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Fission Yields for reactor applications: Development of a new program at CEA-Cadarache

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Content

Fission Yields for reactor applications: Development of a new program at CEA-Cadarache

1/ Fission yield measurements using the LOHENGRIN recoil mass spectrometer

2/ Evaluation of fission yields in the thermal energy region: Example of the ^{239}Pu(n_{th},f) reaction

3/ From pre-neutron to post neutron fission yields: Case of the ^{235}U(n_{th},f) reaction

1. Fission yield measurements with the recoil mass spectrometer LOHENGRIN

Institut Laue Langevin (Grenoble, France)

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High Flux Reactor of the Institute Laue-Langevin

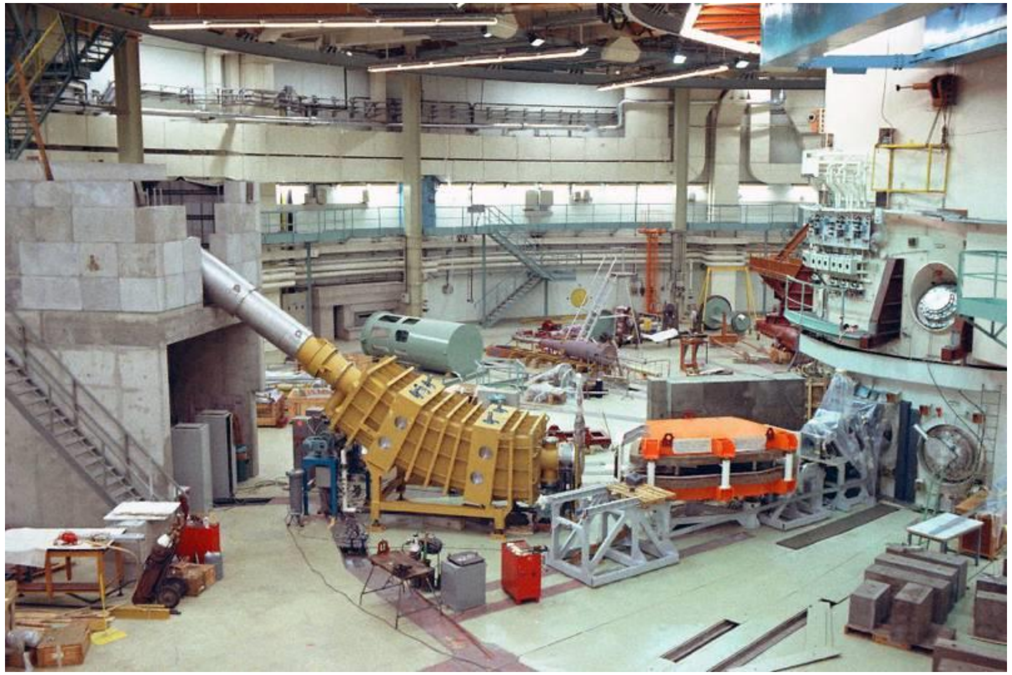


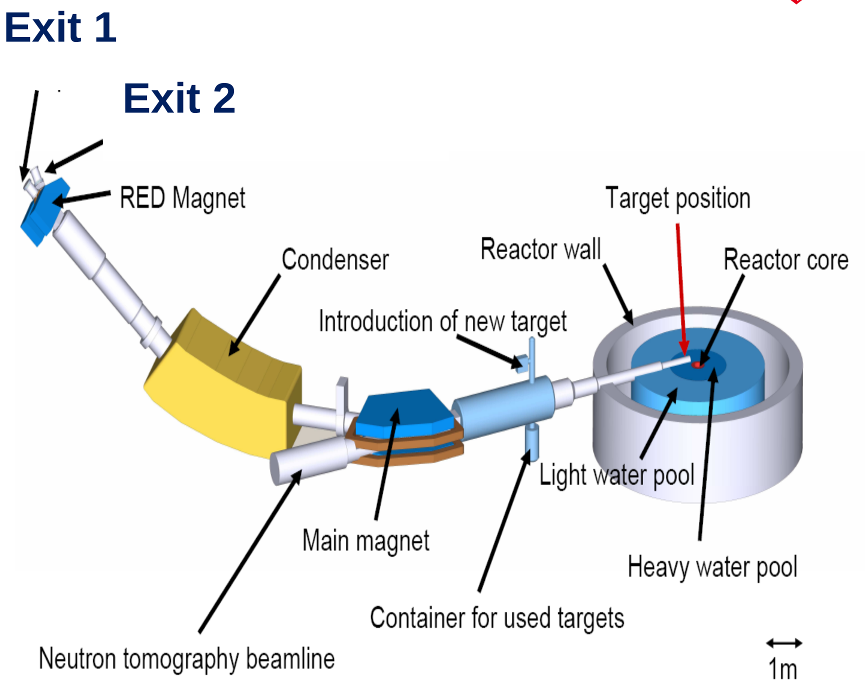
Photo of the LOHENGRIN spectrometer during its construction phase in 1975

Isotopic yield Measurements by gamma spectroscopy

Mass yield Measurements

Experimental Activities on LOHENGRIN

Isomeric Ratio Measurements



Schematic view of the recoil mass spectrometer LOHENGRIN

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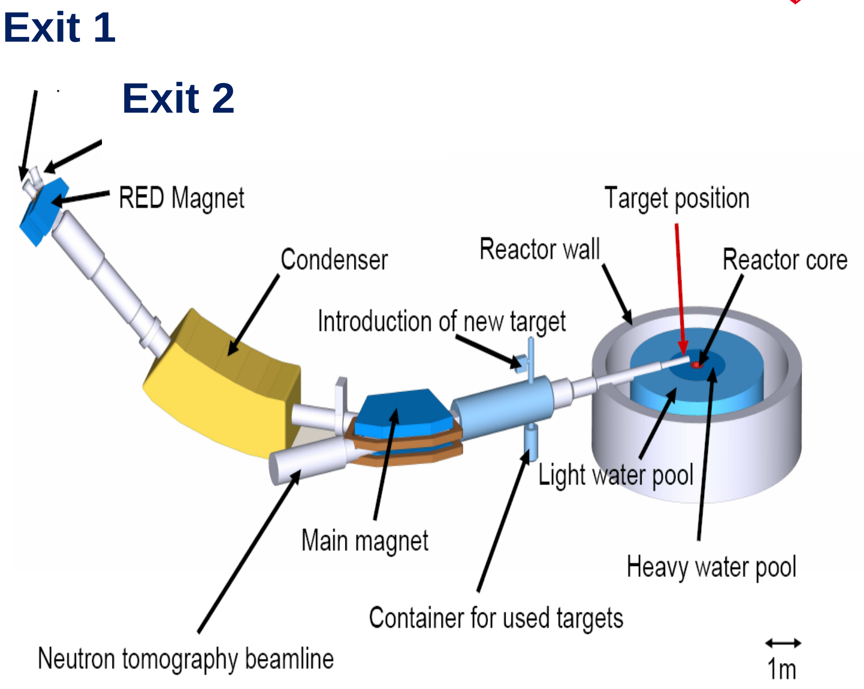
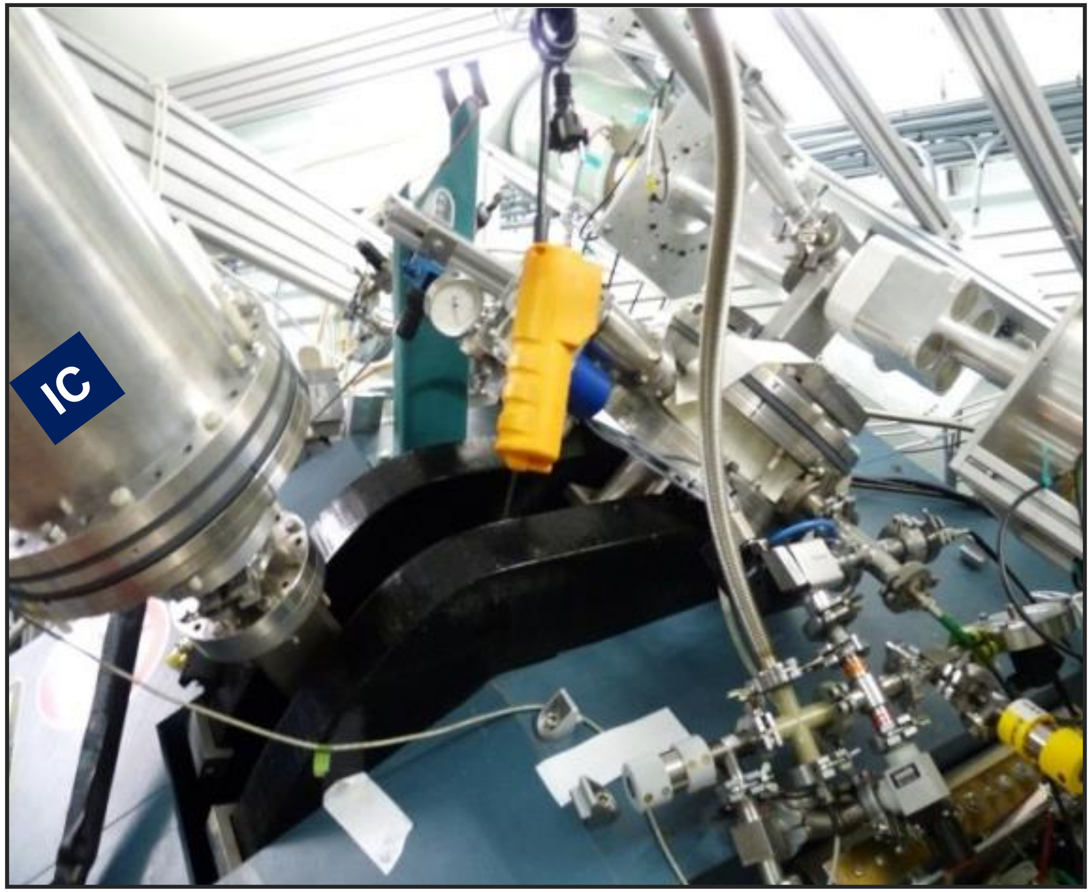
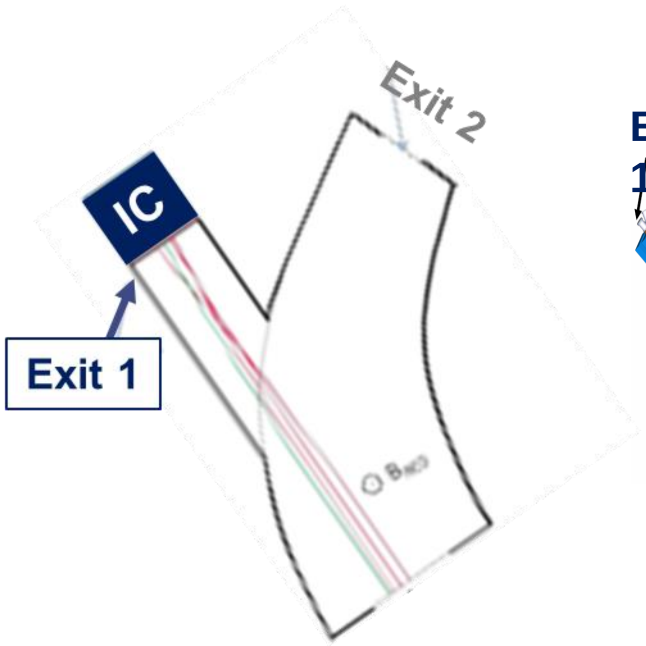


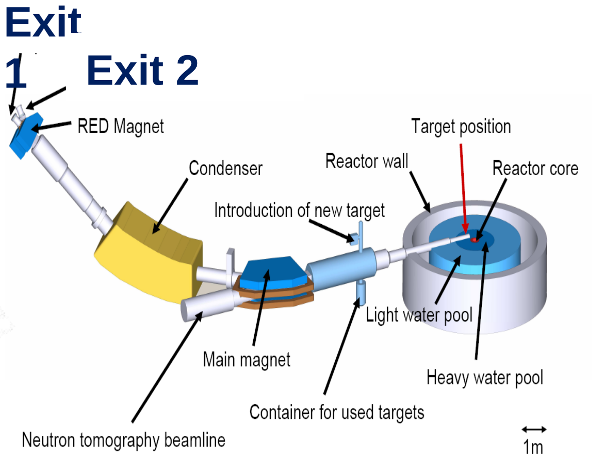
Schematic view of the recoil mass spectrometer LOHENGRIN

Ionization Chamber (IC) used for the Mass yield measurements, positioned at the EXIT 1 place

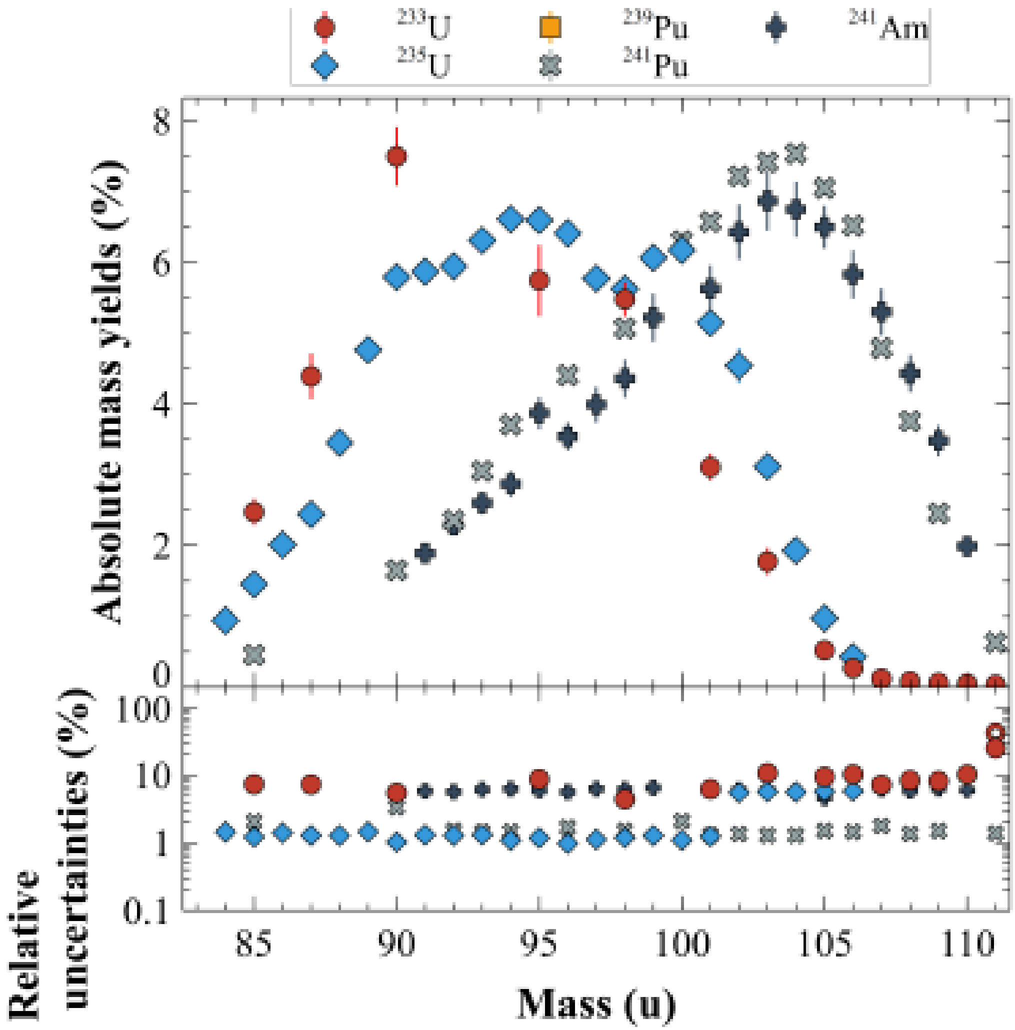




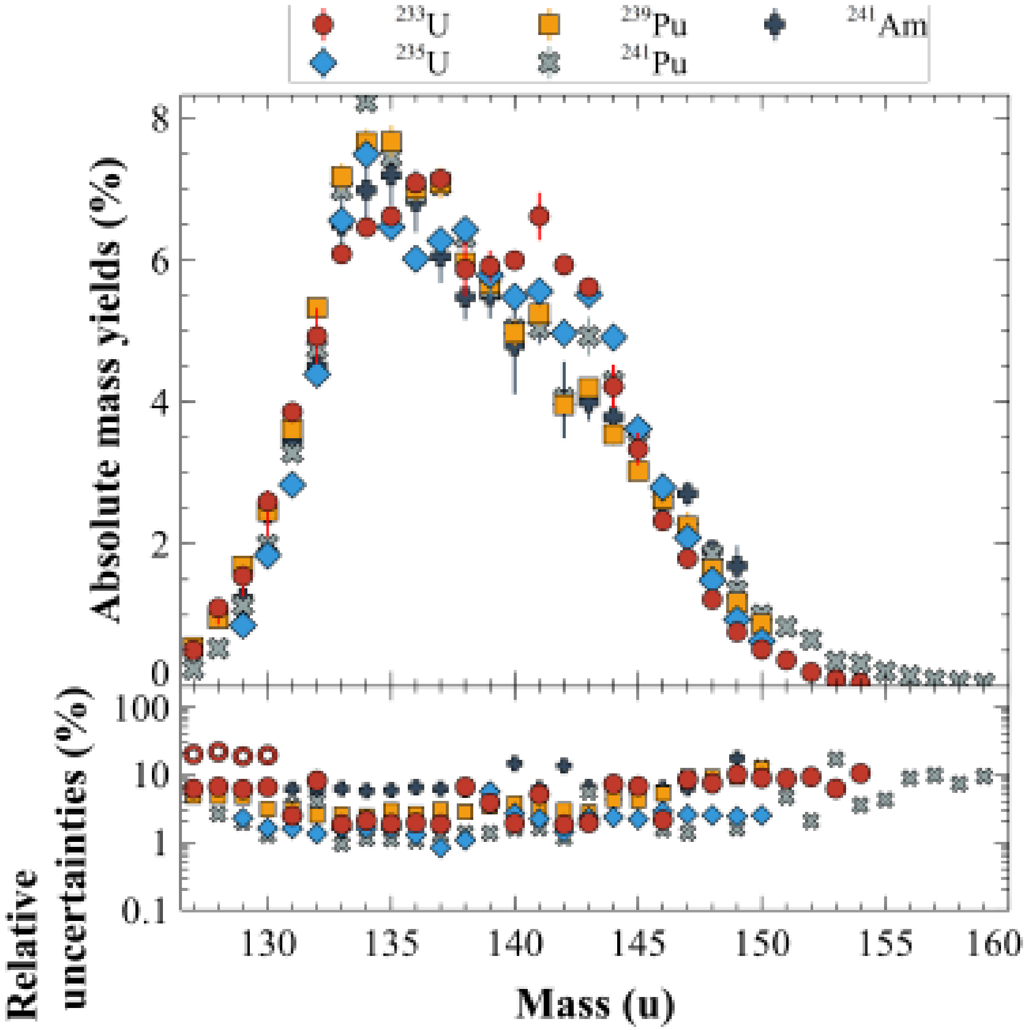
(Schema provided by A. Chebbouba and G. Kessedjian)



