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NUCLEAR TECHNOLOGY
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International criticality benchmark comparison for nuclear data validation

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IRSN

International criticality benchmark comparison for nuclear data validation

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Benchmark Intercomparison Study

- New benchmark intercomparison using various
  - Codes: COG (LLNL) , KENO (ORNL), MCNP (LANL), MORET (IRSN)
  - Nuclear data libraries: JEFF-3.3, ENDF/B-VII.1 and ENDF/B-VIII.0
- Use of codes validations suites benchmark → independent modeling

Provide a rigorous basis for quality and validating nuclear data libraries

ADVANCE, VaNDaL, ICSBEP/DICE

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Data available at IRSN (1/2)

Systems \ Codes/libraries	MORET 5 (IRSN) ENDF/B-VII.1 ENDF/B-VIII.0 JEFF-3.3	COG (LLNL) ENDF/B-VII.1 ENDF/B-VIII.0 JEFF-3.3	MCNP ENDF/B-VII.1	KENO (ORNL) ENDF/B-VII.1 ENDF/B-VIII.0
PU	**215**	**526**	**261**	**93**
HEU	**457**	**761**	**378**	**102**
IEU	176	188	13	13
LEU	522	366	209	159
MIX	164	28	73	61
U233	32	193	158	190

2019: HEU and Pu systems

Data available at IRSN (2/2)

- PU: 748 Experiments available (95 evaluations) in ICSBEP Handbook (2018)
  - Only 33 experiments common to the four codes
  - *Benchmarks with polystyrene-moderated plutonium oxide were discarded from the MORET validation suites (quality of the 61 experiments)*
- HEU: 1426 Experiments available (225 evaluations) in ICSBEP Handbook (2018)
  - Only 35 experiments common to the four codes

Main issues for the intercomparison (1/3)

- ICSBEP revisions
  - Not indicated in MCNP, COG and SCALE Excel files
  - Always the last revision in the MORET 5 validation suites (check each year)
  - Could impact geometrical or material data → explain some observed differences
  - Benchmark keff and its associated uncertainty could sometimes help to solve

HEU systems (225 evaluations)

- 148 revisions 0
- 37 revisions 1
- 28 revisions 2
- 9 revisions 3
- 3 revisions 4

Pu systems (95 evaluations)

- 50 revisions 0
- 32 revisions 1
- 9 revisions 2
- 3 revisions 3
- 1 revisions 4

Main issues for the intercomparison (2/3)

- Simplified or detailed model ?
  - Not always indicated in MCNP and SCALE Excel files
  - Benchmark keff and uncertainty could sometimes help to solve this issue
  - Could explain small significant discrepancies observed between codes

- Cross references in ICSBEP
  - HMF-007: cases 11, 12, 14 and 31 are cross referenced in HMI-007 and cases 13, 15, 16, 17, 18, and 36 to 43 in HMM-009

Main issues for the intercomparison (3/3)

- Benchmark and DICE numbering
  - Numbering in DICE could be different to the numbering in the benchmark when some experiments are considered as unacceptable

