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NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM

Preliminary Results for Thermal Epithermal eXperiments (TEX), Ten New Critical Experiments with Plutonium-Aluminum Zero Power Physics Reactor (ZPPR) Plates

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Catherine Percher, Soon Kim, David Heinrichs
Lawrence Livermore National Laboratory
Rene Sanchez, Travis Grove, Jesson Hutchison, Theresa Cutler, George McKenzie
Los Alamos National Laboratory
Lawrence Livermore National Laboratory, P.O. Box 808, L-186, Livermore, CA 94551-0808
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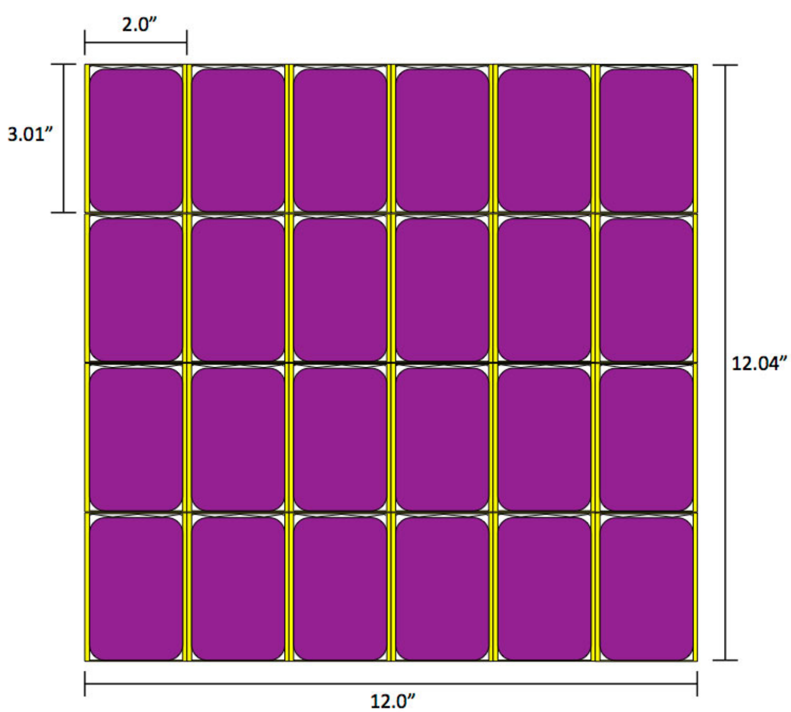
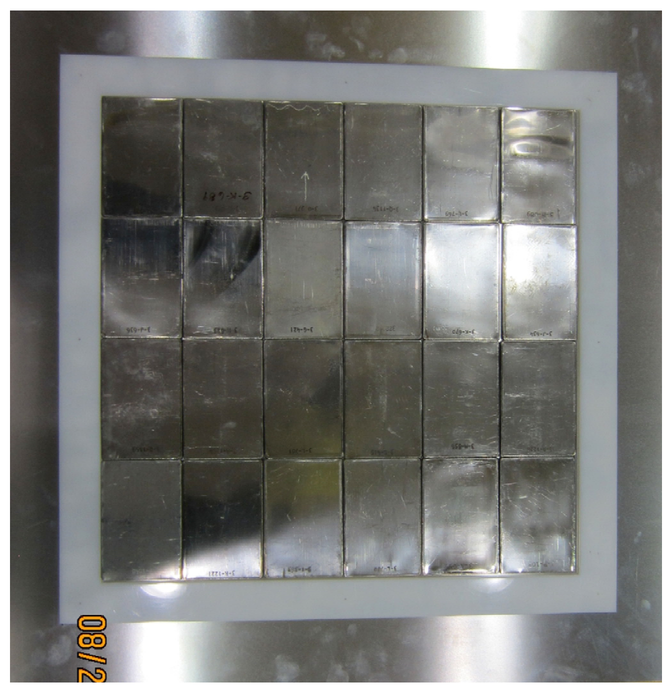
Thermal/Epithermal eXperiments (TEX)

- TEX Goals
  - Using available US Department of Energy fissile materials, create critical benchmarks to address the nuclear data and validation needs for criticality safety
  - July 2011 at Sandia National Laboratories, Albuquerque, NM
    - Representatives from US, UK, and France
    - Main take-aways
      - Intermediate spectrum experiments needed (only 2.1% of ICSBEP Benchmarks)
      - Test-bed assemblies that span multiple energy spectra are incredibly useful for nuclear data validation
      - Consensus prioritization of nuclear data needs (in order):
        - **^{239}Pu, ^{240}Pu**, ^{238}U, ^{235}U, Temperature variations, Water density variations, Steel, Lead (reflection), Hafnium, **Tantalum**, Tungsten, Nickel, Molybdenum, Chromium, Manganese, Copper, Vanadium, Titanium, and Concrete (reflection, characterization, and water content)

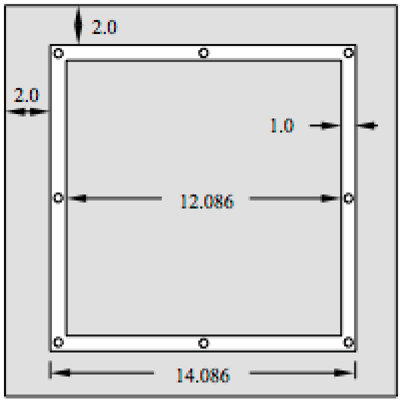
Plutonium TEX Experiments

- Plutonium test bed experimental series, using excess plutonium/aluminum Zero Power Physics Reactor (ZPPR) plates
- Five baseline experiments, covering thermal, intermediate and fast fission energy regimes and five similar experiments that include tantalum
- Pu plates arranged in approximately 30 cm x 30 cm (12” x 12”) layers (6 plates by 4 plates)

