LA-UR-16-xxxxx



Testing ENDF/B-VIII.0β Data Files with ICSBEP Benchmarks

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

Cross Section Evaluation Working Group Annual Meeting Brookhaven National Laboratory November, 2016

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Abstract

We review and compare criticality data testing results performed at Los Alamos with ENDF/B-VII.1 and ENDF/B-VIII.0β nuclear data evaluations.







<u>Outline</u>

ENDF/B-VIII.0β3 Overview

- A caution about NJOY Processing and Doppler broadening!
- Data Testing
 - Criticality calculations with ICSBEP HMF, HMI, HST, IMF, LCT, PMF, PMI and PST benchmarks.
- Summary

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ENDF/B-VIII.0β3

 ENDF/B-VIII.0β3 files are available from the BNL NNDC: (<u>https://ndclx4.bnl.go</u> v/gf/project/endf/).



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<u>CIELO</u>

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

File Edit View History Bookmarks Tools Help _ 🗆 🗙 🛁 National Nuclear Data Cen... 🗴 (W) CIELO (WPEC-SG40) C Q Search https://www-nds.iaea.org/CIELO/ **F** â \equiv X 自 IAEA.org | NDS Mission | About Us | Mirror: India International Atomic Energy Agency Nuclear Data Services Go Section Données Nucléaires, AIEA Databases » EXFOR ENDE CINDA IBANDL Medical PGAA NGAtlas RIPL FENDL ☆ Participants **CIELO Project (WPEC-SG40)** R.Capote A.Trkov V.G.Pronyae **IAEA** Data Development Project within the O.Cabellos T.Kawano International Pilot Project of the OECD/NEA P.Talou O.Iwamot IAEA DDP Coordinators: R.Capote and A. Trkov S.Hilaire P.Romain **Overall Objective** B.Morillon E.Bauge The overall objective of the CIELO Pilot Project (OECD/NEA WPEC SG-40) is to test the scheme of broad G.Noguere international collaboration to improve evaluated nuclear data files of the major nuclides: H-1, O-16, Fe-56, U-235, D.Bernard U-238 and Pu-239. The collaboration scheme is similar to that employed in the IAEA CRP on Evaluated Nuclear Data M.B.Chadwick for the Th-U Fuel Cycle, which resulted in a very successful new evaluation of Th-232 and improvements to the A.C.(Skip)Kahler evaluations for other relevant nuclides. Y Danon Subjects/issues to address

- 1. Review of the status of experimental data and identification of high priority measurement requests
- 2. Review of the capabilities and limitations of theoretical models
- 3. Identification of relevant benchmark experiments for data validation
- 4. Analysis and verification of the consistency of covariance information
- 5. Possibilities and limitations of data adjustment

Update to IAEA-CIELO as of 5 November 2016

A preliminary release of the Standards_2016 evaluations became available in October. Although the changes were relatively small, they had a severe impact on benchmarking. Re-tuning of the cross sections was done to restore the performance. For additional information please chect the U-235 and U-238 tabs below. The two evaluations supersede those from the release of 18 August 2016.

- U-238 Version: u238beta2STD compressed ENDF file (internal IAEA designation u238ib51brlFsST1)
- U-235 Version: u235beta2STD compressed ENDF file (internal IAEA designation u235ib25o23g6DNcnu5ef4)

Evaluations for IAEA-CIELO as of 8 August 2016 (+update 18 August 2016)





An NJOY Processing Caution ...

- A note of caution when Doppler broadening evaluated data files ...
 - NJOY's default upper energy limit for Doppler broadening is the lowest energy among ...
 - The top of the resolved resonance range;
 - The lowest reaction threshold;
 - A user input value (thnmax);
 - 1.0 MeV.
 - If the user input, thnmax, is negative then Doppler broadening will occur up to |thnmax|, regardless of the other criteria.
 - For many years the "top of the resolved resonance range" was the de facto upper limit.
 - It has become increasingly common in modern evaluated data files for lowest reaction threshold to establish the Doppler broadening upper limit.





