The Study of ^{116}Sn via Gamma-ray and Conversion-electron Spectroscopy

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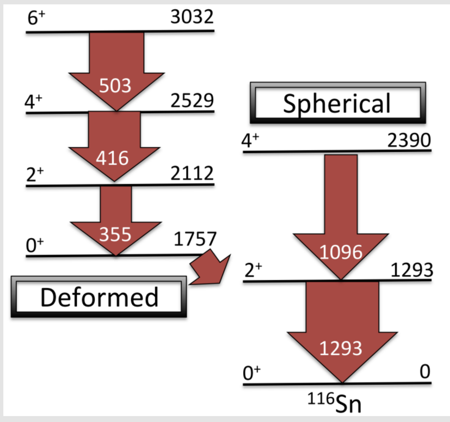
MOTIVATION

As discussed in a survey of shape coexistence in nuclei [1], the singly-closed shell isotopes of Tin offer a method of studying the interplay between effects observed in closed-shell nuclei and in mid-shell nuclei within the same nucleus. The nucleus ^{116}Sn is a good candidate for such study as it is at a proton closed shell (Z = 50) but occupies the neutron mid-shell (N = 66). In this case we can study the interplay of spherical and deformed structures.

INTRODUCTION

Deformation of Nuclei

- Associated with collective transitions, driven by proton-neutron interactions. An example of existing known spherical and deformed bands in ^{116}Sn is shown on the right.



Shape Coexistence

- Characterized by nuclear states closely spaced in energy which have different shapes (and thus are in different bands), as in the example of the potential energy surface of ^{186}Pb.
- *E0* transitions between these bands are thus indicators of the degree of mixing of the shapes [3], due to the large change of the charge radius from one shape to another. Previous experiments (e.g. by Savelius *et al.* [4]) using nuclear reactions have probed coexisting structures within ^{116}Sn.

Weak Gamma Ray Branches

- Improve our understanding of the overall structure of ^{116}Sn, and thus refine branching ratio calculations as well as transition strengths (B(E2) values).

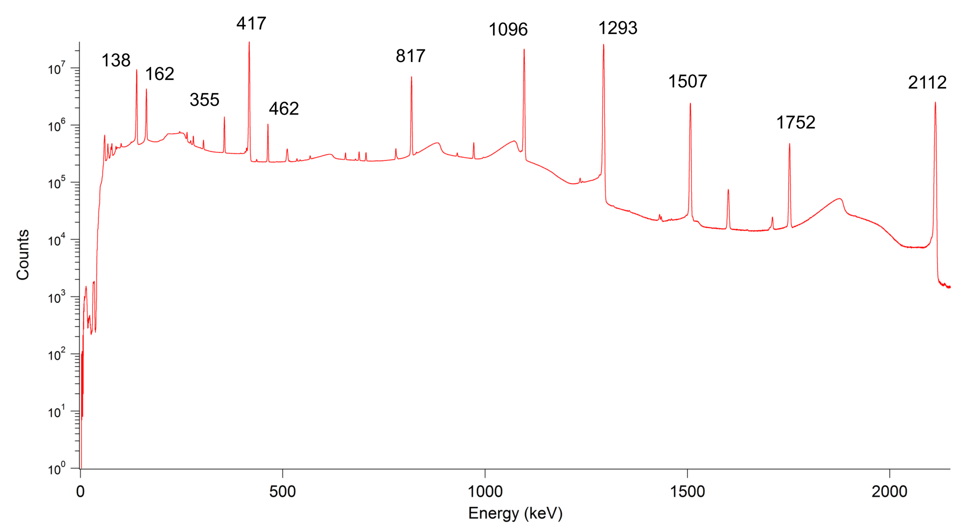


Figure 1. Scaled-down γ singles. Selected transitions are labelled in keV.

