Status of the International Criticality Safety Benchmark Evaluation Project (ICSBEP) Including New and Revised Evaluations

Presented at the Cross Section Evaluation Working Group
Brookhaven National Laboratory

November 5, 2024

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International Criticality Safety Benchmark Evaluation Project (ICSBEP) Chair

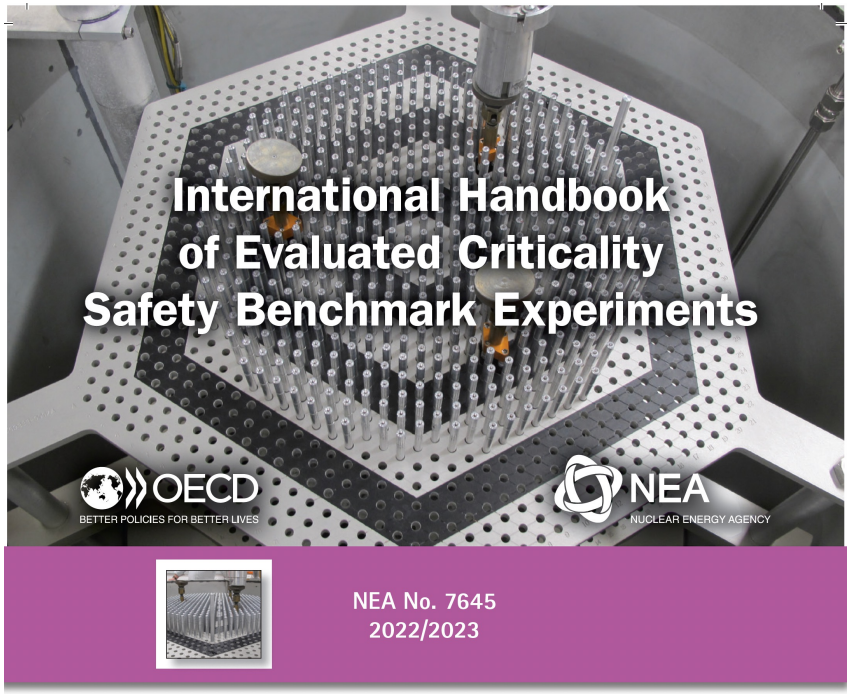
LLNL-PRES-871032

Lawrence Livermore National Laboratory

Acknowledgments

- The International Criticality Safety Benchmark Evaluation Project (ICSBEP) is a Collaborative Effort
  - Numerous Scientists, engineers, administrative support, and program sponsors
  - 28 different countries have participated in evaluating and reviewing benchmark data for almost 30 years
  - Without these dedicated individuals, the international benchmark projects would not exist
- Immediate Past Chair, John Bess
  - Guided the ICSBEP for almost ten years, contribution cannot be overstated

2022/2023 Handbook Edition Status

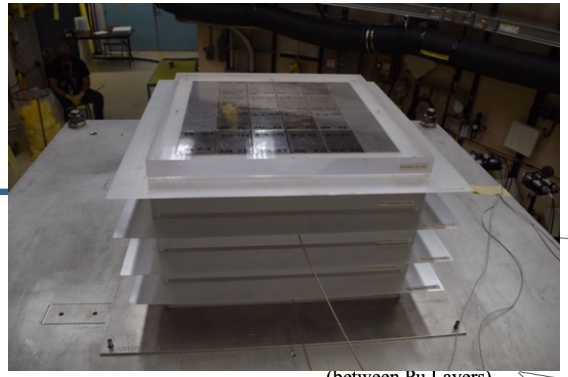


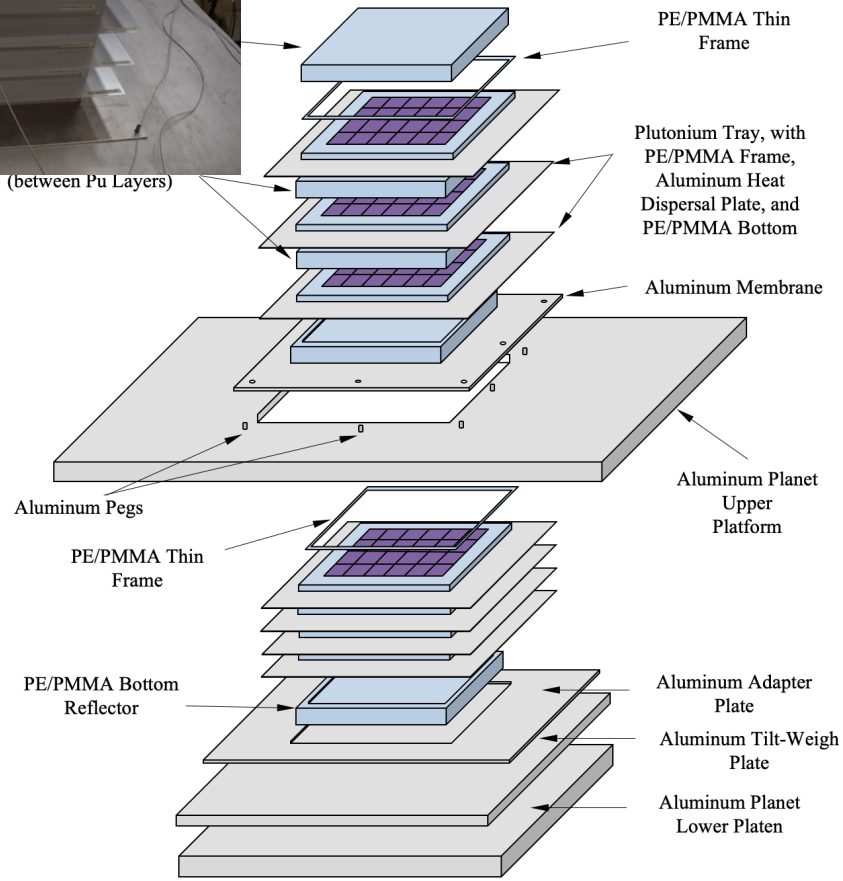
- Combined 2022/2023 Edition of the Handbook is ready for release
- Expect web publishing imminently, DVD assembly slightly longer
- Cover art in memorium to Gary Harms, USA, from his last benchmark, LCT-111

Content for the 2022/2023 Edition of the ICSBEP Handbook

- 13 new evaluations with 41 critical configurations, 1 fundamental physics configuration, and 4 alarm/shielding configurations
  - Volume I: Two new thermal Pu evaluations
  - Volume II: Two new fast HEU, one intermediate HEU, and one mixed HEU evaluations
  - Volume III: One new fast IEU evaluation
  - Volume IV: Two new thermal LEU evaluations
  - Volume VII: Three new ^{252}Cf source shielding evaluations
  - Volume IX: One new neutron slowing down fundamental physics evaluation
- Two major revisions to PU-MET-MIXED-002 and PU-SOL-THERM-028

