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Dissociation of ^{12}C and ^{16}O into Alpha Particles in Emulsion At 4.5 A GeV/c

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Abstract

The events of the pure dissociation of ^{12}C and ^{16}O have been selected from a big sample of their interactions with emulsion nuclei. The transverse momentum distribution of the alpha particles inside the projectile nuclei has been found. The distribution of the angle between the different pairs of alpha particles, in an event, has been investigated and two mechanisms have been concluded for the dissociation process.

1 Introduction:

The break-up of the projectile nucleus by the Coulomb field of the target nucleus, known as electromagnetic dissociation, has been studied theoretically (Singh, \& Jain, 1992) and experimentally (Bertulani, \&Baur, 1986). These types of dissociation occur when a virtual gamma photon is exchanged between a target and projectile nuclei. The values of the impact parameter of the electromagnetic dissociation are larger than the range of the nuclear force (Bertulani, \& Baur, 1985). The photons may be considered as representing the time dependent electromagnetic field caused by the target charge and seen by the projectile (Berchtman, \& Heinrich, 1988). The electromagnetic dissociation is a type of interaction in which the interacting nuclei do not penetrate each other, i.e., the projectile nucleus is excited by virtual-photon absorption in the electromagnetic field of the target nucleus and then decays by particle emission. Weizsaker and Williams made the first theoretical trials to study the basis and the mechanism of the electromagnetic dissociation, they introduced a simple classical approach to describe the reaction mechanism (Weizsaker,\&-Williams,1934). Hoffman et al. introduced a theoretical study on the Coulomb dissociation over a wide range of projectile energies(Hoffman , \& Baur,1984). They found that, at low energy, around and below the Coulomb barrier, the Coulomb dissociation is small. While at higher energies, the first order Coulomb excitation theory would become more accurate. At sub-Coulomb barrier, break-up was generally quite well understood in the framework of the distorted wave Born approximation. Llope et al. developed a framework for the quantitative analysis of the electromagnetic dissociation of the relativistic nuclei(Llope, Braun,\&Munzinger, 1990) . Their calculations included a treatment of multiple excitations of the giant dipole resonance, in the framework of the statistical model. This model is conceptually consistent with the Bohr hypothesis stating that the manner in which the ion breaks up depends only upon the energy and the momentum deposited in the ion during the collision, and not on the particular mechanism involved in the energy- momentum transfer. The target nucleus acts only to inject energy into the incident heavy ion, raising it to a state of high excitation, causing it to explode into a number of fragments (Feshbach, \& Huang, 1973). There is no memory of how the energy was transferred, the relative probability for the production of a given fragment being independent of the way the incident heavy ion was excited. In the present work, the dissociation reactions $^{12}C \rightarrow 3\alpha$ and $^{16}O \rightarrow 4\alpha$, being of particular interest, were studied separately. The events characterized by the presence of only 3 charged secondaries in the case of ^{12}C and 4 charged secondaries in the case of ^{16}O, each charge being emitted at an angle of $\theta \leq 3^0$ and with charge Z = 2 (determined by the δ -electron density method).

It is interesting to investigate the mechanism of dissociation of ^{12}Cand ^{16}O into alpha particles. In particular, there are two main mechanisms: a direct mechanism in which $^{12}C \rightarrow 3\alpha$ and $^{16}O \rightarrow 4\alpha$ occur and a cascade mechanism in which $^{12}C \rightarrow {}^{8}Be + \alpha$ and then $^{8}Be \rightarrow 2\alpha$ occur In section 2, the transverse momentum distribution of the alpha particles inside ^{12}C and ^{16}O nuclei has been discussed. The distribution for the relative angle between pairs of alpha particles emitted in the coherent reactions $^{12}C \rightarrow 3\alpha$ and $^{16}O \rightarrow 4\alpha$ is presented in section 3. The effective mass distribution of the fragment system has been investigated at the primary momentum 4.5 GeV/c per nucleon in section 4. Discussion and conclusions are presented in section 5.

