



# Improvements of the $^{239}\text{Pu}$ Evaluation for JEFF-3

**D. BERNARD**

[david.bernard@cea.fr](mailto:david.bernard@cea.fr)

**A. SANTAMARINA**

[alain.santamarina@cea.fr](mailto:alain.santamarina@cea.fr)

**E. FORT**

[eric.fort@cea.fr](mailto:eric.fort@cea.fr)

**A. COURCELLE**

[arnaud.courcelle@cea.fr](mailto:arnaud.courcelle@cea.fr)

**O. LITAIZE**

[olivier.litaize@cea.fr](mailto:olivier.litaize@cea.fr)

**G. NOGUERE**

[gilles.noguere@cea.fr](mailto:gilles.noguere@cea.fr)

**C. VAGLIO-GAUDARD**

[claire.vaglio-gaudard@cea.fr](mailto:claire.vaglio-gaudard@cea.fr)

## Summary:



### ✘ Needs for improvement:

- ICSBEP/Pu-Sol-Therm
- $k_{\text{eff}}$  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 $^{239}\text{Pu}$ file.

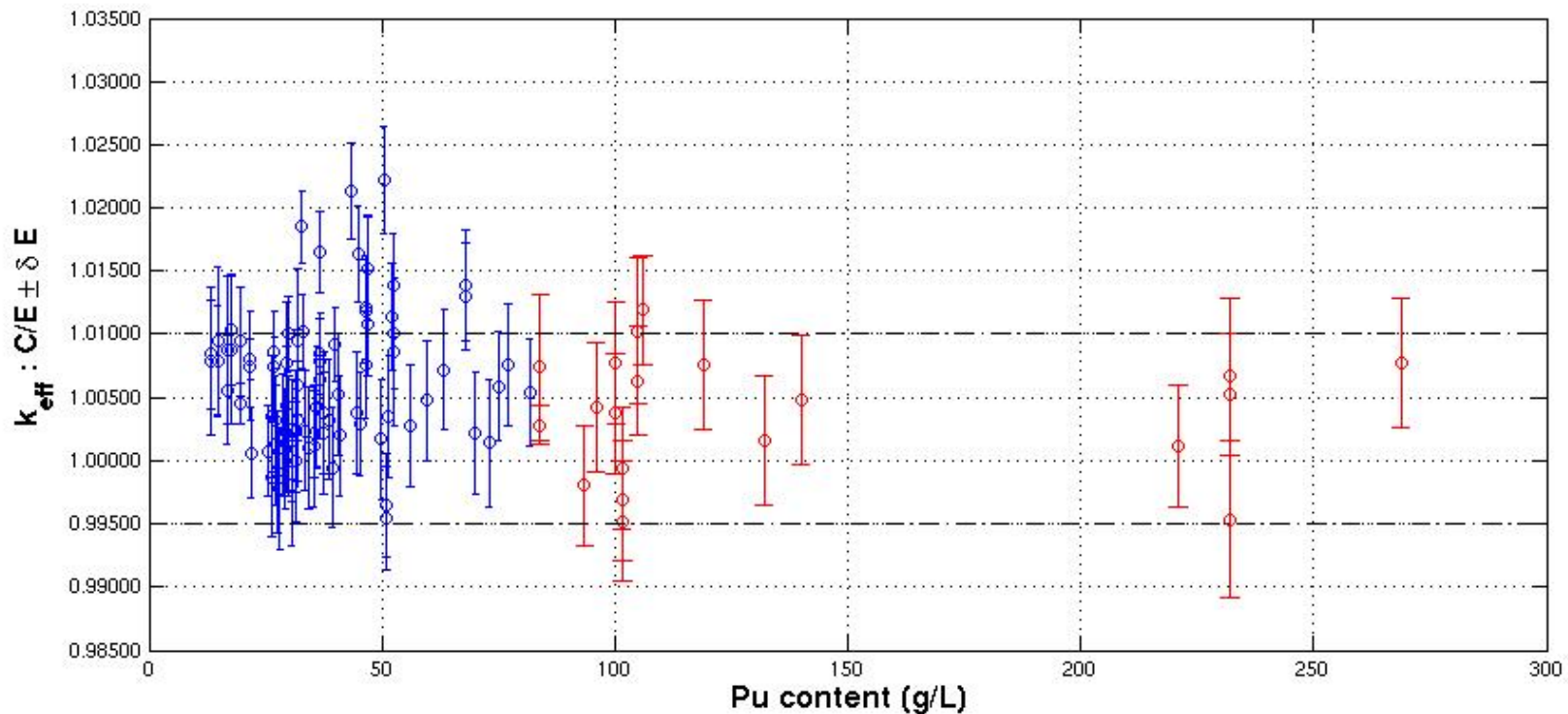
### ✘ Conclusion.

