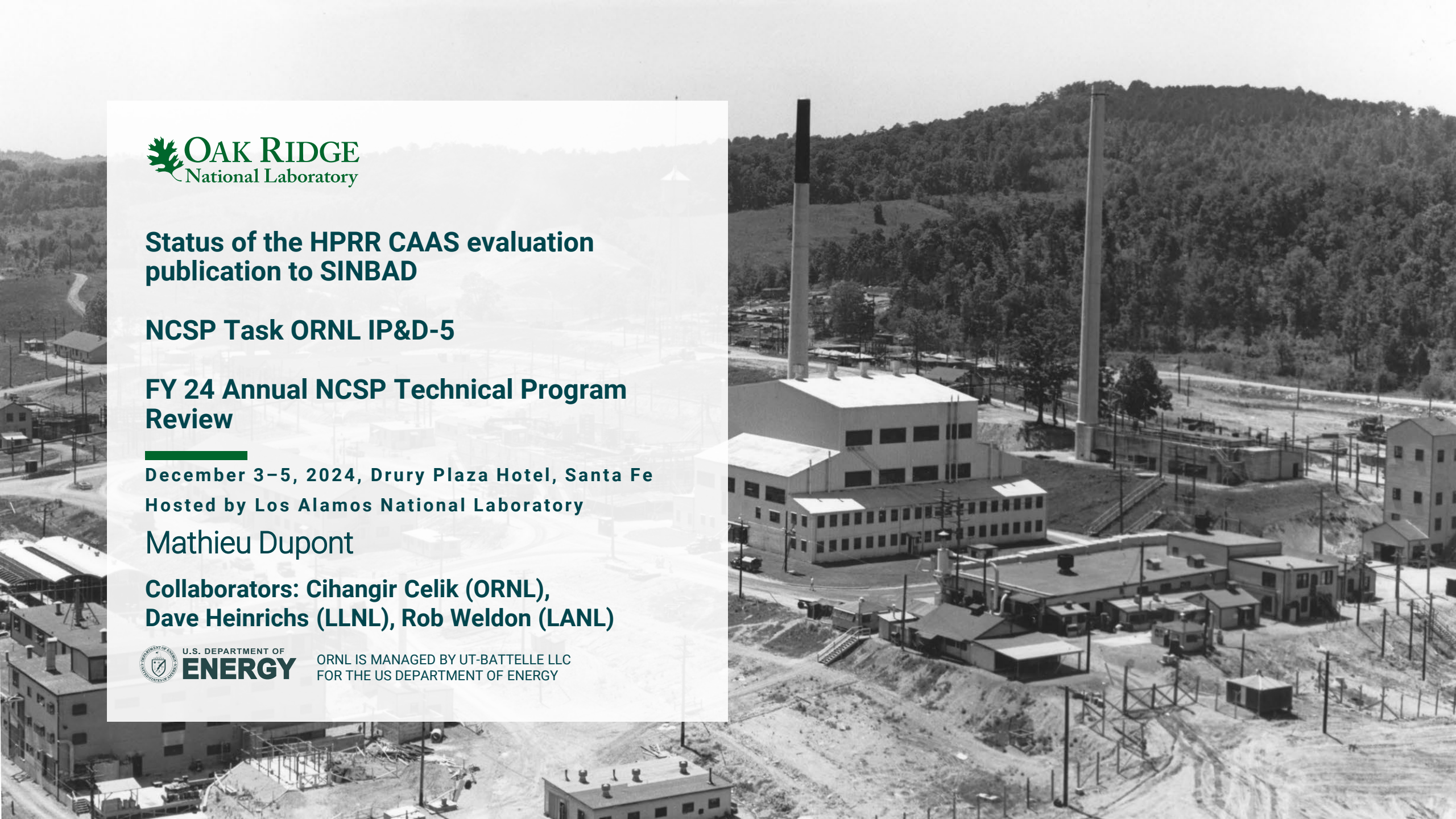

OAK RIDGE National Laboratory

Status of the HPRR CAAS evaluation publication to SINBAD

NCSP Task ORNL IP&D-5

FY 24 Annual NCSP Technical Program Review

December 3–5, 2024, Drury Plaza Hotel, Santa Fe

Hosted by Los Alamos National Laboratory

Mathieu Dupont

Collaborators: Cihangir Celik (ORNL), Dave Heinrichs (LLNL), Rob Weldon (LANL)

U.S. DEPARTMENT OF ENERGY

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FOR THE US DEPARTMENT OF ENERGY

Nuclear Criticality Safety Program (NCSP) Task IP&D-5: Goal

Use available data from Health Physics Research Reactor (HPRR) operation to create a benchmark report for inclusion in the International Criticality Safety Benchmark Evaluation Project (ICSBEP) Handbook as a Criticality Accident Alarm System (CAAS) shielding benchmark

