IER-523: Feasibility of Experiments Focused on Measuring the Effects of UO_2BeO Material on Critical Configurations using 7uPCX

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Introduction

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  - 7uPCX
- Motivation
- Experiment Design
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  - Base Concept 2
- Critical Configurations Analysis
- Sensitivity Analysis
- Future Plans
- Conclusion

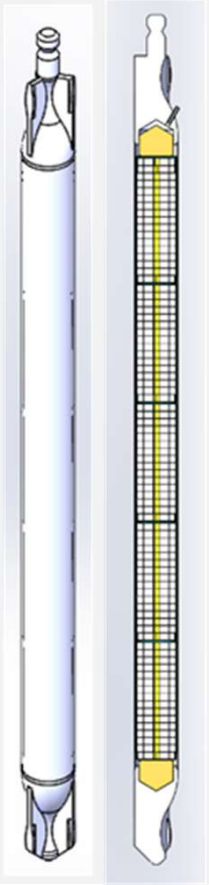
Background

Annular Core Research Reactor (ACRR)

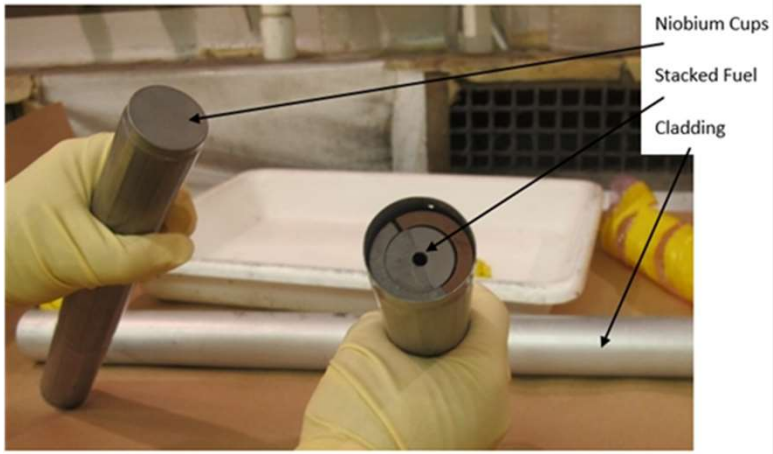
- Water-moderated pool-type research reactor
- Uranium dioxide-beryllium oxide (UO_2BeO) fuel
- 35 weight percent ^{235}U
- 21.5 weight percent UO_2
- Density (UO_2BeO) ~3.4 g/cm^3
- Significant amounts of unused fuel
  - Elements (~25 elements and 2.8 kg ^{235}U total)
  - Loose pellets (~2 kg ^{235}U)
- Data from historical records (fuel composition and geometry)

