Shape coexistence in the neutron-deficient Hg isotopes studied via lifetime measurements

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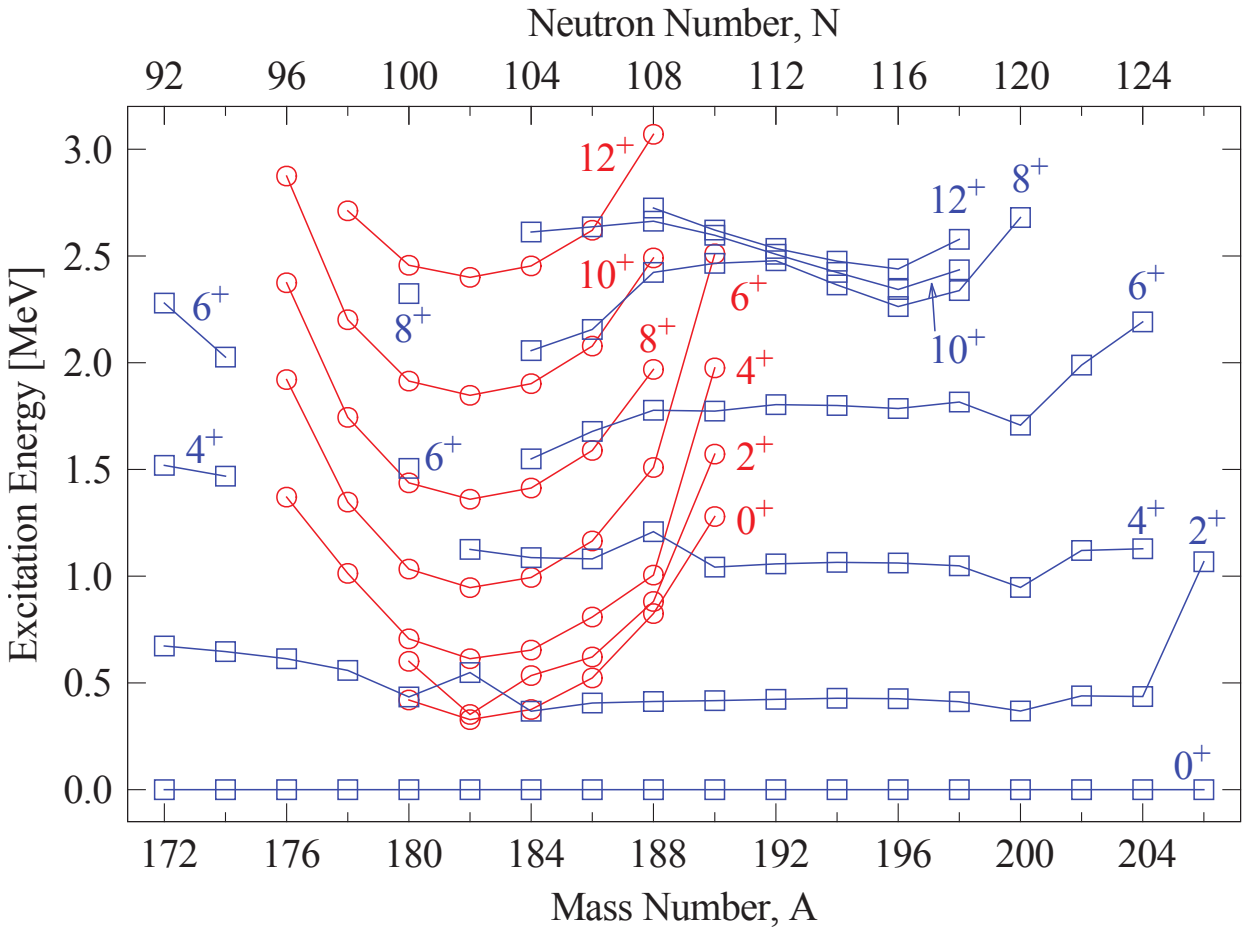
June 29, 2016

The neutron-deficient isotopes around $N \approx 104$

- Intruder bands observed for $^{176-190}$Hg
- Different deformation:
  - ground state band oblate deformed
  - Intruder band prolate deformed

K. Heyde and J.L. Wood, Rev. Mod. Phys. 83 (2011)



˜ *Adapted from L.P. Gaffney et al., Phys. Rev. C 89, 024307 (2014)*

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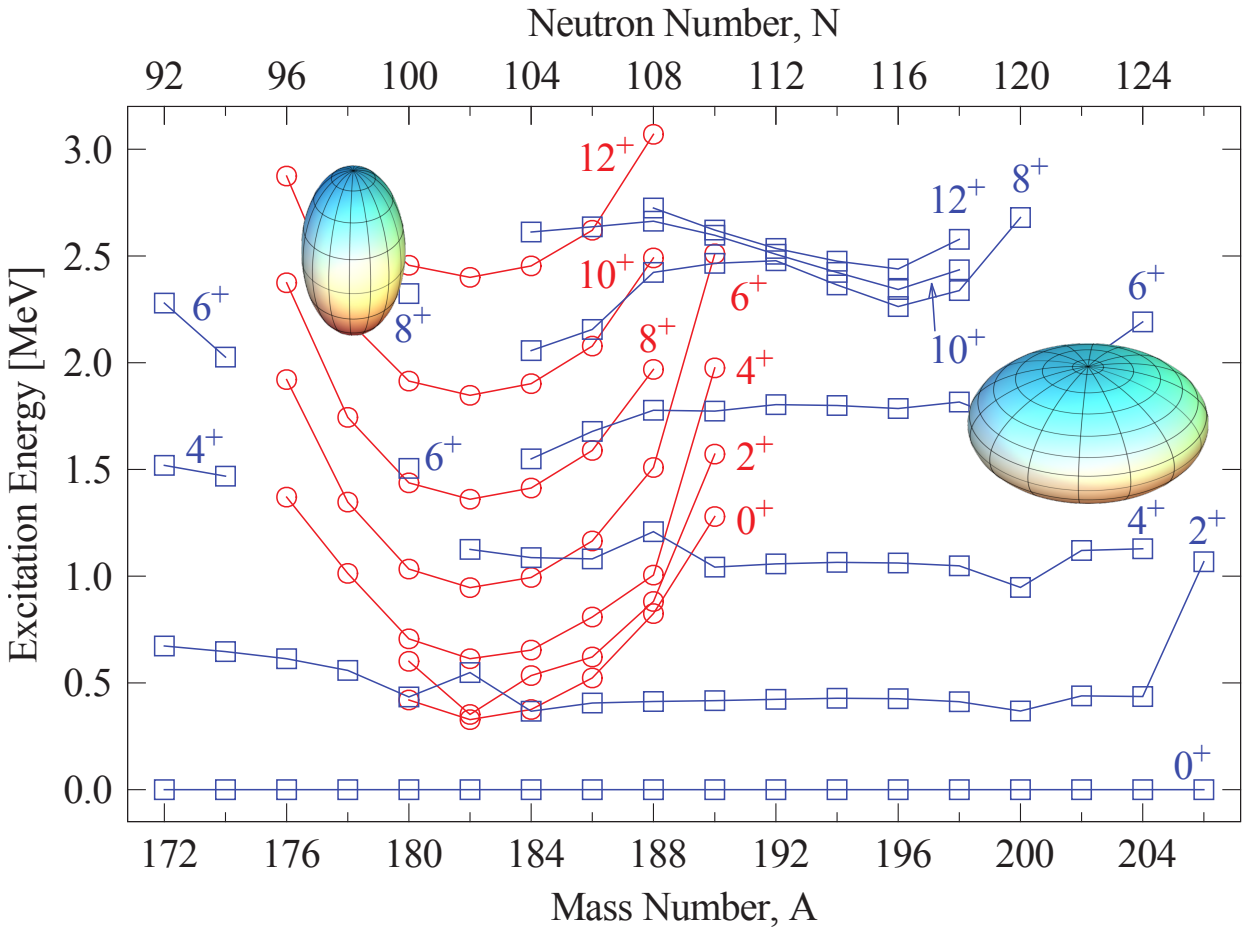

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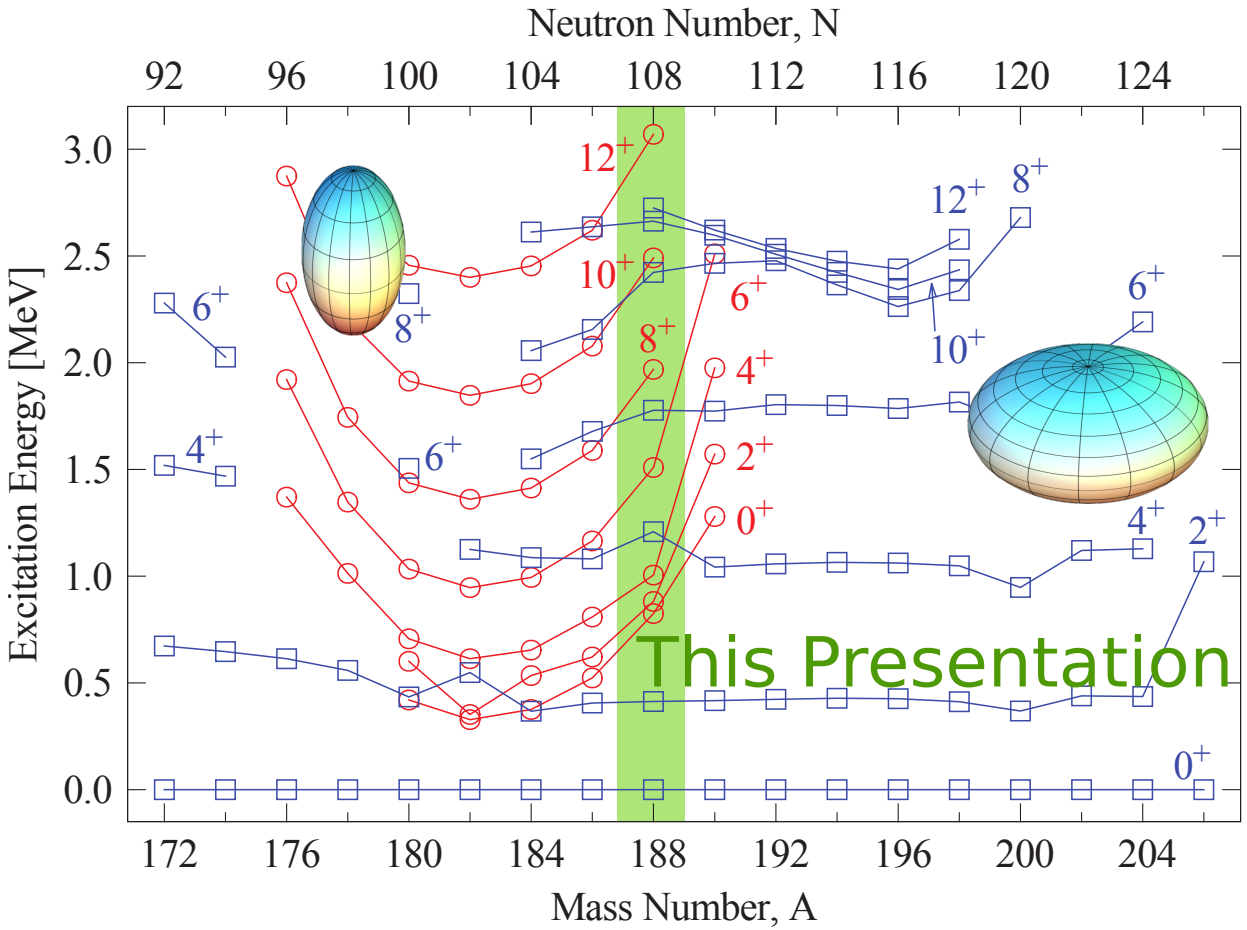

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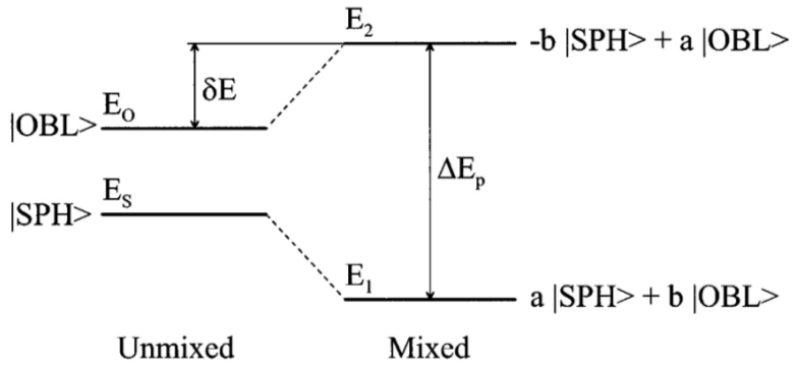
Two state configuration mixing