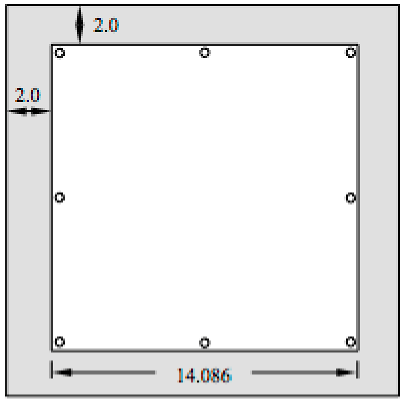




Trays Used to Facilitate Stacking Layers

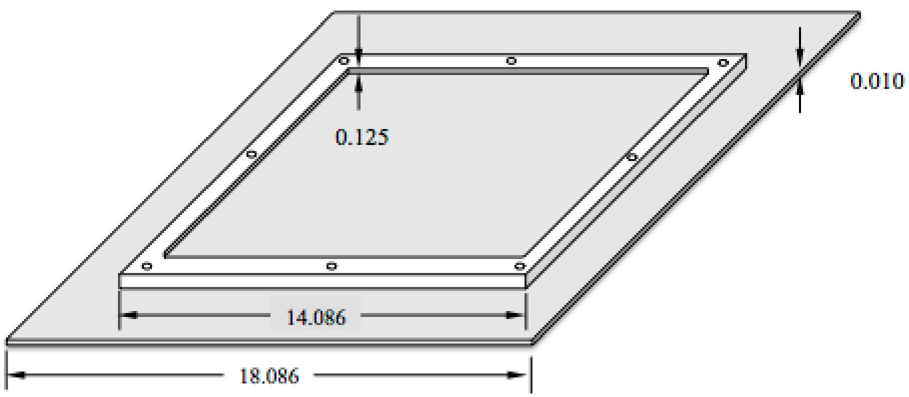


Top View of Tray

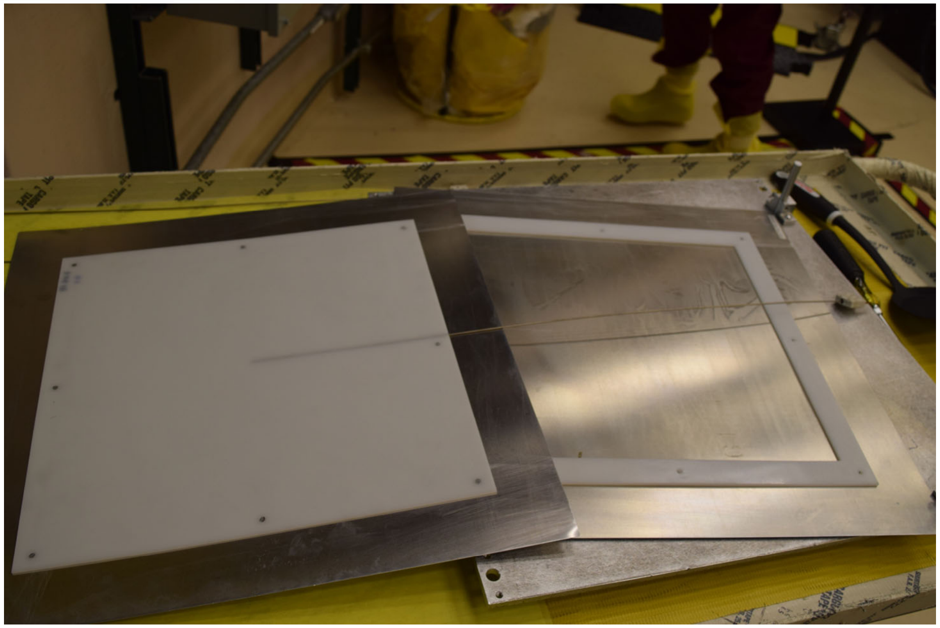


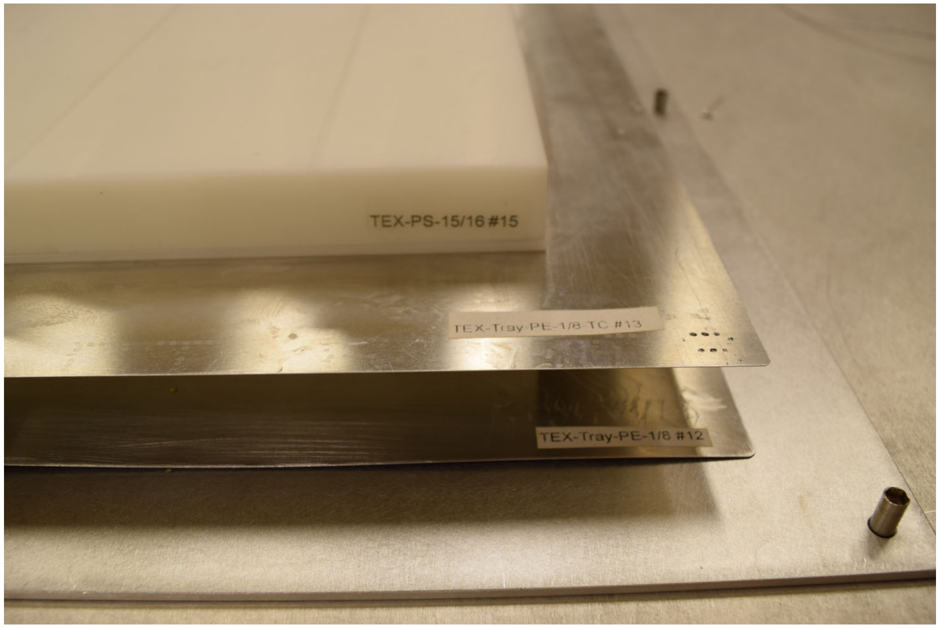
Bottom View of Tray

Side View of Tray

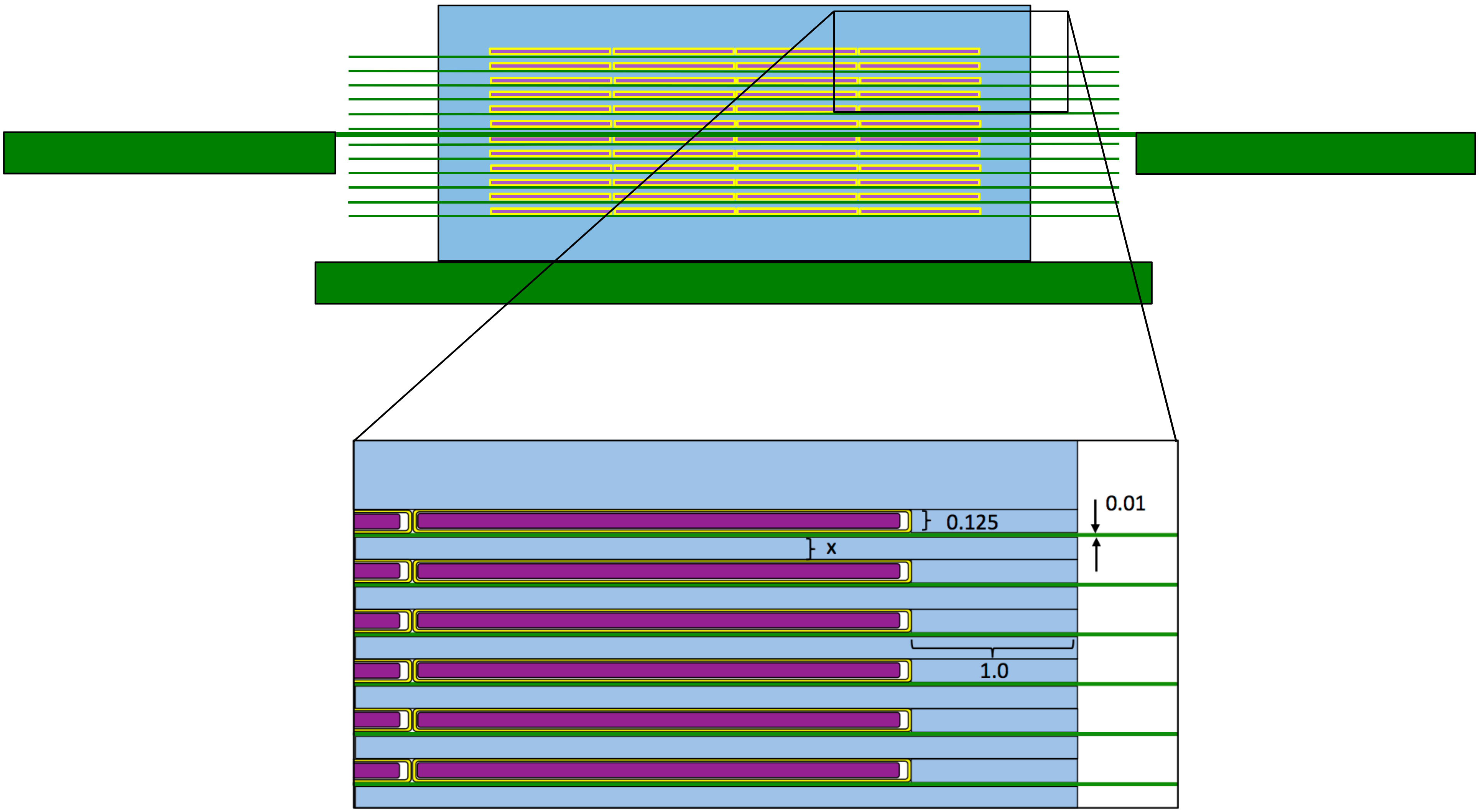


Perspective View of Top of Tray



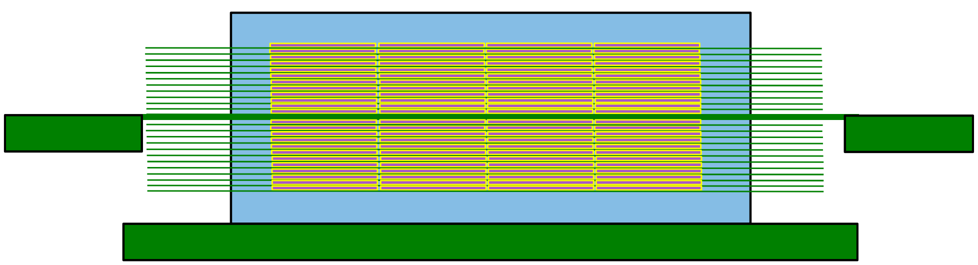


