



Improvements of the ^{239}Pu Evaluation for JEFF-3

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Summary:



✘ Needs for improvement:

- ICSBEP/Pu-Sol-Therm
- k_{eff} overestimation for MOx cores
- Mod. Temp. Coef. in LWR-MOX

✘ Description of the improved JEFF-3 file:

- $\nu_{t,p}$ ($E_n < 23\text{eV}$)
- $\sigma_{t,f,\gamma}$ ($E_n < 0.1\text{eV}$)

✘ Experimental validation of the new ^{239}Pu file.

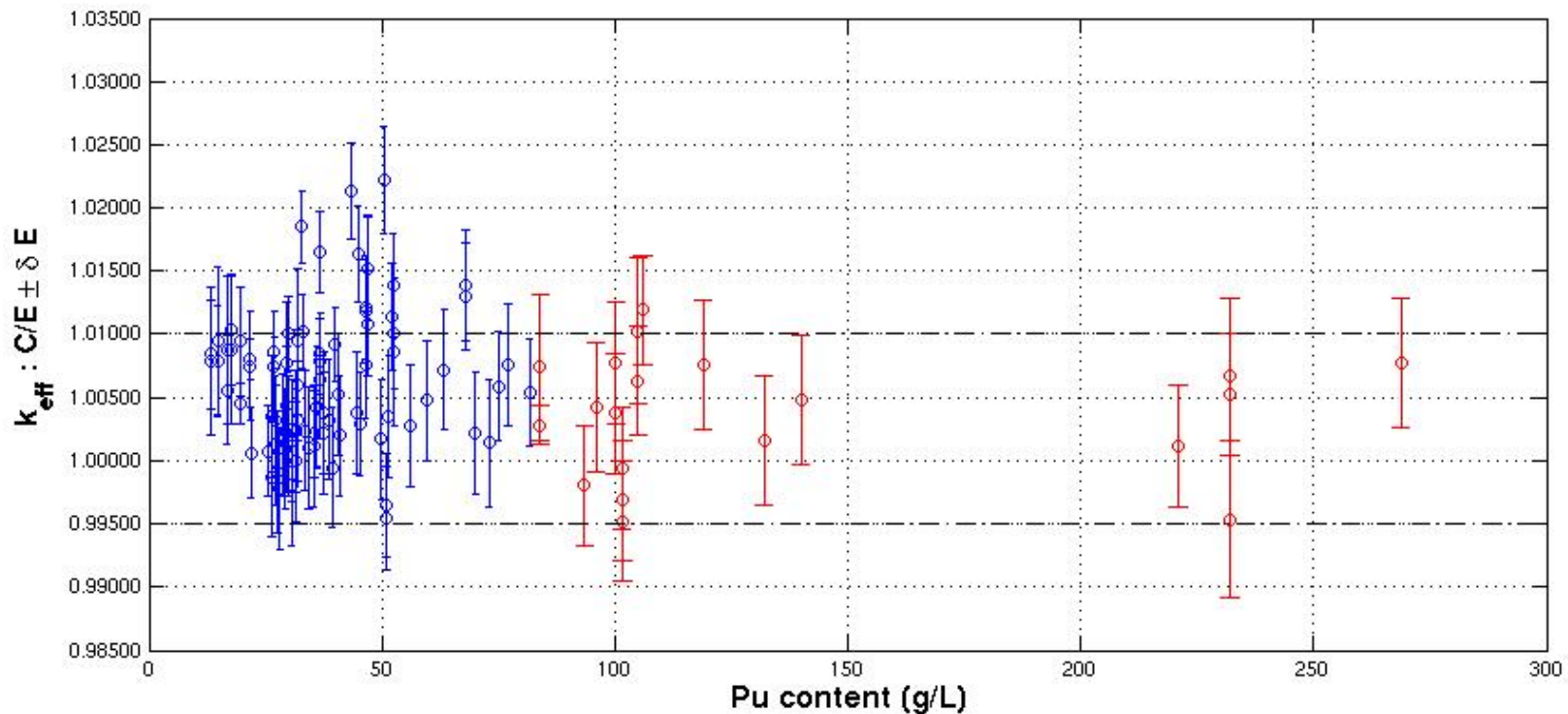
✘ Conclusion.

Needs for improvement:

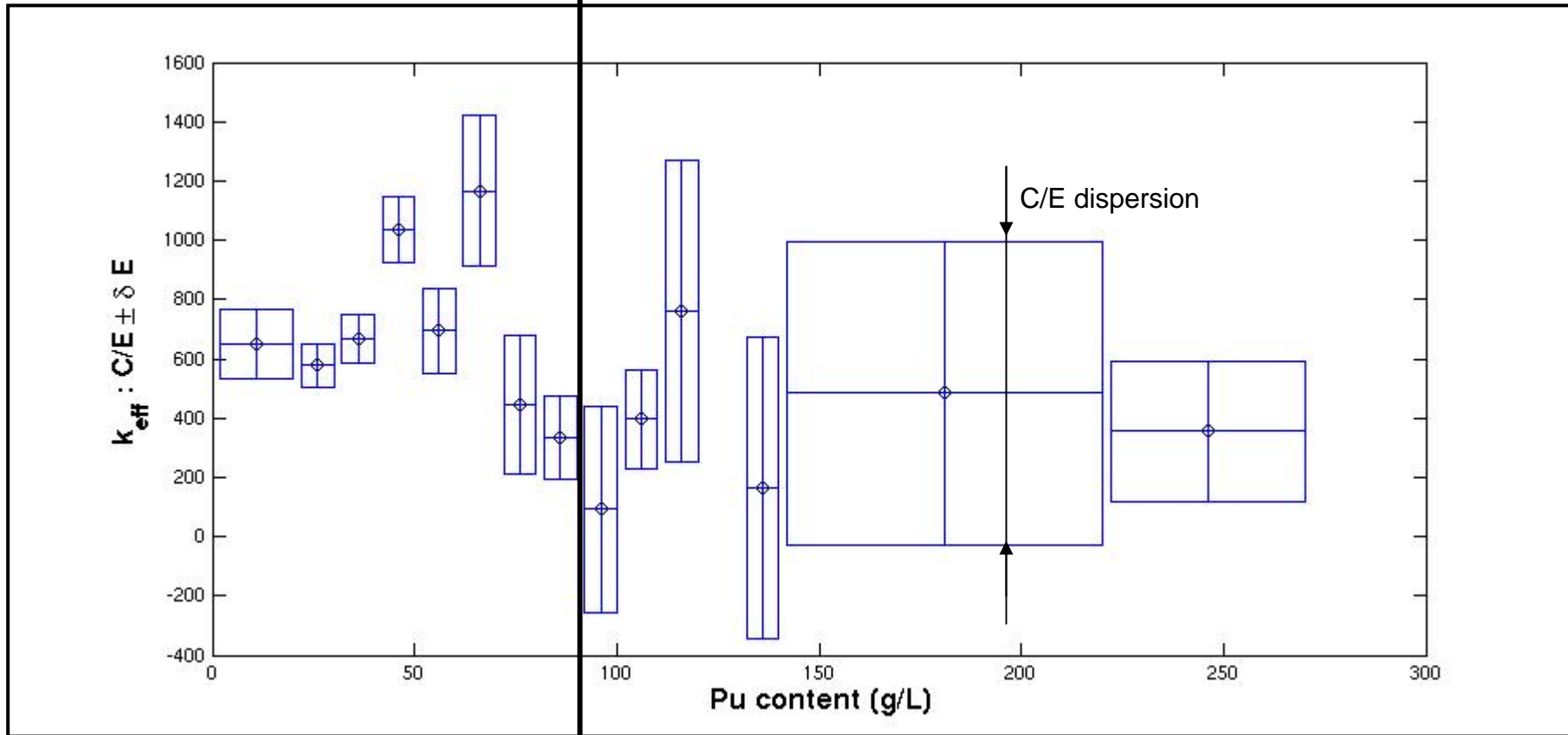
✘ ICSBEP/PU-SOL-THERM Benchmarks show an overestimation of the k_{eff} prediction using JEFF-3.1 (see MCNP4.c3 results from S.Van Der Marck JEF/DOC-1107):

PST001 → PST011: ^{240}Pu content < 4.8%

PST012 (Valduc): ^{240}Pu content = 19%



k_{eff} overestimation per quantiles ICSBEP/PST-001 to 012



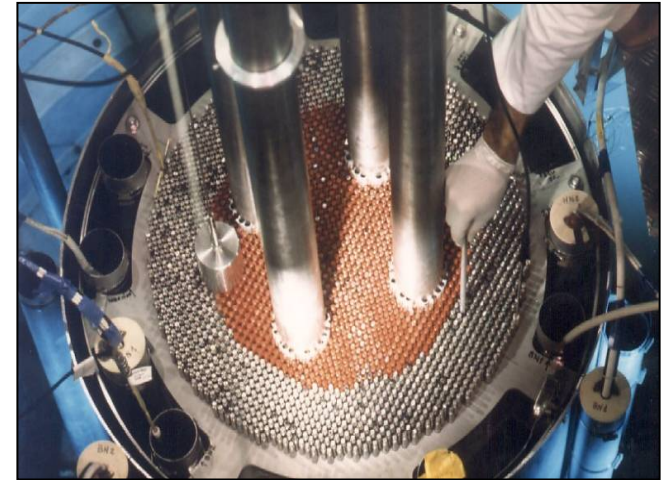
C/E-1 = +700 ± 200 pcm

C/E-1 = +340 ± 200 pcm

Needs for improvement:

✘ Qualification results show systematic JEFF-3.1 overestimation of the whole core k_{eff} prediction using Monte Carlo codes (see TRIPOLI4 results from O. Litaize et al.: JEF/DOC-1143 and N. Thiollay):

⇒ For standard Pu-aging
(small ^{241}Am poisoning),
Keff overestimation by 200-300 pcm



EOLE mock-up	Plutonium Aging	Moderation Ratio (or Void Fraction)	(C-E) ± (δE) (pcm)
MH1.2 (PWR-MOx mixed core)	4 years	MR=1.2	280 ± 250 (1σ_{T4}=20pcm)
MISTRAL-2 (PWR-MOx)	8 years	MR=1.7	630 ± 250 (1σ_{T4}=20pcm)
MISTRAL-3 (PWR-MOx)	10 years	MR=2.1	710 ± 250 (1σ_{T4}=20pcm)
BASALA-Hot (BWR-MOx)	12 years	42% void	610 ± 250 (1σ_{T4}=20pcm)
BASALA-Cold (BWR-MOx)	13 years	0% void	700 ± 250 (1σ_{T4}=20pcm)
FUBILA-Hot (BWR-MOx)	1 year	0% void	250 ± 250 (1σ_{T4}=20pcm)

Needs for improvement:

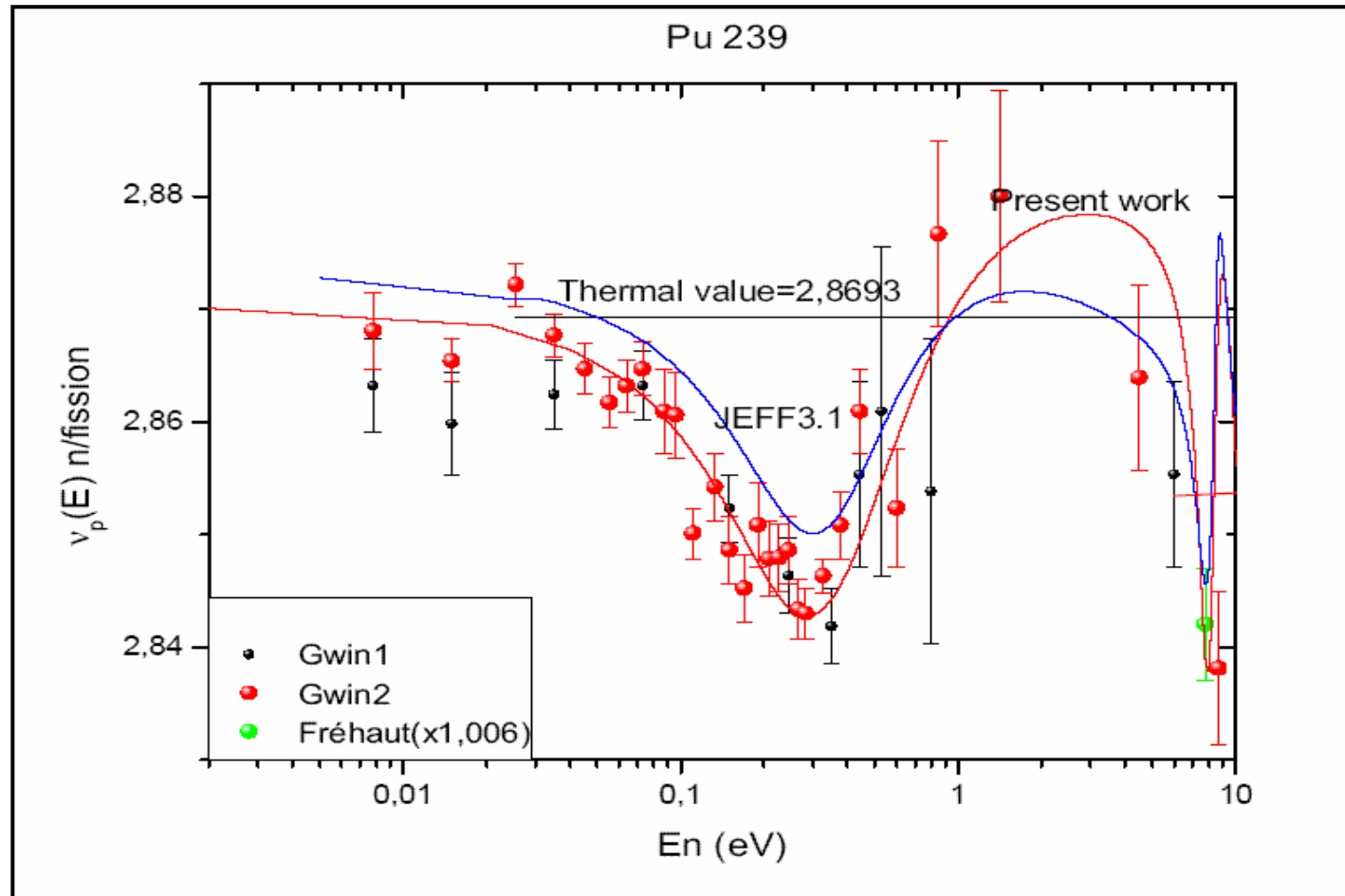
✘ Qualification results of the Isothermal Temperature Coefficient in MOx lattices show :

(see L. Erradi and A. Santamarina: NSE 144,47-74 (2003) and C. Vaglio et al.: PHYSOR'06)

