Probing the evolution of transitional structure in ^{158}Er via β-decay of Tm isotope

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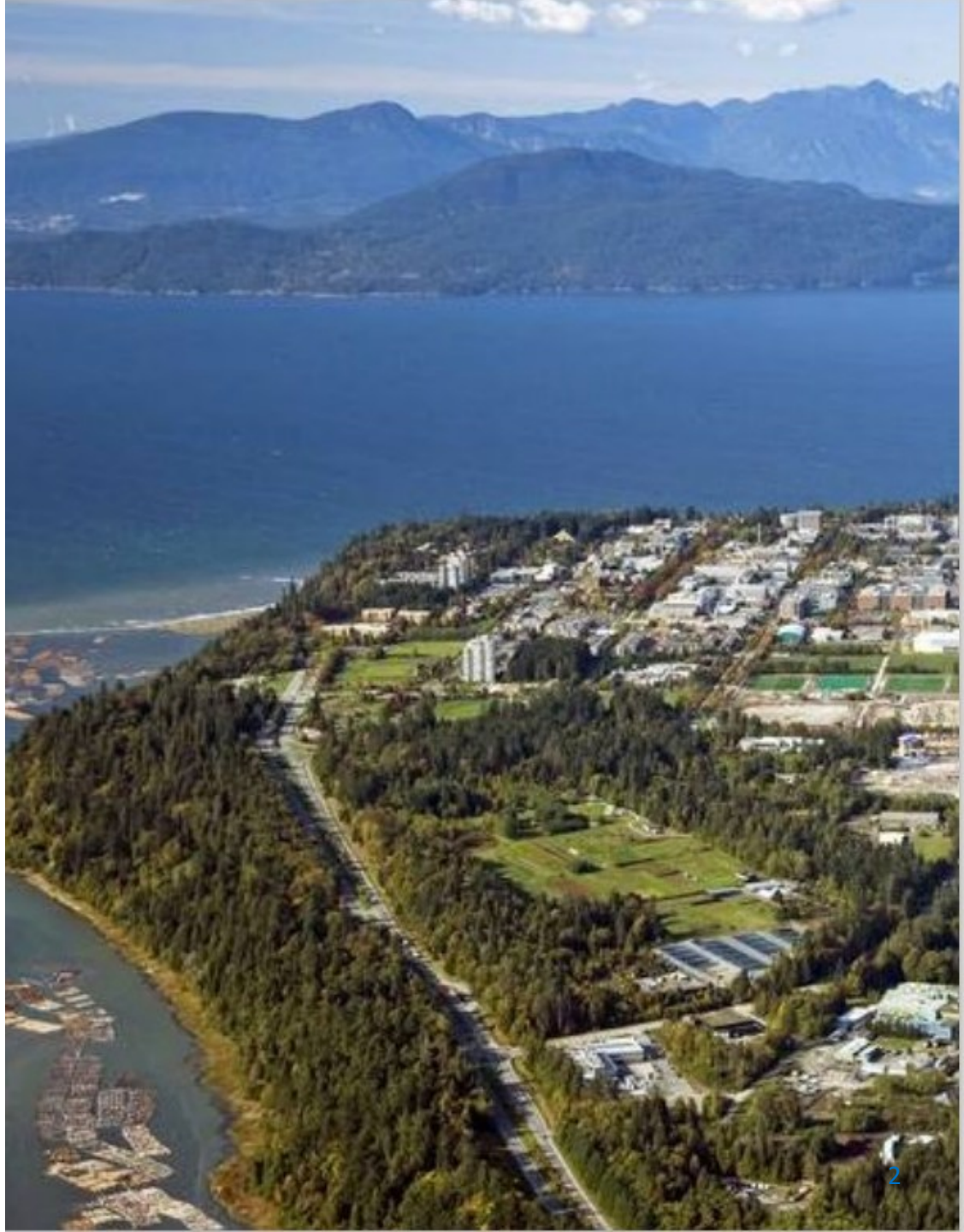
GRIFFIN

INPC - 2025 Daejeon, South Korea

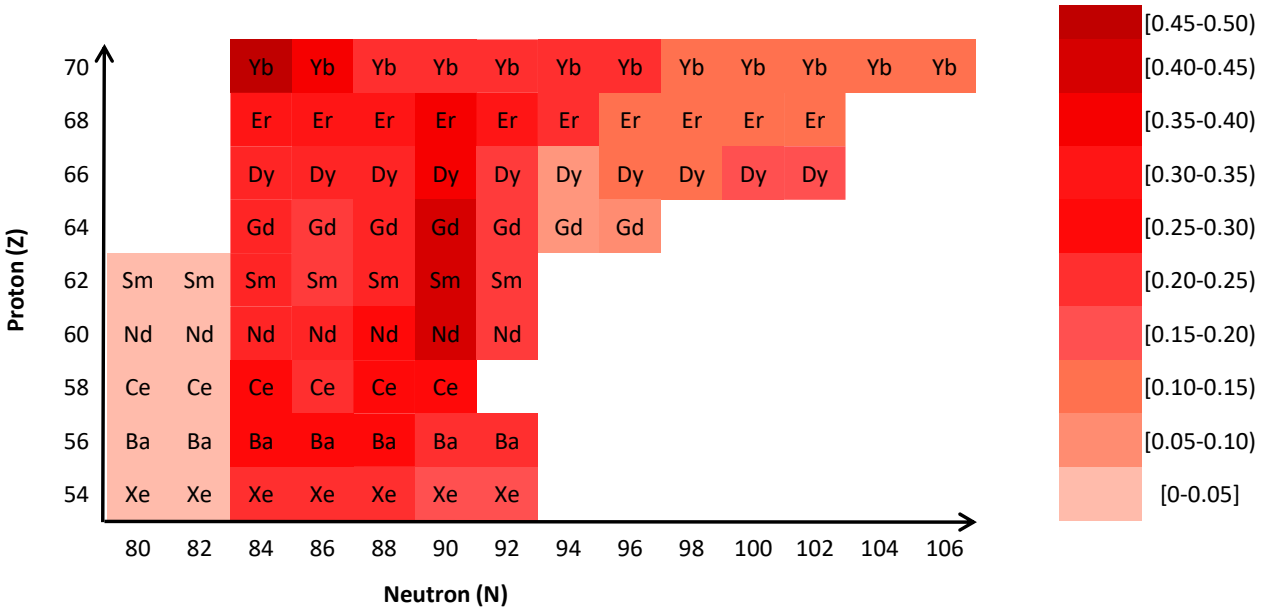
Land Acknowledgement

TRIUMF is located on the traditional, ancestral, and unceded territory of the xʷməθkʷəy̓əm (Musqueam) people, who for millennia have passed on their culture, history, and traditions from one generation to the next on this site.

TRIUMF's home has always been a seat of cutting-edge research



Rare Earth Transitional Region Z~ 64, $N \sim 90$



- Nuclei around the $Z \sim 64, N \sim 90$ exhibit Large valence space, Enhanced collectivity, Rapid onset of deformation, configuration mixing of different shapes

[1] Victoria Vedia, GRSI collaboration meeting (2022)

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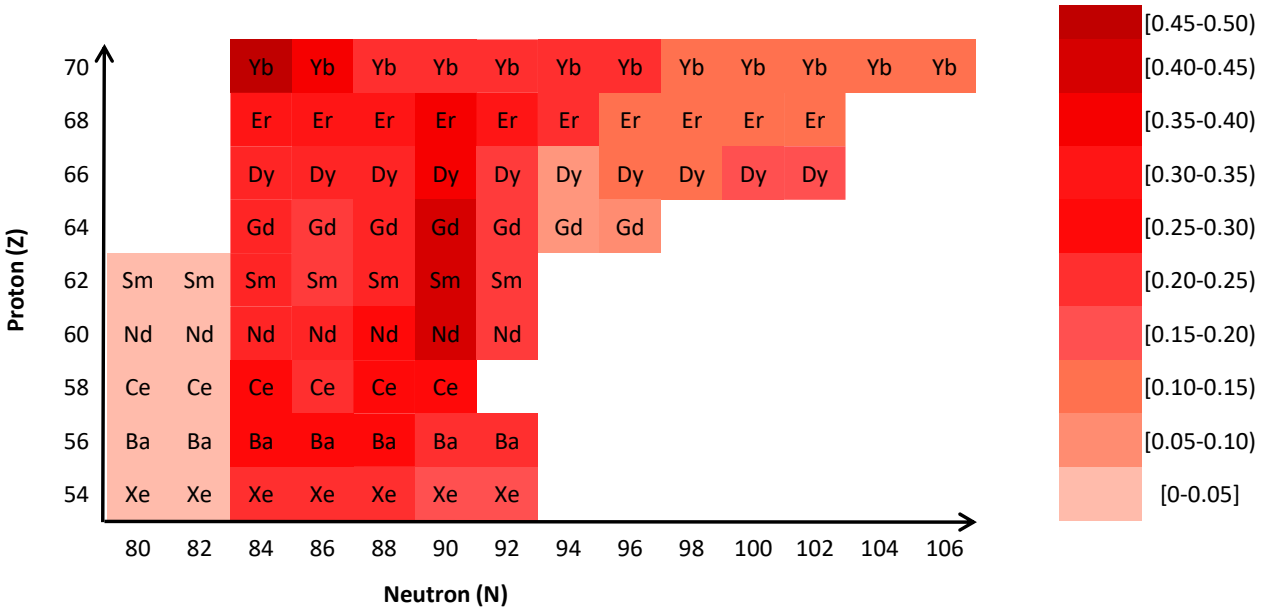
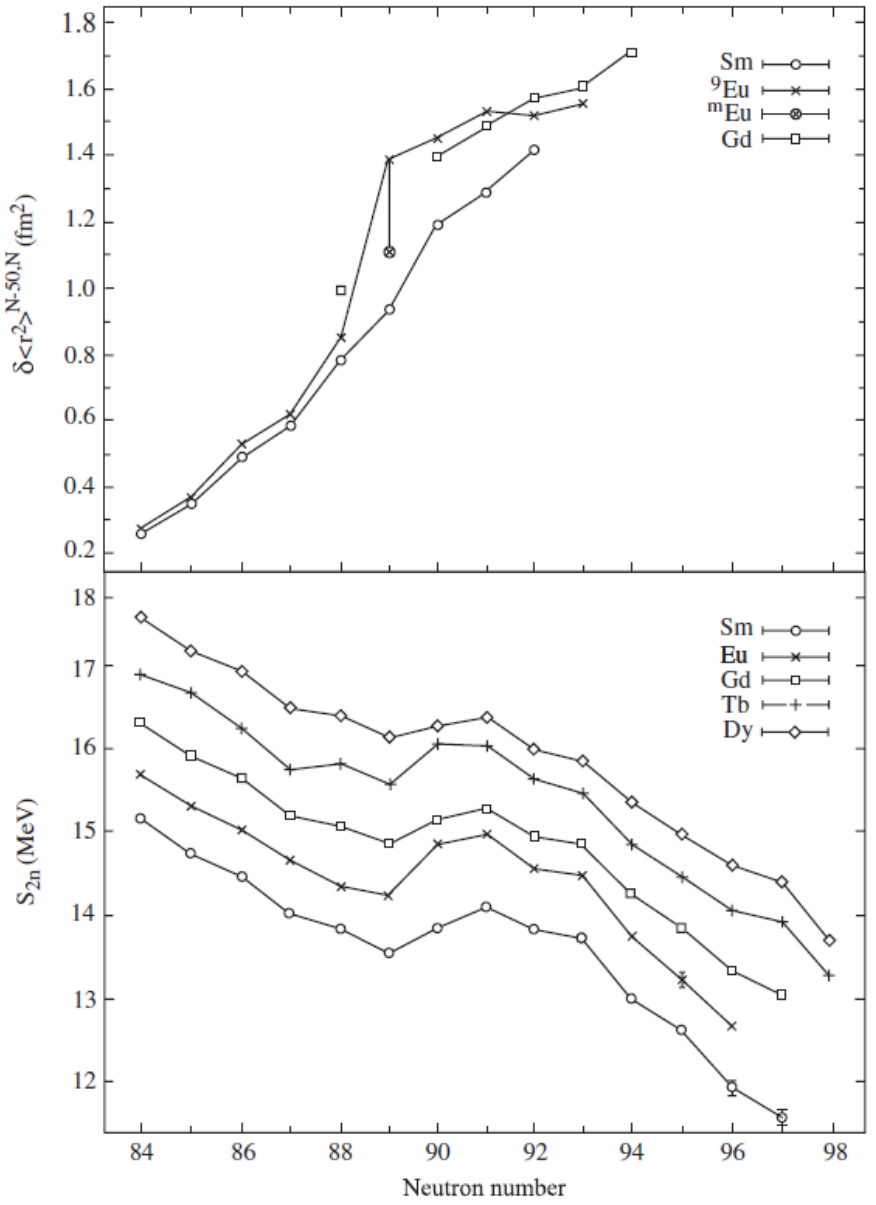


- Nuclei around the $Z \sim 64, N \sim 90$ exhibit Large valence space, Enhanced collectivity, Rapid onset of deformation, configuration mixing of different shapes

- The discontinuities in the isotope shifts and two-neutron separation energies are strongly localized at $N = 90$, just as they are at $N = 60$.

- Sudden changes in isotopic shift values are a key indicator of mass regions where large $E0$ transition strengths can be expected to occur.

