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Investigating shape evolution and the emergence of collectivity through the synergy of Coulomb excitation and β decay

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Abstract. The synthesis of Coulomb excitation and β decay offers very practical advantages in the study of nuclear shapes and collectivity. For instance, Coulomb excitation is unique in its ability to measure the electric quadrupole moments, i.e., $\langle I_2^\pi || M(E2) || I_1^\pi \rangle$ matrix elements, of excited, non-isomeric states in atomic nuclei, providing information on the intrinsic shape. However, the Coulomb excitation analysis and structural interpretation can be strongly dependent upon weak transitions or decay branches, which are often obscured by the Compton background. Transitions of particular interest are those low in energy and weak in intensity due to the E_γ^5 attenuation factor. These weak decay branches can often be determined with high precision from β-decay studies. Recently, ^{106}Mo and ^{110}Cd were studied by both Coulomb excitation and β decay. Preliminary results of new weak decay branches following β decay of ^{110m}Ag to ^{110}Cd are presented; these results will challenge competing interpretations based on vibrations and configuration mixing.

1 Introduction

Low-energy decay branches of excited states are often weaker than alternative decay paths with higher energy; this is due to an energy-dependent attenuation factor. Even decays with large reduced transition probabilities, e.g., $B(E2)$, can appear weak when attenuated, $I_\gamma \propto B(E2) \times E_\gamma^5$. The $B(E2)$ magnitudes of these weak, low-energy transitions can often provide a way to differentiate between competing interpretations and calculations. However, these weak transitions can be difficult to observe. γ-γ coincidence measurements following β decay can often be used to measure weak decay branches with high precision, cf. [1]. The absolute $B(E2)$ magnitudes or $\langle I_2^\pi || M(E2) || I_1^\pi \rangle$ matrix elements can then be determined from Coulomb excitation data by normalizing through the strong decay branches.[1]

^{106}Mo and ^{110}Cd were recently studied by both Coulomb excitation and β decay. New weak decay branches of ^{110}Cd following β decay of ^{110m}Ag are presented. The ^{110}Cd study is largely motivated by a previous Coulomb-excitation study of ^{114}Cd [2] and recent evidence against a vibrational interpretation of nuclei in the Cd region based on measurements of lifetimes and intensities of weak decay branches [3–8].

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2 Experiment and Results

A ^{110m}Ag(249.83 d) source was made at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) by activating a natural Ag foil. The foil was then placed into the center of the γ-ray detector array CLARION [9], consisting of 11 Compton-suppressed HPGe Clover detectors at a distance of 21.75 cm with a total photo-peak efficiency of 3% at 1 MeV. This investigation focused on high-precision, ultra-high statistics measurements of weak γ-ray transitions between excited states.

Nearly 3 billion, 3×10^9, γ-γ coincidence events were recorded. A sample γ-ray spectrum is shown in Fig. 1, which reveals 9 new transitions in coincidence with the 1783-keV transition (i.e., a 1.1×10^{-4} decay branch [10]). These new transitions are very weak. For instance, the 379-keV transition has a decay branch of roughly 1 in 200,000 β decays.

The branching ratios and transition strengths of the γ rays from these data will test the so called "strong vibration-intruder mixing" scenario [11–13] used to explain the anomalous 0_2^+ and 0_3^+ decay strengths. Within this interpretation, the transitions outlined in Fig. 1 are an extensive set of new transitions from weakly collective states to intruder states. Based on the selective population of the (^{3}He,n) reaction [14], these intruder-state candidates are thought to be of π 2p-4h nature [15]. Most importantly, the new transitions, when combined with the Coulomb excitation data, will further complete the model-independent Kumar-Cline sum rules (shape invariants) [16] of the low-lying, non-yrast states.

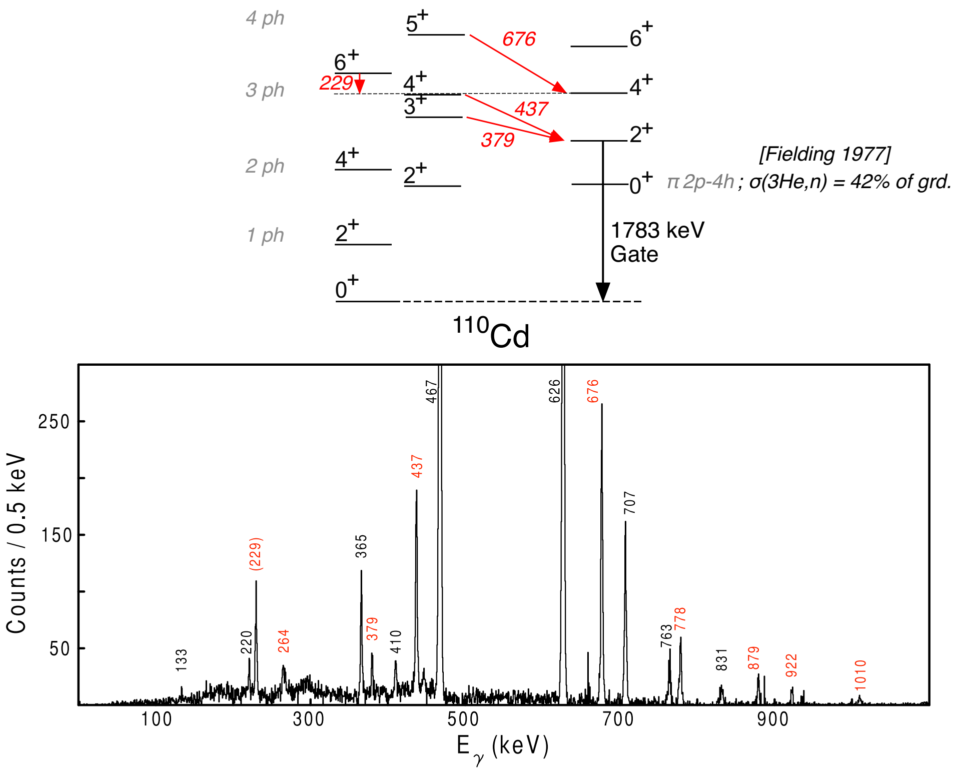

Figure 1. A partial level scheme and γ-ray spectrum of ^{110}Cd following ^{110m}Ag β decay and a gate on the 1783-keV γ-ray transition (a 1.1×10^{-4} per β decay branch [10]). The new transitions are labeled by energy in red ; the 229-keV γ ray was recently reported for the first time by Garrett *et al.*, [6]. These new transitions are incredibly weak. For instance, the 379-keV transition has a decay branch of roughly 1 in 200,000 β decays.

3 Conclusions

When these decay data are coupled with multiple-step Coulomb excitation data, the result will be an unprecedented set of electromagnetic moments for a weakly collective nucleus; this is an essential step in elucidating the nature of emergent collectivity.

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