PMT-004 Validation Testing for Thermal Scattering Laws and Some Interesting Temperature-Dependent Implications

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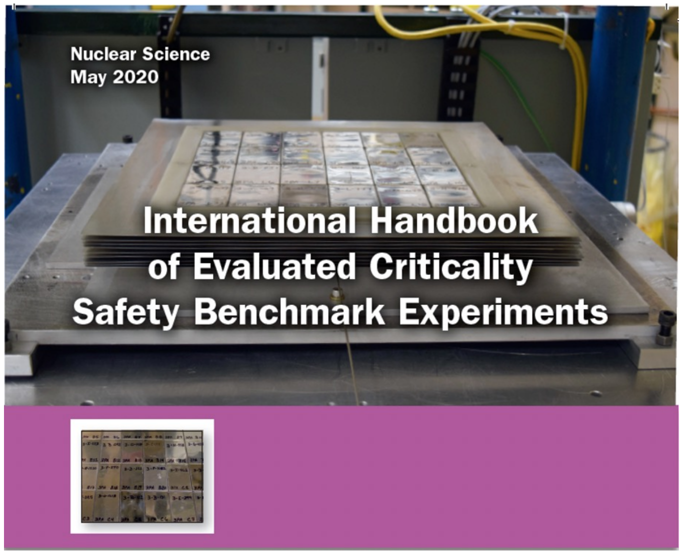
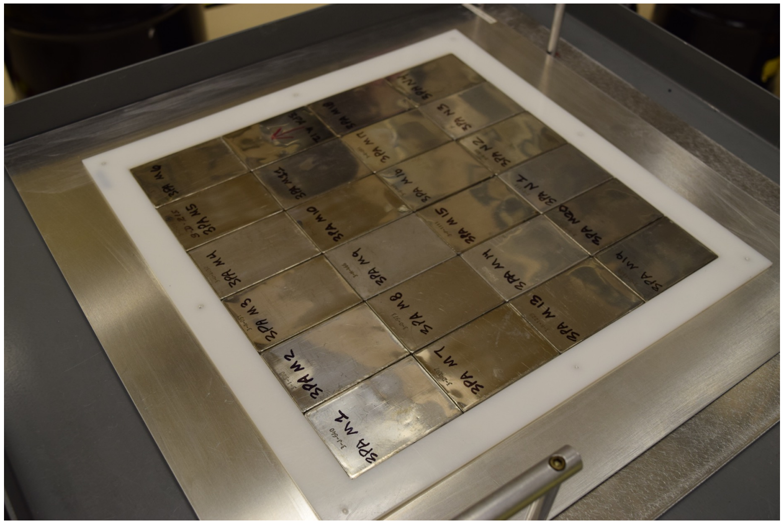
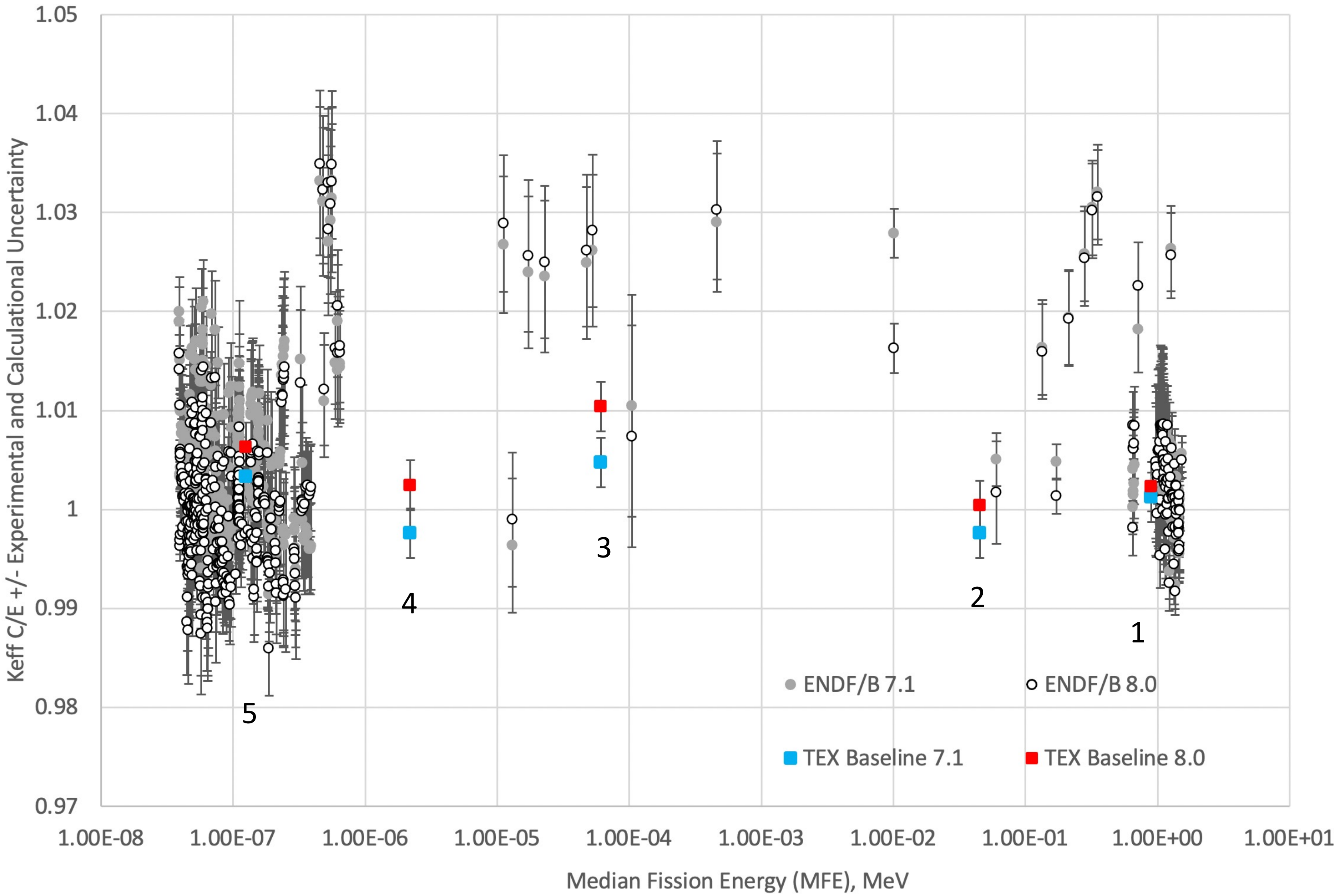
PU-MET-MIXED-002

