

Critical Eigenvalue Calculations of Selected ICSBEP Benchmarks with Various ^{239}Pu Evaluated Data Files

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Abstract

We discuss variations in calculated eigenvalues for plutonium bearing critical benchmarks, using cross sections from ENDF/B-VII.1, JEFF-3.1.2, JENDL-4.0 and a recent ORNL/CEA ^{239}Pu evaluation performed for the WPEC “Coordinated Evaluation of ^{239}Pu in the Resonance Region” Subgroup.

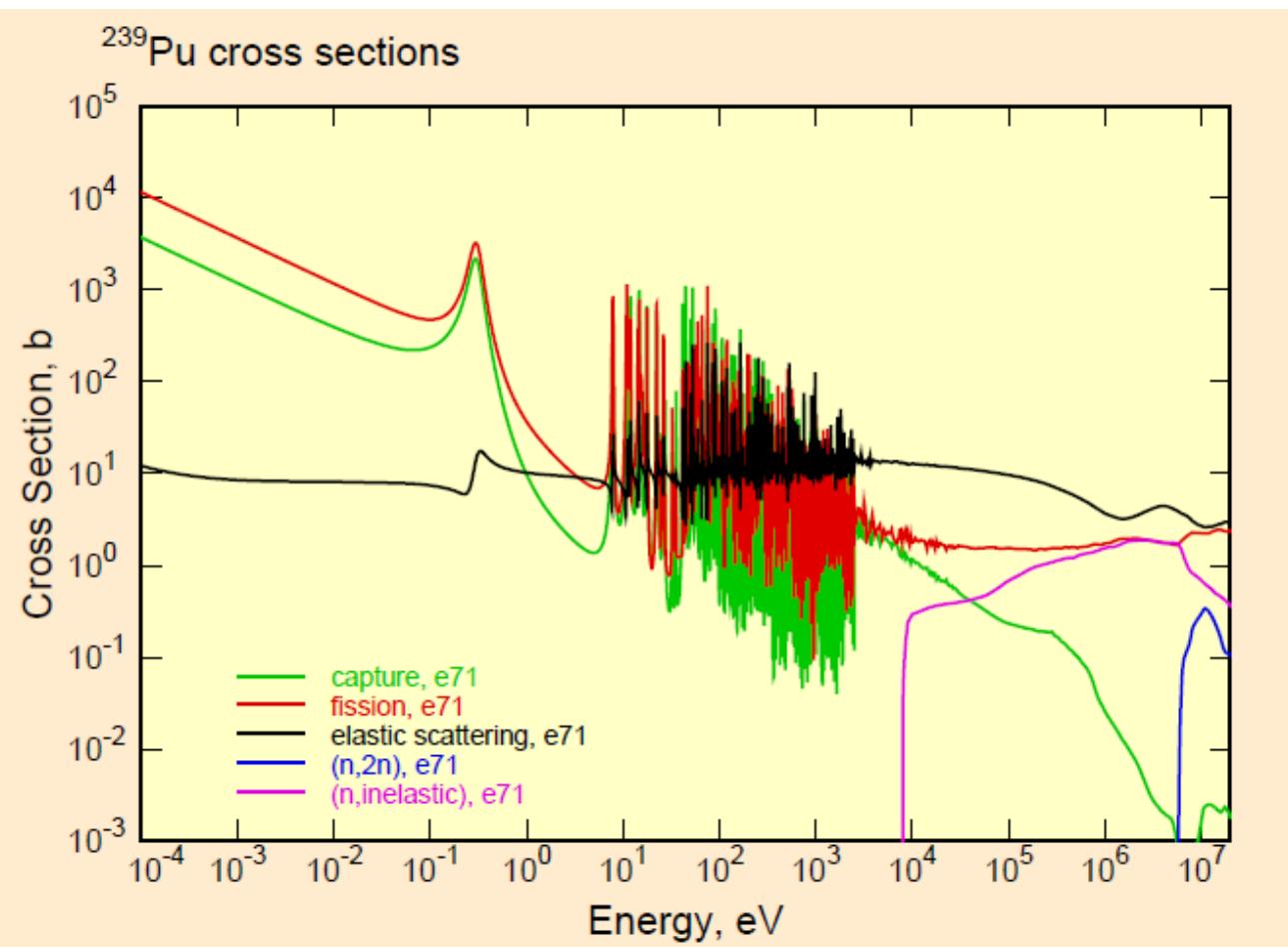
Presentation Outline

- Opening Remarks/Introduction
- ICSBEP/Suite of Benchmarks Used in this Study
- Range of Calculated Results
- Conclusions

Introduction

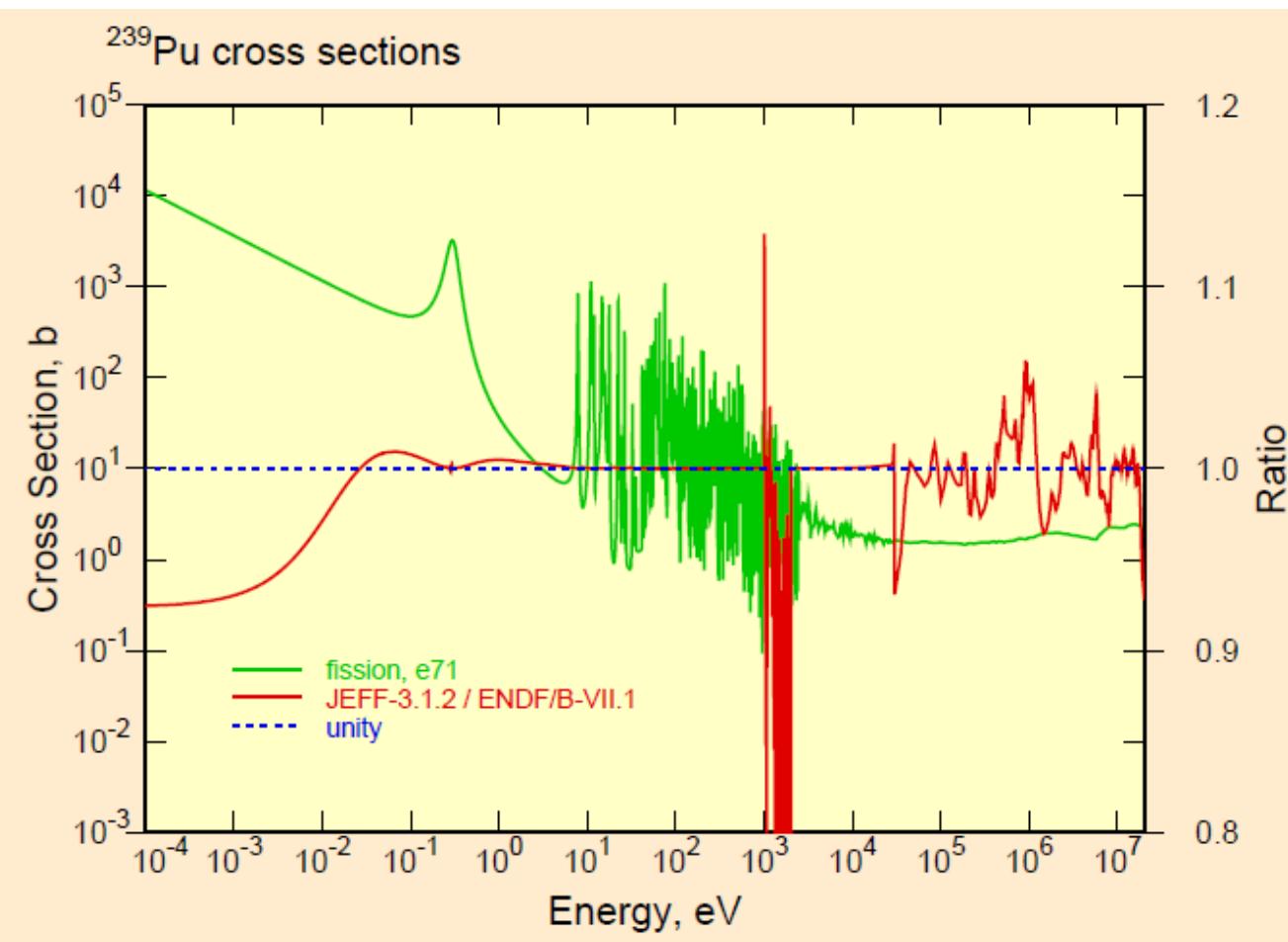
- Eigenvalue calculations for Critical Assemblies have been performed for decades.
- $^{235,238}\text{U}$ and ^{239}Pu are often referred to as the “Big 3”.
- The international community has converged upon a common evaluation for $^{235,238}\text{U}$ in the RR region.
 - ORNL Resolved Resonance parameters (at least for several hundred eV)
- This is NOT true for ^{239}Pu – in the RR Region:
 - ENDF/B-VII.0 = ENDF/B-VI.2; JENDL4 = ORNL (ND2007);
 - JEFF = ENDF, but different bound levels yielding thermal cross section values consistent with Mughabghab unc's.
 - Other differences in all libraries for ν , pfns and beyond the RR

