Coulomb Diffraction Interference Effects in $^{12}C(^{23}Al,^{22}Mg)X$ Reaction at 40 MeV/n and its Sensitivity on Separation Energy

Surender* and Ravinder Kumar†
Department of Physics, Deenbandhu Chhotu Ram University of Science and Technology, Murthal, Sonepat -131039, INDIA.

Introduction

The amazing nuclear structural features of exotic nuclei attracted lot of attention in last three decades, specially because of their key role in r-p processes in astrophysical nuclear reactions[1]. So investigation of these exotic nuclei via breakup reactions is quite important for their structural information. The Coulomb breakup of neutron rich nuclei is very well understood but proton halo breakup is more complicated because of its valence proton. Also the interference between Coulomb and diffraction mechanism has also been reported to play important role in breakup reactions which may over predict or under predict the breakup observable [2, 3, 4]. Recently, ^{23}Al is reported to have one proton halo structure [1, 5] having very small separation energy with large uncertainty. So it is interesting to investigate interference between Coulomb and diffraction mechanisms with different separation energies, which were reported to influence the single proton breakup cross-section in knockout reactions. Therefore, in $^{12}C(^{23}Al,^{22}Mg)X$ reaction at 40 MeV/n, we have investigated the effects of different separation energy (S_p= 0.123, 0.141 and 0.282 MeV) on total breakup cross-section and Coulomb diffraction interference.

Theoretical Formalism

The longitudinal momentum distribution of core fragment in diffraction breakup mechanism is calculated using Eikonal approximation whereas in Coulomb mechanism we have used the well known semi-classical method that treat full Coulomb interaction to all order, discussed in detail in references [2, 4, 6]. The projectile i.e., ^{23}Al is assumed to be a two body system (Core + proton) who's radial wavefunction is calculated by numerically solving the Schrodinger equation in a Woods-Saxon nuclear potential whose depth is tuned to reproduce the separation energy of valence proton. Here we have calculated radial wave function for $[0^+ \otimes 1d_{5/2}]$ ground state configuration only. The range (r_0), diffuseness (a_0) parameters of Woods-Saxon potential and L-S coupling potential (V_{ls}) are taken as 1.25 fm, 0.7 fm and 20.72 MeV respectively through out the calculations. The core-target and proton-target s-matrices are calculated using MOMDIS code based on $t\rho\rho$ formalism using the HF core and target densities [7].

Results

Using the theoretical formalism discussed in ref. [2, 3, 4, 6], we have calculated the longitudinal momentum distribution(LMD) of core fragment for Diffraction and Coulomb Dissociation mechanism. Calculations are performed for different separation energies i.e., 0.123, 0.141 and 0.282 MeV, lying in uncertainty range and there after the valence proton breakup cross sections are obtained by integrating the respective LMD over the momentum in z-direction. The calculated cross sections corresponding to different binding energies are shown in Table I and their respective projectile radial wave functions are also shown in Figure 1.

It is found that in both Diffraction and Coulomb mechanisms the breakup cross-section decreases (≈5%) with increases in separation energy from 0.123 to 0.282 MeV, which can be understood by the fact that

*Electronic address: surender.schphy@dcrustm.org
†Electronic address: drravinderkumarphy@dcrustm.org

TABLE I: The single proton breakup cross-section and Coulomb diffraction interference (in percentage) for different separation energies of valence proton in ^{23}Al

S_p (MeV)	σ^{Diff} (mb)	σ^{Coul} (mb)	$\sigma^{Coul+Diff}$ (mb)	$\sigma^{Diff}+\sigma^{Coul}$ (mb)	% Interference
0.123	10.42	5.32	16.53	15.74	5.00
0.141	10.37	5.27	16.42	15.64	5.01
0.282	9.98	4.87	15.60	14.85	5.08

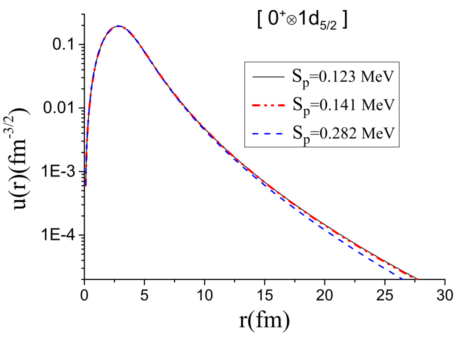

FIG. 1: ^{23}Al radial wave function for different separation energies.

breakup possibility reduces as projectile become more bound. Also the Coulomb diffraction interference is observed almost insensitive to the valence proton separation energies i.e., 0.123, 0.141, and 0.282 MeV and lies thoroughly around 5% for each separation energy case.

Conclusions

We have studied the single proton knockout from ^{23}Al nucleus on ^{12}C target at 40 MeV/n beam energy using eikonal and all order formalism [2, 3, 4, 6]. Keeping in view that this nucleus has large uncertainty in its valence proton separation energy, so we have investigated the sensitivity of Coulomb diffraction interference on separation energy of valence proton. The Coulomb diffraction interference is found almost insensitive to variation in separation energy (i.e., 0.123, 0.141 and 0.282 MeV) and is found ≈ 5% for all the cases considered in this reaction.

References

[1] A. Banu, Trache, and other, Physical Review C **84**, 015803 (2011).
[2] A. García-Camacho, G. Blanchon, A. Bonaccorso, and D. Brink, Physical Review C **76**, 014607 (2007).
[3] R. Kumar and A. Bonaccorso, Physical Review C **86**, 061601 (2012).
[4] R. Kumar and A. Bonaccorso, Physical Review C **84**, 014613 (2011).
[5] R. Panda, M. Panigrahi, M. K. Sharma, and S. Patra, Physics of Atomic Nuclei **81**, 417 (2018).
[6] A. Garcia-Camacho, A. Bonaccorso, and D. Brink, Nuclear Physics A **776**, 118 (2006).
[7] B. N. L. National Nuclear Data Center, *Nudat (nuclear structure and decay data)*, URL https://www-nds.iaea.org/RIPL/.