The Conversion Electron Study of ^{110}Cd

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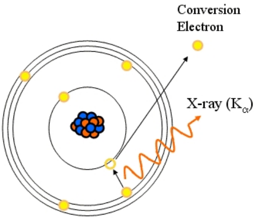
Internal Conversion Process

Internal conversion is a radioactive decay process.

In this process an excited nucleus interacts with an electron in one of the lower atomic orbitals.
This causes the electron to be emitted from the atom.

In this case, a high-energy electron is emitted from the radioactive atom.

$$E_e = (E_i - E_f) - E_B \tag{1}$$



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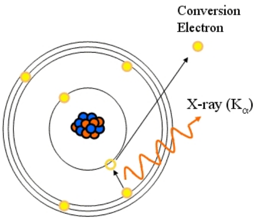
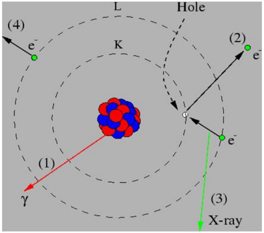
$$E_e = (E_i - E_f) - E_B \qquad (1)$$

The internal conversion process (2) competes with gamma decay(1).
This competition is defined by the internal conversion coefficient:

$$\alpha = I_e / I_\gamma \qquad (2)$$

I_e is the intensity of the conversion electrons and
I_γ is the intensity of the gamma radiation.





This can result in the emission of an X-ray(3) or the emission of an Auger electron(4).

Introduction

- The motivation of this study is simply to investigate **vibrational motion** in nuclei.
- We chose **Cadmium (Cd)** because this is the best example of a vibrational nuclei.
- Cd isotopes have been studied with many techniques but not with $\mathbf{e^-}$-γ **coincidence (conversion electron)**.

Collective model

- The vibrational motion of nucleus is described by the Collective Model which was first introduced by Borh and Motelson [1]
- In the Collective Model, the nucleus vibrates with an average spherical shape[2].
- An instantaneous, time dependent shape of the nucleus is described by spherical harmonics.

$$R(t) = R_{av} + \sum_{\lambda \geq 1} \sum_{\mu=-\lambda}^{+\lambda} \alpha_{\lambda\mu} Y_{\lambda\mu}(\theta, \phi) \tag{3}$$

- Every single λ corresponds to a different nuclear shape.

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[1] *A. Bohr and B.R. Mottelson, Phys. Rev. 89, 316 (1953).*

[2] *K.S.Krane. Introductoty Nuclear Physics., p139, (1987).*

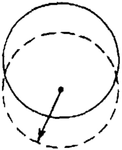
- λ=0, the monopole term, zero change in the shape of the nucleus.
- λ=1, the dipole term, a shift in the nuclear mass centre (8-20 MeV).

These two terms are ignored in this work.

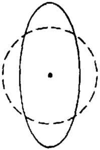
- λ=2, quadrupole term, quadrupole vibrations,
- λ=3, octupole term, octupole vibrations,

The lowest order expansion will be λ=2 in this study.

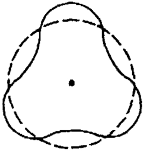
$$R(\theta,\phi) = R_0[1 + \sum_{\mu=-2}^{+2} \alpha_{2\mu}(t) Y_2^{\mu}(\theta,\phi)] \qquad (4)$$



λ=1



λ=2



λ=3

As a vibrational nucleus, ^{110}Cd exhibits multiphonon states.

The energy of multiphonon states increases linearly with number of phonons

$$E_n = \hbar\omega(n + \frac{5}{2}) \qquad (5)$$

Where
n is phonon number.

