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Thermal Epithermal eXperiments (TEX) Plutonium Critical Configurations

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Catherine Percher, Soon Kim, David Heinrichs
Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory, P.O. Box 808, L-186, Livermore, CA 94551-0808
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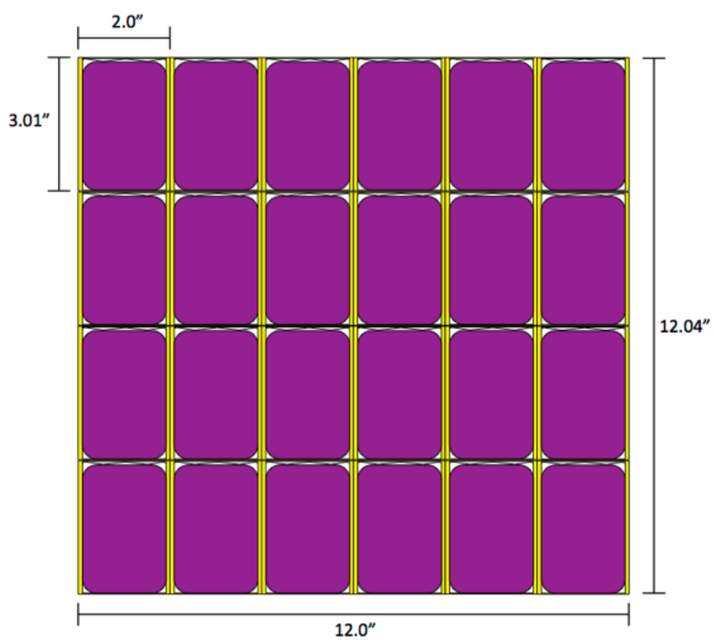
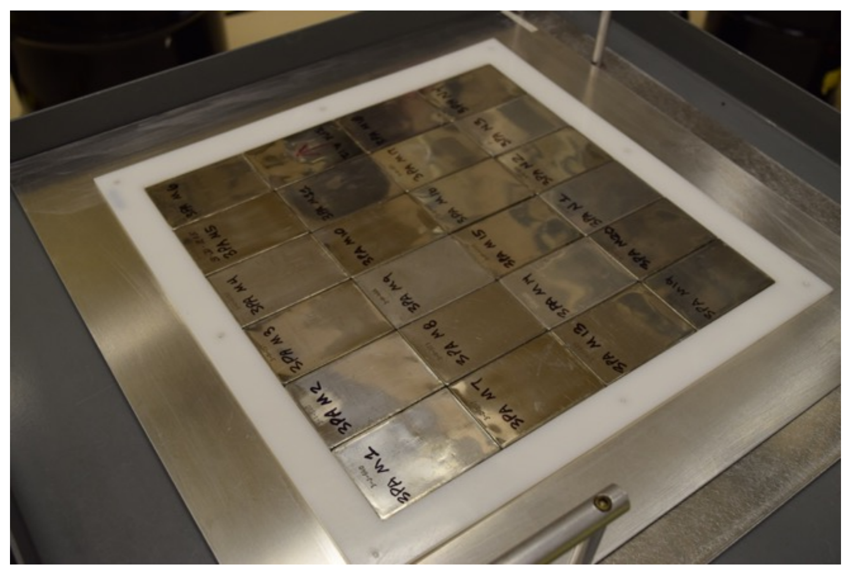
Thermal/Epithermal eXperiments (TEX)

- 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)
  - LLNL and LANL completed 3 critical configurations in FY17 and 17 configurations in FY18

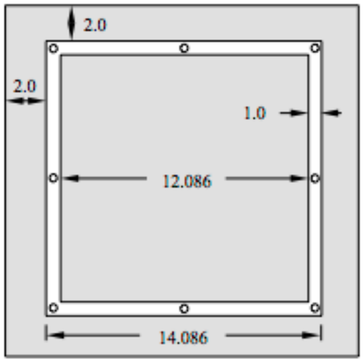
Plutonium TEX Experiments

- 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” by 12”) layers (6 plates by 4 plates)

