Fission program at ILL

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Contents

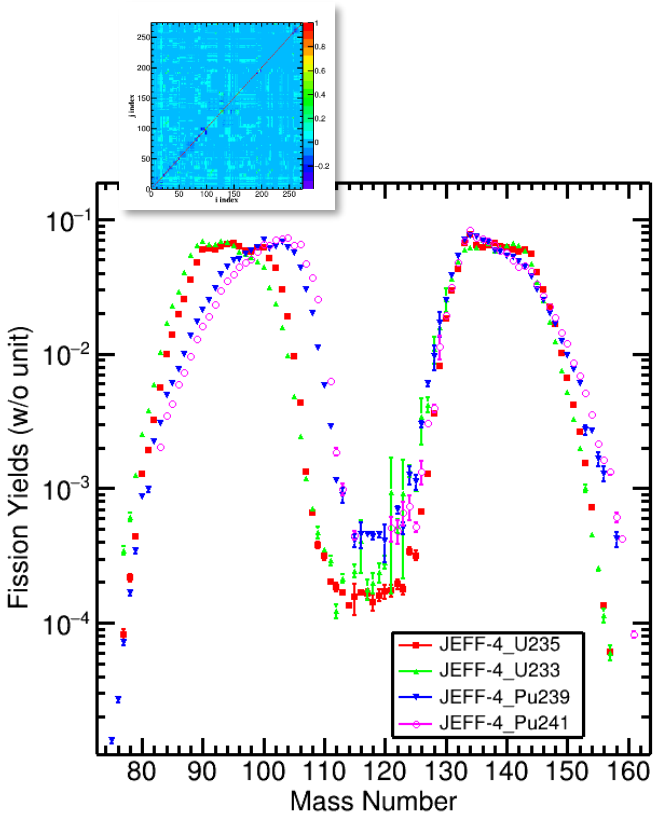
- Context of experimental program on FY@CEA/DES
- Mass Yields: Upgrade of set-up and proof of concept; e.g. $^{233}U(n_{th},f)$
- Angular momentum: Isomeric Ratio observable; e.g. $^{241}Am(2n_{th},f)$
- Cumulative and chain yields : FIPPS e.g. $^{235}U(n_{th},f)$
- Perspectives & Conclusion

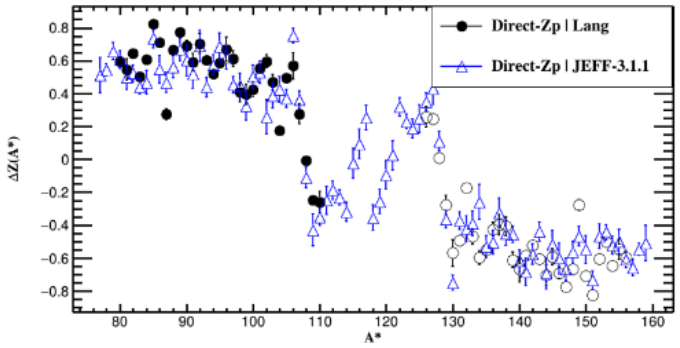
Context: a new methodology of FY Evaluation to define future experimental programs

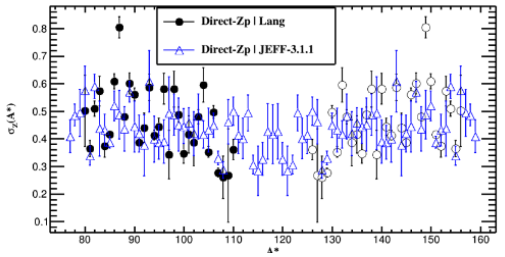
Theoretically $Y(A^*, Z, E^*, J^\pi) = Y(A^*, Z) \times P(E_K|A^*, Z) \times P(E^*, J^\pi|A^*, Z, EK)$ ↔ *Experimentally* $Y(A, Z, E_K, I) = Y(A) \times P(Z|A, E_K) \times P(E_k|A, Z) \times P(m|A, Z, E_K)$

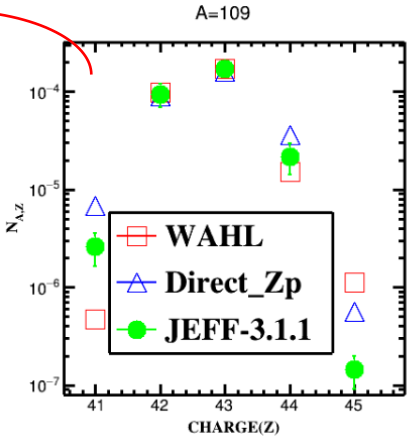
Pre-neutron Mass, charge, excitation energy

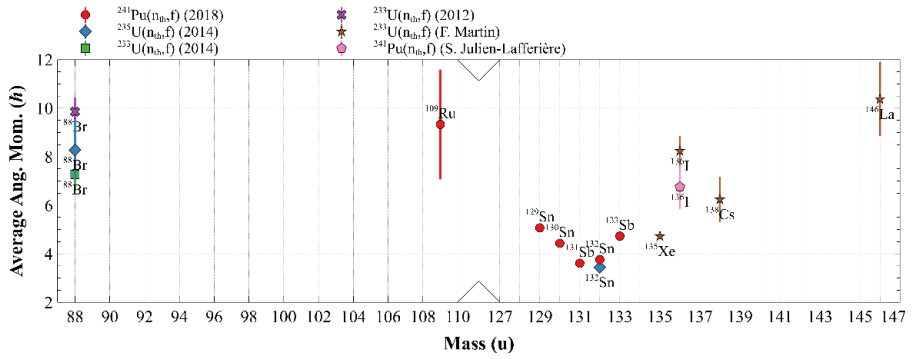
Mass Charge Kinetic Energy Isomeric

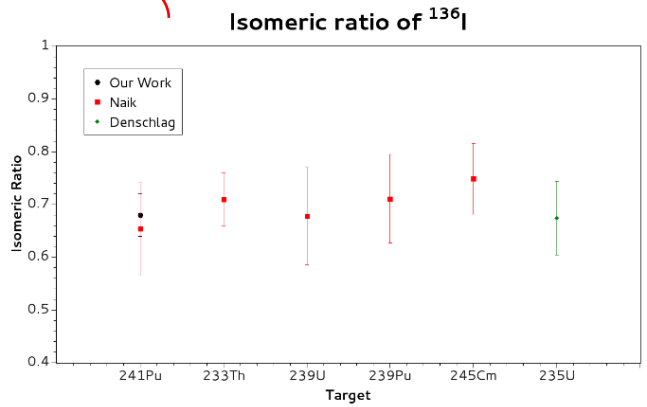












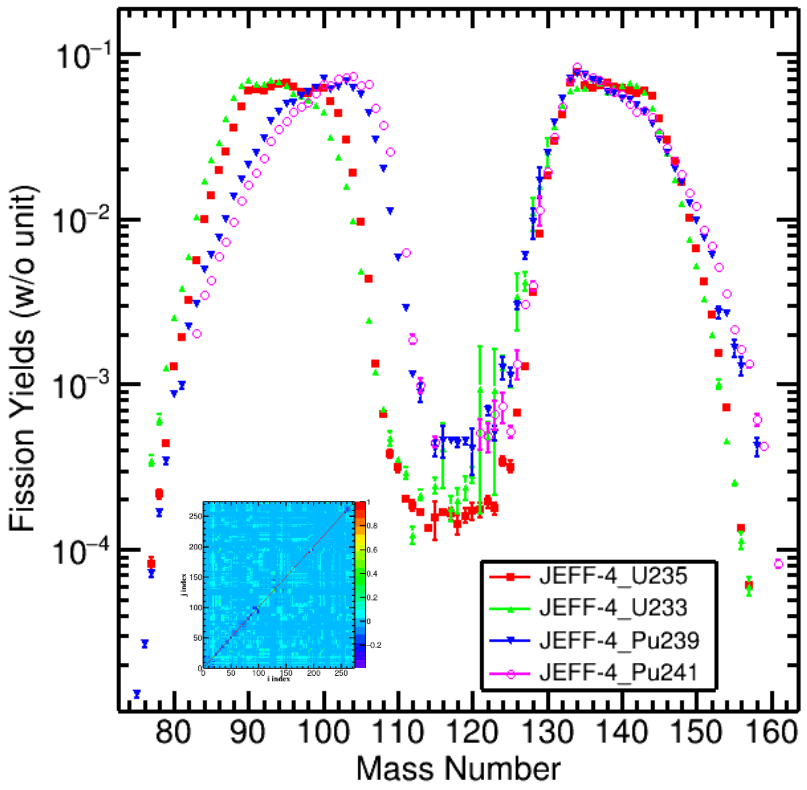
Experimental Data for FY Evaluation

Theoretically *Experimentally*

$$Y(A^*, Z, E^*, J^\pi) = Y(A^*, Z) \times P(E_K|A^*, Z) \times P(E^*, J^\pi|A^*, Z, EK) \leftrightarrow Y(A, Z, E_K, I\ ) = Y(A) \times P(Z|A, E_K) \times P(E_k|A, Z) \times P(m|A, Z, E_K)$$

Pre-neutron Mass, charge, excitation energy

Mass Charge Kinetic Energy Isomeric



- New experiments in mass and chain in the symmetric and asymmetric mass regions :
  - Kinetic energy distribution
  - test of fission mode and quantification of their intensity

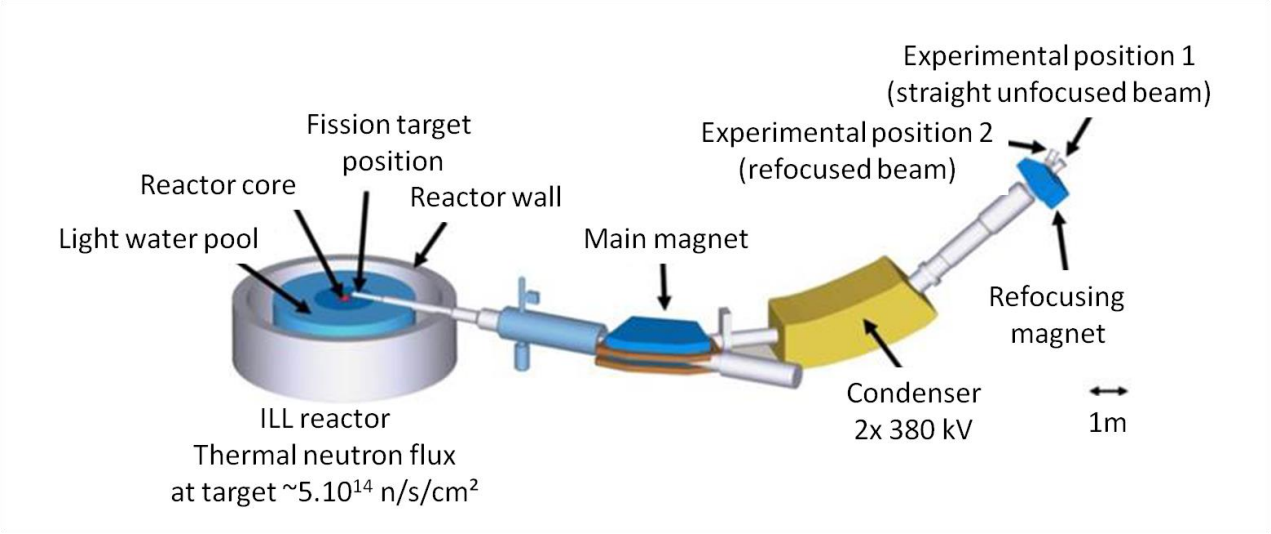
  → A. Vieville's PhD (2023-2026)
- Incident neutron energy studies of mass yields
  Y(A*, E_n) and ν(A*)

