Fission Yields Evaluations :

$^{235}U(n_{th},f)$; $^{239}Pu(n_{th},f)$ & perspectives

S. M. Cheikh[1], A. Regonesi[1], G. Kessedjian[1], O. Serot[1], D. Bernard[1], A. Chebboubi[1], V. Vallet[1], R. Mills[2] and L. Capponi[2]

[1] CEA, DES, IRESNE, DER, SPRC, LEPh, Cadarache center, F-13108 Saint Paul lez Durance, France
[2] National Nuclear Laboratory, Central Laboratory, Sellafield, Seascale CA20 1PG, England

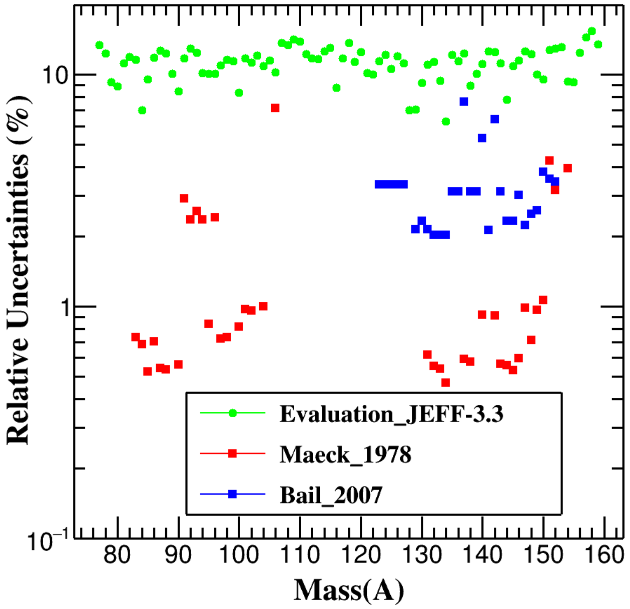
Context of new FY evaluation

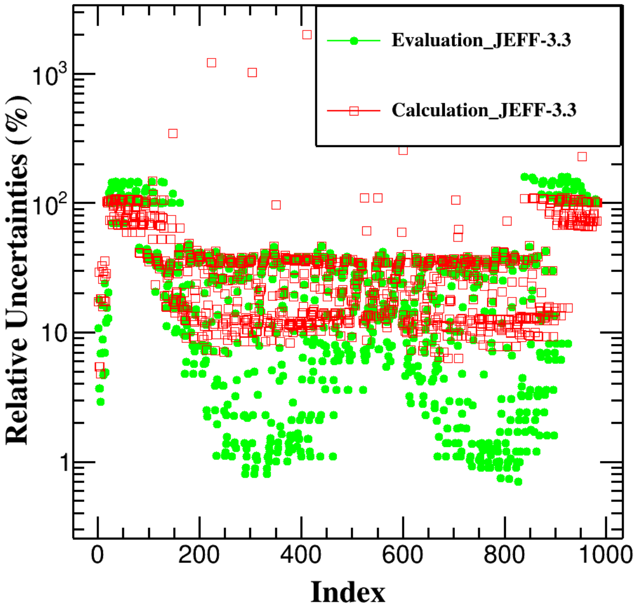
- $Y^{Cal}(A) = \sum_{Z,I} Y^{eval}(A,Z,I)$
- $\sigma^{exp}[Y(A)] < \sigma^{cal}[Y(A)]$

  Incompatibility due to lack of correlation matrix

- $C = Q \cdot Y$
- $\sigma[C_i] \neq \sigma[QY_i]$

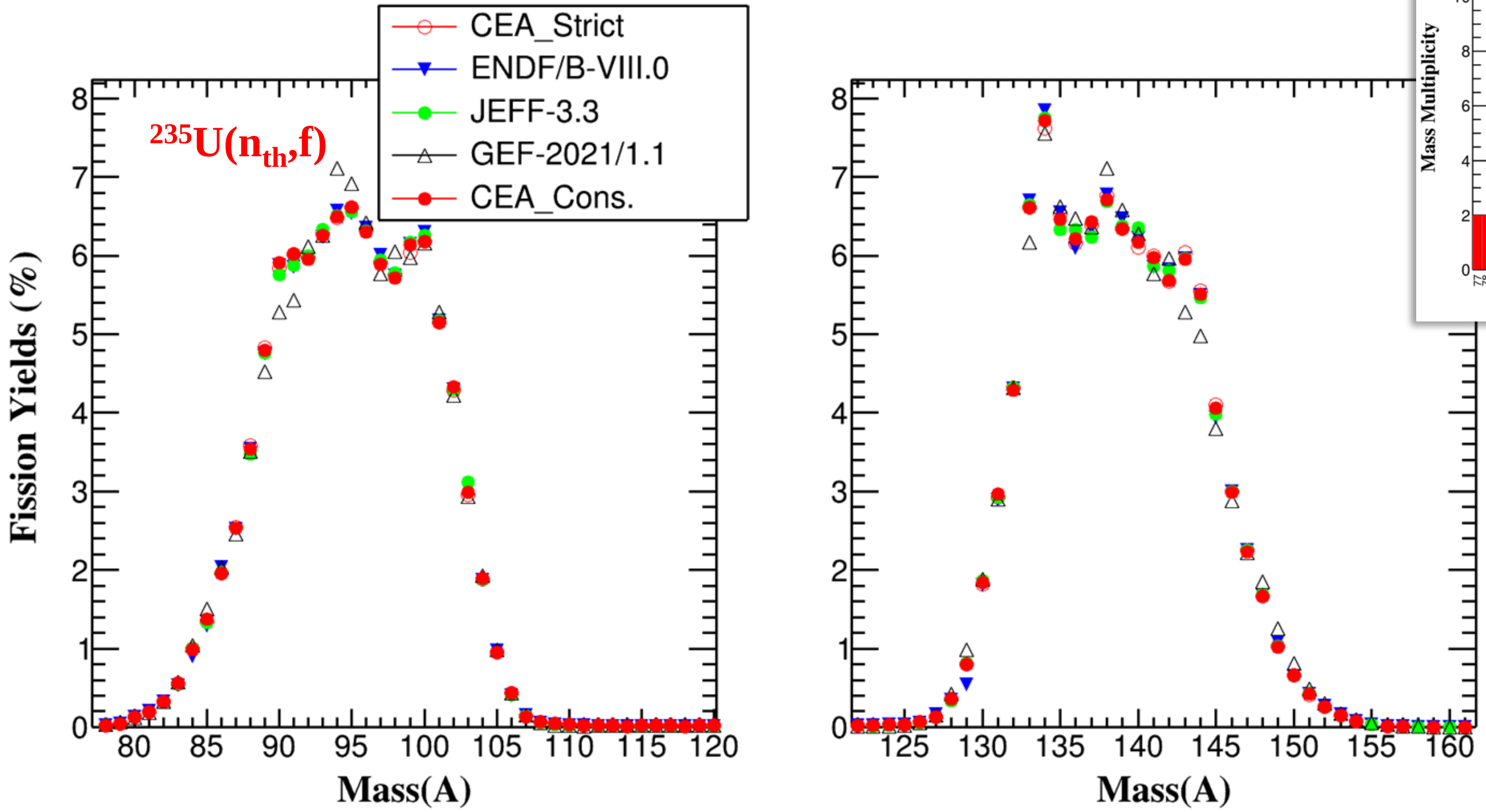
  → *Incompatibility*
  → *inconsistency*
  → *Lack of correlations*

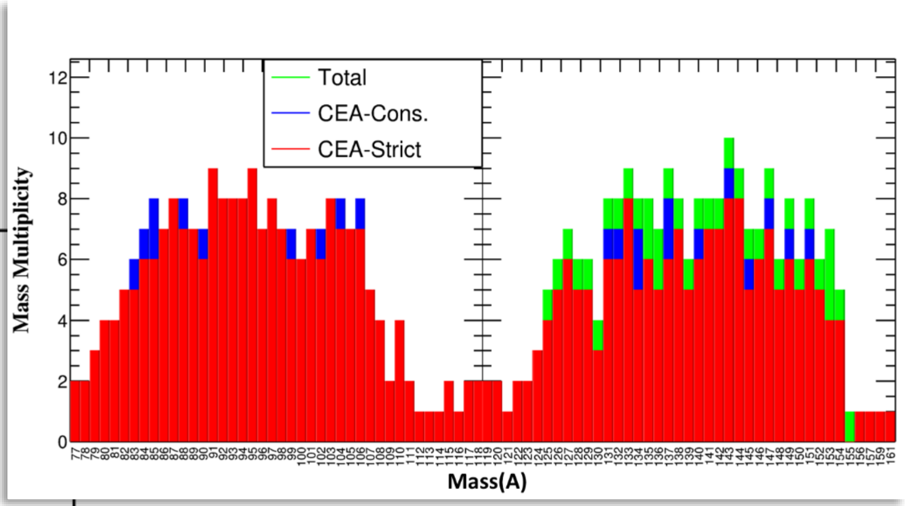


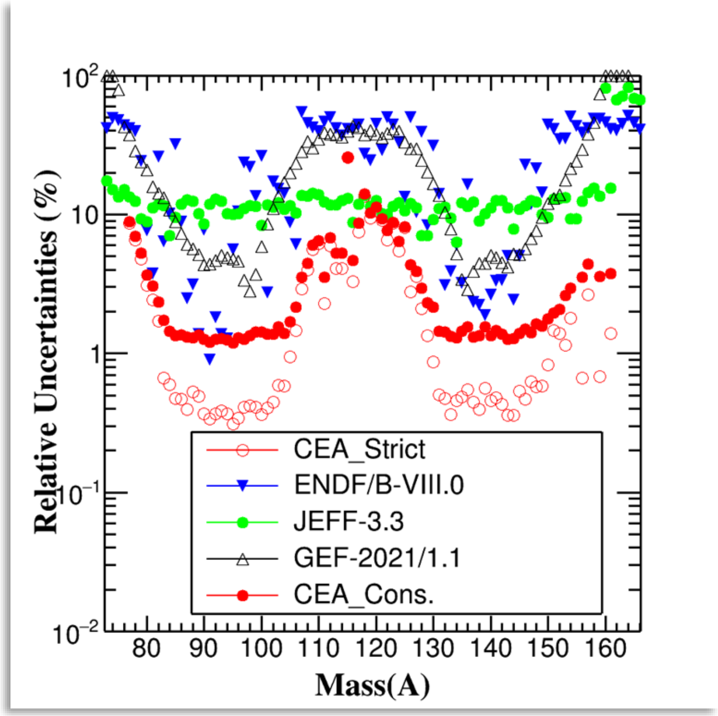


$^{235}U(n_{th},f)$ FY evaluation : JEFF-4T3 proposal → Mixed CEA-NNL Eval. method

