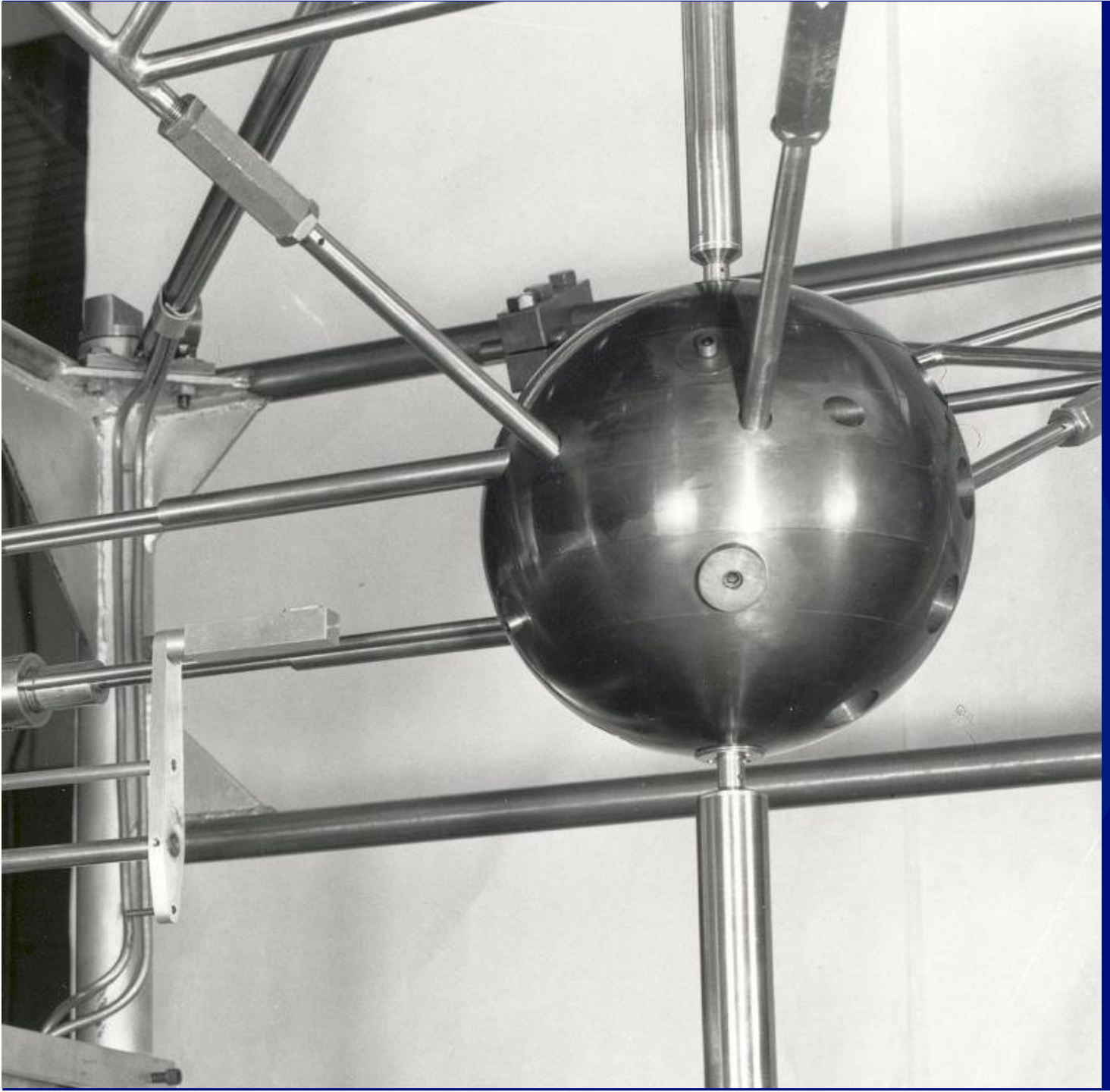

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PAST and PLANNED NCERC Integral Experiments

IEs for Structural Material Validation

Peter Brain, K. Amundson, J. Hutchinson,
C. Kostelac, and G. Siemers

INDEN Structural Meeting 2024

Vienna, Austria // Hybrid

December 16-22, 2024

LA-UR-24-33184

Outline

Summary of NEN contributions to ND validation

- Past years of NCERC Experiments
- Looking to the future
- Integral Experiments and secondary measurements

NCERC is the only general-purpose critical experiments facility in the US

- Location: Device Assembly Facility (DAF) at the Nevada National Security Site (NNSS)
- Operated by: Los Alamos National Laboratory

What is necessary for a successful experimental facility?

- Facility
- Safety basis
- Work authorization
- Nuclear material
- Critical assembly machines
- Metrology
- Detection equipment
- Other support equipment

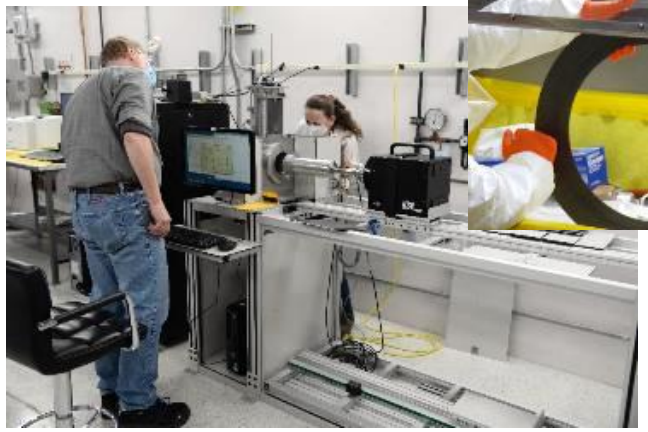
- **People!** with expertise in:
  - Criticality safety
  - Critical experiments
  - Engineering design
  - Radiation detection
  - Radiation protection
  - Cognizant system engineering
  - Neutron noise
  - Reactor dosimetry
  - Metrology
  - **Reactor Physics**

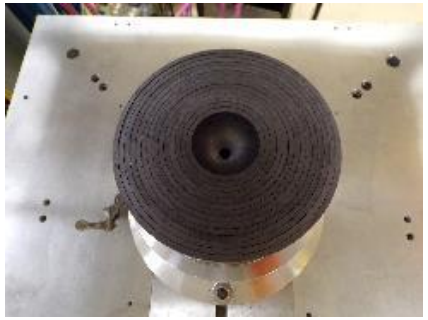
How do you maintain an experimental capability? Continuously perform new and challenging experiments!

