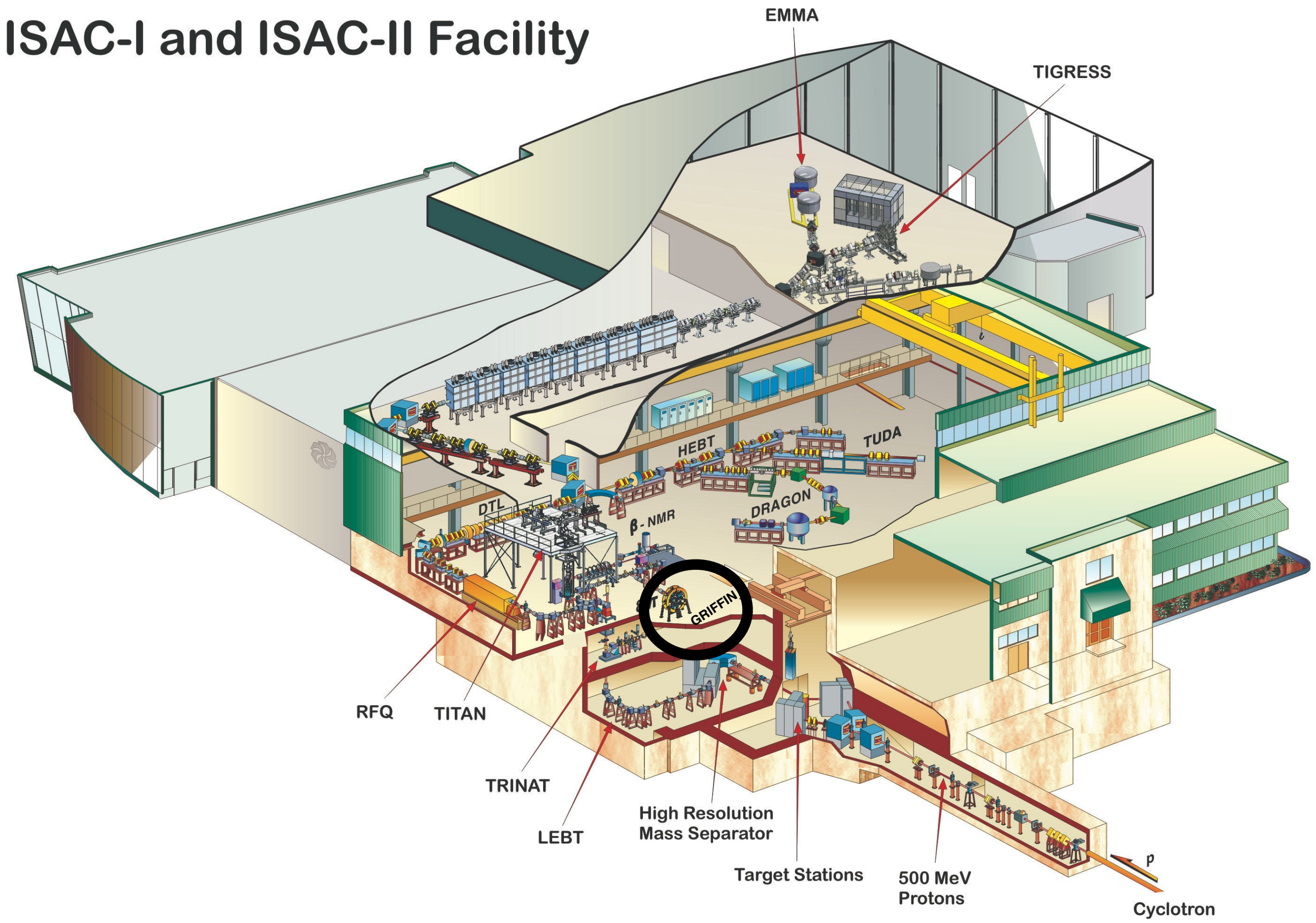
Gamma-Gamma Angular Correlation Measurements With GRIFFIN

Andrew MacLean
University of Guelph

Experimental Facilities At TRIUMF-ISAC



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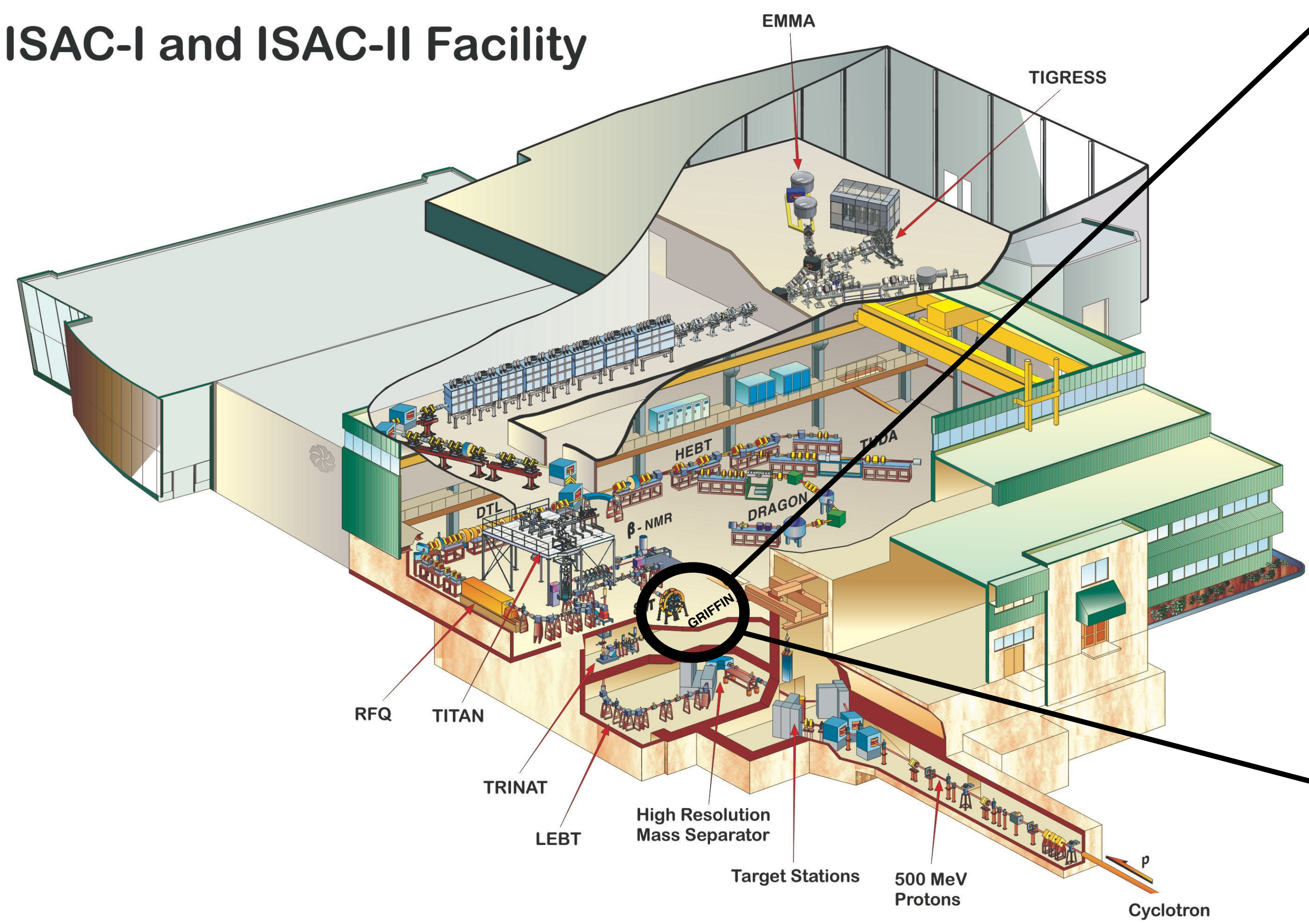

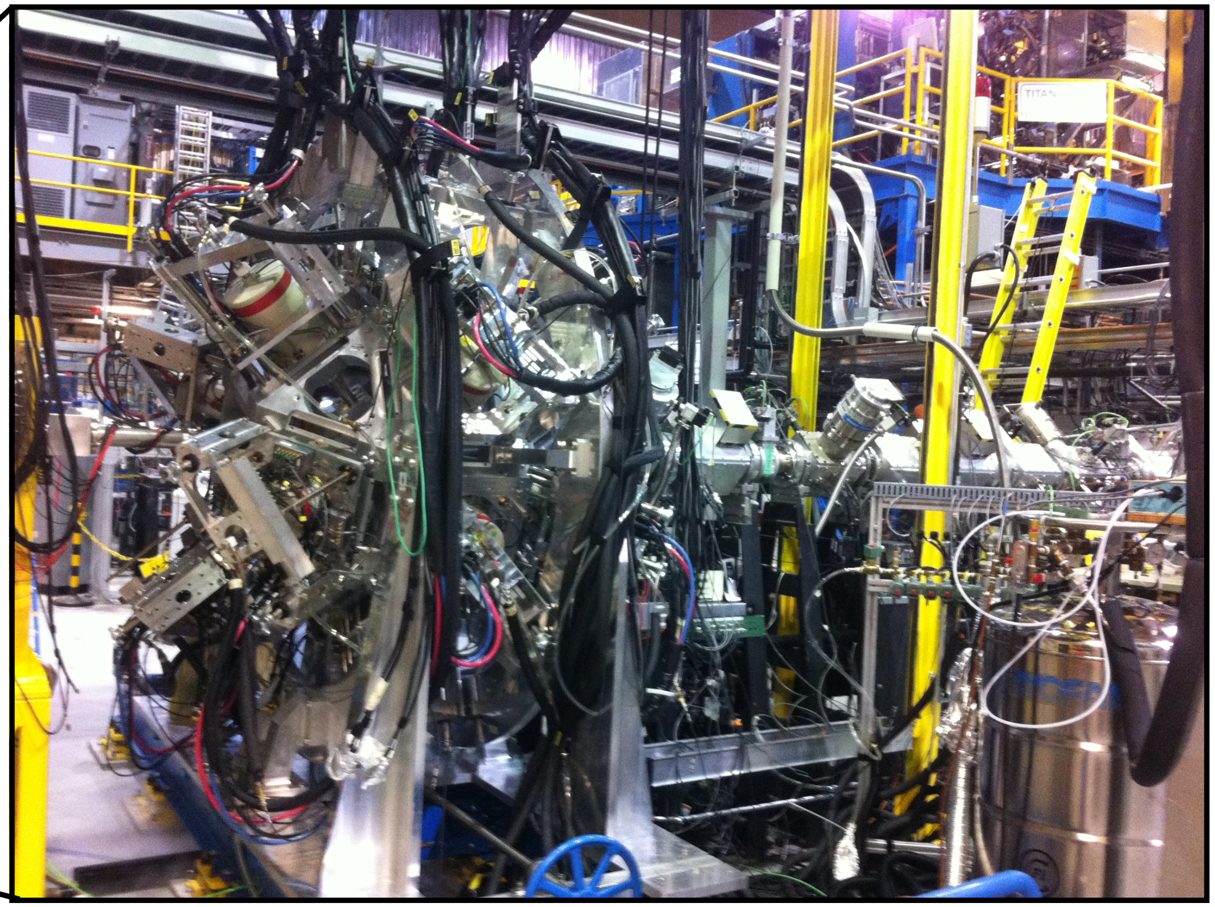

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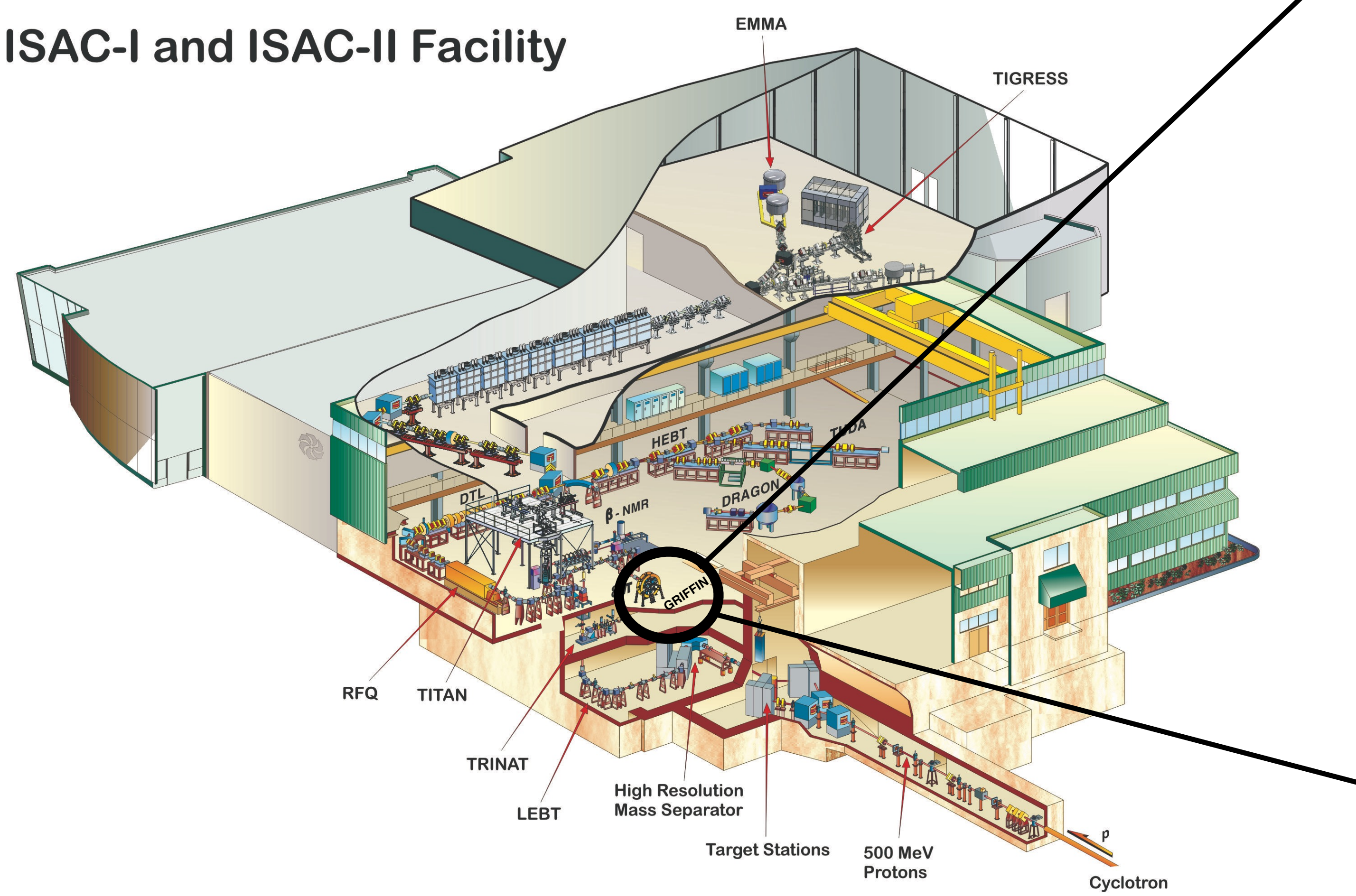

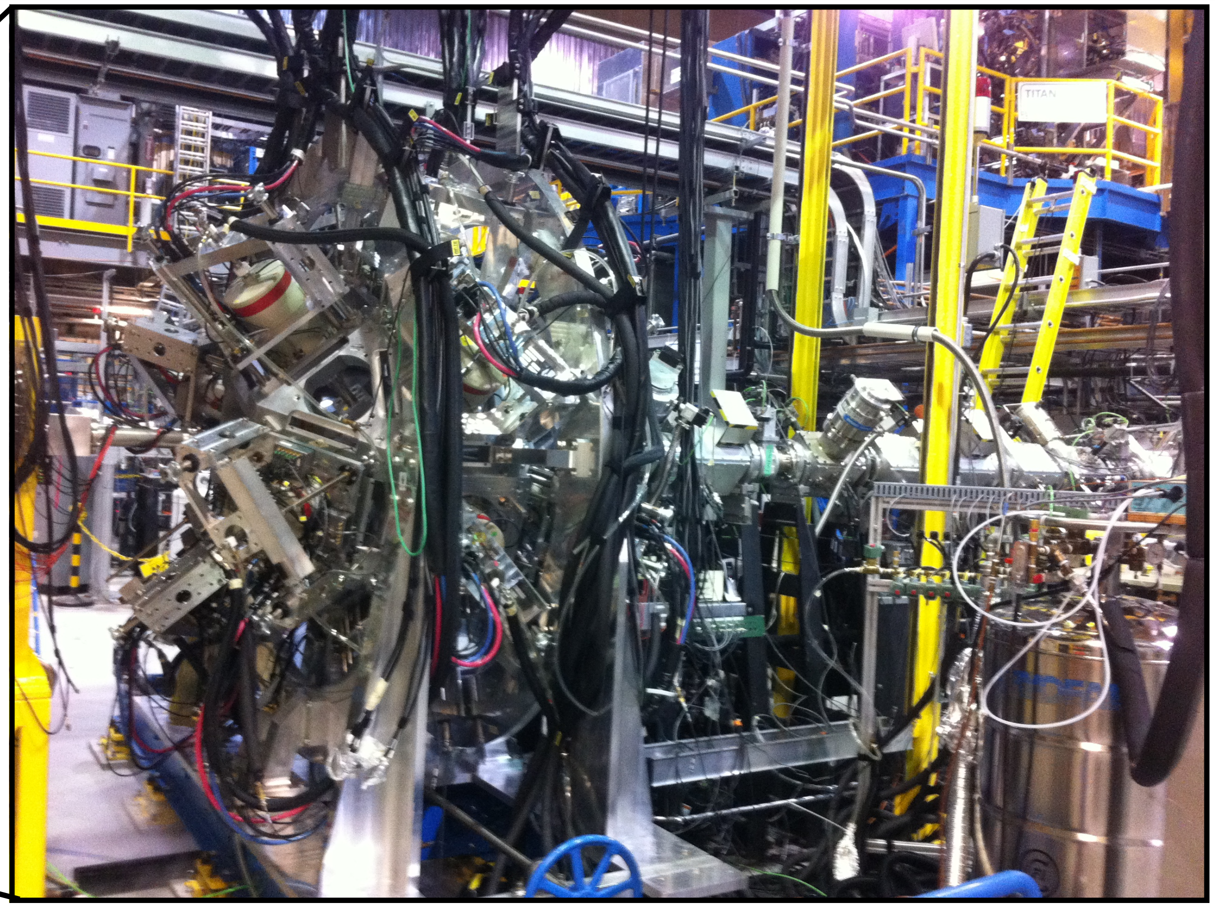

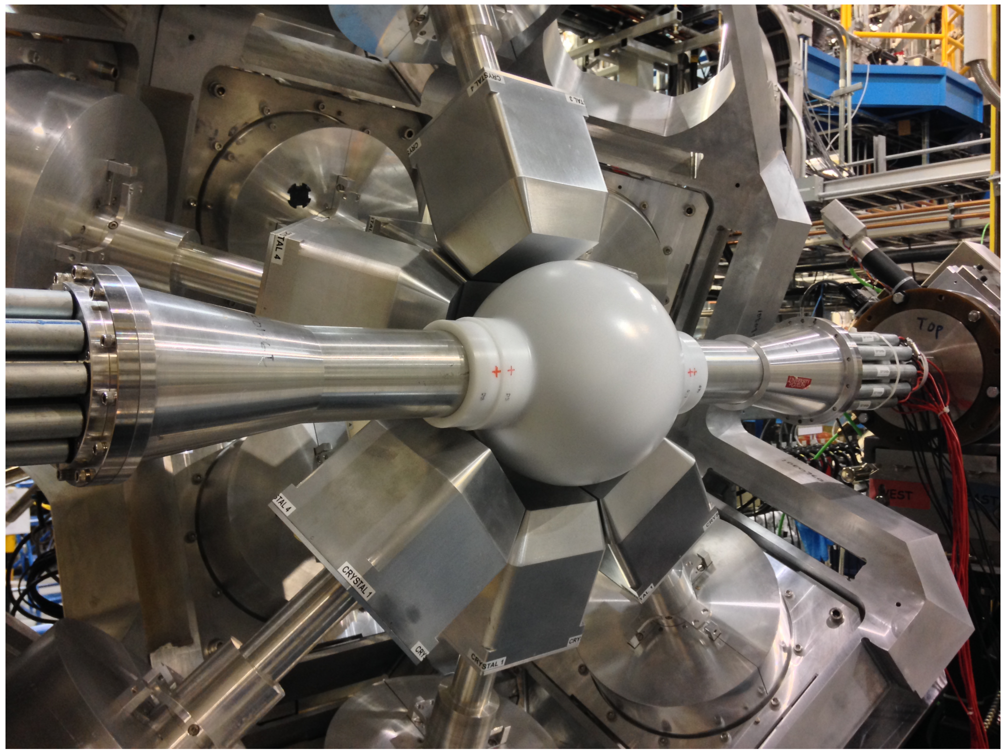

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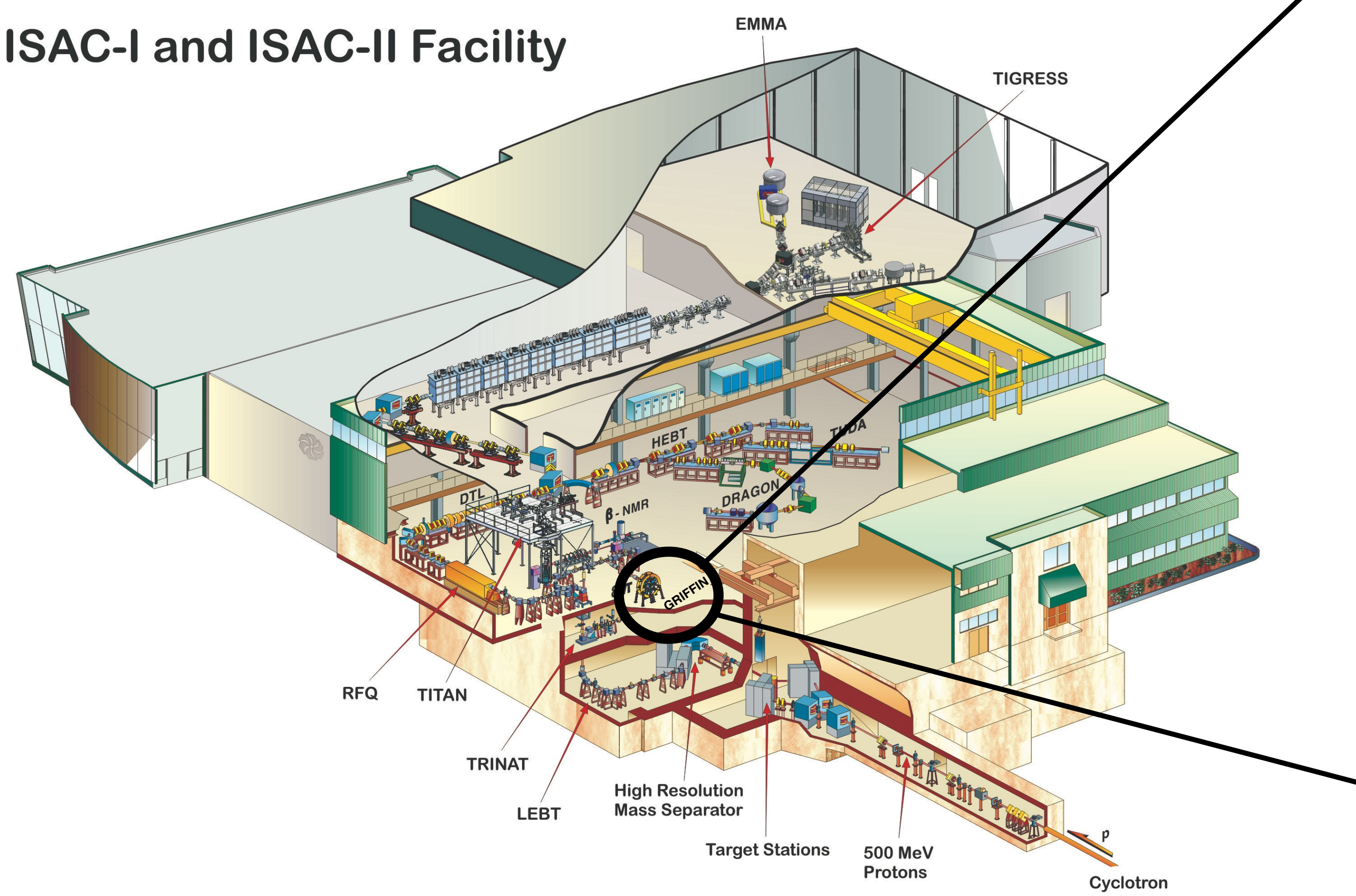

