IER-304
Preliminary Design of Temperature Dependent Critical Experiments at Atmospheric Pressure with Low Enriched UO_2 Fuel

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Nuclear Criticality Safety Program

Technical Program Review

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OAK RIDGE National Laboratory

Outline

- Introduction
- Thermal expansion / compression and equilibrium
- Evolution of k_{eff} with temperature and moderator density for existing room temperature benchmark configurations
- Potential temperature dependent critical configurations
- Conclusions and future work

Introduction

- Motivation
  - Provide more integral data to validate on-the-fly Doppler energy broadening
  - Temperature dependence at atmospheric pressure with low enriched UO_2 applicable to spent nuclear fuel (pools, storage casks, etc.)
- Concept
  - Start with existing SNL critical experiments (7uPCX and BUCCX)
  - Modify these to be critical at different temperatures
  - Preliminary design shows that temperature dependent critical experiments are viable using these existing experiments
    - Note: LCT-079 benchmark uncertainty ~100 pcm

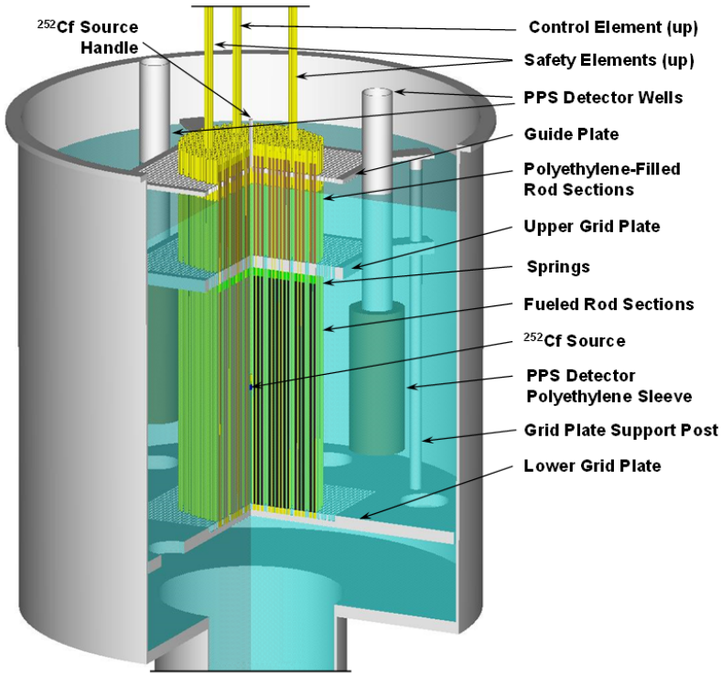


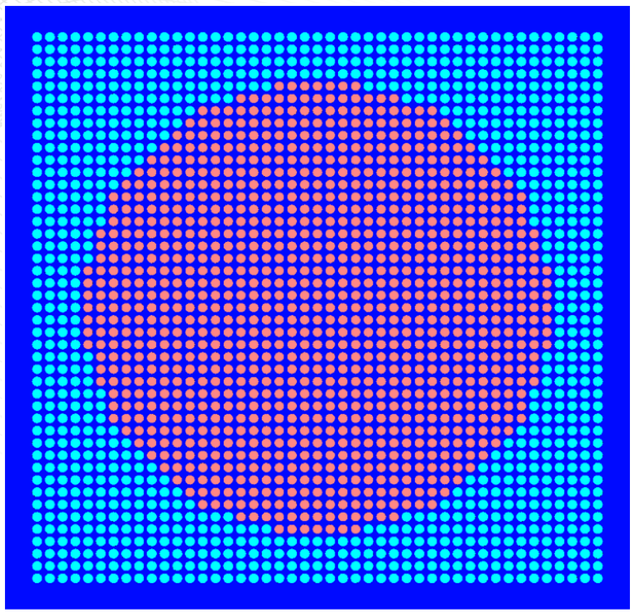
Figure 1. Critical assembly concept of the 7uPCX (thanks Gary).

Thermal Expansion / Compression and Equilibrium

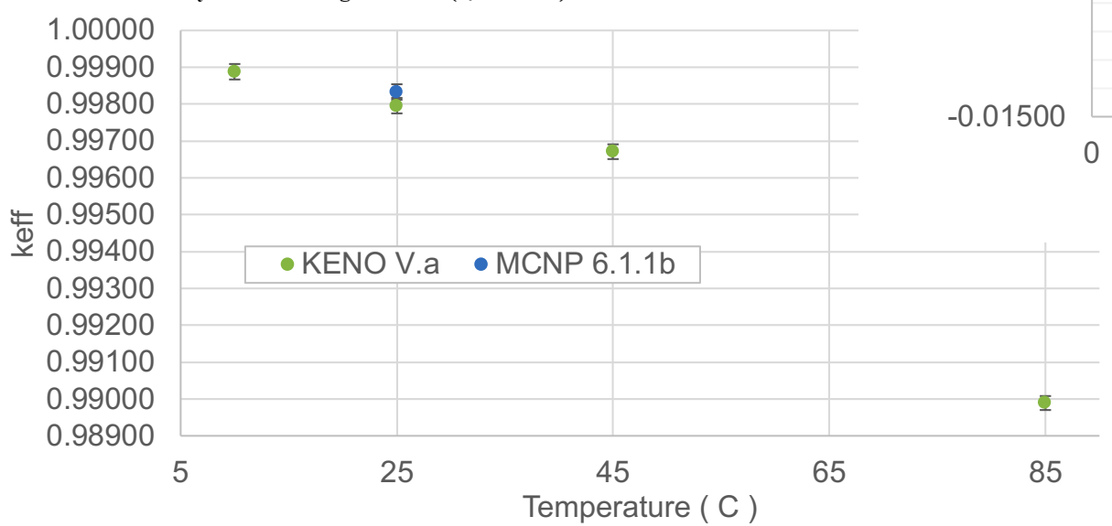
- Concerns when modeling a temperature dependent experiment
  - What is the temperature and is the system temperature homogenous?
  - When the system temperature changes, how does the volume / density change?
- Strategy
  - Find linear expansion coefficients in the open literature and calculate volume expansions
  - Model materials at different temperatures
- At the temperatures and pressures of interest the change in volume and density is insignificant, except for the water moderator / reflector