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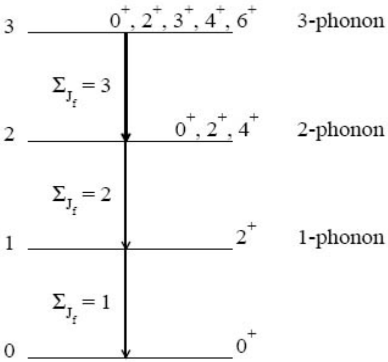

Multiphonon states in Vibrational Model.

level energy – angular momentum and parity – transition strengths
Even though the Collective Model describes many features of nuclei

it is not enough to accurately describe real nuclei.

Interacting Boson Model

- A new approach to nuclear structure, IBM, was first introduced by Arima and Iachello[3].
- IBM-1, makes no distinction between protons and neutrons.
- IBM-2 involves an explicit distinction between protons and neutrons.
- In this model the collective features of nuclei are expressed in the language of group theory based on dynamical symmetries.
- This model well describes the collective low-lying states of even-even nuclei.
- For ^{110}Cd, we are going to use a U(5) symmetry limit (used for spherical vibrators).

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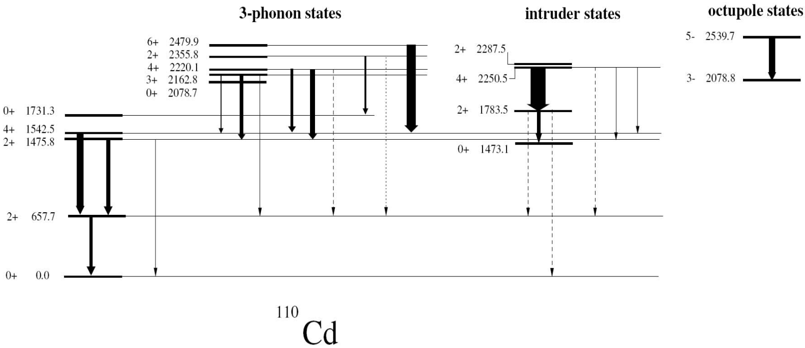
[3] *A. Arima and F. Iachello, Ann. Phys. 99, 253 (1976).*



The experimental level scheme of ^{110}*Cd from*[4]*.*

multiphonon states, additional states (intruder states)

Why are there additional states?

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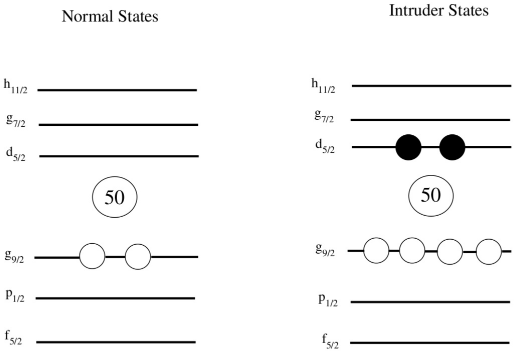
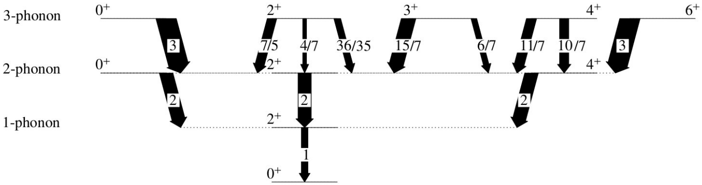
[4] *F. Corminboeuf et al., Phys. Rev. C 63, 014305 (2000).*



Proton configurations for the normal and intruder states in $^{110}_{48}Cd$

This configuration gives another set of states.

Those states are called the intruder states.



Multiphonon states with normalized B(E2) in Vibrational Model from [5].