Light mass Region



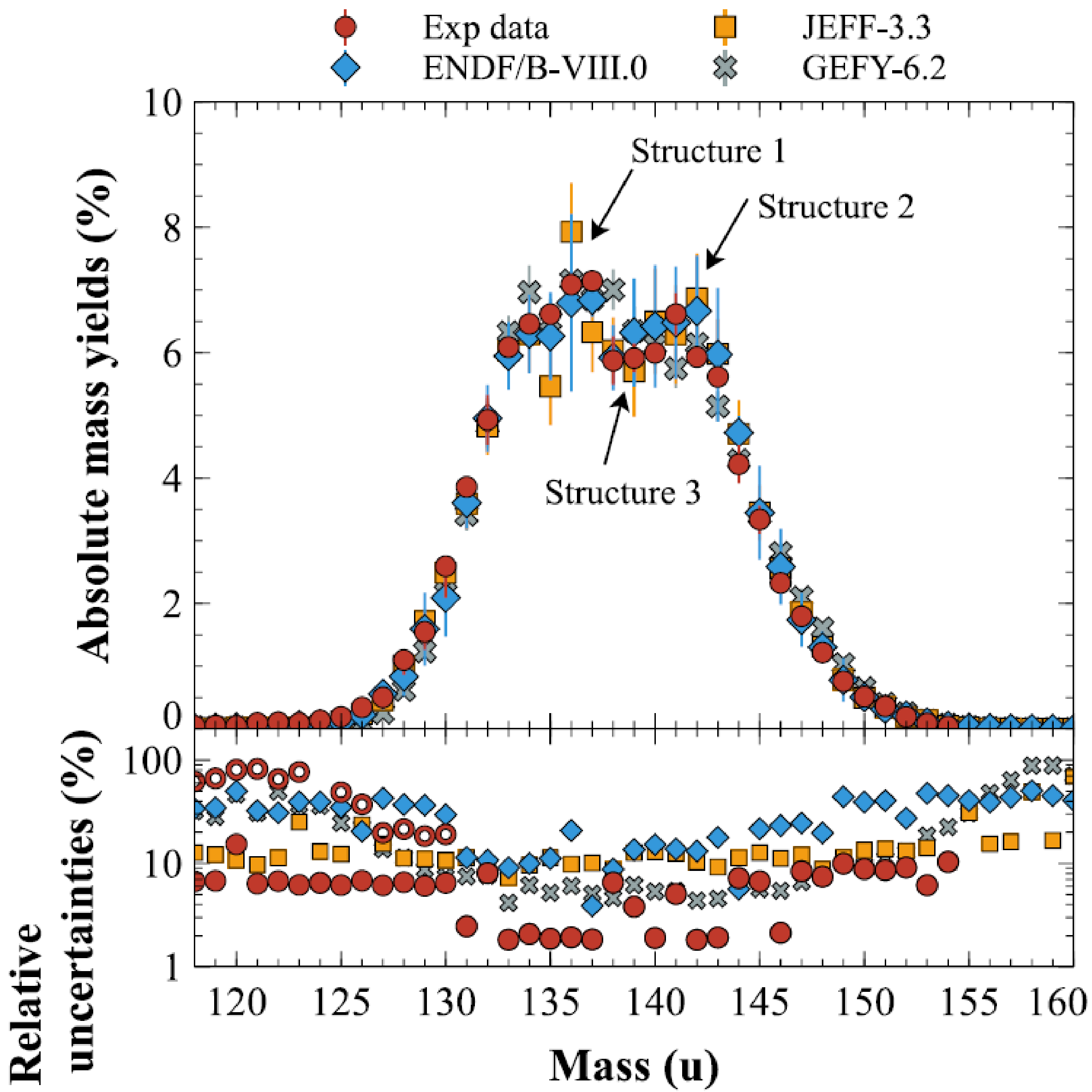
Heavy mass Region



Figures taken from R. Vogt et al., Fission Yields of Actinides, CRP-IAEA (2020-2025),
To be published in EPJ-A (2026)

Example:
Mass yield of the heavy mass region measured for the $^{233}U(n_{th},f)$ reaction

The precision of mass yields measured with LOHENGRIN, using our experimental procedure: **of the order of 2% in the heavy mass peak** and around 10% in the wings

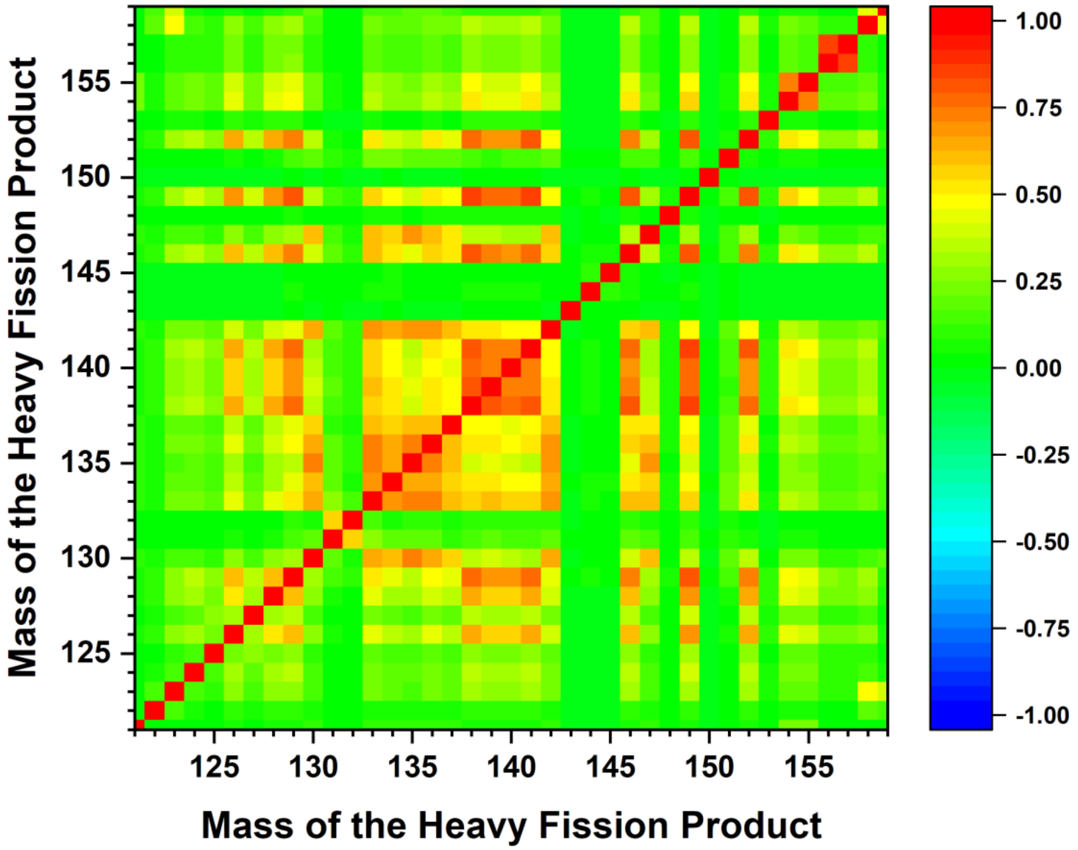


(from A. Chebboubi, G. Kessedjian, O. Serot, et al., Eur. Phys. J. A (2021) 57:335

Example $^{241}Pu(n_{th},f)$ reaction

Experimental Variance – Covariance Matrix calculated from the analysis procedure:

- Counting Rates (statistics)
- Correlation between $<E_k>$ and q
- Correction of the Burn-up
- Normalization…



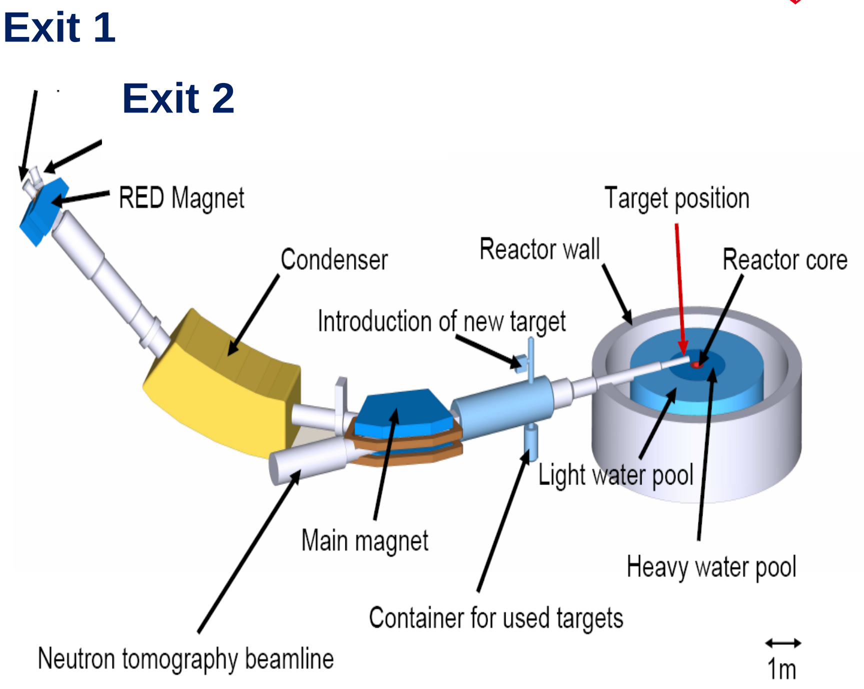
S. Julien-Laferriere, A. Chebboubi, G. Kessedjian, and O. Serot, EPJ web of Conference, Workshop Covariance Aix-en-Provence, 2017

Isotopic yield Measurements by gamma spectroscopy

Experimental Activities on LOHENGRIN

Mass yield Measurements

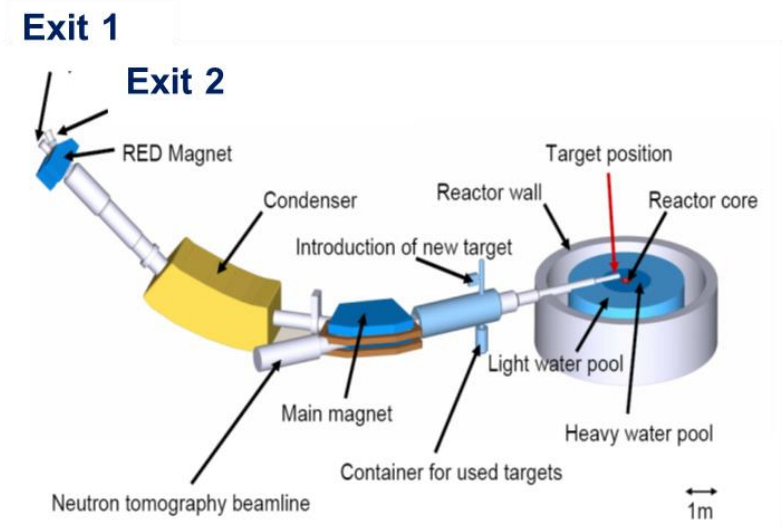
Isomeric Ratio Measurements



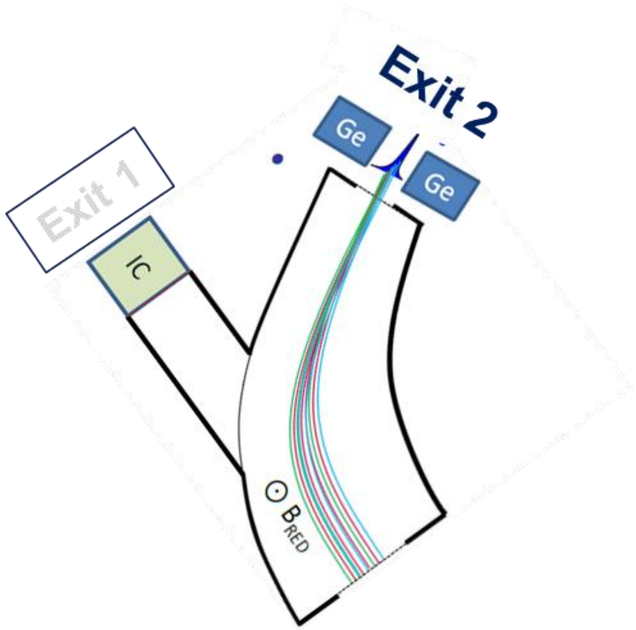
Schematic view of the recoil mass spectrometer LOHENGRIN

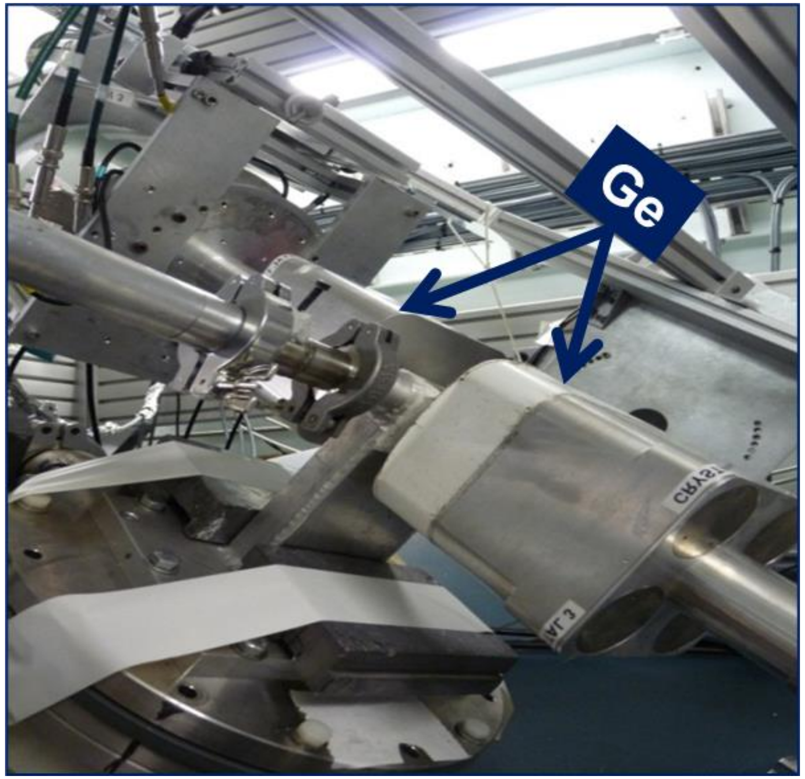
Isotopic Yield measurements in the heavy mass region

Two germanium clover detectors used to measure isotopic yields in the heavy mass region (gamma-spectrometry technic)



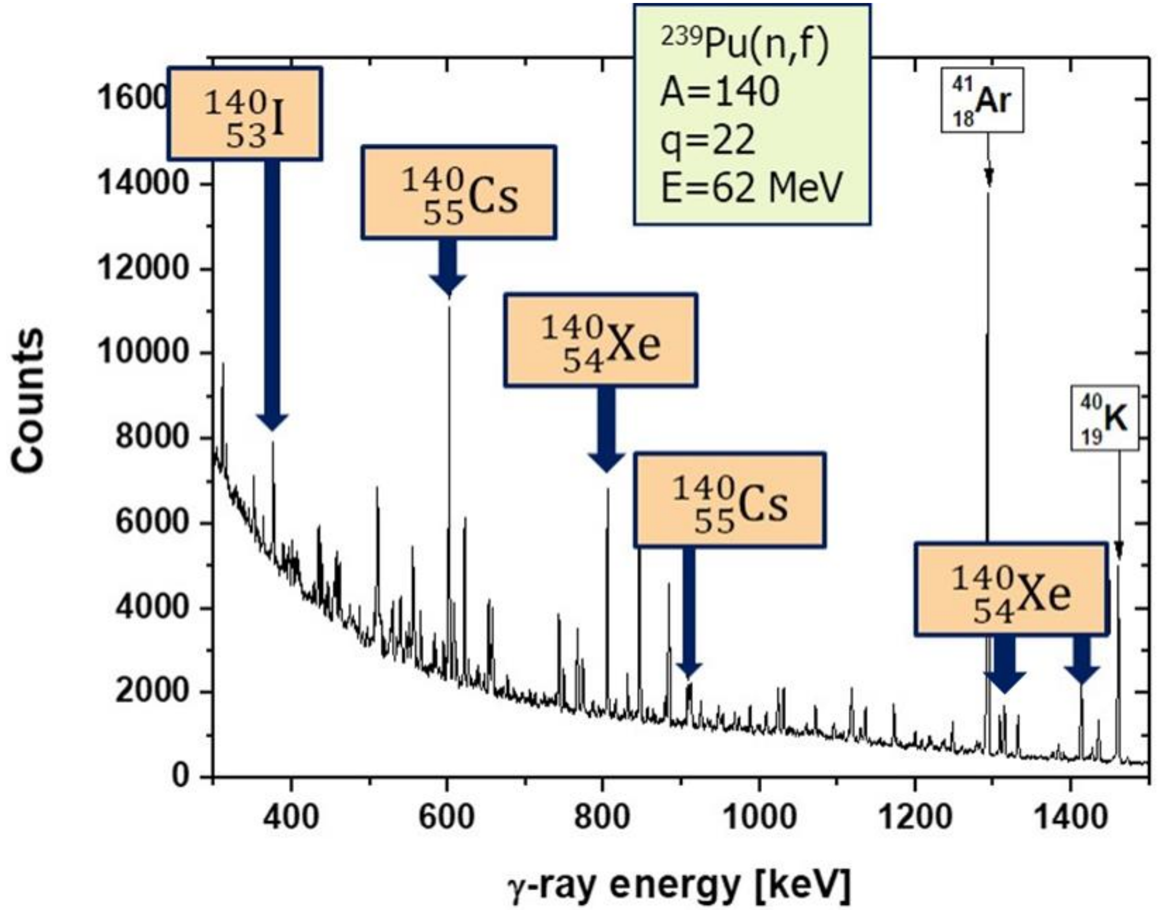
(Schema provided by A. Chebboubi and G. Kessedjian)





Selection of the γ-rays emitted after the β- decay of the fission products

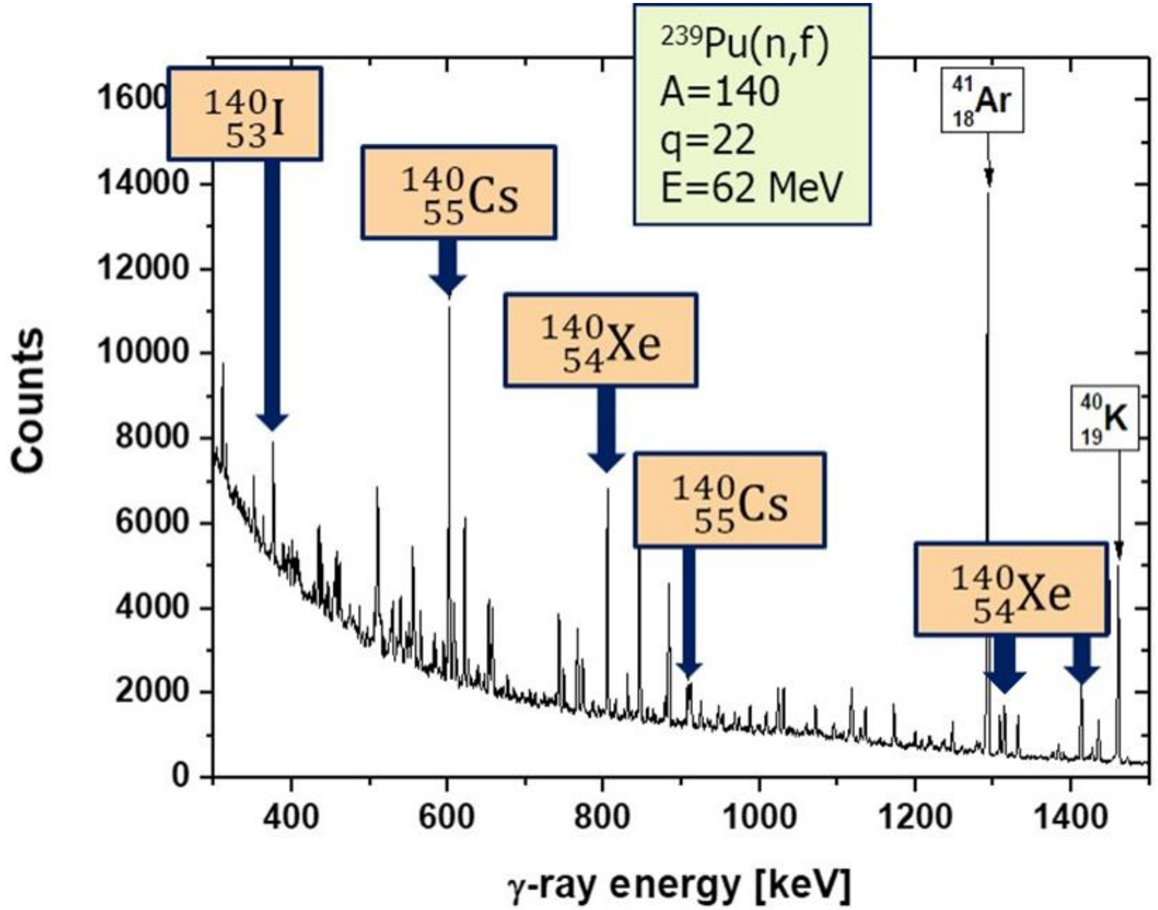
Identification of the Fission Products by gamma spectrometry:



Selection of the γ-rays emitted after the β- decay of the fission products

Identification of the Fission Products by gamma spectrometry:

- Selection of the mass thanks to Lohengrin (here A=140)
- From the measured γ-rays spectrum, 3 fission products are clearly observed:
  - ^{140}I (Z =53)
  - ^{140}Xe (Z =54)
  - ^{140}Cs (Z =55)



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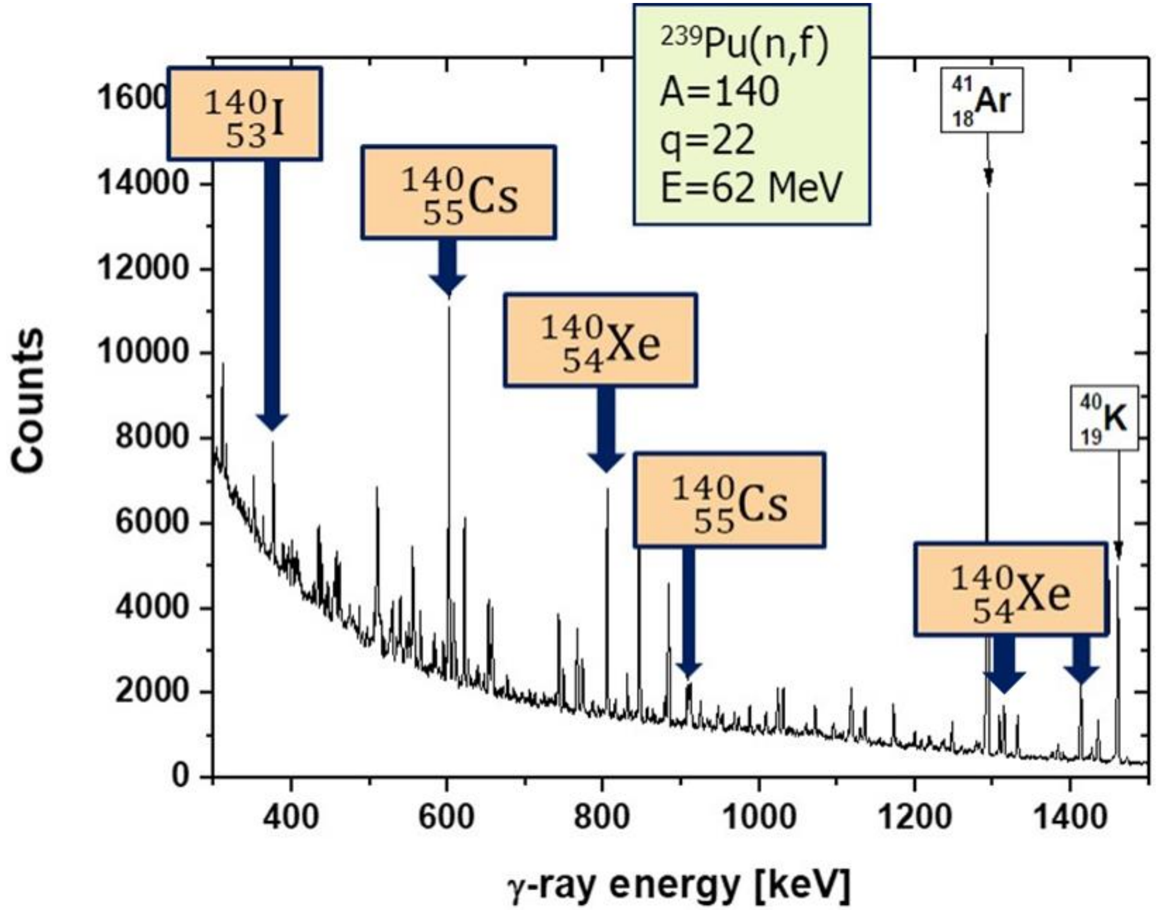
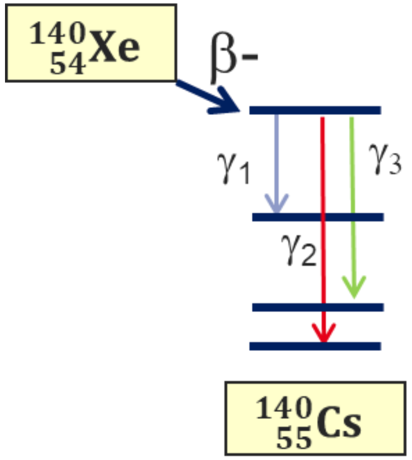
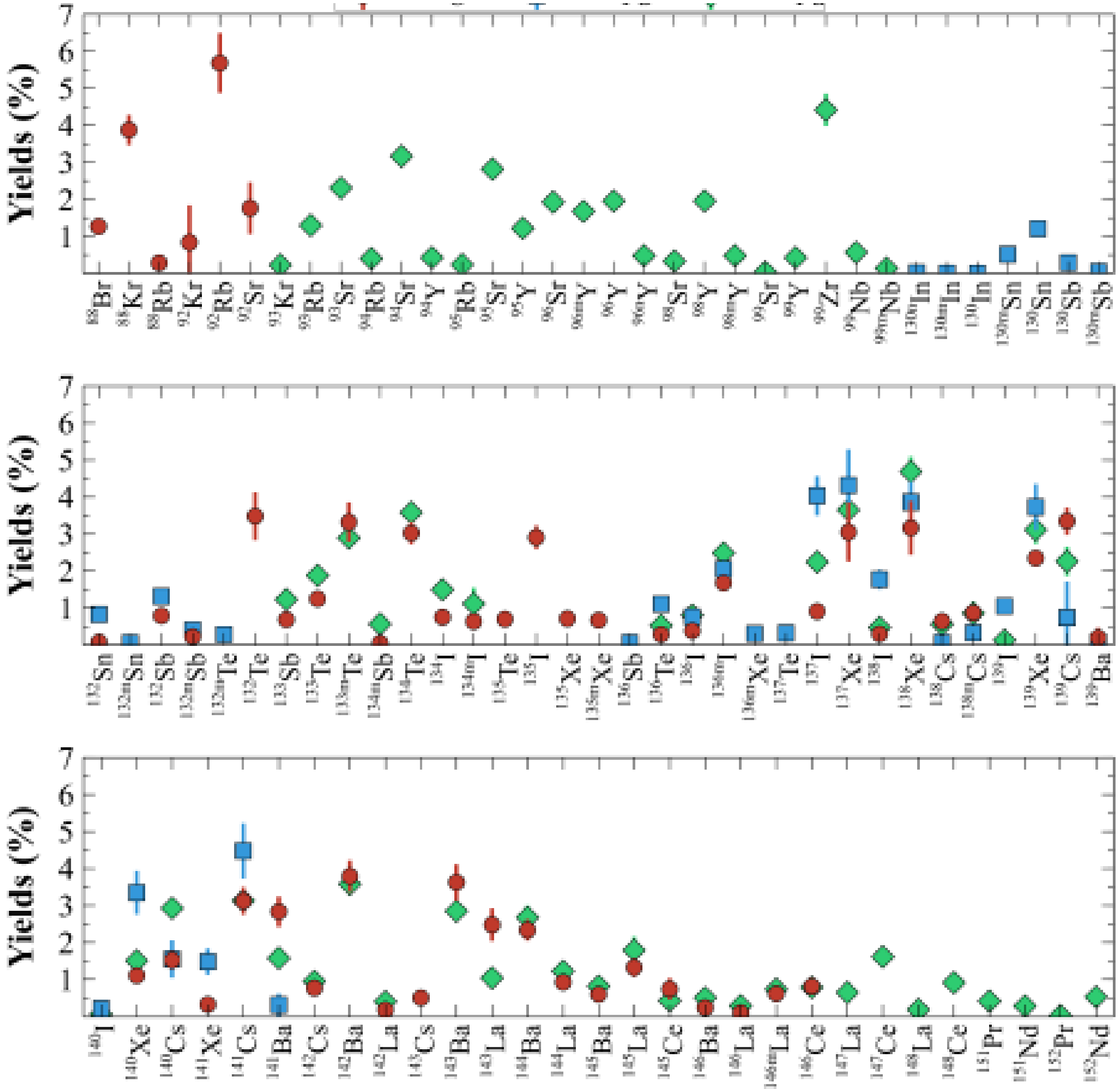


In particular, three γ-rays following the β^- decay of the ^{140}Xe are seen



$E_{\gamma1} = 805.52\ keV$
$E_{\gamma2} = 1413.66\ keV$
$E_{\gamma3} = 1315.05\ keV$



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

$^{239}Pu(n_{th},f)$

$^{241}Pu(n_{th},f)$

$^{233}U(n_{th},f)$:
F. Martin, Ph.D. thesis, Universite de Grenoble (2013)

$^{239}Pu(n_{th},f)$:
A. Bail, O. Serot, L. Mathieu, O. Litaize, T. Materna, U. Koster, H. Faust, A. Letourneau, S. Panebianco, Phys. Rev. C 84, 034605 (2011)

$^{241}Pu(n_{th},f)$:
A. Chebboubi, G. Kessedjian, O. Serot, D. Bernard, O. Litaize, J. Nicholson, S. Julien-Lafferiere, O. Meplan, C. Sage, M. Ramdhane et al., EPJ Web of Conf. 329, 05005 (2025)

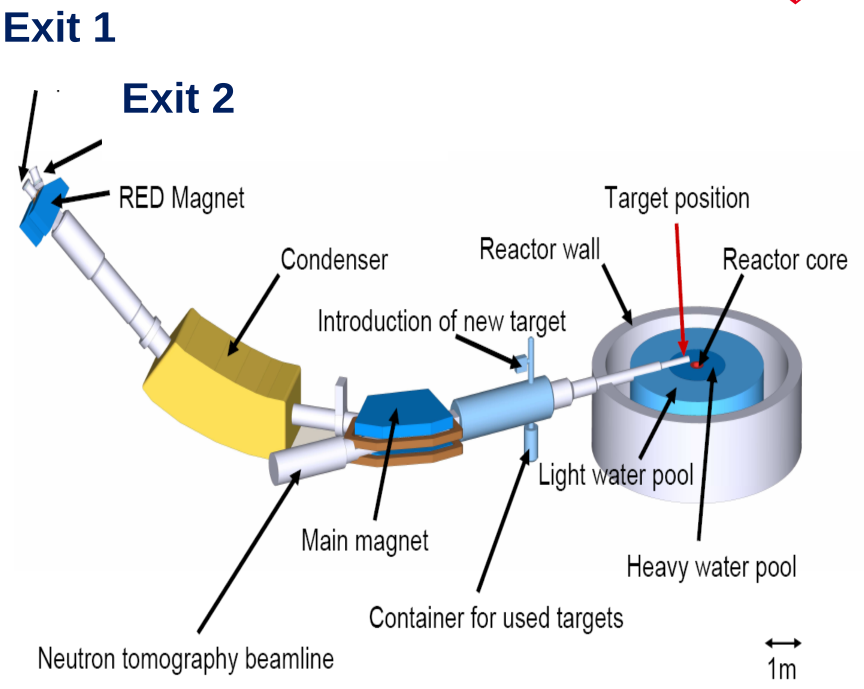
Figure taken from R. Vogt et al., Fission Yields of Actinides, CRP-IAEA (2020-2025), To be published in EPJ-A (2026)

Experimental Activities on LOHENGRIN

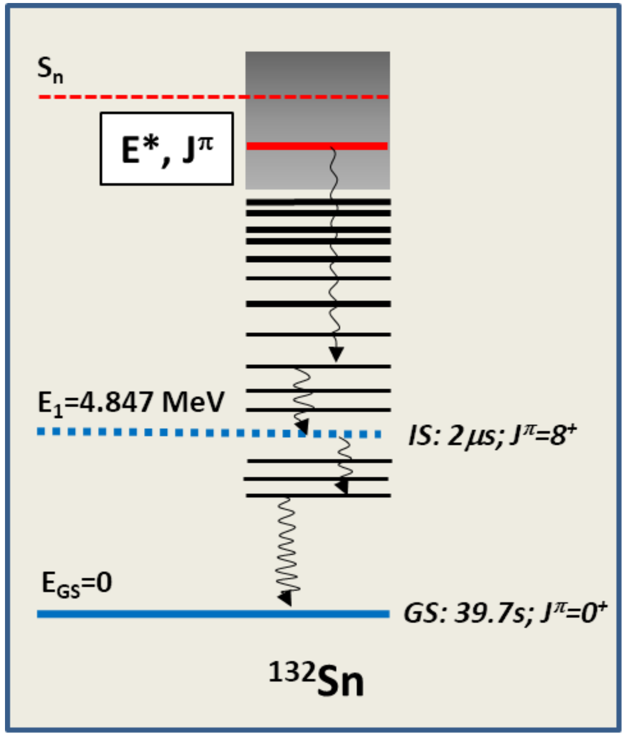
Isotopic yield Measurements by gamma spectroscopy

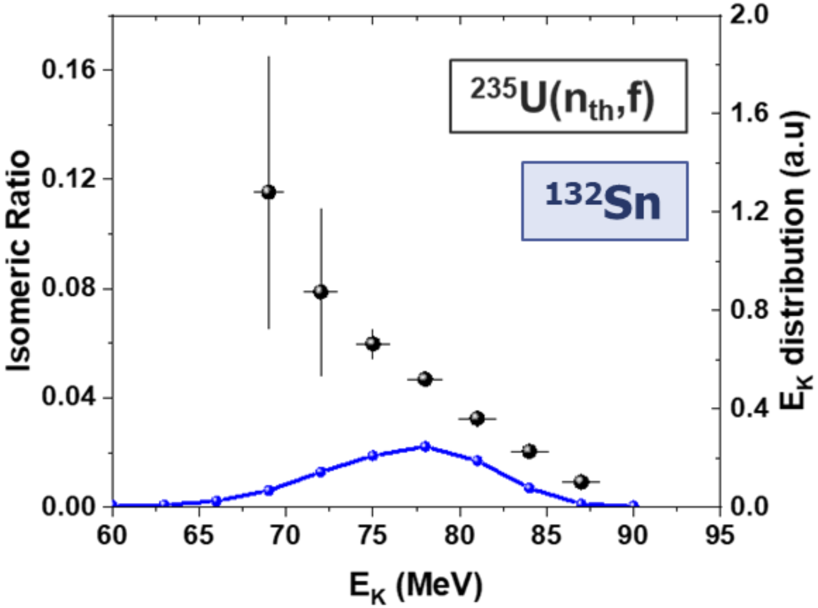
Mass yield Measurements

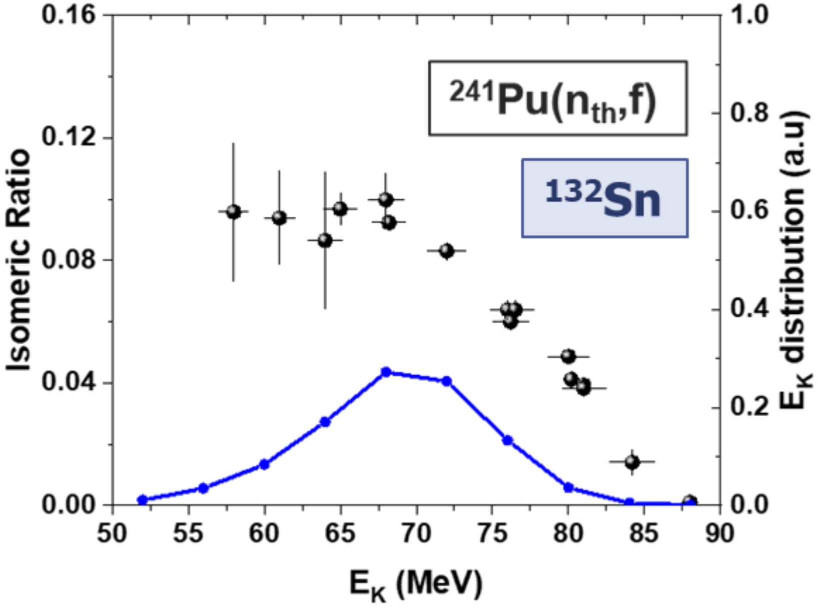
Isomeric Ratio Measurements



Schematic view of the recoil mass spectrometer LOHENGRIN

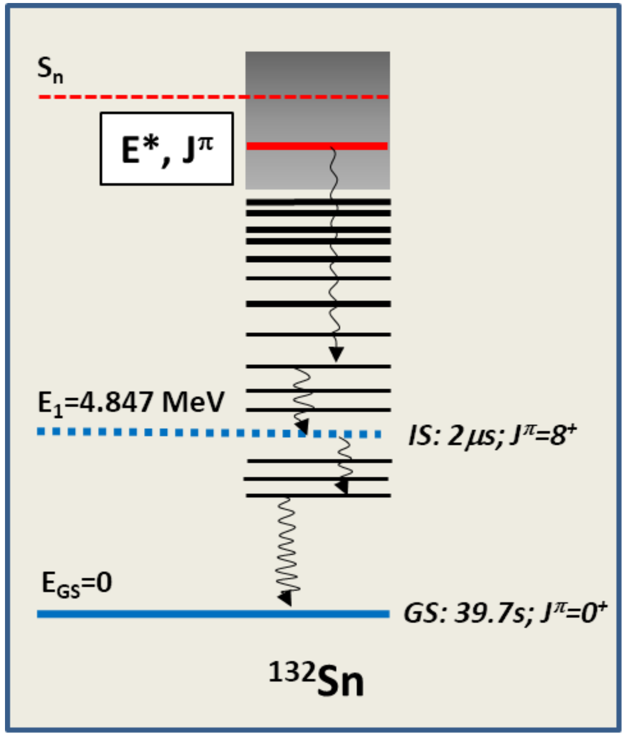


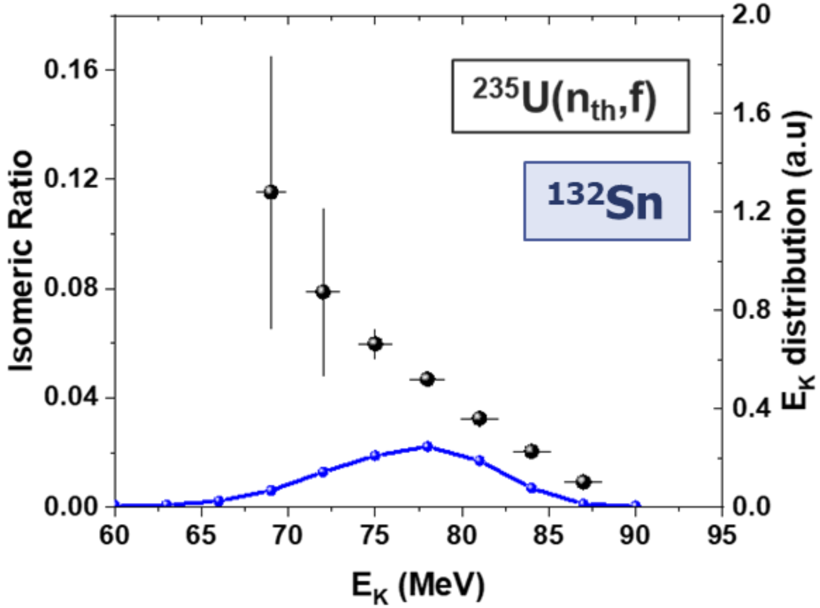


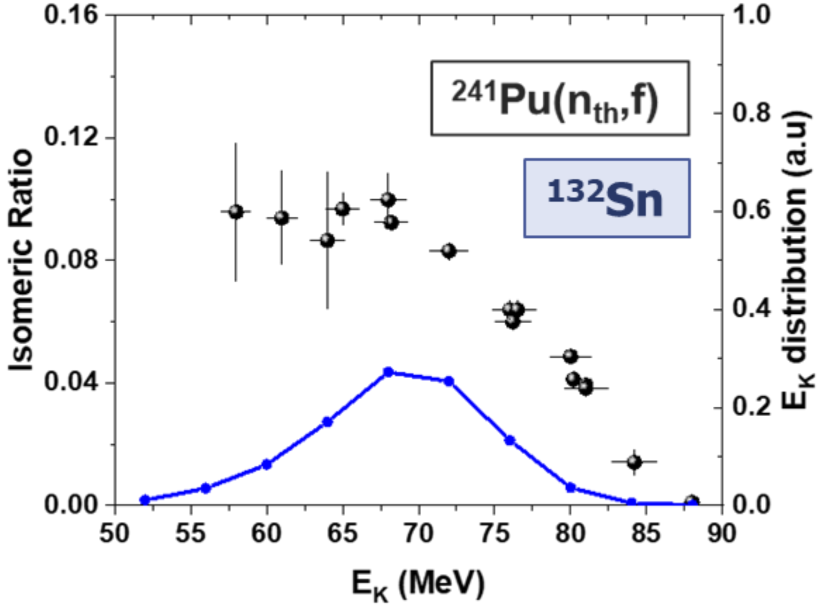


Examples of Isomeric Ratio of ^{132}Sn measured on LOHENGRIN from the $^{235}U(n_{th},f)$ and $^{241}Pu(n_{th},f)$ reactions