Background

Fuel element



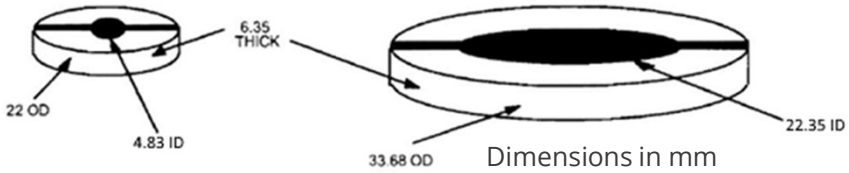
UO_2BeO fuel pellets



ACRR fuel element

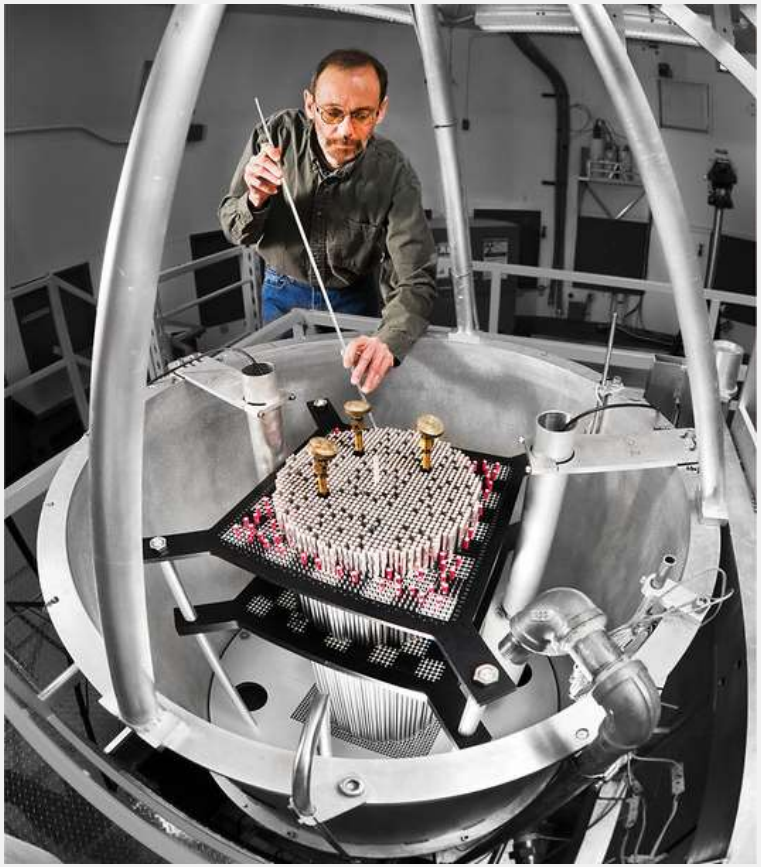
- Stainless-steel cladding
  - OD~3.75 cm
  - L~54.5 cm
- Trifluted end fittings
- 5 niobium insulation cups
- 4 fuel pellet pieces formed into a disk and stacked in niobium cups

UO_2BeO fuel pellets



Dimensions in mm

Background



Sandia Critical Experiments (SCX)

- 7uPCX
- 6.9 weight percent ^{235}U
- 2175 fuel rods
  - OD ~0.6 cm
  - Fueled length ~48.8 cm
- Approach-to-critical experiments
  - Number of fuel rods and water height
  - Six critical benchmark evaluations (ICSBEP)
- Flexibility in design
  - Authorization Basis allows modifications to accommodate designs outside the current limits

Motivation

Access to unused ACRR fuel

- Unique in its enrichment 35% and material composition BeO
  - Produce data useful to NCS
- Recently removed from storage and inspected
- Available in significant quantities

Facility and Experience

- Sandia Pulsed Reactor Facility (SPRF)
- Sandia Critical Experiments (SCX)
  - Experimenters, reactor operators, and other support staff
  - History of performing similar approach-to-critical experiments

