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Nuclear fragmentation at 4.5 A GeV/c in ^{28}Si with emulsion interactions

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ABSTRACT

The experimental results of complete charge distribution of projectile fragments (PFS) and the total charge of the projectile fragments (PFS) are presented. Also the multiplicity distributions of (PFS) and the rapidity distribution of shower tracks produced from events with n_h = 0 from ^{28}Si with emulsion at 4.5 A GeV/c are obtained.

Keywords: Multiplicity Distribution; Total Chare and Rapidity Distribution

1. INTRODUCTION

Nuclear fragmentation and its possible connection with a critical phenomenon of a phase transition has been the subject intensive theoretical and experimental investigation in the interaction of relativistic heavy nuclei nucleus collision [1,2] the overlapping region of nuclear volumes is called the participant region, where multiple productions of new particles occurs and the matter breaks up into nucleons. An estimate the degree of centrality of a collision of the nuclei can be made if we determine the total charge Q of the non interacting nucleons or fragments of the projectile nucleus, to which we assign the relativistic particles emitted at an angel $\theta < 3^\circ$ [3,4]. Then the number of interacting nucleons of the projectile nucleus is on the average $n_{int} = 28 - 2Q$ [5]. In the collision of two nuclei, the elementary interaction is more amplified than in the case of hadrons-nucleus interaction. At such high energy (4.5 A GeV/c) the rapidity gap between the projectile target fragmentation regions is quite wide, which provides us with a good possibility for testing the limiting fragmentation hypothesis [6,7] in playing that no correlations exist between the projectile and target fragments.

These results were obtained from the study of single partied inclusive experiments where the degree of target fragmentation can take any value. It is interesting to compare these results with those of projectile fragments angular distribution from the special class of events $n_h = 0$, where there is no target fragmentation but only a projectile fragmentation.

2. EXPERIMENTS

In our experiments, the layers of photo emulsions NIKFI-BR2, with dimensions of 20 cm × 10 cm × 600 μm were irradiated by the ^{28}Si beam from the synchophastron in the high energy laboratory of JINR, at Dubna with an average beam momentum of 4.5 A GeV/c. Along the track double scanning was carried out, fast in the forward direction and slow in the backward direction. The scanned beam tracks were further examined by measuring the delta electron density on each of them to exclude the tracks having the secondary particles is classified as follows:

1) Black particle tracks (n_b) having a range $L < 3$ mm in emulsion which corresponds to a proton kinetic energy of 26 MeV.

2) Grey particle tracks (n_g) relative ionization I^* ($= I/I_0$) < 1.4 and $L > 3$ mm which correspond to a proton kinetic energy of 26 - 400 MeV, where I is the particle track ionization and I_0 is the ionization of a shower track in the narrow forward cone of an opening angel of $\theta < 3^\circ$ (the b and g particle tracks are called heavy ionization particle tracks (n_h)).

3) Shower particle (n_s) having $I^* < 1.4$ (tracks of such type with an emission angel of $\theta < 3$ were further subjected to rigorous multiple scattering measurement for moment determination and consequently, for separating the produced pions and singly charged projectile fragments (protons, deuterons, tritons).

A total of 1000 interactions of ^{28}Si with the nuclei of the emulsion were observed by following a primary track length of 78.12 meters, which led to a mean free path of $\lambda = 8.71 \pm 0.30$ cm. In each event, the charge $Z \geq$

2 of individual projectile fragments were determined by the combination of several methods, which include grain and delta ray densities. More details on the charge determinations of projectile fragments are given in Reference [8]. Projectile fragments essentially travel with the same speed as that if the parent beam nucleus, so the energy of the produced projectile fragments as high enough to distinguish them easily from the target fragments.

