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INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

Use of integral experiments in support to the validation of JEFF-3.2 nuclear data evaluation

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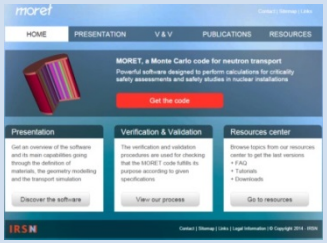
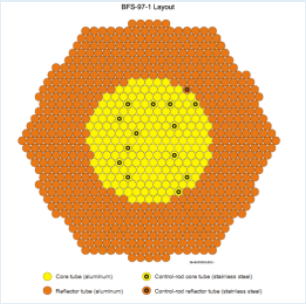
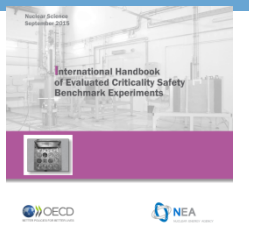




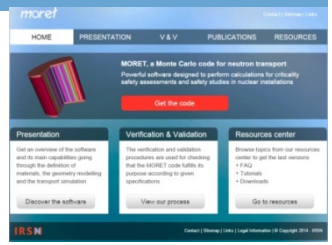
Methodology



- Selection of experimental cases in the ICSBEP Handbook
  - Huge variety of configurations and neutron spectrum
  - Quality of experimental data
  - Selection according to experimental uncertainties

- Selection of 238 cases covering:
  - FAST energy range,
  - INTERMEDIATE energy range,
  - THERMAL energy range,
  - SPECIAL isotopes (^{233}U, ^{237}Np,..)
    - Privilege few cases per series and many independent series to avoid Correlations between cases and between series

Methodology



- Calculations run with Monte Carlo Continuous energy code MORET 5.C.1
  - Use of JEFF-3.1.1 and JEFF-3.2 evaluations for nuclear data
  - Use of probability tables for unresolved energy range
  - $?_{MC}$ = 0.00020

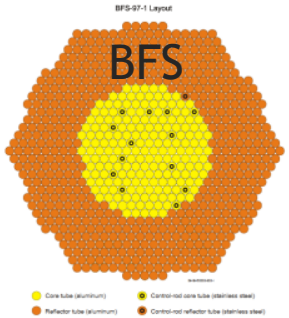
- Comparison of MORET 5.C.1 k_{eff} results run with JEFF-3.1.1 and JEFF-3.2 with the benchmark k_{eff}
  - If difference of k_{eff} exceeds $3?_{comb}$ then a bias has been detected, otherwise no bias

with $\sigma\downarrow comb = \sqrt{\Delta k\downarrow eff\uparrow 2 + \sigma\downarrow MC\uparrow 2}$

Selection of experiments

FAST energy range

- Uranium
  - 89.5 wt.% < ^{235}U < 97.7 wt.%
  - Reflectors: none, water, depleted uranium, CH_2, alumina, tungsten
- Plutonium
  - 1.8 wt.% < ^{240}Pu < 20.16 wt.%
  - Reflectors: none, water, ^{nat}U, CH_2, alumina, tungsten



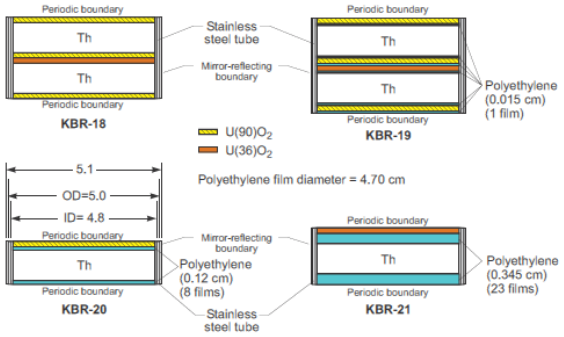
INTERMEDIATE energy range

- HEU powders: 93.3 wt.% ^{235}U
  - Various water content and interstitial moderators (Water, CH_2)
  - Reflector: 15.24 cm CH_2
- BFS experiments
  - Hexagonal lattice of tubes with stacked pellets of U(dep)O_2, Pu(95)
  - Variable water content: CH_2 pellets and dowels,

Selection of experiments (continued)

