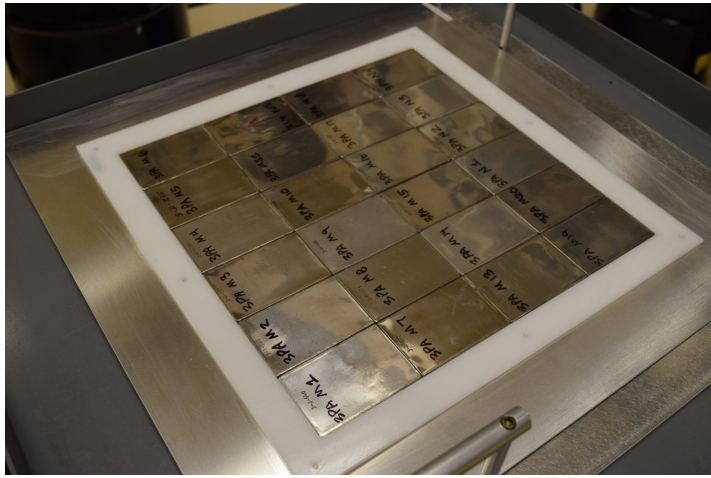
IER-520 and IER-553: Final Design for Follow-on Plutonium TEX Configurations

Eric Aboud, Catherine Percher, Daniel Siefman

Nuclear Criticality Safety Program
Technical Program Review

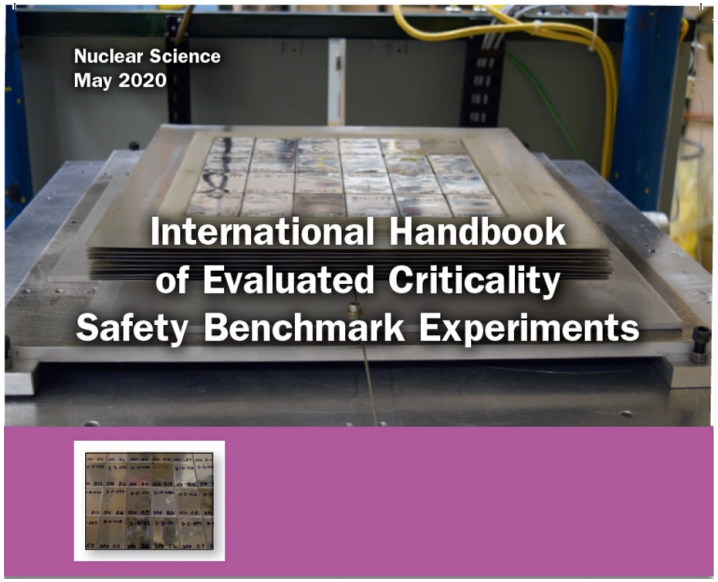
Plutonium Thermal Epithermal eXperiments (TEX)

- Goal: Produce new Pu critical benchmarks to address the nuclear data and validation needs for criticality safety
  - Minimum of materials
  - Designed to span multiple neutron fission energy spectra (fast through thermal) using high density polyethylene (HDPE) moderator
  - Assembly designed to be easily modified to test materials of interest
  - Zero Power Physics Reactor (ZPPR) Plutonium-Aluminum No-Nickel (PANN) plates in 6x4 plate layers (12” x 12”)