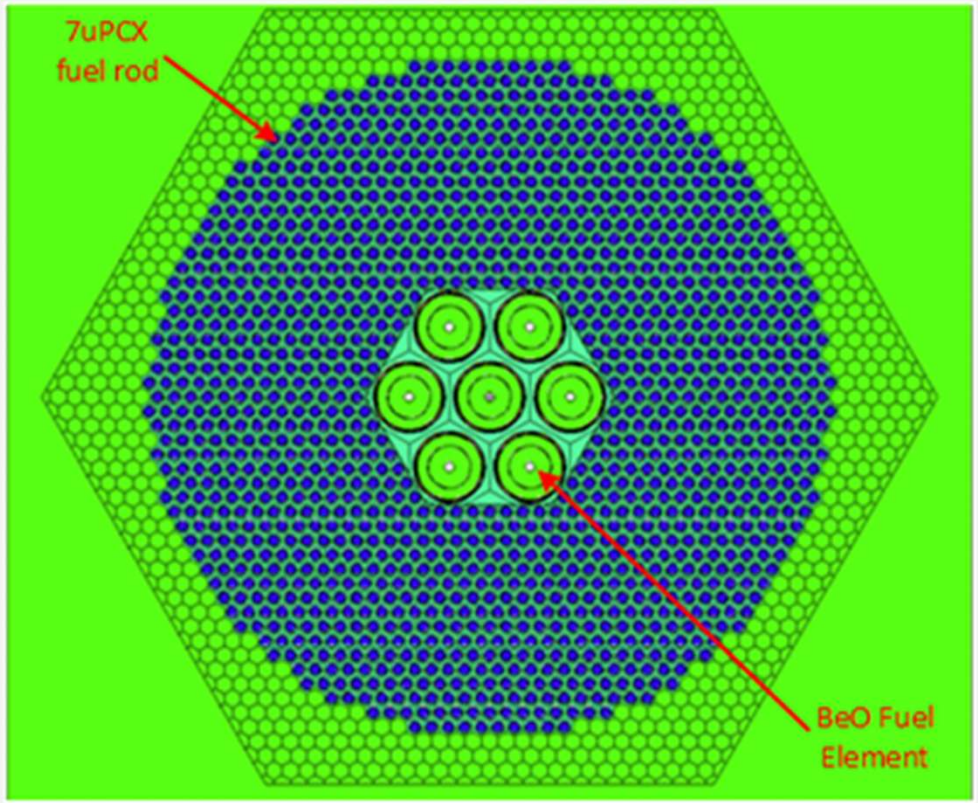
Sandia Management Interest

- ACRR fuel health program
- Safety basis codes validation
- Supports ND mission and long term success

Experiment Design – Base Concept 1

Base Concept 1

- Central test region containing 7 BeO fuel elements
- 1366 7uPCX fuel rods
  - Hex pitch of 0.86 cm
- Fully reflected and water moderated
- Approach-to-critical on number of 7uPCX fuel rods

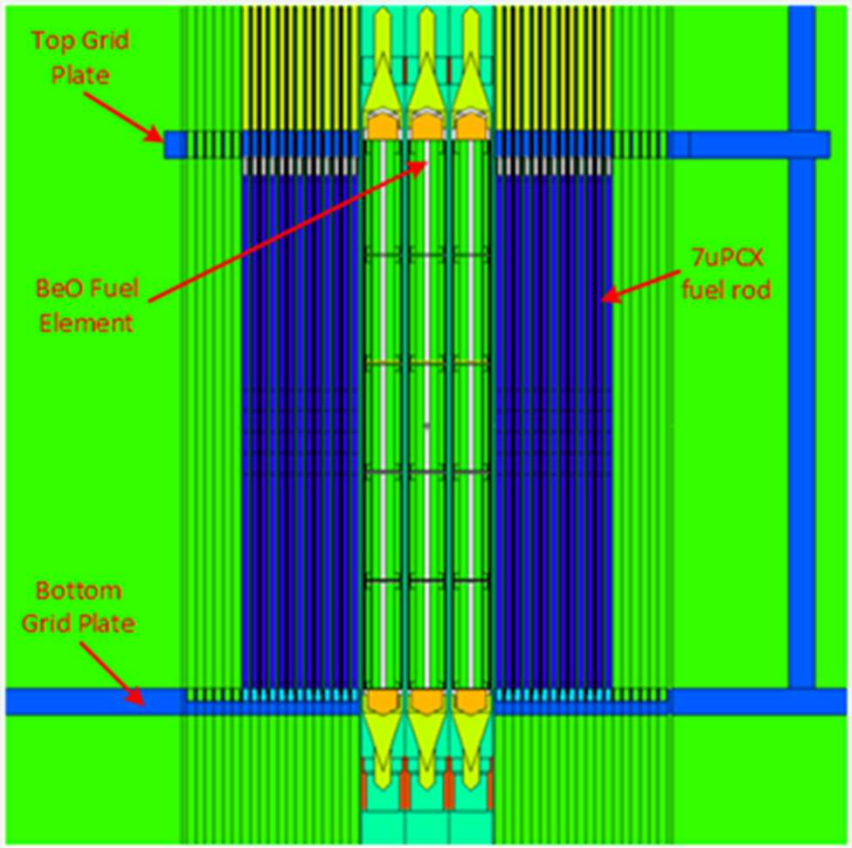


Radial Cross Section View

Experiment Design – Base Concept 1

Base Concept 1

- Central test region containing 7 BeO fuel elements
- 1366 7uPCX fuel rods
  - Hex pitch of 0.86 cm
- Fully reflected and water moderated
- Approach-to-critical on number of 7uPCX fuel rods