	MORET	COG	MCNP	KENO
PST007-002	1.00382 +/- 0.00010	1.00406 +/- 0.00018	1.00361 +/- 0.00013	1.00901 +/- 0.00010

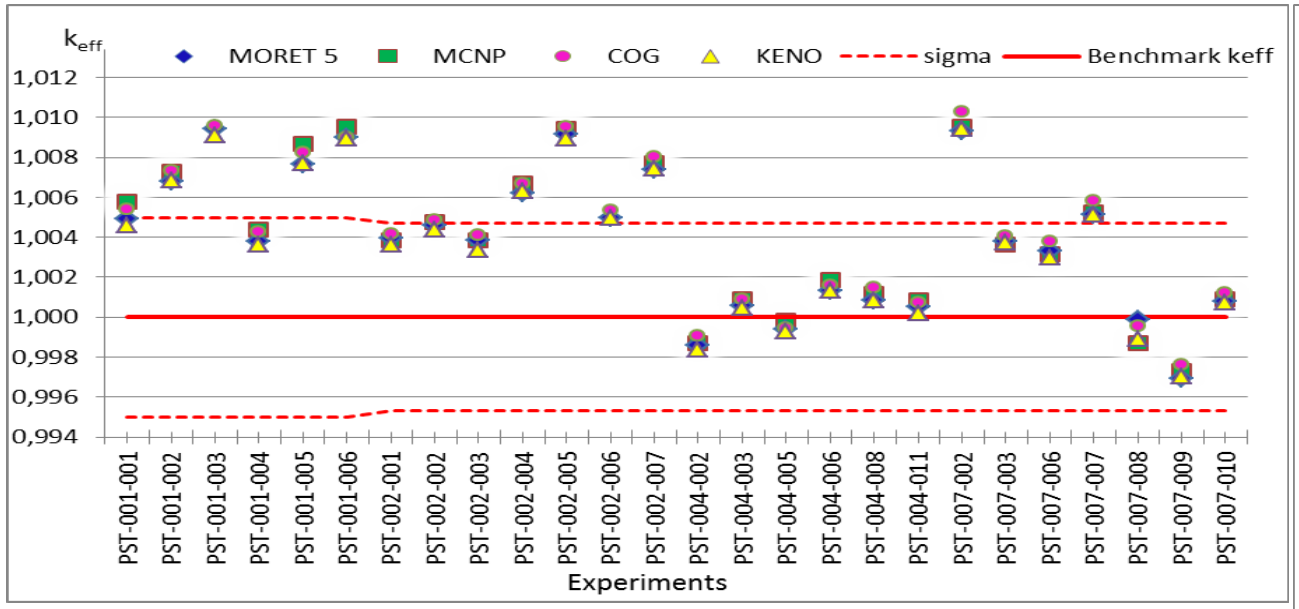
1.00376

DICE	Benchmark
1	**Experiment n° 2**
2	Experiment n° 3
3	Experiment n° 5
4	Experiment n° 6
5	Experiment n° 7
6	Experiment n° 8
7	Experiment n° 9
8	Experiment n° 10

- ICSBEP/DICE issues
  - Quality of the data (*polystyrene-moderated PuO_2 or UO_2-PuO_2)*
  - Large experimental uncertainties (not adapted for ND validation)
- Modeling issues and misunderstandings of benchmarks
  - **Reported to validation teams to improve the validation suites**

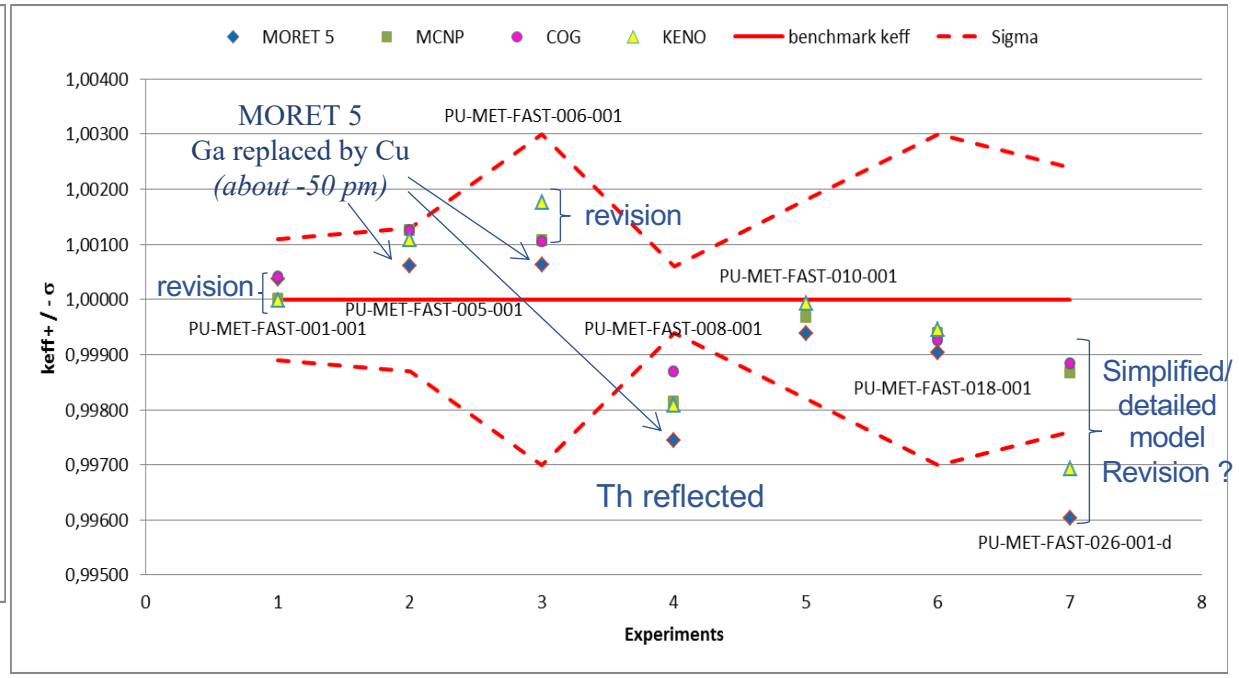
Results of common benchmarks – ENDF/B-VII.1 (1/2)

Pu in thermal spectra (26 PST)*



- Slight over-prediction for Pu in thermal spectra with a possible trend with the plutonium concentration
- All codes consistent