- 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

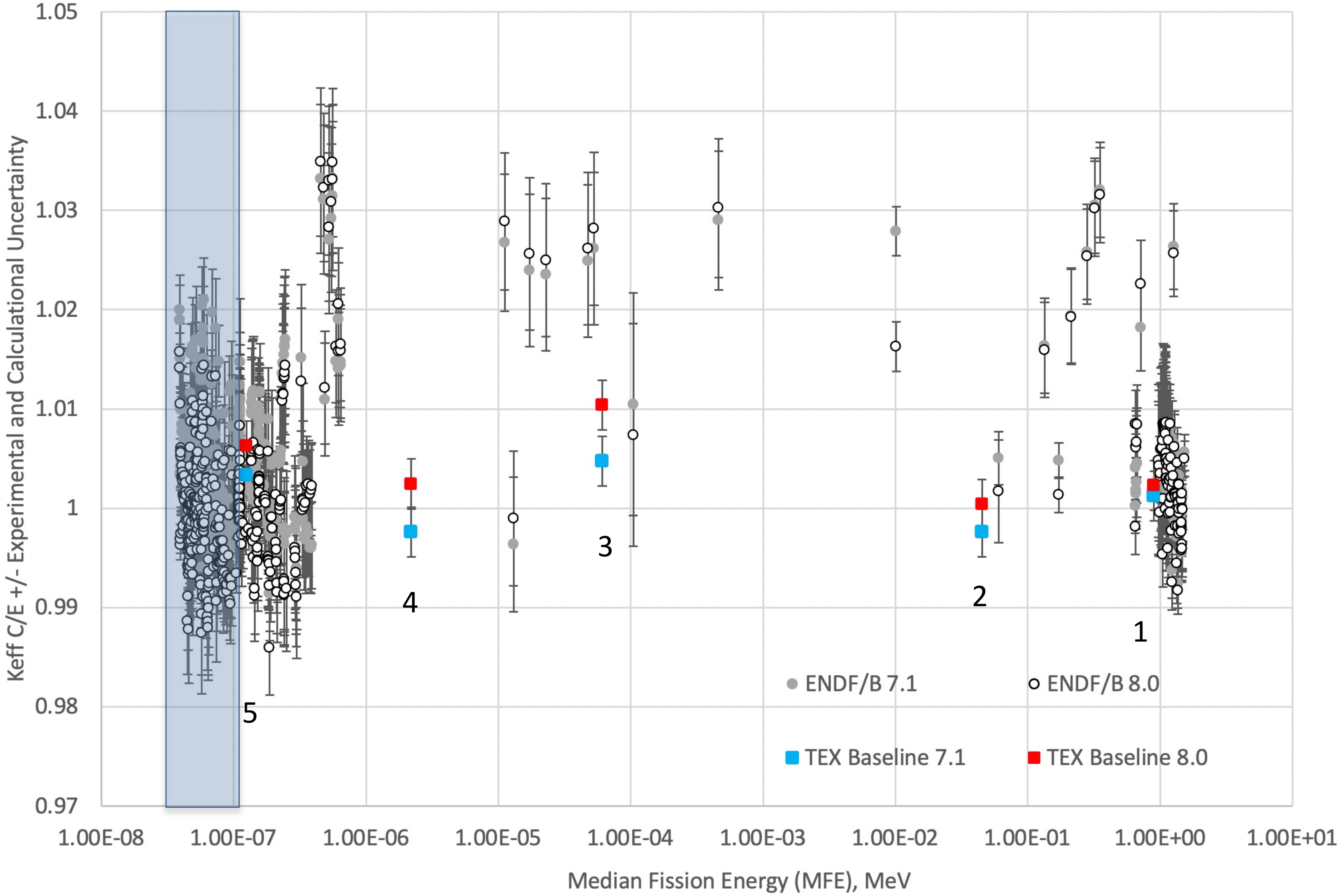