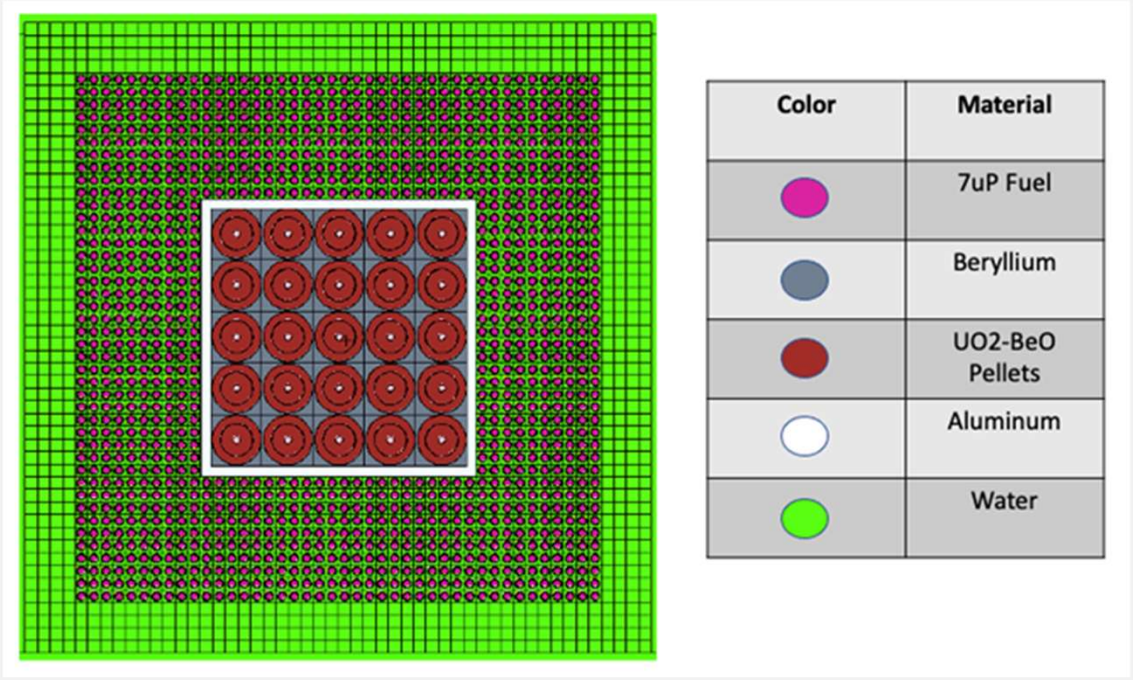


Axial Cross Section View

Experiment Design – Base Concept 2

Base Concept 2

- Central test region containing 1000 UO_2BeO pellets
  - 5x5 grid on pellets
  - 40 layers offset by 0.77 cm
  - Contained in beryllium material
- 1280 7uPCX fuel rods
  - Square pitch of 0.85 cm
  - Water moderated and reflected
- Approach-to-critical on number of 7uPCX fuel rods

