RDDS lifetime measurements in ^{184,186}Hg

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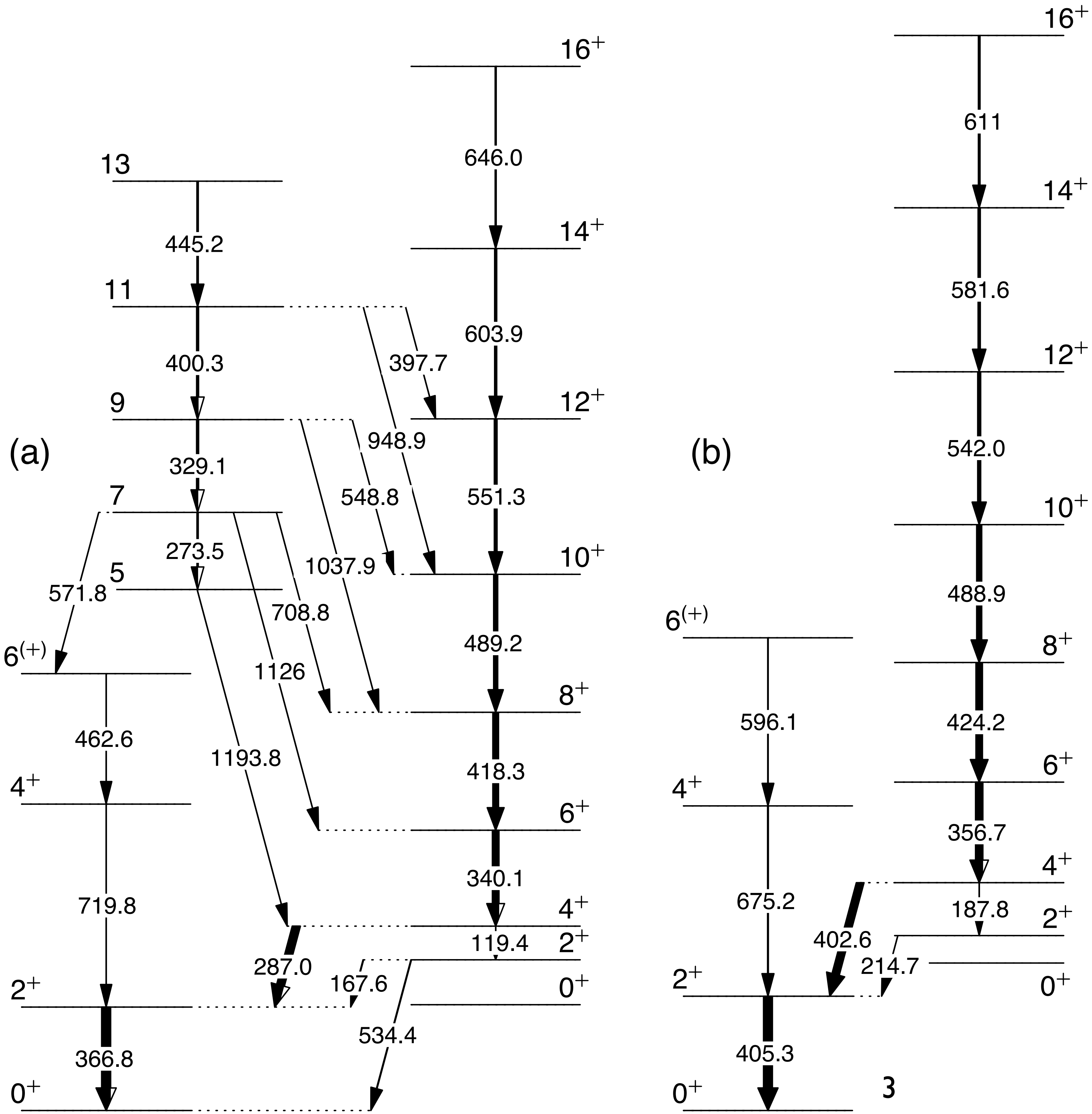
Workshop on “Shape coexistence across the chart of nuclides” – York, April 2013

Shape coexistence in the Hg region...

(a) ^{184}Hg - (b) ^{186}Hg



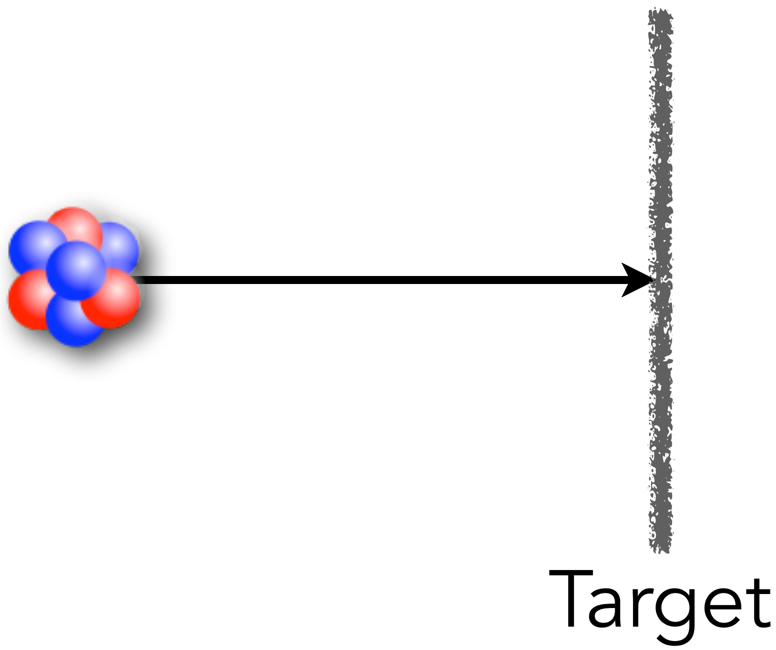
- Yrast lifetimes measured, but with poor precision
- Extraction of transitional matrix element useful to constrain Coulex analysis

... Kasia Wrzosek-Lipska

$$B(E2; I \rightarrow I') = \frac{1}{2I+1} \langle I' || E2 || I \rangle^2$$

$$B(E2; I \rightarrow I') = \frac{0.08197 \cdot b'}{1 + \alpha_{IC}(E_\gamma)} \frac{E_\gamma^{-5}}{\tau}$$

Recoil Distance Doppler Shift (RDDS)



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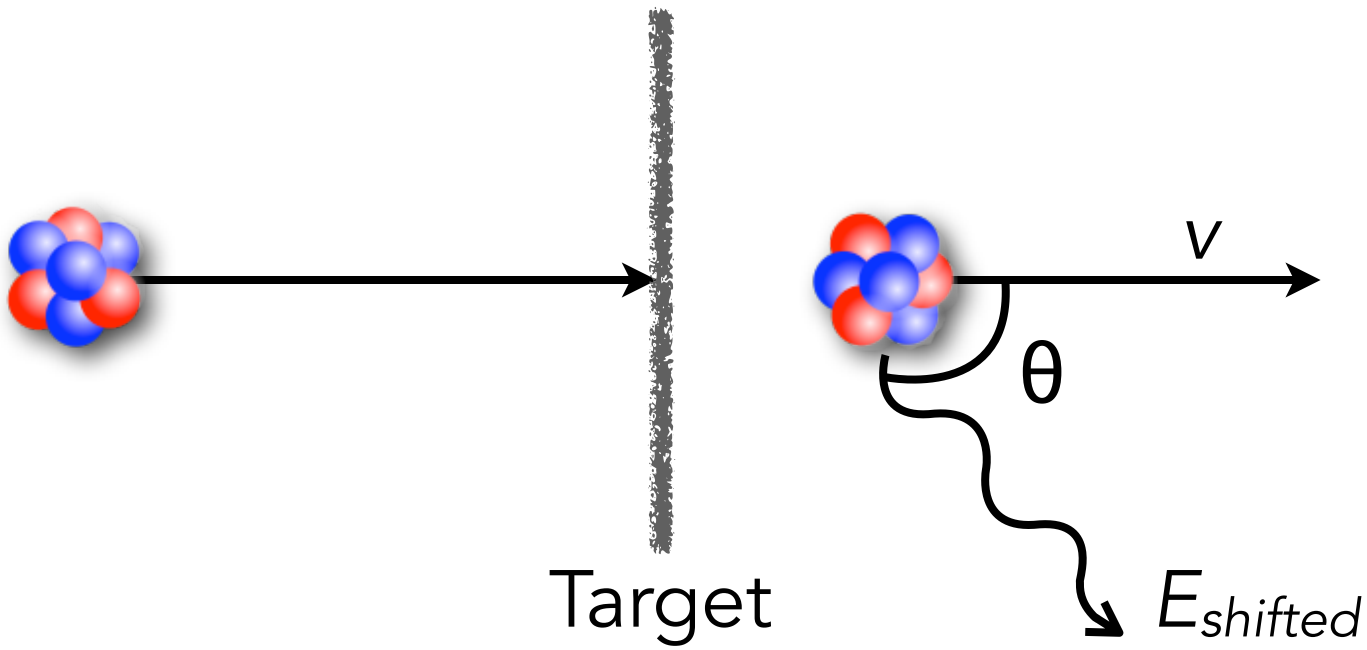

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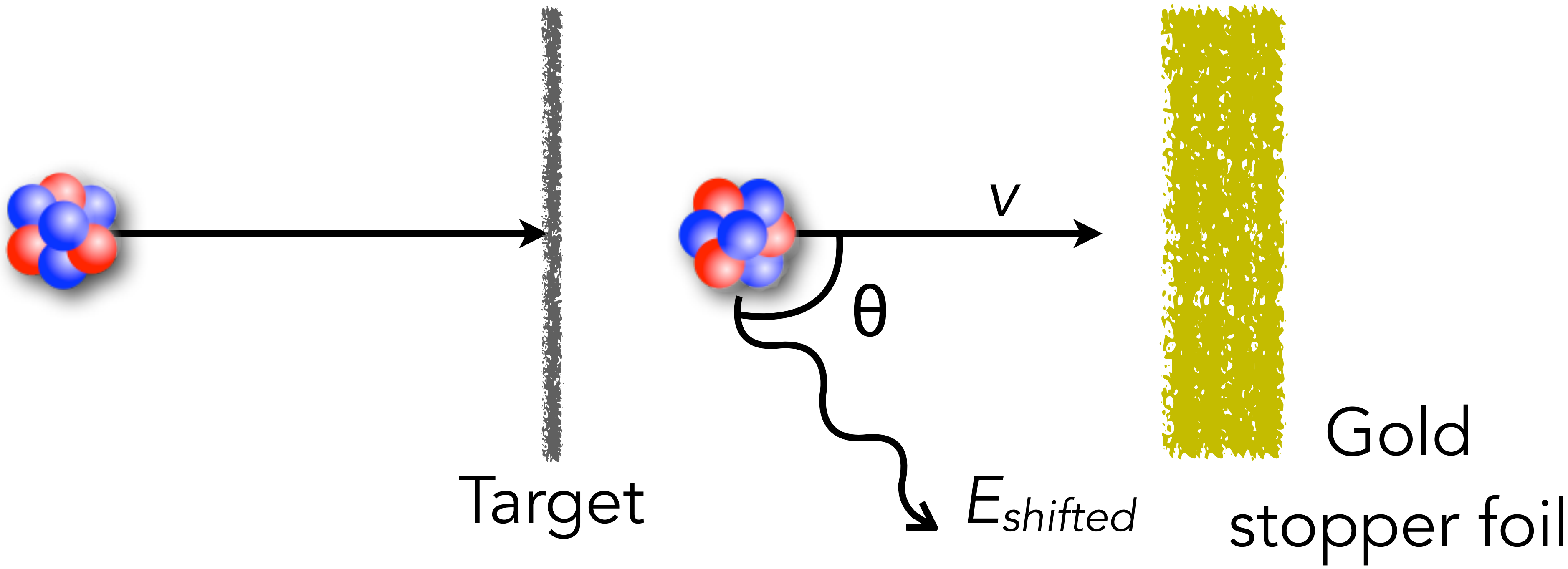

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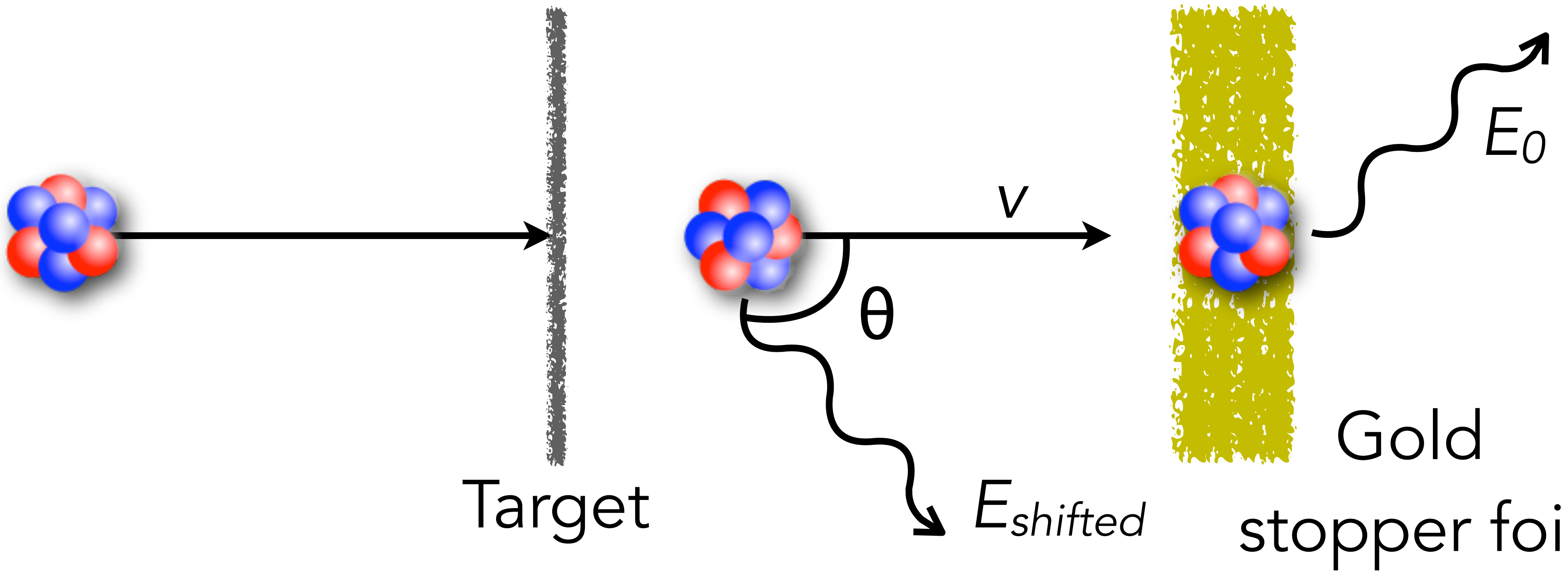

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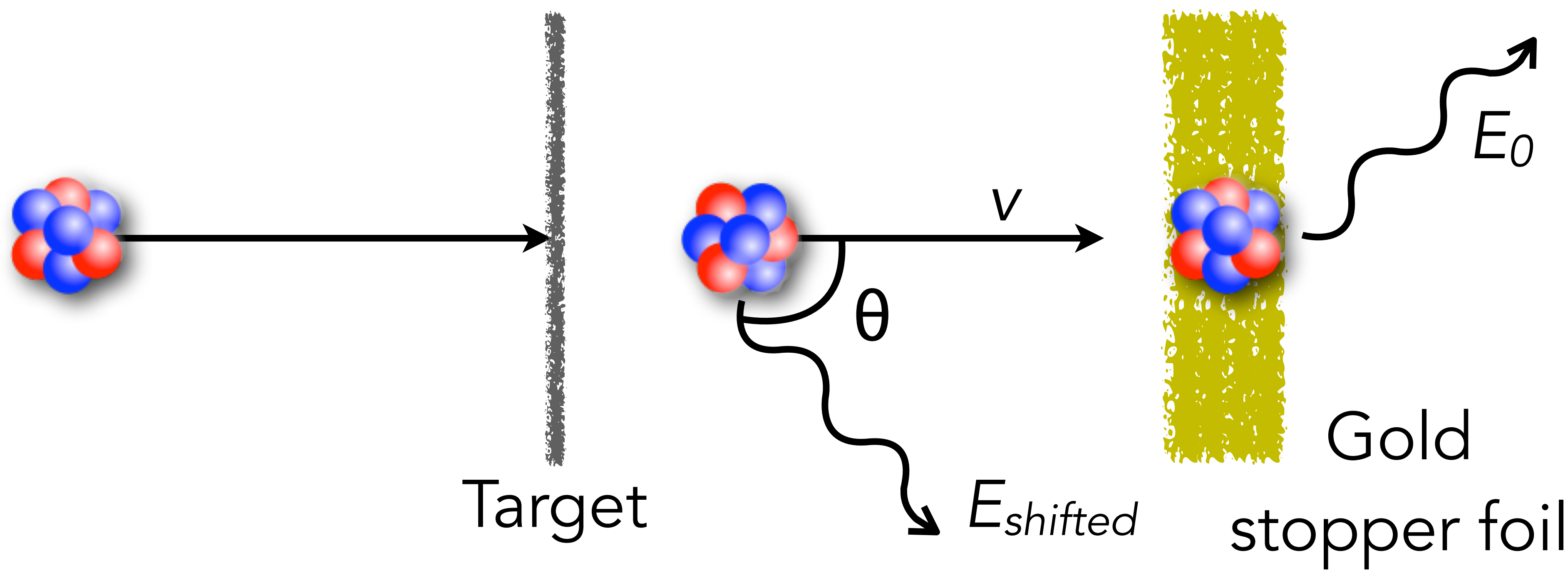
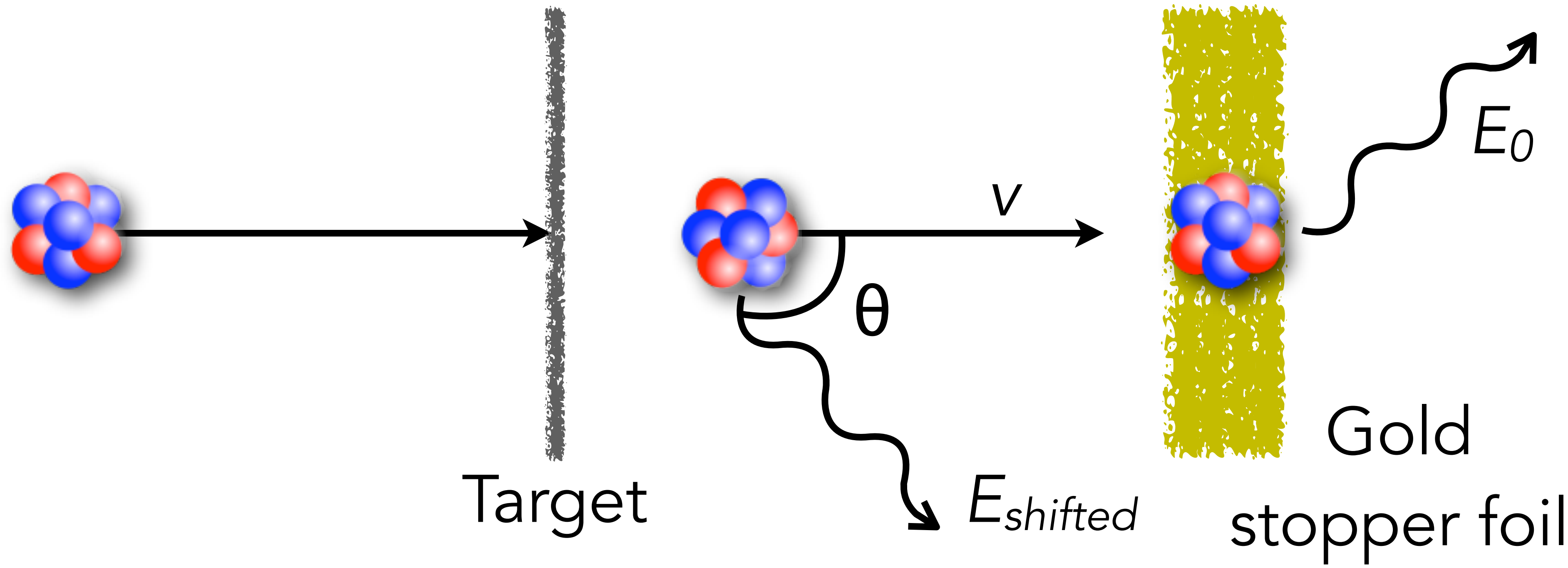


$$E_{shifted} = E_0 \cdot (1 + v/c \cos\theta)$$

Recoil Distance Doppler Shift (RDDS)



