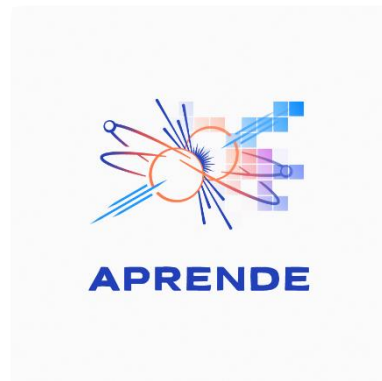




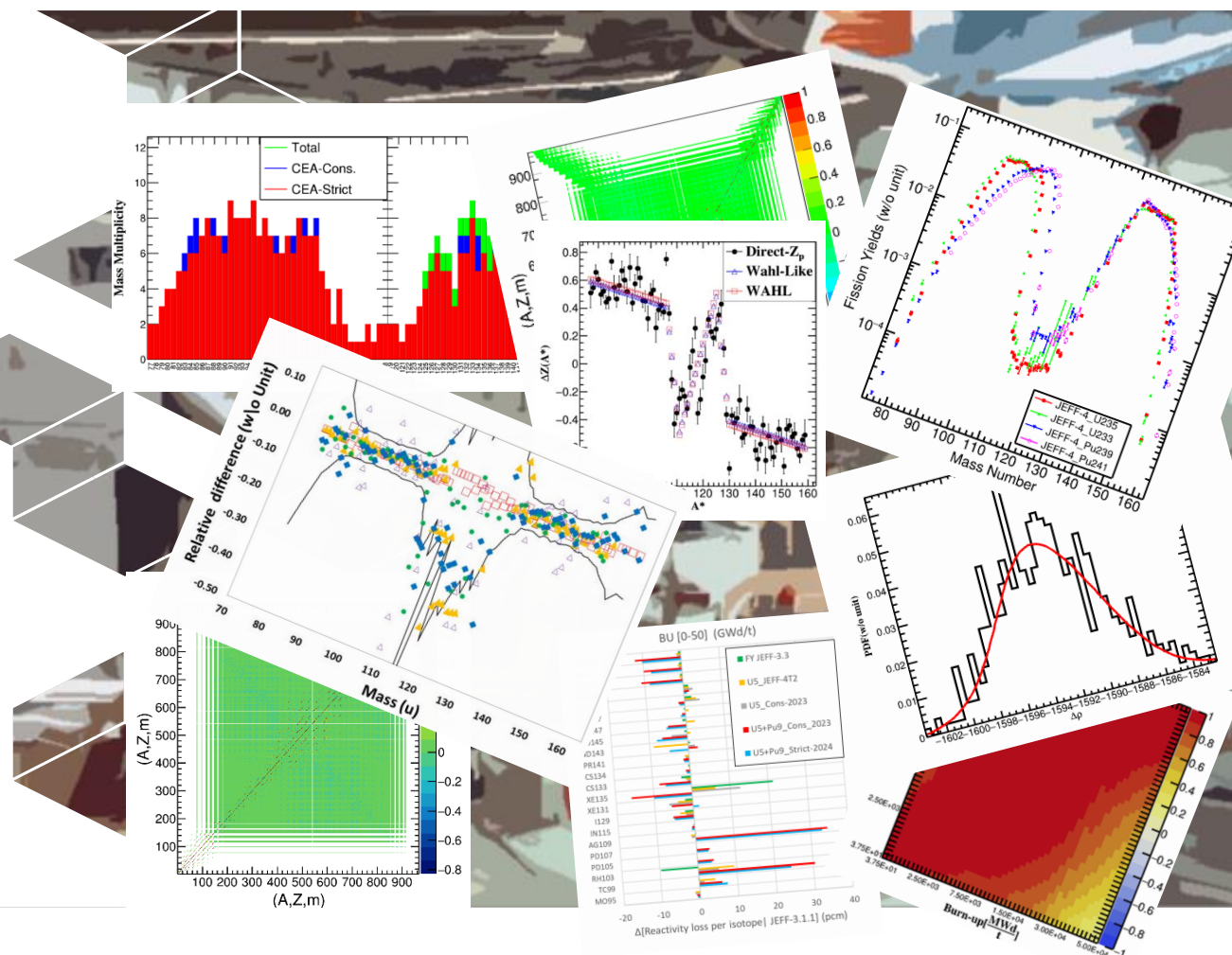
PEPR SCIAM

Fission Yield Evaluations : from thermal point to fast neutron energy range

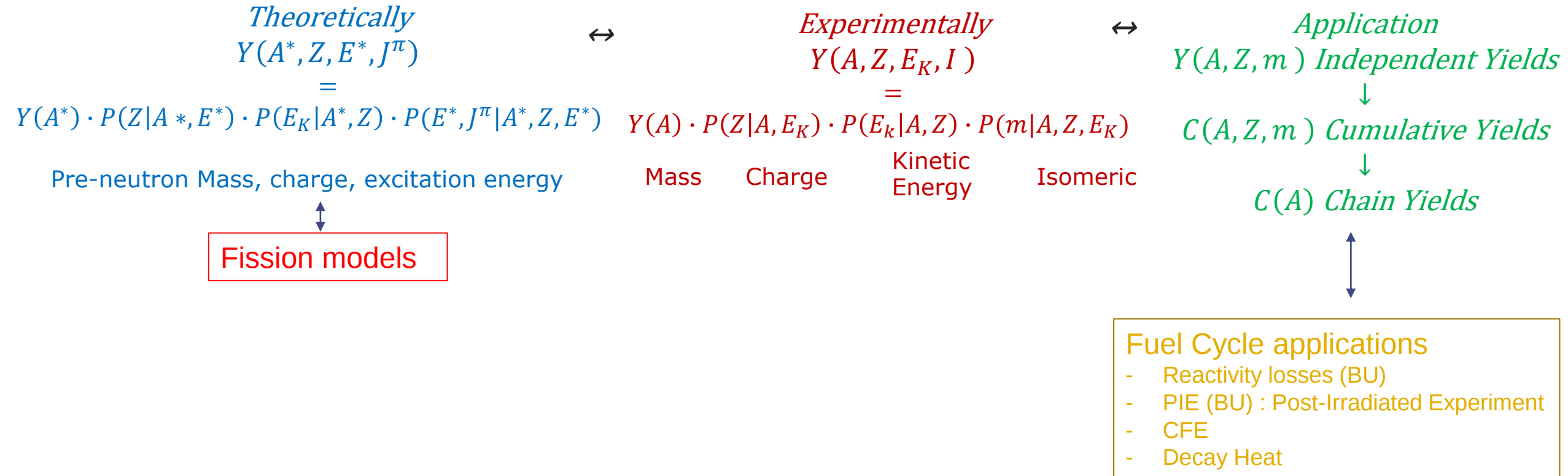
A.Regonesi, N. Teixeira-Rua, G. Kessedjian, A. Chebboubi, S. M. Cheikh, O. Serot, D. Bernard, O. Litaize

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

9 june 2026
PEPR SCIAM



Context: methodology of FY Evaluation for thermal neutron induced fission



$$Y(A^*, Z, E^*, J^\pi)$$

==

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

Pre-neutron Mass, charge, excitation energy

Fission models

Experimentally

$$Y(A, Z, E_K, I)$$

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

Kinetic Energy

Isomeric

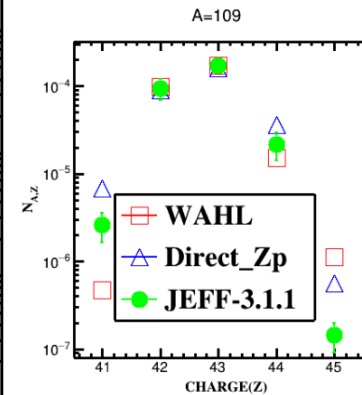
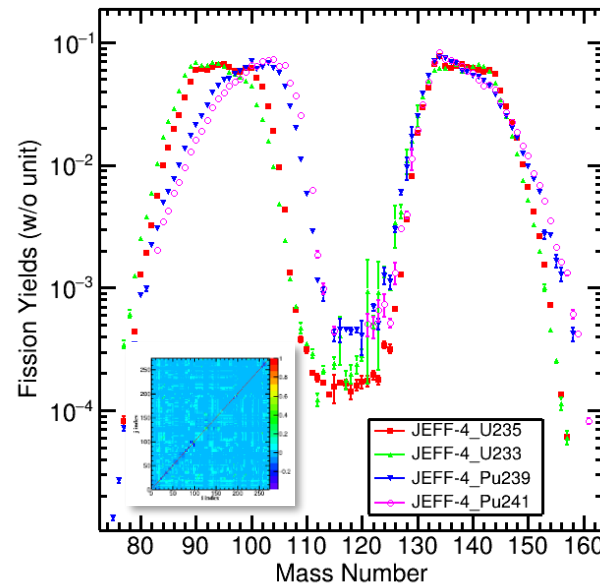
Application

