

Shape coexistence in neutron-deficient ^{190}Pb

Adrian Montes Plaza ^{1,2,*}

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Outline

- **Motivation**
- **JYU-ACCLAB setup**
- **^{190}Pb case of study**

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- **1st Exp.: Simultaneous in-beam γ -ray and conversion electron spectroscopy**
- **2nd Exp.: Lifetime measurements**
- **^{190}Pb results and interpretation**

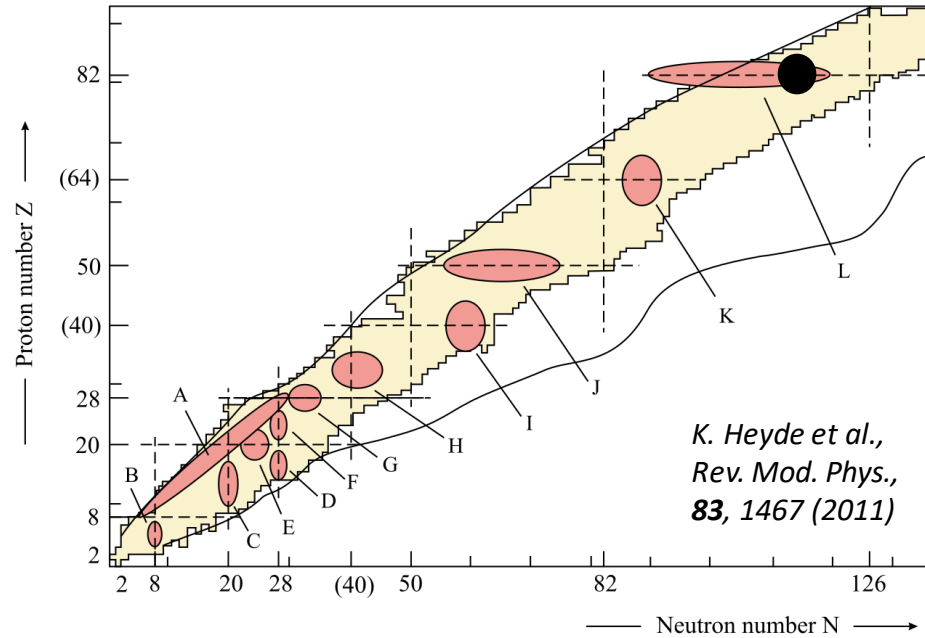
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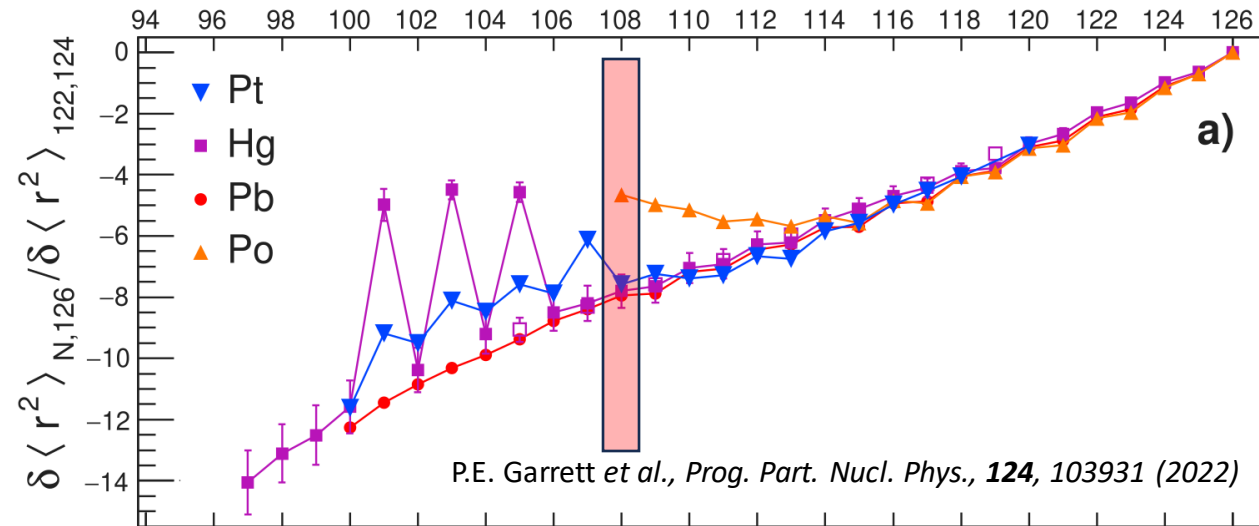
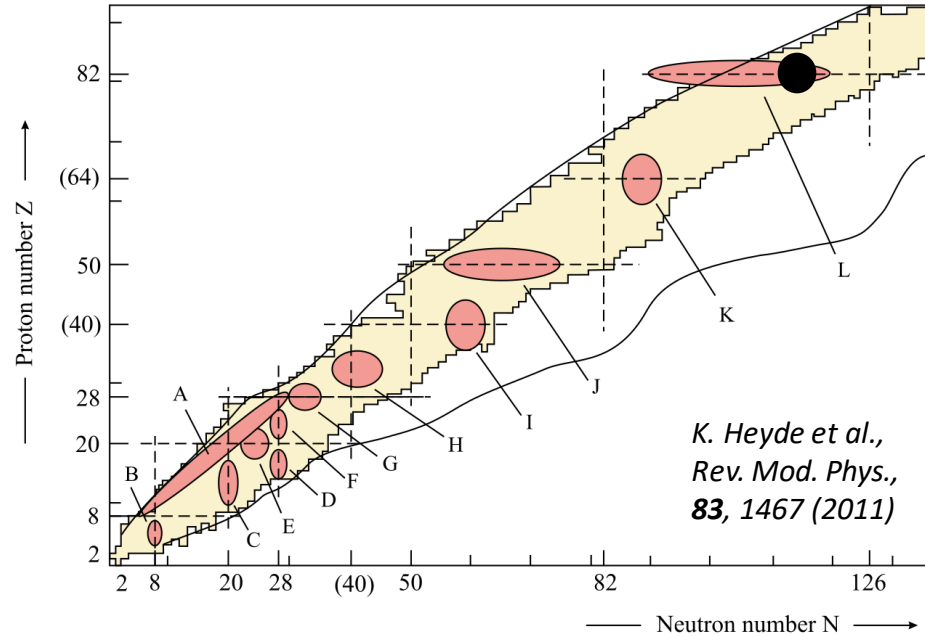
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- **Neutron-deficient $^{186,188,190}\text{Pb}$ overview**
- **Conclusion**

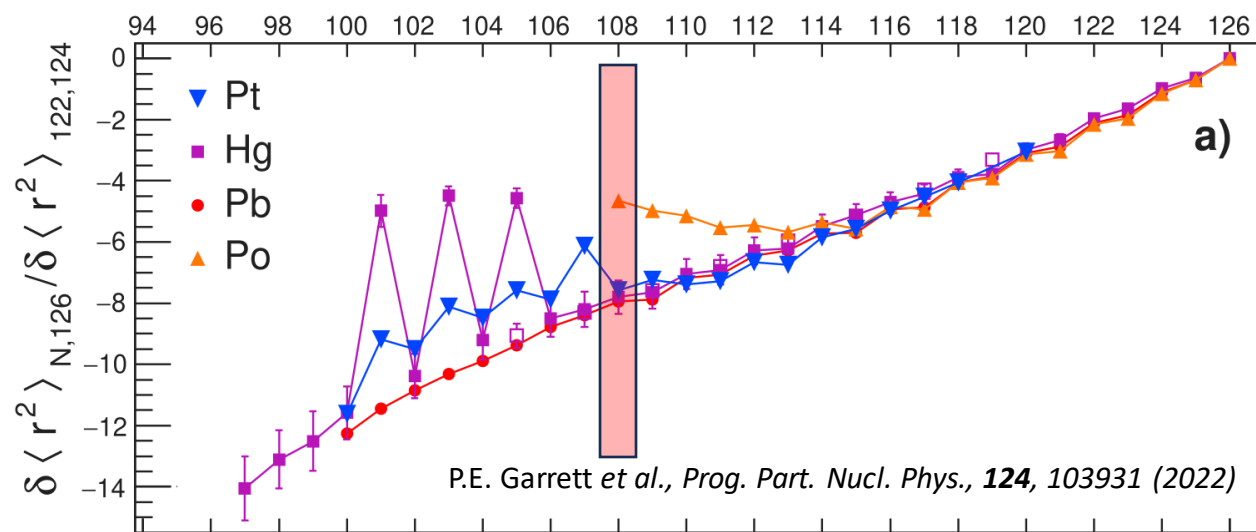
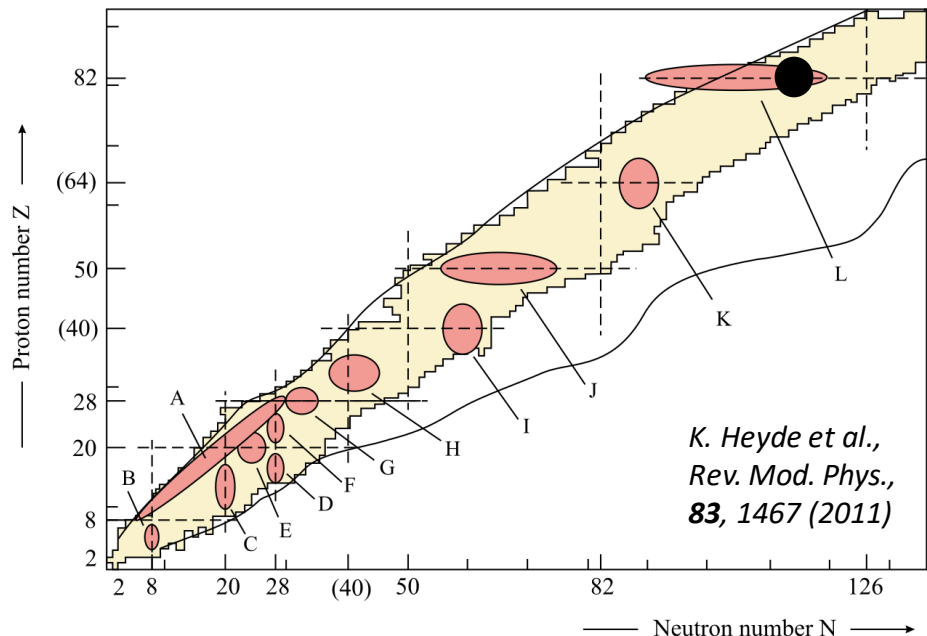
Shape coexistence in neutron-deficient Pb isotopes



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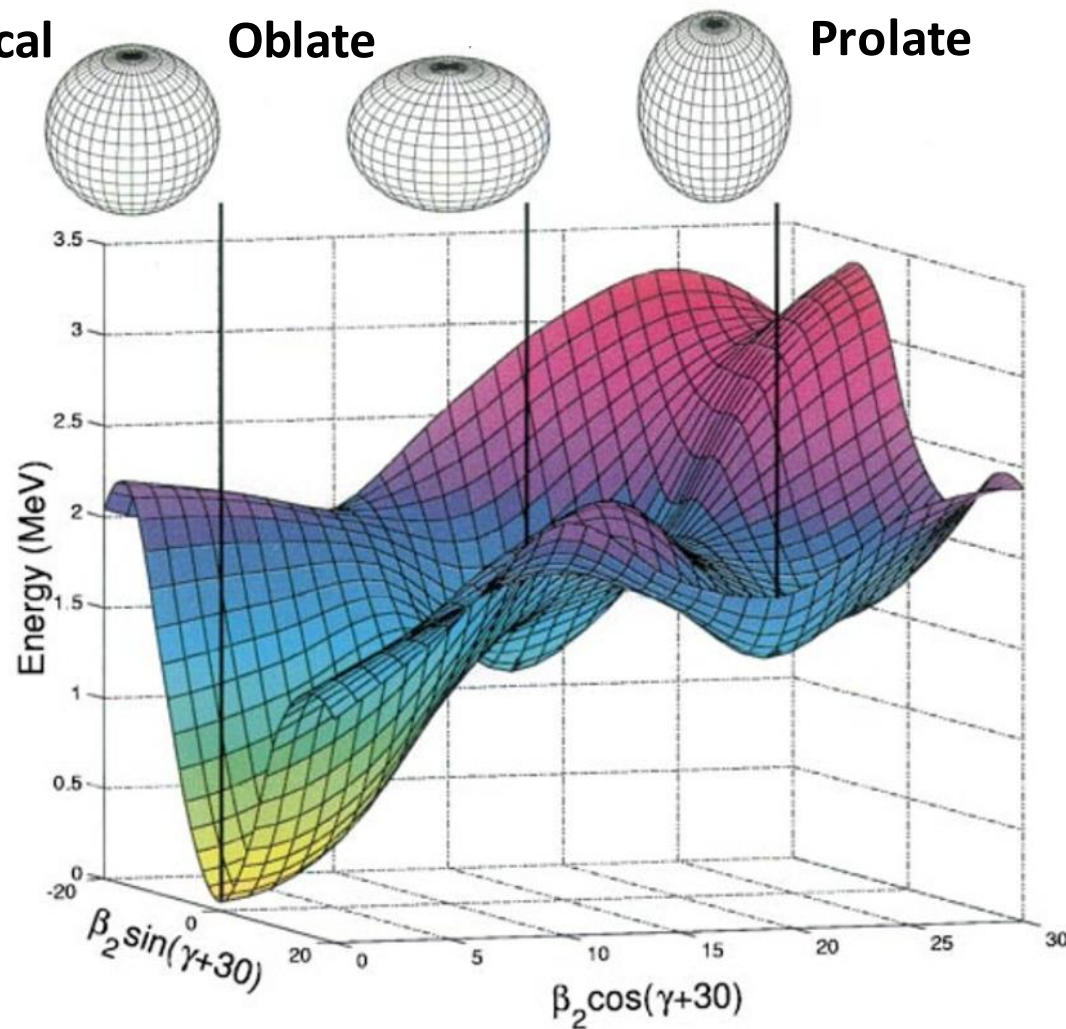
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Spherical

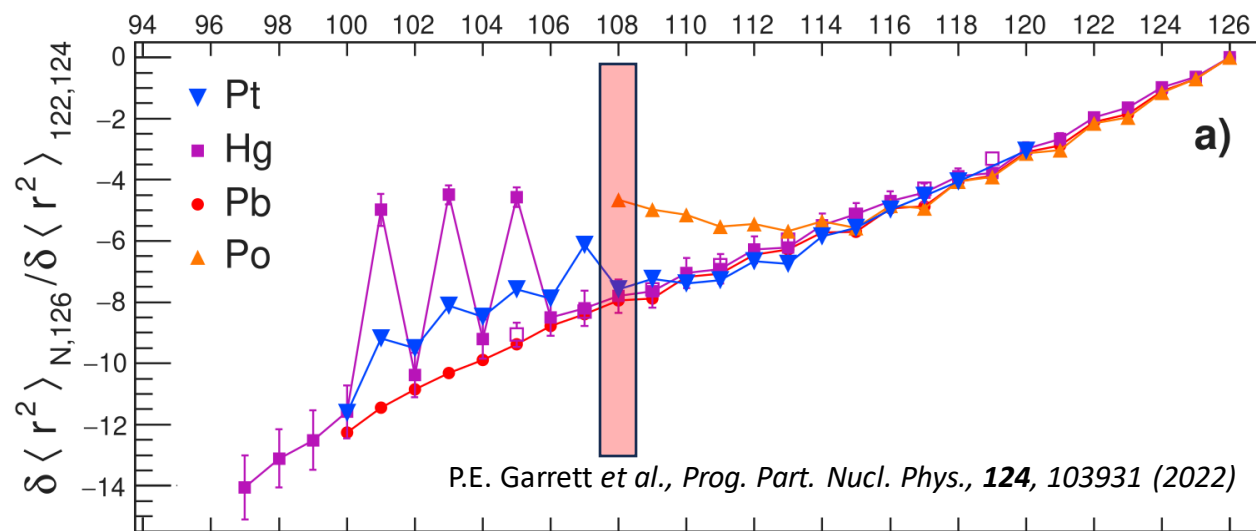
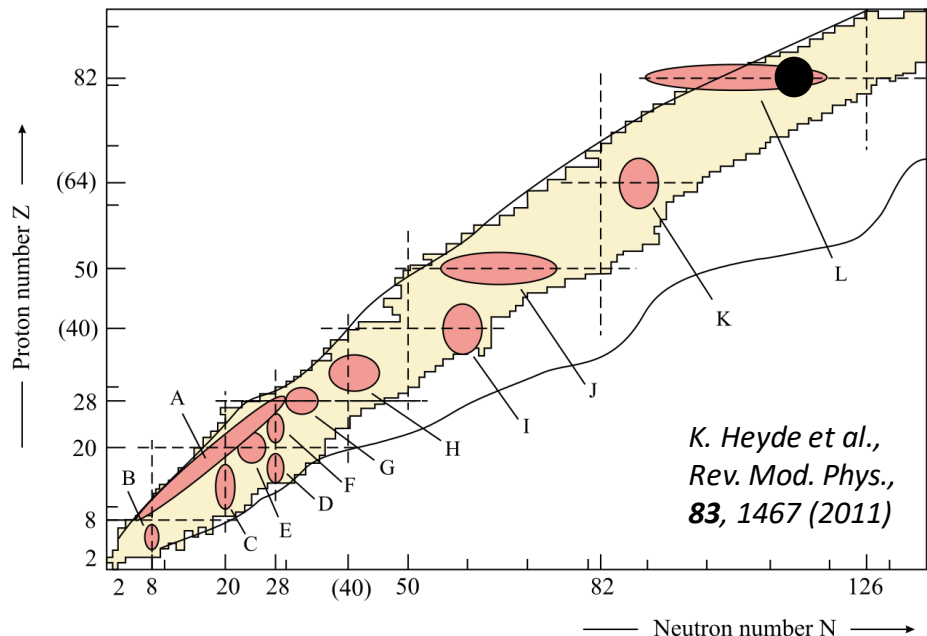
Oblate

Prolate



A. N. Andreyev et al., Nature, 405, 430 (2000)

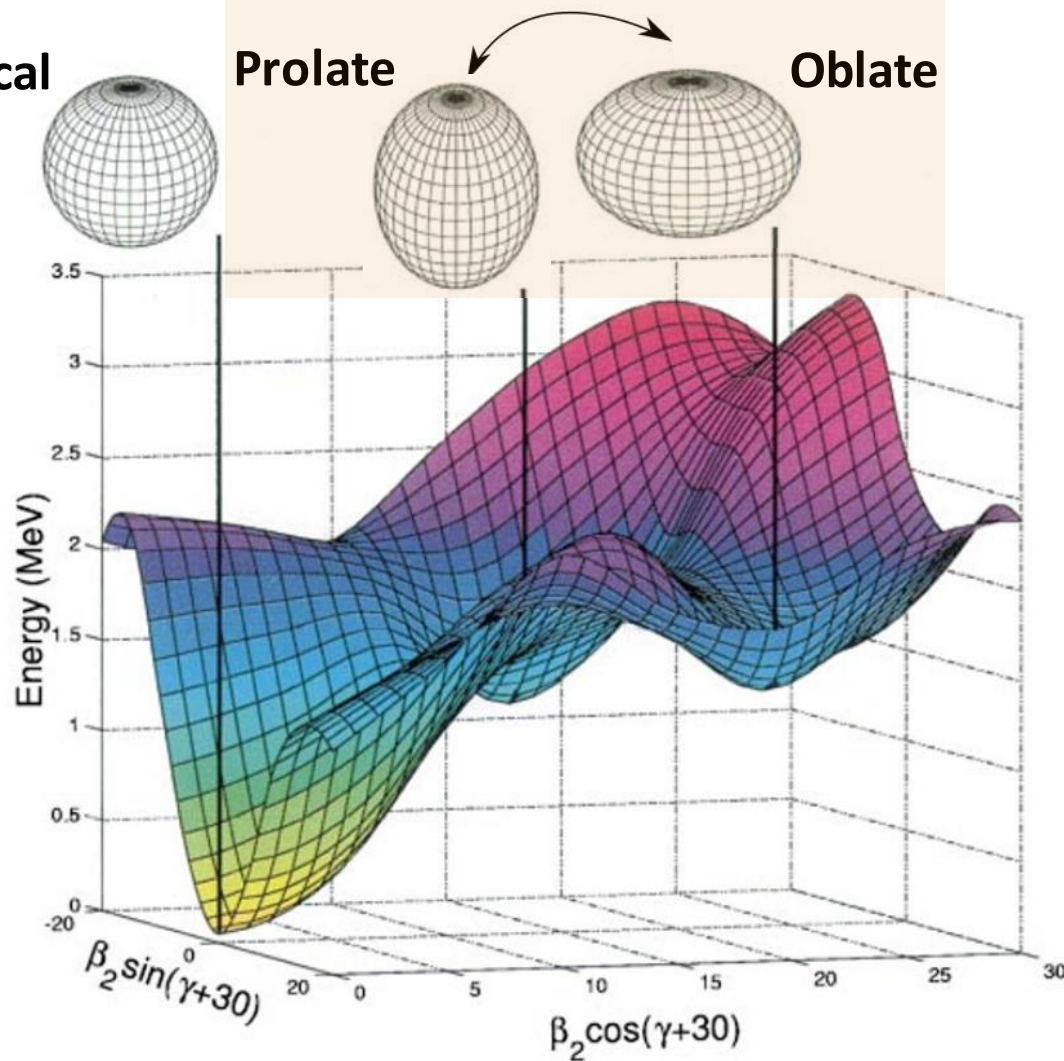
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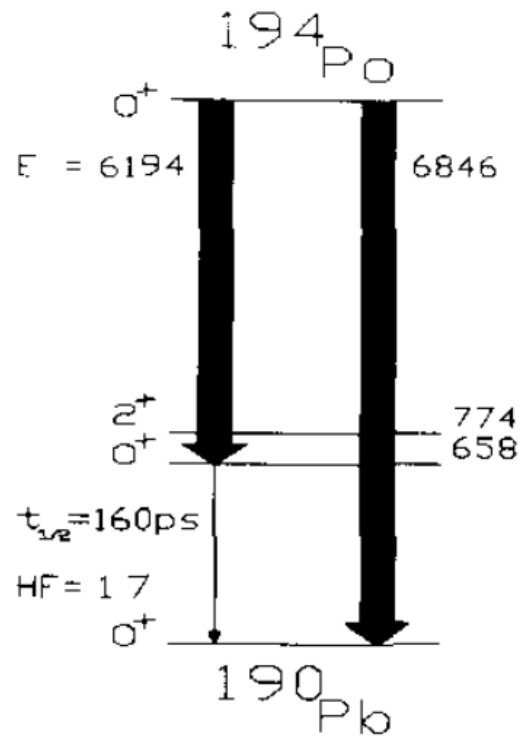
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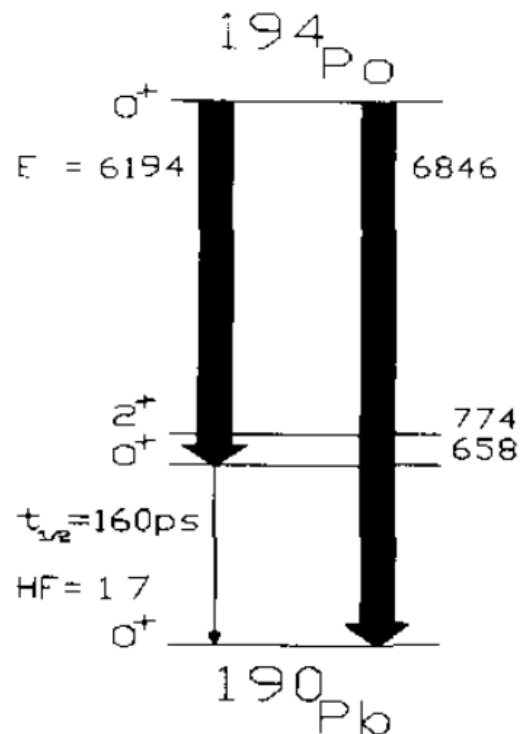
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^{190}Pb previous experiments