- Two state configuration mixing model: observed states are a mixture between these two unperturbed intrinsic states $|J_o\rangle, |J_p\rangle$:

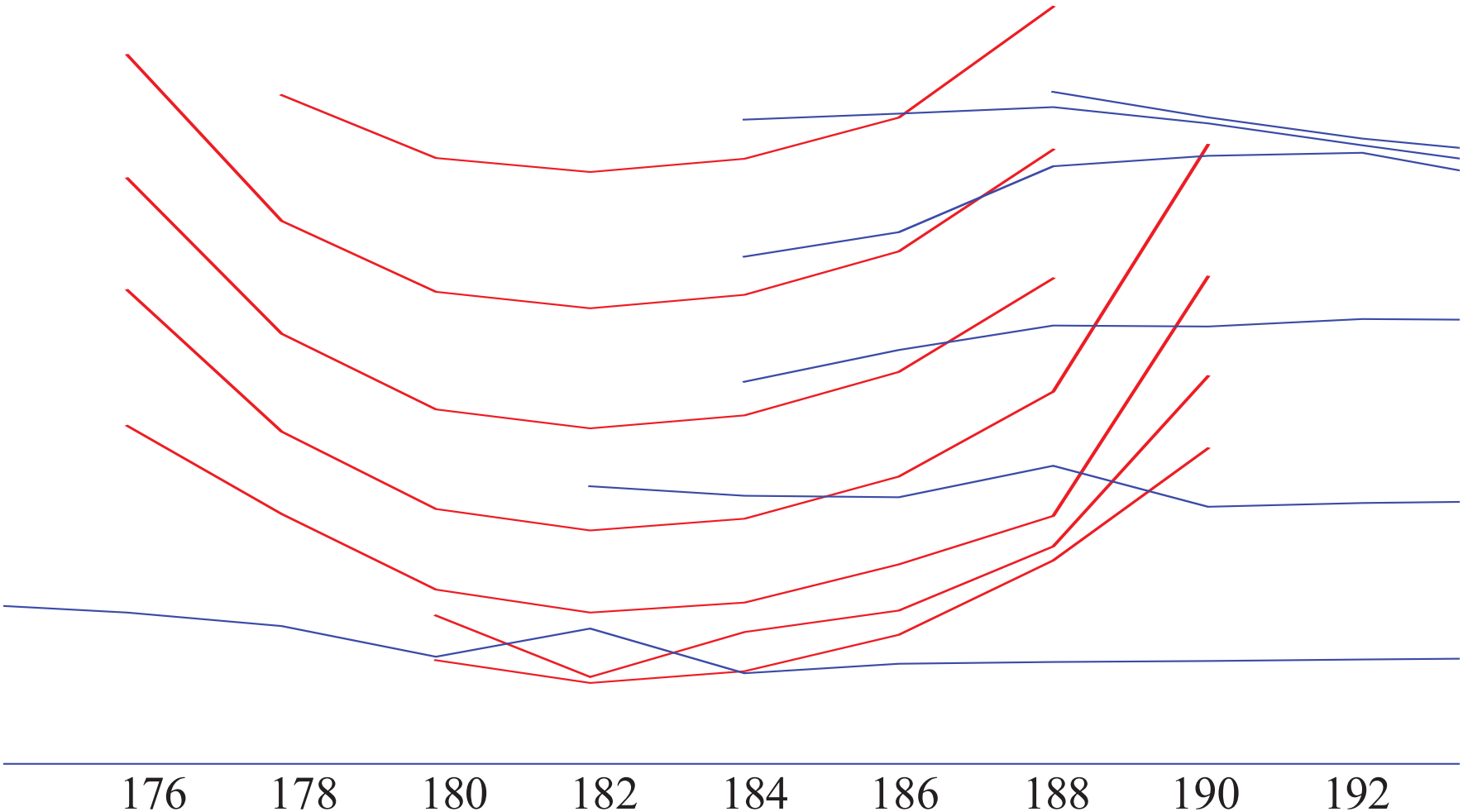
$$|J_a\rangle = \alpha_1 |J_p\rangle + \alpha_2 |J_o\rangle$$
$$|J_b\rangle = -\alpha_2 |J_p\rangle + \alpha_1 |J_o\rangle$$



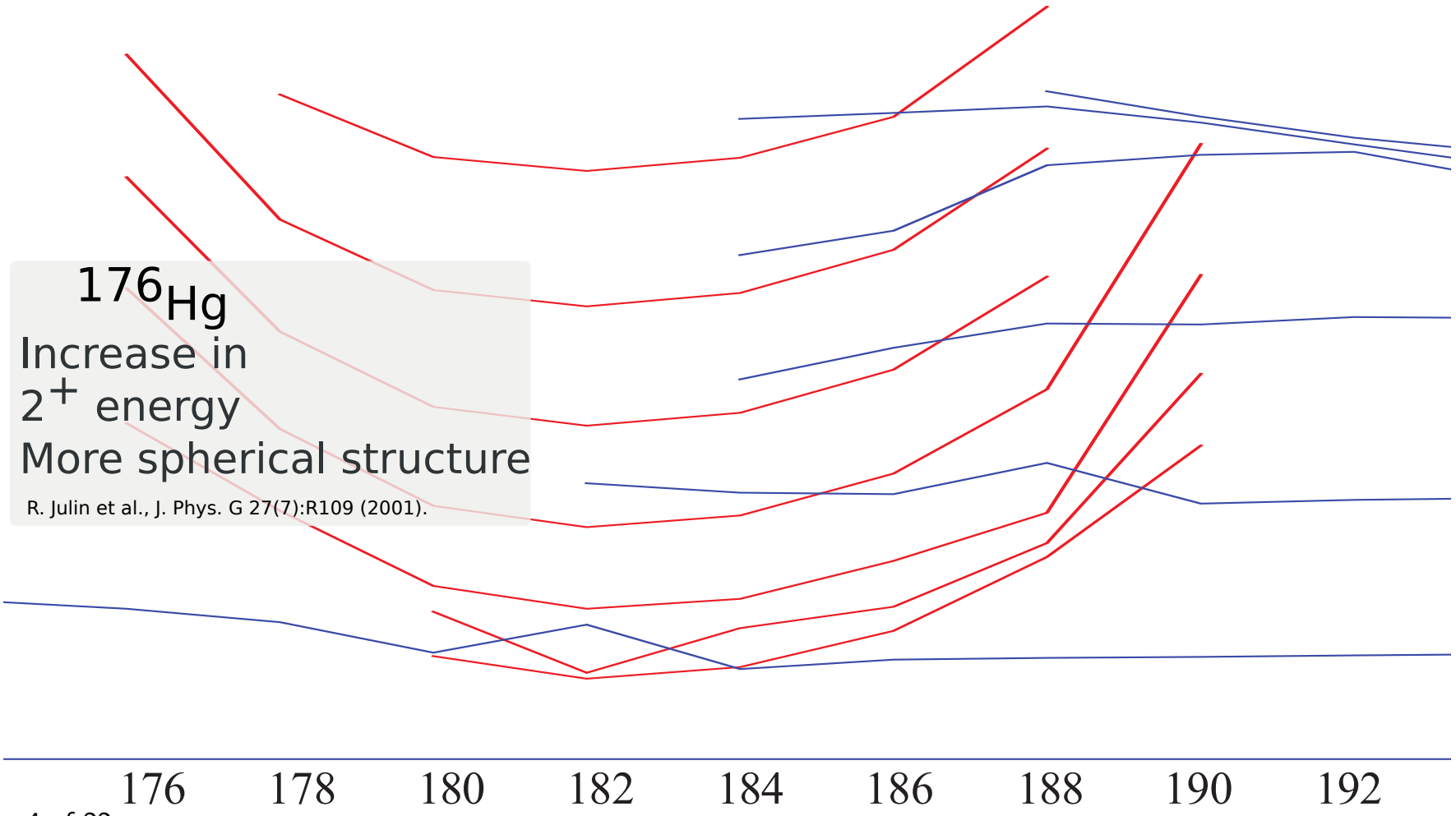
- Changing contribution as a function of neutron number
- Transition prolate deformed $\rightarrow$ mixing $\rightarrow$ oblate deformation
- Maximum mixing in the 2_1^+ state for ^{184}Hg

K. Heyde and J.L. Wood, Rev. Mod. Phys. 83 (2011)

What we know about this region



What we know about this region



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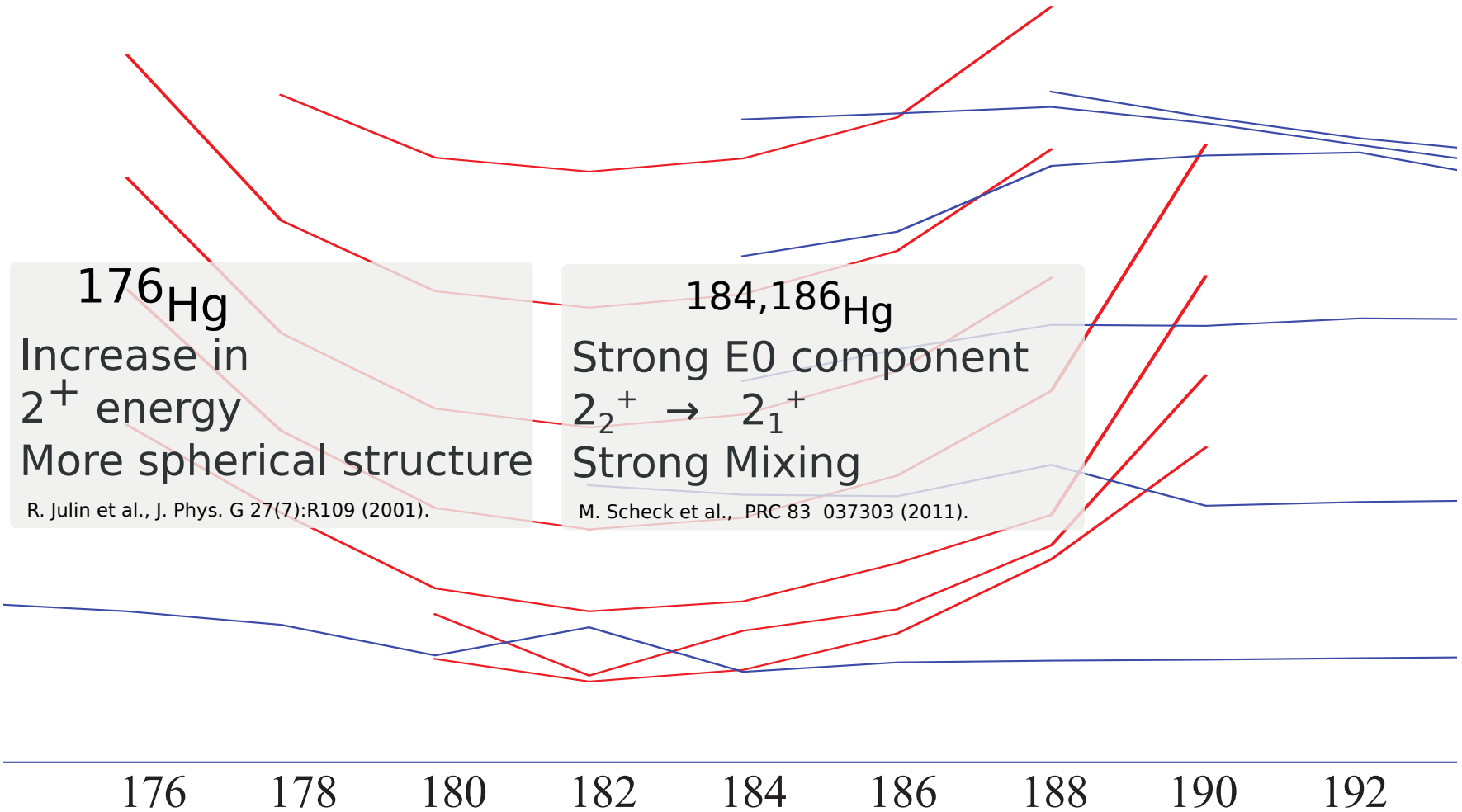

