APRENDE WP2-WP4 workshop
Lausanne, 6-7 July 2025

From experimental data to FY evaluation : JEFF4.0 and future program

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APRENDE Subtask 4.3.1 Fission yield evaluation

JEFF-4 Goal → New methodology : complete and consistent

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- ## Previous FY evaluations :

- Independent and Cumulative FY evaluations are two different evaluations : only mean values follow conservation laws
- Driven by the cumulative data
- Uncertainties of Ind. FY are overestimated due to the lack of correlation matrix as by-product of the analysis
- Covariance/correlation matrix of Ind FY is extrapolated assuming the C. Devillers methodology : Assumption Corr (C, C') = I

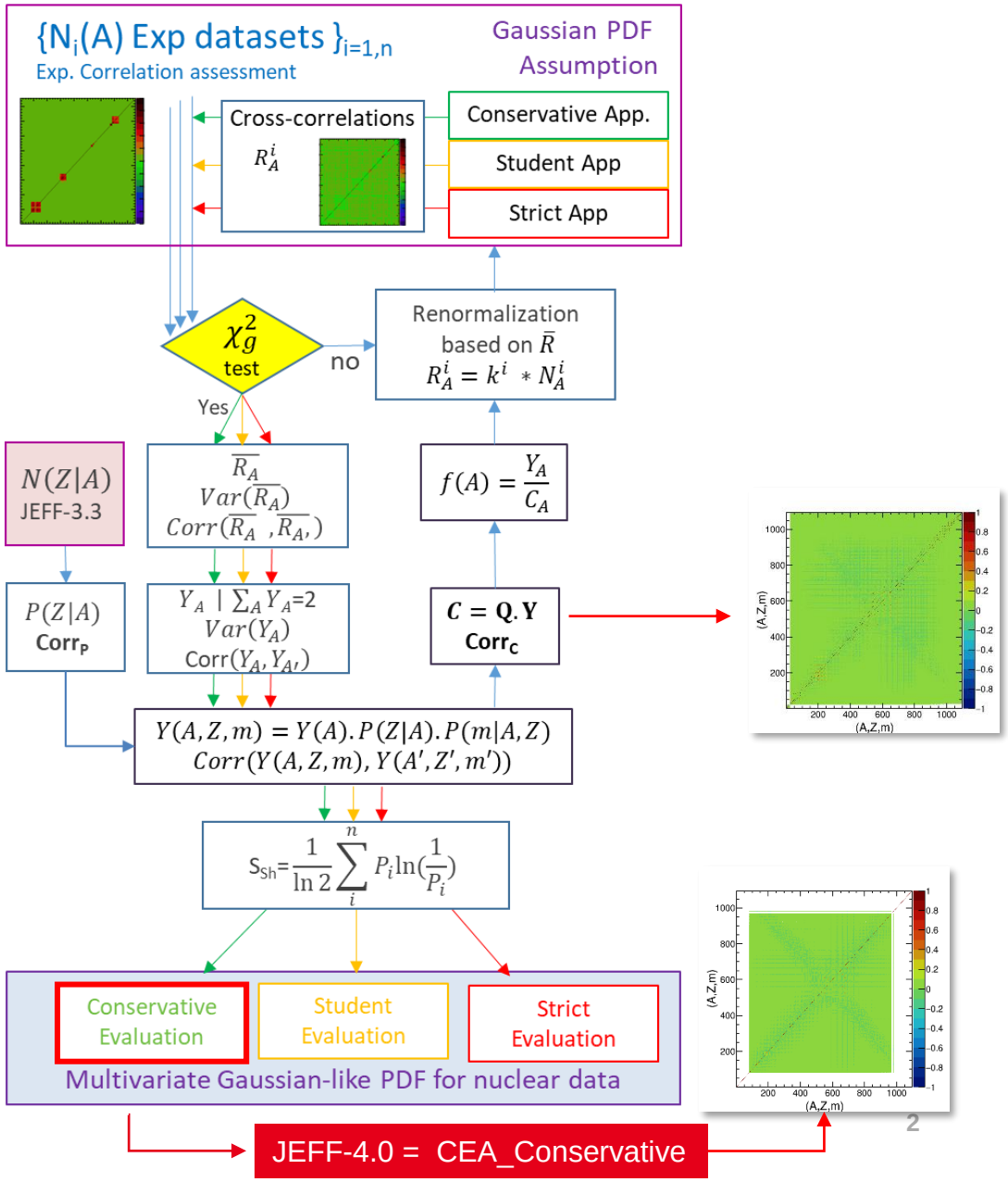
- ## JEFF-4 Evaluation

- Independent and Cumulative FY come from a unique evaluation
- Take into account the experimental correlation matrix available or deduced from literature
- Complete description of the fission yield observables: covariances
- Consistent according to the conservation laws for :

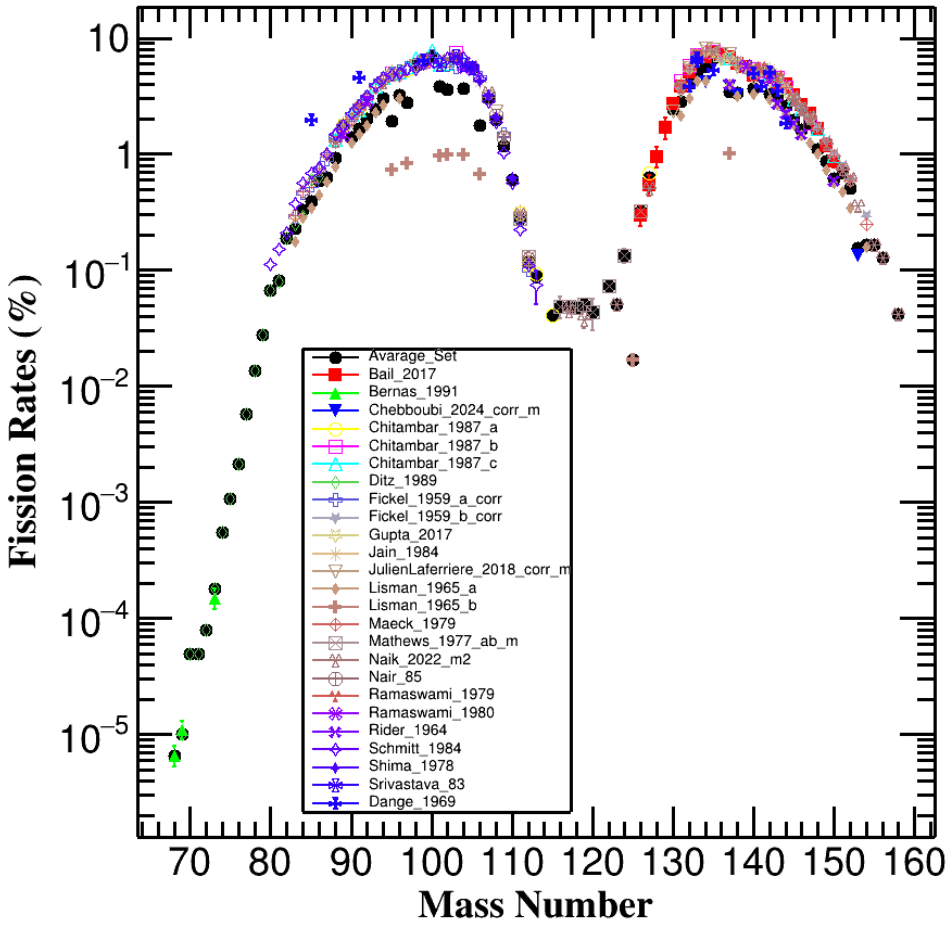
  mean values, uncertainties and correlation matrices

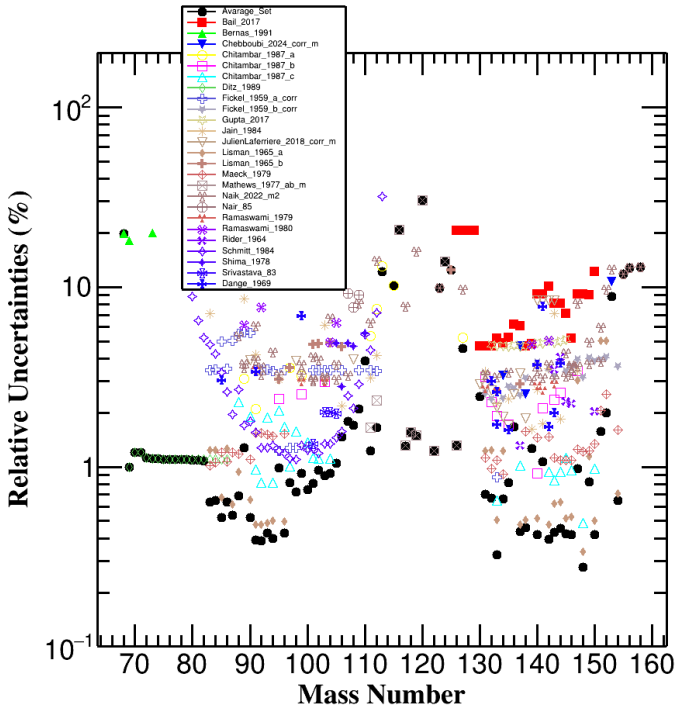
- Monte Carlo Fission yield sampling files (MCFYF)

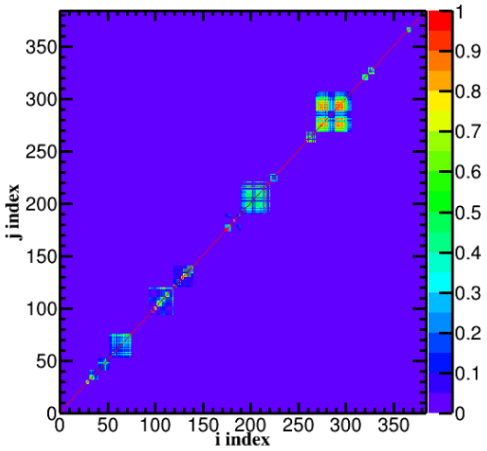
APRENDE Subtask 4.3.1 Fission yield evaluation



$^{239}Pu(n_{th},f)$ Mass yield data: raw data







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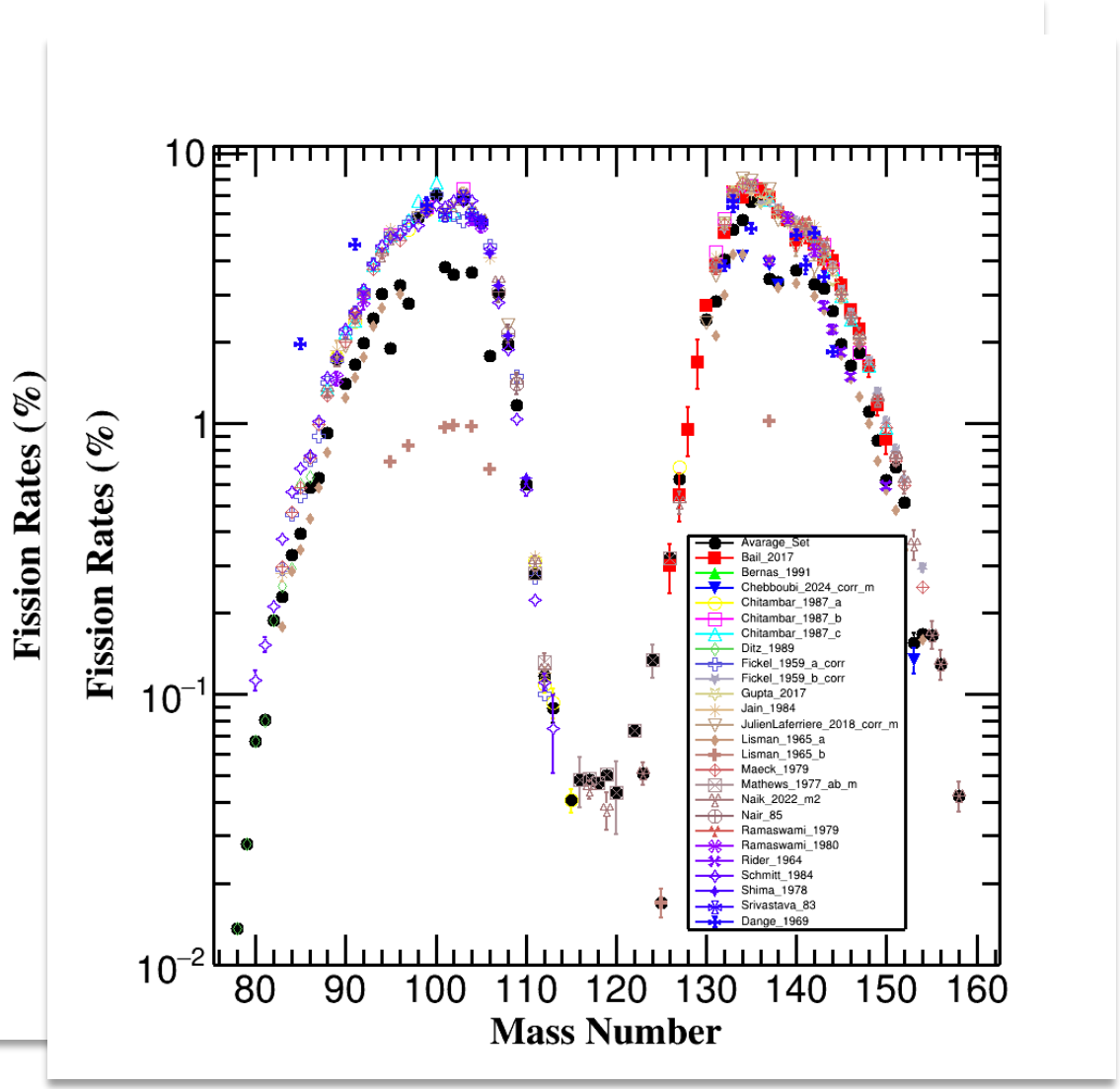
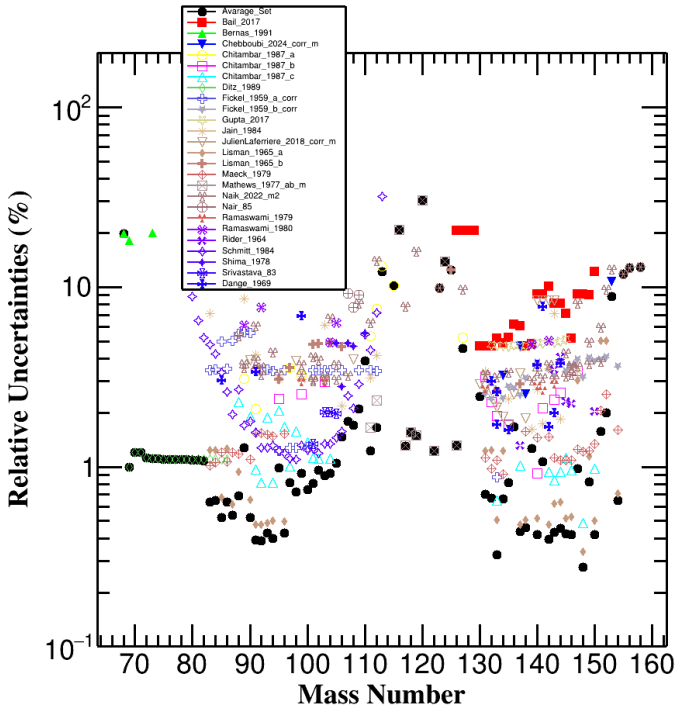
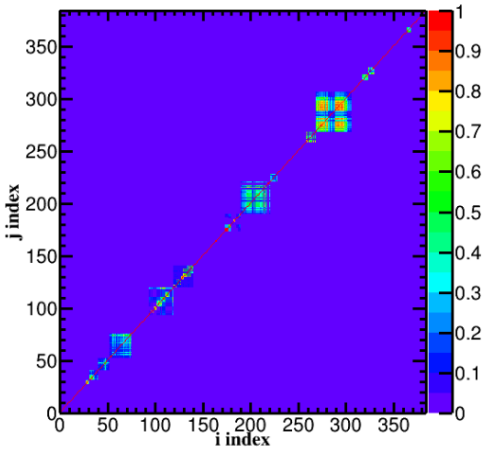
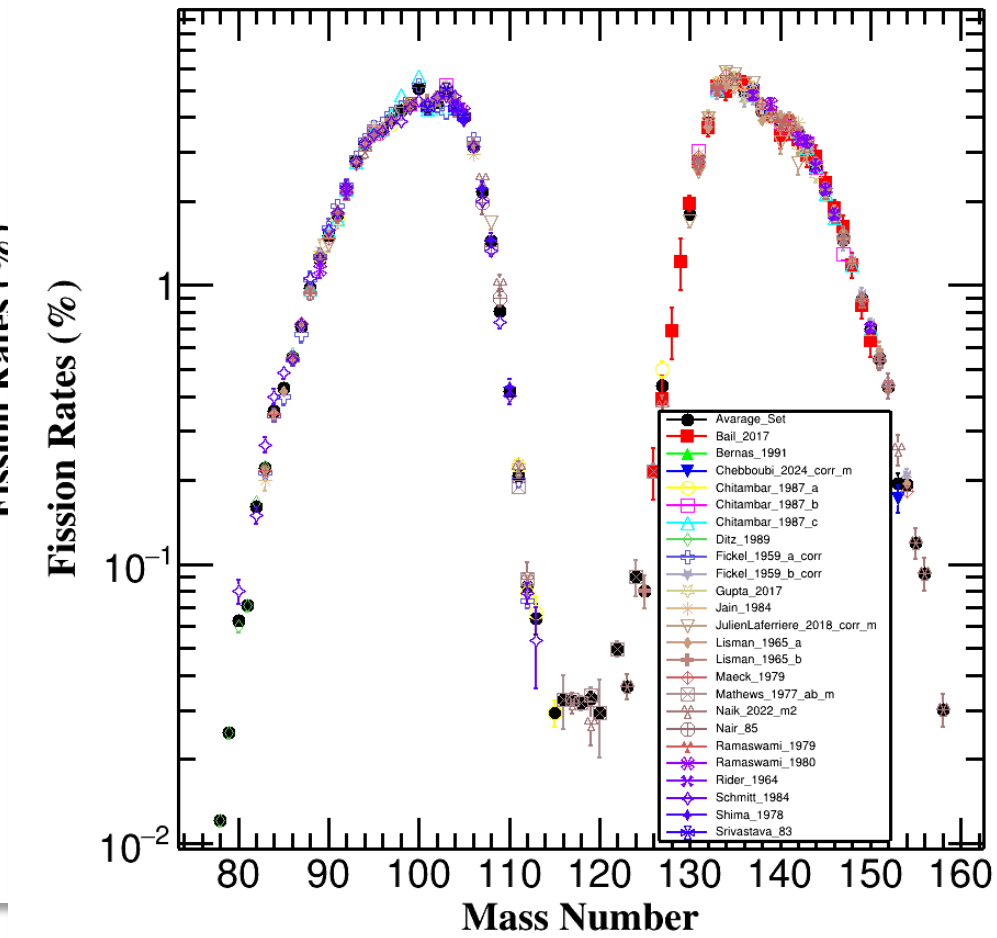
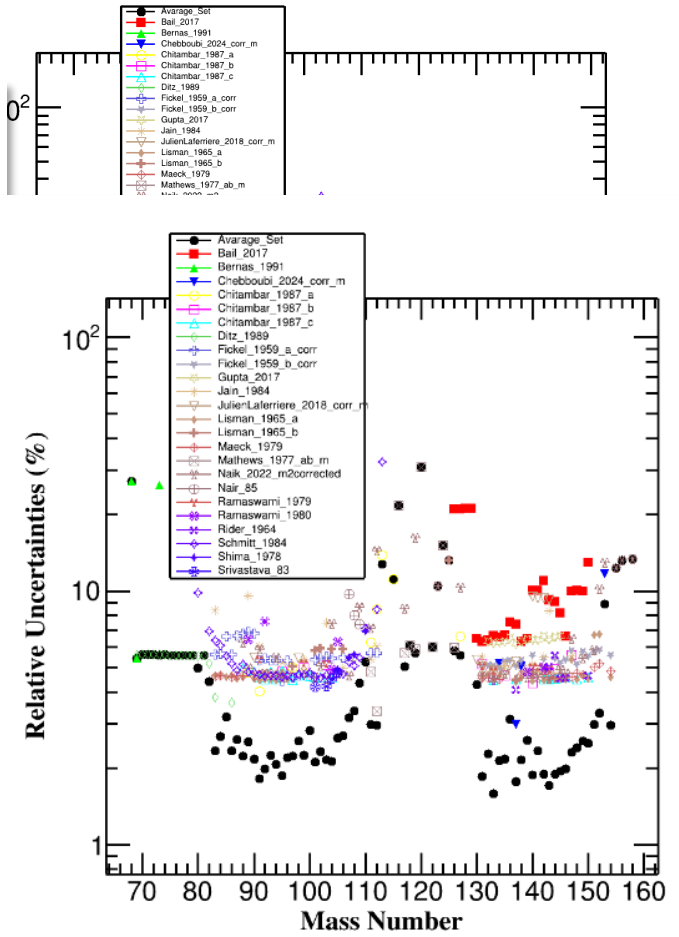


