



ADVANCED REACTOR SAFEGUARDS

# Experimental Validation of NDA Capabilities for MSR Safeguards

PRESENTED BY

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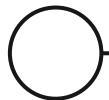
# This work will enable maximum use of rapid, cost-effective nondestructive assay (NDA) to meet safeguards requirements for MSRs

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## Objective:

- Conduct the first modern experimental nondestructive assay campaign focused on MSR safeguards to produce a comprehensive set of validated measurement capabilities for safeguards models.
- Directly measure NDA uncertainty
- Potential to include other non-traditional fuels like TRISO pebbles

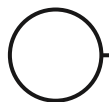


# Goals

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1. Measure gamma-ray and neutron signatures from nuclear material samples that have characteristics similar to material at an operating MSR
2. Assess limits of rapid anomaly detection and characterization of material compositions with traditional and advanced NDA technologies
3. Evaluate NDA concepts for harsh, high-radiation environments



# Collaboration



Mark Croce, Matthew Carpenter, Daniela Henzlova, Katrina Koehler, Howard Menlove, David Mercer, Athena Sagadevan, Katherine Schreiber, Rico Schoenemann, Sophie Weidenbenner, Duc Vo



Michael Dion, Bruce Bevard, Robert Morris, Joe Giaquinto, Wade Ivey, Ben Roach, Riley Hunley, Robert McElroy



Jeffrey Sanders



Daniel Becker, Joel Ullom

# Project highlights

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## **FY20: Gamma measurement campaign at LANL**

- Irradiated fuel and separation process samples received from Argonne
- Direct comparison of performance between high-purity germanium and microcalorimeter gamma spectrometers

## **FY21: Neutron measurement campaign at ORNL**

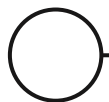
- Irradiated fuel rod sections measured at IFEL hot cell
  - Process monitoring signatures demonstrated
  - Direct comparison of performance between miniHDND,  $^3\text{He}$ , and fission chamber neutron detectors
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# Example Comparison Data

Measured at ORNL Irradiated Fuels Examination Facility Hot Cells



| Item ID | Dose rate [R/h] | Burnup [GWd/MTU] | Cooling Time [Years] | MiniHDND                 |          | <sup>3</sup> He          |          | Fission Chamber          |          |
|---------|-----------------|------------------|----------------------|--------------------------|----------|--------------------------|----------|--------------------------|----------|
|         |                 |                  |                      | Neutron Count Rate [cps] | $\sigma$ | Neutron Count Rate [cps] | $\sigma$ | Neutron Count Rate [cps] | $\sigma$ |
| 1       | 208             | 64               | 21.2                 | 92.04                    | 3.00     | 133.6                    | 1.2      | 2.64                     | 0.09     |
| 2       | 140             | 49               | 32.3                 | 75.27                    | 3.04     | 108.8                    | 1.3      | -                        | -        |
| 3       | 144             | 57               | 26.7                 | 39.83                    | 2.99     | 58.0                     | 1.3      | -                        | -        |
| 4       | 192             | 59               | 17.1                 | 72.92                    | 3.01     | 103.5                    | 1.9      | -                        | -        |
| 5       | 244             | 57               | 10.7                 | 83.2                     | 3.00     | 113.2                    | 1.8      | 2.13                     | 0.13     |



# FY22 Tasks

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ORNL measurement campaign focused on gamma measurements of dissolved irradiated fuel materials

- Radiochemistry laboratory samples with precisely known composition – compare NDA and DA results
- Hybrid K-edge Densitometry to evaluate NDA based on X-ray interrogation

INL measurement campaign focused on gamma measurements of salt-based irradiated fuel materials

- Materials and Fuels Complex Analytical Laboratory
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# ORNL measurements – Summer 2022



Primary goal is to evaluate gamma NDA against DA for unusually well-characterized spent fuel solution samples

Gamma standard solution measurements will enable evaluation of absolute activity quantification

Direct comparison of SOFIA microcalorimeter spectrometer, HPGe, and CZT performance

Currently coordinating with NA-241 Safeguards Technology Development program on SOFIA measurement schedule – demo for IAEA/NWAL proposed in August





