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# Angular Distribution and Transverse Momenta of Projectile Fragments of Oxygen Nucleus Collided with Emulsion at 3.7A GeV

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***Abstract –*** Transverse-momentum and angular distributions of all residual charges due to fragmentations for 16O projectile on emulsion at 3.7A GeV are recorded and compared with that obtained for 12C, 22Ne, 24Mg and 28Si at the same momentum. The experimental parameters that indicate the mechanism responsible for projectile fragmentation are discussed. The effect of target size on fragmentation process for both 16O and 24Mg projectiles are studied. The results, in the given range of masses and energy show that there is unified mechanism responsible for projectile fragmentation.

***Keywords***- projectile fragmentation, Transverse-momentum, angular distributions, mechanism and angular distributions.

## 1. INTRODUCTION

During the last few decades, nuclear heavy ion collisions at high energies become more important. Nowadays, it is still of great interest due to the development in the accelerator facilities at CERN superproton synchrotron (SPS), the BNL alternating gradient synchrotron (AGS) and the JINR Dubna Synchrophasotron. Many experimental and theoretical efforts have been devoted to describing the reaction mechanism that is responsible or nuclear fragmentations [1-4].

In previous work [5] the charges of all possible channels of projectile fragmentation Pf, for $^{32}$S and $^{16}$O nuclei were studied. Now we investigate some of the experimental parameter that gives information on this process. We will concern by the angular distributions of all residual charges due to Pf for $^{16}$O nucleus. The results compared with that obtained for $^{24}$Mg at the same momentum [6]. The effects of target size on the fragmentation process for both projectiles are studied. The events are divided into three different interaction groups according to the size of the target emulsion nuclei (H, CNO and AgBr nuclei).

## 2. MEASUREMENT DETAILS

The emulsion stacks used in the present experiment are of type NIKFI-BR-2 and was exposed to the 3.7 A GeV $^{16}$O beam at Dubna sychrophastron. Each stack has dimensions 20cm, 10cm and 600 μm. Total 1323 events were recorded where the respective mean free path are12.7± 0.35cm corresponding to inelastic reaction cross-section with emulsion nuclei 988.3±27mb.

Nuclear emulsion is sensitive for the magnitude of charge of any fragment. When charged particle passes through the photographic nuclear emulsion, it will slow down via losing its kinetic energy due to its inelastic interactions with the nuclear emulsion atoms along its path. The charged particle loses its kinetic energy via the ionizations of the grains of silver halides and via multiple elastic and inelastic scattering, which leads to trails of ionized silver halides along its path. The grain density is defined as the number of developed grains of silver halides per unit path length of the particle's track. It is denoted by (g) in a track corresponding to a particular value of specific ionization of such particle, so obviously it depends on some factors such as the degree of the development of the

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nuclear emulsion, the velocity and the charge of the ionizing particle. In order to obtain high accurate results, determine the normalized grain density $g^*$ where, $g^*=g/g_o$. The value g is the observed grain density per 100 μm for the emitted secondary particles after performing the dip angle correction. The magnitude $g_o$ is the grain density per 100 μm of the energy relativistic track of minimum ionization i.e. singly charged particle or electron. Both values of g and $g_o$ are counted in the same plateau region and at the same depth in the nuclear emulsion. The tracks of the secondary charged particles, which are produced, are classified into three types according to the normalized grain density $g^*$. First, the shower tracks of multiplicity $n_s$, $g^* \leq 1.4$ and $\beta = v/c \geq 0.7$ it is charged K-mesons, antiprotons, and hyperons. Second grey tracks of multiplicity $N_g$, $1.4<g^*\leq 10$, and the value of the velocity $0.3 < \beta < 0.7$, it most recoil protons having range > 3000μm, which correspond to proton energies in the range from 26 MeV up to 400 MeV. Some of the grey tracks may be due to emitted deuterons, tritons, helium nuclei and nearly about (5%) due to slow π-mesons. Third kind are black tracks $N_b$ of $g^*\geq 10$ and $\beta \leq 0.3$, most of them are due to protons having range ≤ 3000μm, corresponding to proton energies < 26 MeV. The grey and black tracks are known as tracks of the heavily ionizing particles with the value of the velocity $\beta<0.7$. The heavily ionizing particles multiplicity is denoted by $N_h$, where $N_h = N_g + N_b$.

