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## Godiva IV Shielding Benchmark Overview

**Description** This presentation outlines a shielding benchmark project using Godiva IV as a source (ID Number IER-498) and discusses the implications of the Godiva IV Reproducibility work (IER 557)

Riley Cumberland



- Shielding Benchmarks: what they are and how they help
- The character of an integral experiment
- Why Godiva IV?
- The IER 498 benchmark quantity
- Proposed CED-2 test matrix ranges from low power to burst
- IER 498 enables several activities
- IER 557 has aided IER 498

# SHIELDING BENCHMARKS SUPPORT NUCLEAR DEVELOPMENT

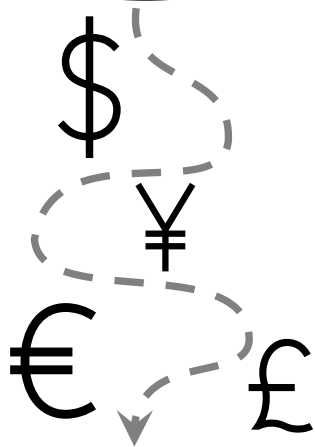


- Dose can vary by 10 orders of magnitude
- 20% is more than sufficient in many applications,
  - and 1-2 cm of extra lead is often cheap.
  - dose is often easy to measure and check

However...

- For mobile applications such as casks, micro reactors, space reactors, ocean-going reactors, shielding is expensive.

80 years into the nuclear era, substantial work remains to develop a database of shielding benchmarks