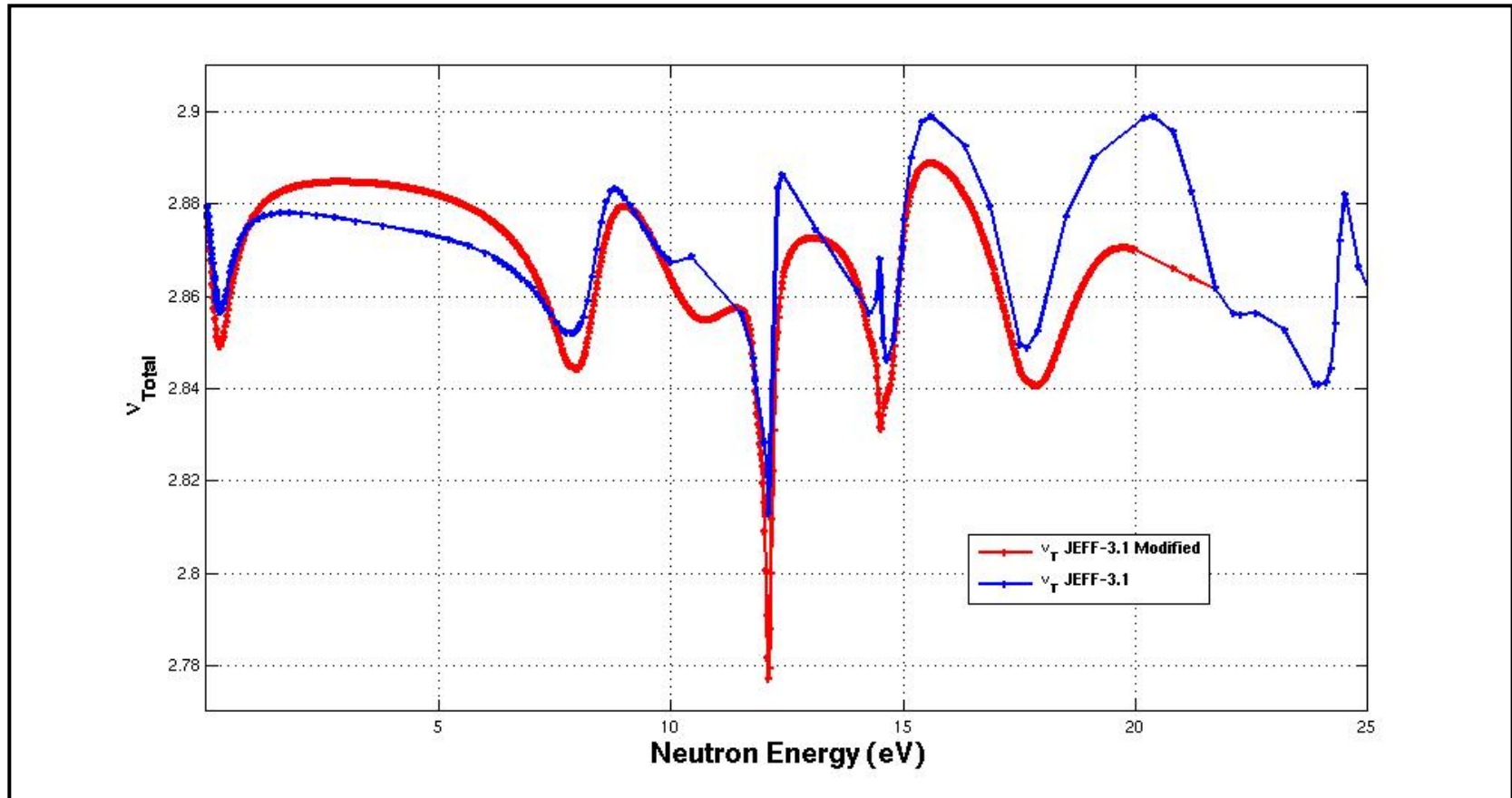
- -2.0 ± 0.3 pcm/K due to the $\alpha = \sigma_\gamma / \sigma_f$ value in the subthermal and thermal range in the cold operation conditions (20°C-60°C) (JEF-2.2 interpretation of MISTRAL experiment)
- -1.7 ± 0.3 pcm/K in cold operation conditions (10°C-80°C) (JEFF-3.1 interpretation of BASALA experiment)
- $+1.0 \pm 2.1$ pcm/K in hot operation conditions (150°C-300°C). α value is accurate enough in the 0.3 eV resonance. (JEF-2.2 interpretation of CREOLE experiment)

Proposed modifications:

Mean number of neutron emitted by fission: $\nu_{t,p}$
E. Fort & A. Courcelle (WONDER'06)



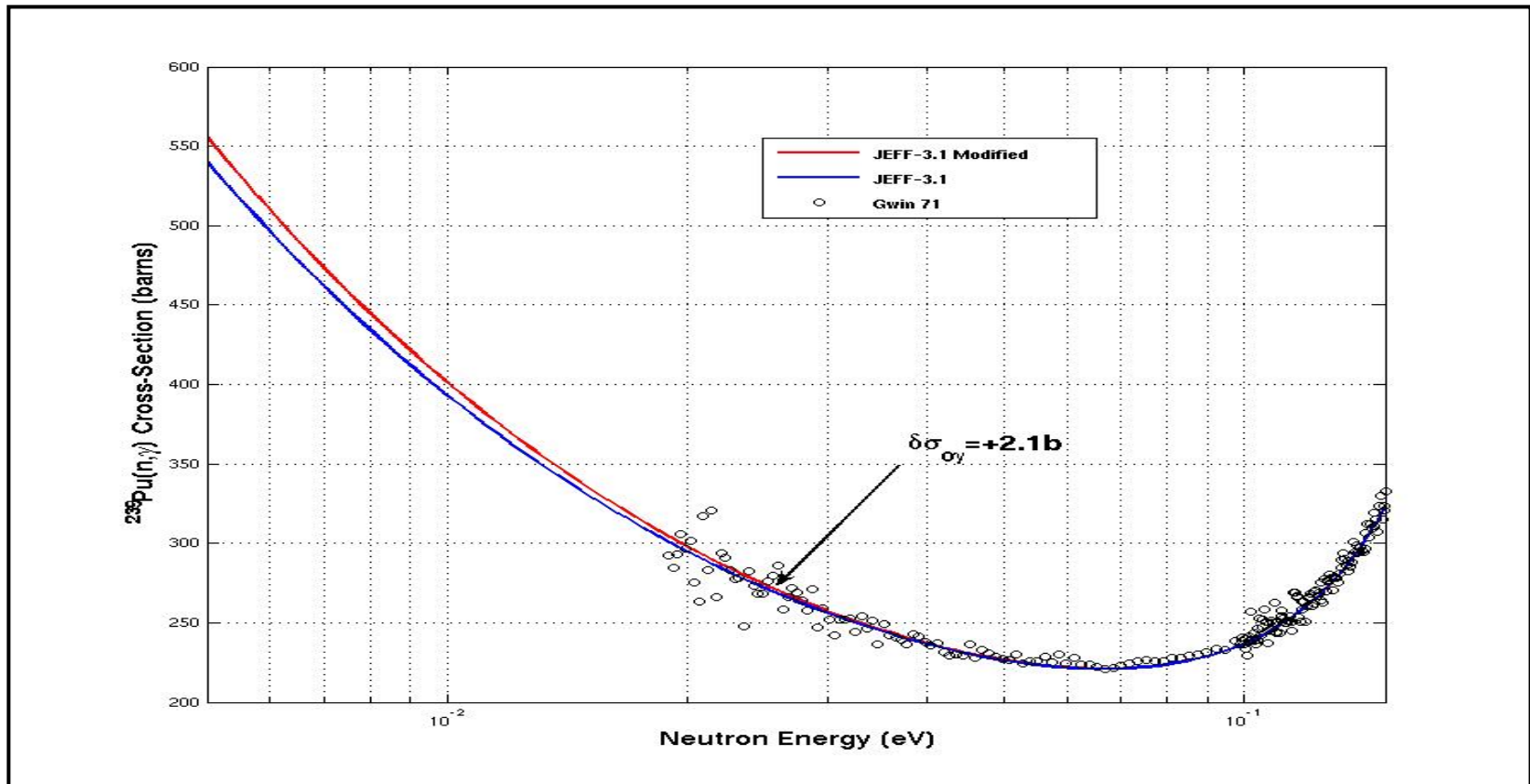
New evaluation using the fluctuation analysis up to 20eV