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

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

1

C(A) Chain Yields



Fuel Cycle applications

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

[illegible]

Context: methodology of FY Evaluation for thermal neutron induced fission



Theoretically
 $Y(A^*, Z, E^*, J^\pi)$



Experimentally
 $Y(A, Z, E_K, I)$



Application

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



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



$C(A)$ Chain Yields



ISOTOPE	YIELD	YIELD ERROR	YIELD TYPE	YIELD UNIT	YIELD SCALE
235	0.000000	0.000000	1	1	1
235	0.000000	0.000000	2	1	1
235	0.000000	0.000000	3	1	1
235	0.000000	0.000000	4	1	1
235	0.000000	0.000000	5	1	1
235	0.000000	0.000000	6	1	1
235	0.000000	0.000000	7	1	1
235	0.000000	0.000000	8	1	1
235	0.000000	0.000000	9	1	1
235	0.000000	0.000000	10	1	1
235	0.000000	0.000000	11	1	1
235	0.000000	0.000000	12	1	1
235	0.000000	0.000000	13	1	1
235	0.000000	0.000000	14	1	1
235	0.000000	0.000000	15	1	1
235	0.000000	0.000000	16	1	1
235	0.000000	0.000000	17	1	1
235	0.000000	0.000000	18	1	1
235	0.000000	0.000000	19	1	1
235	0.000000	0.000000	20	1	1
235	0.000000	0.000000	21	1	1
235	0.000000	0.000000	22	1	1
235	0.000000	0.000000	23	1	1
235	0.000000	0.000000	24	1	1
235	0.000000	0.000000	25	1	1
235	0.000000	0.000000	26	1	1
235	0.000000	0.000000	27	1	1
235	0.000000	0.000000	28	1	1
235	0.000000	0.000000	29	1	1
235	0.000000	0.000000	30	1	1
235	0.000000	0.000000	31	1	1
235	0.000000	0.000000	32	1	1
235	0.000000	0.000000	33	1	1
235	0.000000	0.000000	34	1	1
235	0.000000	0.000000	35	1	1
235	0.000000	0.000000	36	1	1
235	0.000000	0.000000	37	1	1
235	0.000000	0.000000	38	1	1
235	0.000000	0.000000	39	1	1
235	0.000000	0.000000	40	1	1
235	0.000000	0.000000	41	1	1
235	0.000000	0.000000	42	1	1
235	0.000000	0.000000	43	1	1
235	0.000000	0.000000	44	1	1
235	0.000000	0.000000	45	1	1
235	0.000000	0.000000	46	1	1
235	0.000000	0.000000	47	1	1
235	0.000000	0.000000	48	1	1
235	0.000000	0.000000	49	1	1
235	0.000000	0.000000	50	1	1
235	0.000000	0.000000	51	1	1
235	0.000000	0.000000	52	1	1
235	0.000000	0.000000	53	1	1
235	0.000000	0.000000	54	1	1
235	0.000000	0.000000	55	1	1
235	0.000000	0.000000	56	1	1
235	0.000000	0.000000	57	1	1
235	0.000000	0.000000	58	1	1
235	0.000000	0.000000	59	1	1
235	0.000000	0.000000	60	1	1
235	0.000000	0.000000	61	1	1
235	0.000000	0.000000	62	1	1
235	0.000000	0.000000	63	1	1
235	0.000000	0.000000	64	1	1
235	0.000000	0.000000	65	1	1
235	0.000000	0.000000	66	1	1
235	0.000000	0.000000	67	1	1
235	0.000000	0.000000	68	1	1
235	0.000000	0.000000	69	1	1
235	0.000000	0.000000	70	1	1
235	0.000000	0.000000	71	1	1
235	0.000000	0.000000	72	1	1
235	0.000000	0.000000	73	1	1
235	0.000000	0.000000	74	1	1
235	0.000000	0.000000	75	1	1
235	0.000000	0.000000	76	1	1
235	0.000000	0.000000	77	1	1
235	0.000000	0.000000	78	1	1
235	0.000000	0.000000	79	1	1
235	0.000000	0.000000	80	1	1
235	0.000000	0.000000	81	1	1
235	0.000000	0.000000	82	1	1
235	0.000000	0.000000	83	1	1
235	0.000000	0.000000	84	1	1
235	0.000000	0.000000	85	1	1
235	0.000000	0.000000	86	1	1
235	0.000000	0.000000	87	1	1
235	0.000000	0.000000	88	1	1
235	0.000000	0.000000	89	1	1
235	0.000000	0.000000	90	1	1
235	0.000000	0.000000	91	1	1
235	0.000000	0.000000	92	1	1
235	0.000000	0.000000	93	1	1
235	0.000000	0.000000	94	1	1
235	0.000000	0.000000	95	1	1
235	0.000000	0.000000	96	1	1
235	0.000000	0.000000	97	1	1
235	0.000000	0.000000	98	1	1
235	0.000000	0.000000	99	1	1
235	0.000000	0.000000	100	1	1
235	0.000000	0.000000	101	1	1
235	0.000000	0.000000	102	1	1
235	0.000000	0.000000	103	1	1
235	0.000000	0.000000	104	1	1
235	0.000000	0.000000	105	1	1
235	0.000000	0.000000	106	1	1
235	0.000000	0.000000	107	1	1
235	0.000000	0.000000	108	1	1
235	0.000000	0.000000	109	1	1
235	0.000000	0.000000	110	1	1
235	0.000000	0.000000	111	1	1
235	0.000000	0.000000	112	1	1
235	0.000000	0.000000	113	1	1
235	0.000000	0.000000	114	1	1
235	0.000000	0.000000	115	1	1
235	0.000000	0.000000	116	1	1
235	0.000000	0.000000	117	1	1
235	0.000000	0.000000	118	1	1
235	0.000000	0.000000	119	1	1
235	0.000000	0.000000	120	1	1
235	0.000000	0.000000	121	1	1
235	0.000000	0.000000	122	1	1
235	0.000000	0.000000	123	1	1
235	0.000000	0.000000	124	1	1
235	0.000000	0.000000	125	1	1
235	0.000000	0.000000	126	1	1
235	0.000000	0.000000	127	1	1
235	0.000000	0.000000	128	1	1
235	0.000000	0.000000	129	1	1
235	0.000000	0.000000	130	1	1
235	0.000000	0.000000	131	1	1
235	0.000000	0.000000	132	1	1
235	0.000000	0.000000	133	1	1
235	0.000000	0.000000	134	1	1
235	0.000000	0.000000	135	1	1
235	0.000000	0.000000	136	1	1
235	0.000000	0.000000	137	1	1
235	0.000000	0.000000	138	1	1
235	0.000000	0.000000	139	1	1
235	0.000000	0.000000	140	1	1
235	0.000000	0.000000	141	1	1
235	0.000000	0.000000	142	1	1
235	0.000000	0.000000	143	1	1
235	0.000000	0.000000	144	1	1
235	0.000000	0.000000	145	1	1
235	0.000000	0.000000	146	1	1
235	0.000000	0.000000	147	1	1
235	0.000000	0.000000	148	1	1
235	0.000000	0.000000	149	1	1
235	0.000000	0.000000	150	1	1
235	0.000000	0.000000	151	1	1
235	0.000000	0.000000	152	1	1
235	0.000000	0.000000	153	1	1
235	0.000000	0.000000	154	1	1
235	0.000000	0.000000	155	1	1
235	0.000000	0.000000	156	1	1
235	0.000000	0.000000	157	1	1
235	0.000000	0.000000	158	1	1
235	0.000000	0.000000	159	1	1
235	0.000000	0.000000	160	1	1

