IER 518: Data Analysis for High Multiplication Subcritical Experiments

2024 NCSP Technical Program Review

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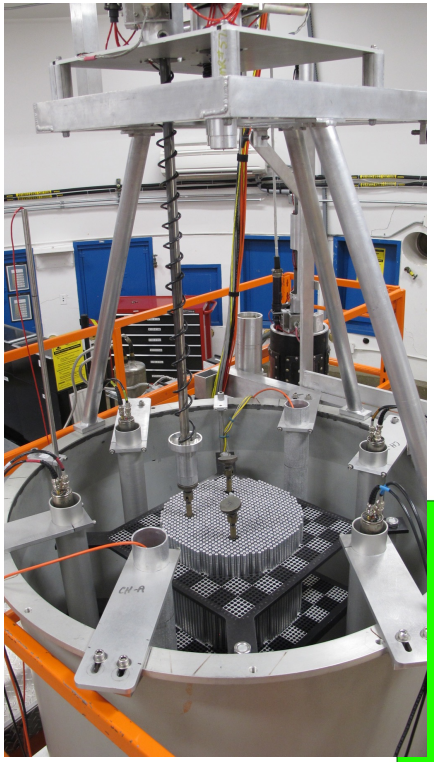
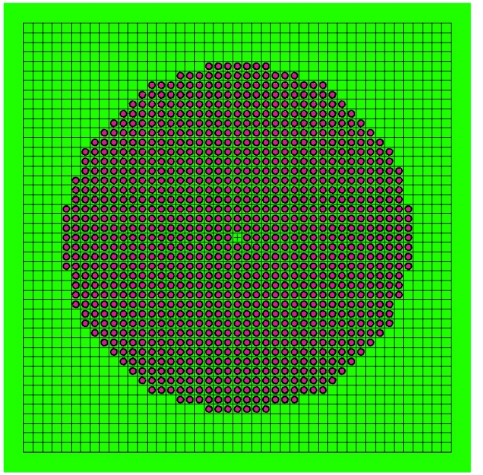
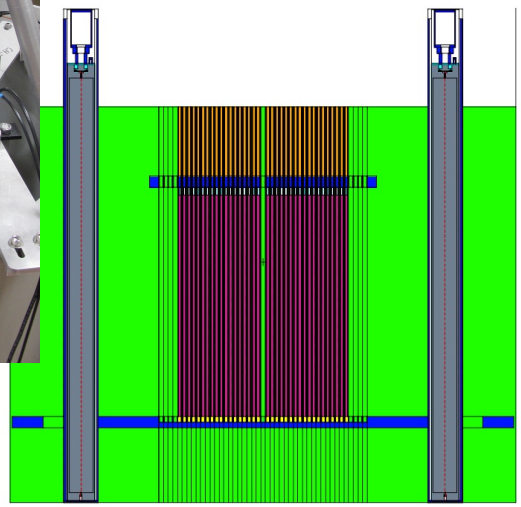
Lawrence Livermore National Laboratory

Overview

- Goals & Motivation
- Experimental Configurations & Computational Models
- Experimental Measurements & Simulations
- Data Analysis & Results
- Conclusion





