Recent Advances in Experimental Uncertainty Quantification for Fission Yields data

A.Regonesi, G. Kessedjian, S. M. Cheikh, O. Serot, N. Teixeira-Rua, A. Chebboubi, D. Bernard, O. Litaize

CEA, DES, IRESNE, DER, SPRC, LEPh, Cadarache center, F-13108 Saint Paul lez Durance, France

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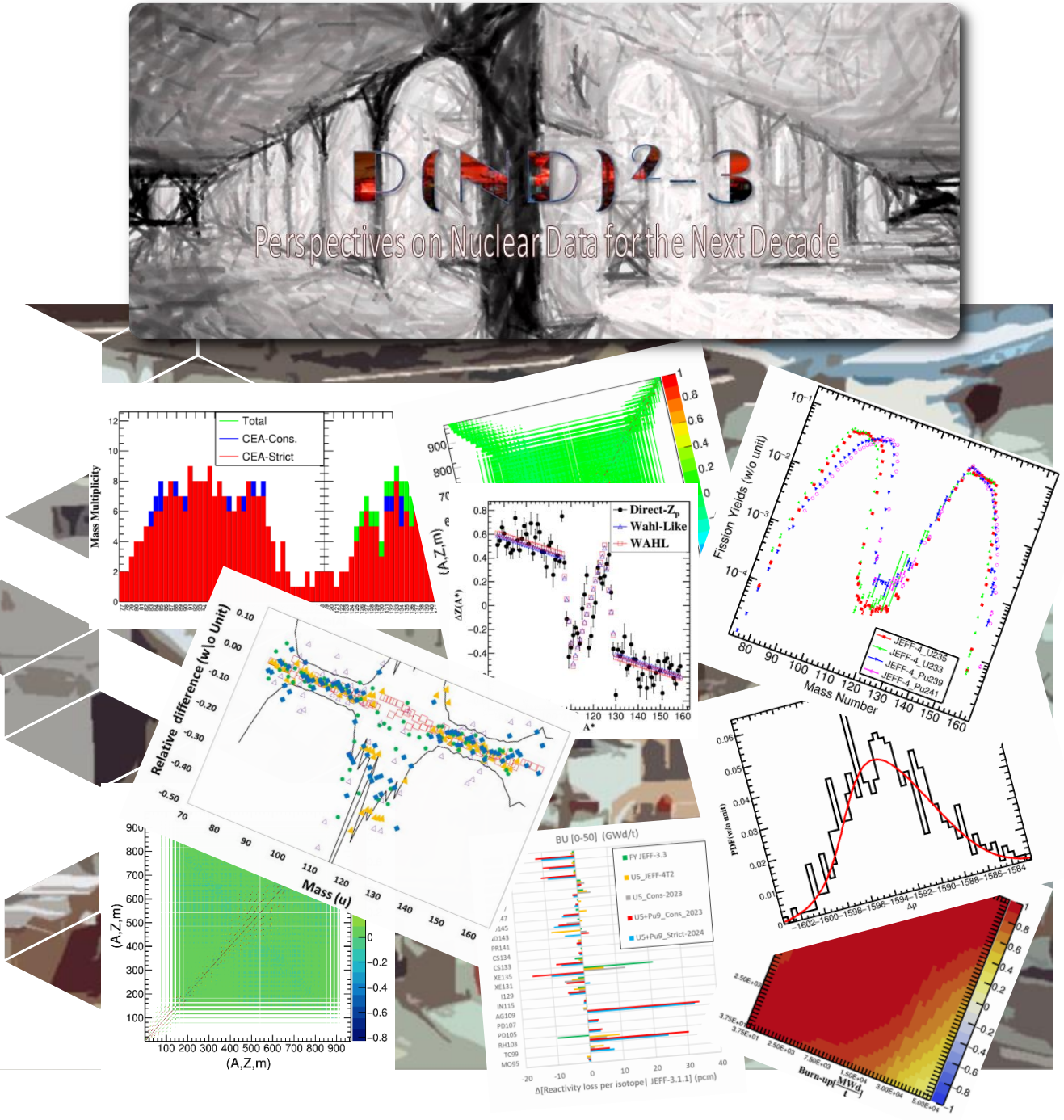

- **Evaluation program on FY@CEA/DES**
- **From experimental data to evaluation; e.g. from mass to chain in JEFF-4.0**
- **Pre-neutron mass yields : Limit of resolution ; e.g. $^{235}U(n_{th}, f)\ Y(A^*)$**
- **Prompt Neutron emission per mass : e.g. $^{235}U(n_{th}, f)\ \nu(A^*)$**
- **Conclusion & Perspectives:**

Context: methodology of FY Evaluation

Theoretically

$$Y(A^*, Z, E^*, J^\pi) = Y(A^*) \cdot P(Z|A*, E^*) \cdot P(E_K|A^*, Z) \cdot P(E^*, J^\pi|A^*, Z, E^*)$$

Pre-neutron Mass, charge, excitation energy

↕

Fission models

↔

Experimentally

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

Mass Charge Kinetic Energy Isomeric

↔

Application

$Y(A, Z, m)$ *Independent Yields*

↓

$C(A, Z, m)$ *Cumulative Yields*

↓

$C(A)$ *Chain Yields*

↕

Fuel Cycle applications

- Reactivity losses (BU)
- PIE (BU) : Post-Irradiated Experiment
- CFE
- Decay Heat

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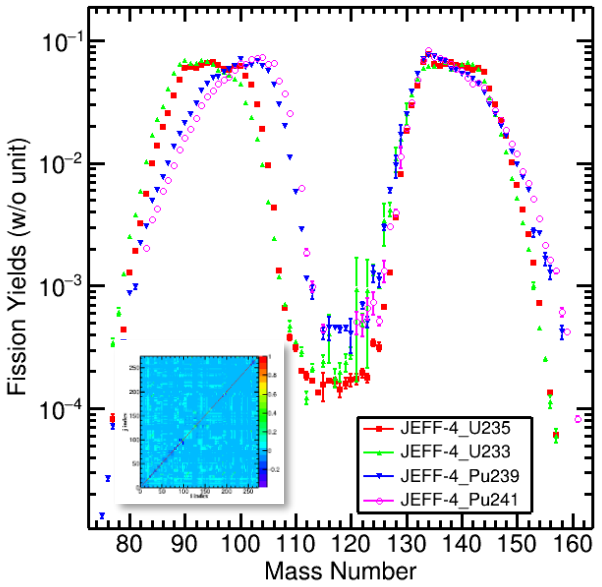

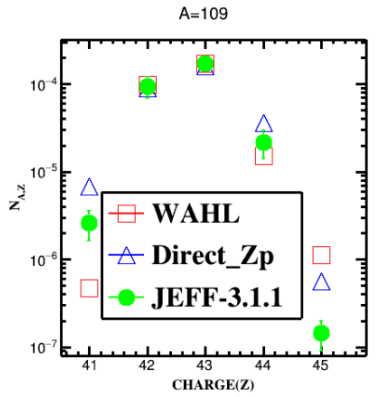

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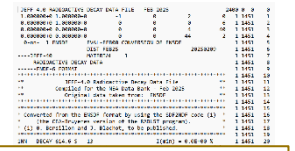

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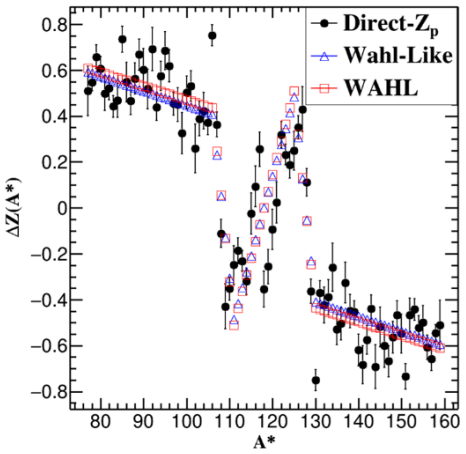

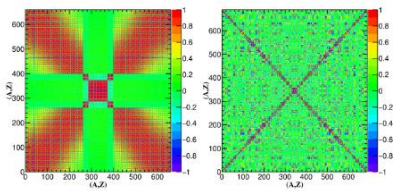

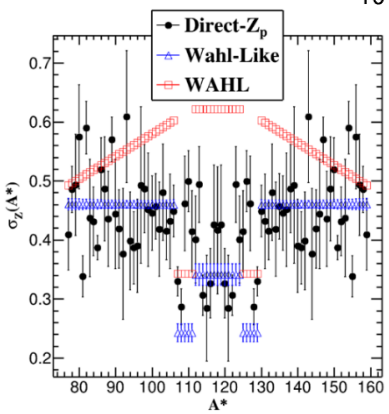

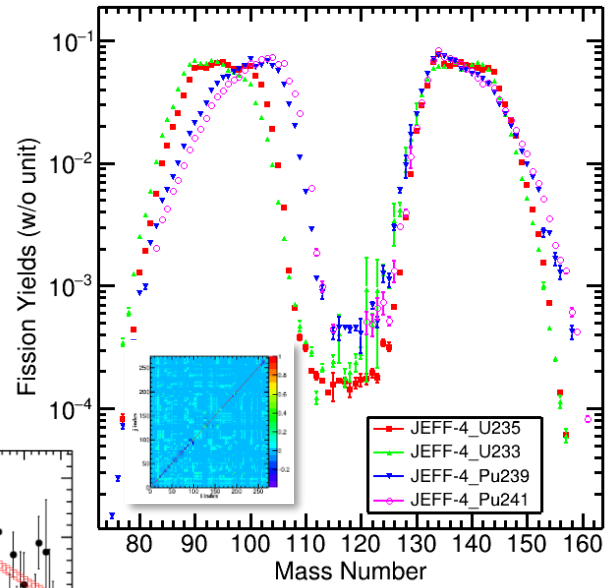

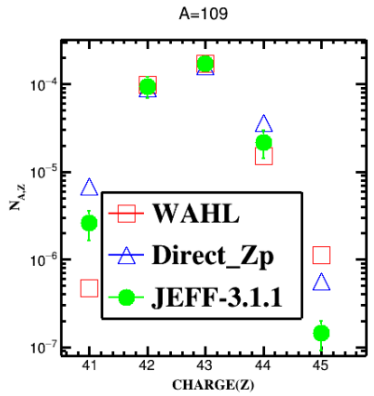

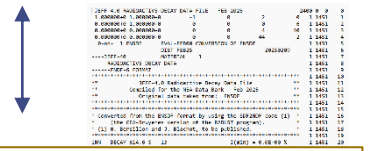

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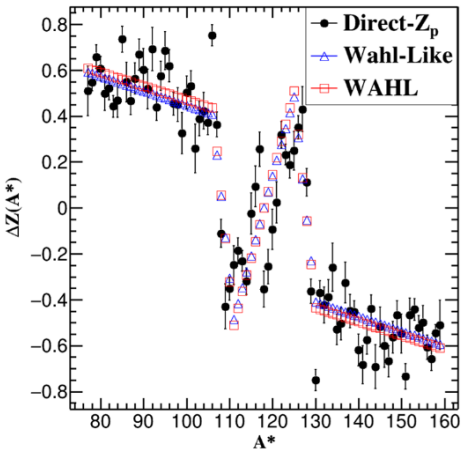

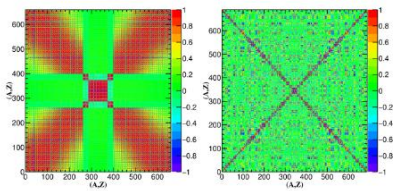

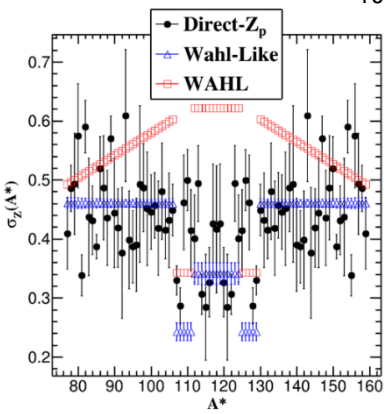

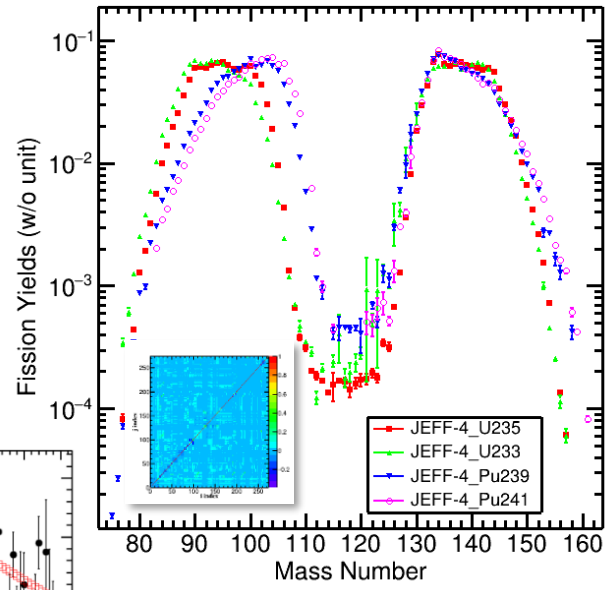

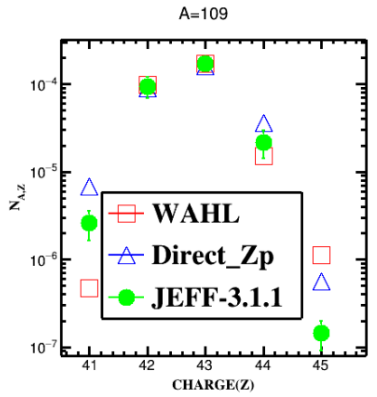

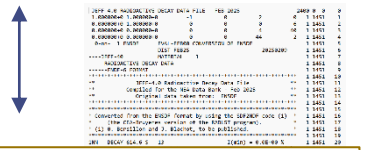

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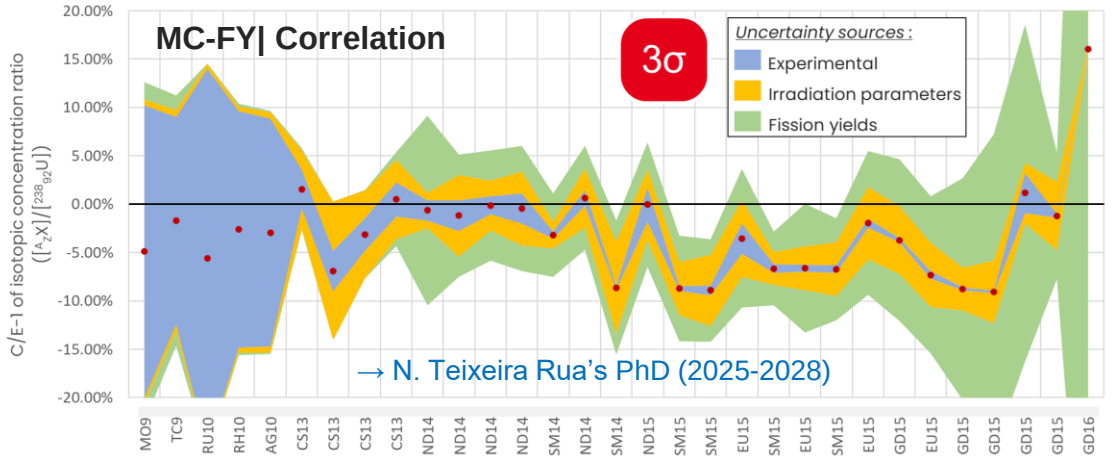


JEFF-4.0 → New methodology : complete and consistent

S-M. Cheikh, PhD thesis (2023)
S.-M. Cheikh et al., Eur. Phys. J. A, 60 11 (2024) 222
IAEA/CRP FY 2020-2024

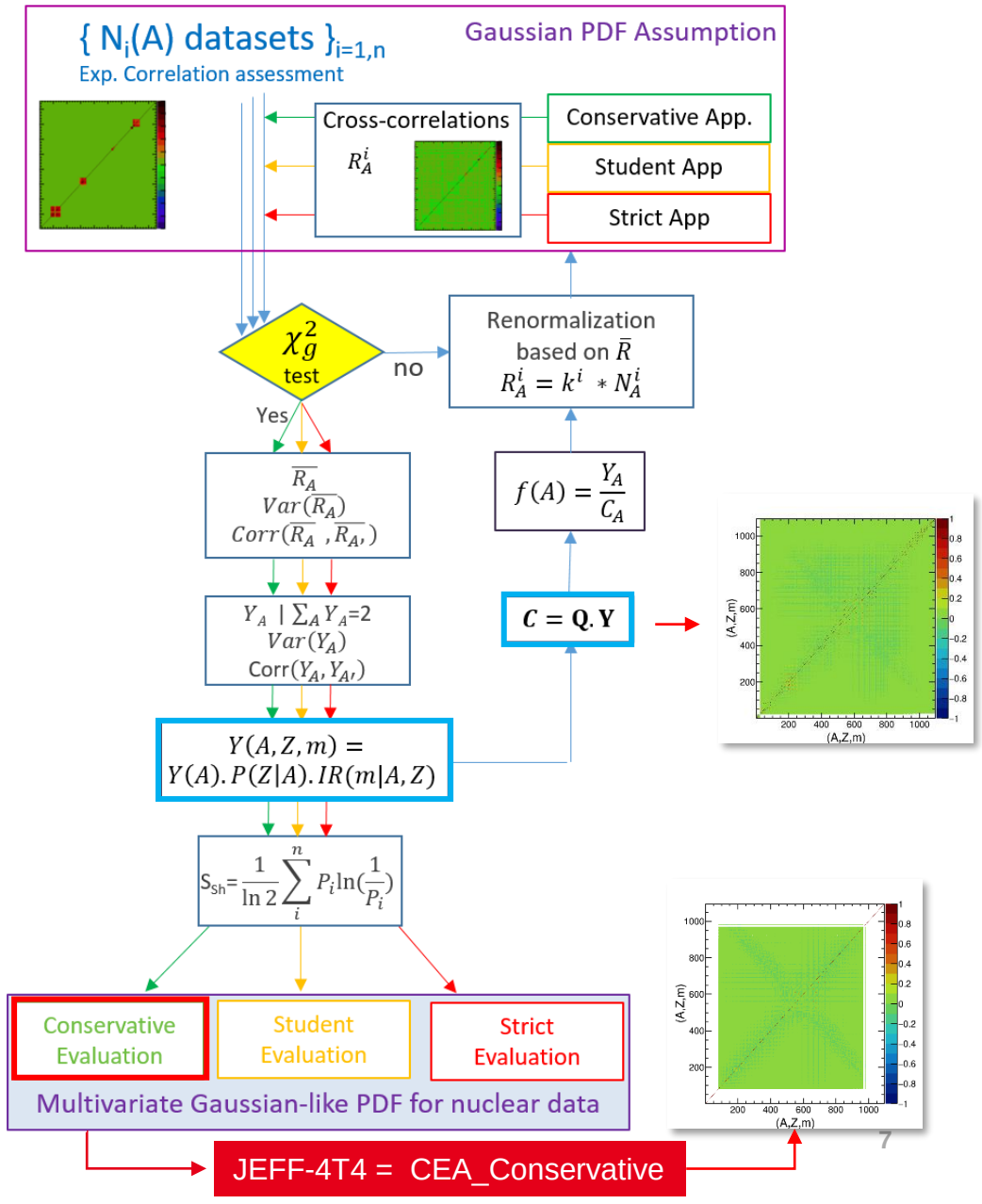
- ## Previous FY evaluations :

- 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-4.0 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
- Consistent according to the conservation laws for :

