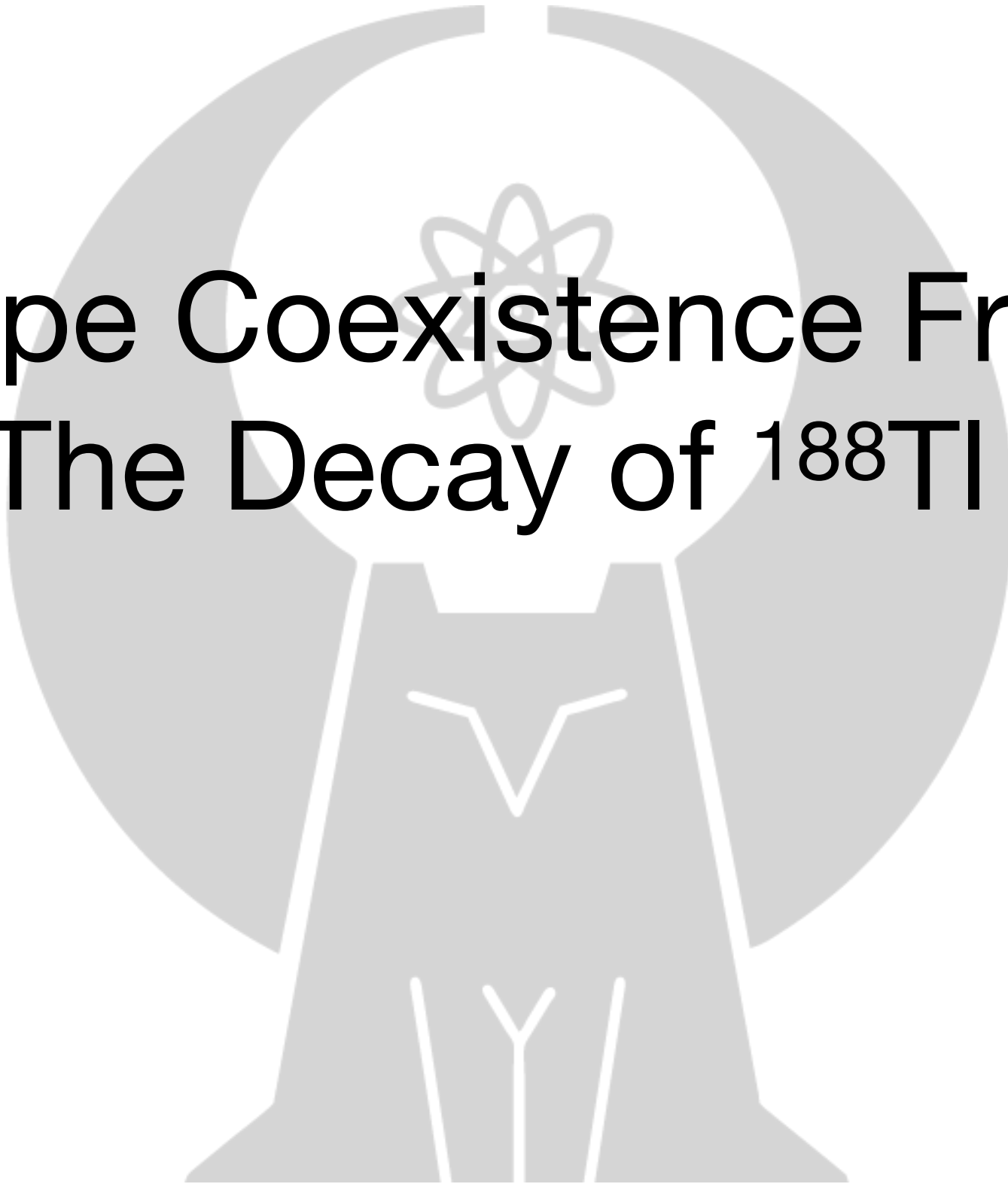




Shape Coexistence From The Decay of ^{188}Tl

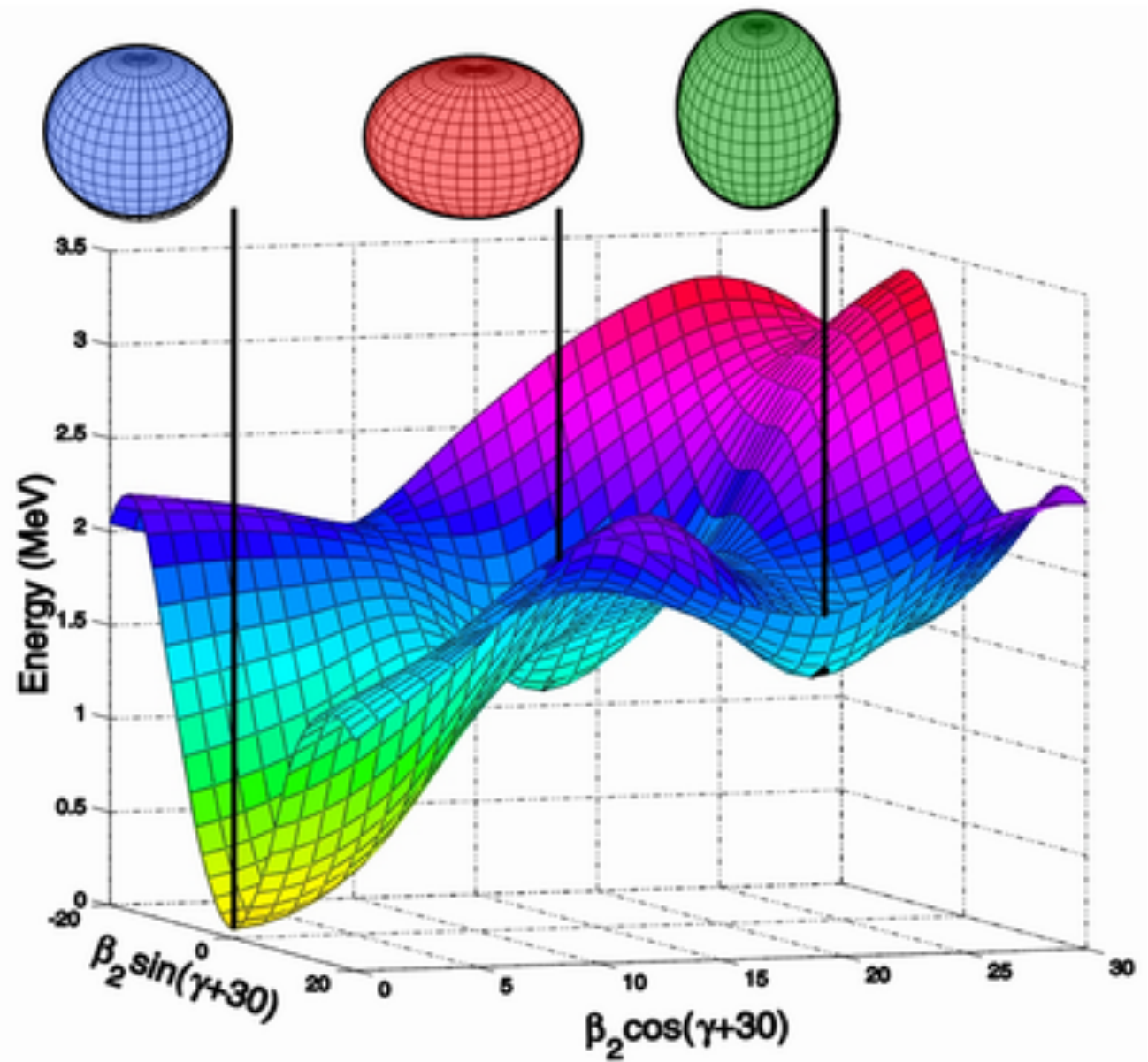
Andrew MacLean
University of Guelph
WNPPC, February 16th 2019

Shape Coexistence

What is it?

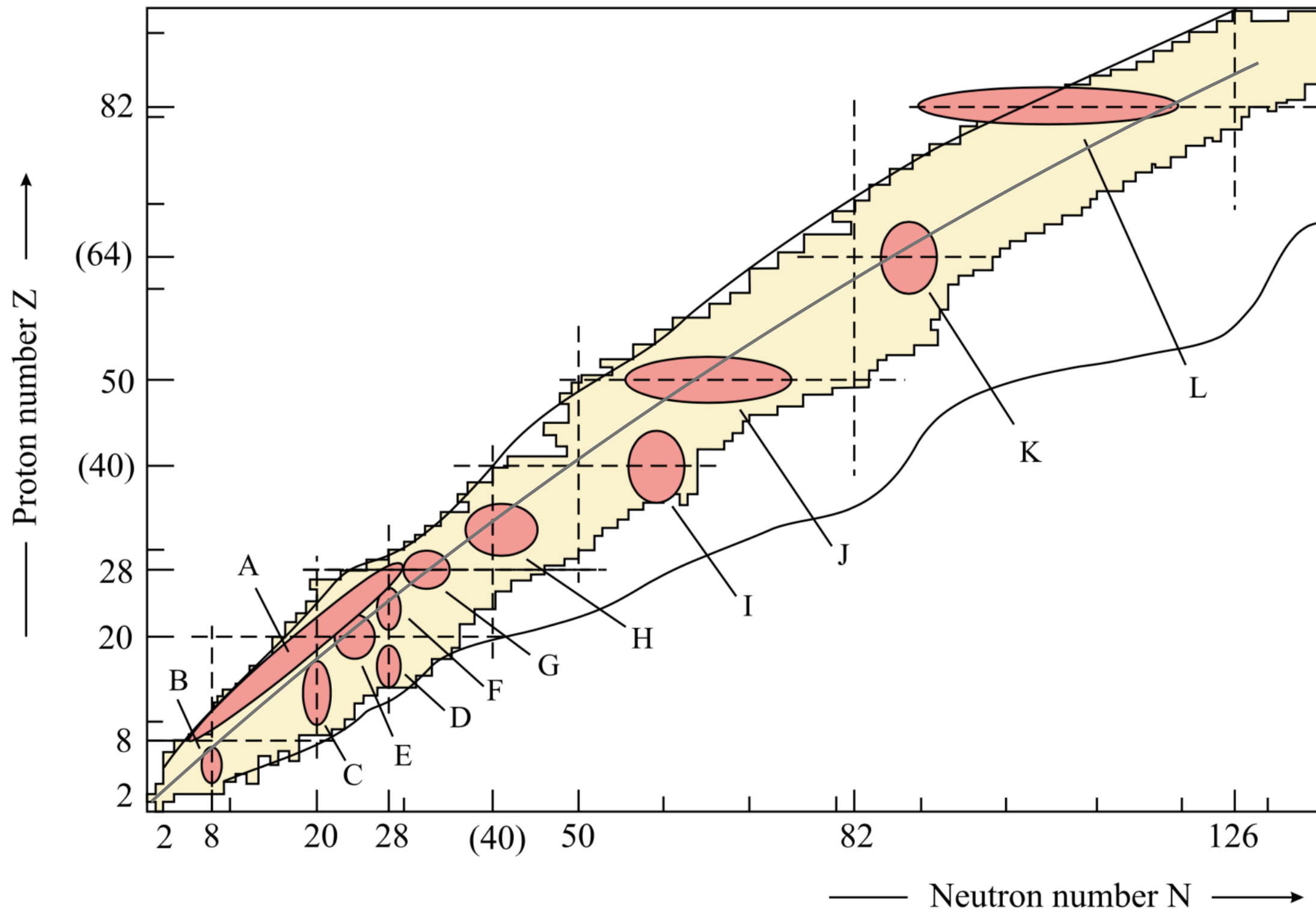
- Shape coexistence - unique deformations existing at similar energies.
- Stabilizing effects of closed shells, causing spherical symmetry, and the residual interaction between the protons and neutrons.

