



European Nuclear Physics Conference 2025

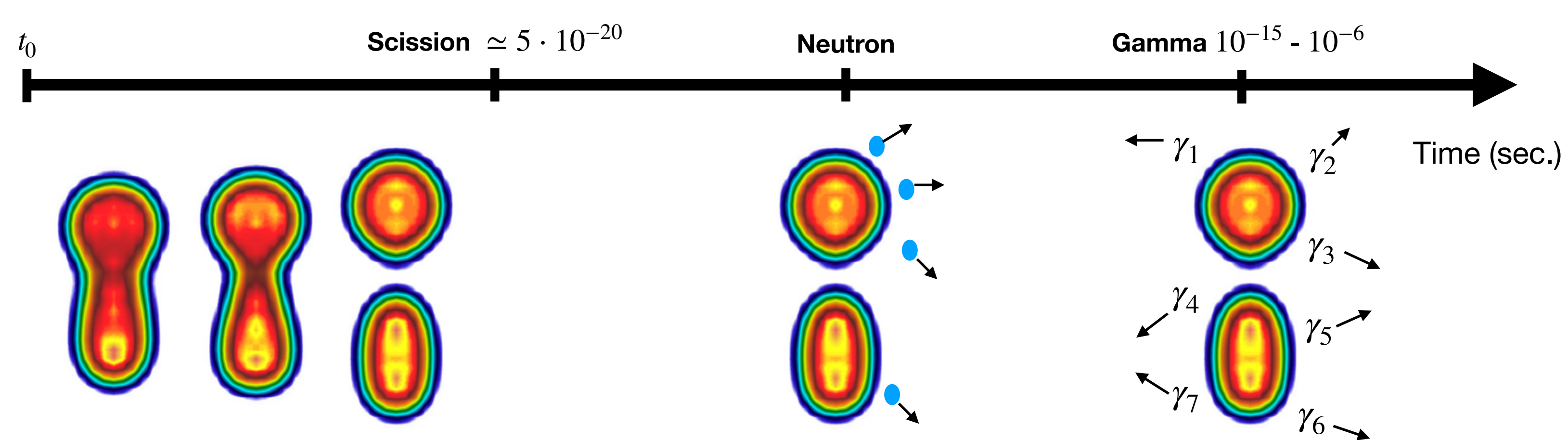
Insights on Fission from the neutronless channel

L. Gaudefroy - CEA - Saclay

A. Francheteau, O. Roig, G. Scamps, V. Méot, A. Ebran

Sept. 2025

Studying the decay of the fragments?



A. Bulgac et al., PRL **116**, 122504 (2016)

Fission numbers for ^{252}Cf

$$\bar{Q} \sim 218 \text{ MeV}$$

$$\overline{TKE} = 184 \text{ MeV}$$

$$\overline{TXE} = \bar{Q} - \overline{TKE} \sim 34 \text{ MeV}$$

$$\bar{E}_n = \bar{\nu} * (\bar{B}_n + \bar{\eta}) = 27 \text{ MeV}$$

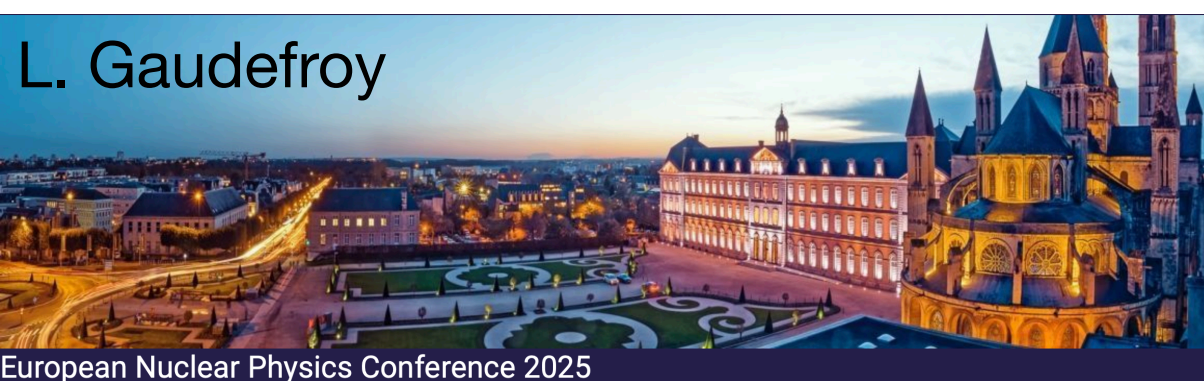
$$\bar{M}_\gamma = 8.4 \gamma / \text{fis}$$

$$\bar{J}_l + \bar{J}_H \sim 10-15 \hbar$$

An experimental challenge to :

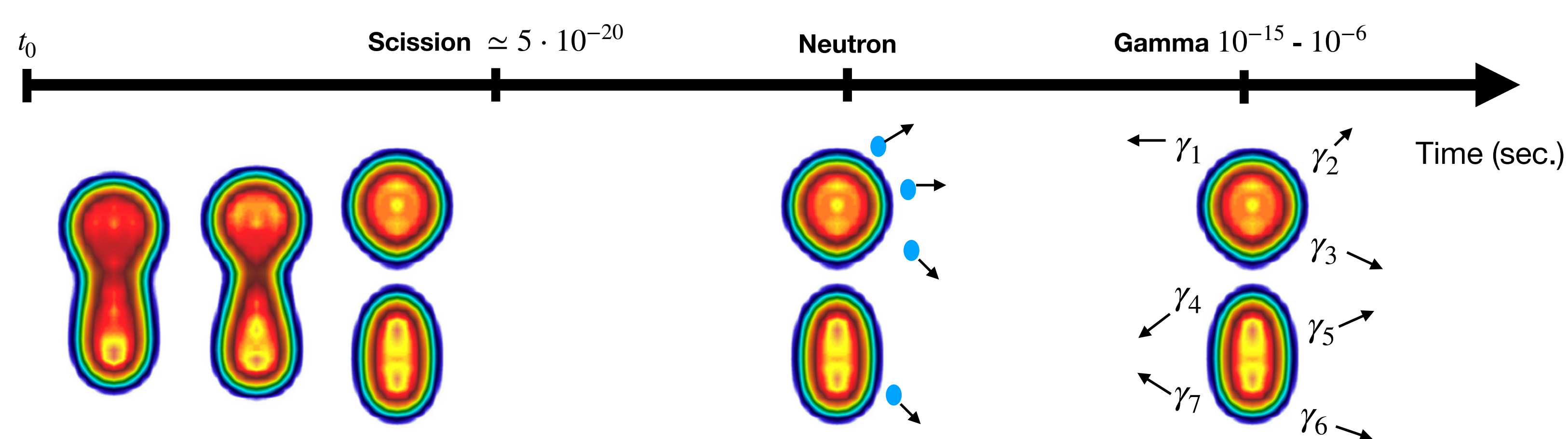
Identify the fragments

Correctly measure their decay



L. Gaudefroy

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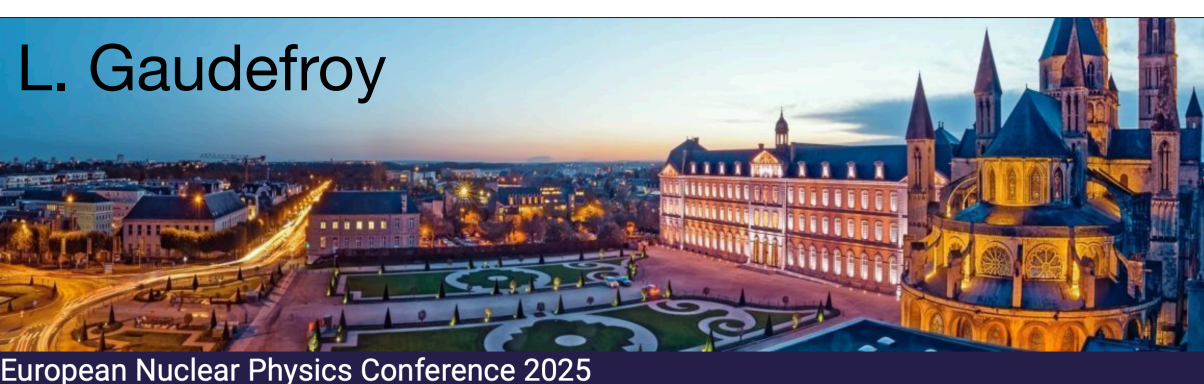
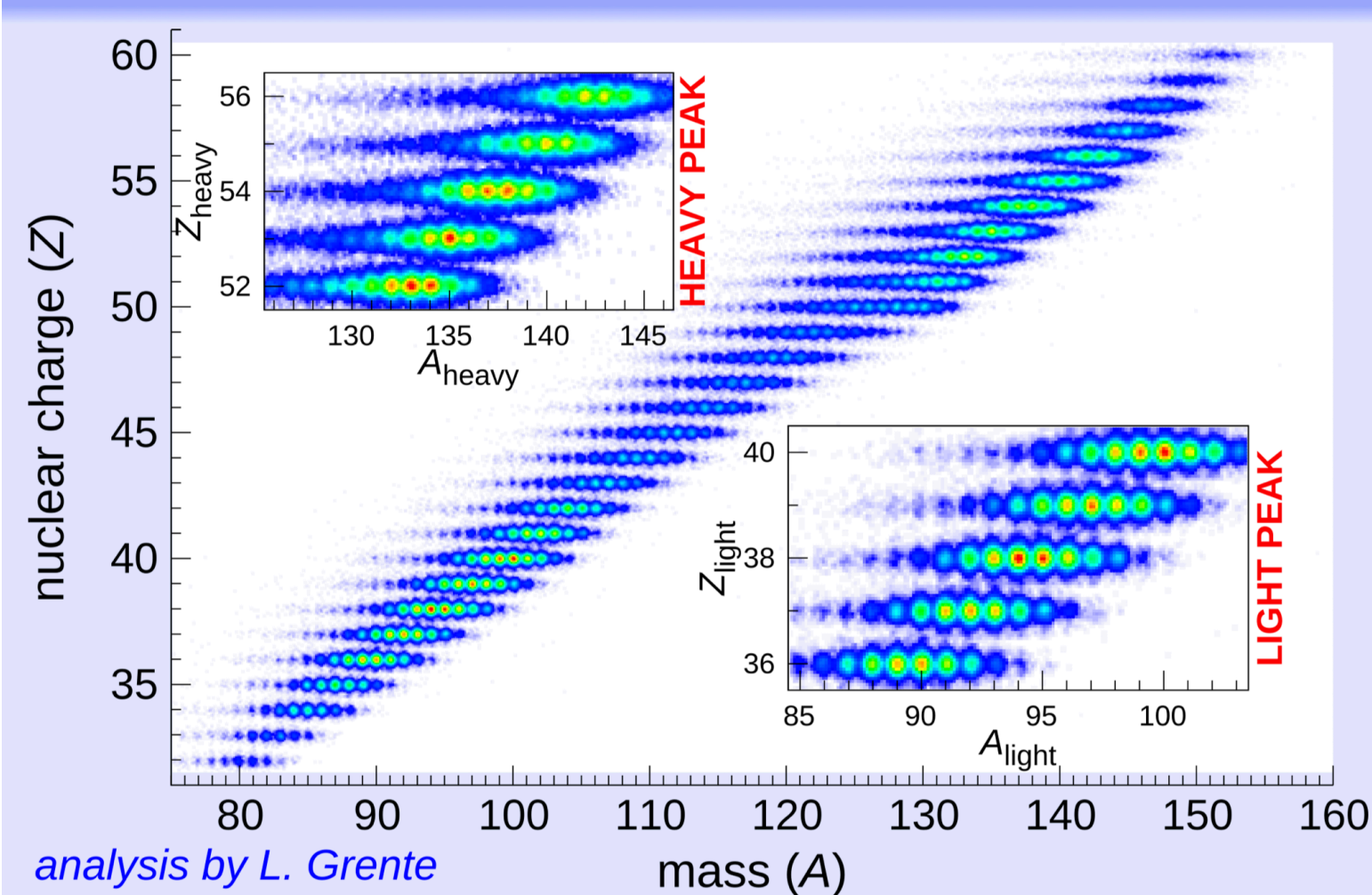
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Sofia @ GSI or alternatively VAMOS @ GANIL

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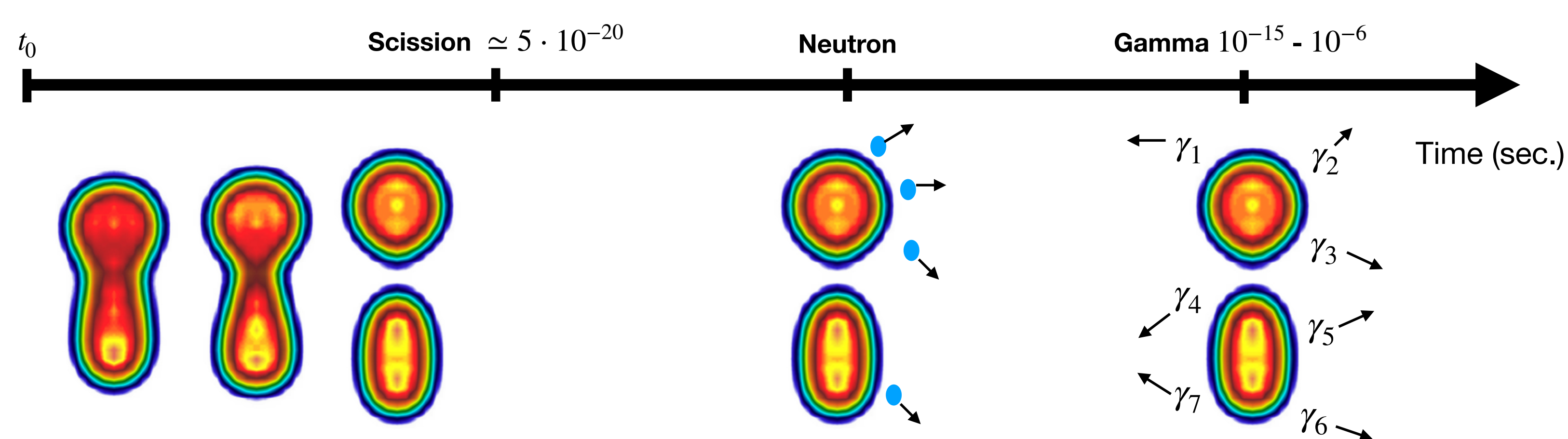
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ΔE -B ρ -ToF applied at Cave C



L. Gaudefroy

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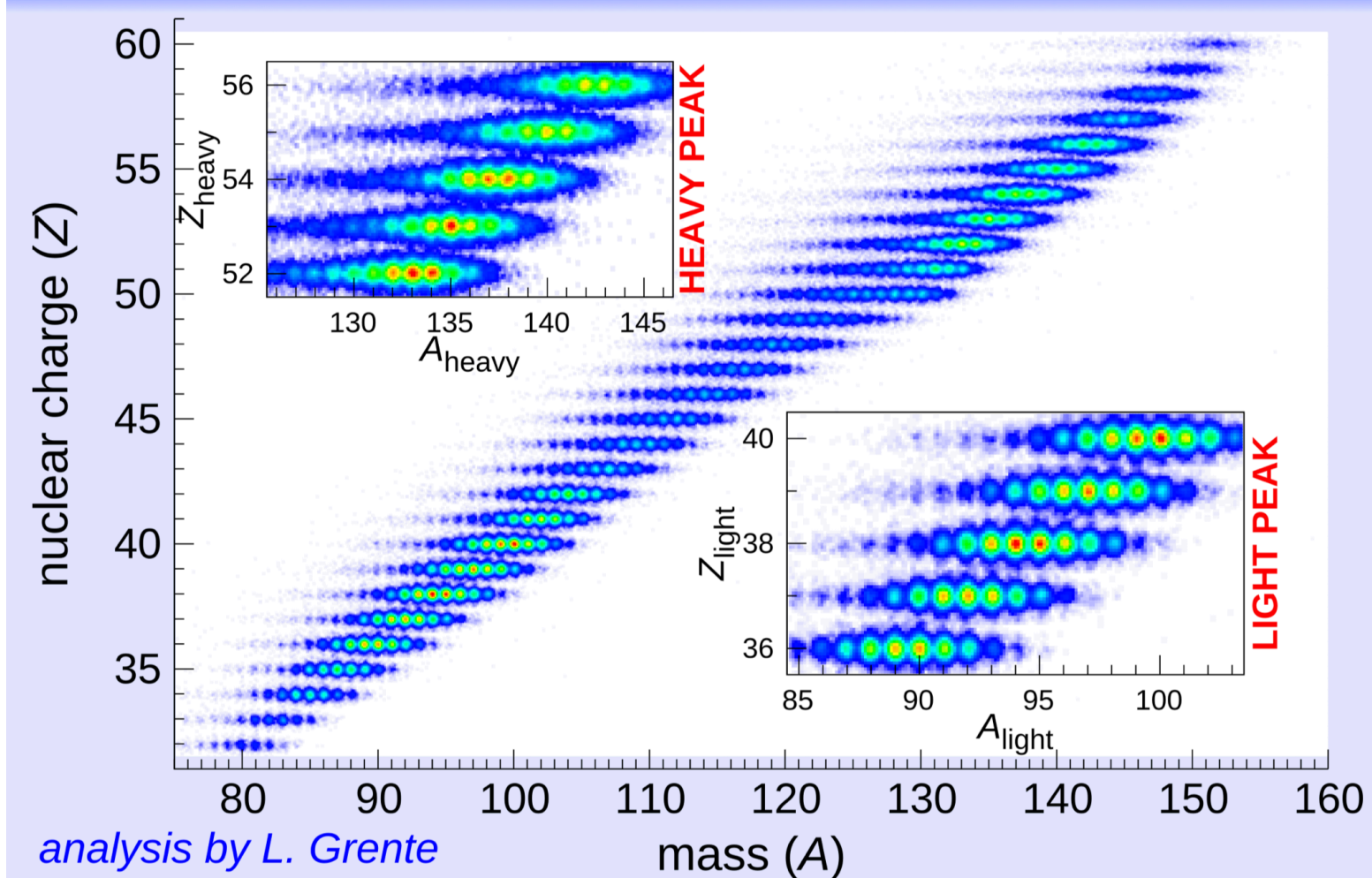
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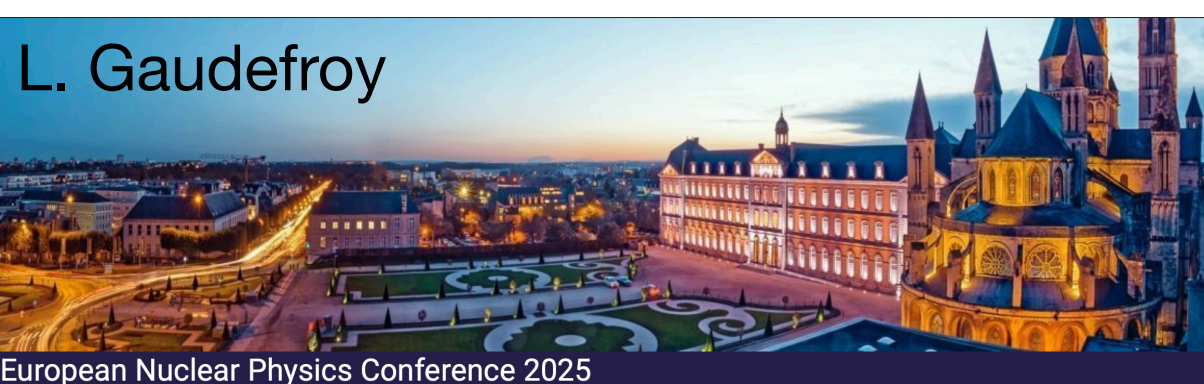
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An experimental challenge to :

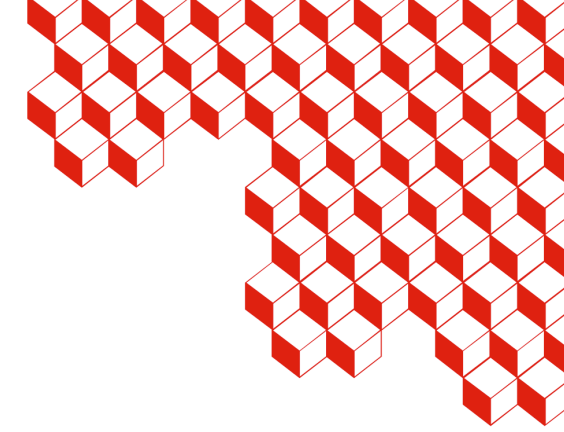
- Identify the fragments
- Correctly measure their decay

How do we combine FF Id + decay measurement ?