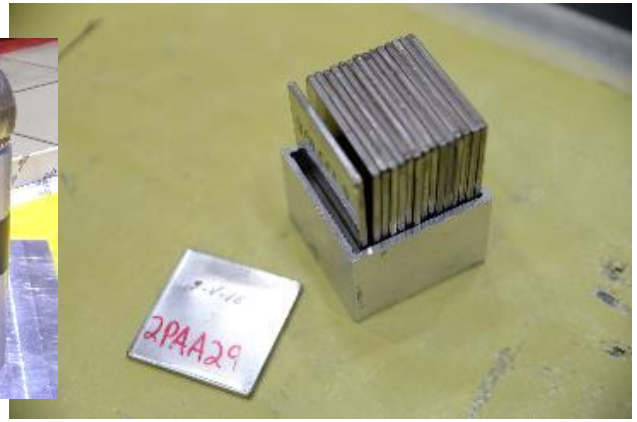
NCSP NUCLEAR CRITICALITY SAFETY PROGRAM

NCERC NATIONAL CRITICALITY EXPERIMENTS RESEARCH CENTER

NCERC currently has four critical assembly machines, high bays, vaults, a count lab, and a large inventory of nuclear material







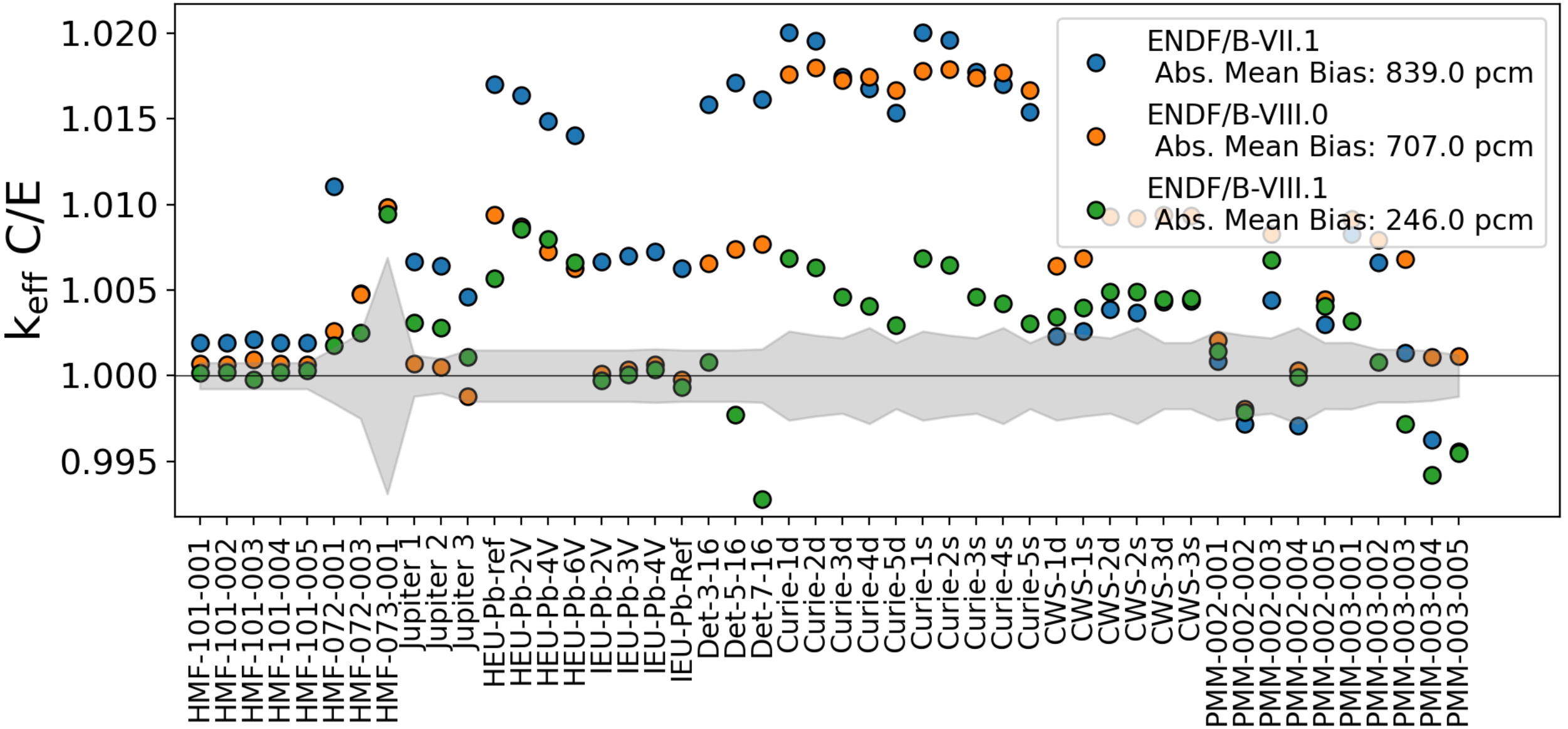
ENDF/B-VIII.1

Minor version update major isotopes

- Addressing problematic light, structural, actinide isotopes, and expanded thermal scattering law (TSL) library
- Utilized NJOY2016.74c to process into ACE and MCNP6.3
- Analyzed a NCERC-only suite focusing on structural materials with final release

- $^{3}_{2}He$, $^{6}_{3}Li$, $^{9}_{4}Be$, $^{16,18}_{8}O$, $^{19}_{9}F$
- $^{28-30}_{14}Si$, $^{51}_{23}V$, $^{50-54}_{24}Cr$, $^{55}_{25}Mn$
- $^{54,56,57}_{27}Fe$, $^{63,65}_{29}Cu$
- $^{103}_{45}Rh$, $^{139}_{57}La$, $^{140,142}_{58}Ce$, $^{156-164}_{66}Dy$
- $^{181}_{73}Ta$, $^{190-198}_{78}Pt$, $^{206,207,208}_{82}Pb$
- $^{233,234,235,236,238}_{92}U$
- $^{239-241}_{94}Pu$
- TSLs

PLOT OF ENDF/B-VII.1, ENDF/B-VIII.0, and ENDF/B-VIII.1



JAEA-LANL

Jupiter - Pb, Al, Pu, and Cu core

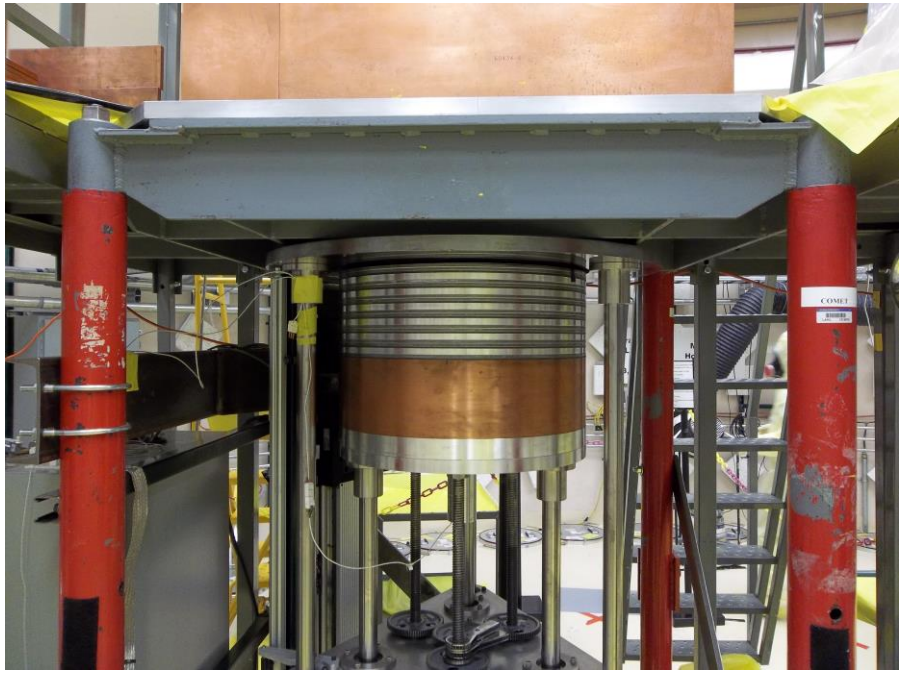
- Studying of Pb void coefficients for accelerator driven systems
- Pu and Pb put deviating pressure on keff

Configuration	ENDF/B-8.0	New Pu	New Pb	New Cu	ENDF/B-8.1
Case 1	1.00072	+250 pcm	+130 pcm	-50 pcm	1.00308
Case 2	1.00049	+250 pcm	+130 pcm	-40 pcm	1.00252
Case 3	1.00017	+250 pcm	+130 pcm	-40 pcm	1.00223

JAEA-LANL

IEU (HEU + NatU), Pb, Cu core

- Already good agreement with experiment
- Pb doesn't "ruin" keff like other JAEA exp.