An NJOY Processing Caution ...

- The following ENDF/B-VII.0β nuclides may require definition of [thnmax] in the User's input deck to assure Doppler broadening occurs through the top of the resolved resonance range ...
 - ²³Na, ³²S, ³⁵Cl, ³⁸Ar, ⁴¹K, ⁴⁵Sc, ⁵⁰V, ⁵²Cr, ^{54,56,57}Fe, ⁵⁸Co, ⁶⁵Cu, ^{64,66,68,70}Zn, ^{70,72,73}Ge, ^{235,238}U.
 - CIELO nuclides are highlighted in red.

 NJOY/BROADR's standard output contains the statement ... "max energy for broadening and thinning = x.xxxE+xx" ... so that User's know the maximum Doppler broadening energy for any particular NJOY job.







ICSBEP Benchmark Data Testing

- ICSBEP Nomenclature ...
 - <u>XXX-YYY-ZZZ-###</u>, where XXX=fuel material; YYY=fuel form;
 ZZZ=spectrum; ###=sequence number.
- Data testing categories discussed herein ...
 - FAST Los Alamos systems: HMF1 (Godiva), HMF28 (Flattop-25), IMF1 (Jemima), IMF7 (Big-10), PMF1 (Jezebel), PMF6 (Flattop-Pu).
 - HMF7: A suite of ORNL assemblies with HEU plates and polyethylene.
 - HST: HEU solution systems with varying leakage.
 - PST: Pu solution systems with varying leakage.
 - LCT: UO_2 lattice configurations.
 - HMF, HMI, PMF, PMI & LCT systems with iron/steel.
 - PMF systems with various reflectors.



"FAST" Los Alamos Assemblies

- HMF1 (Godiva)
- HMF28 (Flattop-25)
- PMF1 (Jezebel)
- PMF6 (Flattop-Pu)
- IMF7 (Big-10)
- IMF1 (Jemima)

Calculated Eigenvalues with ENDF/B-VII.1 plus ENDF/B-VIII.0β2 & β3 Cross Sections



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HMF7 A suite of



HST Benchmarks - 235U (& 1H, 16O)

- 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?".



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HST Benchmarks - ²³⁵U (& ¹H, ¹⁶O)

 ... and the answer is "we are still ok".

 For e80β3 + IAEA "STD"
 ^{235,238}U files
 the intercept
 and slope
 are:

> -1.0006(31) --0.0009(84).



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PST Benchmarks - ²³⁹Pu (& ¹H, ¹⁶O) Los Alan

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- A suite of 158 Pu-SOL-THERM benchmark critical configurations have exhibited a long standing k_{calc} bias for many years and for many generations of evaluated data sets.
 - The average k_{eff} C/E bias is about 450 pcm with ENDF/B-VII.1.
 - Work by WPEC Sub-Group 34 lead to revisions to the ²³⁹Pu evaluated data file (primarily RR parameters and nu(e)) which eliminated about 75% of this bias.
 - Tests of revised data sets must answer the question ... "have we made further improvements in PST benchmark performance, have we taken a step backward, or is there more work to do?".





PST Benchmarks - ²³⁹Pu (& ¹H, ¹⁶O) Los A

... and the answer is "there has been significant further improvement in benchmark performance"



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Slide 15

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

Good e71 results for this benchmark category remain good with e80β2 and e80β3.



Assemblies with Iron (Steel)



- 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.
- HMF84.7, 84.19 & 85.3 Cylindrical HEU with Fe reflectors.
- HMF87 HEU cylindrical assembly with interstitial steel.
- HMF88 HEU cylindrical assembly with interstitial steel or steel & polyethylene plus a polyethylene radial/axial reflector.
- HMI1 Argonne ZPR-9/34.
- LCT10, 17 & 42 multiple UO₂ rod clusters with steel reflecting walls
- 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.
- PMI2 Argonne ZPR-6/10.