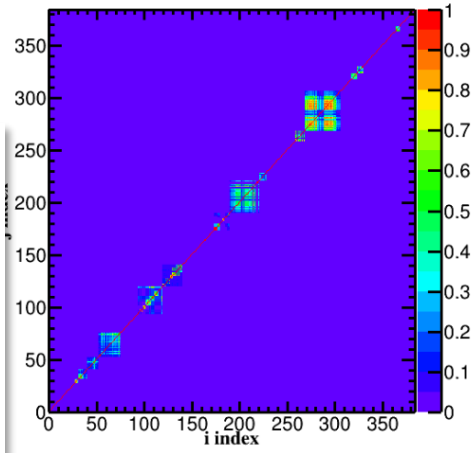


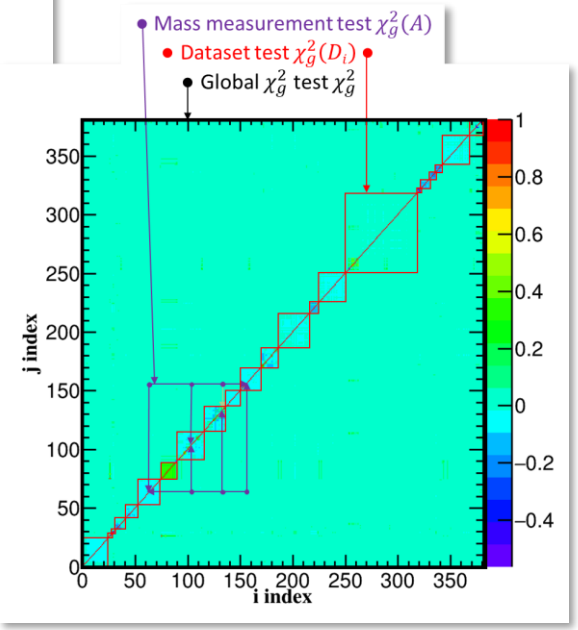


$^{239}Pu(n_{th},f)$ Mass yield data: renormalized and sorted









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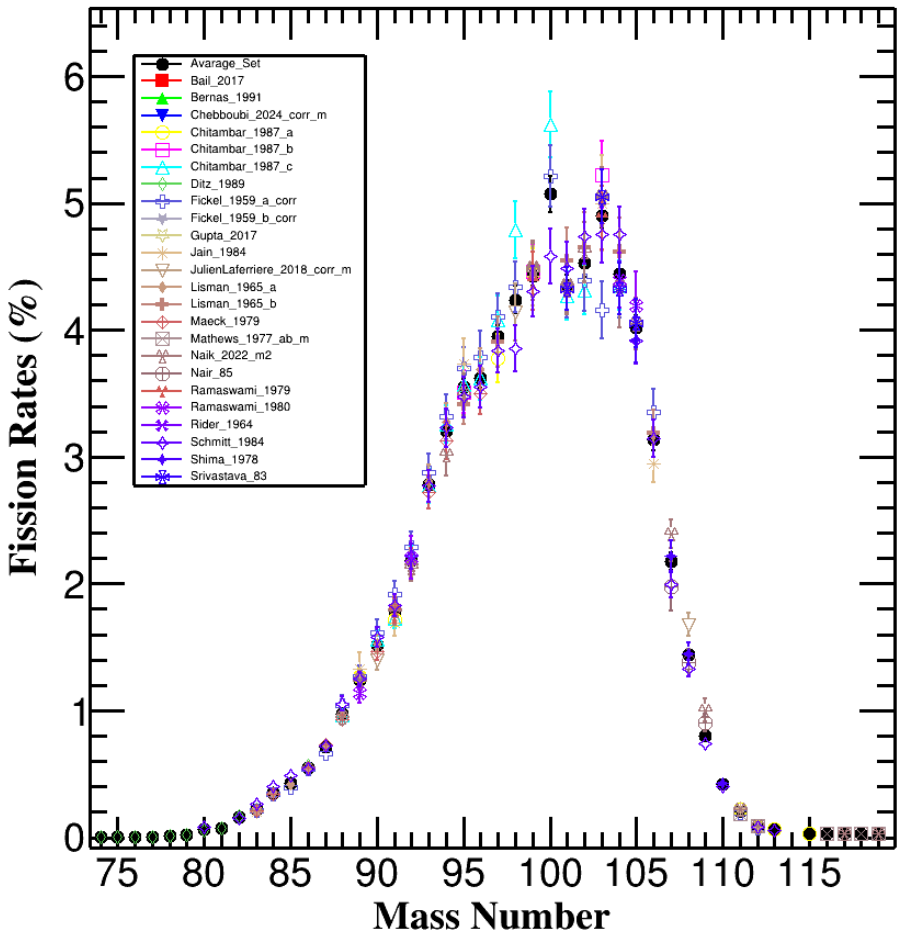

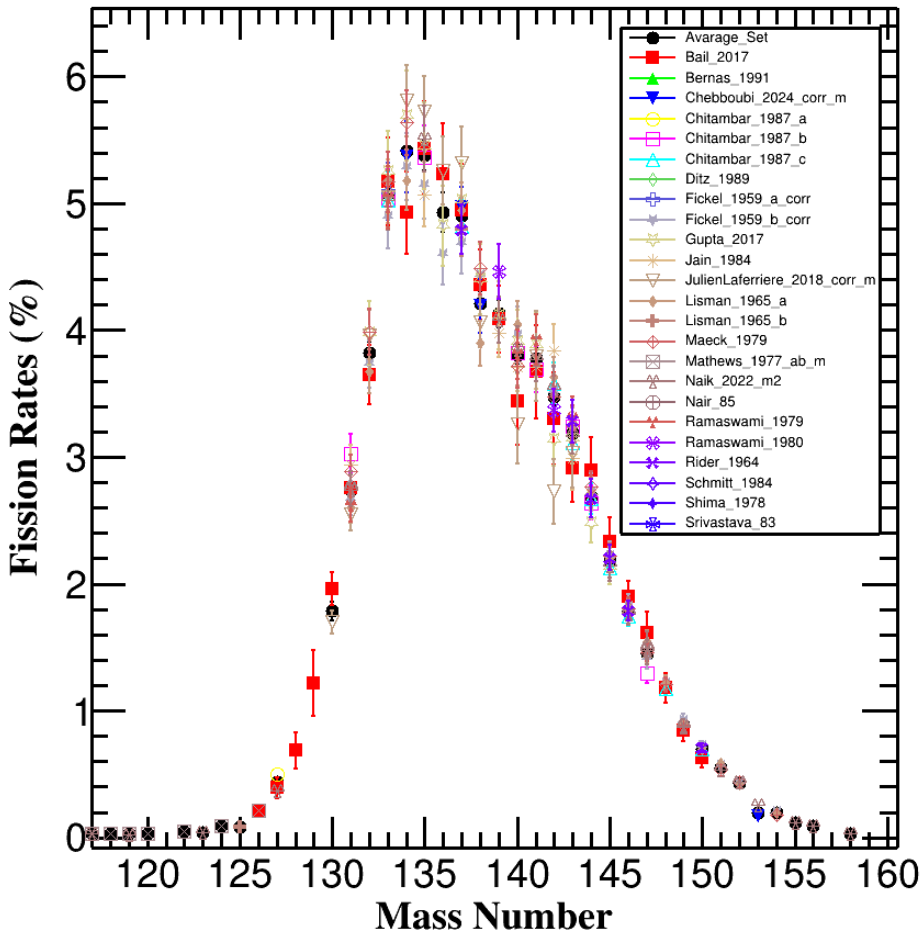

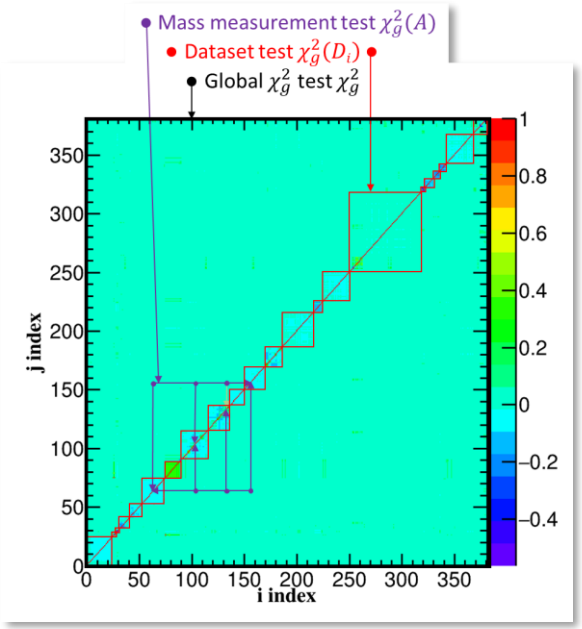

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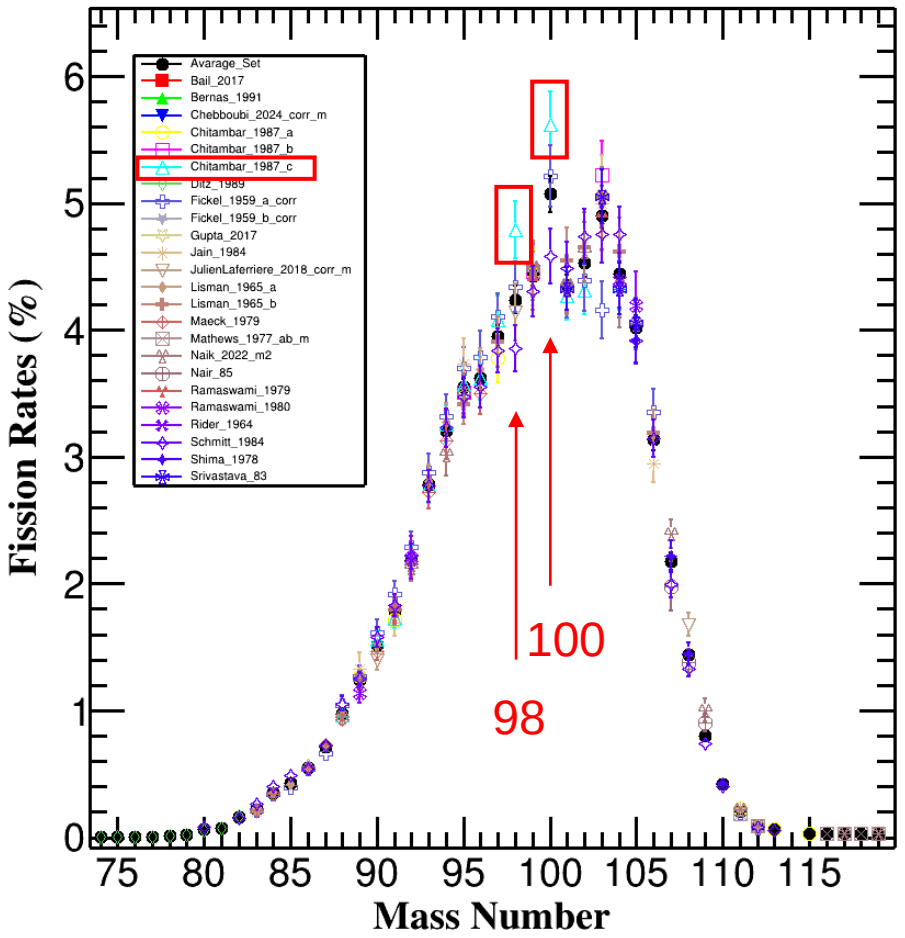

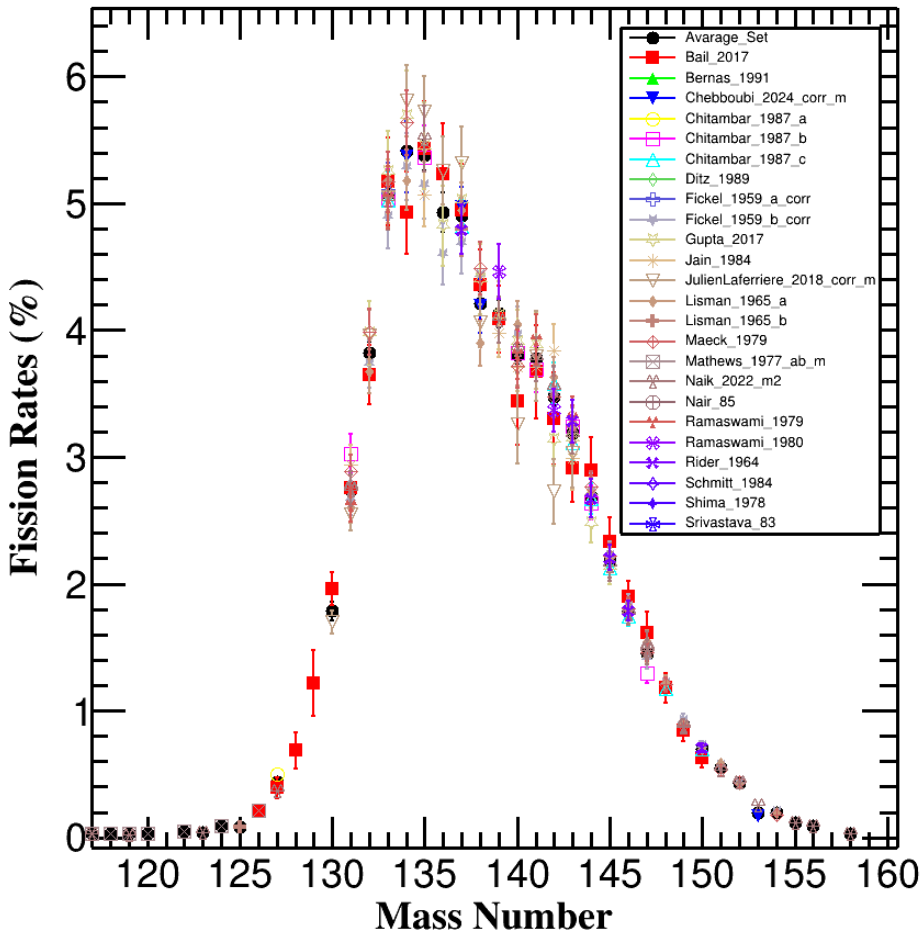

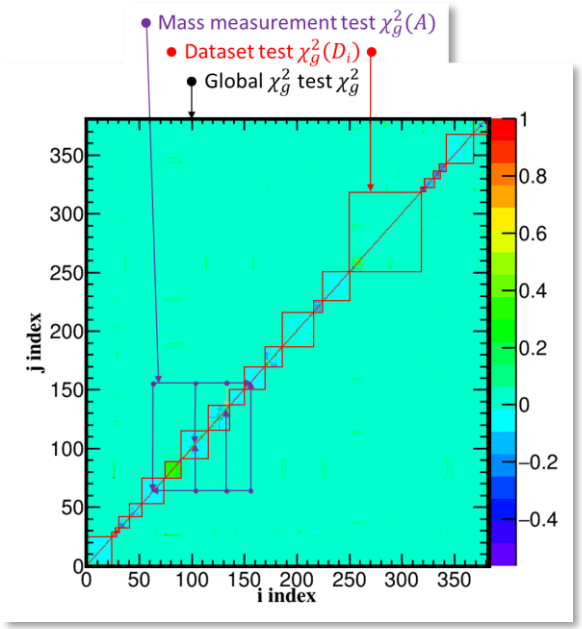

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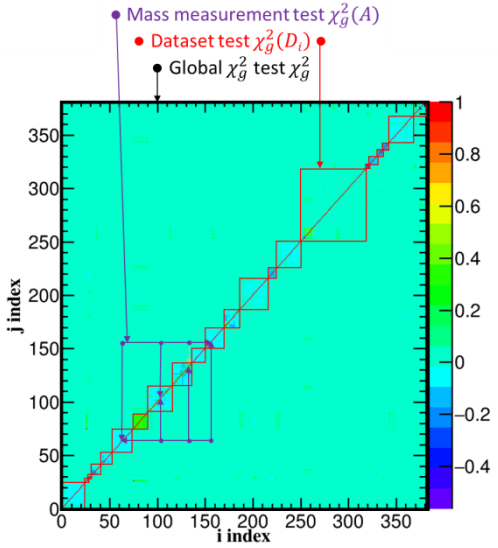

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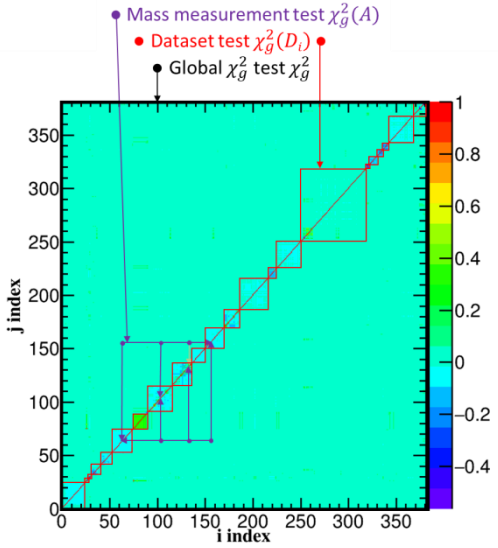

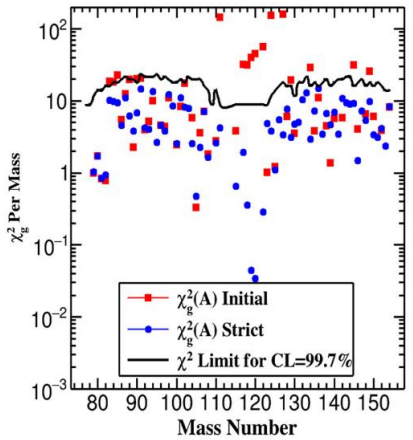

Fig. 10 Local test per mass for strict approach. Red dots represent the generalized χ^2 before regularization, blue dots after regularization in comparison to the black line corresponding to the limit for 99.7% confidence level

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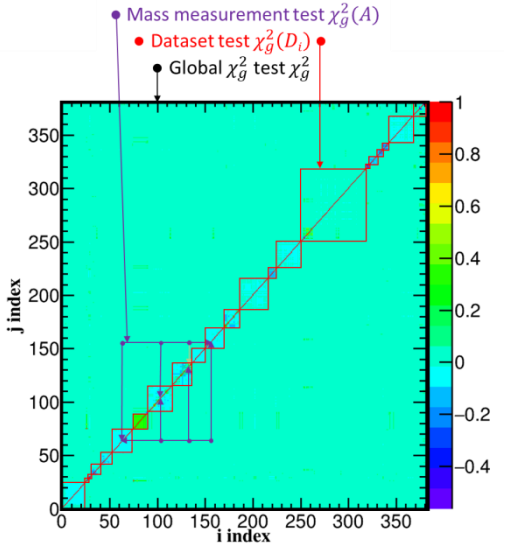


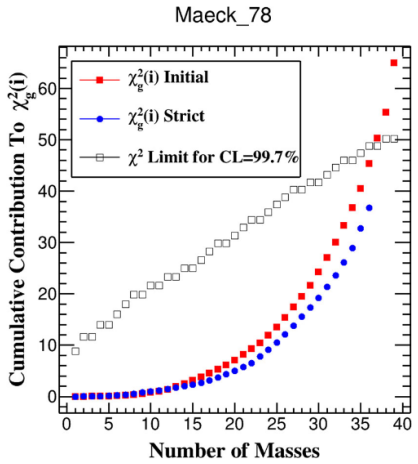
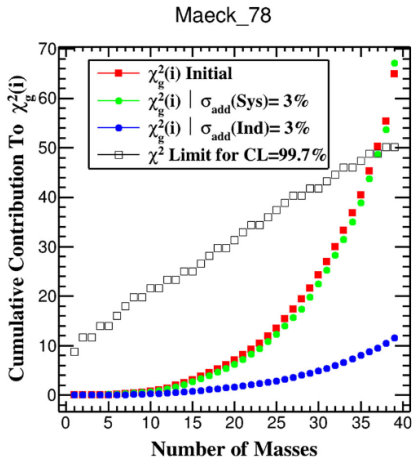


Fig. 9 Cumulative chi-square (test per dataset) as a function of the number of measurements considered for the strict approach for Maeck's dataset



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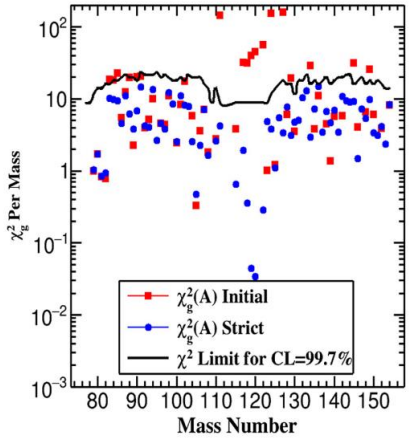

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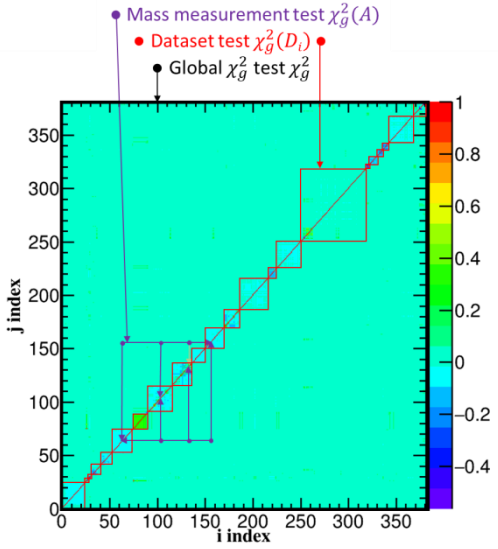

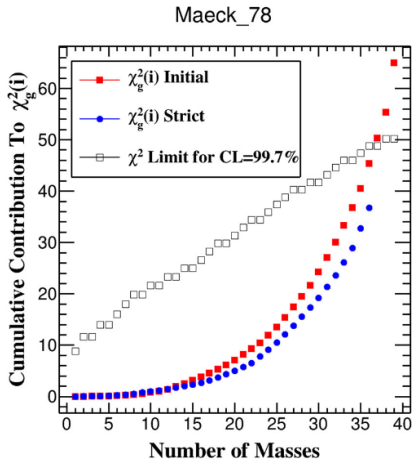

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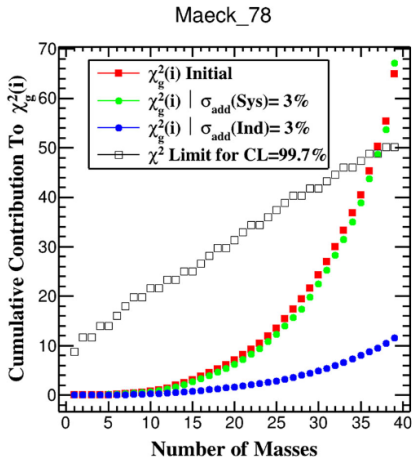

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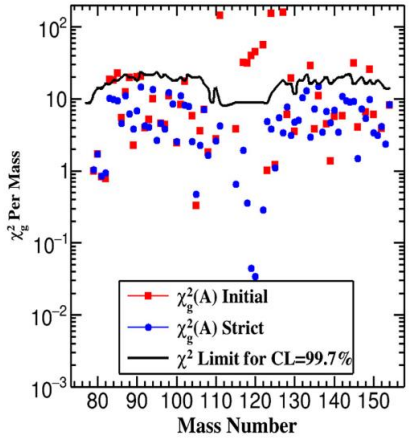

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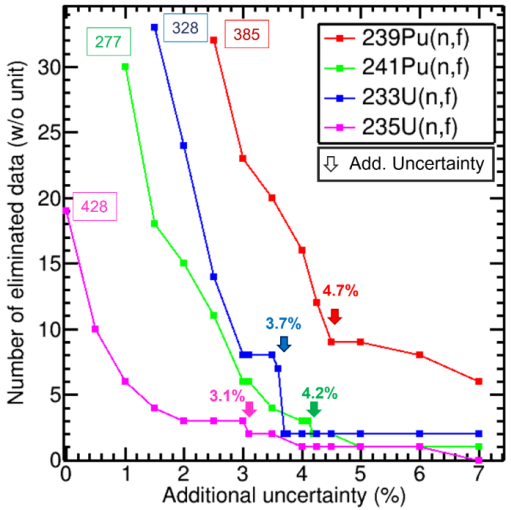