Intermediate energy range

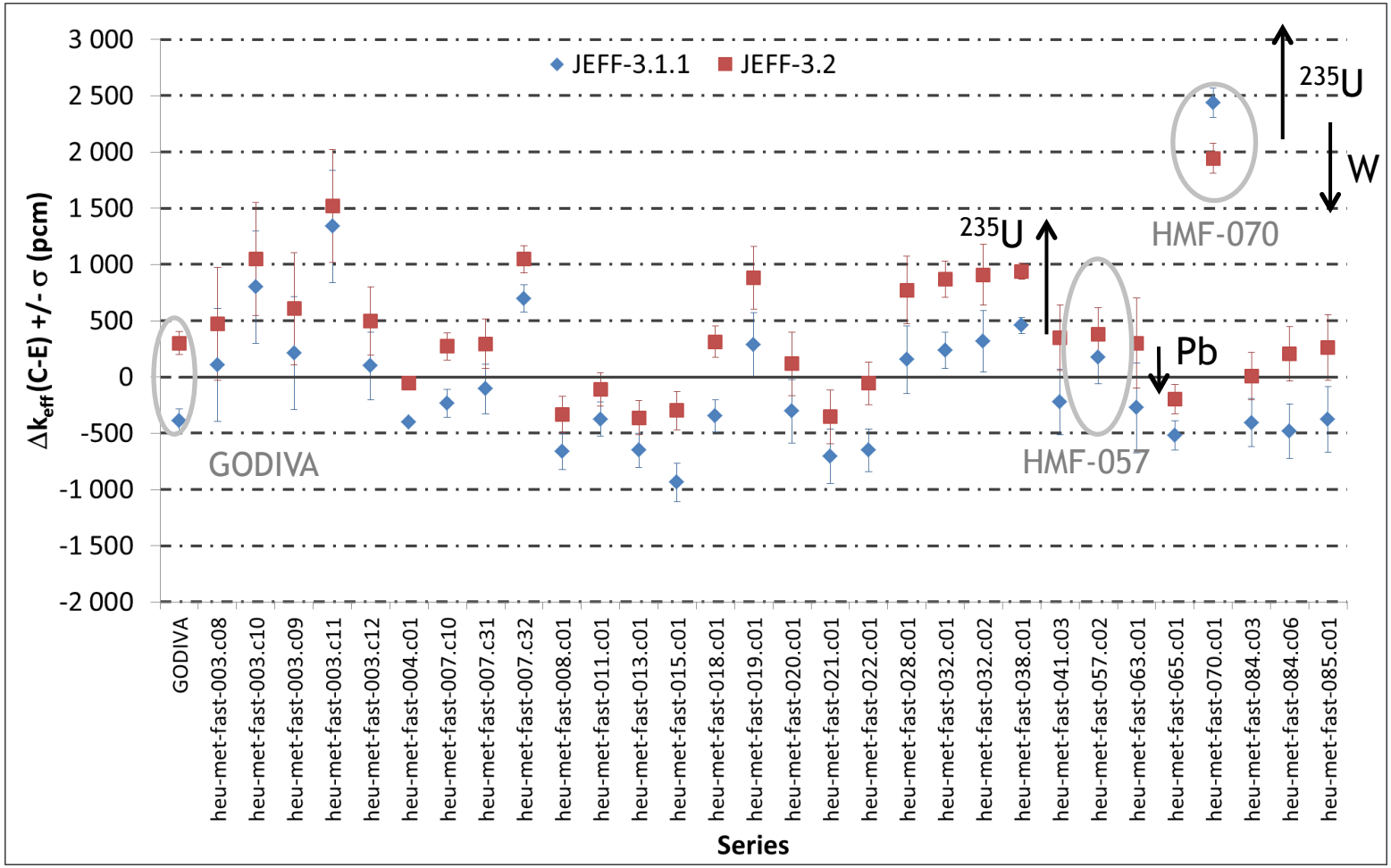
- ICI: Infinite lattice of stacked pellets
  - Intermediate and highly enriched uranium and thorium