New Evaluation 1: PU-MET-THERM-004





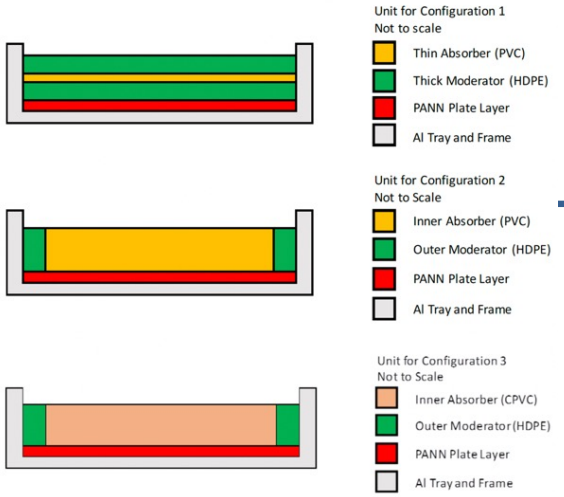
TEX Plutonium Thermal Assemblies: Plutonium-Aluminum Metal Alloy Plates with Thick Polyethylene or Polymethyl Methacrylate (Lucite) Moderators

- TEX-Pu Variant Experiments On Planet Machine at NCERC/NNSS
- PANN Plutonium ZPPR Plates
- 4 cases with 2 cases each of **Polyethylene** and **Lucite** of varying thickness
- Provide test for **Thermal Scattering Laws**

New Evaluation 2: PU-MET-THERM-005

Thermal-Spectrum Critical Assemblies with a Polyvinyl Chloride And Chlorinated Polyvinyl Choride-Plutonum-Aluminum Metal Alloy Core Surrounded by a Polyethylene Reflector

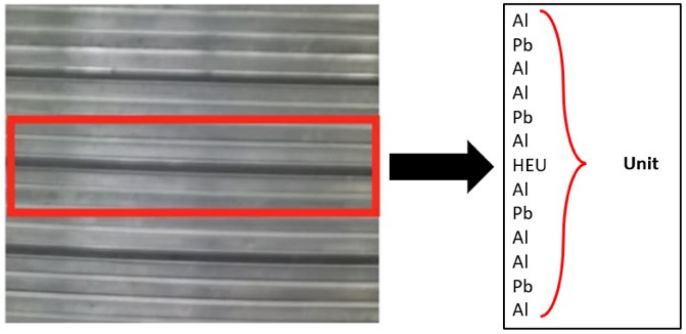
- **Chlorine Worth Study** on Planet Machine at NCERC/NNSS
- PANN plutonium ZPPR Plates
- 3 cases that varied the level of moderation and **chlorine** content to target different plutonium chloride solution concentrations

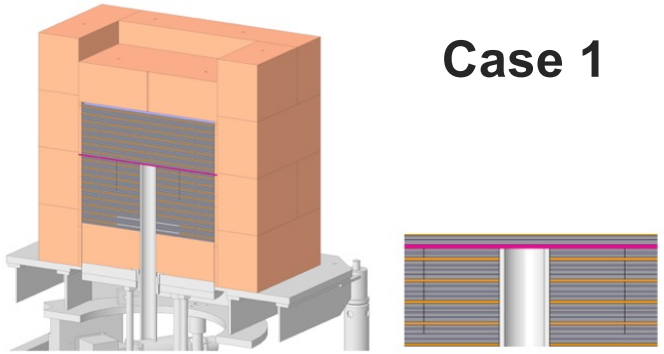


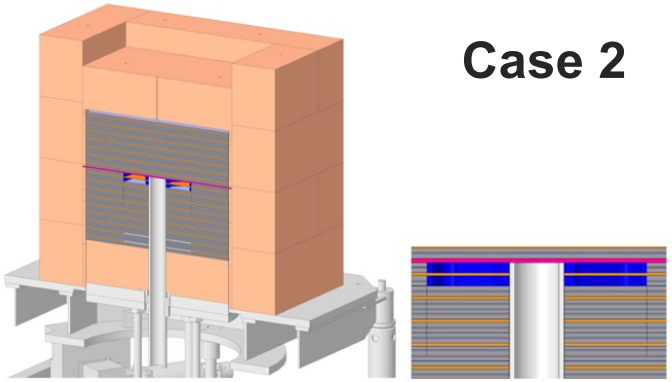
New Evaluation 3: HEU-MET-FAST-102

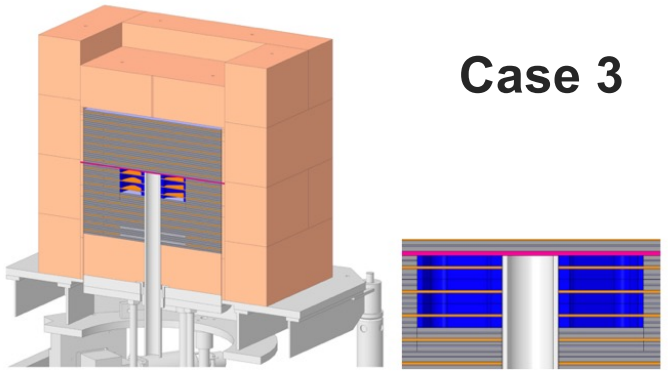
Zeus: Fast Spectrum Critical Assembly with a Pb-HEU Core Surrounded by a Copper Reflector

- Comet Assembly Machine at NCERC/NNSS with Zeus Copper Reflector and HEU Jemima Plates
- Collaboration between JAEA and LANL
- 3 cases with increasing **central void of lead**