(Spherical) (Oblate) (Prolate)



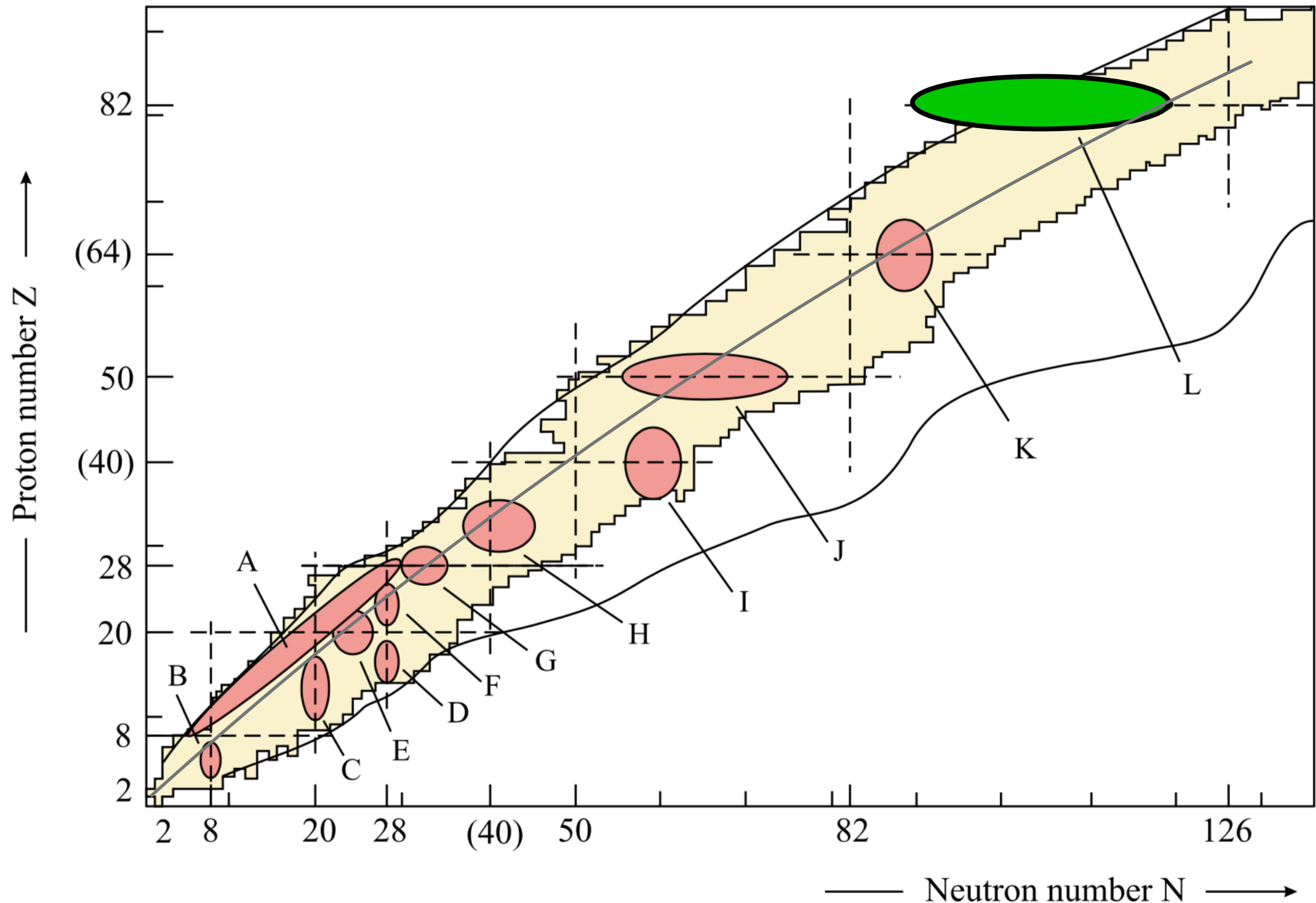
Shape Coexistence

Thought to be a common phenomenon in all but the lightest of nuclei.



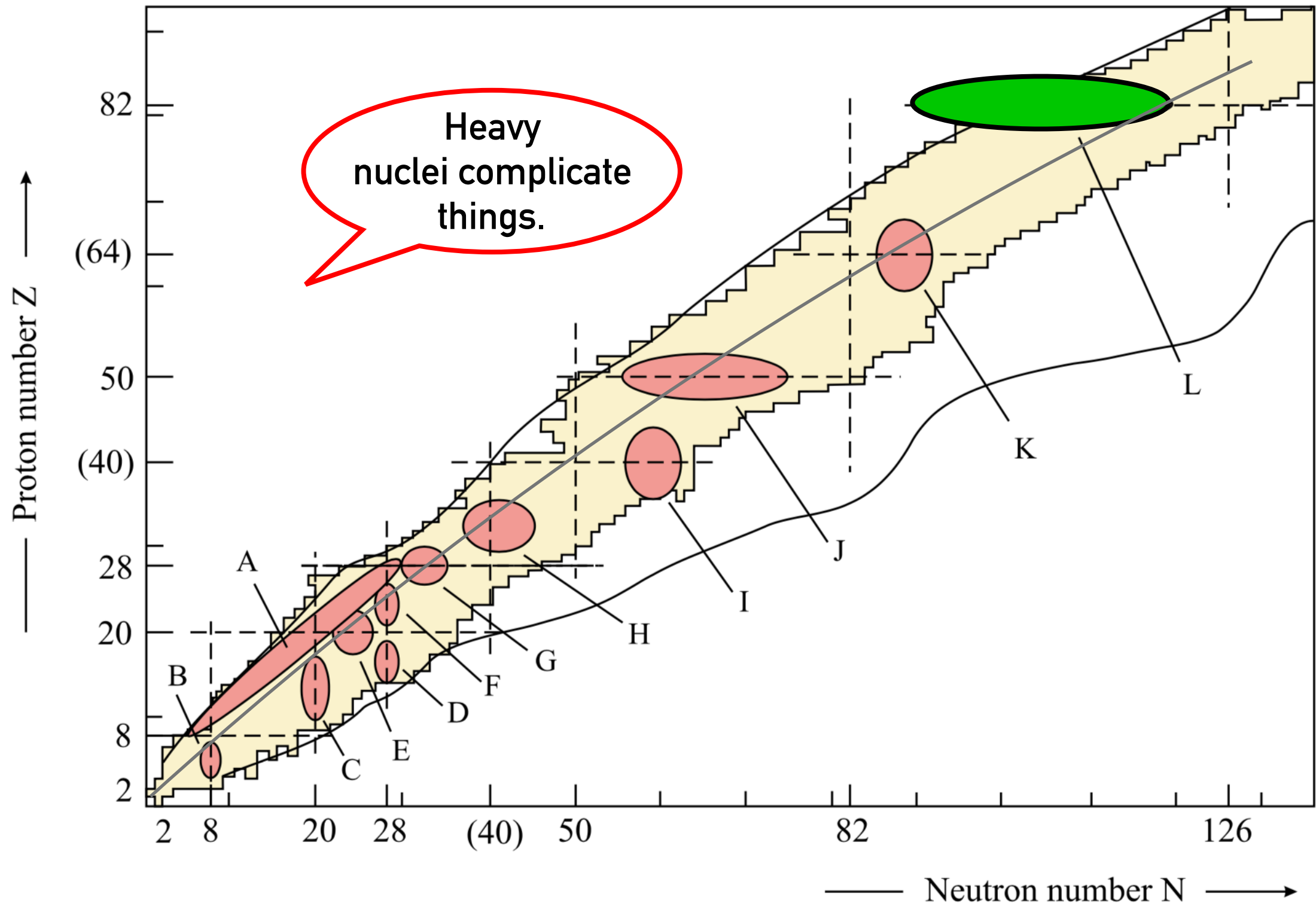
Heavy Nuclei

Neutron deficient $Z \sim 82$ nuclei exhibit the most extensive manifestation of shape coexistence known in the nuclear chart.



Heavy Nuclei

Neutron deficient $Z \sim 82$ nuclei exhibit the most extensive manifestation of shape coexistence known in the nuclear chart.





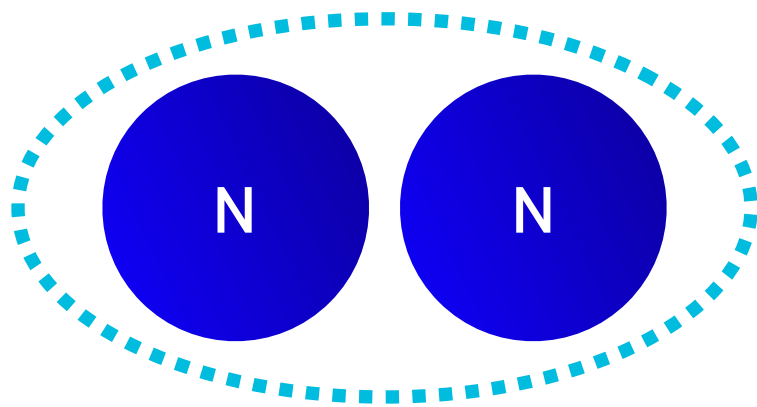
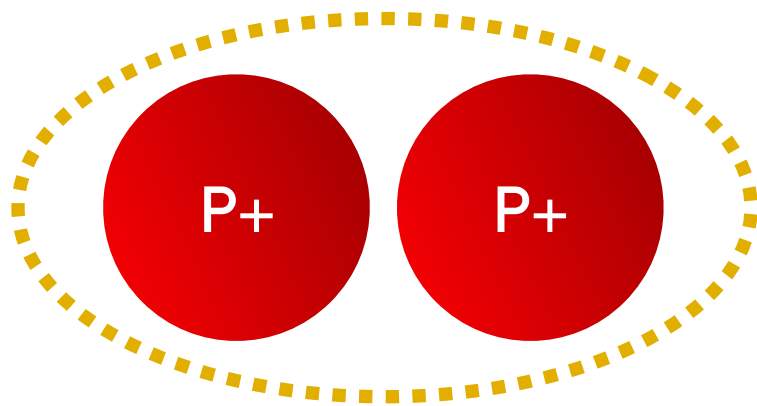
Matrices become too large with heavy nuclei ($A > 100$), can't be solved with modern computers. Need to simplify the model.



Matrices become too large with heavy nuclei ($A > 100$), can't be solved with modern computers. Need to simplify the model.

Interacting Boson Model

Bosons



Truncate model space by coupling pairs of nucleons to form bosons.

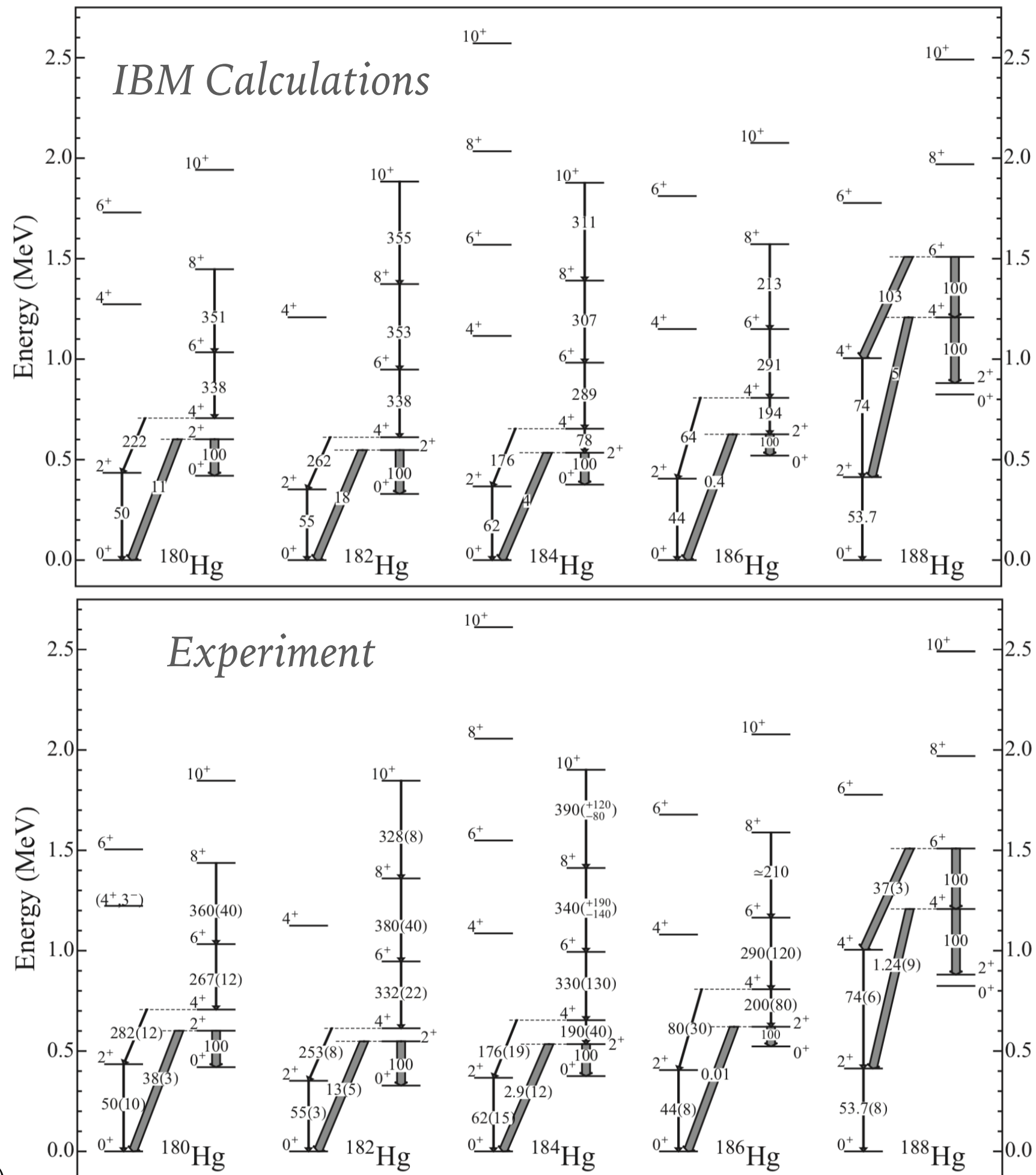
Example: ^{154}Sm in the fermion basis has 3.5×10^{14} $I^\pi = 2^+$ configurations. In the boson basis it has 63 $I^\pi = 2^+$ configurations.

