Contribution ID: **6** Type: **Poster**

The first investigation of unbound states of 53,55Ca populated from neutron-knockout reactions

Tuesday, 1 August 2023 16:45 (3 hours)

The calcium isotopes are an ideal test bench for studying the evolution of shell structure and magic numbers. Although many properties of surface nucleons in calcium have been successfully described by experiments and theories, it is still challenging to predict the shell structure for deeply bound nucleons. In this study, we report the first investigation of unbound states in 53Ca and 55Ca, populated from 54,56Ca (p,pn) reactions at a beam energy of around 216 MeV/nucleon. These states were analyzed in terms of their resonance properties, partial cross-sections, and momentum distributions. The momentum distributions are compared to calculations using the distorted wave impulse approximation (DWIA) reaction model, allowing orbit momentum l assignments for the observed states. The resonances at excitation energies of 5516(43)-keV in 53Ca and 5946(195)-keV in 55Ca, show clear signs of 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 excitation energies and strengths of the observed states are compared to shell-model calculations using the effective GXPF1Bs interaction and ab initio calculations and found in good agreement with theoretical predictions. The vf7/2 single-particle strength was found to be very robust until N=36 where it's starting to show signs of fragmentation.

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Session Classification: Poster session with canapés