MEASUREMENT OF YRAST 6+ ISOMERS IN $^{136,138}\text{Sn}$

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Motivations

• Sn nuclei very interesting – testing neutron-neutron part of effective interaction (with respect to $^{132}$Sn core).

• Measure nuclear structure in a very-neutron rich region and observe evolution of shells.

• Study of r-process nuclei.

• Aim to obtain reliable shell-model predictions – useful for predictions of nuclear properties relevant to r-process (masses, $\beta$ decay rates, excited-state energies).
12 and 14 neutrons from last stable Sn nucleus. Just beyond N=82 shell gap.

No excited states known in $^{136,138}$Sn.
Variation between energy predictions of rescaled, empirical, and realistic shell-model calculations.
Astrophysical r-process

Occurs after core collapse of type-II supernovae.

High neutron flux

Produces $\sim 1/2$ of matter in the universe heavier than Fe.
Brett et al. tested 3 global mass-model predictions and altered parameters to see each nucleus’ influence on the abundances.

“The nuclei with greatest impact on the r-process - neutron-rich isotopes of cadmium, indium, tin, and antimony in the N = 82 region...”

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<th>FRDM</th>
<th>DZ</th>
<th>HFB-21</th>
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<td>24.59</td>
<td>$^{132}$Cd</td>
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<td>$^{86}$Zn</td>
<td>10.24</td>
<td>$^{139}$Sn</td>
<td>17.25</td>
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BigRIPS & ZeroDegree spectrometer

345-MeV/u $^{238}$U beam (provided by RRC, fRC, IRC, SRC) illuminating Be target.

SRC has K value of 2500-MeV.

Measures $\Delta E$, ToF and $B_\rho$ on an event-by-event basis to determine Z and m/q.

Utilises position sensitive PPACs, plastic scintillation counters & MUSIC.
To apply gate on specific nuclei define an acceptable region of $Z$ and $A/Q$. 

![Diagram showing $Z$ vs AoQ with specific nuclei $^{135}\text{Sn}$, $^{136}\text{Sn}$, $^{137}\text{Sn}$, and $^{138}\text{Sn}$ highlighted.]}
**Wide Angle Silicon-Strip Stopper Array for $\beta$ and Ion detection**

- 8 layered position sensitive DSSSD
- Highly segmented (60x40)
- 14400 1-mm$^2$ pixels

Ions implanted into WAS3ABI after leaving ZDS.

~60 ions/s implanted.
Euroball-RIKEN Cluster Array

12 HPGe detectors, each with 7 crystals.

Placed around WAS3ABI in close geometry.

Placed around WAS3ABI in close geometry.
Results

$^{136}$Sn transitions were measured to be in coincidence with all other transitions.

$^{138}$Sn transitions did not have enough statistics for $\gamma$-$\gamma$ correlation.

Flight time through BigRIPS $\sim$640-ns

$\sim$10 half-lives of the $^{136}$Sn decay

$\sim$0.1% of $^{136}$Sn nuclei reach WAS3ABI in excited state.

Calculations predict the energies of the levels well.

Comparison

CD-Bonn free n-n potential potential, renormalized by $V_{\text{low-k}}$ method. Neutron charge = 0.65e.

Calculations predict the energies of the levels well.

Treating nuclei as purely $\nu = 2$ excitations origination from $f^2_7 \frac{Z}{2}$ gives good predictions of energies.
Tuning shell model interactions

B(E2, 6^+→4^+) in ^{136}\text{Sn} are not properly reproduced by shell model.

Correct B(E2) by reducing \(f_7^2\) pairing by \(~150\text{-keV.}\)

Incorrect prediction of transition rates shows that the structure of the 4^+ states of ^{136}\text{Sn} is not as simple as purely caused by \(\nu = 2.\)
Comparison to Ni isomer predictions

Analogous situation in very neutron-rich Ni.

Shell model predicts \( \sim \mu s \) isomer in \({\text{\textsuperscript{72}}\text{Ni}}\), but has not been observed experimentally.

Same effect in two heavy regions neutron-rich in nuclear chart.

H. Grawe, Nuclear Physics A704 (2002)
Summary

- 3 delayed $\gamma$ rays from $^{136,138}$Sn have been observed from decays of (6+) seniority isomeric states.

- Low energy structure of Sn shown not just $\nu = 2$ excitations.

- These states were used to tune $B(E2, 6^+ \rightarrow 4^+)$ calculations in an extremely neutron rich region of the nuclear chart.
Acknowledgements

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BigRIPS team and EURICA collaboration.

Thank you for listening!