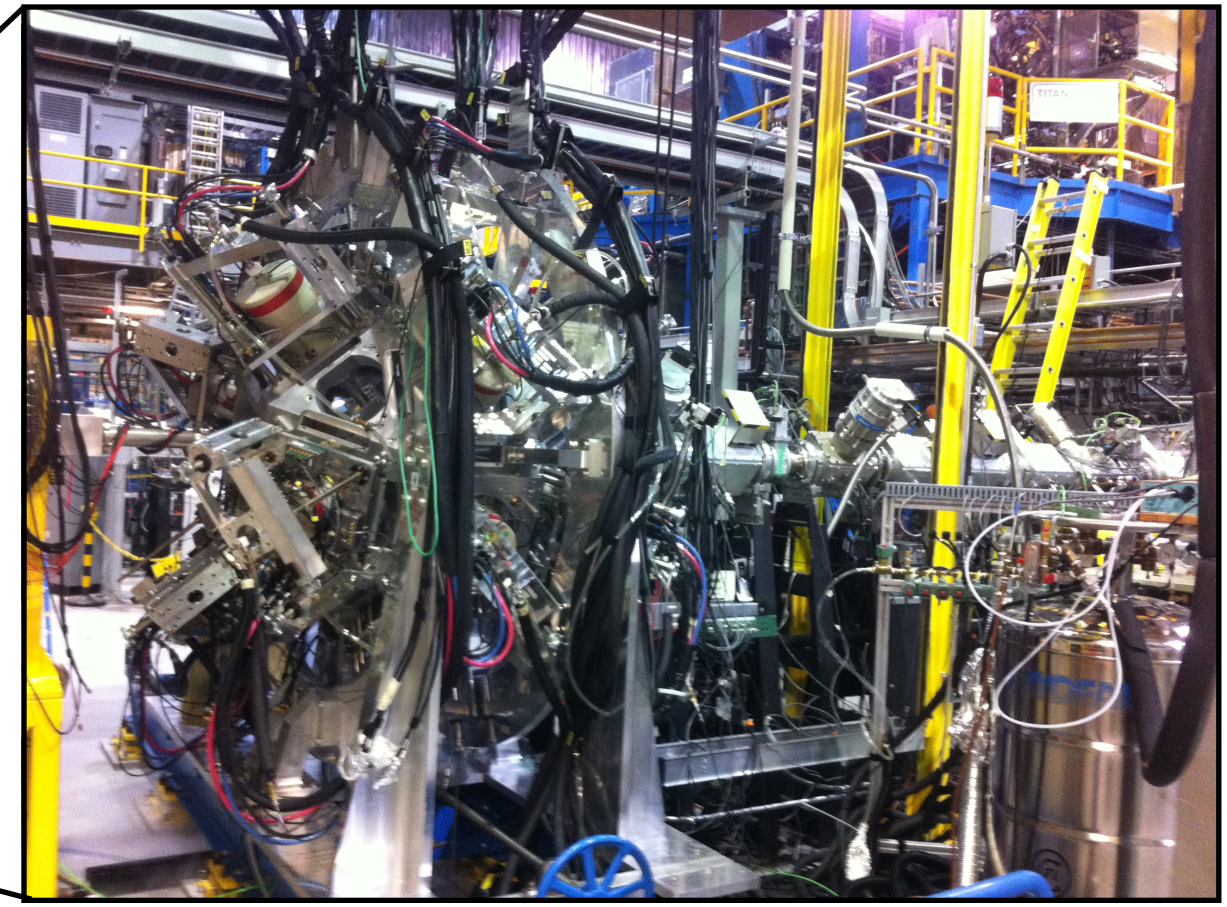

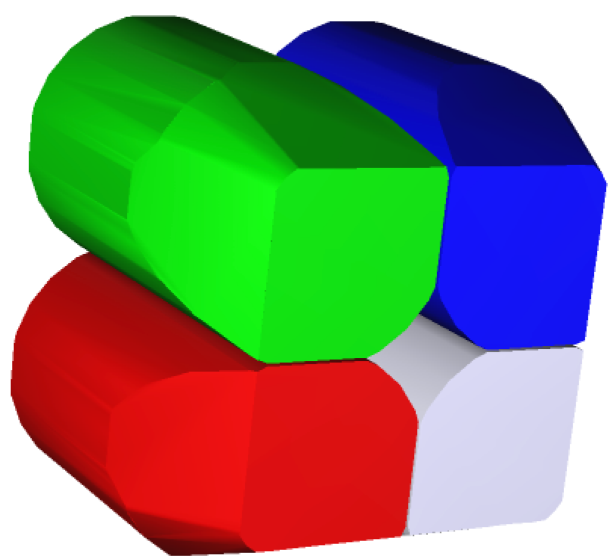

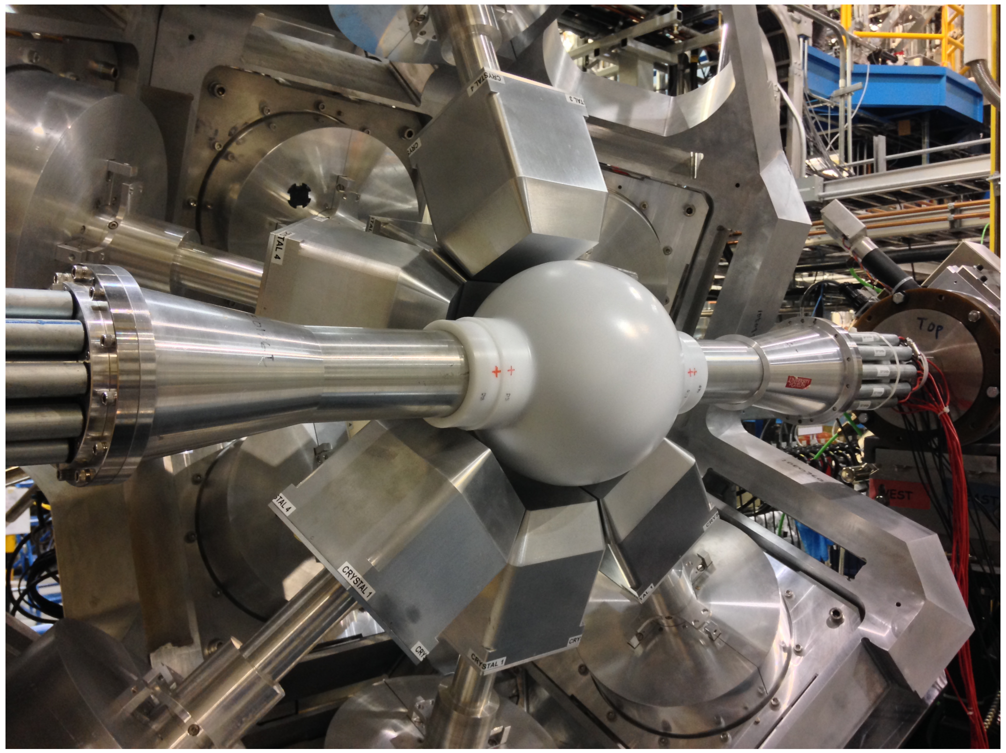

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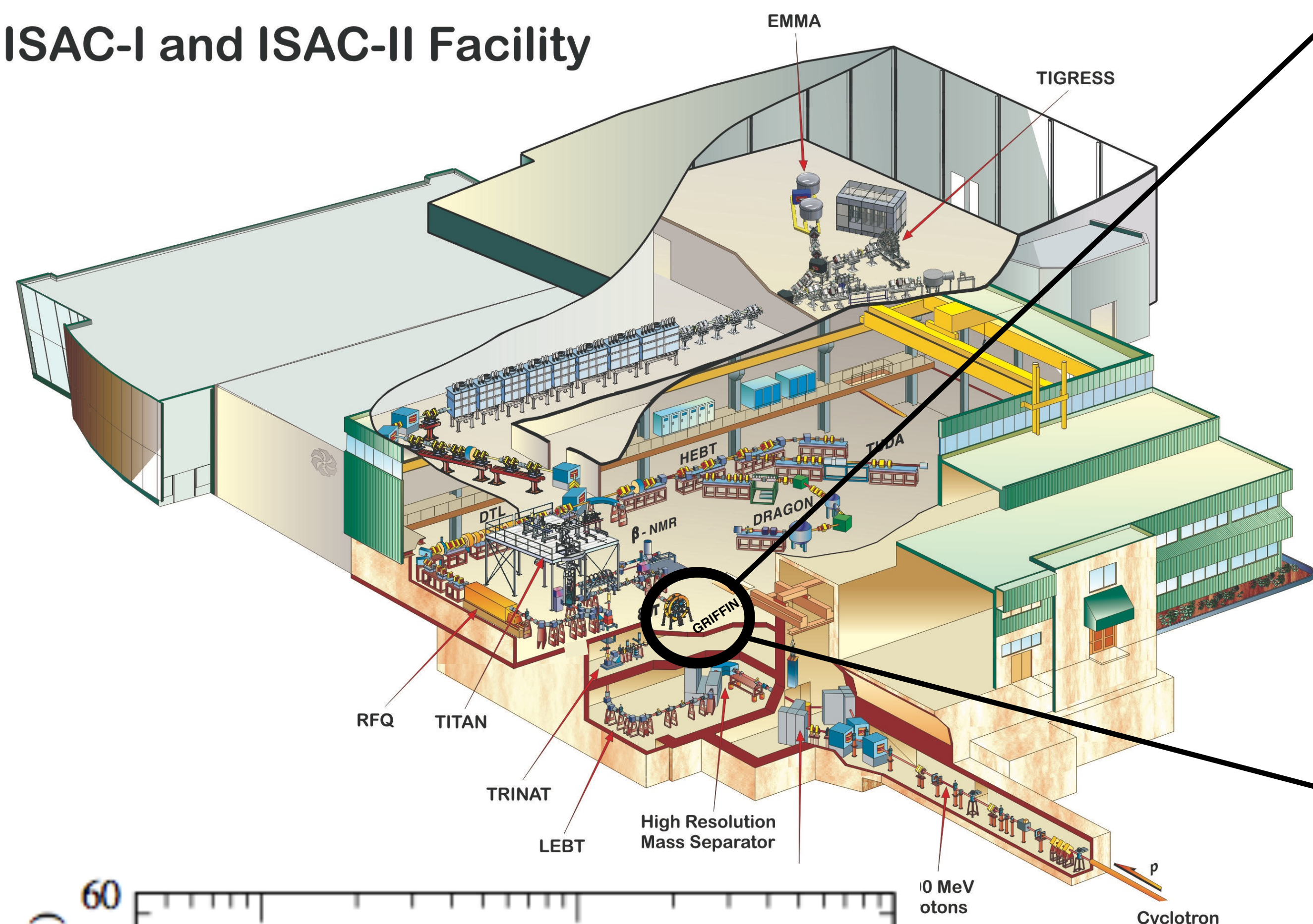

