Core excitation in the breakup of mirror nuclei with A=12

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Introduction

Due to their anomalous structural properties and vast role in astrophysics, halo nuclei are being studied widely throughout the world since their discovery. Proton halo has an enormous role [1] in stellar reactions and the challenges in experiments with proton halo make its theoretical study more essential. The information about their structure is obtained by performing many reactions like transfer, charge exchange, etc. Apart from these, the breakup process is also being studied extensively owing to its significant role in deciphering the structure of exotic nuclei. At first, the ground state of weakly bound nuclei was reported to have a halo structure but later on the possibility of a halo was sought by considering excited states of some nuclei like ^{11}Be and ^{13}C [2, 3]. The excited state of ^{12}N with energy $E_x^p = 1.19MeV$ and of ^{12}B with energy $E_x^p = 1.67MeV$ having J^π=2^- have been predicted as proton halo and neutron halo, respectively[6]. The enhancement in rms radii for the excited state has been observed. The ground state 1^+ of ^{12}N nuclei is also considered as a proton halo and core excited components in the ground state wavefunction have been reported.[4]. Moreover, core excitation also has a significant role in breakup observables[5]. So keeping in mind the importance of core excitation and projectile excited state, we have examined the effects of core excitation for the nuclear breakup of the excited state with J^π= 2^- of the mirror nuclei pair ^{12}N-^{12}B.

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Theoretical Formalism

The proton and neutron breakup from ^{12}N and ^{12}B, respectively, on target ^{28}Si at an incoming beam energy of 40 MeV/n is studied. The structure of ^{12}N(^{12}B comprises ^{11}C(^{11}B) as core and one proton(neutron) having separation energy of 0.6 MeV(3.37 MeV). We have calculated the single nucleon removal cross-section and longitudinal momentum distributions(LMD) using the Glauber model [8]. The radius parameter $r_0 = 1.1fm$ and diffuseness $a_0 = 0.5fm$[4], $V_{so} = 5.5MeV$ are used for Wood-Saxon potential for calculating the wavefunction. The S-matrices for core-target and nucleon-target interaction are calculated from the t-$\rho\rho$ approximation. The single-particle configurations for the final J^π are formed by coupling excited core states with valence nucleon in 2s and 1d states. The excitation energy of the different core states is taken from Ref. [9]. The effective separation energy is found using the formula, S_p^{eff}=S_p+E_x^c-E_x^p.

Results

The calculated results for ^{12}N and ^{12}B are shown in Table I and Table II, respectively. The sixth and seventh columns in the tables contain the single proton removal cross-section and width of LMDs(FWHM) for the core from the breakup. The FWHM for the configurations having valence nucleon in the s-state is comparable to the well-established halo nuclei. The change in the FWHM(cross-section) per MeV of core excitation energy is ∼15%(11.5%) and ∼ 6%(6.8%) for the s- and d- configuration, respectively, for ^{12}N nuclei. A change in FWHM(cross-section) of ∼5.7%(4.1%) and ∼ 5%(6.4%) per MeV in core excitation energy is found for the s- and d- configuration, respectively, for the case

TABLE I: Calculated nuclear breakup cross-section and LMD width corresponding to different configurations for 2^- of ^{12}N.

J^π	E_x^p (MeV)	$single-particle$ $state$	E_x^c (MeV)	S_p^{eff} (MeV)	σ_{-1p} (mb)	$FWHM$ (MeV/c)
2^-	1.19	$^a3/2^- \otimes 2s_{1/2}$	0.0	0.59	158.60	59.91
		$1/2^- \otimes 1d_{5/2}$	2.0	1.41	55.77	263.61
		$5/2^- \otimes 2s_{1/2}$	4.3	3.73	79.91	98.43
		$5/2^- \otimes 1d_{5/2}$	4.3	3.73	46.99	302.57

[a]unbound state

TABLE II: Calculated nuclear breakup cross-section and FWHM corresponding to different configurations for 2^- of ^{12}B .

J^π	E_x^p (MeV)	$single-particle$ $state$	E_x^c (MeV)	S_p^{eff} (MeV)	σ_{-1p} (mb)	$FWHM$ (MeV/c)
2^-	1.67	$3/2^- \otimes 2s_{1/2}$	0.0	3.37	92.16	84.62
		$1/2^- \otimes 1d_{5/2}$	2.1	3.82	42.15	273.22
		$5/2^- \otimes 2s_{1/2}$	4.4	6.14	75.56	105.96
		$5/2^- \otimes 1d_{5/2}$	4.4	6.14	35.94	304.12

of ^{12}B nuclei. A large value of FWHM for the l=2(d-configurations) as compared to the l=0(s-configurations) indicated the possibility of valence proton(neutron) in the s-state coupled with higher energy core states. Further, the SF and D_1 coefficients of ^{12}B for l=0 state is more as compared to l=2 state for the $J^\pi = 2^-$ ([12] and ref. therein), pillars the present results.

Conclusion

In conclusion, we have studied the nuclear breakup of the proposed halo excited state $J^\pi = 2^-$ of mirror nuclei ^{12}N(proton halo) and ^{12}B(neutron halo). For ^{12}N breakup, more change in FWHM and cross-section with core excitation has been found than the case of ^{12}B. Also, the change per MeV core excitation energy for the configurations for which valence proton occupy s-state is approx. double of the configurations for which d-state is occupied for ^{12}N breakup. For ^{12}B, the change in breakup observables are 4-6% per MeV change in core state energy.

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