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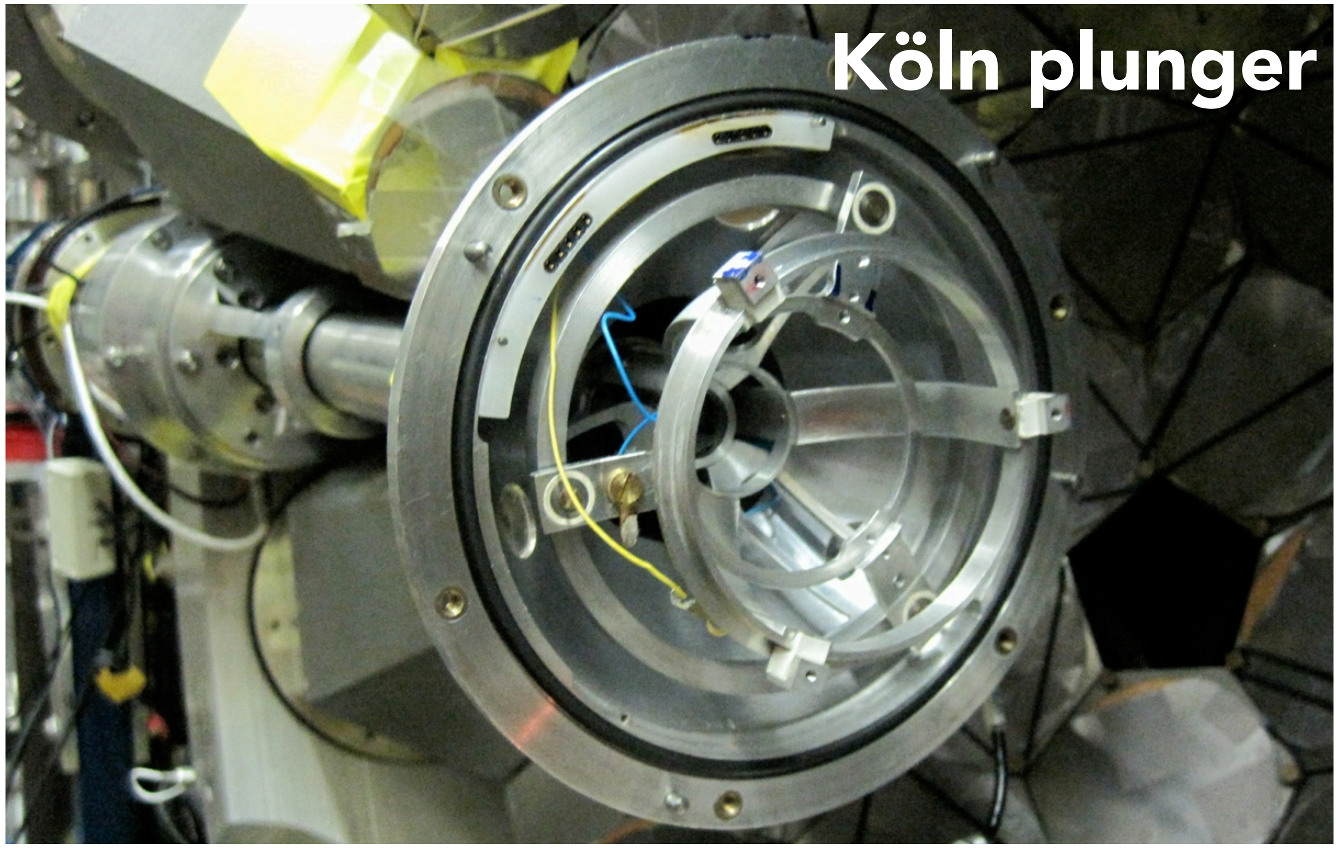

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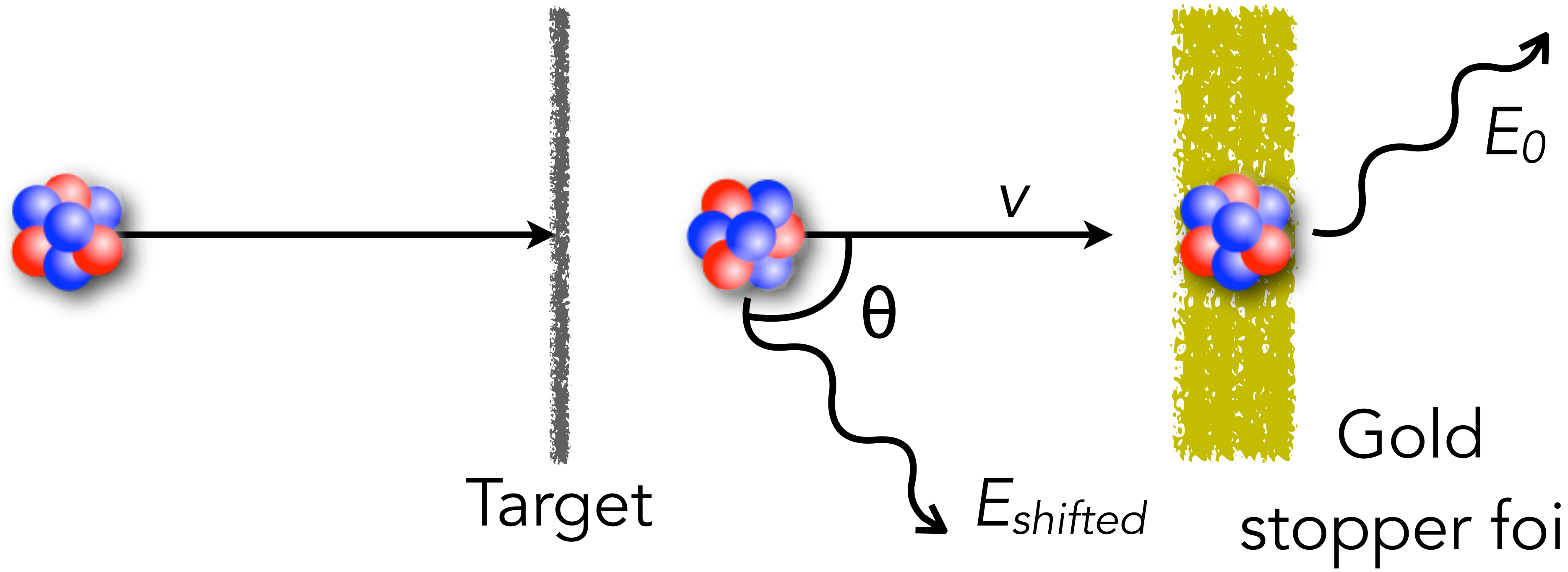
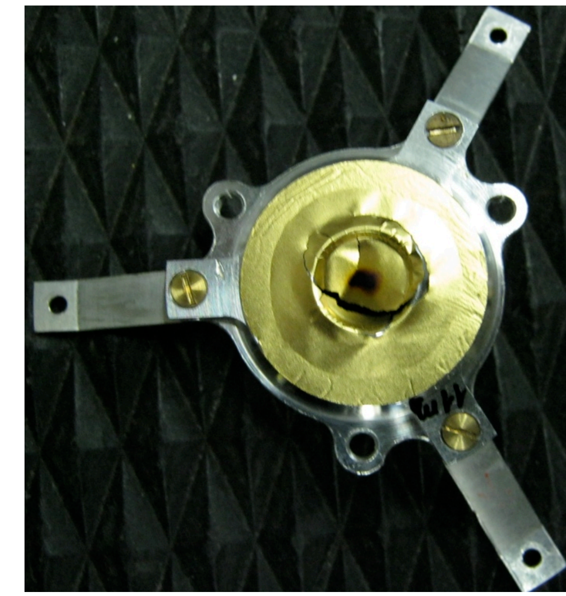
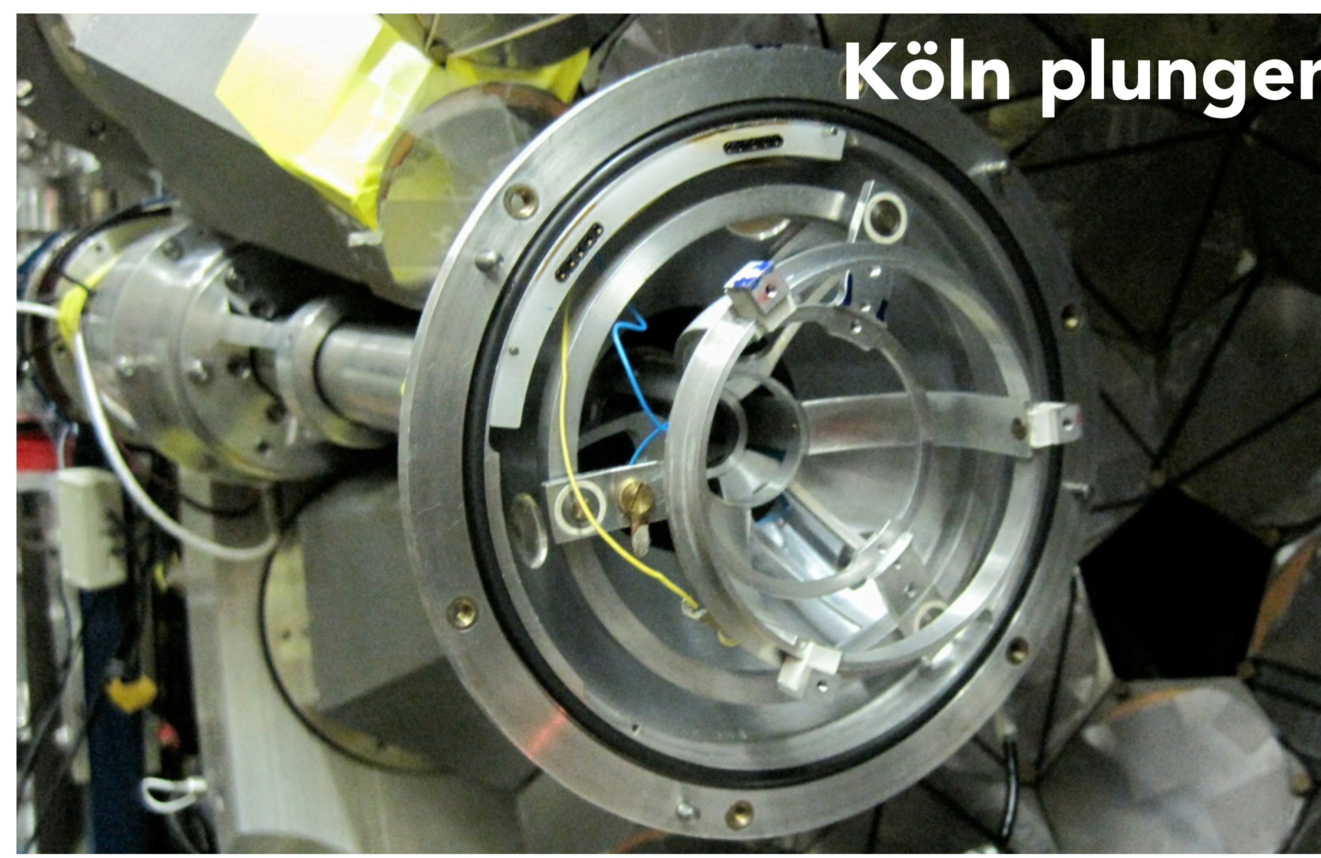




