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Data Testing Revised ^{235}U, ^{239}Pu and ^{63,65}Cu Files with ICSBEP Benchmarks

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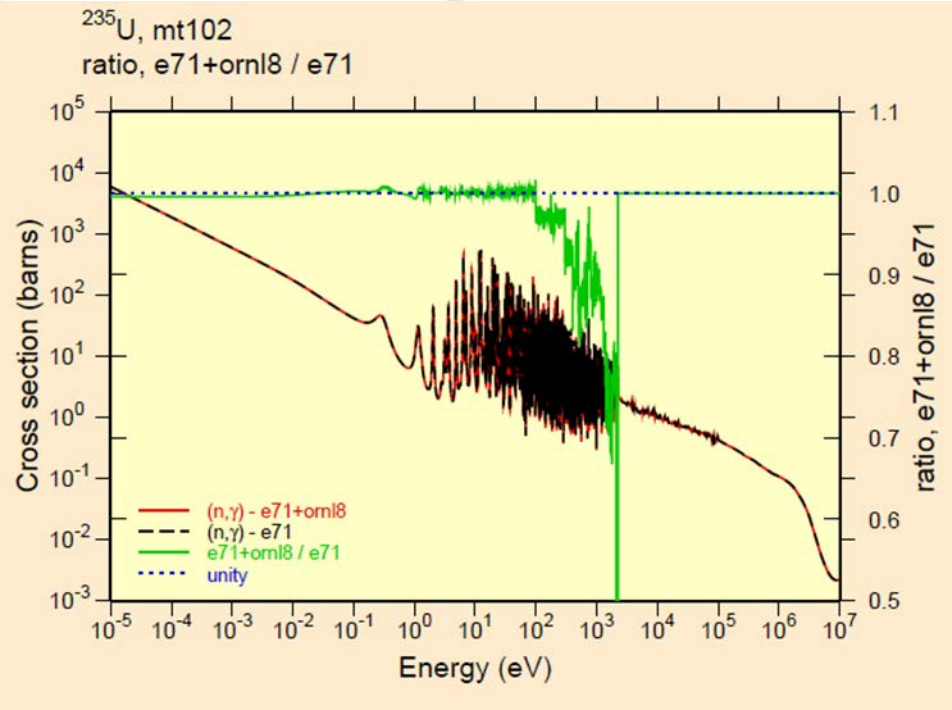
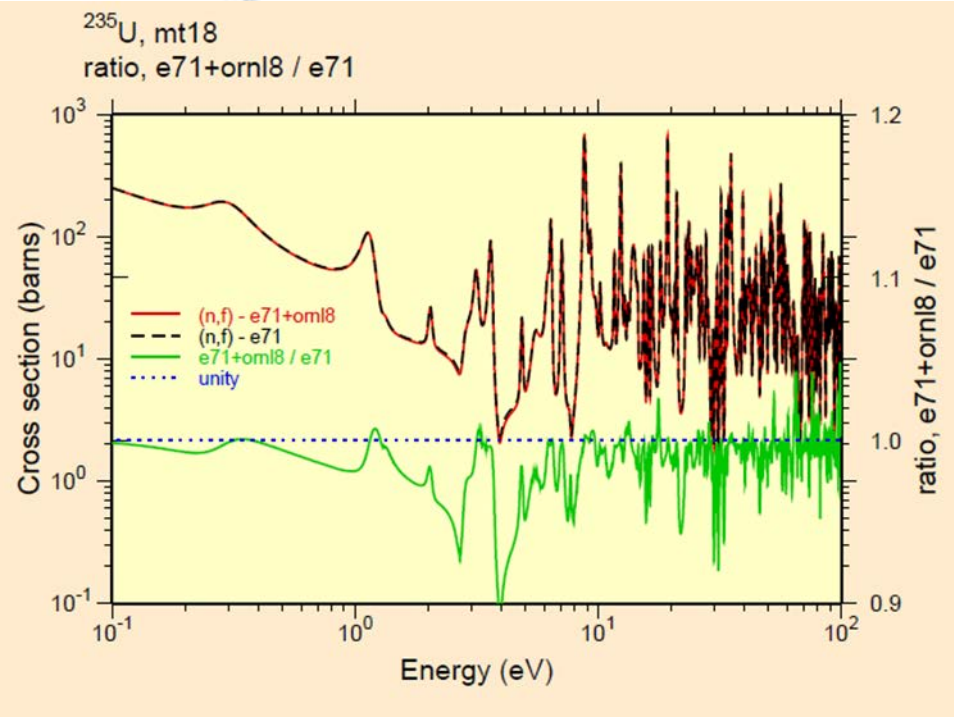
Abstract: We review recent critical benchmark calculations with revised ^{235}U, ^{239}Pu and $^{63,65}Cu$ evaluated data files.