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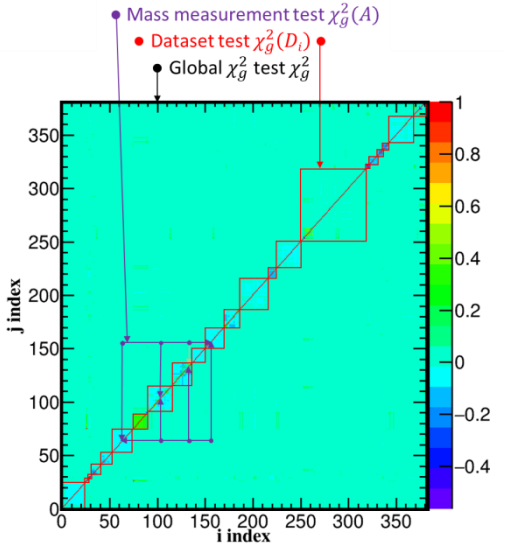

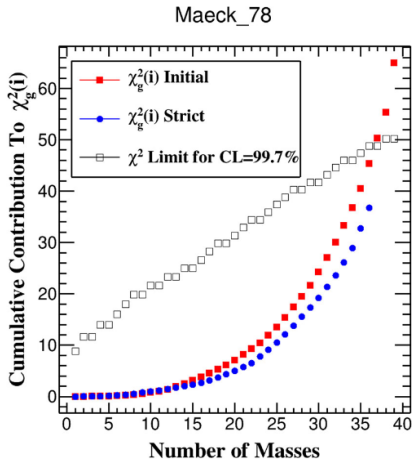

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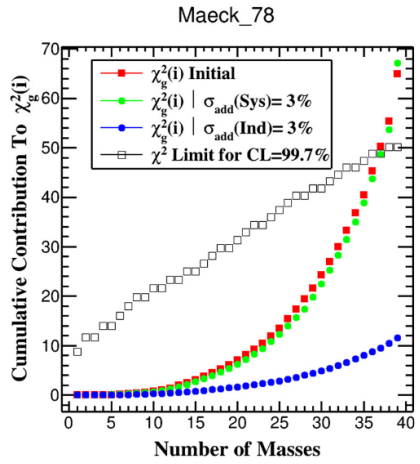

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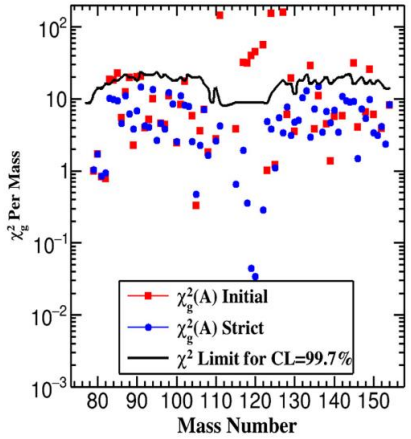

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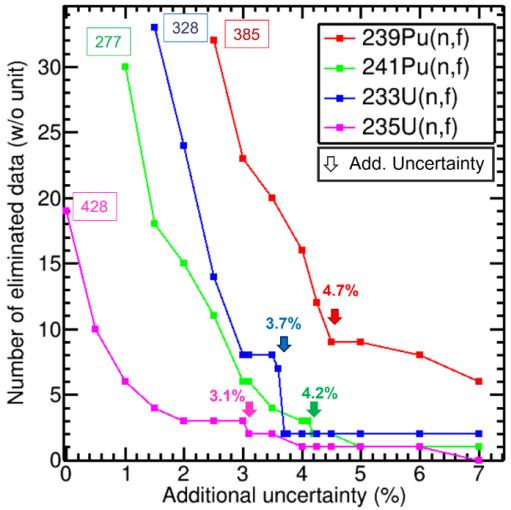

Table 4 Eliminated data using conservative approach for $^{235}U(n_{th},f)$ and $^{239}Pu(n_{th},f)$ reactions with the additional uncertainties show in Fig. 45

Reaction	dataset	Eliminated data
$^{235}U(n_{th},f)$	Maeck_78	(135+136) unresolved
Additional	Tsoukatos_68_1	153
uncertainty 3.1%	Dilorio_77	153
	Koblik	all dataset
	Fickel_1959_a_corr	109
	Shima_1978	106
$^{239}Pu(n_{th},f)$	Maeck_1979	85, 150
Additional	Chitambar_1987_b	132
uncertainty 4.5%	Schmitt_1984	81, 111
	Ditz_1989	84, 85
	Dange_1969	all data set
	Chebboubi_2024_corr	133
	Mathiews_1977	121

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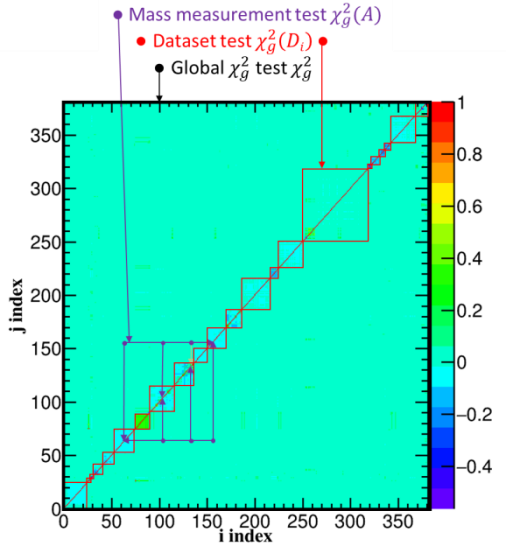

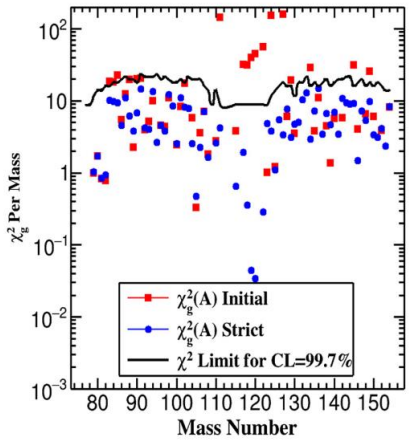

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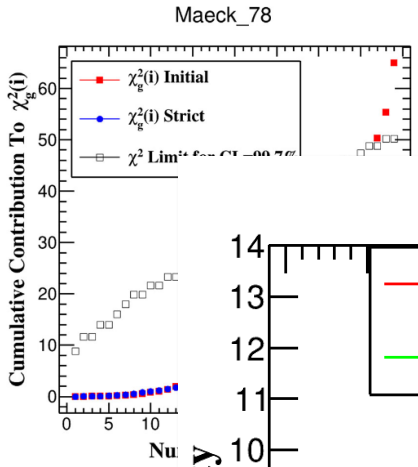

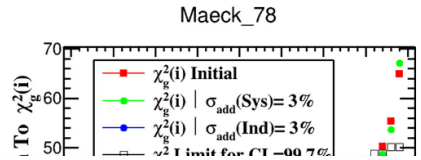

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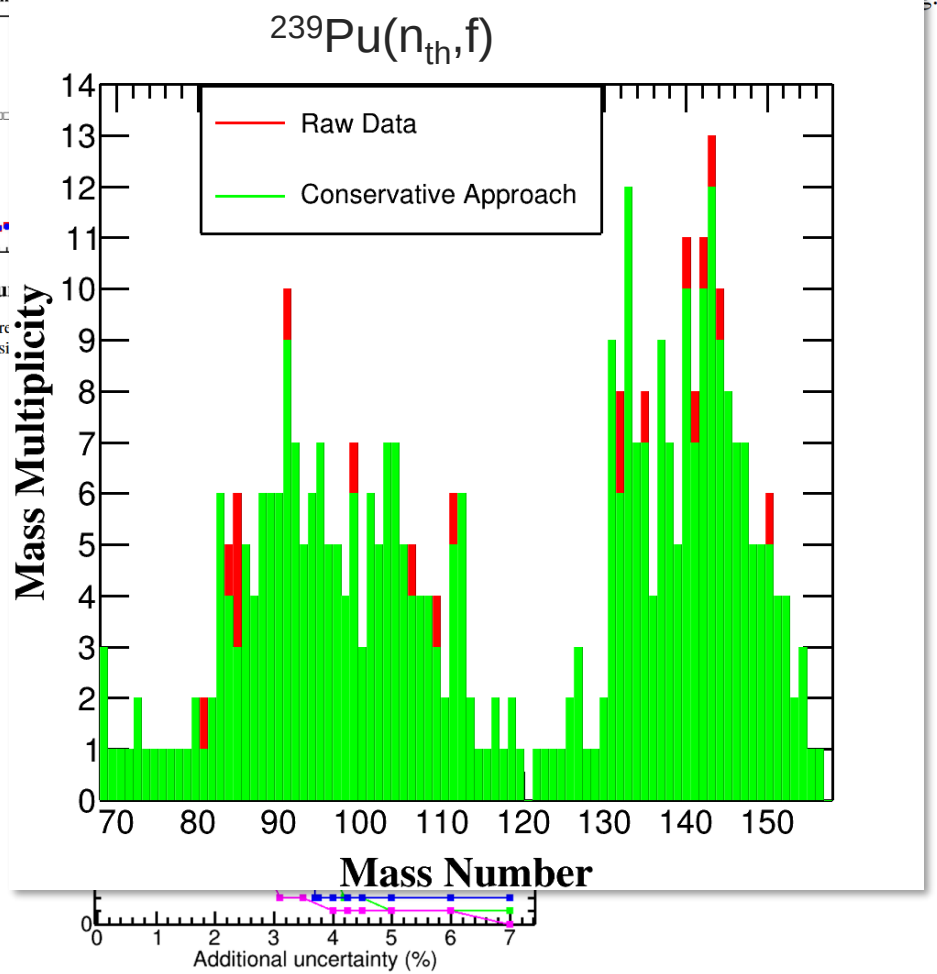

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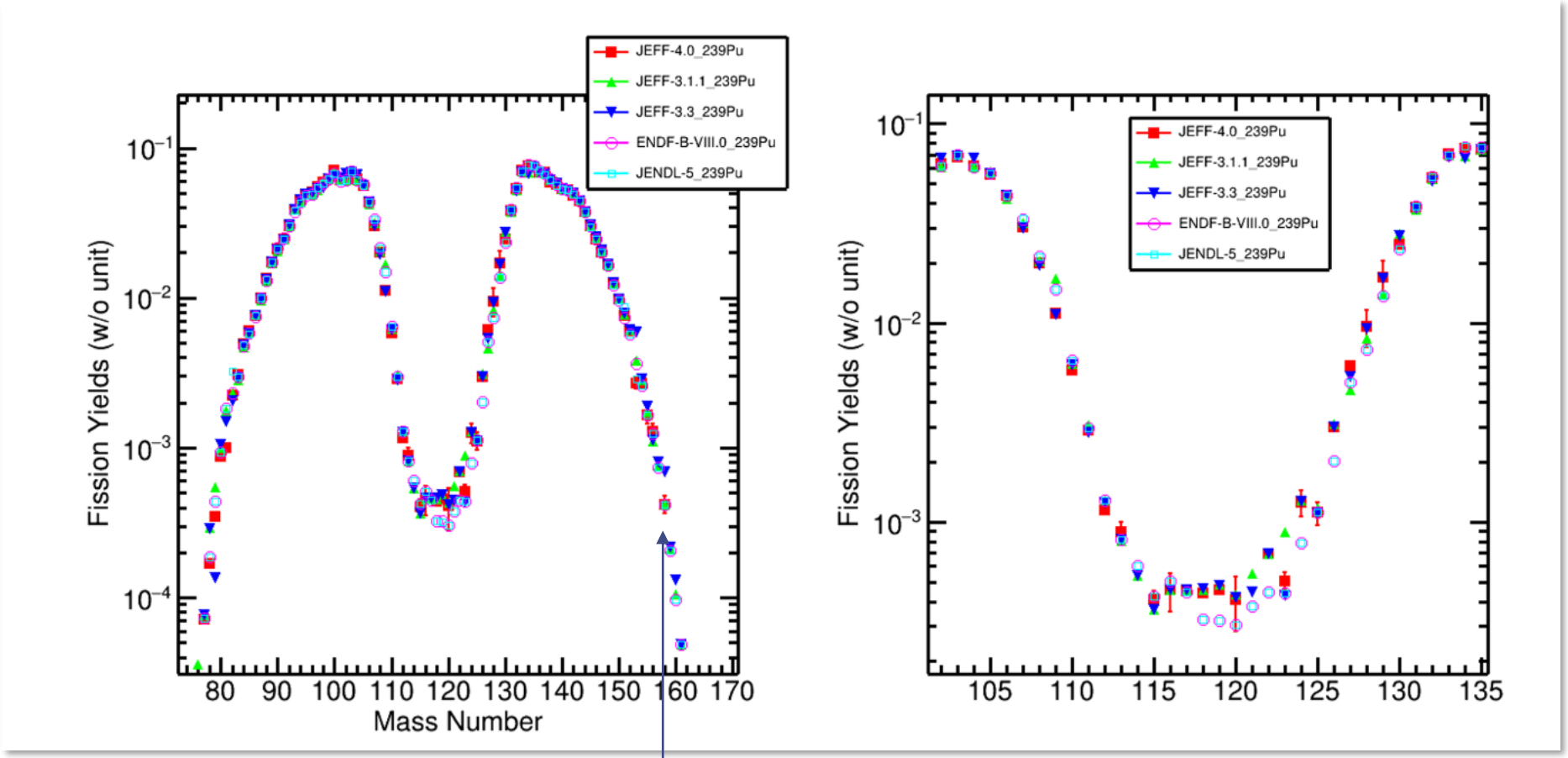
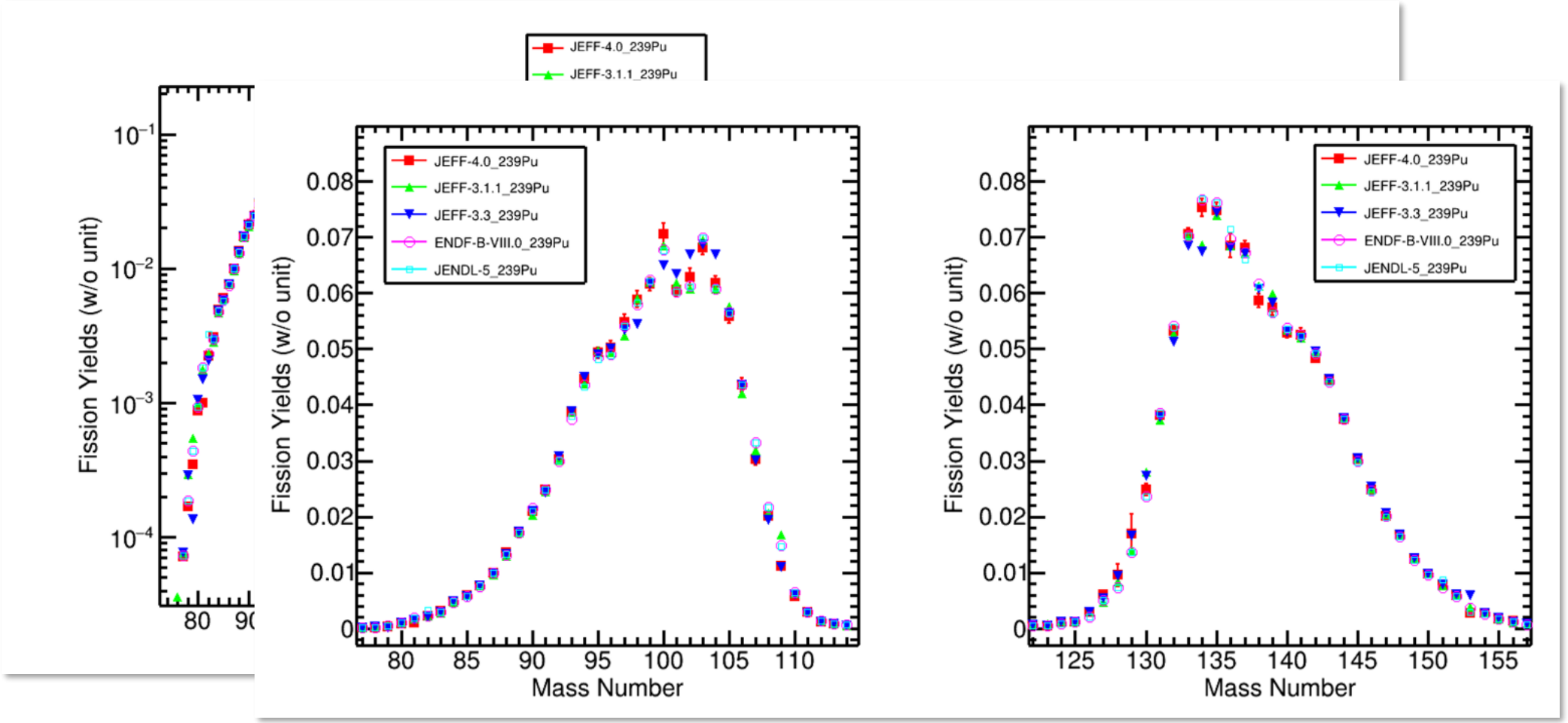
JEFF-4T4 →T5 →JEFF-4.0 : $^{239}Pu(n_{th},f)$ Mass yields



Heaviest measurement

JEFF-4T4 →T5 →JEFF-4.0 : $^{239}Pu(n_{th},f)$ Mass yields



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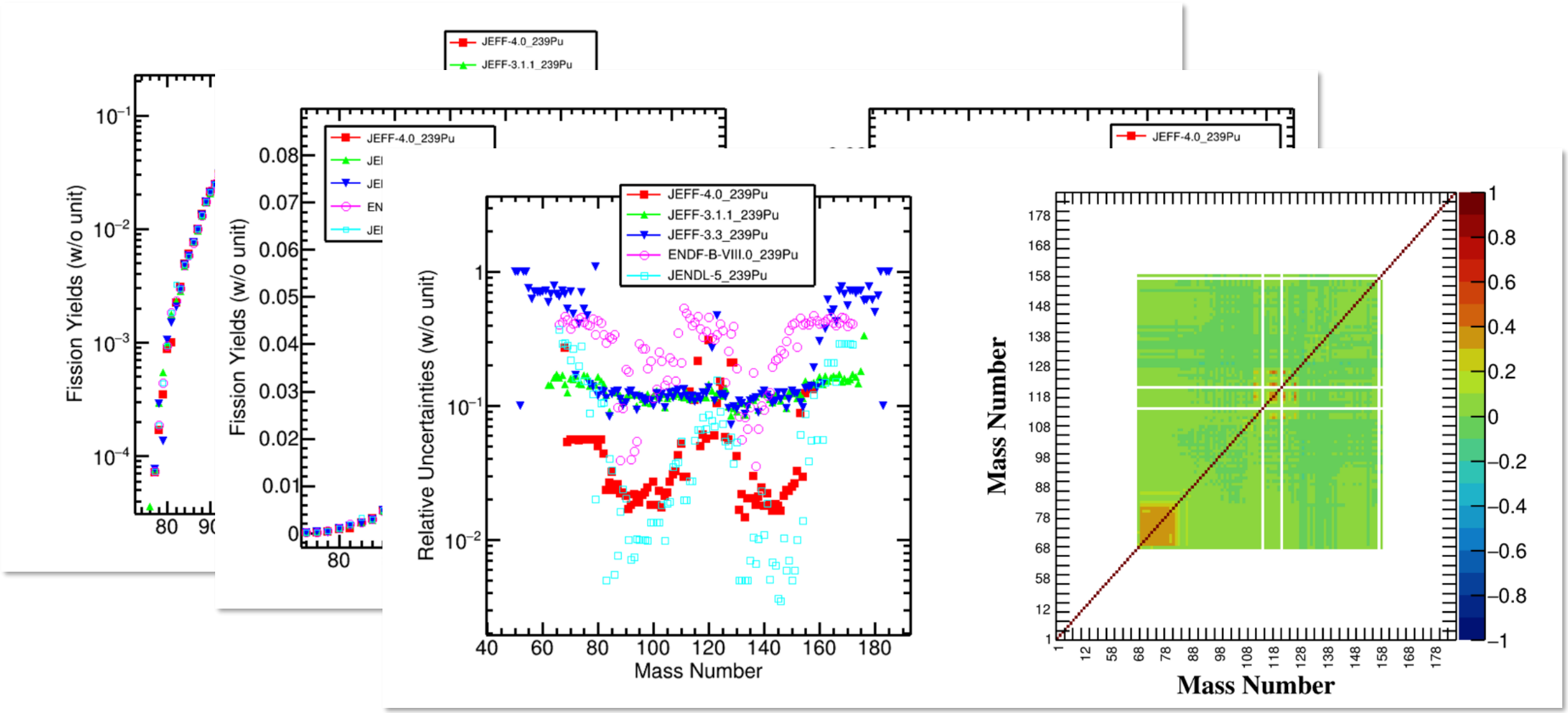
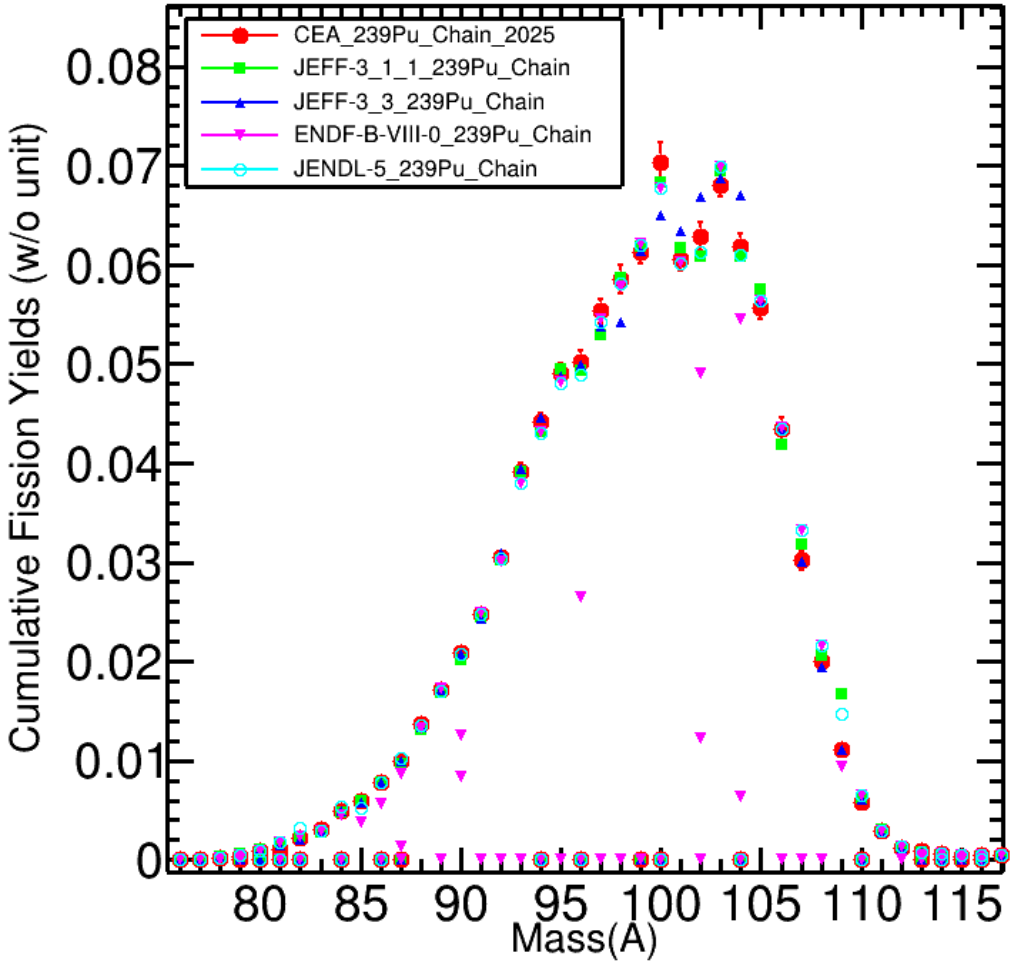
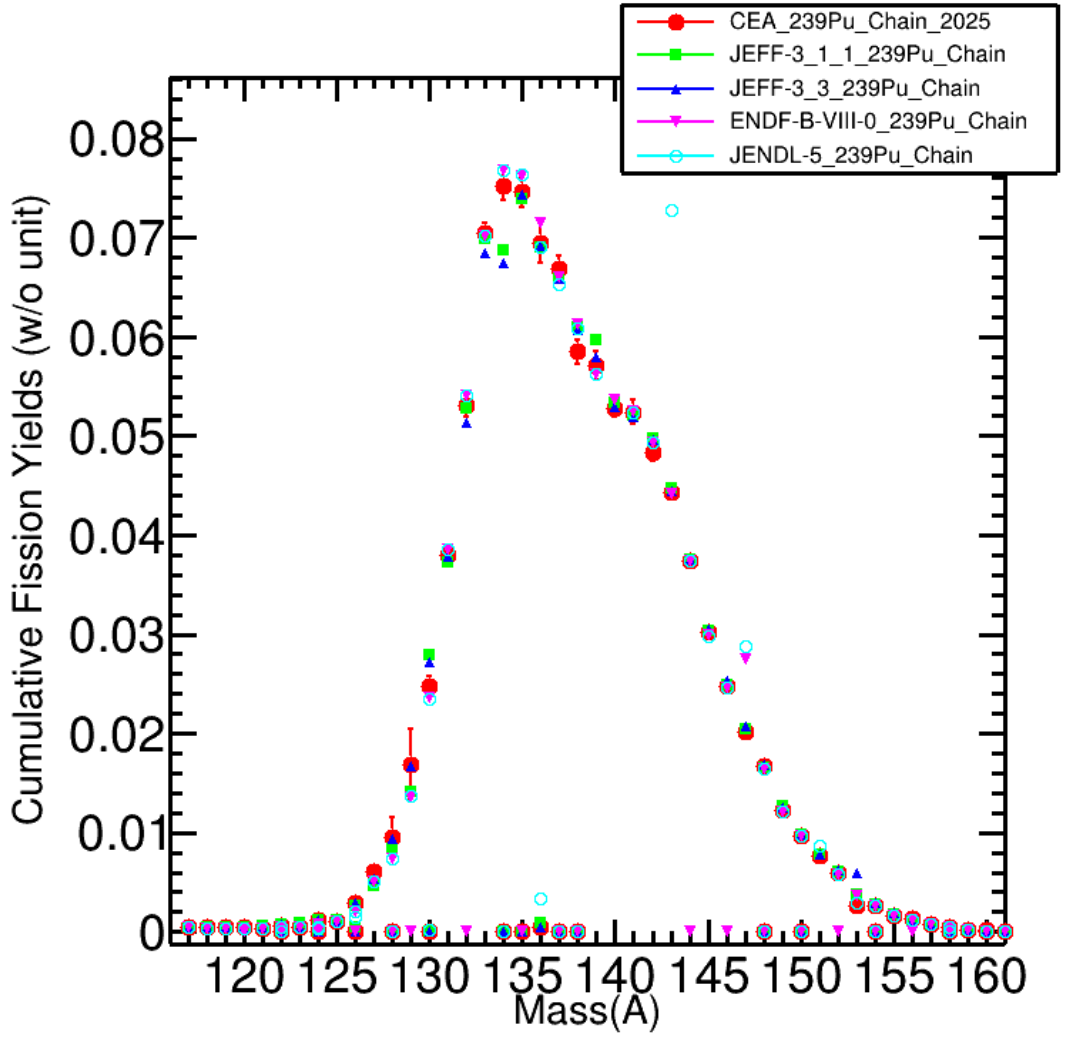