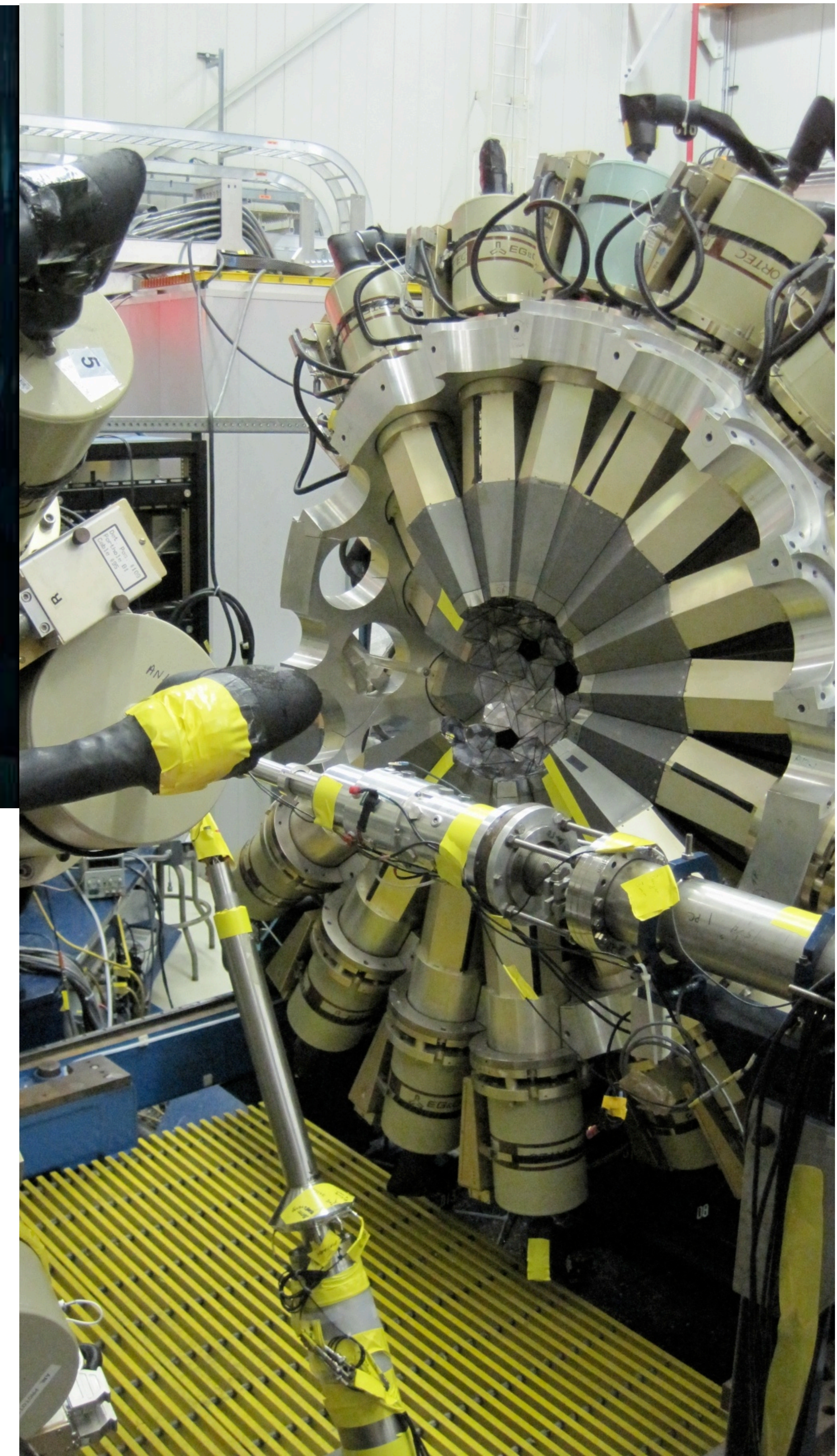


$$E_{shifted} = E_0 \cdot (1 + v/c \cos\theta)$$

Gammasphere @ ANL

$^{150}Sm(^{40}Ar,4n)^{186}Hg$ @ 195MeV

$^{148}Sm(^{40}Ar,4n)^{184}Hg$ @ 200MeV



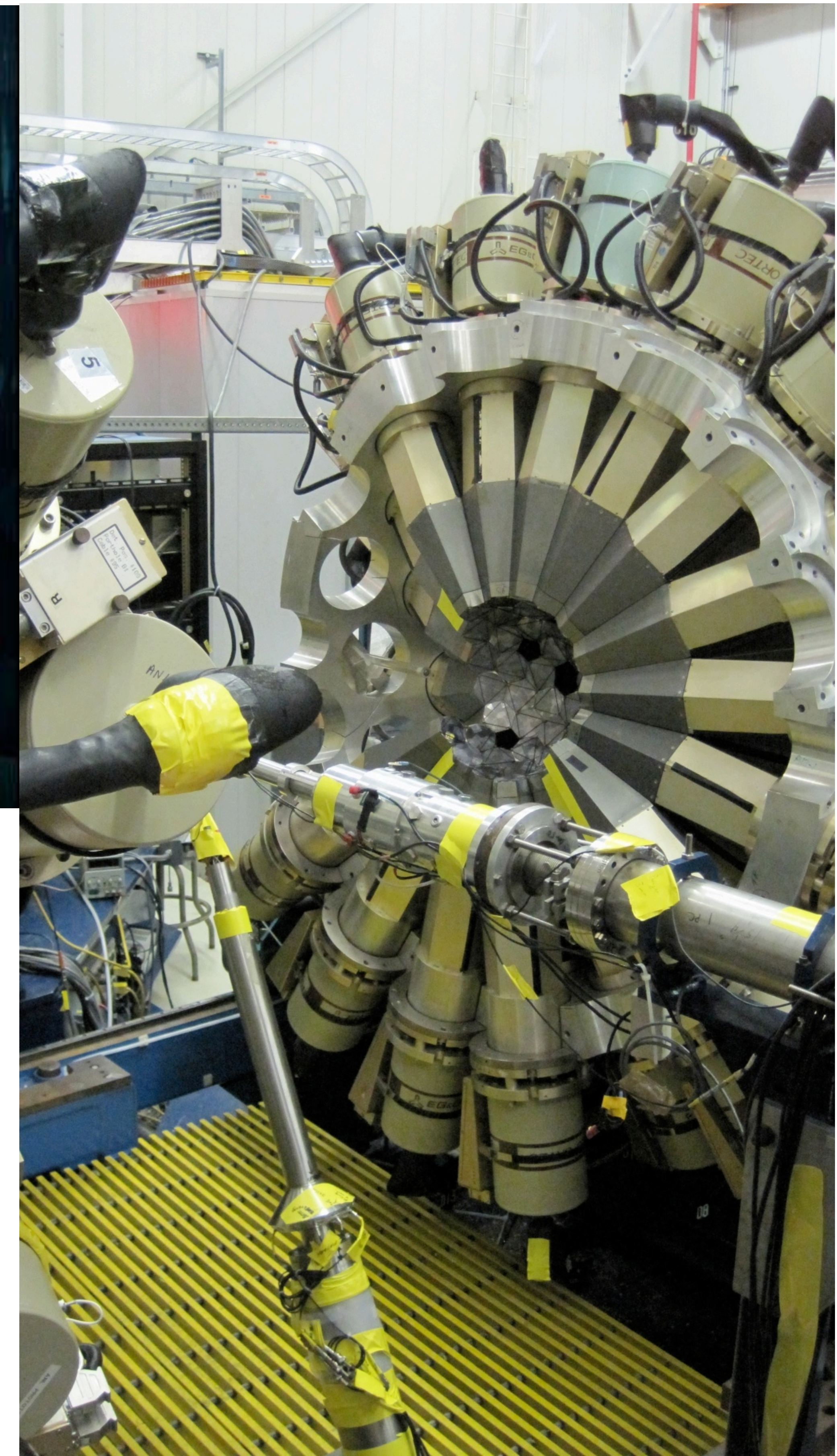
Gammasphere @ ANL

$^{150}Sm(^{40}Ar,4n)^{186}Hg$ @ 195MeV

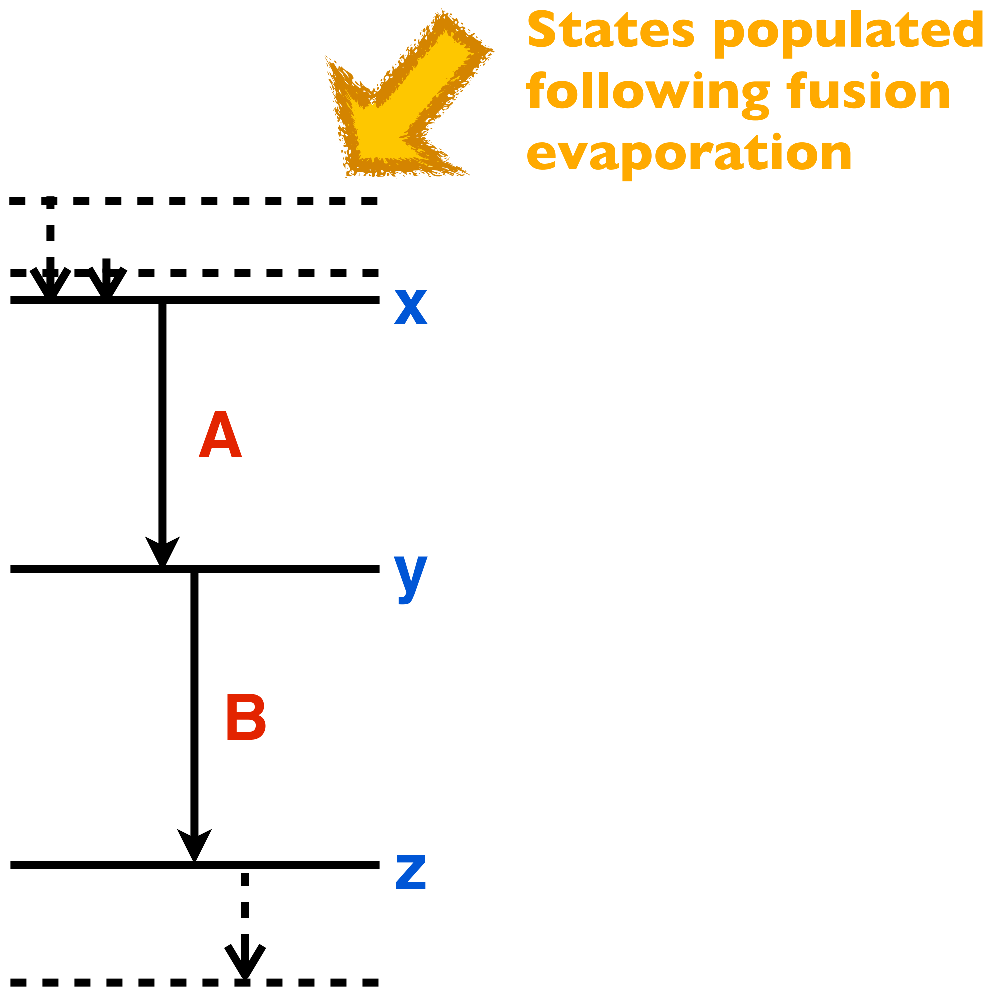
$^{148}Sm(^{40}Ar,4n)^{184}Hg$ @ 200MeV

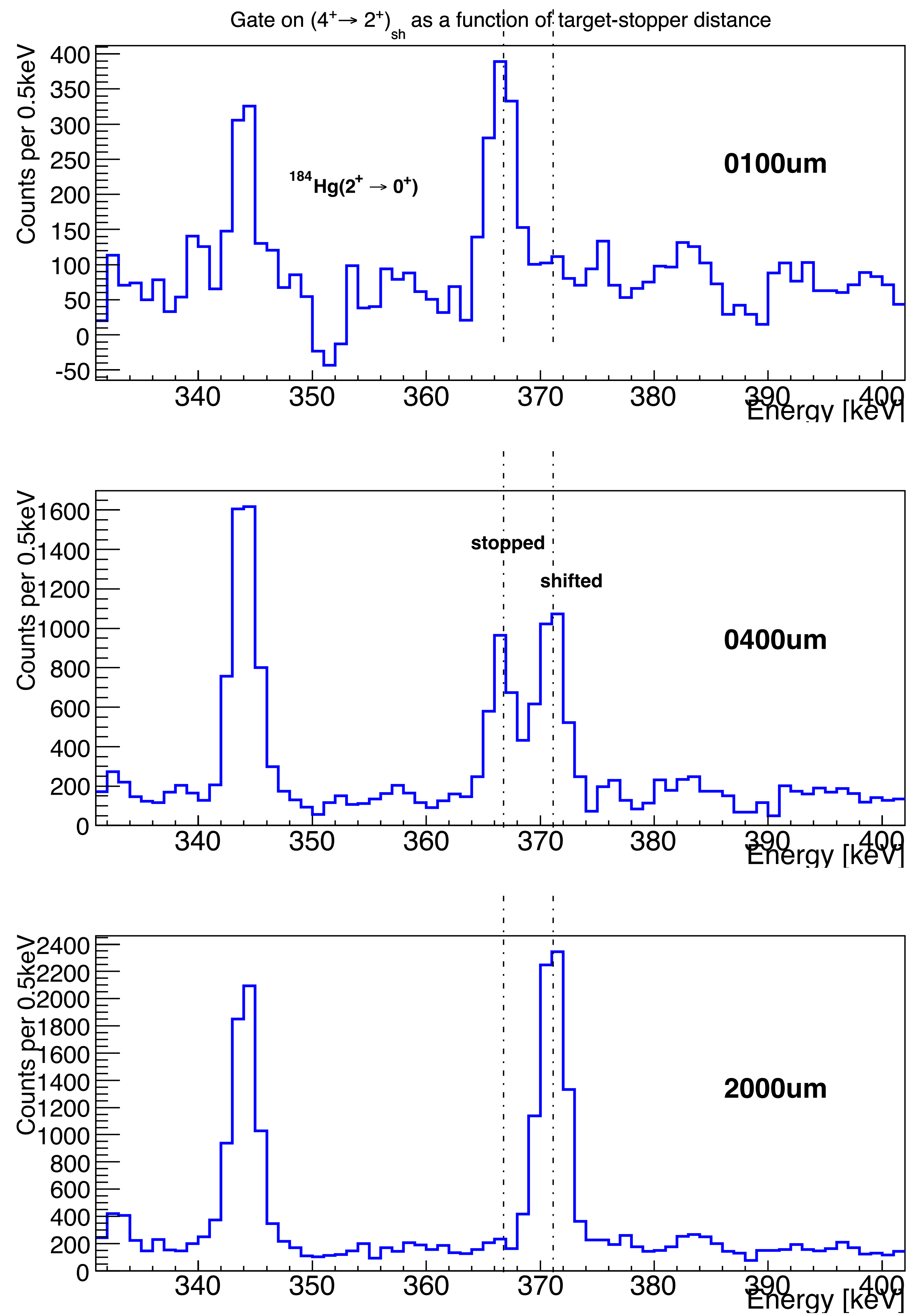
Ring	GS Angle		Ring	GS Angle	
0	17.27465	x0	9	99.29040	x5
1	31.71747	x5	10	100.81232	x5
2	37.37737	x5	11	110.17967	x10
3	50.06504	x10	12	121.71747	x5
4	58.28253	x5	13	129.93496	x10
5	69.82033	x10	14	142.62263	x5
6	79.18768	x5	15	148.28253	x5
7	80.70960	x5	16	162.72535	x5
8	90.00000	x10			

Ring	Ave Angle
A	34.54742
B	52.80420
C	69.82033
D	110.17967
E	127.19580
F	145.45258
G	162.72535



Coincidence method - **shifted**

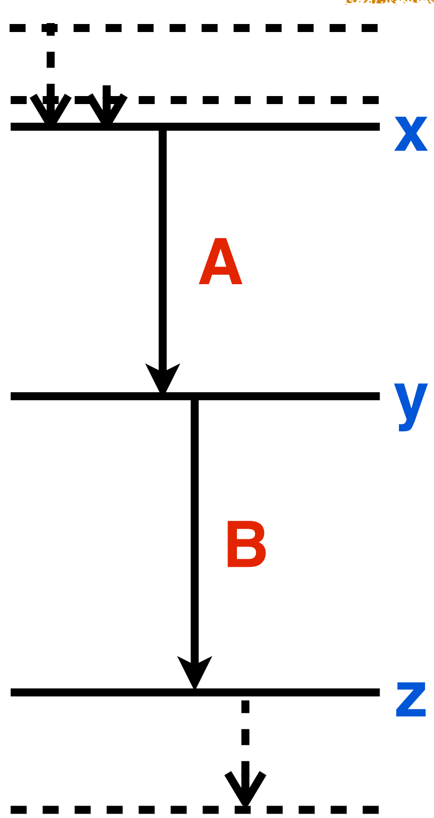




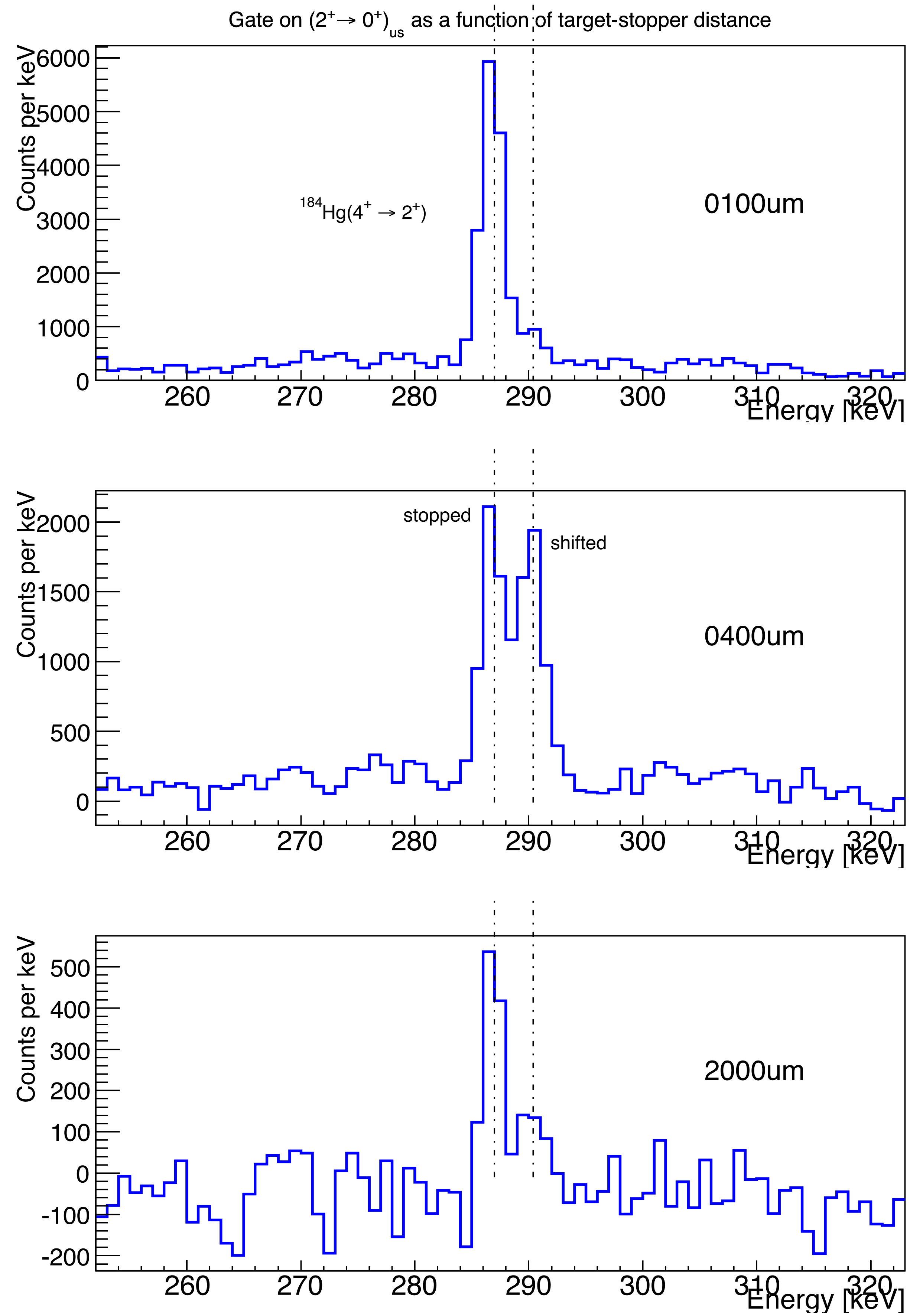
- Gate on shifted component of feeding transition, **A**
- Nucleus in flight *and* in state of interest, **y**
- Time(distance) behaviour of depopulating transition, **B**, describes lifetime of state **y**.

Coincidence Method - **stopped**

States populated following fusion evaporation



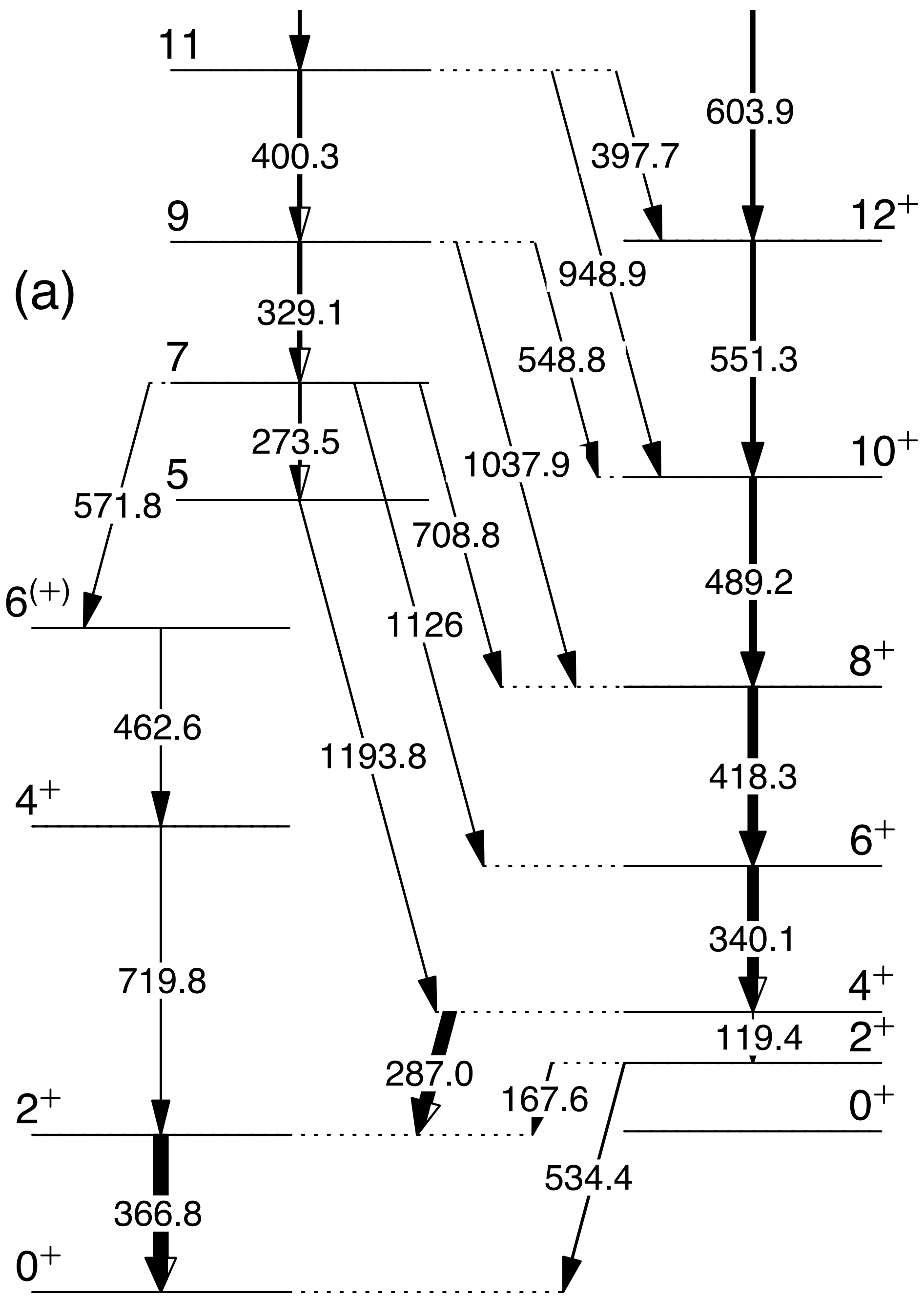
- Gate on stopped component of depopulating transition, **B**
- Nucleus stopped when **y** decays
- Time(distance) behaviour of feeding transition, **A**, describes lifetime of state **y** but susceptible to side-feeding