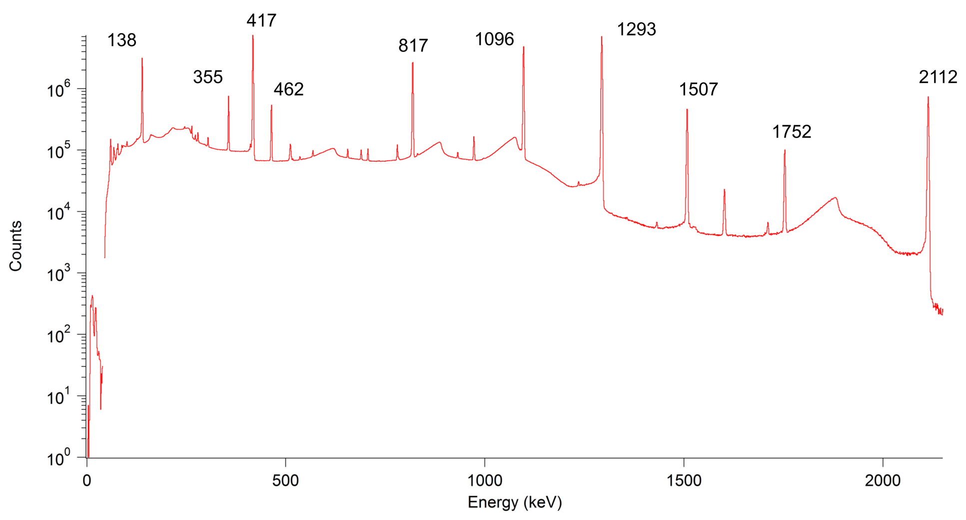


Figure 2. Projection from the $\gamma\gamma$ matrix. Selected transitions are labelled in keV (note the removal of the ^{116m2}In IT).

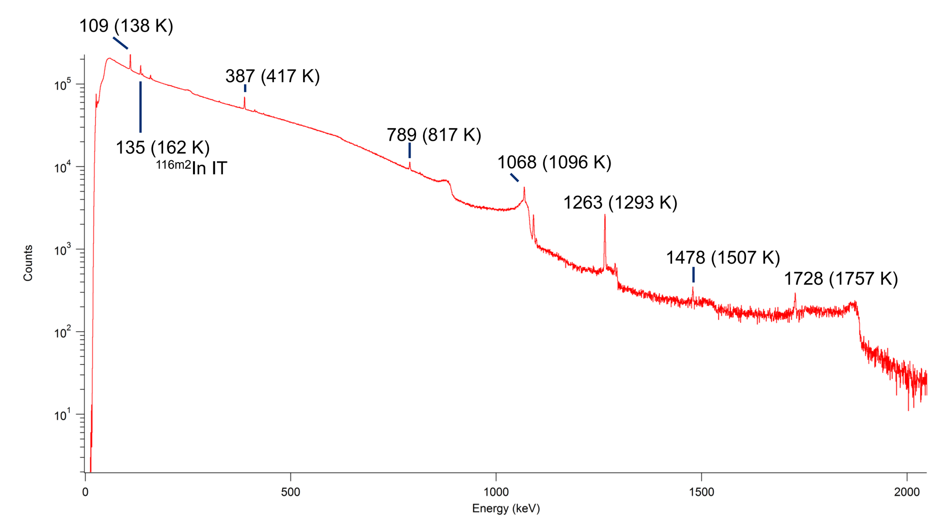


Figure 3. Projection from the γe^- matrix. Selected *K* lines are labelled in keV.

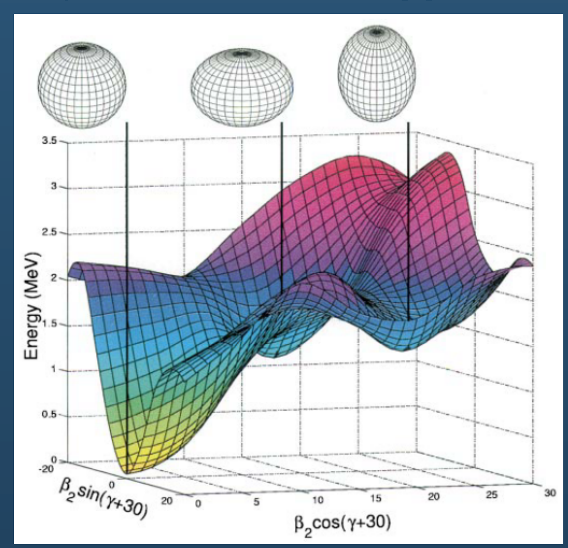
EXPERIMENT

Using the ISOL production technique which utilizes the 500 MeV driver cyclotron to impinge protons onto a tantalum target, ions of ^{116m,g}In were implanted into the 8π spectrometer's Delrin implantation chamber and subsequently decayed into ^{116}Sn. In doing so, the excited states below ~3.4 MeV were predominantly populated and decayed to the ground state.