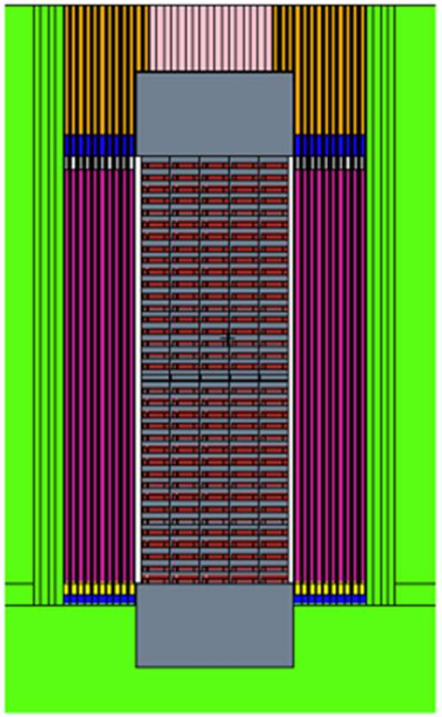


Horizontal Cross Section View

Experiment Design – Base Concept 2

Base Concept 2

- Central test region containing 1000 UO_2BeO pellets
  - 5x5 grid on pellets
  - 40 layers offset by 0.77 cm
  - Contained in beryllium material
- 1280 7uPCX fuel rods
  - Square pitch of 0.85 cm
  - Water moderated and reflected
- Approach-to-critical on number of 7uPCX fuel rods



Color	Material
	7uP Fuel
	Beryllium
	UO2-BeO Pellets
	Aluminum
	Water
	Air
	Polyethylene
	6061 aluminum
	3003 aluminum

Vertical Cross Section View

Concept 1 – Critical Configuration Analysis

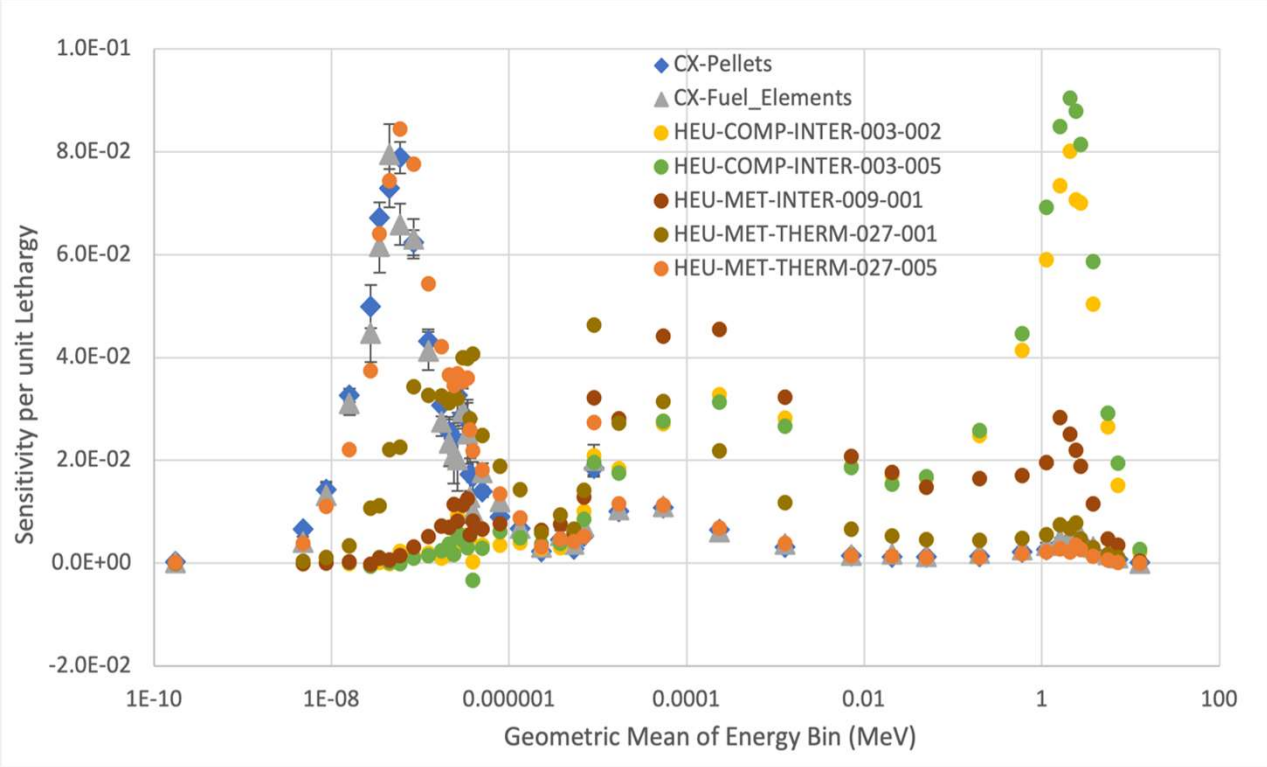
Critical Configuration ⟶	1 BeO Fuel Element 7uPCX rods = 1476 Pitch = 0.86 cm	7 BeO Fuel Elements 7uPCX rods = 1366 Pitch = 0.86 cm	7 BeO Fuel Elements 7uPCX rods = 318 Pitch = 1.55 cm
Changes to Critical Configuration	Reactivity Worth (%)	Reactivity Worth (%)	Reactivity Worth (%)
-Replace BeO fueled region with void	-0.478 ± 0.009	-4.506 ± 0.008	-12.208 ± 0.007
-Replace BeO fuel element(s) with void	-0.389 ± 0.009	-3.339 ± 0.008	-9.797 ± 0.007
-Replace BeO fuel element(s) with aluminum	-0.311 ± 0.009	-3.701 ± 0.008	-11.445 ± 0.007
-Replace BeO fuel element(s) with water	0.975 ± 0.009	-4.090 ± 0.008	-14.120 ± 0.008
-Replace BeO fuel element(s) with 7uPCX rods	0.375 ± 0.009	0.779 ± 0.007	2.189 ± 0.010

