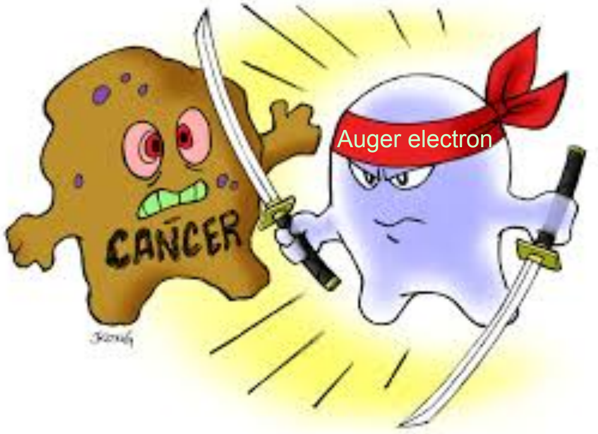
Australian National University

Auger and conversion electron spectroscopy of medical radioisotope ^{125}I

A magic bullet for cancer therapy

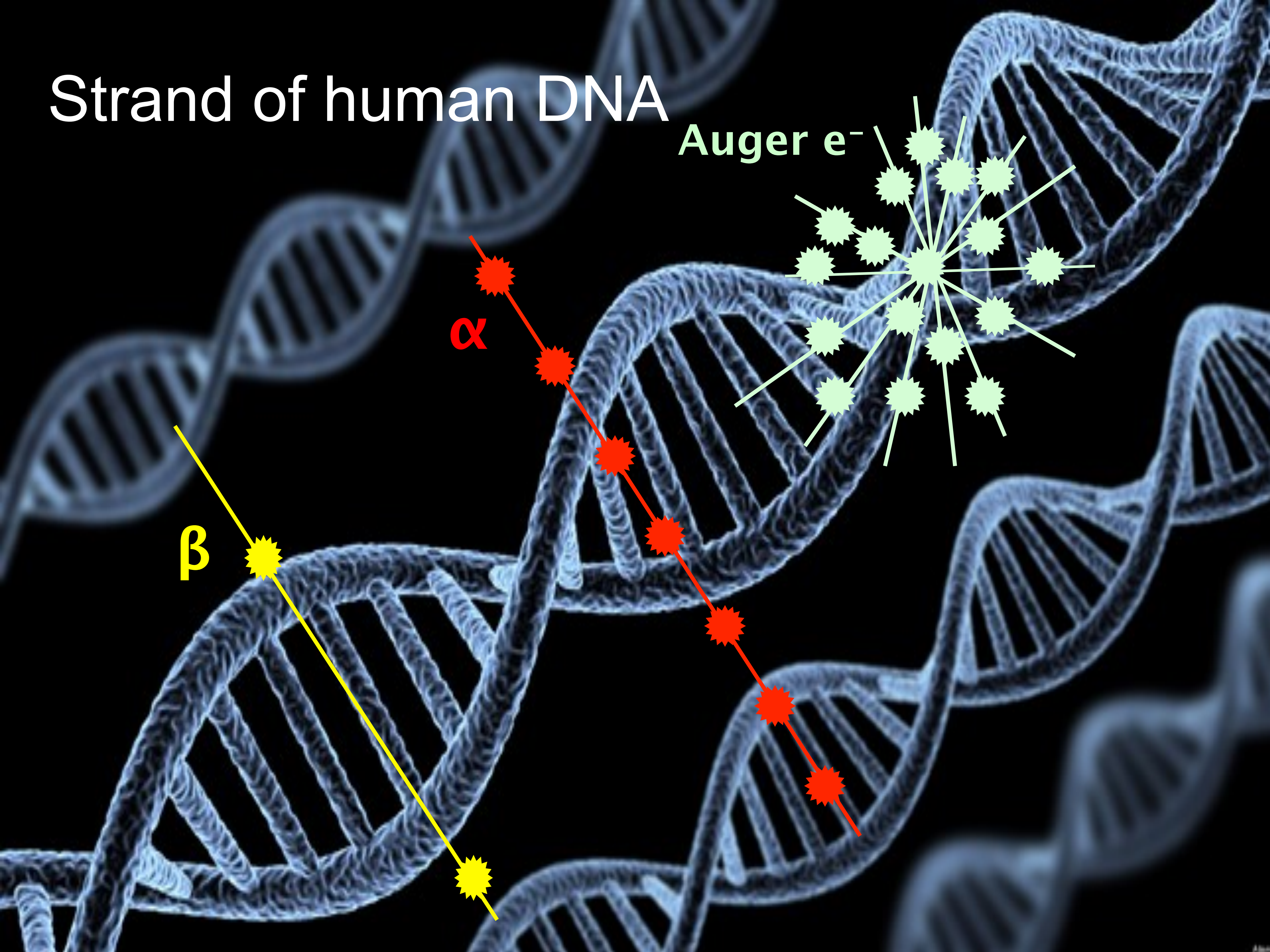


Presented by: ***Bryan Tee Pi-Ern***

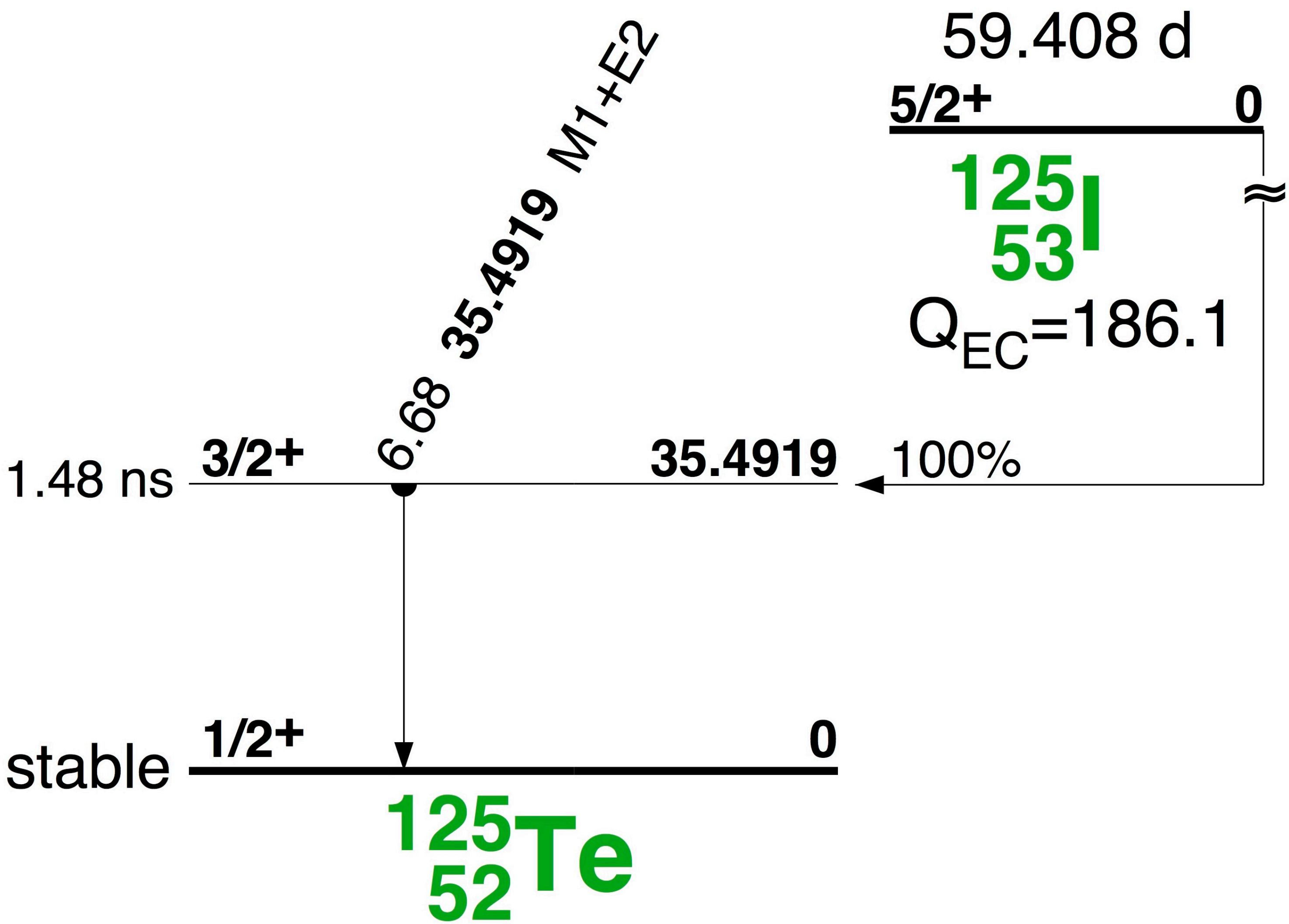
Date: *19th October 2018*

Supervised by ***Dr Tibor Kibédi, A/Prof Maarten Vos and Professor Andrew Stuchberry***