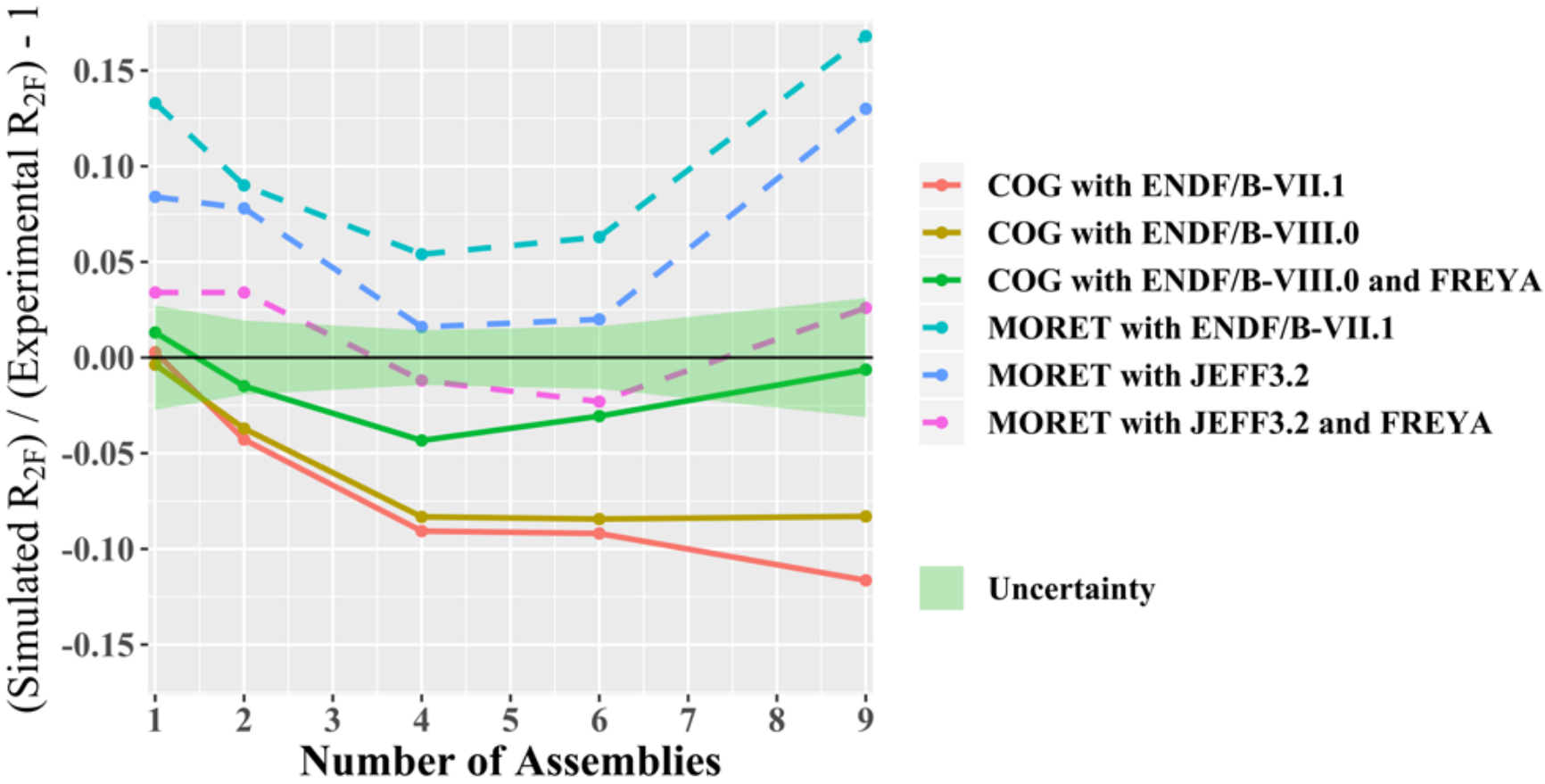


Goals

- Measure time-tagged list-mode data for configurations exceeding 20-100 multiplication
  - Overlap and extend existing subcritical multiplication measurements
  - Provide intercomparison between LLNL, LANL, and IRSN detector systems
- Create fundamental physics benchmarks for ICSBEP with greater than 20 multiplication
  - Currently none exist with greater than about 20 multiplication
- Leverage existing critical experiment and detector system benchmarks to limit required modeling and uncertainty analysis
  - Minimize cost required to produce benchmark

Motivation

Inherently Safe Subcritical Assembly (ISSA, FUND-LLNL-ALPHAN-HE3-MULT-001)



Nelson, A., et. al., "Fundamental Physics Subcritical Neutron Multiplicity Benchmark Experiments Using Water Moderated Highly Enriched Uranium Fuel." International Conference on Nuclear Criticality Safety. Paris, France (2019).

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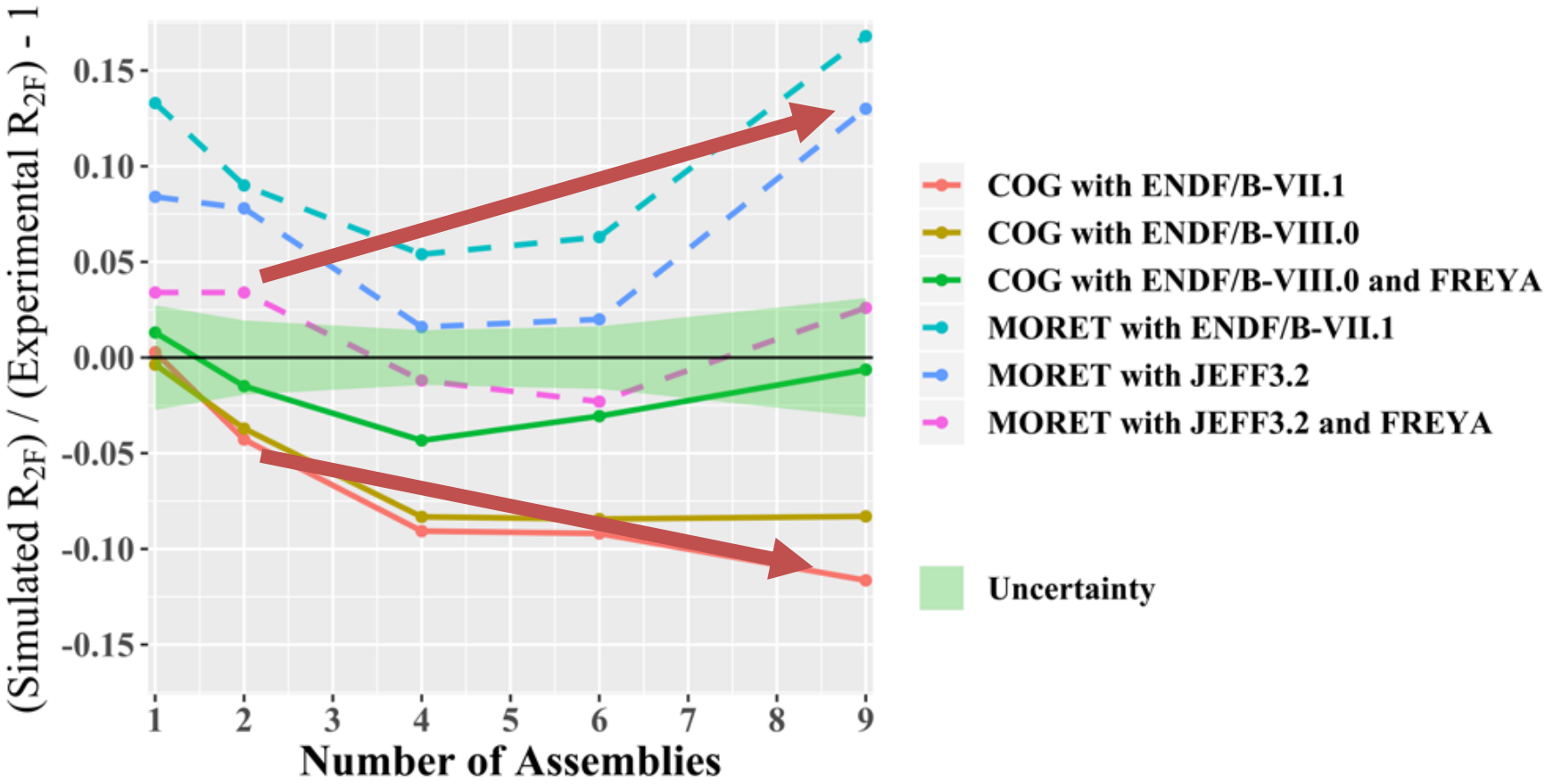

