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Title: Criticality Data Testing with CIELO Candidate Evaluations

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Criticality Data Testing with CIELO Candidate Evaluations

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Abstract

We review criticality data testing performed at Los Alamos during FY14 with a combination of ENDF/B-VII.1 + potential CIELO nuclear data evaluations.

Outline

- CIELO Overview
- Data Testing
- Current and Continuing Work
- 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 … that are recognized by the international community.

- Why: The major international evaluated nuclear data libraries don't agree on the internal cross section details of these most important nuclides!

CIELO Overview

- Pu-MET-FAST-001 (Jezebel)
  - k_{calc}(ENDF/B-VII.1) = 1.00004(6)
  - k_{calc}(JEFF-3.2) = 1.00031(6)
  - So far so good, but …
  - *^{239}Pu E71 but JF32 σ_{inel} and k_{calc} drops 537 pcm!*
  - *^{239}Pu E71 but JF32 $\sigma_{capture}$ and k_{calc} drops 250 pcm!*
  - *^{239}Pu E71 but JF32 σ_{elscat} and k_{calc} increases 309 pcm!*
  - *^{239}Pu E71 but JF32 σ_{elscat} plus JF32 angular distributions and k_{calc} increases 658 pcm!*

The PMF1 model is
- a bare sphere
- containing only Pu and Ga.

The variation due to swapping other data such as ν(E), χ(E) or $\sigma_{fission}$(E) is small … typically less than 50 pcm per component.

Most likely E71 & JF32 are getting the right answer for the wrong reason!

CIELO Overview

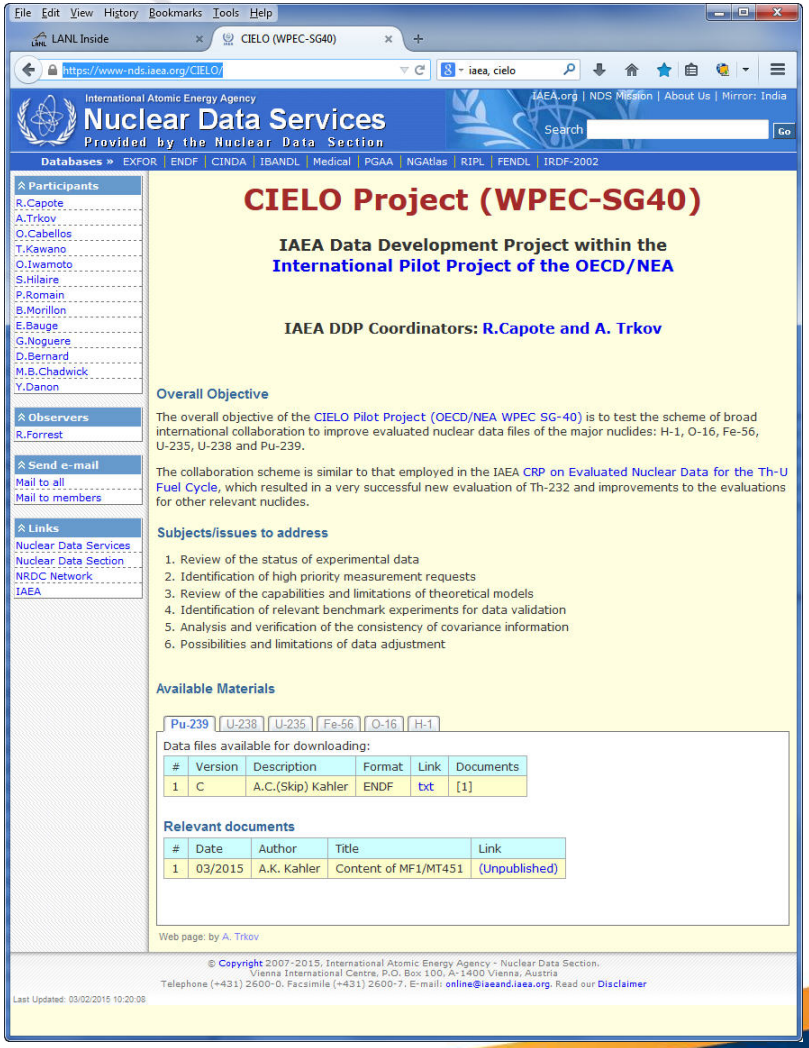
- Recent status …
  - ^{1}H: Little done to date, will most likely take what comes from the latest IAEA “Standards” recommendation.
    - A new WPEC Subgroup, SG42 “Thermal Scattering Kernel S(α,β): Measurement, Evaluation and Application”, dealing with thermal scattering kernels will also contribute … a new H-H_2O scattering kernel is already available for testing.
  - ^{16}O: ORNL has contributed a resonance based evaluation; LANL (Hale) has a partial re-evaluation … differences in evaluated (n,α) cross sections are an open issue.
  - ^{56}Fe: ORNL produced a new RRR evaluation up to 2 MeV last year; BNL work on the higher energy region is a work in progress with a new file expected any day (will hear more on a 3/30 conference call).

