Total disintegration of Ag and Br nuclei by 4.5 A GeV/c silicon nuclei

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Complete disintegrations of Ag and Br nuclei caused by a 4.5 A GeV/c ^{28}Si projectile have been analyzed to study the characteristics of the collisions with small impact parameters. The results are systematically compared with their corresponding values obtained for the interactions with comparatively larger impact parameters at the same beam momentum per nucleon. The variations of the mean multiplicity of the relativistic charged particles with the mean number of the interacting nucleons of the projectile nuclei and the normalized pseudorapidity density have also been examined.

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I. INTRODUCTION

There has been a great spurt of interest in the study of the characteristics of interactions caused by relativistic nuclei, especially interactions with small impact parameters, the so-called central collisions. This is primarily due to the possibility of studying the effects of multinucleon interactions, collective properties of nuclear matter, and its possible transitions to the quark-gluon phase.

In central collisions of nuclei with energy close to 4 GeV/nucleon, an increase in the density of the nuclear matter close to more than twice the equilibrium density of nucleons ($\rho=0.16$ fm^{-3}) may occur, and this effect is envisaged to be accompanied by an appreciable excitation of nuclear matter [1]. In such interactions, collective processes of statistical nature are expected to occur; these processes lead to thermodynamic equilibrium of nucleons. A study of the properties of nuclear matter in such extreme conditions is possible on the basis of investigation of the characteristics of particle spectra and of particle yields in the complete disintegration of Ag and Br nuclei and inclusive interactions.

The main objective of this paper is to investigate the differences in the mechanism of multiparticle production in complete disintegration of Ag and Br nuclei and inclusive collisions caused by silicon nuclei with momentum 4.5 A GeV/c ($N_h \leq 27$, where N_h represents the number of particles in an interaction emitted with relative velocity $\beta \leq 0.7$). In order to address this problem adequately, multiplicity distributions of the relativistic charged particles, angular distributions, and the relative pseudorapidity densities in different rapidity regions are investigated.

II. EXPERIMENTAL DETAILS

Experimental data included in the present investigation have been obtained by scanning NIKFI-BR2 nuclear photoemulsion plates of dimensions $(16.9\times9.6\times0.06)$ cm^3 irradiated by a 4.5 A GeV/c ^{28}Si beam at the Dubna Synchrophasotron. Events were collected by the method of along-the-track scanning in the beam direction. A total of 1024 interactions with $N_h \geq 0$ were selected randomly for the present study. The general characteristics of these events have already been presented in our earlier publications [2–4].

Secondary particles are generally divided into three usual categories: namely, singly charged shower ($\beta>0.7$), gray ($0.3\leq\beta\leq0.7$), and black ($\beta<0.3$) particles; their numbers in an interaction are denoted by N_s, N_g, and N_b, respectively. The shower tracks correspond to relativistic charged particles, whereas gray and black tracks are produced by comparatively slower particles emitted from the target nuclei. Gray tracks are mostly recoil protons with momenta lying in the interval $\sim$0.2–1.0 GeV/c, with less than a few percent admixture of low momenta pions. The black tracks are due to slow particles and evaporated fragments. The sum of gray and black tracks in an interaction is represented by N_h $(=N_g+N_b)$ referred to as heavy tracks.

III. EXPERIMENTAL RESULTS

Several workers [5–8] have suggested that events with at least 28 heavily ionizing particles, i.e., $N_h \geq 28$, corresponding to a total charge close to the average charge of Ag and Br ($\bar{Z}=41$), may be classified as events of the total disintegration of Ag and Br nuclei. It may be mentioned that one of the important characteristics of the total disintegration of Ag and Br nuclei is the probability W, defined as the ratio of the number of interactions with $N_h \geq 28$ and the total number of events involving Ag and Br nuclei.

The probability of total disintegration of Ag and Br nuclei caused by 4.5 A GeV/c silicon nuclei is plotted in Fig. 1 as a function of projectile mass (A_p). These results are compared with the total disintegration events produced by other lighter projectiles at the same beam momentum per nucleon. It is seen that the probability of total disintegrations of Ag and Br nuclei grows with increasing mass of the projectile nuclei. It may be of in-