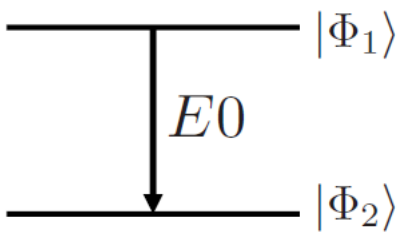


[2] K. Heyde and J. I. Wood, Rev. of Mod. Phys. 83,(2011)
[3] P. Garrett, M. Zelinka, E. Clement, PPNP 124 (2021)

$E0$ transition strengths around $N \sim 90$

- For two intrinsic structures with some degree of mixing

$$\Phi_1 = \alpha\Psi_1 + \beta\Psi_2$$
$$\Phi_2 = -\beta\Psi_1 + \alpha\Psi_2$$
$$\rho^2(E0) \simeq \alpha^2\beta^2(\Delta\langle r^2\rangle)^2$$



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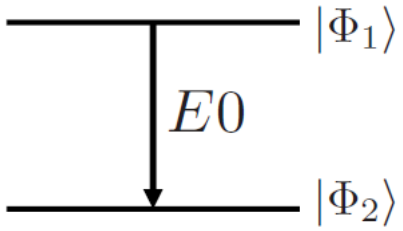
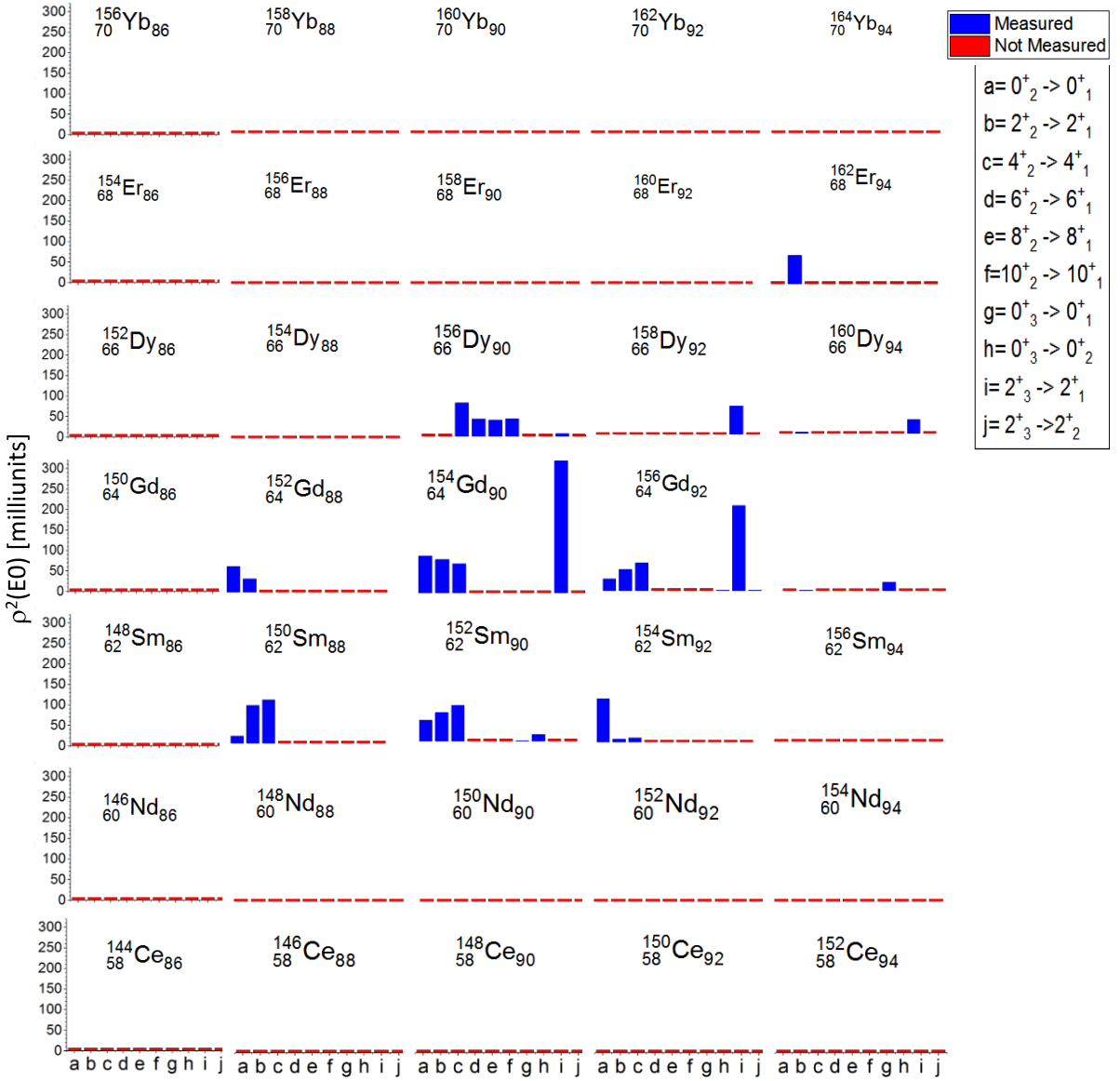


- E0 transition strengths, are key probe of shape-mixing effects.

- However, experimental data on E0, transitions are lacking



[1] Victoria Vedia, GRSI collaboration meeting (2022)
[4] T. Kibedi, A. Garnsworthy & J.L Wood, PPNP 123 (2022)

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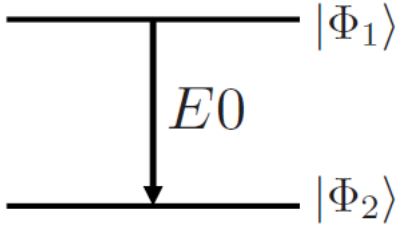
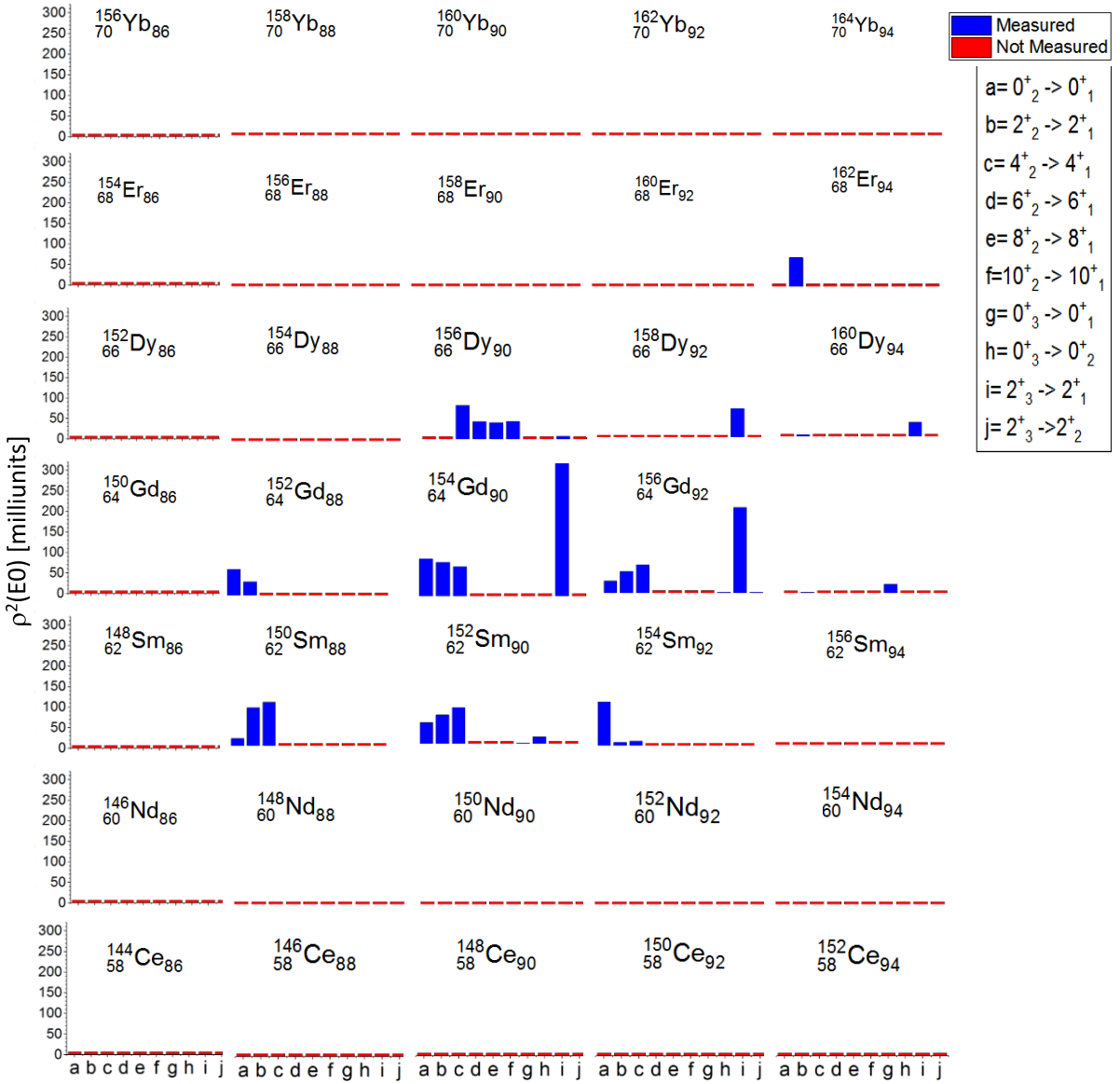


- E0 transition strengths, are key probe of shape-mixing effects.

- However, experimental data on E0, transitions are lacking across this region

- Specifically, it is the absence of internal-conversion data and the lack of lifetimes that precludes the assignment of monopole strengths.

$$\rho^2(E0) = \frac{I_K(E0)}{I_K(E2)}\frac{\alpha_K(E2)}{\Omega_K(E0)}\frac{BR(E2_\gamma)}{\tau}$$



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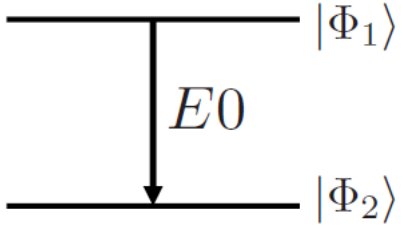

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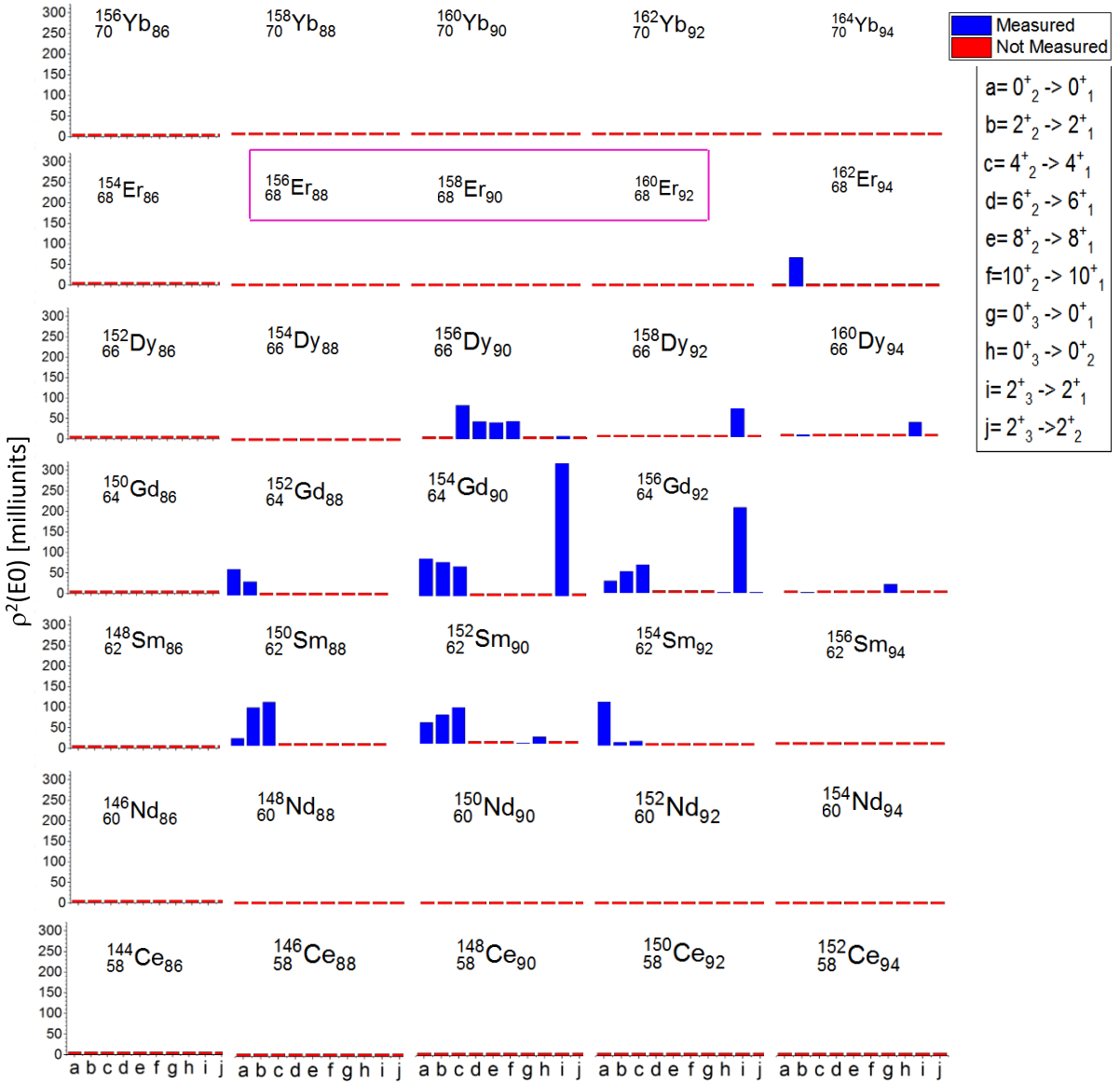

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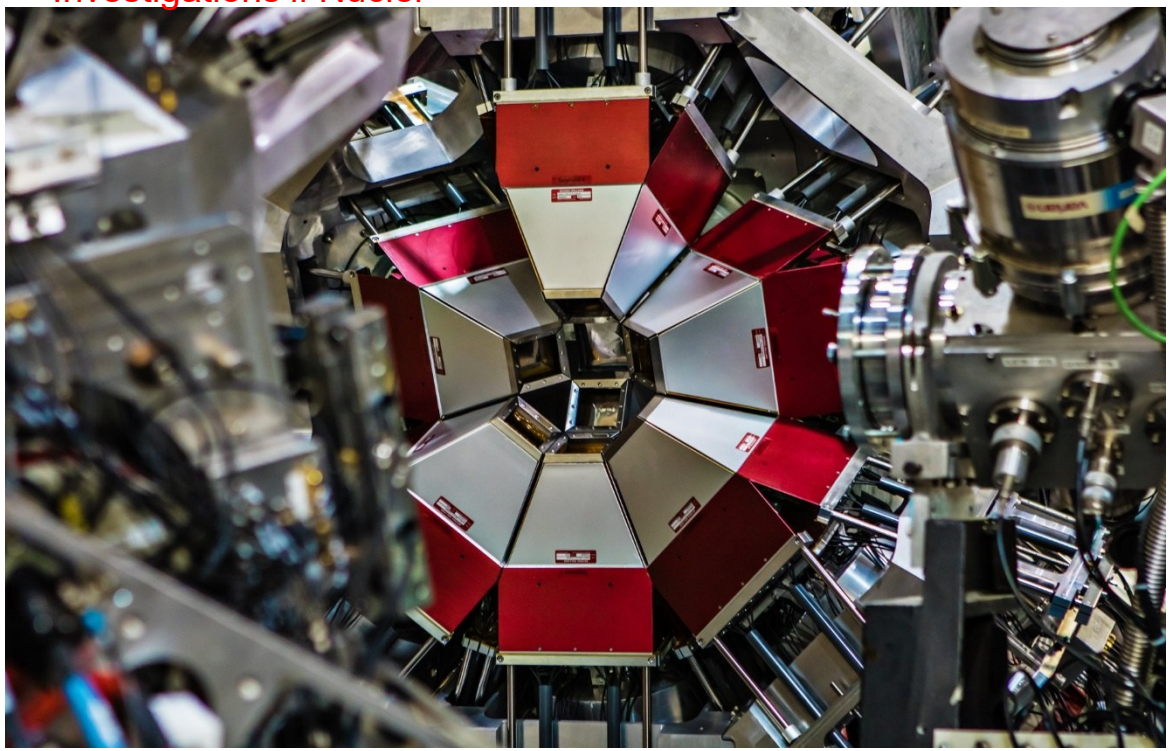
Experimental technique

GRIFFIN – Gamma-Ray Infrastructure For Fundamental Investigations if Nuclei



- 15 Compton-suppressed HPGe Clovers

- HPGe - γ – ray branching ratio and *M1*/*E2*, mixing ratios via $\gamma - \gamma$ angular correlations.