## Needs for improvement:

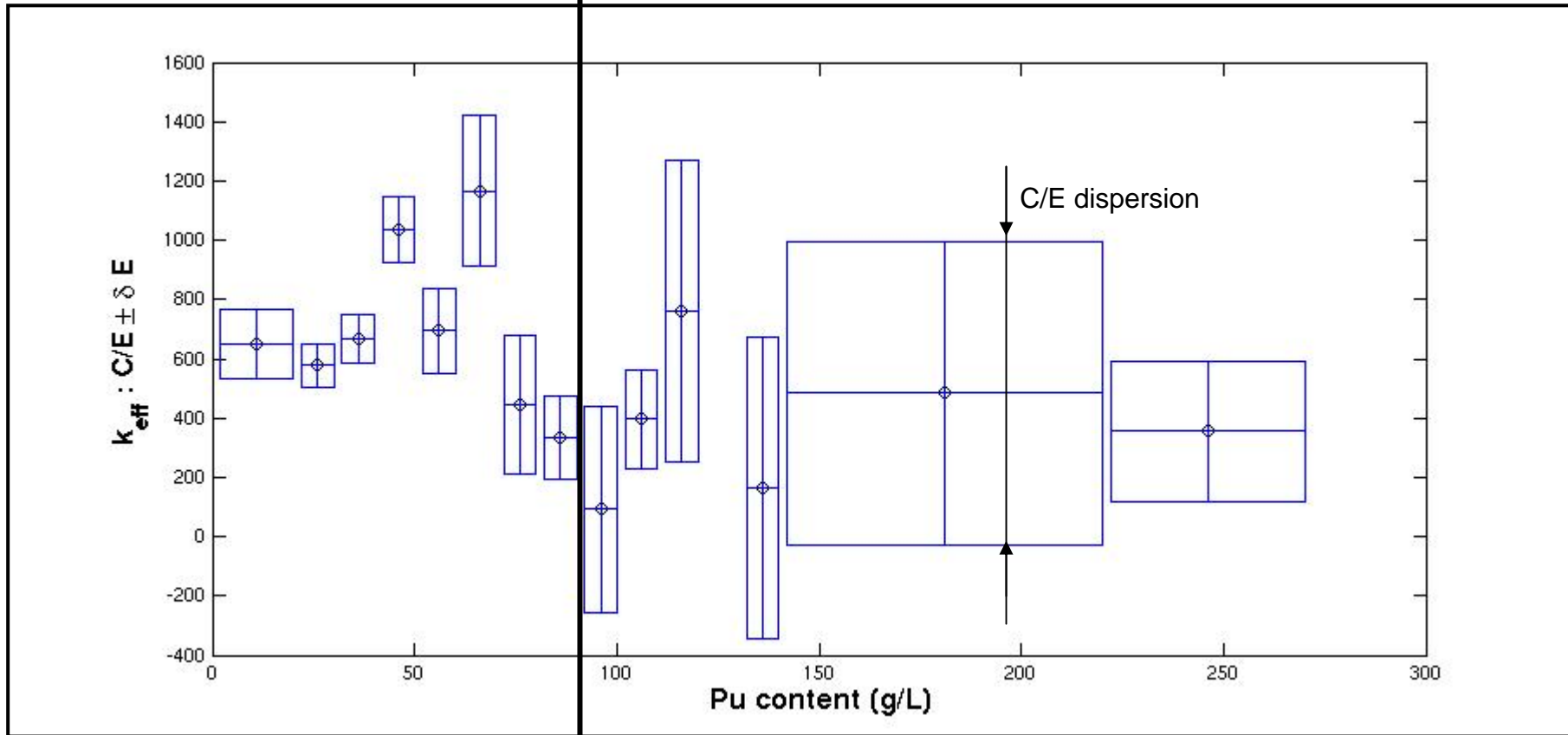
✘ ICSBEP/PU-SOL-THERM Benchmarks show an overestimation of the  $k_{\text{eff}}$  prediction using JEFF-3.1 (see MCNP4.c3 results from S.Van Der Marck JEF/DOC-1107):