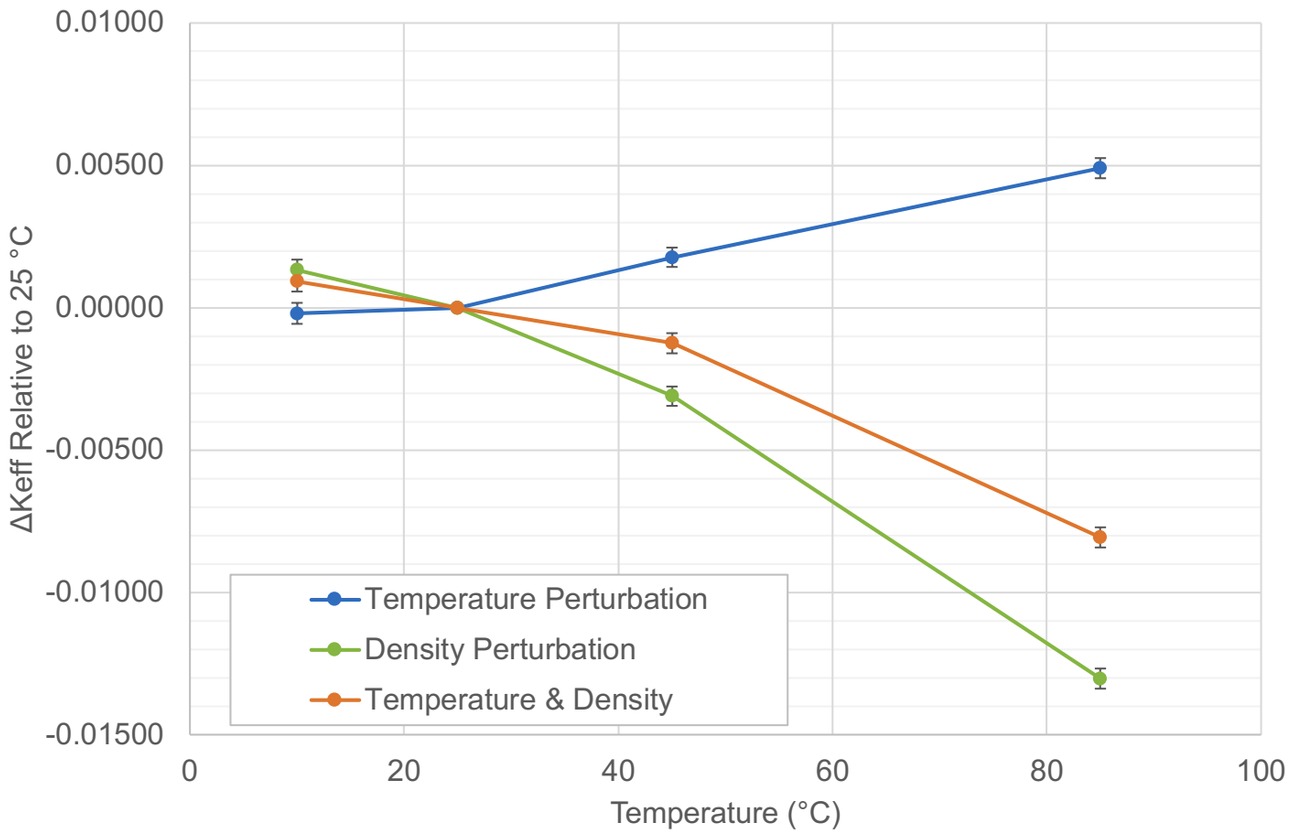
Case	keff	Sigma (pcm)	k_{eff} difference (pcm)
LCT078 Case 1 at 25 °C	0.99820	21	0
5 °C without thermal compression	0.99888	19	1
5 °C with thermal compression	0.99889	20	
95 °C without thermal expansion	0.98782	21	19
95 °C with thermal expansion	0.98801	21	
All materials at 5°C	0.99888	19	1
Only water at 5°C	0.99887	20	
All materials at 95°C	0.98782	21	182
Only water at 95°C	0.98964	21	

Configuration 1 Evolution of k_{eff} with Temperature (LCT-078 Case 1)

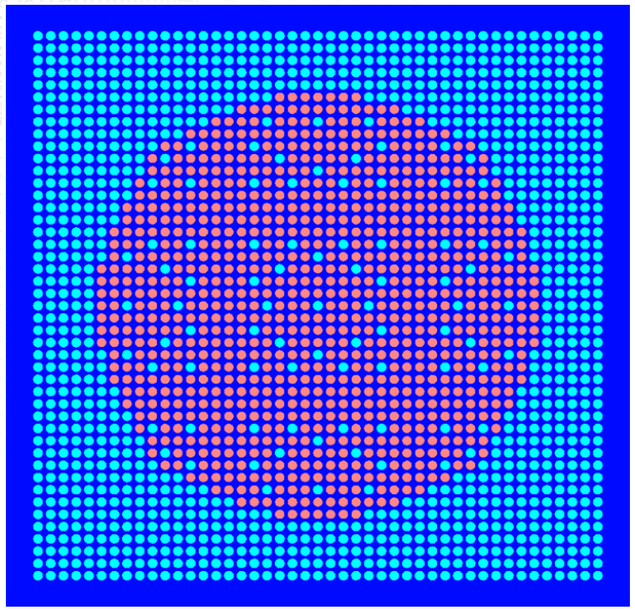


Fuel rod layout for Configuration 1 (1,057 rods).