THERMAL energy range

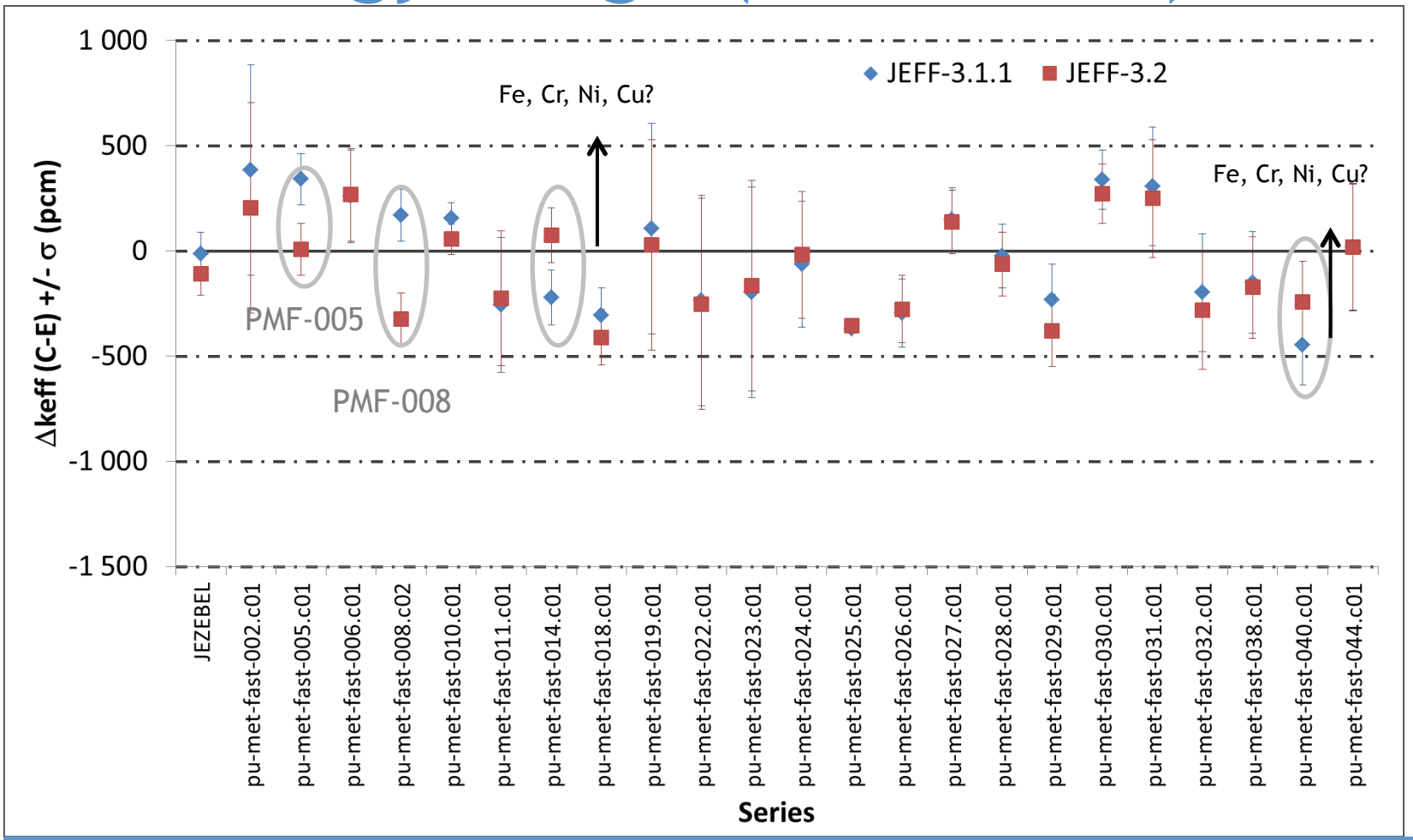
- Lattices of UO_2 rods in water
  - 2.6 wt.% < ^{235}U < 6.9 wt.%
  - Reflectors: water
- Lattices of UO_2 rods in water with absorber and SS, lead reflector
  - 2.6 wt.% < ^{235}U < 6.9 wt.%
  - Absorber: B, Cd, Gd…
  - Reflectors: lead, stainless steel, water
- Lattices of UO_2-PuO_2 rods in water
  - 3 wt.% < Pu/UPu < 22 wt.%
  - 8.5 wt.% < ^{240}Pu < 22.2 wt.%
  - 1.7 < V_{mod}/V_{ox} < 17.5