Introduction



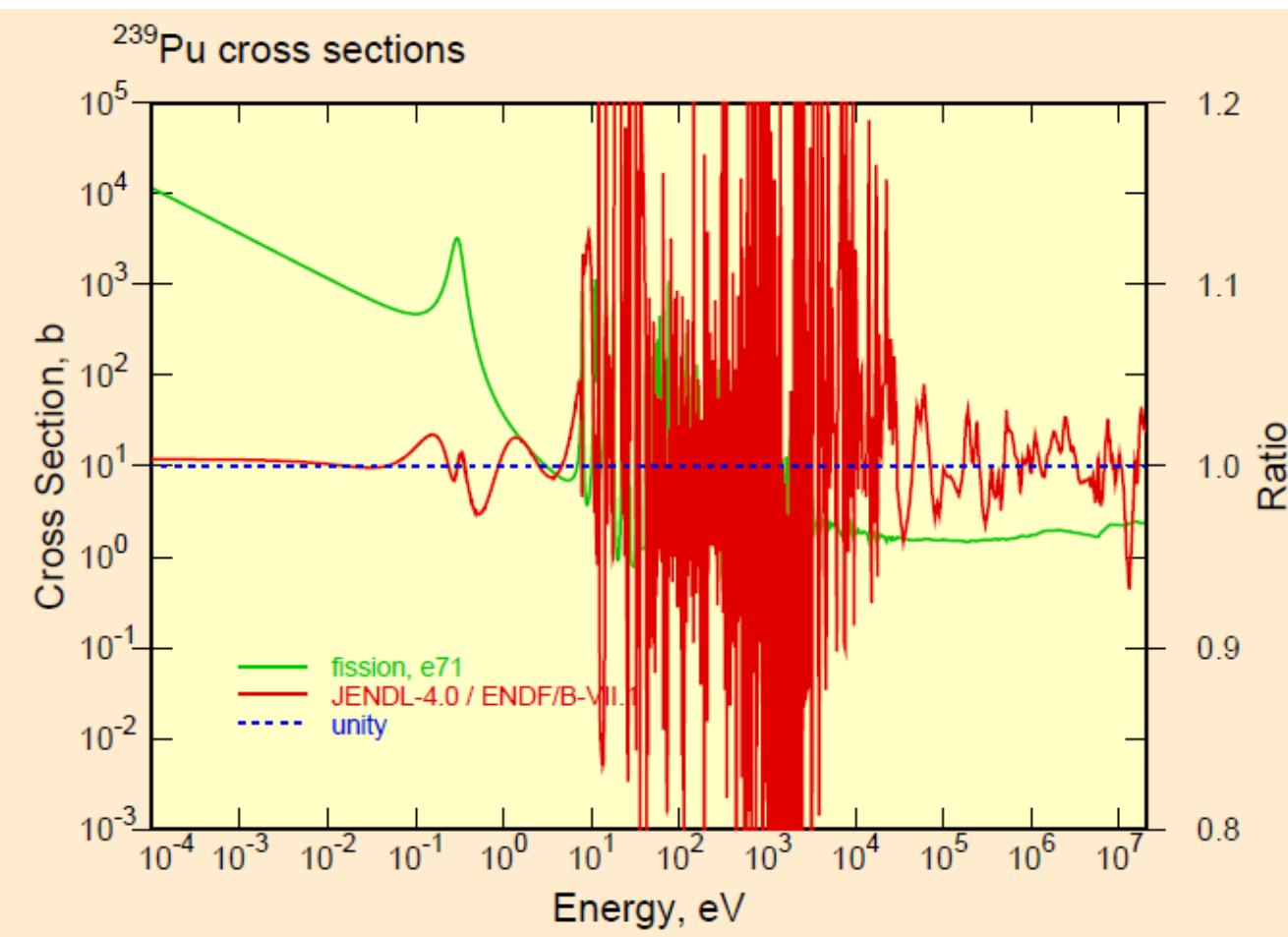
Various
ENDF/B-VII.1
(E71) cross
sections for
 ^{239}Pu

Introduction



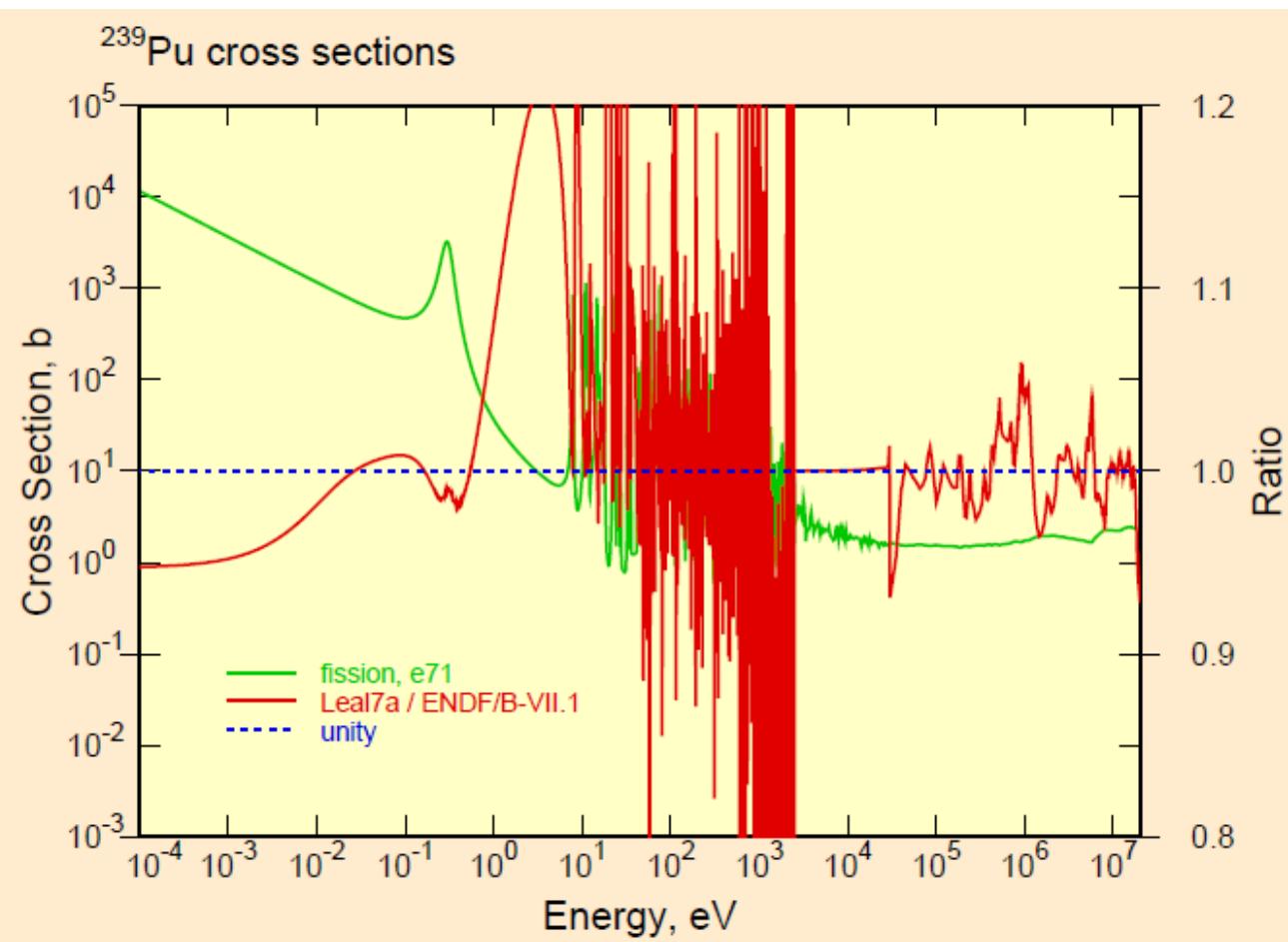
**Ratio,
JF312/E71 for
the ^{239}Pu
fission cross
section**