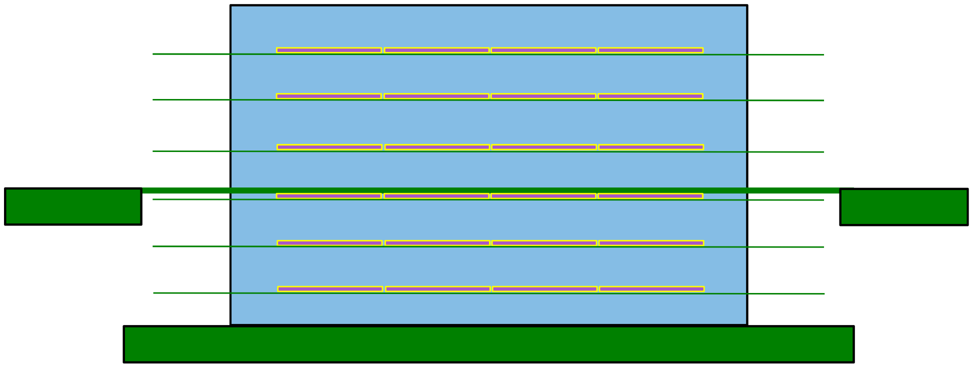
Plutonium Baseline Experiments



Baseline Experiments

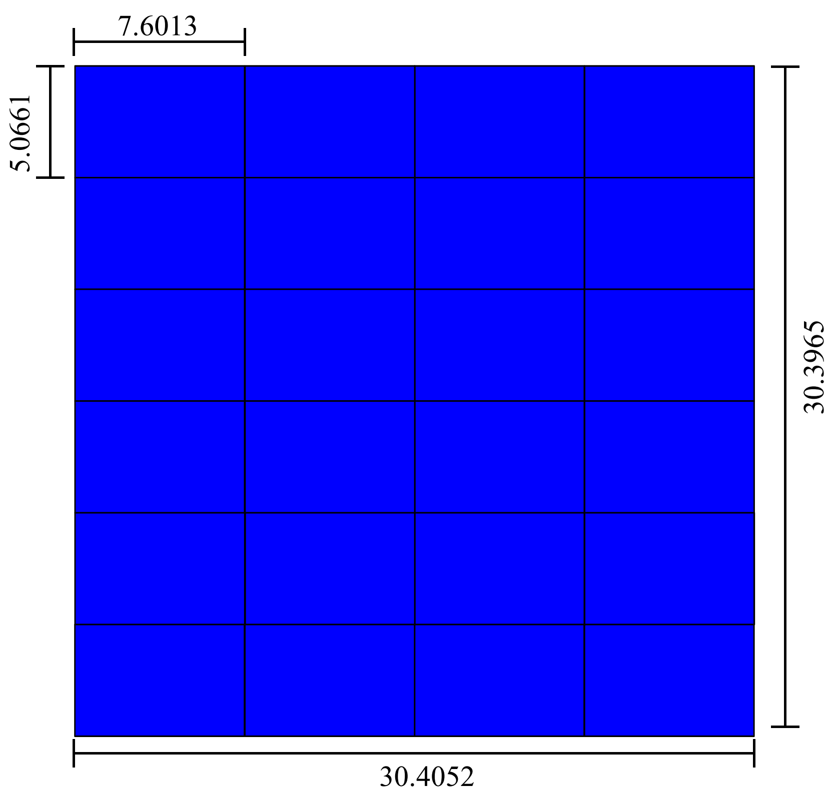
Experiment Number	Thickness of PE Plates (cm)	Thermal Fission Fraction (<0.625 eV)	Intermediate Fission Fraction (0.625 eV-100 KeV)	Fast Fission Fraction (>100 KeV)
1	0 (no PE)	0.09	0.18	0.73
2	0.159	0.14	0.38	0.48
3	0.476	0.28	0.43	0.29
4	1.111	0.50	0.32	0.18
5	2.540	0.66	0.21	0.13