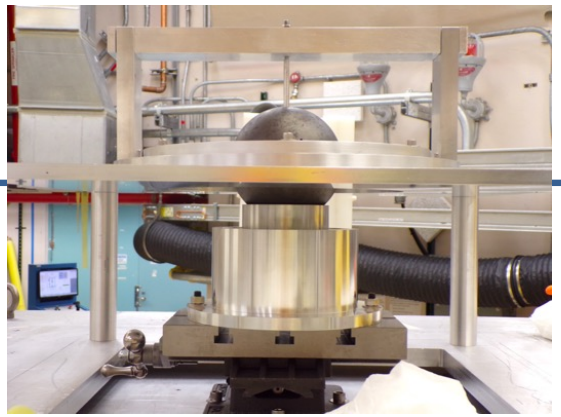






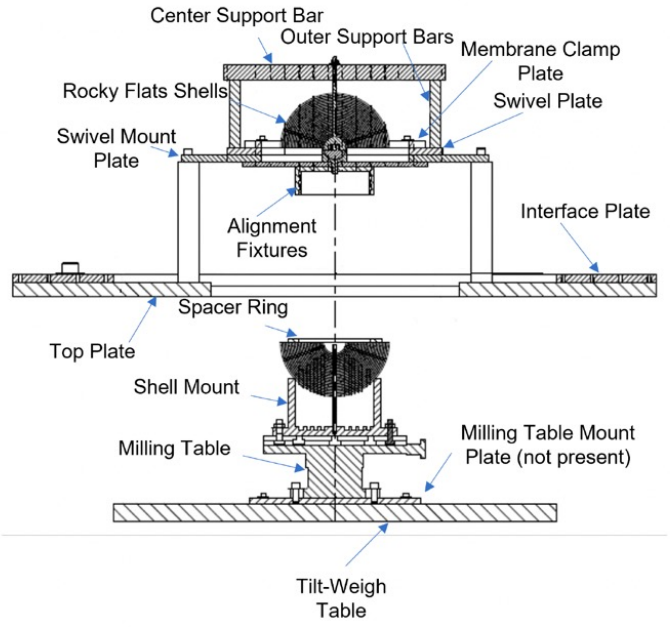


New Evaluation 4: HEU-MET-FAST-104



MUSiC: Critical Experiments with Bare Highly Enriched Uranium

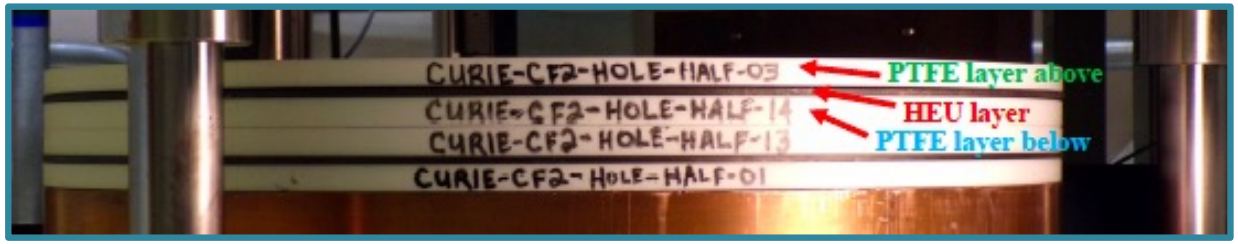
- MUSiC Experiments on Planet Assembly Machine at NCERC/NNSS with Rocky Flats Shells
- 2 cases with different shell configurations and degree of separation between assembly halves
- 8 subcritical configurations measured but not yet benchmarked



New Evaluation 5: HEU-MET-INTER-011

Intermediate-Spectrum Critical Assemblies with a Polytetrafluoroethylene-HEU Core Surrounded by a Copper Reflector

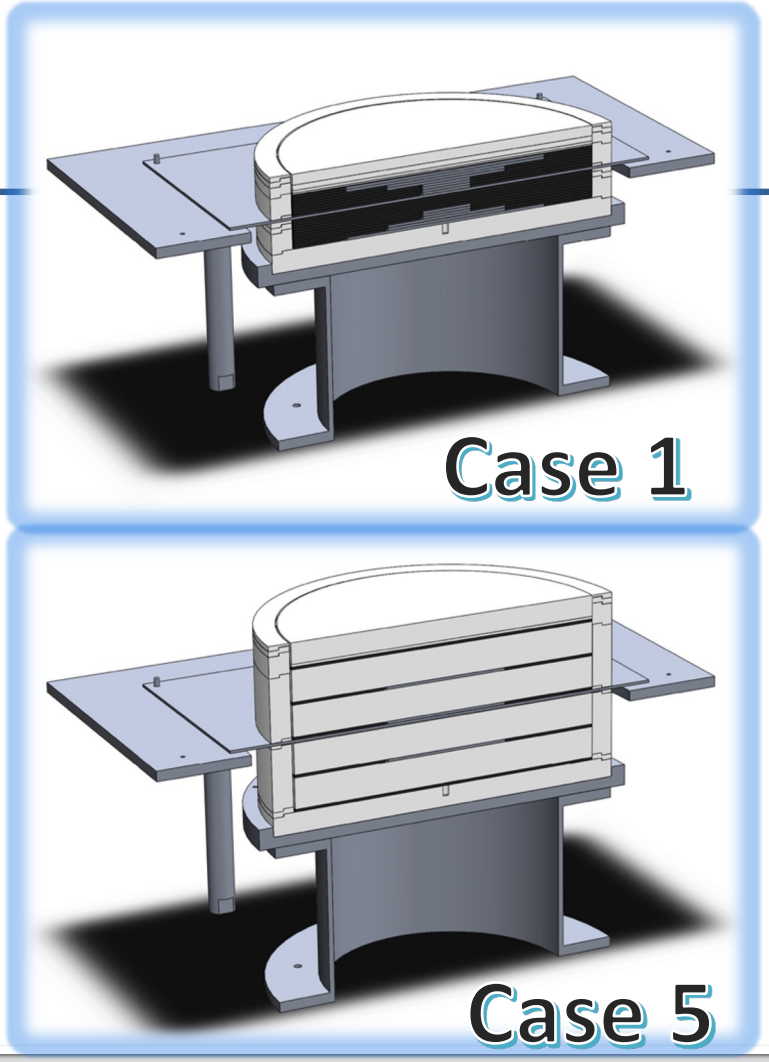
- CURIE Experiment on Comet Assembly at NCERC/NNSS with HEU Jemima Plates
- PTFE **(Teflon)** to test **Unresolved Resonance Region** (URR) of U-235
- 5 cases varying quantity of PTFE



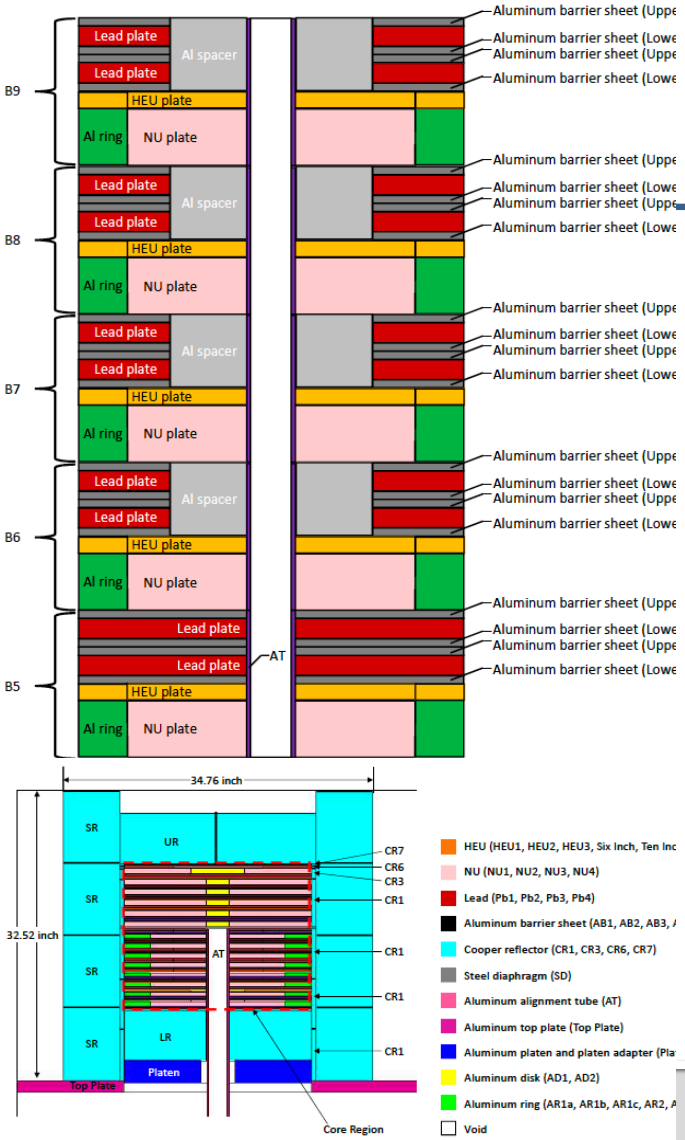
New Evaluation 6: HEU-MET-MIXED-021

TEX-HEU Baseline Assemblies: Highly Enriched Uranium Plates with Polyethylene Moderator and Polyethylene Reflector

