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Author(s):	Lemke, Zachariah Rudy
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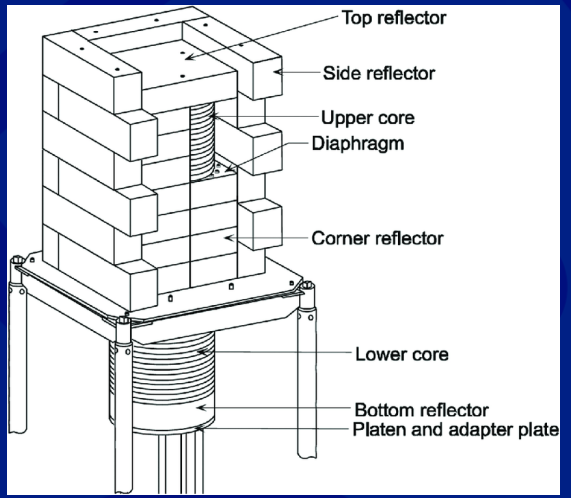
Increased Fidelity and Associated Computational cost of Detailed Integral Experiment Benchmarks

Zach Lemke

July 8, 2025

The CERBERUS Integral Experiment

- “Critical Experiment Reflected By copper to bEtteR Understand Scattering”
- Designed to be particularly sensitive to Cu scattering
- “Zeus” style experiment
  - Fuel arrangement and reflector used in many previous experiments
- Fueled by the Jemima plates, 21” diameter HEU disks
- Utilized both a Cu reflector and Cu interstitial plates
- Executed August-September 2023



CERBERUS Pictures

The ICSBEP Benchmark

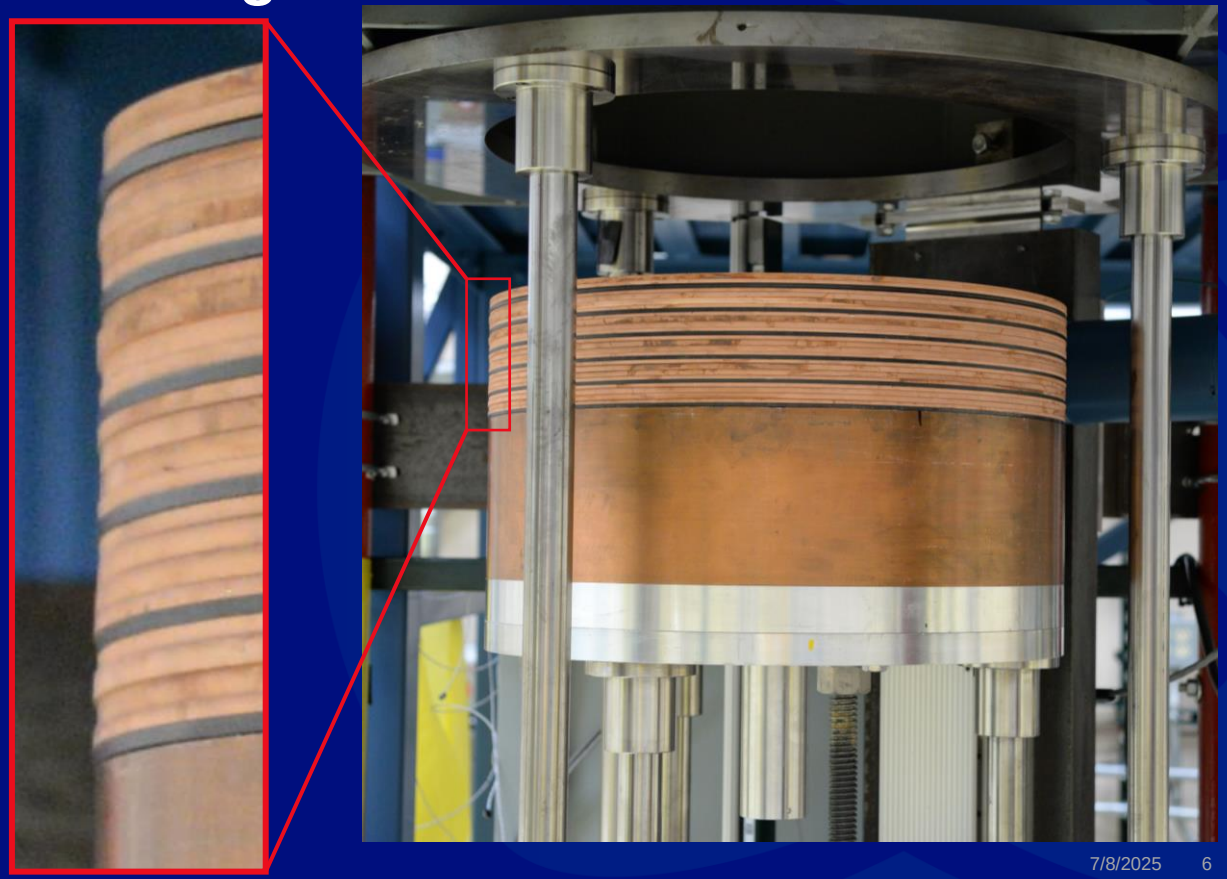
- International Criticality Safety Benchmark Evaluation Project
- Foremost a collection of benchmarks for criticality safety
- Used by nuclear data adjusters
- Validates differential measurements
- “Section 2” of the ICSBEP Benchmark focuses on uncertainty quantification
- Requires a plethora of perturbations to parts
  - Masses, compositions, dimensions, positioning
- Used to determine the effect of each uncertainty on the overall criticality measurement

Section 2 of CERBERUS

- Over 1000 simulations were performed for Section 2 of CERBERUS
  - Add even more considering reruns
  - Totaled ~305k computer hours as given by the MCNP output
- This is a notable increase from other Zeus benchmarks
- Why?
  - Desire to see the effect of each individual part
  - “Minimal” effort increase utilizing python

Example: Diameter and Alignment of HEU Interstitial

- HEU modeled as perfectly aligned with nominal dimensions
- Clearly not the case
- Does this matter?
- Need to simulate to find out



How is CERBERUS Different?

- Traditionally, all Jemima plate diameters would be perturbed at the same time
- For CERBERUS, each Jemima plate diameter was perturbed individually
- Allowed for the investigation of the sensitivity of the system to each specific item of fuel
- Accomplished utilizing python scripting (see my talk from last year)
  - Required more upfront effort, but designed to be applicable to other Zeus-like configurations
- Required significantly more computational resources
  - Whether this is justified is likely use-case dependent

Summary of Results

- It does not seem like the system is significantly more sensitive to diameters of components near the center of the core
  - Intuitively it is, but was not detectable with simulations run to a Monte Carlo k_{eff} uncertainty of 0.00002
- The system is more sensitive to heights of components near the center of the core
  - Most (if not all) Zeus style benchmarks have perturbed core component heights indivivually

Acknowledgments

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Thank You!