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Complete Destruction of Ag Br Emulsion Nuclei BY^{28}Si Ions with 4.5 GeV/Nucleon Energy

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Abstract

The main experimental characteristics (multiplicity characteristics) of secondary particles have been investigated in interactions of ^{28}Si with emulsion at 4.5 GeV/c per nucleon at rest of emulsion, nuclei. The complete destruction of the heavy target nuclei (Ag, Br) has been studied. The average of shower particles $<n_s>$ is weakly dependent on the target mass whereas the average multiplicity of grey particles $<n_g>$ is strongly dependent on it. The correlations between the multiplicities of the charged secondaries at different mass number of the projectile and center-of-mass-available energy are investigated.

Keywords

Multiplicity Characteristics, Probability and Energy Available

1. Introduction

The study of the phenomena of complete destruction of heavy target nuclei is very interesting. This interest stems from the fact that most of these interactions are due to central collisions. The central collisions provide a unique opportunity to investigate the consequences of nuclear compression, such as hydrodynamic effects [1]-[4]. In addition, there is a good possibility to obtain valuable information on the excitation and consequent decay of residual target nucleus. A detailed and systematic study of this phenomenon was carried out in [5]. In this work the criterion $n_h \geq 28$, since [$n_h = (n_g + n_b)$ gray particles and black particles] was used to select events of complete destruction of (Ag, Br) nuclei. Nowadays, there are huge amounts of data concerning the study of this phenomenon. Different beam nuclei at various energies have been used in the experiments. There are two main directions for the interpretation of the experimental results of complete destructions. The first direction

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considers such events as a tail in the multiplicity distribution which can be accounted for by the cascade evaporation process inside the target nucleus. The second one implies a one-step like process which occurs due to the collectivity of the target nucleons together. In the present work, we study complete destruction $n_h \geq 28$ of (Ag, Br) emulsion nuclei induced by 4.5 A GeV/c ^{28}Si nuclei. The average multiplicities of the different emitted charged particles have been compared with the corresponding experimental values obtained from the interactions of different types of nuclei with emulsion at the same incident momentum per nucleon. The energy available in the centre of mass system for the complete destruction of the target nucleus has been studied for different projectiles. The multiplicity correlations between the charged secondaries produced in these interactions and both the mass number of the projectile and the available energy have also been analyzed. The previous detailed analysis [6] has shown that the selection criterion $n_h \geq 28$ corresponds to the complete destruction of the target nucleus, nearly, into individual nucleons and light fragments leaving no measurable residual nucleus.

2. Experimental Techniques

Nuclear emulsions of the type BR-2 were exposed to 4.5 A GeV/c ^{28}Si beams at the Dubnasynchrophasotron. The pellicles of emulsion have the dimensions of 20 cm × 10 cm × 600 µm (undeveloped emulsion). The intensity of the beam was ~10^4 particles/cm^2 and the beam diameter was approximately 1 cm. Along the track, a double scanning has been carried out fast in the forward direction and slow in the backward one. In the measured interactions, all the charged secondary particles have been classified according to the range L in the emulsion and the relative ionization $g^* = g/g_0$, where g is the particle track ionization and g_0 is the ionization of a relativistic shower track in the narrow forward cone of an polar angle $\theta \leq 3^\circ$, (the polar angle θ of each track, *i.e.* the space angle between the direction of the beam and that of the given tracks) into the following groups:

1) Shower tracks of produced particles, "s-particles"; have a relative ionization $g^* \leq 1.4$; these tracks have an emission angle $\theta \leq 3^\circ$; they have been further subjected to multiple scattering measurements for momentum determination in order to separate the produced pions from the single charged projectile fragments. 2) Grey tracks of produced particles, "g-particles", having a relative ionization ($1.4 \leq g^* < 10$) and $L > 3$ mm. 3) Black tracks of produced particles, "b-particles", having $L \leq 3$ mm. 4) The b and g tracks, taking together, are both called heavily ionizing particles, "h-particles".