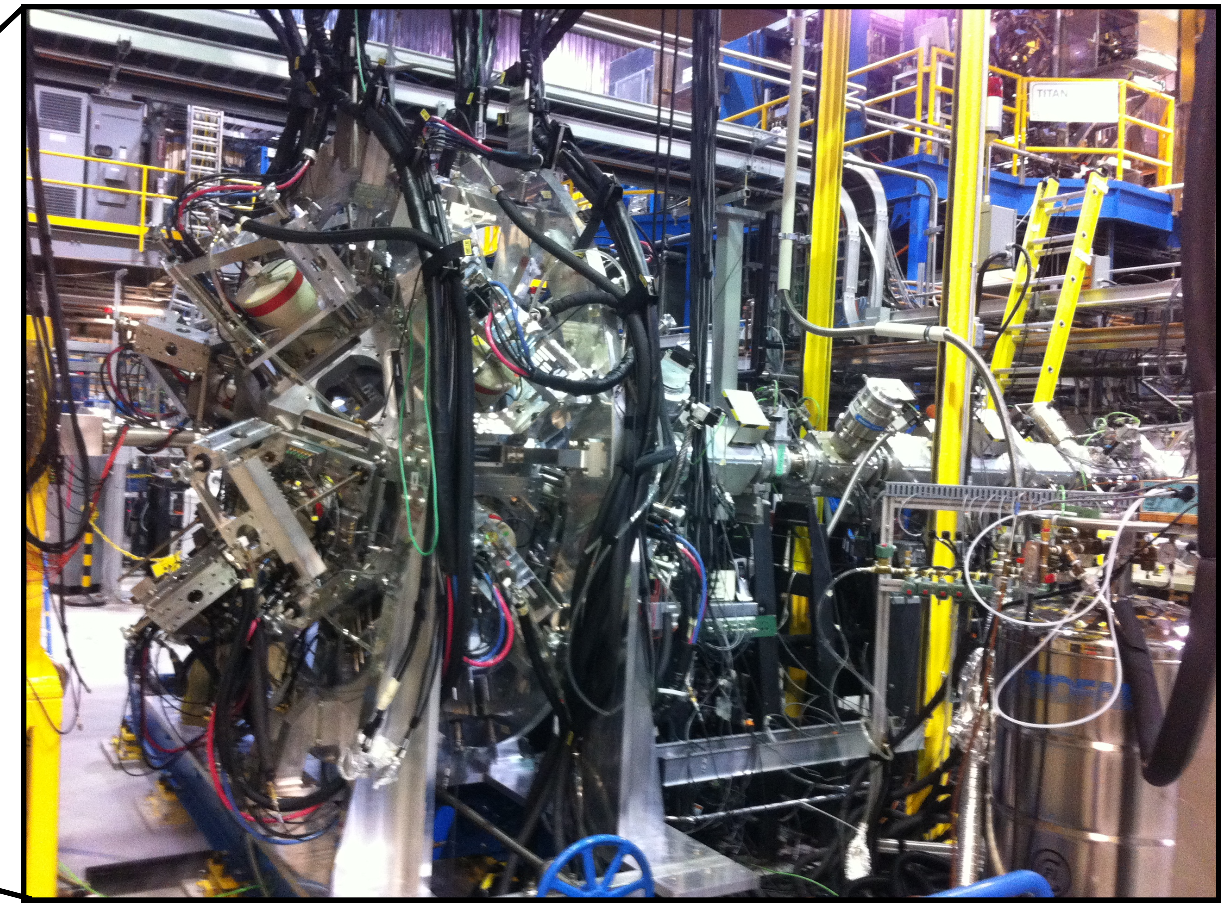

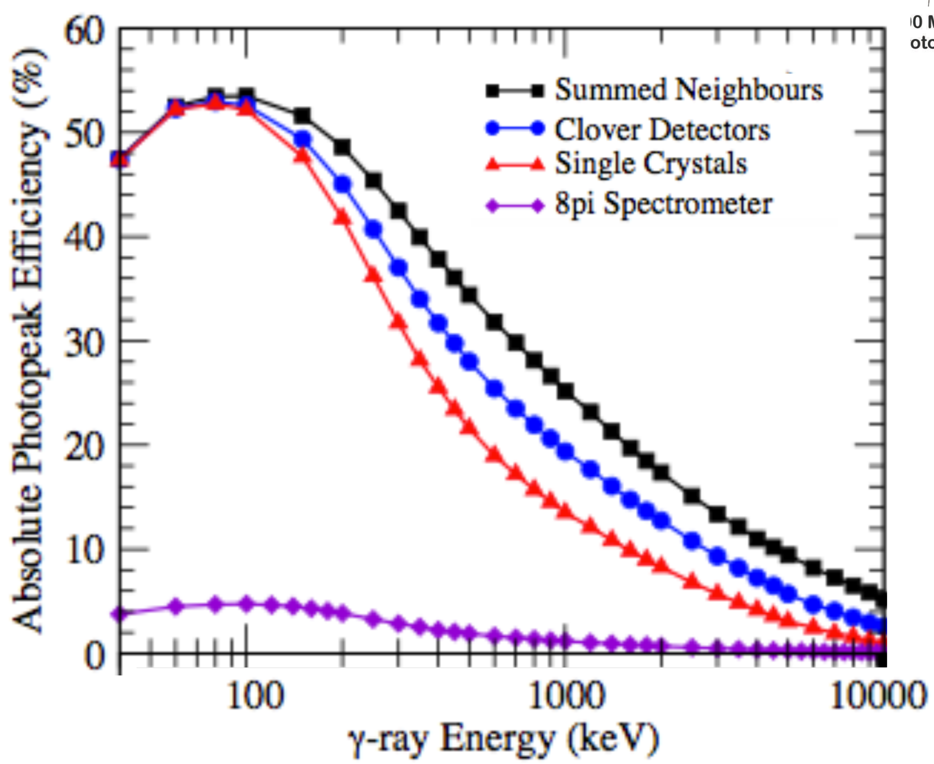

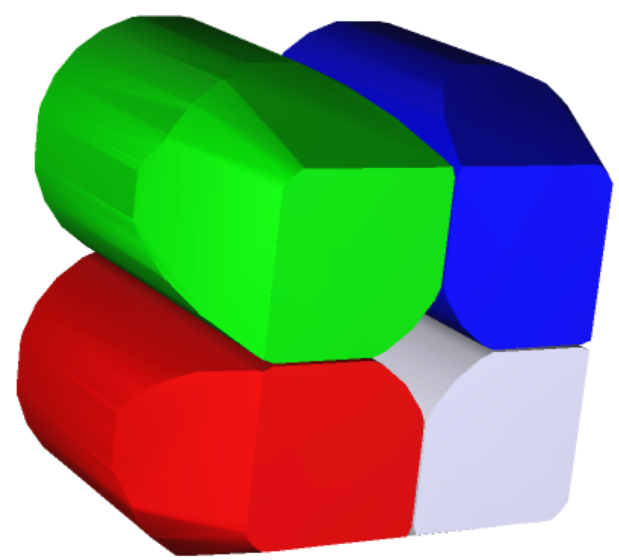

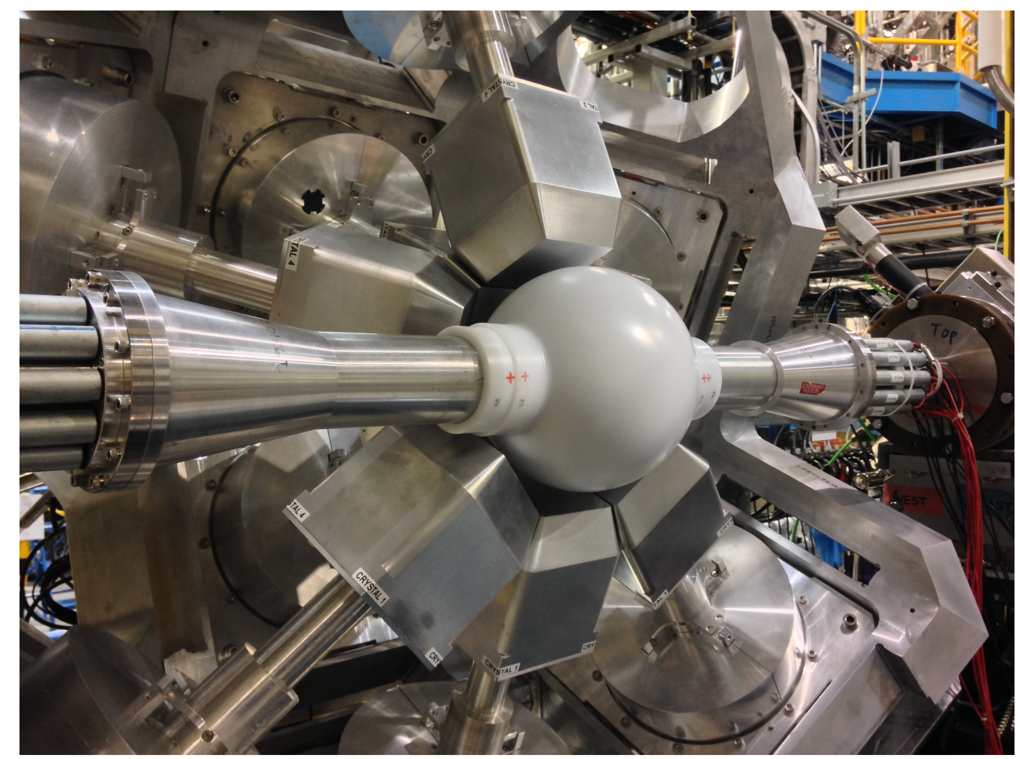

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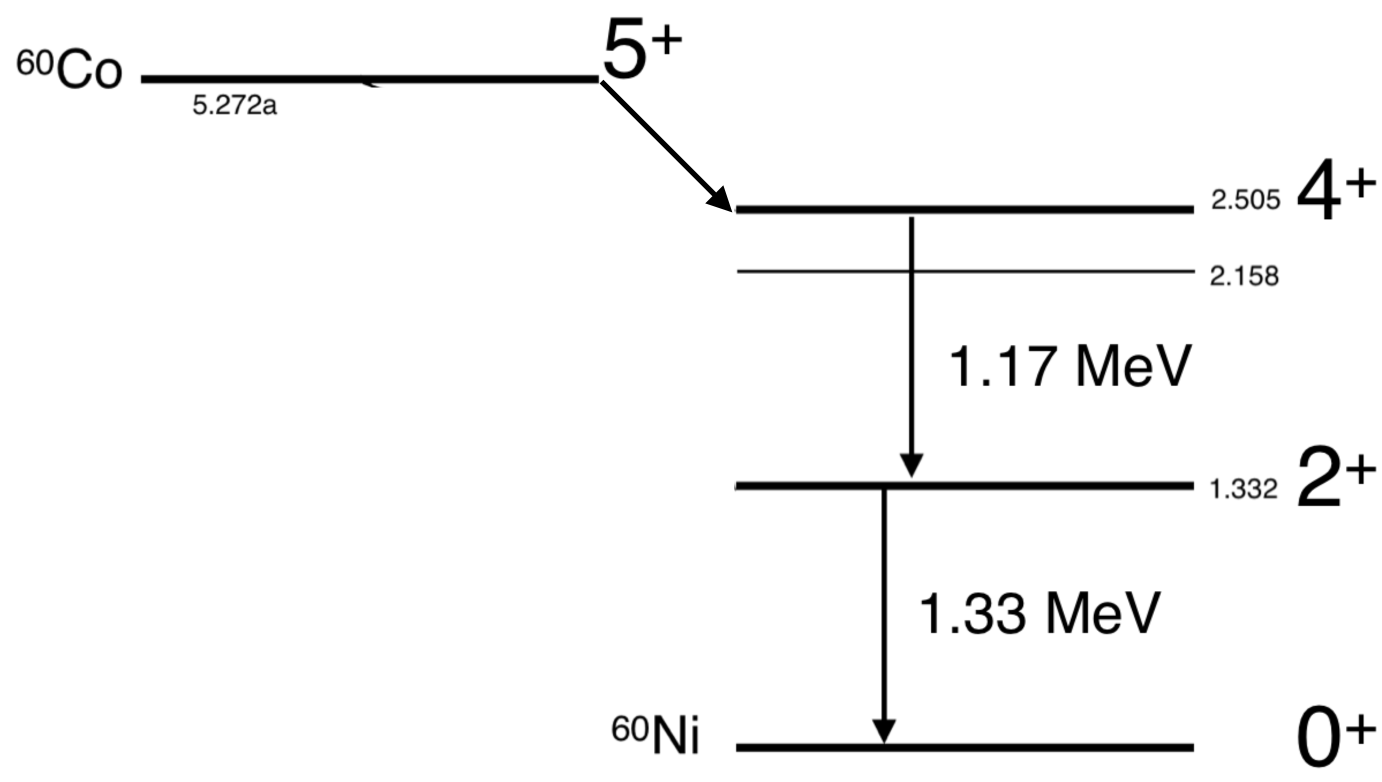
Gamma-Gamma Angular Correlations

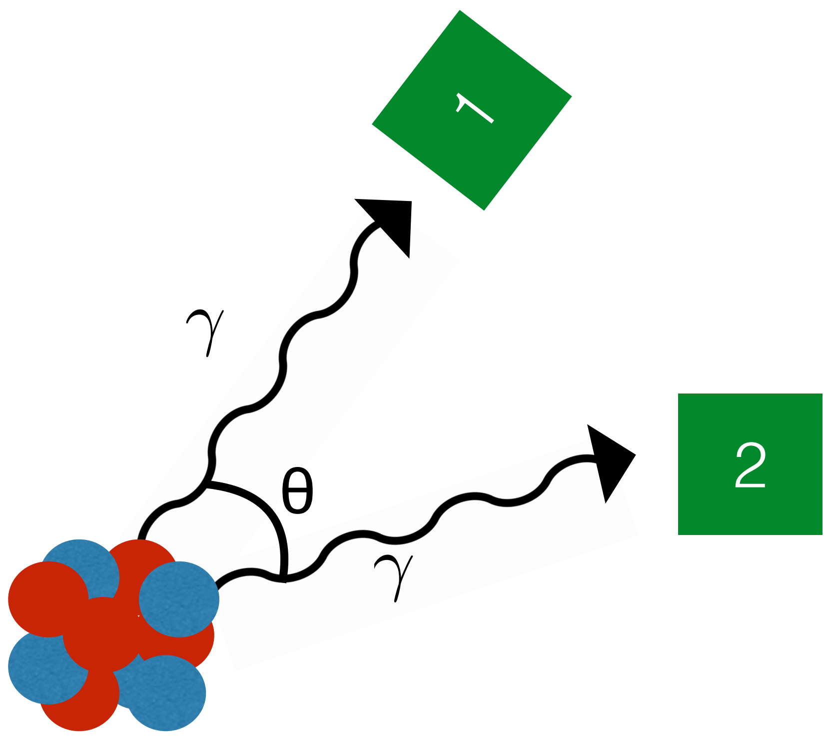
γ-γ angular correlations can be expressed as:

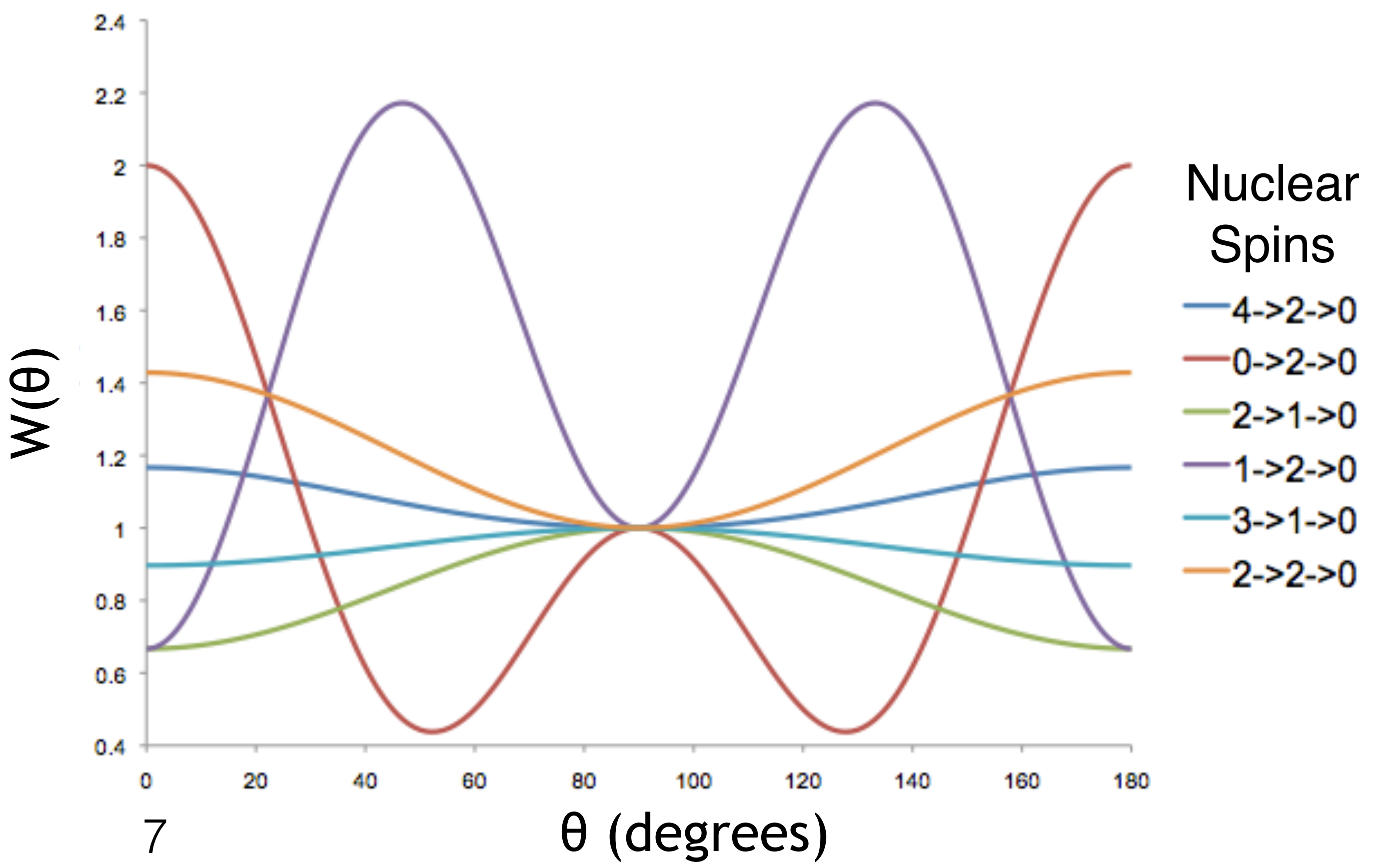
$$W(\theta) = 1 + \sum_{k=even}^{2L} a_k P_k(cos\theta)$$

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

In the GRIFFIN geometry there are 51 distinct opening angles between HPGe crystals. Solid angle effects are treated through Geant4 simulated templates







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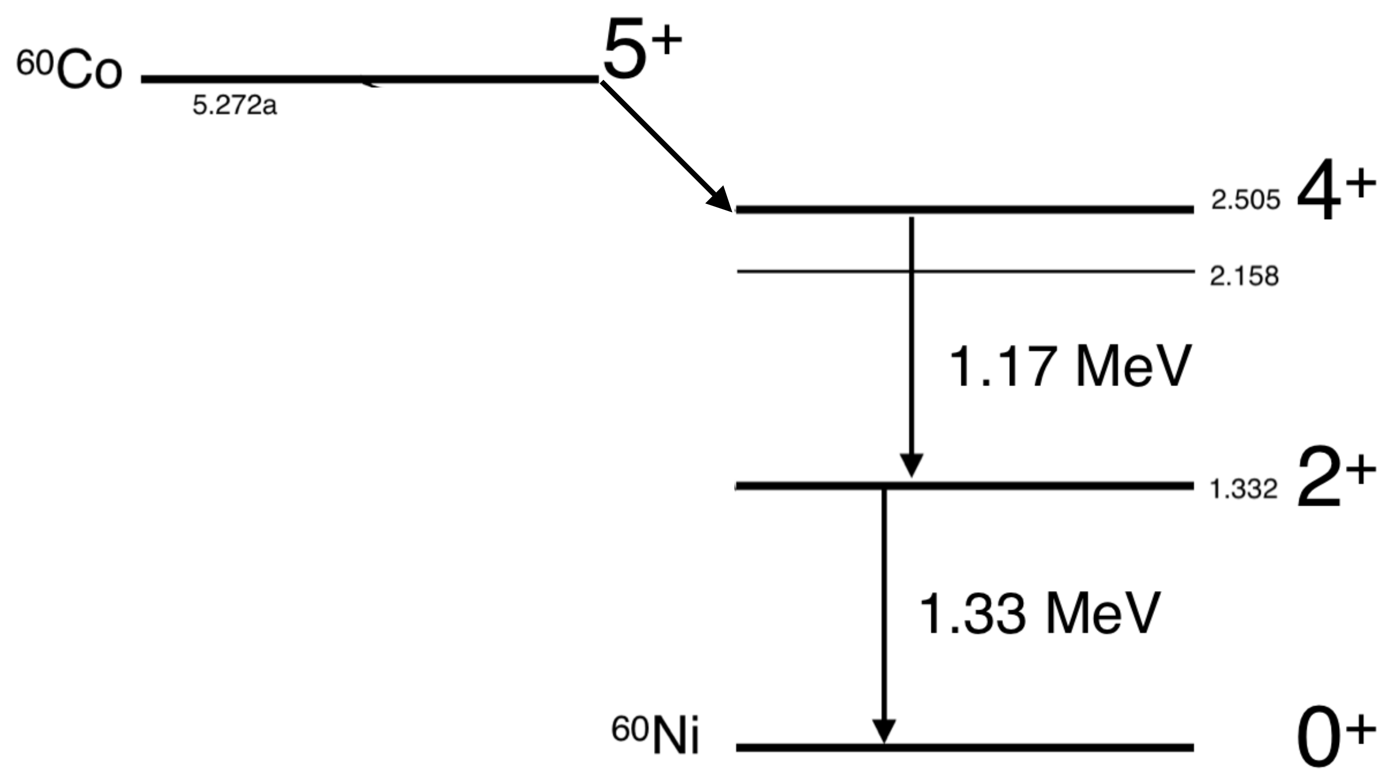
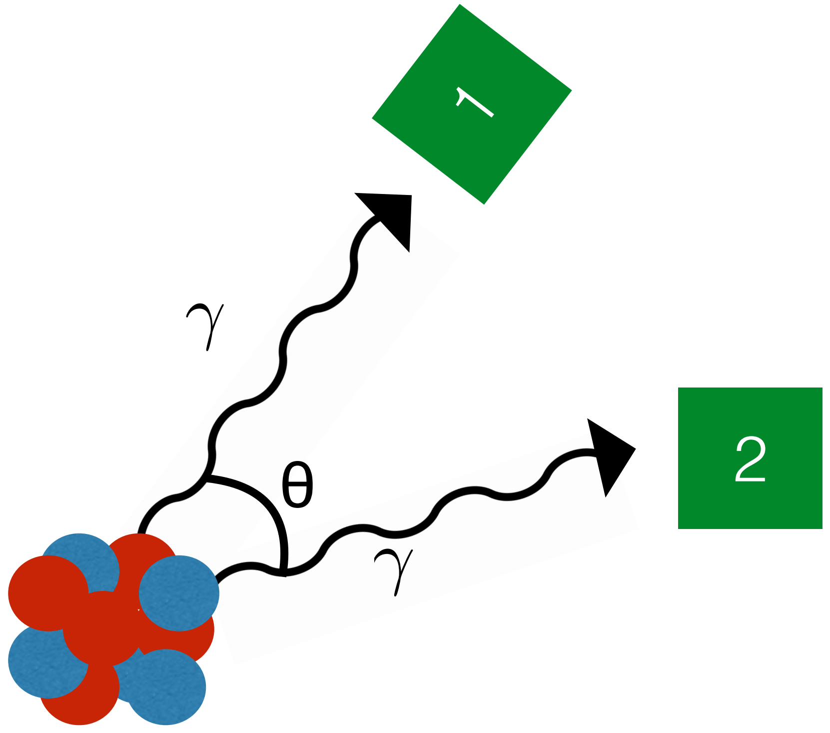
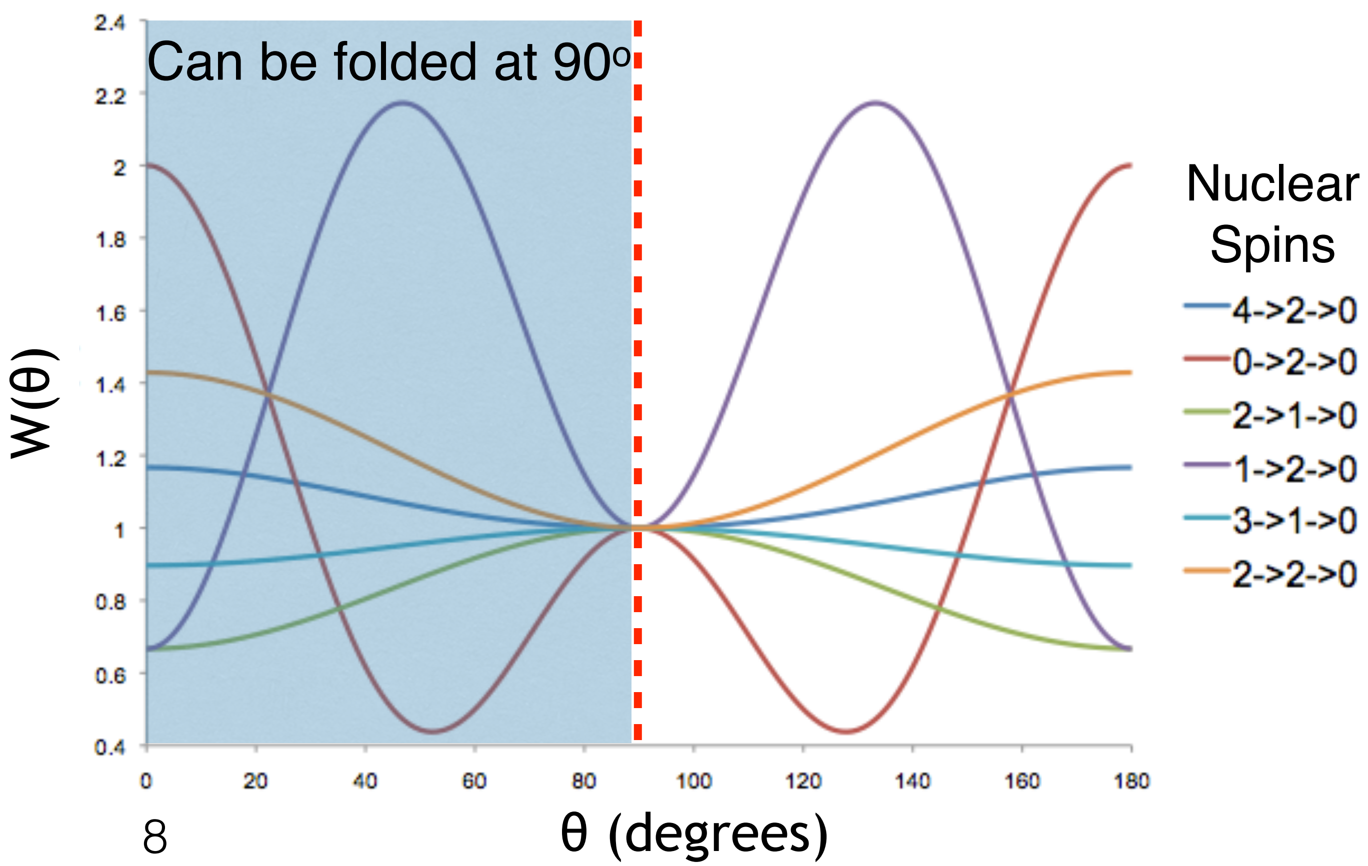


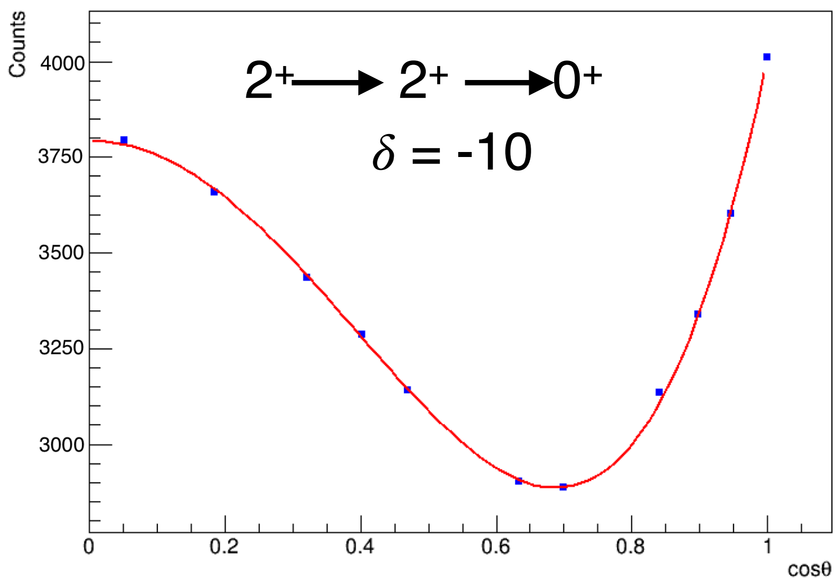


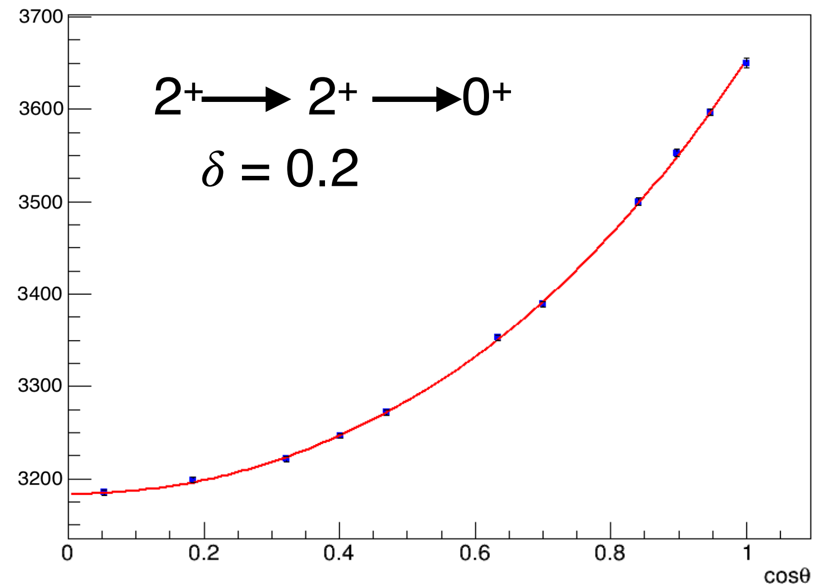


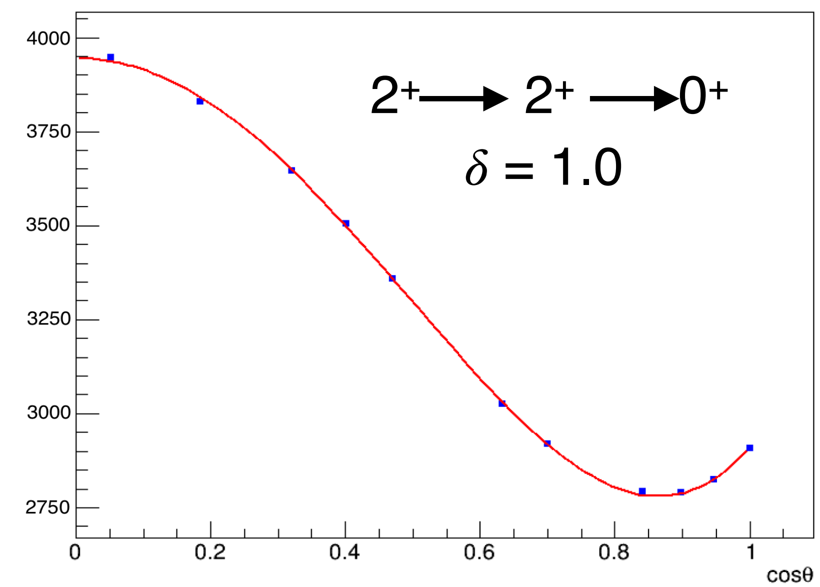
Gamma-Gamma Angular Correlations

For mixed transitions, e.g.. M1/E2, correlations depend strongly on the mixing ratio, δ.