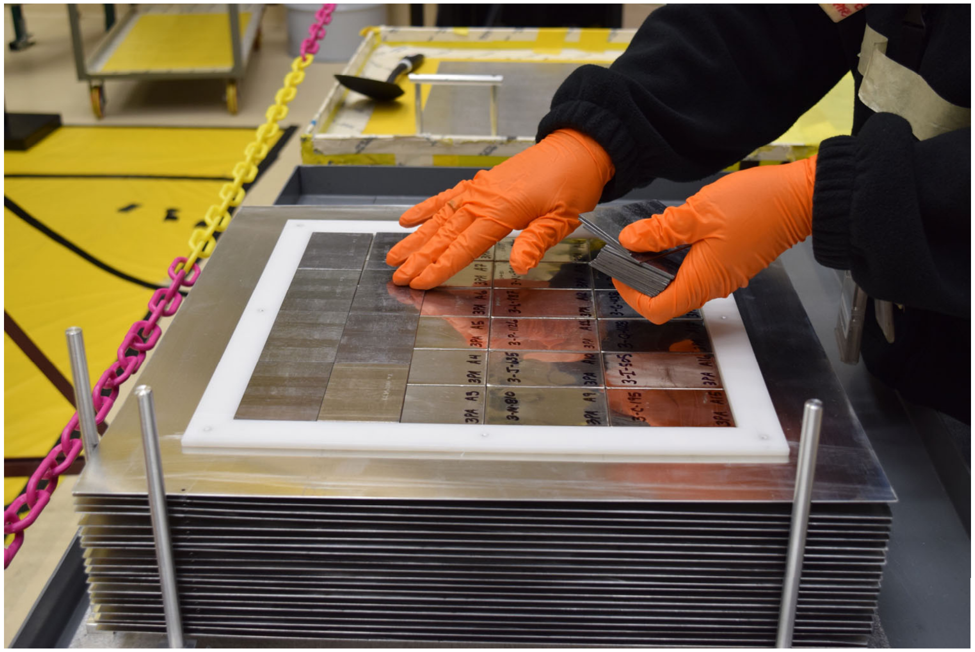




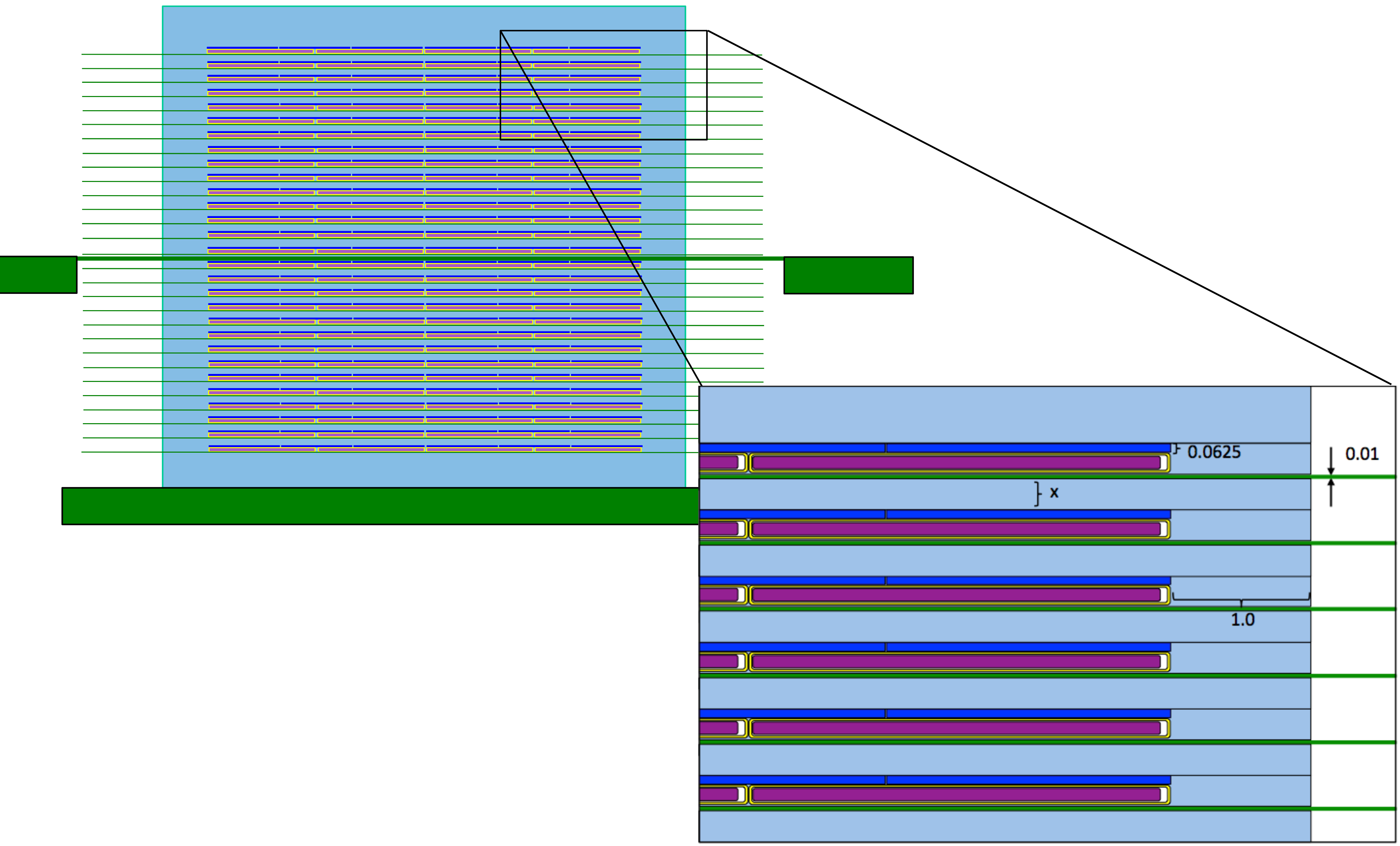
Tantalum Diluted Cases

- As part of the ZPPR inventory, ANL had approximately 15,000 very pure tantalum plates
- Nominal outer dimensions of 5.08 cm x 7.62 cm by 0.159 cm
- Additional trays were manufactured to accommodate both Pu and Ta plates
  - 0.476 cm (3/16”) tray depth