3. THE TOTAL CHARGE OF THE PROJECTILE FRAGMENTS (PFS)

In the **Table 1** we have given the data obtained on the average multiplicities of h and s particles as functions of n_{int}. It can be seen that the number of thin prongs in a disintegration increases linearly with increase of n_{int}, and within experimental error this occurs in a completely identical way for the light and heavy emulsion components. This dependence of $< n_s >$ on Q is consistent with the model of independent interactions and indicates a decisive roll of the first interaction. In collisions of light nuclei the values of $< n_h >$ do not depend on n_{int}, while for heavy nuclei they rise almost linearly.

In **Figures 1(a)** and **(b)** we have shown the distribution in Q for events in standard emulsion, and also the distributions obtained by the different methods for three different groups of nuclei, normalized to the corresponding probability of inelastic interaction. It is evident that the distributions in Q depend substantially on the type of target nucleus. The average total charge for disintegration of an incident ^{28}Si nucleus in hydrogen, light and heavy emulsion nuclei were respectively 11.71 to 0.17, 9.62 ± 0.11 and 4.68 ± 0.16. Note that in **Figures 1(a)** and **(b)** in the light emulsion nuclei (H,C,O) there are practically no central interactions (Q = 0), collisions with the heavy component are characterized by a wide set of A values. Study of the dependence of the total charge of the spectator fragments on the impact parameter for events produced in heavy emulsion nuclei. **Figures 1(a)** and **(b)** show that for large impact parameters ($n_h \le 7$) this distribution is practically the same as the distribution in Q for hydrogen of the emulsion and for $8 \le n_h \le 15$ it is close the distribution for events in nuclei (C,N,O). For large n_h a dominance of central interactions is observed. In order to see the dependence of the number of interacting nucleons on the collision geometry, we have shown in **Figure 2** n_{int} as a function of n_h. This figure indicate that even in collisions where no, or very little

Table 1. Experimental dependence of average multiplicities $<n_h>$ and $<n_s>$ on the number of interacting nucleon and the parameter Q.

Q	n_{int}	target nucleus			
		CNO		AgBr	
		$<n_h>$	$<n_s>$	$<n_h>$	$<n_s>$
14	0	1.3 ± 1.9	1.0 ± 1.4	6.2 ± 0.6	1.0 ± 0.0
13	2	2.3 ± 2.2	2.5 ± 1.8	8.3 ± 0.5	3.0 ± 0.8
12	4	3.1 ± 2.4	3.4 ± 2.4	12.3 ± 3.9	5.8 ± 3.0
11	6	2.9 ± 2.4	4.1 ± 3.0	14.1 ± 4.7	5.6 ± 2.1
10	8	3.5 ± 2.4	5.9 ± 3.2	14.4 ± 4.8	6.4 ± 2.6
9	10	3.3 ± 2.3	6.4 ± 3.0	16.5 ± 6.7	8.8 ± 4.0
8	12	3.8 ± 2.2	8.2 ± 2.6	16.2 ± 6.7	10.4 ± 4.1
7	14	4.6 ± 1.9	10.0 ± 2.8	16.6 ± 7.4	13.3 ± 4.7
6	16	4.5 ± 1.8	12.3 ± 4.7	16.5 ± 7.4	13.8 ± 5.1
5	18	4.1 ± 2.1	12.6 ± 4.5	22.7 ± 8.8	16.5 ± 5.2
4	20	4.4 ± 1.5	11.4 ± 5.2	25.3 ± 9.2	19.7 ± 6.8
3	22	5.3 ± 1.3	17.7 ± 2.1	24.5 ± 9.4	22.0 ± 6.8
2	24	5.6 ± 1.0	17.6 ± 1.6	26.3 ± 9.7	22.7 ± 7.2
1	26			31.0 ± 6.9	26.6 ± 6.5
0	28			33.4 ± 7.6	32.2 ± 6.8