Excited 0^+ from α -decay

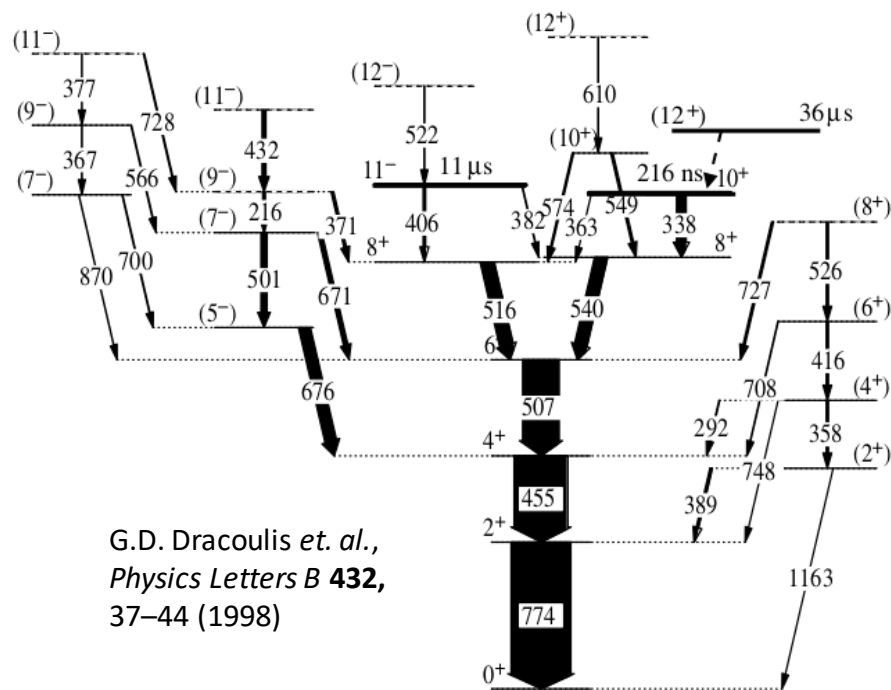
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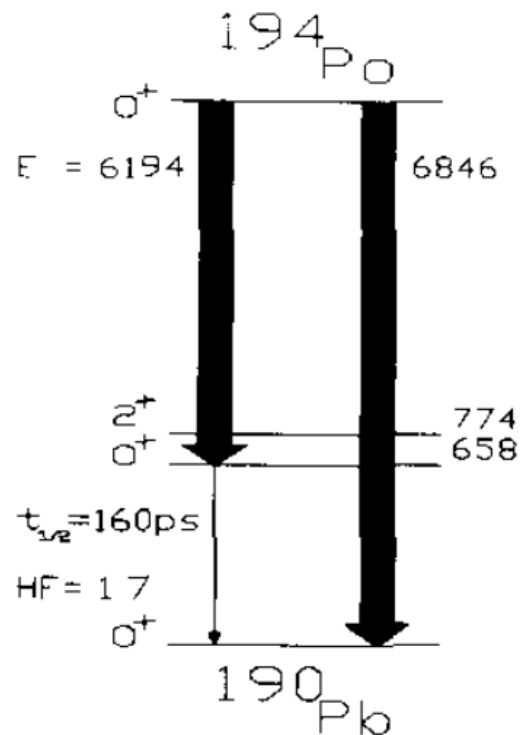
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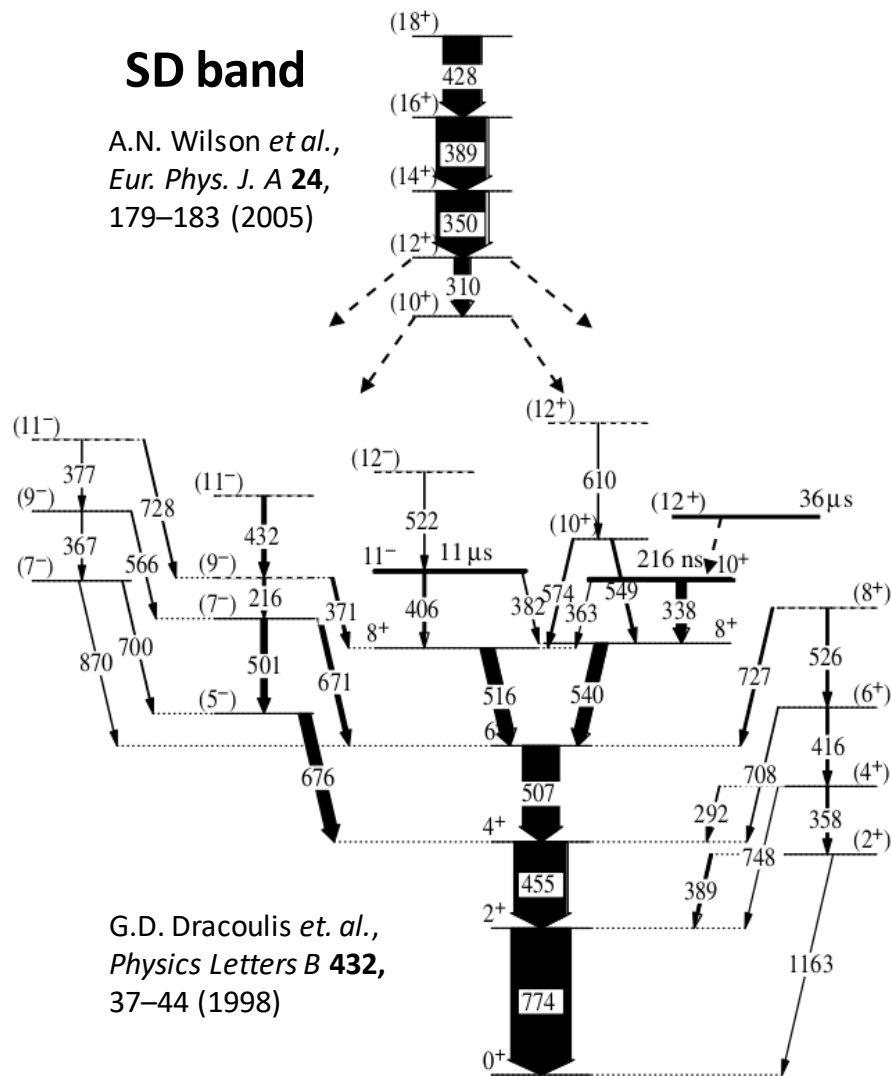


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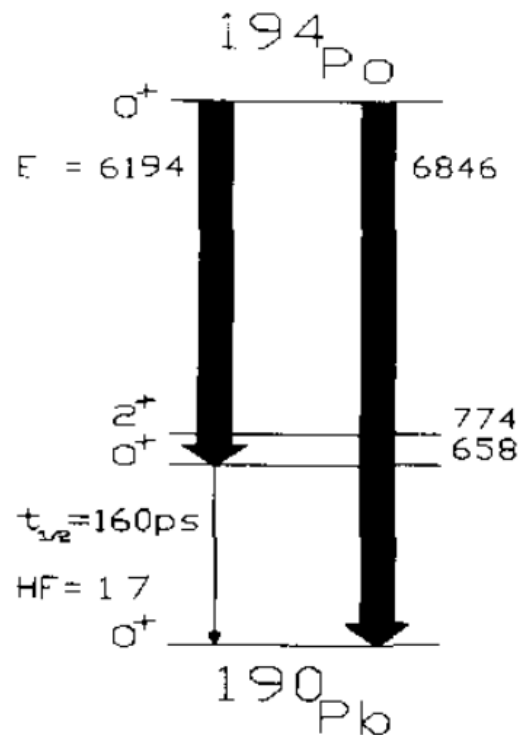
SD band

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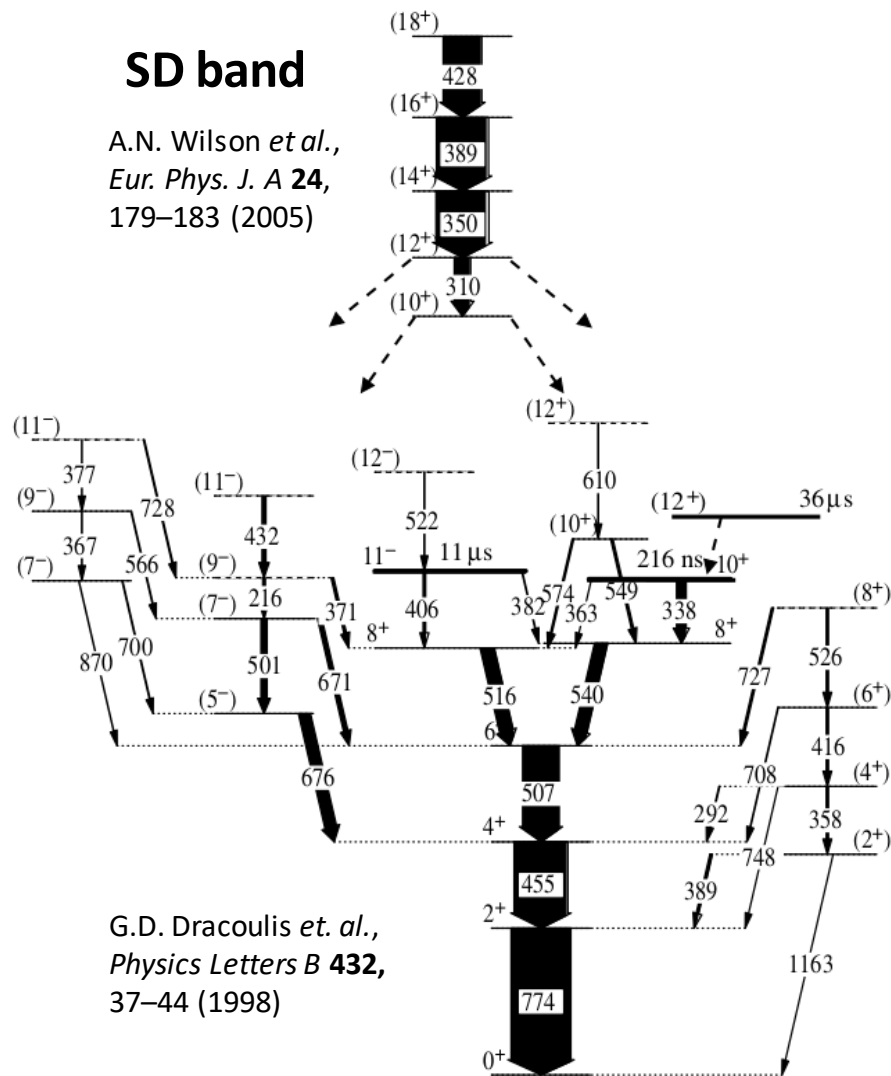


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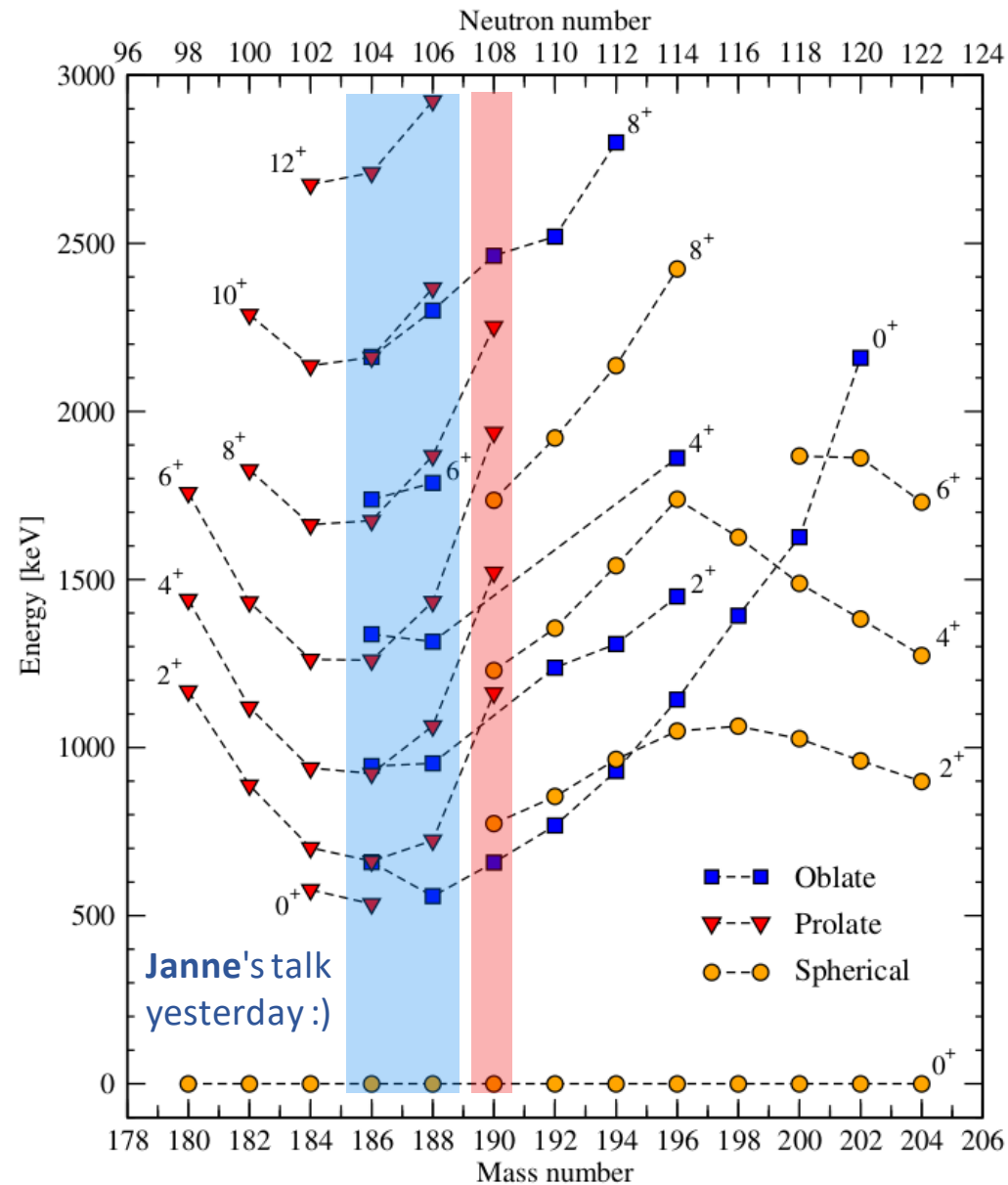
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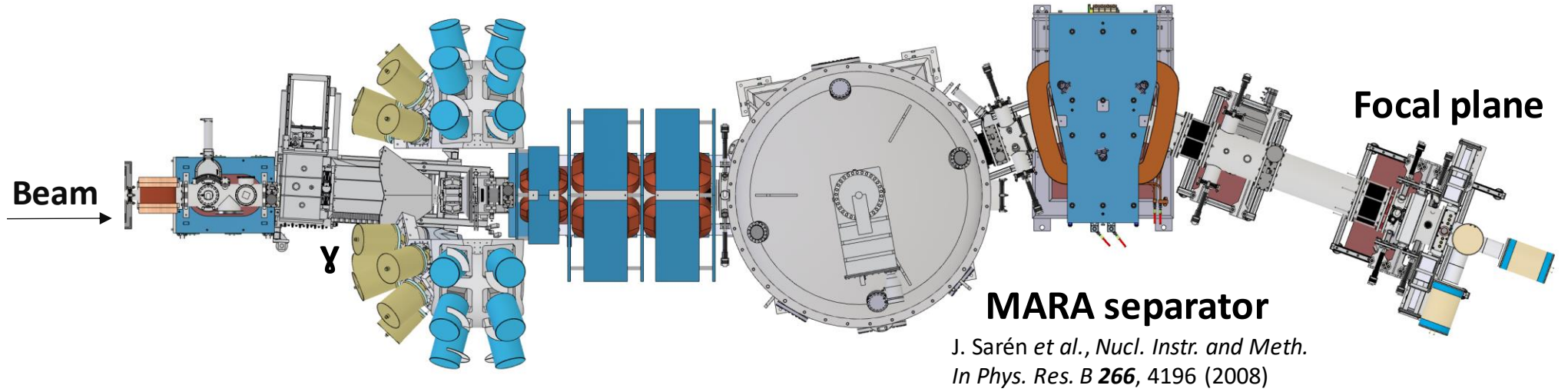


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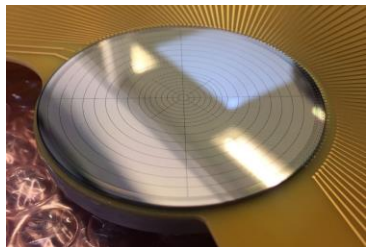


Level energy systematics of even Pb isotopes

Simultaneous in-beam γ -ray and conversion electron spectroscopy (2021)

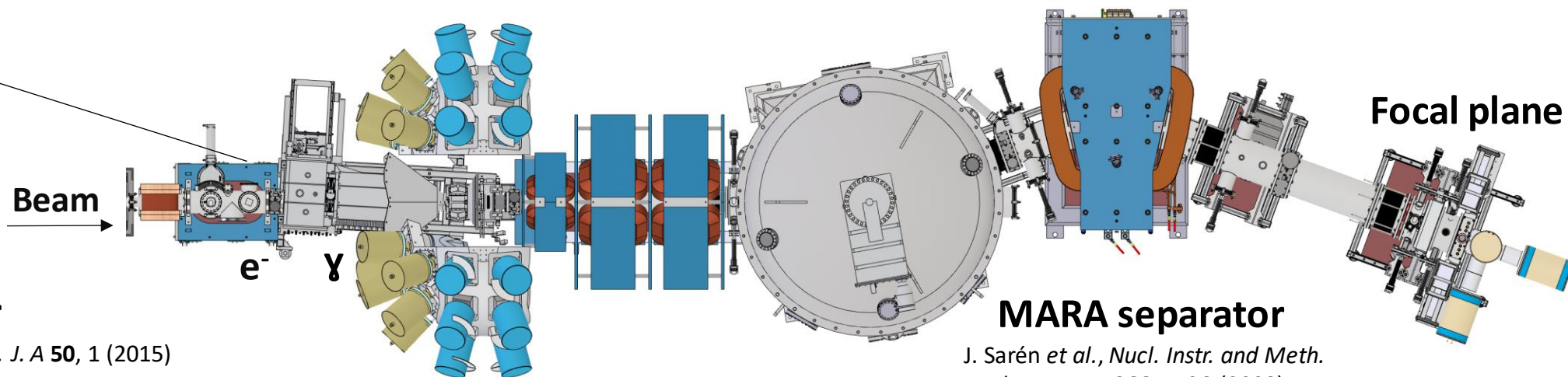


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SAGE e⁻ detector

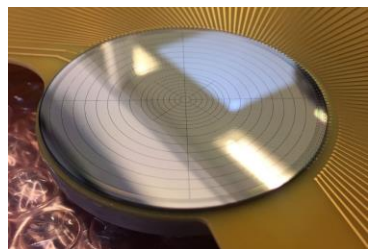
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MARA separator

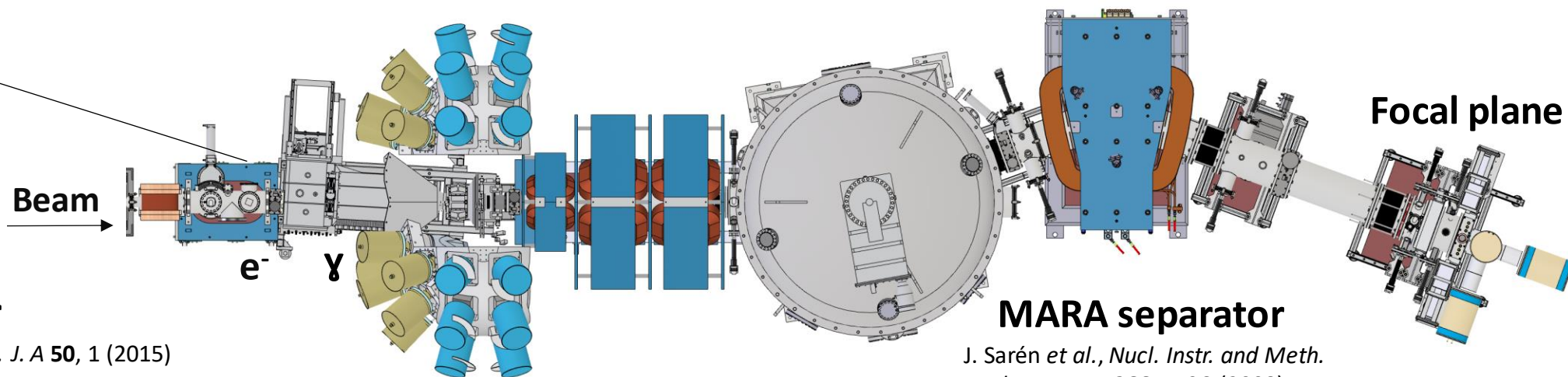
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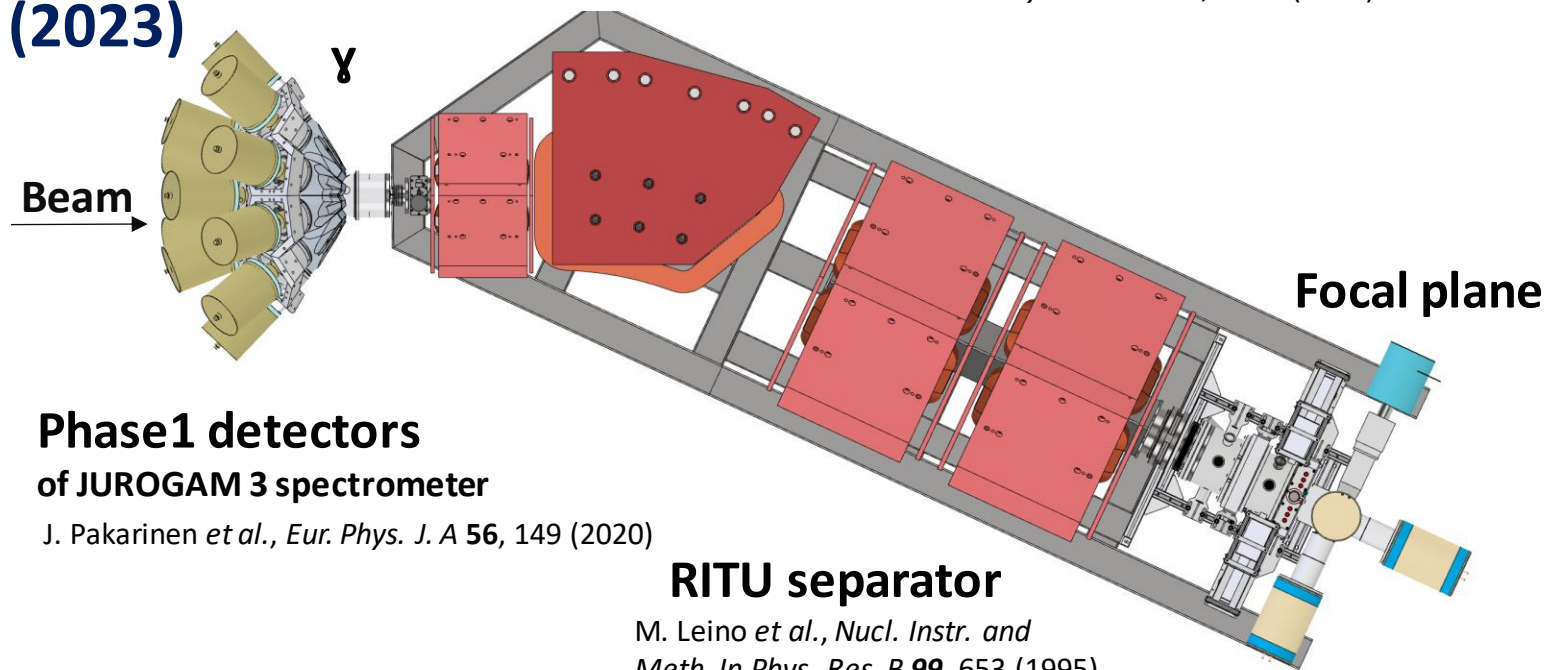
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Lifetime measurements (2023)



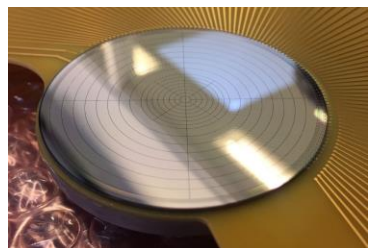
**Phase1 detectors
of JUROGAM 3 spectrometer**

J. Pakarinen et al., Eur. Phys. J. A 56, 149 (2020)

RITU separator

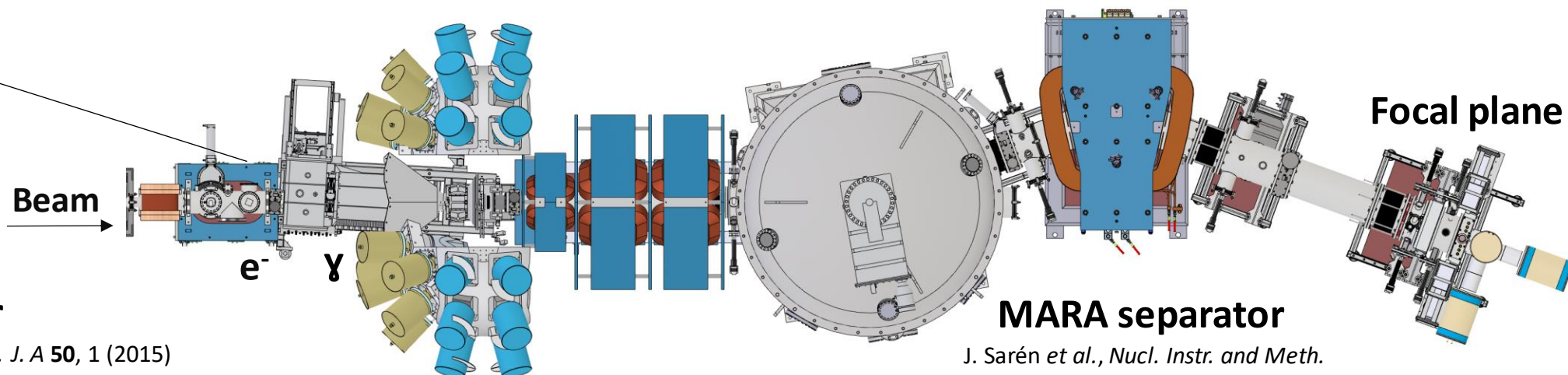
M. Leino et al., Nucl. Instr. and Meth. In Phys. Res. B 99, 653 (1995)

