Low-lying structure of ^{50}Ar and the $N = 32$ subshell closure†

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It is now well known that far from the line of β stability the nuclear magic numbers can change from their standard values. For example, in the pf shell, the onset of a new magic number at $N = 32$ has been reported along the Cr, Ti, and Ca isotopic chains, while a sizable gap at $N = 34$ was deduced from the structure of ^{54}Ca[1)]. Very recently, the persistence of the $N = 32$ subshell closure was established in systems below the $Z = 20$ core[2)]. In the present work, the low-lying structure of ^{50}Ar has been investigated to shed light on the character of the $N = 32$ magic number at more extreme neutron-to-proton ratios. Preliminary results are discussed in Ref.[3)].

A primary beam of ^{70}Zn^{30+} ions with a typical intensity of ~ 60 pnA was used to generate a fast radioactive beam containing ^{54}Ca, ^{55}Sc, and ^{56}Ti, amongst other products. The constituents were identified using the BigRIPS separator and focused on a 10-mm-thick ^{9}Be reaction target at the eighth focal plane. Reaction products emerging from the target were identified by the ZeroDegree spectrometer (ZDS); despite the fact that the ZDS was optimized for the transmission of ^{54}Ca[1)], a sufficient number of ^{50}Ar ions fell within the acceptance of the spectrometer to extract structural information. The reaction target was surrounded by the DALI2 γ-ray detector array to measure transitions emitted from nuclear excited states.

The γ-ray energy spectra—corrected for the Doppler effect—are presented in Fig. 1 using the sum of the ^{9}Be(^{54}Ca, ^{50}Ar)X, ^{9}Be(^{55}Sc, ^{50}Ar)X, and ^{9}Be(^{56}Ti, ^{50}Ar)X multinucleon removal reactions. The line at 1178(18) keV, which is the most intense peak in the spectra, is assigned as the transition from the yrast 2^+ state to the 0^+ ground state in ^{50}Ar. A weaker, tentative peak is present at 1582(38) keV, and is suggested as the transition between the 4_1^+ and 2_1^+ levels. Statistics were insufficient to confirm the proposed decay scheme using $\gamma\gamma$ coincidence relationships.

The 2_1^+ state in ^{50}Ar indicates an increase in energy relative to its even-even neighbour ^{48}Ar and, therefore, naively suggests the presence of a sizable subshell closure at $N = 32$ in Ar isotopes. In order to investigate the nature of the increase in energy in more detail, large-scale shell-model calculations employing a modified version of the SDPF-MU Hamiltonian[4)] were performed; the modifications were based on recent experimental data from exotic Ca[1)] and K[5)] isotopes. The predictions reproduce the experimental energy levels in lighter Ar isotopes, and the results of the present work, in a satisfactory manner. Moreover, the calculations indicate that the magnitude of the $N = 32$ subshell closure in ^{50}Ar is equally as significant as the gaps in ^{52}Ca and ^{54}Ti, where the experimental evidence for this magic number is well documented. The calculations also indicate a rather high 2_1^+ energy in ^{52}Ar and, therefore, experimental input on this nucleus is encouraged to investigate the significance of the $N = 34$ subshell closure in more exotic systems.

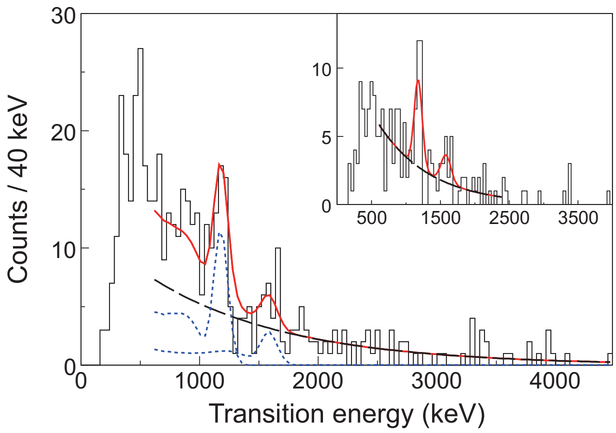

Fig. 1. (colour) Doppler-corrected γ-ray energy spectra for ^{50}Ar. The main and inset panels display $M_\gamma \geq 1$ and $M_\gamma \leq 3$ data, respectively. The black dashed lines are exponential fits to the backgrounds and the blue dashed lines are GEANT4 simulations; the solid red lines are total (sum) fits.

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