Strand of human DNA


Strand of human DNA
Auger e⁻
α
β

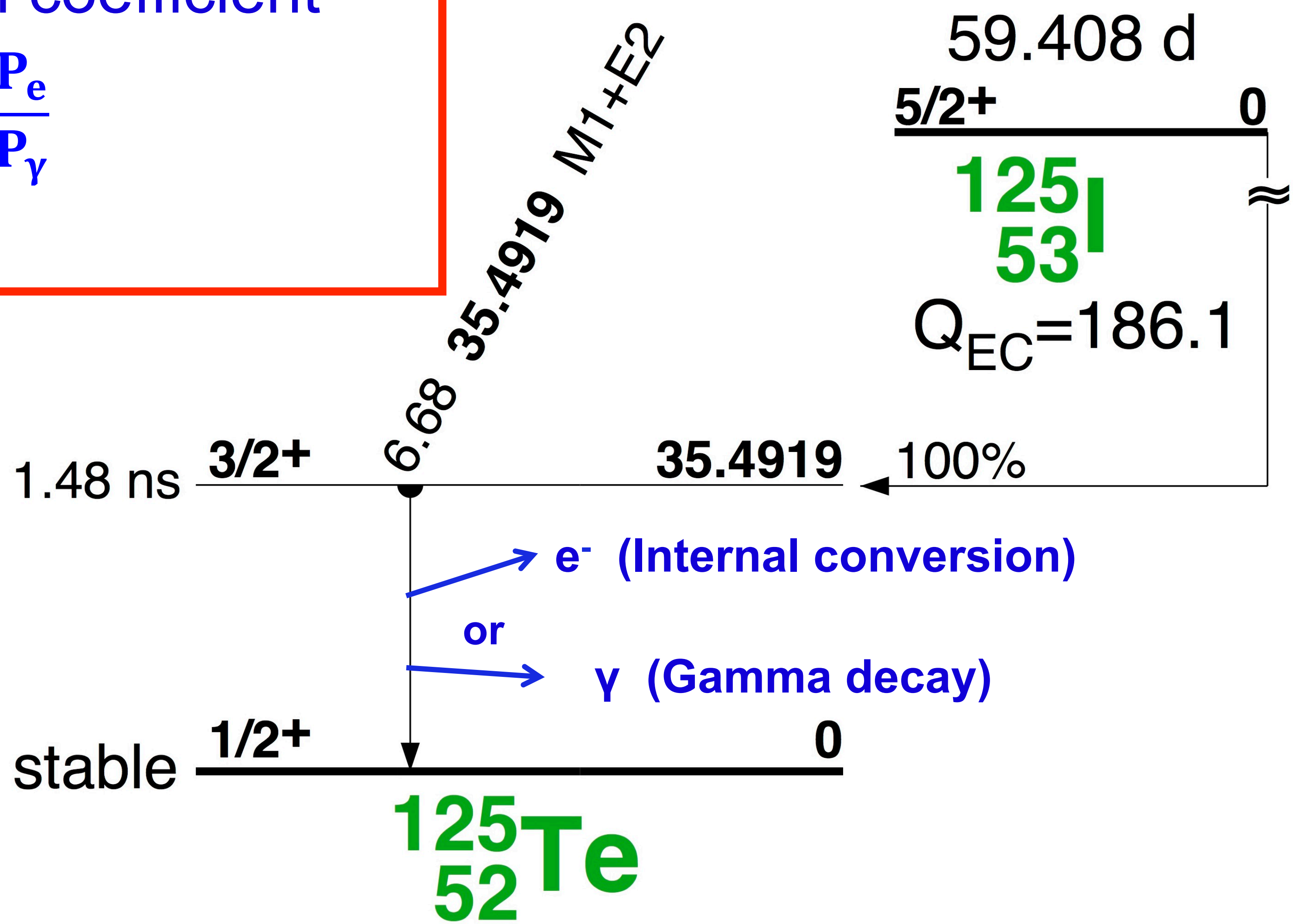
Decay scheme of ^{125}I



Decay scheme of ^{125}I

Conversion coefficient

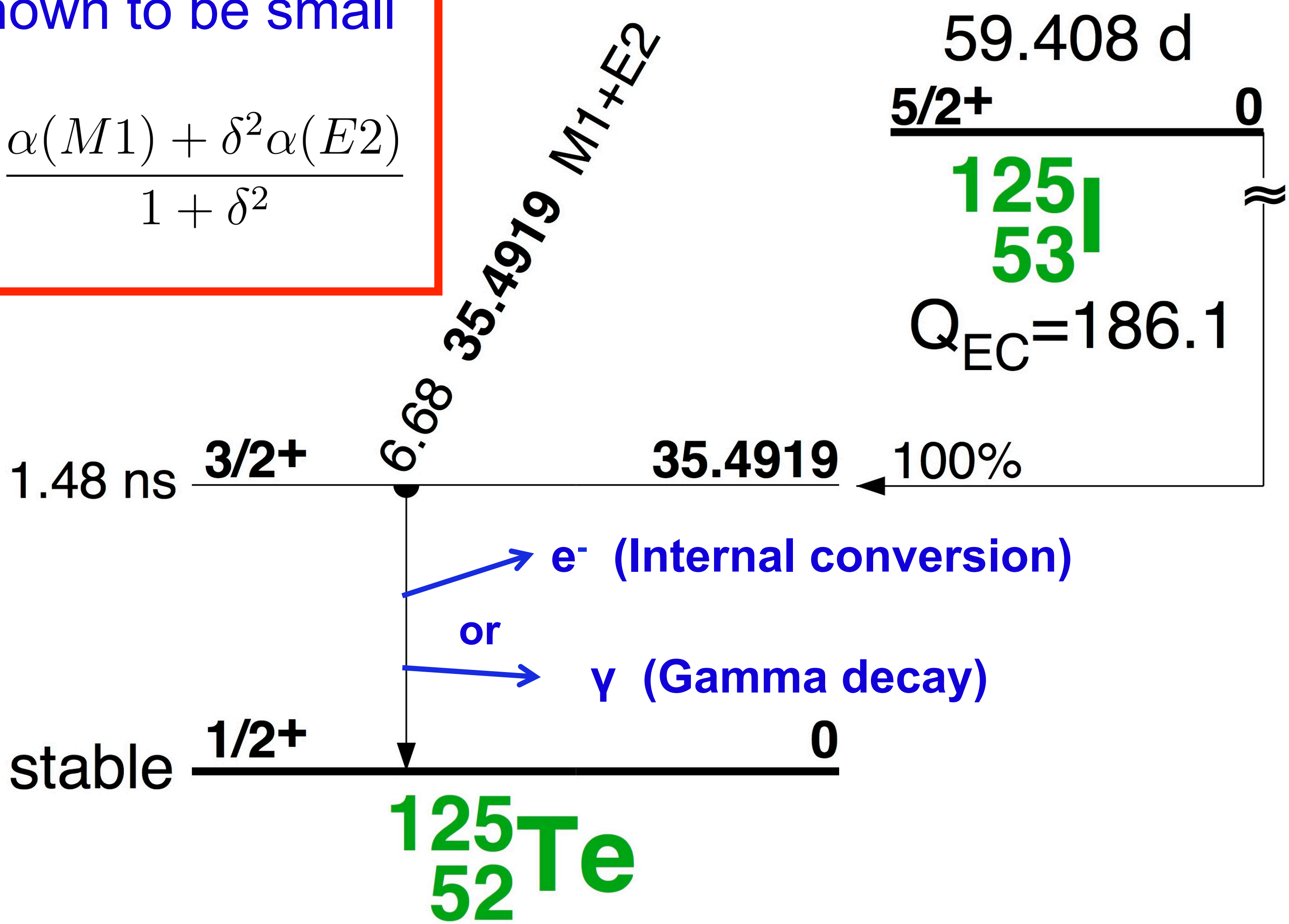
$$\alpha = \frac{P_e}{P_\gamma}$$



Decay scheme of ^{125}I

Mixing ratio of the M1+E2 transition is known to be small (δ<< 1).