3. The Multiplicity Characteristics

To investigate the dependence of the average multiplicity $\langle n_s \rangle$ and $\langle n_g \rangle$ on the mass number of the beam nucleus A_p, we consider the reactions listed in **Table 1**.

In these reactions, the momentum per incident nucleon is constant and it equals 4.5 GeV/c. The experiments were carried out under the same conditions. **Figure 1(a)** and **Figure 1(b)** show the dependence of the average multiplicities $\langle n_s \rangle$ and $\langle n_g \rangle$ on the mass number of the beam nucleus A_p. The points are the experimental data while the continuous lines are the result of fitting by the relation

$$\langle n_i \rangle = a_i A_p^{\alpha_i} \quad (1)$$

where i = s or g. The values of the coefficients α_i are 0.39 ± 0.05 and 0.18 ± 0.01 and a_i are 2.21 ± 0.66 and

Table 1. The average multiplicities $\langle n_s \rangle$ and $\langle n_g \rangle$ of shower and grey tracks produced in the reactions of different projectiles with emulsion at 4.5 A GeV/c.

Projectile	$\langle n_s \rangle$	$\langle n_g \rangle$	Ref
^{1}H	1.6 ± 0.1	2.8 ± 0.1	[7]
^{2}H	2.5 ± 0.1	3.9 ± 0.1	[8]
^{3}H	3.6 ± 0.1	3.1 ± 0.1	[9]
^{4}He	3.8 ± 0.1	4.4 ± 0.1	[7]
^{12}C	7.6 ± 0.2	5.9 ± 0.3	[7]
^{16}O	10.5 ± 0.6	7.6 ± 0.6	[10]
^{28}Si	11.9 ± 0.5	7.3 ± 0.3	Present work

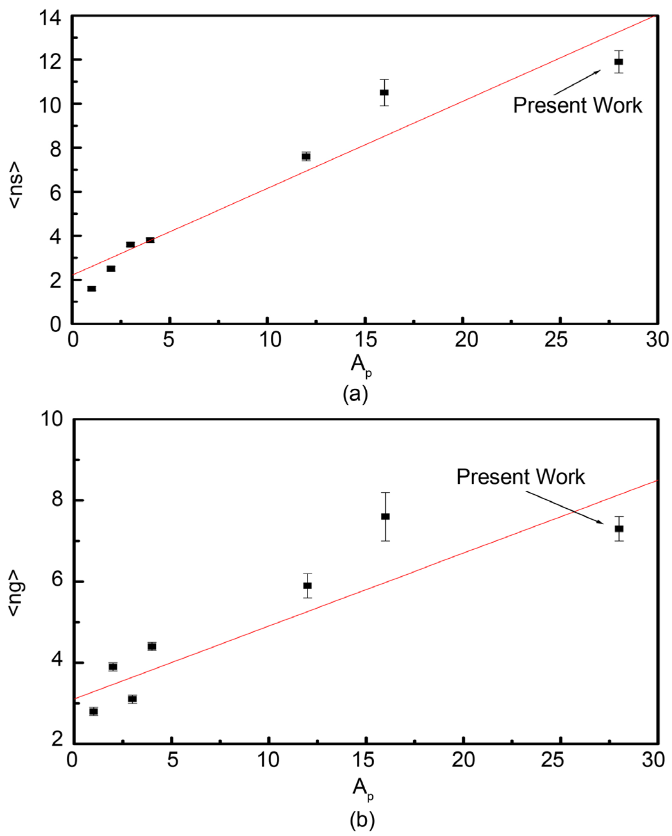

Figure 1. Projectile mass number for different elements at 4.5 GeV/c per Nucleon: (a) versus $<n_s>$ and (b) versus $<n_g>$ plots.

3.11 ± 0.06 for shower and grey particles respectively. This result agrees with the fact that the interaction cross section is proportional to $A_p^{2/3}$ and is proportional to $A_p^{1/3}$ from $<n_s>$ and $<n_g>$.