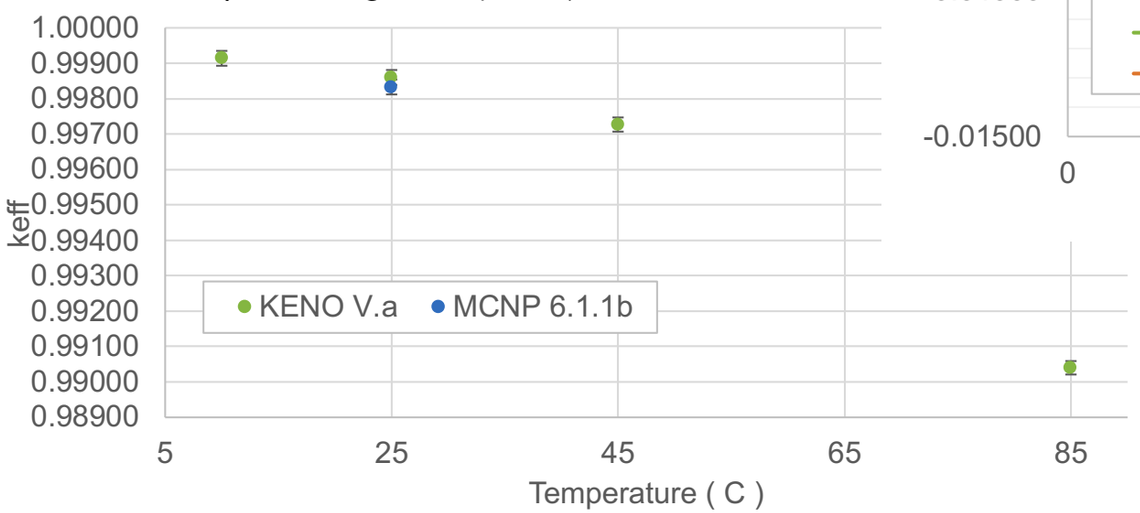


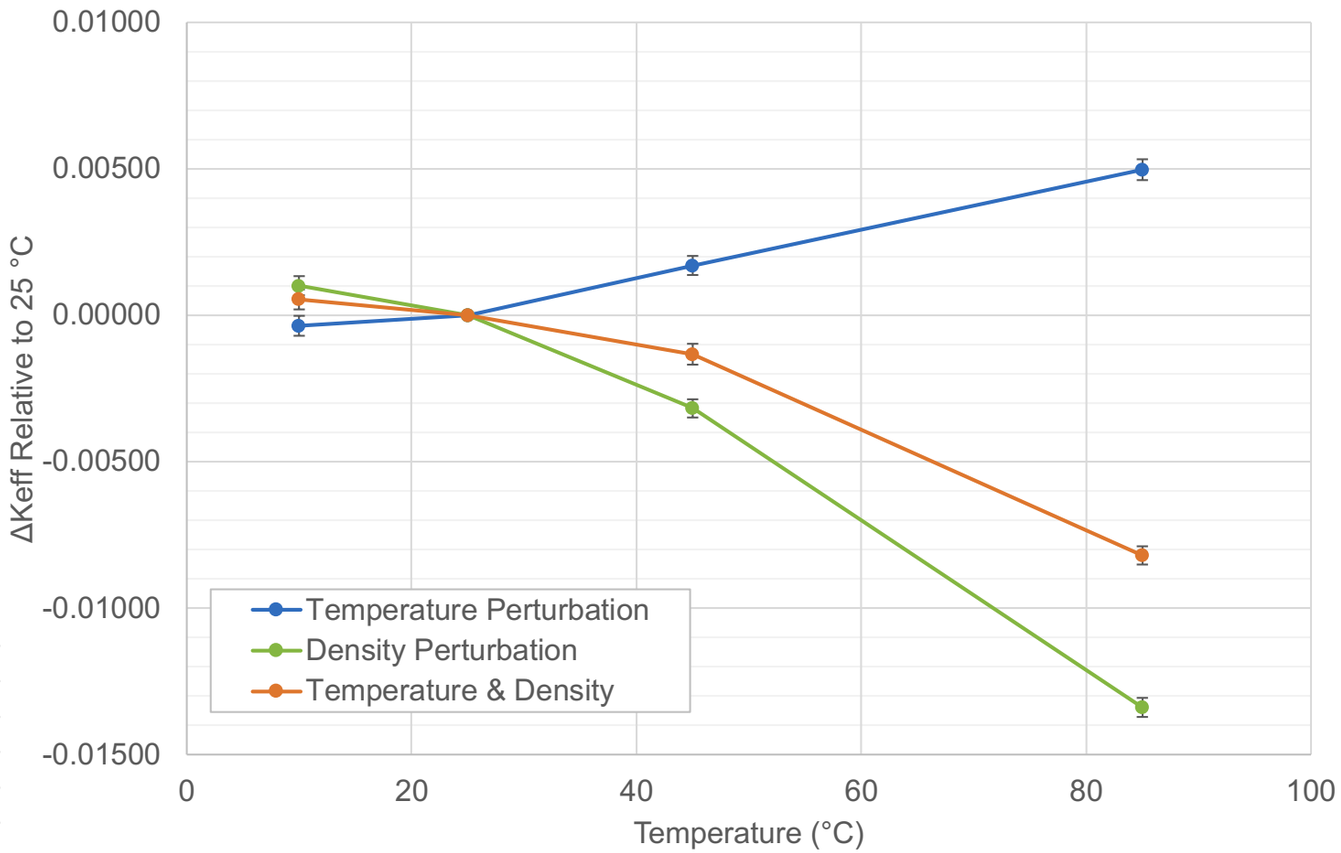


Configuration 2 Evolution of k_{eff} with Temperature (LCT-078 Case 15)



Fuel rod layout for Configuration 2 (872 rods).