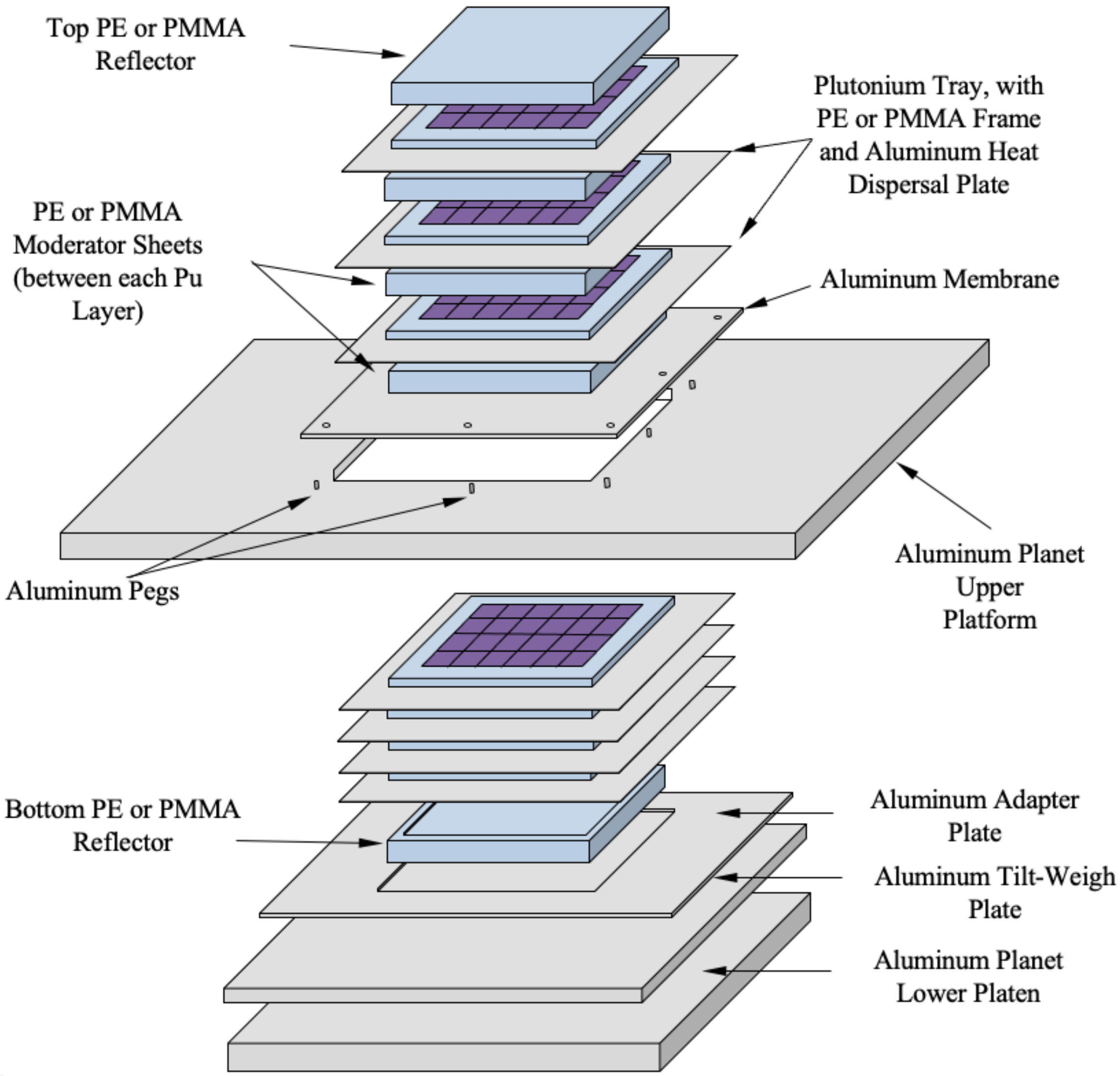
PMM-002 Results Against ICSBEP Pu Benchmarks- MCNP6.1