JEFF-4T4 →T5 →JEFF-4.0 : $^{239}Pu(n_{th},f)$ Chain yields

Based on: jefdoc-2370
jefdoc-2371





$T_{1/2}^{cut-off}$ = 1000 y

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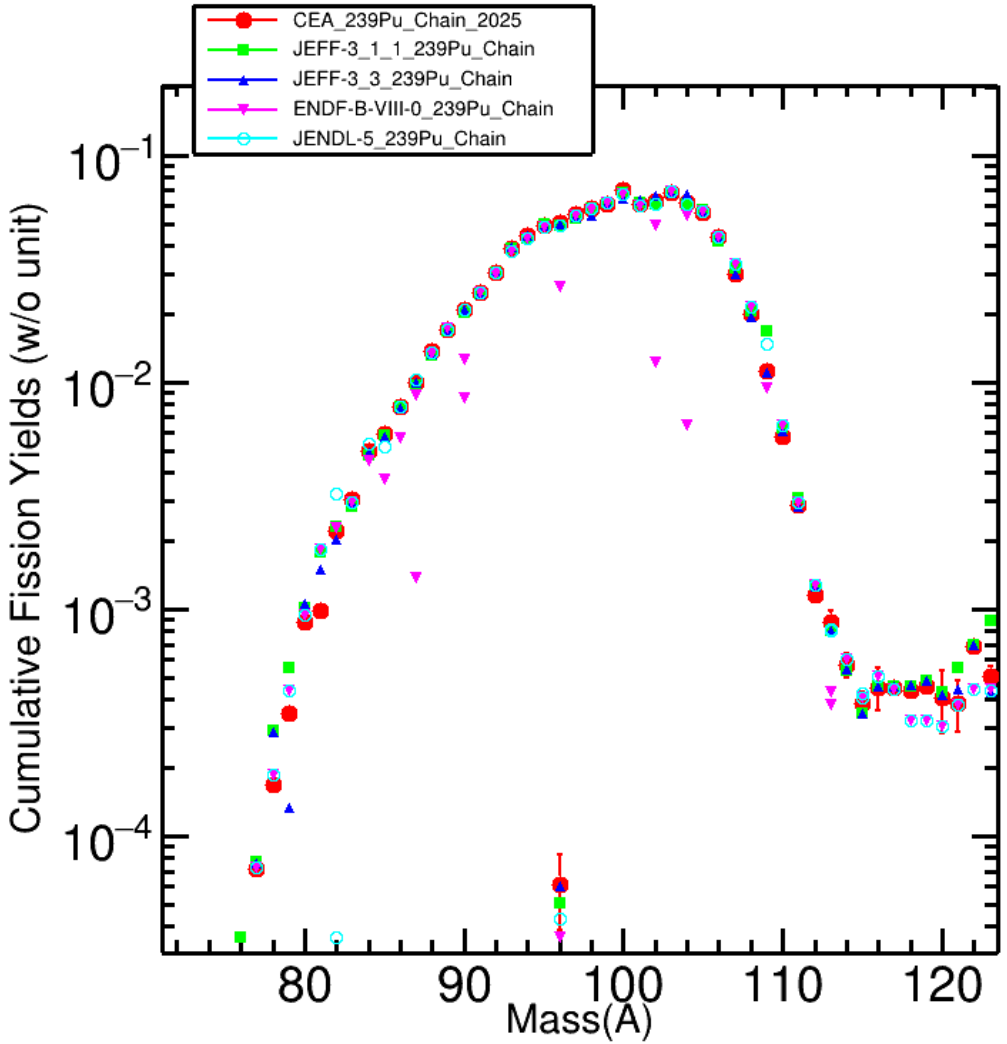

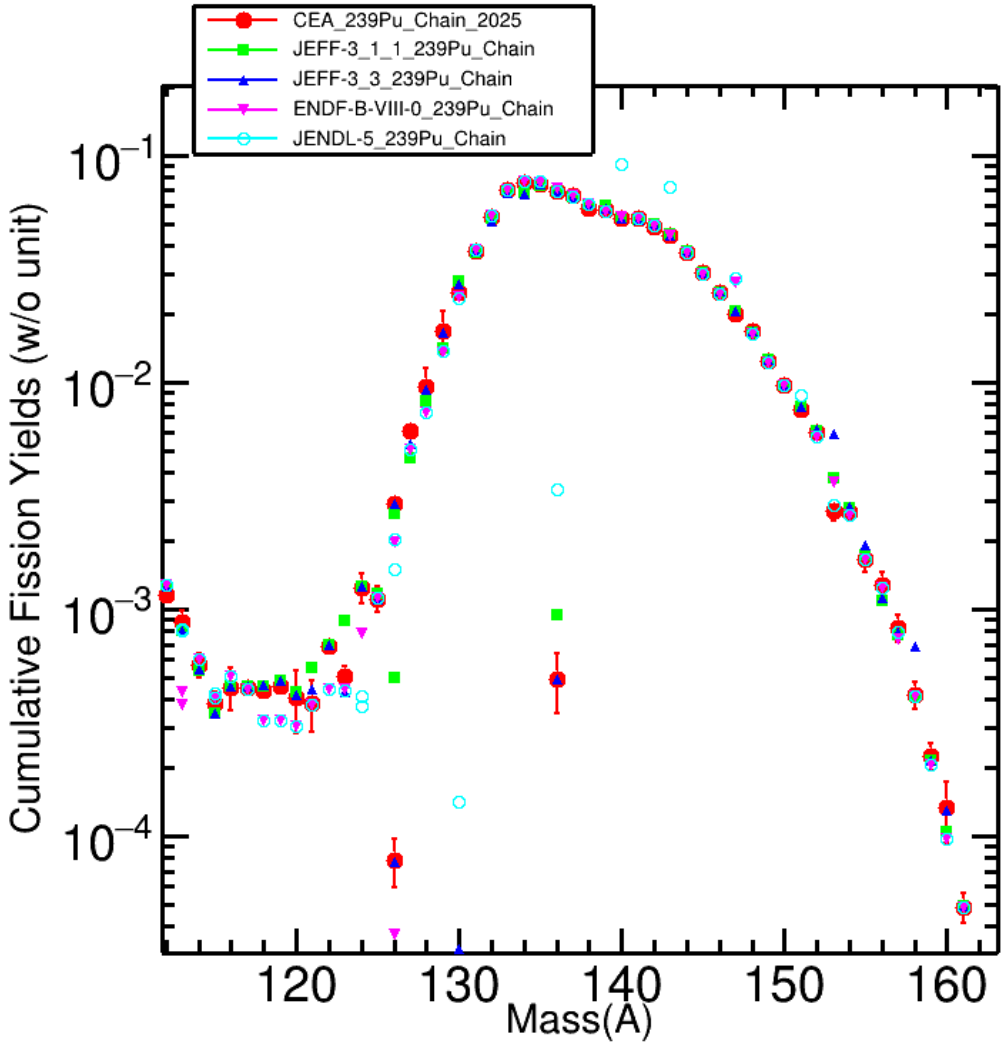

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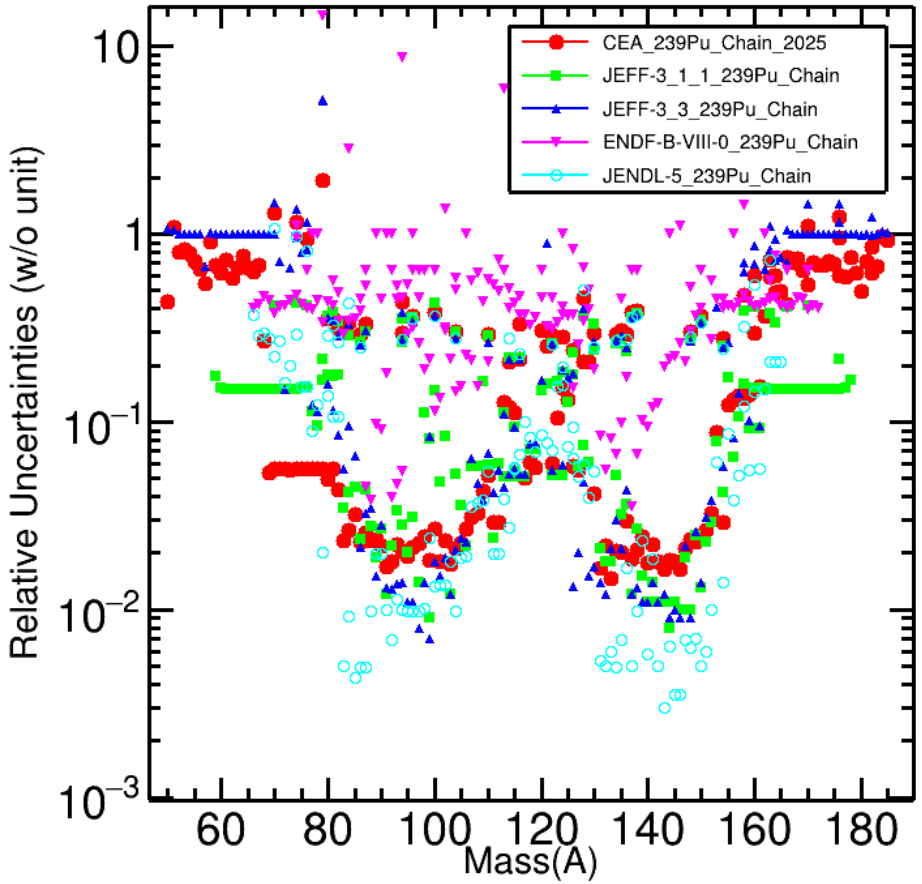
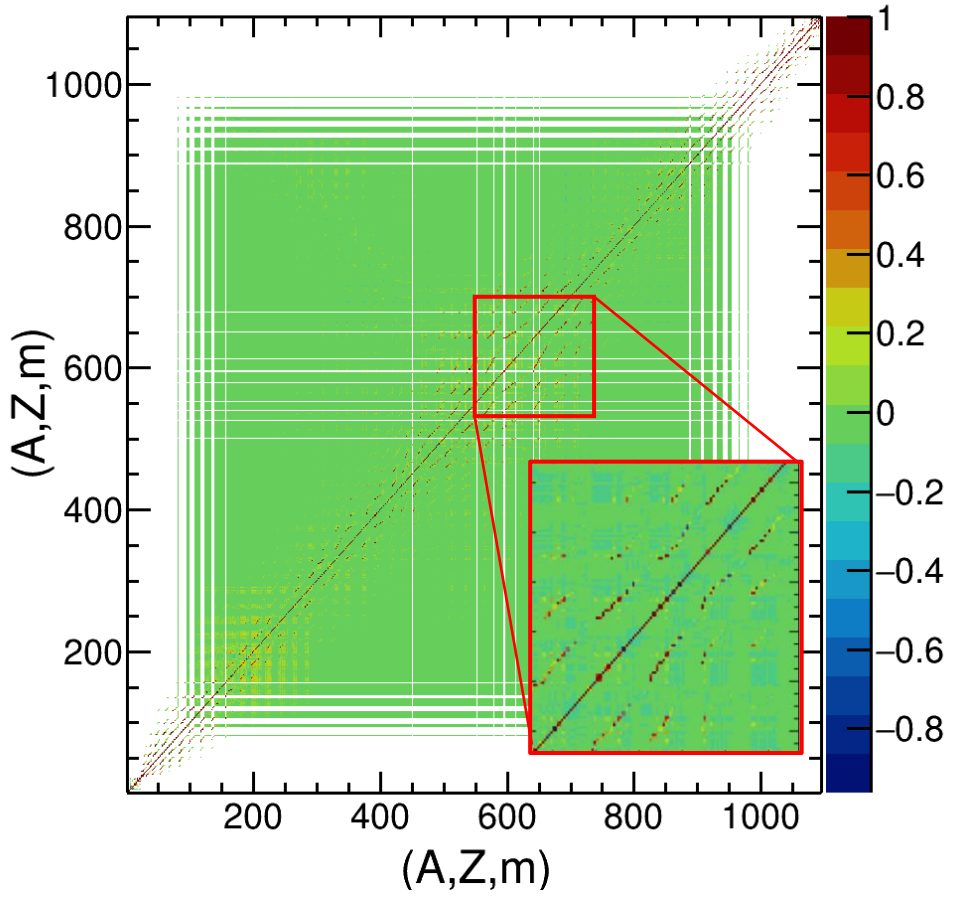
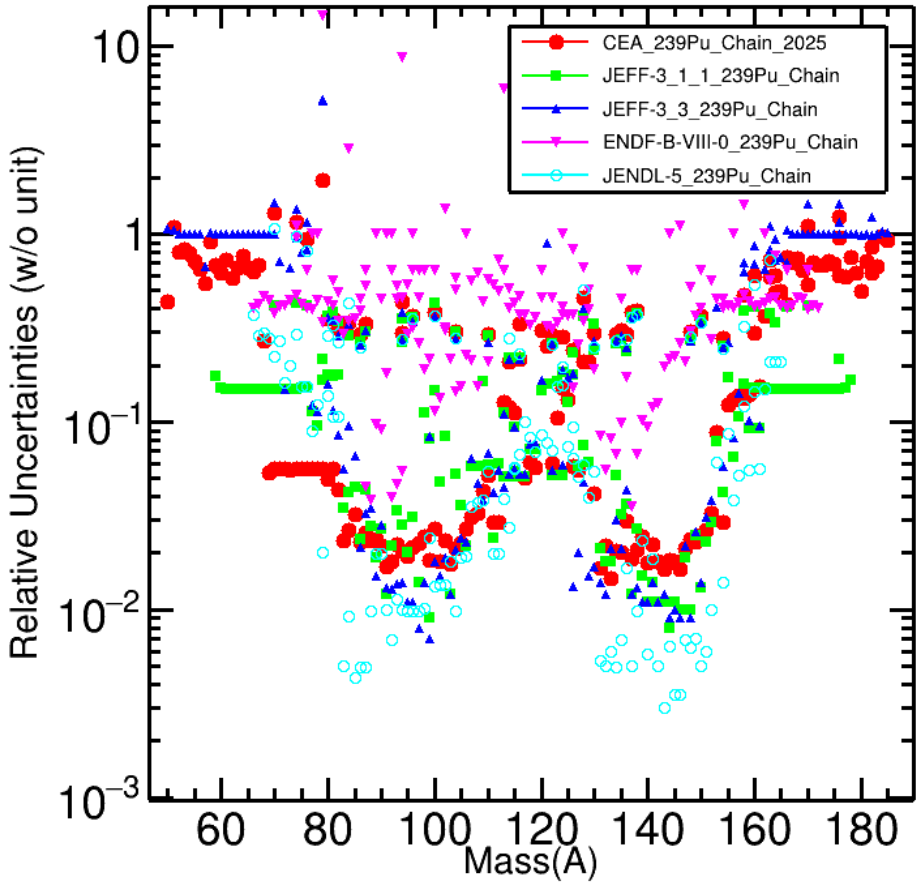
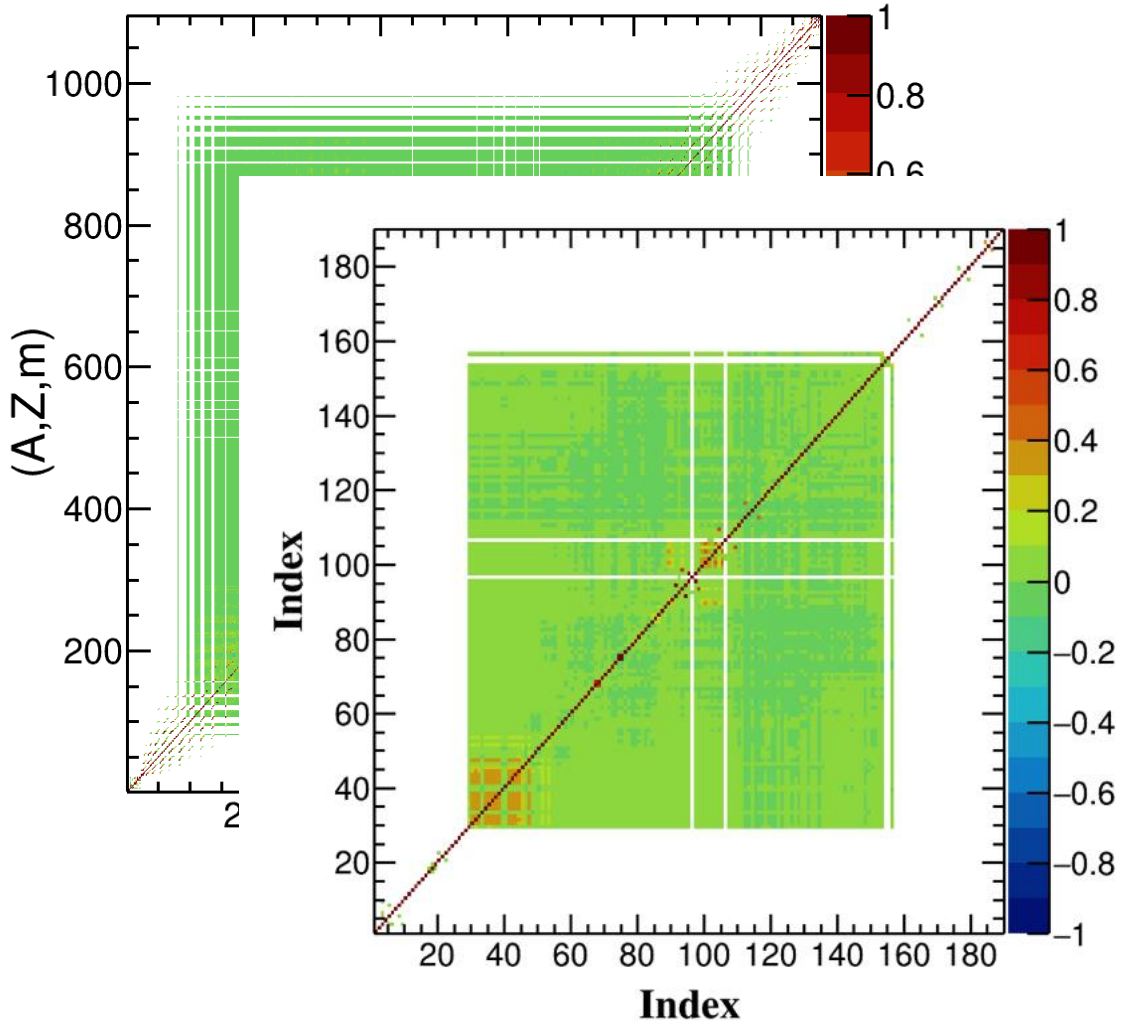