^{235}U – Mostly Revised Capture xs



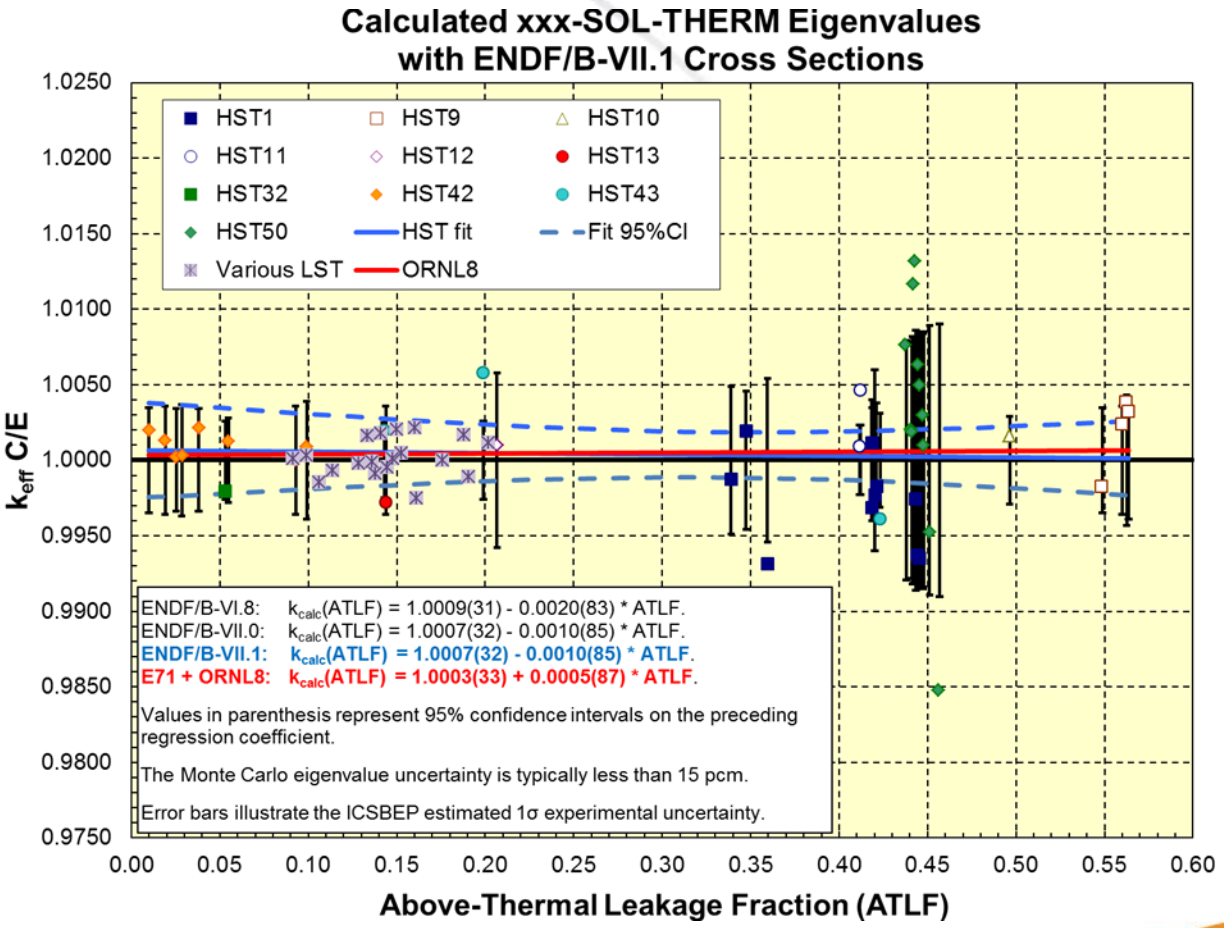


Comparison of ^{235}U(n,γ) and ^{235}U(n,f) cross sections … recent ORNL re-evaluation, designated ORNL8, based upon new LANL and RPI data versus the current (ENDF/B-VII.1) evaluation … "a work in progress" per Luiz Leal.