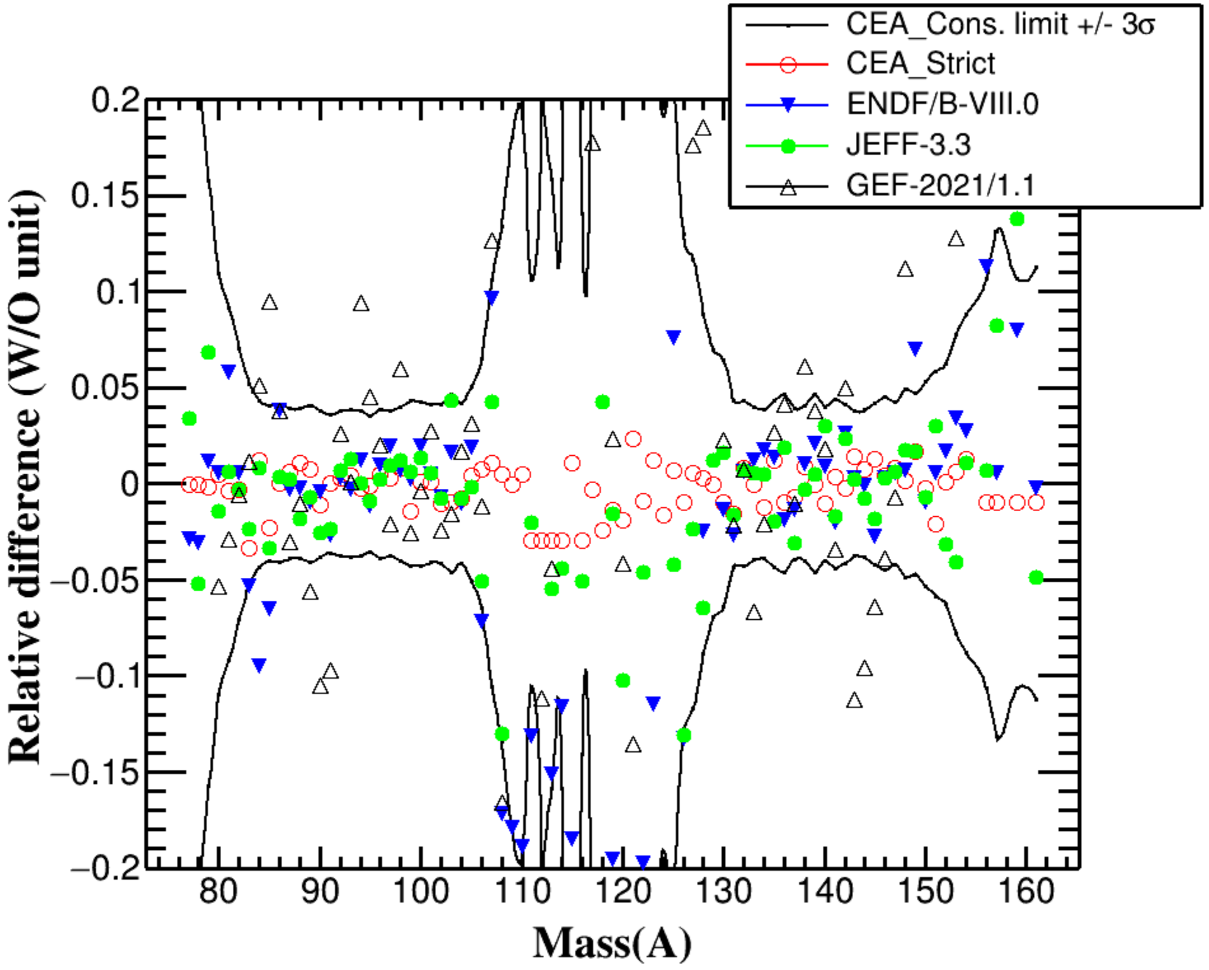
$$Y(A,Z,E_K,I\,|En) = Y(A,Z).\,P(E_K|A,Z).\,P(I|A,Z,E_k)$$



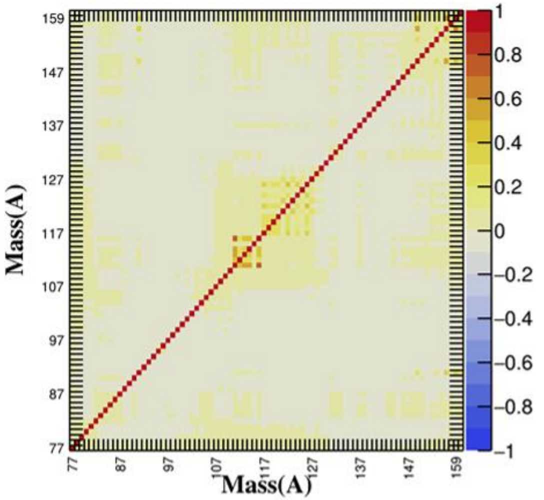




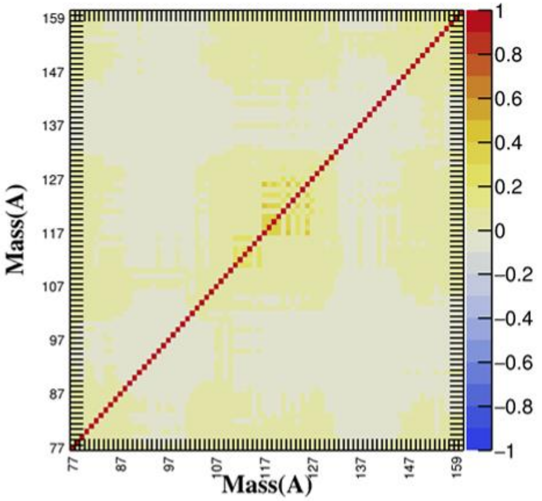
$^{235}U(n_{th},f)$ Y(A) evaluation : JEFF-4T3 proposal → Mixed CEA-NNL Eval. method



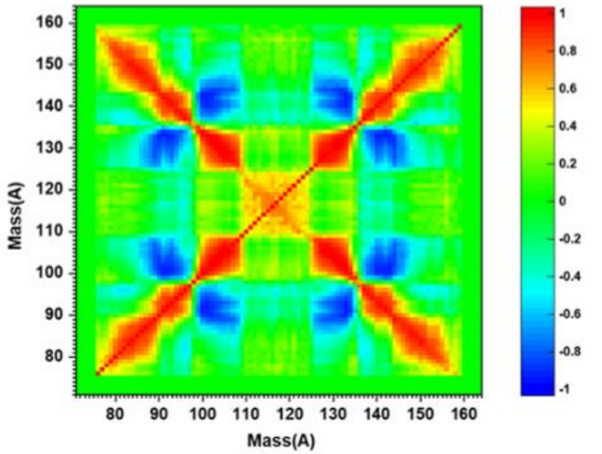
CEA_Strict



CEA_Cons.

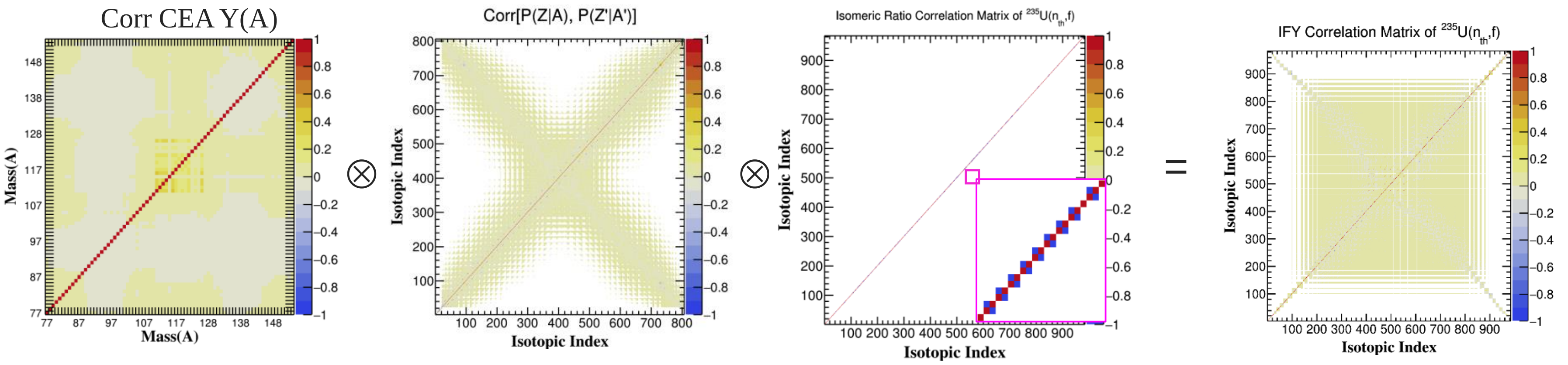


GEF →

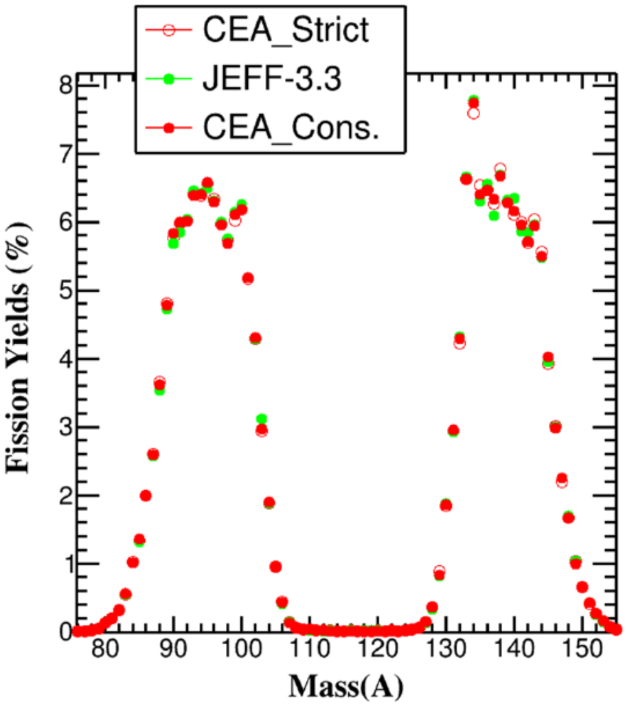


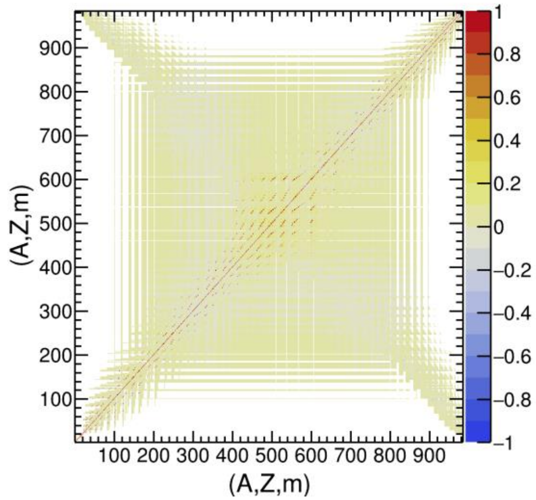
$^{235}U(n_{th},f)$ FY evaluation : JEFF-4T3 proposal → Mixed CEA-NNL Eval. method