- Si(Li) - Expt. ICC, $E0/E2$ mixing ratio using $e^{-}\gamma$ angular correlations

- Main goal was to determine absolute $E2$ and $E0$ transition strength between low-lying bands through a complementary β-decay and Coulomb-excitation studies using GRIFFIN and TIGRESS in ^{56,158,160}Er isotopes.

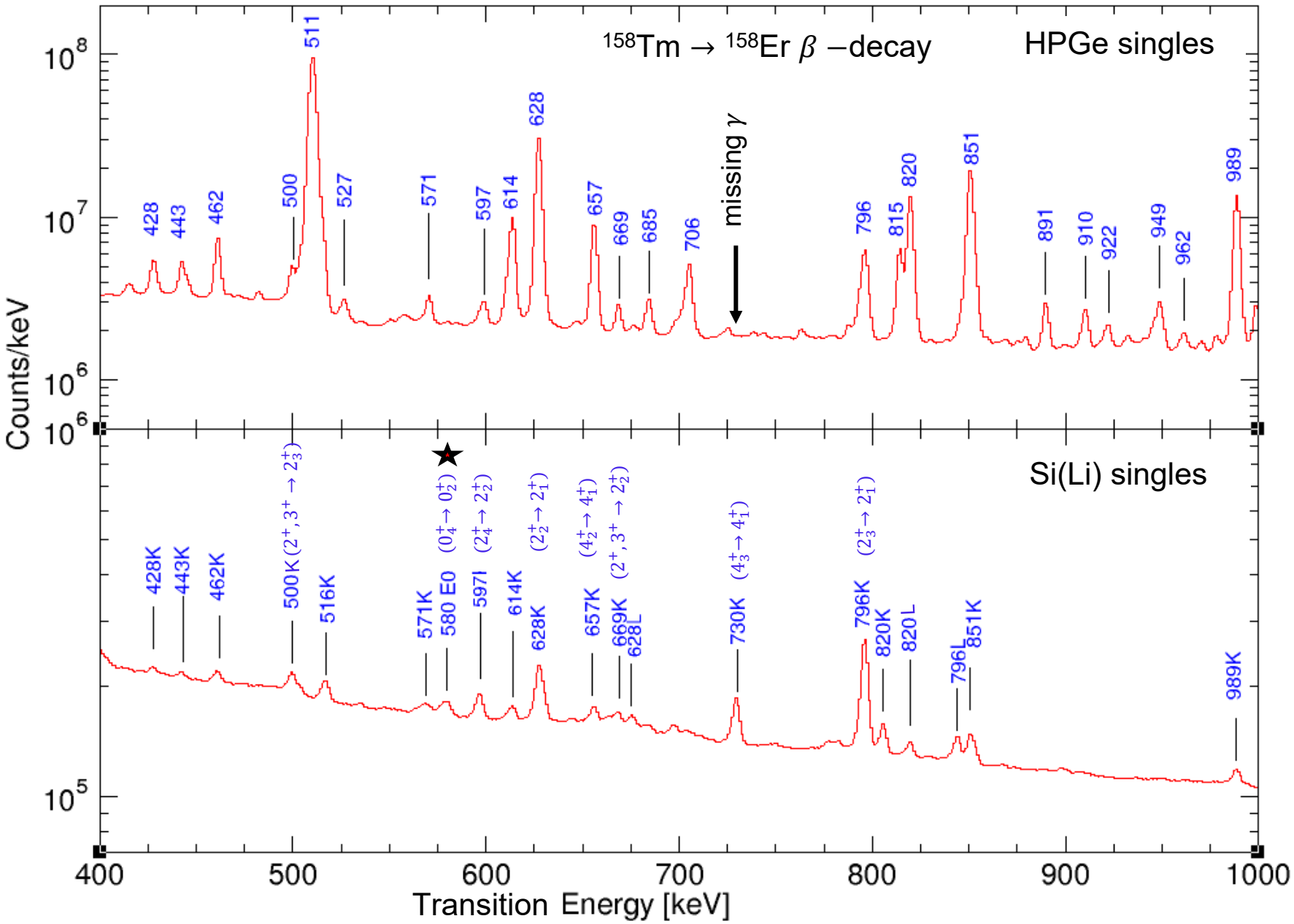
- Run time for ^{158}Er isotope was ~ 6 hours

- PACES (5 cooled Si(Li) detectors)

- ZDS for β tagging

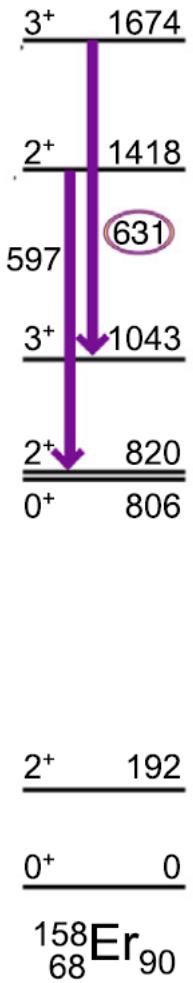
[5] A.B. Garnsworthy, et al., NIMA 918 (2019)

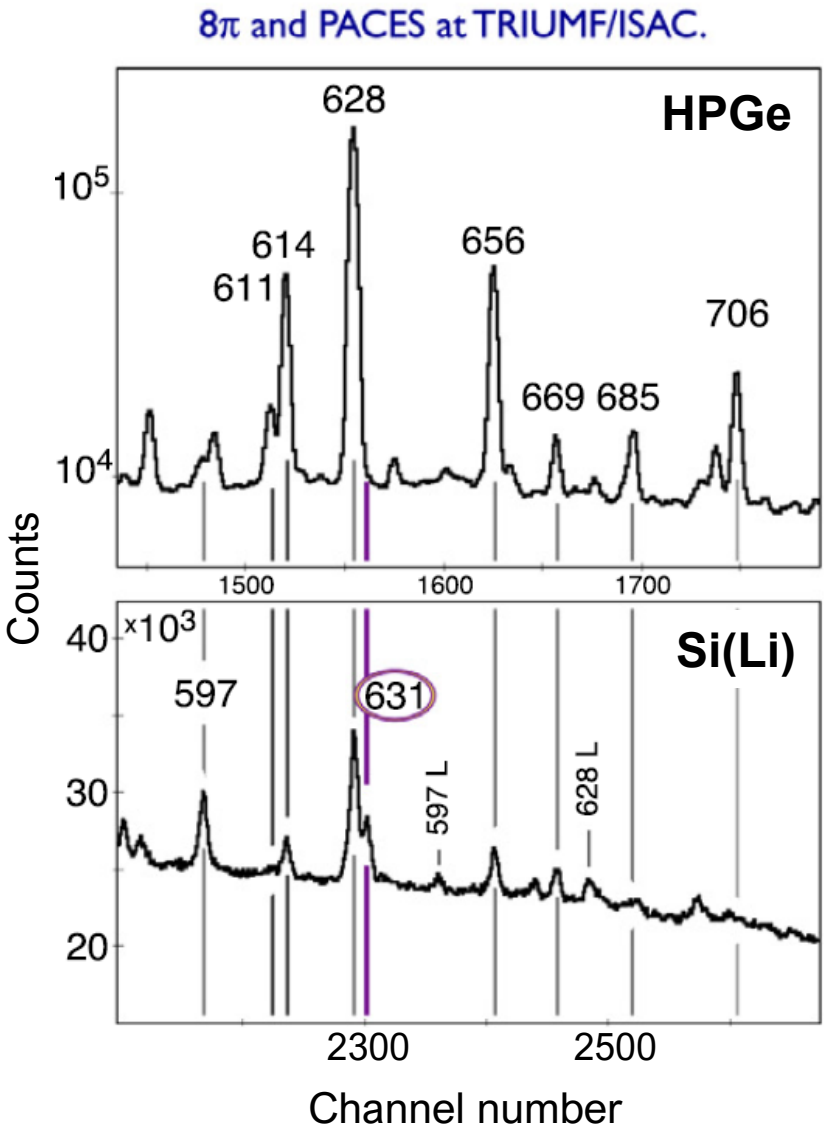
Preliminary results – Peak identification



- Singles spectra of measured transitions
- The electron spectrum has been offset by the binding energy of the K shell in erbium
- The black star is the 3rd excited 0^+ state that was tentatively placed in ENSDF

Previous studies

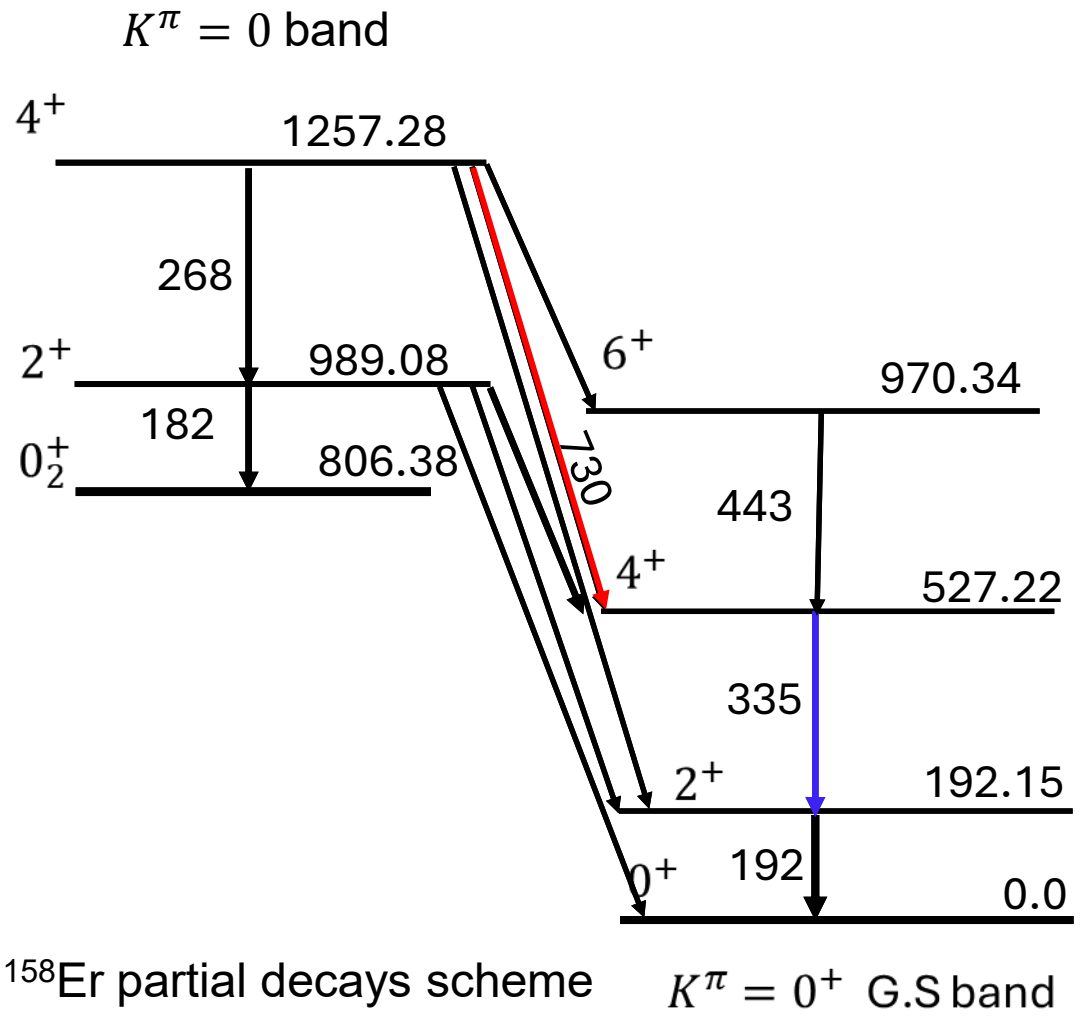


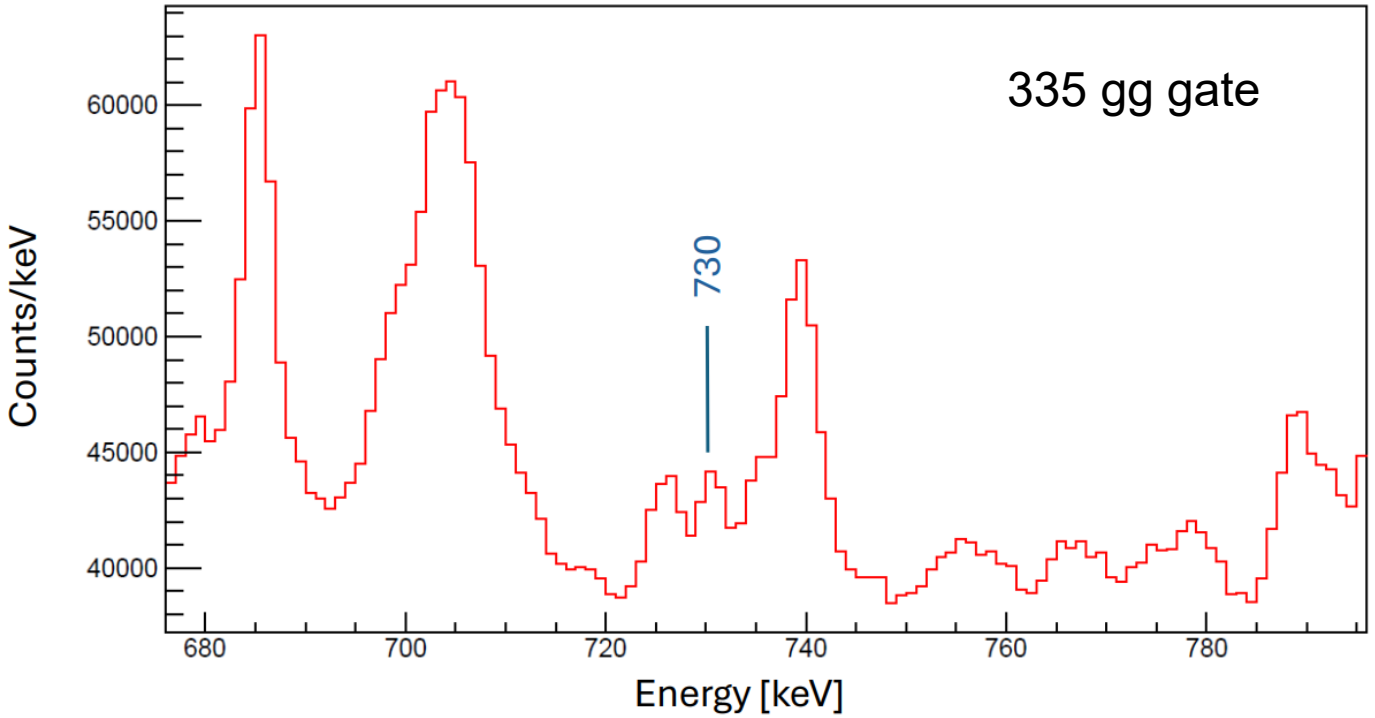


- A similar scenario where a CE is observed in $J^{\pi} \rightarrow J^{\pi}$ $(J \neq 0)$ transition with no visible γ − ray.
- This was ascribed to an accidental cancellation of the E2 matrix element which, following the Wigner–Eckart theorem depends on a Clebsch–Gordan coefficient as $3K^2 - I(I+1)$