Observables

IBM tries to obtain the best agreement possible with the excitation energies and the B(E2) values.

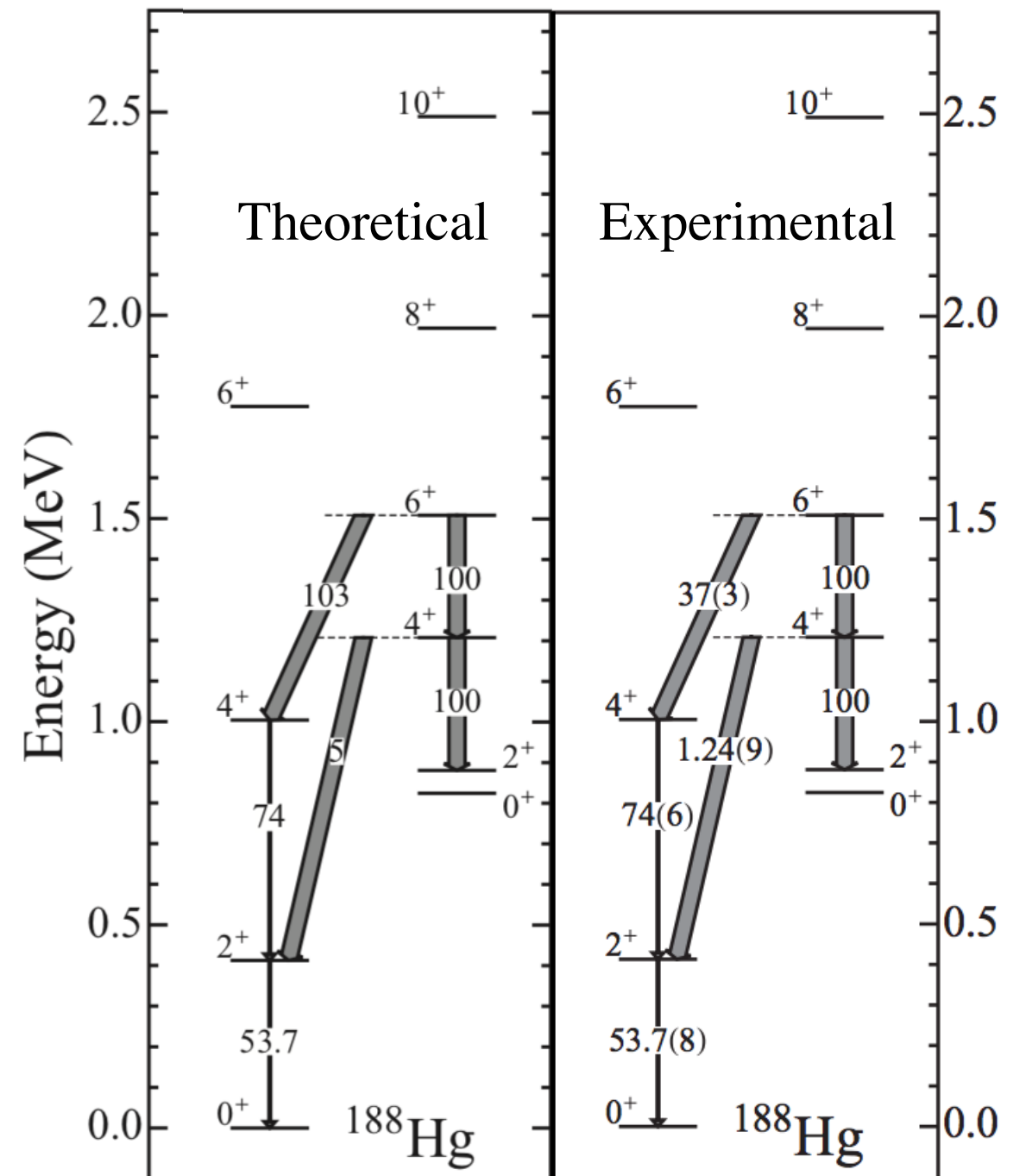
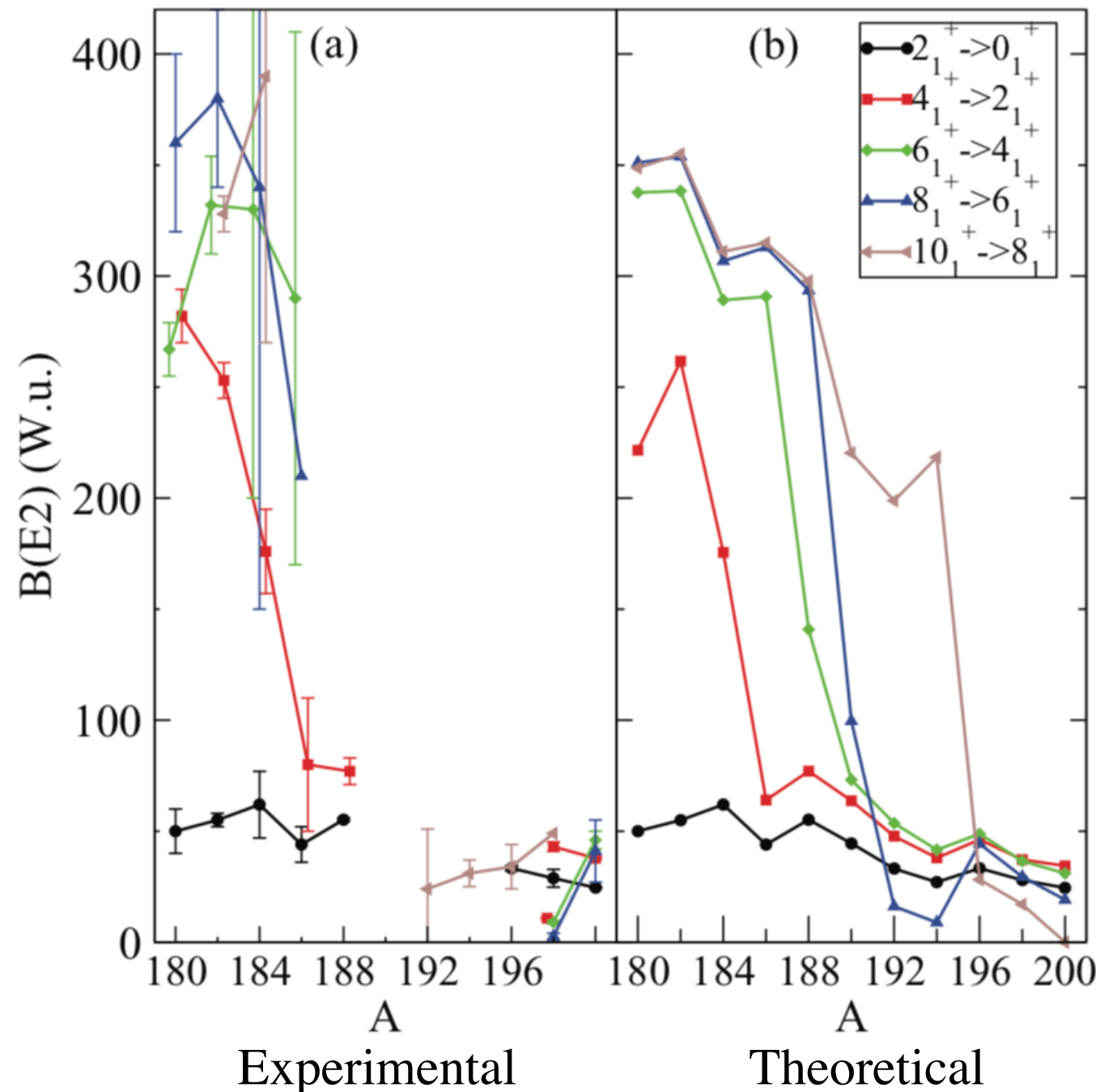
Related to the collectivity (deformation) of the transition.

Dependent on the half-lives, excitation energies and branching ratios.



Purpose of Experiment

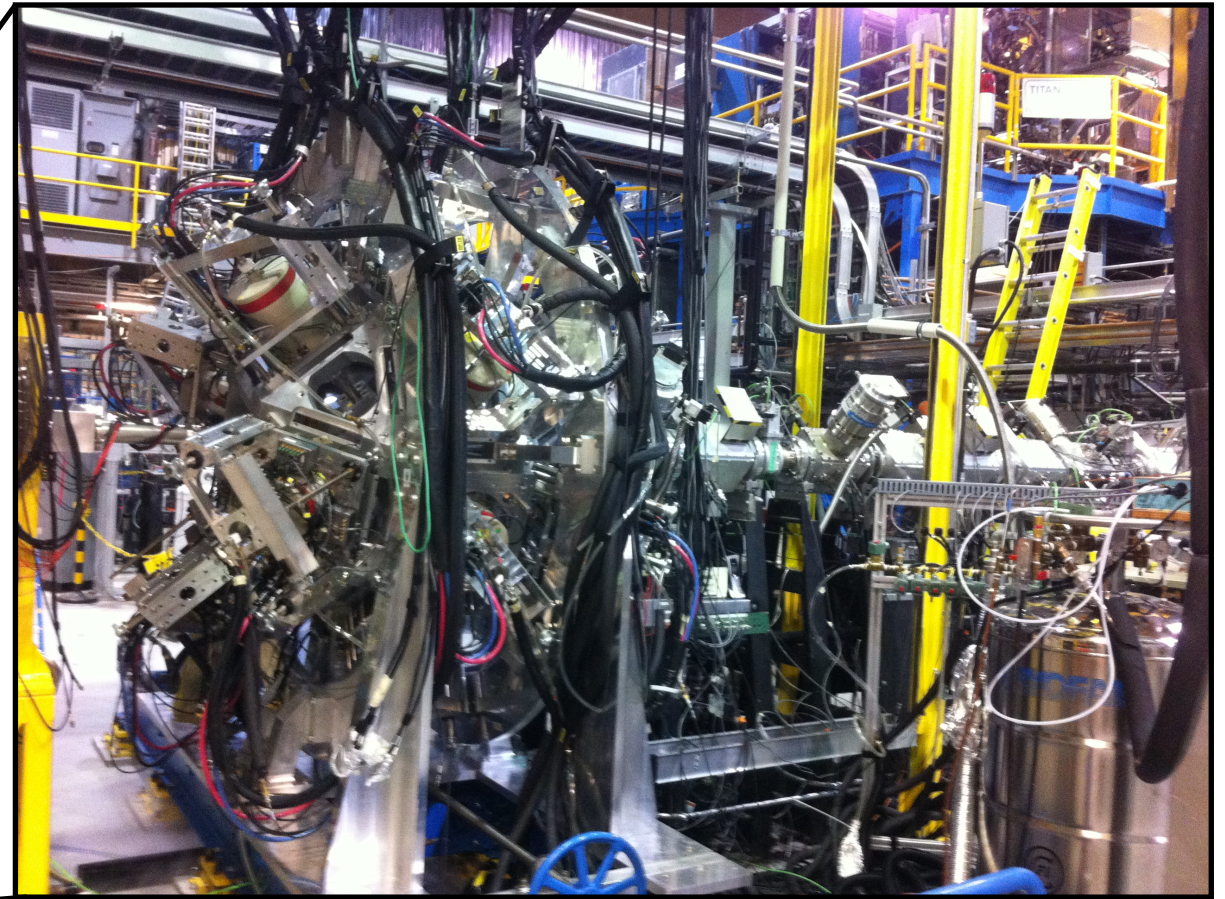
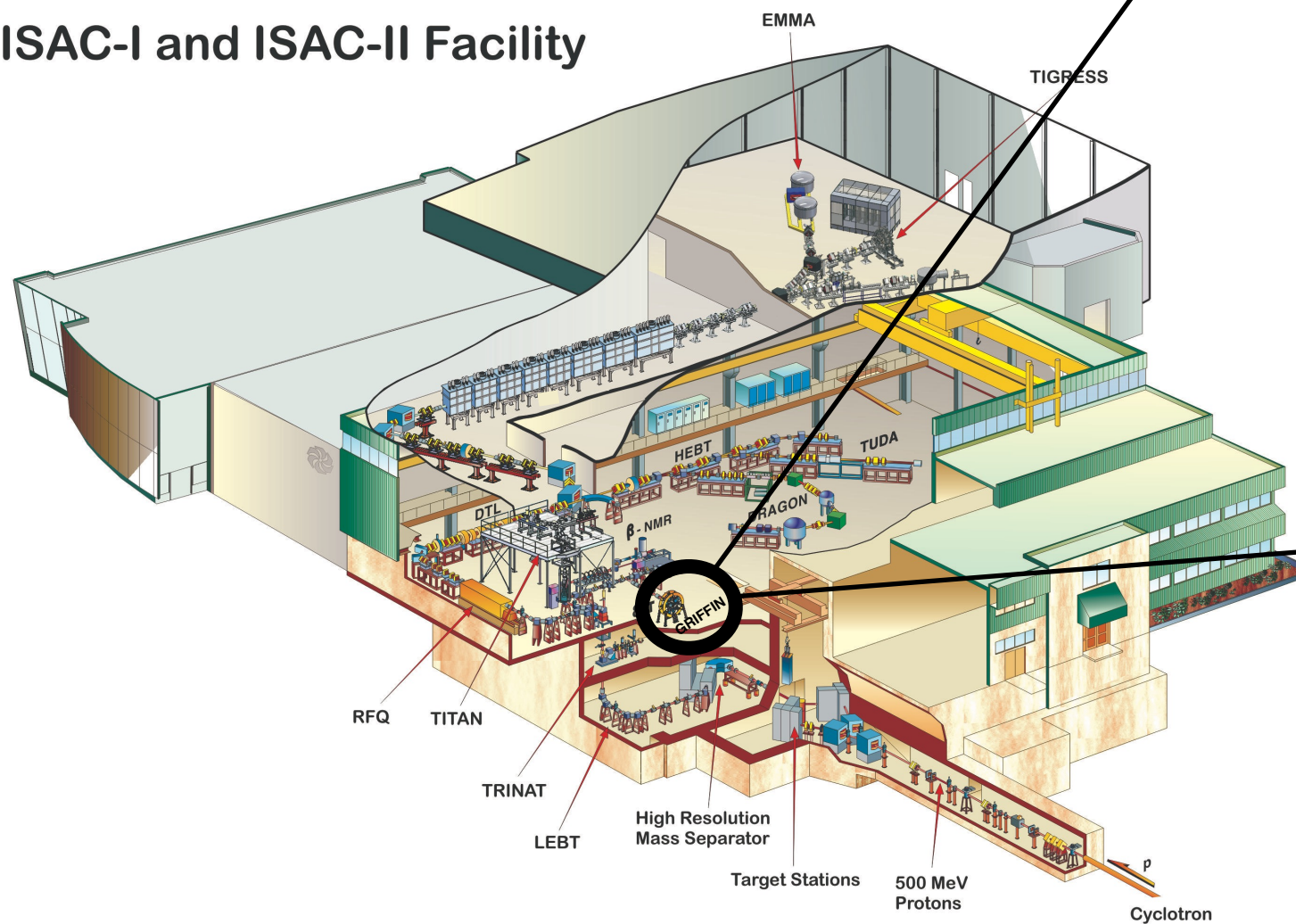
Yrast band



