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Spectroscopy of deeply bound orbitals in neutron-rich Ca isotopes

Nuclear shell evolution towards the driplines, characterized by the quenching or collapse of conventional magic numbers, may lead to the emergence of new sub-shell closures. Notably, the calcium isotopes, featuring a robust proton Z = 20 shell closure and encompassing the doubly magic isotopes 40Ca and 48Ca, alongside experimental evidence of new neutron sub-shell closures at N = 32 and 34, provide an ideal testing ground for exploring the evolution of shell structure and magic numbers.

Although surface nucleons properties in calcium have been extensively studied, probing the structure of deeply bound nucleons remains a challenge. In this presentation, we will report the first invariant-mass measurement of unbound states in 53Ca and 55Ca, populated from one-neutron knockout reaction at the RIKEN Radioactive Isotopes Beam Factory. The reaction of interest was induced by the secondary beam of 54,56Ca bombarding on a 151-mm-long liquid hydrogen (LH2) target within the MINOS device, featuring a surrounding time projection chamber for reconstructing the reaction vertex. Population to unbound states of 53,55Ca was followed by forward directed neutron emission, detected by two large-acceptance NEBULA and NeuLand plastic scintillator array. The de-excitation γ rays emitted from fragments were detected by the DALI2+ array, consisting of 226 NaI(Tl) crystals surrounding the MINOS device. Reaction residues were identified and measured by the SAMURAI spectrometer.

The resonance properties, partial cross sections, and momentum distributions of these unbound states were analyzed. Orbital angular momentum l assignments were extracted from momentum distributions based on calculations using the distorted wave impulse approximation (DWIA) reaction model. The resonances at excitation energies of 5516(41) keV in 53Ca and 6000(250) keV in 55Ca indicate a significant l = 3 component, providing the first experimental evidence for the f7/2 single-particle strength of deeply bound hole-states in the neutron-rich Ca isotopes. The observed excitation energies and cross-sections point towards extremely localized and well separated strength distributions, with some fragmentation for the νf7/2 single-particle in 56Ca. These results are in good agreement with predictions from shell-model calculations using the effective GXPF1Bs interaction and ab initio calculations.

Collaboration

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