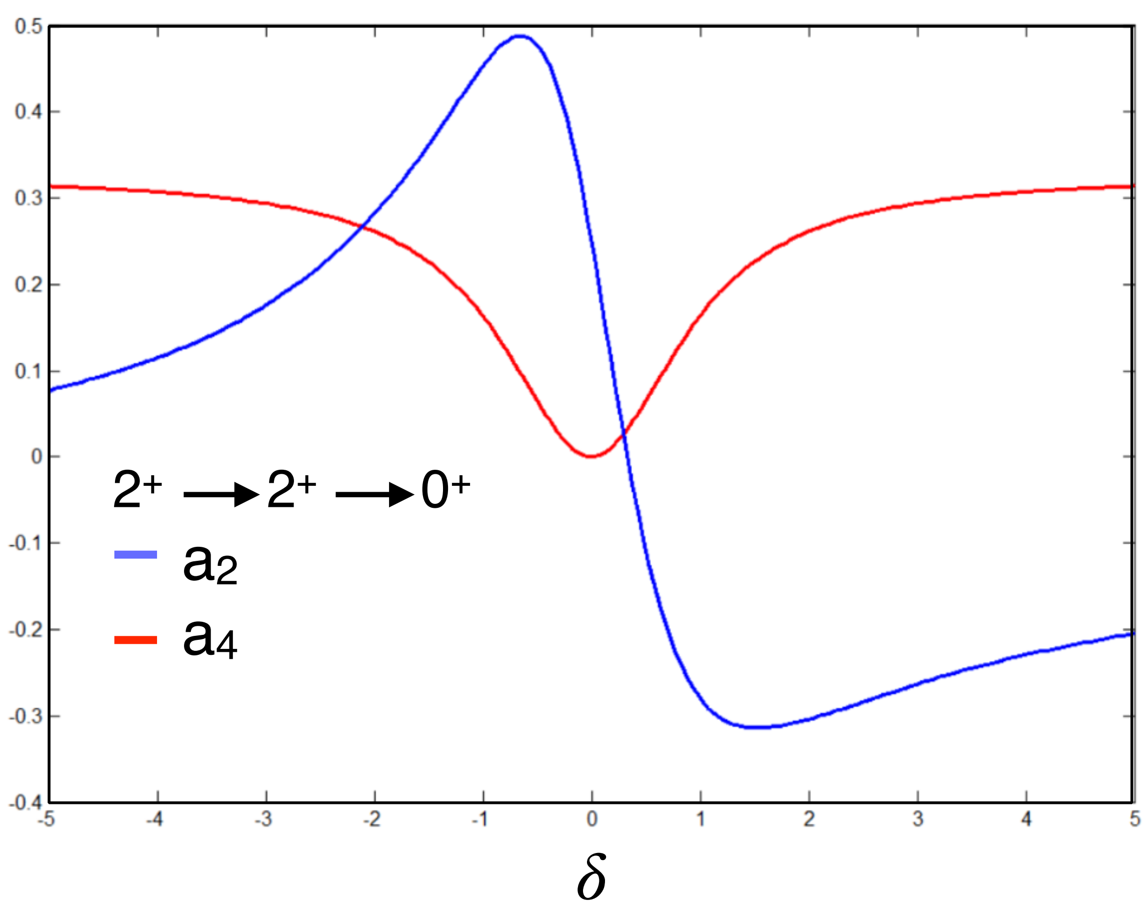
Geant4 simulated templates were made varying the mixing ratio for a 2→2→0 cascade.

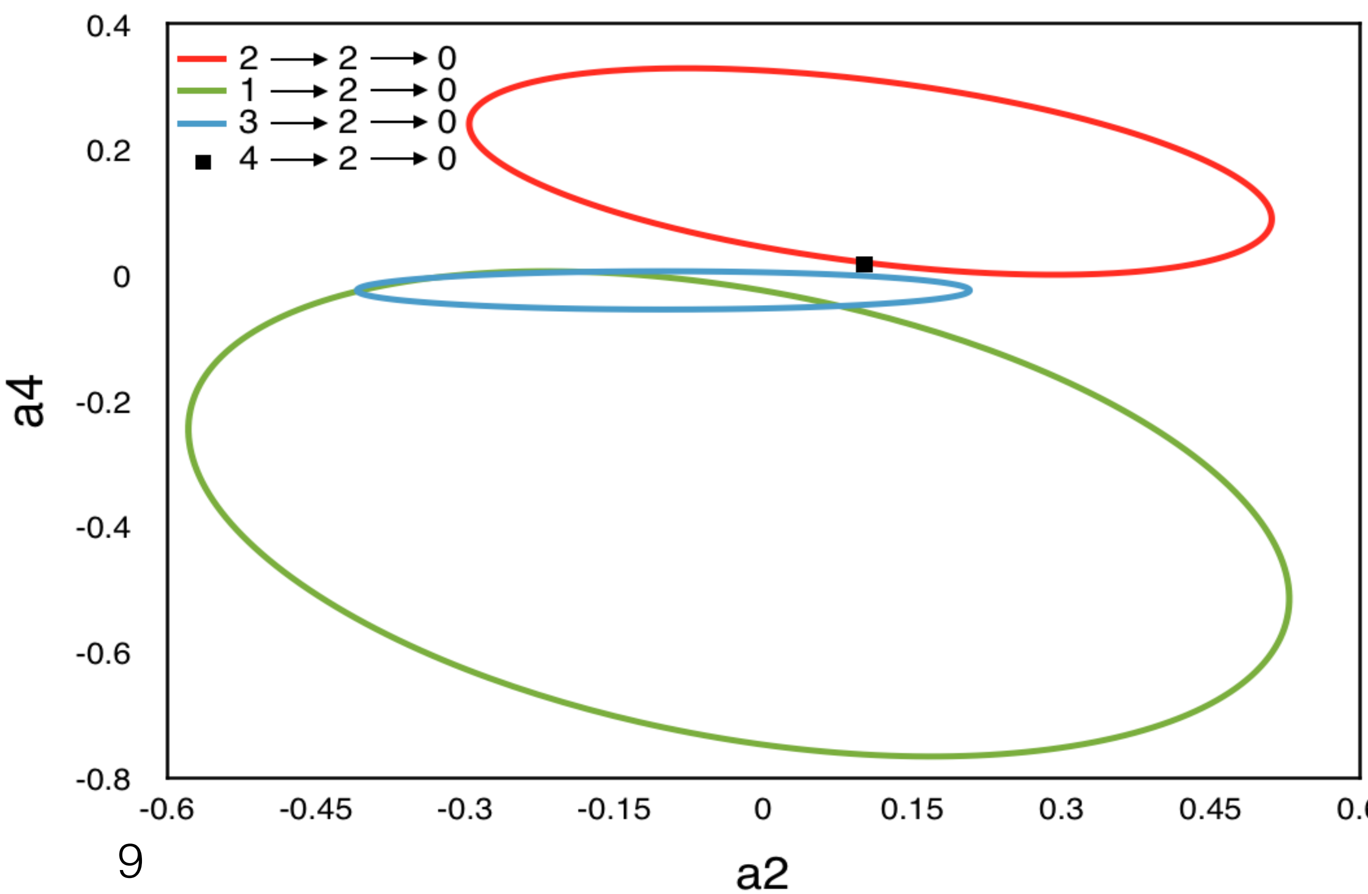




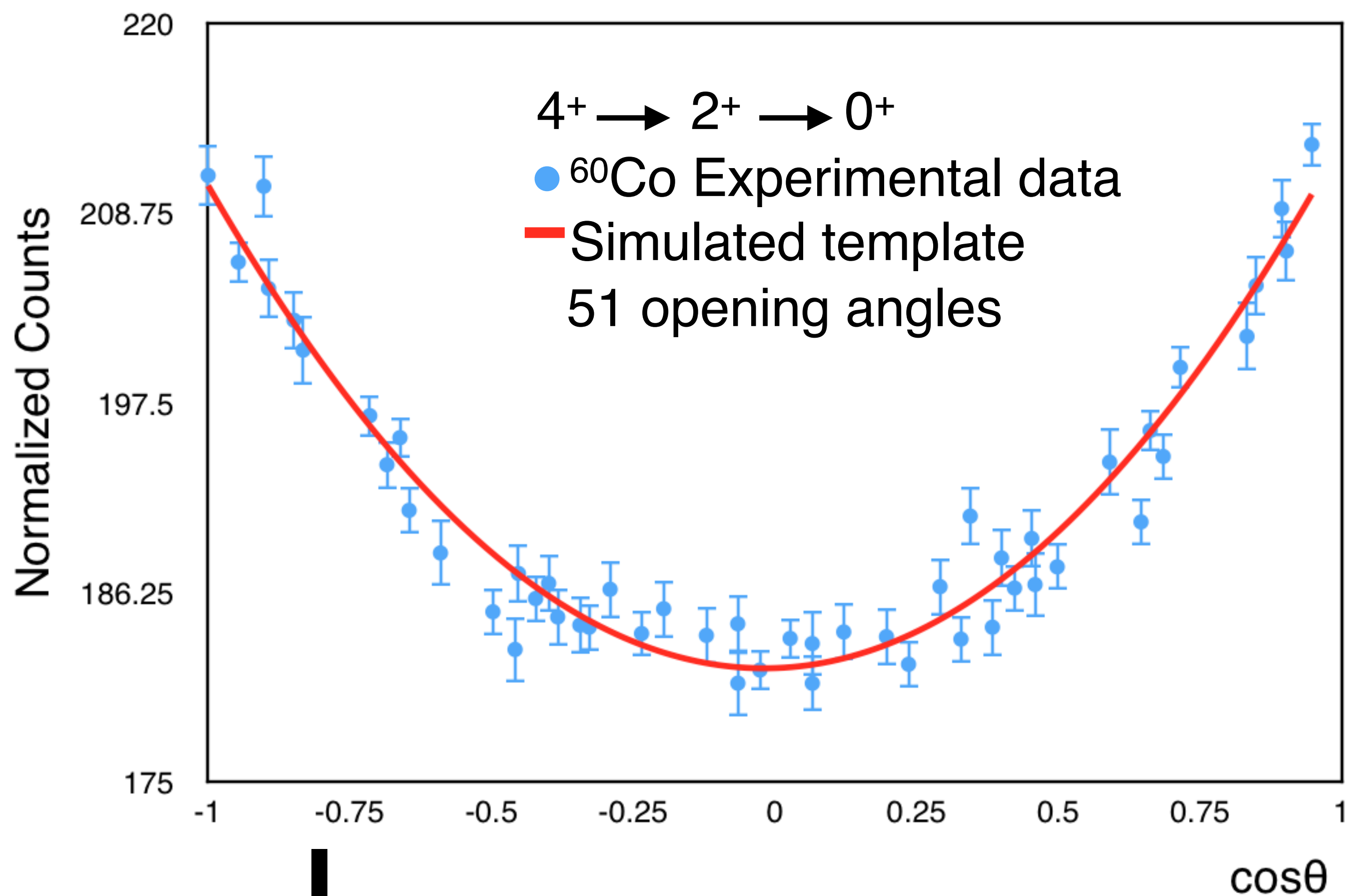


To determine likeness of unique cascades relationships were investigated to comprehend these similarities.



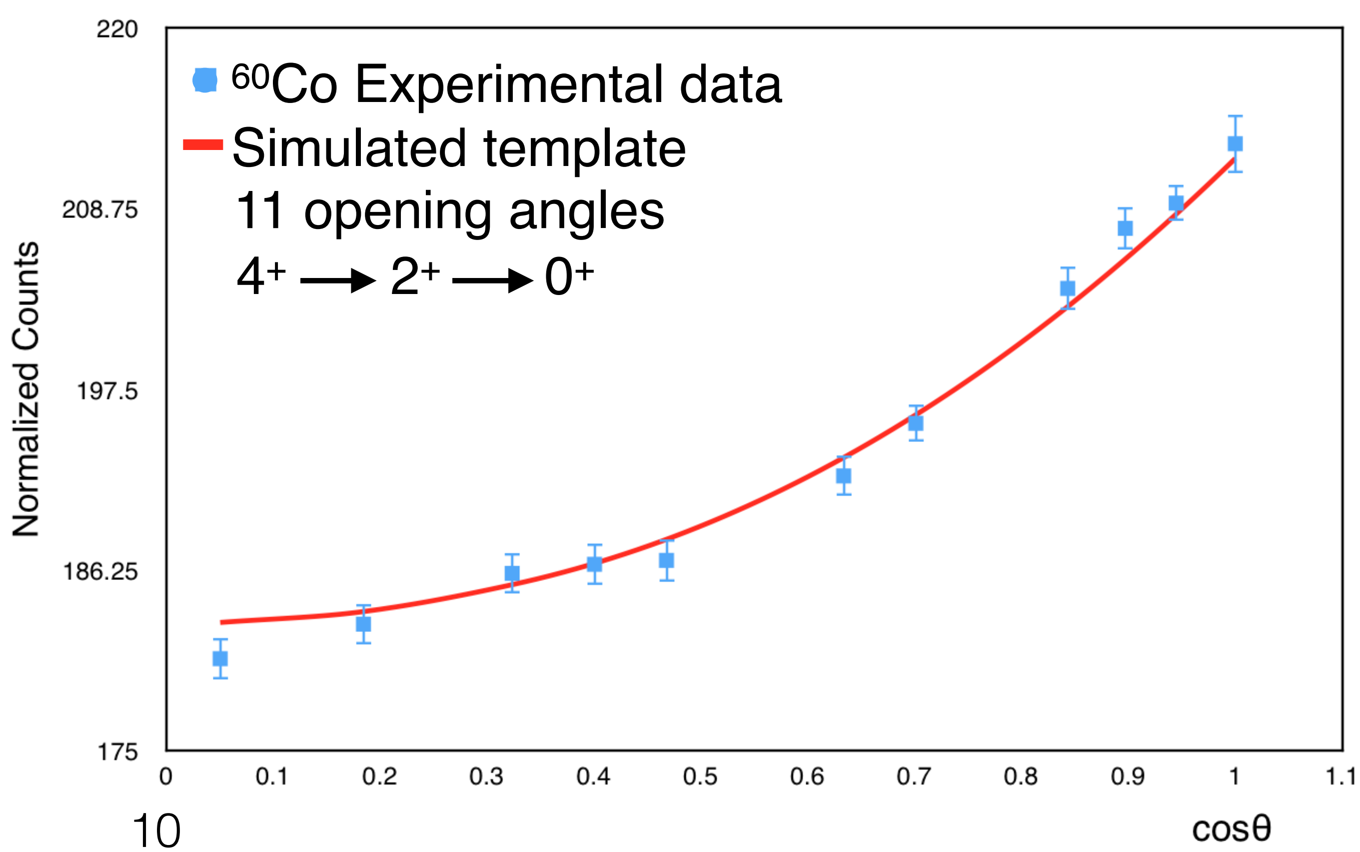


Gamma-Gamma Angular Correlation Measurements With GRIFFIN



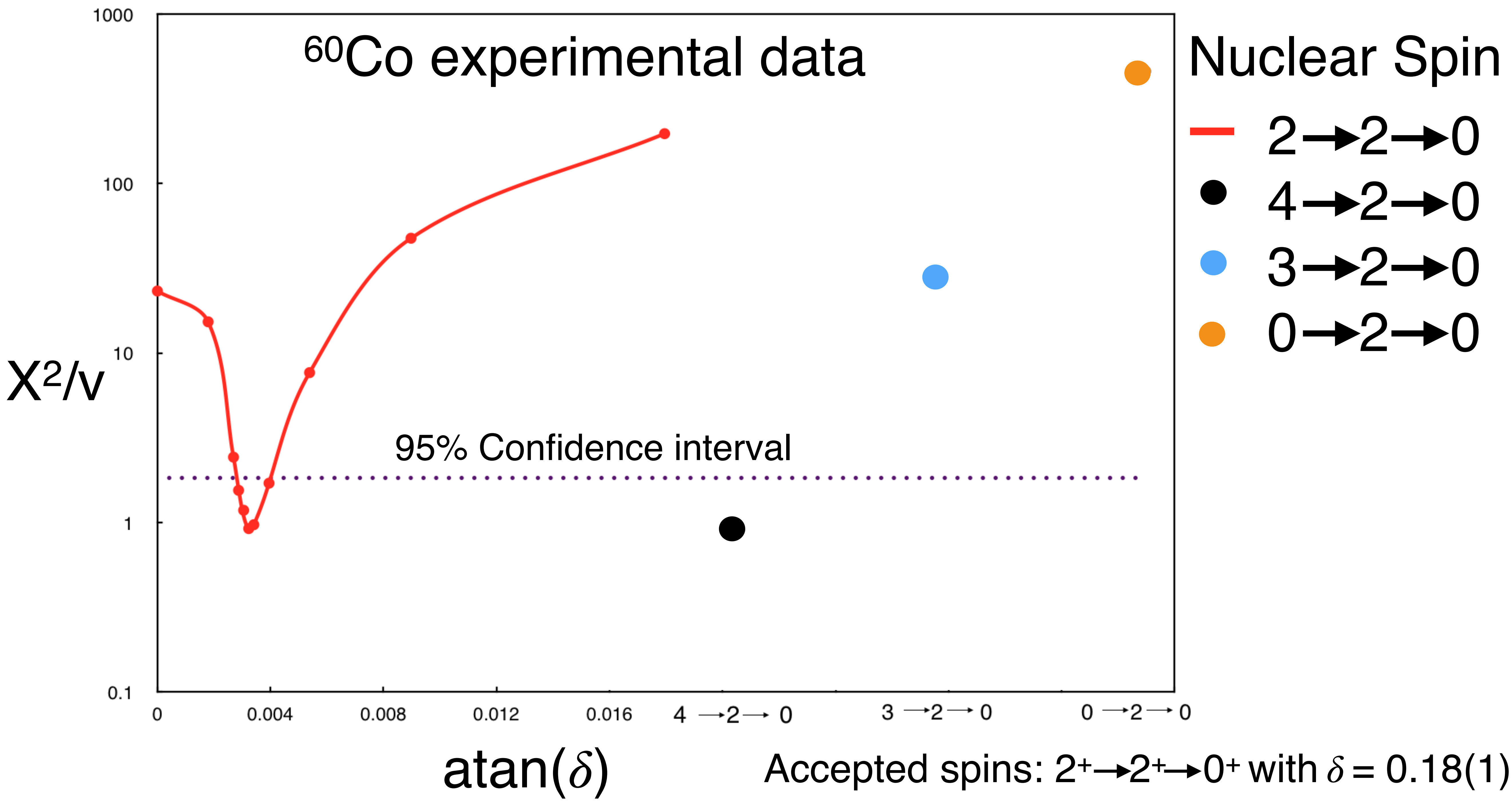
- ^{60}Co data taken from a source placed in the centre of the array.
- This is then overlaid with the Geant4 simulated template.

Grouped similar angles and folded about 90°. Reduces angular bins from 51 to 11.



Gamma-Gamma Angular Correlation Measurements With GRIFFIN

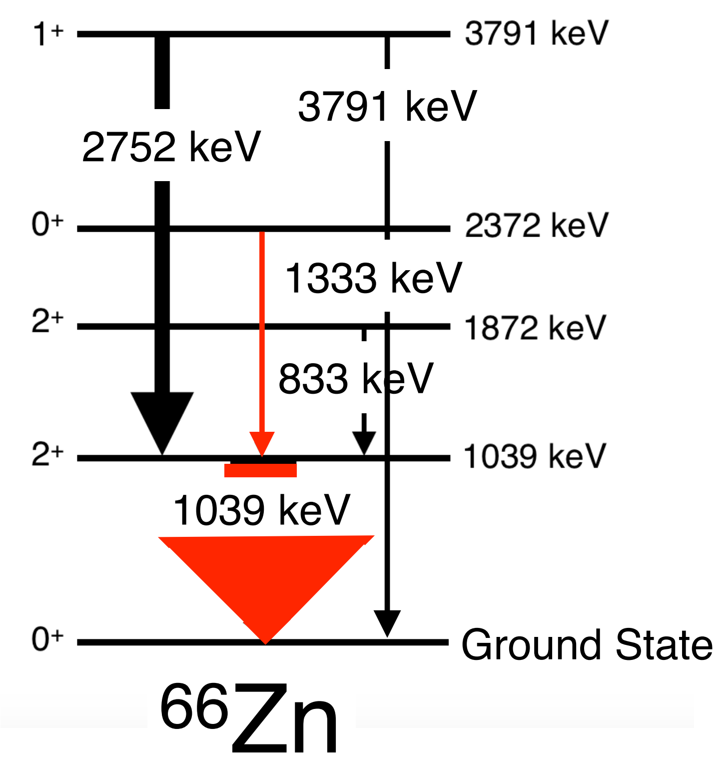
- A reduced chi squared is then made for each simulated template to determine which spin assignments and mixing ratios match the experimental data.