Pre-neutron Mass, charge, excitation energy

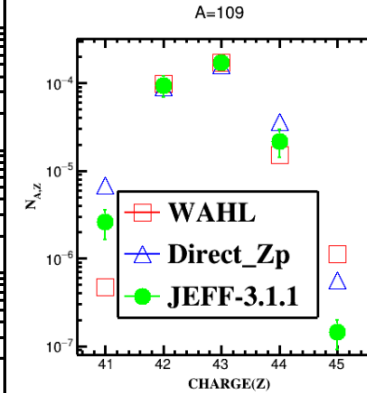
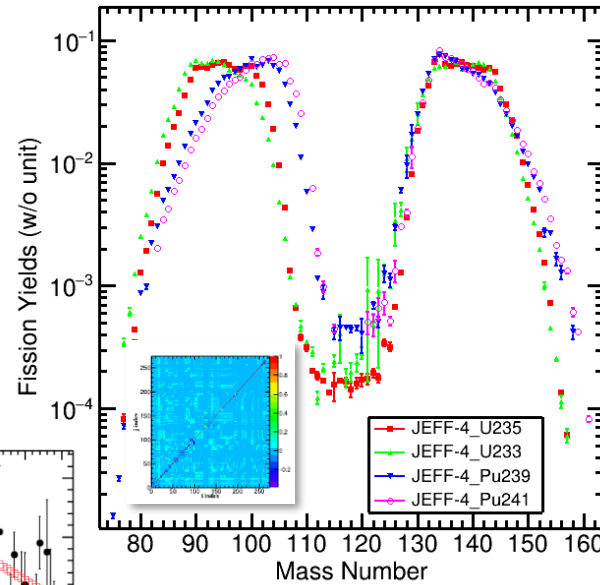
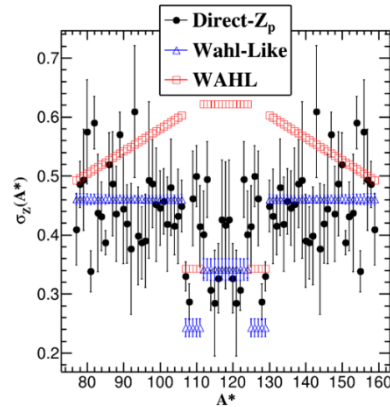
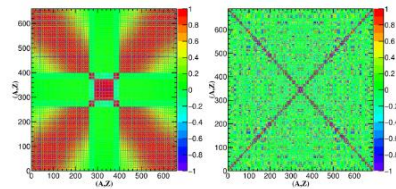
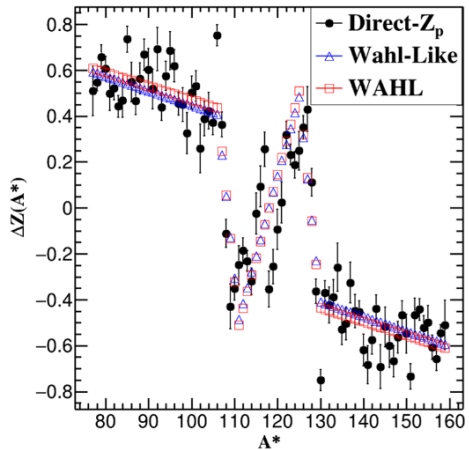
Mass

Charge

Kinetic Energy

Isomeric

Fission models



Fuel Cycle applications

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

$$Y(A, Z, E_K, I)$$

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

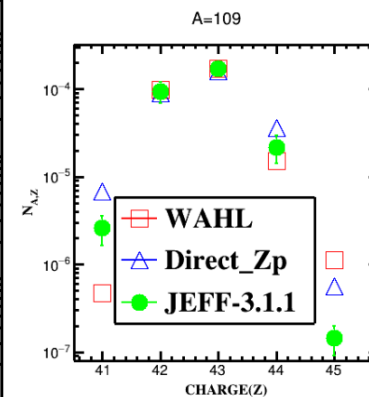
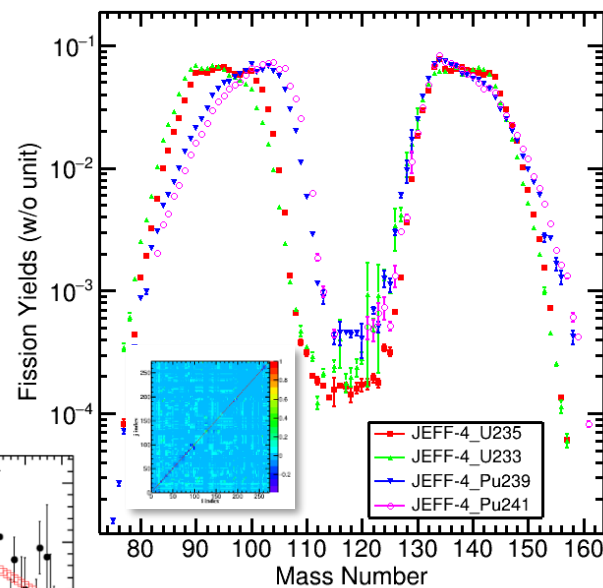
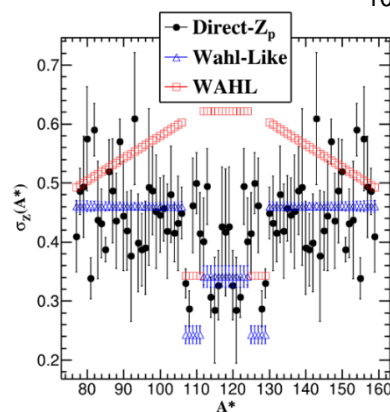
$C(A, Z, m)$ Cumulative Yields

C(A) Chain Yields

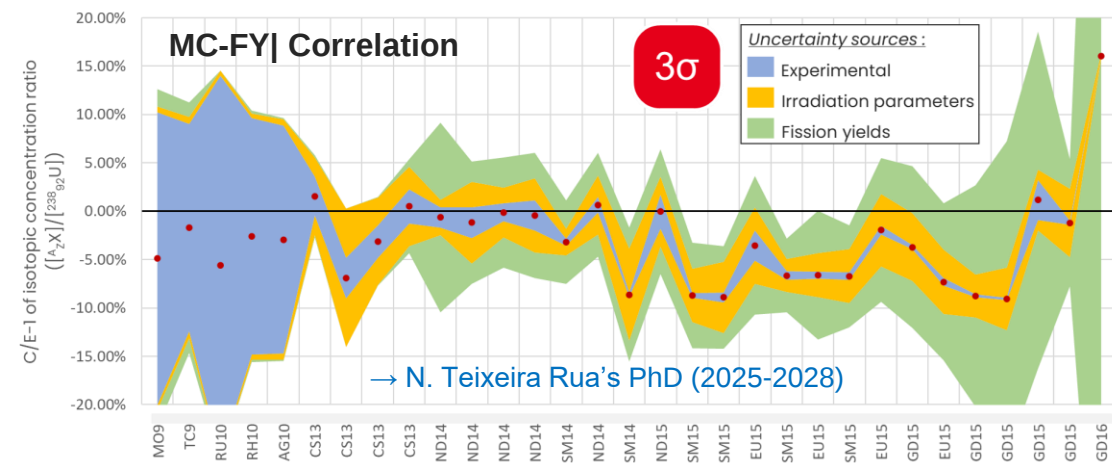
Mass Charge

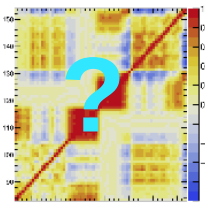
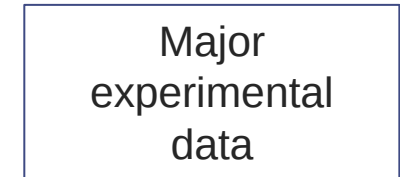
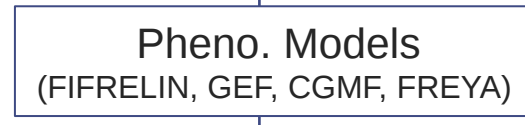
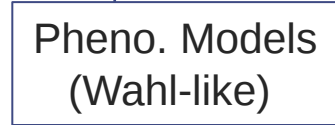
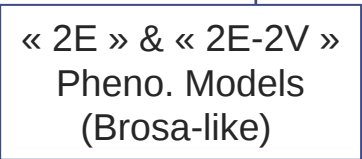
Kinetic Energy

Isomeric

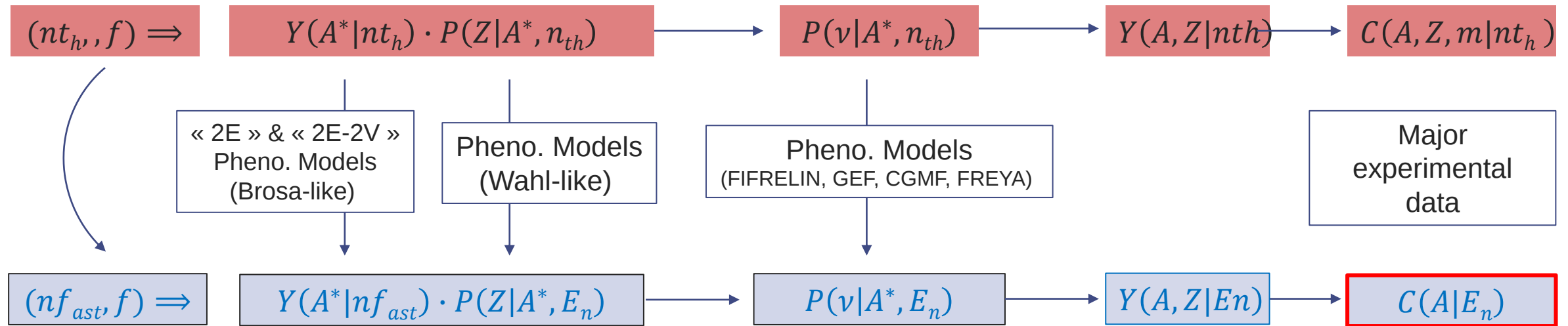


- Reactivity losses (BU)
- PIE (BU) : Post-Irradiated Experiment
- CFE
- Decay Heat