Plutonium TEX Experimental Program

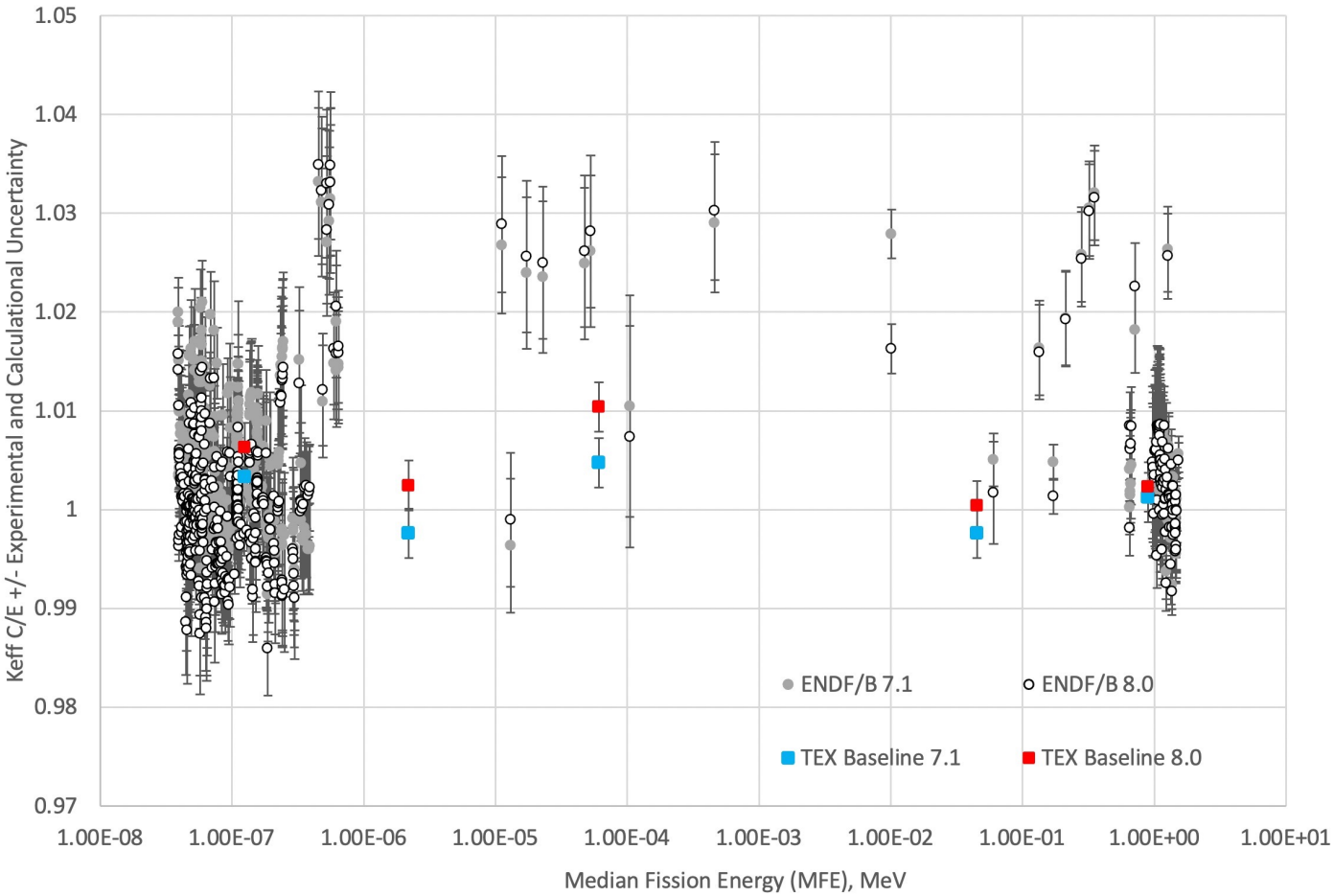
- Three Experimental Benchmarks
  - PMM-002, Baseline Pu TEX Configurations with HDPE- 5 cases
  - PMM-003, Pu TEX configurations with HDPE and tantalum- 5 cases
  - PMT-004, Pu TEX configurations with thick HDPE or Lucite moderators to test thermal scattering laws- 4 cases (submit to ICSBEP in April 2023)



- Additional Pu TEX Variants
  - IER 519: Thermal TEX configurations to test Fe and Mn Absorbers for Hanford Tank Farms- Final Design Complete 2021
  - **IER 520: Pu TEX configurations with higher ^{240}Pu Content plates- Final Design Complete 2022**
  - **IER 553: Additional baseline Pu TEX configurations with HDPE to provide intermediate energy data- Final Design Complete 2022**