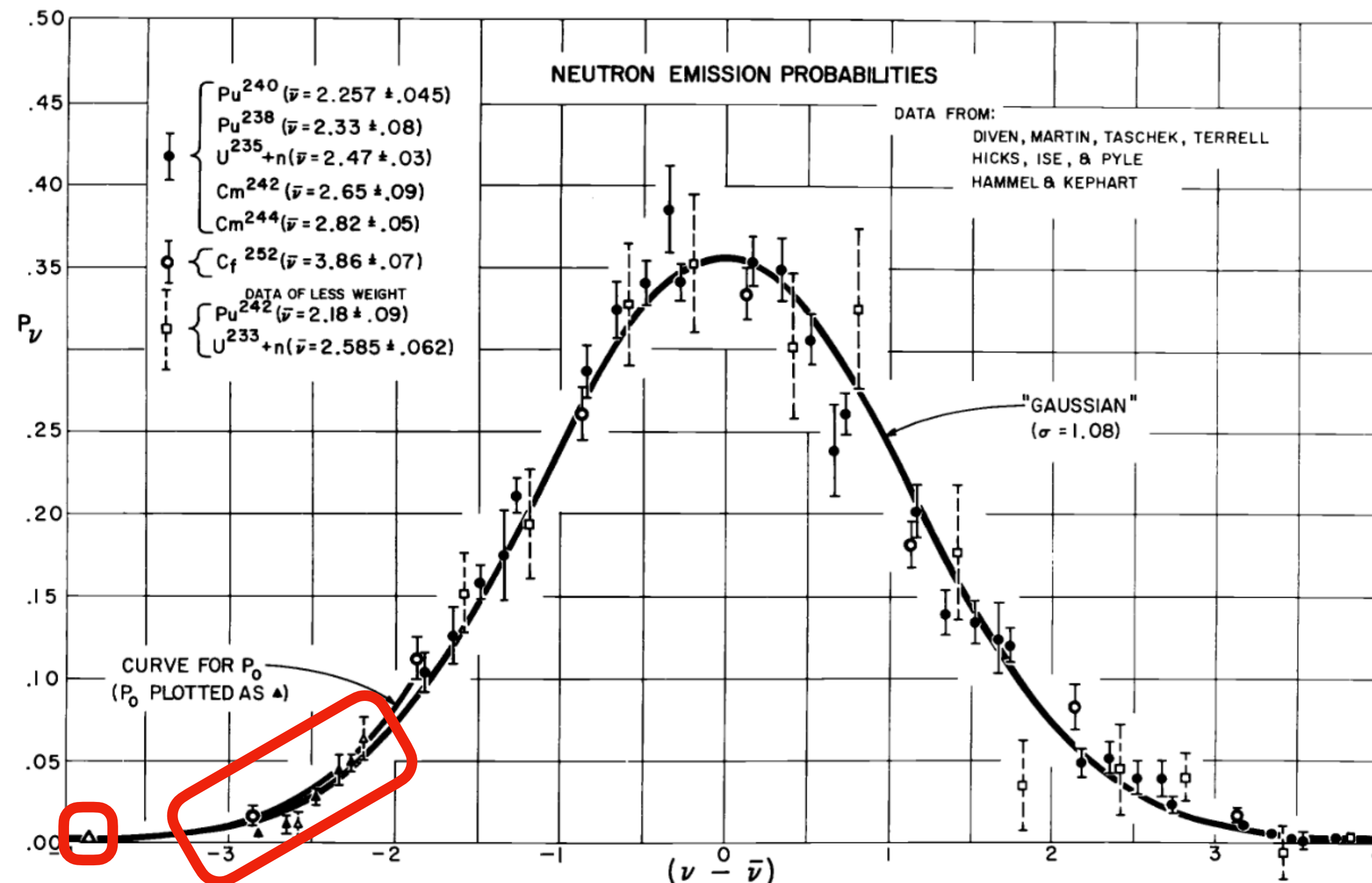


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The neutronless side of fission



J. Terrell, Phys. Rev. **108** 783 (1957)



Huge experimental simplification for fragment ID

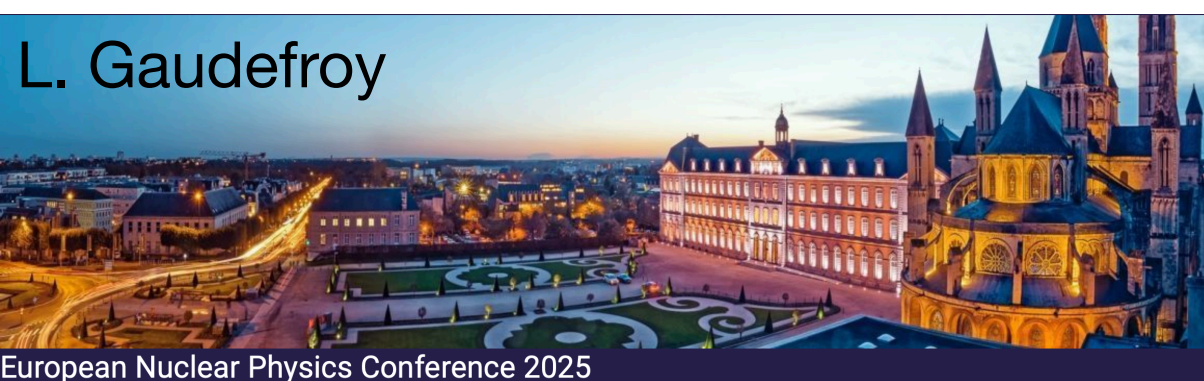
=> Possibility of compact FF detector

$$KE_L/KE_H = A_H/A_L$$

=> Decay = only gamma rays

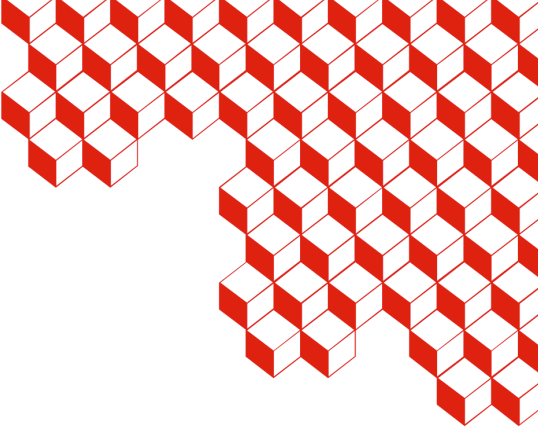
=> Highly efficient gamma array

$P_{\nu=0}$: Small Probability of occurrence

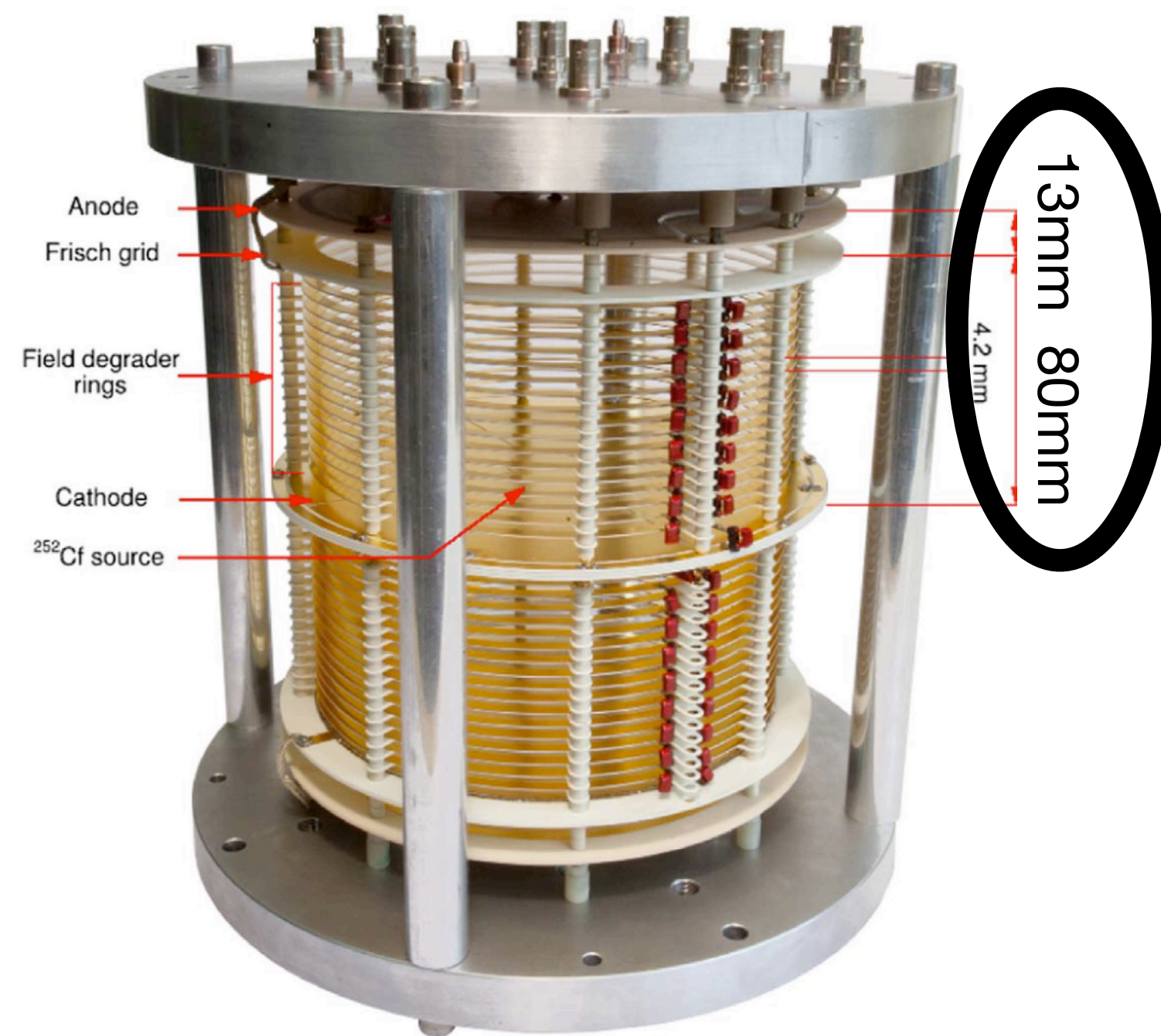


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Studying neutronless fission



A fragment detector...

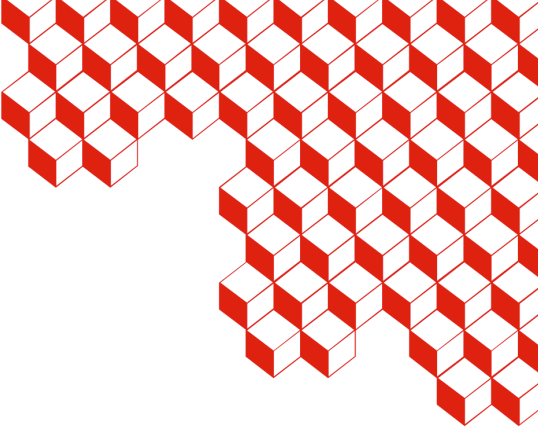


Twin Frisch Ionization Chamber ($\sigma_E = 400keV$)

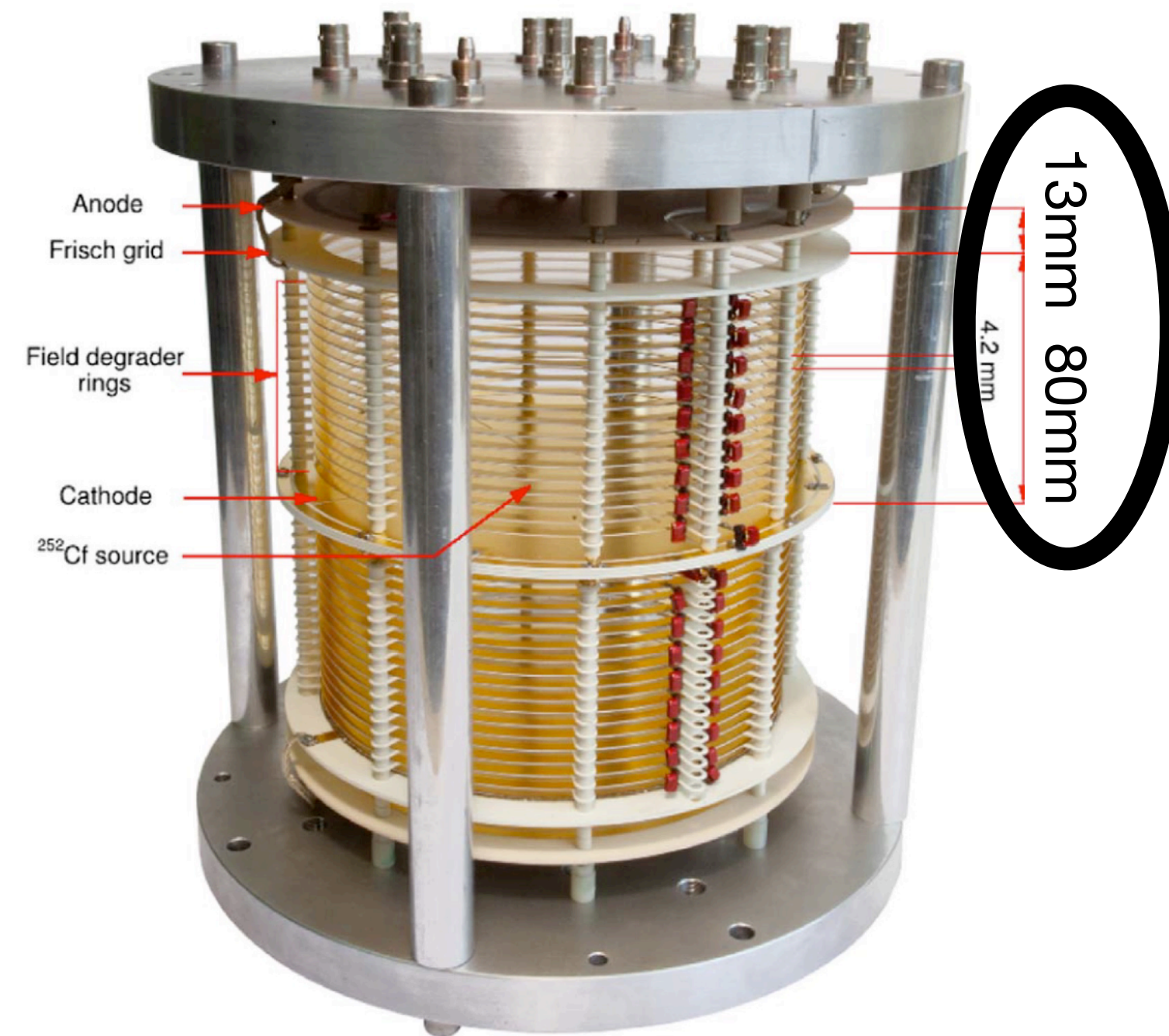
L. G. et al., NIMA **855**, 133 (2017)



