UNIVERSITÀ DEGLI STUDI DI MILANO
FACOLTÀ DI SCIENZE E TECNOLOGIE

Istituto Nazionale di Fisica Nucleare

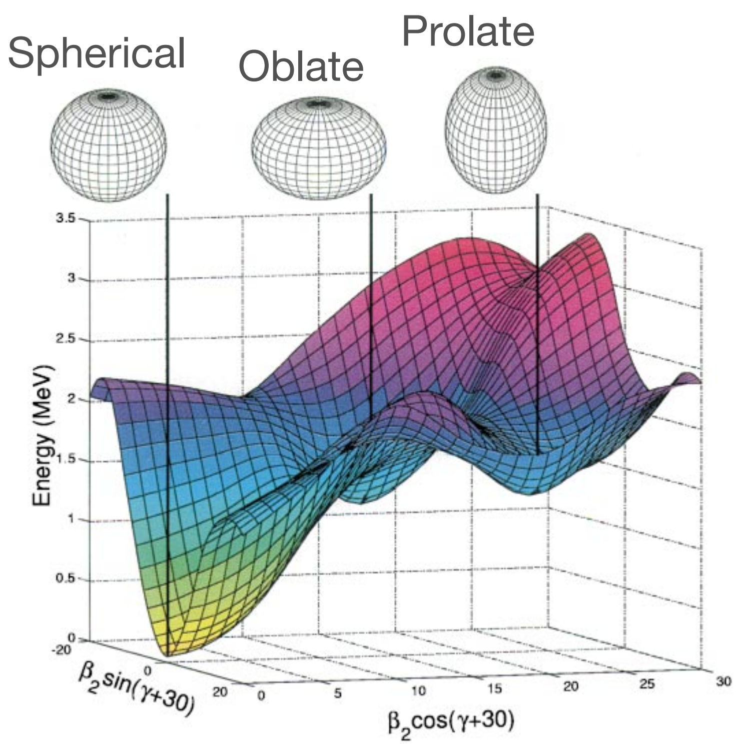
Configuration mixing investigation in germanium isotopes through measurement of *E0* transition strengths

Carlotta Porzio
(Università di Milano/TRIUMF)

CAP Congress

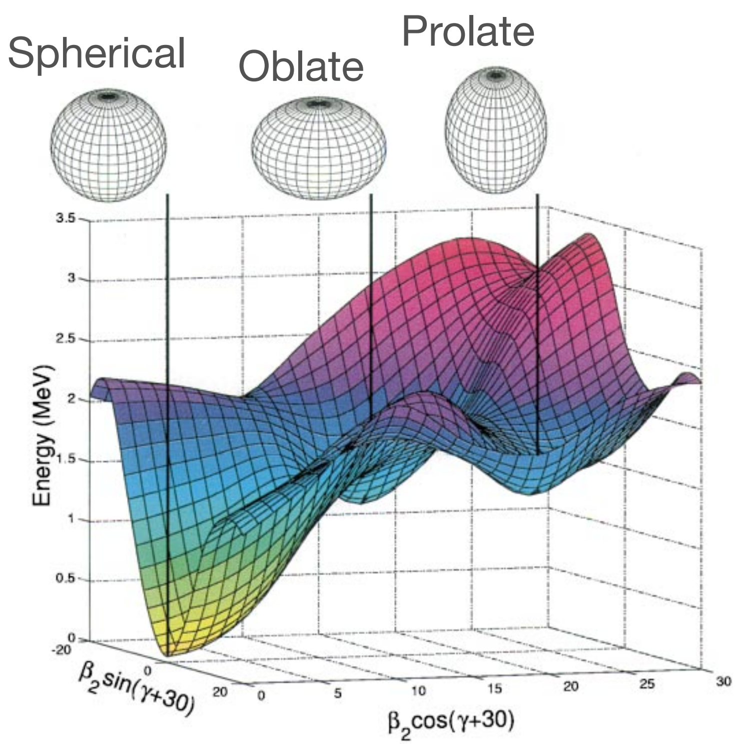
2019 June 4th

The Shape Coexistence Phenomenon



Potential energy surface of ^{186}Pb
(Andreyev *et al.*, Nature **406** (2000))