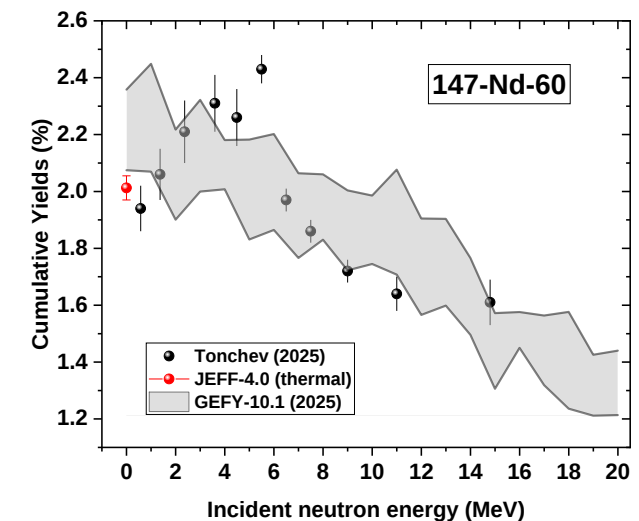
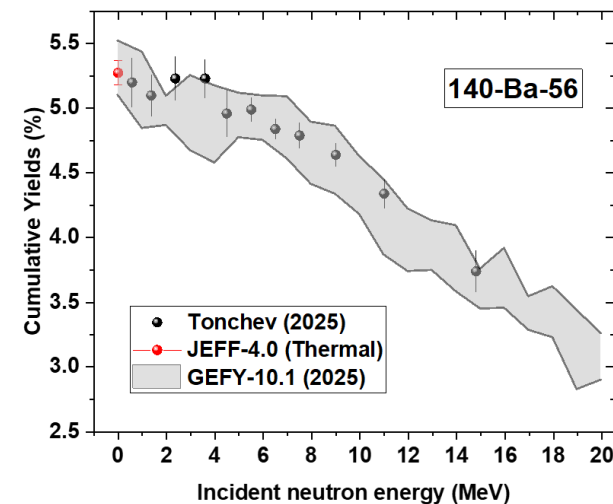
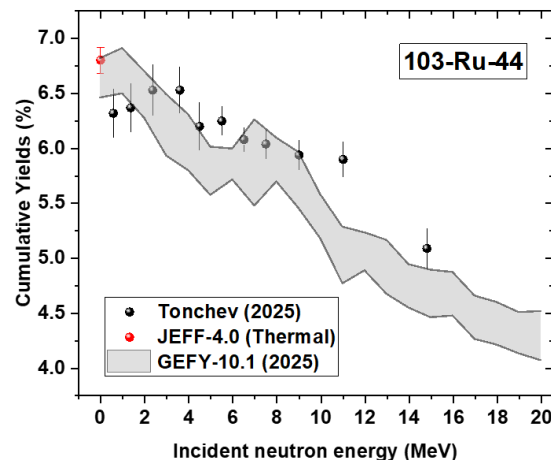
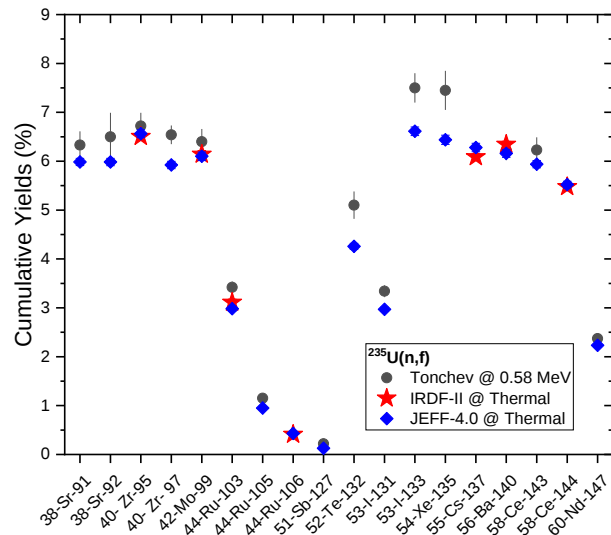


Context: methodology of FY Evaluation for fast neutron induced fission



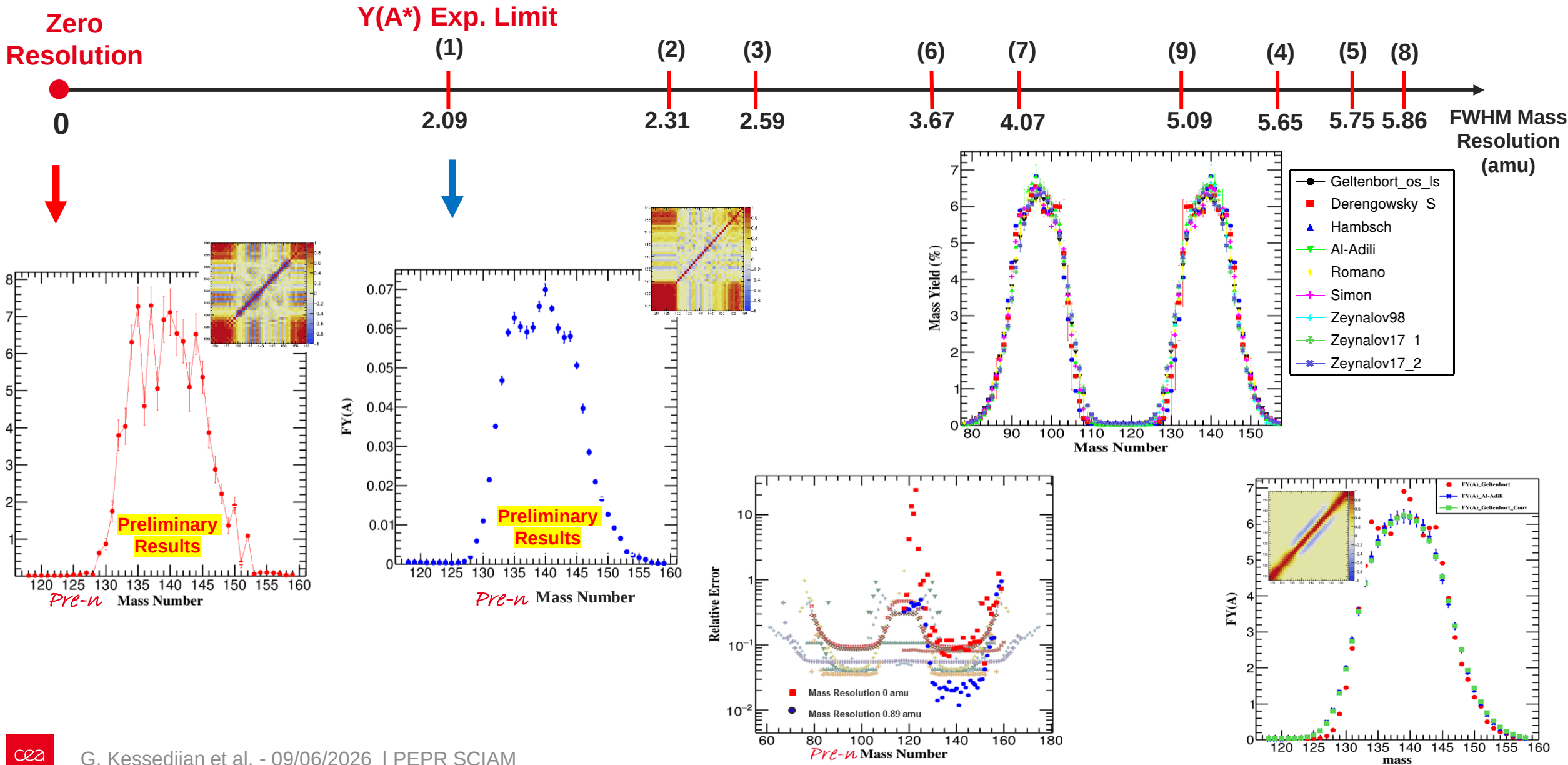
O. Serot, JEFDOC_2550 / APRENDE (Avril 2026)