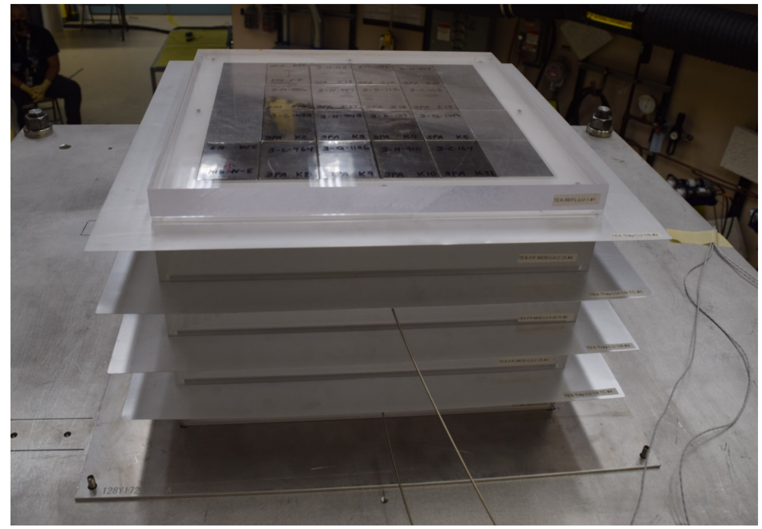


Region of Interest for TEX TSL Experiments



Experimental Set-up





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Four Additional Thermal TEX-Pu Experiments-Completed in September 2021