CEA & NNL mixed method : Cov. from Conservation laws

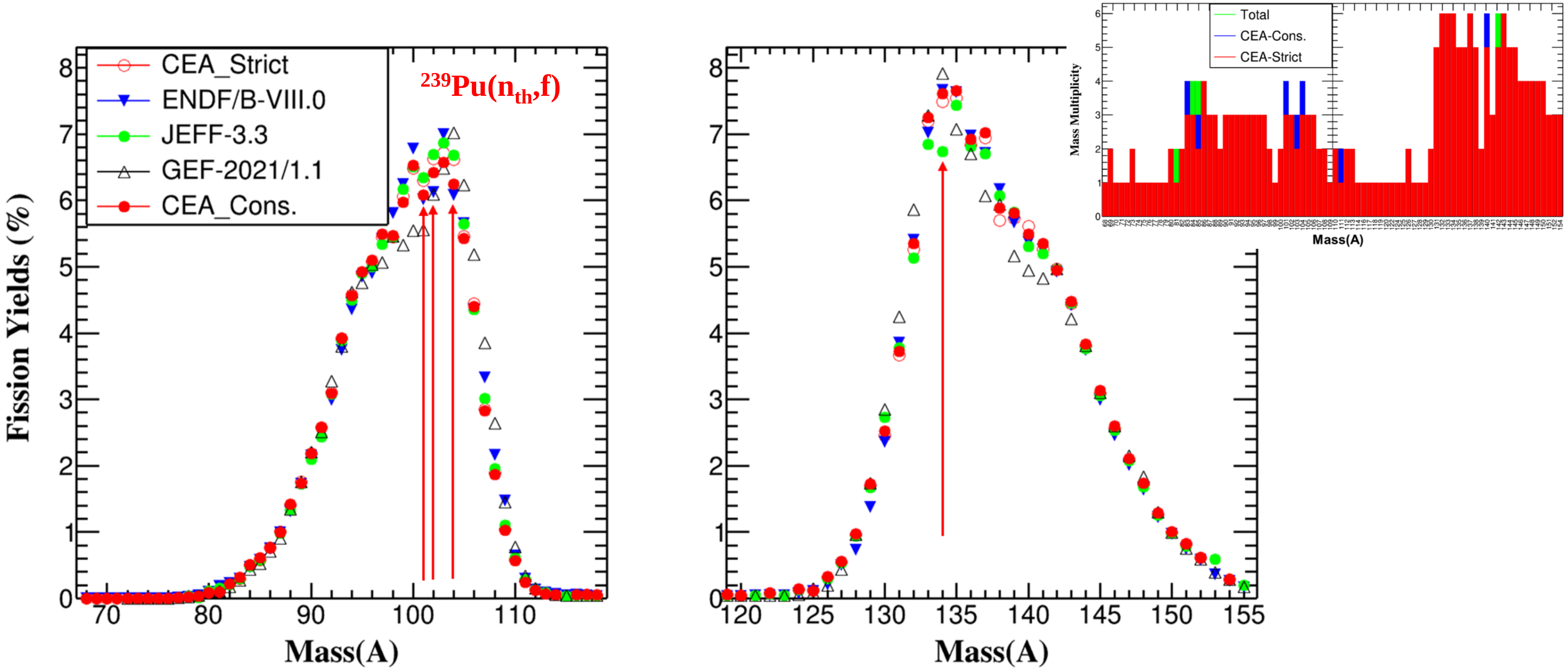


Chain yields

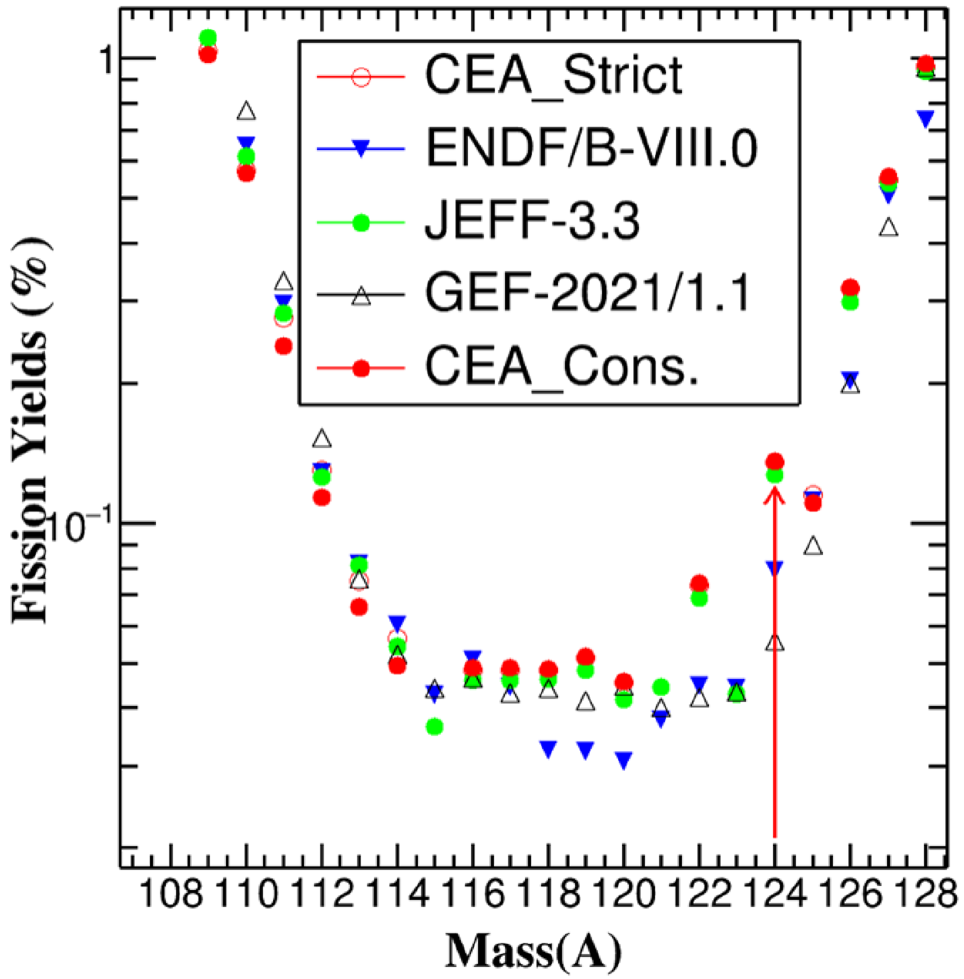


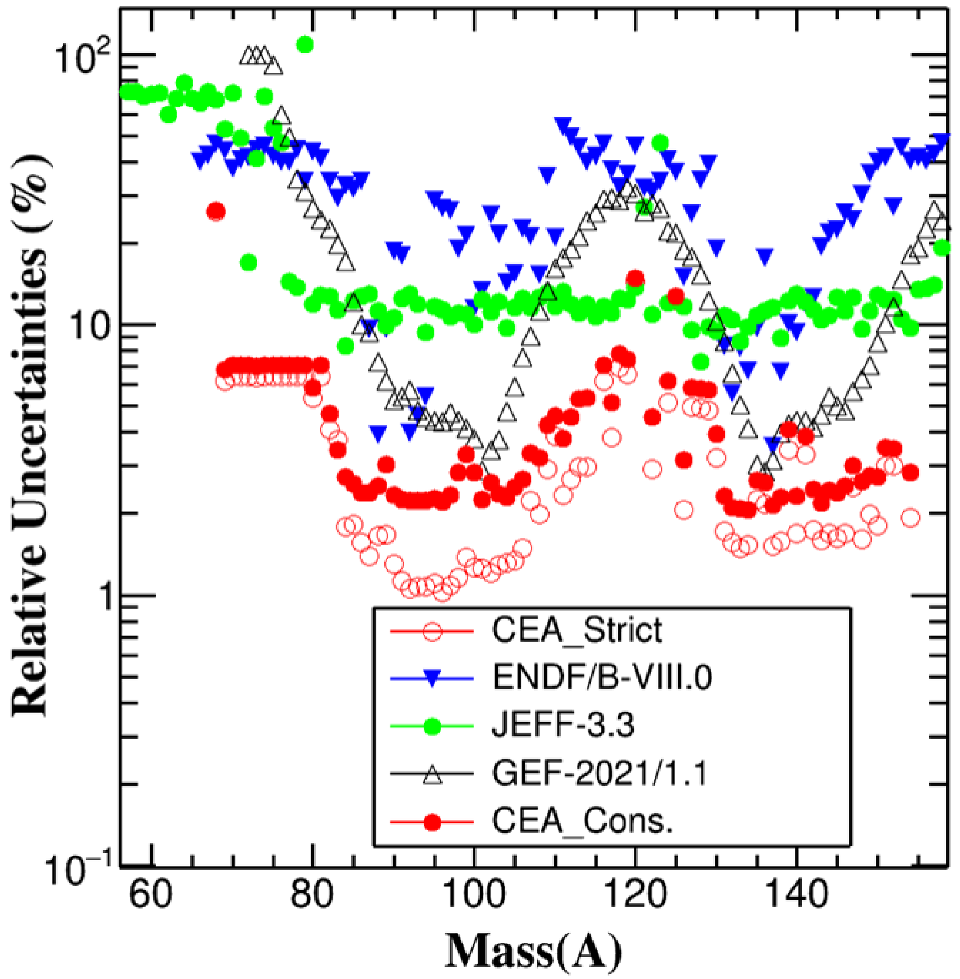


$^{239}Pu(n_{th},f)$ FY evaluation : JEFF-4T3 proposal → Mixed CEA-NNL Eval. method

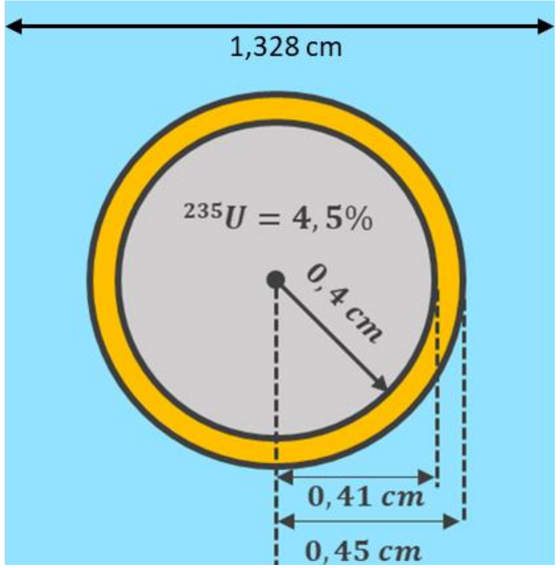


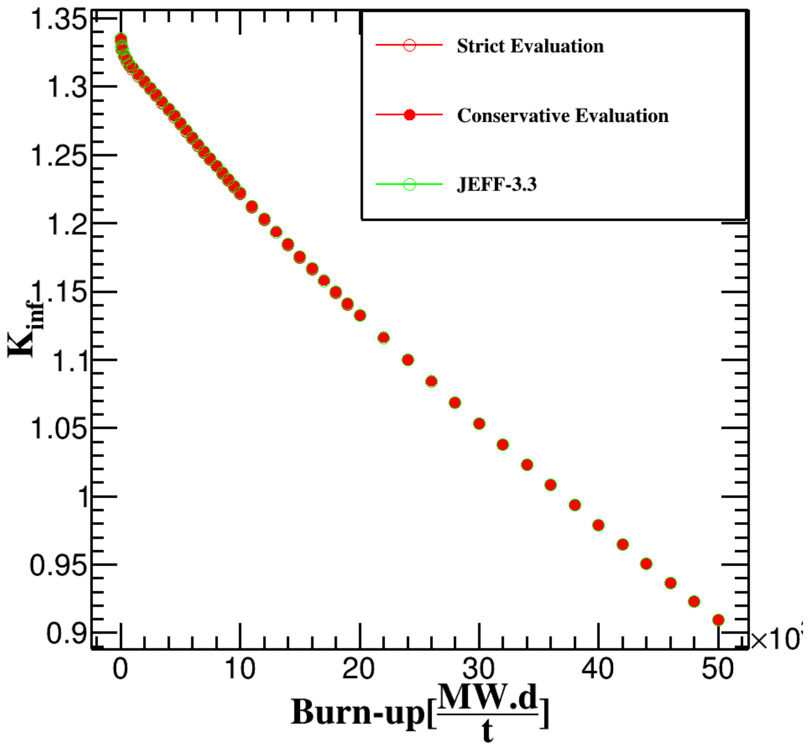
$^{239}Pu(n_{th},f)$ FY evaluation : JEFF-4T3 proposal → Mixed CEA-NNL Eval. method

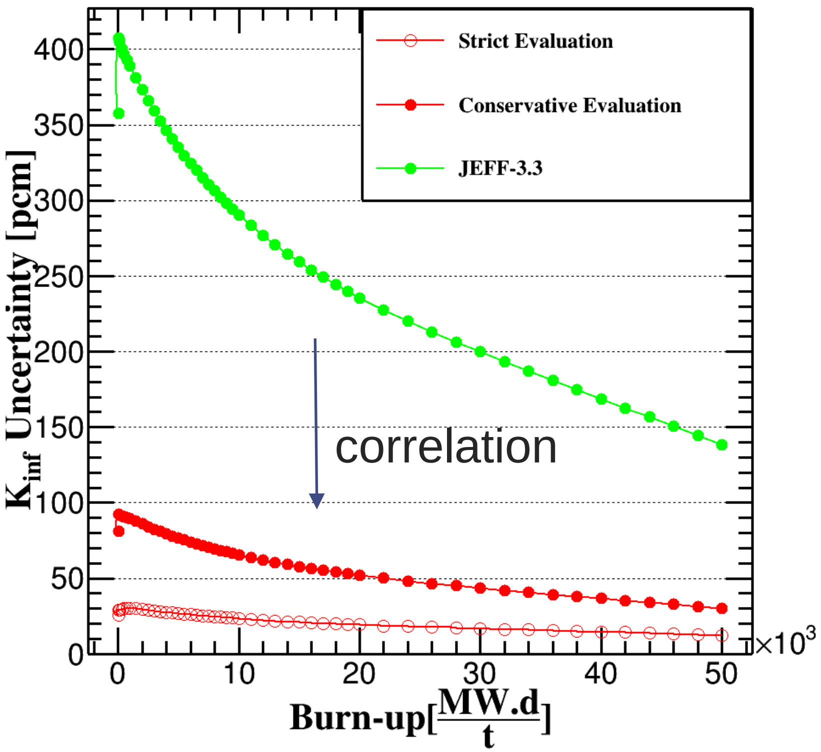




Impact of Fission Yields on the K_{inf} : UOX pin-cell calculations







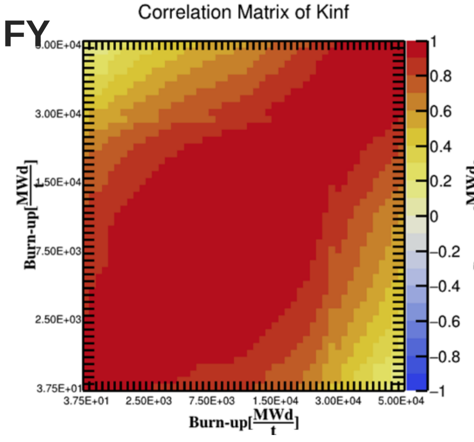
APOLLO 2 Calculations with JEFF-3.3 library (without correlation) + JEFF-4TX or ^{235}U(n,f) FY