The Shape Coexistence Phenomenon



Potential energy surface of ^{186}Pb
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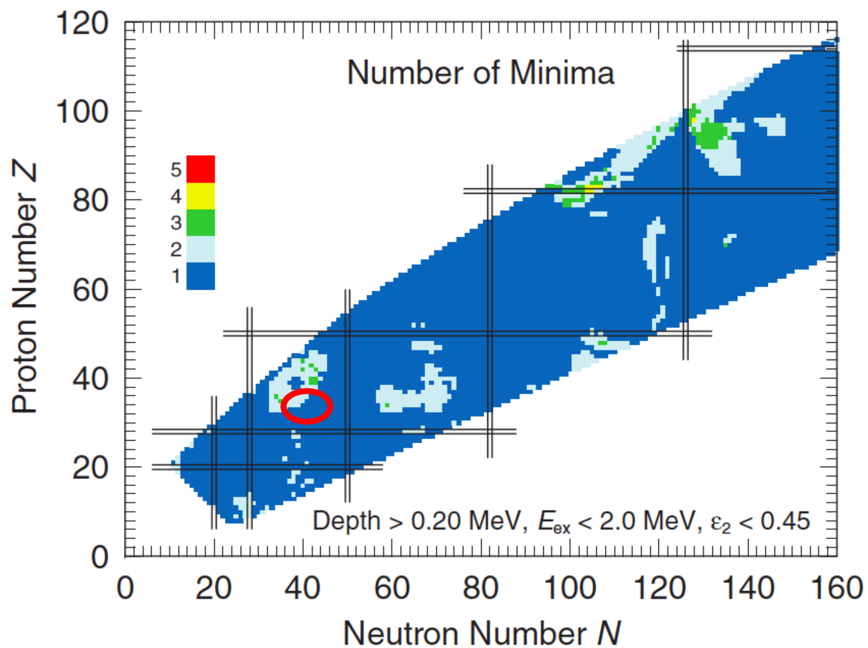
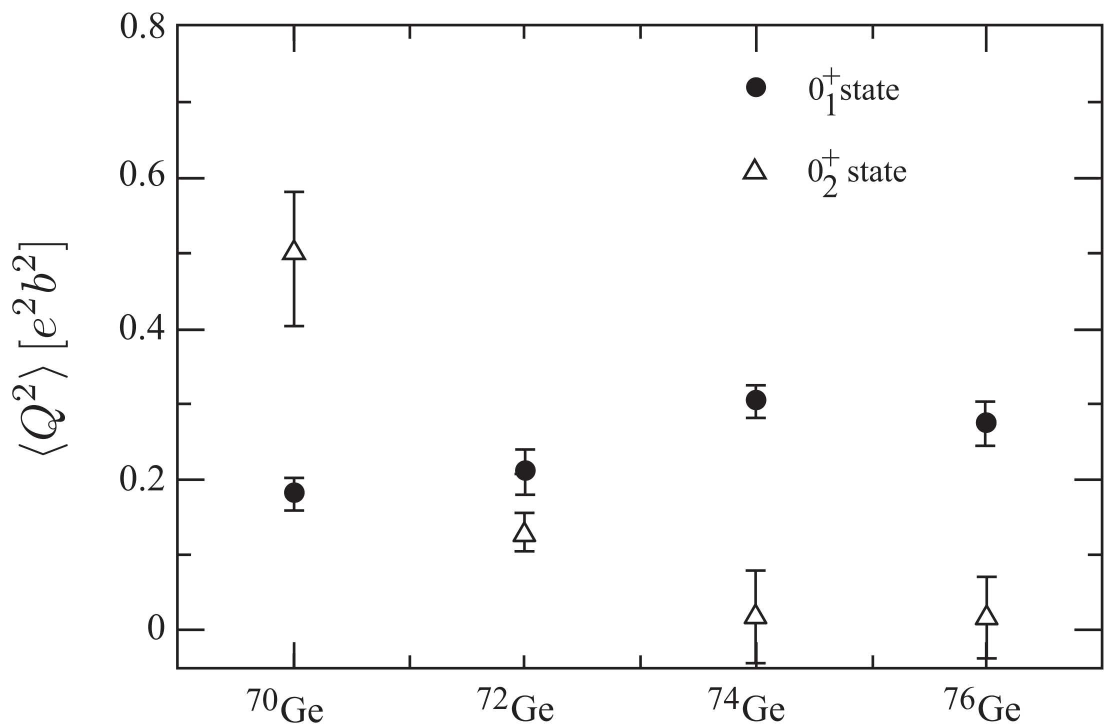


Number of minima in potential energy surfaces calculated using the Macroscopic-Microscopic Finite-Range Liquid Drop Model
(Möller *et al.*, Phys. Rev. Lett. **103** 212501 (2009))

- Heyde and Wood, Rev. Mod. Phys. **83** 1467 (2011).

The Nuclear Structure of Ge isotopic chain



$\langle Q^2 \rangle$ values for the 0^+_1 and 0^+_2 states in Ge isotopes, obtained via multi-step Coulomb excitation measurements.

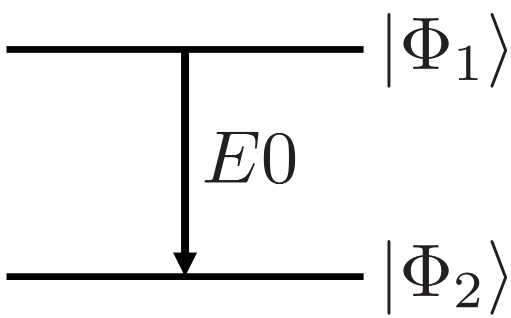
(Heyde and Wood, Rev. Mod. Phys. **83** 1467 (2011))

The Nuclear Structure of Ge isotopic chain

In a two-state mixing scenario

$$\Phi_1 = \alpha\Psi_1 + \beta\Psi_2$$
$$\Phi_2 = -\beta\Psi_1 + \alpha\Psi_2$$

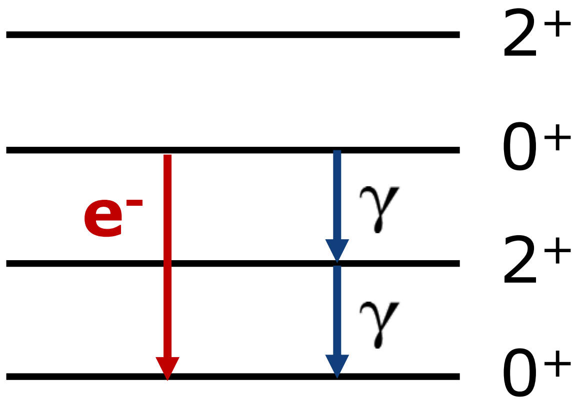
the *E0* transition strength can be related to the degree of mixing:



$$\rho^2(E0) \simeq \alpha^2\beta^2(\Delta\langle r^2\rangle)^2$$

E0 Transitions

- $\Delta J=0$
- Same parity



- Between 0^+ states, decay only via *E0* transitions
- γ-ray decay forbidden in *E0* transitions
  due to angular momentum selection rules

