Coulomb breakup of proton halo nuclei

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Introduction:

Coulomb dissociation, being the inverse of the radiative capture reaction, is a useful technique for studying stellar nucleosynthesis involving short-lived nuclei where direct measurements are difficult such as rp process. Owing to the associated astrophysical interest more and more measurements of cross section are performed by Coulomb dissociation technique these days worldwide. However in order to extract reliable information for radiative capture reactions the Coulomb dissociation mechanism has to be understood in detail. In the present era the Coulomb dissociation of loosely bound neutron-rich nuclei has been studied extensively and is fairly well understood while the proton rich nuclei lying close to drip lines are still under investigation.

So in order to elucidate the differences between the well-understood Coulomb breakup mechanism of neutron rich halo nuclei and those involving proton rich nuclei, we have studied exclusively the role of interaction of valence proton with the target. Here we have studied the Coulomb breakup reaction of proton rich nuclei i.e. ^{8}B and ^{17}F on ^{208}Pb target at 72 AMeV energy [1].

Theoretical formalism:

We used a semi classical method that treat the full Coulomb interaction to all orders[1-3]. The Coulomb potential causing the Coulomb breakup is given by

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

where

$V_c = Z_c Z_t e^2, V_v = Z_v Z_t e^2$ *and* $V_0 = (Z_v + Z_c) Z_t e^2$

while 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 numbers, respectively. The coordinate system used is shown in Fig. 1.

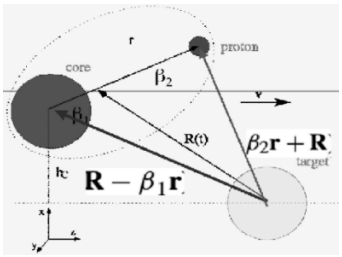

Fig. 1 Coordinate system

The momentum probability distributions at fixed impact parameter is given as [1]

$$\frac{dP(b_c)}{d\vec{k}_z} = \frac{1}{8\pi^3}\int d\vec{k}_\perp \left| g^{Coul}(b_c)\right|^2$$

where $g^{\text{Coul.}}(b_c) = g^{rec}(b_c) + g^{dir}(b_c)$ are core-target (recoil) and valence proton- target (direct) Coulomb amplitude in all order [4]

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

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

b_c and b_v are core and valence nucleon impact parameter. The projectile is taken as two-body object whose radial wave function is obtained by numerical solution of the Schrodinger equation in the Woods-Saxon potentials with depths adjusted to reproduce the experimental separation energies (0.137 and 0.6 MeV for ^{8}B and ^{17}F respectively). The radius parameter of the Woods-Saxon potential has been taken as 1.3 fm and the diffuseness as 0.6 fm.

Results

In order to study the contributions of recoil core target Coulomb interaction and direct proton target Coulomb interactions, we have calculated the momentum probability distributions at fixed impact parameter and is shown in Fig. 2 and 3, for both the projectiles, i.e. ^{8}B and ^{17}F, here, we separately show the effect of the recoil [dashed (red) line] while the dotted (green) line represents the direct term obtained from g^{dir}. The solid (black) line contains both. It is clear that the interference between the two is mostly destructive and it becomes constructive only at very large impact parameters.

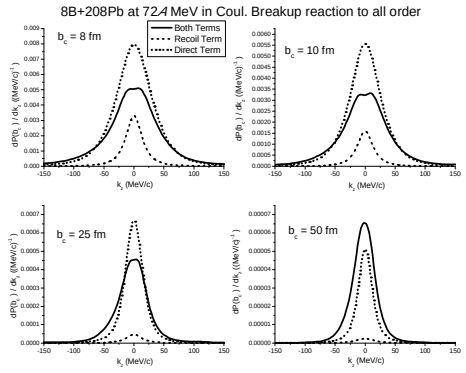

Fig. 2

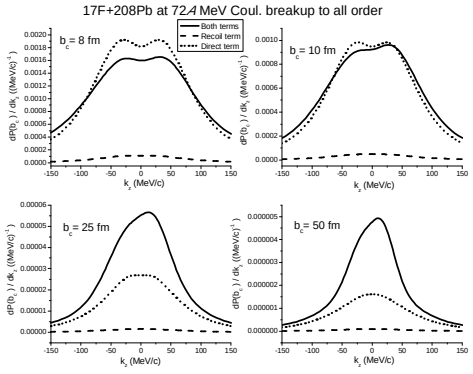

Fig. 3

Fig. 2, 3. Momentum probability distributions at fixed impact parameters in proton breakup from ^{8}B and ^{17}F projectile on ^{208}Pb target at 72A MeV.

This effect is the equivalent in our model of what Liang *et al.* [5] call the "shielding effect" of the proton by the core. The direct term alone, being proportional to β_2, is indeed always larger in absolute value than the recoil term. However, it is the effect of the interference between the direct and the recoil terms that causes the reduction of the Coulomb breakup in the proton halo case.

Conclusion

Through this study it clear that in Coulomb breakup mechanism the contributions of direct and recoil terms are complicated, some time it seems constructive and some time destructive and also depends on the chosen target and beam energy recently discussed in ref [6].

We hope that the present study will be helpful to understand the complicated proton breakup reactions of proton rich exotic nuclei and also the interpretations of the experimental results involving exotic nuclei.

References:

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