[6] W.D. Kulp, J.W. Wood, and P.E. Garrett (unpublished)
[4] T. Kibedi, A. Garnsworthy & J.L Wood, PPNP 123 (2022)

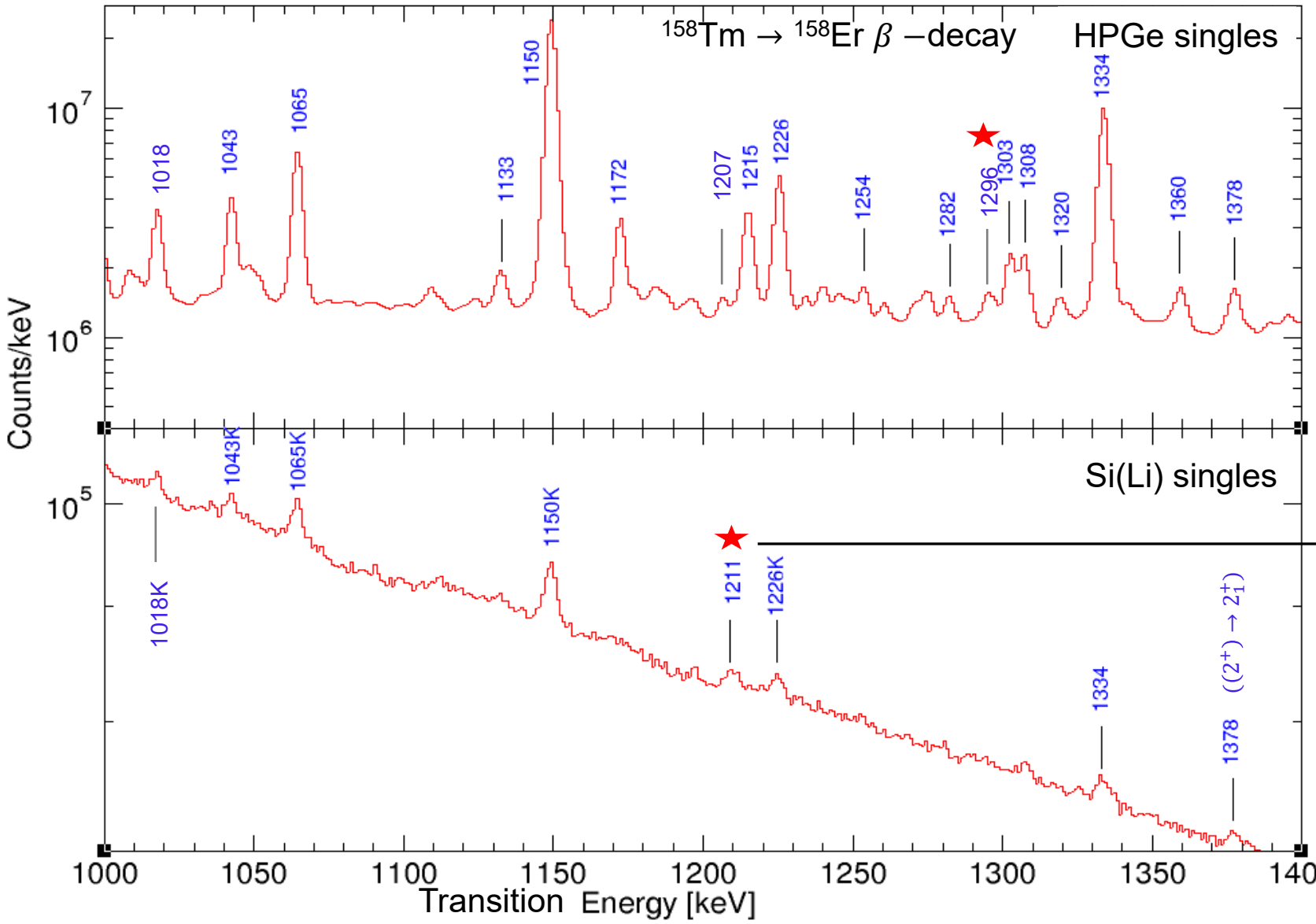
Preliminary results - missing gamma

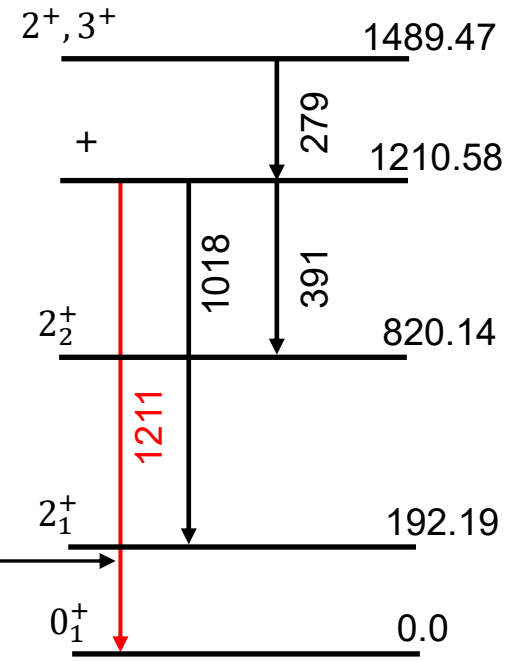




- By zooming on the 335 gate, the 730 keV can be seen.

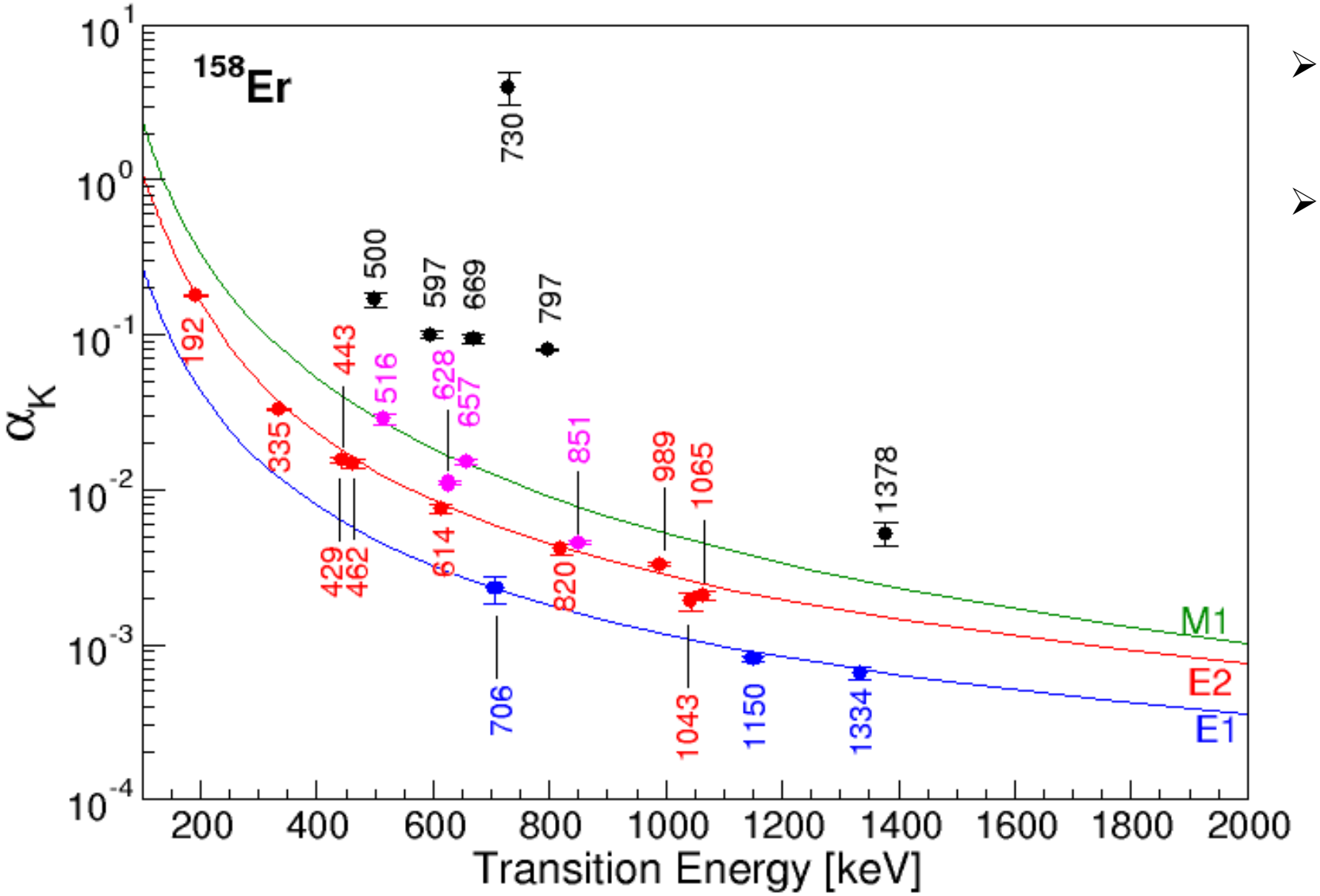
Preliminary results – Peak identification





- The 1210.58 keV level was assigned a positive parity with no spin.
- The lack of $\gamma - ray$ associated with the new 1211 kev transition, suggests J = 0

Preliminary results – Internal conversion coefficients (ICC)

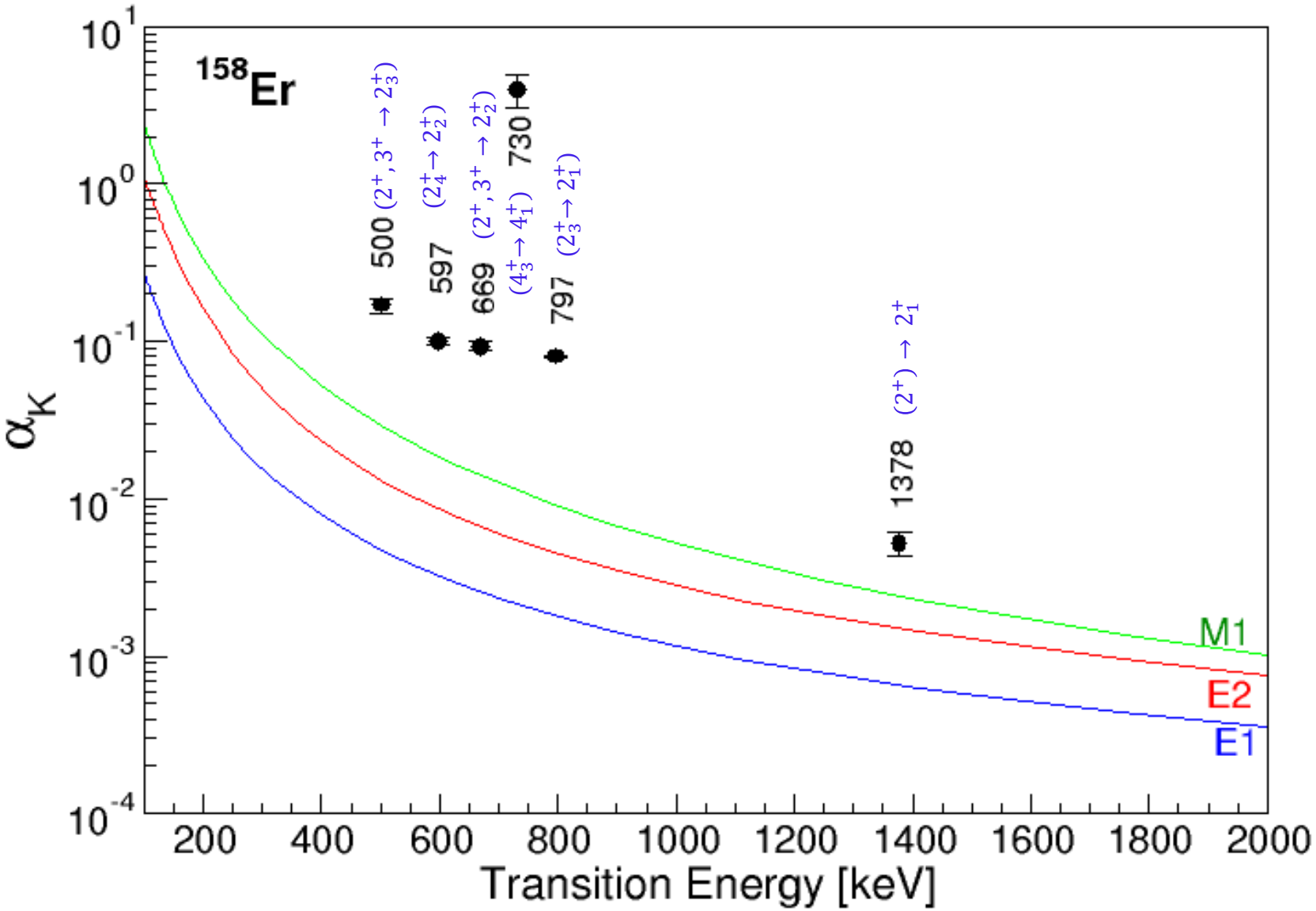


- Experimental K conversion coefficients compared with BrIcc values [4]
- ICC values are a useful tool in spin assignment and transition multipolarity

$$\alpha_{K\,exp} = \frac{I_e}{I_\gamma}$$

[7] T. Kibedi, *et al*., Nucl. Inst. and Meth. In Phy. Res. 589 (2008)

Preliminary results – E0 candidates



- According to angular momentum selection rules $E0$ admixture is allowed in $J^{\pi} \rightarrow J^{\pi}$ transition
- The ICC results favors J = 2 for the 500 keV and 669 keV transitions

$\gamma - \gamma$ angular correlation

- The correlation between the directions of emission of two gamma-rays provide crucial information about the fundamental properties of the nucleus such as:

  - spin and parity of excited nuclear states,
  - multipole orders, and
  - mixing ratios.