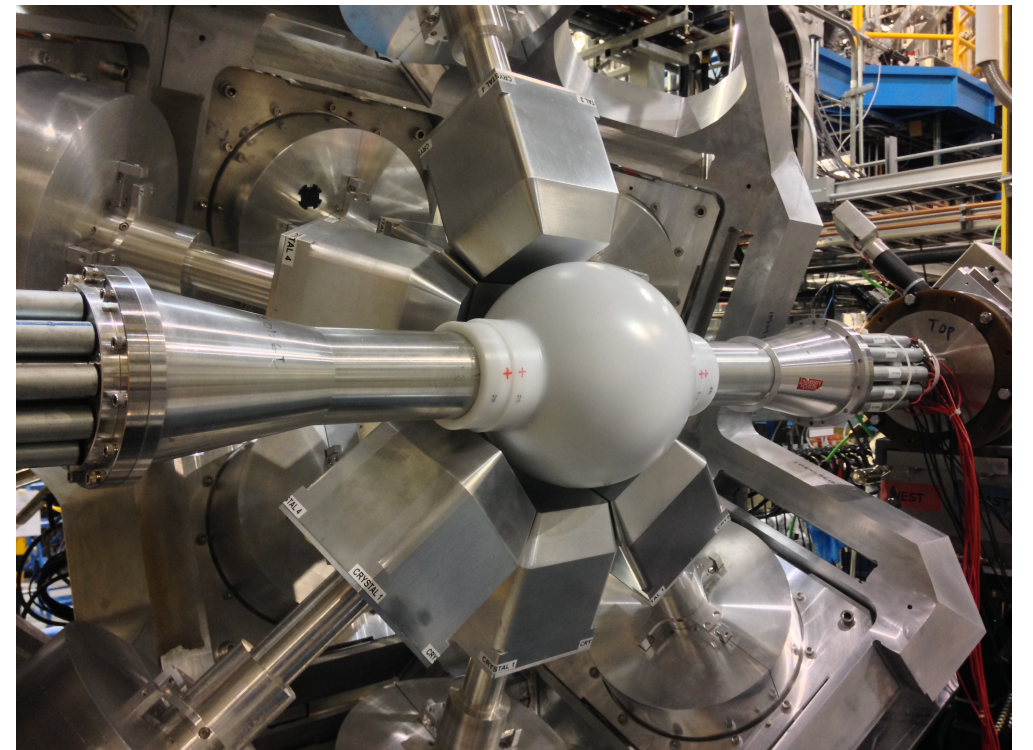
- This data set was part of a series of nuclei consisting of $^{188-198}\text{Hg}$.

GRIFFIN at TRIUMF-ISAC

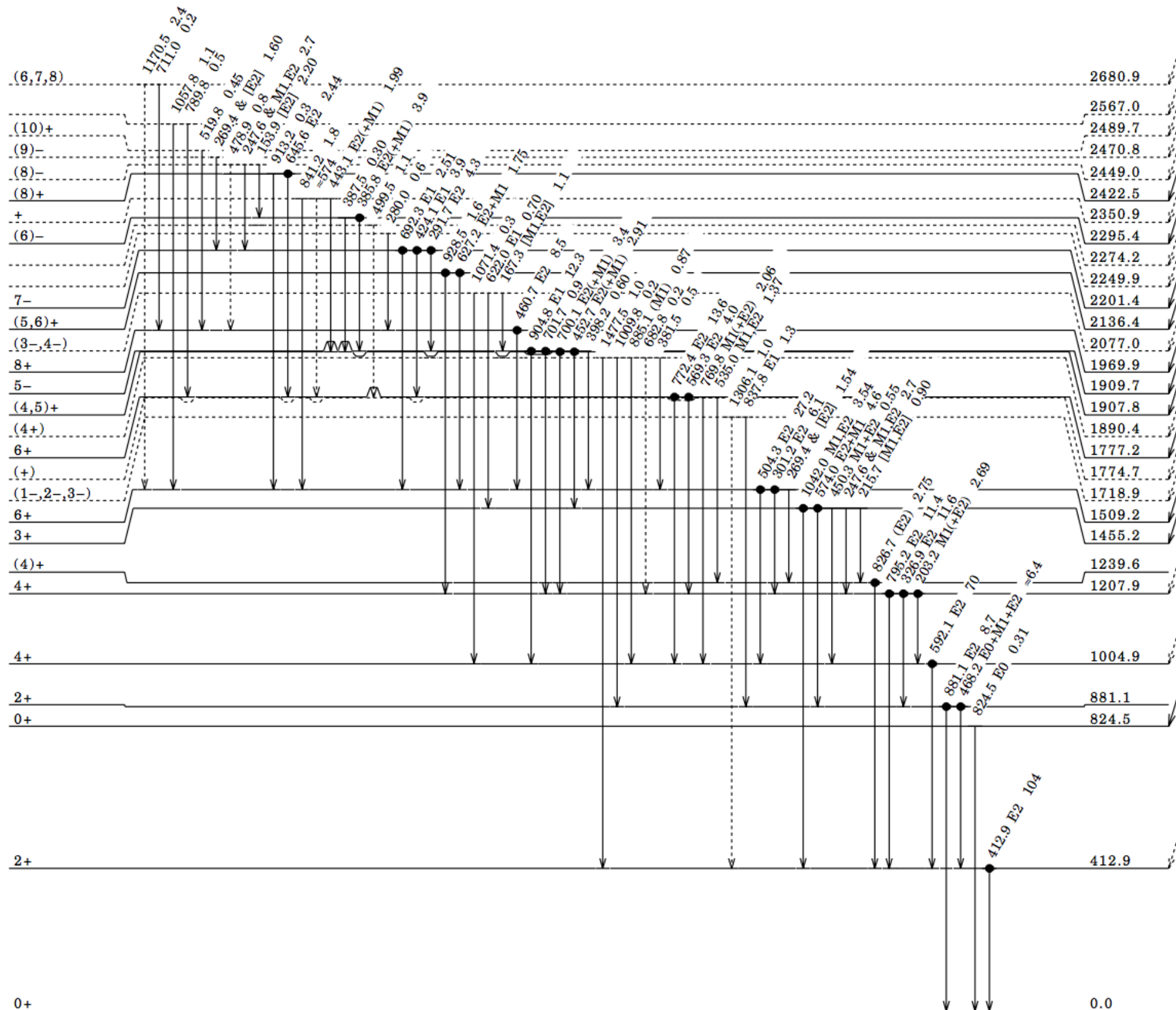
ISAC-I and ISAC-II Facility



GRIFFIN is a new high-efficiency gamma-ray spectrometer for decay spectroscopy with low-energy (30 keV) radioactive ion beams from TRIUMF-ISAC.