- Comet Assembly with HEU Jemima Plates at NCERC/NNSS
- Varied Polyethylene Thickness to Adjust Neutron Spectra
- **5 Cases, 1 thermal, 1 intermediate, 2 mixed, 1 fast**



New evaluation 7: IEU-MET-FAST-025



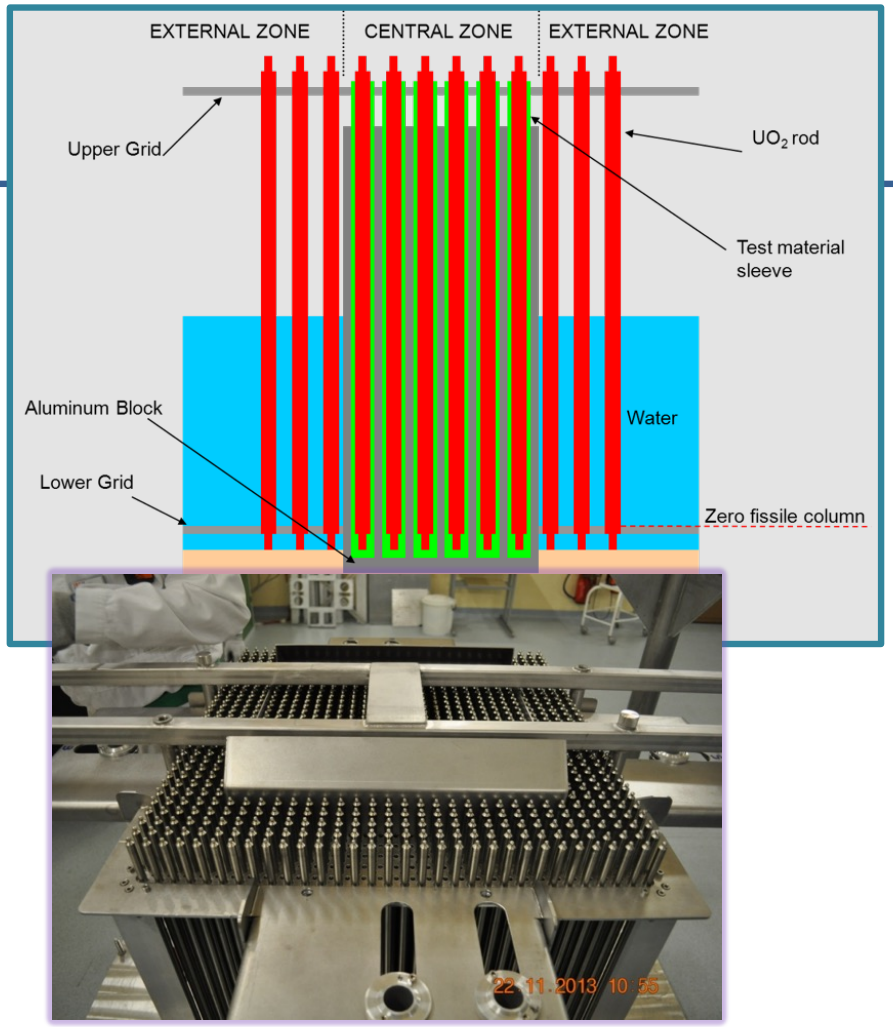
Zeus: Fast-Spectrum Critical Assembly with a Mixed Core of Highly Enriched and Natural Uranium Containing Lead Surrounded by a Copper Reflector

- ZEUS Experiments On COMET Assembly at NCERC/NNSS
- Collaboration between LANL and JAEA
- HEU, Nat-U, and Pb Plates
- 4 Cases with increasing **central void of lead**

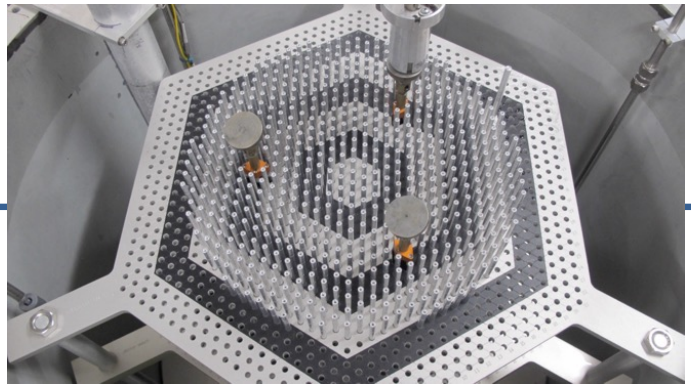
New Evaluation 8: LEU-COMP-THERM-110

4.738-wt.%-Enriched-Uranium-Dioxide-Fuel-Rod Arrays in Water, Surrounded by Steel or Copper Sleeves in Water or in an Aluminum Block

- MIRTE Program on Apparatus B Assembly at CEA Valduc Center
- Purpose: measure integral reactivity characteristics of various structural material
- 6 Cases: **H2O, Cu in H2O, SS in H2O, Cu in Al, S in Al, Al**