- These angular correlations have the form:

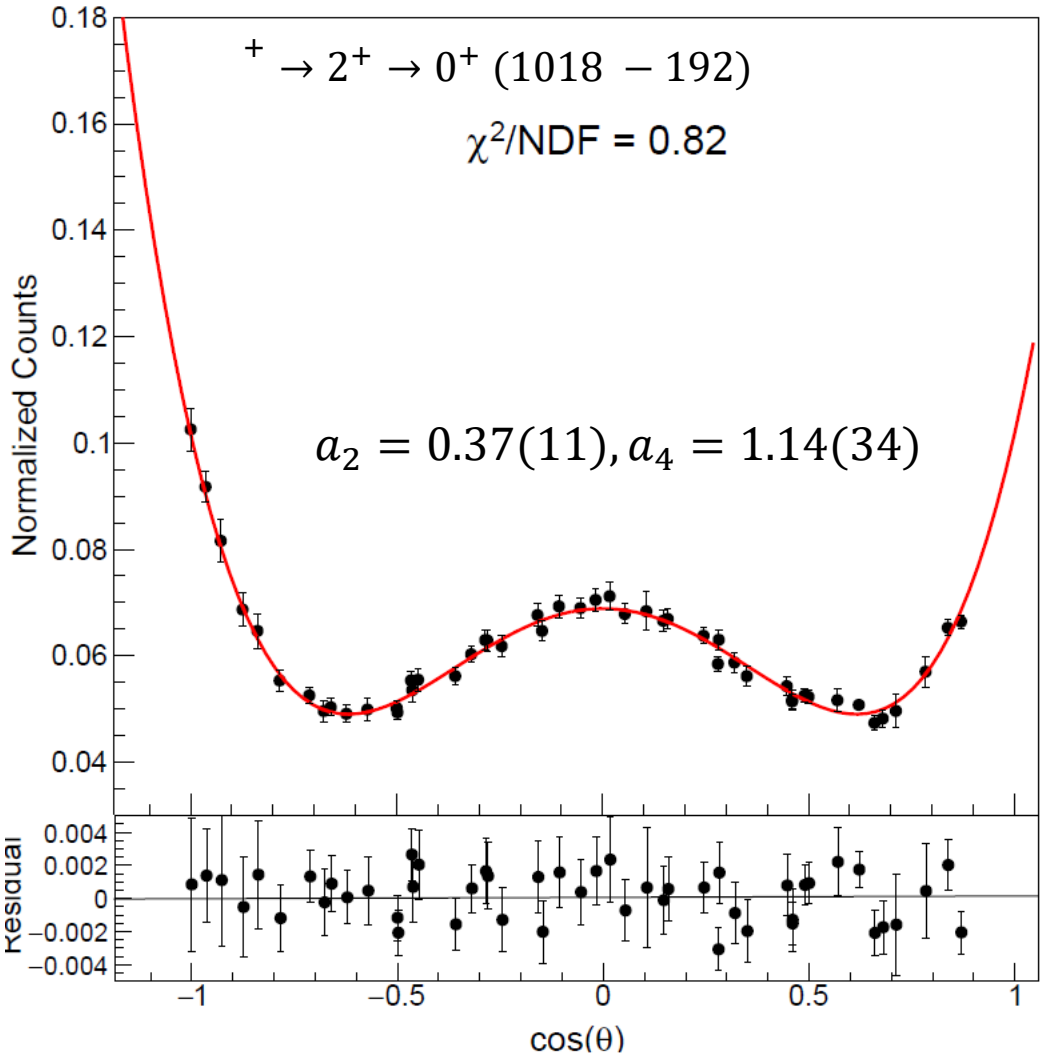
$$W(\theta) = \sum_{i=0,even}^{\infty} B_{ii} G_{ii}(t) A_{ii} P_i\,(cos\theta)$$

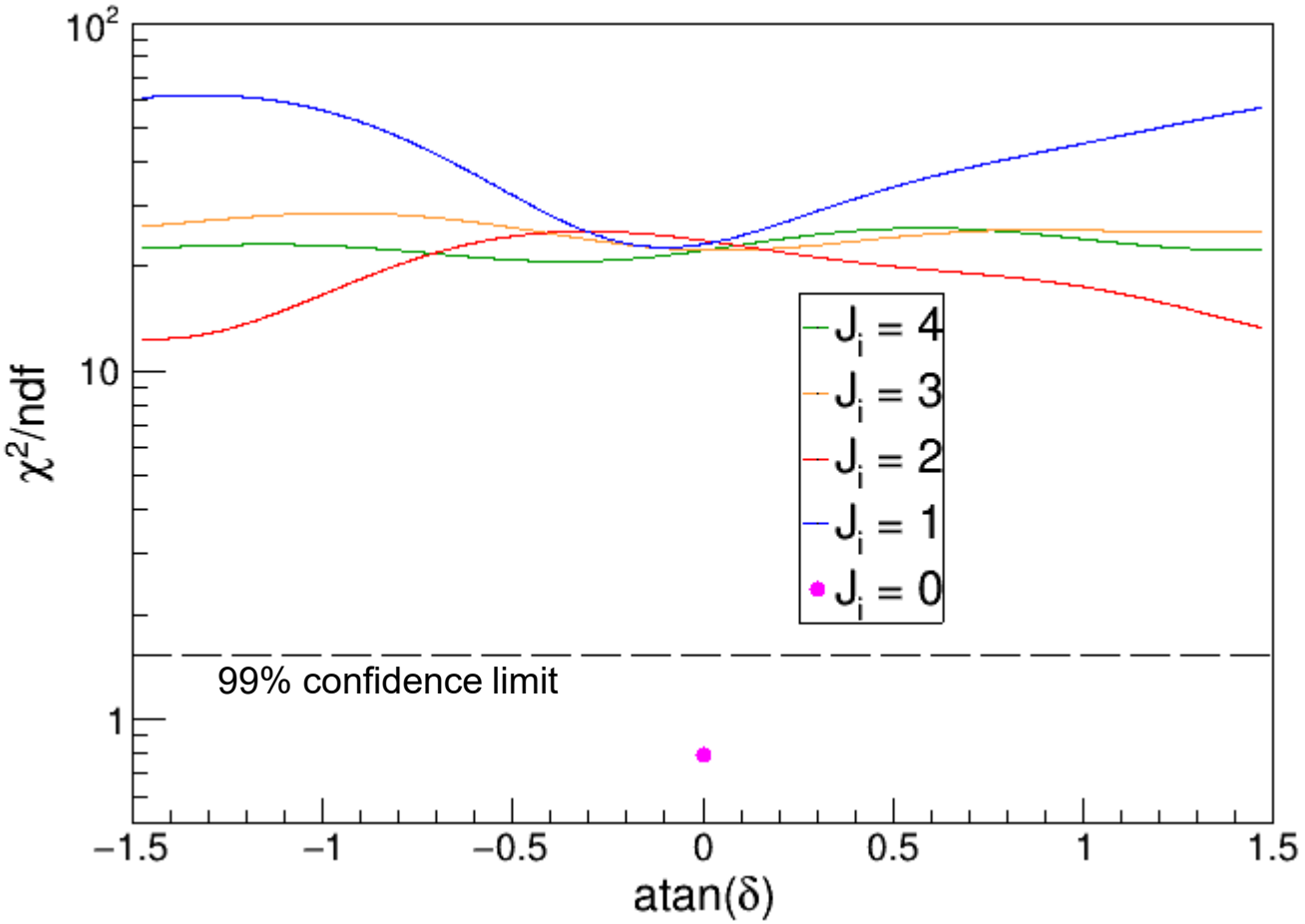
- For Griffin, we take the situation of an isotropic initial nuclear orientation from a short lived state populated via $\beta -$ decay. Therefore, rendering $B_{ii} G_{ii}(t) = 1$

$$W(\theta) = A_{00}[1 + a_2 p_2(cos\theta) + a_4 p_4(cos\theta)$$

[8] J.K Smith *et al.*, NIMA 922 (2019)

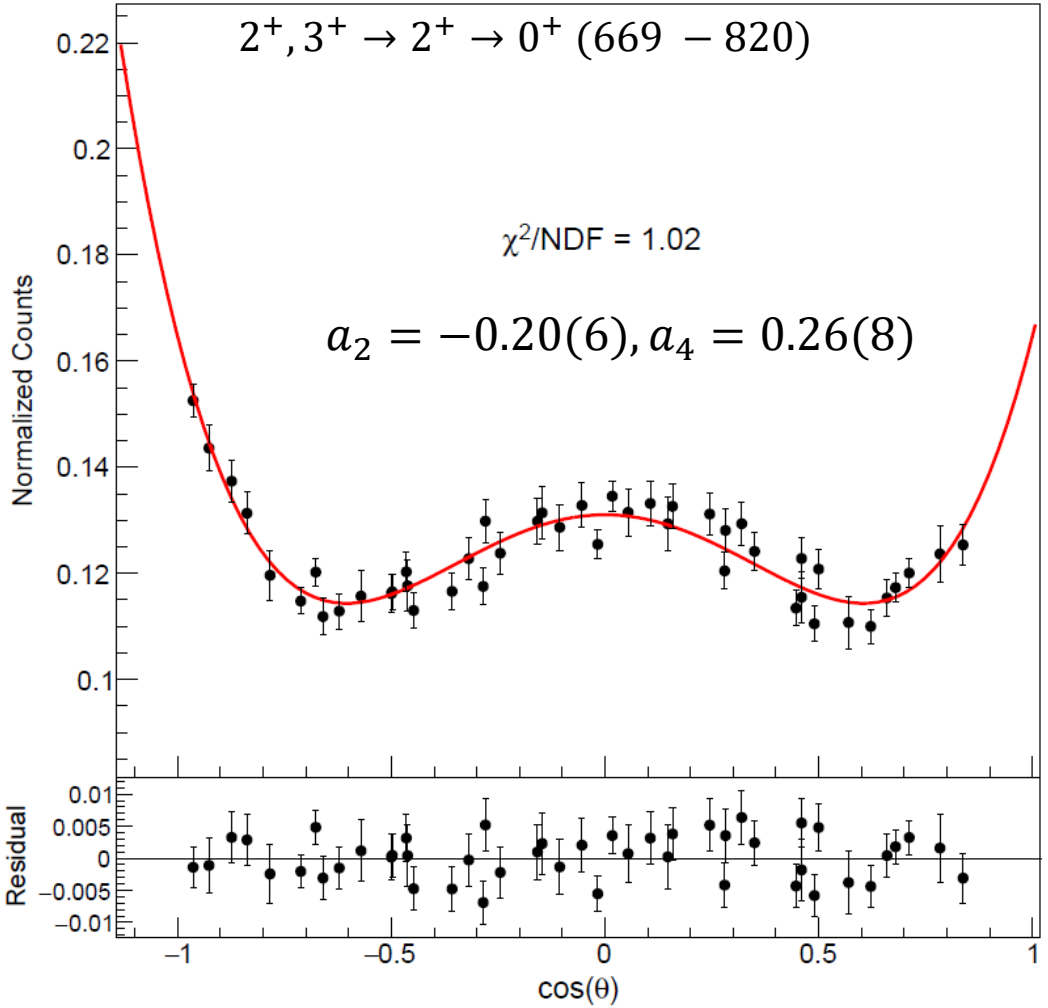
Preliminary results - $\gamma - \gamma$ angular correlation

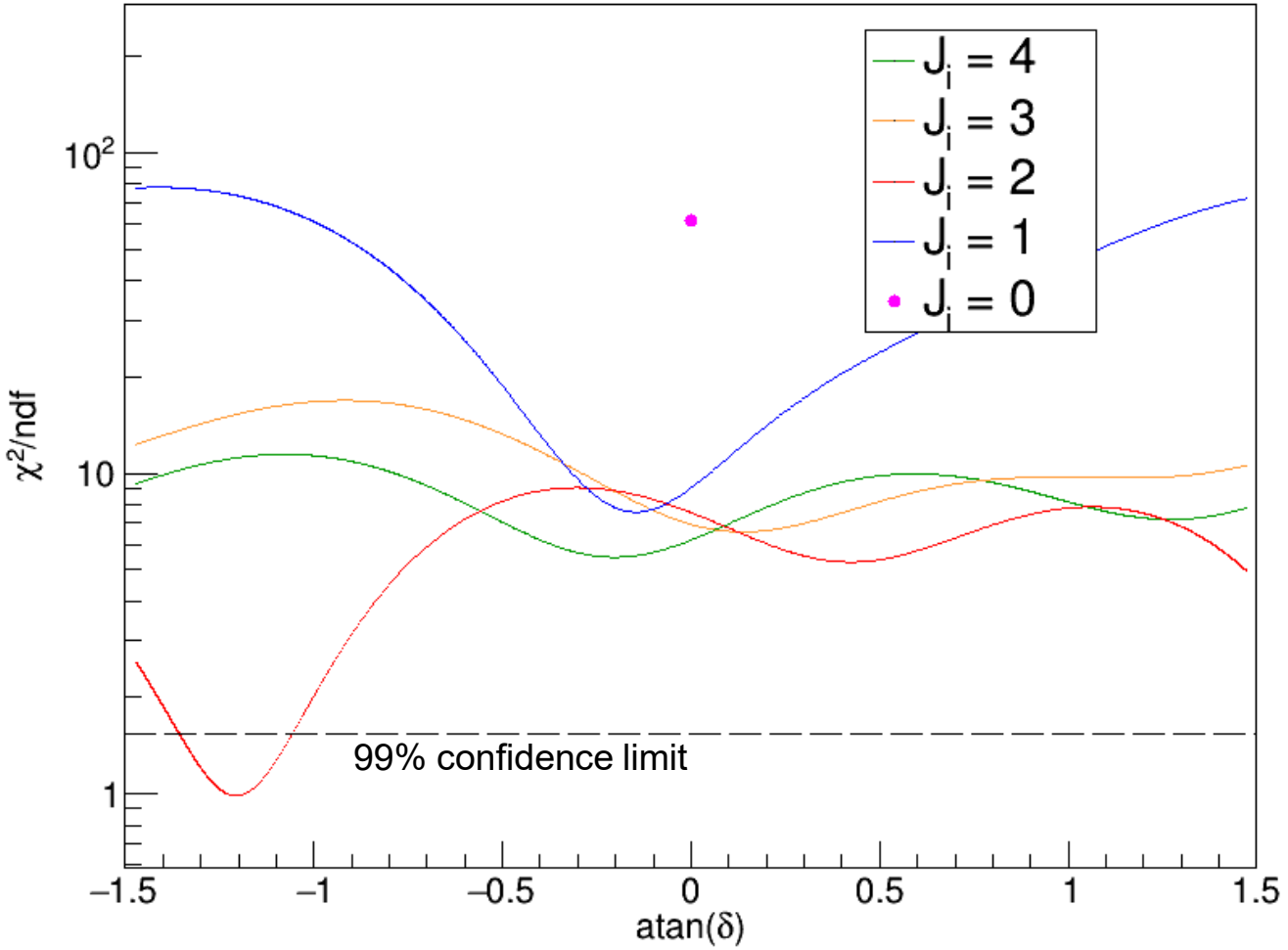




χ^2 fit to measured $\gamma - \gamma$ angular correlation for different spin hypothesis.

