IER 480: TEX-Pu Benchmark (PU-MET-THERM-004) to Test Polyethylene and Lucite Thermal Scattering Laws

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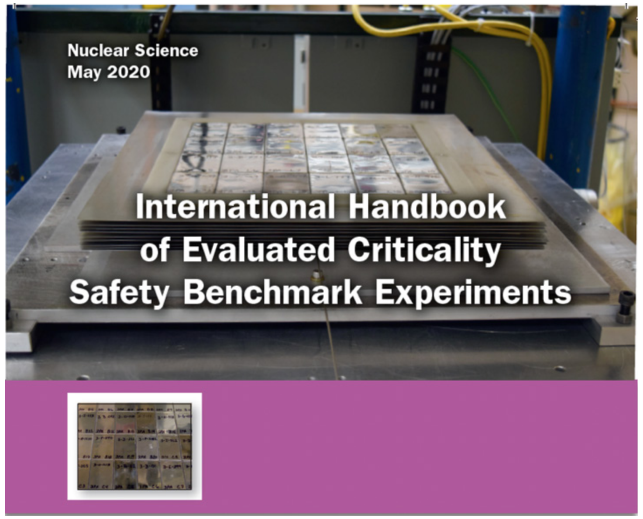
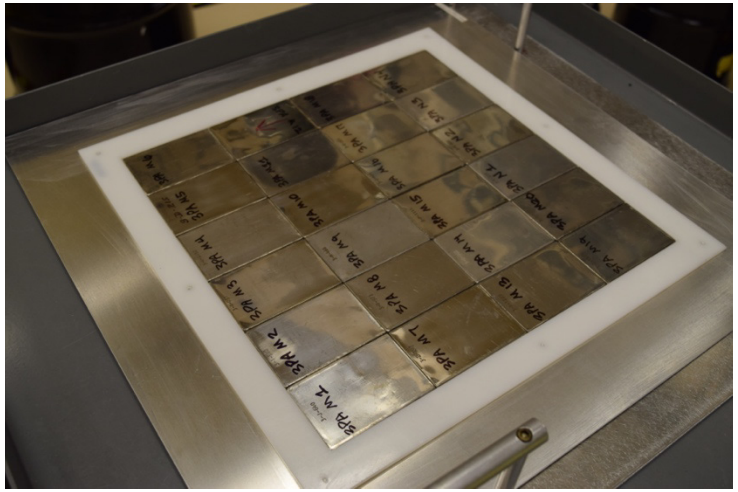
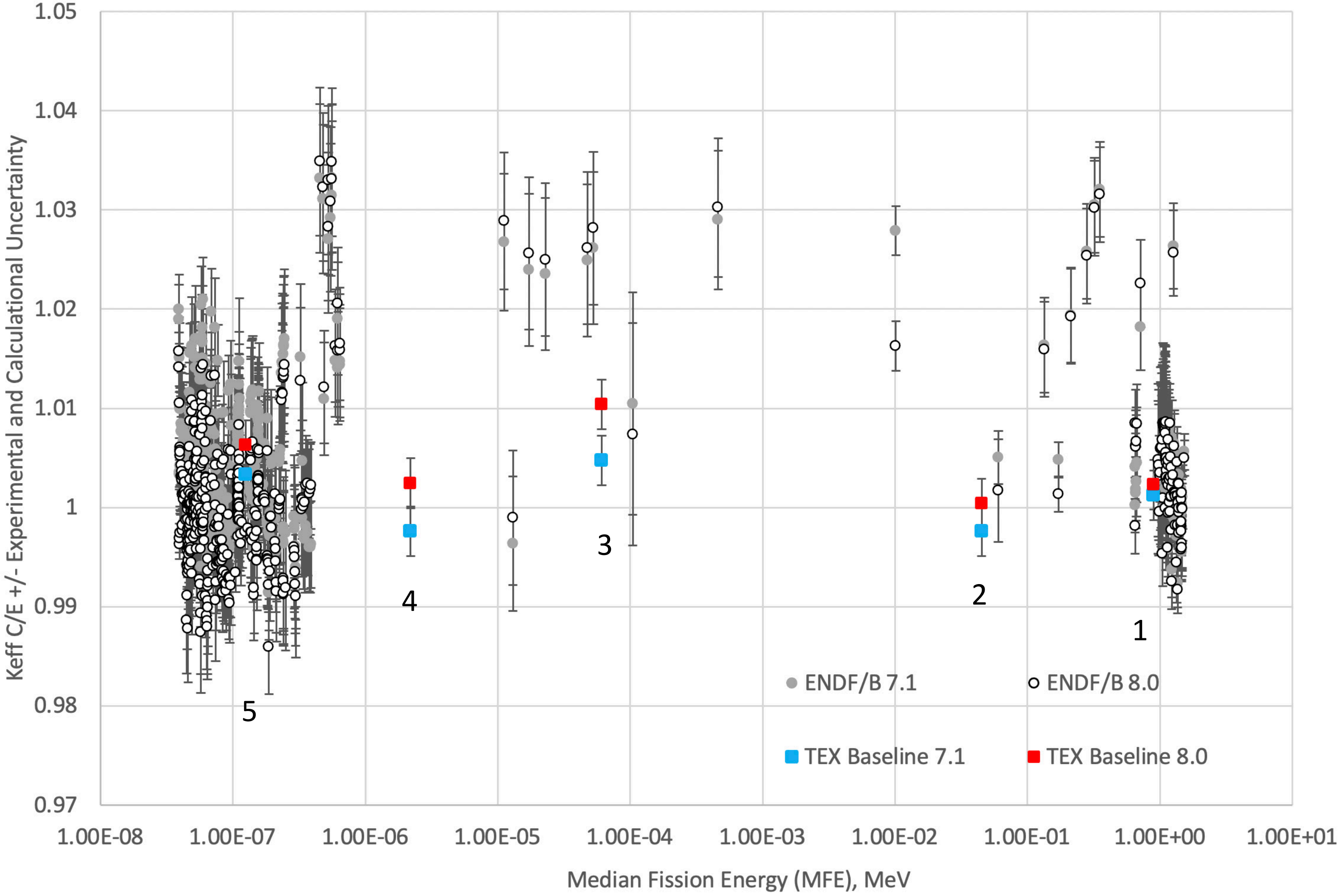
PU-MET-MIXED-002- Plutonium Baseline Evaluation