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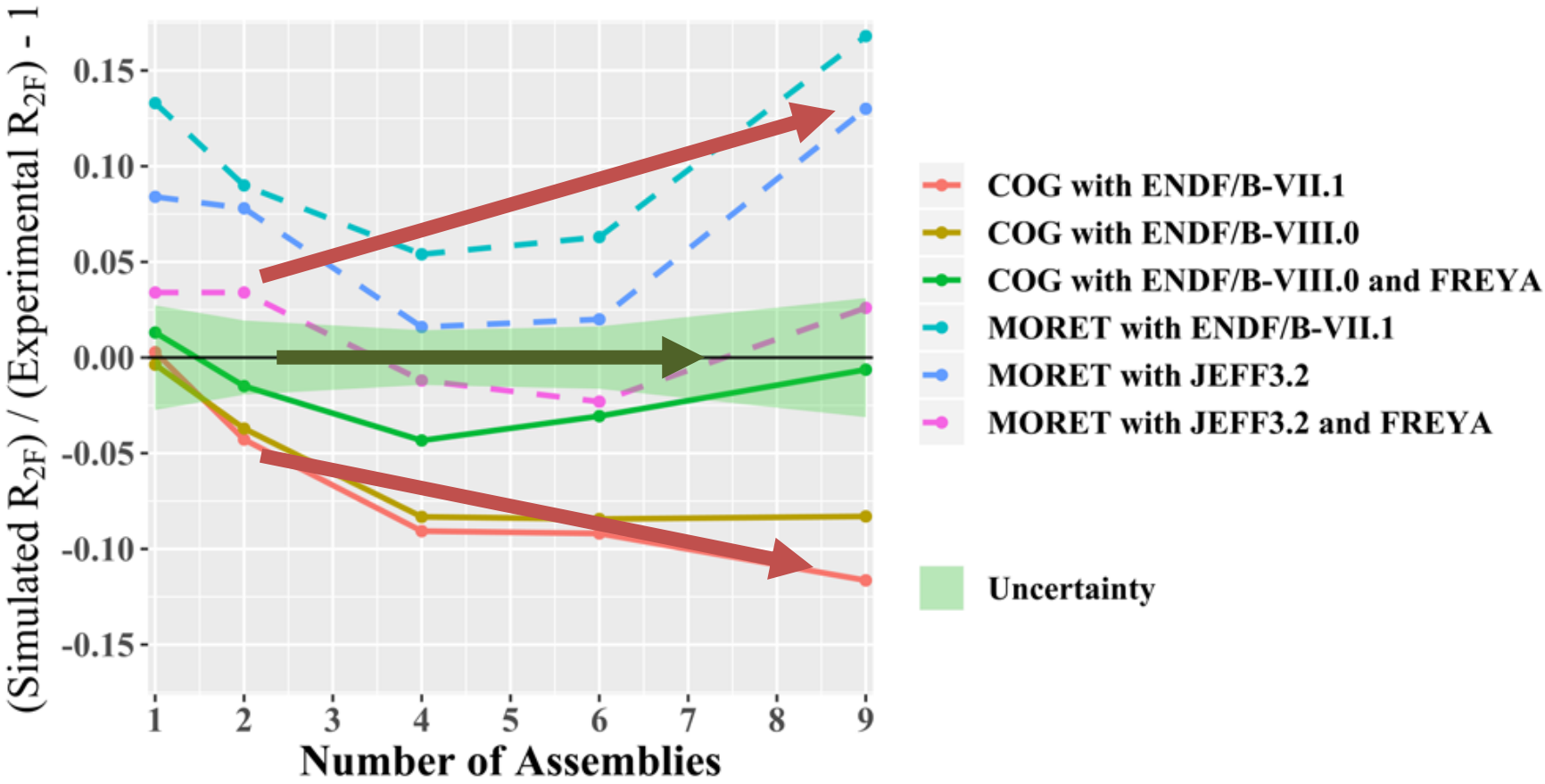