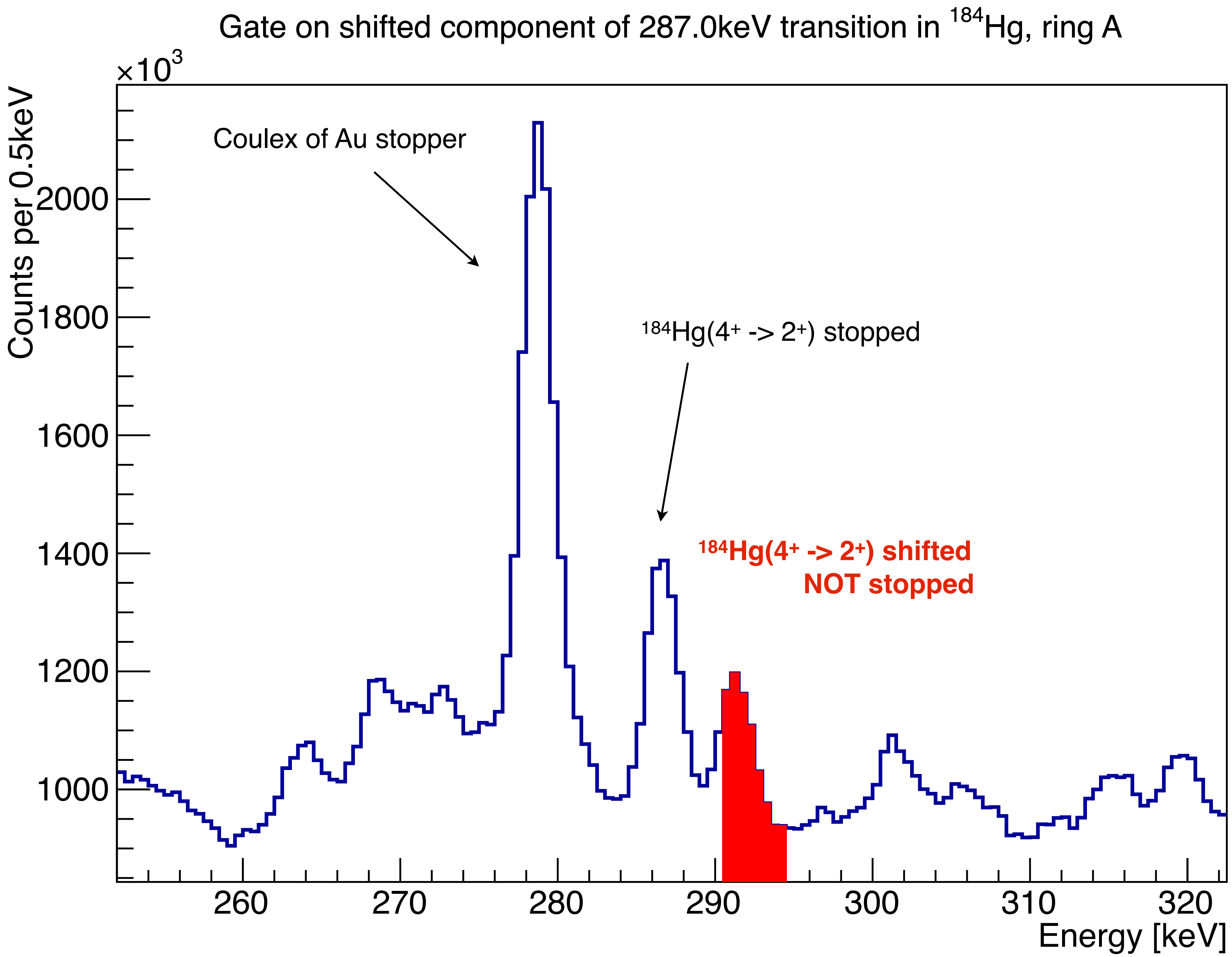


^{184}Hg - Analysis

- Simplest and cleanest way of determining the lifetime with coincidence method

- Feeding history not important





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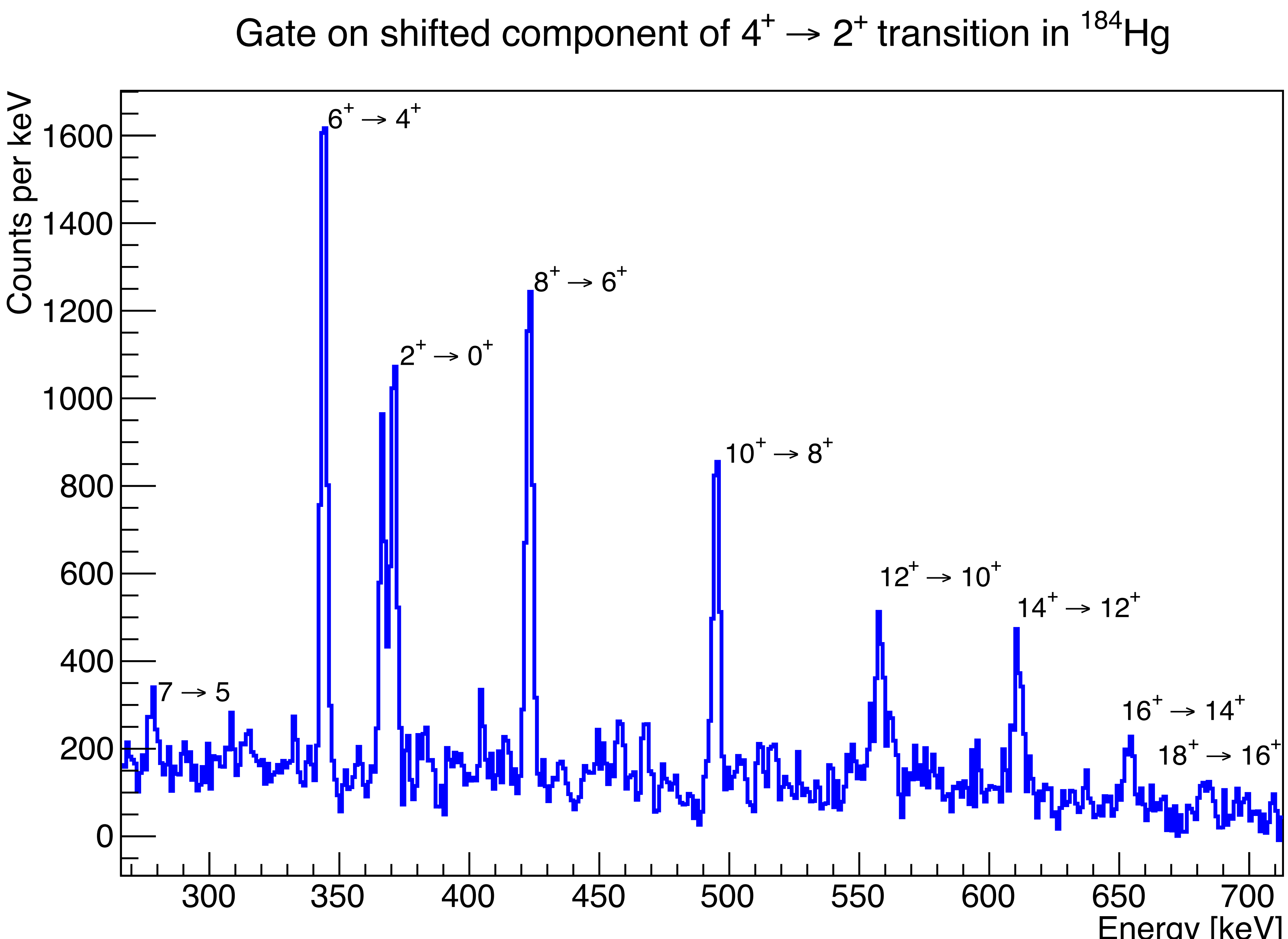
- Good statistics, clean gates
- τ possible up to 8^+
- $12^+ \rightarrow 10^+$ not clean



^{184}Hg - Analysis

- Simplest and cleanest way of determining the lifetime with coincidence method
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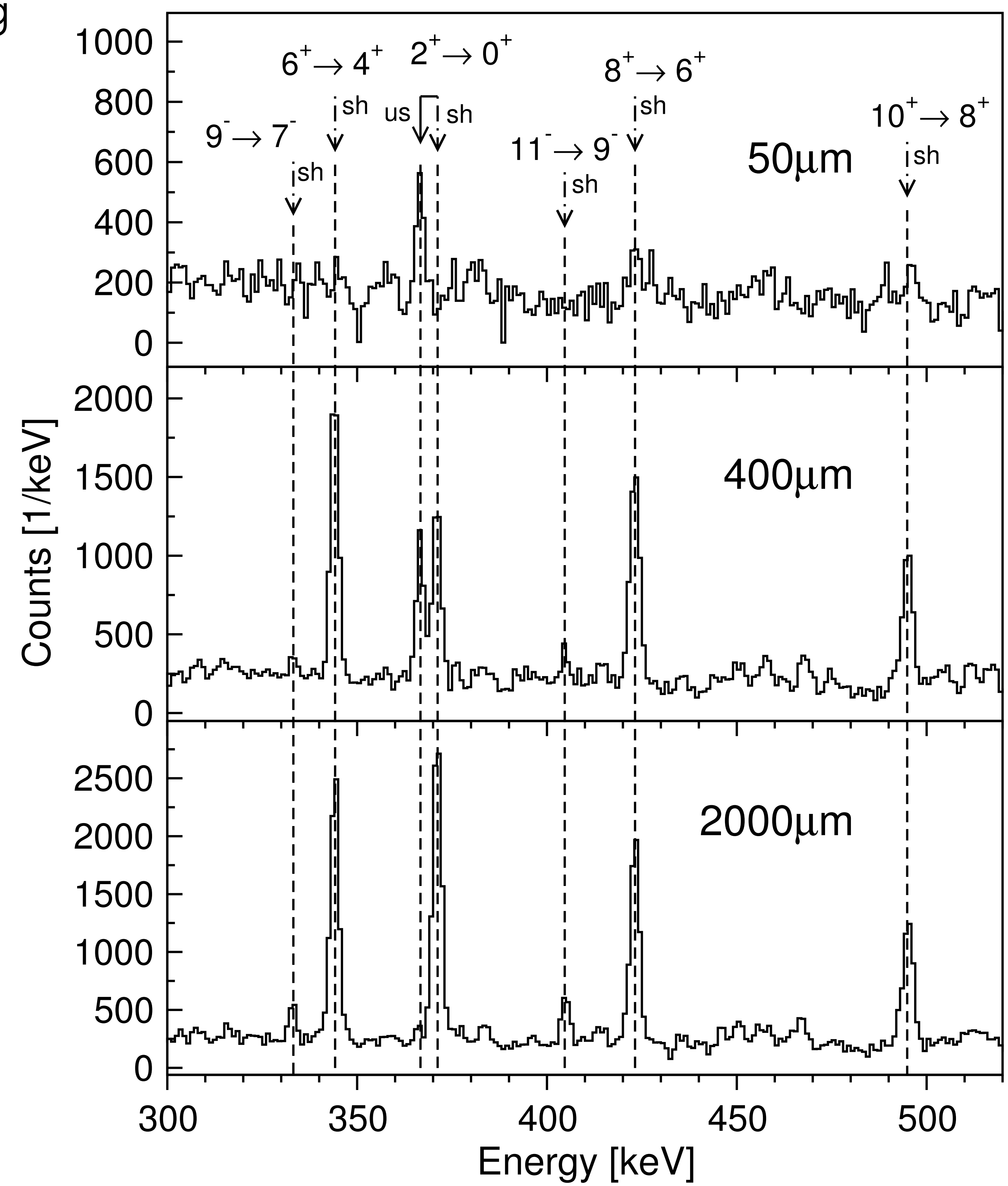
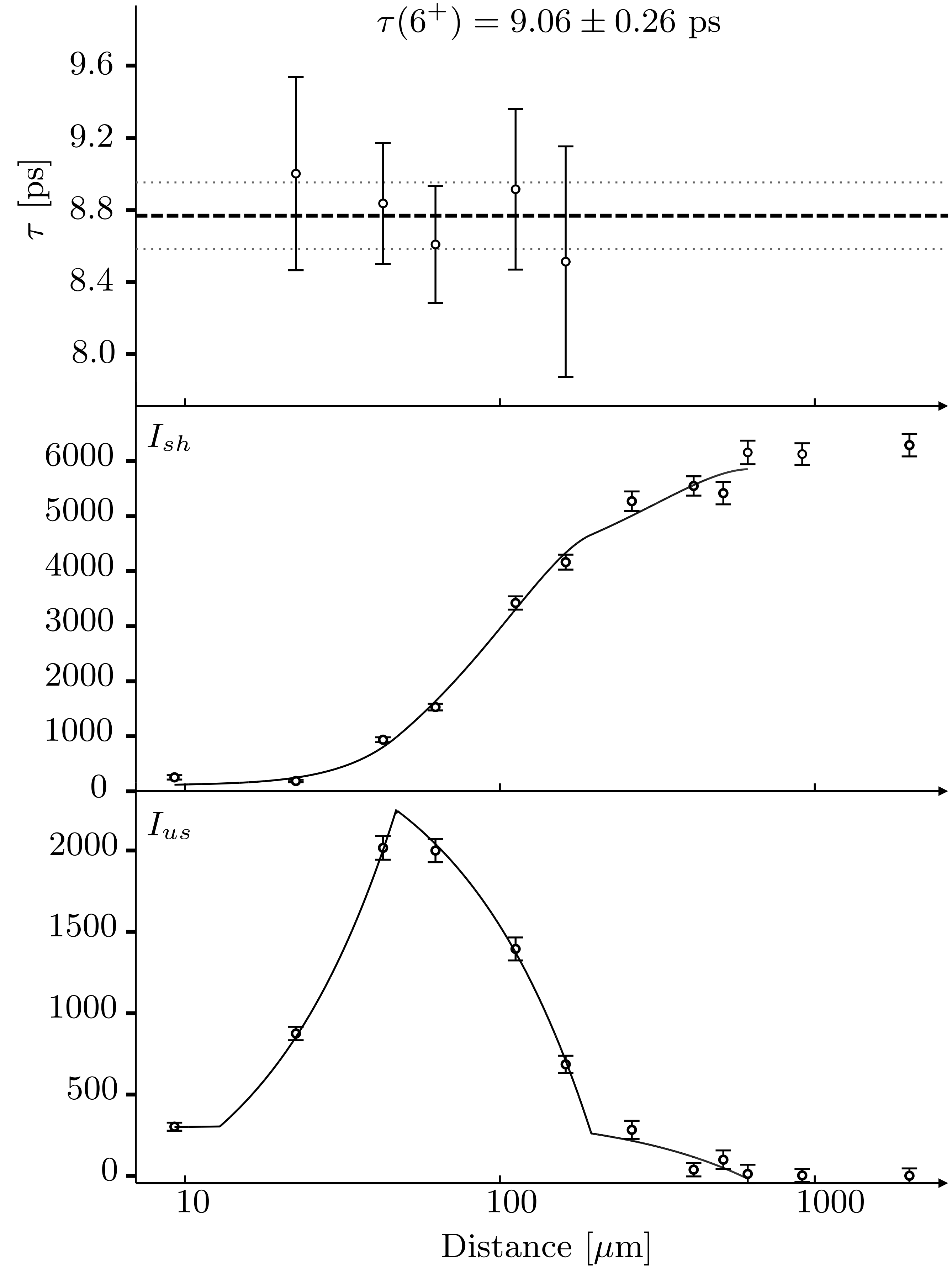
- 9- state also measured



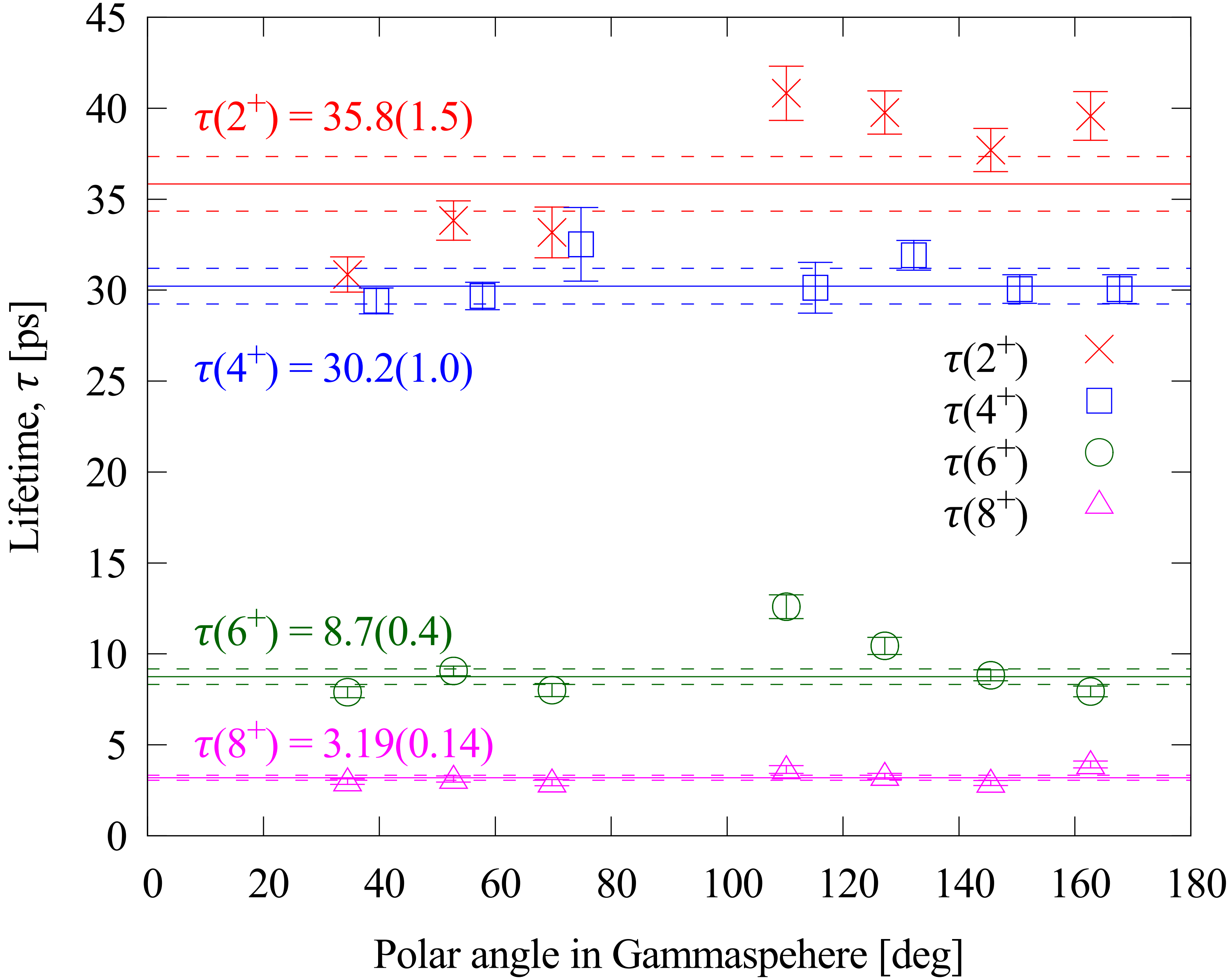
^{184}Hg - Lifetimes

- Differential Decay Curve Method (DDCM) [1]
- Can be done for each 'ring' independently
- 7 measurements for each state.