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

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



# $k_{\text{eff}}$ overestimation per quantiles ICSBEP/PST-001 to 012



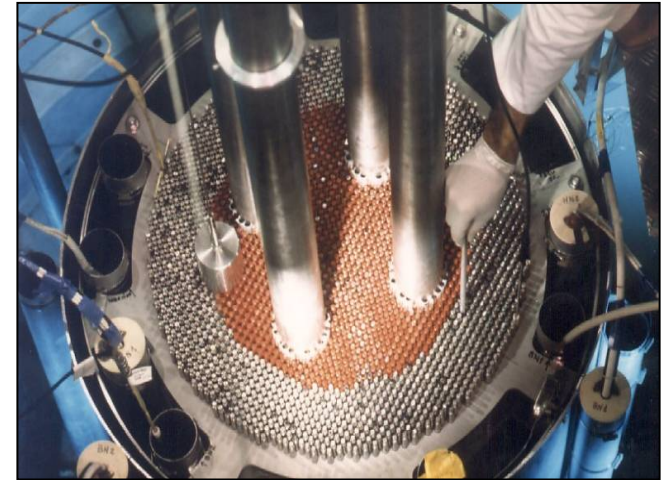
**C/E-1 = +700 ± 200 pcm**

**C/E-1 = +340 ± 200 pcm**

## Needs for improvement:

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

⇒ For standard Pu-aging  
(small  $^{241}\text{Am}$  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	<b>280 ± 250 (1σ<sub>T4</sub>=20pcm)</b>
MISTRAL-2 (PWR-MOx)	8 years	MR=1.7	<b>630 ± 250 (1σ<sub>T4</sub>=20pcm)</b>
MISTRAL-3 (PWR-MOx)	10 years	MR=2.1	<b>710 ± 250 (1σ<sub>T4</sub>=20pcm)</b>
BASALA-Hot (BWR-MOx)	12 years	42% void	<b>610 ± 250 (1σ<sub>T4</sub>=20pcm)</b>
BASALA-Cold (BWR-MOx)	13 years	0% void	<b>700 ± 250 (1σ<sub>T4</sub>=20pcm)</b>
FUBILA-Hot (BWR-MOx)	1 year	0% void	<b>250 ± 250 (1σ<sub>T4</sub>=20pcm)</b>

## Needs for improvement:

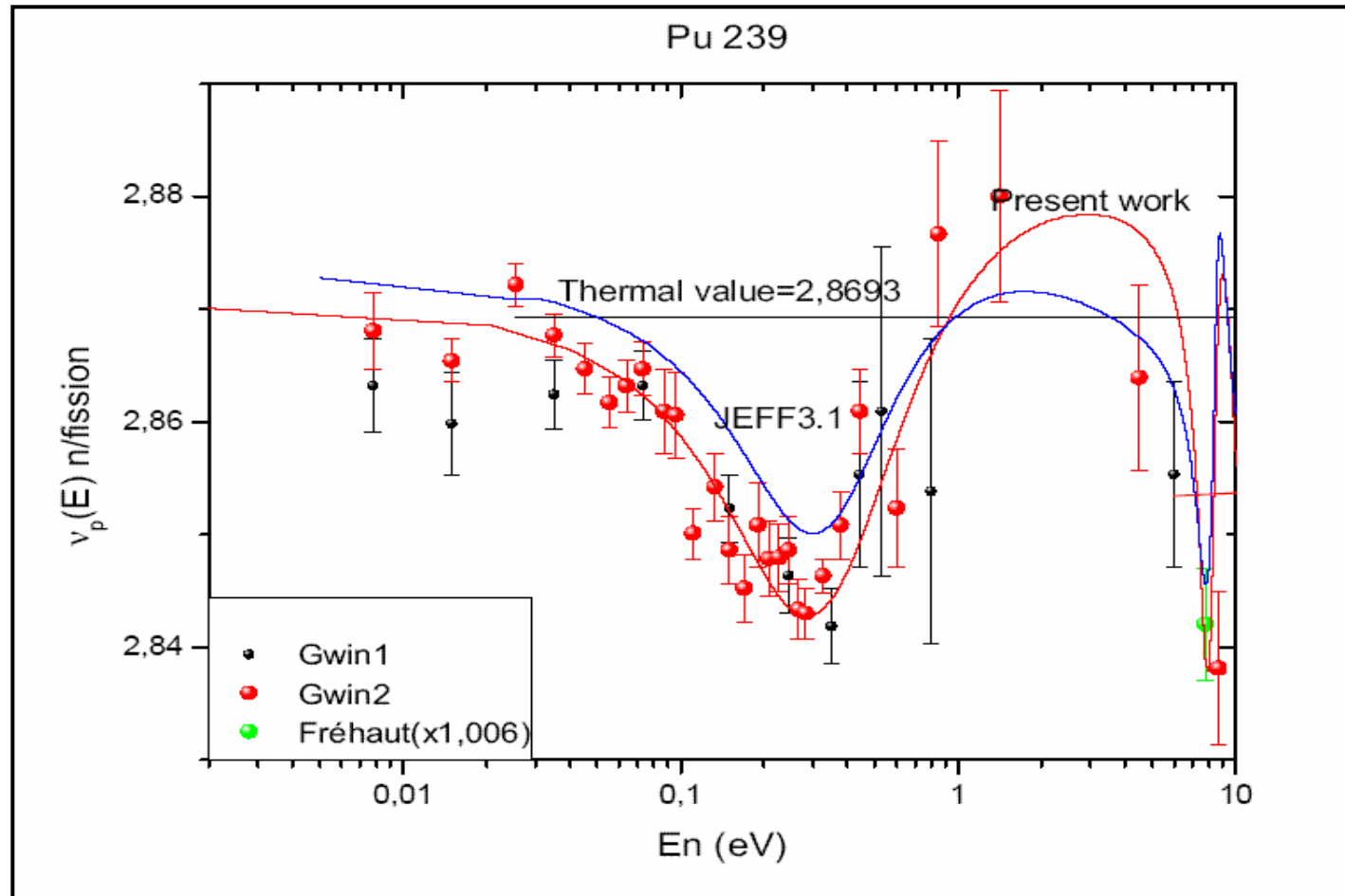
✘ Qualification results of the Isothermal Temperature Coefficient in MOx lattices show :