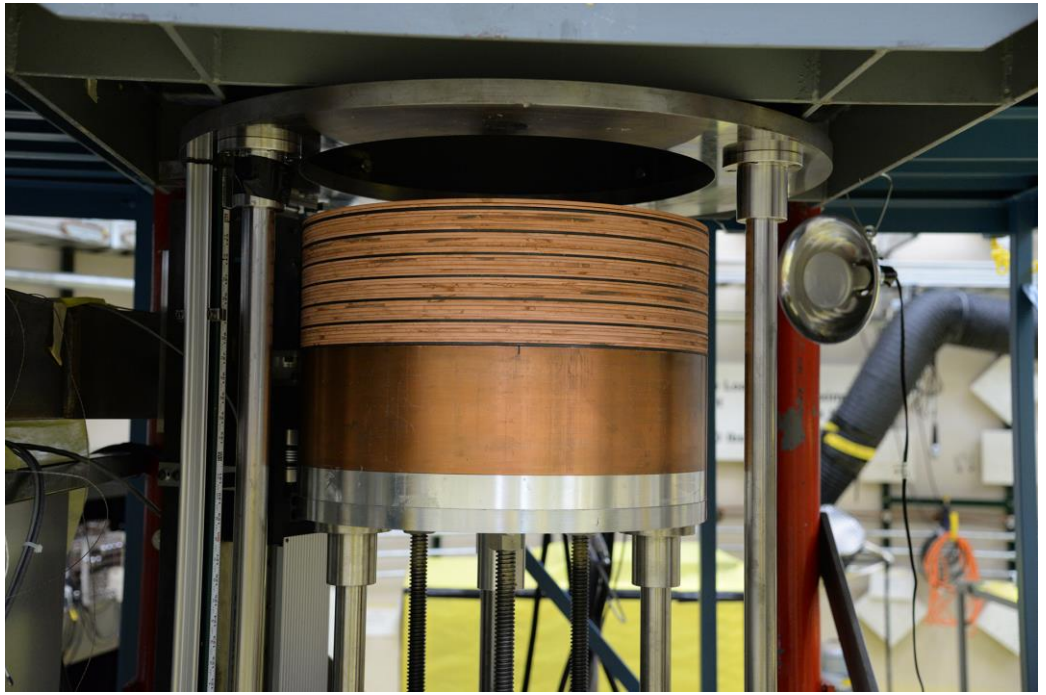
Configuration	ENDF/B-8.0	New Cu	New Pb	New U	ENDF/B-8.1
Simp-Mod-Ref	1.00153	-90 pcm	-13 pcm	+18 pcm	1.00114
Simp-Mod-2V	1.00177	-90 pcm	-4 pcm	+30 pcm	1.00146
Simp-Mod-3V	1.00205	-90 pcm	-1 pcm	+6 pcm	1.00175
Simp-Mod-4V	1.00118	-80 pcm	+50 pcm	+40 pcm	1.00075

Critical Experiment Reflected By copper to bEtter Understand Scattering (CERBERUS)

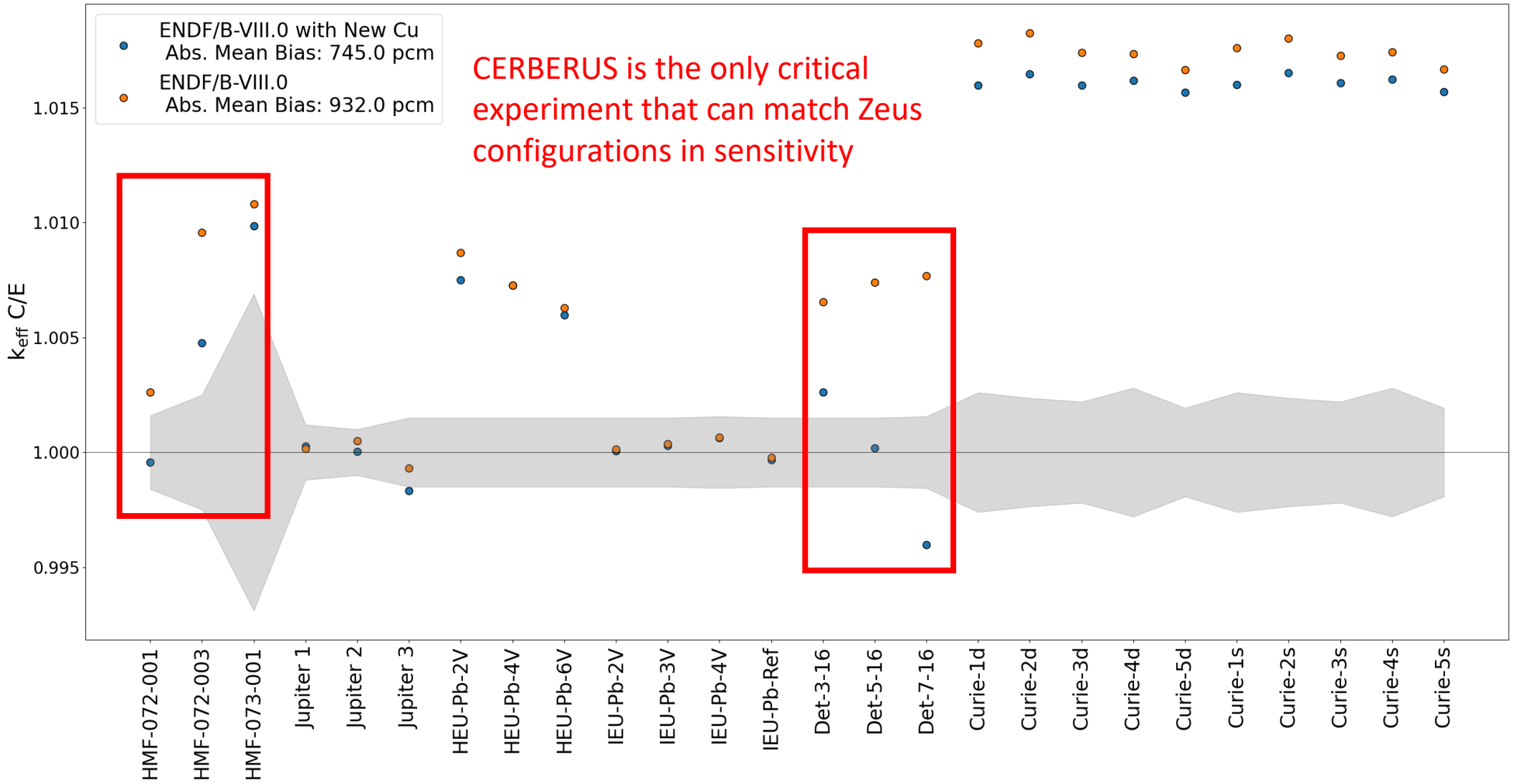
Fast Energy Cu and HEU experiment, with some Al shims