[1] Dewald, A., Möller, O., & Petkov, P. (2012). *Prog. Part. Nucl. Phys.*, ***67***(3), 786–839. doi:10.1016/j.ppnp.2012.03.003

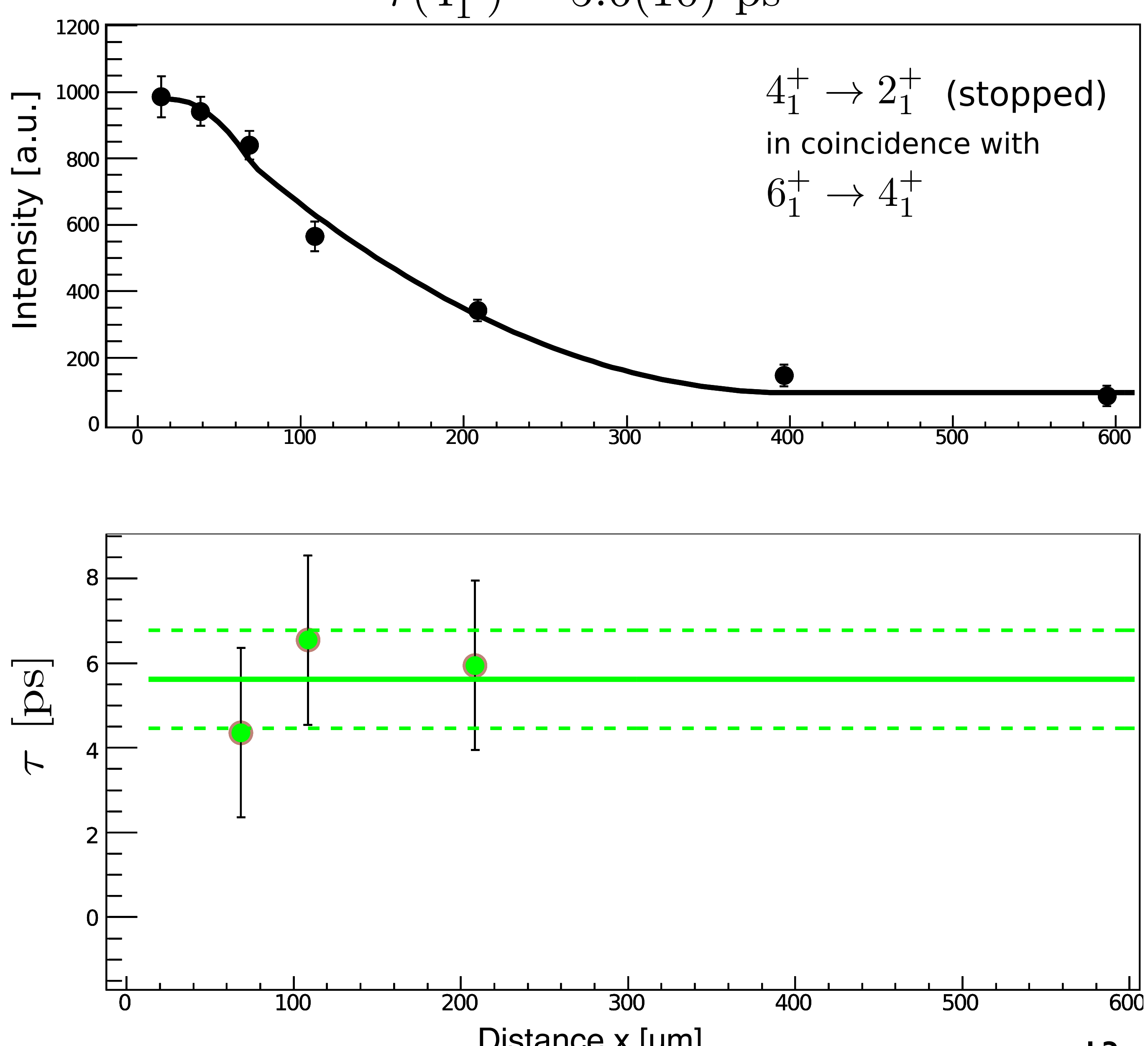
^{184}Hg - Lifetimes

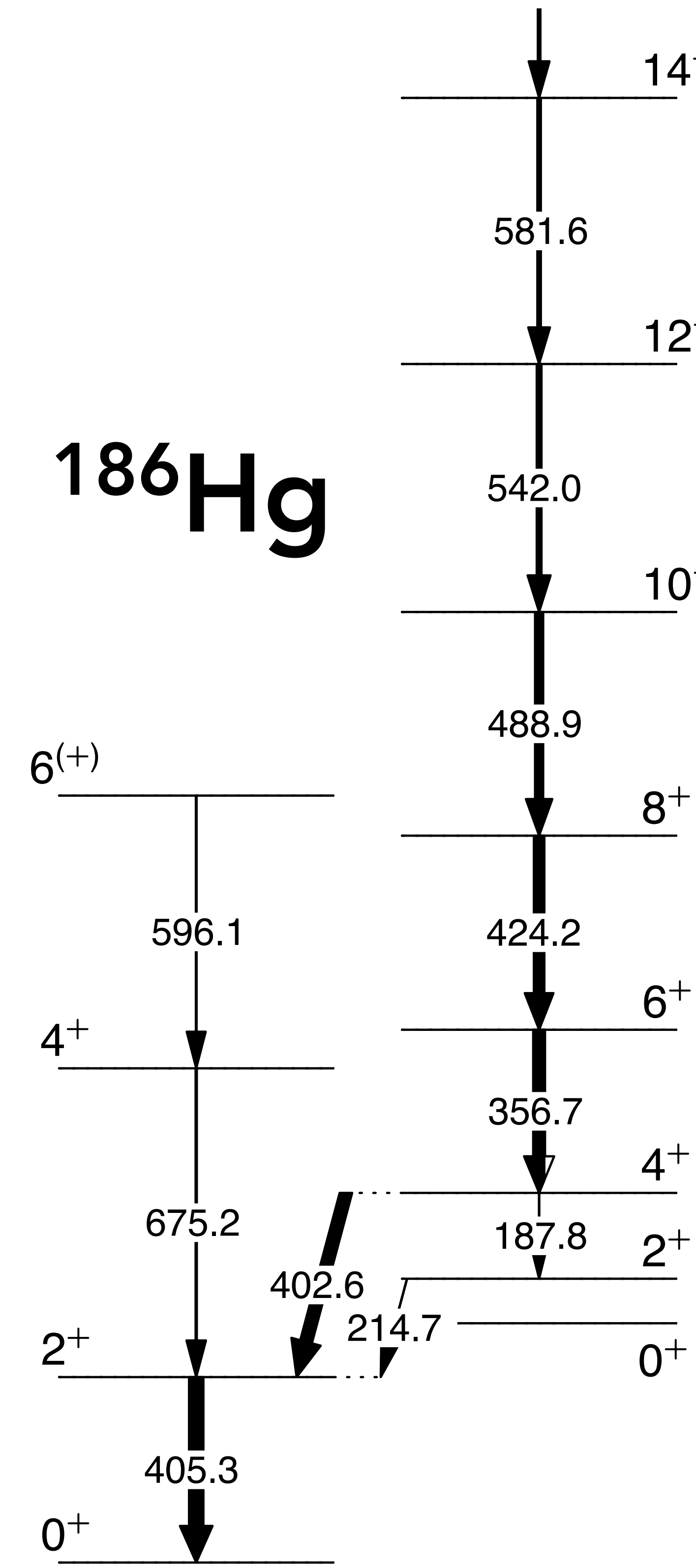


^{186}Hg - Analysis

- "Gate from above" up to yrast 10^+
- Weighted average of intensities in each ring used, leading to 1 decay curve for each state.

$\tau(4_1^+) = 5.6(10)$ ps





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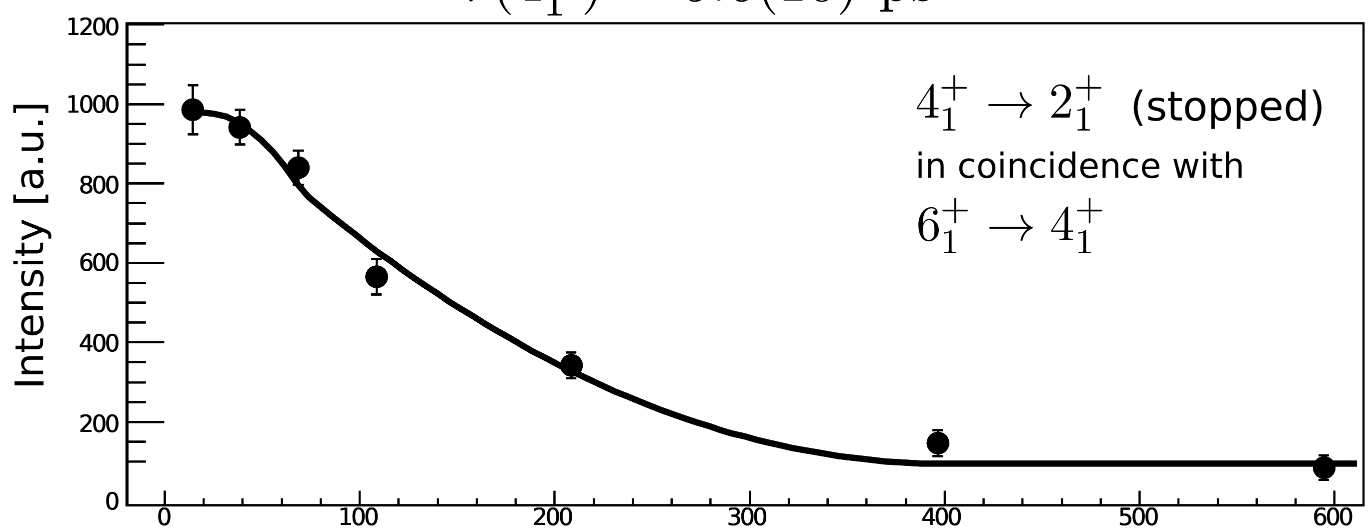
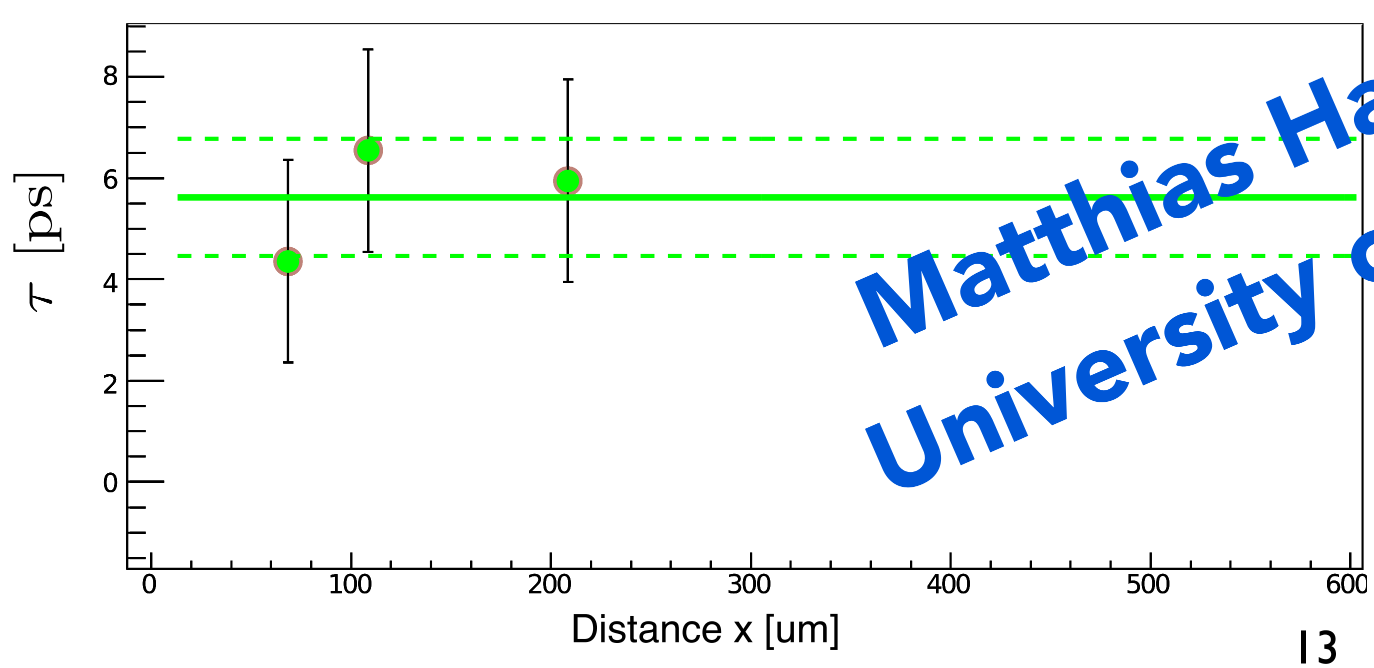
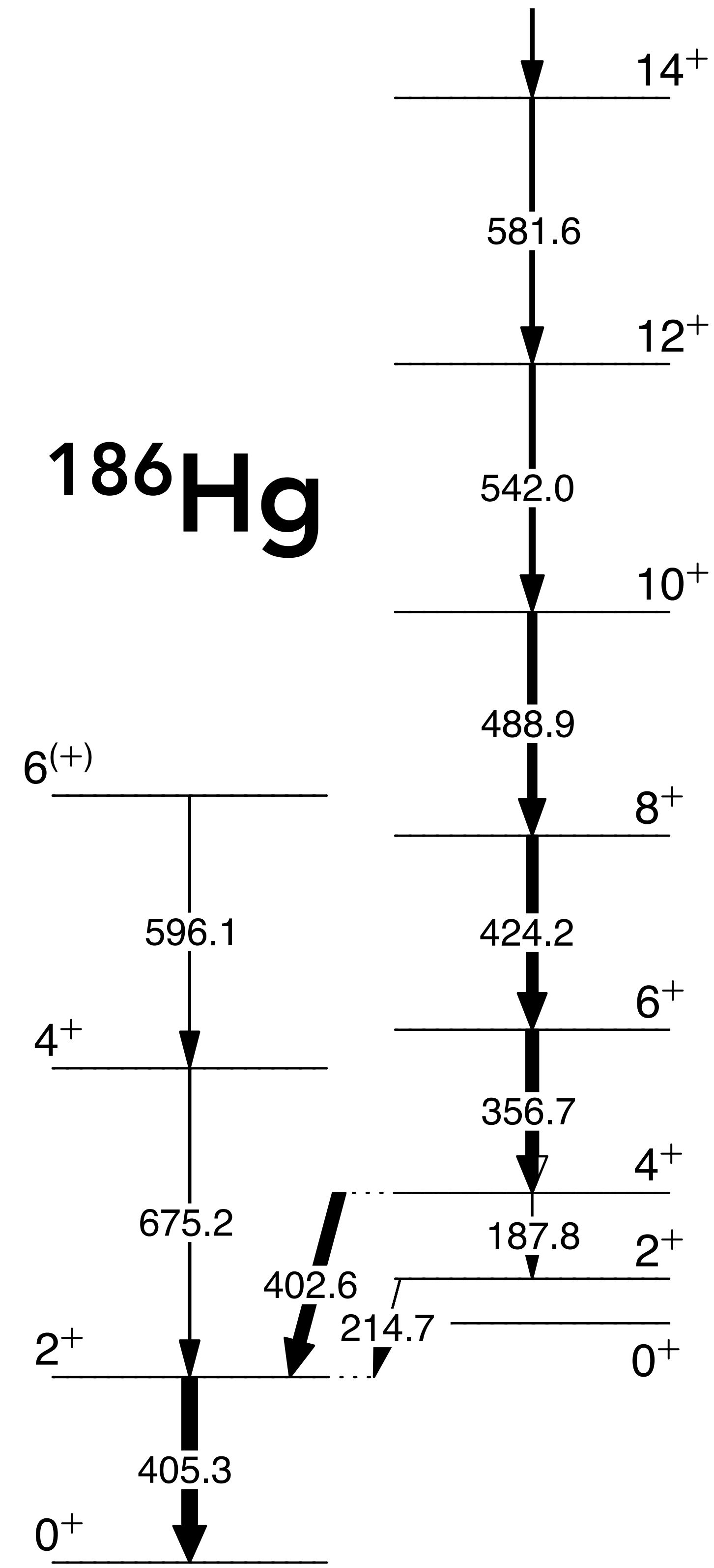
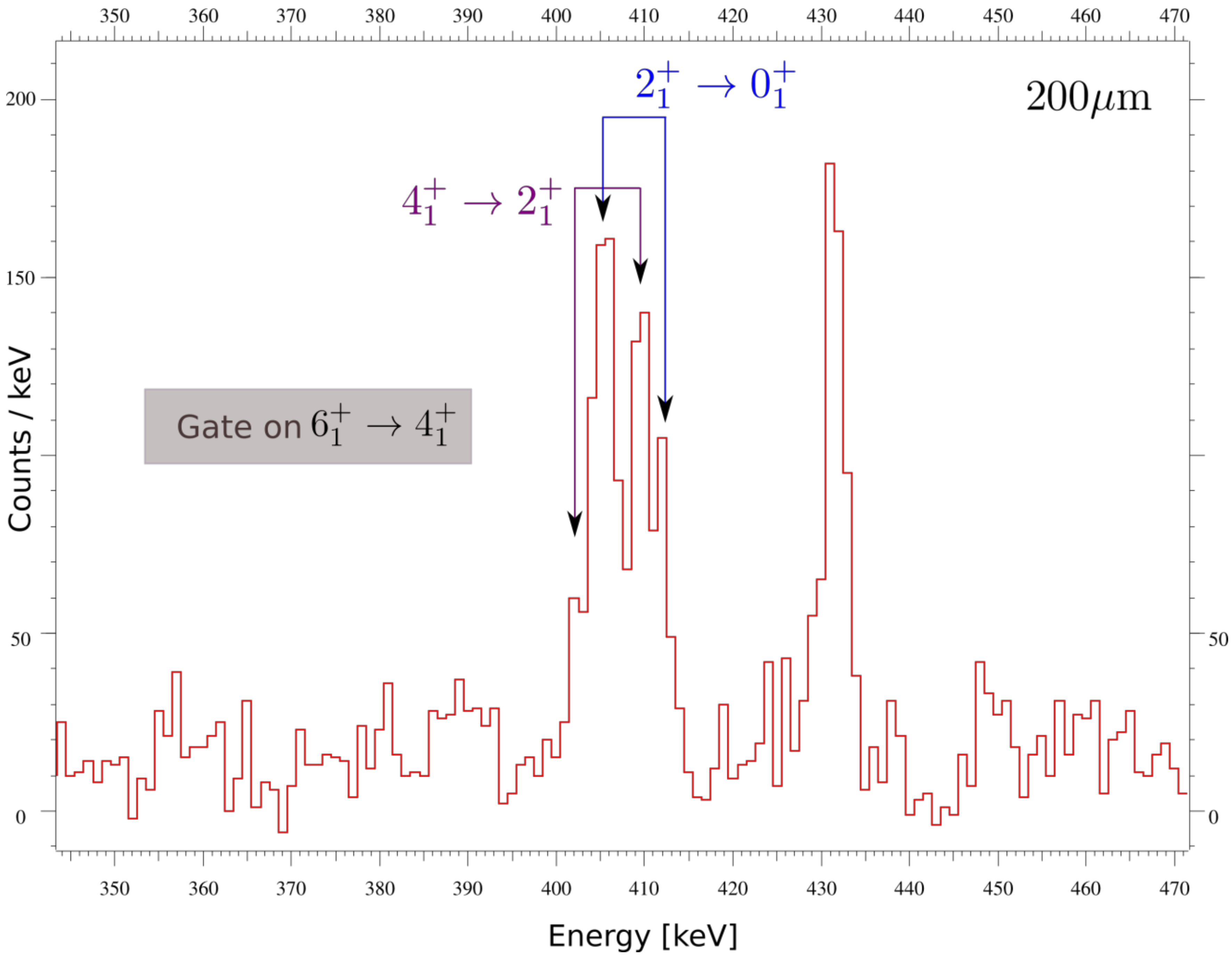
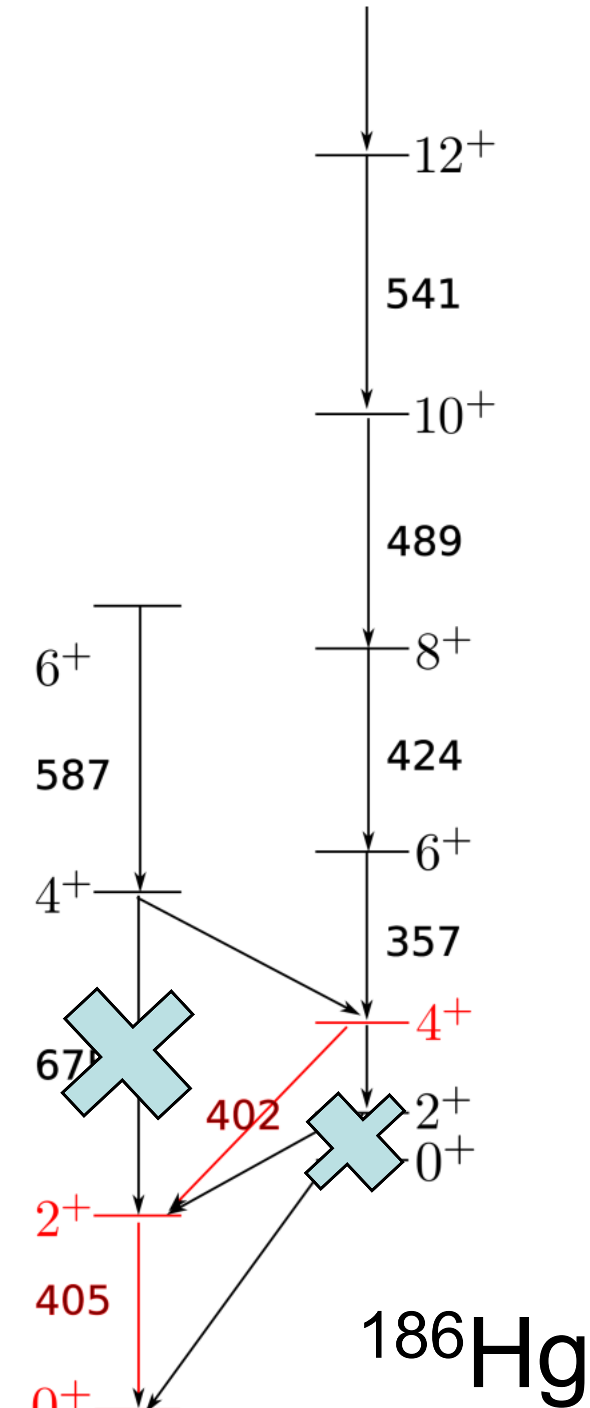