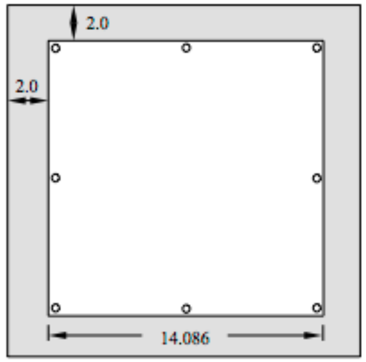




Trays Used to Facilitate Stacking Layers

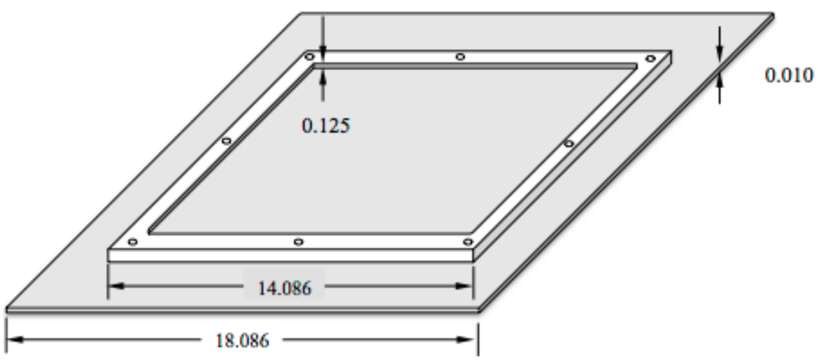


Top View of Tray

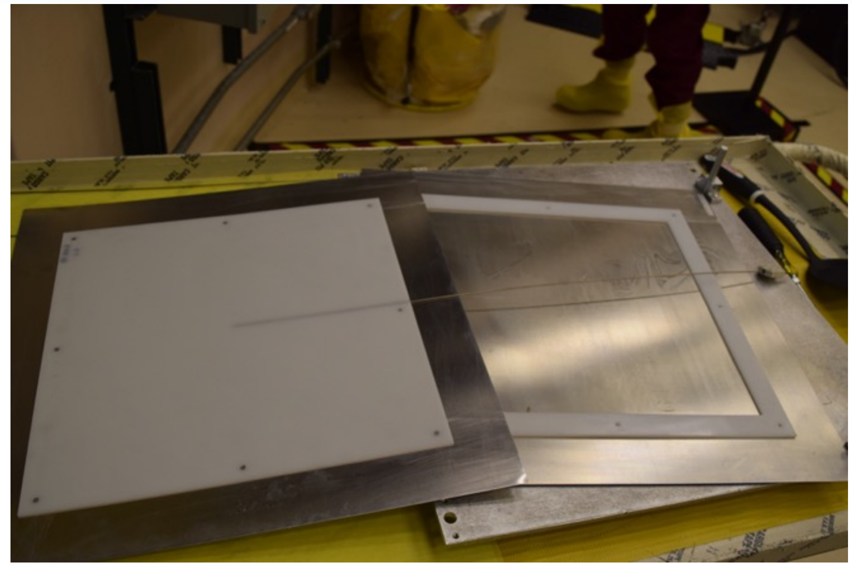


Bottom View of Tray

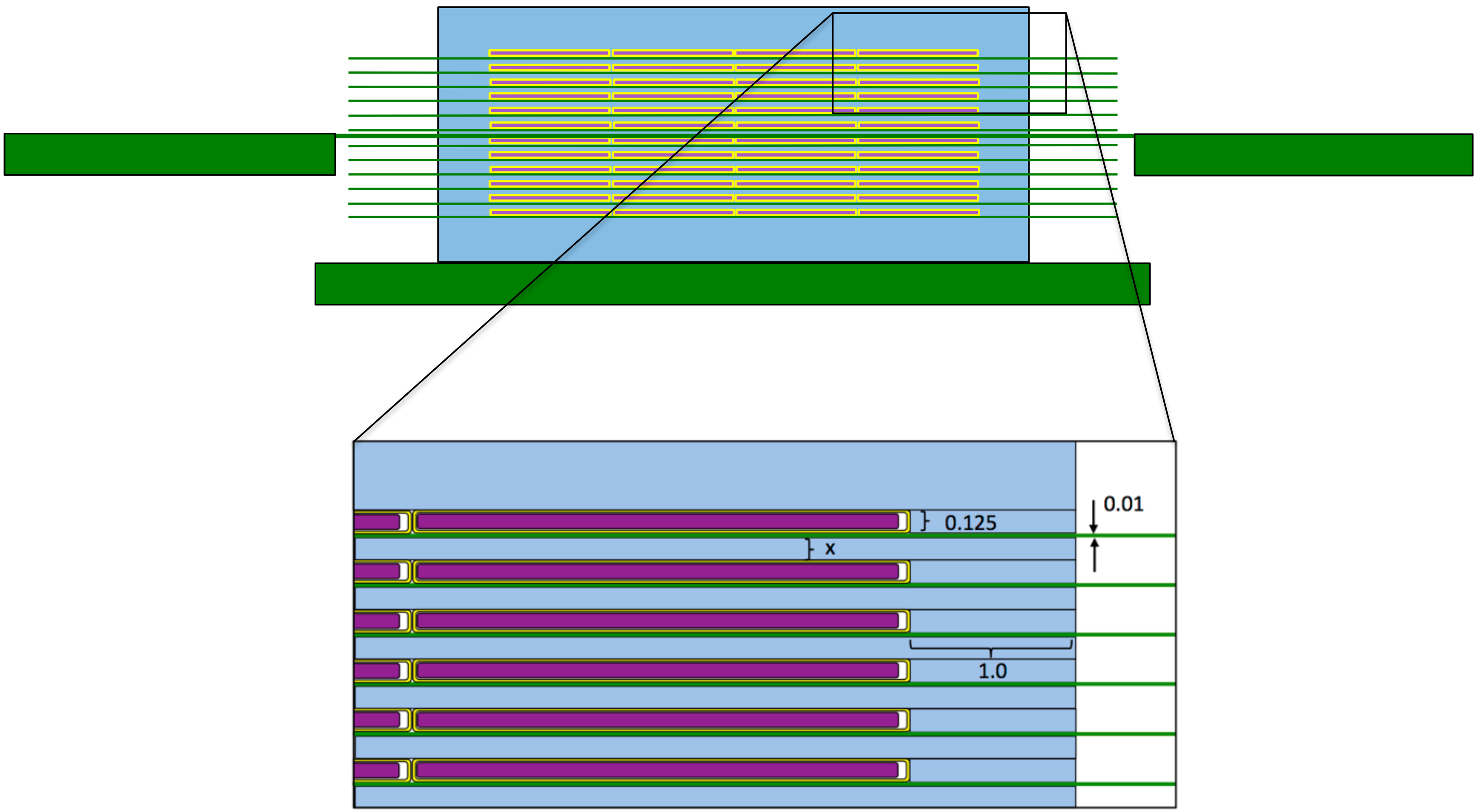
Side View of Tray



Perspective View of Top of Tray

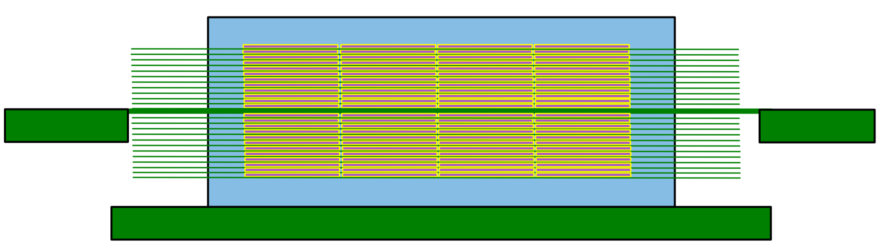


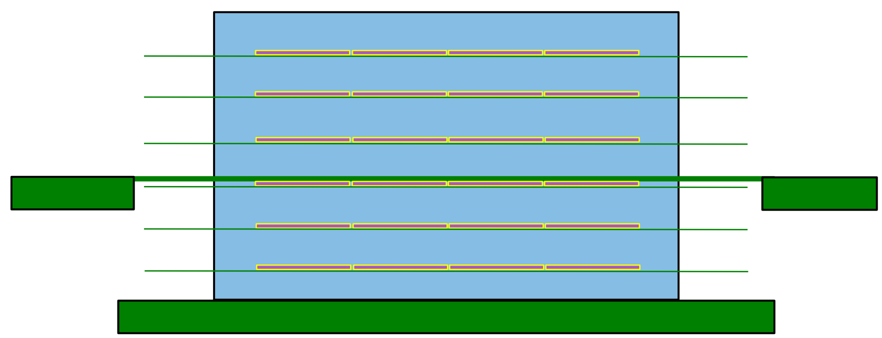