- A. Chebboubi et al., EPJ web of Conference (2016)
- A. Chebboubi et al., Phys. Lett. B775,190-195 (2017)
- J. Nicholson, PhD thesis, Univerity of Grenoble Alpes, 2021
- J. Nicholson, A. Chebboubi, O. Serot, et al., EPJ Web of Conferences **256**, 00011 (2021)







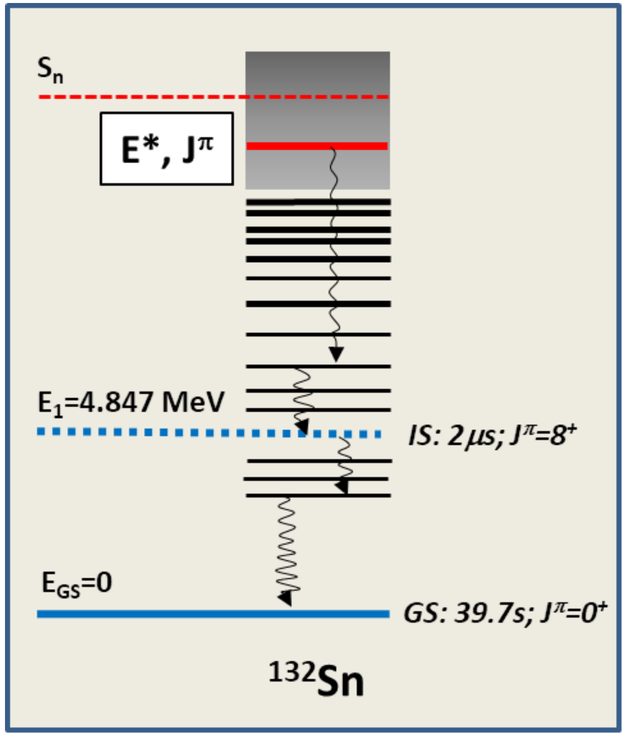
Examples of Isomeric Ratio of ^{132}Sn measured on LOHENGRIN from the ^{235}U(n$_{th}$,f) and ^{241}Pu(n$_{th}$,f) reactions

P_1 is the production rate of the **isomeric state** characterized by ***E1***

P_{gs} is the production rate of the **ground state**

$$IR = \frac{P_i}{P_i + P_{gs}}$$

- A. Chebboubi et al., EPJ web of Conference (2016)
- A. Chebboubi et al., Phys. Lett. B775,190-195 (2017)
- J. Nicholson, PhD thesis, Univerity of Grenoble Alpes, 2021
- J. Nicholson, A. Chebbouti, O. Serot, et al., EPJ Web of Conferences **256**, 00011 (2021)



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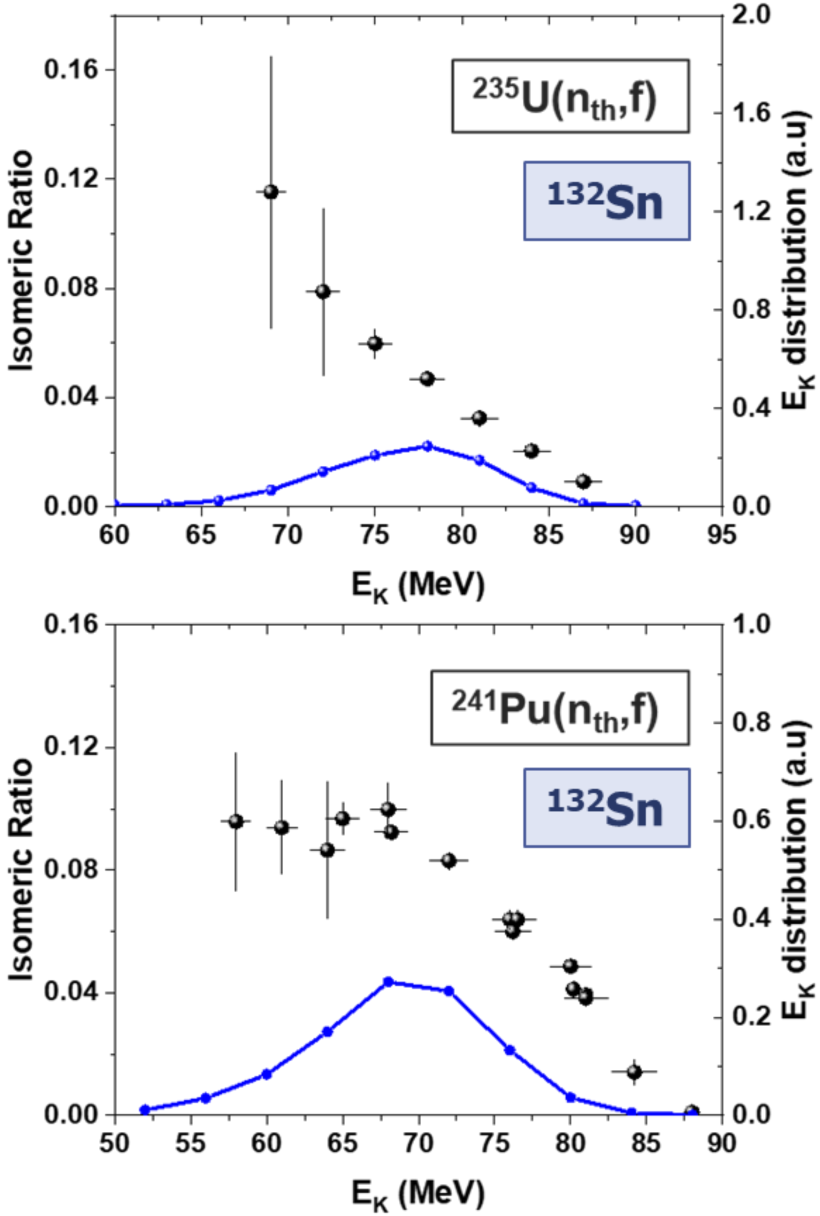
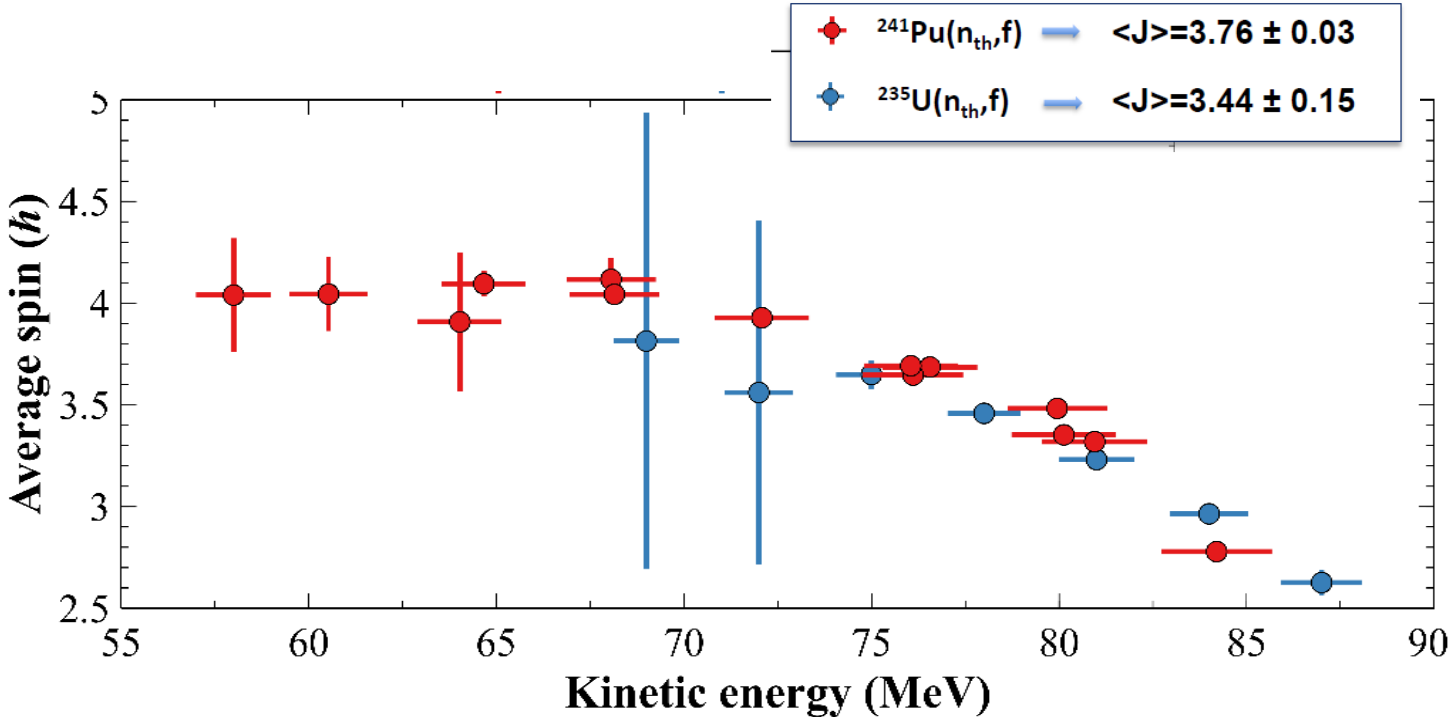


Examples of Isomeric Ratio of ^{132}Sn measured on LOHENGRIN from the ^{235}U(n$_{th}$,f) and ^{241}Pu(n$_{th}$,f) reactions

IR are measured as a function of kinetic energy for the ^{132}Sn: **Important for constraining the models**

- A. Chebboubi et al., EPJ web of Conference (2016)
- A. Chebboubi et al., Phys. Lett. B775,190-195 (2017)
- J. Nicholson, PhD thesis, Univerity of Grenoble Alpes, 2021
- J. Nicholson, A. Chebboubi, O. Serot, et al., EPJ Web of Conferences **256**, 00011 (2021)



See presentation of Anna SKOULOUDAKI,
Angular Momentum in Fission through $^{241}Am(2n_{th},f)$ Isomeric Ratio measurements with the Lohengrin spectrometer

Isomeric Ratio Measurements:

- Provide Isomeric Ratios (IR) for the future fission yield evaluation
- Compare and test our experimental data with different models (code GEF, England-Madland model, code FIFRELIN)
- **Deduce the spin of the fission products thanks to the FIFRELIN code**

Experimental Activities on LOHENGRIN

Isotopic yield Measurements by gamma spectroscopy

Accurate Kinetic Energy Measurement

Mass yield Measurements

Isomeric Ratio Measurements

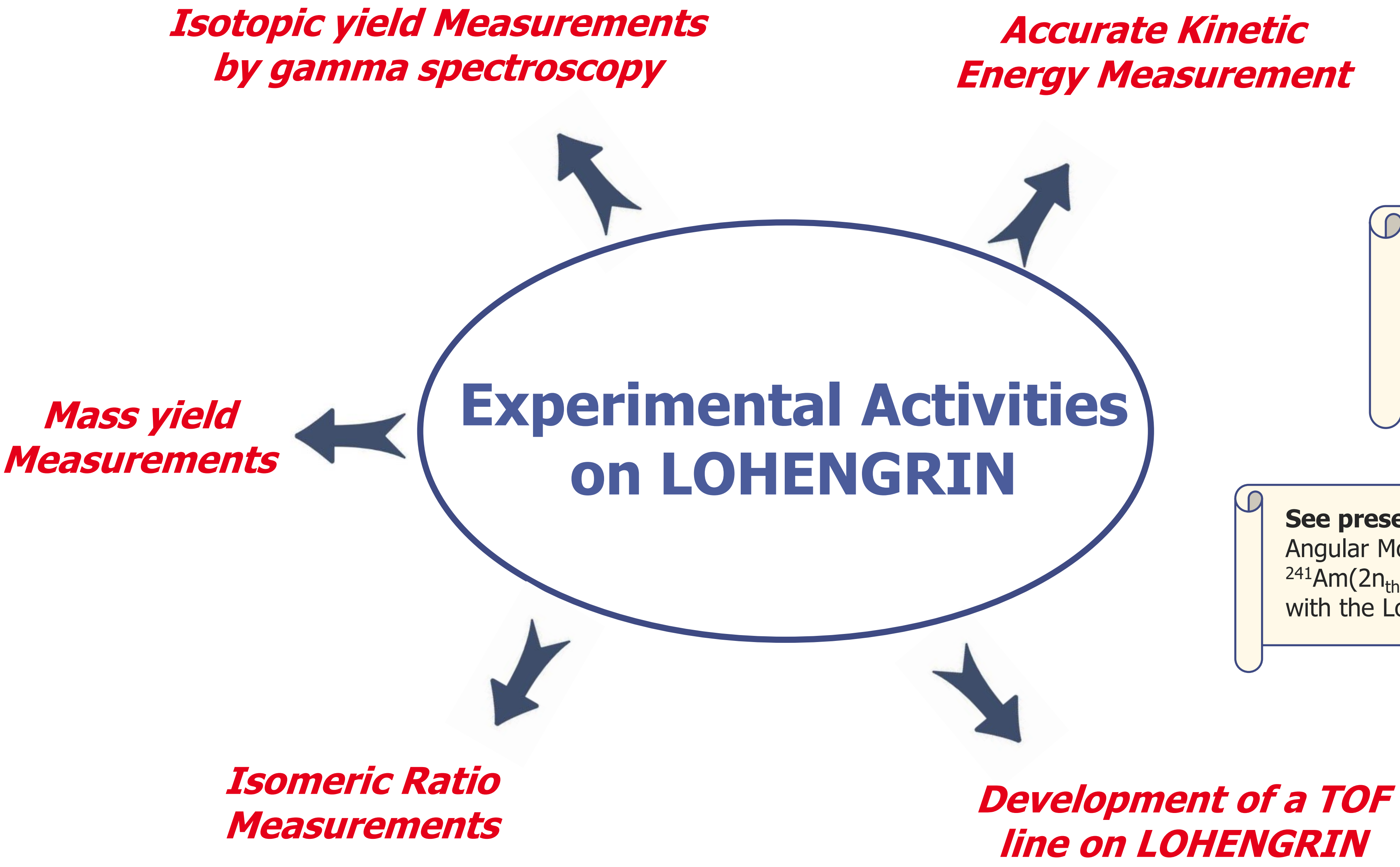
Development of a TOF line on LOHENGRIN

Experimental Activities on LOHENGRIN

- *Isotopic yield Measurements by gamma spectroscopy*
- *Accurate Kinetic Energy Measurement*
- *Mass yield Measurements*
- *Isomeric Ratio Measurements*
- *Development of a TOF line on LOHENGRIN*

Since 2006: 8 PhD thesis (collaboration between the CEA-Cadarache and the LPSC)

1. **Adeline BAIL,**
Université Bordeaux, Mai 2009
2. **Florence MARTIN**
Université de Grenoble, Décembre 2013
3. **Charlotte AMOUROUX,**
Université paris-sud, Sept 2014
4. **Abdelaziz CHEBBOUBI,**
Université de Grenoble, Octobre 2015
5. **Sylvain JULIEN-LAFERRIÈRE**
Université de Grenoble, Octobre 2018
6. **Jehaan Nauzer NICHOLSON**
Université de Grenoble, Septembre 2021
7. **Adrien VIEVILLE**
Université de Grenoble, Soutenance prévue en Novembre 2026 ?
8. **Anna SKOULOUDAKI,**
Université Aix-Marseille en cotutelle avec Université polytechnique nationale d'Athènes, Thèse démarrée en Sept, 2025



See presentation of Jean-Michel DAUGAS, Study opportunities with the LOHENGRIN fission fragment separator

See presentation of Anna SKOULOUDAKI, Angular Momentum in Fission through $^{241}Am(2n_{th},f)$ Isomeric Ratio measurements with the Lohengrin spectrometer

2. Fission Yield Evaluations for the JEFF-4.0 library: Example of the $^{239}Pu(n_{th},f)$ reaction

- S.-M. Cheikh, PhD thesis, University of Grenoble Alpes, 2023
- G. Kessedjian et al., JEFDOC-2203, Nov. 2022
- G. Kessedjian et al., JEFF-Doc 2247, April 2023
- S.-M. Cheikh et al., JEFF-Doc 2205, nov. 2022
- O. Serot et al., JEFF-Doc 2370, nov. 2024
- S.-M. Cheikh et al., Eur. Phys. J. A (2024) 60:222
- S.-M. Cheikh et al., Nucl. Sc. and Eng., Vol. 199, S507–S520, Supp. 1 (2025)
- R. Vogt et al., CRP Fission yields of actinides, to be published in EPJ-A (2026)
- A. Plompen et al., The Joint Evaluated Fission and Fusion Nuclear Data Library: JEFF-4.0, to be published in EPJ-A (2026)

Our aim: Provide the best synthesis of experimental and theoretical knowledge in order to determine the best estimation of independent and cumulative fission yields with their variance-covariance matrices

Independent fission yields described by 3 components:

$$Y(A,Z,I) = Y(A).\ P(Z|A).\ P(I|A,Z)$$

Mass yield evaluation:
CEA-Cadarache work

Our aim: Provide the best synthesis of experimental and theoretical knowledge in order to determine the best estimation of independent and cumulative fission yields with their variance-covariance matrices

Independent fission yields described by 3 components:

$$Y(A,Z,I) = Y(A) \cdot P(Z|A) \cdot P(I|A,Z)$$

Mass yield evaluation: **CEA-Cadarache work**

Nuclear charge distribution per mass: **NNL work**

Our aim: Provide the best synthesis of experimental and theoretical knowledge in order to determine the best estimation of independent and cumulative fission yields with their variance-covariance matrices

Independent fission yields described by 3 components:

$$Y(A,Z,I) = Y(A) \cdot P(Z|A) \cdot P(I|A,Z)$$

- $Y(A)$ — Mass yield evaluation: **CEA-Cadarache work**
- $P(Z|A)$ — Nuclear charge distribution per mass: **NNL work**
- $P(I|A,Z)$ — Proba. to populate the metastable or the ground state: **NNL work**

Our aim: Provide the best synthesis of experimental and theoretical knowledge in order to determine the best estimation of independent and cumulative fission yields with their variance-covariance matrices