Identification of the charge of the PFs depends on the following essential properties. It travels with the same speed as that of the parent beam nucleus, and without change in the ionization along their path where followed up to a distance of at least 2cm from the interaction centre. The energy of the produced PFs is high enough to distinguish them easily from the target fragments. The charges with $Z \geq 2$ are identified by its δ-ray density measurements. A δ-ray is low-energy electron which produces a track containing four or more grains has an energy >15 KeV. The number of these δ-ray $N_\delta$, ejected by a charged particle of charge Z in its passage through the target material helps to identify the particle producing the track where $N_\delta$ is directly with $Z^2$. At each interaction we measure the δ-ray density of each PFs and compared with respect to its primary beam. For this purpose, a calibration line is done by using six primary beams available in our laboratory $^4$He, $^{12}$C, $^{16}$O,$^{22}$Ne, $^{24}$Mg, and $^{32}$S at 3.7A GeV from Dubna sychrophastron. The relationship between the average number of δ-rays per mm for a sample of 40 tracks from each beam and corresponding charge is shown in Fig.1. The data are fitted by the linear relation $N_\delta = AZ^2 + B$ where A= 0.171±0.004 and B= -0.420 ± 0.089. On the other hand, at each interaction point the PF with Z=1 can be well separated by visual inspection of tracks where their ionizations are similar to those of shower (≈ 30 grains per 100 micron ) while He PFs chosen as charge references and is easily identified in all labs.

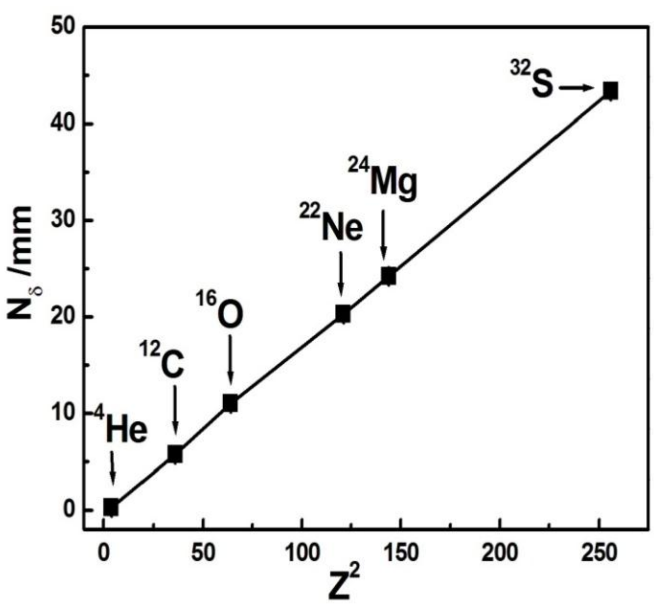


**Fig. 1:** Charges of the tracks in nuclear emulsion using delta-ray measurements.

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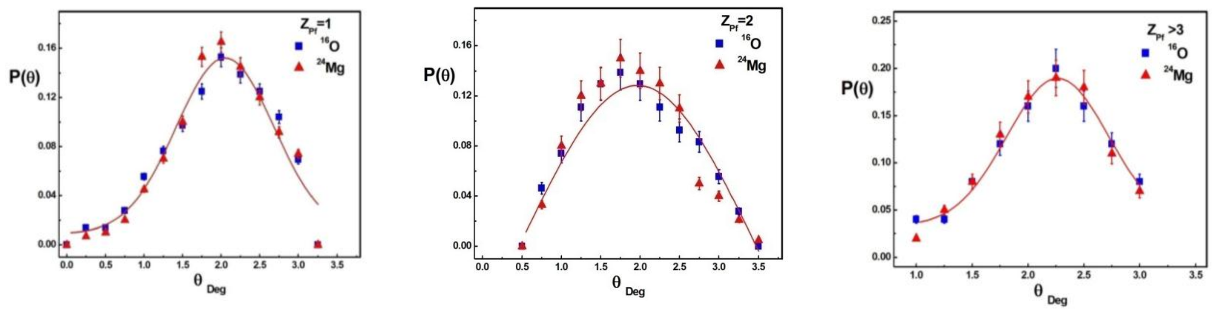
## 3. Experimental results and discussions

In this experiment each collision of $^{16}O$ with emulsion nuclei at 3.7 A GeV, the PFs representing the projectile-like non-interacting fragments with a charge Z=1, Z=2 and $Z \geq 3$ are recorded where charge of each of these PFs is identified according to magnitudes of δ-ray measurements.



(a) (b) (c)

**Fig. 2:** The angular frequency distributions of secondary charged projectile fragments (a) single charge fragments z=1, (b) for double charge and (c) for charge z≥3 emitted from 16O and 24Mg interaction at momentum 4.5A GeV/c [6]. The solid line is the corresponding Gauss's distribution.