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



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

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



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

→ A. Regonesi's PhD (2024-2027)

Res Zero

(1)

(2)

(3)

(6)

(7)

(9)

(4)

(5)

(8)

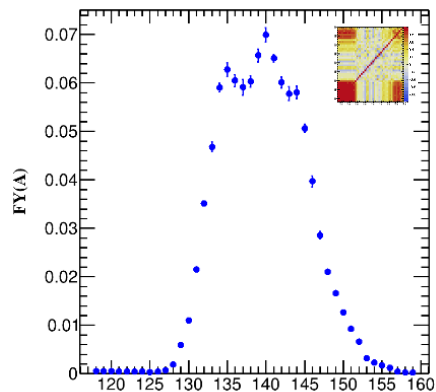
FWHM Mass Resolution (amu)

$Y(A^*)$ Eval
Exp. Limit

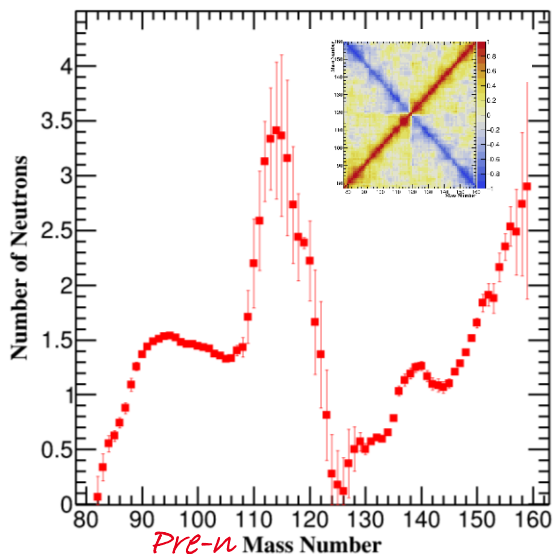
Exp. Evaluation
(Student PDF)

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

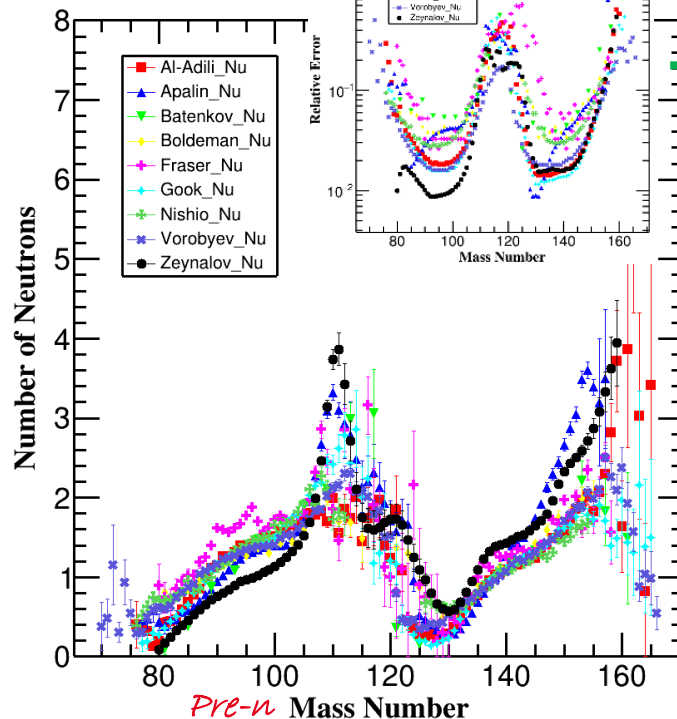
→ Important Biases



Pre-n mass



Pre-n Mass Number

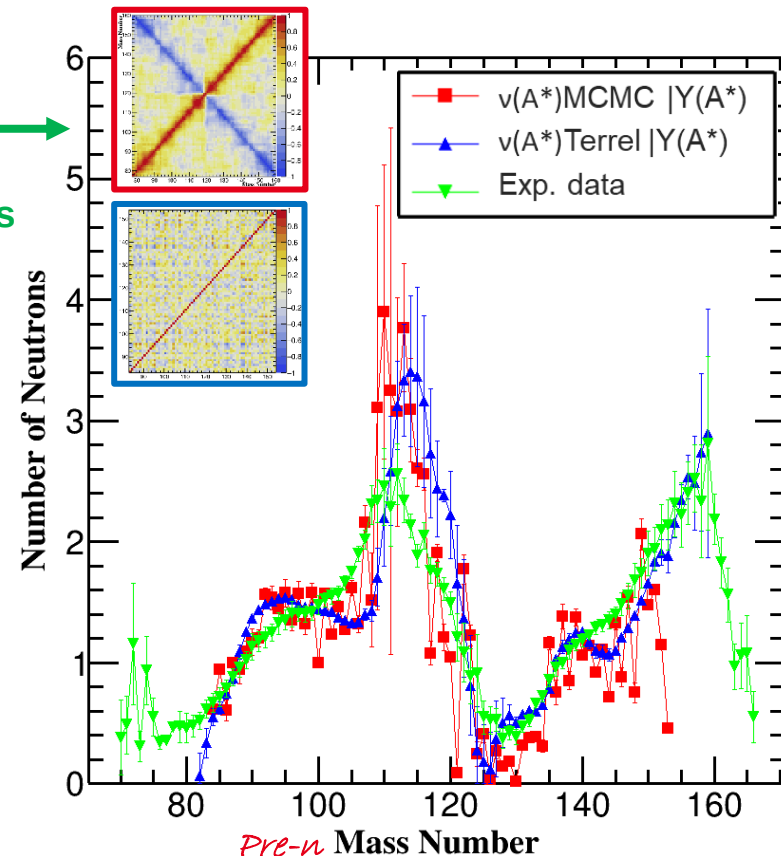


Pre-n Mass Number

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

MCMC Evaluation

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



Pre-n Mass Number

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

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

→ A. Regonesi's PhD (2024-2027)