Previous work with ^{188}Tl decay



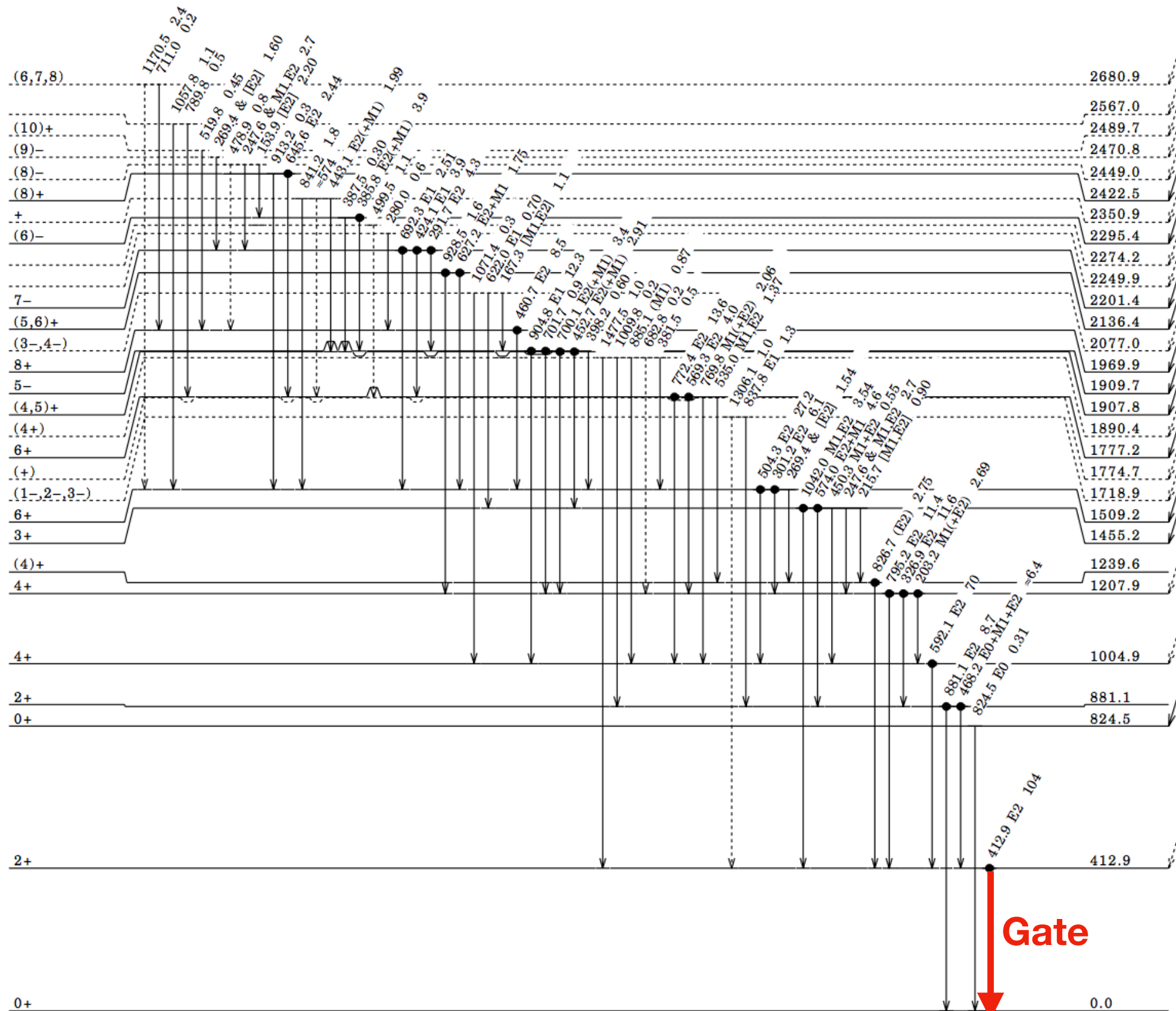
Levels

- 16 confirmed
- 12 tentative
- 11 with firm spin assignments

Gammas

- 53 confirmed
- 6 tentative
- 1 pure E0 transition

Previous work with ^{188}Tl decay



Levels

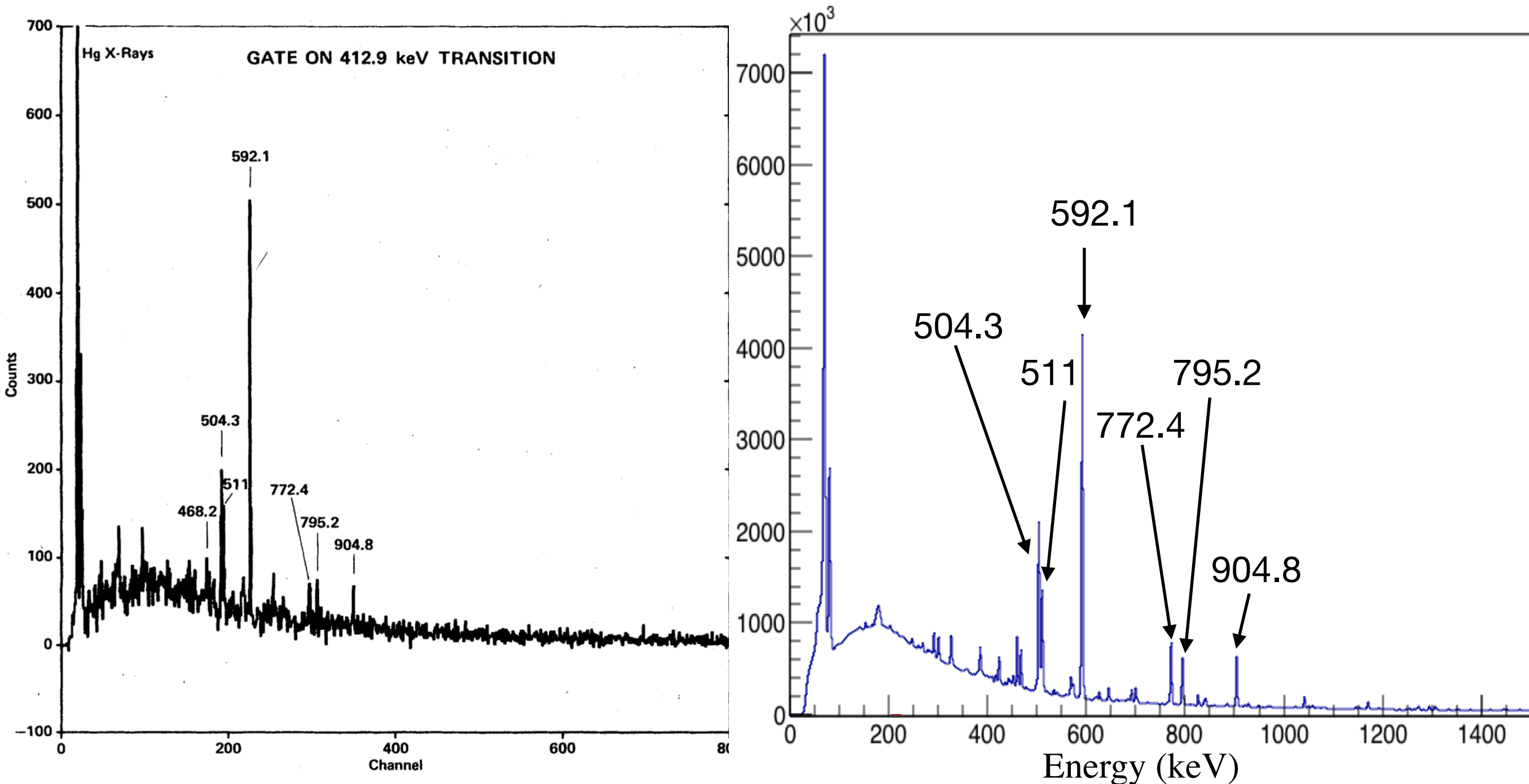
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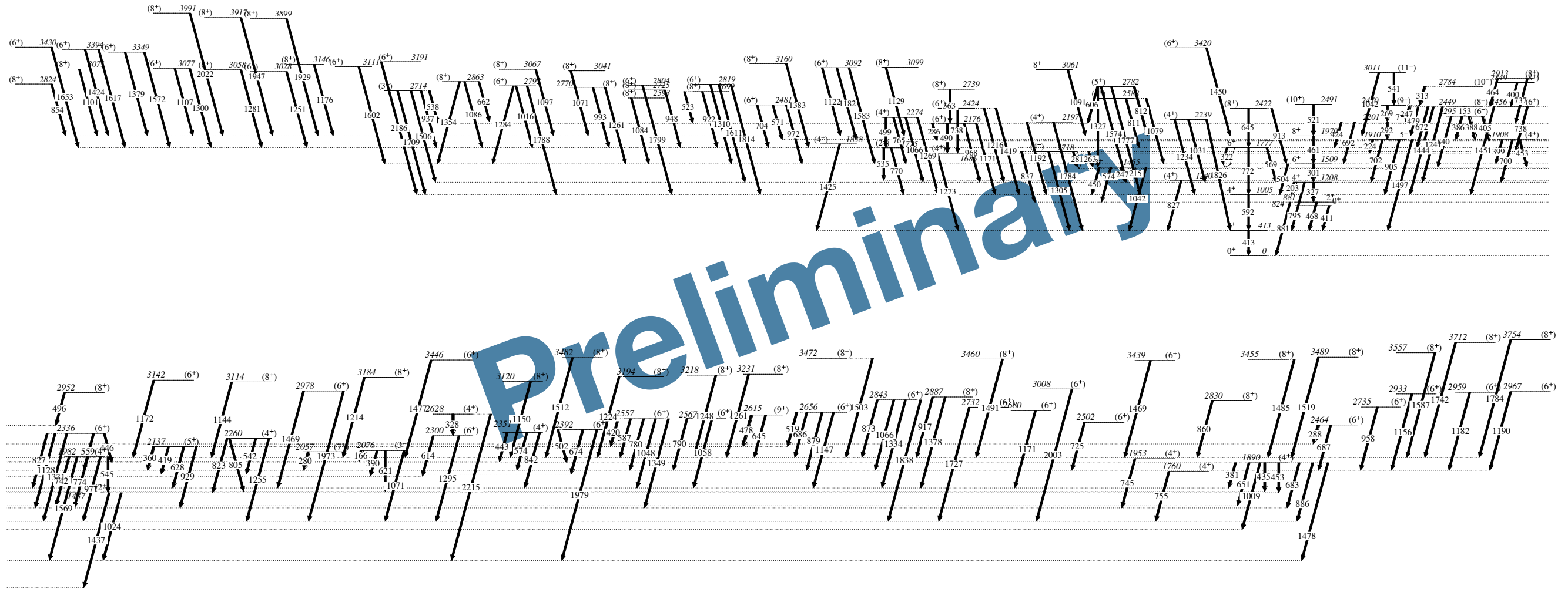
Comparison to Previous Data

Look at coincidences with a gate on the 412.9 keV gamma-ray.



Have ~26 million counts in 592 keV coincident with 413 keV in this data set.

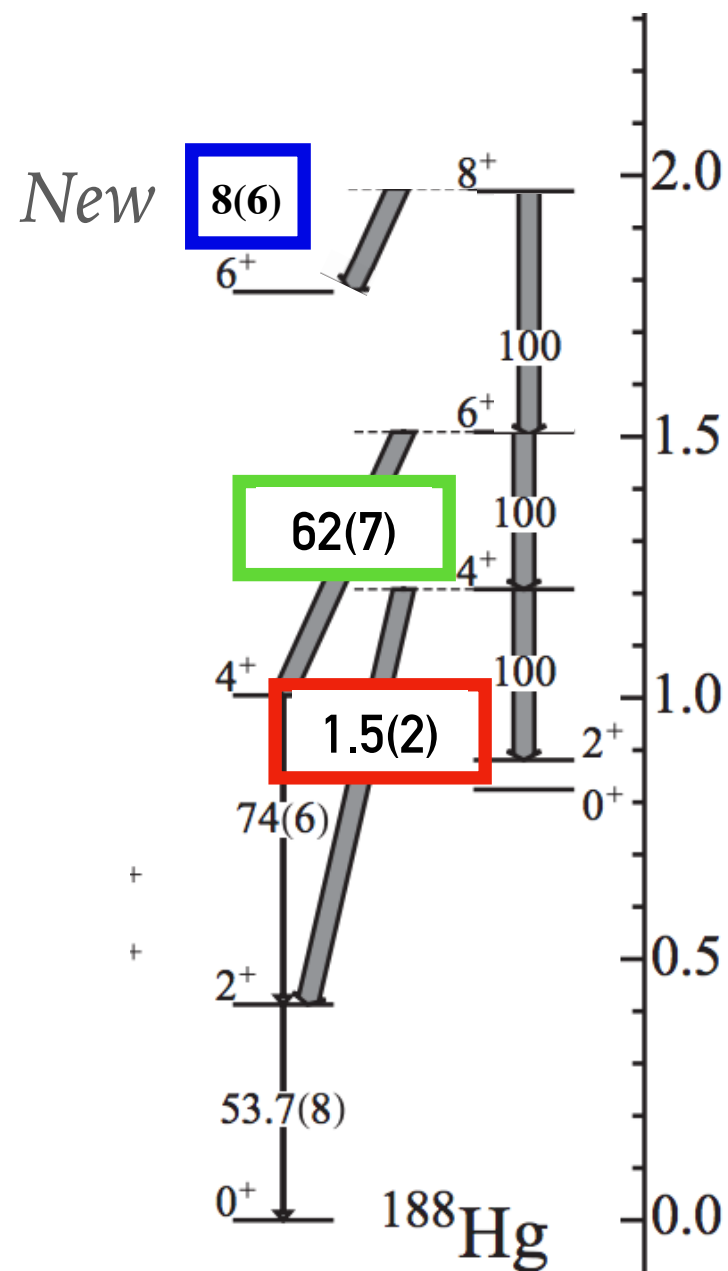
Current Level Scheme



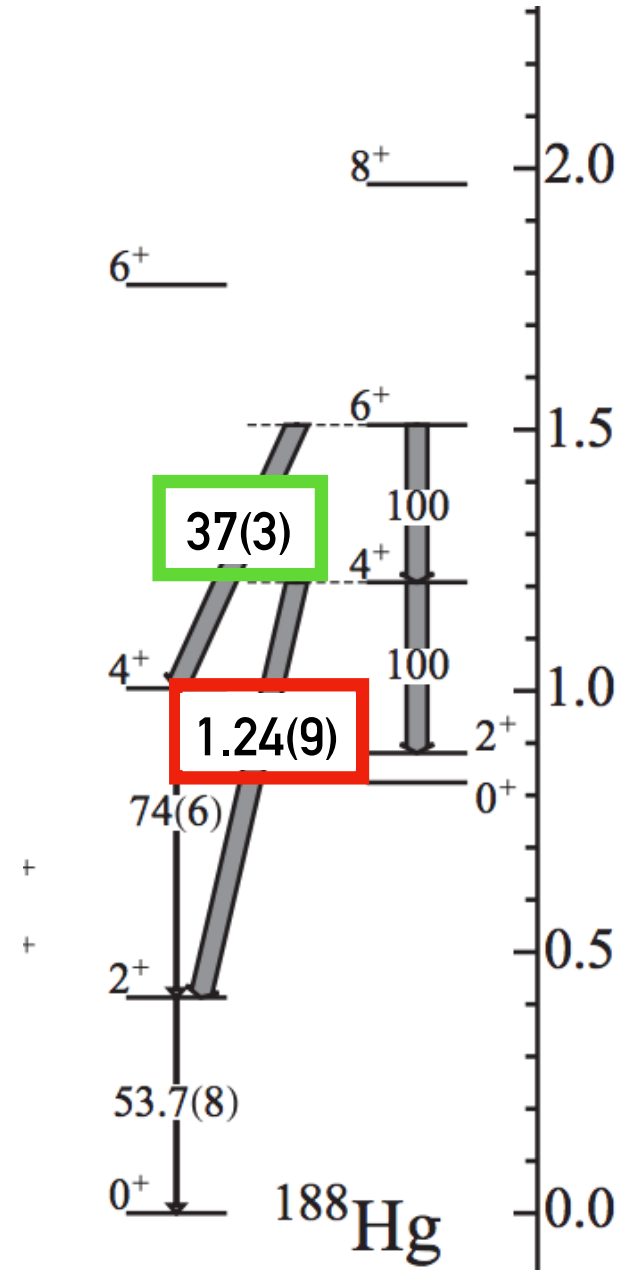
- Currently 236 transitions belonging to 115 levels.
- From that 183 transitions and 84 levels are new.
- Confirmed 5 previous tentatively assigned gamma-rays and 10 of the 12 tentatively assigned levels.
- Next is measuring branching ratios and assigning spins.

