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PIONISATION IN GeV TO TeV HADRON-NUCLEUS AND NUCLEUS-NUCLEUS INTERACTION – COHERENT OR CHAOTIC ?

D. Ghosh, J. Roychowdhury, B. Biswas

High Energy Physics Division,
Department of Physics
Jadavpur University, Calcutta, India

J. Roy

Regional Computer Centre,
Calcutta, India

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This paper reports detailed study of coherent and chaotic production of pions in hadron-nucleus interactions over a wide range of incident energy viz., 200 GeV to 9.5 TeV and nucleus-nucleus interactions at 2.1 to 4.5 GeV/c/n. The experimental multiplicity distribution in different overlaping pseudorapidity bins are matched with Poissonic and Chaotic form. It is observed that disagreement with Poissonian distributions strongly indicated by the data in all cases and for low energy hadron-nucleus interactions and nucleus-nucleus interactions, the central-most region is most Chaotic while for hadron-nucleus interactions at comparatively high energy, the multiplicity distribution is more or less Chaotic in all bins.

I. INTRODUCTION

Multiplicity distribution study in full phase space as well as in different rapidity bins gives an idea in the understanding of the mechanism of the particle production process in hadron-hadron, hadron-nucleus and nucleus-nucleus collisions at high energies.

On the basis of multiplicity distribution of pions in different pseudo-rapidity windows, one can study pion coherence. The study of pion coherence is important because it has been suggested by Fowler et al. [1] that in case of hadron-nucleus and nucleus-nucleus interactions a partially coherent mesonic field can be created and the the response of the nuclear medium will be non-linear in the mesonic field. The

presence of coherence can be inferred through the shape of multiplicity distribution; when the mesonic field is completely coherent, multiplicity distribution should be Poissonic [2].

The multiplicity distribution of shower particles over full phase space does not agree with Poisson distribution. The interest in analysing the multiplicity distribution of the shower particles was then switched over from whole phase space to different pseudorapidity bins.

In the past some studies on coherence in the production of mesons have been made in cases of hadron-hadron [3] and hadron-nucleus [4] collisions.

Recently some observations by Zajc et al., in heavy ion collisions at 1.8 GeV [5] and by Ghosh et al., in the case of ^{24}Mg-AgBr collisions at 4.5 GeV/c/n [6], confirm the occurence of partially coherent mesonic field during the interaction process. Studies of pion coherence for all the above mentioned hadron-hadron, hadron-nucleus and nucleus-nucleus interactions have been done in different non-overlapping pseudorapidity bins.

The objective of the present paper is to study the coherence in overlapping pseudorapidity bins for all available data in our laboratory and ultrahigh energy cosmic ray data. In overlapping bins the situation appears to be different - a strong disagreement with poissonian distribution is indicated by all data for all bins. We therefore extended our analysis to study Chaotic pionisation process.

II. EXPERIMENTAL DATA

The considered hadron-nucleus interactions consist of

1) p-AgBr interaction at 200 GeV and 400 GeV [7].

2) Cosmic ray p-AgBr interaction at energies 0.5 to 9.5 TeV obtained from ICEF collaboration [8].

3) π^--AgBr interactions at 200 GeV and 350 GeV [9].

The experimental data for heavy ion interactions were obtained from

1) ^{16}O-AgBr interaction at 2.1 GeV/c/n [10].

2) ^{12}C-AgBr interaction at 4.5 GeV/c/n [11].

3) ^{24}Mg-AgBr interaction at 4.5 GeV/c/n [10].

The details of scanning and measurements etc. are given in the references 7 - 11.

III. METHOD OF ANALYSIS

The analysis has been done in terms of pseudo-rapidity variable η in the laboratory frame, where $\eta = -\ln\tan\theta/2$, θ being the emission angle in the laboratory frame.

For the purpose of our analysis, the whole pseudo-rapidity range was divided into four overlapping pseudorapidity bins of sizes 1, 2, 3 & 4 each centered about

central rapidity value. In each of the events the total shower multiplicity was classified and say, n_i is the multiplicity of the shower in the ith class. The total shower multiplicity is thus obtained by

$$n = \sum_{i=1}^{k} n_i \tag{1}$$

where k is the number of bins. Here the whole phase space was divided into four intervals. In each interval multiplicity distribution matched to the Poissonic form and the Chaotic form. The corresponding χ^2 per degree of freedom (d.o.f.) values were tested to find out the best fit. The Poisson distribution corresponding to the estimated mean multiplicities $\langle n_i\rangle$ is given by

$$P(n_i) = e^{-\langle n_i\rangle}\langle n_i\rangle^{n_i}/n! \tag{2}$$

On the other hand the Chaotic distribution is given by

$$P(n_i) = \frac{1}{1+\langle n_i\rangle}\left[\frac{\langle n_i\rangle}{1+\langle n_i\rangle}\right]^{n_i} \tag{3}$$

with the same mean value.