The Health Physics Research Reactor

Facts about the HPRR

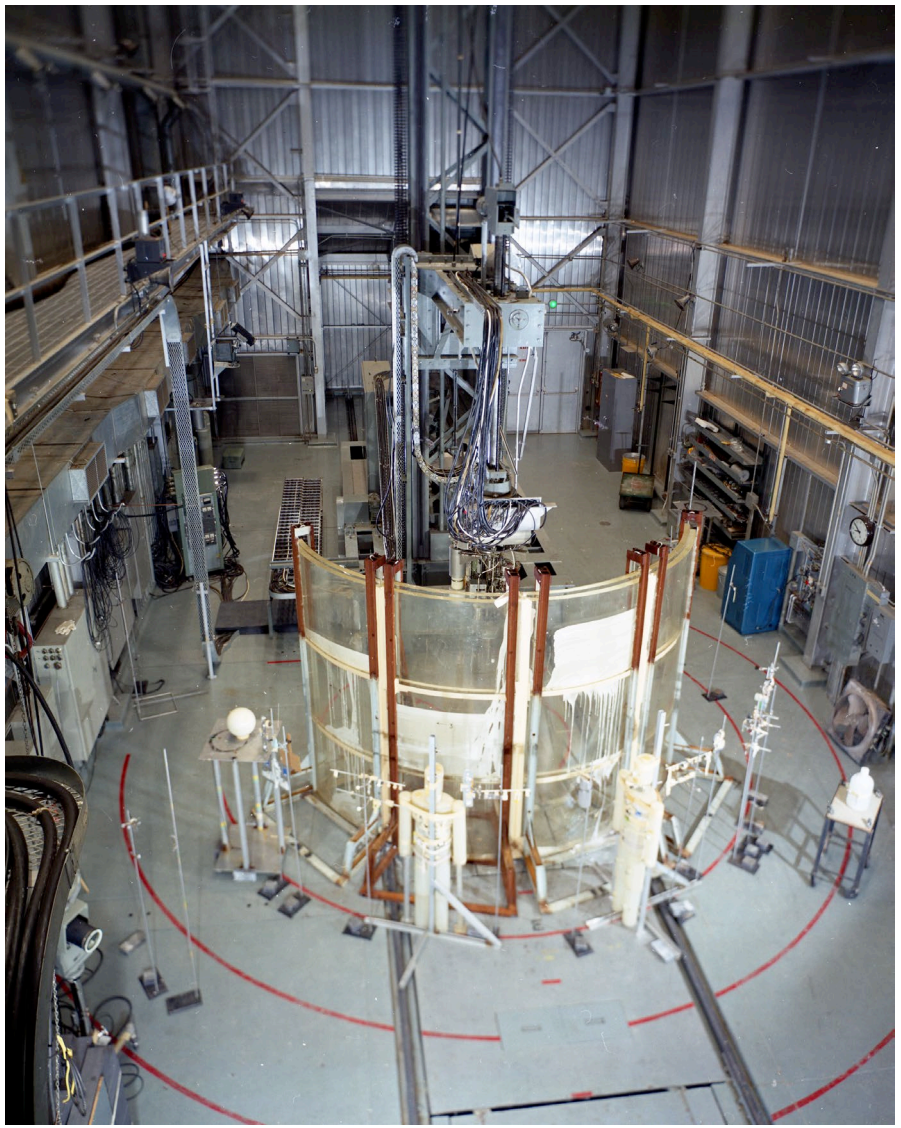
- The HPRR, or Fast Burst Reactor (FBR), designed and built at ORNL in 1961
- Part of the Dosimetry Application Research (DOSAR) facility at ORNL from 1963 to 1987
- Operated for thousands of hours; achieved criticality 10,000 times
- Numerous relevant studies and publications on dosimetry, plant radiobiology, radiation alarms, teaching, and training
- Decommissioned in 1987

DOSAR Facility, A History of Research Reactors Division (1987)

The Health Physics Research Reactor

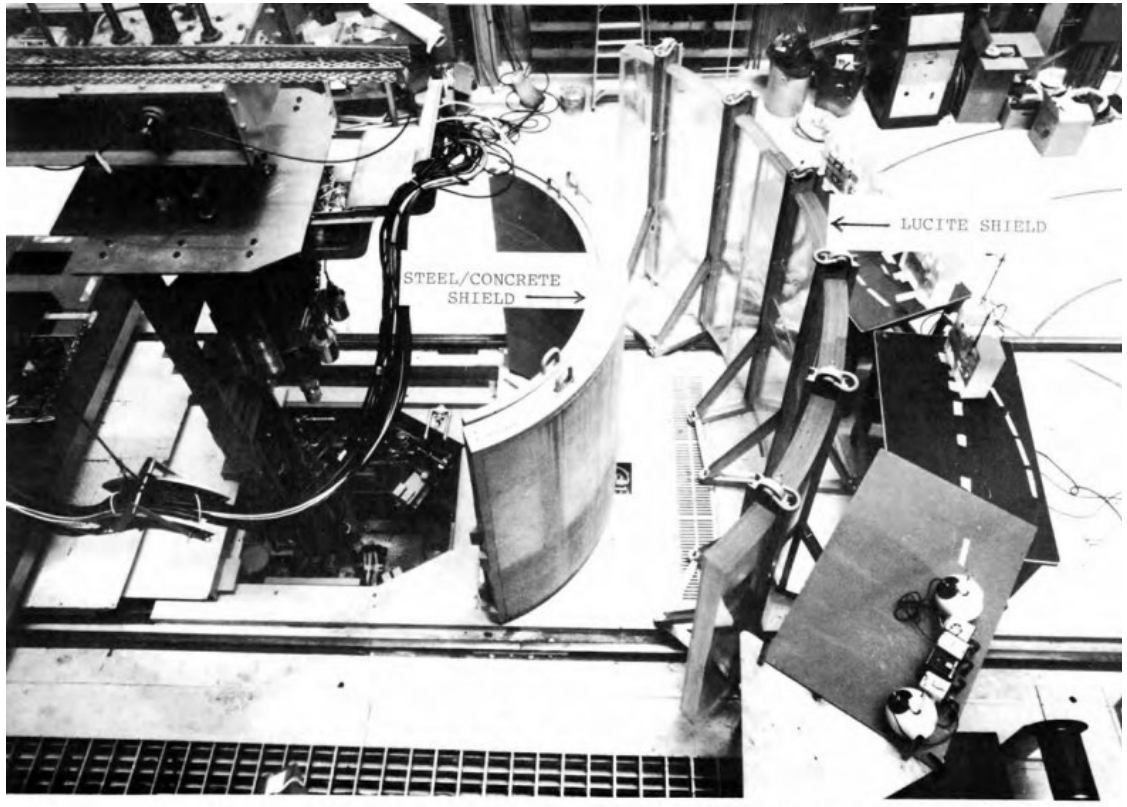
Figure 53: HPRR

A History of Research Reactors Division (1987)

