 6I_0$, I_0 being the minimum ionisation of a singly charged particle.

ii) Grey particles with ionisation $1.4\,I_0 \leq I \leq 6I_0$.

iii) Relativistic shower particles, mainly pions with ionisation $I \leq I_0$.

These particles have grain density $g \leq 1.4\,g_0$, where g_0 is the plateau value.

The emission angles were measured for each track by taking the coordinates (x, y, z) of two points on each secondary track, the coordinate of the centre (x_0, y_0, z_0) and the two points on the incident beam track (x_1, y_1, z_1).

In this note, the multiparticle correlations based on fluctuation for the produced pions have been analysed in the pseudo-rapidity phase space. For each event, the pseudo-rapidities $\eta = -\ln \tan\theta / 2$ (where θ is the polar angle of the particle) are scanned with a window size $\delta\eta$ across the full η range. The maximum density of particles as defined by [9] is equal to $\rho_{max} = \delta\eta_{max} / \delta\eta$, where $\delta\eta_{max}$ is the maximum number of particles in each event of the interval $\delta\eta$. ρ_{max} for all N events are then calculated and the distribution $dN / d\rho_{max}$ with respect to ρ_{max} is analysed.

To compare the behaviour of the experimental data with that of the uncorrelated one, the same procedure has been followed with the events generated by Monte Carlo simulation. The data are generated following the independent emission hypothesis :

i) The shower particles are emitted independently.

ii) The multiplicity distribution of the simulated events is the same as the empirical multiplicity spectrum of the experimental ensemble.

iii) The single particle spectrum $d\sigma / d\eta$ of the simulated events, reproduces the empirical distribution $d\sigma / d\eta$ for the real ensemble.

The distribution $dN / d\rho_{max}$ (with experimental data set) and $(dN / d\rho_{max})_{MC}$ (with Monte Carlo simulated data set) for $\delta\eta$ (window sizes) = 0.1, 0.5, 0.8 and 1 are shown in the Figures 1a, 1b, 1c and 1d respectively. From the figures, it can be seen that there exists a remarkable deviation between experimental and simulated data sets, suggesting that the produced pions are emitted in a correlated fashion.

We also have calculated (not shown) χ^2 per degrees of freedom $[(\chi^2) = \Sigma$ ((simulated value-experimental value) / *error*)^2]. Sufficiently high values for χ^2 per N degrees of