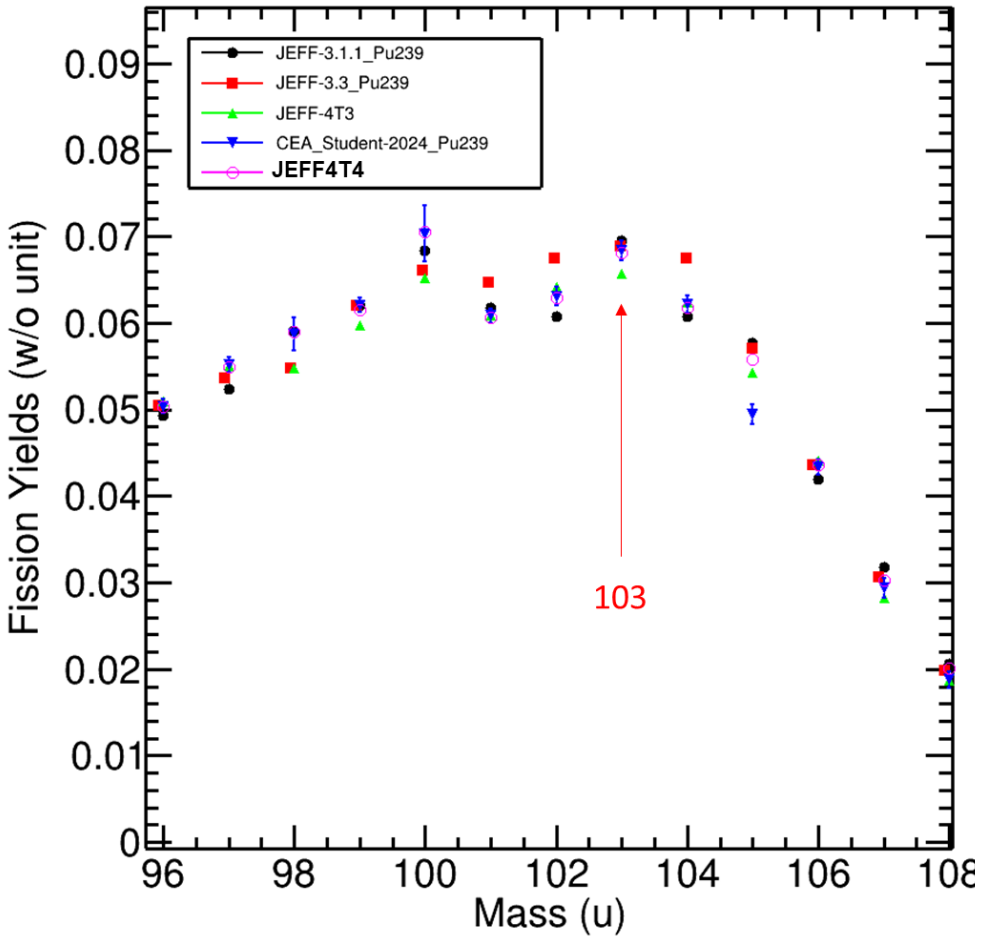
$T_{1/2}^{cut-off}$ = 1000 y

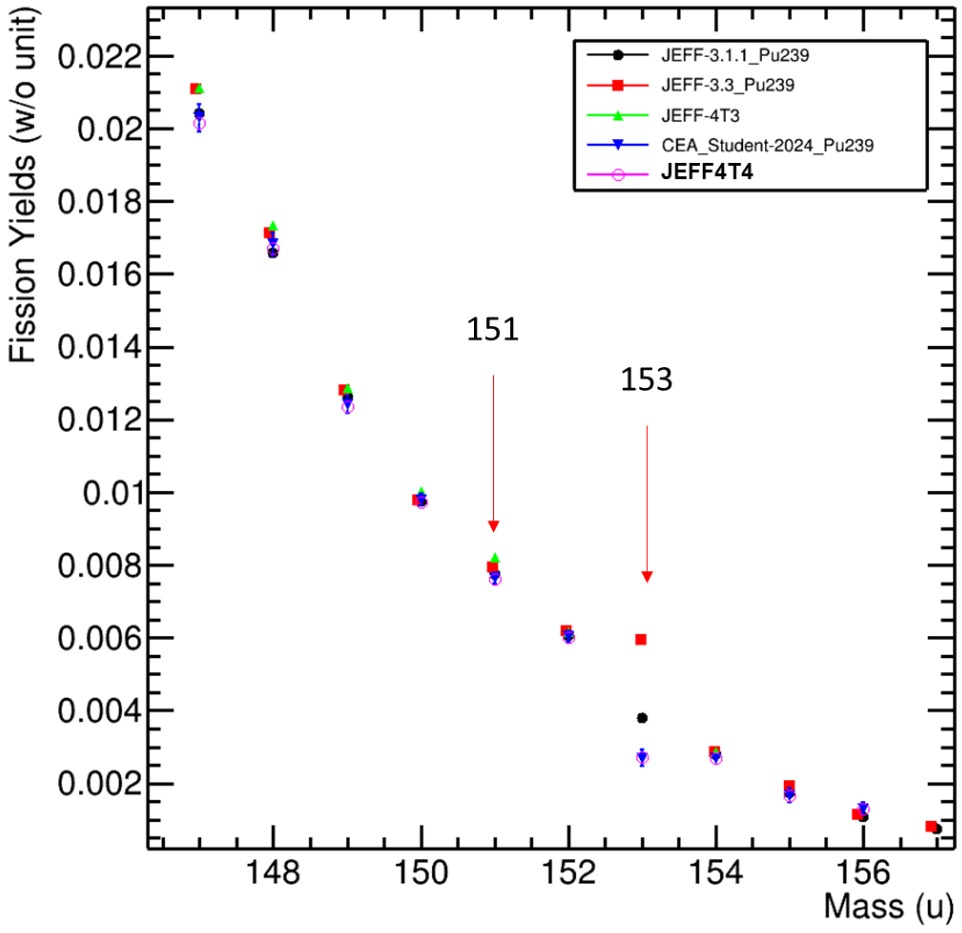
JEFF-4T4 →T5 →JEFF-4.0 : $^{239}Pu(n_{th},f)$ Chain yields





JEFF-4T4 →T5 →JEFF-4.0 : $^{239}Pu(n_{th},f)$ → Impact of database and data sorting





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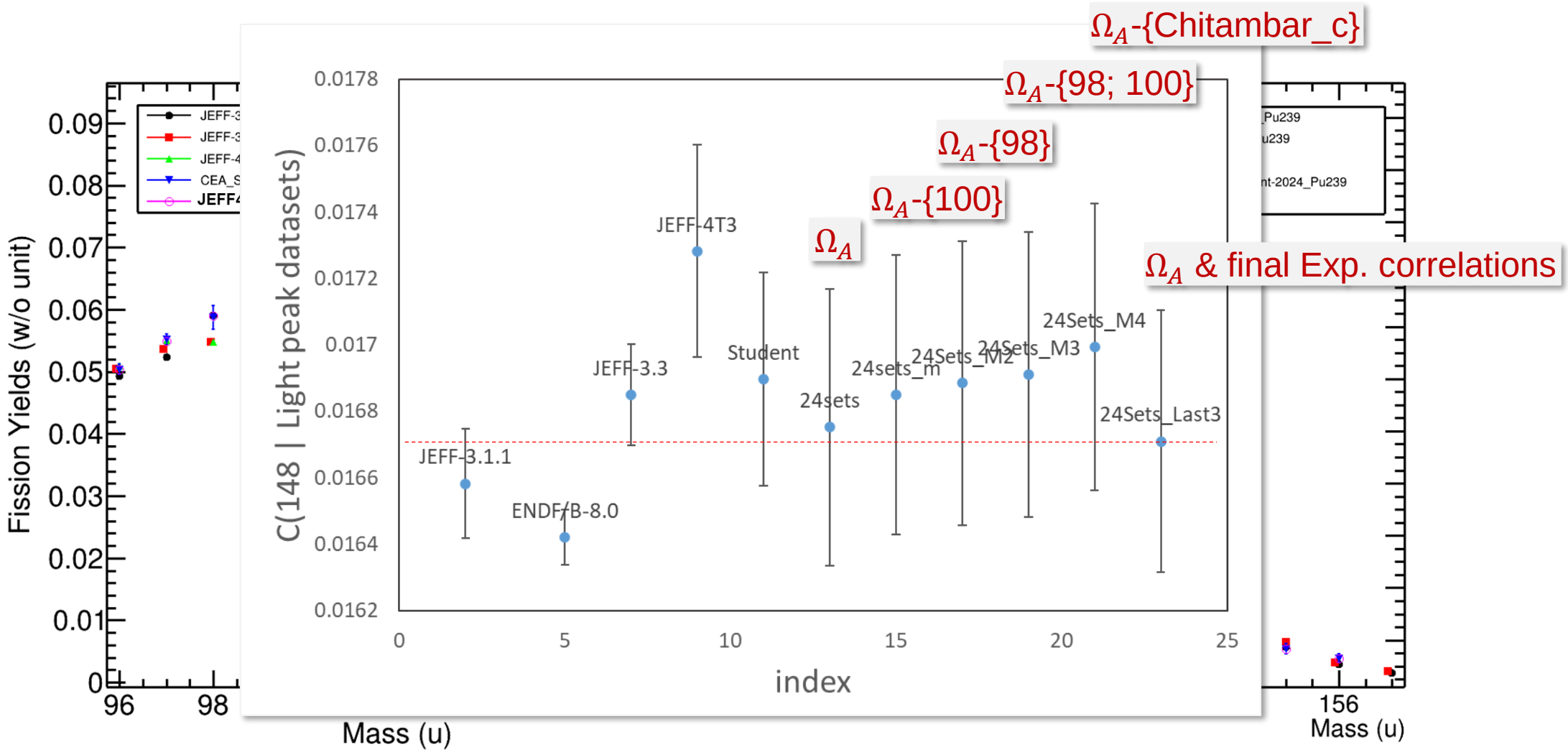

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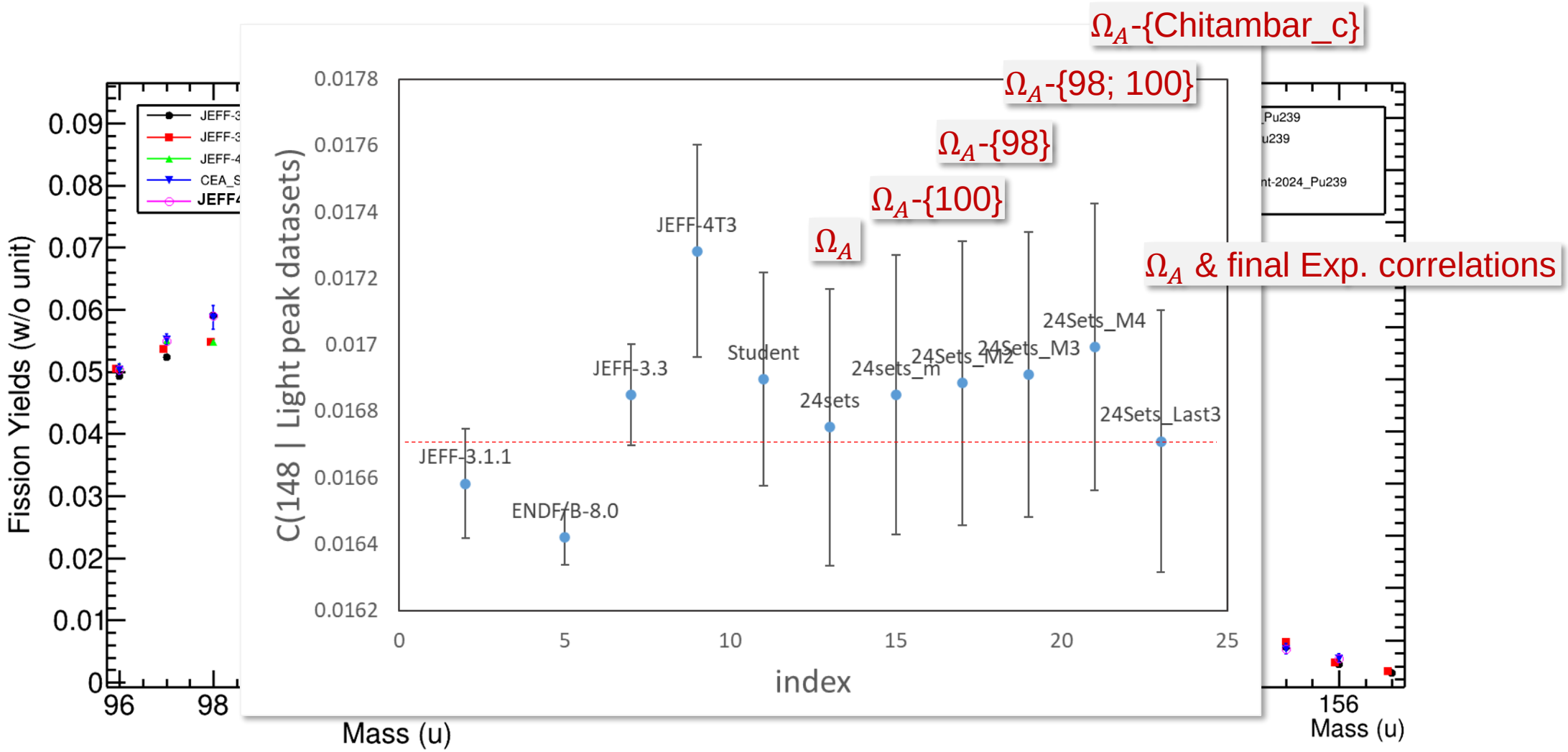

Chitambar_1987_c: 98 & 100 masses drive the absolute normalization and then the heavy peak → Y(148) → $C(148Nd)$

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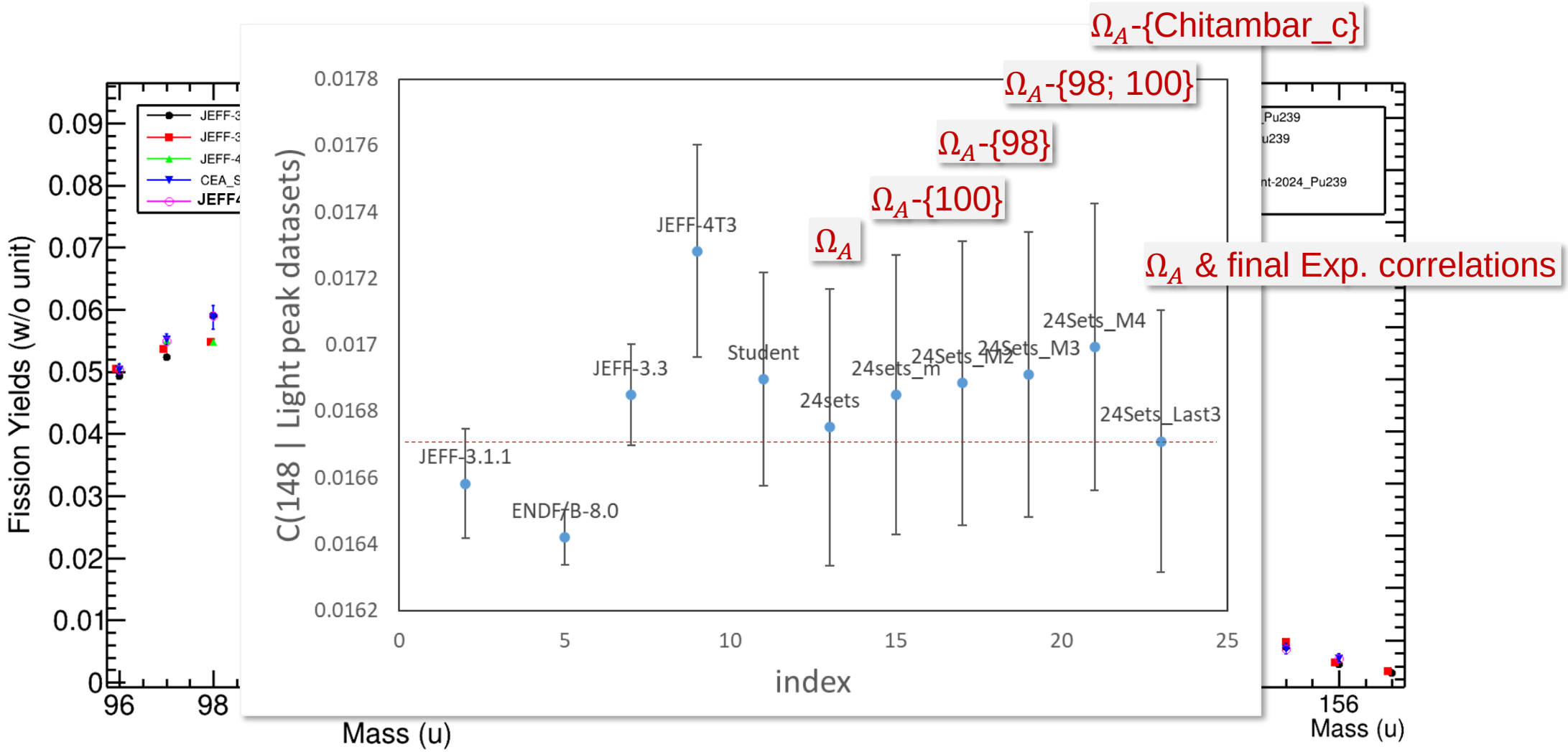

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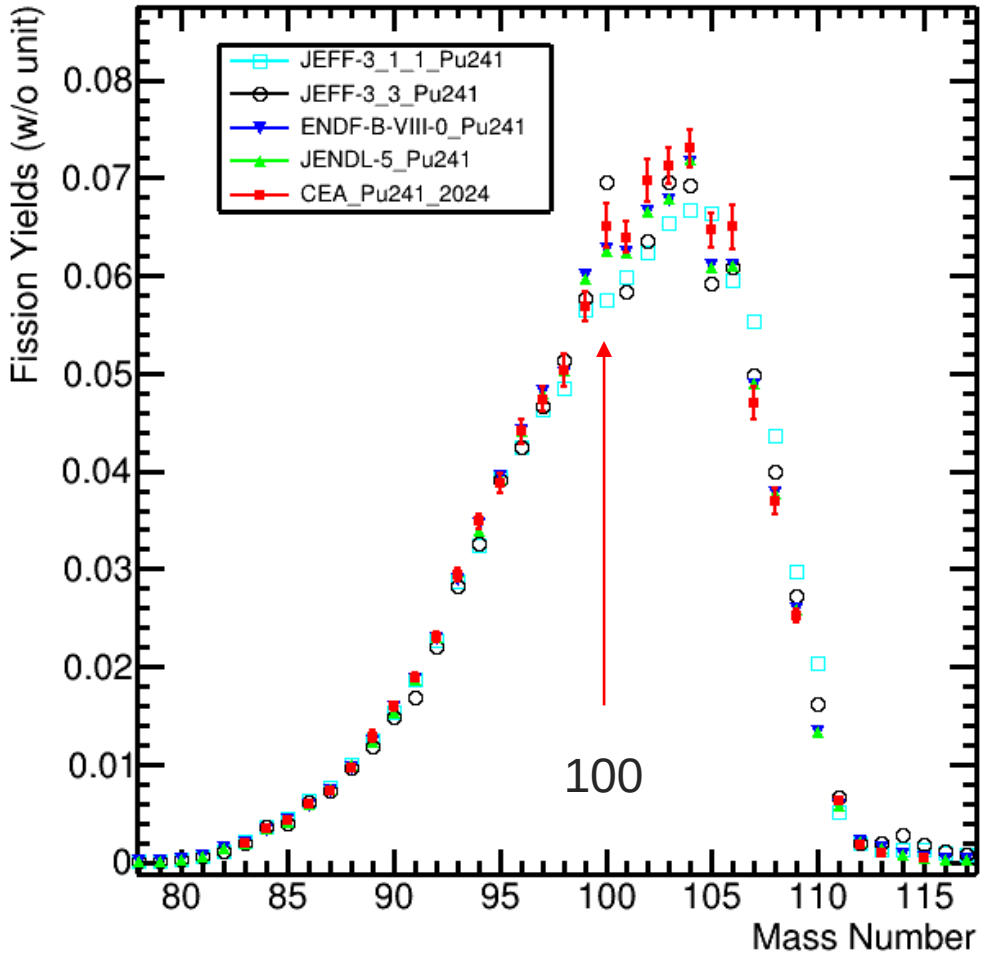
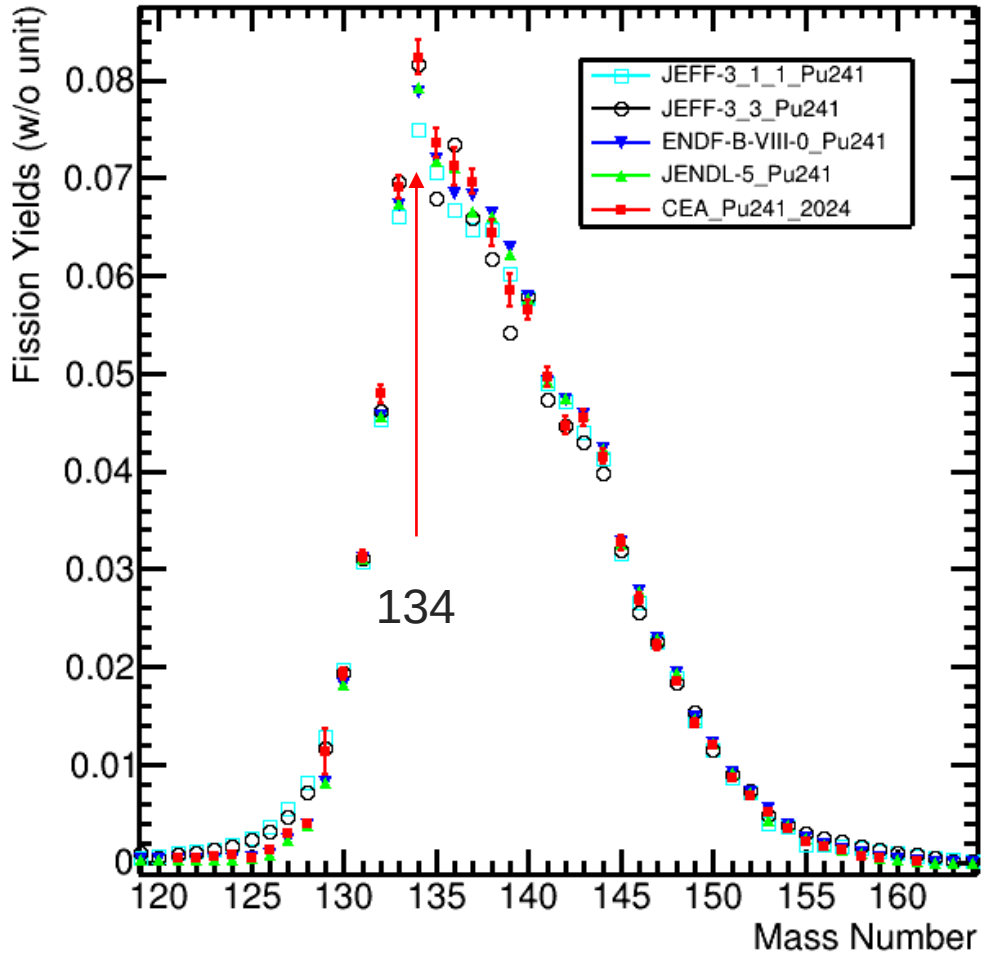
JEFF-4.0: $^{241}Pu(n_{th},f)$ Mass yields





