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

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# Summary:

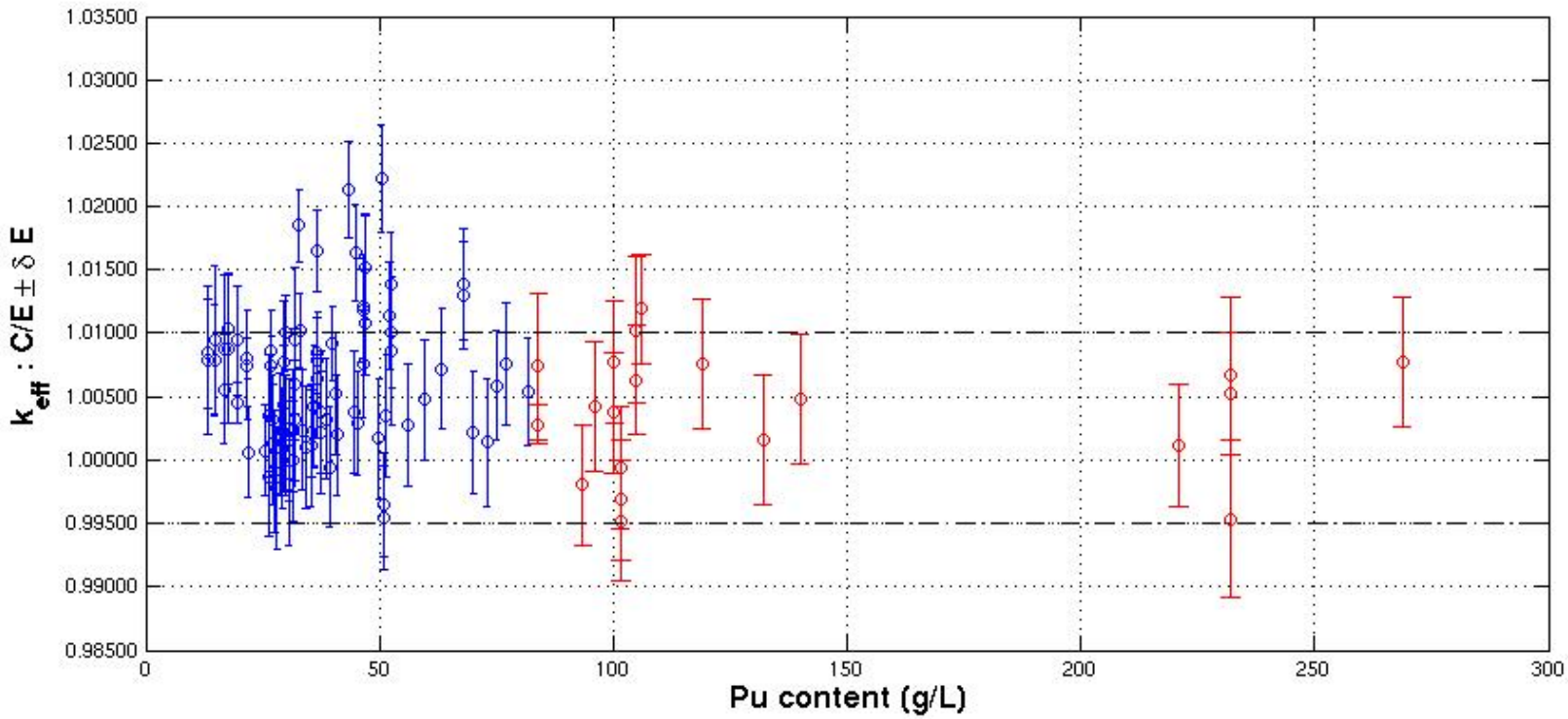
- Needs for improvement:
  - ICSBEP/Pu-Sol-Therm
  - $k_{eff}$ overestimation for MOx cores
  - Mod. Temp. Coef. in LWR-MOX
- Description of the improved JEFF-3 file:
  - $\nu_{t,p}$ ($E_n$<23eV)
  - $\sigma_{t,f,\gamma}$ ($E_n$<0.1eV)
- Experimental validation of the new $^{239}$Pu file.
- Conclusion.