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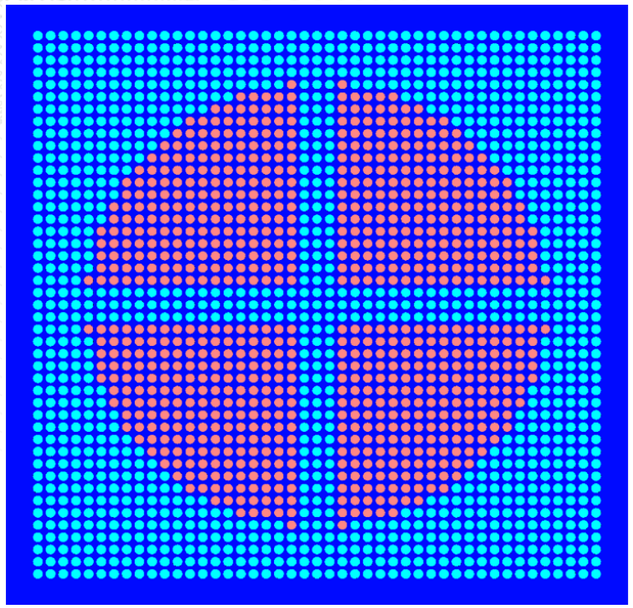
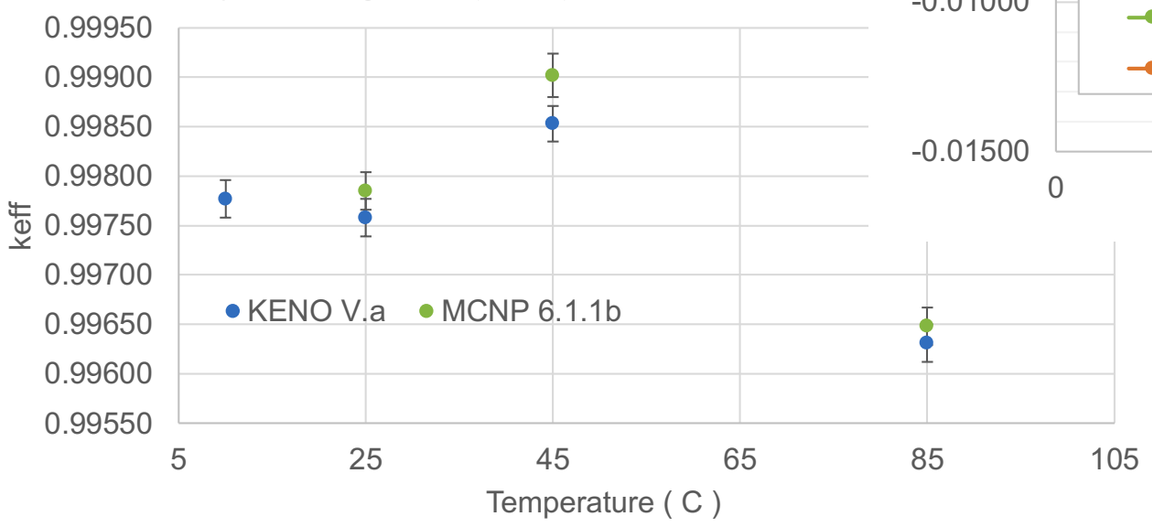
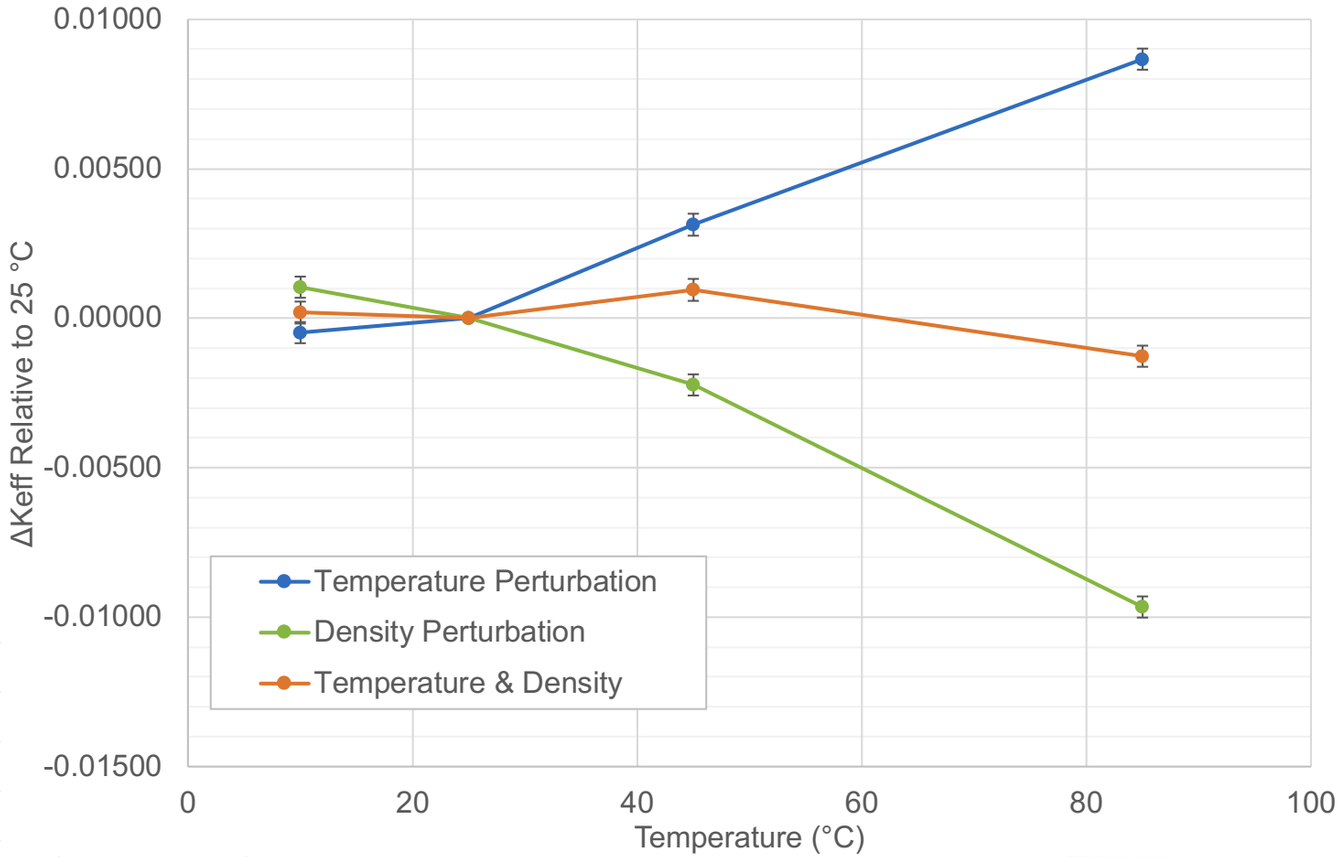
Configuration 3 Evolution of k_{eff} with Temperature



Fuel rods layout for Configuration 3 (828 rods).