  mean values, uncertainties and correlation matrices



$^{235}U(n_{th},f)$: Raw datasets from EXFOR

S-M. Cheikh, PhD thesis (2023)
S.-M. Cheikh et al., Eur. Phys. J. A, 60 11 (2024) 222
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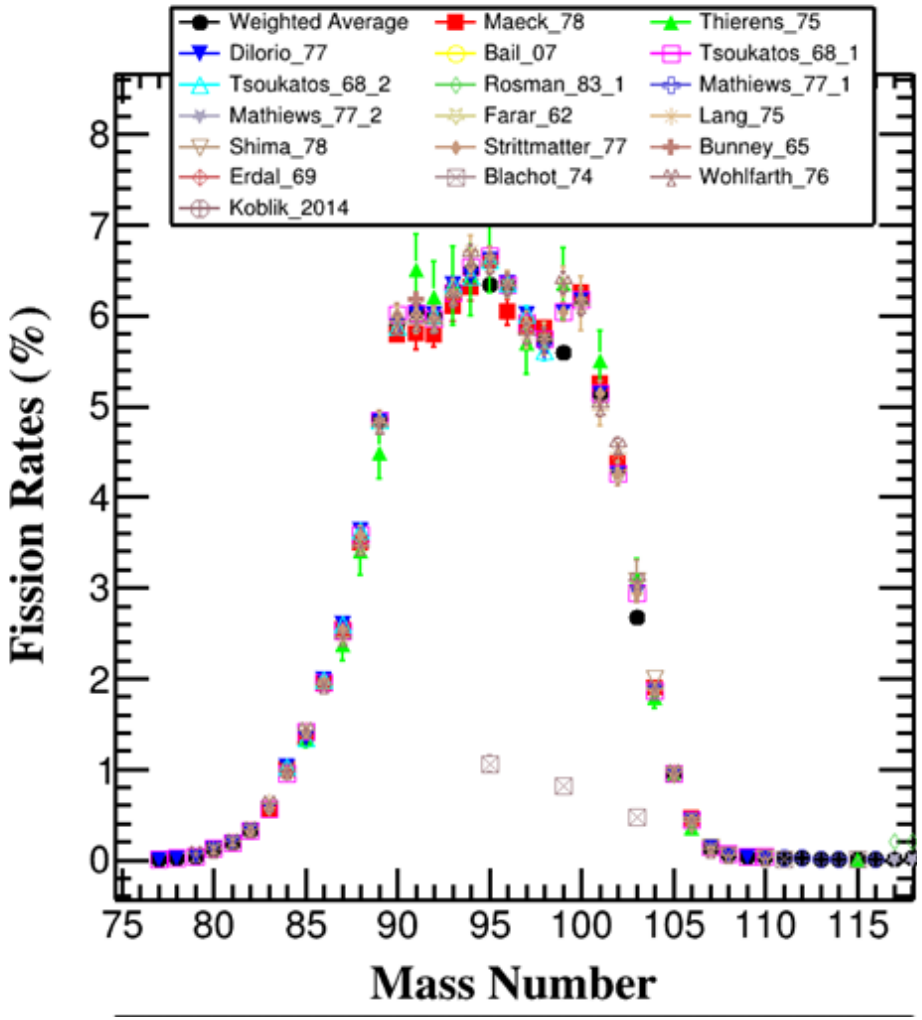
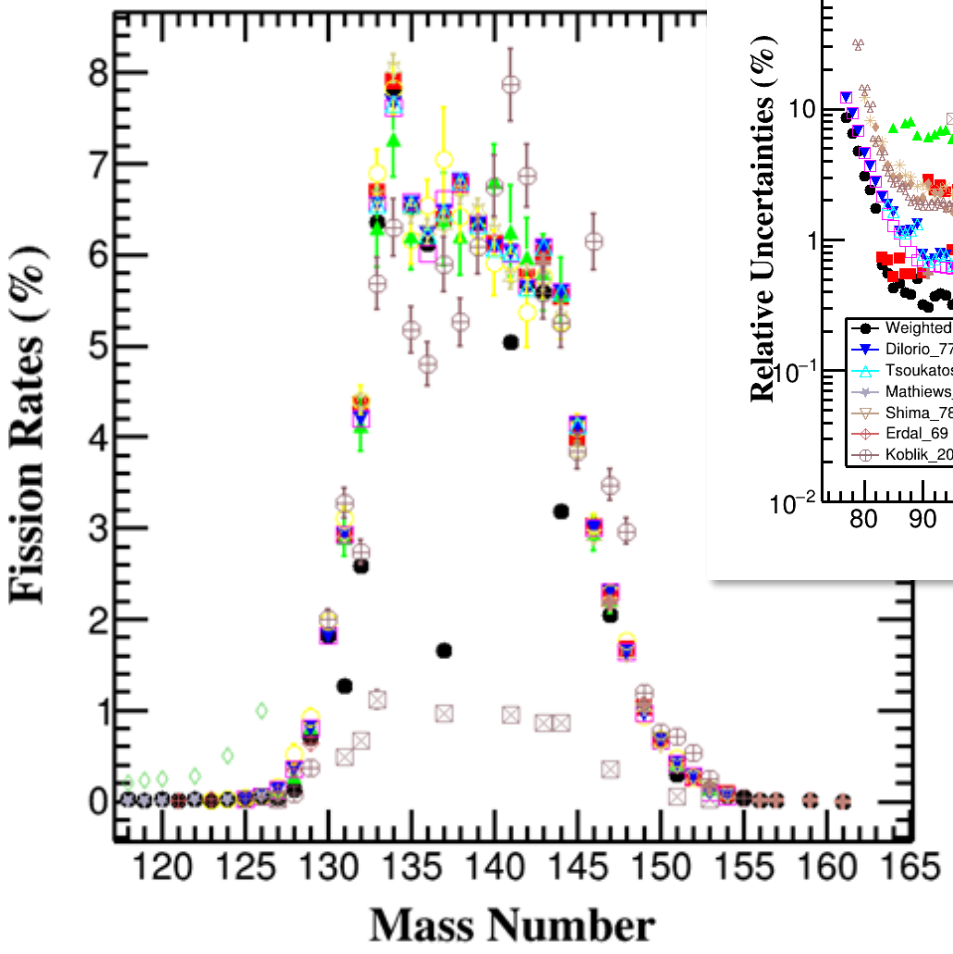
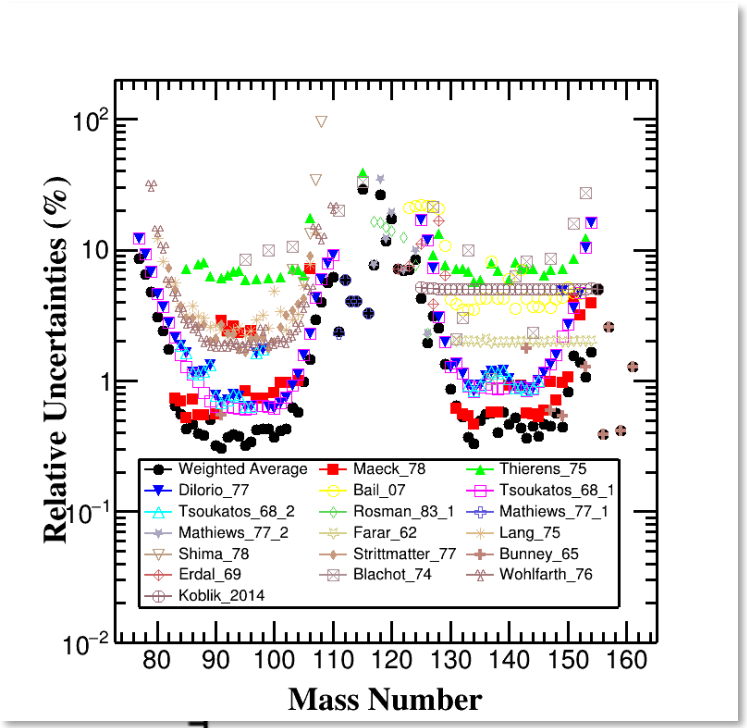




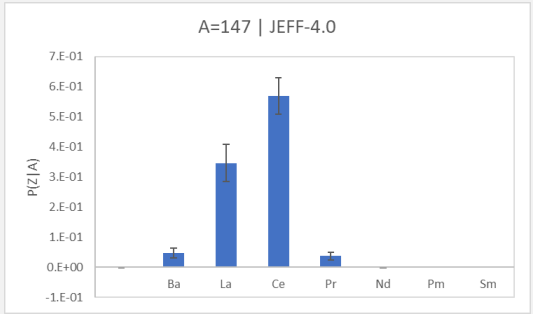


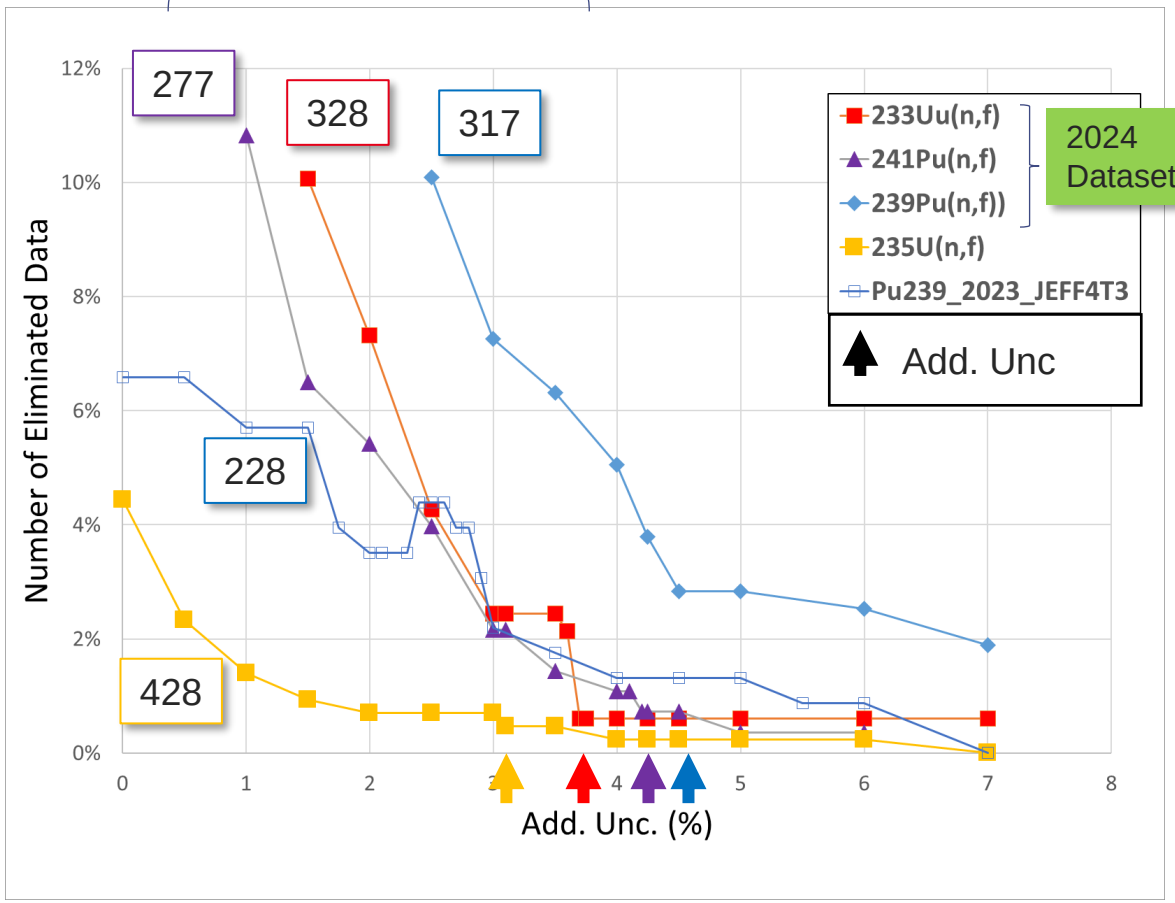
Test and sorting of available experimental data for the 4 main fissile nuclei

S-M. Cheikh, PhD thesis (2023)
S.-M. Cheikh et al., Eur. Phys. J. A, 60 11 (2024) 222
IAEA/CRP FY 2020-2024

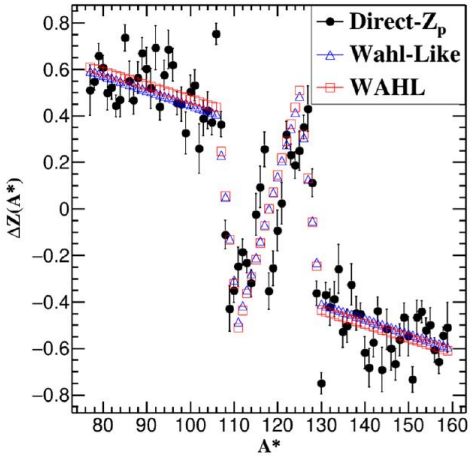
Integrating several cumulative yields ≡ chain yields according to P(Z|A,JEFF3.3) sorting

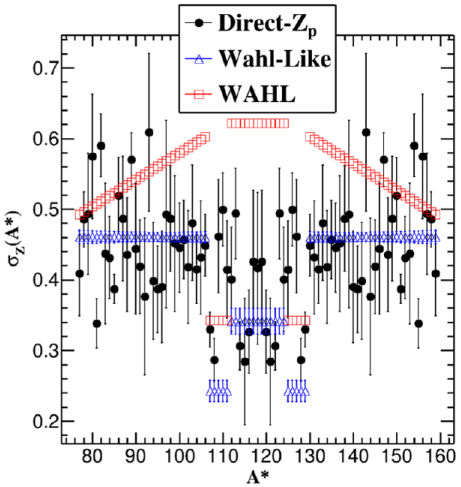
- Only mass yields and chain yields used in these analyses for 235U
- But quasi-chain for 233U, 239Pu and 241Pu, sorting of experimental data depends to P(Z|A) distribution





sorting depends on mean nuclear charge

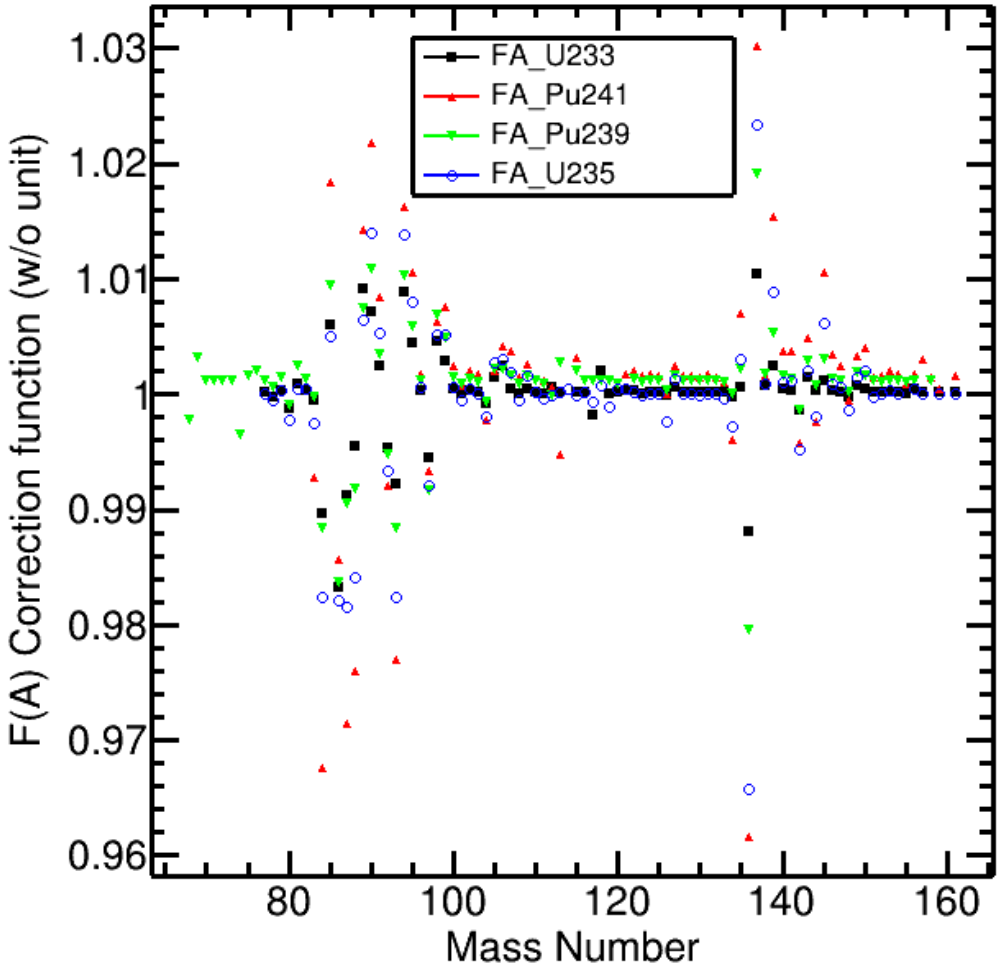




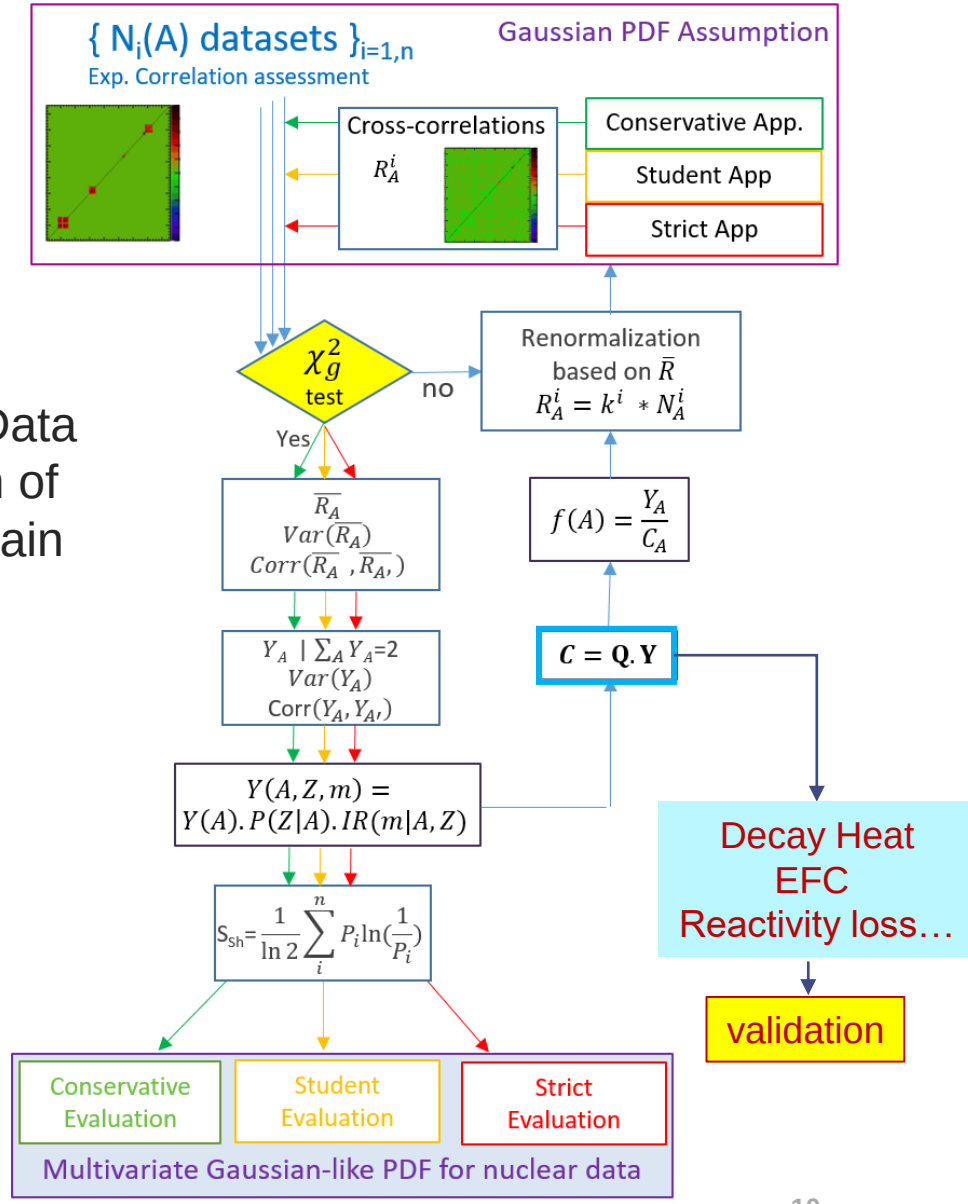
- S.-M. Cheikh, PhD thesis, UGA, 18 Oct. 2023
- S.-M. Cheikh, G. Kessedjian et al., Covariance Workshop 2022, Tokyo, Japan, EPJ Web of Conferences 281, 00023 (2023)

FY & applications dependency to Decay data

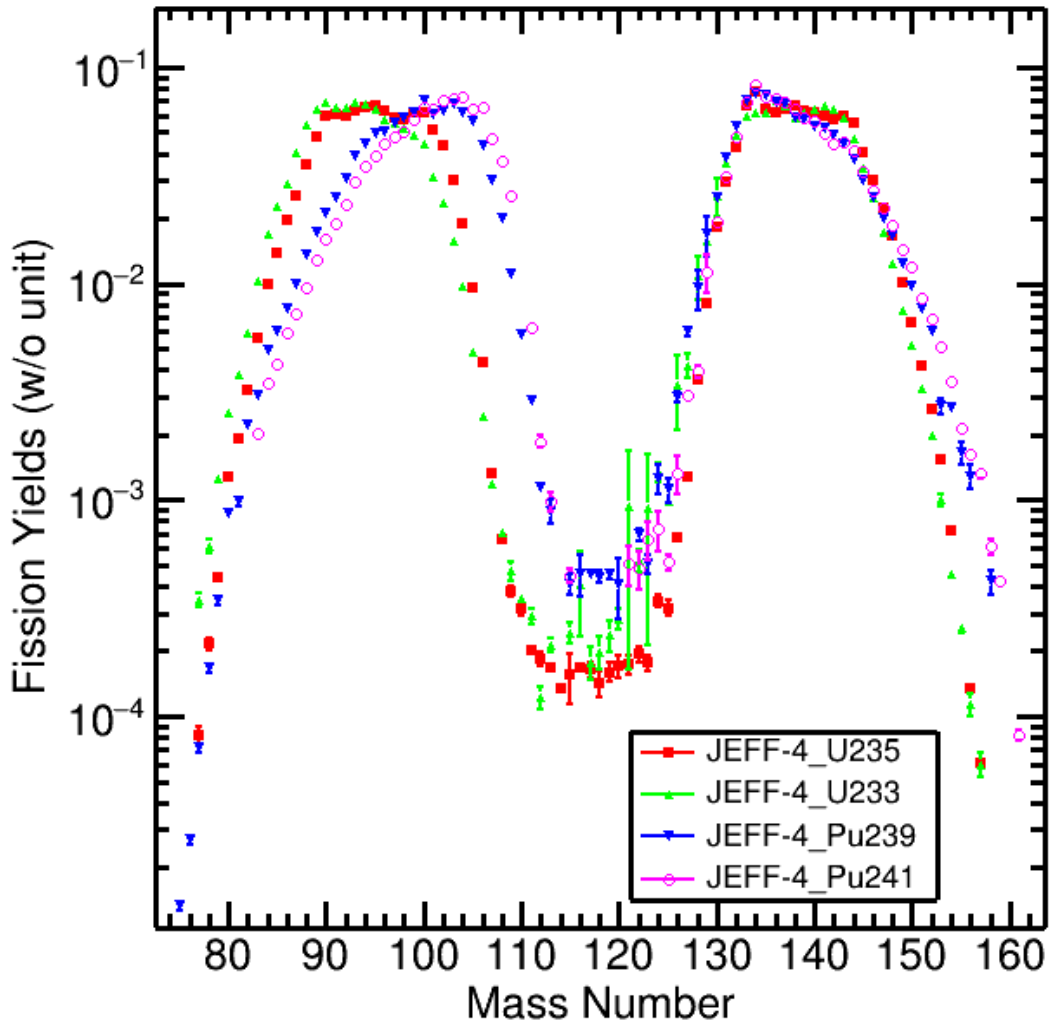
S-M. Cheikh, PhD thesis (2023)
S.-M. Cheikh et al., Eur. Phys. J. A, 60 11 (2024) 222
IAEA/CRP FY 2020-2024

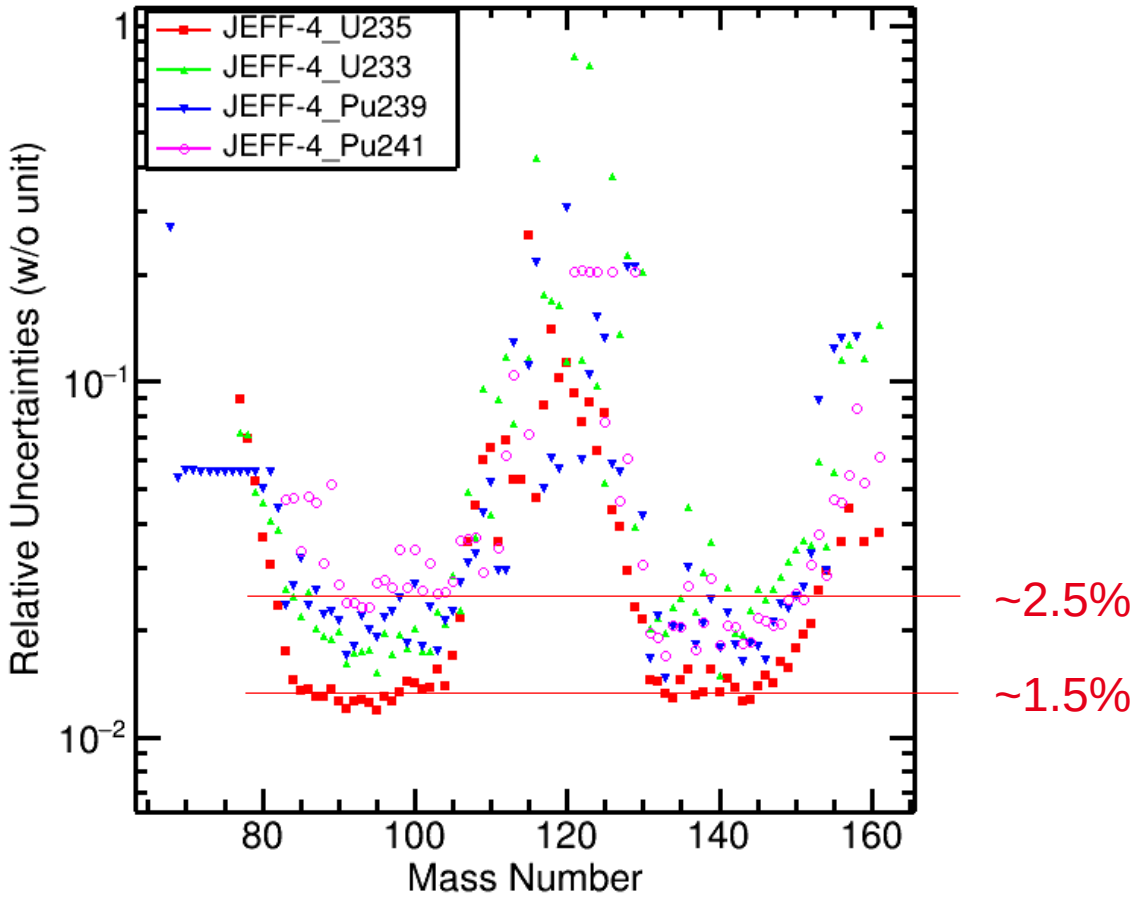


Up to 7% effect of JEFF-3.3 Decay Data in the combination of mass yield and chain yield datasets