B(E2) Comparisons (Preliminary)

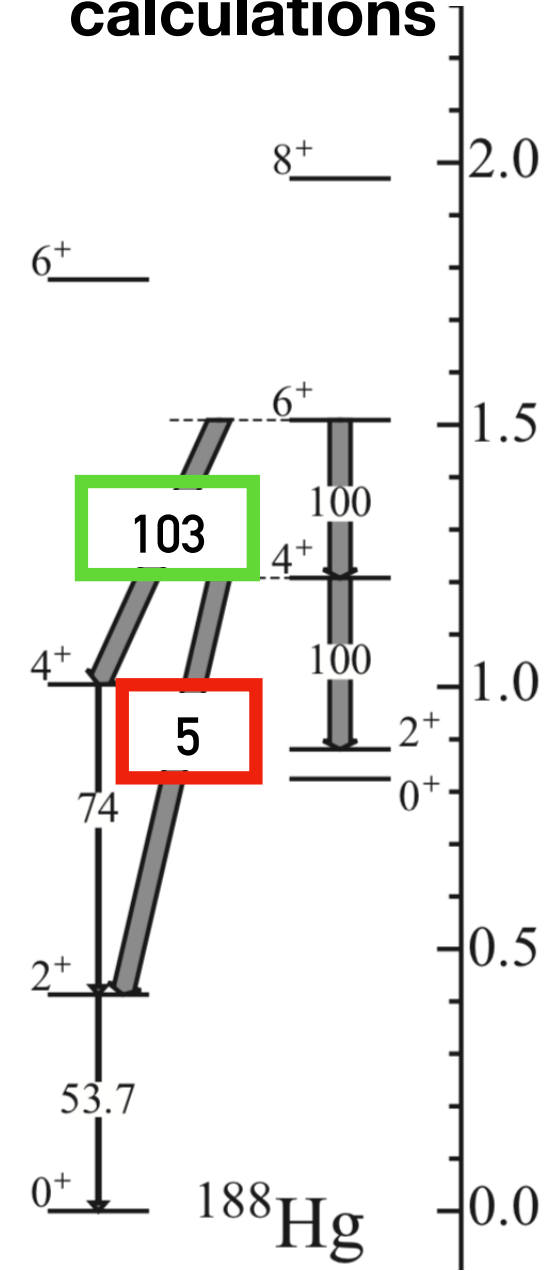
This Experiment



Previously Experiment



Theoretical IBM-CM calculations



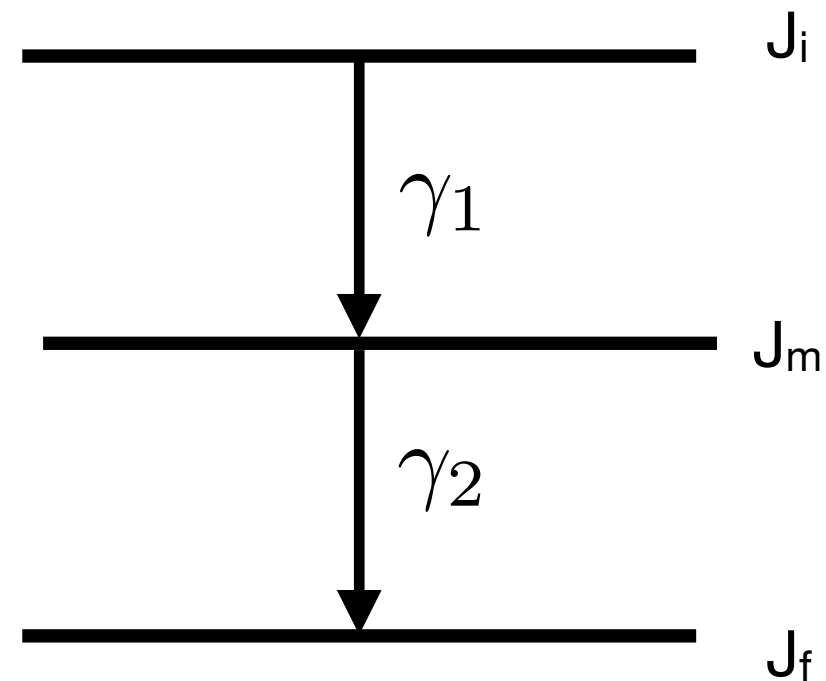
Pure E2 transitions Relative B(E2) values :
$$B(E2)_{rel} = 100 \times \frac{I_{\gamma}}{I_{\gamma}^{ref}} \times \frac{E_{\gamma}^{ref}}{E_{\gamma}}$$

Angular Correlations

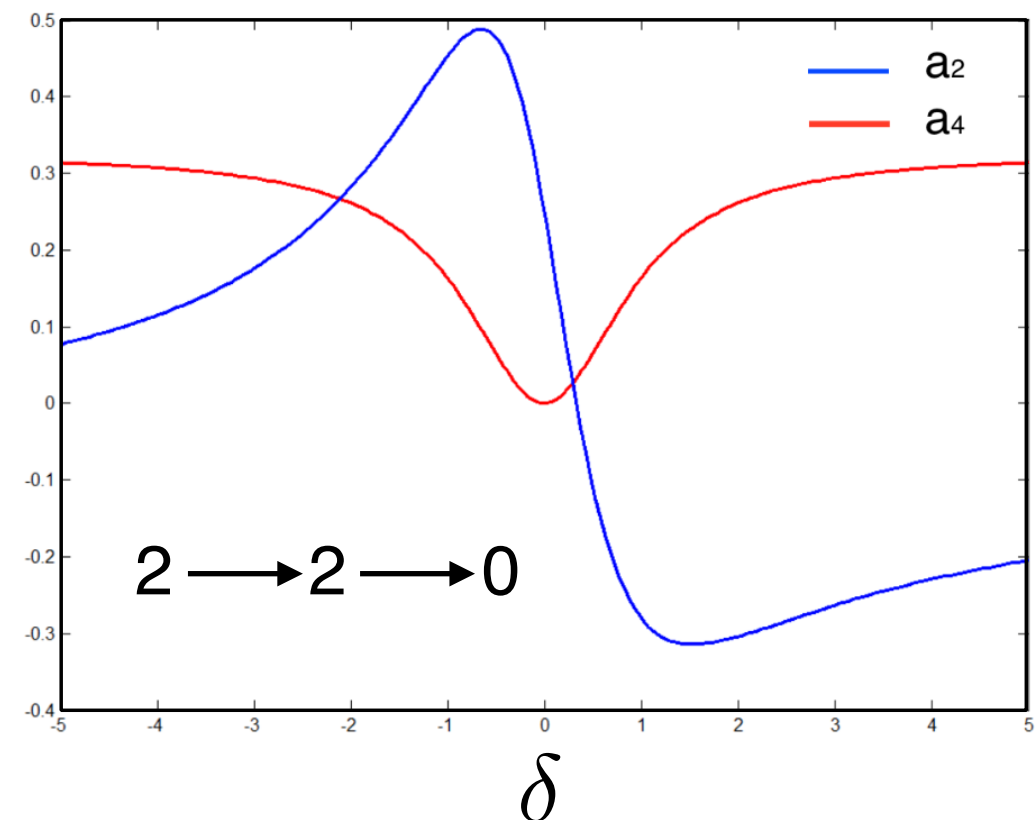
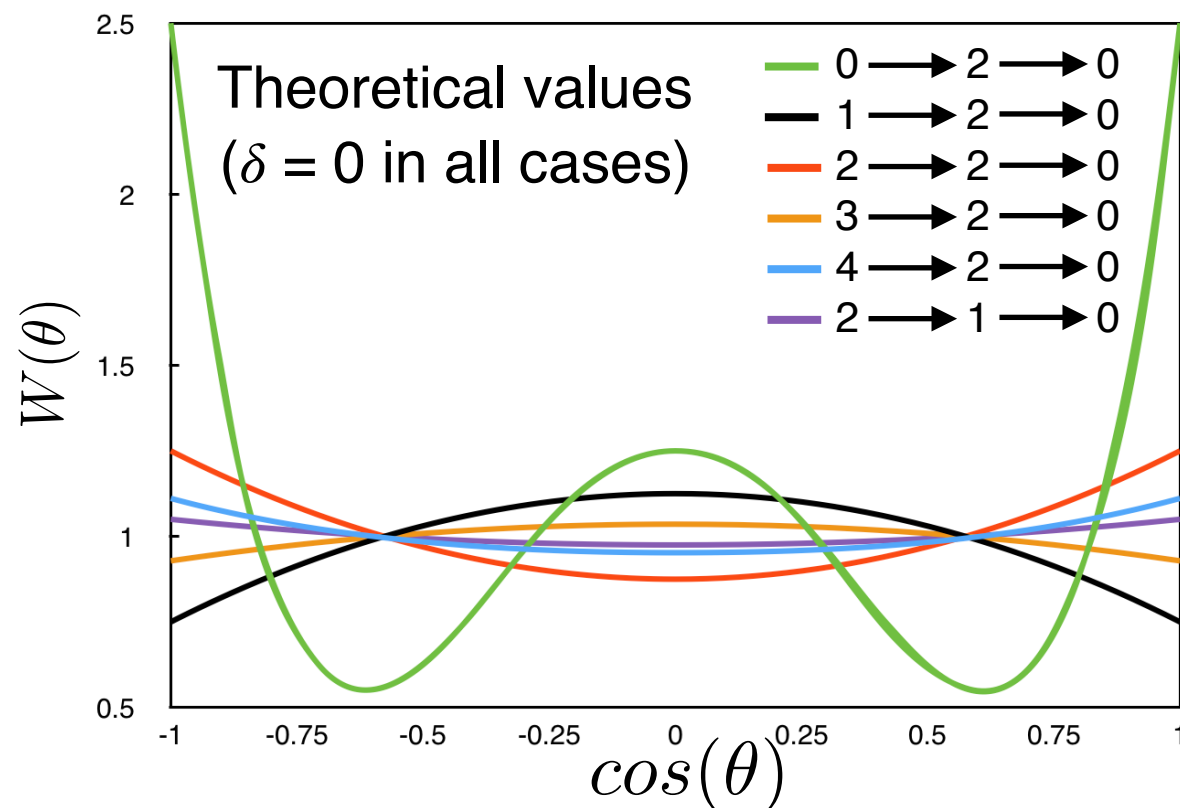
γ - γ angular correlation measurements are sensitive to the spins of the nuclear states involved and can be used to assign nuclear spins in decay spectroscopy measurements.

$$W(\theta) = 1 + \sum_{k=\text{even}}^{2L} a_k P_k(\cos\theta)$$

Here, a_k are coefficients dependent on the nuclear spins, mixing ratios and γ -ray multipolarities and $P_k(\cos\theta)$ are the Legendre polynomials.



In some cases transitions can be mixed M1/E2 in character producing a mixing ratio, δ .