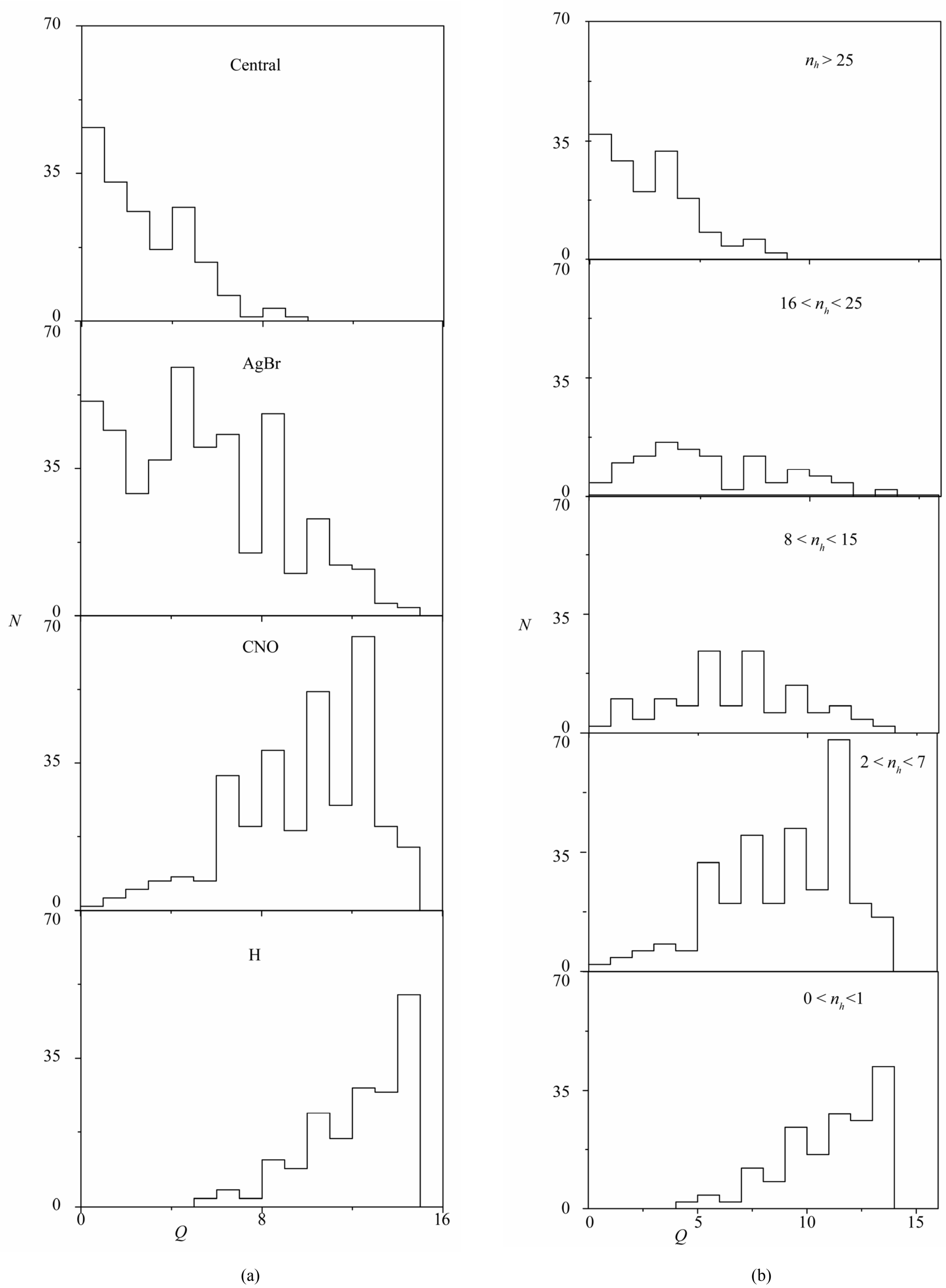


Figure 1. Distribution in total charge Q of fragments of the incident ^{28}Si nucleus with the groups of emulsion nuclei (a) and distribution in Q for events in nuclei (a) and distribution in Q for events in heavy nuclei (AgBr) with different numbers of h-particles (b). The dot. Dash histogram shows interactions in H, and the solid histogram in (CNO). The dashed histogram is in (AgBr) nuclei, and the doted histogram is for center emulsion.

