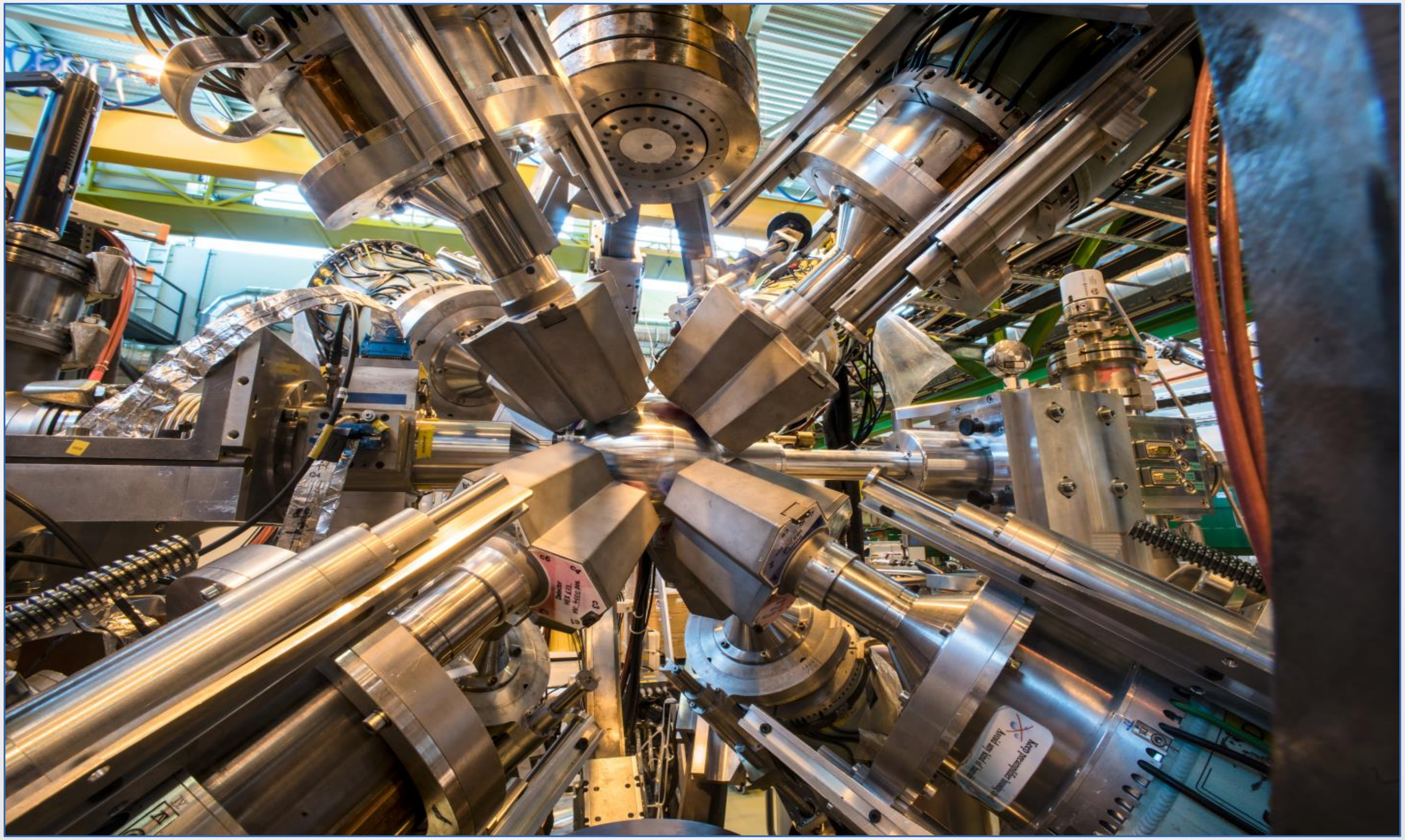
Enhancement of E2 collectivity in ^{66}Ge