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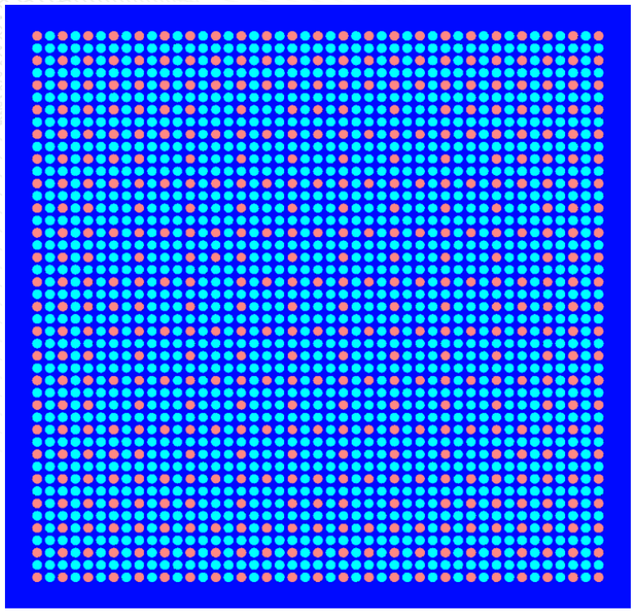
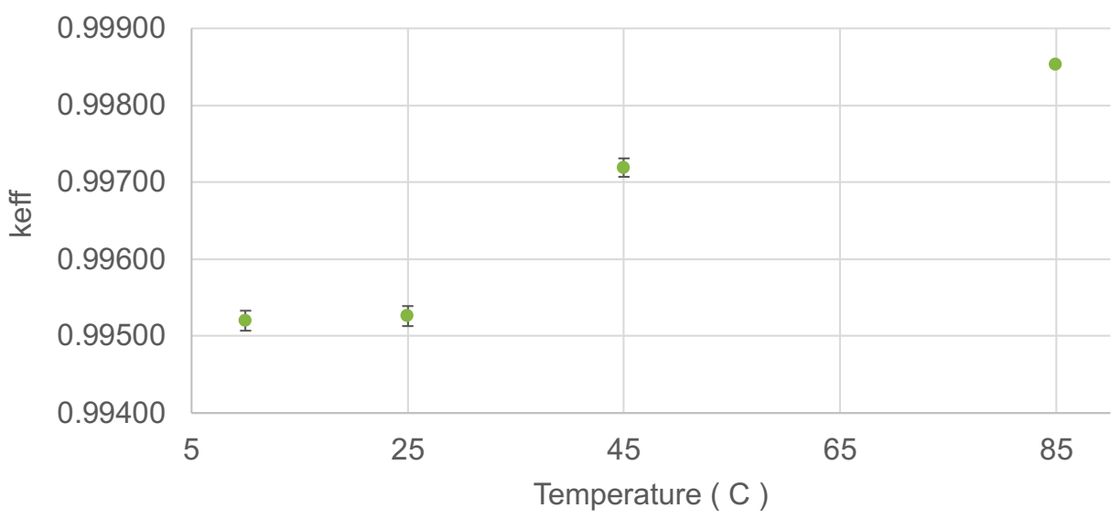
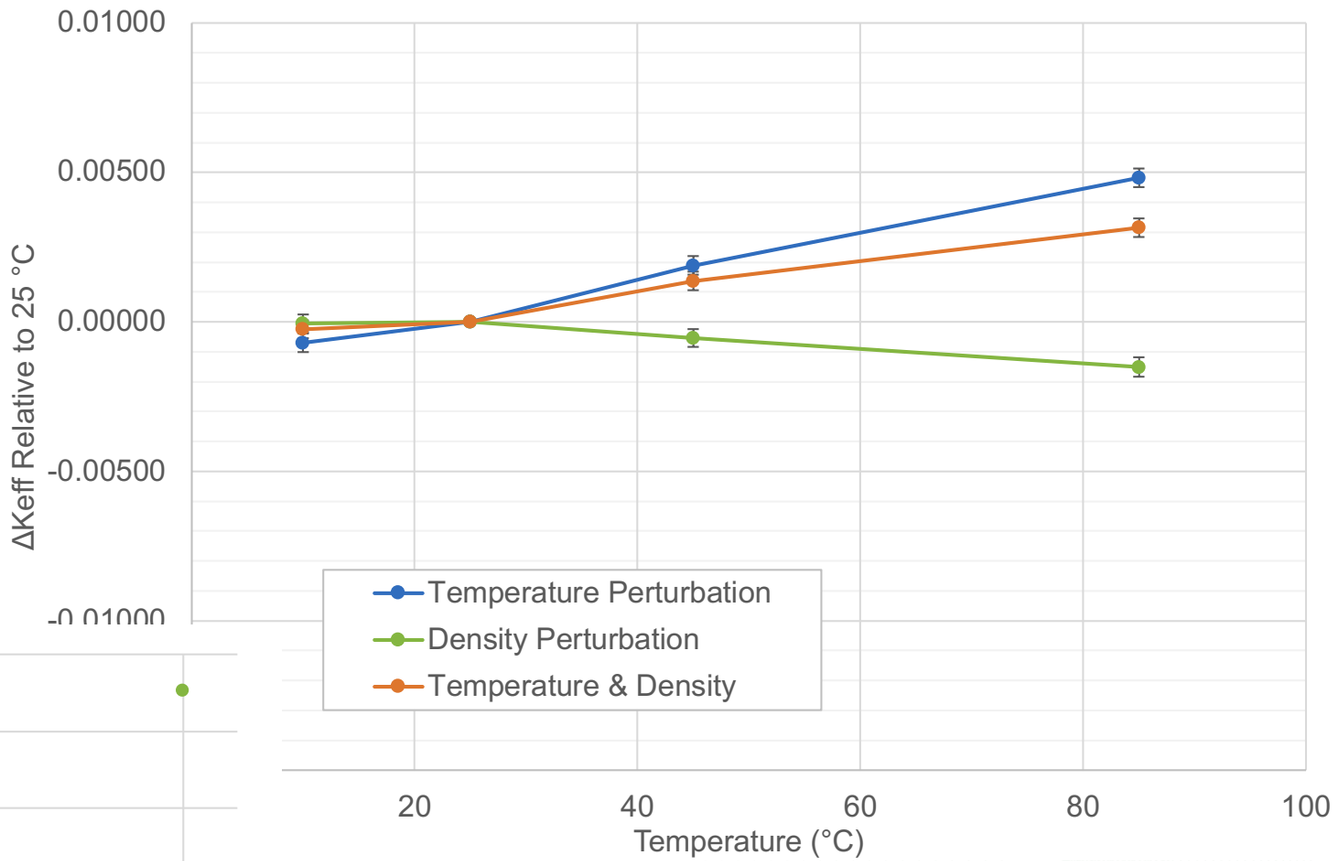
Configuration 6 Evolution of k_{eff} with Temperature