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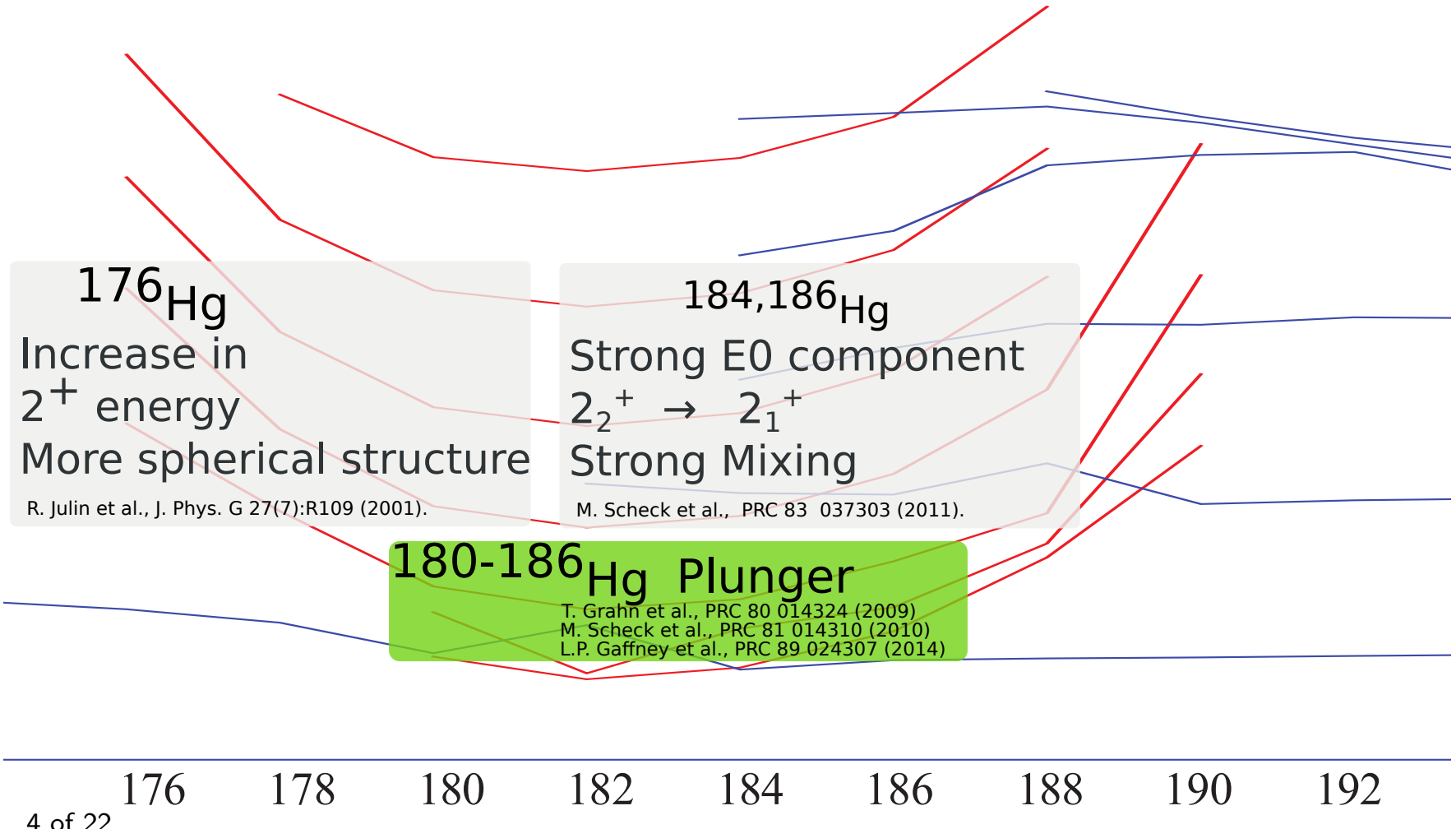

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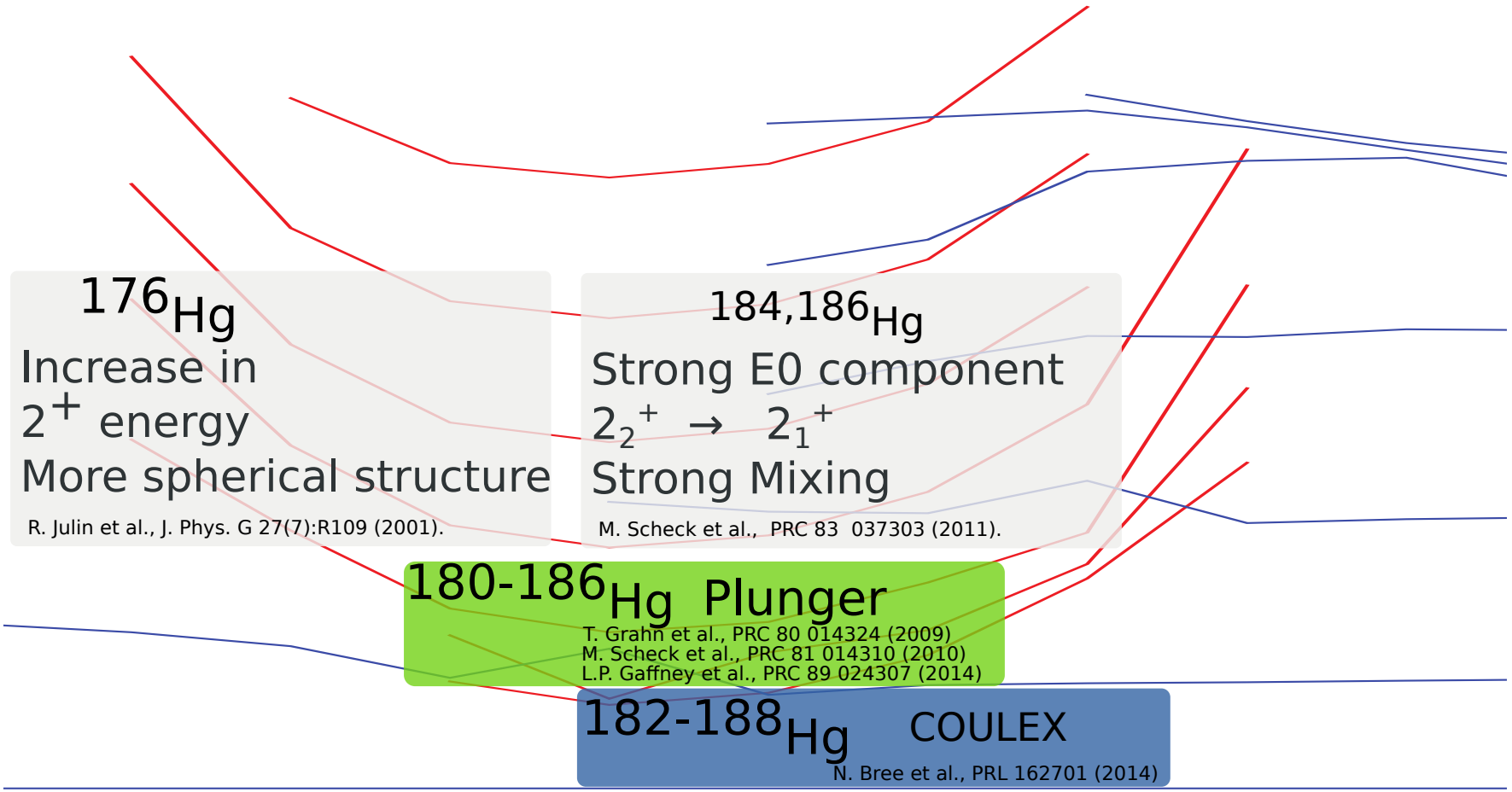

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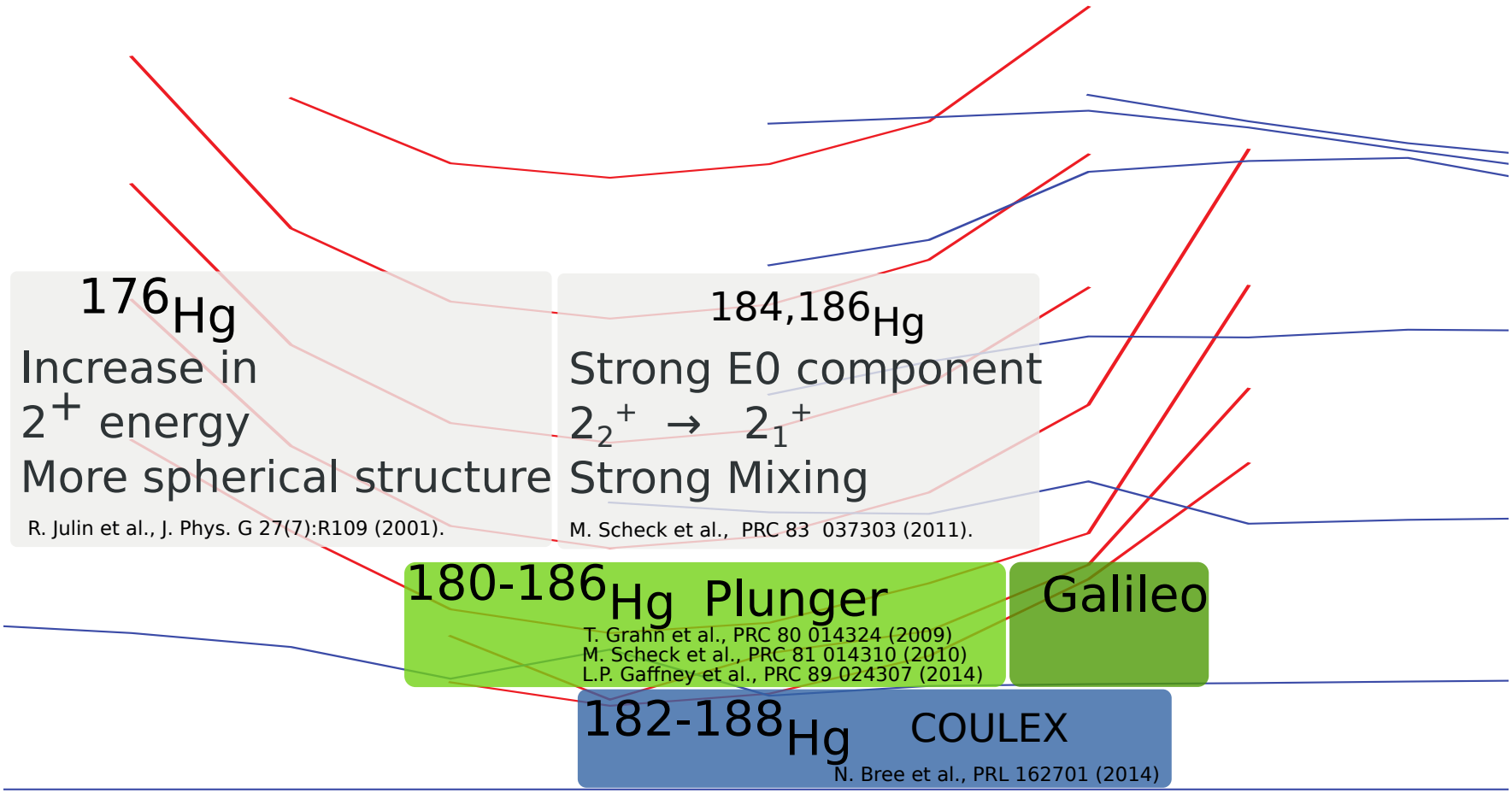
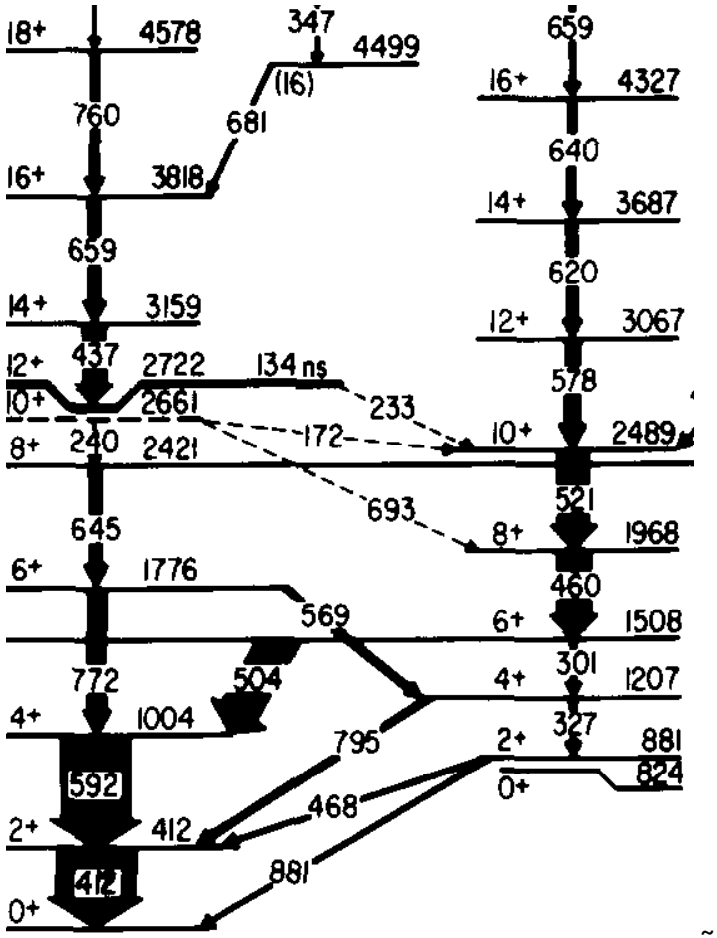