^{186}Hg - Doublet

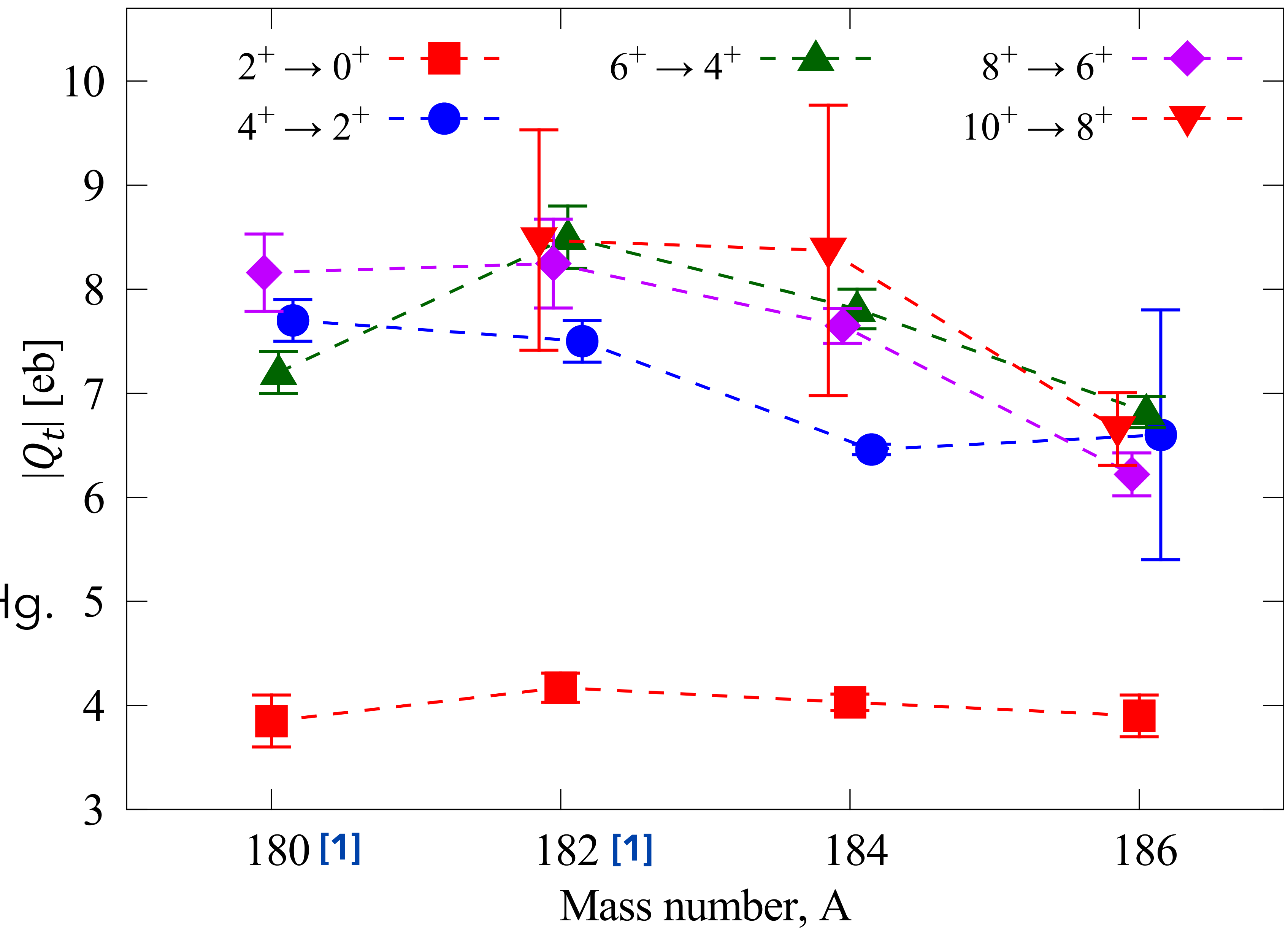




Matthias Hackstein,
University of Cologne

Results and discussion

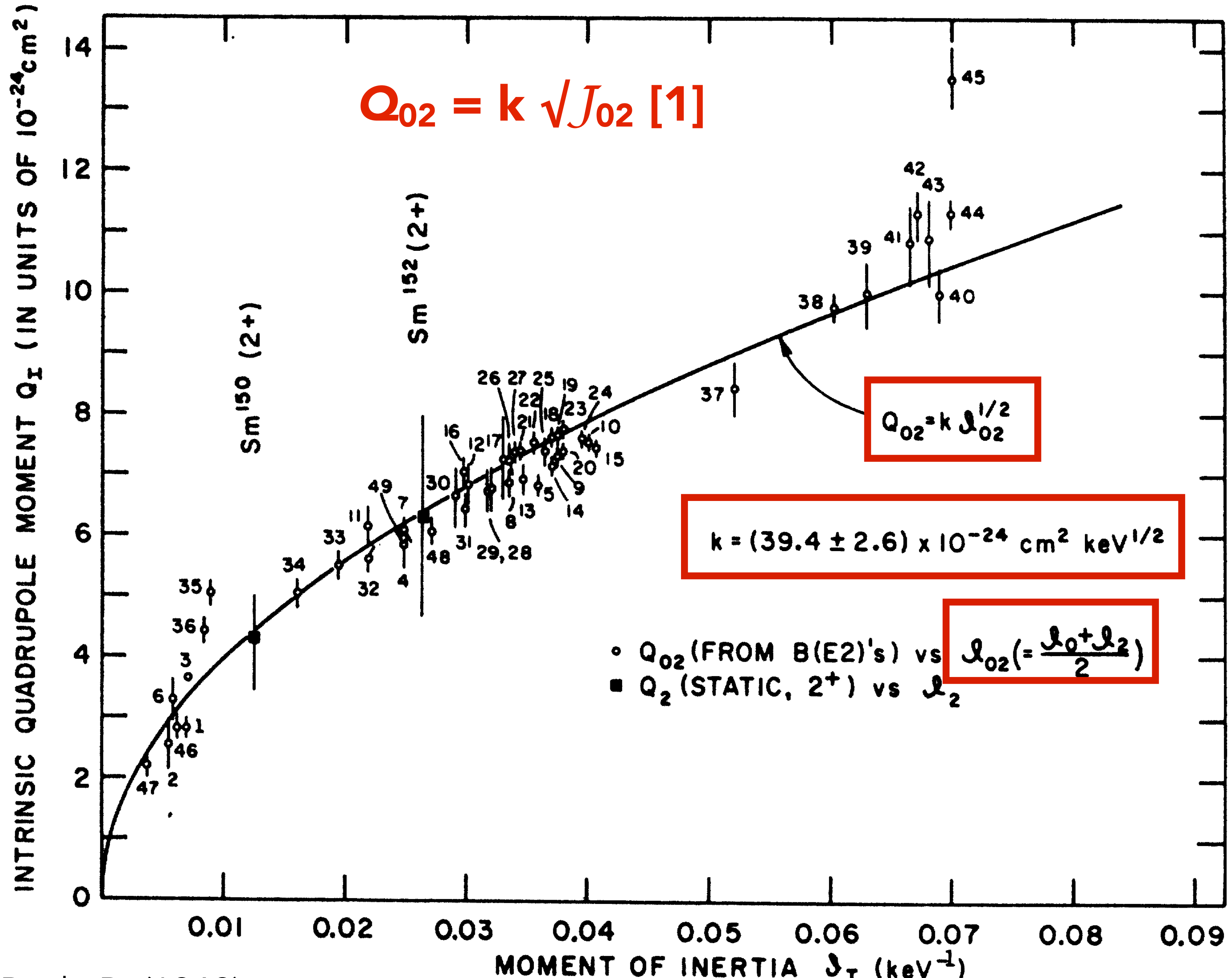
- Transitional quadrupole moments, Q_t, compared.
- Strikingly similar 2+ across mass range measured.
- Reduction of collectivity at ^{186}Hg.



[1] Grahn, T., et al. (2009). *Phys. Rev. C*, ***80***(1), 14324. doi:10.1103/PhysRevC.80.014324

Results and discussion

• Mixing calculations from Robert Page... To be discussed.



[1] Mariscotti, M. A. J., Scharff-Goldhaber, G., & Buck, B. (1969). *Phys. Rev.*, ***178***(4), 1864–1886. doi:10.1103/PhysRev.178.1864

[2] G.D. Dracoulis et al. (1988), *Nucl. Phys. A* ***486***(2), 414-428 doi:10.1016/0375-9474(88)90244-8

Results and discussion

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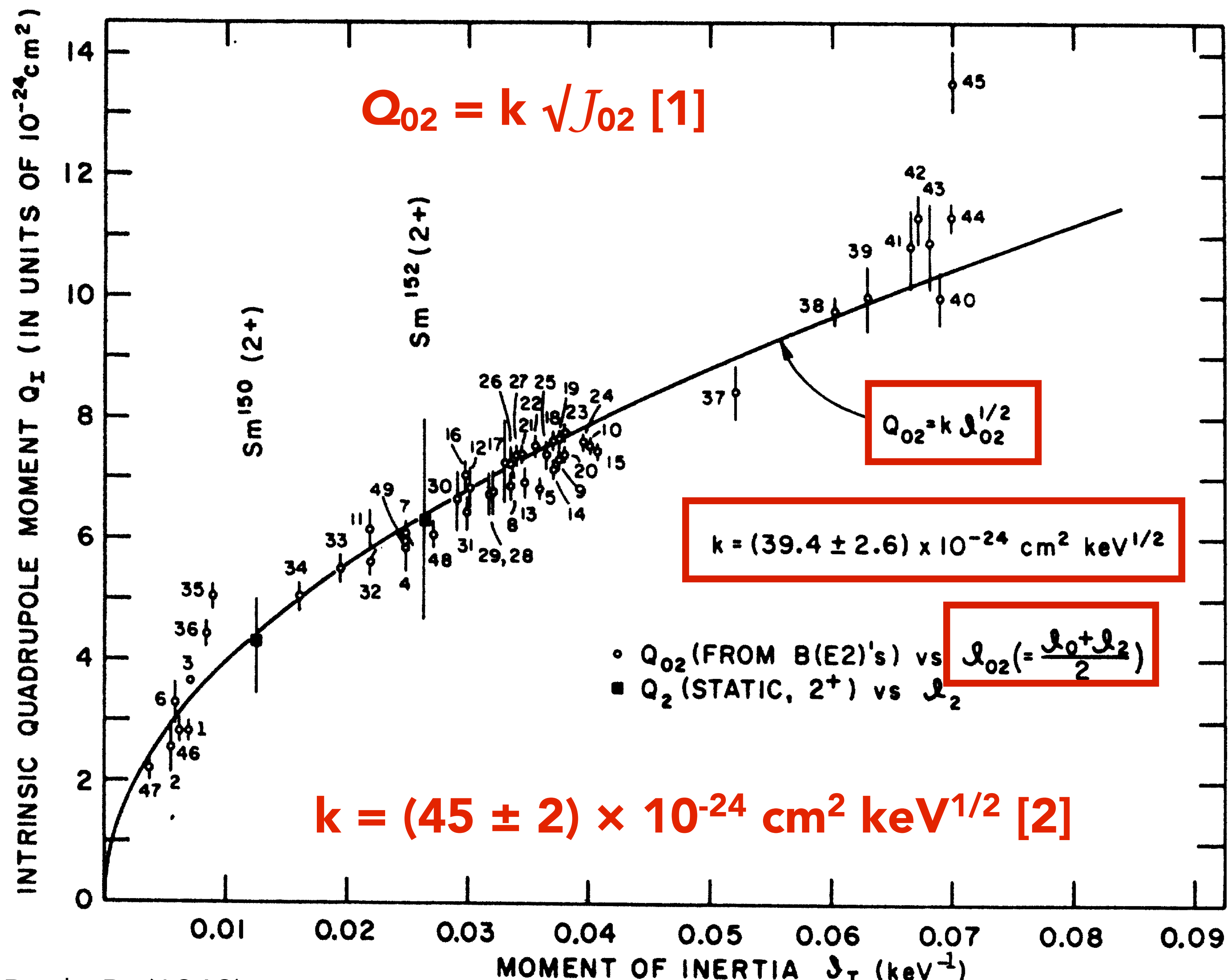
- VMI model; extract quadrupole moment from moment of inertia.



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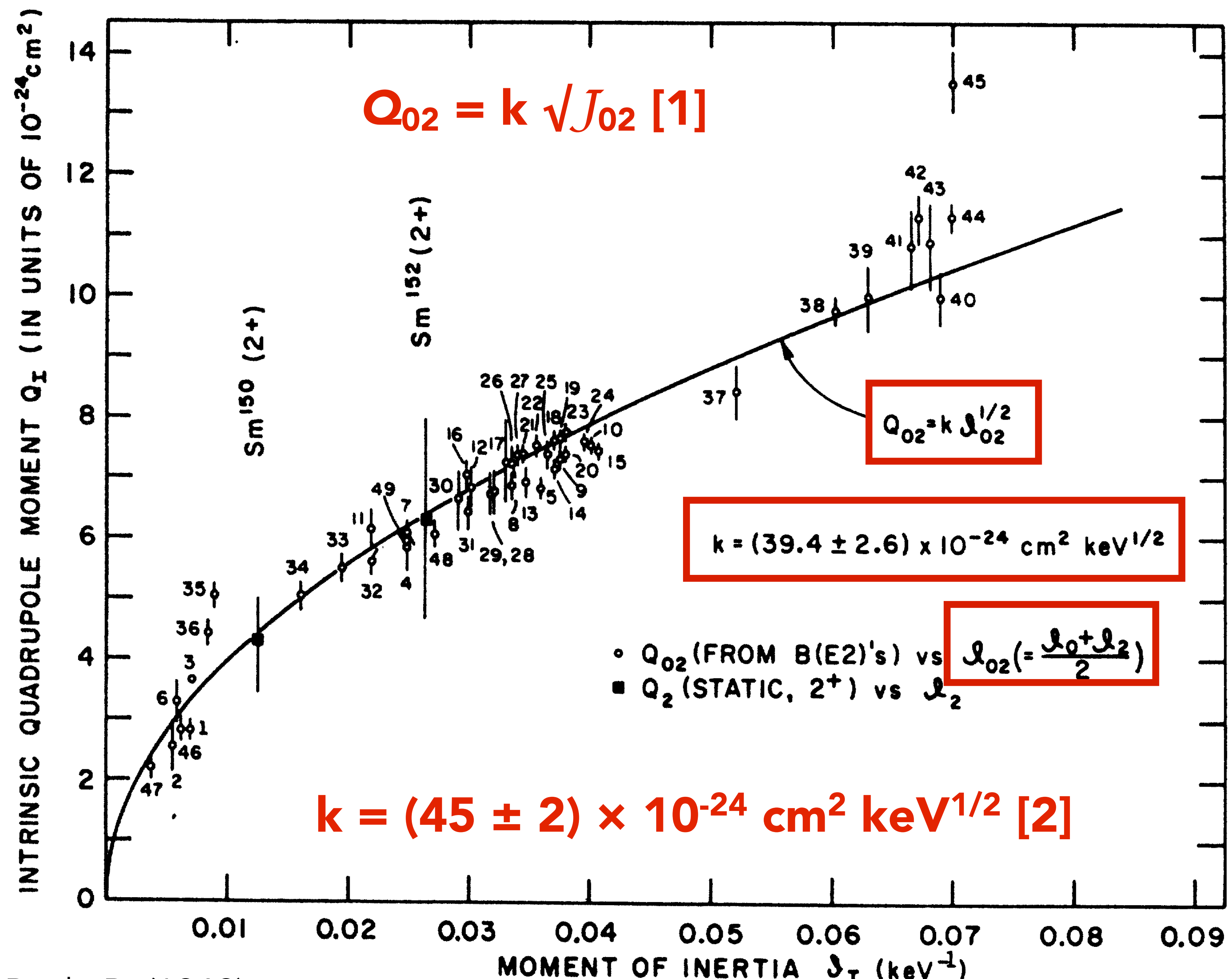