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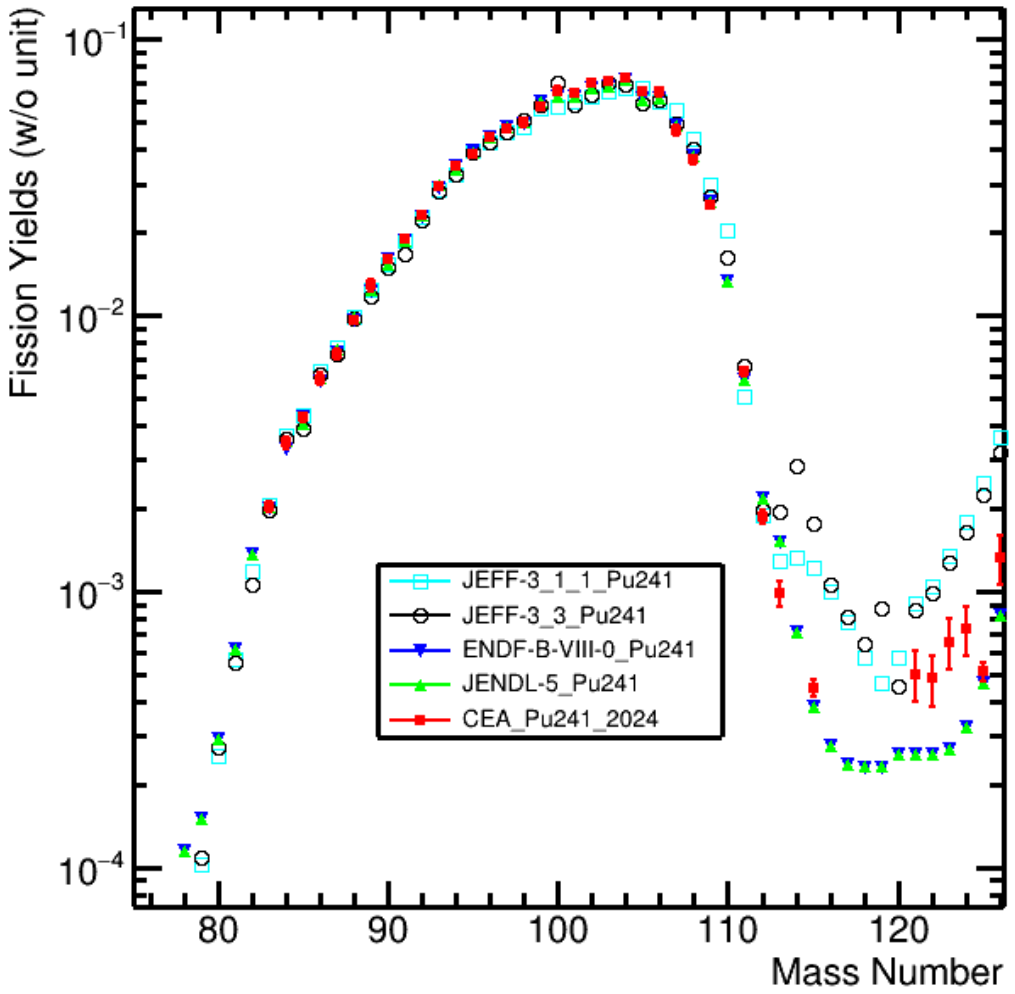
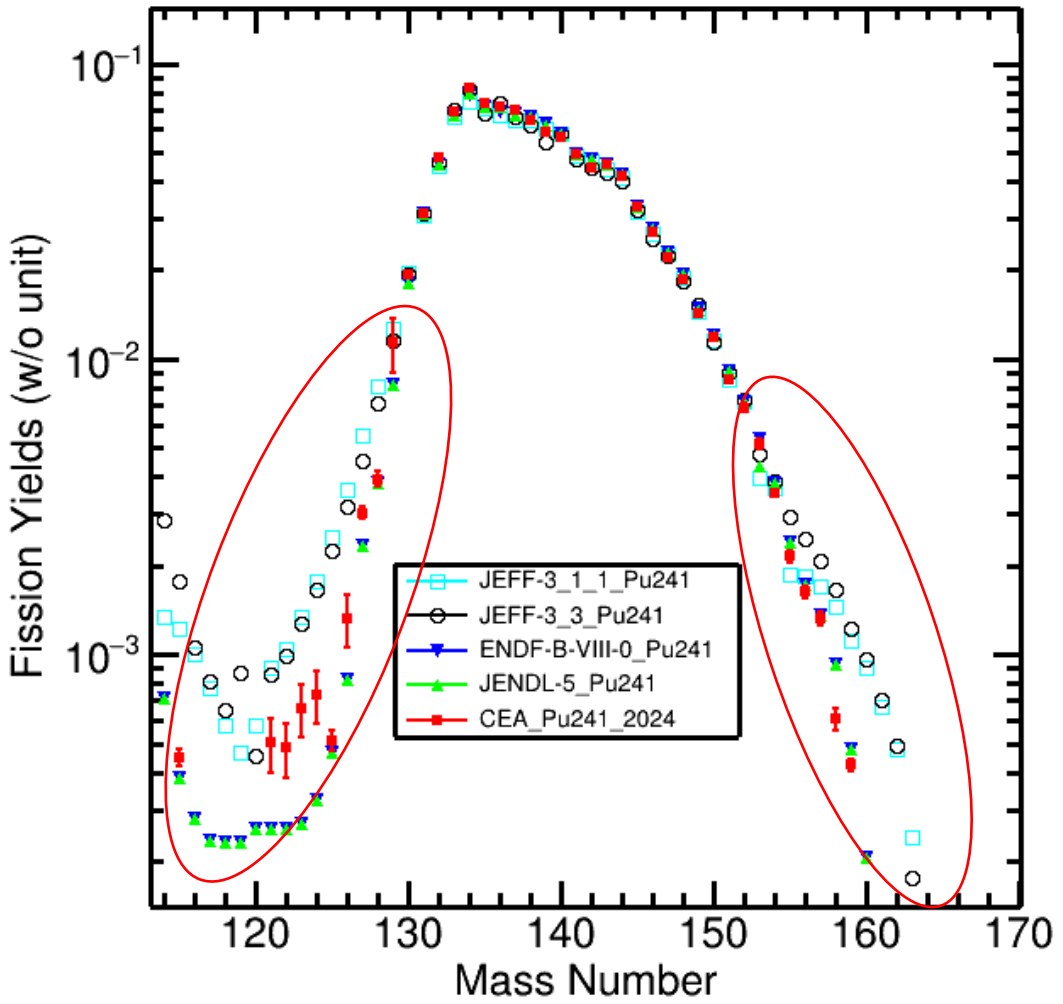
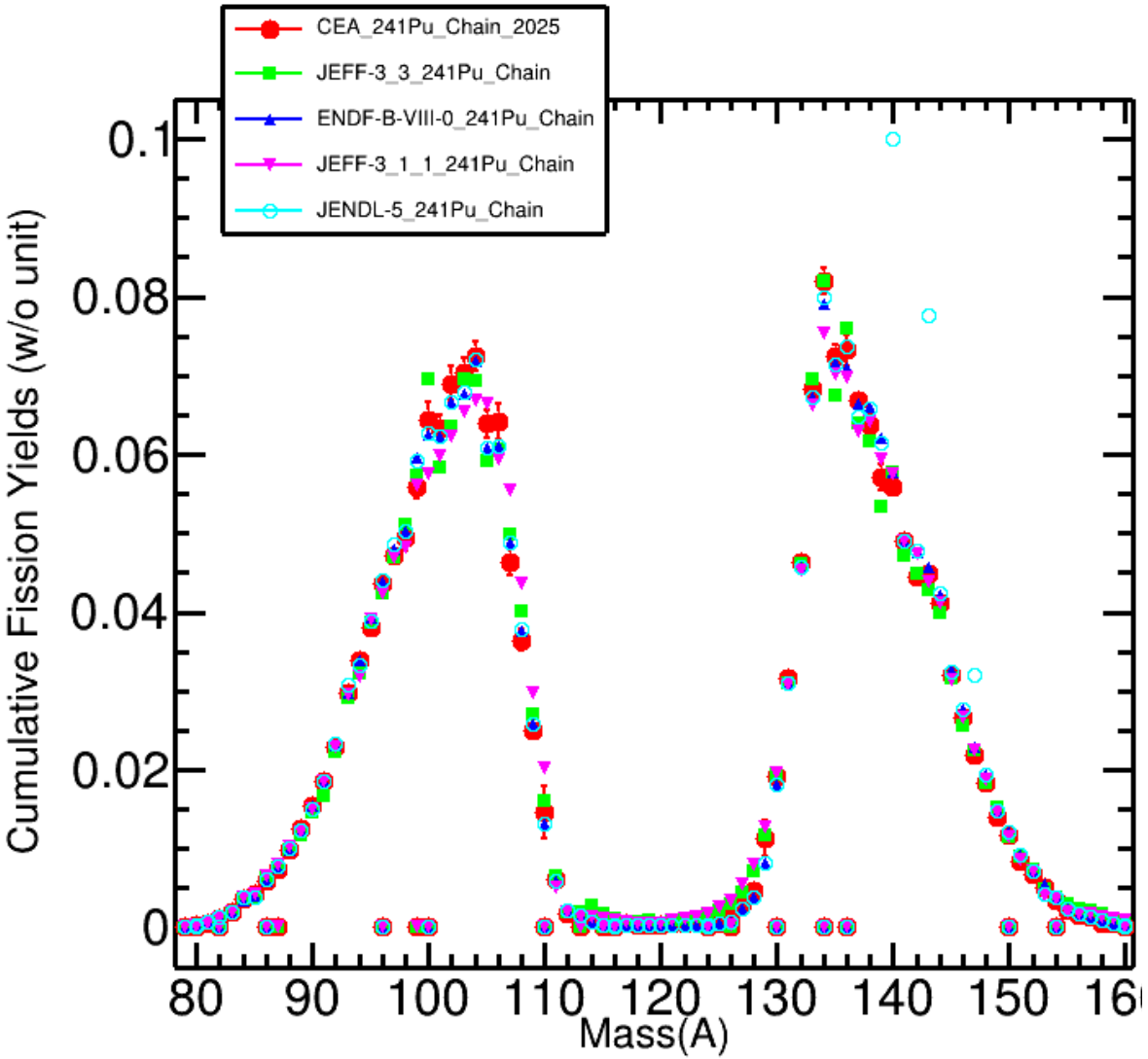
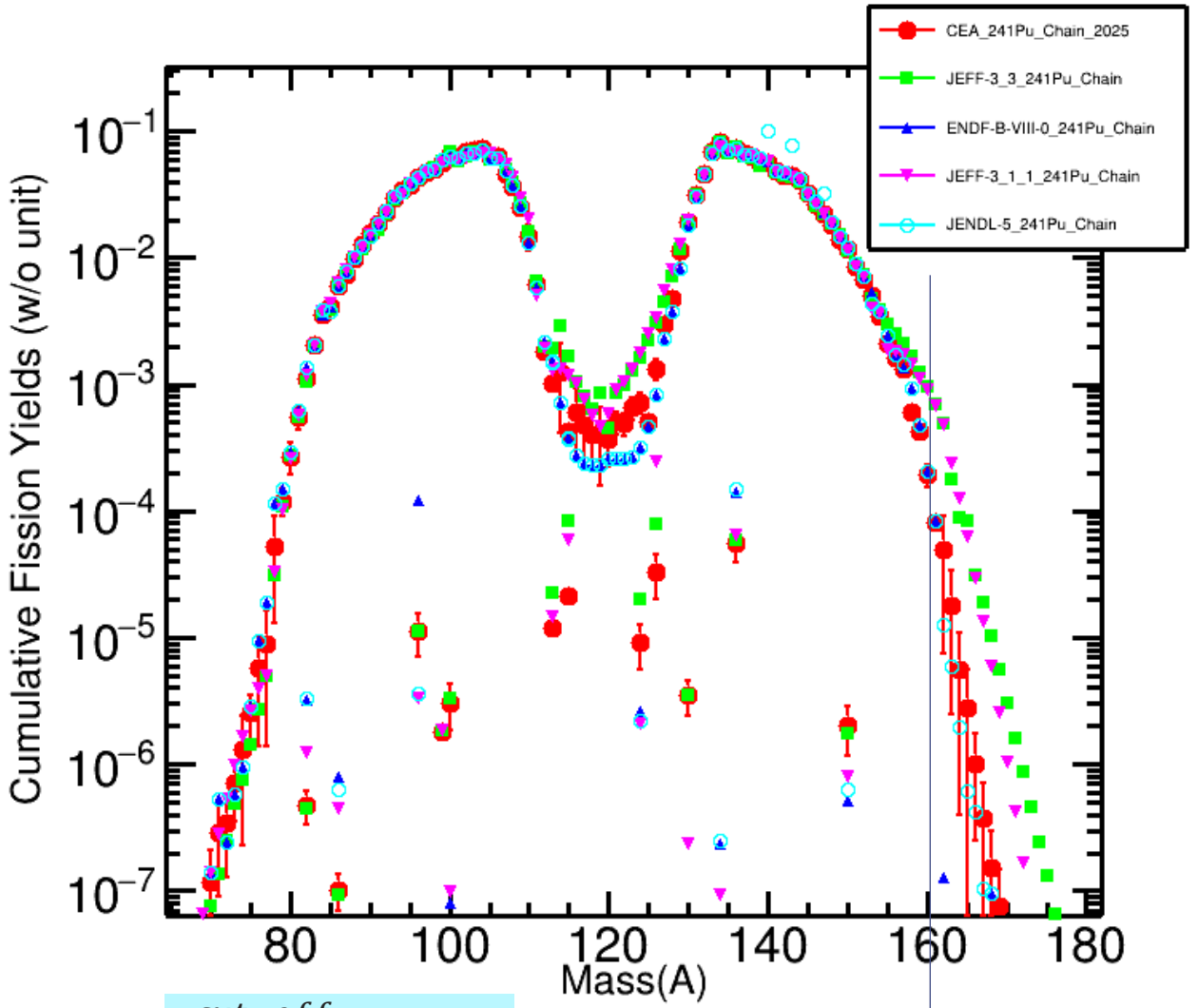




JEFF-4.0: $^{241}Pu(n_{th},f)$ Chain yields





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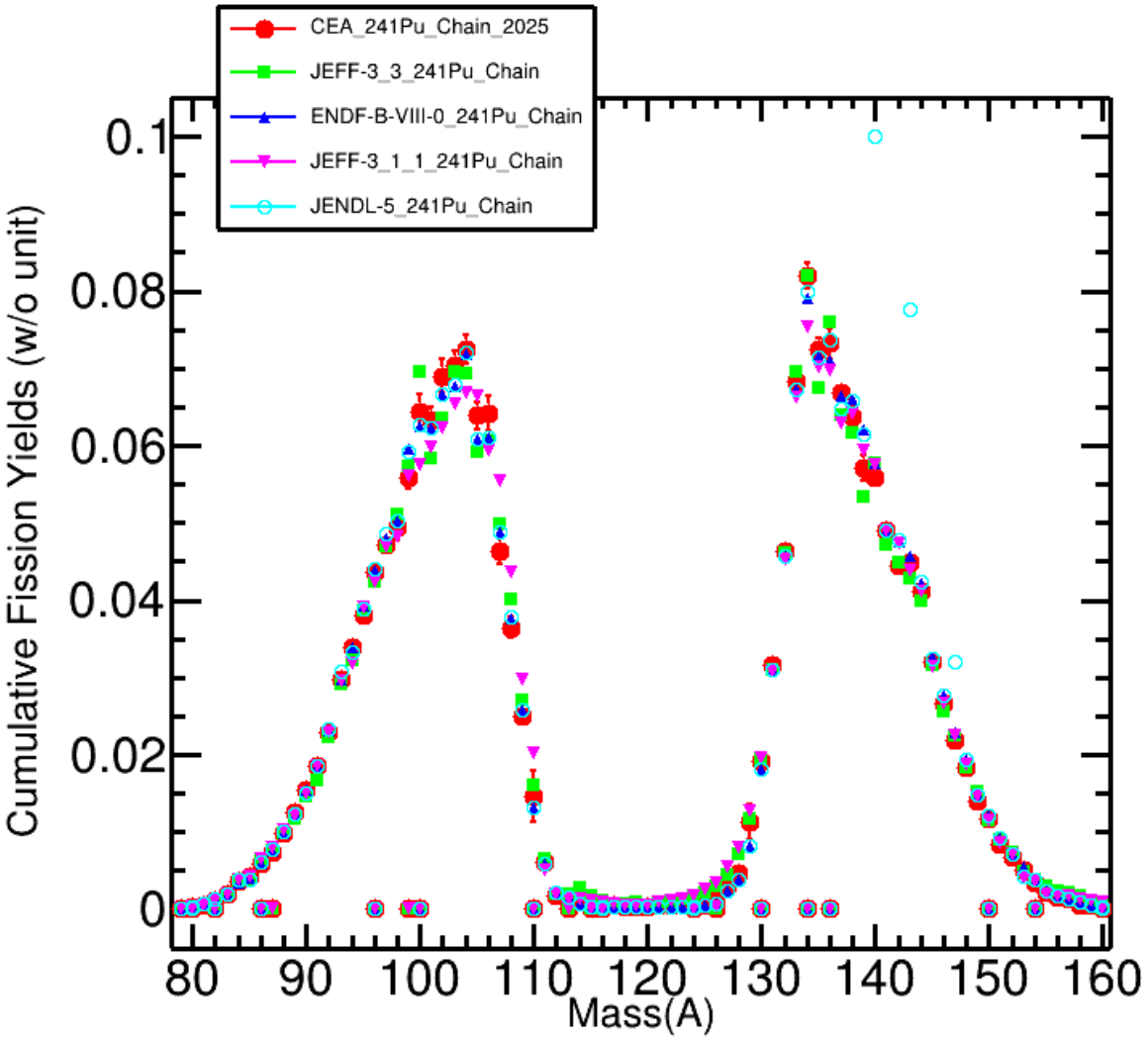