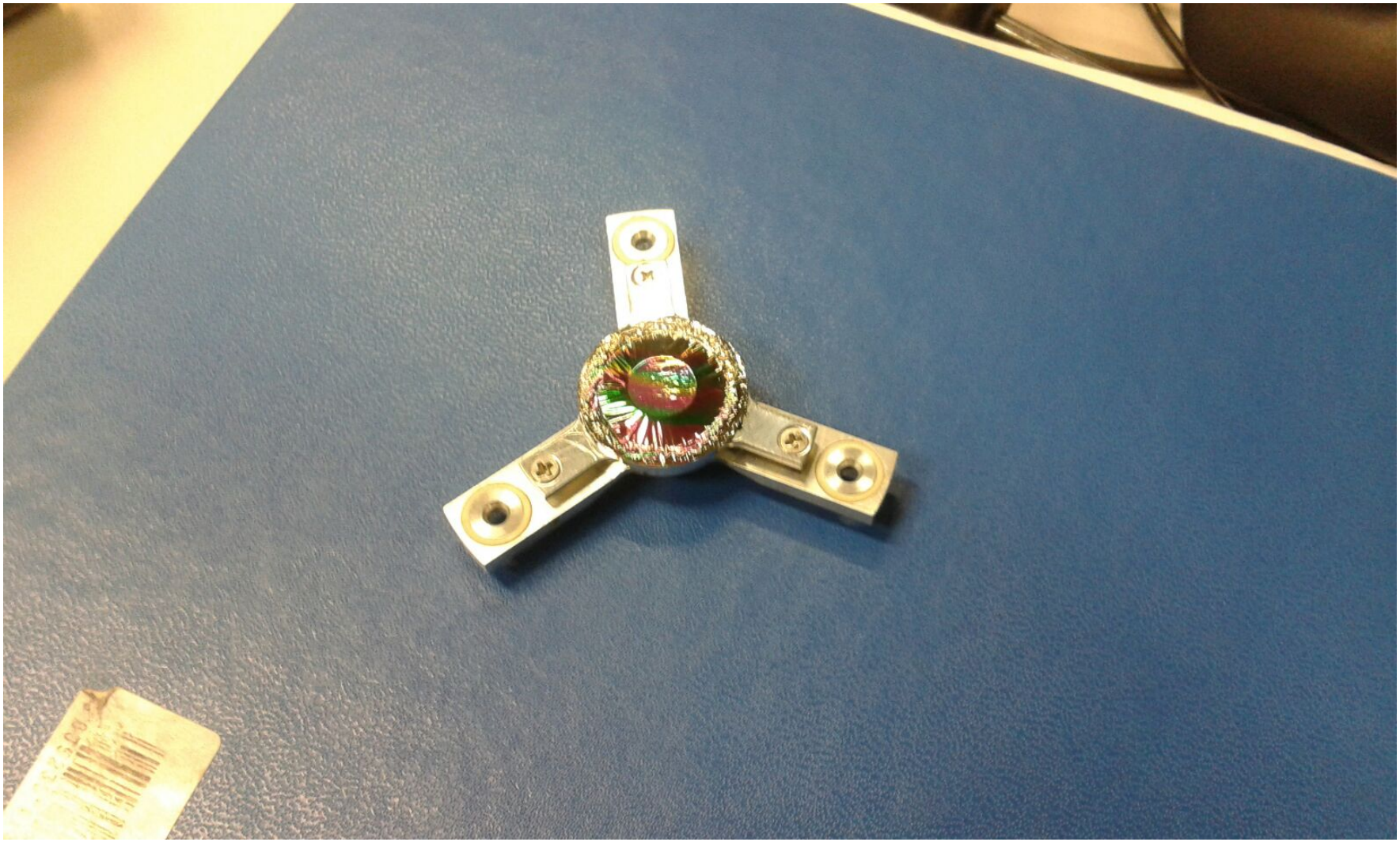
^{188}Hg – at the edge of shape coexistence

- At the heavy edge of the shape coexistence
- Ground state band supposed oblate deformed
  N. Bree et al., Phys. Rev. Let. 112:162701 (2014).
- Degree of mixing not yet firmly confined



Adapted from F. Hannachi et al., Nucl. Phys. A 481, 135-160 (1988)

Experiment using Galileo (+NeutronWall)



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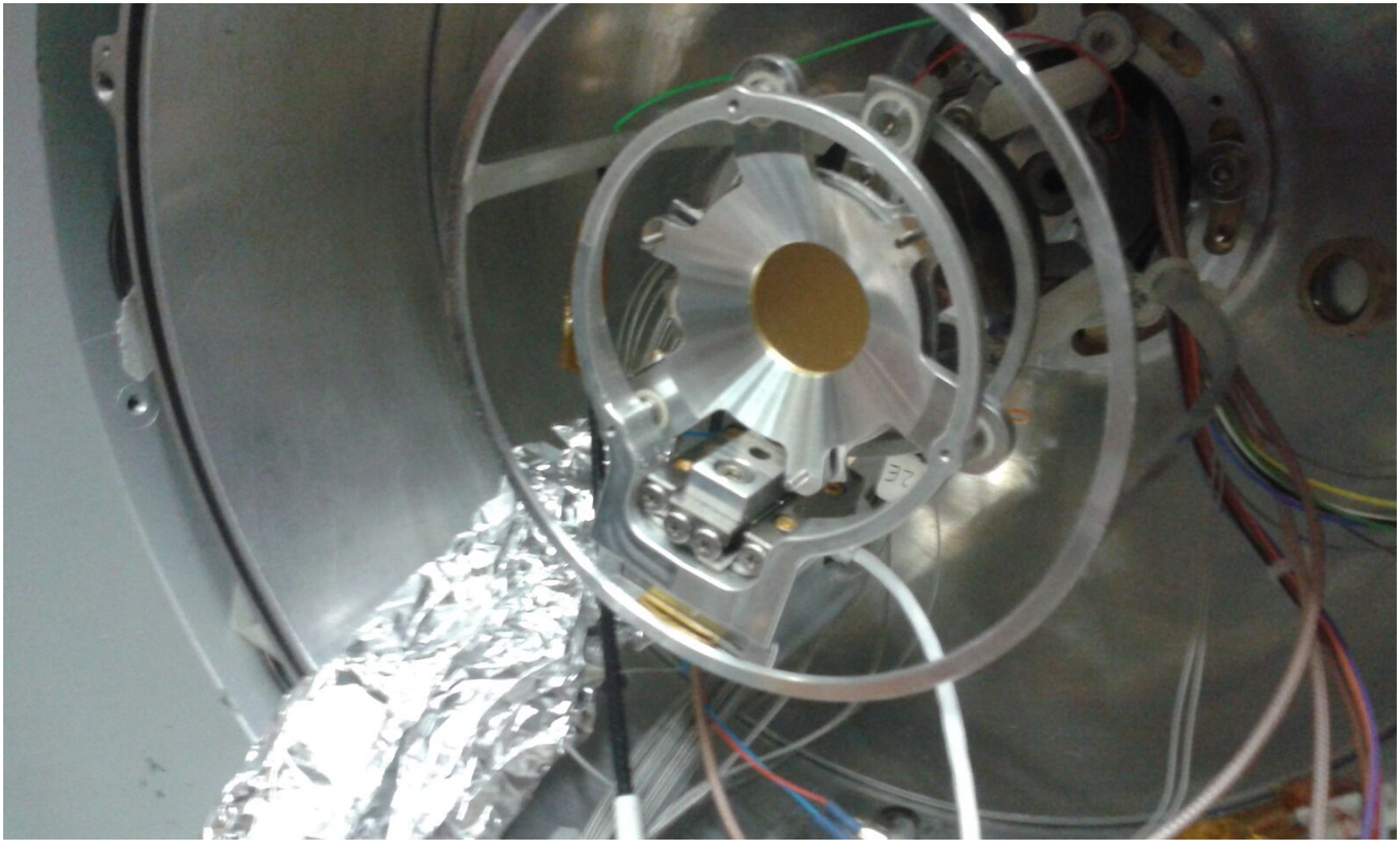

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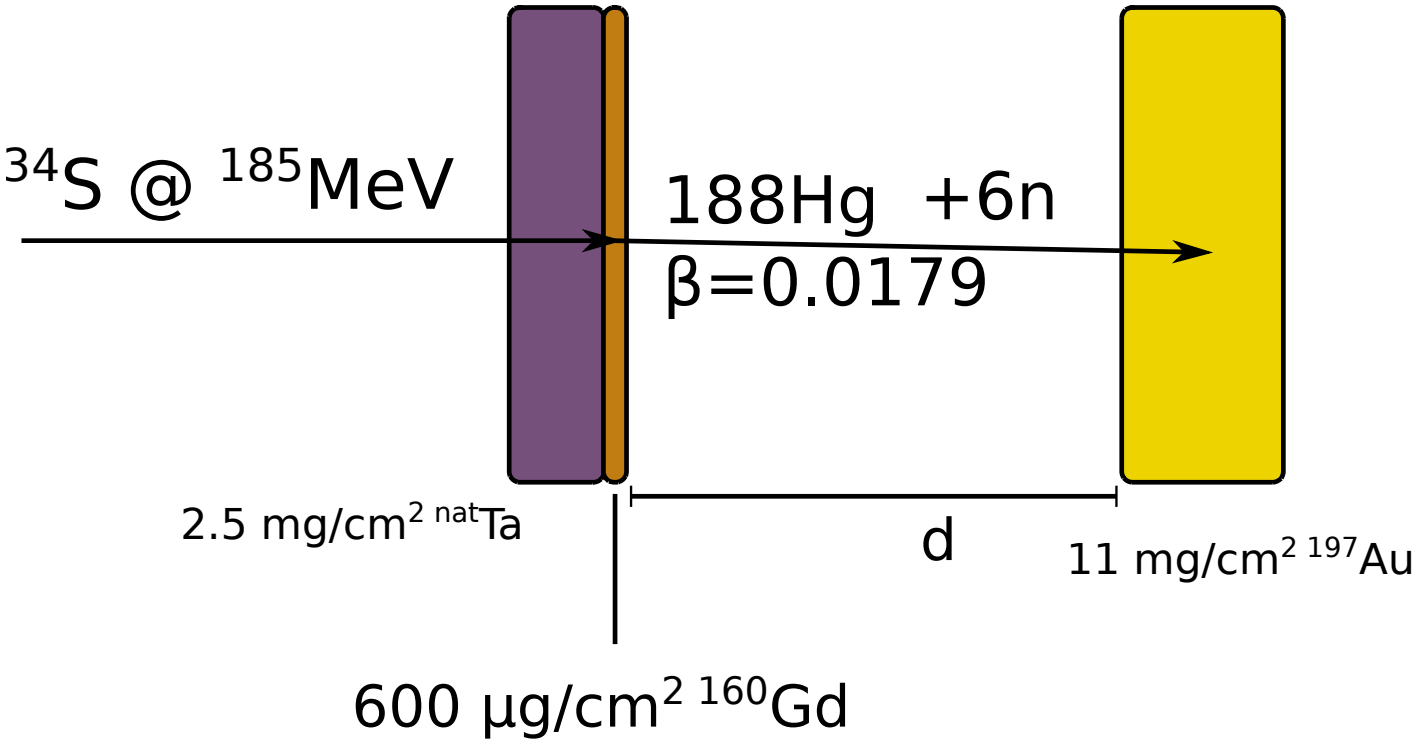
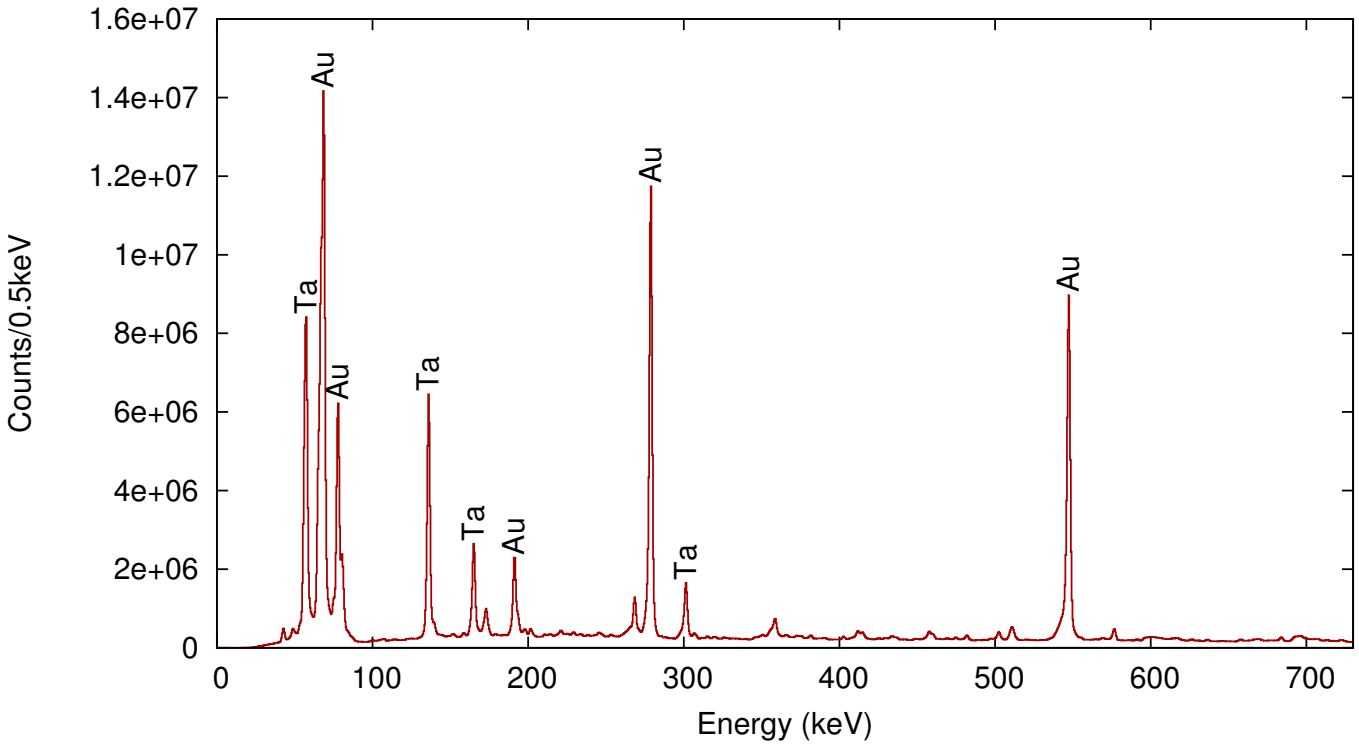