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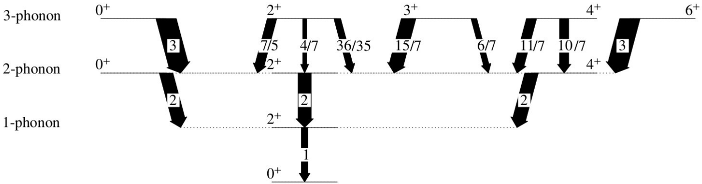
[5] *Jack C. Bangay, Msc., Thesis (2010).*



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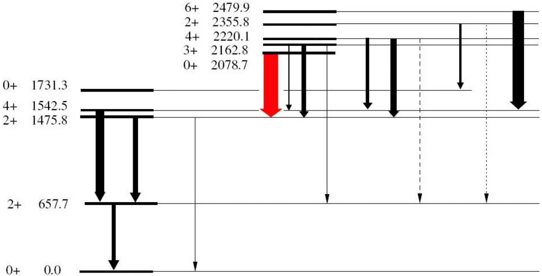

- If we compare them
- The nuclear structure of ^{110}Cd is well described up to 2 phonon level.
- Serious deviation become evident at 3 phonon level.
- more probable than others
- This transition hasn't been observed

The most pressing question is whether a 0+ state exists in the 3-phonon level

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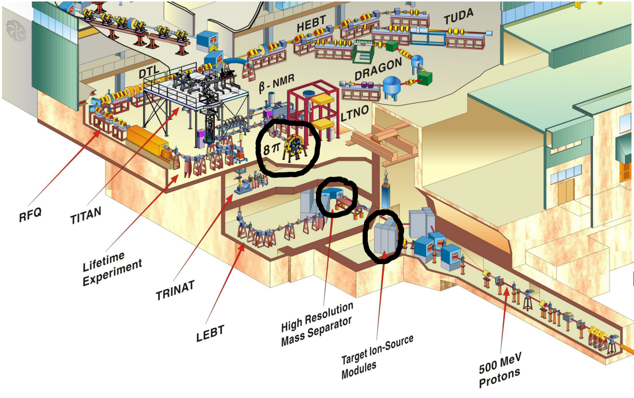
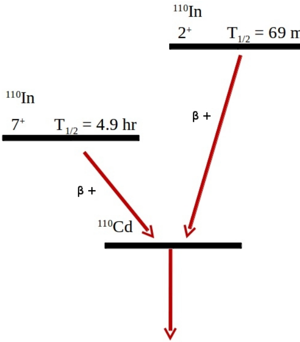
[5] *Jack C. Bangay, Msc., Thesis (2010).*

Experimental Details (TRIUMF-ISAC)

- Used β^+ decay of ^{110}In, produced, Ta target, 500 MeV protons, mass separated

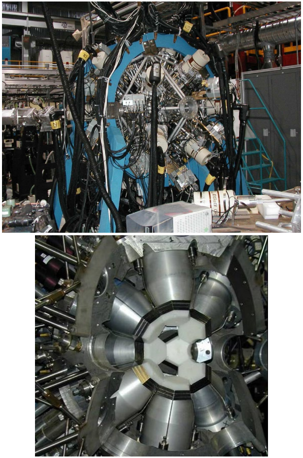




Beam consists of ^{110}In

- 7+ isomeric state (1.2×10^7 ions/s)
- 2+ ground state (1.7×10^6 ions/s)

Experimental Details



8π γ-ray spectrometer.

The 8π γ-ray spectrometer consists of 20 Compton-suppressed high-purity germanium detectors is used for γ-ray detection.

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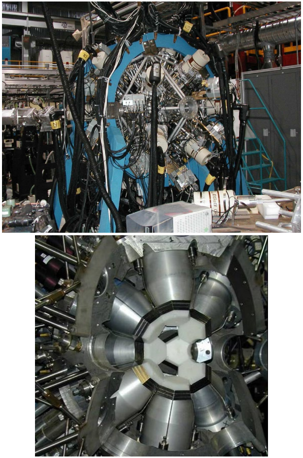