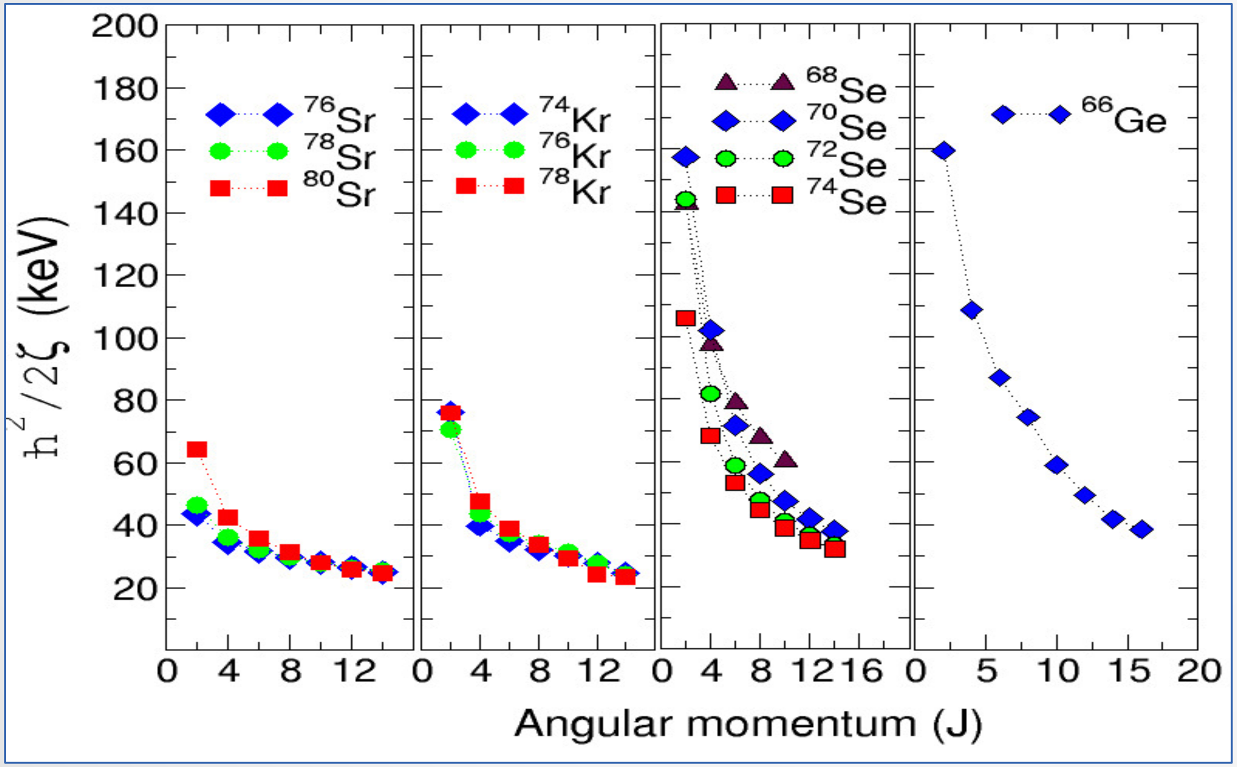
Kenzo Abrahams

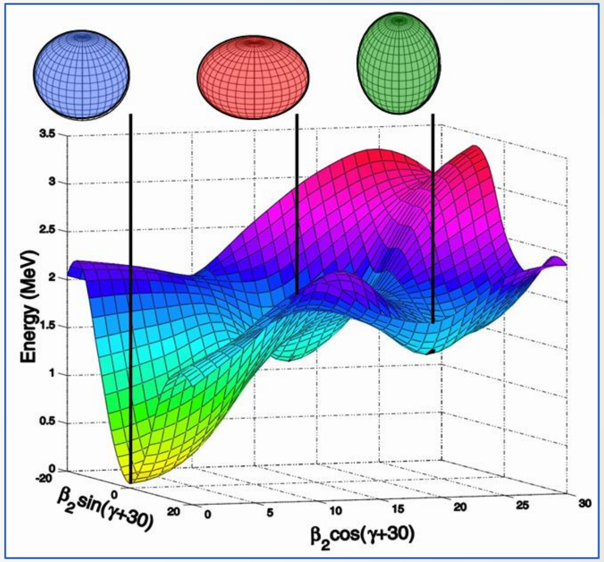


https://cds.cern.ch/record/2273290

An experimental curiosity

Anomalously high 2^+ rotational parameter -> signature for shape coexistence

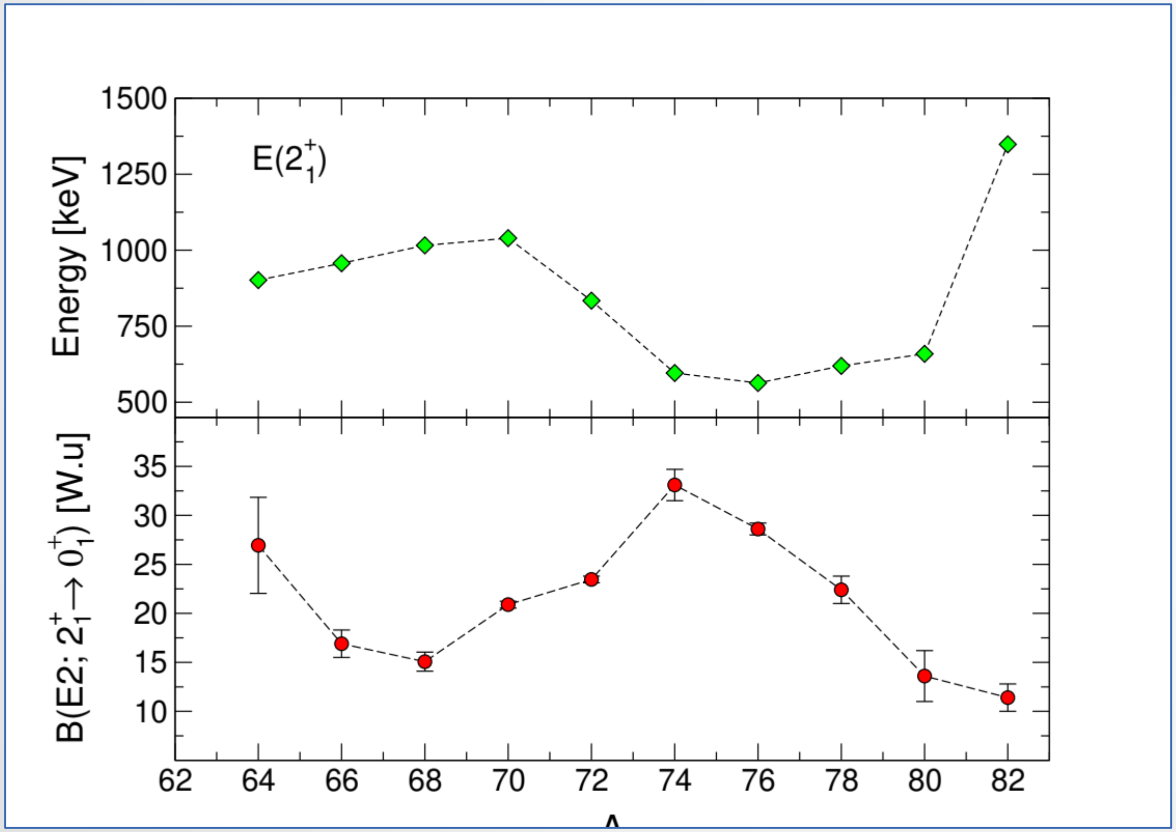


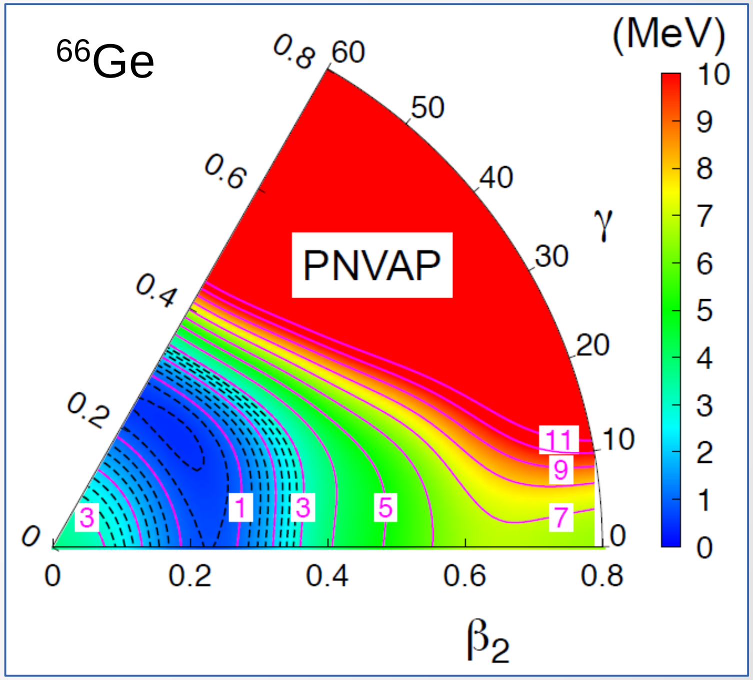


Two-state mixing between (g.s. and first excited) 0^+ states push down the ground state 0^+ and the 2^+ excitation energy looks anomalously high