Plutonium Baseline Experiments



Baseline Experiments

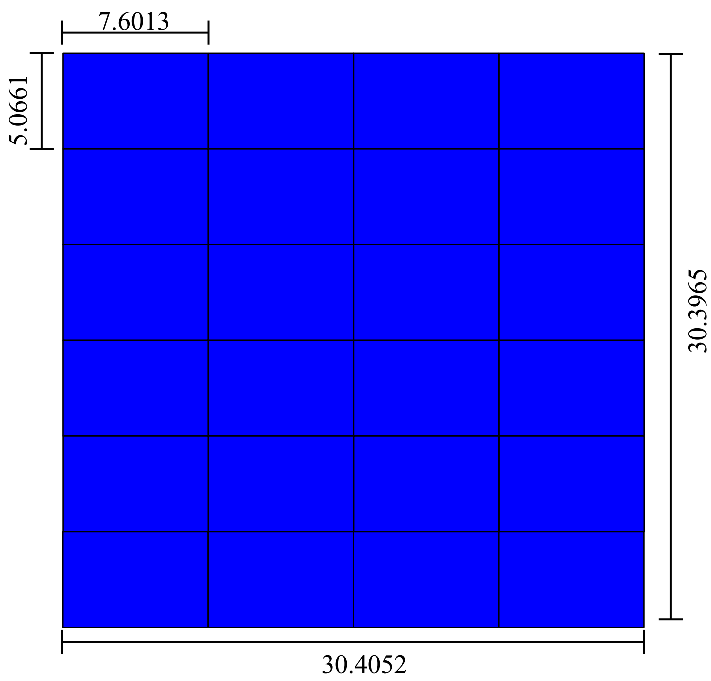
Experiment Number	Thickness of PE Plates (cm)	Thermal Fission Fraction (<0.625 eV)	Intermediate Fission Fraction (0.625 eV-100 KeV)	Fast Fission Fraction (>100 KeV)
1	0 (no PE)	0.09	0.18	0.73
2	0.159	0.14	0.38	0.48
3	0.476	0.28	0.43	0.29
4	1.111	0.50	0.32	0.18
5	2.540	0.66	0.21	0.13