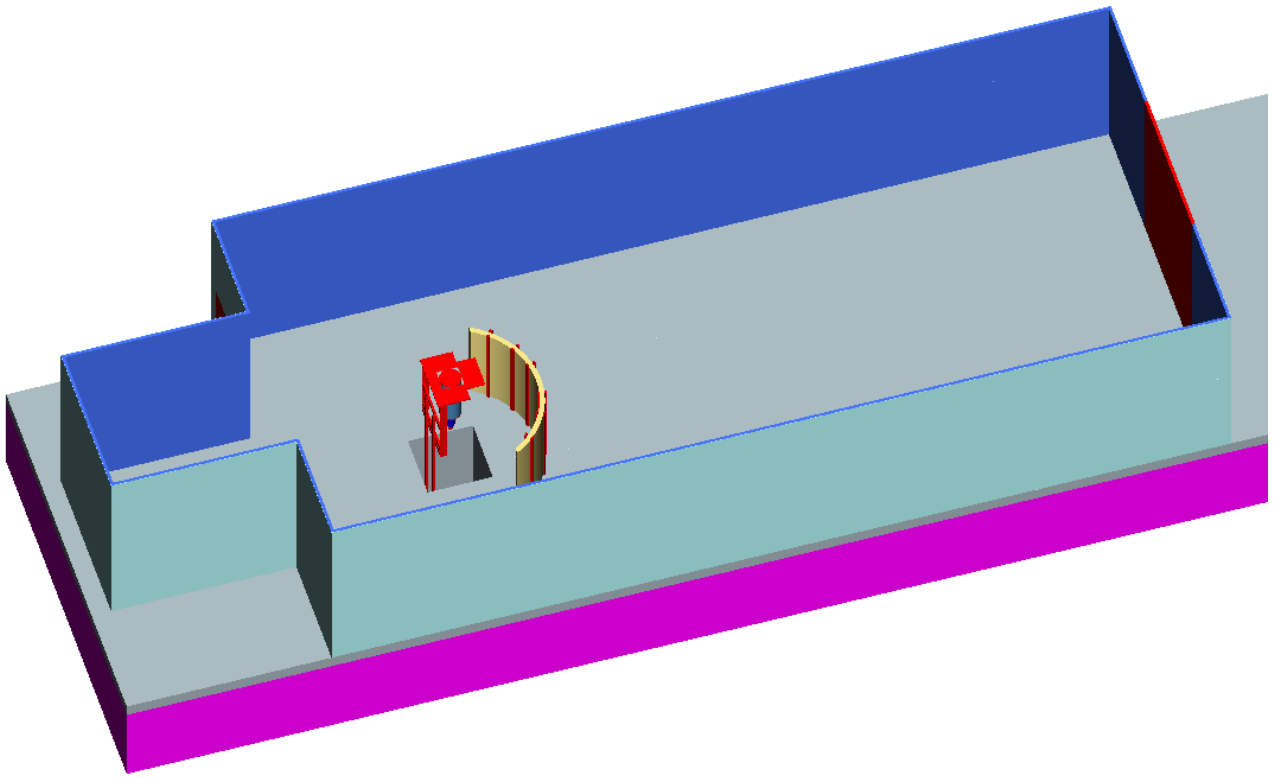


Phantom setup inside of HPRR building, August 7, 1970

The Health Physics Research Reactor



Health Physics Research Reactor Reference Dosimetry, ORNL-6240 (1987)

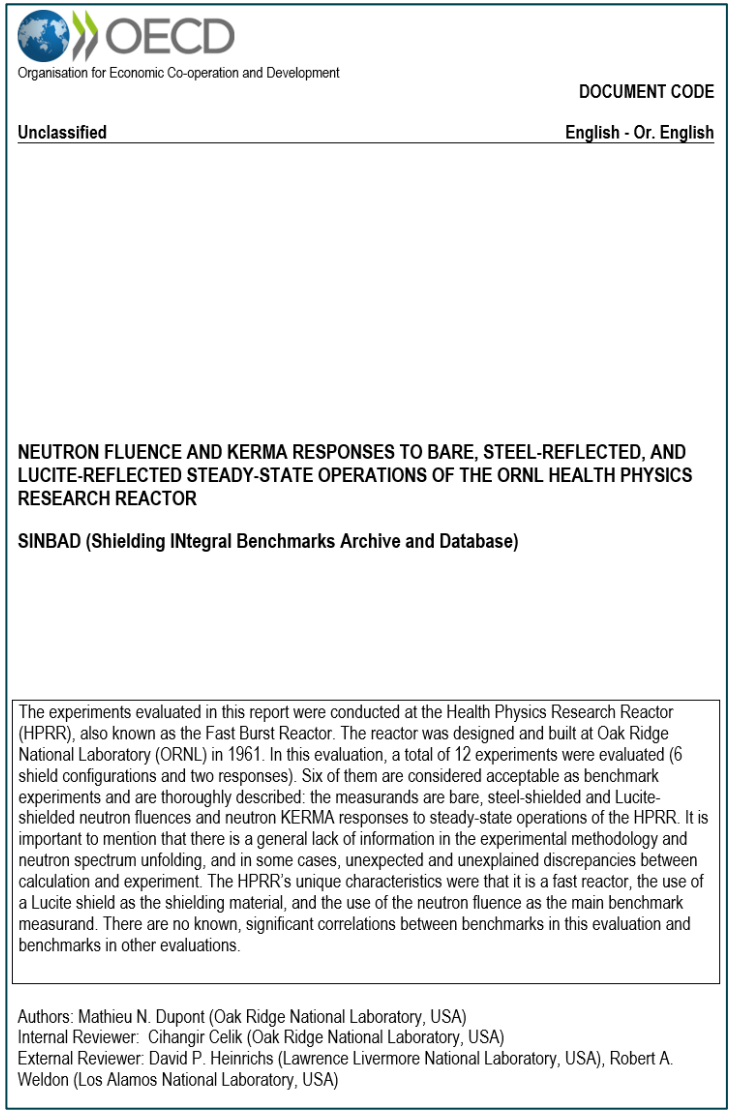


SCALE model

Evaluation contents and status

Planned evaluation contents

1. Total neutron fluence from steady-state operation of the HPRR measured by Bonner sphere spectrometry, shielded and unshielded (Version 1)
2. Derived neutron kerma results from step 1 (Version 1)
3. Sulfur pellet activation at different distances from an HPRR pulse, shielded and unshielded (to be added in Version 2)
4. Gamma dose from an HPRR pulse measured by Geiger-Müller (G-M) counter and thermoluminescent dosimeter (TLD) (to be added in Version 2)



OECD
Organisation for Economic Co-operation and Development

DOCUMENT CODE

Unclassified | English - Or. English

NEUTRON FLUENCE AND KERMA RESPONSES TO BARE, STEEL-REFLECTED, AND LUCITE-REFLECTED STEADY-STATE OPERATIONS OF THE ORNL HEALTH PHYSICS RESEARCH REACTOR

SINBAD (Shielding INtegral Benchmarks Archive and Database)

The experiments evaluated in this report were conducted at the Health Physics Research Reactor (HPRR), also known as the Fast Burst Reactor. The reactor was designed and built at Oak Ridge National Laboratory (ORNL) in 1961. In this evaluation, a total of 12 experiments were evaluated (6 shield configurations and two responses). Six of them are considered acceptable as benchmark experiments and are thoroughly described: the measurands are bare, steel-shielded and Lucite-shielded neutron fluences and neutron KERMA responses to steady-state operations of the HPRR. It is important to mention that there is a general lack of information in the experimental methodology and neutron spectrum unfolding, and in some cases, unexpected and unexplained discrepancies between calculation and experiment. The HPRR's unique characteristics were that it is a fast reactor, the use of a Lucite shield as the shielding material, and the use of the neutron fluence as the main benchmark measurand. There are no known, significant correlations between benchmarks in this evaluation and benchmarks in other evaluations.