Pu in fast spectra (7 PMF)*

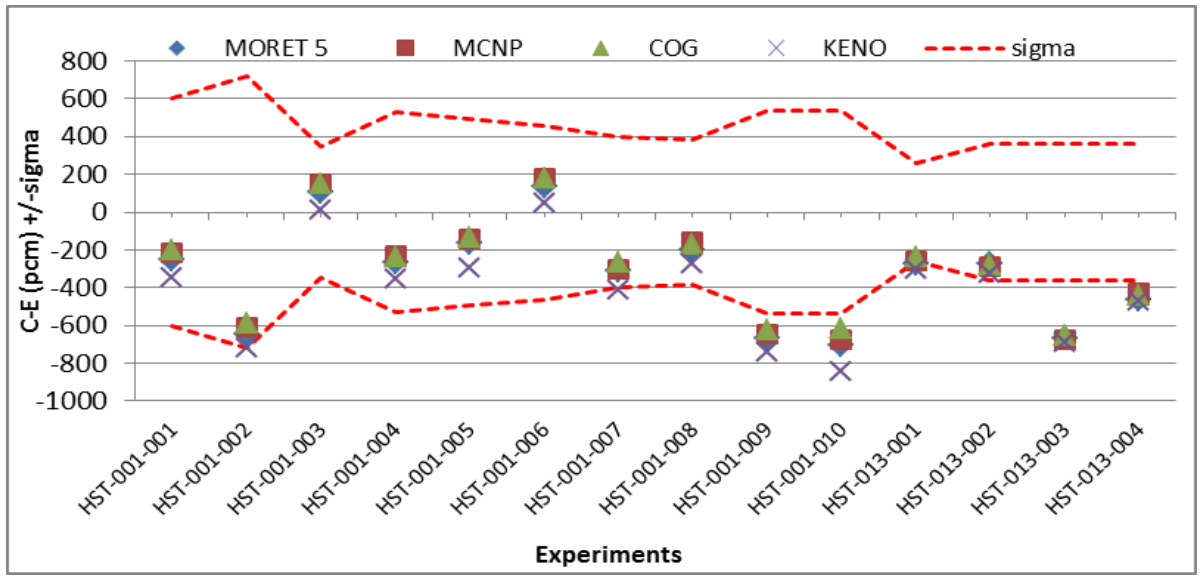


- ^{239}Pu in fast spectra quite well evaluated
- ICSBEP Revision and model (simp./det.) effects
- Underestimation for Th reflected experiment

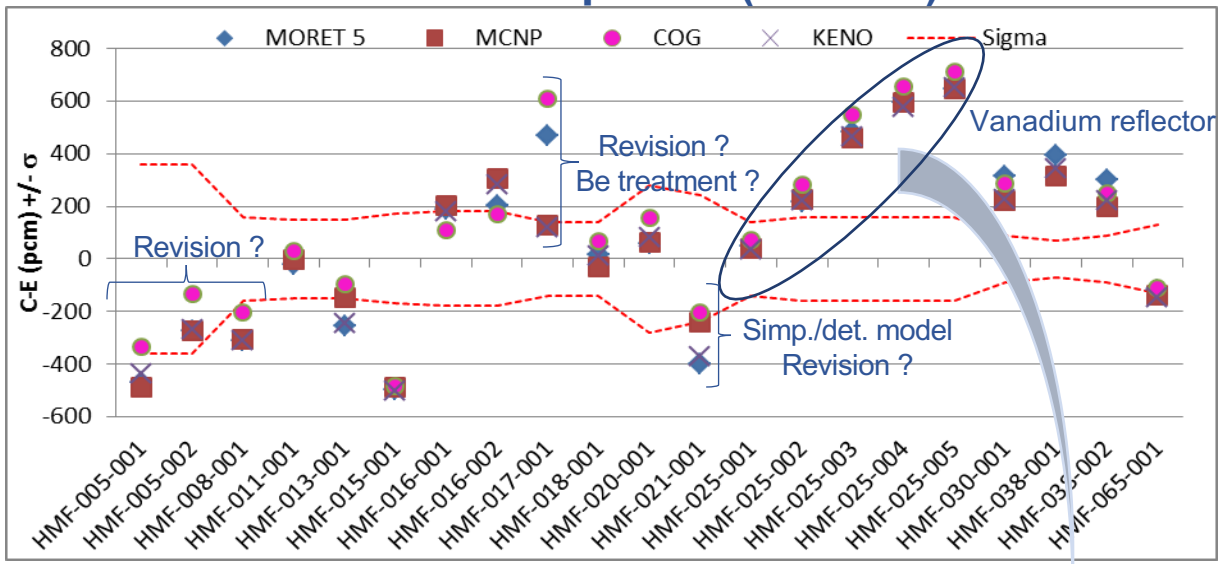
* MC Standard deviations below 0.00020

Results of common benchmarks – ENDF/B-VII.1 (2/2)