4. Probability of Complete Destruction of Target Nuclei

In the present work, the probability of complete destruction of (Ag, Br) emulsion nuclei p is defined as the ratio between the number of events of $n_h \geq 28$ to the total number of inelastic interactions of the incident particle with (Ag, Br) nuclei. **Figure 2** illustrates the dependence of the probability p on A_p for various projectile nuclei, all at 4.5 A GeV/c. It is seen that the probability p increases linearly with $A_p^{2/3}$ up to the carbon nucleus. The values of the probability p, predicted by the cascade evaporation model [8], are larger than the corresponding experimental values. Moreover, the behavior of probability p versus A_p in the present experiment does not agree with the calculations of the cascade evaporation model.

5. Energy Available

For the events having $n_h \geq 28$, and implying the complete destruction of the target nuclei, the relation between $<n_s>$ and the energy available E_{av} in the centre of mass system is shown in **Figure 3**. The value of E_{av} is given by:

$$E_{av} = \left(M_p^2 + M_t^2 + 2M_t E_p\right)^{\frac{1}{2}} - \left(M_t + M_p\right), \quad (2)$$

where M_p, is the projectile rest mass in GeV and $E_p = \left(p_0^2 + M_p^2\right)^{\frac{1}{2}}$ where p_0 is the projectile momentum in GeV/c. The effective target mass M_t is equal to $\frac{3}{2}\left(A_p^{\frac{2}{3}} A_t^{\frac{1}{3}}\right)m$, where m = 0.931 GeV. The relation between $<n_s>$

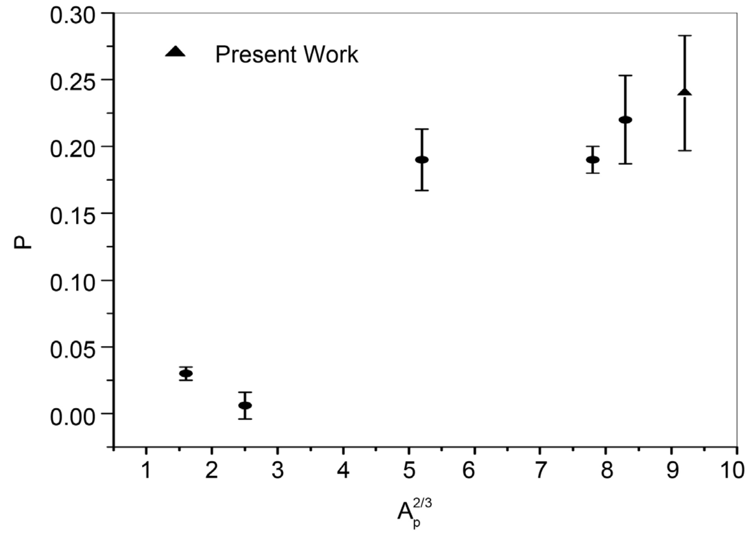

Figure 2. The probability, p, of complete destruction of (Ag, Br) nuclei due to the interactions of different projectile at 4.5 GeV/c per nucleon.

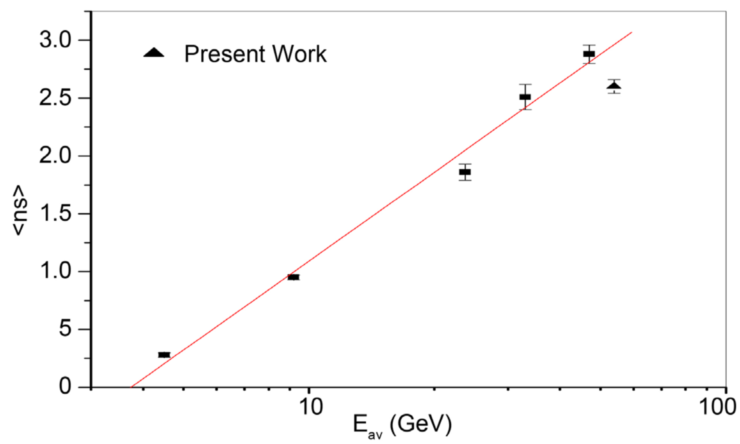

Figure 3. The average multiplicity of shower particles $\langle n_s \rangle$ versus the energy in available c.m.s. for different projectile mass numbers having momentum 4.5 GeV/c per nucleon . for the collisions characterized by $n_h \geq 28$.