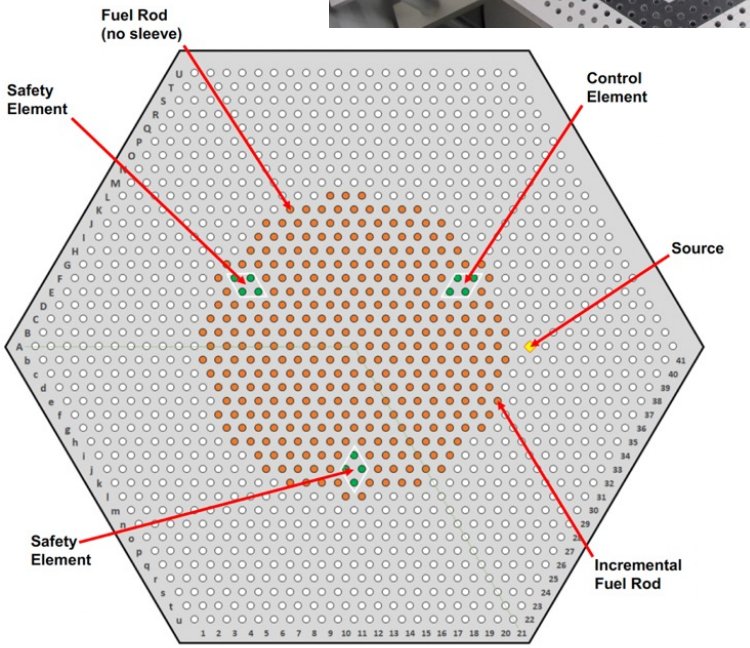


New Evaluation 9: LEU-COMP-THERM-111

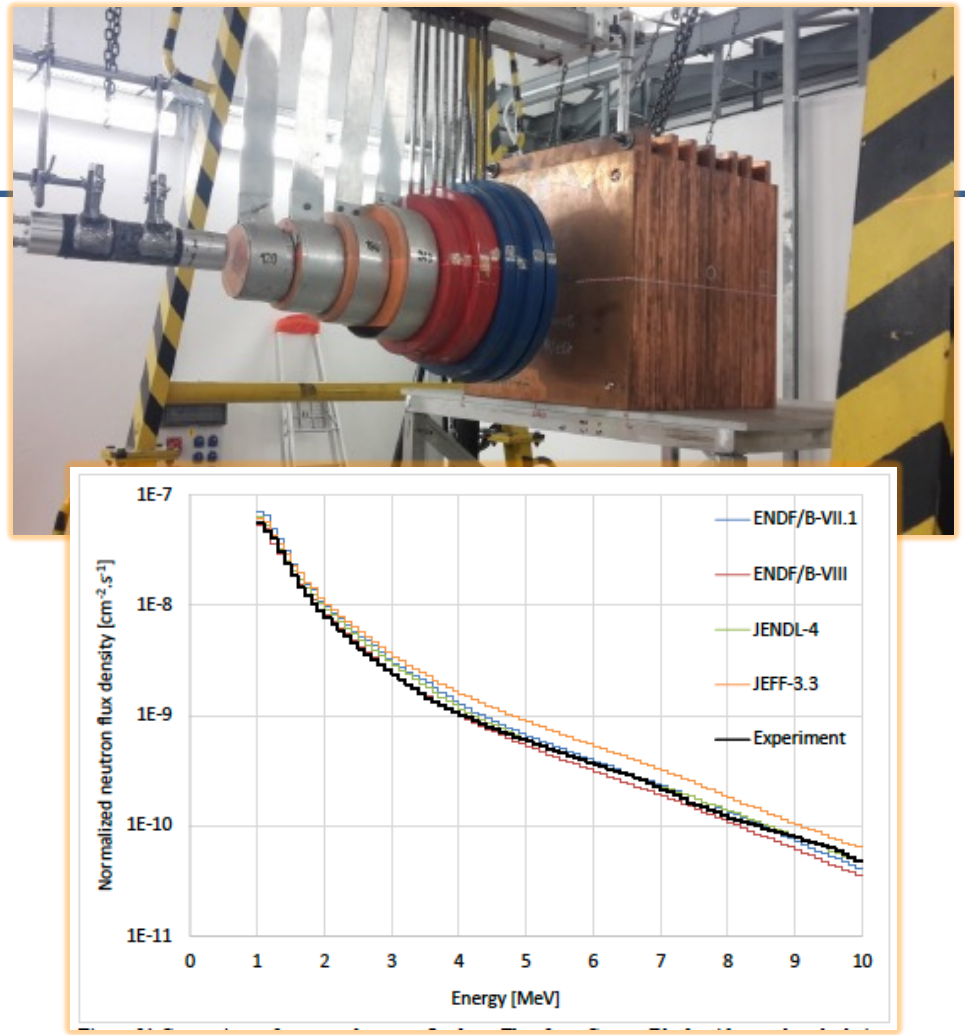


Molybdenum Sleeve Experiments in Fully-Reflected Water-Moderated Triangular-Pitched U(6.90)O_2 Fuel Rod Lattices (1.55 cm Pitch)

- SCX Facility at Sandia with 7uP fuel
- Purpose of the experiment was to measure the **effects of Mo** in nearly-critical systems
- 5 Cases with varying numbers and configurations of Mo sleeves around fuel pins



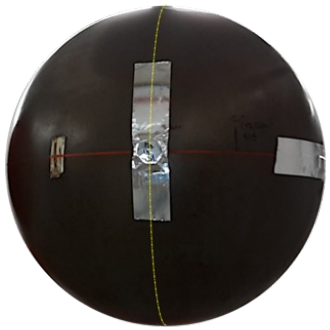
New Evaluation 10: ALARM-CF-CU-SHIELD-001



Measurement of Fast Neutrons Leakage Spectra from Copper Block with Cf-252 Source in Center

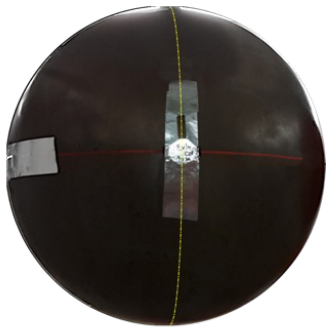
- Performed at Research Center Rez
- Measured proton recoil spectra to obtain neutron leakage flux/spectra
- Useful to test the validity of neutron cross section data, very sensitive to **Cu scattering**