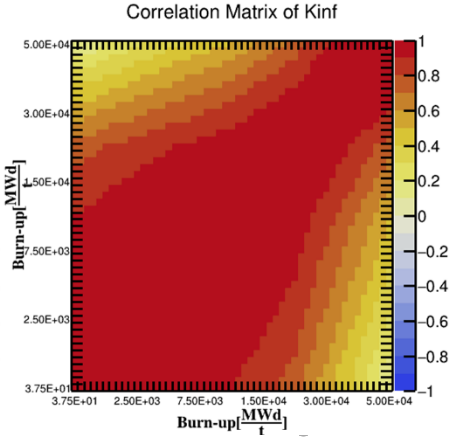
Supercell (moderation ratio = assembly moderation ratio), 4 rings in the fuel, natB: 500ppm

Doppler for some isotopes (all actinides and some PF)

Space dependent mutual shielding at BOC (Livolant-JeanPierre U5,U8,P9+P0)

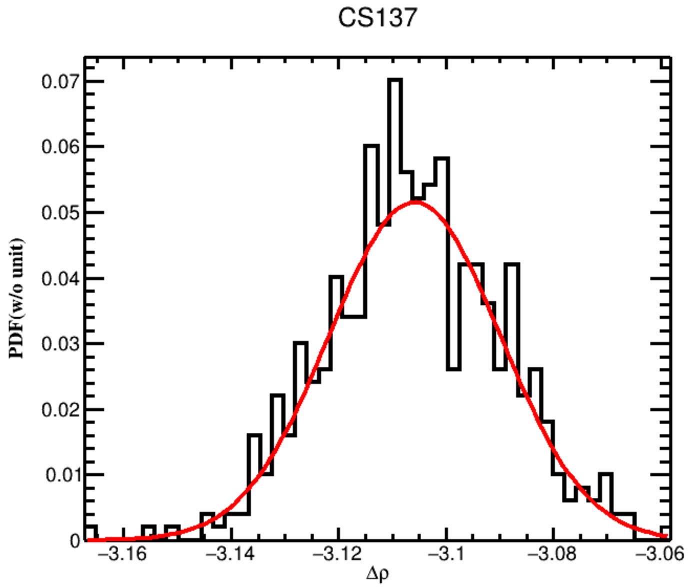
P_{ij} integral transport equation, B1 homogeneous critical leakage

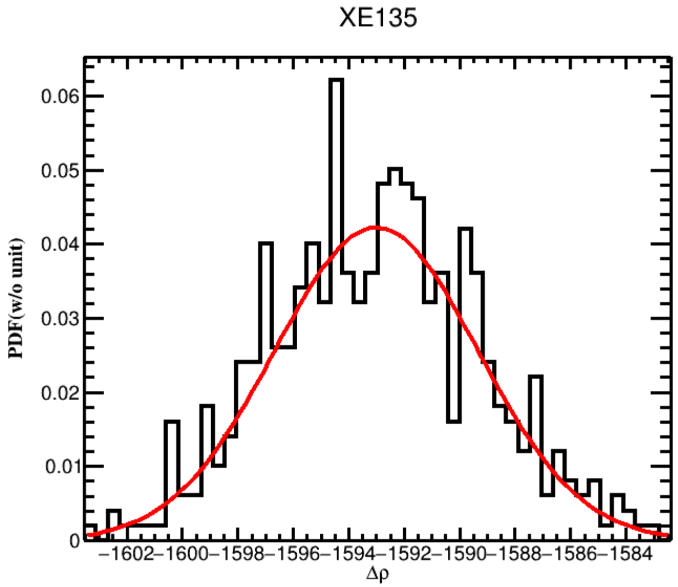




Impact of Fission Yields on the Reactivity Loss : UOX pin-cell calculations

Apollo2 + TMC on FY JEFF-4T2 using covariance matrix → M&C2023 & NSE submitted

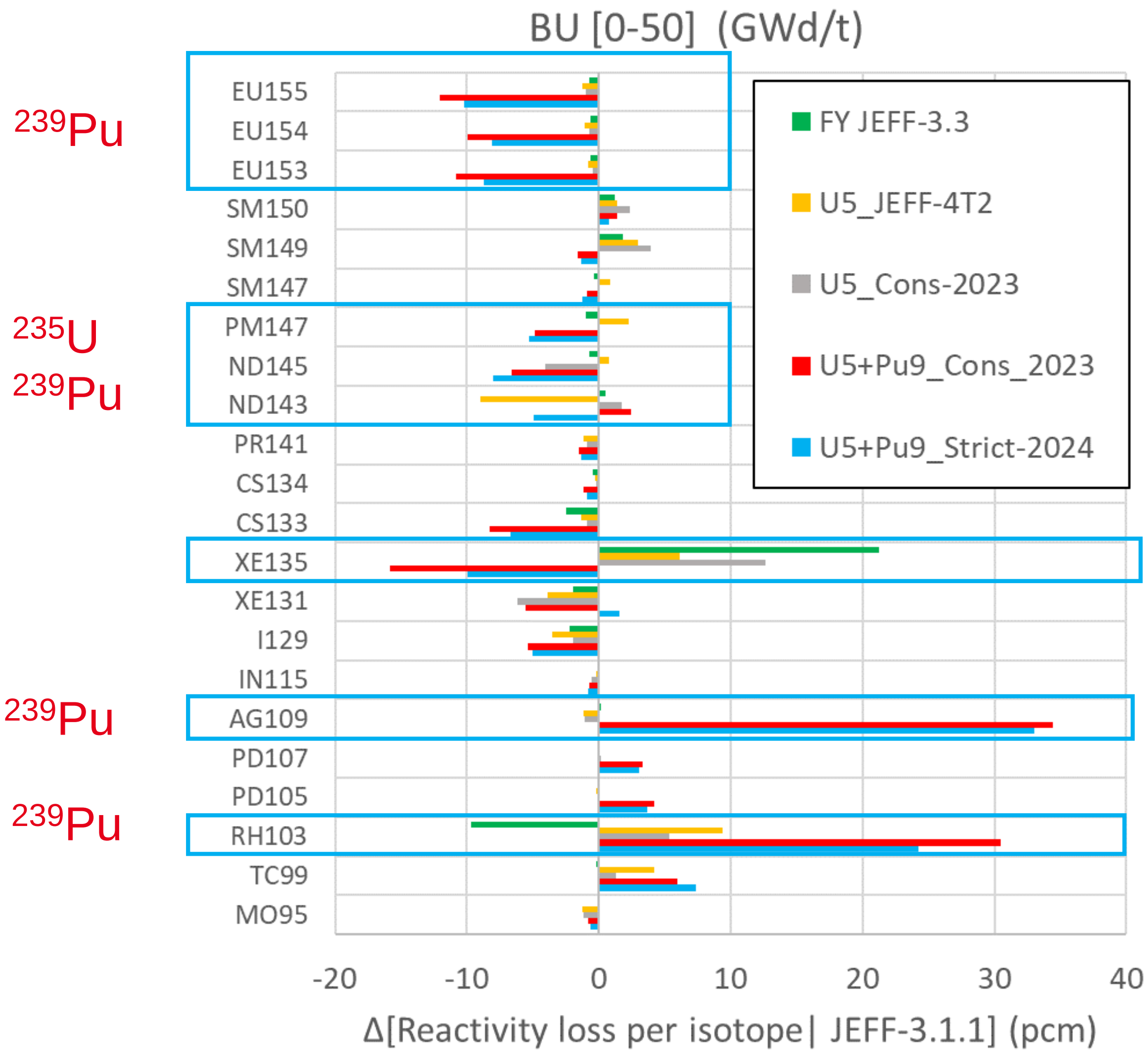


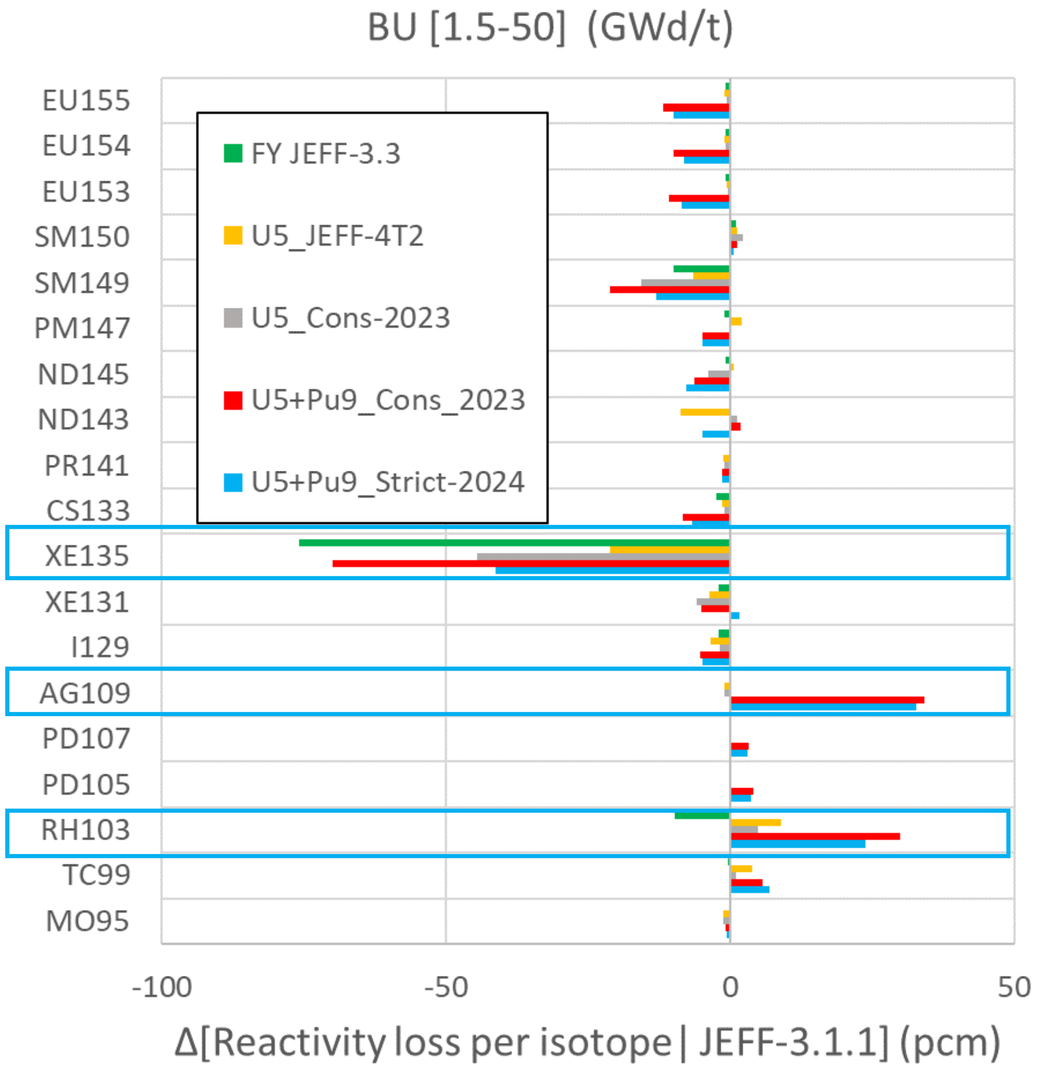


$\sigma[\Delta\rho] \sim 24$ pcm with JEFF-4T2
$\sigma[\Delta\rho] \sim 60$ pcm with CEA-Cons-2022