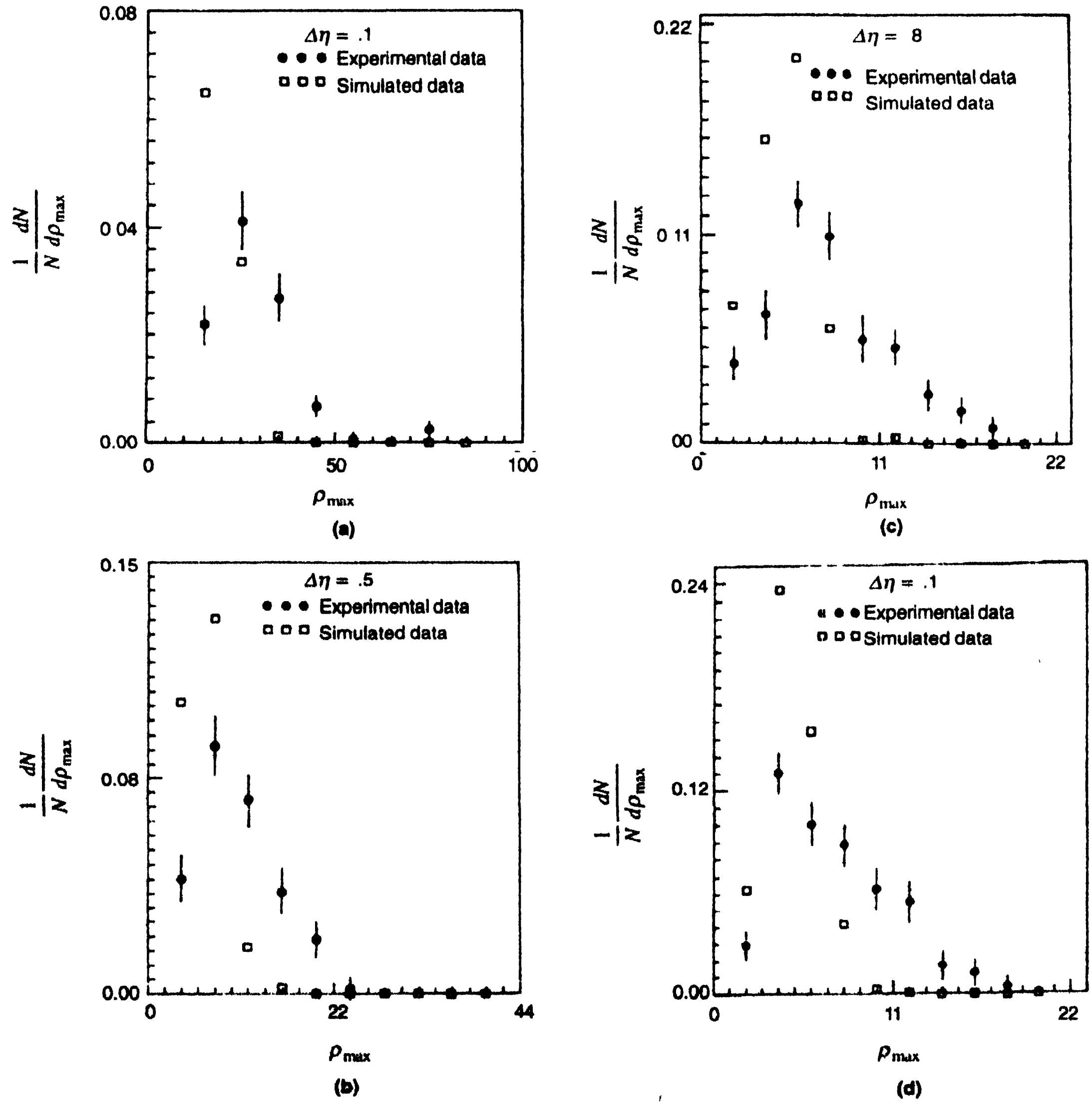

Figure 1 (a-d). Plot of the normalised ρ_{max} distribution for ^{16}O-AgBr interactions at 2.1 AGeV in pseudo-rapidity windows $\delta\eta$ = .1, .5, .8 and 1 respectively.

freedom $[\chi^2 / N_{d.f}]$ also supports the notion of correlated pion emission, for pseudo-rapidity interval of range $\delta\eta = 0.1$ to 1.

We also have studied the dependence of average maximum particle density on charged multiplicity for the entire pseudo-rapidity range. To carry out the above study, the entire multiplicity region have been divided into six equal intervals (1-4, 5-8, 9-12, 13-16, 17-20, 21-24). For any particular multiplicity (n), interval weighted average of n is given by $\bar{n} = \sum P_n n$ where P_n represents the probability of getting an event with multiplicity n. We have determined $\langle \rho_{max} \rangle$ for the above six intervals and plotted $\langle \rho_{max} \rangle$ as a function of $\bar{n}$ for $\delta\eta = 0.1, 0.3, 0.5$ and 0.8 in the Figures 2(a-d). For each set, least square fit of the form $\langle \rho_{max} \rangle = a\bar{n} + b$ has been performed. The slope values 'a' for different $\delta\eta$'s are given in Table 1. Table 1 suggests that with increase of $\delta\eta$, the slope value decreases.

Table 1. The slopes obtained in least squares fits of the $\langle \rho_{max} \rangle = a\bar{n} + b$ for ^{16}O-AgBr interactions at 2.1 AGeV for $\delta\eta$ = .1, .3, .5 and .8.

Window size ($\delta\eta$)	slope values
0.1	1.21
0.3	0.80
0.5	0.71
0.8	0.57

Hence, we conclude that

i) the data reveal a correlation and clusterisation within the pseudo-rapidity interval $d\eta = 0.1$ to 1.

ii) $\delta\eta$-dependent linear relation exists between average maximum particle density and the multiplicity over the entire multiplicity region.