- $^{34}\mathrm{S} + {}^{160}\mathrm{Gd} \Rightarrow {}^{188}\mathrm{Hg} + 6\,\mathrm{n}$
- We arrived up-to 7 pnA using Tandem and Alpi
- Main evaporation residual ^{188}Hg $> 50\%$ of total ER
- Probability of detecting at least 1n > 1

Experiment using Galileo (+NeutronWall)



- Background from Fission (e.g. Fusion-Fission)
- Background from Coulex
  $\Rightarrow$ Reduced by condition 1n > 1

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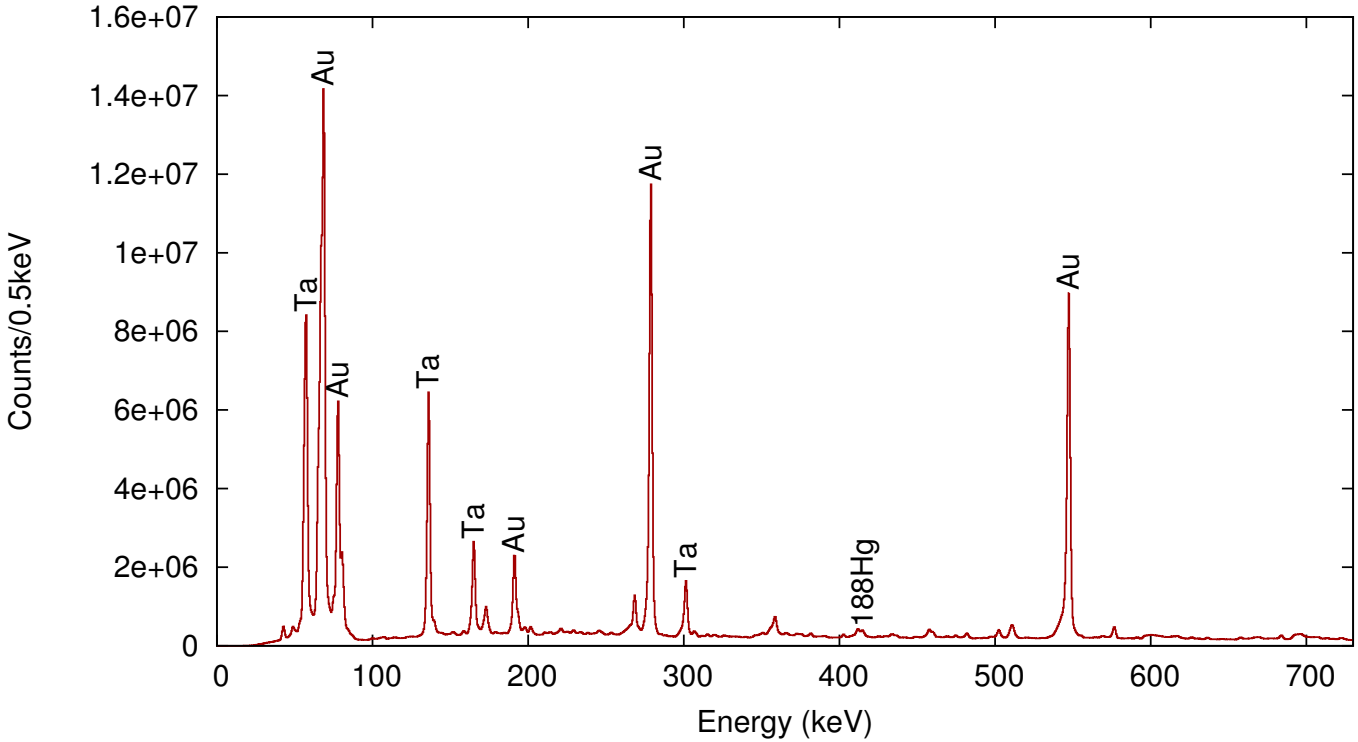

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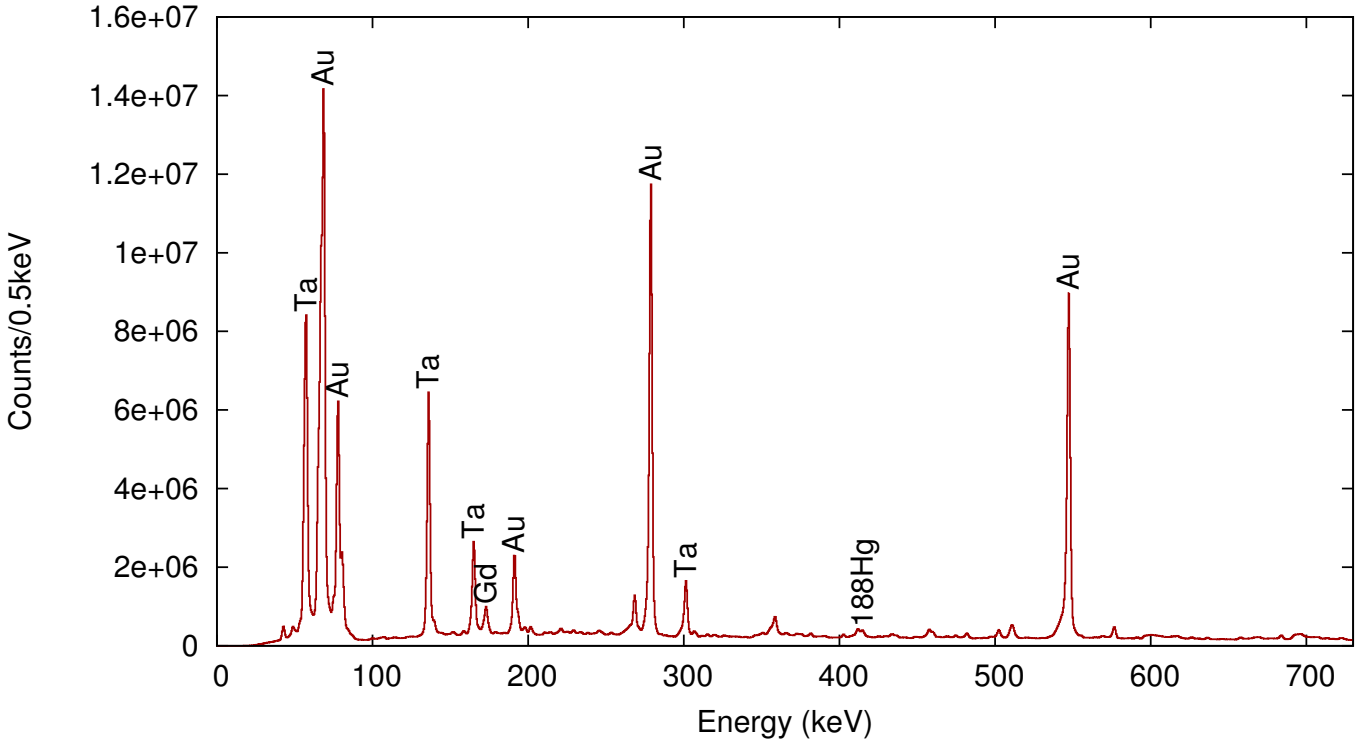

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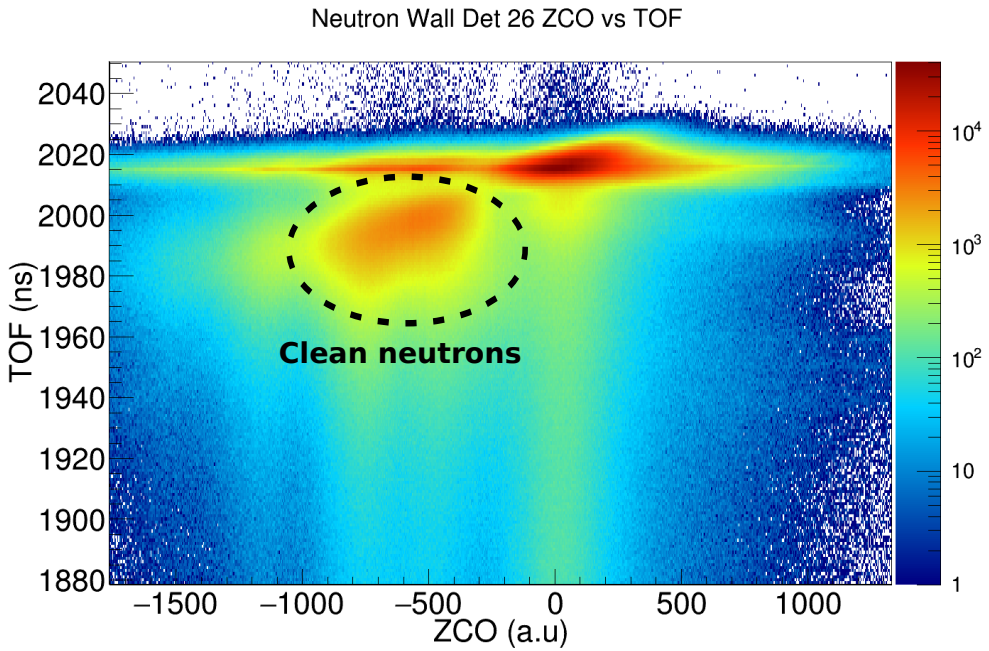
(Ab)Using for suppressing Coulex

- First time completely digital NeutronWall
- Very “dirty” selection of neutrons
- Fast online selection of ZCO in order to reduce data rate
- Nearly dead-time free