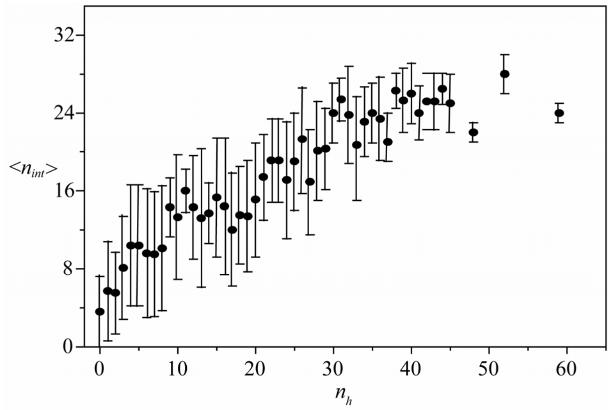


Figure 2. Variation of <n_{int}> with n_h.

excitation of the target occurs (*i.e.* $n_h = 0$ and 1).

Some of the nucleons of the projectile take part in the interactions. We also observe that the mean number of interacting projectile nucleons increases quickly as the value of n_h increases, as expected, but attains amore or less constant value for extreme central collisions.

4. MULTIPLICITY DISTRIBUTIONS OF PROJECTILE FRAGMENTS

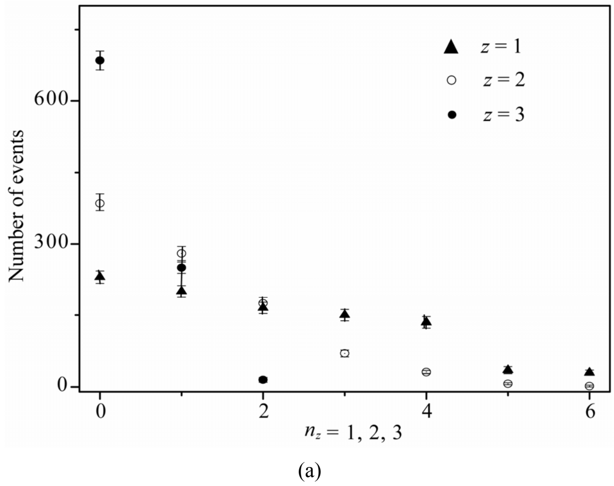
In this part 950 ^{28}Si inelastic interactions emulsion were measured, 856 events were observed to have emitted projectile fragments, 90% o the total events represent peripheral and quasi peripheral collisions. This percentage is about two times larger than the corresponding one in interaction of a- particle with emulsion 9(9) at the same energy per nucleon.The multiplicity distributions of the emitted charge projectile fragments are shown in **Figures 3(a)**, **(b)** for a class of events without target fragmentation as well as sample. It can be seen that there is no great difference between these distributions.

5. ANGULAR DISTRIBUTIONS OF PROJECTILE FRAGMENTS

Figure 4 represent the angular distribution of $Z = 1,2$ and Y3 projectil fragments, in terms of cosθ where θ is the space angle between the emitted projectile fragments and the beam direction. It can be seen clearly that the angular distribution becomes narrow with increase of fragment charge Z, in all these distributions there are pronounced peaks cos $\theta = 1$.