- Plutonium-fueled benchmark accepted into the International Criticality Safety Benchmark Evaluation Project (ICSBEP) Handbook
  - Fuel was plutonium/aluminum Zero Power Physics Reactor (ZPPR) plates
  - Pu plates arranged in 12” x 12” layers (6 plates by 4 plates)
- First Benchmark for the Thermal/ Epithermal eXperiments (TEX) Project
  - Minimum of materials
  - Designed to span multiple neutron fission energy spectra (fast through thermal) using polyethylene moderator
  - Assembly designed to be easily modified to test materials of interest

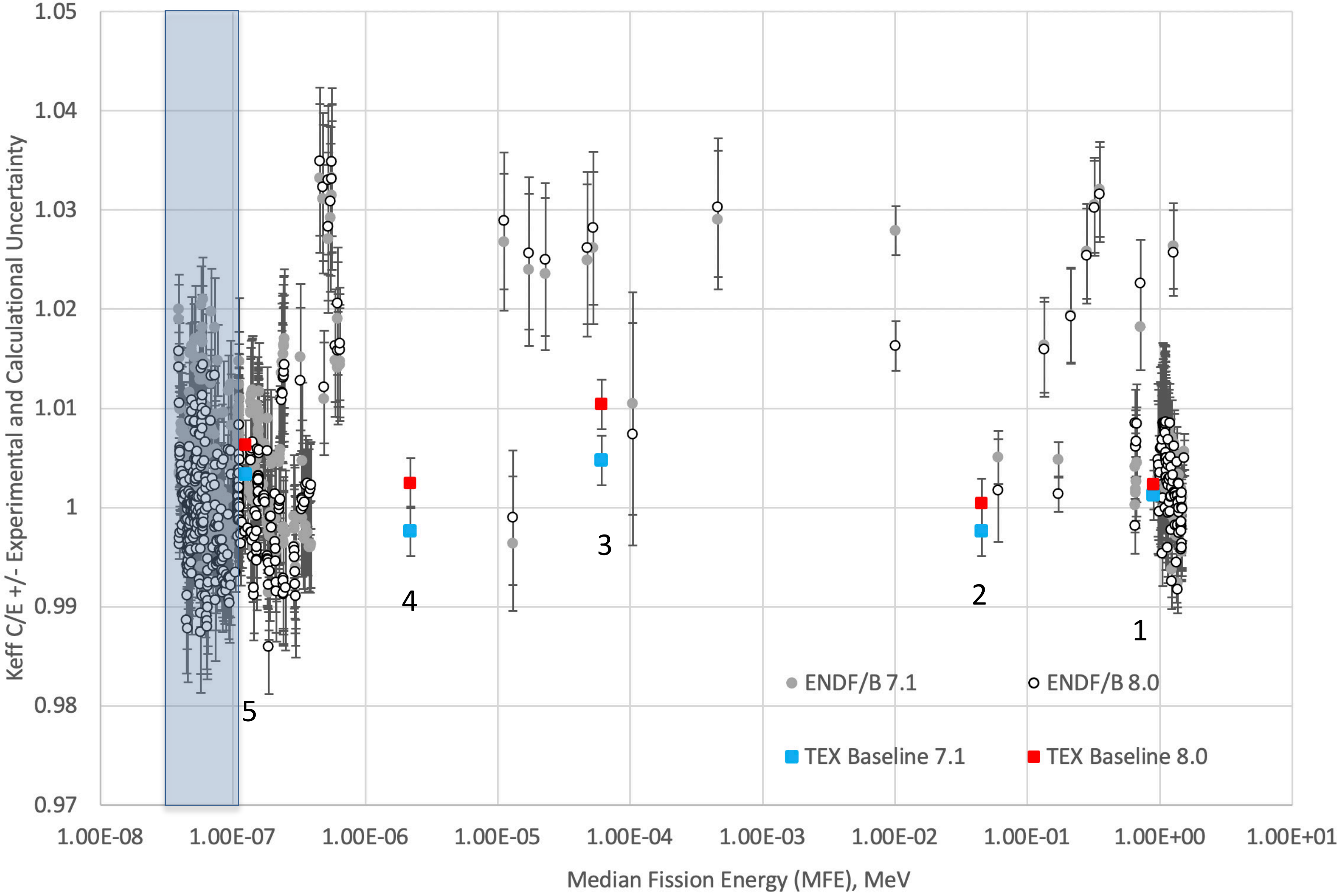




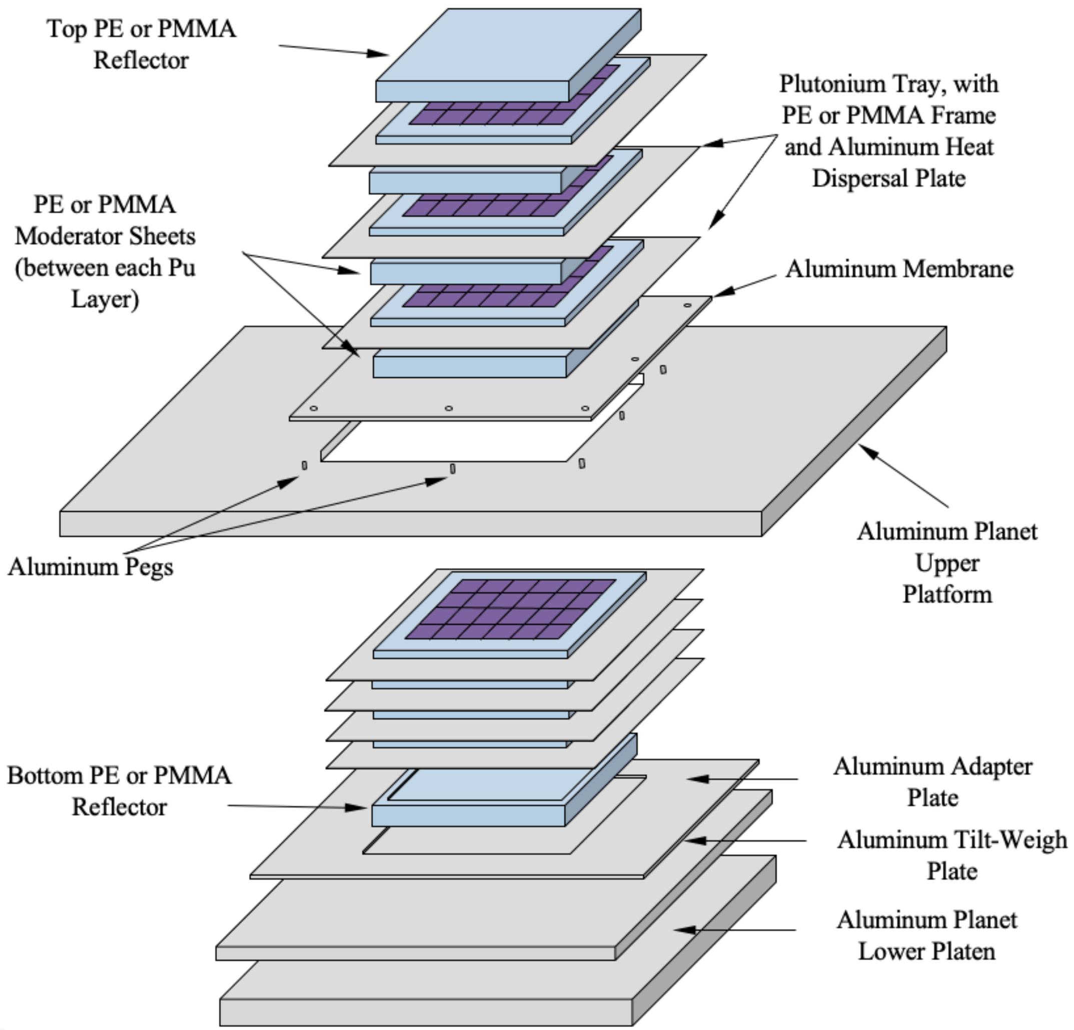
PMM-002 Results Against ICSBEP Pu Benchmarks- MCNP6.1