Concept 2 – Critical Configuration Analysis

Changes to Baseline Case	k_{eff}	Reactivity Worth (%)
Baseline case	1.00433 ± 0.00083	na
Replace entire central cavity with 7uPCX fuel	1.08283 ± 0.00091	7.22 ± 0.11
Replace BeO pellets with aluminum	0.97207 ± 0.00083	-3.30 ± 0.12
Replace BeO pellets with water	0.98299 ± 0.00078	-2.16 ± 0.12
Replace BeO pellets with void	0.97682 ± 0.00079	-2.80 ± 0.12

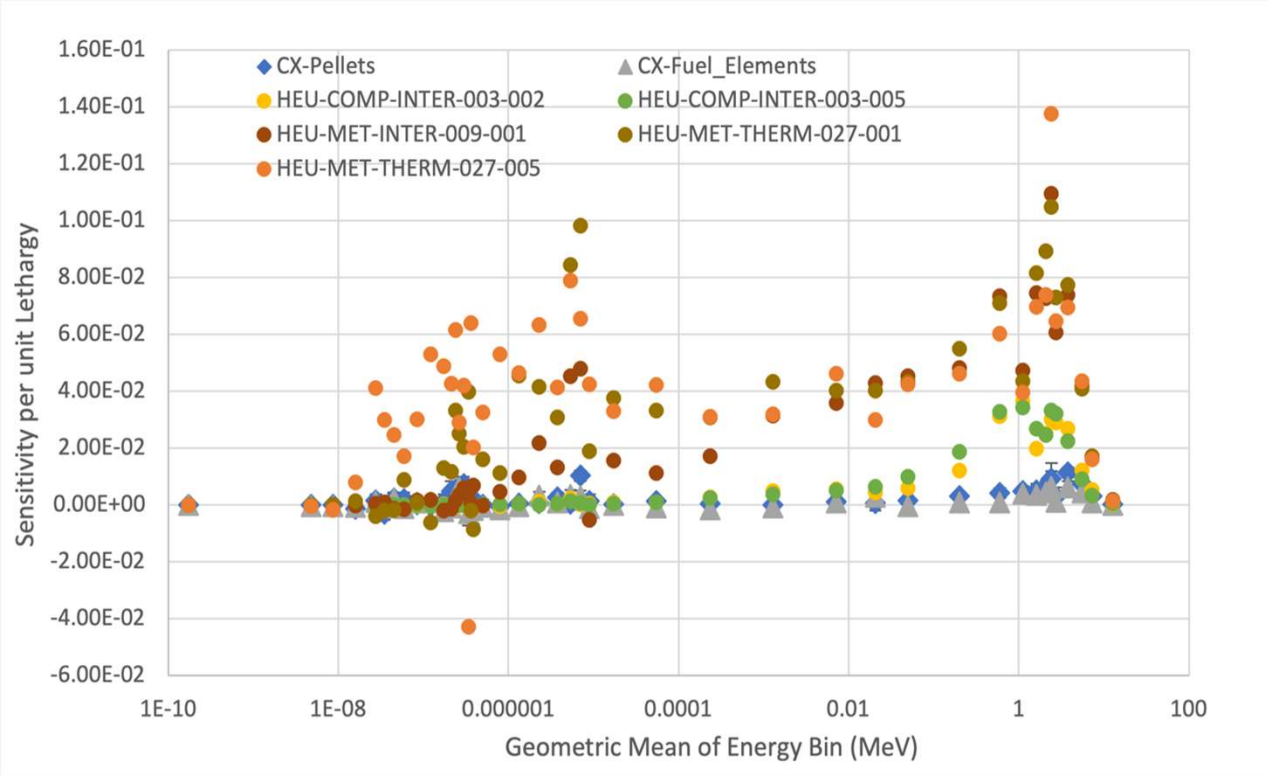
Sensitivity Analysis – ^{235}U Fission

- Sensitivities [(Δk/k)/(Δσ/σ)] computed for:
  - Various reactions
  - In energy 44-groups
  - For both base concepts (gray & blue)
  - And existing Be benchmark models available at Sandia
- This plot examines sensitivity to ^{235}U fission cross-section
- Both base concepts show large thermal sensitivity