U235 in thermal spectra (14 HST)*

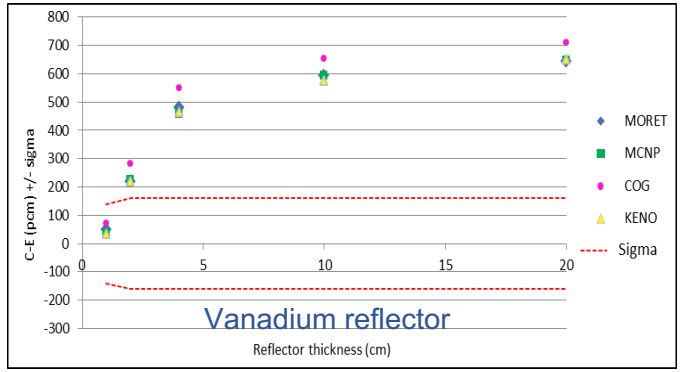


U235 in fast spectra (21 HMF)*



- ^{235}U in thermal spectra quite well evaluated
- Small discrepancies with KENO are being analysed

- ^{235}U evaluation in fast spectra satisfying (3σ)
- Over prediction for Vanadium reflected experiments increasing with reflector thickness



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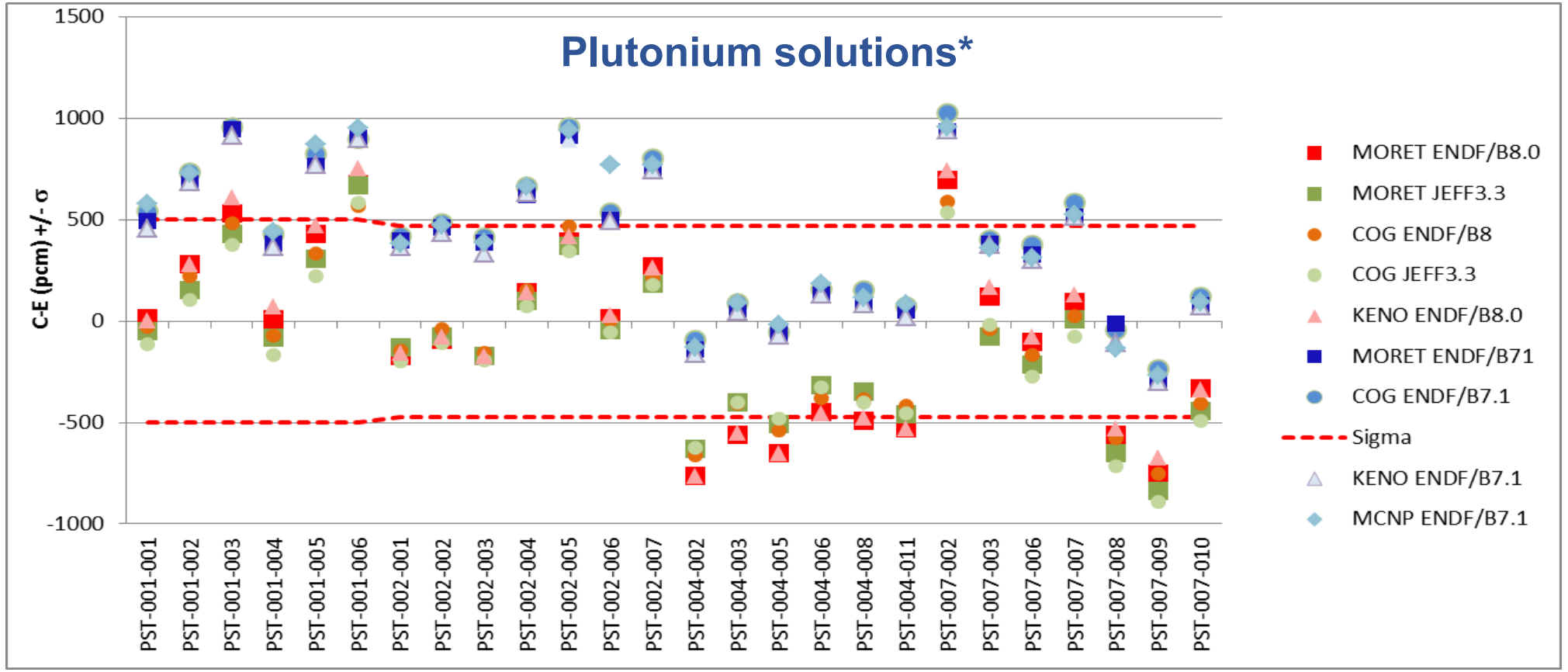
Feedback on nuclear Data (1/5)



- Pu improvement in thermal spectrum with ENDF/B-VIII.0 and JEFF-3.3
- Small significant discrepancies (150-200 pcm) observed between COG and MORET/KENO with ENDF/B-VIII.0
  - Processing issues ?

