EPJ Web of Conferences **66**, 02029 (2014)
DOI: 10.1051/epjconf/ 20146602029
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High-Statistics Study of the β^+/EC-Decay of ^{110}In

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Abstract. A study of the ^{110}In β^+/EC decay was performed at the TRIUMF Isotope Separator and Accelerator (ISAC) facility to probe the nuclear structure of ^{110}Cd. The data were collected in scaled-down γ-ray singles, $\gamma-\gamma$ coincidence, and γ-electron coincidence mode. The data were sorted and a random-background subtracted $\gamma-\gamma$ matrix was created containing a total of 850 million events. We expanded the level scheme of ^{110}Cd significantly by identifying 75 levels under 3.8 MeV, including 12 new ones, and increased the number of previously observed transitions from these levels to 273. The γ-ray branching intensities have been extracted through an analysis of the coincidence intensities. The branching ratios were combined with a reanalysis of lifetimes measurements obtained in an $(n, n'\gamma)$ reaction with monoenergetic neutrons for the calculation of $B(E2)$ values and these results have lead to the proposal of a γ-soft rotor, or O(6) nucleus, rather than a vibrational, or U(5) pattern for the nature of the low-lying, low-spin levels in ^{110}Cd.

1 Introduction

The collective Bohr model and the interacting boson model (IBM) have both been used to describe the stable even-even Cd isotopes as examples of spherical vibrational nuclei for decades. Experiments with the $(\alpha, 2n)$ reaction by Kern *et al.* [1], β decay measurements by Bertschy *et al.* [2], light-ion induced reactions and decays by Kumpulainen *et al.* [3], and an $(n, n'\gamma)$ study by Corminboeuf *et al.* [4] have identified multi-phonon states in the ^{110}Cd decay scheme indicating vibrational motion. The Cd nuclei have been considered as some of the best examples of near-harmonic vibrational behavior [5]. There is, however, evidence of the breakdown of vibrational motion in the low-spin states leading

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Article available at http://www.epj-conferences.org or http://dx.doi.org/10.1051/epjconf/20146602029

to systematic deviations in the three-phonon levels that occur across the Cd isotopic chain [6]. Taking into account mixing between the spherical vibrational states and the more-deformed intruder states based on 2p-4h proton excitations, IBM-2 calculations have been successful in reproducing the low-lying level schemes for $^{110\text{-}114}$Cd [6]. However, this relies on fine tuning of the mixing matrix element and the location of the unperturbed states, and a consequence is that higher-lying states mix resulting in the appearance of enhanced low-energy transitions between the configurations [6–8]. These low-energy transitions, however, must compete with high-energy branches, and due to the E_γ^5 factor in the transition rate, are often so weak that they have remain unobserved. High-statistics γ-ray spectroscopy following β-decay is an ideal tool to observe such transitions as the low-energy backgrounds are typically much lower than in reaction studies. For this purpose, we have initiated a program of high-statistics β-decay measurements with the 8π spectrometer at the TRIUMF-ISAC radioactive-beam facility.

2 Experimental Details

This study of ^{110}Cd was performed at the Isotope Separator and Accelerator (ISAC) facility at TRIUMF in Vancouver, Canada. A 65 μA, 500 MeV proton beam from the TRIUMF main cyclotron induced spallation reactions in a Ta target. The spallation products were surface ionized and mass separated to select $A = 110$. The beam was implanted onto the tape of a Moving Tape Collector at the center of 8π spectrometer, an array consisting of 20 Compton-suppressed HPGe detectors. Five Si(Li) detectors for conversion electrons and a fast plastic scintillator for β-particle tagging were also used. The beam consisted of 1.2×10^7 ions/s of ^{110}In in the 7^+ $t_{1/2} = 4.9$ hr ground state, and 1.7×10^6 ions/s in the 2^+ $t_{1/2} = 69$ min isomeric state. The 7^+ ground state provided access to the high-spin states by populating spins 6^+,7^+,8^+, while the 2^+ isomer populates spins 1^+,2^+,3^+, enabling the study of a wide range of excited states in the final nucleus.

3 Results

The 3.5-day experiment resulted in a very-high-statistics data set. The random background subtracted γ-γ coincidence matrix contains 850 million events and demonstrates that many levels over a wide range of excitation energies are populated. A total of 75 levels were observed, 12 of which had not been seen in previous works. Decaying from these levels, 273 transitions were identified and placed; 116 were newly observed. Kawase *et al.* in 1972 [9] first proposed a doublet of levels with spins 0^+ and 3^- at 2079 keV. This was later confirmed [1–3]. An upper limit was determined by Corminboeuf *et al.*, Ref [4], for the 1421.1-keV transition from the 2078.6-keV 0^+ level. The difference in relative intensities of the transitions from both levels is clearly seen in the left side of Figure 1 with the decay paths on the right.