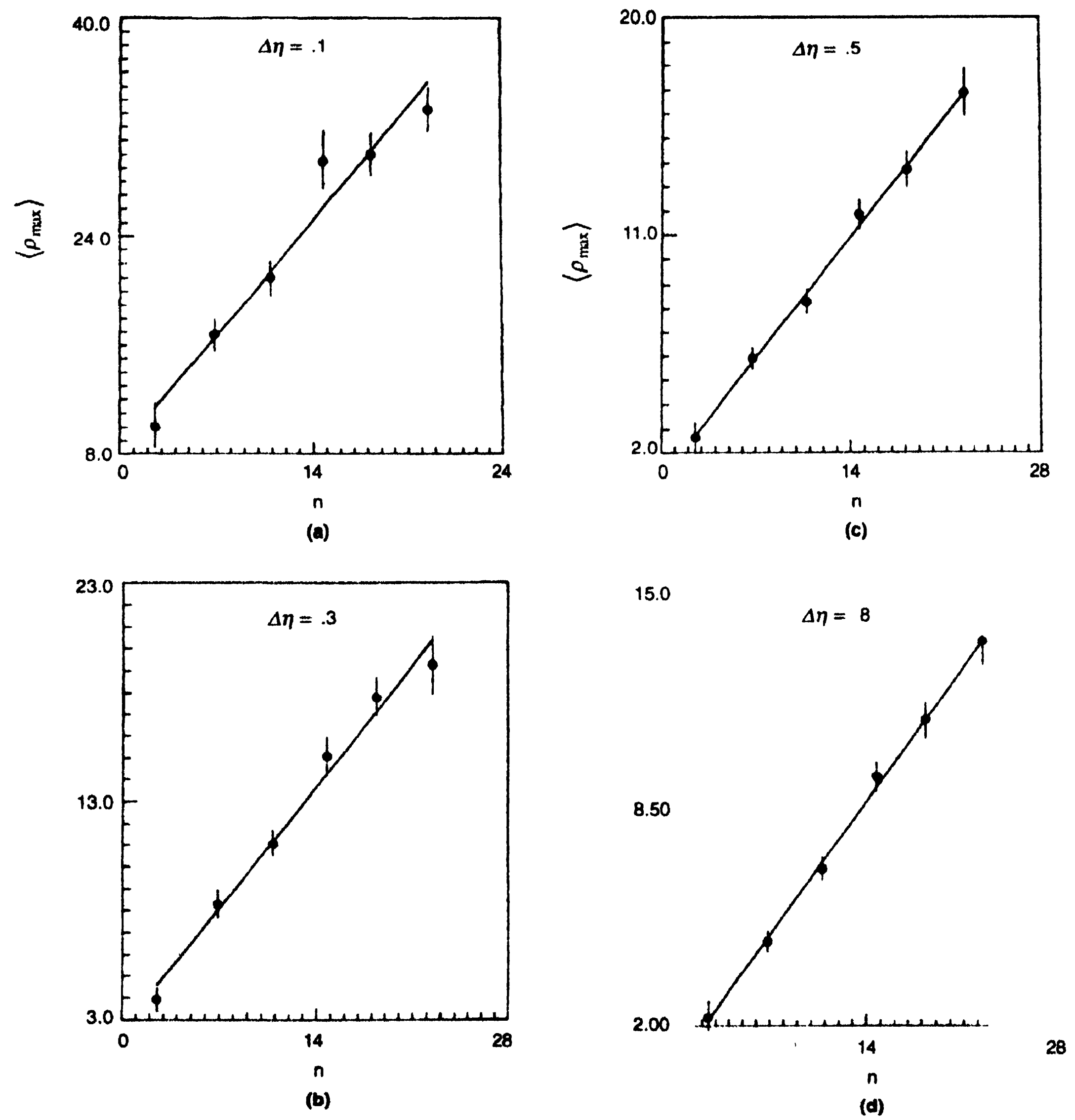

Figure 2 (a-d). Plot of average maximum particle density $< \rho_{max} >$ as a function of charged particle multiplicity $\bar{n}$ in pseudo-rapidity windows $\delta\eta$ = .1, .3, .5 and .8 respectively for ^{16}O-AgBr interactions at 2.1 AGeV.

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