# AN APPROACH FOR THE STUDY OF MULTIPLICITY CORRELATIONS AND FLUCTUATIONS IN RELATIVISTIC HEAVY ION COLLISIONS

**M. AYAZ AHMAD, AMEER A. NANDALUR, MIR.HASHIMRASOOL, SHAFIQ AHMAD**

**Abstract** : In this paper an attempt has been made to study the multiplicity correlations of produced charged particles in the interaction of 28Si + Emulsion collisions at an energy 409 GeV (28 × 14.6 GeV per nucleons). This analysis is based on the maximum fluctuation of the charged particle density in narrow pseudorapidity intervals of experimental data and compared with the simulated Monte Carlo data in η and ϕ phase spaces. The study reveals the existence of dynamical multipions correlation in the pseudorapidity interval 0.1–1 for both the data sets.

**Keywords :** Relativistic heavy ion collisions, Multiplicity correlations and fluctuations.

**Introduction** : The existence of multiparticle phenomena provides valuable informations about the processes involved in nuclear collisions at ultra-relativistic energies. Global features such as multiplicity and pseudorapidity fluctuations of relativistic charged particles can be described to a good approximation by various models [1, 2] based on multipions production in hadron-hadron, hadron-nucleus and nucleus-nucleus collisions at very high energies. The event-by-event study of produced charged particles gives an idea that these particles are assumed to be emitted in a correlated way [3]. The reason for such type of correlation behavior, suggested by various theoretical physicists [4, 5], might be due to the production of resonance phenomena and the formation of a newly state of matter called quark gluon plasma (QGP) [6]. The study of the experimental results reveals the formation of clusterization, which may be the main cause of such correlation effect. In view of this, the study of correlation and clusterization of relativistic charged particles in such processes is used as a tool to extract vital information.

**Experimental Details** : Two Stacks of FUJI - type nuclear emulsion, exposed horizontally of $^{28}$Si beam at energy 14.6 AGeV from the Alternating Gradient Synchrotron at Brookhaven National Laboratory (BNL AGS) have been utilized for data collection. A NIKON (LABOPHOT and Tc-BIOPHOT, Japan made)microscopewith a 40 Xobjective and 10 Xeyepieces provided with a semi-automatic scanning stage was used to scan the plates. Each plate was scanned by two independent observers to increase the scanning efficiency. The final measurements were done using an oil immersion 100 Xobjective. The measuring system fitted with it has 1 μmresolution along the X and Y axes and 0.5 μm resolutionalong the Z-axis.The angle of emission of a particle is determined by finding the space angle ($\theta_S$) of the corresponding tracks with respect to the primary by the relation:

$\theta_S = \cos^{-1}[\cos\theta_P \times \cos\theta_d]$, where ($\theta_P$) is projected angle and ($\theta_d$) is dip angle.In order to study the correlations and fluctuations in relativistic nuclear collisions in different phase spaces, the measurement of azimuthal angle is taken into account. This is the angle between the projections of secondary track in the Y-Z plane with respect to Y-axis. The azimuthal angle, $\phi$, is determined by the following relation:

$$\phi = \cos^{-1}[\cos\theta_d \ \sin\theta_p \ / \sin\theta_S].$$

The other relevant details of the present experiments can be seen in our earlier publications [7 - 9].

**Results And Discussions** : In order to analyze the dynamical fluctuations in the pseudorapidity distributions of η-phase space and azimuthal angle $\phi$ -phase space, the following method has been used. The pseudorapidity of all the relativistic charged particles is arranged in increasing or decreasing order for particular events as well as for whole data. For each event η-values are examined with a fixed rapidity intervals, Δη, over the full range of η-values and the number of relativistic shower particles in each η-window of interval, Δη, are determined. The maximum particle density, $\rho_{\max}$, is defined by [6, 10, 11]: $\rho_{\max} = \Delta n_{\max} / \Delta\eta$ in each η-window, where $\Delta n_{\max}$ is the maximum number of particles in each event within rapidity intervals, Δη. Similar procedure has been adopted in case of uncorrelated events generated by Monte Carlo simulation [12]. It is characterized to obtain the dynamical correlations of fluctuations.