$$\alpha(M1+E2) = \frac{\alpha(M1) + \delta^2\alpha(E2)}{1+\delta^2}$$

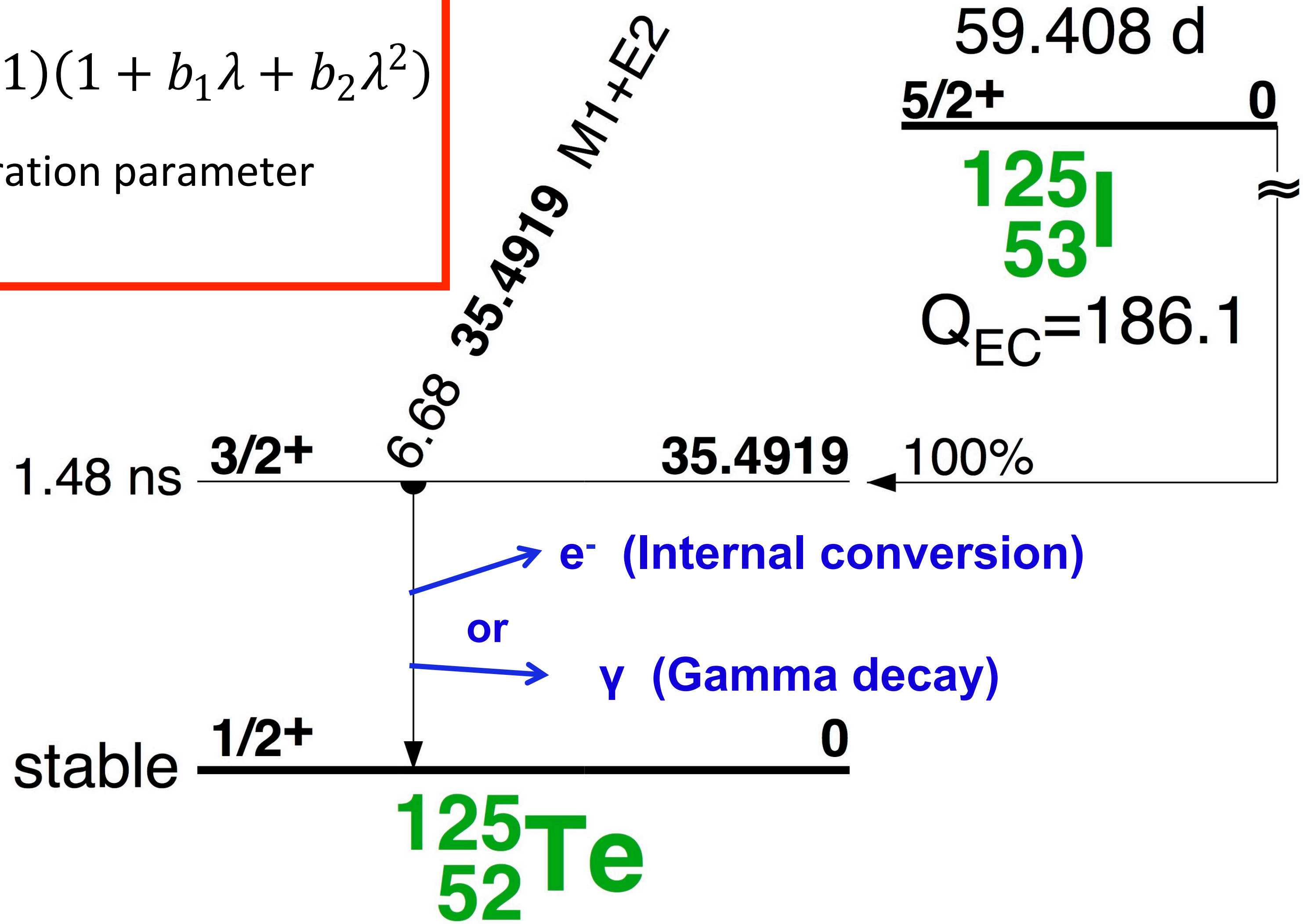


Decay scheme of ^{125}I

Penetration effects

$$\alpha(\mathrm{M1}) = \alpha_0(M1)(1 + b_1\lambda + b_2\lambda^2)$$

Where λ = penetration parameter



X-ray and Auger transitions

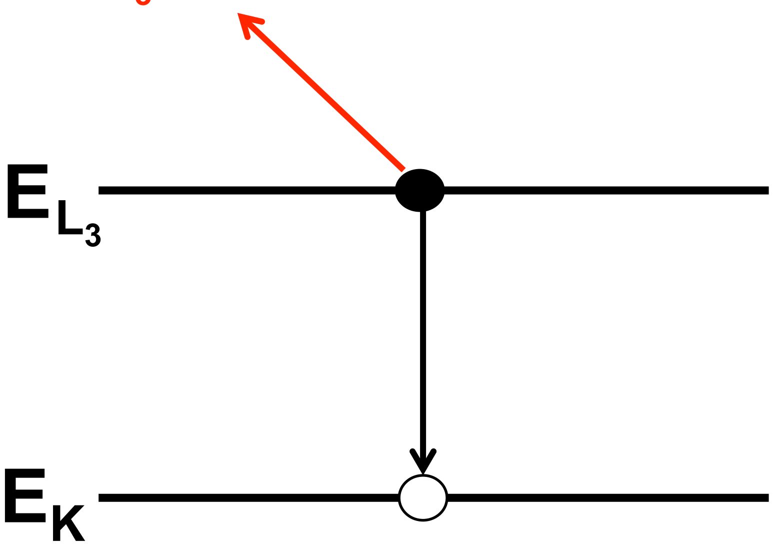
X-ray transition

K Auger yield

$$\omega_K + a_K = 1$$

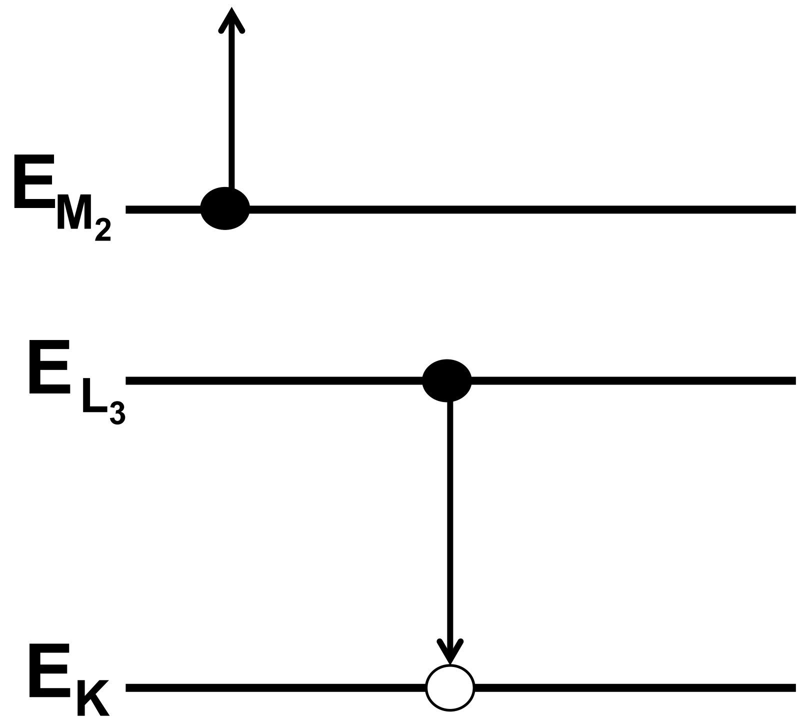
K fluorescence yield

$$E_{KL_3} \approx E_K - E_{L_3}$$



Auger transition

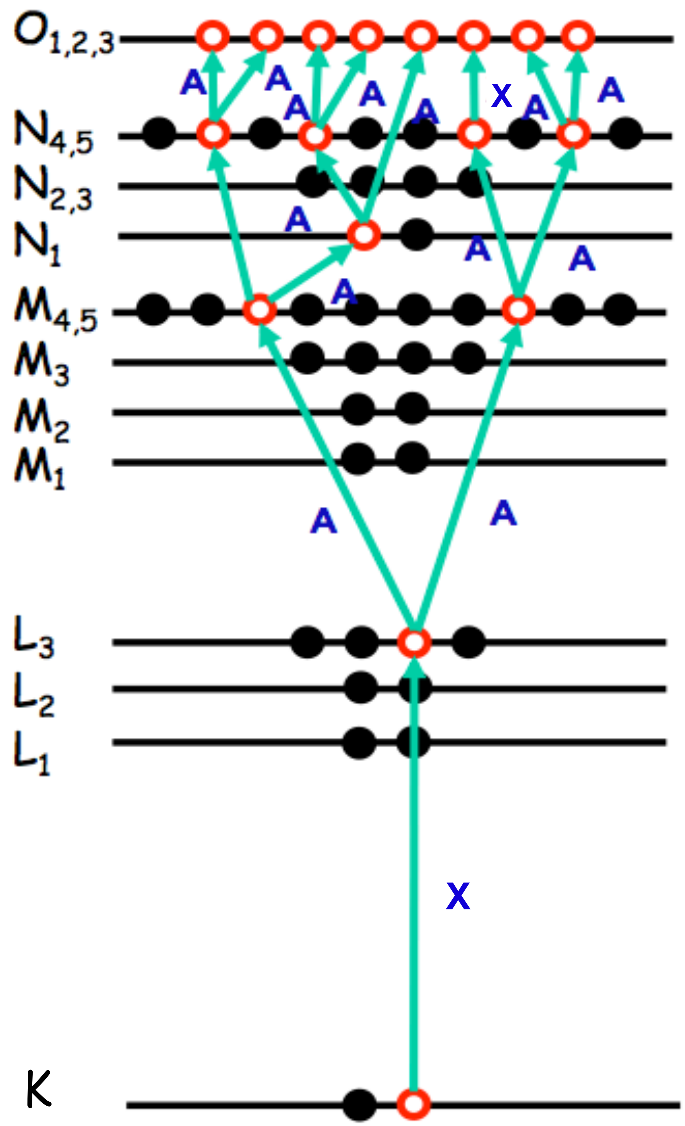
$$E_{KL_3M_2} \approx E_K - E_{L_3} - E_{M_2}$$



*Atomic notations: $K = 1s_{1/2}$, $L_3 = 2p_{3/2}$, $M_2 = 3p_{1/2}$

Vacancy cascade

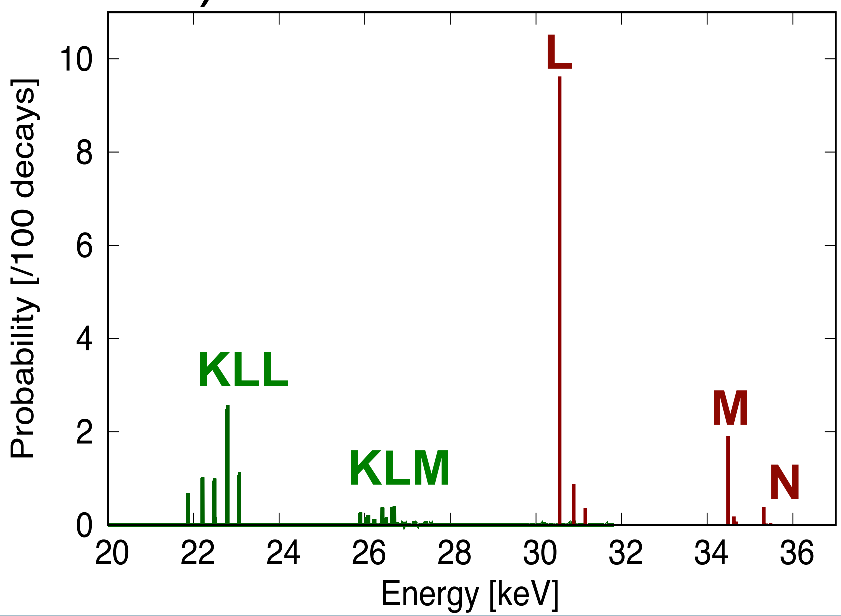
- Resulting in heaps of Auger electrons
- Energy range: a few eV to 30 keV (for ^{125}I case)



Note: X = X-ray transition, A = Auger transition

Computational model - BriccEmis

- Calculate the Auger and X-ray spectra using a Monte Carlo approach
- Transition probabilities from Evaluated Atomic Data Library (EADL) (Perkins 1991)
- Transition energies are calculated using the relativistic self-consistent-field Dirac Fock method, using RAINE code (Band 2002)



Project Aims

❖ Measure an accurate Auger yield from medical radioisotope ^{125}I

<u>Approach</u>

I. Determine the nuclear parameters (λ and δ)
II. Measure the Auger to conversion electrons intensity ratios.
III. Deduce the absolute intensity of Auger electrons from the conversion coefficients.

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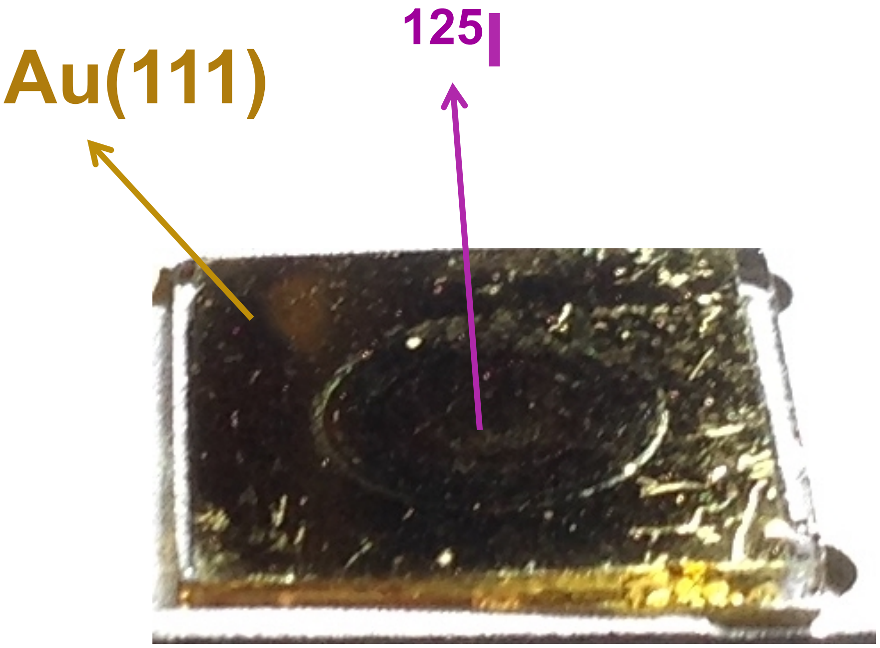
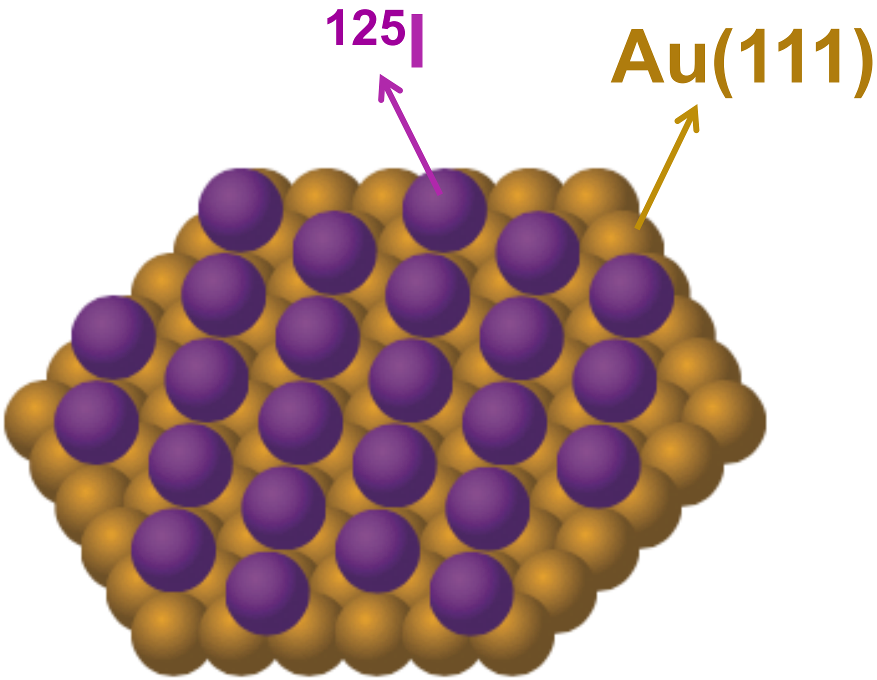
Project Aims