Introduction



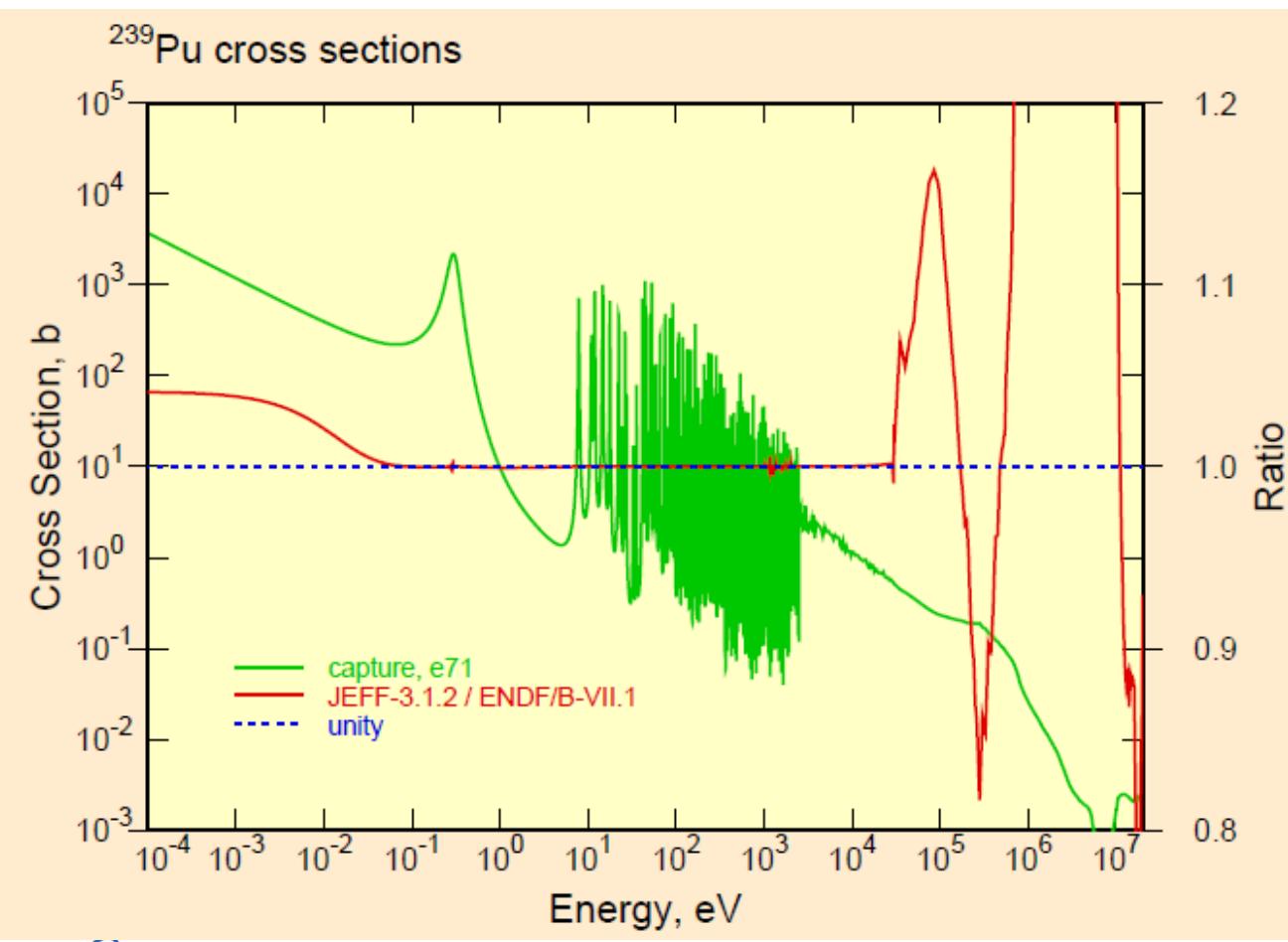
**Ratio, J40/E71
for the ^{239}Pu
fission cross
section**

Introduction



**Ratio,
Leal7a/E71 for
the ^{239}Pu
fission cross
section**

Introduction



**Ratio,
JF312/E71 for
the ^{239}Pu
capture
cross section**

ICSBEP Introduction

- **The International Criticality Safety Benchmark Evaluation Project**
 - Started as a DOE activity in the early 1990s but quickly became an International activity
 - First edition of the Handbook was seven bound volumes, published in ~1995.
 - An ongoing DOE/OECD NEA Activity
 - Technical contributions from ~20 countries
 - The Handbook is revised and updated annually
 - Technical review group annual meeting typically reviews 15 to 20 new evaluations
 - Distributed on DVD through the OECD/NEA Data Bank

