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

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Summary:

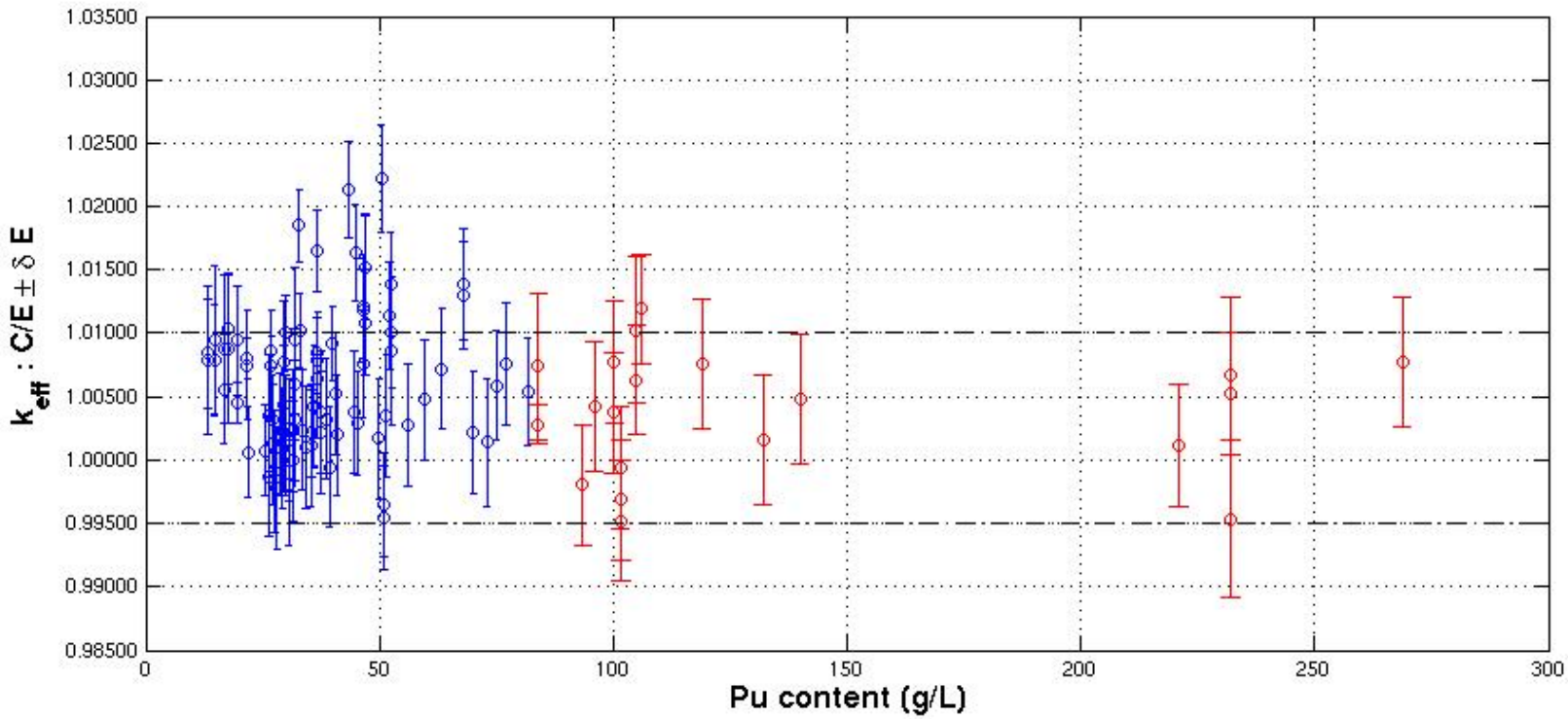
- Needs for improvement:
  - ICSBEP/Pu-Sol-Therm
  - k_{eff} overestimation for MOx cores
  - Mod. Temp. Coef. in LWR-MOX
- Description of the improved JEFF-3 file:
  - $\nu_{t,p}$ (E_n<23eV)
  - $\sigma_{t,f,\gamma}$ (E_n<0.1eV)
- Experimental validation of the new ^{239}Pu file.
- Conclusion.