New Evaluation 11: ALARM-CF-FE-SHIELD-002



Position 3

Position 2

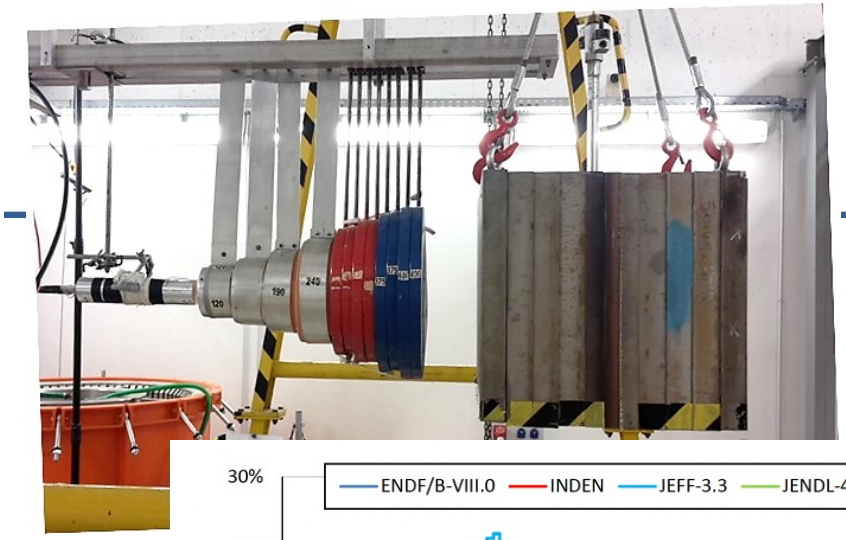


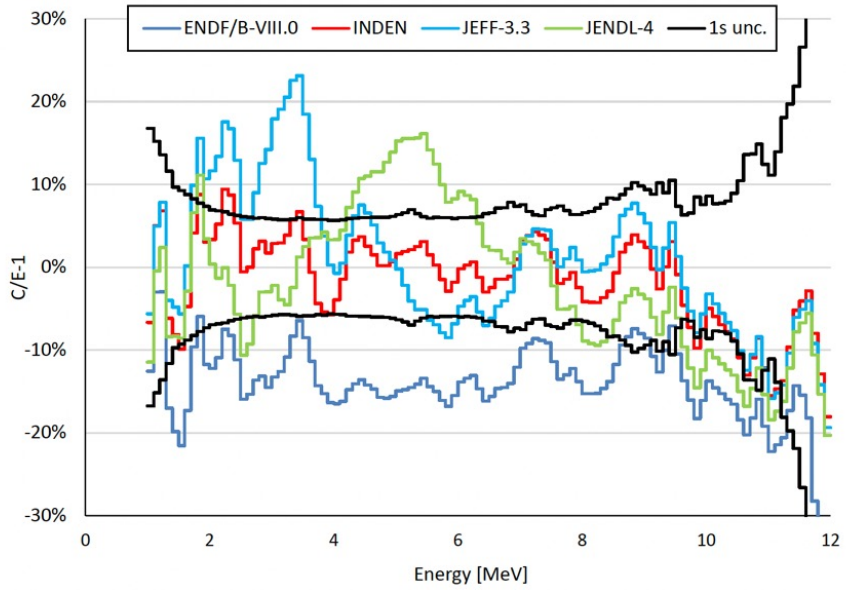
Position 1

Neutron Activation Foils and Fast Neutron Leakage Spectra from Iron and Nickel Spheres with a ^{252}Cf Source in the Center

- Performed at Research Center Rez
- Neutron fluence spectra measured with two detectors
- Neutron activation foils placed at the surface of the spheres
- 2 cases, one with **iron** and one with **nickel**
- Useful to test the validity of neutron cross section data, particularly scattering

New Evaluation 12: ALARM-CF-SST-SHIELD-001

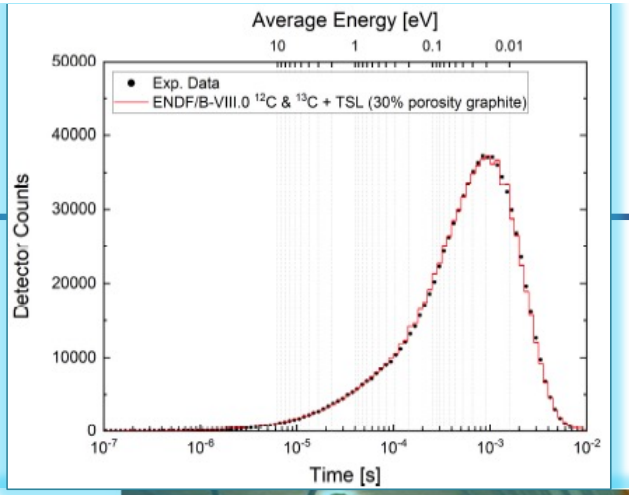


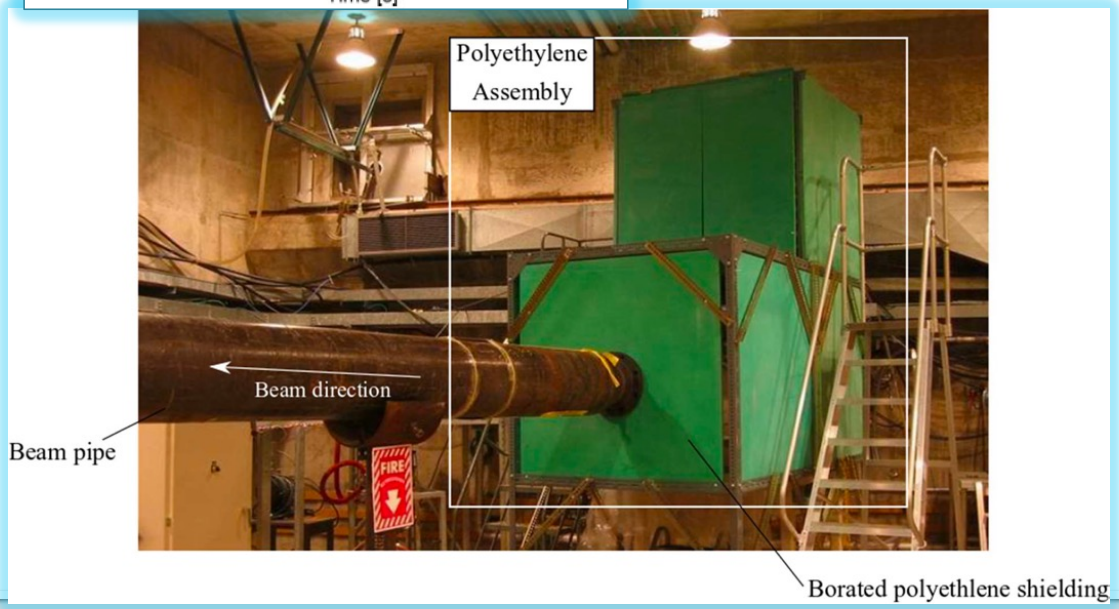


Neutron Activation Foils and Fast Neutron Leakage Spectra from a Stainless Steel 31 Block with a ^{252}Cf Source in the Center

- Performed at Research Center Rez
- Neutron fluence spectra measured with two detectors
- 3 cases, with different locations of types of neutron activation foils
- Useful to test the validity of **stainless steel** neutron cross section data, particularly scattering

New Evaluation 13: FUND-ORELA-ACC-GRAPH-PNSDT-001





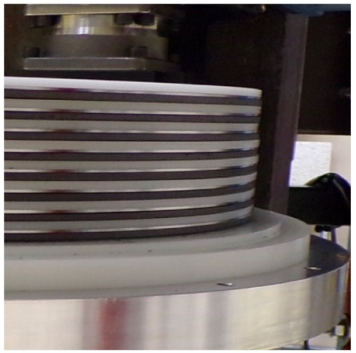
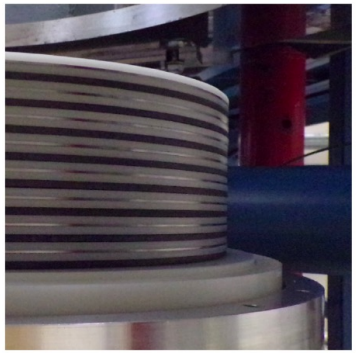
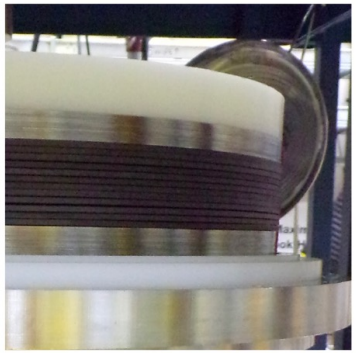
Benchmark of Neutron Thermalization in Graphite using the Slowing-Down-Time ORELA Experiment