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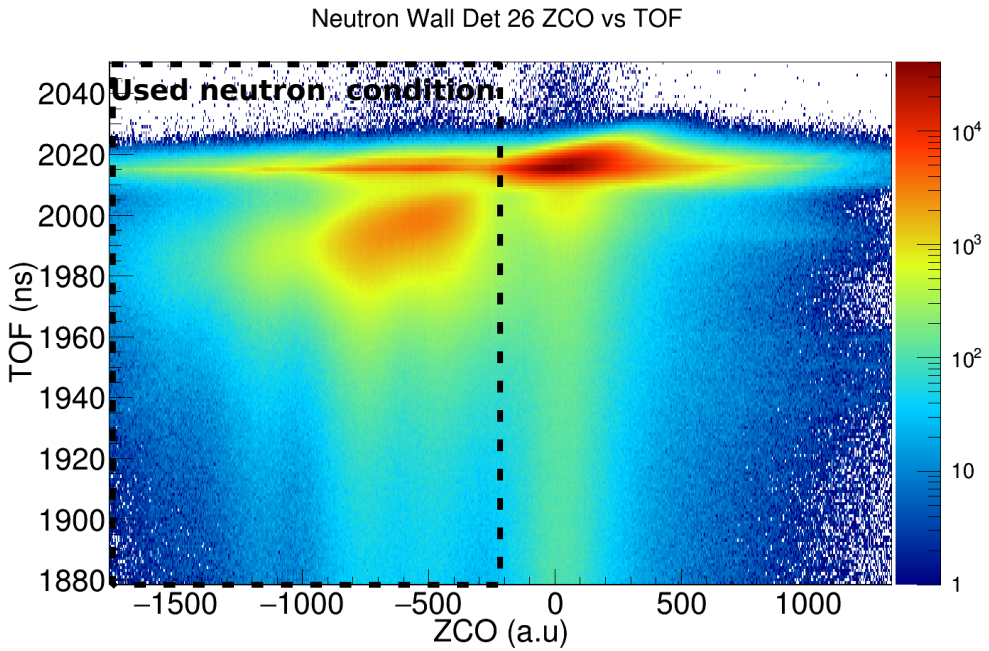

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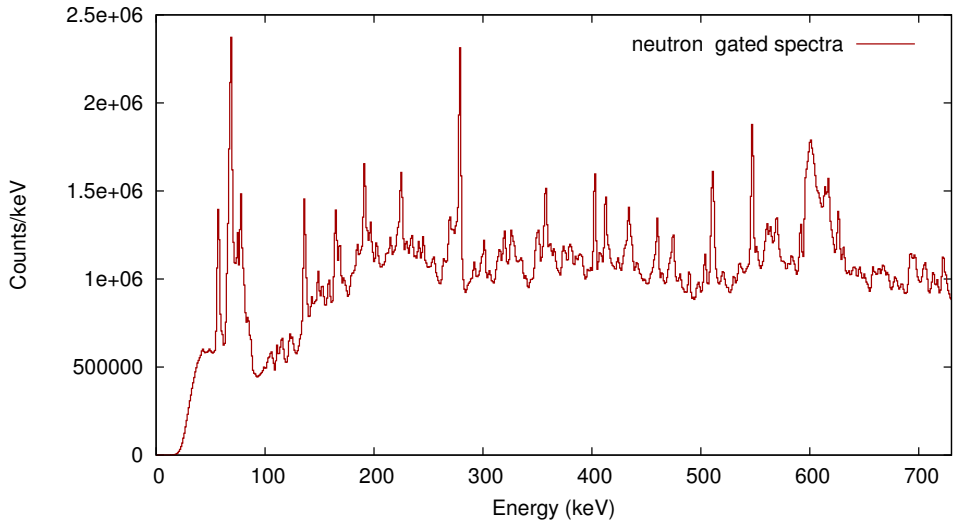
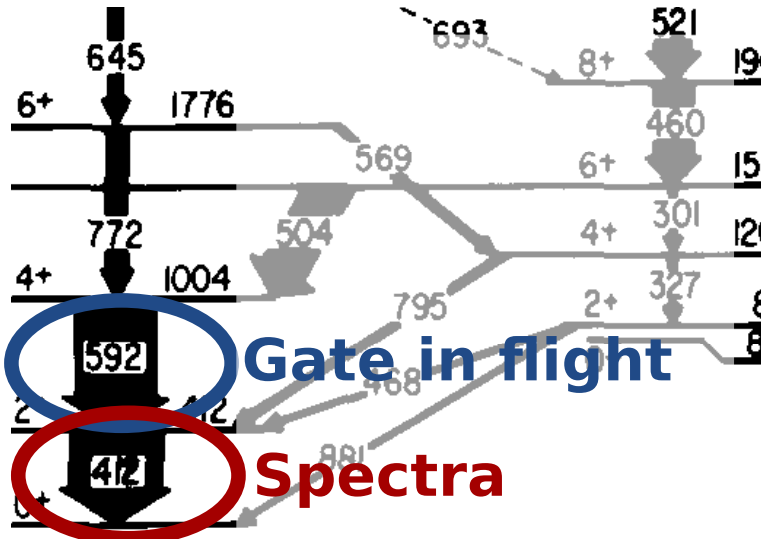


Very preliminary results

$2_1^+ \Rightarrow 0_{gs}^+$ transition @ 152°

- Accelerator problems during experiment ⇒
  only 2.5 days of beam time
- Analysis is still in its early phase



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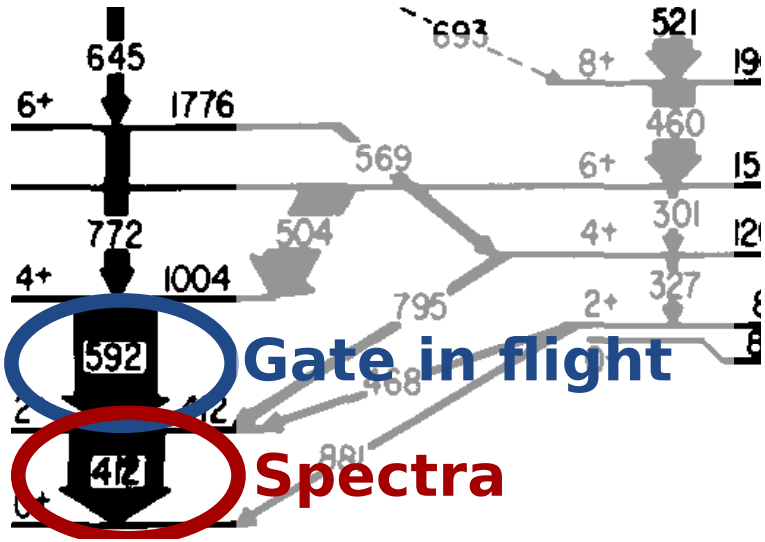

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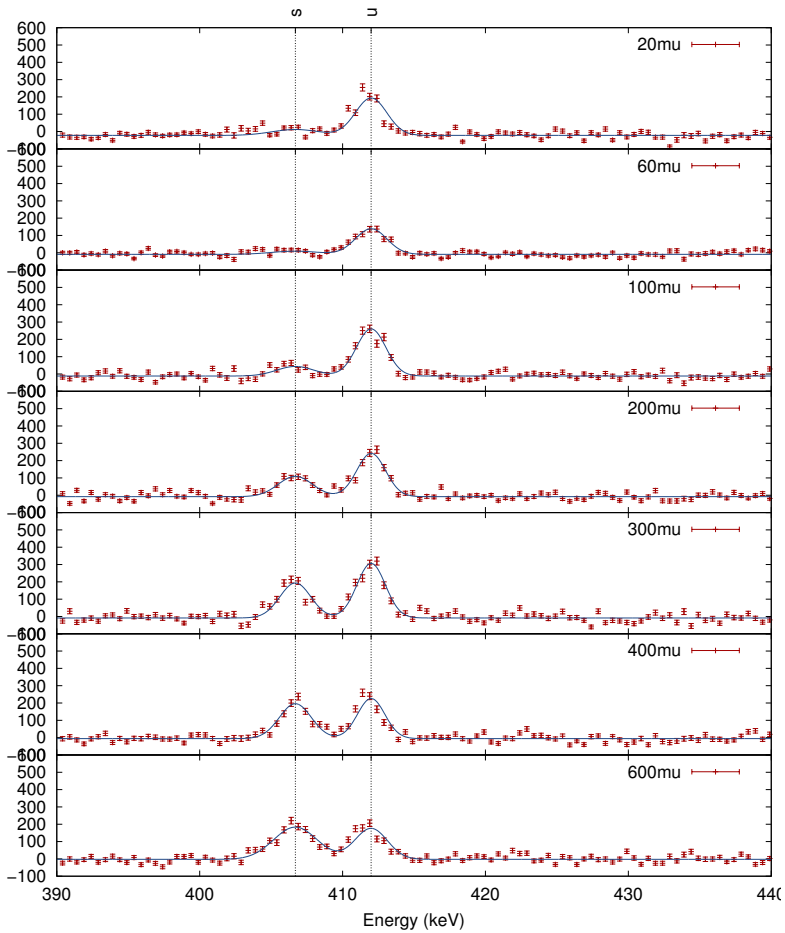

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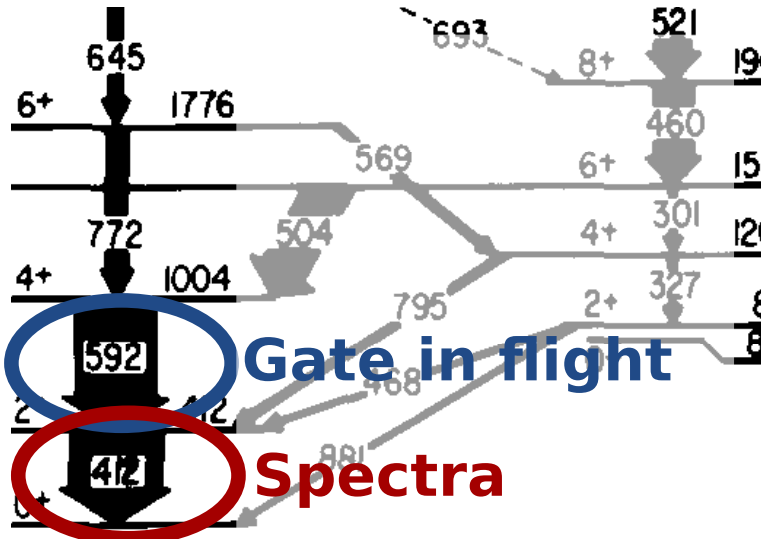
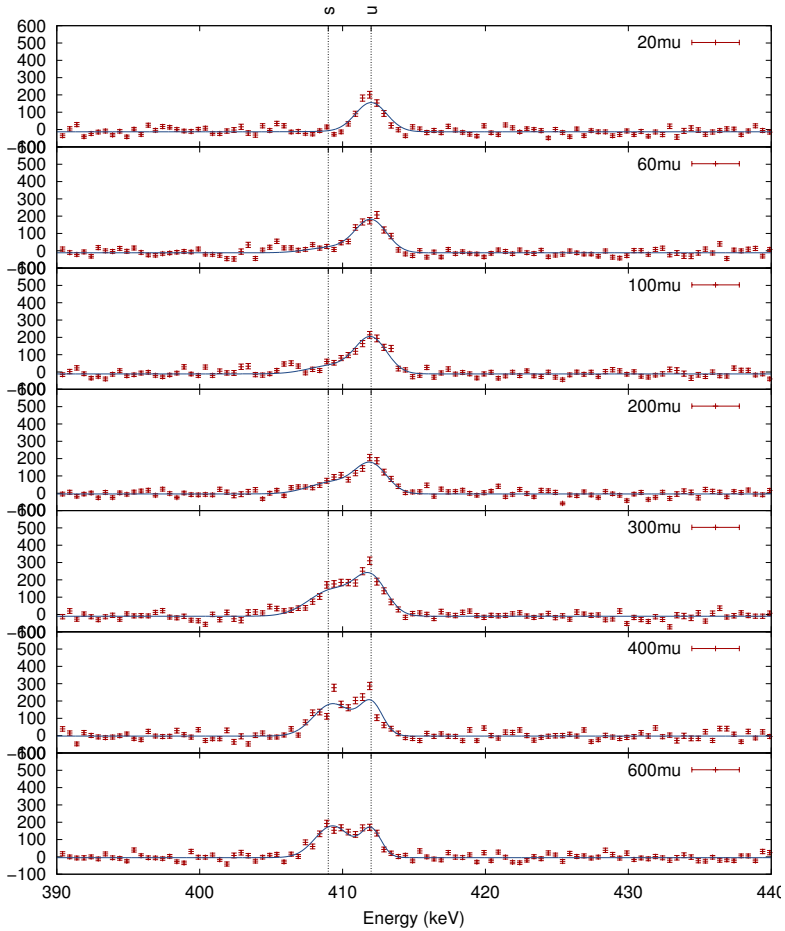
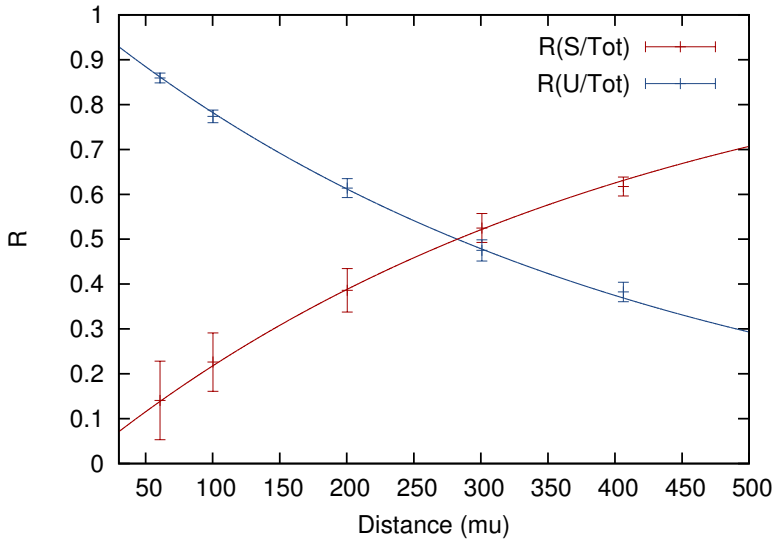