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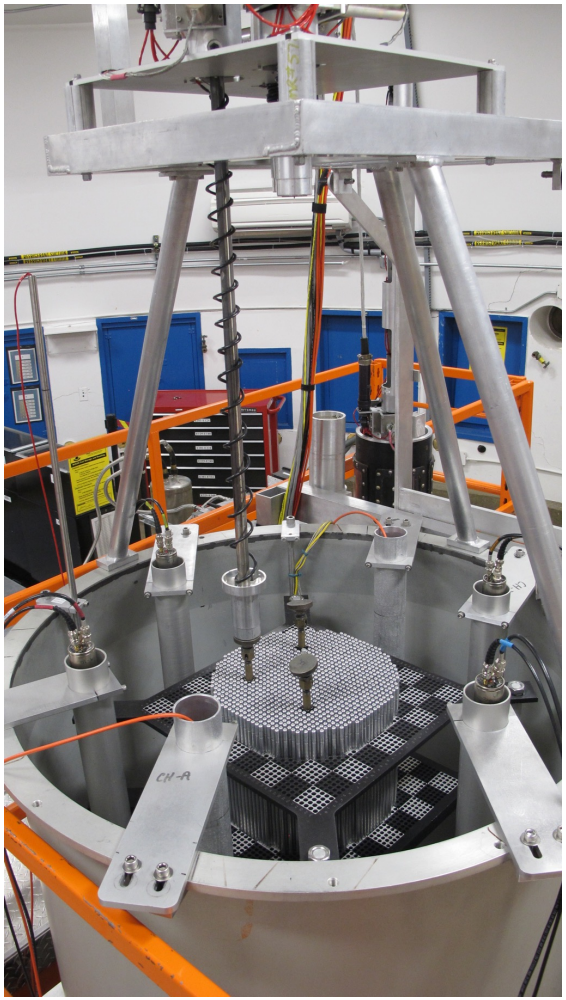
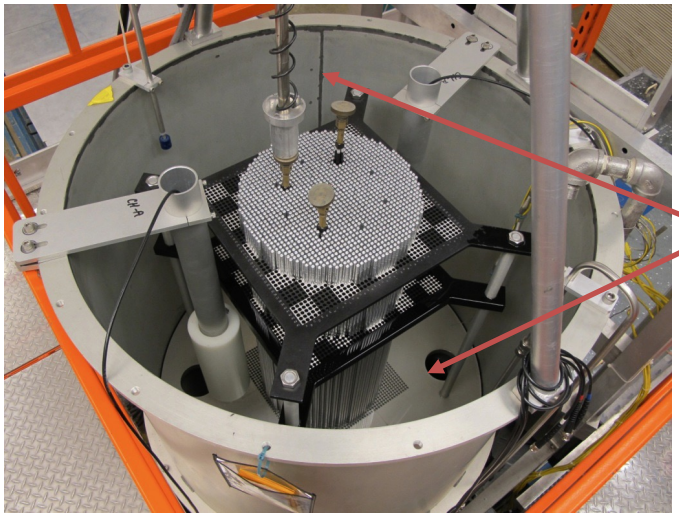
Experimental Configuration

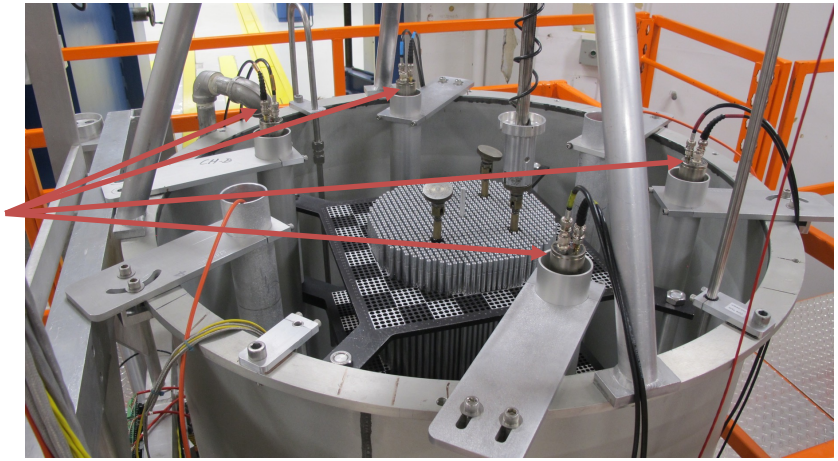
Photos courtesy of Sandia National Laboratory (SNL)