# Needs for improvement:

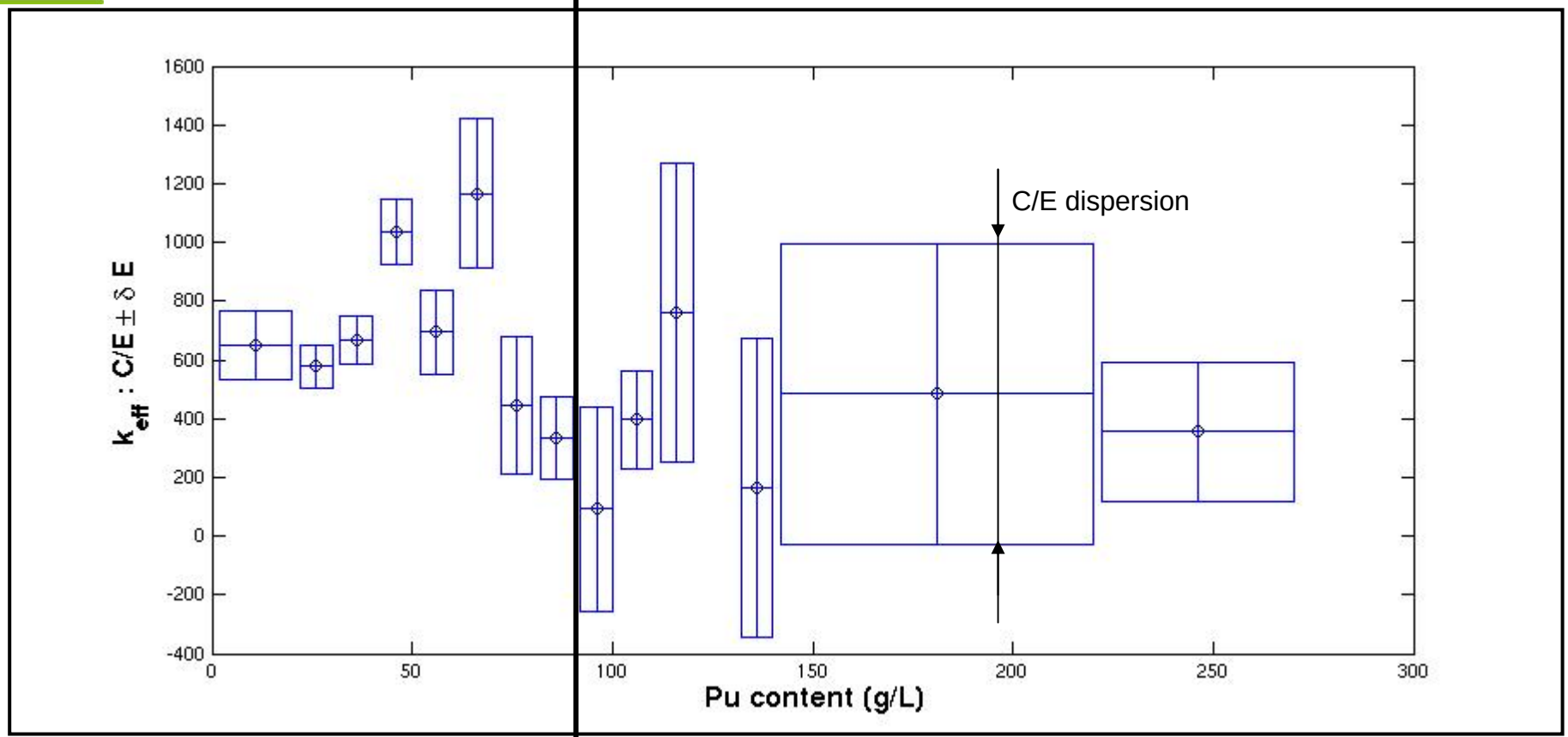
- ICSBEP/PU-SOL-THERM Benchmarkes show an overestimation of the $k_{eff}$ prediction using JEFF-3.1 (see MCNP4.c3 results from S.Van Der Marck JEF/DOC-1107):