Simultaneous in-beam γ -ray and conversion electron spectroscopy (2021)



SAGE e^- detector

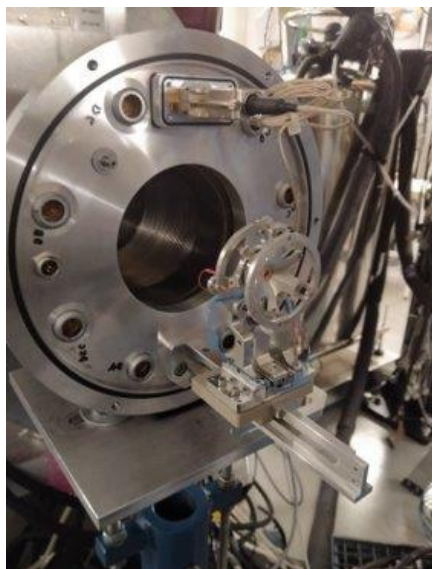
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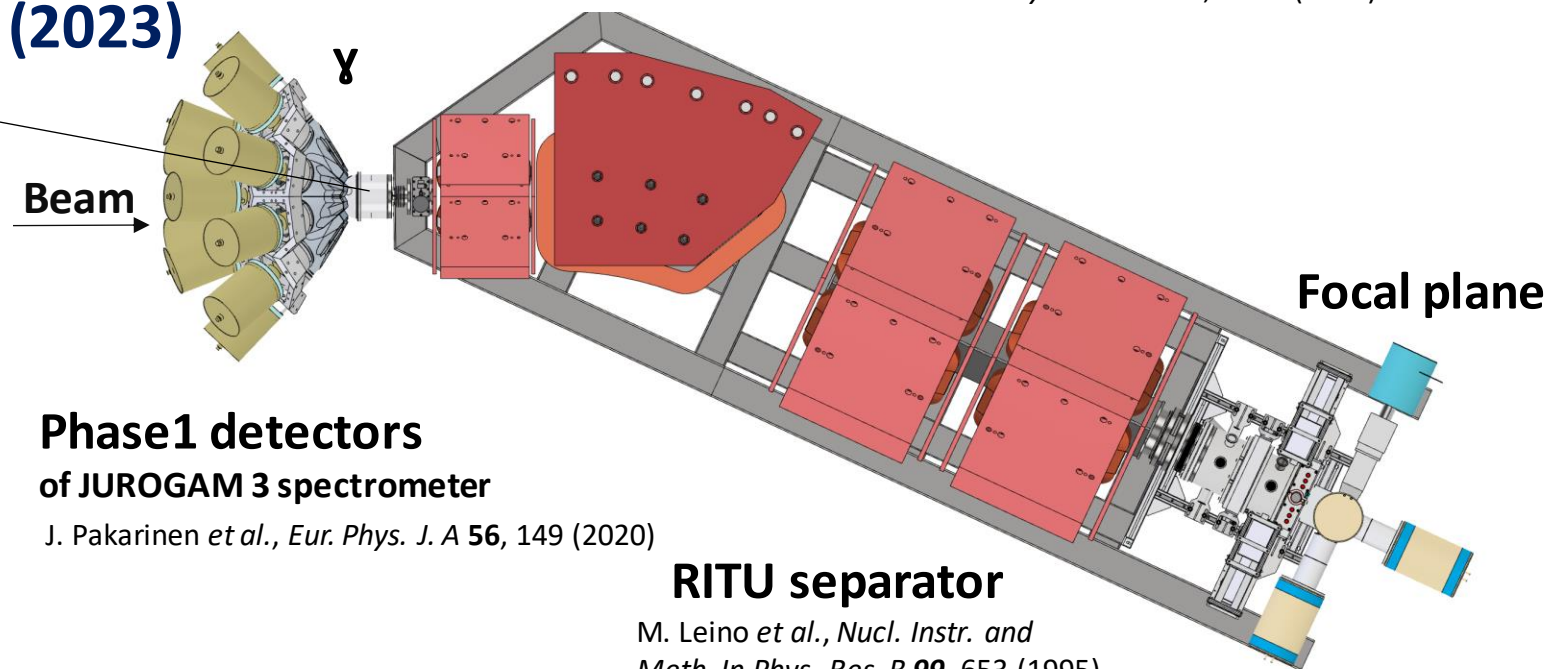
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APPA plunger device

J. Sarén *et al.*, *Nucl. Instr. and Meth. In Phys. Res. B* **541**, 33 (2023)



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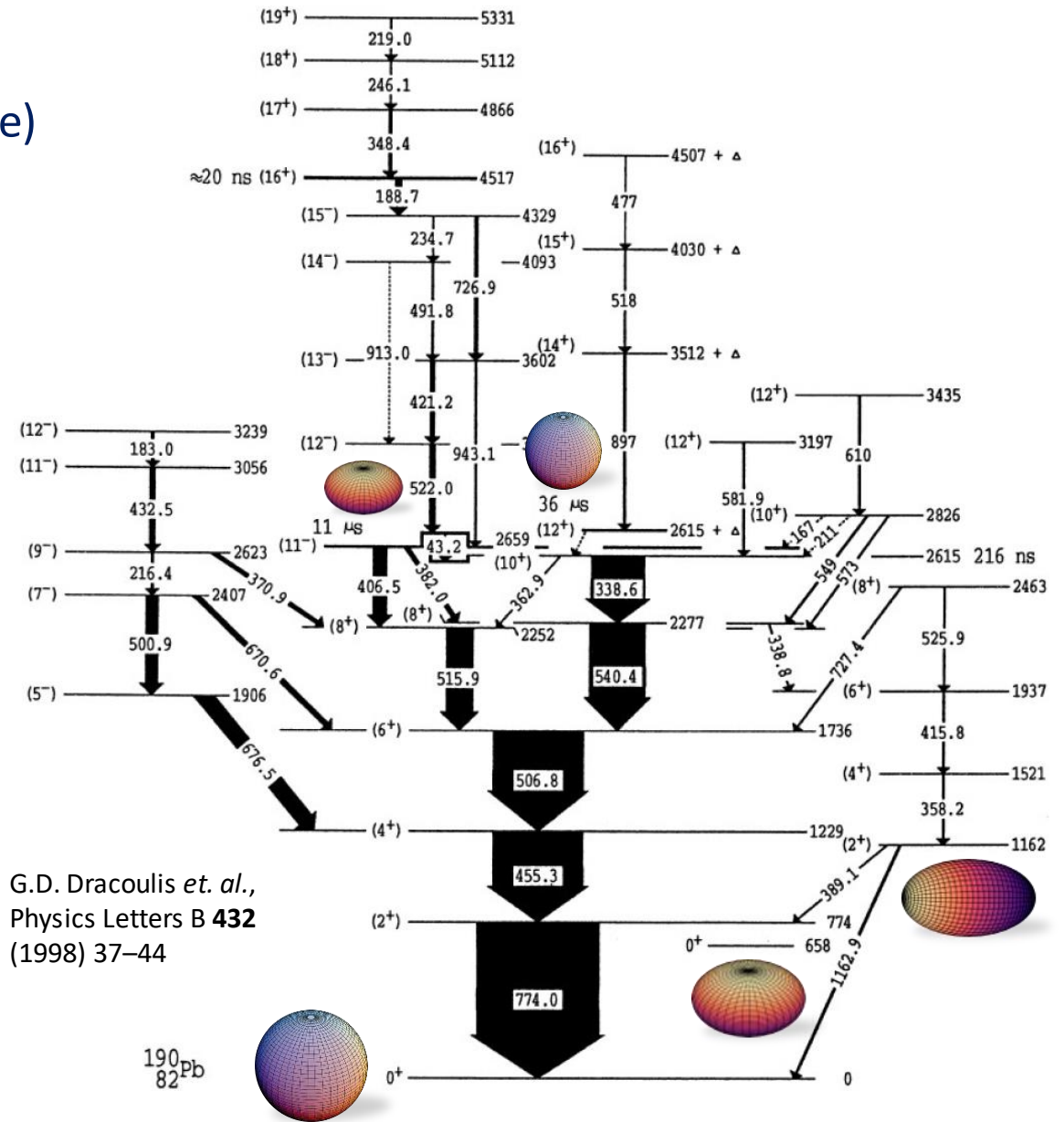
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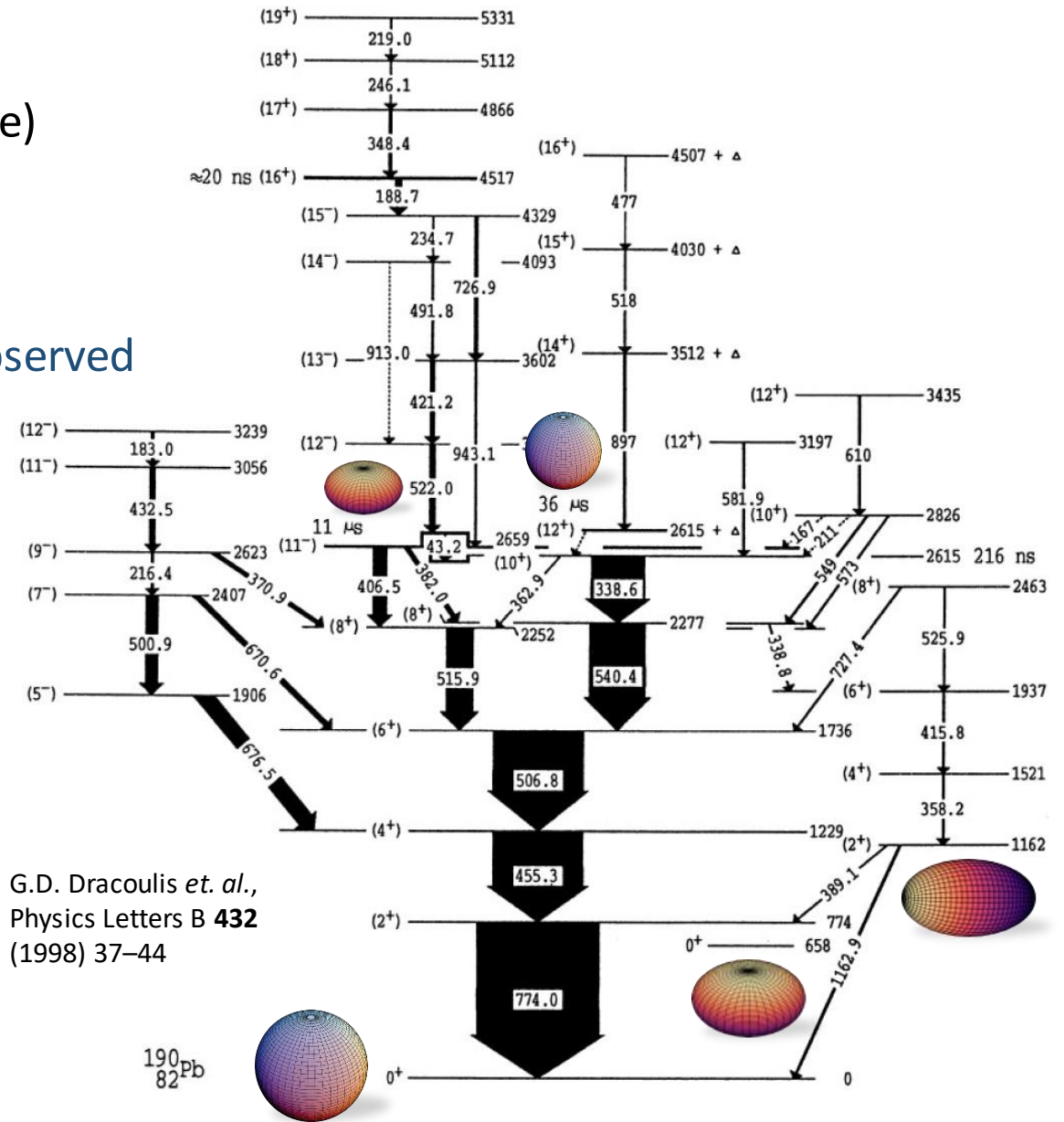
^{190}Pb details

- Triple shape coexistence (spherical, oblate & prolate)
- 2 isomers ($\sim 10\text{s } \mu\text{s}$)
- 8^+ states triplet



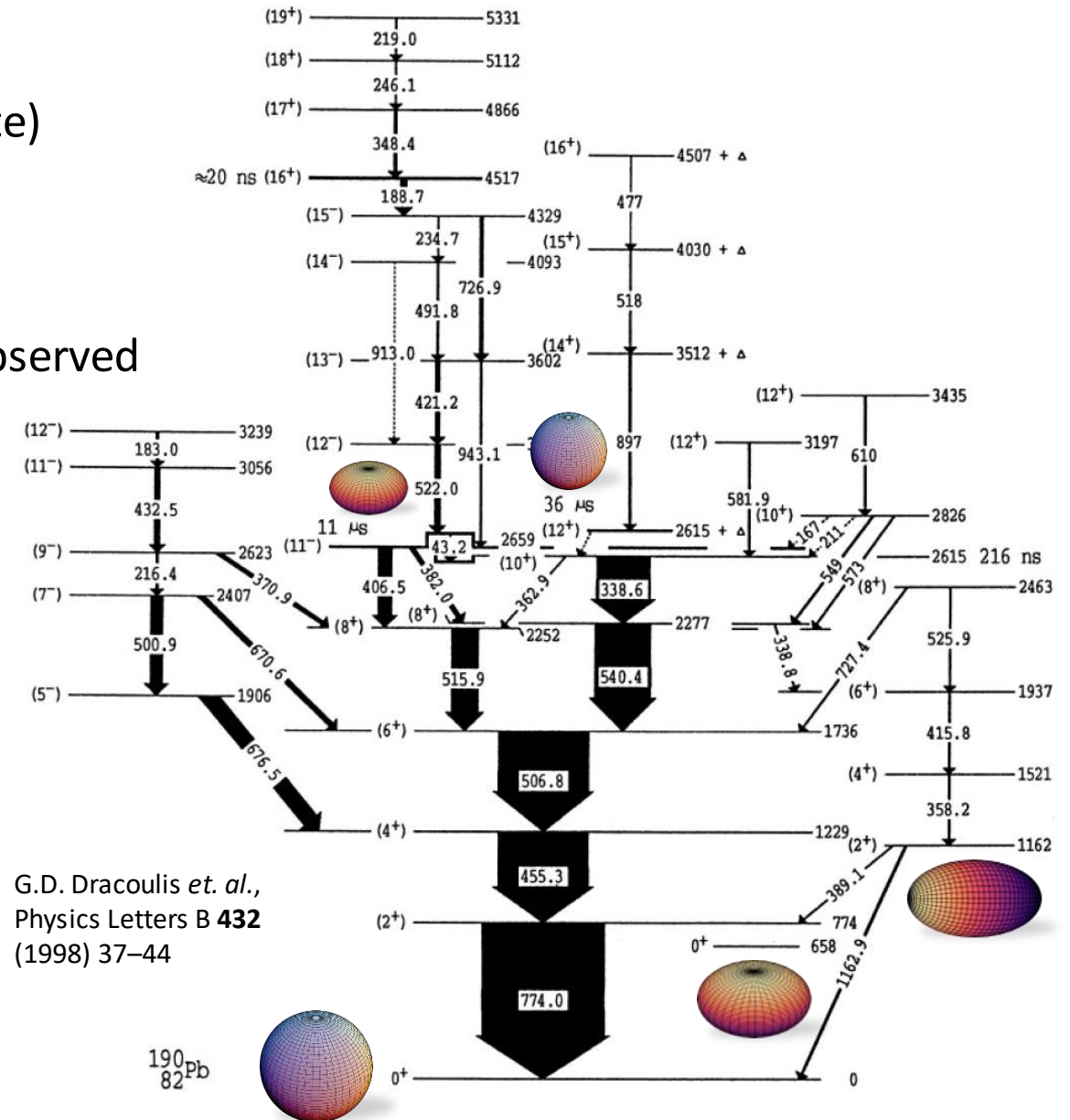
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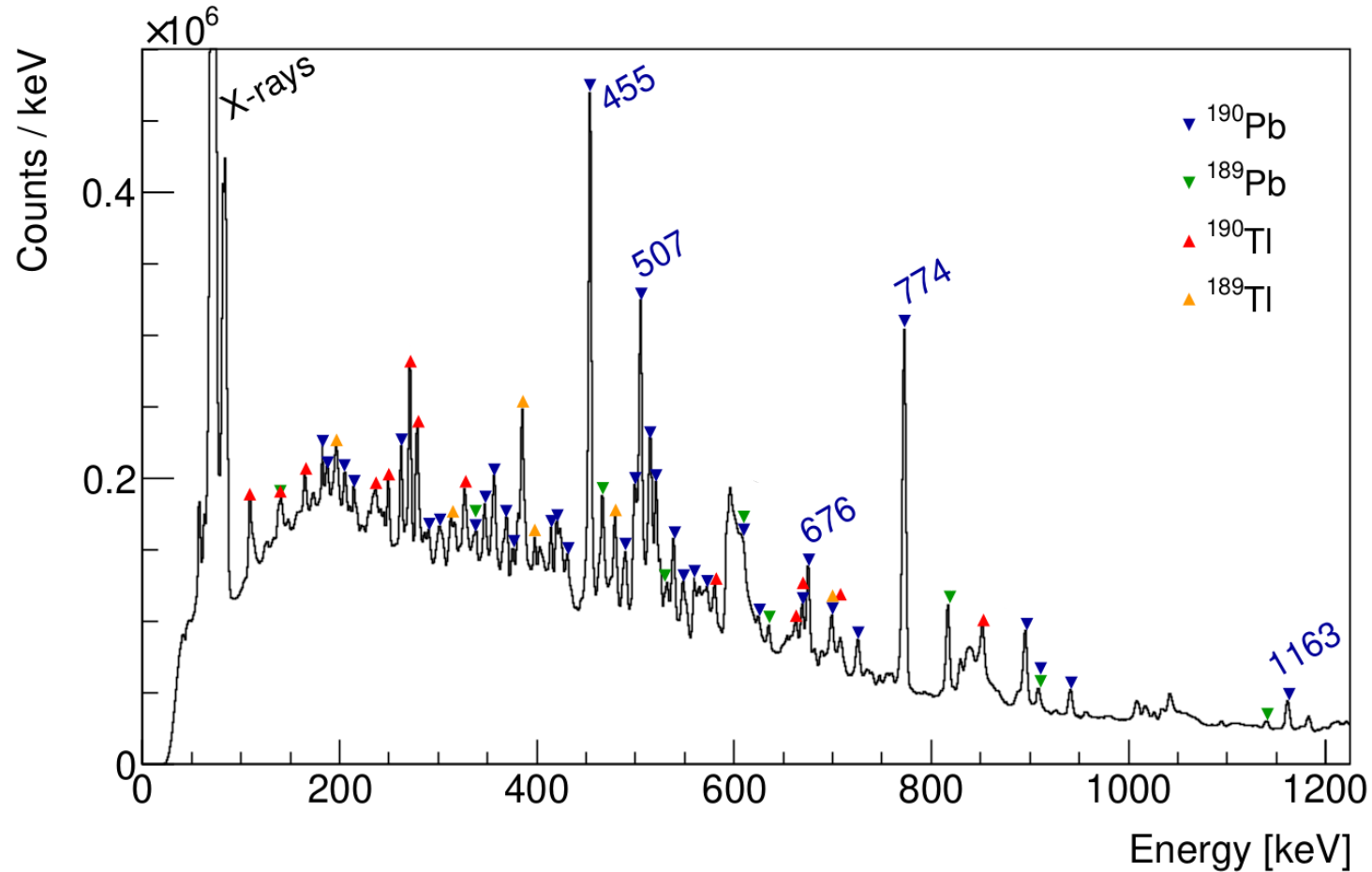


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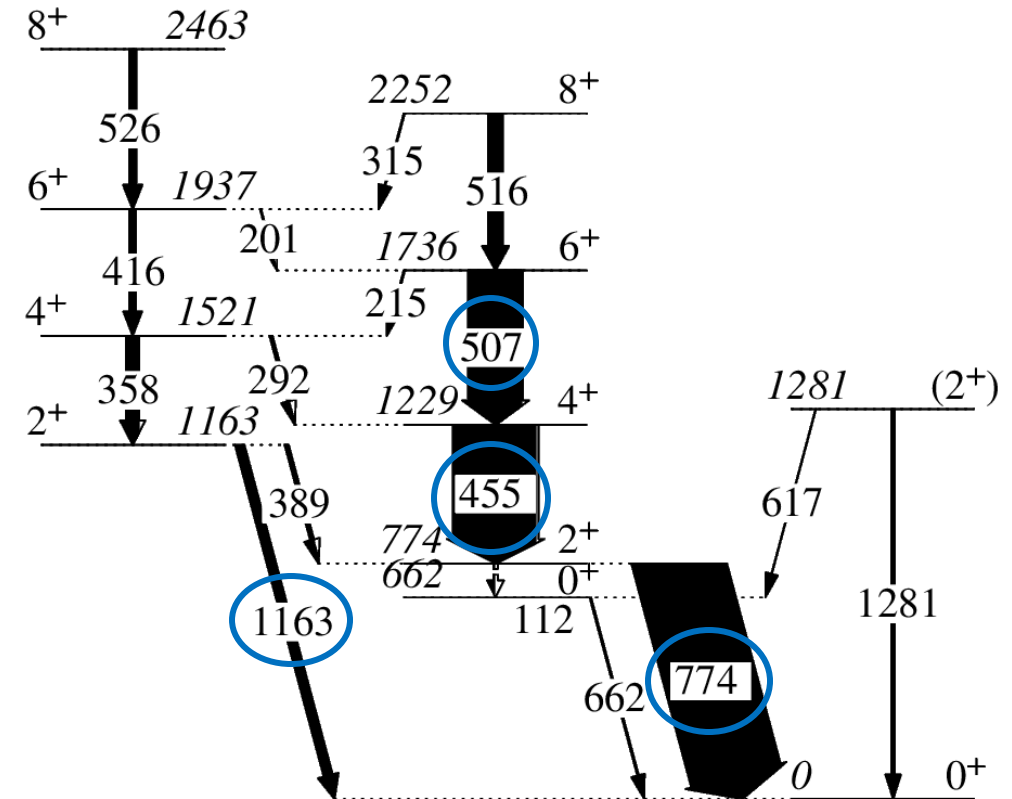
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- Interband transitions (shape change)
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- β branch $\sim 99.6\%$
- α branch $\sim 0.4\%$ (no decay tagging)



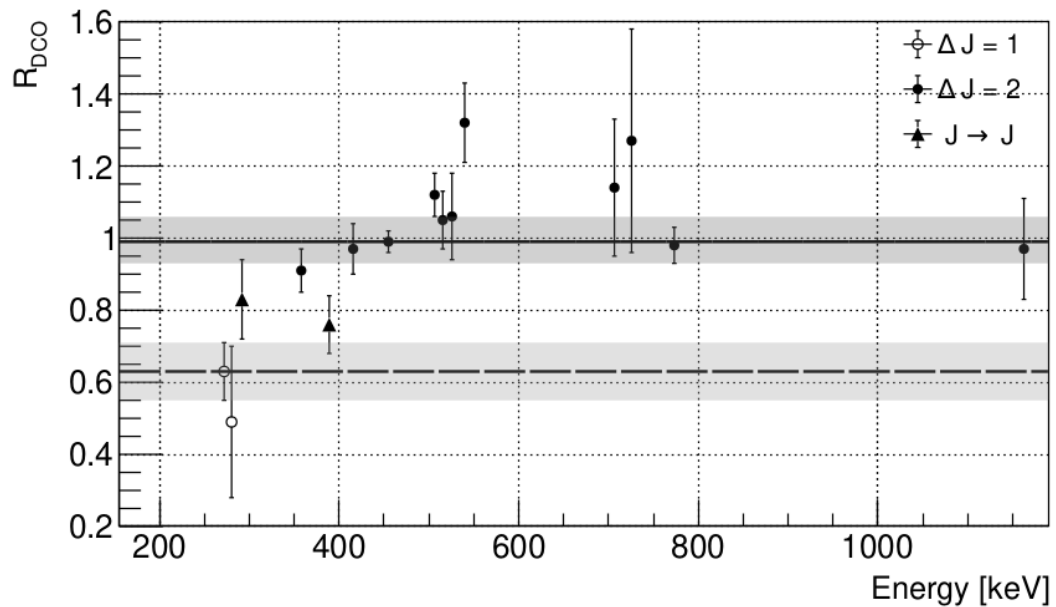
Simultaneous in-beam γ -ray and conversion electron spectroscopy