IV. EXPERIMENTAL RESULTS

Table 1. presents χ^2/d.o.f. values for the experimental data fitted to Poisson and Chaotic distributions for different overlapping pseudorapidity bins in the cases of ^{16}O-AgBr, ^{12}C-AgBr and ^{24}Mg-AgBr interactions. In Table-2, values of χ^2/d.o.f. for the data fitted to Poisson and Chaotic distributions are shown for p-AgBr. interactions at 200 GeV, 400 GeV and at TeV energies (cosmic ray events) and π^--AgBr interactions at 200 GeV and 350 GeV.

The observations from Table 1. are as follows:

At an energy 4.5 GeV/c/n, for both ^{12}C-AgBr and ^{24}Mg-AgBr interactions, the χ^2/d.o.f. value for experimental data fitted to Chaotic distribution is less in all the bins than that value for data fitted to Poisson distribution. Not only that, the χ^2/d.o.f. value for Chaotic distribution is minimum in the smallest bin i.e., in the central-most region for both the aforesaid interactions.

In case of ^{16}O-AgBr interaction at 2.1 GeV/c/n, we have the same observation.

The above observations suggest that the experimental data favour Chaotic distribution most in the central-most region for all the considered nucleus-nucleus interactions irrespective of mass and energy of the projectile.

From Table 2. one can have the following observations:

a) In case of 200 GeV p-AgBr & π^--AgBr interactions, the χ^2/d.o.f. for data fitted to Chaotic distribution is less in all the bins than that for data fitted to Poisson distribution and the χ^2/d.o.f. for Chaotic distribution is minimum in the central most bin, which is also observed in case of 350 GeV π^--AgBr interaction.

b) At 400 GeV p-AgBr interaction and cosmic ray p-AgBr interaction at 0.5 to 9.5 TeV energy, the χ^2/d.o.f. when the data compared with Chaotic distribution is less in all the bins than that when compared with Poissonian distribution.

Table 1

The chi-square per degree of freedom values for the Poissonic and Chaotic fits to the experimental data at different overlapping pseudorapidity bins in the cases of ^{16}O-AgBr interaction at 2.1 GeV/c/n and ^{12}C-AgBr & ^{24}Mg-AgBr interactions at 4.5 GeV/c/n.

Type of inter-action	Energy in GeV/c/n	Distri-bution	Values of χ^2/d.o.f. for window size			
			1	2	3	4
^{16}O-AgBr	2.1	Poisson	21.48	18.91	07.56	07.29
		Chaotic	01.04	02.66	02.50	02.38
^{12}C-AgBr	4.5	Poisson	04.53	07.08	05.46	04.74
		Chaotic	00.76	01.96	01.91	02.11
^{24}Mg-AgBr	4.5	Poisson	04.06	12.89	10.77	08.31
		Chaotic	00.65	01.38	01.63	00.98

Table 2

The chi-square per degree of freedom values for the Poissonic and Chaotic fits to the experimental data at overlapping pseudorapidity bins in the cases of 200 GeV p-AgBr, 200 GeV π^--AgBr, 350 GeV π^--AgBr, 400 GeV p-AgBr interactions and cosmic ray p-AgBr interaction at 0.5 to 9.5 TeV energy.

Type of interaction	Distribution	Values of χ^2/d.o.f. for window size			
		1	2	3	4
200 GeV p-AgBr	Poisson	13.34	02.94	07.17	05.83
	Chaotic	01.64	02.83	02.74	03.44
200 GeV π^--AgBr	Poisson	06.14	05.91	05.17	06.13
	Chaotic	01.83	02.18	03.61	03.84
350 GeV π^--AgBr	Poisson	06.36	07.76	10.46	05.13
	Chaotic	01.87	03.18	02.45	04.49
400 GeV p-AgBr	Poisson	03.45	14.02	29.87	13.56
	Chaotic	02.09	01.63	01.23	01.58
0.5 to 9.5 TeV Cosmic ray p-AgBr	Poisson	05.54	03.84	05.06	07.55
	Chaotic	01.75	01.39	02.03	02.35

V. DISCUSSION

The observations from table 1 & 2 suggest that for nucleus-nucleus interaction and comparatively low energy hadron-nucleus interactions, the multiplicity distribution favours Chaotic distribution most in central-most region and becomes less Chaotic as we are heading towards full phase-space. But for comparatively high energy interactions, the multiplicity distribution obeys Chaotic distribution in all the bins.

The summarise we have observed from the above analysis that

(a) all data at widely different energies indicates no pion coherence if one analyses multiplicity distribution in overlapping pseudorapidity bins.
(b) Chaotic pionisation is favoured by all data and a systematic dominance of Chaoticity in all overlapping phase space with energy is indicated strongly.

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