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Coulomb breakup of ^{23}O

LAND-FRS Collaboration

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Abstract

The ground-state structure of the near-drip-line nucleus ^{23}O has been investigated in a one-neutron Coulomb breakup reaction. Differential cross sections $d\sigma/dE^*$ for electromagnetic excitation of ^{23}O projectiles (422 MeV/nucleon) incident on a lead target have been obtained from the measurement of the momenta of all breakup products including γ rays. The analysis of the deduced dipole-transition probability into the continuum infers a $2s_{1/2} \otimes {}^{22}\mathrm{O}(0^+)$ ground state configuration with a spectroscopic factor of 0.77(10) and thus a ground-state spin $I^\pi(^{23}\mathrm{O}) = 1/2^+$, resolving earlier conflicting experimental findings.

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Final-state interaction is of significant influence, an effective reduced scattering length for low-energy $p_{3/2}$ neutron scattering could be derived from the data.

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1. Introduction

During the past decade, the availability of secondary radioactive beams facilitated the investigation of unstable nuclei by means of nuclear reaction studies. Yet, isotopes at the neutron drip line are within reach in case of light elements only, with oxygen as the heaviest one. The neutron drip line of oxygen was found to be located at $A = 24$ [1–5], nearer the line of the β-stability than expected. This observation attracted interest and (sub)shell closures for the oxygen isotopes at neutron numbers $N = 14$ and $N = 16$ are discussed together with a weakening of that at $N = 20$ [6–10].

Approaching the neutron drip line, special phenomena related to the weak binding of the nuclei have been observed. In measurements of interaction cross sections, Tanihata et al. found a sudden rise for several light drip-line nuclei [11,12], which was attributed to an extended density distribution of the valence neutron(s), frequently referred to as a nuclear halo [13]. Corresponding measurements for neutron-rich oxygen isotopes [7] inferred that ^{23}O is a good halo-nucleus candidate. According to the conventional level sequence in a single-particle model, the least bound neutron in ^{23}O is expected to occupy the $2s$ orbital. Neutrons in orbitals of angular momentum $l = 0$ do not feel a centrifugal barrier and thus favorably form a halo. In case of ^{23}O, however, the valence neutron is relatively strongly bound with a separation energy $S_n = 2.74$ MeV [14], thus its wave function should spatially be rather confined.

The ground-state structure of ^{23}O was firstly investigated via a one-neutron removal reaction at 47 MeV/nucleon at GANIL observing the longitudinal momentum distribution of the core ^{22}O [15], which is expected to be related to the spatial extension of the wave function of the valence neutron. Another inclusive measurement making use of an ^{23}O beam was performed at intermediate energy at RIKEN [16]. Here, not only the one-neutron but also the two-neutron removal channel was studied. Even if the experimental results of the one-neutron removal channel from both measurements are in agreement, their analysis led to controversial conclusions in the spin assignment of the ground state. A modification of the ^{22}O core in the ground-state configuration of ^{23}O was proposed by Kanungo et al. [16,17], in conjunction with a spin and parity assignment of $I^\pi = 5/2^+$. Their interpretation was called into question by Brown et al. [18]. Two recent results, i.e., a proton knock-out reaction from ^{24}F [19] and a neutron knock-out reaction from ^{23}O [20], the latter involving a γ-coincidence measurements, do not support the necessity to assume such a core modification.

These conflicting results, all of them obtained from knock-out reactions, call for probing the ^{23}O ground state configuration by an independent method. It was shown recently that the mechanism of non-resonant Coulomb breakup in energetic heavy-ion collisions provides information on configuration mixing and delivers reliable spectroscopic factors [21,22]. There, the spectroscopic information was derived from the cross section $d\sigma/dE^*$ (excitation energy E^*), further differentiated according to the (excited) states of the remaining nucleus employing a γ-ray coincidence measurement. Here, we follow this approach in exploring and clarifying the ground-state structure of ^{23}O.

2. Experimental technique and results

The experimental technique was essentially identical to the one used in Ref. [22], where a more detailed description can be found. The main exception was a newly developed compact CsI(Na) array for the γ-ray measurement providing an improved angular resolution and thus less Doppler broadening of the measured γ-ray energies.