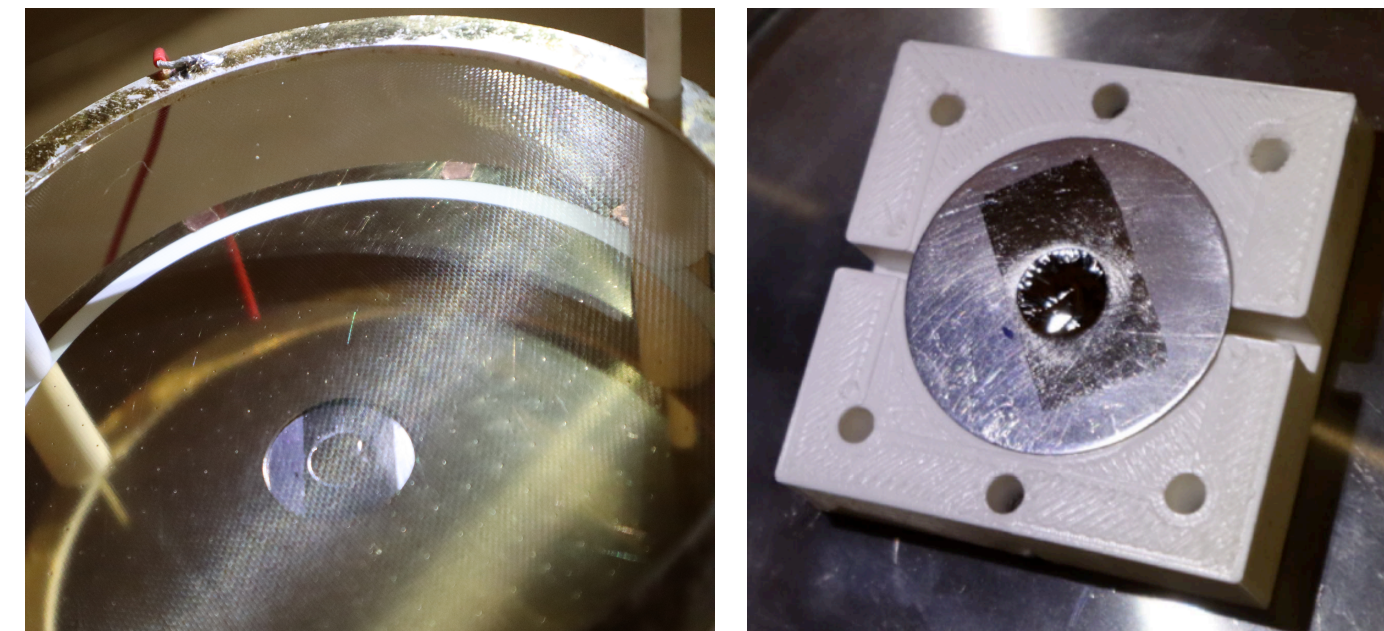
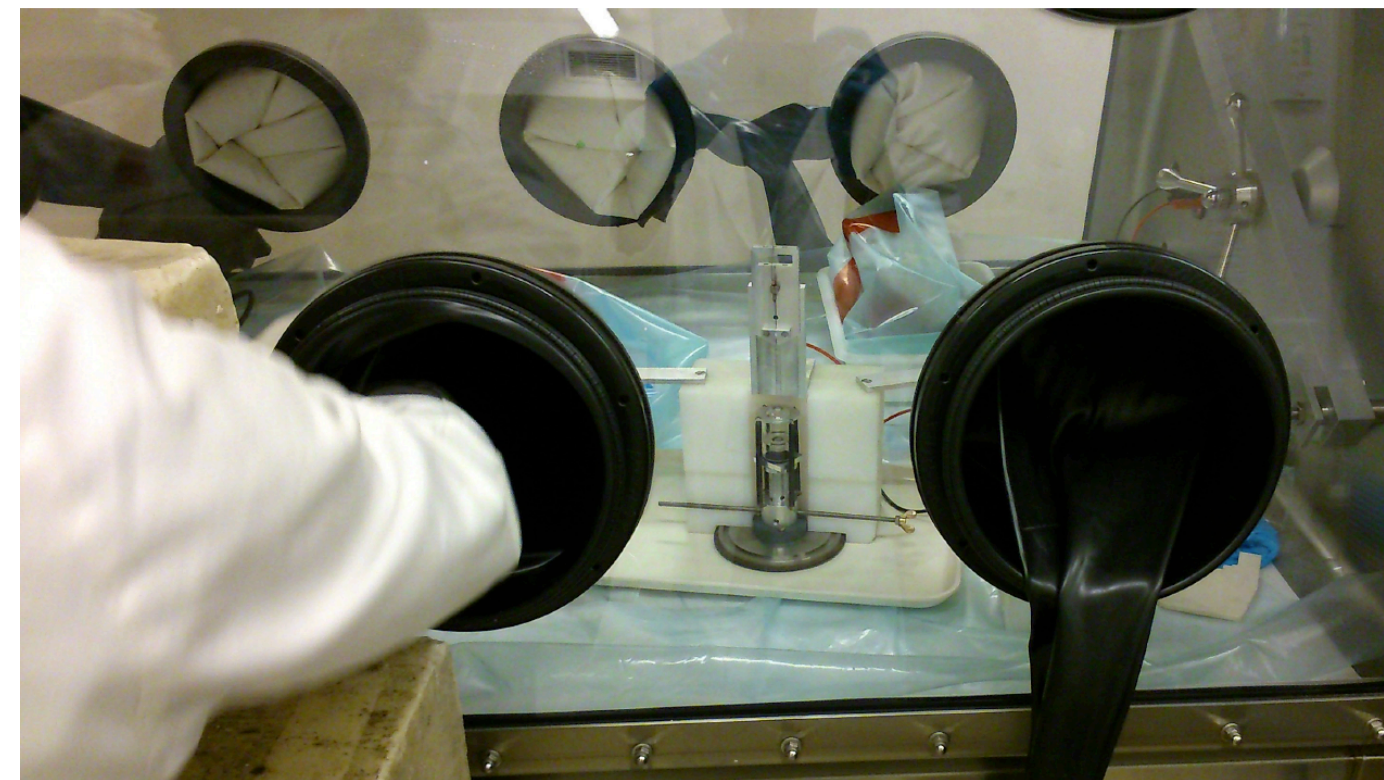
Studying neutronless fission



A fragment detector...



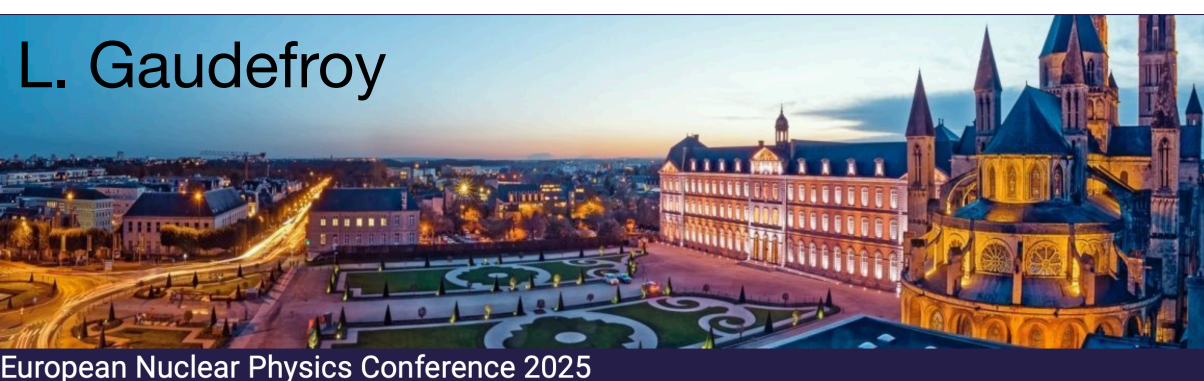
... loaded with an high quality fission sample ...



Twin Frisch Ionization Chamber ($\sigma_E = 400\text{keV}$)

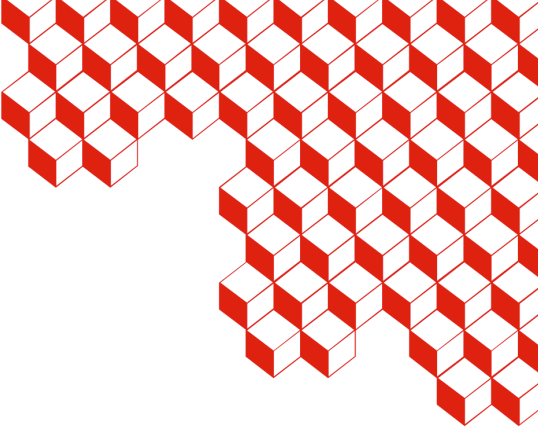
L. G. et al., NIMA **855**, 133 (2017)

1200 Bq ^{252}Cf sample
on a 25nm ultra-thin C-backing

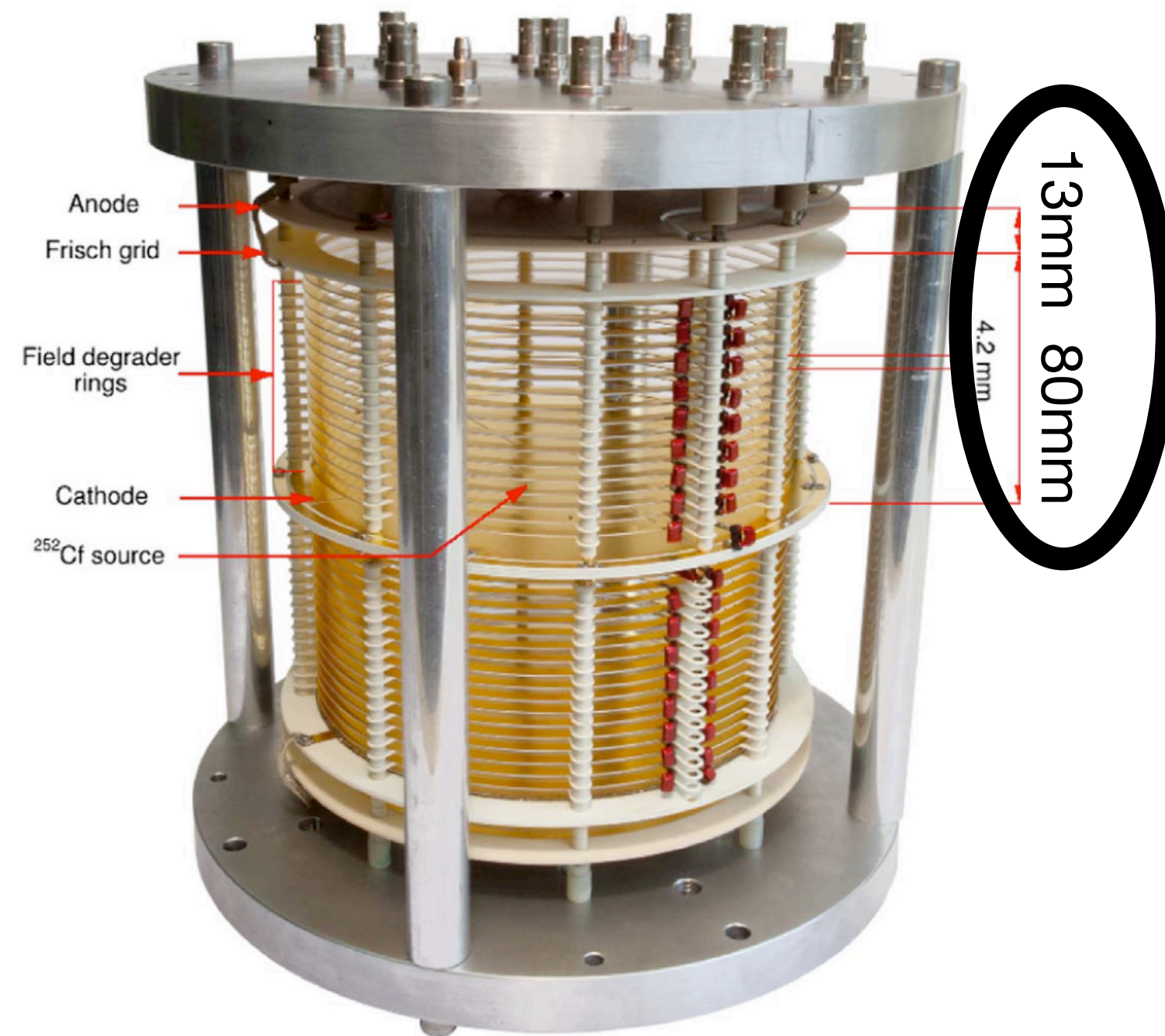


L. Gaudefroy

Studying neutronless fission



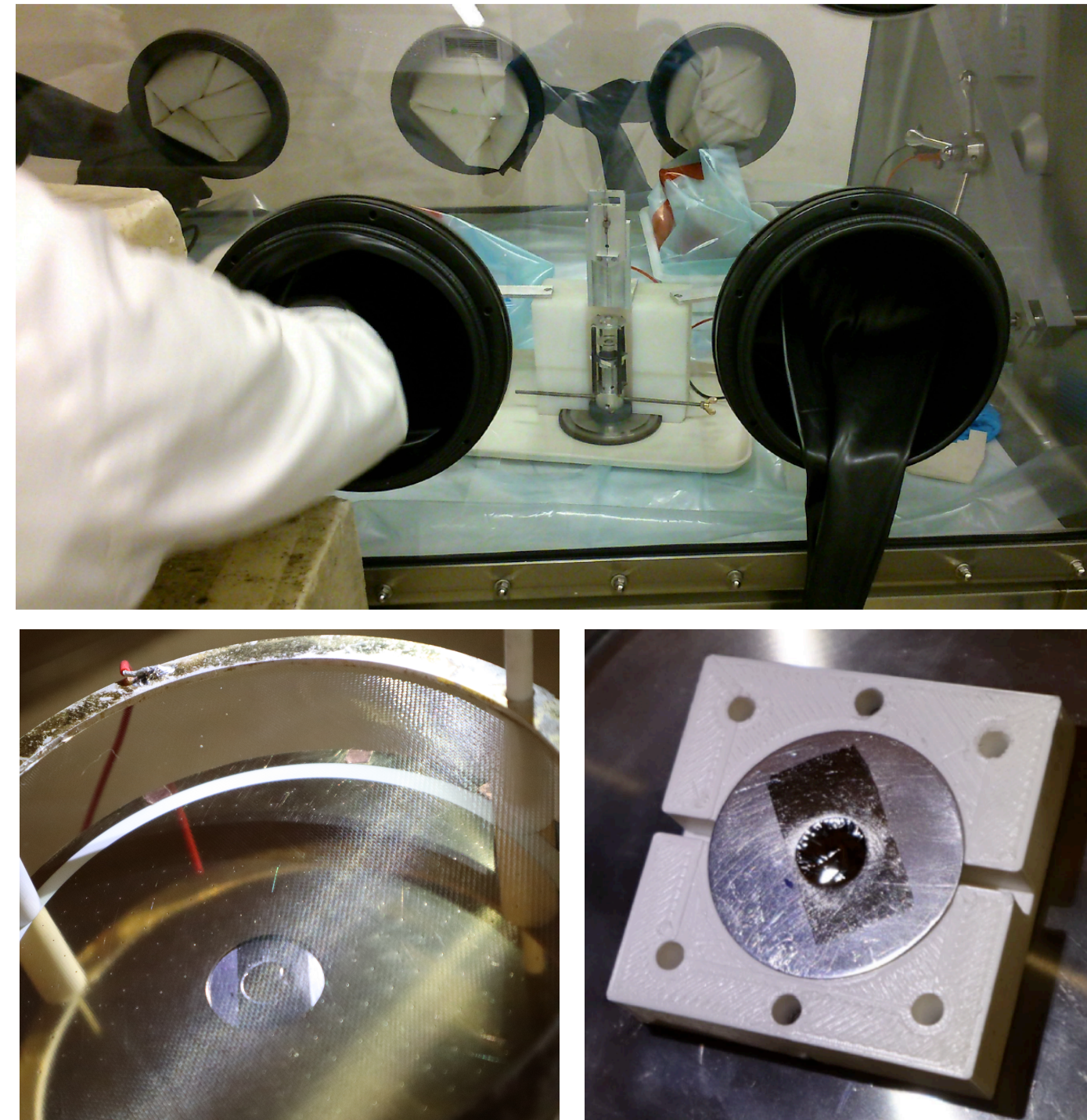
A fragment detector...



Twin Frisch Ionization Chamber ($\sigma_E = 400\text{keV}$)

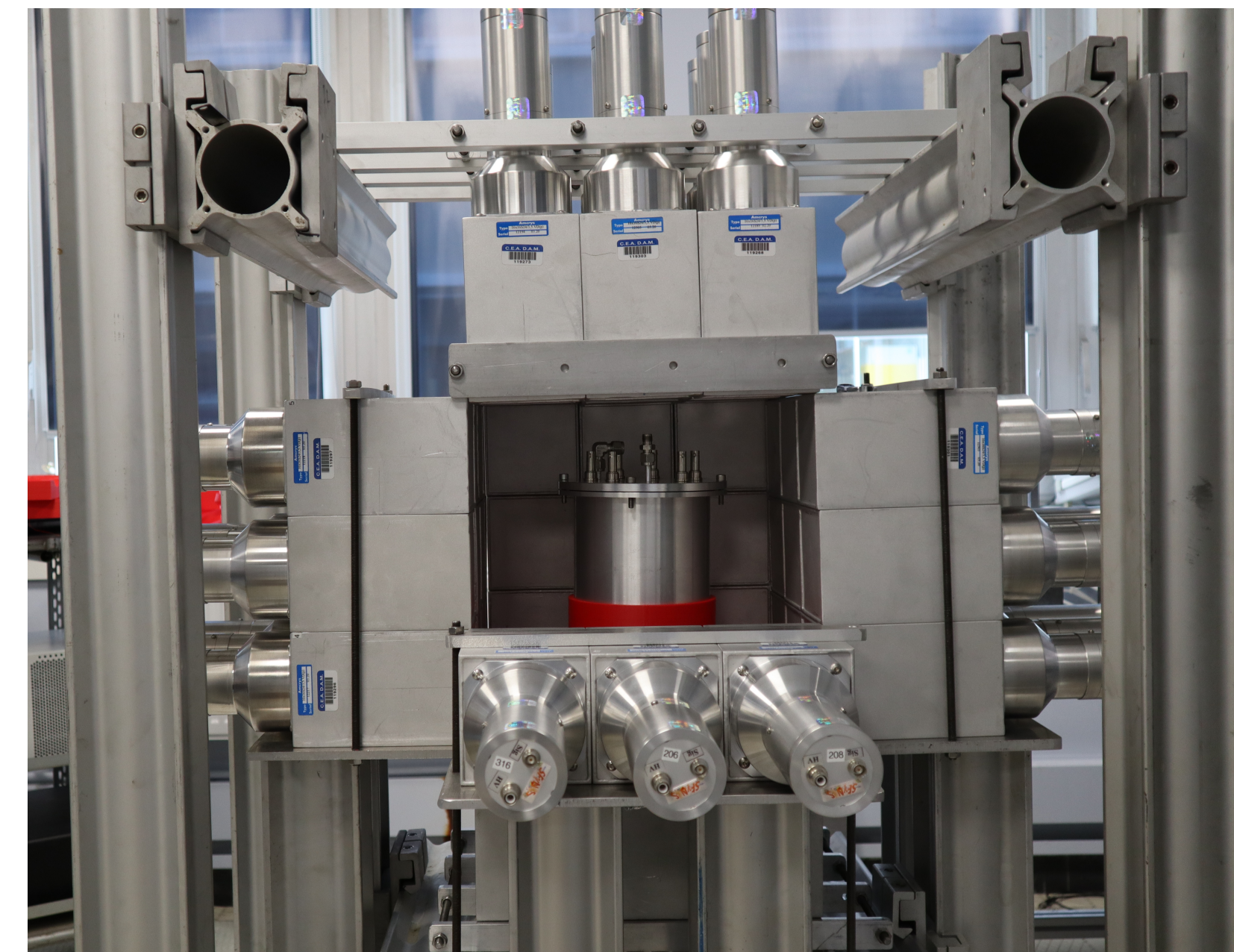
L. G. et al., NIMA **855**, 133 (2017)

... loaded with an high quality fission sample ...