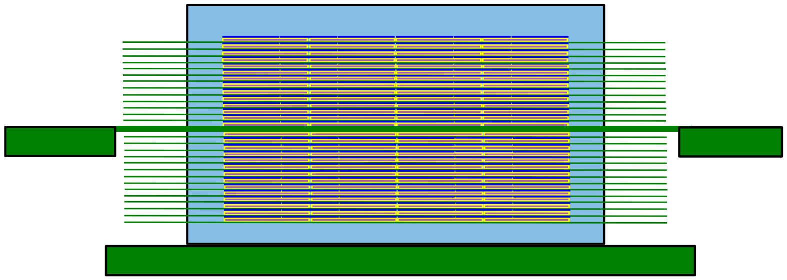


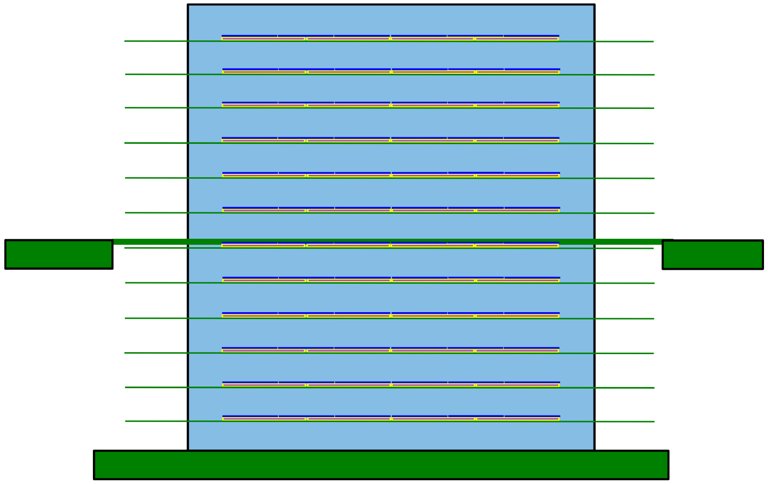
Tantalum Diluent Experiments



Tantalum Experiment Characteristics

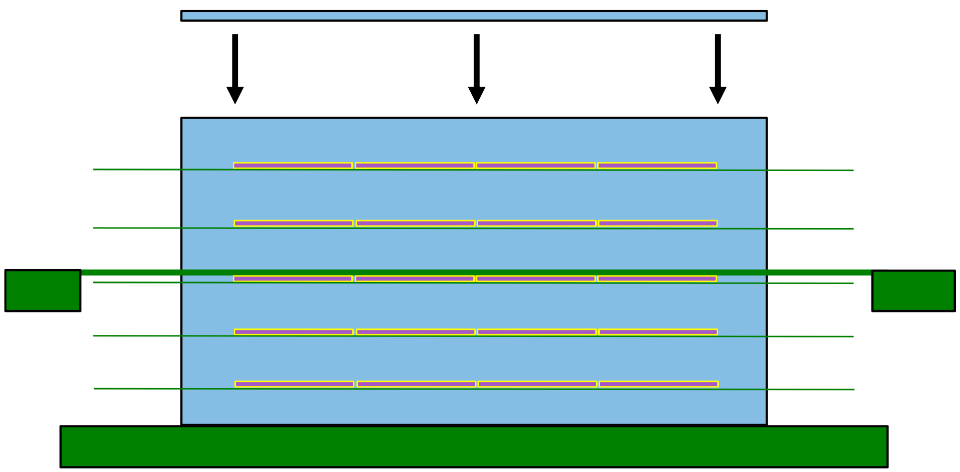
Experiment Number	Thickness of PE Plates (cm)	Thermal Fission Fraction (<0.625 eV)	Intermediate Fission Fraction (0.625 eV-100 KeV)	Fast Fission Fraction (>100 KeV)
6	0 (no PE)	0.07	0.14	0.79
7	0.159	0.8	0.36	0.56
8	0.476	0.19	0.45	0.36
9	1.111	0.43	0.36	0.21
10	2.540	0.64	0.22	0.14