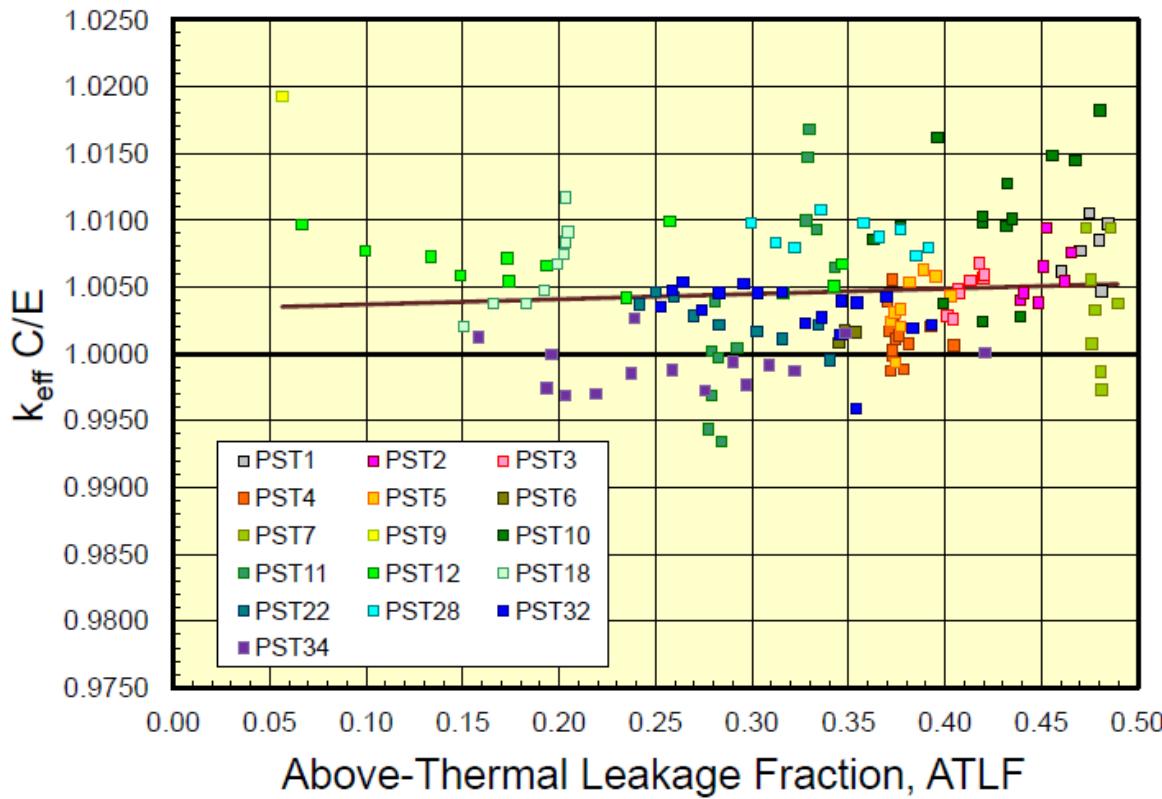
ICSBEP Introduction

- **The basic organization of the Handbook is by Fuel type:**
 - HEU, IEU, LEU (uranium) systems ...
 - > 90 w/o, 10 w/o to 90 w/o, < 10 w/o ^{235}U
 - Pu systems
 - Mixed (U-Pu) systems
 - ^{233}U systems
 - SPEC (Special Isotope Systems)
- **For each Fuel type there is a further breakdown:**
 - Composition
 - Metal, Oxide, Solution, Misc (miscellaneous)
 - Spectrum
 - Fast, Intermediate, Thermal (or Mix) energy ranges
 - Defined by having at least 50% of the flux above 100 keV, between 0.625 eV and 100 keV, below 0.625 eV

ICSBEP Introduction

- **ICSBEP Nomenclature – XXX-YYY-ZZZ-###**
 - XXX = Fuel (HEU, IEU, LEU, Pu, MIX(U/Pu), U233, SPEC).
 - YYY = Fuel Form (MET (metal), COMP (compound), SOL (solution)).
 - ZZZ = Spectrum (FAST, INTER, THERM).
 - ### = sequential index.
- **Can get by with XYZ#**
 - E.g. ...Pu-SOL-THERM-001 → PST1
 - Pu-MET-FAST-001 → PMF1 (LANL Jezebel)

^{239}Pu Thermal Solution Criticals

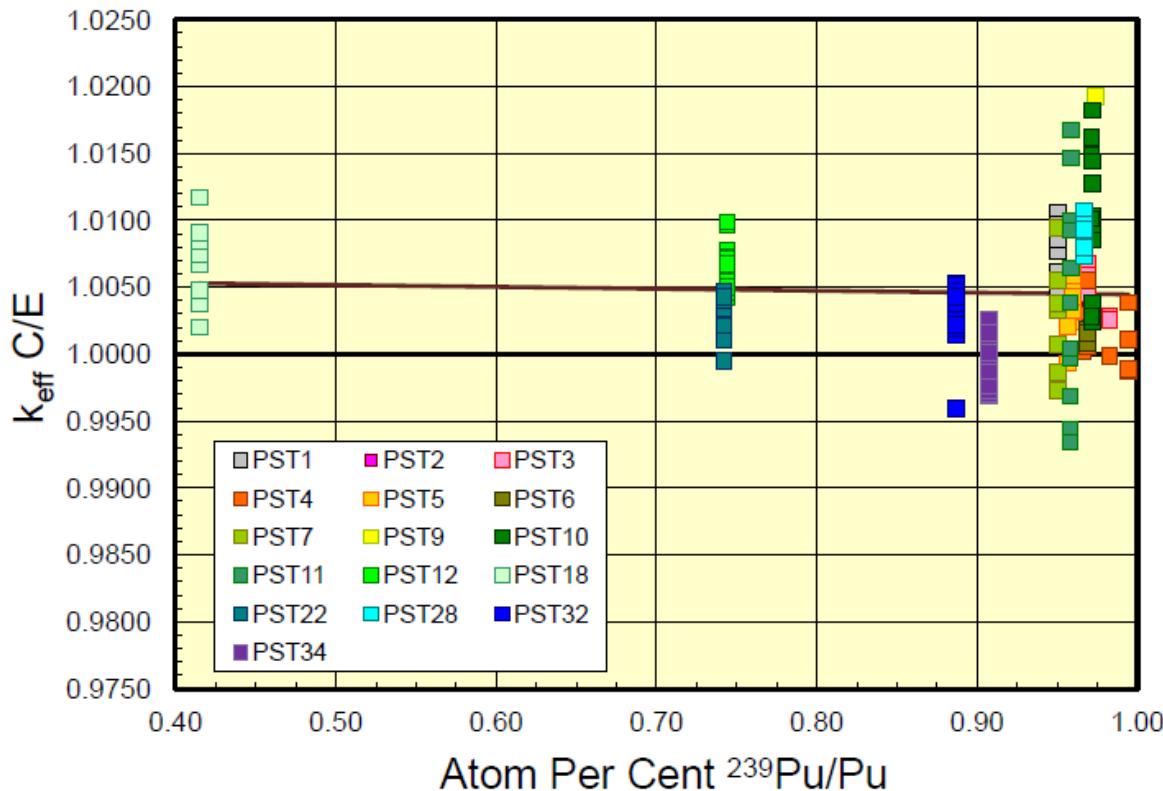


Calculated eigen-values for a selection of ICSBEP PST benchmarks (using ENDF/B-VII.1 cross sections).

Average bias is ~ 500 pcm.

This bias has been present for decades!