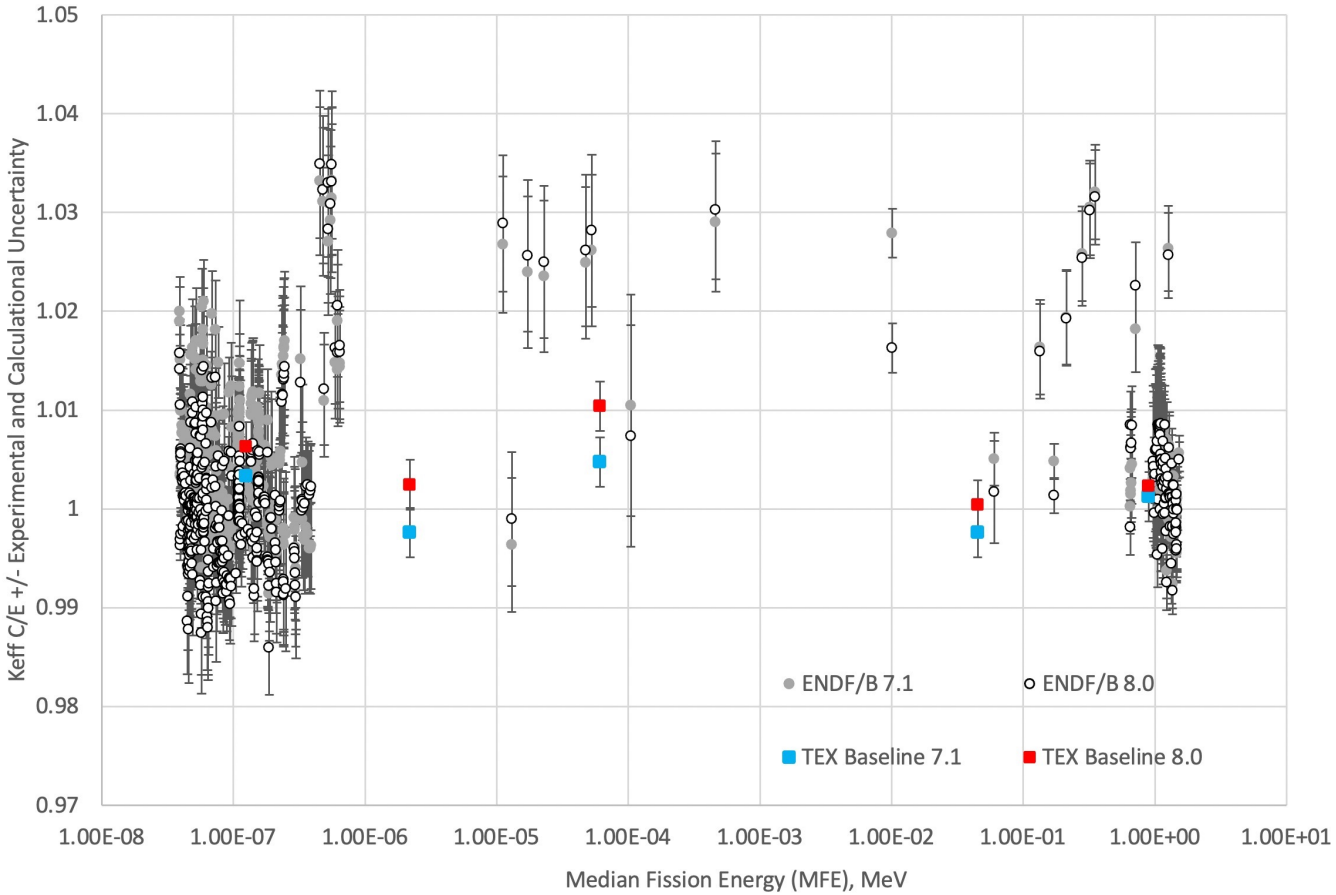
PU-MET-MIXED-002 (IER-184)

- TEX Plutonium Baseline against previous plutonium benchmarks



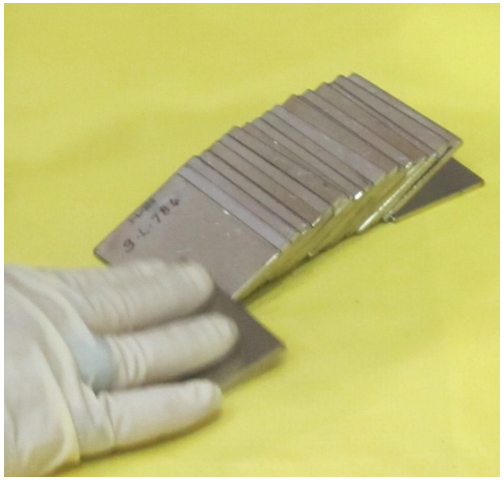
IER 520: High ^{240}Pu Variant of TEX-PU Baseline