E0 Transitions

- $\Delta J=0$
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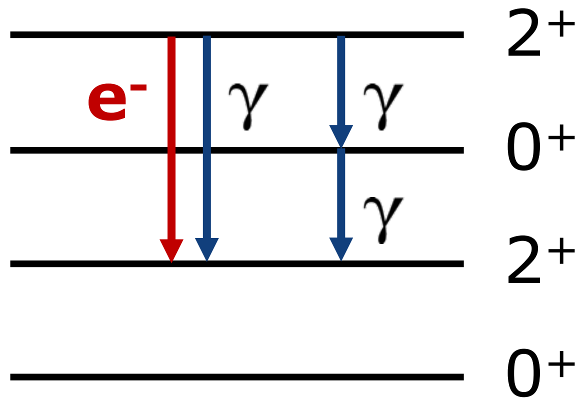
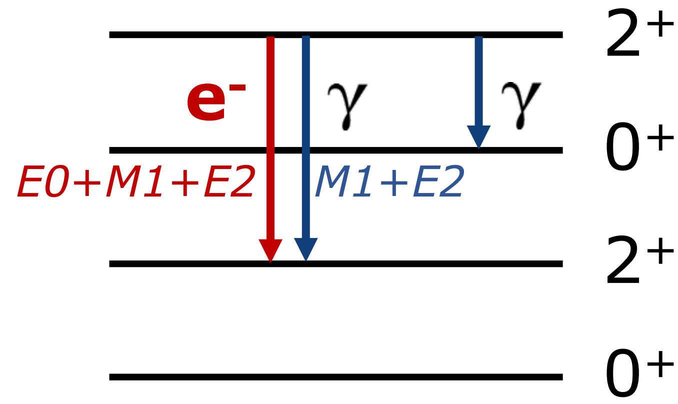


- Between 0^+ states, decay only via *E0* transitions
- γ-ray decay forbidden in *E0* transitions
  due to angular momentum selection rules
- Between J^+ ($J\neq0$) states, decay via *E0*+*M1*+*E2*
  (γ-rays only emitted in *M1*+*E2*)

E0 Strength Measurements



Branching ratio
of *E0*/*E2* transitions

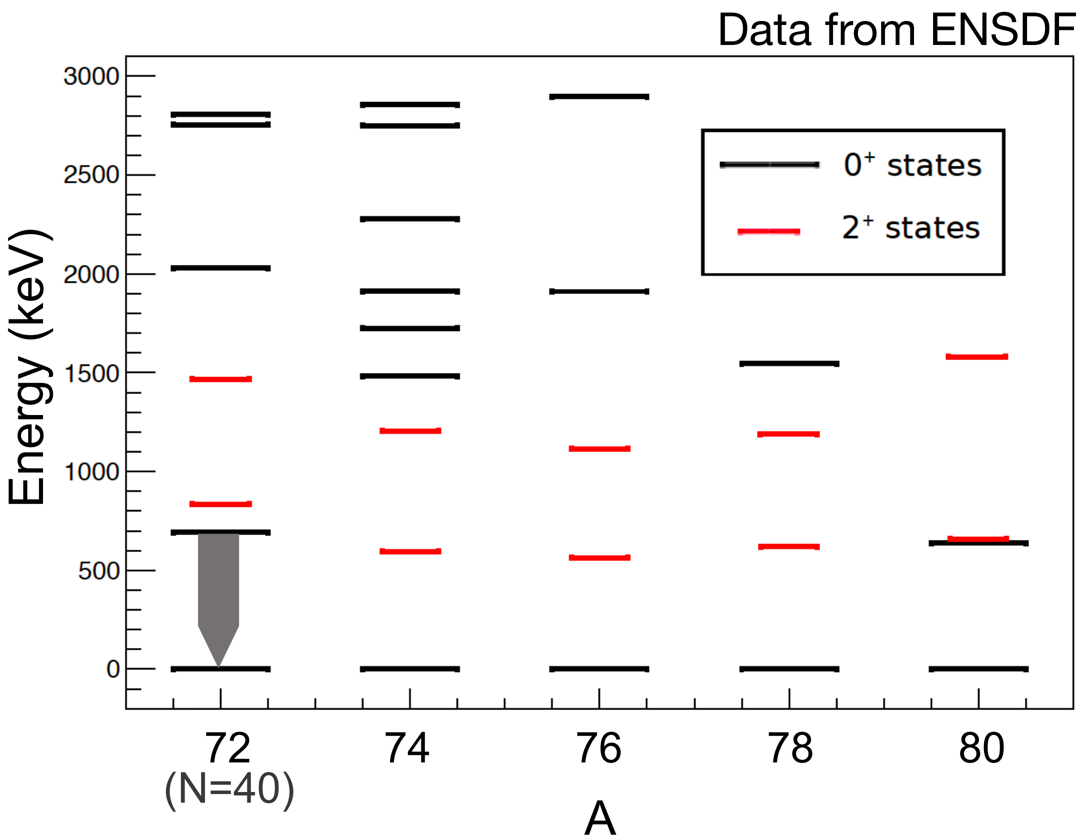
Atomic
factors

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

Branching
ratio of *E2*

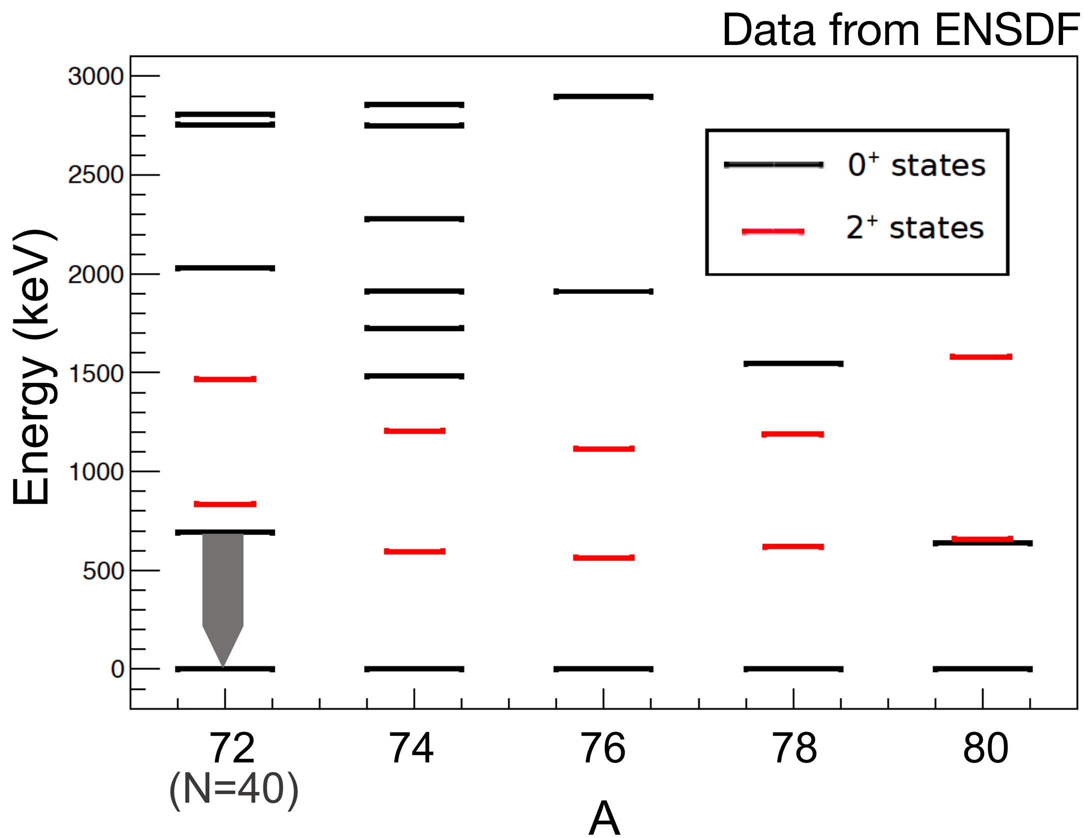
State lifetimes
(already measured
for Ge states of interest)