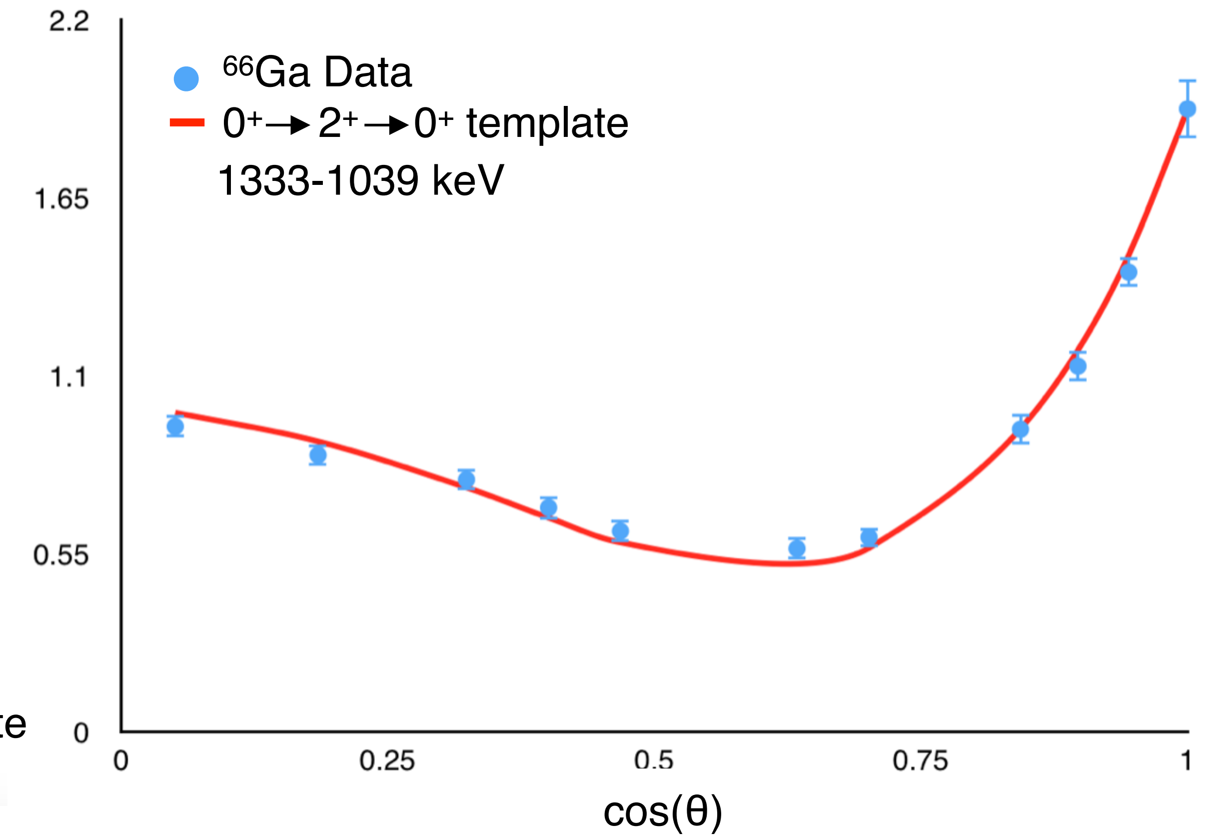


Accepted spins: $2^+ \rightarrow 2^+ \rightarrow 0^+$ with $\delta = 0.18(1)$

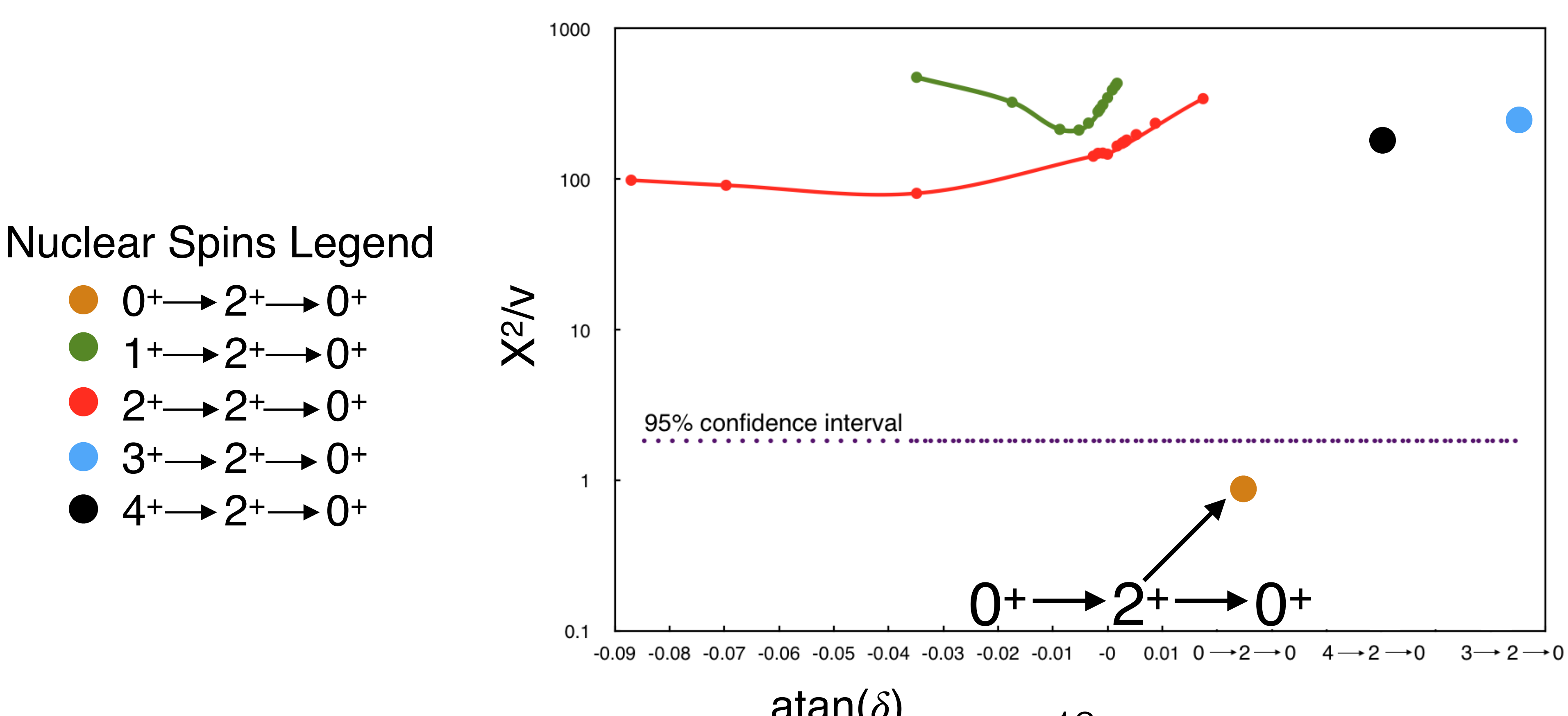
$4^+ \rightarrow 2^+ \rightarrow 0^+$ with no mixing

^{66}Ga Radioactive Beam Experimental Data



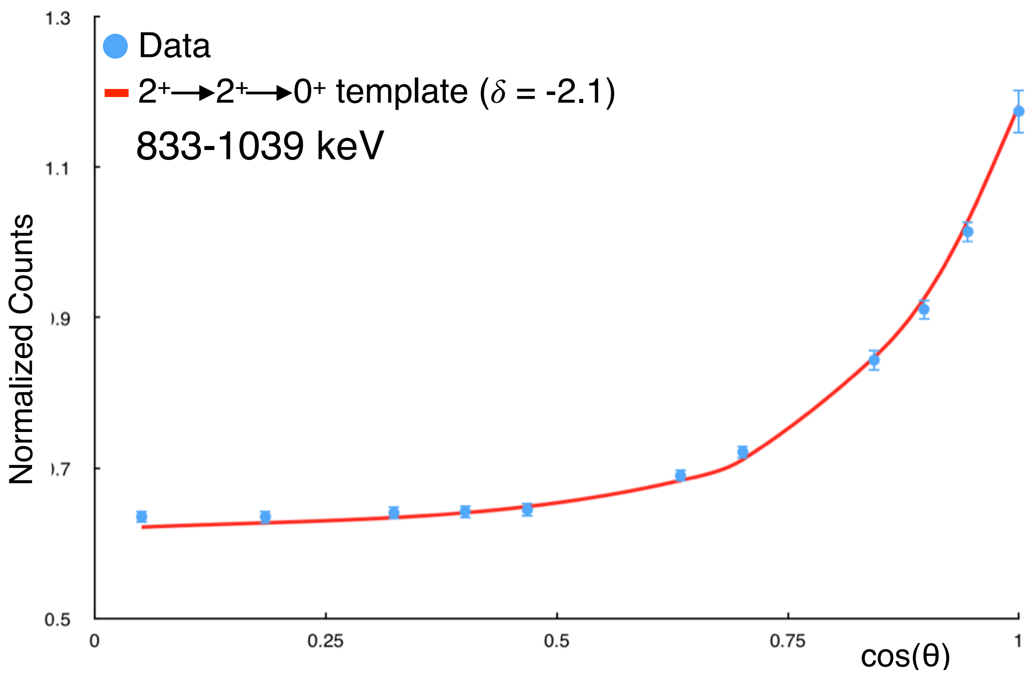


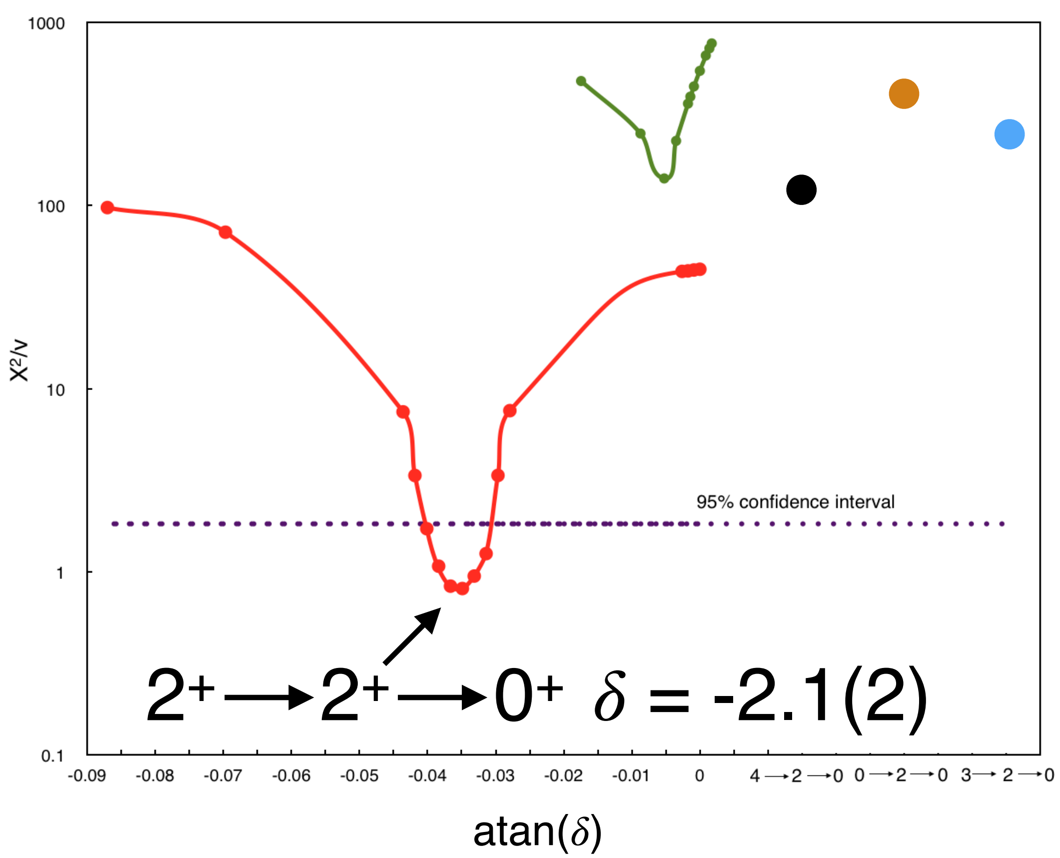
The first in-beam measurement was to investigate a $0^+ \rightarrow 2^+ \rightarrow 0^+$ cascade between the 1333-1039 keV gamma-rays following ^{66}Ga beta decay.

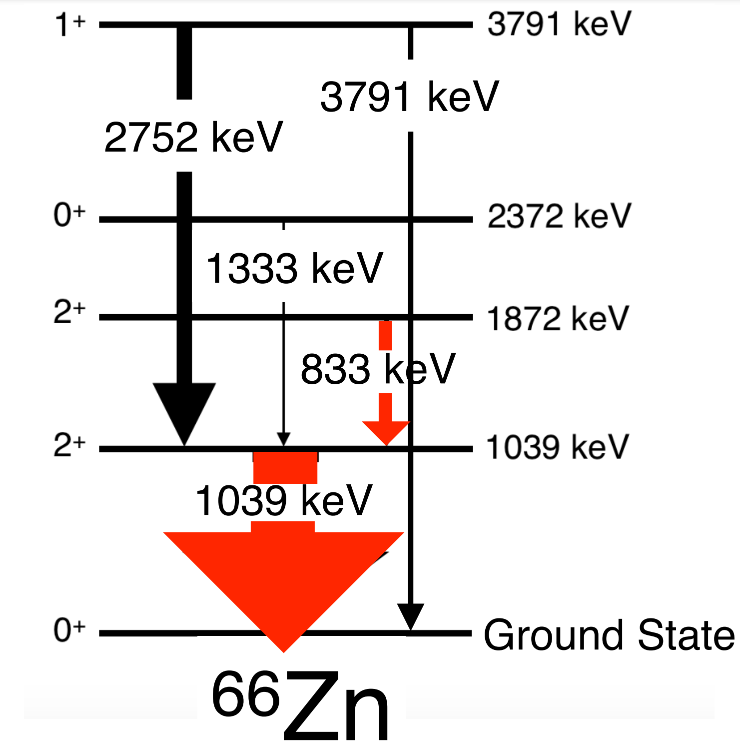


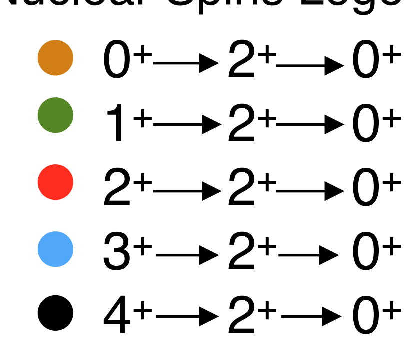
The distinct $0^+ \rightarrow 2^+ \rightarrow 0^+$ template yields a X^2/v = 0.96 when compared to experimental data, while all other spin sequences yield X^2/v >100.

^{66}Ga Radioactive Beam Experimental Data









Cascade	[1]	[2]	δ (This work)
833-1039 keV	-1.9(3)	-1.6(2)	-2.1(2)
2752-1039 keV	-0.09(3)	-0.12(2)	-0.08(3)

[1] M. R. Bhat, Nucl. Data Sheets **83**, 83.
[2] A. Gade, Phys. Rev. C **65**, 054311.

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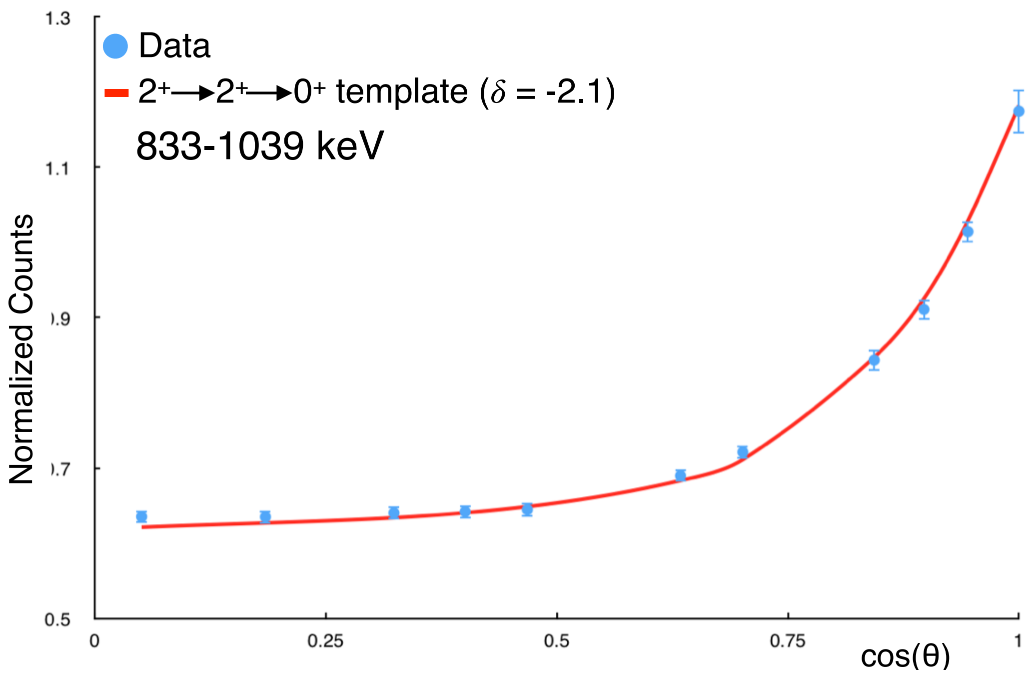

