FY 21 ORNL Integral Experiment Work

Justin Clarity

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ORNL IER

- IER-441 – Epithermal 7uPCX experiments at SPRF/CX
  - CED-3a – minor support from ORNL

- **IER-304 – Temperature dependent criticals at SPRF/CX**
  - CED-2 completed FY21Q4

- **IER-498 - GODIVA CAAS Shielding Benchmark**
  - CED-2 completed FY21Q4

- Analytical methods support for IER-539 HST Design (LLNL)

- IER-554 – Neutron absorber plates in SPRF/CX
  - CED-1 Starting

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IER-304 Overview

- Currently there is a lack of LCT experiments at temperatures other than 25 °C
  - Important for fuel storage applications
  - Ability to test codes and data off of nominal conditions

- Establish standard critical benchmarks through approach on number of rods.
  - Goal to work with companion ITC inversion temperature experiments

- Provide flexibility for SNL staff in arrays that are ultimately chosen for experiments

- Provide input to component modifications that are necessary

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Nuclear Design

- Examined a variety of arrays for 7uPCX and BUCCX fuels
  - Either in ICSBEP handbook or from SNL ANS paper

- Generated ENDF/B-VII.1 library with TSL data every 5 °C

- Ran cases that included water temperature and density and fuel temperature to select
  - Most positive temperature response (PTR)
  - Most negative response (NTR)
  - Minimum temperature response (MTR)

- Using the above cases
  - Separate effects calculations
  - Regional water calculations
  - Sensitivity and estimated experimental uncertainty calculations
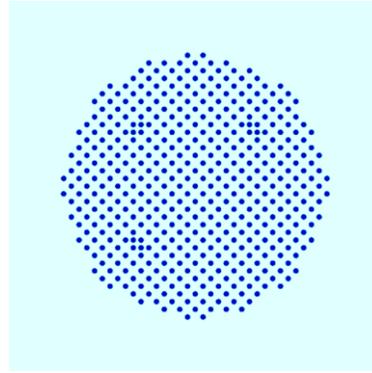
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7uPCX Fuel Arrays Considered
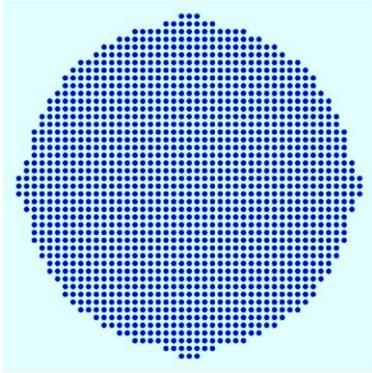
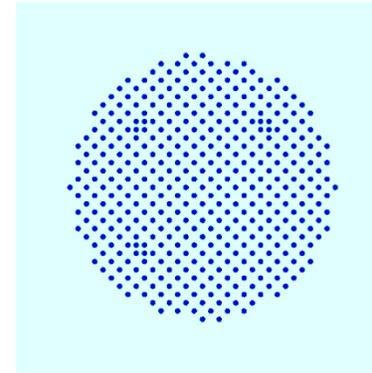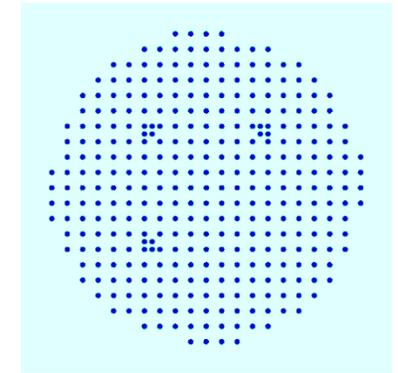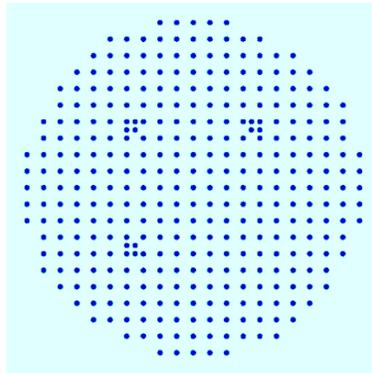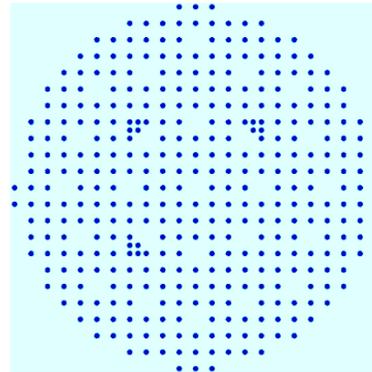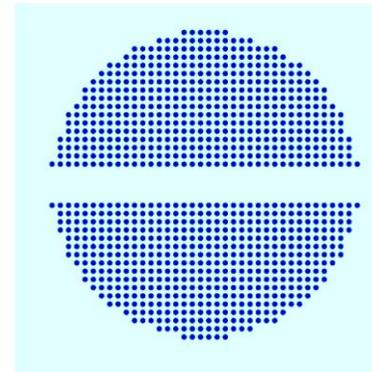LCT-102-001
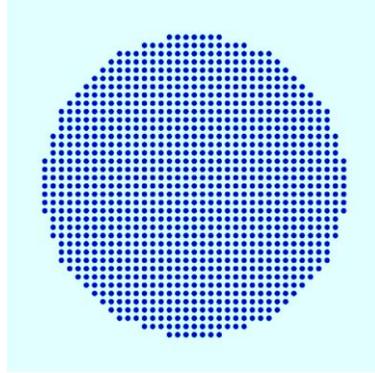
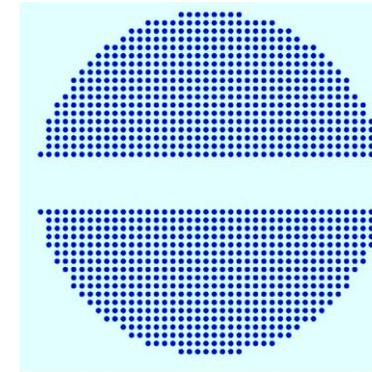LCT-102-007