- New copper evaluation (ORNL/INDEN) really drove keff in the right direction
- Is the most sensitive and lowest uncertainty of Cu experiments
  - Includes IMF-20, -21, and -22

Configuration	ENDF/B-8.0	New Cu	ENDF/B-8.1
Det-3-16	1.00796	-390 pcm	1.00343
Det-5-16	1.00881	-630 pcm	1.00094
Det-7-16	1.00909	-1170 pcm	0.99665



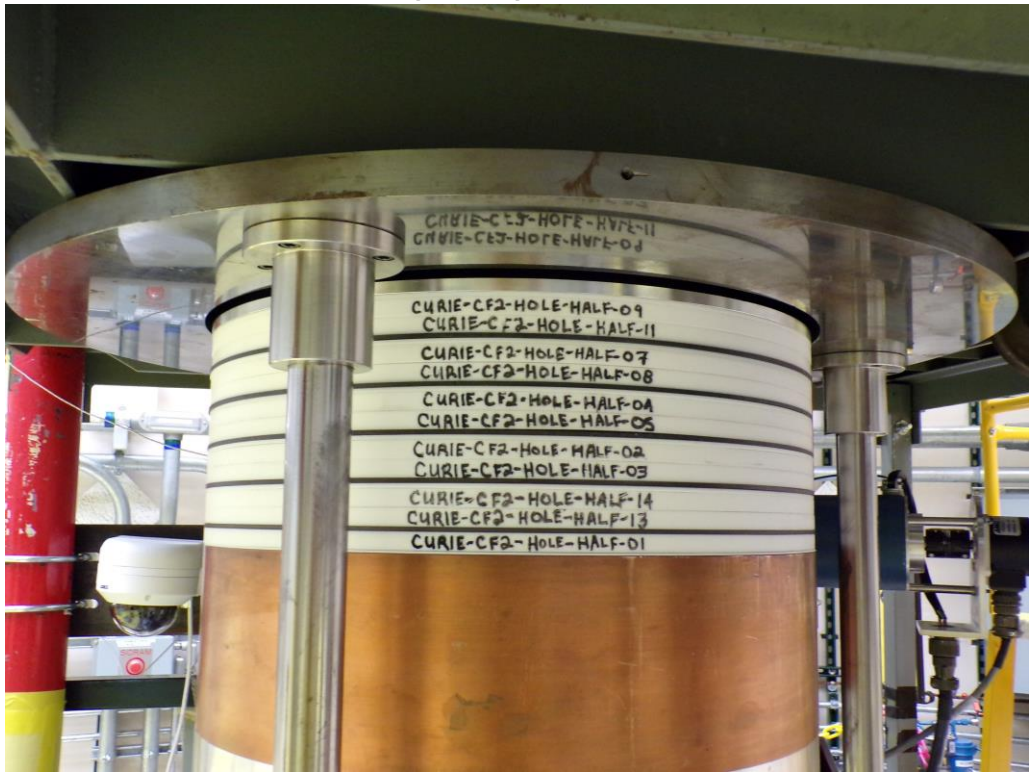
All Zeus Cu Reflected Experiments



Critical Unresolved Region Integral Experiment (CURIE)

Explored Teflon moderated HEU disks

- Led to finding poor F-19 performance (n,n’ cross section)
- No TSL for CF2 available → used poly



Critical Unresolved Region Integral Experiment (CURIE)

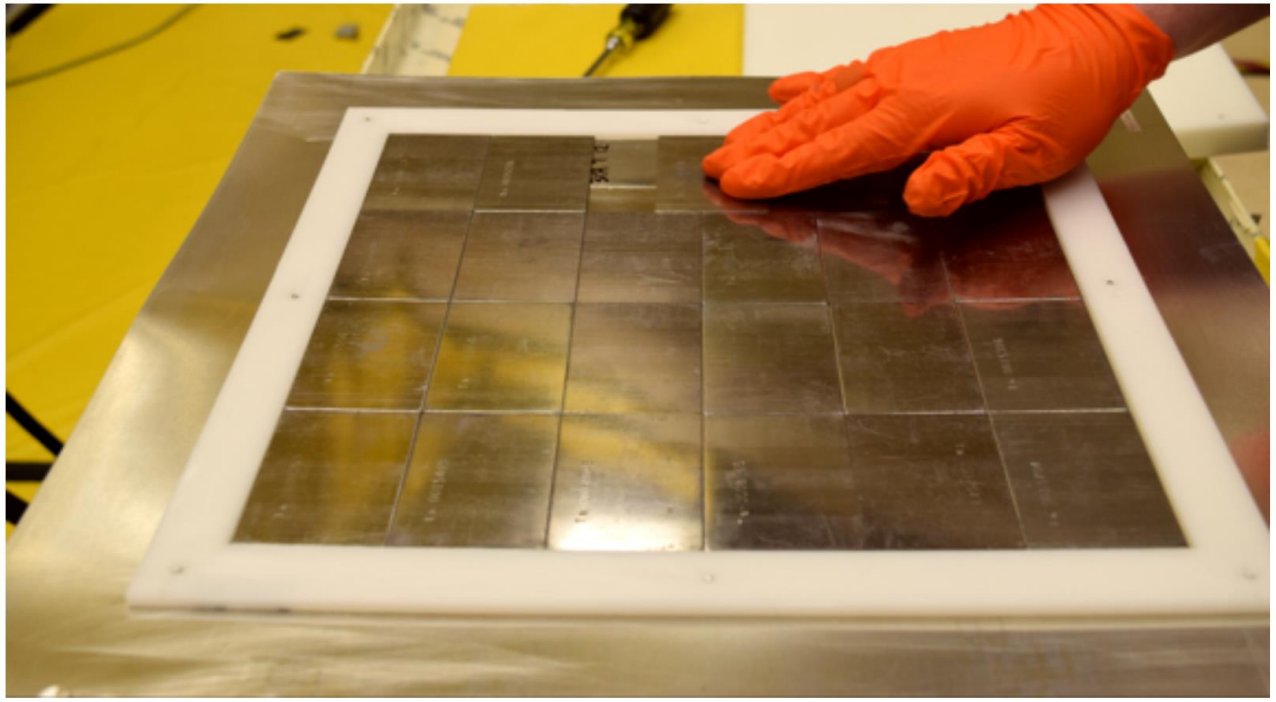
Configuration	ENDF/B-8.0	New F	New Cu	ENDF/B-8.1
Detailed 1	1.01852	-1000 pcm	-180 pcm	1.00755
Detailed 2	1.01850	-1100 pcm	-180 pcm	1.00653
Detailed 3	1.01810	-1200 pcm	-150 pcm	1.00530
Detailed 4	1.01815	-1300 pcm	-100 pcm	1.00489
Detailed 5	1.01605	-1300 pcm	-100 pcm	1.00232

Configuration	ENDF/B-8.0	New F	New Cu	ENDF/B-8.1
Simplified 1	1.01852	-1000 pcm	-180 pcm	1.00758
Simplified 2	1.01850	-1100 pcm	-180 pcm	1.00671
Simplified 3	1.01810	-1200 pcm	-150 pcm	1.00531
Simplified 4	1.01815	-1300 pcm	-100 pcm	1.00502
Simplified 5	1.01605	-1300 pcm	-100 pcm	1.00245