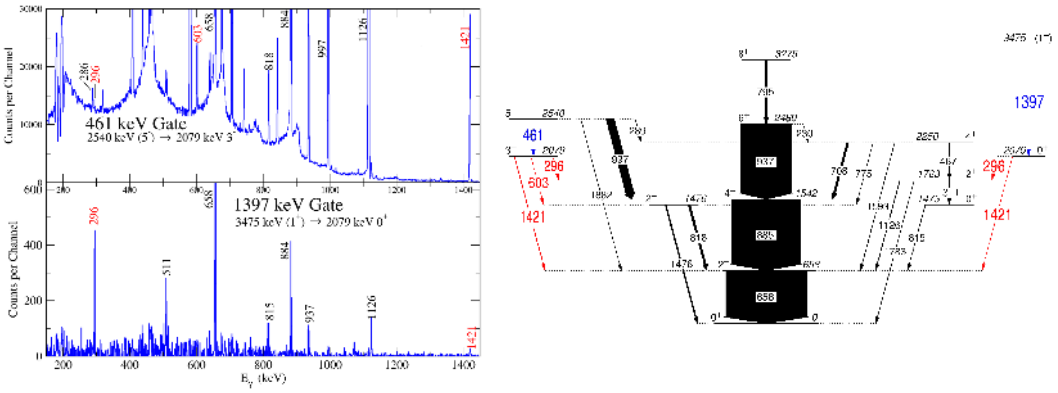

Figure 1. Distinction between levels at 2079-keV γ-ray spectrum. The blue arrows represent the gates taken from above and the red arrows represent important coincidences.

Spectra leading to the placement of the 3737-keV level and the resultant level are illustrated in Figures 2 and 3. Transitions labeled in red in these two figures are newly observed and placed. (Ten observed transitions decaying from the 3737.3-keV 6^+ level are not included.) Figure 2 is a gate on the 393-keV transition with all γ rays decaying from the 3344.6-keV level in coincidence, except for one at 783 keV, which is shown in the inset, seen in the gate from below on the 1085-keV transition.

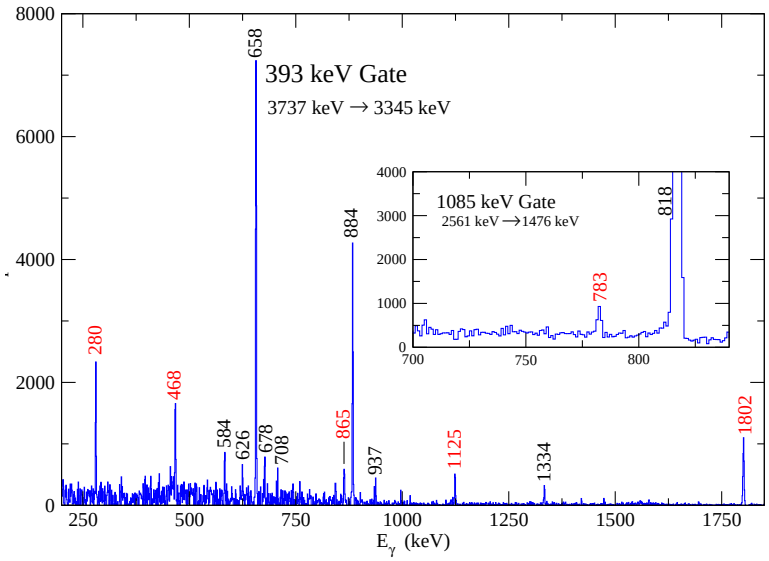

Figure 2. Coincidence spectrum observed with a gate on the 393-keV γ ray from the 3737.3-keV 6_8^+ level $\rightarrow$ 3344.6-keV (6_6^+) level. The inset shows a gate on the 1085 keV γ ray from the 2561.2-keV 4_4^+ level to the 1475.6-keV 2_2^+ level.

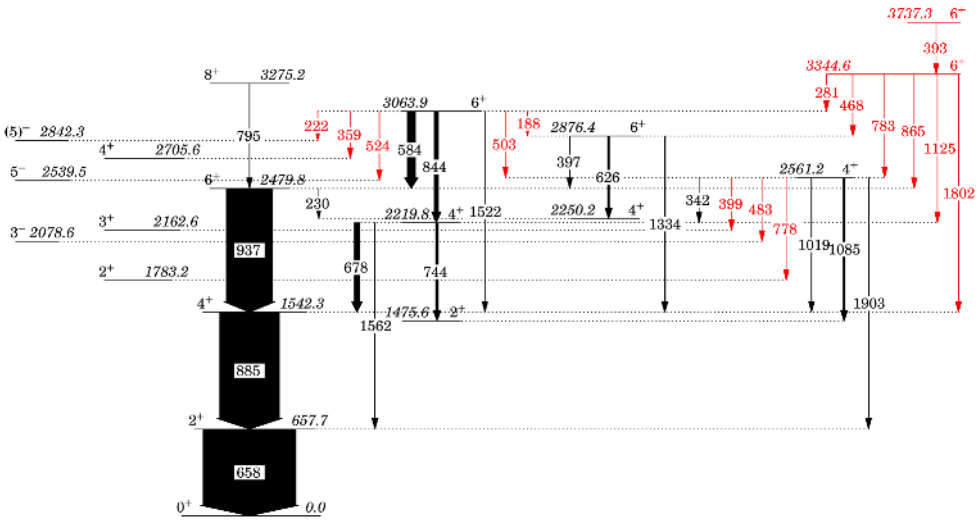

Figure 3. Part of the ^{110}Cd level scheme, emphasizing the decay path of the 393-keV transition from the 3737.1-keV level, and some subsequent transitions.

4 Conclusions

The newly measured branching ratios were combined with a reanalysis of lifetimes observed from the $(n, n'\gamma)$ reaction with monoenergetic neutrons for the calculation of $B(E2)$ values in W.u. The previous interpretation of the decay scheme of the excited 0^+ states required that there be strong mixing between assigned phonon states and the deformed intruder states. An absence of predicted linking transitions between these configurations refutes this scenario, and has lead to the proposal of a γ-soft deformed rotor, or $O(6)$ nucleus, rather than a vibrational, or $U(5)$ nucleus [10].

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