Coulomb diffraction interference in $^{12}C(^{31}Cl,^{30}S)X$ reaction

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Introduction

The study of exotic nuclear structures lying close to neutron/proton drip lines has become the frontier of nuclear physics research in the last three decades, and knockout reactions have appeared as a lucid tool to investigate these exotic nuclei. During the interaction with the target, breakup occurred because of nuclear interaction and Coulomb interaction of projectile with the target nucleus. Both breakup mechanisms are well understood in the case of neutron halos. Still, in the case of Proton, halos interactions are more complicated because the valence proton is also interacting with the target and makes the situation more complicated. So it is needed to be understood for a clear understanding of experimental data and extracting information from that reaction, as pointed out in ref [1]. In the light of work presented in ref [2-5], we have investigated the Coulomb diffraction interferences in single proton breakup from recently discovered $^{31}_{17}$Cl proton-rich nuclei on $^{12}_{6}C$ target at 44MeV/n beam energy [1]. The motivation behind the investigation of ^{31}Cl nuclei is that this nucleus has weakly bound proton (Sp=0.294 MeV) and long-tail in proton density distribution which indicates its existence of halo structure. Still, on the other hand, no enhancement of the interactions cross-section stresses the need for further investigation for our better understanding [2]. Since measurement of longitudnal momentum distribution and breakup cross-sections are an efficient tool to reveal the structural information. So in this work, we have theoretically calculated the diffraction and Coulomb breakup cross-section and respective parallel momentum distribution of fragment.

Theoretical formalism

The diffraction breakup is studied by using Eikonal approximation, while Coulomb breakup is studied by treating Coulomb interaction to all orders as discussed in ref [2-5], where the Coulomb potential which causes the breakup is given by

$$V(\vec{r},\vec{R}) = \frac{V_c}{|\vec{R}-\beta_1\vec{r}|} + \frac{V_v}{|\vec{R}+\beta_2\vec{r}|} - \frac{V_0}{R}$$

here, $V_c = Z_c Z_t e^2$, $V_v = Z_c Z_t e^2$ and $V_0 = (Z_c + Z_v) Z_t e^2$ while β_1 and β_2 are the mass ratio of valence proton and core to that of projectile. Z_p and Z_t are the projectiles and the target charge number. The co-ordinate system used is shown in Fig.1.

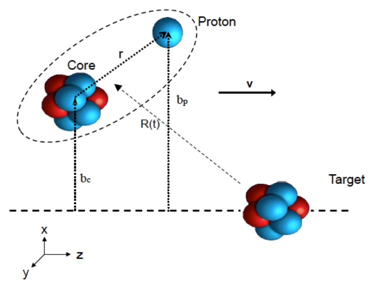

Fig.1 Co-ordinate System

The longitudinal momentum distribution in the Coulomb breakup mechanism is calculated by

$$\frac{d\sigma}{d\vec{k}} = \frac{1}{8\pi^3}\int d\vec{b_c}\,\left|S_{ct}(\vec{b_c})\right|^2 |g^{Coul.}|^2$$

Where $g^{Coul} = g^{Recoil}(b_c) + g^{Direct}(b_v)$, g^{Recoil} as a core-target and g^{Direct} as valence proton-target Coulomb amplitude to all order [ ] and are written as

$$g^{Recoil}(b_c) = \int d\vec{r}\, e^{-i\vec{k}.\vec{r}} \phi_i(\vec{r}) \left(e^{i\frac{2V_c}{\hbar v}\log\frac{b_c}{R_\perp}} - 1 - i\frac{2V_c}{\hbar v}\log\frac{b_c}{R_\perp} + i\chi(\beta_1, V_c) \right)$$

$$g^{Direct}(b_c) = \int d\vec{r}\, e^{-i\vec{k}.\vec{r}} \phi_i(\vec{r}) \left(e^{i\frac{2V_n}{\hbar v}\log\frac{b_v}{R_\perp}} - 1 - i\frac{2V_n}{\hbar v}\log\frac{b_v}{R_\perp} + i\chi(-\beta_2, V_v) \right)$$

and for nuclear diffraction dissociation we have used the well-known Eikonal approximation which is gives as [3]

$$\frac{d\sigma}{d\vec{k}} = \frac{1}{8\pi^3}\int d\vec{b_c}\,\left|S_{ct}(\vec{b_c})\right|^2 |g^{Diff.}|^2$$