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* MC Standard deviations Below 0.00020

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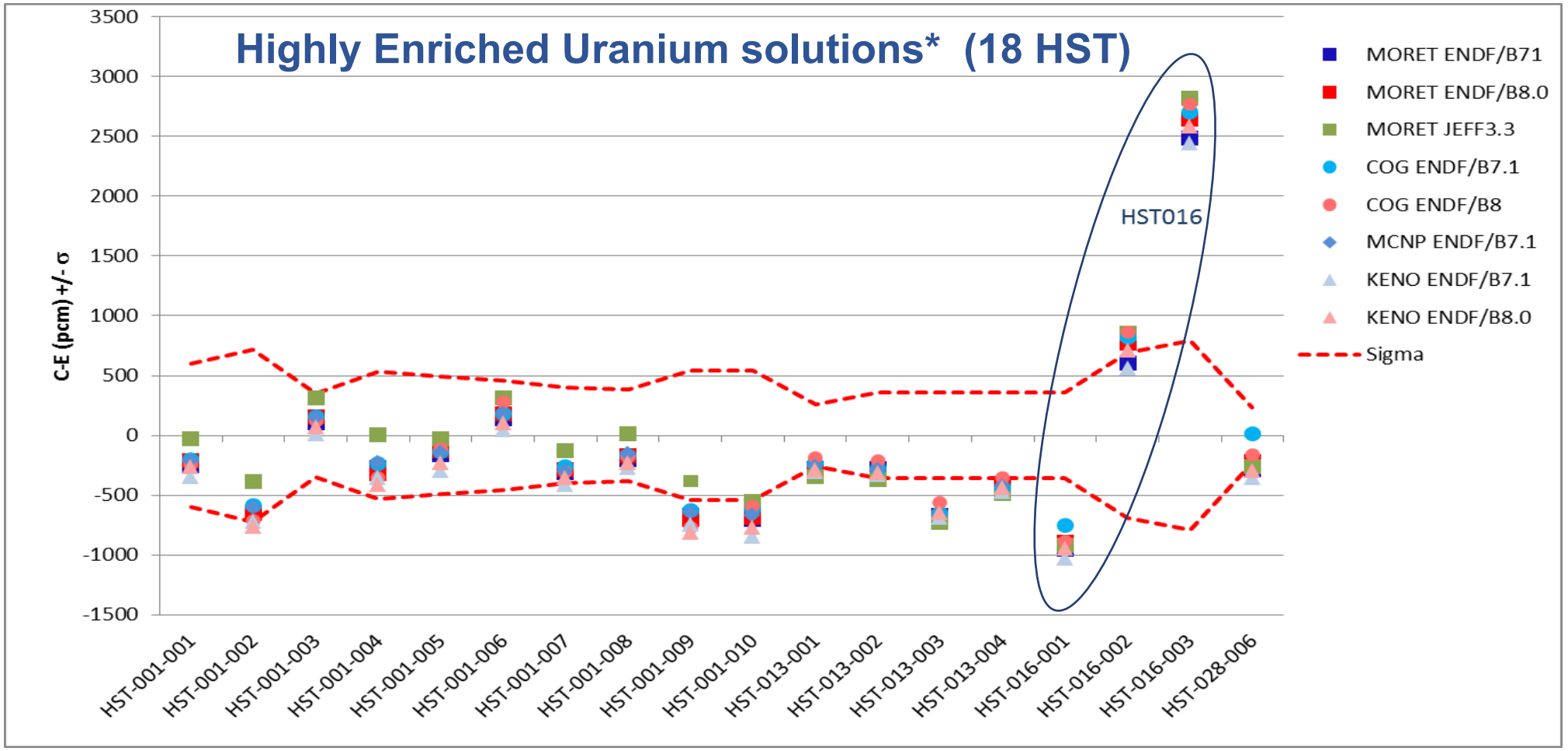
Feedback on nuclear Data (2/5)



- No significant change using ENDF/B-VIII.0 (less than 80 pcm) except for HST016
- Increase of keff (about 200 pcm) using JEFF-3.3
- HST016 results → trend with Gd concentration