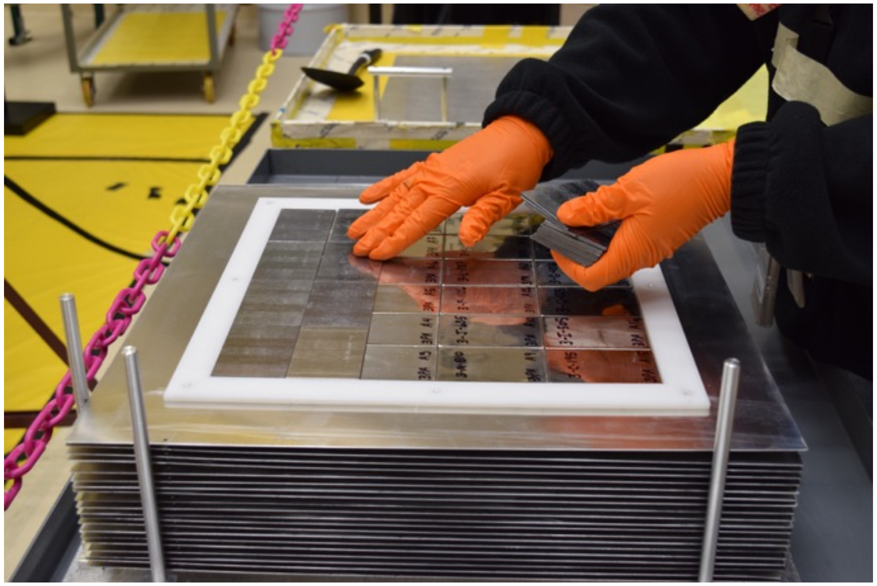




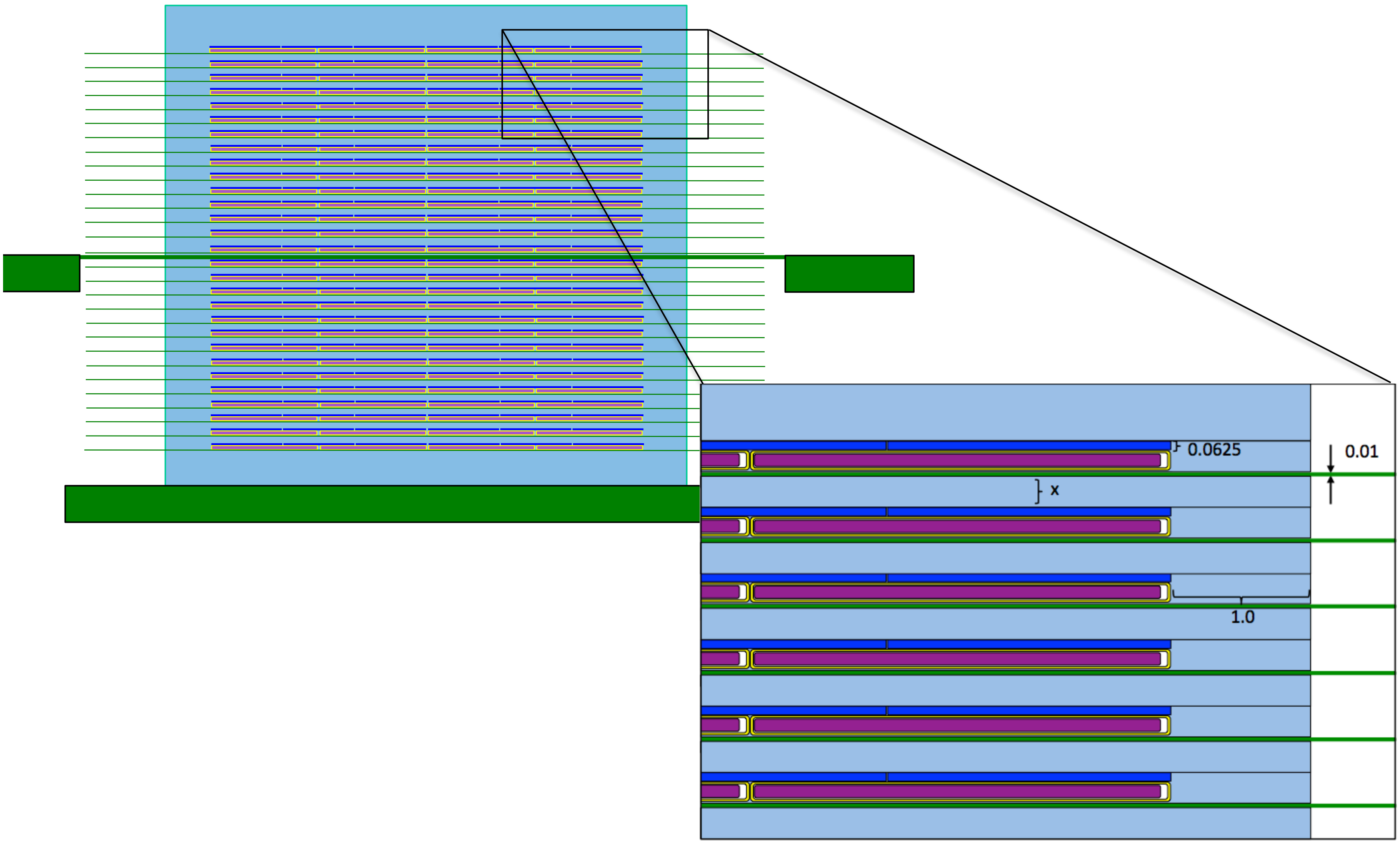
Tantalum Diluted Cases

- 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 (2” by 3” by 1/16”)
- Additional trays were manufactured to accommodate both Pu and Ta plates
  - 0.476 cm (3/16”) tray depth