- Measure an accurate Auger yield from medical radioisotope ^{125}I
- Test and benchmark the model

Source preparation

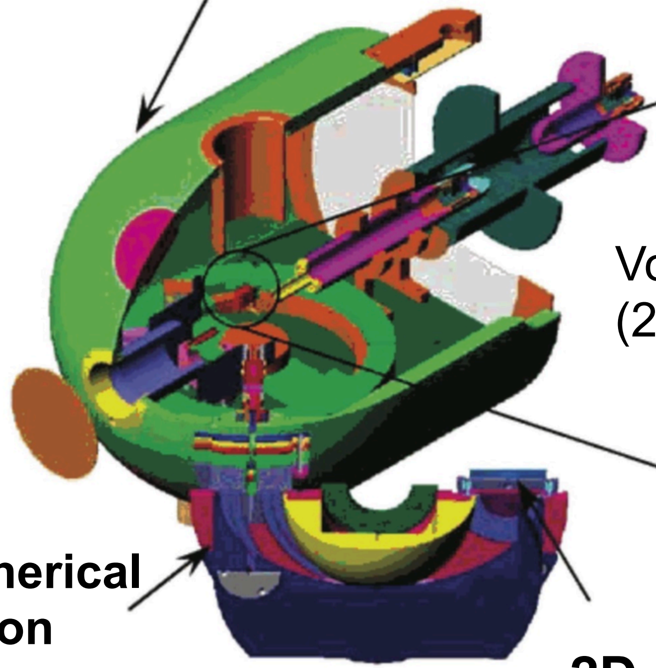
❖ Monolayer of ^{125}I on top of a gold substrate

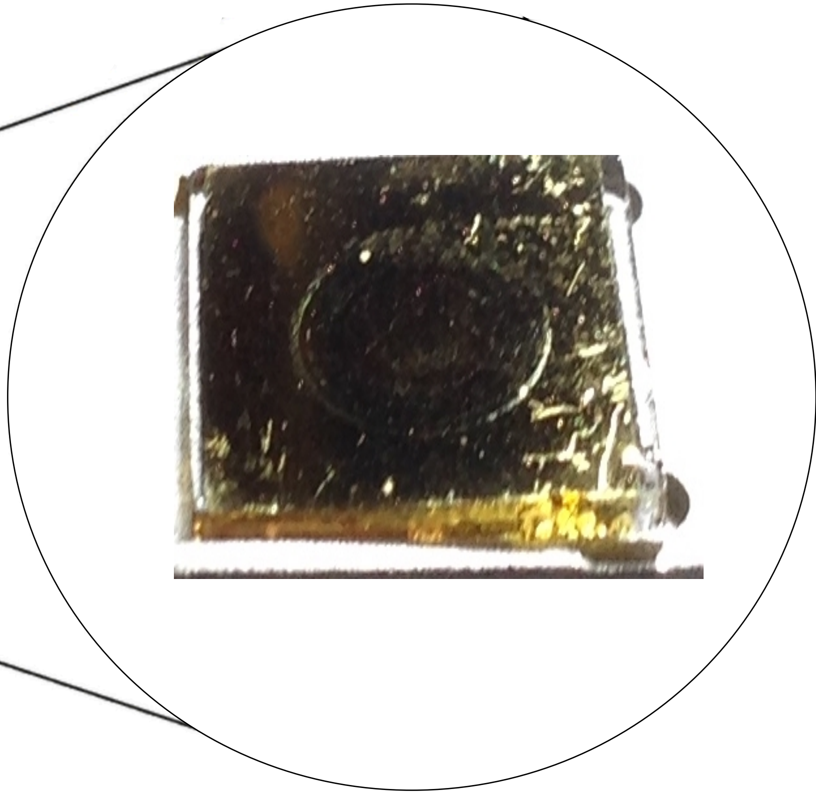




High-energy electrostatic spectrometer

HV hemisphere **(Positive high voltage)**





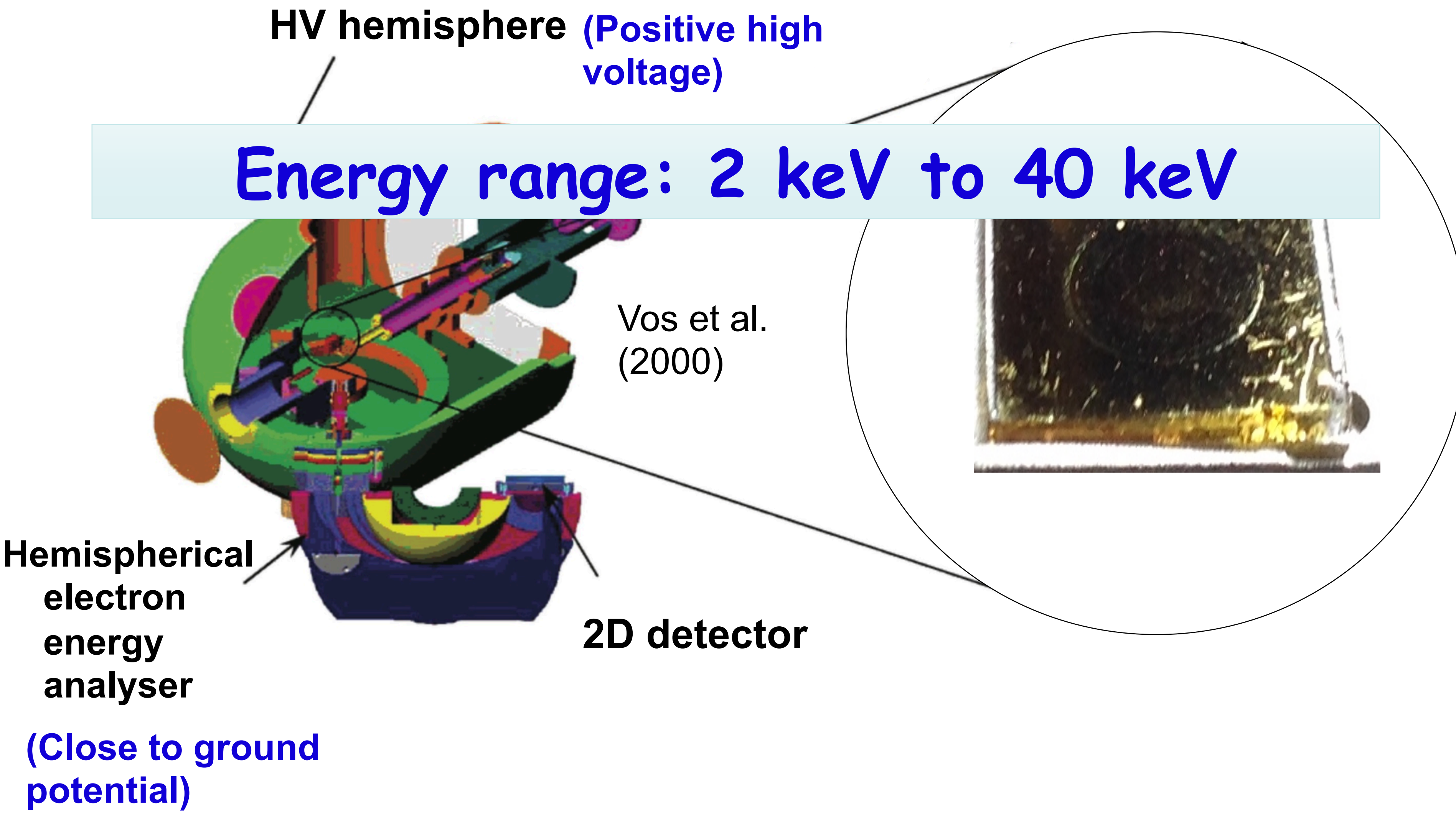
Vos et al. (2000)

