Contribution ID: **86** Type: **Invited talk**

Spectroscopy of 52Ar and 54Ca with (p,2p) and (p,3p) reactions

Monday, 31 July 2023 15:50 (25 minutes)

Shell gaps represent the backbone of the nuclear structure and are a direct fingerprint of the in-medium many-body interactions. The nuclear shell structure is found to change, sometimes drastically, with the number of protons and neutrons, revealing how delicate the arrangement of interacting nucleons is. Recent experimental evidence favors a new doubly-magic nucleus 54Ca with a neutron subshell closure at N = 34, although the systematics of E(2+) and B(E2) in Ti and Cr isotopes do not show any evidence for the N = 34 magicity.

In order to study how the N = 34 subshell evolves below Z < 20 towards more neutron-rich systems, we measured the low-lying structure of 52Ar using the 53K(p,2p) one-proton removal reaction at ~210 MeV/u at the RIBF facility. The 2+ excitation energy is found at 1656(18) keV, the highest among the Ar isotopes with N > 20. This result is the first experimental signature of the persistence of the N = 34 subshell closure beyond 54Ca. Shell-model calculations with phenomenological and chiral-effective-field-theory interactions both reproduce the measured 2+ systematics of neutron-rich Ar isotopes and support a N = 34 subshell closure in 52Ar.

For the doubly magic nucleus 54Ca, several state-of-the-art nuclear structure calculations predict that it has a bond first excited 0+ state but with very different excitation energies. In particular, shell model calculations with the effective LNPS-U interaction predict significant intruder configurations in the first excited 0+ state in 54Ca, and suggest that its excitation energy can provide information on correlations of the gds orbitals lying above the N = 34 subshell closure, which will constrain the predictions for 60Ca (N = 40) and the dripline of the Ca isotopes. We therefore propose to search for the first excited 0+ state in 54Ca using 56Ti(p, 3p) reactions by means of missing-mass and in-beam γ spectroscopy, which is approved to by the NP-PAC committee at RIKEN. To summarize, in order to explore the shell evolution from N = 34 towards N = 40, we measured the first 2+ state in 52Ar and will search for the first excited 0+ state in 54Ca.

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Session Classification: Shell migration at the neutron numbers N=32,34 around Ca