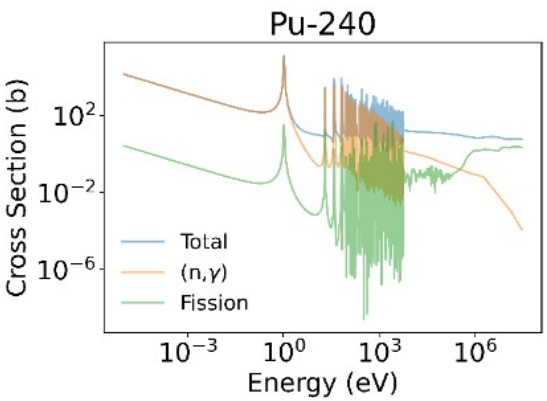
Use available stock of ZPPR plates with higher ^{240}Pu loading and optimize 5 baseline configurations for testing ^{240}Pu cross sections

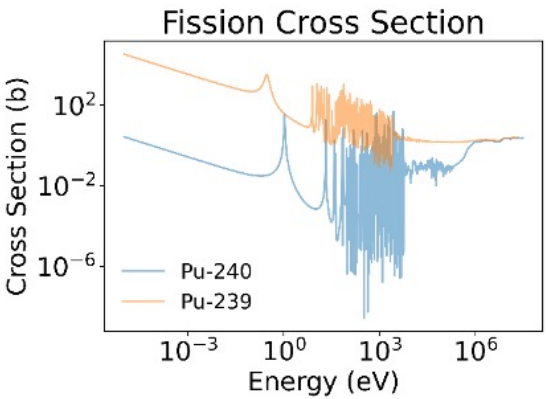


IER 520: High ^{240}Pu Variant of TEX-PU Baseline

- NCERC received additional types of ZPPR plates from the INL inventory, including Plutonium/Aluminum High ^{240}Pu No Nickel (PAHN) Plates
  - Designed to be interchangeable with PANN plates
  - 22% ^{240}Pu vs 5% ^{240}Pu in the PANN plates
  - ~39 3” plates (equivalent) at NCERC, with an additional 35 that might be available still at INL







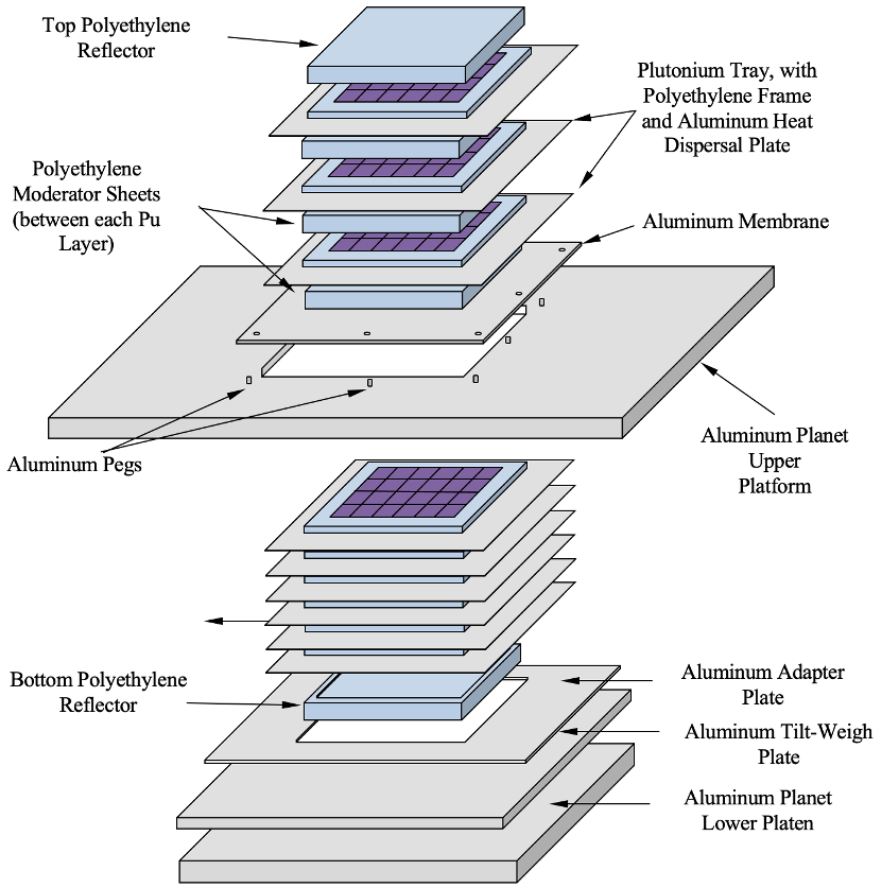
- Design Goals:
  - Using available plates, optimize baseline TEX design to ^{240}Pu capture (moderated cases) and fission (fast case) cross sections
  - Determine if we need/want additional 35 plates from INL