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

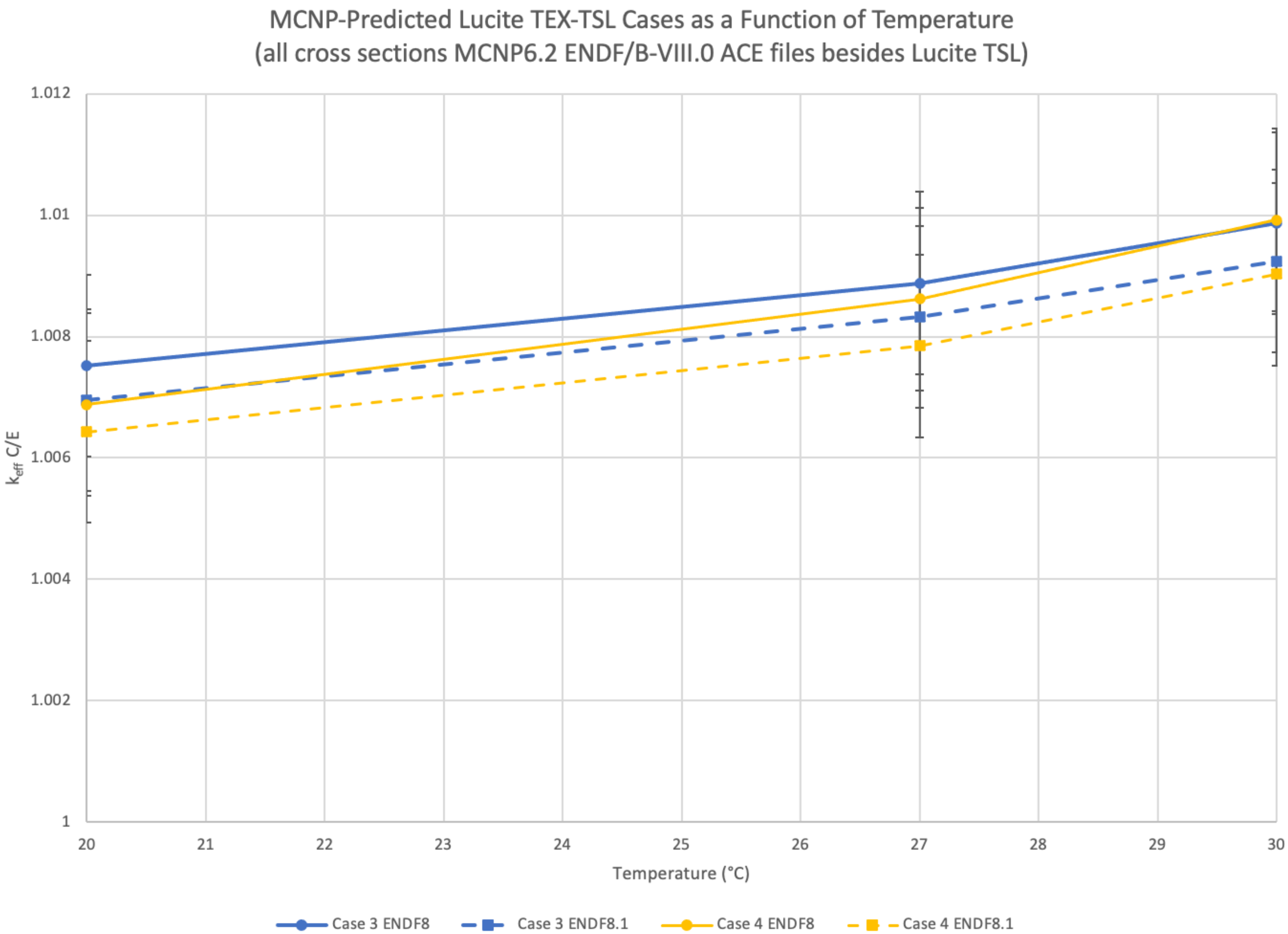
- Experimental measurements showed 1 °C change produced reactivity differences of ~0.00025 in k_{eff}
- Consistent with findings from design calculations from thermal cases of temperature-dependent critical experiments
- Effect dominated by TSL temperature dependence

Preliminary PMT-004 Benchmark Results

Case	Moderator Thick (cm)	Mod Type	Preliminary C/E ENDF/B-VIII.0	Estimated Uncertainty
1	4.264	PE	0.99921	0.00152
2	5.080	PE	1.00312	0.00172
3	4.922	PMMA	1.00869*	0.00146
4	5.313	PMMA	1.00830*	0.00132

*For ENDF/B-VIII.0, Lucite TSL at 27 ºC used, as it is the only temperature included in the library for Lucite.

ENDF/B-VIII.1 Lucite TSL is an Small Improvement, Large Temperature Dependence



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Larger Implications of TSL Temperature Dependence

- Not all benchmarks are at 20 °C, but we're validating (and likely adjusting!!!) using mostly (only?) 20 °C data

3.4 Temperature Data

The temperature of each experiment was 25• C (298 kelvin).

PST-001

3.4 Temperature Data

The temperature of each experiment was 27°C (300 kelvin).