In-beam γ -ray energy spectrum

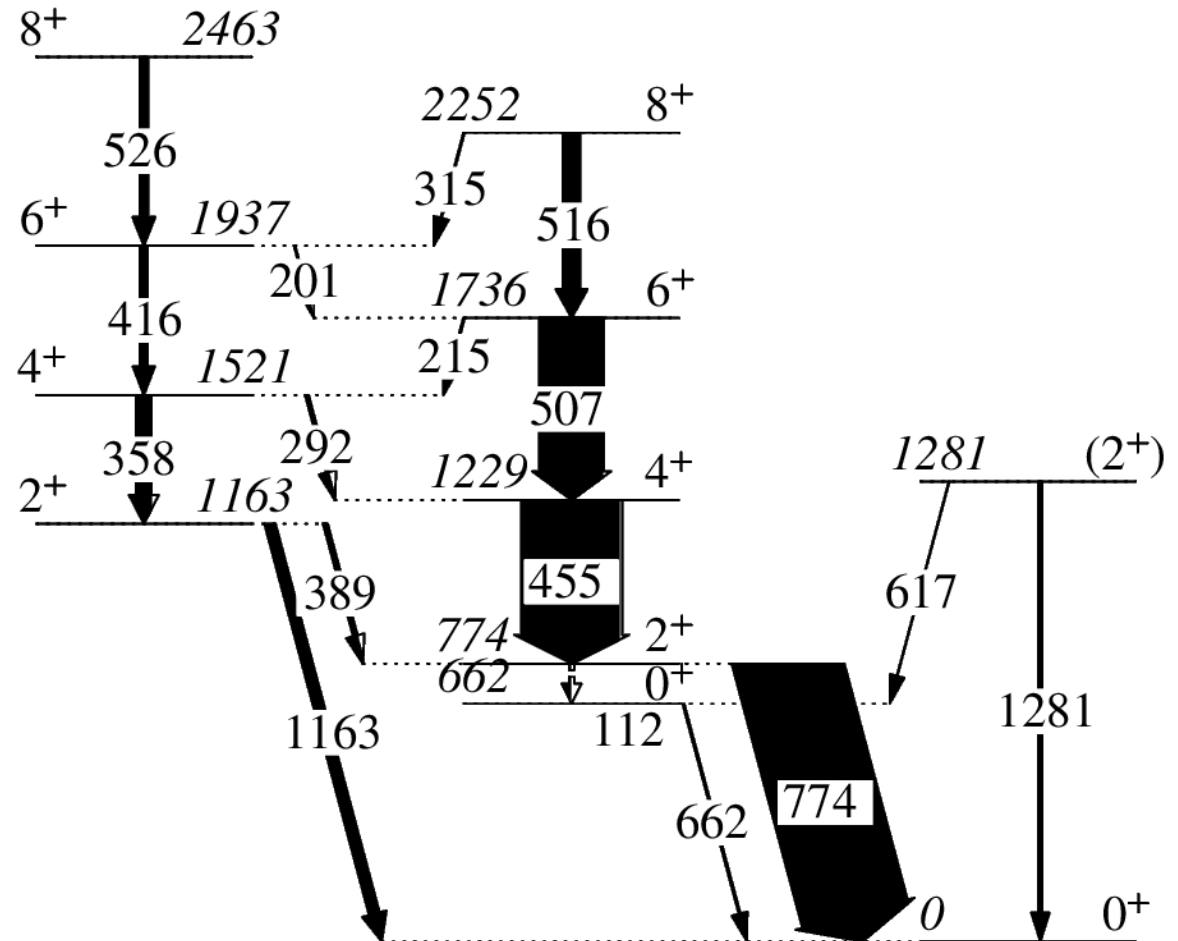


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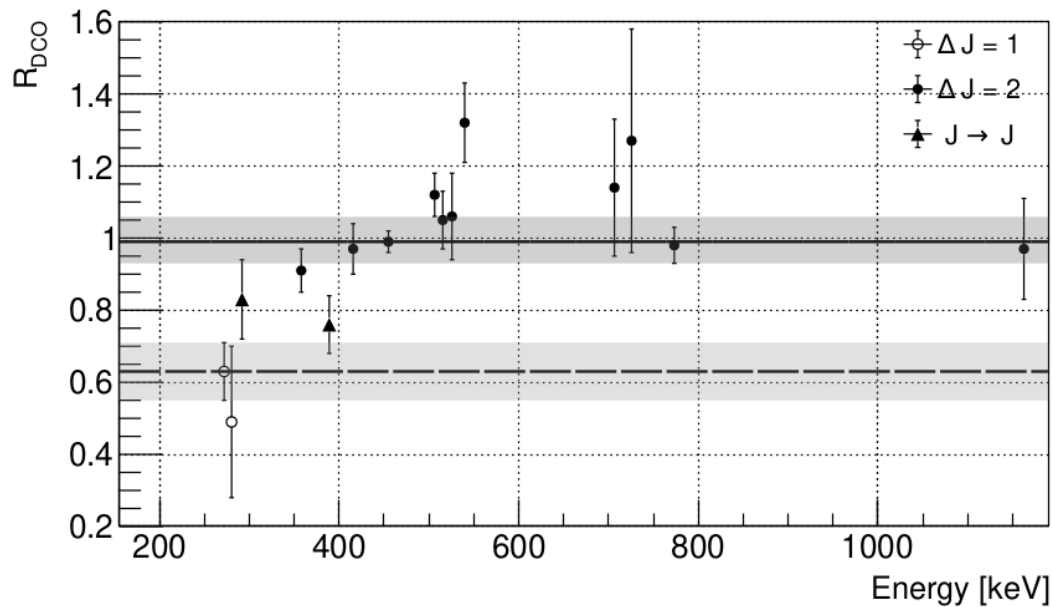


γ -ray angular correlations

Spin & parity assignments

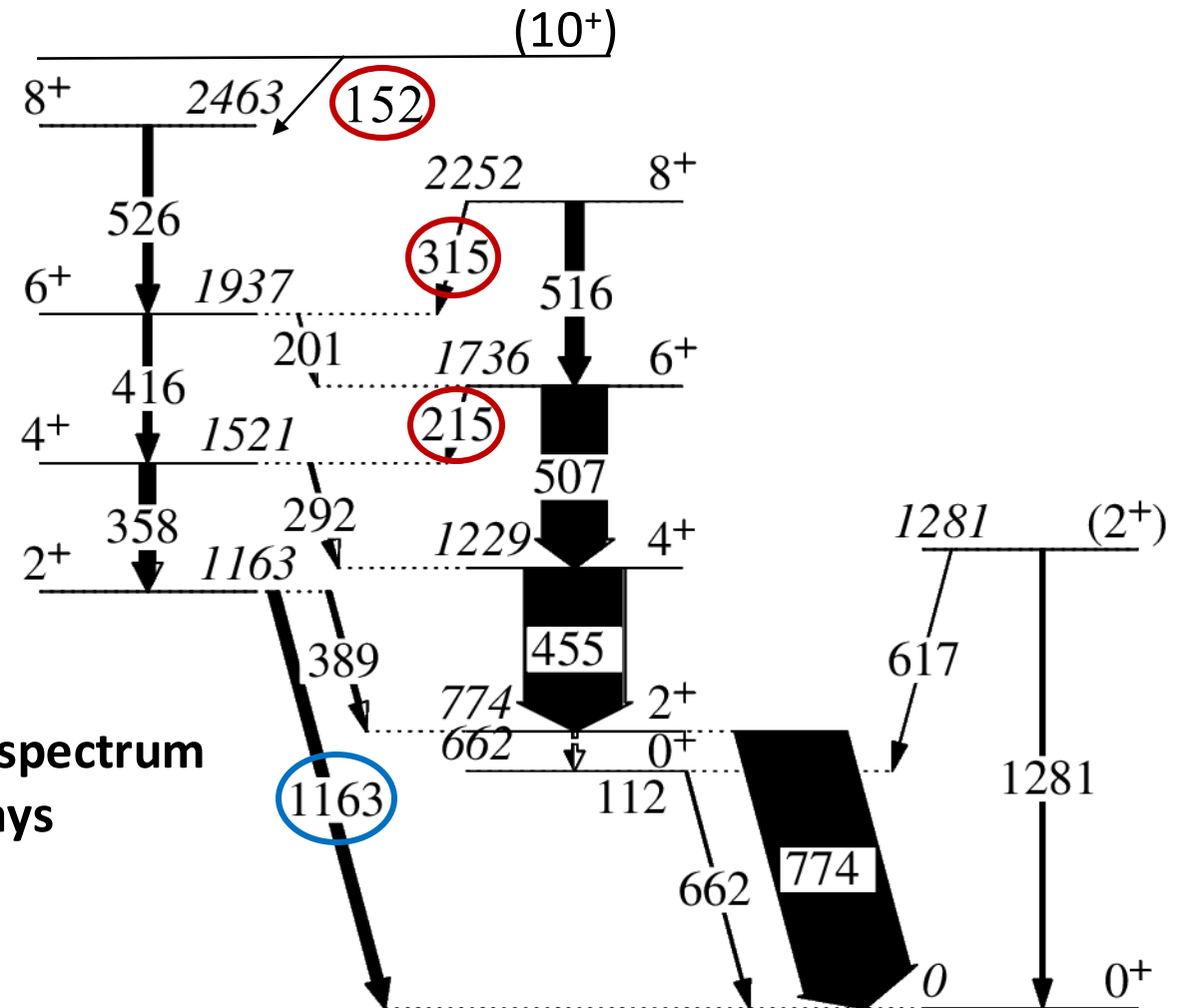
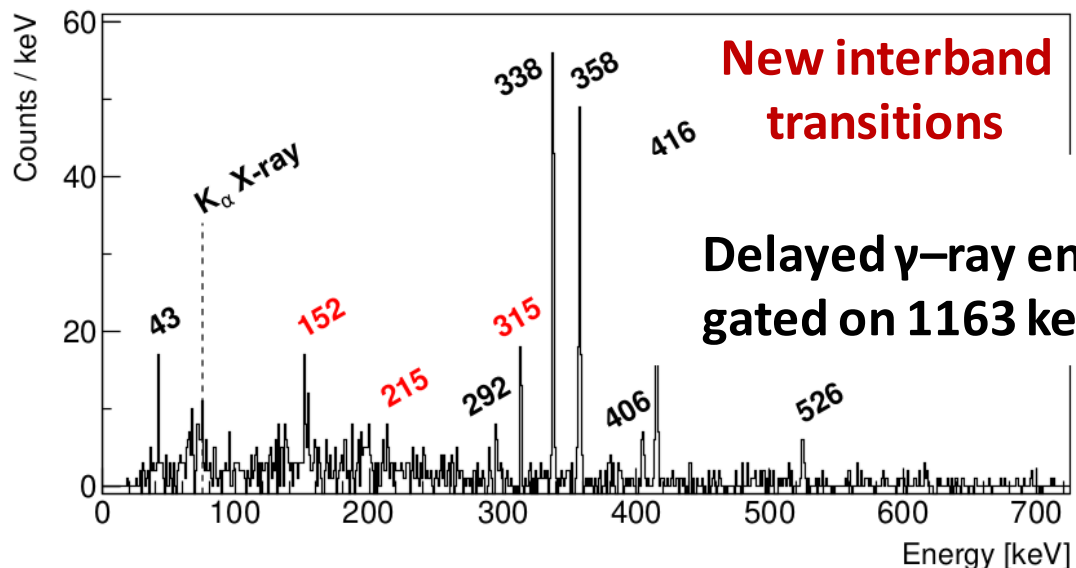


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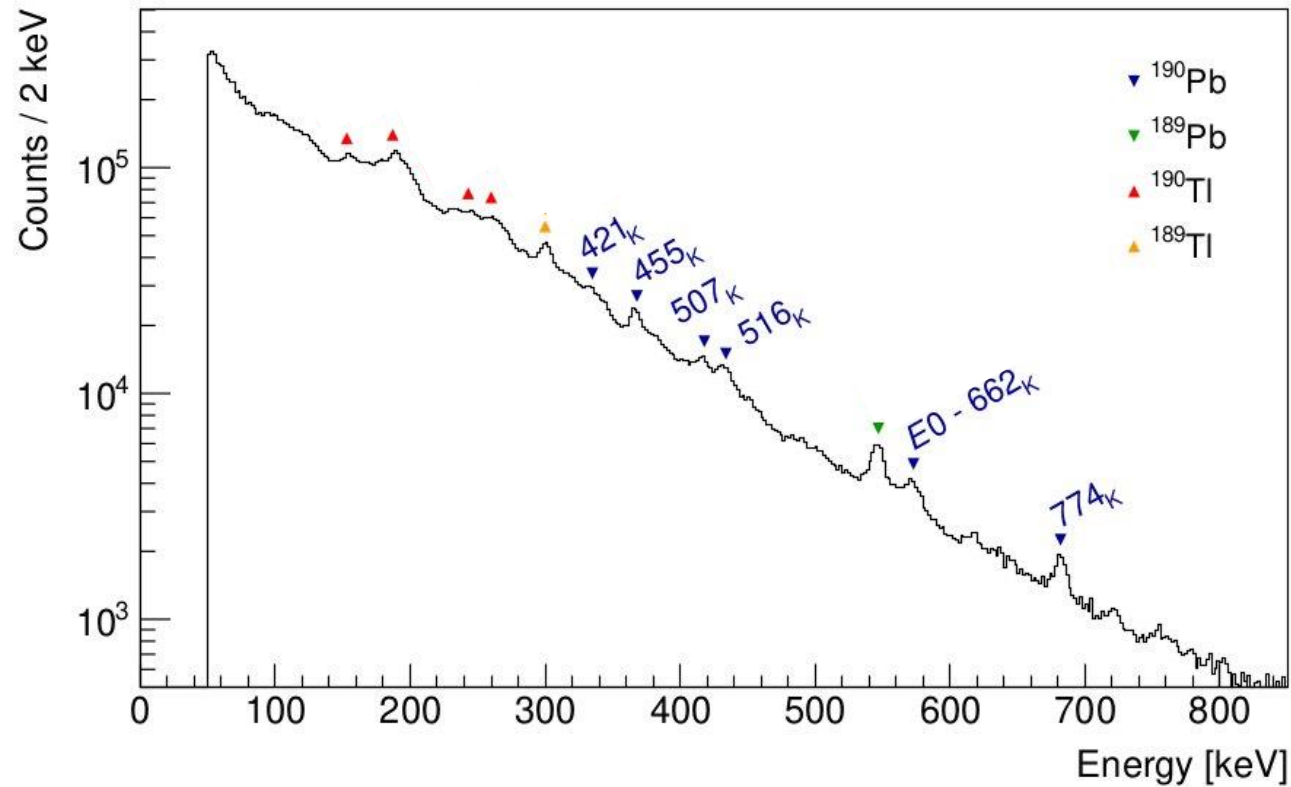