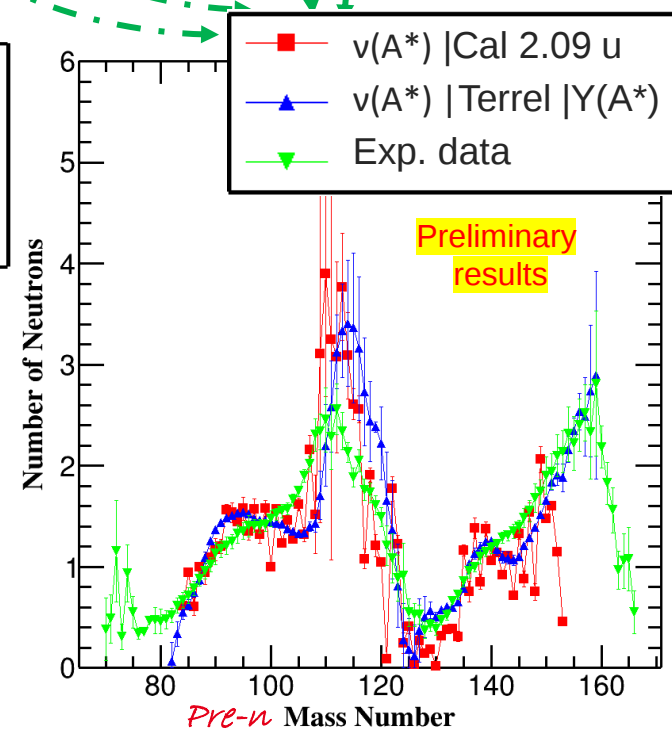
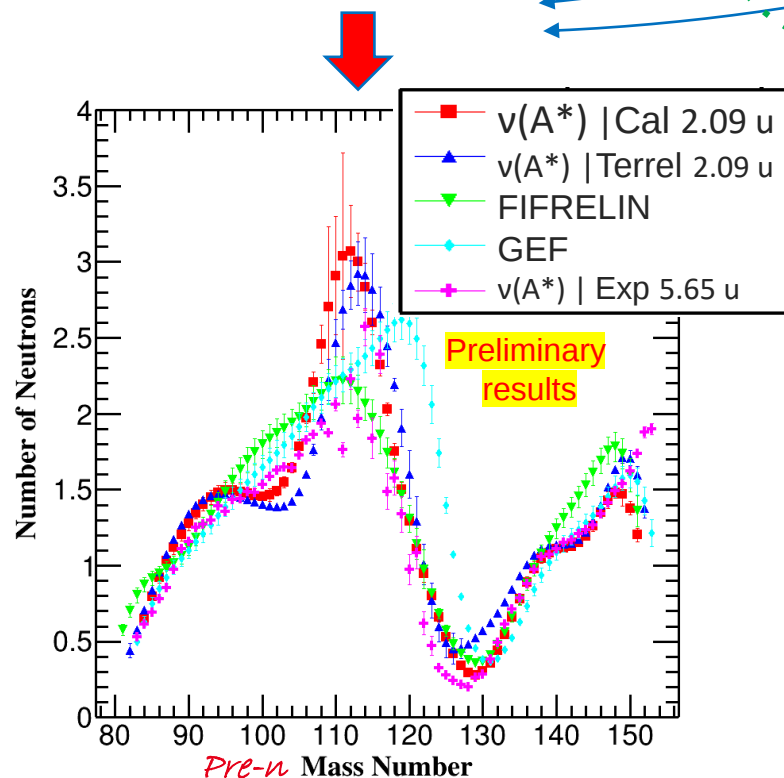
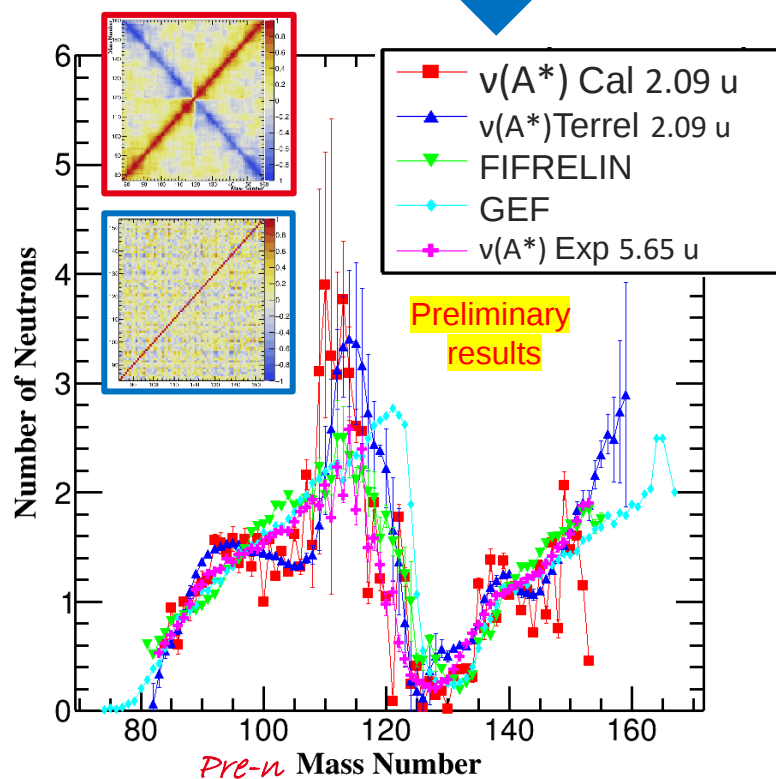


$Y(A)$
Resolved

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

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

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

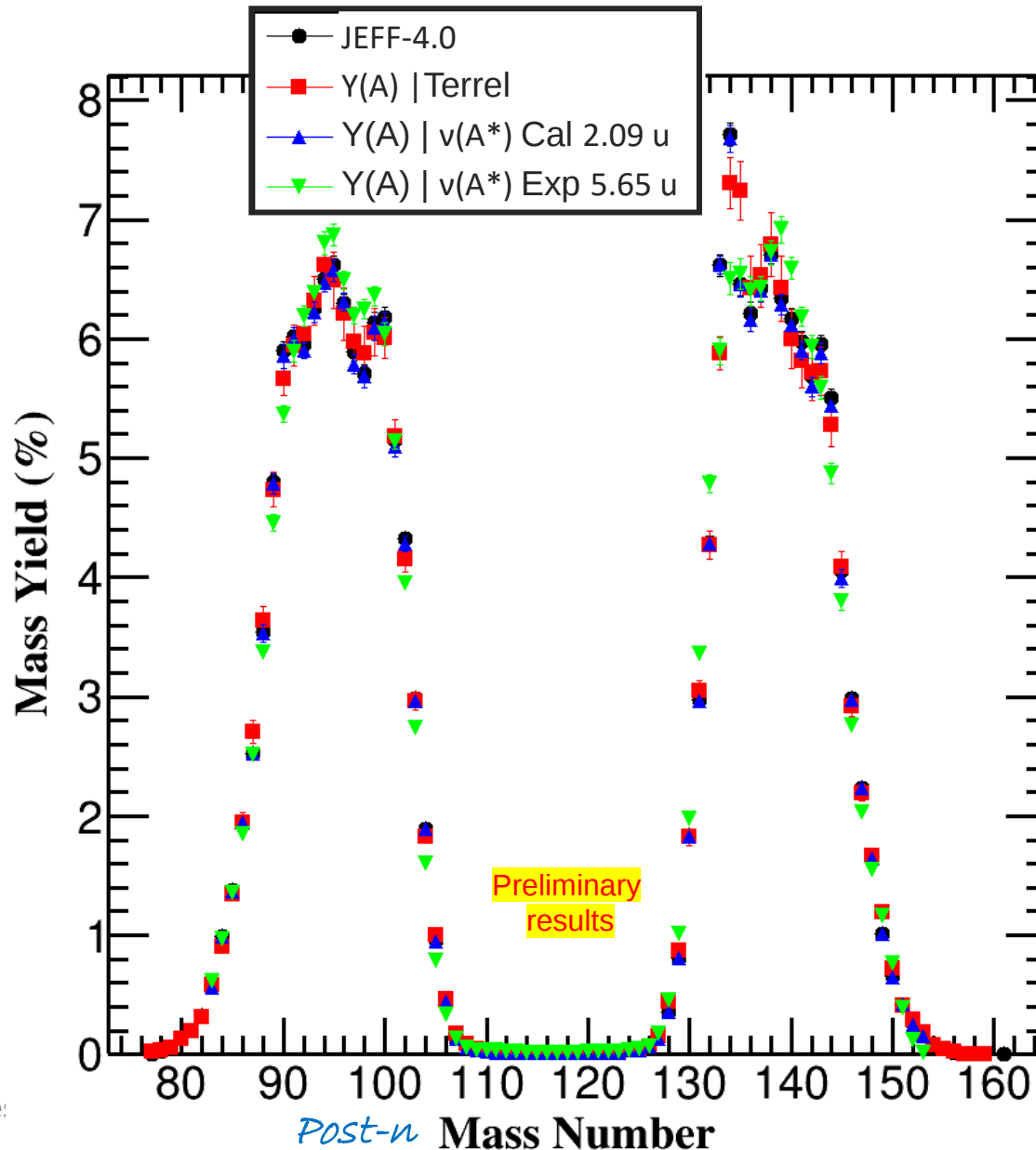


$\nu(A^*)$ Evaluation
FWHM 5.65 u

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

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

→ A. Regonesi's PhD (2024-2027)



$\nu(A^* | \text{TERRELL}) \rightarrow \text{Pvalue} \approx 0$

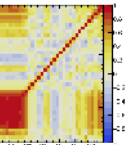
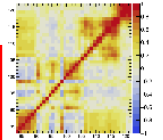
$\nu(A^* | \text{Exp 5.65 u}) \rightarrow \text{Pvalue} \approx 0$

$\nu(A^* | \text{Cal 2.09 u}) \rightarrow \begin{cases} \text{L} \rightarrow \text{Pvalue} = 22.6\% \\ \text{H} \rightarrow \text{Pvalue} = 7.2\% \end{cases}$