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

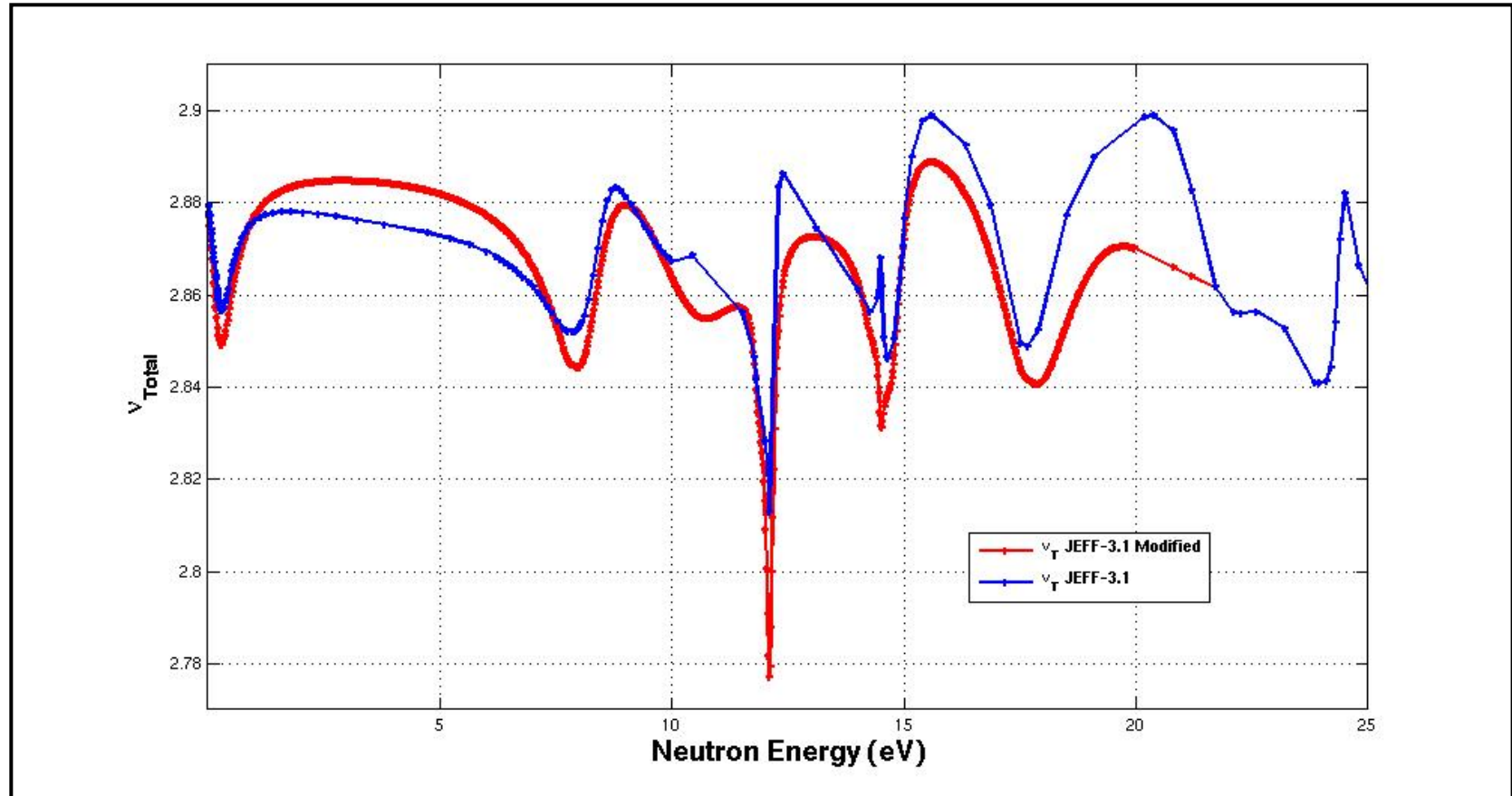
- $-2.0 \pm 0.3$  pcm/K due to the  $\alpha = \sigma_\gamma / \sigma_f$  value in the subthermal and thermal range in the cold operation conditions (20°C-60°C) (JEF-2.2 interpretation of MISTRAL experiment)
- $-1.7 \pm 0.3$  pcm/K in cold operation conditions (10°C-80°C) (JEFF-3.1 interpretation of BASALA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