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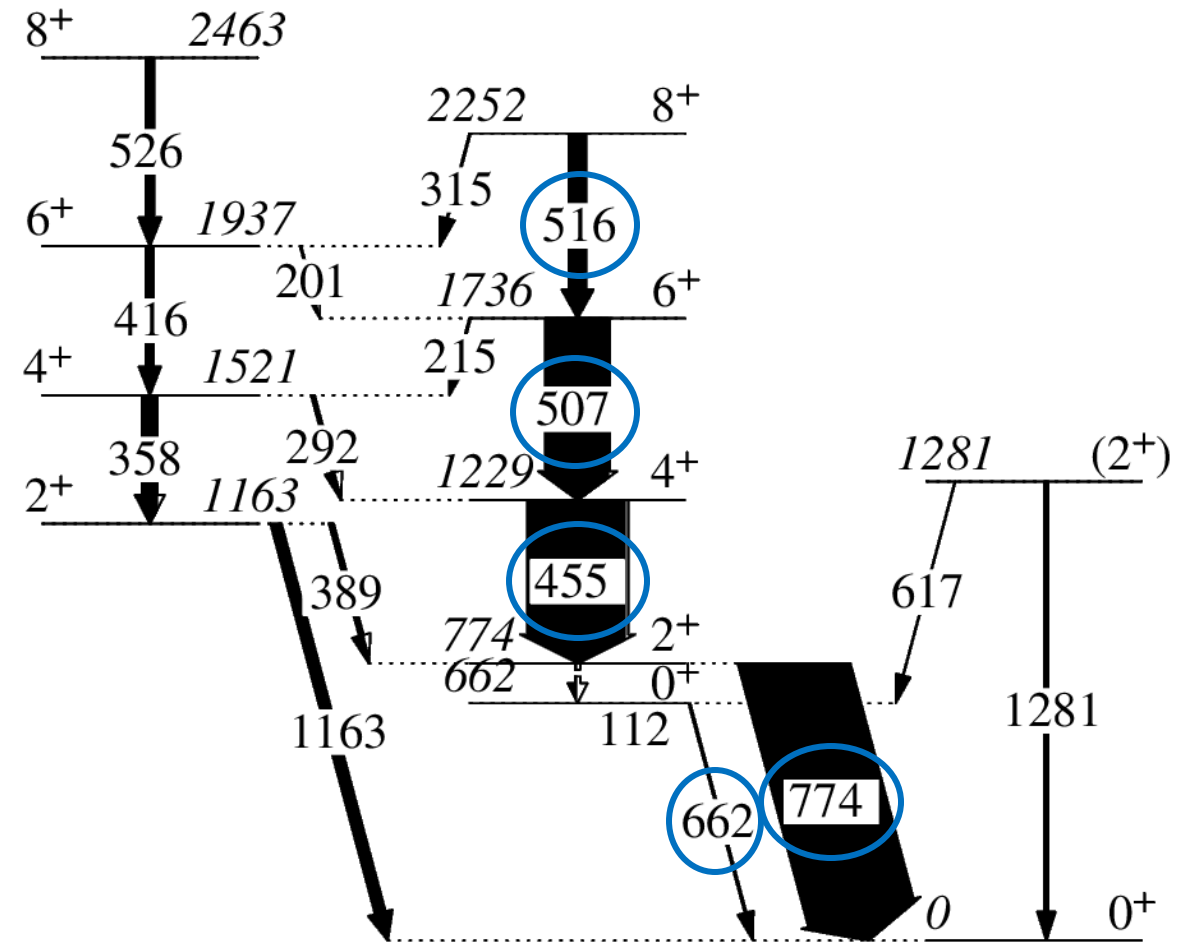
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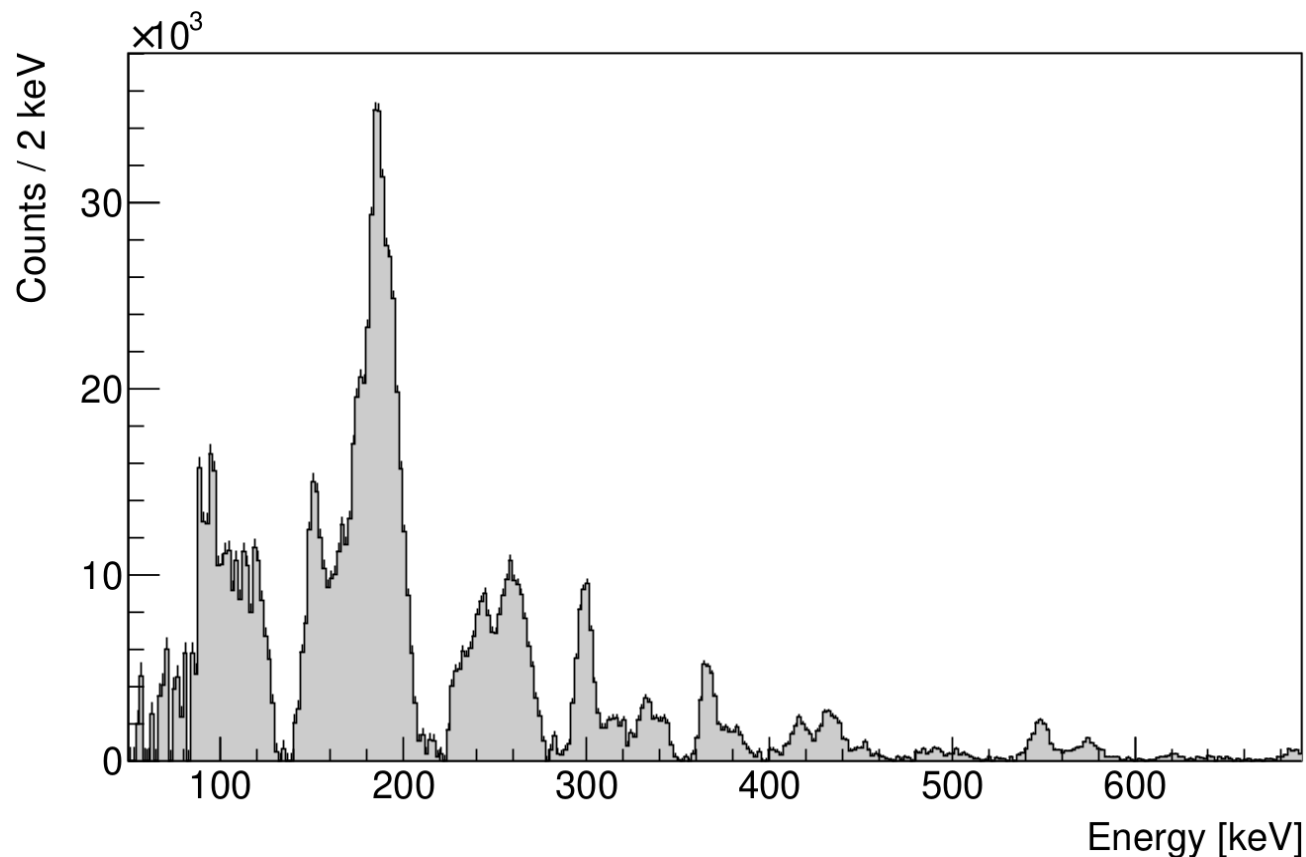
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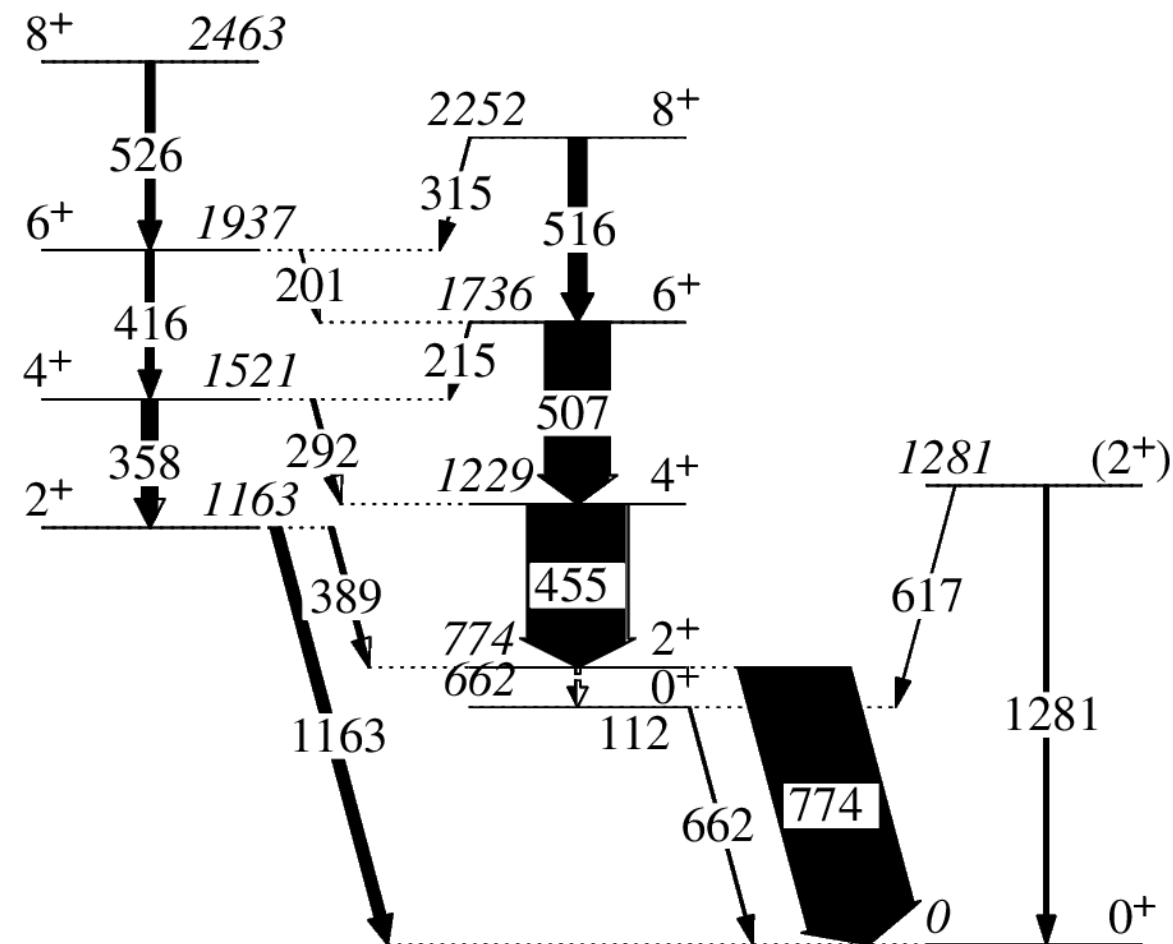
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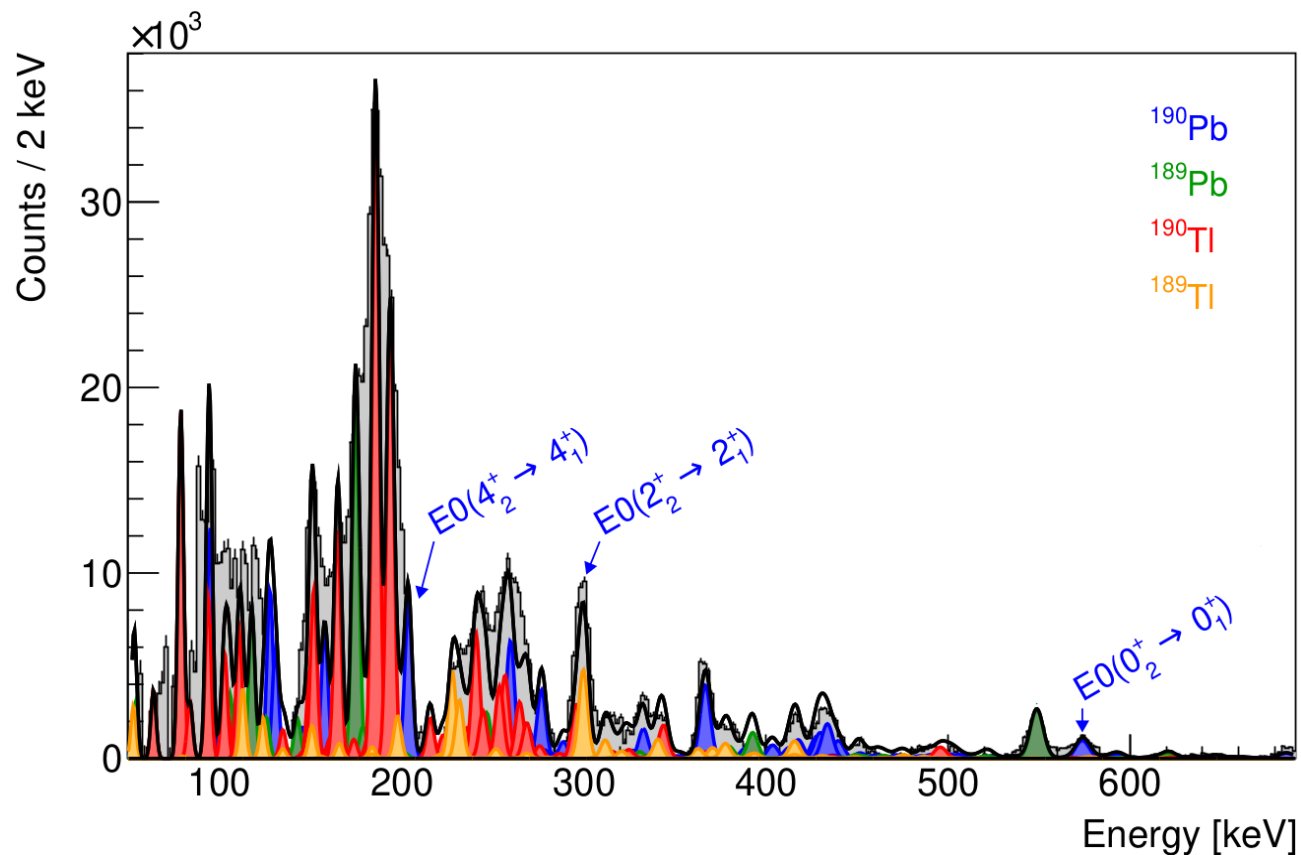
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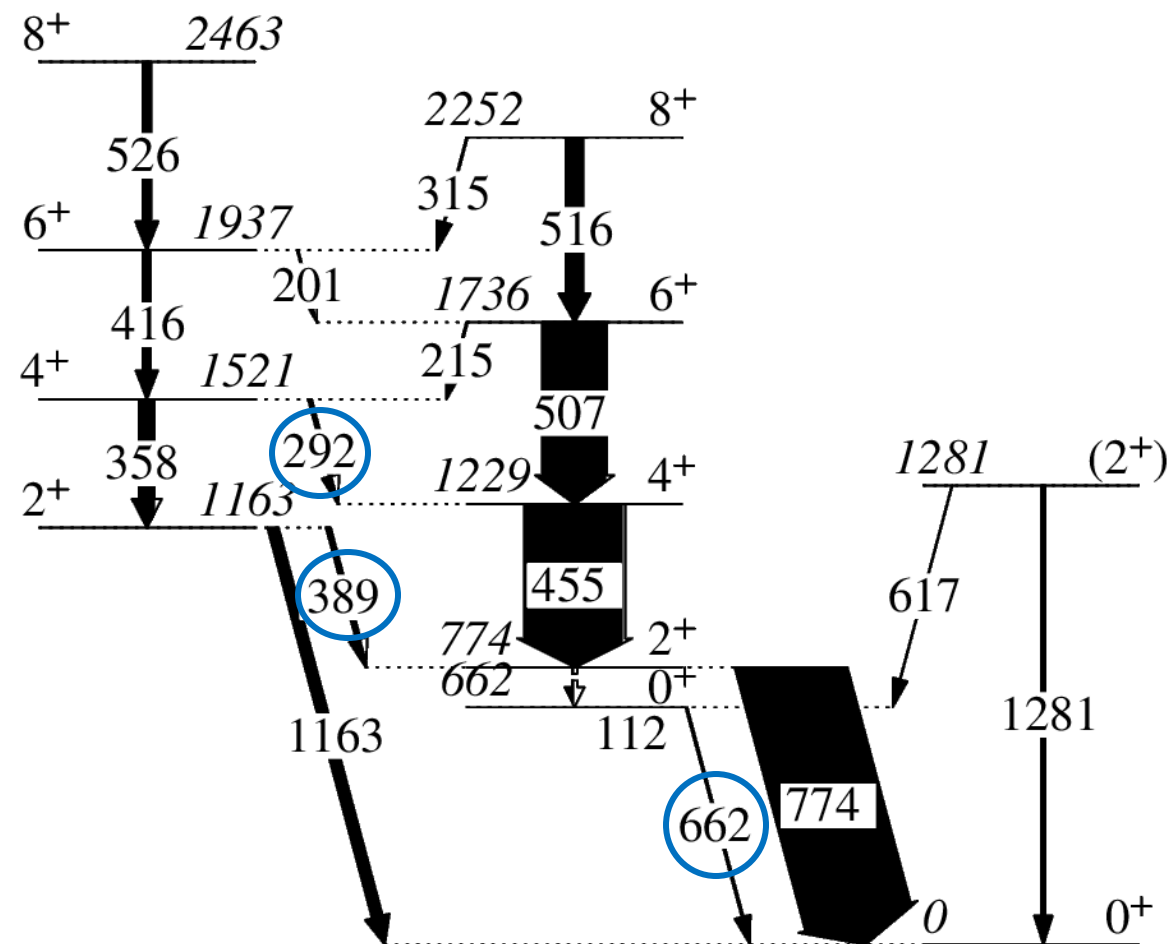
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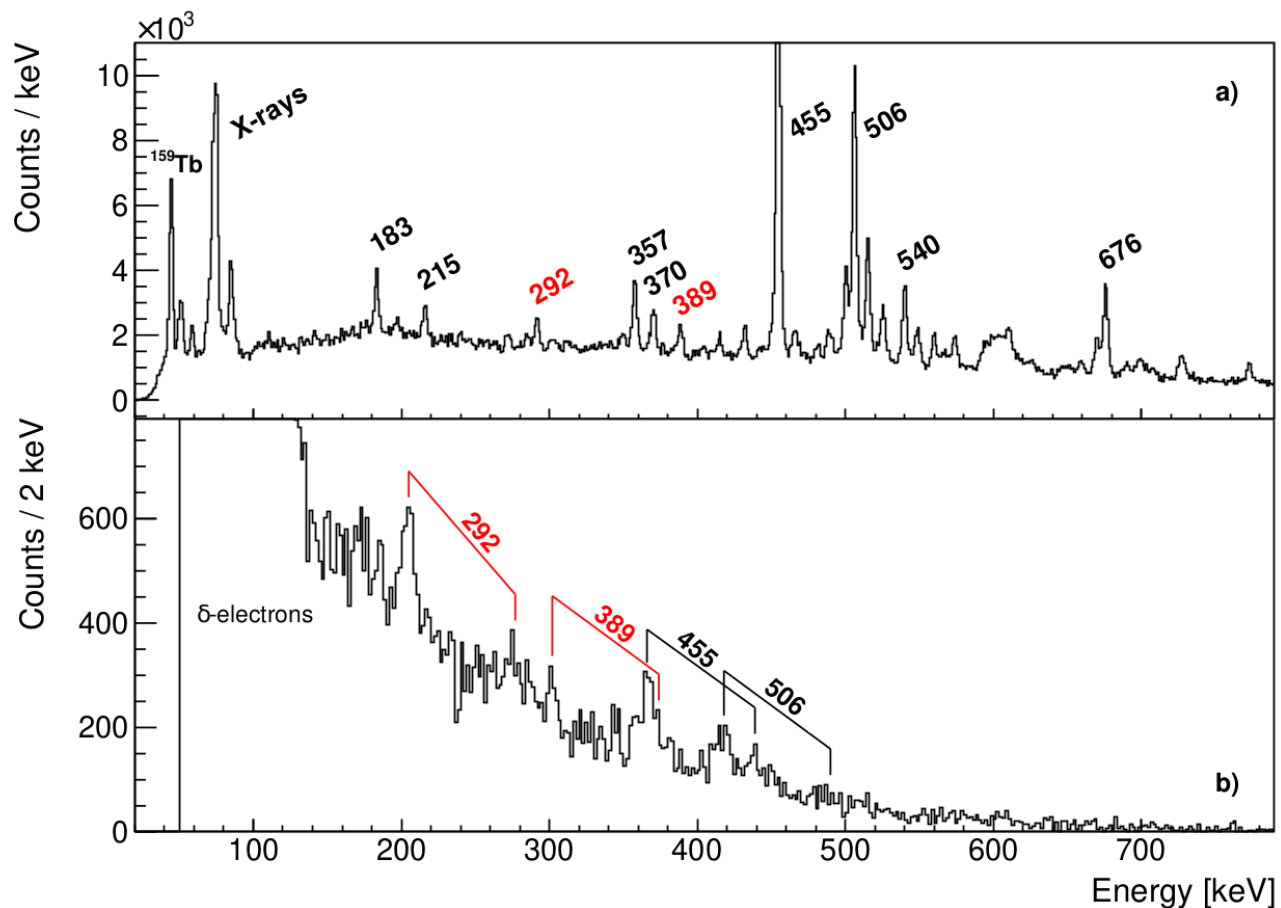
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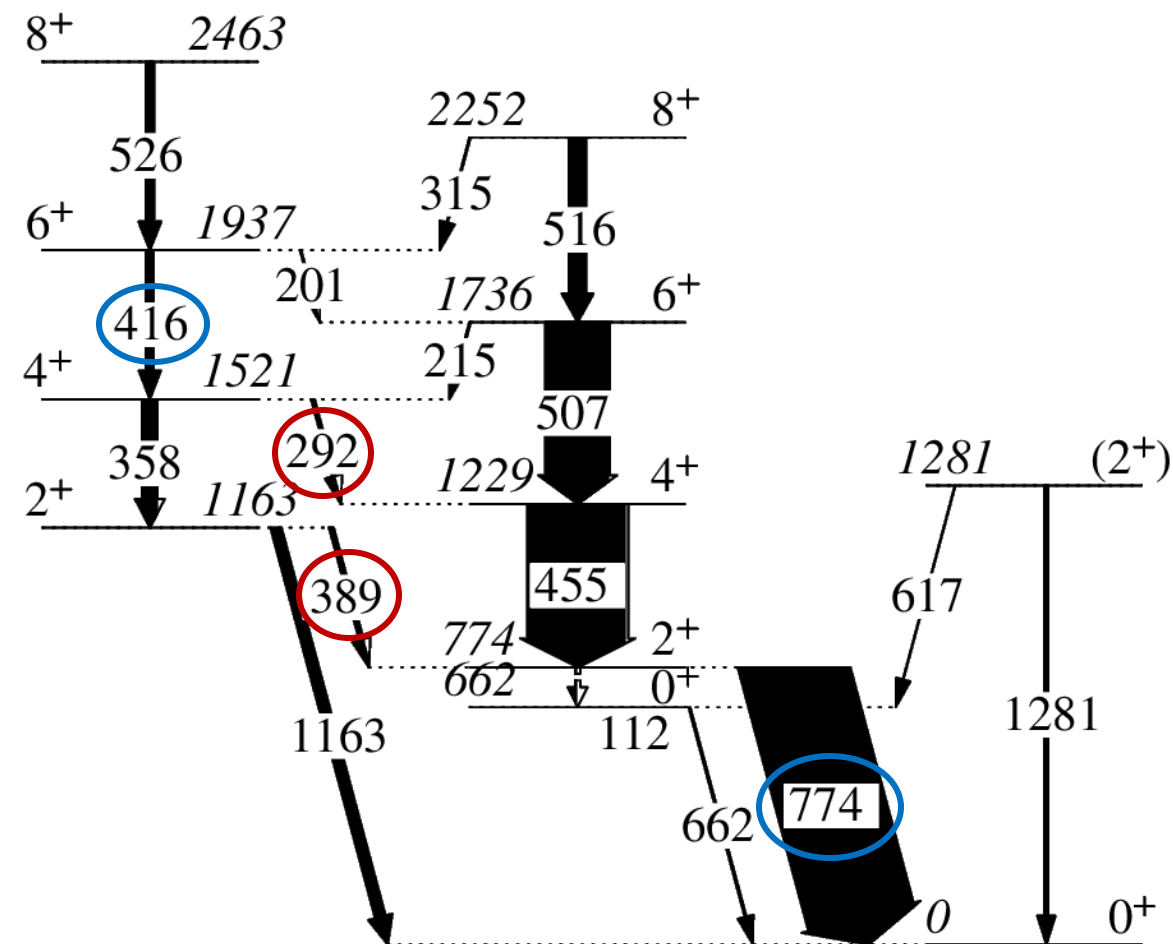
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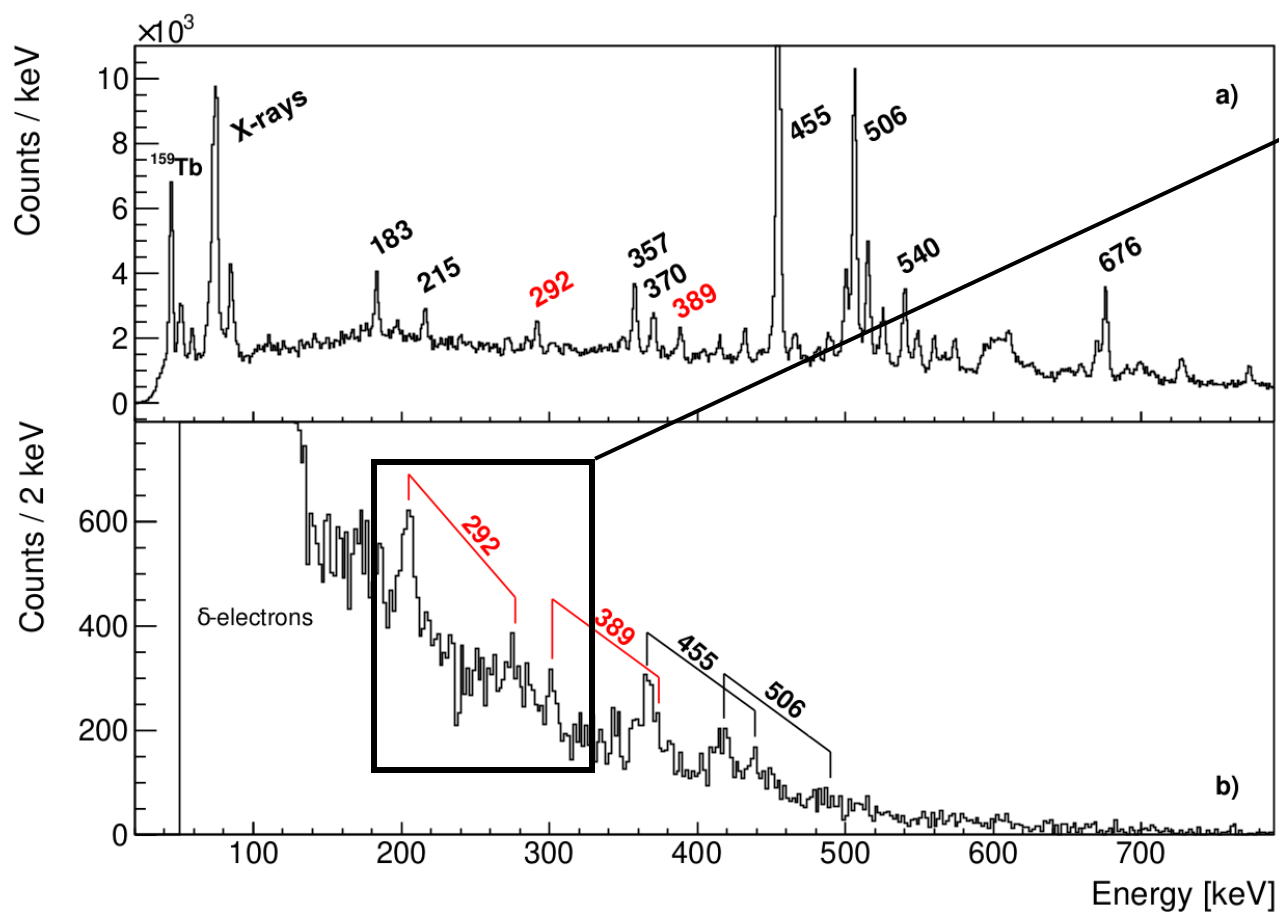
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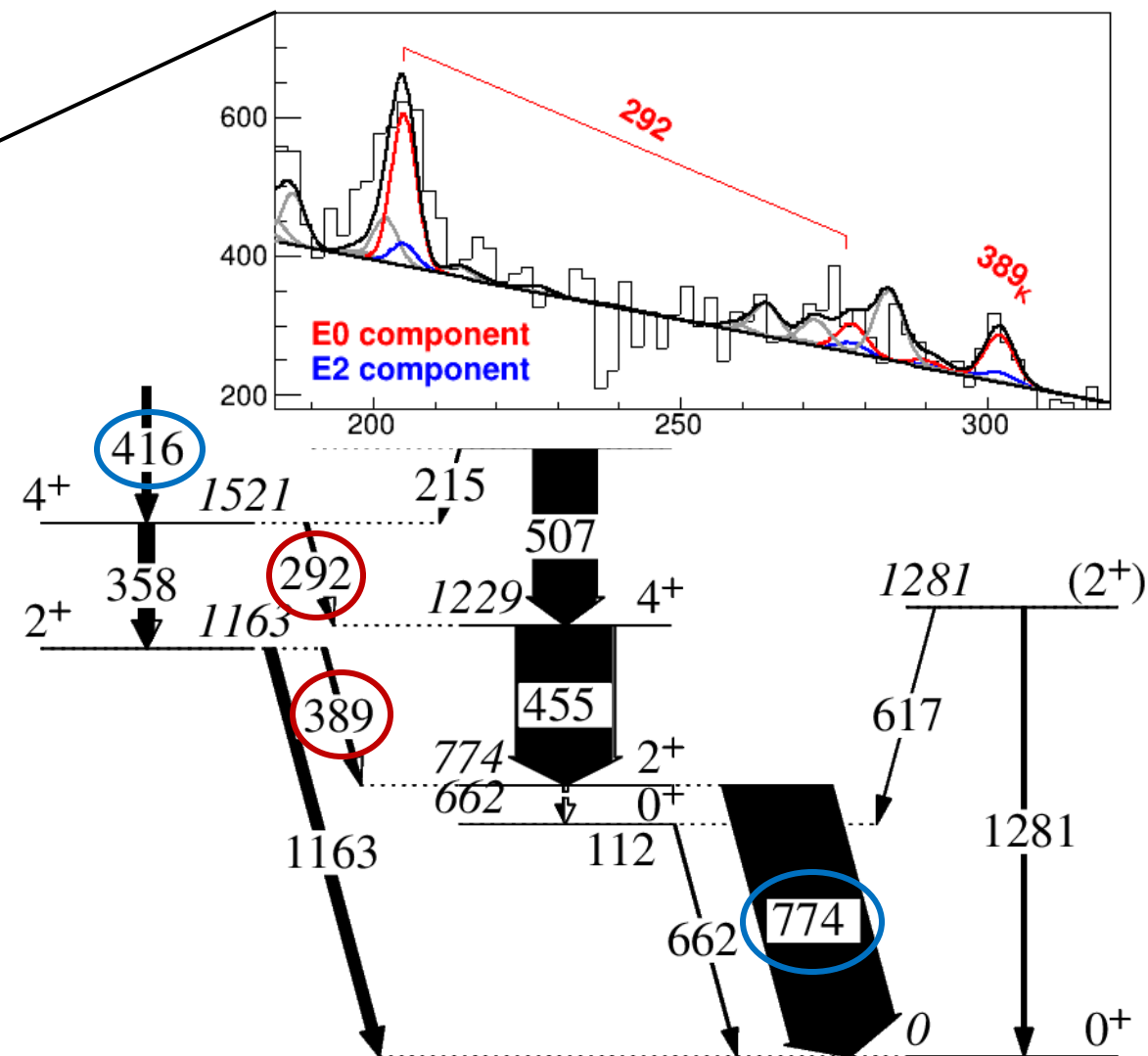
In-beam electron energy spectrum
gated on 774 & 416 keV γ rays



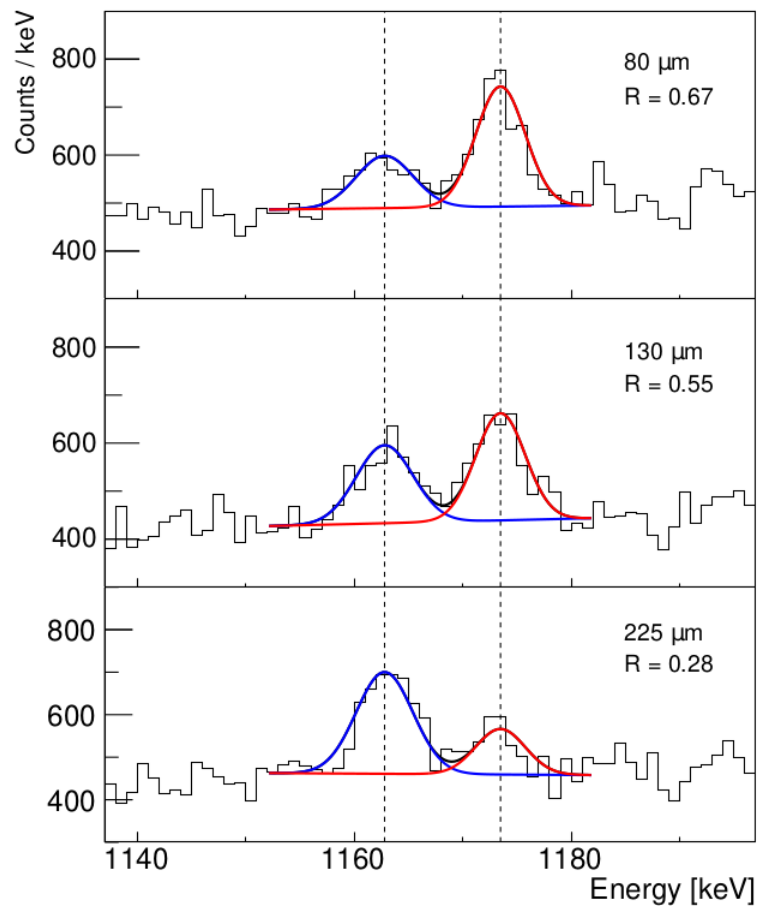
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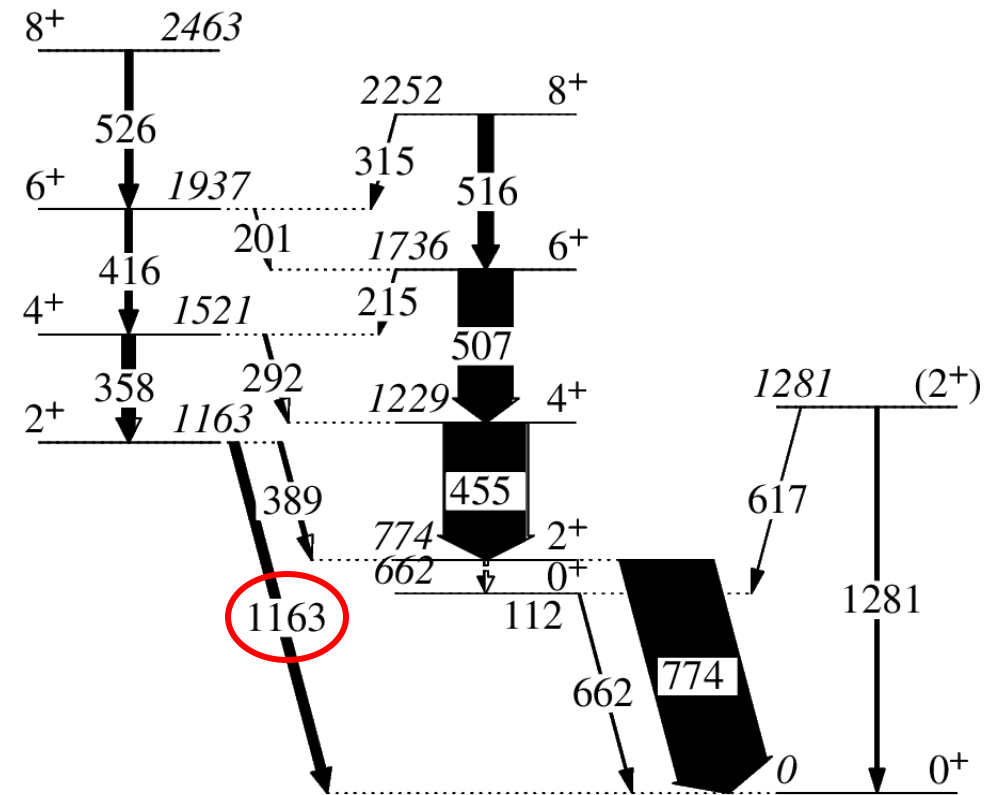
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Lifetime measurements