LCT-102-012

LCT-102-016

LCT-102-020

LCT-102-024

LCT-102-027

0.855 cm pitch
4 Row Channel

0.855 cm pitch
6 Row Channel

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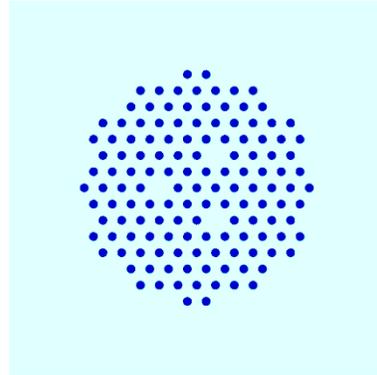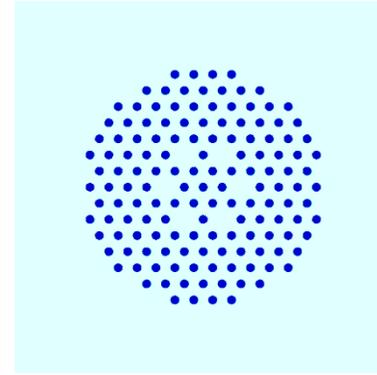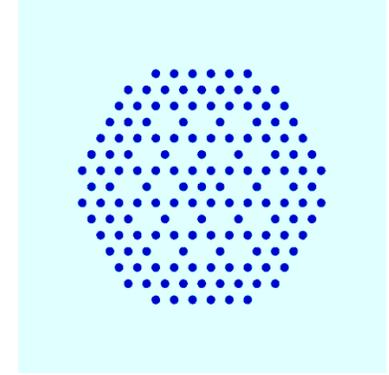
BUCCX Fueled Arrays Considered
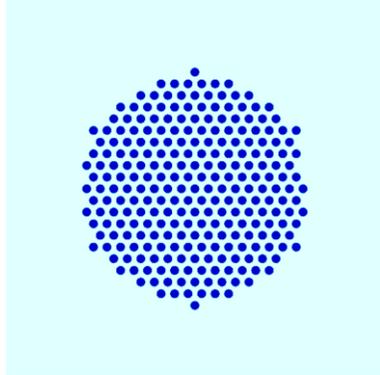
LCT-079-001
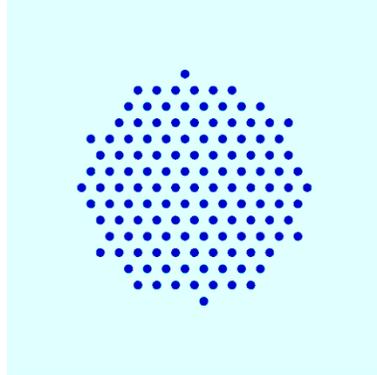
LCT-079-006