HST Benchmarks

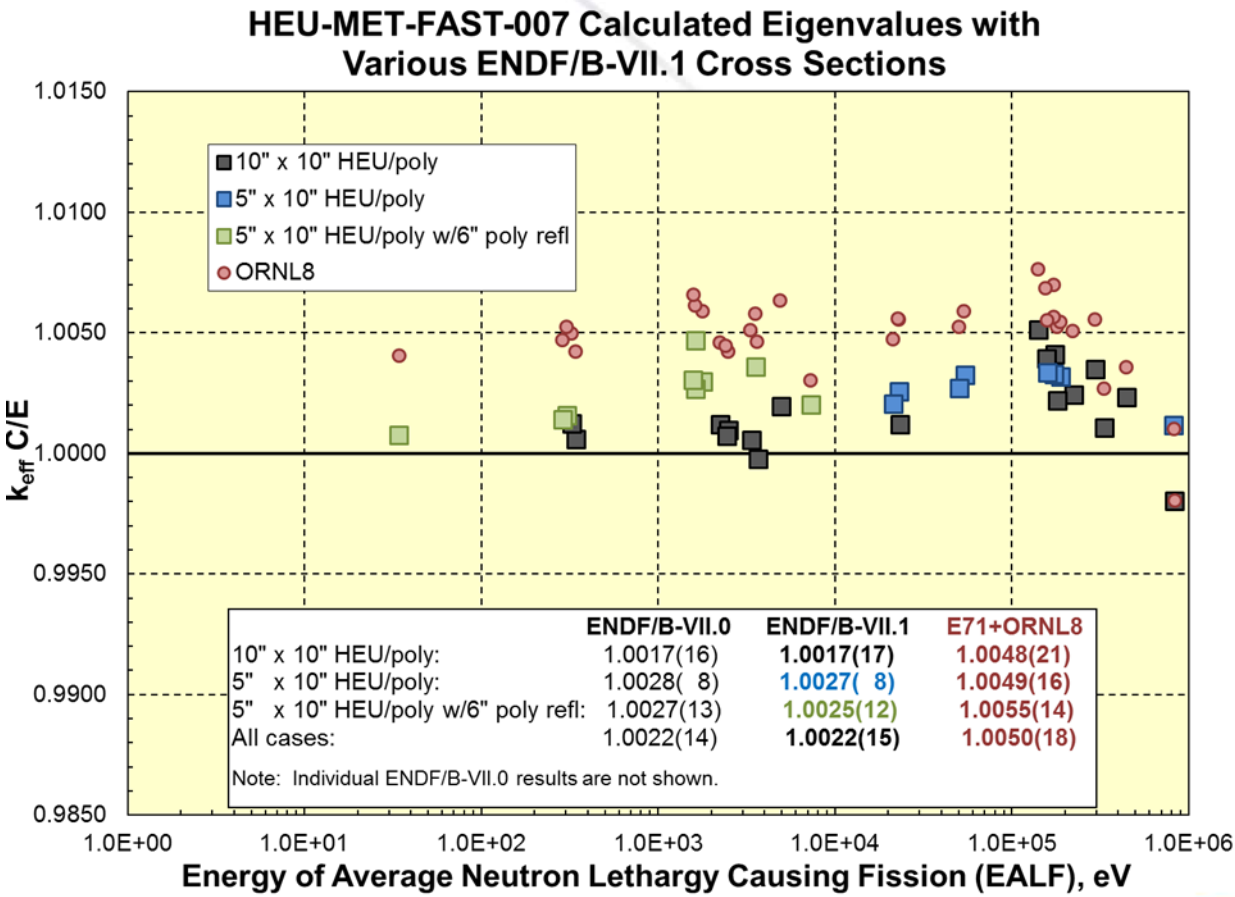
- Regression fit to HST benchmarks versus ATLF has been excellent since ENDF/B-VI.3 (Lubitz).

- This excellent fit is retained with the latest (ORNL8) ^{235}U evaluated data file.



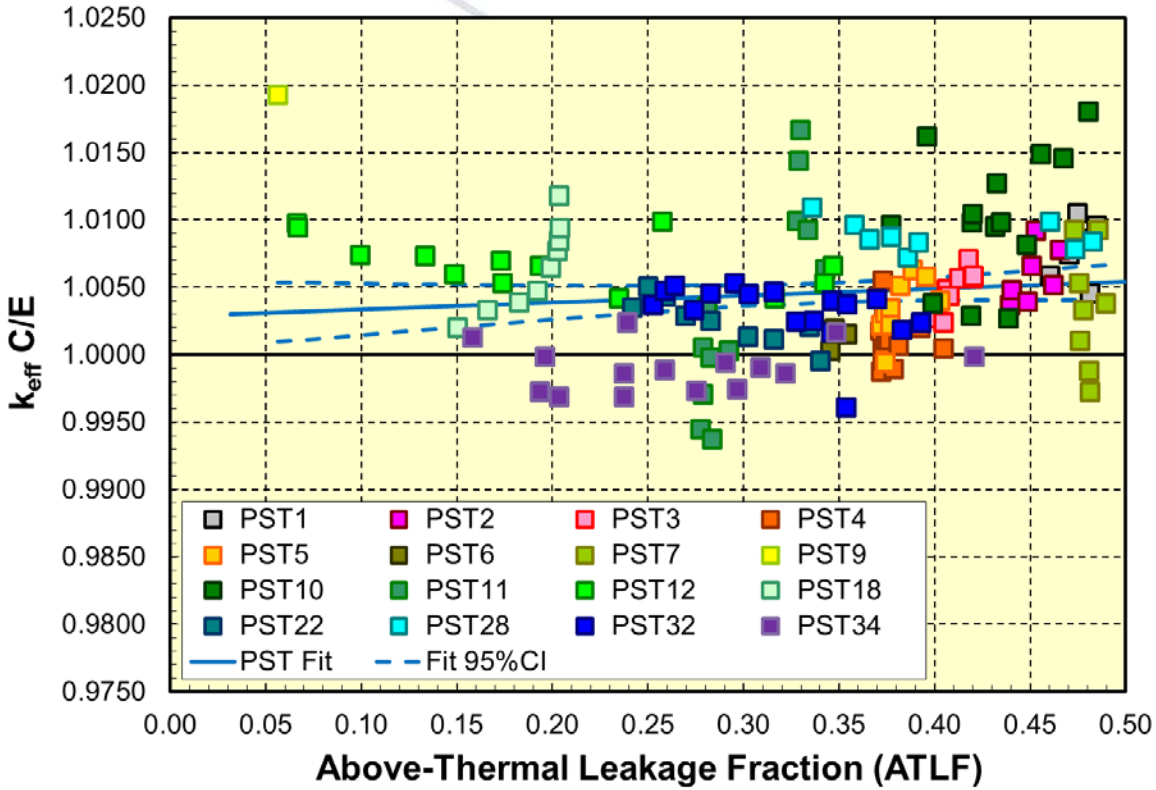
HMF7 (HEU + CH_2) Benchmarks

- HEU + poly system tests xs data over several orders of magnitude.
- E70 & E71 results are near unity at either energy extreme but are biased high in the intermediate energy range.
- This bias is worsened (?) with the latest ORNL8 ^{235}U evaluated file.