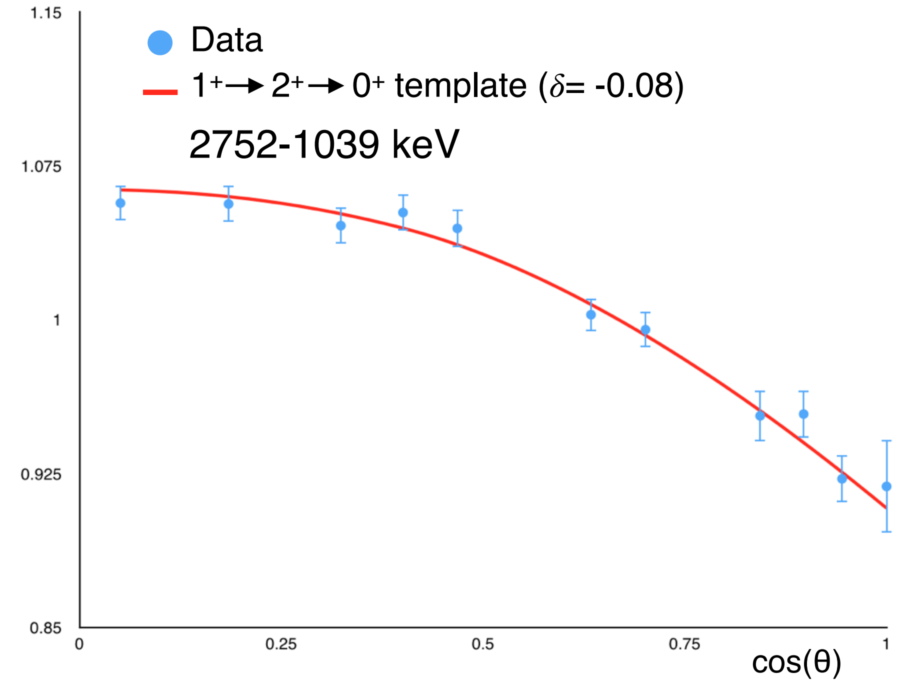

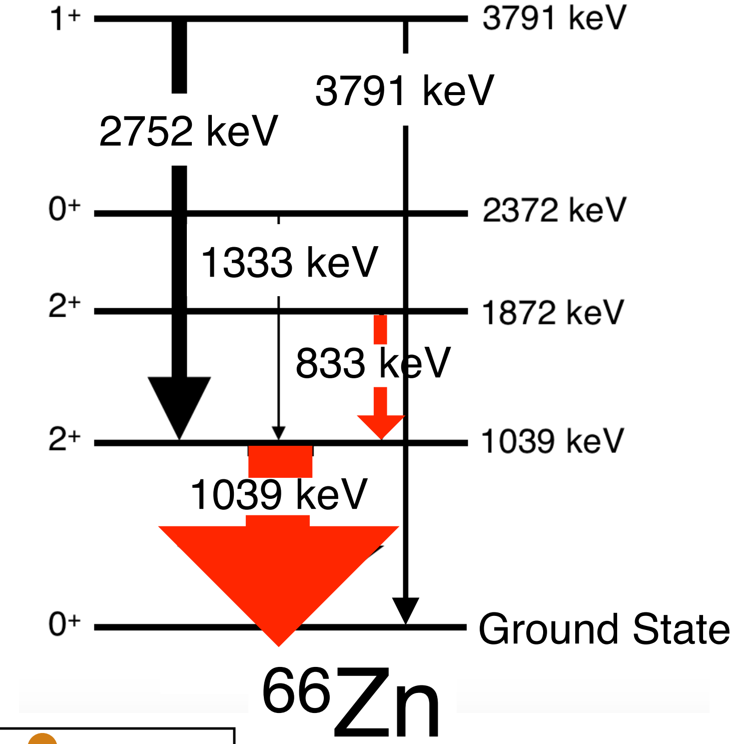

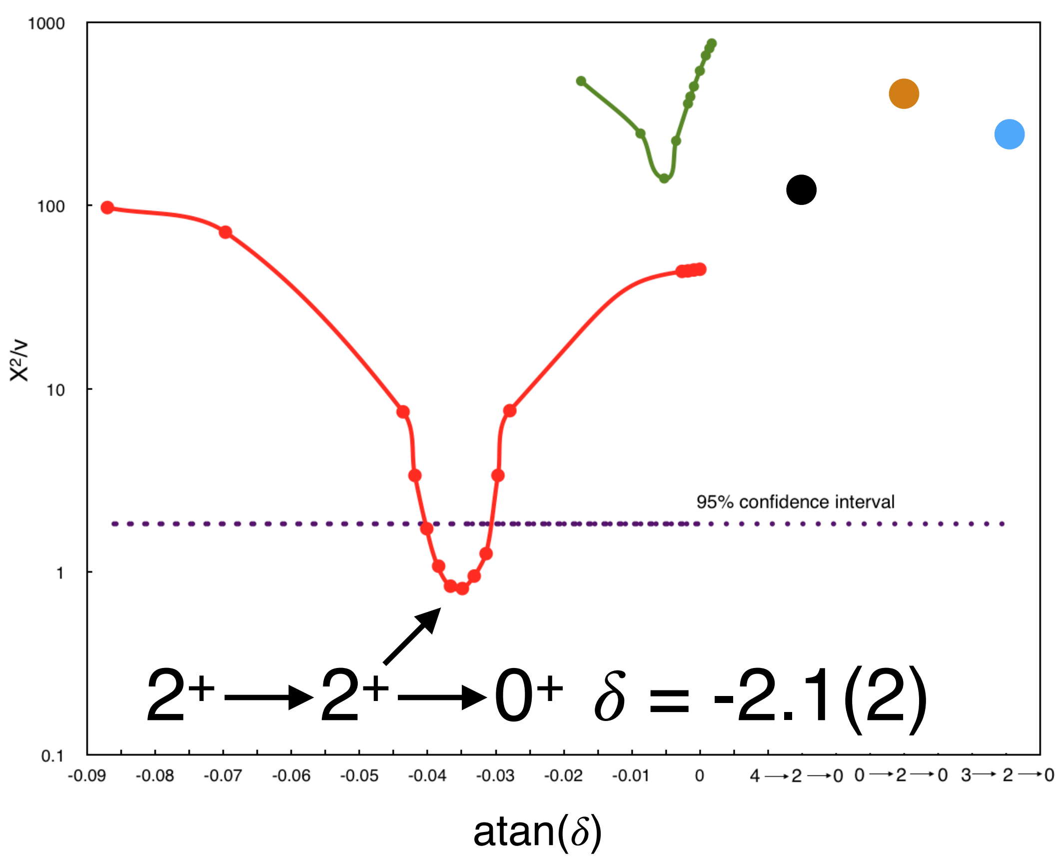

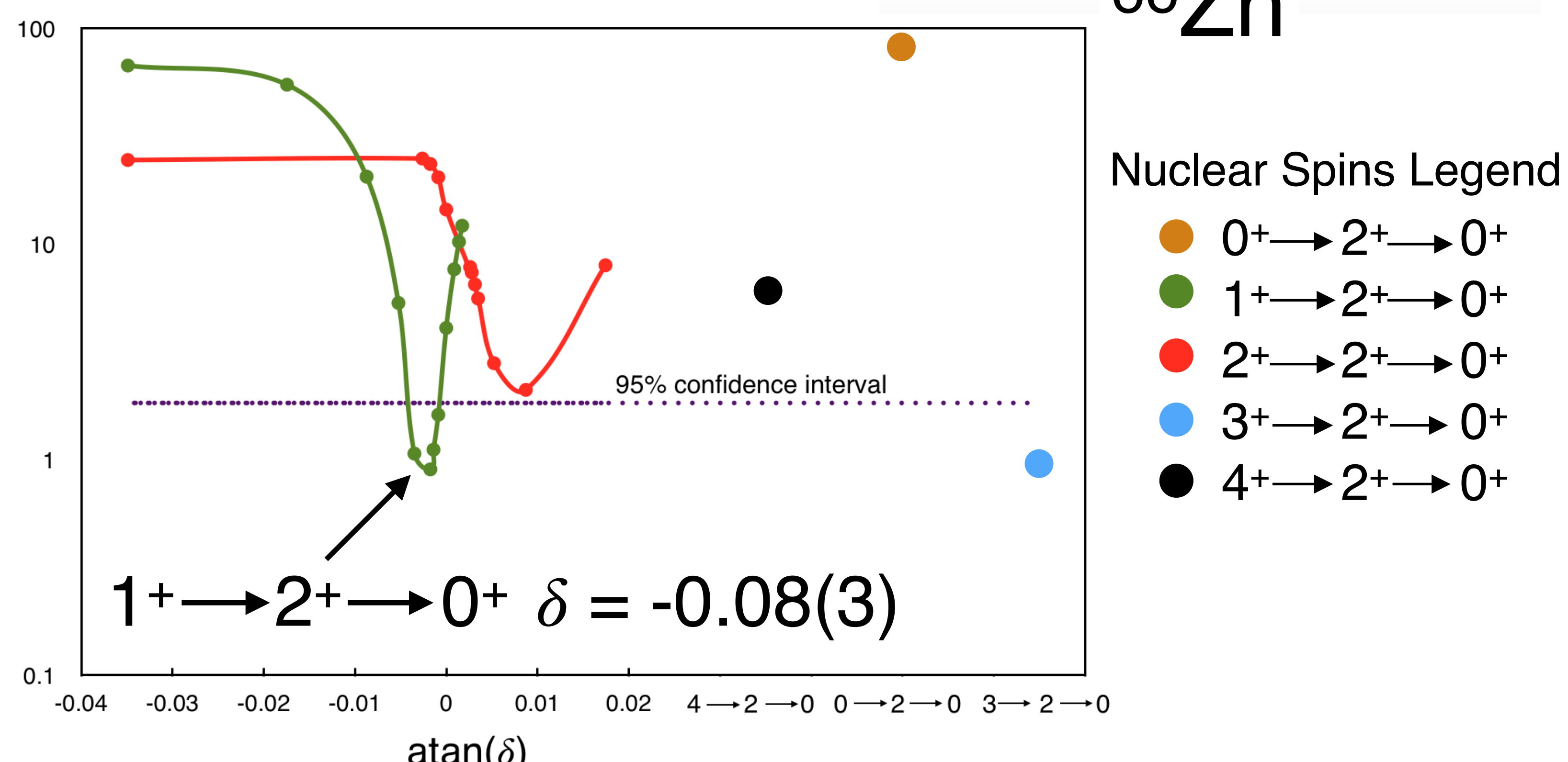

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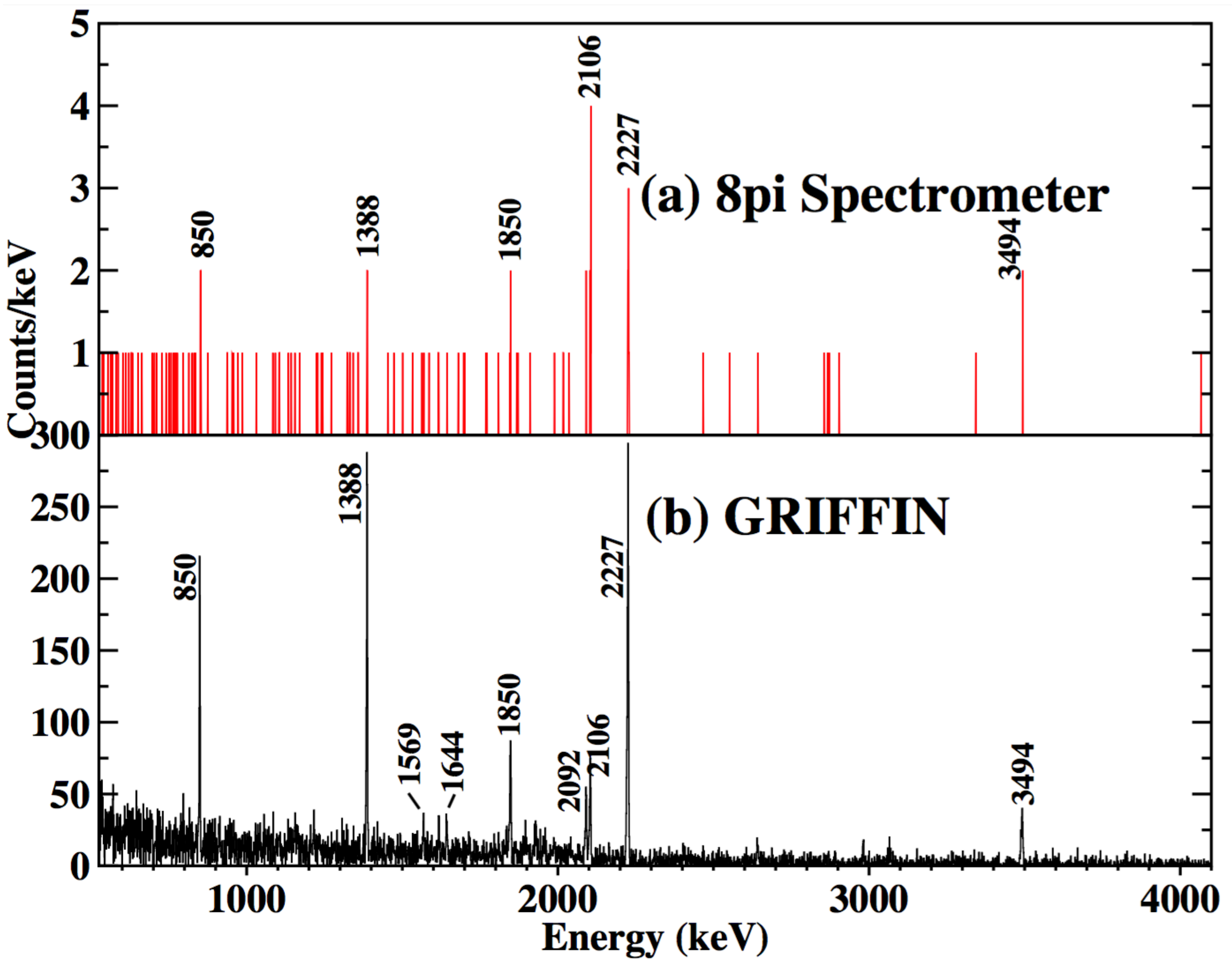
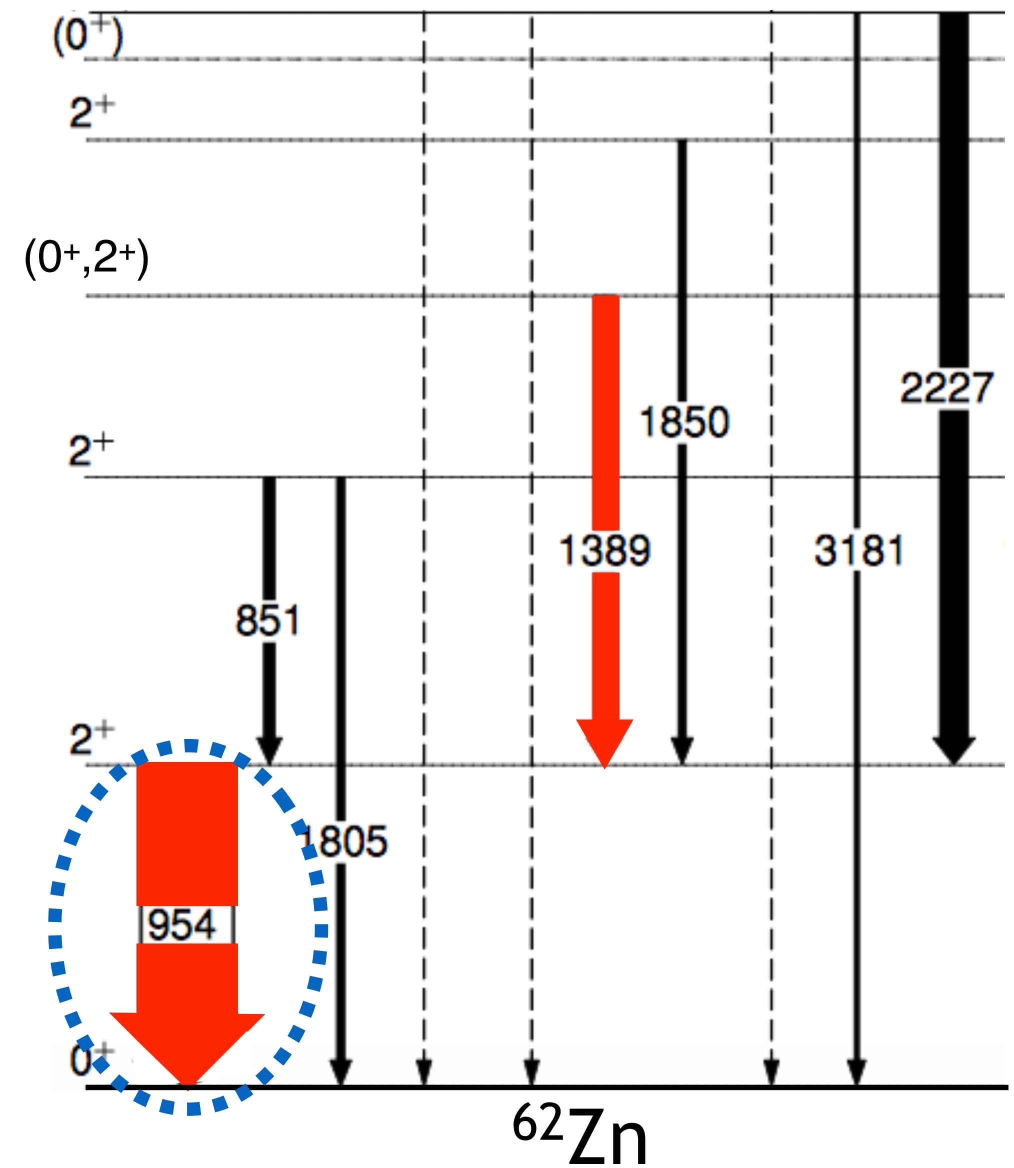
^{62}Ga Superallowed Beta Decay Data (Preliminary)

With techniques demonstrated a preliminary experiment was preformed with a radioactive ^{62}Ga beam to resolve a recently disputed spin assignment to the 2.34 MeV excited state in ^{62}Zn.

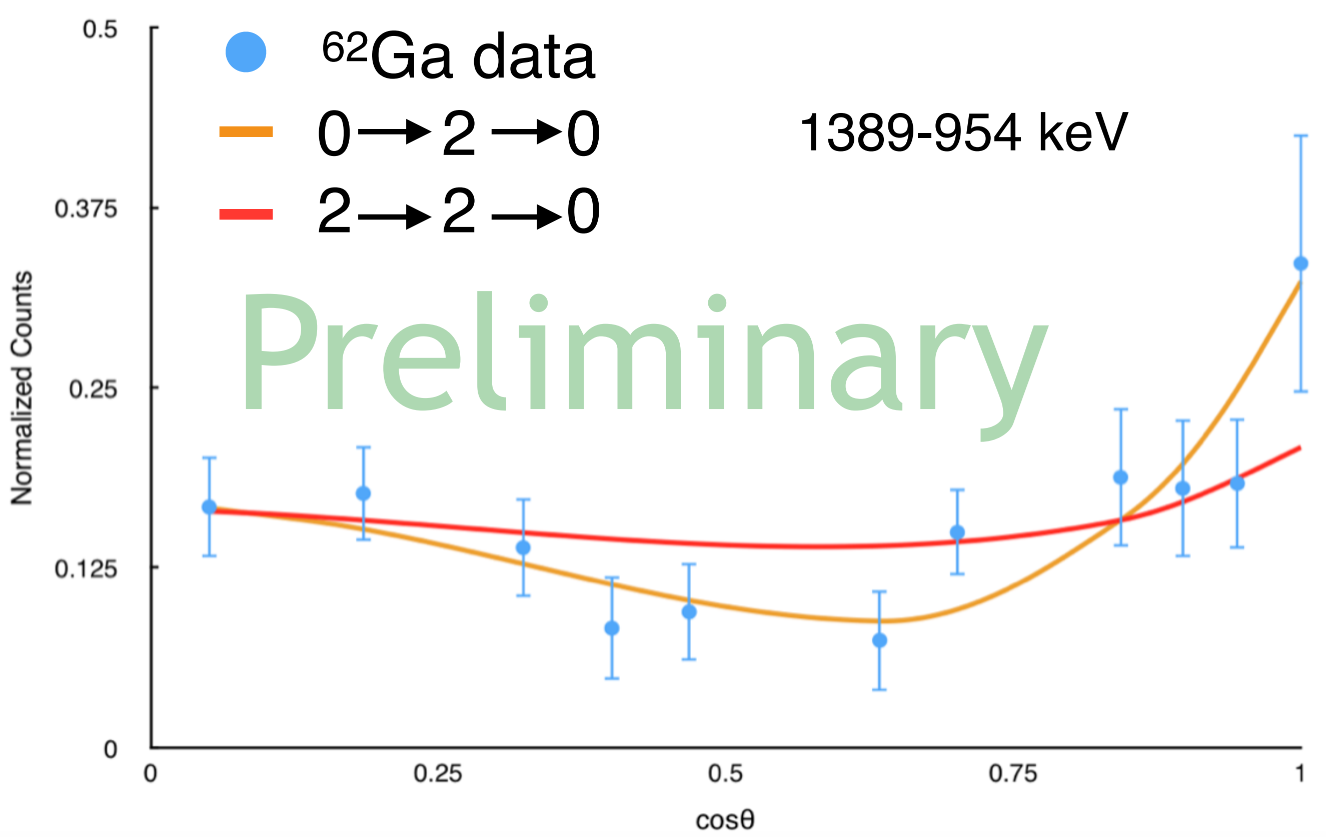


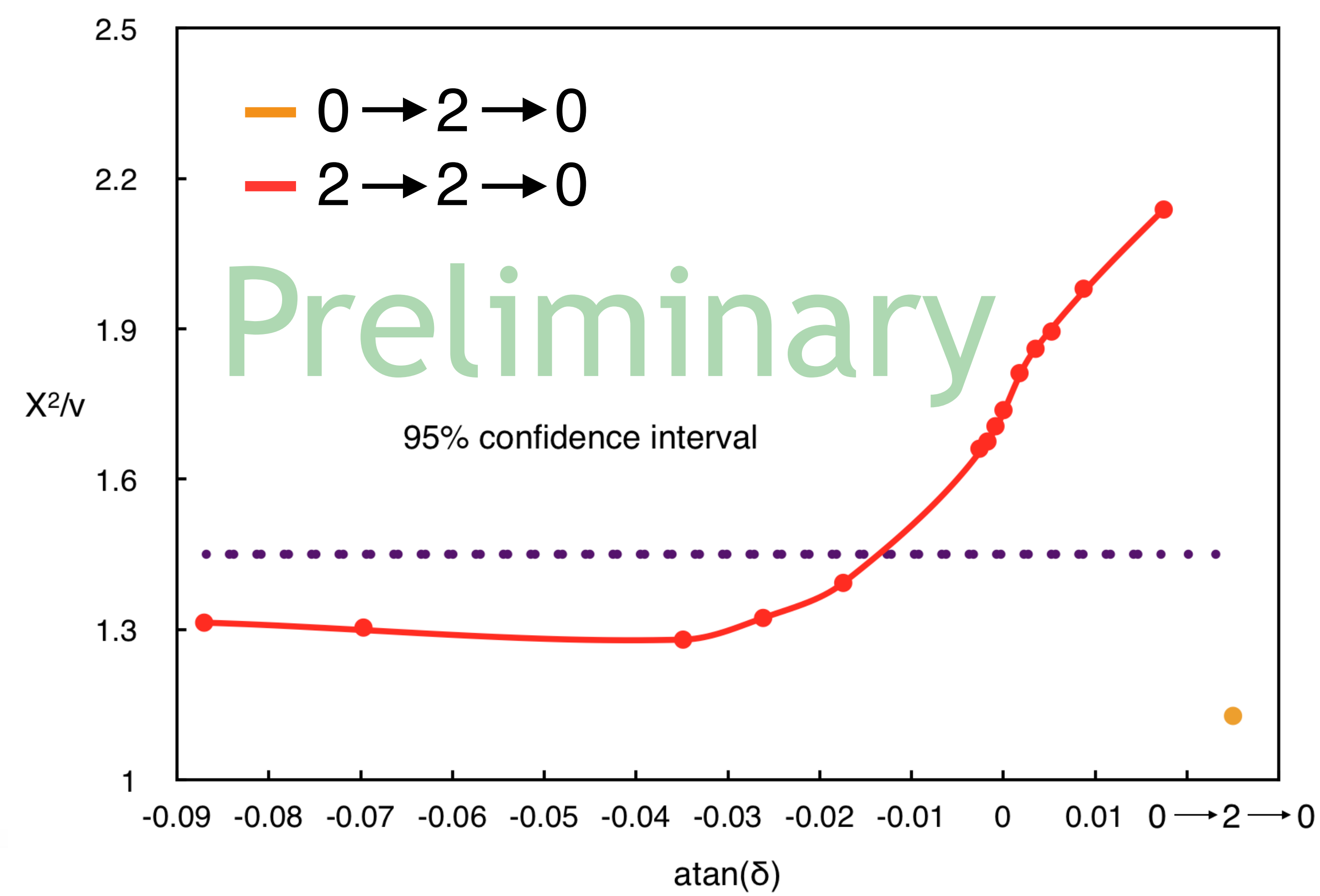


In comparison to a previous experiment at TRIUMF, the high efficiency of GRIFFIN provided two orders of magnitude more statistics with half the number of decays using the 8π array.

^{62}Ga Superallowed Beta Decay Data (Preliminary)

With a beam rate of 1250 ions per second and a beta branch of 191ppm to the 2.34 MeV state, the measurement favoured the assignment of this state as a 0^+. A higher statistic experiment will be run with GRIFFIN to make a definitive spin assignment for this state.





GRIFFIN at ISAC-I is a powerful new facility for gamma-gamma angular correlation measurements to establish nuclear spins and transition mixing ratios in decay spectroscopy with radioactive ion beams.

Thank You!

C. E. Svensson, P. E. Garrett, V. Bildstein,
C. Burbadge, A Diaz Varela, R. Dunlop,
M. Dunlop, B. Jigmeddorj, A. T. Laffoley,
B. Olaizola, E.T. Rand, T. Zidar

University of Guelph

G. C. Ball, M. Bowry, D. S. Cross, I. Dillman,
L. Evitts, A. B. Garnsworthy, G. Hackman,
S. Hallan, M. Moukaddam, P. Ruotsalainen,
J. Smallcombe, J. K. Smith.

TRIUMF

J. Pore — SFU

H. Leslie — Queen’s

K. G. Leach — Colorado School of Mines

P. Finlay — KU Leuven

The GRIFFIN Collaboration!