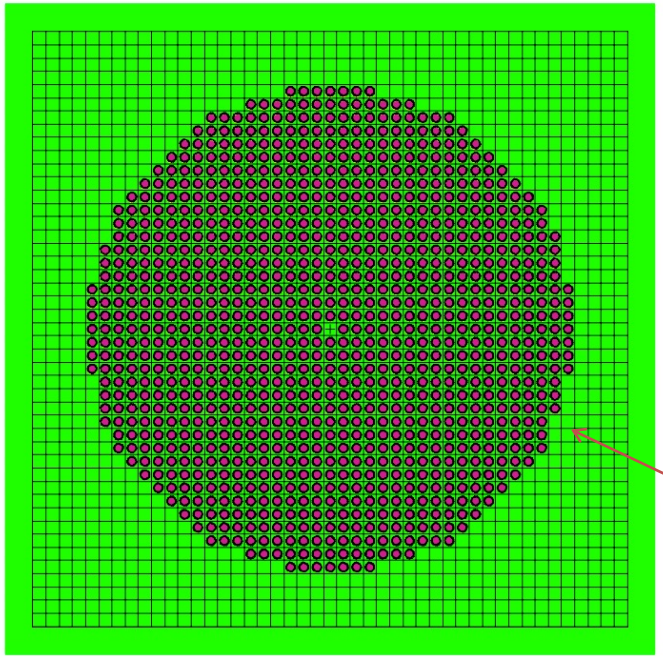
Location for dry wells inside the tank

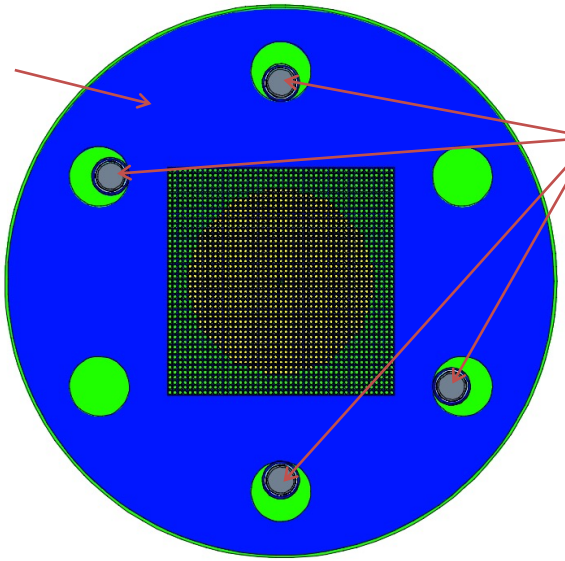
Detectors within dry wells inside the tank



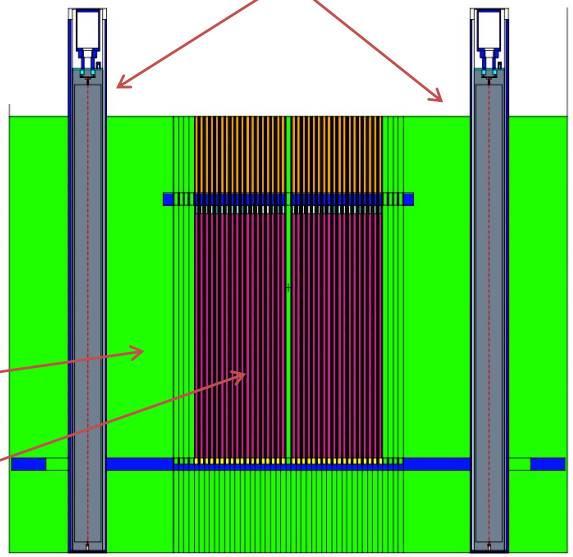
Computational Model

Modeled by Eric Hudec (OSU) with the LCT-078 Benchmark Model from SNL





Case 1 with
1058 Fuel Elements



Experimental Measurements

Case*	Number of Fuel Rods	Estimated k_{eff}	Estimated Multiplication	Measurement Time (s)
1	1058	0.99892	925.9	3600
2	1056	0.99849	662.3	3600
3	1048	0.99684	316.5	3600
4	1032	0.99388	163.4	3600
5	1004	0.98776	81.7	3600
6	948	0.97610	41.8	3600
Background	-	-	-	14400
Efficiency	-	-	-	3600