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

- Evaluation program on FY@CEA/DES
- From experimental data to evaluation; e.g. from mass to chain JEFF-4.0
- **Pre-neutron mass yields : Limit of resolution ; e.g. $^{235}U(n_{th}, f)\ Y(A^*)$**
- **Prompt Neutron emission per mass : e.g. $^{235}U(n_{th}, f)\ \nu(A^*)$**
- **Perspectives & Conclusion : $^{235}U(n_{th}, f)\ C(A|En)$**

Pre-neutron mass yields : Limit of resolution ; e.g. $^{235}U(n_{th},f)$ $Y(A^*)$

→ Jefdoc2458
→ A. Regonesi's PhD (2024-2027)

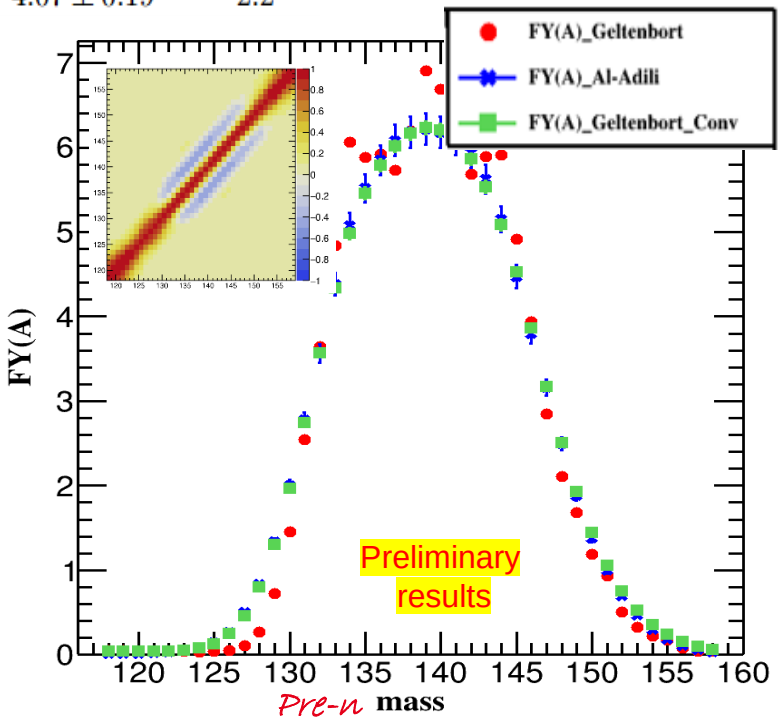
Experimental Data (EXFOR database): 2E & (2Ex1v)² methods

Experimental data								Selected data			
Name	Year	Method	$\nu(A)$	Unc.	Sym.	Mass Range	$P_{val}(\%)$	Region ($FY \geq x\%$)	$\sigma_{add}(\%)$	FWHM (amu)	$P'_{val}(\%)$
Geltenbort (1)	1985	2E-2v	No	Yes	Yes	77–159	100	0 %	0.0	2.09 ± 0.56	100
Derengowski (2)	1970	2E-2v	No	Yes	No	78–109, 127–154	54	0 %	0.0	2.31 ± 0.26	68.5
Hambsch (3)	1989	2E	Apalin	Yes	No	61–168	0.0	1 %	1.0	2.59 ± 0.23	11.1
Al-Adili (4)	2020	2E	Wahl	Yes	No	66–167	0.0	1 %	2.5	5.65 ± 0.12	3.6
Romano (5)	2007	2E	Maslin	Yes	No	71–165	0.0	0 %	0.0	5.75 ± 0.12	99.6
Simon (6)	1989	2E	Cold frag.	No	No	79–110, 126–157	0.0	0 %	3.0	3.67 ± 0.16	49.6
Zeynalov (7)	2006	2E	Apalin	Yes	No	118–160	0.0	1 %	5.0	4.07 ± 0.19	2.2
Zeynalov S1 (8)	2017	2E	measured $\bar{\nu}$	No	No	79–157	0.0	1 %	6.0		
Zeynalov S2 (9)	2017	2E	Apalin	No	No	79–157	0.0	1 %	5.0		

$P'_{val} \geq 0.3\%$ (3σ)

Resolution determined by FY post in comparison to JEFF4

- ❑ 9 series of data symmetrised, recalibrated (based on post-n FY when available) and normalised to 200%
- ❑ Generalised χ^2_g tests using correlations on two-by-two series
  - ❖ Geltenbort et Derengowski (2e2v) : Y(A*) and Y(A) available data, mass resolution determined in comparison to JEFF4.0 Y(A) Geltenbort's data recalibrated to JEFF4.0 Y(A)
  - ❖ 2E data mass resolutions → Compatibility test with 2E-2v measurements



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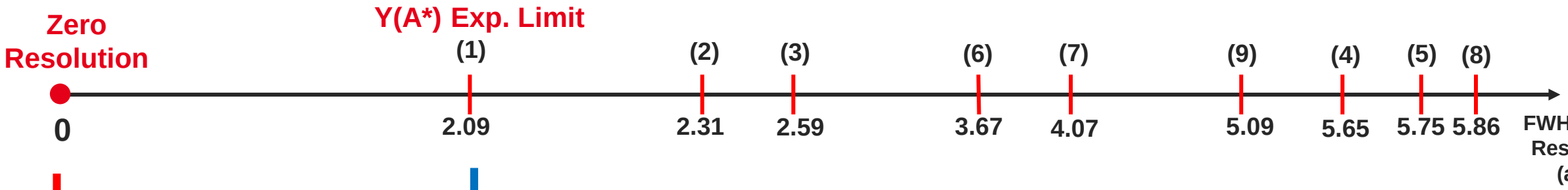
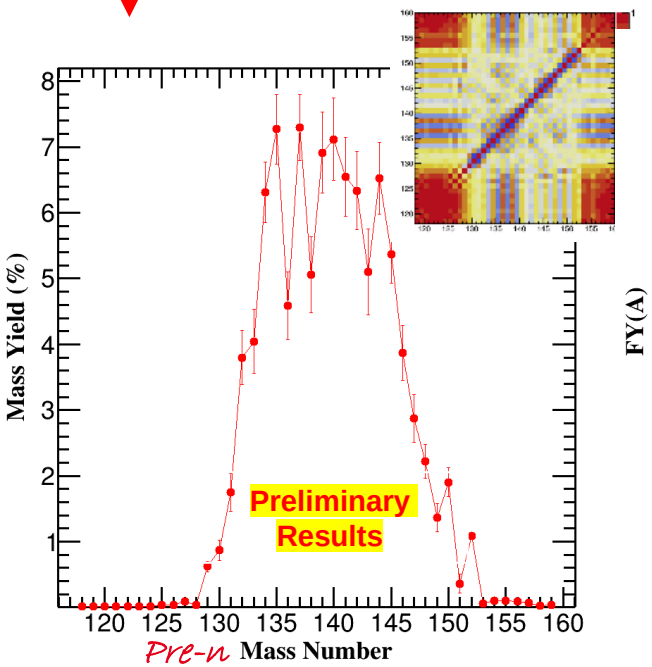
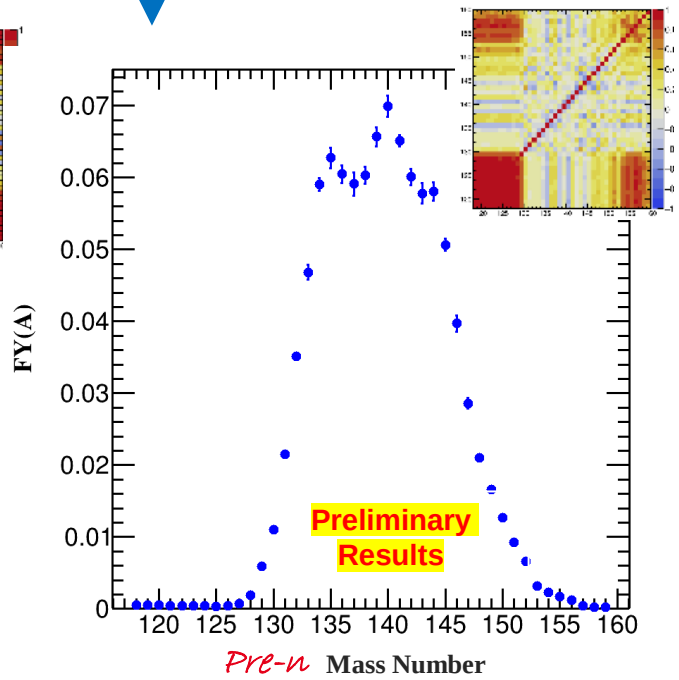
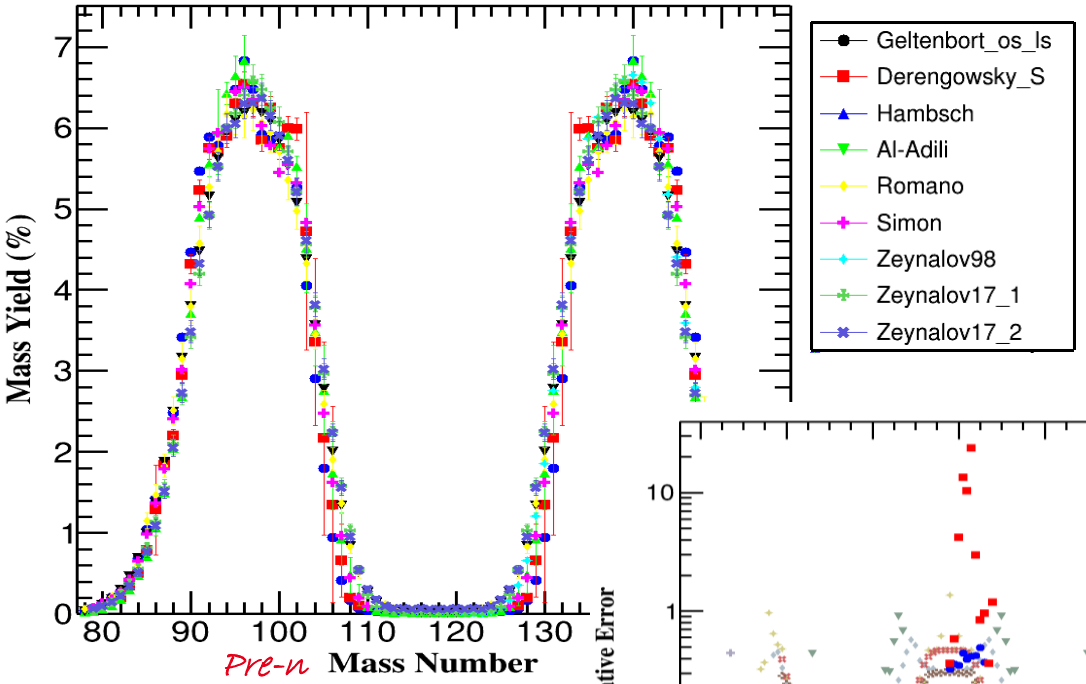
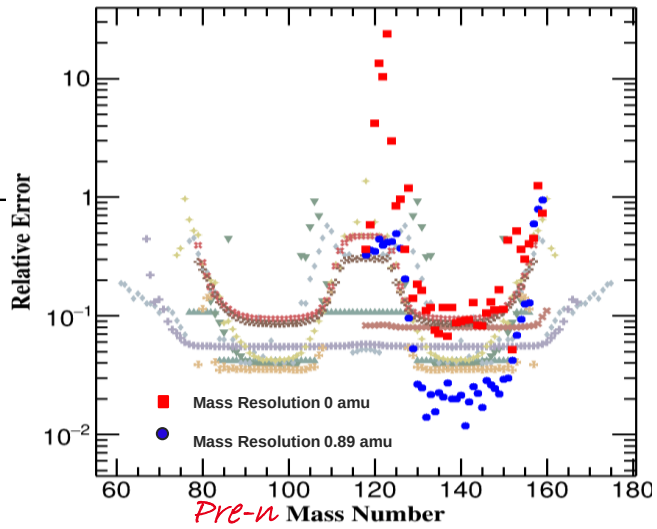
→ A. Regonesi et al. ND2025
→ A. Regonesi's PhD (2024-2027)









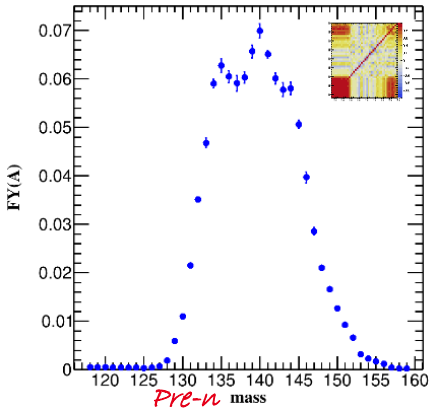


Prompt Neutron emission per mass : e.g. $^{235}U(n_{th},f)$ $\nu(A^*)$

Res Zero

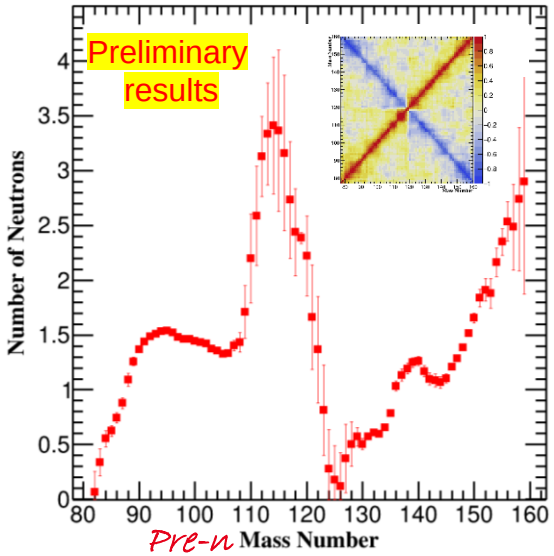
(1) (2) (3) (6) (7) (9) (4) (5) (8) FWHM Mass Resolution

2.09 2.31 2.59 3.67 4.07 5.09 5.65 5.75 5.86 (amu)



Y(A*) Eval

Exp. Limit



Terrel's $\nu(A^*)$ | Y(A*) Exp. Limit

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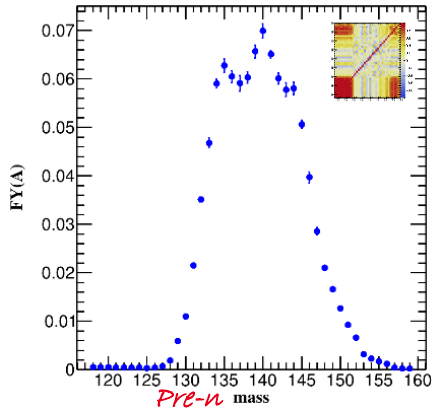
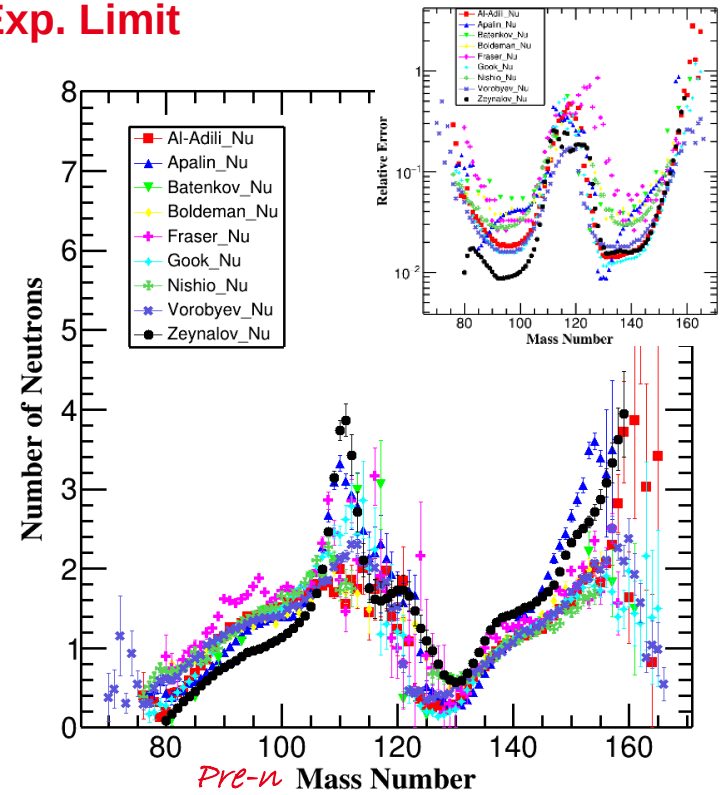
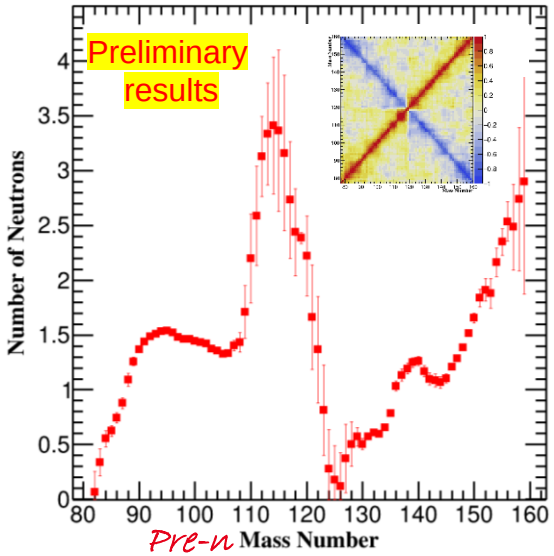
Al Adili et al.



Y(A*) Eval
Exp. Limit



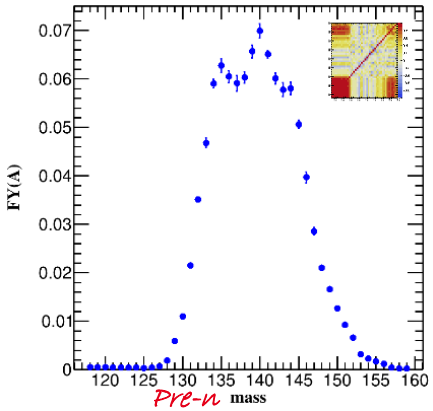


Terrel's $\nu(A^*)$ | Y(A*) Exp. Limit

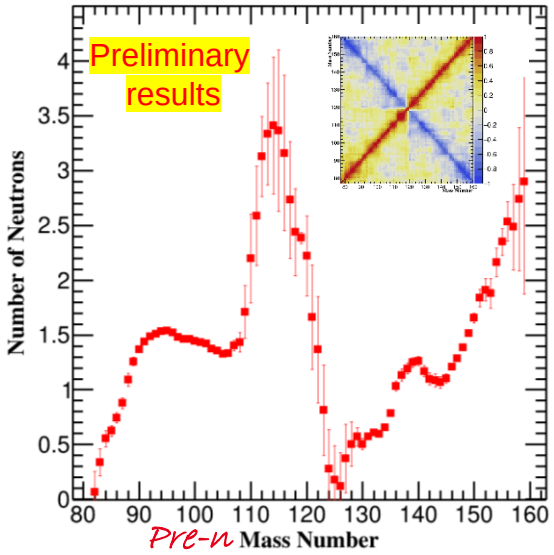
Prompt Neutron emission per mass : e.g. $^{235}U(n_{th},f)$ $\nu(A^*)$

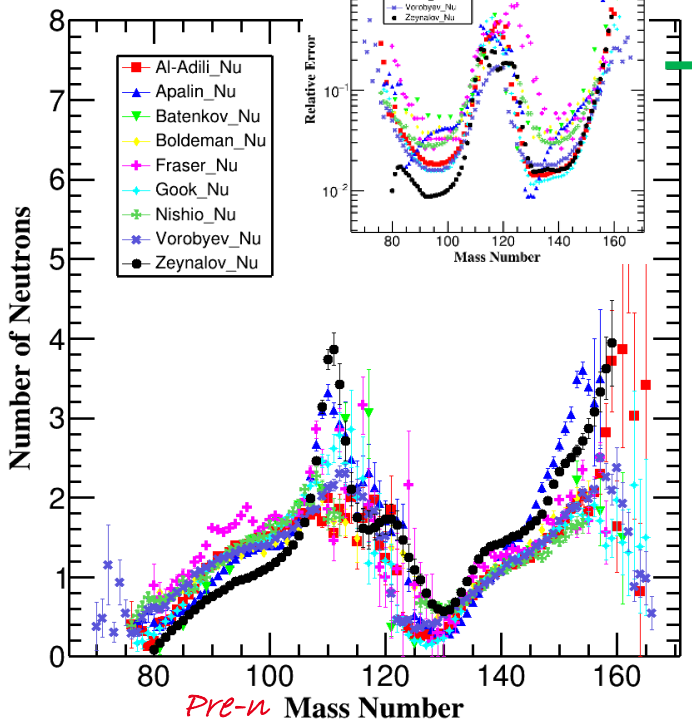
Res Zero

(1) 2.09 | (2) 2.31 | (3) 2.59 | (6) 3.67 | (7) 4.07 | (9) 5.09 | (4) 5.65 | (5) 5.75 | (8) 5.86 — FWHM Mass Resolution (amu)



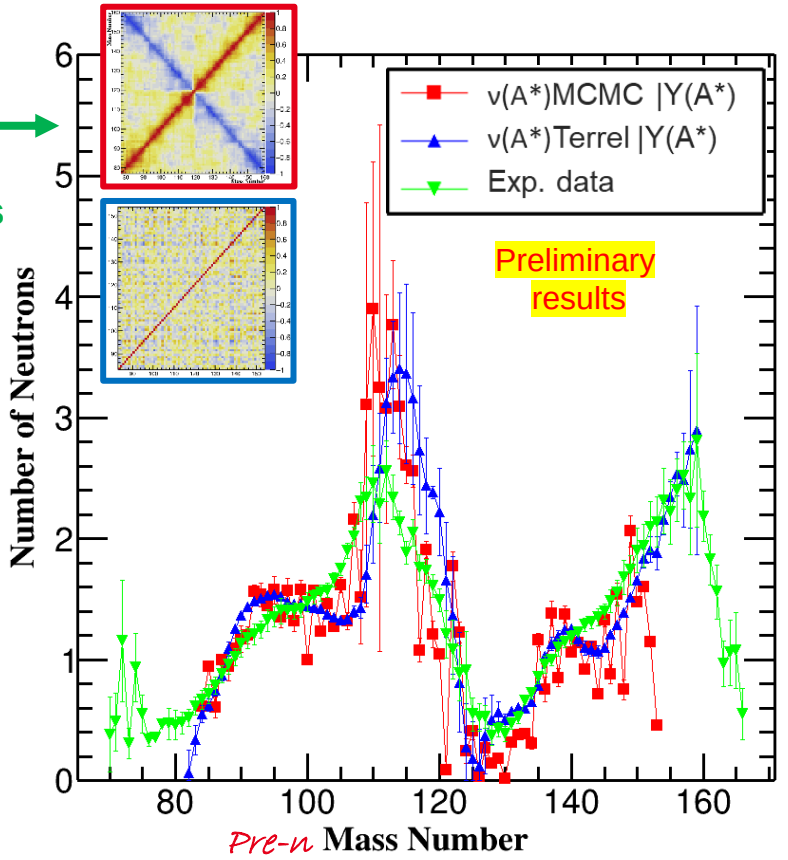
Y(A*) Eval Exp. Limit





Exp. Evaluation (Student PDF)

