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Multiplicity Correlation Studies in 4.5 A GeV/c Nucleus-Nucleus Interactions

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Abstract

The interactions of 4.5 A GeV/c nucleus-emulsion have been studied. The multiplicity distributions of different emitted particles from these interactions have been investigated. The correlations between the various groups of particles have been presented. A strong correlation between the number of produced shower particles and the number of the recoil nucleons has been observed .The experimental data have been systematically compared with the corresponding ones from events simulated using the modified cascade evaporation model. An agreement has been shown between the experimental values and the theoretically calculated ones.

1 Introduction:

The study of the hadron-nucleus and nucleus-nucleus interactions may provide valuable information on the nature of the interaction process, and on the space-time development of the considered reaction. In the high-energy nucleus-nucleus interactions one can get created particles which are instantaneously produced plus the multiparticle production occurring via an intermediate step. The intermediate system or the produced fast particles may collide with one or more target nucleons before decaying. The struck nucleon recoils and may leave the target nucleus. Thus, the hadron-nucleus or the nucleus-nucleus interaction can be viewed as a cascade of hadron-nucleon collisions. Finally the fragmentation of the target nucleus occurs, via an evaporation process. The study of the multiplicity and the angular characteristics of the emitted particles in the nucleus-nucleus collisions and the correlation between them may shed light on the mechanism of the interaction (El-Naghy et al. ,1995 and Krasznovszky , Can .J. ,1998). Many theoretical models (Bialas et al. ,1976 and Cugnon 1997) have been proposed to account for the high-energy hadron or nucleus-nucleus interactions. The present work deals with the study of the multiplicity characteristics of the different secondary particles emitted from the interaction of different projectiles at 4.1 and 4.5 A GeV/c and the multiplicity correlations between these particles. A comparison between the experimental data and the corresponding theoretical ones calculated according to the modified cascade evaporation model (MCEM) was done (Musulmanbekov,1992).

2 Experimental Techniques:

Nuclear emulsion stacks of the type Br-2 were exposed to different projectiles (4.1 A GeV/c ^{22}Ne and 4.5 A GeV/c ^{12}C and ^{28}Si beams) at the Dubna Synchrophasotron. The pellicles have dimensions of 20 cm x 10 cm x 600 μm (undeveloped emulsion) . The beam flux was about 10^4 particles / cm^2 and its diameter was about one centimeter. Along the track scanning was carried out. All charged secondary particles have been classified, according to the velocity $\beta = v/c$, the range L in the emulsion and the relative ionization $I^* = I/I_o$ where I is the particle track ionization and I_o is that for a singly charged relativistic shower track in the narrow forward cone of an opening angle $\theta \leq 3^o$ (El-Naghy et al. ,1994). The groups of particles are shower (s) particles having $I^* \leq 1.4$ ($\beta \geq 0.7$),grey (g) particles, having $I^* > 1.4$ having $L \leq 3$ mm ($\beta < 0.3$) , these are slow nucleons and nuclear target fragments.

i.e.$(0.3 \leq \beta < 0.7)$ and L > 3 mm. These are charged recoil nucleons . Black (b) particles, having $L \leq 3$ mm (β< 0.3) , these are slow nucleons and nuclear target fragments.The sum of b and g particles is called heavily ionizing tracks producing particles " h-particles". The determination of the momentum of s-particles emitted within $\theta \leq 3^o$ enables the separation of produced pions from the non-interacting single-charged particle fragment . The grey particles emitted within $\theta \leq 3^o$ and having L>2 cm are considered to be projectile fragments having Z=2 . The b-particles of $\theta \leq 3^o$ and L>1 cm are due to projectile fragments having $Z \geq 3$. Thus all the particles have been adequately divided into projectile fragments ; target fragments and the generated shower particles (El-Naghy et al., 1994).

3 Results and Discussion:

Table (1): The experimental average values $<n_s>$, $<n_g>$, and $<n_b>$, for the interactions of ^{12}C, ^{22}Ne,and ^{28}Si with emulsion nuclei .The values between parentheses are due to MCEM .