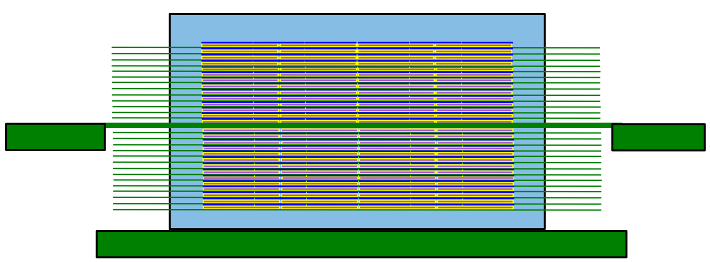


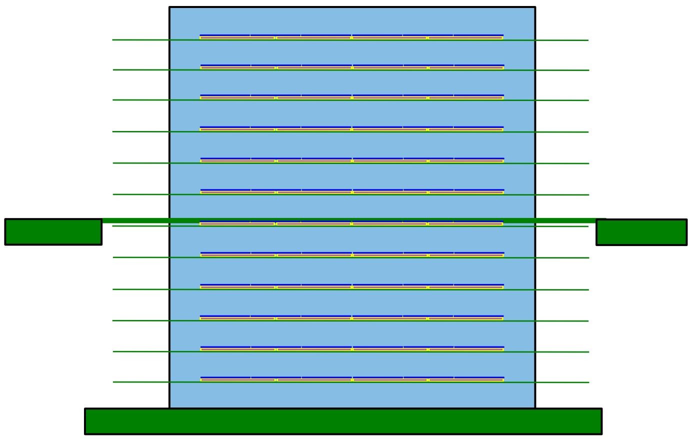
Tantalum Diluent Experiments



Tantalum Experiment Characteristics

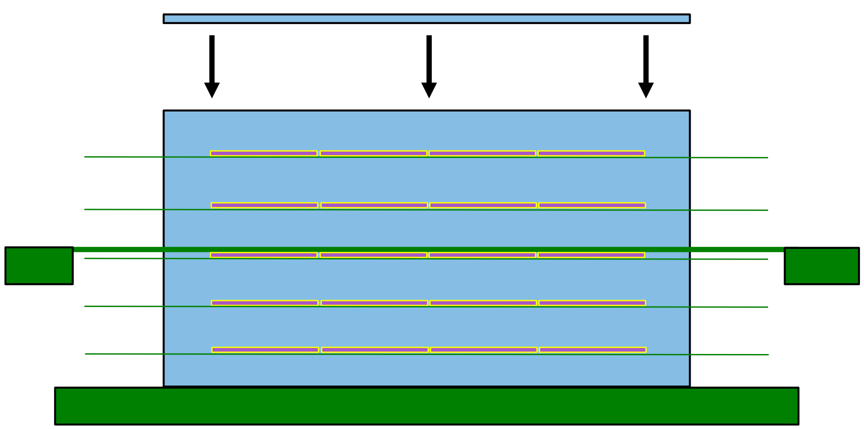
Experiment Number	Thickness of PE Plates (cm)	Thermal Fission Fraction (<0.625 eV)	Intermediate Fission Fraction (0.625 eV-100 KeV)	Fast Fission Fraction (>100 KeV)
6	0 (no PE)	0.07	0.14	0.79
7	0.159	0.8	0.36	0.56
8	0.476	0.19	0.45	0.36
9	1.111	0.43	0.36	0.21
10	2.540	0.64	0.22	0.14