An experimental curiosity

- ^{66}Ge (N=34) has a similar E2 strength compared to ^{80,82}Ge (N=50)
- Competing shape minima in the PES can be formed by different configurations





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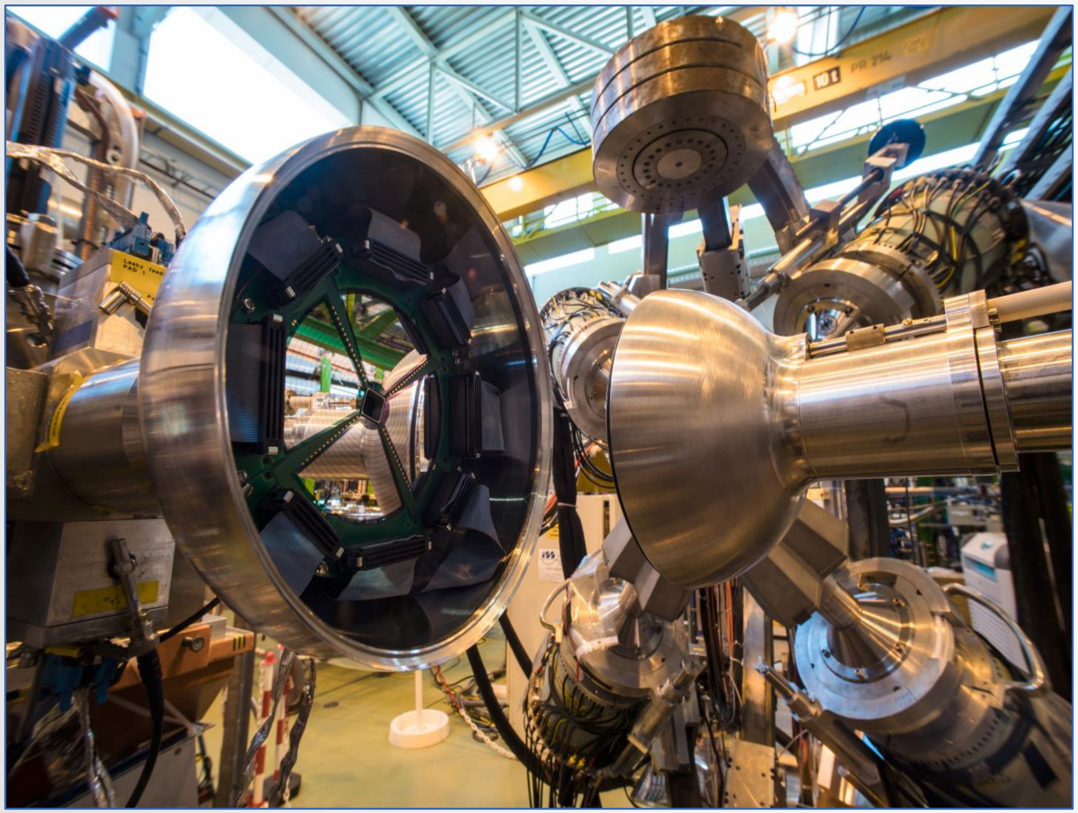
What is the deformation of ^{66}Ge in the first 2^+ state?

First determination of $Q_S(2^+)$ in ^{66}Ge



- First time ^{66}Ge was accelerated at low energies: $^{66}Ge^{32}S$ molecules from ZrO_2 target @ 4.395 MeV/u bombarded onto a 4 mg/cm^2 ^{196}Pt target
- 8 HPGe Cluster detectors to detect gammas
- DSSSD (16 rings, 12 sectors) used to detect scattered particles (beam and target)
- CD distance to target = 27.4 mm covering [18.2^o – 56.2^o]

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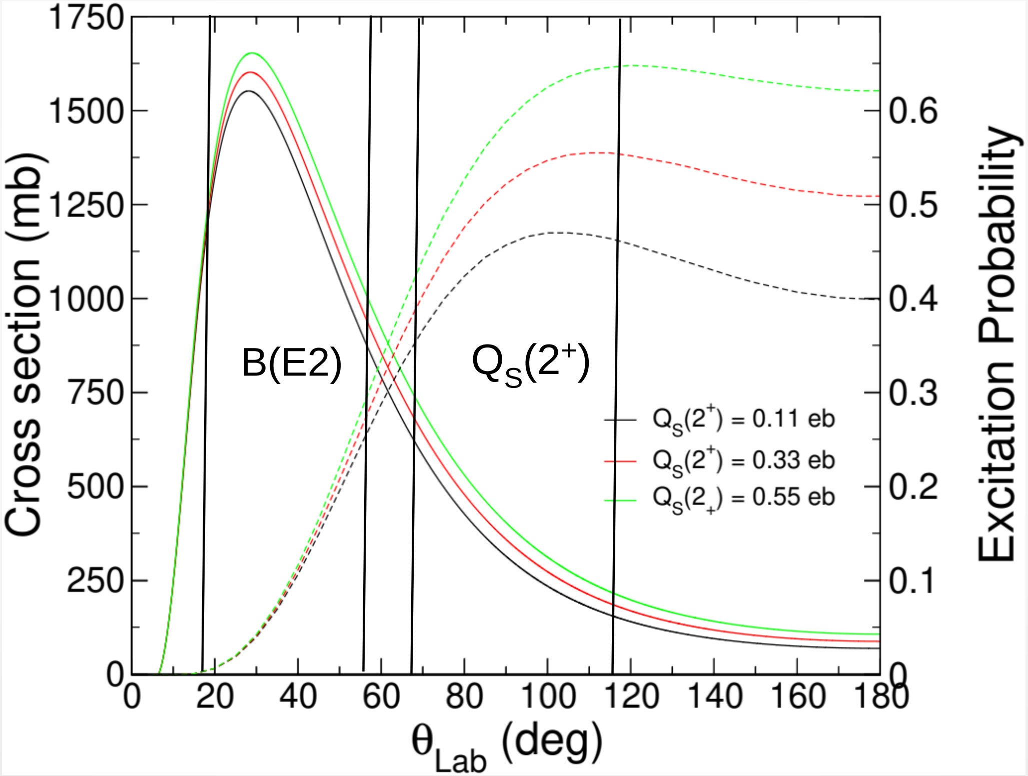
Coulex cross section and excitation probability

- B(E2) determined at forward angles using beam gated data [18.2° – 56.2°] and $Q_S(2^+)$ at backward angles using target gated data [52.1° – 128.1°]