Authors: Mathieu N. Dupont (Oak Ridge National Laboratory, USA)
Internal Reviewer: Cihangir Celik (Oak Ridge National Laboratory, USA)
External Reviewer: David P. Heinrichs (Lawrence Livermore National Laboratory, USA), Robert A. Weldon (Los Alamos National Laboratory, USA)

Front page of evaluation, to be released

Evaluation contents and status

Overview of HPRR SINBAD evaluation

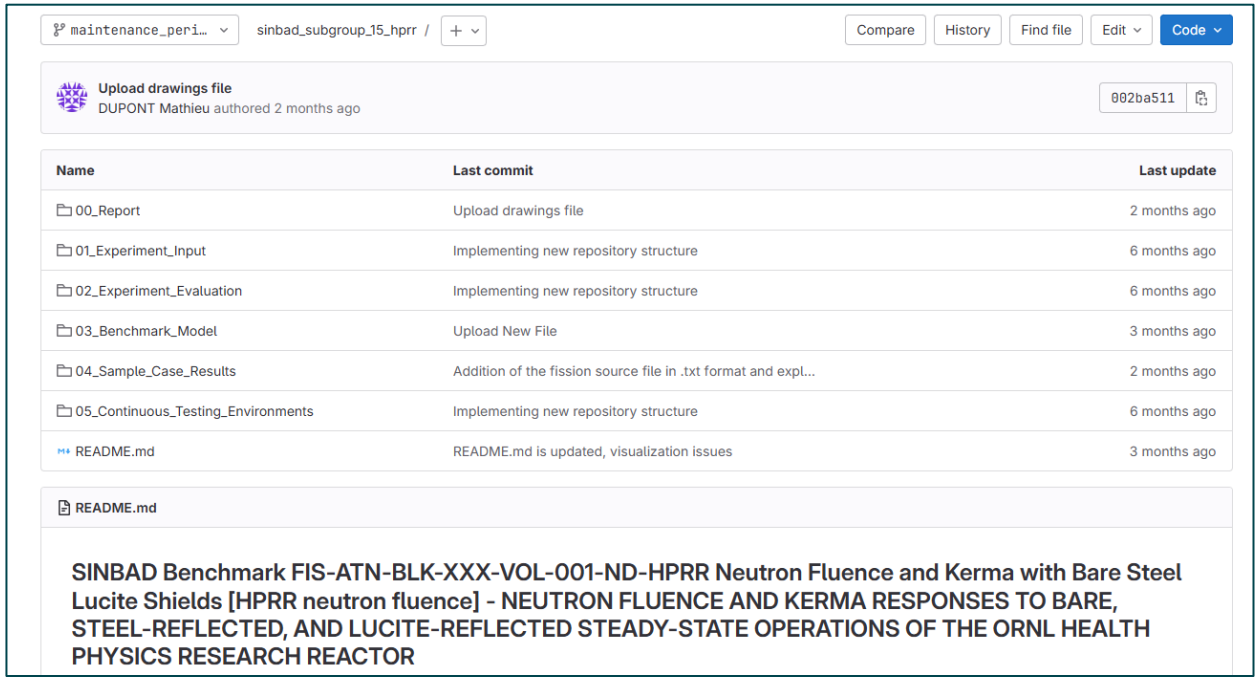
Shield	Neutron fluence	Neutron kerma	Sulfur foil activation	Gamma dose
Bare	✓	✓	!	X
Steel	✓	✓	!	X
Lucite	✓	✓	X	X

✓: Included in initial release
! : Done before, will be updated in Version 2
X : Needs full evaluation, will be added in Version 2

Evaluation contents and status

Status of the evaluation at the end of FY24

- Version 1 ready with neutron fluence and kerma with bare, steel, and Lucite shields (6 configurations)
- Passed internal and independent reviews
- Gitlab repo with everything related to the evaluation (input/output files, references, data in excel format)
- In queue for SINBAD taskforce review
- To be released to NEA through RSICC in FY25



Evaluation contents and status

SINBAD taskforce new process

- SINBAD maturity level: 4

SINBAD Maturity Level: 4

Process ID	Prerequistes	Maturity Level: 1	2	3	4	5
1	Re-distribution rights for experimental data and documentation has been obtained	☒				
2	Experiment documentation according to Section 1 of Evaluation Guide by SINBAD TRG, 2019					
2.1	- Description of the measurement facility		☒			
2.2	- Description of each measurement configuration		☒			
2.3	- Description of materials		☒			
2.4	- Description of radiation sources		☒			
2.5	- Measurement of input and output variables		☒			
2.6	- Data in basic machine-readable format (e.g. CSV)		☒			
3	Evaluation of measurement data according to Section 2 of Evaluation Guide by SINBAD TRG, 2019					
3.1	- Evaluation of measurement configuration			☒		
3.2	- Evaluation of radiation source			☒		
3.3	- Evaluation of the measured data			☒		
3.4	- Provision of computation models which have been used for evaluations			☒		
3.5	- Sensitivity and uncertainty analysis (including provision of computation models)				☒	
3.6	- Definition of scientific relevance based on 1*-3* scheme				☒	
4	Benchmark model (see Section 3 of Evaluation Guide SINBAD TRG, 2019)				☒	
5	Sample case results and input files for related computational models (see Section 4 of Evaluation Guide SINBAD TRG, 2019)				☒	
6	Geometry as CAD model					☐
7	Data in hierarchical machine readable data format (e.g. HDF5)					☐
8	Provision of automatic pre- & post-processing chain for the benchmark models					☐

Evaluation contents and status

SINBAD taskforce new process

- SINBAD scientific relevance: **

Current Scientific Relevance Rating of Benchmark: ** Benchmark of intermediate quality, suitable for education and training