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

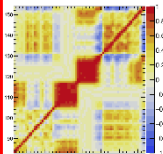
L $\sigma_{gauss} = 1.08 \pm 0.043$

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



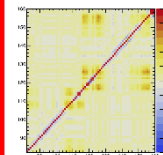
$\nu(A^* | \text{Exp 5.65 u})$

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



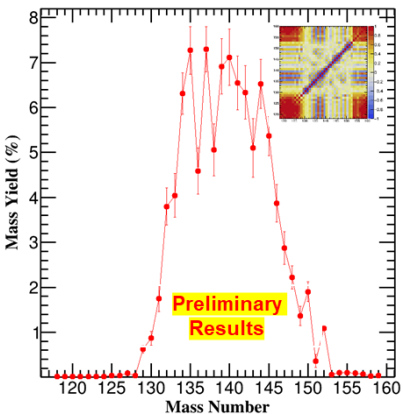
$\nu(A^* | \text{TERRELL})$

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

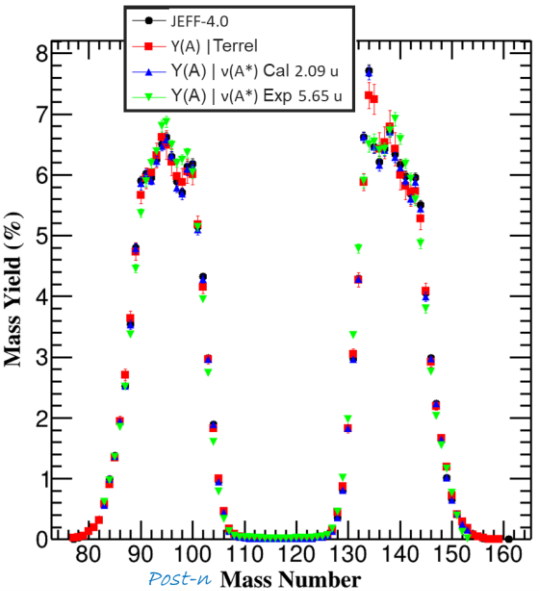
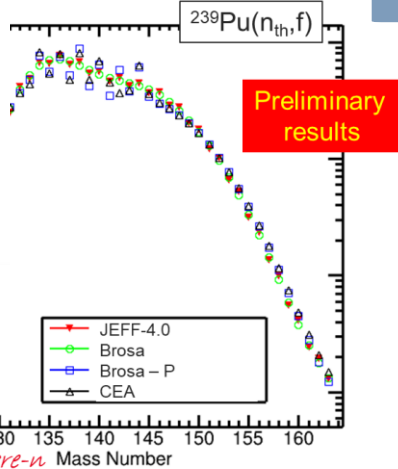
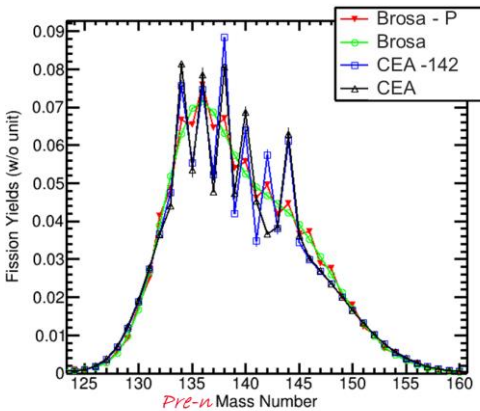
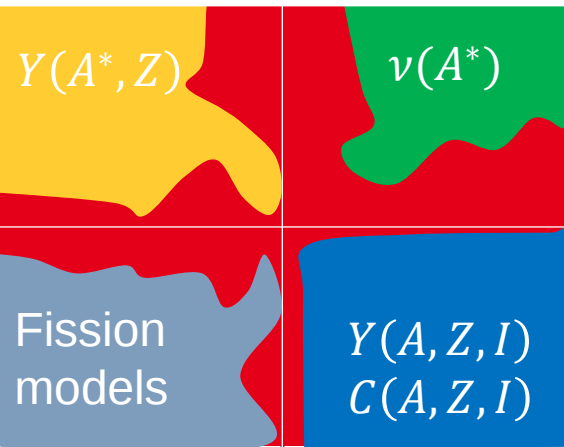
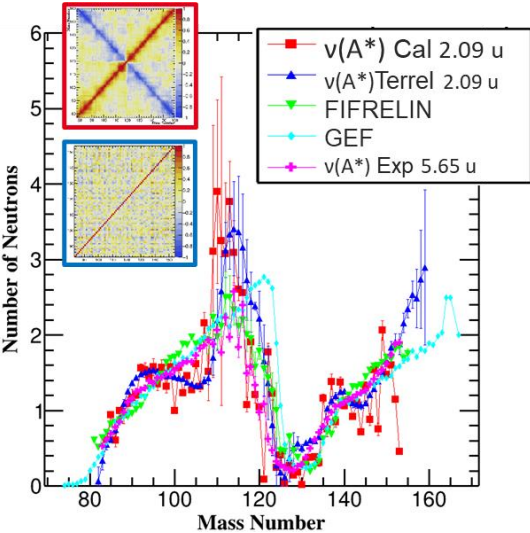
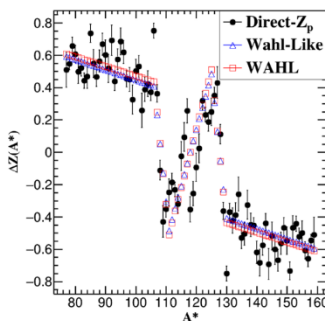


11

Conclusion & perspectives



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



1st - Accuracy
2nd - Biases

Conclusion & perspectives → P(ND)²⁻³

- 2018-2025 : independent & cumulative FY evaluation → **JEFF-4.0**
with **correlation matrix** for the first time around the world

→ based on EXFOR database
→ S-M. Cheikh's PhD (2020-2023)

■ Program for the next ½ Decade :

- Develop methodology of **Evaluation from pre-n observables**
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

→ based on EXFOR database
→ A. Regonesi's PhD (2024-2027)

- Complete the **(n_{th},f)** FY evaluations : from P(Z|A) to PIE
- Adjusted fission model parameters in order to interpreted **fast neutron energy range** data [0; 6 MeV] & **Evaluation as a function of incident neutron energy**
- **Threats/risks** : manpower alongside the experimental program

→ based on EXFOR database
→ N. Teixeira Rua's PhD (2026-2029)

→ PhD thesis subject (2027-2030)

→ Towards JEFF-4.1 ???