2.8 cm pitch
3 holes

2.8 cm pitch
6 holes

2.8 cm pitch
18 holes
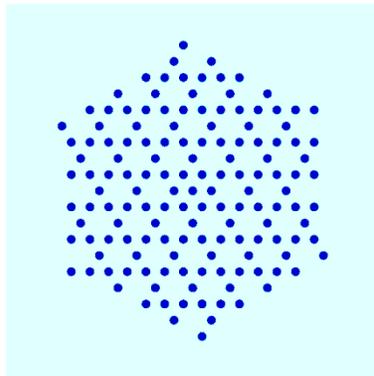
2.8 cm pitch
42 holes
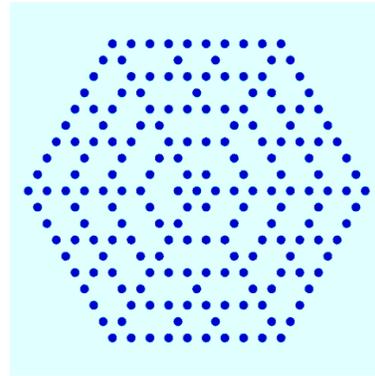
2.8 cm pitch
81 holes
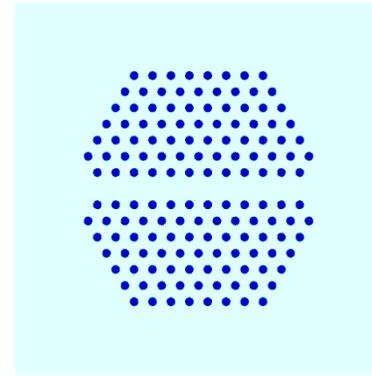
2.8 cm pitch
1 row channel

2.8 cm pitch
2 row channel

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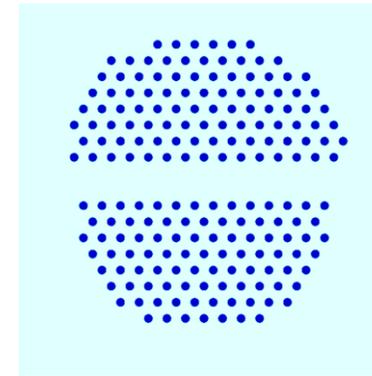
Full Effects Cases

- 7uPCX
  - NTR - LCT-102-012
  - PTR – 6 Row Channel
  - MTR – LCT-102-027

- BUCCX
  - NTR – LCT-079-001
  - PTR – 2.8 cm – 81 holes
  - MTR – 2.8 cm – 6 holes