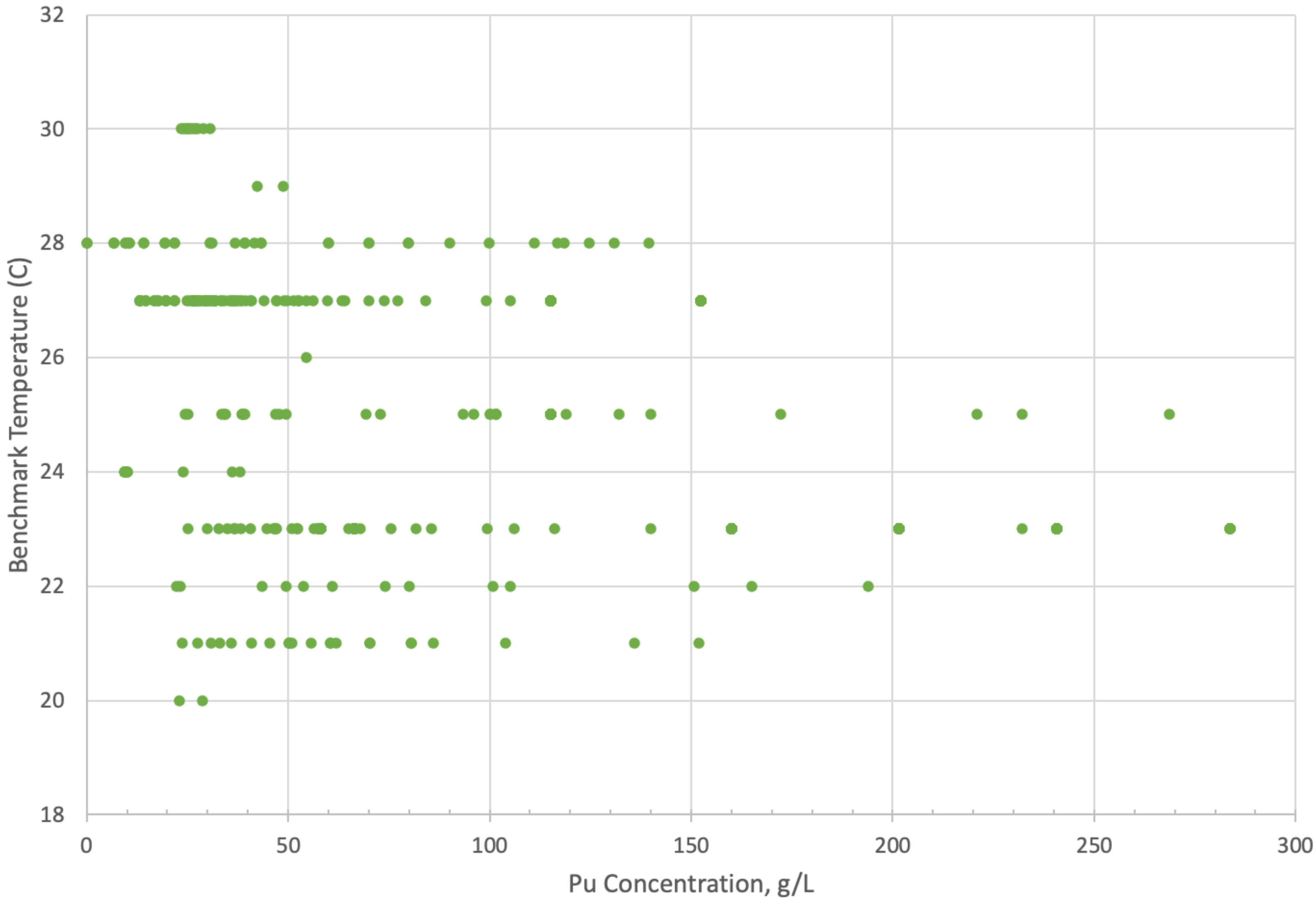
PST-002

3.4 Temperature Data

The experiments were performed at approximately 27°C (see Table 1) for the nitrate solution and 24°C for the water reflector.