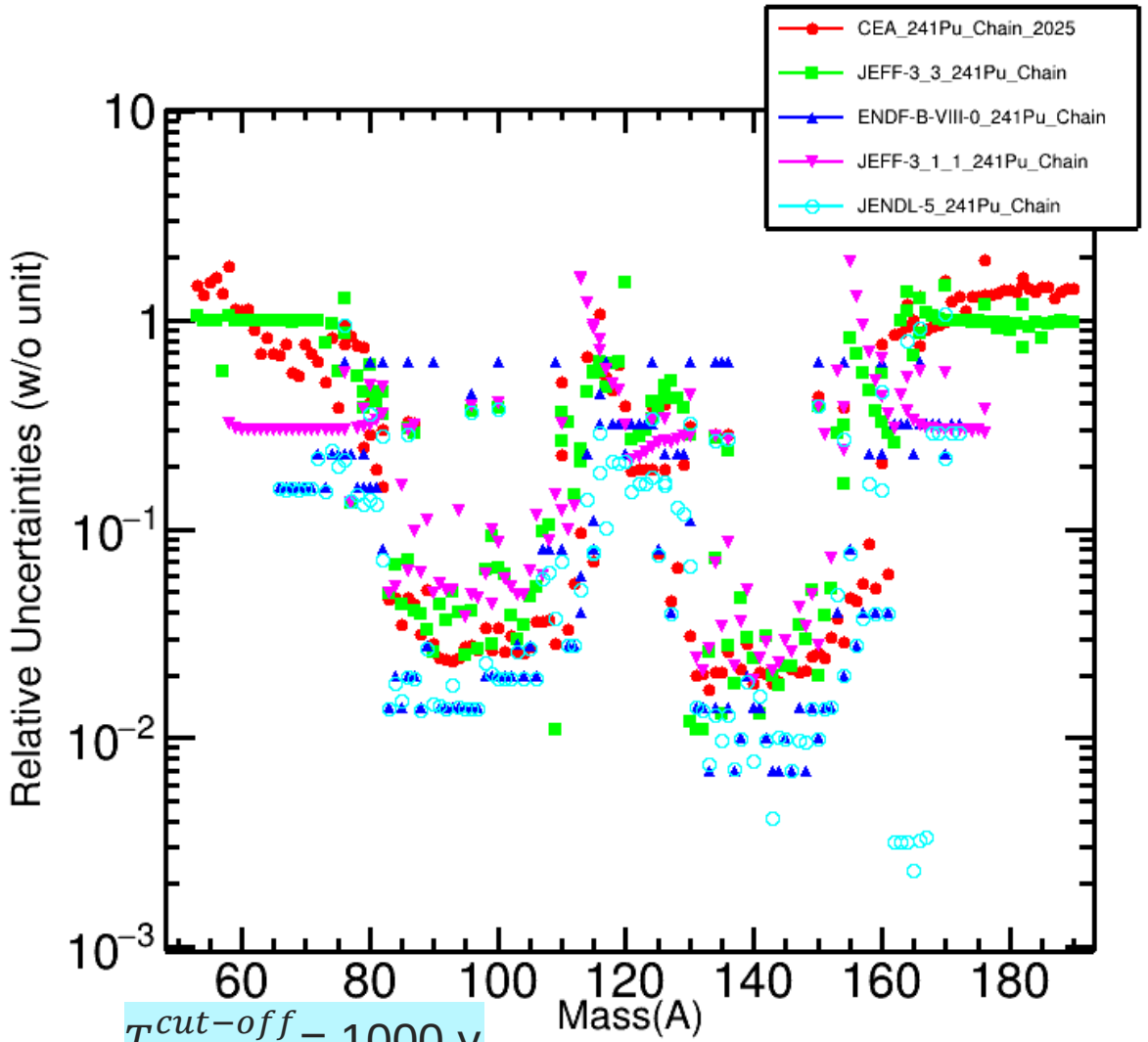

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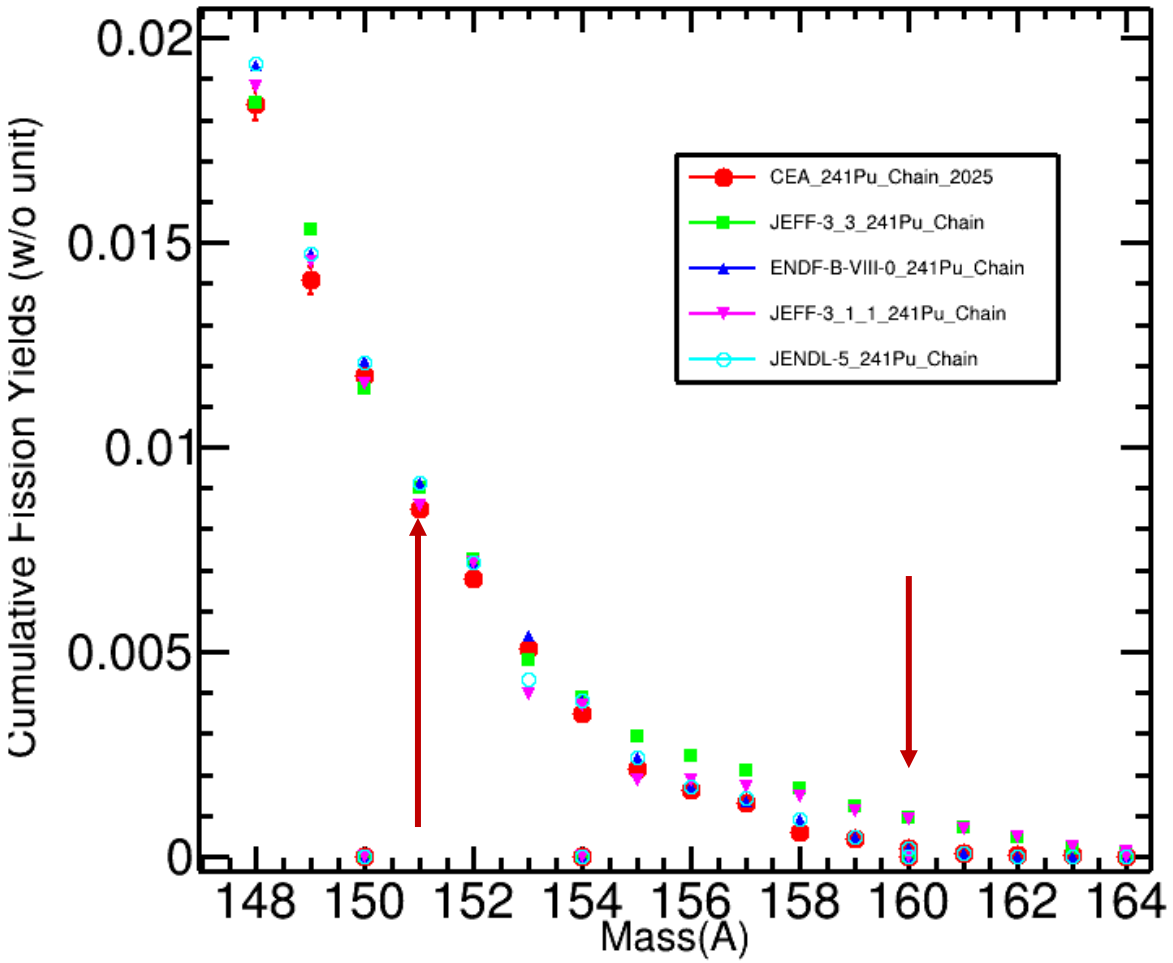
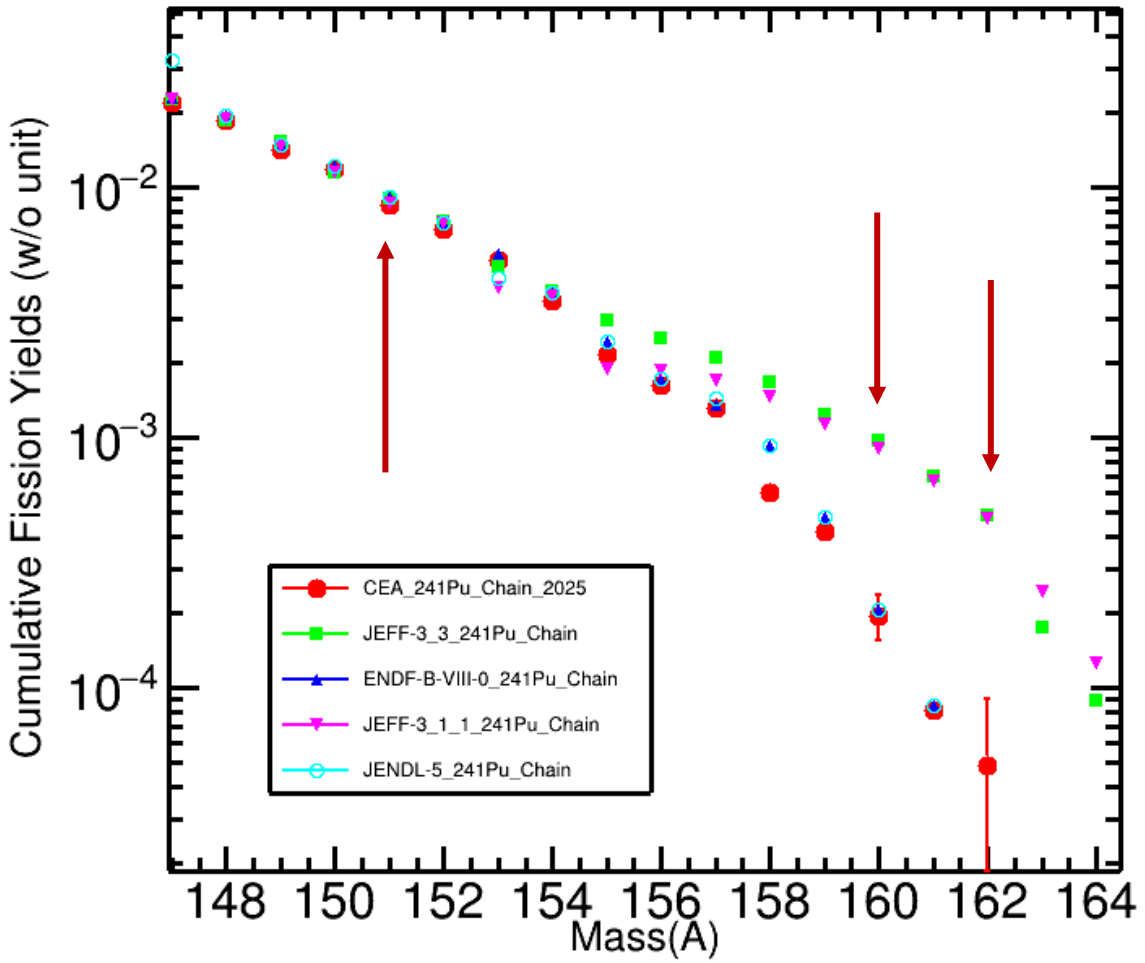


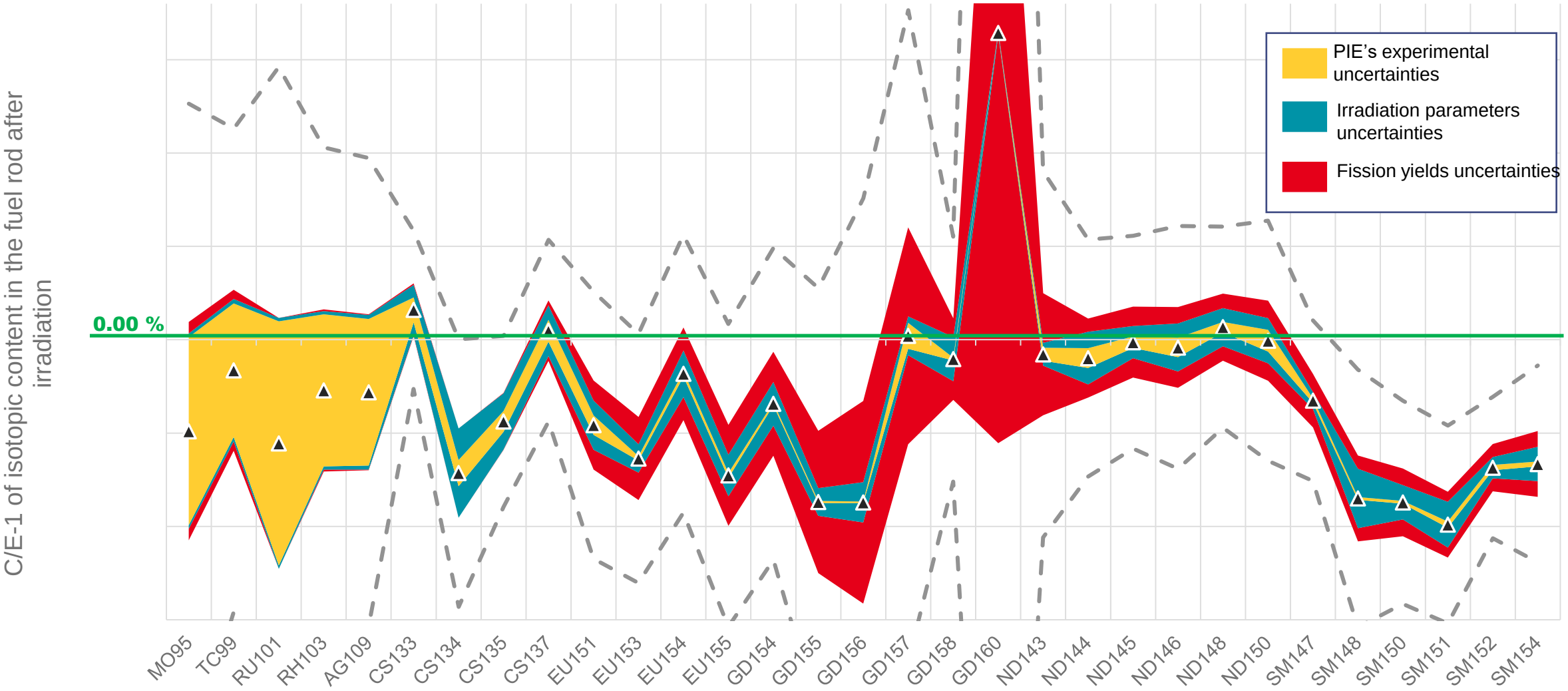


$T_{1/2}^{cut-off}$ = 1000 y

Post-irradiated experiments (PIE)

→ N. Teixeira Rua PhD (2025-2028)

Test and validation of JEFF-4.0



CEA is indebted to EDF for its financial support on the realization of the PIE used

From JEFF-4.0 to JEFF-4.1

→ S.-M. Cheikh 's PhD thesis (2023)

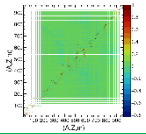
$(nth, f) \Longrightarrow$

$P(Z|A^*, n_{th})$

JEFF-4.0

$Y(A\,|nth)$ → $C(A, Z, m|nth\,)$

$P(Z|A, n_{th}, \text{JEFF}-3.3)$



(n_{fast} ,f) data

Radiochemical data → full (A, Z) identification

$\beta; \gamma$ spectrometry

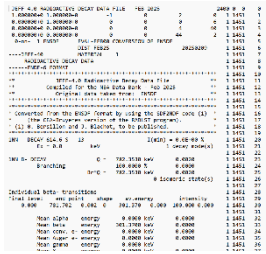
~~ELM Mass spectrometer~~ → full A & limited Z identification

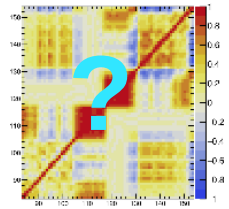
« 2E-2V »

« 2E » → Limited A & A^* identification

(x,f) data

VAMOS, SOFIA … → full Z & limited A identification





From JEFF-4.0 to JEFF-4.1

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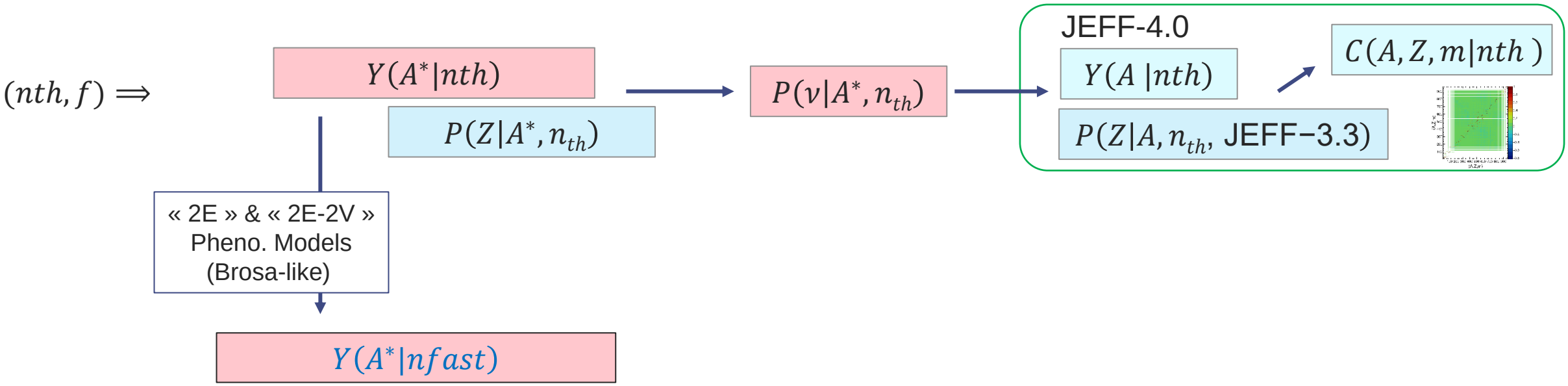
→ A. Regonesi's PhD (2024-2027)



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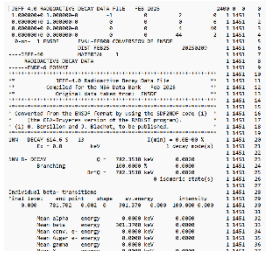

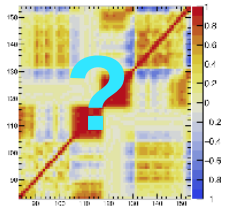

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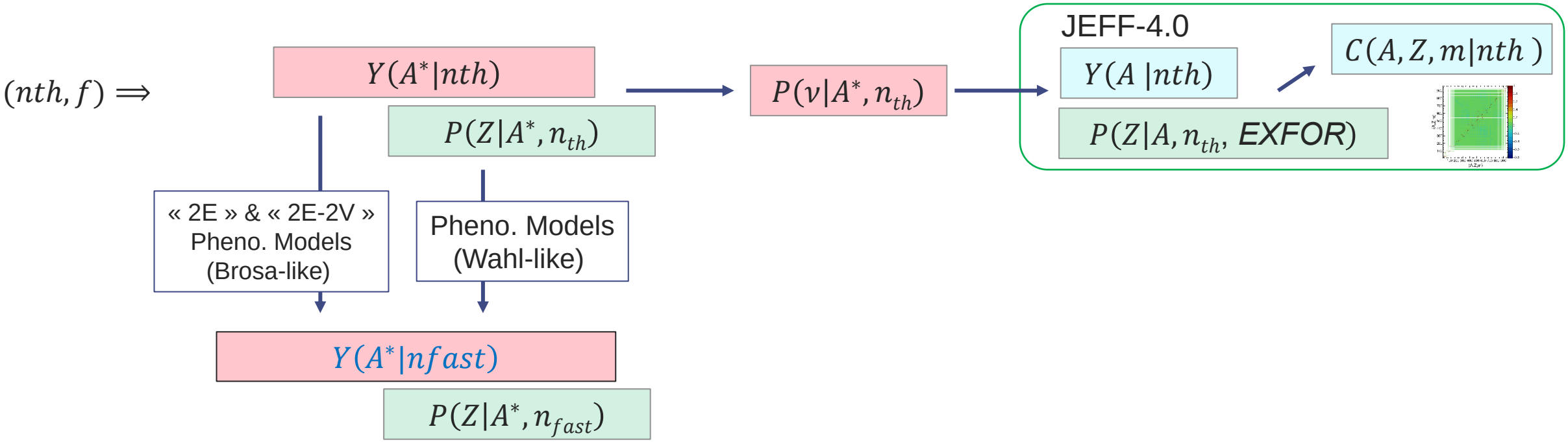

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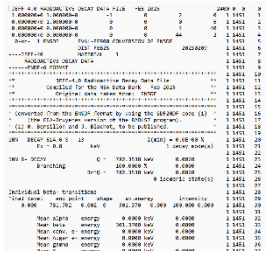

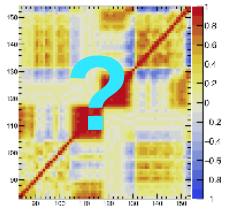

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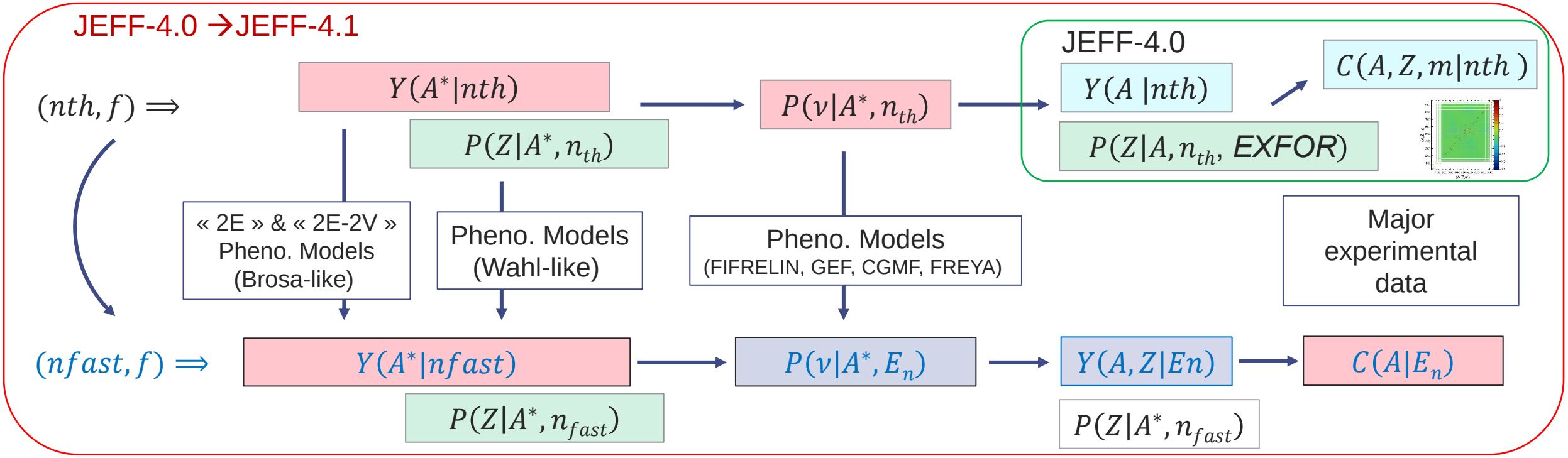

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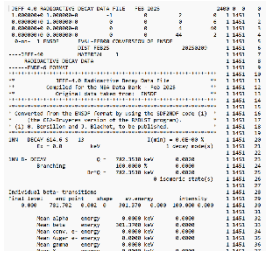
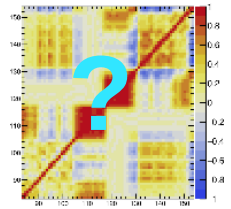




Conclusion & perspectives: P(ND)^2 -3

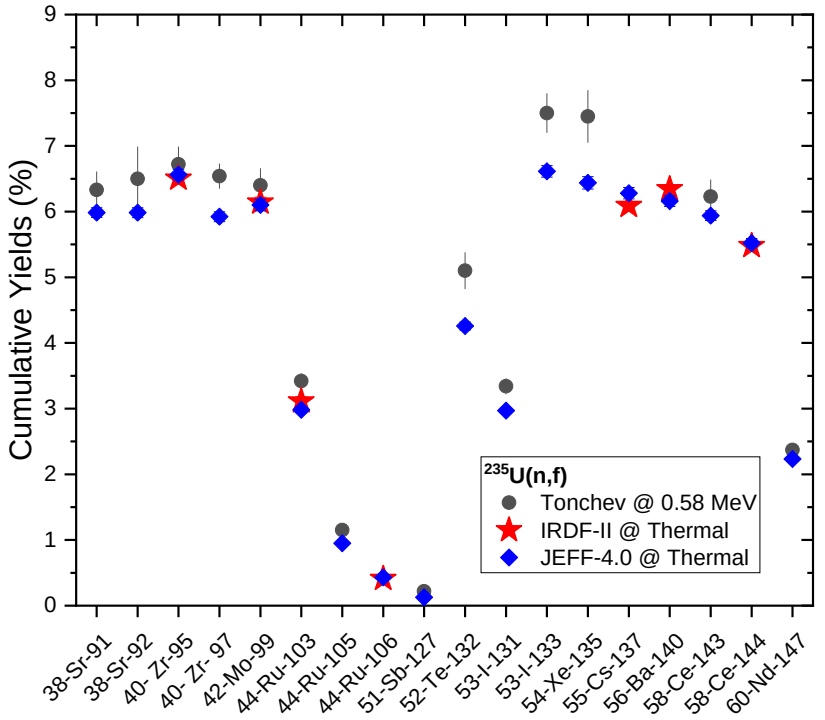
NEEDS for JEFF-4.1:

- New charge distribution in the region of Eu and Sm
- New complete mass yield measurements of $^{239}Pu(n_{th},f)$
- Symmetric and far asymmetric mass yields measurements of $^{241}Pu(n_{th},f)$

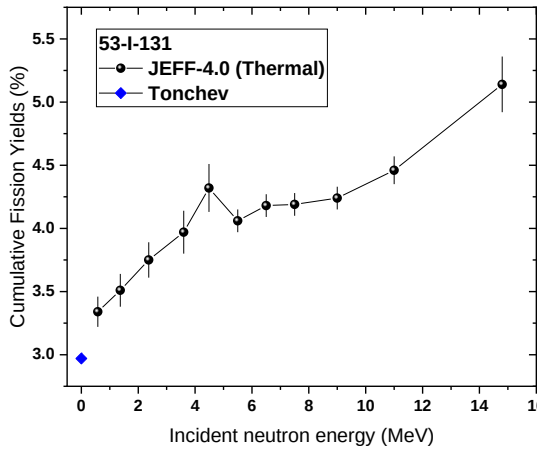
Program for the next Decade:

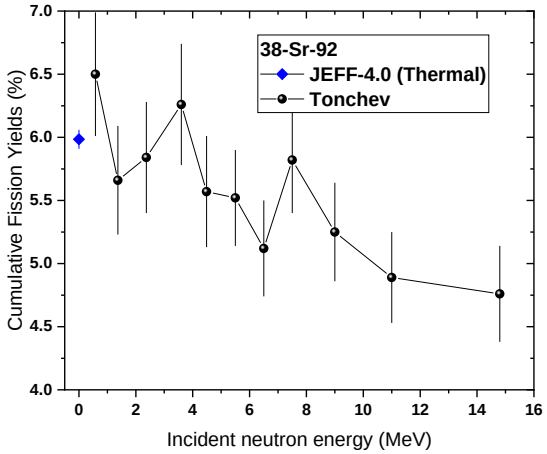
- Complete the (n_{th},f) FY evaluations
- Develop methodology of Evaluation from pre-n observable to PIE
- Adjust phenomenological models considering :
  - correlation matrices at all steps to propagate uncertainties
  - default model to estimate the biases
  - statistical tests to validate the uncertainty and the biases
- Adjusted fission model parameters in order to interpreted fast neutron energy range data [0; 6 MeV]
- Evaluation as a function of incident neutron energy

