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More Light on the Interactions of Heavy Nuclei at Dubna Energy

E. I. Khalil [2], S. Abdelhalim [2], Y. A. Mansour [1], A. S. Bakr [1] and M.M. Sherif [1]

[1] *Physics Department, Faculty of Science, Cairo University, 12613 Giza, Egypt*

[2] *Physics Department, Faculty of Science, Zagazig University, Cairo, Egypt.*

Abstract

An analysis for the emitted shower slow particles in ^{16}O and ^{28}Si + Em interactions at energies from 3.7 to 200 A GeV is made. The multiplicities of the slow particles and the fragmentation ratios of the incident nuclei and angular distributions are energy independent. Further more the percentage ratios of the He-projectile fragments seen to be independent of the incident projectile energy.

1 Experimental Results:

The emitted slow particles in relativistic heavy ion collision are a good probe of cascading mechanisms inside the target nucleus. A lot of results from fixed target heavy ion experiments at CERN (60 and 200 A GeV)[(1)], Brookhaven (14.6 A GeV) and Dubna (3.7 A GeV) (this work) using ^{16}O and ^{28}Si have been performed. The events used for this investigations BR-2 emulsion exposed with ^{16}O and ^{28}Si at Dubna (4.5 A GeV/c). The sensitivity of this emulsion is almost 30 grains per 100 µm for minimum ionization particle. The interactions were found by along the track scanning which has a high detection efficiency. The following experimental definition of particle categories are used in this work.

- Shower particles (n_s): singly charged particles with a velocity $\beta \geq 0.7$. These particles are predominately pions and produced outside the fragmentation cone ($\theta \geq 3^\circ$).
- Grey prongs (N_g): charged particles producing tracks with a range ≥ 3mm and having a velocity <0.7c. These are mainly protons in the energy range 26-375 MeV. The admixture of pions (12-56 MeV) are estimated to be 10% and for kaons (20-198 MeV) the corresponding number is 1%.
- Black prongs (N_b): charged particles producing tracks with range <3mm. These particles include low energy singly and doubly charged particles (less than 26 A MeV for P and α) and all target fragments with $z \geq 3$ mm. The admixture of pions is estimated to be of the order 1%.

The data also divided into central ($n_g + n_b$ >7 and Q_z = 0) and noncentral subsample based on

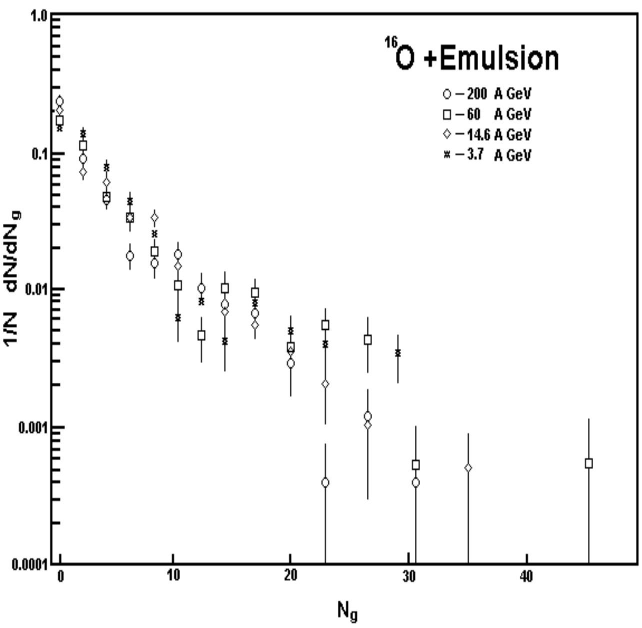

Fig 1: The multiplicity distribution of grey prongs in ^{16}O-emulsion interactions at different energies.

the total charge, Q_z, observed in narrow forward cone ($\theta_{cone}(rad) = P_{fermi} / P_{beam}$) which measure the emitted projectile fragments where P_{fermi} is the fermi momentum of nucleons inside nucleus and P_{beam} is the momentum of the incident beam per nucleon.