and the energy available in the centre of mass system, E_{av}, for different projectiles at the same incident momentum, which shows that as the projectile mass number increases, E_{av} increases and consequently $\langle n_s \rangle$ increases. The dependence of $\langle n_s \rangle$ on E_{av}, shown in **Figure 3**, can be fitted by the universal relation:

$$\langle n_s \rangle = A + B \ln(E_{av}) \tag{3}$$

with $A = -13.09$ and $B = 11.46$.

6. Multiplicity Correlation in Complete Destruction of ^{28}Si Ions

In the present work, we studied the correlation of complete destruction ($n_h \geq 28$) of (Ag, Br) emulsion nuclei induced by 4.5 A GeV/c ^{28}Si nuclei. The probability of complete destruction of AgBr nuclei different projectile at various energies is shown in [11]. The correlation in complete destruction dependencies between the charge particle multiplicities allows us to discuss the mechanism of nucleus-nucleus interactions. The dependencies $\langle ng \rangle = f(n_s)$ and $\langle n_s \rangle = f(n_g)$ for the event with $n_h \geq 28$ accompanied by total target disintegration are presented in **Figure 4** and **Table 2**. In this case there is no strong dependence of $\langle n_g \rangle$ on the value of ns or of $\langle n_s \rangle$ on the value of n_g. This can be seen from the value of χ^2 for each type of particle. This means that the degree of