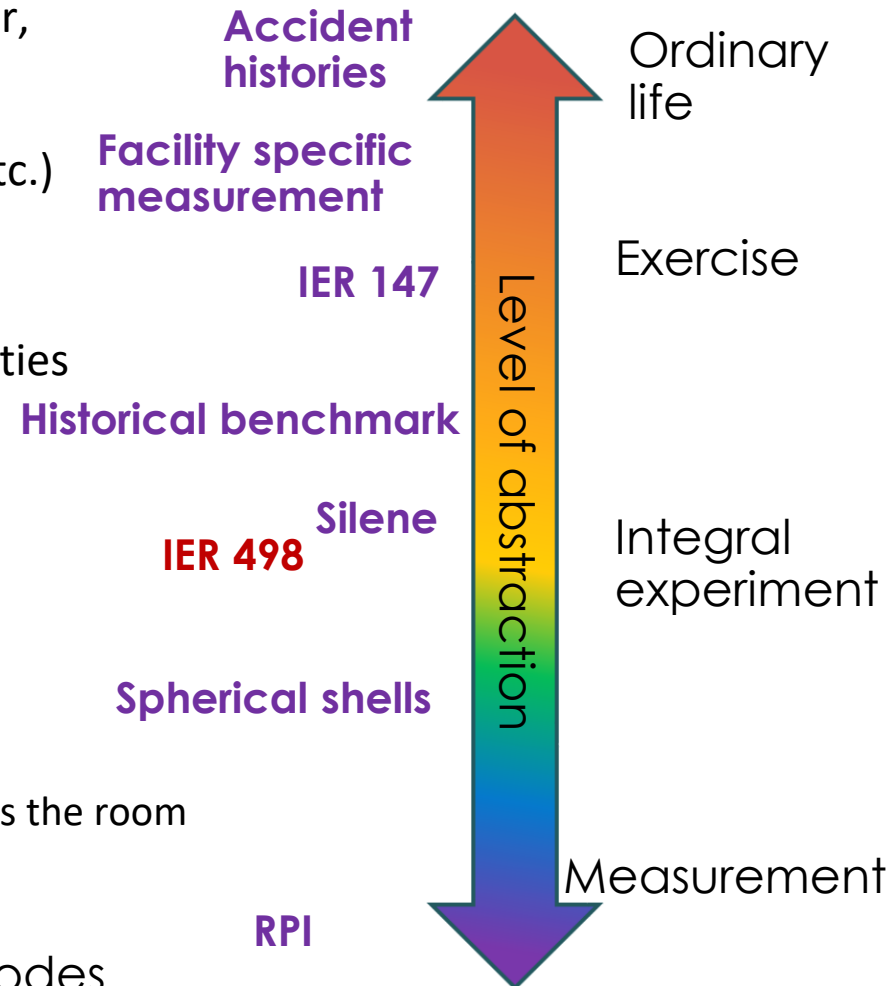


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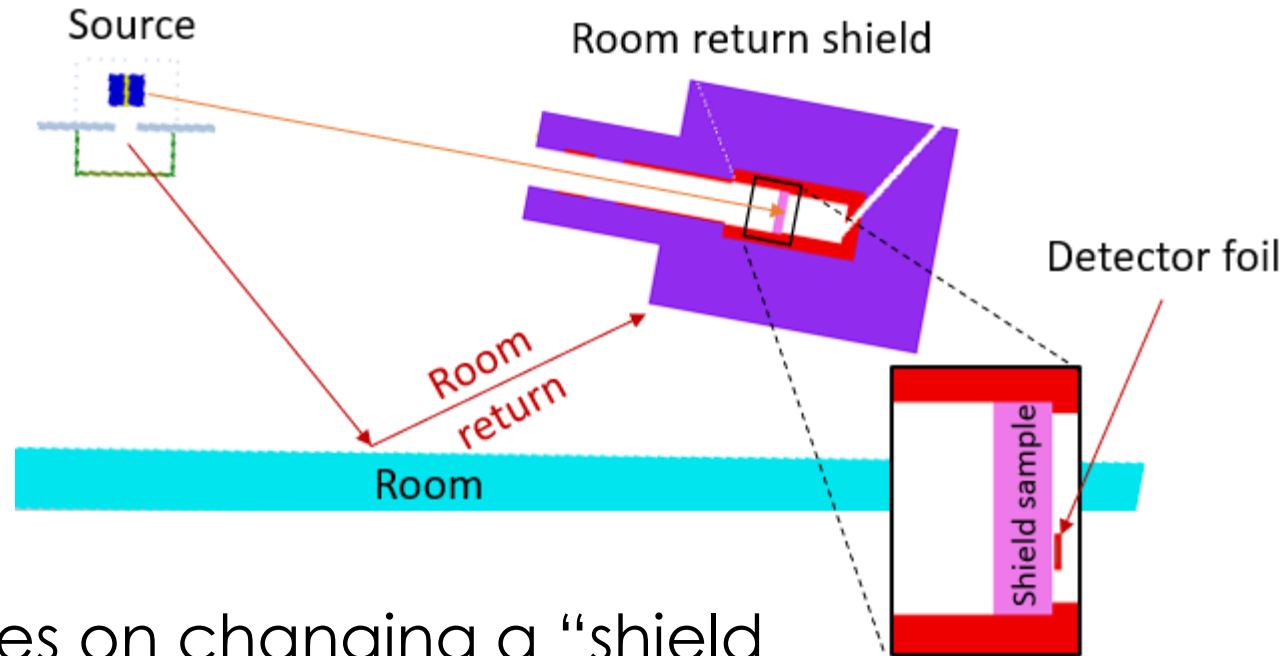
<sup>b</sup>Adam Malin/Oak Ridge National Laboratory, U.S. Dept. of Energy

# BENCHMARK DIVERSITY AND DEPTH ARE BOTH IMPORTANT

- Similar enough to applications of nuclear simulation codes
  - Applicable materials (fuel, reflector, moderator, absorber, structural, and shield)
  - Applicable neutron and gamma spectrum
  - Applicable metrics (dose, reaction rate, flux, etc.)
  - Similar source
- Tractability
  - Easily manageable and/or justifiable uncertainties
  - Easy to simulate benchmark geometry
- “Good” data
  - Uncertainty < 20% for a shielding benchmark
- Informs nuclear data needs
  - e.g., “How bad is the (n,γ) data?”
- Provides tacit knowledge
  - How much variation is due to detector uncertainty vs the room environment?
  - When does geometry matter?
- A level of validation to CAAS simulation codes and geometries



# DESIGN IS FOCUSED ON ISOLATING THE SHIELDING EFFECT OF A MATERIAL



- Experiment focuses on changing a “shield sample” between measurements.
- Radiation scattered from the room can dominate measurements.
  - Therefore a room return shield is used.

# COMPARISONS MITIGATE PERFORMANCE RISK



The test relies on a comparison of shield sample vs no-shield sample to reduce uncertainty