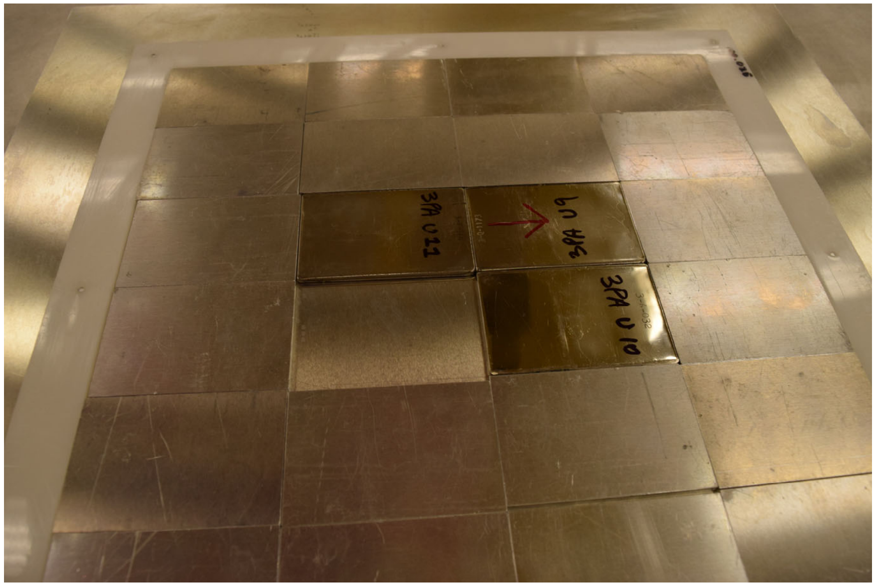




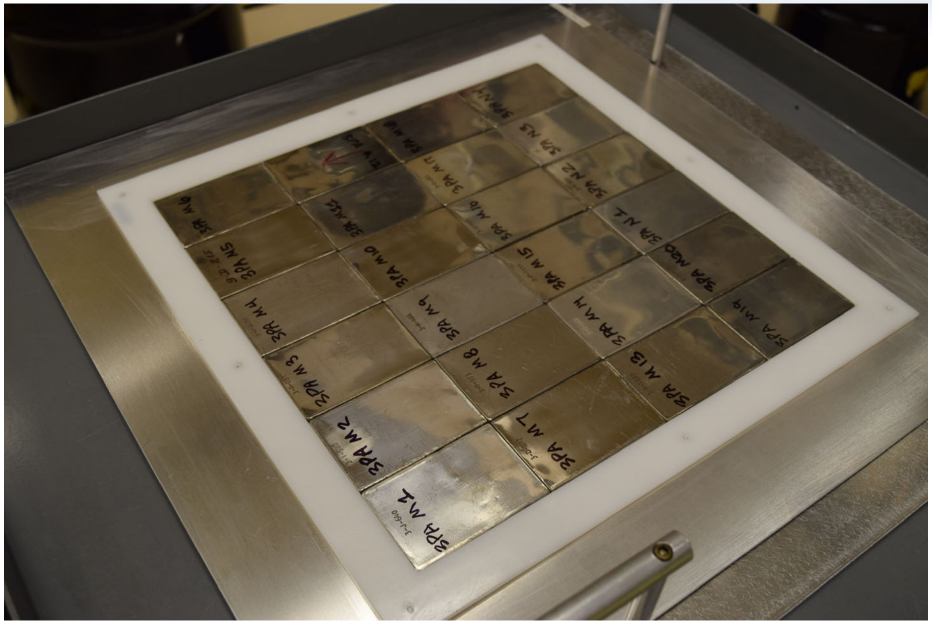
Fine Reactivity Adjustment

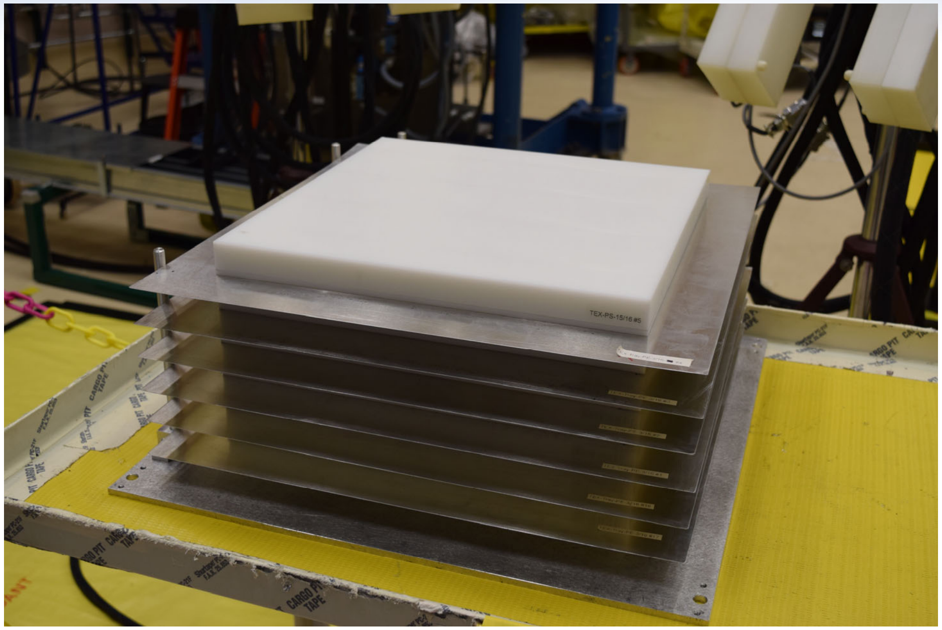
- Need a way to add small amounts of reactivity to the assembly near critical to ensure we hit the delayed critical window (between 1 and ~1.0016)
- Two Methods:
  - Add thicker upper reflector sheets
  - Partial layer of plutonium plates in upper layer, using aluminum blanks to maintain spacing within tray