  →Towards JEFF-4.1

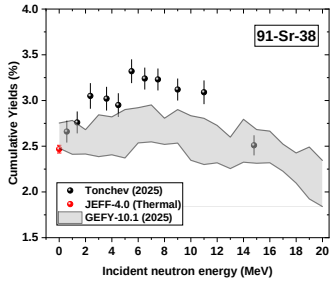


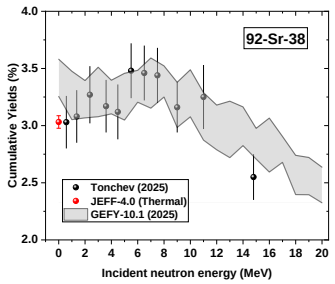
A. Tonchev et al., Nuclear Data Sheets 202, 12 (2025)

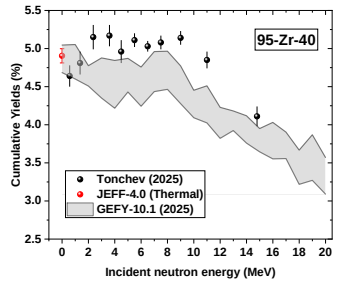


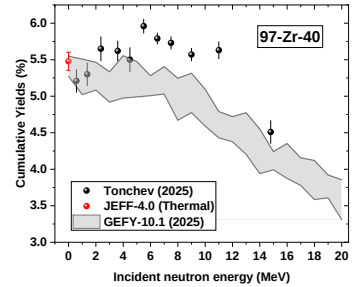


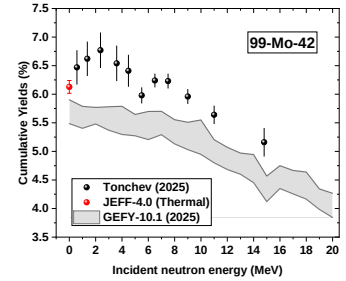
Overview of the 17 Cumulative Fission Products yields measured by Tonchev

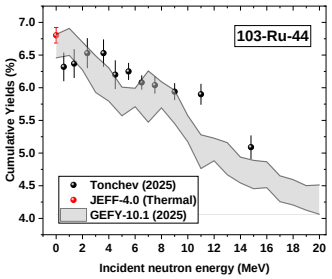


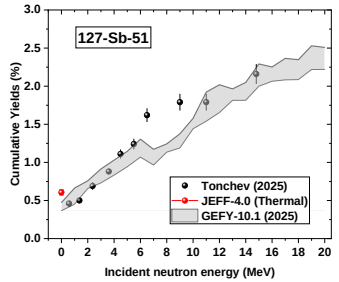


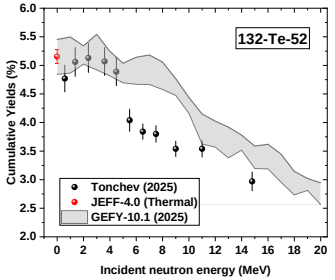


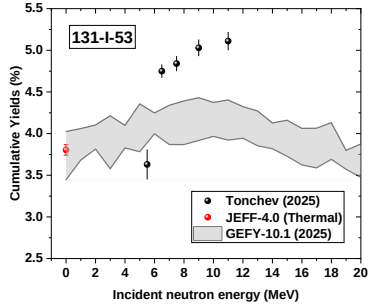


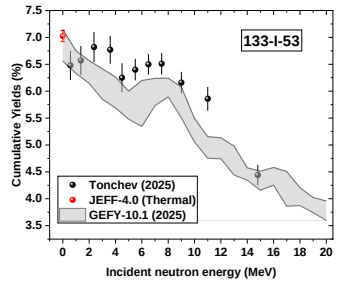


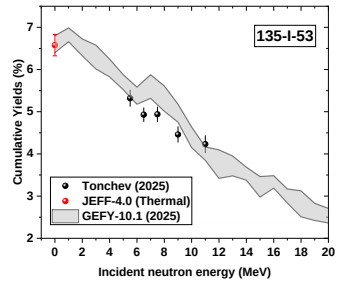


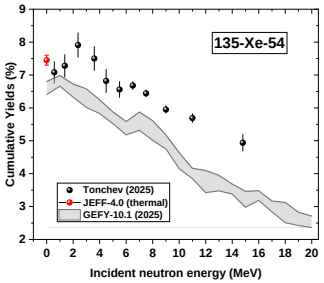


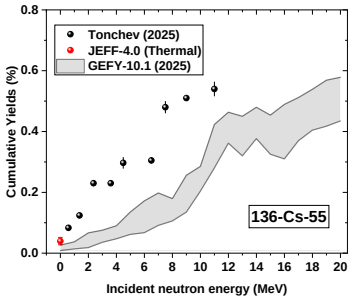


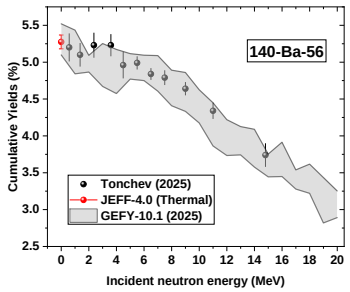


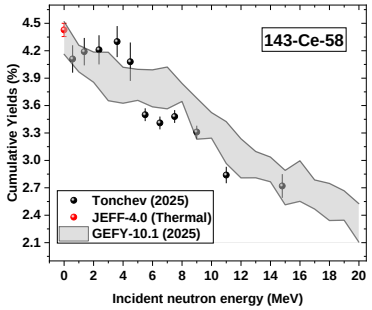


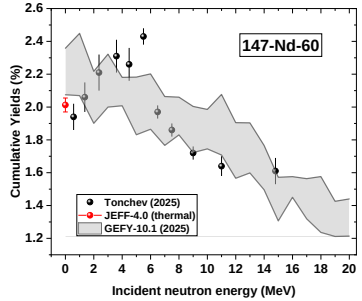


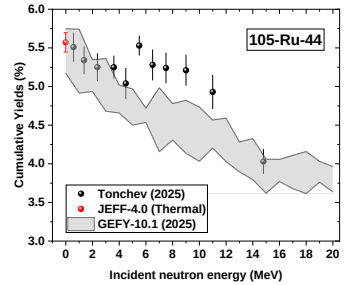












JEF DOC 2550

WP 4.3.2 « Fission yield benchmarking »
Project NIFPYF :
« Neutron Induced Fission Product Yields in Fast energy range »

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Thank you for your attention

jefdoc-1902
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jefdoc-2203 - B. Voirin, G. Kessedjian et al, EPJ N - Nuclear Sciences & Technologies, EDP Sciences, 4, pp.26 (2018)
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jefdoc-2205 - G. Kessedjian, S.-M. Cheikh et al., FPY 2019, Santa Fe, EPJ Web of Conferences 242, 05001 (2020)
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jefdoc-2488 - CRP IAEA on Fission Yields 2020-2024, submitted
jefdoc-2549 - JEFF-4.0 library article, on going
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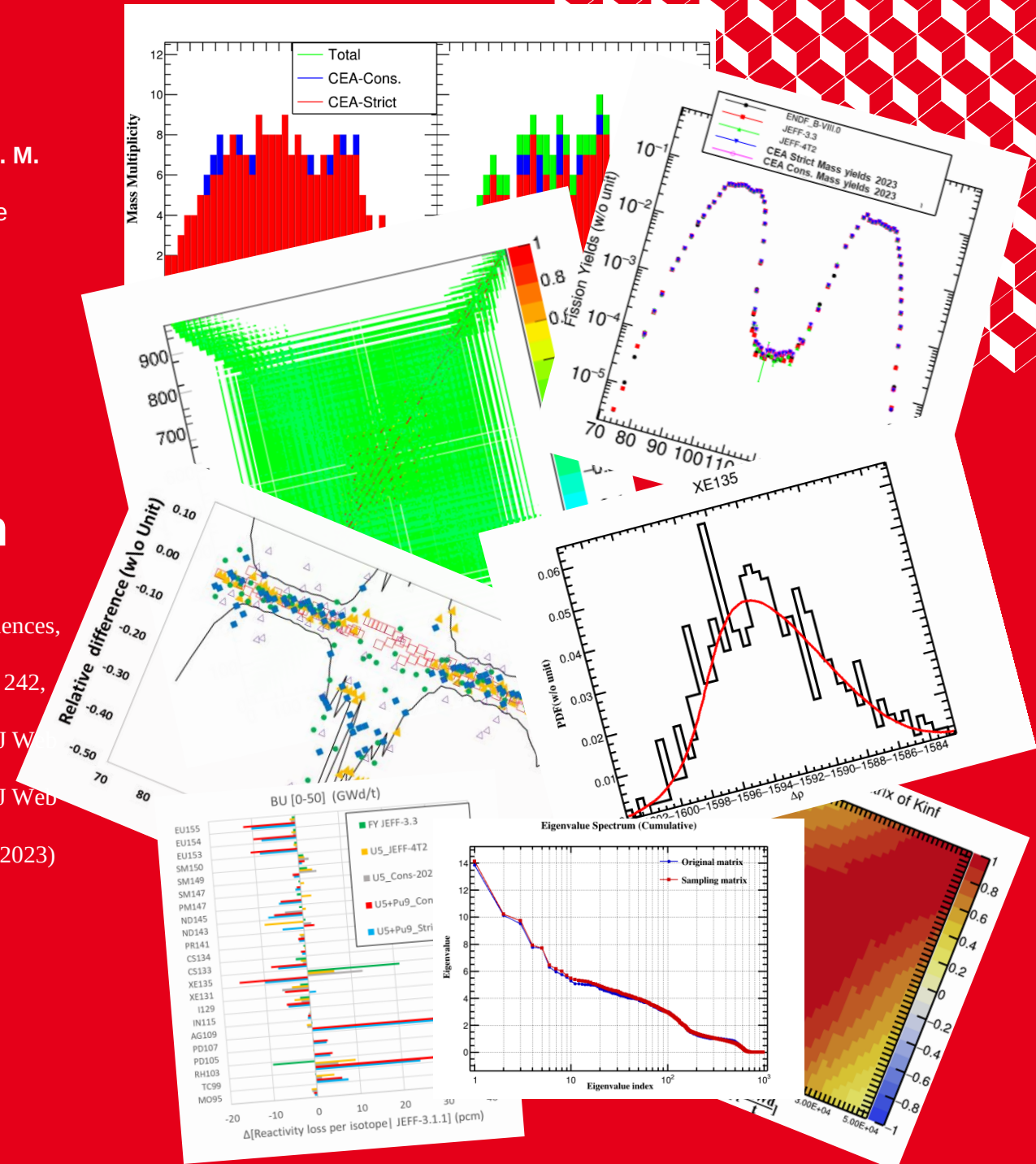
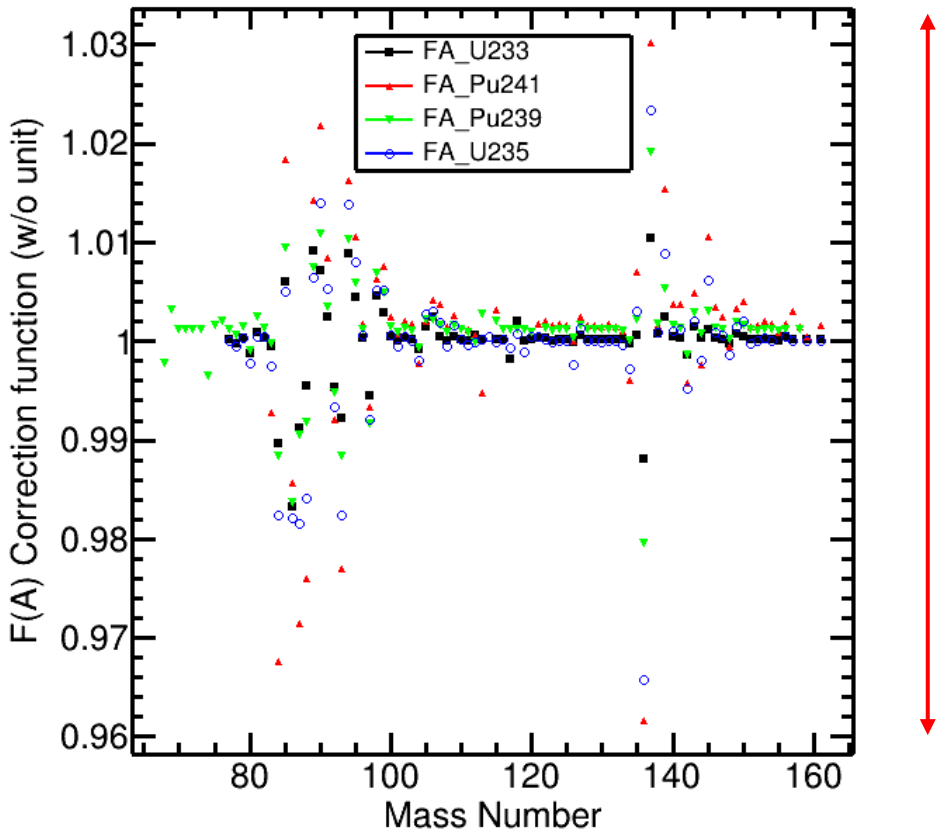
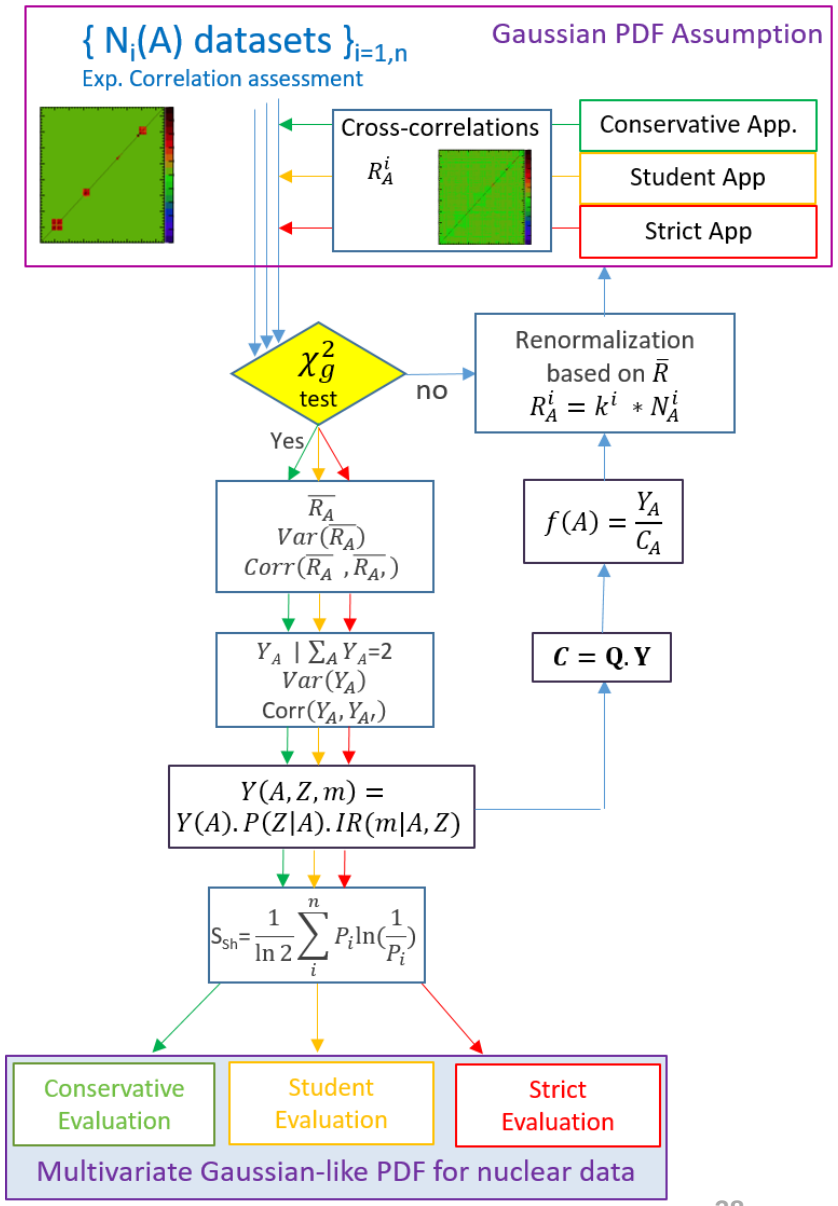


Decay data for JEFF-4.1 : Delayed neutron probabilities



Up to 7% effect of JEFF-3.3 Decay Data in the combination of mass yield and chain yield datasets

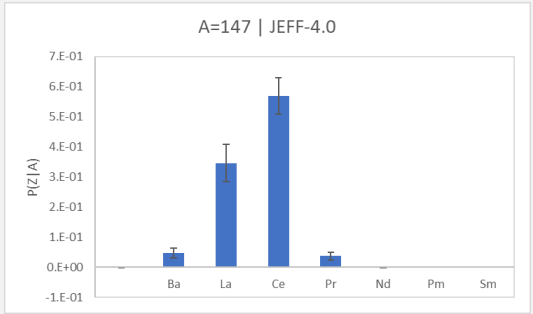


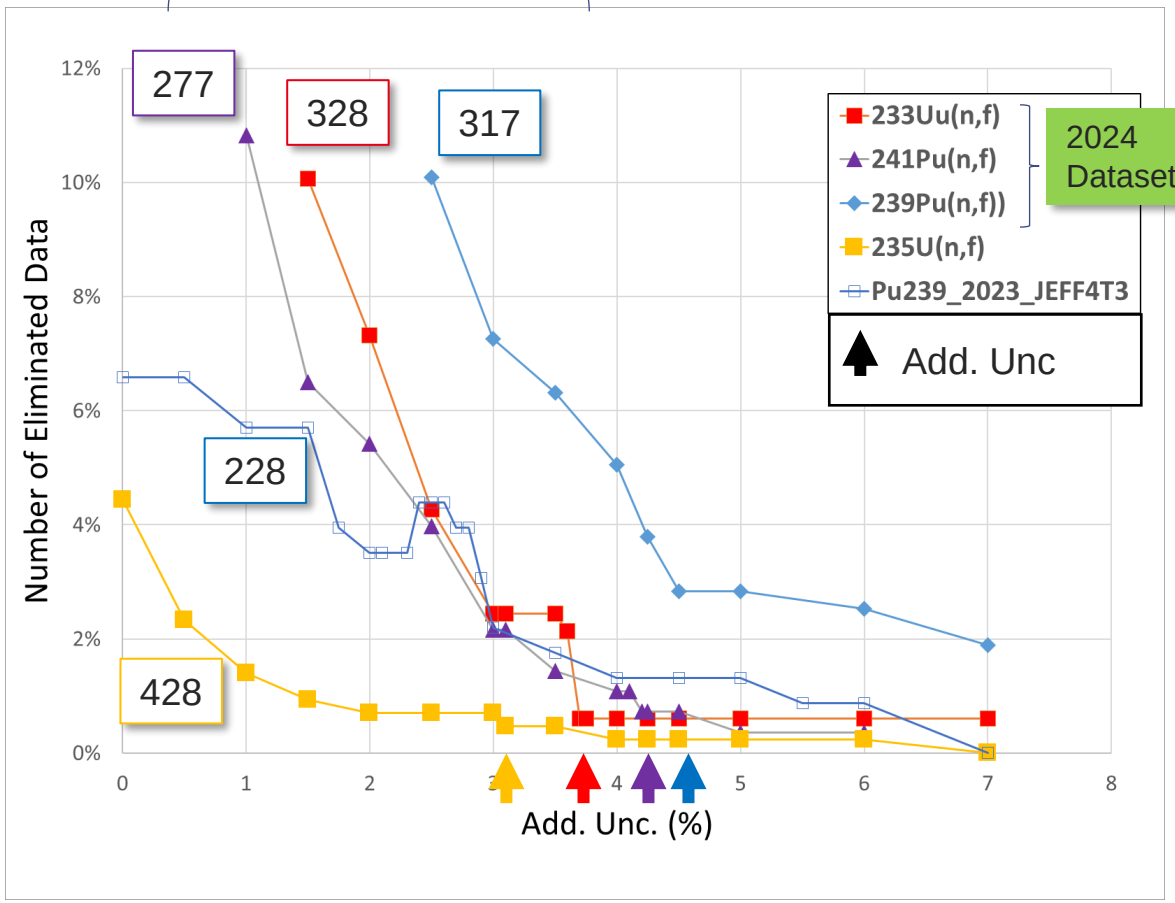
- Combined analysis of Mass & chain yields with delayed neutron probability in order to the update the Decay data & the charge distributions

Test and sorting of available experimental data for the 4 main fissile nuclei

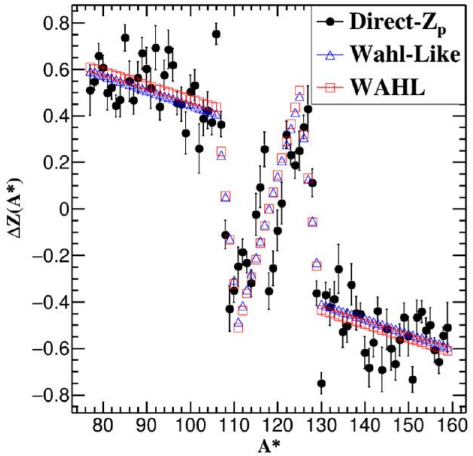
Integrating several cumulative yields ≡ chain yields
according to P(Z|A,JEFF3.3) sorting

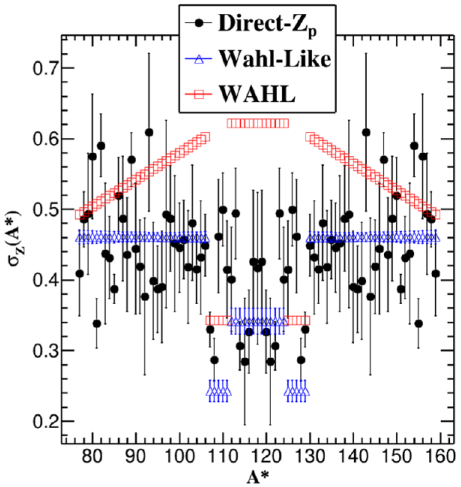
- Only mass yields and chain yields used in these analyses for 235U
- But quasi-chain for 233U, 239Pu and 241Pu, sorting of experimental data depends to P(Z|A) distribution





sorting depends on mean nuclear charge





- S.-M. Cheikh, PhD thesis, UGA, 18 Oct. 2023
- S.-M. Cheikh, G. Kessedjian et al., Covariance Workshop 2022, Tokyo, Japan, EPJ Web of Conferences 281, 00023 (2023)