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

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



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

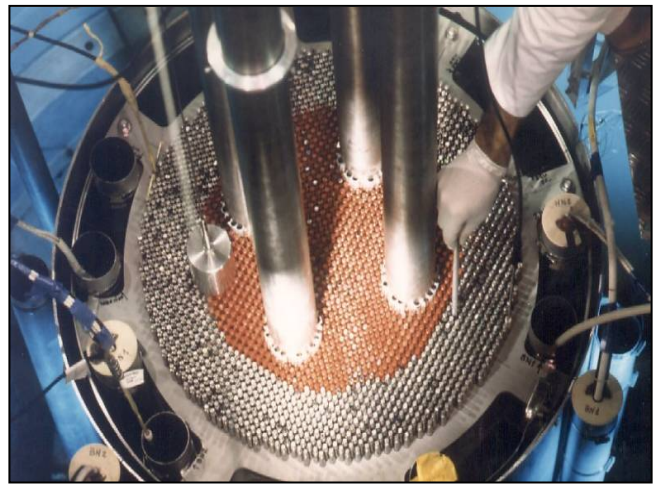



**C/E-1 = +700 ± 200 pcm**

**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)

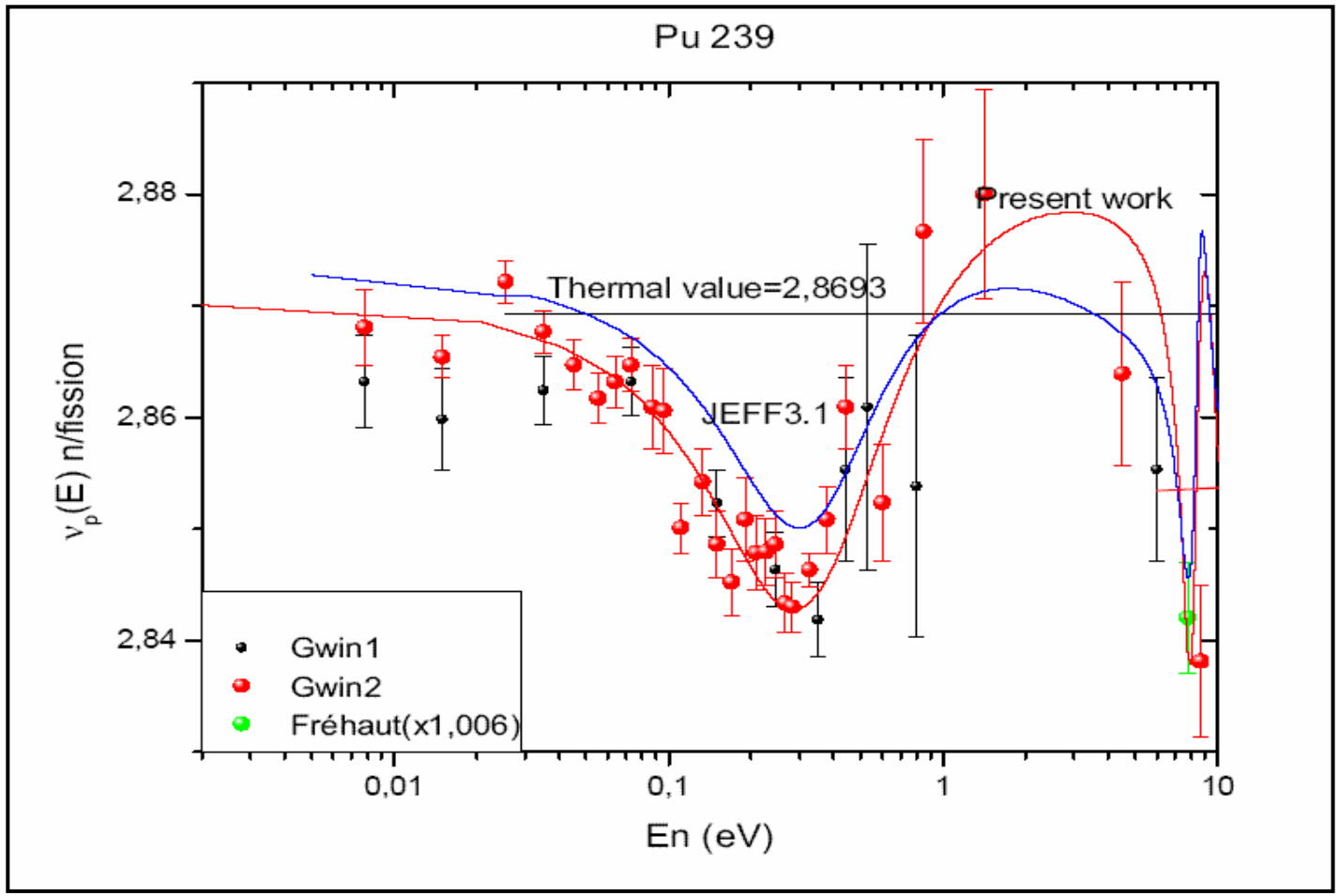
  - -2.0 $\pm$ 0.3 pcm/K due to the $\alpha=\sigma_\gamma/\sigma_f$ value in the subthermal and thermal range in the cold operation conditions (20°C-60°C) (JEF-2.2 interpretation of MISTRAL experiment)

