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ICSBEP Benchmark Data Testing to Support ENDF/B-VIII.0

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Abstract

We review and compare criticality data testing results performed at Los Alamos with ENDF/B-VII.1, CIELO/ENDF/B-VIII.0β2 and later nuclear data evaluations.

Acknowledgement

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Outline

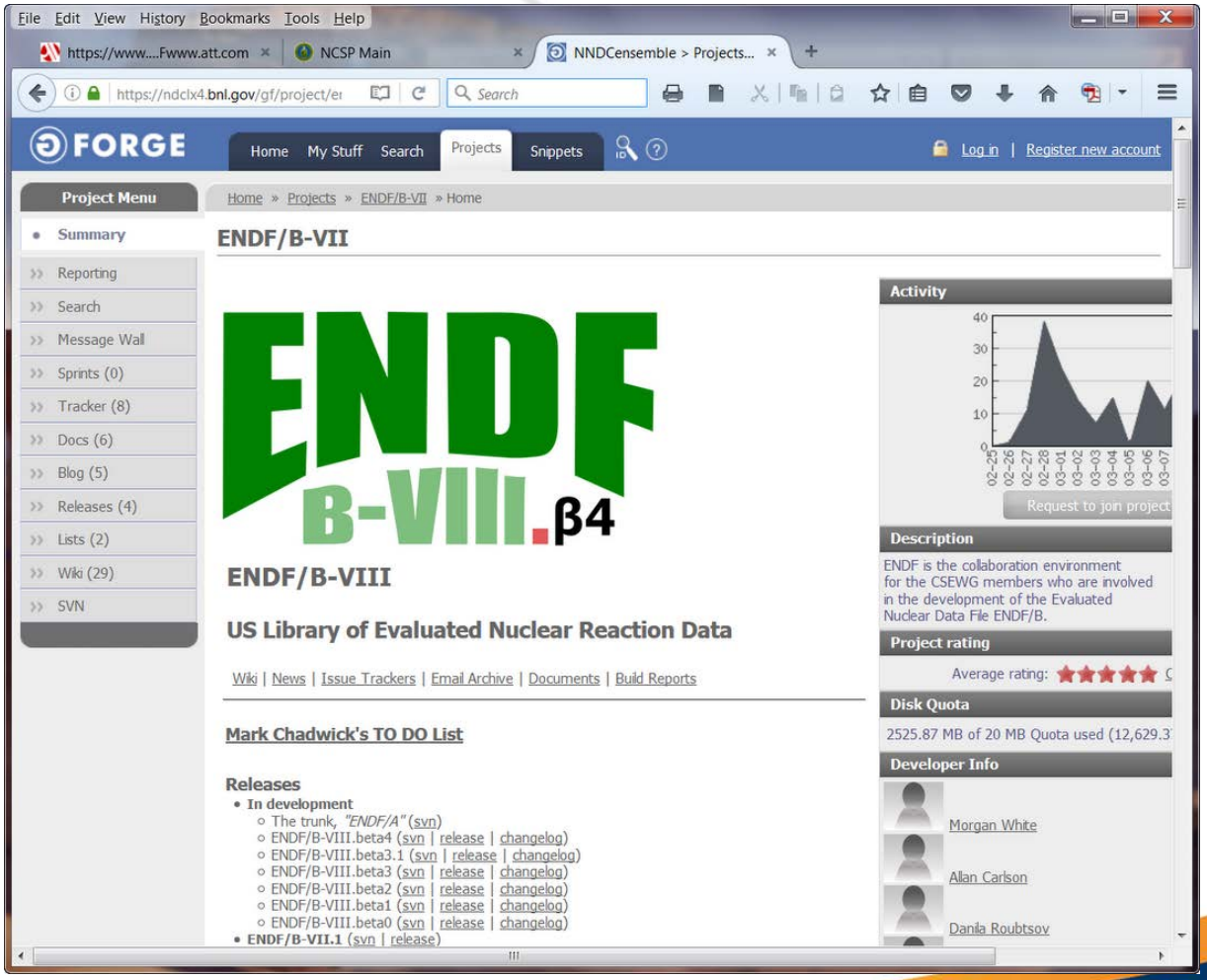
- CIELO and ENDF/B-VIII.0β2(*4*) Overview

- Data Testing
  - Criticality calculations with ICSBEP HMF, HMI, HST, IMF, LCT, PMF, PMI, PST, USI, UCT and UST benchmarks.

- Summary

ENDF/B-VIII.0β4

- ENDF/B-VIII.0β4 files are available from the BNL NNDC: (https://ndclx4.bnl.gov/gf/project/endf/).

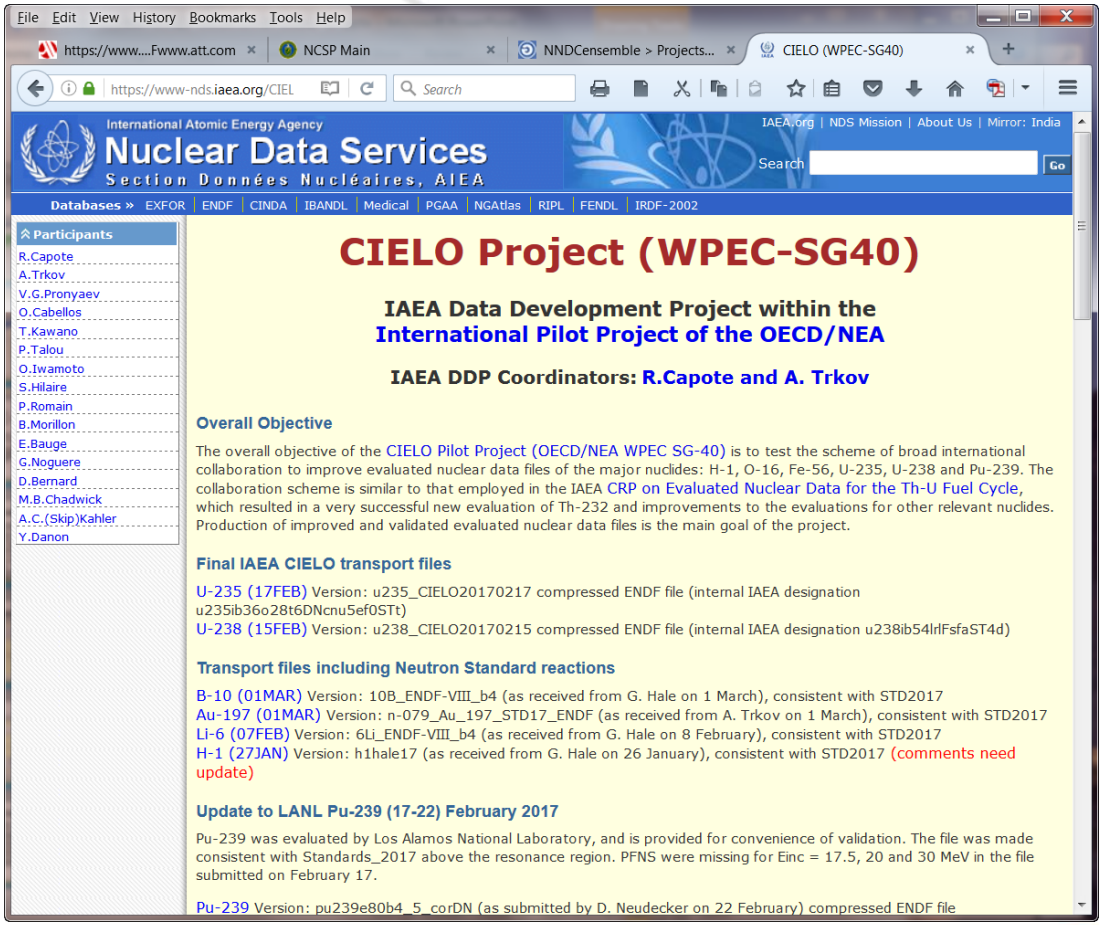


CIELO Overview

- CIELO = **C**oordinated **I**nternational **E**valuated **L**ibrary **O**rganization (WPEC Subgroup 40).
- Goal: To develop updated, best available evaluated nuclear data files for a select group of nuclides … ^{1}H, ^{16}O, ^{56}Fe, ^{235,238}U and ^{239}Pu.
  - *"… The goal is to provide evaluations that perform in integral simulations (k_{eff}, spectral indices, etc.) as well as, or better, compared to existing evaluations, whilst using more accurate fundamental cross sections and spectra data. CIELO data will not be adjusted in the formal sense, but we recognize that some aspects of CIELO will include evaluation choices based upon feedback from simulations of integral experiments. …"*
- Why: The major international evaluated nuclear data libraries don't agree on the internal cross section details of these most important nuclides!

CIELO

- The IAEA Nuclear Data Section has created a CIELO web page … https://www-nds.iaea.org/CIELO/ … with links to candidate evaluated data files.
- ***The US Nuclear Data Program has greatly benefitted from contributions by the IAEA's Nuclear Data Section.***



NJOY Processing …

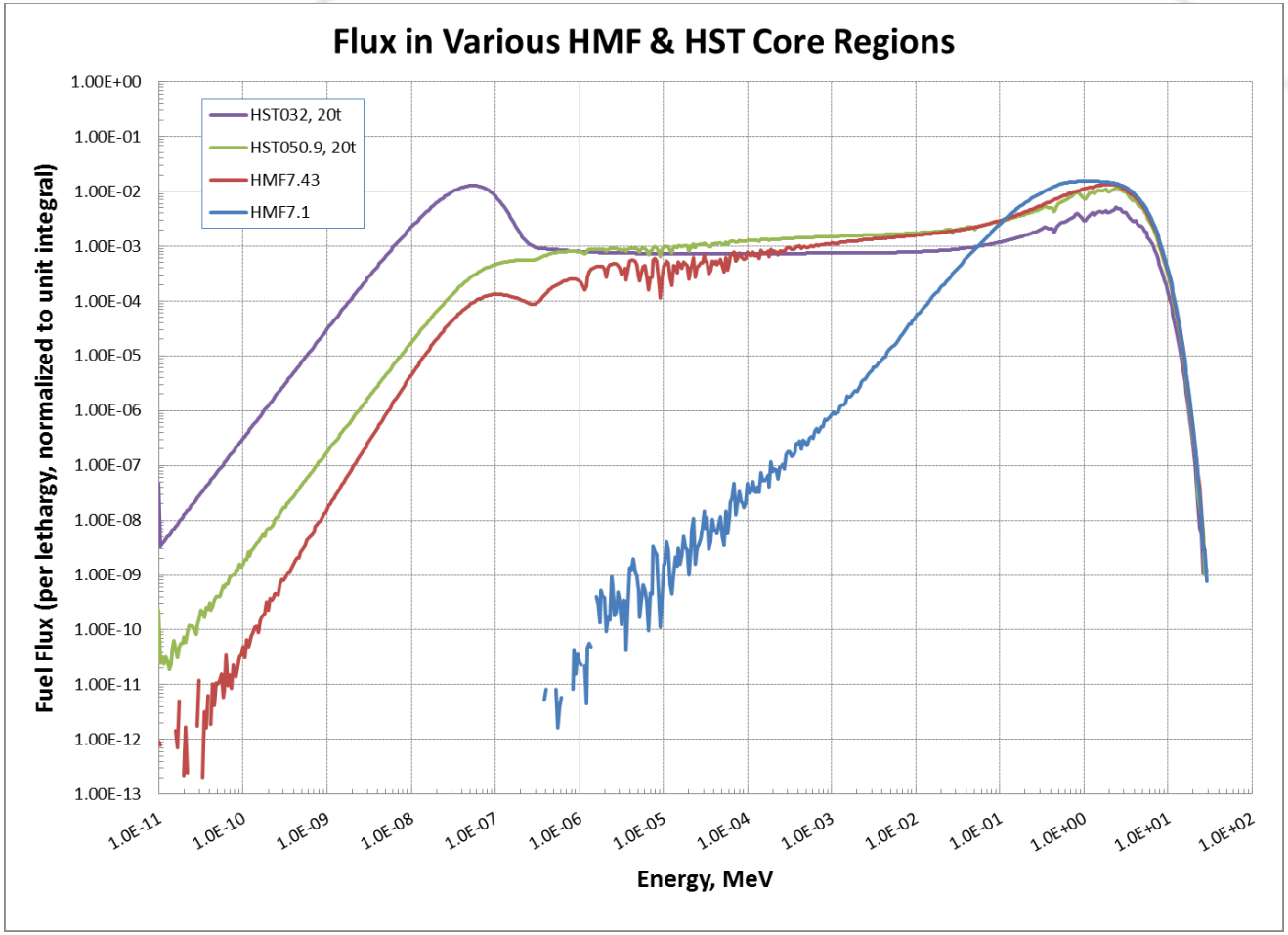
- NJOY2012.50 + local updates were used to process ENDF/B-VIII.0 beta files up through β3.1.

- NJOY2016 was released in early January, 2017
  - NJOY2016 is “open source”.
  - NJOY2012.82, consistent with NJOY2016.3 was released at the same time.
    - NJOY2012 will be maintained for several months.
  - These latest NJOY versions eliminated a subtle but important mis-conception with respect to the Doppler broadening energy range.
  - LANL used NJOY2016 to process the recently released ENDF/B-VIII.0β4 neutron and some tsl data files.

ICSBEP Benchmark Data Testing

- ICSBEP Nomenclature …
  - XXX-YYY-ZZZ-###, where XXX=fuel material; YYY=fuel form; ZZZ=spectrum; ###=sequence number.
- Data testing categories …
  - FAST Los Alamos systems: HMF1 (Godiva), HMF28 (Flattop-25), IMF1 (Jemima), IMF7 (Big-10), PMF1 (Jezebel), PMF6 (Flattop-Pu).
  - HMF7: A suite of ORNL assemblies with HEU plates and polyethylene.
  - HST: HEU solution systems with varying leakage.
  - PST: Pu solution systems with varying leakage.
  - LCT: UO_2 lattice configurations.
  - HMF, HMI, PMF, PMI & LCT systems with iron/steel.
  - PMF systems with various reflectors.
  - USI, UCT & UST systems (water, polyethylene, be reflected).

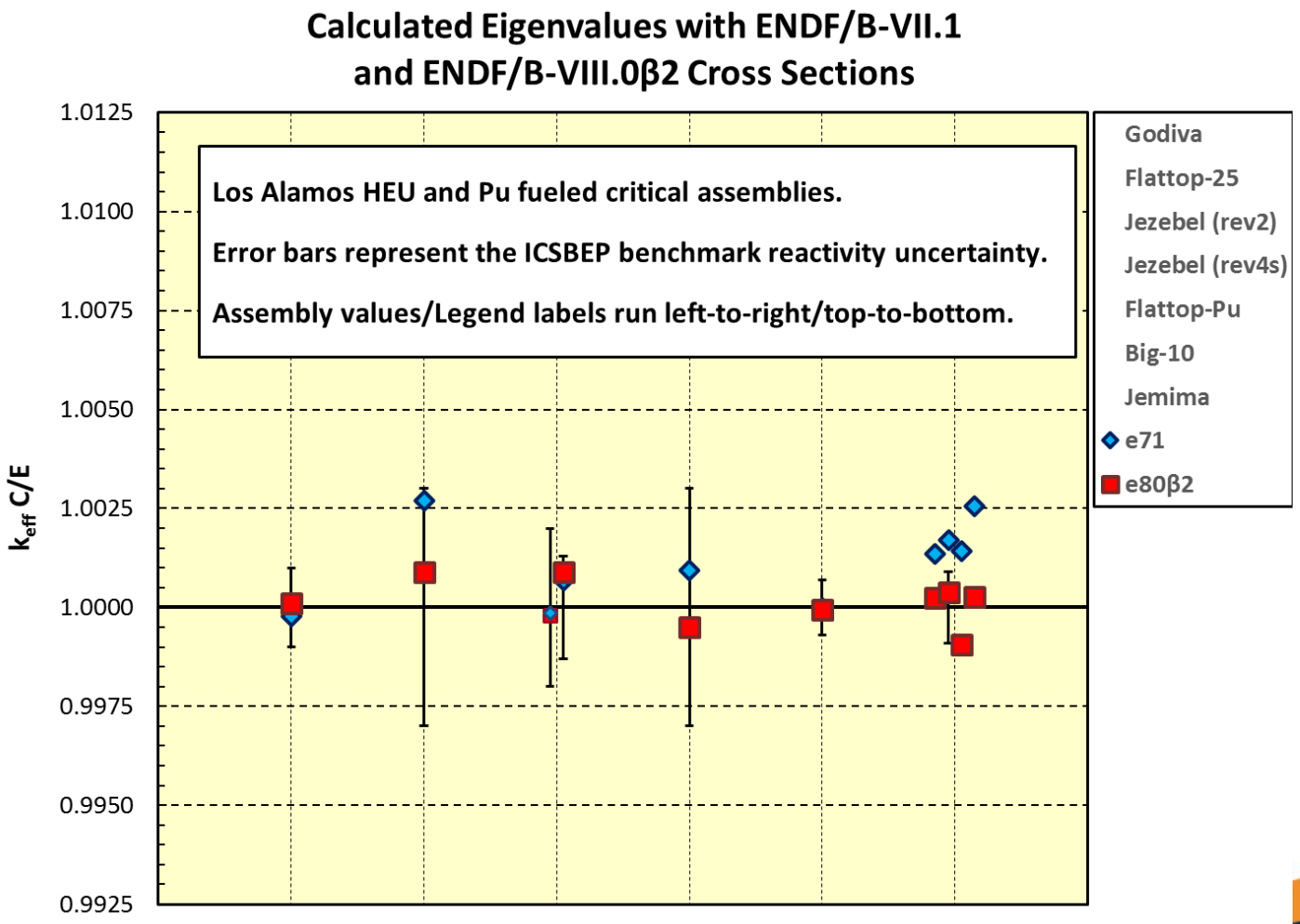
LANL Data Testing



Proper benchmark selection allows for data testing over energy intervals of many decades.

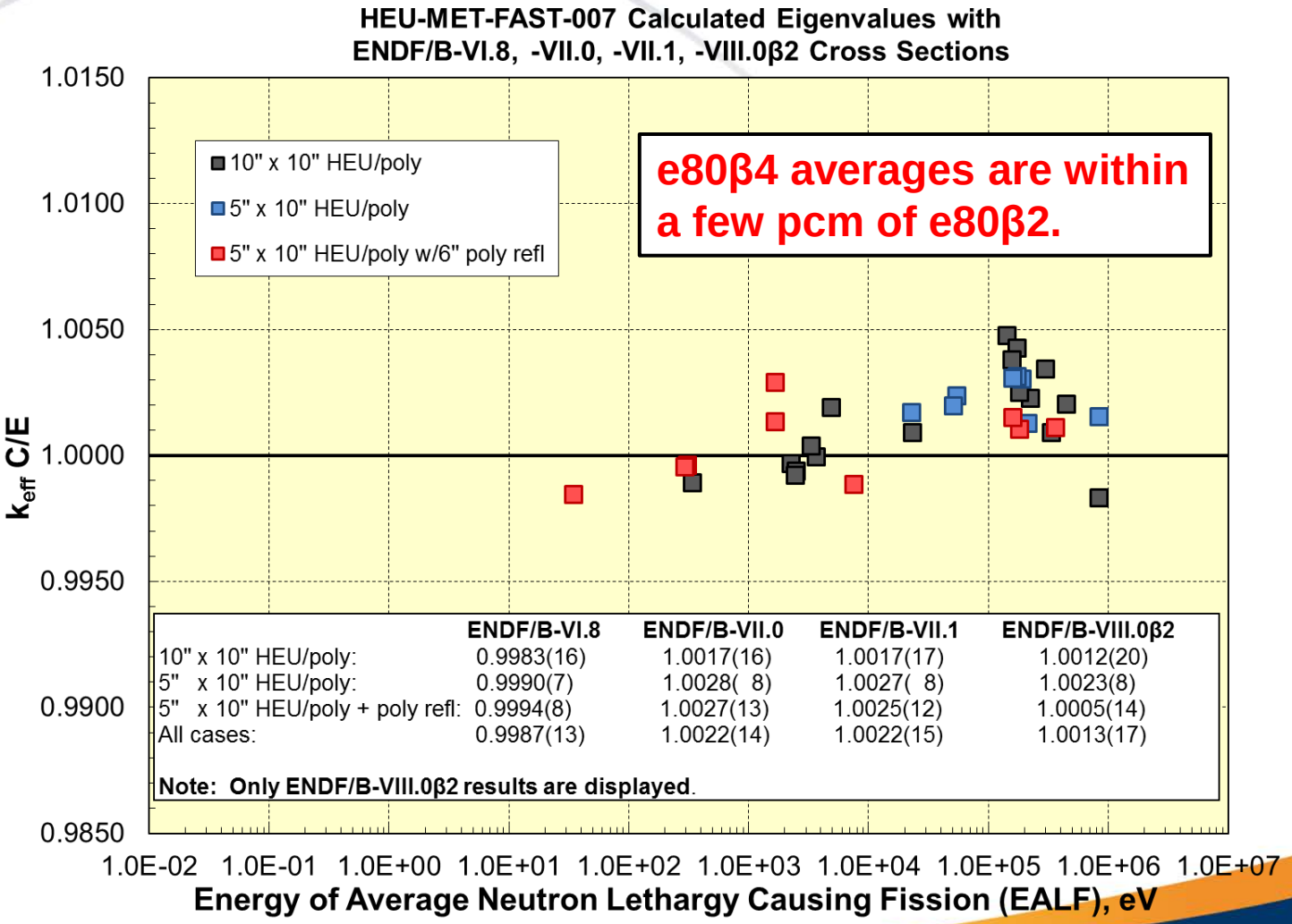
"FAST" Los Alamos Assemblies

- HMF1 (Godiva)
  - **E80β4=1.00009(8)**
- HMF28 (Flattop-25)
  - **E80β4=1.00082(9)**
- PMF1 (Jezebel)
  - **E80β4=1.00073(8)**
- PMF6 (Flattop-Pu)
  - **E80β4=1.00008(10)**
- IMF7 (Big-10)
  - **E80β4 C/E = 0.99992(7)**
- IMF1 (Jemima)
  - **E80β4=0.9991 to 1.0003.**



HMF7

- A suite of HEU metal plates and polyethylene assemblies
  - Varying degrees of moderation test our nuclear data over an energy range from tens of eV to an MeV.

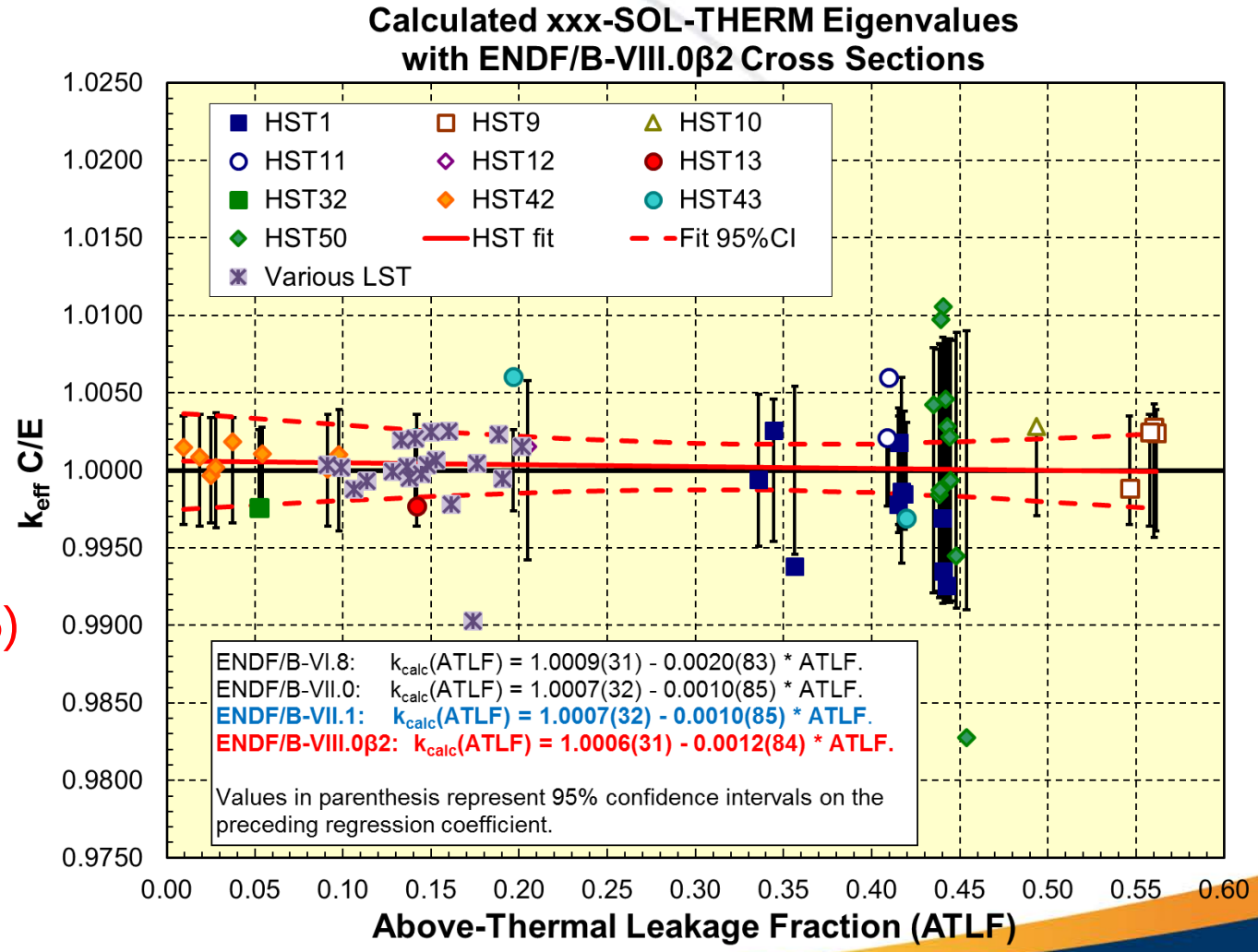


HST Benchmarks - ^{235}U (& ^{1}H, ^{16}O)

- A suite of 42 HEU-SOL-THERM benchmark critical configurations has been used for many years.
  - Accurate calculated eigenvalues, correlated against Above-Thermal Leakage Fraction (ATLF), have been obtained since ENDF/B-VI.3 in the early 1990s.
    - No trends observed for other regression analyses such as k_{calc} versus Above-Thermal Fission Fraction (ATFF); versus Average Energy of a Neutron causing Fission (EAF); versus Energy of Average Lethargy of a Neutron causing Fission (EALF) or versus solution H/U ratio.
  - Tests of revised data sets must answer the question … “are we still ok or did we break something?”.

HST Benchmarks - ^{235}U (& ^{1}H, ^{16}O)

- … and the answer is “we are still ok”.
- E80β4 regression coefficients:
  - m = -0.0008(85)
  - b = 0.9999(32)

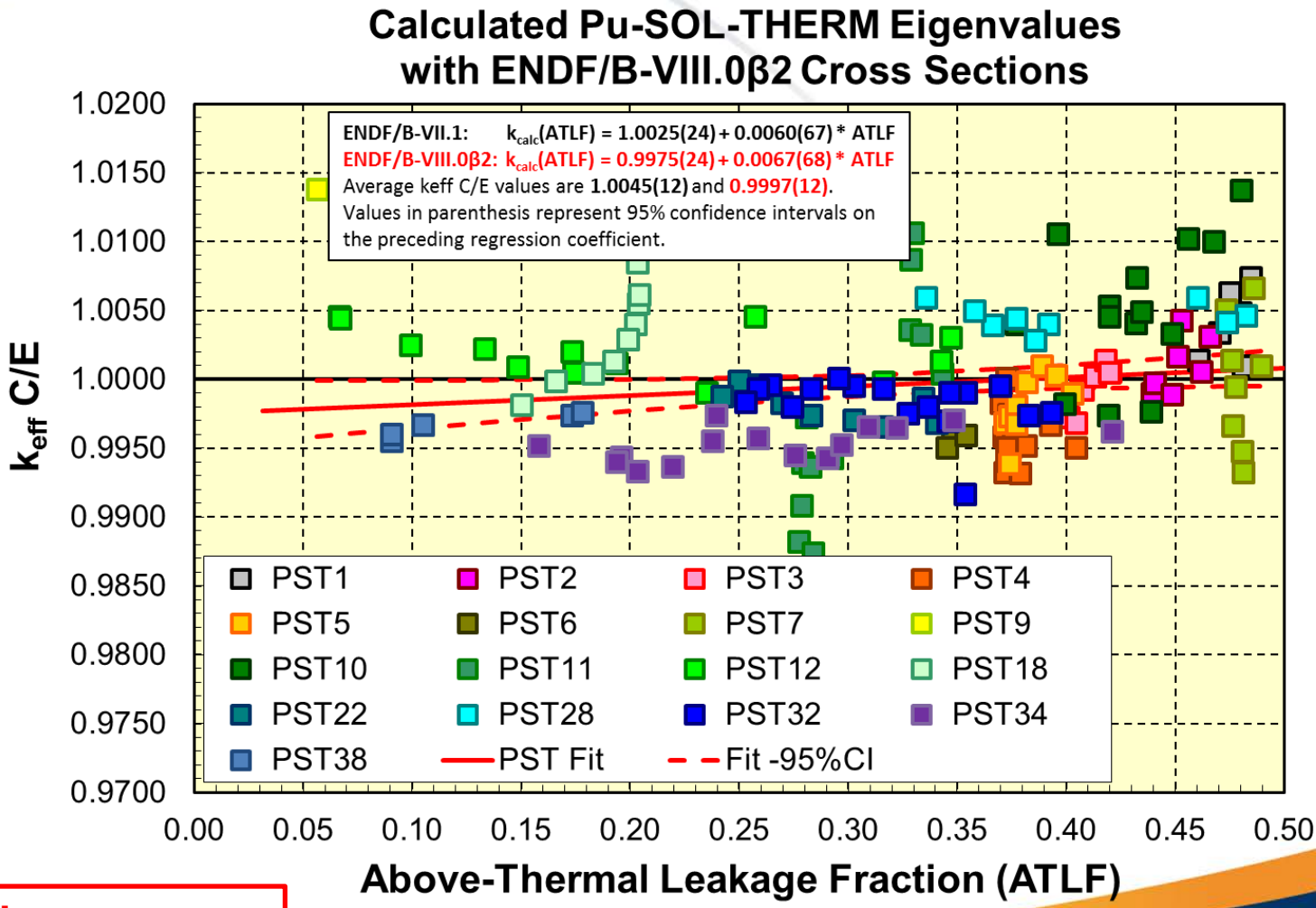


PST Benchmarks - ^{239}Pu (& ^{1}H, ^{16}O)

- A suite of 158 Pu-SOL-THERM benchmark critical configurations have exhibited a long standing k_{calc} bias for many years and for many generations of evaluated data sets.
  - The average k_{eff} C/E bias is about 450 pcm with ENDF/B-VII.1.
    - Work by WPEC Sub-Group 34 lead to revisions to the ^{239}Pu evaluated data file (primarily RR parameters and ν(e)) which eliminated about 75% of this bias.
  - Tests of revised data sets must answer the question … “have we made further improvements in PST benchmark performance, have we taken a step backward, or is there more work to do?”.

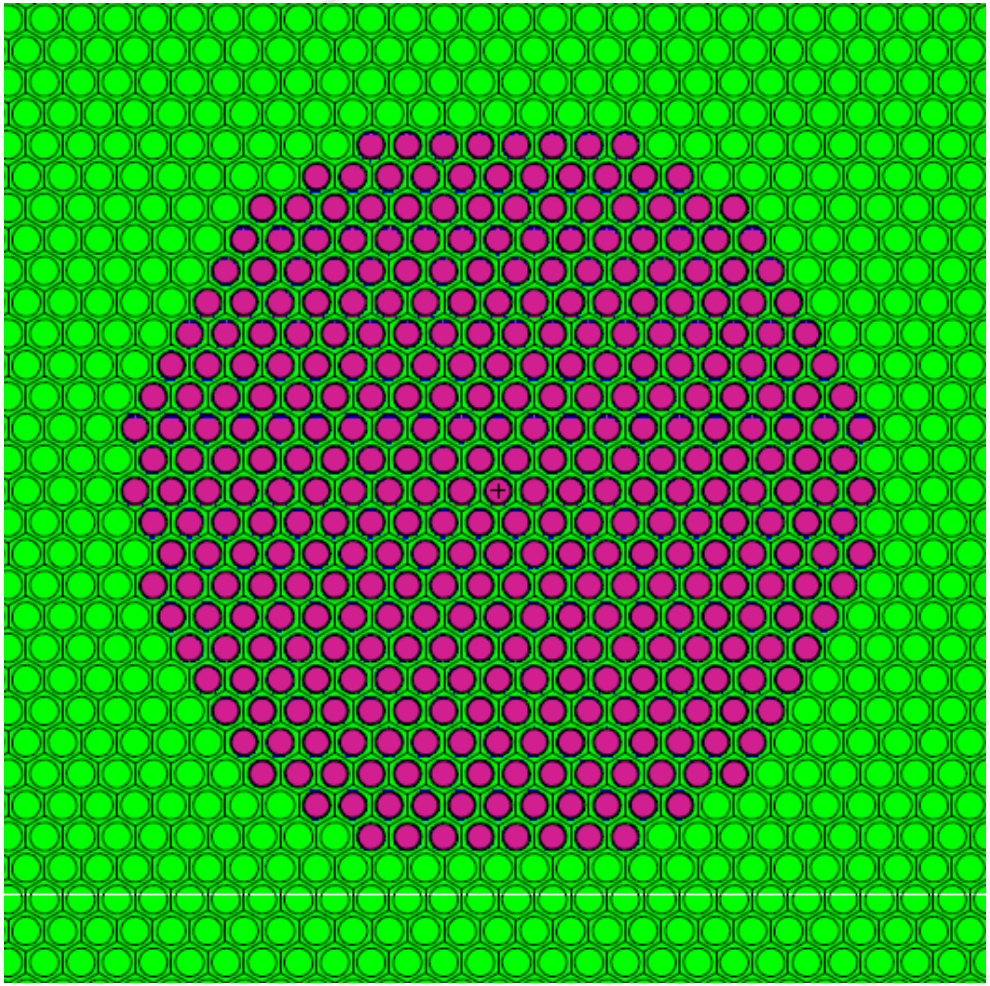
PST Benchmarks - ^{239}Pu (& ^{1}H, ^{16}O)

- … and the answer is "there has been significant further improvement in benchmark performance" … but there's still more work to do.



e80b4 slope, intercept are 0.0035(70) and 0.9987(24).

LCT Benchmarks – ^{235}U (& ^{1}H, ^{16}O, ^{238}U)



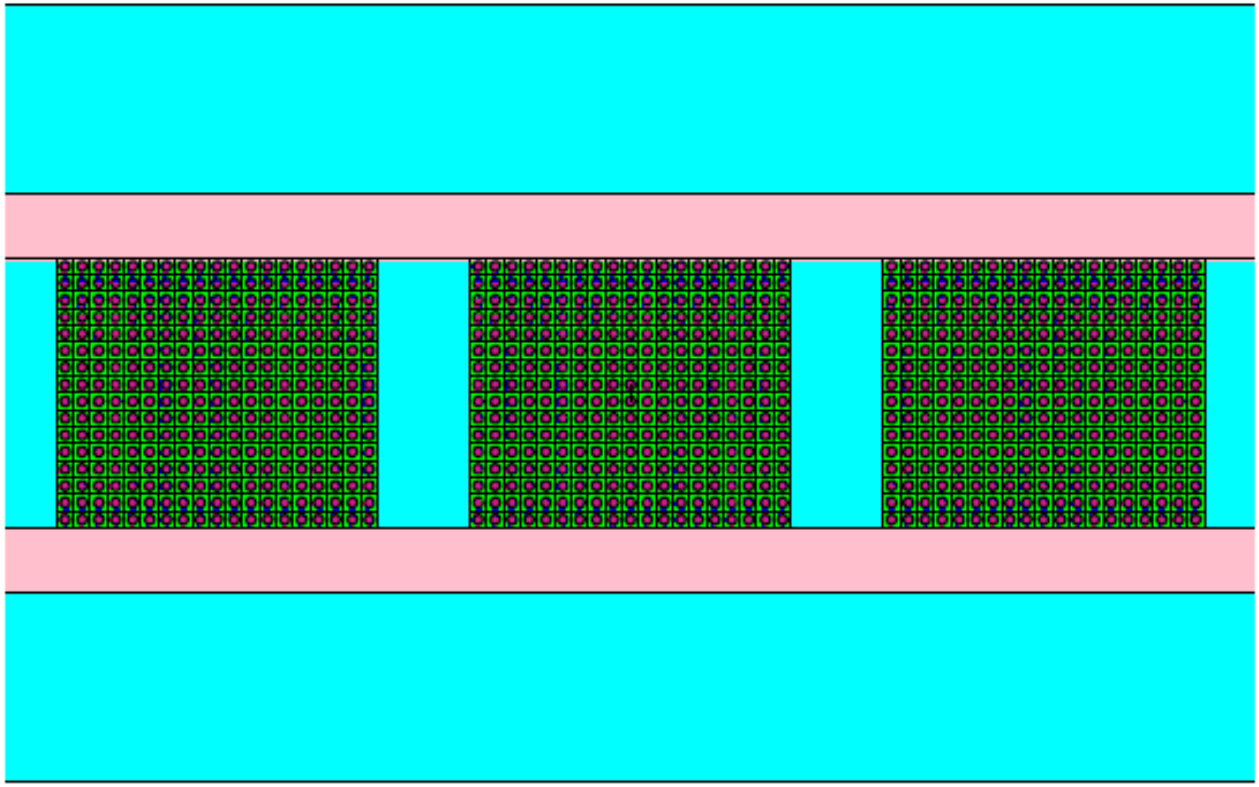
Some typical LEU-COMP-THERM lattice geometries …

LEU-COMP-THERM-005, case 5 is shown
- 378 rods, 1.801 cm pitch.

Other LCT5 cases include:
- case 1: 132 rods, 2.398 cm pitch;
- case 12: 1185 rods, 1.598 cm pitch.

These three configurations do not contain soluble Gd poison, but other LCT5 cases do.

LCT Benchmarks – ^{235}U (& ^{1}H, ^{16}O, ^{238}U)



LEU-COMP-THERM-017 geometry (three 19x16 clusters on a 2.032 cm rod pitch).

- LEU-COMP-THERM-001 uses the same fuel without walls.

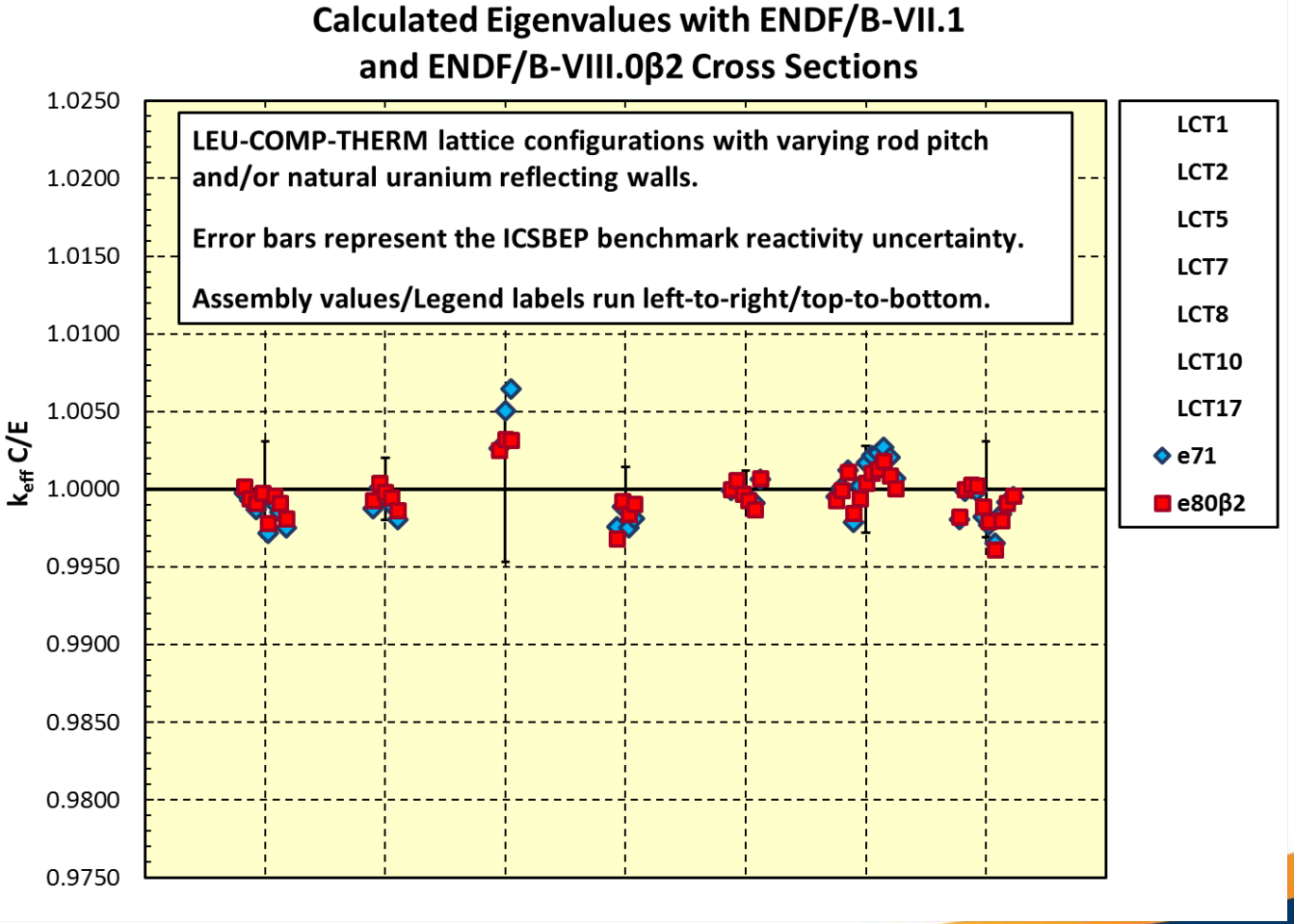
LEU-COMP-THERM-010 employs smaller clusters (mostly 13x8 on a 2.54 cm rod pitch).

- LEU-COMP-THERM-002 uses the same fuel without walls.

LEU-COMP-THERM-042 employs 20x18 and 25x18 clusters on a 1.684 cm rod pitch with steel reflecting walls and various intracluster absorber plates.

LCT Benchmarks – ^{235}U (& ^{1}H, ^{16}O, ^{238}U)

- Good e71 results for this benchmark category remain good with e80β2.
- **e80β4 results are similar.**

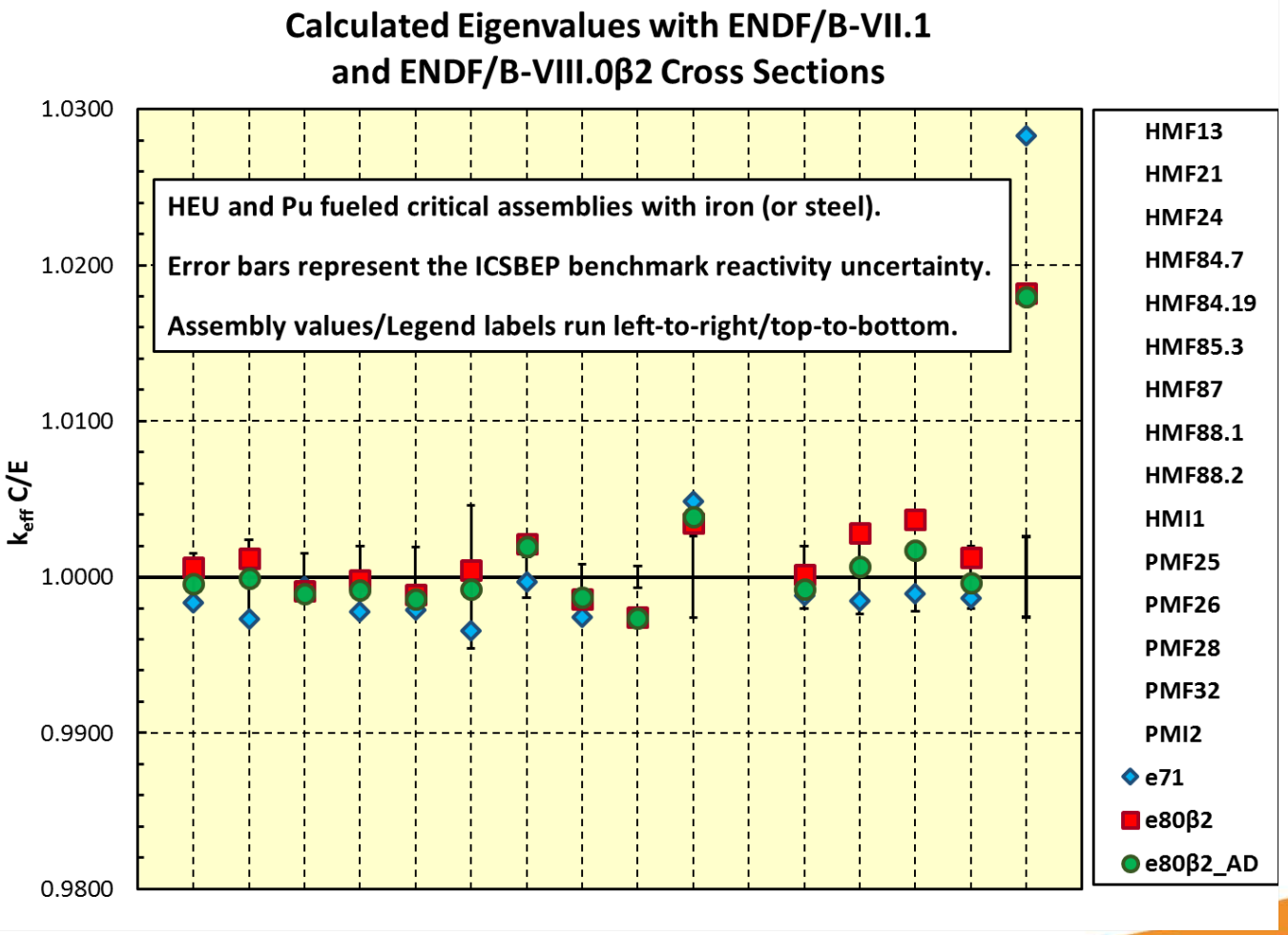


Assemblies with Iron (Steel)

- HMF13 – Spherical HEU assembly with 3.65 cm thick steel.
- HMF21 – Spherical HEU assembly with 9.7 cm thick steel.
- HMF24 – Spherical HEU assembly with 0.8 cm thick steel & 9.65 cm thick polyethylene.
- HMF84.7, 84.19 & 85.3 – Cylindrical HEU with Fe reflectors.
- HMF87 – HEU cylindrical assembly with interstitial steel.
- HMF88 – HEU cylindrical assembly with interstitial steel or steel & polyethylene plus a polyethylene radial/axial reflector.
- HMI1 – Argonne ZPR-9/34.
- LCT10, 17 & 42 – multiple UO_2 rod clusters with steel reflecting walls
- PMF25 – Spherical ^{239}Pu assembly with 1.55 cm thick steel.
- PMF26 – Spherical ^{239}Pu assembly with 11.9 cm thick steel.
- PMF28 – Spherical ^{239}Pu assembly with 19.65 cm thick steel.
- PMF32 – Spherical ^{239}Pu assembly with 4.49 cm thick steel.
- PMI2 – Argonne ZPR-6/10.

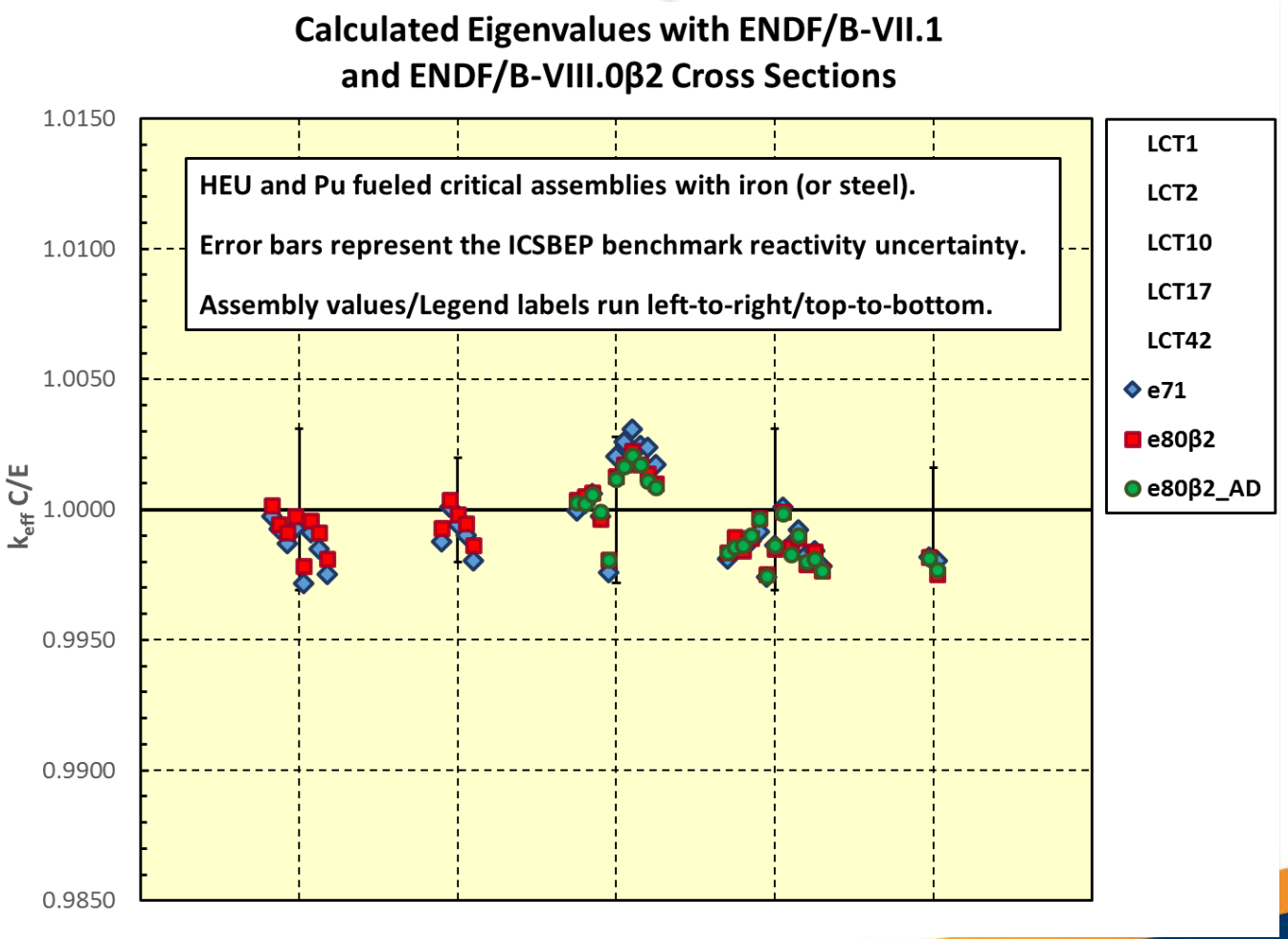
FAST Assemblies with Iron (Steel)

- Most iron bearing FAST critical assembly calculated eigenvalues have improved with e80β2 evaluated nuclear data.



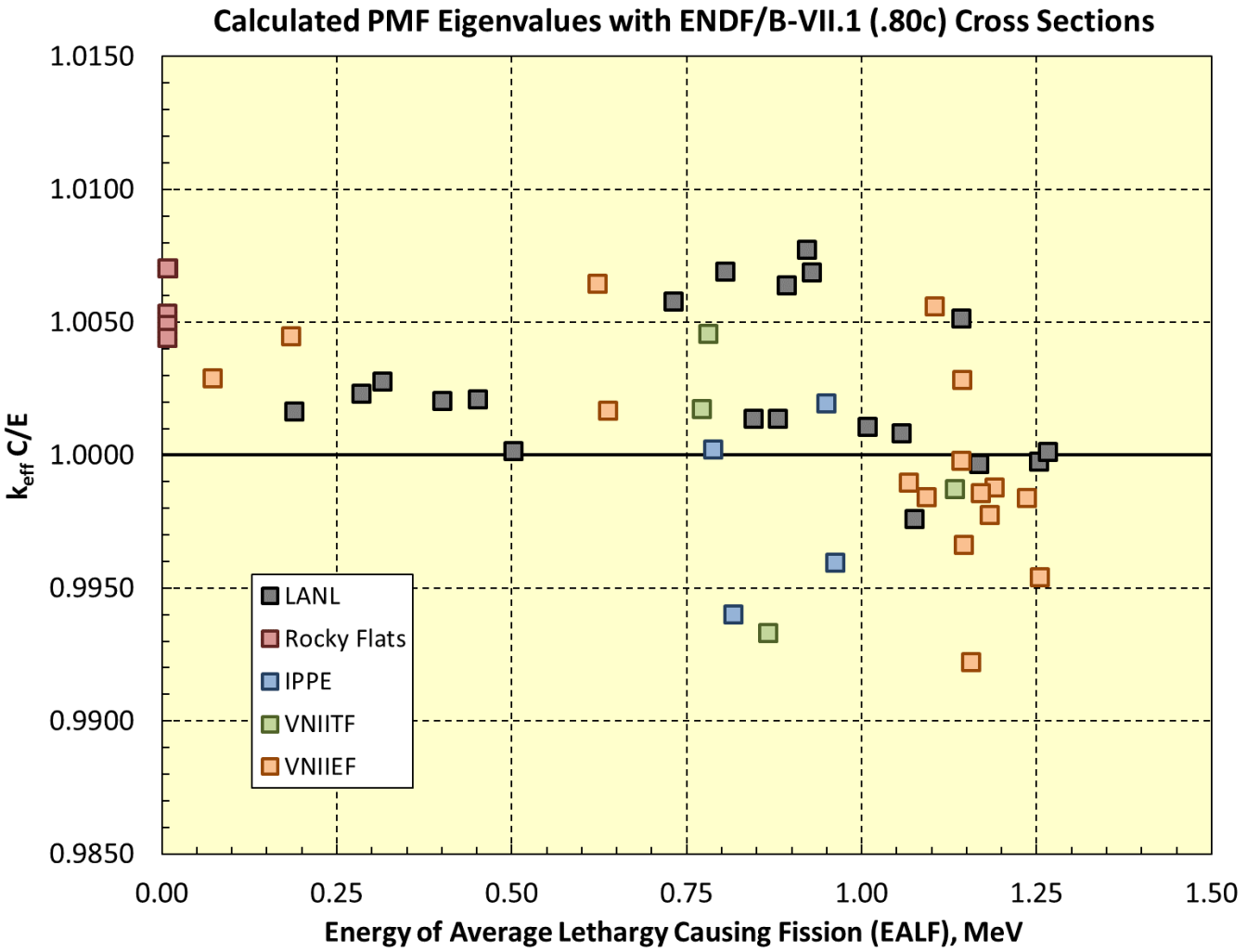
THERMAL Assemblies with Iron (Steel)

- Thermal assembly calculated eigenvalues remain accurate.



PMF Assemblies – ENDF/B-VII.1

- k_{eff} C/E exhibits a clear trend with ENDF/B-VII.1 cross sections



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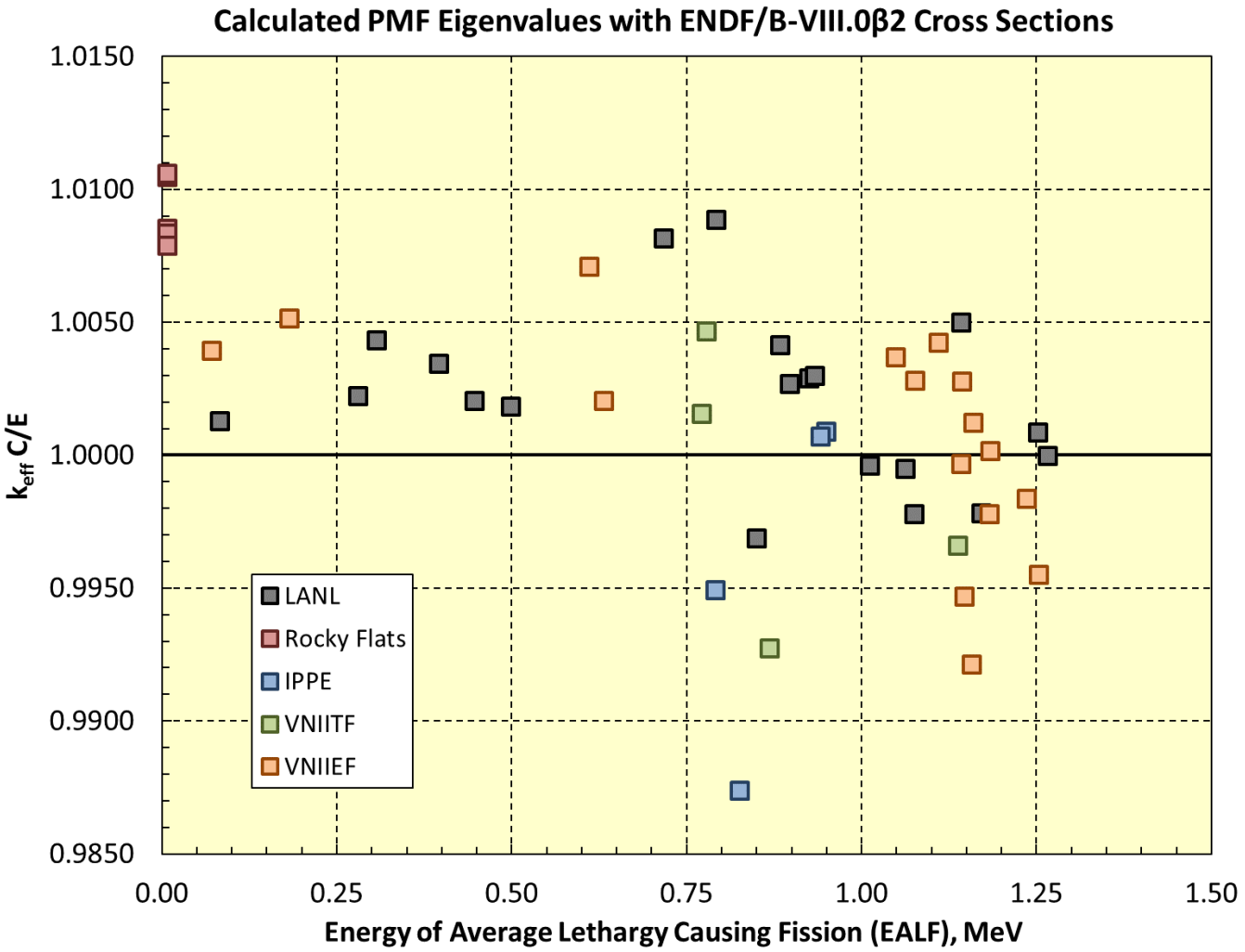
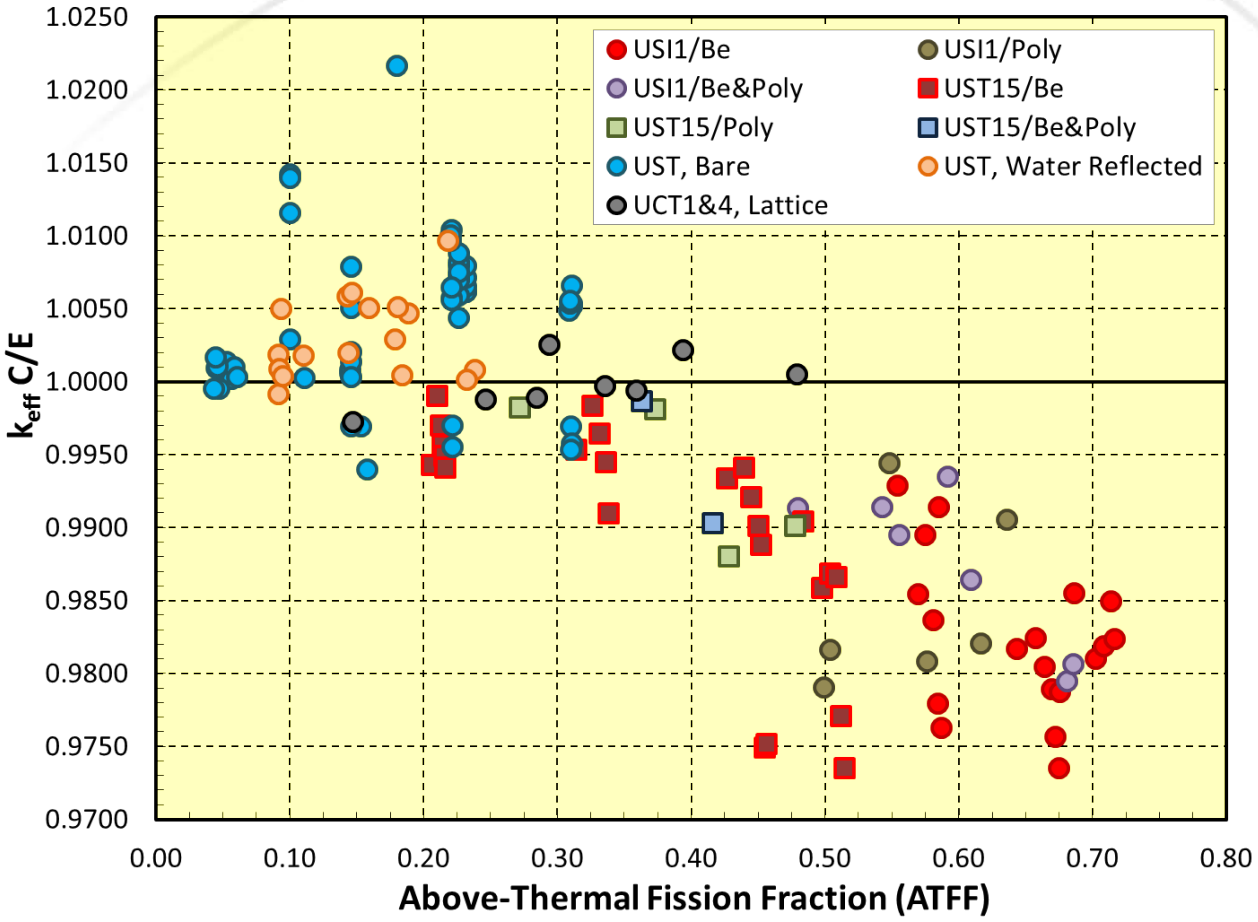
PMF Assemblies – ENDF/B-VIII.0β2

- Lots of changes but there's more work to do here.
- **e80β4 results are similar, and so still more work to be done.**

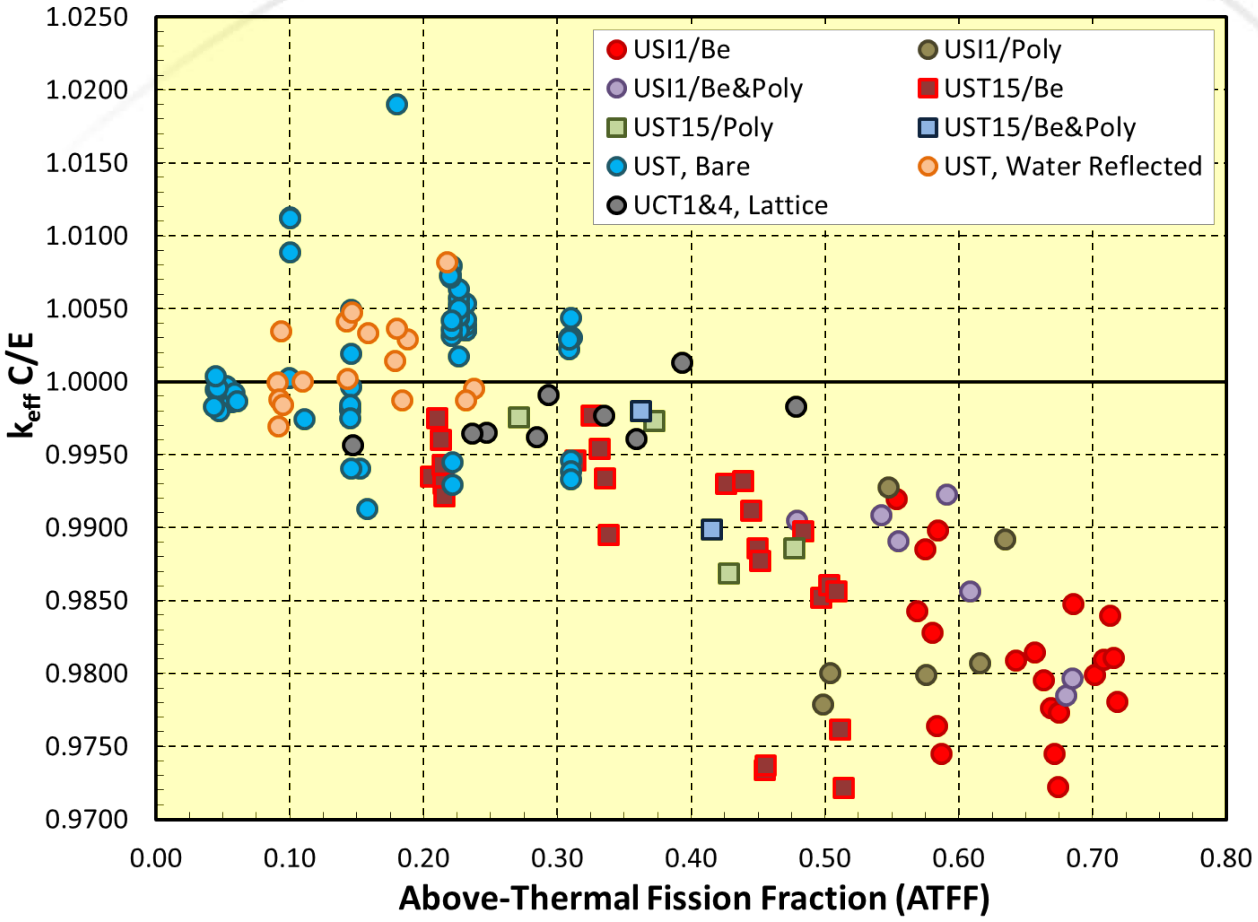


^{233}U Intermediate & Thermal Assemblies



- ENDF/B-VII.1 results …
- UCT1 are LWBR lattice configurations.

^{233}U Intermediate & Thermal Assemblies



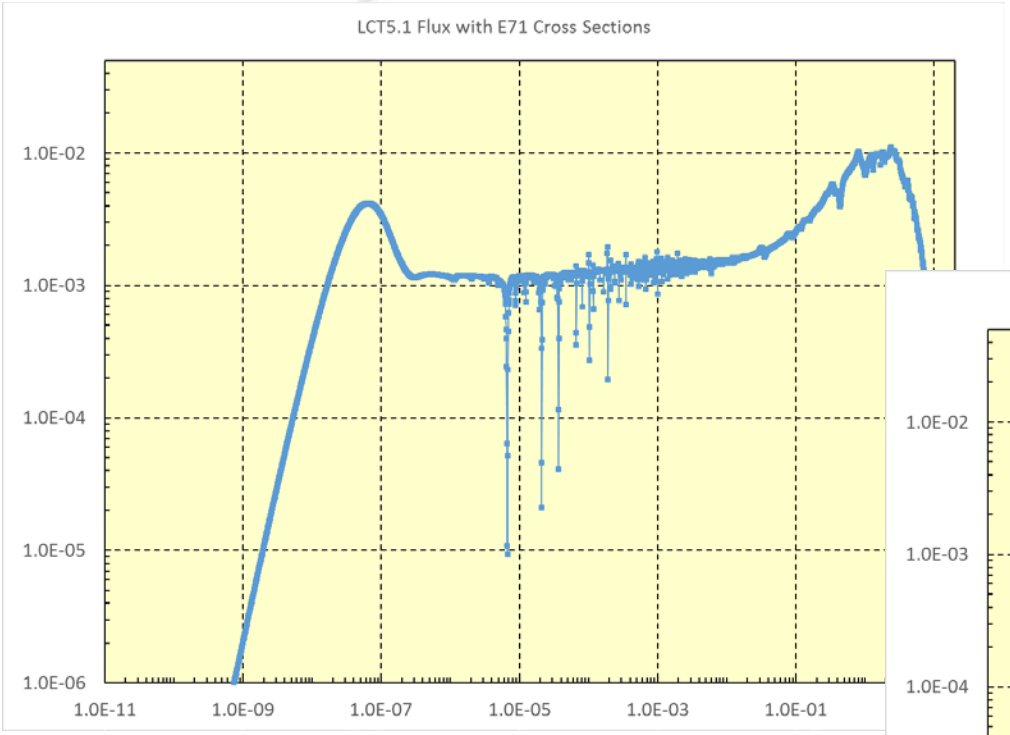
- ENDF/B-VIII.β3 results …
- UCT1 are LWBR lattice configurations.

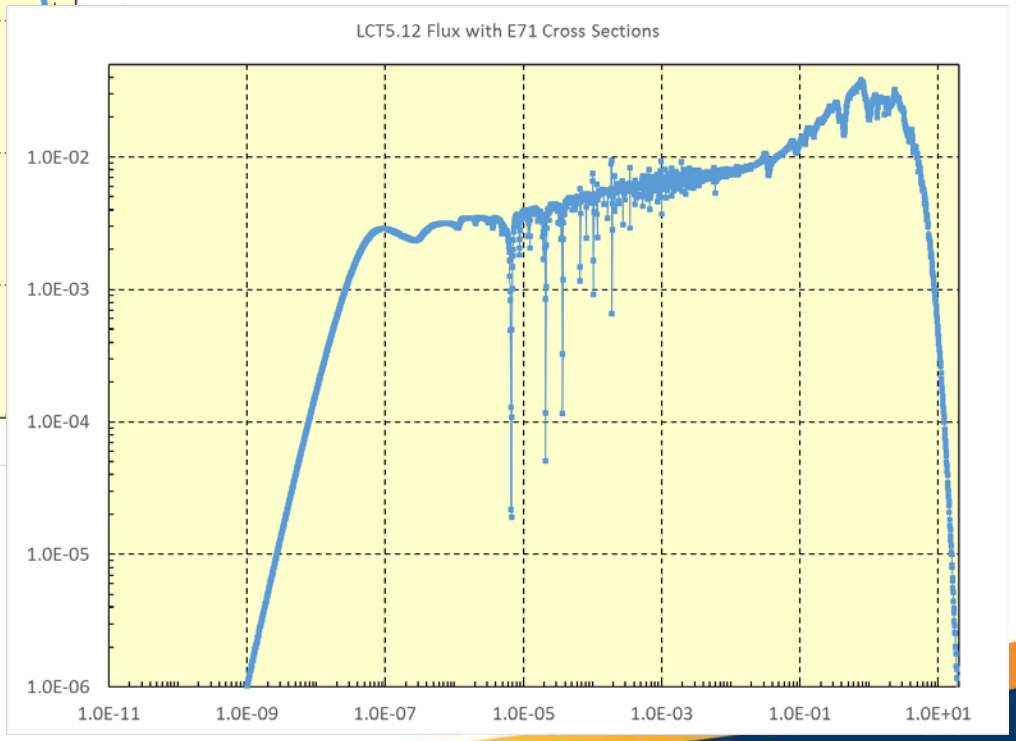
Summary

- Work to revise the CIELO evaluated data files (^{1}H, ^{16}O, ^{56}Fe, ^{235,238}U and ^{239}Pu) continues … with significant international participation.
  - **The final CIELO files will be incorporated into ENDF/B-VIII.0**
- LANL testing to date has concentrated on ICSBEP benchmark eigenvalues. Reaction rate (spectral indices) data, pulsed sphere spectra, shielding (SINBAD) and reactor physics (IRPhEP) benchmarks are also important resources to be utilized in a comprehensive data testing regimen (and are being utilized by our international colleagues).
- New tools are becoming available to assist data testing.
  - DICE = Database for ICSBEP & NDaST = Nuclear Data Sensitivity Tool.

- … extra …

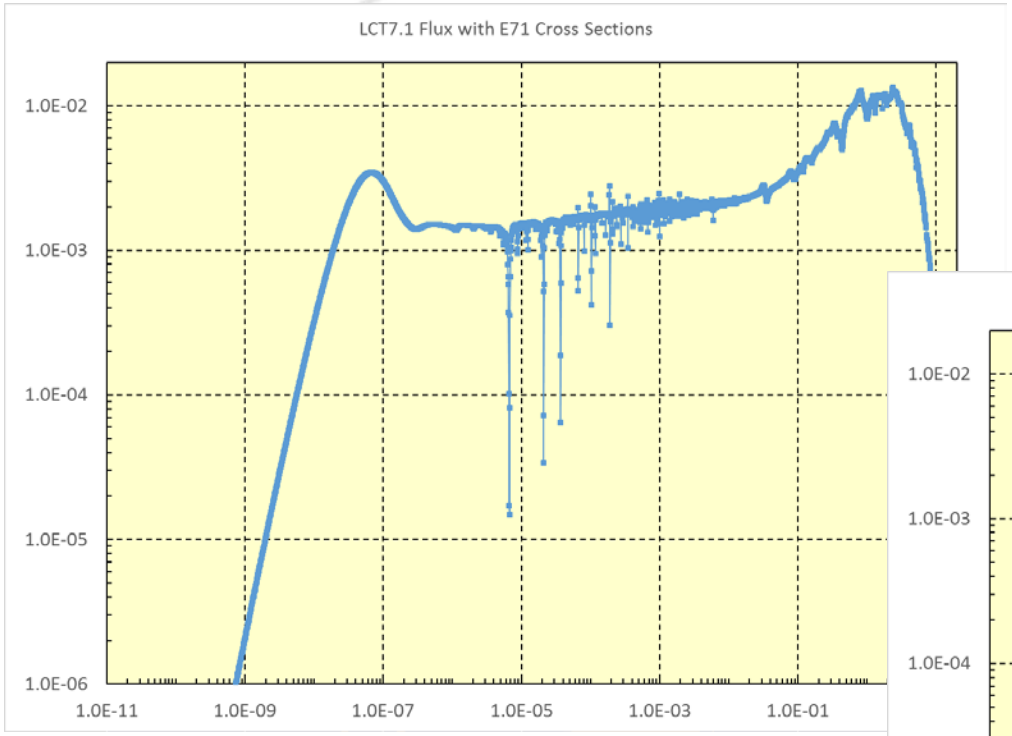
LANL Data Testing

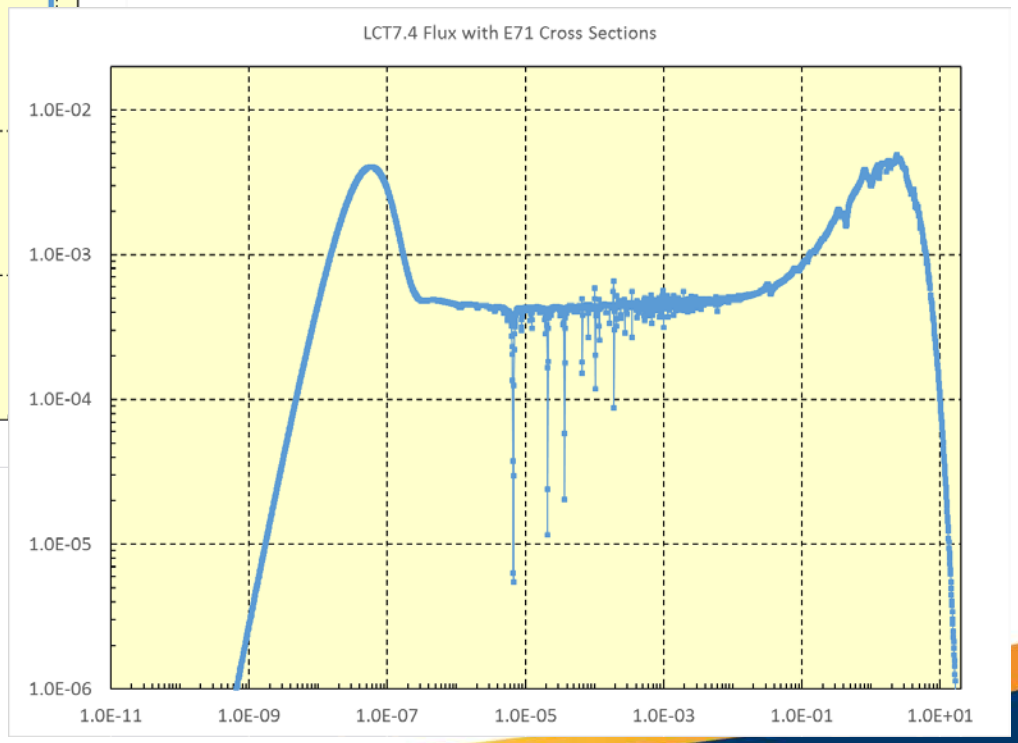




Flux in UO_2; 250 equi-lethergy spaced energy points per decade.

LANL Data Testing





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