PST-012

PST Temperatures versus Pu Solution Conc



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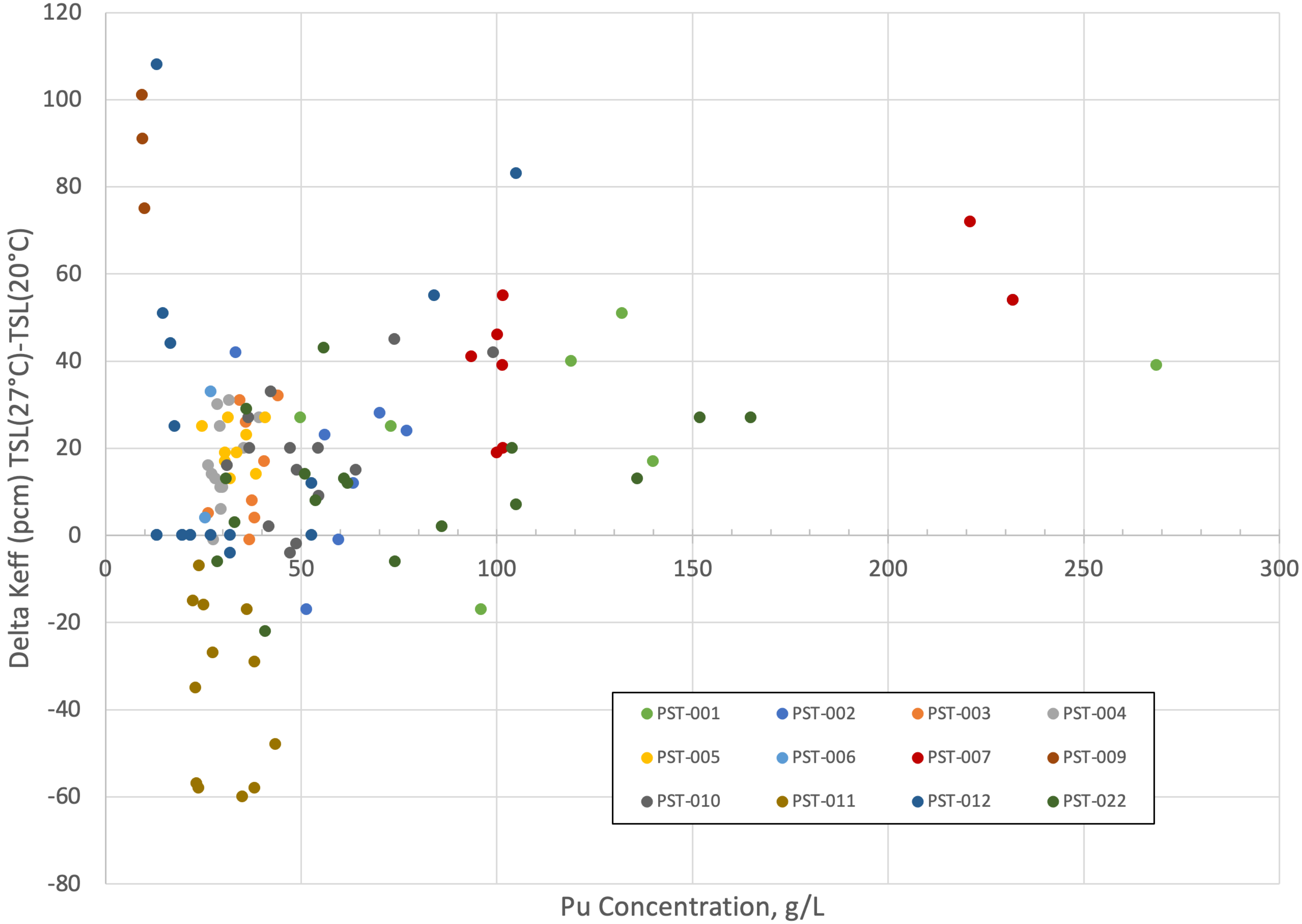
K_{eff} Effect of TSL Temp on Subset PST Benchmarks



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K_{eff} Effect of TSL Temp on Subset PST Benchmarks