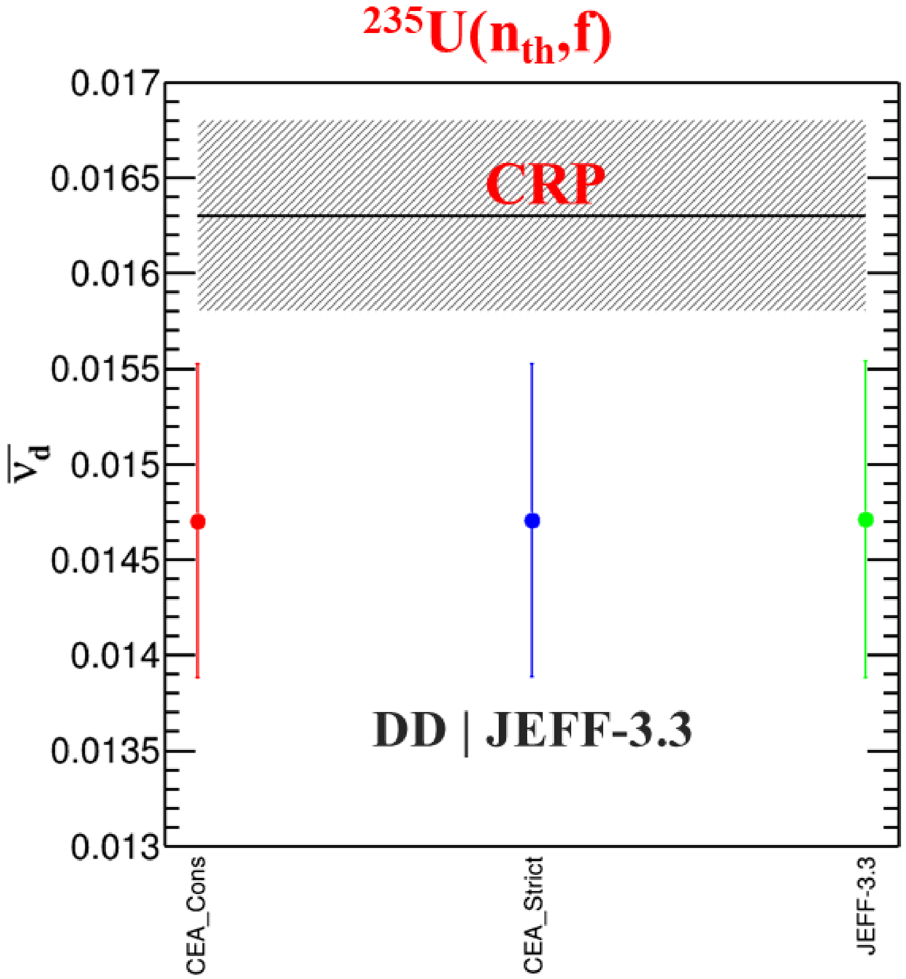
	Δρ [50-0] GWd/t [pcm]	Δρ [50-1.5] GWd/t [pcm]
JEFF-3.1.1 (XS+FY) Total	-37486	-33904
JEFF-3.1.1 (XS+FY) due to FY	-10695	-7301
Impact JEFF-4T2/FY_$^{235}U_{th}$	4	-32
Impact CONS-2023/FY_$^{235}U_{th}$	4	-68
Impact CONS-2023/FY_$^{239}Pu_{th}$	-26	-23

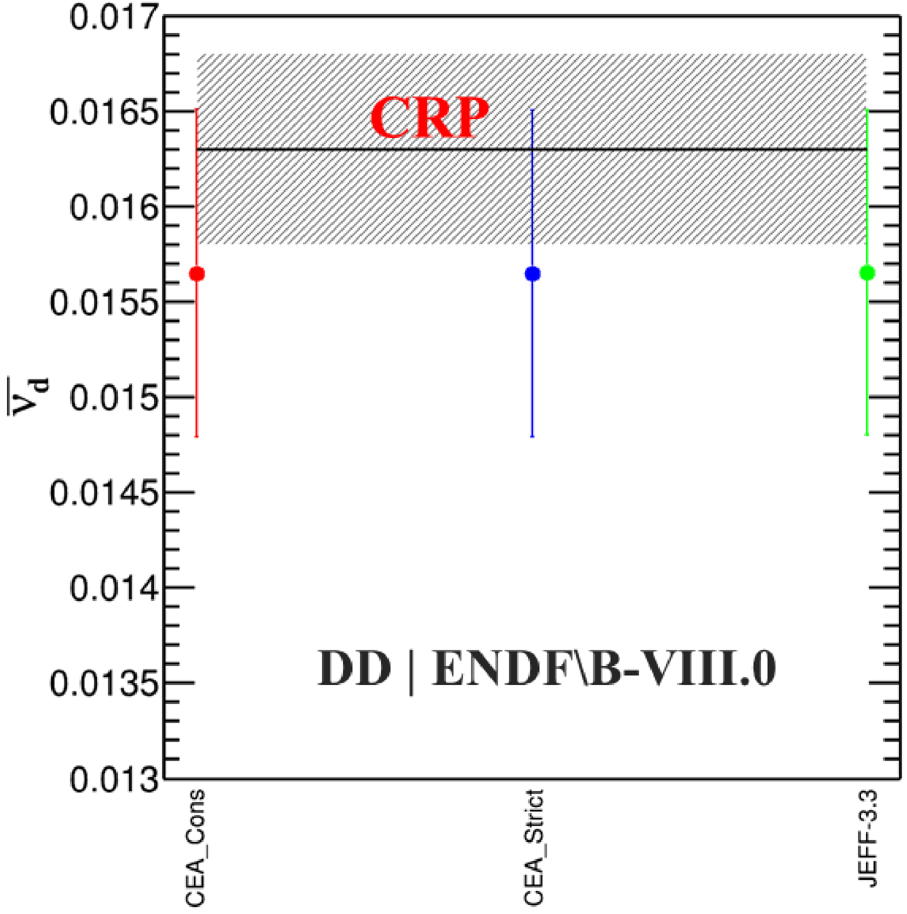
Impact of Fission Yields on the Reactivity Loss : Contributions per nucleus



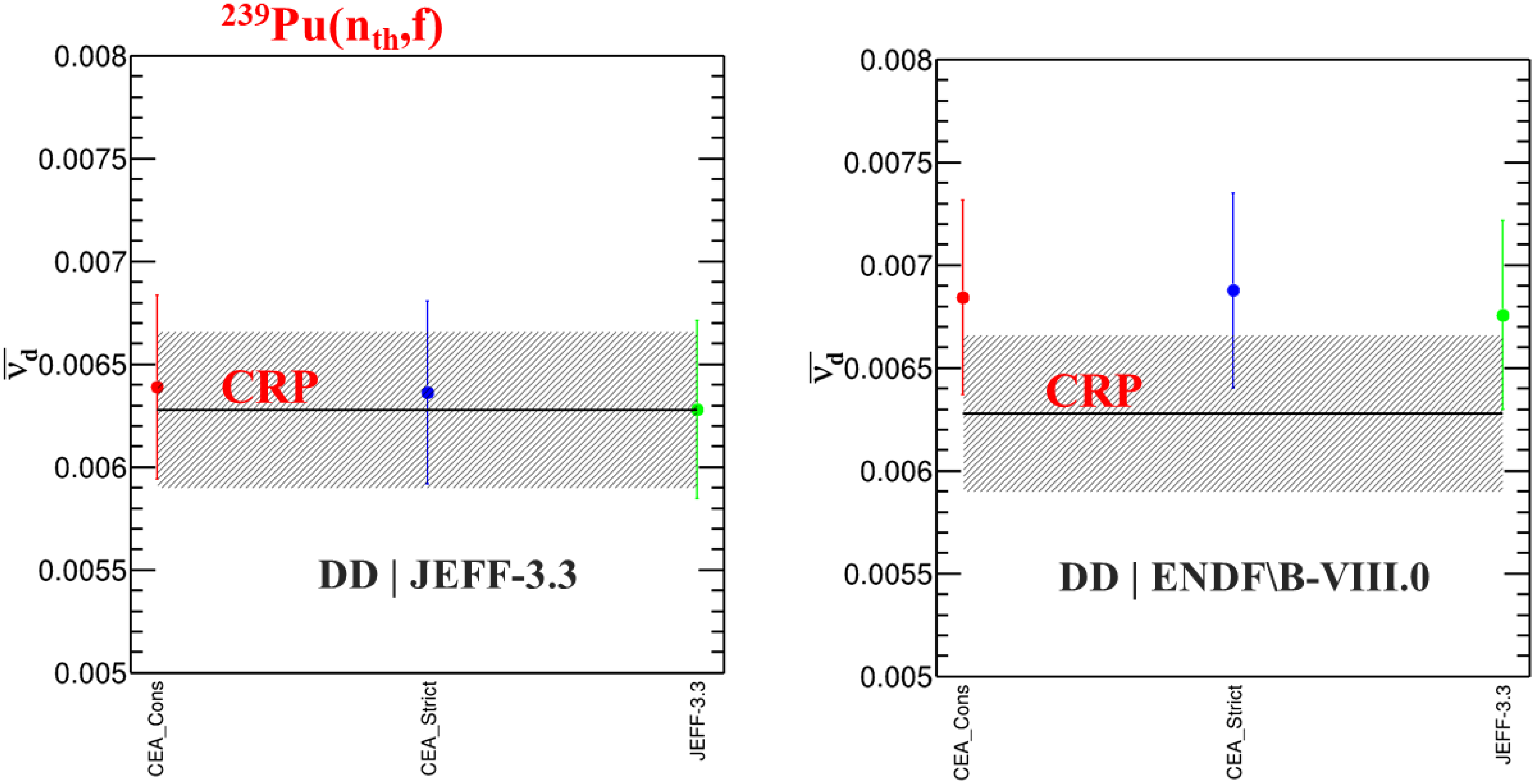


Impact of Fission Yields on ν_d calculations : $^{235}U(n_{th},f)$





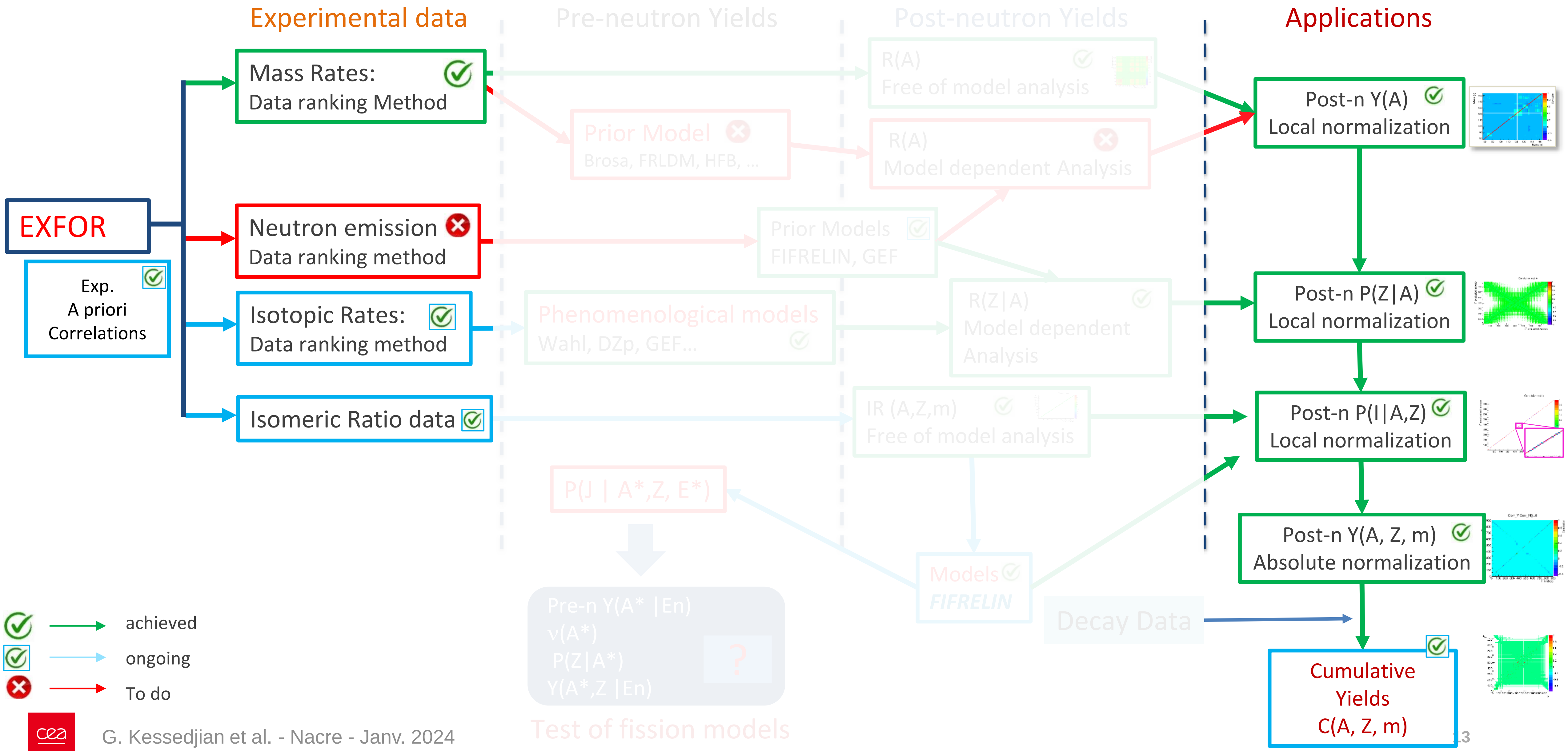
Impact of Fission Yields on ν_d calculations : $^{239}Pu(n_{th},f)$