Some Changes from PU-MET-MIXED-002

Applies to both IER 520 and 553

- Interstitial HDPE has been redesigned with upper and lower recesses in order to self-align the stack and to minimize gaps

- New impurity analysis of PANN plate
  - 0.165 g of impurities per plate versus historical information of 0.007 g



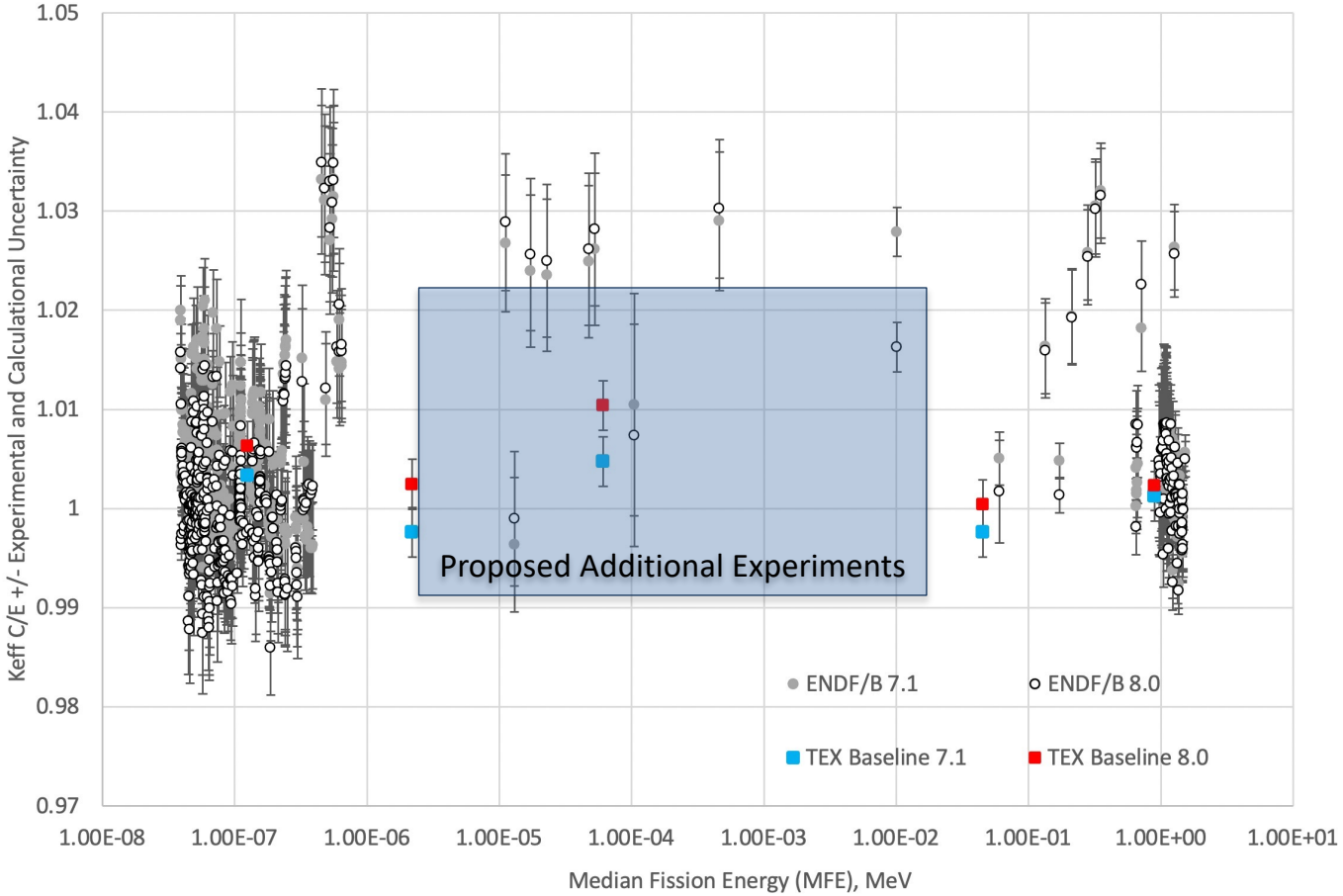
IER 520 Results

- Five critical configurations designed, placing available ^{240}Pu plates in high reactivity worth locations (center of the stacks)
- Most of the sensitivity of the configurations with 74 plates can be achieved using only 39 plates

