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Shell evolution from N = 34 towards N = 40: first 2^+ state in ^{52}Ar and the first excited 0^+ state in ^{54}Ca

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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 ^{54}Ca with a neutron subshell closure at N = 34 [1-3], although the systematics of $E(2_1^+)$ [4-5]and $B(E2; 0_1^+ \rightarrow 2_1^+)$ [6,7] in Ti and Cr isotopes does not show any evidence for the N = 34 magicity.

To study how the N = 34 subshell evolves below Z < 20 towards more neutron-rich systems, we measured the low-lying structure of ^{52}Ar using the ^{53}K(p, 2p) one-proton removal reaction at ~210 MeV/u at the RIBF facility [8]. The 2_1^+ 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 ^{54}Ca. Shell-model calculations with phenomenological and chiral-effective-field-theory interactions both reproduce the measured 2_1^+ systematics of neutron-rich Ar isotopes and support an N = 34 subshell closure in ^{52}Ar. For the doubly magic nucleus ^{54}Ca, several state-of-the-art nuclear structure calculations predict that it has a bond first excited 0^+ state but with very different excitation energies [9-10]. In particular, shell model calculations with the effective LNPS-U interaction [11] predict significant intruder configurations with rather strong correlations in the first excited 0^+ state in ^{54}Ca, 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 ^{60}Ca (N = 40) and the dripline of the Ca isotopes. We, therefore, propose to search for the first excited 0^+ state in ^{54}Ca using ^{56}Ti(p, 3p) reactions using missing-mass and in-beam γ spectroscopy, which is approved by the NP-PAC committee at RIKEN. To summarize, to explore the shell evolution from N = 34 towards N = 40, we measured the first 2^+ state in ^{52}Ar and will search for the first excited 0^+ state in ^{54}Ca.

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Topic

Experiment

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