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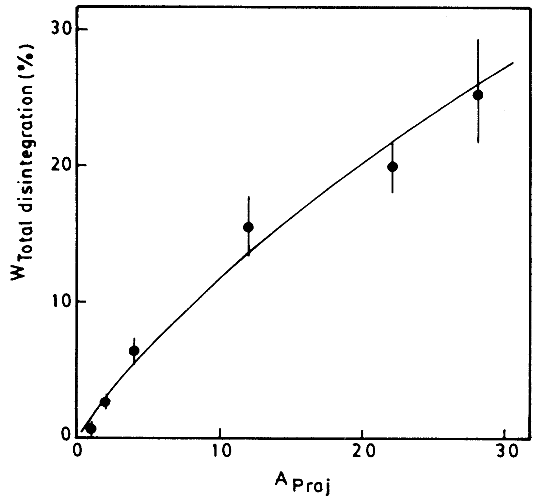

FIG. 1. Probability distributions for totally disintegrated events as a function of projectile mass.

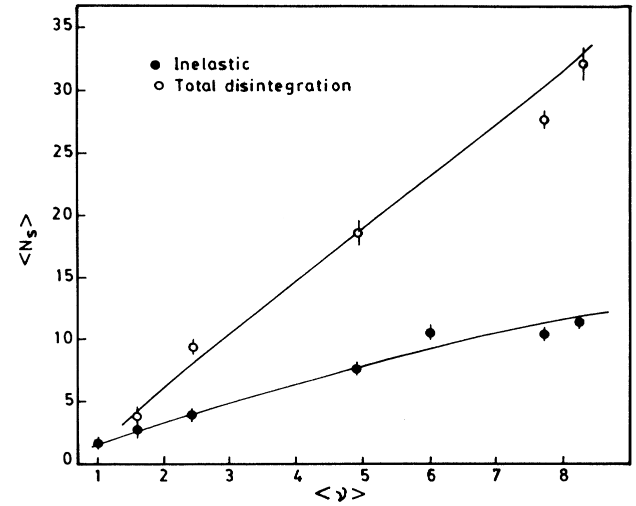

FIG. 3. Variation of $\langle N_s \rangle$ with $\langle \nu \rangle$.

terest to mention that the solid line in the figure can be represented by the expression

$$W(A_p)=\beta A^{\alpha} . \tag{1}$$

The best-fitting values of α and β are 0.82 ± 0.05 and 1.99 ± 0.27, respectively.

A. Multiplicity distribution of shower particles

Multiplicity distribution of relativistic charged particles produced in the case of total disintegrations of Ag and Br nuclei by the $4.5A$ GeV/c silicon nuclei are shown in Fig. 2. This distribution is compared with the corresponding distribution for the events (inclusive) having $N_h \leq 27$ caused by the same projectile. It is observed that the distribution tends to become relatively wider due to catastrophic destruction of heavy nuclei. It may be noted that a comparatively higher value of N_s might arise as a consequence of the low value of the impact parameter.

Variation of the mean multiplicity of relativistic charged particles for the total disintegration events with the mean number of intranuclear collisions, $\langle \nu \rangle$, is exhibited in Fig. 3. The value of $\langle \nu \rangle$ is calculated using a phenomenological formula as reported in Ref. [9]:

$$\langle \nu \rangle = 0.73 A_p^{0.72} , \tag{2}$$

where A_p is the projectile mass. Variation of $\langle N_s \rangle$ with $\langle \nu \rangle$ for inelastic interactions is also plotted in this figure.

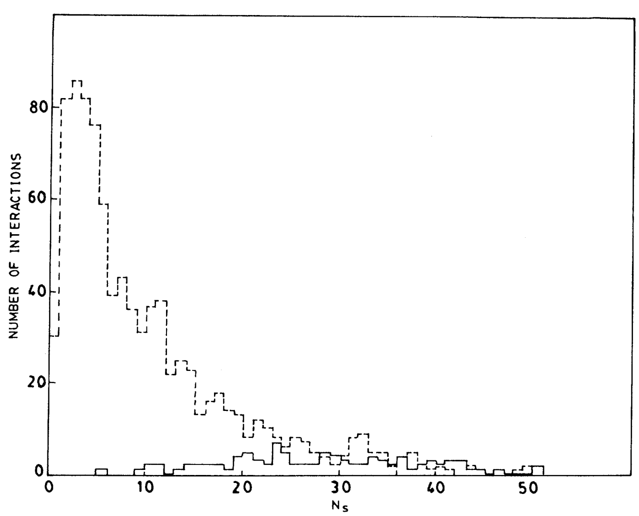

FIG. 2. Multiplicity distrubtion shower tracks for the totally disintegrated collisions (——) and inclusive collisions (— — —).