2 Transverse Momentum Distribution of Alpha Particles inside the Dissociating Nuclei:

It is assumed that the momentum of each alpha particle emitted from such dissociation reaction events($^{12}C \rightarrow 3\alpha$ and $^{16}O \rightarrow 4\alpha$) is equal to 1/n of the momentum P_o of the incident projectile nucleus, where n is the number of alpha particles inside the dissociation projectile nucleus. Consequently, the transverse momentum of each secondary alpha particle is equal to

$$P_{Ti} = \tfrac{1}{n} P_0 \sin(\Theta_i) \qquad (1)$$

where n equals 3 in case of ^{12}C and n equals 4 in case of ^{16}O and θ is the emission angle of α - particle. The vector sum of P_{Ti} is equal to the transverse momentum transferred to the projectile nucleus in the diffraction scattering process. To a first approximation, the transverse momentum of each secondary alpha - particle in the projectile nucleus is equal to :

$$\bar{P}_{Ti} = \bar{P}_{Ti} - \tfrac{1}{n} \sum_{i=1}^{n} \bar{P}_{Ti} \qquad (2)$$

the distribution of the transverse momentum $\bar{P}_{Ti}$ values is shown in figure (1).

Although there is a structure in figure (1), one can not distinguish between the direct and cascade mechanisms.

The average transverse momentum calculated equals 124.5 MeV/c.

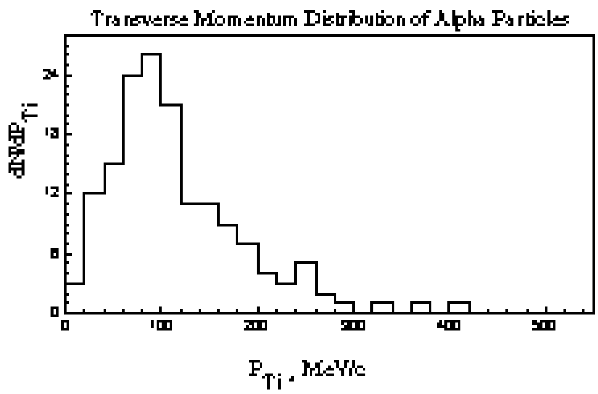

Figure 1: The transverse momentum distribution for alpha particles due to the dissociation of ^{12}C and ^{16}O nuclei

3 Distribution of the Relative Angle between Pairs of Alpha Particles:

The distributions for the pairs of alpha particles emitted in the coherent reactions $^{12}C \rightarrow 3\alpha$ and $^{16}O \rightarrow 4\alpha$ have been studied at the primary momentum of 4.5 GeV/c per nucleon. These investigations of the correlation characteristics were aiming to find the mechanism of fragmentation, in

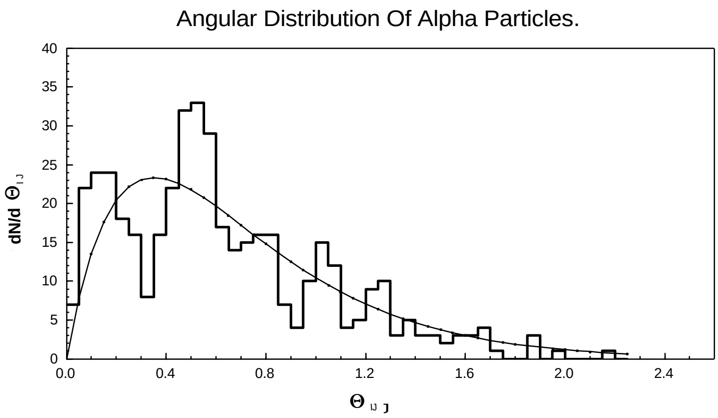

Figure 2: The angle distribution for the pairs of alpha particles due to the dissociation of ^{12}C and ^{16}O nuclei

particular to have an answer for the role of direct cascade process such as
$^{12}C \rightarrow {}^{8}Be + \alpha \rightarrow 3\alpha$. Figure (2) shows two distinguished narrow maxima at the relative angle Θ_{ij} =0.15,and 0.55.The position of the second maximum is near to that of the model of direct statistical decay (Feshbach,\& Huang,1973). This statistical process provides an explanation of the observed result. It has been found that there is no measurable difference between direct and cascade processes for the previous reactions. This result has been observed before (Goldhaber, 1974).