$\nu(A^*)$ Effective mass resolution

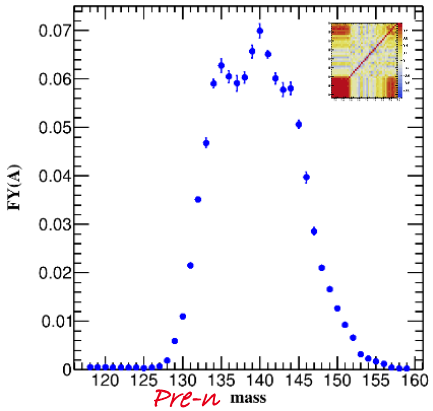


Terrel's $\nu(A^*)$ | Y(A*) Exp. Limit

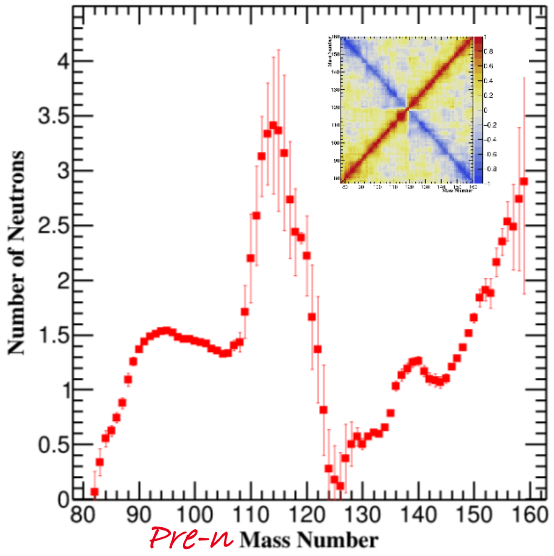
Prompt Neutron emission per mass : e.g. $^{235}U(n_{th},f)$ $\nu(A^*)$

Res Zero

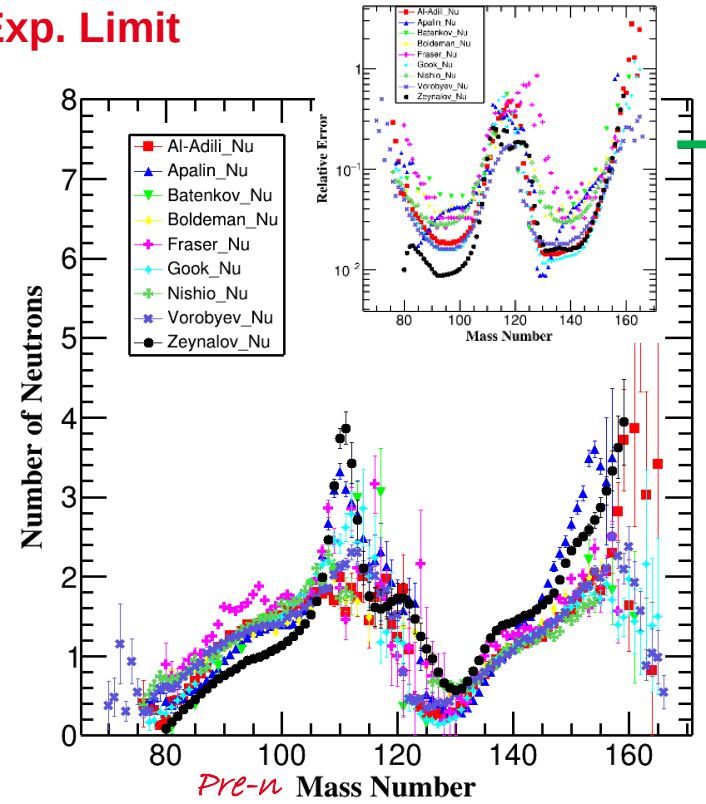
(1) 2.09 | (2) 2.31 | (3) 2.59 | (6) 3.67 | (7) 4.07 | (9) 5.09 | (4) 5.65 | (5) 5.75 | (8) 5.86 — FWHM Mass Resolution (amu)



Y(A*) Eval Exp. Limit



Terrel's $\nu(A^*)$ | Y(A*) Exp. Limit



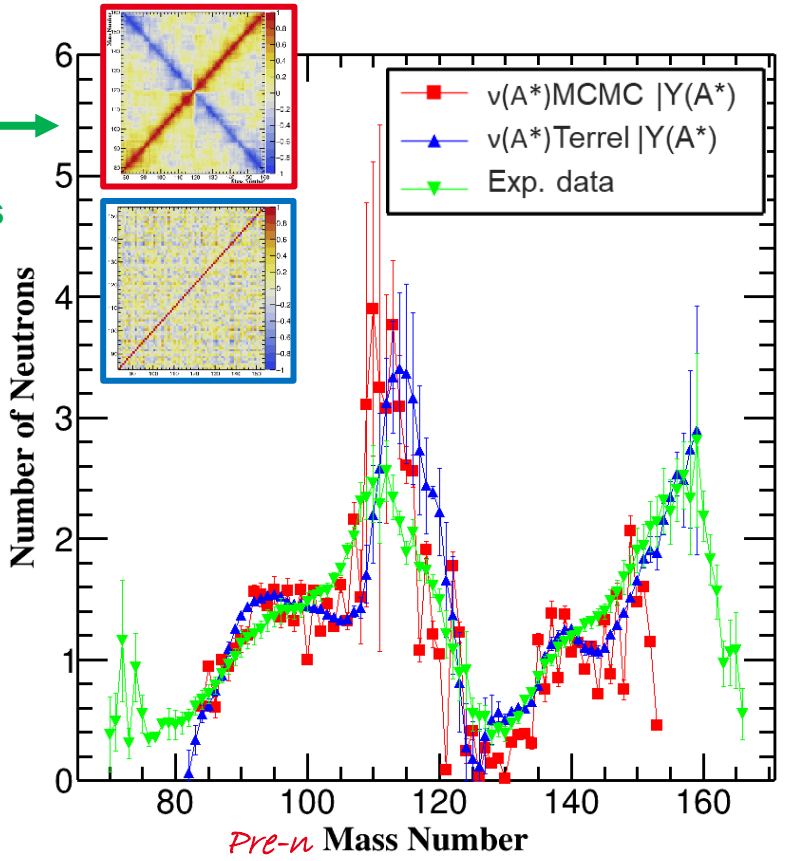
$$Y(A) = \sum_{\nu} Y(A^*)\,P(\nu|A^*), \quad A^* = A + \nu$$

MCMC Evaluation

$\nu(A^*)$ Evaluation Ref. mass resolution → (4) Al Adili et al.

Exp. Evaluation (Student PDF)

$\nu(A^*)$ Effective mass resolution



Prompt Neutron emission per mass : e.g. $^{235}U(n_{th},f)$ $\nu(A^*)$

→ A. Regonesi's PhD (2024-2027)

$Y(A)$
Resolved

$Y(A^*)$
Best Exp.
Resolution 2.09 u

$\{Y, \nu\}$ (A^*)
Best Exp.
Resolution

$Y(A^*)$?
$\nu(A^*)$?

Prompt Neutron emission per mass : e.g. $^{235}U(n_{th},f)$ $\nu(A^*)$

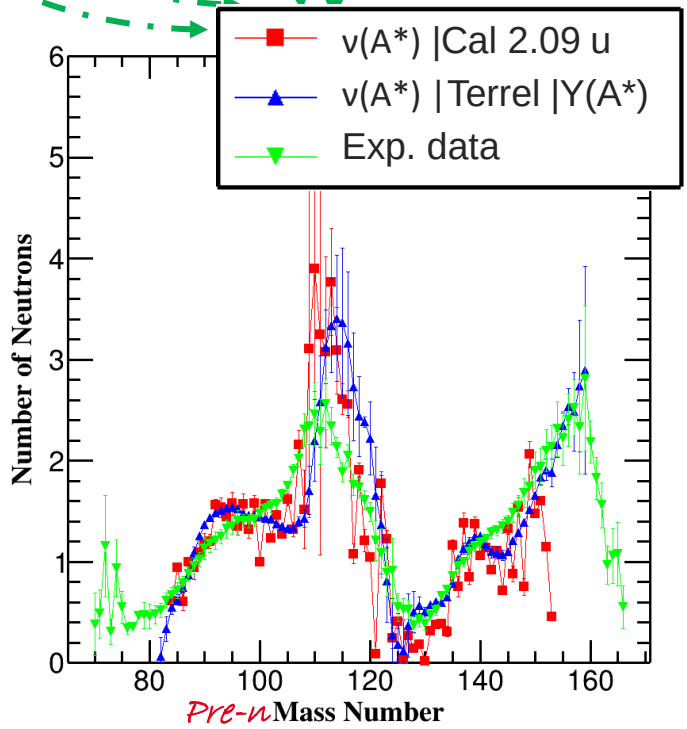
→ A. Regonesi's PhD (2024-2027)

$Y(A)$
Resolved

$Y(A^*)$
Best Exp.
Resolution 2.09 u

$\{Y,\nu\}(A^*)$
Best Exp.
Resolution

$Y(A^*)$?
$\nu(A^*)$?



$\nu(A^*)$ Effective mass resolution

Prompt Neutron emission per mass : e.g. $^{235}U(n_{th},f)$ $\nu(A^*)$

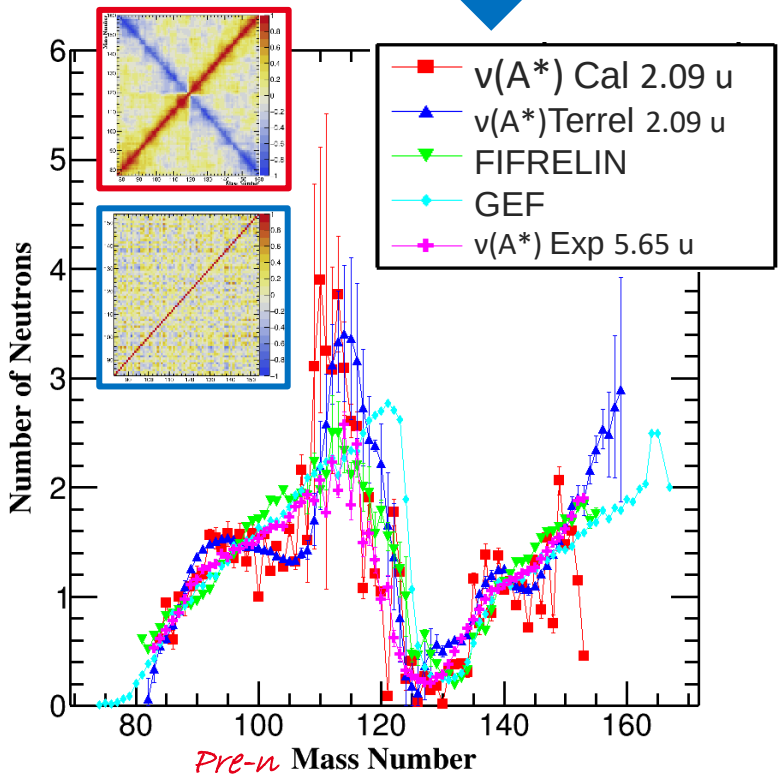
→ A. Regonesi's PhD (2024-2027)

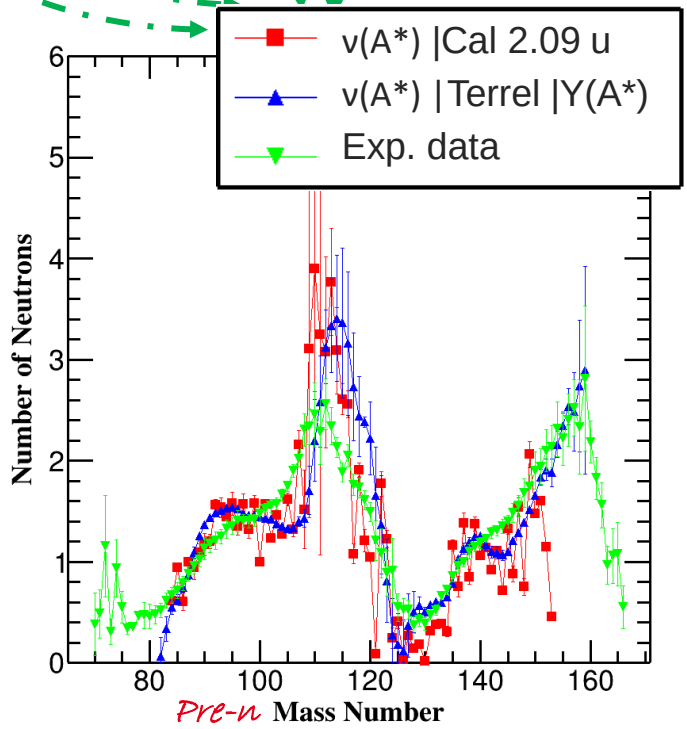
$Y(A)$
Resolved

$Y(A^*)$
Best Exp.
Resolution 2.09 u

$\{Y,\nu\}(A^*)$
Best Exp.
Resolution

$Y(A^*)$?
$\nu(A^*)$?





Terrel's $\nu(A^*)$ | Y(A*) Exp. Limit (2.09 u)

$\nu(A^*)$ Effective mass resolution

Prompt Neutron emission per mass : e.g. $^{235}U(n_{th},f)$ $\nu(A^*)$

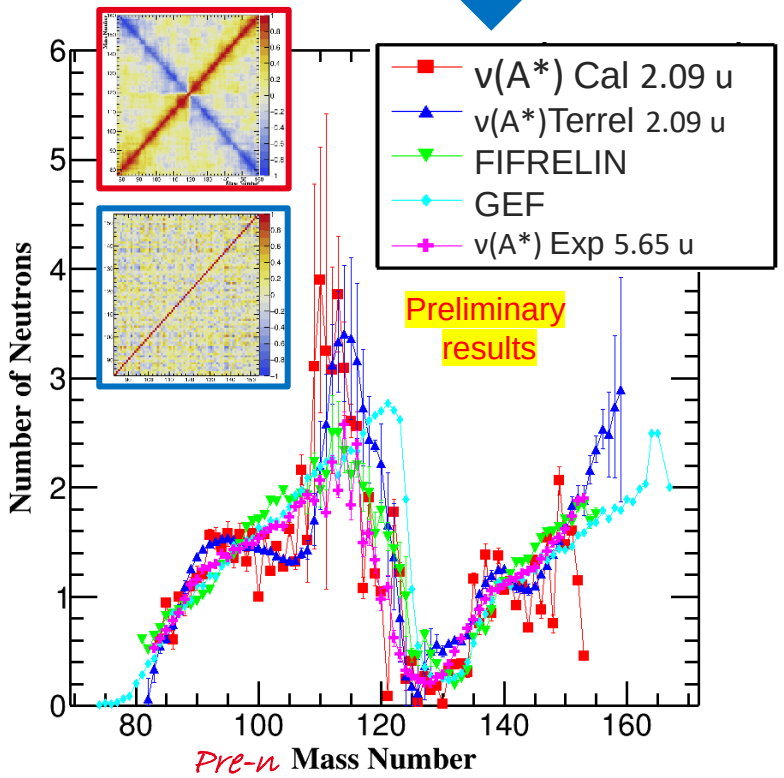
→ A. Regonesi's PhD (2024-2027)

$Y(A)$
Resolved

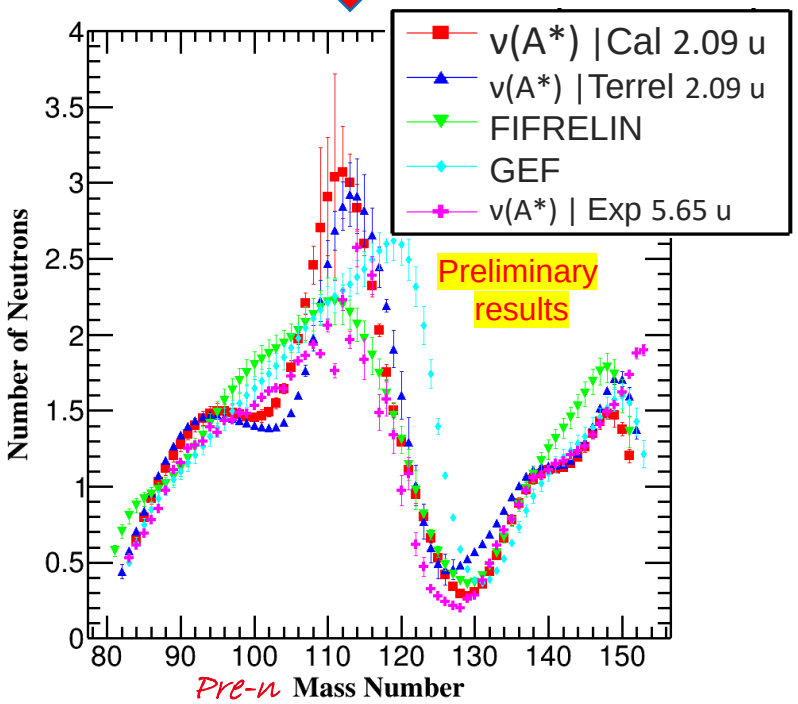
$Y(A^*)$
Best Exp.
Resolution 2.09 u

$\{Y,\nu\}(A^*)$
Best Exp.
Resolution

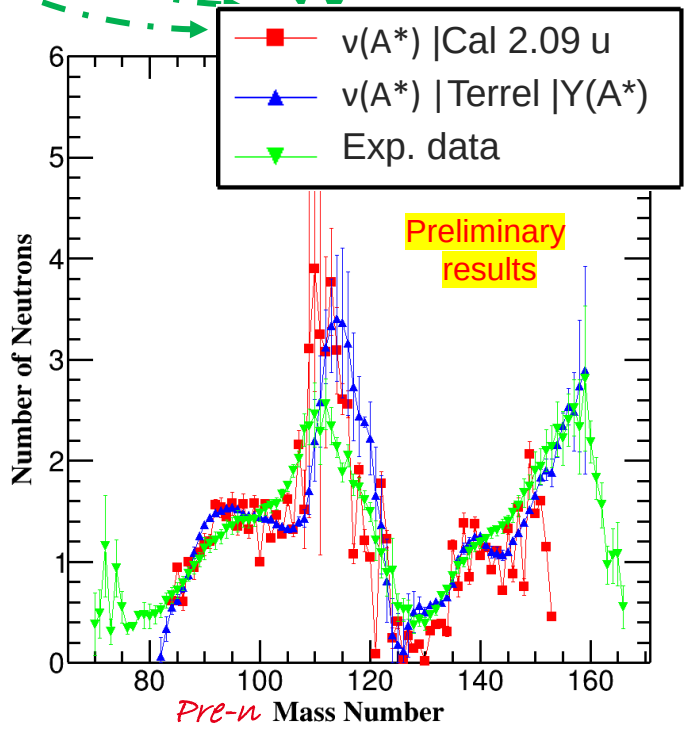
$Y(A^*)$?
$\nu(A^*)$?



Terrel's $\nu(A^*)$ | Y(A*) Exp. Limit (2.09 u)



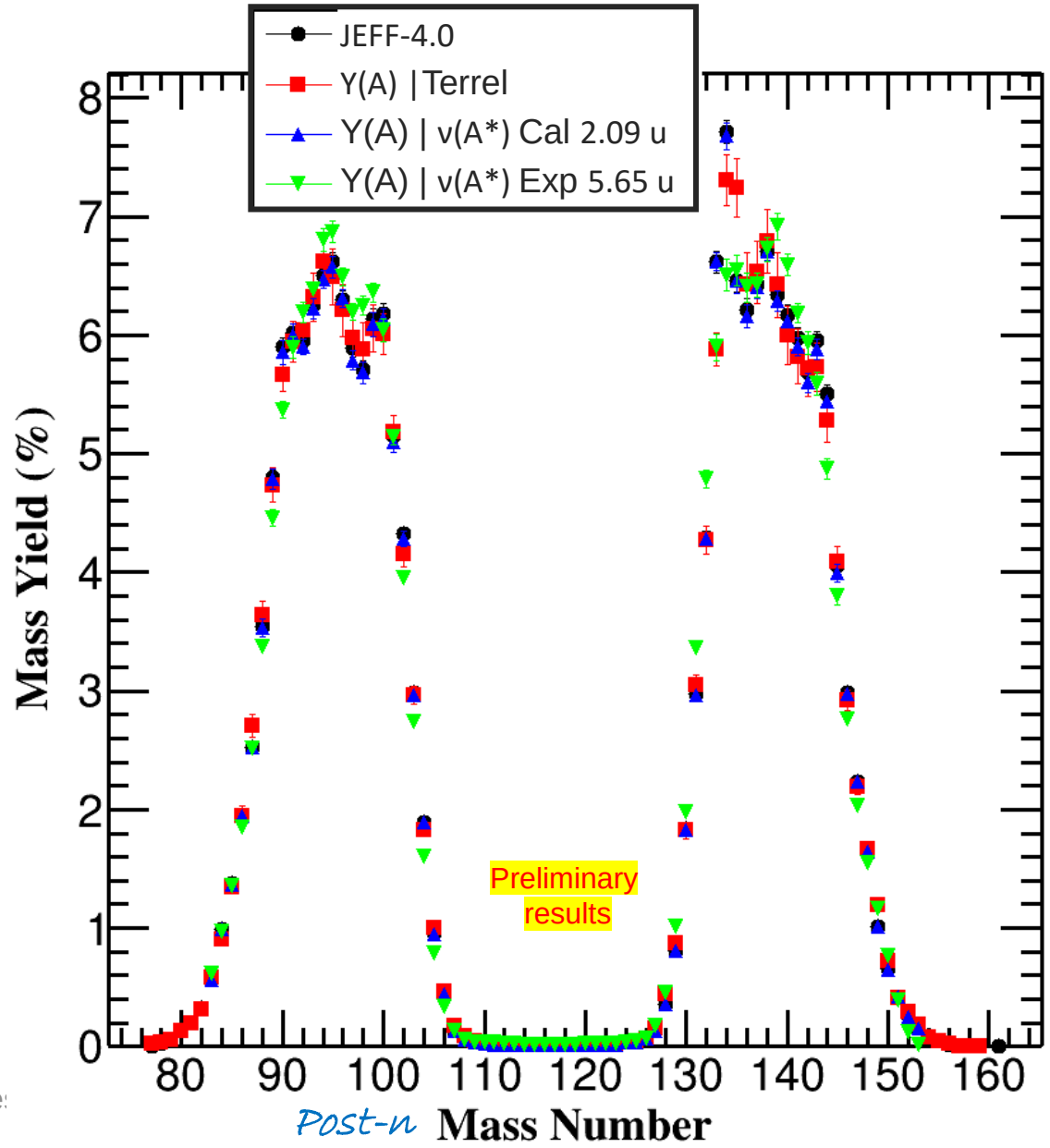
$\nu(A^*)$ Evaluation
FWHM 5.65 u



$\nu(A^*)$ Effective mass resolution

Post-neutron mass yields : consistency test e.g. $^{235}U(n_{th},f)$ $Y(A)$

→ A. Regonesi's PhD (2024-2027)