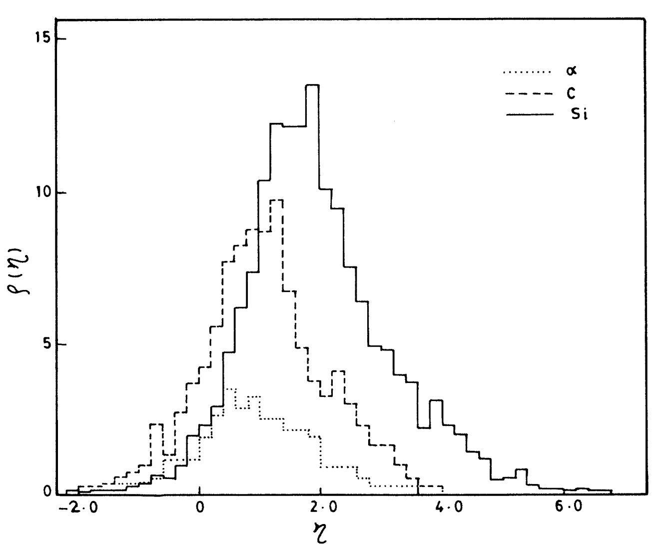

FIG. 4. Pseudorapidity distributions of shower particles produced in totally disintegrated events for different projectiles at $4.5A$ GeV/c.

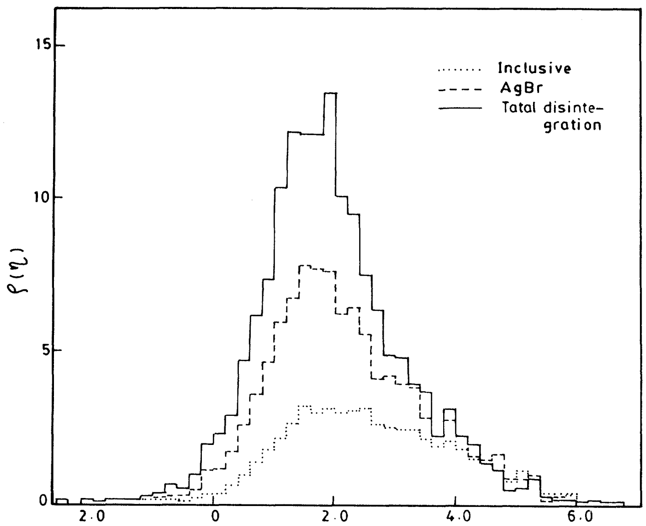

FIG. 5. Pseudorapidity distributions of shower particles produced in ^{28}Si-emulsion interactions for different impact parameters.

In this figure it is noticed that the total disintegration events are characterized by a rapid growth of $\langle N_s \rangle$ as compared to the corresponding values for the total ensemble of inelastic interactions. This behavior may be explained in terms of the predictions of the superposition model [10].

B. Pseudorapidity distribution of relativistic charged particles

The angular distribution of relativistic charged particles has been examined in terms of the pseudorapidity variable η, which is defined as $\eta = -\ln \tan\theta/2$, where θ is the emission angle of a relativistic charged particle in the laboratory frame.

Pseudorapidity density distributions of relativistic charged particles produced in totally disintegrated nuclei for different projectiles at 4.5A GeV/c are displayed in Fig. 4. With increasing projectile mass, the distribution is observed to become relatively broader. Furthermore, the peaks of the η spectra tend to shift toward higher values of η with increasing projectile mass.

Figure 5 shows the pseudorapidity density distribution of shower particles for different impact parameters (N_h bins), viz., $N_h \le 7$, $N_h \le 27$, and $N_h \ge 28$. It is observed that with increasing N_h (decreasing impact parameter), the average multiplicity of shower particles per η bin increases in the target ($\eta \le 1$) as well as the central ($1 < \eta \le 4$) fragmentation regions, whereas in the projectile ($\eta > 4$) fragmentation region the average multiplicity per η bin remains essentially constant.