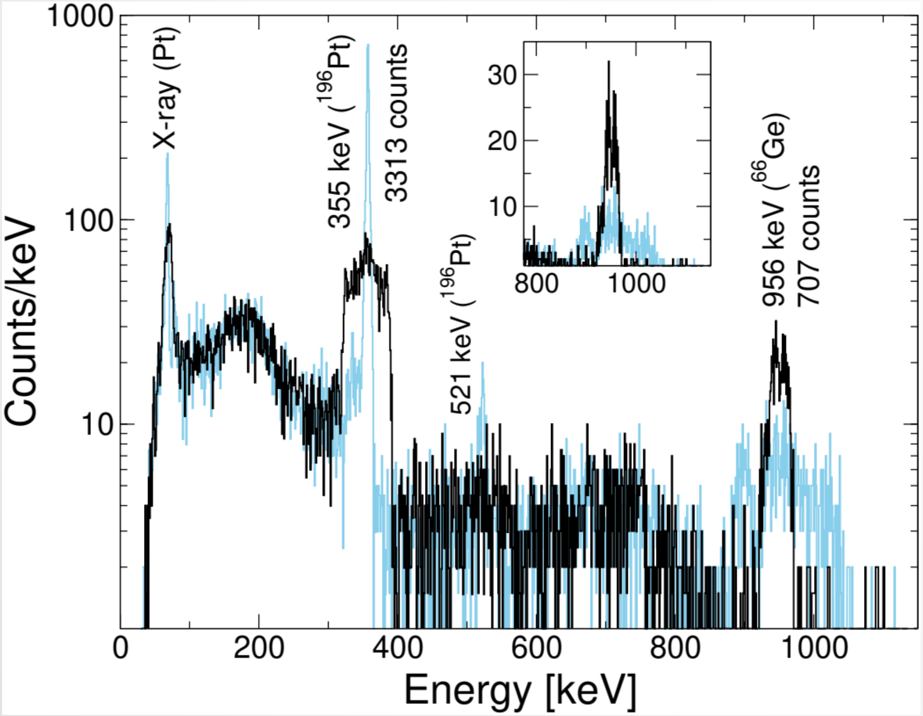
4% difference between $Q_S(2^+)$=0.11 eb and 0.55 eb between [18.2° – 56.2°]

Normalization method

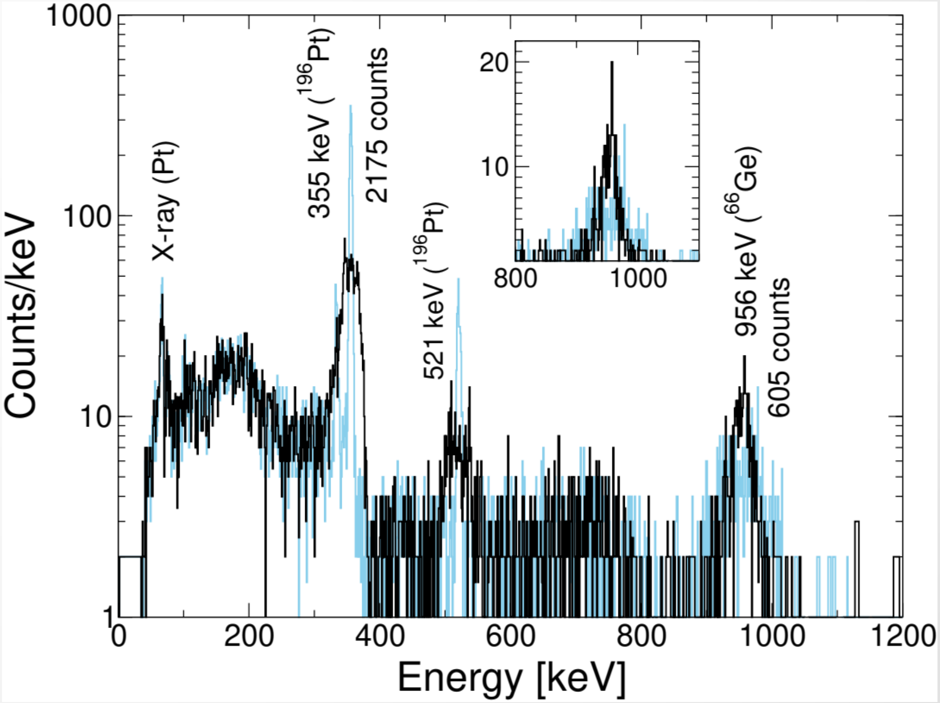
- Minimizes systematic uncertainties (e.g. dead time and difference in beam currents)
- ^{196}Pt/^{66}Ge intensity ratio = 2.24(5)

$$\frac{I_\gamma^T}{I_\gamma^P} = \frac{\sigma_{E2}^T W(\vartheta)^T}{\sigma_{E2}^P W(\vartheta)^P} = \frac{0.91}{0.9725}\frac{N_\gamma^T \varepsilon_\gamma^P}{N_\gamma^P \varepsilon_\gamma^T}$$

Beam gated



Target gated



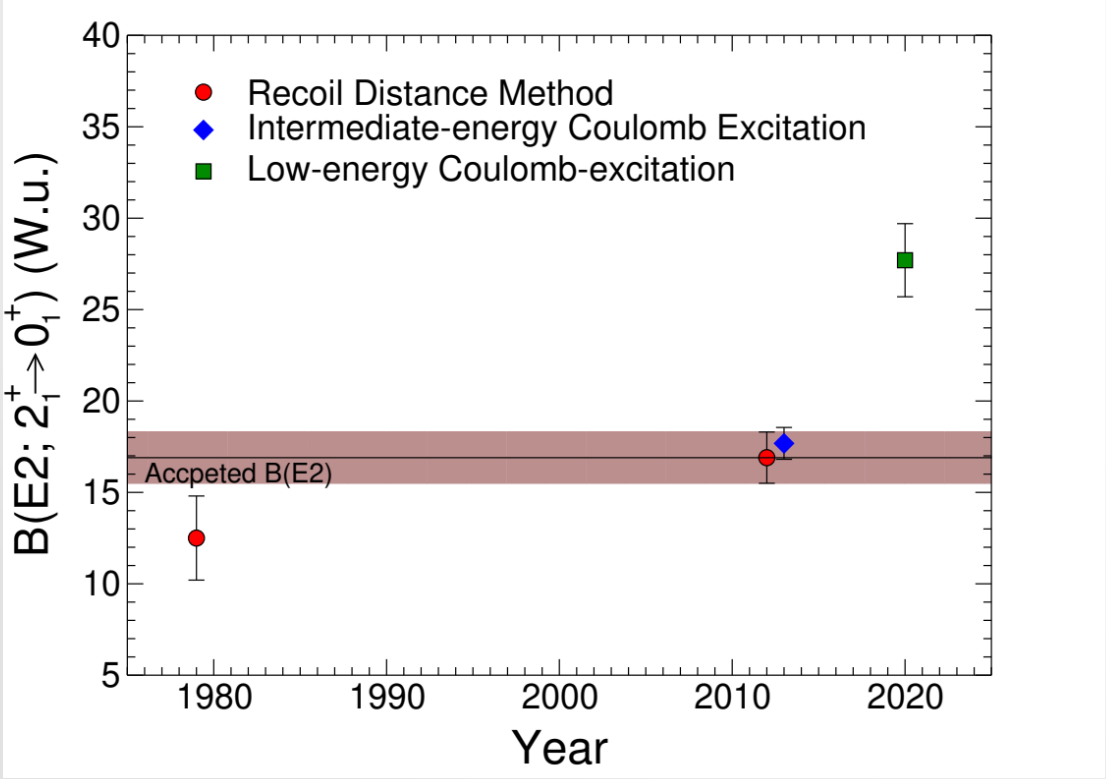
Similar spectra for target gated with a ^{196}Pt/^{66}Ge intensity ratio of 1.72(5)