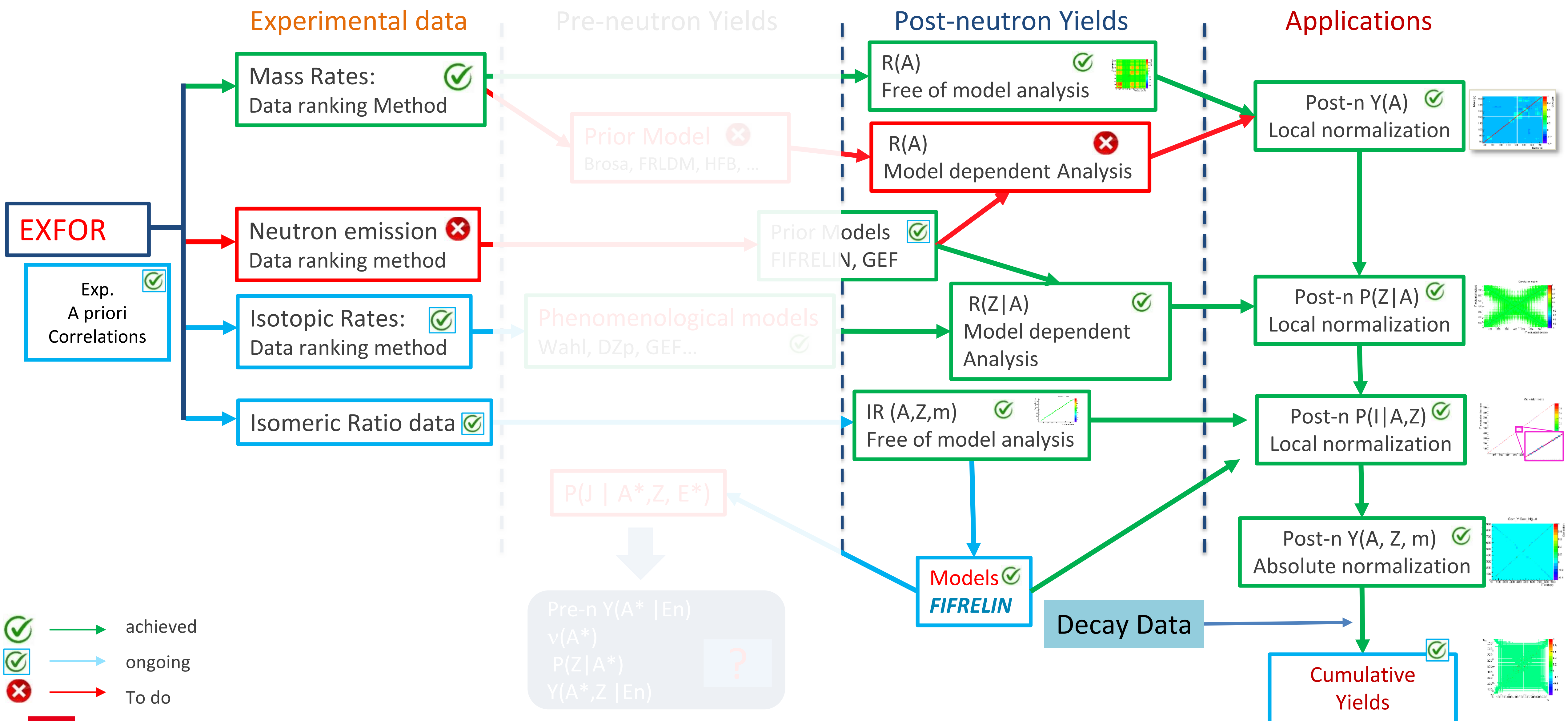
→ ENDF s JEFF Decay Data present contradictory effects in the vd calculations

→ nuclear charge distributions per mass is questioned for $^{235}U(n_{th},f)$

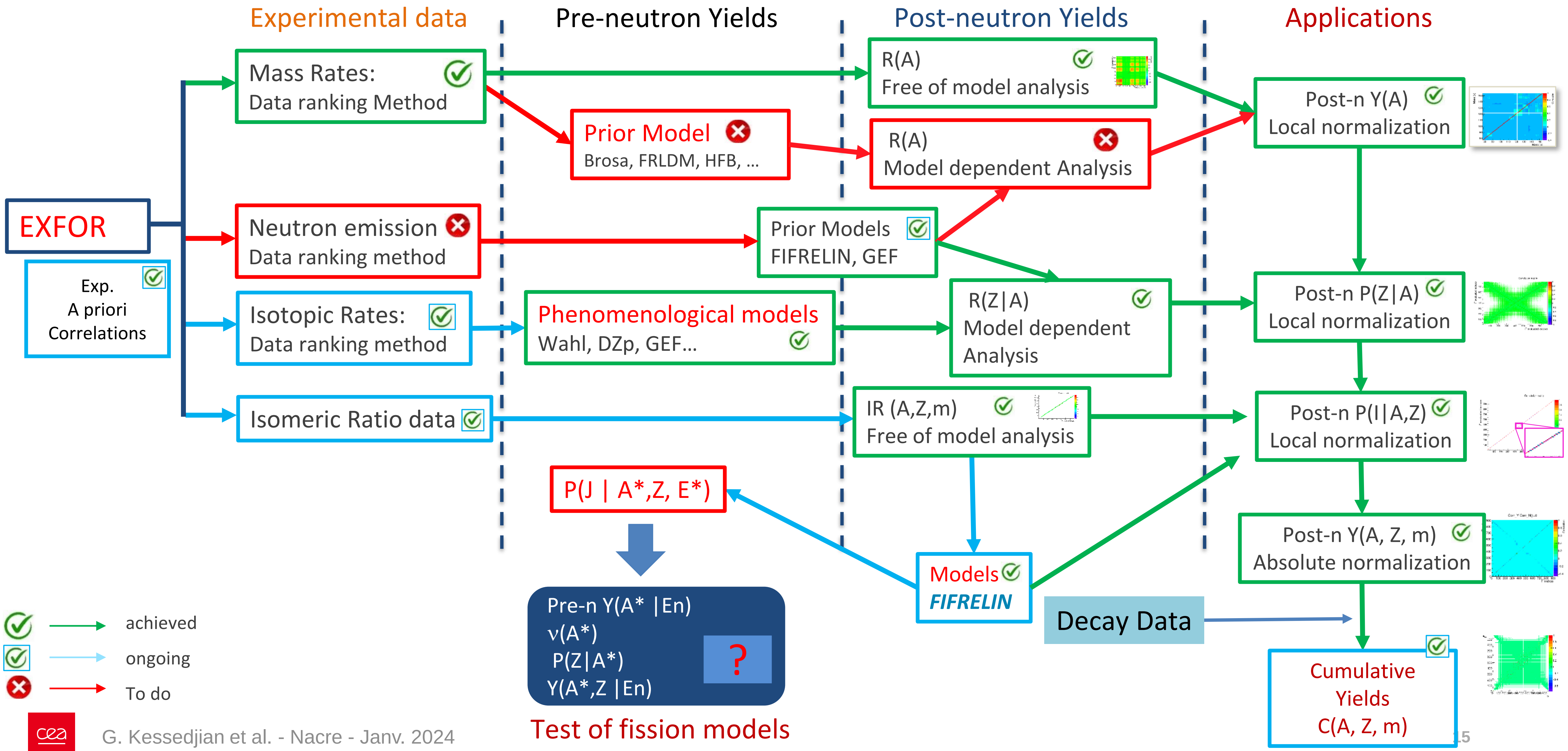
Goal → $^{235}U(n_{th},f)$ & $^{239}U(n_{th},f)$ complete and consistent evaluation



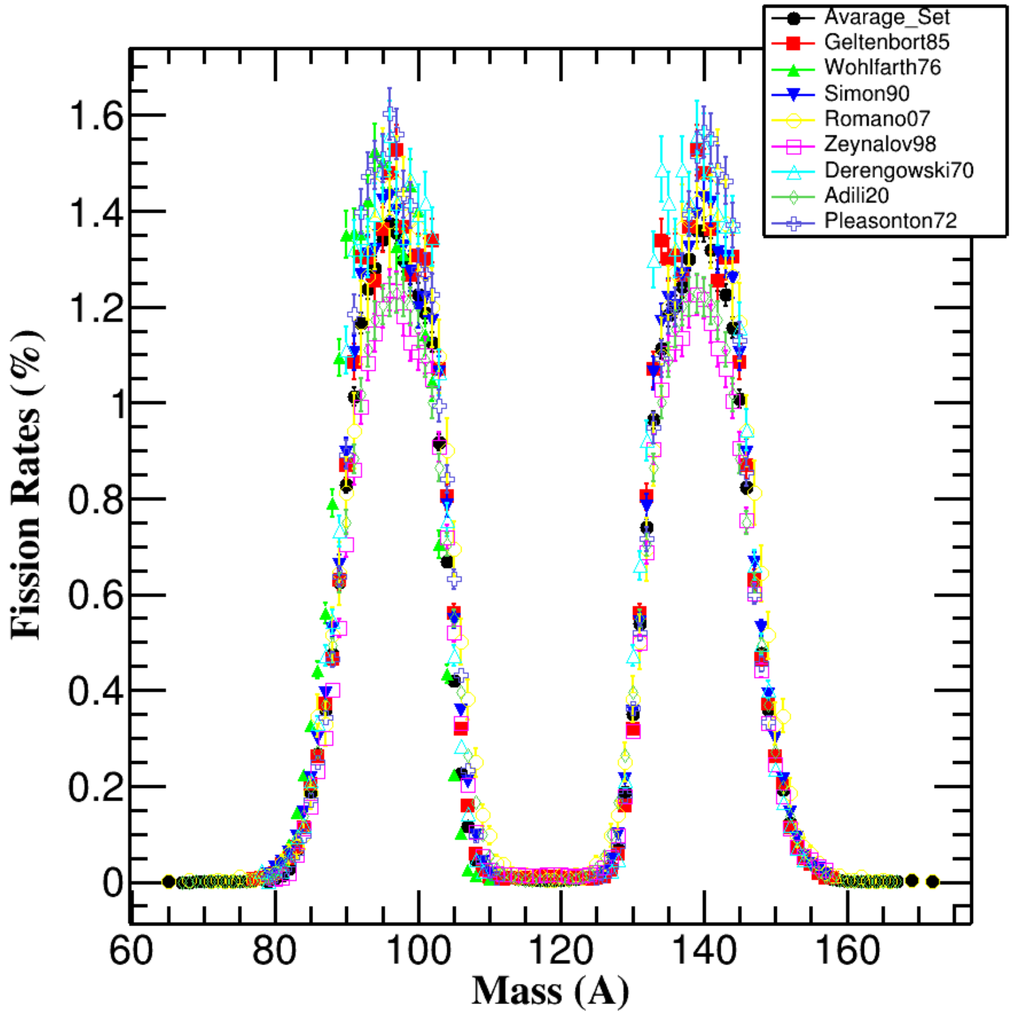
Goal → $^{235}U(n_{th},f)$ & $^{239}U(n_{th},f)$ complete and consistent evaluation

