Electric quadrupole and dipole-quadrupole interference effects in Coulomb breakup of ^{15}C

*Pardeep Singh[1] and Rajiv Kumar[2]
[1]*Department of Physics, DCR University of Science & Technology, Murthal, Sonepat-131039, Haryana*
[2]*Department of Applied Sciences, HCTM, Kaithal, Haryana*
**email: panghal005@gmail.com*

The neutron capture reaction ^{14}C(n, ɔ)^{15}C attracts significant attention primarily because it plays a crucial role in CNO cycle and considerably contribute in the synthesis of elements heavier than A>20. Secondly, this reaction is important in context of the ground state of ^{15}C, which is final state achieved by ^{14}C through neutron capture, as it has a moderate sized neutron halo with low neutron binding energy[1-4]. Therefore, the accurate information regarding the ground state configuration of ^{15}C and the precise measurement of reaction cross section are required for estimating the rate of reaction ^{4}C(n, ɔ)^{15}C.

Ideally the reaction cross sections are to be directly measured in the laboratory. But, despite of many experimental efforts, the required high temperature and density cannot be attained in the laboratory. However, in recent years several indirect methods like elastic scattering; Coulomb excitation and dissociation; transfer reactions; nuclear knockout reactions; quasifree reactions; charge-exchange reactions etc. have been developed to extract cross sections relevant to astrophysical processes [5]. Owing to the simplicity the Coulomb dissociation is being used frequently for obtaining the capture cross section in connection to astrophysical problems. But it is not free from bias because of the presence of the contribution of electric quadrupole (E2) and dipole-quadrupole interference (E1-E2) terms [6-7]. So, for exploiting the Coulomb breakup method to obtain conclusive observations regarding the astrophysical problems one has to estimate the exact contribution of E2 and E1-E2 interference terms. Further as far as information about the ground state configuration is concerned the cross section differential in longitudinal momentum of fragments, being insensitive to the reaction mechanism, offers prolific probe to investigate the structure of projectile. Theoretically, in the energy range of interest the eikonal approximation is the most convenient model to describe the coulomb breakup process.

Within the framework of eikonal approximation the explicit expressions for calculating the longitudinal momentum distribution of ^{14}C emerging out from the Coulomb breakup of ^{15}C on Ta target at beam energy 85MeVA, corresponding to E1, E2 and E1-E2 electric transitions may be expressed as

$$\frac{d\sigma_{E1}}{dq_z} = \int_{|q_z|}^{\infty} \frac{4Z_t^2 (Z_1^{eff})^2 \alpha^2}{3\gamma^2\beta^2} \xi^2 I_{011}^2$$
$$\times \left[(K_1^2 - K_0^2)\left\{(1+2P_2) - (1-P_2)\gamma^2\right\} + \frac{2}{\xi} K_0 K_1 (1-P_2)\gamma^2 \right]$$
$$\times\, q\, dq$$

$$\frac{d\sigma_{E2}}{dq_z} = \int_{|q_z|}^{\infty} \frac{Z_t^2 (Z_2^{eff})^2 \alpha^2}{105\gamma^2\beta^4} \left(\frac{\omega}{c}\right)^2 \xi^2\, I_{022}^2$$
$$\times \left[\frac{4}{\xi^2} K_1^2 (7 - 10P_2 + 3P_4) + (K_1^2 - K_0^2)(28 + 20P_2 + 57P_4) \right.$$
$$+ (7 + 5P_2 - 12P_4)\gamma^2 (2-\beta^2)^2$$
$$\left. \times \left(\frac{2}{\xi} K_0 K_1 - (K_1^2 - K_0^2) \right) \right] q\, dq$$

$$\frac{d\sigma_{E1-E2}}{dq_z} = \int_{|q_z|}^{\infty} \frac{4Z_t^2 Z_1^{eff} Z_2^{eff} \alpha^2}{5\gamma^2\beta^3} \left(\frac{\omega}{c}\right) \xi^2 I_{011} I_{022}$$
$$\times \left[(K_1^2 - K_0^2)(2P_1 + 3P_3) \right.$$
$$\left. + [\frac{2}{\xi} K_0 K_1 - (K_1^2 - K_0^2)](P_1 - P_3)\gamma^2 (2-\beta^2) \right]$$
$$\times q dq$$

respectively. Where all symbols have same meaning as defined in Ref.[7,8].

The major input required in numerical calculations is the radial part of the ground state wave function of the projectile and it has been obtained by solving the radial part of Schrodinger equation in Woods-Saxon potential. The strength of the potential has been determined to reproduce ground state binding energy of ^{15}C [1.218MeV] and the so obtained value is 76MeV. The range and diffuseness parameters are fixed at 2.34fm and 0.60fm respectively. In Fig. 1 we compare the preliminary results of present calculations with the corresponding experimental data taken from Ref.[9]. It is quite clear from this figure that the inclusion of these terms introduce an asymmetry in the shape of LMD, leading to a better matching between the calculated results and experimental data especially in peak region of the spectrum. Nevertheless the long tail in momentum distribution requires further investigations and the work in this direction is in progress [10].

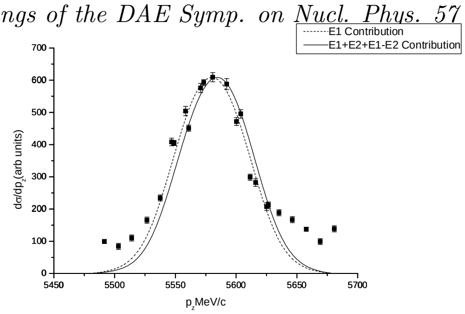

Fig.1. Longitudinal momentum distribution of ^{14}C emerging from ^{181}Ta(^{15}C, ^{14}C+n)^{181}Ta reaction. Dashed and solid lines depict the results obtained by considering E1 and then by considering E2 and E1-E2 interference effects respectively.

To conclude, the matching between the data and prediction in the near peak region of the longitudinal momentum distribution of ^{14}C coming from ^{181}Ta(^{15}C, ^{14}C+n)^{181}Ta Coulomb breakup reaction improves significantly due to the inclusion of E2 and E1-E2 interference terms in the formalism.

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