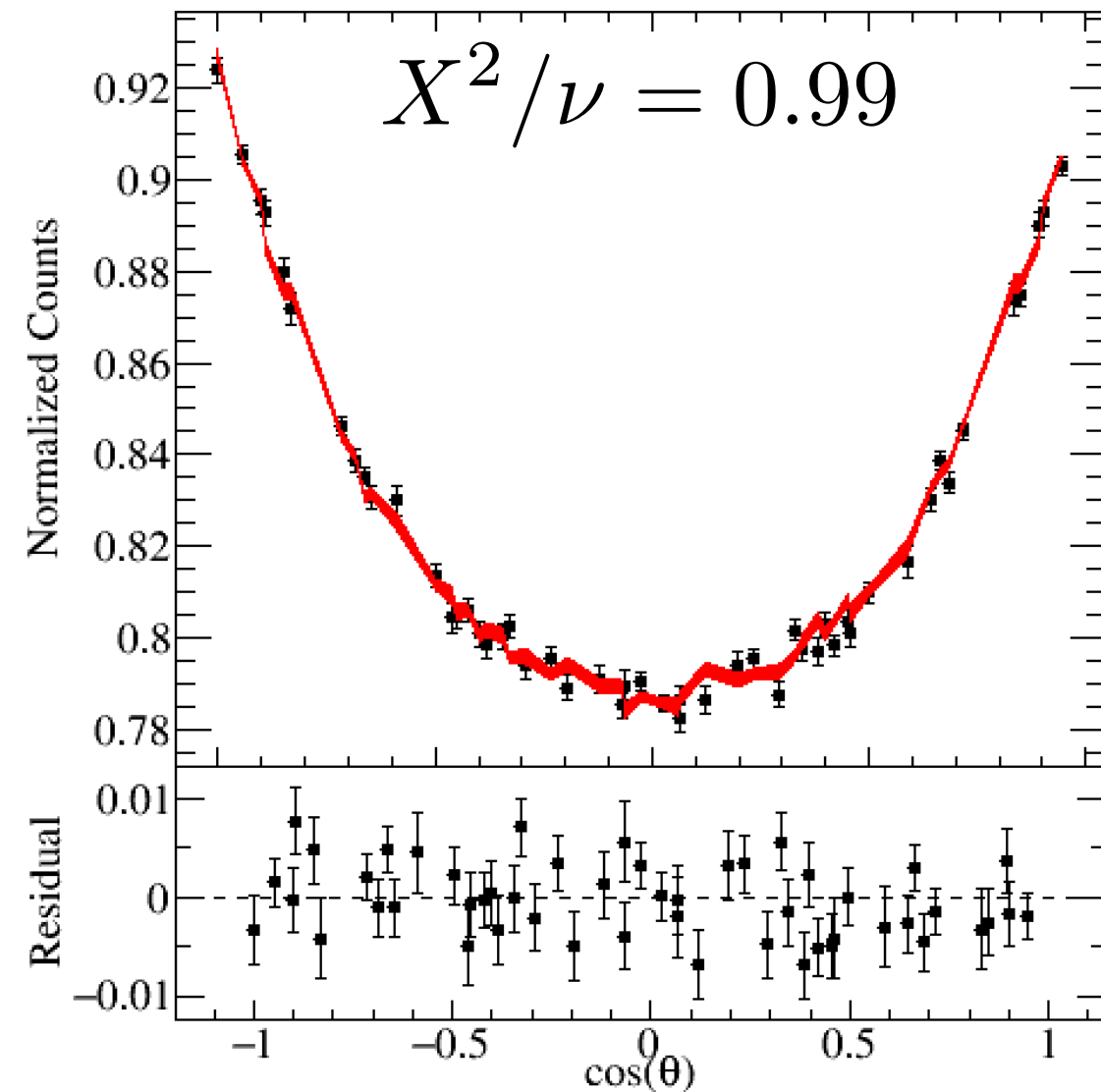
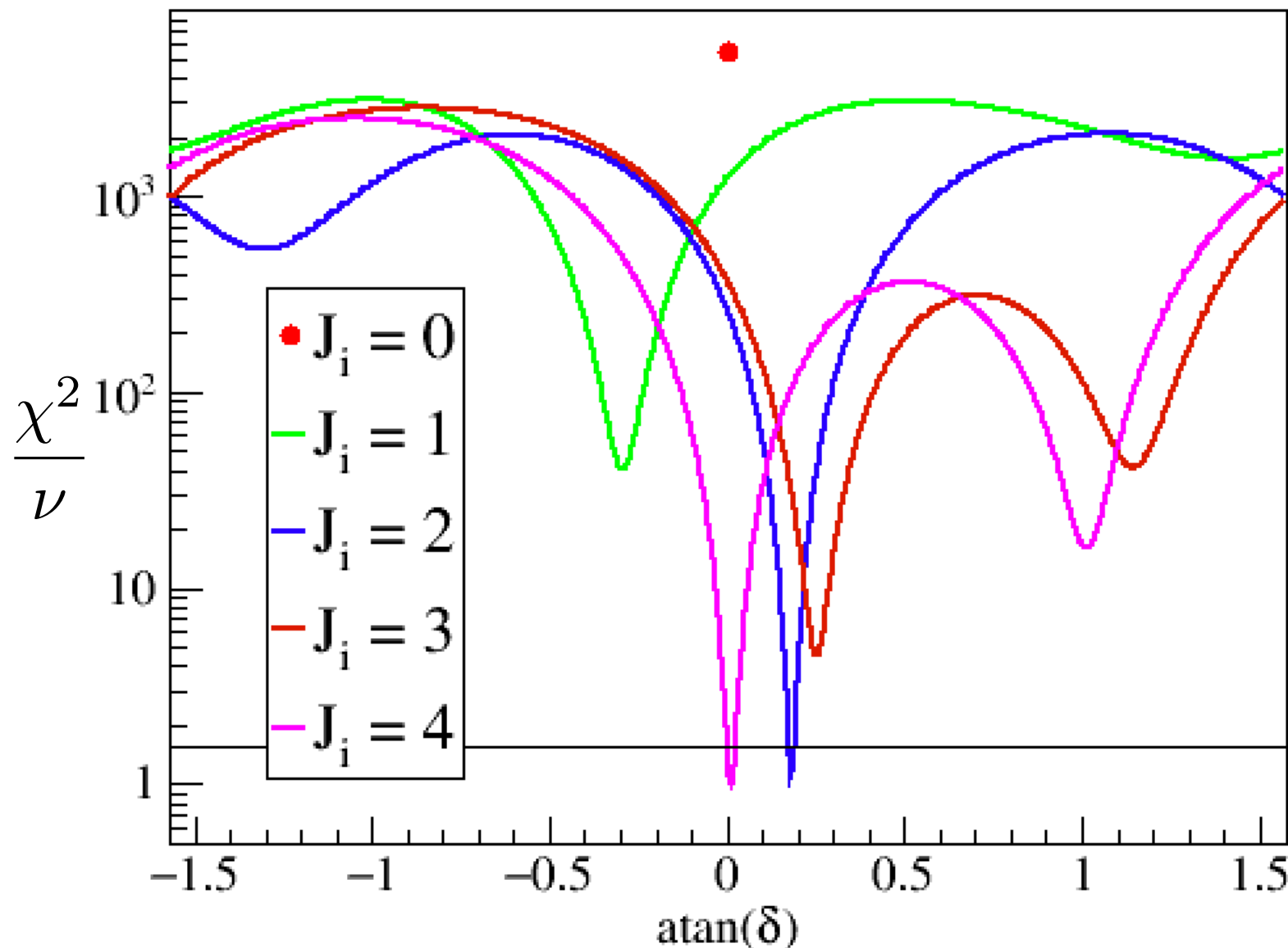


Angular Correlations (Preliminary)

$$4_1^+ \rightarrow 2_1^+ \rightarrow 0_1^+$$

- Cascading gamma-rays are correlated spatially and by comparing to simulation we can assign spins and determine mixing ratios.

$$\delta = 0.002(3)$$

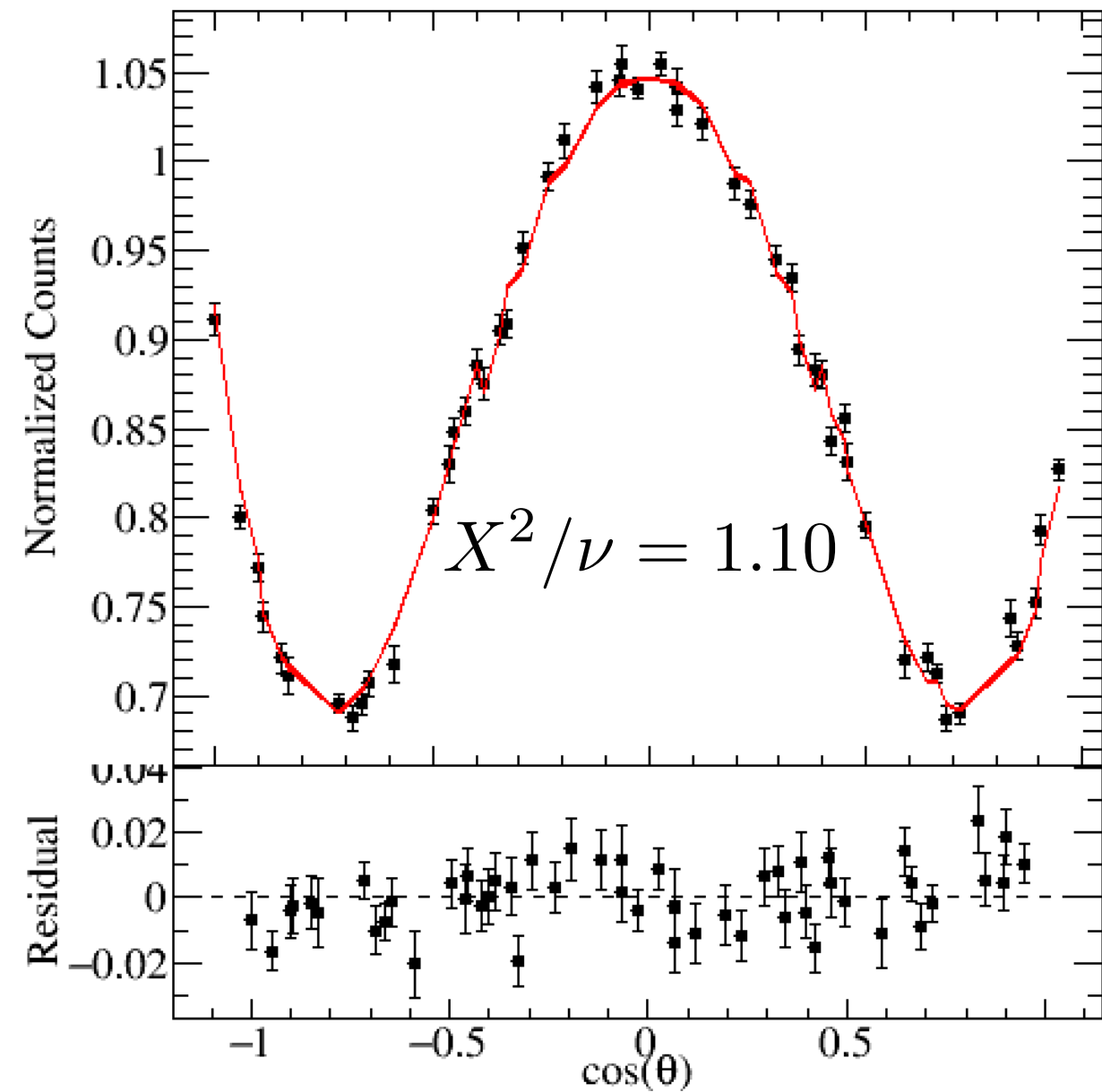
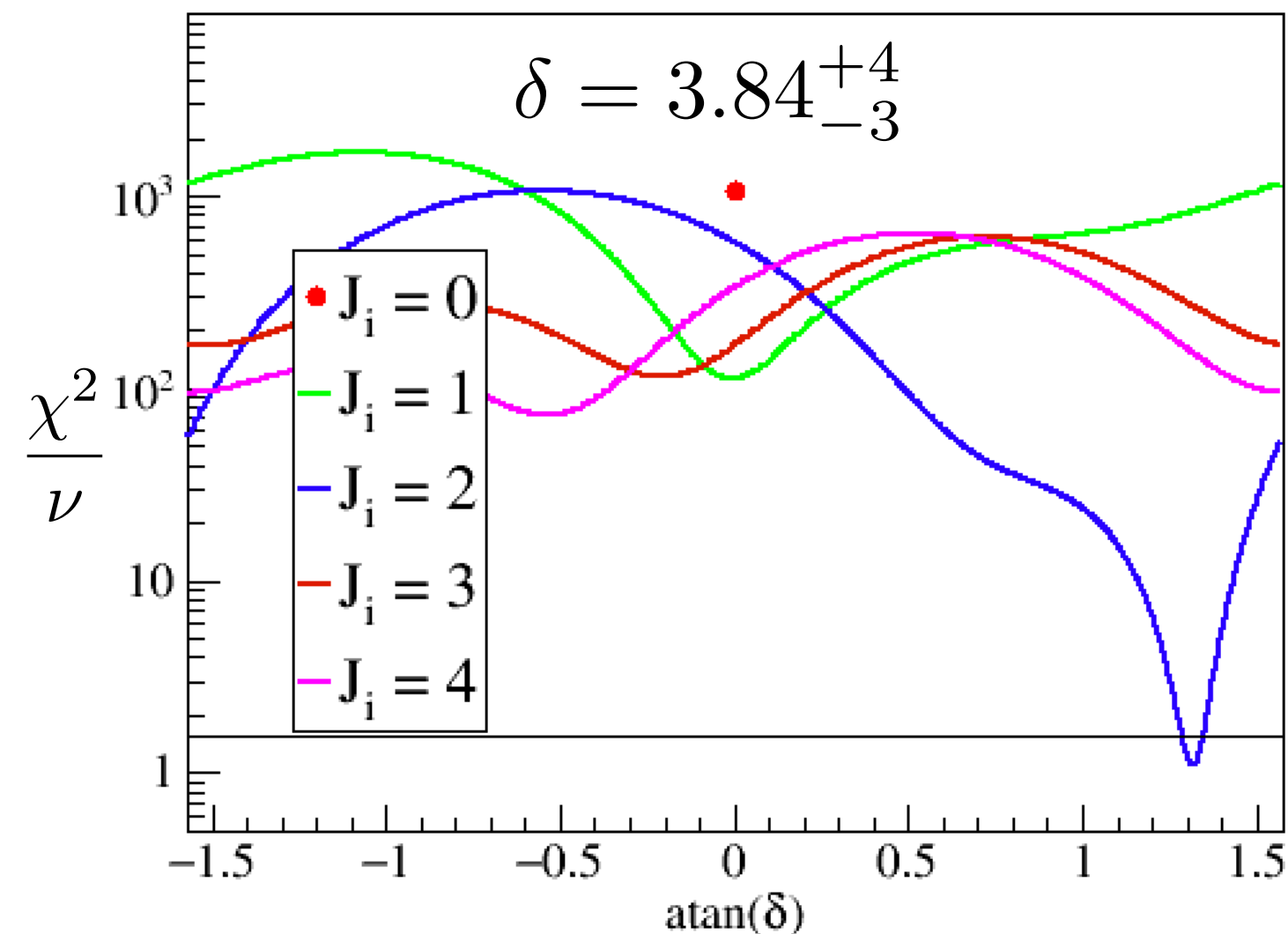


Although sometimes nature is unkind this is a good test that we see the expected result.