4 Effective Mass Distribution of the Fragmenting System:

The effective mass distribution M^*_{IJ} for the dissociation reactions $^{12}C \rightarrow 3\alpha$ and $^{16}O \rightarrow 4\alpha$ has been investigated in the present study. The effective mass distribution for the α -particle pair with relative angle θ_{ij} can be calculated from the relations

$$M*_{ij} = \sqrt{2(m^2 + E_i E_j - p_i p \cos(\Theta_{ij})} \qquad (3)$$

where m is the mass of alpha particle, E_i and E_J are the energy of alpha particle i and j respectively, p_i and p_j are the momenta of alpha particle i and j respectively and θ_{ij} is the relative angle between the alpha particle pair i and j. Figure (3) ,has two maxima for the mass defect $M_{IJ.}$ The first is at M_{IJ}<0.25 MeV and the second wide maximum is at M_{IJ}~0.5-2. MeV.

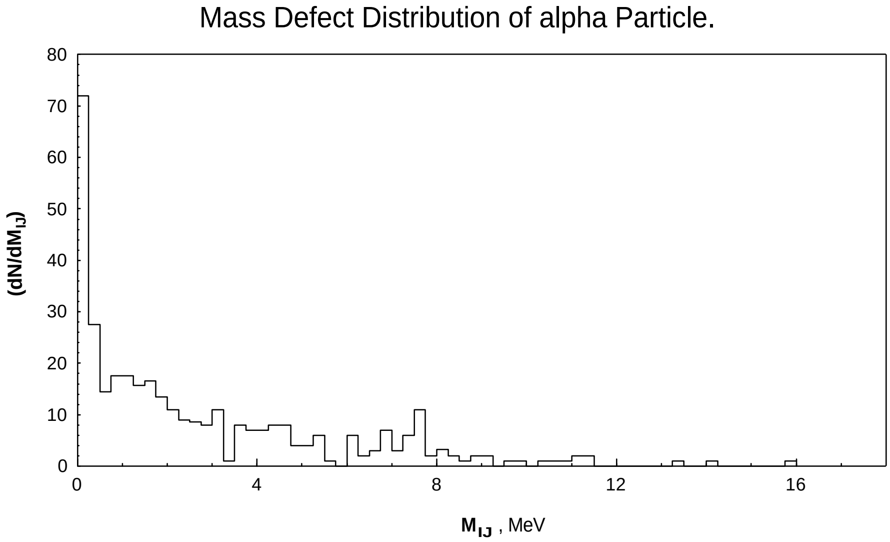

Figure 3: The mass defect distribution for the alpha particle due to the dissociation of ^{12}C and ^{16}O nucleus.

The angular moment can not explain the two maxima in θ_{ij} distribution. From the mass defect distribution, the maximum occurs at the value of the mass defect of ^{8}Be, this means that the cascade reaction process has a predominant role in the dissociation of $^{12}C$and ^{16}O nuclei.

5 Results and Discussion:

In the studies of $^{12}C \rightarrow 3\alpha$ and $`^{16}O \rightarrow 4\ \alpha$ dissociation reactions in the field of the emulsion nucleus, one can get the distribution of the transverse momentum inside both ^{12}C and^{16}O nuclei. Also, the effective mass and the relative angle distributions for the pairs of alpha emitted in the coherent reactions of ^{12}C and ^{16}O have been investigated at the primary momentum of 4.5 GeV/c per nucleon. It was shown that both distributions displayed narrow peaks which cannot be explained by the simple statistical model. From this study, we predict that the cascade process has a predominant role in the dissociation reactions of both ^{12}C and ^{16}O nuclei. The angular moment can not explain the two maxima in relative angle Θ_{ij} distribution and the mass defect M_{ij} distribution. The angular moment may affect the width only. To explain the first maximum, it is necessary to assume a cascade process, for example $^{12}C \rightarrow {}^{8}Be + \alpha$ and then $^{8}Be \rightarrow 2\alpha$.

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