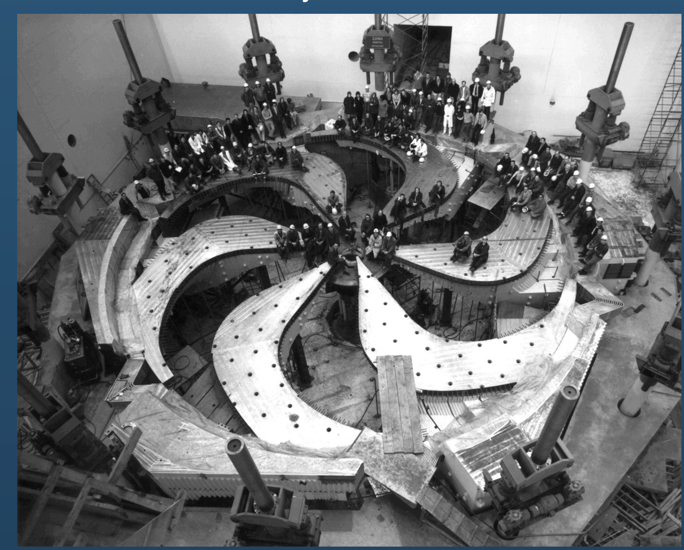
Detectors Used

- 20 HPGe detectors,
- A plastic scintillator mounted directly behind the implantation spot,
- DANTE, an array of $LaBr_3$(Ce) and BaF_2 detectors,
- PACES, consisting of five silicon detectors for in-beam conversion-electron spectroscopy.

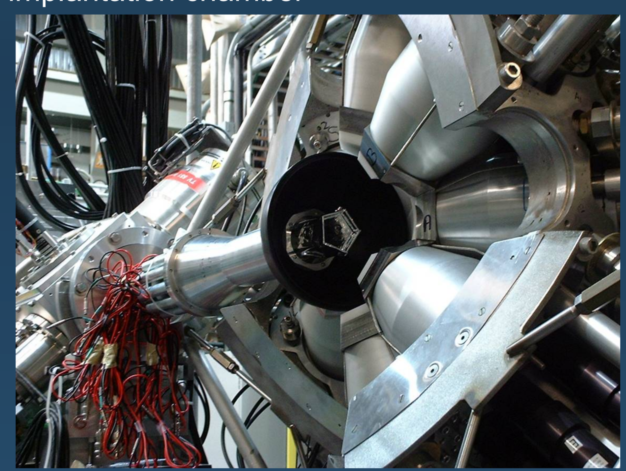
Shape Coexistence in ^{186}Pb [2]



TRIUMF 500 MeV cyclotron



Part of the 8π array surrounding the Delrin beam implantation chamber



PACES array mounted in Delrin chamber

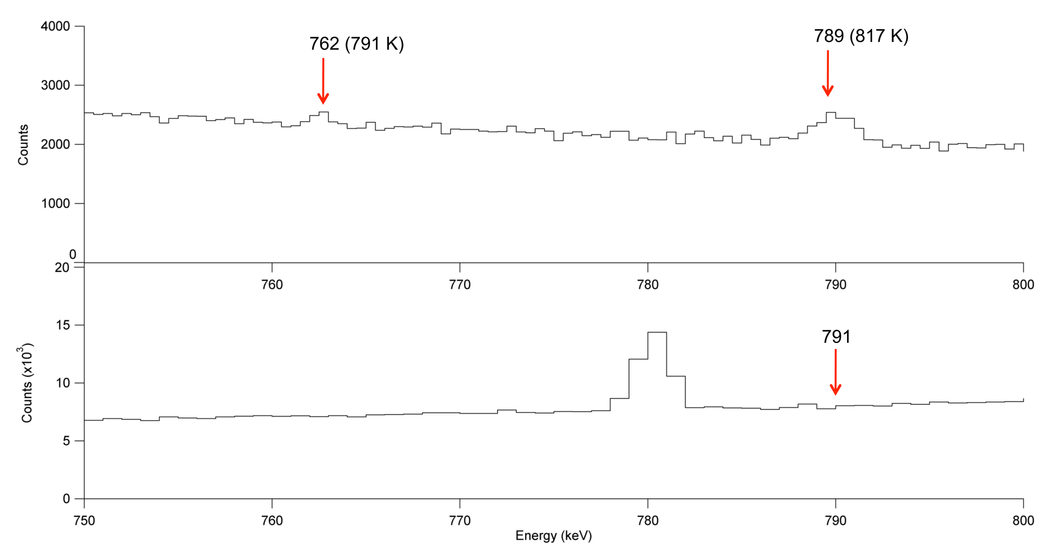


Figure 4. Projections from a gate on the 1293 keV gamma ray showing coincident gamma lines (bottom) and coincident conversion electron lines (top) in the region of 750 - 800 keV. Note the absence of a 791 keV γ ray.