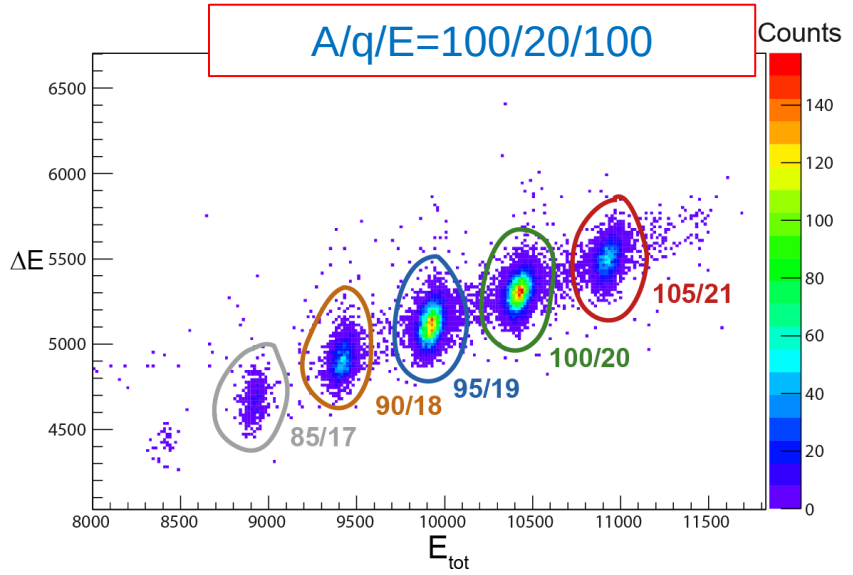
  → A. Regonesi's PhD (2024-2027)
- New Evaluation of charge yields Y(Z) & fractional Ind. Yields P(Z|A)

  → N. Teixeira Rua's PhD (2025-2028)
- IR Study to improve the Madland-England model used in evaluation with a more physical approach
  Fine structure measurements of KE to test the P(E*|A,Z) and ν(A*)

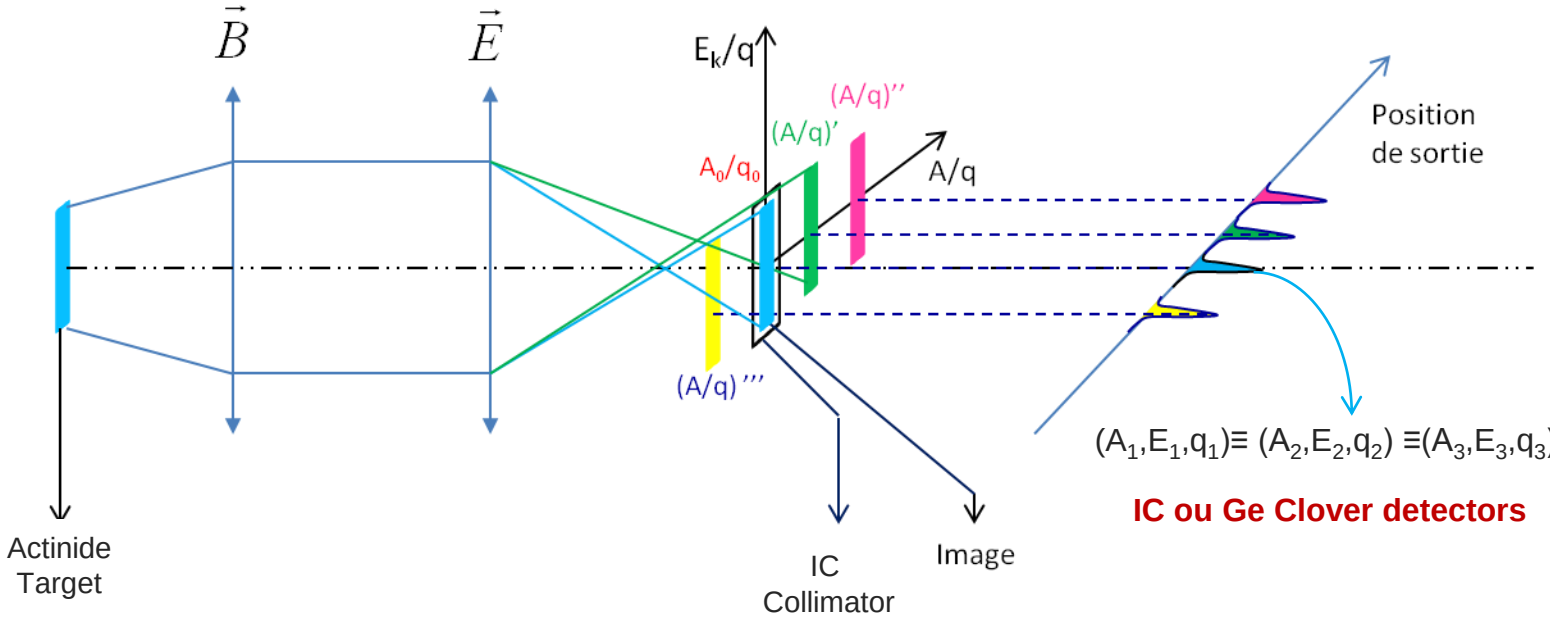
  → A. Skouloudaki's PhD (2025-2028)

Lohengrin facility & instrumental setup improvement: High yields





Ionization chamber $\Delta E - E$



IC ou Ge Clover detectors

$$\begin{cases} B\rho\ Magnet: B\rho = \dfrac{A_0 \cdot V_0}{q_0} = \dfrac{A_1 \cdot V_1}{q_1} \\ Condenser: \ \dfrac{E_0}{q_0} = \dfrac{E_1}{q_1} \Leftrightarrow \dfrac{A_0 V_0^2}{q_0} = \dfrac{A_1 V_1^2}{q_1} \Leftrightarrow V_0 = V_1 \\ IC\ Constraints: \ E_0 = \dfrac{1}{2} A_0 V_0^2 \neq E_1 = \dfrac{1}{2} A_1 V_1^2 \end{cases}$$

Mass A_0 identification through measurement of kinetic energy E_0
↪ IC → Removing mass degeneracy

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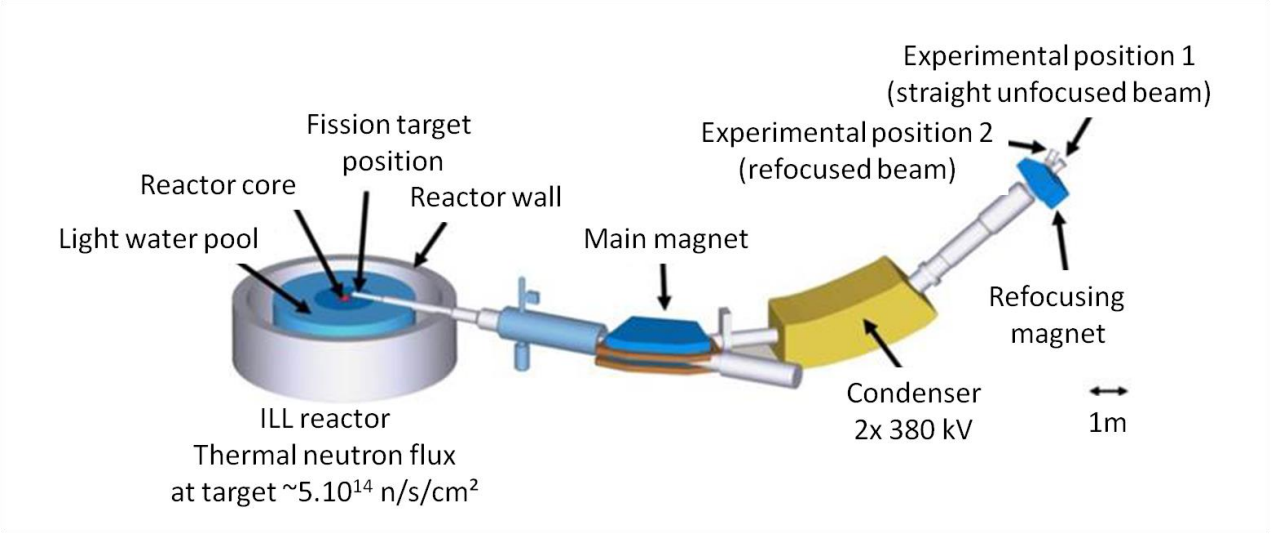
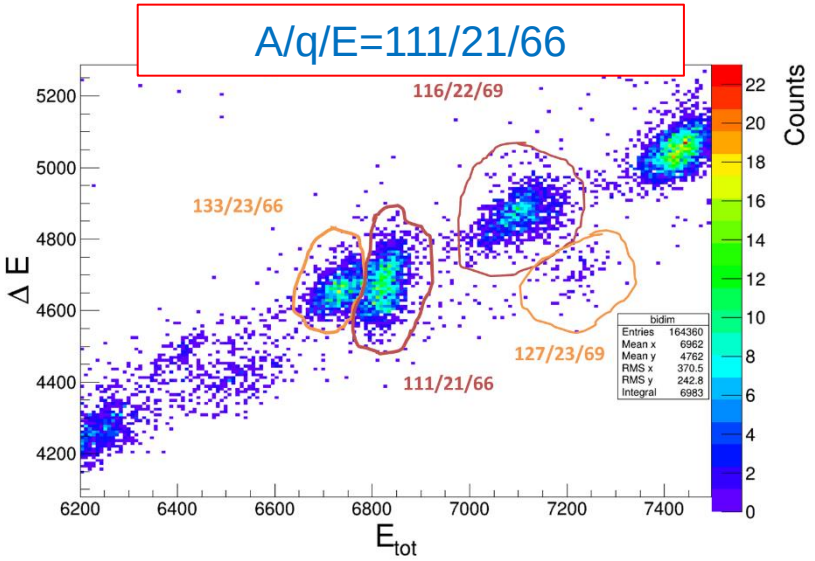
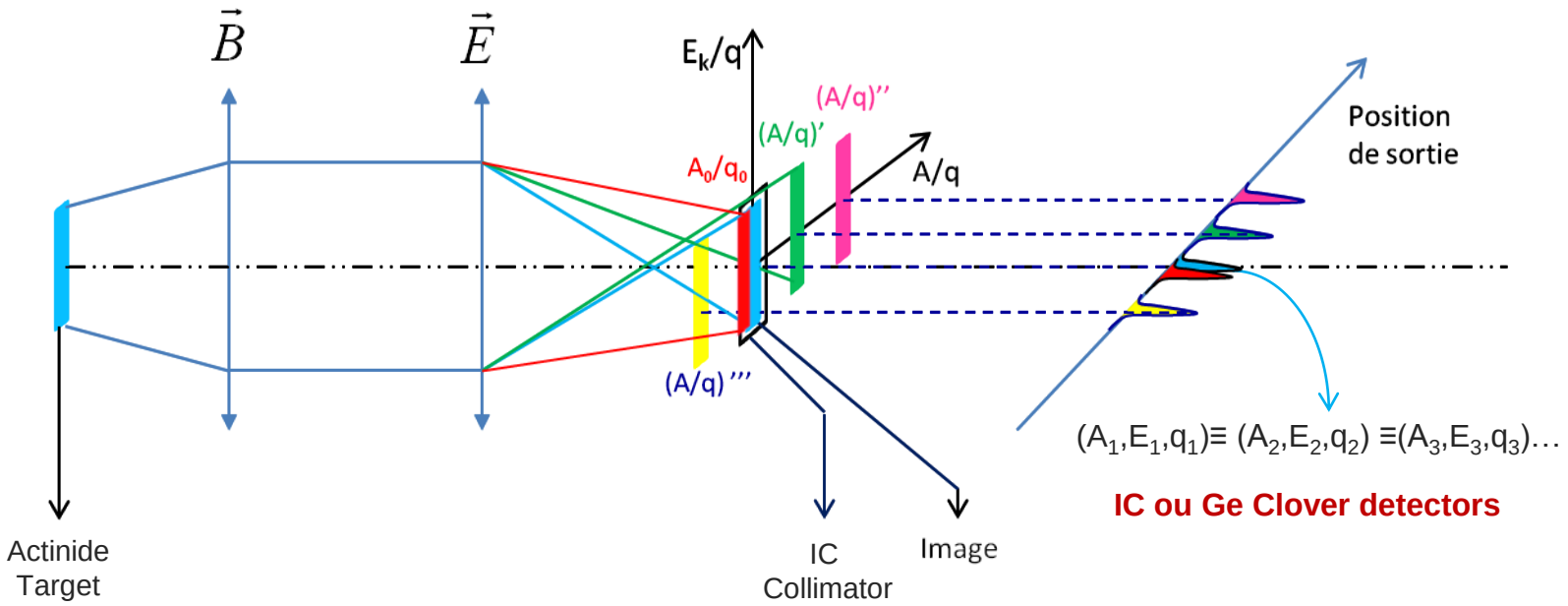
Lohengrin facility & instrumental setup improvement: Low yields