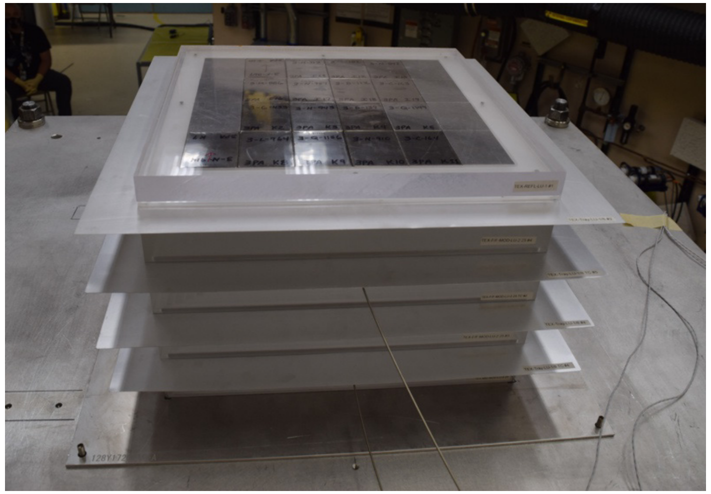


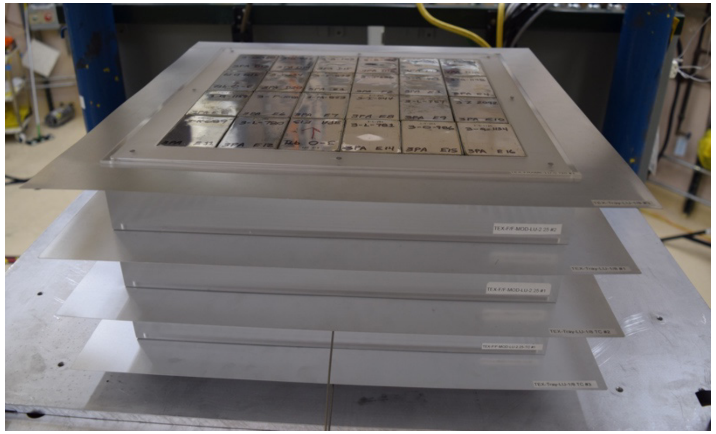
Region of Interest for TEX TSL Experiments



TEX TSL (PU-MET-THERM-004) Experimental Set-up

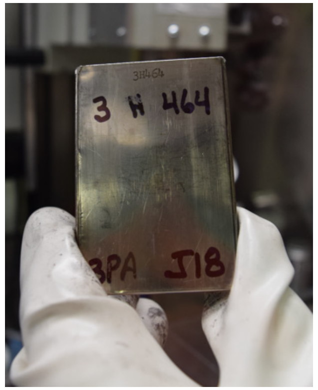


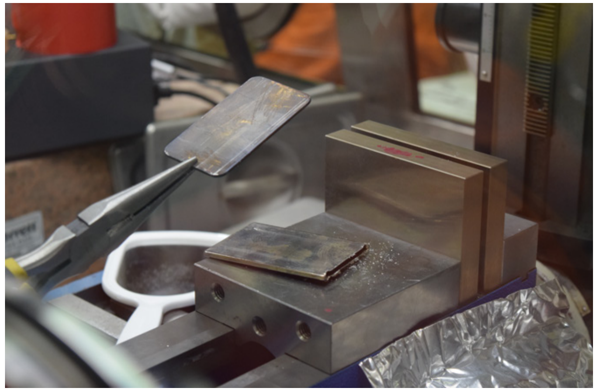




Benchmark Incorporated Modern ZPPR Plate Characterization

- One Pu plate was taken apart and sampled in the glovebox at DAF
- Isotopic and chemical composition analysis was performed at LLNL
- Plate was found to have an additional ~2000 ppm of impurities at the time of manufacture that have never been accounted for