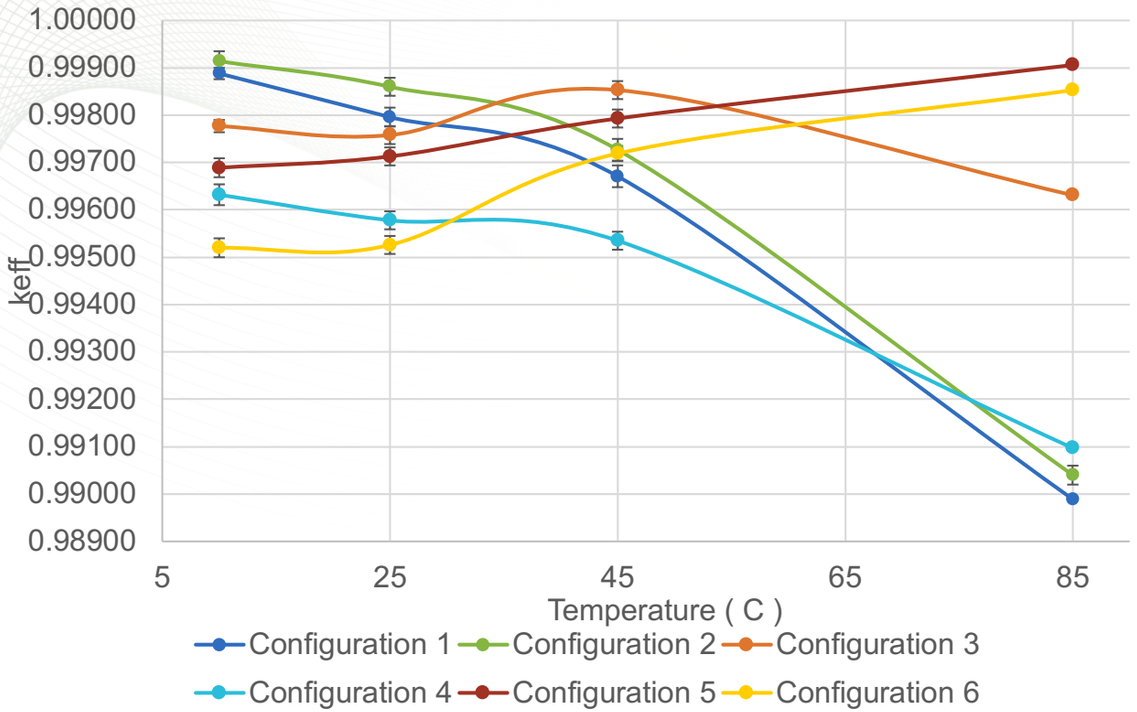


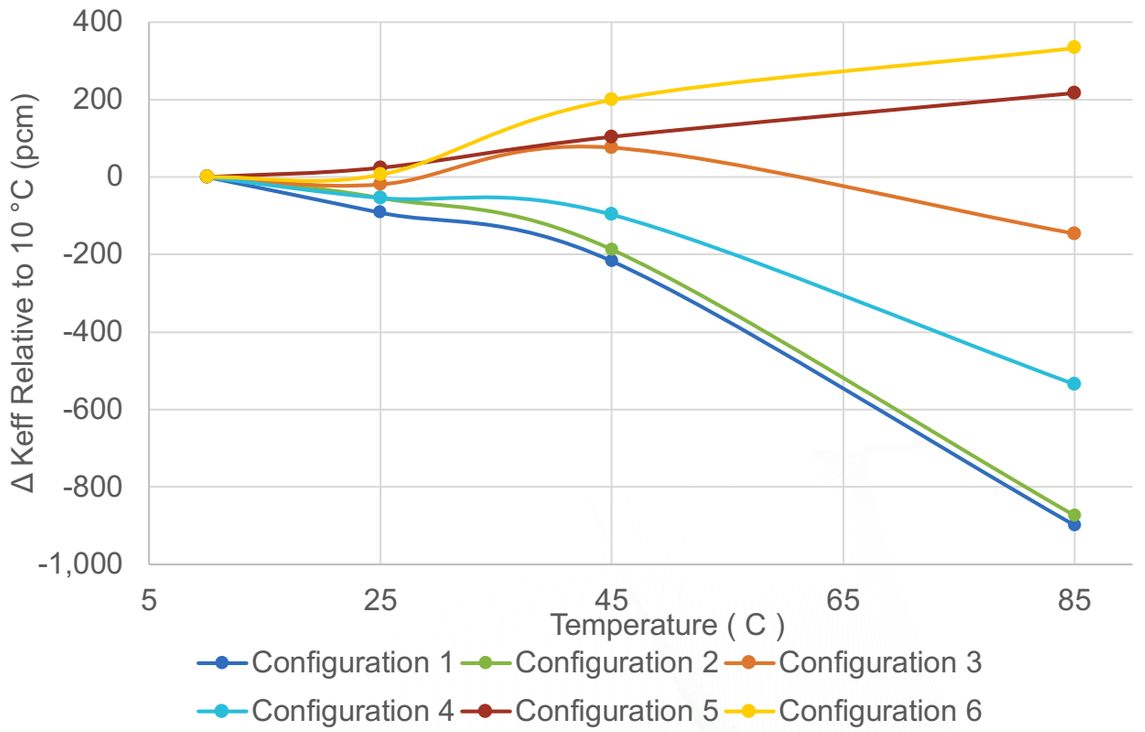
Fuel rod layout for Configuration 6 (464 rods).