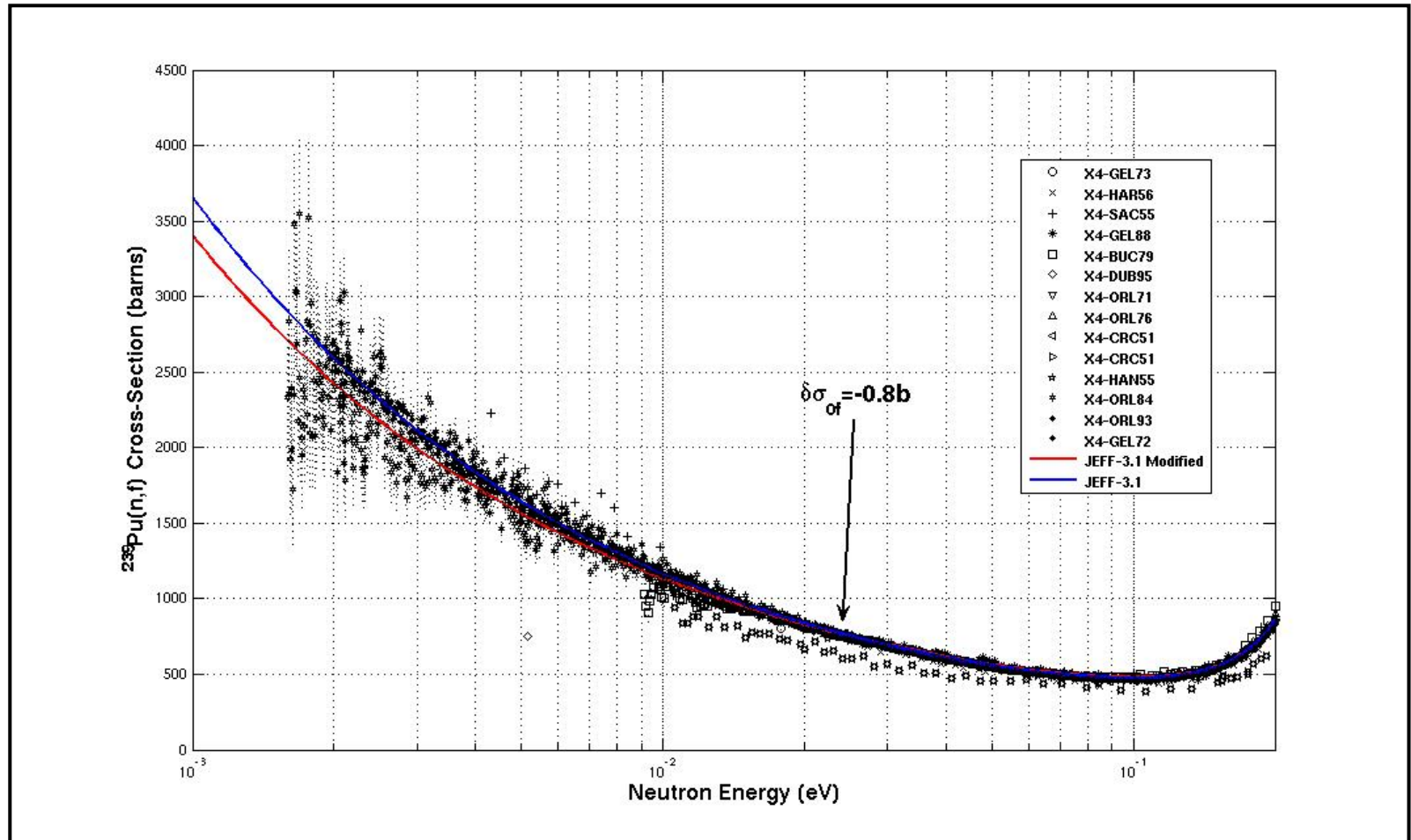
New subthermal/thermal neutron induced cross-sections by adding no more than a new bound level:

$$E_0 = -0.02\text{eV} ; J^\pi = 0^+ ; \Gamma_n = 10^{-10}\text{meV} ; \Gamma_\gamma = 6\text{meV} ; \Gamma_{f1} = -36\text{meV} ; \Gamma_{f2} = 0\text{meV}$$