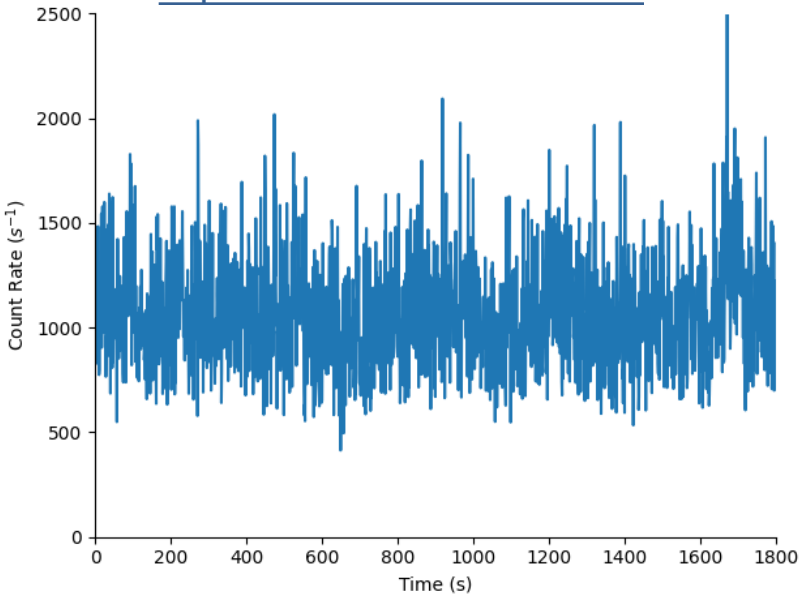
- Background and efficiency measurements were performed to characterize the detector system configuration

Experimental Measurements

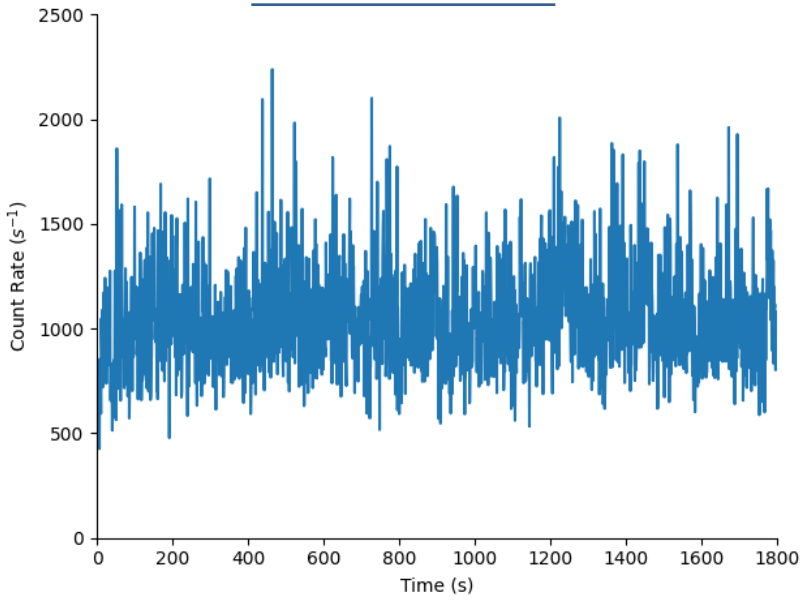
Comparison to MCNP Simulation

- The experimental measurements produced time-tagged neutron count rate data
- This count rate data can be simulated and analyzed to determine a benchmark quantity for comparison to simulation