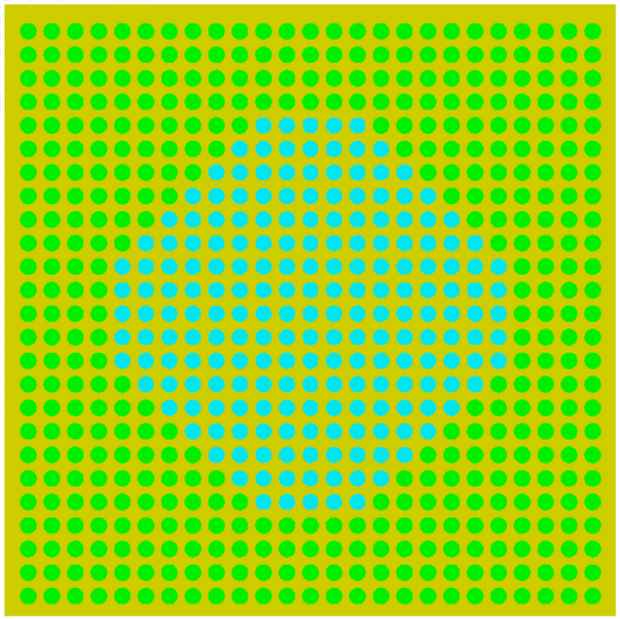
Summary of 7uPCX Configurations



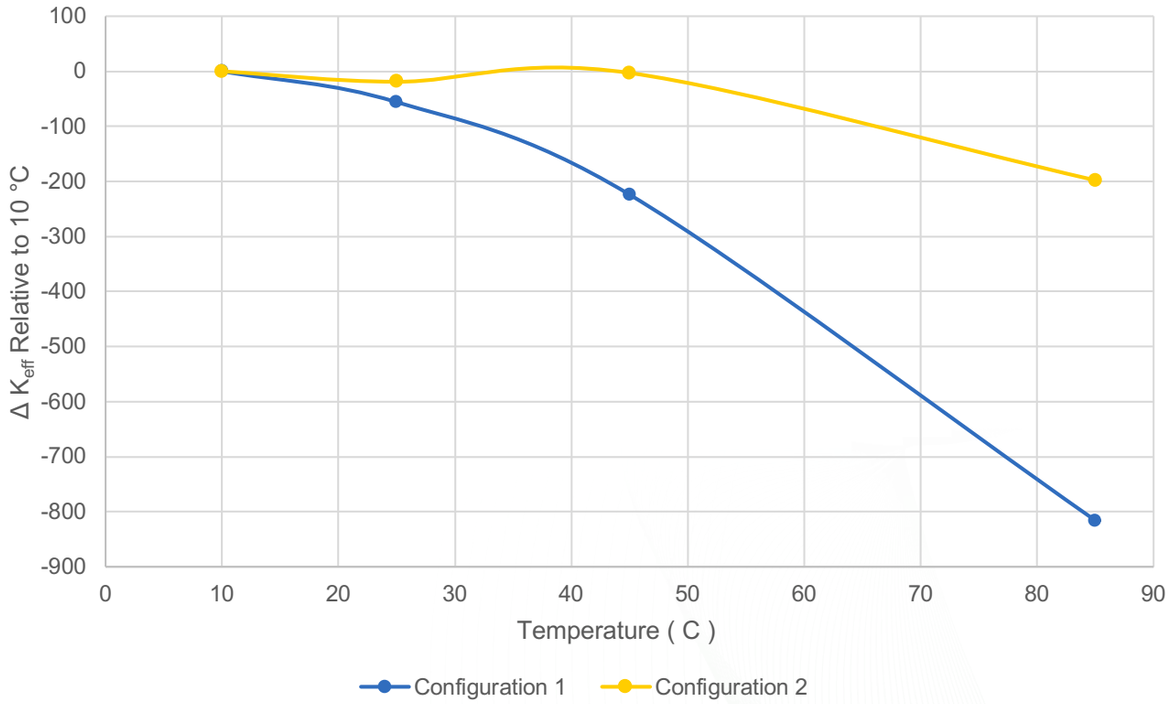


- Configurations 1, 2, and 4 are under moderated
- Configurations 5 and 6 are over moderated
- Configuration 3 near optimum moderation (most interesting config.)

Summary of BUCXX Configurations

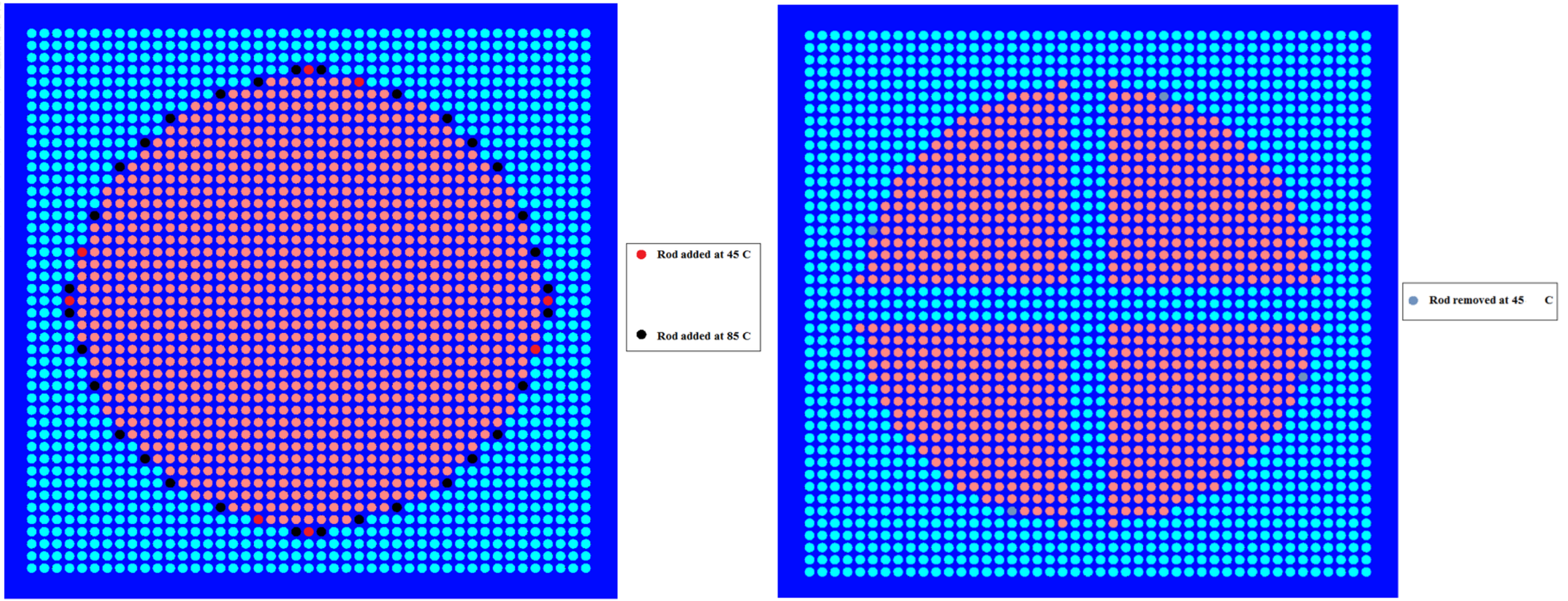


Fuel rod layout for Configuration 7 (205 rods).