CIELO Overview

- Recent status …
  - ^{235}U: Work is being coordinated by France; a revised RRR evaluation has been contributed by ORNL that includes new LANL and RPI data and resolves the large capture cross section difference in the low keV region with Japan; a revised pfns will come from the recent IAEA PFNS Coordinated Research Project.
  - ^{238}U: New RR parameters are available for data testing. Also an updated (n,2n) evaluation incorporating advanced reaction theory and new measured data (part of the IAEA's new IRDFF library).
  - ^{239}Pu: Will build on the improvements developed in the recently completed SG34 that yielded improved PST calculated eigenvalues. Reaction theory refinements, particularly for capture and inelastic scattering, continues. Also a new LANL evaluation for the pfns and its uncertainty is nearing completion.

CIELO Overview

- Previously data files have been shared informally among the interested parties.
  - Not the most efficient system.
- More recently the IAEA Nuclear Data Section has created a web page … https://www-nds.iaea.org/CIELO/ … with links to candidate evaluated data files.



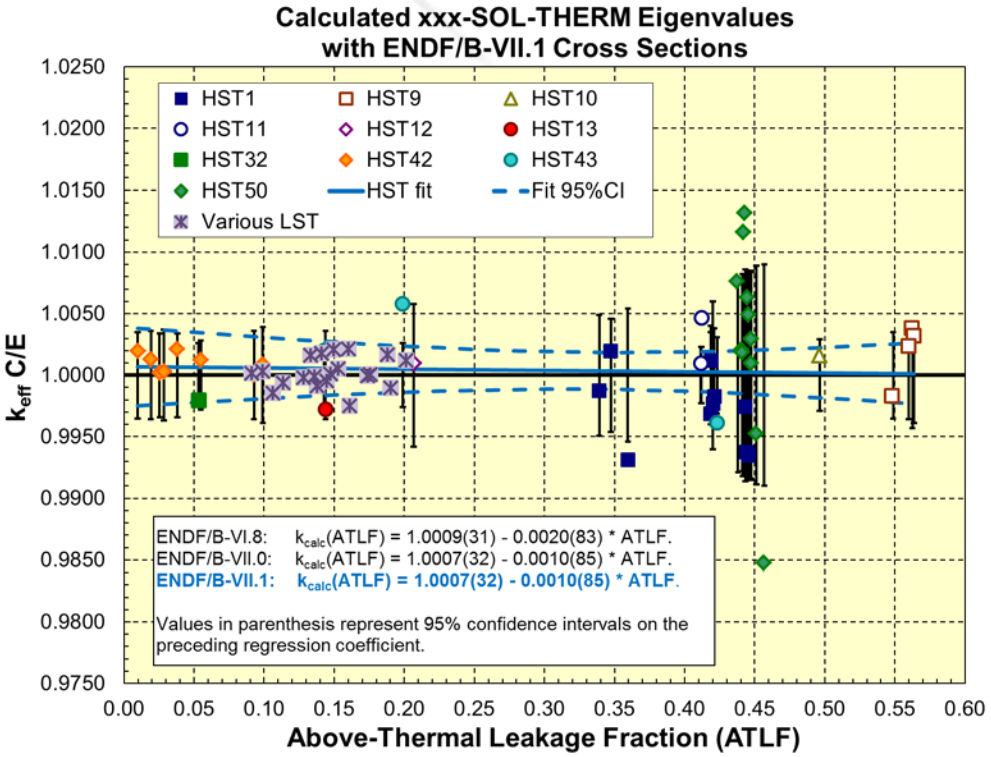
^{235}U (& ^{1}H, ^{16}O) – HST Benchmarks

- 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.
  - Tests of revised data sets must answer the question … “are we still ok or did we break something?”.

- Also use a subset of LEU-COMP-THERM benchmarks
  - The variable rod pitch in LCT7 allows testing of undermoderated, optimally moderated and overmoderated conditions.
    - Results with revised ^{16}O files, shown later, exhibit a small decrease in calculated eigenvalue.