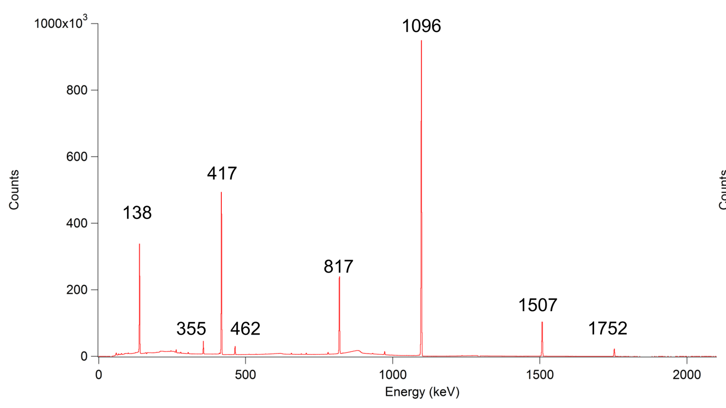


Figure 5. Projection from a gate on the 1293 keV γ ray in the $\gamma\gamma$ matrix.

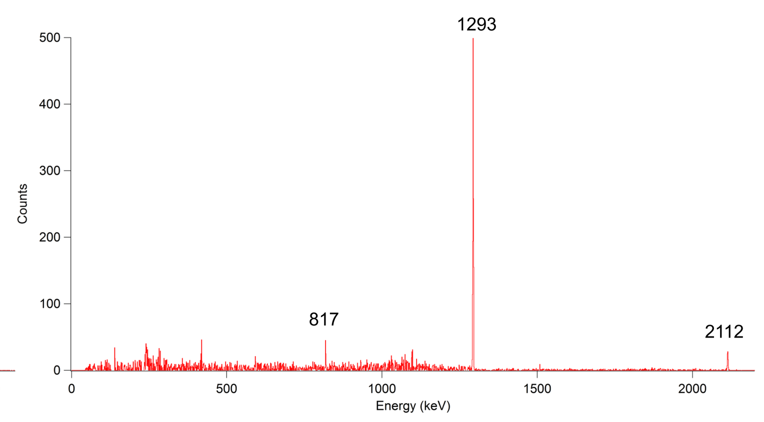


Figure 6. Projection from a gate in the $\gamma\gamma$ matrix on the 1511 keV γ ray, allowing its placement as a feeding transition into the 2112 keV state.

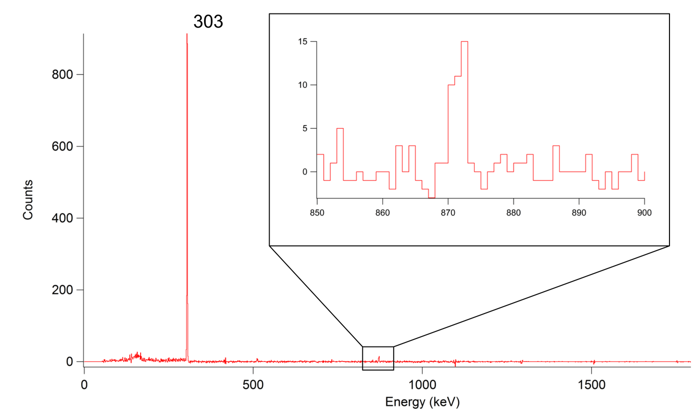


Figure 7. Projection from a gate in the $\gamma\gamma$ matrix on the 2225 keV γ ray. (inset: 871 keV γ ray)