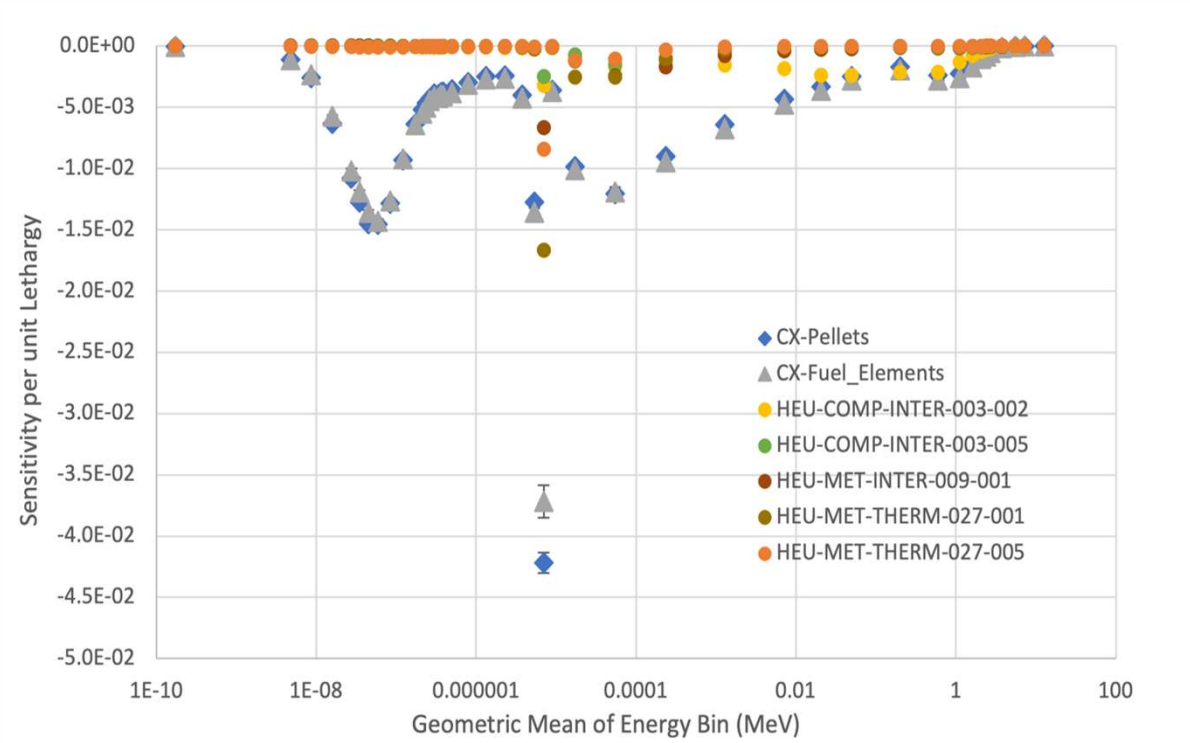
Sensitivity Analysis – ^{9}Be Total

- Beryllium has several different reactions that contribute: (n,2n), (n,α), (n,γ), elastic scattering
- Both base concepts tend to have lower sensitivity to Be than existing benchmark models



Sensitivity Analysis – ^{238}U Radiative Capture

- Lower enrichment of the base concepts (versus selected comparison models) does have a tangible effect on neutron multiplication
- Not exhaustive



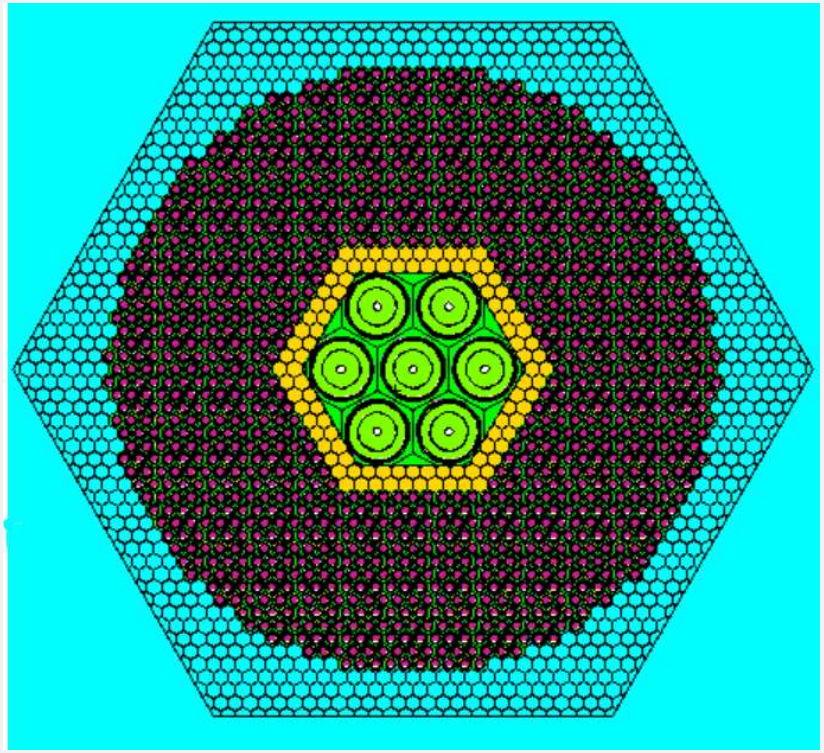
Future Plans

Finalize Experimental Design

- Concept #1
- Additional measurements of fuel composition
  - Pellet spectroscopy

Investigate Testing Region Modifications

- Dry/wet central test region
- Thermal shielding material
  - Cadmium
  - Flex Boron
  - Gadolinium



Conclusions

Access to unused ACRR fuel

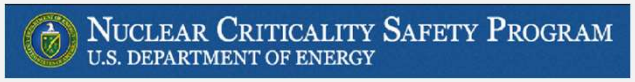
- Unique in its enrichment 35% and material composition BeO
- Available in quantities well above what is needed for experiments

Two experiment concepts investigated

- UO_2BeO fuel elements and pellets with 7uPCX fuel
- Worth of UO_2BeO large enough to be well above the anticipated experiment uncertainties.

ACRR Management Support

Acknowledgements



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Questions?

Sensitivity Analysis – ^{9}Be Reactions