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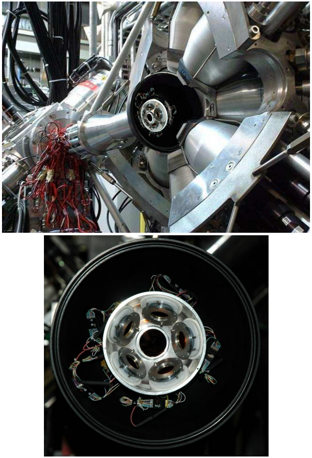
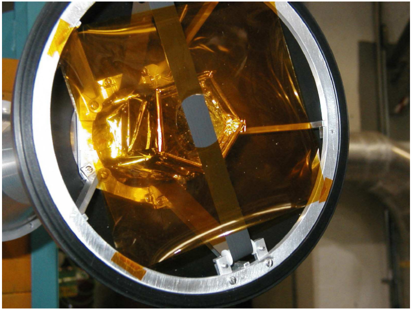


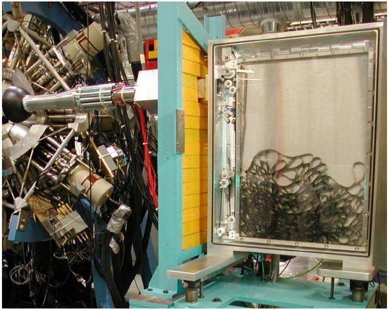
PACES array.

The PACES (Pentagonal Array for Conversion Electron Spectroscopy) array of 5 Si(Li) detectors is used for conversion e^- detection.

Experimental Details



Tape setup through the array.

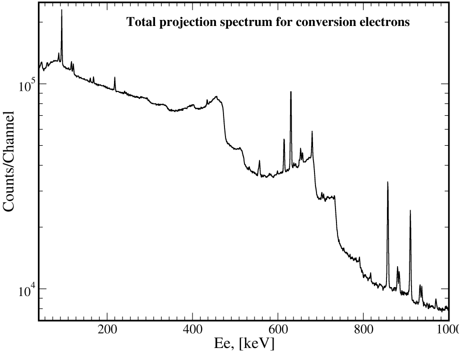


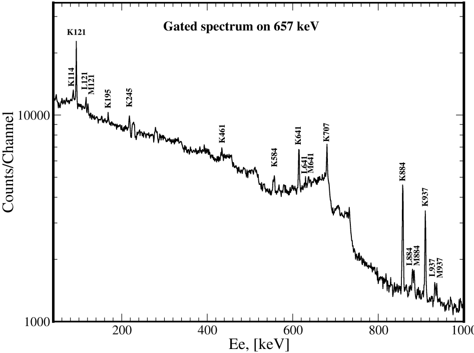
The Moving Tape Collector.

The beam was implanted onto the tape of a Moving Tape Collector at the center of 8π spectrometer.

The tape was moved into the moving tape collector which is behind the lead shielding to remove any long-lived contaminants.

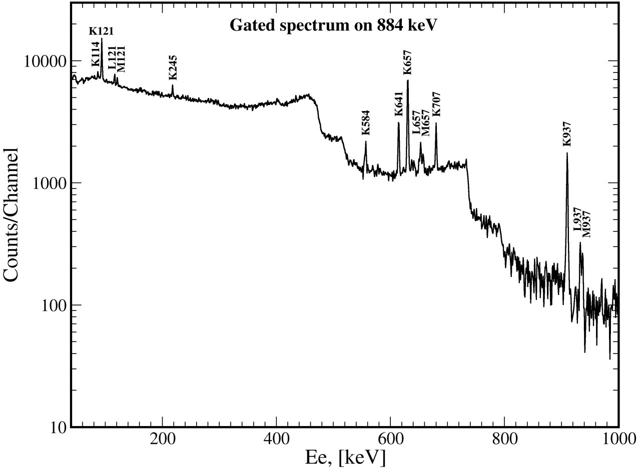
Preliminary Results

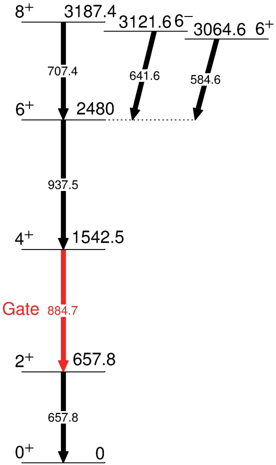




We used the Radware package to fit peaks in the coincidence spectra.
This package allows us to determine the energies and intensities of conversion e^- transitions.
We took 15 gates on γ energies.