→ A. Vieville's PhD (2023-2026)







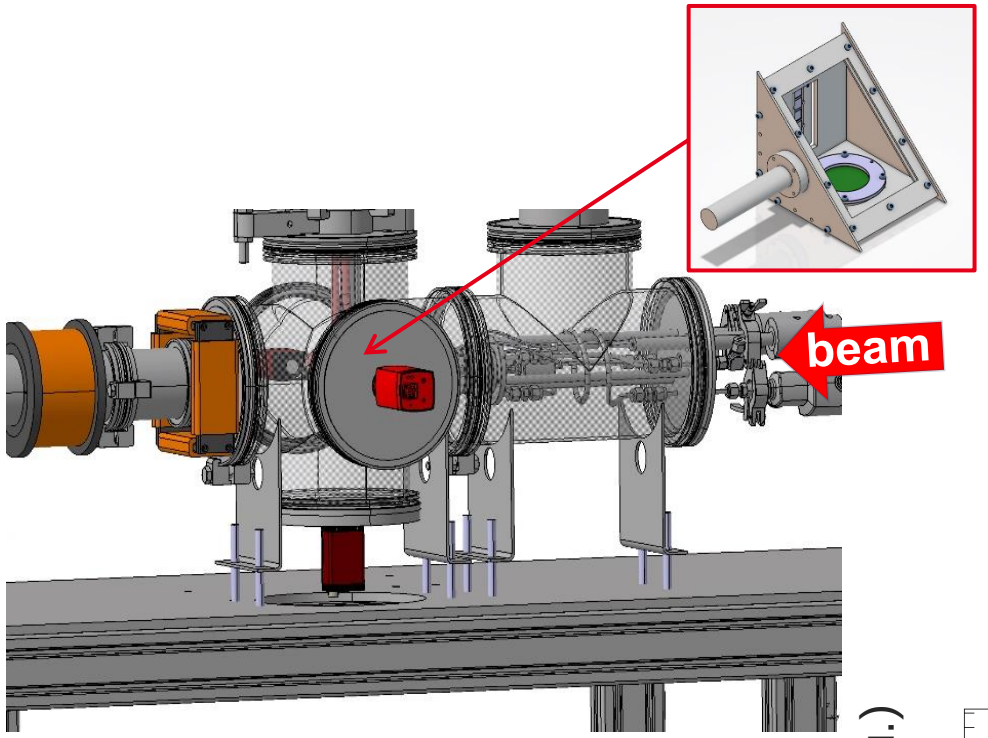
$$\begin{cases} \textit{Bρ Magnet Constraints: } \dfrac{V_0}{V_1} = \dfrac{A_1}{q_1} \cdot \dfrac{q_0}{A_0} \\ \textit{Atomic collisions: } q_1 \rightarrow q_1' = q_1 \pm 1 \pm 2 \pm \cdots \\ \textit{Condenser: } \dfrac{E_0}{q_0} = \dfrac{E_1}{q_1'} \Leftrightarrow \dfrac{A_0 V_0^2}{q_0} = \dfrac{A_1 V_1^2}{q_1'} \Leftrightarrow V_0 \neq V_1 \\ \textit{IC Constraints: } E_0 = E_1 \Leftrightarrow q_1' = q_0 \Leftrightarrow \dfrac{A_1}{A_0} = \left(\dfrac{V_0}{V_1}\right)^2 \end{cases}$$

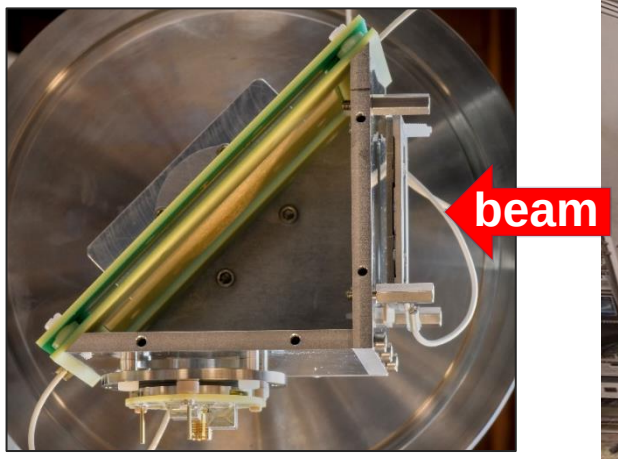
$$\boldsymbol{A_c \equiv A_1 = \left(\frac{q_1}{q_0}\right)^2 A_0}$$

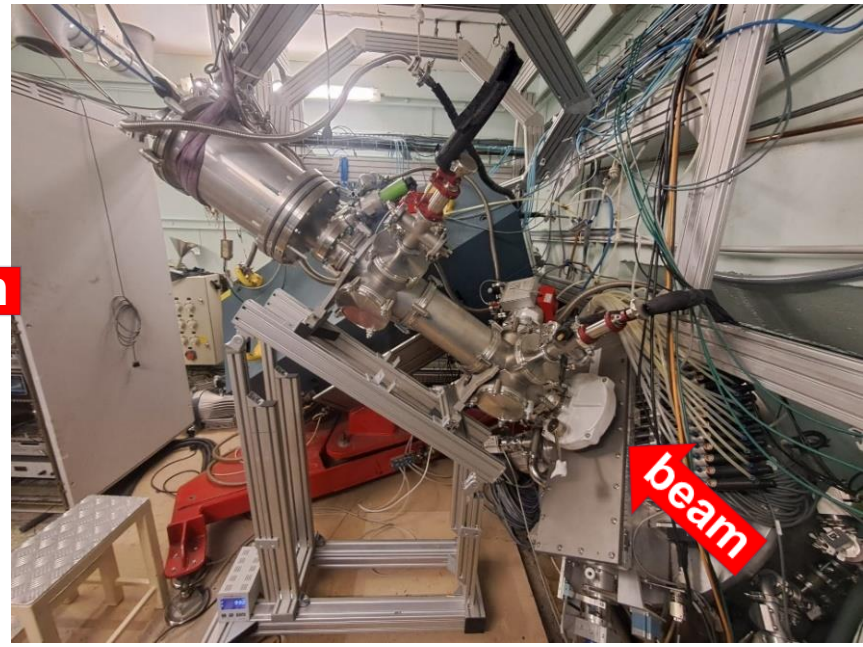
$$\hookrightarrow \textit{tof} = \textit{New celerity filter}$$

Lohengrin facility & instrumental setup improvement: Low yields

→ A. Vieville's PhD (2023-2026)

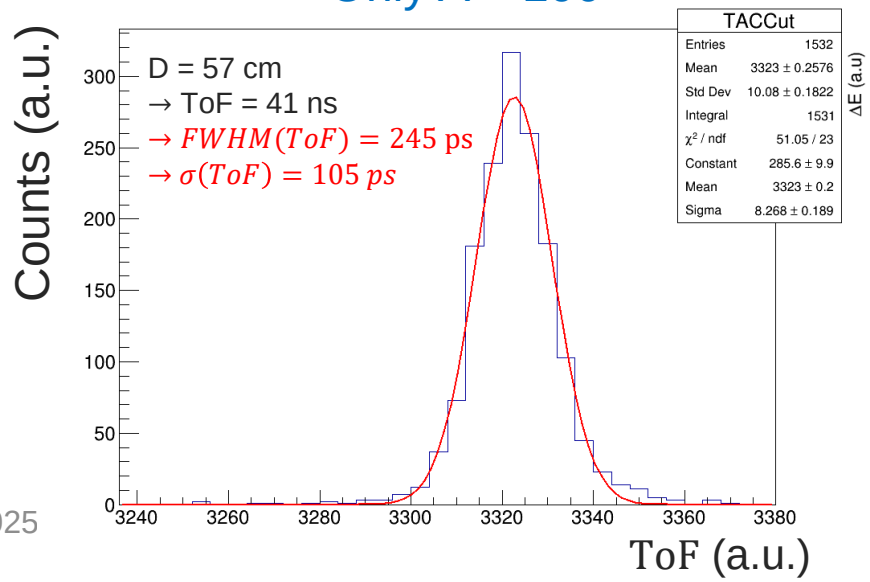




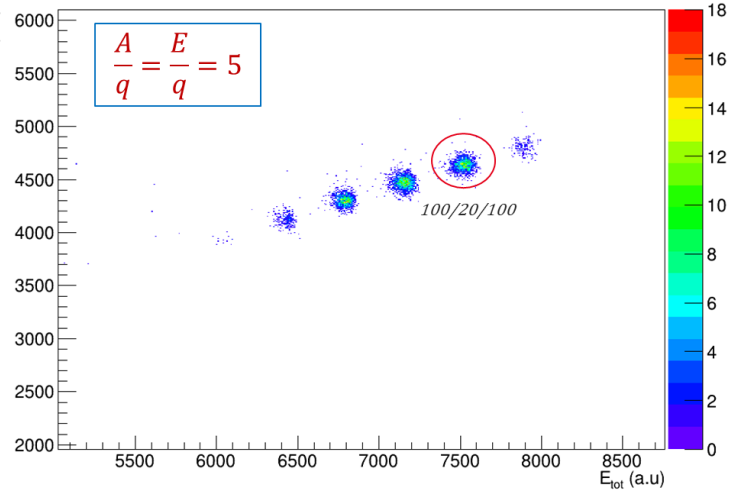


- MCP detectors @ $[2-8]\times10^{-7}\ mbar$
- Electrostatic mirror
- ToF distance ~ 57 cm
- SiN e^- emissive foils ~ 50 nm