Hemispherical electron energy analyser

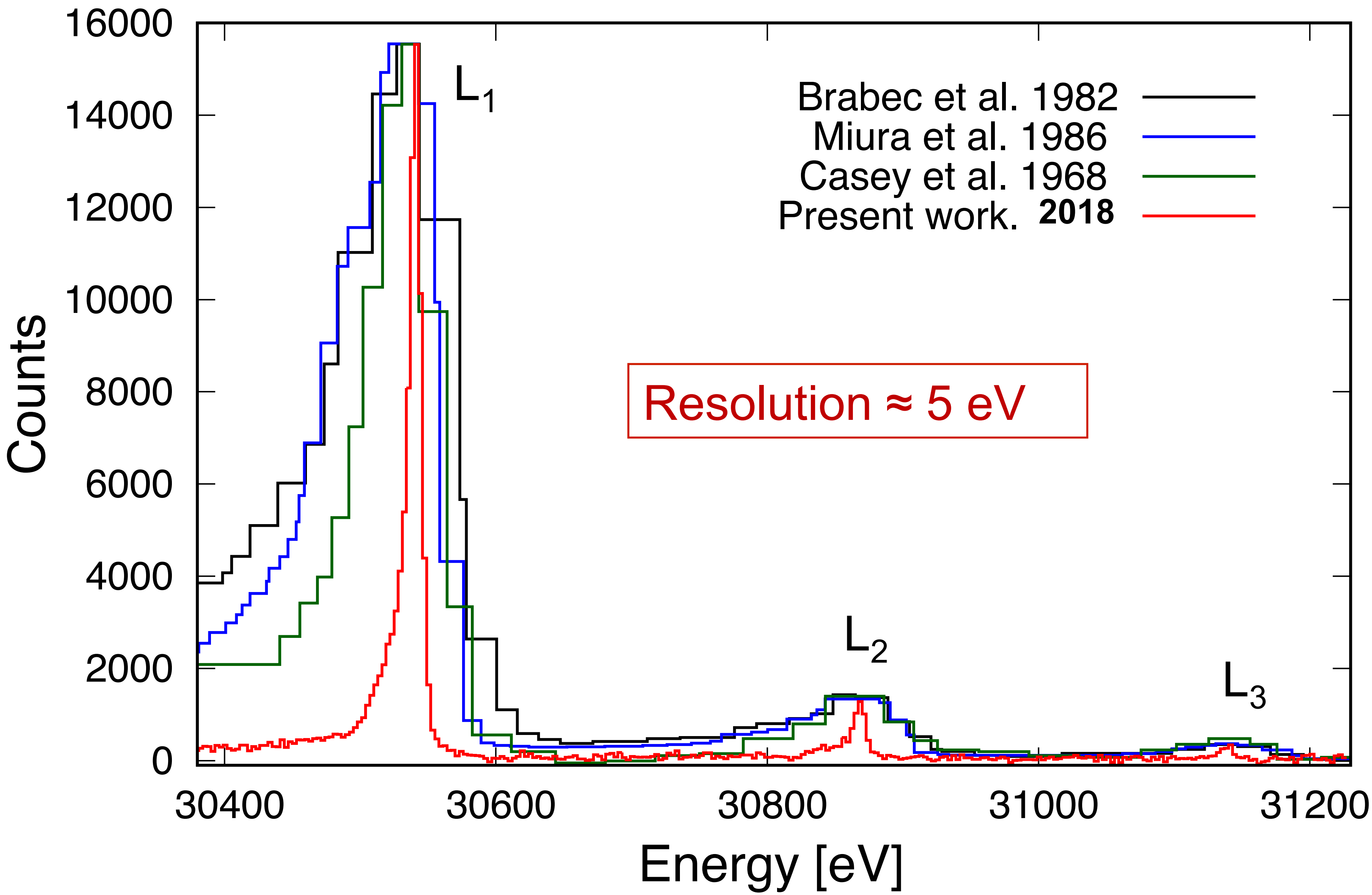
(Close to ground potential)

2D detector

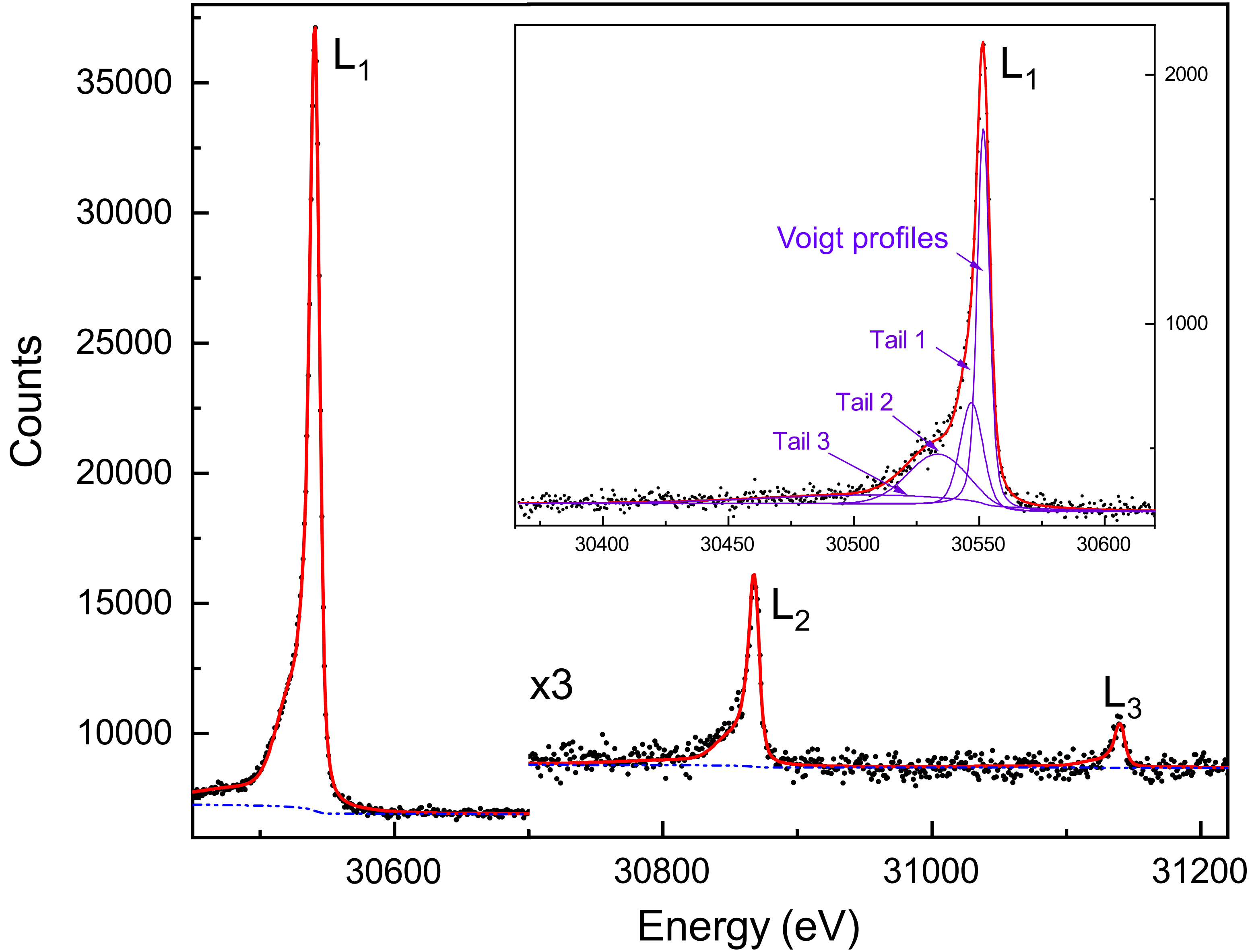
High-energy electrostatic spectrometer



Conversion electron measurements



Conversion electron line shapes



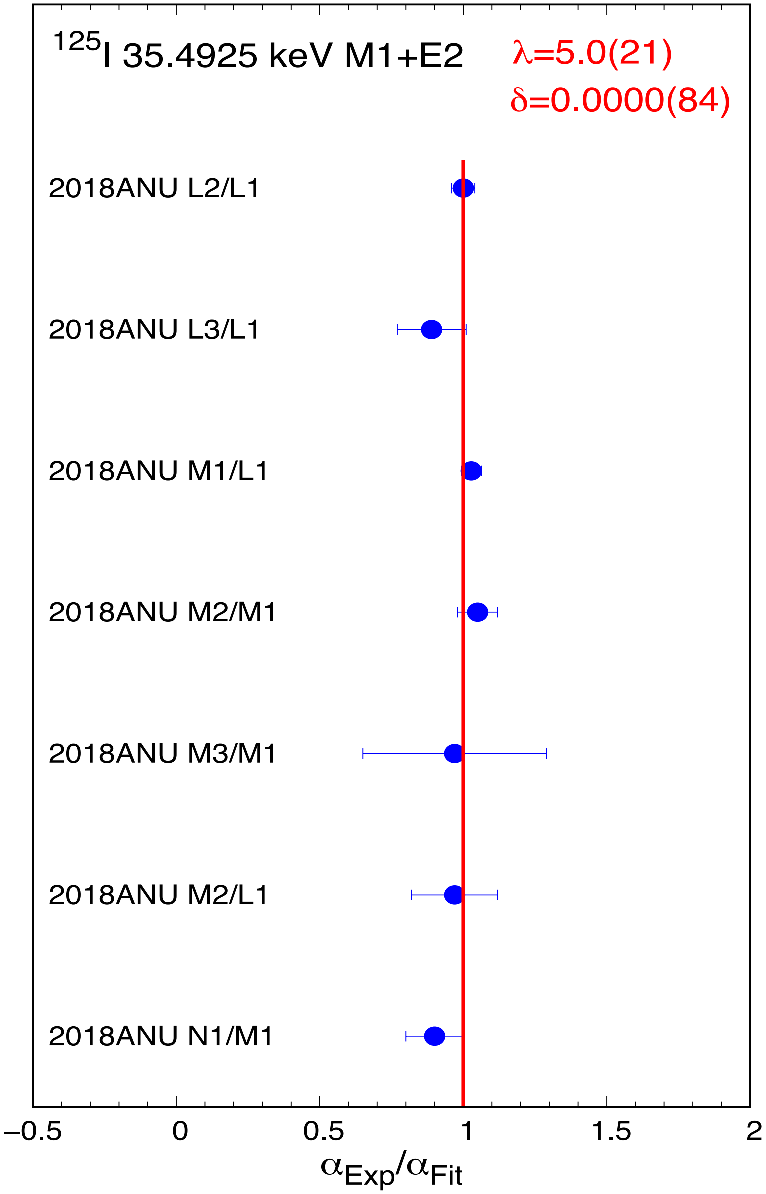
Nuclear parameters determination

ANU data only

- Chi-square fitting method
- Reduced $\chi^2 = 0.63$
- $\lambda = 5.0(21)$, $\delta = 0.0000(84)$

Atomic shell	Experiment: Present work	Experiment: Literature
$100/(1+Tot)$		6.68(14) [12] 6.55(13) [13]
Tot		12.95(28) [15] [a] 14.25(64) [8]
$K/(1+Tot)$		0.80(5) [16] 0.804(10) [17]
$L/(1+Tot)$ $M/(1+Tot)$		0.11(2) [16] 0.020(4) [16]
K		11.78(18) [a] [15] 11.90(31) [8]
L K/L L/M M/N		1.4(1) [18] 12.3(25) [10] 5.21(26) [9] 4.87(20) [9]
$L_1{:}L_2{:}L_3$	1:0.085(2):0.019(2)	1:0.089(4):0.024(2) [7] 1:0.106(22):0.041(2) [10] 1:0.082(4):0.019(3) [8] 1:0.095(2):0.023(5) [9]
$L_1{:}M_1$	1: 0.204(7)	-
$M_1{:}M_2{:}M_3$	1:0.094(6):0.022(7)	1:0.092(5):0.044(3) [8] 1:0.101(5):0.030(5) [9]
$L_1{:}M_2$ $M_1{:}N_1$	1:0.0173(26) 1:0.179(20)	- 1:0.214(6) [9]