^{239}Pu Thermal Solution Criticals

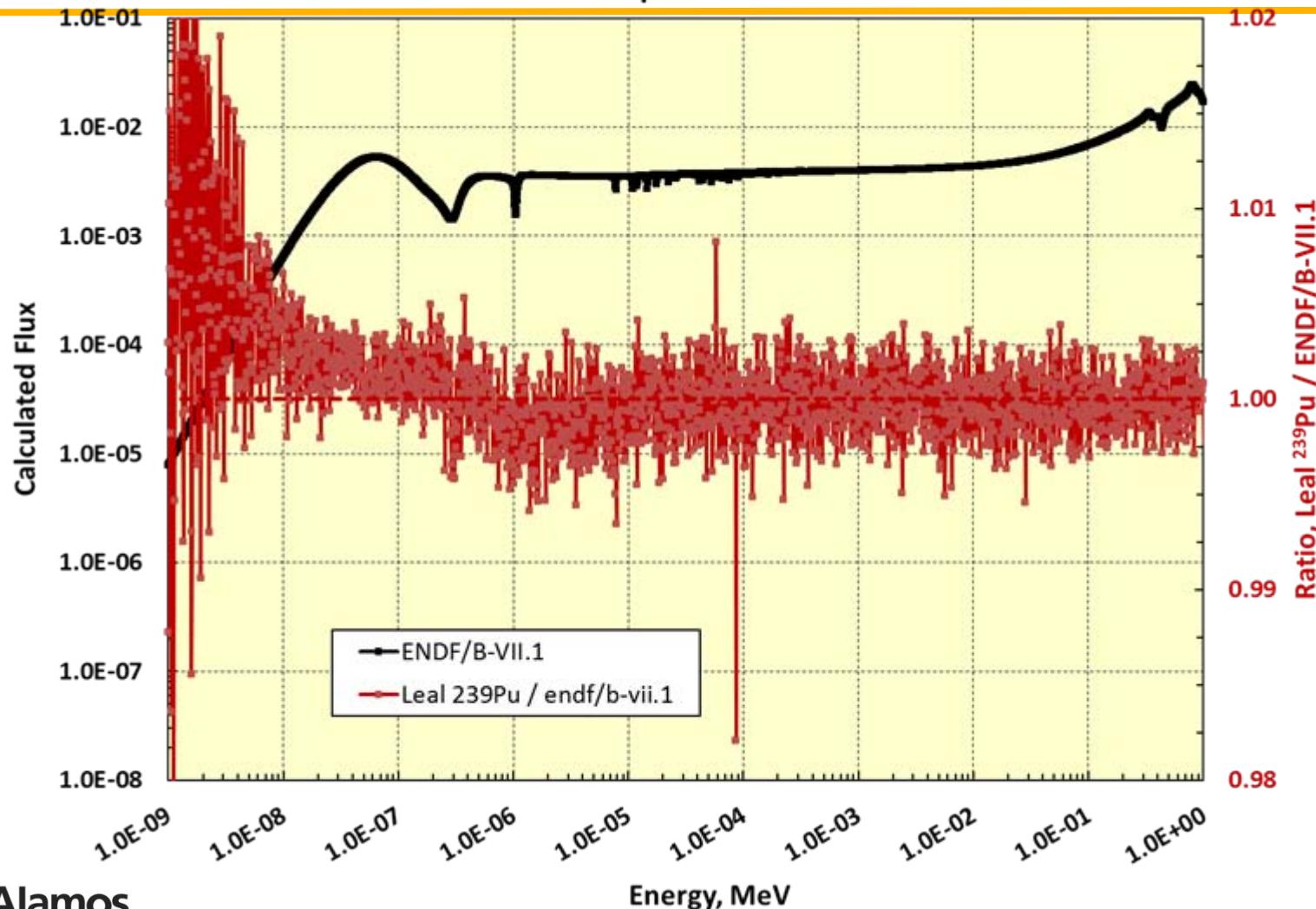


Another view ... but it doesn't change the general conclusion of a ~500 pcm bias.

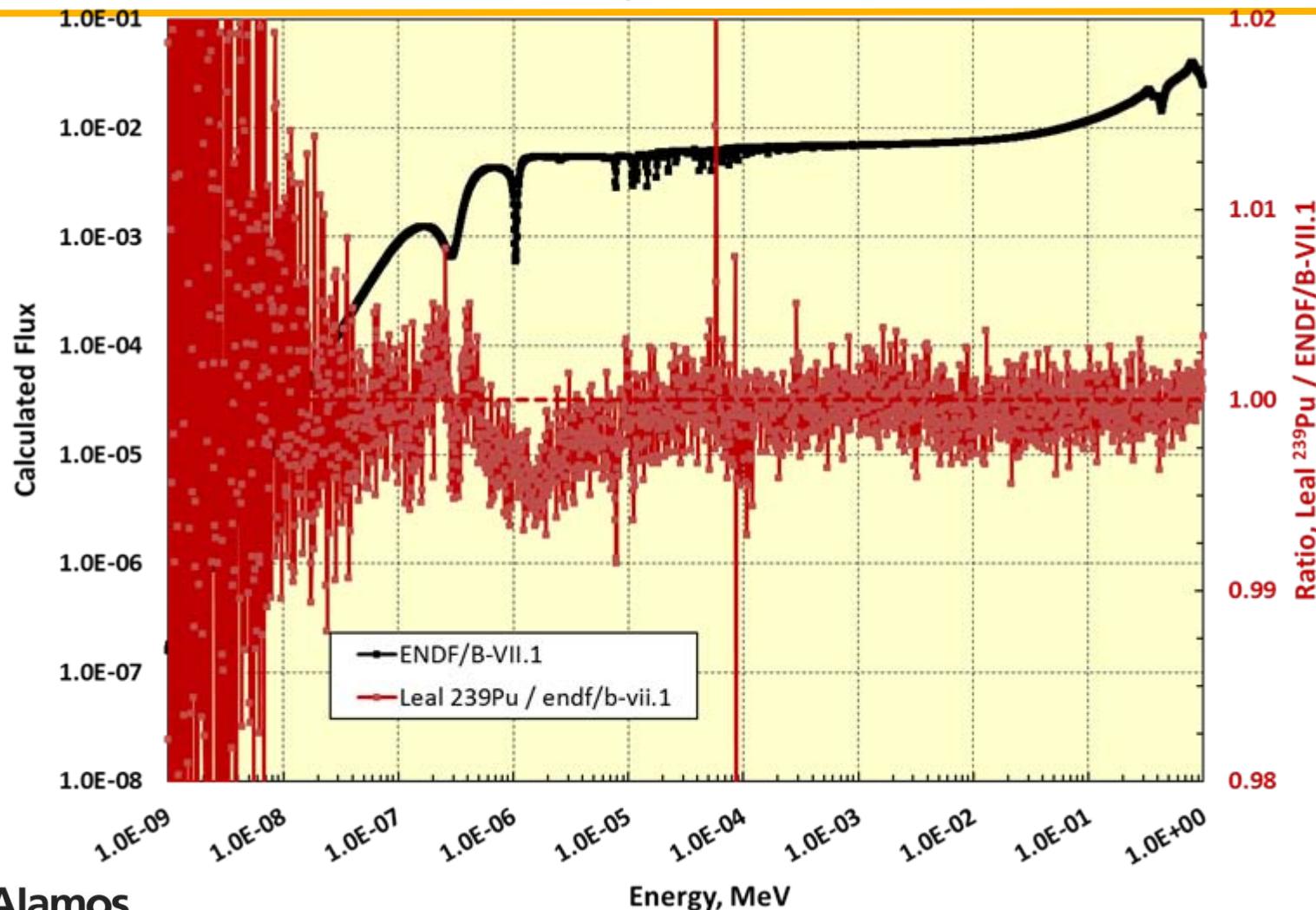
^{239}Pu Thermal Solution Criticals

- A set of seven Pu-SOL-THERM benchmarks have been extracted from the larger set.
 - 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.
- All benchmark experiments are performed in simple geometry
 - PST1.4 & PST4.1 are a water-reflected spheres;
 - PST18.6, PST34.4 & PST34.15 are water-reflected cylinders;
 - PST12.10 & PST12.13 are a water-reflected slabs;