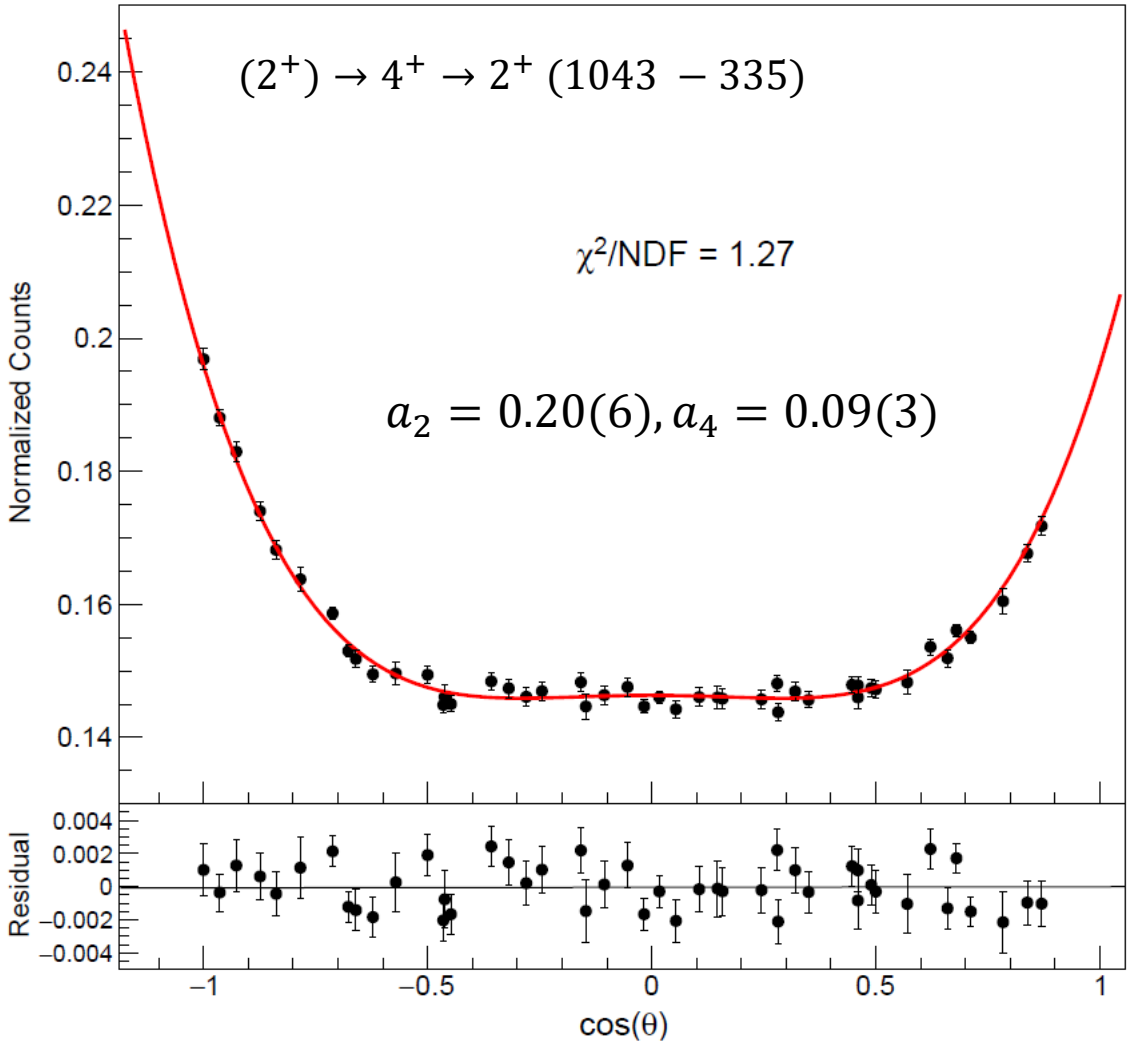
Preliminary results - $\gamma - \gamma$ angular correlation

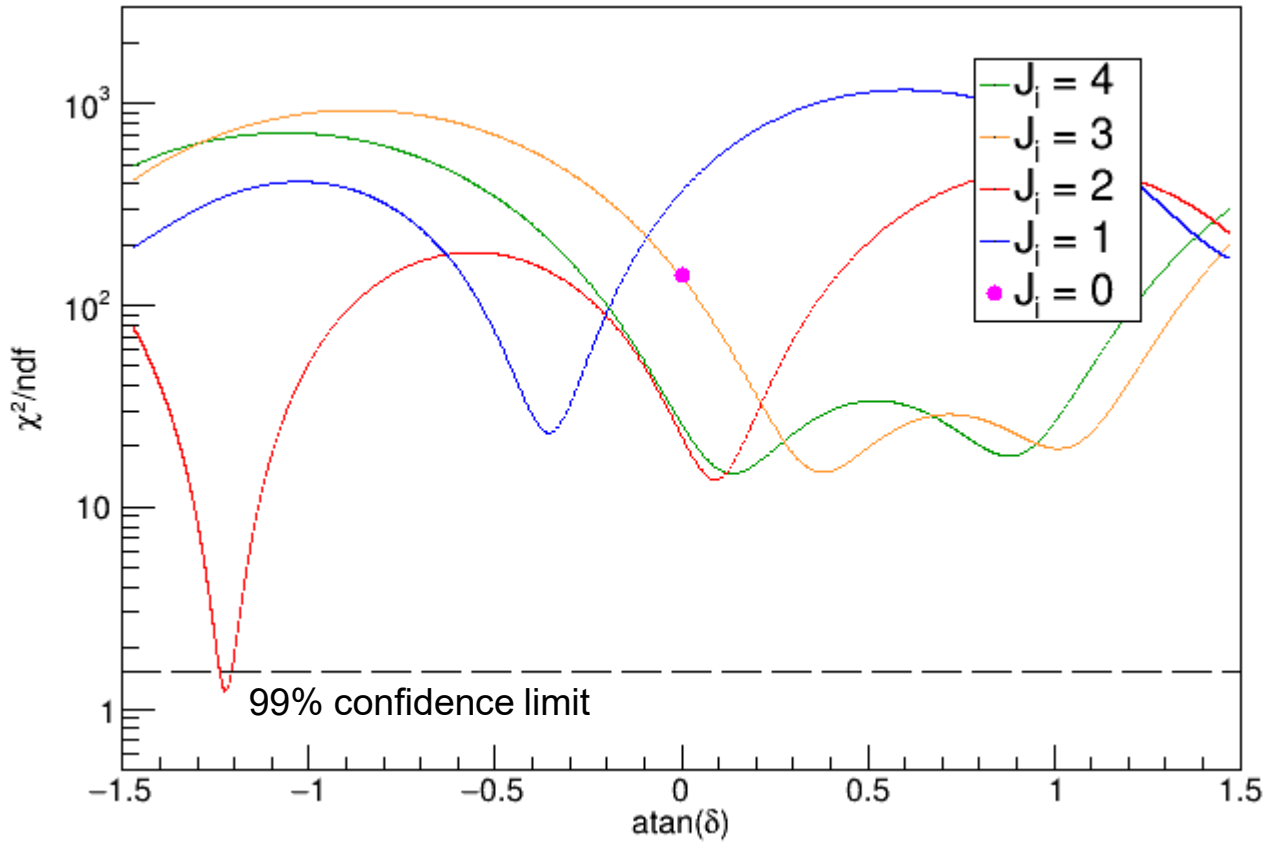




- χ^2 fit to measured $\gamma - \gamma$ angular correlation for different spin hypothesis. The fit favors $J = 2$ with $\delta\,(E2/M1) = -2.6(2.5)$

Preliminary results - $\gamma - \gamma$ angular correlation

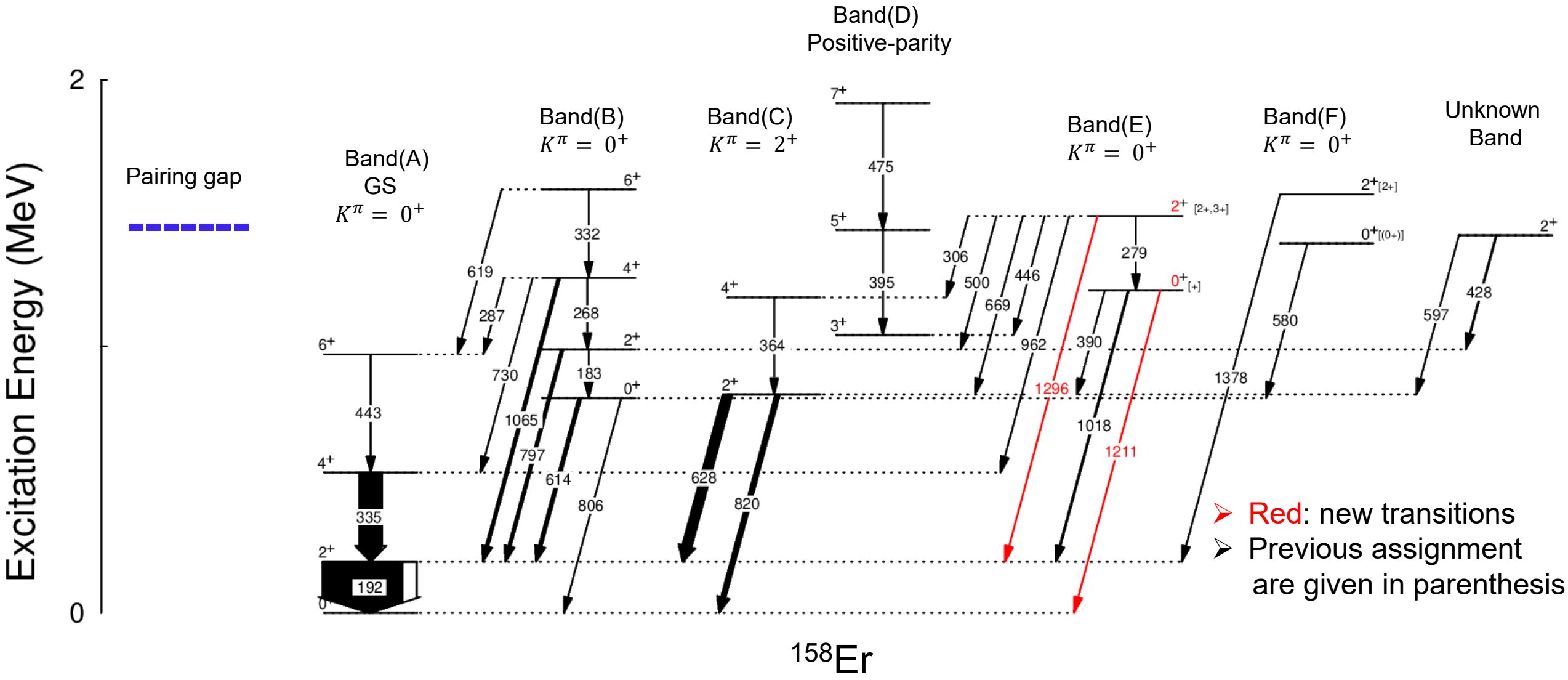




χ^2 fit to measured $\gamma - \gamma$ angular correlation for different spin hypothesis. The best fit is made with $J = 2$

