One-neutron knockout reaction of ^{17}C on a hydrogen target at 70 MeV/nucleon†

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Much of our knowledge on the quantum nature of atomic nuclei comes from the studies of nuclear reactions. Among the various collision processes, the nucleon knockout reaction is recognized as one of the most sensitive tools for spectroscopy, especially of unstable nuclei. The knockout residue produced by removing a nucleon from a fast-moving beam particle is efficiently observed in inverse kinematics by a detector placed in the forward hemisphere. The removed nucleon(s) will be selected democratically from the valence space, allowing the states with unique, often rarely accessible, configurations to be populated in this process. The final state in the residue is identified by tagging de-excitation γ rays and by observing decay neutrons and constructing the invariant mass. For one-nucleon knockout case, the momentum spread of the residue reflects the Fermi motion of the nucleon suddenly removed, and is sensitive to its orbital angular momentum (the l value). The cross sections leading to the individual final states relate to the occupancy of single-particle orbits, providing a link to understand the details of the nuclear structure.

This study aims at exploring the unbound states in ^{16}C through an application of the one-neutron knockout technique to a ^{17}C beam. This is done by focusing on searching the lowest-lying cross-shell transitions, whose location reflects the shell gap between the p and sd orbits. The experiment was performed at the RIPS facility of RIKEN using the setup given in Refs.[1,2]. The ^{17}C beam was produced from a 110-MeV/nucleon ^{22}Ne beam, which impinged on a Be target. The secondary target was pure liquid hydrogen contained in a cylindrical cell. The average energy of ^{17}C at the middle of the target was 70 MeV/nucleon. The target was surrounded by a NaI(Tl) scintillator array. The fragment was bent by a dipole magnet behind the target, and was detected by a plastic counter hodoscope. The neutrons were detected by plastic scintillator arrays placed ~5 m downstream from the target. The relative energy ($E_{\rm rel}$) of the final system was calculated from the momentum vectors of the charged fragment and the neutron.

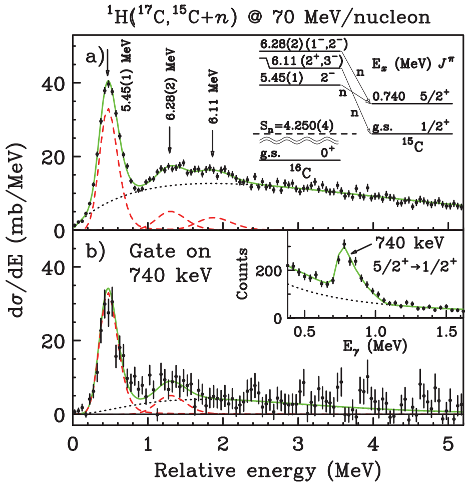

Fig. 1. Relative energy spectra for the (a) ^{1}H(^{17}C,^{15}C+n) and (b) ^{1}H(^{17}C,^{15}C($5/2^+$; 0.74 MeV)+n) reactions.

Fig. 1 shows the $E_{\rm rel}$ spectra for the (a) ^{1}H(^{17}C,^{15}C+n) and (b) ^{1}H(^{17}C,^{15}C($5/2^+$; 0.74 MeV)+n) reactions. Shown in the inset of Fig. 1 (b) is the energy spectrum for γ rays emitted from ^{15}C. Fig. 1 (a) was used in a fitting analysis to extract the resonance parameters.

Two new states at 5.45(1) and 6.28(2) MeV were populated together with a known state at 6.11 MeV. For the 5.45-MeV state, an attempt was made to deduce the l value of the knocked-out neutron from the $p_{||}$ distribution associated with the unbound residue. This, together with a comparison in terms of the measured and calculated knockout cross sections, has led to a spin-parity assignment of 2^- for this state. Possible spins and parities have been suggested for the other states, bringing about an advanced understanding of the level scheme of ^{16}C. The energy of the first 2^- state was adequately reproduced by the standard shell-model calculation using the WBT interaction without invoking modifications to the residual interaction.

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