FAST energy range: ^{235}U



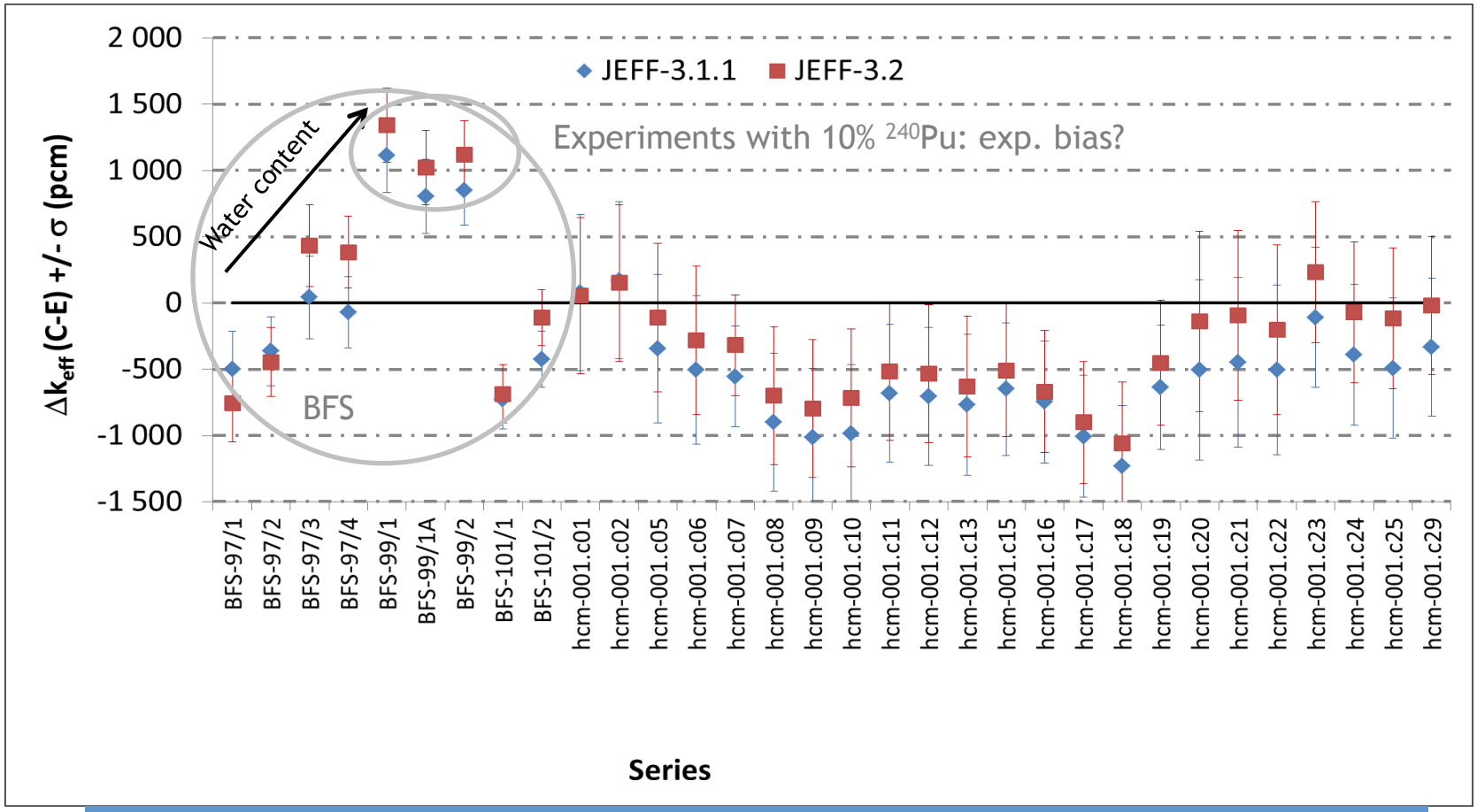
- Shift of +500 pcm of results, due to ^{235}U
- W (HMF-070) and Pb (HMF-057): compensation effects due to new evaluation