Experimental Measurement



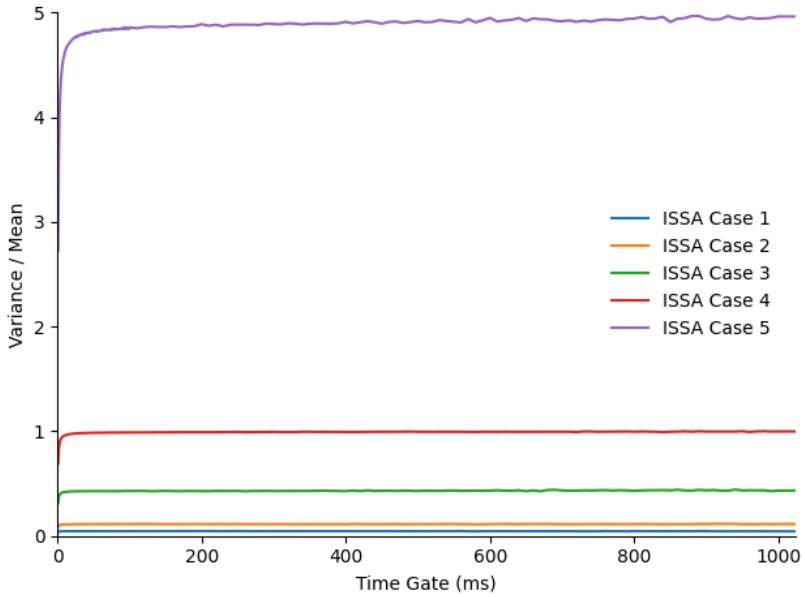
MCNP Simulation



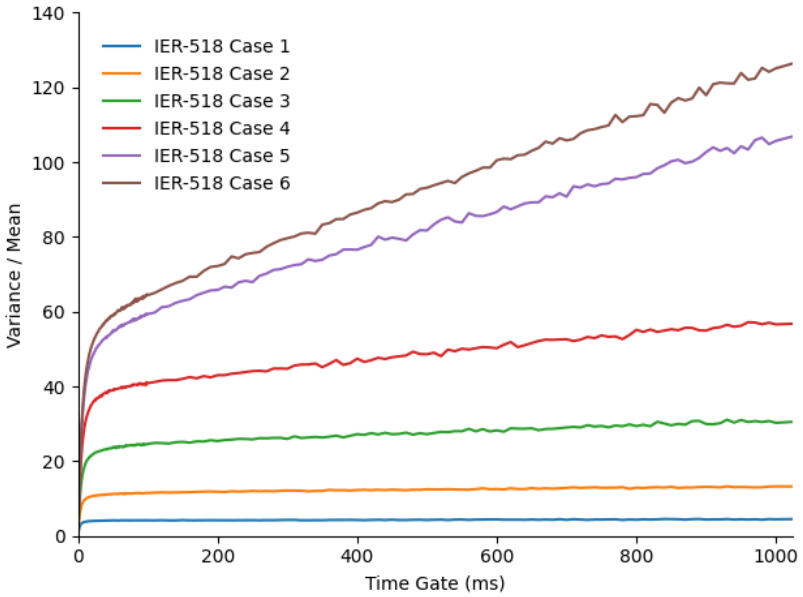
Data Analysis

Reduced Factorial Moments

Inherently Safe Subcritical Assembly (ISSA)
FUND-LLNL-ALPHAN-HE3-MULT-001



IER-518
(High Multiplication Subcritical Experiments)



$$Y_{2F} = R_{2F}\left(1 - \frac{1 - e^{-T_G\lambda}}{T_G\lambda}\right)$$

$$\lim_{T_G \to \infty} Y_{2F} = R_{2F}$$

Data Analysis

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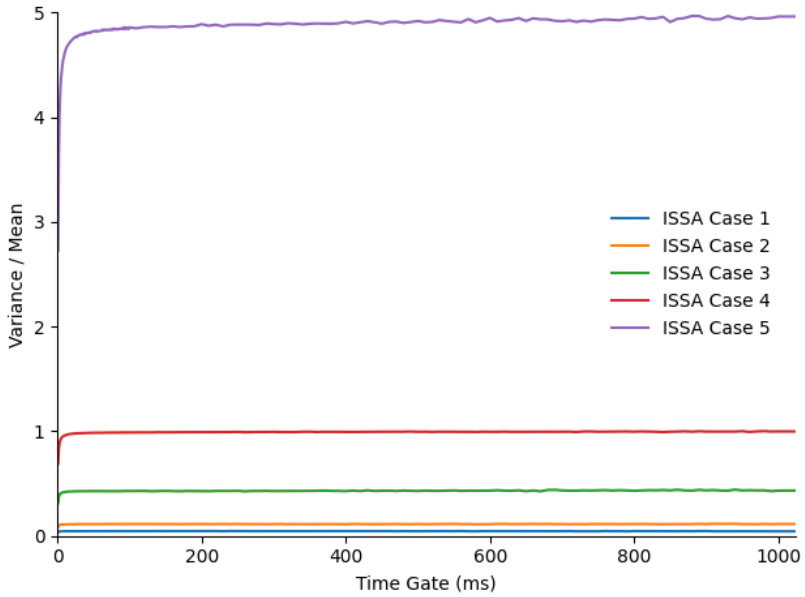

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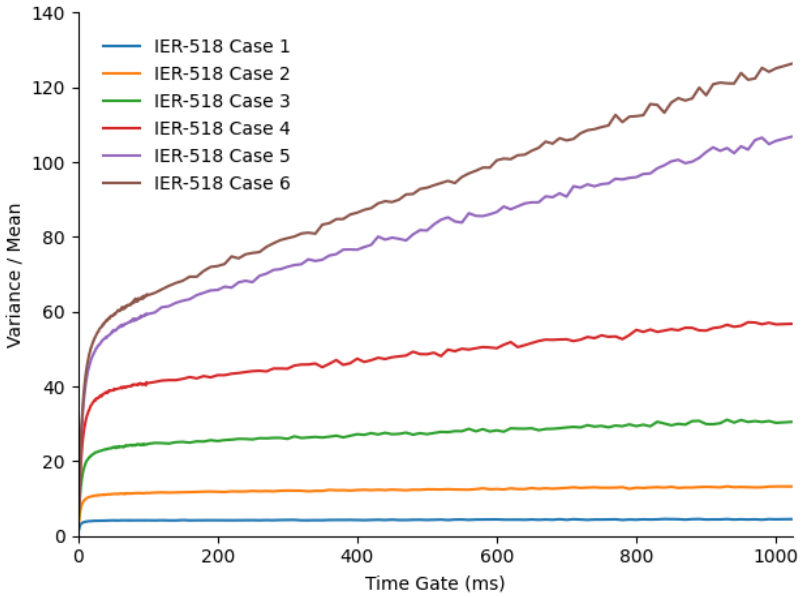

