Core Excitation in $^{12}C(^{23}Al,^{22}Mg)X$ at energy 74 MeV/n

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Introduction

A lot of attention from experimentalists and physicists has been carried out by the novel structure named 'halo'. Halo contains a two or three-body system with a "core+ valance nucleon(s)" structure where valance nucleon(s) have a low binding energy [1]. Neutron halos are larger in numbers than proton halos due to the existence of the Coulomb Barrier in the proton halo. Besides this, some proton halos are discovered like ^{8}B,$^{26-28}$P, ^{17}Ne, ^{17}F [2-3], and many are under investigation. ^{23}Al plays a vital role in ^{22}Mg(p,γ)^{23}Al astrophysical reaction and has been studied by many researchers to find more clear structural information in past years [4-7]. In the study by R. N. Panda et. al. [6], the reaction cross-section of ^{23}Al at carbon target at 30 MeV/n and 74 MeV/n beam energy is produced theoretically by using diffusion parameter value a_0=0.6 fm, but this value is unable to produce the LMD (Longitudinal Momentum Distribution) data rather a_0=2.0 fm provides a more accurate picture of momentum distribution. On the other hand, a study carried out by A. Banu et. al. at 50 MeV/n (using a_0=0.6 fm) provided a good interpretation of these observables [7]. Also, the binding energy used in both studies is different. Also, in Ref. [6], the core excitation is not taken into account but must be taken as the core ^{22}Mg is supposed to be highly deformed, and the ground state of ^{23}Al is supposed to have core excited components [7] and many studies revealed the significance of excitation in reaction mechanisms for a clear interpretation of the experimental data [8-11].

So, here we studied the nuclear breakup reaction ^{12}C(^{23}Al,^{22}Mg)X at 74 MeV/n beam states. The ^{23}Al is supposed to have in its ground state with $J^{\pi}=5/2^{+}$, which is produced by coupling core states (I_c) and valance proton state ($2s_{1/2}$ or $1d_{5/2}$). The core is assumed in states $0^{+}(E_x^c = 0.0)$, $2_1^+(E_x^c = 1.247)$, 4_1^+ $(E_x^c = 3.308)$, and $4_2^+(E_x^c = 5.293)$ [7]. The well-known Glauber Eikonal model-based code MOMDIS for the knockout reaction has been used for the calculations [12]. The parameters used for the wavefunction calculations are taken the same from Ref. [7], which are a_0 = 0.6 fm and r_0 = 1.18 fm. The effective binding energy $S_p^{eff} = E_x^c + S_p$ is produced keeping all parameters fixed where S_p = 0.141 MeV. The Hartree-Fock densities of ^{22}Mg (core) and ^{12}C (target) are used for calculating S-matrix using t-ρρ formalism. The Spectroscopic Factor (SF) is taken as unity throughout the calculations.

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Results

We have calculated the proton removal breakup cross-section and Full Width at Half Maxima (or width) of LMD for the breakup reaction of halo ^{23}Al on target ^{12}C at 74 MeV/n incident beam energy. Table 1 shows all the assumed configurations as well as the calculated results for the nuclear breakup (both stripping and diffraction contribution).

Table 1: Breakup cross-section and width of LMD corresponding to different core excited states for ^{23}Al ($J^{\pi}=5/2^{+}$).

E_x^c (MeV)	$I_c \otimes$ proton Configuration	σ_{total} (mb)	FWHM (MeV/c)
0.0	$0^+ \otimes 1d_{5/2}$	37.13	213.97
1.247	$2_1^+ \otimes 1d_{5/2}$	31.61	236.17
3.308	$4_1^+ \otimes 1d_{5/2}$	26.39	260.47
5.293	$4_2^+ \otimes 1d_{5/2}$	23.27	277.53
1.247	$2_1^+ \otimes 2s_{1/2}$	56.79	80.77

The observed pattern in cross-section and LMD width with core excitation energy are plotted in Fig. 1 and Fig. 2 for $1d_{5/2}$ configurations. The decrease (increase) in the cross-section (width of LMD) is observed. The variations are per the uncertainty principle i.e. effective binding energy increases with excitation which results in decreasing halo character.

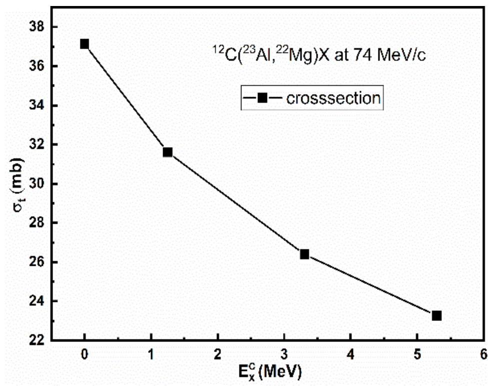

Fig 1. Breakup cross-section variation with core excitation energy for d-state.

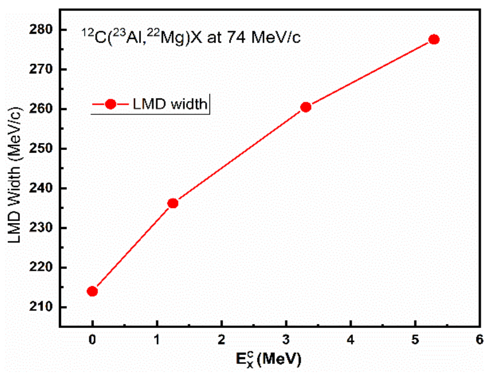

Fig 2. LMD width variation with core excitation energy for d-state.

Here, it can be seen that the LMD width for all the d-configurations lies in the range of experimental data i.e. 232 ± 28 MeV/c, ranges between 204 to 260 MeV/c (expect $4_2^+ \otimes 1d_{5/2}$ gives 270 MeV/c). But $2_1^+ \otimes 1d_{5/2}$ configuration shows the LMD width closer (236 MeV/c) to the mean exp. value (232 MeV/c) as seen in Ref. [7] (the inclusive mean value of LMD width is 180 MeV/c which matches for $2_1^+ \otimes 1d_{5/2}$ value).

Conclusion

The core excitation is included in $^{12}C(^{23}Al,^{22}Mg)$ X breakup reaction at incident energy 74 MeV/n. The excitation effect of the core states on single proton breakup cross-section and width of LMD has been found. It has been observed that the cross-section decreases with increasing core excitation energy while the LMD width increases as in Ref. [13]. The observed changes for d-state in cross-section are ~37% however in LMD width is ~30%. The changes are 7.05% and 5.6%, respectively, with per MeV change in core excitation energy. Thus, core excitation amended the results in a significant way.

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