Fine Group Flux in PST1.4



Fine Group Flux in PST34.15



**Calculated Eigenvalues^(a) for a Selection of PST Assemblies
Using Various ^{239}Pu Cross Sections**

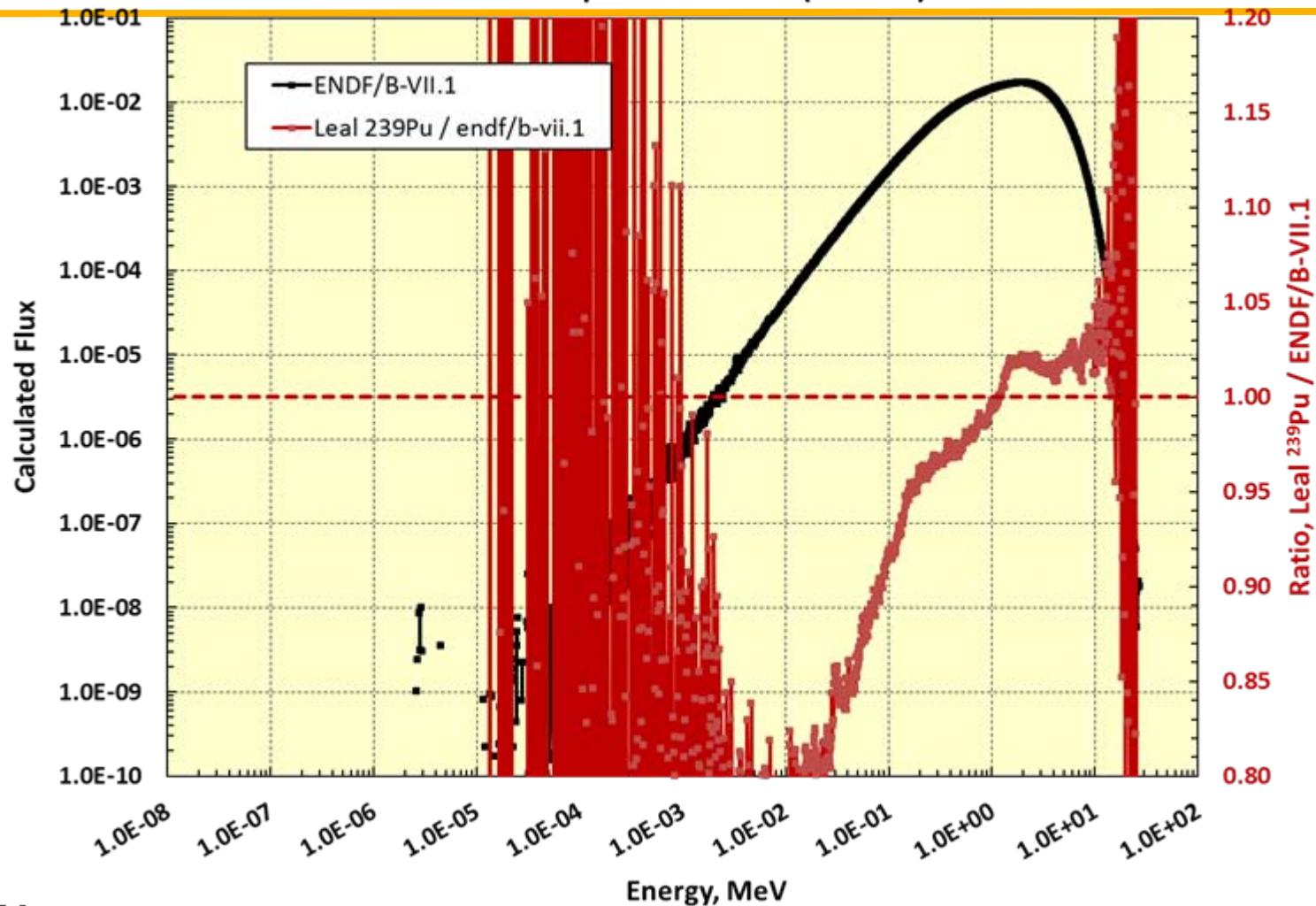
Assembly	ENDF/B-VII.1	JEFF-3.1.2 ^(b)	JENDL-4.0 ^(b)	Leal7a ^(c) + e71	Leal7a (RR, nu, pfns only) + e71
PST1.4	1.00448	1.00127	1.00588	1.00199	1.00202
PST4.1	1.00383	0.99907	1.00482	1.00044	1.00044
PST9	1.01939	1.01367	1.02510	1.01543	1.01546
PST12.10	1.00412	0.99973	1.00498	1.00083	1.00080
PST12.13	1.00955	1.00468	1.01069	1.00611	1.00620
PST18.6	1.00472	1.00153	1.00557	1.00202	1.00208
PST34.4	1.00258	0.99999	1.00417	0.99922	0.99937
PST34.15	0.99742	0.99563	0.99844	0.99679	0.99707
Average	1.00576	1.00195	1.00746	1.00285	1.00293

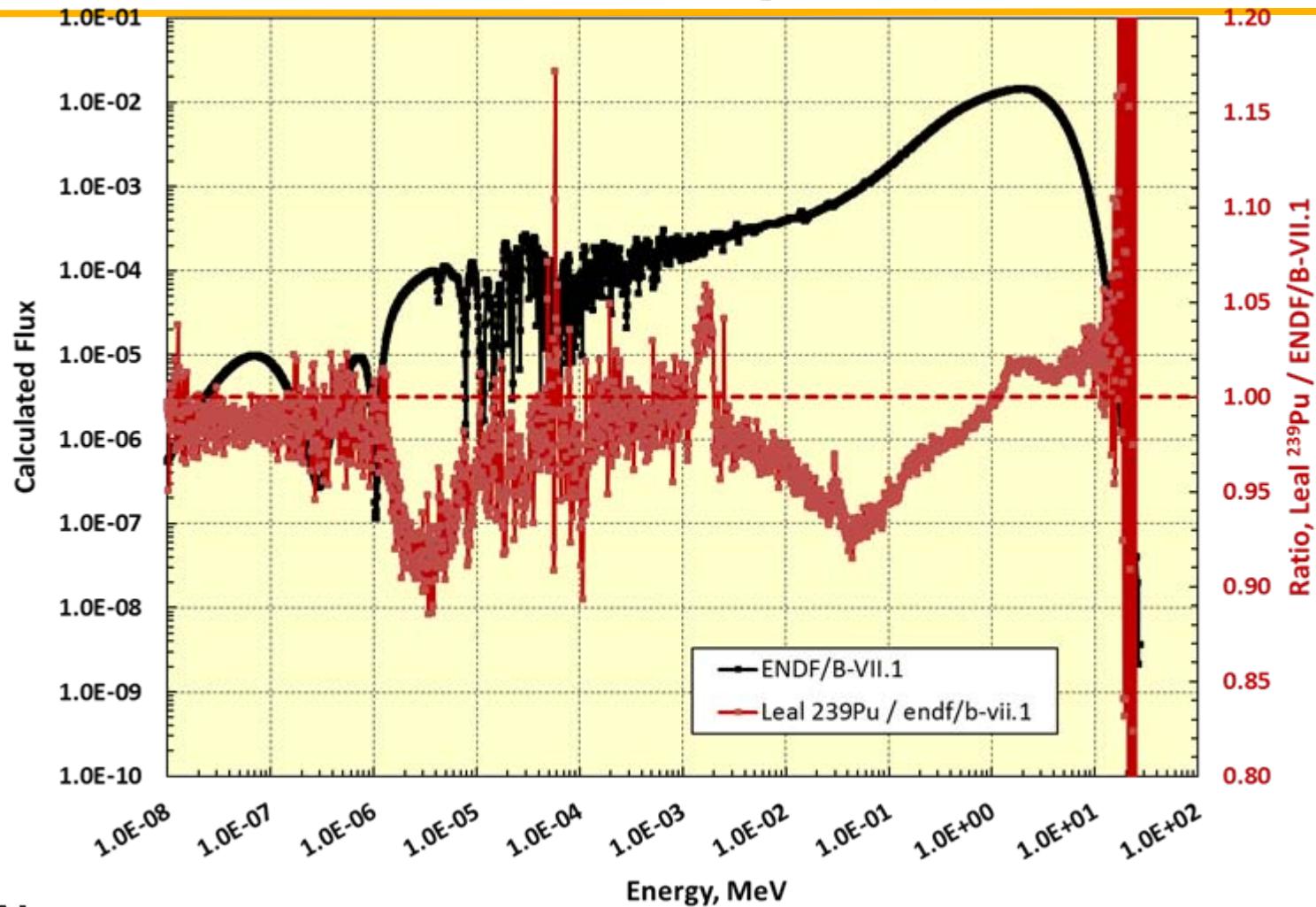
a) MCNP calculations are for 250M histories; stochastic uncertainty is ~5 pcm.
 b) JEFF-3.1.2 and JENDL-4.0 ^{239}Pu only; remaining nuclides are ENDF/B-VII.1
 c) "LEAL7a" evaluation provides revised resolved resonance parameters coupled to a joint ORNL/CEA evaluated ^{239}Pu file; the "LEAL7a (RR,nu,pfns)" file couples just these data to the existing ENDF/B-VII.1 ^{239}Pu file.