$2_1^+ \Rightarrow 0_{gs}^+$ transition @ 119°



Very preliminary results

- Accelerator problems during experiment $\Rightarrow$
  only 2.5 days of beam time
- Focused on the 2_1^+ state
- only 2-3 distances with in-flight component for higher-spin states



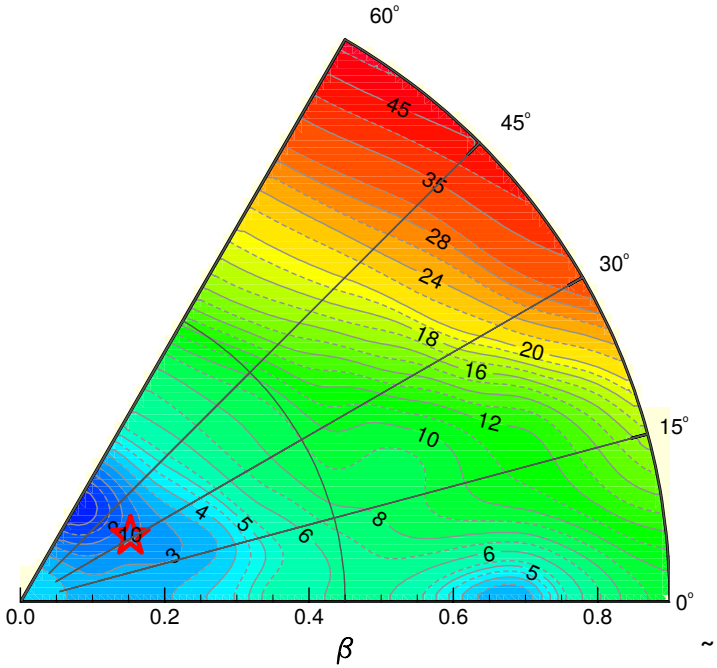
- $T_{1/2} = 26\,(3)$ ps
- not corrected for $\approx 30\%$ feeding of $135\,(15)$ ns isomeric state
- Very preliminary result, analysis still ongoing
- From Coulex: $T_{1/2} = 13.1^{+23}_{-18}$ ps *N. Bree et al., Phys. Rev. Let. 112:162701 (2014).*

Outlook and future perspective

- Promising data and great performance of the system, Plunger stable up-to 7 pnA
- Finish to analyse the data
- Investigate the option to use NeutronWall as a multiplicity filter
- Accelerator problems during the experiment $\Rightarrow$ Recovery beam time in July
- Study of ^{190}Hg

^{190}Hg – a γ-soft nucleus?

- Transition between shape coexistence and single minimum
- Change in configuration
- Signs of γ-softness
  J.P. Delaroche et al., Phys. Rev. C 50:2332, (1994).
- Dipole bands with $\pi(2p4h)$ configuration observed
  A.N. Wilson et al., Phys. Let. B 81, B 505(1):614, (2001).
- Super deformed band observed
  A.N. Wilson et al., PRL 104, 162501 (2010).



Adapted from J.-P Delaroche et al., Phys. Rev. C 81, 014303 (2010)

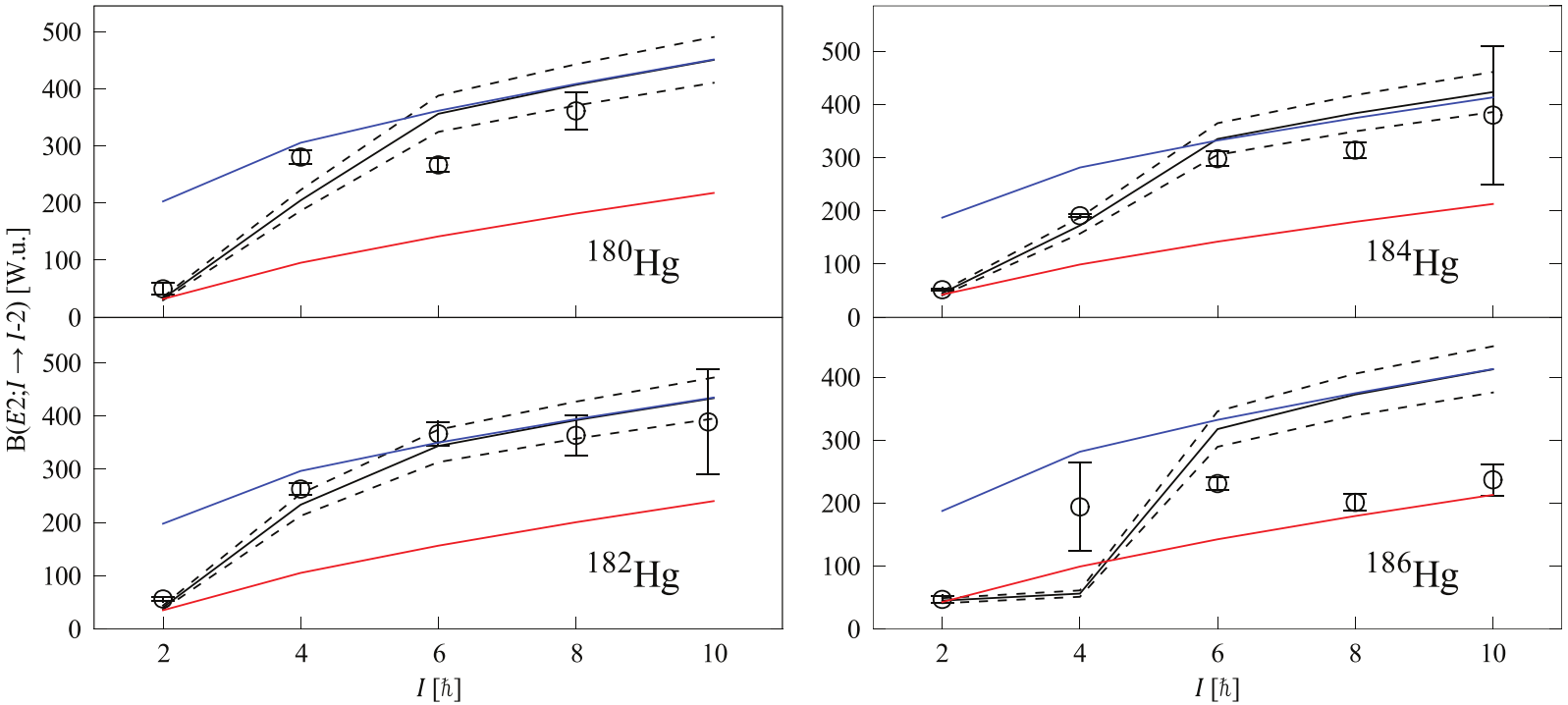
Thank you for your attention

Also special Thanks to M. Loriggiola and A. Goasduff, G. Jaworski

Shape coexistence and lifetime measurements

- Transition strengths very sensitive to the wave functions
- Huge change in nuclear structure, but $B(E2; 2_1^+ \rightarrow 0_{gs}^+) \approx 50\,\text{W.U.}$
- Change in major contribution with higher spins

L.P. Gaffney et al., Phys. Rev. C 89, 024307 (2014)



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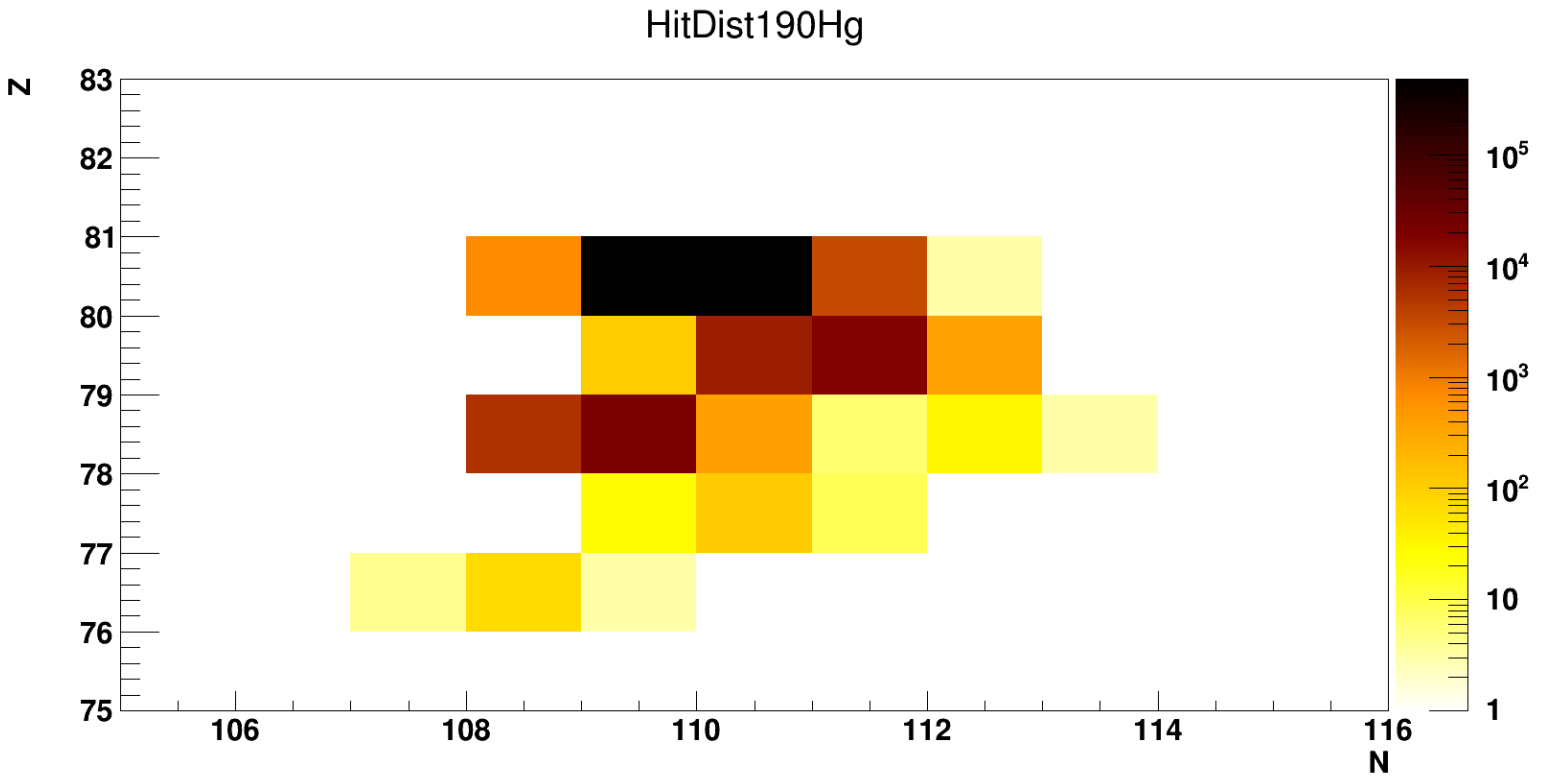
Cross section estimate ^{190}Hg