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Inverse of the Neutron Lifetime

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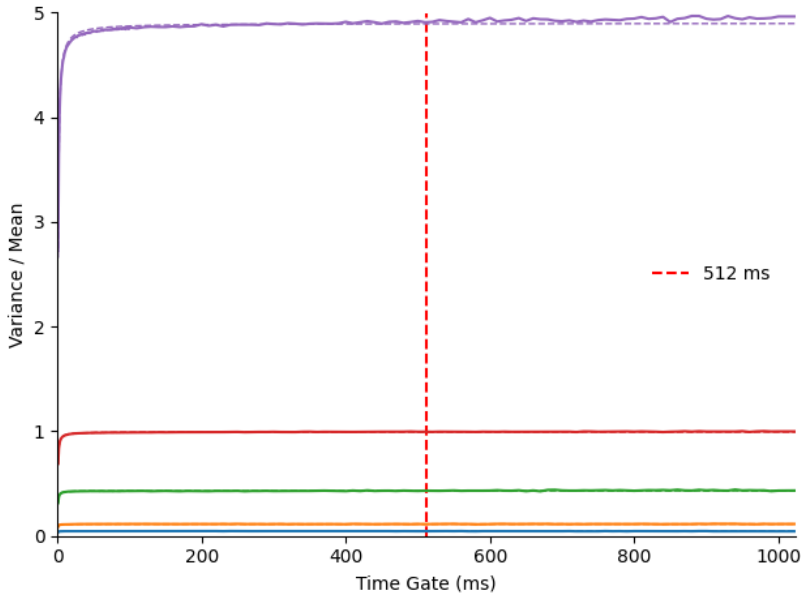

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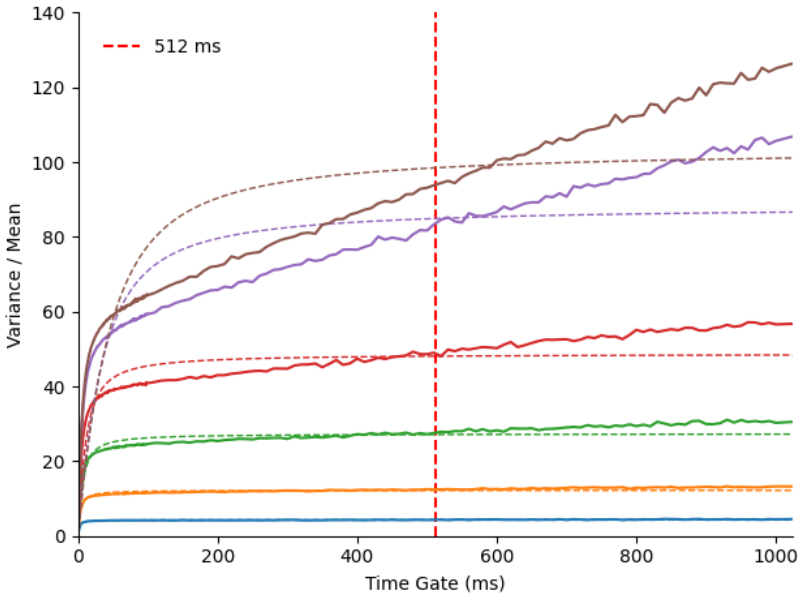

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$$\lim_{T_G \to \infty} Y_{2F} = R_{2F}$$

Conclusion

- Computational models of the six IER-518 experimental configurations are complete
  - List mode simulations of the benchmark models and uncertainty perturbations are also complete
  - Performed by Eric Hudec (OSU) with aid of LCT-078 Benchmark Model provided by SNL
- Discrepancies when applying the accepted method used in determining the benchmark quantity in the ISSA Benchmark Evaluation (FUND-LLNL-ALPHAN-HE3-MULT-001)
  - There are a variety of other methods now being explored, as well as work applying these methods to the ISSA Benchmark Measurements

Acknowledgements

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- Thanks to the Sandia National Laboratory SCX operators for their support of the experiment
- Thanks to Gary Harms (SNL) for the photographs of the experiment setup and configurations
- Thanks to IRSN for funding their participation and involvement in this experiment

Acknowledgements

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Laboratory	Participants
LLNL	Jesse Norris, Samuel Varghese, Daniel Siefman, Eric Hudec, William Zywiec, Catherine Percher, David Heinrichs
LANL	Nicholas Whitman, Jesson Hutchinson, Geordie McKenzie, Jessie Walker, Joetta Goda
SNL	Gary Harms, David Ames, Rafe Campbell, Beth Hanson, Jason Soares, Patrick Ward, and John Hall
IRSN	Wilfried Monange, Jean Baptiste Clavel, Aurelie Bardelay

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