VS



Shielded measurement, with bias uncertainty

Baseline measurement, with bias uncertainty

Effect of shielding

$$\text{Benchmark Quantity } Q = \frac{x_{i,shielded}}{x_{i,baseline}}$$

$Q_{Trial1} \cong Q_{Trial2}$   $\Rightarrow$  Confidence in the measurements

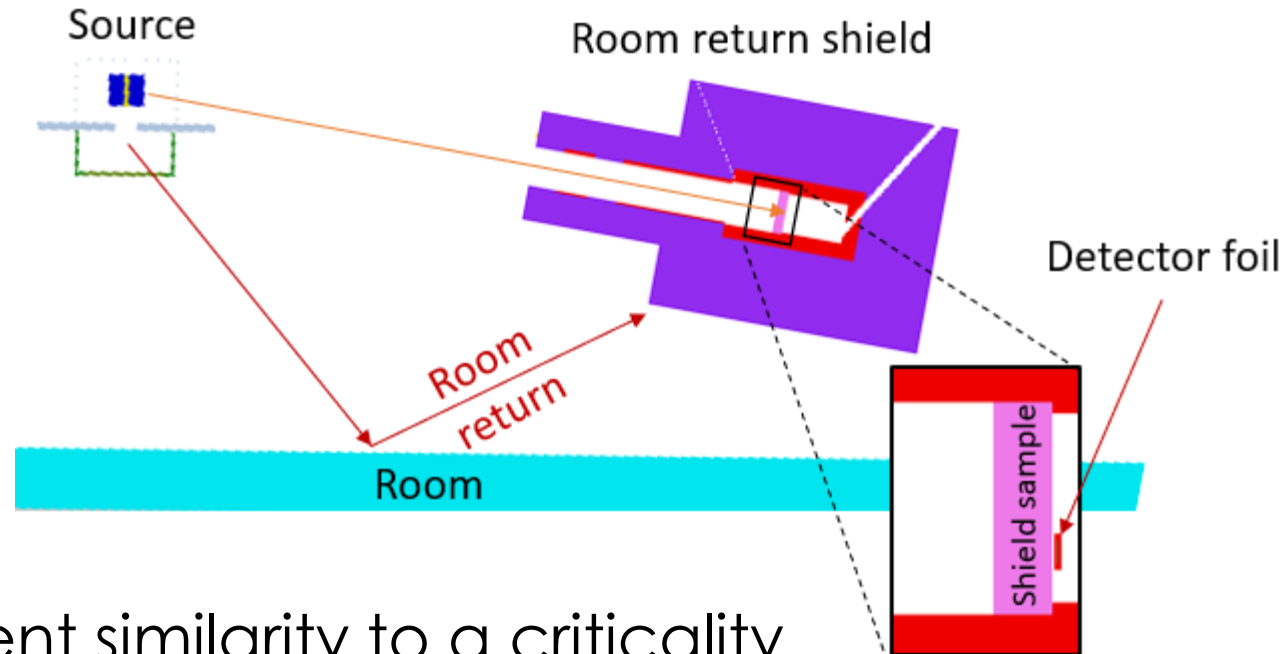
$Q \cong Q_{simulated}$   $\Rightarrow$  Confidence in the simulation of shielding sample

$x \cong x_{simulated}$   $\Rightarrow$  Confidence in full simulation (very lucky)

Ensuring sufficient similarity in burst is fundamentally necessary for this method

\*Fantasy Art Bogeyman in Deep by David S. Soriano. Creative commons share and share alike 4.0

# GODIVA IV CAN PROVIDE A UNIQUE SERIES OF BENCHMARKS



- Source has inherent similarity to a criticality accident
  - Can we inform on other uncertainties besides nuclear data?
  - When is nuclear data the dominant uncertainty?
- Real super prompt critical fast spectrum burst with limited room return
- Source is strong enough to use foils as detectors