FAST energy range (continued): Pu



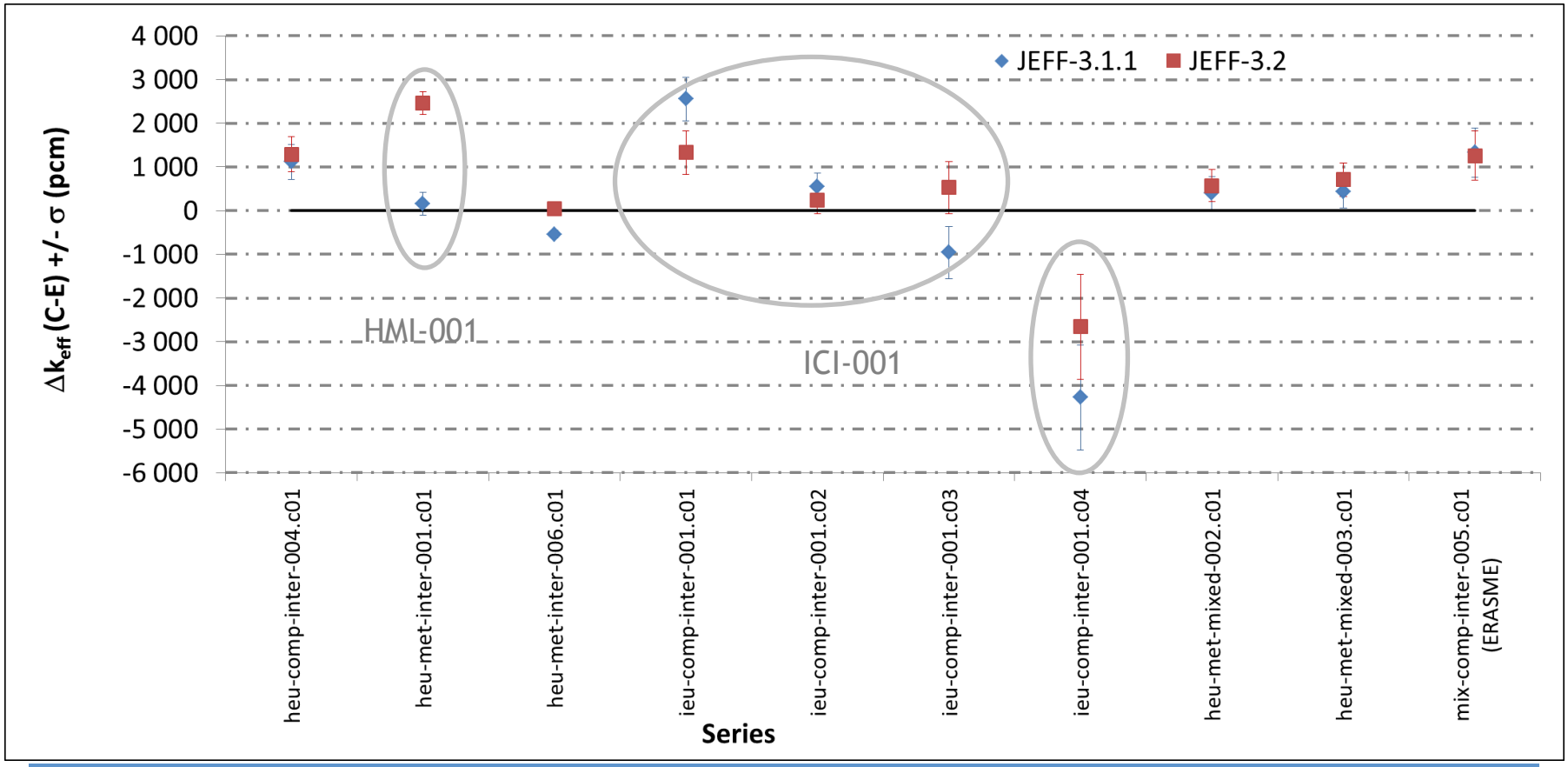
- No significant modification for JEZEBEL due to Pu
- No significant impact of ^{240}Pu
- Strong reduction of k_{eff} by -500 pcm with JEFF-3.2 for ^{232}Th (PMF-005, -008)

INTERMEDIATE energy range: U and Pu



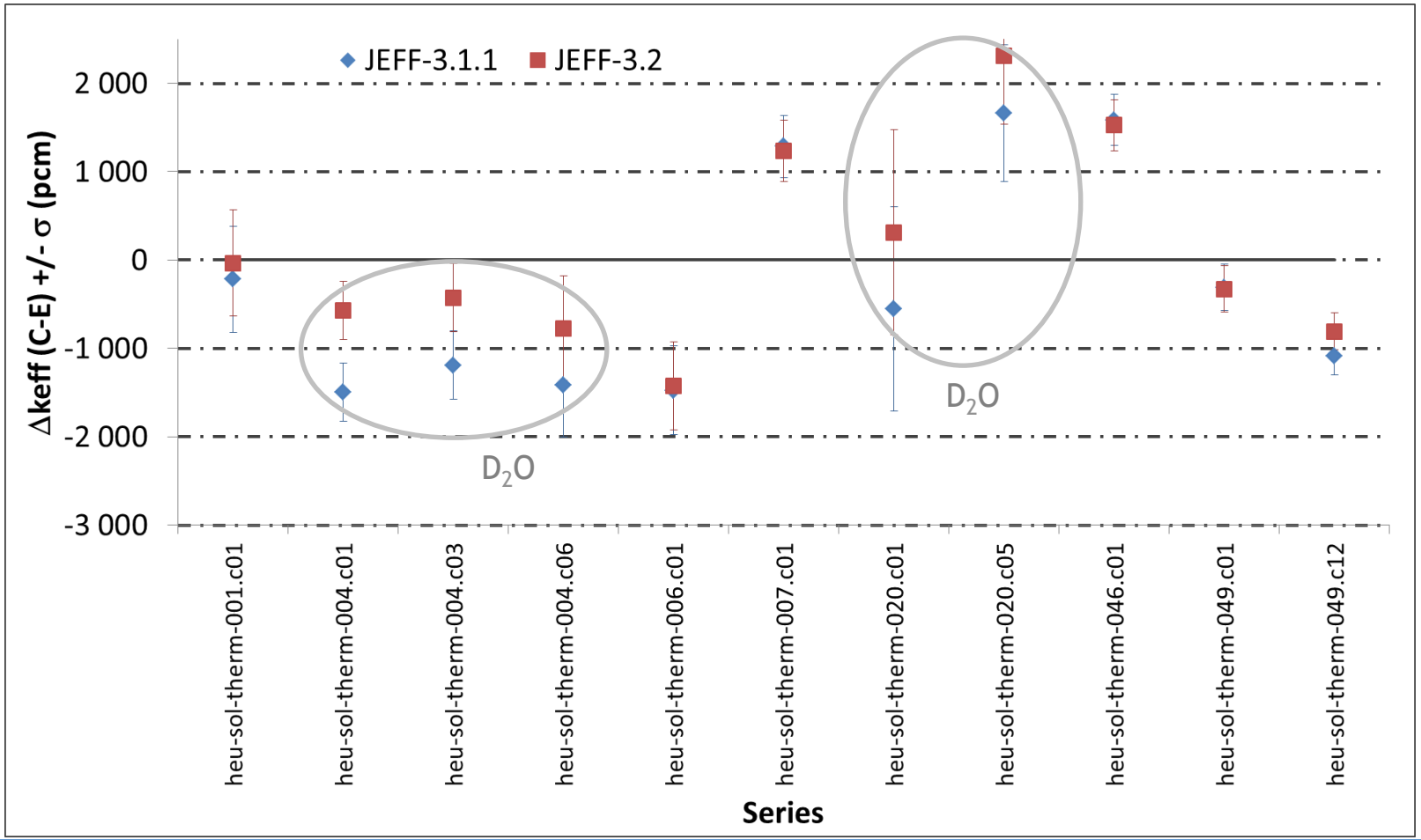
- BFS: evolution of k_{eff} with JEFF-3.2 depending of neutron spectrum
  - Tendency of k_{eff} results with water content still observed with JEFF-3.2
- HCM-001: slight improvement of results