Only A = 100



LPSC Detector and acquisition servic

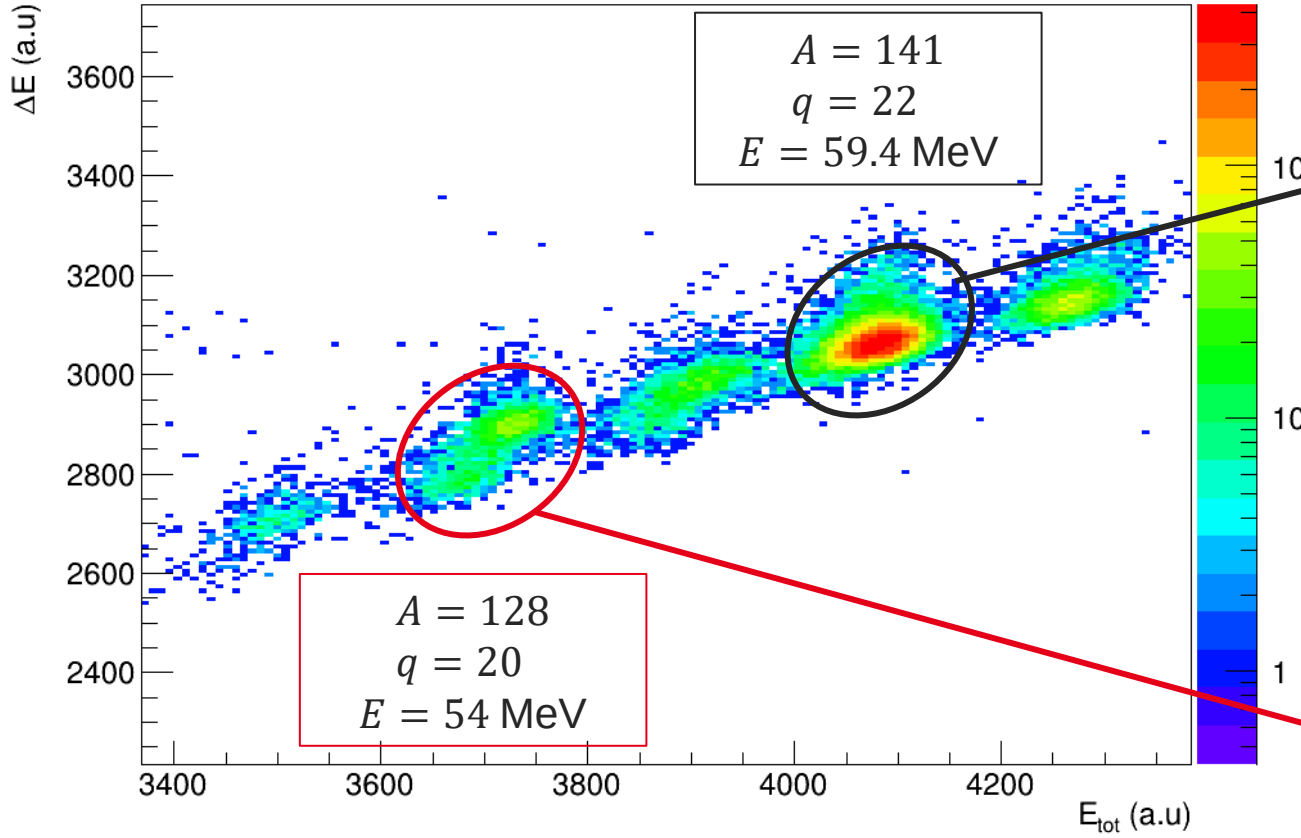


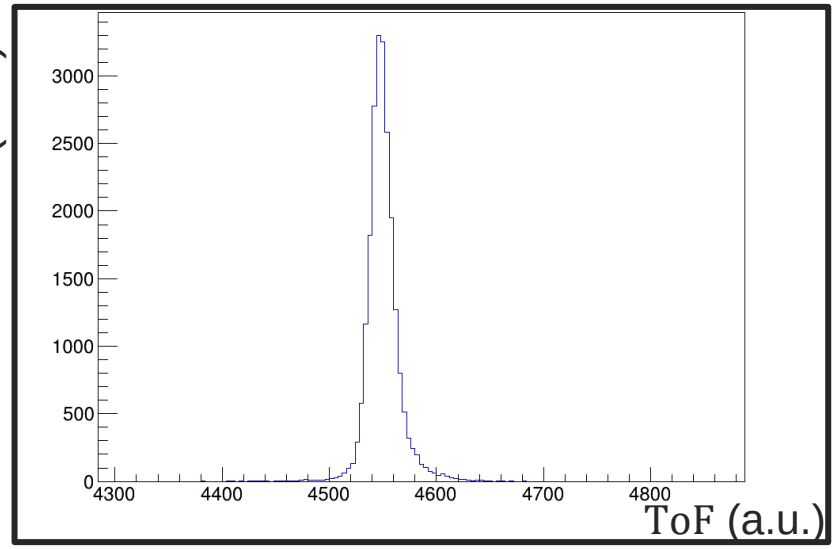
Proof of concept and first experimental tests: $\Delta E \times E_{tot} \times ToF$

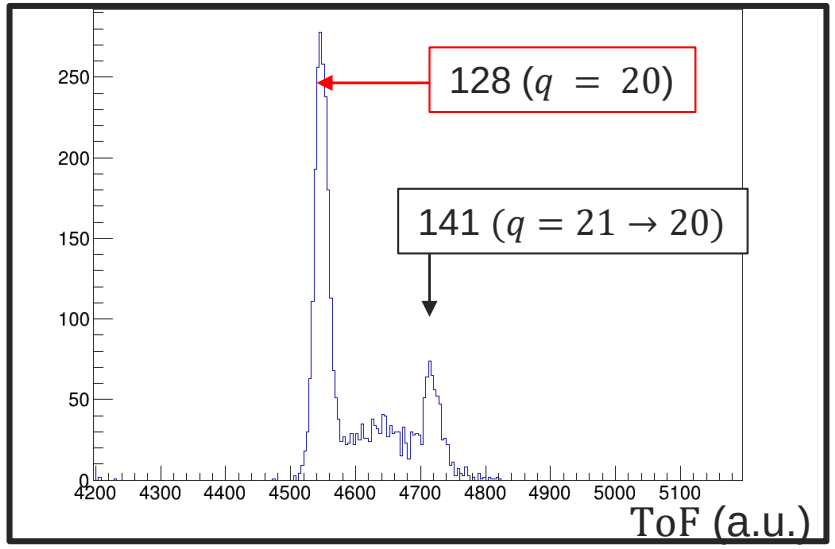
→ A. Vieville's PhD (2023-2026)

- A/q/E = 128/20/54

  → Calculation: $A_c = \{116; 141\}@q \pm 1$ & $\{104; 154\}@q \pm 2$







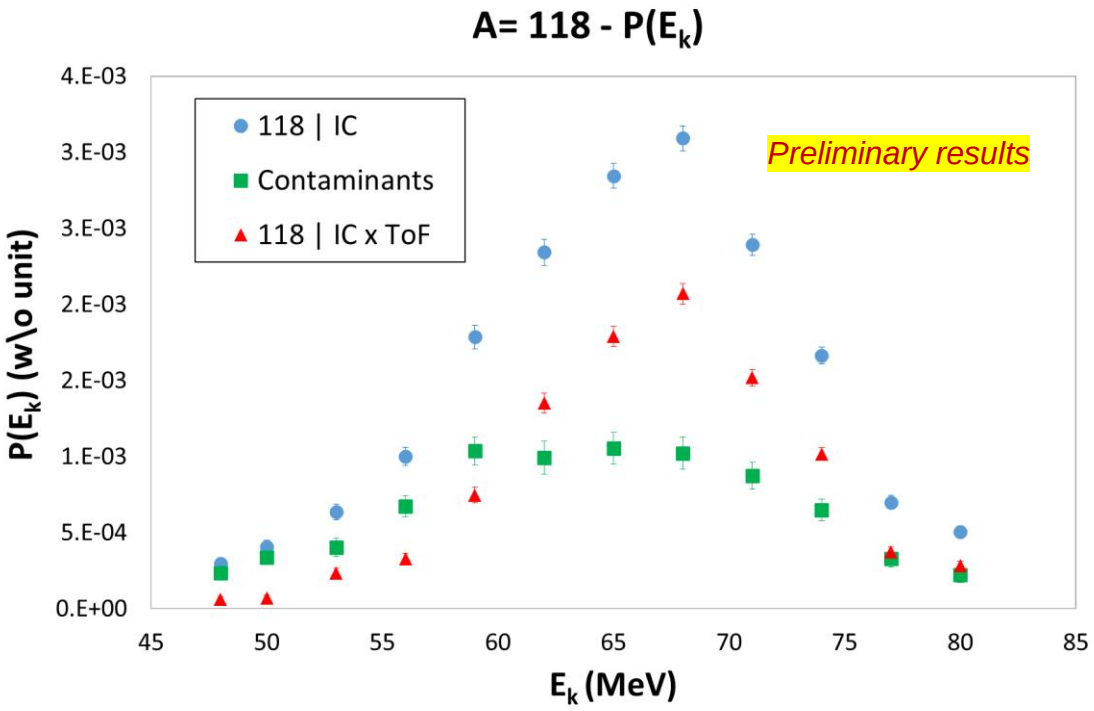
- Absolute calibration of ToF: channel →Time(T) → A (ET²)