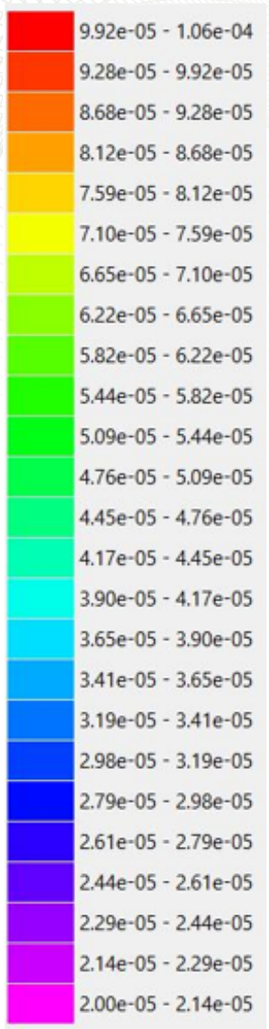


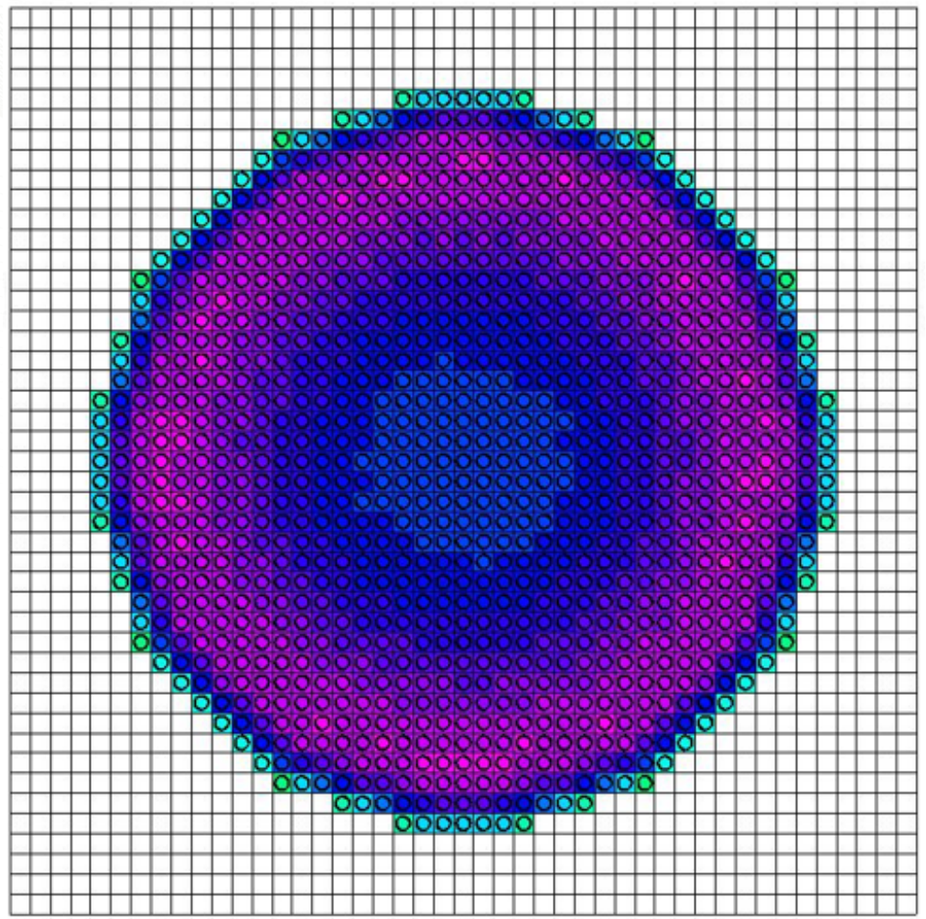
- BUCXX fuel rods on a square pitched lattice (new hardware) were investigated
- An under moderated and near optimum moderation array were identified

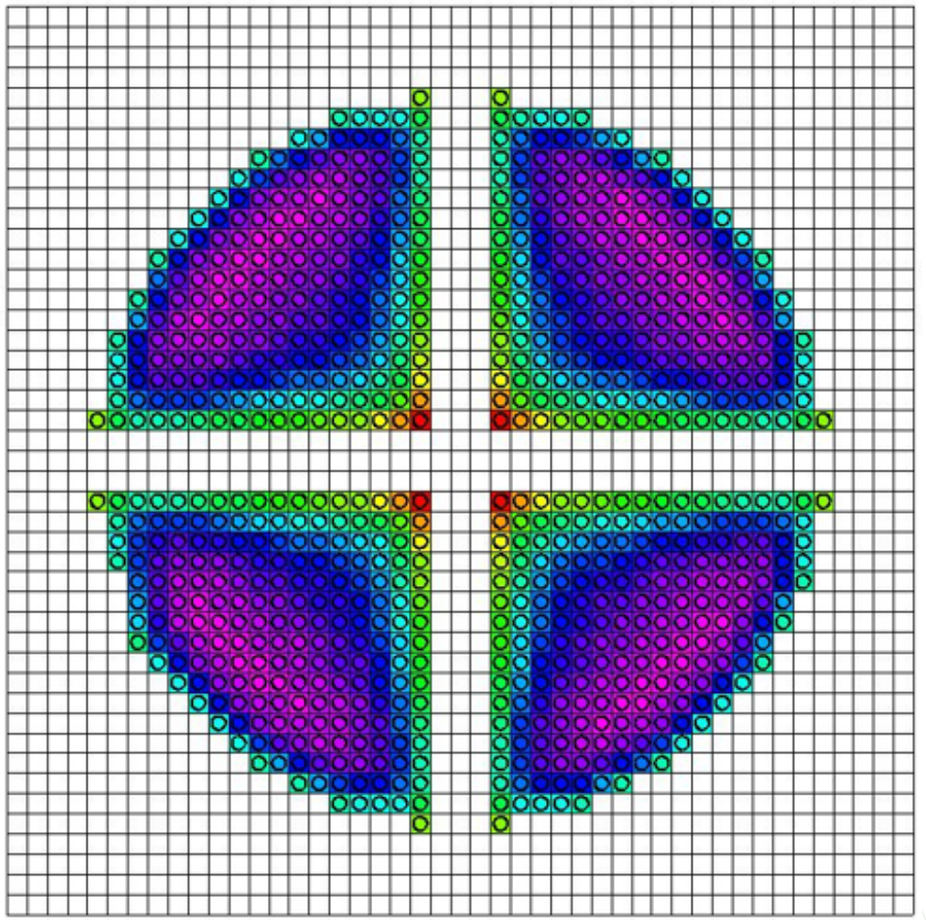
Two Proposed 7uPCX Configurations



Fission Distributions at 25°C







Conclusions and Future Work

- Conclusions
  - For configurations investigated, changes in temperature at atmospheric pressure without boiling produced experimentally interesting changes in k_{eff}
  - Uncertainties at this time are expected to be very similar to LCT-078 & 79 (7uPCX & BUCXX) – assuming temperature is homogenous and temperature measurement error 1°C or less
- Future work
  - Final design due at the end of FY18 Q4
  - Perform KENO simulations without thermal scattering data to evaluate effect on results
  - Perform simulations to determine time to reach thermal equilibrium
  - Perform KENO calculations with temperature gradients in the experiments to better estimate uncertainties
  - Begin considering options to heat and insulate Sandia critical assembly

Questions?

- This work was funded by the US DOE Nuclear Criticality Safety Program