Figure 2 shows the angular frequency distributions of charged Pfs for single charge fragments with z=1, double charge and for z≥3. The Pfs emitted from $^{16}O$ interaction at momentum 4.5AGeV/c (this work), compared with the corresponding distributions at emitted from $^{24}Mg$ at the same momentum [6]. One can notice from this figure that the angular distributions of possible charged projectile fragments due $^{16}O$ and $^{24}Mg$ collisions with emulsions are similar and can be described by Gaussian distribution.

**Table 1.**The values of average space angle <θ> of different projectile fragments from interactions of $^{16}O$ and $^{24}Mg$ projectile with emulsion nuclei at momentum 4.5 A GeV/c.

| Interactions | $^{16}O$ | | $^{24}Mg$ [6] | |
|---|---|---|---|---|
| Charge of the projectile fragments Z | $\langle P_t \rangle$ GeV/c | $\langle \theta \rangle$ | $\langle P_t \rangle$ GeV/c | $\langle \theta \rangle$ |
| Z=1 | $0.105 \pm 0.01$ | 0.103 | $0.103 \pm 0.01$ | 0.08 |
| Z=2 | $0.388 \pm 0.01$ | 0.26 | $0.436 \pm 0.01$ | 0.36 |
| Z>=3 | $0.502 \pm 0.02$ | 0.28 | $0.515 \pm 0.02$ | 0.32 |

Table1 shows that the average emission angles <**θ**> increases with charge of Pfs and independent on the projectile size at the same energy.

Transverse momentum $p_T$ for the charged Pfs is related to the emission angle and magnitude of the charge [5] where

$$p_T = 2 z_f \, p_\circ \sin\theta$$

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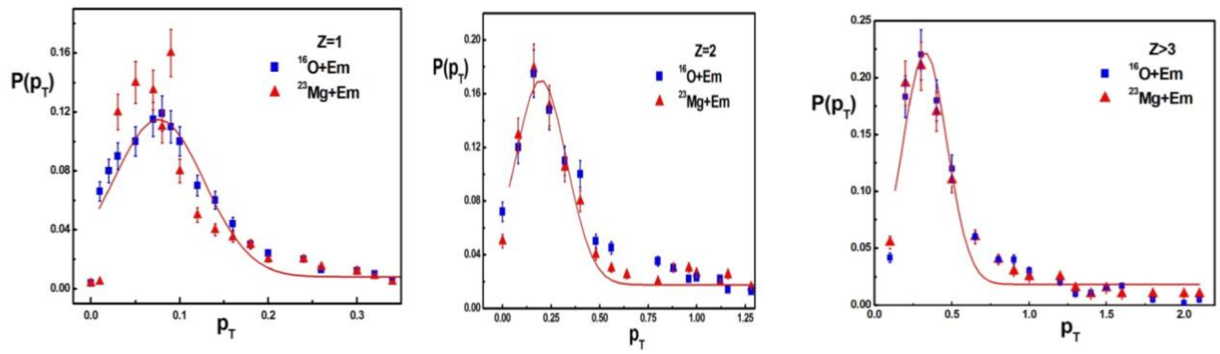


(a) (b) (c)

Fig. 3. Transverse momentum distribution for (a) single charge fragments z=1, (b) for double charge and (c) for charge z≥3 emitted from 16O and 24Mg interaction at momentum 4.5A GeV/c. The solid line is the corresponding Gauss's distribution.

There are two observed distributions, one is for low transverse momenta $p_T$ represents by symmetric Gauss distribution and the other is for high $p_T$ which described by exponential decay curve. Each distribution represents a specific mechanism responsible for production of projectile fragments at different temperatures. The obtained results suggested that there are two mechanisms for nuclear fragmentation first is sudden fragmentation by explosive mechanisms, shock wave-like type and the other is slow fragmentation by the "fission" of the spectator regions, mainly because of the interactions with the particles or fragments emitted from the participant region at transverse angles in CMS.

## 4. CONCLUSIONS

This study investigates the angular distribution and transverse Momenta of projectile fragments of oxygen nucleus collided with emulsion at 3.7A GeV. Our studies can conclude the following:

- Angular and transverse momentum distributions of possible charged projectile fragments due $^{16}O$ and $^{24}Mg$ collisions with emulsions are similar and described by Gauss distributions.

- Maximum probability of emission angles and mean transverse momentum $<p_T>$ increase with charge of fragments

- There are two observed distributions one is for low transverse momenta $p_T$ represents by symmetric Gauss distribution and the other is for high $p_T$ described by exponential decay curve. Each distribution represents a specific mechanism responsible for production of projectile fragments at different temperatures

## ACKNOWLEDGMENT

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