Moving to Higher Energies – FAST Pu Metal Systems

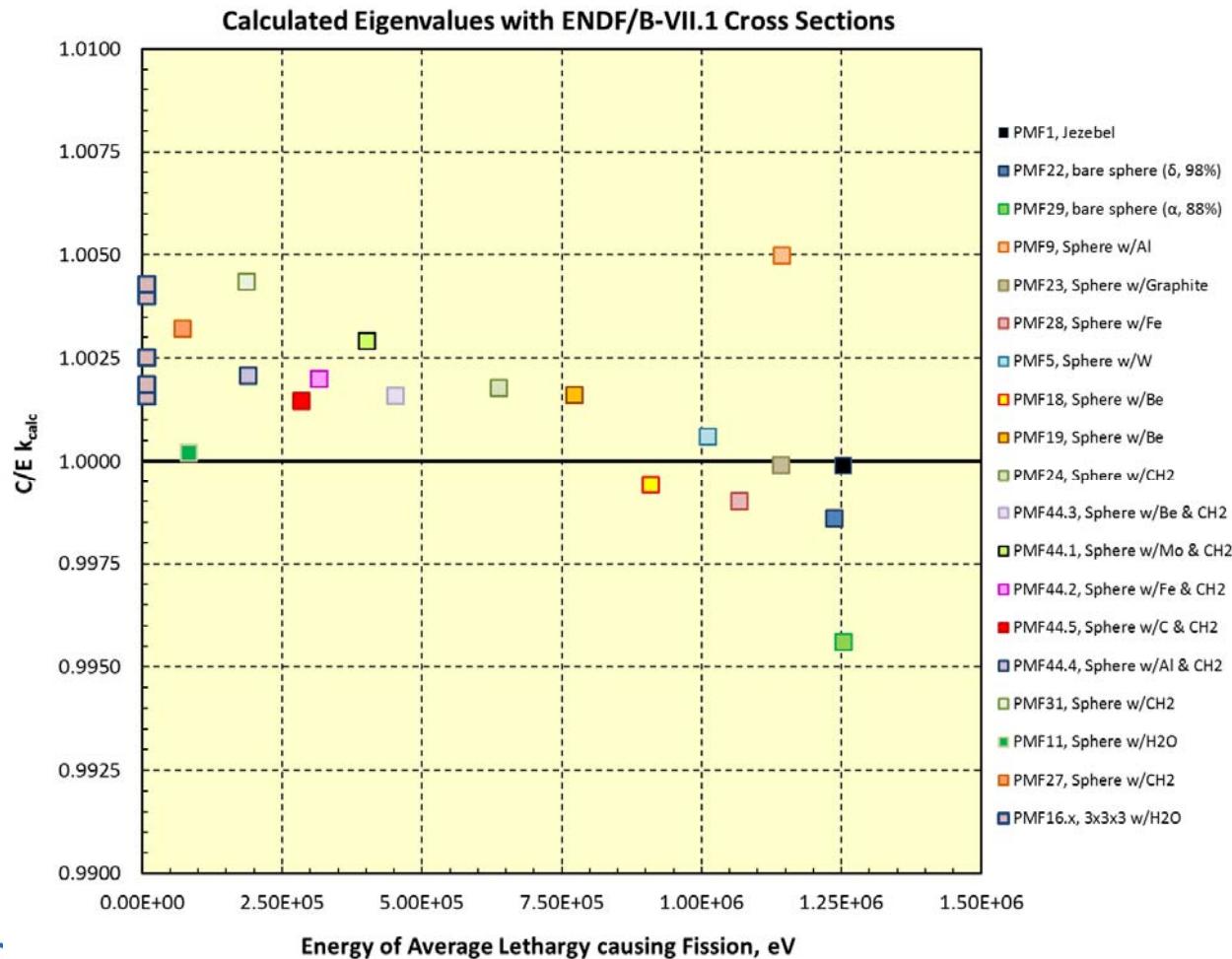
- Previous results have focused upon THERMAL systems
 - Characterized by significant flux and production in the eV and sub-eV range.
- Is all well at higher energies?
 - Sadly ... no!
 - ENDF/B-VII.1 higher energy data are tuned so that the calculated eigenvalue for Jezebel (PMF1), a bare Pu metal “sphere” is virtually unity ...
 - But we see trends in k_{calc} for all major libraries for fast Pu systems with various reflectors that influence the average fission energy.

Fine Group Flux in PMF1 (Jezebel)



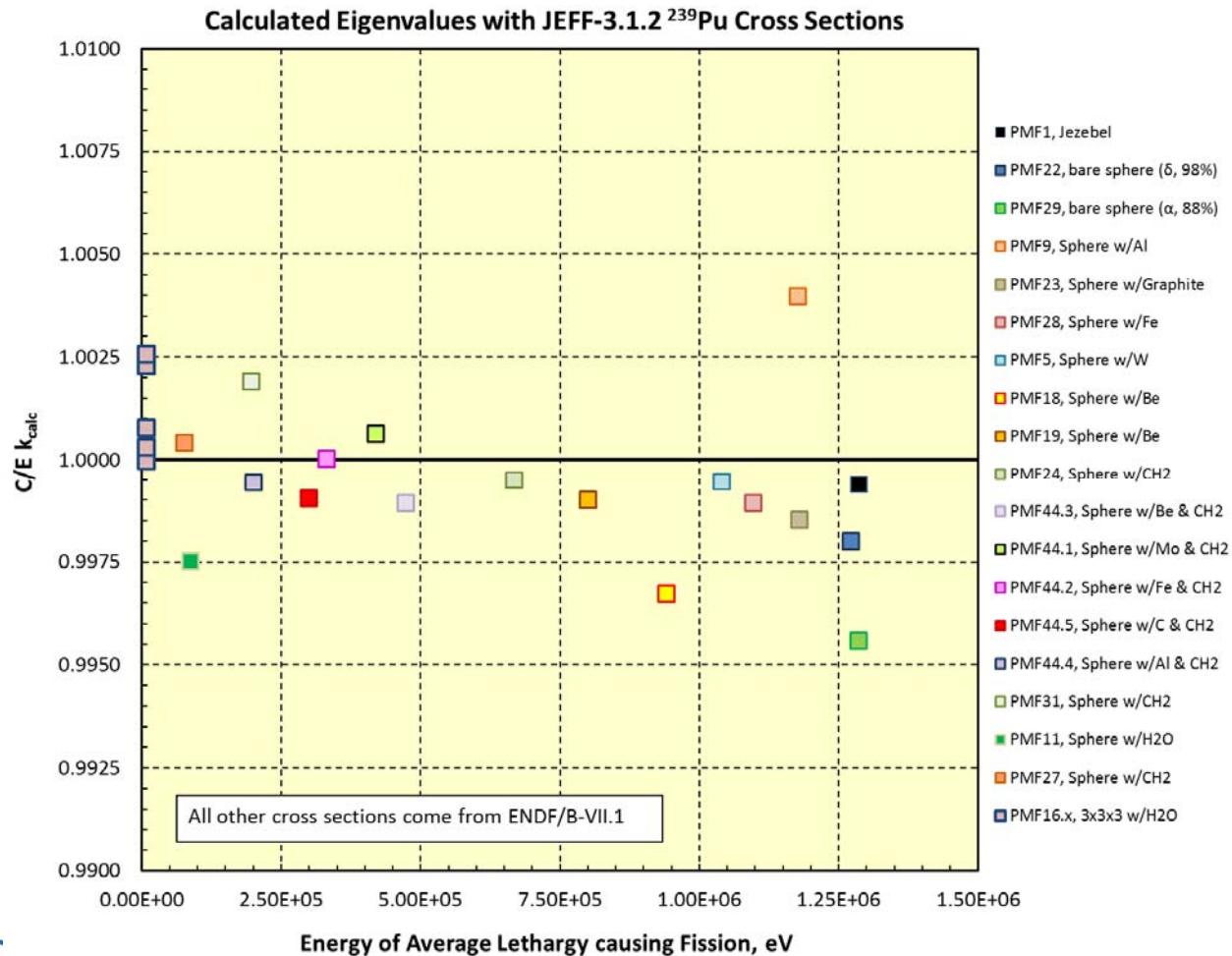
Fine Group Flux in PMF27 (CH_2 reflected sphere)