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

- Near unity intercept and near zero slope confirm no bias in calculated eigenvalues.
  - Latest ^{235}U produces a positive slope.
  - Hale's latest ^{16}O produces a negative slope.
  - Testing with the new thermal scattering kernel and integrated testing with all changes remains.



^{239}Pu – PST Benchmarks

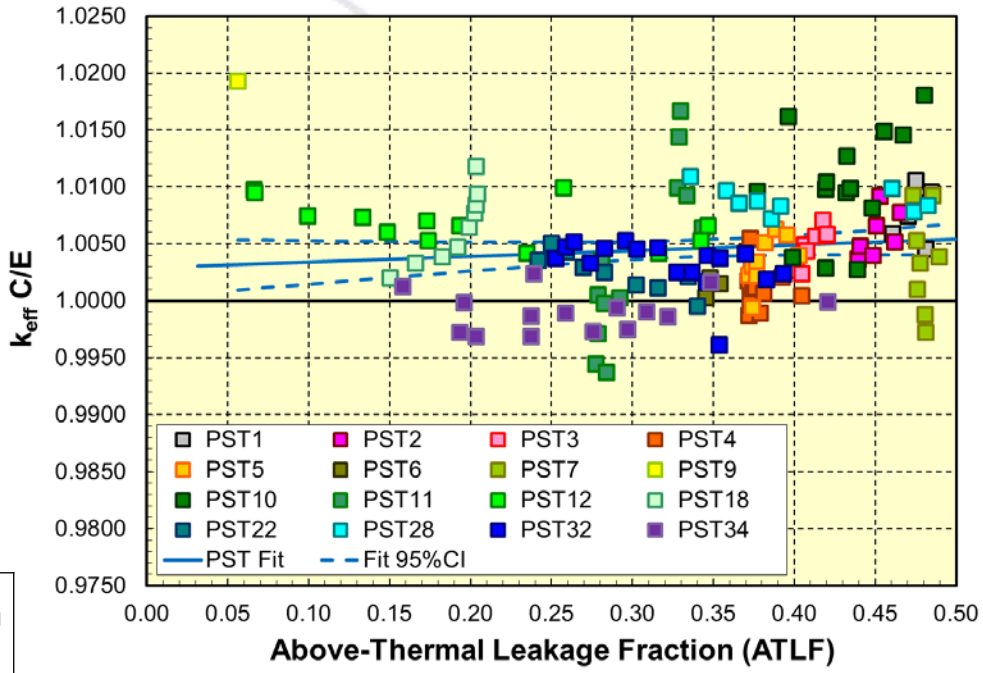
- The average calculated eigenvalue for the Pu-SOL-THERM benchmark class has been biased high by about 500 pcm for many years.

- The revised ^{239}Pu evaluation produced by WPEC SG34 eliminates more than half of this bias.

- Recent KAPL (Romano/Lubitz) work indicates that revisions to the pfns can eliminate much of the remaining bias.
  - LANL work, to better characterize the pfns uncertainty and the high energy portion of the pfns continues.

^{239}Pu – PST Benchmarks

- We use a small subset of the PST benchmark population to assess candidate evaluated files …



Benchmark	E71 (w/fixed ^{239}Pu)	E71 + SG34 ^{239}Pu low energy improvements	E71 + SG34 ^{239}Pu with hybrid pfns
PST1.4	1.00500	1.00219	1.00089
PST4.1	1.00389	1.00052	0.99918
PST12.10	1.00402	1.00108	1.00011
PST12.13	1.00970	1.00604	1.00591
PST18.6	1.00462	1.00208	1.00152
PST34.4	1.00254	0.99934	0.99845
PST34.15	0.99731	0.99705	0.99669
PST average:	*1.00387*	*1.00119*	*1.00039*

^{239}Pu – PFNS Uncertainty

- Impact of pfns uncertainty on calculated eigenvalue and reaction rates …
  - Use the LANL Pu-MET-FAST-001 (Jezebel) critical assembly
  - ENDF/B-VII.1 cross sections plus the latest ^{239}Pu pfns yields a calculated eigenvalue of 0.99878.
  - Generate a suite of 486 pseudo-random pfns data sets, based upon evaluated uncertainty
    - Standard deviation of the calculated eigenvalue population is 0.00058.
    - Standard deviation of the C/E low energy reaction rate population is 0.1% - 0.6%.
      - e.g., ^{239}Pu(n,f)/^{235}U(n,f) = 0.9936 ± 0.0007; ^{238}U(n,f)/^{235}U(n,f) = 0.964 ± 0.006
    - Standard deviation of the C/E high energy reaction rate population is ~3% - ~5%.
      - e.g., ^{238}U(n,2n)/^{235}U(n,f) = 1.185 ± 0.037; ^{169}Tm(n,2n)/^{235}U(n,f) = 1.087 ± 0.054.

