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ICSBEP Benchmark Testing of CIELO & ENDF/B-VIII.0β1 Nuclides at LANL

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WPEC/SG40

May 9 - 11, 2016

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Abstract

We review criticality data testing performed at Los Alamos with CIELO and ENDF/B-VIII.0β1 nuclear data evaluations.

Outline

- CIELO and ENDF/B-VIII.0β1 Overview
- Criticality Data Testing
  - ICSBEP HMF, HST, IMF, LCT, PMF, PST benchmarks
- Summary

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!

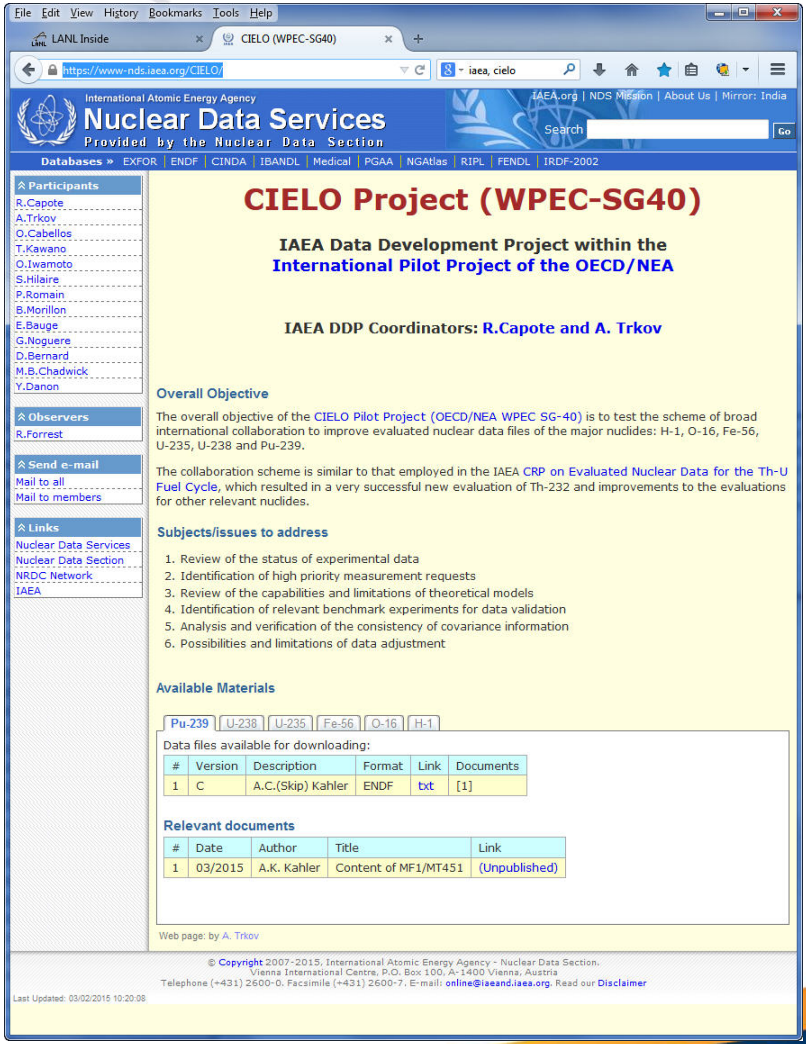
CIELO & ENDF/B-VIII.0β1 Nuclides

- ^{1}H – using endf/b-vii.1
- ^{16}O – (06c), Hale 4/2016 evaluation.
- ^{54,56,57,58}Fe – (01c,03,01c,01c), BNL GForge v222, v219, v234 & v224, respectively.
- ^{235}U – (23c), IAEA u235ib06ao17g6cnu5cf2.
- ^{238}U – (06c), IAEA “ib46rjFs”.
- ^{239}Pu – (23c), ENDF/B-VII.1 plus SG34 plus recent Romano & LANL pfns revisions and LANL high energy ν(E) tweak.

- ENDF/B-VIII.0β1 – candidate files available at
  - https://ndclx4.bnl.gov/gf/project/endf/scmsvn/?action=browse&path=%2Ftags%2FENDF-B-VIII.beta1%2F for the svn repo, or
  - https://ndclx4.bnl.gov/gf/project/endf/frs/ for the tarballs.

CIELO Overview

- The IAEA Nuclear Data Section has created a web page … https://www-nds.iaea.org/CIELO/ … with links to candidate evaluated data files.

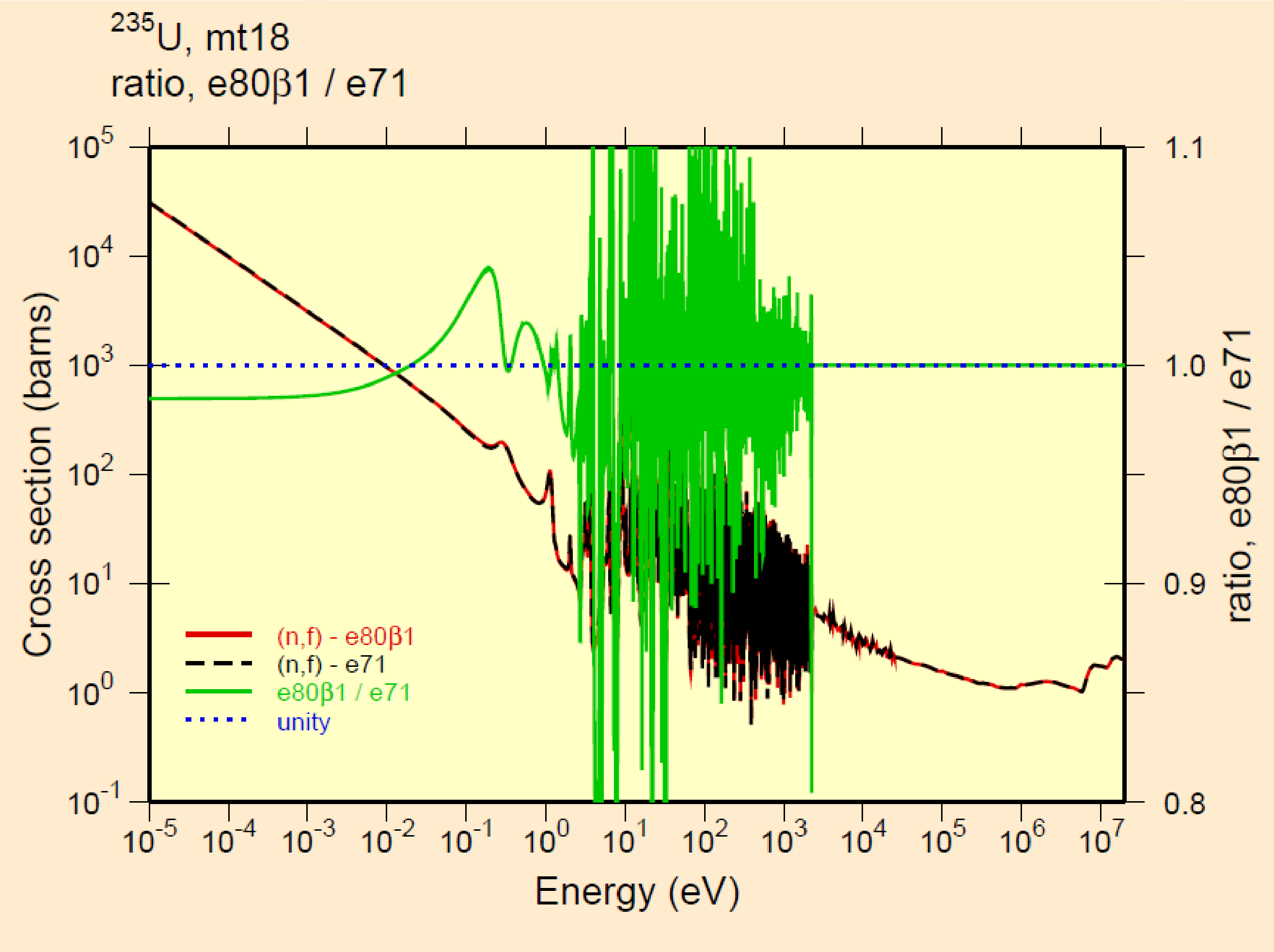


ENDF/B-VIII.0β1 Overview

- ENDF/B-VIII.0β1 candidate files are available from the BNL NNDC (https://ndclx4.bnl.gov/gf/project/endf/, or see links on an earlier slide).

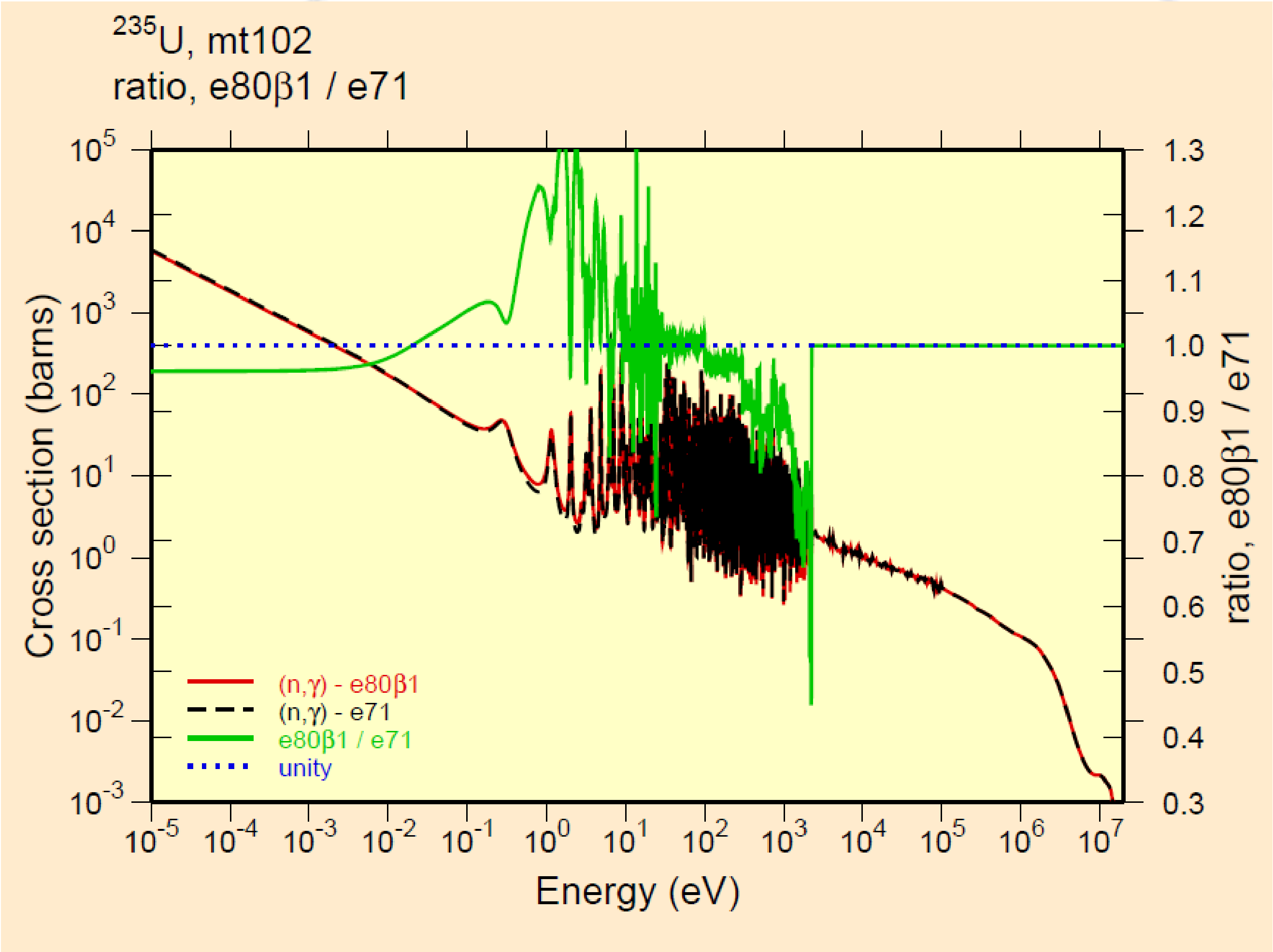
^{235}U, ^{239}Pu & FAST Criticals

^{235}U Cross Sections …



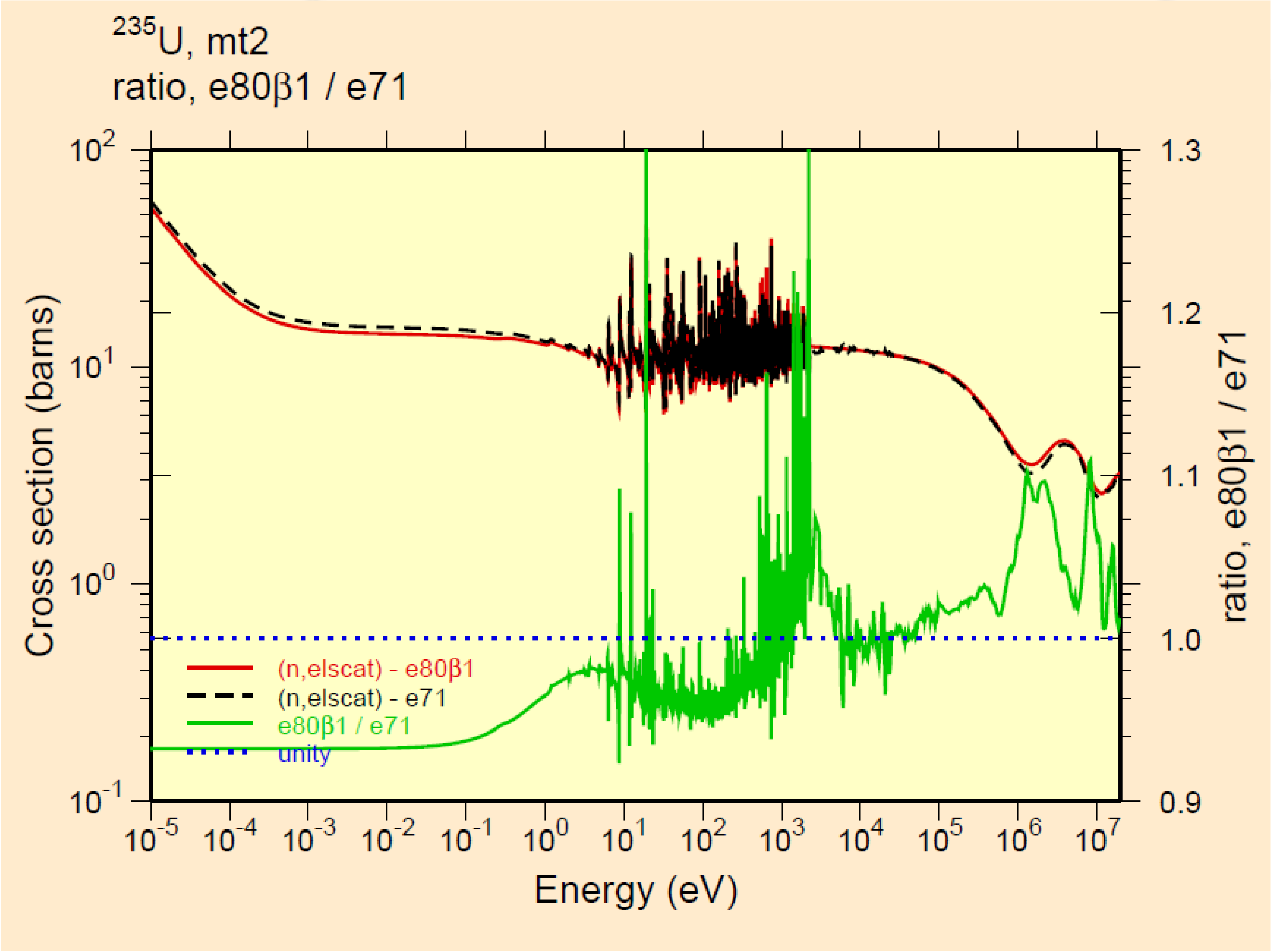
Revised resolved resonance parameters tend to fill in the gaps between resonances.

^{235}U Cross Sections …



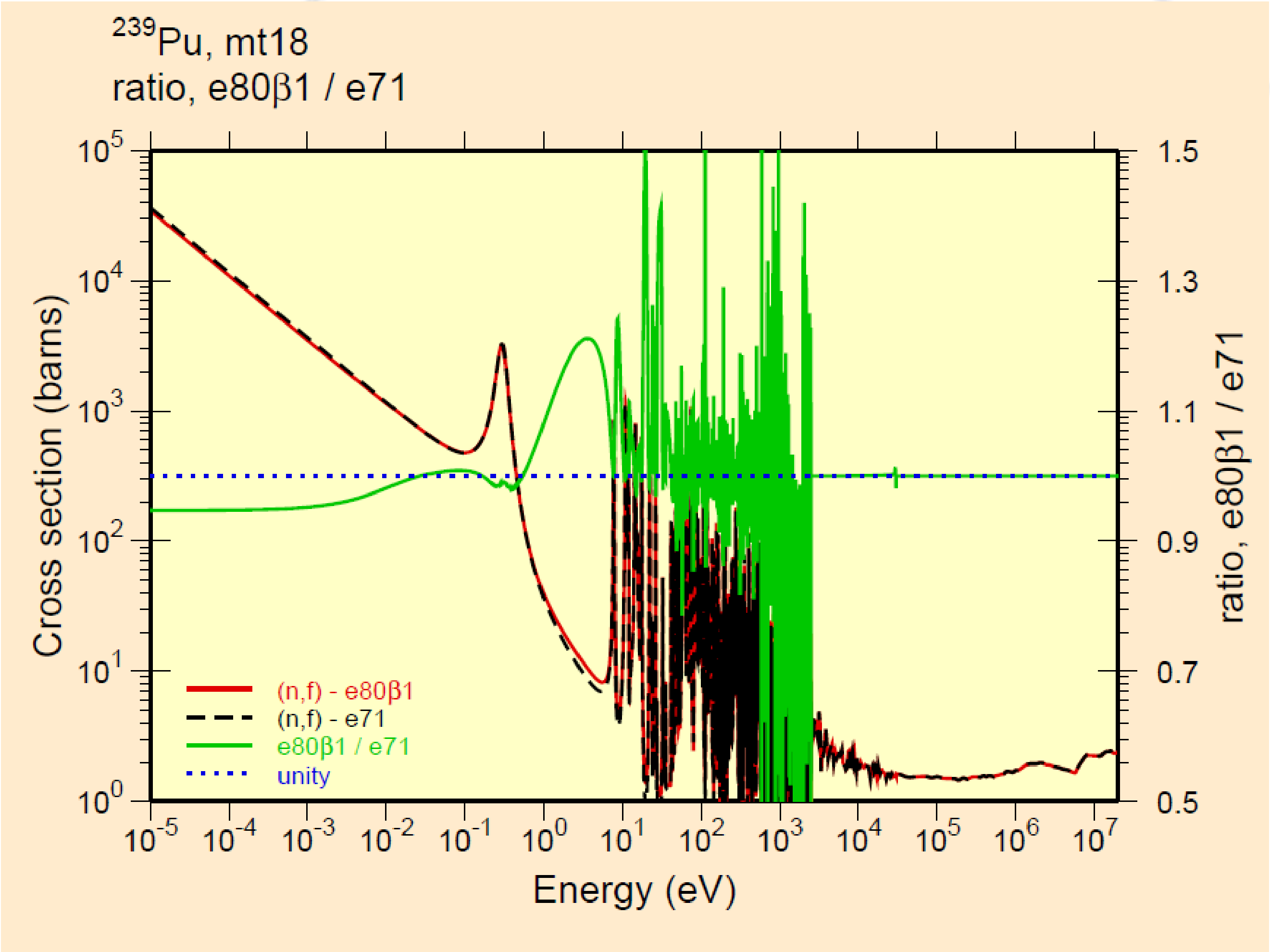
Should the large decrease in capture cross section stop at the top of the RRR?

^{235}U Cross Sections …



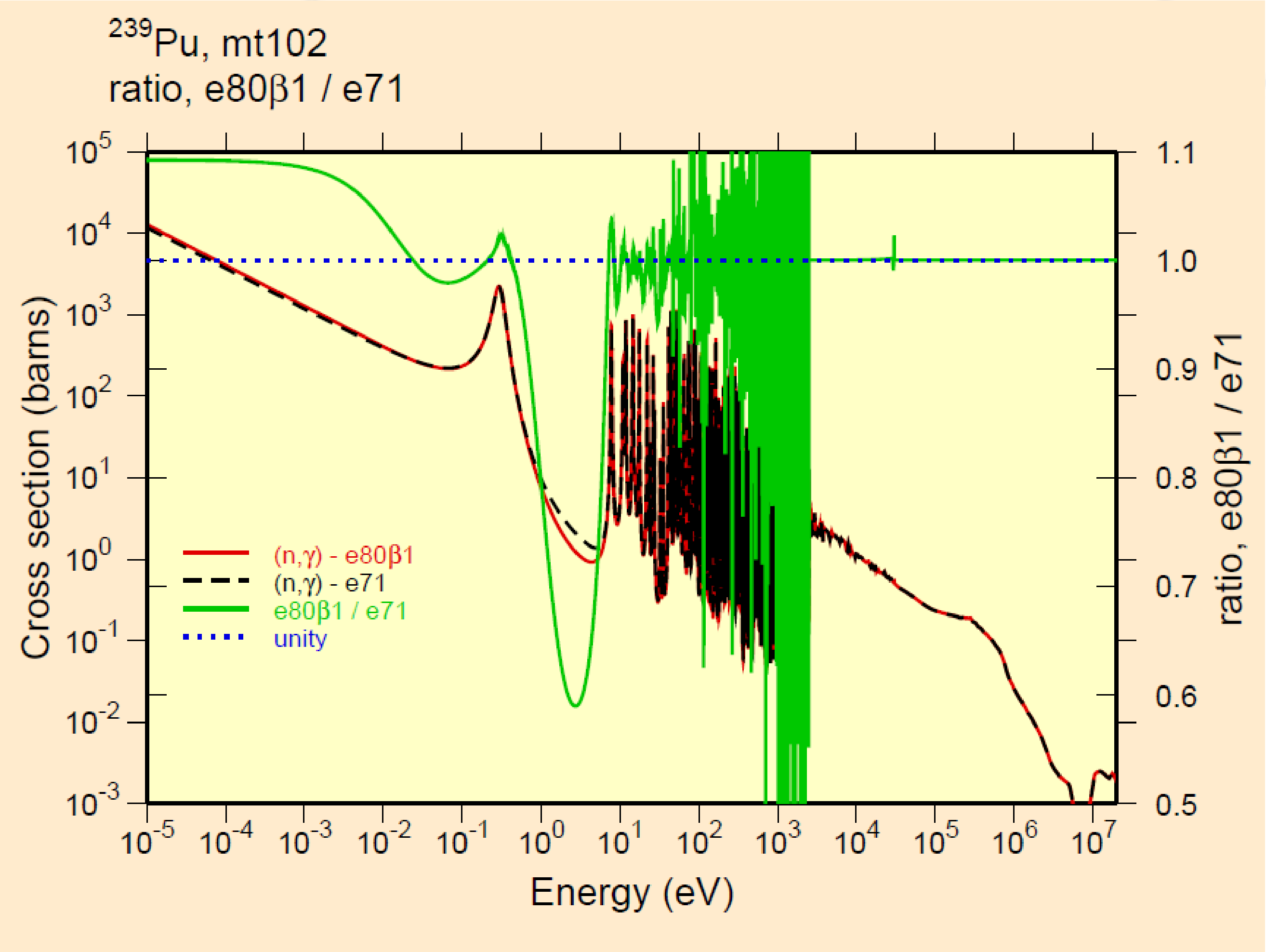
Reduced elastic scattering through the low energy region, increased above the RRR.

^{239}Pu Cross Sections …



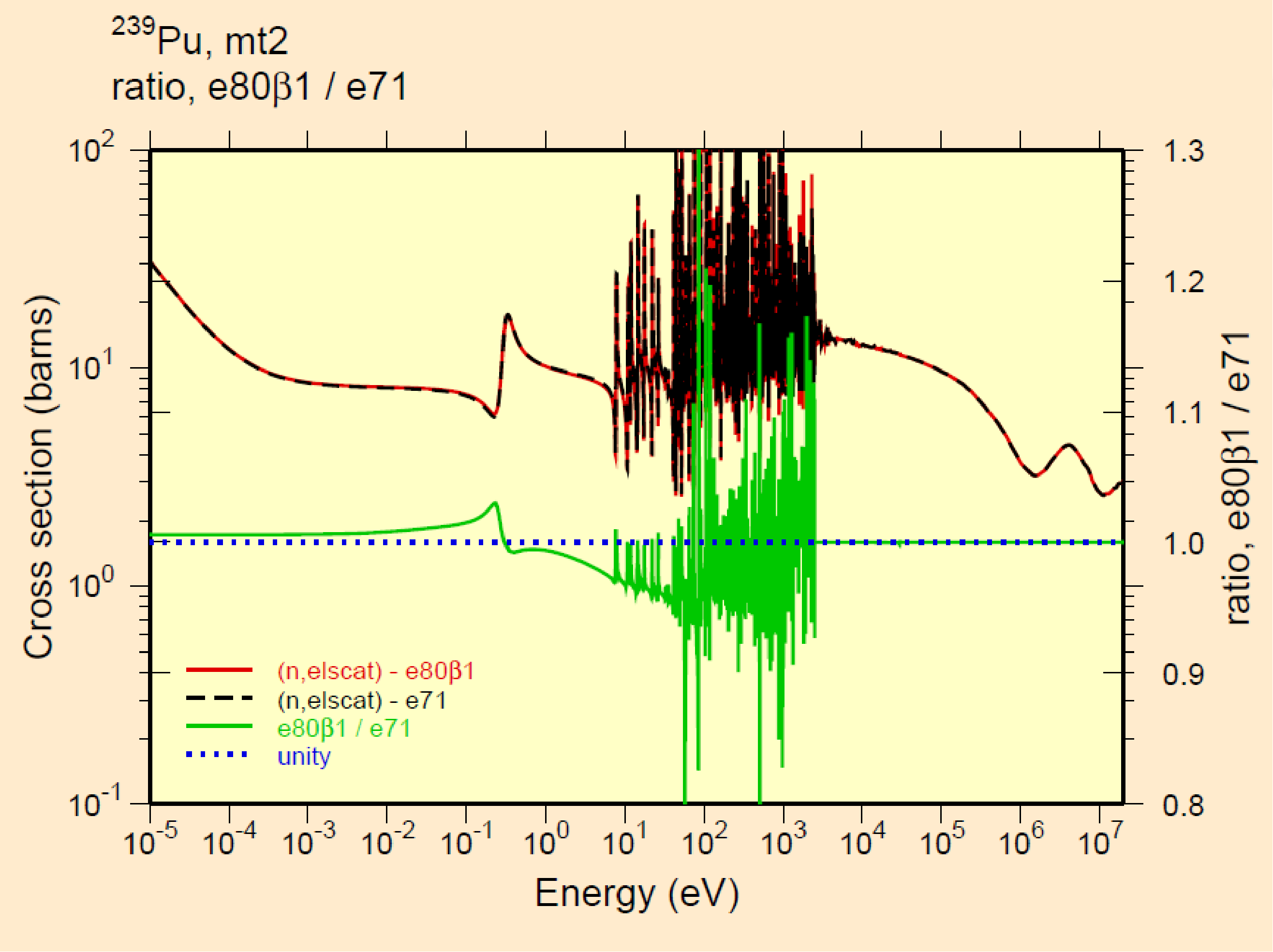
Changes in the resolved resonance parameters with greatest impact in the valleys between individual resonances. Little or no change at higher energies.

^{239}Pu Cross Sections …



Changes in the resolved resonance parameters with greatest impact in the valleys between individual resonances. Little or no change at higher energies.

^{239}Pu Cross Sections …



Changes in the resolved resonance parameters with greatest impact in the valleys between individual resonances. Little or no change at higher energies.

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^{235,238}U, ^{239}Pu – HMF & PMF Benchmarks

Benchmark	Benchmark k_{eff}	endf/b-vii.1 (e71)	e8 starter (Fall, 2015)	e80b1 (April, 2016)
HMF1 (Godiva)	1.0000	0.99989	1.00010	1.00086
HMF28 (Flattop-25)	1.0000	1.00284	1.00380	1.00129
IMF7 (Big-10)	1.0045	1.00448	1.00329	1.00438
IMF1.1 (Jemima)	0.9988	1.00014		0.99921
IMF1.2 (Jemima)	0.9988	1.00049		0.99956
IMF1.3 (Jemima)	0.9990	1.00042		0.99832
IMF1.4 (Jemima)	0.9990	1.00155		0.99943
PMF1, rev3 (Jezebel)	1.00000	1.00069	1.00024	1.00088
PMF6 (Flattop-Pu)	1.0000	1.00093	1.00164	0.99945

Small increase in Godiva.

Significant improvement in Flattop-25.

Big-10 remains good.

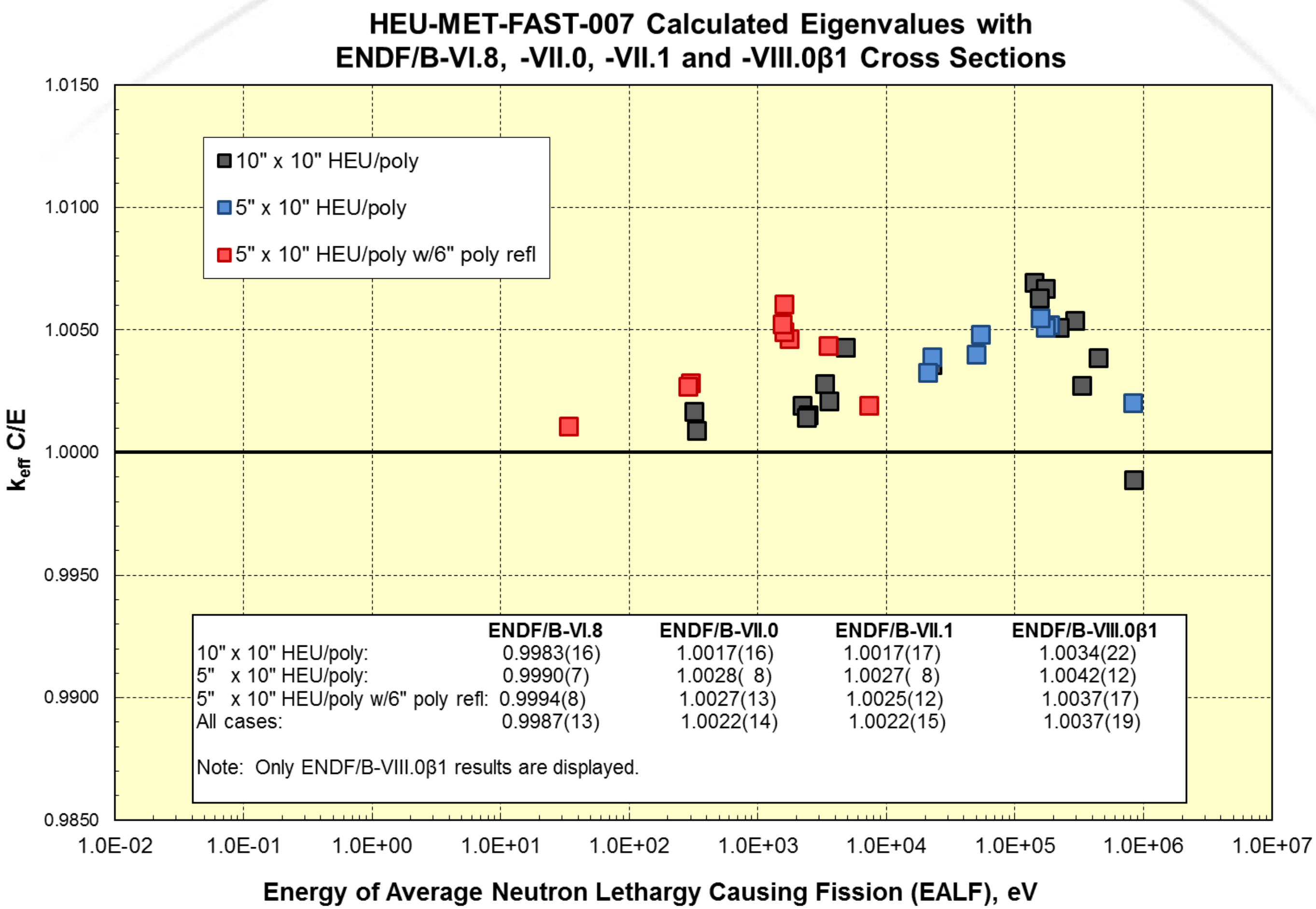
Improved results for Jemima.

Small increase in Jezebel.

Decrease, but overall improvement in Flattop-Pu.

All-in-all results are good.

$^{235,238}U$, ^{239}Pu – HMF & PMF Benchmarks



HMF7 … HEU plates with varying amounts of interstitial CH_2 and reflector CH_2.

k_{calc} was better with ENDF/B-VI.8 and has gotten progressively worse with more recent ENDF/B cross sections.

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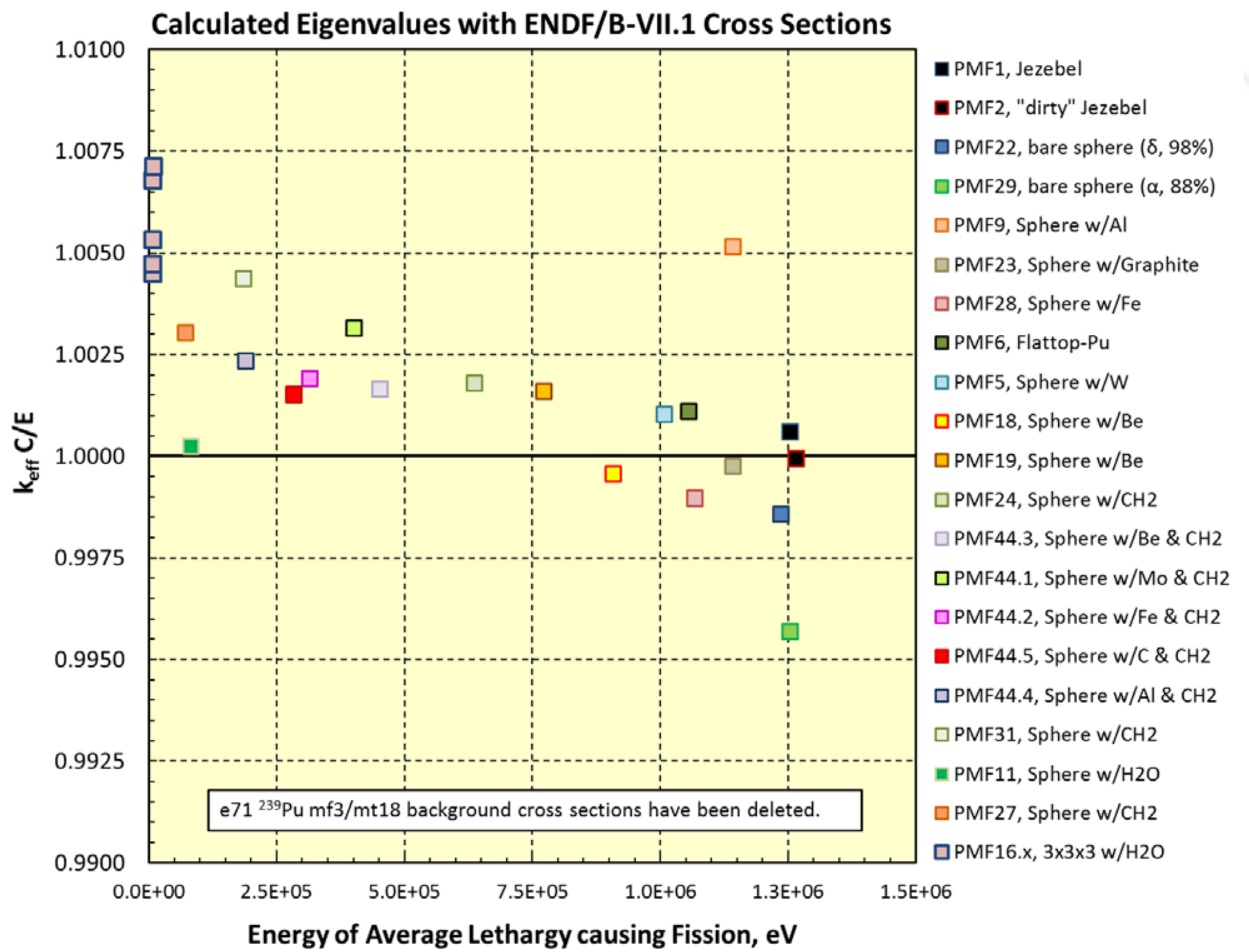
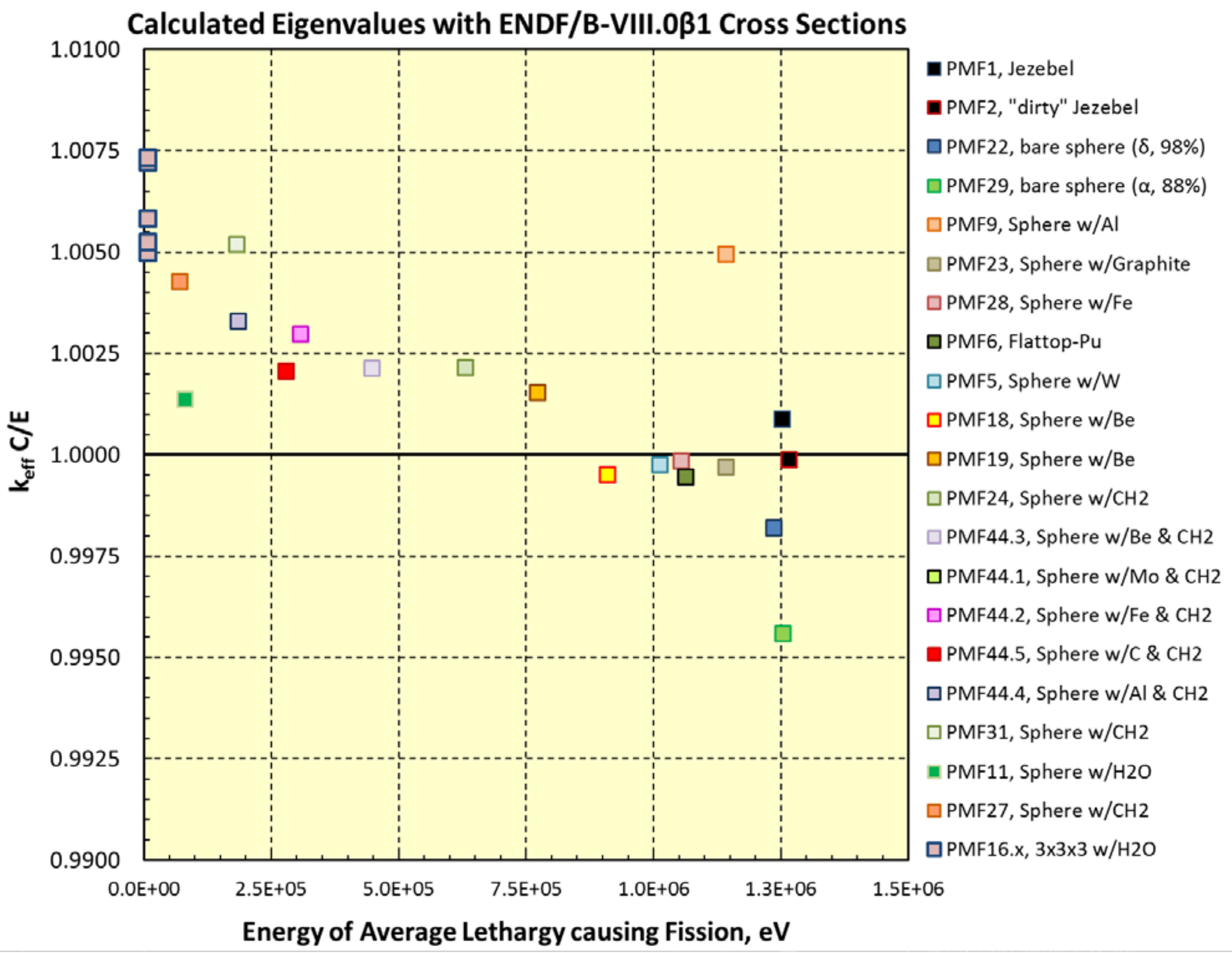
$^{235,238}U$, ^{239}Pu – HMF & PMF Benchmarks



There is an obvious positive bias in endf/b-vii.1 k_{calc} for the PMF class as a function of decreasing average fission energy.

$^{235,238}U$, ^{239}Pu – HMF & PMF Benchmarks



The increasing trend in k_{calc} with decreasing average fission energy is virtually unchanged in e80b1.

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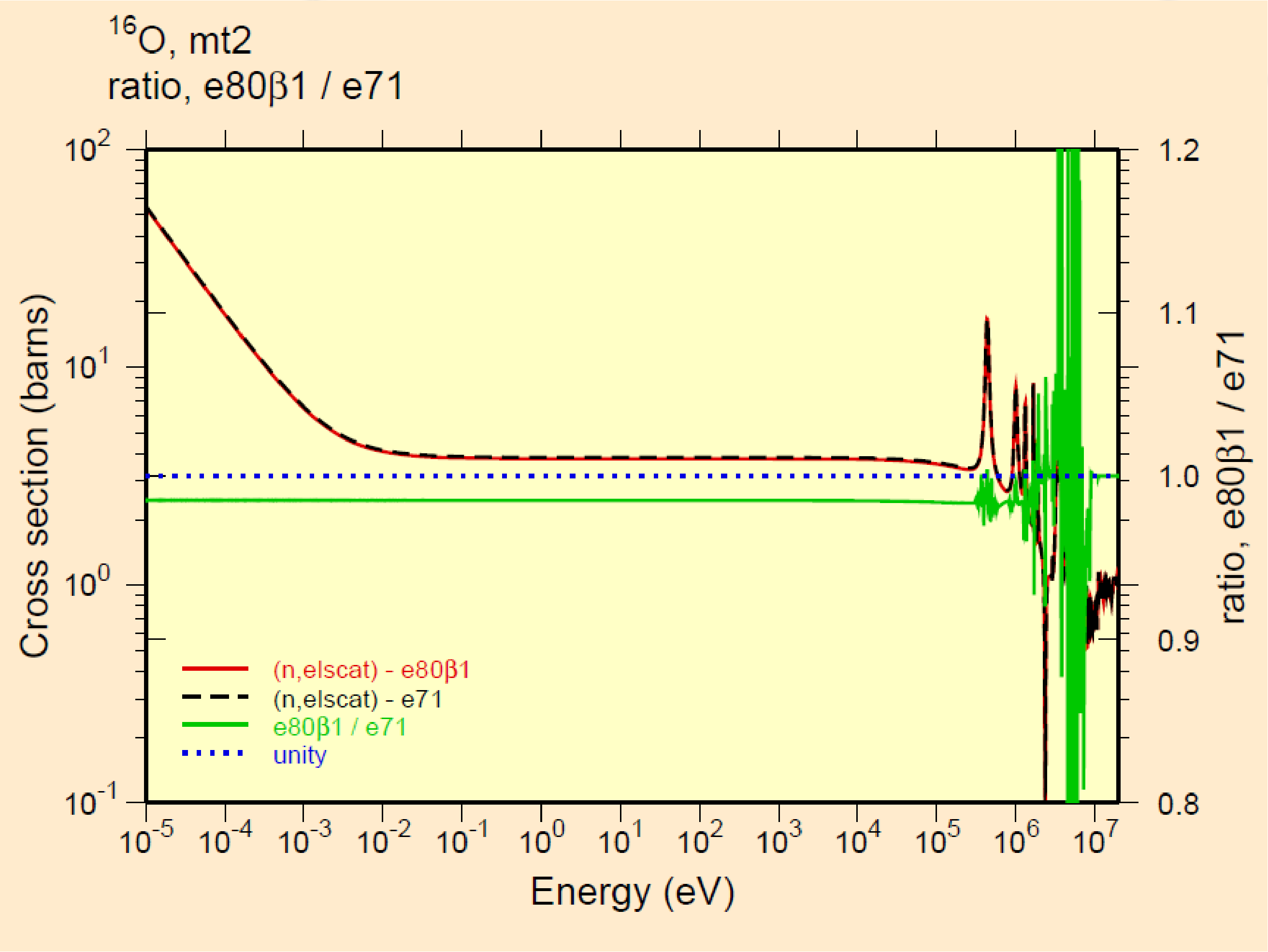
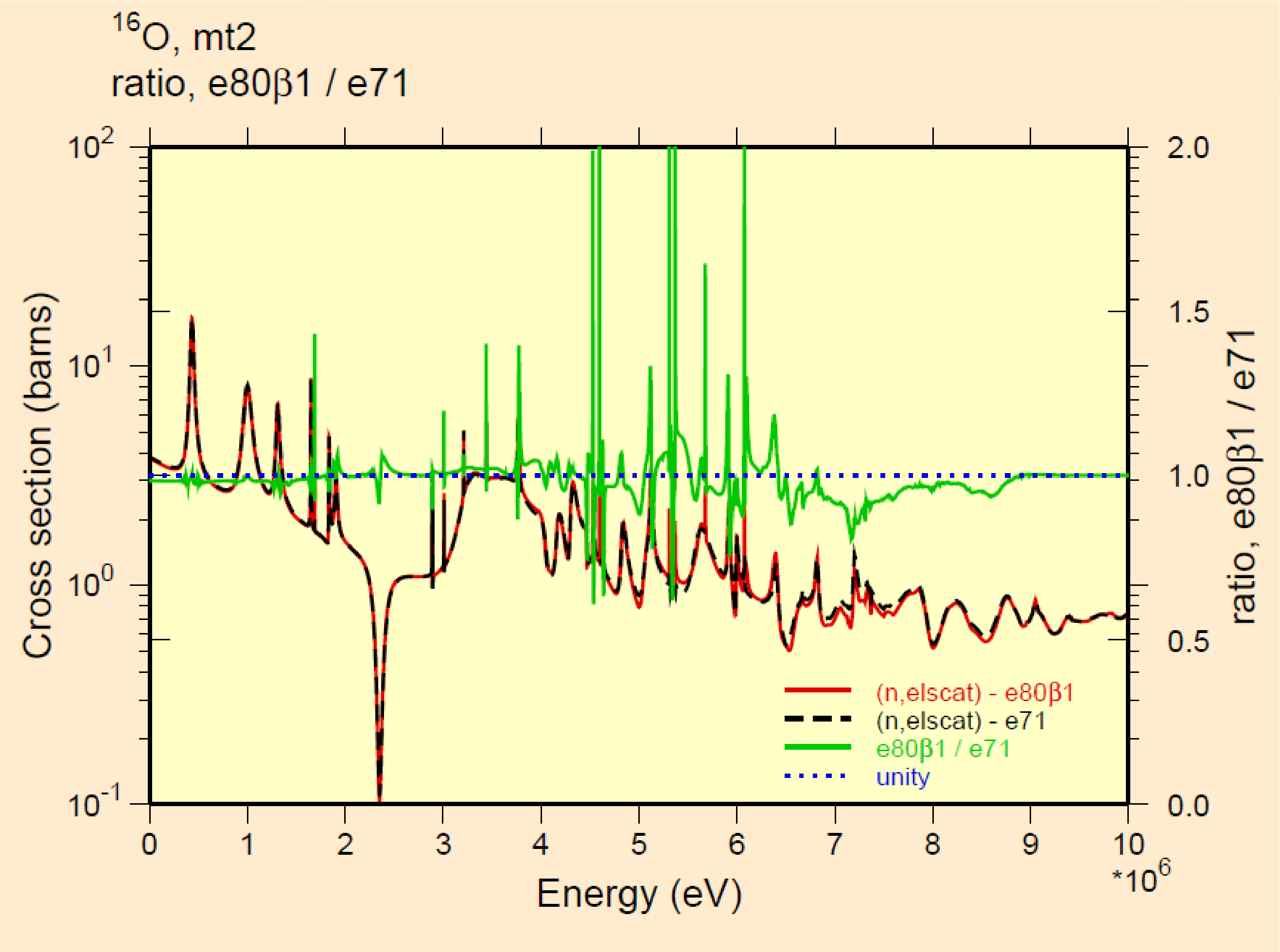
Oxygen & HST …

^{16}O – Cross Sections



Small, essentially constant decrease in elastic scattering in the first MeV.

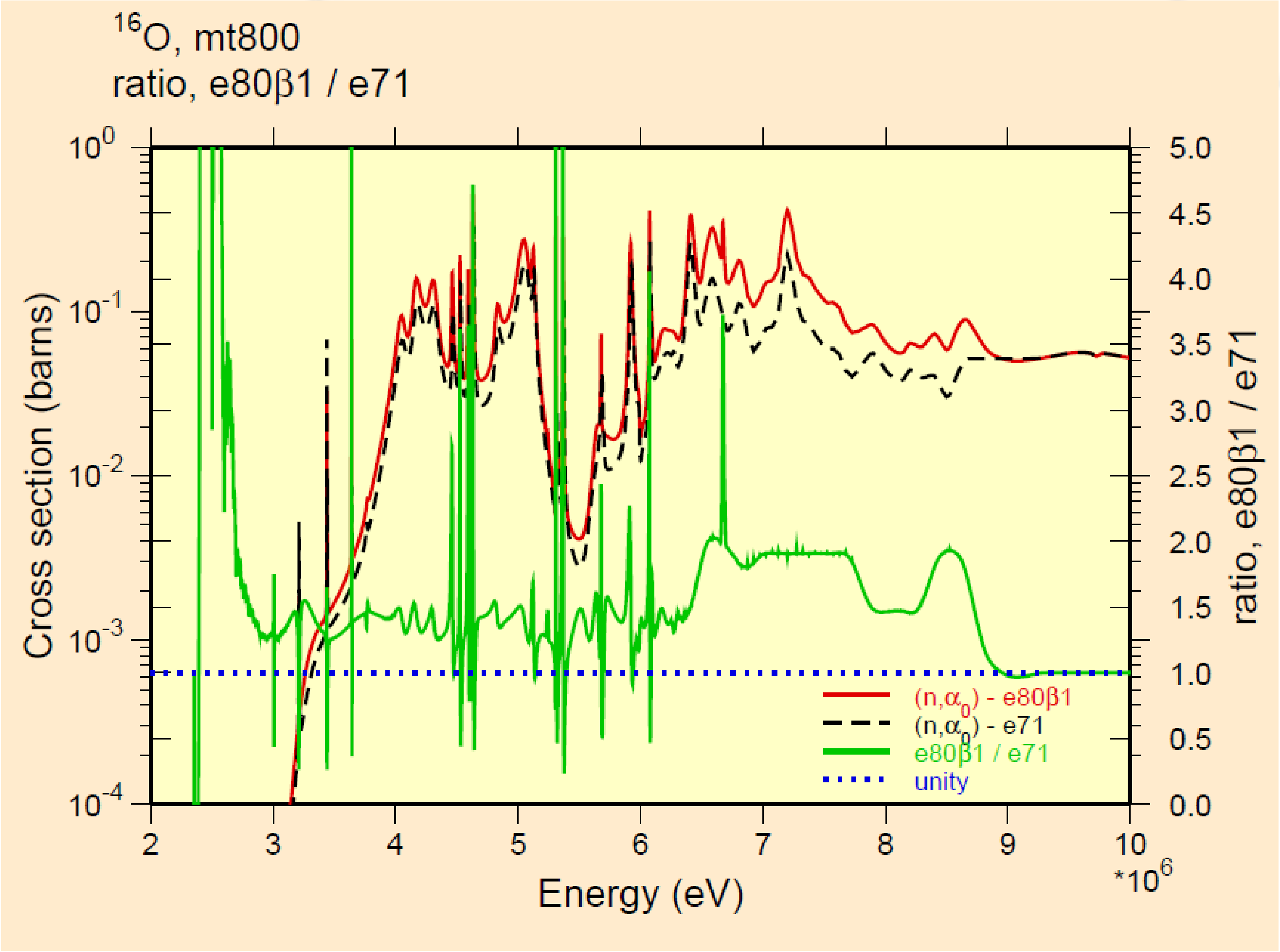
^{16}O – Cross Sections



Small localized changes due to minor tweaks in the underlying resonances.

No changes above about 9 MeV.

^{16}O – Cross Sections



Large changes in (n,α_0) from threshold through several MeV.

No changes above about 9 MeV.

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

- 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?”.

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

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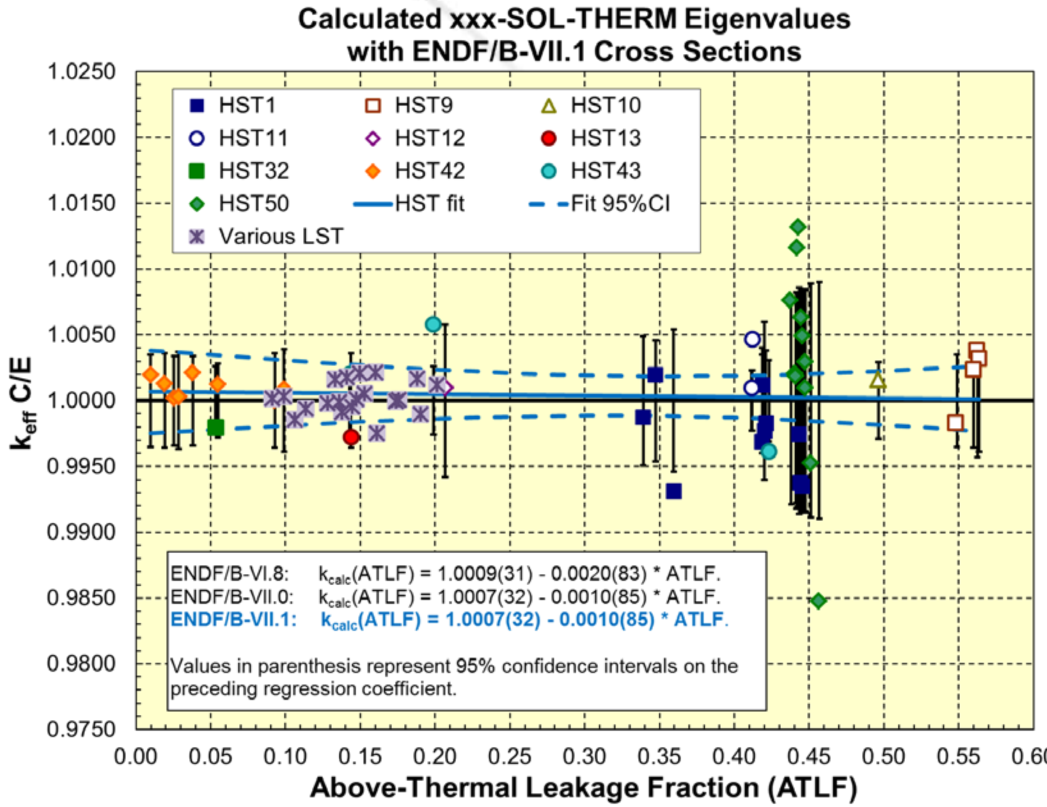
- Near unity intercept and near zero slope indicate no bias in calculated eigenvalues for the HST benchmark class (with e71).
  - e71 + ^{235}U_19c + ^{238}U_04c + ^{16}O_05c:
    - b = 1.0002(31)
    - m = +0.0019(83)
  - e71 + CAB h-h$_2$o kernel:
    - b = 1.0003(33)
    - m = -0.0005(87)



***** Where we were last Fall *****

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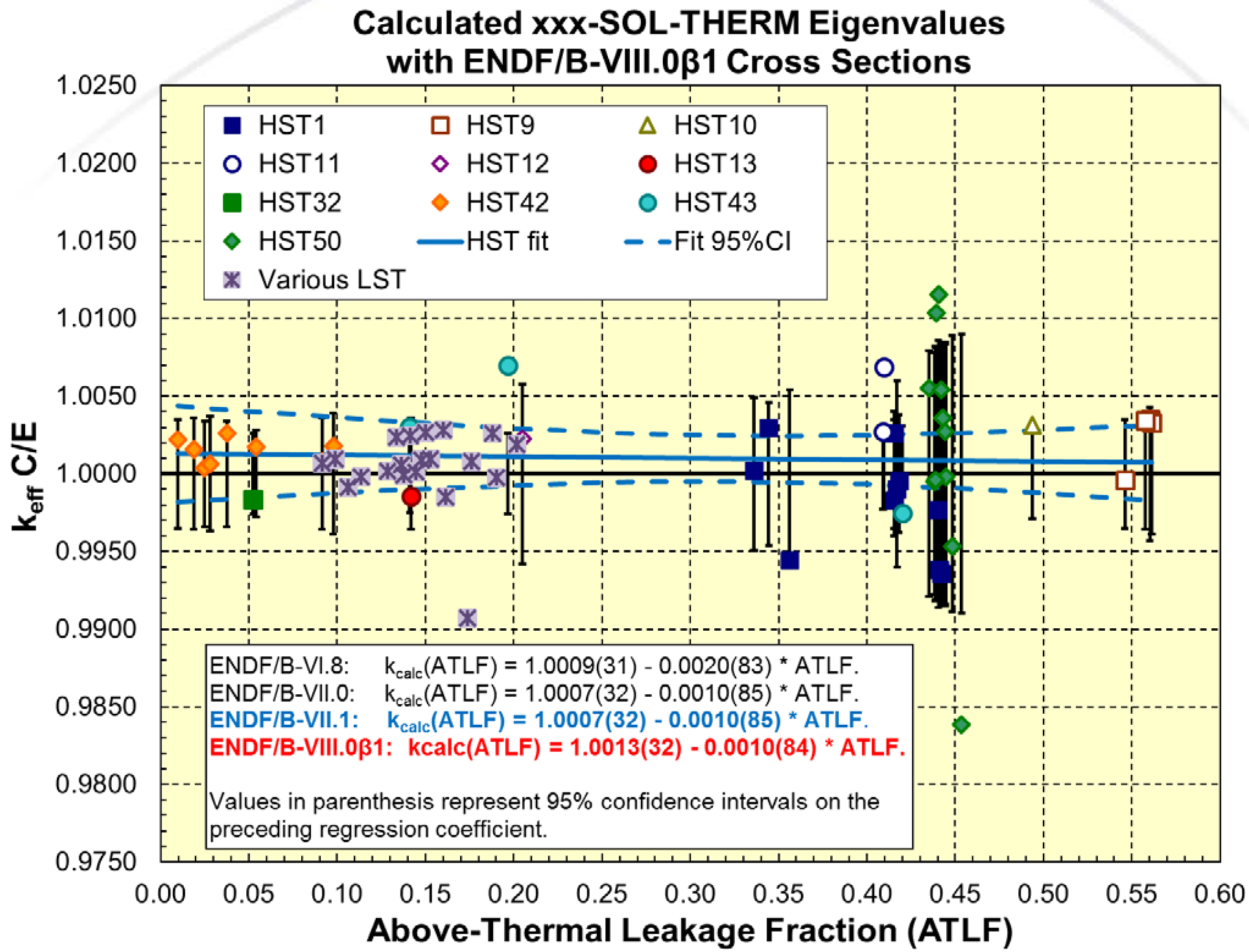
^{235}U (& ^{1}H, ^{16}O) – HST Benchmarks



Accurate HST k_{calc} values have been obtained for several generations of ENDF/B cross sections.

^{238}U & LCT Benchmarks

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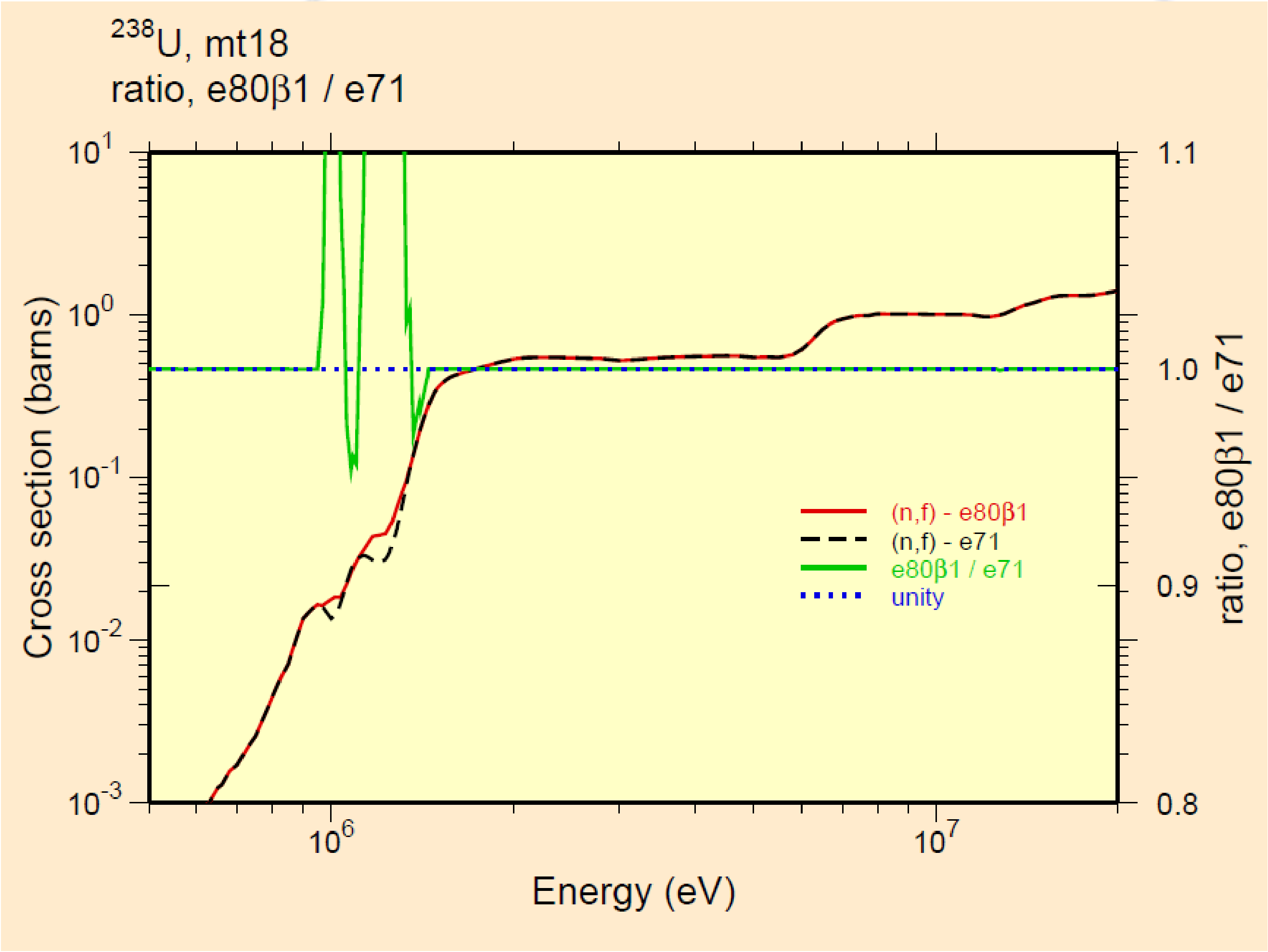
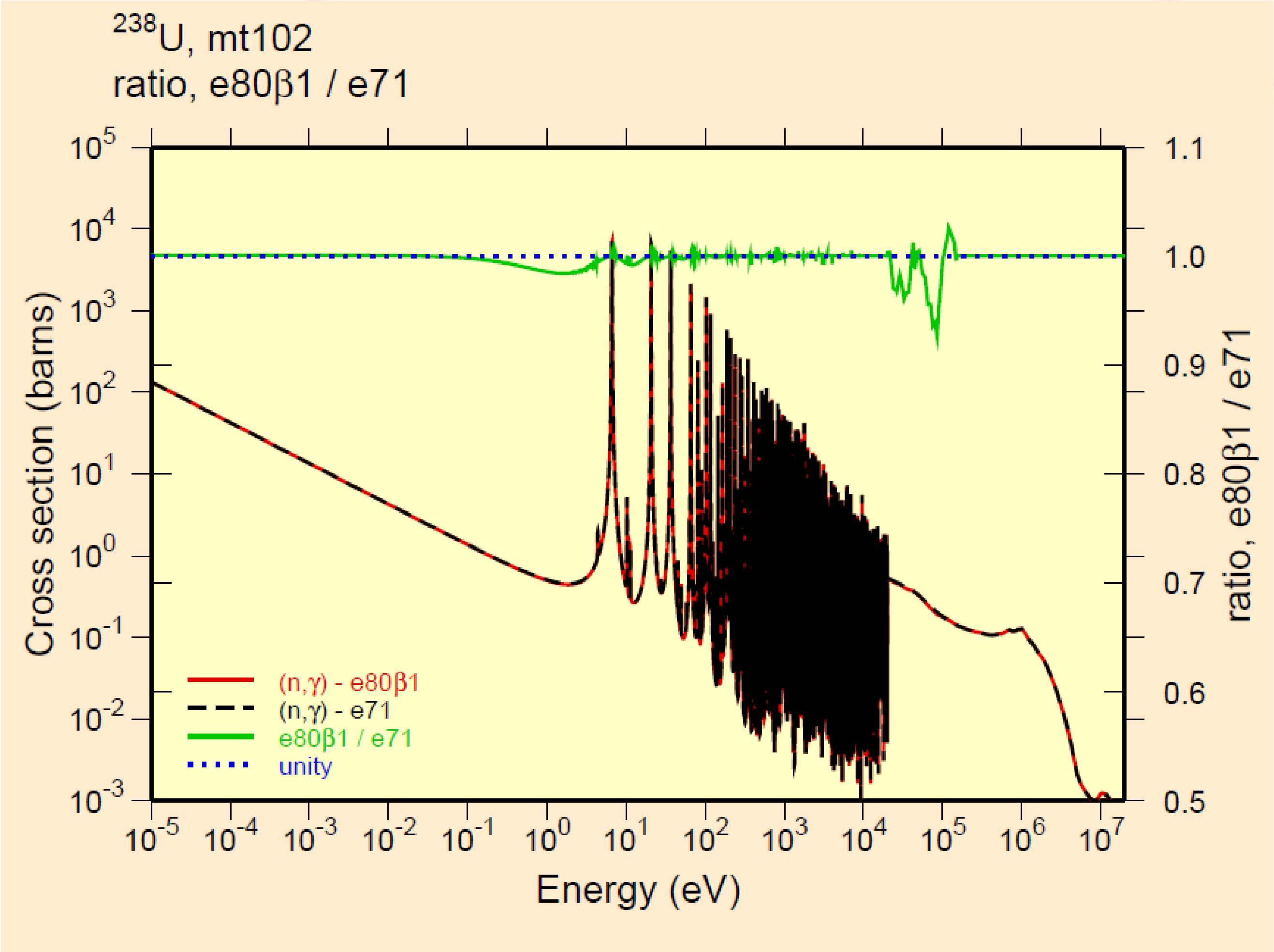
^{238}U Cross Sections …



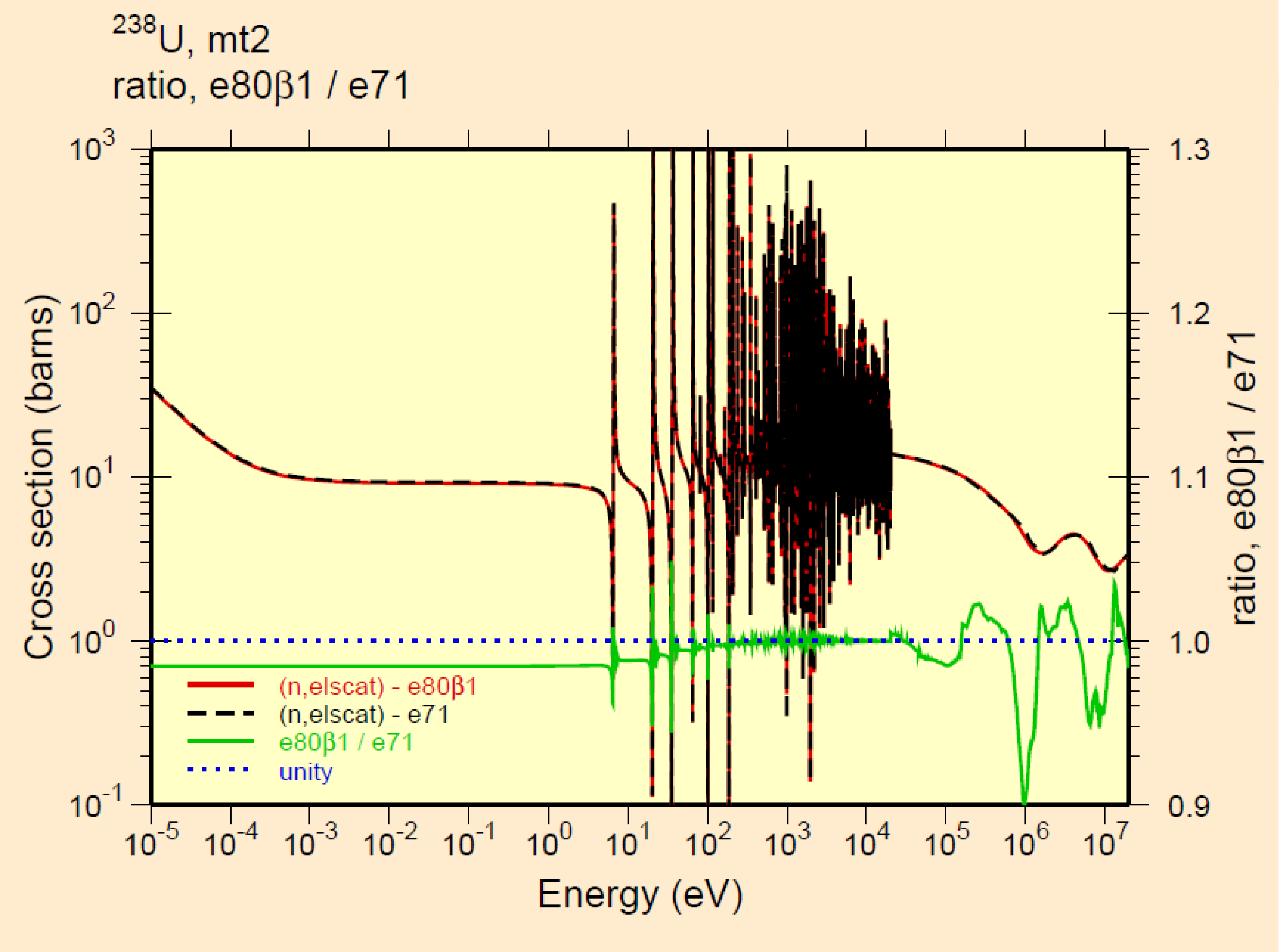
Fission cross section is virtually unchanged from e71 to e80β1.

^{238}U Cross Sections …



The (n,γ) cross section is virtually unchanged from e71 to e80β1.

^{238}U Cross Sections …

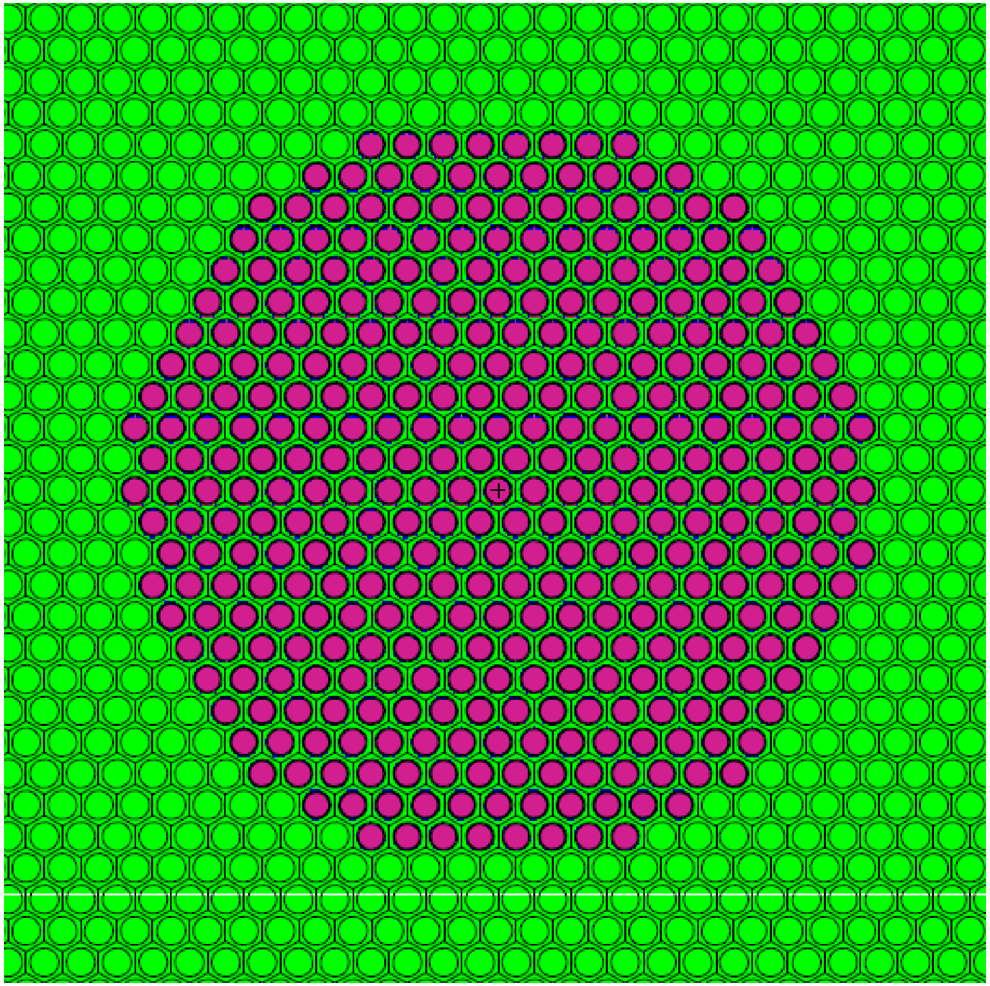


Small elastic scattering cross section changes in the thermal region and some differences in the hundreds of keV to MeV energy region from e71 to e80β1.

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

- Use a subset of LEU-COMP-THERM (LCT) benchmarks
  - LCT5 cases 1, 5 and 12 have water-to-fuel volume ratio of 2.7, 1.0 and 0.5, respectively.
  - The variable rod pitch in LCT7 allows testing of under-moderated (1.26 cm rod pitch), near optimally moderated (1.6 cm and 2.1 cm rod pitch) and over-moderated (2.52 cm rod pitch) conditions.
  - LCT10 and LCT17 consist of several clusters plus one of (i) Lead; (ii) ^{nat}U; or (iii) Steel reflectors.
    - Can use LCT2 and LCT1, respectively, for unreflected “base case” comparison.
  - LCT8 are B&W lattices with varying amounts of soluble boron.
  - LCT42 is similar to LCT10 and LCT17 but also includes metal plates between the clusters.
- As with HST, we’re in pretty good shape for this benchmark class, so “… if it isn’t broke, don’t fix it!”.

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

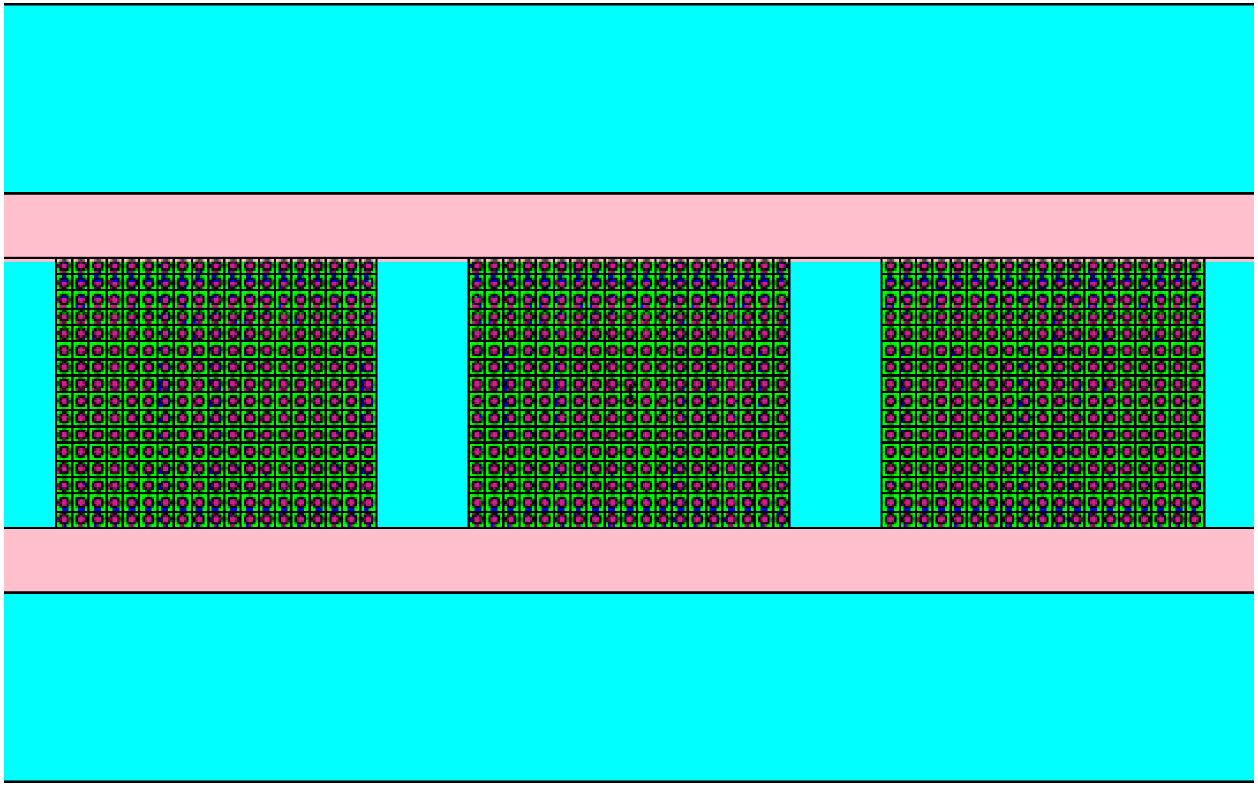


LEU-COMP-THERM-005, case 5 is shown
- 378 rods, 1.801 cm pitch.

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.

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



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.

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

*** Where we were last Fall ***

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Benchmark	Benchmark keff	endf/b-vii.1 (e71)	e71 + 235U_19c + 238U_04c + 16O_05c + 56Fe_02c	"new" - e71, pcm
LCT1.1	0.9998	0.99955	0.99871	-84
LCT1.2	0.9998	0.99906	0.99786	-120
LCT1.3	0.9998	0.99850	0.99762	-88
LCT1.4	0.9998	0.99908	0.99813	-95
LCT1.5	0.9998	0.99695	0.99604	-91
LCT1.6	0.9998	0.99890	0.99784	-106
LCT1.7	0.9998	0.99829	0.99726	-103
LCT1.8	0.9998	0.99732	0.99641	-91
				-97
LCT2.1	0.9997	0.99845	0.99805	-40
LCT2.2	0.9997	0.99978	0.99941	-37
LCT2.3	0.9997	0.99914	0.99877	-37
LCT2.4	0.9997	0.99870	0.99847	-23
LCT2.5	0.9997	0.99772	0.99712	-60
				-39
LCT5.1	1.0000	1.00265	1.00197	-68
LCT5.5	1.0000	1.00504	1.00137	-367
LCT5.12	1.0000	1.00645	1.00062	-583
				-339

MCNP stochastic uncertainty is typically 10 pcm, or less.

Benchmark	Benchmark keff	endf/b-vii.1 (e71)	e71 + 235U_19c + 238U_04c + 16O_05c + 56Fe_02c	"new" - e71, pcm
LCT7.1	1.0000	0.99759	0.99574	-185
LCT7.2	1.0000	0.99884	0.99852	-32
LCT7.3	1.0000	0.99750	0.99786	36
LCT7.4	1.0000	0.99810	0.99784	-26
				-52
LCT8.1	1.0007	1.00060	0.99677	-383
LCT8.2	1.0007	1.00087	0.99724	-363
LCT8.5	1.0007	1.00042	0.99665	-377
LCT8.7	1.0007	1.00017	0.99665	-352
LCT8.8	1.0007	0.99981	0.99624	-357
LCT8.11	1.0007	1.00135	0.99747	-388
				-370
LCT10.5	1.0000	0.99950	0.99812	-138
LCT10.6	1.0000	1.00008	0.99910	-98
LCT10.7	1.0000	1.00122	1.00071	-51
LCT10.8	1.0000	0.99788	0.99747	-41
				-82
LCT17.4	1.0000	0.99803	0.99660	-143
LCT17.5	1.0000	0.99989	0.99846	-143
LCT17.6	1.0000	1.00002	0.99882	-120
LCT17.7	1.0000	0.99986	0.99880	-106
LCT17.8	1.0000	0.99822	0.99721	-101
LCT17.9	1.0000	0.99770	0.99670	-100
				-119

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

Benchmark	Benchmark k_{eff}	endf/b-vii.1 (e71)	e8 starter (Fall, 2015)	e80b1 (April, 2016)
LCT1.1	0.9998	0.99955	0.99871	1.00004
LCT1.2	0.9998	0.99906	0.99786	0.99961
LCT1.3	0.9998	0.99850	0.99762	0.99927
LCT1.4	0.9998	0.99908	0.99813	0.99966
LCT1.5	0.9998	0.99695	0.99604	0.99735
LCT1.6	0.9998	0.99890	0.99784	0.99935
LCT1.7	0.9998	0.99829	0.99726	0.99882
LCT1.8	0.9998	0.99732	0.99641	0.99788
LCT2.1	0.9997	0.99845	0.99805	0.99900
LCT2.2	0.9997	0.99978	0.99941	1.00037
LCT2.3	0.9997	0.99914	0.99877	0.99998
LCT2.4	0.9997	0.99870	0.99847	0.99977
LCT2.5	0.9997	0.99772	0.99712	0.99857
LCT5.1	1.0000	1.00265	1.00197	1.00277
LCT5.5	1.0000	1.00504	1.00137	1.00236
LCT5.12	1.0000	1.00645	1.00062	1.00236

Good results …
- small negative bias in e71 LCT1 & LCT2 results is reduced.
- Trend in LCT5 is eliminated.

MCNP stochastic uncertainty is typically 10 pcm, or less.

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

Benchmark	Benchmark k_{eff}	endf/b-vii.1 (e71)	e8 starter (Fall, 2015)	e80b1 (April, 2016)
LCT7.1	1.0000	0.99759	0.99574	0.99690
LCT7.2	1.0000	0.99884	0.99852	0.99942
LCT7.3	1.0000	0.99750	0.99786	0.99890
LCT7.4	1.0000	0.99810	0.99784	0.99958
LCT8.1	1.0007	1.00060	0.99677	1.00041
LCT8.2	1.0007	1.00087	0.99724	1.00091
LCT8.5	1.0007	1.00042	0.99665	1.00020
LCT8.7	1.0007	1.00017	0.99665	0.99978
LCT8.8	1.0007	0.99981	0.99624	0.99901
LCT8.11	1.0007	1.00135	0.99747	1.00123
LCT10.5 (U)	1.0000	0.99950	0.99812	0.99931
LCT10.6 (U)	1.0000	1.00008	0.99910	0.99999
LCT10.7 (U)	1.0000	1.00122	1.00071	1.00157
LCT10.8 (U)	1.0000	0.99788	0.99747	0.99846
LCT17.4 (U)	1.0000	0.99803	0.99660	0.99811
LCT17.5 (U)	1.0000	0.99989	0.99846	1.00002
LCT17.6 (U)	1.0000	1.00002	0.99882	1.00027
LCT17.7 (U)	1.0000	0.99986	0.99880	1.00027
LCT17.8 (U)	1.0000	0.99822	0.99721	0.99878
LCT17.9 (U)	1.0000	0.99770	0.99670	0.99836

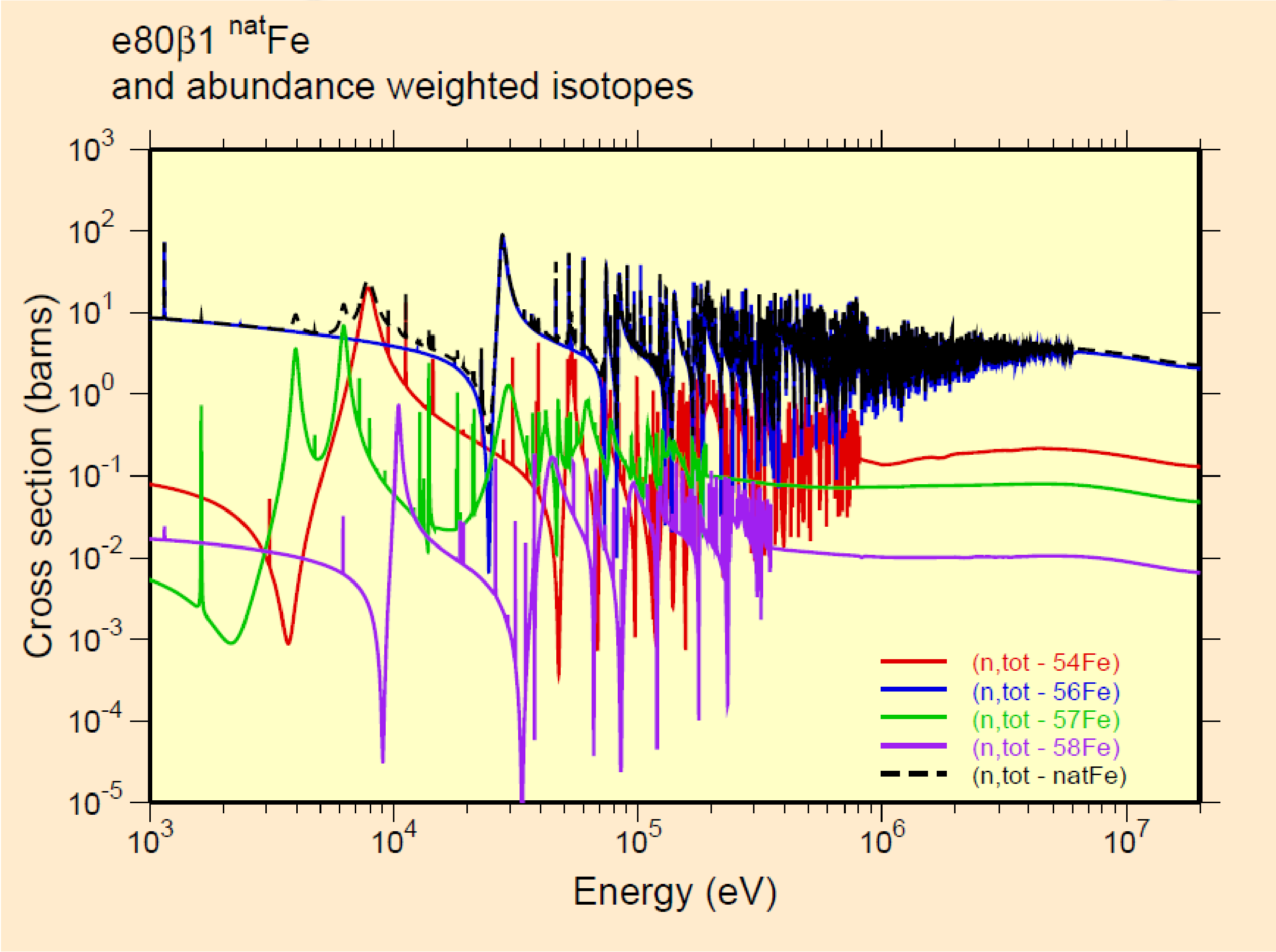
Good results …

- LCT8 results were poor with “e8 starter” files but are now satisfactory.
- Little to no difference in other LCT cases between e71 and e80β1.

MCNP stochastic uncertainty is typically 10 pcm, or less.

^{56}Fe & HMF, PMF and LCT …

^{iso}Fe Cross Sections …



^{nat}Fe is not the same as ^{56}Fe!

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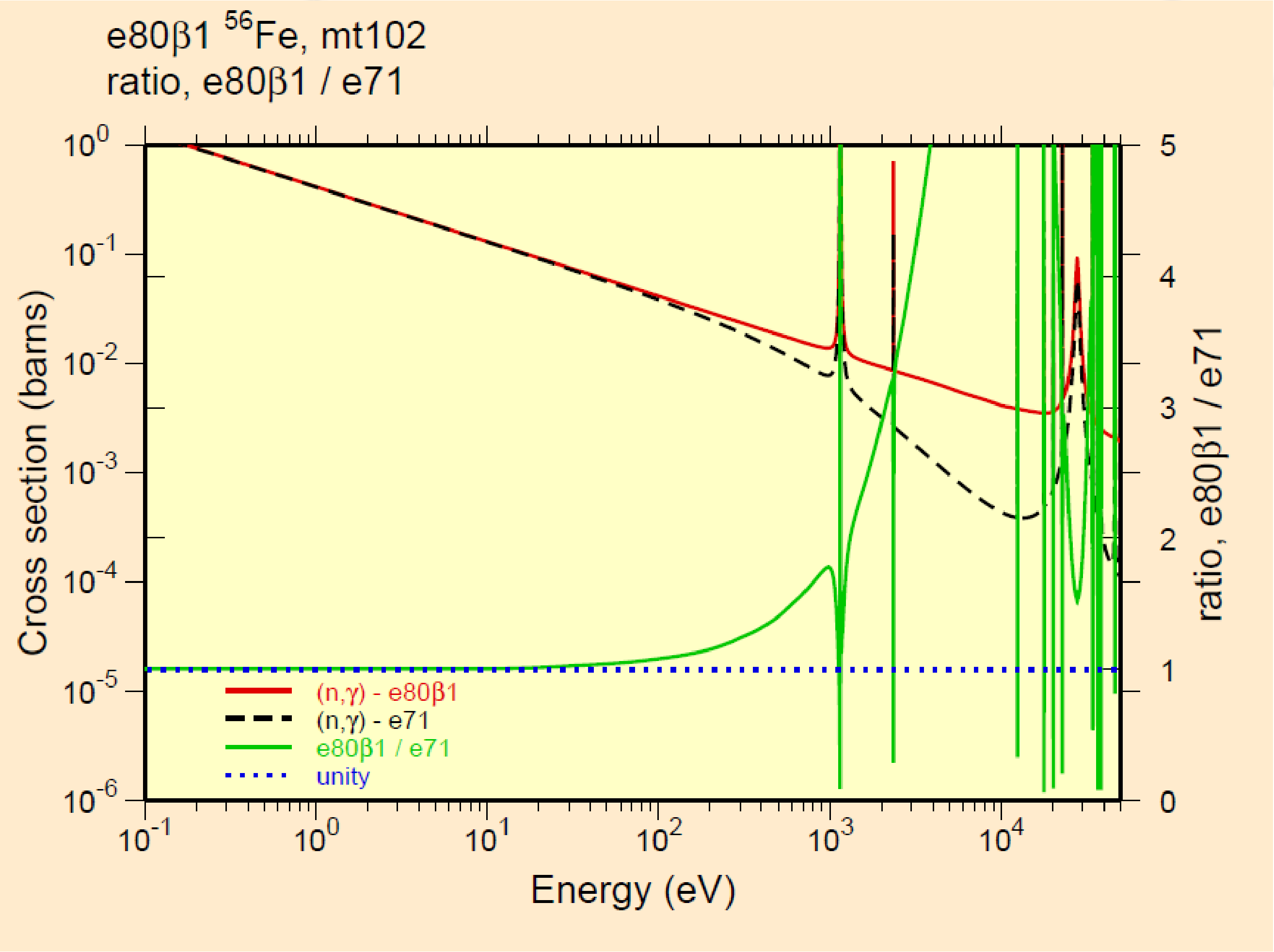
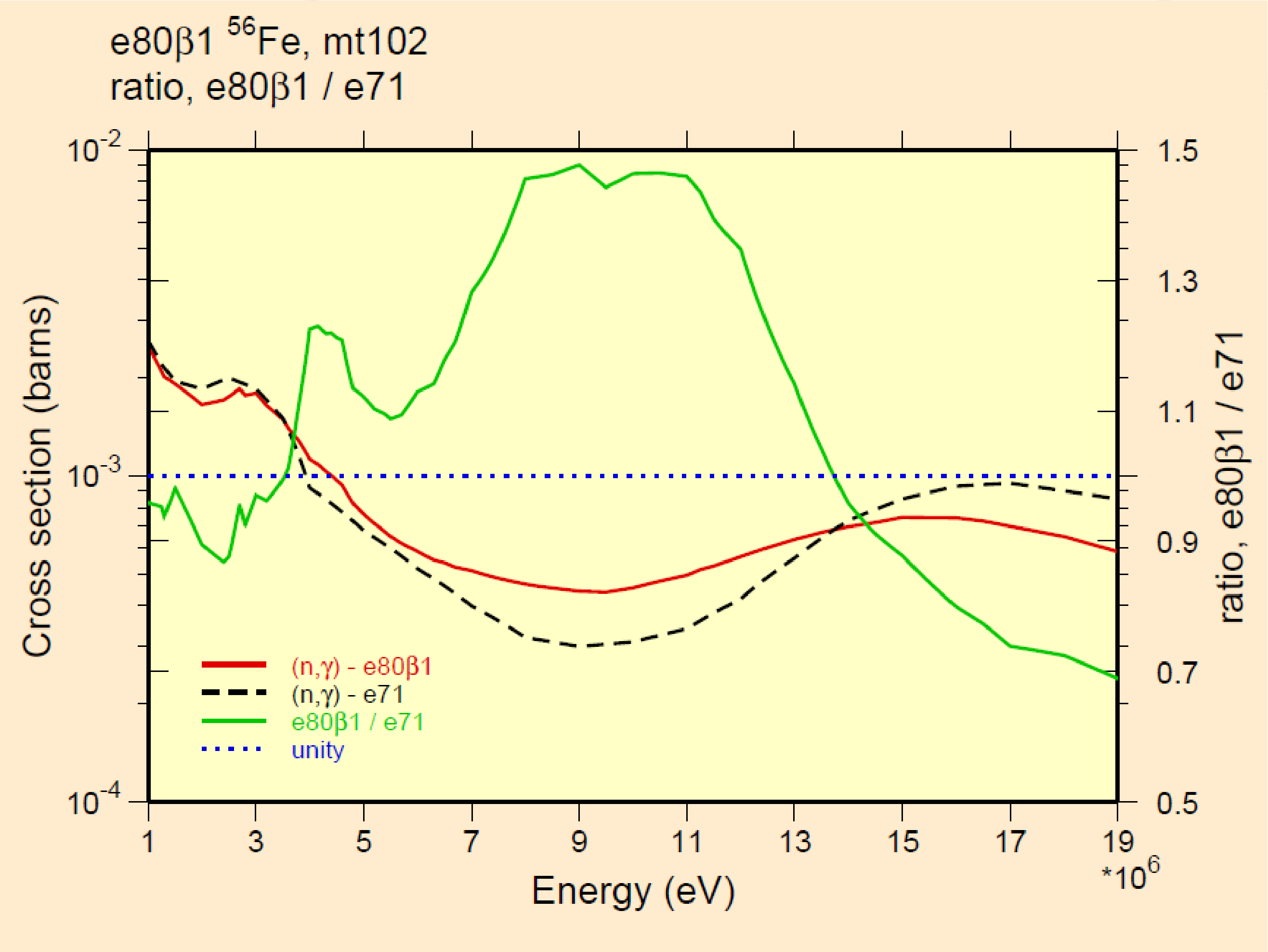
^{56}Fe Cross Sections …



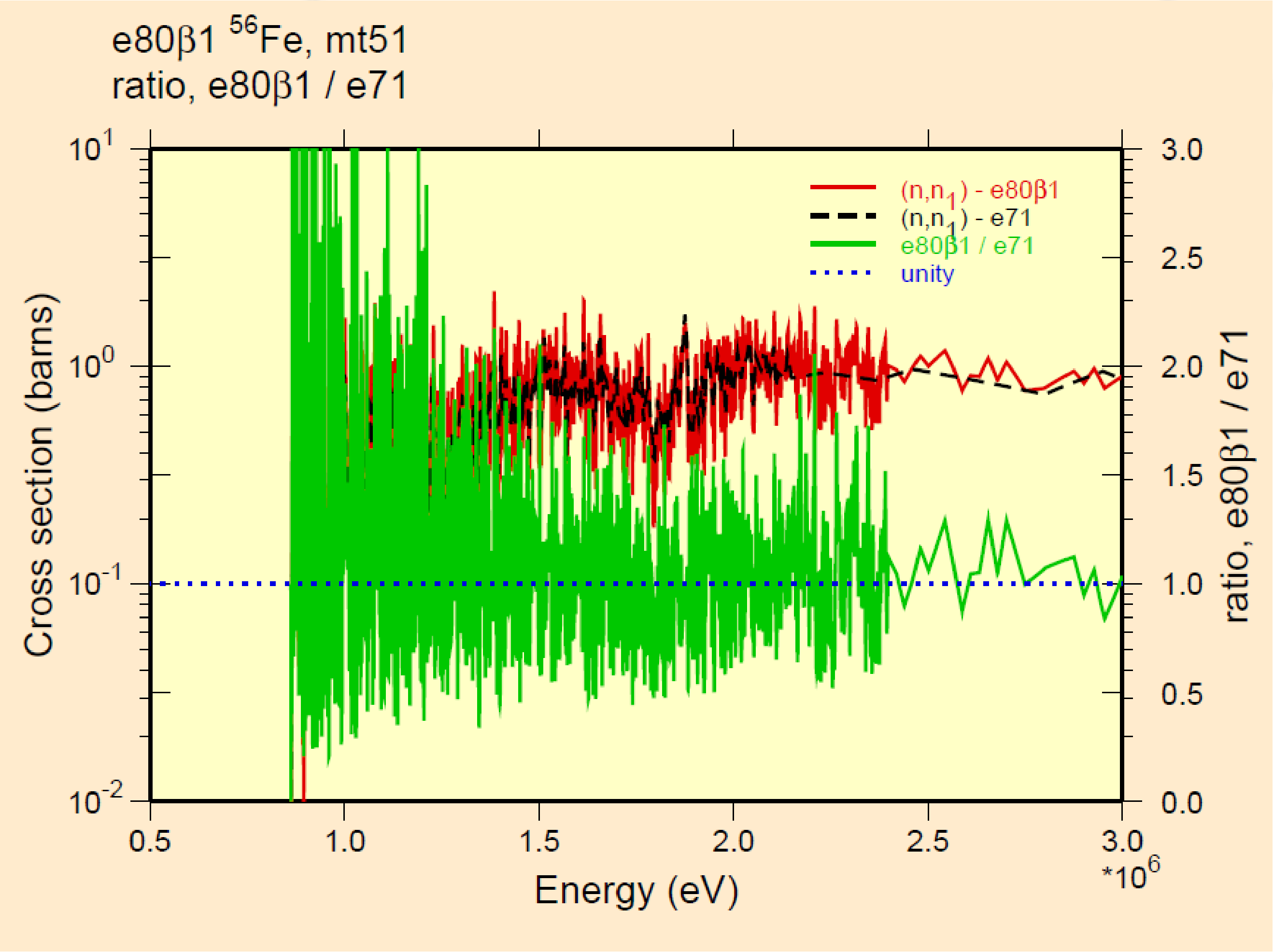
Very large changes in the capture resolved resonance shape … is this real???

^{56}Fe Cross Sections …



The absolute capture cross section is small but it's surprising to see 50% changes … is this real?

^{56}Fe Cross Sections …

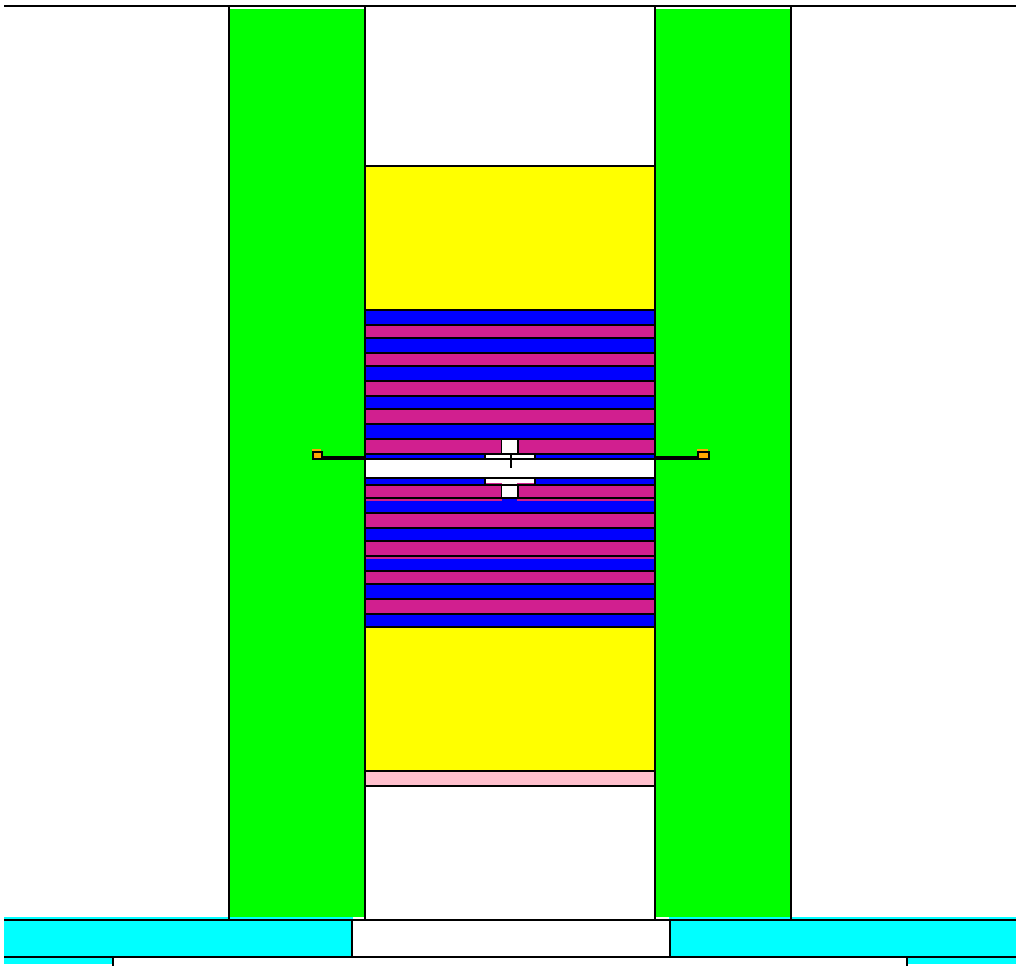


Inelastic scattering to the first excited level … not as much fluctuation in e80β1 as in earlier CIELO candidate files or in e71.

(Some) ICSBEP Benchmarks with Iron

- 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.
- HMF87 – HEU cylindrical assembly with interstitial steel.
- HMF88 – HEU cylindrical assembly with interstitial steel or steel & polyethylene plus a polyethylene radial/axial reflector.
- LCT10, 17 & 42 – multiple UO_2 rod clusters with steel reflecting walls (LCT42 also has absorber plates between clusters).
- 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.

ICSBEP's HMF88.1 Geometry



HEU-MET-FAST-088, case 1 (interstitial steel with radial and axial CH_2 reflectors).

Similar benchmarks, such as HEU-MET-FAST-087, do not have axial or radial reflectors.

^{235}U, ^{239}Pu & ^{56}Fe – HMF & PMF assemblies

*** Where we were last Fall ***

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Benchmark	Benchmark keff	endf/b-vii.1 (e71) kcalc C/E	e71 + ^{235}U (19c) + ^{238}U (04c) + ^{16}O (05c)	e71 + ^{235}U (19c) + ^{238}U (04c) + ^{16}O (05c) + ^{56}Fe (02c)	"new" - e71, pcm
HMF13	0.9990	0.99834	0.99843	0.99817	-17
HMF21	1.0000	0.99730	0.99732	0.99651	-79
HMF24	0.9990	0.99939	0.99986	0.99944	5
HMF87	0.9987	0.99970	1.00001	1.00040	70
HMF88.1	0.9993	0.99745	0.99872	0.99862	117
HMF88.2	0.9993	0.99734	0.99858	0.99782	48
Benchmark	**Benchmark keff**	**endf/b-vii.1 (e71) kcalc**	**e71 + ^{239}Pu (23c)**	**e71 + ^{239}Pu (23c) + ^{56}Fe (02c)**	**"new" - e71, pcm**
PMF25	1.0000	0.99880	0.99821	0.99857	-23
PMF26	1.0000	0.99845	0.99786	0.99725	-120
PMF28	1.0000	0.99896	0.99830	0.99743	-153
PMF32	1.0000	0.99862	0.99780	0.99790	-72

^{235}U, ^{239}Pu & ^{56}Fe – HMF & PMF assemblies

Benchmark	Benchmark keff	endf/b-vii.1 C/E (e71)	e8 starter C/E (Fall, 2015)	e80β1 C/E (April, 2016)
HMF13	0.9990	0.99834	0.99817	0.99901
HMF21	1.0000	0.99730	0.99651	0.99844
HMF24	0.9990	0.99939	0.99944	0.99973
HMF87	0.9987	0.99970	1.00040	1.00137
HMF88.1	0.9993	0.99745	0.99862	0.99930
HMF88.2	0.9993	0.99734	0.99782	0.99814
PMF25	1.0000	0.99880	0.99857	0.99888
PMF26	1.0000	0.99845	0.99725	0.99893
PMF28	1.0000	0.99896	0.99743	0.99975
PMF32	1.0000	0.99862	0.99790	0.99883

The small reactivity loss seen in FAST systems with last Fall's "starter" files has been largely eliminated.

^{235,238}U, ^{16}O & ^{56}Fe – LCT assemblies

Benchmark	Benchmark keff	endf/b-vii.1 (e71) kcalc	e71 + ^{235}U (19c) + ^{238}U (04c) + ^{16}O (05c)	e71 + ^{235}U (19c) + ^{238}U (04c) + ^{16}O (05c) + ^{56}Fe (02c)	"new" - e71, pcm
LCT10.9	1.0000	0.99994	0.99874	1.00001	7
LCT10.10	1.0000	1.00024	0.99920	1.00025	1
LCT10.11	1.0000	1.00062	0.99940	1.00037	-25
LCT10.12	1.0000	0.99975	0.99873	0.99939	-36
LCT10.13	1.0000	0.99758	0.99706	0.99696	-62
LCT17.10	1.0000	0.99809	0.99692	0.99742	-67
LCT17.11	1.0000	0.99842	0.99731	0.99771	-71
LCT17.12	1.0000	0.99860	0.99735	0.99731	-129
LCT17.13	1.0000	0.99881	0.99775	0.99772	-109
LCT17.14	1.0000	0.99915	0.99777	0.99810	-105
LCT42.1	1.0000	0.99816	0.99592	0.99658	-158
LCT42.2	1.0000	0.99804	0.99563	0.99608	-196
LCT42.3	1.0000	0.99897	0.99652	0.99690	-207
LCT42.4	1.0000	0.99838	0.99615	0.99622	-216
LCT42.5	1.0000	0.99930	0.99712	0.99756	-174
LCT42.6	1.0000	0.99937	0.99727	0.99780	-157
LCT42.7	1.0000	0.99776	0.99538	0.99588	-188

*** Where we were last Fall ***

LCT10 has the largest rod pitch (2.54 cm).

LCT17 is smaller (2.032 cm).

LCT42 is smallest (1.684 cm).

$^{235,238}U$, ^{16}O & ^{56}Fe – LCT assemblies

Benchmark	Benchmark keff	endf/b-vii.1 (e71)	e8 starter (Fall, 2015)	e80b1 (April, 2016)
LCT10.9 (Fe)	1.0000	0.99994	1.00001	0.99984
LCT10.10 (Fe)	1.0000	1.00024	1.00025	0.99993
LCT10.11 (Fe)	1.0000	1.00062	1.00037	1.00025
LCT10.12 (Fe)	1.0000	0.99975	0.99939	0.99988
LCT10.13 (Fe)	1.0000	0.99758	0.99696	0.99815
LCT17.10 (Fe)	1.0000	0.99809	0.99742	0.99811
LCT17.11 (Fe)	1.0000	0.99842	0.99771	0.99836
LCT17.12 (Fe)	1.0000	0.99860	0.99731	0.99839
LCT17.13 (Fe)	1.0000	0.99881	0.99772	0.99902
LCT17.14 (Fe)	1.0000	0.99915	0.99810	0.99948
LCT42.1 (Fe)	1.0000	0.99816	0.99658	0.99745
LCT42.2 (Fe)	1.0000	0.99804	0.99608	0.99700
LCT42.3 (Fe)	1.0000	0.99897	0.99690	0.99771
LCT42.4 (Fe)	1.0000	0.99838	0.99622	0.99701
LCT42.5 (Fe)	1.0000	0.99930	0.99756	0.99770
LCT42.6 (Fe)	1.0000	0.99937	0.99780	0.99846
LCT42.7 (Fe)	1.0000	0.99776	0.99588	0.99669

LCT10 has the largest rod pitch (2.54 cm).

LCT17 is smaller (2.032 cm).

LCT42 is smallest (1.684 cm).

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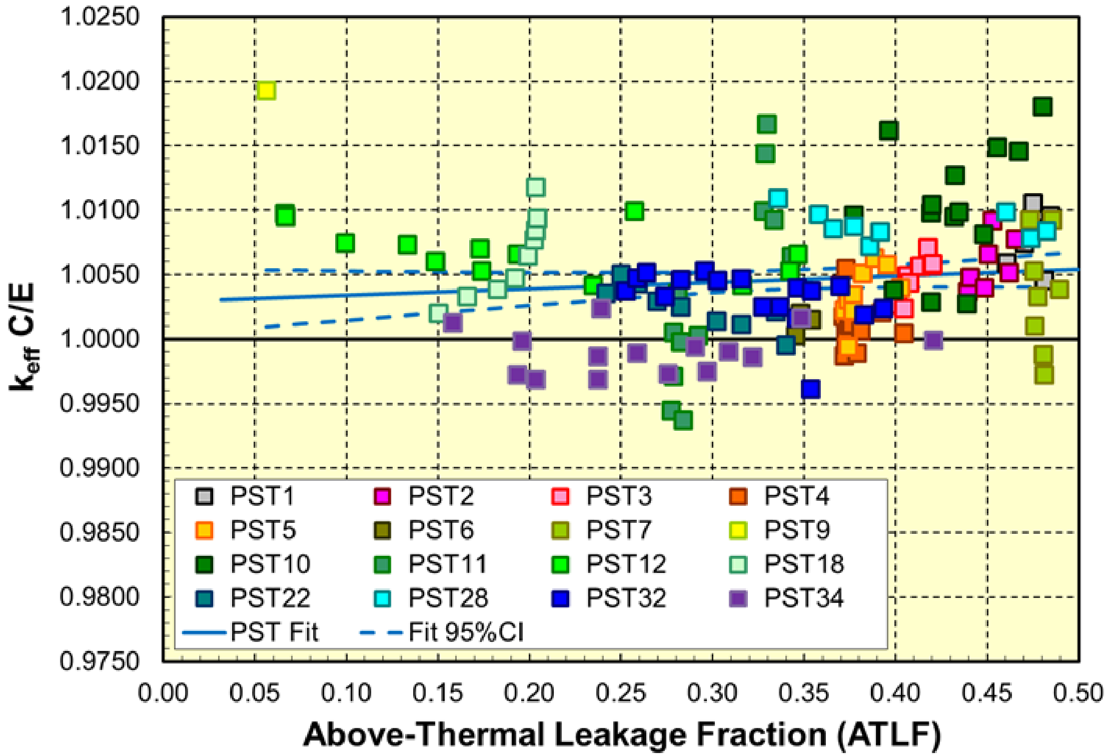
^{239}Pu (& ^{1}H, ^{16}O) – PST Benchmarks

- The average calculated eigenvalue for the Pu-SOL-THERM benchmark class has been biased high by about 450 pcm for many years (ENDF/B-VII.1 results shown).



We use a small subset of the Pu-SOL-THERM benchmark population to assess candidate files.
- 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.

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

- k_{eff} C/E results with various SG34 and CIELO candidate files …

Benchmark	Benchmark keff	e71 (with mf3/mt18 background fix)	e71 + SG34 ^{239}Pu	e71 + ^{239}Pu (23c) + ^{16}O (05c)	e71 + ^{239}Pu (24c) + ^{16}O (05c)
PST1.4	1.0000	1.00451	1.00209	0.99969	0.99846
PST4.1	1.0000	1.00411	1.00052	0.99870	0.99763
PST12.10	1.0000	1.00417	1.00078	0.99931	0.99806
PST12.13	1.0000	1.00974	1.00623	1.00503	1.00396
PST18.6	1.0000	1.00484	1.00195	1.00082	0.99956
PST34.4	1.0000	1.00248	0.99933	0.99767	0.99540
PST34.15	1.0000	0.99733	0.99719	0.99590	0.99914
PST average:		***1.00388***	***1.00116***	***0.99959***	***0.99889***

239Pu_24c is 23c but Leal "inic12" RR parameters to 4 keV; URR to 30 keV.

*** Where we were last Fall ***

For ENDF, WPEC Subgroup 34 efforts eliminated ~70% of the historical *average* k_{calc} bias.

On average, the latest ^{239}Pu and ^{16}O files eliminate the remaining bias.

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

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- k_{eff} C/E results with various SG34 and CIELO candidate files …

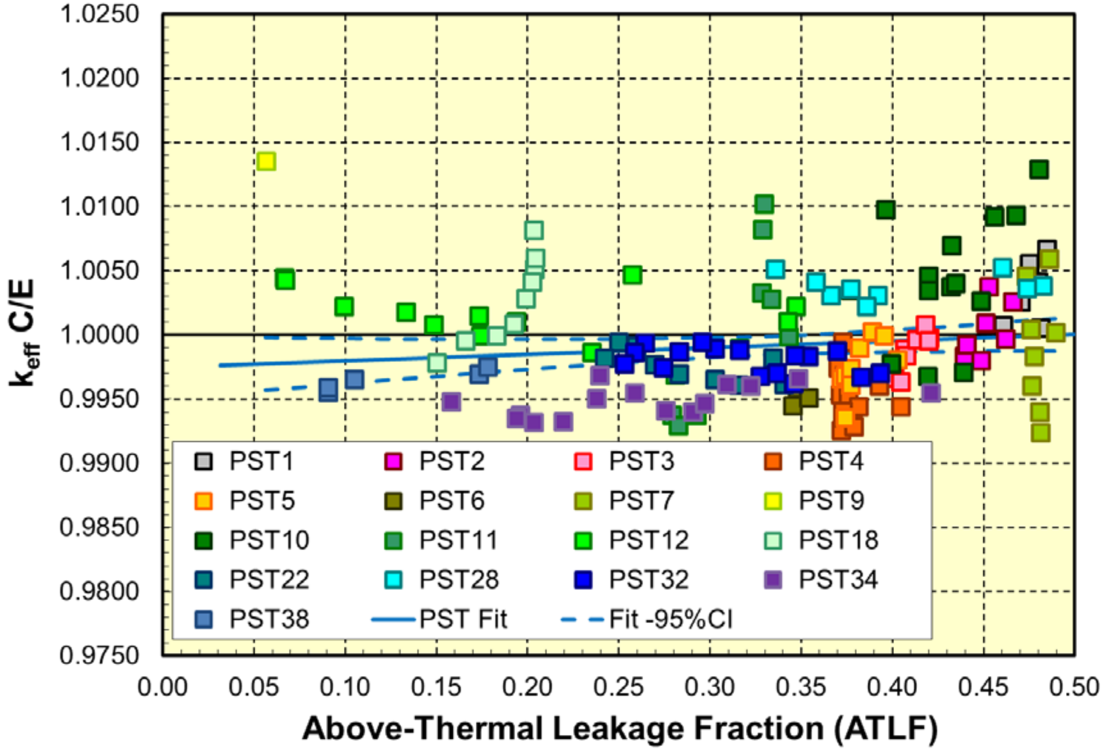
Benchmark	Benchmark keff	e71 (80c)	e71 + SG34 ^{239}Pu	e8 starter (Fall, 2015)	e80b1 (April, 2016)
PST1.4	**1.0000**	**1.00470**	1.00209	**0.99969**	**1.00058**
PST4.1	**1.0000**	**1.00385**	1.00052	**0.99870**	**0.99749**
PST12.10	**1.0000**	**1.00418**	1.00078	**0.99931**	**0.99864**
PST12.13	**1.0000**	**1.00967**	1.00623	**1.00503**	**1.00425**
PST18.6	**1.0000**	**1.00472**	1.00195	**1.00082**	**1.00088**
PST34.4	**1.0000**	**1.00226**	0.99933	**0.99767**	**0.99684**
PST34.15	**1.0000**	**0.99733**	0.99719	**0.99590**	**0.99351**
PST average:		***1.00382***	***1.00116***	***0.99959***	***0.99888***

WPEC Subgroup 34 efforts eliminated ~70% of the historical *average* k_{calc} bias.

On average, the latest ^{239}Pu, ^{16}O and h-h$_2$o files eliminate the remaining bias.

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

- The average calculated eigenvalue for the Pu-SOL-THERM benchmark class is now 0.9992(4) with a population standard deviation of 461 pcm.



ATLF regression parameters are:
- slope = 0.0052(68)
- intercept = 0.9974(24)

(Note: Values in () represent 95% confidence intervals.)

These results suggest the somewhat ad hoc “Romano” pfns tweak in ^{239}Pu can be relaxed.

PFNS Uncertainty (^{239}Pu)

- Impact of pfns uncertainty on k_{calc} and reaction rates …
  - Use the LANL Pu-MET-FAST-001 (Jezebel) critical assembly
    - ENDF/B-VII.1 cross sections plus a recent Neudecker ^{239}Pu pfns yields a calculated eigenvalue of 0.99797(3).
    - Generate a suite of 1000 pfns data sets, based upon evaluated uncertainty
      - Average k_{calc} is 0.99798, *population* standard deviation is 107 pcm.
      - The standard deviation in calculated spectral indices varies from a fraction of a per cent to almost 10%, depending upon the reaction rate average energy …
        - e.g., ^{239}Pu(n,f)/^{235}U(n,f) = 1.4203 ± 0.0017; ^{238}U(n,f)/^{235}U(n,f) = 0.2031 ± 0.0022
        - e.g., ^{238}U(n,2n)/^{235}U(n,f) = 0.0119 ± 0.0007; ^{169}Tm(n,2n)/^{235}U(n,f) = 0.00307 ± 0.00029.
  - For the Pu-SOL-THERM-001.4 critical assembly …
    - ENDF/B-VII.1 cross sections plus a recent Neudecker ^{239}Pu pfns yielded a calculated eigenvalue of 1.00948(6).
    - 1000 sample average is 1.01042 with a *population* standard deviation of 283 pcm (wow!).

Summary

- Work to revise the evaluated data files for ^{1}H, ^{16}O, ^{56}Fe, $^{235,238}U$ and ^{239}Pu continues …
- 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.
  - See https://www-nds.iaea.org/index-meeting-crp/CM_Compensating_Effects_2015/, and in particular the contribution by Oscar Cabellos, OECD/NEA.
    - DICE = Database for ICSBEP & NDaST = Nuclear Data Sensitivity Tool.
- The CIELO evaluated data files are expected to be an important component in the next ENDF/B release.