^{36}Ar to be published as a letter in PRC

Large B(E2) value compared to previous work

$$\frac{I_\gamma^T}{I_\gamma^P} = \frac{\sigma_{E2}^T W(\vartheta)^T}{\sigma_{E2}^P W(\vartheta)^P} = \frac{0.91}{0.9725}\frac{N_\gamma^T \varepsilon_\gamma^P}{N_\gamma^P \varepsilon_\gamma^T}$$

Transitional matrix element (TME) = 0.469(15) eb corresponds to B(E2; $2^+ \rightarrow 0^+$)= 27.7(20) W.u.



Error in quadrature

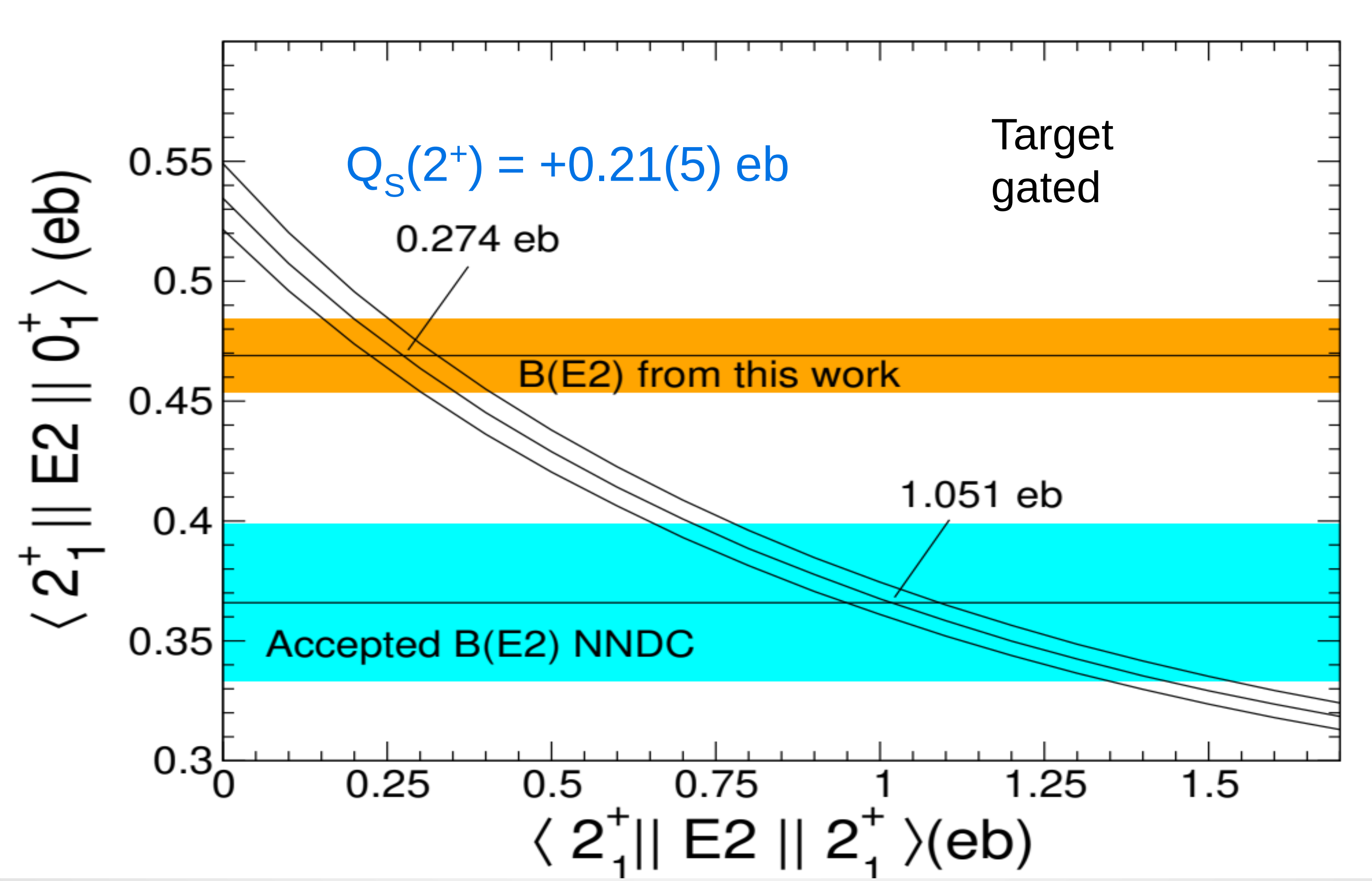
- 2% statistical uncertainty in intensity ratio
- 1% high-lying effects on $2^+ \rightarrow 0^+$ TME
- 4% difference in Q_S between Q_S = 0.11 and Q_S = 0.55 (1σ from accepted)