- Both fuels generate similar NTR cases, PTR appears to be easier to achieve with BUCCX
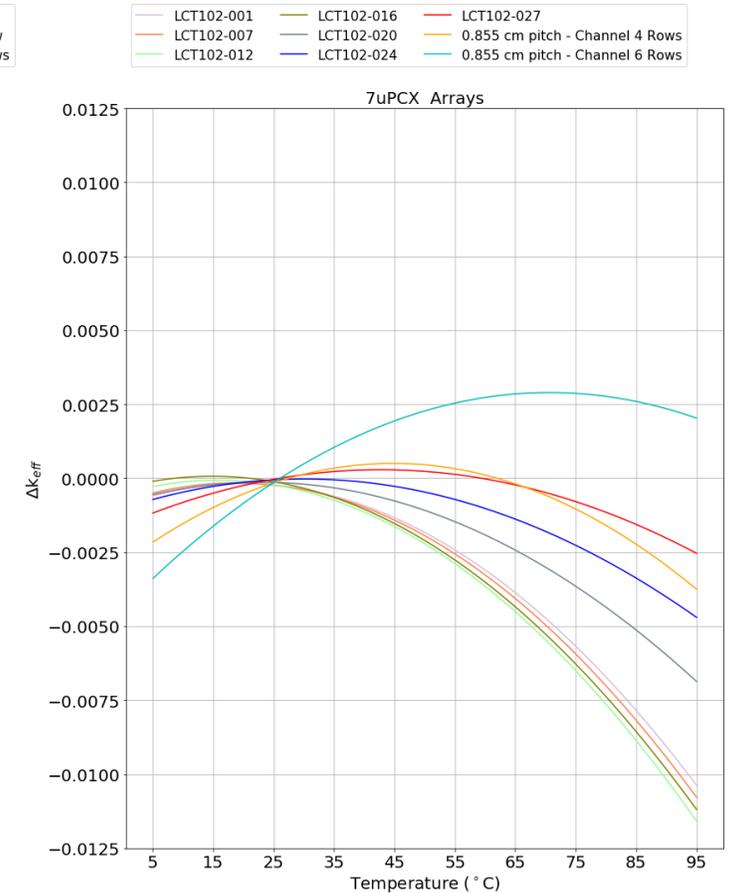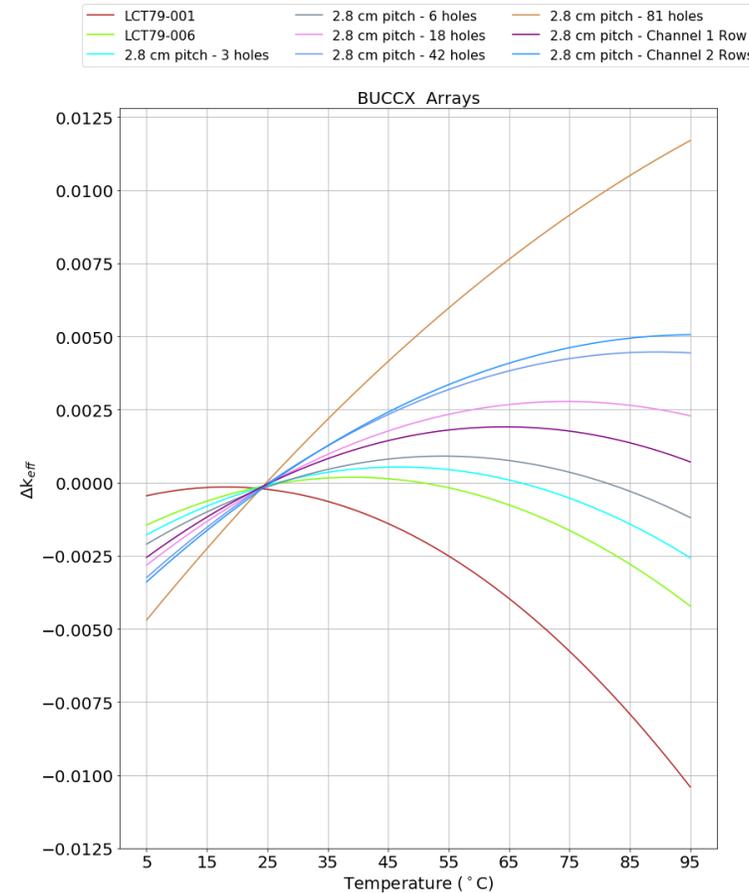
Potential Upgrades

- List of hardware upgrades were suggested using the results of thermal analyses
  - Larger capacity dump tank
  - Immersion heater and controller
  - Fiberglass insulation jackets
    - Optional heated jacket on assembly tank
  - Recirculation chiller
  - Custom assembly tank cover