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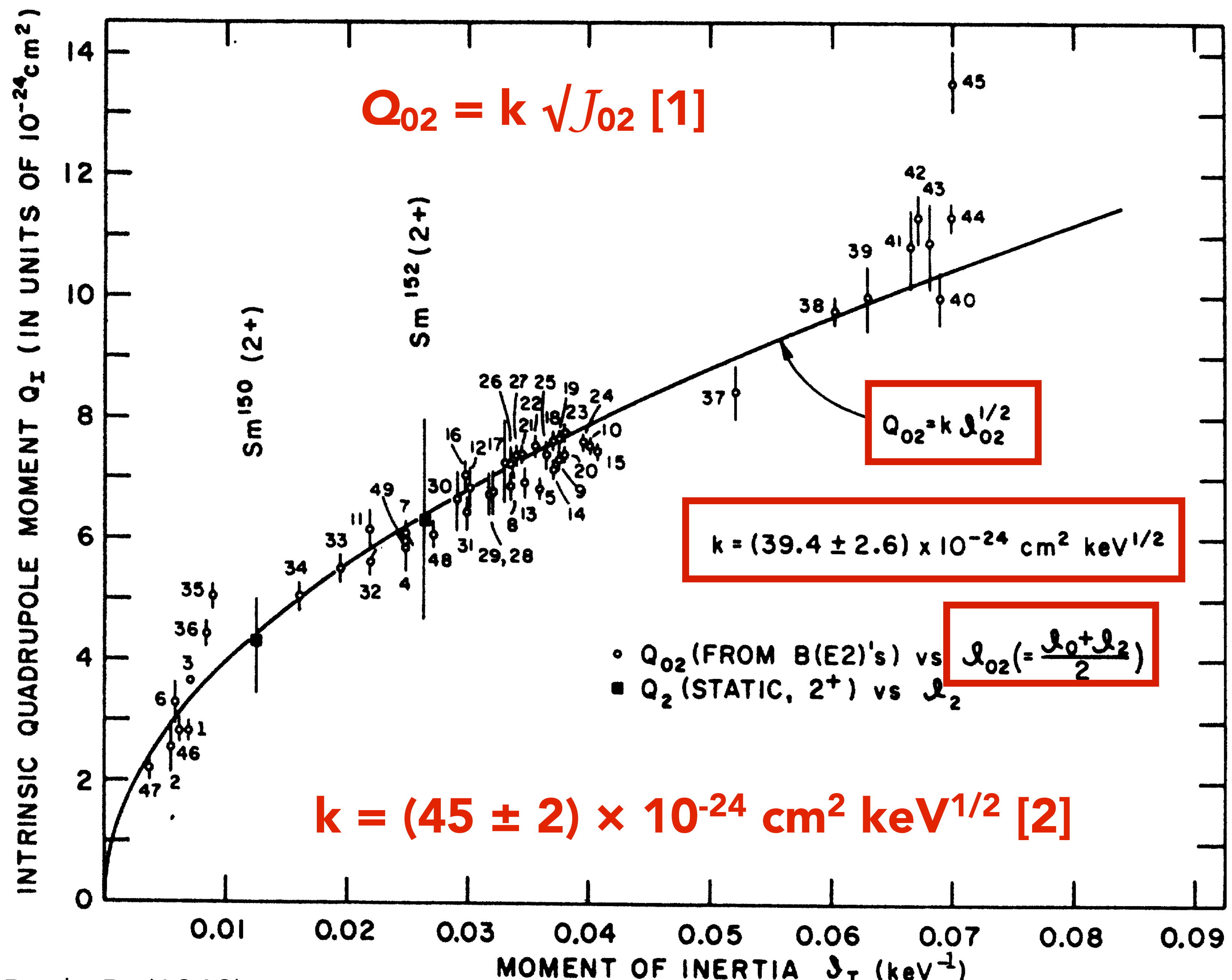

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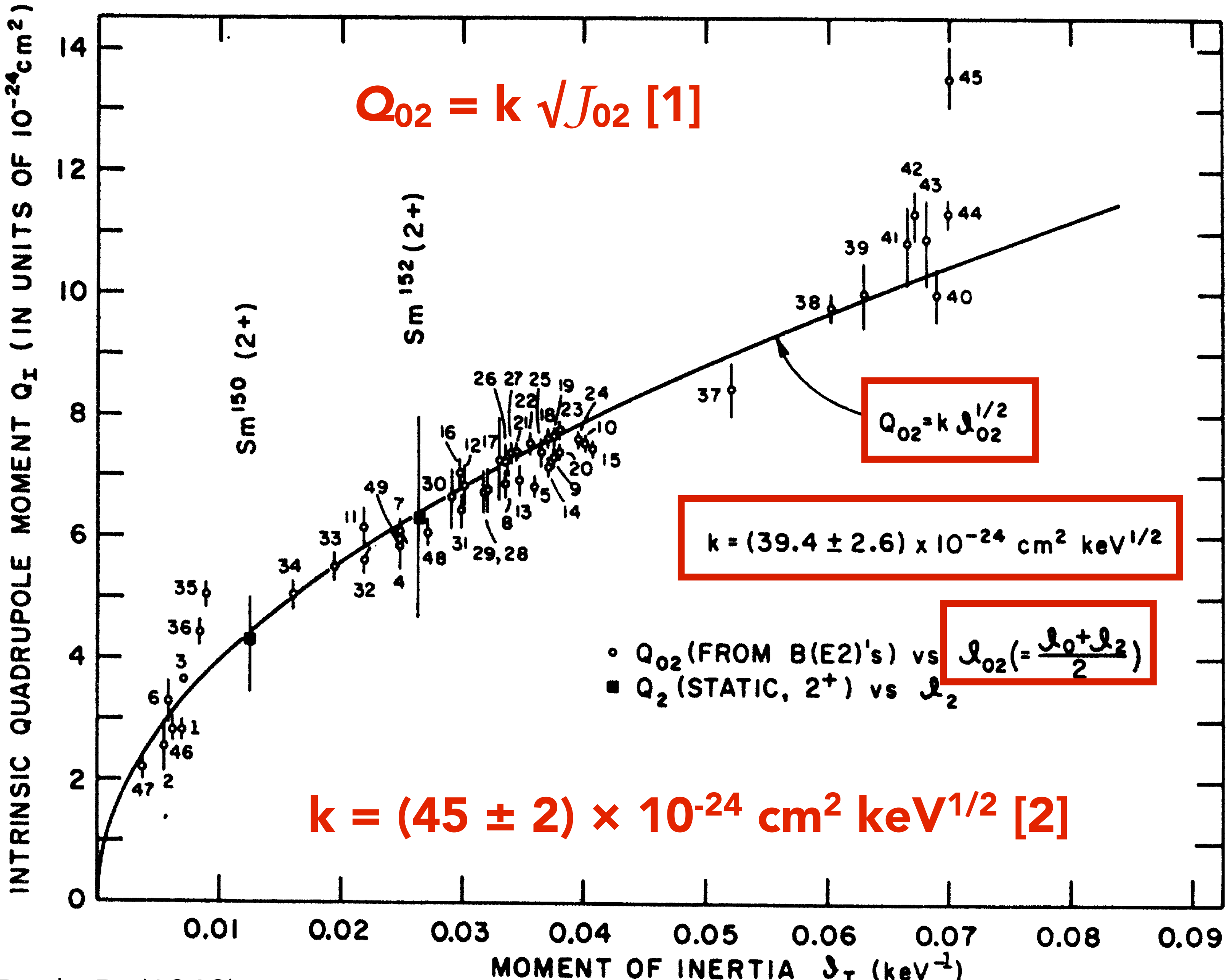
- Some assumptions, i.e. inter-band MEs equal to zero.
- Experimental B(E2)s



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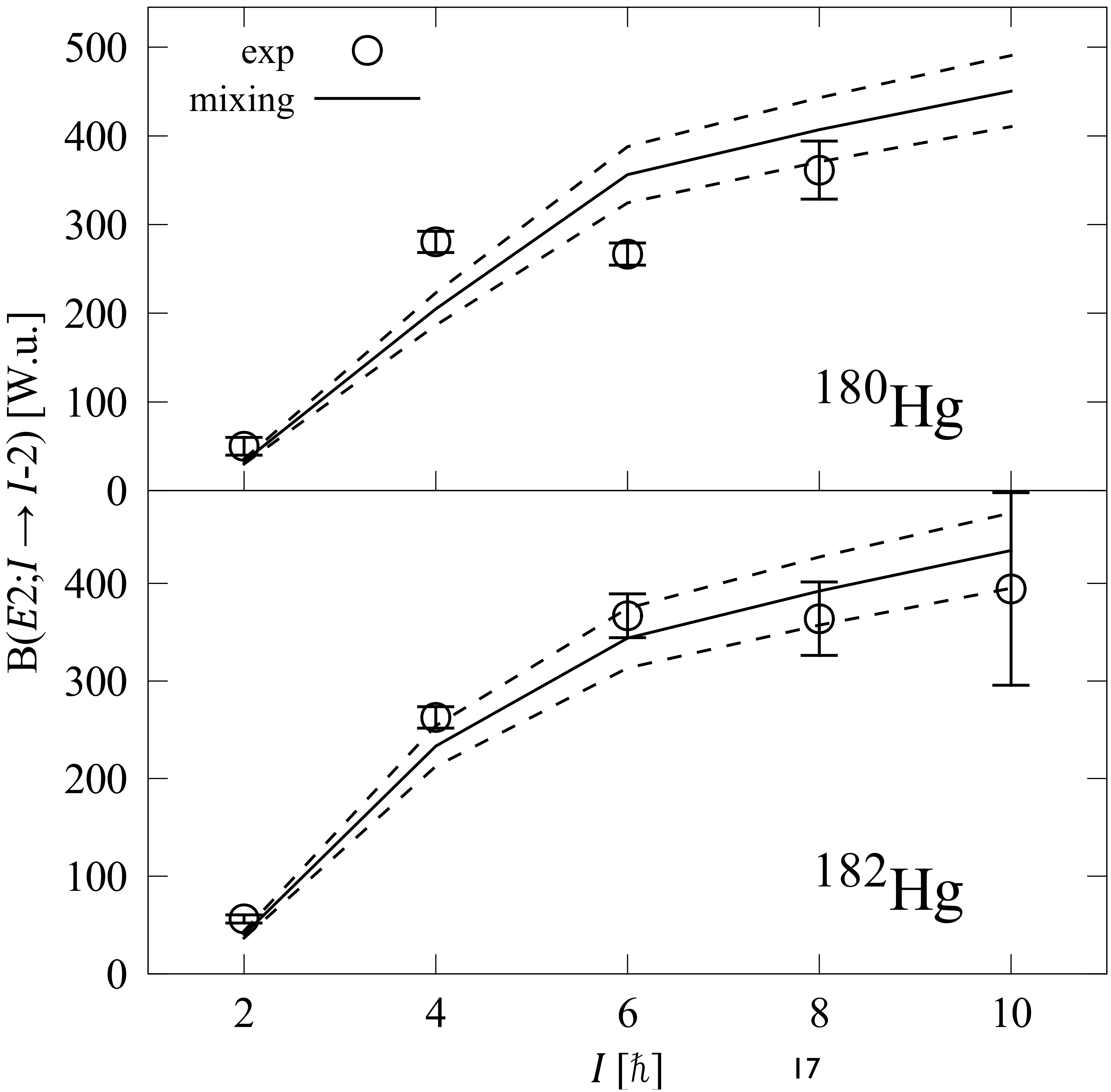

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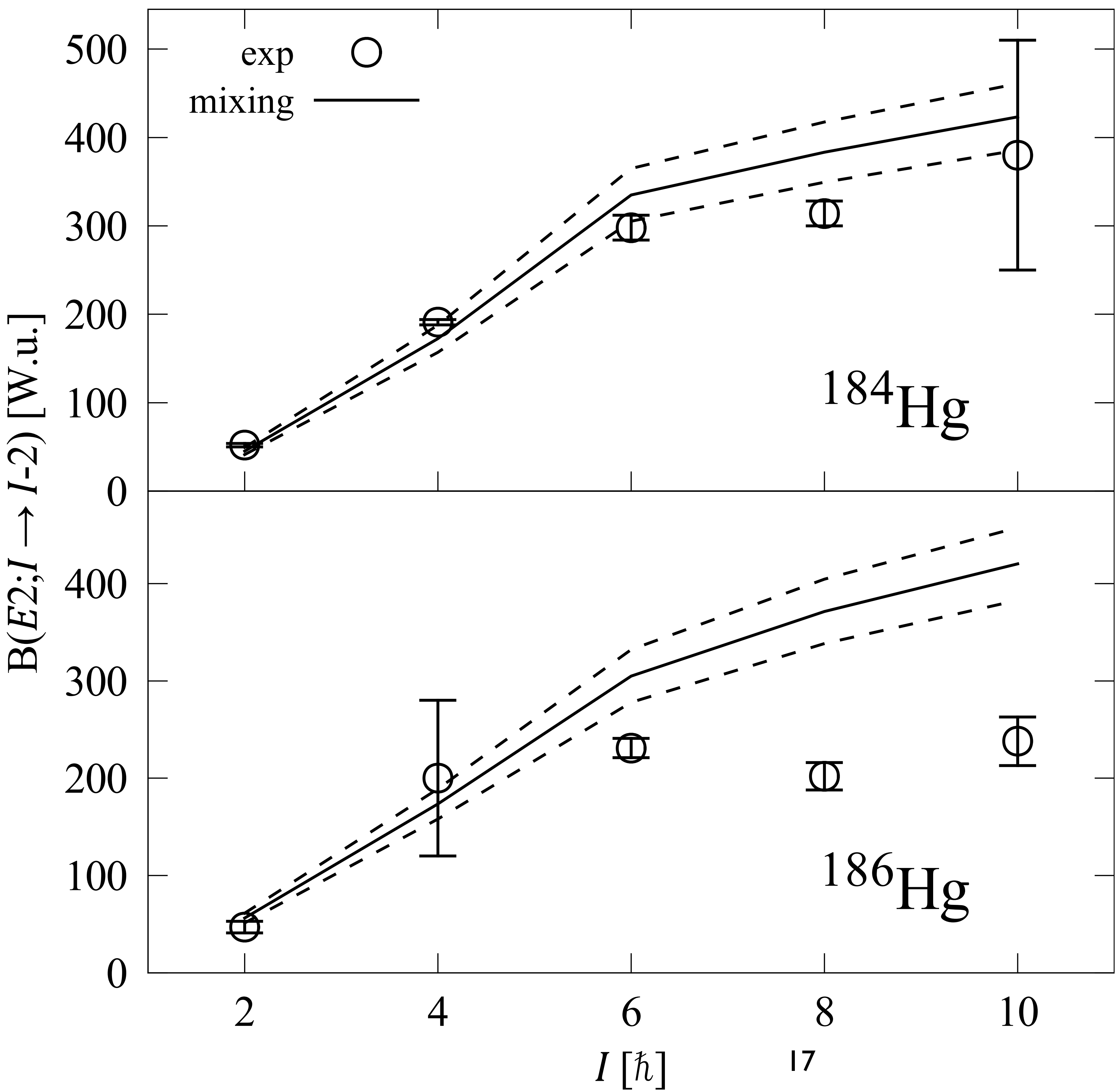