Needs for improvement:

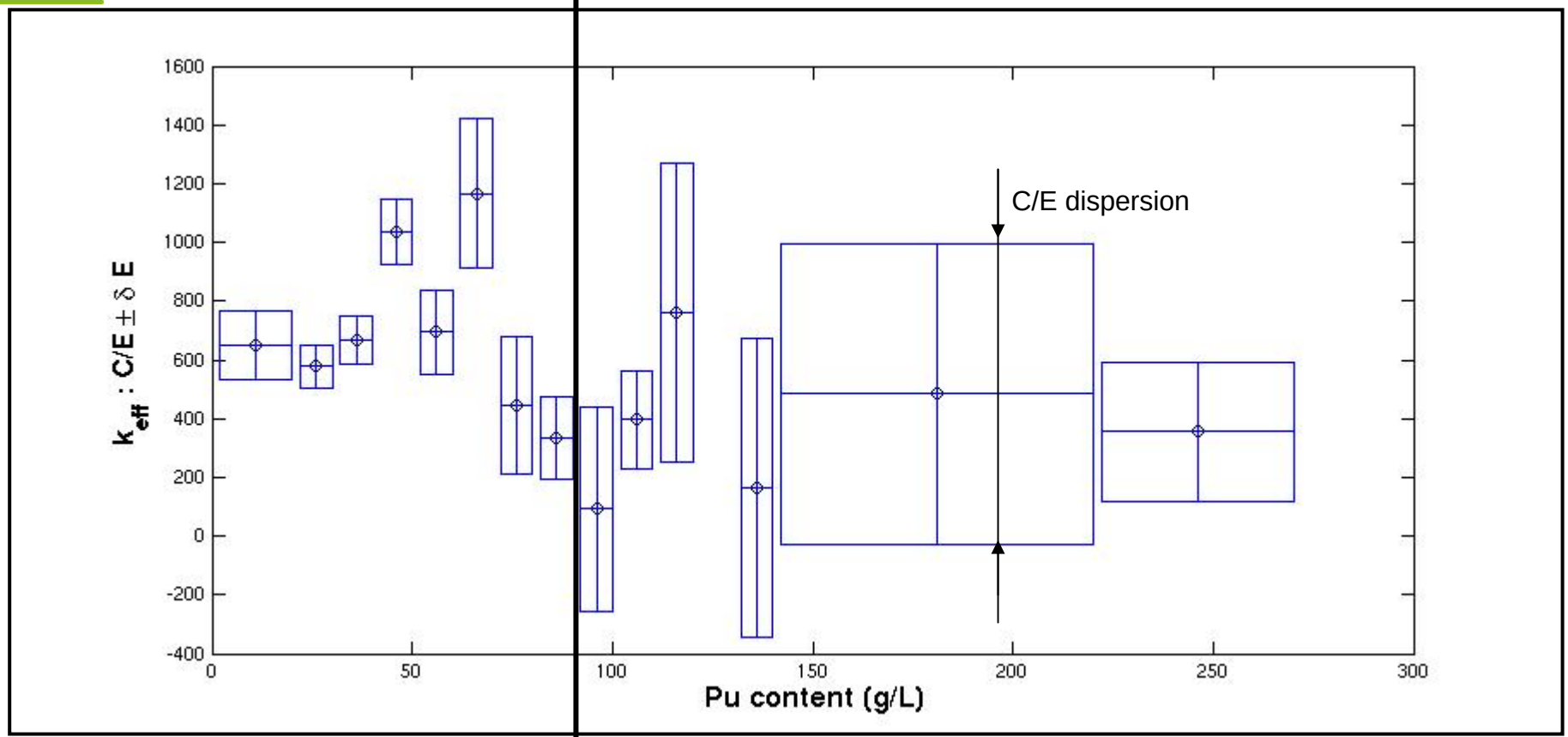
- ICSBEP/PU-SOL-THERM Benchmarkes show an overestimation of the k_{eff} prediction using JEFF-3.1 (see MCNP4.c3 results from S.Van Der Marck JEF/DOC-1107):

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

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



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

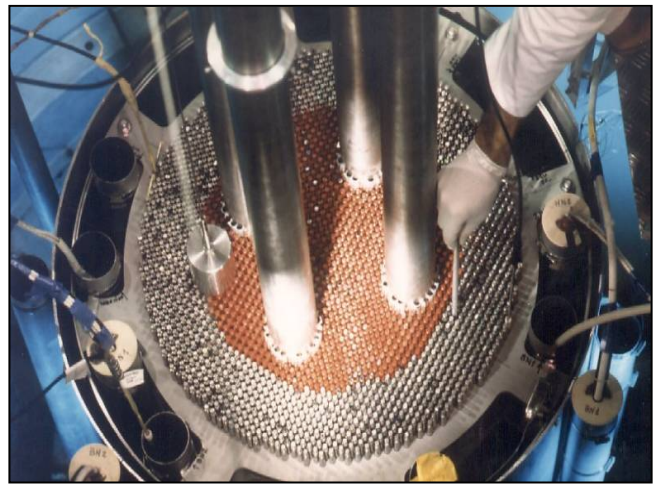


C/E-1 = +700 ± 200 pcm

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** ($1\sigma_{T4}$=20pcm)
MISTRAL-2 (PWR-MOx)	8 years	MR=1.7	**630 ± 250** ($1\sigma_{T4}$=20pcm)
MISTRAL-3 (PWR-MOx)	10 years	MR=2.1	**710 ± 250** ($1\sigma_{T4}$=20pcm)
BASALA-Hot (BWR-MOx)	12 years	42% void	**610 ± 250** ($1\sigma_{T4}$=20pcm)
BASALA-Cold (BWR-MOx)	13 years	0% void	**700 ± 250** ($1\sigma_{T4}$=20pcm)
FUBILA-Hot (BWR-MOx)	1 year	0% void	**250 ± 250** ($1\sigma_{T4}$=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)