INTERMEDIATE energy range: U and Pu



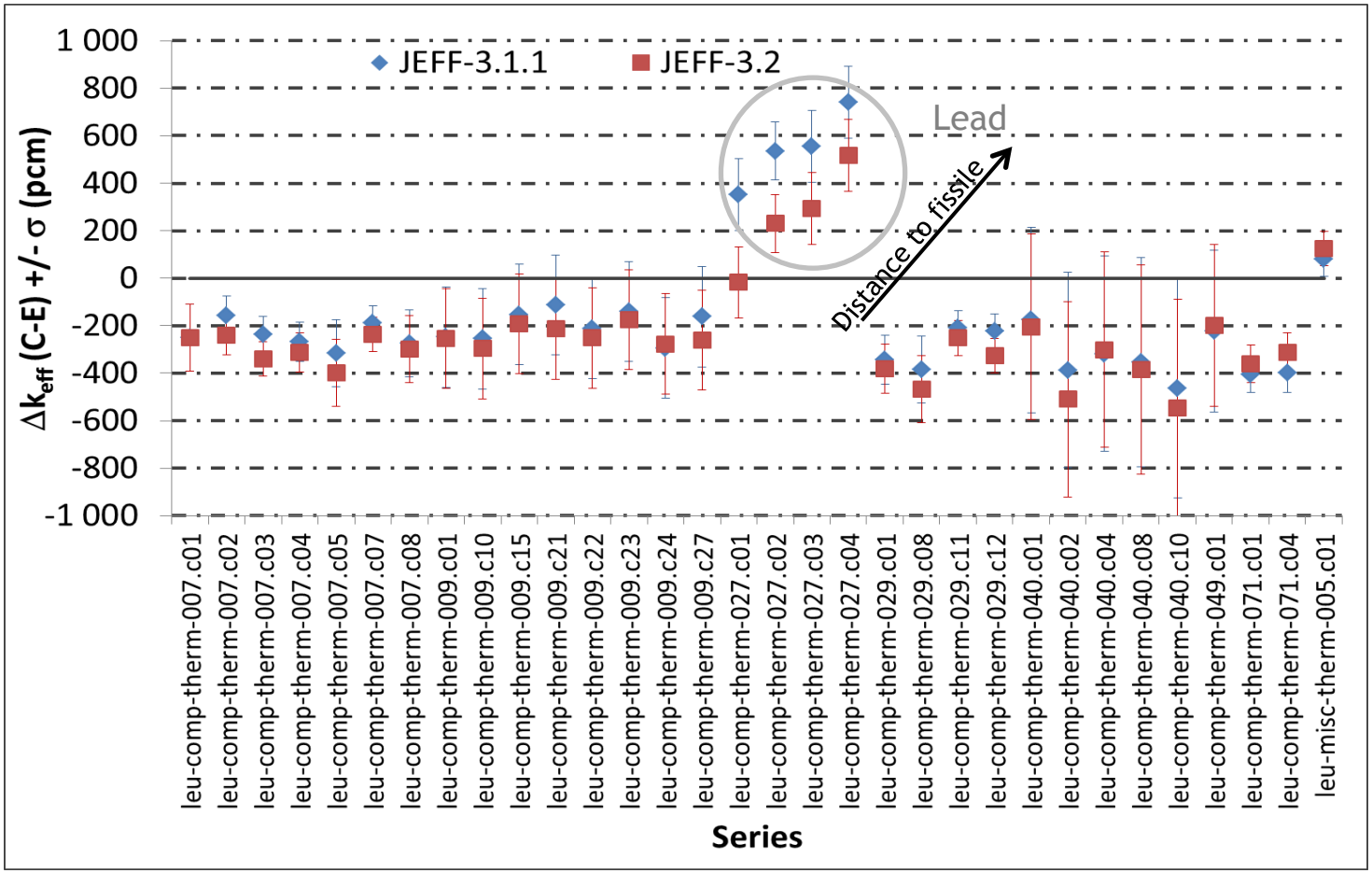
- For HMI, increase of k_{eff} until 2500 pcm (HMI-001) ? Fe, Cr, Ni, Cu?
- ICI:
  - Fast energy range: decrease by -300 to -1200 pcm (^{232}Th)
  - Intermediate and thermal energy ranges: increase by +1000 pcm (^{232}Th)