1200 Bq ^{252}Cf sample
on a 25nm ultra-thin C-backing

...surrounded by a gamma array.



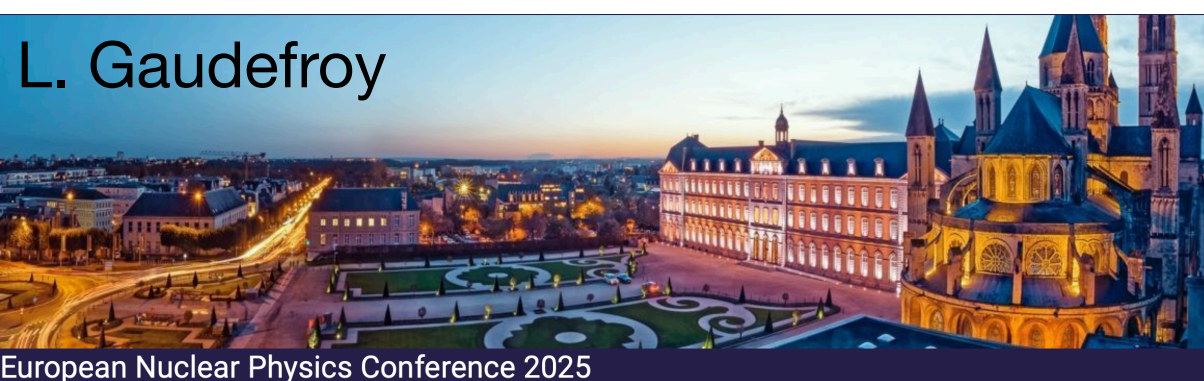
O.Roig et al., NIM A **1073**, 170243 (2025)

54 large Volume NaI detectors

$\epsilon_{Geo} = 92\%$

$\epsilon_{tot} = 50\% @ 300\text{keV}$

$\epsilon_{tot} = 30\% @ 1300\text{keV}$



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Achievements

Détection

L. G. et al., NIMA **855**, 133 (2017)

Spectroscopie

L. G. et al., PRC **97**, 064317 (2018)

Production Isomère

L. G. et al., EPJ Web Conf. **242**, 01003 (2020)

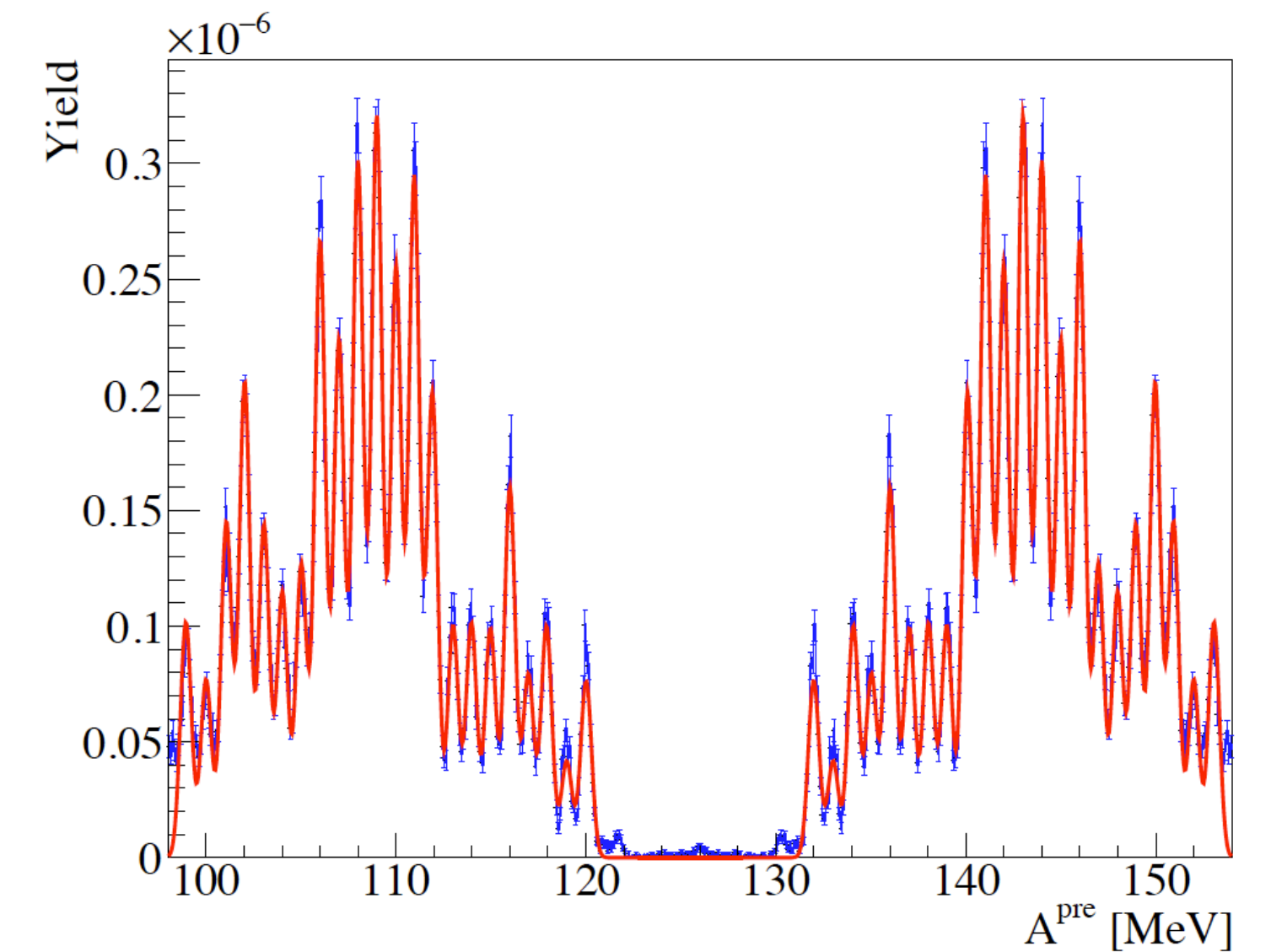
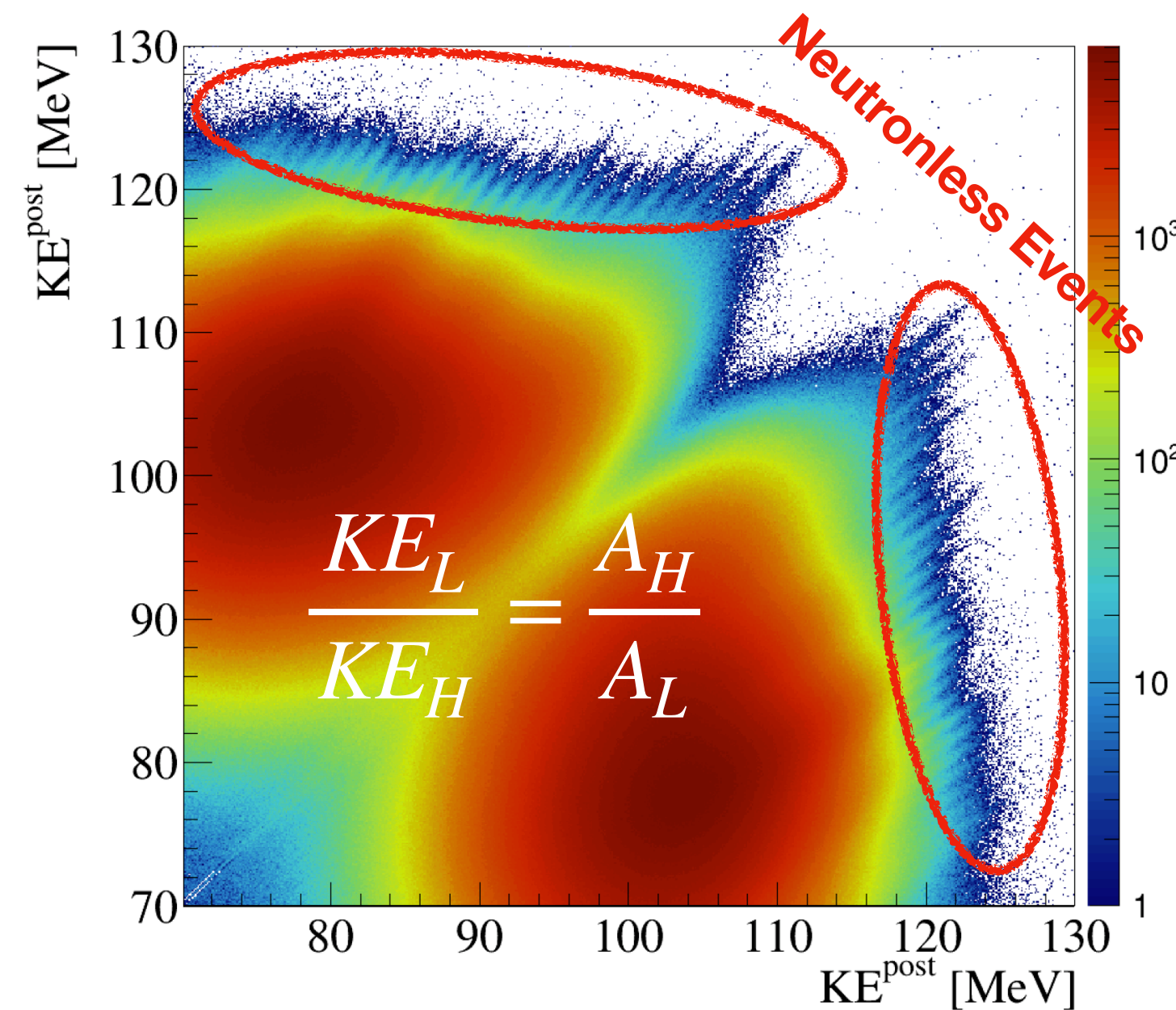
Propriétés Fission/Fragments

A. Francheteau et al., PRL **132**, 142501 (2024)
(=>Presented in this Conf.)

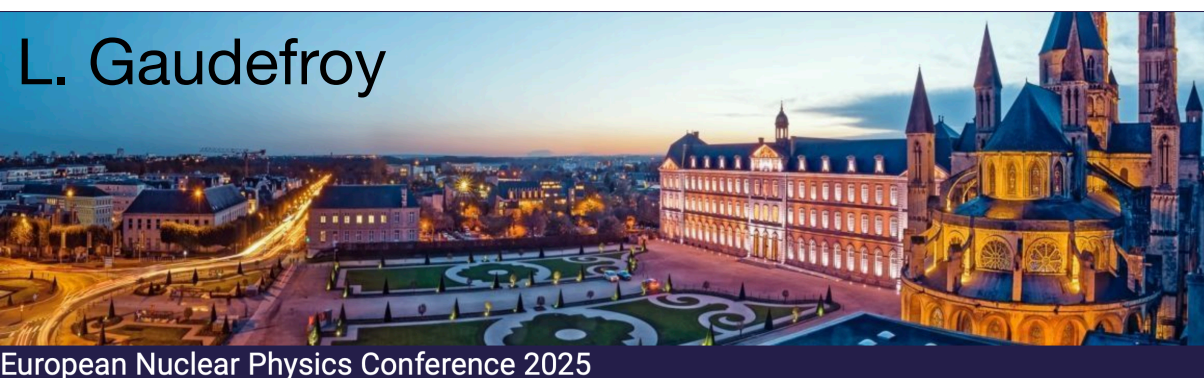
A. Francheteau et al., PRC **111**, 034608 (2025)

+ the results of this talk (paper in preparation)

A. Francheteau - PhD work.
Talk in this Conf. on the exceptional
case of $^{120}\text{Cd}/^{132}\text{Sn}$

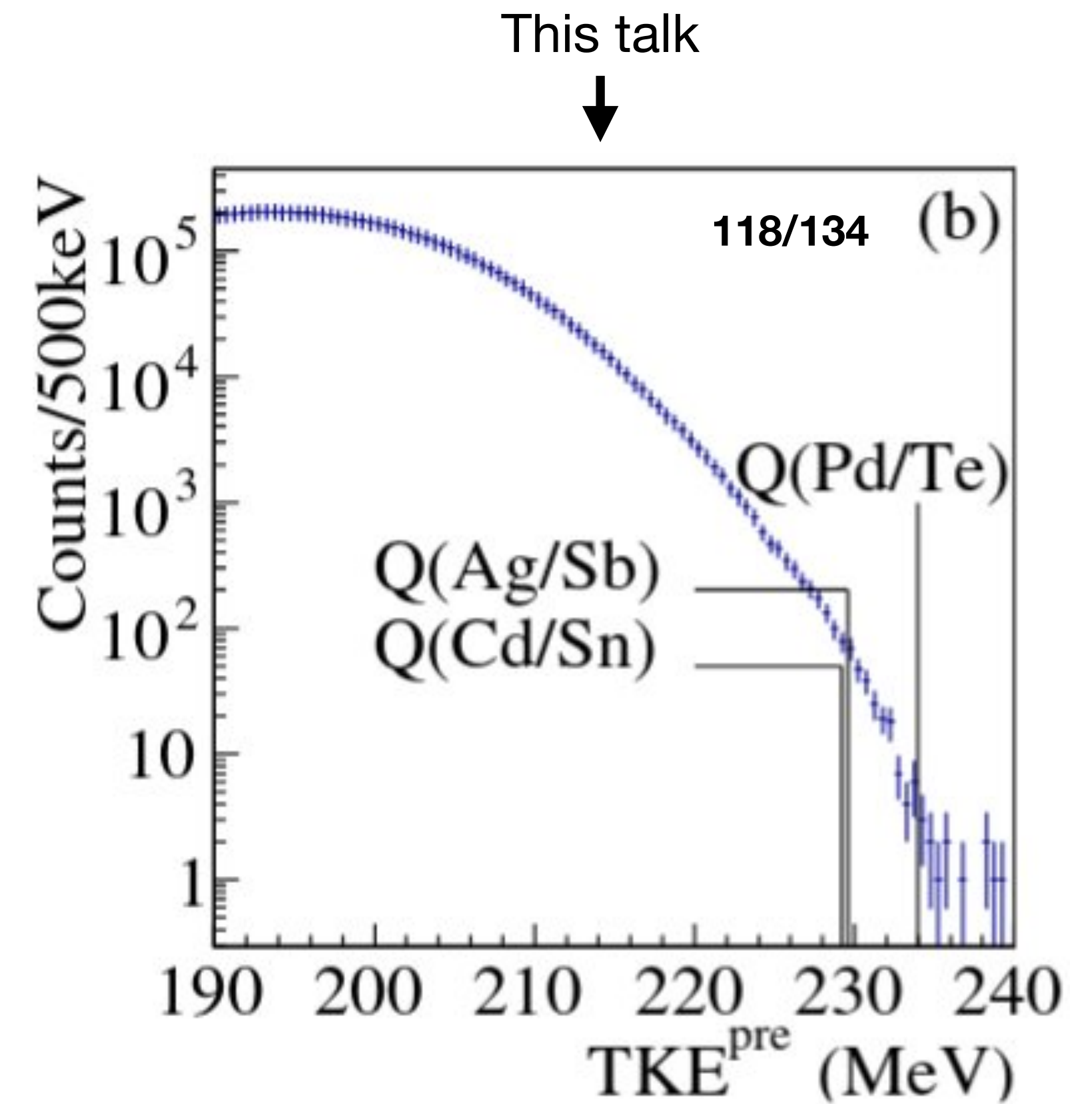
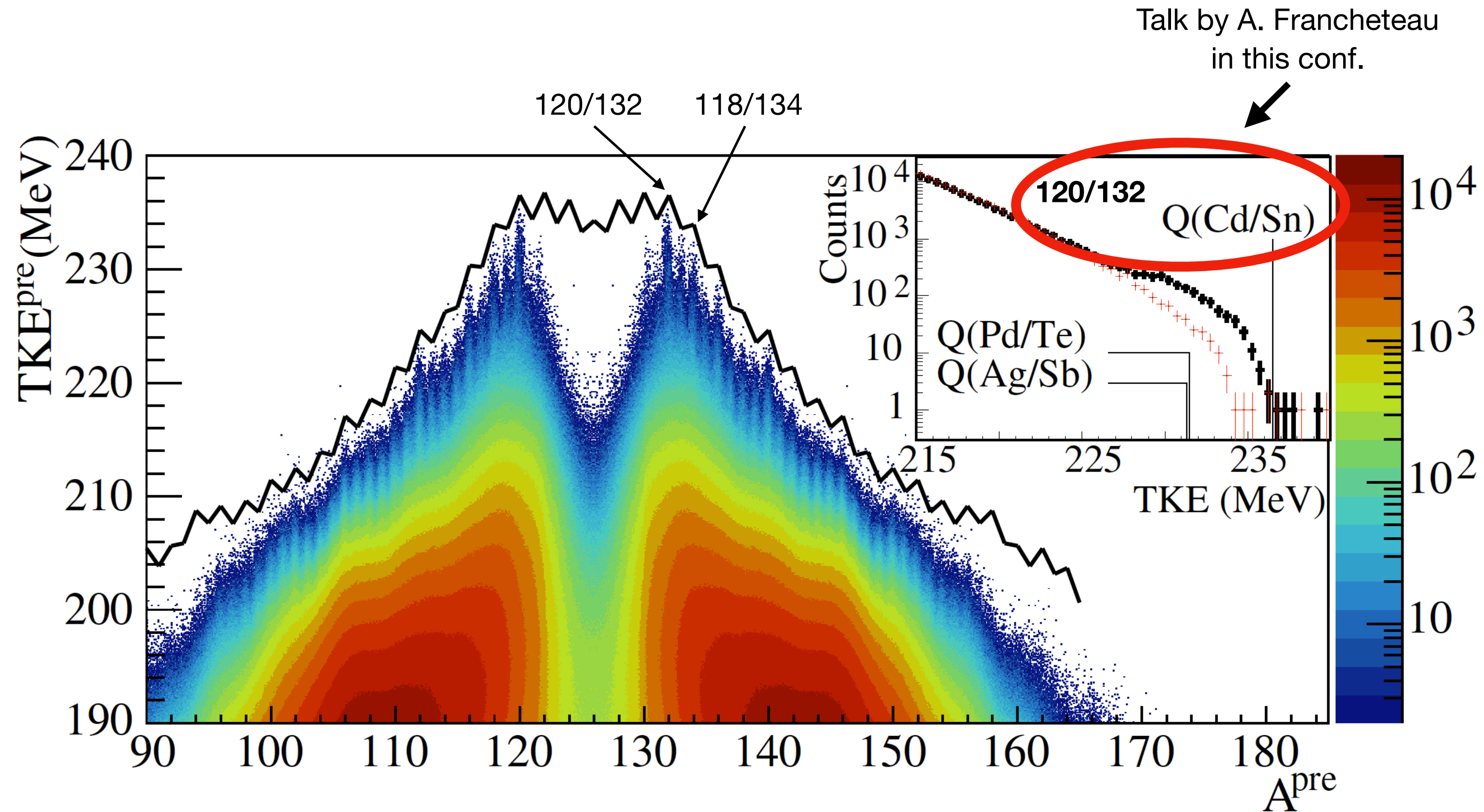
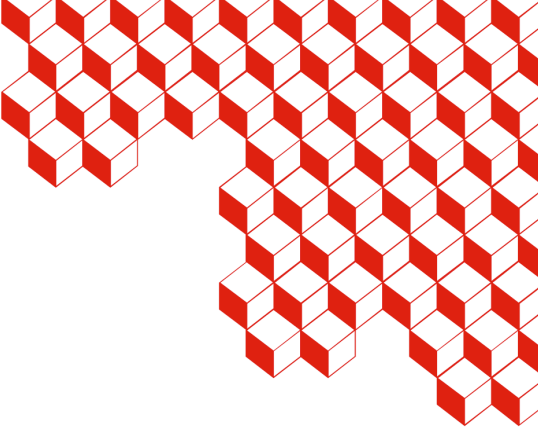