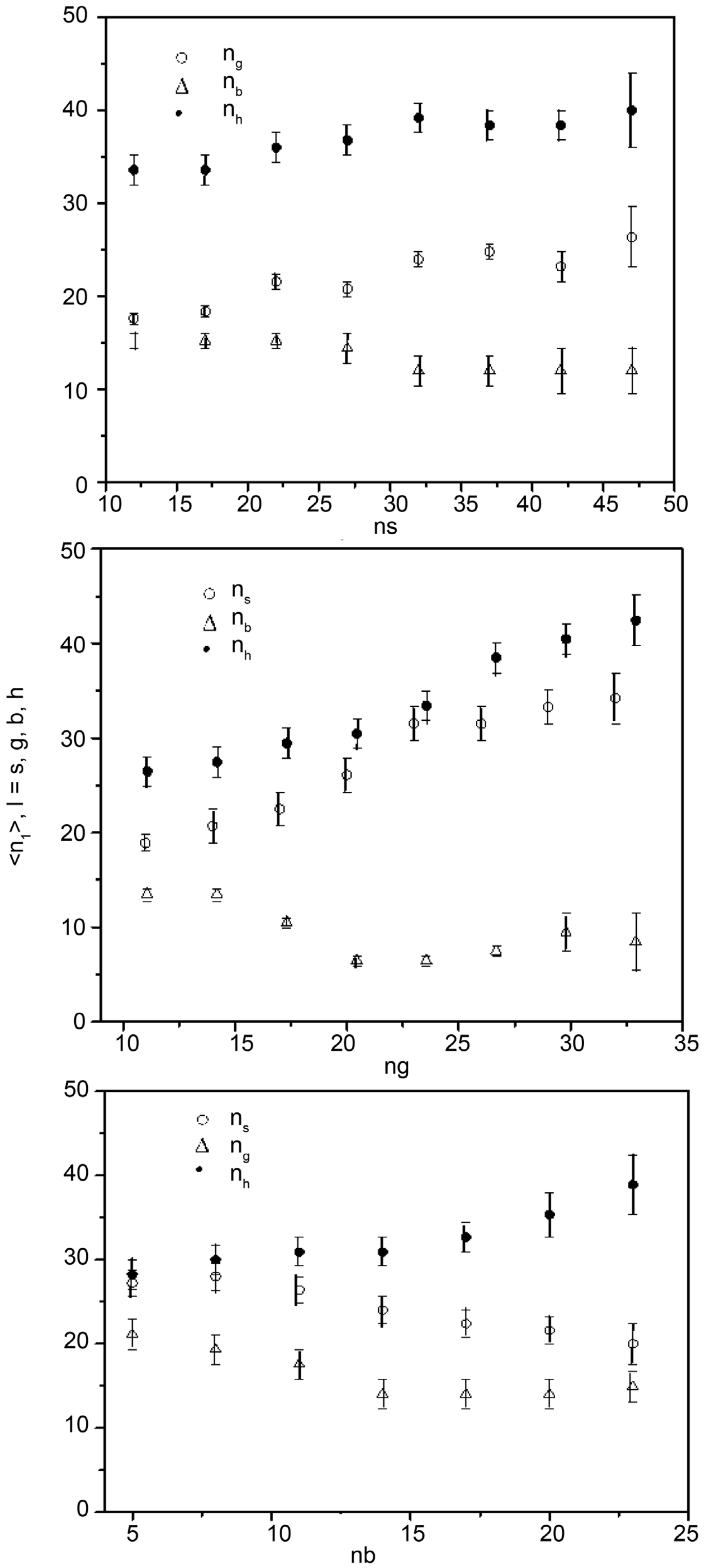

Figure 4. The correlations between the secondary particles multiplicities for complete destructions (events with $n_h > 28$) in Si^{28} interactions with emulsions.

Table 2. Results of approximate fit of the experimental data for the multiplicity correlation from complete destruction in ^{28}Si ions interactions with emulsion using the dependence $\langle n_i \rangle = a + kn_j$.

	$\langle n_s \rangle$	x^2	$\langle n_g \rangle$	x^2	$\langle n_b \rangle$	x^2	$\langle n_h \rangle$	x^2
n_s	…	…	14.02 ± 0.23	0.87	-15.60 ± 0.07	0.56	29.65 ± 0.16	0.95
n_g	10.42 ± 0.76	0.96	…	…	19.60 ± 0.25	0.65	20.30 ± 0.69	0.95
n_b	-33.10 ± 0.54	0.94	14.02 ± 0.23	0.84	…	…	27.09 ± 0.58	0.87

disintegration of the target does not depend strongly on the number of shower particles. One can observe the correlation between the fast and the slow stages of the inelastic interactions of tow nuclei by studying the dependencies $\langle n_b \rangle = f(n_s)$, $\langle n_b \rangle = f(n_g)$ and (n_s), (n_g) on the (n_b). From **Figure 4**, one can see that the correlations have a different character. This can be seen from the fast that the $\langle n_b \rangle$ dependencies on n_s and n_g have negative slopes. Also, from the correlation dependencies of $\langle n_s \rangle$, $\langle n_g \rangle$ and $\langle n_h \rangle$ on n_b, one can see that the slope of $\langle n_h \rangle$ is positive while the slopes of others are negative. From the above results, one can see that $\langle n_b \rangle$ has a negative correlation with n_s and n_g and the correlation of $\langle n_s \rangle$ and $\langle n_g \rangle$ with the n_b is negative. This may be due to increase the number of interacting projectile nucleons as the impact parameter decreases.

7. Conclusion

From the present study, one may concluded that the average number of the shower particles is proportional to $A_p^{2/3}$ and the average number of grey particles is proportional to $A_p^{1/3}$. While that the probability of the complete destruction increases with increasing projectile mass number A_p, and the average multiplicity of the emitted shower particles depends strongly on the projectile mass number, while does not for the grey and black can be particles. A good correlation between the energy available at the center of mass system, E_{av}, and the average multiplicity of the shower particles emitted in the complete destruction is found.

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