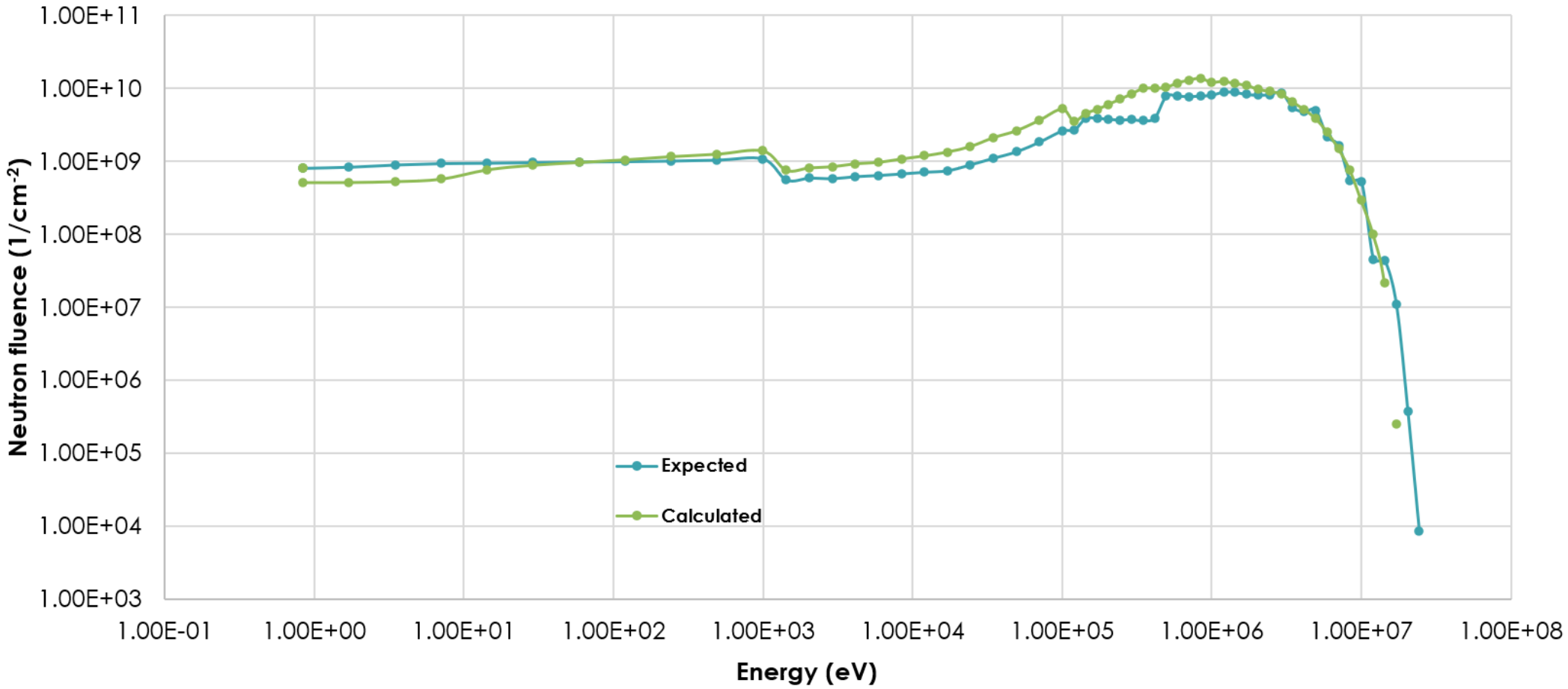
The maturity levels refer to the maturity of a benchmark evaluation and its documentation. The maturity level of a benchmark does not categorize its scientific relevance or its suitability for specific validation purposes. However, if a benchmark evaluation has reached a high maturity level, then the scientific relevance of the benchmark and its suitability with respect to a specific validation purpose can be easily derived from its evaluation. To categorize the scientific relevance and suitability of different SINBAD entries, the 1*-3* scheme as proposed by I. Kodeli and E. Sartori in "SINBAD – Radiation shielding benchmark experiments", Annals of Nuclear Energy, Vol. 159, is adopted:

- ***: Valid for nuclear data and code benchmarking
- **: Benchmarks of intermediate quality, suitable for education and training
- *: Benchmarks of historical interest The categorization might depend on the application case and the target accuracy of a related validation activity. If the scientific relevance categorization has not been performed yet, then it will be rated Rating to be done.