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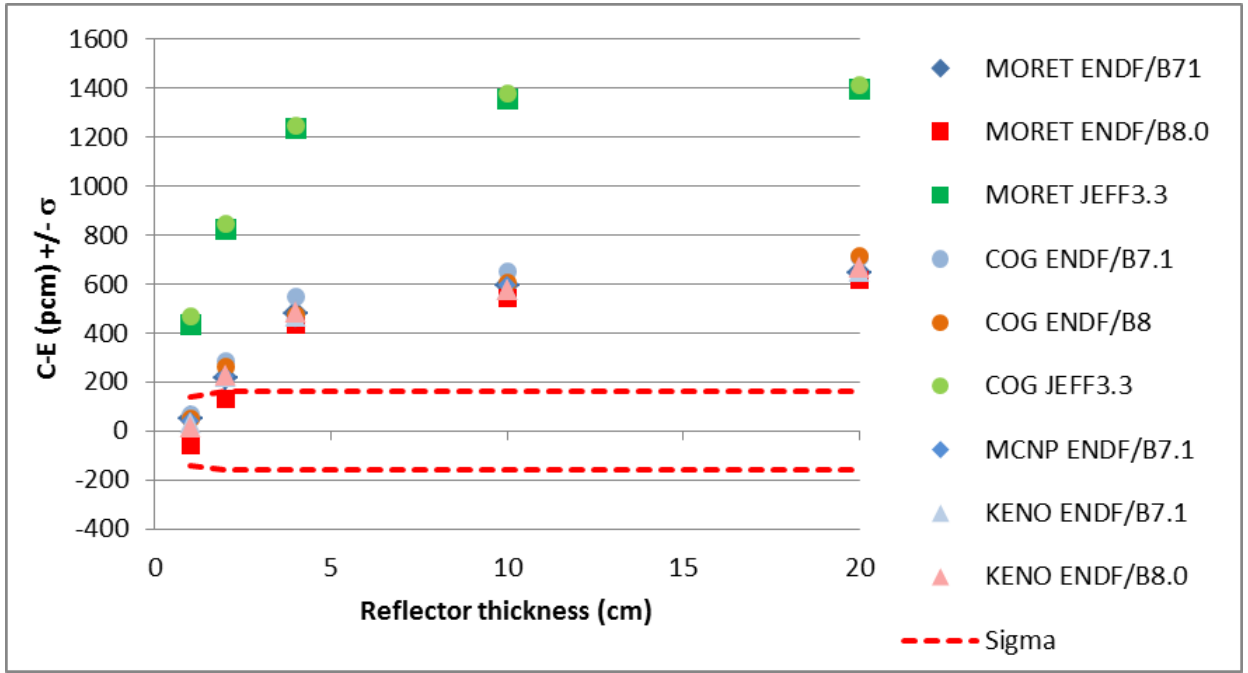
Feedback on nuclear Data (3/5)

HEU-MET-FAST

- Bare and CH_2 reflected configurations
  - Satisfying results observed with ENDF/B.VII.1 retained with the ENDF/B-VIII.0 and JEFF-3.3
  - Small impact of ENDF/B-VIII.0 (+/- 200 pcm max.)
- Vanadium reflected experiments
  - Worse results using JEFF-3.3 for Vanadium reflected experiments
  - No significant change with ENDF/B-VIII.0
  - Tendency with the reflector thickness for all libraries