$\nu(A^*|\text{TERRELL})$ → Pvalue ≈ 0

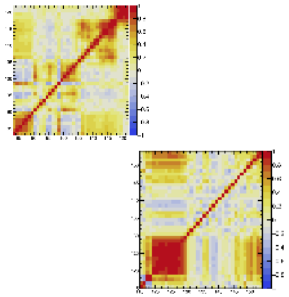
$\nu(A^*|$ Exp 5.65 u) → Pvalue ≈ 0

$\nu(A^*|$ Cal 2.09 u) → L → Pvalue = 22.6%; H → Pvalue = 7.2%

$\nu(A^*|$ Cal 2.09 u)

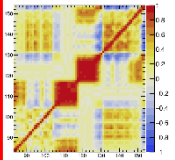
L $\sigma_{gauss} = 1.08 \pm 0.043$

H $\sigma_{gauss} = 0.76 \pm 0.01$



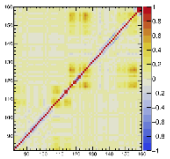
$\nu(A^*|$ Exp 5.65 u)

$\sigma_{gauss} = 0.91 \pm 0.06$

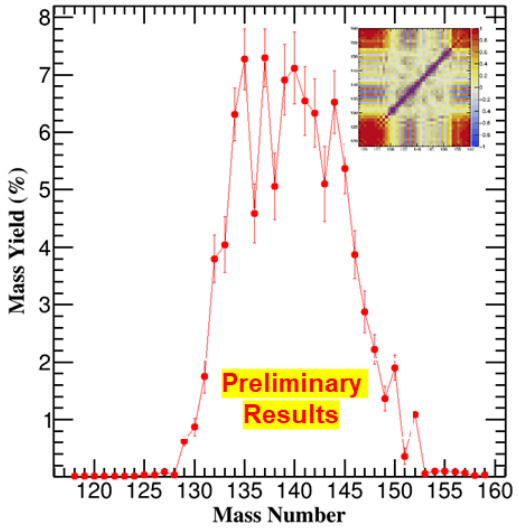


$\nu(A^*|\text{TERRELL})$

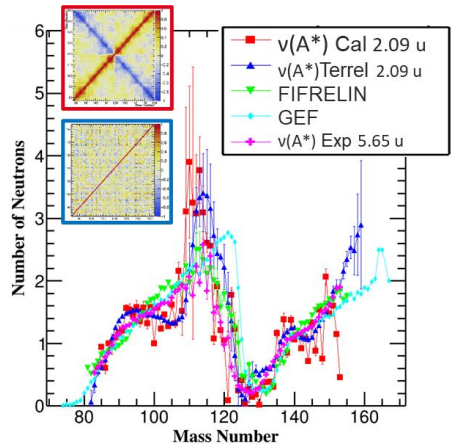
$\sigma_{gauss} = 0.57 \pm 0.055$

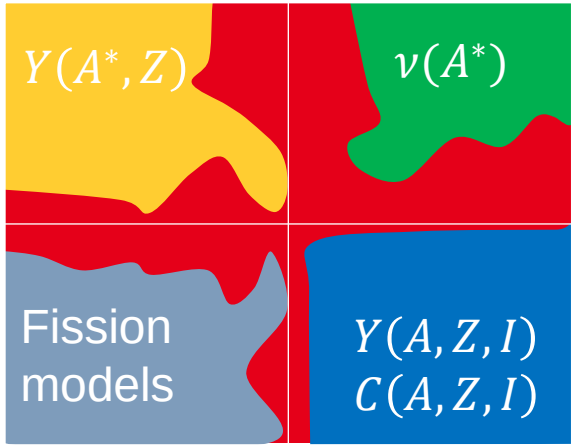


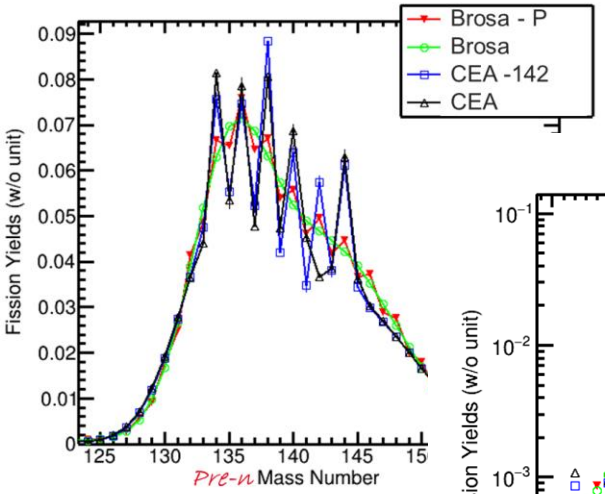
Conclusion & perspectives

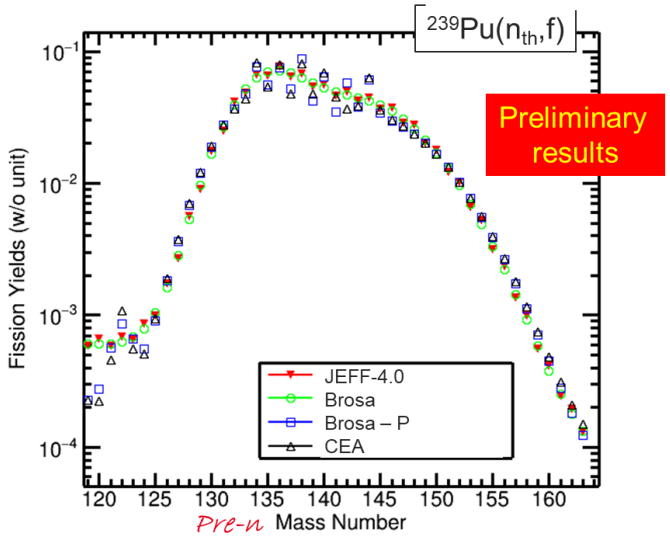


1st - unblurring
2nd - Biases
3rd - Accuracy

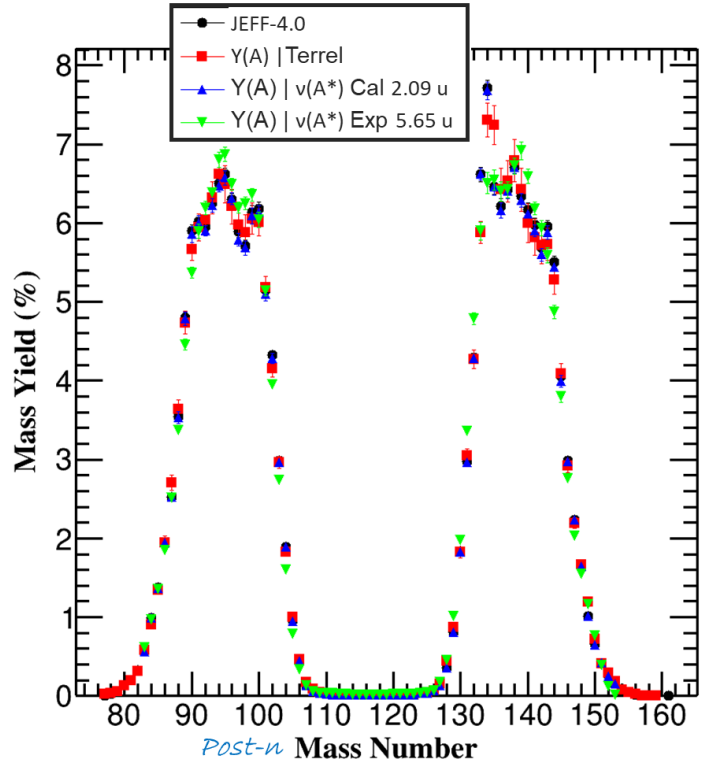








1st - Accuracy
2nd - Biases

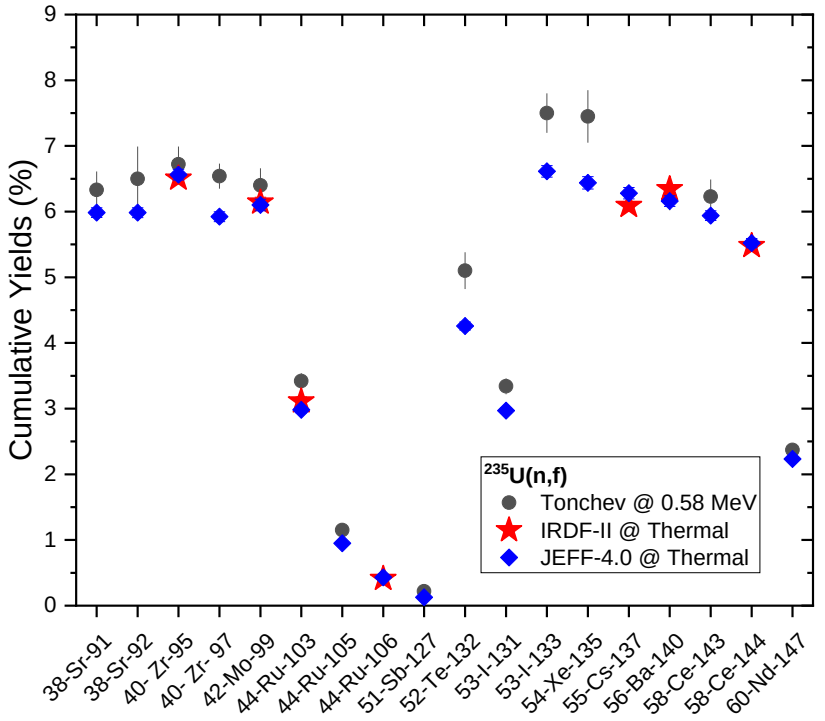


Conclusion & perspectives

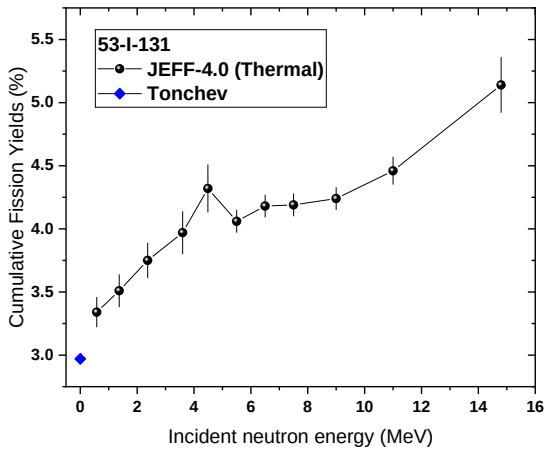
Program for the next Decade :

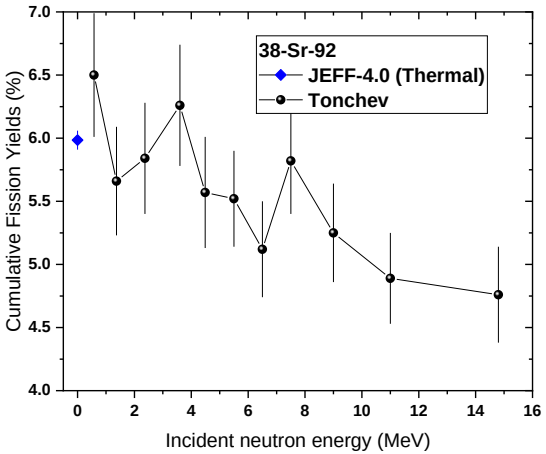
- Complete the (n_{th},f) FY evaluations
- Develop methodology of Evaluation from pre-n observable to PIE
- Adjust phenomenological models considering :
  - correlation matrices at all steps to propagate uncertainties
  - default model to estimate the biases
  - statistical tests to validate the uncertainty 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)





N. Teixeira-Rua, A. Regonesi, G. Kessedjian, S. M. Cheikh, O. Serot, A. Chebboubi, D. Bernard, O. Litaize

CEA, DES, IRESNE, DER, SPRC, LEPh, Cadarache center, F-13108 Saint Paul lez Durance, France

Thank you for your attention

jefdoc-1902
jefdoc-1982
jefdoc-2007
jefdoc-2038
jefdoc-2056
jefdoc-2027 - B. Voirin, G. Kessedjian et al, EPJ N - Nuclear Sciences & Technologies, EDP Sciences, 4, pp.26 (2018)
jefdoc-2203 - G. Kessedjian, S.-M. Cheikh et al., FPY 2019, Santa Fe, EPJ Web of Conferences 242, 05001 (2020)
jefdoc-2204 - S.-M. Cheikh, G. Kessedjian et al., Covariance Workshop 2022, Tokyo, Japan, EPJ W of Conferences 281, 00023 (2023)
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jefdoc-2207 - S.-M. Cheikh, G. Kessedjian et al., M&C2023 conference, Niagara Falls, Canada (2023)
jefdoc-2247 - S.-M. Cheikh, G. Kessedjian et al., M&C2023 proceedings
jefdoc-2295 - S-M Cheikh, G. Kessedjian et al., NSE 2024, 1–14. https://doi.org/10.1080/00295639.2024.2347693
jefdoc-2296 - S.-M. Cheikh, PhD thesis, UGA, 18 Oct. 2023
jefdoc-2370 - S.-M. Cheikh, G. Kessedjian et al., Eur. Phys. J. A, 60 11 (2024) 222
jefdoc-2371 - G. Kessedjian et al, ND 2025, Madrid
jefdoc-2372 - CRP IAEA on Fission Yields 2020-2024, submitted
jefdoc-2416 - JEFF-4.0 library article, on going
jefdoc-2457 - JEFF-4.0 Fission yields evaluations, on going
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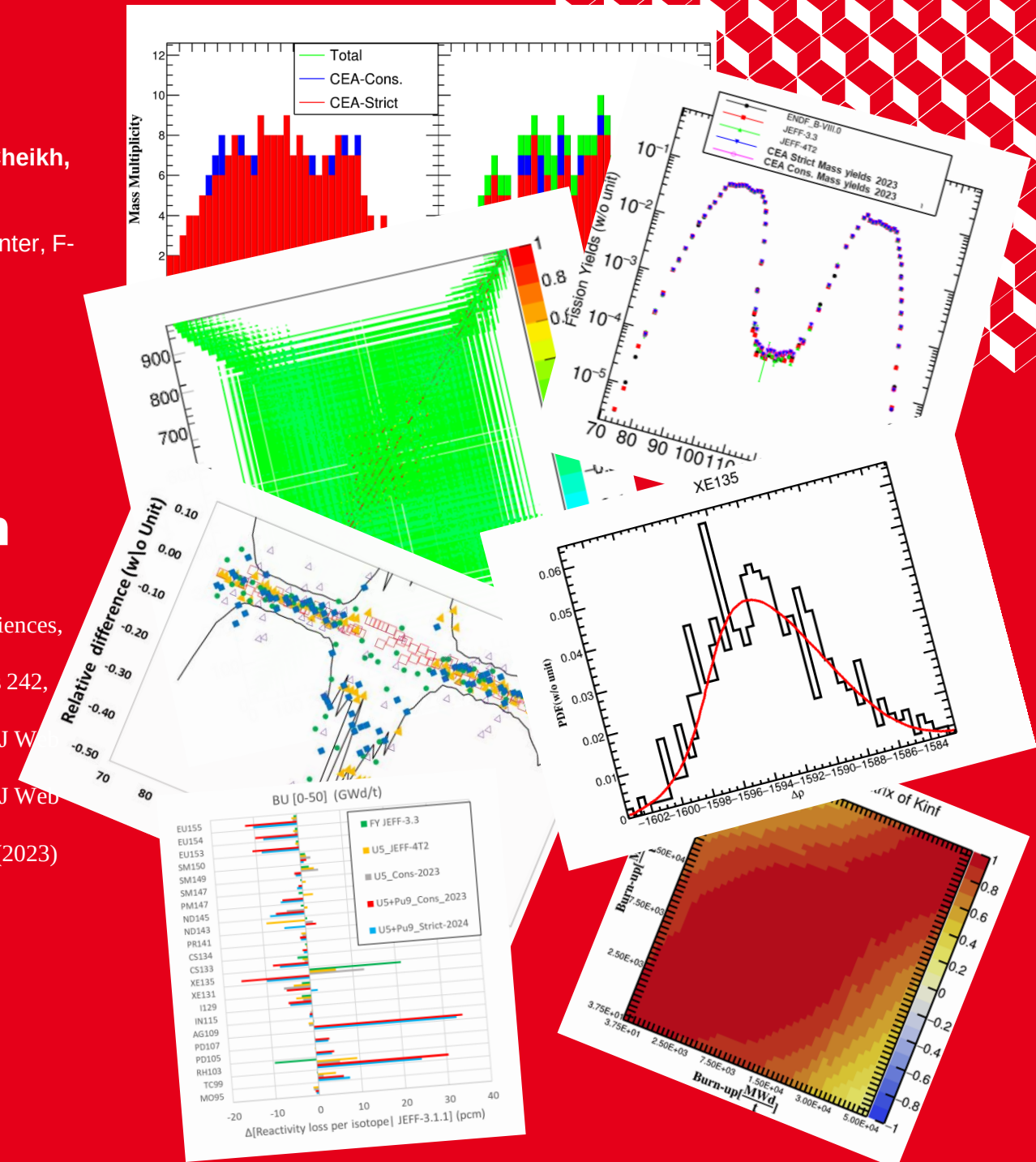
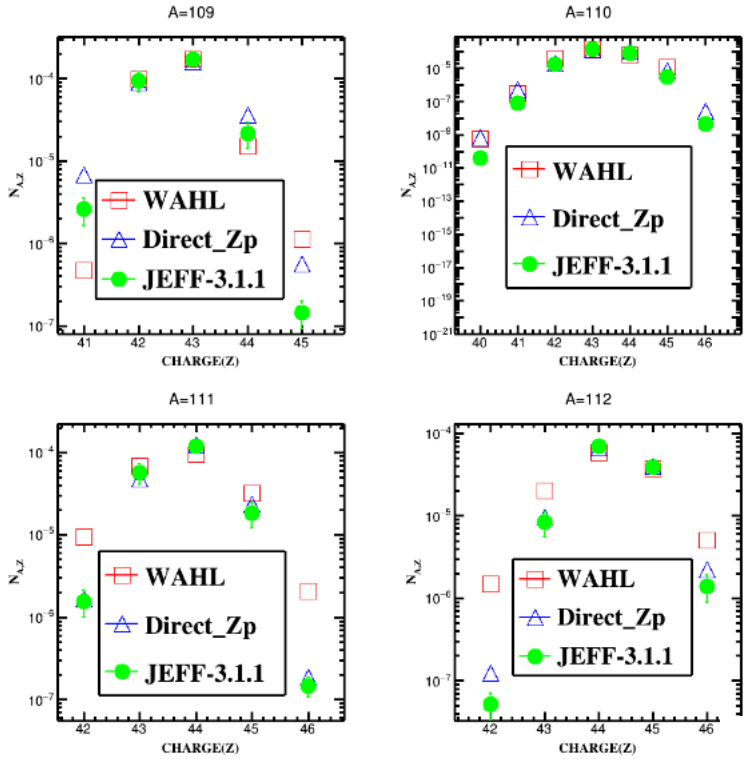


S-M. Cheikh, PhD thesis (2023)
S.-M. Cheikh, G. Kessedjian et al., Eur. Phys. J. A, 60 11 (2024) 222



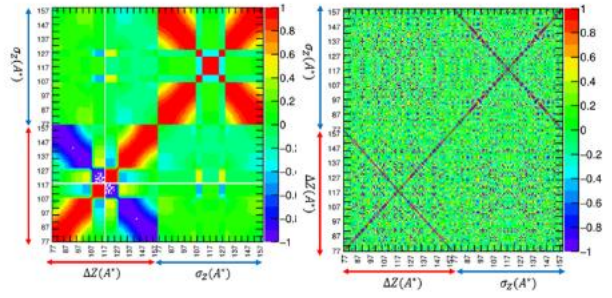
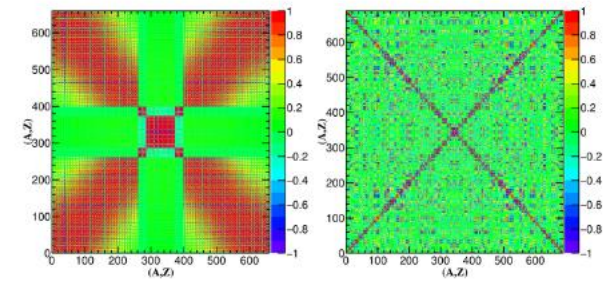
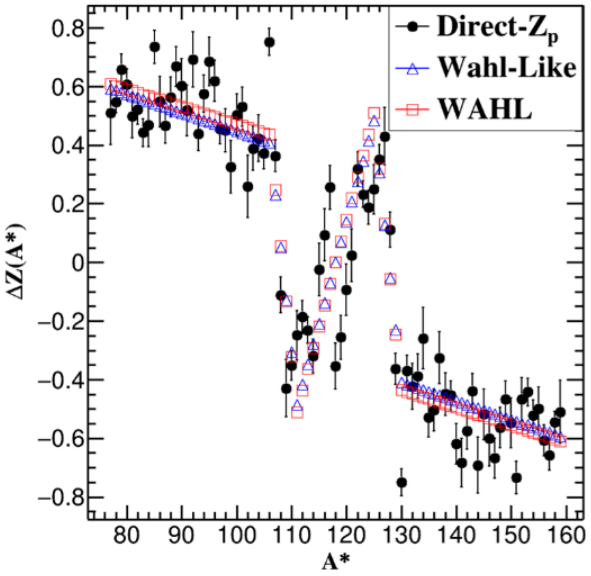
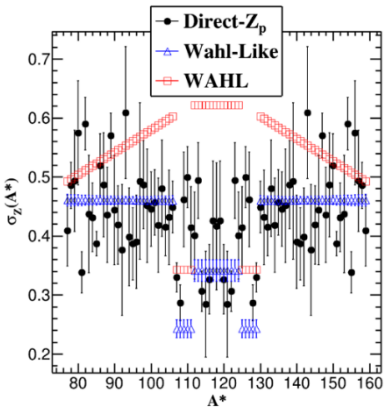
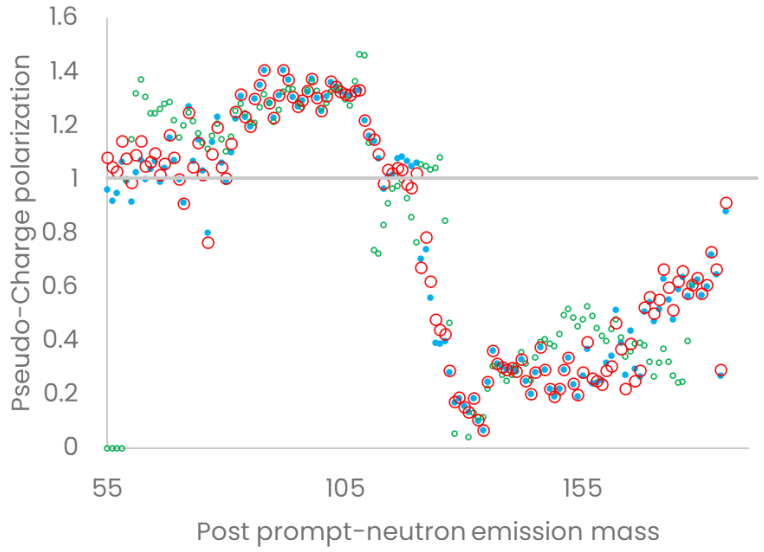


FIGURE 5.26 – (à gauche) la matrice de corrélations des paramètres de 'Wahl-like'. (à droite) la matrice de corrélations des paramètres de l'approche 'direct-Zp' pour l'^{235}U(n_{th},f).