# Preliminary test matrix in CED2 report ranges from low power to burst

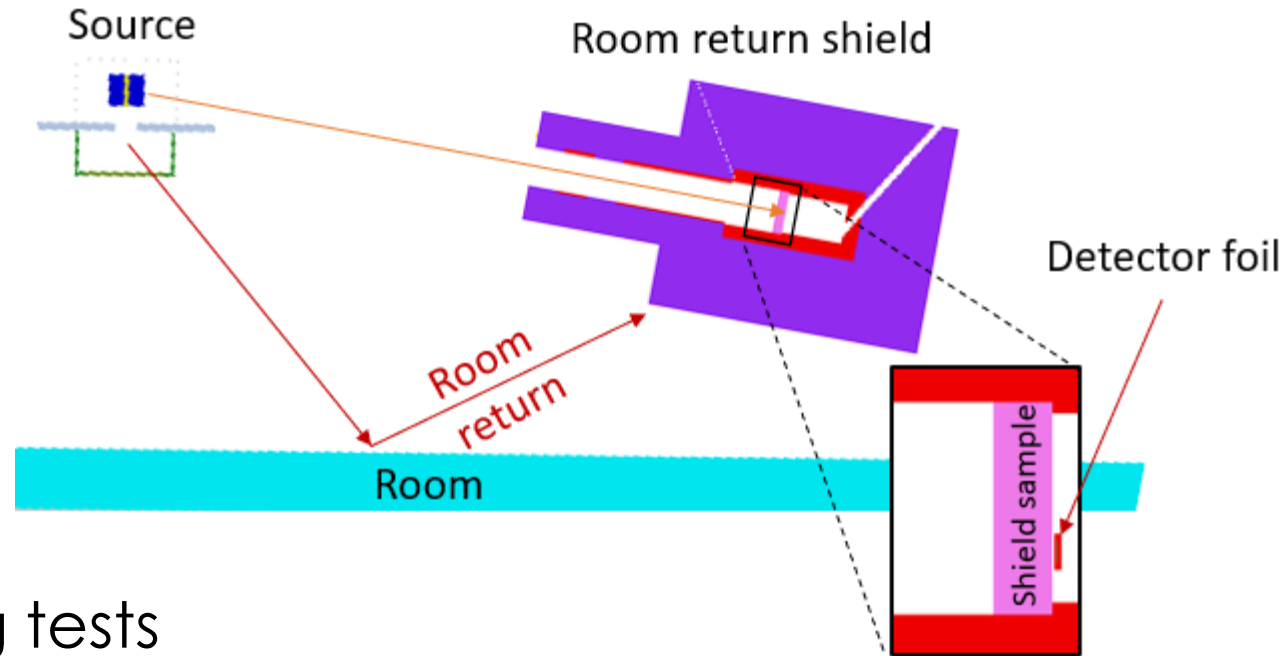


- The burst operations can provide more foil information
- The steady-state operation provides contrasting data, with fewer passive detectors
- The steady-state operation with electronic detectors can provide a second cross-comparison
  - Could enable streamlined experiments
- Materials are selected to minimize nuclear data and material data used

Table 17. Test matrix.

Shielding Sample	Number of Detectors		
	Steady state operation electronic detectors	Steady state operation passive detectors	Burst operation passive detectors
Blank	2+	2	2
Pb 10cm	1	1	2
Pb 5cm	1	1	2
PE 10cm	1	1	2
PE 5cm	1	1	2
SiO <sub>2</sub> 10cm	1	1	2
SiO <sub>2</sub> 5cm	1	1	2
total	8+	8	14

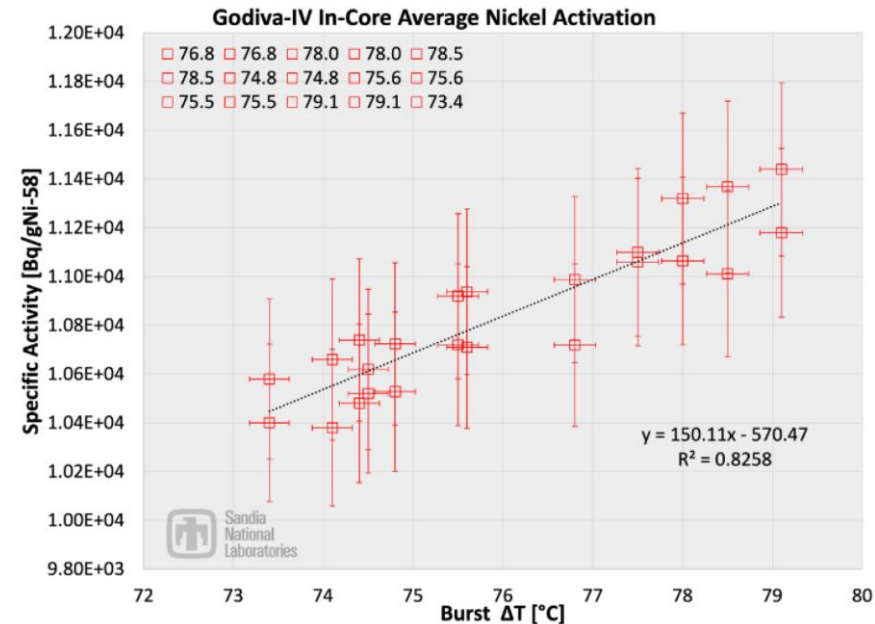
# IER 498 ENABLES SEVERAL ACTIVITIES



- A suite of shielding tests
  - Highlight (n, $\gamma$ ) reaction
  - Highlight material mixtures (resonance overlaps)
- Diagnostic measurements of room reflection at specific locations and perhaps from specific materials
- Sufficient agreement using electronic detectors could enable further use, potentially streamlining experiments

# IER 557 Evaluated Godiva IV Burst Reproducibility

- Provided recent onsite experience with foil counting
- Sandia, PNNL and LANL performed measurements and analysis
- Demonstrated the reproducibility for  $\Delta T=70C$ 
  - We can claim a  $1\sigma$  uncertainty of 3%
  - All we needed was 7%



- Integral experiments increase the level of realism from that of data measurements.
- Godiva IV is capable of intensities to activate foils
- IER 498 uses a relative measurement to provide an intermediate level of realism.
  - Reproducibility and room return management are key components
  - The test matrix put forward in CED-2 enables numerous cross-comparisons
- IER 498 facilitates various additional works using a room return shield to isolate the source
- IER 557 demonstrated burst reproducibility sufficient for IER 498