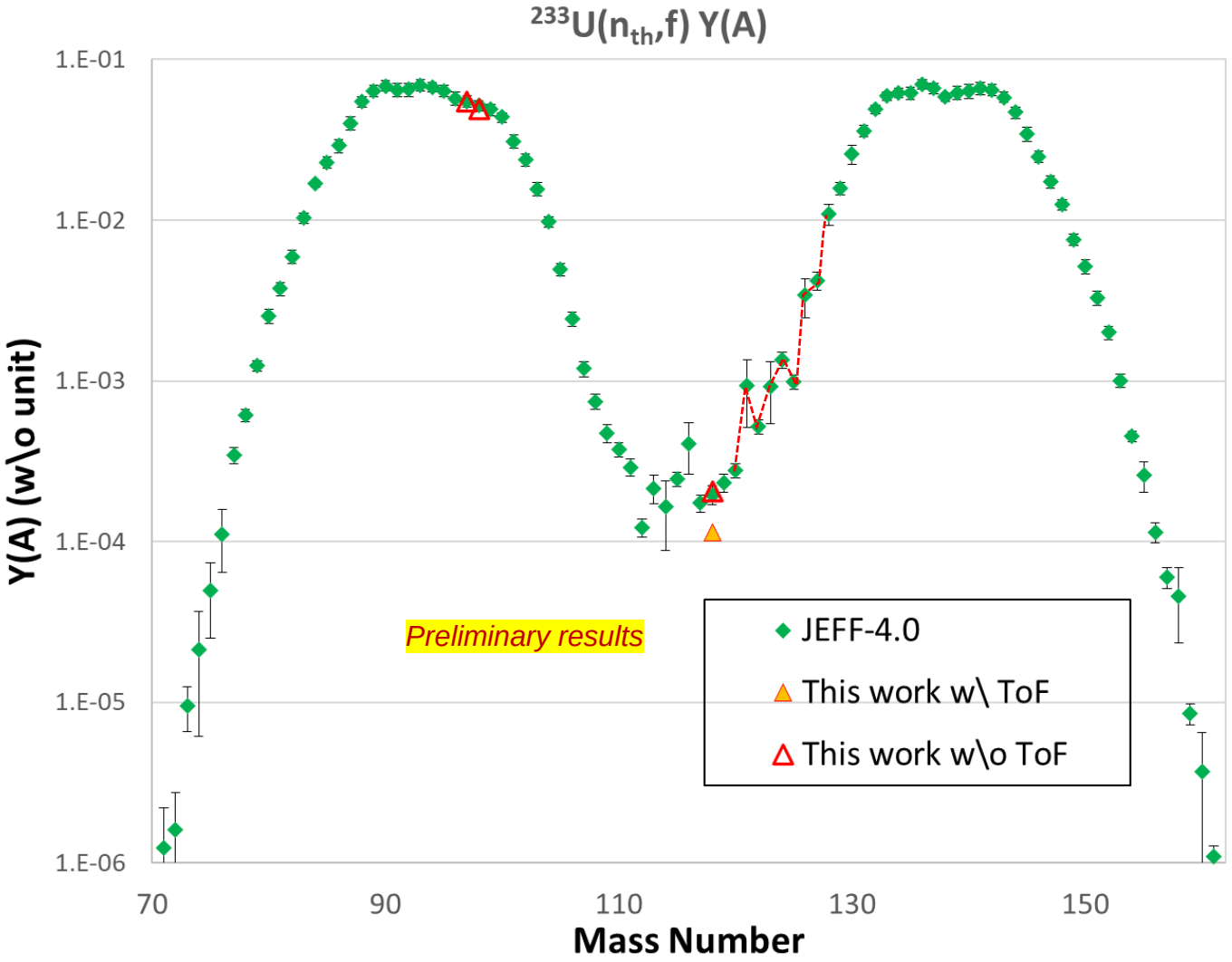
  $A = 128.06 \pm 0.02 \rightarrow A_c = 140.87 \pm 0.06$

→ A. Vieville's PhD (2023-2026)

$^{233}U(n_{th},f)$ Results

→ A. Vieville's PhD (2023-2026)



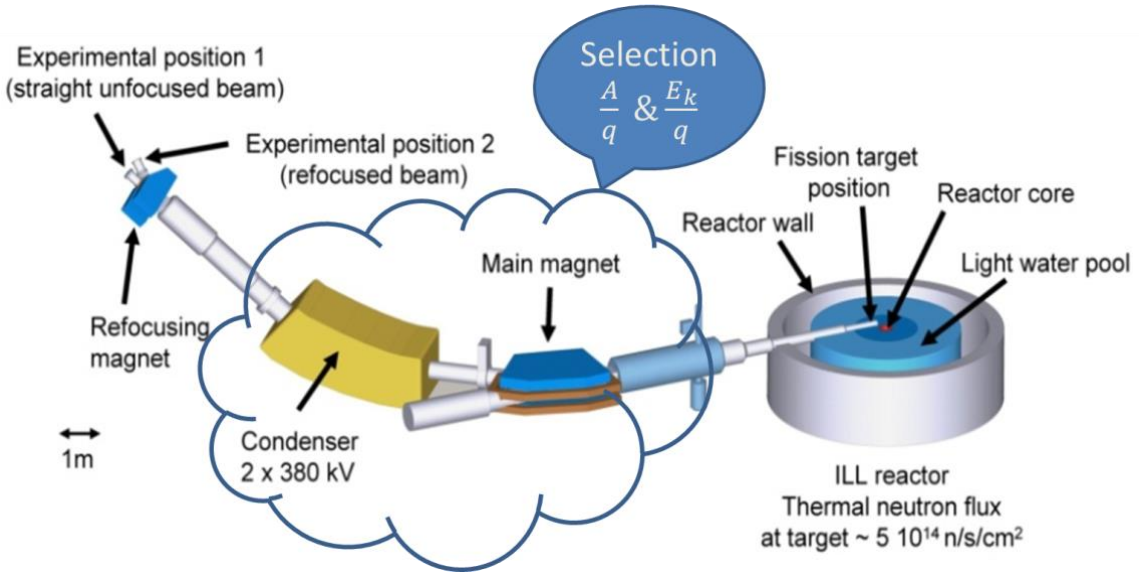


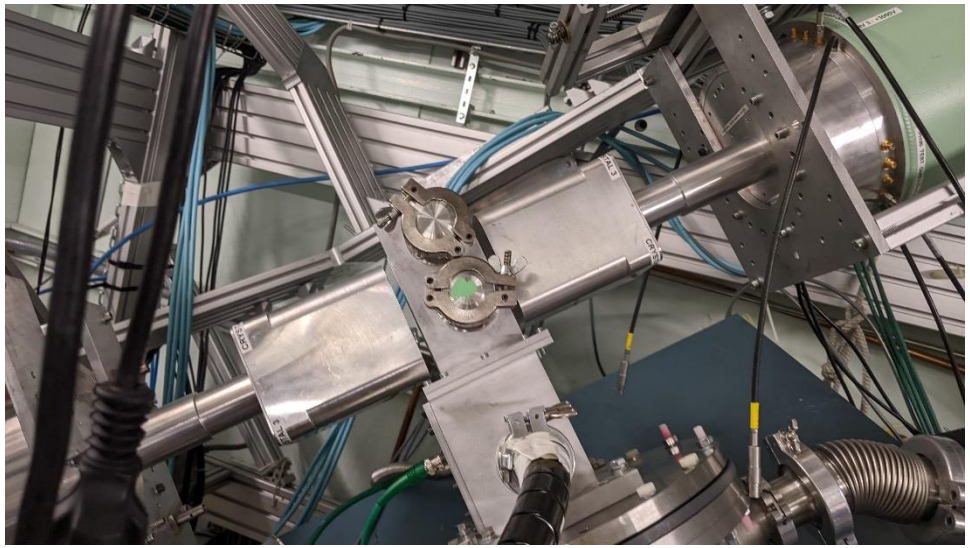
→ A. Vieville's PhD (2023-2026)

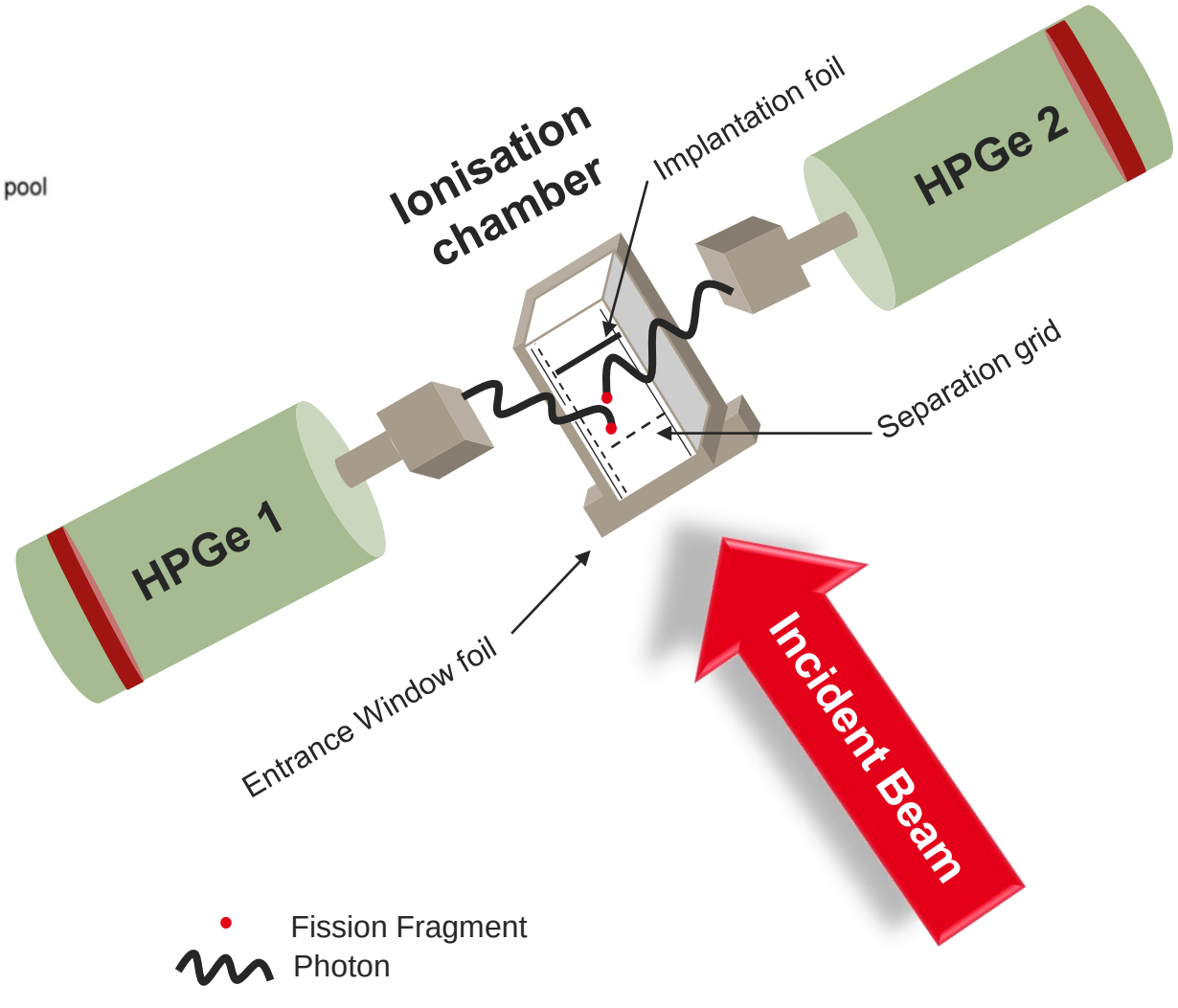
Contents

Angular momentum: Isomeric Ratio observable; e.g. 241Am(2nth,f)

→ A. Skouloudaki's PhD (2025-2028)