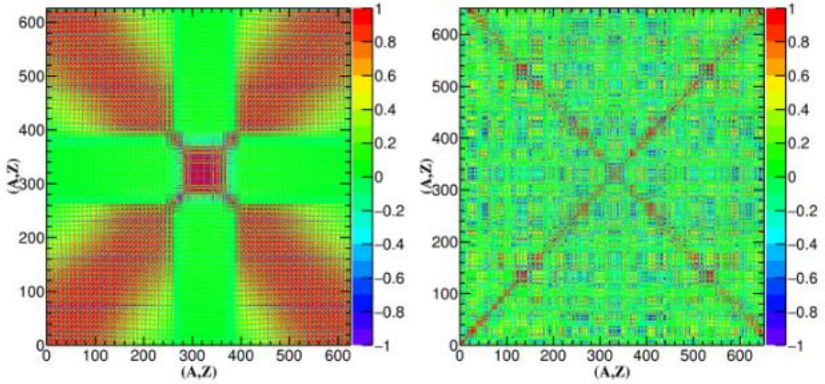


FIGURE 5.29 – Matrices de corrélations des rendements de fission post-émission de neutrons basées sur l'approche 'Wahl-like' (à gauche) et l'approche 'directe-Zp' (à droite) pour l'^{235}U(n_{th},f). Les axes représentent les indices pour chaque couple (A, Z).

> JEFF-4.0 results obtained

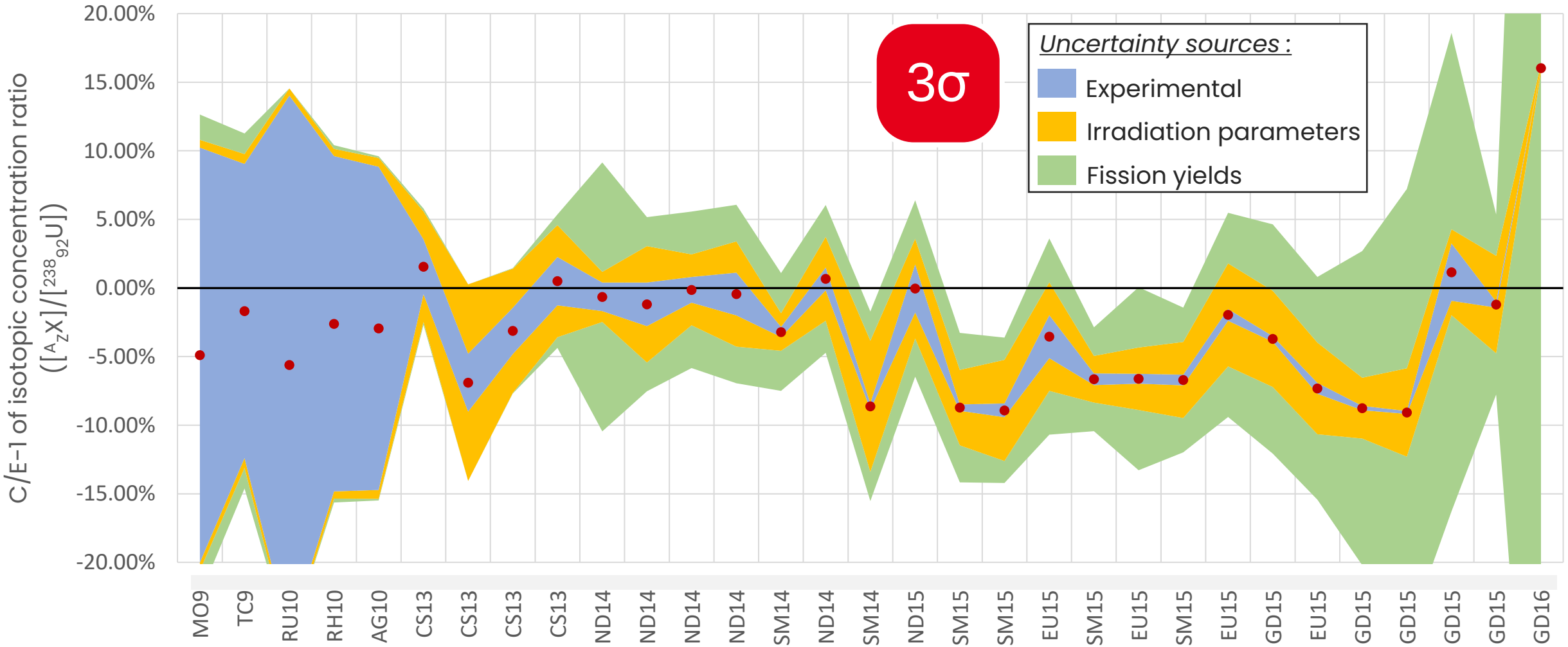
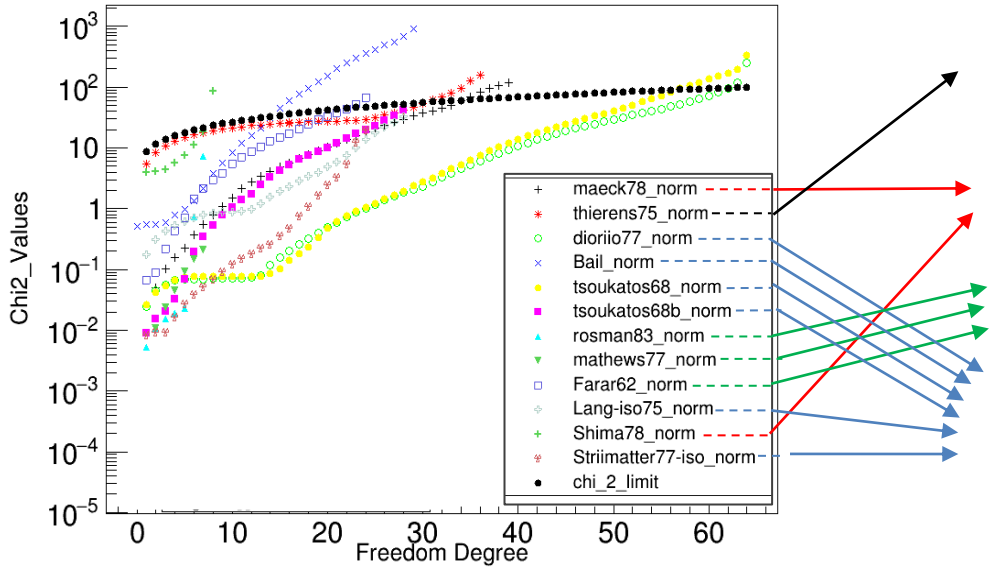


Figure 7. *C/E-1 of the isotopic concentration in the rod for the fission products and the uncertainties propagation with JEFF-4.0*

Gaussian compatibility tests and sorting of data

S-M. Cheikh, PhD thesis (2023)
S.-M. Cheikh, G. Kessedjian et al., Eur. Phys. J. A, 60 11 (2024) 222
IAEA/CRP FY 2020-2024

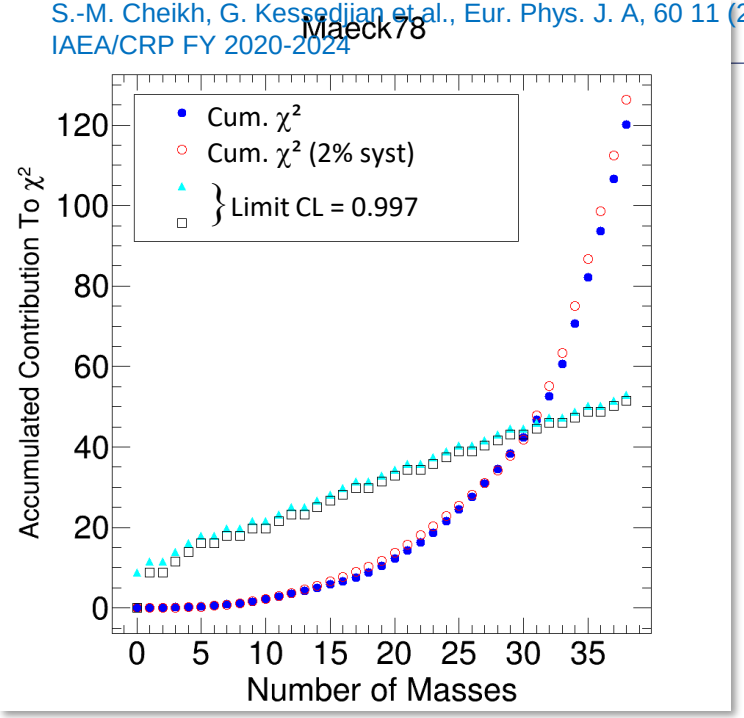


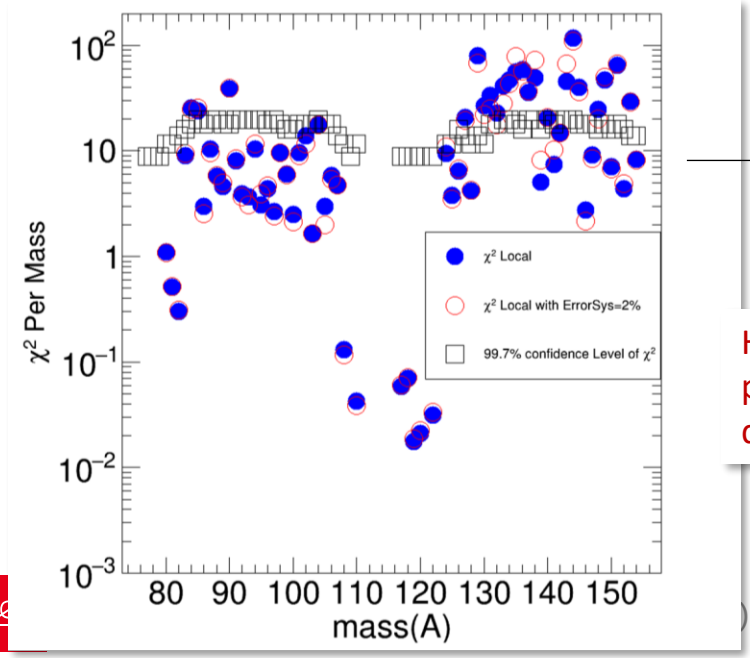
Cumulative yields
Gamma spectrometry

Cumulative yields
Radiochimical separation

Cumulative yields
Magnetic separation

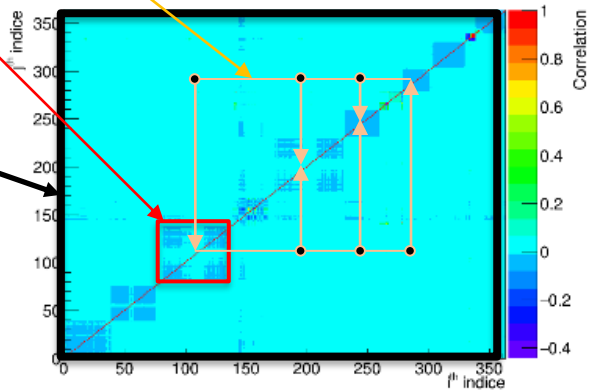
Magnetic spectrometers
HIAWATHA, LOHENGRIN





Heavy mass region presents a maximum of discrepancies

Mass measurement $\chi^2_g(A)$ test
Dataset $\chi^2_g(Dataset)$ test
Global χ^2_g test



Gaussian compatibility tests and sorting of data

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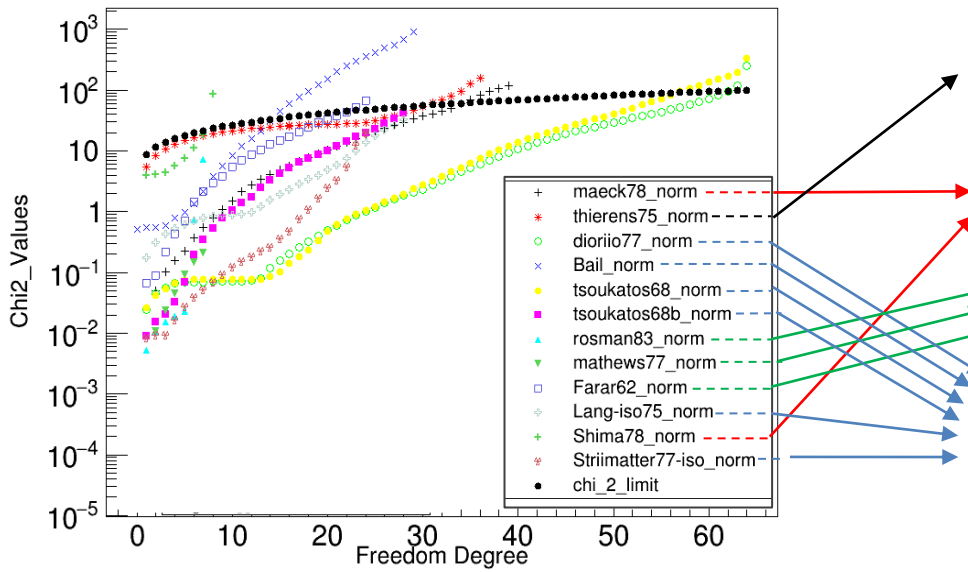
S.-M. Cheikh, G. Kessedjian et al., Eur. Phys. J. A, 60 11 (2024) 222
IAEA/CRP FY 2020-2024

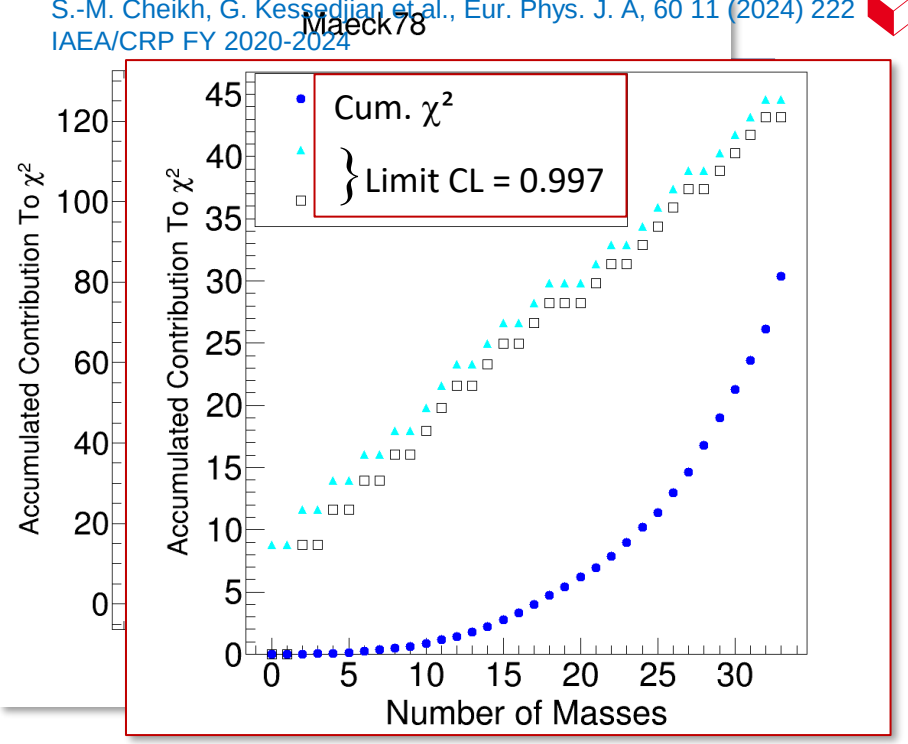


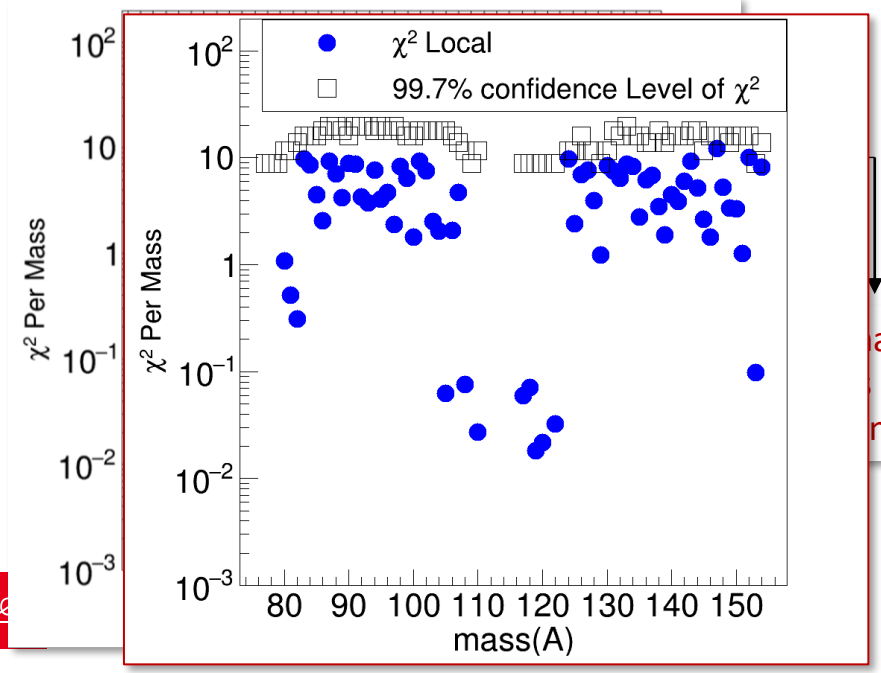
Cumulative yields
Gamma spectrometry

Cumulative yields
Radiochimical separation

Cumulative yields
Magnetic separation

Magnetic spectrometers
HIAWATHA, LOHENGRIN





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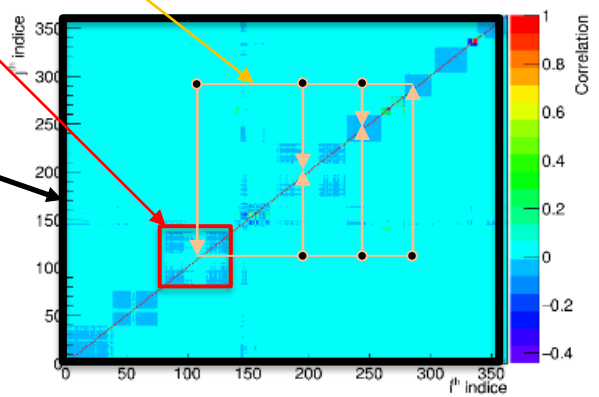
a maximum of
ncies

Mass measurement $\chi^2_g(A)$ test
Dataset $\chi^2_g(Dataset)$ test
Global χ^2_g test



Example of re-interpretation of experimental data: reproducibility

S.M. Cheikh, PhD thesis (2023)
S.-M. Cheikh, G. Kessedjian et al., Eur. Phys. J. A, 60 11 (2024) 222
IAEA/CRP FY 2020-2024

Fickel1959 Chain yields

TABLE IX

Mass spectrometric and isotope dilution data for Cs^{133} produced in the thermal neutron fission of Pu^{239}

Sample	Isotope	Ratio before isotope dilution	No. of atoms of isotope added per g of Pu^{239}, $\times 10^{19}$	Ratio after isotope dilution	Calculated fission yield, atoms $\times 10^{18}$/g Pu^{239}
9	133	1.000	5.938	1.000	16.01
	137	0.9329±0.0089	—	0.1421±0.0008	—
8	133	1.000	7.853	1.000	18.35
	137	0.9322±0.0089	—	0.1765±0.0010	—
3	133	1.000	5.938	1.000	1.145
	137	0.9233±0.0135	—	0.02144±0.00028	—

TABLE X

Mass spectrometric and isotope dilution data for Sr^{90} produced in the thermal neutron fission of Pu^{239}

Sample	Isotope	Ratio before isotope dilution	No. of atoms of isotope added per g of Pu^{239}, $\times 10^{19}$	Ratio after isotope dilution	Calculated fission yield, atoms $\times 10^{18}$/g Pu^{239}
9	88	0.6595±0.0062	1.274	3.307±0.022	—
	90	1.000	—	1.000	4.846
8	88	0.6599±0.0062	1.122	2.593±0.011	—
	90	1.000	—	1.000	5.849
3	88	1.191±0.012	0.6678	1.975±0.035	—
	90	1.000	—	1.000	0.3656

TABLE XIII

Cumulative fission yields of the light fragments in the thermal neutron fission of Pu^{239} normalized to the 6.90% Cs^{133} yield

Isotopic mass	Sample 3		Sample 8		Sample 9		Average % yield
	Atoms $\times 10^{18}$	% yield	Atoms $\times 10^{18}$	% yield	Atoms $\times 10^{18}$	% yield	
72–82							0.59*
Kr^{83}							0.29
Kr^{84}							0.47
Rb^{85} (Kr^{85})			1.460	0.5456	1.262	0.5251	0.535
Kr^{86}							0.75
Rb^{87}			2.487	0.9291	0.2150	0.8942	0.912
Sr^{88}	0.2387	1.438	3.819	1.440	3.164	1.368	1.43
Sr^{89}	0.2868	1.728	4.589	1.726	3.802	1.639	1.71
Sr^{90}	0.3656	2.203	5.849	2.199	4.846	2.089	2.16
Zr^{91}							2.59
Zr^{92}							3.12
Zr^{93}							3.94
Zr^{94}							4.45
Mo^{95} (Zr^{95})			13.37	5.025	11.58	4.991	4.99
Zr^{96}							5.13
Mo^{97}			14.97	5.630	12.97	5.590	5.61
Mo^{98}			15.60	5.861	13.50	5.818	5.84
99							6.44*
Mo^{100}			1.882	7.072	1.629	7.020	7.05
Ru^{101}					13.60	5.860	5.86
Ru^{102}					13.78	5.939	5.94
Ru^{103}					13.06	5.626	5.63
Ru^{104}					13.64	5.877	5.88
105							5.50*
Ru^{106}					1.051	4.530	4.53
107							3.40*
108							2.44*
109							1.50†
110							0.76*
111							0.27†
112							0.10†
113							0.080*
114							0.060*
115							0.041*
116–118							0.122*
Cs^{133}	1.45	6.90	18.35	6.90	16.01	6.90	
Total % yield							100.12

*Interpolated values.
†Radiochemical yields.