TRIUMF

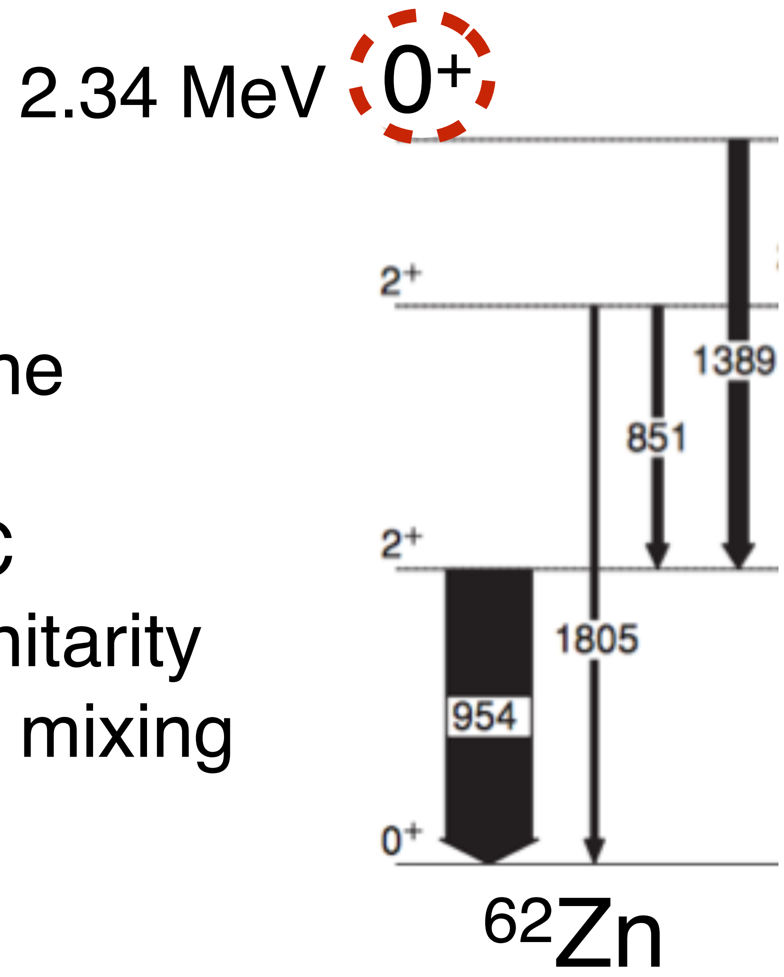
UNIVERSITY of GUELPH

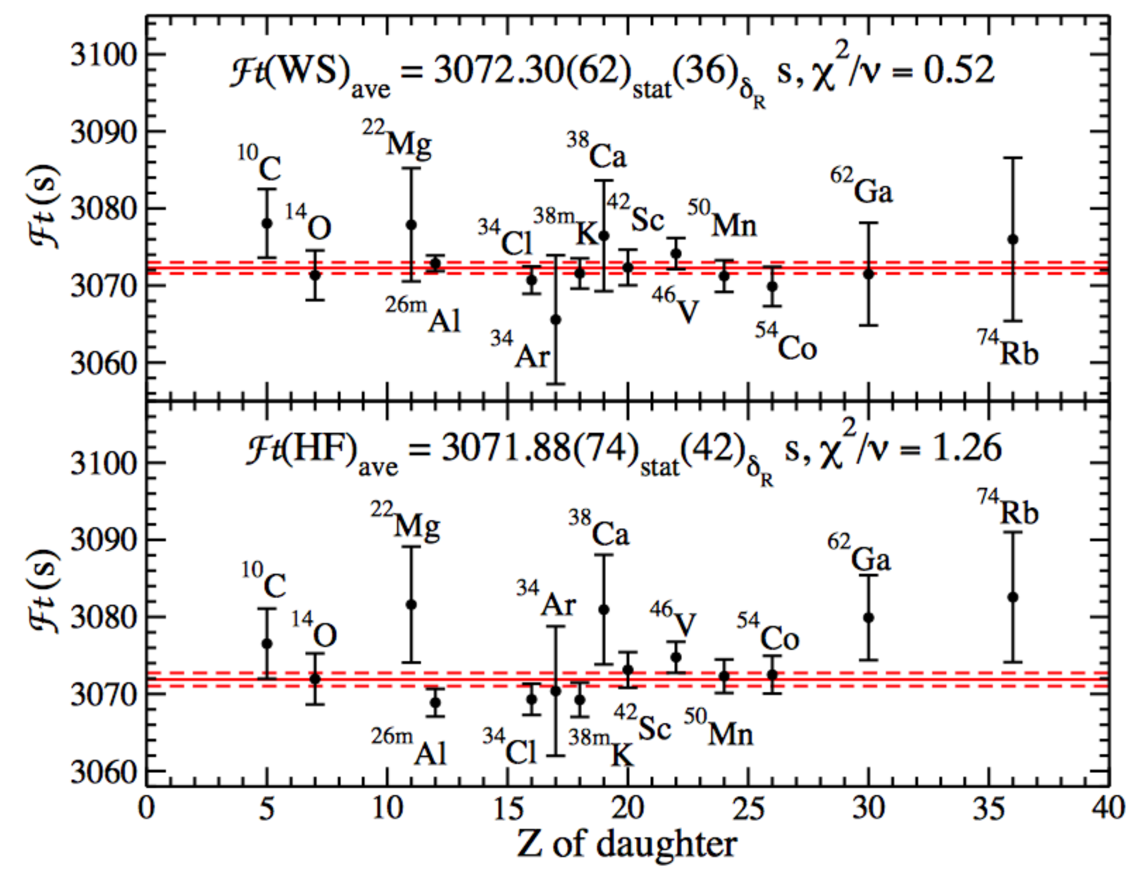
Canada Foundation for Innovation
Fondation canadienne pour l’innovation

NSERC CRSNG

Superallowed β+ Emitter ^{62}Ga

$$\mathcal{F}t = ft(1+\delta_R)(1-\delta_C) = \frac{2\pi^3\hbar^7 ln(2)}{2G_v m_e^5 c^4(1+\Delta_R)}$$



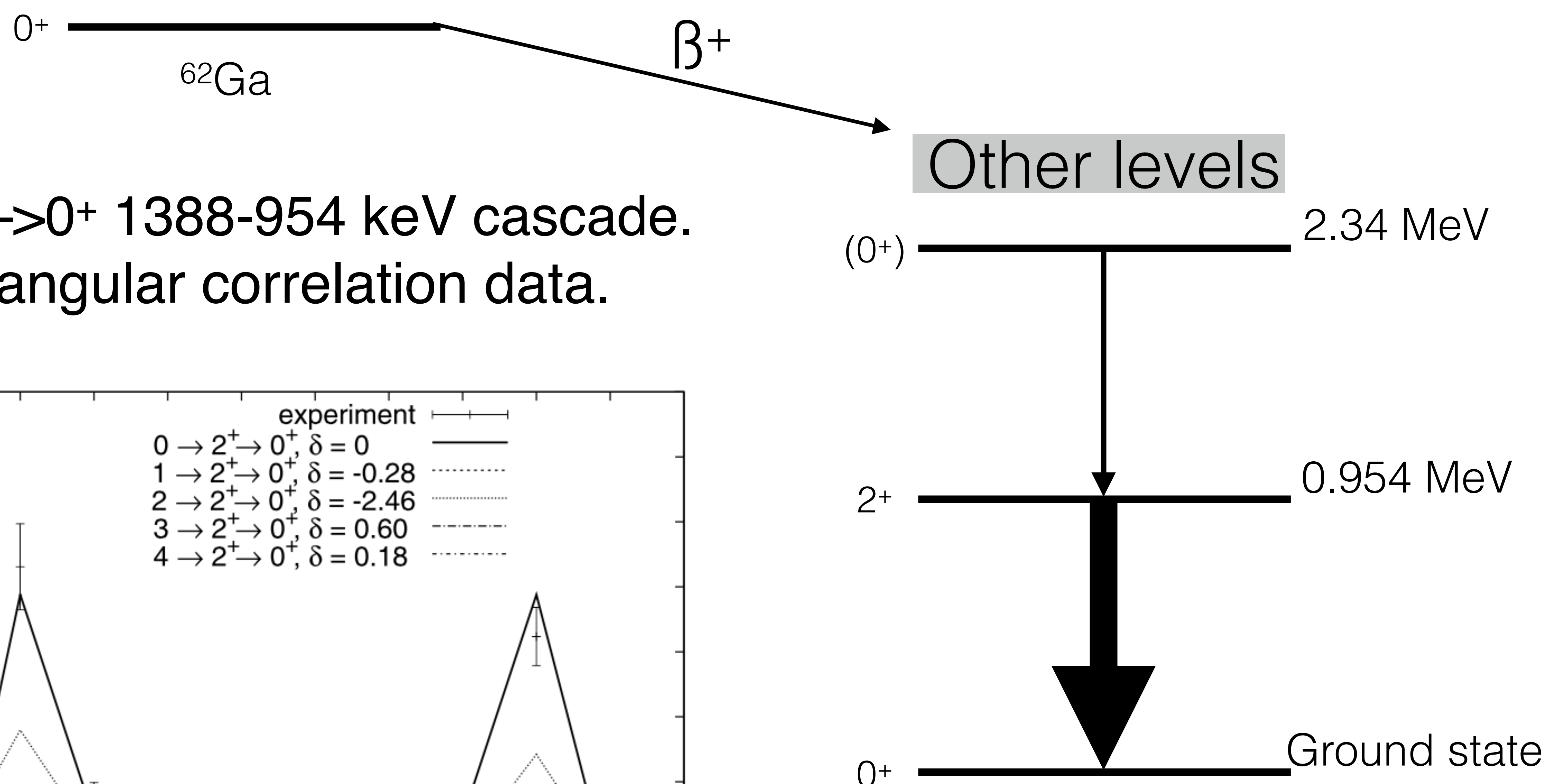


Used for testing the Standard Model including the CVC hypothesis and unitarity of the CKM quark mixing matrix.

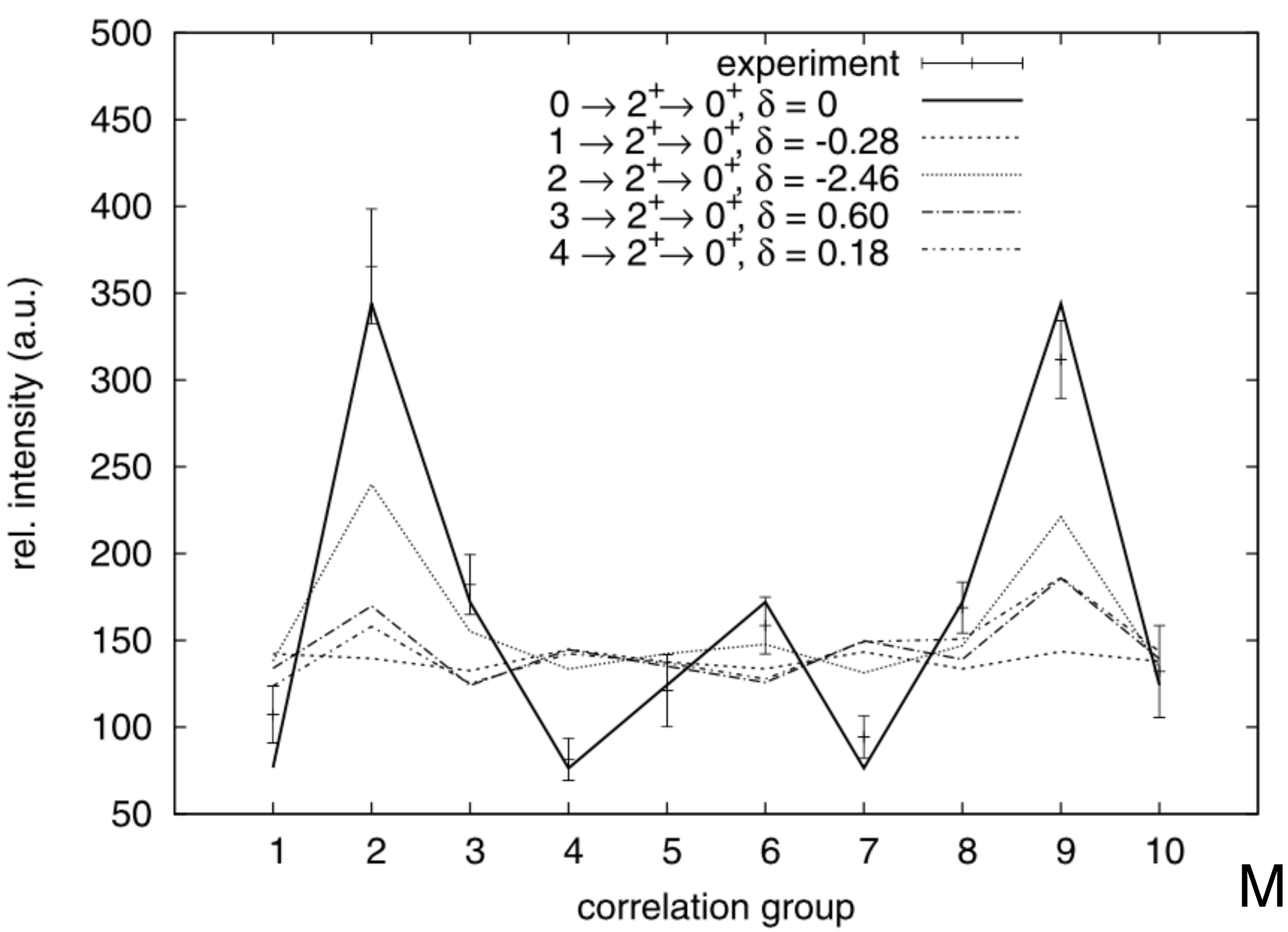
A. T. Laffoley, High-Precision Half-Life Measurement for the Superallowed Fermi β Emitters ^{14}O and ^{18}Ne, Ph.D. Thesis, University of Guelph

K. G. Leach et al., Phys. Rev. Lett. **96**, 032002 (2013).

Previous Measurements To Assign Spin of 2.34 MeV State in ^{62}Ga



$(0^+) \rightarrow 2^+ \rightarrow 0^+$ 1388-954 keV cascade.
γ-γ angular correlation data.



M. Albers et al., Nuc. Phys. **847**, 180 (2010).

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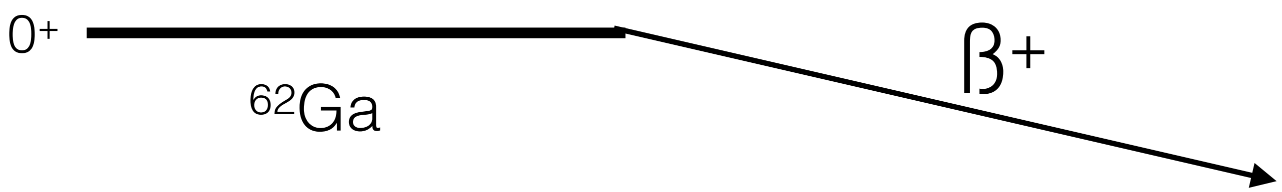
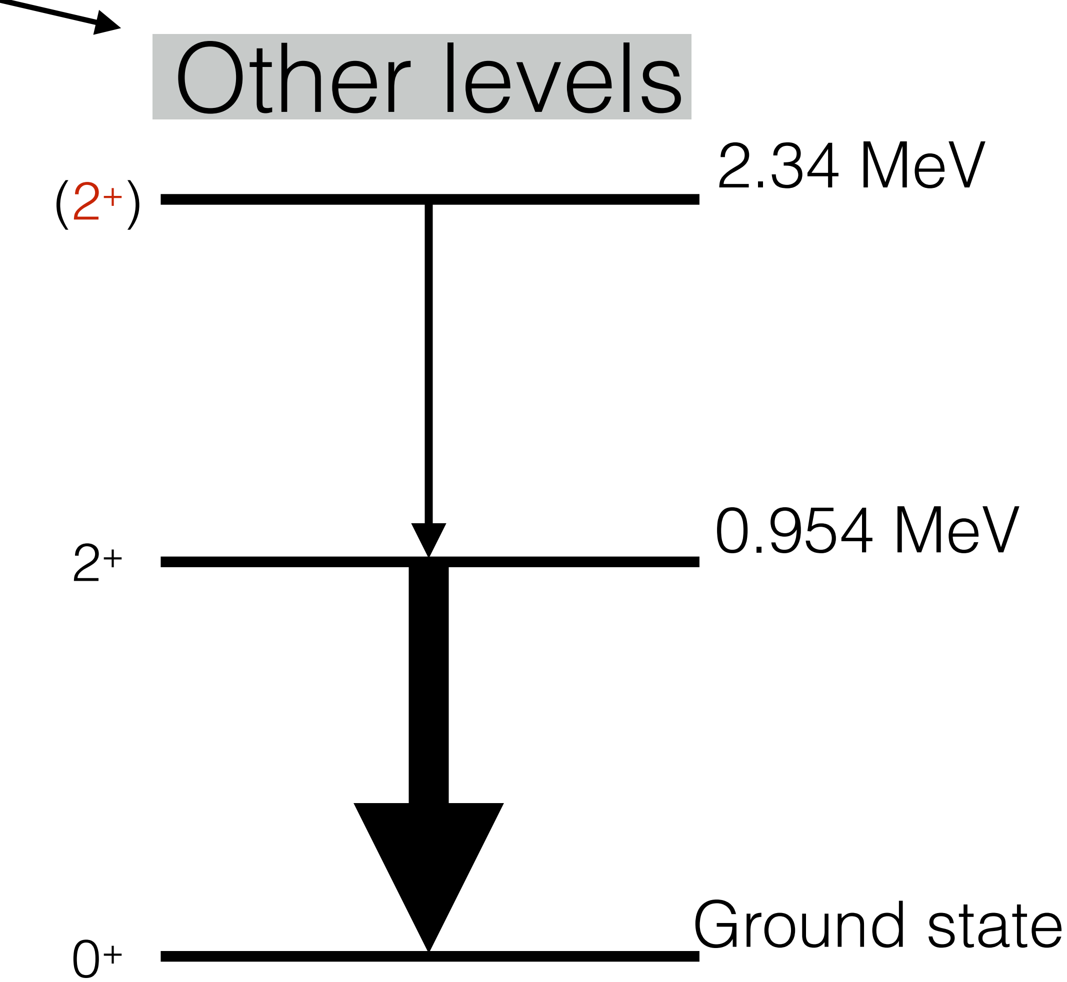
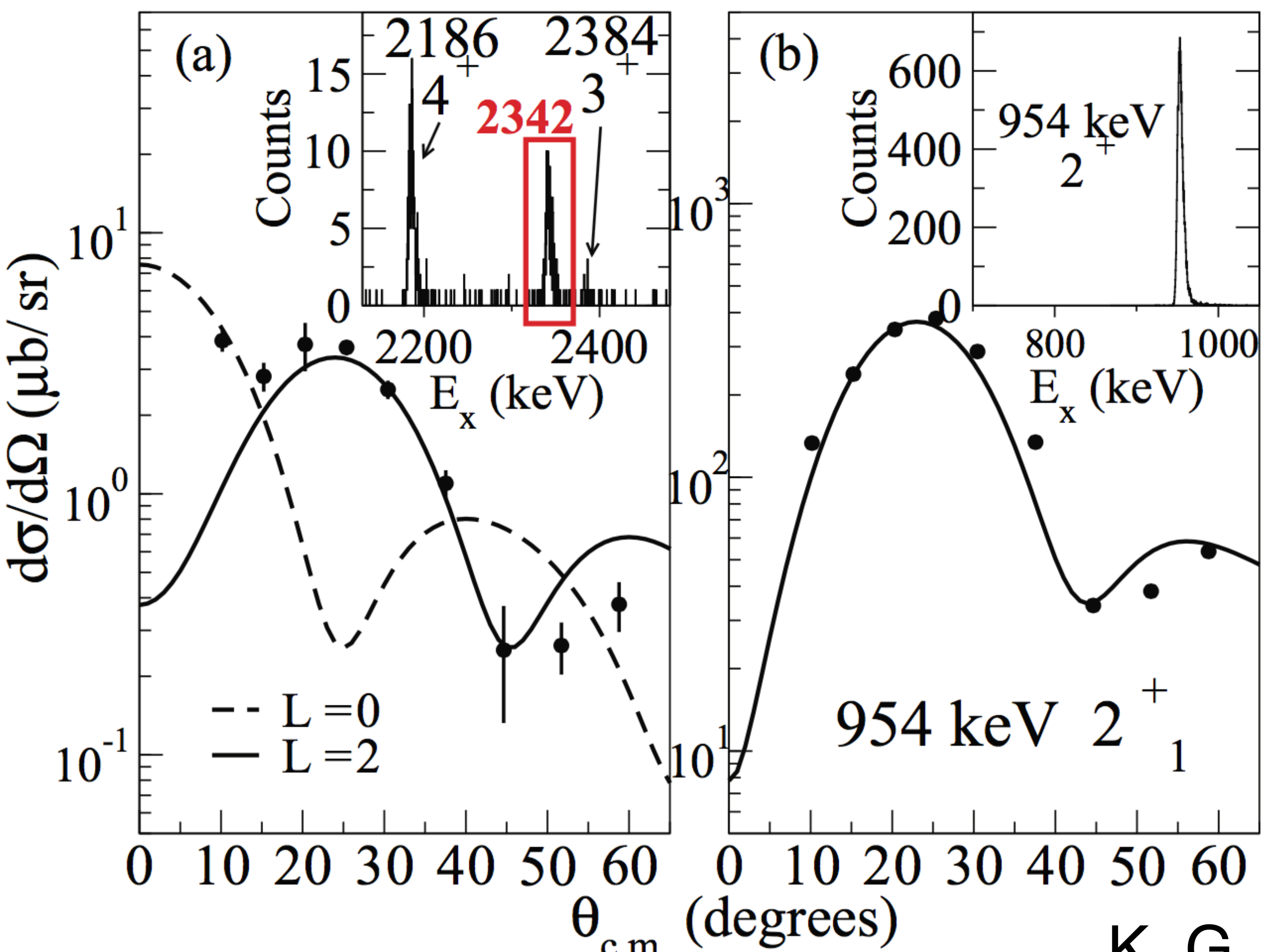




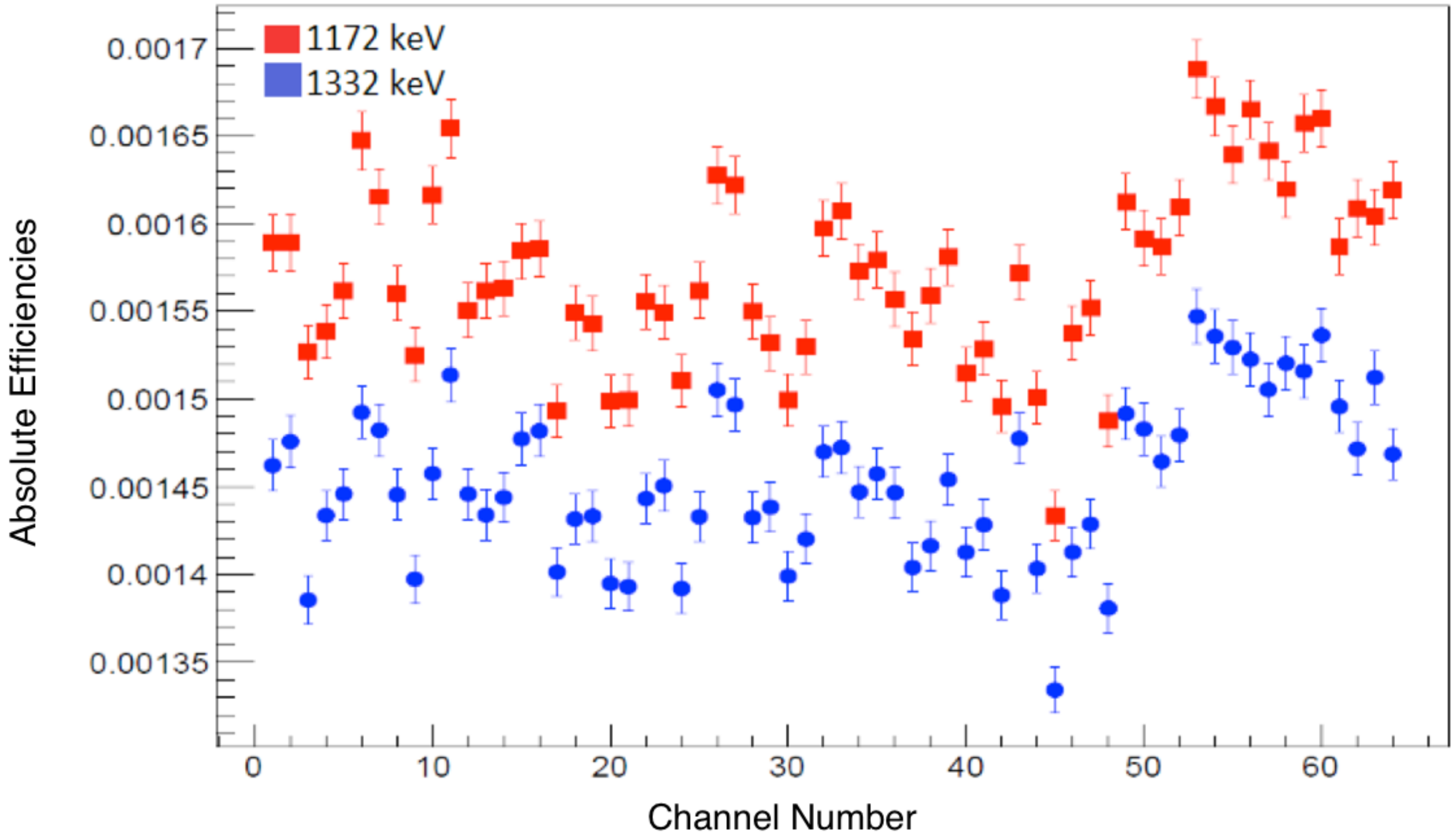
(2$^+$)–>2$^+$–>0$^+$ 1388-954 keV cascade.
^{64}Zn(p,t)^{62}Zn reaction data.