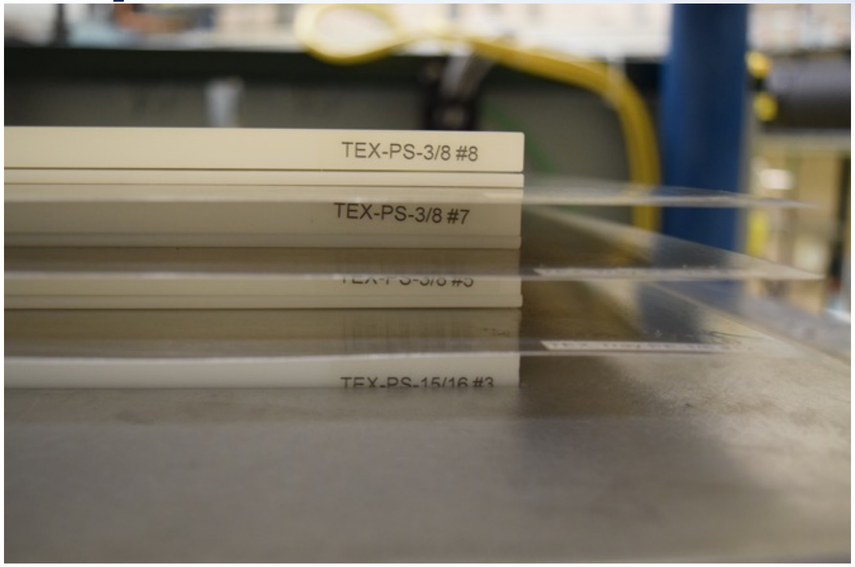


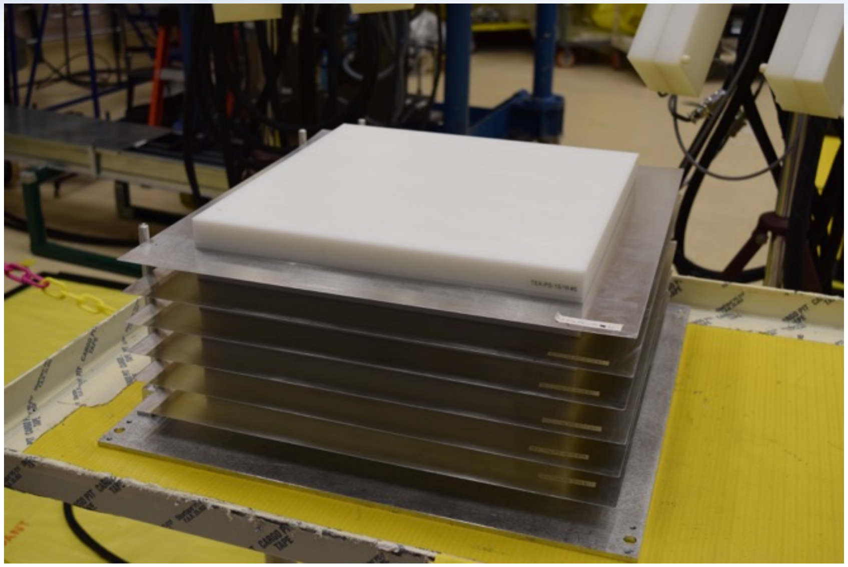
Fine Reactivity Adjustment

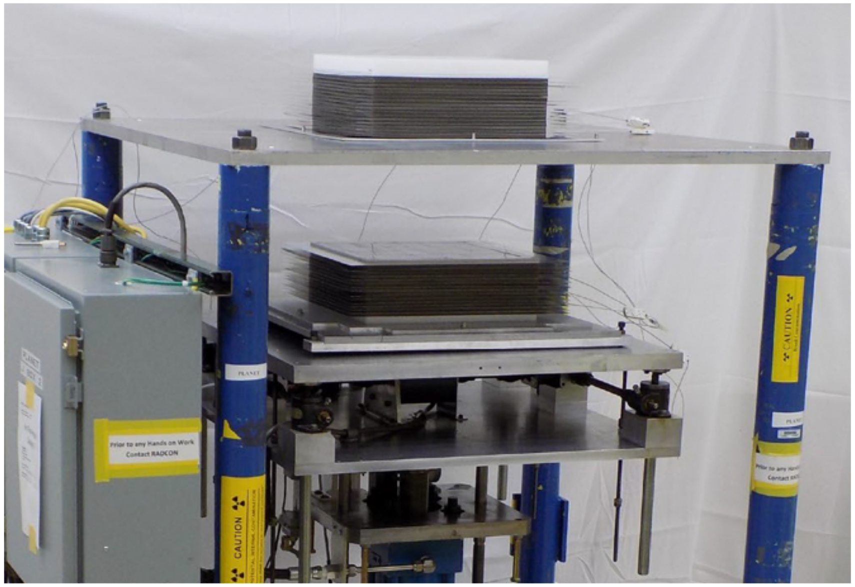
- Need a way to add small amounts of reactivity to the assembly near critical to ensure we hit the delayed critical window (between 1 and ~1.0016)
- Two Methods:
  - Add thicker upper reflector sheets
  - Partial layer of plutonium plates in upper layer, using aluminum blanks to maintain spacing within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