$$\left|Q_s(2_1^+)_{B(E2)}\right| = 0.9059B(E2;0_1^+ \rightarrow 2_1^+)^{1/2}$$

B(E2) = 16.9 W.u. → $Q_S(2^+)$ = 0.33 eb

Determination of $Q_S(2^+)$ using normalization method

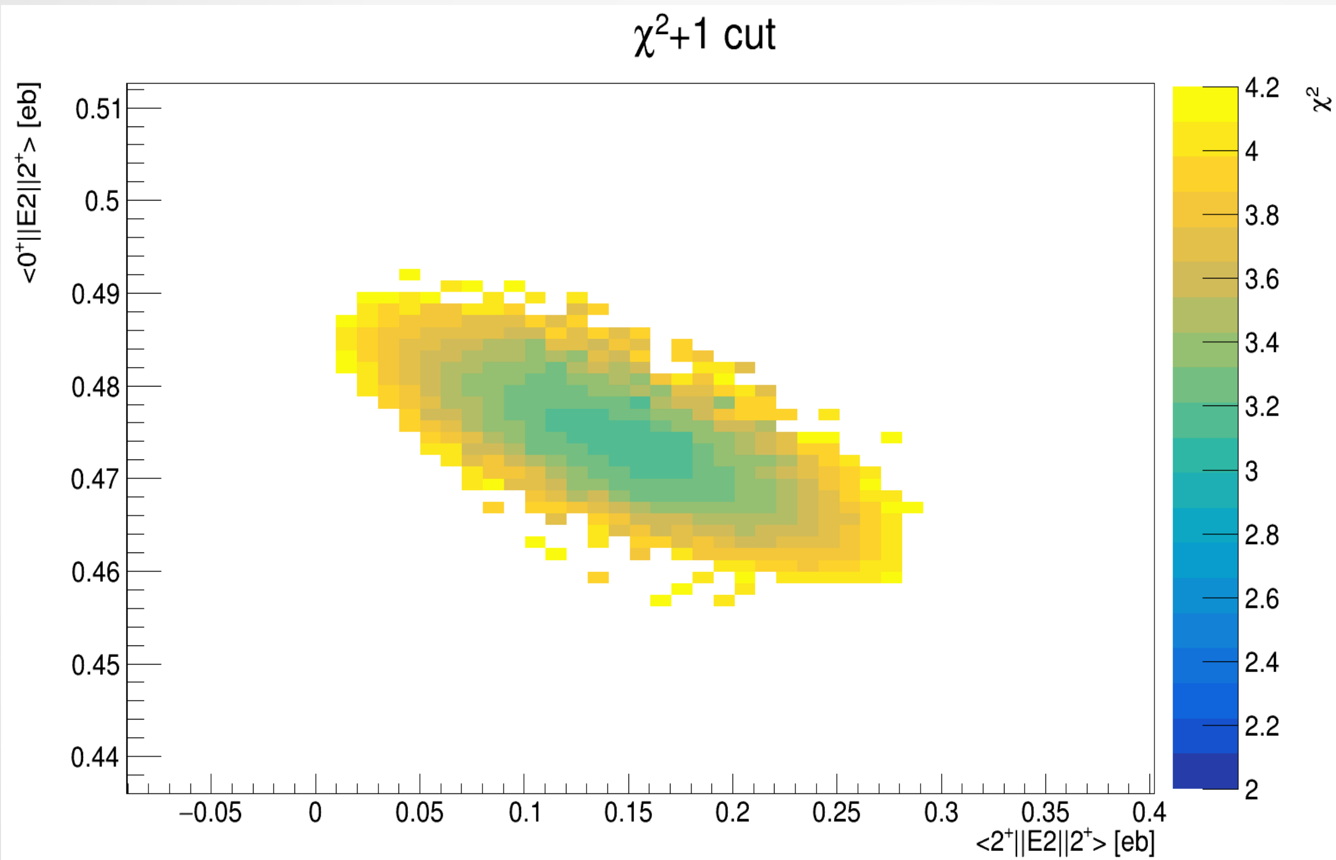
Intersection with B(E2) value from NNDC and from this experiment



Anomously large diagonal matrix element using NNDC value

Gosia minimization method

- TME = 0.4744(18) eb → B(E2; $2^+ \rightarrow 0^+$) = 28.4 W.u.
- DME = 0.15(-0.13,+0.14) eb → $Q_S(2^+)$ = 0.11 eb



Target yield correction

$$F = \frac{1}{1 + \sum_c \left(r_c \frac{\sigma_t(Z_c, A)}{\sigma_t(Z_X, A)} \right)}$$

Beam yield correction

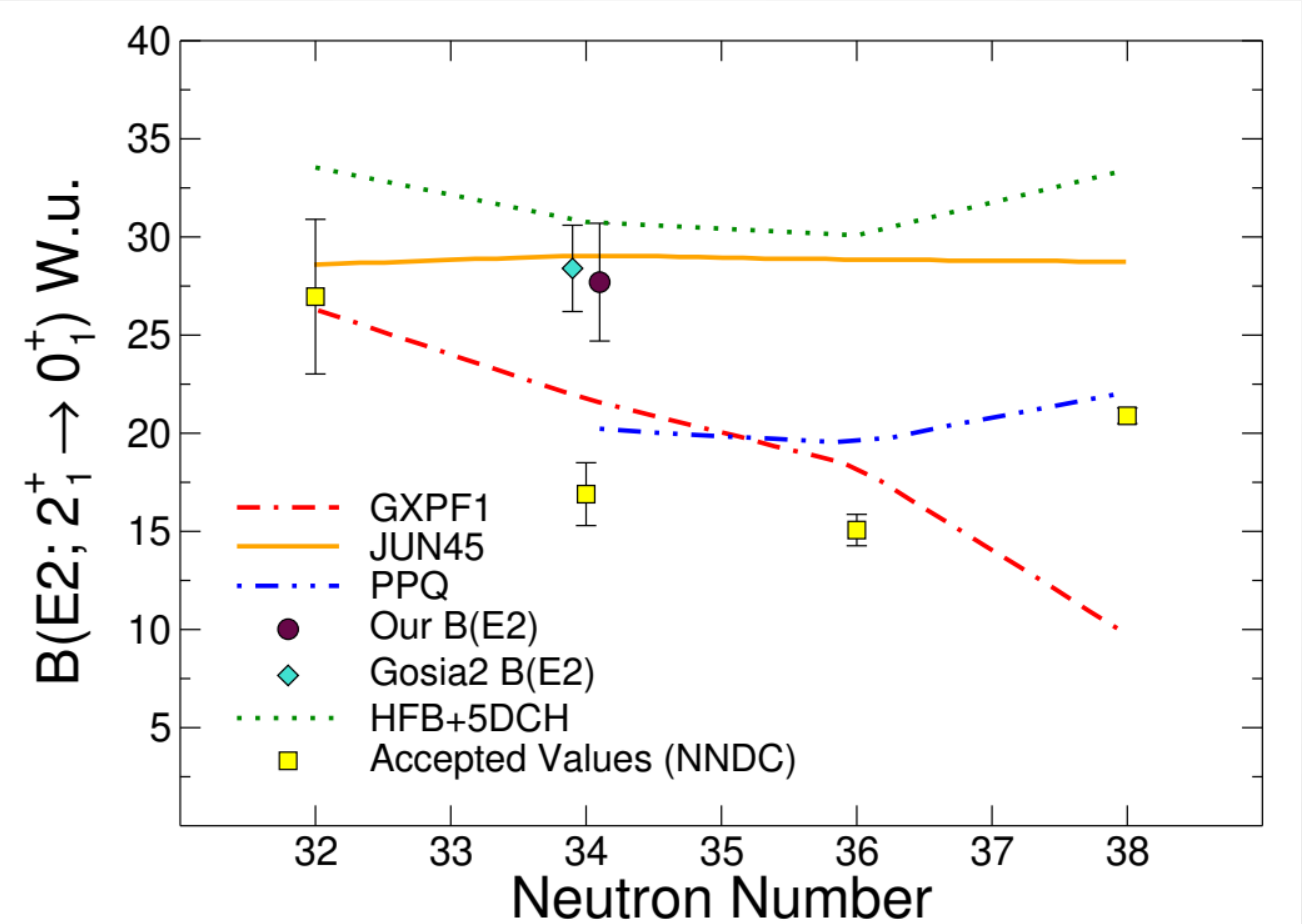
$$F_i = \left(1 + \frac{1}{P} \cdot \frac{\sigma_i(Z', A')}{\sigma_i(Z, A)} \right)$$

