Coulomb breakup of ^{31}Ne using finite range DWBA

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Introduction

Coulomb breakup of nuclei away from the valley of stability have been one of the most successful probes to unravel their structure. However, it is only recently that one is venturing into medium mass nuclei like ^{23}O and ^{31}Ne. This is a very new and exciting development which has expanded the field of light exotic nuclei to the deformed medium mass region.

The ^{31}Ne nucleus is interesting to study as it lies in the "island of inversion", with suggested spin parity ($J^{\pi} = 3/2^{-}$) [1], and a large uncertainty in its neutron binding energy. It is also thought to have a deformed ground state structure.

In this contribution we report an extension of the previously proposed [2] theory of Coulomb breakup within the post-form finite range distorted wave Born approximation to include deformation of the projectile. The electromagnetic interaction between the fragments and the target nucleus is included to all orders and the breakup contributions from the entire non-resonant continuum corresponding to all the multipoles and the relative orbital angular momenta between the fragments are taken into account. Only the full ground state wave function of the deformation projectile, of any orbital angular momentum configuration, enters in this theory as input, thereby making it is free from the uncertainties associated with the multipole strength distributions that may exist in many of the other theories.

We shall present the one neutron removal cross section and other reaction observables in the Coulomb breakup of ^{31}Ne on heavy targets at 234 MeV/u beam energy and we will also compare our results with the recent experimental data [1]. The effect of deformation on various reaction observables will be studied.

Formalism

We consider the elastic breakup of a two body composite 'deformed' projectile a in the Coulomb field of target t as: $a + t \rightarrow b + c + t$, where projectile a breaks up into fragments b (charged) and c (uncharged). The reduced transition amplitude, $\beta_{\ell m}$, is given by

$$\hat{\ell}\beta_{\ell m}(\mathbf{q}_b, \mathbf{q}_c; \mathbf{q}_a) = \int\int d\mathbf{r}_1 d\mathbf{r}_i \chi_b^{(-)}(\mathbf{q}_b, \mathbf{r}) \chi_c^{(-)}(\mathbf{q}_c, \mathbf{r}_c) V_{bc}(\mathbf{r}_1) \phi_a^{\ell m}(\mathbf{r}_1) \chi_a^{(+)}(\mathbf{q}_a, \mathbf{r}_i), \quad (1)$$

where, $\hat{\ell} = \sqrt{2\ell + 1}$, $\mathbf{q}_b$, $\mathbf{q}_c$ and $\mathbf{q}_a$ are the wave vectors of b, c and a corresponding to Jacobi vectors $\mathbf{r}$, $\mathbf{r}_c$ and $\mathbf{r}_1$, respectively. $\chi_b^{(-)}$ and $\chi_c^{(-)}$ are the distorted waves for relative motions of b and c with respect to t and the center of mass (c.m.) of the $b - t$ system, respectively, with ingoing wave boundary conditions. $\chi_a^{(+)}(\mathbf{q}_a, \mathbf{r}_i)$ is the Coulomb distorted wave of the projectile with outgoing boundary conditions. It describes the relative motion of c.m. of projectile with respect to the target. Further, $\phi_a^{\ell m}(\mathbf{r}_1) = u_\ell(r_1) Y_{\ell m}(\hat{\mathbf{r}}_1)$ is the ground state wave function of the projectile with relative orbital angular momentum state ℓ and projection m ($u_\ell(r_1)$ is the radial part and $Y_{\ell m}(\hat{\mathbf{r}}_1)$ is the angular part).

$V_{bc}(\mathbf{r}_1)$ [in Eq. (1)] is the interaction between b and c, in the initial channel. This is where we introduce an axially symmetric quadrupole-deformed potential, similar to Ref. [3] as

$$V_{bc}(\mathbf{r}_1) = V_{bc}(r_1, \theta) = \frac{-V_0}{1 + \exp[\frac{r_1 - R(\theta)}{a}]} \quad (2)$$

where V_0 is the strength of the potential and a is the diffuseness parameter. For the deformed projectile, $R(\theta) = R_0[1 + \beta_2 Y_2^0(\theta)]$,

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where $R_0 = r_0 A^{1/3}$ (r_0 is the radius parameter) and β_2 is the quadrupole deformation parameter. θ is the angle which $\mathbf{r}_1$ makes with the symmetry axis.