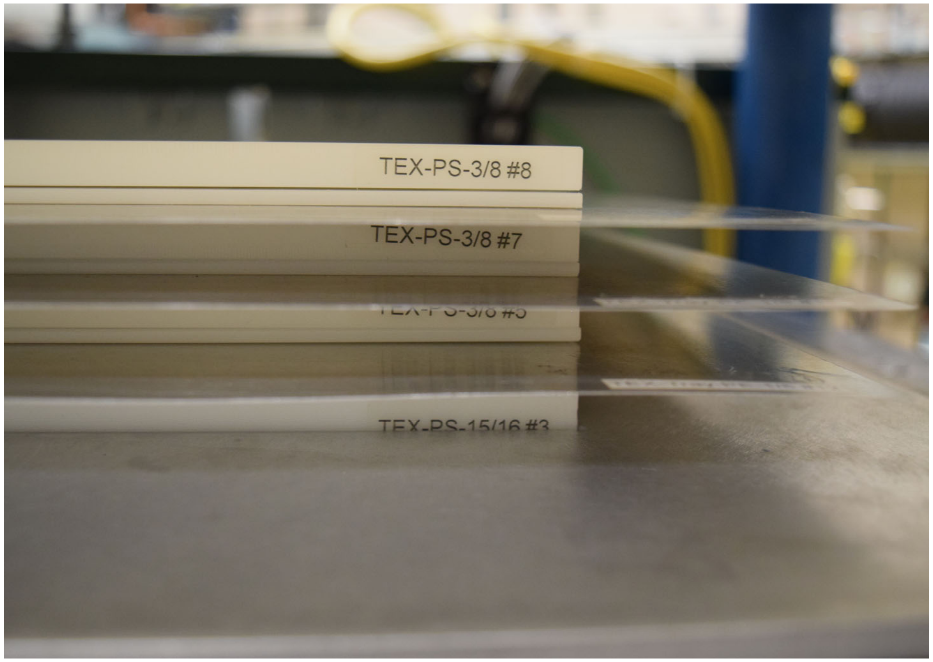


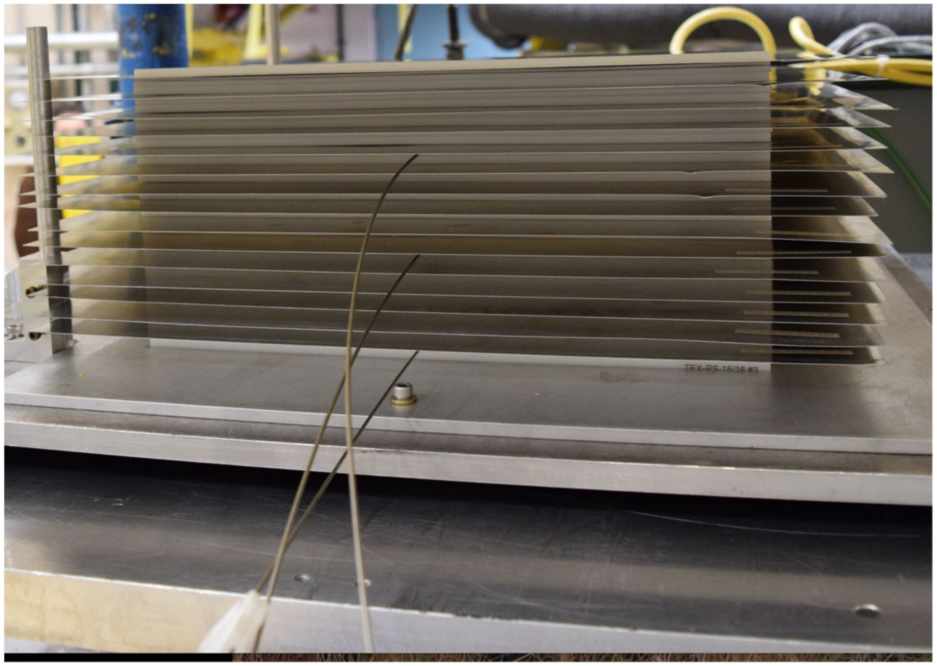


Experiment Photos









PRELIMINARY Baseline Results

Exp Number	PE Moderator Thickness (cm)	Upper Reflector Thickness (cm)	Number of Critical Pu Plates	Peak Temperature (C)	Estimated C/E (k_{eff})
1	0 (no PE)	2.540	480	40.5	1.0082
2	0.159	2.540	404	45.0	1.0095
3	0.476	2.699	280	39.6	1.0087
4	1.111	2.540	172	34.1	1.0003
5	2.540	3.175	120	32.4	0.9978

- Why preliminary results?
  - Values calculated with MCNP6, version 1.2, with ENDF/B-VII.1 cross sections using design parameters and do not incorporate all experimental measurements or temperature effects
  - Experimental k_{eff}s are based on fast plutonium delayed neutron parameters for all configurations
  - LOTS of work to do for a benchmark