[a] Corrected ω_K to 0.875



Nuclear parameters determination

Australian National University

All data

- Chi-square fitting method
- Reduced $\chi^2 = 1.55$
- $\lambda = 0.2(7)$, $\delta = 0.0132(71)$

Atomic shell	Experiment: Present work	Experiment: Literature
$100/(1+Tot)$		6.68(14) [12] 6.55(13) [13]
Tot		12.95(28) [15] [a] 14.25(64) [8]
$K/(1+Tot)$		0.80(5) [16] 0.804(10) [17]
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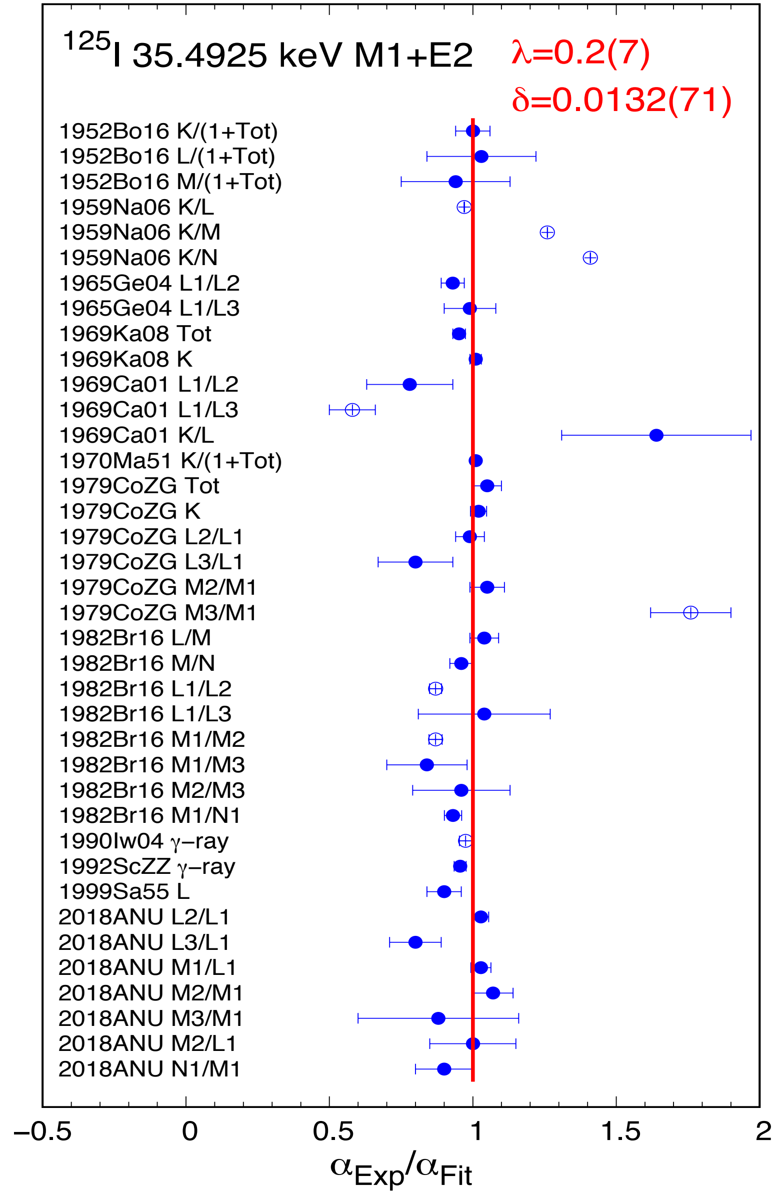
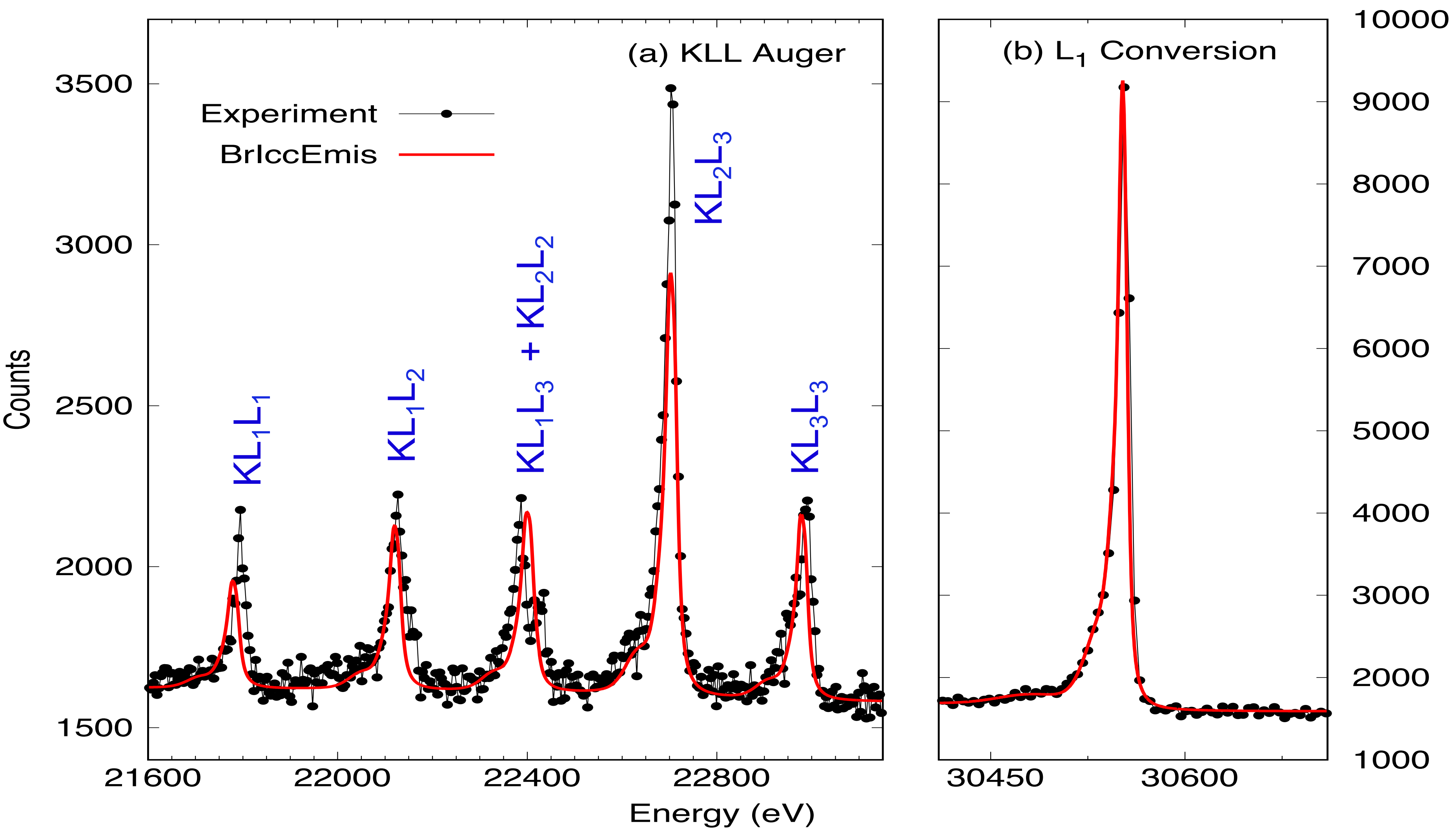
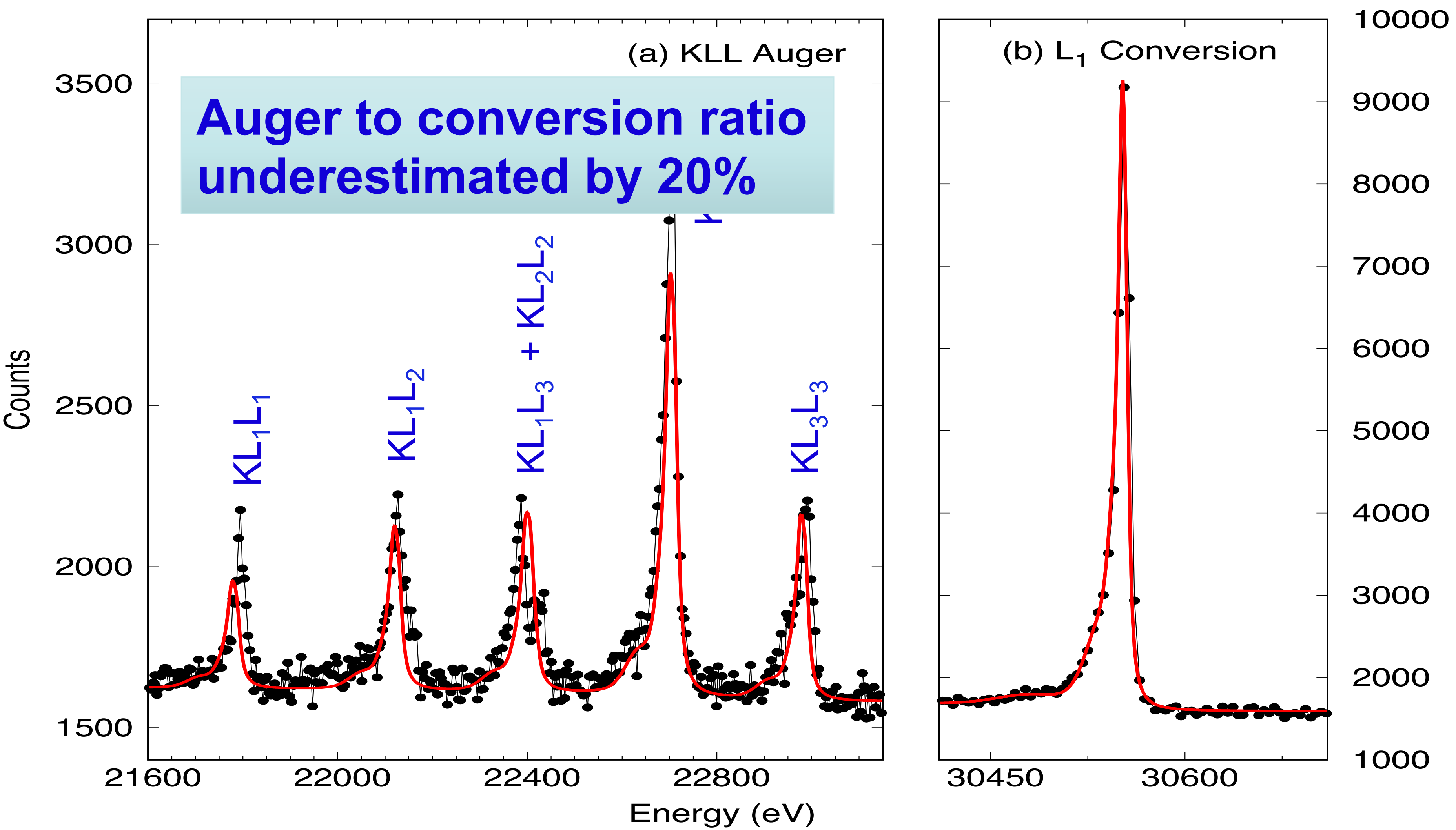