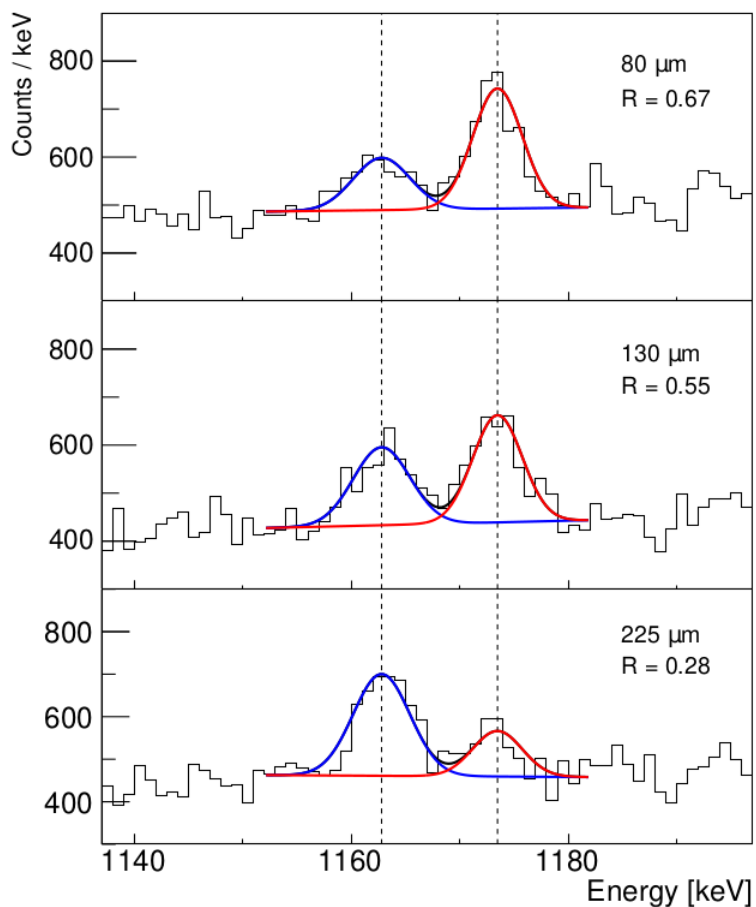


1163 keV transition
(singles)

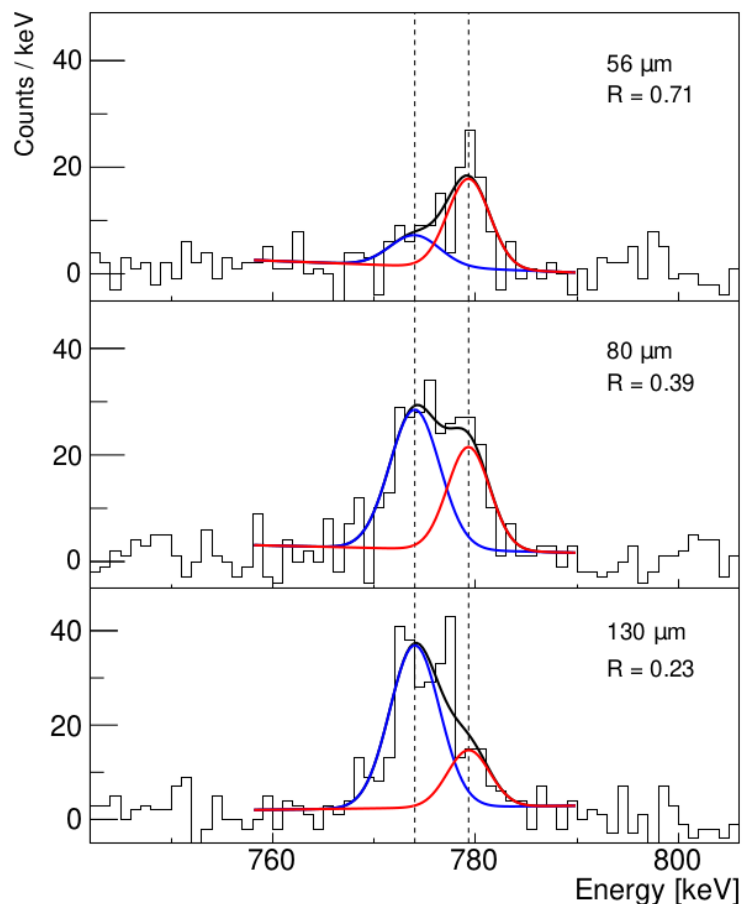


B(E2) = 0.6 W.u.

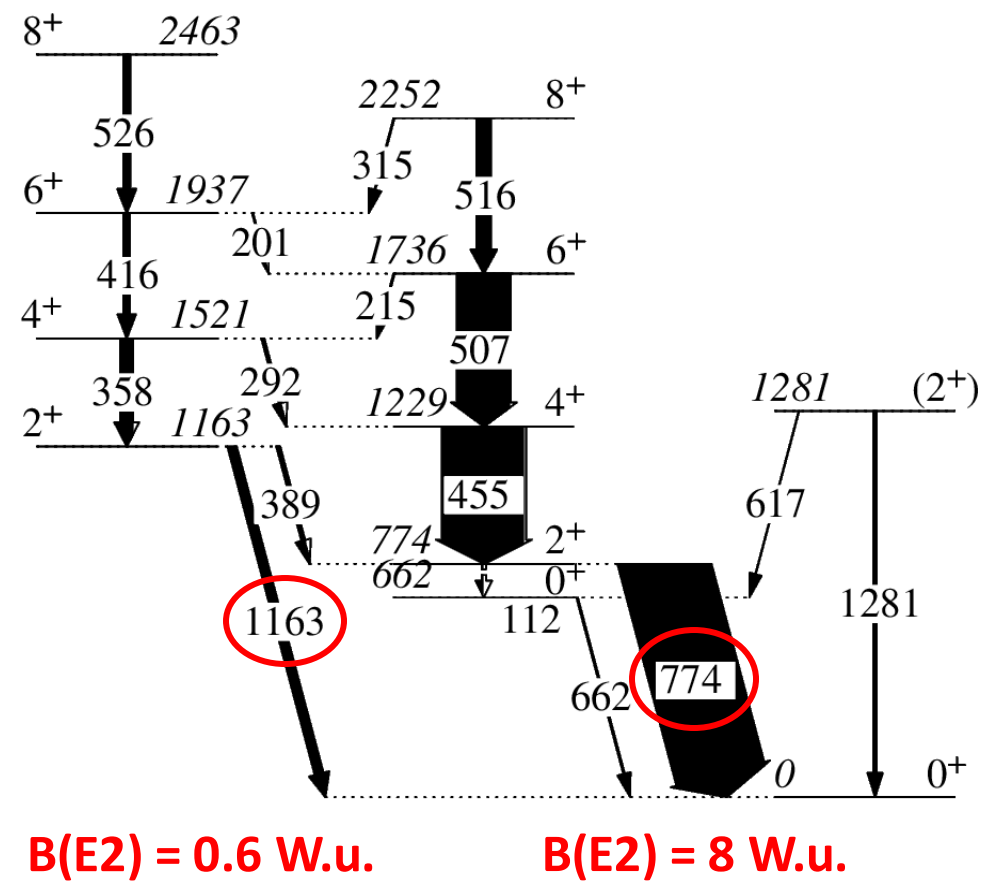
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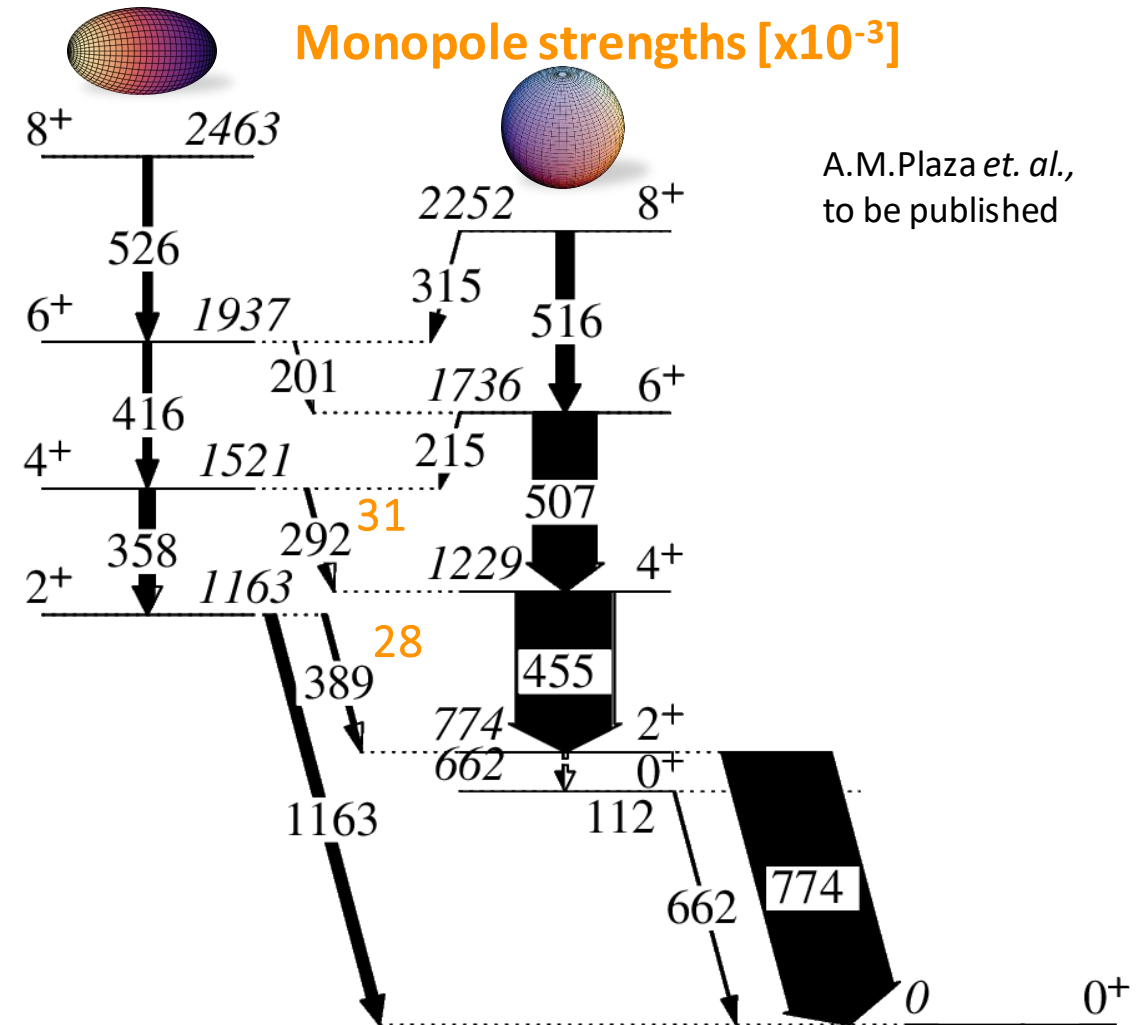


774 keV transition
(gated on 455)



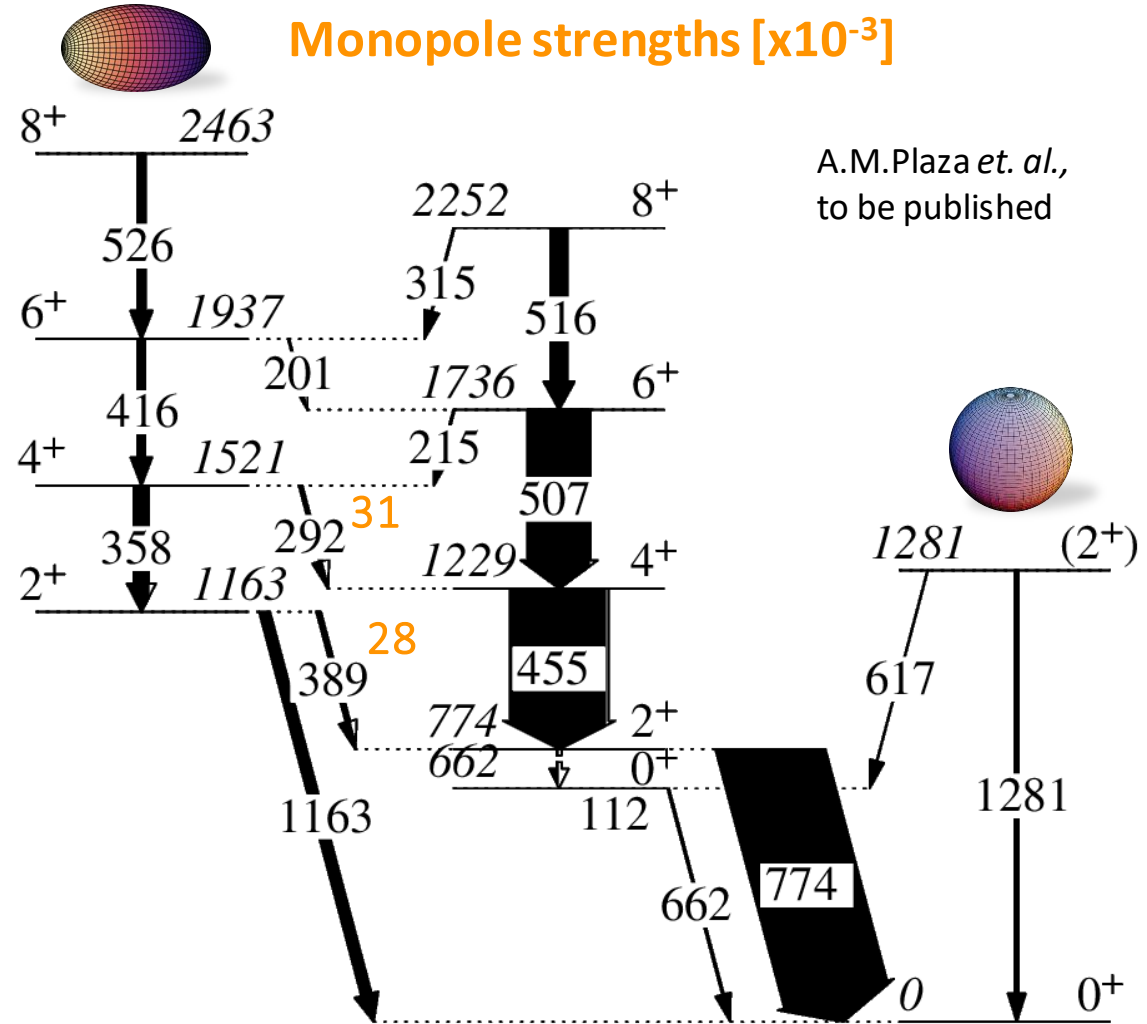
^{190}Pb : Assigning the yrast band ...

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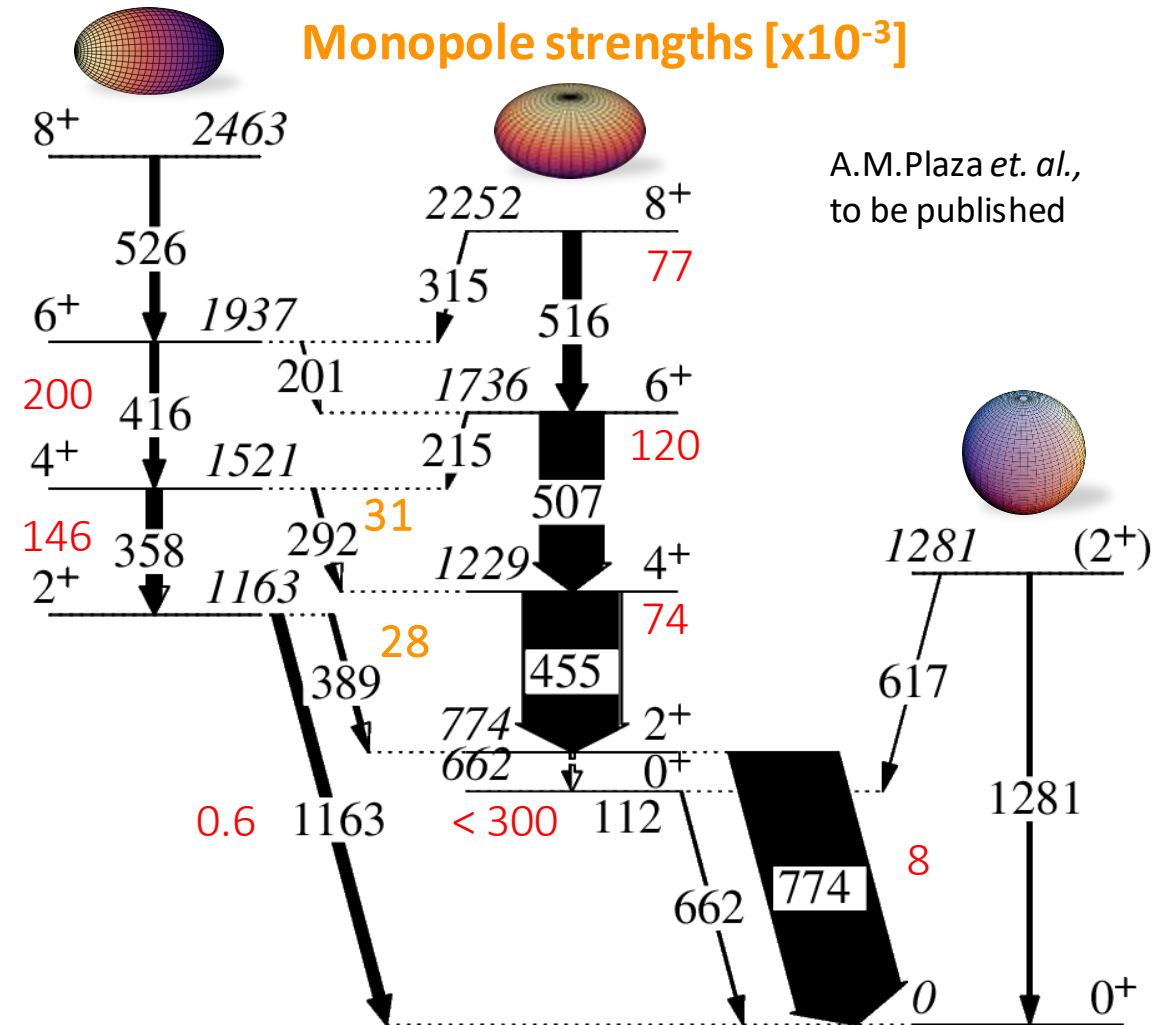


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- Limits obtained for the **feeding** transition/s of the 0^+_2

Experimental B(E2) [W.u.]

Monopole strengths [$\times 10^{-3}$]



¹⁹⁰Pb: Assigning the yrast band with an OBLATE shape

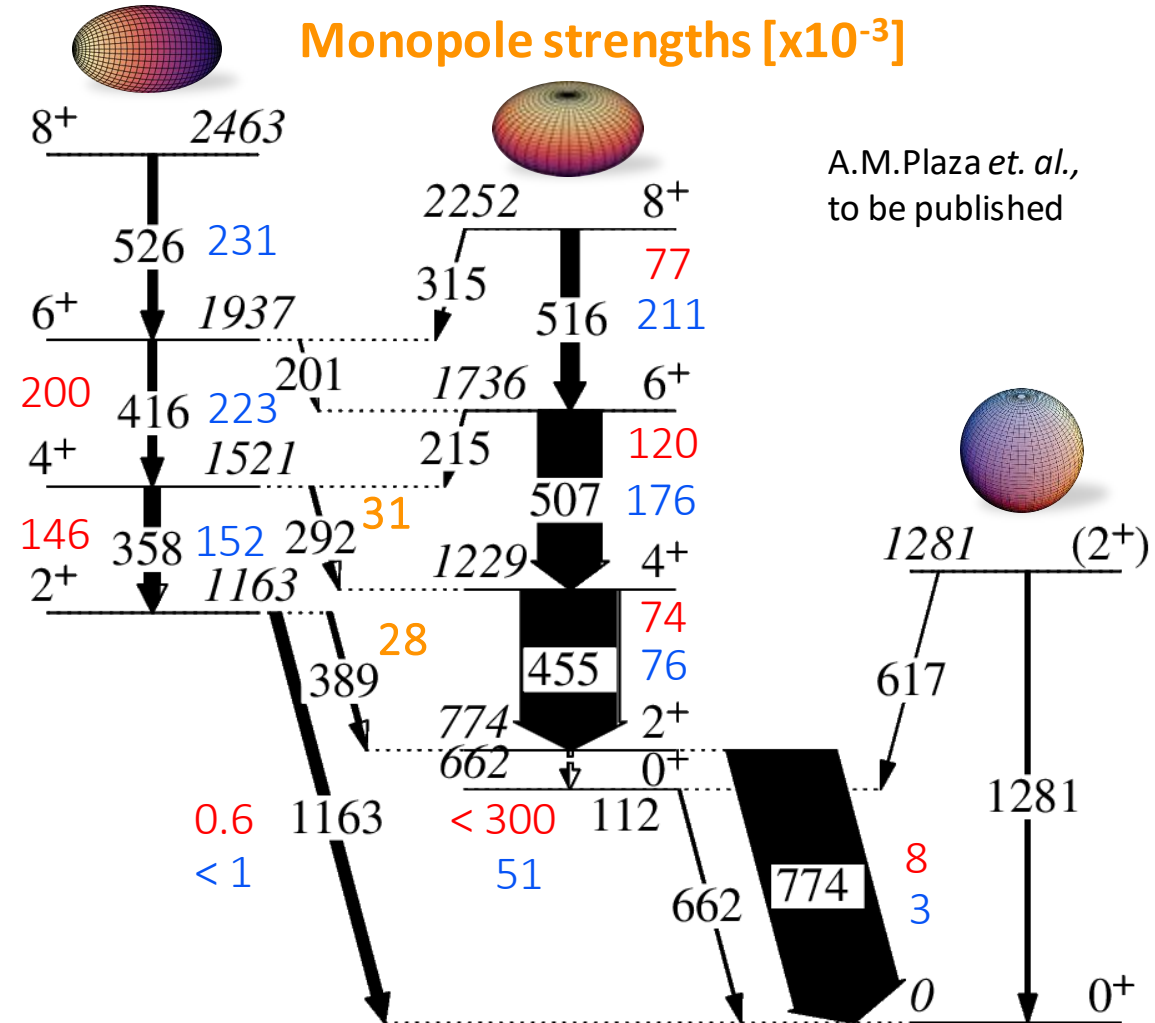
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IBM B(E2)[W.u.]