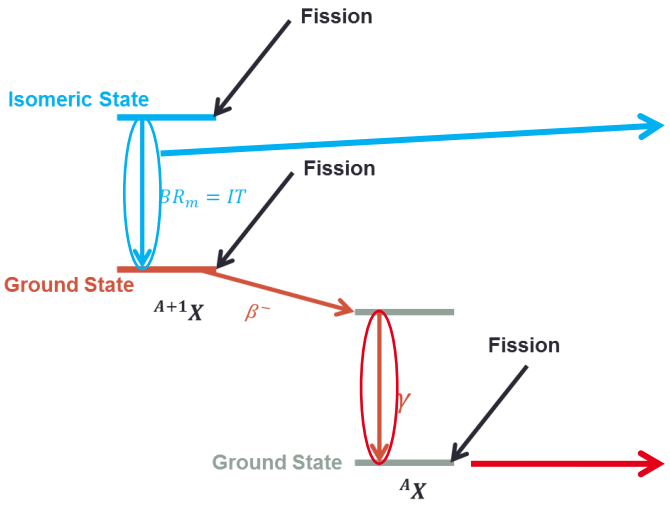




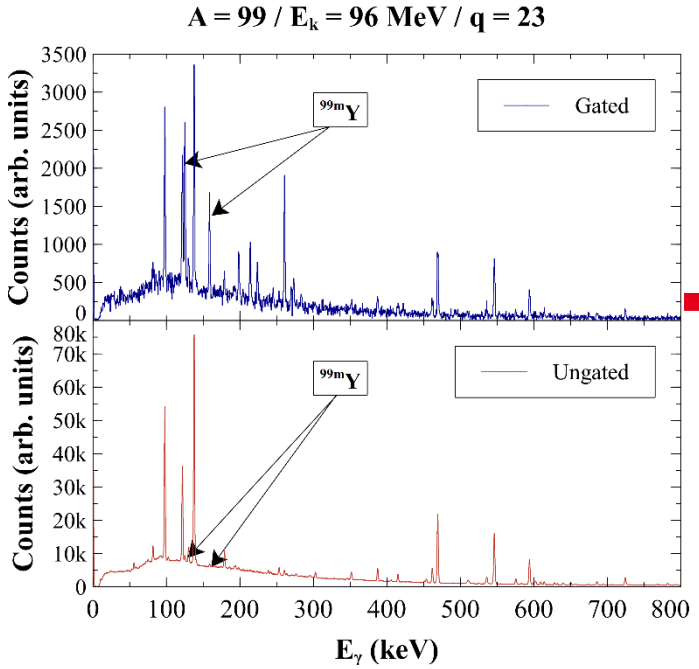


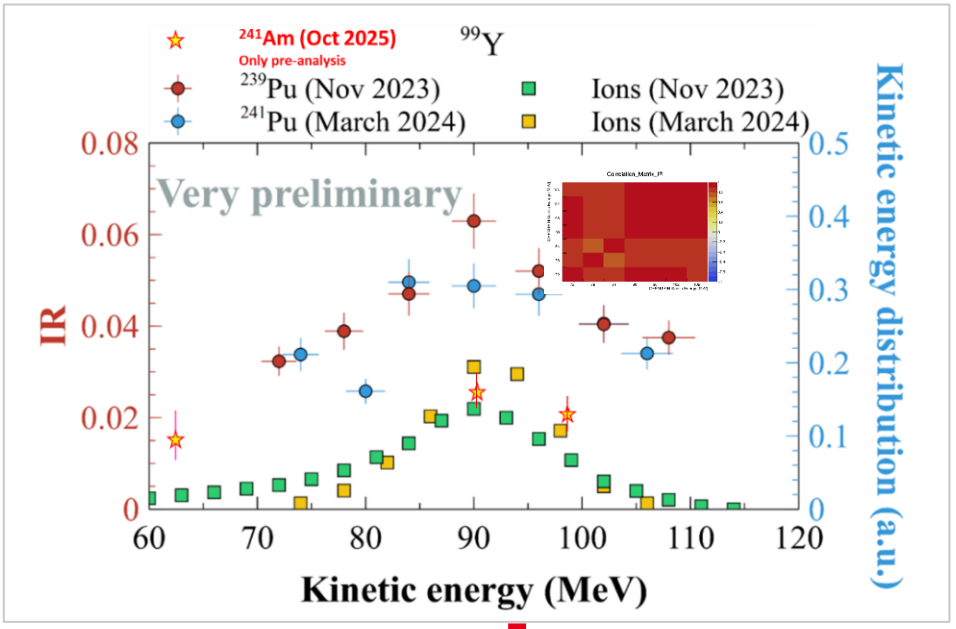
Angular momentum: Isomeric Ratio observable; e.g. 241Am(2nth,f)

→ A. Skouloudaki's PhD (2025-2028)



$$IR_{exp} = \frac{\tau_f(IS)}{\tau_f(IS) + \tau_f(GS)}$$





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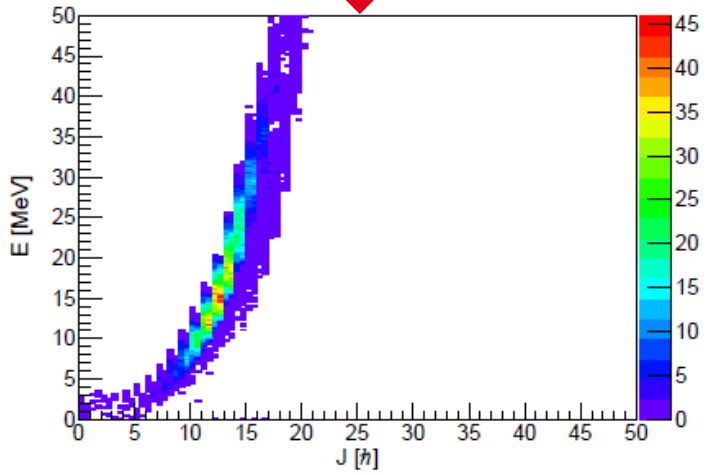
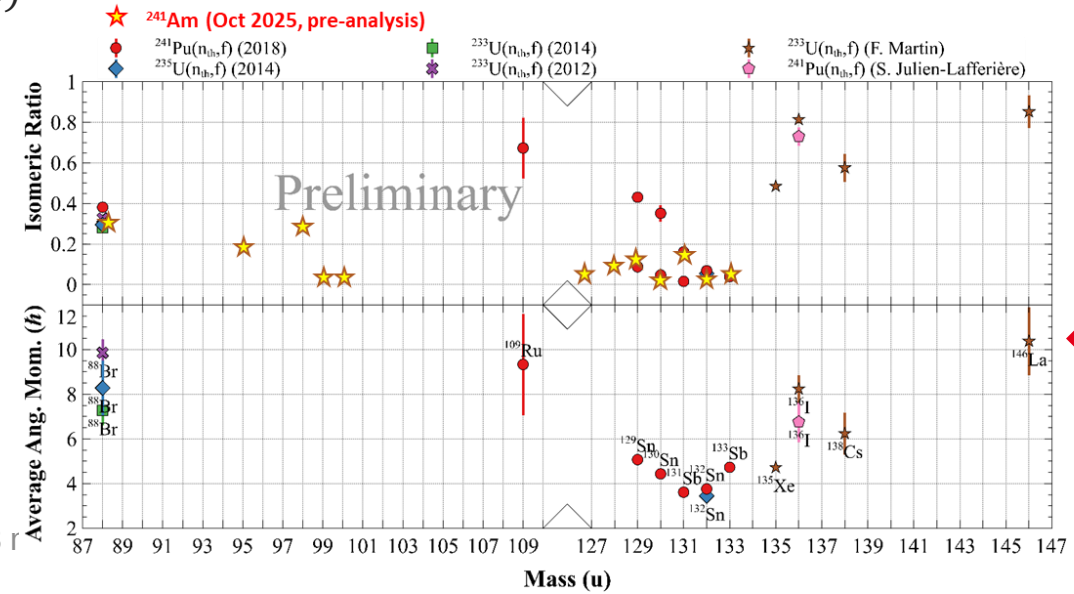
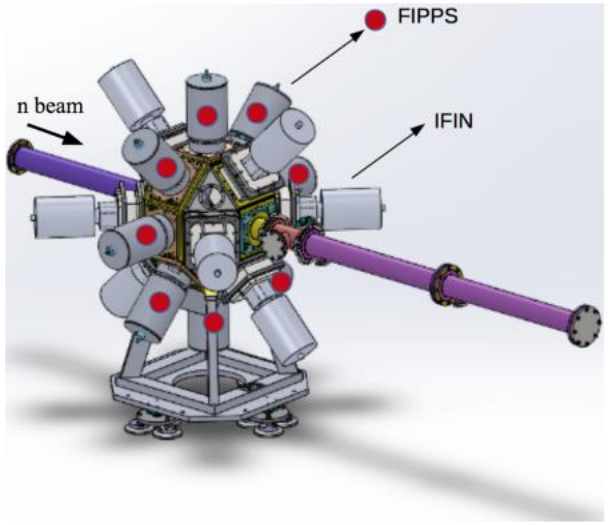


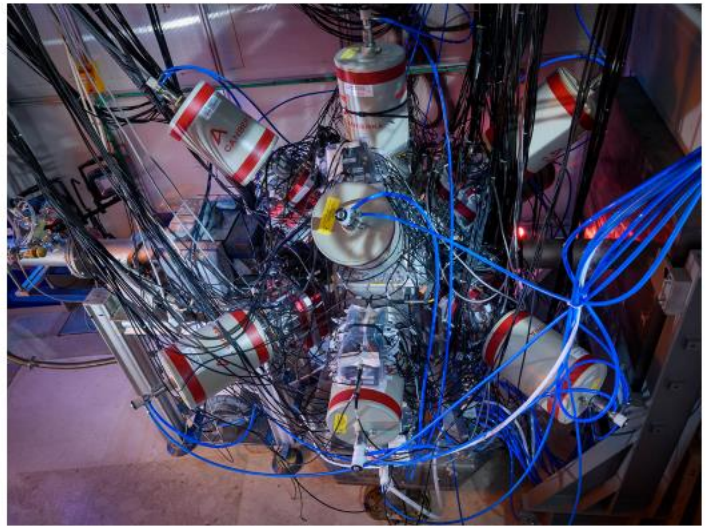


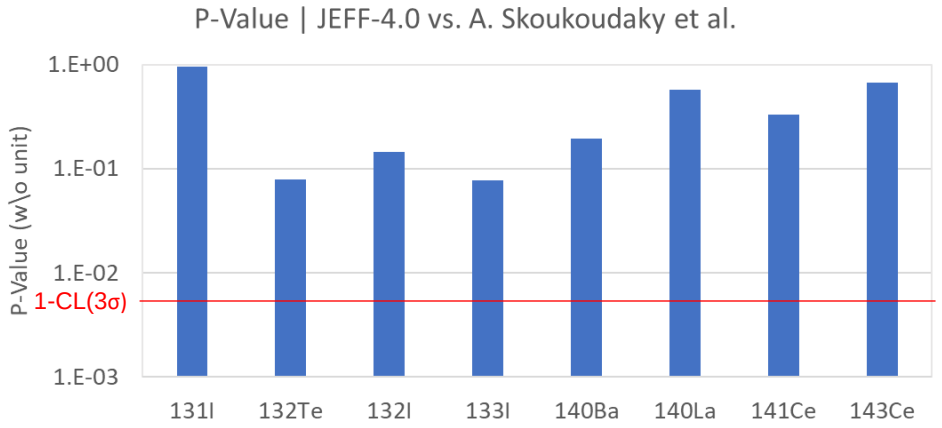
Contents

Cumulative and chain yields : FIPPS e.g. 235U(nth,f)

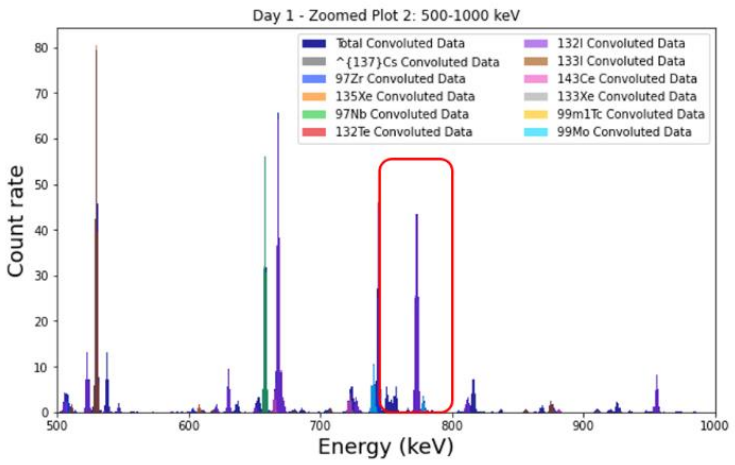
→ A. Skouloudaki's PhD (2025-2028)