In figure (1) we have compared the multiplicities of the grey emitted particles N_g emitted in our experiment and compared with other energies (14.6, 60 and 200 A GeV)[1] while in figure (2) we show the multiplicity of the black particles of our work in comparison with the other energies of ^{16}O-Em data. The multiplicity distributions for grey and black prongs for ^{16}O induced interaction with different incident energies are the same within the errors of experiments and independent on the energy of the incident beam. In figure (3) the multiplicity of the emitted shower particles is plotted against the normalized multiplicity for different energies. We can say that grey,

reveal any new/or abnormal behavior relates to the energy of the incident beam. Its known that the angular distribution in proton induced interactions up to incident energies of 800 GeV[2] is described by $e^{0.96.\cos\theta}$. Also the angular distribution in the energy range 3.7 (this work), 14.6, 60, and 200 A GeV[1] for ^{16}O-Em interaction is described by the same relation. The different data are summarized in table 1, where the average quantities are given. Each data is divided into central and noncentral events based on the total charge, Q_z, observed in narrow forward cone ($\theta_{cone} = 3^\circ$), which measure the emitted projectile nucleons. Also in table 2 the multiplicity ratios of emitted He projectile fragments. It is clear that the central samples contain approximately 10% of the total production cross section. The average number of black and grey particles and the multiplicity

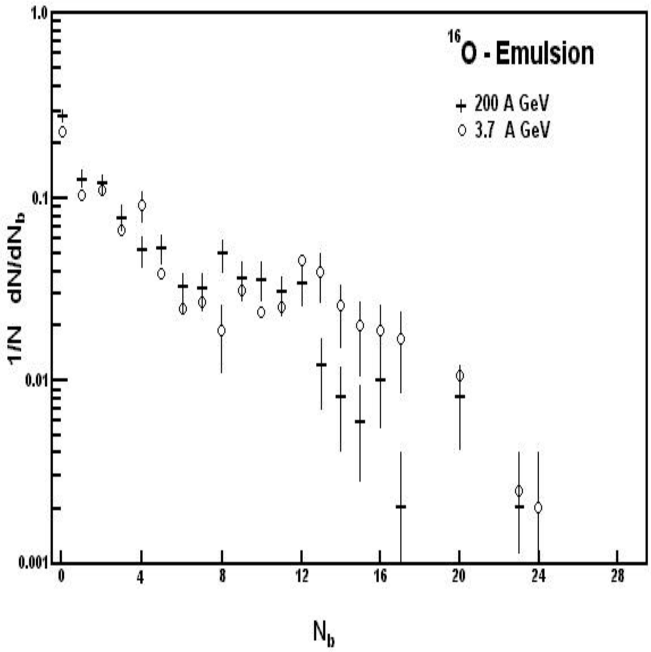

Fig 2: The multiplicity distribution of black prongs in ^{16}O-emulsion interactions at different energies.

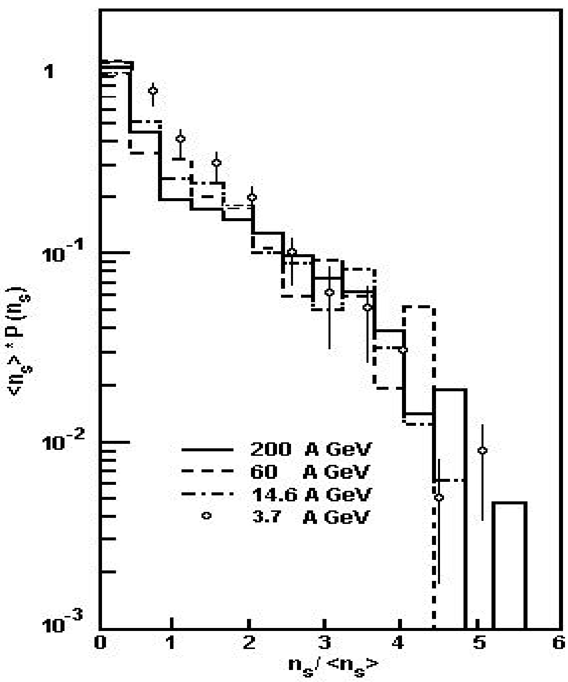

Fig. 3: The multiplicity ratio for shower particles vs. the scaled n_s with the average multiplicity for each energy.