Benchmark and sample calculation results

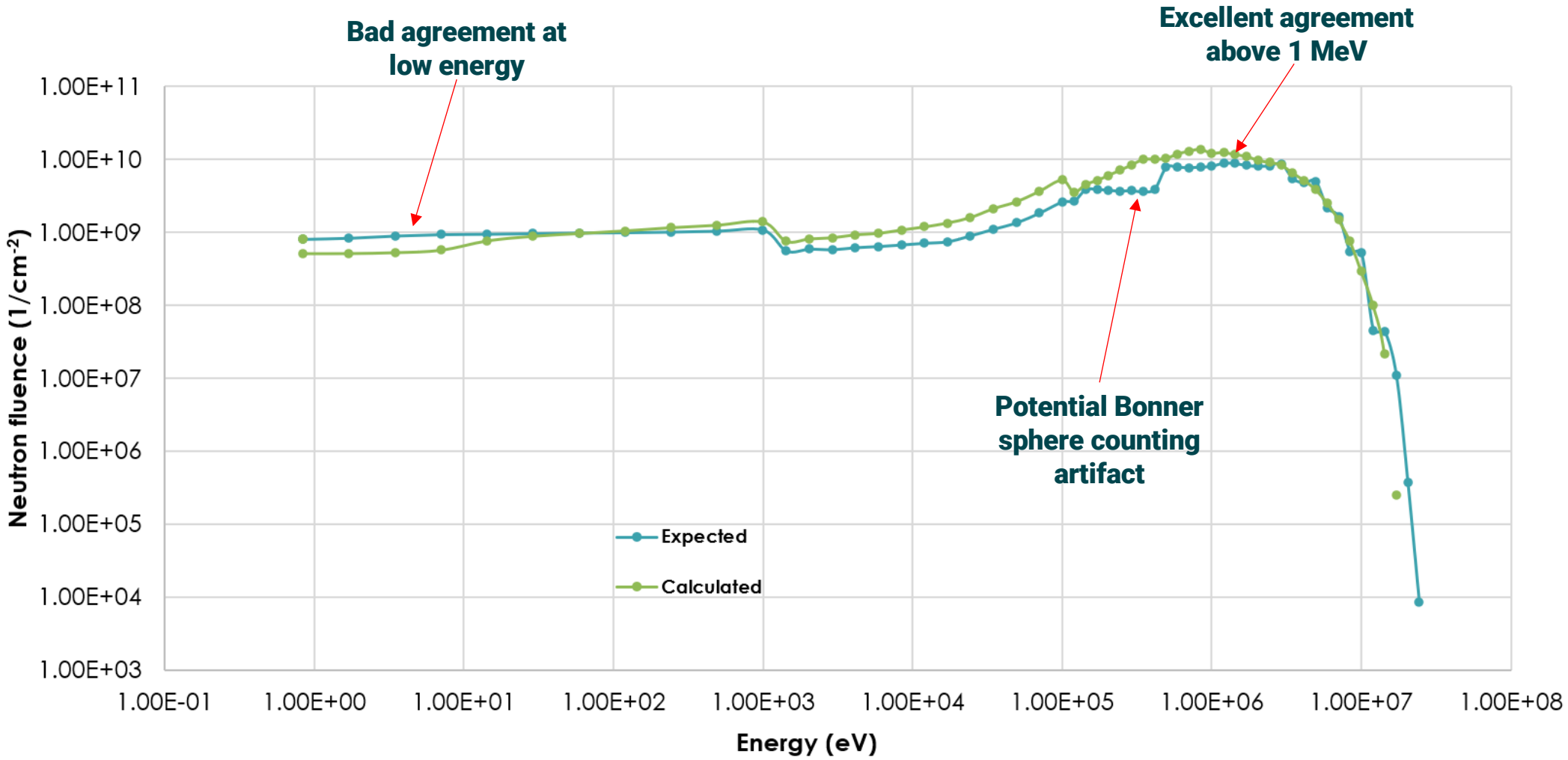
	Neutron fluence at 3 m from 10^{17} fissions of the HPRR							
	Expected		Calculated (SCALE 6.3.1 MAVRIC with ENDF/B-VIII.0)			Calculated (COG 11.3 with ENDF/B-VIII.0)		
Configuration	Neutron fluence (cm^{-2})	Relative standard uncertainty (%)	Neutron fluence (cm^{-2})	Relative standard uncertainty (%)	C/E	Neutron fluence (cm^{-2})	Relative standard uncertainty (%)	C/E
Bare	1.64E+11	20.40	2.33E + 11	0.07	1.42	2.16E + 11	0.12	1.32
Steel shield	9.08E+10	21.28	1.14E + 11	0.16	1.26	1.08E + 10	0.34	1.19
Lucite shield	3.55E+10	28.92	3.89E + 10	0.27	1.10	3.52E + 10	0.55	0.99