TEX-Ta

Pu, Poly, Ta, and Al

- Explore Ta absorption effects in thermal systems
- If you have Ta in your system, PMM-03-001 is great to use



Configurations	ENDF/B-8.0	New Pu	New TSLs	New Ta	ENDF/B-8.1
PMM-003-001	1.00940	-100 pcm	-30 pcm	-600 pcm	1.00289
PMM-003-002	1.00771	-350 pcm	-20 pcm	-400 pcm	1.00027
PMM-003-003	1.00710	-640 pcm	-20 pcm	-300 pcm	0.99750
PMM-003-004	1.00282	-450 pcm	-20 pcm	-140 pcm	0.99536
PMM-003-005	1.00064	-430 pcm	-70 pcm	-80 pcm	0.99513

Next Five Years

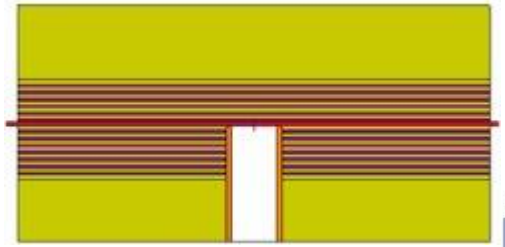
Integral Experiments Planned as of Now

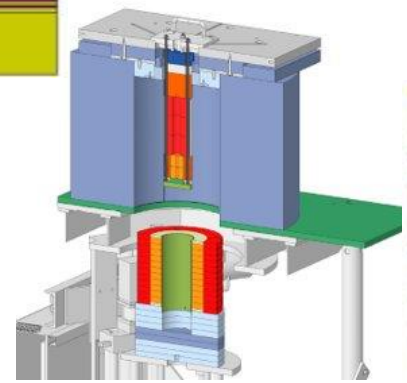
- Deimos Variants (HALEU w/ Steel, Poly, FLiBe, etc.)
- PARADIGM (Intermediate Pu with Cu and Al/C)
- Thales (Fast Pu with Ta)
- MOBY DICK (Molybdenum with HEU)
- ZTA (Zirconium Test Assembly – Full spectra HEU + Zr)
- TEX (Li, Cold, MOX)
- Hanford (Steel and Pu absorption)
- CERBERUS II (Intermediate Cu)
- Fe-Cr Stainless Steel Assemblies

MOBY DICK (Molybdenum)

Moly Optimized Experiment with HEU

- Full spectral testing of Mo cross sections
- Focus is on (n,γ) for Mo-95 but, there are decent capture for many Mo isotopes
- MOBY DICK is going to be the largest Mo experiment by two order of magnitude → magnificent sensitivity



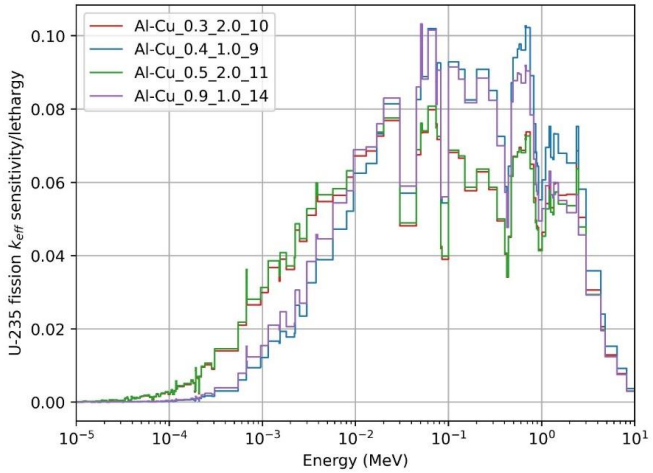


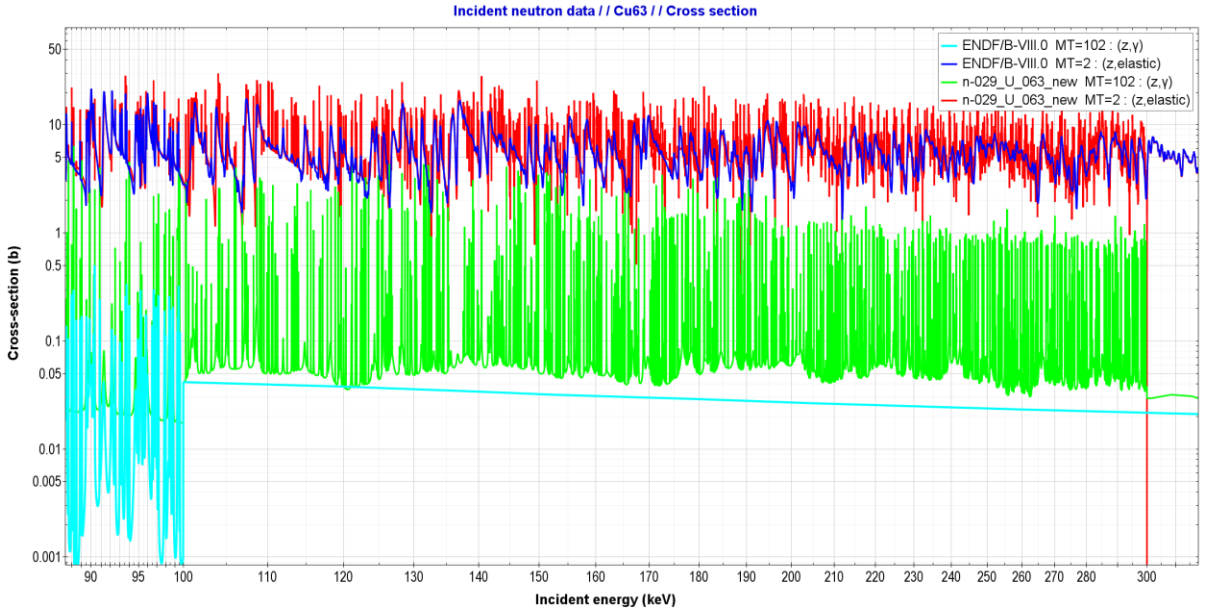
	Moby Dick Fast	KRUSTY	Godiva-IV
Weight % Mo	73.4 %	7.6 %	1.5 %
Mo Mass	491 kg	2.3 kg	~1 kg

CERBERUS II: Cu Boogaloo

Second campaign of CERBERUS allows intermediate energies

- Uses Al2O3 or BeO to target slower spectrum for HEU/Cu
- Over 60% of fissions caused by intermediate neutrons
- Has twice the sensitivity to (n,γ) in 100 – 300 keV region
  - Region with low differential data
  - Finishes the trends for CERBERUS I



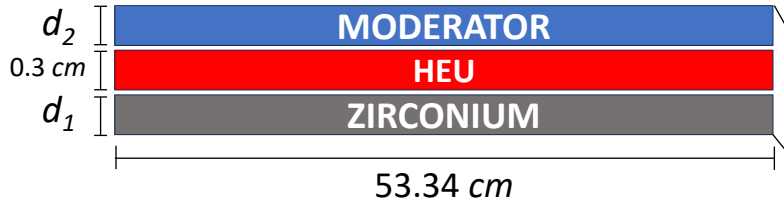


Zirconium Test Assembly (ZTA)