6. SOME FEATURES OF EVENTS WITH PROJECTILE FRAGMENTATION ONLY (n_h = 0)

In the 94 events satisfying the criteria $n_h = 0$ from our sample of 950 inelastic interactions, the projectile fragments are divided into $Z = 1, 2, 3, \cdots, 14$. We explicitly in



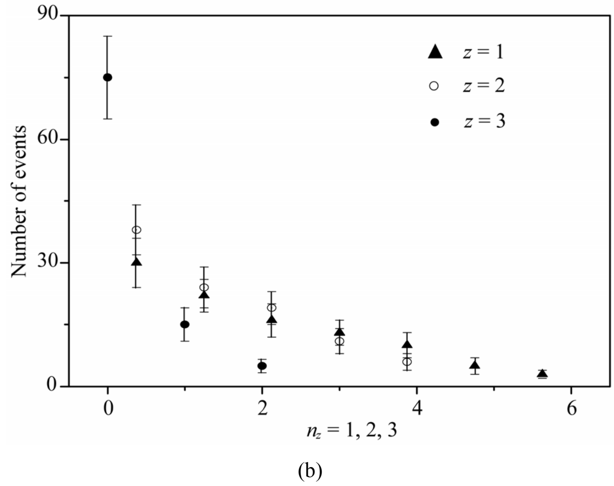


Figure 3. The multiplicity distribution of charged projectile fragments $z = 1$, $z = 2$ and $z = 3$, (a) Total sample; (b) $n_h = 0$.

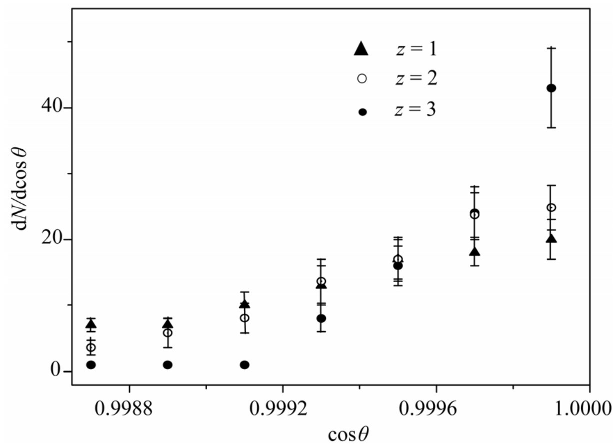


Figure 4. The angular distribution of $z = 1$, $z = 2$, $z = 3$ for a class of events with $n_h = 0$.

all the reaction produced observed in these 94 events which are ordered according to the value of Z*, the total charge the emitted projectile fragments. The production frequency of event s in ^{28}Si with emulsion interactions as a function of Z_{max}, the highest charged projectile fragment emitted in the interactions, is shown in **Figure 5**. It should be noted that the fragmentation probability is higher for events with Z_{max} = 2, 6 and 8. This is interpreted as due to the structure of ^{28}Si nucleus, which is an even-even nucleus of total spin $I = 0$. This means that the nuclear structure of the projectile may play an important role in the fragmentation process. **Figure 6** represent the frequency distribution of Z^*, the total charge of the emitted projectile fragments in an interaction for our sample of n_h =0 events the distribution is smooth and the frequency increases with Value of Z^*.

The average value of Z^* equals (11.9 ± 2.1) and the average number of produced pions charged in these

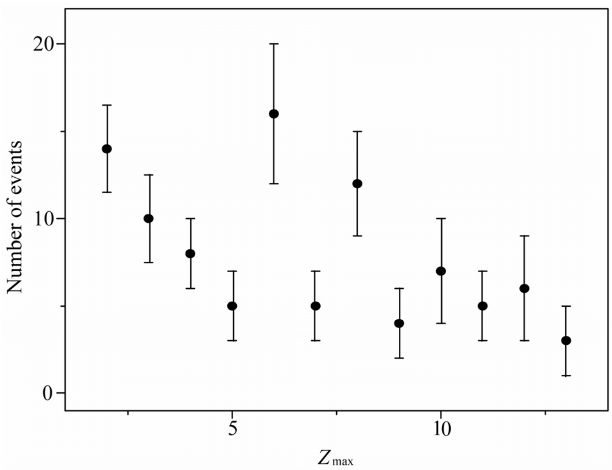


Figure 5. The production frequency of $n_h = 0$ events as a function of Z_{max} the highest charge of projectile fragments in an event.