K. G. Leach et al., Phys. Rev. C. **96**, 032002 (2013).

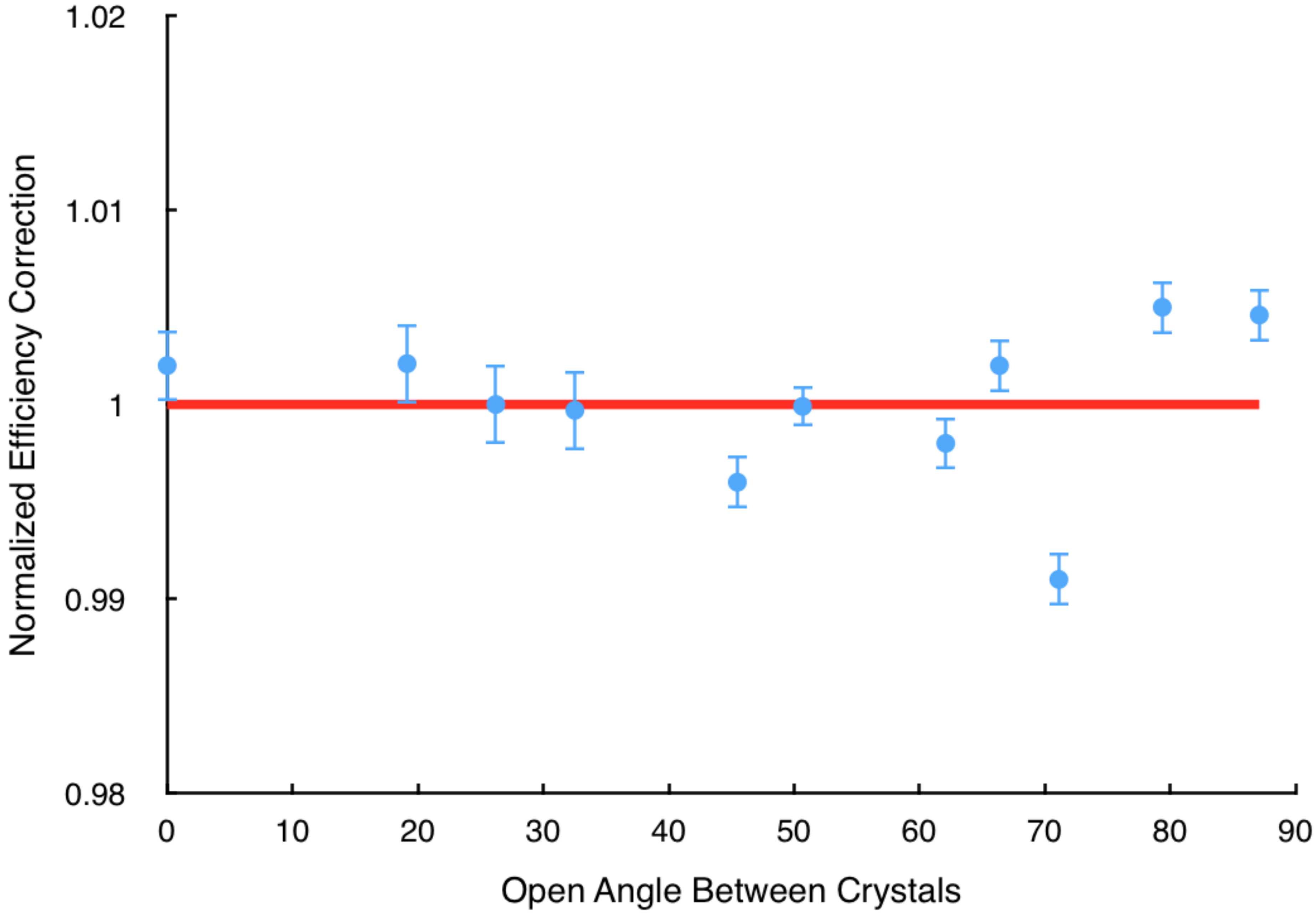
Crystal Efficiency Corrections

Efficiencies of different crystals can differ and effect the angular correlations.



Crystal Efficiency Corrections

Efficiencies for the opening angles of GRIFFIN after grouping and folding.

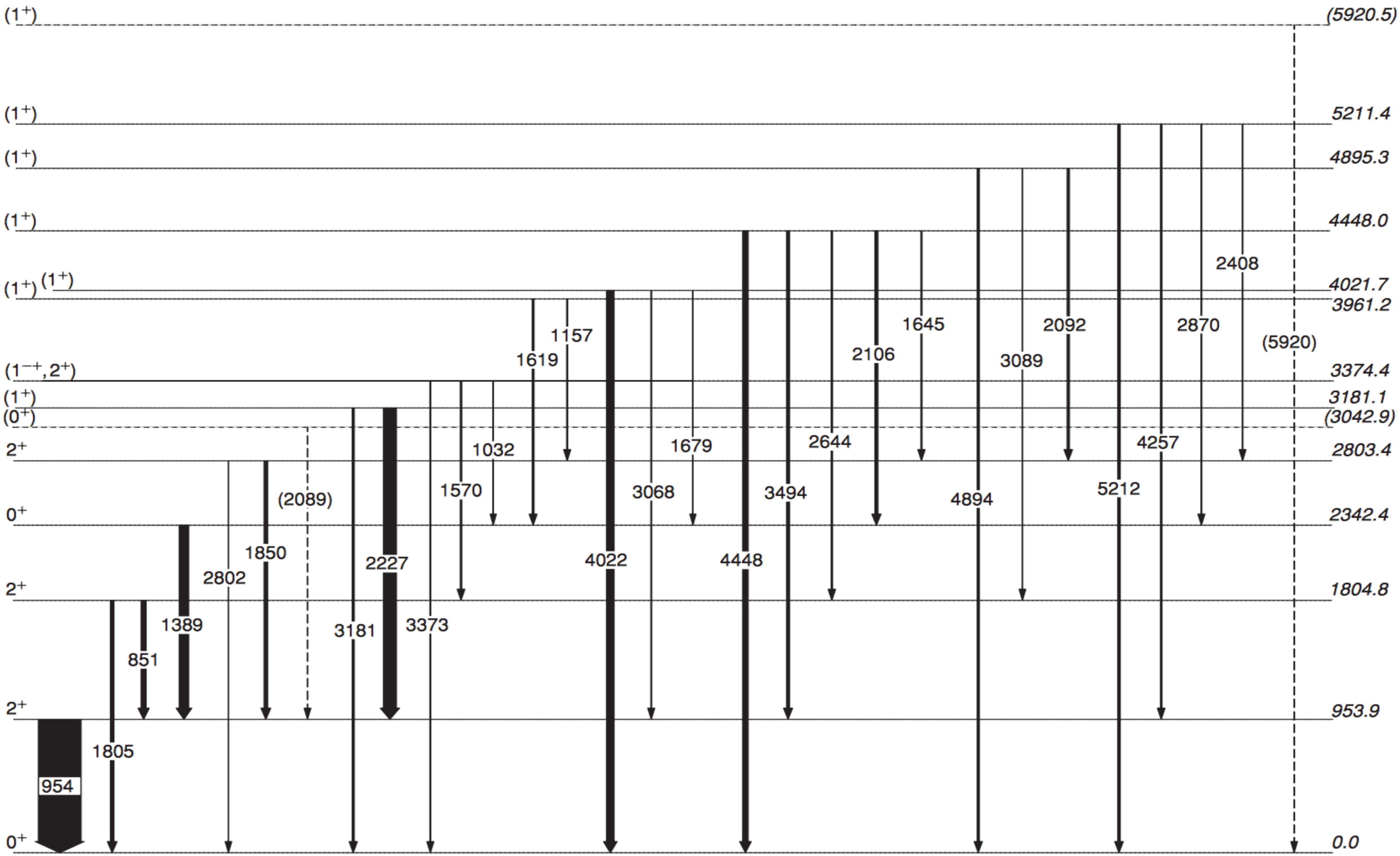


Isospin Symmetry Breaking Correction Calculations

Parent nucleus	ft (s)	$\delta_C^{(X)}$ (%)	$\delta_C^{(Y)}$ (%)	$\delta_C^{(Z)}$ (%)	$\delta_C^{(SV)}$ (%)	$\mathcal{F}t$ (s)	$\delta_C^{(exp)}$ (%)	χ_i^2	$\delta_C^{(SHZ2)}$ (%)	$\mathcal{F}t$ (s)
$T_z = -1$:										
^{10}C	3041.7(43)	0.559	0.559	0.823	0.65(14)	3062.1(62)	0.37(15)	3.7	0.462(65)	3067.8(49)
^{14}O	3042.3(11)	0.303	0.303	0.303	0.303(30)	3072.3(21)	0.36(06)	0.8	0.480(48)	3066.9(24)
^{22}Mg	3052.0(70)	0.243	0.243	0.417	0.301(87)	3080.5(75)	0.62(23)	1.9	0.342(49)	3079.2(72)
^{34}Ar	3052.7(82)	0.865	0.997	1.475	1.11(29)	3056(12)	0.63(27)	3.1	1.08(42)	3057(15)
$T_z = 0$:										
^{26}Al	3036.9(09)	0.308	0.308	0.494	0.370(95)	3070.5(31)	0.37(04)	0.0	0.307(62)	3072.5(23)
^{34}Cl	3049.4(11)	0.809	0.679	1.504	1.00(38)	3060(12)	0.65(05)	48.4	0.83(50)	3065(15)
^{42}Sc	3047.6(12)	—	—	—	0.77(27)	3069.2(85)	0.72(06)	0.5	0.70(32)	3071(10)
^{46}V	3049.5(08)	0.486	0.486	0.759	0.58(14)	3074.6(47)	0.71(06)	4.5	0.375(96)	3080.9(35)
^{50}Mn	3048.4(07)	0.460	0.460	0.740	0.55(14)	3074.1(47)	0.67(07)	3.1	0.39(13)	3079.2(45)
^{54}Co	3050.8(10)	0.622	0.622	0.671	0.638(68)	3074.0(32)	0.75(08)	2.0	0.51(20)	3078.0(66)
^{62}Ga	3074.1(11)	0.925	0.840	0.881	0.882(95)	3090.0(42)	1.51(09)	44.0	0.49(11)	3102.3(45)
^{74}Rb	3084.9(77)	2.054	1.995	1.273	1.77(40)	3073(15)	1.86(27)	0.1	0.90(22)	3101(11)
					$\overline{\mathcal{F}t} =$	3073.6(12)	$\chi^2 =$	112.2	$\overline{\mathcal{F}t} =$	3075.0(12)
					$\lvert V_{ud}\rvert =$	0.97397(27)	$\chi_d^2 =$	10.2	$\lvert V_{ud}\rvert =$	0.97374(27)
						0.99935(67)				0.99890(67)

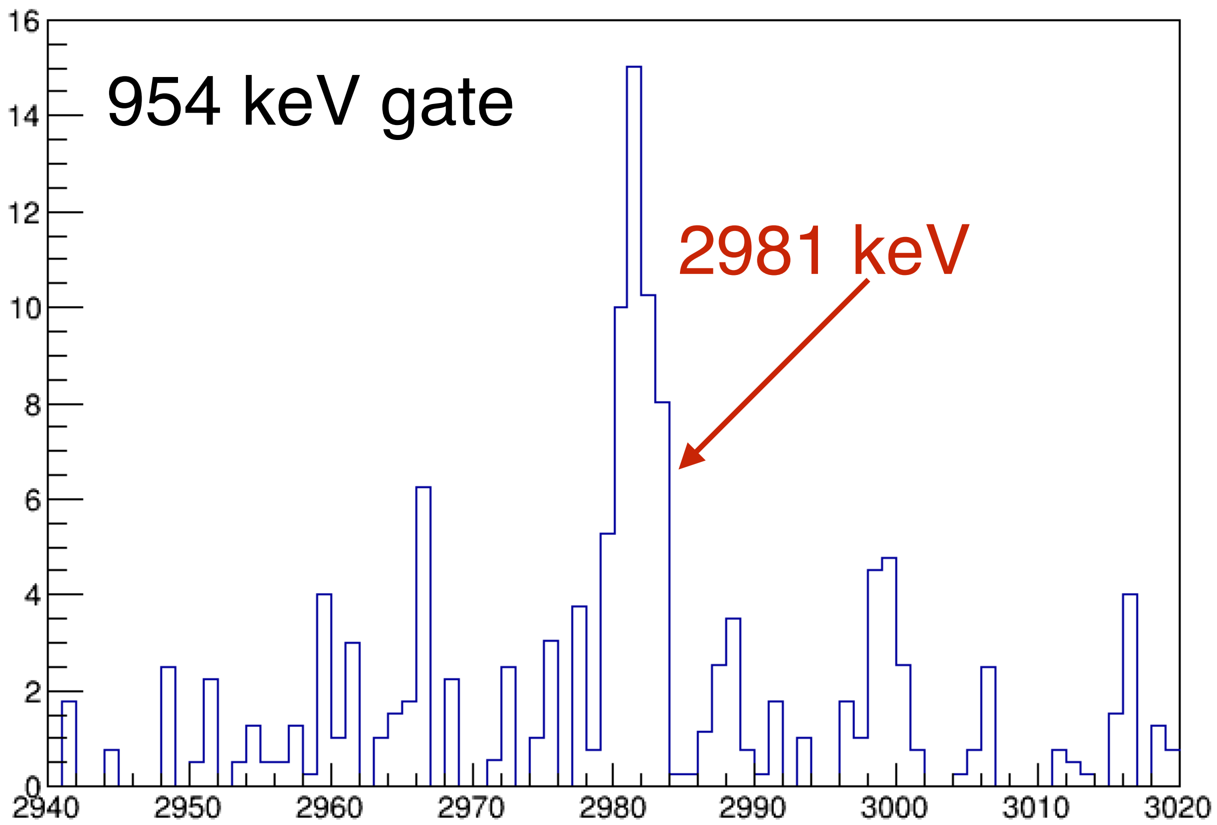
W. Satuła et al., Phys. Rev. C **86**, 054316

^{62}Ga Structural Developments

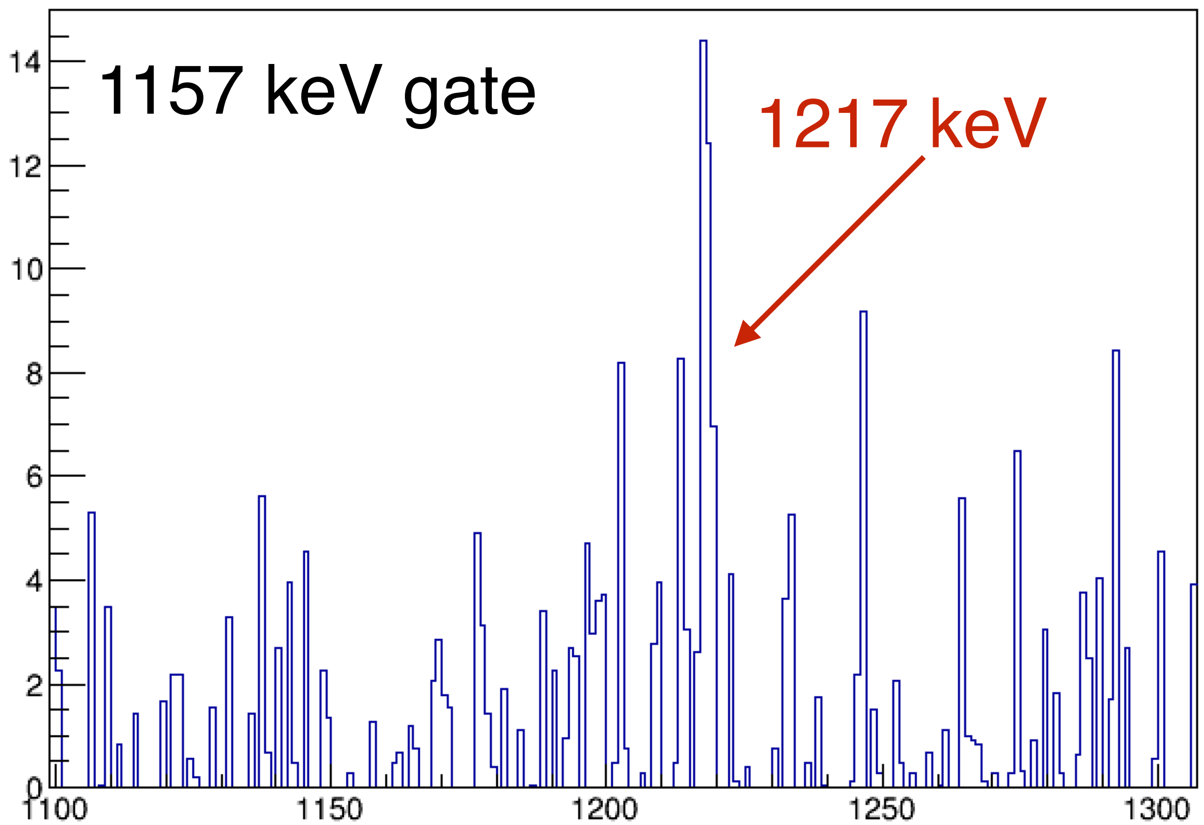


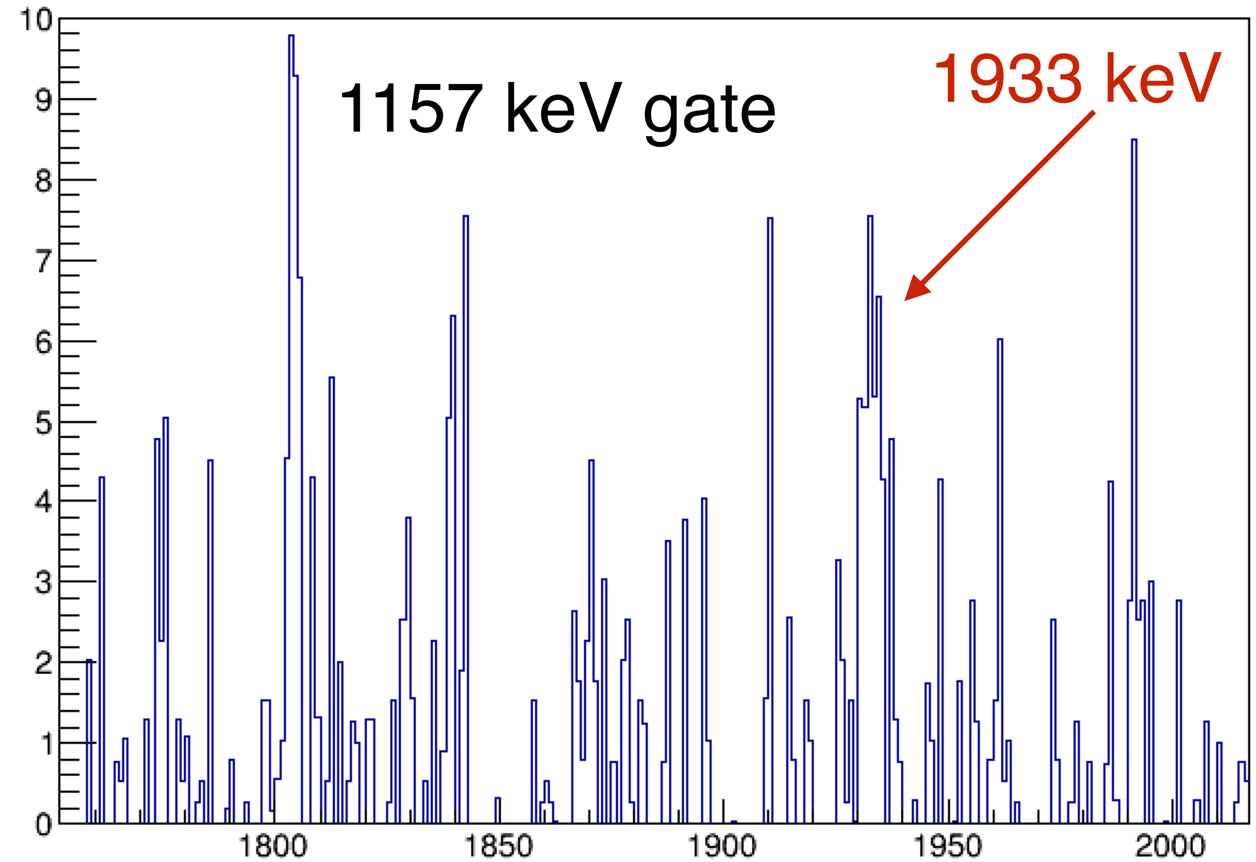
P. Finlay *et al. Phys. Rev. C* **78**, 025502 (2008).

Some ^{62}Ga Structural Developments - New Gammas



- With GRIFFIN new transitions are found even with half of the total beam in comparison to the previous experiment.





Some ^{62}Ga Structural Developments - Corrected Levels