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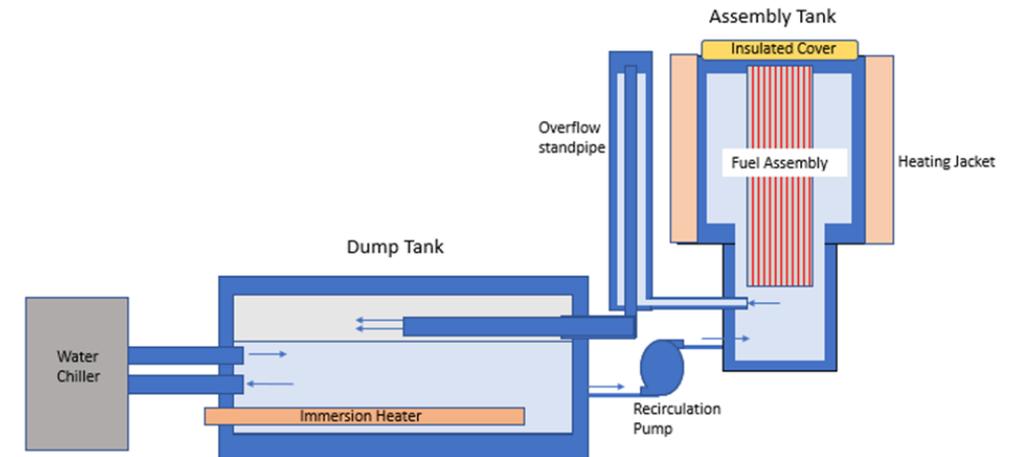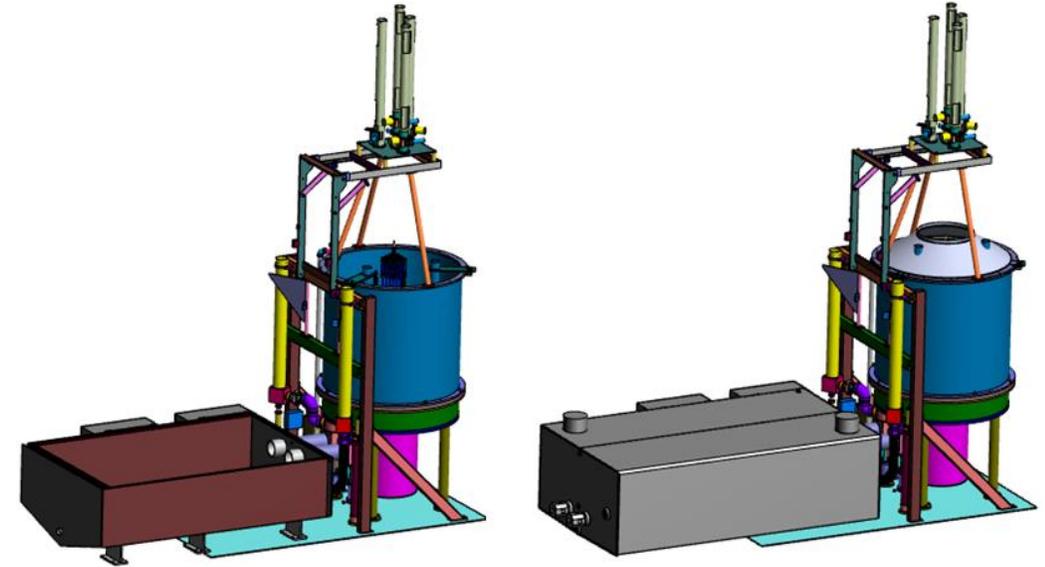
Thermal simulations

- Thermal insulation on tank and dump tank needed to mitigate convective losses

- Lid for evaporative losses

- Results in line with hot tub energy consumption

- ANSYS calculations for centerline fuel temperature

- Time to heat centerline of rod to equilibrium temperature
  - ~4.5 min for BUCCX and ~2 min for 7uPCX

