$N = 32$ shell closure below calcium: Low-lying structure of ^{50}Ar[†]

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An interesting region to study shell evolution is around Ca isotopes, where the development of shell closures for $N = 32$ and $N = 34$ has been suggested. The $N = 32$ sub-shell closure was evidenced by its relatively high $E(2^+)$ energy,[1)] and confirmed by two-proton knockout cross sections[2)] and mass measurements.[3)] For the $N = 34$ shell closure, evidence was provided by $E(2^+)$,[4)] systematic mass measurements,[5)] and neutron-knockout cross sections.[6)] The preservation of the $N = 32$ shell closure has been determined in Ti and Cr via spectroscopy, reduced transition probabilities, and precision mass measurements, while for $N = 34$, it has been suggested to disappear above Ca. In contrast, the recent measurement of the $E(2^+)$ of ^{52}Ar suggests the conservation of the $N = 34$ shell closure for $Z = 18$.[7)] The first spectroscopy of ^{50}Ar showed a relatively high $E(2^+)$,[8)] hinting at the conservation of the $N = 32$ shell closure below Ca. A candidate for the 4^+ state was also reported. No further spectroscopic information is available for this very exotic nucleus. This work reports low-lying states in ^{50}Ar.

A beam of ^{70}Zn with an average intensity of 240 particle nA was fragmented on a Be target. Isotopes were identified using BigRIPS[9)] and delivered to the 151.3(13)-mm-long liquid hydrogen target of MINOS[10)] placed in front of the SAMURAI magnet. Outgoing fragments were identified using SAMURAI and associated detectors.[11)] The DALI2$^+$ array,[12,13)] composed of 226 NaI(Tl) detectors, was used to detect the emitted γ-rays. Doppler-corrected γ-ray spectra were obtained using the reaction vertex and the velocity of the fragment reconstructed with MINOS.

Based on the spectra and $\gamma\gamma$ analysis of the proton- and neutron-knockout, inelastic-scattering, and multinucleon-removal reactions, the level scheme shown

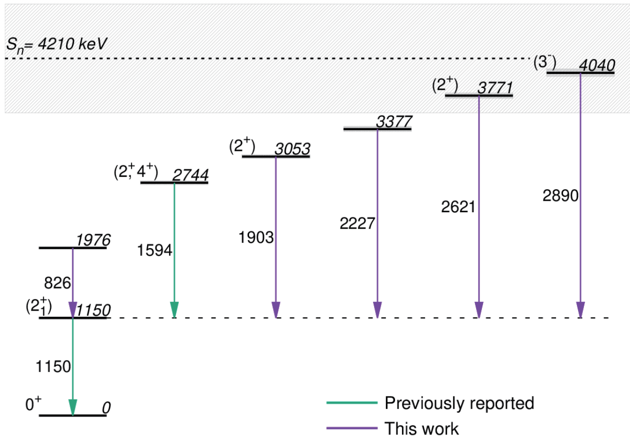

Fig. 1. Experimental level scheme of ^{50}Ar.

in Fig. 1 was constructed. The two previously reported transitions and five new ones were identified. Theoretical level energies and spectroscopic factors for the proton- and neutron-knockout reactions were obtained with shell-model calculations using the SDPF-MU interaction, as well as with *ab initio* calculations using the VS-IMSRG approach. Tentative spin assignments were made based on the comparison of the calculations and the experimental results. In both calculations, states with $J^\pi = 2^+$ are preferably populated by the reactions, as shown in the figure. In addition, a (3^-) state is suggested to be populated following the proton inelastic scattering. Both theoretical calculations provide consistent results and a relatively good agreement with the experimental data, emphasizing the subshell closure at $N = 32$ and strengthening our understanding of shell evolution in this region.

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