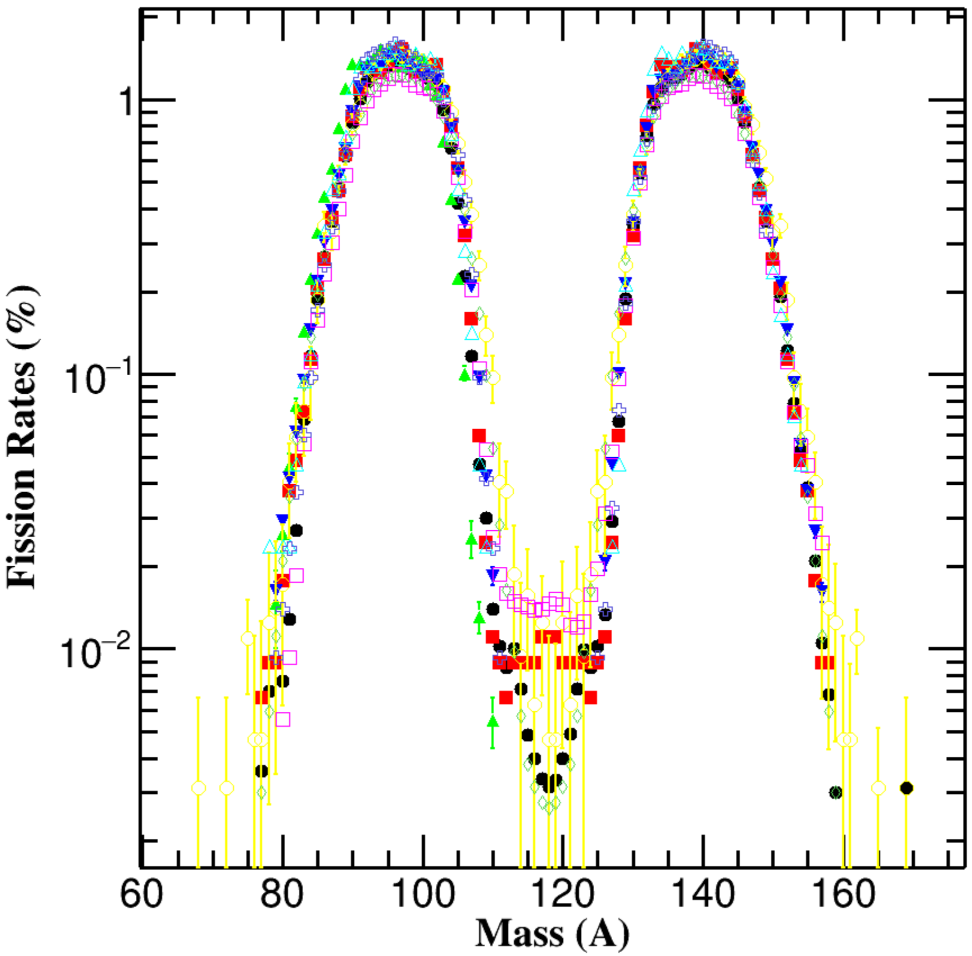


Goal → $^{235}U(n_{th},f)$ & $^{239}U(n_{th},f)$ complete and consistent evaluation



$^{235}U(n_{th},f)$ Y(A*) available experimental data on EXFOR/JANIS

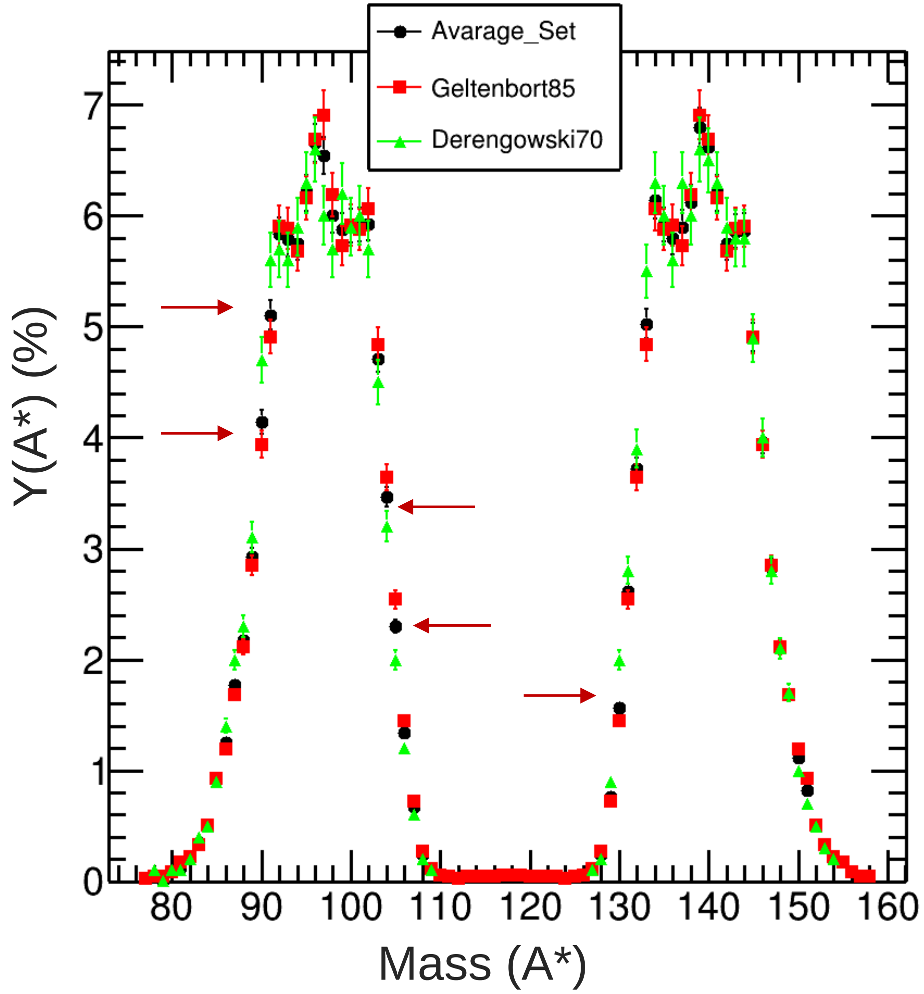




Biases : - Mass resolution of experimental data
- Saw-tooth dependency of exp. results

$^{235}U(n_{th},f)$ Y(A*) available experimental data on EXFOR/JANIS

Data	Year	Method	Obs.	P-val *
Geltenbort *	1985	2E-1v	Y(A*), Ek	1
Derengowsky	1970	2E-1v	Y(A*)	3E-11
Hambsch	1989	2E	Y(A*), Ek, σ_{Ek}	0
Al-Adili	2020	2E	Y(A*), Ek, σ_{Ek}	0
Pleasonton	1972	2E	Y(A*)	0
Romano	2007	2E	Y(A*)	0,9
Zeynalov_1	2017	2E	Y(A*)	0
Zeynalov_2	2017	2E	Y(A*)	0
Zeynalov	1998	2E	Y(A*), Ek	0
Simon	1989	2E	Y(A*), Ek	0
Ajitanand_1	1978	2E	Y(A*)	0
Ajitanand_2	1978	2E	Y(A*)	0
Ajitanand	1983	2E	Y(A*), Ek	1,4E-8

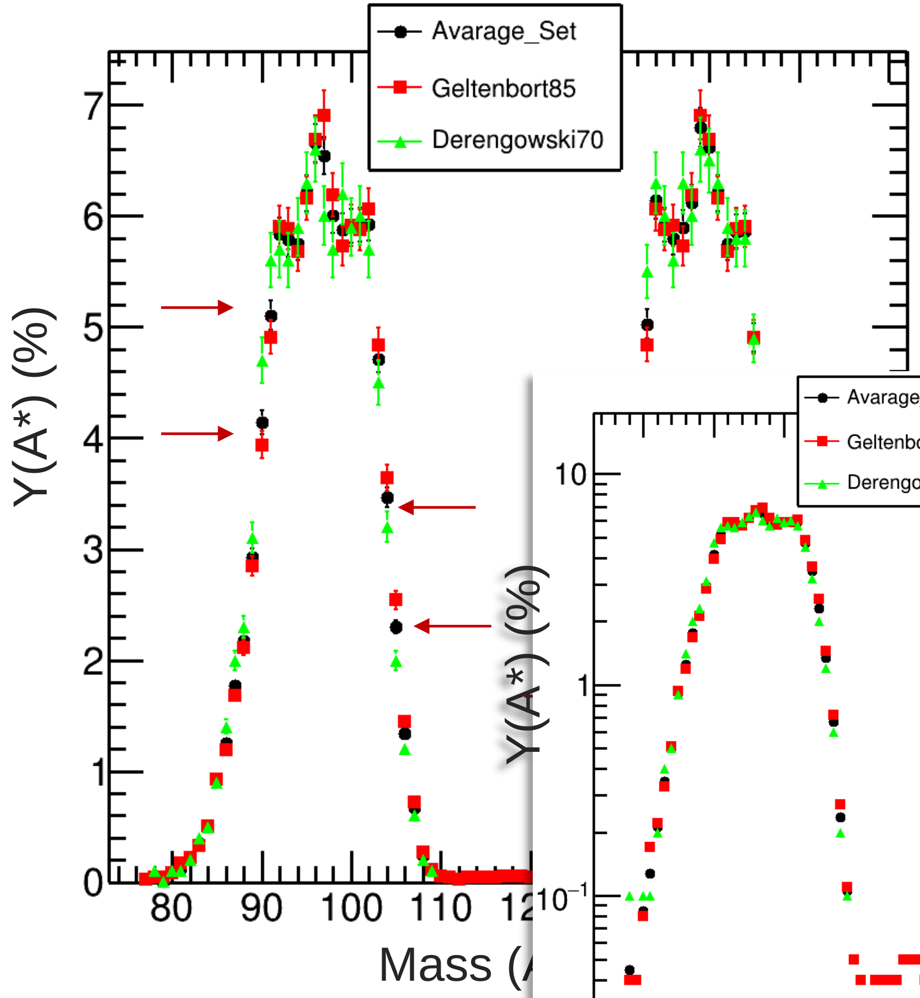


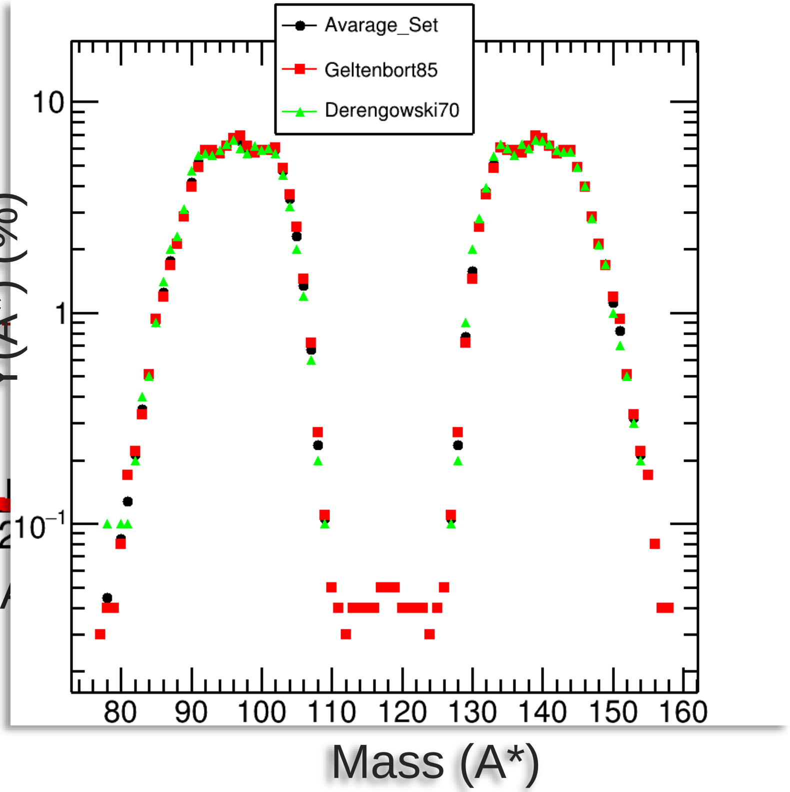
PhD thesis 2024-2027
A. Regonesi et al.