Angular Correlations (Preliminary)

$$2_2^+ \rightarrow 2_1^+ \rightarrow 0_1^+$$

- Solid confirmation of level spins and parities are determined.
- 468 - 413 keV cascade from the intruder band to the ground state band.

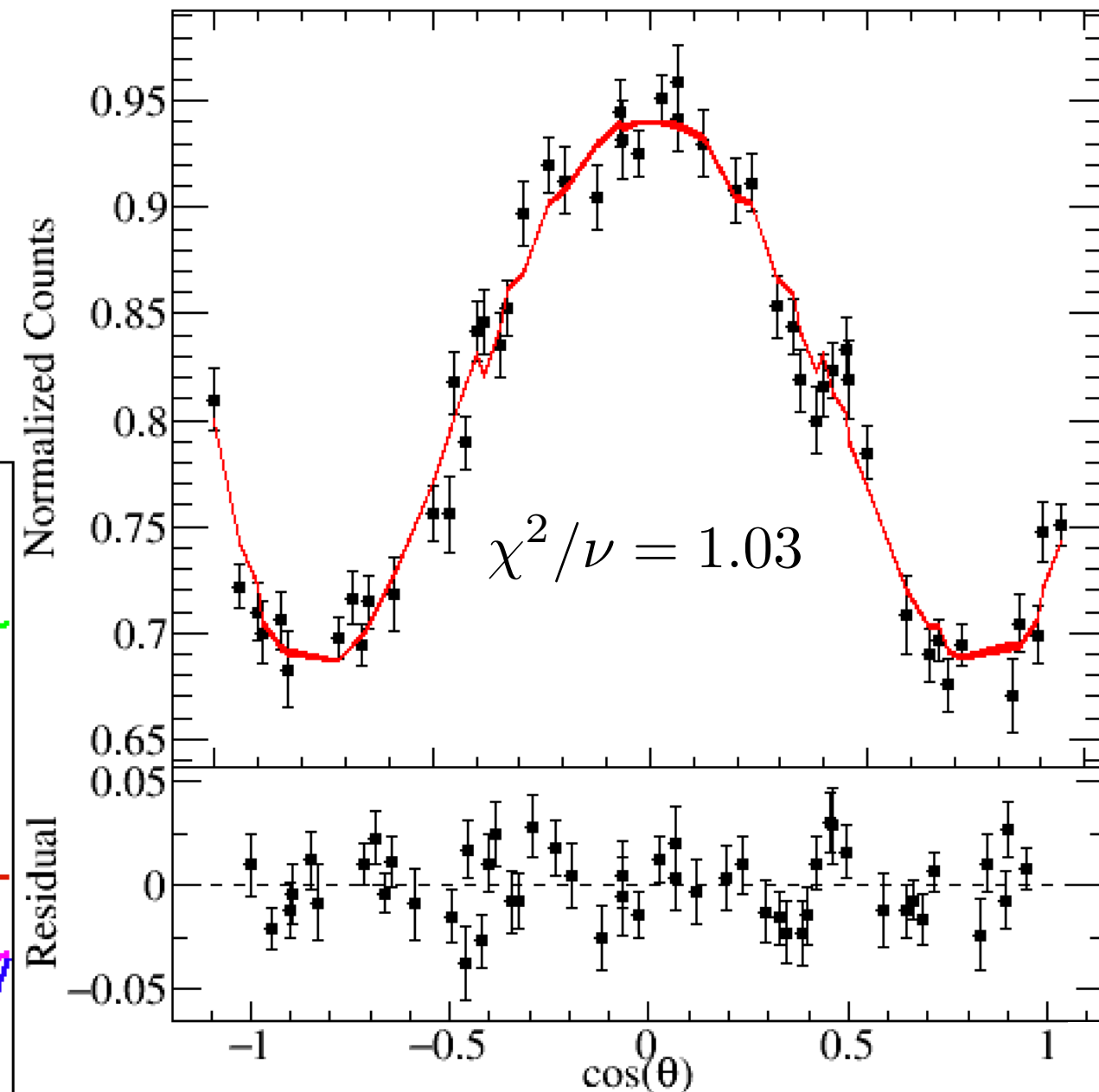
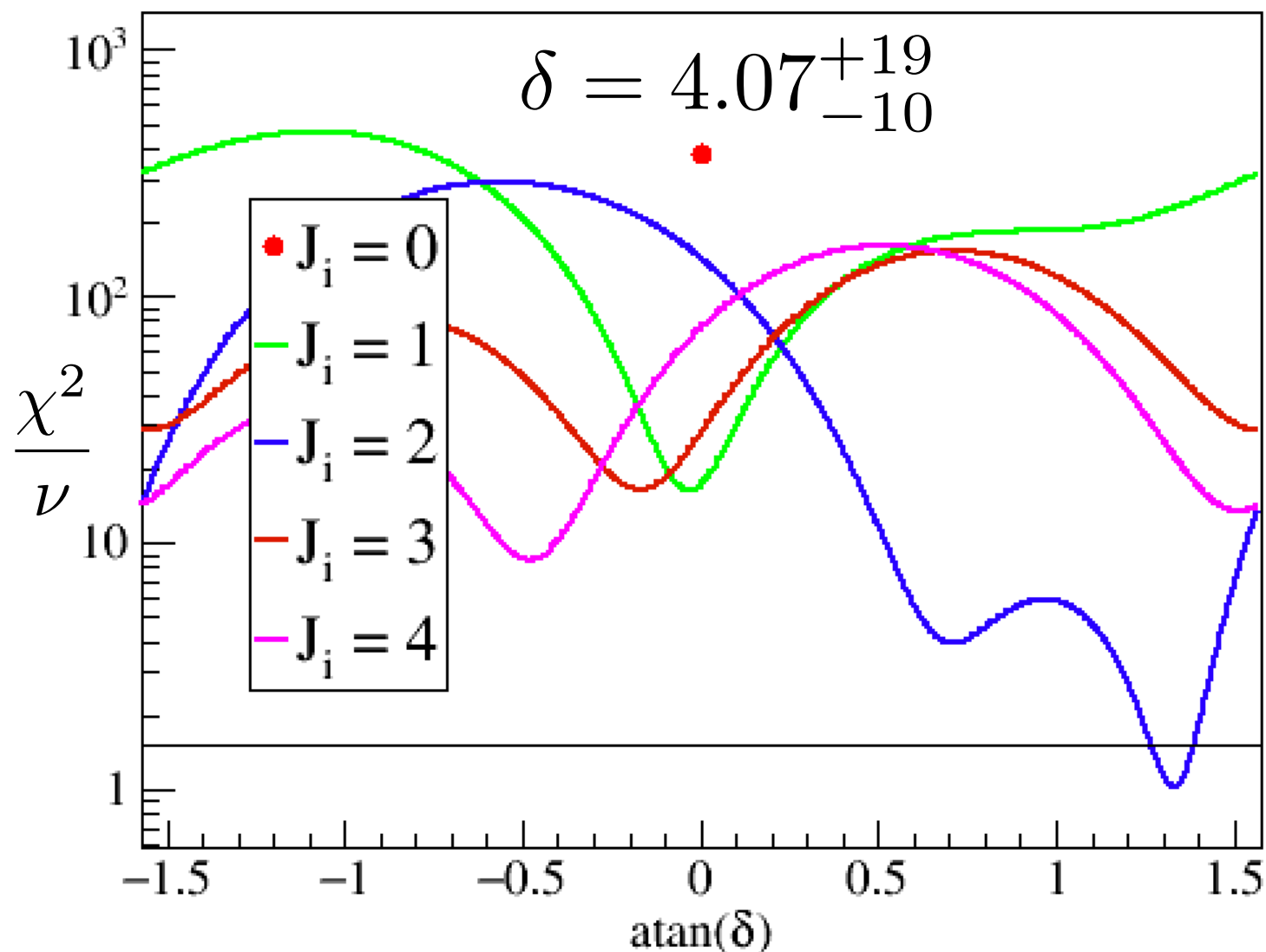


Can determine B(E2) values once mixing ratios are established.

Angular Correlations (Preliminary)

$$(4_3^+) \rightarrow 2_1^+ \rightarrow 0_1^+$$

- Correct states with spins that are assigned.
- The labelling of these states can have major impacts on the comprehension of nuclear structure.
- Further our understanding when comparing to theoretical models.



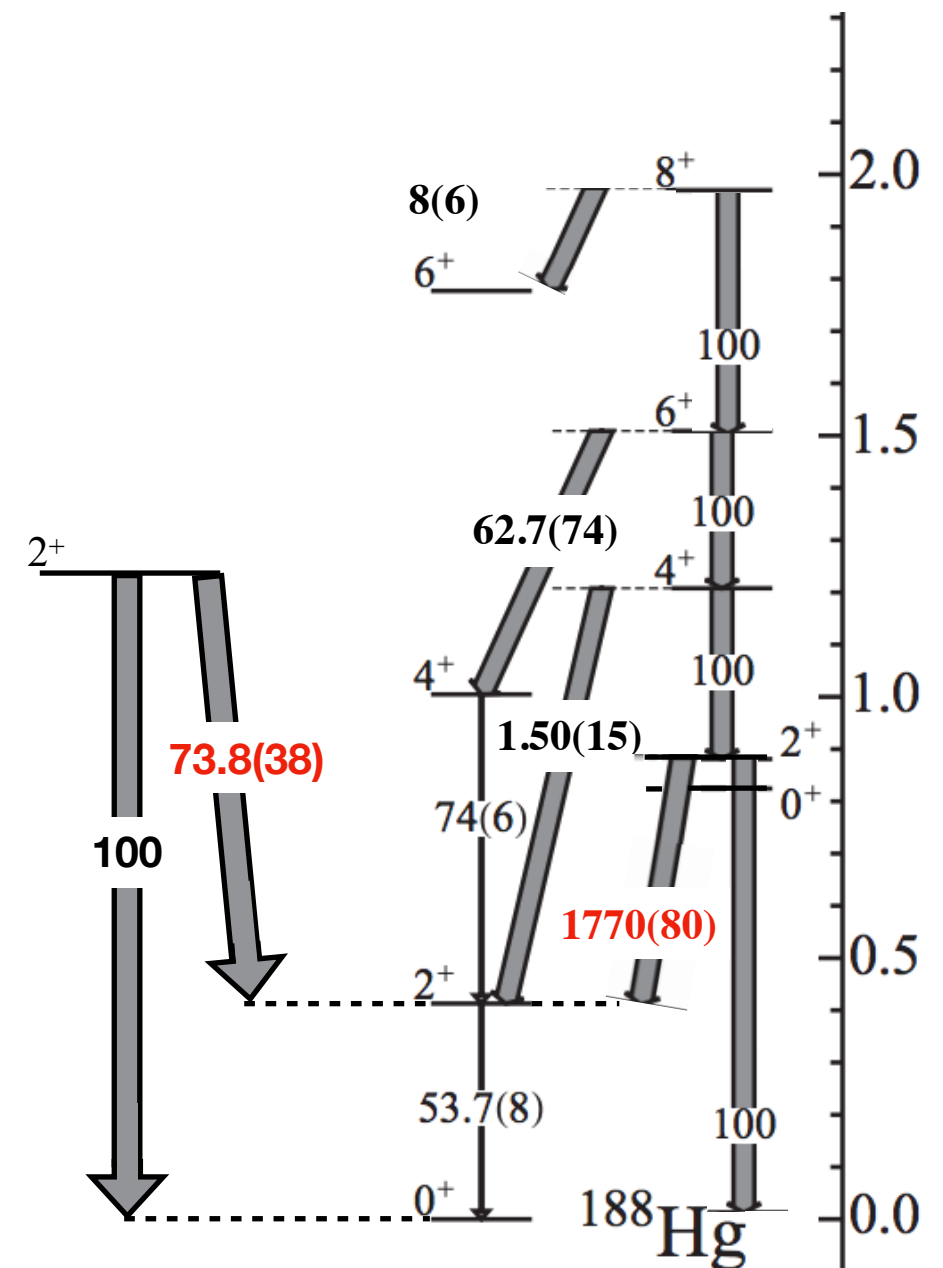
Mixed B(E2)'s

- For mixed transitions need the mixing ratios, δ , to extract the relative B(E2) values.

$$B(E2)_{rel} = 100 \times \frac{I_{\gamma}}{I_{\gamma}^{ref}} \times \frac{E_{\gamma}^{ref}}{E_{\gamma}} \times \frac{\delta^2}{1 + \delta^2}$$

- First time mixing ratios have been measured allowing the determination of the relative B(E2) values for mixed transitions.
- This information will constrain the constraints of nuclear structure in this region.
- Many more exciting results to come from this data set!

This Experiment



Thanks!

**UNIVERSITY
of GUELPH**

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