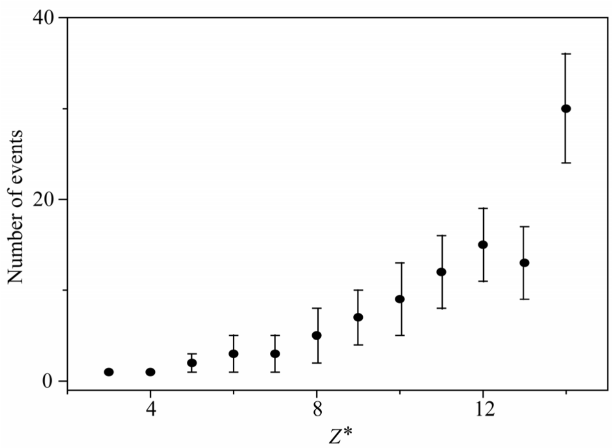


Figure 6. The production frequency of $n_h = 0$ events as a function of Z^* the highest charge of projectile fragments in an event.

events equals (2.2 ± 1.2). **Figure 7** illustrates the rapidity ($\eta = -\ln \tan\theta/2$) distribution for all shower tracks emerged from stars of $n_h = 0$ in comparison with corresponding distributions of shower tracks from central event, *i.e.* events with $Z^* = 0$. A pronounced rapidity gap is observed between the two distributions. The distribution of central events extends from the target fragmentation region to the projectile fragmentation region due to the absence of the spectator and the complete dominance of actors. The distribution from $n_h = 0$ events is dominated by the projectile spectators, thus it is mainly concentrated in the projectile fragmentation region.

7. CONCLUSIONS

From the investigation of particles emitted from ^{28}Si with emulsion collisions, we can make the following conclusions:

1) We notice that the distribution in Q depend substantially on the type of nucleus and the average total charge for this integration of an incident ^{28}Si nucleus in hydrogen, light and heavy emulsion nuclei were respectively 11.71 ± 0.17, 9.62 ± 0.11 and 4.68 ± 0.16.

2) We observe that the mean number of interacting projectile nucleons increases quickly as the value of n_h increases, as expected but attains a more or less constant value for extreme central collisions.

3) The fragmentation probability is higher for events with Z_{max} = 2, 6 and 8. This interpreted as due to the structure of ^{28}Si nucleus, which is an even – even nucleus of total spin1 = 0.

4) The rapidity distribution of shower tracks from n_h = 0 events has its peak the high rapidity region, *i.e.* the projectile fragmentation region, it is separated by a

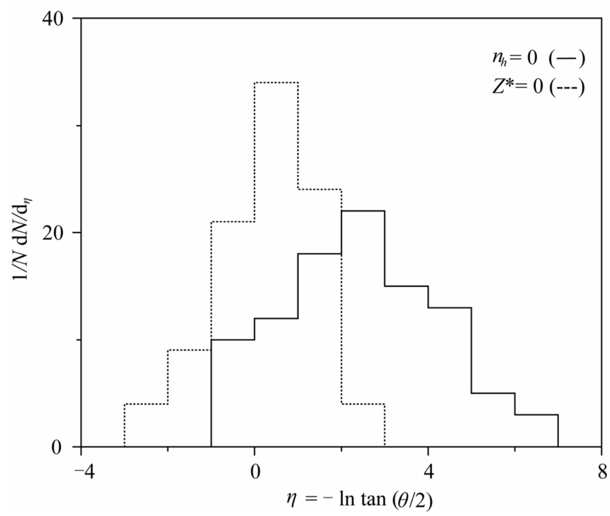


Figure 7. The rabidity ($\eta = -\ln \tan \theta/2$) distribution of shower tracks produced from events with n_h = 0 and from central events $Z^* = 0$.

measurable rapidity gap from the target fragmentation region.

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