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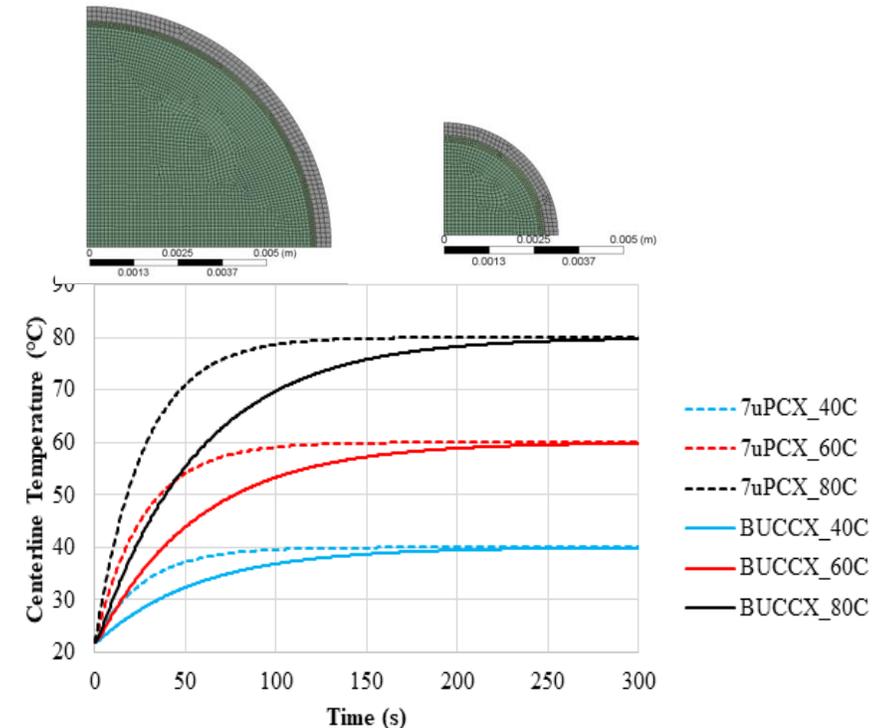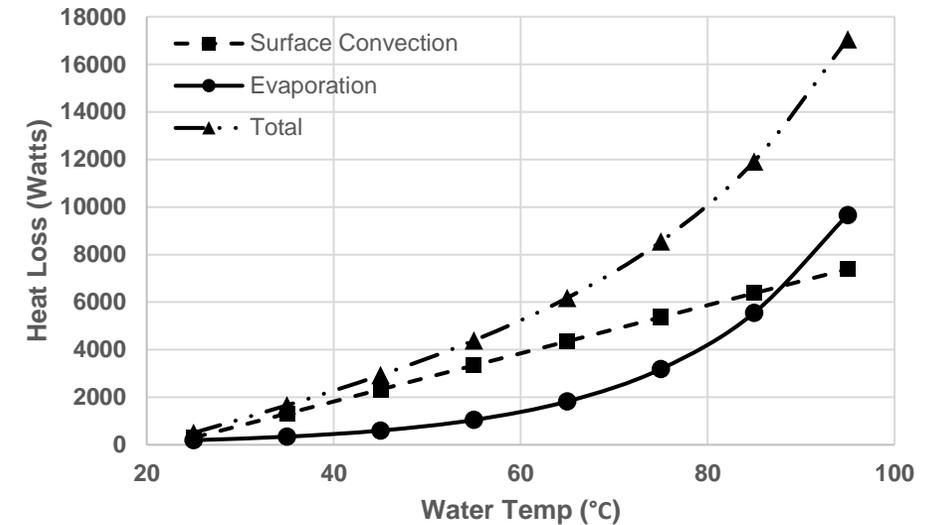
IER 498 Goal -- create CAAS benchmark capability for Godiva-IV to:

- create a shielding benchmark for NCSP software and data,

- add geometrically diverse benchmark(s) to the ICSBEP Handbook,

- enable more precise measurements at NCERC by eliminating room return, and

- help assure CAAS performance is as-stated.

- The benchmark is more complex than an experimental measurement test, but simpler than a real-world geometry.

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Using room return shield to address room return

- Concrete reflects neutrons around whatever shield we're trying to test
  - Shadow cone method leaves behind too much uncertainty.
  - Putting the shield all the way around the source doesn't work
  - Placing shield around detector requires big shield and still leaves room return