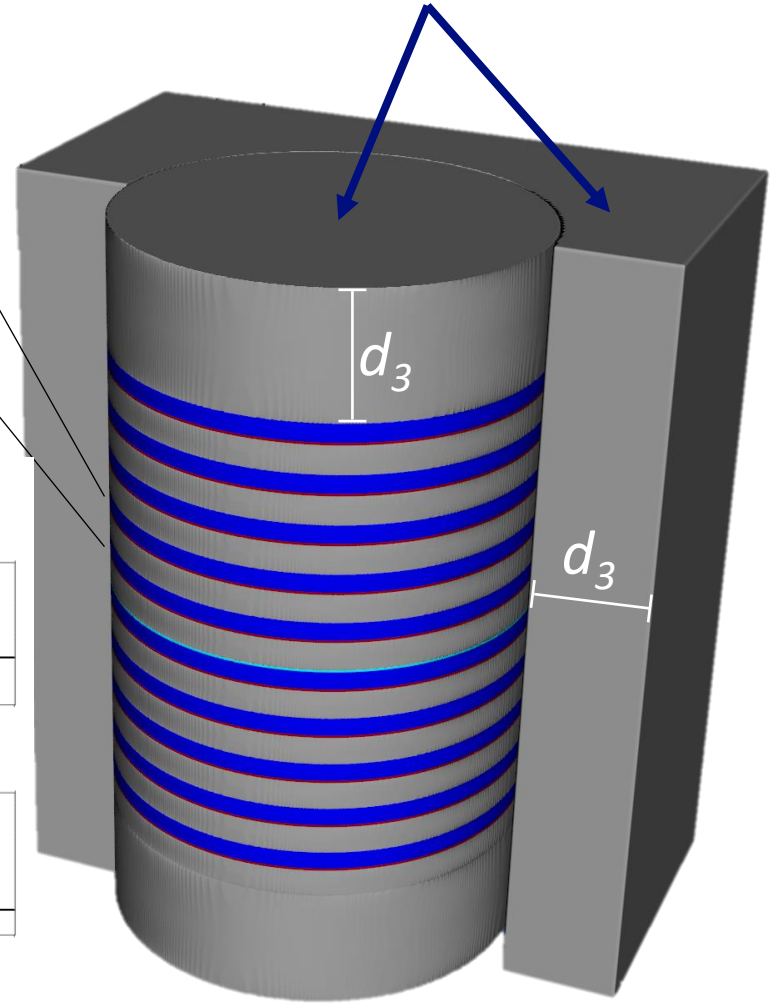
21” HEU Plates – Zeus-Style Zirconium Reflector – Comet Critical Assembly Machine

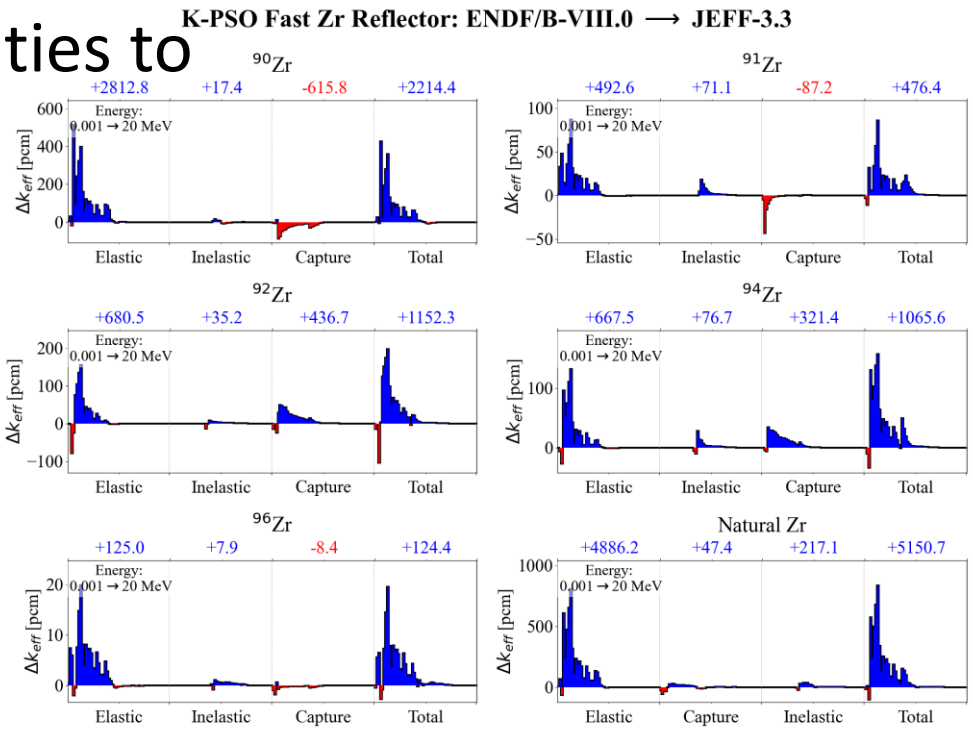
- Full spectrum campaign using new Zr reflector
- Leverages preexisting configuration capabilities to drive down uncertainties
- Fast Zr looking at 5000 pcm difference from JEFF-3.3 and ENDF/B-VIII.1