Mass Resolution : 0.6-0.7 amu FWHM



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When Shell Closures help us!

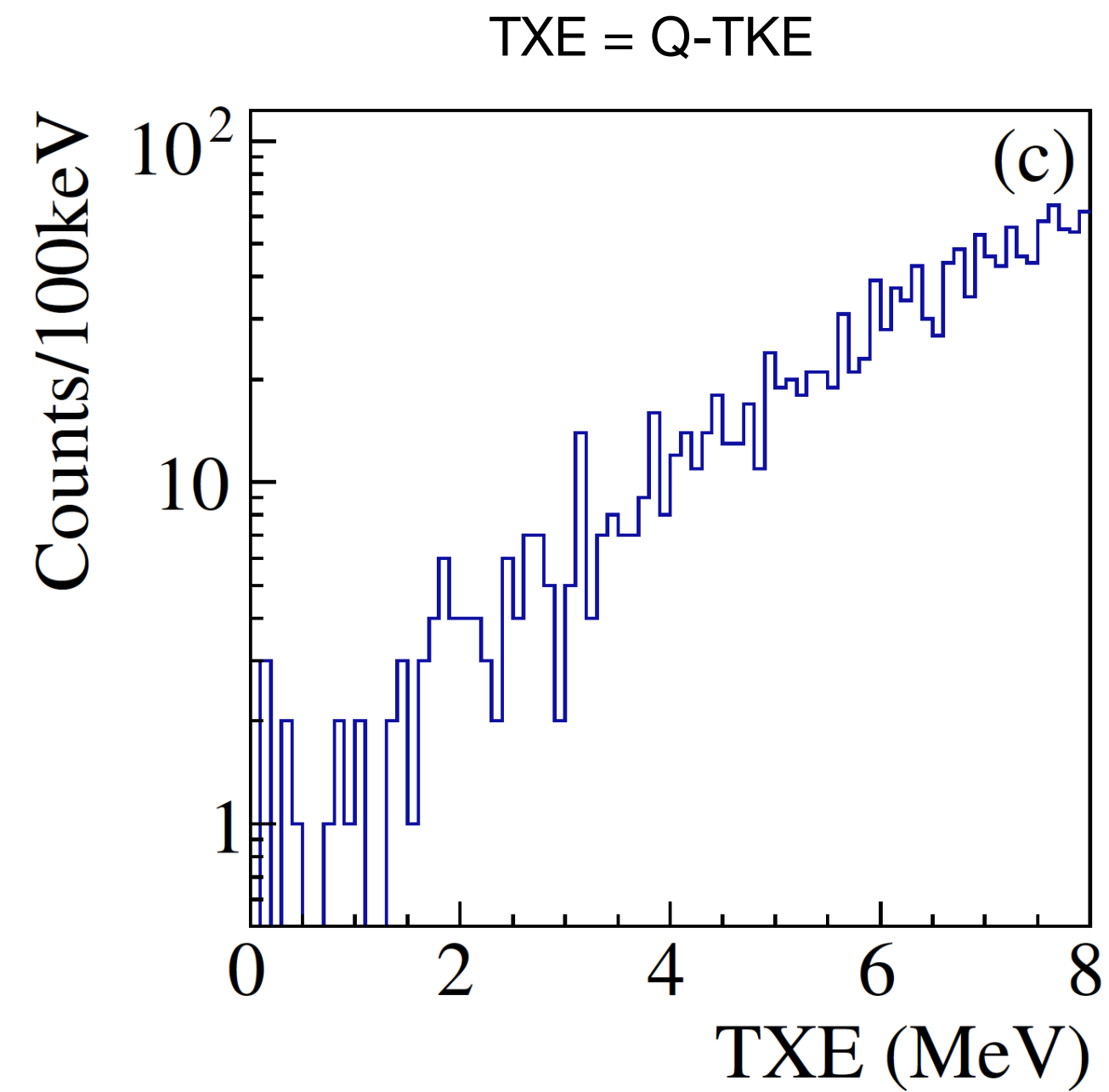


Simple TKE Selection = 90% purity on Fragment selection



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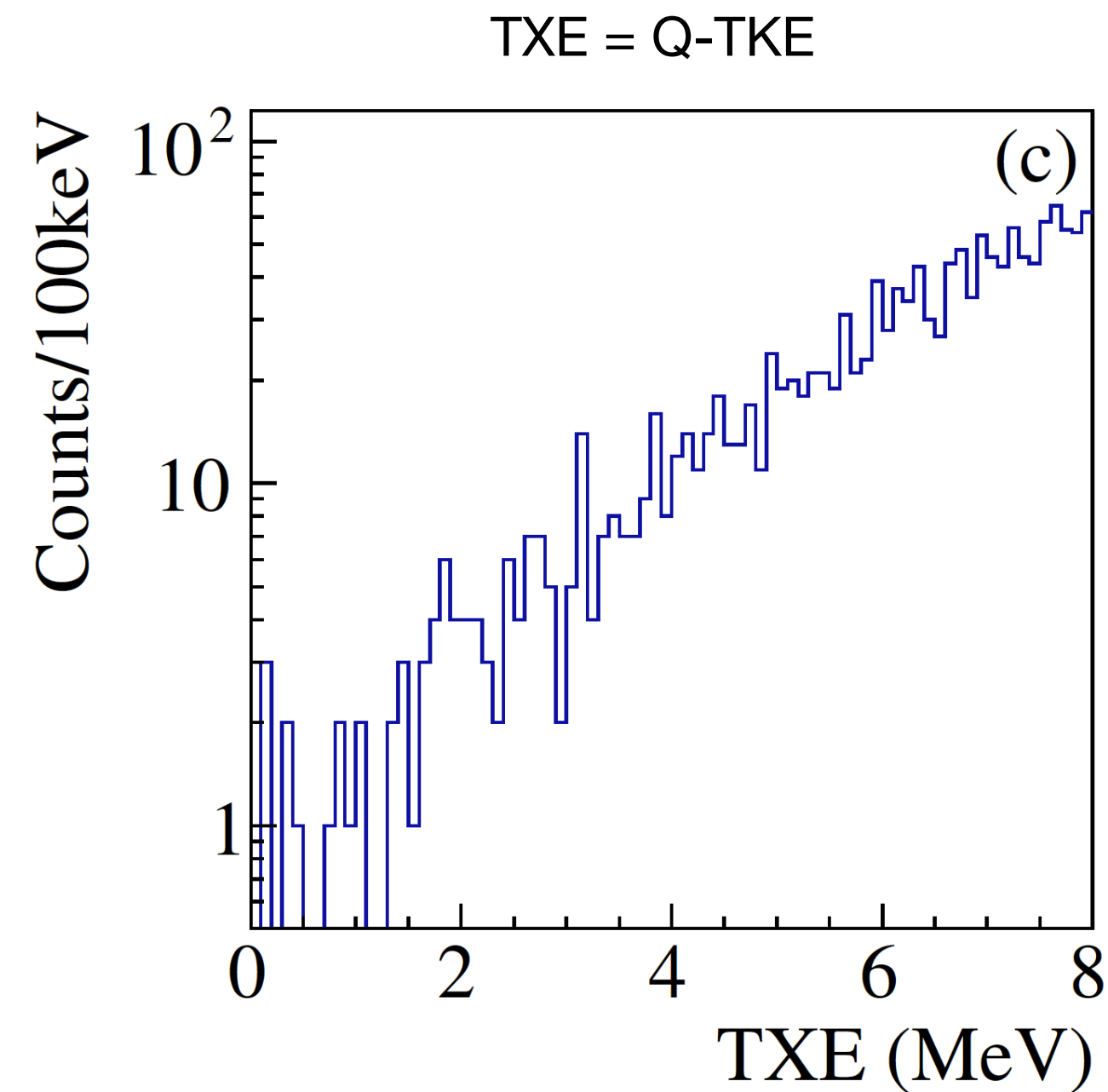
What we measured 1/3



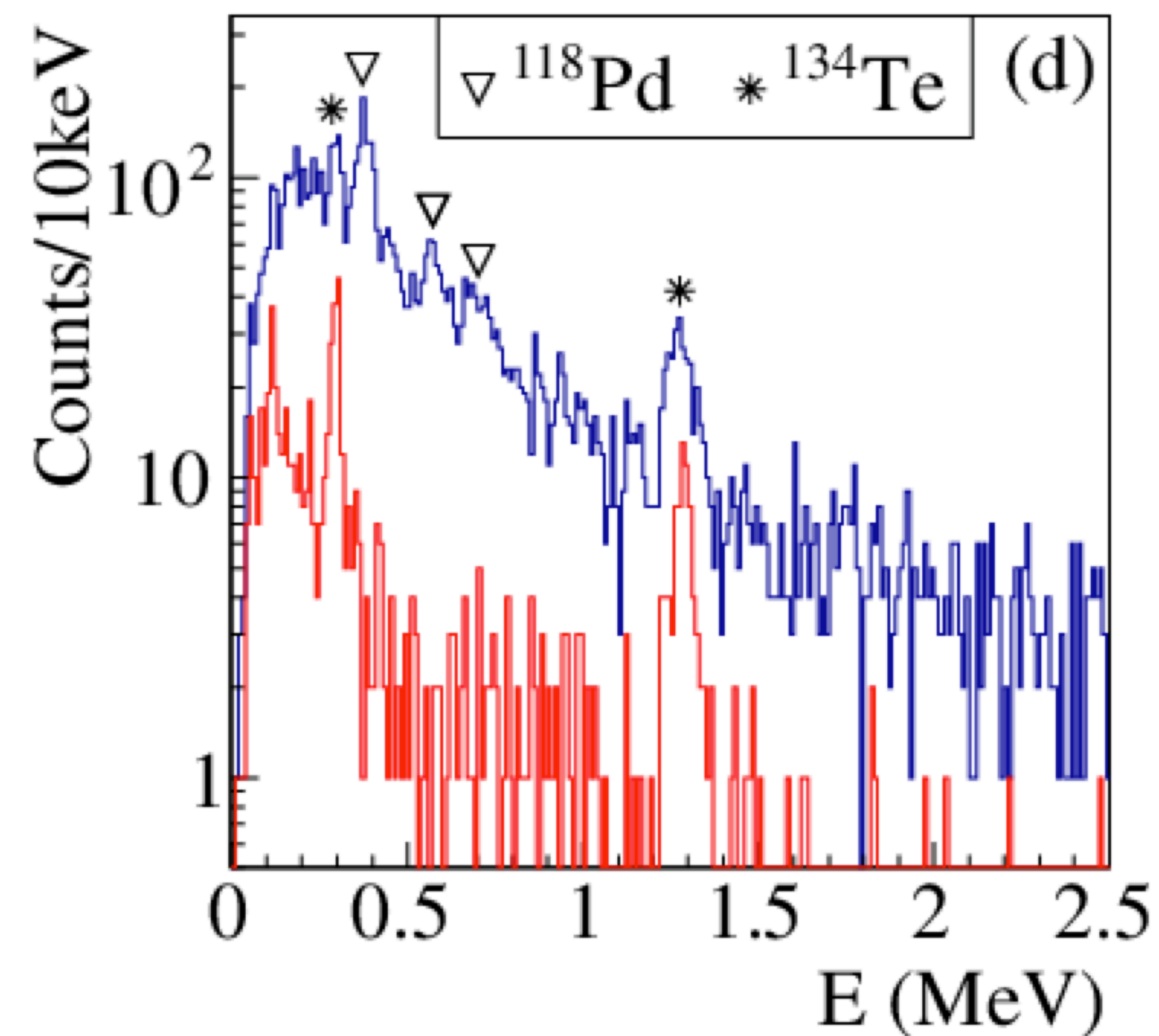
We know $TXE = E_x^H + E_X^L$
But don't know (yet) $E_x^{H,L} = f(TXE)$



What we measured 2/3



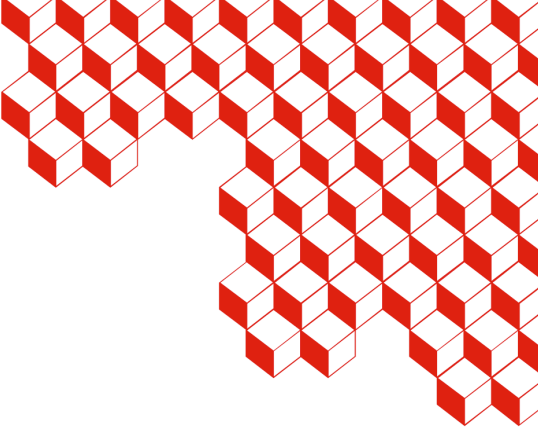
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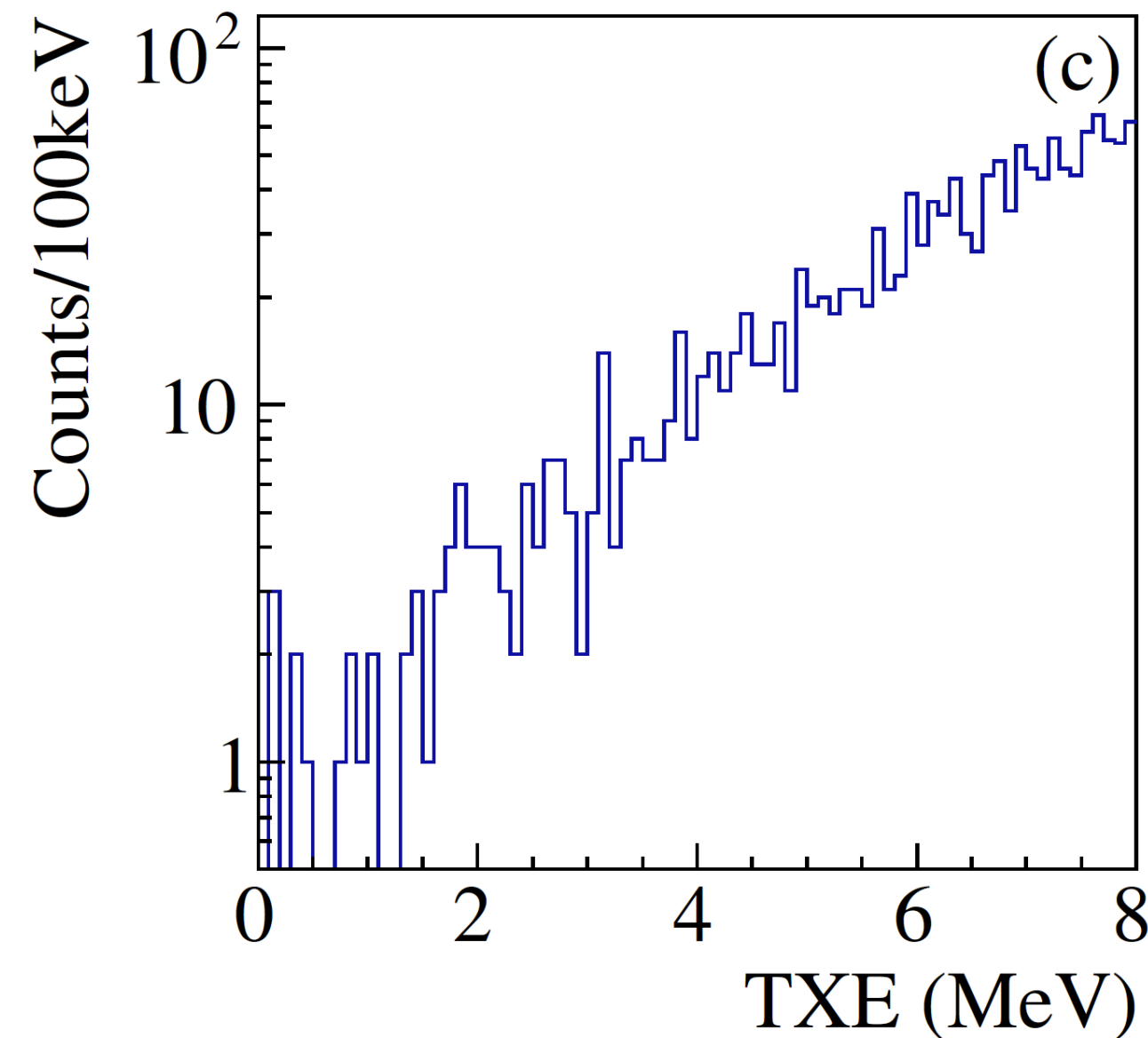
We know the decay of the fragments