In order to investigate these features thoroughly, we examine the behavior of the normalized pseudorapidity density $R(\eta)$, defined as

$$R(\eta) = \frac{\rho_x(\eta)}{\rho_{N_h=0,1}(\eta)} , \tag{3}$$

where $\rho(\eta) = (1/N)(dNs/d\eta)$ the shower particle density determined for a total of N interactions. The term $\rho_x(\eta)$ may denote the pseudorapidity density in either totally disintegrated events or inclusive collisions. The normalized pseudorapidity densities are exhibited in Fig. 6 for both totally disintegrated nuclei and inclusive silicon-emulsion interactions at 4.5A GeV/c. From this figure, it is noticed that the normalized pseudorapidity density is less than unity in the projectile fragmentation region for both types of collisions. In turn this would indicate that the additional particles created in consecutive intranuclear collisions carry away some of the energy of the projectile nucleus thereby reducing its momentum as compared to the peripheral collisions.

The mean normalized pseudorapidity density increases rapidly in the target fragmentation region. This behavior may be explained in terms of the fragmentation zone hypothesis, which envisages that some more time is needed

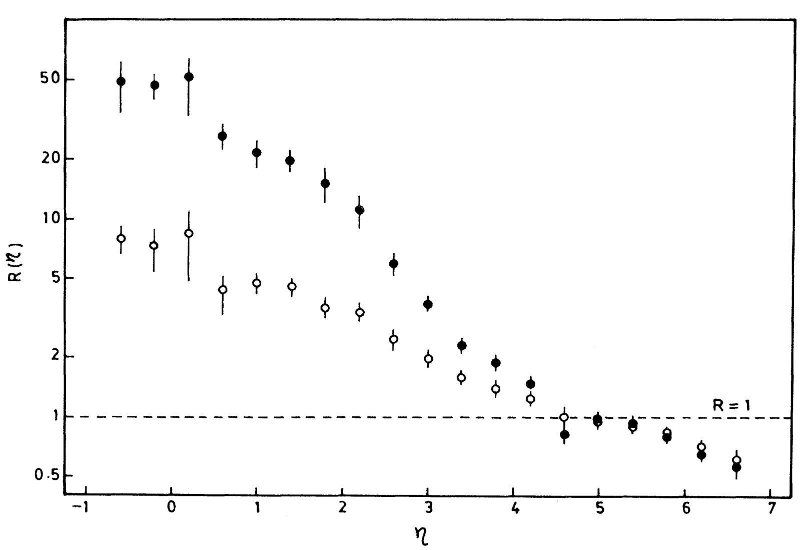

FIG. 6. Normalized pseudorapidity denstied $R(\eta)$ for inclusive (○) and totally disintegrated (●) interactions.

for the creation of particles in its own rest frame of reference.

IV. CONCLUSIONS

The results obtained in the present study reveal that the probability of total disintegration of Ag and Br nuclei strongly depends on the projectile mass. The multiplicity distribution of relativistic charged particles becomes relatively broader for the total disintegration events. The average multiplicity of relativistic charged particles produced in total disintegration interactions increases rapidly. The angular distributions of relativistic charged particles depend strongly on the projectile mass. The normalized pseudorapidity density $R(\eta)$ exhibits a similar variation with η throughout the pseudorapidity range for both inclusive and total disintegration events. The observed high values of normalized shower particle densities in the target fragmentation region can be explained in terms of the occurrence of some cascading effect inside the target nucleus due to secondary interactions of low-energy pions produced in this η region.

[1] A. S. Goldhaber and H. H. Heckman, Annu. Rev. Nucl. Part. Sci. **28**, 161 (1978).
[2] Tauseef Ahmad and M. Irfan, Phys. Rev. C **44**, 1555 (1991).
[3] Tauseef Ahmad and M. Irfan, Phys. Rev. C **46**, 1483 (1992).
[4] Tauseef Ahmad and M. Irfan, Nuovo Cimento (to be published).
[5] K. D. Tolstov, Joint Institute for Nuclear Research, Report No. P1-9286, Dubna, Russia, 1975 (unpublished).
[6] M. El-Nadi, A. T. Baranik, A. El-Naghy, N. Mettwali, O. E. Badawy, and S. Abd El-Halim, Z. Phys. A **310**, 301 (1983).
[7] Tauseef Ahmad, M. Tariq, M. Irfan, M. Zafar, M. Z. Ahsan, and M. Shafi, Can. J. Phys. **67**, 519 (1989).
[8] B. U. Ameera, Institute of High Energy Physics, Report No. 87-09, Alma-Ata, 1987 (unpublished).
[9] M. T. Ghoniem, A. El-Naghy, S. Saleh, and M. Mohery, J. Phys. Soc. Jpn. **61**, 827 (1992).
[10] A. Capella and J. Tran Than Van, Phys. Lett. **93B**, 146 (1980).