A Field-Portable Neutron Resonance Capture Analysis System

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Introduction and Motivation:

The thorium fuel cycle presents new safeguards challenges

- The thorium fuel cycle (molten salt reactor and traditional reactor concepts) will feature an array of fuel isotopics in diverse chemical and physical forms
- Fissile and fertile actinides subject to safeguards accountancy will be co-mingled in fuel
- Many of these isotopes have overlapping or indistinguishable passive signatures (Worrall et al. 2016; Swift et al. 2020)

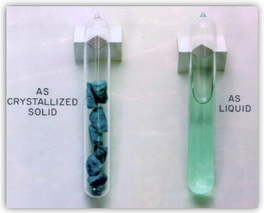
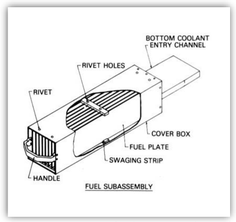


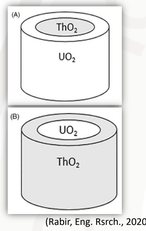
Photo: ORNL / DOE

MSR Fuel
(LiF –BeF-ThF_4-UF_4)



(Baghwat, Nuc. Tech., 1993)

Kamini Th LWR Plate Fuel
(Al-clad ^{233}U)



(Rabir, Eng. Rsrch., 2020)
also, (van der Walt, Nuc. Eng., 2023)

Heterogeneous or duplex PWR fuel pins
(ThO_2-UO_2)

Research Question:

Can we develop an active, portable neutron resonance analysis system that is sensitive to nuclear fuel cycle isotopes in varying forms and concentrations?

Mission Relevance:

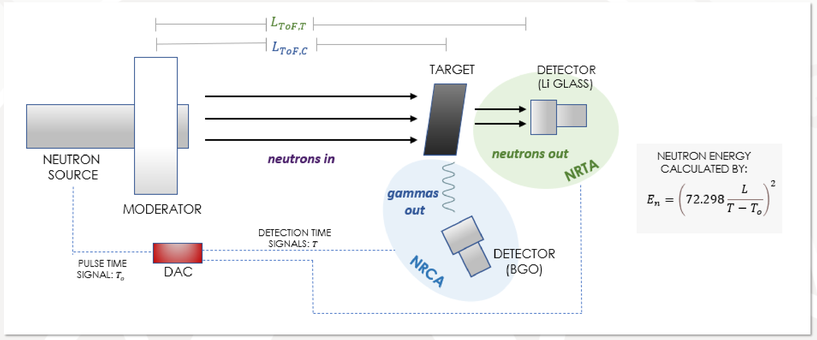
Techniques that assay a range of materials in emerging nuclear fuel cycles can increase safeguards efficiency and effectiveness

- The development of safeguards tech facilitates the IAEA in verifying State declarations are correct and complete
- This is a critical aspect of NNSA's mission to build IAEA capability to implement safeguard obligations

Technical Approach:

Neutron Resonance Capture Analysis (NRCA) is nondestructive and isotopically-sensitive

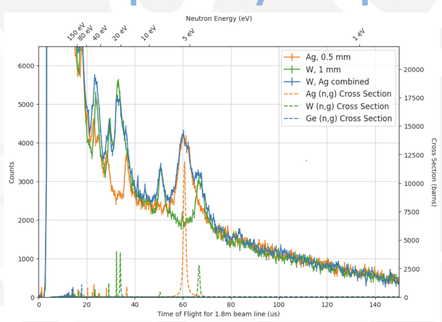
- This research uses time-correlated radiative capture gamma rays to reconstruct the epithermal resonance profile of the sample
- It builds upon a successful demonstration of portable Neutron Resonance Transmission Analysis (NTRA) (Klein, et al. 2021)

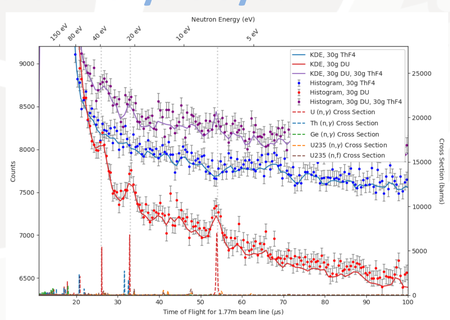


- Experimental design: a DT generator and 2-meter beam path miniaturize a previously large-facility analysis technique
- NCRA may be performed simultaneously on a sample with NRTA

Results:

NRCA is sensitive to isotopic content and quantity in a portable analysis system





- (Left) Radiative capture gamma counts as a function of neutron time of flight, 3" BGO detector, 20 minute runs (background-subtracted). Initial results show good agreement with target isotopic composition.
- (Right) Small samples of U-238 (30g) and ThF4 (30g), and a combined sample (60g) show U-238 resonance structure is visible even when combined with the higher-activity thorium. Quantity studies are underway (note: TOF plots have background removed and energy cuts applied to select gammas between 1.1-2.4 MeV and greater than 2.8 MeV)

Expected Impact:

A field-portable system that can distinguish isotopes in mixed samples

MTV Impact:

Research Partnerships:
Pacific Northwest National Laboratory
Lawrence Livermore National Laboratory (DPF)
MIT Bates Accelerator Research Lab

MTV Researchers Since 2020:
6 Grad Students
2 Undergrads
2 Summer Interns
2 Post-Docs

Conclusion:

Initial actinide experiments indicate NRCA sensitivity to changing quantities of isotopes relevant to the thorium fuel cycle, with the potential to fill critical information gaps

This work has a strong potential to contribute to the NNSA mission of nonproliferation through the development and testing of a robust and portable new safeguards technology.

Next Steps

- Collaboration with PNNL continues
- NRCA experiments on fissile isotopes at PNNL planned for April 2024
- NRTA neutron detector trade study is ongoing

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National Nuclear Security Administration

PNNL Release Number: