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Data Testing CIELO Evaluations with ICSBEP Benchmarks

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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.

Acknowledgement

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Outline

- CIELO Overview
- Criticality Data Testing
  - ICSBEP LANL Metal (HMF1, HMF28, IMF7, PMF1, PMF6), HST and LCT benchmarks
- PFNS Uncertainty Impact on k_{calc} and Reaction Rates (^{239}Pu and PMF1)
- 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 Nuclides

- ^{1}H – waiting for final Standards evaluation
- ^{16}O – (02c, 05c), Hale 7/2014 evaluation spliced to existing ENDF/B-VII.1 (IAEA 16O_halead).
- ^{56}Fe – (02c), BNL GForge v88.
- ^{235}U – (19c, 20c, 21c), ENDF/B-VII.1 plus (i) Leal “isrn_v2” RR; (ii) IAEA low energy $\nu(E)$ + IAEA & LANL pfns revisions.
  - *19c is available from the IAEA CIELO web site.*
- ^{238}U – (04c, 05c), IAEA “ib44” and “ib44rjFs”.
  - *04c, 05c are available from the IAEA CIELO web site.*
- ^{239}Pu – (23c), ENDF/B-VII.1 plus SG34 plus recent Romano & LANL pfns revisions and LANL high energy $\nu(E)$ tweak .
  - *23c is available from the IAEA CIELO web site.*

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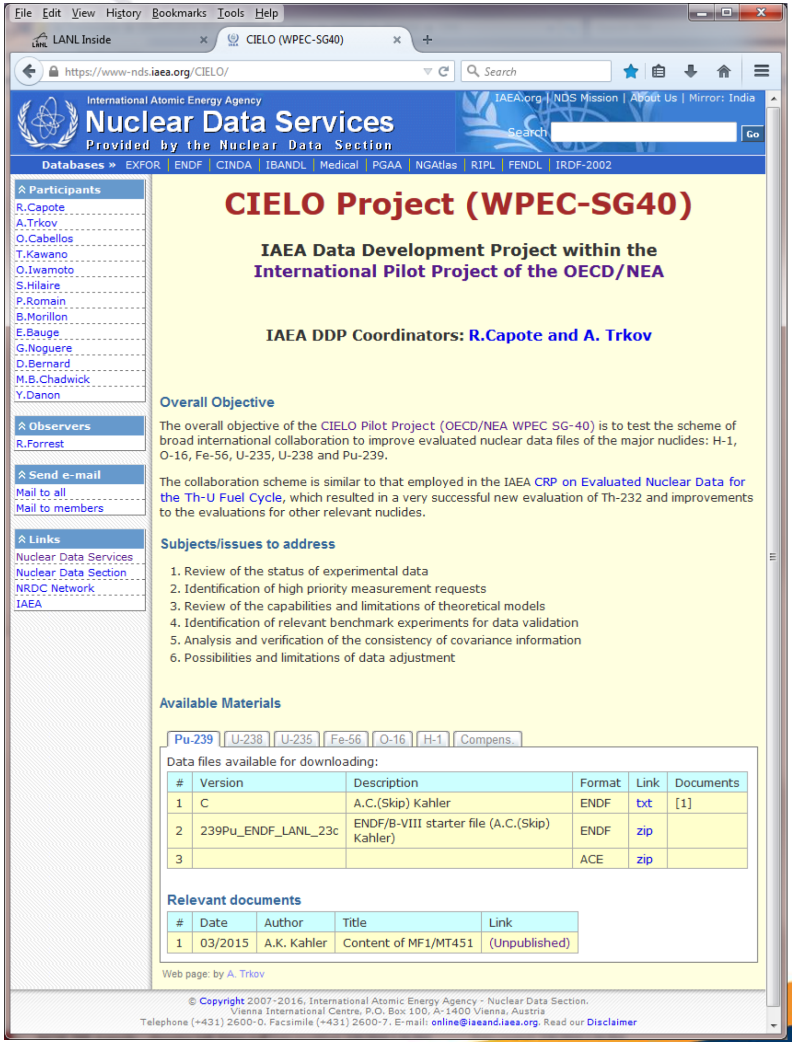
CIELO Overview

- 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 ^{56}Fe files are also available from the "CIELO-Iron" project from the BNL NNDC GForge server.



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

Benchmark	Benchmark keff	endf/b-vii.1 (e71)	e71 + ^{235}U_19c + ^{238}U_04c	"new" - e71, pcm
HMF1 (Godiva)	1.0000	0.99989	1.00010	21
HMF28 (Flattop-25)	1.0000	1.00284	1.00380	96
IMF7 (Big-10)	1.0045	1.00448	1.00329	-119
			e71 + ^{239}Pu_23c + ^{238}U_04c	"new" - e71, pcm
PMF1, rev3 (Jezebel)	1.0000	1.00061	1.00024	-37
PMF6 (Flattop-Pu)	1.0000	1.00111	1.00164	53

Fast, bare (Godiva and Jezebel) system calculated eigenvalues remain near unity.

Fast, reflected (Flattops, Big-10) system calculated eigenvalues aren't as good, ☹.

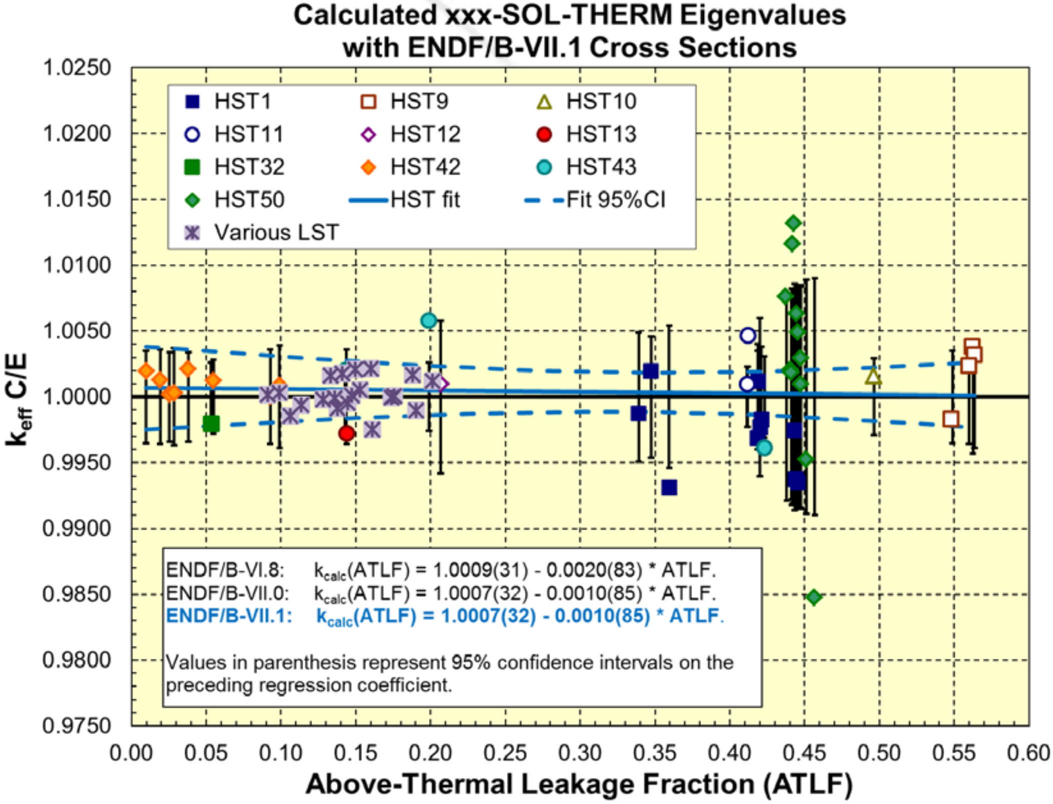
Switching to ^{235}U_21c + ^{238}U_05c recovers the e71 IMF7 and PMF6 results; HMF28 remains biased high.

^{235}U (& ^{1}H, ^{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?".

^{235}U (& ^{1}H, ^{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}U_19c + ^{238}U_04c + ^{16}O_05c:
    - b = 1.0002(31)
    - m = +0.0019(83)
  - e71 + CAB h-h_2o kernel:
    - b = 1.0003(33)
    - m = -0.0005(87)



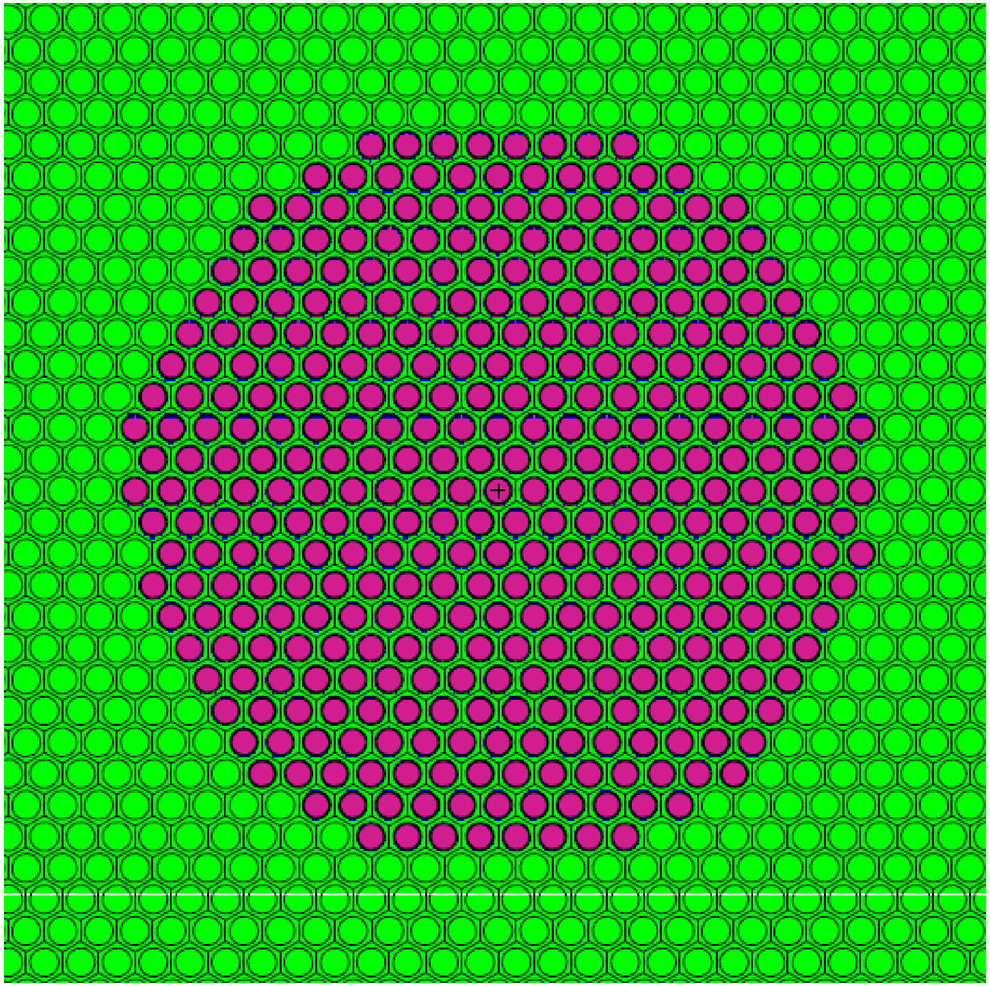
Satisfactory regression parameters are obtained when updated $^{235,238}U$ files are tested.

LA-UR-16-21528

^{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 differing rod pitch (1.26cm, 1.6cm, 2.1cm & 2.52cm) in LCT7 allows testing under varying moderation 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

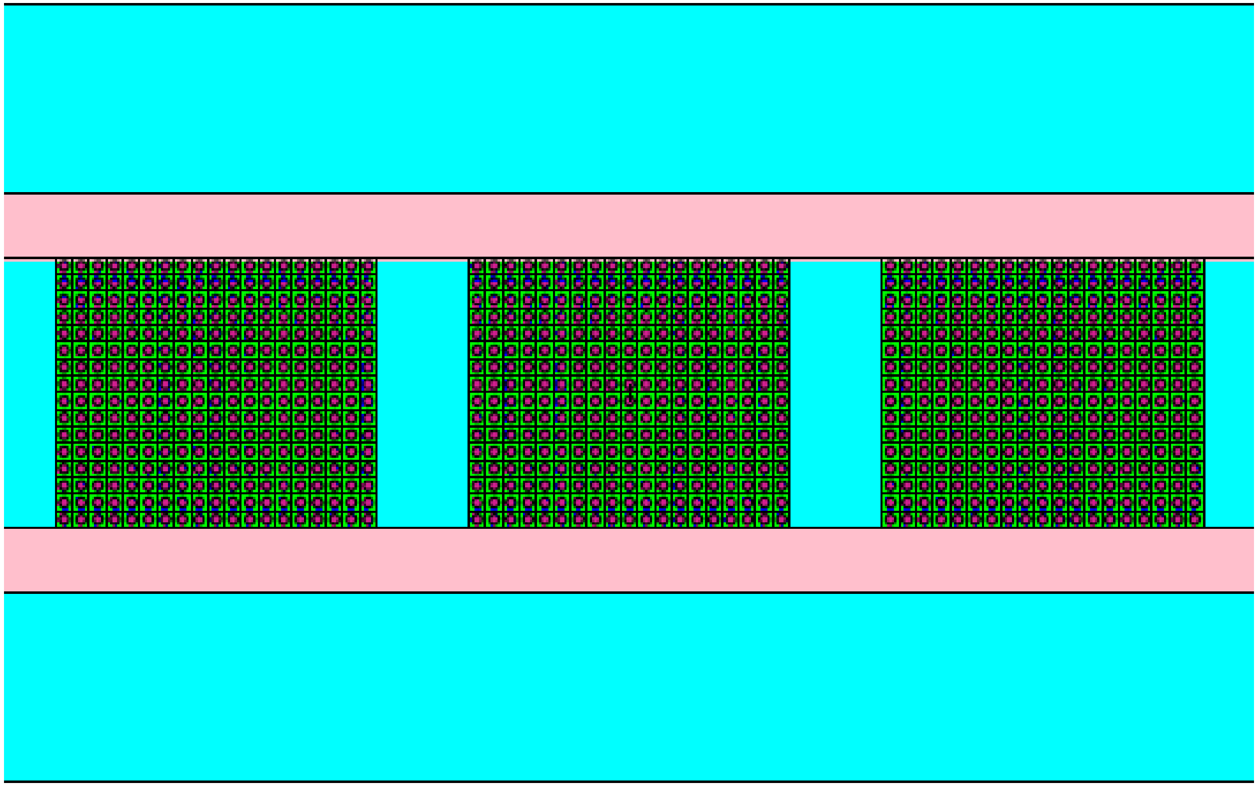
- 378 rods, 1.801 cm pitch.

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

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

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.

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.