KLL Auger electron measurements

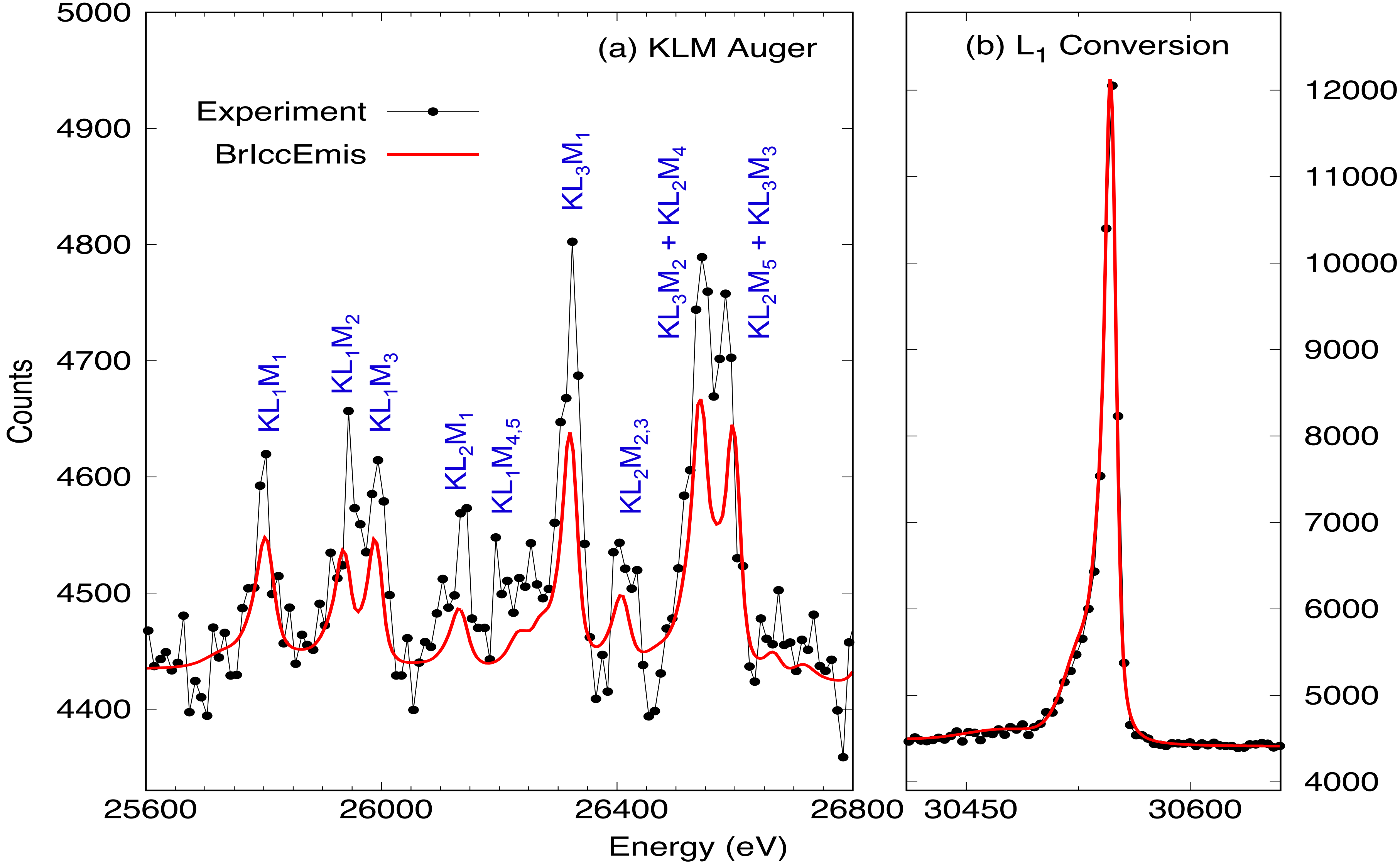


KLL Auger electron measurements

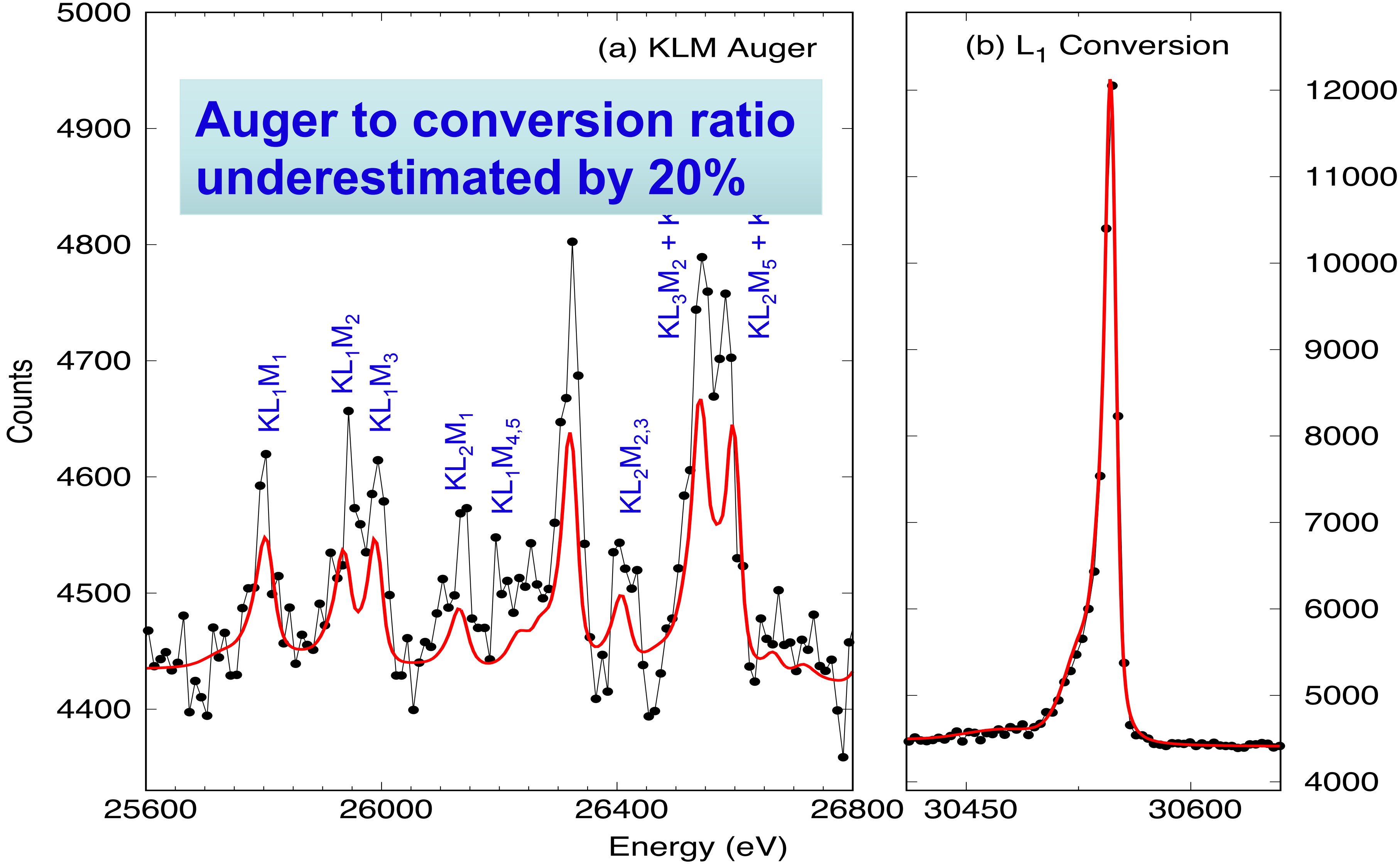


Auger to conversion ratio underestimated by 20%

KLM Auger electron measurements



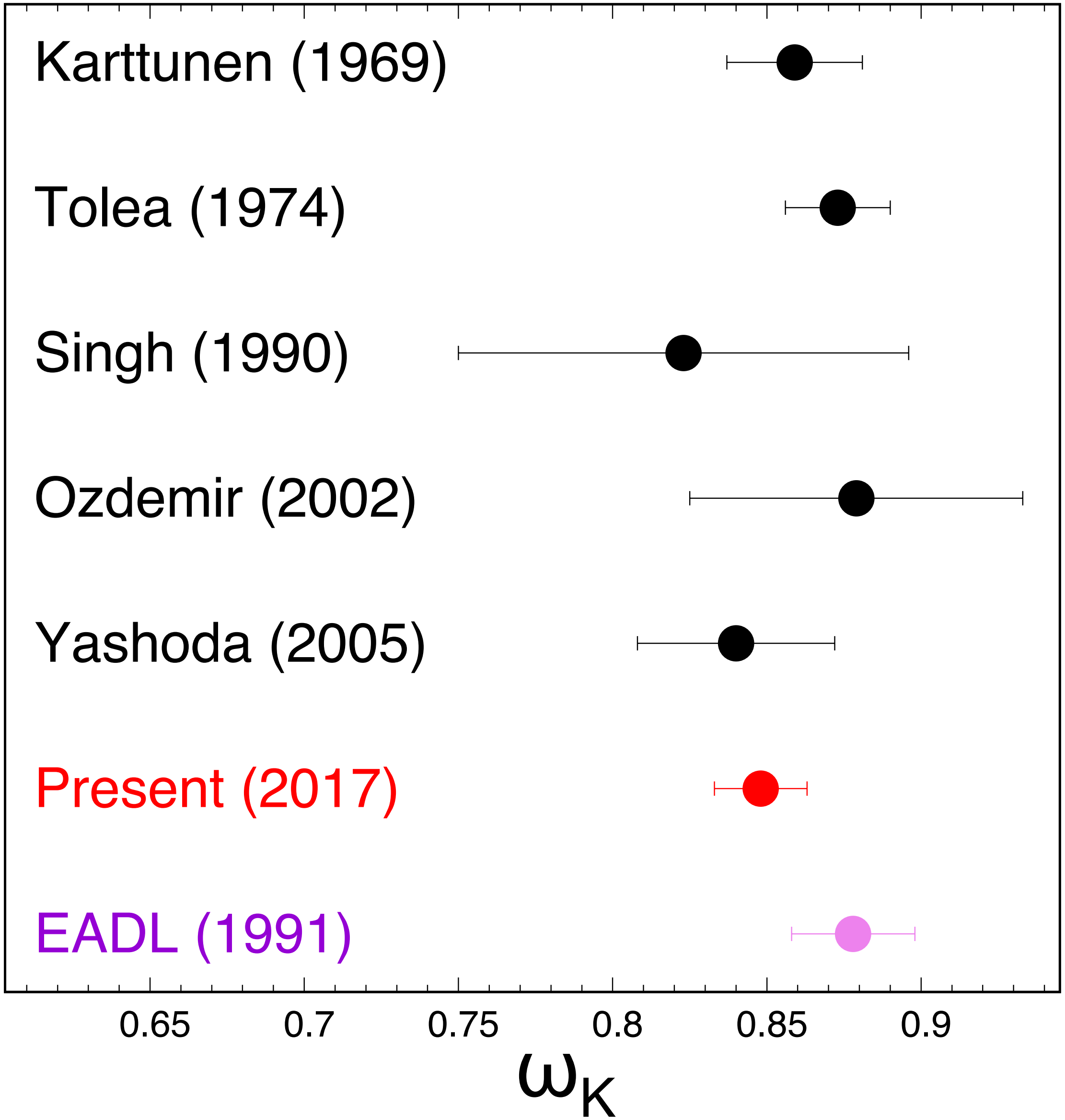
KLM Auger electron measurements



K fluorescence yield determination

$$\omega_K + a_K = 1$$

ω_K	a_K
0.87	0.13
5%	**30%**
0.85	0.15
2%	**10%**
0.88	0.12
3%	**20%**



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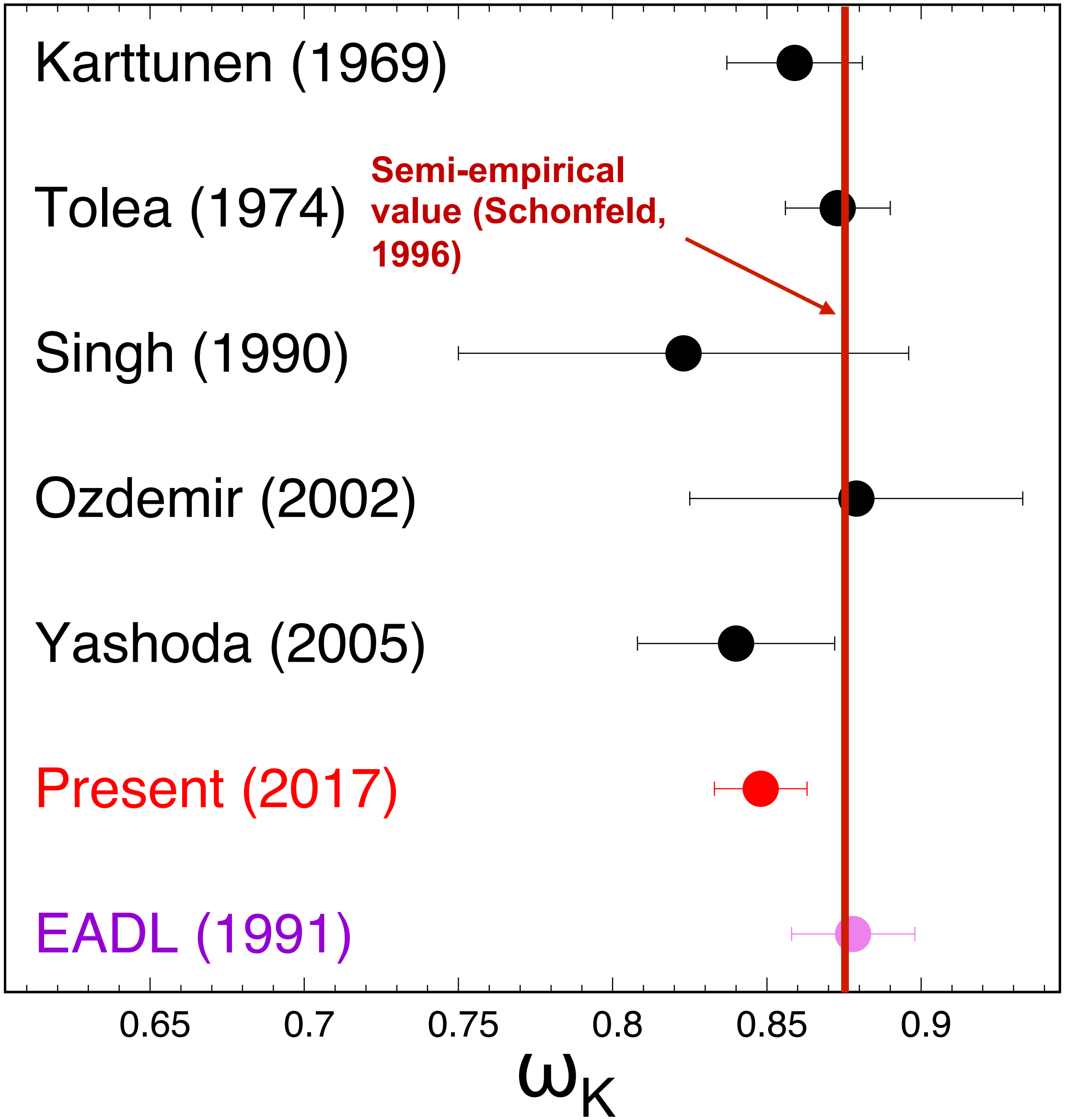
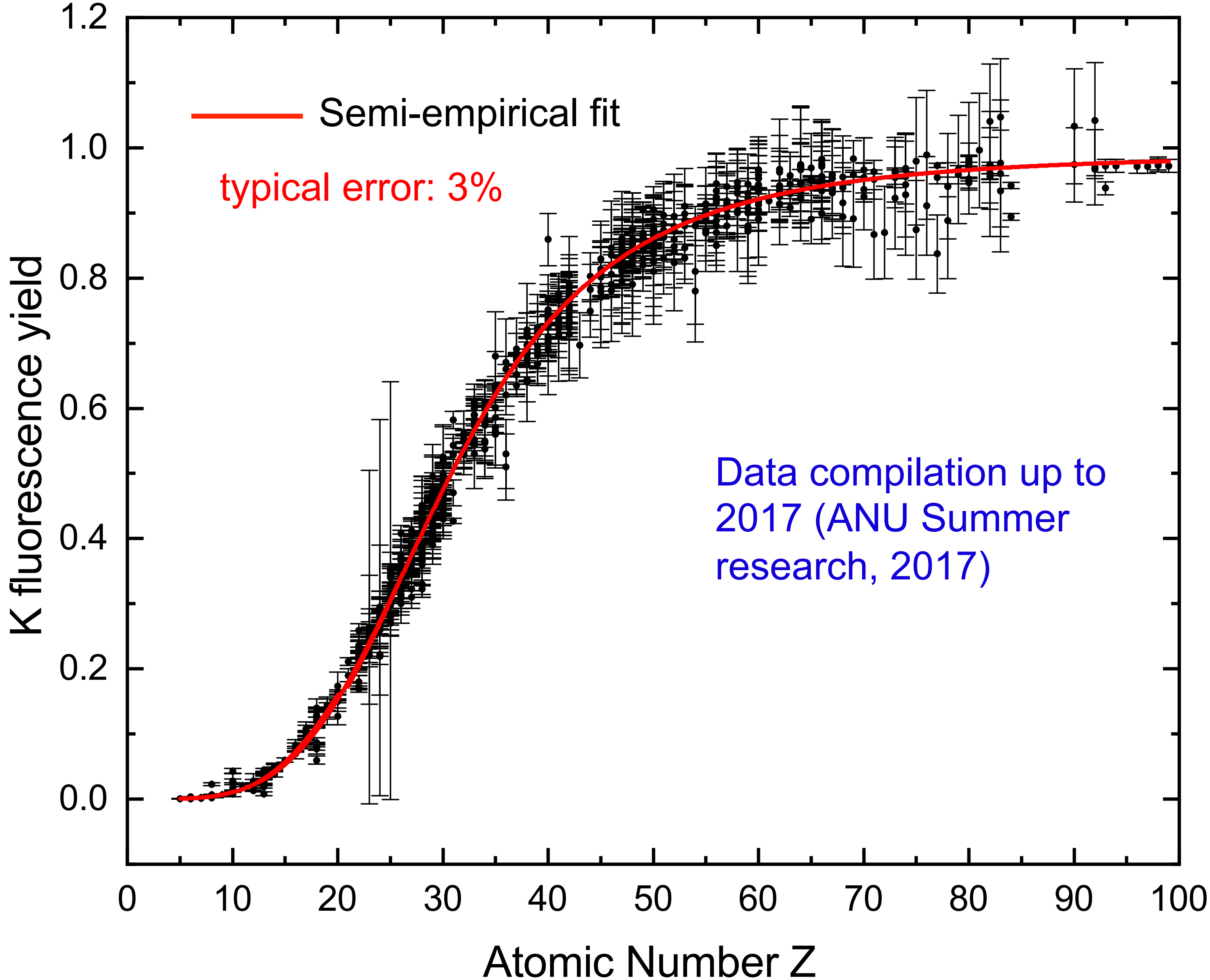


K fluorescence yield global fit curve



What to do next?

- Quantify the Auger electrons with energy < 1 keV
- Effects of electron shake-off following internal conversion and Auger transition (the tails)
- Atomic structure effect: What is the atomic field after electron capture
- Potential medical isotopes to study: ^{80m}Br, ^{99m}Tc, ^{99}Mo, ^{119}Sc, ^{153}Sm, ^{177}Lu, ^{193m}Pt, ^{195m}Pt, ^{201}Tl, ^{80m}Br

Acknowledgement

- <u>Supervisors</u>

1. Dr. Tibor Kibédi
2. A/Prof. Maarten Vos
3. Prof. Andrew Stuchbery

- <u>Collaborators</u>

1. M. Alotiby
2. B.Q Lee
3. ANSTO (Australian Nuclear Science and Technology Organisation)