- Gemini



Cross section estimate ^{188}Hg

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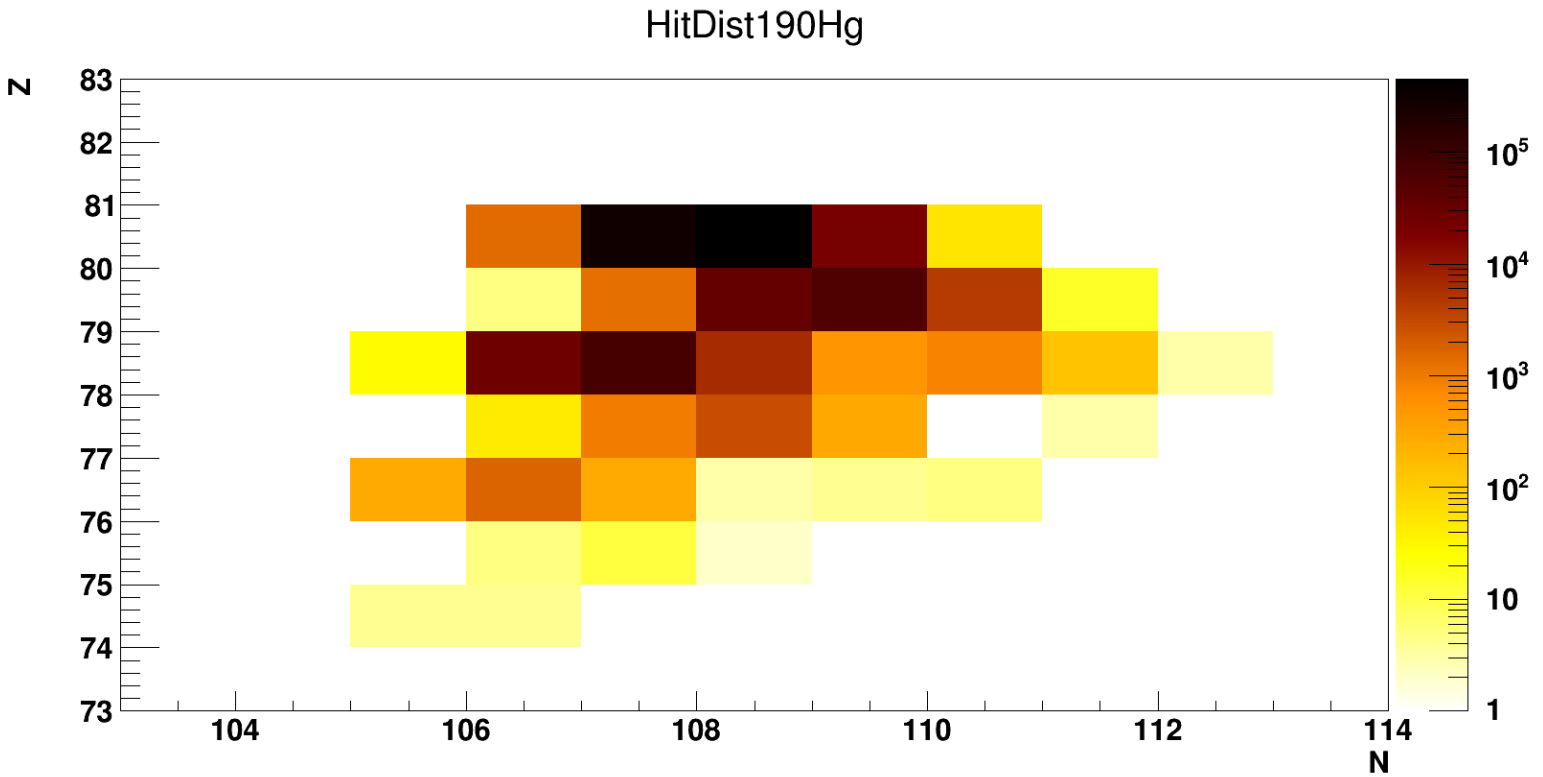
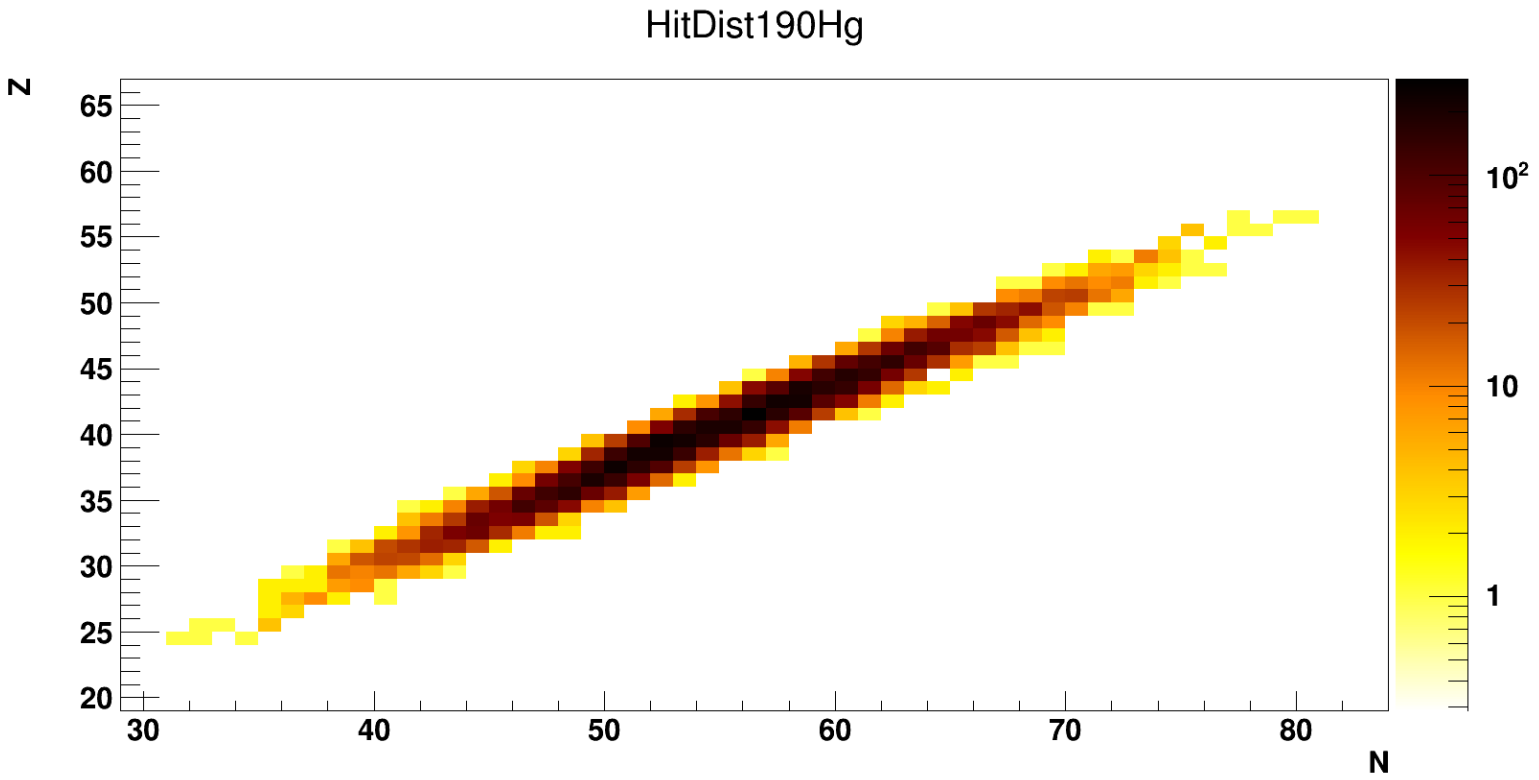


Fission ^{190}Hg

- Gemini



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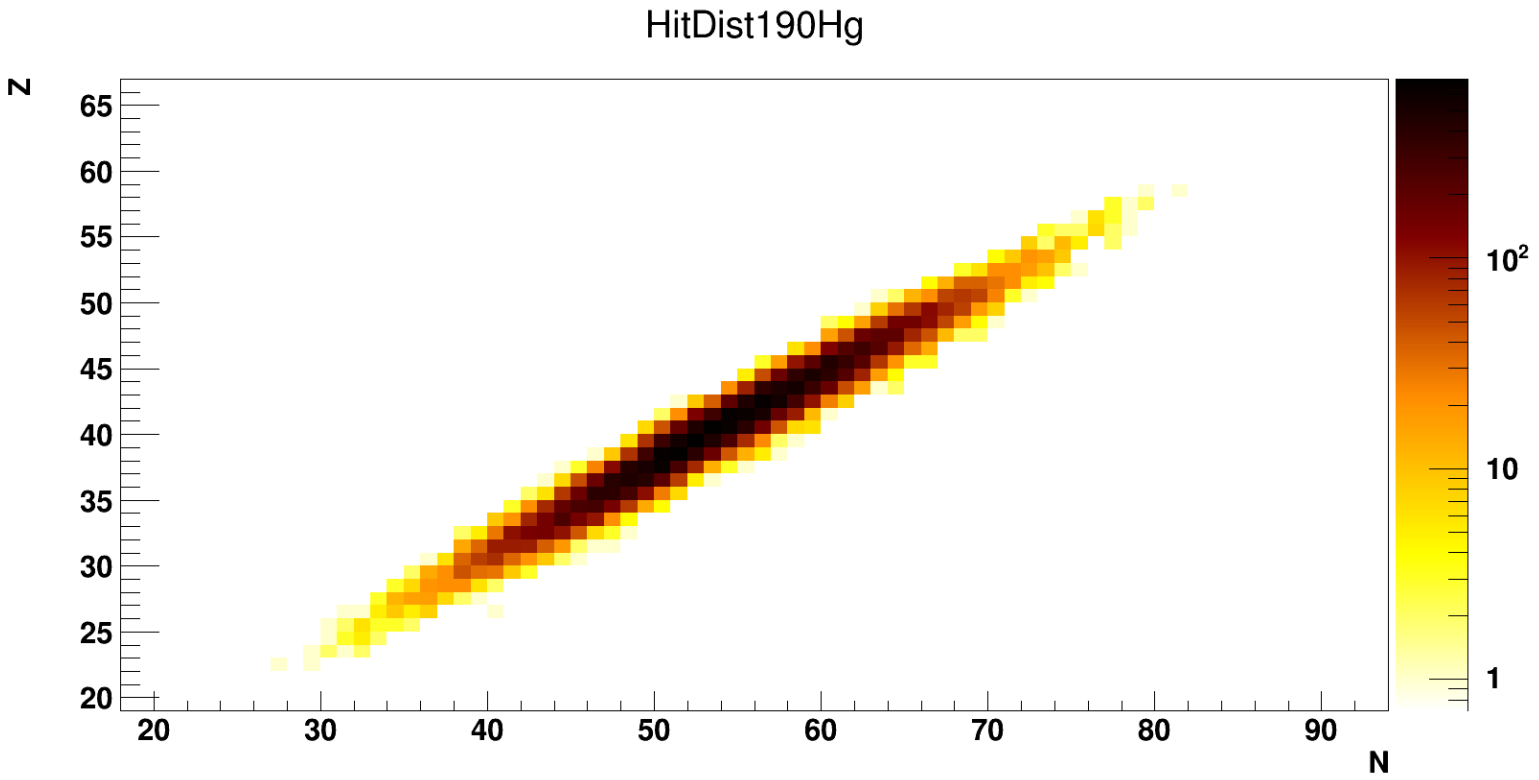

Proposed experiment (alternative)

- Setup **Galileo + Cologne Plunger** *(+ Euclides as veto)*
- Reaction ^{40}Ar + ^{154}Sm and ^{152}Sm (500 μg/cm^2 evaporated on 1.2 mg/cm^2 ^{181}Ta) 1 pnA
- Reaction channel $-4n$ for ^{188}Hg and ^{190}Hg
- 12 target-stopper distances between 10 μm and 1200 μm each 4 h
- Energy lower $\Rightarrow$ less contribution of fission

Energy	Channel	$\sigma_{\text{-xn}}$	Fraction	$\gamma-\gamma$-coinc./h $2^+/4^+$
172 MeV	$-4n$ ^{190}Hg	13 mbarn	55.4%	900
178 MeV	$-4n$ ^{188}Hg	19 mbarn	72%	1200

+ 1 day for change of energy + calibration

$\Rightarrow$ **5 days of beam time**

^{190}Hg a γ-soft nucleus