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Study of Normalized Moments of Relativistic Charged Shower Particles Produced in ^{12}C-Nucleus Collisions at 4.5 A GeV

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Abstract: ***An attempt has been made to study the characteristics of charged shower particles produced in ^{12}C-nucleus interactions at 4.5 A GeV. Results shows that the values of normalized moments of the multiplicity distribution of relativistic charged particles produced in relativistic energy in proton-nucleus and nucleus-nucleus reactions are almost constant within the statistical limit. Furthermore, it is reported that the leading particle multiplicity strongly depends on the mass of the projectile.***

Keywords: Normalized moments, multiplicity distributions, charged shower particles, leading particle etc.

1. Introduction

The study of the characteristics of secondary charged particles produced in nucleus-nucleus reactions at relativistic energies has received considerable attention during recent years [1-6]. The reasons for investigating the production mechanism of secondary particles in heavy ion interaction might provide some valuable information about reaction mechanism in the nucleus-nucleus collisions. In relativistic heavy ion collisions, the secondary hadrons are formed instantaneously. There is a formation time between the collision and hadronization of the final state particles. They hadronize within the target nucleus and may re-interact with the surrounding target matter and produce cascade particles. Moreover, the studies on heavy ion interactions provide the means of discrimination between the various theoretical models put forward to explain the mechanism of hadronization of final state charged particles in nucleus-nucleus reactions at relativistic energies and the characteristics of secondary charged particles produced in such collisions may be obtained by analyzing the experimental data on the secondary charged particles.

2. Experimental Technique

In the present investigation, nuclear emulsion stacks of several pellicles of NIFKI-BR2 type are used. The dimension of each Pellicle is 18.7×9.7×0.06cm^3.The stacks were exposed to a beam of ^{12}C-ions with momentum 4.5 A GeV/c at the Joint Institute for Nuclear Research (JINR) at Dubana, Russia. The search for inelastic interactions was carried out. A random sample of 485 events having $N_h \geq 0$, were picked up by using along the track doubly scanning method for detailed study. It may be pointed out that the interactions which were within 30 μm from the top or bottom surface of the nuclear emulsion were not considered for the final investigation. Secondary tracks produced in each event were classified in to shower, grey, black, and heavily ionized tracks in a disintegration and are denoted by N_s, N_g, N_b, and N_h $(= N_b + N_g)$, respectively. The details of the scanning procedure, selection criteria used for collecting the experimental data and the method of measuring angles etc. may be found elsewhere [22-24]. The secondary tracks emerging from each interaction are classified in accordance with their ionization or normalized grain density (g*), range (L) and velocity (β) as shower, grey and black particles. Shower particles are freshly created, singly charged relativistic particles with g* less than 1.4. These particles have relativistic velocity $\beta \geq 0.7$. They are mostly fast pions with a small mixture of Kaons and released protons from the projectile which have undergone an interaction. For the case of proton, kinetic energy (E_p) should be less than 400 MeV. The number of charged shower particles in an event is represented by N_s. Particles with range $L > 3$ mm and $1.4 < g* < 6.0$ are defined as grey particles. They have β in the range of $0.3 < \beta < 0.7$. These are generally knocked out protons of targets with kinetic energy in between $30 - 400$ MeV, and traces of deuterons, tritons and slow mesons. The number of charged grey particles in an event is represented by N_g. Particles having $L < 3$ mm from interaction vertex from and $g* > 6.0$. This corresponds to $\beta < 0.3$ and protons of kinetic energy less than 30 MeV. Most of these are produced due to evaporation of residual target nucleus. The number of charged black particles in an event is represented by N_b. Black and grey particles are mainly product of breakup of target nucleus. The number of heavily ionizing charged particles (N_h) are equal to the sum of black (N_b) and grey (N_g) fragments i.e. N_h $(= N_b + N_g)$.

3. Experimental Results and Discussion

3.1 The normalized moments of the multiplicity distributions

The normalized moments of the multiplicity distributions of relativistic charged particles produced in high energy hadron-nucleus collisions has been investigated by several workers in the energy range ~ (6-800) GeV. However, a little attention has been paid to study the normalized moments of the multiplicity distributions of the relativistic charged particles produced in nucleus-nucleus interactions

[8-9]. Thus, it is considered worthwhile to investigate the normalized moments of the distributions and their dependence on the mass of the projectile and the stuck nucleus [17-21]. The normalized moments of the multiplicity distributions of relativistic charged particles is defined as

$$C_k = < N_s^k > / < N_s >^k \qquad (1)$$

Where, k is a constant and can have any value 2, 3, 4 etc.

For studying the dependence of C_k on the size of the target nucleus, the values of C_2, C_3, C_4 are calculated for the different groups of emulsion nuclei in 4.5 A GeV/c ^{12}C-nucleus interactions. The value of C_k obtained in 4.5 A GeV/c ^{12}C-nucleus reactions are listed in Table1:

Table 1: value of C_k obtained in 4.5 A GeV/c ^{12}C-nucleus reactions

Types of Interactions	C_k	C_k	C_k	References
^{12}C-CNO	1.41±0.10	2.42±0.23	4.73±0.58	Present work
^{28}Si-CNO	1.41±0.01	2.44±0.007	4.41±0.003	4
^{12}C-AgBr	1.27±0.06	2.20±0.13	3.09±0.24	Present work
^{12}C-AgBr	1.29±0.26	2.48±0.08	-	3
^{28}Si-AgBr	1.31±0.007	4.56±0.004	3.55±0.35	Present work
P-Em	1.44±0.002	2.55±0.04	-	1
^{12}C-Em	1.43±0.05	2.51±0.12	5.15±0.33	Present work
^{12}C-Em	1.58±0.007	2.67±0.13	-	3
^{28}Si-Em	1.53±0.01	3.06±0.013	7.19±0.01	Present work

It is interesting to note in the table that the values of C_k in 4.5 A GeV/c proton-nucleus and nucleus-nucleus reactions are almost constant within the statistical limits. However, the value of this parameter is observed to increase with the increasing values of k.