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

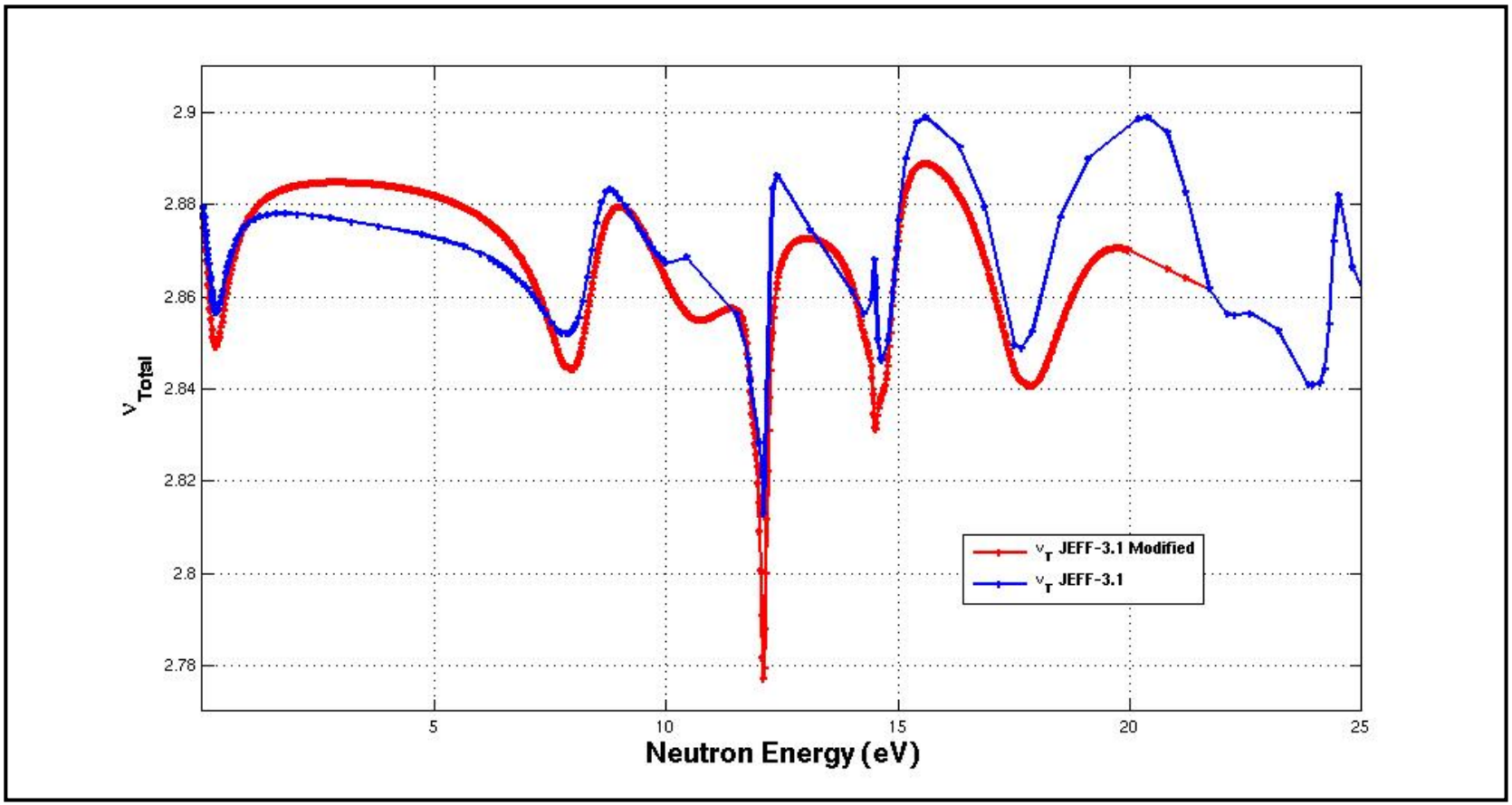
  - +1.0 $\pm$ 2.1 pcm/K in hot operation conditions(150°C-300°C). $\alpha$ value is accurate enough in the 0.3 eV resonance. (JEF-2.2 interpretation of CREOLE experiment)