- Oak Ridge Electron Linear Accelerator Facility
- Nuclear **graphite** pile
- Useful to test **thermal scattering law** data

2024 ICSBEP Activities

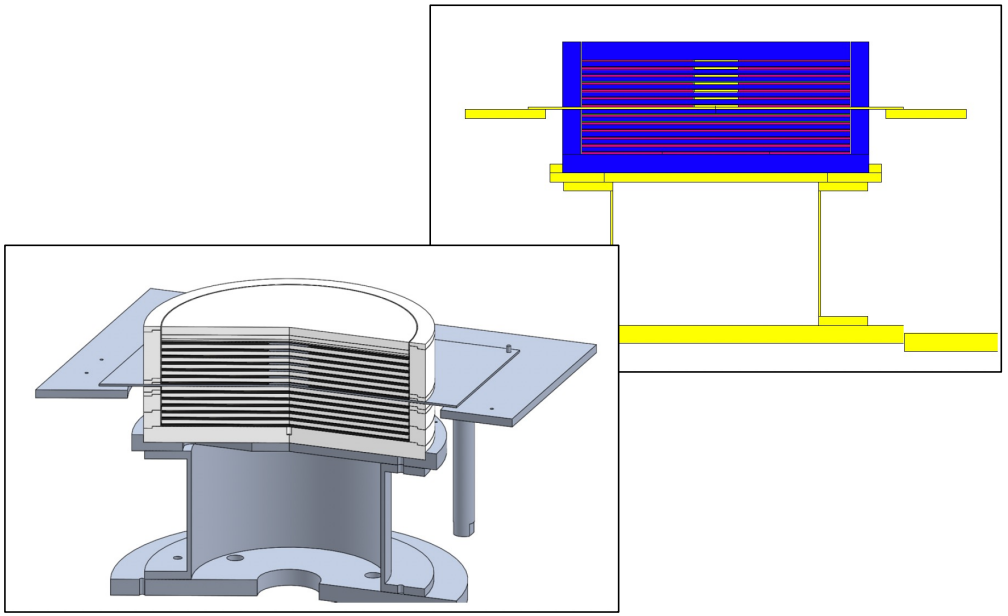
- Held annual Technical Review Group (TRG) meeting in Livermore, CA, USA in April 2024
  - 55 in person attendees, 40 virtual
  - Tours at Lawrence Livermore National Laboratory, including benchmark experiment labs and the National Ignition Facility
- Five benchmarks presented, four received conditional approval (pending comment resolution), three ultimately finalized for publication
- 2024 version of the handbook being assembled

New Evaluation 1: HEU-MET-INTER-013

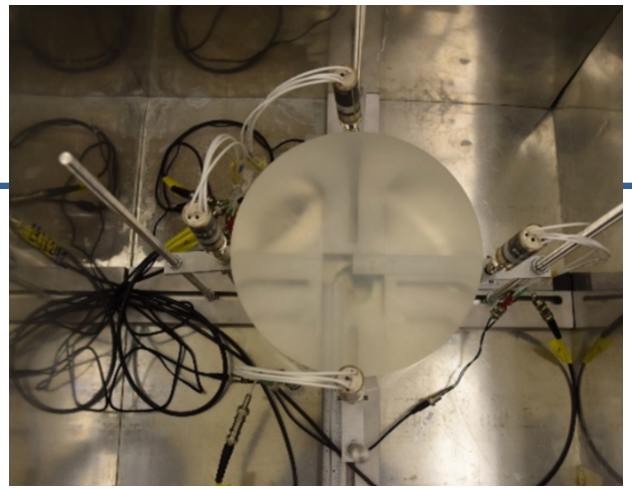




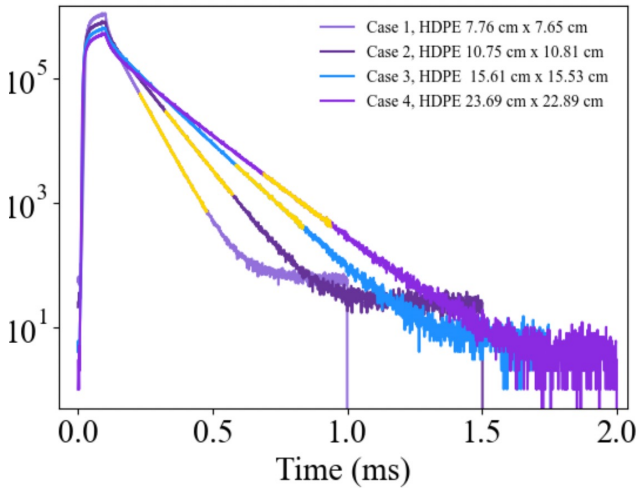
TEX-Hf Assemblies: Highly Enriched Uranium Plates with Hafnium Using Polyethylene Moderator and Polyethylene Reflector

- Comet Assembly with HEU Jemima Plates at NCERC/NNSS
- Varied polyethylene moderator thickness to adjust neutron spectra
- Included **hafnium** in different configurations (**interstitially and as a reflector**)
- 7 Cases, **1 thermal, 3 intermediate, 1 mixed, 2 fast**



New Evaluation 2: FUND-LLNL-DT-PE-PNDA-001

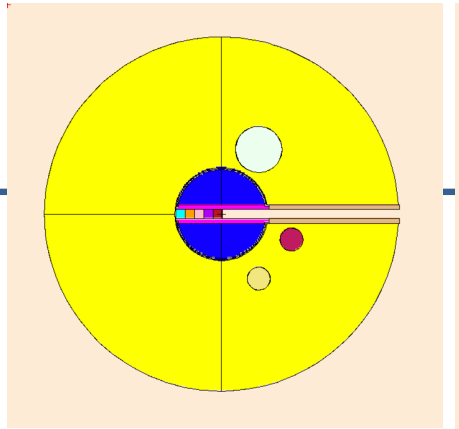


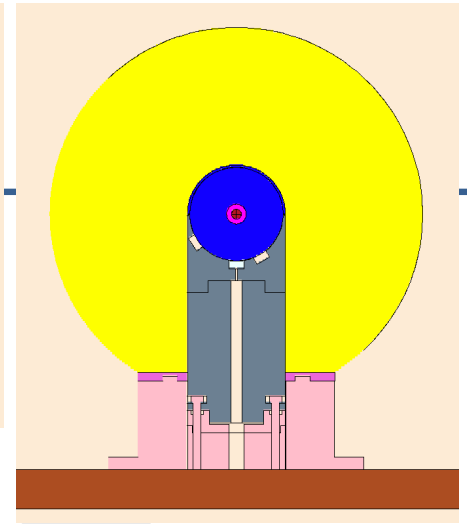


Pulsed-Neutron Die-Away Response of Polyethylene and Polymethyl Methacrylate Targets to a D-T Neutron Generator Pulse