3.2 Characteristics of charged shower particles produced in the forward (θ<90^0) and backward (θ>90^0) hemispheres:

Study of the characteristics of charged shower particles produced in the forward (θ<90^0) and backward (θ>90^0) hemispheres, where θ is the emission angle of relativistic charged particles in the laboratory system, has received considerable attention during the recent years in the nucleus-nucleus interactions [10-16]. It is reported [8] that the probability of the existence of leading particle is much higher in the forward hemisphere than in the backward hemisphere. Thus, the leading particle effect in 4.5 A GeV/c ^{12}C-nucleus reactions is investigated by studying the dependence of dispersion of relativistic charged particles in forward hemisphere, $D(N_S^F)(=< {N_S^F}^2 > - < N_S^F >^2)^{1/2}$ on the average number of charged shower particles produced in forward hemisphere,<N_S^F>. The variation of D (N_S^F) with <N_S^F> is plotted in Fig. 1. It is evidently clear from the figure that the dispersion, D(N_S^F) grows linearly with <N_S^F> in 4.5 A GeV/c ^{12}C-nucleus interactions. The experimental data obtained in the present work are found to satisfy the following relation.

$$D(N_S^F) = \alpha < N_S^F > + \beta \qquad (2)$$

The values of the coefficients α and β are found to be (0.45 ± 0.04) and(0.64 ± 0.27) in 4.5 A GeV/c ^{12}C-nucleus interactions. The parameter α is called leading particle multiplicity. However, the value of α is reported to be (1.04±0.13) in 4.5 A GeV/c ^{28}Si-nucleus interactions [8].

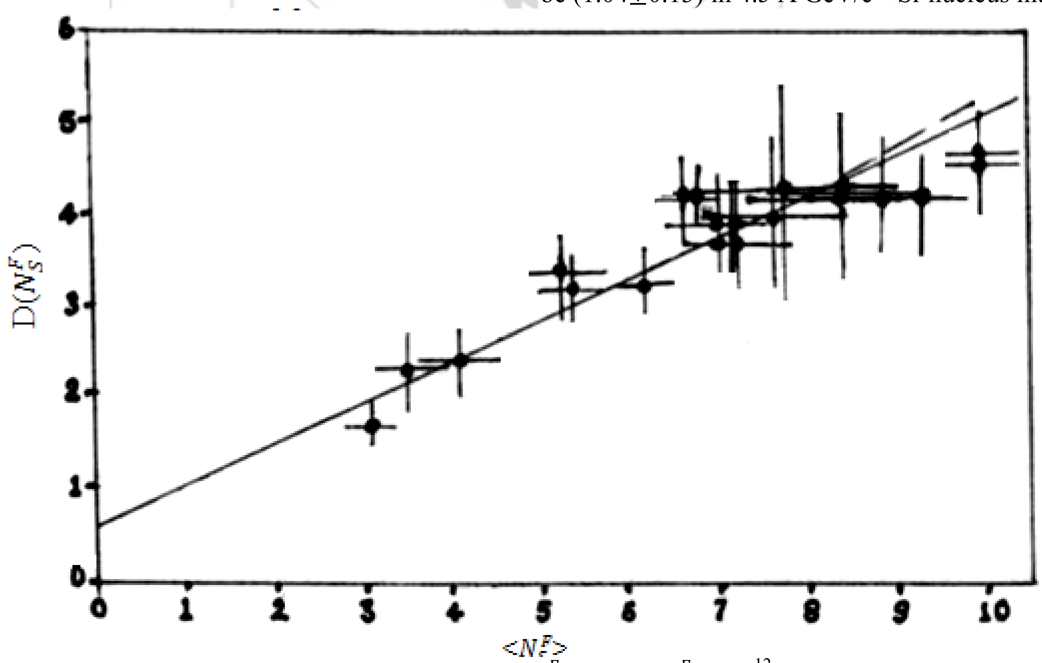

Figure 1: Variation of D (N_S^F) with < N_S^F > in ^{12}C

Thus, on comparing the value of α obtained in the present work with those obtained in ref.9 and13. It may be concluded that the leading particle multiplicity strongly depends on the mass of the projectile.

On comparing these observations with those obtained in high energy hadron-nucleus [7] and proton-proton [6-9] collisions, it may be concluded that there is at least a quantitative similarity in the mechanism of hadronization in the final stage of high energy hadron-nucleus as well as nucleus-nucleus reactions.

4. Conclusions

1) The probability of the existence of leading particle is much higher in the forward hemisphere than in the backward hemisphere. This results indicates that the leading particle effect in 4.5 A GeV/c ^{12}C-nucleus reactions is investigated by studying the dependence of dispersion of relativistic charged particles in forward hemisphere.
2) The leading particle multiplicity strongly depends on the mass of the projectile.
3) In high energy hadron-nucleus and proton-proton collisions, there is at least a quantitative similarity in the mechanism of hadronization in the final stage of high energy hadron-nucleus as well as nucleus-nucleus reactions.

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