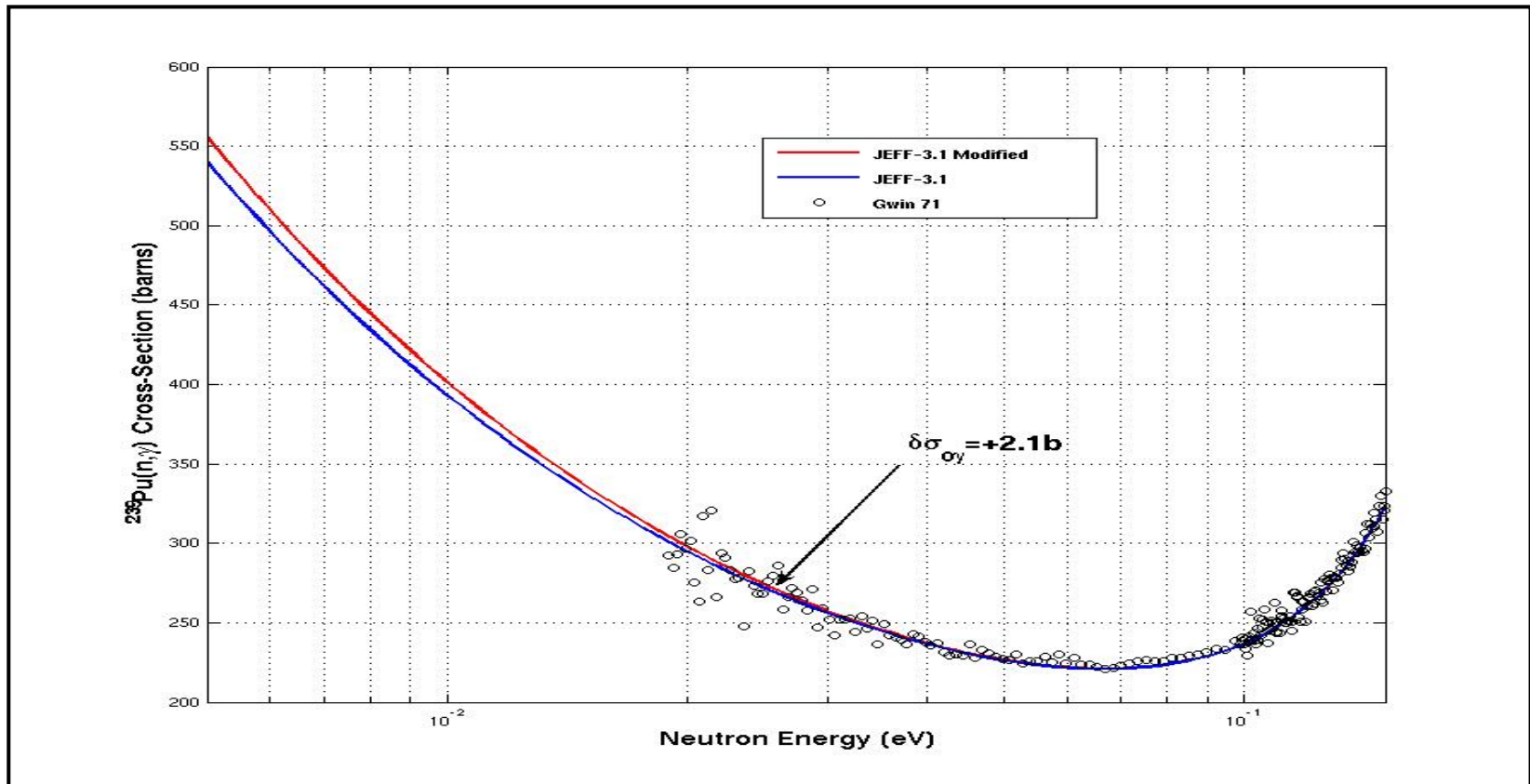




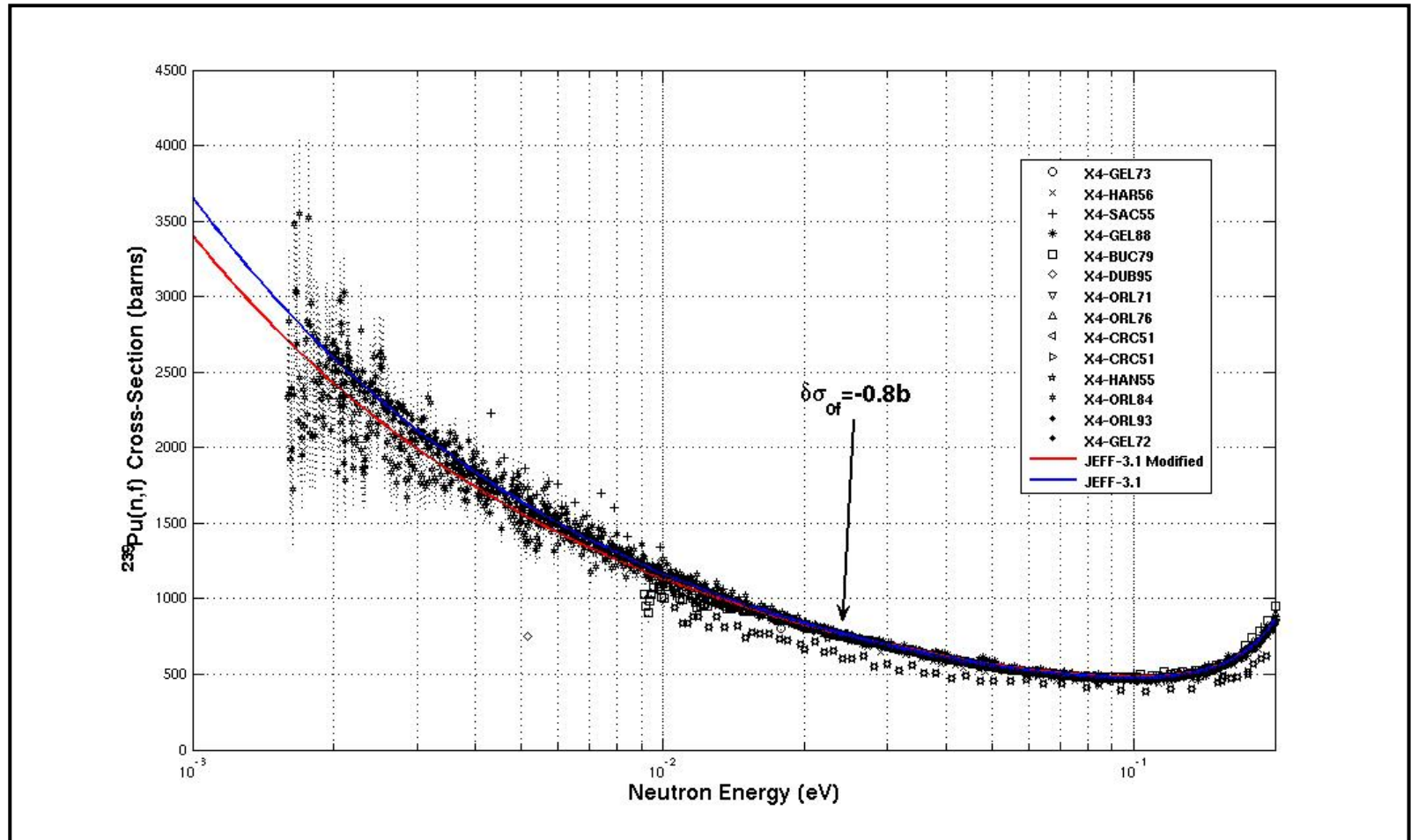
New subthermal/thermal neutron induced cross-sections by adding no more than a new bound level:

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

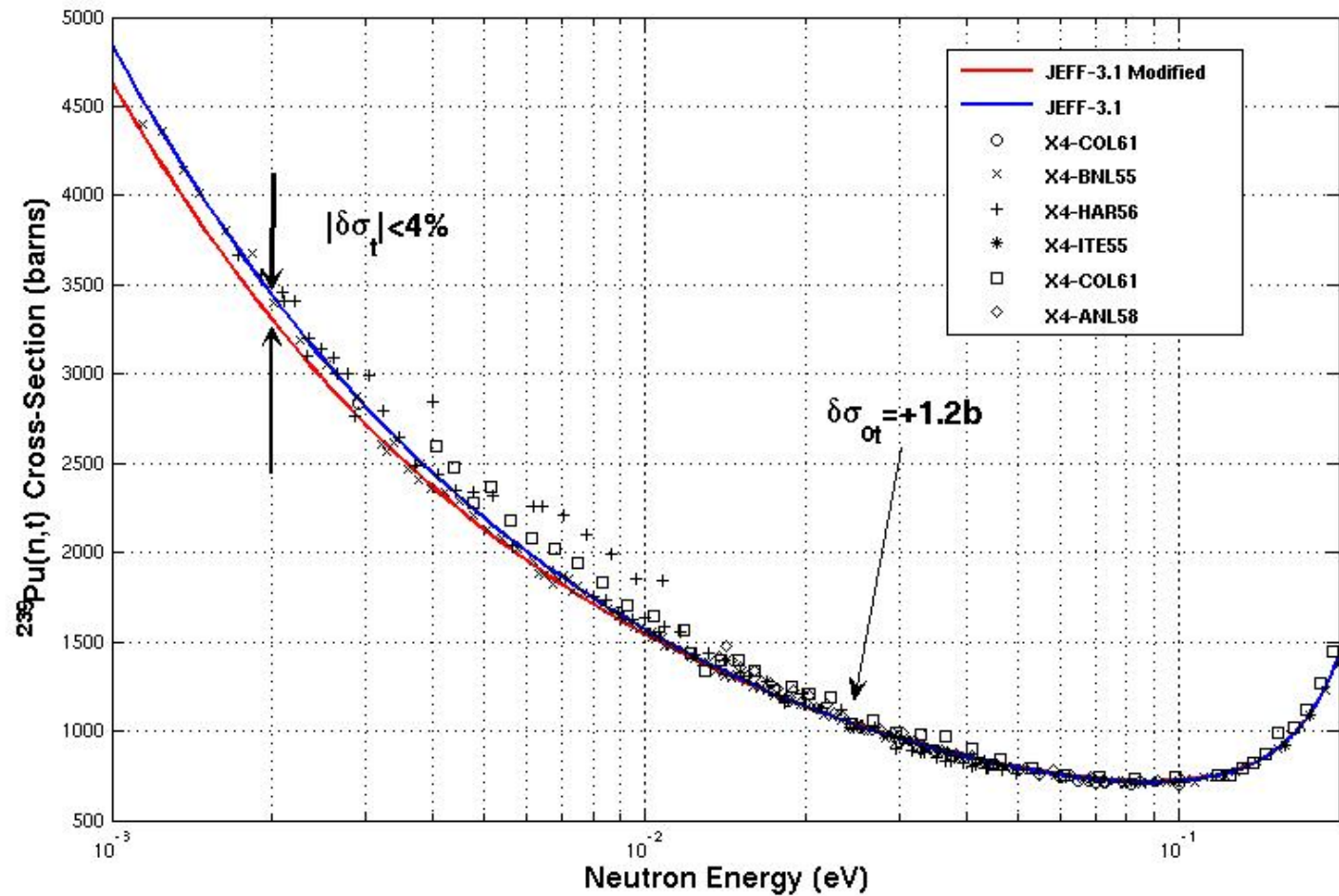
## Subthermal capture cross-section:



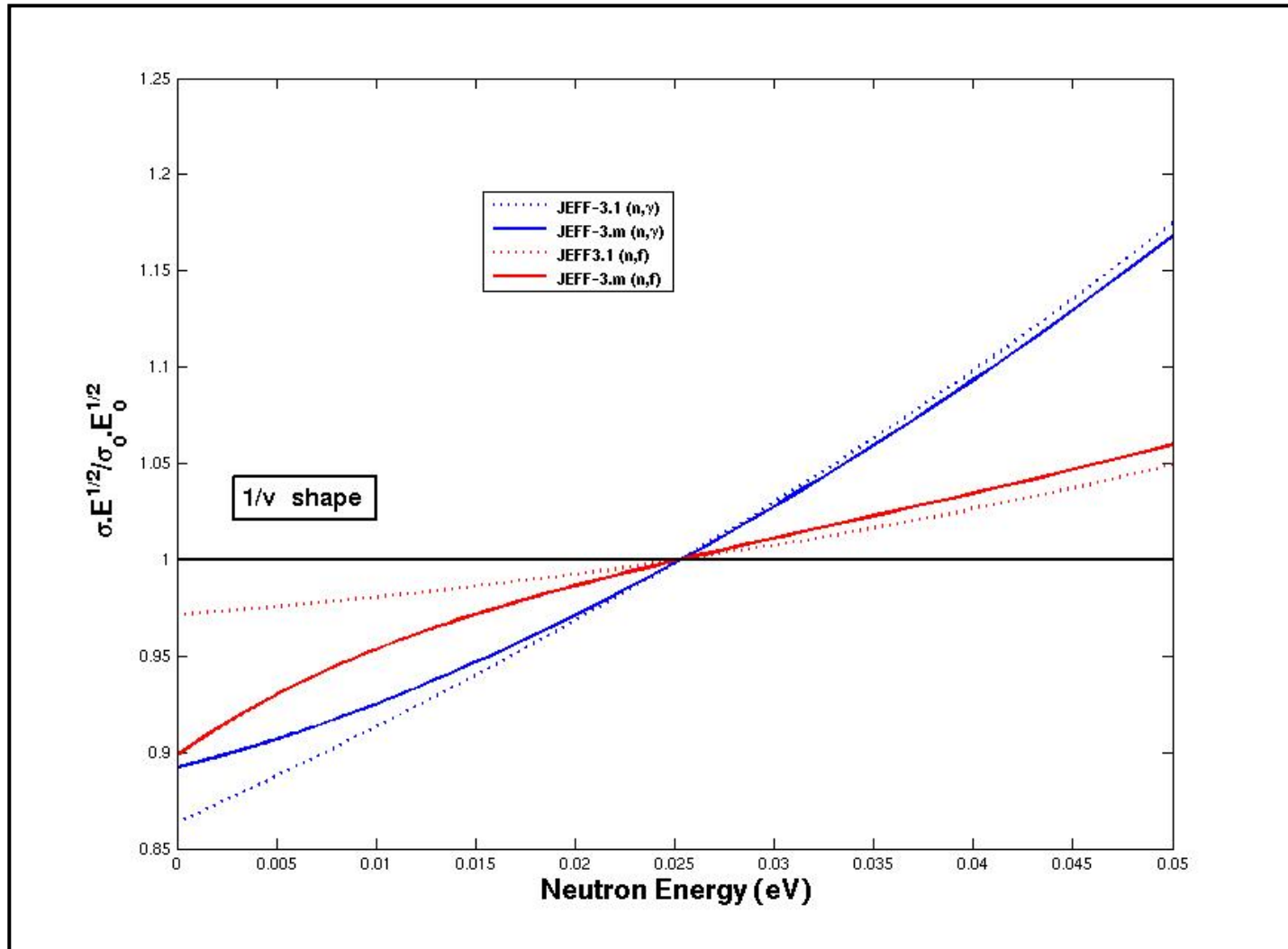
# Subthermal fission cross-section:



## Subthermal total cross-section:



# Thermal shape modifications: (compared to 1/v)



# JEFF-3.2 $\beta$ file



- ▶ Modification of the  $v_{t,p}$  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
9437 1451 47
***** JEFF-3.0 *****9437 1451 48
NEW evaluation 9437 1451 49
9437 1451 50
This evaluation is built from contributions of several individuals 9437 1451 52
in various laboratories. 9437 1451 53
** BRC : J. P. Delaroche, P. Dossantos-Uzarralde, S. Hilaire, 9437 1451 54
C. Le luel, M. Lopez-Jimenez, P. Morel, B. Morillon, 9437 1451 55
P. Romain 9437 1451 56
** CAD : E. Dupont, E. Fort, O. Serot, J-Ch Sublet. 9437 1451 57
** + : H. Derrien, T. Nakagawa. 9437 1451 58
*****9437 1451 59
MF=1 Descriptive and Nubar Information *****9437 1451 60
*****9437 1451 61
MT=452: Number of neutrons per fission 9437 1451 62
Total Nubar. Sum of MT=455 and 456. 9437 1451 63
9437 1451 64
MT=455: Delayed nubar evaluation (from WPEC/S6 6) 9437 1451 65
See JEF/DOC-920 9437 1451 66
Energy dependent delayed neutron spectrum introduced 9437 1451 67
9437 1451 68
MT=456: Prompt nubar evaluation (E. Fort and B. Morillon) 9437 1451 69
The evaluation below 650 eV is based on experimental 9437 1451 70
data [30]. 9437 1451 71
From 650 eV to 30 MeV, the adopted values are obtained 9437 1451 72
Terminal - Konsole | j6 CHARME2 | JEFF31N9437_4

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# Benchmarking of the new $^{239}\text{Pu}$ 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 +  $^{239}\text{Pu}$  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 $^{239}\text{Pu}$ file:



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



**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  $-1.7 \pm 0.3$  pcm/K  
  to         $-1.4 \pm 0.3$  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  $k_{\text{eff}}$ : MOX cores and Pu solutions

✘  $^{239}\text{Pu}$  JEFF-3.2 $\beta$  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.