IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

Benchmark Inter-comparison Study

J.L. Alwin, F.B. Brown, M.E. Rising,

K.Y. Spencer - LANL

D. Heinrichs, S. Kim - LLNL

B.J. Marshall, E.M. Saylor – ORNL

Isabelle Duhamel – IRSN

NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM

IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

OAK RIDGE
National Laboratory

Los Alamos
NATIONAL LABORATORY
EST.1943

June 2019

Benchmark Intercomparison Study: COG, KENO, MCNP, MORET

- New benchmark intercomparison using various nuclear data libraries
  - JEFF-3.3, ENDF/B-VII.1 and ENDF/B-VIII.0
- Use of codes validations suites benchmarks → independent modeling

Provide a rigorous basis for quality and validating nuclear data libraries

ADVANCE, VaNDaL, ICSBEP/DICE

Data available at IRSN

Systems	MORET 5 (IRSN)	COG (LLNL)	MCNP (LANL)	KENO (ORNL)
PU	**215**	**526**	**261**	**93**
HEU	**457**	**761**	**378**	**102**
IEU	18	188	13	13
LEU	449	366	209	159
MIX	164	28	73	61
U233	32	193	158	190

- Comparison envisioned over 3 years
  - 2019 : HEU and Pu systems
- PU systems : 748 cases available (95 evaluations) in ICSBEP Handbook (2018)
  - Only **33** commons cases for PU in KENO, MCNP, COG and MORET validation suites
- HEU: 1426 cases available (225 evaluations) in ICSBEP Handbook (2018)
  - Only **35** commons cases for HEU

Main issues for the intercomparison

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 materials data *(sometimes revisions are issued to add new calculations in section 4)*
- Benchmark k_{eff} and uncertainty could sometimes help to solve this issue

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

JEZEBEL experiment (PMF001-001)

4 releases since 1995 – Last one in September 2016 by J. Favorite LANL

Revisions 0 to 2

A solely simplified model based on 2 configurations

Bare sphere of Delta phase Plutonium alloy
17.02 kg with density of 15.61 g/cm3
R= 6.3849 cm

Simplified Benchmark
keff = 1.0000+/- 0.002

Revision 3 (2013)

4 detailed configurations and a simplified model

Bare sphere of Delta phase Plutonium alloy
17.073 kg with density of 15.61 g/cm3
R= 6.39157 cm

Simplified Benchmark
keff = 1.0000+/- 0.00129

Revision 4 (2016)

4 detailed configurations and a simplified model

Mass, densities and dimensions have been reviewed for detailed configurations

Simplified Benchmark
keff = 1.0000+/- 0.0011

MCNP; KENO

COG; MORET

Main issues

Simplified or detailed model ?

- Not always indicated in MCNP and SCALE Excel files
- Benchmark k_{eff} and uncertainty could sometimes help to solve this issue
- Could explain small significant discrepancies observed between codes

Cross references in ICSBEP

- Example: HEU-MET-FAST-007
  - Cases 11, 12, 14 and 31 are referenced as HEU-MET-INTER-007
  - Cases 13, 15, 16, 17, 18, and 36 to 43 as HEU-MET-MIXED-009

Some cases referenced differently in validation suites

Main issues

Benchmark and DICE numbering

- PU-SOL-THERM-07: Numbering in DICE (1 to 8) doesn't correspond to numbering in the benchmark (2, 3, 5 to 10, cases 1, 4 and 11 being unacceptable)
- KENO uses DICE numbering, whereas MCNP, COG and MORET use benchmarks one

	MORET	COG	MCNP	KENO
Case 3	1.00382 +/- 0.00010	1.00406 +/- 0.00018	1.00361 +/- 0.00013	1.00901 +/- 0.00010

Corresponds to case 5

1.00376 +/- 0.00010
(PST007-002 in KENO validation suite)

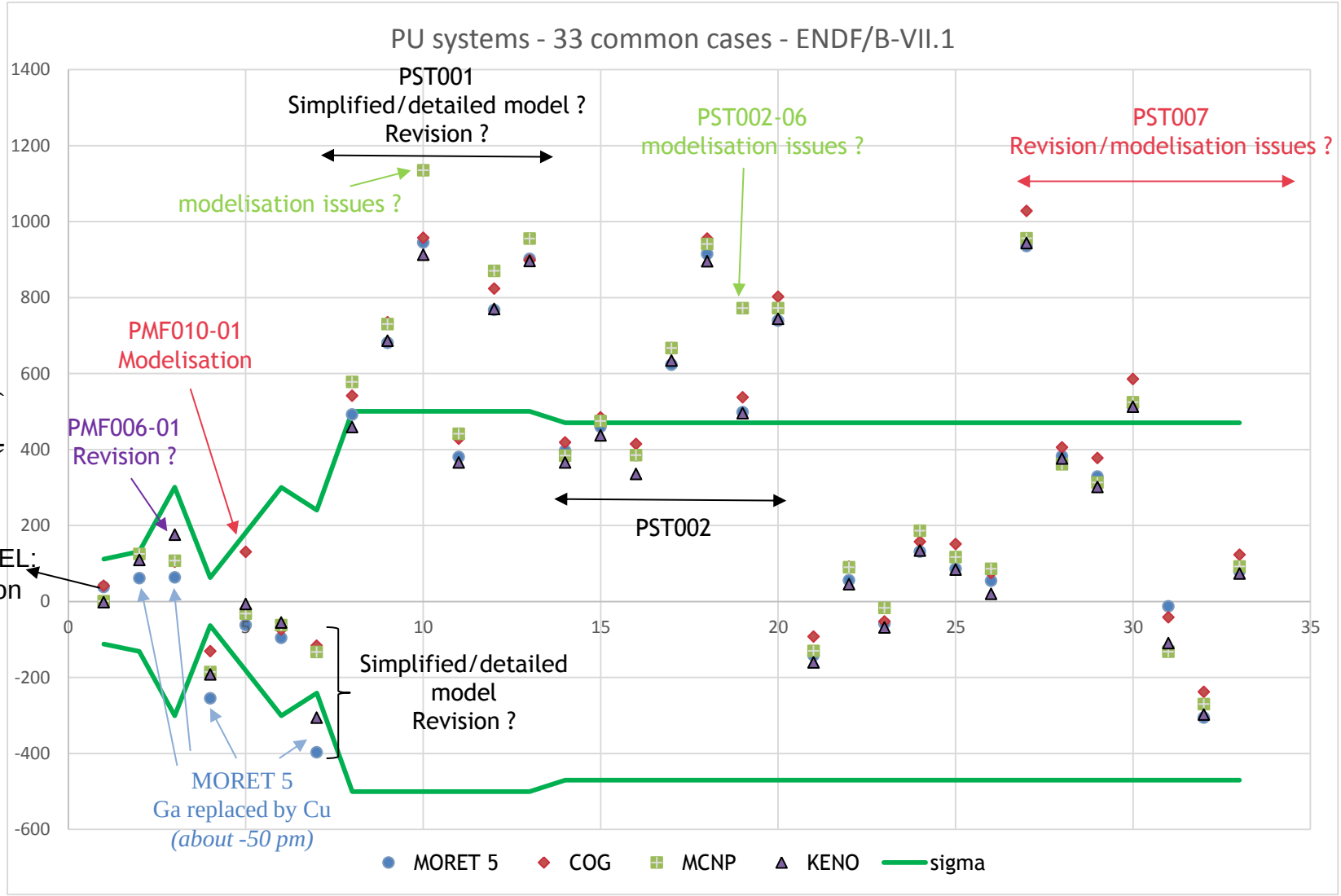
ICSBEP/DICE issues

- HCM-003 – sigma = **0 !**
- HMF004-01 - sigma = **0 !**

Modeling issues and misunderstandings of benchmarks

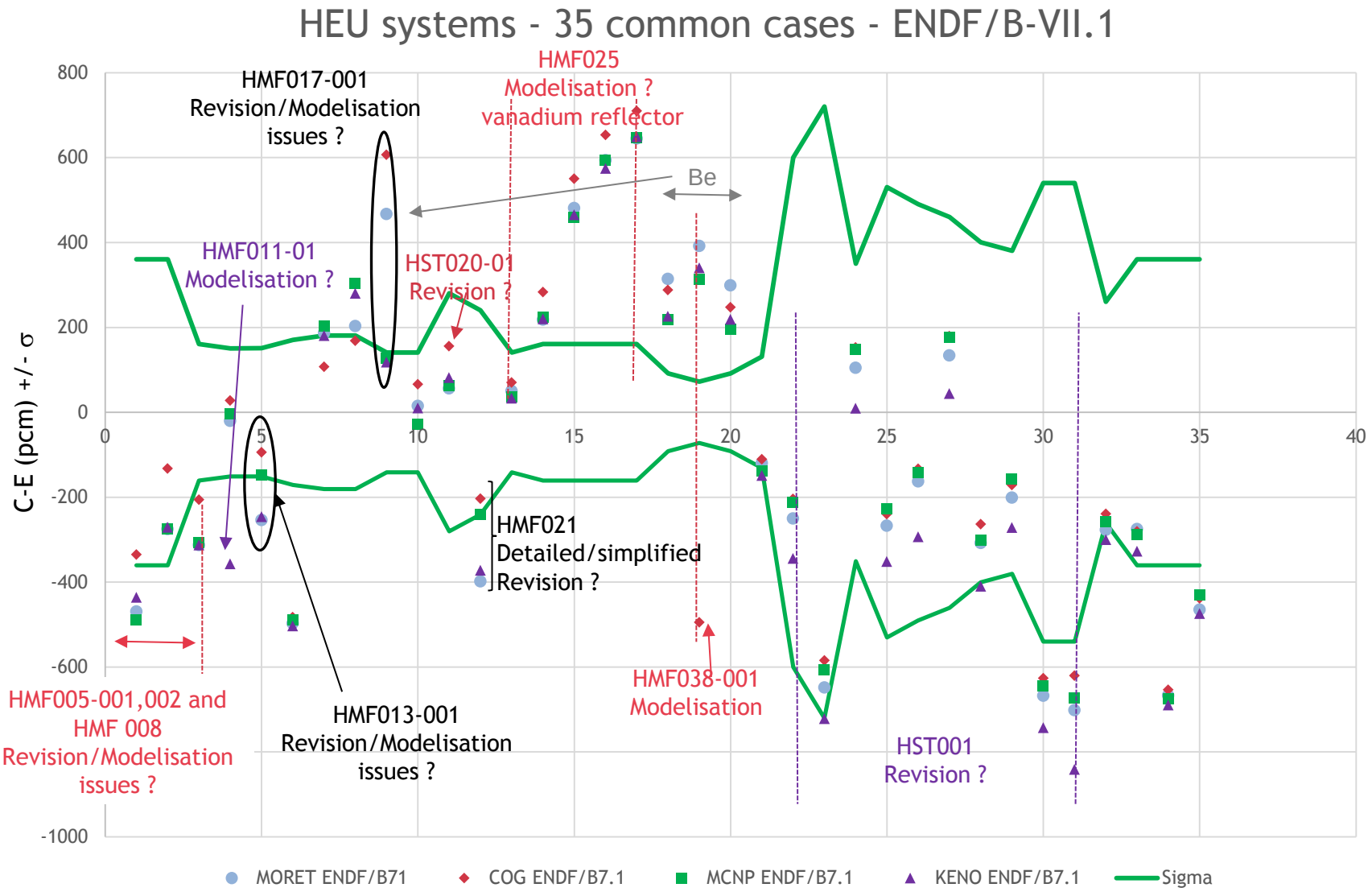
Preliminary analyses

- MC Standard deviations
  - Below 0.00020



Preliminary analyses

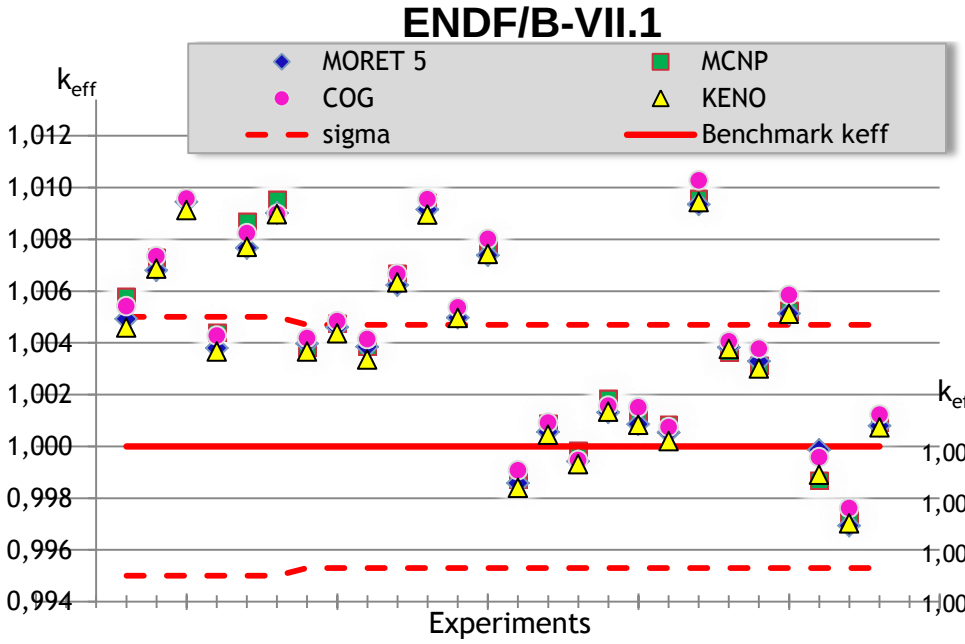
- MC Standard deviations
  - Below 0.00020

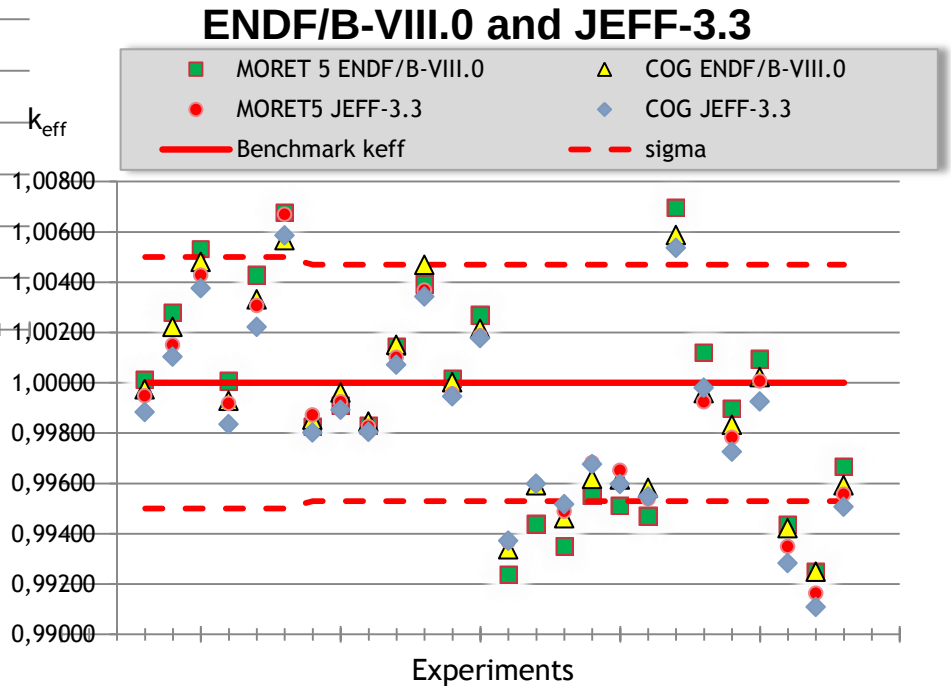


Feedback on nuclear Data

- MC Standard deviations
  - Below 0.00020

Plutonium solutions





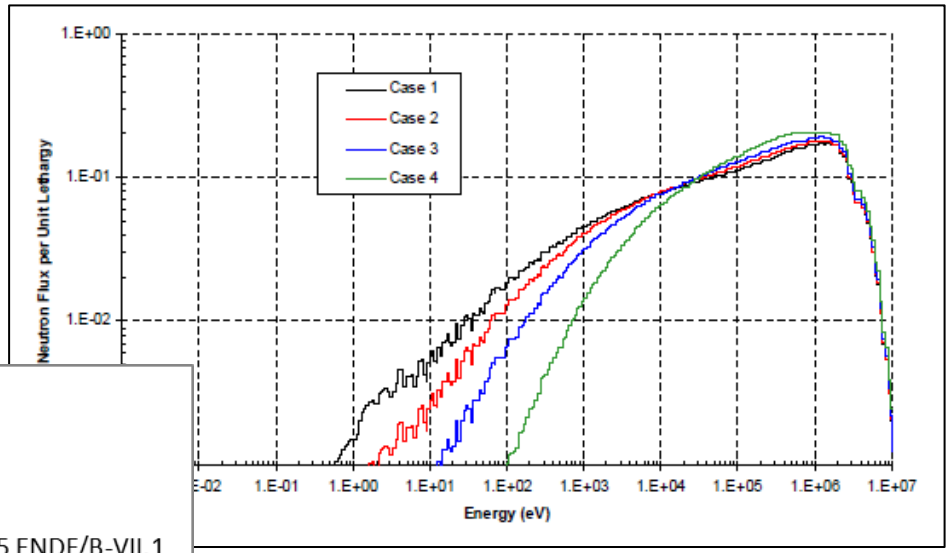
- Pu improvement in thermal spectrum with ENDF/B-VIII.0 and JEFF-3.3