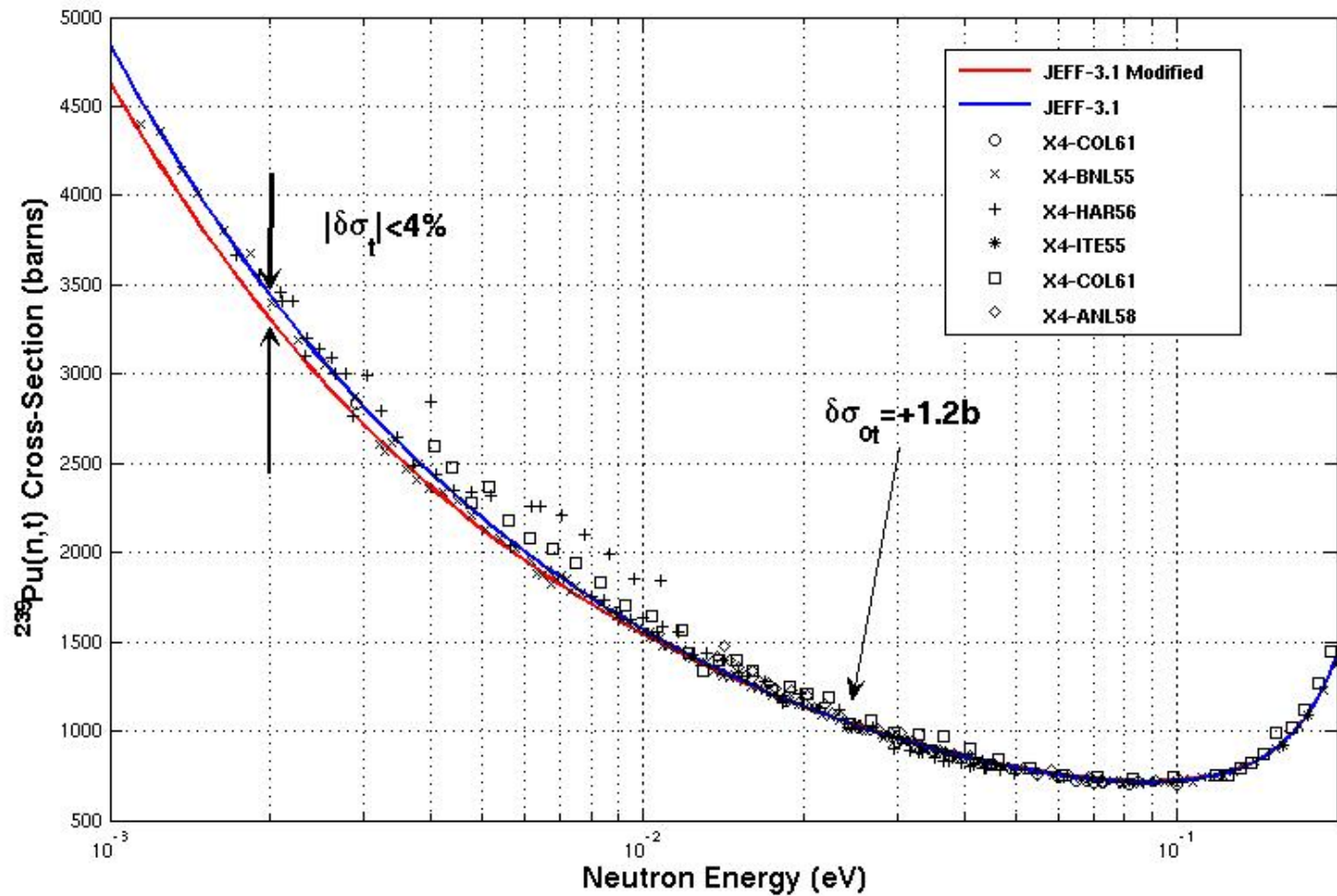
Subthermal capture cross-section:



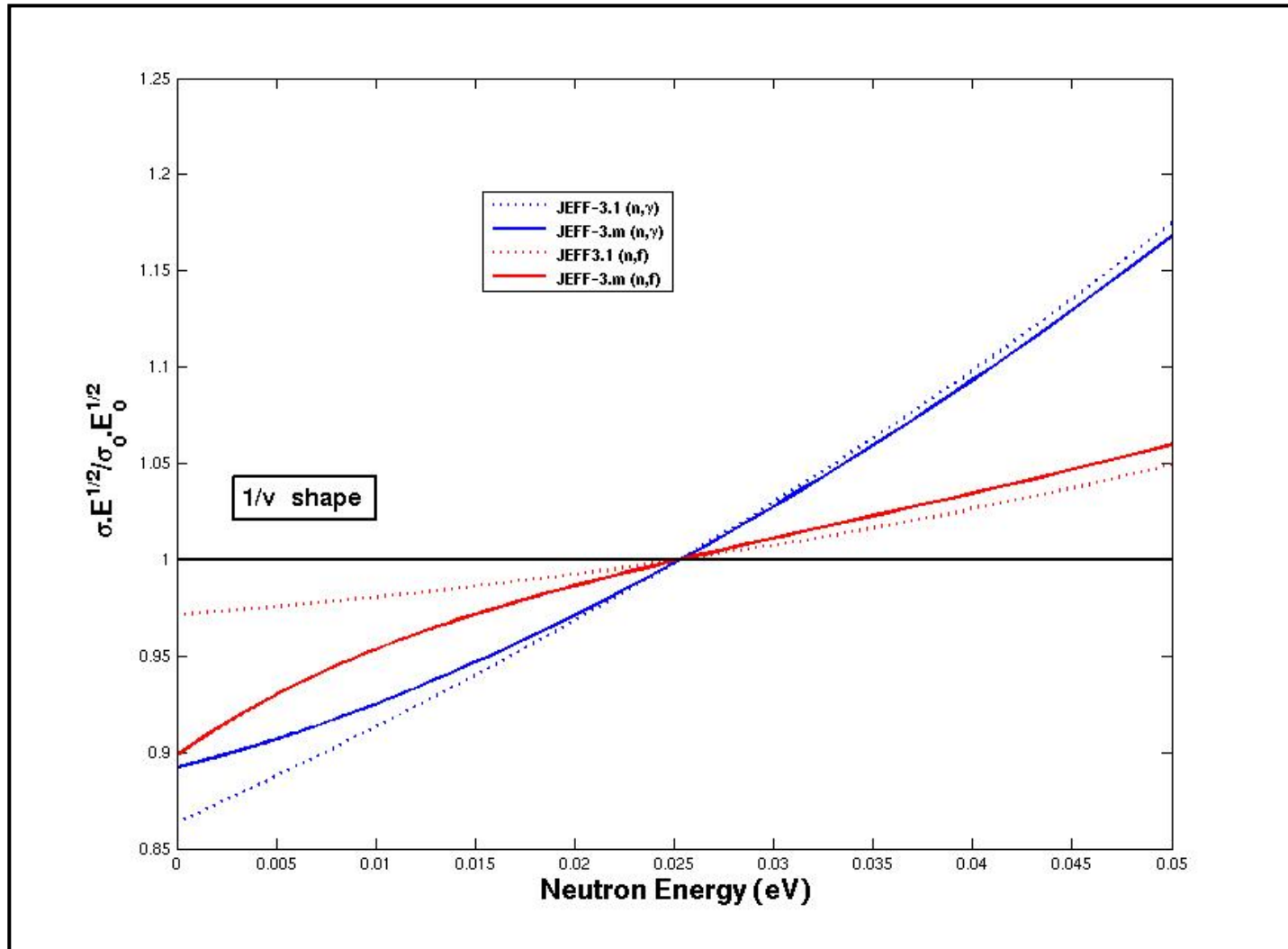
Subthermal fission cross-section:



Subthermal total cross-section:



Thermal shape modifications: (compared to 1/v)