Example of re-interpretation of experimental data: reproducibility

Fickel1959 Chain yields

REFAIRE TABLEAU PROPRE

A	Sample 1	Sample 2	Sample 3	Emirical Mean	Empirical Sandard Deviation	Student Standard deviation
83	0.29					
84	0.47					
85	0.5456	0.5251		0.53535	0.0145	4.9%
86	0.75					
87	0.9291	0.8942		0.91165	0.0247	4.9%
88	1.438	1.44	1.368	1.41533333	0.0580	5.4%
89	1.728	1.726	1.639	1.69766667	0.0719	5.6%
90	2.203	2.199	2.089	2.16366667	0.0915	5.6%
91	2.59					
92	3.12					
93	3.94					
94	4.45					
95	5.025	4.991		5.008	0.0240	0.9%
96	5.13					
97	5.63	5.59		5.61	0.0283	0.9%
98	5.861	5.818		5.8395	0.0304	0.9%
100	7.072	7.02		7.046	0.0368	0.9%
101	5.86					
102	5.94					
103	5.63					
104	5.88					
106	4.53					
109	1.5					
111	0.27					
112	0.1					
133	6.9					

Mean Student Unc.	3.34%
Min Student Unc.	0.9%

A	Sample 1	Sample 2	Emirical Mean	Empirical Sandard Deviation	Student Standard deviation
131	3.8	3.73	3.77	0.0495	2.4%
132	5.3	5.21	5.26	0.0636	2.2%
133	6.96	6.83	6.90	0.0919	2.4%
134	7.52	7.39	7.46	0.0919	2.2%
135	7.32	7.17	7.25	0.1061	2.7%
136	6.69	6.56	6.63	0.0919	2.5%
137	6.54	6.42	6.48	0.0849	2.4%
138	0	6.25	6.25		3.0%
140	5.5	5.66	5.58	0.1131	3.7%
142	4.9	5.03	4.97	0.0919	3.4%
143	4.5	4.61	4.56	0.0778	3.1%
144	3.78	3.89	3.84	0.0778	3.7%
145	3.08	3.16	3.12	0.0566	3.3%
146	2.53	2.6	2.57	0.0495	3.5%
147	2.02	1.96	1.99	0.0424	3.9%
148	1.69	1.73	1.71	0.0283	3.0%
149	1.32	1.28	1.30	0.0283	4.0%
150	1	1.03	1.02	0.0212	3.8%
151	0.814	0.79	0.80	0.0170	3.8%
152	0.625	0.606	0.62	0.0134	4.0%
154	0.297	0.289	0.29	0.0057	3.5%

Mean Student Unc.	3.2%
Min Student Unc.	2.2%

Example of re-interpretation of experimental data: experimental correlation matrix

Lowest possible estimation of the correlation matrix

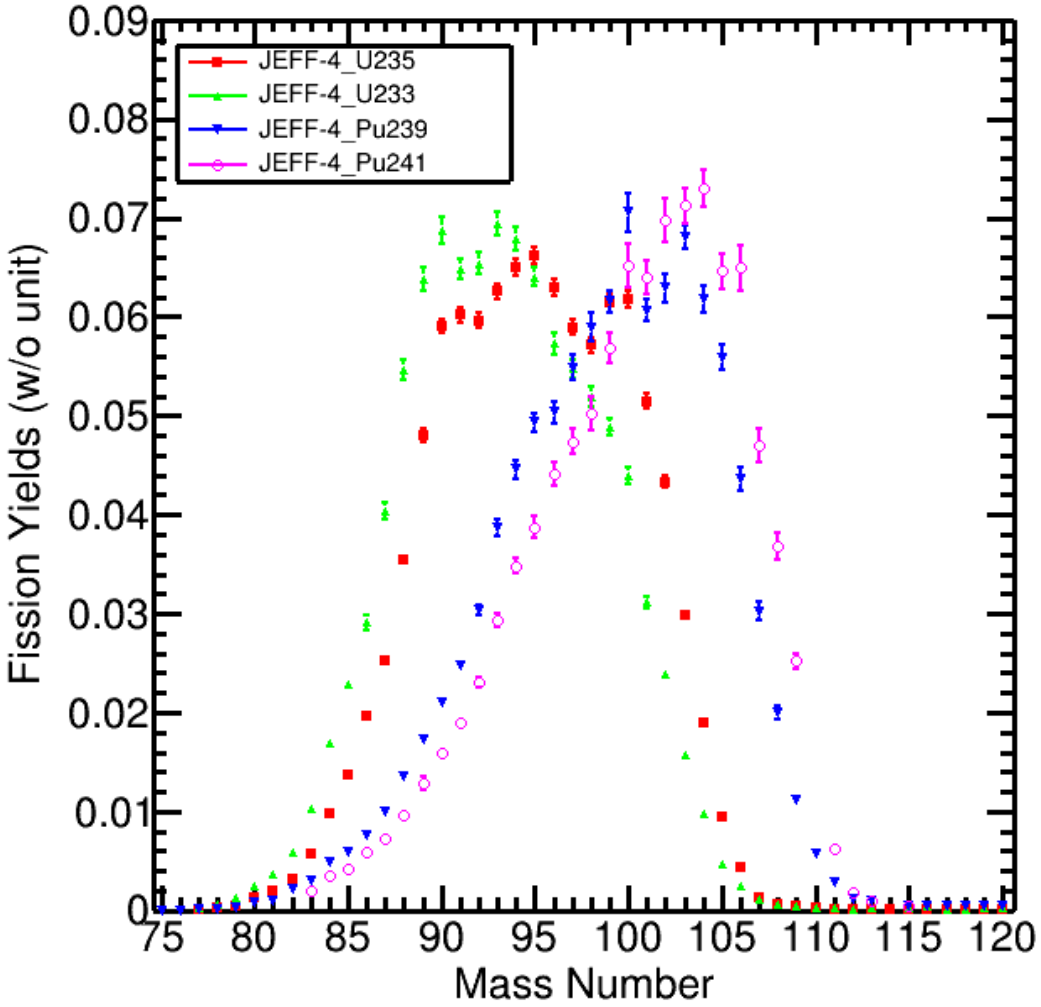
Fickel1959_a

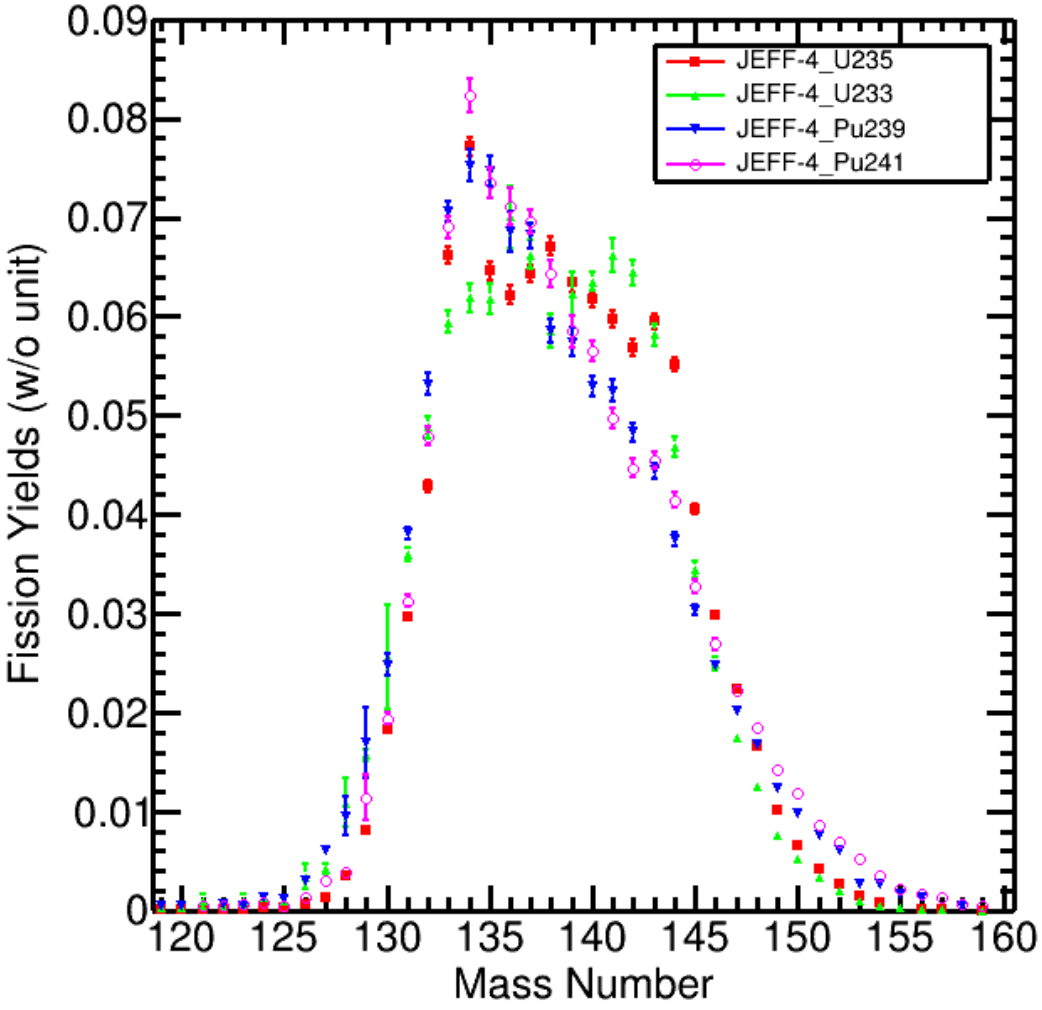
A	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	100	101	102	103	104	106	109	111	112	133	
83	1.000	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.253	1
84	0.064	1.000	0.044	0.064	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.253	0.9
85	0.044	0.044	1.000	0.044	0.871	0.028	0.027	0.027	0.044	0.044	0.044	0.044	0.123	0.044	0.120	0.118	0.118	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.175	0.8
86	0.064	0.064	0.044	1.000	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.253	0.7
87	0.044	0.044	0.871	0.044	1.000	0.028	0.027	0.027	0.044	0.044	0.044	0.044	0.123	0.044	0.120	0.118	0.118	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.175	0.6
88	0.041	0.041	0.028	0.041	0.028	1.000	0.612	0.789	0.041	0.041	0.041	0.041	0.113	0.041	0.110	0.109	0.108	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.160	0.5
89	0.039	0.039	0.027	0.039	0.027	0.612	1.000	0.776	0.039	0.039	0.039	0.039	0.110	0.039	0.107	0.105	0.105	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.155	0.4
90	0.039	0.039	0.027	0.039	0.027	0.789	0.776	1.000	0.039	0.039	0.039	0.039	0.110	0.039	0.107	0.105	0.105	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.155	0.3
91	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	1.000	0.344	0.713	0.482	0.446	0.508	0.175	0.172	0.171	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.253	0.2
92	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.344	1.000	0.482	0.326	0.302	0.344	0.175	0.172	0.171	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.253	0.1
93	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.713	0.482	1.000	0.677	0.626	0.713	0.175	0.172	0.171	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.253	0
94	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.482	0.326	0.677	1.000	0.423	0.482	0.175	0.172	0.171	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.253	-0.1
95	0.179	0.179	0.123	0.179	0.123	0.113	0.110	0.110	0.446	0.302	0.626	0.423	1.000	0.345	0.488	0.241	0.411	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.707	-0.2
96	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.508	0.344	0.713	0.482	0.345	1.000	0.175	0.348	0.595	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.253	-0.3
97	0.175	0.175	0.120	0.175	0.120	0.110	0.107	0.107	0.175	0.175	0.175	0.175	0.488	0.175	1.000	0.467	0.467	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.690	-0.4
98	0.172	0.172	0.118	0.172	0.118	0.109	0.105	0.105	0.172	0.172	0.172	0.172	0.241	0.348	0.467	1.000	0.586	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.678	-0.5
100	0.171	0.171	0.118	0.171	0.118	0.108	0.105	0.105	0.171	0.171	0.171	0.171	0.411	0.595	0.467	0.586	1.000	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.677	-0.6
101	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	1.000	0.701	0.794	0.698	0.363	0.064	0.064	0.064	0.253	-0.7
102	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	0.701	1.000	0.557	0.489	0.254	0.064	0.064	0.064	0.253	-0.8
103	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	0.794	0.557	1.000	0.554	0.288	0.064	0.064	0.064	0.253	-0.9
4	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	0.698	0.489	0.554	1.000	0.253	0.064	0.064	0.064	0.253	-1
4	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	0.363	0.254	0.288	0.253	1.000	0.064	0.064	0.064	0.253	
4	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	0.064	0.064	0.064	0.064	0.064	1.000	0.064	0.064	0.253	
4	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	0.064	0.064	0.064	0.064	0.064	0.064	1.000	0.064	0.253	
4	0.064	0.064	0.044	0.064	0.044	0.041	0.039	0.039	0.064	0.064	0.064	0.064	0.179	0.064	0.175	0.172	0.171	0.064	0.064	0.064	0.064	0.064	0.064	0.064	1.000	0.253	
3	0.253	0.707	0.253	0.690	0.678	0.677	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	1.000	

Fickel1959_b

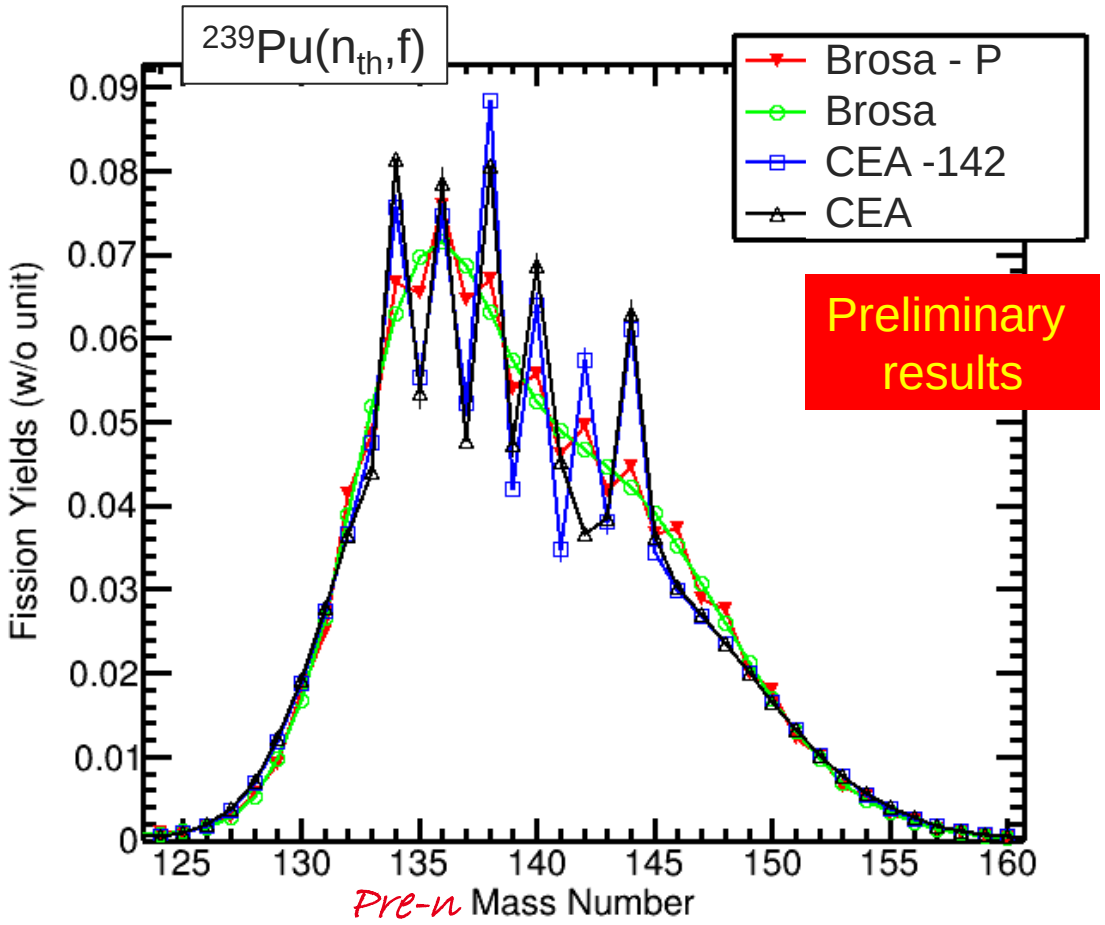
0	131	132	133	134	135	136	137	138	140	142	143	144	145	146	147	148	149	150	151	152	154
131	1.000	0.105	0.772	0.131	0.113	0.118	0.124	0.101	0.084	0.091	0.098	0.083	0.093	0.087	0.080	0.101	0.078	0.081	0.080	0.078	0.087
132	0.105	1.000	0.081	0.141	0.121	0.127	0.134	0.109	0.090	0.098	0.105	0.090	0.100	0.094	0.086	0.108	0.084	0.087	0.086	0.084	0.094
133	0.772	0.081	1.000	0.130	0.111	0.117	0.123	0.100	0.082	0.090	0.097	0.082	0.092	0.086	0.079	0.100	0.077	0.080	0.079	0.077	0.086
134	0.131	0.141	0.130	1.000	0.119	0.493	0.132	0.802	0.088	0.096	0.104	0.088	0.098	0.092	0.084	0.107	0.083	0.086	0.085	0.082	0.092
135	0.113	0.121	0.111	0.119	1.000	0.108	0.113	0.092	0.076	0.083	0.089	0.076	0.084	0.080	0.072	0.092	0.071	0.074	0.073	0.071	0.079
136	0.118	0.127	0.117	0.493	0.108	1.000	0.119	0.615	0.080	0.087	0.093	0.080	0.088	0.083	0.076	0.096	0.074	0.077	0.076	0.074	0.083
137	0.124	0.134	0.123	0.132	0.113	0.119	1.000	0.102	0.084	0.091	0.098	0.084	0.093	0.088	0.080	0.101	0.078	0.081	0.080	0.078	0.088
138	0.101	0.109	0.100	0.802	0.092	0.615	0.102	1.000	0.068	0.074	0.080	0.068	0.076	0.071	0.065	0.082	0.064	0.066	0.065	0.064	0.071
140	0.084	0.090	0.082	0.088	0.076	0.080	0.084	0.068	1.000	0.802	0.669	0.056	0.062	0.059	0.054	0.068	0.053	0.055	0.054	0.052	0.059
142	0.091	0.098	0.090	0.096	0.083	0.087	0.091	0.074	0.802	1.000	0.835	0.061	0.068	0.064	0.058	0.074	0.057	0.059	0.059	0.057	0.064
143	0.098	0.105	0.097	0.104	0.089	0.093	0.098	0.080	0.669	0.835	1.000	0.782	0.787	0.724	0.063	0.682	0.062	0.743	0.063	0.062	0.069
144	0.083	0.090	0.082	0.088	0.076	0.080	0.084	0.068	0.056	0.061	0.782	1.000	0.616	0.566	0.054	0.533	0.053	0.581	0.054	0.052	0.059
145	0.093	0.100	0.092	0.098	0.084	0.088	0.093	0.076	0.062	0.068	0.787	0.616	1.000	0.570	0.060	0.537	0.058	0.585	0.060	0.058	0.065
146	0.087	0.094	0.086	0.092	0.080	0.083	0.088	0.071	0.059	0.064	0.724	0.566	0.570	1.000	0.056	0.494	0.055	0.538	0.057	0.055	0.062
147	0.080	0.086	0.079	0.084	0.072	0.076	0.080	0.065	0.054	0.058	0.063	0.054	0.060	0.056	1.000	0.065	0.520	0.052	0.367	0.410	0.316
148	0.101	0.108	0.100	0.107	0.092	0.096	0.101	0.082	0.068	0.074	0.682	0.533	0.537	0.494	0.065	1.000	0.064	0.506	0.065	0.063	0.071
149	0.078	0.084	0.077	0.083	0.071	0.074	0.078	0.064	0.053	0.057	0.062	0.053	0.058	0.055	0.520	0.064	1.000	0.051	0.660	0.737	0.567
150	0.081	0.087	0.080	0.086	0.074	0.077	0.081	0.066	0.055	0.059	0.743	0.581	0.585	0.538	0.052	0.506	0.051	1.000	0.052	0.051	0.057
151	0.080	0.086	0.079	0.085	0.073	0.076	0.080	0.065	0.054	0.059	0.063	0.054	0.060	0.057	0.367	0.065	0.660	0.052	1.000	0.521	0.401
152	0.078	0.084	0.077	0.082	0.071	0.074	0.078	0.064	0.052	0.057	0.062	0.052	0.058	0.055	0.410	0.063	0.737	0.051	0.521	1.000	0.448
154	0.087	0.094	0.086	0.092	0.079	0.083	0.088	0.071	0.059	0.064	0.069	0.059	0.065	0.062	0.316	0.071	0.567	0.057	0.401	0.448	1.000

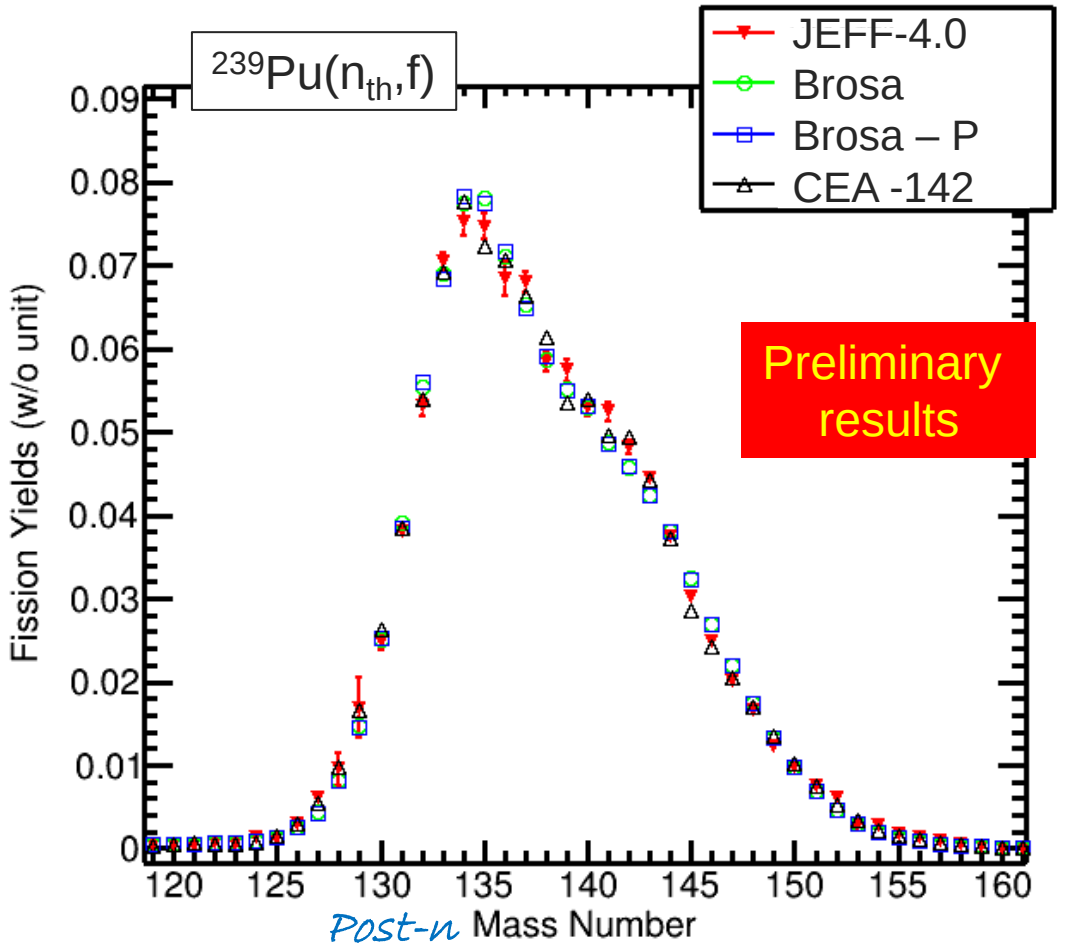
Intercomparison of Y(A)'s : $^{233}U(n_{th},f)$ - $^{235}U(n_{th},f)$ - $^{239}Pu(n_{th},f)$ - $^{241}Pu(n_{th},f)$