Cross section

Concept drawing of room return shield
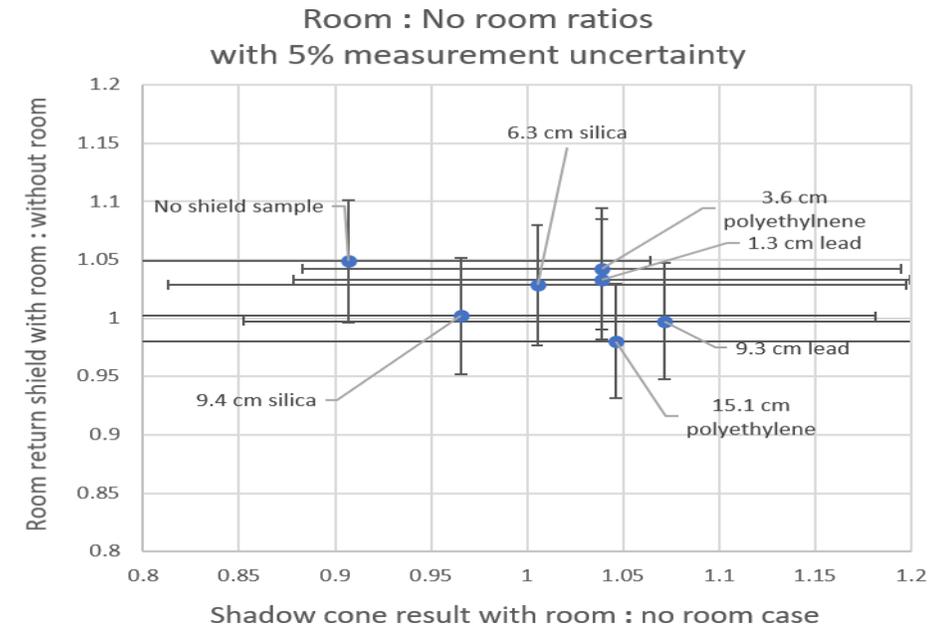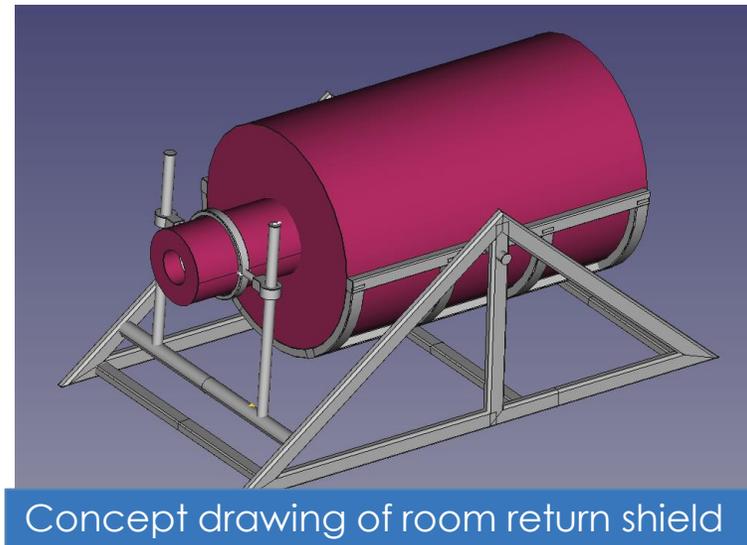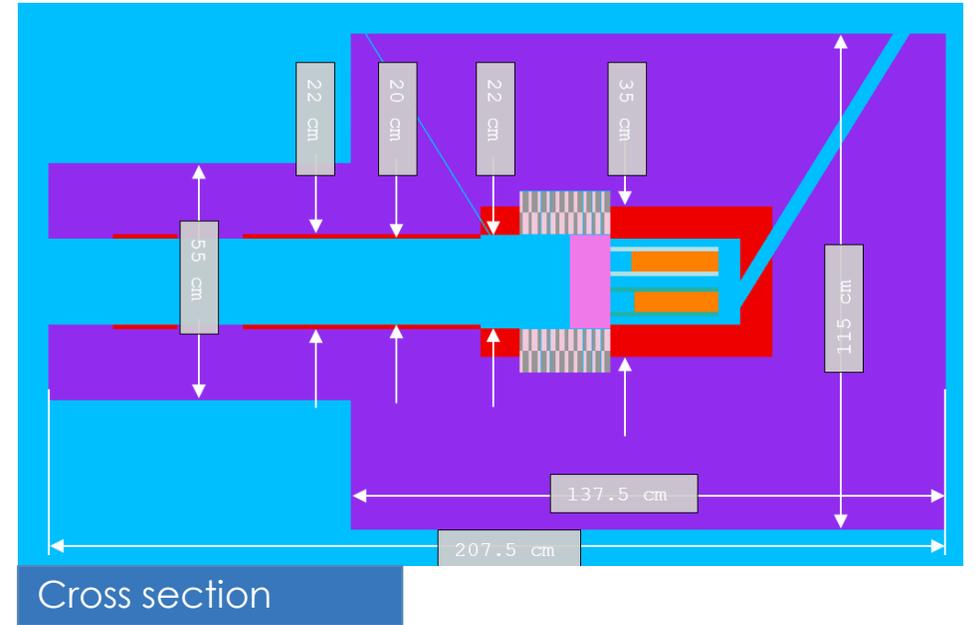
Benchmark parameters

- Integrated counts in ranges
  - windows in sensitive region of detector

- Benchmark quantities (Q)
  - Rescales counts (C) to baseline unshielded case
  - Compensates for source intensity (S)

$$Q = \frac{C_{treatment} S_{baseline}}{C_{baseline} S_{treatment}}$$

Flux as a fraction of baseline (blank)