The normalized distributions, $(1/N_{ev}\, dn/d\rho_{\max})$ as a function of $\rho_{\max}$ for various fixed Δη values, Δη = 0.1, 0.4, 0.7 and 1.0 are depicted in Figs. 1 (a-d) for the interactions of 14.6A GeV/c $^{28}$Si nuclei with nuclear emulsion in η-space and $\phi$-space, respectively.

Monte Carlo simulated result is also shown in the same figures. From these figure one can examine that the distributions tends to become wider and have longer tails with decreasing bin width, Δη, for both the space. The normalized distributions for η-space are quite same as the distributions for $\phi$-space. Some deviations between experimental and simulated data are observed, which indicates that pions are emitted in a correlated fashion for our data. The average values of the maximum particle density, $<\rho_{\max}>$, and dispersion, $D(\rho_{\max})$, for each distribution are given in Table 1. It may be of interest to mention that the experimental values of $<\rho_{\max}>$, and $D(\rho_{\max})$ in $\phi$-space are comparatively higher than those for η-space and as well as Monte Carlo simulated events. The observed higher values of the two parameters in comparison to the corresponding values for the correlation free simulated events, in turn, reveal the occurrence of higher particle densities in small η-windows for the experimental data. Thus our data support the presence of dynamical correlations and clusterization withinpseudorapidity intervals in relativistic nucleus-nucleus collisions.

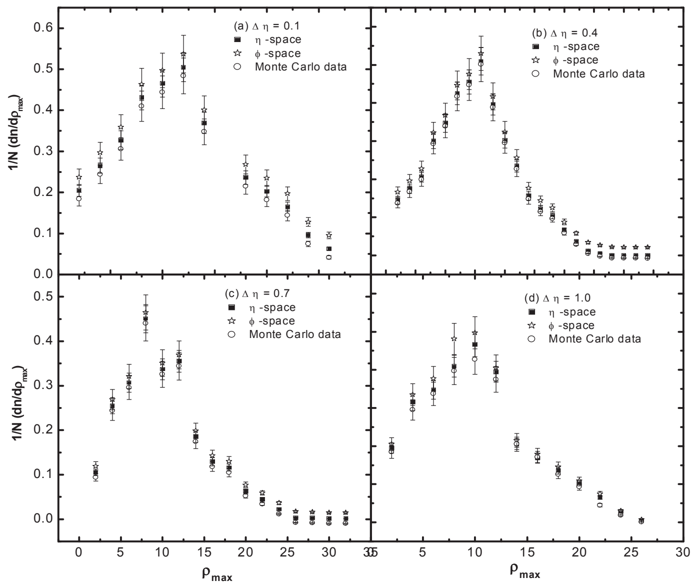


**Fig. 1 (a-d):** Distributions of $1/N(dn/d\rho_{max})$ as a function of maximum particle density $\rho_{max}$ for $^{28}Si$-Em collisions at 14.6A GeV.

Table I: Values of $<\rho_{max}>$, and $D(\rho_{max})$ in nucleus-nucleus collisions.

| Type of Interaction | $\Delta\eta$ | $<\rho_{\max}>$ | $D(\rho_{\max})$ | References |
|---|---|---|---|---|
| $\eta$-Space $^{28}Si$-Em 14.6AGeV | 0.1<br>0.4<br>0.7<br>1.0 | 23.3±2.2<br>15.7±1.2<br>10.1±0.9<br>7.04±0.5 | 13.3±1.0<br>8.2±0.7<br>6.2±0.6<br>4.9±0.5 | Present work |
| $\phi$-Space $^{28}Si$-Em 14.6AGeV | 0.1<br>0.4<br>0.7<br>1.0 | 24.4±2.7<br>16.3±1.7<br>10.9±0.8<br>8.0±0.6 | 14.6±1.0<br>9.0±0.8<br>6.9±0.5<br>4.7±0.4 | Present work |
| MC-data | 0.1<br>0.4<br>0.7<br>1.0 | 22.9±1.9<br>14.1±0.9<br>9.1±0.6<br>6.4±0.4 | 12.7±0.9<br>7.9±1.1<br>6.0±0.8<br>4.2±0.4 | Present work |

**Conclusion :**The present experimental investigations lead us to the following conclusions:

The study of multiplicity correlations and clusterization in terms of maximum fluctuations of relativistic charged particles in high-energy heavy ion collisions processes has been made. It is used as a tool to extract vital information regarding the formation of QGP and to find out its signature. It may be of interest to mention that the experimental values of $< \rho_{\max} >$ and $D(\rho_{\max})$ in $\phi$- phase space is comparatively higher than those for $\eta$- phase space as well as Monte Carlo simulated events. The observed higher values of the above two parameters in comparison to the corresponding values for the correlation free simulated events, in turn, reveal the occurrence of higher particle densities in small η-windows for the experimental data. Thus our data support the presence of dynamical correlations and clusterization within pseudorapidity intervals in relativistic nucleus-nucleus collisions.