V. Hellemans *et al.*, Phys Rev. C **77** (2008), 064324

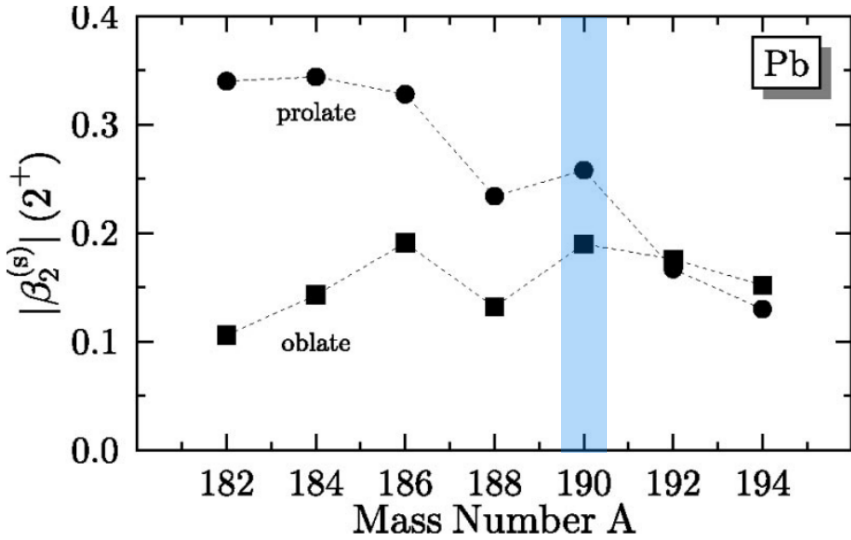
Monopole strengths [x10⁻³]



A.M.Plaza *et al.*,
to be published

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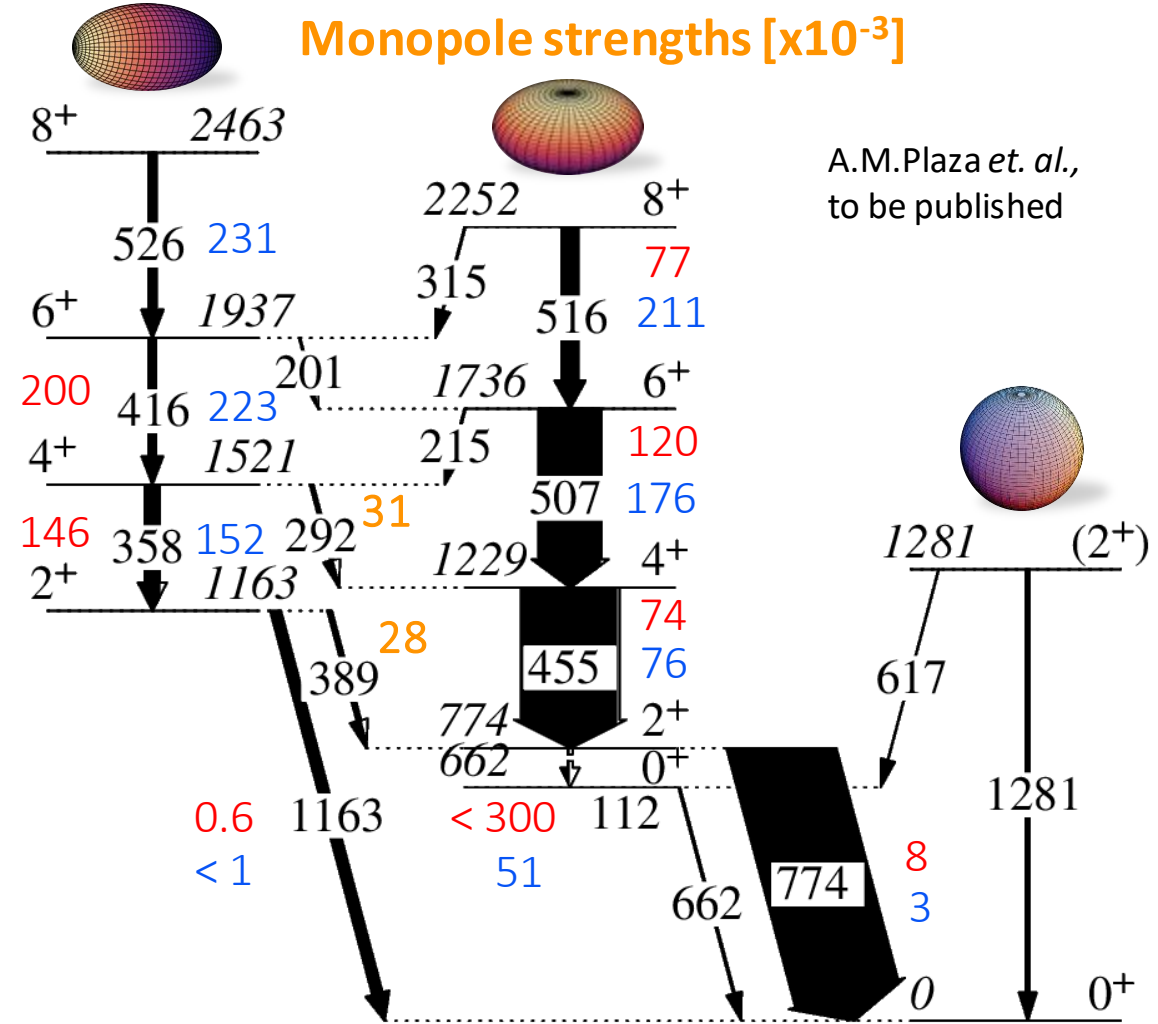
M. Bender *et al.*,
Phys. Rev. C **69**
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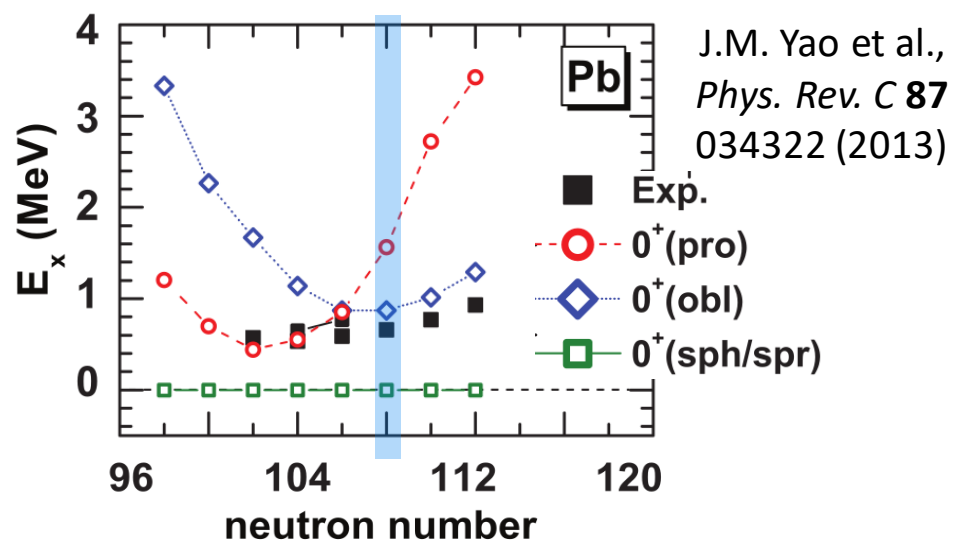
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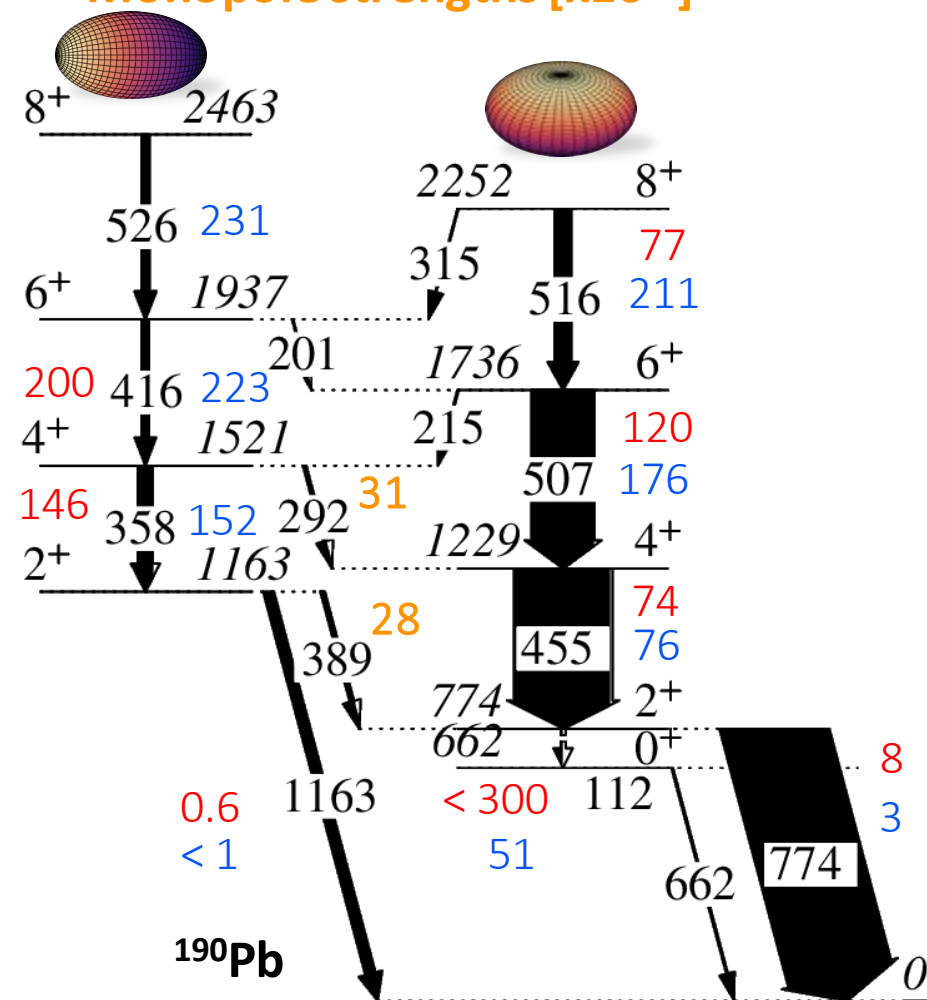
Transition properties of the low-lying states in $^{186,188,190}\text{Pb}$



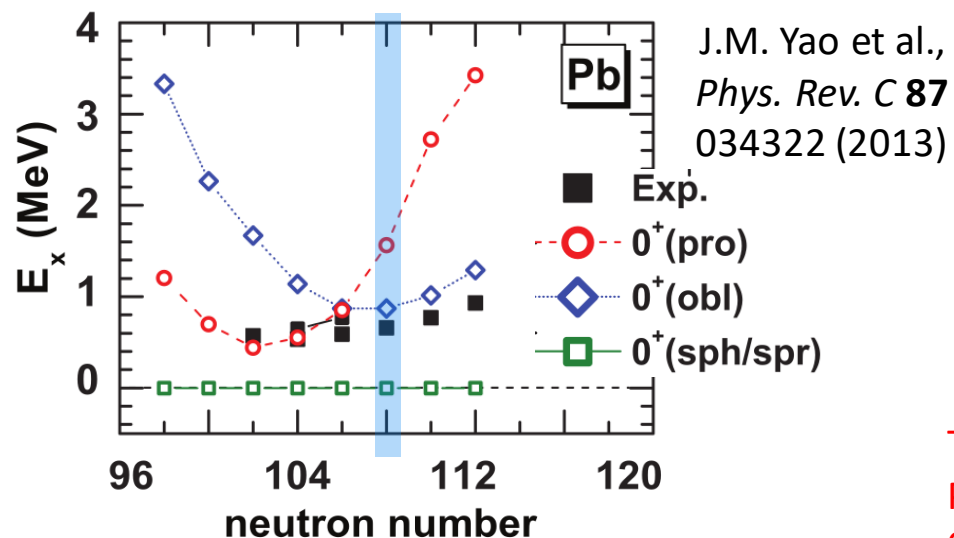
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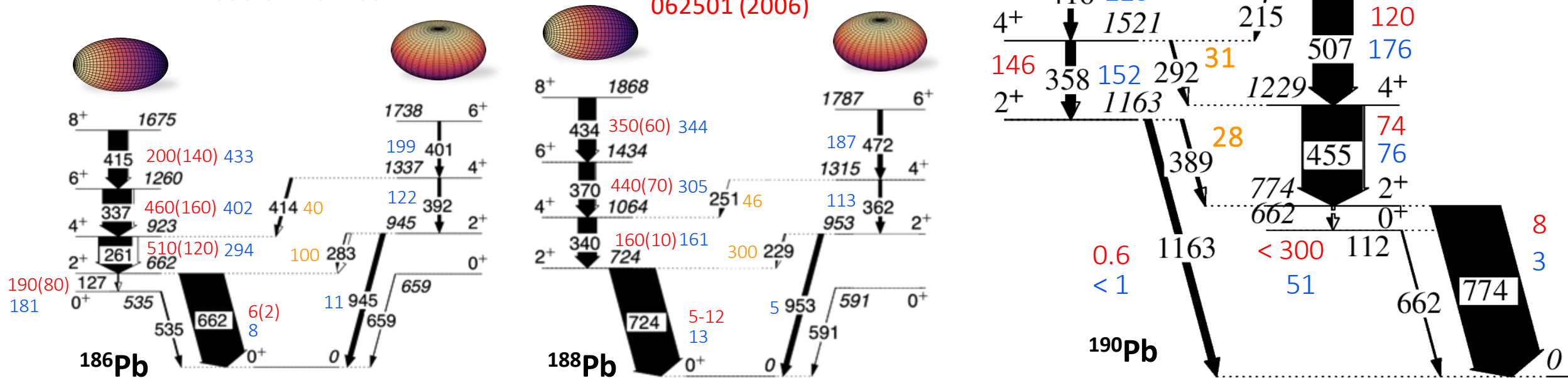
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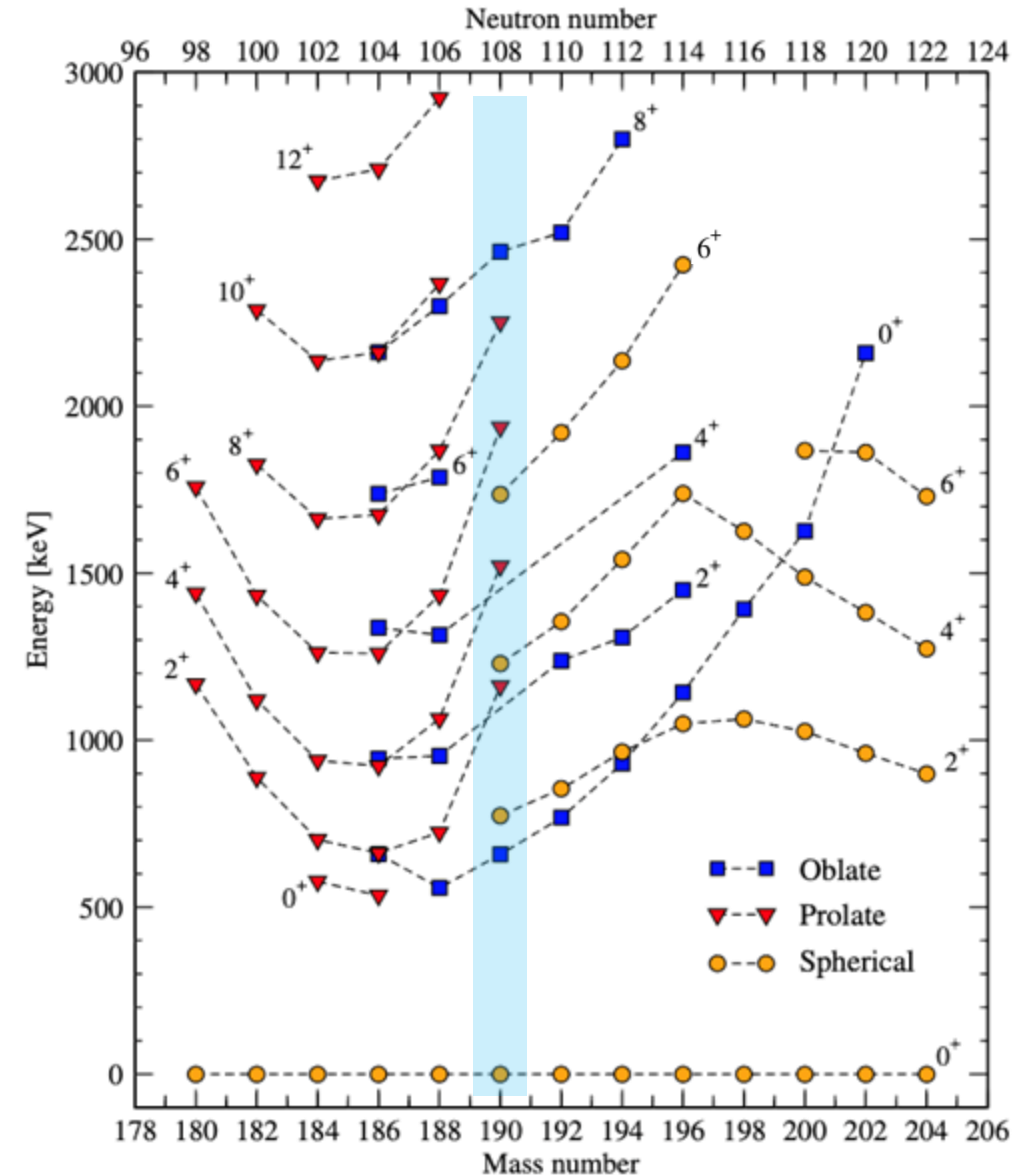
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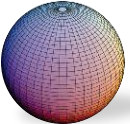


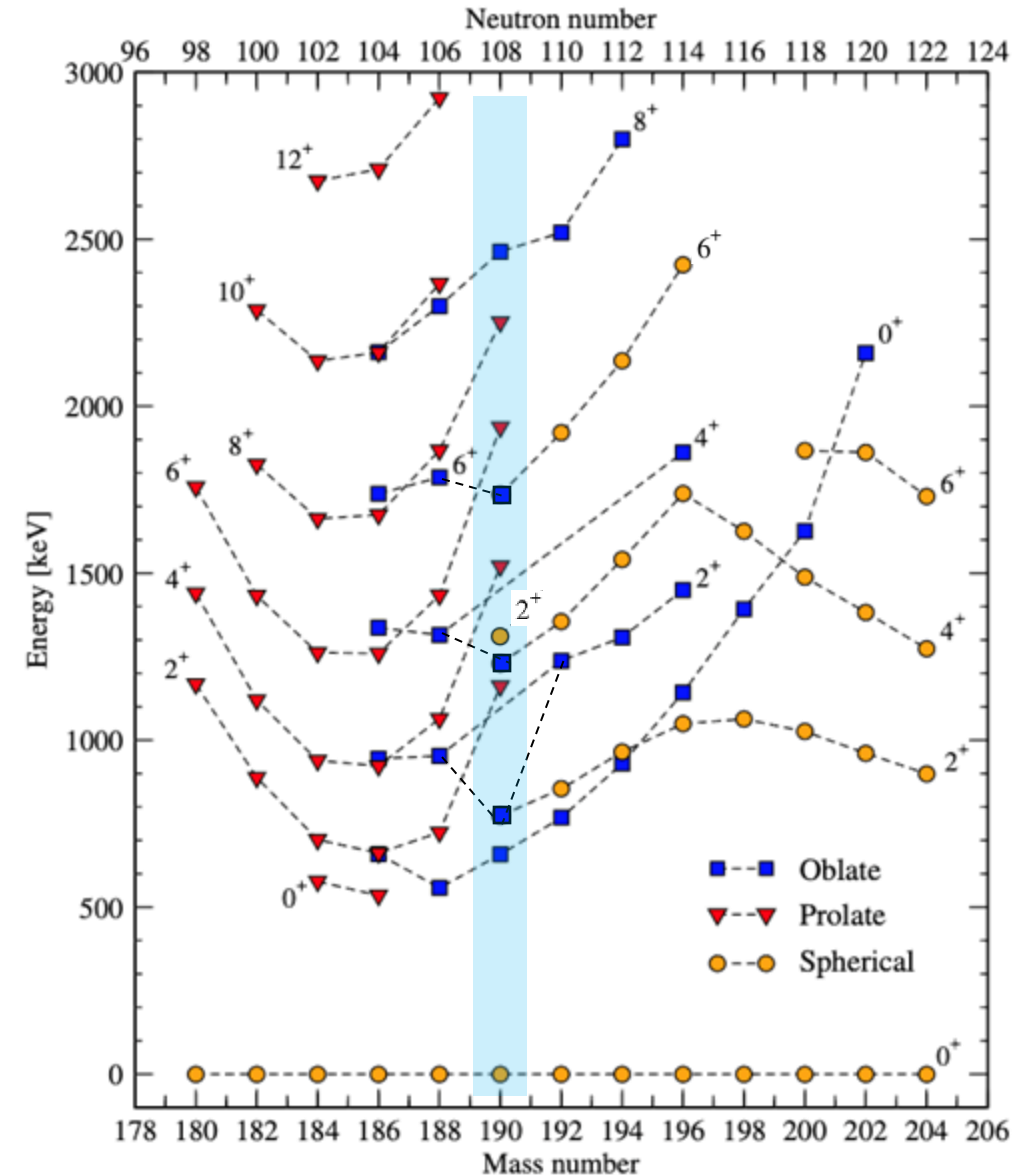
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- 2nd Exp.: Lifetime measurements



Conclusion - ^{190}Pb

- 1st Exp.: Simultaneous in-beam γ -ray & conversion electron spectroscopy
- 2nd Exp.: Lifetime measurements
- Reassigned yrast-band shape: 
- New 2⁺ state 
- Low-lying triple shape coexistence



Thank you!

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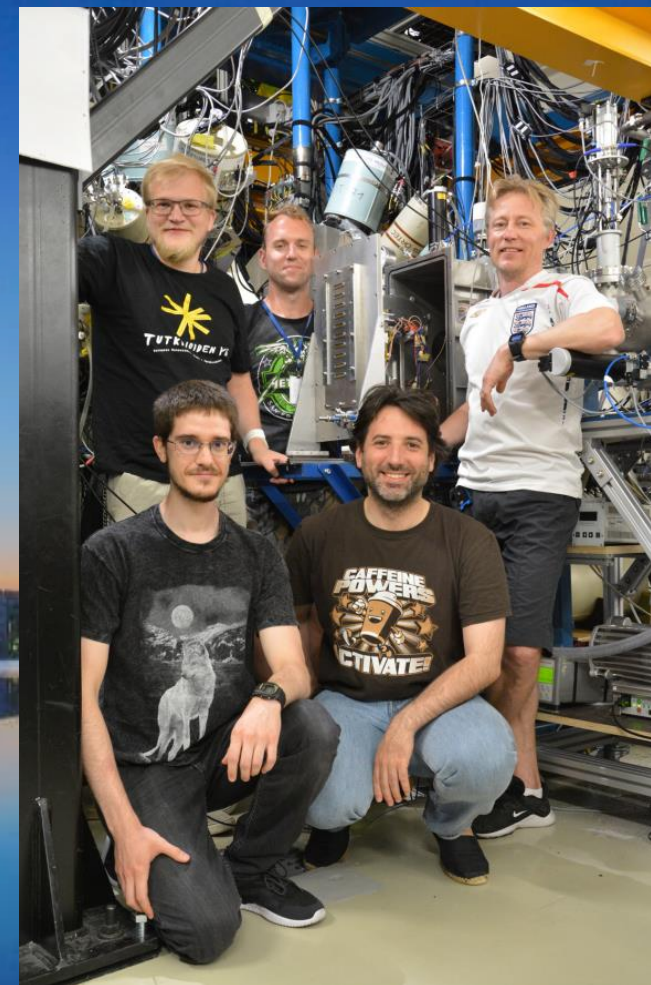
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Facilities Council

Thank you!

SAGE team



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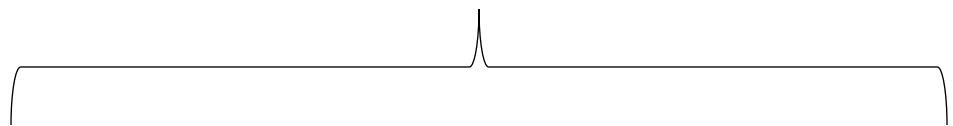


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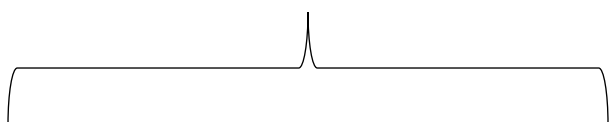
Backup slides

2nd EXPERIMENT

Lifetime measurements

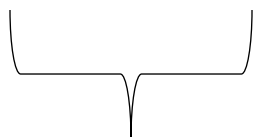


Coulex E2 matrix elements



τ (+branching) \Rightarrow B(E2) \Rightarrow Q \Rightarrow β (shapes)

I(E0)_{inter-bands}⁺ ...

