Determination of contribution of s and d states in ^{22}N

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The advancement in experimental techniques and theoretical tools uplift the knowledge, regarding nuclei lying far away from the stability line. Consequently, the numerous experiments performed with the dedicated radioactive nuclear beams (RNBs) facilities have disclosed some peculiar properties of exotic nuclei such as skins, proton/neutron halos, Borromean structure and disappearance of magic number. The neutron halo is the most remarkable and unusual feature of exotic nuclei, which is basically a two-fold structure (core + valence neutron) where loosely bounded outermost valence neutron tunnel out to the classically forbidden region from the tightly bound core giving rise to enhanced matter radii. Due to enhanced reaction cross section of ^{22}N as compared to neighbouring isotope ^{21}N and small binding energy (1.28±12 MeV), it has attracted considerable attention of scientific community. Subsequently, Ozawa et al [1], suggested the existence of one-neutron halo structure in ^{22}N. Since reaction cross section or narrow parallel momentum distribution of core fragment is very sensitive and efficient tool to identify the halo character of nuclei, therefore here we have employed CSC_GM code [2] based on Eikonal Glauber model to analyze nuclear breakup observables for reactions ^{12}C (^{22}N, ^{21}N+n) ^{12}C and ^{9}Be (^{22}N, ^{21}N+n) ^{9}Be at 965 and 700 MeV/n beam energies respectively.

The detailed description of theoretical formalism is given in Refs. [2]. The key inputs for calculating the reaction cross section and parallel momentum distribution are: (i) profile functions of core –target and neutron- target interaction and (ii) core-target densities in terms of 2 point Gaussian coefficients. The values of profile functions parameters σ_{NN} (nucleon-nucleon cross section), α (ratio of real to imaginary nucleon-nucleon scattering amplitudes) and β (slope parameter) at energies 700 and 965 MeV/n are obtained by method as described in refs [3-5]. The parameters for core and target densities are obtained by imposing conditions as mentioned in ref. [6]. Beside this, the relative wave function of core and valence neutron is another essential ingredient. Although spin parity $J^{\pi} = 0^{-}$ [7]was reported for ^{22}N, but here we have considered all the possible spin coupling configurations of core and valence nucleon ($1/2^{-} \otimes 2s_{1/2}$, $3/2^{-} \otimes 1d_{3/2}$ and $5/2^{-} \otimes 1d_{5/2}$) with resultant $J^{\pi} = 0^{-}$. The corresponding single particle ground state wave function of last nucleon is deduced through the solution of radial Schrodinger equation for Wood-Saxon potential. Diffuseness (a) = 0.6 fm and range (r_0) = 1.24 fm parameters are taken from ref [8] while depth of the potential is adjusted to reproduce the effective separation energy of valance neutron ($S_n^{eff} = E_c^x + S_n$).

Results and Discussion

The calculated reaction cross section for ^{12}C (^{22}N, ^{21}N+n) ^{12}C system is listed in table I.

Table I. Reaction cross section for ^{12}C (^{22}N, ^{21}N+n) ^{12}C reaction at 965 MeV/n beam energy.

Core ⊗ n configuration	E_c^x **(MeV)**	$S_n^{eff} = E_c^x + S_n$ **(MeV)**	σ_{-R}^{th} **(mb)**	σ_{-R}^{expt} **(mb) [9]**
$1/2^{-} \otimes 2s_{1/2}$	0.000	1.280	1327	1245± 49
$3/2^{-} \otimes 1d_{3/2}$	1.177	2.457	1278	
$5/2^{-} \otimes 1d_{5/2}$	2.405	3.685	1277	

It is well observed from the table I that the calculated reaction cross section for $1/2^{-} \otimes 2s_{1/2}$ configuration overestimated the data whereas for the $3/2^{-} \otimes 1d_{3/2}$ and $5/2^{-} \otimes 1d_{5/2}$ configuration the results are consistent with the data. Though, reaction cross section alone is not sufficient tool to establish the halo structure and to assign spin parity of nuclei. Therefore, we have also calculated the parallel momentum distribution (PMD) of ^{21}N core residues emerging after breakup of ^{22}N projectile on target ^{9}Be at 700 MeV/n beam energy with a specific motive to determine the orbital occupancy of valance nucleon. The possible admixture of s and d state for ^{22}N has also been examined. Calculated widths of PMDs along with experimentally measured value are given in table II.

Table II. Calculated FWHM widths of PMDs corresponding to different configurations.

Configuration [core ⊗ neutron]	**Calculated FWHM (MeV/c)**	**Measured FWHM (MeV/c) [10]**
$1/2^- \otimes 2s_{1/2}$	57	77±32
$3/2^- \otimes 1d_{3/2}$	231	
$0.74(1/2^- \otimes 2s_{1/2}) + 0.26(3/2^- \otimes 1d_{3/2})$	77	
$1/2^- \otimes 2s_{1/2}$	57	
$5/2^- \otimes 1d_{5/2}$	243	
$0.74(1/2^- \otimes 2s_{1/2}) + 0.26(5/2^- \otimes 1d_{5/2})$	78	

From table 2, it becomes very clear that none of the considered states, $1/2^- \otimes 2s_{1/2}$, $3/2^- \otimes 1d_{3/2}$ and $5/2^- \otimes 1d_{5/2}$, reproduce the measured width of PMD. However, the consideration of possible admixture of s and d states reproduces it. For sake of clarity the PMD also plotted in figure.

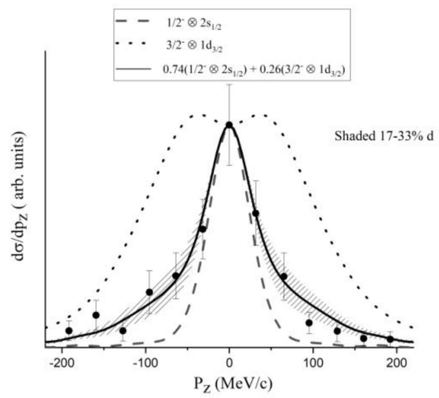

Figure 1. Parallel momentum distribution of core residues ^{21}N coming after one neutron removal from ^{22}N on ^{9}Be. The well suited configuration mixing is shown by shaded portions. The experimental datum are taken from Refs. [10].

Here the results corresponding to $1/2^- \otimes 2s_{1/2}$ configuration shows narrow distributions (dash line) as compared to data however for $3/2^- \otimes 1d_{3/2}$ configuration distribution are much wider (dotted line). But the results obtained using $0.74(1/2^- \otimes 2s_{1/2})$ + $0.24\,(3/2^- \otimes 1d_{3/2})$ admixed configuration are comparable with data (solid line). The similar results are obtained while considering $0.74(1/2^- \otimes 2s_{1/2})$ $+0.26(5/2^- \otimes 1d_{5/2})$ state. The shaded portions in figure represent the relative contribution (17-33%) of $1d_{3/2}$ and $2s_{1/2}$ state.

Conclusively, we have analyzed the structural aspects of ^{22}N. All possible spin-coupling states have been considered and found that the admixture of $2S_{1/2}$ with $1d_{3/2}$ state (17-33%) reproduce the spectrum of measured parallel momentum distribution of ^{21}N core fragment.

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