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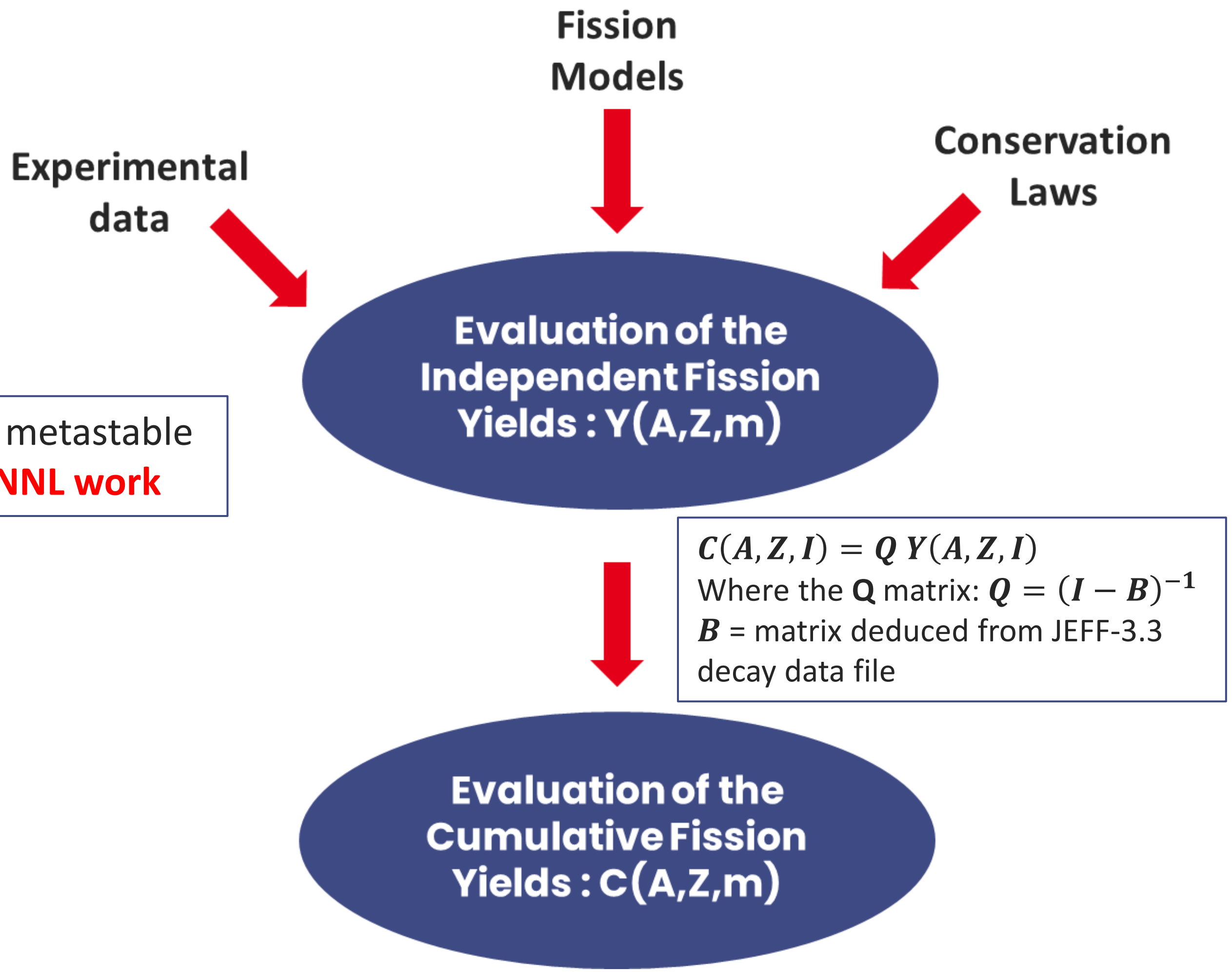
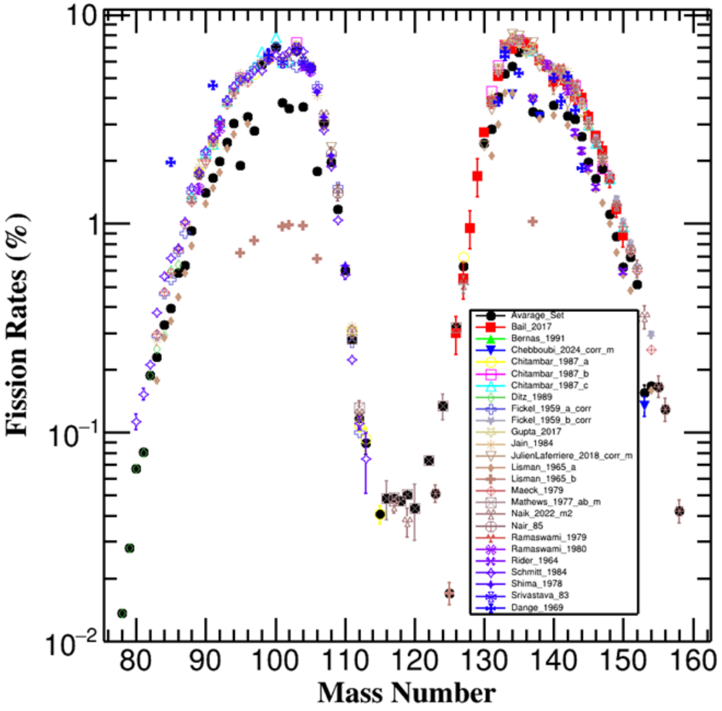
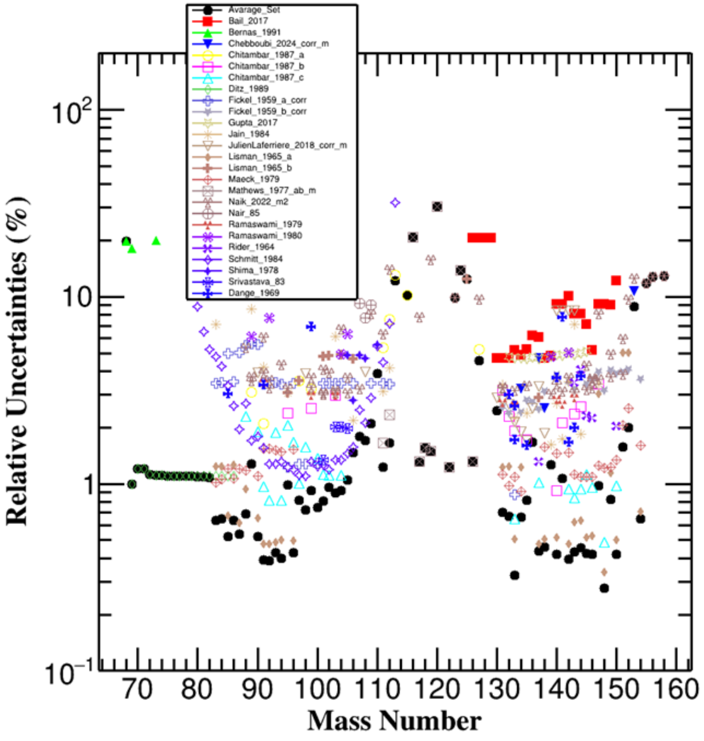


Example of the $^{239}Pu(n_{th},f)$

1 **Selection of experimental data:** measurements from **LOHENGRIN** + Cumulative / Chain yields (γ-spectrometry, radiochemical separation)

- ❑ 25 datasets
- ❑ 385 experimental data points
- ❑ Covers the mass range: [68 - 158]
- ❑ 3 masses not measured: A=114, A=121 and A=157





- ❑ R. Vogt, O. Serot, R. Capote, et al., Fission Yields of Actinides, CRP-IAEA (2020-2025), to be published in EPJ-A (2026)
- ❑ G. Kessedjian, S.-M. Cheikh, A. Chebboubi, D. Bernard, V. Vallet, O. Serot, JEF-doc 2370, Nov. 2024

Example of the $^{239}Pu(n_{th},f)$

2 **Construction of the experimental correlation matrix**

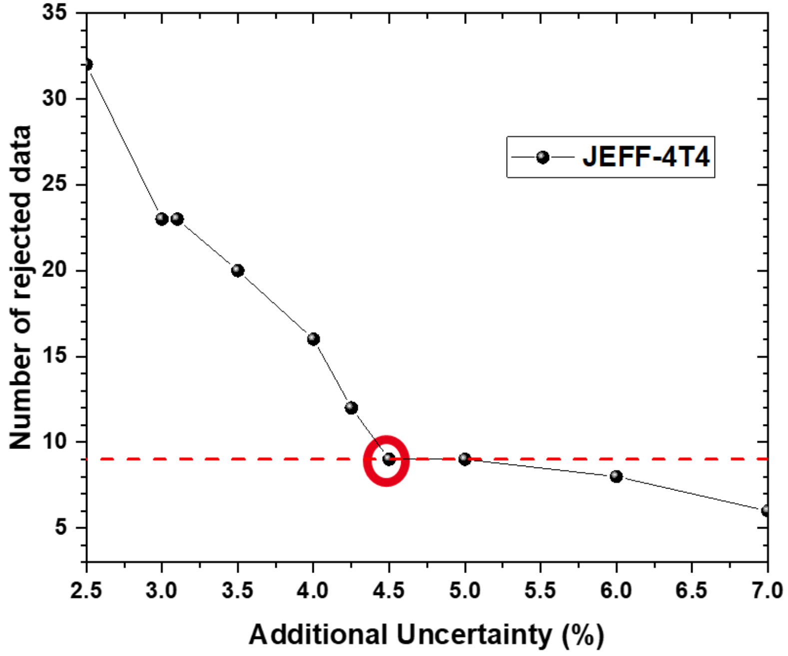
3 **Renormalization of the experimental data**

4 **Regularization of the data** in order to reduce the observed incompatibility between experimental data: "Conservative approach" used for JEFF-4.0 evaluation

- The "conservative approach" assumes that the measured mean values are correct, but their uncertainties are underestimated

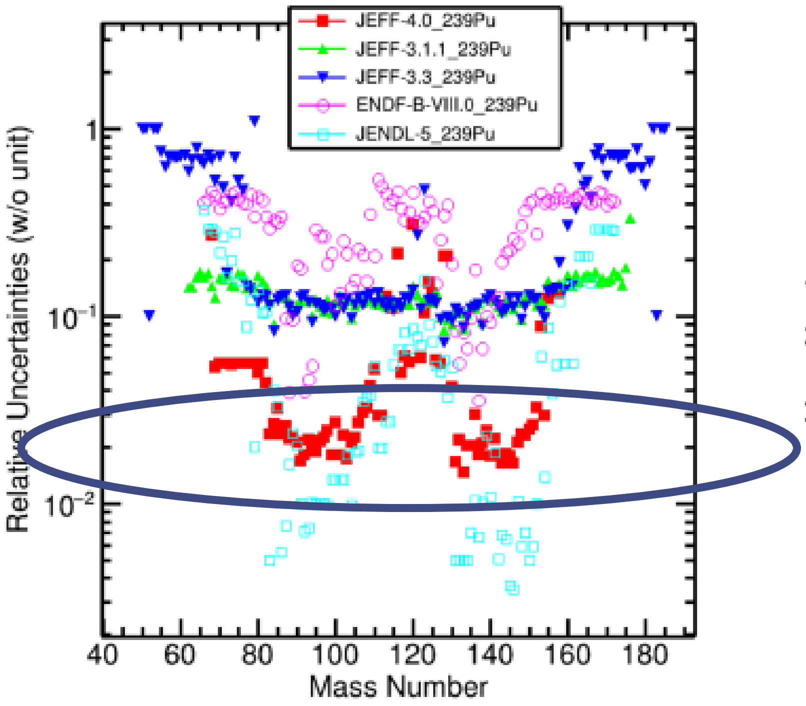
- Additional uncertainties for all datasets are required to achieve a good compatibility between experimental data

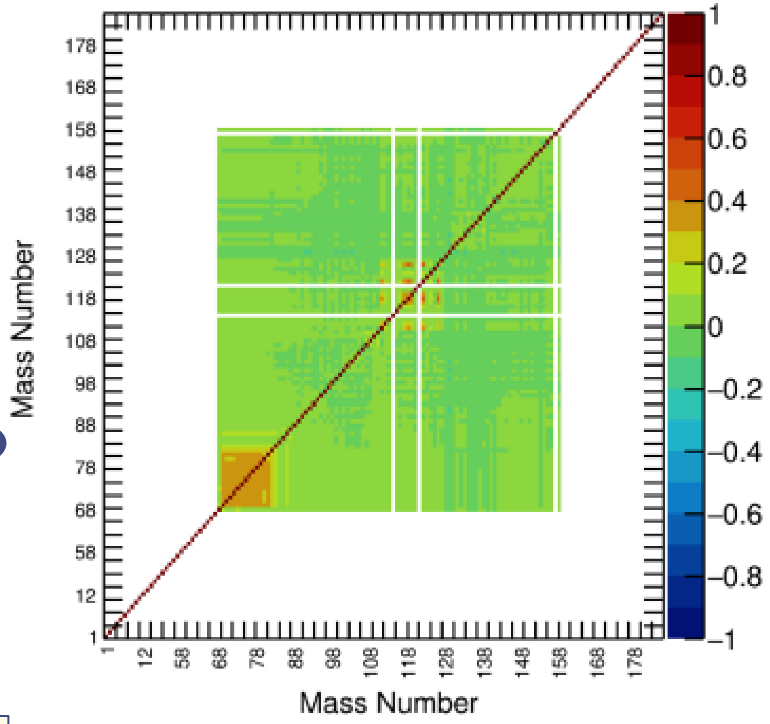
JEFF-4.0: 4.5 % additional uncertainty → **11 experimental data points are rejected**

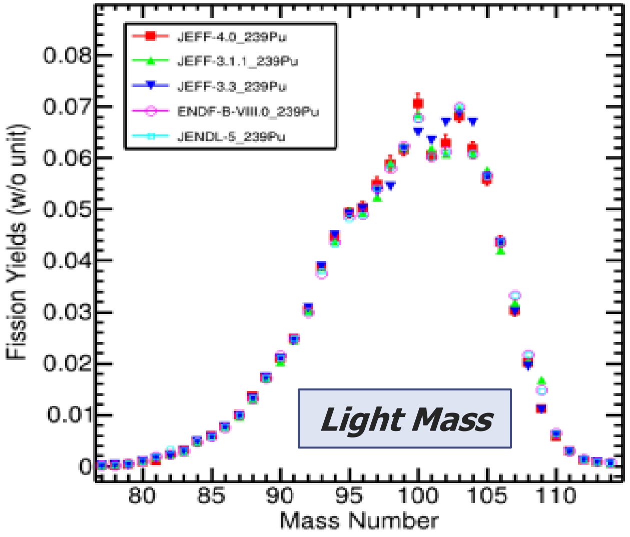


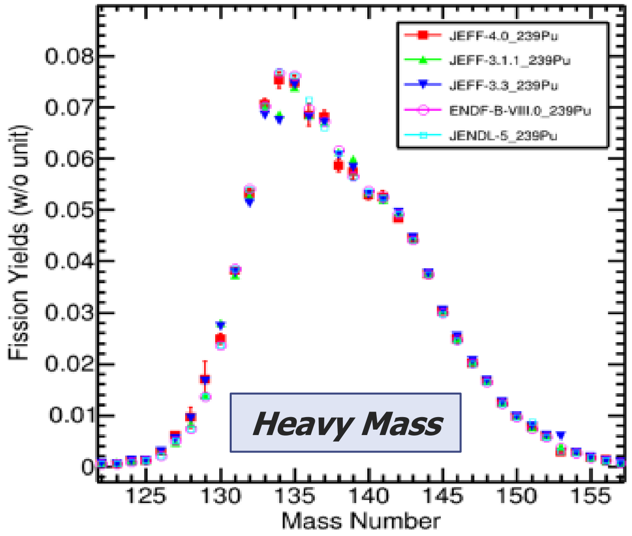
Example of the $^{239}Pu(n_{th},f)$

5 Results of Mass Yields









Significant reduction of the uncertainties:
About 2 to 3% for high yields

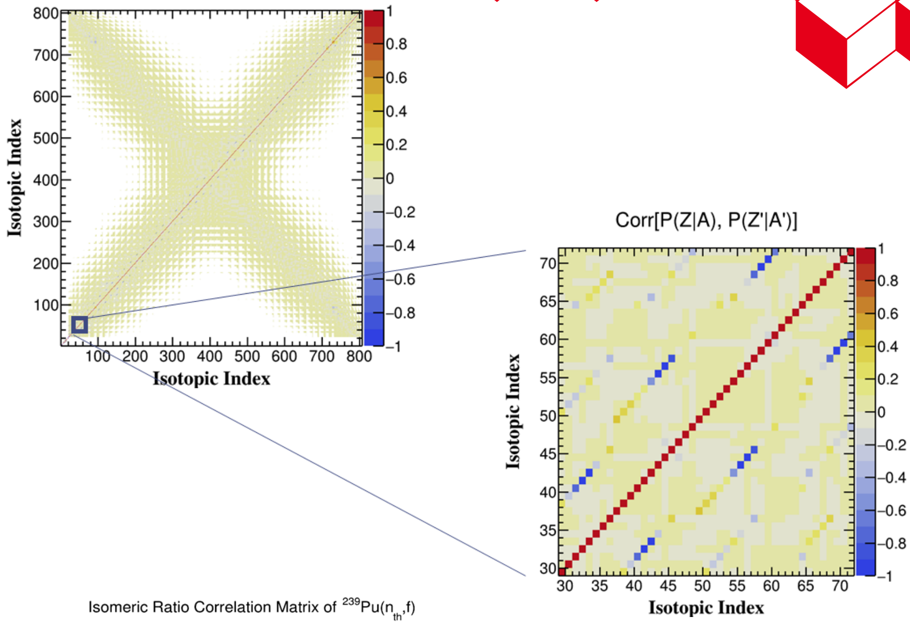
Example of the ^{239}Pu(n$_{th}$,f)

6 Nuclear charge distribution per mass: $P(Z\,|\,A)$

- Based on the JEFF-3.3 evaluation: **Combination of experimental data (EXFOR) and GEF calculation**

- Conservation laws:
  - Conservation of the nuclear charge $N(Z_L) = N(Z_H)$ (induces a cross pattern in the correlation matrix)
  - Self-normalization of nuclear charge distribution per mass

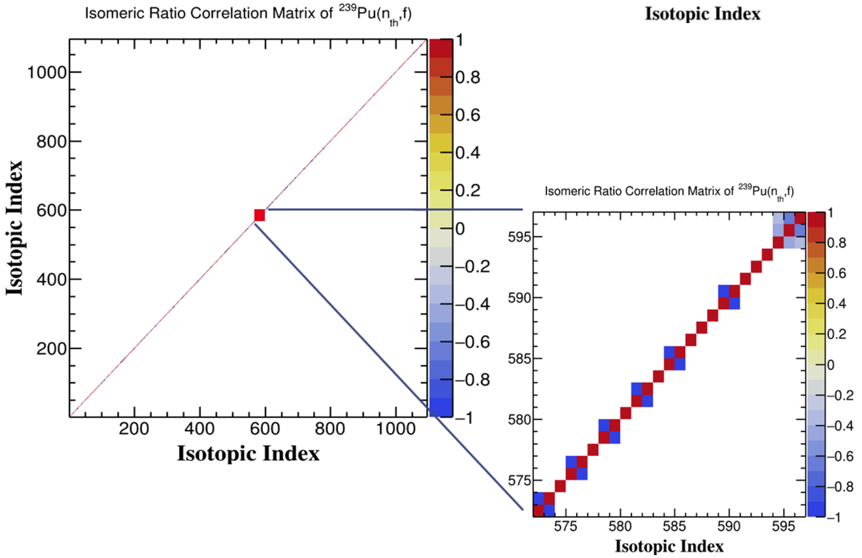
$$P(Z|A) = \frac{N(A,Z)}{\sum_Z N(A,Z)}$$



7 Isomeric Yields Distribution: $P(I\,|\,A,Z)$

- Based on the JEFF-3.3 evaluation: **Combination of experimental data (EXFOR) and Madland-England model**

- Self-normalization: $P(I|A,Z) = \frac{N_{A,Z,I}}{N_{A,Z,GS} + \sum N_{A,Z,I}}$



Fission Yield Evaluations for the $^{233}U(n_{th},f)$, $^{235}U(n_{th},f)$ $^{239}Pu(n_{th},f)$ and $^{241}Pu(n_{th},f)$ reactions have been proposed and accepted for the JEFF-4.0 library

↓

- ***Mass yields Evaluation:***
  - Based only on experimental data (free of model)
  - Experimental correlation matrices are accounting for
  - "Conservative approach" is proposed: additional uncertainties are applied on all datasets in order to achieve a good compatibility between experimental data

- ***Independent Isotopic and isomeric yields*** :
  - Based on JEFF-3.3 library

- ***Cumulated yields:***
  - Deduced from independent yields via decay data (JEFF-3.3)

