Exploring the N=16 sub-shell closure: level structure of ^{22}C and search for ^{21}B

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The investigation of the most neutron-rich dripline nuclei is one of the principal themes of nuclear structure physics. These studies have, however, been limited for the most part to the He, Li and Be isotopes owing to the difficulty in producing beams of heavier nuclei at the dripline. With the advent of the RIBF and the coupling of the BigRIPS separator to intense ^{48}Ca beams, the path has been opened to exploring structure at and beyond the neutron dripline up to Z≈12. In the present work, measurements aimed at elucidating the evolution of shell structure in the most neutron-rich isotopes of B and C were undertaken. These measurements are a natural extension of the NP1106–SAMURAI04 experiment which explored ^{16,18}B and ^{21}C[1] and observed unbound ^{20}B[2] for the first time, and took advantage of recent developments in the ^{48}Ca primary beam intensity and the enhanced neutron detection capabilities offered by the coupling of the large-area fast neutron arrays NeuLAND[3] and NEBULA[4].

The principal goal of the NP1512–SAMURAI36 experiment was to investigate the level structure of ^{22}C and, in particular, locate the first 2^+ state. In parallel, an attempt was made to extend our recent observation of ^{20}B to search for ^{21}B. The nuclei in question are located in a region of considerable interest in terms of the evolution of shell-structure far from stability. Specifically, they lie at the N=16 sub-shell closure below doubly-magic ^{24}O. In terms of the evolution of the single-particle orbits, the O isotopes exhibit magicity at N=14 and 16. When protons are removed, the N=14 gap is predicted to disappear and the neutron $s_{1/2}$ and $d_{5/2}$ single-particle orbitals become degenerate[5]. Such behaviour is expected to be at the origin of the formation of the s-wave halo neutron configuration in ^{22}C[6], rather than the naive shell model d-wave valence neutron occupation. Moreover, spectroscopy of ^{21}C, performed within the context of SAMURAI04, indicates that the physical $5/2^+$ and $1/2^+$ levels are inverted[1].

The measurements were accomplished using the SAMURAI facility[7], which comprised the superconducting 7 Tm spectrometer coupled to the neutron array NEBULA, which was complemented by elements of NeuLAND (four so-called "double-planes" each composed of two crossed layers of 250 cm long 5×5 cm^2 scintillator modules). In addition, the newly completed CATANA CsI(Na) γ-ray multi-detector[8] was mounted around the secondary target position. The setup was identical to that employed in the SAMURAI27 experiment[9] which was run in tandem with the present measurements. It is worthwhile noting that this experiment represented the beam commissioning of CATANA and the on-line analysis of well-know γ-rays, such as the 1.6 MeV line arising from the decay of the ^{18}C 2^+_1 state, indicated that the detector and electronics performed as expected.

Primary beam intensities as high as some 800 pnA were provided and allowed secondary beam rates of up to ∼700 pps of ^{23}N (over an order of magnitude higher than available during SAMURAI04) at ∼270 MeV/nucleon to be delivered by the RIBF. Single and two-proton removal reactions on the 2 g/cm^2 secondary carbon target will be analysed in order to establish the level structure of ^{22}C and search for ^{21}B. As ^{22}C was also present in the secondary beam (∼35 pps), efforts will be also made to investigate the population of the excited states via inelastic scattering. In the case of both the ^{22}C exited states and ^{21}B, beam velocity "core" fragments (^{20}C and ^{19}B) plus two-neutron events will be employed to reconstruct the corresponding invariant mass spectra from the measured momenta.

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