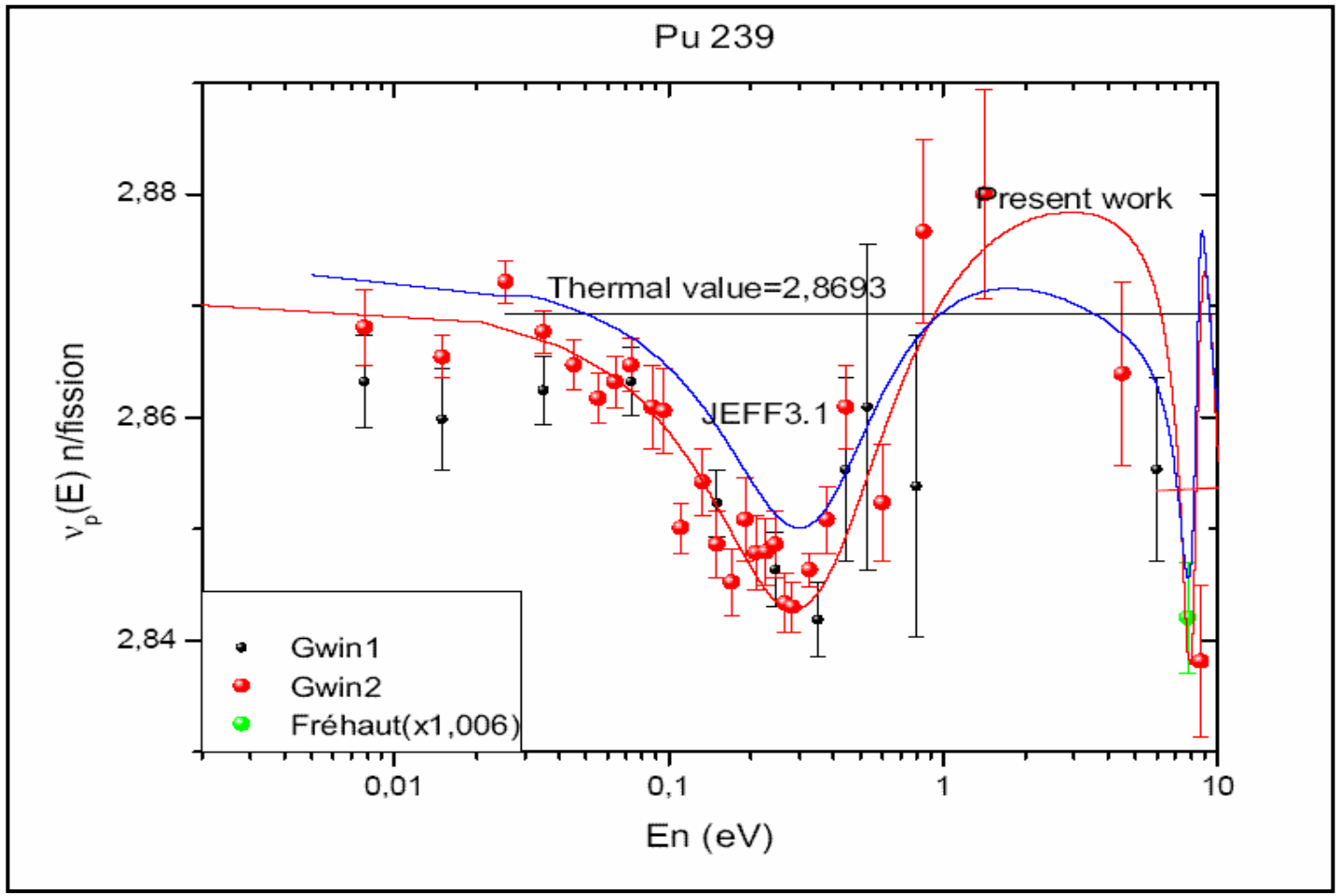
  - -2.0 $\pm$ 0.3 pcm/K due to the $\alpha=\sigma_\gamma/\sigma_f$ value in the subthermal and thermal range in the cold operation conditions (20°C-60°C) (JEF-2.2 interpretation of MISTRAL experiment)

  - -1.7 $\pm$ 0.3 pcm/K in cold operation conditions (10°C-80°C) (JEFF-3.1 interpretation of BASALA experiment)