↓

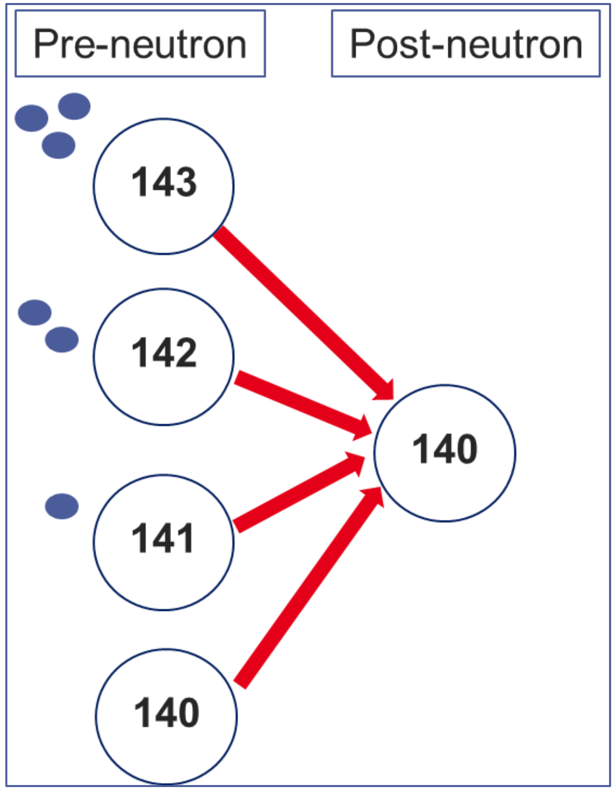
Complete description of the fission yields:
Mean values, variance and covariance (Consistent according to the conservation laws)

3. From pre-neutron to post neutron Fission Yields: Case of the $^{235}U(n_{th},f)$ reaction

- A. Regonesi, PhD thesis, Université of Grenoble Alpes. April 2027
- A. Regonesi, G. Kessedjian, O. Serot, Pre-neutron mass yield evaluation of $235\boldsymbol{U}(\boldsymbol{nth},\boldsymbol{f})$, Proc. ND-2025, Madrid (Spain)
- A. Regonesi, G. Kessedjian, O. Serot, S.-M. Cheikh, From pre to post fission yields for 235U(nth,f) : a consistent approach, JEF-DOC, Nov. 2025

Example of the $^{235}U(n_{th},f)$

The link between the **post-neutron mass yields** $Y_{Post}(A)$ and the **pre-neutron mass yields** $Y_{Pre}(A+\nu)$ is given by the following equation:

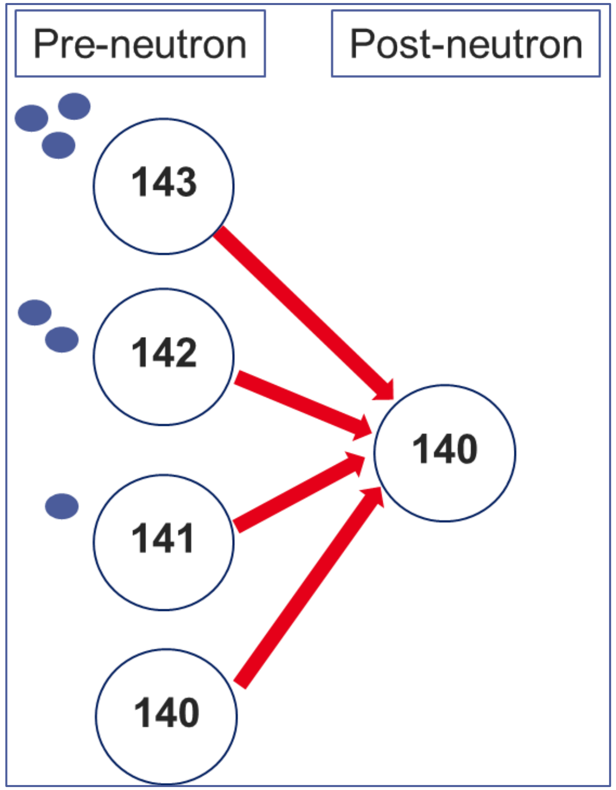


$$Y_{Post}(A) = \sum_{\nu=0}^{\infty} Y_{Pre}(A+\nu)\, P_{A+\nu}(\nu)$$

$$\sum_{A} Y_{Post}(A) = 2$$

Example of the $^{235}U(n_{th},f)$

The link between the **post-neutron mass yields** $Y_{Post}(A)$ and the **pre-neutron mass yields** $Y_{Pre}\ (A+\nu)$ is given by the following equation:

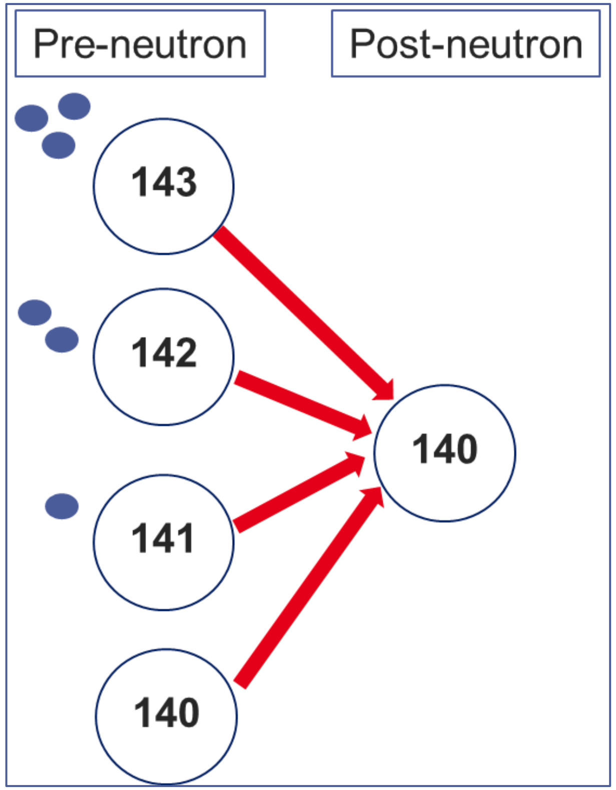


$$Y_{Post}(A) = \sum_{\nu=0}^{\infty} Y_{Pre}(A+\nu)\, P_{A+\nu}(\nu)$$

$$\sum_{A} Y_{Post}(A) = 2$$

Y_{Post} → We use our JEFF-4.0 evaluation

Example of the $^{235}U(n_{th},f)$



The link between the **post-neutron mass yields** $Y_{Post}(A)$ and the **pre-neutron mass yields** $Y_{Pre}(A+\nu)$ is given by the following equation:

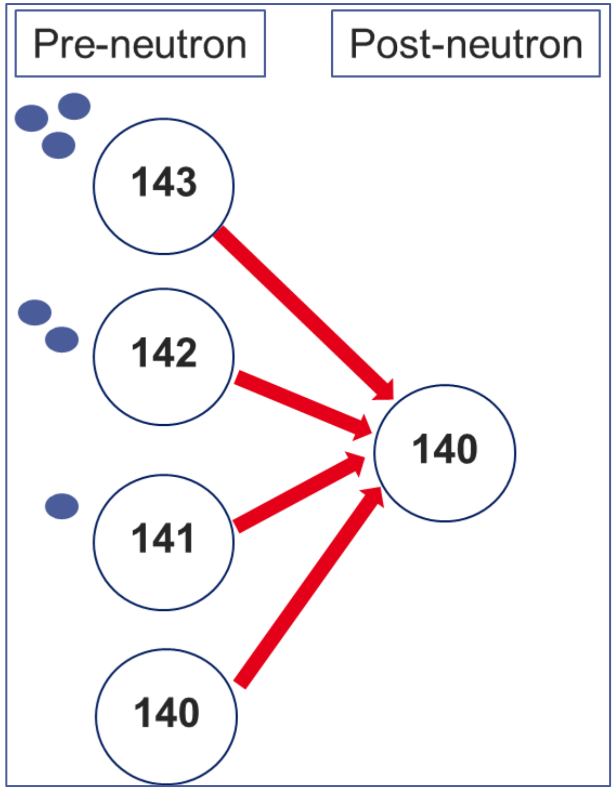
$$Y_{Post}(A) = \sum_{\nu=0}^{\infty} Y_{Pre}(A+\nu)\, P_{A+\nu}(\nu)$$

$$\sum_{A} Y_{Post}(A) = 2$$

Y_{Post} ➔ We use our JEFF-4.0 evaluation

Y_{Pre} ➔ We use the Pre-neutron mass yields evaluation performed by A. Regonesi (PhD thesis, CEA-Cadarache), based on the (2E-2v) and 2E measurements, after renormalization, re-calibration and accounting for the mass resolution of each measurement

The link between the **post-neutron mass yields** $Y_{Post}(A)$ and the **pre-neutron mass yields** $Y_{Pre}\ (A{+}\nu)$ is given by the following equation:



$$Y_{Post}(A) = \sum_{\nu=0}^{\infty} Y_{Pre}(A+\nu)\, P_{A+\nu}(\nu)$$

$$\sum_{A} Y_{Post}(A) = 2$$

Y_{Post} → We use our JEFF-4.0 evaluation

Y_{Pre} → We use the Pre-neutron mass yields evaluation performed by A. Regonesi (PhD thesis, CEA-Cadarache), based on the (2E-2v) and 2E measurements, after renormalization, re-calibration and accounting for the mass resolution of each measurement

$P_{A+\nu}(\nu)$ → Corresponds to the probability that a fission fragment of mass $A+\nu$ emit ν prompt neutrons:
We assume a Gaussian distribution characterized by an average value (saw-tooth) and a constant width σ

Generalised Least square Method used for adjusting the prompt neutron multiplicity distribution per mass: $P(\nu \mid A)$

Pre-neutron mass yields

$Y_{Pre}(A^{*})$

CONRAD

Post-neutron mass yields

$Y_{Ind}(A)$

$$Y_{Ind}(A) = \sum_{\nu=0}^{\infty} Y_{Pre}(A+\nu)\, P_{A+\nu}(\nu)$$

For this adjustment: $P(\nu \mid A)$ follows a Gaussian distribution with:

- average values = $\overline{\nu}(A)$ = free parameters (saw-tooth)
- width σ : free parameter, assumed to be constant for all masses

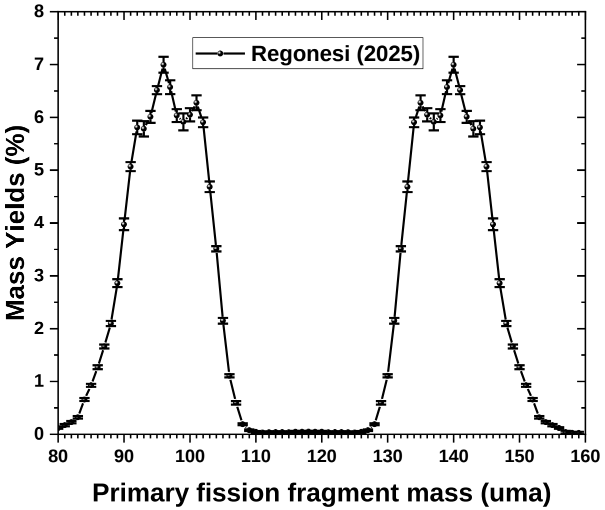
Generalised Least square Method used for adjusting the prompt neutron multiplicity distribution per mass: $P(\nu \mid A)$

Pre-neutron mass yields

CONRAD

Post-neutron mass yields

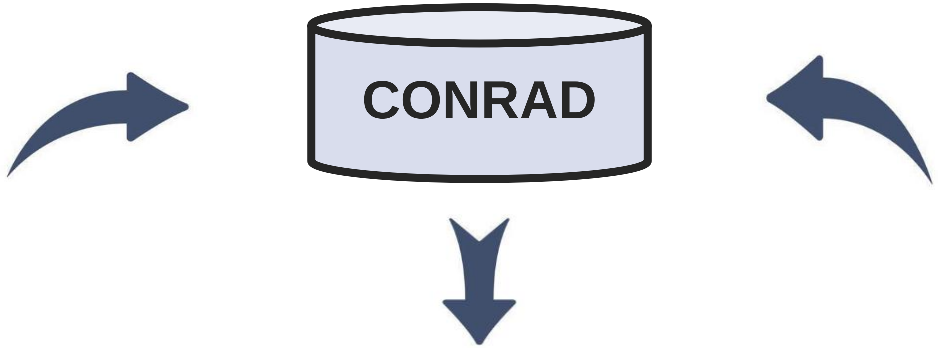
$Y_{Ind}(A)$



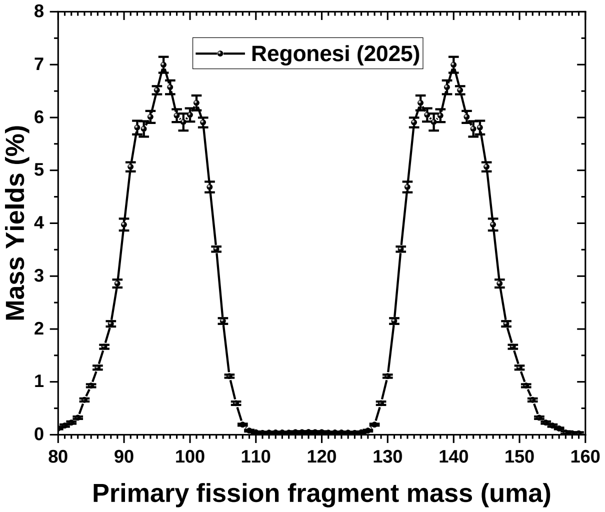
$$Y_{Ind}(A) = \sum_{\nu=0}^{\infty} Y_{Pre}(A+\nu)\, P_{A+\nu}(\nu)$$

Pre-neutron mass yields evaluation: A. Regonesi (PhD thesis, CEA-Cadarache), based on 9 series of data: symmetrized, recalibrated and normalized. Mass resolution: σ=0.89 uma (FWHM=2.09 uma

Generalised Least square Method used for adjusting the prompt neutron multiplicity distribution per mass: $P(\nu \mid A)$



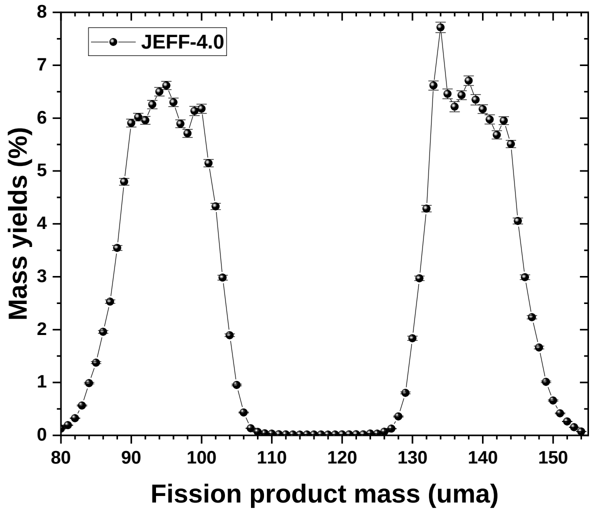
Pre-neutron mass yields



Pre-neutron mass yields evaluation: A. Regonesi (PhD thesis, CEA-Cadarache), based on 9 series of data: symmetrized, recalibrated and normalized. Mass resolution: σ=0.89 uma (FWHM=2.09 uma

$$Y_{Ind}(A) = \sum_{\nu=0}^{\infty} Y_{Pre}(A+\nu)\, P_{A+\nu}(\nu)$$

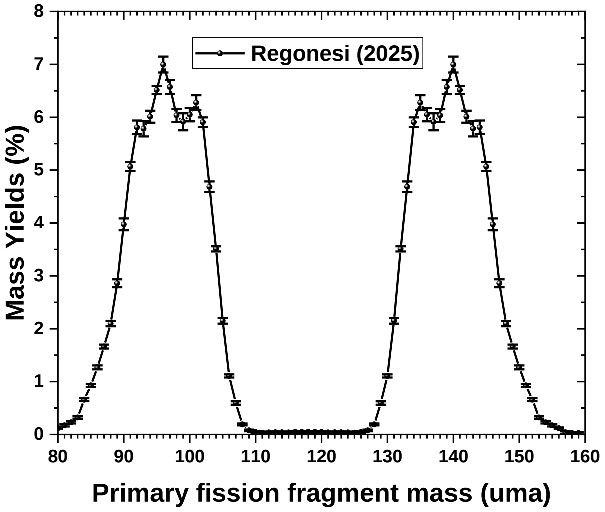
Post-neutron mass yields

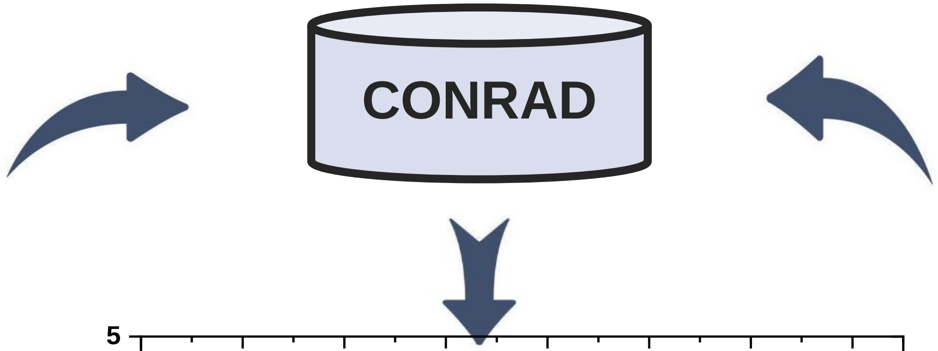


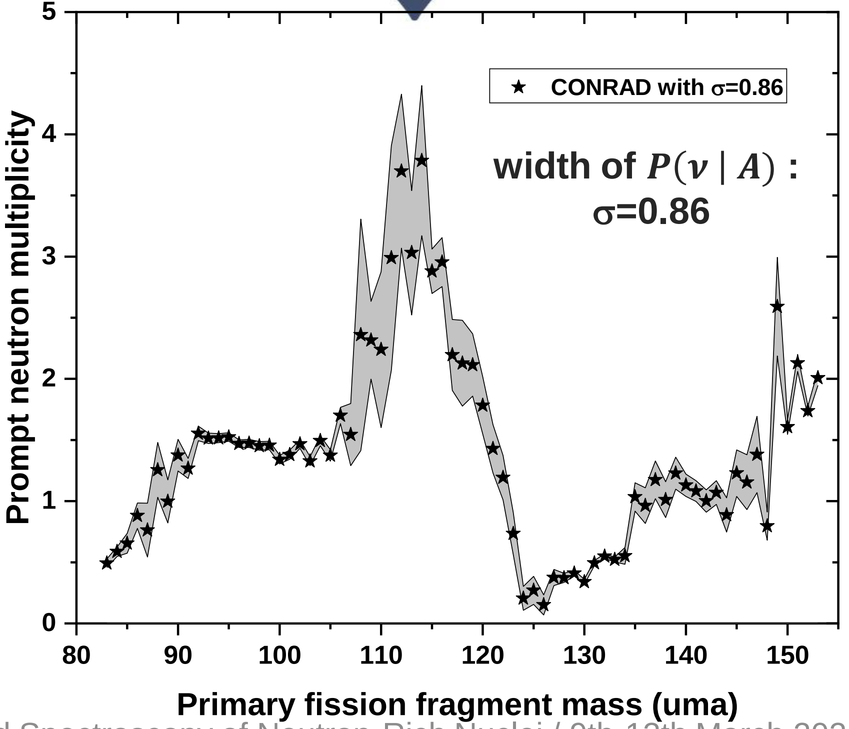
Post-neutron mass yields = JEFF-4.0 evaluation: strong reduction of the uncertainties thanks to the correlation matrix

Generalised Least square Method used for adjusting the prompt neutron multiplicity distribution per mass: $P(\nu \mid A)$