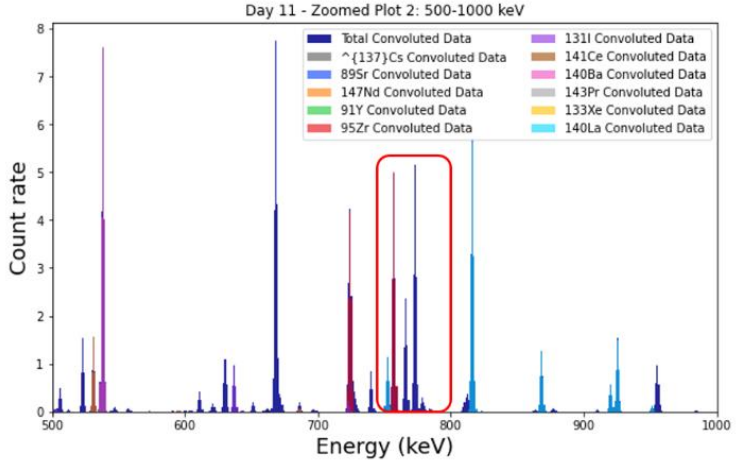






$1\text{-CL}(3\sigma) = 3.10^{-3}$





	A. Skoukoudaky		JEFF-4.0		
	FY ($.10^{-2}$)	Rel. Unc. (%)	FY ($.10^{-2}$)	Rel. Unc. (%)	P-value
131I	**2.96**	5.60	**2.97**	1.44	0.95
132Te	**3.95**	4.20	**4.26**	1.46	0.08
132I	**4.43**	1.66	**4.29**	1.42	0.14
133I	**6.11**	4.42	**6.61**	1.32	0.08
140Ba	**5.91**	2.99	**6.16**	1.34	0.19
140La	**6.06**	2.99	**6.17**	1.34	0.57
141Ce	**6.13**	2.28	**5.97**	1.46	0.33
143Ce	**5.68**	10.74	**5.94**	1.26	0.67
Global dataset					0.12

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Conclusion & Perspectives for the next decade !

- New device for mass yield experiment the symmetric and far asymmetric mass regions :
  - Kinetic energy distribution
  - test of fission mode and quantification of their intensity

  → A. Vieville's PhD (2023-2026)

- IR Study to improve the Madland-England model used in evaluation with a more physical approach
  Fine structure measurements of KE to test the P(E*|A,Z) and ν(A*)

  → A. Skouloudaki's PhD (2025-2028)

- Measurement & evaluation of charge yields Y(Z) & fractional Ind. Yields P(Z|A) in order to describe the charge polarization and consider the exp. Correlation in P(Z|A)

  → N. Teixeira Rua's PhD (2025-2028)

- Nuclei of interest: $^{235}U(n_{th},f)$, $^{239}Pu(n_{th},f)$, $^{241}Pu(n_{th},f)$, $^{241}Am(2n_{th},f)$, $^{233}U(n_{th},f)$, $^{237}Np(2n_{th},f)$ … $^{245}Cm(n_{th},f)$, $^{251}Cf\ (n_{th},f)$

  → with Exp. correlation matrices

- From JEFF-4.0 evaluation analysis, the needs are :

  - new Independent and cumulative yields {Value, Uncertainties, Correlations} : $^{239}Pu(n,f)$ light peak & far asymmetric heavy mass region

  - descent on symmetry mass region in order to connect radiochemical measurements and electro-magnetic spectrometry measurements for the major actinides

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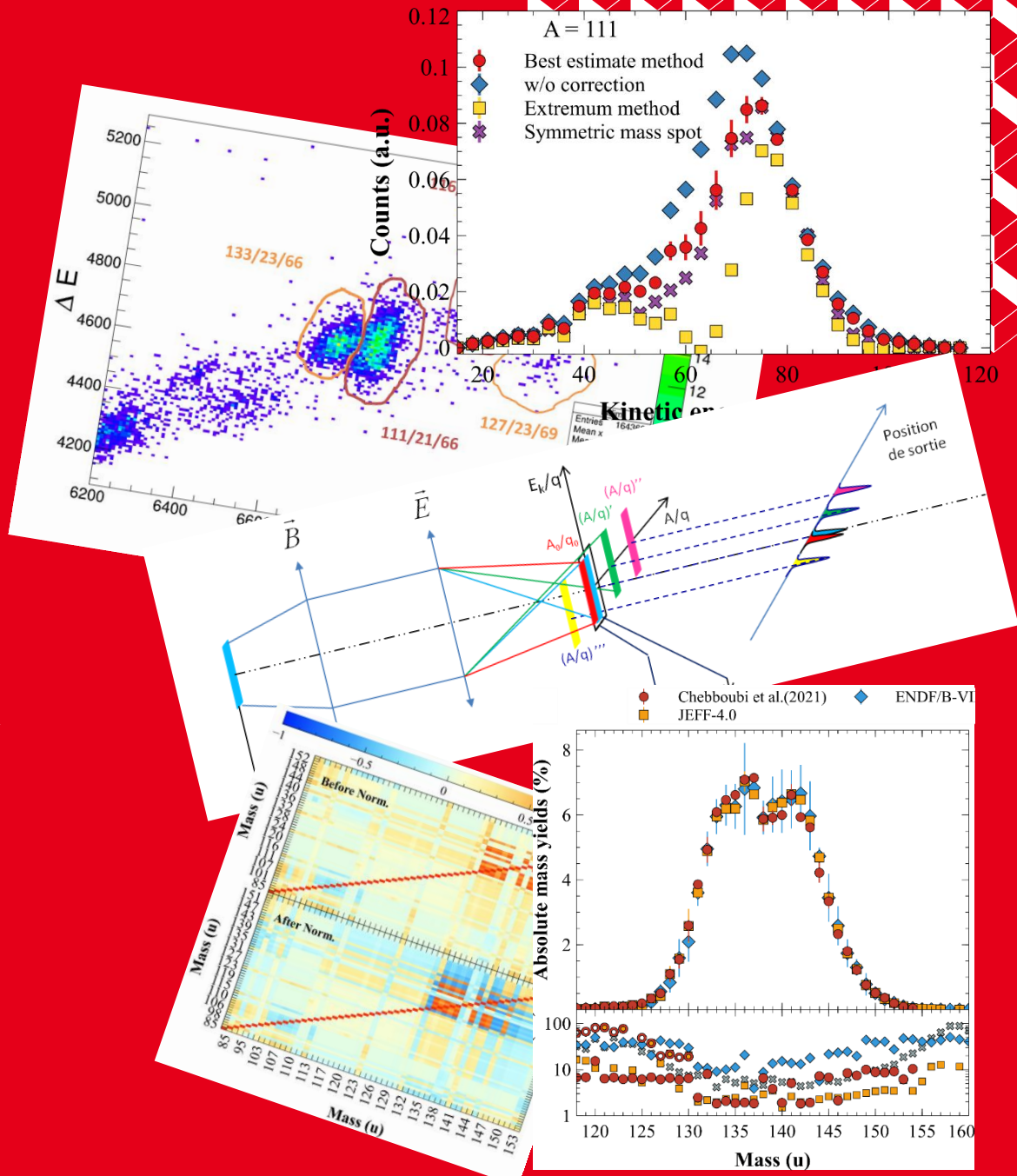
D. Bernard2, S-M. Cheikh2
U. Köster3, J.M. Daugas3, P. Mutti3

Thank you for your attention



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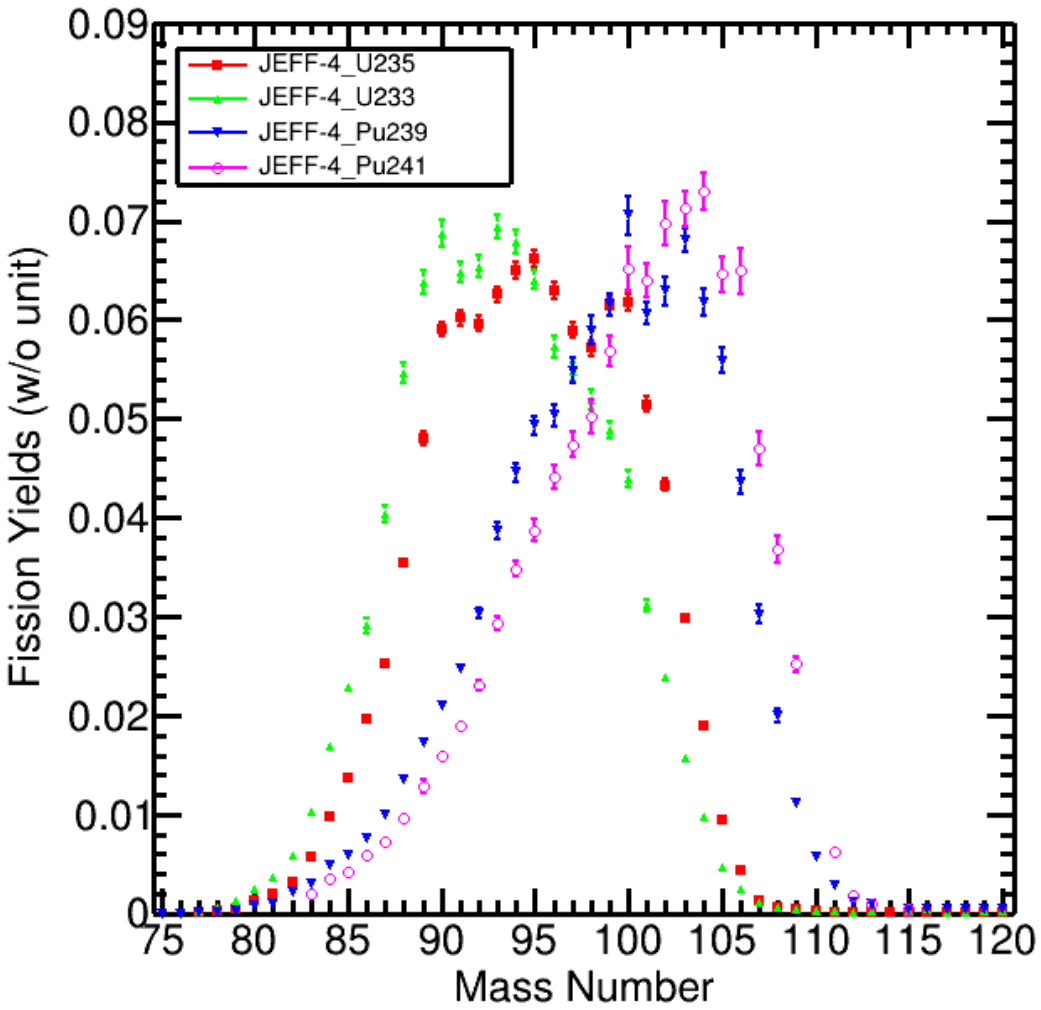
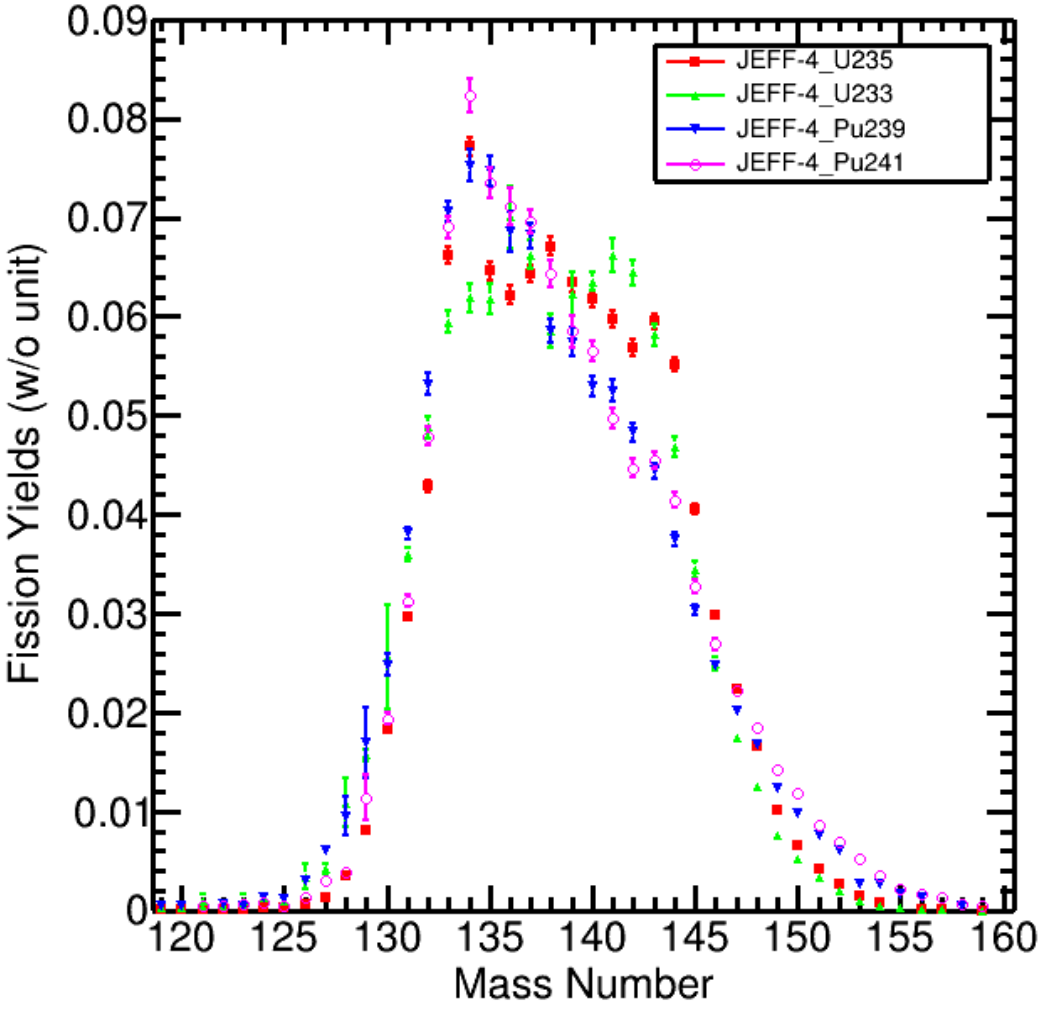
ND2025