Unit Cell



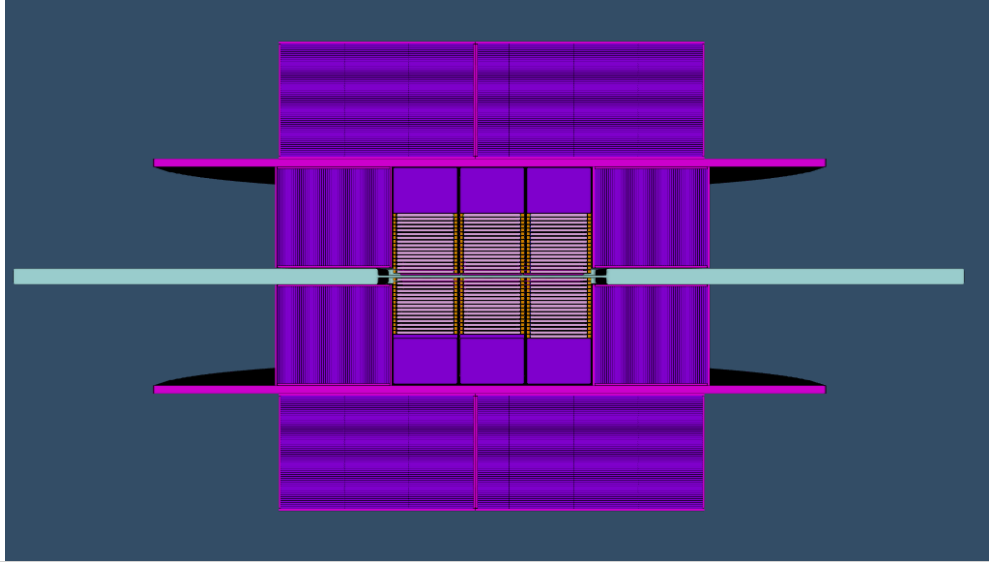
Zirconium Reflector



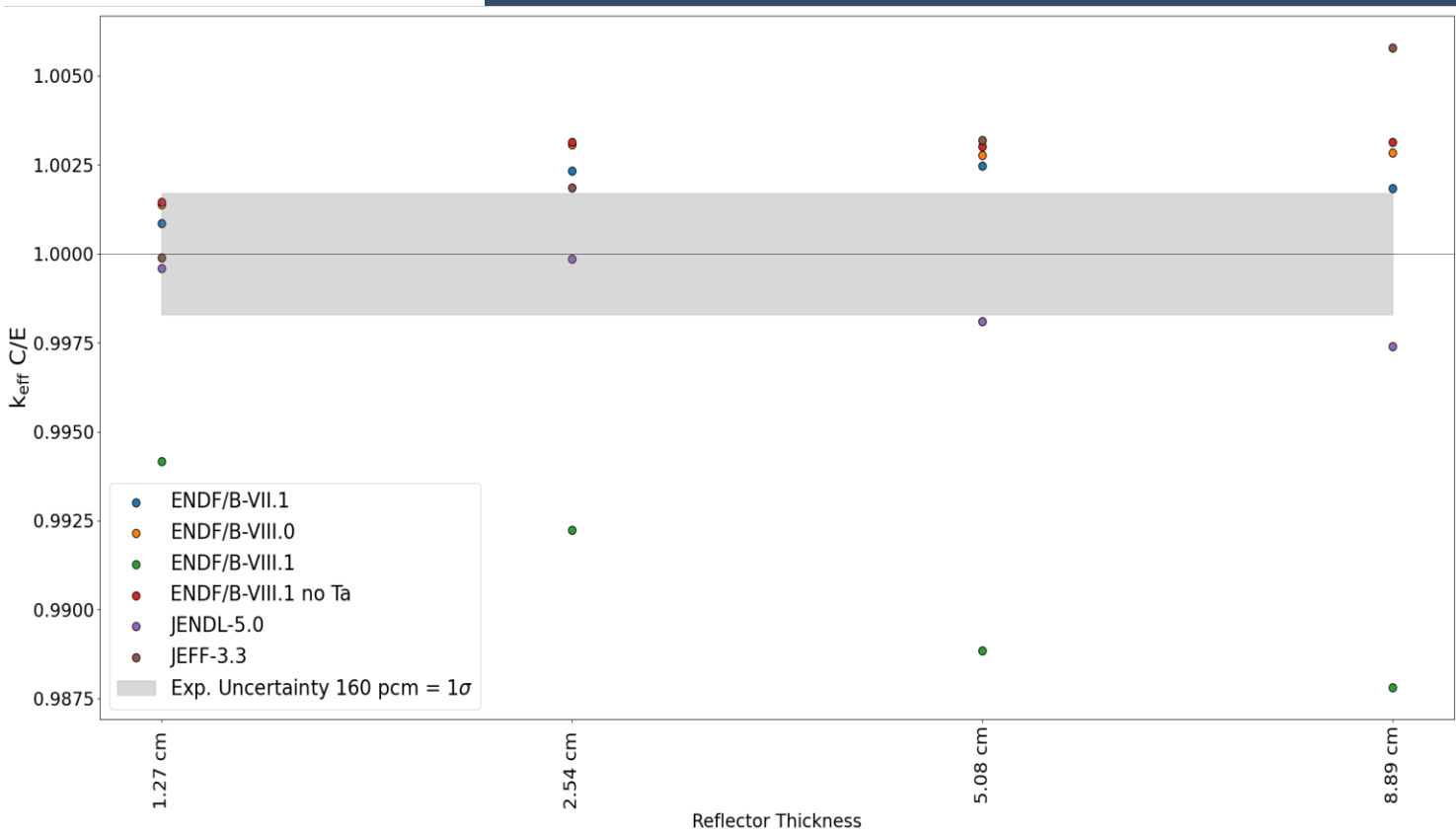


Thales

Ta-reflected Pu experiment



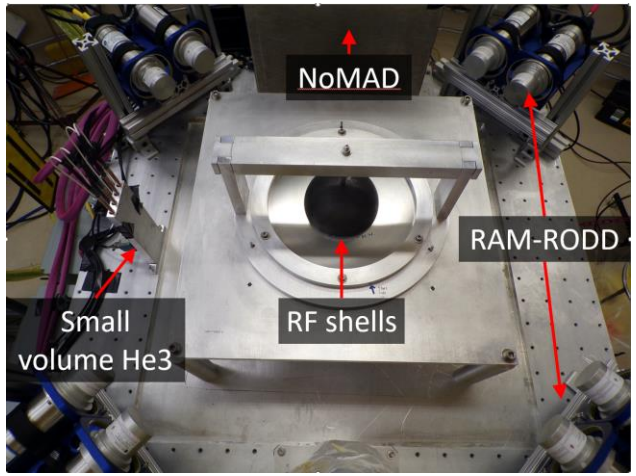
- Experiment to validate new scattering cross sections for LANL NCS
- Designing with ENDF/B-8.0 but ENDF/B-8.1 shows very different trend
  - Expect results between JENDL and ENDF/B-VIII.1
- Can be used for any reflector going forward



Secondary Measurements

More than just Keff

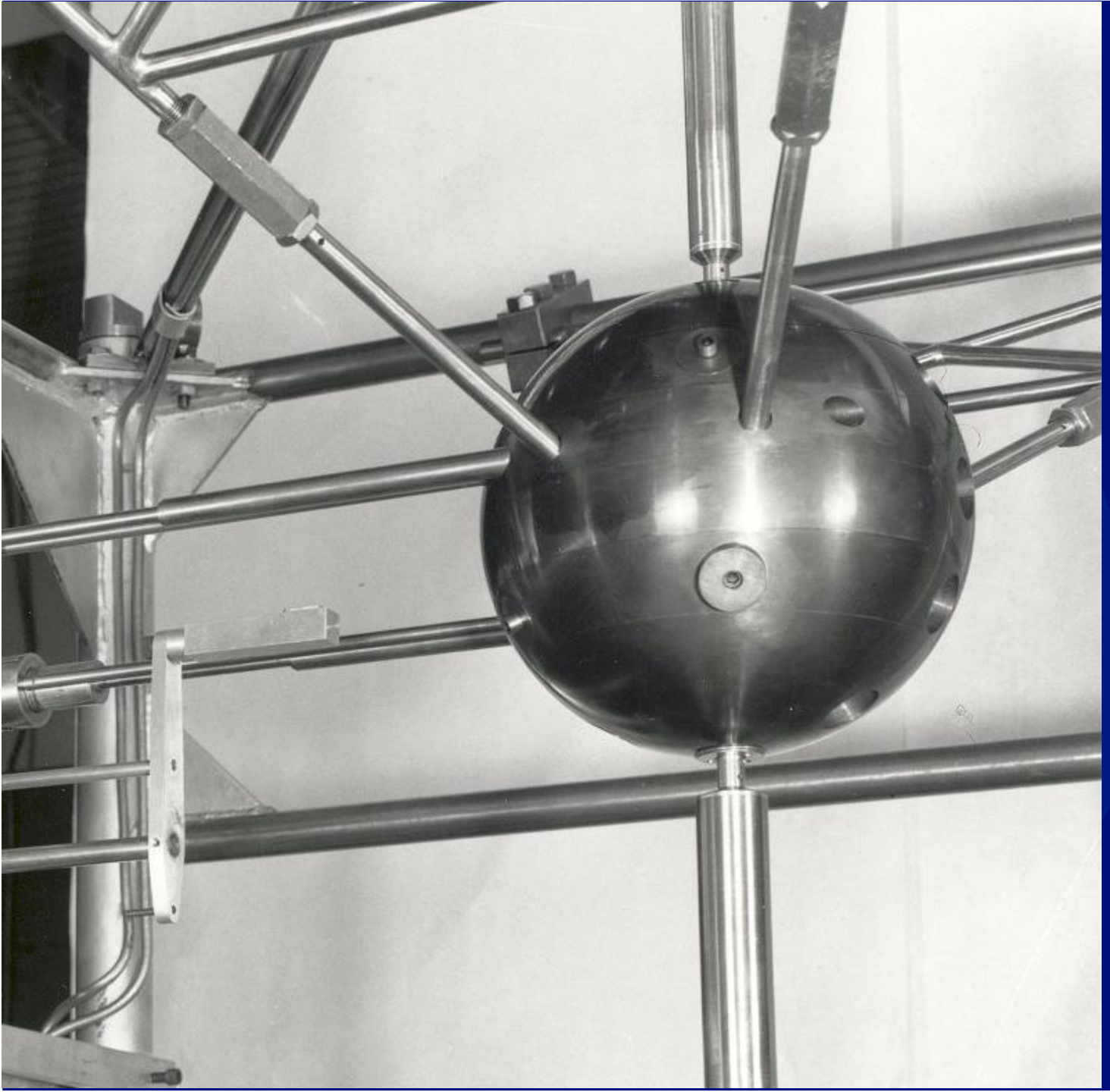
- EUCLID lesson learned: irradiation foils and leakage spectra can inform performance
- Recently NCERC has extended significant effort to measure secondary responses
- Most of the activation foils are structural, so any future adjustments can be sensitive to production cross sections



