Low-lying dipole strength and single-particle structure of oxygen isotopes

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The large spatial extension of the wave function of the loosely bound valence neutron(s) of halo nuclei gives rise to non-resonant dipole transitions to the continuum with large transition probabilities close to the neutron threshold. The fact that this dipole strength is characteristic for the ground-state structure of the projectile was used to extract the single-particle properties, so far only for loosely bound nuclei with neutron separation energies below 1.2 MeV [1, 2, 3]. Here we shall discuss the Coulomb breakup of the odd oxygen isotopes, where the last neutron is relatively well bound, e.g. $S_n = 4.1$ MeV for ^{17}O and $S_n = 2.3$ MeV for ^{23}O. This study will serve as a testing ground to explore the scope of the Coulomb breakup method as a spectroscopic tool.

The unstable oxygen ions were produced by fragmentation of a primary ^{40}Ar beam, separated by the Fragment Separator FRS and directed onto secondary carbon and lead targets. The dipole-strength function has been extracted from the electromagnetic excitation of the projectile (in the Coulomb field of the lead target) to the continuum followed by neutron decay. The coincident measurement of the charged fragment, neutron, and γ-rays allows to determine the differential cross section exclusively for the different fragment states populated. Contributions from nuclear excitations were estimated by measuring cross sections with a carbon target. The spectroscopic factors associated with the individual configurations are obtained from the ratio of the measured cross section to the cross section calculated in a direct-breakup model using the wave function of the concerned configuration as an input. Details of the method are found in [2].

For ^{17}O ($J^\pi = 5/2^+$) the Coulomb breakup reaction yields the ^{16}O core mainly in the ground state as expected. The differential cross section $d\sigma/dE_{rel}$ is shown in Fig. 1 as a function of relative energy between ^{16}O(0^+) and the neutron. A comparison with similar results obtained for ^{11}Be [3] shows that the distribution is much broader and the peak cross section is much smaller (by about two orders of magnitude). Obviously, this reflects the fact that the valence neutron of ^{17}O is well bound in a $l = 2$ state, while ^{11}Be has a well pronounced halo structure. It clearly demonstrates the tremendous sensitivity of the Coulomb breakup cross section to a halo-like tail of the wave function. Our preliminary analysis yields a spectroscopic factors of 0.8(1), very close to the expected value of 1 and also to the result of S = 1.04(10) obtained from an electron scattering experiment [4], thus giving confidence that Coulomb breakup can be utilized to extract quantitative nuclear structure information.

The results obtained for ^{19}O and ^{21}O demonstrate the importance of an exclusive measurement including γ-ray coincidences. In both cases, the main contributions to the ground state involve excited states. From the γ-γ coincidence measurement, the 4^+ to 2^+ and 2^+ to 0^+ cascade in ^{20}O was observed and the spectroscopic weight for the contribution $|1d_{5/2}\nu \otimes 4^+ >$ in the wave function was obtained. A preliminary analysis results in a value of 2.3(2), which is rather close to the shell-model prediction of Brown of 2.59 [5].

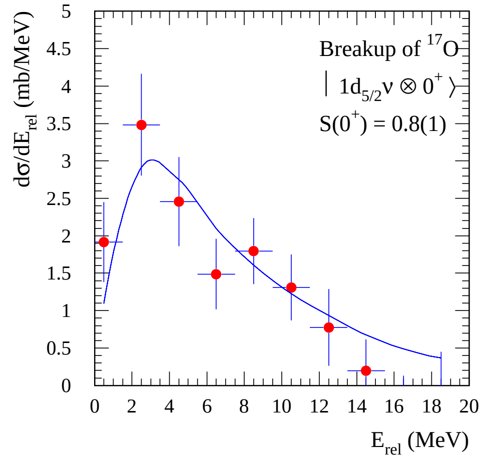

Figure 1: Relative energy spectrum of (^{16}O+n) for Coulomb breakup reactions of ^{17}O populating ^{16}O in its ground state. The solid curve shows the result of the direct breakup model for a $1d_{5/2}$ neutron coupled to the ^{16}O ground state with a spectroscopic factor of 0.8.

Although the cross sections are much smaller for the non-halo nuclei with comparatively large separation energies, the shape of the cross section as well as the absolute magnitude is well reproduced by the direct-breakup model. The enormous sensitivity of the cross section to the tail of the wave function makes Coulomb breakup one of the most efficient spectroscopic methods to extract quantitative structure information on the ground-state configuration of unstable nuclei even with very low beam intensities. In this context we finally mention a recent experiment studying ^{23}O. A ground-state spin assignment of $J^\pi = 1/2^+$ could be made and a spectroscopic factor was deduced [6] from the differential Coulomb breakup cross section measured with a ^{23}O beam intensity of about 1 ion/sec only.

References

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