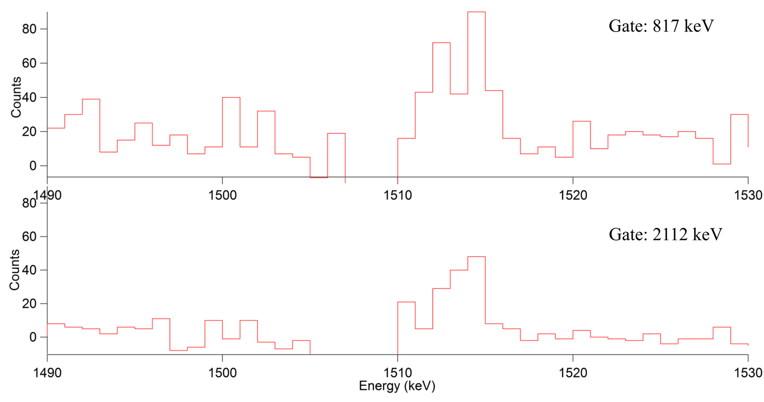


Figure 8. Confirmation of the 1511 keV γ ray placement.

PRELIMINARY RESULTS

Over the course of three days, using beam cycles optimized for the ^{116m1}In $t_{½}$ = 54.29 min decay, gamma singles and silicon singles were recorded, as well as coincidences between the HPGe array and the PACES array. We also observed the decays of a small (~0.1%) amount of the isobaric contaminant ^{116}Sb.

Spectra

- Figures 1-3 show the representative quality of data we have obtained in this experiment in both scaled-down singles and coincidence mode.

Observed Transitions Improving the Level Scheme

- We observe a 762 keV *K* line for which no gamma ray can be observed in the same gate (Fig. 4) Thus, this may affect the spin-parity assignment of the 3157 keV state in ^{116}Sn. This is the first time such a transition has been observed via β decay, as previous confirmation of the state was via inelastic particle scattering experiments [5]. This demonstrates the capability of the 8π and PACES in observing coincidences not previously seen in β decay.
- We observe, and tentatively place, several new gamma rays via examination of the $\gamma\gamma$ matrix, among them a 1511 keV transition which establishes the presence of ^{116}Sb in our beam; others include 871 and 984 keV gamma rays indicating possible transitions between different bands. (Figs. 5-9)

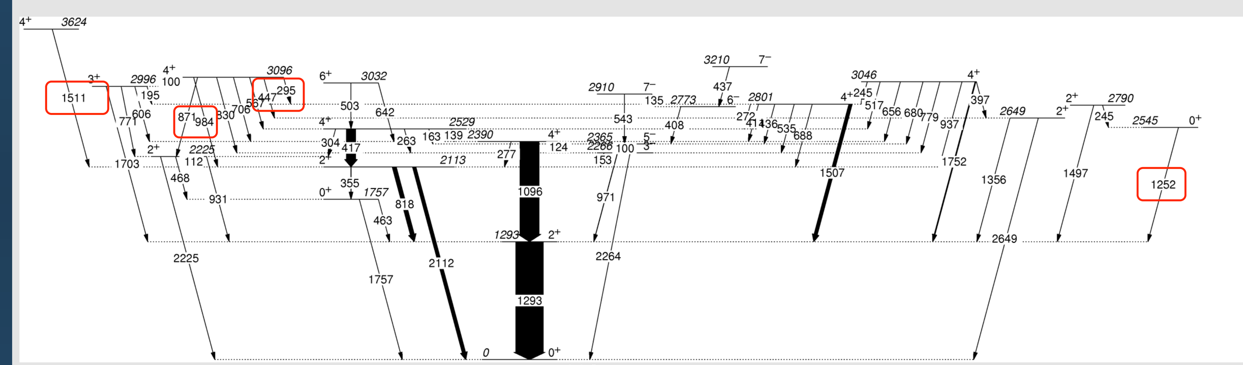


Figure 9. Partial level scheme of ^{116}Sn. Observed gamma and known E0 transitions are placed. Selected new transitions are highlighted.

Internal Conversion Branches and Collectivity

- We are re-calculating internal conversion coefficients to attempt to determine *E0* components of transitions between states of the same spin and parity. As one example, an experimentally determined α_K = 0.25(3) has been calculated for the 138 keV transition connecting two I^{π} = 4^+ states. This value, obtained via an in-beam PACES relative efficiency measurement, is undergoing further refinement.

FUTURE WORK

To extract B(E2) values and branching ratios for other weak γ ray transitions to gain a better understanding of shape coexistence in the case of ^{116}Sn. We wish to continue this program across other neutron-rich isotopes of Tin, thus furthering our understanding of shape coexistence in singly closed shell nuclei.

ACKNOWLEDGEMENTS

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