	$<n_s>$	$<n_g>$	$<n_b>$	Ref.
Si^{28}	11.8 ± 0.3	6.4 ± 0.2	4.8 ± 1.0	El-Naghy A. ,1995
	11.8 ± 0.34	6.4 ± 0.23	4.4 ± 0.12	Present work
	(16.7 ± 0.5)	(6.1 ± 0.4)	(5.5 ± 0.2)	,, ,,
Ne^{22}	10.5 ± 0.1	6.3 ± 0.4	4.2 ± 0.3	Andreeva ,1987
	10.3 ± 0.3	6.2 ± 0.23	4.2 ± 0.12	Present work
	(10.2 ± 0.1)	(6.9 ± 0.1)	(4.3 ± 0.1)	,, ,,
O^{16}	10.5 ± 0.6	7.6 ± 0.6	4.9 ± 0.3	Antonchik,1984,
	9.6 ± 0.25	5.8 ± 0.21	4.3 ± 0.12	Present work
	(10.8 ± 0.1)	(7.7 ± 0.2)	(4.5 ± 0.1)	,, ,,
C^{12}	7.7 ± 0.2	6.1 ± 0.3	4.4 ± 0.2	El-Naghy, 1980
	8.0 ± 0.2	5.1 ± 0.18	4.6 ± 0.13	Present work
	(8.3 ± 0.1)	(7.3 ± 0.2)	(4.6 ± 0.1)	,, ,,
He^4	3.8 ± 0.1	4.4 ± 0.2	4.3 ± 0.3	Adamovich,1977
	3.8 ± 0.08	4.4 ± 0.15	4.4 ± 0.13	Present work
	(4.9 ± 0.1)	(5.4 ± 0.1)	(5.6 ± 0.1)	,, ,,

The experimental (EXP) values for the average multiplicities $<n_s>$, $<n_g>$, and $<n_b>$, for s, g, and b-particles for the interactions of different projectiles (4.1 A GeV/c ^{22}Ne and 4.5 A GeV/c ^{12}C and ^{28}Si) with emulsion and the orresponding values calculated according to MCEM are presented in the table. From this table, it can be seen that, the average multiplicity for s-particles, $<n_s>$, for both EXP and MCEM data increase with the mass number of the projectile, A_p, while for g-particles both EXP and MCEM data increase with A_p up to certain value (A_p= 16), then $<n_g>$ saturates (for ^{22}Ne and ^{28}Si) . The values of $<n_b>$ are approximately constant (within errors) for all projectiles either for EXP or MCEM data. The calculated values of $<n_s>$, $<n_g>$, and $<n_b>$ are onsistent with the corresponding EXP values (within errors) expect the values of $<n_s>$ for ^{28}Si ,the values of $<n_g>$ for low A_p (^4He, ^{12}C, and ^{16}O), and $<n_b>$ for ^4He and ^{28}Si.Figure (1) shows the K.N.O. scaled (Koba et al. , 1972) multiplicity distributions of shower particles $\Psi(Z_s)$ (= $< n_s >$. n_s / N_t) as a function of the scaled variable $Z_s = n_s / <n_s>$, where N (n_s) is the number of events at a certain value of n_s and N_t is the total number of events for each interaction (4.1 A GeV/c ^{22}Ne and 4.5 A GeV/c ^{12}C and ^{28}Si with emulsion). From this figure one can notice that the experimental points obey (within the experimental errors) the K.N.O. scaling function given by the following formula

$$\Psi(Z_s) = (2.52 Z + 3.09 Z^3 \quad 0.9 Z^5 + 1.04 Z^7) e^{-4.08 Z} \qquad (1)$$

which is represented by the solid curve. As the grey particles are emitted shortly after the passage of the leading hadron, it is worthy to use the compound multiplicity, n_c, of grey and shower particles, $n_c = n_s + n_g$. This variable is used to study the particle production mechanism. Figure (2) represents the K.N.O. scaled compound multiplicity distributions for the previously mentioned interactions . It is noticed that the experimental data points are fitted by the solid curve given by the following formula:

$$\Psi(Z_c) = (2.52 Z_c + 3.09 Z_c^3 \quad 2.5 Z_c^5 + 1.0 Z_c^7) e^{-4.08 Z} \qquad (2)$$

Figures (1) and(2) show that the n_s and n_c distributions are independent on the energy available in the center of mass system within the given energy range. Figure (3a, b) show the dependence of $<n_s>$ and $<n_b>$ on n_g for the previously mentioned interactions together with the theoretical correlations calculated according to MCEM. The experimental data show strong correlations between $<n_s>$ and n_g, also between $<n_b>$ and n_g. The agreement between the experimental data and the corresponding calculated ones in Figure (3a) is more pronounced than that in Figure (3b). This may be due to the relatively long time lagging the evaporation process from the cascade stage of the interaction.

4 Conclusions

From the present study of the interactions of ^{12}C, ^{22}Ne and ^{28}Si with emulsion at nearly the same momentum, it may be concluded that the average values of shower, grey and black particles are in fair agreement with the corresponding values calculated according to the MECM. Also both the n_s and n_c distributions obey the K.N.O. scaling. The study of the multiplicity correlation has shown that both n_s and n_b are strongly correlated with n_g and these correlations agree qualitatively with the MCEM ones.