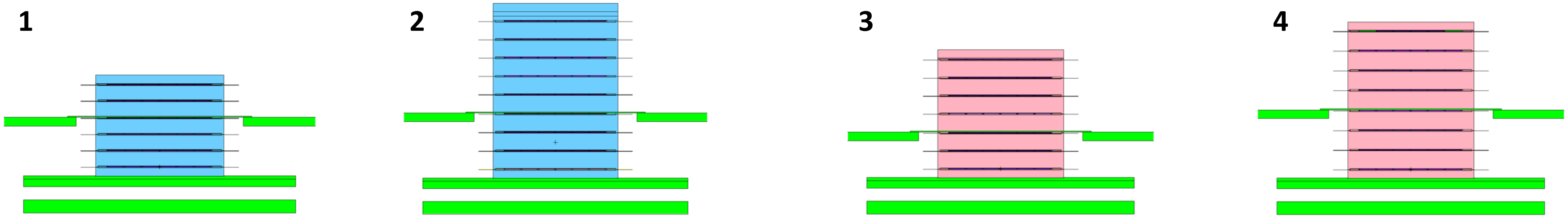


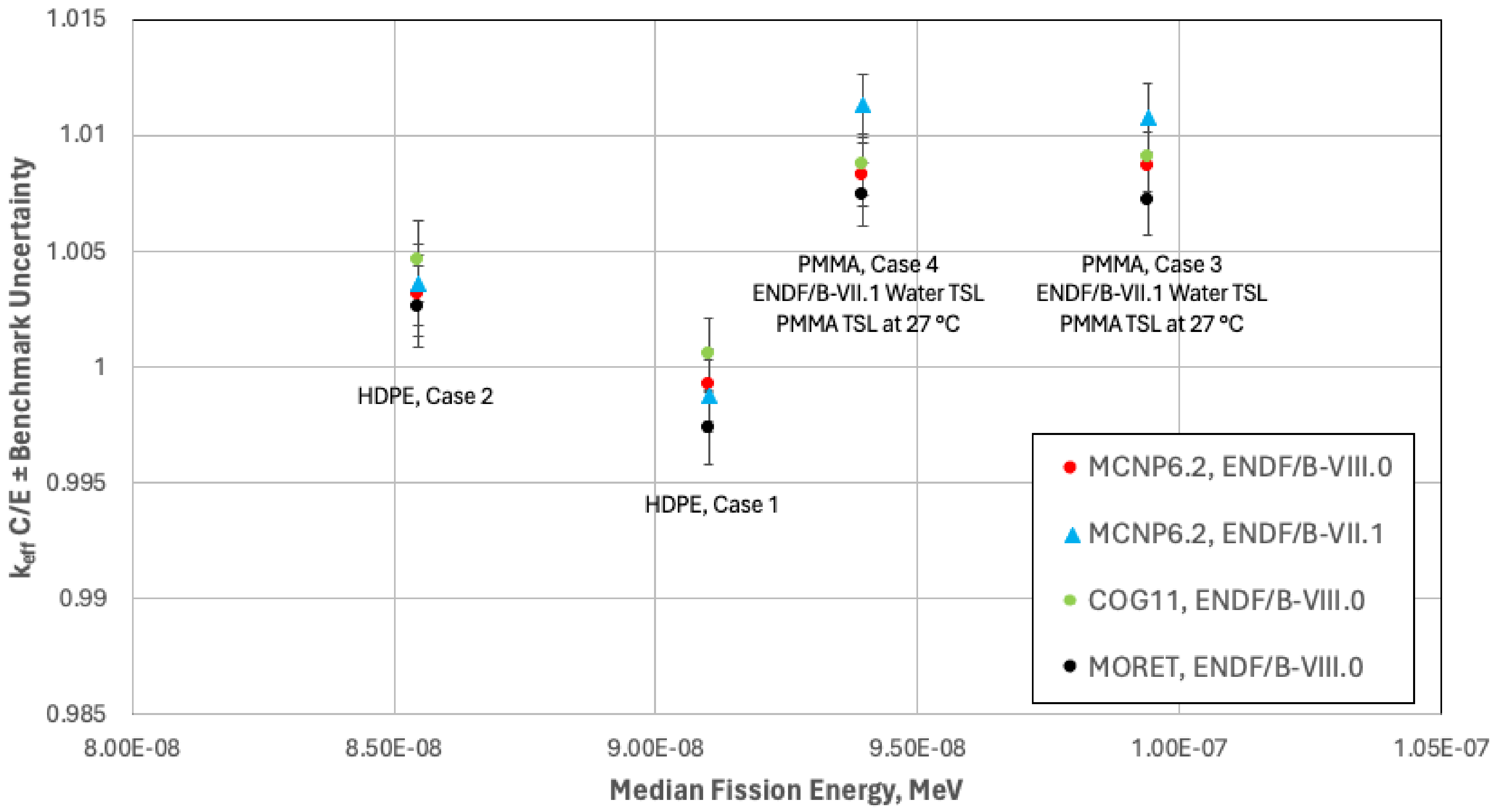
Element/ Isotope	Adjustment to 1960 Plate Mass ppm (mg/kg)	Adjustment to 1960 Average Plate Mass of 105.383 (g)
C	+260	0.027
O	+75	0.008
Mg	+16	0.002
Cr	+149	0.016
Fe	+277	0.029
Ni	+487	0.051
Cu	+32	0.003
Ga	+175	0.018
Mo	+28	0.003
^{238}Pu	+82	0.009
^{241}Pu	+354	0.037
^{238}U	+30.7	0.003
^{237}Np	+67.7	0.007
Mn	+11.7	0.007 Combined, modeled as void
Co	+12.8	
In	+0.26	
Ta	+11	
W	+10	
Pt	+8	
Pb	+13	
^{236}U	+3.9	
Total	2104.06	0.220