JEFF-3.2 β file



- ▶ Modification of the $\nu_{t,p}$ and 1 bound level is added (modified thermal values within the differential measurement uncertainties)
- ▶ Feedback on JEFF-3.1 file (E. Dupont and C. Dean) for the upper limit of the URR is taken into account.
- ▶ The file was sent to NEA last week.

```

JEFF31N9437_4.ASC_copy - /home/dbernard/DONUT/PU239/NJOY/
File Edit Search Preferences Shell Macro Windows Help
JEFF-3.1 General Purpose Neutron File, September 2006.
9.423900+4 2.369984+2 1 1 2 2310 0 0 1
0.000000+0 0.000000+0 0 0 0 09437 1451 2
1.000000+0 3.000000+7 0 0 10 69437 1451 3
0.000000+0 0.000000+0 0 0 879 319437 1451 4
94-Pu-239 BRC, CAD, + EVAL: ROMAIN, MORILLON, DOSSANTOS-UZARRALDE 9437 1451 5
DIST-MAY05 REV1-MAY05 20050504 9437 1451 7
-----JEFF-31 MATERIAL 9437 9437 1451 8
-----INCIDENT NEUTRON DATA 9437 1451 9
-----ENDF-6 FORMAT 9437 1451 10
***** JEFF-3.1 *****9437 1451 11
** **9437 1451 12
** Original data taken from: JEFF-3.0 (slight changes) **9437 1451 13
** **9437 1451 14
*****9437 1451 15
2006-09 Bernard, Fort, Santamarina, Noguere, Courcelle (CEA) 9437 1451 16
Slight modifications in the subthermal-thermal range: 9437 1451 18
1) MF1: MT452 and MT456 from E. Fort and A. Courcelle 9437 1451 19
from 1meV to 23eV: 9437 1451 20
[Proceeding of WONDER'06 Workshop] 9437 1451 21
[To be published at ND2007 Conference] 9437 1451 22
to reduce the systematic keff overestimation: 9437 1451 23
* of MISTRAL-MOX mock-up [JEF/DOC-1143] 9437 1451 24
* of IGSEEP/PU-SOL-THERM [JEF/DOC-1107] 9437 1451 25
2) MF2: MT151 from D. Bernard and A. Santamarina: 9437 1451 26
1 Bound level added to reduce the overestimation of 9437 1451 27
the Isothermal Temperature Coefficient 9437 1451 28
in MOX lattices [NSE 144,47-74 (2003)]. 9437 1451 29
This implies slight changes on thermal values, 9437 1451 30
consistent with differential uncertainties (see 9437 1451 31
Mughabghab, ENL 2006): 9437 1451 32
* thermal capture XS change: +2.1b 9437 1451 33
* thermal fission XS change: -0.8b 9437 1451 34
* thermal total XS change: +1.2b 9437 1451 35
9437 1451 36
2005-06 E. Dupont (CEA) and Ch. Dean (Serco Group) 9437 1451 37
Unresolved Resonance Parameters (MF2, MT151, LRU=2) 9437 1451 38
Extension of average parameters up to EH = 30 keV 9437 1451 39
9437 1451 40
2005-01 NEA/OECD (Rugama) 8 delayed neutron groups, Jefdoc-976, 9437 1451 41
Spriggs, Campbell, Piksaikin, Prog Nucl Ener 41,223(2002) 9437 1451 42
9437 1451 43
2003-06 CAD (Dupont) Unresolved Resonance Parameters 9437 1451 44
(MF=2, MT=151, LRU=2) for L=1 and AJ=1.0 resonances: 9437 1451 45
AMUN changed from 1. to 2. AND GNU divided by 2. 9437 1451 46
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***** JEFF-3.0 *****9437 1451 48
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This evaluation is built from contributions of several individuals 9437 1451 51
in various laboratories. 9437 1451 52
** BRC : J. P. Delaroche, P. Dossantos-Uzarralde, S. Hilaire, 9437 1451 53
C. Le luel, M. Lopez-Jimenez, P. Morel, B. Morillon, 9437 1451 54
P. Romain 9437 1451 55
** CAD : E. Dupont, E. Fort, O. Serot, J-Ch Sublet. 9437 1451 56
** + : H. Derrien, T. Nakagawa. 9437 1451 57
*****9437 1451 58
MF=1 Descriptive and Nubar Information *****9437 1451 59
*****9437 1451 60
MT=452: Number of neutrons per fission 9437 1451 61
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MT=455: Delayed nubar evaluation (from WPEC/S6 6) 9437 1451 64
See JEF/DOC-920 9437 1451 65
Energy dependent delayed neutron spectrum introduced 9437 1451 66
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MT=456: Prompt nubar evaluation (E. Fort and B. Morillon) 9437 1451 68
The evaluation below 650 eV is based on experimental 9437 1451 69
data [30]. 9437 1451 70
From 650 eV to 30 MeV, the adopted values are obtained 9437 1451 71
9437 1451 72
Terminal - Konsole | CHARM2 | JEFF31N9437_4

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Benchmarking of the new ^{239}Pu file:



JEFF-3.1 library

**ICSBEP/PST: $C_{\text{Pu}} < 80\text{g/L}$
C/E-1 = $+700 \pm 200$ pcm**

**ICSBEP/PST: $C_{\text{Pu}} > 80\text{g/L}$
C/E-1 = $+340 \pm 200$ pcm**

JEFF-3.1 library + ^{239}Pu new file
should give the following results:

**ICSBEP/PST: $C_{\text{Pu}} < 80\text{g/L}$
C/E-1 $\approx +200 \pm 200$ pcm**

**ICSBEP/PST: $C_{\text{Pu}} > 80\text{g/L}$
C/E-1 $\approx 0 \pm 200$ pcm**

Qualification of the new ^{239}Pu file:




EOLE mock-up	JEFF-3.1 (C-E) \pm (δE) (pcm)	JEFF-3.1 + new ^{239}Pu (C-E) \pm (δE) (pcm)
MH1.2 (PWR-UOx/MOx mixed)	280 \pm 250 ($1\sigma_{T4}=20\text{pcm}$)	160 \pm 250 ($1\sigma_{T4}=20\text{pcm}$)
MISTRAL-2 (PWR-MOx)	630 \pm 250 ($1\sigma_{T4}=20\text{pcm}$)	490 \pm 250 ($1\sigma_{T4}=15\text{pcm}$)
MISTRAL-3 (PWR-MOx)	710 \pm 250 ($1\sigma_{T4}=20\text{pcm}$)	560 \pm 250 ($1\sigma_{T4}=10\text{pcm}$)
BASALA-H (BWR-MOx)	610 \pm 250 ($1\sigma_{T4}=20\text{pcm}$)	470 \pm 250 ($1\sigma_{T4}=20\text{pcm}$)
BASALA-C (BWR-MOx)	700 \pm 250 ($1\sigma_{T4}=20\text{pcm}$)	540 \pm 250 ($1\sigma_{T4}=20\text{pcm}$)
FUBILA-H (BWR-MOx)	250 \pm 250 ($1\sigma_{T4}=20\text{pcm}$)	110 \pm 250 ($1\sigma_{T4}=20\text{pcm}$)



Improvement by about -120 to -160 pcm ($1\sigma_{T4}=25\text{pcm}$)

Moderator Temperature Coefficient Improvement

- 
- no modification for the Hot MTC
 - Cold MTC (BASALA): C/E-1 from -1.7 ± 0.3 pcm/K
 to -1.4 ± 0.3 pcm/K

No modification in PIE analysis.

Conclusion



✘ Concerted efforts (CEA) will be devoted to Pu evaluations (via HPRL, NUDAME...) in the near future.

✘ The slight modification of subthermal capture and fission cross-section shape, is consistent with differential measurements:

⇒ improvement on the C/E of MTC measurements

✘ Decrease of multiplicity by 0.2% in agreement with diff. measurements (a new file is available up to 500eV and URR)

⇒ improvement on the C/E of k_{eff} : MOX cores and Pu solutions

✘ ^{239}Pu JEFF-3.2 β was sent to NEA last week.

✘ The file was processed at CEA for TRIPOLI4 and APOLLO2 codes.

✘ The associated APOLLO2 library (CEA2005.V1.2) is already **recommended and will be used worldwide** in the AREVA-NP group for PWR and BWR applications.