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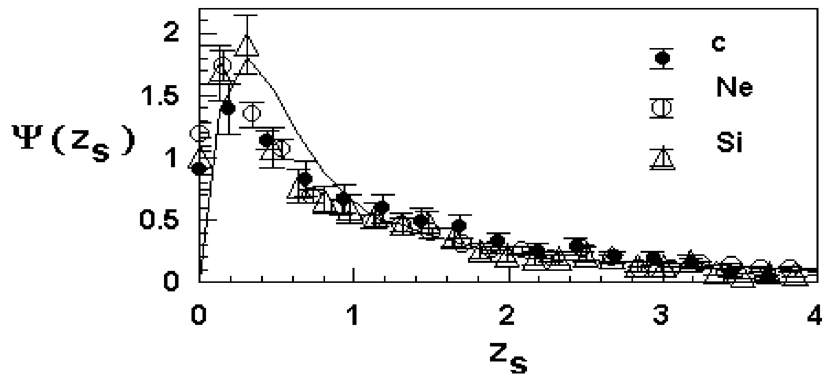

Figure (1) : The K.N.O. scaled shower particles multiplicity distributions $\Psi(Z)$ as a function of the scaled variable Z for the interactions of 4.1 A GeV/c ^{22}Ne and 4.5 A GeV/c ^{12}C and ^{28}Si with emulsion . The solid curve represents the best fit giving by the formula (1)

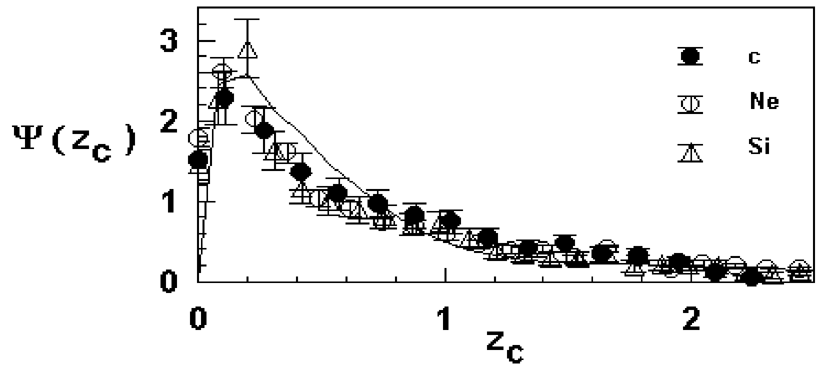

Figure (2) : The K.N.O. scaled shower particles multiplicity distributions $\Psi(Z)$ as a function of the scaled variable Z for the interactions in fig.(1) The solid curve represents the best fit giving by the formula (2)

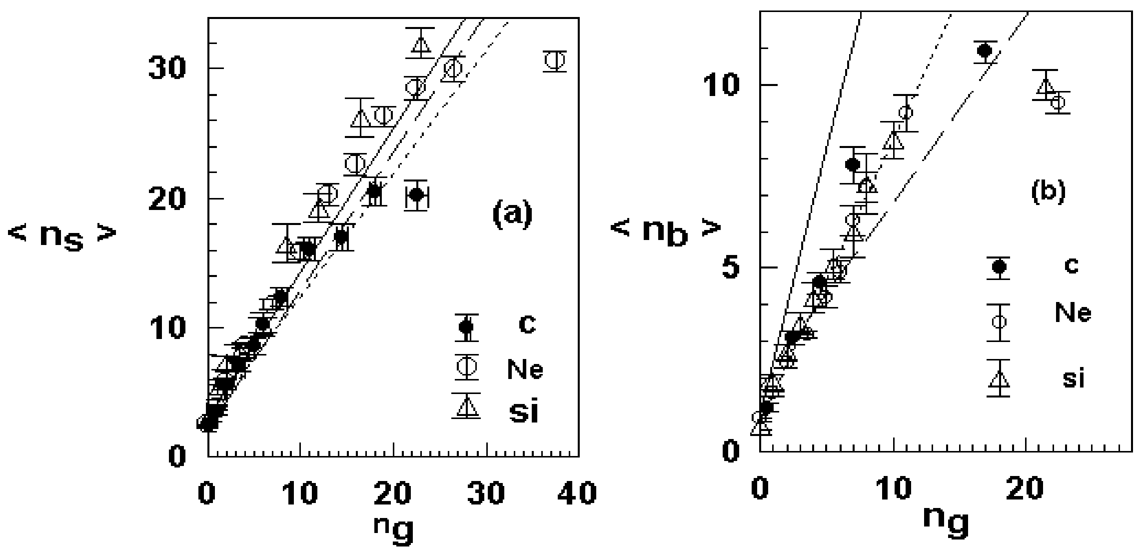

Figure (3) : Multiplicity correlations of : (a) <ns>,and (b) <nb> both as a function of a ng for ^{12}c , ^{22}Ne, ^{28}Si