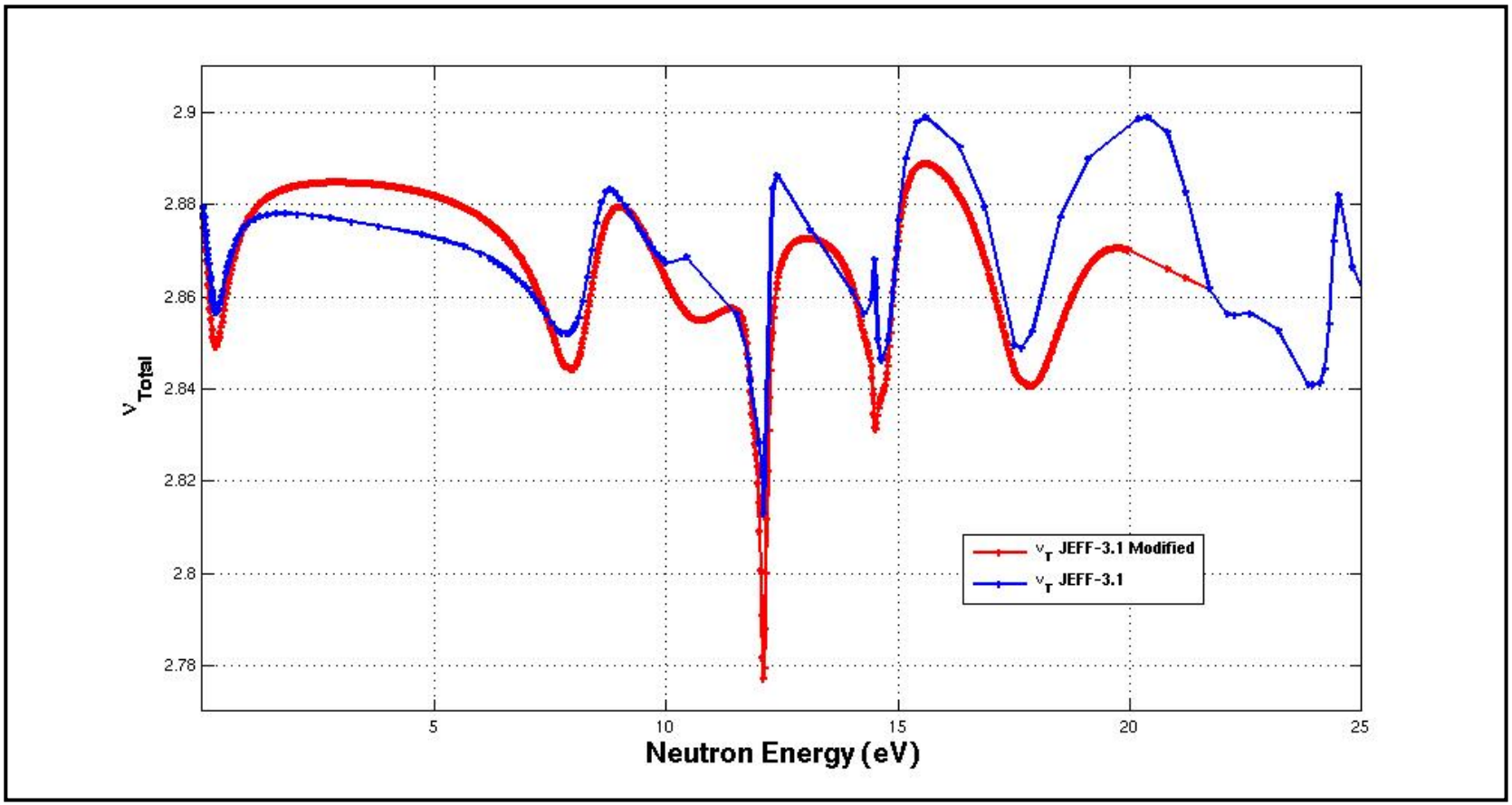
  - +1.0 $\pm$ 2.1 pcm/K in hot operation conditions(150°C-300°C). α value is accurate enough in the 0.3 eV resonance. (JEF-2.2 interpretation of CREOLE experiment)

Proposed modifications:

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



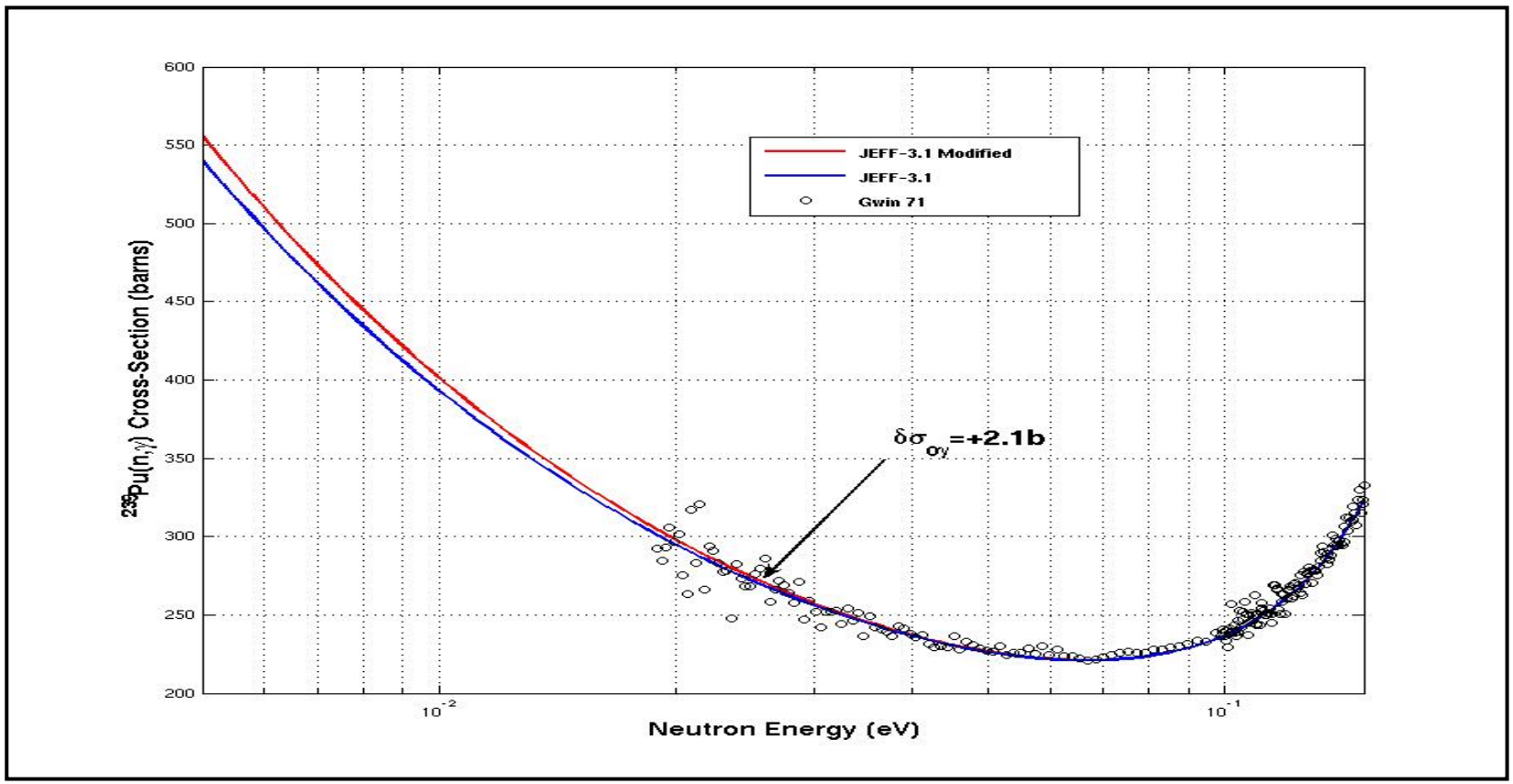
New evaluation using the fluctuation analysis up to 20eV