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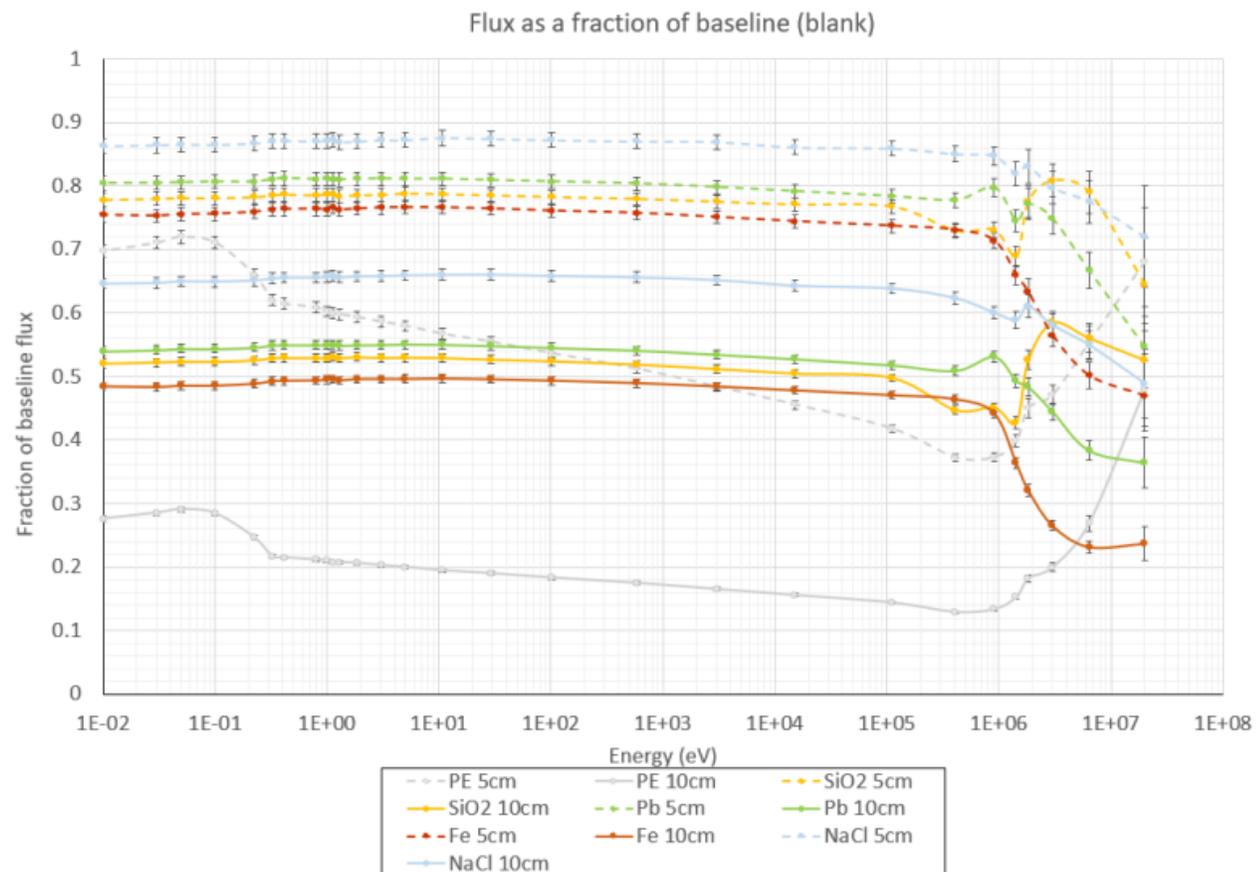
Perturbation study

- Gamma total flux RMS response was ~15%

- Neutron flux RMS response was ~7%

- Monte Carlo error appears to be a major contributor to both

- Room return shield cavity radius and runout should be maintained to within a millimeter

- The room return shield should be positioned carefully (perhaps with a laser range finder)

- Detectors should be mounted in a lightweight fixture such as aluminum, so their positioning is assured

Table 14. Hypothetical uncertainty for two measurement neutron benchmark quantity.

	Baseline	Treatment
Far-from-source geometric and density relative uncertainty in measurement	3.30%	3.30%
Detector relative uncertainty in measurement	2.00%	2.00%
Relative uncertainty in source strength proxy	3.00%	3.00%
Relative uncertainty in source strength normalized measurement	4.89%	4.89%
Relative uncertainty benchmark quantity subtotal		*6.91%*
Near-source geometric and density relative uncertainty in benchmark quantity		1.47%
Total uncertainty		**7%**

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IER 498 CAAS Test Moving Forward

- The CED-2 report was delayed due to disagreement about burst reproducibility at Godiva

- Further study did not resolve the issue

- The dispute spawned a second IER (557) to examine burst reproducibility

- Pending results of IER 557, IER 498 may proceed

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