^{239}Pu – the problem …

- A ~500 pcm bias in calculated PST reactivity is a long-standing issue.
- WPEC Sub-Group 34 was tasked with defining a new (better?) set of resolved resonance parameters for ^{239}Pu in an attempt to resolve this issue.
- Define a sub-set of these 150 benchmarks to test revised data files.



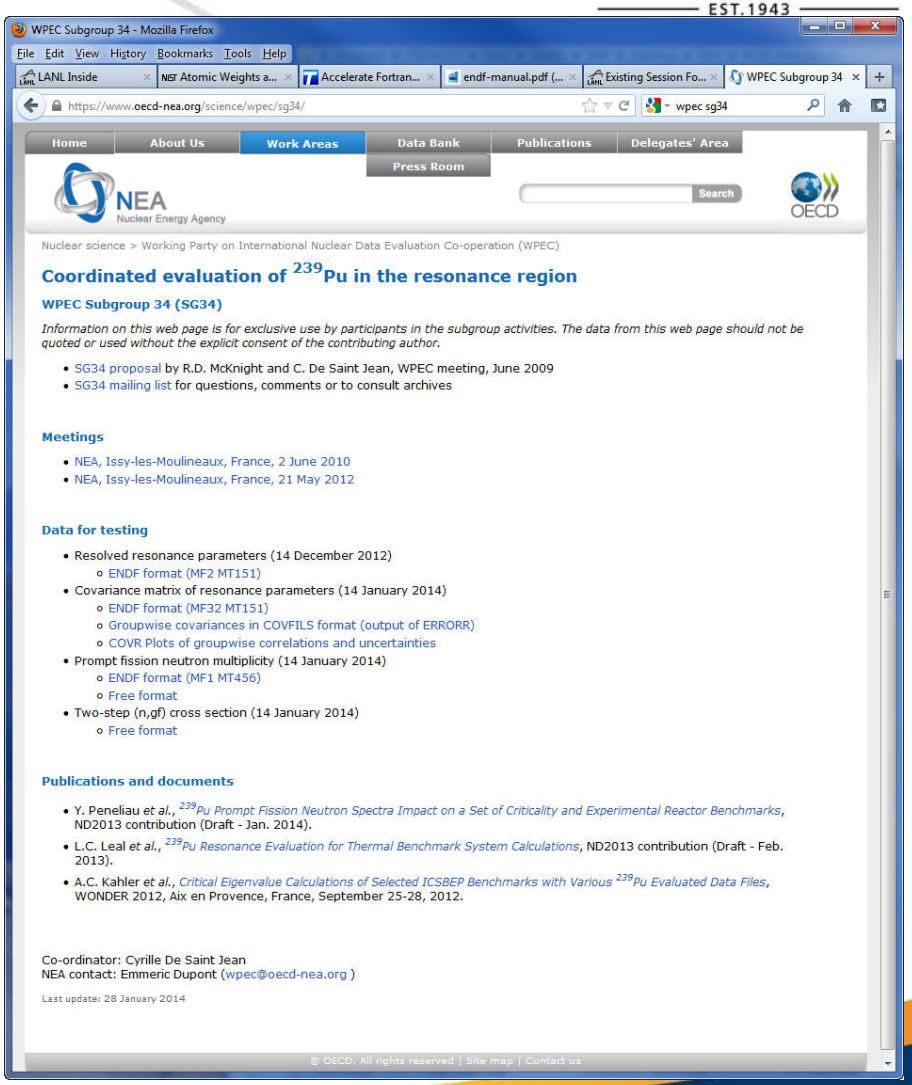
Consider benchmark attributes such as (i) ATLF; (ii) ^{239}Pu atom-% in Pu; (iii) Above-Thermal Fission Fraction (ATFF); (iv) H/Pu number density (or gPu per liter) to define this sub-set.

Pu-SOL-THERM Benchmarks

- A set of seven Pu-SOL-THERM benchmarks have been extracted from the larger set.
  - PST1.4 & PST12.13 span the ATLF space;
  - PST12.10 & PST34.15 span the ATFF space;
  - PST4.1 & PST18.6 span the ^{239}Pu atom percent space;
  - PST12.10 & PST34.4 span the g Pu per liter space;
  - PST9 has the largest H/Pu ratio.
- All benchmark experiments are performed in simple geometry
  - PST1.4 & PST4.1 are a water-reflected spheres;
  - PST18.6, PST34.4 & PST34.15 are water-reflected cylinders;
  - PST12.10 & PST12.13 are a water-reflected slabs;
  - PST9 is a large, unreflected sphere.