Summary

Integral experiments can happen along side differential

- NCERC has provided over a 100 individual configurations for criticality safety, the majority of which can be used for ND validation
  - CERBERUS – Validation changed the observable trend for Cu
  - JAEA – Pb shows mixed results as U, Pu, and Cu changed with Pb
  - TEX-Ta – New Ta URR and Fast Region improve C/E
- Expect uncertainties ~ 120 – 200 pcm for modern experiments if your legacy uncertainties are **smaller, revisit!**
- New experiments underway and are happy to help with other campaigns
- Incorporating secondary measurements as standard accompaniments



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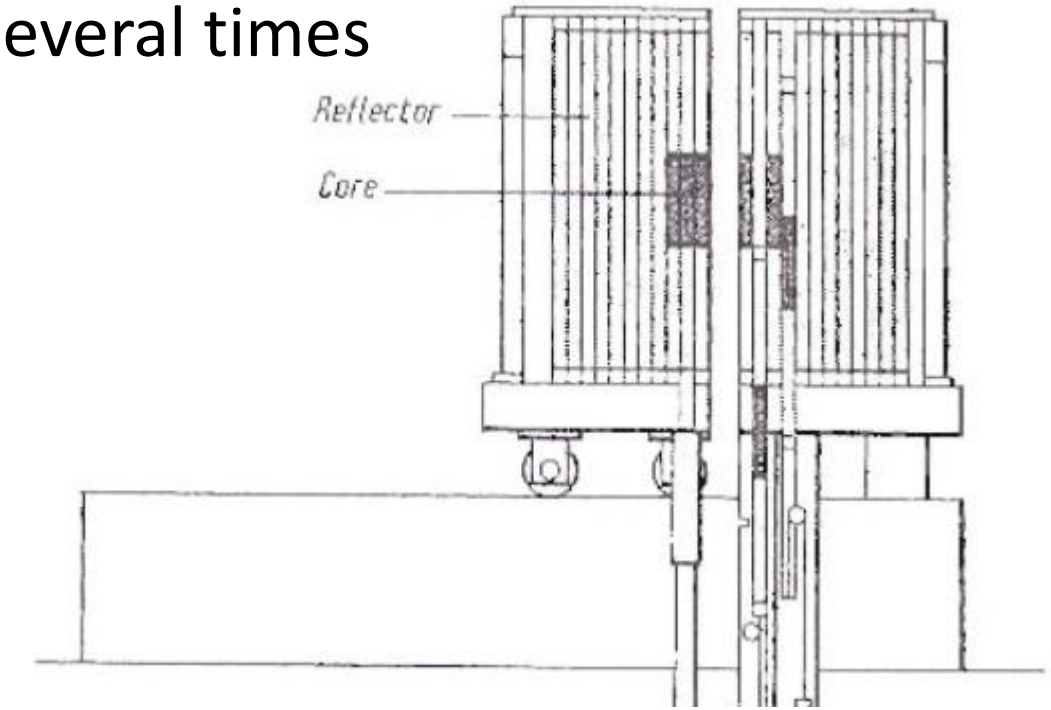
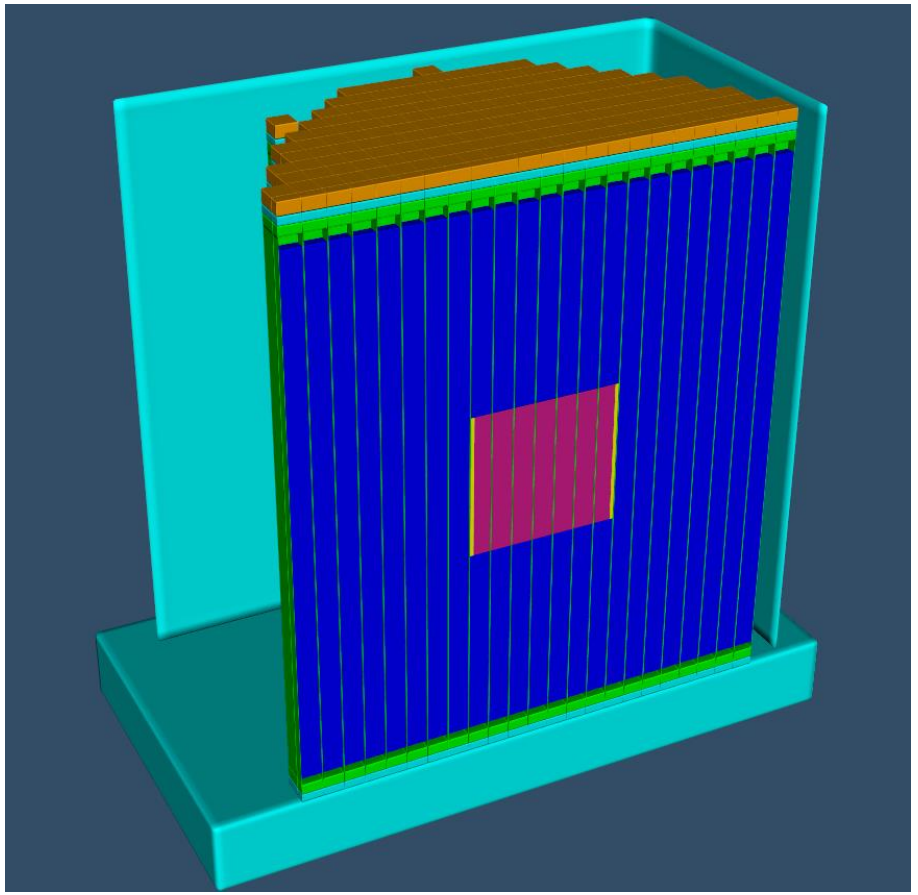
IMF-20

IEU cylinder reflected by copper

- Swedish experiments during 1964 – 1971
- Evaluation written in 2007, revised several times





IMF-20

Potential unaddressed areas of evaluation

- Homogenization of materials vs. air gaps
- Material compositions are largely unknown
- Fuel enrichment, coatings, and weight(density)