Proj.	Energy A GeV	Sample events	$<n_s>$	$<N_g>$	$<N_b>$
^{16}O	3.7	Total (980) Non-Cent. (739) Central (241)	8.801 ± 0.5 5.7 ± 0.2 18.4 ± 1.5	3.4 ± 0.1 1.6 ± 0.1 9.0 ± 0.7	5.5 ± 0.2 3.2 ± 0.1 12.6 ± 1.0
^{16}O	14.6	Total (631) Non-cent. (527) Central (64)	20.3± 0.8 16.0± 0.7 58.1± 2.3	4.8± 0.2 4.4± 0.2 8.9± 0.5	5.2± 0.2 4.2± 0.2 14.0± 0.9
^{16}O	60	Total (327) Non-cent. (336) Central (36)	39.0± 2.1 31.0± 1.8 114± 6	4.5± 0.2 4.0± 0.2 8.6± 0.7	5.7± 0.4 4.5± 0.3 17.1± 1.5
^{16}O	200	Total (503) Non-cent. (447) Central (56)	56.5± 2.7 42.0± 2.1 172± 7	4.1± 0.2 3.4± 0.2 9.4± 0.6	4.3± 0.3 3.1± 0.2 13.5± 0.8
^{28}Si	3.7	Total (1384) Non-cent. (1218) Central (166)	10.8 ± 0.6 10.9 ± 0.6 24.2 ± 1.8	5.5 ± 0.3 5.7 ± 0.3 14.4 ± 1.1	5.8 ± 0.3 6.4 ± 0.4 12.2 ± 1.0
^{28}Si	14.6	Total (573) Non-cent. (509) Central (64)	28.2± 1.3 21.1± 1.0 84.5± 3.4	4.6± 0.2 4.1± 0.2 8.5± 0.5	5.4± 0.3 4.1± 0.2 15.5± 1.0

Table 1: The multiplicity ratios of average n_s, N_g and N_b for ^{16}O and ^{28}Si at several energies.

The ^{16}O projectile energy (A GeV)	Number of events	The percentage relative production of the projectile fragments								Ref
		None (without Z ≥ 2 p. f.	1He	2He	3He	4He	(1-4)He			
3.7	980	35.5 ± 1.9	23.3 ± 1.1	13.3 ± 1.5	5.2	0.5	42.2 ± 2.0			This work
60	410 131	34.4 ± 1.9 30.5	15.6 ± 1.6 20.6	12.7 ± 1.4 10.7	7.8 ± 1.1 3.8	0.7 ± 0.3 0.8	36.8 ± 1.9 35.9			[1] [1]
200	1928 591 1088	29.0 ± 1.2 29.1 34.7 ± 1.9	17.0 ± 1.0 16.8 16.9 ± 1.2	12.1 ± 0.8 12 12.0 ± 1.0	5.6 ± 0.7 5.9 5.5 ± 0.7	0.3 ± 0.2 0 0.3 ± 0.2	35 34.7 34.7 ± 1.9			[3] [3] [3]
The ^{28}Si projectile							5He	6He	(1-7He)	
3.7	1387	18.2 ± 1.0	22.7 ± 1.0	13.5 ± 0.8	4.6 ± 0.7	1.6 ± 0.3	0.29 ± 0.1	0.14 ± 0.1	42.8 ± 2.0	This work
14.6	955	19.3	28.1 ± 2.0	20.9 ± 1.0	6.5 ± 0.7	2.05 ± 0.3	1.47 ± 0.2	0	61.25 ± 2.3	[7]
^{32}S 200	775	18.6	21 ± 1.0	13.4 ± 0.8	6 ± 0.7	2.9 ± 0.4	1.46 ± 0.2	0.2 ± 0.1	(1-8He) 45.2 ± 2.0	[7]

Table 2: The He multiplicity ratios for ^{16}O and ^{28}Si for several energies.

of the emitted He projectile fragments are seems to be independent on the beam energy. Also the results of analysis of small impact parameter (central collisions) of ^{16}O and ^{28}Si nuclei with AgBr nuclear emulsion do not provide evidence for any unusual phenomenon in the energy range 3.7-200 GeV/nucleon. A similar conclusion has been reported from a study on central ^{16}O-collisions [8].

2 Summary:

Both the multiplicity distribution of slow emitted target nucleus and the angular distribution are independent on the energy of the incident projectile. Also the ratios of central and noncentral events and the multiplicities of the emitted He projectile nuclei seems to be independent on the incident projectile energy.

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