Shell evolution towards ^{60}Ca: First spectroscopy of ^{62}Ti[†]

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The study of $N = 40$ isotones can provide insight into the mechanisms governing shell evolution. Along this isotonic chain different behaviors are observed: ^{68}Ni shows a high $E(2^+_1)$ and a low $B(E2)\downarrow$.[1)] For Fe and Cr, a monotonous decrease of the $E(2^+_1)$ when approaching $N = 40$ has been observed,[1)] while the $E(2^+_1)$ of ^{58,60}Ti shows a moderate decrease towards $N = 40$.[2,3)] The very exotic ^{60}Ca, where the Ca isotopic chain meets the $N = 40$ isotones, is difficult to reach experimentally and only recently its existence has been established.[4)] Theoretical calculations in the shell-model framework[5)] concluded that quadrupole correlations in the $N = 40$ isotopes give rise to deformed ground states dominated by intruder neutron orbits beyond the pf shell, leading to an island of inversion below ^{68}Ni. On the other hand, symmetry conserving configuration mixing calculations with the Gogny interaction predict a conservation of the $N = 40$ gap leading to spherical ^{62}Ti and ^{60}Ca.[6)] In this work, the first spectroscopy of ^{62}Ti is presented.

A 345 MeV/nucleon beam of ^{70}Zn with an average intensity of 240 pnA was fragmented on a Be target to produce ^{63}V. The isotopes were identified using BigRIPS[7)] and delivered to the 151.3(13) mm long liquid hydrogen target of MINOS[8)] placed in front of the SAMURAI magnet. Outgoing ^{62}Ti fragments were identified using SAMURAI and associated detectors.[9)] MINOS was surrounded by DALI2$^+$, composed of 226 NaI(Tl) detectors.[10,11)]

Two peaks were clearly identified in the Doppler corrected γ-spectrum, and were found to be in coincidence. Using a 2-dimensional χ^2 minimization the energies of the transitions were deduced to be 683(10) keV and 823(20) keV, which were tentatively assigned to the $2^+_1 \rightarrow 0^+_{gs}$ and $4^+_1 \rightarrow 2^+_1$ transitions, respectively. The evolution of measured $E(2^+_1)$ and $E(4^+_1)$ energies for the

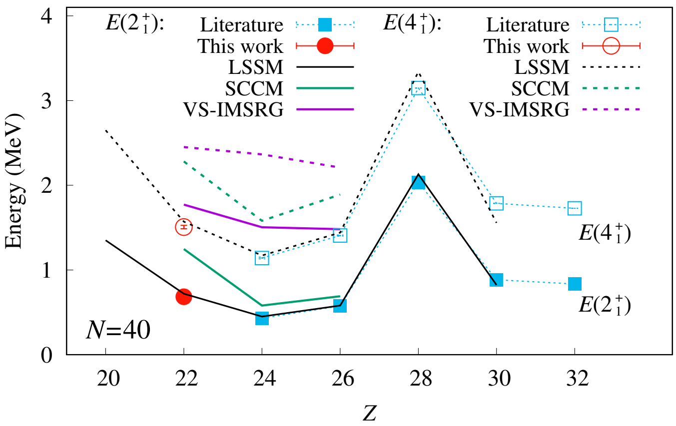

Fig. 1. Systematics of $E(2^+_1)$ and $E(4^+_1)$ for even-even $N = 40$ isotones, including the present measurement. The black, green, and purple lines represent LSSM, SCCM, and VS-IMSRG calculations, respectively.

$N = 40$ isotones between Ti and Ge[1)] is presented in Fig. 1. The $E(2^+_1)$ and $E(4^+_1)$ of ^{62}Ti have a similar value than the ones measured for ^{66}Fe, higher than those of ^{64}Cr. This shows the first increase of $E(2^+_1)$ along the $N = 40$ isotones towards ^{60}Ca. Large Scale Shell Model (LSSM) calculations using the LNPS interaction reproduce very accurately the data, indicating that the island of inversion in this region extends down to ^{60}Ca. Symmetry conserving configuration mixing (SCCM) calculations using the Gogny D1S effective interaction predict $E(2^+_1)$ for ^{64}Cr and ^{66}Fe which lie very close to the LSSM predictions. However, for ^{62}Ti a larger increase of the $E(2^+_1)$ is obtained. For the $E(4^+_1)$ energies, the calculations overestimate the experimental values by about 500 keV, although the minimum value for ^{64}Cr is maintained. Ab initio valence-space in-medium similarity renormalization group (VS-IMSRG) calculations overestimate the $E(2^+_1)$ and $E(4^+_1)$ excitation energies in ^{62}Ti, ^{64}Cr, and ^{66}Fe, predicting all states as spherical.

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