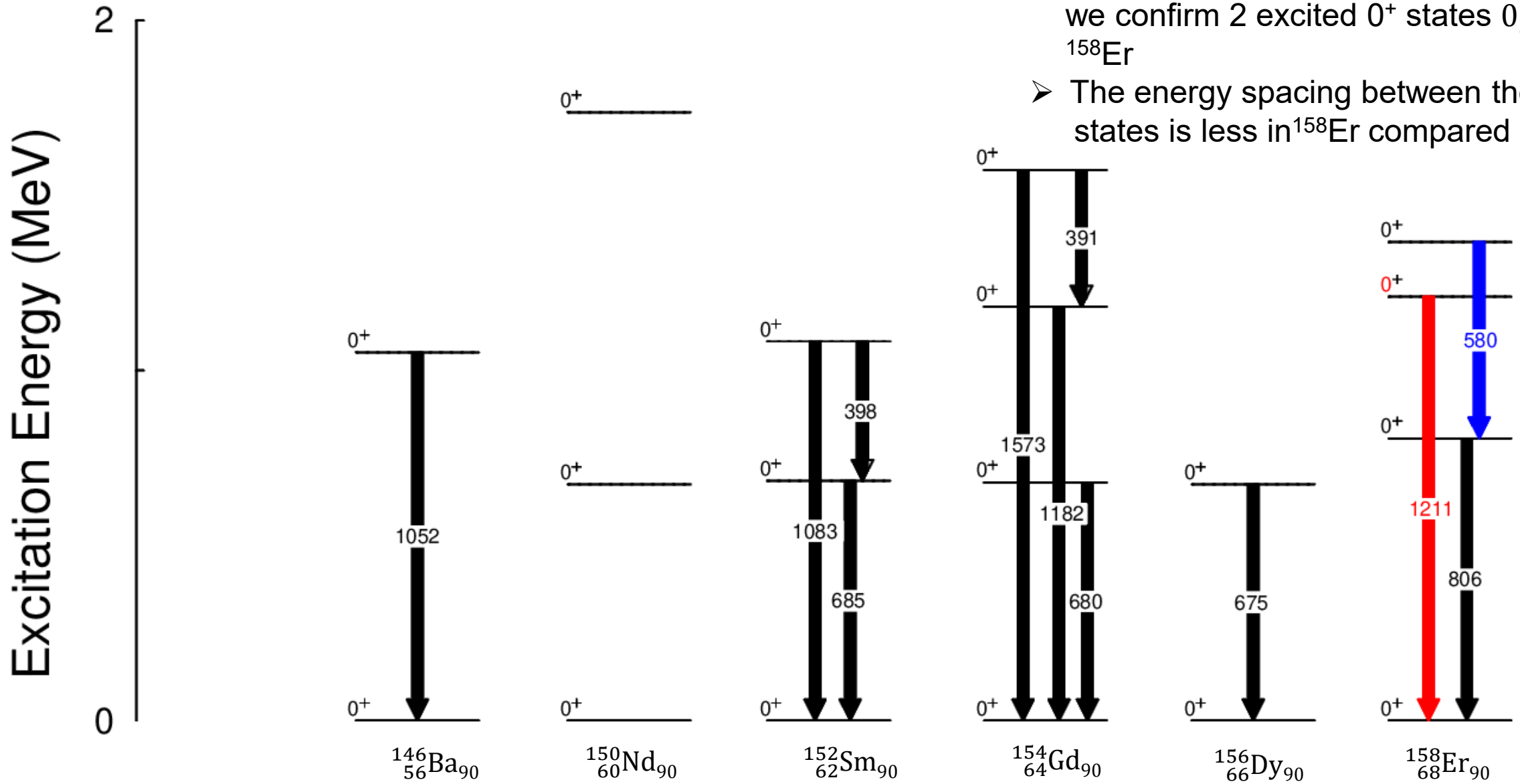
$\delta\,(E2/M3) = -2.8(24)$

Band identification

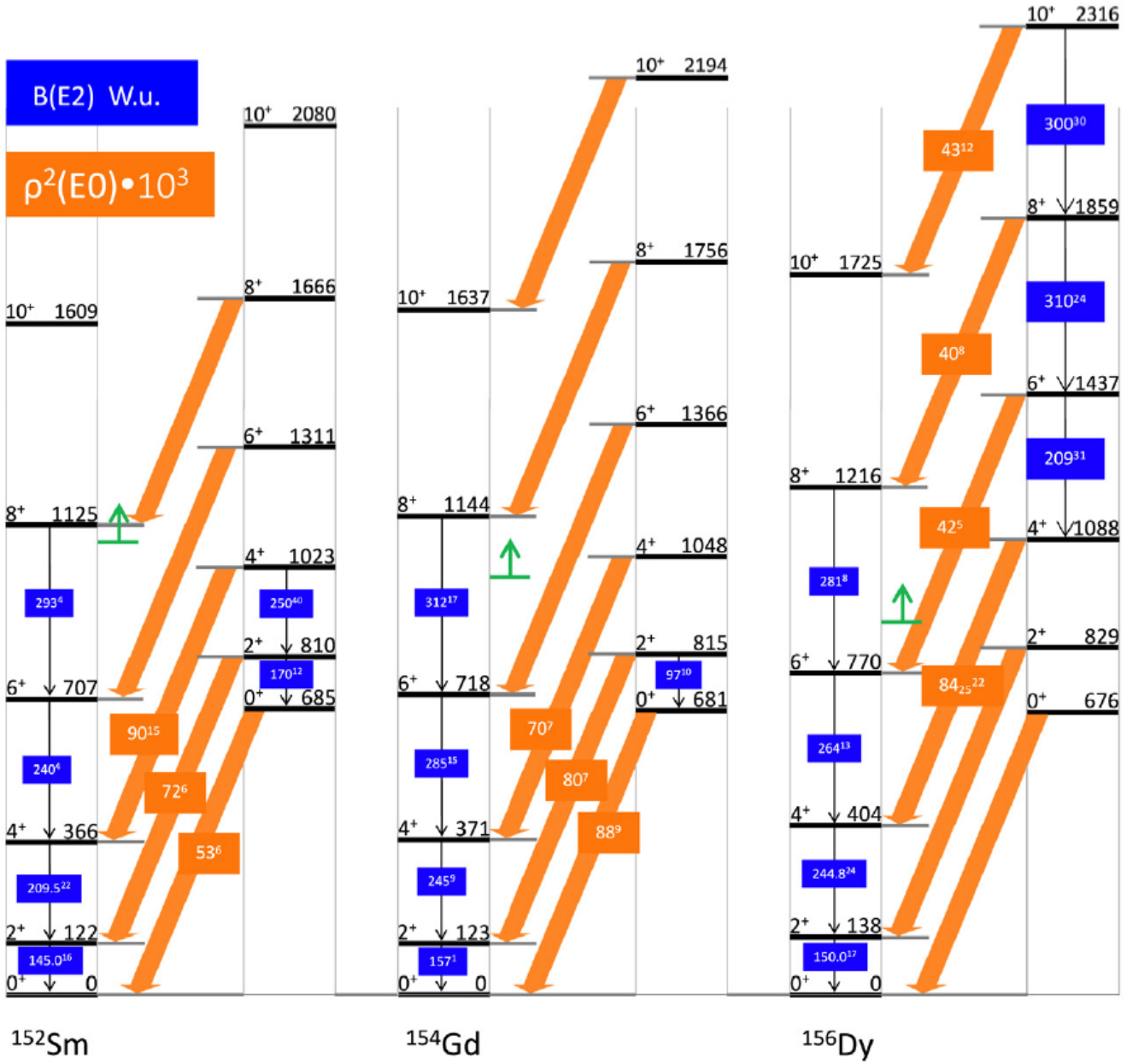


Systematics of 0^+ states in $N = 90$

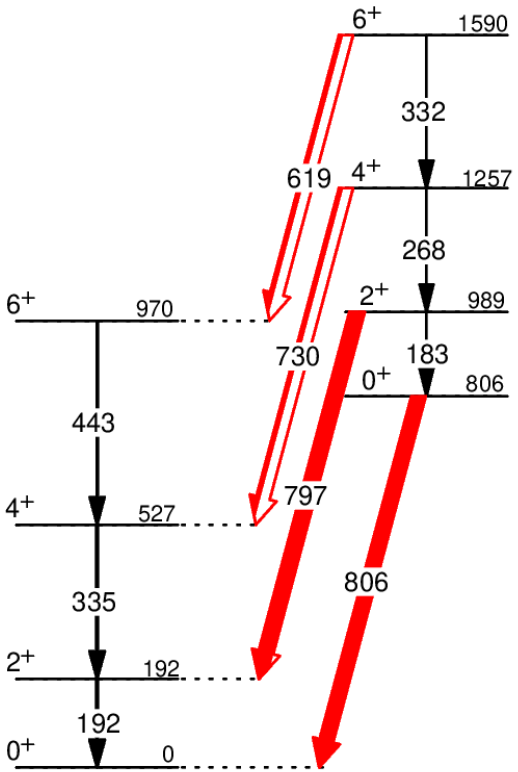
- Based on the $\gamma - \gamma$ angular correlation, we confirm 2 excited 0^+ states $0_3^+, 0_4^+$) in ^{158}Er
- The energy spacing between the 0_2^+ and 0_3^+ states is less in ^{158}Er compared to ^{154}Gd



E0 strength Systematics in $N = 90$



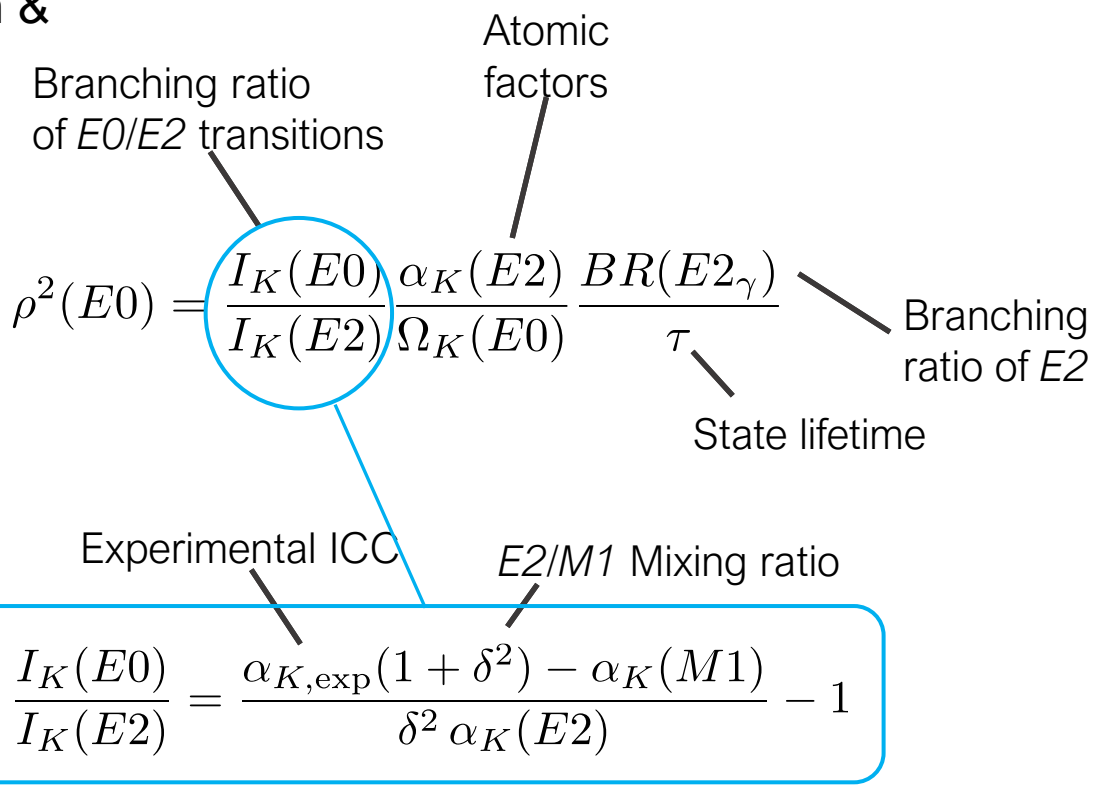
- This study will provide information on ^{158}Er that will shed light on the systematics of the 4^+ & 2^+states built on the $K^\pi = 0$ band



[4] T. Kibedi, A. Garnsworthy & J.L Wood, PPNP 123 (2022)

Summary and outlook

- Identified 6 candidates with large ICC that will be probed for $\rho^2(E0)$ strength
- Identified two new transitions
- We have constrained spin-parity of few transitions using $\gamma - \gamma$ angular correlation
- Firmly assigned multipolarity to one transition &
- Confirmed two $K^\pi = 0$ bands.



Acknowledgement

A.A. Avaa,[1] A.B. Garnsworthy,[1] J. Smallcombe,[2] L. Atar,[3] A. Babu,[1] G.C. Ball,[1] N. Bernier,[1,4] S.S. Bhattacharjee,[1] V. Bildstein,[3] M. Bowry,[1] C. Burbadge,[3] R. Cabellero-Folch,[1] A. Chester,[1] F.H. Garcia,[5] G. Hackman,[1] A.D. MacLean,[3] A.N. Murphy,[1] B. Olaizola,[1] A.J. Radich,[3] Y. Saito,[1,4] P. Šiurytė,[1,6] J.E. Svensson,[3] R. Umashankar,[1] S. Valbuena,[3] K. Whitmore,[5] J. Williams,[5] M.S.C. Winokan,[1,6] and D. Yates[1,4]

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[2] *Advanced Science Research Center, Japan Atomic Energy Agency (JAEA), Tokai, Ibaraki 319-1195, Japan*
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[4] *Department of Physics and Astronomy, University of British Columbia, Vancouver, BC V6T 1Z4, Canada*
[5] *Department of Chemistry, Simon Fraser University, Burnaby, British Colombia V5A 1S6, Canada*
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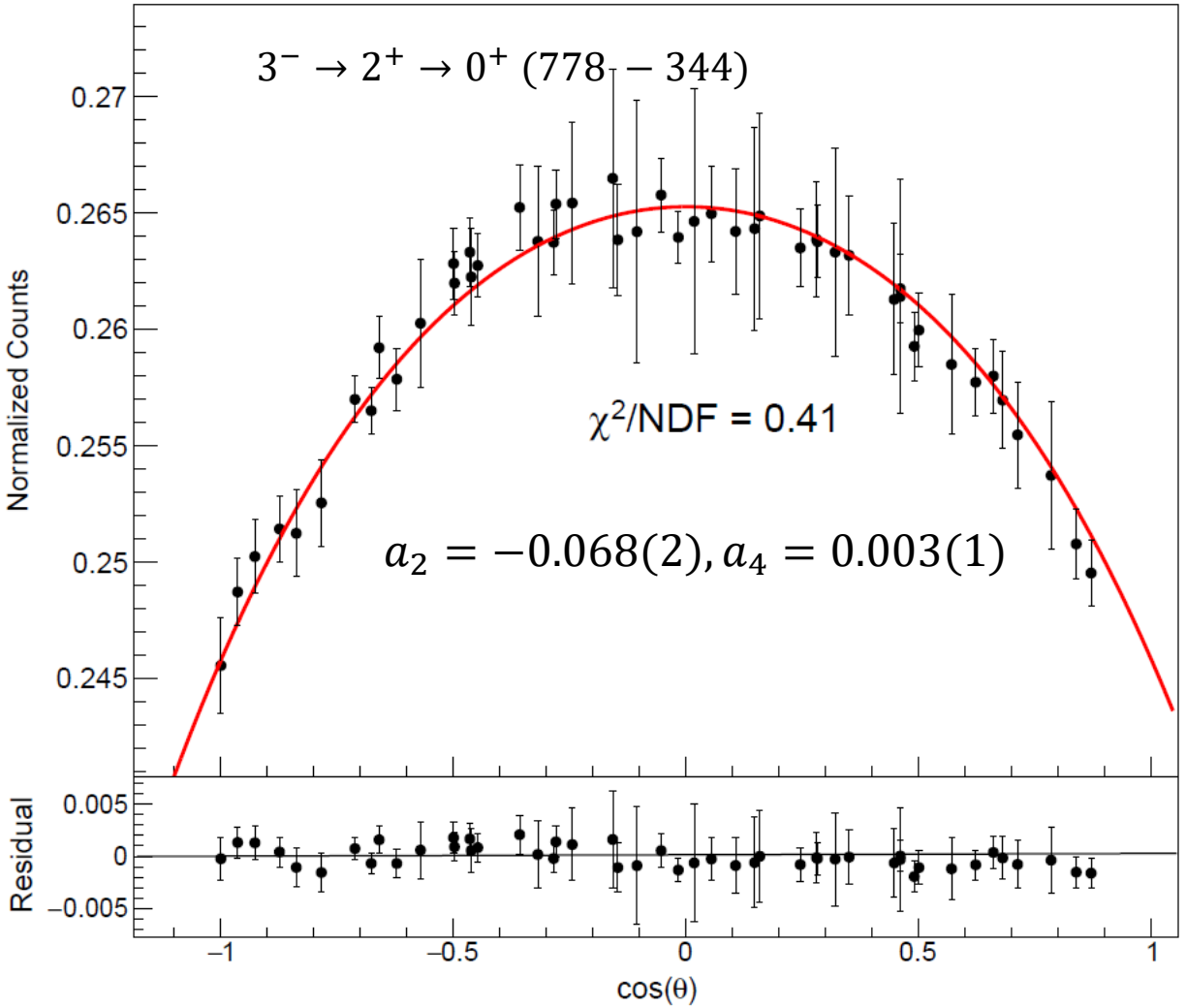
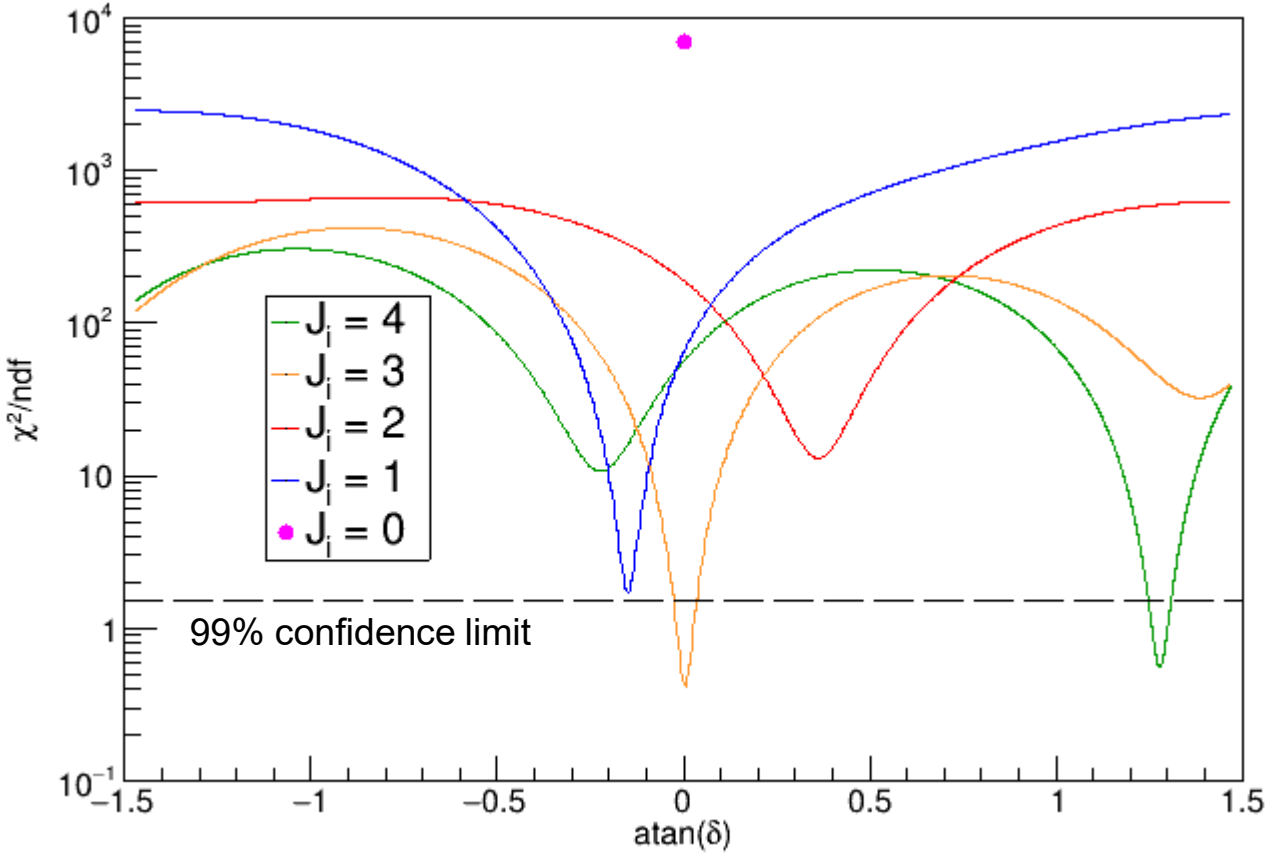
관심 가져 주셔서 감사합니다