Experiment Number	Moderator Thickness (in)	Thermal Fission Fraction (<0.625 eV)	Intermediate Fission Fraction (0.625 eV-100 KeV)	Fast Fission Fraction (>100 KeV)	Sensitivity Achieved (39 vs 74)
1	0	0.10	0.18	0.73	95%
2	1/16	0.14	0.38	0.48	93%
3	3/16	0.17	0.43	0.30	91%
4	7/16	0.48	0.33	0.19	83%
5	1	0.66	0.21	0.13	78%

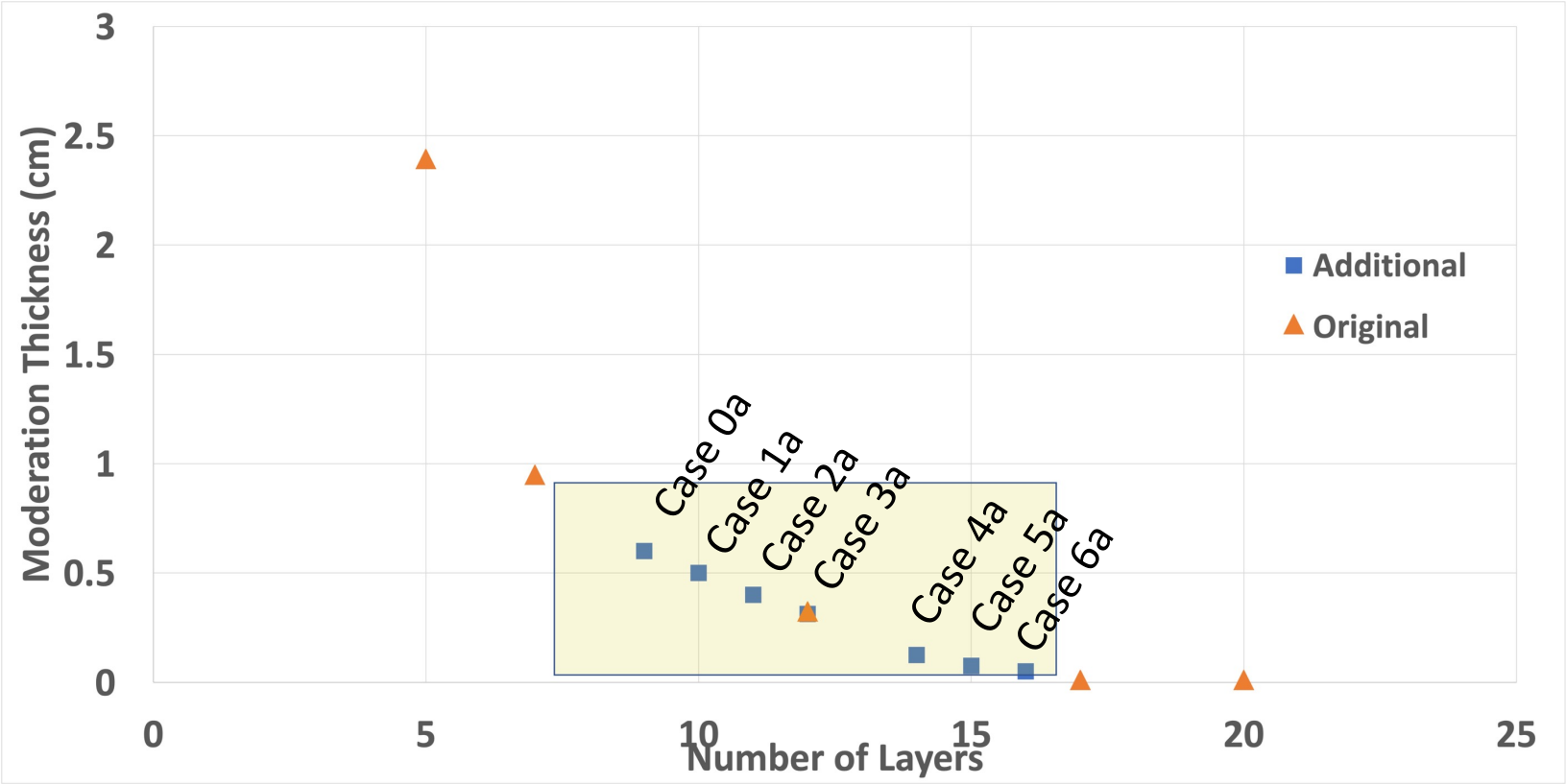
IER 553: Additional Mixed Spectrum Configurations

Most intermediate case was the worst performing, although a big improvement over existing benchmarks- what about additional cases?