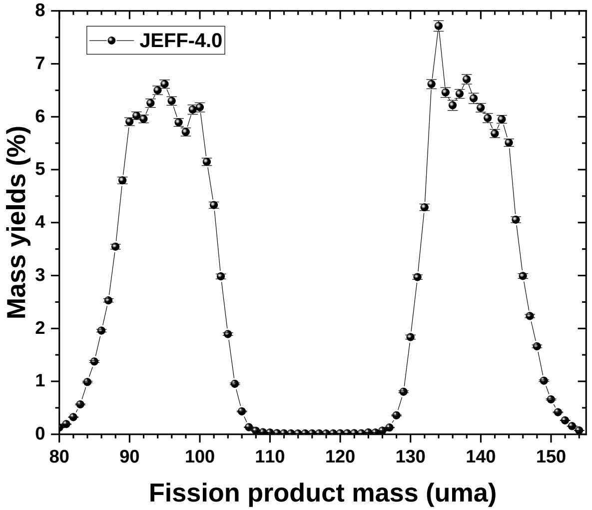
Pre-neutron mass yields





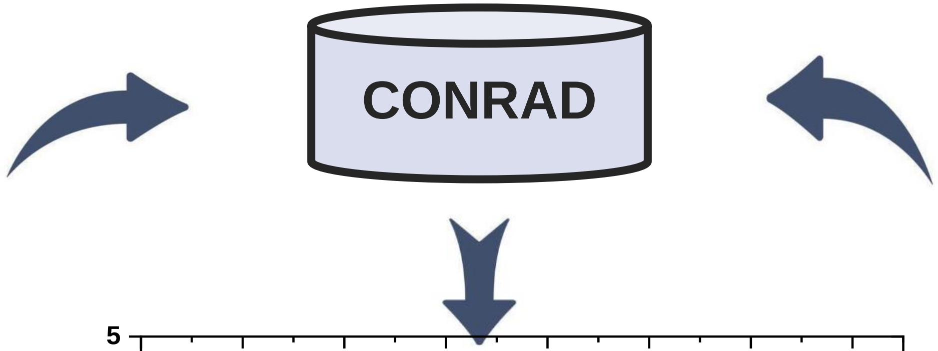


Post-neutron mass yields

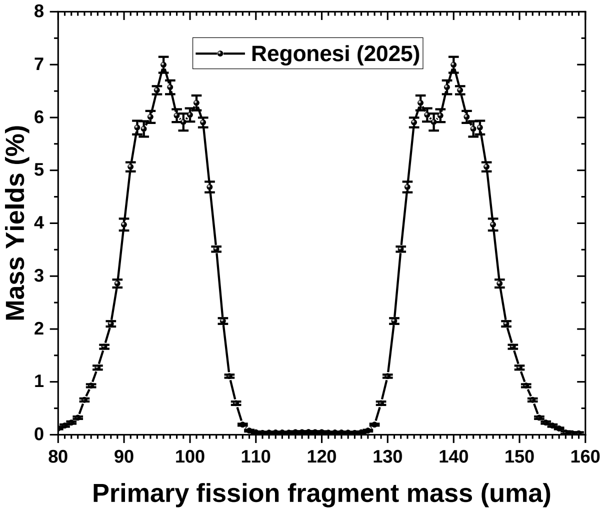


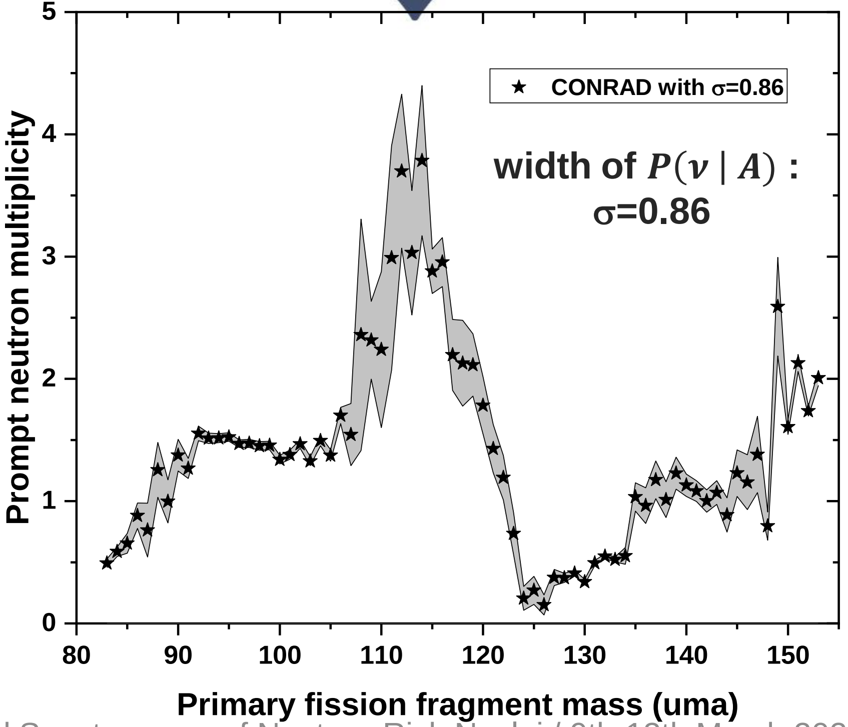
Generalised Least square Method used for adjusting the prompt neutron multiplicity distribution per mass: $P(\nu \mid A)$

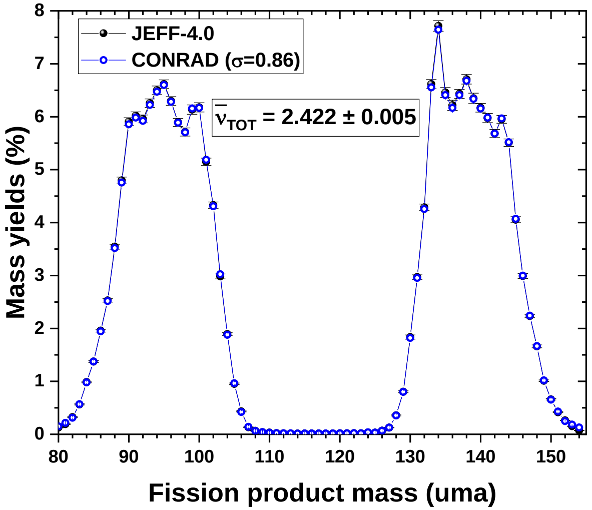
Pre-neutron mass yields



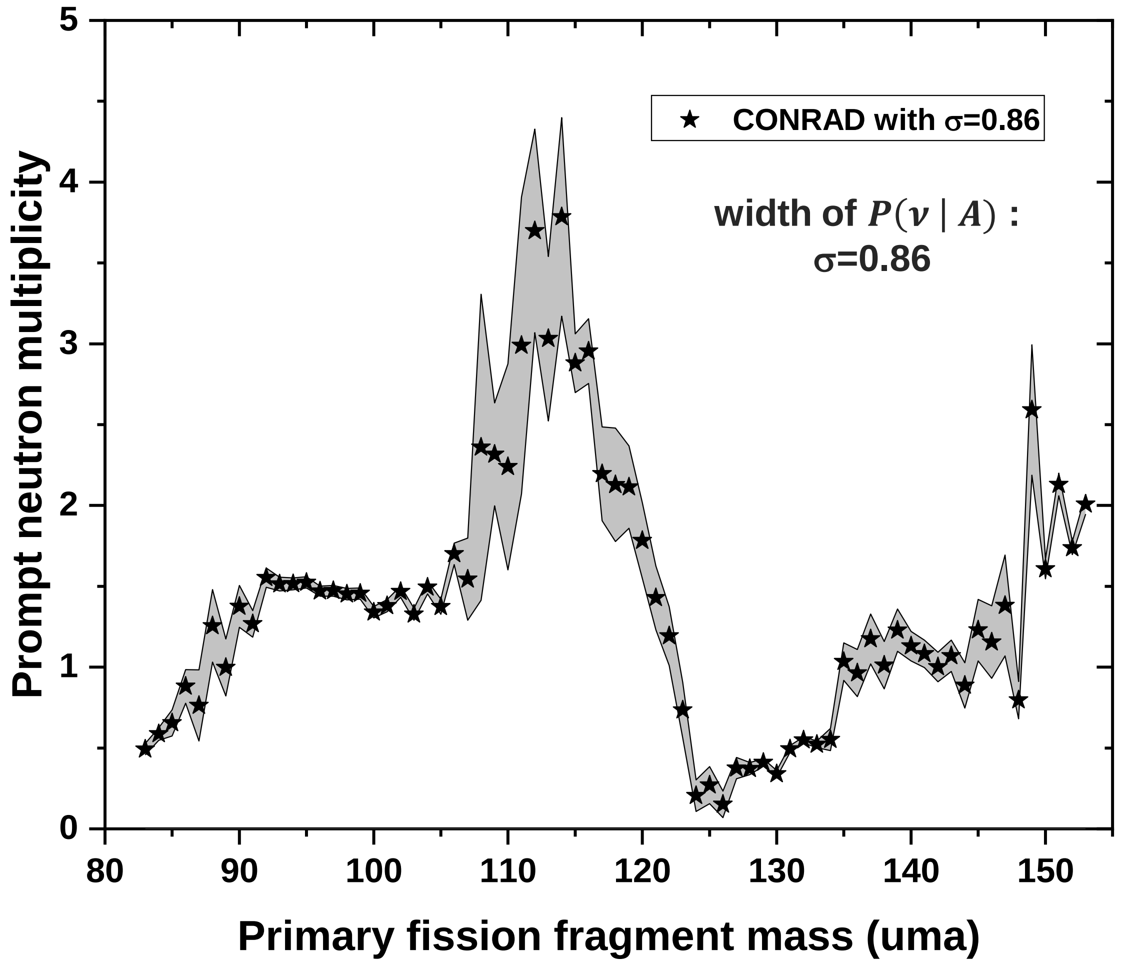
Post-neutron mass yields

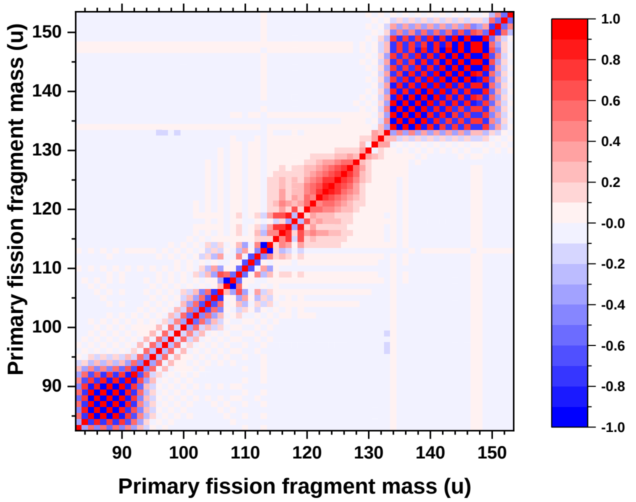




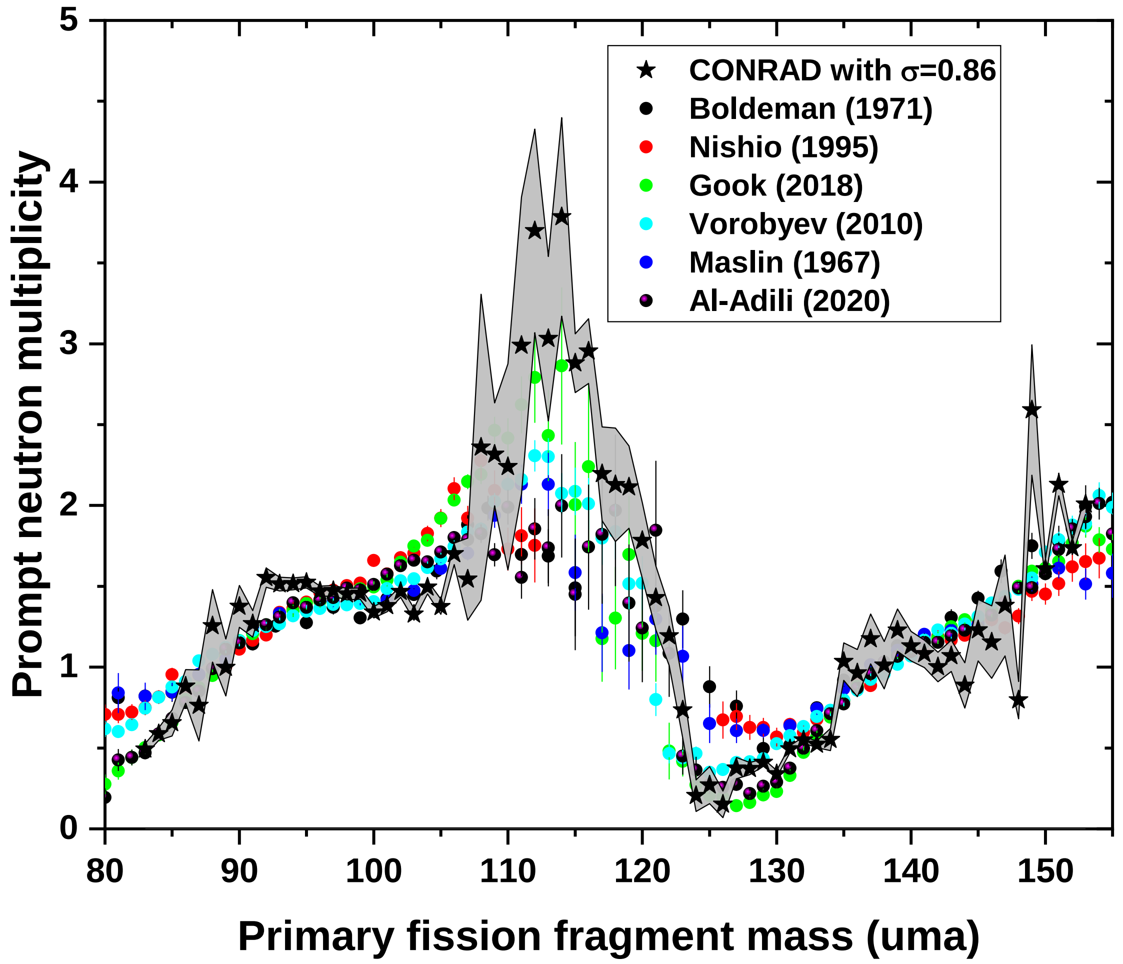


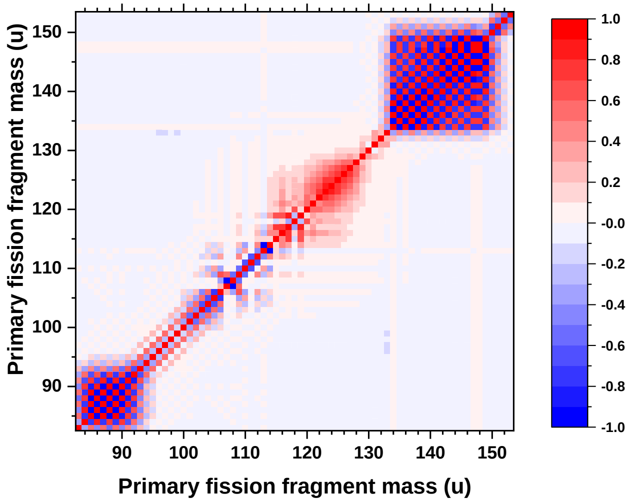
With Regonesi's evaluation (pre-neutron), JEFF-4.0 can be nicely reproduced





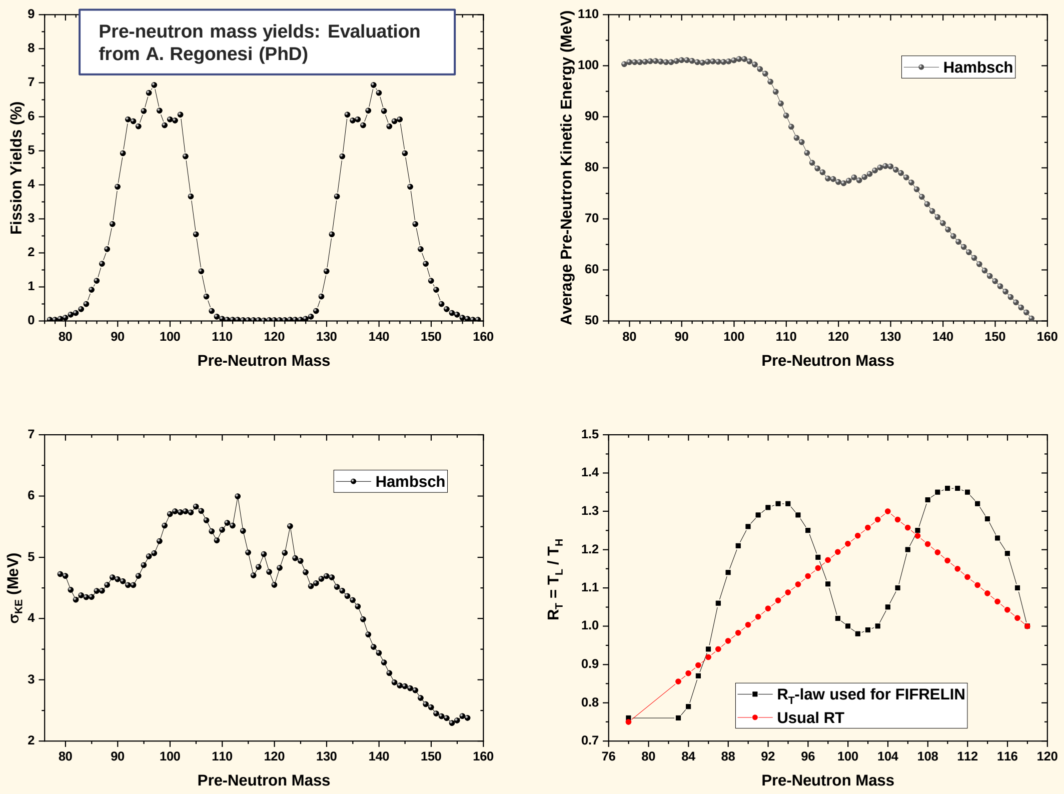
Comparison of the adjusted saw-tooth (CONRAD) with experimental data:





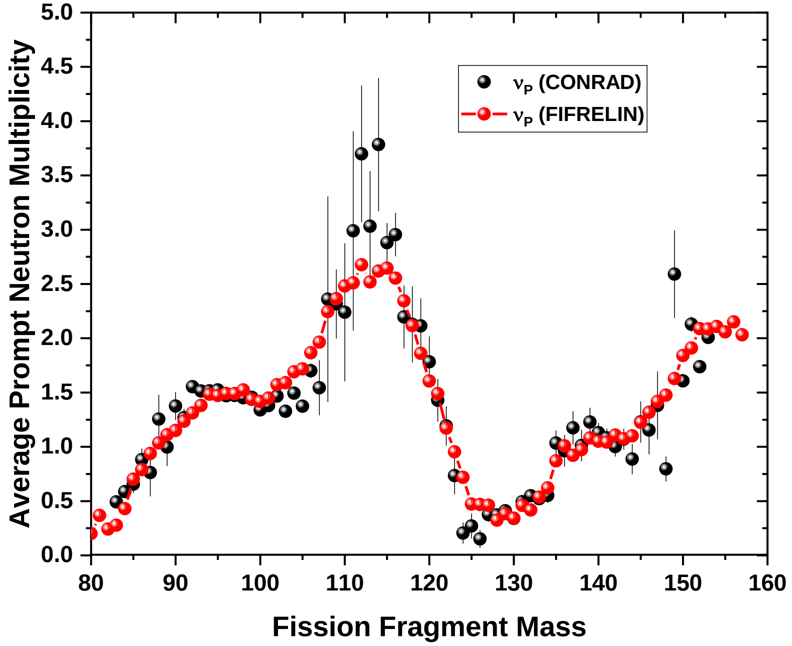
Comparison of the adjusted saw-tooth (CONRAD) with experimental data:

- ❑ Good agreement is achieved
- ❑ Nice consistency between pre and post mass yields



- ❑ Nuclear charge distribution model based on Wahl's model
- ❑ Level density calculated from HFB
- ❑ Level density combinatorial model = HFB+BSk14
- ❑ Shell corrections from Mengoni-Nakajima
- ❑ Strength function model (E1): Enhanced Generalizes Lorentzian (EGLO)
- ❑ Optical model for neutron transmission coefficients based on Koning-Delaroche potential
- ❑ Level scheme origin from RIPL3-2021