Preliminary results - $\gamma - \gamma$ angular correlation

- To verify the method for this experiment, we use the $3^- \rightarrow 2^+ \rightarrow 0^+$ cascade from ^{152}Gd
- The event mixing technique was used for Normalization





- χ^2 fit to measured $\gamma - \gamma$ angular correlation for different spin hypothesis. The fit favors $J = 3, 4$ with $\delta(E1/M2) = 0.006^{+0.0015}_{-0.15}$, and $3.3^{+3.3}_{-3.5}$

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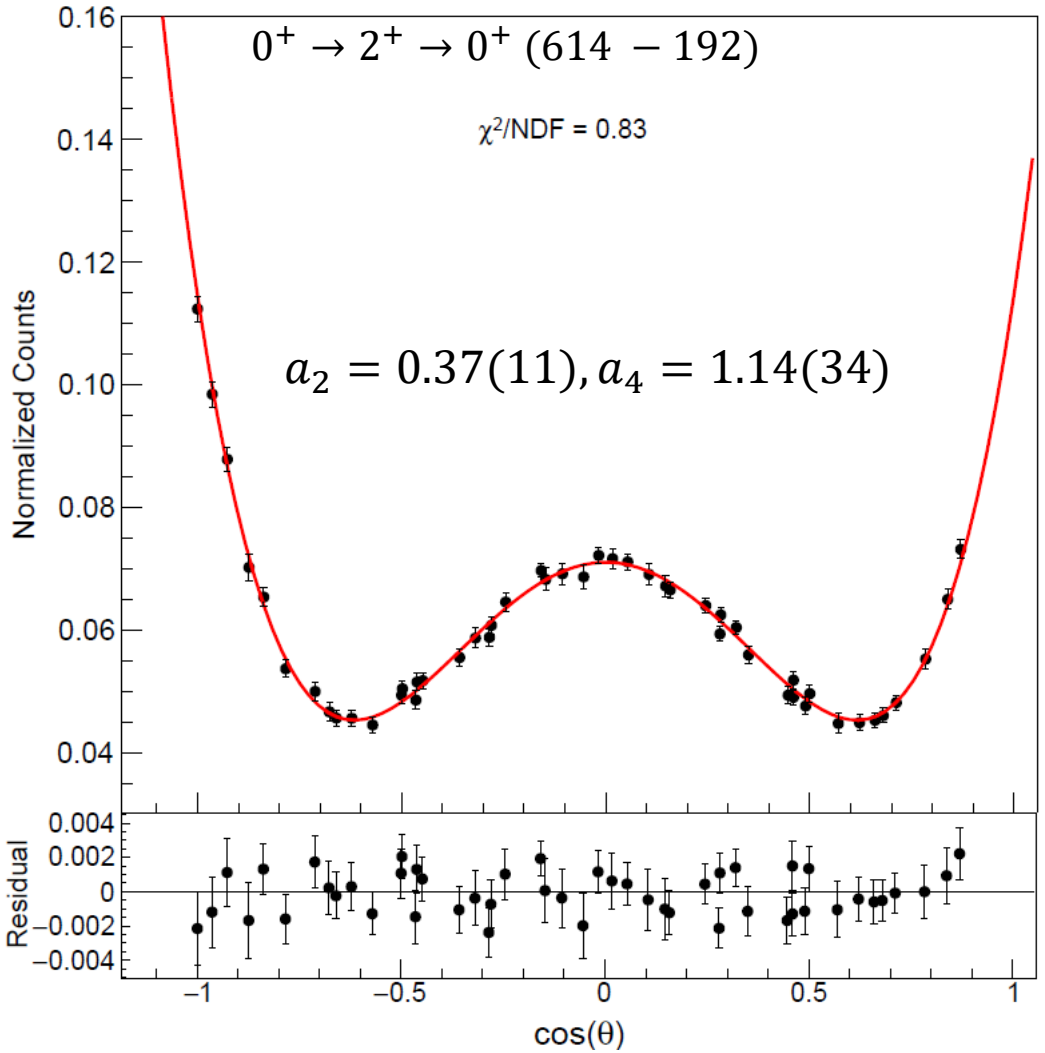

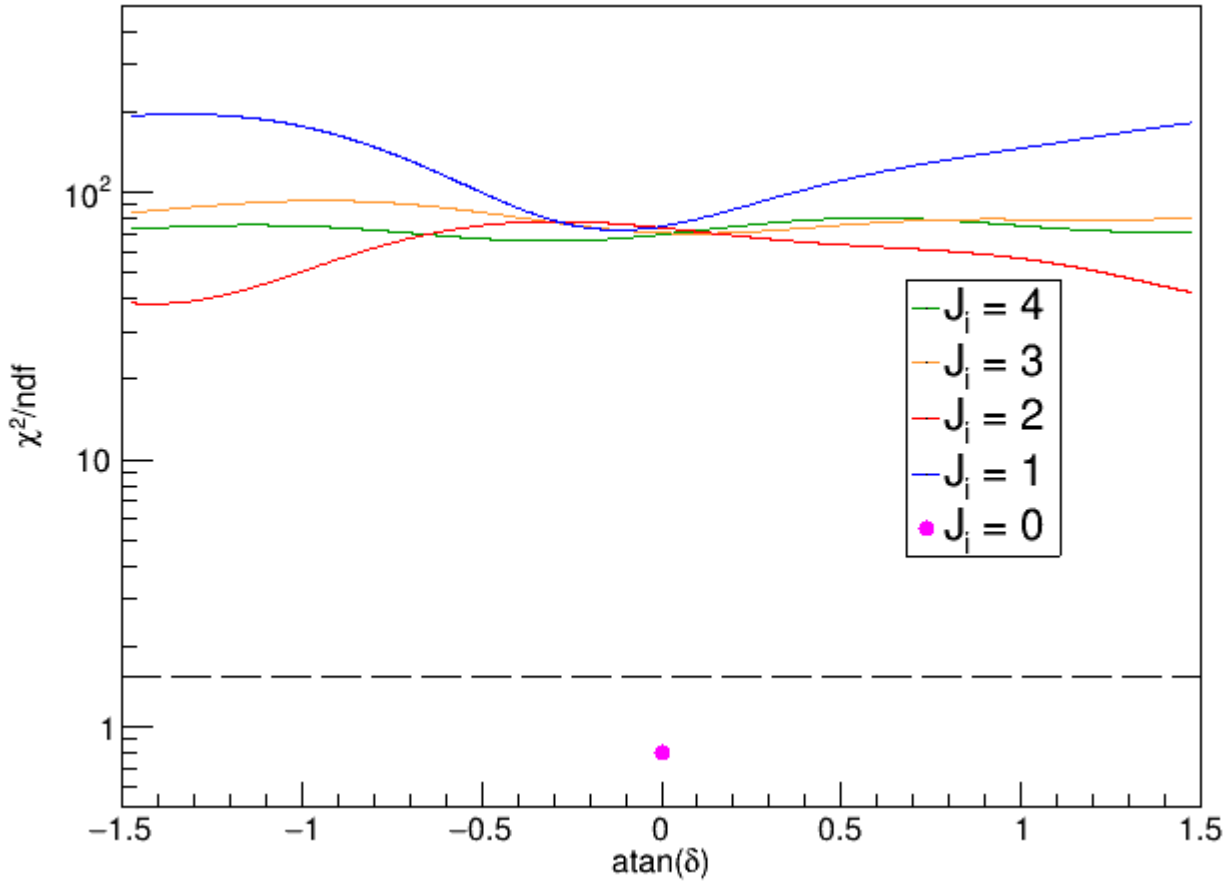

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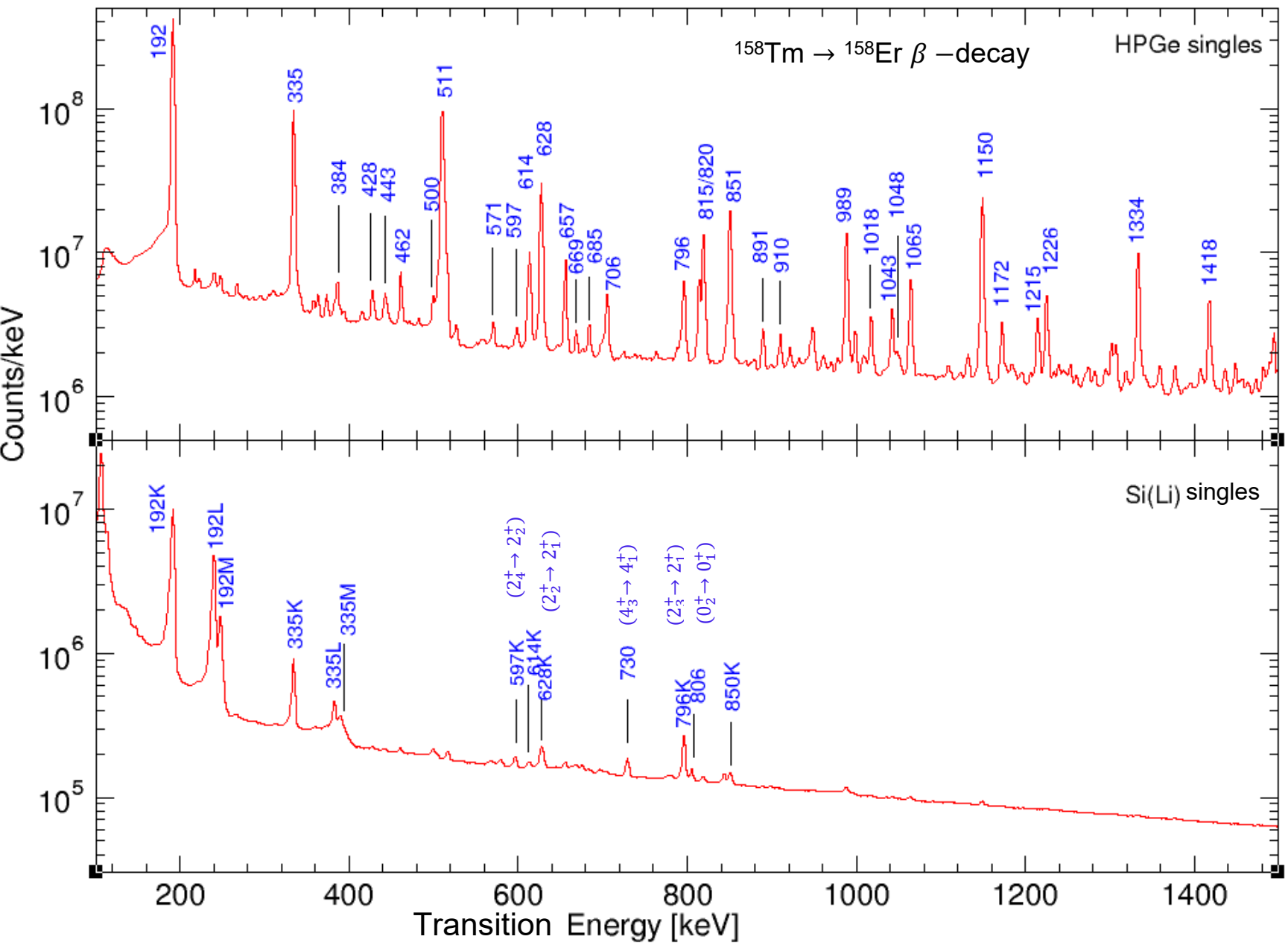

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