* MC Standard deviations Below 0.00020

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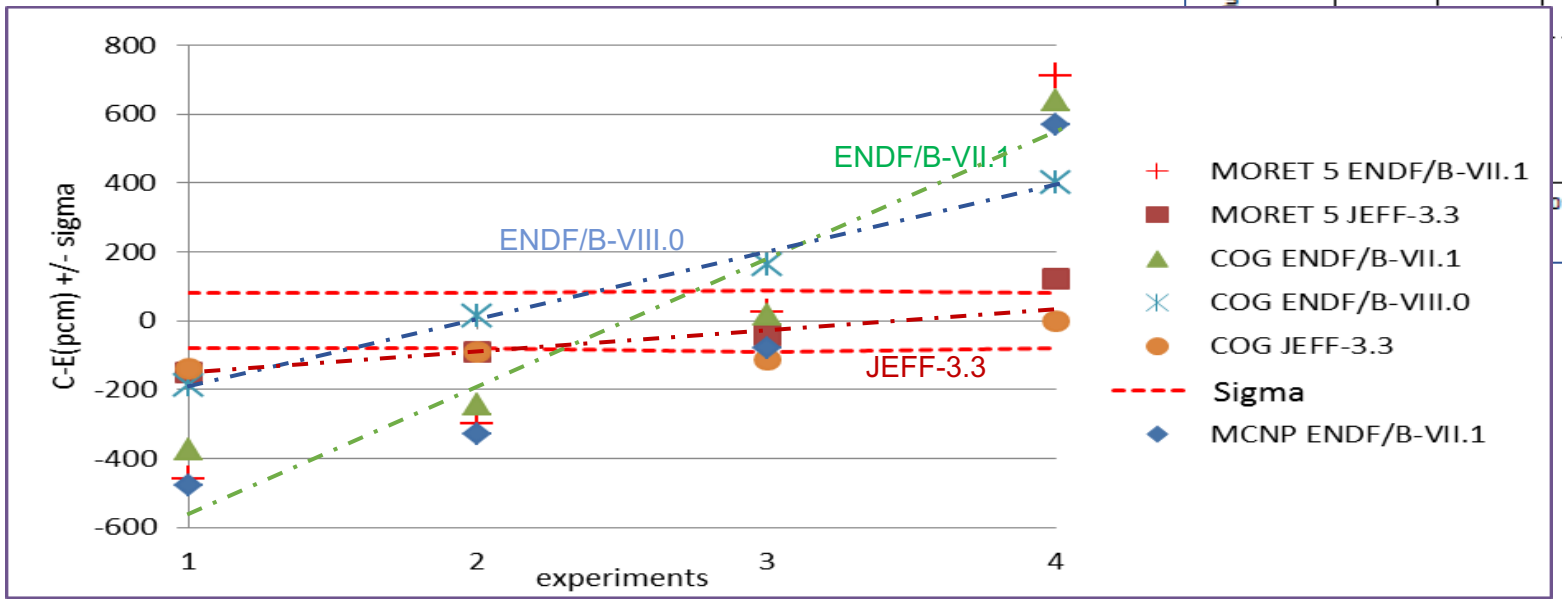
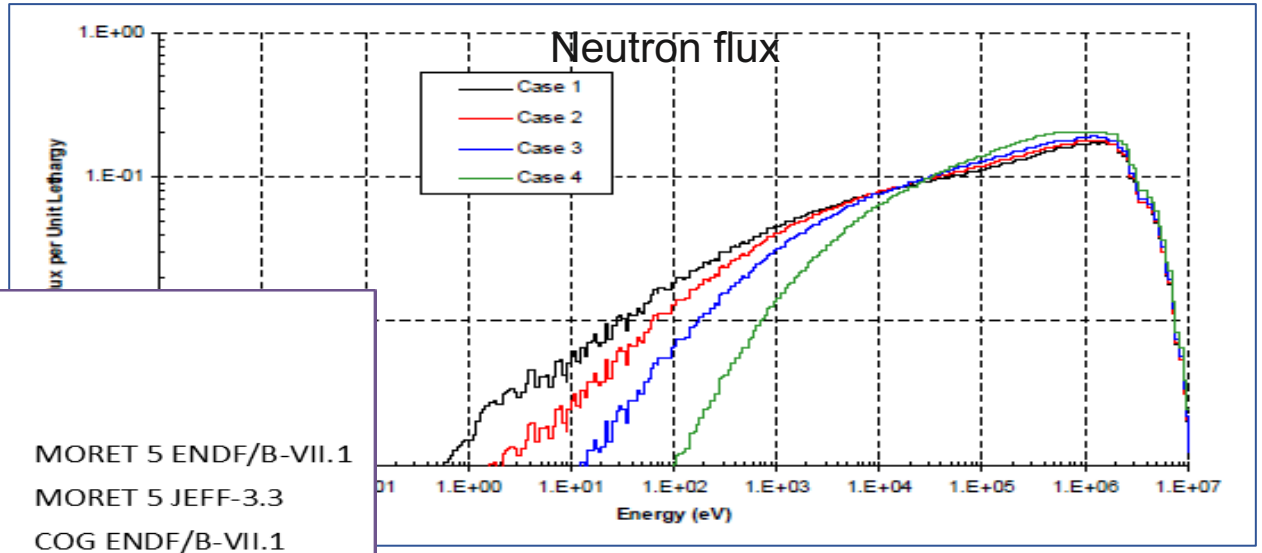
Feedback on nuclear Data (4/5)

Zeus experiments

- HEU in intermediate spectra
- Copper reflected





- Strong improvement with JEFF-3.3
- Tendency versus spectrum with ENDF/B-VII.1 and ENDF/B-VIII.0
- Small discrepancies between COG and MORET using same libraries
  → ICSBEP revision?

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* MC Standard deviations Below 0.00020