**Acknowledgment :** This work is supported in a part by Deanship of Scientific Research of University of Tabuk, Saudi Arabia with project number S-1424-0035/15-02-1434. The author, M. Ayaz Ahmadis highly grateful to Vice Presidency for Graduate / Studies and Scientific Research at University of Tabuk, and Ministry of Higher Education, Kingdom of Saudi Arabia for the kind financial assistance.

**References :**

1. L. Van, Z. Phys. C27, 1985, p. 135 ; C. Y. Wong, "Initial energy density of quark-gluon plasma in relativistic heavy-ion collisions,"Phys. Rev. D30, 1984, pp. 961-971.
2. H. Gordon et al., "pt and Et multiplicity correlations in p-p, p-α, and α-α interactions at √s=31.5 and 44 GeV,"Phys. Rev. D28, 1983, pp. 2736-2740.
3. E. A. De Wolf et al., .,"Scaling laws for density correlations and fluctuations in multiparticle dynamics,"Phys. Rep. vol.270, 1996, pp.1-141.
4. DipakGhosh et al.,"Rapidity dependence of multiplicity fluctuations and correlations in high-energynucleus–nucleus interactions,"Pramana J. of Phys., vol. 77, 2011, pp.297-313.
5. Shafiq Ahmad et al.,"Study of non-statistical fluctuations in relativistic nuclear collisions," J. Phys. Soc. Japan, vol. 75, 2006,pp. 64604 (1-9).
6. E. K. Sarkisyan et al., Sov. J. Nucl. Phys, vol. 53, 1991, pp.824.
7. M. Ayaz Ahmad et al.,"General Characteristics of Heavy Ion Collisions at the Energy of 14.6A GeV," Int. J. Theo. and App. Phys. (IJTAP), vol. 2, 2012, pp.199-211.
8. M. Ayaz Ahmad et al., "A comparative study of multifractal moments in relativistic heavy ion collisions," J. Phys. G: Nucl. Part. Phys, vol. 32, 2006, pp.1279-1293.
9. M. Ayaz Ahmad et al., "Study of angular distribution and KNO scaling in the Collisions of 28Si with Emulsion nuclei at 14.6A GeV," Ukrainian J. Phys. (UJP), vol. 2, 2012, pp.1205-1213.
10. S. Ahmed et al., "Maximum Charged Particle Density Fluctuations in Relativistic Heavy-Ion Collisions,"J. Phys. Soc. Japan, vol. 71, 2002, pp. 1059-1064.
11. E. K. Sarkisyan et al., , "Fractal analysis of pseudorapidity fluctuations in 4.5 AGeV/c C-(Ne, Cu) central collisions," Phys. Lett. B318, 1993, pp. 568-574.
12. Dipakghosh et al., "Maximum fluctuations of particle densities in narrow pseudorapidity space in high-energy interaction of hadrons with nuclei,"Phys. Rev.D47,1993 pp1235-1238.

***

1- Assistant Professor/Physics Department, College of Science, P. O. Box 741, University of Tabuk, Zip 71491, Kingdom of Saudi Arabia/mayaz.alig@gmail.com

2- Assistant Professor/Department of Mathematics, College of Science, P. O. Box 741, University of Tabuk, Zip 71491, Kingdom of Saudi Arabia/n.ameer1234@gmail.com

3- Research Scholar/Physics Department, Exp. High Energy Physics Lab, Aligarh Muslim University, Aligarh-202002, India/hrasool23@gmail.com

4- Professor/Physics Department, Exp. High Energy Physics Lab, Aligarh Muslim University, Aligarh-202002, India/sahmad2004amu@yahoo.co.in