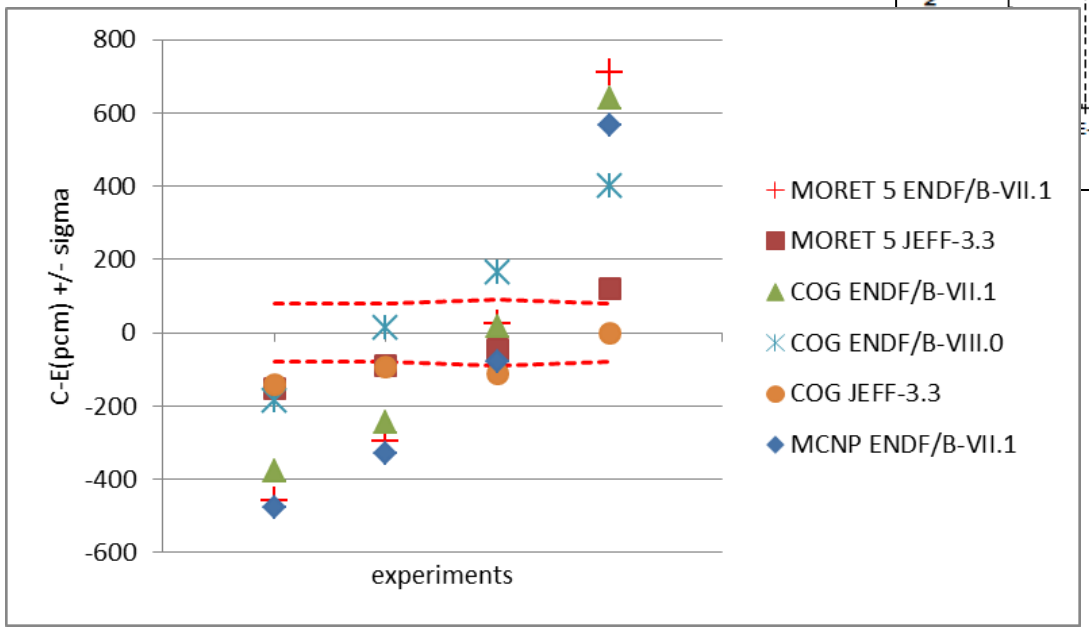
Feedback on nuclear Data

- MC Standard deviations
  - Below 0.00020

Zeus experiments

- HEU in intermediate spectra
- Copper reflected



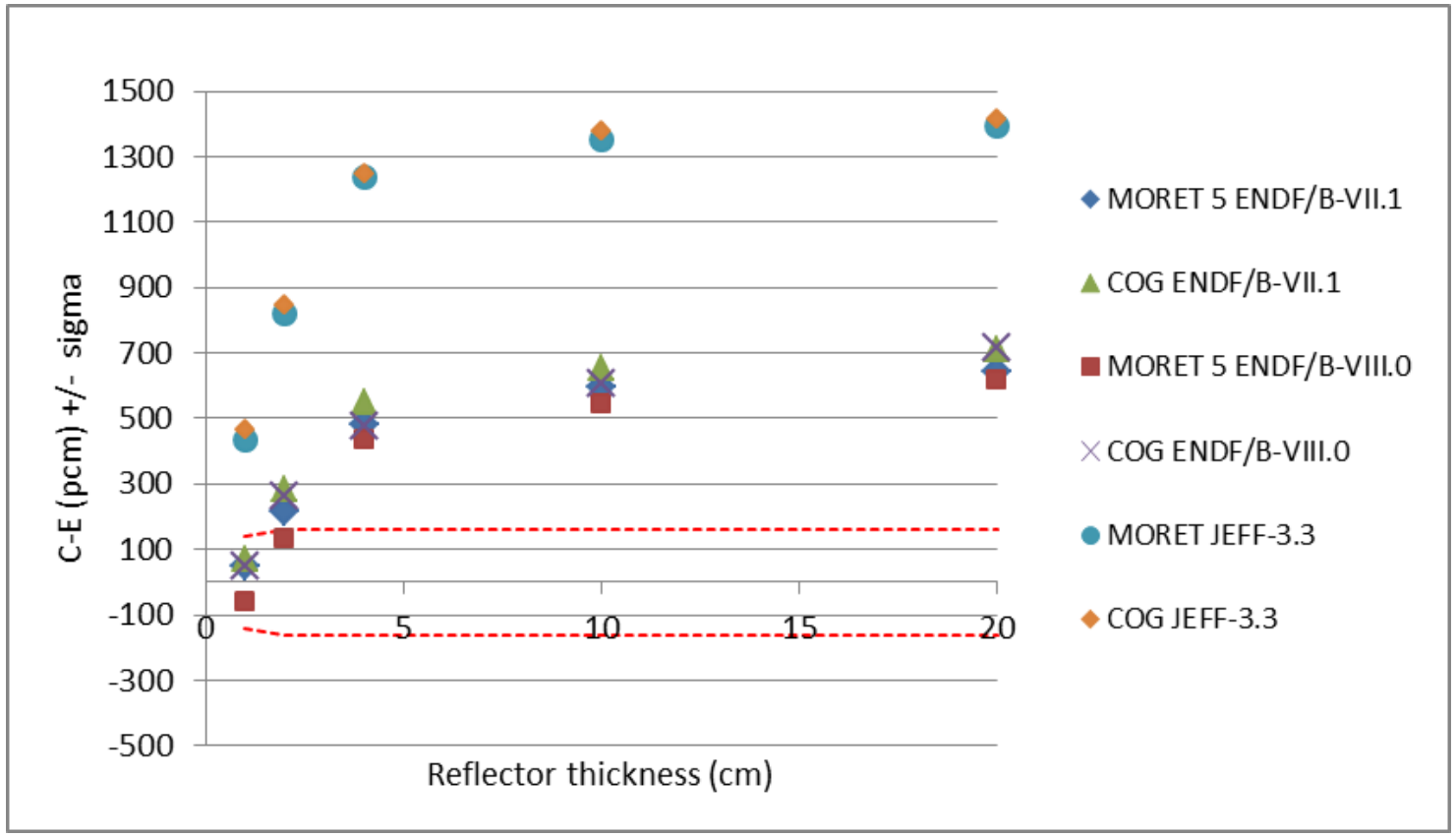


- Strong improvement with JEFF-3.3
- Tendancy with spectrum with ENDF/B-VIII.0

Feedback on nuclear Data

- MC Standard deviations
  - Below 0.00020

Vanadium reflected fast experiments

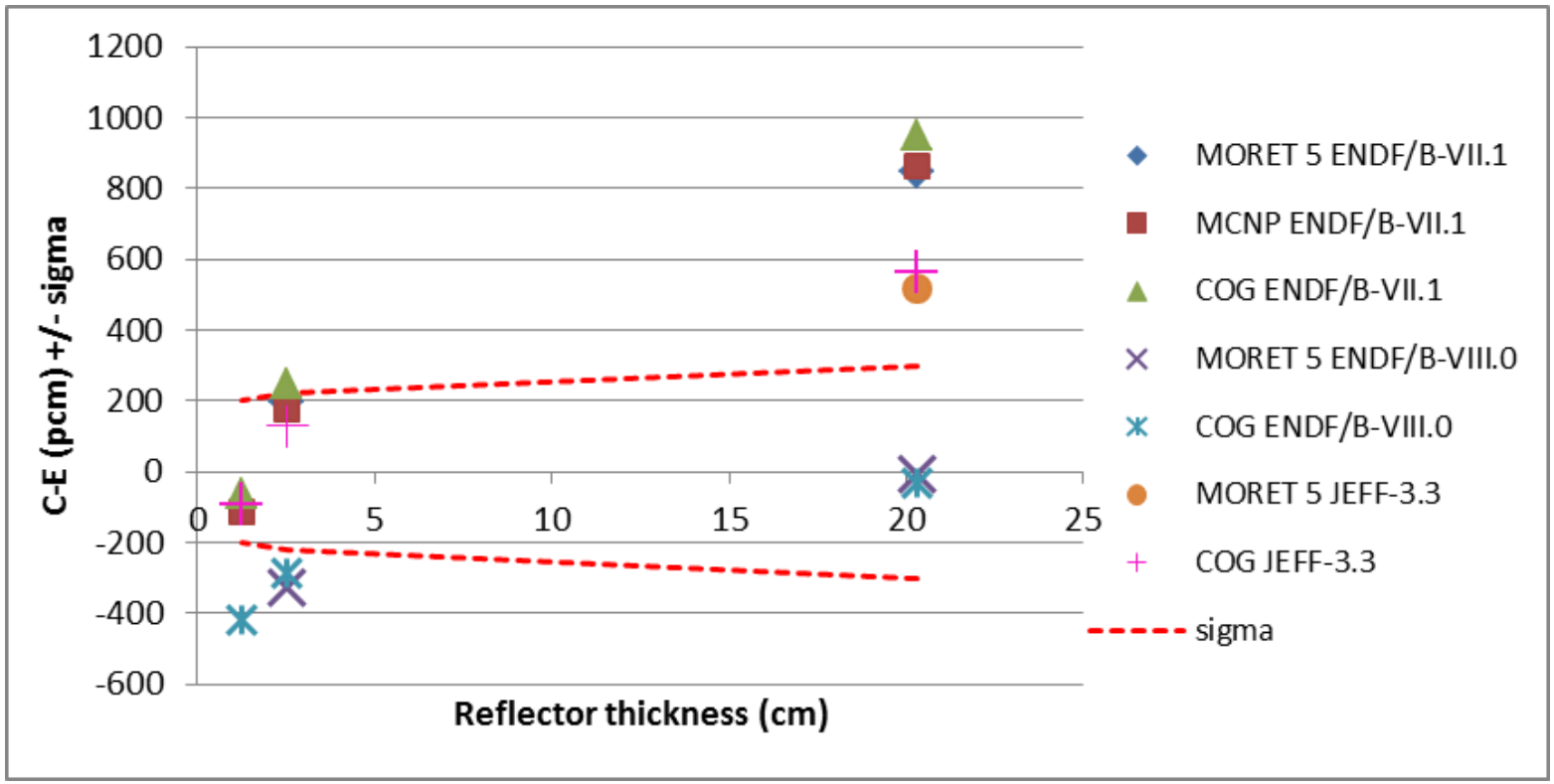


- Worse results with JEFF-3.3
- Small discrepancies between MORET and COG with ENDF/B-VIII.0

Feedback on nuclear Data

- MC Standard deviations
  - Below 0.00020

Nickel reflected fast experiments



- Improvement with ENDF/B-VIII.0 and JEFF-3.3 (2 sigma)
- Improvement still needed, the increasing trend highlighted with the reflector thickness being still observed

Conclusion

- Improvement of the codes validation suites
  - Use for sensitivity/uncertainty studies
- Feedback to ICSBEP
  - Experimental data quality
  - Misunderstanding in benchmark model
  - Suspicious data or experimental uncertainties
- Feedback to Nuclear Data
  - JEFF and ENDF
  - Processing tools
  - New evaluations need
- Need of additional uncorrelated experiments ?

Conclusion

- Common publication planned

- Other systems to be analyzed in FY2020 to FY2022
  - **2020** – IEU, LEU
  - **2021** – MIX, U233, SPEC
  - **2022** – Final report