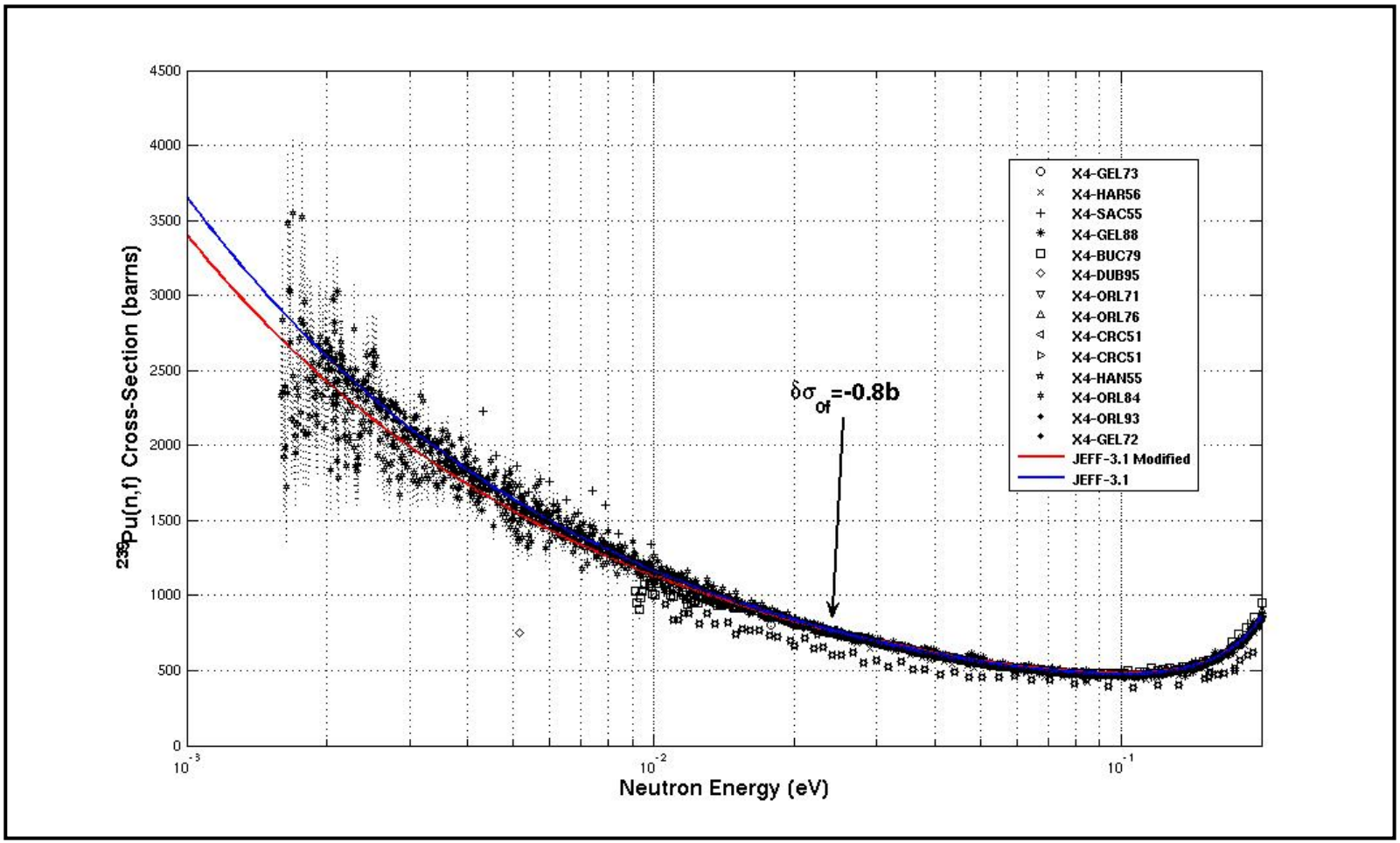
New subthermal/thermal neutron induced cross-sections by adding no more than a new bound level:

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

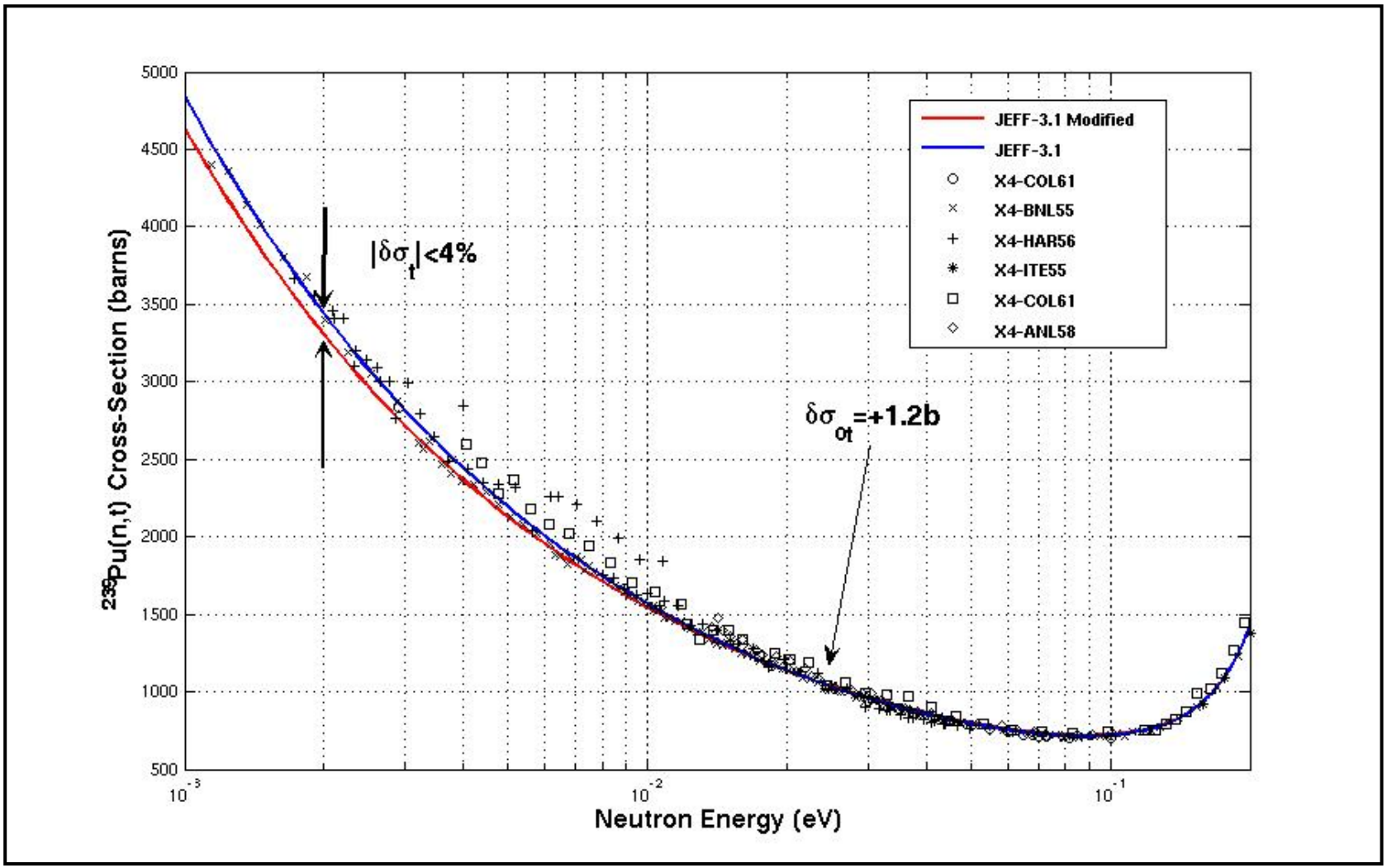
Subthermal capture cross-section:



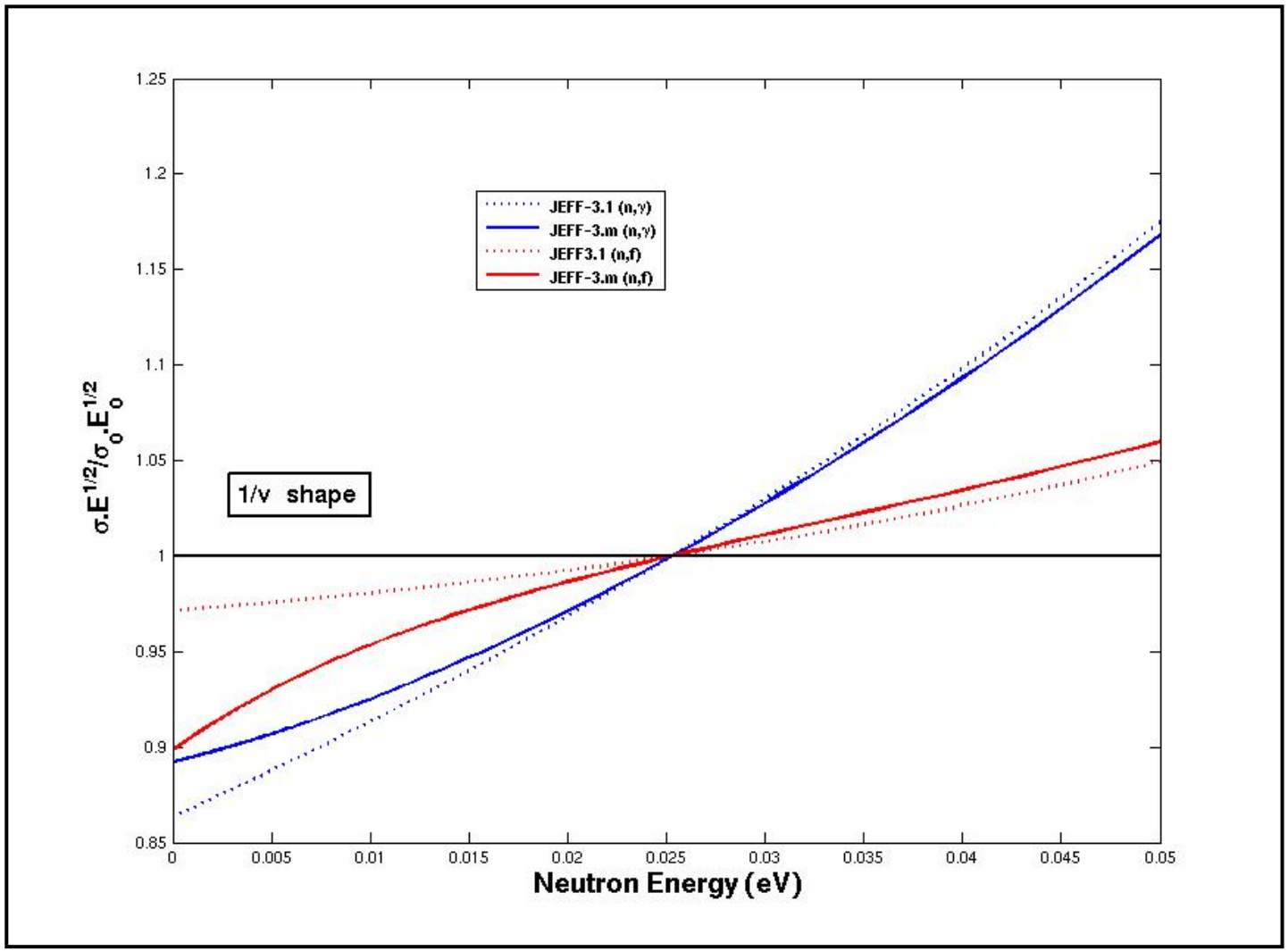
Subthermal fission cross-section:



Subthermal total cross-section:



Thermal shape modifications: (compared to 1/v)

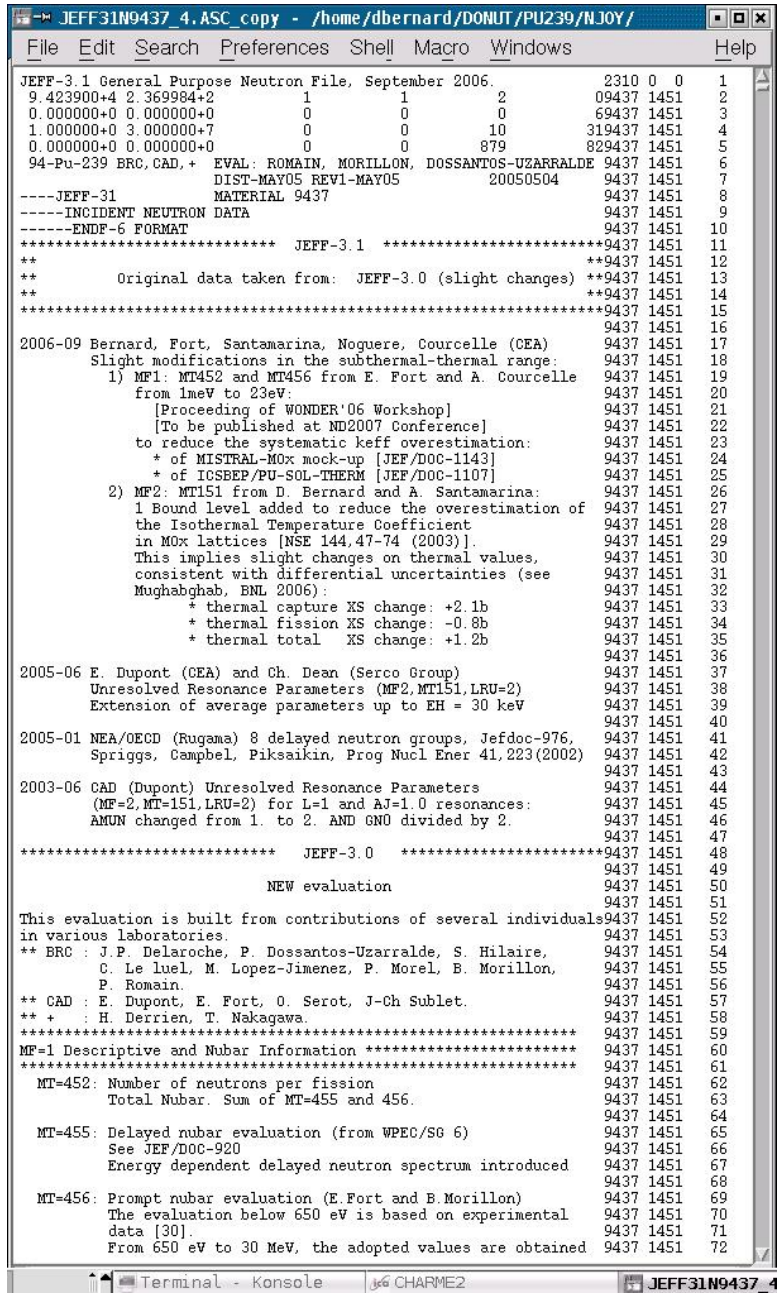


JEFF-3.2β file

- 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.



Benchmarking of the new ^{239}Pu file:

JEFF-3.1 library

ICSBEP/PST: C_{Pu}<80g/L
C/E-1 = +700 ± 200 pcm

ICSBEP/PST: C_{Pu}>80g/L
C/E-1 = +340 ± 200 pcm

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

ICSBEP/PST: C_{Pu}<80g/L
C/E-1 ≈ +200 ± 200 pcm

ICSBEP/PST: C_{pu}>80g/L
C/E-1 ≈ 0 ± 200 pcm

Qualification of the new ^{239}Pu file:

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

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

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:

  $\Rightarrow$ 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)

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

- ^{239}Pu JEFF-3.2β 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 **recommanded and will be used worldwide** in the AREVA-NP group for PWR and BWR applications.