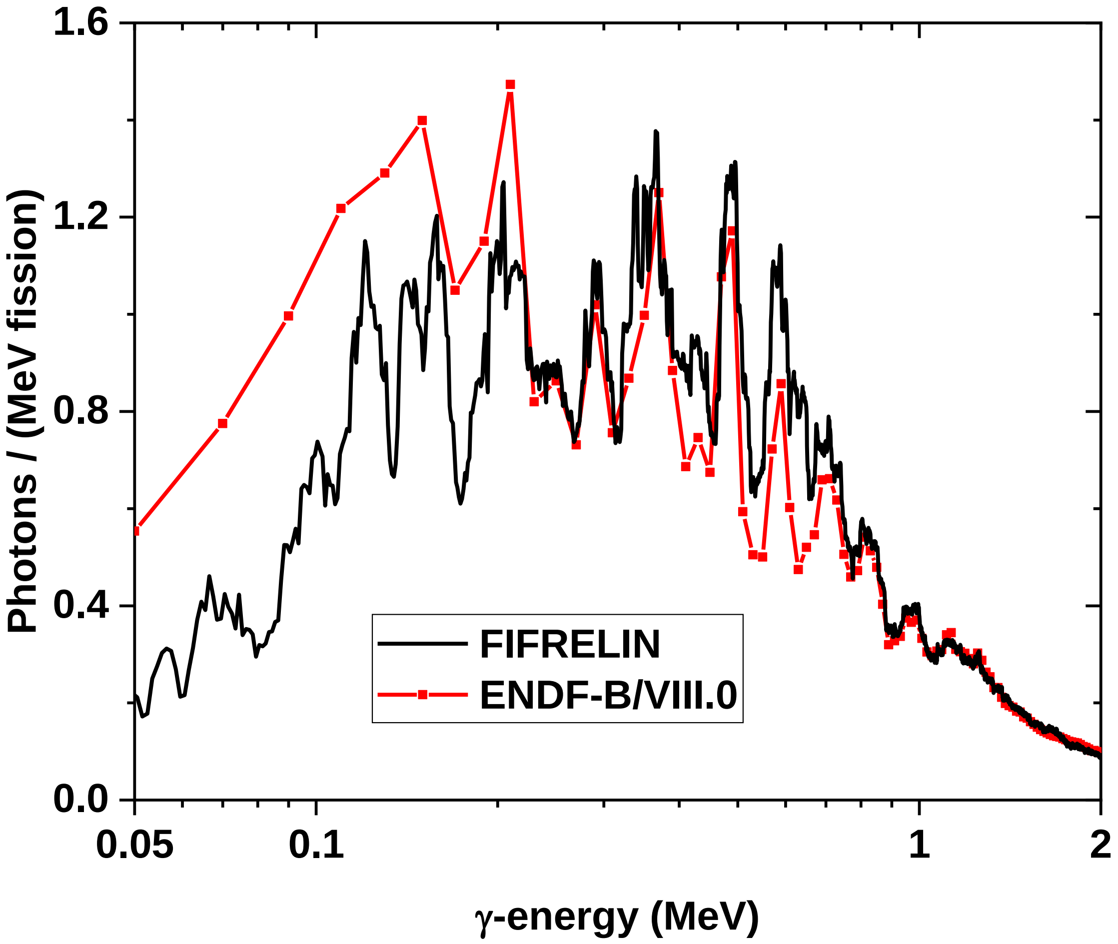
After the adjustment of the free parameters, the saw-tooth from FIFRELIN is close to the saw-tooth from CONRAD

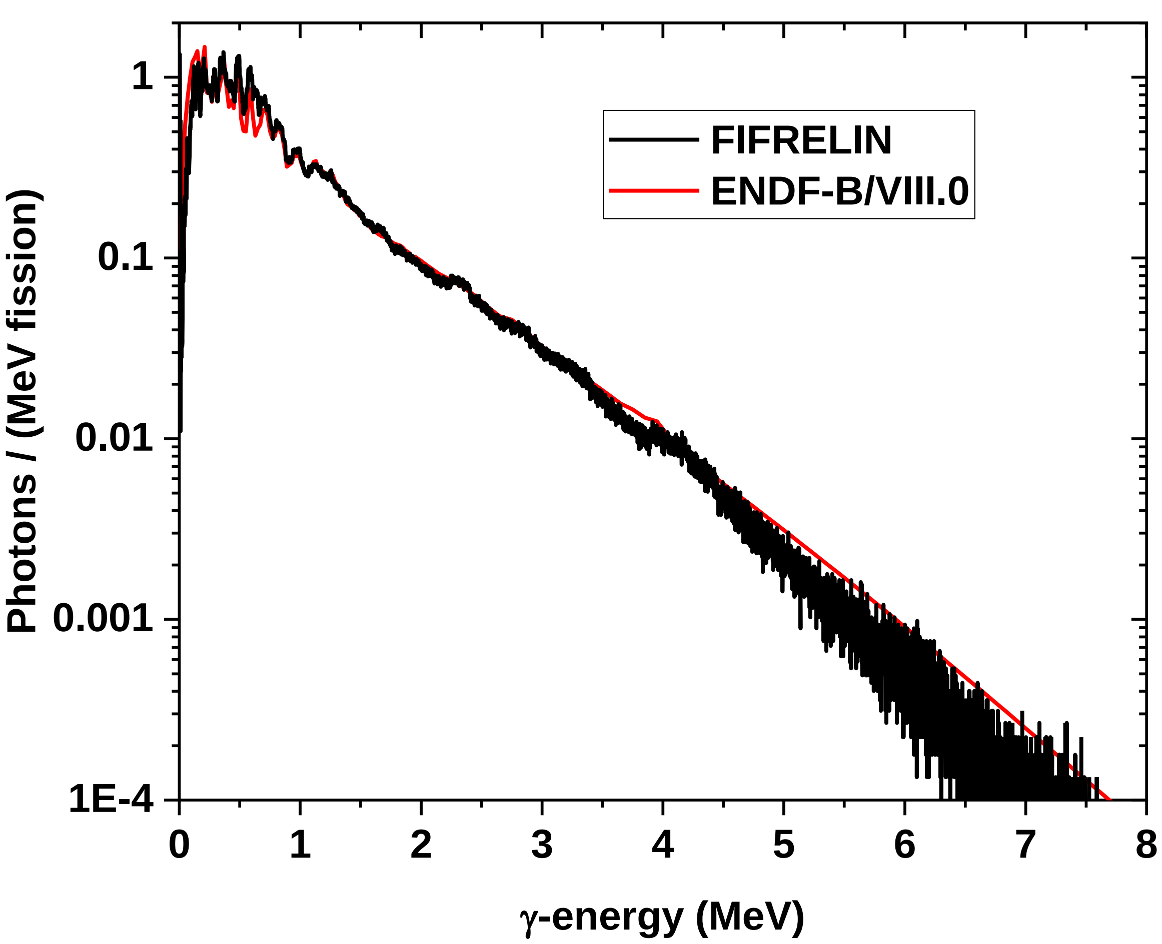


- ❑ F.-J. Hambsch et al., Nucl. Phys. A491, 56 (1989)
- ❑ P. Geltenbort et al., Radiation Effects, vol. 93, 57 (1986)
- ❑ **R_T-law: Machine learning procedure developed by G. Bazelaire, PhD thesis, University Aix-Marseille, 2025**

Results obtained from FIFRELIN calculation: Example of the $^{235}U(n_{th},f)$

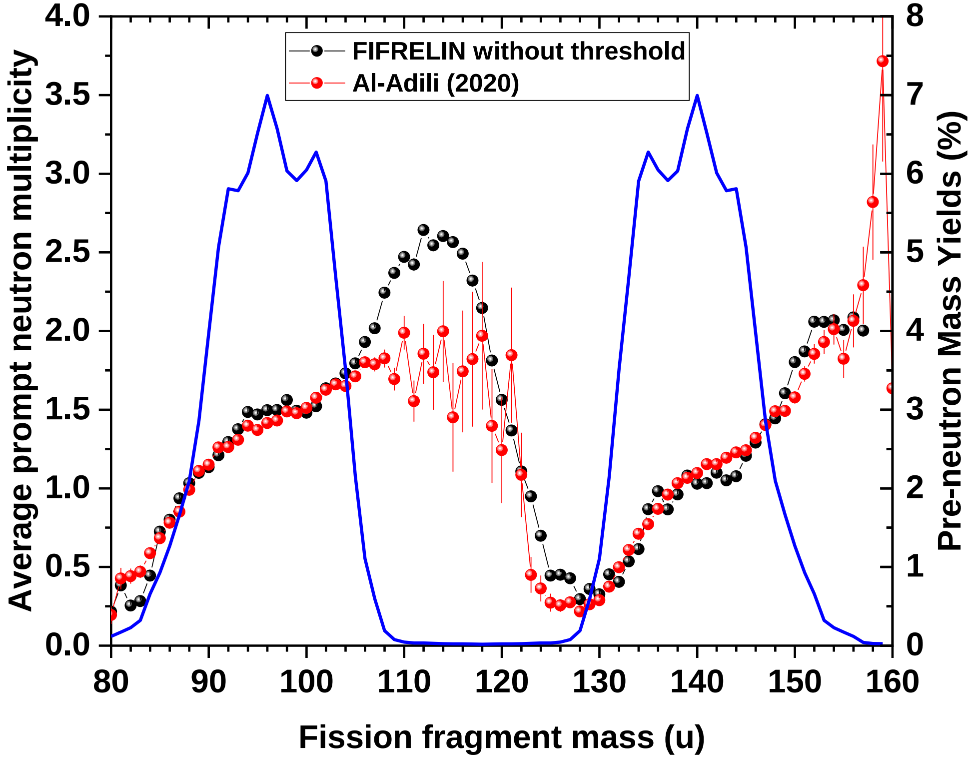
Prompt Fission Gamma Spectrum





Results obtained from FIFRELIN calculation: Example of the $^{235}U(n_{th},f)$

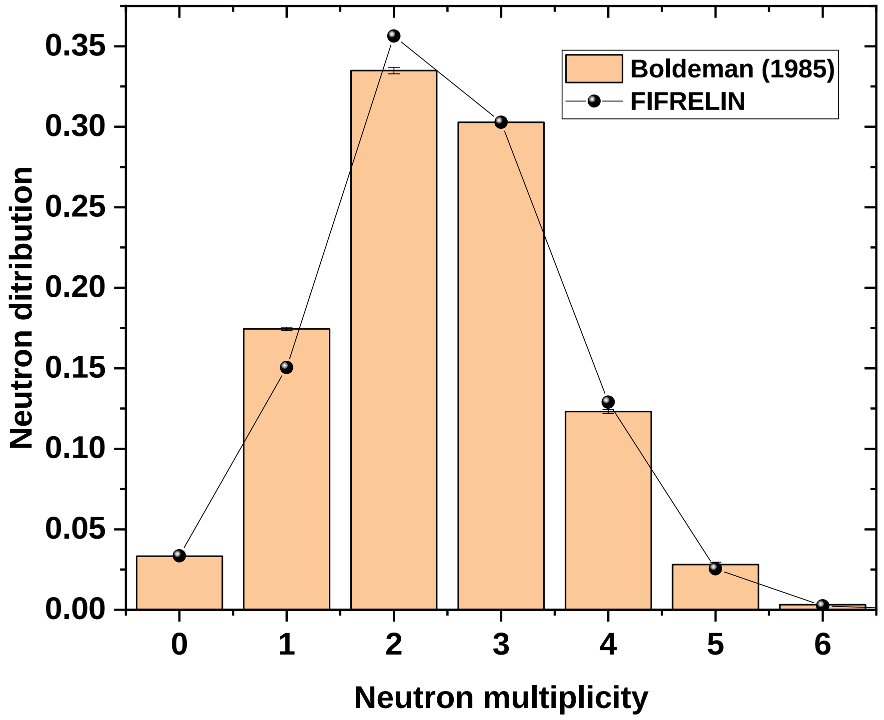
Prompt Fission Neutron Multiplicity



$(\overline{\nu_P})_{Light} = 1.43$

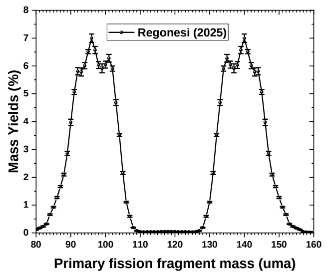
$(\overline{\nu_P})_{Heavy} = 1.00$

$(\overline{\nu_P})_{Total} = 2.43$



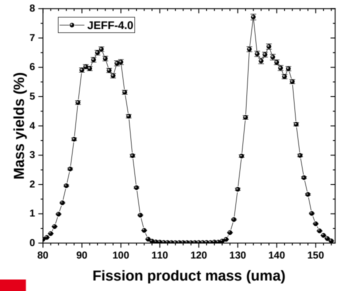
- *A. Al-Adili et al., Phys. Rev. C 102, 064610 (2020),*
- *J. W. Boldeman and M. G. Hines, Nucl. Sc. and Eng. 91, 114 (1985)*

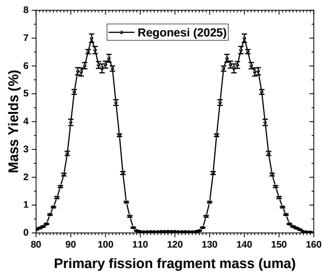
Conclusion



Evaluation of pre-neutron mass yields based on 2E-2v + 2E measurements

Evaluation of post-neutron mass yields mainly based on Lohengrin measurements and γ-spectrometry





Evaluation of pre-neutron mass yields based on 2E-2v + 2E measurements

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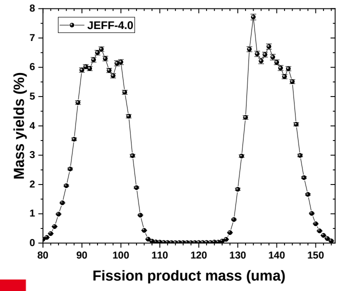
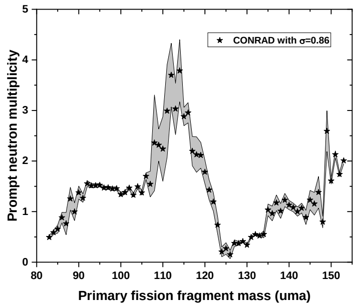
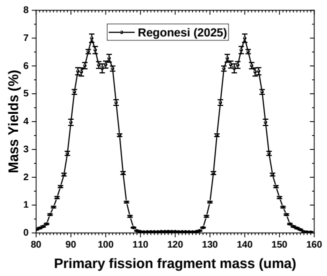
Code CONRAD used to deduce the saw-tooth







Evaluation of pre-neutron mass yields based on 2E-2v + 2E measurements

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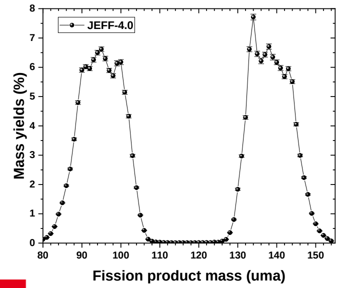
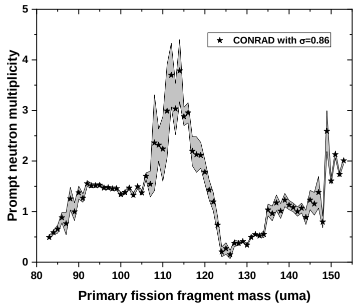
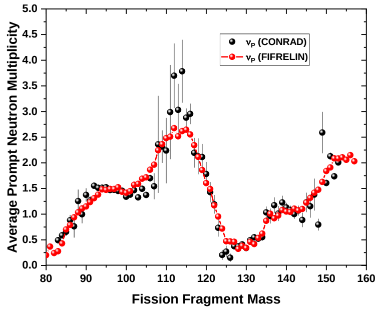
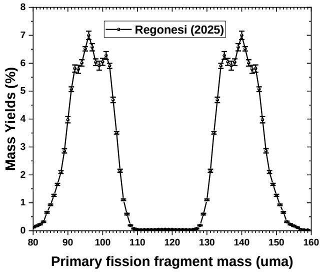
Code CONRAD used to deduce the saw-tooth

Adjustement of the free parameters of the FIFRELIN code (R_T – law) to reproduce the saw-tooth and deduce other fission observables









Evaluation of pre-neutron mass yields based on 2E-2v + 2E measurements

Evaluation of post-neutron mass yields mainly based on Lohengrin measurements and γ-spectrometry

Code CONRAD used to deduce the saw-tooth

Adjustement of the free parameters of the FIFRELIN code (R_T – law) to reproduce the saw-tooth and deduce other fission observables

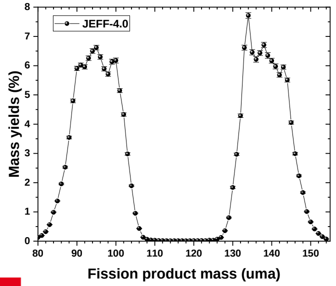
Energy released, Fission Yields…

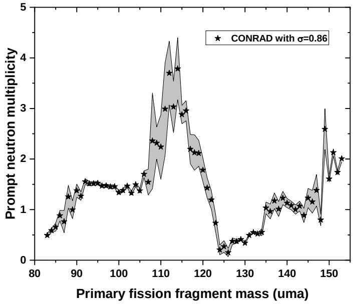
Prompt and delayed neutron characteristics (Spectrum, multiplicity…)

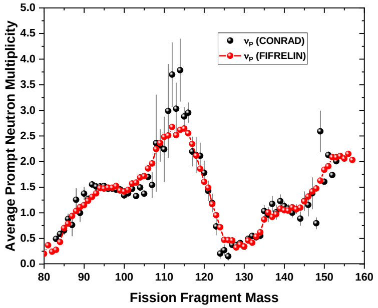
Prompt Gamma characteristics (Spectrum, multiplicity…)

Correlation between fission observables

Nuclear Data for reactor applications







Thank you for your attention

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A. Viéville, C. Sage, O. Méplan, M. Ramdhane, F. Collovati, D. Dauvergne, M.L. Gallin-Martel, J.F. Muraz, O. Guillaudin, S. Marcatili
LPSC, Université Grenoble-Alpes, CNRS/IN2P3, F-38026 Grenoble Cedex, France

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Pre-neutron mass yields evaluation performed by A. Regonesi (on going PhD thesis)

New evaluation of pre-neutron mass performed by Alessandro REGONESI (PhD thesis) based on experimental data available in the EXFOR

Data are analyzed on the basis of their mass resolution

Reference data= Geltenbort (COSI-FAN-TUTTE facility at ILL), but need to be recalibrated

Name	Year	Method	$\nu(A)$	Unc.	Sym.	Mass Range
Geltenbort [3]	1985	2E-2v	No	Yes	Yes	77–159
Derengowski [4]	1970	2E-2v	No	Yes	No	78–109, 127–154
Hambsch [5]	1989	2E	Apalin [6]	Yes	No	61–168
Al-Adili [7]	2020	2E	Wahl [8]	Yes	No	66–167
Romano [9]	2007	2E	Maslin [10]	Yes	No	71–165
Simon [11]	1989	2E	Cold frag.	No	No	79–110, 126–157
Zeynalov [12]	2006	2E	Apalin [6]	Yes	No	118–160
Zeynalov [13] S1	2017	2E	measured $\bar{\nu}$	No	No	79–157
Zeynalov [13] S2	2017	2E	Apalin [6]	No	No	79–157

Name	Region $(FY \geq x\%)$	$\sigma_{add}(\%)$	FWHM (amu)
Geltenbort [3]	$0\ \%$	0.0	2.09 ± 0.56
Derengowski [4]	$0\ \%$	0.0	2.31 ± 0.26
Hambsch [5]	$1\ \%$	1.0	2.59 ± 0.23
Al-Adili [7]	$1\ \%$	2.5	5.65 ± 0.12
Romano [9]	$0\ \%$	0.0	5.75 ± 0.12
Simon [11]	$0\ \%$	3.0	3.67 ± 0.16
Zeynalov [12]	$1\ \%$	5.0	4.07 ± 0.19
Zeynalov [13] S1	$1\ \%$	6.0	5.86 ± 0.19
Zeynalov [13] S2	$1\ \%$	5.0	5.09 ± 0.21

Selected data after applying convolution and selecting the region and the additional uncertainty for compatibility with Geltenbort's dataset

See: A. Regonesi et al., Proceedings of the ND-2025 conference