PU-MET-THERM-004 Benchmark Results

Case	Fission Fraction (%)			Moderator Thick (cm)	Mod Type	Benchmark k_{eff}	Benchmark Uncertainty
	Thermal (<0.625 eV)	Intermediate (0.625 eV - 100 keV	Fast (> 100 keV)				
1	72.91	16.09	11.00	4.264	PE	0.99900	0.00155
2	74.59	14.78	10.63	5.080	PE	0.99743	0.00176
3	70.27	18.06	11.67	4.922	PMMA	0.99834	0.00149
4	71.52	17.08	11.39	5.313	PMMA	0.99790	0.00136



Results of Sample Benchmark Calculations

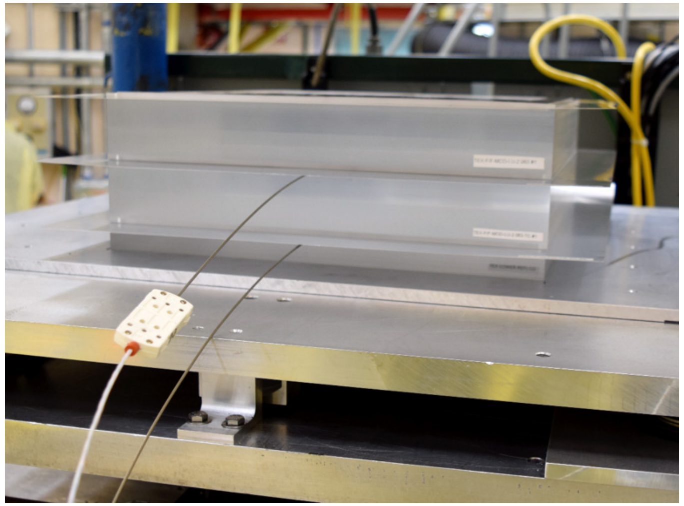


Large Effect of Temperature

Moderator Material	Moderator Thickness (cm)	Pu Layers	Average Temperature (°C)	Temperature Correction to 20°C, Δk_{eff}	Δk_{eff}/°C
PE	4.264	6	23.8 ± 3.0	-0.00131	0.00034
PE	5.080	9	26.4 ± 3.0	-0.00355	0.00055
PMMA	4.922	7	29.3 ± 3.0	-0.00245	0.00026
PMMA	5.313	8	29.5 ± 3.0	-0.00287	0.00030

Temperature had a large impact on reactivity of the critical configuration

- Experimental measurements showed 1 °C change produced reactivity differences of ~0.00025 in k_{eff}
- Consistent with findings from design calculations from thermal cases of temperature-dependent critical experiments
- Effect dominated by TSL temperature dependence



Conclusions

- PMT-004 has four new benchmark cases highly sensitive to PE TSL (2 cases) and PMMA TSL (2 Cases)
  - PE cases were well predicted using MCNP6.2 and ENDF/B-VIII.0
  - PMMA cases overpredicted by approximately 0.6-0.7% in k_{eff} at 20°C
  - Accepted into 2023 version of the ICSBEP Handbook

- Temperature had a large impact on reactivity of the critical configuration
  - Implications for validation work for thermal cases- need to adjust TSL data to correct temperature as it can have hundreds of pcm effects for a few °C
  - Future thermal experiments should try and measure reactivity at multiple temperatures to aid in data testing and benchmark adjustment

Acknowledgements

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