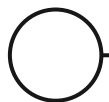
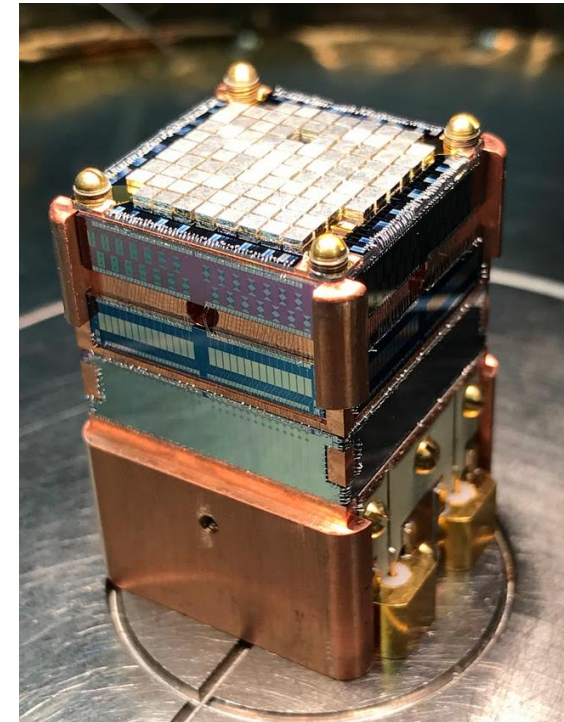
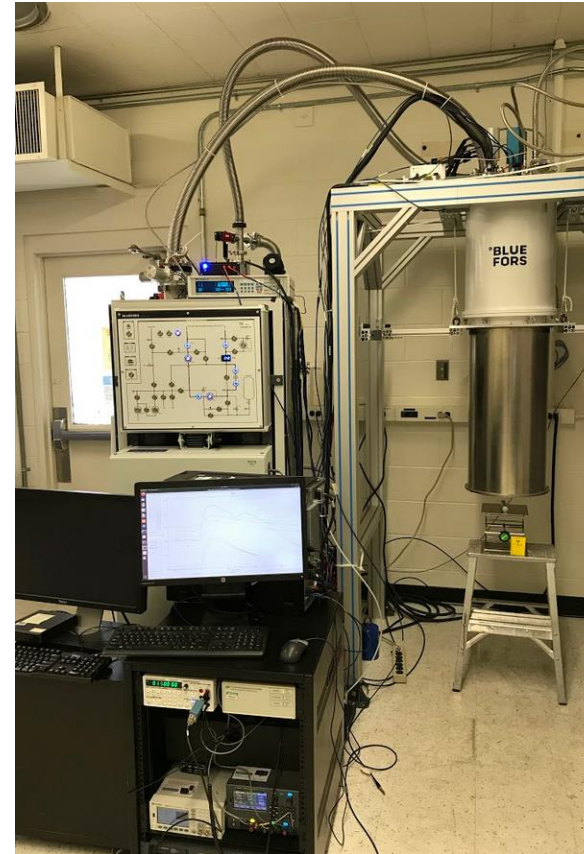
# INL Measurements – Summer 2022



Primary goal is to evaluate gamma NDA for salt-based irradiated fuel materials in MFC analytical laboratory

Solidified electrorefiner salt samples with varying fissile material composition

Direct comparison of microcalorimeter spectrometer, HPGe, and CZT performance



# FY23 Opportunities



Refocus on pebble bed reactors:

How effective are NDA technologies for rapid composition measurements of individual pebbles?

- Irradiated TRISO fuel compacts available at ORNL
- Short-lived fission products
  - Fuel testing at INL, ORNL
  - Fission product studies at PNNL



*FY21 experience at ORNL IFEL*

# Summary

Contact:

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## FY20-22: gamma and neutron measurement campaigns

- Direct comparison between HPGe and microcal for irradiated fuel samples
- Direct comparison between  $^3\text{He}$ , fission chamber, and miniHDND for irradiated fuel rod sections in increasingly realistic environment
- Move to increasingly realistic materials at ORNL and INL to directly compare gamma detector technologies

## FY23: pebble bed reactor focus

– move towards supporting demonstration reactors?

- Irradiated TRISO compacts
- Short-lived fission products

*Thank you to the Advanced Reactor Safeguards Program for supporting this work*