THERMAL energy range (HEU-SOL)



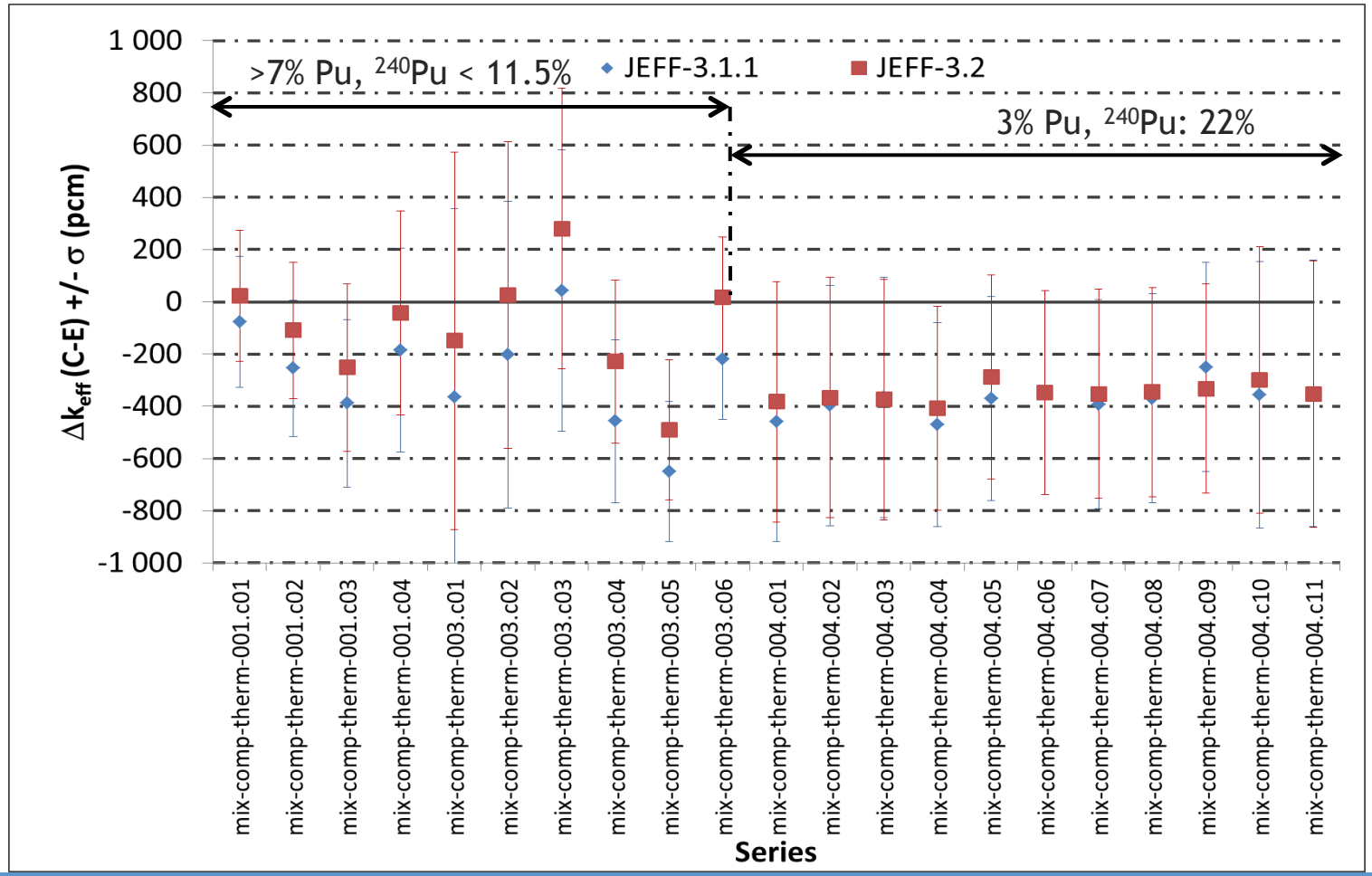
- Light water: no significant modification of k_{eff} results
- HST-004 and -020 with heavy water: increase of k_{eff} between +500 and +1000 pcm
- HST-046 involving beryllium reflector: no improvement of results