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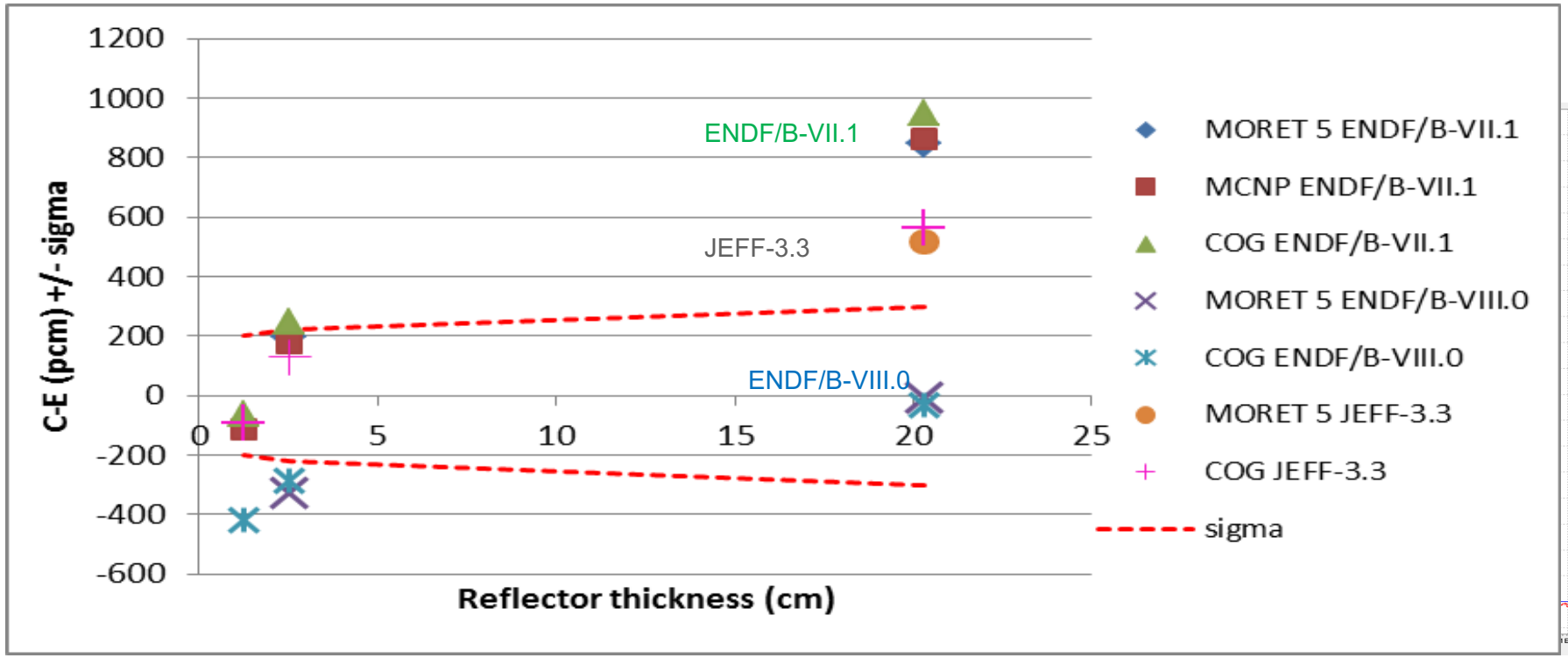
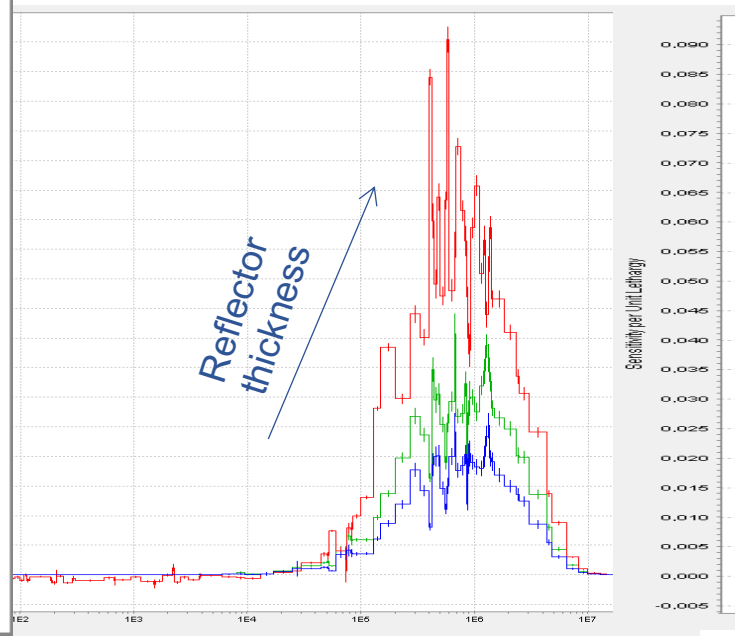
Feedback on nuclear Data (5/5)

Nickel reflected fast experiments



Sensitivity to ^{58}Ni scattering cross section



- Ni scattering cross sections improvement with ENDF/B-VIII.0 and JEFF-3.3
- Improvement still needed, the increasing trend highlighted with the reflector thickness being still observed

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Conclusion (1/2)

- Improvement of the codes validation suites
  - Used for sensitivity/uncertainty studies
- Feedback to ICSBEP
  - Experimental data quality
  - Misunderstanding in benchmark model
  - Suspicious data or experimental uncertainties
- Feedback to Nuclear Data Community
  - JEFF-3.3 and ENDF/B-VIII.0 improvements and isotopes to focus on
  - Processing tools
  - New evaluations needed

- Improvement with JEFF-3.3 and ENDF/B-VIII.0 libraries for Pu in thermal spectra
- ^{235}U in thermal spectra quite well evaluated in ENDF/B-VII.1, ENDF/B-VIII.0 and JEFF-3.3
- Good results retained with ENDF/B-VIII.0 and JEFF-3.3 for ^{235}U and ^{239}Pu in fast spectra
- ENDF/B-VIII.0 and JEFF-3.3: improvement of Ni scattering cross section in fast spectra
- Improvement of ZEUS results using JEFF-3.3
- Vanadium nuclear data to be improved

Conclusion (2/2)

- Need of additional uncorrelated experiments
  - Specific isotope cross section measurement
  - Integral experiment for nuclear data validation
- Work still in progress
  - 2020 – IEU, LEU
  - 2021 – MIX, U233, SPEC
  - 2022 – Final report

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