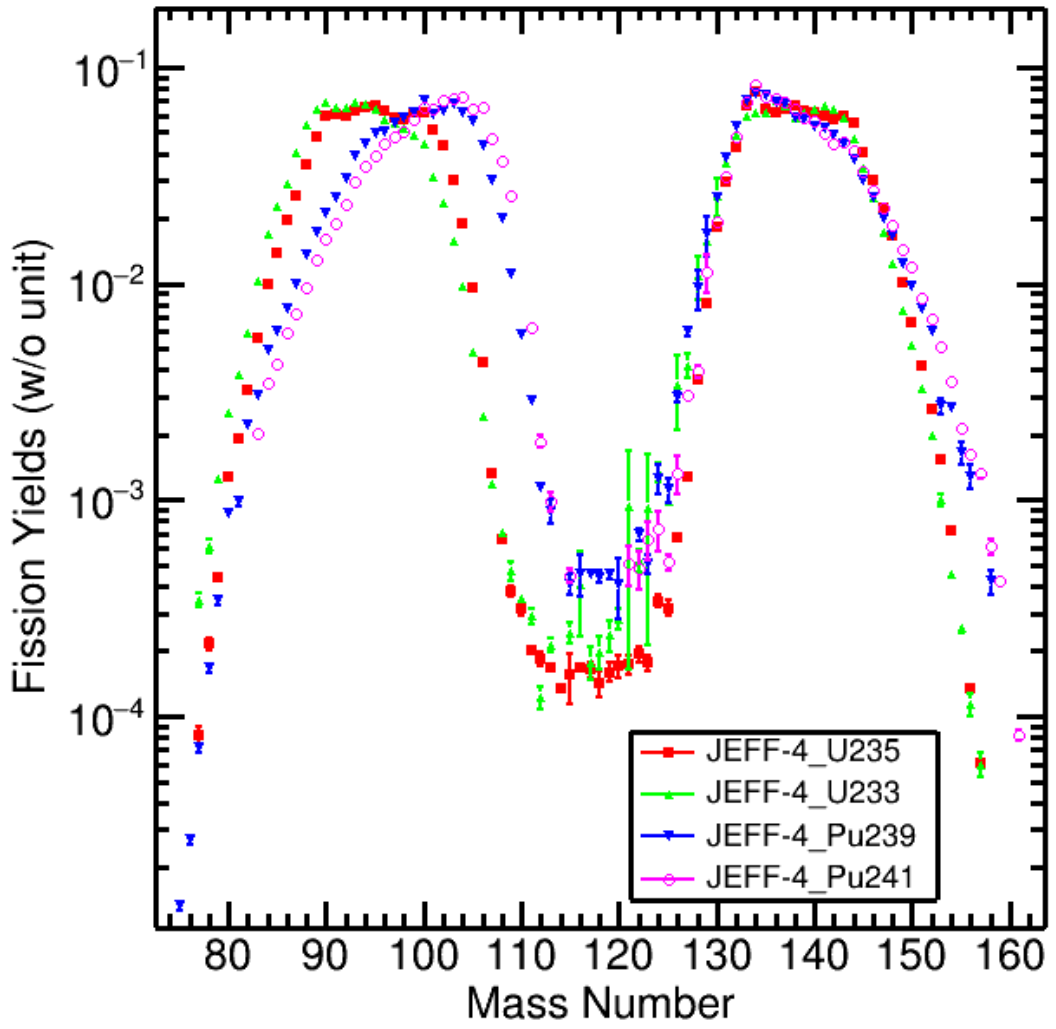
- Measurement of the 99Y isomeric ratio in the 239,241Pu(nth,f) reactions with the
- LOHENGRIN spectrometer. A. Chebboubi et al.
- Characterization of a time-of-flight system for the study of symmetric fission products with the LOHENGRIN spectrometer at ILL. C. Sage et al.
- Intercomparison of fission yields for the 4 major fissionning systems: tests and interpretation of JEFF-4.0 FY evaluation. G. Kessedjian et al.
- Pre-neutron mass yields evaluation of 235U(nth,f). A. Regonesi et al.
- Impact of Thermal Neutron Induced Fission Product Yields Evaluations on LWR Calculation Outcomes. D. BERNARD et al.
- From Wahl's Zp Model to Direct-Zp Model: Improved nuclear charge distribution of 235U(nth, f) and 239Pu(nth, f). Sidi-M. Cheikh et al.

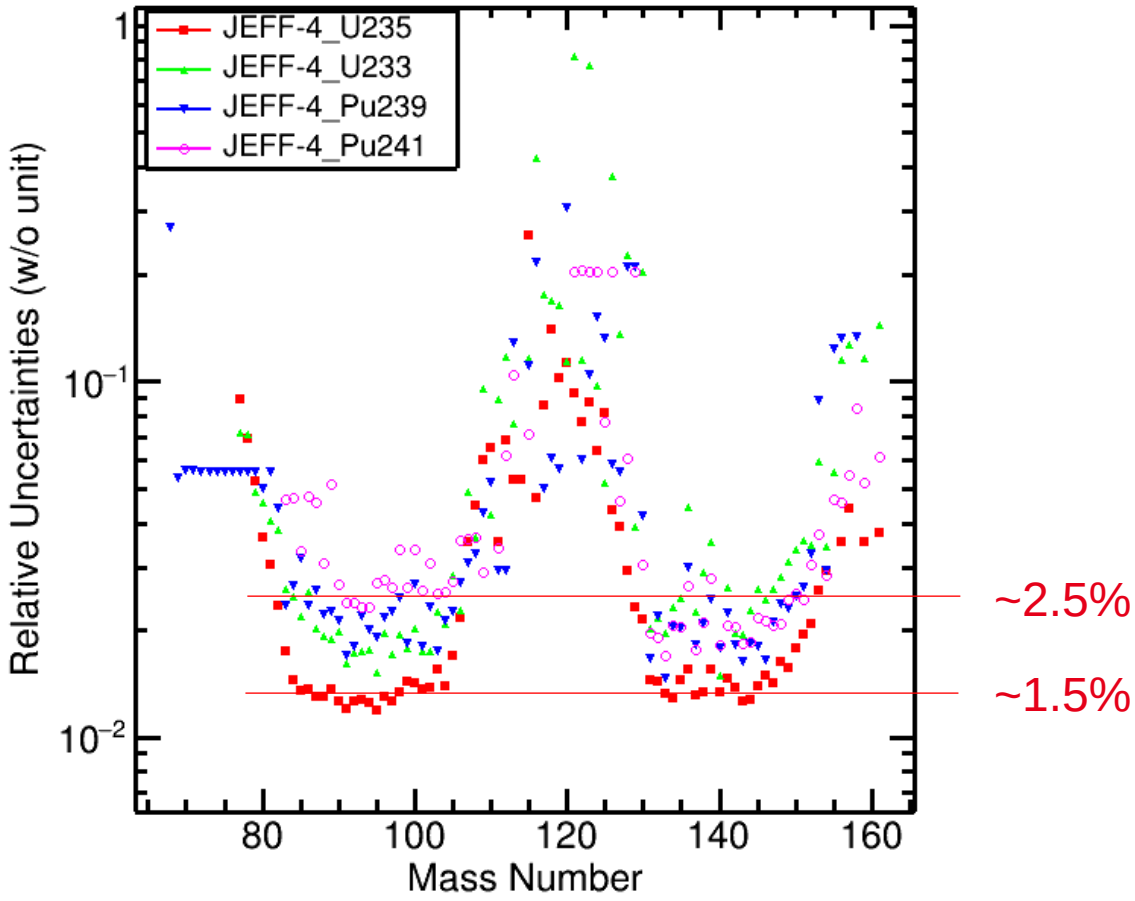
Intercomparison of Y(A)'s : $^{233}U(n_{th},f)$ - $^{235}U(n_{th},f)$ - $^{239}Pu(n_{th},f)$ - $^{241}Pu(n_{th},f)$





Intercomparison of Y(A)'s : $^{233}U(n_{th},f)$ - $^{235}U(n_{th},f)$ - $^{239}Pu(n_{th},f)$ - $^{241}Pu(n_{th},f)$





- New evaluated database of mass yields – free of model input – in order to test phenomenological fission models