On the moderate sized halo in ^{29}Ne

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Introduction

The medium mass nuclei in the 'island of inversion' [1] have garnered the attention of nuclear physicists due to their energy levels where rapid changes in the shell structure lead to $\nu(\mathrm{sd})^{-2}$ $(\mathrm{fp})^2$ mixing and result in the inversion of energy states. Specifically, ^{31}Ne, ^{34}Na and ^{37}Mg have been established to lie within this island and found to have a ground state valence nucleon configuration of $\nu 2p_{3/2}$ [2–4]. One can also find deformed halo nucleii in this region. ^{29}Ne is conjectured to lie at the lower end of this island, but it is speculated to be a moderately halo nucleus [5]. Further, there is an ambiguity in the ground state spin-parity of ^{29}Ne and no information is available about its shape - spherical or deformed. According to shell-model predictions, out of its four low lying energy states with spin parities $3/2^+$, $3/2^-$, $7/2^-$ and $1/2^+$, the $3/2^+$ and $3/2^-$ states are nearly degenerate [5].

^{29}Ne has small one neutron separation energy of 0.96 MeV and its most probable ground state configuration could be $3/2^-$ [5], meaning a p-wave neutron (i.e., $l \leq 1$), which are the typical features and requirements for a halo nucleus. Therefore, ^{29}Ne is a good candidate to be a neutron halo.

As halo nuclei have a large spatial extension, they have narrow widths of momentum distributions to validate the uncertainty principle. In fact the parallel momentum distribution (PMD) (p_z, momentum parallel to the direction of beam) is less affected than the transverse momentum distribution ($p_\perp$) in terms of absorption and other reaction mechanism effects [6]. Therefore, we have calculated the parallel momentum distribution of the charged fragment of ^{29}Ne using the configuration $^{28}\mathrm{Ne} \otimes 2p_{3/2}\nu$ and compared its full width at half maximum (FWHM) with available experimental value.

Formalism

We use the fully quantum mechanical theory of post form finite range distorted wave Born approximation (FRDWBA) for our calculation of ^{29}Ne breaking elastically on ^{208}Pb target at a beam energy of 244 MeV/u to give ^{28}Ne and a neutron due to Coulomb effects. The main ingredient of this theory is the ground state wave function of the projectile.

The parallel momentum distribution for any $a + t \longrightarrow b + c + t$ reaction is written as

$$\frac{d\sigma}{dp_z} = \int \frac{2\pi}{\hbar v_{at}} \rho(E_b, \Omega_b, \Omega_c) d\Omega_c dp_x dp_y \times \{\sum_{l,m} |\beta_{lm}^{FRDWBA}|^2 \frac{1}{2l+1}\} \quad (1)$$

where, β_{lm}^{FRDWBA} is the reduced transition amplitude from initial to final state with angular momentum of the wave function l and m its projection, $\rho(E_b, \Omega_b, \Omega_c)$ is the three body final state phase space factor [7] and v_{at} is the relative velocity between projectile and target in the entrance channel. The reduced transition amplitude under the FRDWBA scheme is written as

$$\beta_{lm} = \int d\mathbf{r}_1 e^{-(\gamma \mathbf{q}_c - \alpha \mathbf{K}).\mathbf{r}_1} V_{bc}(\mathbf{r}_1) \phi_a^{lm}(\mathbf{r}_1) \times \int d\mathbf{r}_i e^{-(\delta \mathbf{q}_c.\mathbf{r}_i)} \chi_b^{(-)*}(\mathbf{q}_b, \mathbf{r}_i) \chi_a^{(+)}(\mathbf{q}_a, \mathbf{r}_i)$$

Here $\mathbf{q}_i$'s are the wave vectors in Jacobi

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*Electronic address: `mdan@ph.iitr.ac.in` co-ordinate system and χ_i's are the pure Coulomb distorted wave of the i^{th} particle (i = a, b, c). V_{bc} is the Woods-Saxon potential without deformation and ϕ_a is the ground state wave function of the projectile (a).

More details on the formalism can be found in Ref. [8].

Results and discussion

The ground state wave function of ^{29}Ne is constructed by adjusting the depth of the Woods-Saxon potential to reproduce its binding energy of 0.96 MeV while considering a $2p_{3/2}$ state neutron bound to a ^{28}Ne(0^+) core. We have fixed the radius and diffuseness parameters at 1.24 fm and 0.62 fm.

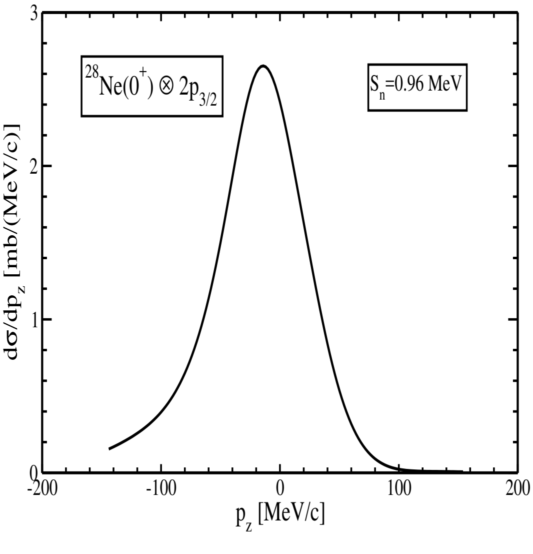

FIG. 1: Parallel momentum distribution of ^{28}Ne calculated from the elastic Coulomb breakup of ^{29}Ne on ^{208}Pb at a beam energy of 244 MeV/u.

Figure 1 shows the calculation of parallel momentum distribution of the charged core in the elastic Coulomb breakup of ^{29}Ne on Pb at 244 MeV/u. The p-state configuration of ^{29}Ne gives an FWHM of the PMD equal to 82 MeV/c. The experimental value of the FWHM is 98±12 MeV/c [5] where the breakup was done on a light (carbon) target. Nevertheless, given the fact that the PMD should be independent of the reaction mechanism [6], our results are in good agreement with the experimental data. It is also known that the FWHM of PMD of the charged core in the breakup of light halo nuclei like ^{11}Be and ^{19}C is around 44 MeV/c, whereas for the corresponding case of stable nuclei, it is about 140 MeV/c. Therefore, it appears that there may be a moderately sized halo in the ground state of ^{29}Ne.

We also plan to investigate the PMD and calculate other reaction observables (with and without deformation) for the other conjectured spin-parities of ^{29}Ne.

Acknowledgments

[MD] acknowledge MHRD, Govt. of India, for the research fellowship.

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