PRELIMINARY Tantalum Results

Exp Number	PE Moderator Thickness (cm)	Upper Reflector Thickness (cm)	Number of Critical Pu Plates	Peak Temperature (C)	Estimated C/E (k_{eff})
6	0 (no PE)	2.540	648	47.1	1.0170
7	0.159	2.540	768	48.3	1.0208
8	0.476	2.699	768	43.6	1.0156
9	1.111	2.540	438	40.6	1.0082
10	2.540	3.175	264	34.6	1.0002

- Why preliminary results?
  - Values calculated with MCNP6, version 1.2, with ENDF/B-VII.1 cross sections using design parameters and do not incorporate all experimental measurements or temperature effects
  - Experimental k_{eff}s are based on fast plutonium delayed neutron parameters for all configurations
  - LOTS of work to do for a benchmark

PRELIMINARY Conclusions

- Thermal configurations calculated very well
- Intermediate and fast baseline systems calculated approximately 1% high
  - Potentially pointing to issues with ^{239}Pu unresolved resonance region
- Intermediate and fast tantalum systems calculated approximately 1.5-2% high
  - Possible issues with tantalum scattering and angular distributions, potentially too much resonance absorption
- Temperature will have some effect, however, the effect is expected to be small and not explain the magnitude of the C/E differences
  - 15 degree temperature cross section change gave a calculated k_{eff} change of -0.00016
  - Thermal expansion of the polyethylene gave a calculated k_{eff} change of -0.00026
  - Experimental results showed temperature effects on the order of a few cents of reactivity (less than 0.0002 effect)

Current Work for TEX-Pu

- Complete chemical and metallurgical characterization of one Pu/Al ZPPR plate to determine impurity content and confirm historical isotopic and chemical composition
- Prepare ICSBEP benchmark for inclusion in the 2019 version of the handbook
  - Detailed analysis of temperature and thermal expansion effects
  - Incorporating all experimental measurements
  - Thorough experimental uncertainty quantification

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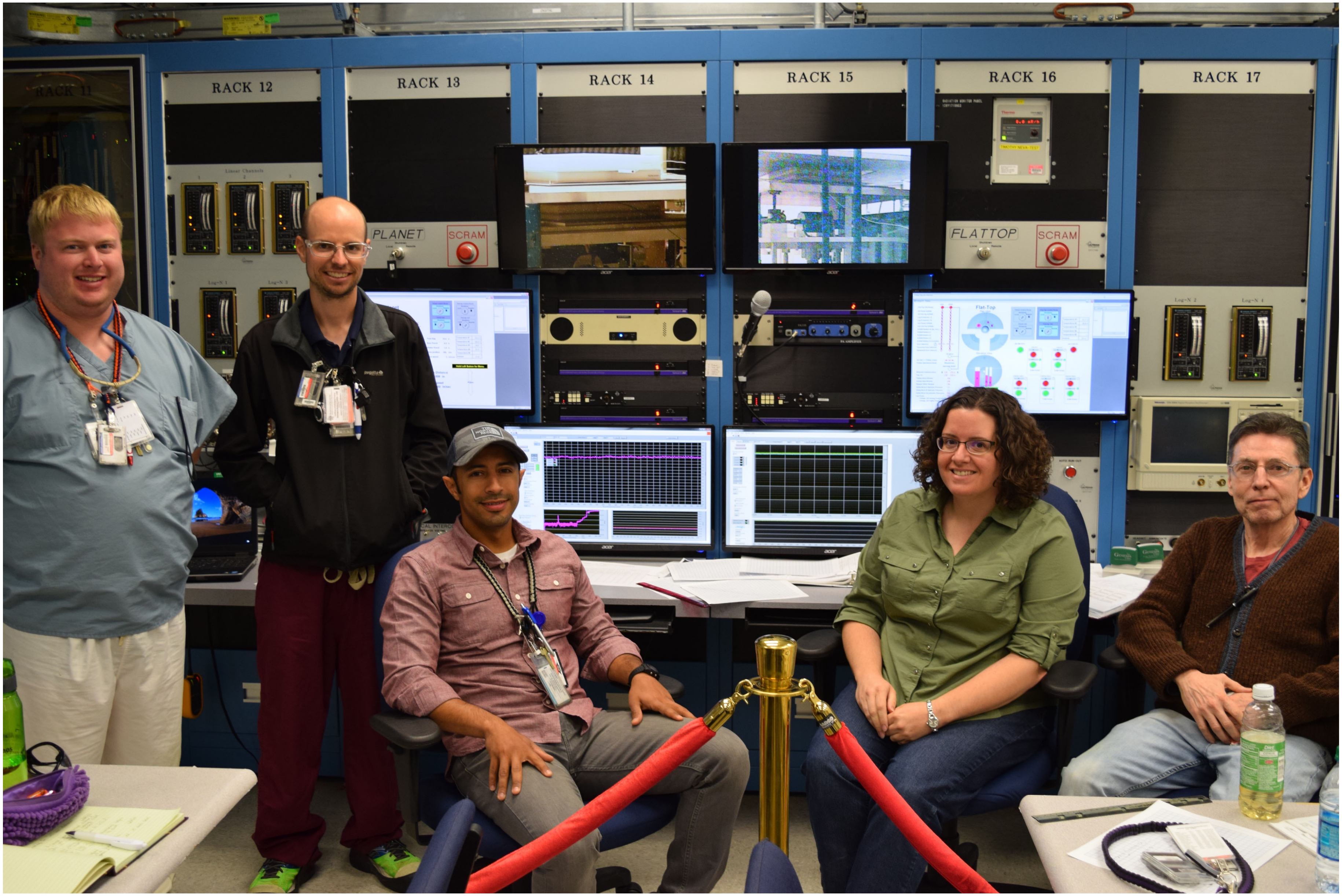
Thanks to LANL and NCSP!



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