^{239}Pu – WPEC SG34

- Revised resolved resonance parameters have been defined (Leal/ORNL).
- Revised ν_p(E) data, up to 650 eV, have been defined (CEA).
- Revised pfns have been defined (but not likely the last say … IAEA PFNS CRP final report is still to come).
- Differences between JEFF and ENDF remain, ☹.
- Although the Sub-Group is near an end, this work remains a “work in progress” that will continue under CIELO.



^{239}Pu – PST Benchmark Results …

- The E71fix 1.00581 k_{calc} average demonstrates that the 8 benchmark subset reflects the larger population.
- Data revisions in the "Leal7a" ^{239}Pu evaluated file have eliminated ~50% of the long-standing k_{calc} bias …
- … but it's the $\nu_p(E)$ changes that have the largest impact!

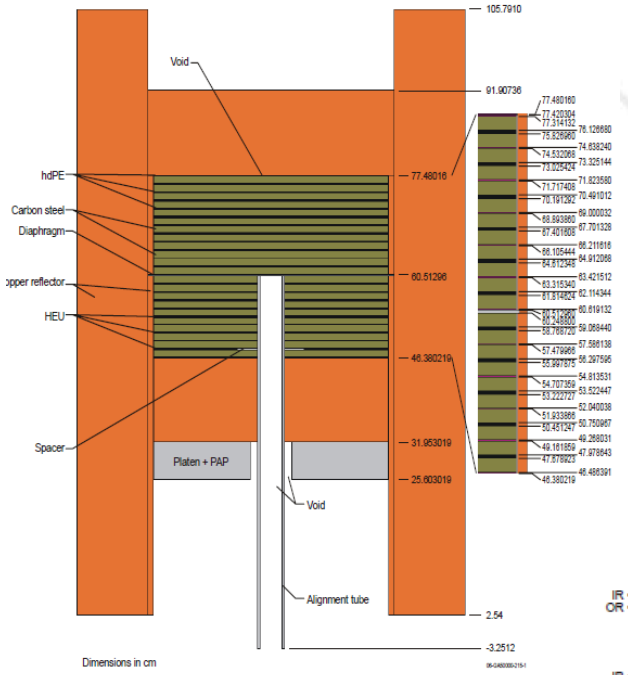
Calculated Eigenvalues[a] for a Selection of PST Assemblies Using Various ^{239}Pu Cross Sections

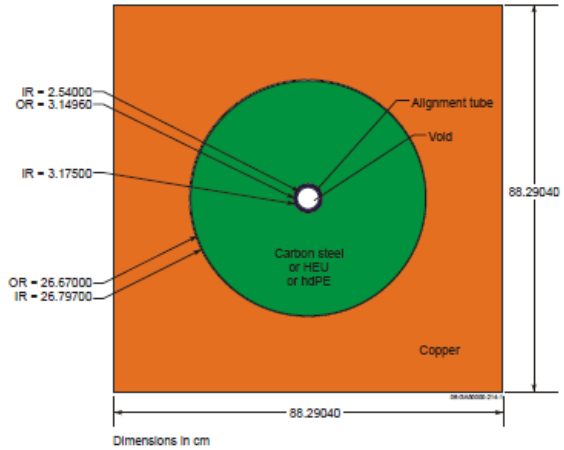
Assembly	ENDF/B-VII.1 (w/MT18 fix[d])	JEFF-3.1.2 [b]	JENDL-4.0 [b]	Leal7a [c]	Leal7a RR, nu_p, pfns & e71fix[d] + e71
PST1.4	1.00500	1.00127	1.00588	1.00199	1.00222
PST4.1	1.00389	0.99907	1.00482	1.00044	1.00035
PST9	1.01930	1.01367	1.02510	1.01543	1.01548
PST12.10	1.00402	0.99973	1.00498	1.00083	1.00060
PST12.13	1.00970	1.00468	1.01069	1.00611	1.00623
PST18.6	1.00462	1.00153	1.00557	1.00202	1.00210
PST34.4	1.00254	0.99999	1.00417	0.99922	0.99927
PST34.15	0.99731	0.99563	0.99844	0.99679	0.99727
Average	**1.00581**	**1.00195**	**1.00746**	**1.00285**	**1.00294**

a) MCNP calculations are for 50M histories; stochastic uncertainty is ~10 pcm.
b) JEFF-3.1.2 and JENDL-4.0 ^{239}Pu only; remaining nuclides are ENDF/B-VII.1
c) "LEAL7a" evaluation provides revised resolved resonance parameters coupled to a joint ORNL/CEA evaluated ^{239}Pu file; remaining nuclides are ENDF/B-VII.1. The "LEAL7a (RR,nu_p,pfns)" file couples just these data to the existing ENDF/B-VII.1(fix) ^{239}Pu file.
d) "MT18fix" is removal of ^{239}Pu(n,f) background cross sections near 1-to-2 keV (Kawano).