- LLNL, USA
- Four different target sizes of **PE and PMMA**
- Benchmark quantity is characteristic exponential decay eigenvalue, α
- Useful to **test thermal scattering law data**
  - Smaller targets- more sensitive to scattering
  - Larger targets- more sensitive to absorption

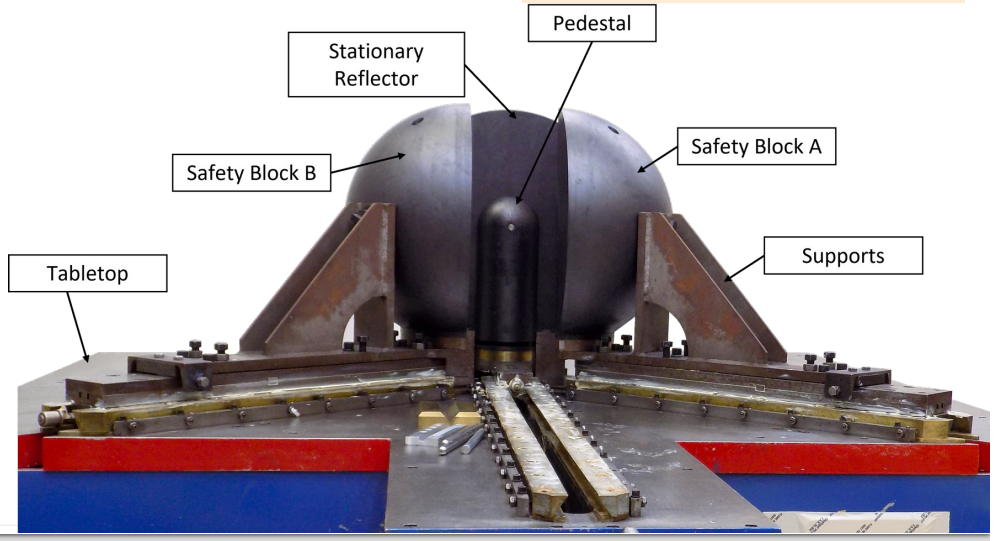
Revised Evaluation: HEU-MET-FAST-028





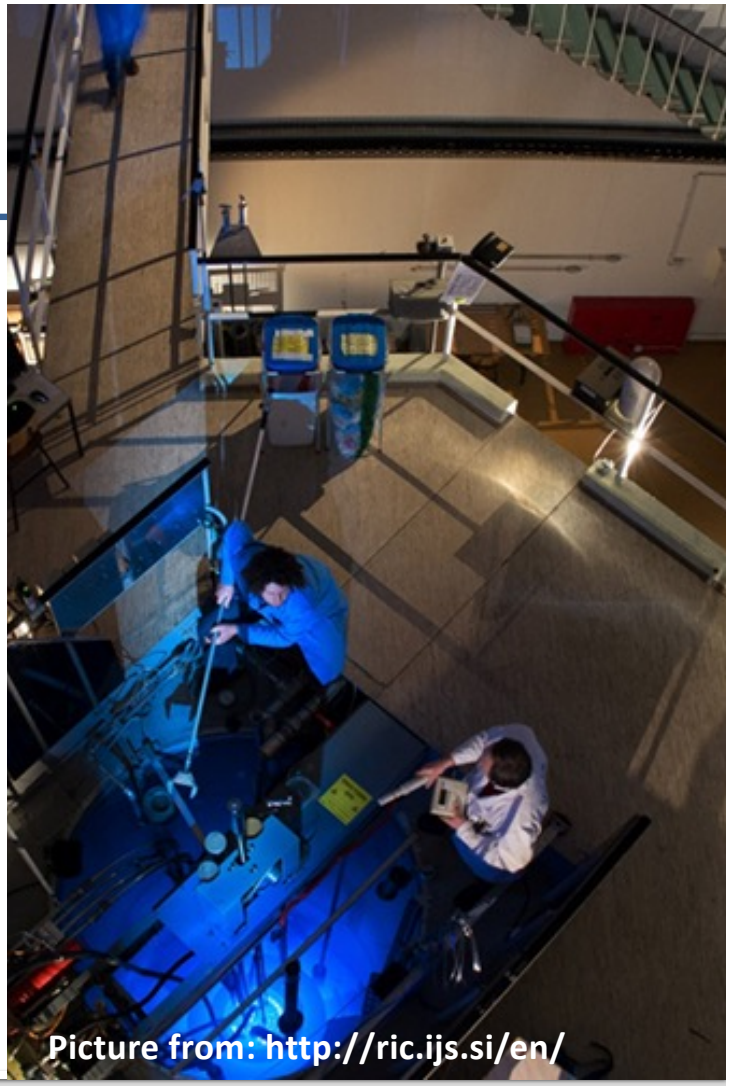
Uranium-235 Sphere Reflected by Normal Uranium Using Flattop

- Flattop Assembly with HEU Core at NCERC/NNSS
- **Major revision based on new dimensional and critical measurements**
- High fidelity models, one detailed and one simplified
  - Results with ENDF/B-VIII.0 agree within 1 sigma of HMF-028, Rev 2



Upcoming Meeting

- **Jožef Stefan Institute, Ljubljana, Slovenia**
- April 14-18, 2024
- Joint meeting with SINBAD, SFCOMPO and IRPhEP
- Tours of JSI experimental facilities



Benchmarks Expected at Upcoming Meeting

1. Instituto de Pesquisas Energéticas e Nucleares (Brazil) – IPEN/MB-01 New Core Evaluation with U_3Si_2-Al, 19.75% enriched in U-235 Plate Type Fuel
2. Instituto de Peruano de Energia Nuclear (Brazil) – IPEN/RP01 New Core Evaluation with U_3Si_2-Al, 19.75% enriched in U-235 Plate Type Fuel
3. Lawrence Livermore National Laboratory (USA) – *Pulsed-Neutron Die-Away Experiments with Water Targets (Fundamental Physics Benchmark)*
4. Lawrence Livermore National Laboratory (USA) – *TEX-HEU Thermal Critical Benchmarks with Chlorine*
5. Lawrence Livermore National Laboratory (USA) – *High Multiplication Subcritical Benchmark at Sandia National Laboratory LEU SPR/CX Facility* (Fundamental Physics Benchmark)
6. Los Alamos National Laboratory (USA) – *Cerberus Copper Critical Experiments*
7. Los Alamos National Laboratory (USA) – *Jupiter High ^{240}Pu Configurations*
8. Sandia National Laboratory (USA) – *Epithermal Hex Lattices with 6.9% UO2 Fuel with Tantalum*
9. University of New Mexico (USA) – *AGN Reactor Critical Benchmark*
10. University of Tennessee (USA) – *HEU cylinders with Graphite*

Conclusions

- B.J. Marshall has stepped down as Vice Chair and so we are looking for nominations for the ICSBEP Vice Chair position (wpncs@oecd-nea.org)
- Please reach out to Catherine Percher (percher1@llnl.gov) and the WPNCS Secretariate (wpncs@oecd-nea.org) to be added to the TRG mailing list

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