THERMAL energy range (LEU-COMP)



- Lattices in light water, without canister: no significant modification of k_{eff} results
- LCT-027: decrease of k_{eff} results due to lead new evaluation BUT improvement needed (tendency with distance of lead reflector from fissile)

THERMAL energy range (MIX-COMP)



- Improvement of results for high Pu content (MCT-001 and -003)
- No improvement for MCT-004, results in the uncertainty margins

Other Issues

Case	Benchmark k_{eff} (Unc. 1?)	k_{eff}			
		JEFF-3.1.1	JEFF-3.2		
		All isotopes	All isotopes	Only isotope of interest (JEFF-3.1.1 for others)	
IMF-007.c01 (BIG TEN)	1.00480 (0.00020)	0.99783	1.00359	^{238}U	1.00429
				^{235}U	1.00022
				$^{238}U + ^{235}U$	1.00536
HCT-021.c01	1.00080 (0.00290)	0.99280	0.99680	^{232}Th	0.99558
U233-MF-001	1.00000 (0.00100)	1.00639	0.99996	^{233}U	0.99986

- BIG TEN (reflection by DU): increase of k_{eff} due to ^{235}U and ^{238}U
  - Improvement of results
- HCT-021: improvement of results with new ^{232}Th (within 2?)
- U233-MF-001: decrease of k_{eff} by -600 pcm with JEFF-3.2, improvement of results

Conclusions

Thermal energy spectrum

- No significant improvement for Pu, LEU and HEU solutions
- Main improvement due to:
  - The treatment of lead as absorbing elements (canisters)
  - Under-estimation with thorium partly compensated

Intermediate energy spectrum

- Increase of k_{eff} for systems with HEU

Fast energy spectrum

- Pu: no modification
- HEU: no more under-estimation with JEFF-3.2
- Decrease of k_{eff} for systems with ^{232}Th and W reflectors: better agreement with benchmark BUT improvement still needed

Conclusions (continued)

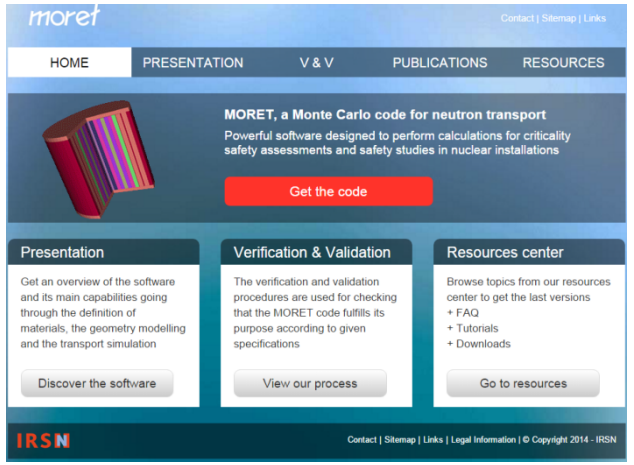
- Fast energy spectrum
  - ^{233}U: decrease of k_{eff} by -600 pcm
    - Good agreement with benchmark
- Analysis based on a restricted number of experiments
  - Focus on few isotopes
    - Main tendencies highlighted
  - Need to go more deeply to explain all the results (compensation between various isotopes)
- To be done:
  - Use of sensitivity coefficients to better understand trends

Thanks for your attention!!

Questions ??

The MORET 5 code

- Two calculation routes
  - Multi-group (281 groups) in APOLLO2-MORET 5 route (CRISTAL package)
  - Continuous energy
- Continuous energy 5.C.1 version using various libraries and probability tables for URR
  - ACE formatted files for nuclear data library: JEFF-3.1 in this study
- Various simulation methods available (default: natural)
- Modular geometry
- Sensitivity calculation module
- Correlated sampling method for chemical perturbations



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