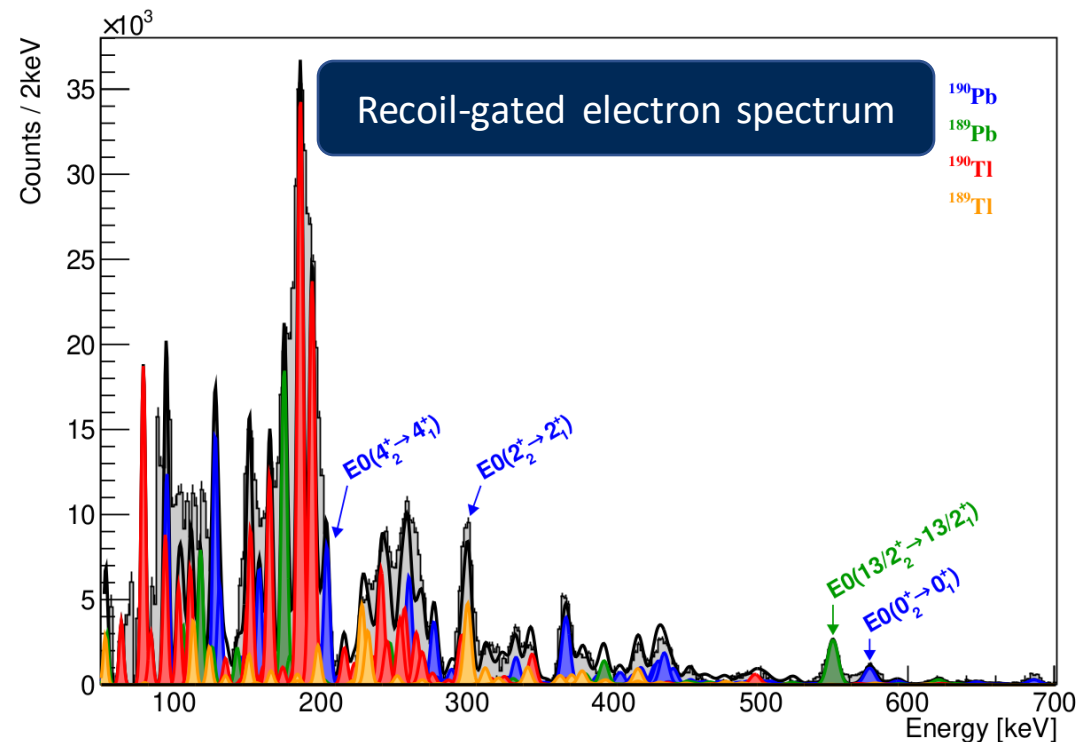
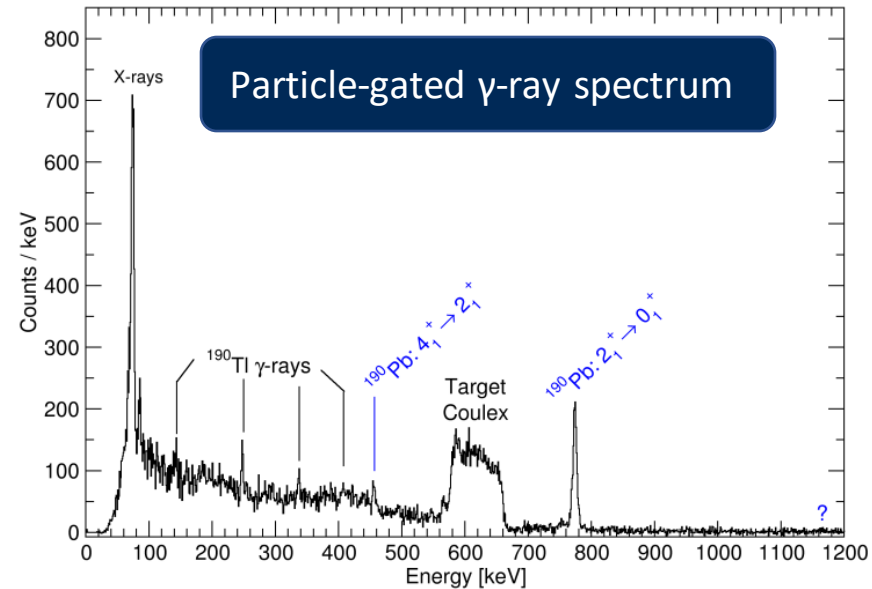


Electron spectroscopy (SAGE)

1st EXPERIMENT

$\rho^2 \Rightarrow a^2, b^2$

mixing amplitudes



Comparison with theory and systematics plot update

The oblate 2^+ state lower than spherical and prolate in ^{190}Pb

F. R. May *et al.*, Phys. Lett. B **68** (1977), 113

W. Nazarewicz, Phys. Lett. B **305** (1993), 195

R. R. Chasman *et al.*, Phys. Lett. B **513** (2001), 325

R. Fossion *et al.*, Phys. Rev. C **67** (2003), 024306

M. Bender *et al.*, Phys. Rev. C **69** (2004), 064303

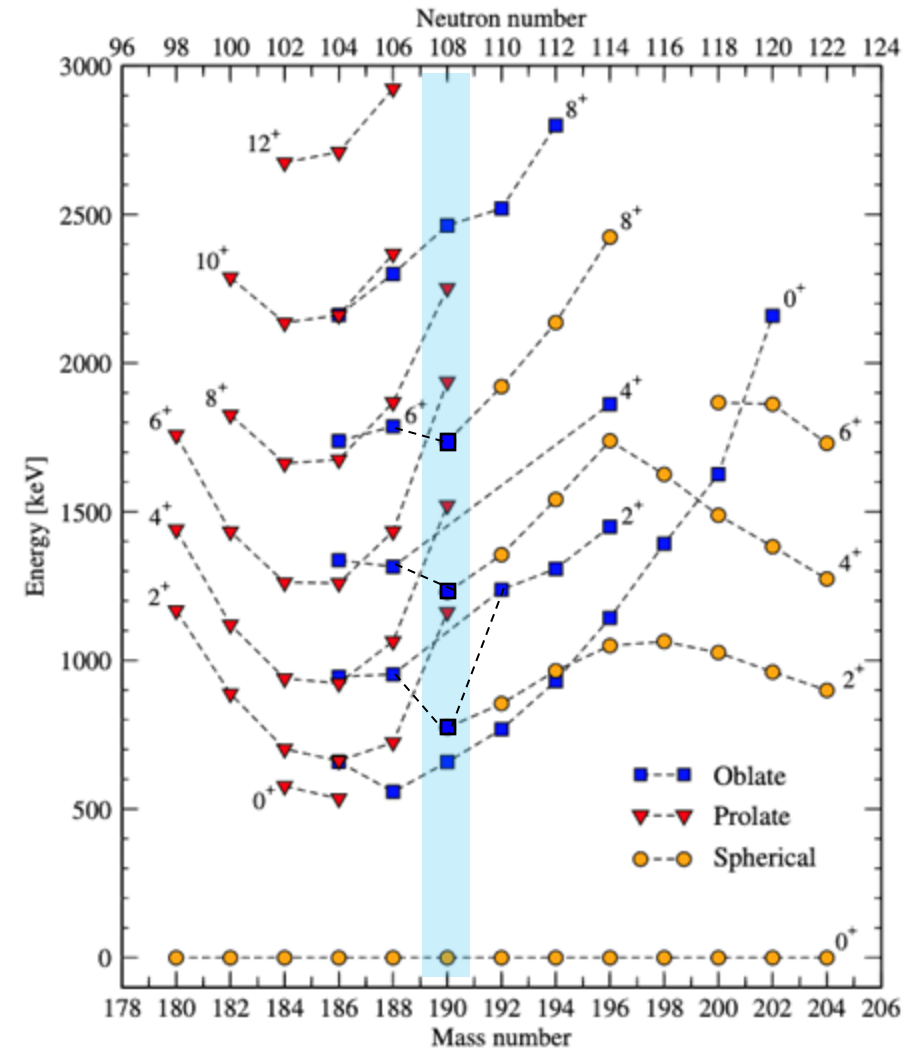
R. R. Rodriguez-Guzmán *et al.*, Phys. Rev. C **69** (2004), 054319

V. Hellemans *et al.*, Phys. Rev. C **77** (2008), 064324

J. M. Yao *et al.*, Phys. Rev. C **87** (2013), 034322

The spherical 2^+ state lower oblate in ^{190}Pb

K. Nomura *et al.*, Phys. Rev. C **86** (2012), 034322



Lifetimes
(γ rays)

τ (+branching) \Rightarrow $B(E2) \Rightarrow Q \Rightarrow \beta$ (shapes)

Experimental

$$B(E2) = \frac{9527}{E_\gamma^5 T_{1/2}(\gamma) A^{4/3}}, \quad \Rightarrow \quad B(E2; I \rightarrow I - 2) = \frac{5}{16\pi} Q_t^2 \langle I020 | I - 20 \rangle^2 \quad \Rightarrow \quad Q_0 = \frac{3}{\sqrt{5\pi}} Z e R_0^2 \beta_2$$

γ rays +
conversion e^-

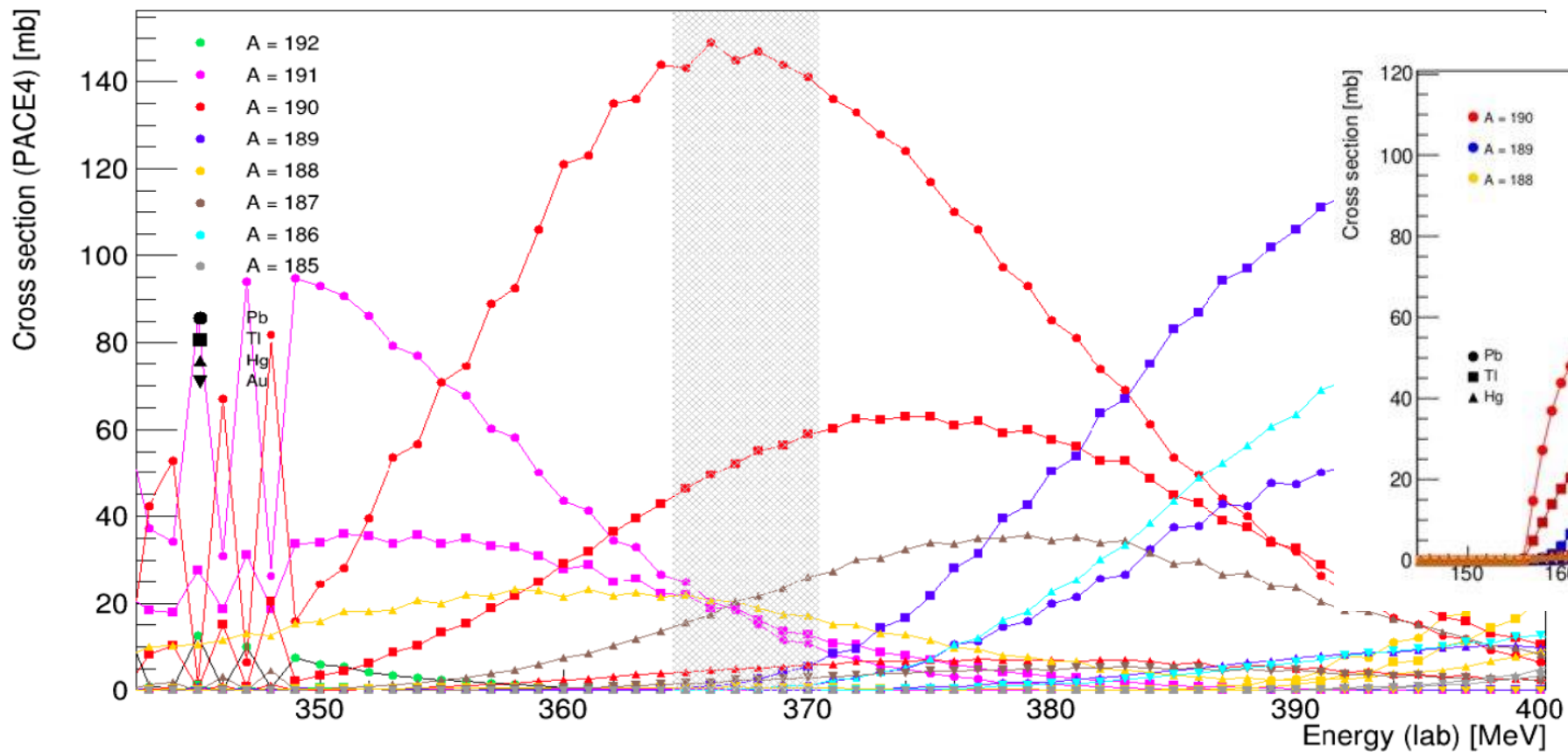
$$\rho^2 = \left| \frac{\langle 0_2^+ | \sum_i e_i r_i^2 | 0_1^+ \rangle}{eR^2} \right|^2$$

$$\rho^2 = \frac{I_K(E0) W_\gamma(E2)}{I_\gamma(E2) \Omega_K(E0)}$$

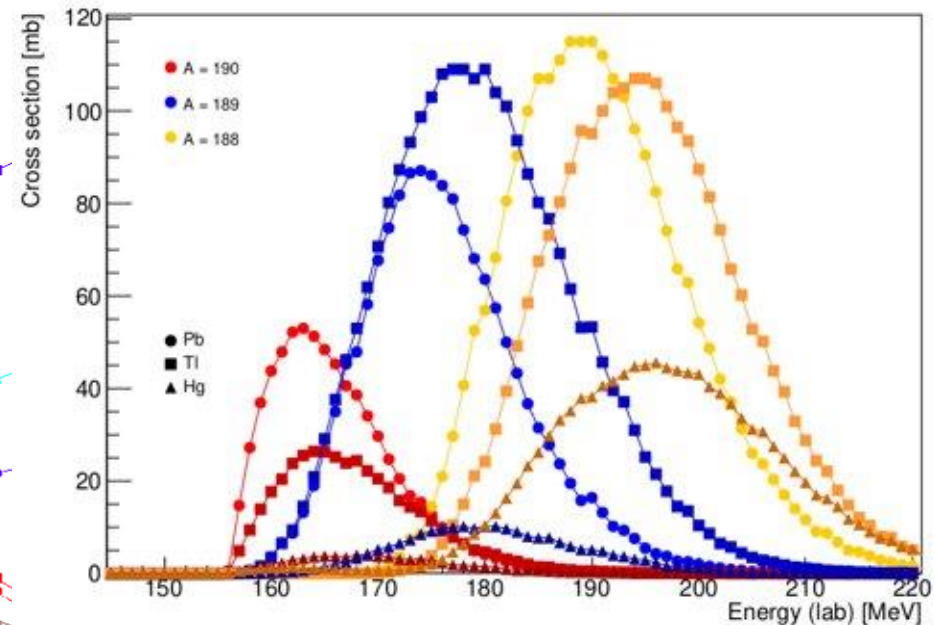
$$\rho^2 = \left(\frac{3}{4\pi} Z \right)^2 a^2 b^2 [\beta_{2,1}^2 - \beta_{2,2}^2]^2, \quad a^2 + b^2 = 1$$

a^2, b^2

Mixing
amplitudes

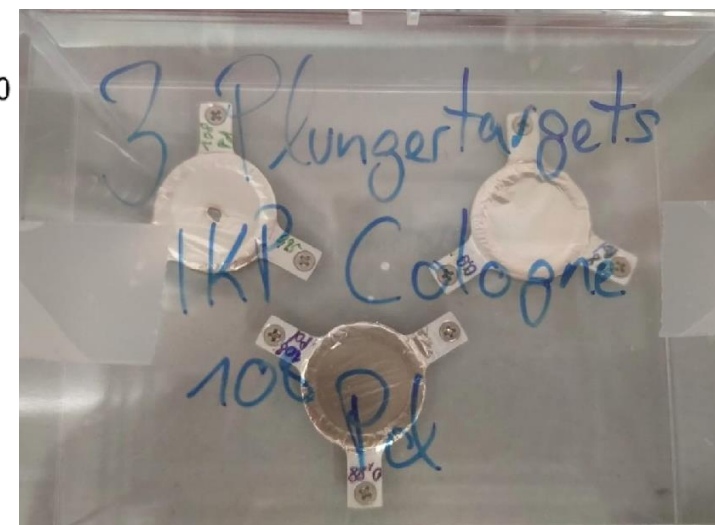


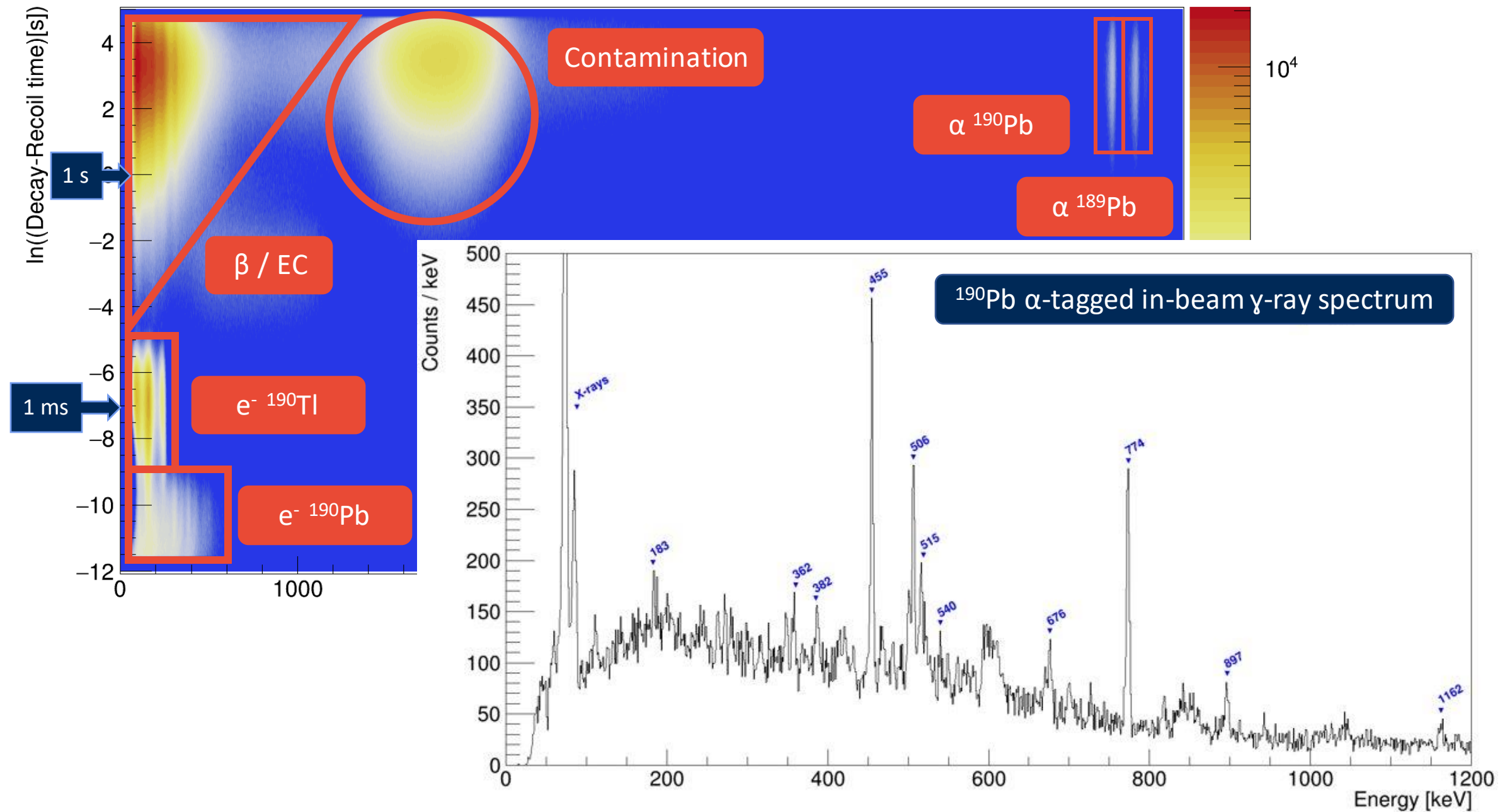
$^{35}\text{Cl} + ^{159}\text{Tb}$ (SAGE exp.)

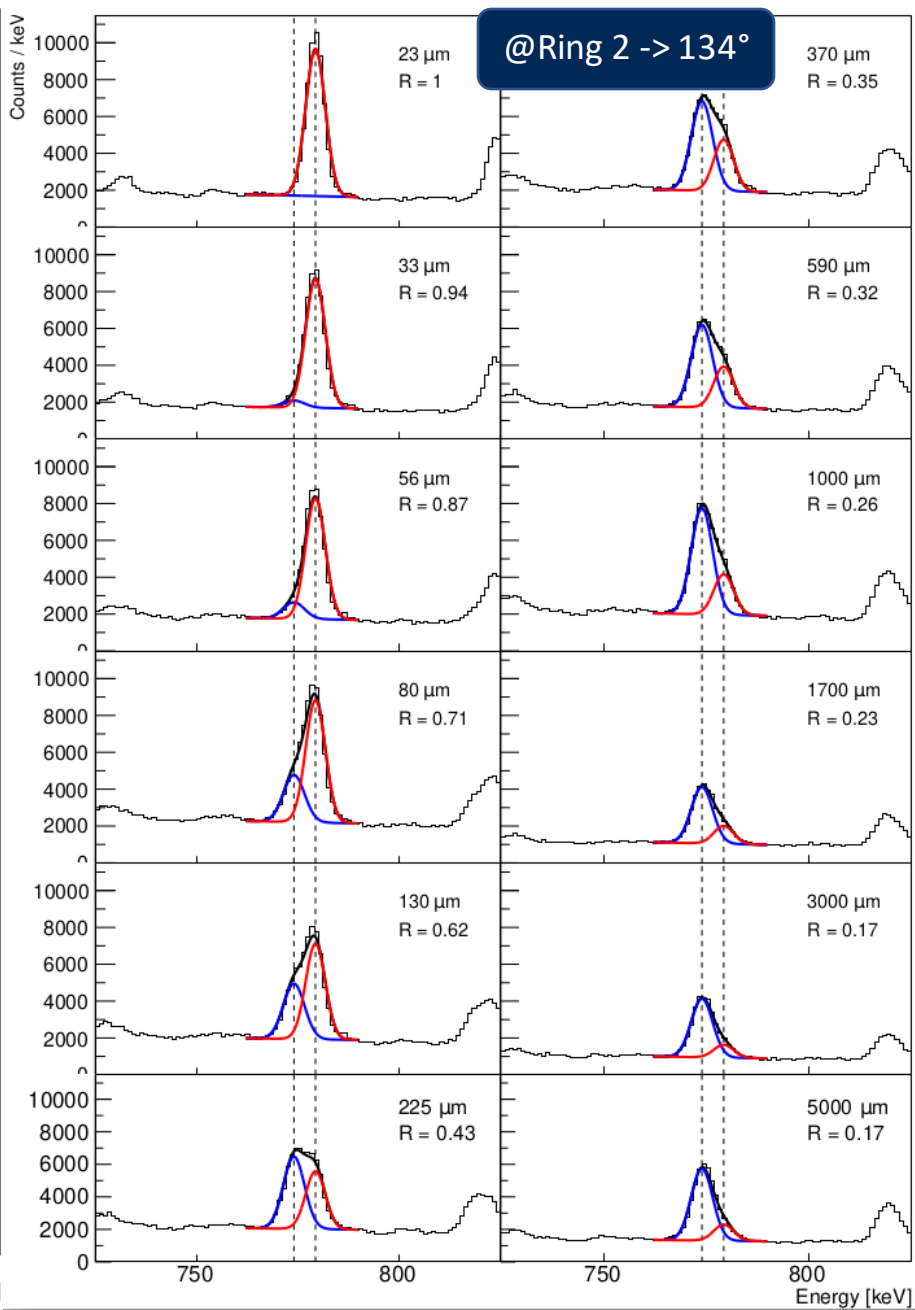
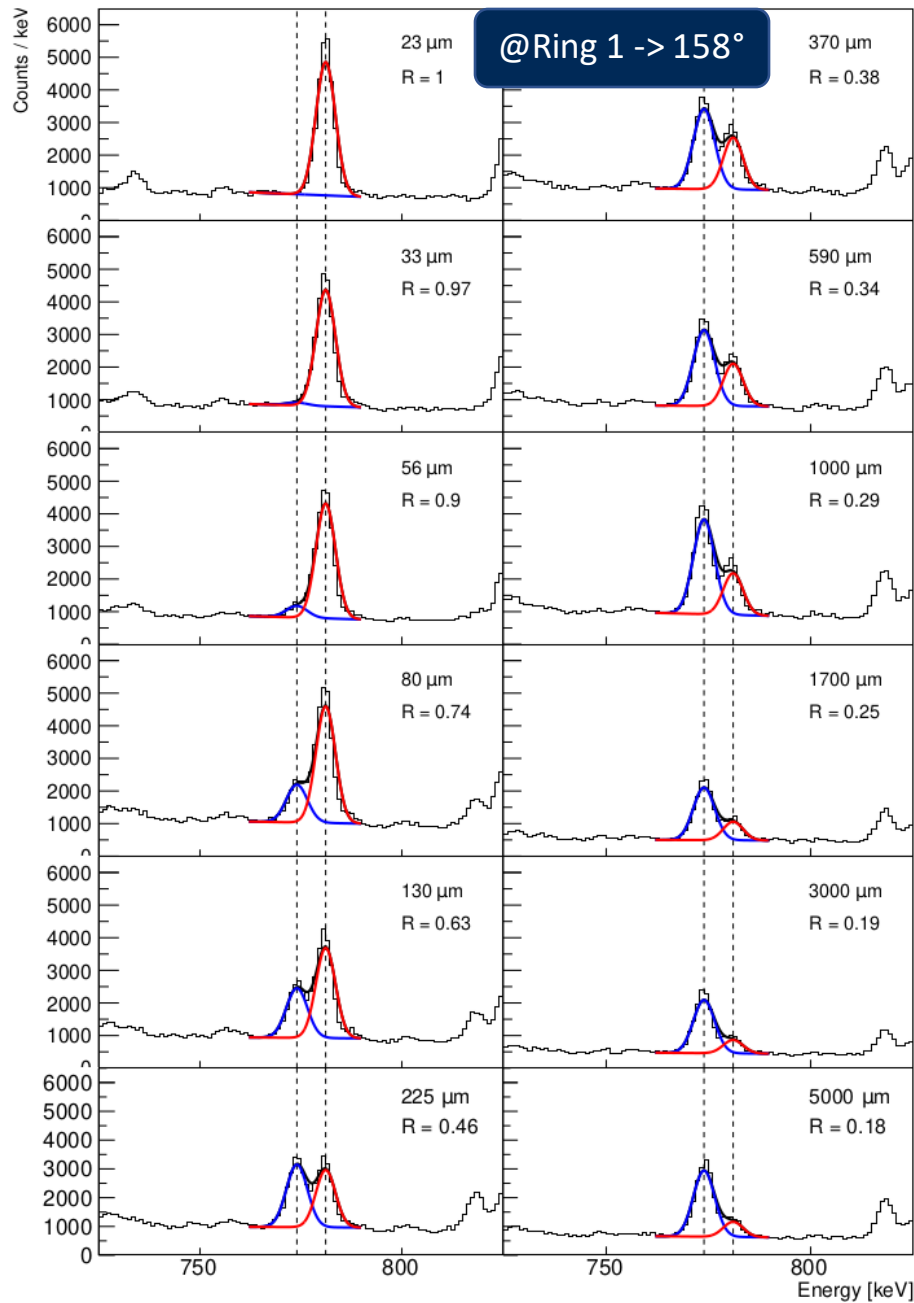


$E_{\text{lab}} = 378 \text{ MeV}$
 $^{108}\text{Pd}(^{86}\text{Kr}, 4n)^{190}\text{Pb}$

Fission ~ 30%
 $^{190}\text{Pb} \sim 35\%$
 $^{190}\text{Tl} \sim 12\%$
 $\{^{191}\text{Pb}, ^{191}\text{Tl}, ^{188}\text{Hg}, ^{187}\text{Hg}\} \sim 12\%$







$2^+_1 \rightarrow 0^+_1$ (774 keV)