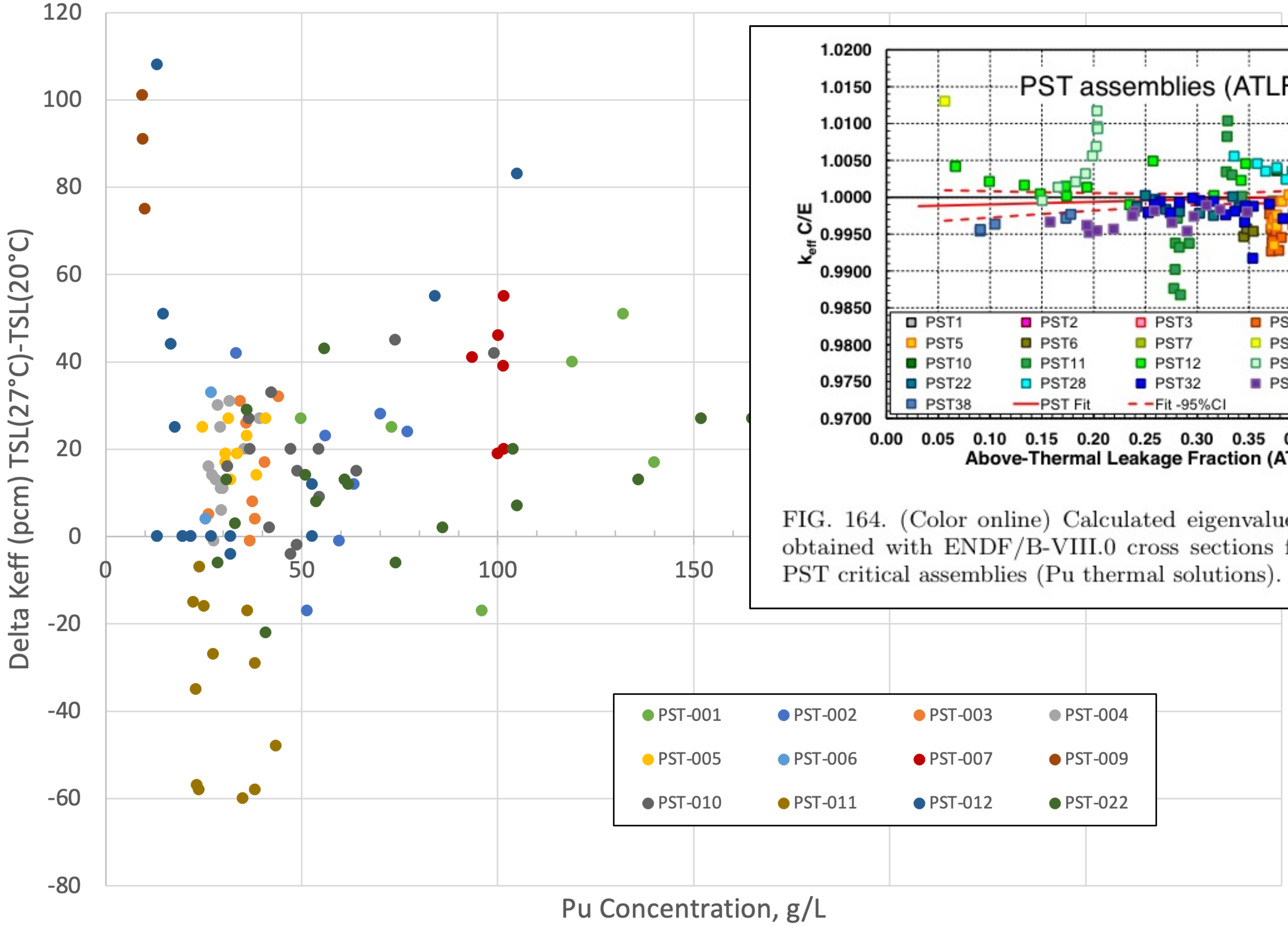

FIG. 164. (Color online) Calculated eigenvalue C/E values obtained with ENDF/B-VIII.0 cross sections for a suite of PST critical assemblies (Pu thermal solutions).

Conclusions and Future Work

- 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} likely due to the lack of integral benchmarks sensitive to PMMA
  - NCSU ENDF/B-VIII.1 PMMA TSL is an improvement over VIII.0
  - Accepted at last ICSBEP meeting pending comment resolution, should be published in 2024 version of the 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 add in data testing and benchmark adjustment

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Acknowledgements

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