E0 Strength Measurements



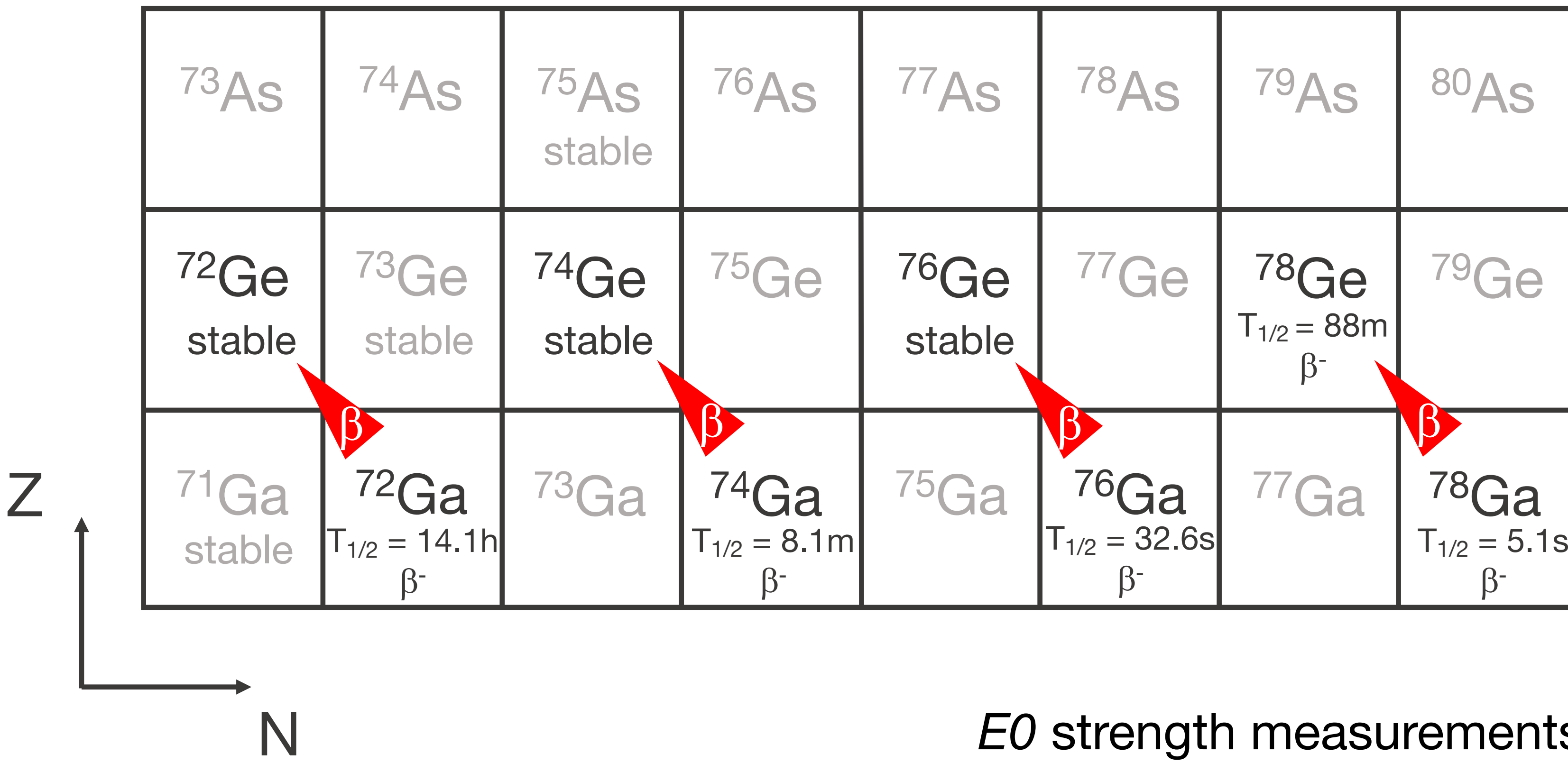
$$\rho^2(E0; 0_2^+ \rightarrow 0_1^+) \times 10^3 = 9.18(2)$$