Pu Metal; Fast & Intermediate Spectrum



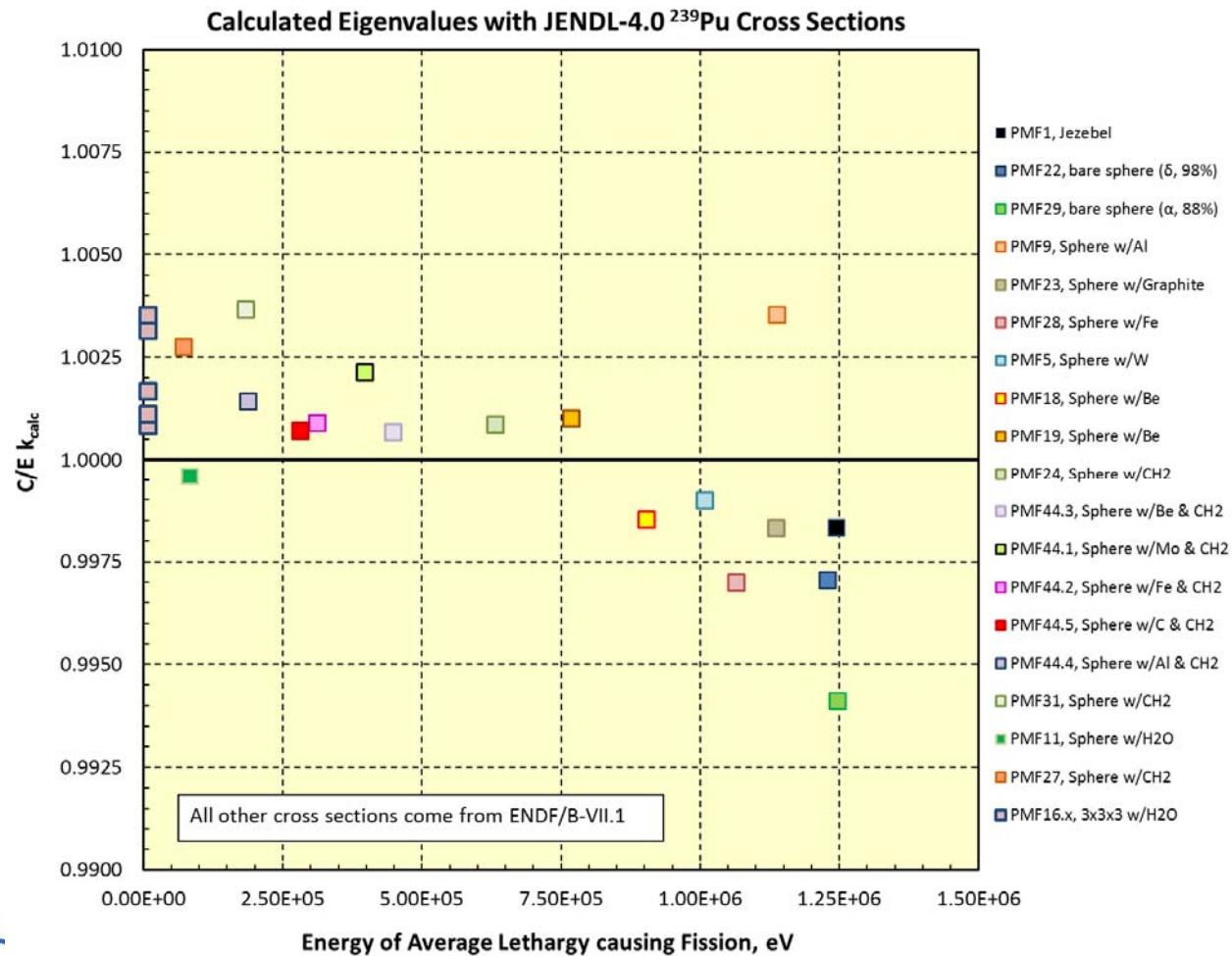
Can couple these with PST to cover the entire energy range from unmoderated to fully-moderated.

Pu Metal; Fast & Intermediate Spectrum



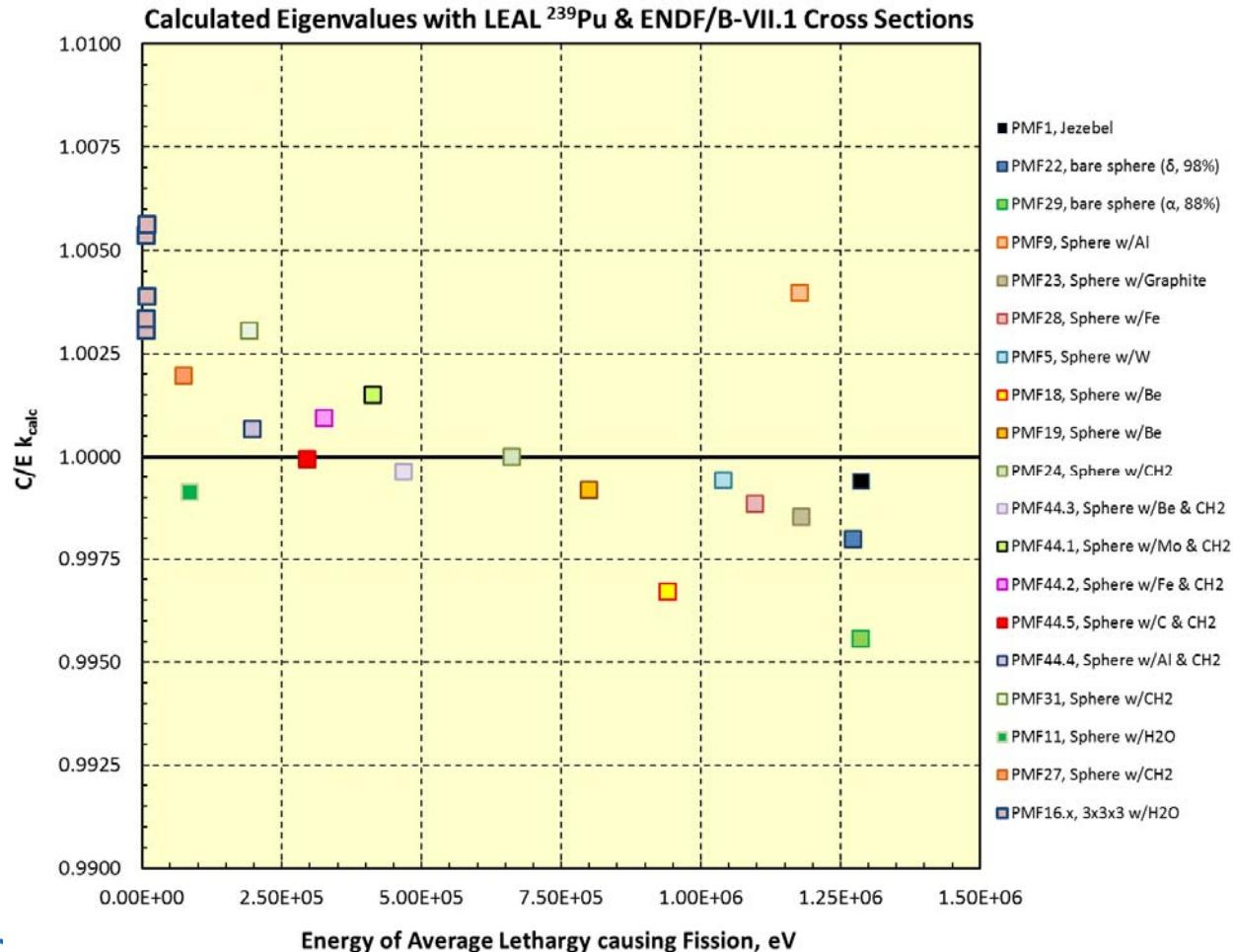
Results
using
JEFF-3.1.2
 ^{239}Pu ;
remaining
cross
sections
come from
ENDF/B-
VII.1.

Pu Metal; Fast & Intermediate Spectrum



Results using JENDL-4.0 ^{239}Pu ; remaining cross sections come from ENDF/B-VII.1.

Pu Metal; Fast & Intermediate Spectrum



Results using the Leal/CEA ^{239}Pu ; remaining cross sections come from ENDF/B-VII.1.

Concluding Remarks

- Despite decades of fundamental evaluation work, supplemented by critical eigenvalue testing, there remain large differences among the major evaluated nuclear data files for even the most important nuclides.
 - This presentation has focused upon ^{239}Pu , but other talks at this workshop have shown the same to be true for ^{235}U .
 - There is only one truly correct answer to the basic nuclear data ... continued work by experimentalists (both for fundamental microscopic data and for integral systems), evaluators and data validators will eventually allow use to converge to this truth.