Exploring the contribution of *s* and *d* states in ^{23}O through the analysis of momentum distribution

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Introduction

The physics of unstable nuclei lying near the nuclear drip lines has drawn a tremendous interest of nuclear science community in the last few decades due to their peculiar properties [1]. Consequently, a lot of work has been done on experimental and theoretical fronts around the globe to study the exotic properties of these nuclei. Which in turn establishes some important and abnormal properties in some nuclei such as neutron/proton halo, Borromean structure and neutron skin etc. Out of these the neutron halo structure is the most exciting and unusual feature wherein tightly bound nuclear core is surrounded by loosely bound valence neutron. However, the occupancy of valence neutron in some of middle mass halo nuclei is still ucertain. In this conference contribution, we study ^{12}C (^{23}O, ^{22}O+n) ^{12}C nuclear breakup reaction with a motive to investigate the occupancy and the relative contribution of *d* state with *s* state in ^{23}O.

The well-known Eikonal approximation based Glauber model is employed here to analyze the nuclear breakup reaction data. As longitudinal momentum distribution (LMD) is quite dependent on structural aspects of projectile, so it has been recognized as an efficient tool to investigate projectile structure and is given as [2]:

$$\frac{d\sigma_{-1\mathrm{N}}^{\mathrm{inel}}}{dp_{\parallel}} = \frac{1}{2\pi\hbar}\int d\boldsymbol{s}\, e^{-2\mathrm{Im}\chi_{\mathrm{CT}}(\boldsymbol{b}_{\mathrm{N}}-\boldsymbol{s})}$$
$$\times \frac{1}{4\pi}\int d\boldsymbol{b}_{\mathrm{N}} \left(1-\mathrm{e}^{-2\mathrm{Im}\chi_{\mathrm{NT}}(\boldsymbol{b}_{\mathrm{N}})}\right)$$
$$\times \int \mathrm{d}z \int \mathrm{d}z'\, e^{\frac{i}{\hbar}P_{\parallel}(z-z')} u_{nlj}(r)\, u_{nlj}^{*}(r')\, P_l(\hat{\boldsymbol{r}}.\hat{\boldsymbol{r}}')$$

The symbols used here have the same meanings as given in ref. [2]. The inputs needed for calculating LMD are profile functions for core-target and neutron-target interaction and nuclear densities of colliding nuclei described in term of 2-point Gaussian coefficients. The value of profile function's parameters $\sigma_{\mathrm{NN}}^{tot}$ (nucleon-nucleon cross section), α_{NN} (real to imaginary ratio of nucleon-nucleon scattering amplitude) and β_{NN} (slope parameter) are deduced by employing methods as given in refs. [3-5]. The parameters of density distribution of core and target nuclei are obtained by realization of certain conditions as described in ref. [6]. Besides this, the single particle wave function of valence neutron also an essential ingredient in our calculations. Here we have considered all possible core plus valence neutron spin coupling configurations keeping ground state spin parity J^{π} $=1/2^{+}$ for ^{23}O projectile [7]. The single particle wavefunctions corresponding to considered configurations are obtained by solving the radial part of Schrödinger wave equation considering Wood-Saxon (WS) potential.

Results and discussion

Here we analyze the LMD of ^{22}O residues emerging after the nuclear breakup of ^{23}O on ^{12}C target at 72 MeV/n beam energy and compare the predictions with the experimental data with a specific motive to determine orbital occupancy of valence neutron. The possibility of *sd* admixture states for ^{23}O have also been examined. The calculated widths of LMD for considered configurations along with measured data are listed in table 1.

From table 1, it is observed that none of the pure configuration $0_1^+ \otimes 2s_{1/2}$, $2_1^+ \otimes 1d_{3/2}$, $2_1^+ \otimes 1d_{5/2}$, $0_2^+ \otimes 2s_{1/2}$, $3_1^+ \otimes 1d_{5/2}$ and $2_2^+ \otimes 1d_{5/2}$ could reproduce the experimental width of LMD. So, we have considered possible admixture of *s* and *d* states to reproduce spectrum and width of LMD and calculated results are depicted in figure 1. It is clearly noticed from figure 1 that the results corresponding $0_1^+ \otimes$ $2s_{1/2}$ configuration shows narrow distributions (dashed line) as compared to data while for

Table. 1. Calculated full width half maxima (FWHM) of LMD corresponding to different configurations.

J^π (^{23}O)	Core ⊗ n configuration	E_c^x (MeV)	S_n^{eff} = E_c^x+S_n (MeV)	Calculated FWHM (MeV/c)	Measured FWHM (MeV/c) [8]
$1/2^+$	$0_1^+ \otimes 2s_{1/2}$	0.00	2.74	74	94±12
	$2_1^+ \otimes 1d_{3/2}$	3.38	6.12	268	
	$2_1^+ \otimes 1d_{5/2}$			259	
	$0_2^+ \otimes 2s_{1/2}$	4.62	7.36	106	
	$3_1^+ \otimes 1d_{5/2}$	4.83	7.57	269	
	$2_2^+ \otimes 1d_{5/2}$	6.50	9.24	278	

$2_1^+ \otimes 1d_{3/2}$ configuration distributions are much wider (dotted line). But results obtained for admixed configuration 0.77($0_1^+ \otimes 2s_{1/2}$) + 0.23($2_1^+ \otimes 1d_{3/2}$) are consistent with data (solid line). The similar results are obtained for considering the admixture of $0_1^+ \otimes 2s_{1/2}$ with $2_1^+ \otimes 1d_{5/2}$, $3_1^+ \otimes 1d_{5/2}$, and $2_2^+ \otimes 1d_{5/2}$ with 0.77 and 0.23 as spectroscopic values for *s* and *d* states respectively [9]. The shaded portion in figure depicts the relative contribution (14-32%) of *d* state with dominant *s* state.

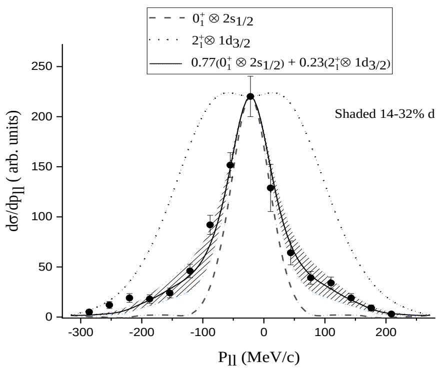

Fig. 1. LMD of core residues ^{22}O coming after one neutron removal from ^{23}O on ^{12}C. The well-suited configuration mixing is shown by shaded portion. The data points are taken from ref. [8].

Conclusively, we have examined the structure of ^{23}O by analysing the LMD of ^{22}O core residue by considering all possible pure and admixed states and found that the probability of occupying *d* orbital of valence neutron is 14-32% in ^{23}O.

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