E0 Strength Measurements



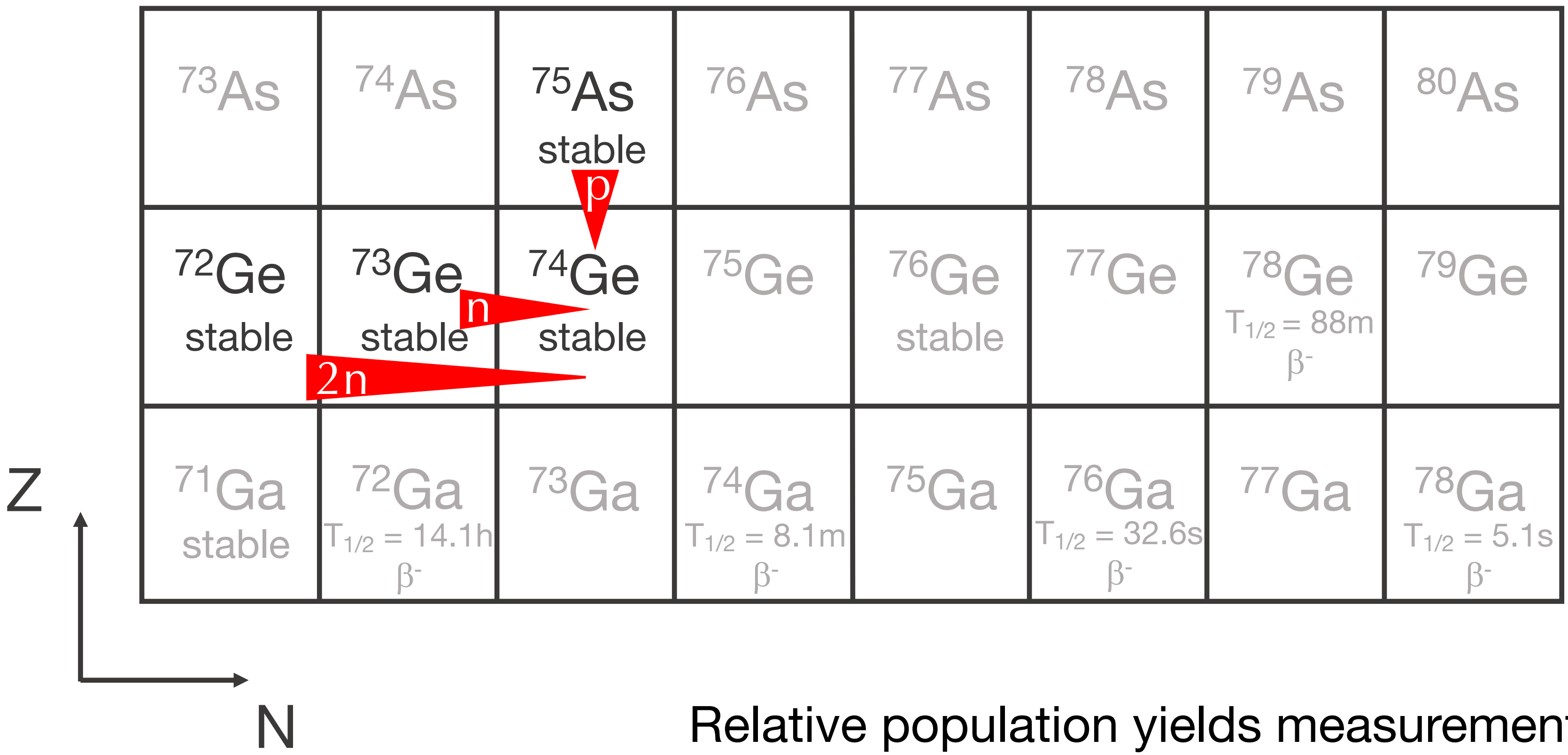
For transitions between states with J≠0 and ΔJ=0 we need also mixing ratio values to measure $\rho^2(E0)$. We can measure them via γγ angular correlations.

How can we clarify this picture



E0 strength measurements
to quantify the degree of configuration mixing

How can we clarify this picture



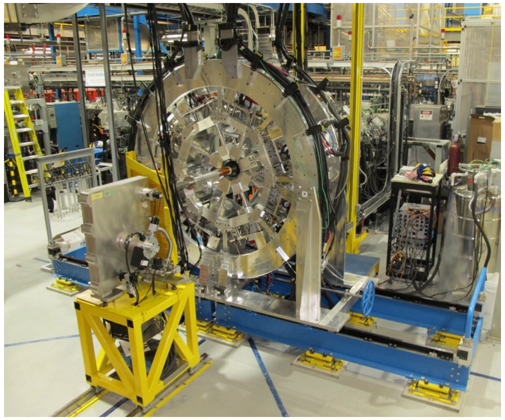
Relative population yields measurement
to probe 0^+ state wave function compositions

^{72}Ga decay data – Setup

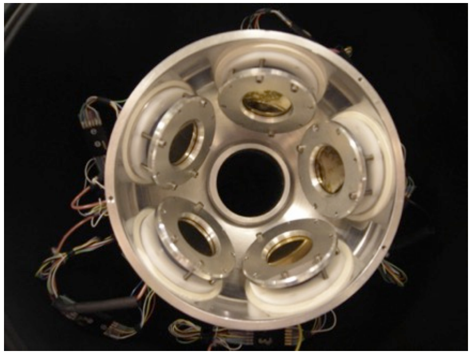
$\underbrace{^{72}\text{Ga beam}}$ delivered from ISAC facility @ TRIUMF

- 2.30×10^{7} pps
- $T_{1/2}$=14 hours

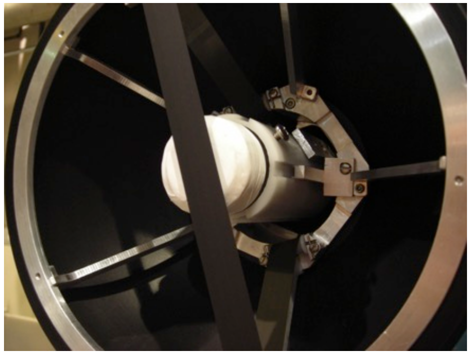
GRIFFIN (15 HPGe clovers w/o suppressors) $\longrightarrow \gamma$



