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Single proton removal reactions in proton halo nuclei

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ABSTRACT

The single proton breakup through stripping and diffraction reactions from weakly bound state in an exotic nucleus (^{8}B) on a heavy target (Pb) at 72 AMeV energy have been studied. In order to elucidate the differences with the well-understood neutron breakup mechanism the dynamics of proton nuclear breakup is compared to that of an *equivalent* neutron of higher binding energy. The parallel momentum distributions (LMD) and breakup cross sections for stripping and diffraction mechanisms have been calculated and observed that in nuclear breakup mechanism the proton behaves exactly as a neutron of higher binding energy. We hope that the present study might be helpful for better understanding of the dynamics of proton halo nuclei.

Keywords: Proton halo, nuclear breakup reactions,

Introduction

Here, we have studied the single proton breakup reaction from an exotic nuclei on heavy target at 72 AMeV energy by using new approach[1-3]. In order to elucidate the differences between the well-understood breakup mechanism of neutron rich halo nuclei. We have studied the dynamics of proton nuclear breakup by assuming proton as an *equivalent* neutron of higher binding energy caused by the combined core-target Coulomb barrier. The concept of effective binding energy of the valence proton to treat it as a neutron was proposed in ref. 2.

The motivation behind this work is that, recently, Liang *et al.* [4] experimentally found that the idea proposed in ref. 2 could successively reproduced the angular distributions using an increase in the binding energy.

According to this formalism the effective binding energy is defined as [1]

$$\tilde{\varepsilon} = \varepsilon_i - \Delta = \varepsilon_i - \frac{Z_p^2}{R_i} - Z_t^2\left(\frac{1}{2}\left(\frac{1}{|d+\beta_2 R_i|} + \frac{1}{|d-\beta_1 R_i|}\right)\right) - \frac{1}{d}$$

Where β_1 and β_2 are the mass ratios of the proton and core, respectively, to that of the projectile. Z_p and Z_t are the projectile and target proton charges, respectively. R_i is the position of the projectile at the top of the Coulomb barrier and d is the distance between the center of the two nuclei for which the tops of the two Coulomb barriers of projectile and target coincide.

The observables parallel momentum distribution and cross section is calculated by using the well known eikonal approximation.

$$\frac{d\sigma}{dk} = \frac{1}{8\pi}\int d\vec{b}_c\,|S_{ct}(b_c)|^2\,|g^{nuc}|^2$$

and

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

Where $|S_{ct}(b_c)|^2$ is the core target s-matrix and b_c and b_v are core and valence nucleon impact parameter. The coordinate system is shown in Fig. 1.

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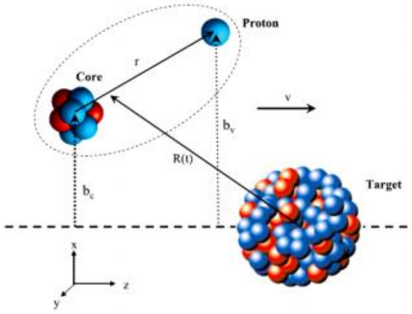

Fig. 1 Coordinate system

This formalism is applied to proton breakup of ^{8}B on the Pb target at beam energy of 72 AMeV, which is a typical energy used in several laboratories and for which our results should be reliable. The projectile is taken as two-body objects whose radial wave functions is been obtained by numerical solution of the Schrodinger equation in the Woods-Saxon potentials with depths adjusted to reproduce the experimental separation energies (0.137 MeV). The radius parameter of the Woods-Saxon potential have been taken as 1.3 fm and the diffuseness as 0.6 fm.

In order to understand the proton vs neutron breakup dynamics, we start by looking at the wave functions in Fig.2 the single-particle wave function (Sp = 0.137 MeV) for a $p3/2$ proton [solid line], for a neutron with the same binding energy (Sn = 0.137 MeV) [dashed line] and, finally, for a neutron with higher binding energy, Sn =0.6 MeV [dotted line] which is in good matching to that of proton curve [solid line].

The various parameters used in these calculations are listed in Table 1. We calculated the parallel momentum distribution and cross section by using actual binding energy (Sp =0.137 MeV) as well as by using effective neutron binding energy (Sn =0.4MeV and 0.6 MeV) and the obtained spectra are shown in Fig. 3 & 4. It is clear from Fig. 3 & 4, that width and cross sections in case of neutron with higher binding energy are very similar to proton case. Hence, we see that the "neutron-like" model works well for the p3/2 ground state ^{8}B at 72 AMeV incident energy on Pb target. The best "model" separation energy here seems to be 0.6 MeV.

Table 1. Barrier radii, initial binding energies, and effective energy parameters for Pb target.

	^{8}**B**	J^π
R_i(fm)	6.0	
[illegible]eV)	-0.14	$1p_{3/2}$
[illegible]eV)	-0.57	$1p_{1/2}$
-Δ (MeV)	-0.4	
[illegible]eV)	-0.54	$1p_{3/2}$
[illegible]eV)	-0.97	$1p_{1/2}$

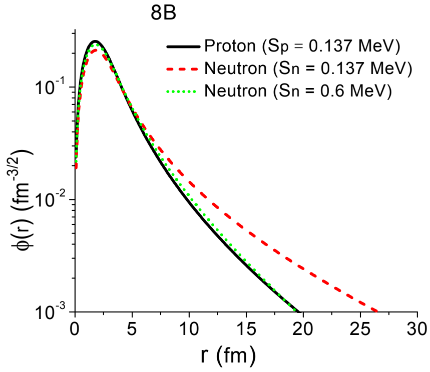

Fig. 2. Proton vs neutron wave functions of ^{8}B for $1p_{3/2}$ state.

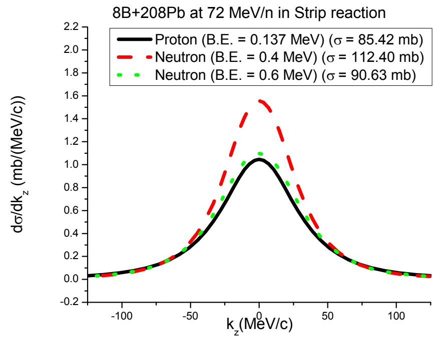

Fig. 3, 4. Proton vs neutron parellel momentum distribution and cross section.

Conclusion

Through this work we have tried to find out effective binding energy for ^{8}B+Pb reaction. The best "model" separation energy for ^{8}B+Pb reaction, from wave function matching comes out to be 0.6 MeV, which have been duly proved the by the parallel momentum distribution and cross section results.

Hence, results show that as far as the stripping and diffraction mechanism is concerned, the idea of replacing proton by neutron with higher separation energy works in these mechanisms and we hope that the present study will be helpful to understand the complicated proton breakup reactions.

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