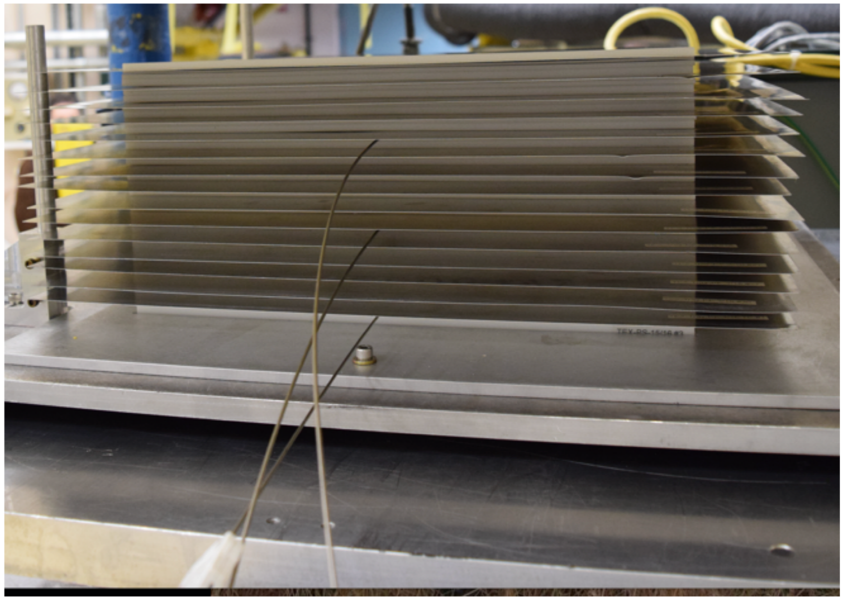


Experiment Photos









PRELIMINARY Baseline Results

Experiment Number	Date Critical	Nominal Moderator Thickness (cm)	Number of Pu Layers	Pu Plates in Last Layer	Nominal Upper Reflector Thickness (cm)
1	9/5/18	0	20	24	2.5400
2A	4/16/18	0.1588	17	20	2.5400
2B	4/16/18	0.1588	17	19	2.5400
2C	4/16/18	0.1588	17	20	2.5400
3A	4/5/18	0.4763	12	16	2.6988
3B	4/5/18	0.4763	12	17	2.6988
3C	9/10/18	0.4763	12	17	2.6988
4A	8/8/17	1.1906	7	24	4.2863
4B	8/9/17	1.1906	8	4	2.3813
5	7/29/17	2.5400	5	24	3.1750