# Proposed modifications:

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



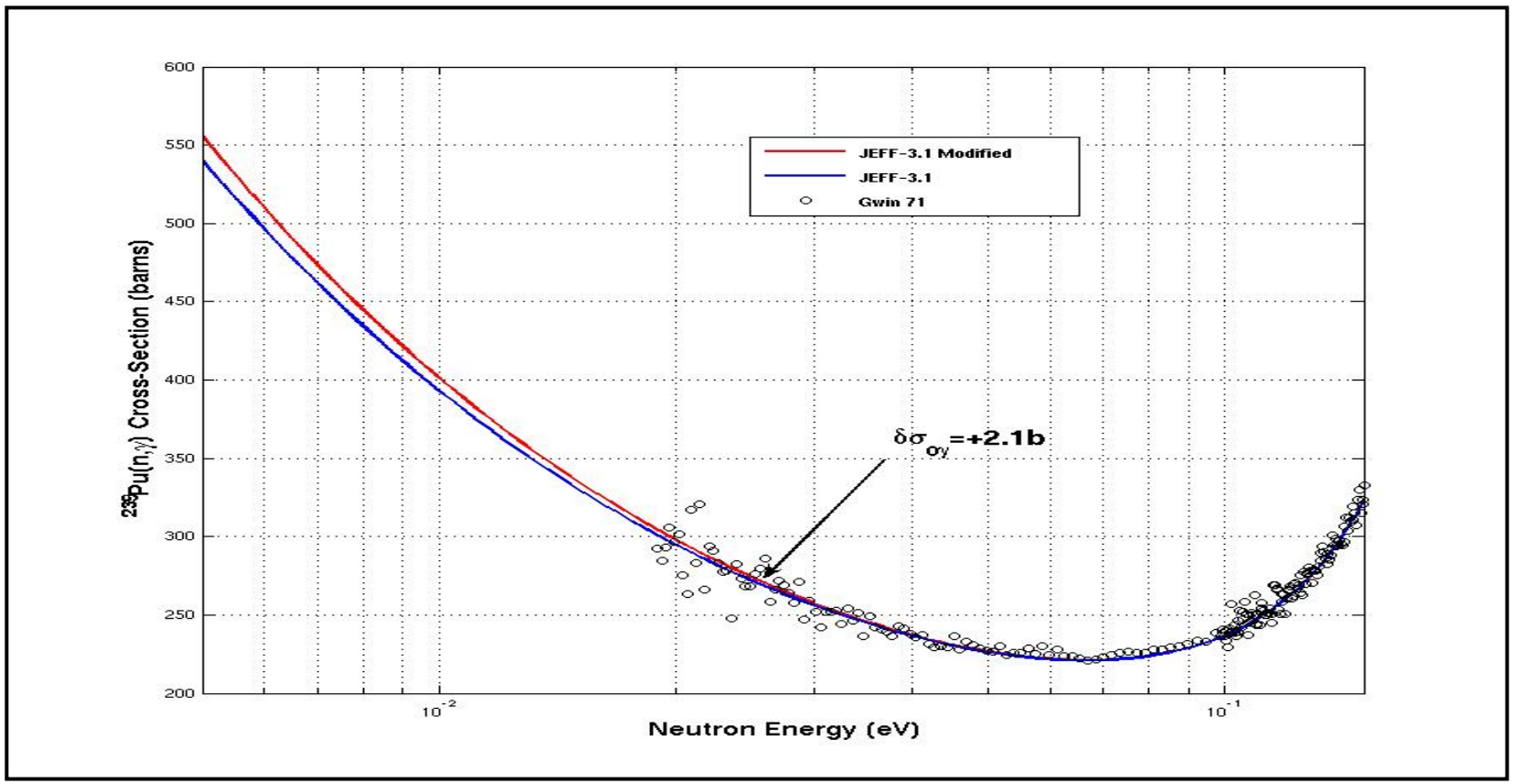
# New evaluation using the fluctuation analysis up to 20eV