- 2E2V & 2E1V experimental data
- Without saw-tooth assumption
- Mass resolution

$^{235}U(n_{th},f)$ Y(A*) available experimental data on EXFOR/JANIS

Data	Year	Method	Obs.	P-val *
Geltenbort *	1985	2E-1v	Y(A*), Ek	1
Derengowsky	1970	2E-1v	Y(A*)	3E-11
Hambsch	1989	2E	Y(A*), Ek, σ_{Ek}	0
Al-Adili	2020	2E	Y(A*), Ek, σ_{Ek}	0
Pleasonton	1972	2E	Y(A*)	0
Romano	2007	2E	Y(A*)	0,9
Zeynalov_1	2017	2E	Y(A*)	0
Zeynalov_2	2017	2E	Y(A*)	0
Zeynalov	1998	2E	Y(A*), Ek	0
Simon	1989	2E	Y(A*), Ek	0
Ajitanand_1	1978	2E	Y(A*)	0
Ajitanand_2	1978	2E	Y(A*)	0
Ajitanand	1983	2E	Y(A*), Ek	1,4E-8





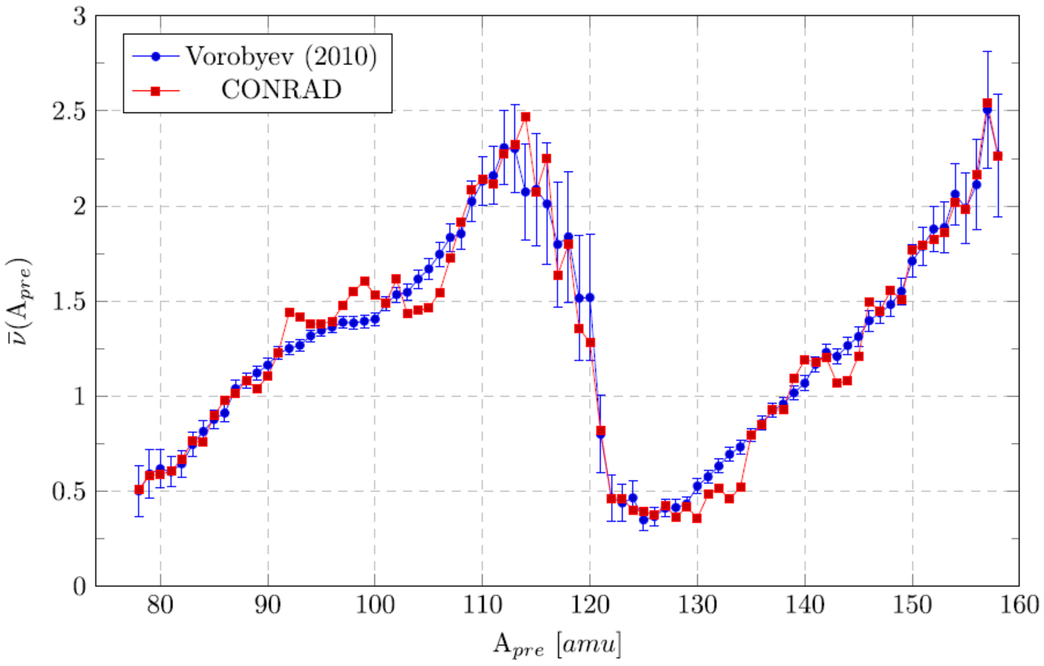
PhD thesis 2024-2027
A. Regonesi et al.

- 2E2V & 2E1V experimental data
- Without saw-tooth assumption
- Mass resolution

$^{235}U(n_{th},f)$ u(A*) available approaches and data

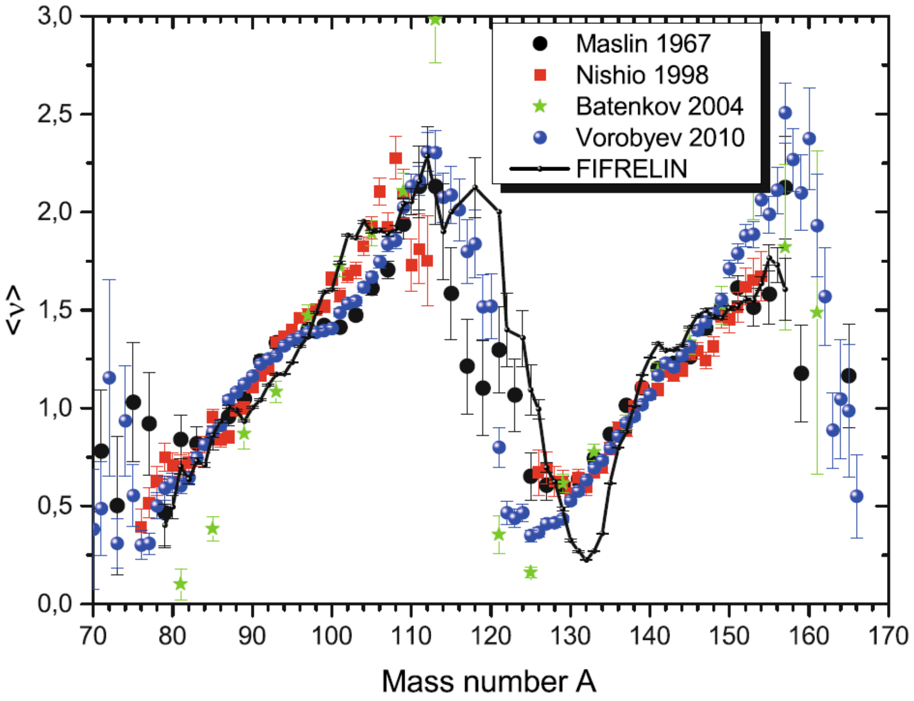
Terranova's approach

N. Terranova et al./Annals of Nuclear Energy 109 (2017) 469–489



Brosa model Vs JEFF3.1.1 : 5% unc. on Y(A)
Unpredictive estimator of neutron emission
Exp. $\nu(A^*)$: Mass resolution of 2-3 u dependency

FIFRELIN



Model using input data
$Y(A^*)$; $\langle E_k(A^*)\rangle$; $\sigma_{E_K}(A^*)$; $P(Z|A^*)$
Adjusted only on $\bar{\nu}$

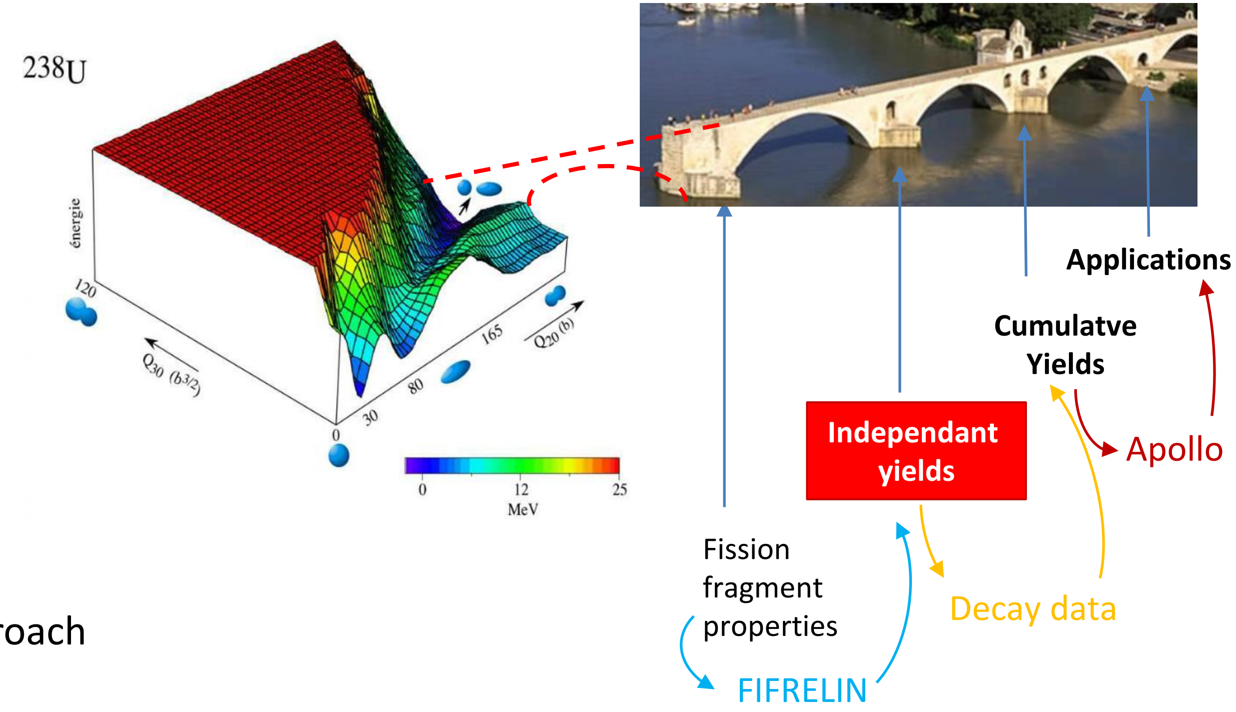
→ Provide $P(\nu|A^*)$

Perspectives

❑ Thermal neutron induced Evaluation $^{235}U(nth,f)$ Y(A*)| Y(A)

- Coupled analysis of pre-neutron $Y(A^*)$ and $P(\nu|A^*)$ is requested to connect pre-N and Post-N fission yields
- KE distribution are requested to determine $P(\nu|A^*)$
- Major Pre-neutron data are dependent to a Saw-Tooth $\nu(A^*)$ dataset
  Multivariate analysis involved to use only the 2E2V method (1 dataset) or 2E1V method (1 dataset)

  → A complete dataset of {Y(A*) ; Y(A) ; C(A)}
  allowing the determination of Brosa Modes or ???
  → Consistent evaluation of fission yields from
  pre-neutron yields up to chain yields
  → **connected to spectroscopy of KE dist. of mass**



❑ Fast neutron induced $^{235}U(n_r,f)$ Y(A*)| Y(A)

- Only partial datasets of fission rates
- Model Inputs are requested to developed evaluation of fast neutron induced fission yields
- ^{235}U is the most complete fissionning system to test this new approach
  → C(A; E_n) exp. Data available

❑ PhD thesis (2024-27) on Fast neutron induced fission : U5, U8, Pu9

$$Y(A^*, E_K) = Y(A^*).P(E_K|A^*)$$

S. M. Cheikh[1], G. Kessedjian[1], O. Serot[1], A. Chebboubi[1], D. Bernard[1], V. Vallet[1], R. Mills[2] and L. Capponi[2]

[1] CEA, DES, IRESNE, DER, SPRC, LEPh, Cadarache center, F-13108 Saint Paul lez Durance, France
[2] National Nuclear Laboratory, Central Laboratory, Sellafield, Seascale CA20 1PG, England

Thank you for your attention

jefdoc-1902
jefdoc-1982
jefdoc-2007
jefdoc-2038
jefdoc-2056
jefdoc-2027
jefdoc-2203
jefdoc-2204
jefdoc-2205
jefdoc-2207
jefdoc-2247
jefdoc-2295
jefdoc-2296

- 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., NSE, Submitted (2023)
- S.-M. Cheikh, PhD thesis, UGA, 18 Oct. 2023
- S.-M. Cheikh, G. Kessedjian et al., EPJ A, in preparation