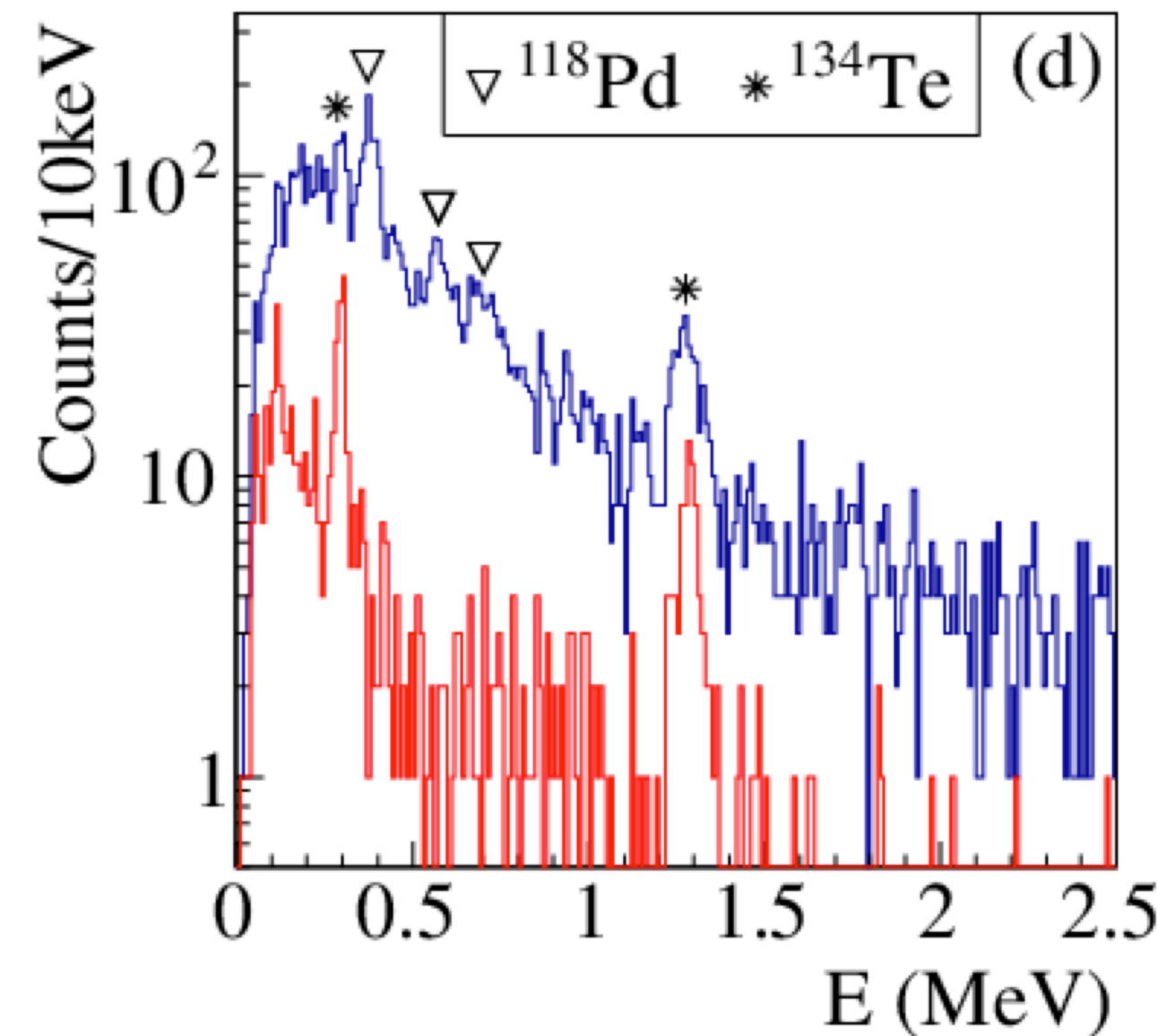
What we measured 3/3



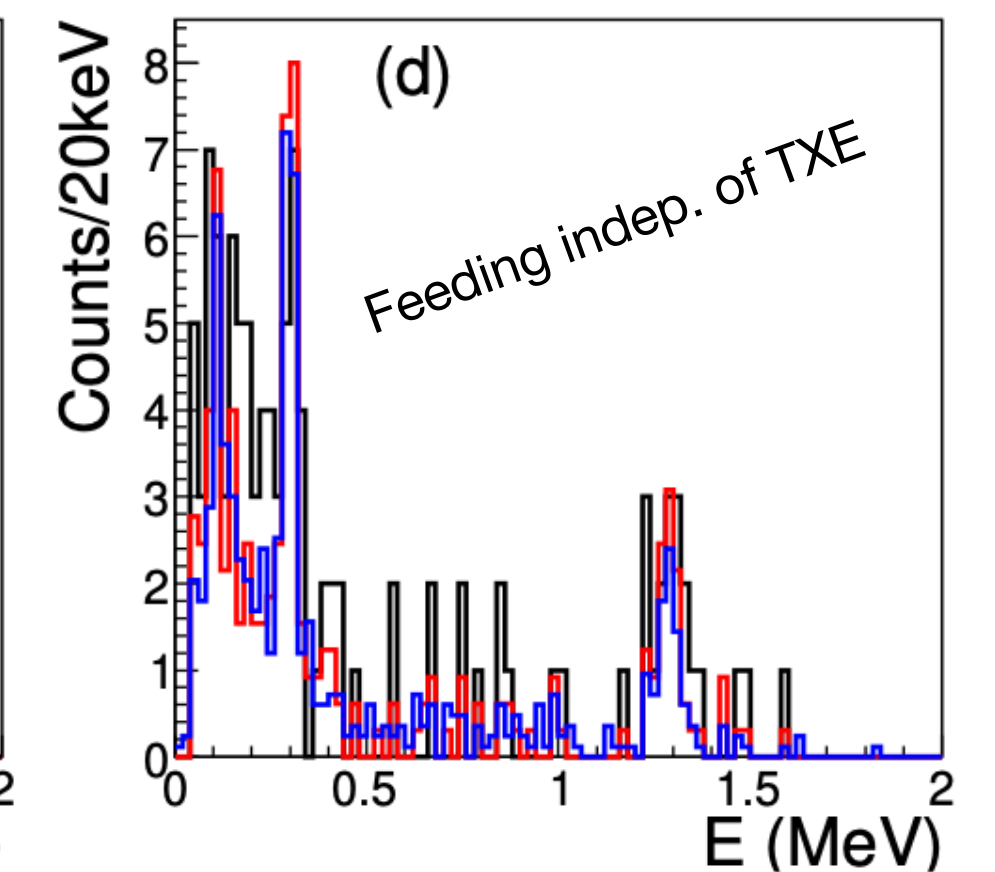
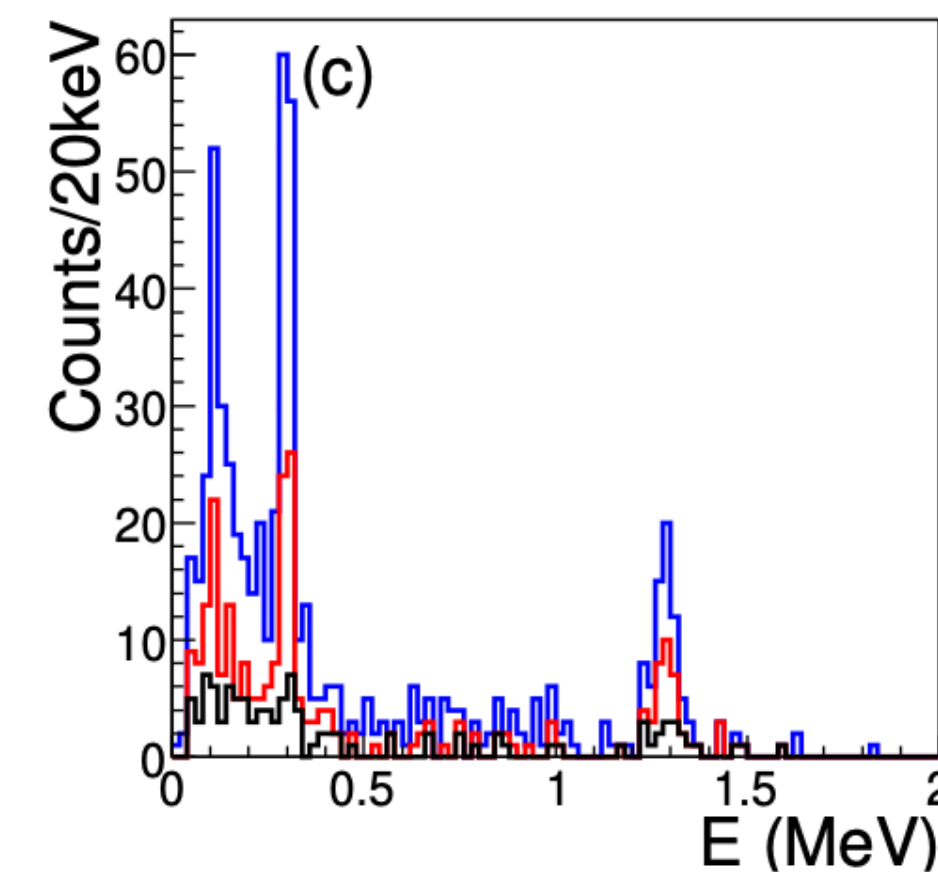
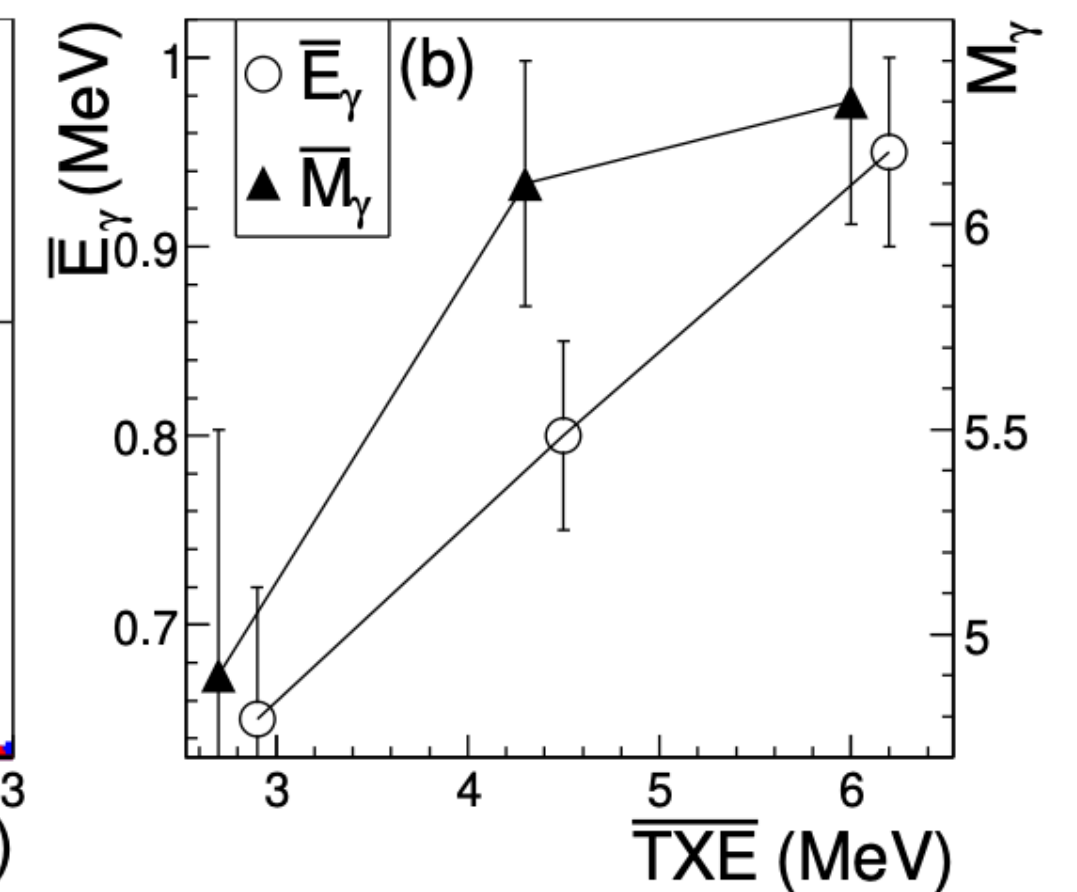
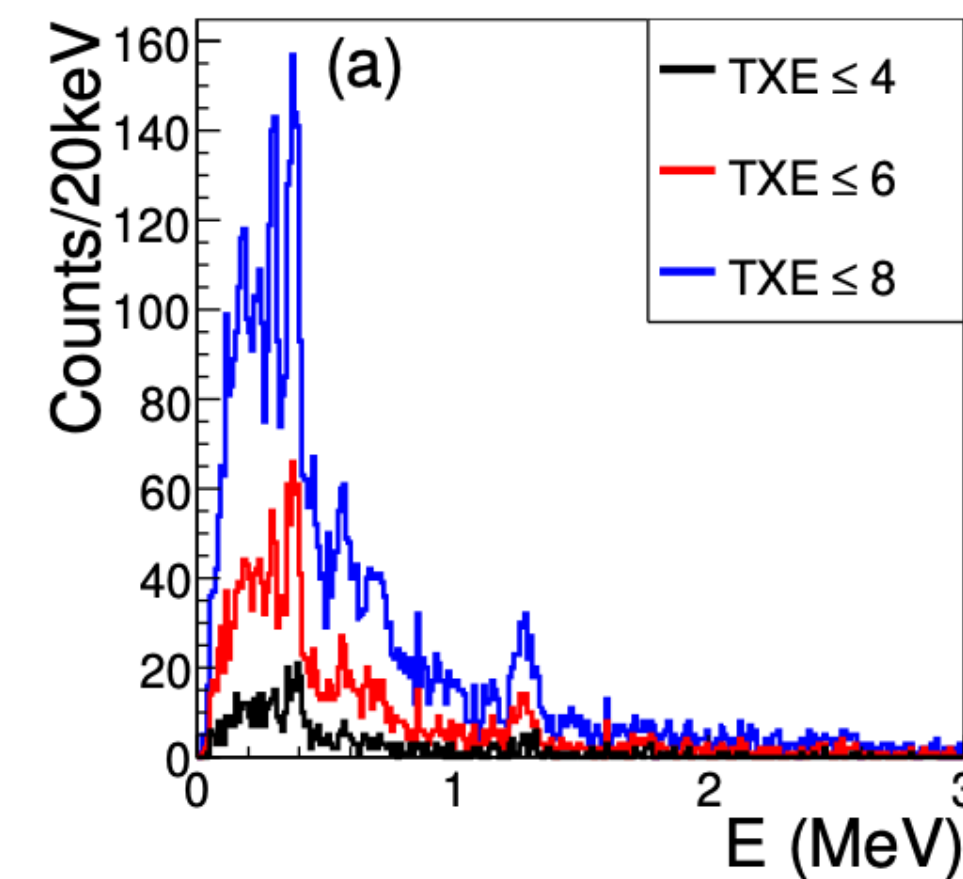
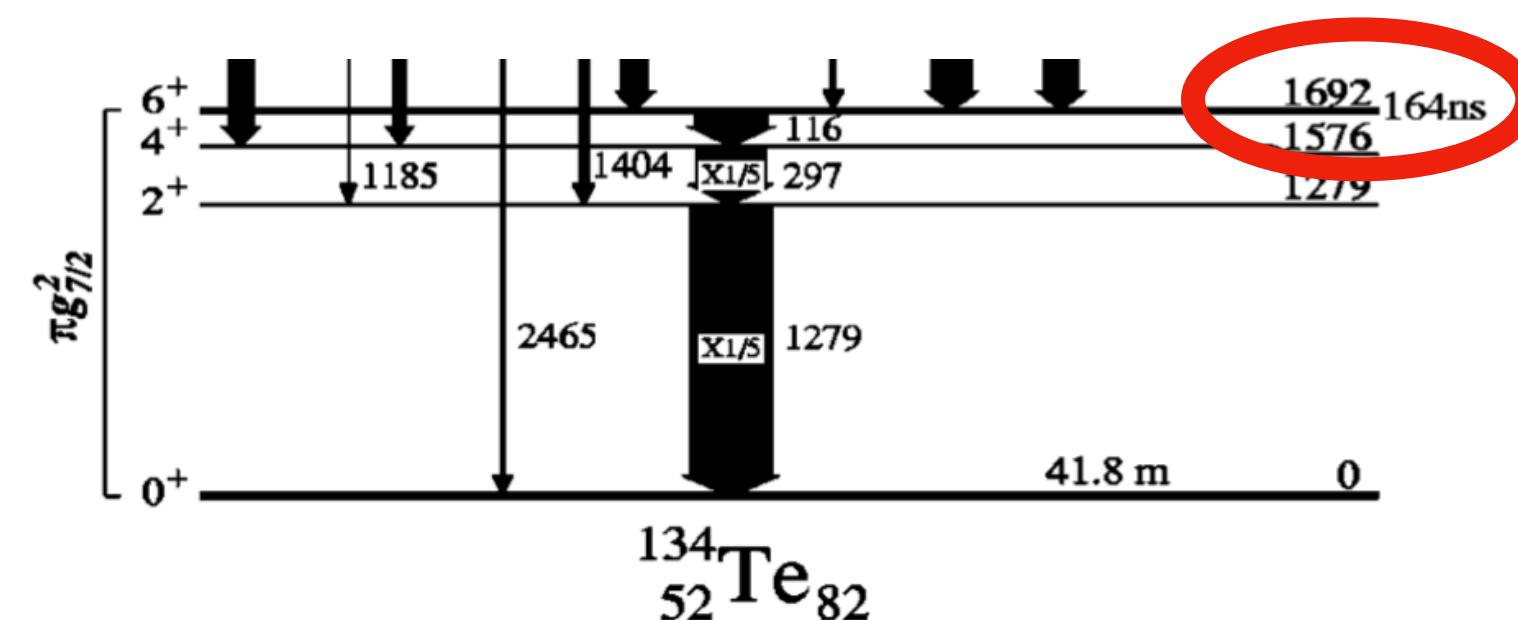
$$\text{TXE} = Q - \text{TKE}$$