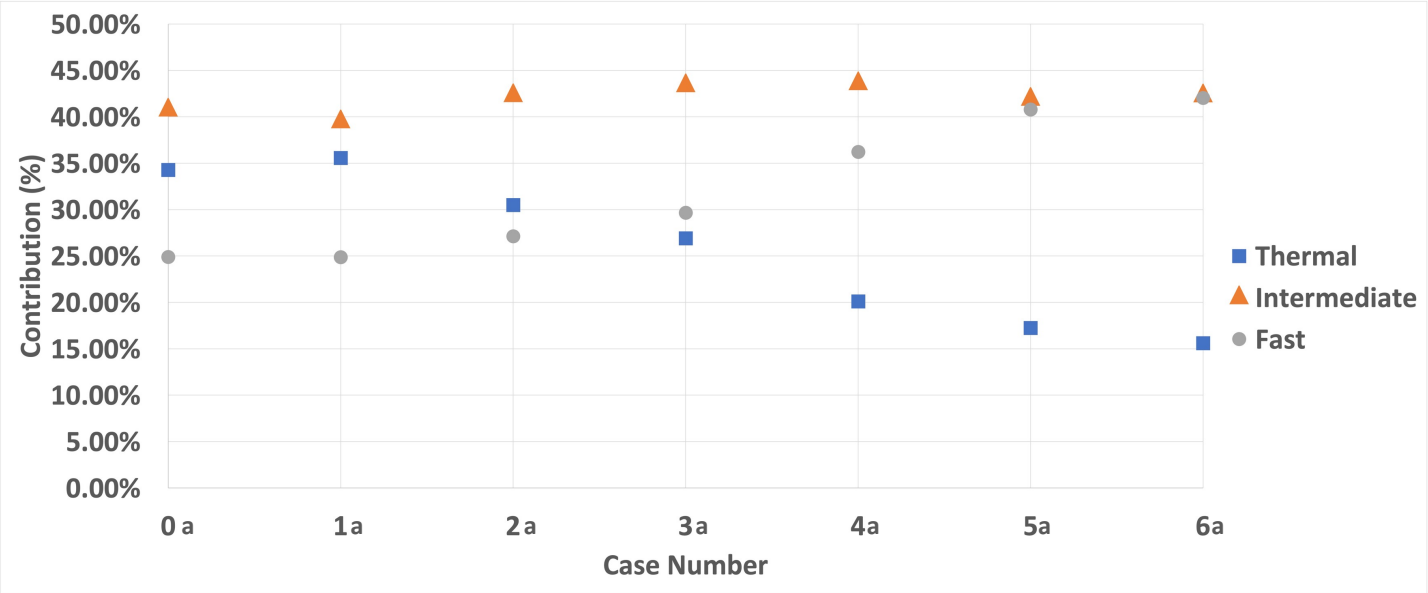


What do additional configurations look like?

- As expected, there is a nice clean trend between the number of layers and the moderation thickness