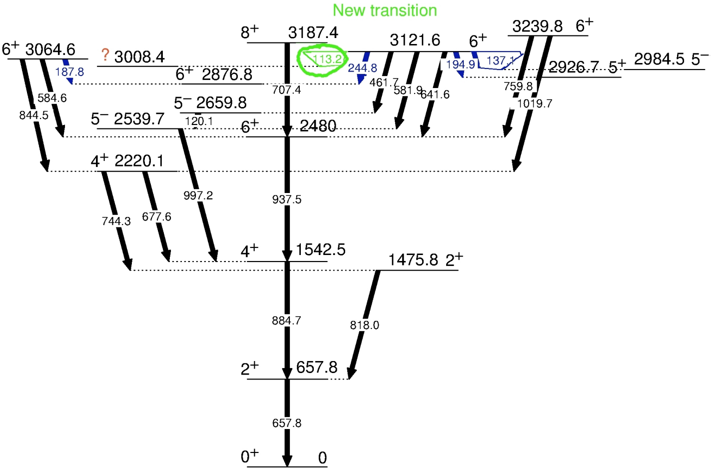
Preliminary Results





This is a spectrum gated on γ energy of 884 keV.
We built a partial level scheme from this spectrum.

Preliminary Results



Partial level scheme of ^{110}Cd displaying the observed conversion electron transitions.

We identified a previously unobserved transition.

We also identified four new transitions which are not in the NNDC data set

This demonstrates that we have good data.

Preliminary Results

Adopted E_γ, [keV]	Identified e^- shells	Multi-polarities	Exp. [K/L]	Theo. E1 [K/L]	Theo. M1 [K/L]	Theo. E2 [K/L]
113.2	K	-	-	-	-	-
120.1	K, L, M	M1 (+E2)	6.59±0.22	8.16	8.01	4.35
137.1	K	E1	-	-	-	-
187.8	K	M1(+E2)	-	-	-	-
194.9	K	E2+M1	-	-	-	-
244.8	K	M1 (+E2)	5.60±0.32	8.36	8.17	6.41
461.7	K	E1	-	-	-	-
560.3	K	E2 (+M3)	-	-	-	-
581.9	K	M1 (+E2)	-	-	-	-
584.7	K, L	M1+E2	3.51±0.48	8.54	8.40	7.82
641.7	K, L	M1 (+E2)	6.44±0.55	8.56	8.42	7.92
657.8	K, L, M	E2	6.70±0.43	8.56	8.43	7.95
677.6	K	M1 (+E2)	-	-	-	-
707.4	K, L, M	E2	4.70±0.15	8.58	8.44	8.02
759.9	K	M1+E2	-	-	-	-
818	K	M1 (+E2)	-	-	-	-
884.7	K, L, M	E2	6.39±0.31	8.63	8.50	8.22
937.4	K, L, M	E2 (+M3)	7.96±0.46	8.64	8.51	8.26
997.2	K	E1 (+M2)	-	-	-	-
1019.5	K	E2	-	-	-	-

Table shows identified conversion electron transitions and subshell ratios.

Conclusion

- This is our first investigation using the e^{-}-γ coincidence method.
- We have identified 4 new transitions and 1 unobserved transition.
- Through sub-shell ratios, we will be able to determine the multipolarities and conversion coefficients.
- We will try to extract the E0 intensities using the absolute conversion coefficients.
- This will allow us to firmly assign the intruder excitations.

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