Yrast 6^+ Seniority Isomers of ^{136,138}Sn†

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The shell model plays a key role in allowing a microscopic description of many of the properties of atomic nuclei. Its two ingredients are single-particle energies and effective nucleon-nucleon interactions. Experimental studies of semi-magic Sn nuclei beyond the doubly magic nucleus ^{132}Sn provide information that allows the neutron-neutron part of effective interactions for the $N = 82 - 126$ valence space to be tested and optimized. More generally, such studies provide a key benchmark for the methods used to construct effective interactions in a heavy-mass region far from stability. Currently there is little experimental data on the Sn isotopes beyond the $N = 82$ shell closure, which are difficult to produce and study.

Excited states in the nuclei ^{136,138}Sn have been investigated by detecting delayed γ-ray cascades using the EURICA spectrometer[1]), which was coupled to the BigRIPS separator of the RIBF facility. These exotic nuclei were produced by the in-flight fission of a 345 MeV/nucleon ^{238}U beam. Cascades containing three delayed γ rays each were observed in coincidence with identified ^{136,138}Sn ions. The spins of the isomeric states of ^{136,138}Sn were assigned as (6^+), in analogy with a very similar delayed cascade previously reported for ^{134}Sn[2]).

The energies of the excited states of ^{134,136,138}Sn have been compared to the predictions of shell-model calculations, which used state-of-the-art realistic effective interactions. These calculations used the full $N = 82 - 126$ valence space and the effective single-particle energies were the experimental ones. The experimentally determined level energies of ^{134,136,138}Sn were all well reproduced. The $B(E2; 6_1^+ \to 4_1^+)$ values were also correctly predicted for ^{134,138}Sn, though this value was more than a factor of 5 away for ^{136}Sn, as shown in Fig. 1. Three other shell-model calculations reported in the literature, using realistic and empirical effective interactions, also failed to reproduce the $B(E2; 6_1^+ \to 4_1^+)$ value for ^{136}Sn and are off by at least a factor of 2.

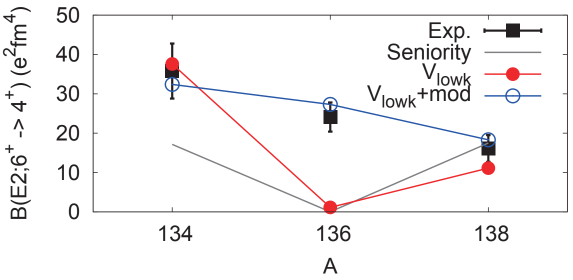

Fig. 1. Experimental (black squares) and theoretical reduced transition rates for $6_1^+ \to 4_1^+$ γ decays in $^{134-138}$Sn. The calculations used a realistic V_{low-k} interaction (red filled circles), a pairing-modified V_{low-k} interaction (blue open circles) and a pure $f_{7/2}$ seniority scheme (grey curve).

The near-constant energies of the (2_1^+), (4_1^+) and (6_1^+) states of ^{134,136,138}Sn are characteristic of dominant seniority 2 (one broken pair) excitations. The $B(E2)$ values of seniority-conserving transitions are expected to follow the shape of a symmetric positive parabola, as shown in Fig. 1. The results obtained with a realistic V_{low-k} interaction follow a similar pattern to the seniority 2 scheme. Additional shell-model calculations have been performed which allowed particle-hole excitations from the neutron $\nu 0h_{11/2}$ and proton $0g_{9/2}$ shells to the $N = 82 - 126$ and $Z = 50 - 70$ valence spaces, respectively. These allowed the influence of core polarization effects on the transition rates of the neutron-rich Sn nuclei to be examined. However, the $B(E2; 6_1^+ \to 4_1^+)$ value for ^{136}Sn was still not correctly reproduced. Reducing the energies of the $\nu 1f_{7/2}^2$ diagonal and off-diagonal matrix elements by ~150 keV allowed the $B(E2, 6_1^+ \to 4_1^+)$ of ^{136}Sn to be correctly predicted. This shift is equivalent to a reduction in the pairing strength. The results using this pairing-modified V_{low-k} interaction are shown in Fig. 1. Similar modifications to pairing were necessary to reproduce the level schemes of ^{72,74}Ni[4]), illustrating the need for additional theoretical efforts on the construction of effective interactions.

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