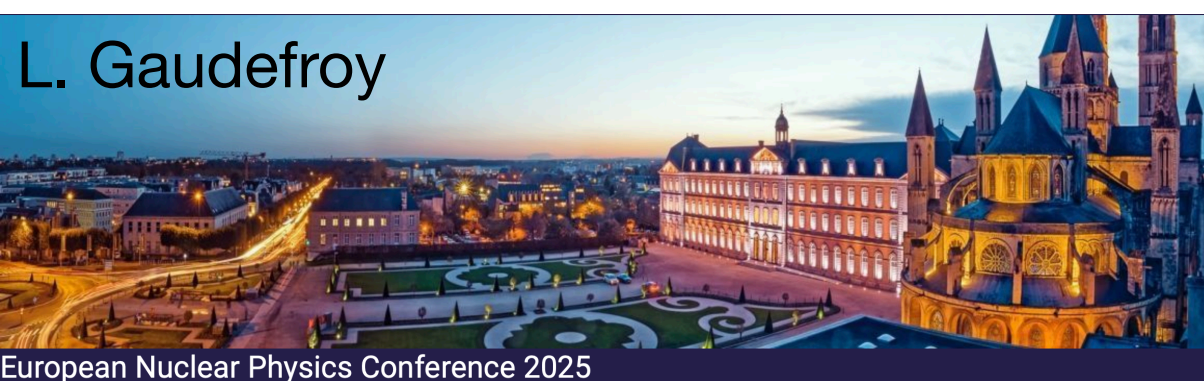
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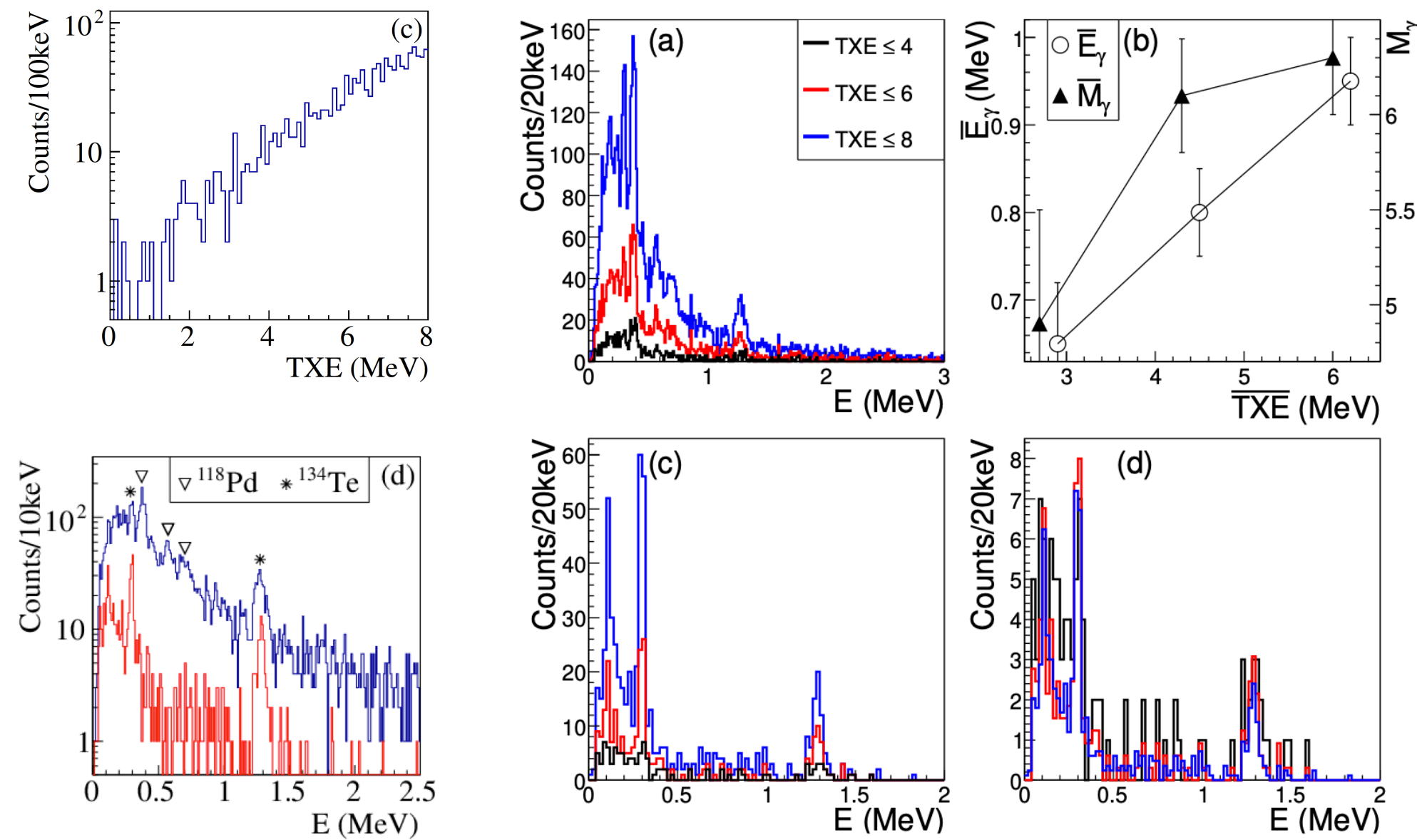
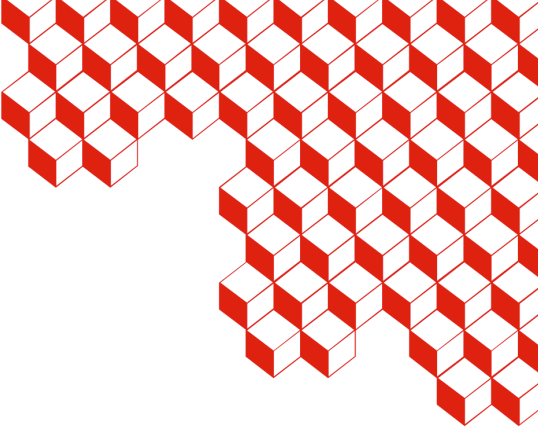


We have some more detailed info as a function of TXE

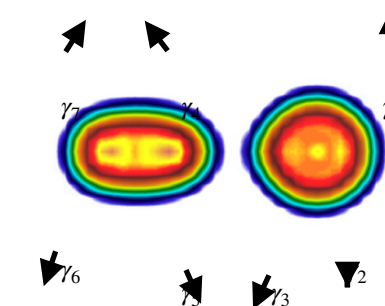


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Reproducing what we measured



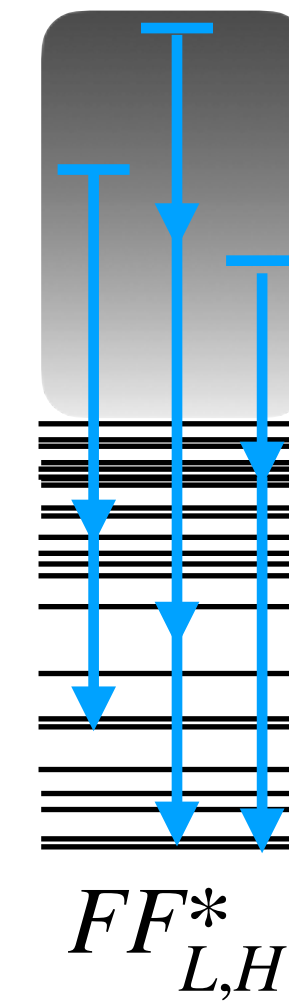
Simulation of γ -ray spectrum



$$E_x^{H,L}$$

$\Rightarrow$ TXE and its sharing

Angular momentum



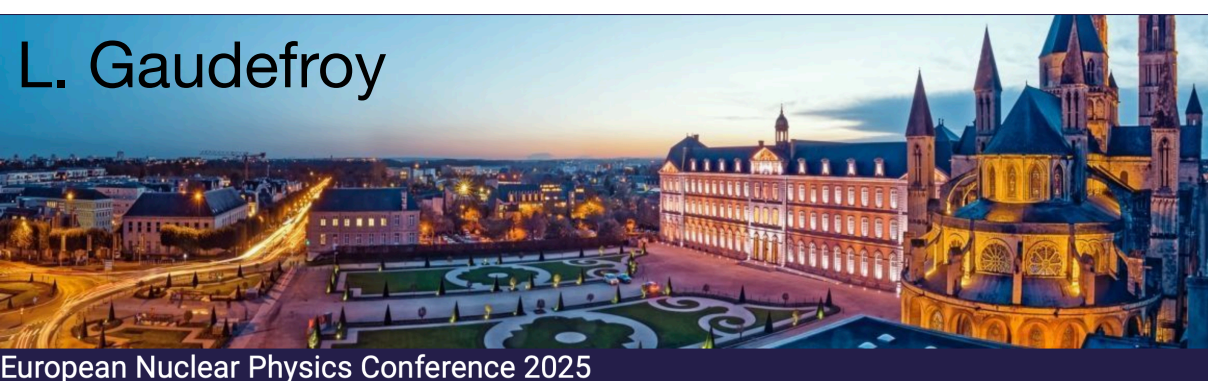
+ Statistical inputs for Hauser-Feshbach description of cascades:

$\Rightarrow$ HFB+combinatorial with Gogny force NLD

S. Hilaire, M. Girod, S. Goriely and A. J. Konig, Phys. Rev. C 86, 064317 (2012)

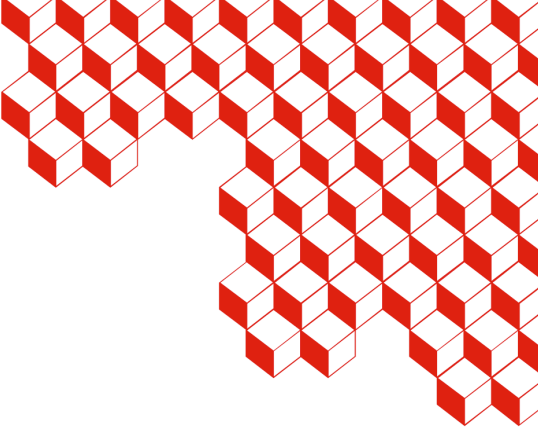
$\Rightarrow$ E1 & M1 BSk27 gSF

Y. Xu, S. Goriely and E. Khan, Phys. Rev. C 104, 044301 (2021)



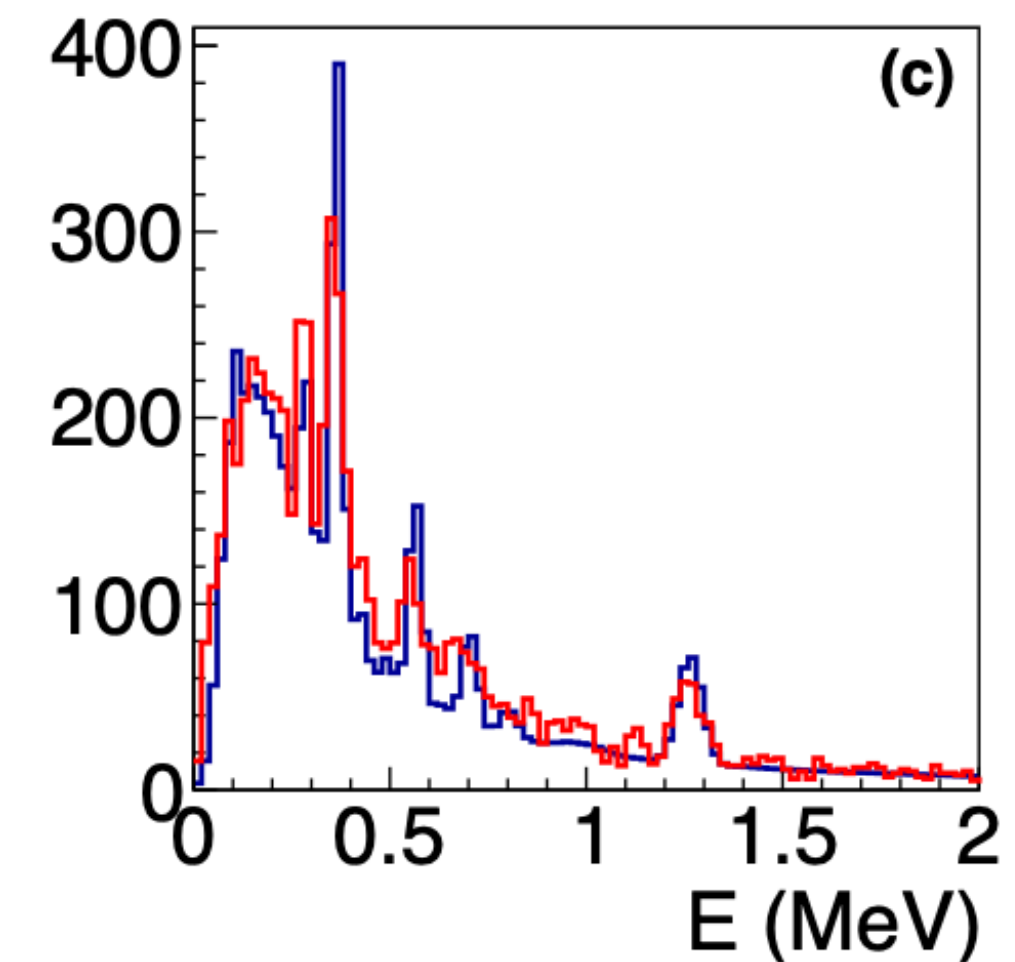
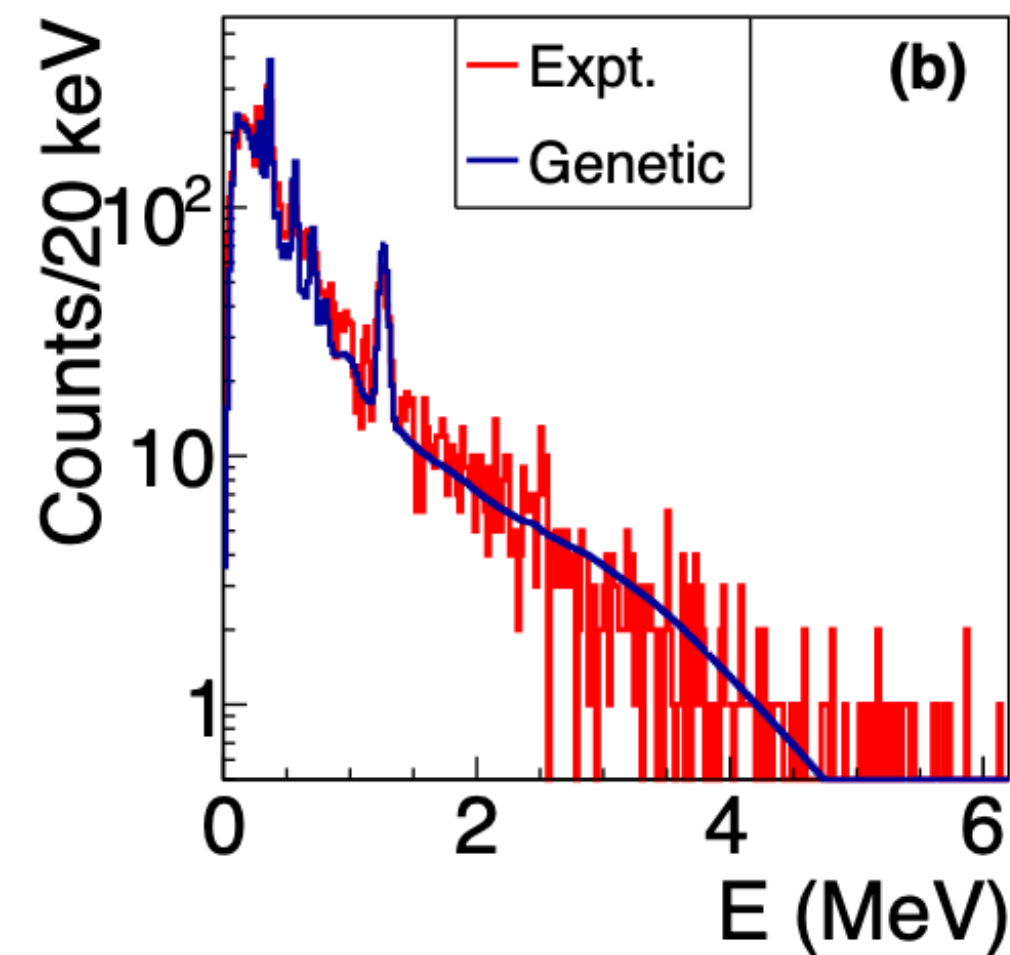
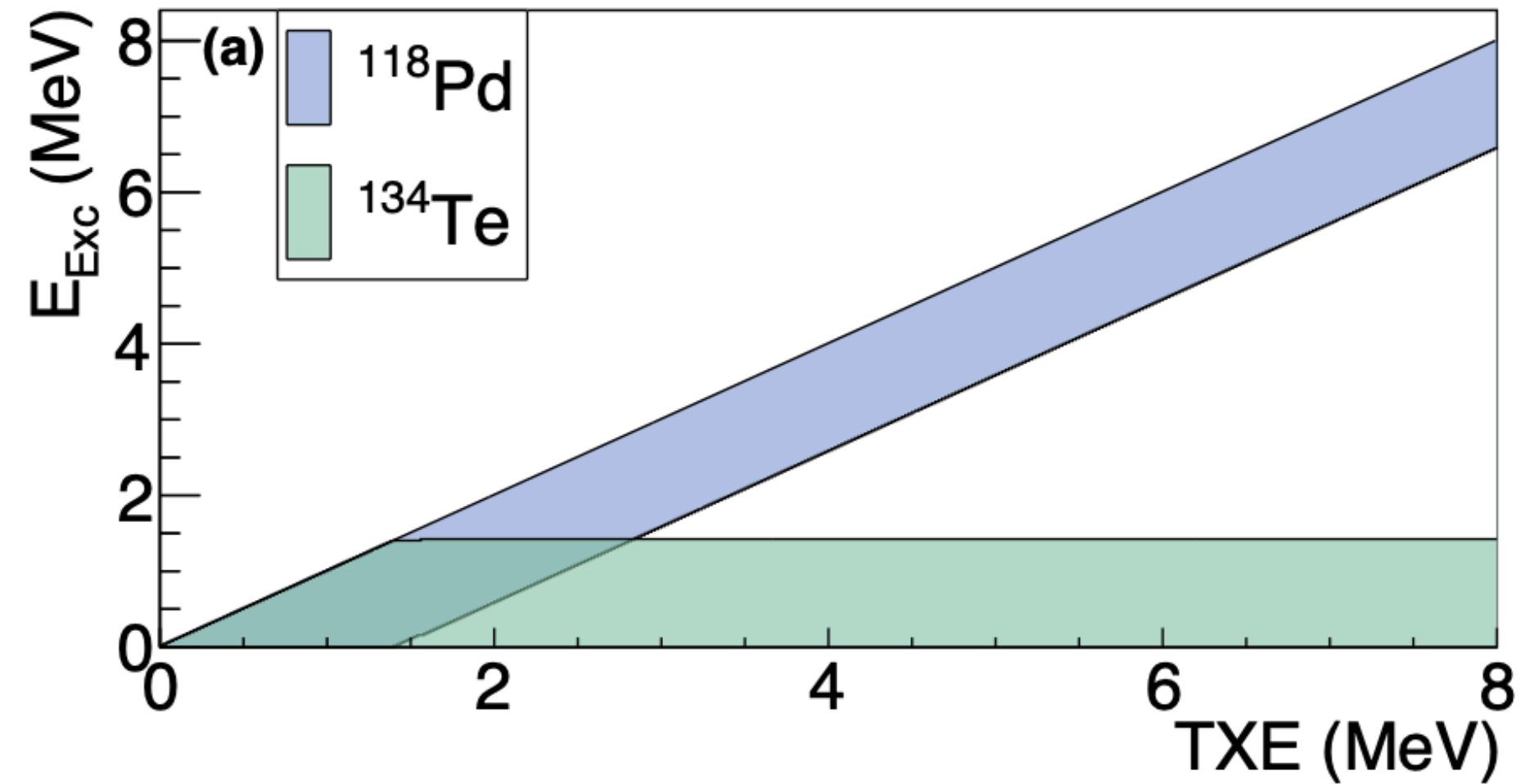
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Optimization with Genetic algorithm