HMI & HEU Benchmarks with Cu

- The LANL "ZEUS" benchmark suite …
  - HMI6
    - Four configurations of HEU fuel plates with varying amounts of interstitutial graphite plus a thick radial and axial Cu reflector
  - HMF72
    - Three configurations of HEU fuel plates with varying amounts of interstitutial carbon steel and/or high density polyethylene plus a thick radial and axial Cu reflector
  - HMF73
    - One configuration of HEU fuel plates plus a thick radial and axial Cu reflector





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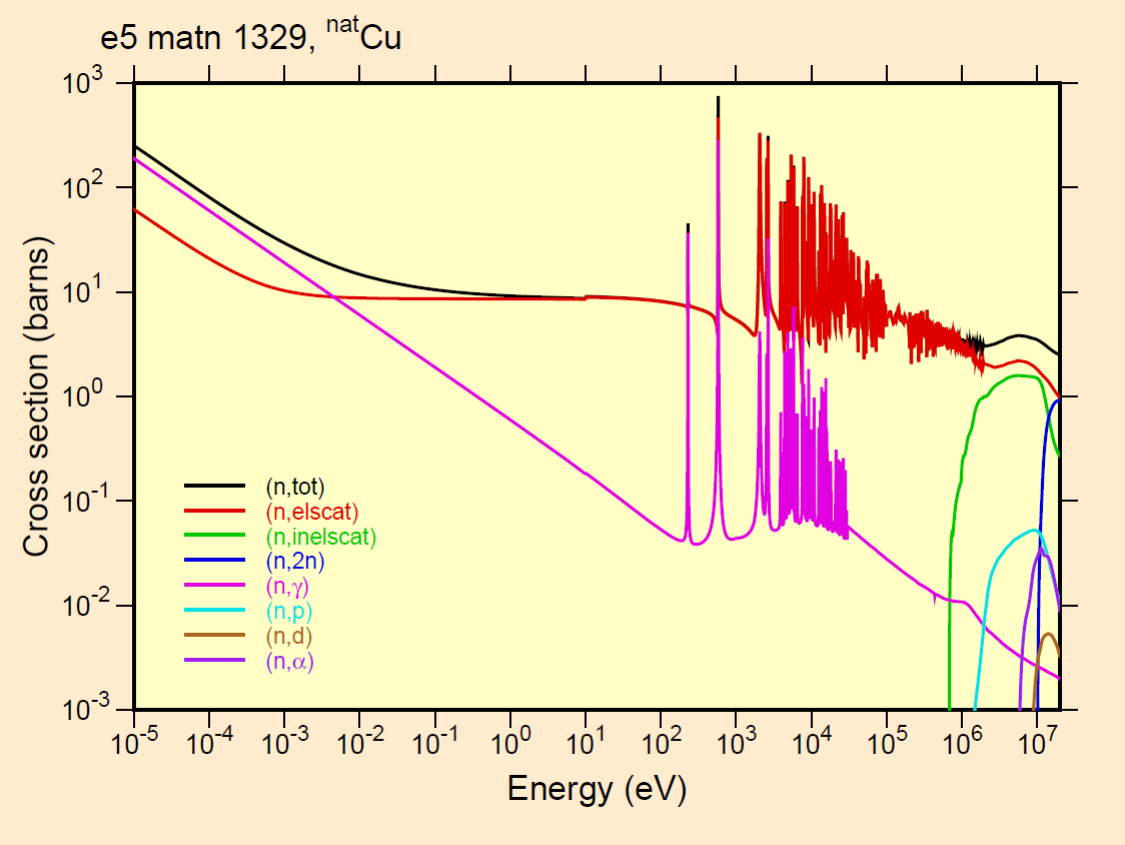
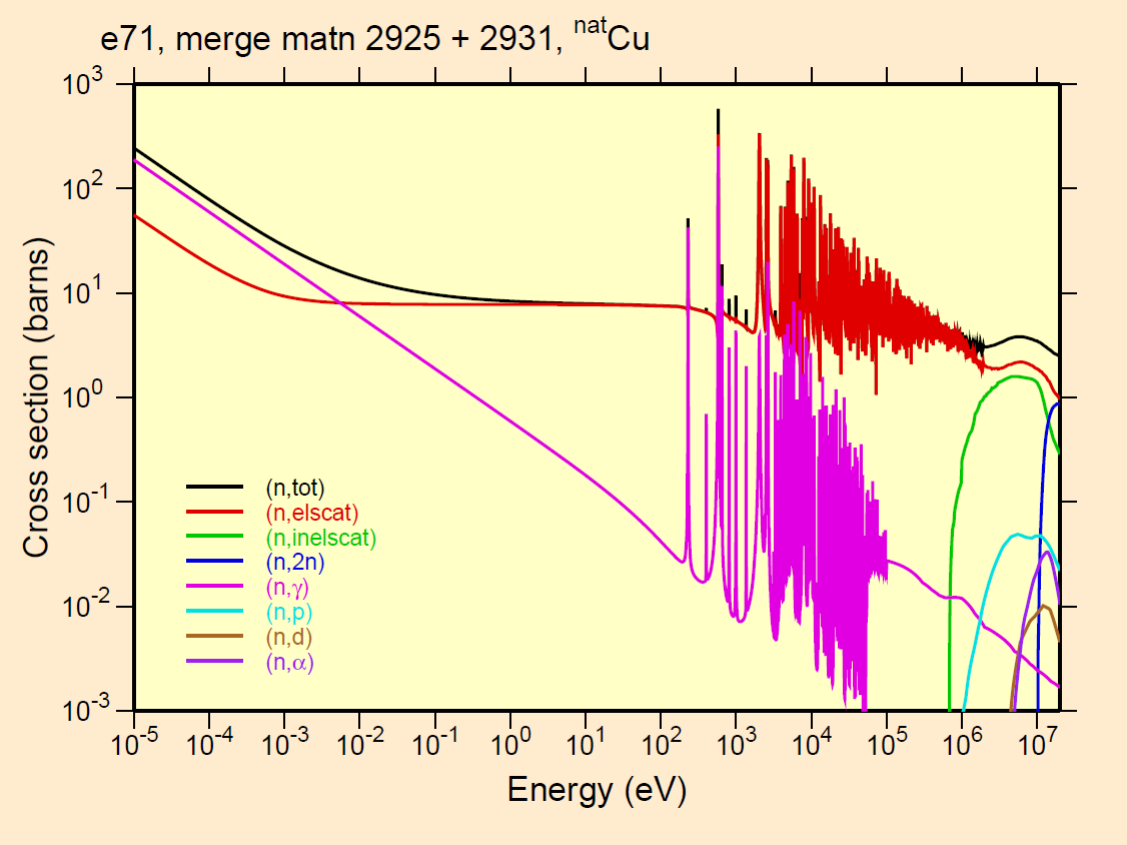
HMI & HEU Benchmarks with Cu