Zielińska, M. et al. Eur. Phys. J. A 52, 99 (2016)

Gosia level schemes includes the 1st and 2nd 2^+ states in ^{66}Ge and ^{196}Pt plus a buffer state

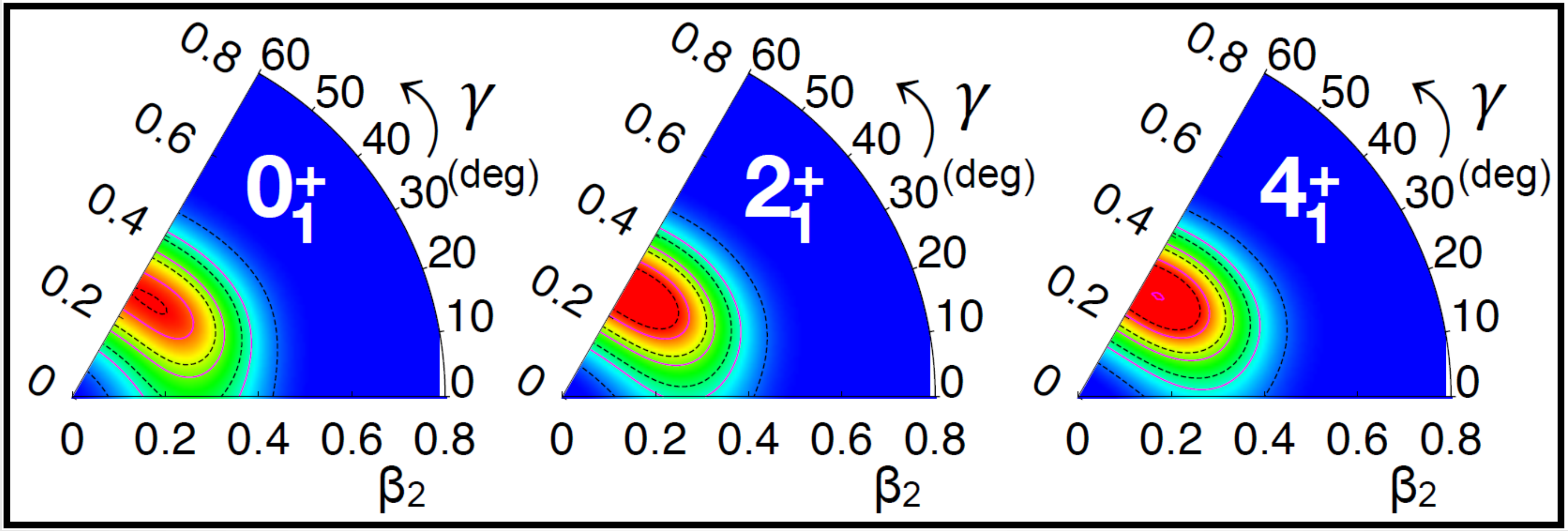
Theory vs B(E2): Constraint of SM calculations

Large B(E2) value in agreement with JUN45



Collective wavefunctions from beyond mean field

- After projection onto angular momentum and configuration mixing, the energy and collective wavefunctions for different states are obtained by solving the Schrödinger equation.



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Oblate deformation with $Q_S(2^+)_{theo}$ = 0.21 eb in ^{66}Ge in agreement with our measurement

Conclusion

- First Coulex of neutron-deficient Ge isotopes at safe energies
- Determination of larger B(E2)=27.7(20) W.u.
- Determination of $Q_S(2+)=+0.21(5)$ eb
- In agreement with the oblate deformation calculated by beyond mean-field calculations
- Constraint of shell model calculations (JUN45)
- Solving finally an experimental curiosity

Acknowledgements

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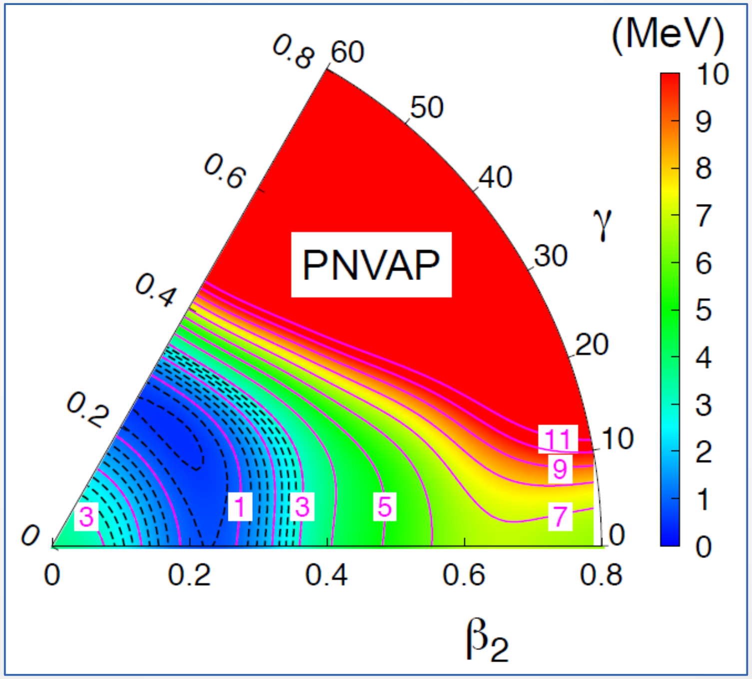
- All the collaborators that helped run and ensure a successful experiment

Potential energy surface

- Particle Number Variation After Projection (PN-VAP) beyond mean-field calculations iteratively vary the shape and minimize the energy to obtain the collective behaviour of a given nucleus (PES).