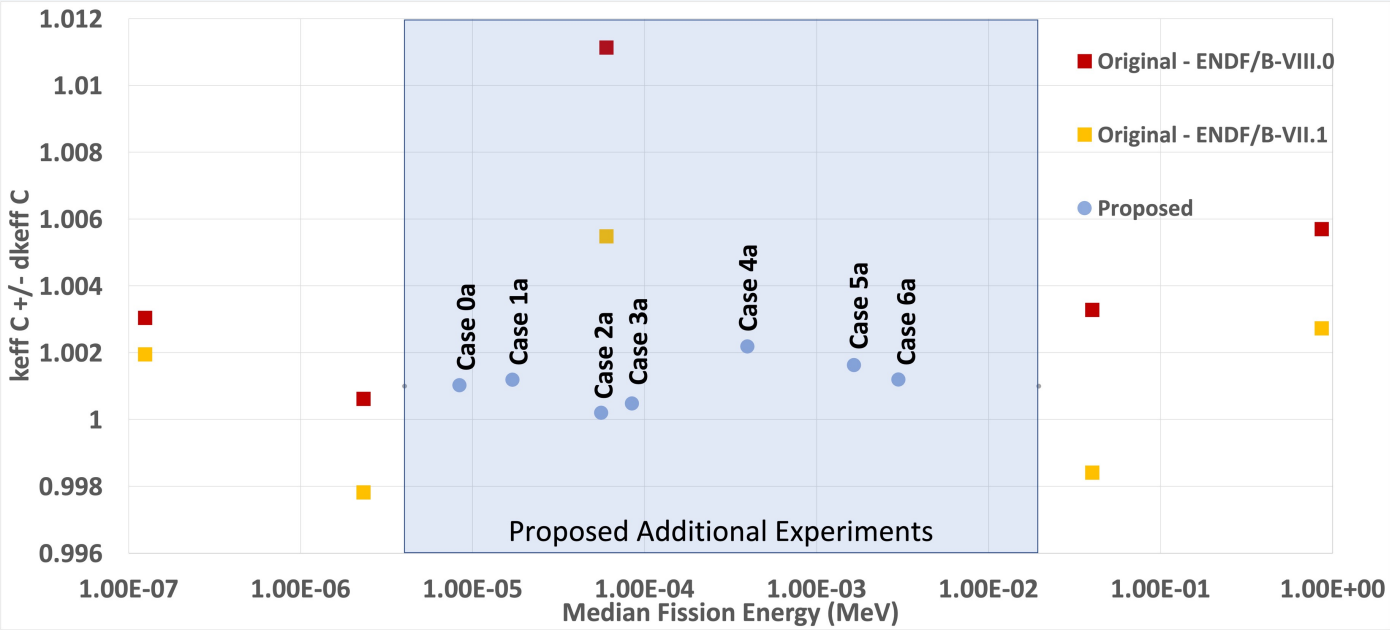


Neutron Fission Energy Distributions



Case Number	Percent Thermal (<0.625 eV)	Percent Intermediate	Percent Fast (>100 keV)	Median Fission Energy (MeV)
Case 0a	39.45	38.42	22.13	8.402E-06
Case 1a	35.58	39.53	24.90	1.733E-05
Case 2a	30.52	42.34	27.14	5.603E-5
Case 3a	28.15	42.26	29.59	8.490E-5
Case 4a	20.12	43.64	36.24	3.965E-4
Case 5a	17.25	41.94	40.81	1.652E-3
Case 6a	15.62	42.32	42.06	2.997E-3

Where do they fit relative to PU-MET-MIXED-002?



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- They are all very well interspersed in the window that we want to probe

Which configurations to pursue?

- Case 3a was chosen because of similarity to Case 3 of PMM-002 and can be used to tie the additional configurations to those of the benchmark
- Two other cases chosen that were primarily in the intermediate energy region and had moderator thicknesses that were logistically feasible to produce

Case Number	Percent Thermal (<0.625 eV)	Percent Intermediate	Percent Fast (>100 keV)	Median Fission Energy (MeV)
~~Case 0a~~	~~39.45~~	~~38.42~~	~~22.13~~	~~8.402E-06~~
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IER 553: Summary of Configurations

- The three configurations have 10, 12, and 14 layers with interstitial moderator thicknesses from 1/8” to 1/4”.
- k_{eff} worth studies for the upper reflector thickness, number of Pu plates in the top layer, and separation distance between to assembly halves completed and documented in CED-2 to aid experimental approach to critical

Case Number	Number of Pu Layers (Top/Bottom)	Total Interstitial Moderator Thickness	Upper Reflector Height	Lower Stack Height	Upper Stack Height	Calculated k_{eff}
Case 1a	10 (5/5)	0.25” (0.64 cm)	0.84” (2.1431 cm)	2.75” (6.9904 cm)	2.82” (7.1780 cm)	1.00119 ± 0.00009
Case 3a	12 (6/6)	0.1875” (0.4763 cm)	0.5938” (1.5081 cm)	2.83” (7.1851 cm)	2.56” (6.5002 cm)	1.00048 ± 0.00009
Case 4a	14 (7/7)	0.125” (0.3175 cm)	0.656” (1.6669 cm)	2.78” (7.0625 cm)	2.51” (6.3778 cm)	1.00219 ± 0.00009

Conclusions

- Two additional experiments were designed as part of the Pu TEX series as part of IER 520 and IER 553
- Only additional material costs for the experiments are fabrication of the moderator parts
- Experiment execution is not currently scheduled

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