Genetic Algorithm in order to determine which excitation energy partition between Pd/Te provides the best description of the measured spectrum.

1. ^{134}Te weakly excited, most E_x goes to light fragment.
2. Distribution of E_x about 1.3 MeV wide.
3. Spin cutoff $\sigma^{\text{Te}} \sim 3\hbar$ and $\sigma^{\text{Pd}} \sim 4.5\hbar$
4. Good reproduction of measured spectrum
5. Compatible with intensities as fonction of TXE

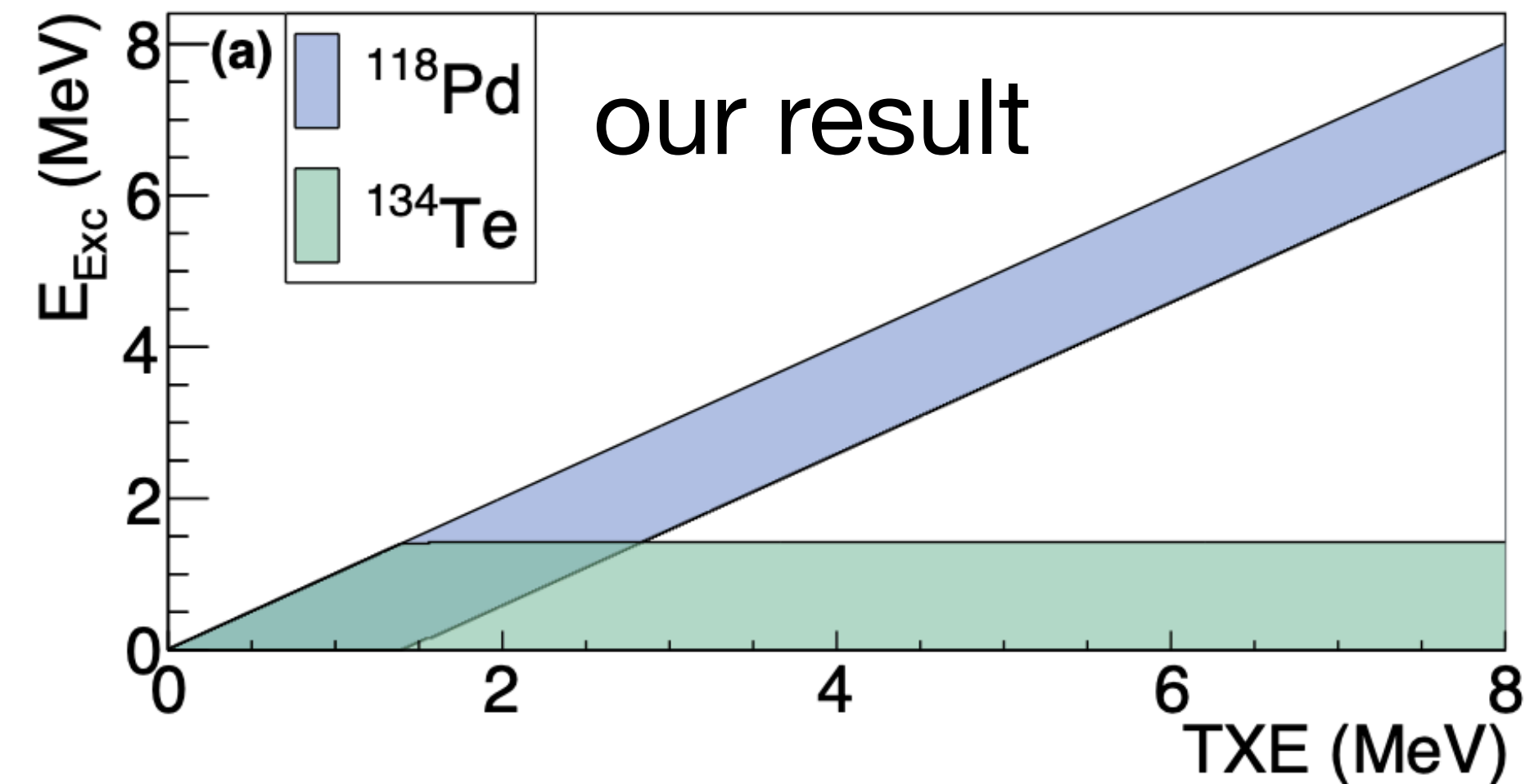
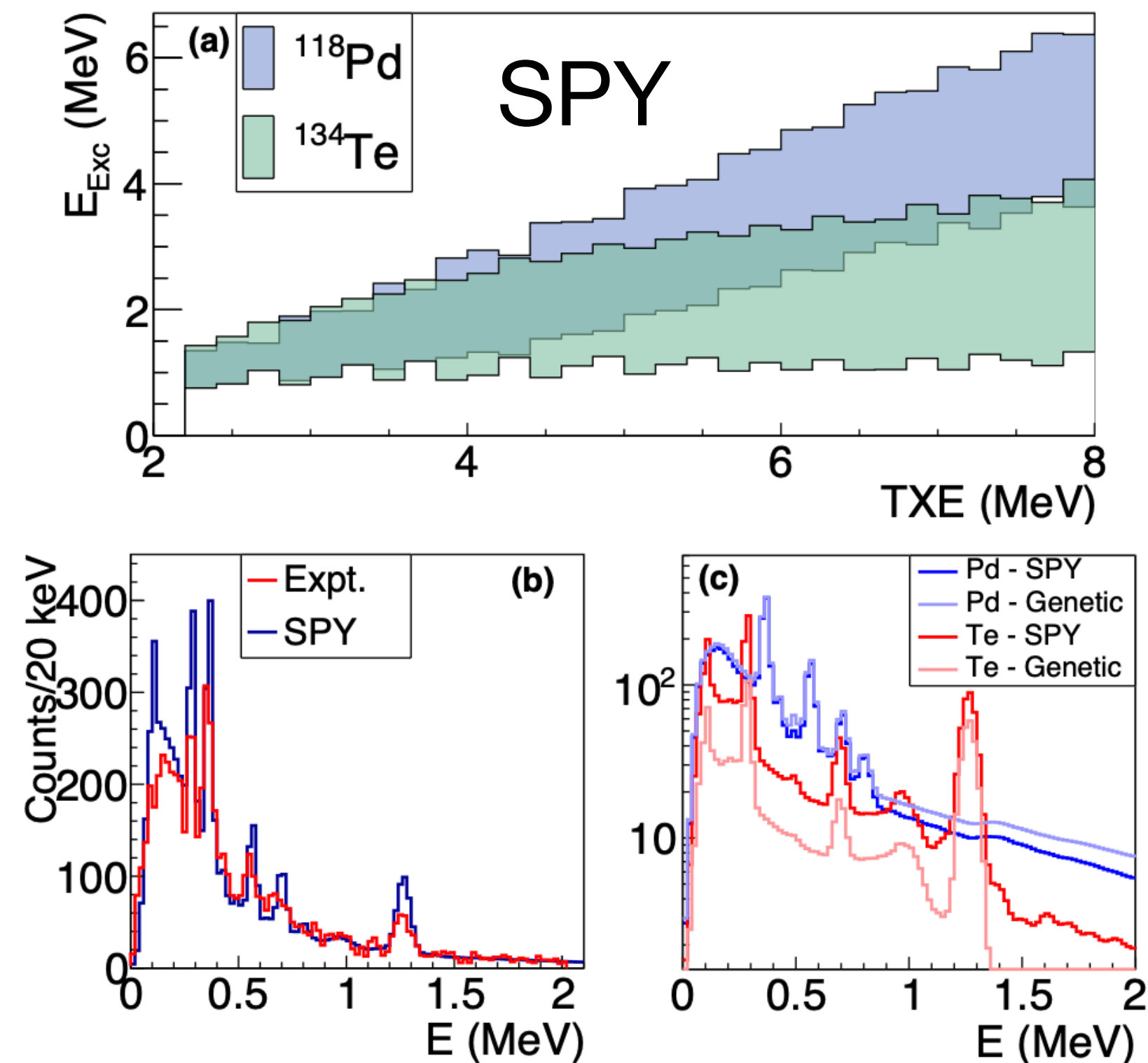


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Comparison with model

SPY, a microscopic scission point model, taking into account pairing, shell effect and deformation

J.-F. Lemaître et al., PRC 99, 034612 (2019)

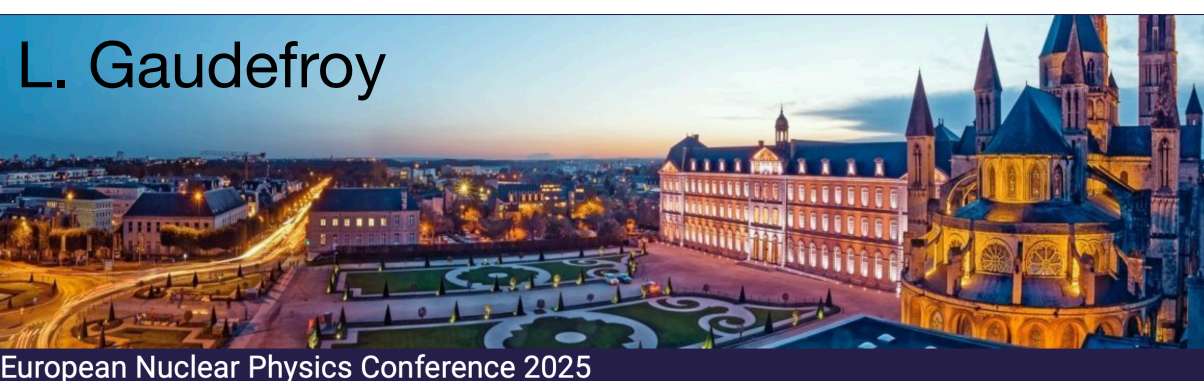


Clear disagreement with our experimental gamma spectrum.

=> Unambiguously attributed to too large excitation of ^{134}Te .

=> Demonstrate the sensitivity of present data.

=> Results from too low deformation of Pd in SPY ($\beta \sim 0.04$) as compared to orientation-pumping predictions ($\beta \sim 0.4$) leading to underestimated E_x^{Pd} and consequently overestimated E_x^{Te} .



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Comparison with Standard fission

For ^{252}Cf standard fission J.N. Wilson et al. Nature 590, 566 (2021) :

$$\sigma^{Te} \sim 2.9\hbar$$

$$\sigma^{Pd} \sim 6\hbar$$

Our results : $\sigma^{Te} \sim 3\hbar$ and $\sigma^{Pd} \sim 4.5\hbar$

Compatible with difference in E_x
and the expected variation of $\sigma^2 \propto \mathcal{J} \frac{a}{\tilde{a}} T$

Here :

$$\bar{E}_x^{Te} \sim 0 \text{ MeV}$$

$$\bar{E}_x^{Pd} \sim 6 \text{ MeV}$$

Standard Fission :

$$\bar{E}_x^{Te} \sim 13 \text{ MeV}$$

$$\bar{E}_x^{Pd} \sim 25.5 \text{ MeV}$$

At low energy constant temperature behavior

$$\text{then } E_x = aT^2$$

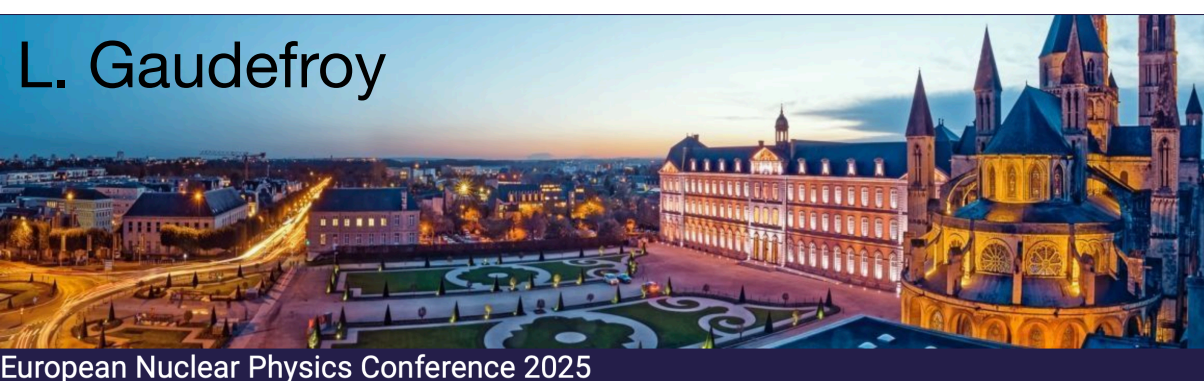
Difference observed for Pd is due to neutron emission

$$\Rightarrow \delta\sigma = 1.5\hbar \text{ corresponds to } \delta J = 2.1\hbar$$

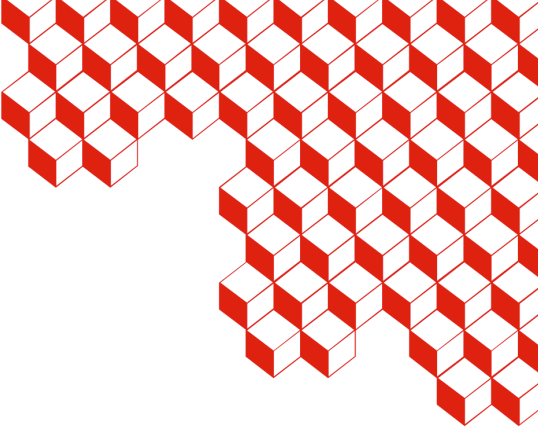
$\Rightarrow$ Neutron emission responsible for removal of $2\hbar$

Good agreement with

I. Stetcu et al. Phys. Rev. Lett. 127, 222502 (2021)



Summary



Study of neutronless fission channel in ^{252}Cf

Identification of fragments

Study of their decay

Determination of TXE distribution

Reproduction of measured gamma spectrum

Determination of E_x distribution ($\sigma \sim 1.3\text{MeV}$)

=> Heavy fragment weakly excited

Determination of spin cutoff parameters

=> Validates recently reported results on J-removal by neutrons

Comparison with models

Measured gamma spectrum cannot be reproduced if E_x^{Te} too high

Points towards a sizable deformation of the light fragment in line with orientation-pumping mechanism