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

- PMF25 – Spherical ^{239}Pu assembly with 1.55 cm thick steel
- PMF26 – Spherical ^{239}Pu assembly with 11.9 cm thick steel
- PMF28 – Steel (19.65 cm thick) reflected ^{239}Pu spherical assembly
- PMF32 – Steel (4.49 cm thick) reflected ^{239}Pu spherical assembly

^{56}Fe Results

Benchmark	Benchmark k_{eff}	E71 k_{eff}	E71 EAL	E71 EALF	**E71 k_{eff} C/E**	E71+ORNL4 ^{56}Fe k_{eff}	**E71+ORNL4 ^{56}Fe k_{eff} C/E**
HMF13	0.9990	0.99726	1.3848	7.66330E-01	**0.99826**	0.99743	**0.99843**
				rem -->	0.99841		*0.99850*
			rem, but original mf4/mt2 -->				*0.99970*
HMF21	1.0000	0.99748	1.3520	7.37680E-01	**0.99748**	0.99732	**0.99732**
				rem -->	*0.99720*		*0.99633*
			rem, but original mf4/mt2 -->				*0.99985*
HMF24	0.9990	0.99827	1.1685	6.54160E-01	**0.99927**	0.99855	**0.99955**
HMF87	0.9987	0.99841	1.3448	7.51180E-01	**0.99971**	0.99855	**0.99985**
HMF88.1	0.9993	0.99674	0.9107	1.32870E-02	**0.99744**	0.99706	**0.99776**
HMF88.2	0.9993	0.99671	0.7620	2.14320E-03	**0.99741**	0.99662	**0.99732**
PMF25	1.0000	0.99879	1.8369	1.18920E+00	**0.99879**	0.99878	**0.99878**
				rem -->	*0.99890*		*0.99892*
			rem, but original mf4/mt2 -->				*0.99997*
PMF26	1.0000	0.99843	1.7358	1.09250E+00	**0.99843**	0.99885	**0.99885**
PMF28	1.0000	0.99898	1.7198	1.06680E+00	**0.99898**	0.99927	**0.99927**
PMF32	1.0000	0.99858	1.8184	1.16950E+00	**0.99858**	0.99865	**0.99865**
				rem -->	*0.99877*		*0.99795*
			rem, but original mf4/mt2 -->				*1.00027*

Previously obtained good eigenvalues are retained … rem results suggest cross section revisions and new angular distribution results undo each other!

^{16}O Results

LCT7.x, cases 1 through 4, vary the rod pitch … undermoderated to overmoderated.

Revised ^{16}O files cause a small, up to ~0.1%, decrease in calculated eigenvalues.

The “Leal” file includes resonance parameter calculated angular distributions.

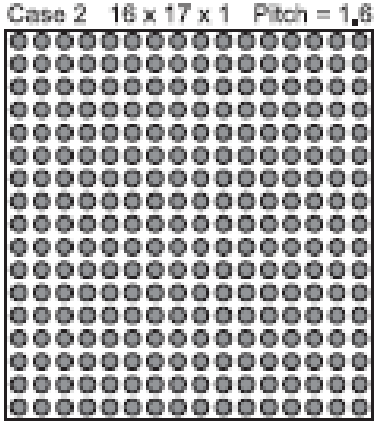
	E71	E71 + Leal ^{16}O	E71 + Hale ^{16}O
	k_{calc}	k_{calc}	k_{calc}
LCT7.1	0.99744	0.99655	0.99632
LCT7.2	0.99882	0.99786	0.99769
LCT7.3	0.99763	0.99686	0.99660
LCT7.4	0.99795	0.99766	0.99710

k_{calc} stochastic uncertainty is ~ 11 pcm

Case 1 is 22x22 on 1.26cm pitch;

Case 3 is 15x15 on 2.10cm pitch;

Case 4 is 18x17 on 2.52cm pitch.



Summary

- Work to revise the evaluated data files for ^{1}H, ^{16}O, ^{56}Fe, $^{235,238}U$ and ^{239}Pu continues … with significant contribution by NCSP funded staff.

- LANL testing to date has concentrated on ICSBEP benchmark eigenvalues. Reaction rate (spectral indices), pulsed spheres and Shielding (SINBAD) benchmarks are also important resources to be utilized in a comprehensive data testing regimen (and are being utilized by our international colleagues).

- The CIELO evaluated data files are expected to be an important component in the next ENDF/B release.