- Some Cu cross section options …
  - **ENDF/B-V (elemental)**
    - **Released in 1978;**
    - **Resolved resonance region from 10 eV to 30 keV (carried forward from ENDF/B-III);**
    - **Uses the Multi-Level Breit-Wigner (MLBW) resolved resonance formalism with File 3 "background" corrections;**
    - **Capture data was "thinned" to reduce file size (from 408 to 48 points!).**
  - ENDF/B-VII.1 (isotopic)
  - mit_ornl isotopic



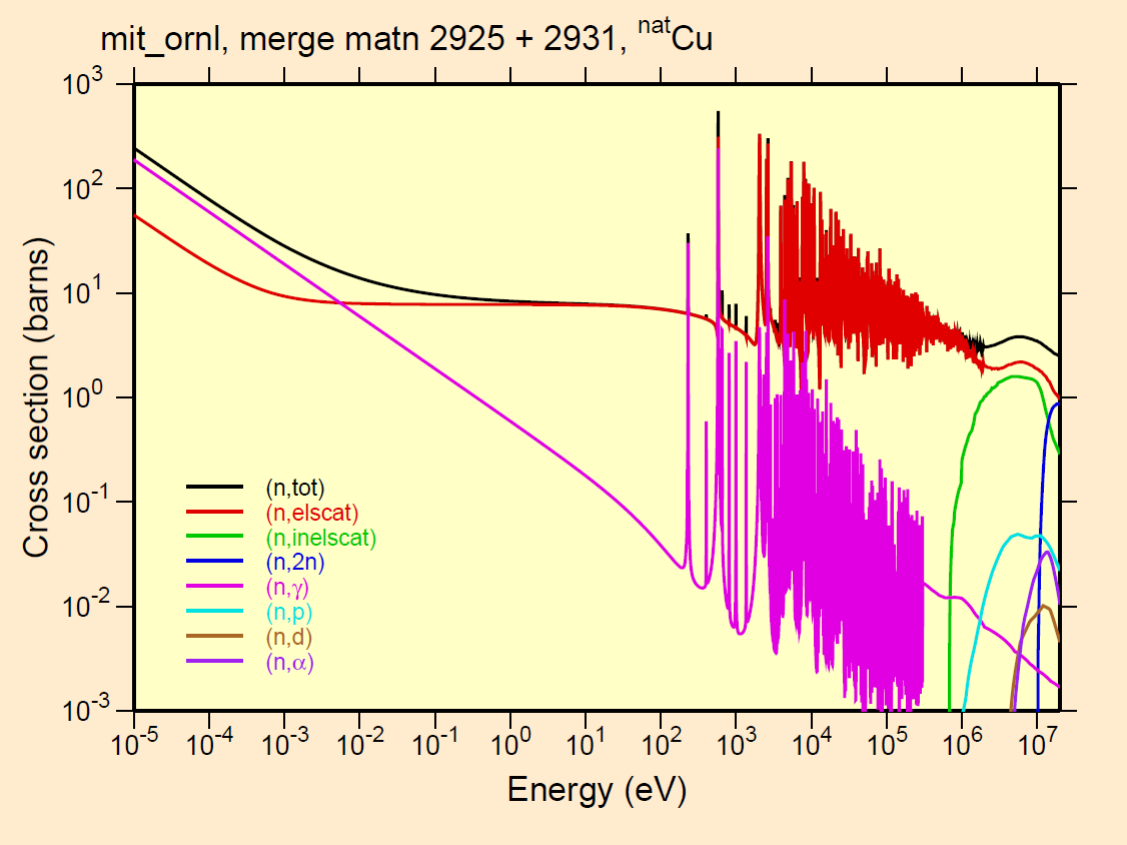
HMI & HEU Benchmarks with Cu

- Some Cu cross section options …
  - ENDF/B-V (elemental)
  - **ENDF/B-VII.1 (isotopic)**
    - **Primarily carried forward from ENDF/B-VI;**
    - **The resolved resonance region is extended to cover from 10^{-5} eV to 99.5 keV (1989);**
    - **Resonance parameters defined using the Reich-Moore formalism.**
  - mit_ornl isotopic