PACES (5 cooled Si(Li)s) $\longrightarrow e^-$

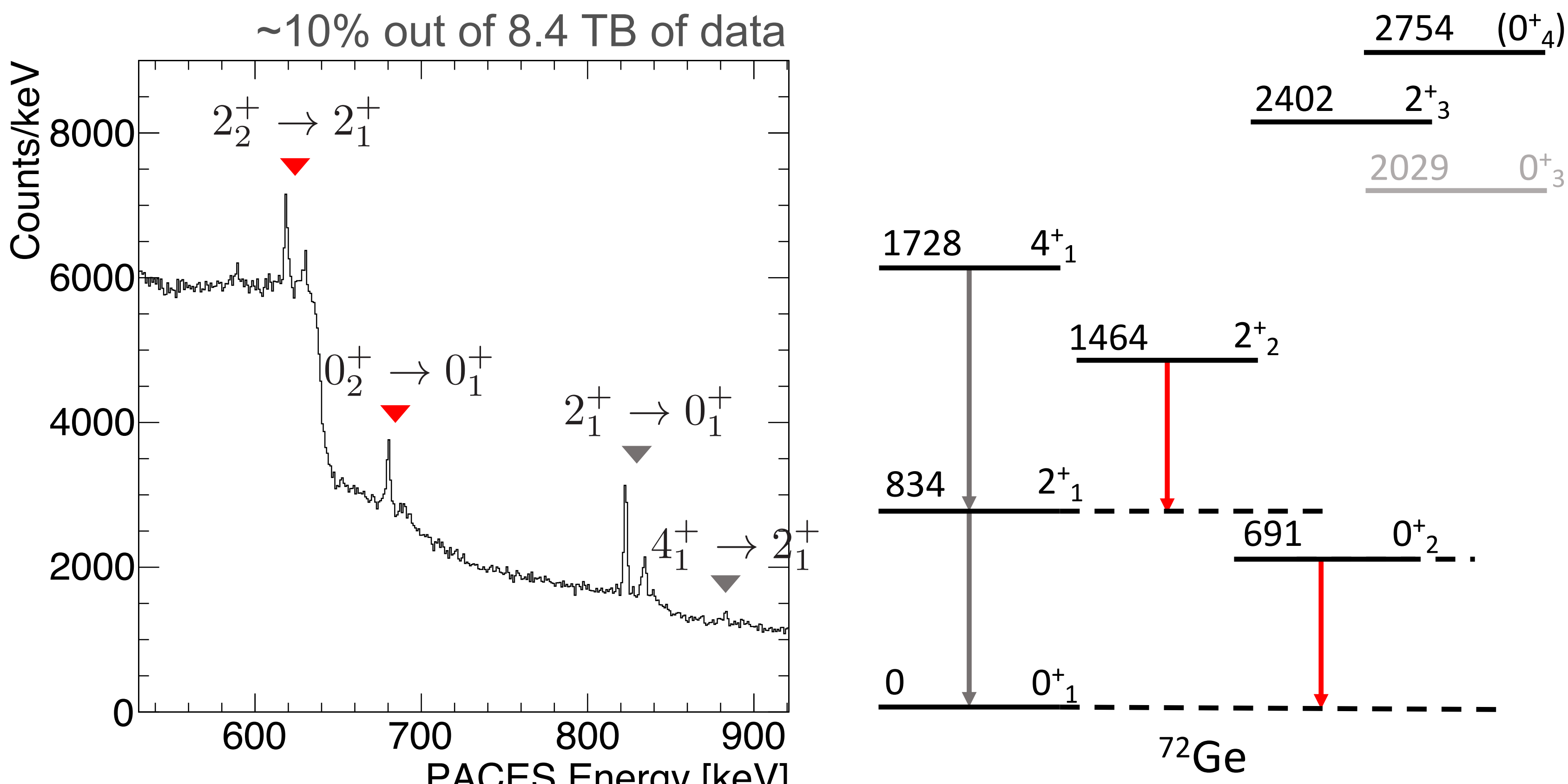


Zero Degree Scintillator $\longrightarrow \beta$



➤ A.B. Garnsworthy *et al.*, NIM A **918**, 9 (2019).
➤ A.B. Garnsworthy *et al.*, NIM A **853**, 85 (2017).

The Electron Spectrum measured by PACES in beta coincidence with the Zero Degree Scintillator



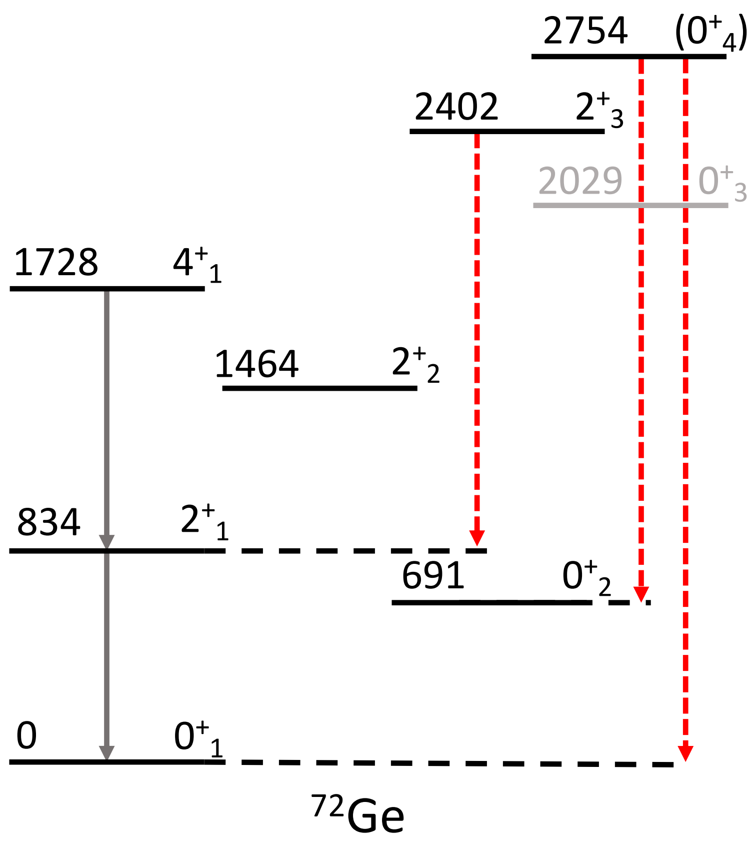
The Electron Spectrum measured by PACES in beta coincidence with the Zero Degree Scintillator

2^+_3 and (0^+_4) states are populated.
Their *E0* decay is not yet observed.