FAST Assemblies with Iron (Steel)

Calculated eigenvalue changes with $\beta 2$ or $\beta 3$ cross sections are generally within the experimental uncertainty.



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Slide 17

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THERMAL Assemblies with Iron (Steel)



Slide 18

Calculated Eigenvalues with ENDF/B-VII.1 plus ENDF/B-VIII.0β2 & β3 Cross Sections





PMF Assemblies – ENDF/B-VII.1

1.0150 $k_{eff} C/E$ exhibits a 1.0100 clear trend with 1.0050 ENDF/B-k_{eff} C/E VII.1 cross 1.0000 sections 0.9950 LANL Rocky Flats IPPE 0.9900 **VNIITF**



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Slide 19

PMF Assemblies – ENDF/B-VIII.0β3^{Los}

Lots of changes when switch to ENDF/B-VIII.0β3, but there's more work to do here.



A-UR-16-xxxxx

Slide 20

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Summary

- 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.
 - DICE = Database for ICSBEP
 - NDaST = Nuclear Data Sensitivity Tool (OECD/NEA).









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Average Calculated Eigenvalues

A high level summary of calculated eigenvalues, by ICSBEP category ...

| e71_80c | | | | | e80β2 | | |
|--------------|------|----------------------|----------------------------------|--|-------|----------------------|----------------------------------|
| Category | # | Average kcalc C/E | kcalc C/E population stdev | | # | Average kcalc C/E | kcalc C/E population stdev |
| HMF | 262 | 1.00076 | 0.00352 | | 254 | 1.00011 | 0.00364 |
| HMI | 5 | 1.00033 | 0.00464 | | 5 | 1.00056 | 0.00280 |
| HCI | 12 | 1.01132 | 0.03884 | | 12 | 1.01402 | 0.03336 |
| HMM | 11 | 1.00201 | 0.00404 | | 11 | 0.99959 | 0.00358 |
| HMT | 4 | 1.00845 | 0.00556 | | 4 | 1.00724 | 0.00490 |
| HST | 178 | 0.99858 | 0.00581 | | 178 | 0.99853 | 0.00637 |
| | | | | | | | |
| IMF | 19 | 1.00208 | 0.00314 | | 19 | 1.00064 | 0.00284 |
| ICF | 2 | 1.00059 | 0.00236 | | 2 | 0.99894 | 0.00183 |
| | | | | | | | |
| LST | 20 | 0.99967 | 0.00265 | | 20 | 1.00000 | 0.00263 |
| LMT | 6 | 0.99846 | 0.00286 | | 6 | 0.99847 | 0.00210 |
| LCT | 247 | 0.99951 | 0.00259 | | 247 | 0.99941 | 0.00252 |
| | | | | | | | |
| PMF | 53 | 1.00180 | 0.00454 | | 53 | 1.00198 | 0.00556 |
| PMI | 3 | 1.01155 | 0.01451 | | 3 | 1.00619 | 0.01042 |
| PST | 158 | 1.00451 | 0.00455 | | 158 | 0.99974 | 0.00461 |
| | | | | | | | |
| MMF | 37 | 1.00370 | 0.00279 | | 37 | 1.00346 | 0.00263 |
| MCF | 7 | 1.00007 | 0.00265 | | 7 | 0.99556 | 0.00196 |
| MMM | 1 | 1.00062 | | | 1 | 1.00106 | |
| MMI | 2 | 1.00806 | 0.00218 | | 2 | 1.00466 | 0.00261 |
| | | | | | | | |
| UMF | 10 | 0.99827 | 0.00185 | | 10 | 0.99755 | 0.00193 |
| USI | 33 | 0.98375 | 0.00563 | | 33 | 0.98273 | 0.00575 |
| UCT | 9 | 0.99947 | 0.00206 | | 9 | 0.99780 | 0.00186 |
| UST | 106 | 0.99989 | 0.00872 | | 106 | 0.99807 | 0.00835 |
| | | | | | | | - |
| | 1185 | 1.00040 | 0.00699 | | 1177 | 0.99931 | 0.00669 |
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