



ICSBEP Benchmark Testing of CIELO Nuclides at LANL

A.C.(Skip) Kahler
Los Alamos National Laboratory

CSEWG

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Abstract

We review criticality data testing performed at Los Alamos with a combination of ENDF/B-VII.1 + potential CIELO nuclear data evaluations.

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Outline

- CIELO Overview
- Criticality Data Testing
 - ICSBEP HMF, HST, IMF, LCT, PMF, PST benchmarks
- Summary

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CIELO Overview

- CIELO = Coordinated International Evaluated Library Organization (WPEC Subgroup 40).
- Goal: To develop updated, best available evaluated nuclear data files for a select group of nuclides ... ^1H , ^{16}O , ^{56}Fe , $^{235,238}\text{U}$ 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!

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CIELO Nuclides

- ^1H – using endf/b-vii.1
- ^{16}O – (06c), Hale 4/2016 evaluation.
- $^{54,56,57,58}\text{Fe}$ – (01c,03,01c,01c), BNL GForge v222, v219, v232 & v224, respectively.
- ^{235}U – (22c,23c & more), IAEA u235ib06o17g6cnu5cf2 (22c); u235ib06ao17g6cnu5cf2 (23c).
 - Variations with “o17” and “nu5” make 24c, 25c & 26c.
- ^{238}U – (06c), IAEA “ib46rjFs”.
- ^{239}Pu – (23c), ENDF/B-VII.1 plus SG34 plus recent Romano & LANL pfns revisions and LANL high energy $\nu(E)$ tweak.

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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.

- CIELO candidate ^{iso}Fe files are also available from the “CIELO-Iron” project from the BNL NNDC GForge server.

The screenshot shows a web browser displaying the CIELO Project (WPEC-SG40) page. The URL in the address bar is https://www-nds.iaea.org/CIELO/. The page header includes the IAEA Nuclear Data Services logo and navigation links for Databases (EXFOR, ENDF, CINDA, IBANDL, Medical, PGAA, NGAtlas, RIPL, FENDL, IRDF-2002). The main content area is titled "CIELO Project (WPEC-SG40)" and describes it as "IAEA Data Development Project within the International Pilot Project of the OECD/NEA". It lists "IAEA DDP Coordinators: R.Capote and A. Trkov". Below this, the "Overall Objective" is defined as testing the scheme of broad international collaboration to improve evaluated nuclear data files of major nuclides like H-1, O-16, Fe-56, U-235, U-238, and Pu-239. The "Subjects/issues to address" section lists six items related to experimental data status, priority requests, capabilities, benchmark experiments, consistency, and data adjustment. The "Available Materials" section shows download links for Pu-239, U-238, U-235, Fe-56, O-16, and H-1. The "Relevant documents" section lists a single document by A.K. Kahler titled "Content of MF1/MT451 (Unpublished)". The footer contains copyright information for the IAEA Nuclear Data Section and a disclaimer.

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235,238U, 239Pu – HMF & PMF Benchmarks

Benchmark	Benchmark keff	endf/b- vii.1 (e71)	e71 + $^{235}\text{U}_{19c} +$ $^{238}\text{U}_{04c}$	e71 + $^{235}\text{U}_{22c}$	e71 + $^{235}\text{U}_{22c} +$ $^{238}\text{U}_{06c}$	e71 + $^{235}\text{U}_{23c} +$ $^{238}\text{U}_{06c}$	e71 + $^{235}\text{U}_{24c} +$ $^{238}\text{U}_{06c}$	e71 + $^{235}\text{U}_{25c} +$ $^{238}\text{U}_{06c}$	e71 + $^{235}\text{U}_{26c} +$ $^{238}\text{U}_{06c}$
HMF1 (Godiva)	1.0000	0.99989	1.00010	1.00073	1.00065	1.00073	0.99990	1.00122	0.99984
HMF28 (Flattop- 25)	1.0000	1.00284	1.00380	1.00329	1.00133	1.00120	1.00085	1.00204	1.00099
IMF7 (Big-10)	1.0045	1.00448	1.00329	1.00304	1.00448	1.00456	1.00322	1.00403	1.00319
			e71 + $^{239}\text{Pu}_{23c} +$ $^{238}\text{U}_{04c}$	e71 + $^{239}\text{Pu}_{25c}$	e71 + $^{239}\text{Pu}_{25c} +$ $^{238}\text{U}_{06c}$				
PMF1, rev3 (Jezebel)	1.0000	1.00061	1.00024	0.99777					
PMF6 (Flattop- Pu)	1.0000	1.00111	1.00164	0.99818	0.99643				

$^{235}\text{U}_{24c} = ^{235}\text{U}_{19c}$ but insert o17 RR.

$^{235}\text{U}_{26c} = ^{235}\text{U}_{19c}$ but insert o17 RR and 23c.

$^{235}\text{U}_{26c} = ^{235}\text{U}_{19c}$ but insert o17 RR and 23c nu below 100 keV.

$^{239}\text{Pu}_{25c}$ contains preliminary LANL capture data.

Results with November, 2015 e8 "starter" files.

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

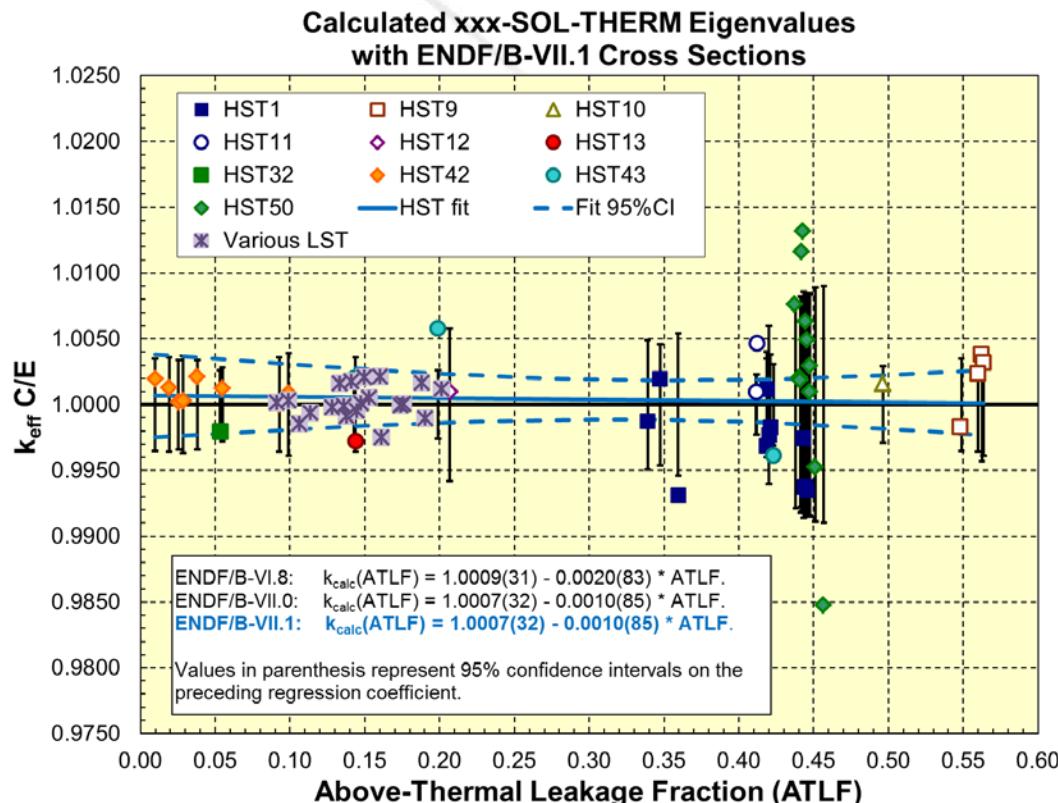


- A suite of 45 HEU-SOL-THERM benchmark critical configurations has been used for many years.
 - Accurate calculated eigenvalues, correlated against Above-Thermal Leakage Fraction (ATLF), have been obtained since ENDF/B-VI.3 in the early 1990s.
 - No trends observed for other regression analyses such 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?”.

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

- Near unity intercept and near zero slope indicate no bias in calculated eigenvalues for the HST benchmark class (with e71).
- e71 + $^{235}\text{U}_\text{19c}$ + $^{238}\text{U}_\text{04c}$ + $^{16}\text{O}_\text{05c}$:
 - $b = 1.0002(31)$
 - $m = +0.0019(83)$
- e71 + CAB h-h₂O kernel:
 - $b = 1.0003(33)$
 - $m = -0.0005(87)$

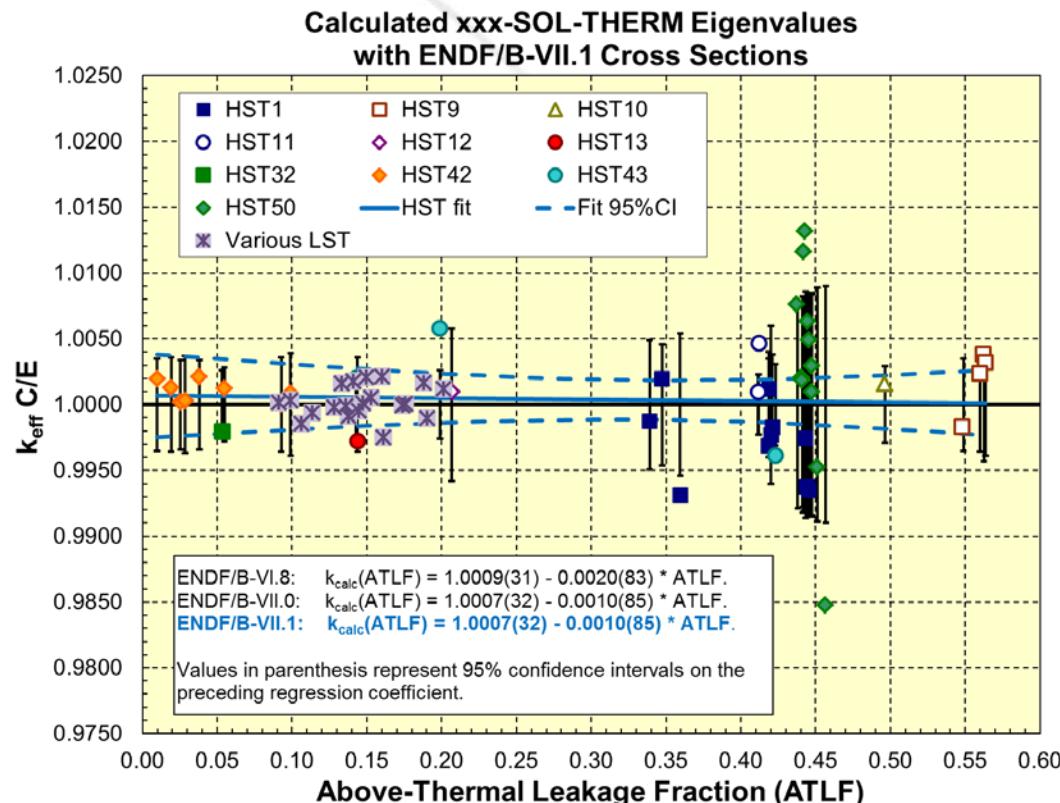


*** Where we were last Fall ***

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

- E71 + $^{235}\text{U}(22c)$:
 - b=1.0026(31); m=+0.0001(82)
- E71 + $^{235}\text{U}(22c)$ + $^{238}\text{U}(6c)$:
 - b=1.0026(31); m=-0.0001(82)
- E71 + $^{235}\text{U}(22c)$ + $^{238}\text{U}(6c)$ + $^{16}\text{O}(6c)$:
 - b=1.0017(32); m=-0.0016(84)
- E71 + $^{235}\text{U}(22c)$ + $^{238}\text{U}(6c)$ + $^{16}\text{O}(6c)$ + CAB h- h_2o :
 - b=1.0013(31); m=-0.0008(84)
- E71 + $^{235}\text{U}(23c)$ + $^{238}\text{U}(6c)$ + $^{16}\text{O}(6c)$ + CAB h- h_2o :
 - b=1.0013(31); m=-0.0010(83)
- E71 + $^{235}\text{U}(24c)$ + $^{238}\text{U}(6c)$ + $^{16}\text{O}(6c)$ + CAB h- h_2o :
 - b=0.9993(32); m=-0.0035(85)
- E71 + $^{235}\text{U}(25c)$ + $^{238}\text{U}(6c)$ + $^{16}\text{O}(6c)$ + CAB h- h_2o :
 - b=1.0013(31); m=-0.0006(84)
- E71 + $^{235}\text{U}(26c)$ + $^{238}\text{U}(6c)$ + $^{16}\text{O}(6c)$ + CAB h- h_2o :
 - b=1.0012(31); m=-0.0006(84)



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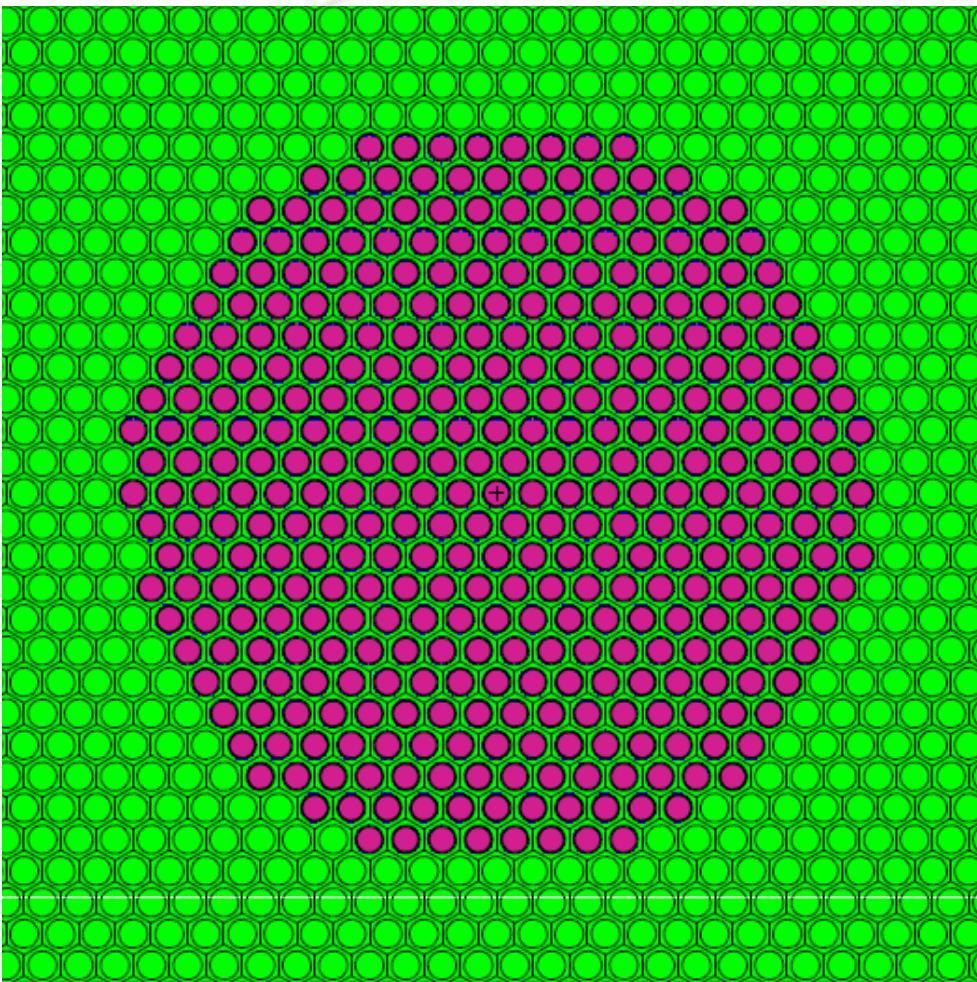
^{235}U (& ^1H , ^{16}O , ^{238}U) – LCT Benchmarks



- 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!”.

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



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LEU-COMP-THERM-005, case 5 is shown

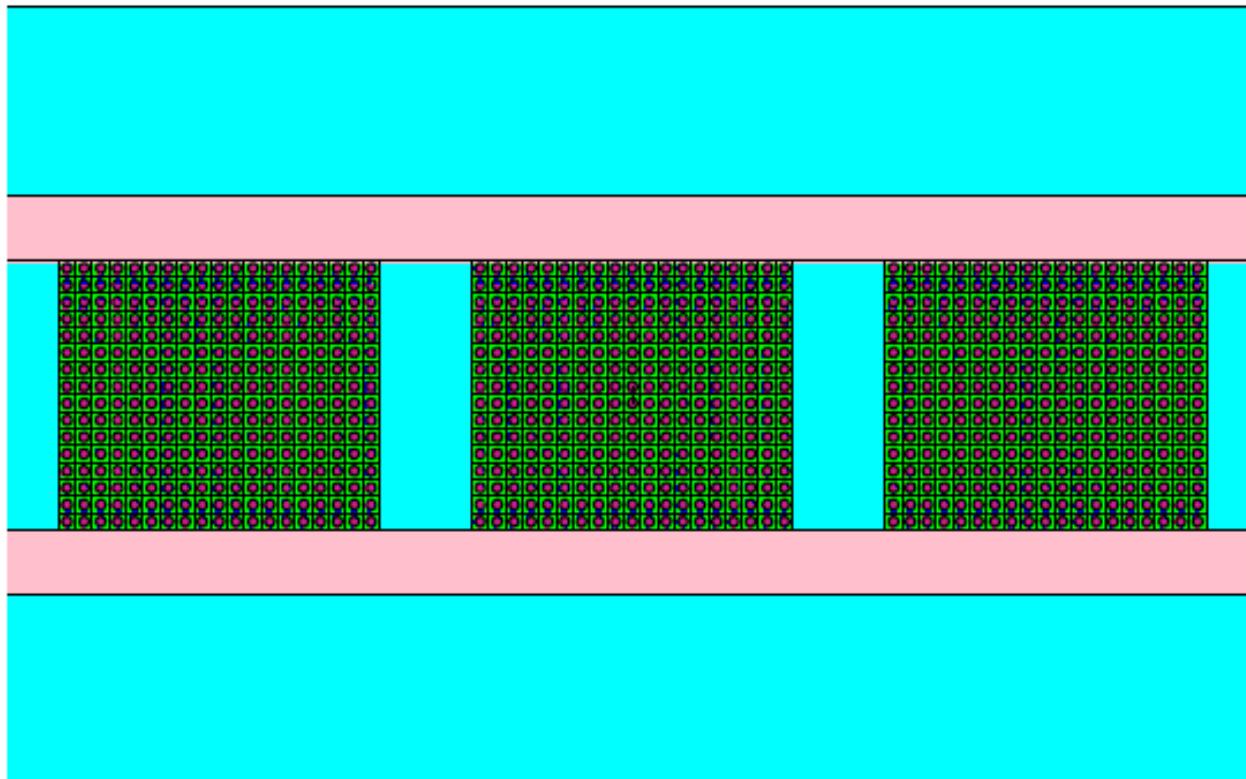
- 378 rods, 1.801 cm pitch.

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 (& ^1H , ^{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.

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

*** Where we
were last Fall ***



Benchmark	Benchmark keff	endf/b-vii.1 (e71)	e71 + $^{235}\text{U}_19\text{c} +$ $^{238}\text{U}_04\text{c} +$ $^{16}\text{O}_05\text{c} +$ $^{56}\text{Fe}_02\text{c}$	"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.

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Benchmark	Benchmark keff	endf/b-vii.1 (e71)	e71 + $^{235}\text{U}_19\text{c} +$ $^{238}\text{U}_04\text{c} +$ $^{16}\text{O}_05\text{c} +$ $^{56}\text{Fe}_02\text{c}$	"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 (& ^1H , ^{16}O , ^{238}U) – LCT Benchmarks

Benchmark	Benchmark keff	endf/b-vii.1 (e71)	e71 + $^{235}\text{U}(22c)$ + $^{238}\text{U}(6c)$	e71 + $^{235}\text{U}(22c)$ + $^{238}\text{U}(6c)$ + $^{16}\text{O}(6c)$	e71 + $^{235}\text{U}(22c)$ + $^{238}\text{U}(6c)$ + $^{16}\text{O}(6c)$ + CAB_lwtr00	e71 + $^{235}\text{U}(23c)$ + $^{238}\text{U}(6c)$ + $^{16}\text{O}(6c)$ + CAB_lwtr00
LCT1.1	0.9998	0.99955	1.00122	1.00001	1.00021	0.99998
LCT1.2	0.9998	0.99906	1.00030	0.99908	0.99939	0.99931
LCT1.3	0.9998	0.99850	0.99998	0.99852	0.99891	0.99907
LCT1.4	0.9998	0.99908	1.00054	0.99925	0.99933	0.99961
LCT1.5	0.9998	0.99695	0.99843	0.99705	0.99769	0.99757
LCT1.6	0.9998	0.99890	1.00022	0.99904	0.99950	0.99957
LCT1.7	0.9998	0.99829	0.99972	0.99851	0.99884	0.99887
LCT1.8	0.9998	0.99732	0.99842	0.99745	0.99791	0.99787
<hr/>						
LCT2.1	0.9997	0.99845	0.99995	0.99850	0.99911	0.99920
LCT2.2	0.9997	0.99978	1.00111	0.99989	1.00062	1.00047
LCT2.3	0.9997	0.99914	1.00063	0.99898	0.99991	1.00026
LCT2.4	0.9997	0.99870	1.00019	0.99882	0.99978	0.99955
LCT2.5	0.9997	0.99772	0.99913	0.99767	0.99844	0.99842
<hr/>						
LCT5.1	1.0000	1.00265	1.00373	1.00232	1.00263	1.00278
LCT5.5	1.0000	1.00504	1.00356	1.00189	1.00287	1.00266
LCT5.12	1.0000	1.00645	1.00338	1.00202	1.00227	1.00231

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.

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

Benchmark	Benchmark keff	endf/b-vii.1 (e71)	e71 + $^{235}\text{U}(22c) +$ $^{238}\text{U}(6c)$	e71 + $^{235}\text{U}(22c) +$ $^{238}\text{U}(6c) +$ $^{16}\text{O}(6c)$	e71 + $^{235}\text{U}(22c) +$ $^{238}\text{U}(6c) +$ $^{16}\text{O}(6c) +$ CAB_lwtr00	e71 + $^{235}\text{U}(23c) +$ $^{238}\text{U}(6c) +$ $^{16}\text{O}(6c) +$ CAB_lwtr00
LCT7.1	1.0000	0.99759	0.99750	0.99627	0.99693	0.99656
LCT7.2	1.0000	0.99884	1.00054	0.99878	0.99940	0.99927
LCT7.3	1.0000	0.99750	0.99987	0.99865	0.99901	0.99898
LCT7.4	1.0000	0.99810	1.00013	0.99916	0.99960	0.99959
LCT8.1	1.0007	1.00060	1.00137	0.99998	1.00037	1.00055
LCT8.2	1.0007	1.00087	1.00175	1.00050	1.00075	1.00066
LCT8.5	1.0007	1.00042	1.00110	0.99985	1.00007	1.00015
LCT8.7	1.0007	1.00017	1.00071	0.99972	0.99983	0.99979
LCT8.8	1.0007	0.99981	1.00051	0.99916	0.99926	0.99891
LCT8.11	1.0007	1.00135	1.00195	1.00099	1.00130	1.00133
LCT10.5 (U)	1.0000	0.99950	0.99998	0.99868	0.99912	0.99910
LCT10.6 (U)	1.0000	1.00008	1.00105	0.99984	1.00022	1.00011
LCT10.7 (U)	1.0000	1.00122	1.00232	1.00103	1.00176	1.00168
LCT10.8 (U)	1.0000	0.99788	0.99913	0.99796	0.99893	0.99860
LCT17.4 (U)	1.0000	0.99803	0.99901	0.99806	0.99811	0.99794
LCT17.5 (U)	1.0000	0.99989	1.00094	0.99968	1.00000	1.00001
LCT17.6 (U)	1.0000	1.00002	1.00115	1.00009	1.00024	1.00032
LCT17.7 (U)	1.0000	0.99986	1.00128	0.99989	1.00011	1.00009
LCT17.8 (U)	1.0000	0.99822	0.99947	0.99832	0.99863	0.99878
LCT17.9 (U)	1.0000	0.99770	0.99897	0.99768	0.99832	0.99804

Good results ...

- LCT8 results remain satisfactory.
- Little to no difference in other LCT cases.

MCNP stochastic uncertainty is typically 10 pcm, or less.

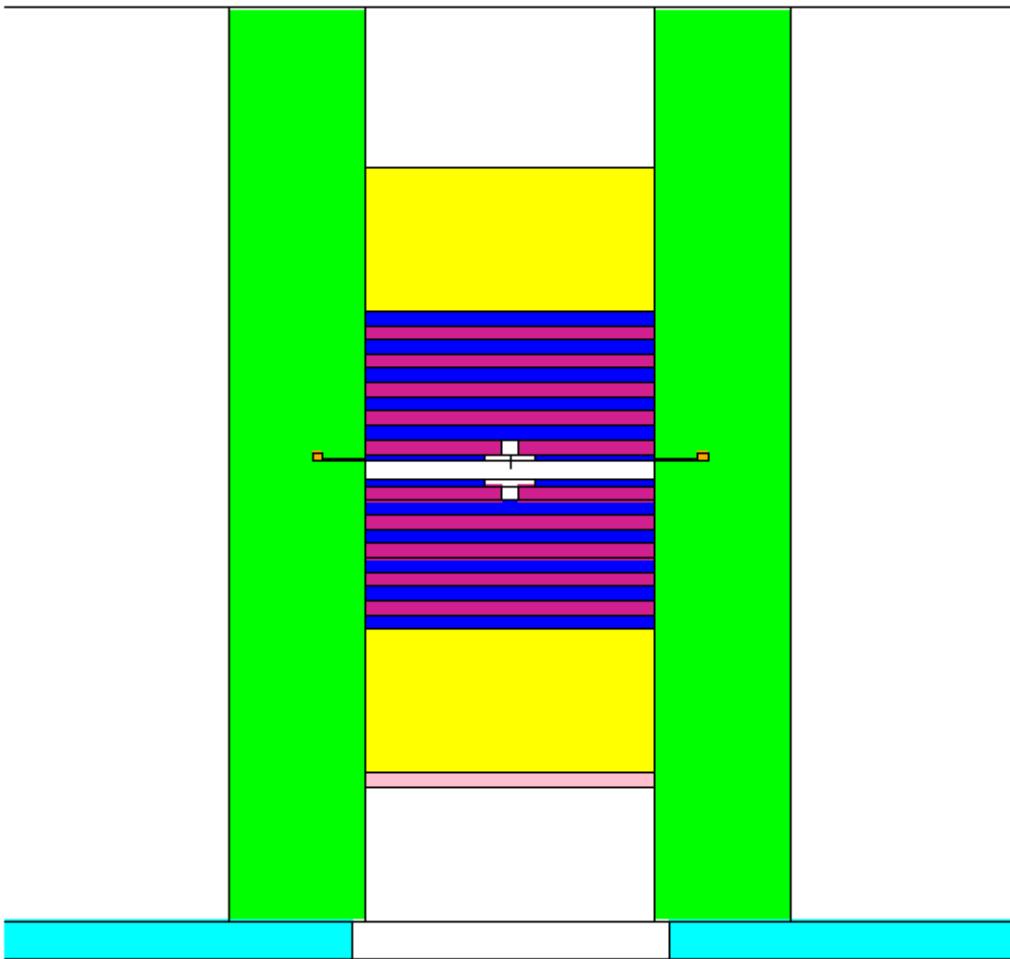
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(Some) ICSBEP Benchmarks with Iron

- 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 UO₂ rod clusters with steel reflecting walls (LCT42 also has absorber plates between clusters).
- PMF25 – Spherical ²³⁹Pu assembly with 1.55 cm thick steel.
- PMF26 – Spherical ²³⁹Pu assembly with 11.9 cm thick steel.
- PMF28 – Spherical ²³⁹Pu assembly with 19.65 cm thick steel.
- PMF32 – Spherical ²³⁹Pu assembly with 4.49 cm thick steel.

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ICSBEP's HMF88.1 Geometry



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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 ***



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

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



Benchmark	Benchmark keff	endf/b-vii.1 (e71) kcalc	e71 + 235U (22c)	e71 + 235U (22c) + 238U (6c)	e71 + 235U (22c) + 238U (6c) + BNL_Fe (1,3,1,1)	e71 + 235U (23c) + 238U (6c) + BNL_Fe (1,3,1,1)
HMF13	0.9990	0.99734	0.99807	0.99766	0.99676	0.99669
HMF21	1.0000	0.99730	0.99788	0.99759	0.99657	0.99652
HMF24	0.9990	0.99839	0.99874	0.99843	0.99842	0.99833
HMF87	0.9987	0.99840	0.99953	0.99958	0.99978	0.99986
HMF88.1	0.9993	0.99675	0.99712	0.99693	0.99871	0.99853
HMF88.2	0.9993	0.99664	0.99655	0.99631	0.99766	0.99762
Benchmark	Benchmark keff	endf/b-vii.1 (e71) kcalc	e71 + 239Pu (25c)	e71 + 239Pu (25c) + BNL_Fe (1,3,1,1)		
PMF25	1.0000	0.99880	0.99821	0.99857		
PMF26	1.0000	0.99845	0.99786	0.99725		
PMF28	1.0000	0.99896	0.99830	0.99743		
PMF32	1.0000	0.99862	0.99780	0.99790		

New isotopic Fe files reduce the HMF calculated eigenvalue by ~0.1%.

Less impact on PMF assemblies.

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235,238U, 16O & 56Fe – 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
<hr/>					
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
<hr/>					
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

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*** 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).

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

Benchmark	Benchmark keff	endf/b-vii.1 (e71) kcalc	e71 + 235U(22c)	e71 + 235U(22c) + 238U(6c)	e71 + 235U(22c) + 238U(6c) + 16O(6c)	e71 + 235U(22c) + 238U(6c) + 16O(6c) + CAB_lwtr00	e71 + 235U(22c) + 238U(6c) + 16O(6c) + CAB_lwtr00 + BNL_Fe (1,3,1,1)
LCT10.9 (Fe)	1.0000	0.99994	1.00087	1.00070	0.99964	0.99999	0.99974
LCT10.10 (Fe)	1.0000	1.00024	1.00158	1.00124	1.00022	1.00022	1.00007
LCT10.11 (Fe)	1.0000	1.00062	1.00199	1.00146	1.00054	1.00029	1.00029
LCT10.12 (Fe)	1.0000	0.99975	1.00070	1.00072	0.99942	0.99993	0.99988
LCT10.13 (Fe)	1.0000	0.99758	0.99901	0.99882	0.99756	0.99825	0.99792
LCT17.10 (Fe)	1.0000	0.99809	0.99927	0.99947	0.99831	0.99825	0.99834
LCT17.11 (Fe)	1.0000	0.99842	0.99982	0.99968	0.99853	0.99863	0.99843
LCT17.12 (Fe)	1.0000	0.99860	0.99975	0.99973	0.99869	0.99869	0.99844
LCT17.13 (Fe)	1.0000	0.99881	1.00004	1.00023	0.99894	0.99915	0.99914
LCT17.14 (Fe)	1.0000	0.99915	1.00051	1.00027	0.99921	0.99934	0.99930
LCT42.1 (Fe)	1.0000	0.99816	0.99856	0.99865	0.99747	0.99784	0.99742
LCT42.2 (Fe)	1.0000	0.99804	0.99827	0.99837	0.99719	0.99683	0.99682
LCT42.3 (Fe)	1.0000	0.99897	0.99913	0.99932	0.99799	0.99776	0.99765
LCT42.4 (Fe)	1.0000	0.99838	0.99868	0.99877	0.99748	0.99736	0.99705
LCT42.5 (Fe)	1.0000	0.99930	0.99951	0.99958	0.99873	0.99821	0.99793
LCT42.6 (Fe)	1.0000	0.99937	0.99941	0.99963	0.99865	0.99863	0.99845
LCT42.7 (Fe)	1.0000	0.99776	0.99807	0.99805	0.99687	0.99692	0.99660

LCT10 has the largest rod pitch (2.54 cm).

LCT17 is smaller (2.032 cm).

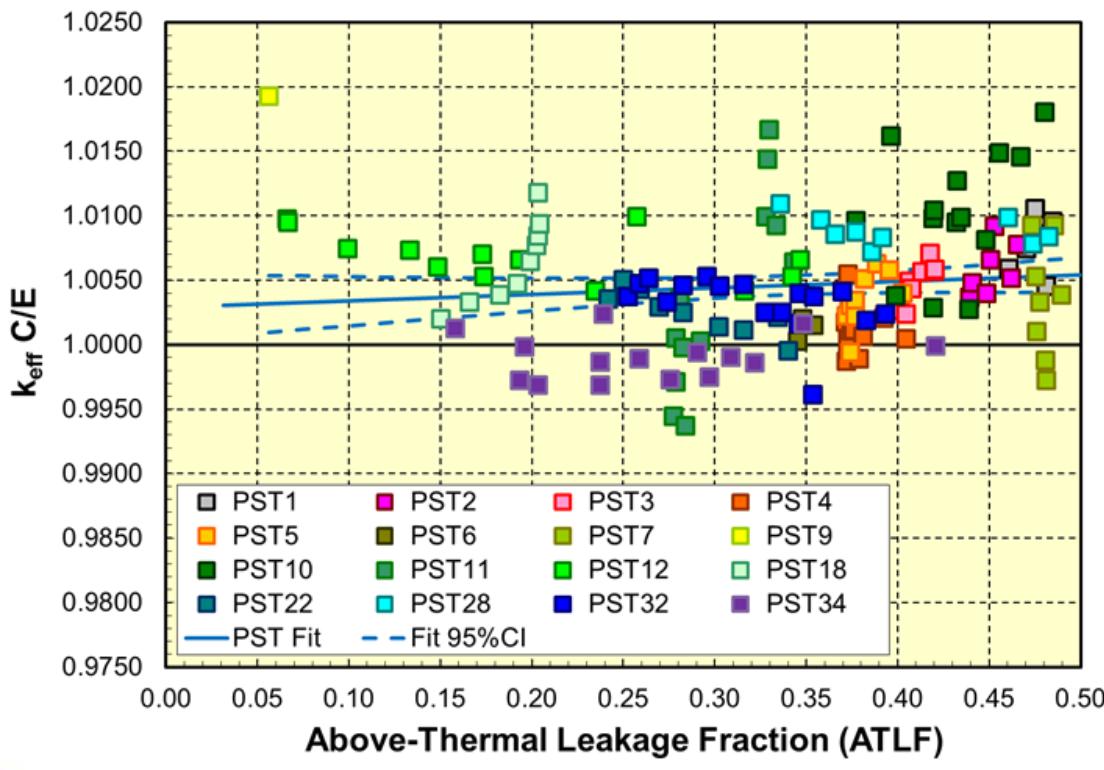
LCT42 is smallest (1.684 cm).

LCT10, 17 ok; LCT42 not as much.

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

- The average calculated eigenvalue for the Pu-SOL-THERM benchmark class has been biased high by about 500 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 (& ^1H , ^{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)
PST1.4	1.0000	1.00451	1.00209	0.99969
PST4.1	1.0000	1.00411	1.00052	0.99870
PST12.10	1.0000	1.00417	1.00078	0.99931
PST12.13	1.0000	1.00974	1.00623	1.00503
PST18.6	1.0000	1.00484	1.00195	1.00082
PST34.4	1.0000	1.00248	0.99933	0.99767
PST34.15	1.0000	0.99733	0.99719	0.99590
PST average:		1.00388	1.00116	0.99959

*** Where we were last Fall ***

For ENDF, WPEC Subgroup 34 efforts eliminated ~75% of the historical average k_{calc} bias.

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

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^{239}Pu (& ^1H , ^{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.

For ENDF, WPEC Subgroup 34 efforts eliminated ~75% of the historical *average* k_{calc} bias.

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

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Isotopic Carbon ($^{12,13}\text{C}$)

- Matn 600, natural Carbon, is the sole remaining elemental evaluation in ENDF.
- New carbon isotopic, matn 625 & matn 628, evaluations have been created (Hale, Paris)
 - ^{12}C to 20 MeV; ^{13}C to \sim 6 MeV but working to extend this to 20 MeV
- Tested with LCT60 (RBMK Graphite Reactor)
 - k_{calc} e71 – Hale for LCT60.1 is -4(8) pcm.
 - k_{calc} e71 – Hale for LCT60.6 is -6(10) pcm.
 - i.e, no difference, as expected.

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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., $^{239}\text{Pu}(n,f)/^{235}\text{U}(n,f) = 1.4203 \pm 0.0017$; $^{238}\text{U}(n,f)/^{235}\text{U}(n,f) = 0.2031 \pm 0.0022$
 - e.g., $^{238}\text{U}(n,2n)/^{235}\text{U}(n,f) = 0.0119 \pm 0.0007$; $^{169}\text{Tm}(n,2n)/^{235}\text{U}(n,f) = 0.00307 \pm 0.00029$.
 - 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!).

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Summary

- Work to revise the evaluated data files for ^1H , ^{16}O , ^{56}Fe , $^{235,238}\text{U}$ 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.

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