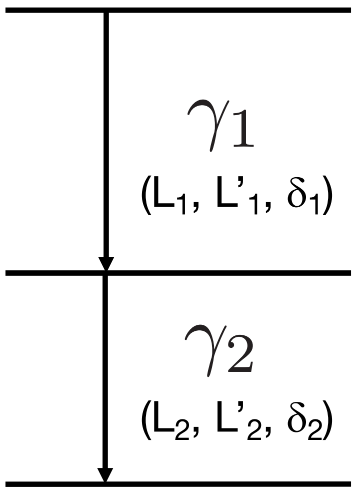
- Just 10% of the data

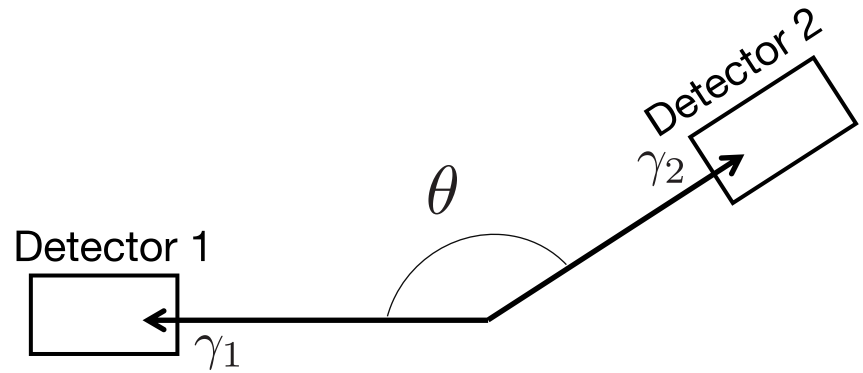
0^+_3 state not yet observed.

Possible spin confirmation of the (0^+_4) level at 2754 keV via $\gamma\gamma$ angular correlations.



The Angular Correlation Analysis to get mixing ratios and assign spins



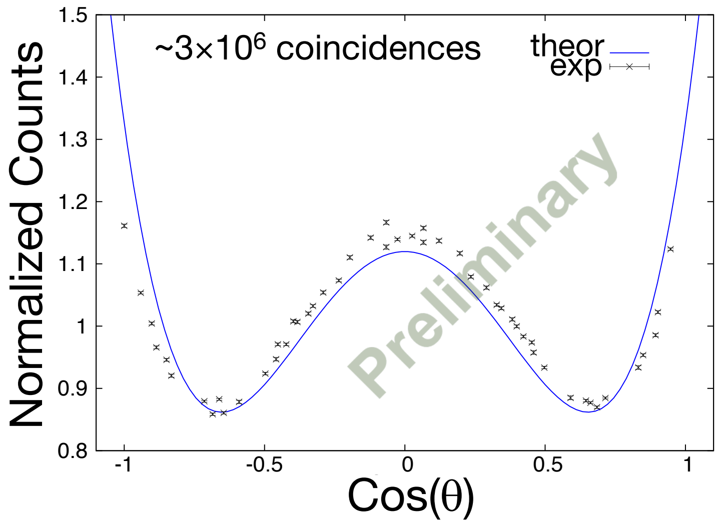


$$W(\theta) = \sum_{even\,k}^{\infty} A_{ii} P_i(\cos\theta)$$

- 51 angle pairs θ at GRIFFIN
- GEANT4 simulations allow to extract the multipolarity mixing ratio values or the spins, given a set of experimental data points

➤ Smith, MacLean *et al.*, NIM A **922** 47 (2019).

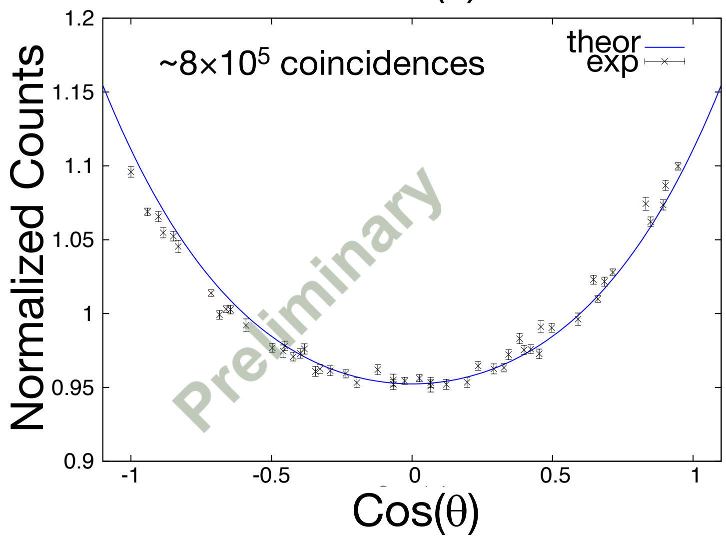
The Angular Correlation Analysis
to get mixing ratios and assign spins



2^+-2^+-0^+

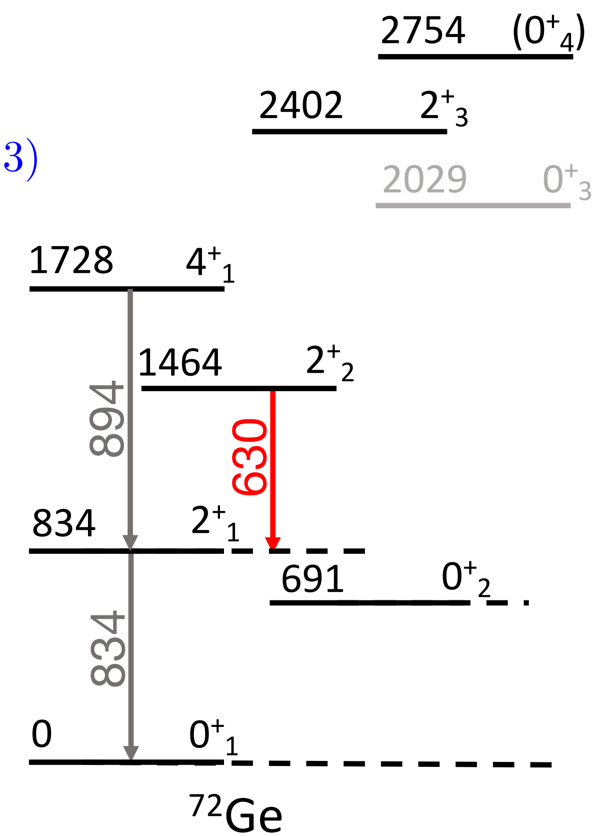
M1+E2 – E2

$$\underbrace{\delta_{630,lit}}_{\frac{\langle J_i||E2||J_f\rangle}{\langle J_i||M1||J_f\rangle}} = -10.3(13)$$



4^+-2^+-0^+

E2 – E2



What's next?