Collaboration

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J. Pakarinen

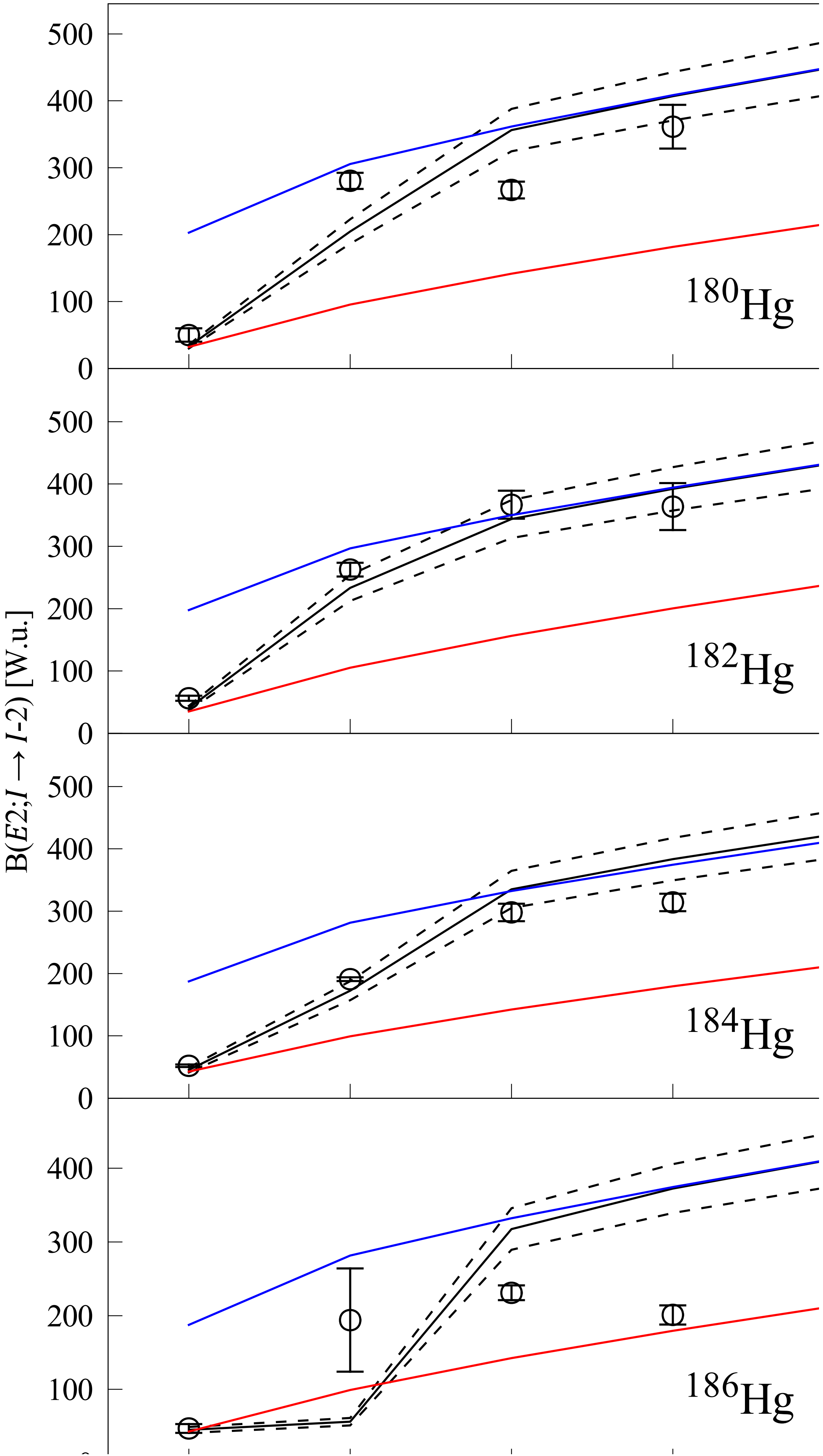
UNIVERSITY OF LIVERPOOL

KU LEUVEN

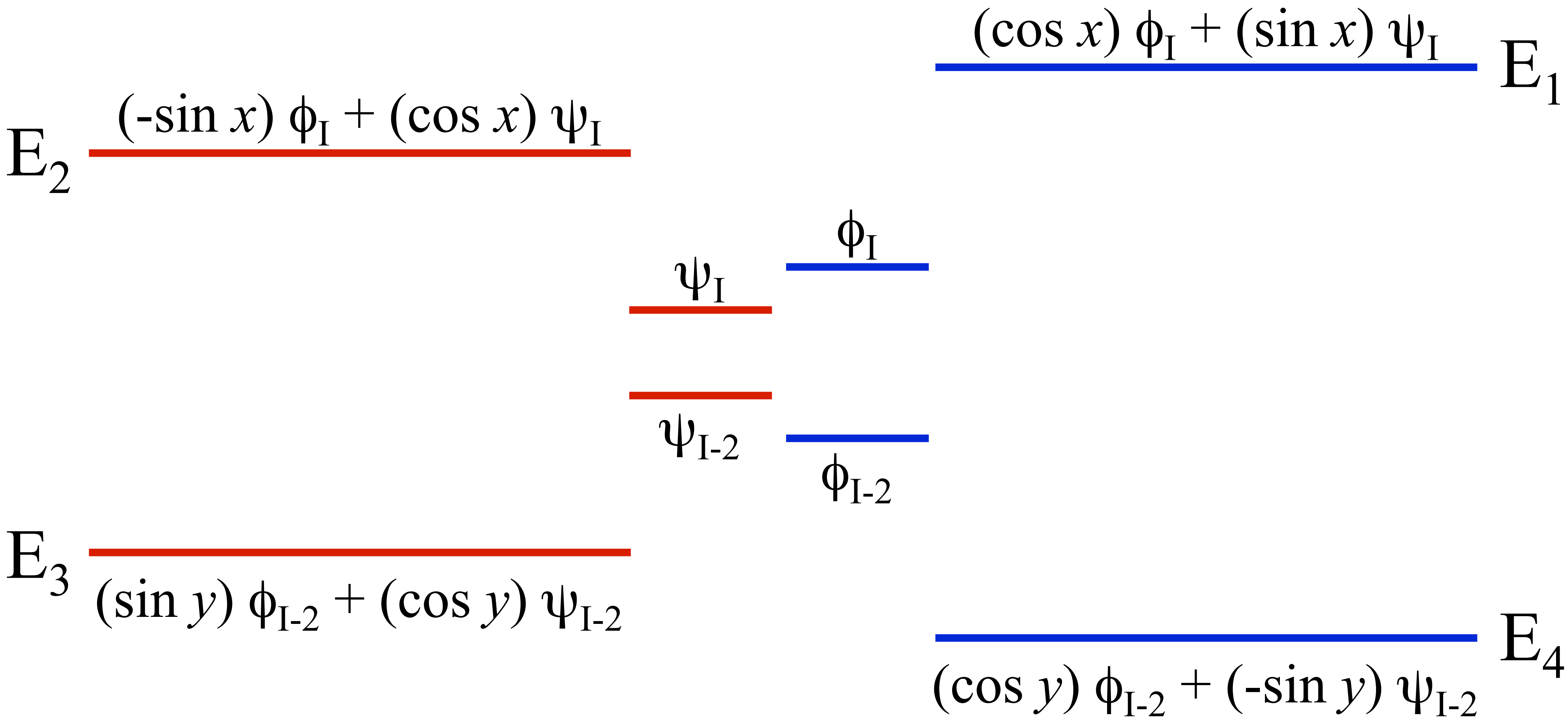
Lifetimes

	E_γ (keV)	I^π	τ_{ave} (ps)	τ_{prev} (ps)	$B(E2)$ (W.u)	$\|Q_t\|$
^{184}Hg	366.7	2_1^+	35.8(15)	30(7)	52(2)	4.03(8)
	287.0	4_1^+	30.2(10)	32.8(34)	191(6)	6.46(10)
	340.1	6_1^+	8.7(4)	8.1(31)	307(15)	7.81(19)
	418.3	8_1^+	3.19(14)	$2.9^{+1.1}_{-1.6}$	309(13)	7.65(17)
	329.1	$9_3^{(-)}$	12.2(8)	–	160(30)	5.5(5)
^{186}Hg	405.3	2_1^+	24(3)	26(4)	47(6)	3.9(2)
	402.6	4_1^+	5.6(20)	13(4)	200(70)	6.6(12)
	356.7	6_1^+	9.1(4)	7(3)	231(10)	6.82(15)
	424.2	8_1^+	4.5(3)	≈ 4	202(14)	6.2(2)
	488.9	10_1^+	1.9(2)	–	238(25)	6.7(4)

Mixing results



B(E2) ↓ values



$$B(E2;1 \rightarrow 3) = \frac{5}{16\pi} e^2 \left[\cos x \sin y \langle I K_\phi 20 | I-2 K_\phi \rangle Q_\phi + \sin x \cos y \langle I K_\psi 20 | I-2 K_\psi \rangle Q_\psi \right]^2$$

$$B(E2;1 \rightarrow 4) = \frac{5}{16\pi} e^2 \left[\cos x \cos y \langle I K_\phi 20 | I-2 K_\phi \rangle Q_\phi - \sin x \sin y \langle I K_\psi 20 | I-2 K_\psi \rangle Q_\psi \right]^2$$

$$\langle \phi | \hat{\mathrm{O}}(E2) | \psi \rangle = 0$$

A matrix of matrices

- Unpacked events into γ-γ-matrices
- Each ring against every other = 28
- Gate lists for each ring (θ) and each transition

AA	AB	AC	AD	AE	AF	AG
	BB	BC	BD	BE	BF	BG
		CC	CD	CE	CF	CG
			DD	DE	DF	DG
				EE	EF	EG
					FF	FG
xy						GG

A matrix of matrices

AA	AB	AC	AD	AE	AF	AG
	BB	BC	BD	BE	BF	BG
		CC	CD	CE	CF	CG
			DD	DE	DF	DG
				EE	EF	EG
					FF	FG
xy						GG

A matrix of matrices

gate on y-, project to x-axis

sum 7 spectra —> Ring A

AA	AB	AC	AD	AE	AF	AG
	BB	BC	BD	BE	BF	BG
		CC	CD	CE	CF	CG
			DD	DE	DF	DG
				EE	EF	EG
					FF	FG
xy						GG

A matrix of matrices

gate on y-, project to x-axis

sum 7 spectra —> Ring A

gate on y-, project to x-axis

only 4 spectra for Ring D

AA	AB	AC	AD	AE	AF	AG
	BB	BC	BD	BE	BF	BG
		CC	CD	CE	CF	CG
			DD	DE	DF	DG
				EE	EF	EG
					FF	FG
xy						GG

A matrix of matrices

gate on y-, project to x-axis

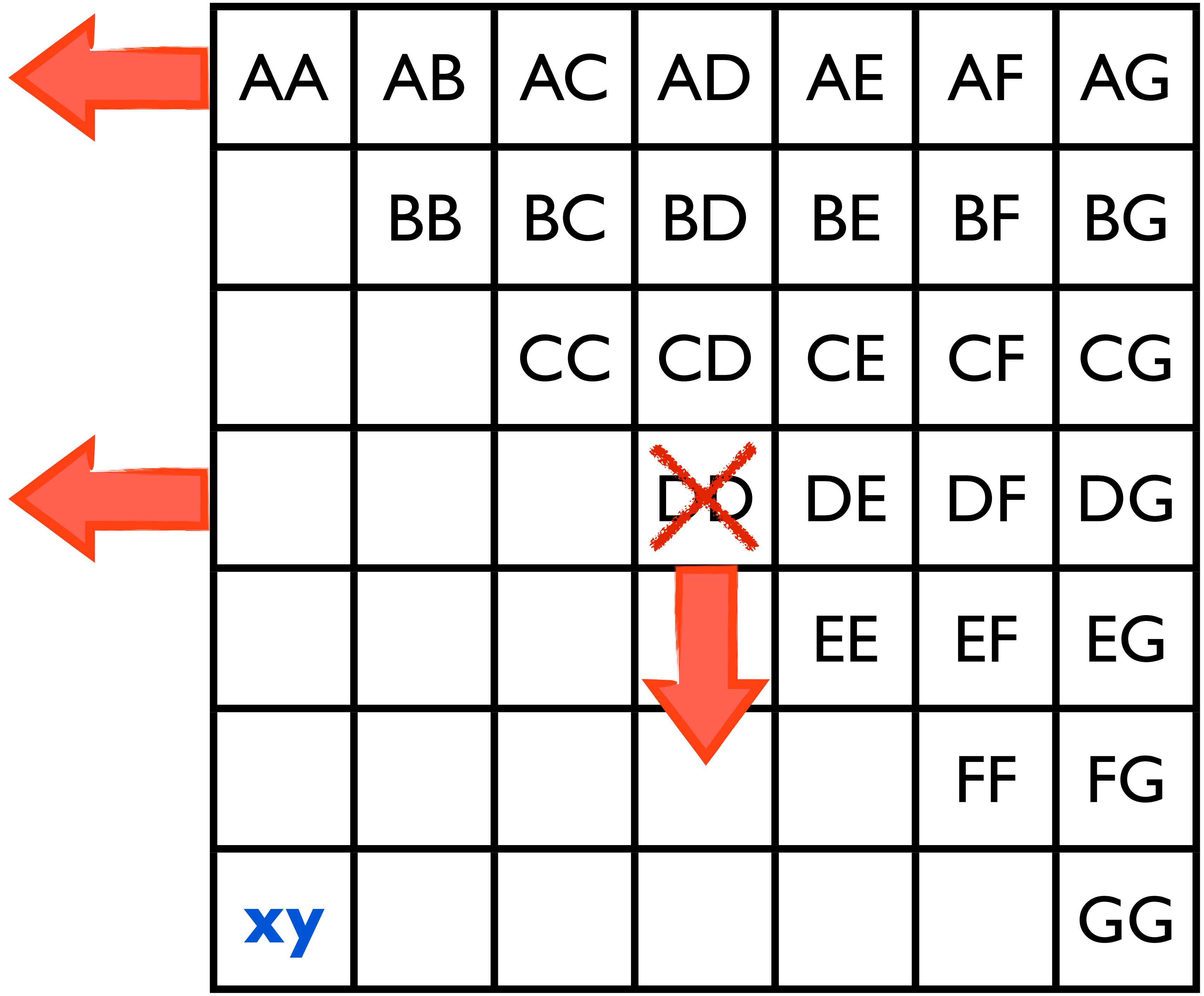
sum 7 spectra —> Ring A

gate on y-, project to x-axis

only 4 spectra for Ring D

gate on x-, project to y-axis

sum 7 spectra —> Ring D



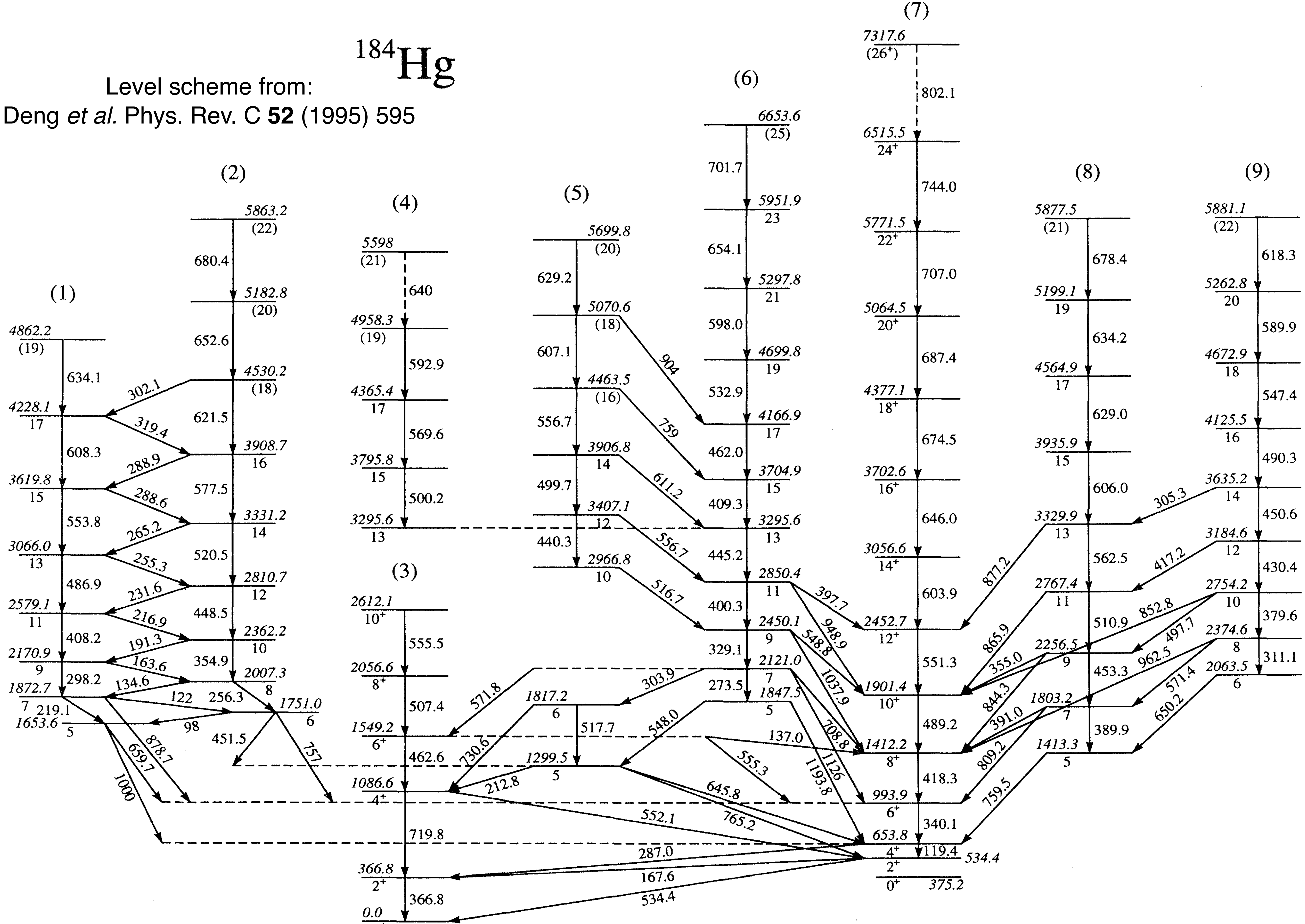
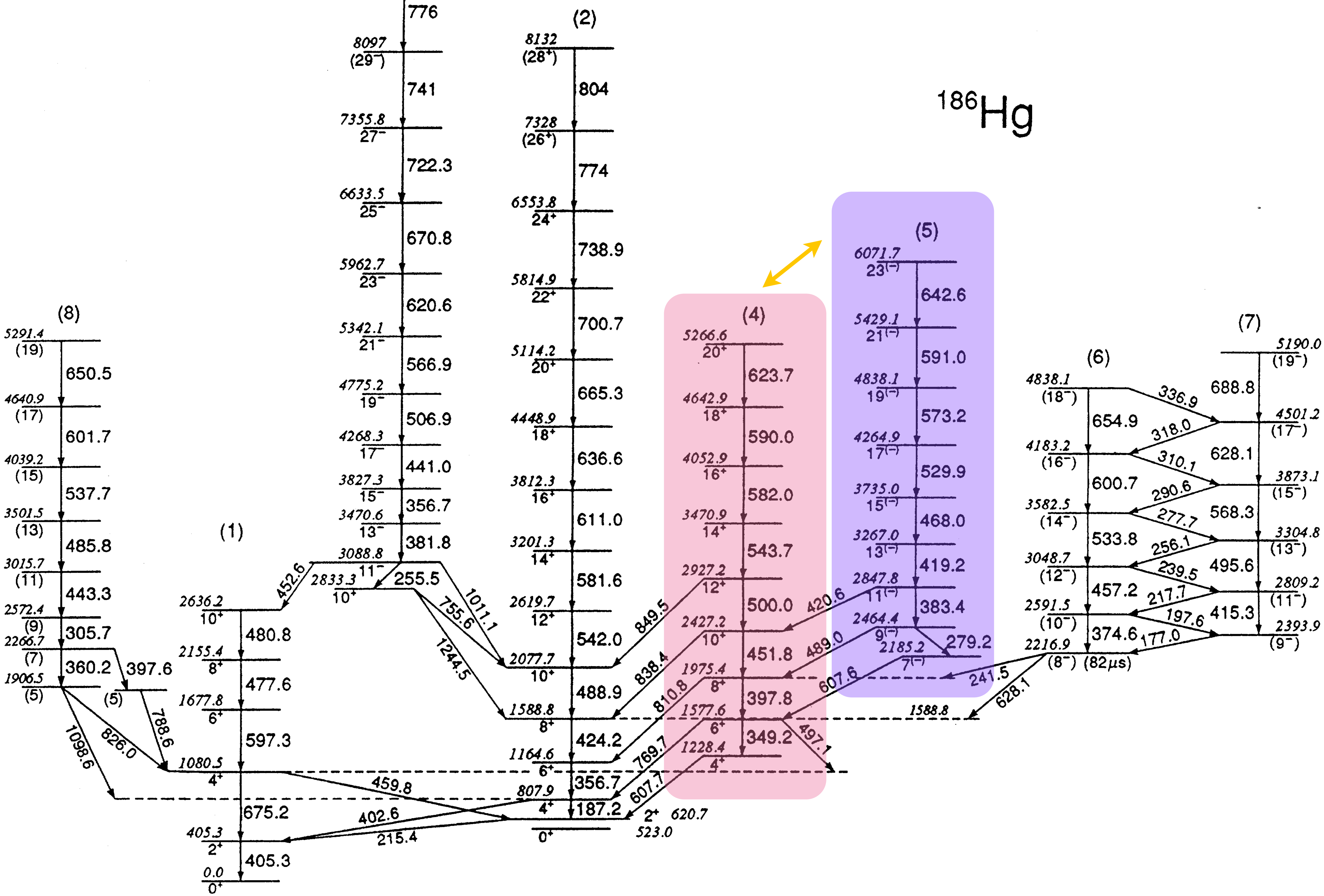


FIG. 1. Proposed level scheme for ^{184}Hg.

Level scheme from:
Ma *et al.* Phys. Rev. C **47** (1993) R5



Level scheme from:
F. Hannaci *et al.* Nucl. Phys. A **481** (1988) 135