Benchmark and SCALE MAVRIC sample calculation results



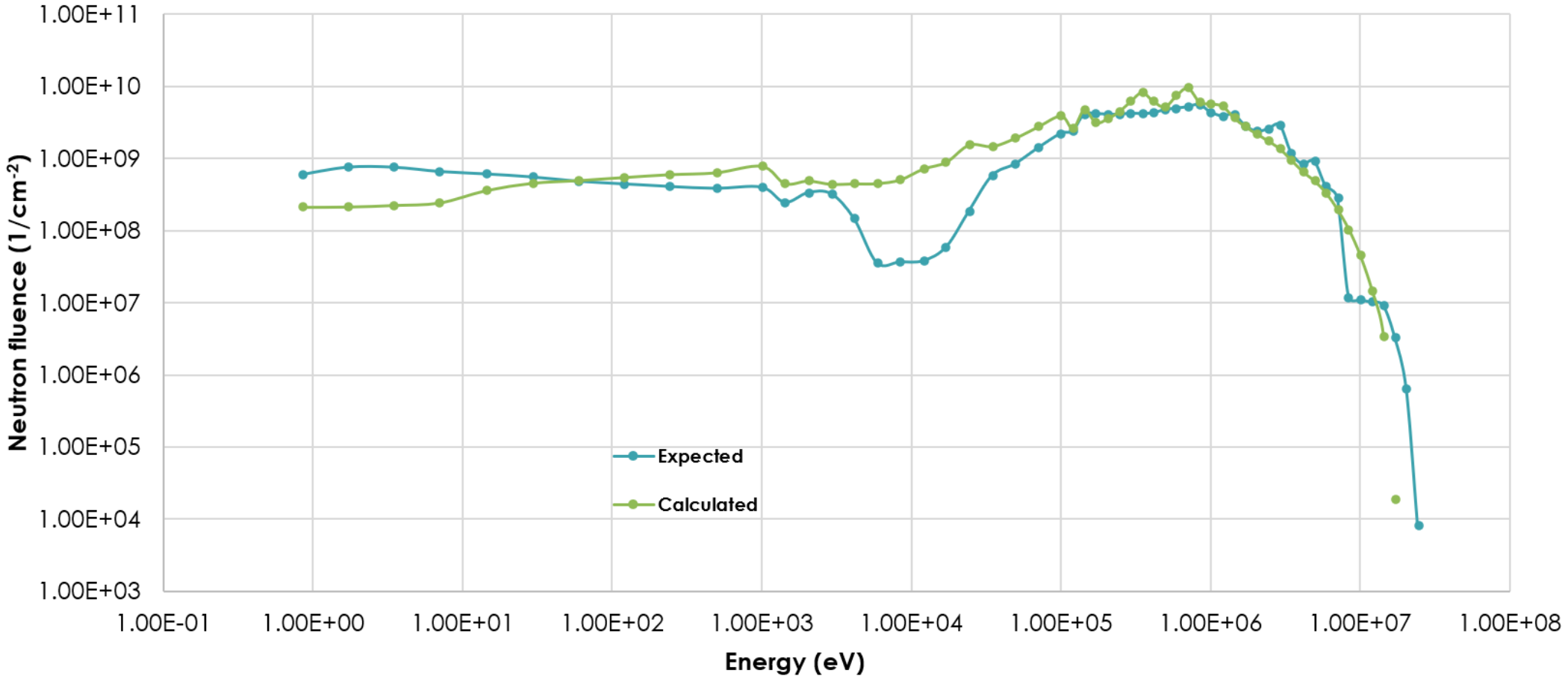
Bare configuration comparison

Benchmark and SCALE MAVRIC sample calculation results



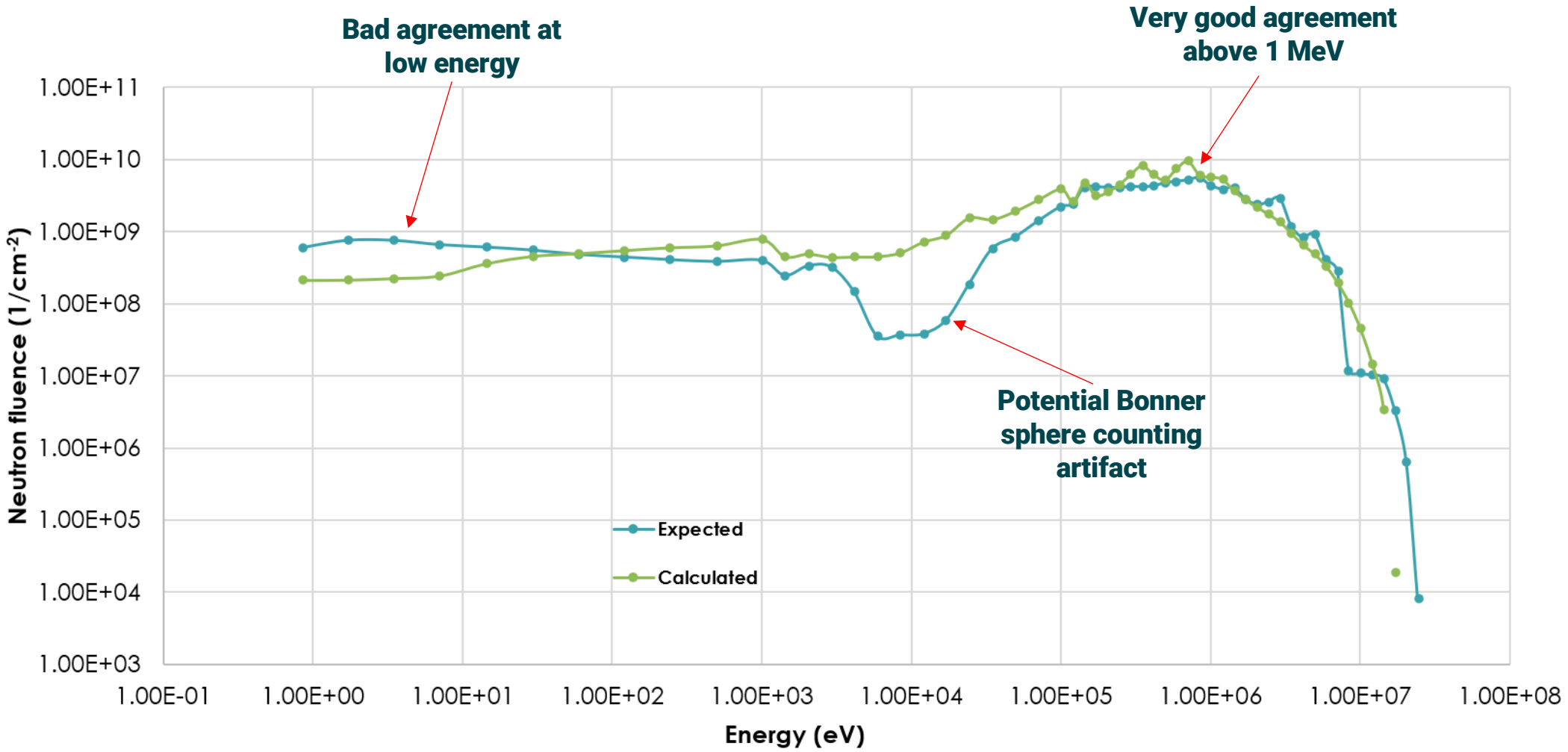
Bare configuration comparison

Benchmark and SCALE MAVRIC sample calculation results



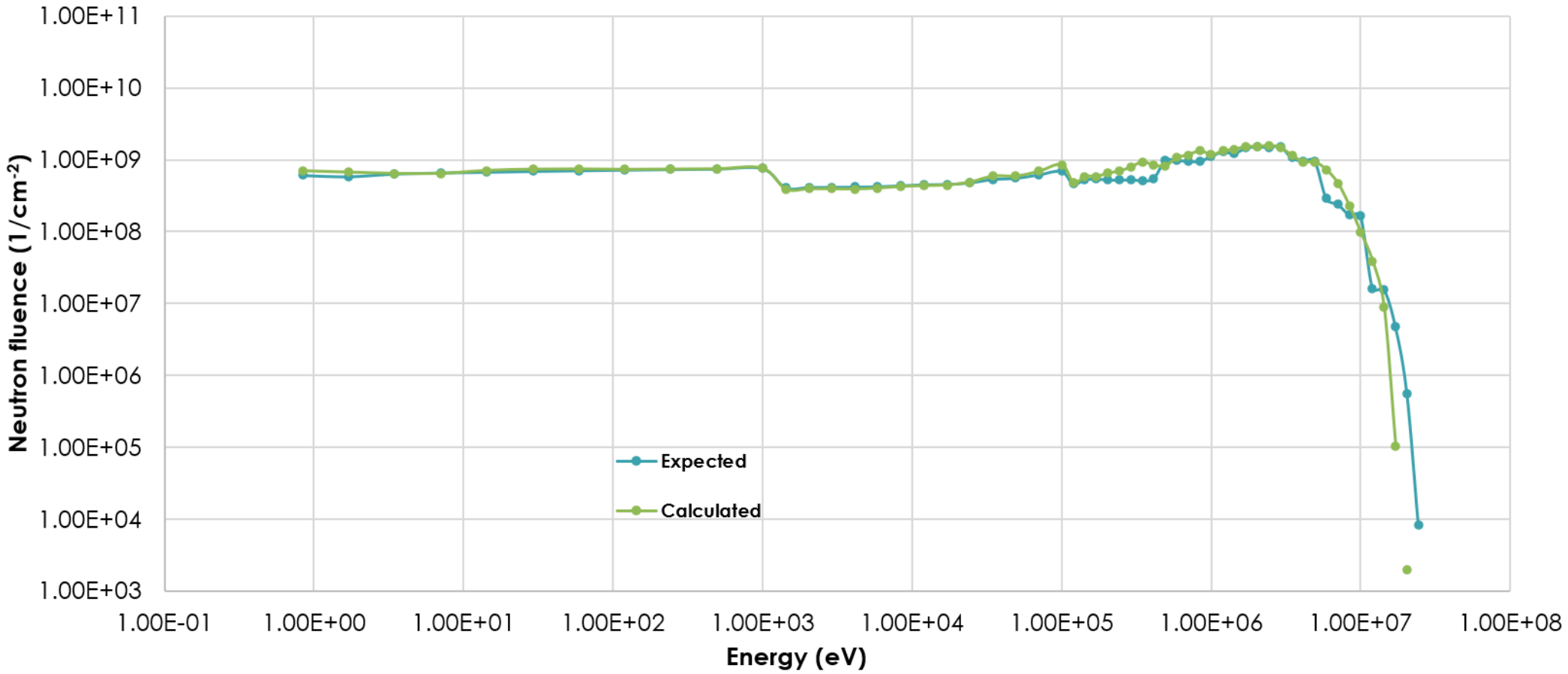
Steel-shielded configuration comparison

Benchmark and SCALE MAVRIC sample calculation results



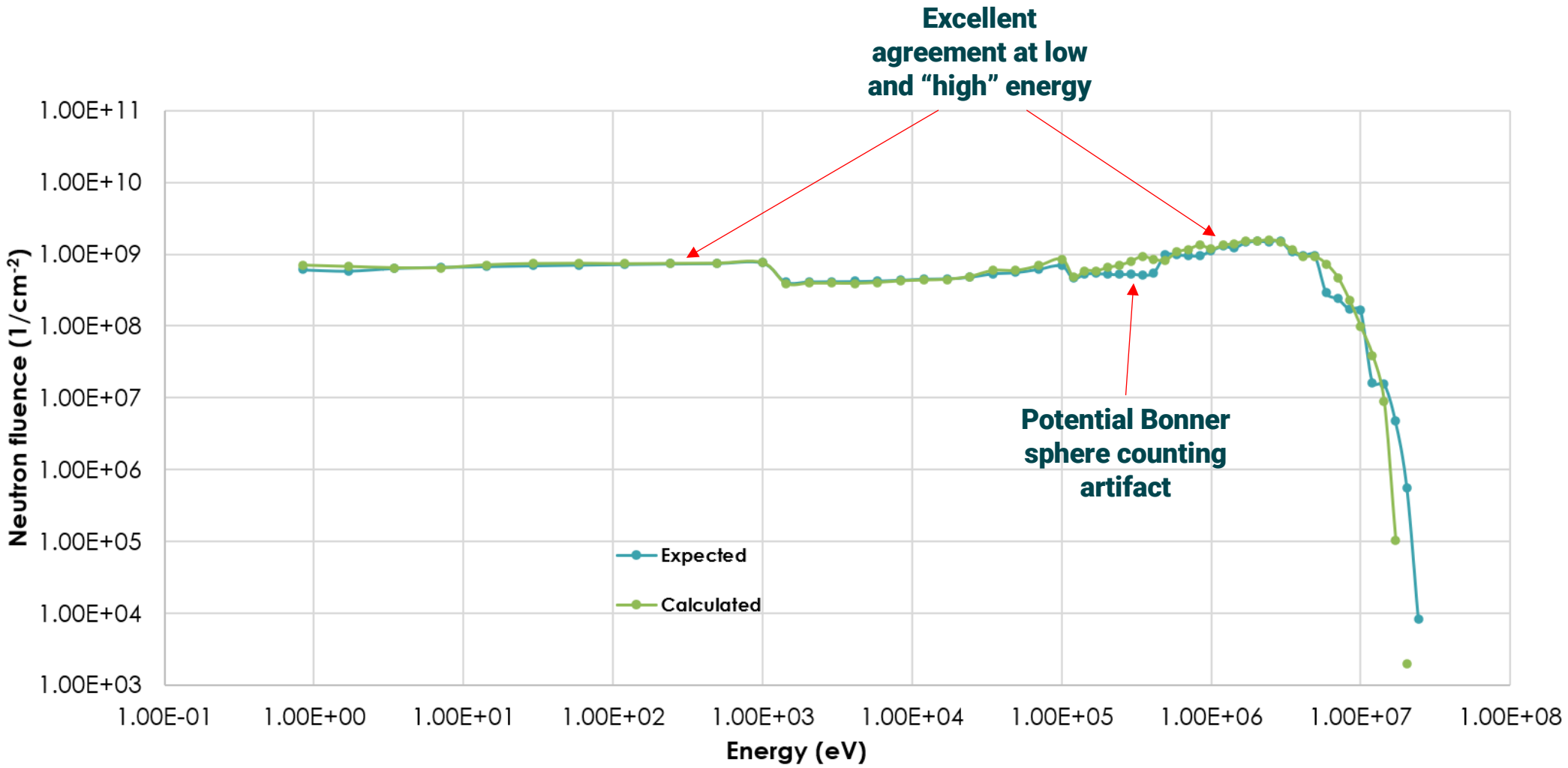
Steel-shielded configuration comparison

Benchmark and SCALE MAVRIC sample calculation results



Lucite-shielded configuration comparison

Benchmark and SCALE MAVRIC sample calculation results



Lucite-shielded configuration comparison

Benchmark and sample calculation results

	Neutron kerma at 3 m from 10^{17} fissions of the HPRR							
	Expected		Calculated (SCALE 6.3.1 MAVRIC with ENDF/B-VIII.0)			Calculated (COG 11.3 with ENDF/B-VIII.0)		
Configuration	Neutron kerma (Gy)	Relative Standard Uncertainty (%)	Neutron kerma (Gy)	Relative standard uncertainty (%)	C/E	Neutron kerma (Gy)	Relative standard uncertainty (%)	C/E
Bare	3.364	19.78	4.518	0.07	1.34	4.100	0.12	1.22
Steel shield	1.478	21.34	1.729	0.15	1.17	1.564	0.38	1.06
Lucite shield	0.561	29.62	0.680	0.26	1.21	0.581	0.55	1.04

Conclusions

- The SINBAD evaluation of legacy HPRR experiments, Version 1, will be released in SINBAD after taskforce review
- The evaluation will include neutron fluence and kerma with no shield, with a steel shield, and with a Lucite shield (6 cases)
- Sample calculation results are mostly good, with notable artifacts resulting from Bonner sphere unfolding imprecisions that seem hard to be solved
- Version 2 will include sulfur pellet neutron activation and gamma dose results with the same shield configurations; fast results may be included if there is interest

This presentation was supported by the Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the US Department of Energy

Questions?

ORNL News Photo - bus lost in front of the Melton Valley Complex, August 1966