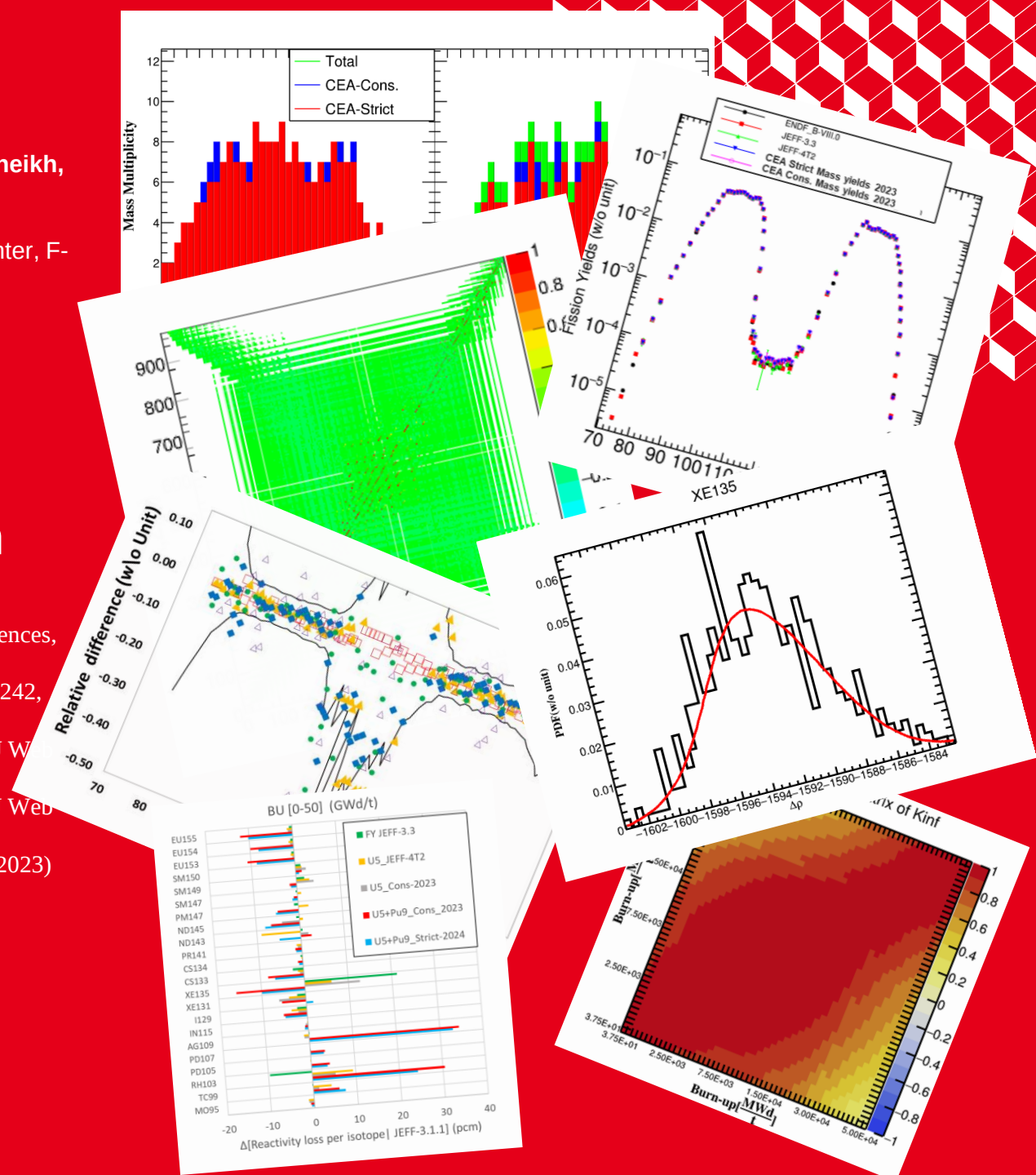


N. Teixeira-Rua, A. Regonesi, G. Kessedjian, S. M. Cheikh,
O. Serot, A. Chebboubi, D. Bernard, O. Litaize

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

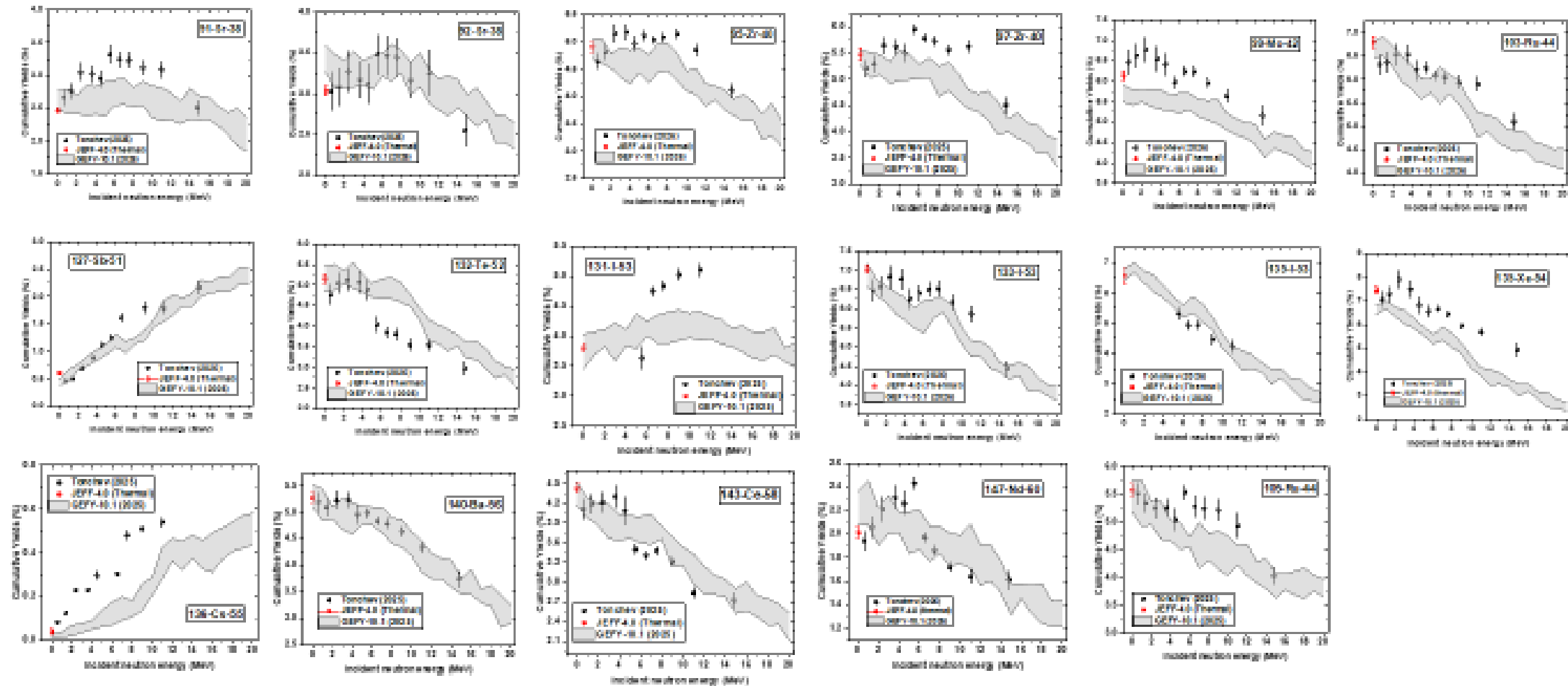
Thank you for your attention

B. Voirin, G. Kessedjian et al, EPJ N - Nuclear Sciences & Technologies, EDP Sciences, 4, pp.26 (2018)
G. Kessedjian, S.-M. Cheikh et al., FPY 2019, Santa Fe, EPJ Web of Conferences 242, 05001 (2020)
S.-M. Cheikh, G. Kessedjian et al., Covariance Workshop 2022, Tokyo, Japan, EPJ Web of Conferences 281, 00023 (2023)
G. Kessedjian, S.-M. Cheikh et al., Covariance Workshop 2022, Tokyo, Japan, EPJ Web of Conferences 281, 00022 (2023)
S.-M. Cheikh, G. Kessedjian et al., M&C2023 conference, Niagara Falls, Canada (2023)
S.-M. Cheikh, G. Kessedjian et al., M&C2023 proceedings
S.-M. Cheikh, G. Kessedjian et al., NSE 2024, 1–14.
<https://doi.org/10.1080/00295639.2024.2347693>
S.-M. Cheikh, PhD thesis, UGA, 18 Oct. 2023
S.-M. Cheikh, G. Kessedjian et al., Eur. Phys. J. A, 60 11 (2024) 222
G. Kessedjian et al, ND 2025, Madrid
CRP IAEA on Fission Yields 2020-2024, submitted
JEFF-4.0 library article, on going
JEFF-4.0 Fission yields evaluations, on going

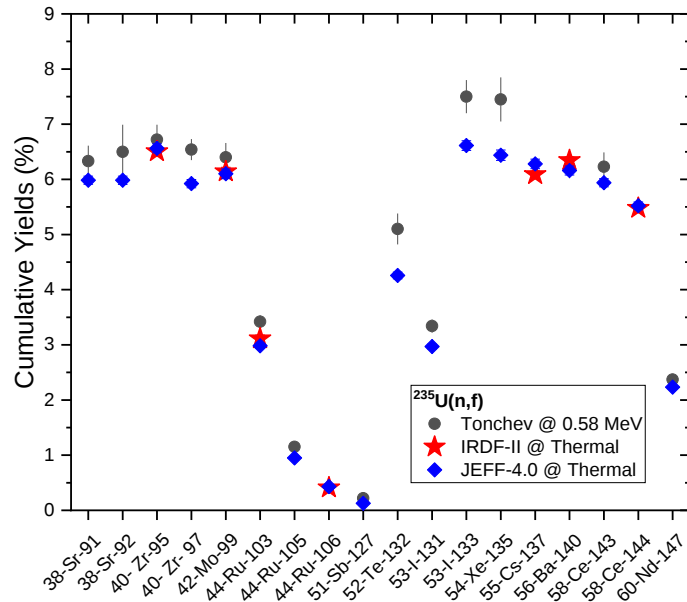
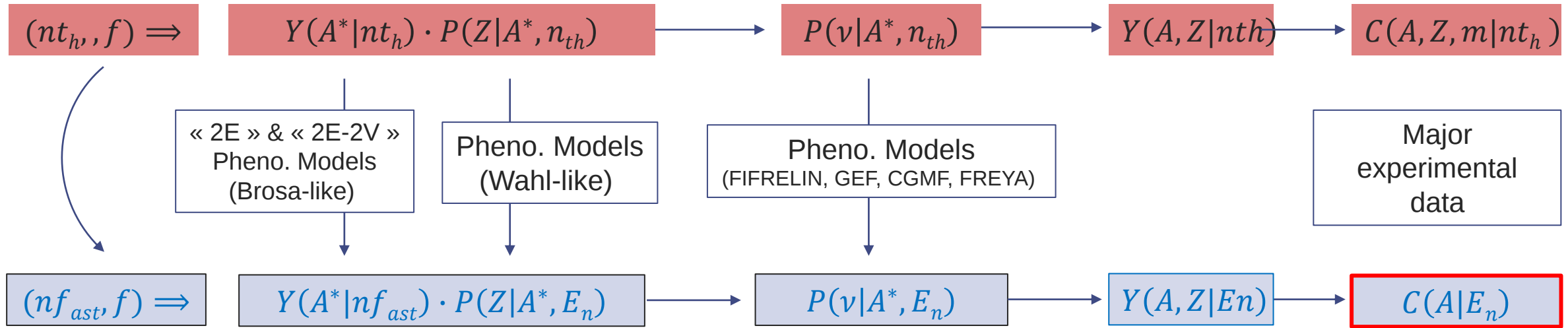




Overview of the 17 Cumulative Fission Products yields measured by Tonchev



Context: methodology of FY Evaluation for fast neutron induced fission



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