- Complete ^{72}Ge analysis in terms of *E0* strength measurements and spin confirmation via $\gamma\gamma$ angular correlations

- Run the same kind of experiment
for the adjacent even-even isotopes ^{74,76,78}Ge
(scheduled in Sept 2019 @ TRIUMF)

- Perform a complementary measurement
of relative population yields of ^{74}Ge low-lying excited states
(scheduled in Sept 2019 @ IFIN-HH, Bucharest)

Thank You

A.B. Garnsworthy[1], J. Henderson[2], J. Smallcombe[3], J. K. Smith[4], S.S. Bhattacharjee[1], V. Bildstein[5], M. Bowry[1], R. Coleman[5], I. Dillmann[1], G. Hackman[1], S. Leoni[6], C. R. Natzke[7], B. Olaizola[1], E. E. Peters[8], C.E. Svensson[5], S. W. Yates[8], T. Zidar[5]

[1]TRIUMF, [2]LLNL, [3]U. of Liverpool, [4]Pierce College, [5]U. of Guelph, [6]U. of Milan, [7]Colorado Mines, [8]U. of Kentucky

The Neutrinoless Double Beta decay

$0\nu\beta\beta$ half-life

Phase space

Effective Majorana neutrino mass

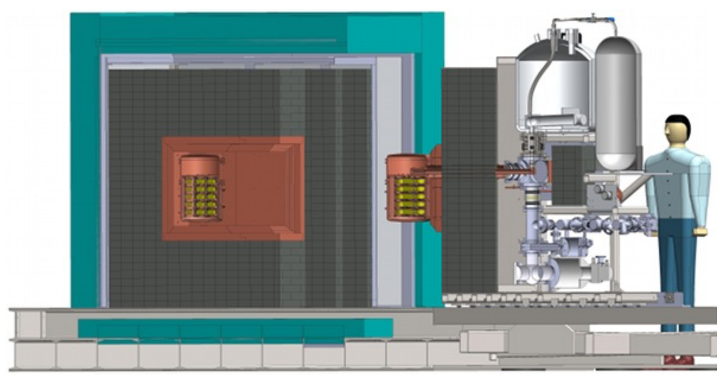
$$(T^{0\nu}_{1/2})^{-1} = G^{0\nu}(Q_{\beta\beta}, Z)|M^{0\nu}|^2\langle m_{ee}\rangle^2$$

Nuclear matrix element

GERDA @ LNGS

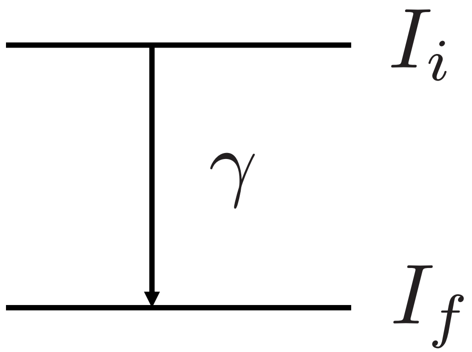
(Ackermann *et al*.
EPJ C (2013) 73:2330)

MAJORANA @ SURF



Looking for ^{76}Ge $0\nu\beta\beta$ decay

Multipolarity mixing Ratio δ

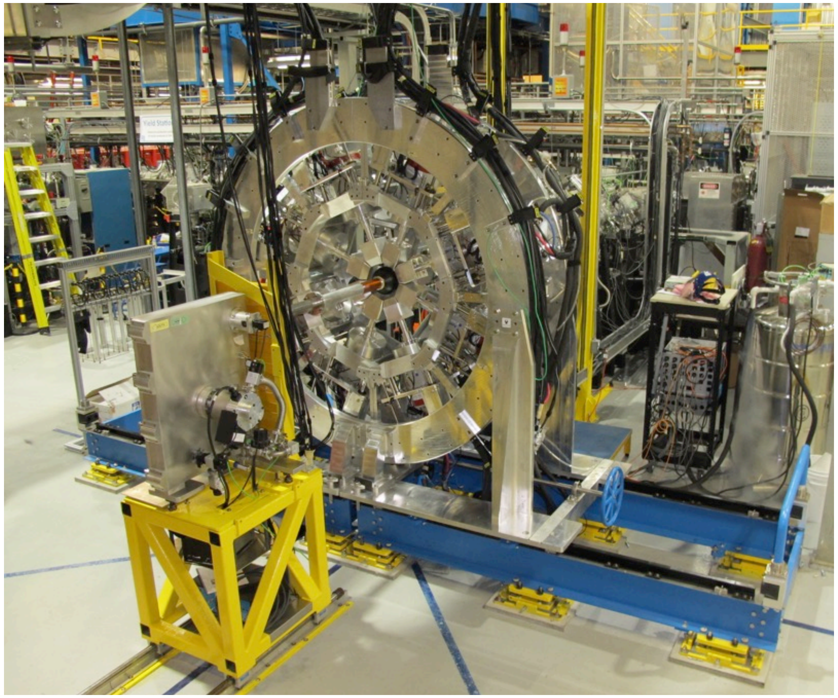


$$\delta(\gamma) = \frac{\langle I_i || L'\pi' || I_f \rangle}{\langle I_i || L\pi || I_f \rangle}$$

- L, L' multipolarities of the γ-ray
- π parity of the transition

GRIFFIN

GRIFFIN clover array



HPGe clover detector