Completed Tantalum Configurations

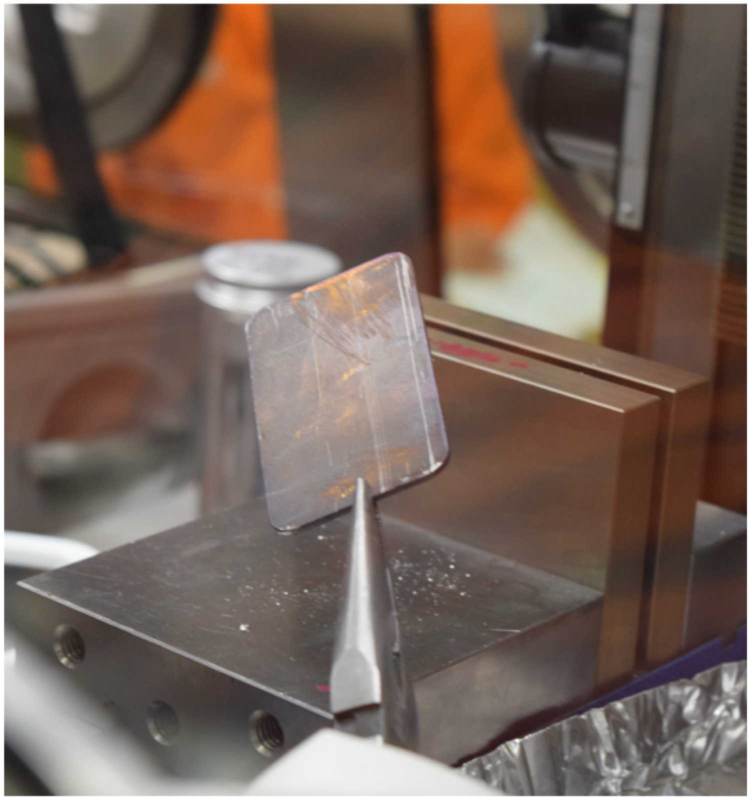
Exp Number	Date Critical	Nominal Moderator Thickness (cm)	Number of Pu Layers	Pu Plates in Last Layer	Nominal Upper Reflector Thickness (cm)
6A	9/19/18	0	27	24	2.5400
6B	9/19/18	0	27	24	2.5400
6C	9/20/18	0	27	24	2.5400
7	9/12/18	0.1588	32	24	2.6988
8A	9/17/18	0.4763	32	24	2.3813
8B	9/18/18	0.4763	32	24	2.3813
8C	9/18/18	0.4763	32	24	2.5400
9	5/8/18	1.1906	19	6	2.3813
10A	5/2/18	2.5400	11	24	2.8575
10B	5/2/18	2.5400	11	24	3.0163

PRELIMINARY Conclusions

- Actively working on the ICSBEP benchmark
- Intermediate baseline systems calculating 0.5-1% high
  - Potentially pointing to issues with unresolved resonance region
- Intermediate and fast tantalum systems calculating approximately 1-1.5% high
  - Possible issues with tantalum resonance absorption or scattering and angular distributions
- 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)

September 2018- Sampling ZPPR Plate

- One ZPPR plate was destructively sampled to obtain unknown impurity data and confirm historical information (isotopics, aluminum alloy percentage, etc)



Current Work for TEX-Pu

- Complete chemical and metallurgical characterization of samples to determine impurity content and confirm historical isotopic and chemical composition
  - Samples shipped to LLNL in March 2019
  - Needed for benchmark
- Preparing ICSBEP benchmark for inclusion in the 2019 version of the handbook
  - Detailed analysis including temperature and thermal expansion effects

Follow-on Work for TEX

TEX-Pu

- Preparing final design for variation of TEX with thicker polyethylene and Lucite moderators to provide a test for new NCState TSLs
- Additional variants proposed to investigate ^{240}Pu and address Hanford/SRS tank farm validation needs

TEX-HEU

- Baseline experiments (HEU Jemima plates and poly) scheduled for FY19, hafnium diluted experiments in FY20
- Low Temperature experiments at -40C (-40F) with HEU preliminary design underway, address transportation and unheated facility validation needs with the UK’s NNL
- ^{6}Li and chlorine diluted experiment preliminary design underway, address validation need from Y12 (electrorefining) and LANL (solutions) and provide a test for ORNL ^{35}Cl evaluation

TEX-^{233}U

- Final design underway for ^{233}U baselines using excess ZPPR oxide plates

Acknowledgements

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