HMI & HEU Benchmarks with Cu

- Some Cu cross section options …
  - ENDF/B-V (elemental)
  - ENDF/B-VII.1 (isotopic)
  - **mit_ornl isotopic**
    - **Built upon ENDF/B-VII.1**
    - **Includes a revised resolved resonance region whose upper energy limit is extended to 300 keV;**
    - **Subsequent revisions (not part of these analyses) use the recently defined LRF=7 "Limited Reich-Moore" ENDF-format and allow for calculation of detailed scattering angular distributions.**

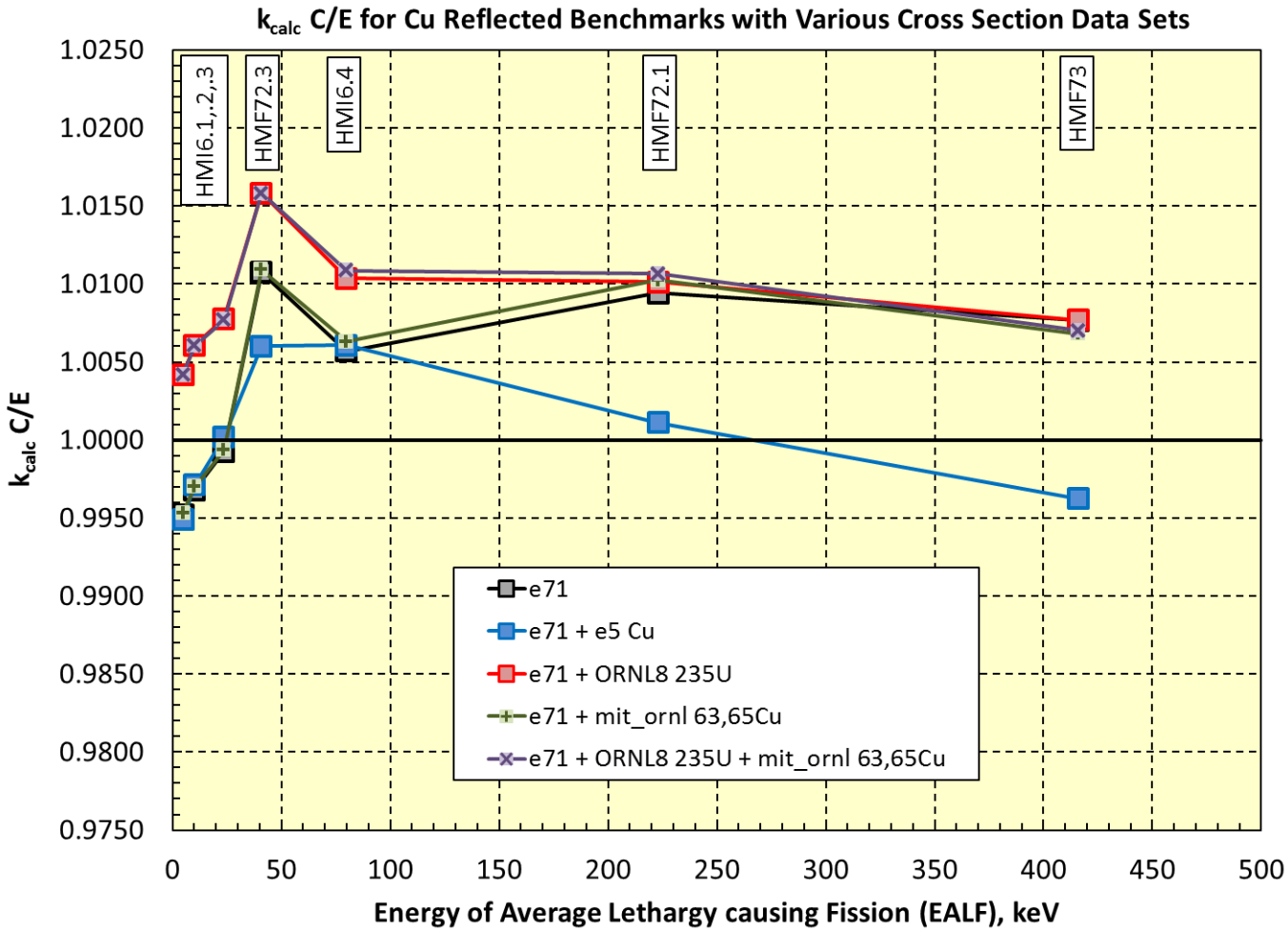


HMI & HEU Benchmarks with Cu

- HMI6 = HEU + graphite + Cu
- HMF72 = HEU + Fe/(poly) + Cu
- HMF73 = HEU + Cu

- k_{calc} is biased high.
- Need better Cu angular distributions?
- Unknown material impurities?

- **Clearly there is more to do!**



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