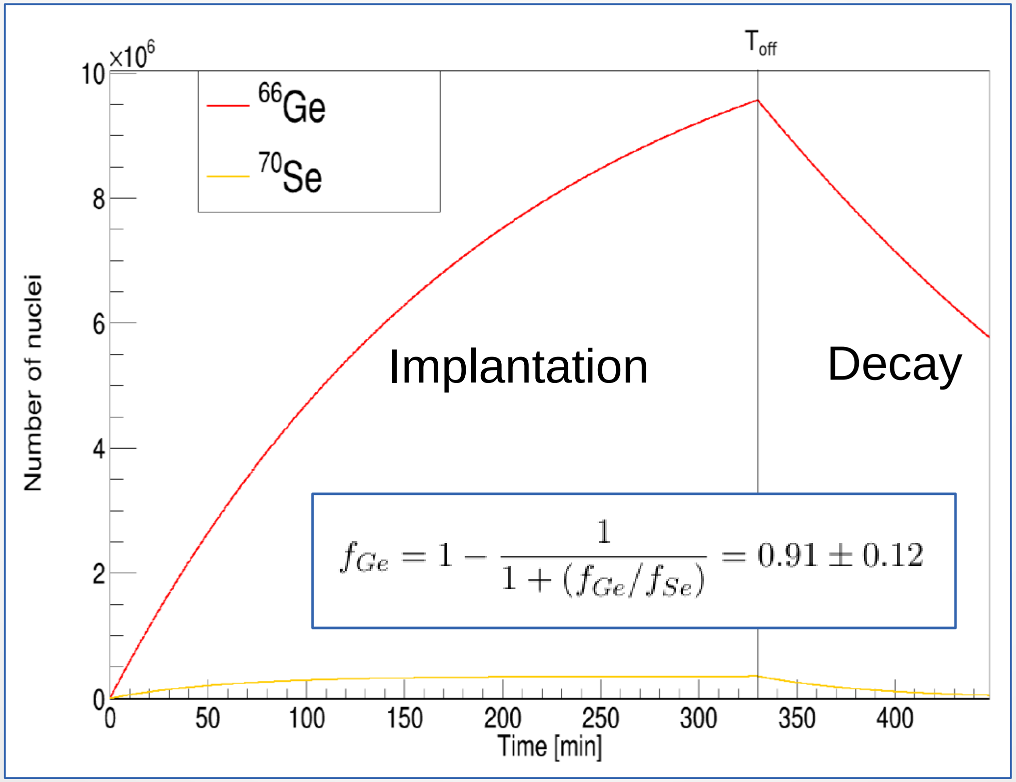
- Competing shape minima in the PES can be formed by different configurations



T. Rodriguez (2020)

Beam composition

- $^{66}Ge^{32}S$ vs $^{70}Se^{12}C^{16}O$ (mass=98)
- 381.85 keV ($^{66}Ge \rightarrow {}^{66}Ga$) and 426.15 keV ($^{70}Se \rightarrow {}^{70}As$)



$$f_{Ge} = 1 - \frac{1}{1 + (f_{Ge}/f_{Se})} = 0.91 \pm 0.12$$

Confirmed by accelerator group with downstream Si????

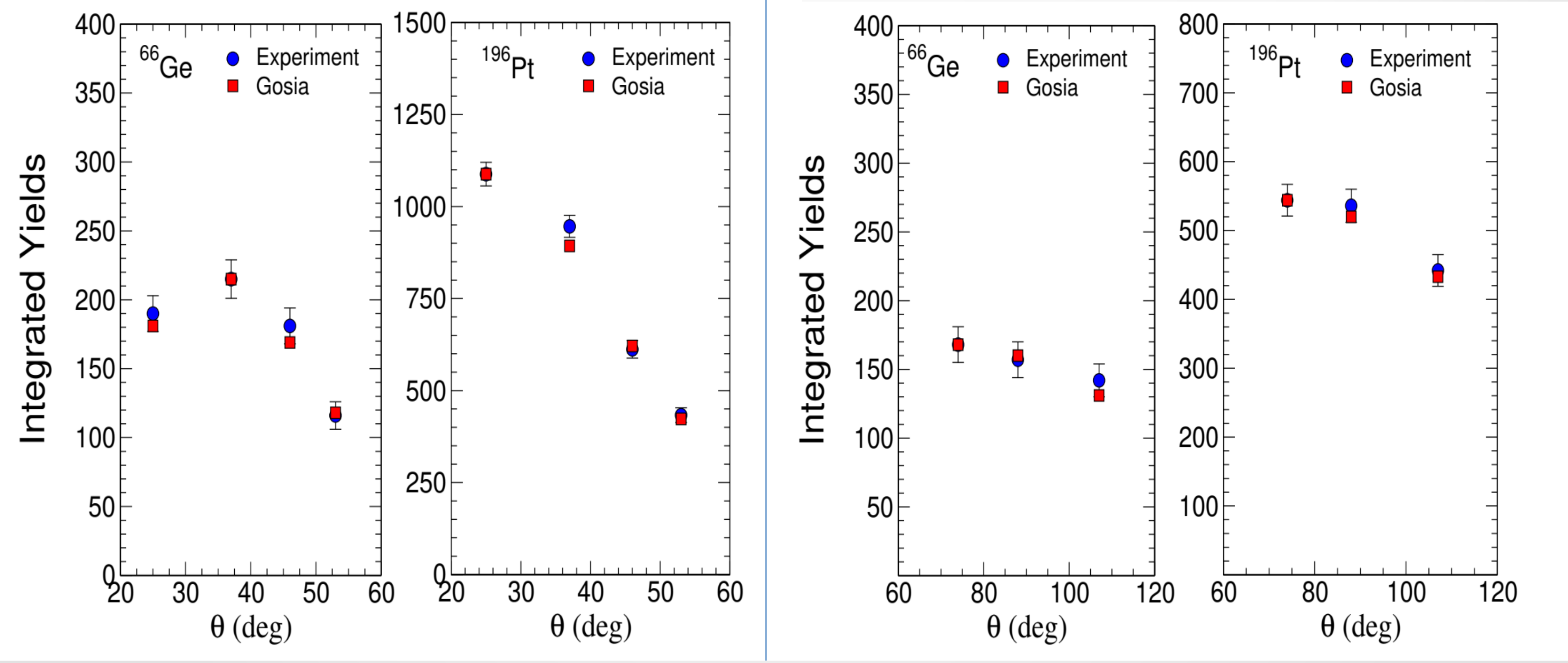
Experiment vs Gosia Heavy-ion angular distributions

Beam-gated integrated yields per 4 rings

[18.2° – 56.2°]

Target-gated integrated yields per 3 rings

[68.6° – 119.1°]



Gosia level schemes