Where $g^{Diff}(b_v) = \int d\vec{r}\, e^{-i\vec{k}.\vec{r}} \phi_i(\vec{r}) (e^{i\chi_{nt}(b_v)} - 1)$

b_c and b_v are core and valence nucleon impact parameter and $S_{ct}(b_c)$, $e^{i\chi_{nt}(b_v)}$ are the core target and proton target S-matrix calculated by MOMDIS code using Hartree-Fock and 2pf form of densities of the core and target [6,7].Here the projectile ^{31}Cl is assumed to have a Core plus clustered proton structure and its radial wave function $\phi_i(\vec{r})$, is obtained by solving the Schrodinger wave equation for $[0^+ \otimes 1d_{3/2}]$ core- nucleon configuration in Woods-Saxon potential, where the binding energy 0.294 MeV was reproduced by adjusting the potential depth. The Woods-Saxon potential parameters, i.e., radius, diffuseness, and V_{ls} are taken as 1.27fm and 0.67fm and 17.0 MeV, respectively, as in ref.[1].

Results

The calculated cross sections for diffraction dissociation and Coulomb breakup are shown in

Table 1, where column 3 shows the simple sum of diffraction and Coulomb cross-section and column 4 shows the diffraction and Coulomb calculated together, and is larger by 3-4 % than of separately calculated (column 3) showing constructive interference, also the respective longitudinal momentum distribution spectrum is shown in Fig. 2 which clearly shows a constructive interference between Coulomb (red dash-dot line) and diffraction (green dash line), resulting in a total (Coul. and diff. calculated together) (thin blue line) which is larger than the simple sum of the Coulomb and diffraction contribution (black full line).

Table 1: Calculated proton breakup cross-section in Diffraction and Coulomb dissociation.

σ^{diff} (mb)	$\sigma^{Coul.}$ (mb)	$\sigma^{diff}+\sigma^{Cou}$ (simple sum) (mb)	σ^{Coul_diff} (Cal. together (mb)	% age change
3.80	2.896	6.697	6.92	+ (3-4)

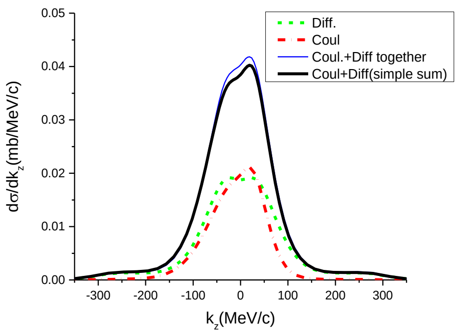

Fig.2 Calculated longitudinal momentum distribution(LMD) corresponding to Diffraction, Coulomb, and Coulomb plus Diffraction mechanisms.

Table 2: Calculated cross-section in Recoil, Direct, and total Coulomb dissociation.

σ^{Recoil} (mb)	σ^{Direct} (mb)	$\sigma^{Recoil}+\sigma^{Direct}$ (Simple sum) (mb)	σ^{Coul} (Recoil+ Direct together) (mb)	% age change
2.386	9.469	11.856	2.897	-75.5

On the other hand, cross-section corresponding to direct, recoil, and total Coulomb (both direct and recoil together) mechanisms are shown in Table 2, Simple sum of the recoil and direct(column 3) calculated separately is much larger than the recoil and direct calculated together(column 4), which shows a destructive interference in direct and recoil interaction and

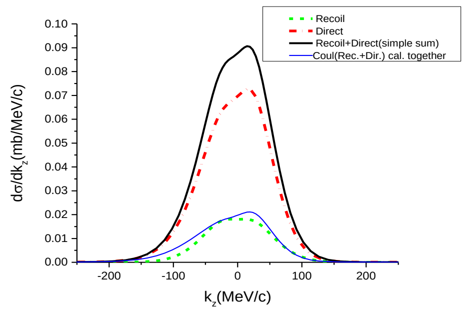

Fig.3 Calculated Longitudinal Momentum Distribution (LMD) corresponding to Recoil, Direct and their interference.

respective longitudinal momentum distribution, and Fig.3 also shows destructive interference between core-target Coulomb interaction(Recoil)(green dash line) and of proton target Coulomb interaction (Direct) (red dash-dot line) in longitudinal momentum distribution where solid black line reflects the simple sum of direct and recoil contributions while blue thin line shows total Coulomb contribution, i.e., recoil and direct calculated together.

Conclusion

It has been observed that the interference between Coulomb and Diffraction dissociation is constructive and it lies around 3-4 %. In comparison, the interference between the recoil and direct Coulomb terms is destructive and lies around 75.5 %. The obtained results are consistent with the results of ref.[2, 3]. So in this study, we come to know qualitatively the interference between Coulomb and diffraction mechanism, and recoil and direct Coulomb terms. We hope that this work will help in better understanding of breakup experimental results of ^{31}Cl.

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