Retaining the first two terms in the Taylor expansion of $V_{bc}(r_1, \theta)$:

$$V_{bc}(r_1, \theta) = V_s - \beta_2 R_0 Y_2^0(\theta) \frac{dV}{dr}|_{R=R_0}, \quad (3)$$

where V_s is the spherical Woods-Saxon Potential.

However, to preserve the analyticity of our method, we still calculate the radial part of the ground state wave function of the projectile from undeformed potential V_s. We emphasize that the deformation parameter (β_2) has already entered into the theory via $V_{bc}(\mathbf{r}_1)$ in Eq. (1).

Further, replacing the $\chi_c^{(-)}$ in Eq. (1) by a plane wave [as c is (uncharged)] and expanding the $\chi_b^{(-)}(\mathbf{q}_b, \mathbf{r})$ using the local momentum approximation [2], we get the factorization of the $\beta_{\ell m}$ in to two three dimensional integrals - the structure part and the dynamics part. The dynamics part remains the same as in Ref. [2], which can be solved analytically in terms of Bremsstrahlung integral. However, the structure part which involves the ground state wave function of the projectile and the effect of deformation is different, which can be simplified analytically to

$$I_f = 4\pi \sum_{l_1 m_1} i^{-l_1} Y_{l_1}^{m_1}(\hat{Q}) \int r_1^2 dr_1 j_{l_1}(Qr_1) u_\ell(r_1) \times \left[V_s \delta_{l_1,\ell} \delta_{m_1,m} - \beta_2 R_0 Y_2^0(\theta) \frac{dV}{dr}|_{R=R_0} I_1 \right],$$

where Q is the momentum dependent on the local momentum of the charged fragment and

$$I_1 = \int d\Omega_{r_1} Y_2^0(\hat{\mathbf{r}}_1) Y_{l_1}^{m_1 *}(\hat{\mathbf{r}}_1) Y_\ell^m(\hat{\mathbf{r}}_1),$$

with $|\ell - 2| < l_1 < |\ell + 2|$ and $m_1 = m$.

Results and discussions

Considering the ground state spin-parity as $J^\pi = 3/2^-$) [1], we calculated the ground state wave function using a Woods-Saxon potential. With the radius and diffuseness parameters as 1.24 fm and 0.62 fm, respectively, the depth turns out to be 50.45 MeV for $S_n = 0.30$ MeV.

FIG.1, shows the effect of deformation on the parallel momentum distribution of the core (^{30}Ne) in the Coulomb breakup of ^{31}Ne on Pb at 234 MeV/u. It is clear that the effect of deformation is maximum at the peak height and also the peak height increases with the deformation. Further, we found that the full width at half maxima decreases with increasing the deformation.

We have also calculated the effect of deformation on the other reaction observables like one neutron removal cross section, relative energy spectra, angular and energy-angular distributions [4], which we shall present.

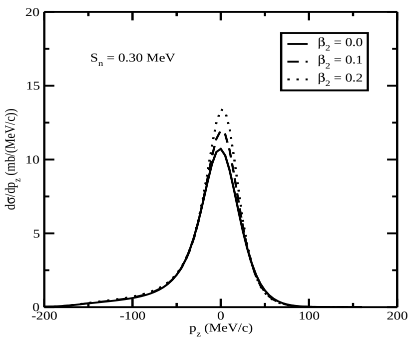

FIG. 1: Parallel momentum distribution of ^{30}Ne calculated from the Coulomb breakup of ^{31}Ne on Au target at 234 MeV/u beam energy for $S_n = 0.30$ MeV and different values of β_2.

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References

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