Attempt to Y(A) fit assuming deformed shell closure structures : $^{239}Pu(n_{th},f)$

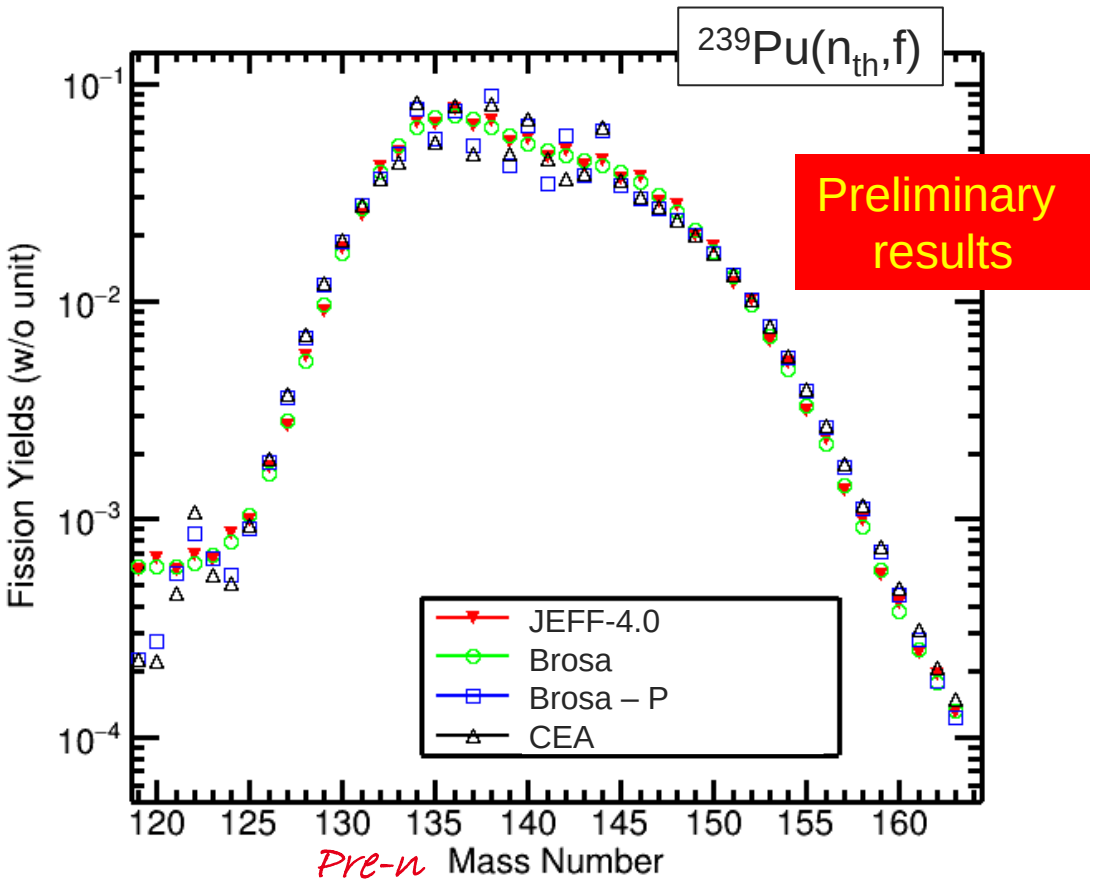


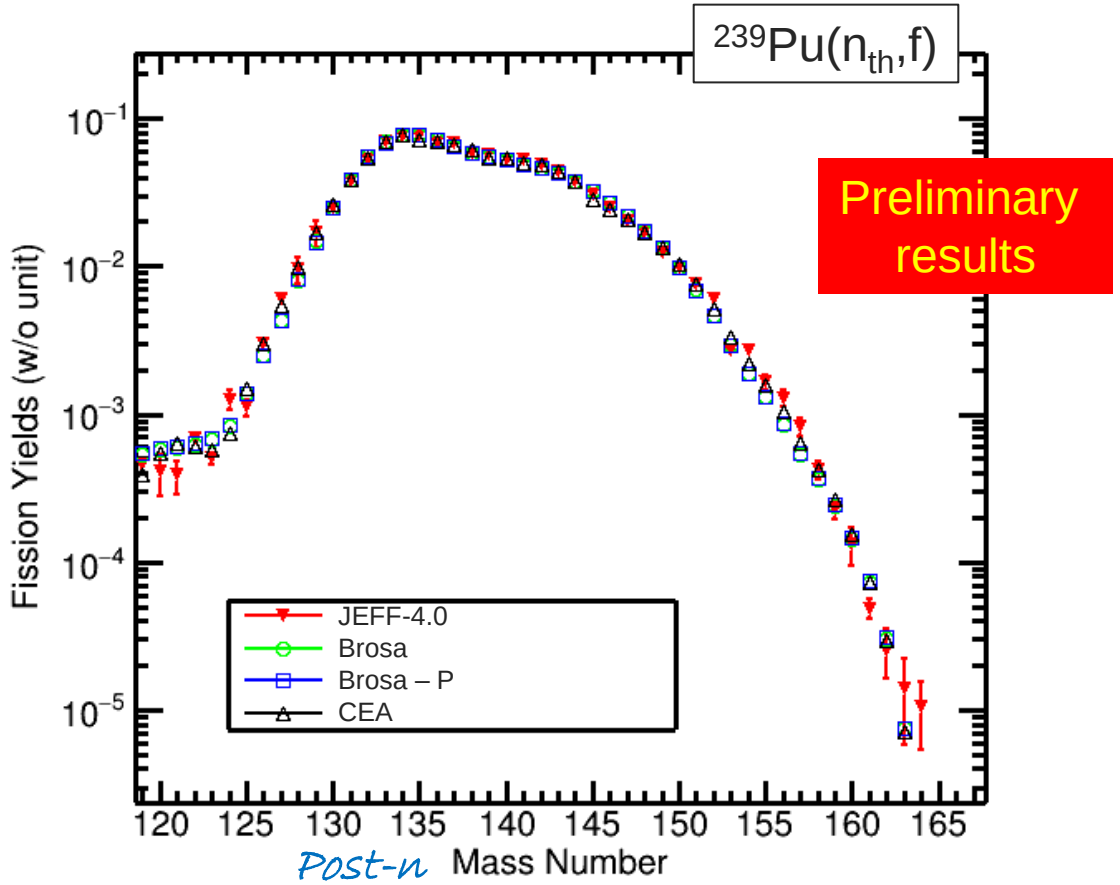


MCMC calculations; but are they validated ?

Best fit with Cea_Model_142, 5000 Step, Chi2 95.02 → P-value ~ 6. 10^{-9}

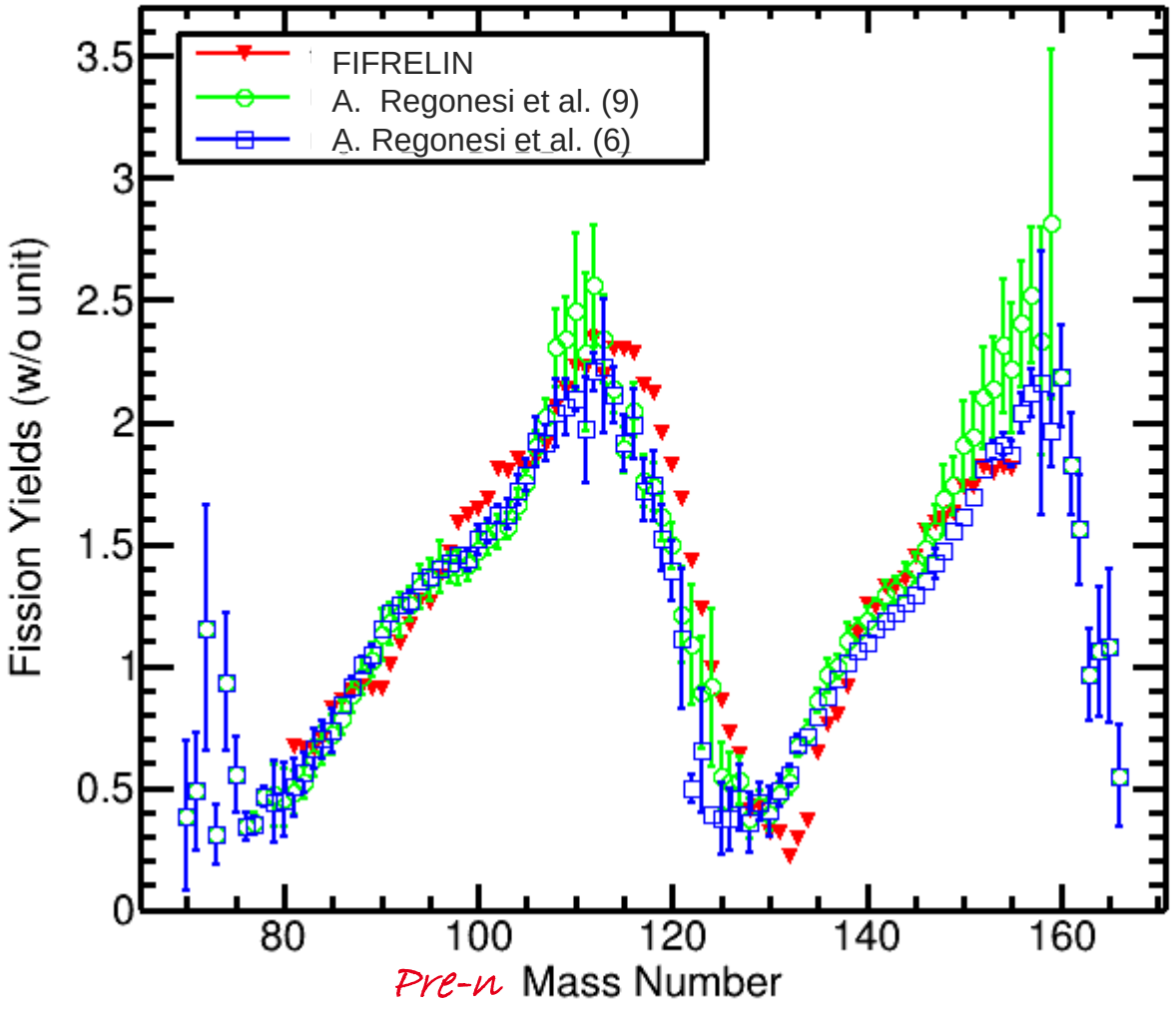
Attempt to Y(A) fit assuming deformed shell closure structures : $^{239}Pu(n_{th},f)$

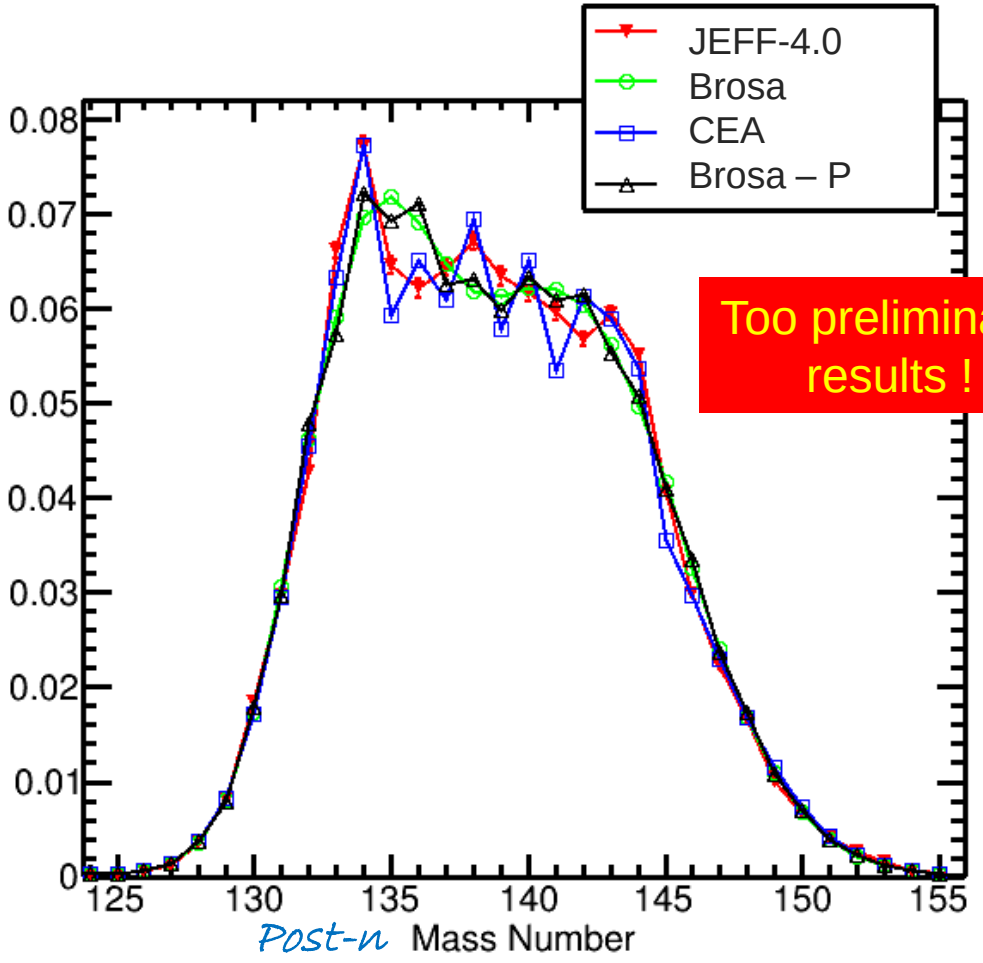




MCMC calculation → Best fit with Cea_Model_142, 5000 Step, Chi2 = 95.02 → P-value ~ 6. 10^{-9} → validated ?

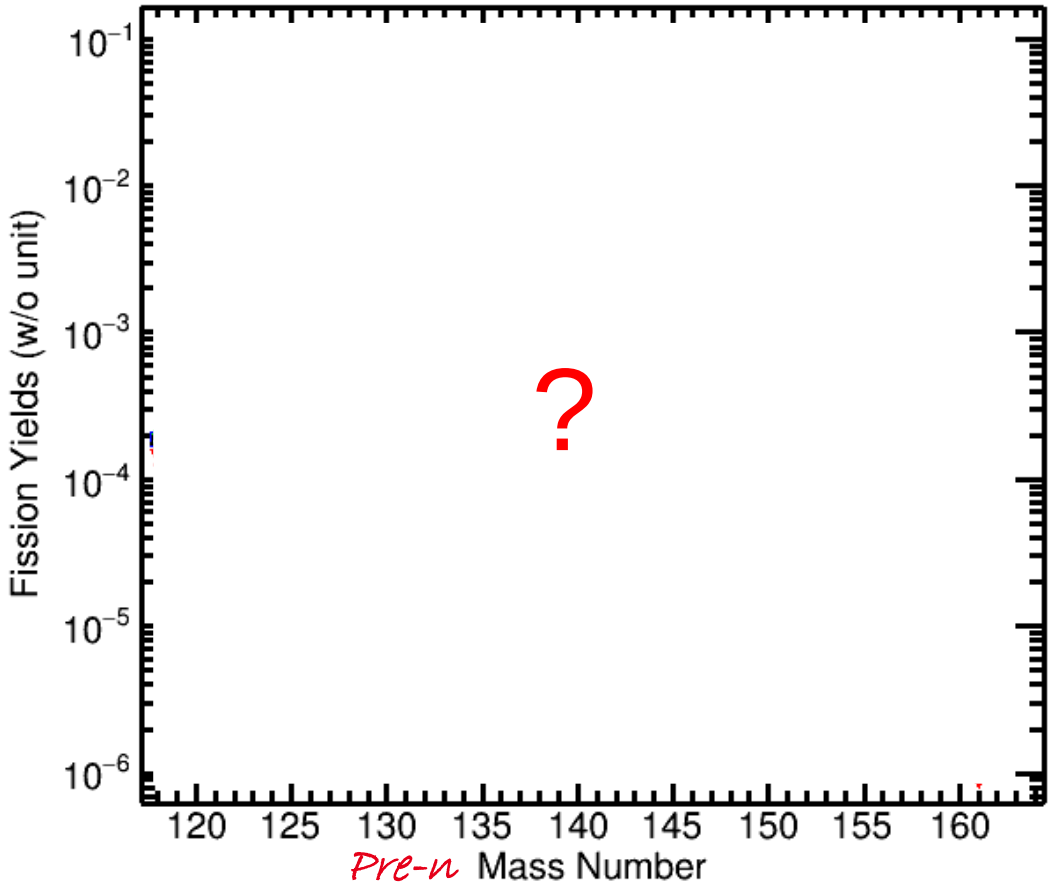
Attempt to Y(A) fit assuming deformed shell closure structures : $^{235}U(n_{th},f)$

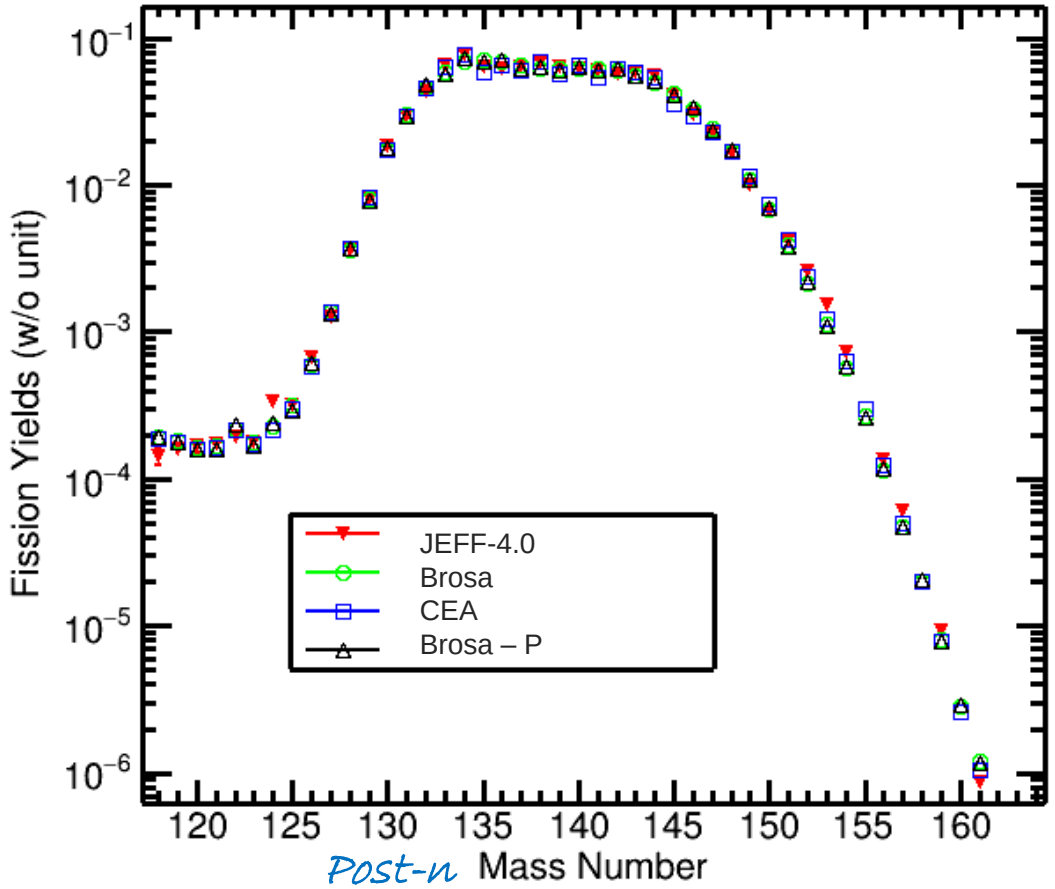




Too preliminary results !

Attempt to Y(A) fit assuming deformed shell closure structures





$^{235}U(n_{th},f)$ calculations → Structures are not precisely reproduced

→ Symmetry and far heavy tail show nice trends comparing our evaluation of experimental data

└> Used at least for extrapolation in the next generation of evaluation (replacing JEFF-3 extrapolation

> Quite more complex actually

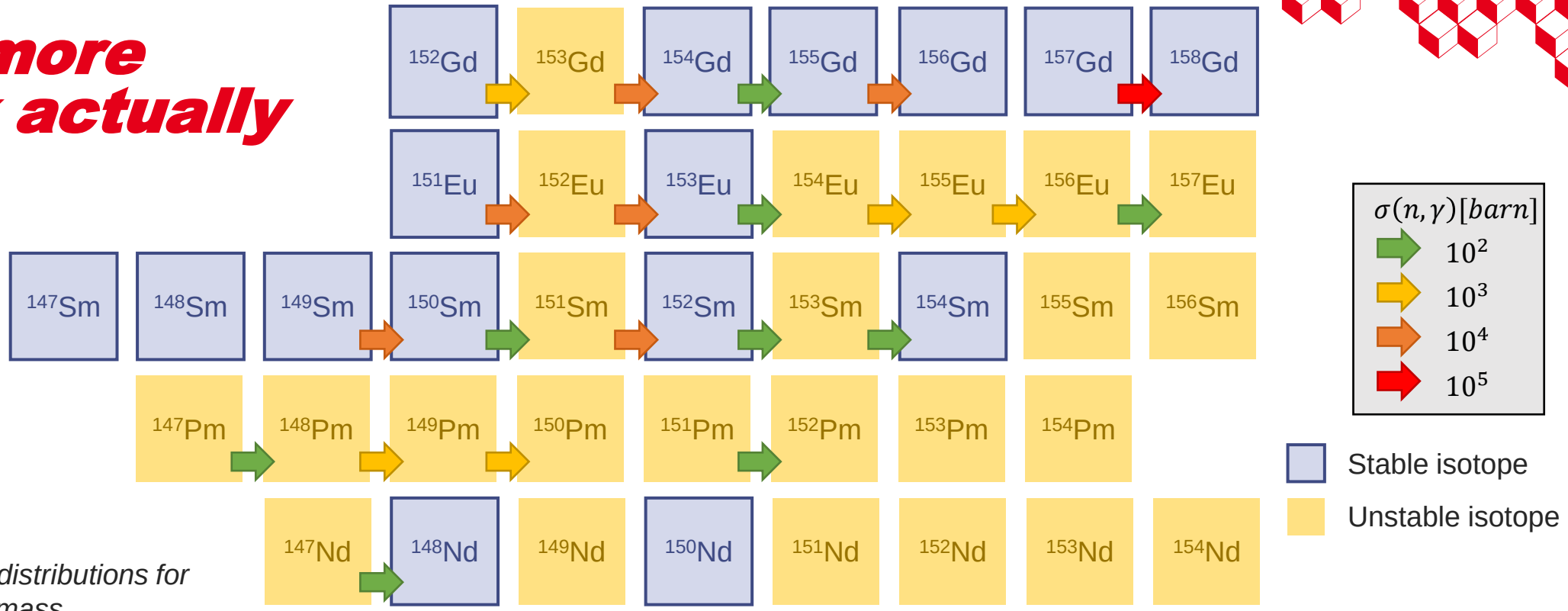


Figure 10. *Charge distributions for a given mass*