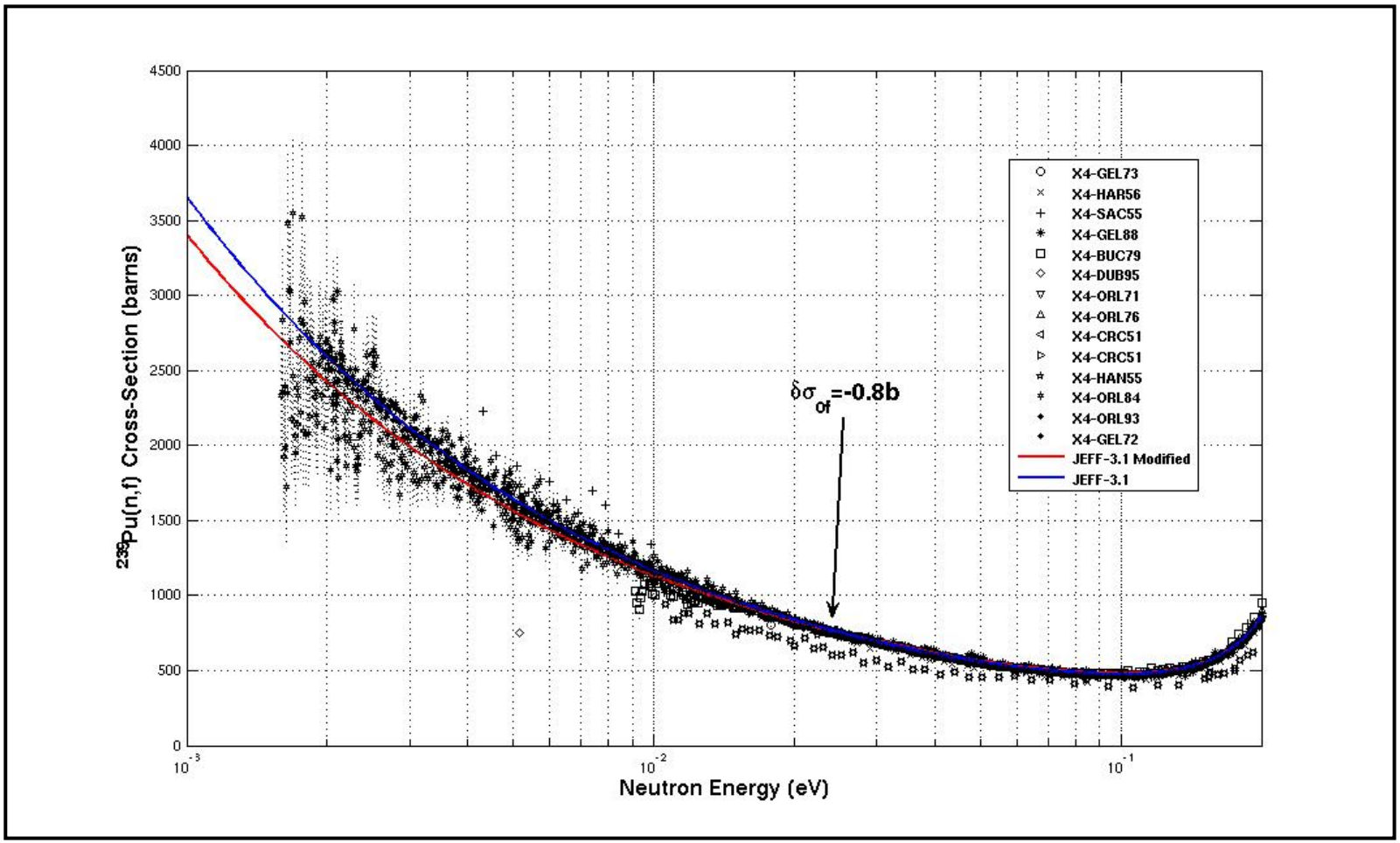
# New subthermal/thermal neutron induced cross-sections by adding no more than a new bound level:

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

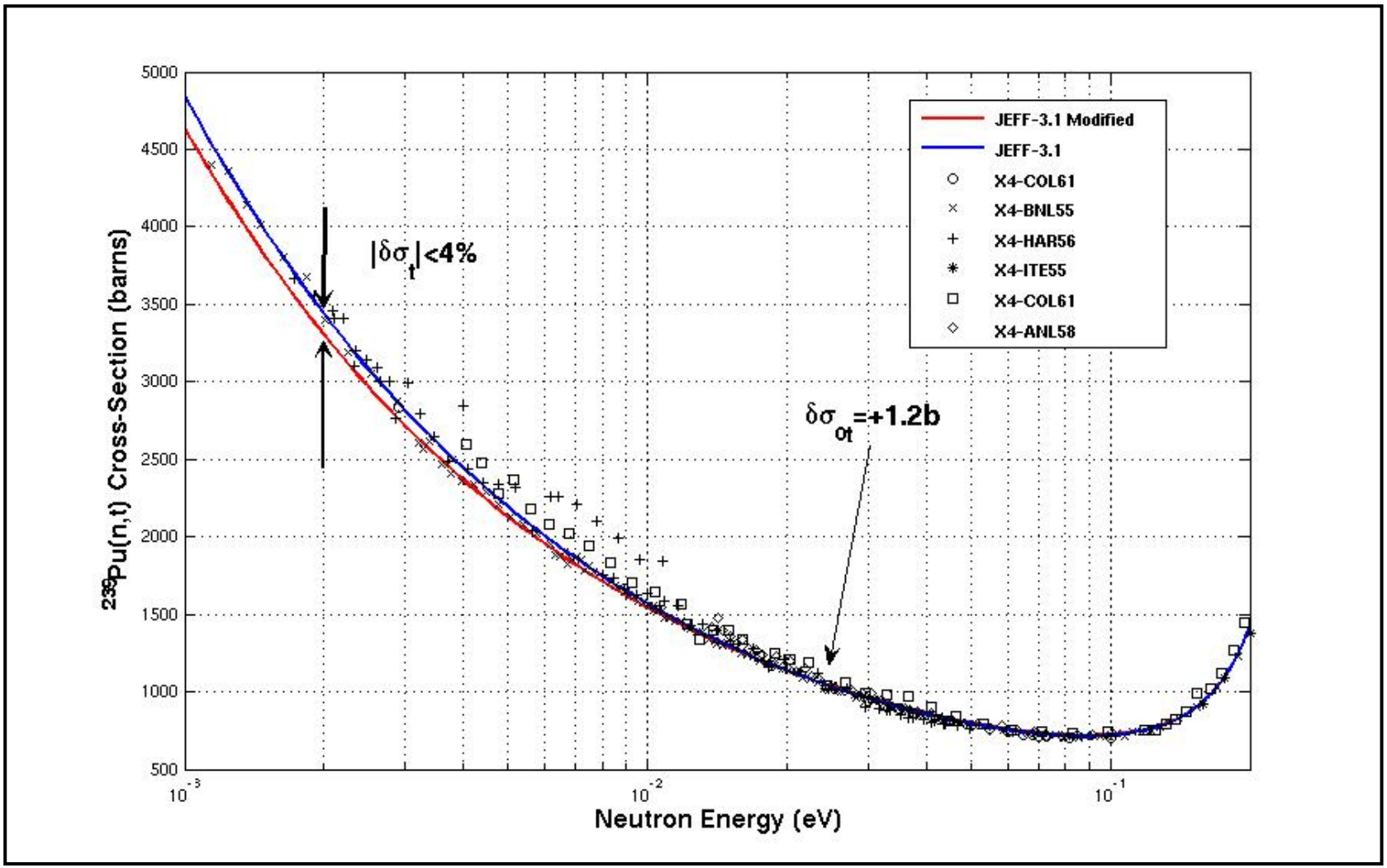
## Subthermal capture cross-section:



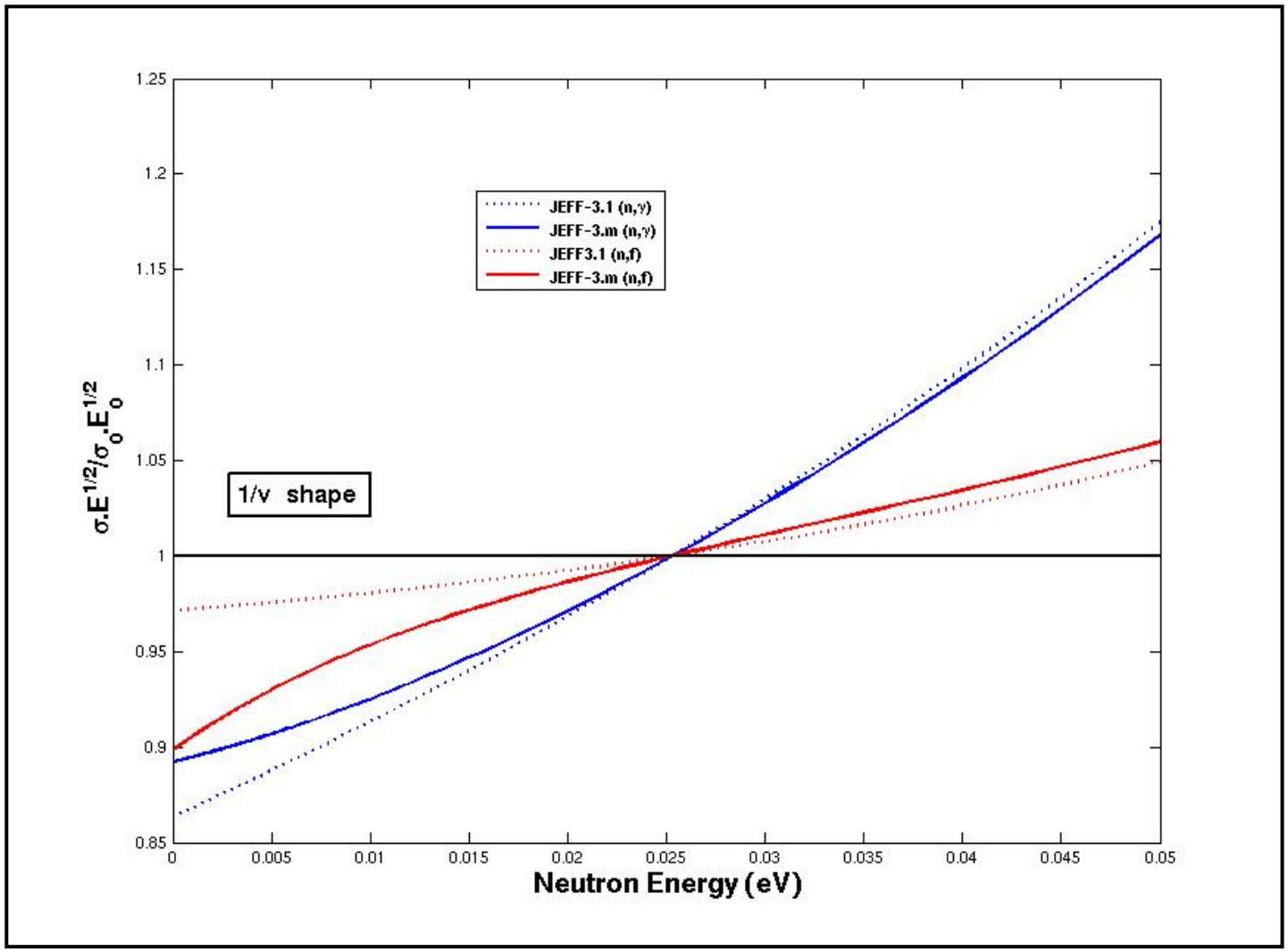
# Subthermal fission cross-section:



# Subthermal total cross-section:



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

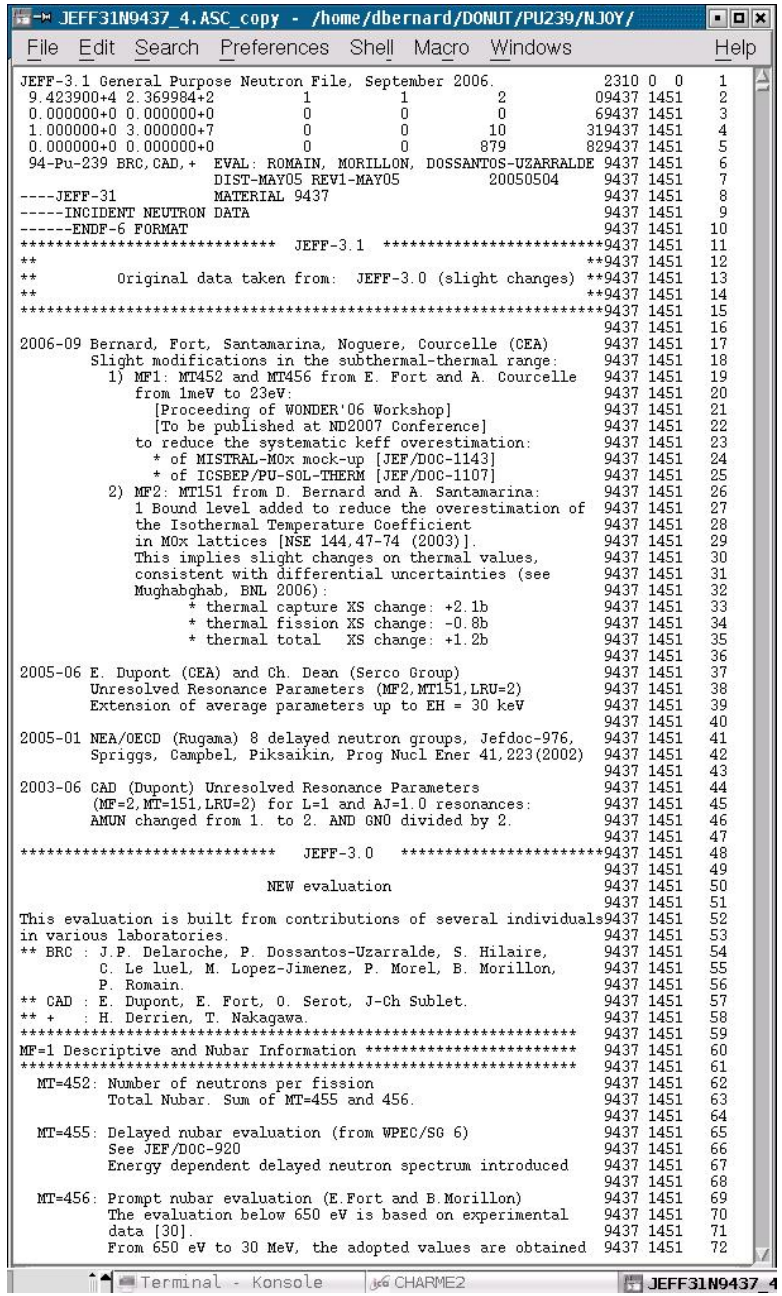


# JEFF-3.2β file

- 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-3.2$\beta$ 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 **recommanded and will be used worldwide** in the AREVA-NP group for PWR and BWR applications.