Nuclear Chemical Engineering and Nuclear Engineering (NCE/NE) Focus Area

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Department of Nuclear Engineering
University of California Berkeley

NSSC3 Kickoff Meeting and Advisory Board Review
April 19-20, 2022

Key Personnel

M. Fratoni, R. Scarlat, R. Abergel, P. Hosemann, J. Vujic

Ken Czerwinski, Dan Koury, Frederic Poineau, Art Gelis

Vlad Sobes

Osman Anderoglu

Angela di Fulvio

Rodolfo Vaghetto

Laboratory Partners

LANL: Marisa Monreal, Keri Campbell

LBNL: Tenzing Joshi, Vassilia Zorba, Wayne Lukens

ORNL: K. Myhre, J. Esseld, C. Phelps, B. Betzler, A. Worrall

SNL: D. Farley, E. Uribe

LLNL: B. Canion, Y. Feldman, L. Kim, V. Mozin, H. Saito

NCE/NE Overview

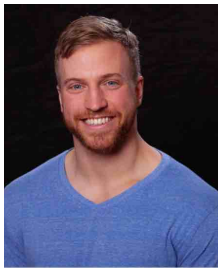
The potential development and deployment of advanced and alternative fuels and the associated fuel cycle facilities pose new challenges to the NNSA mission to detect, secure, and dispose of nuclear and radiological materials, as well as to monitor and safeguard nuclear materials and associated processes.

Relevant topics:

- Safeguards for emerging fuel cycles, including for molten salt reactors (MSRs).
- Proliferation resistant fuel technology.
- Radioisotope production.
- In situ monitoring of alternative fuel cycles.
- Volatility, solubility, and speciation as fuel cycle signatures.

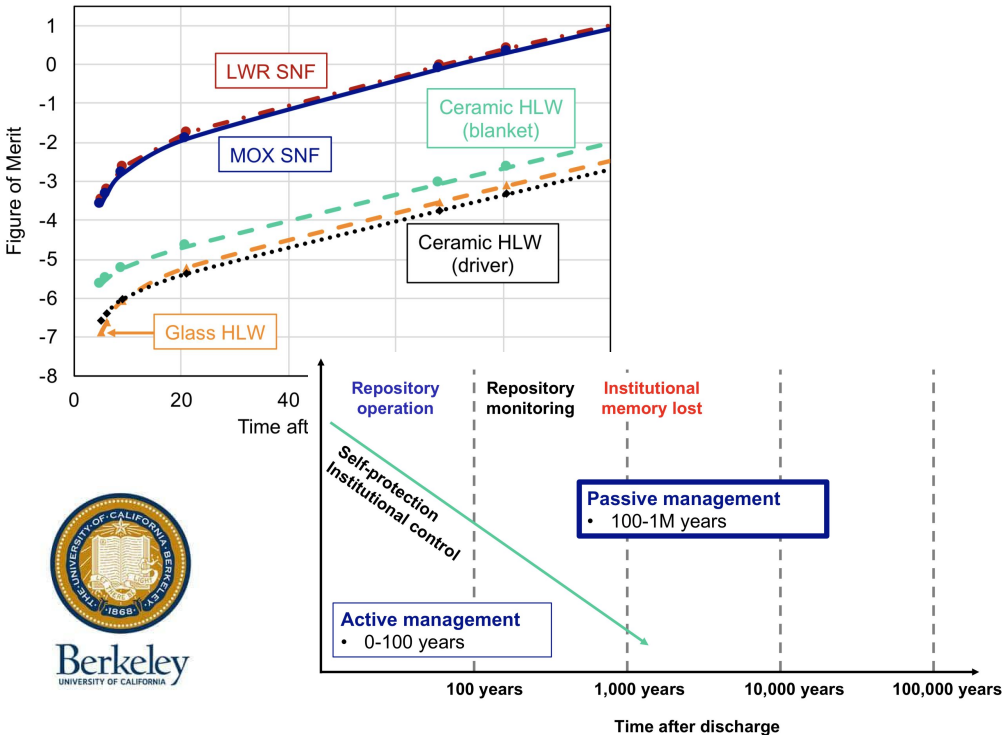
Materials attractiveness in advanced fuel cycles

UCB Student: Milos Atz
UCB Advisor: Massimiliano Fratoni



NNSA-Relevant Outcomes
The materials attractiveness of materials generated by any advanced fuel cycle was evaluated to inform safeguards requirements.

Milos is currently a staff member at ANL



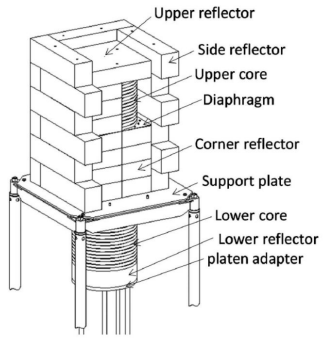
Nuclear interaction uncertainties in lead systems

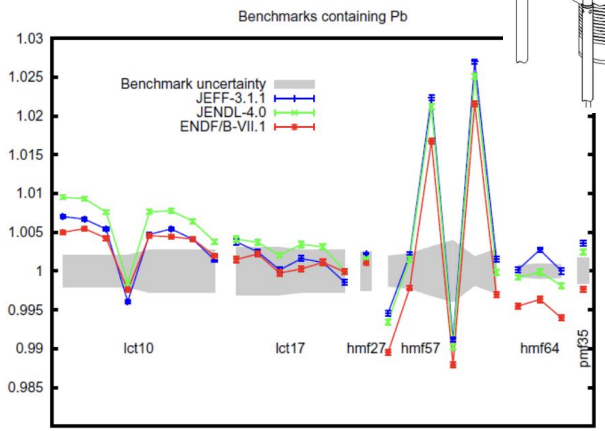
UCB Student: Kelsey Amudson
UCB Advisor: Massimiliano Fratoni

NNSA-Relevant Outcomes

Data of needs for advanced reactors
Repatriation of HEU and Pu from Japan (NA-23 program)

Kelsey is currently a R&D Engineer for Advanced Nuclear Technology at LANL





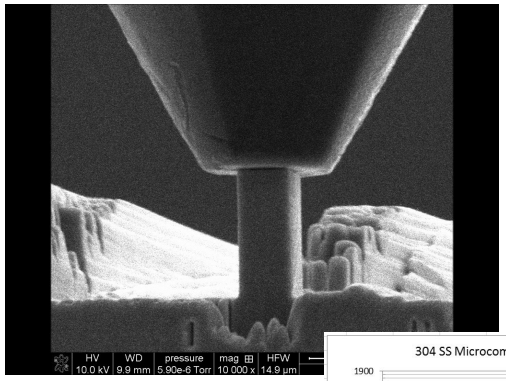
Microscale mechanical testing

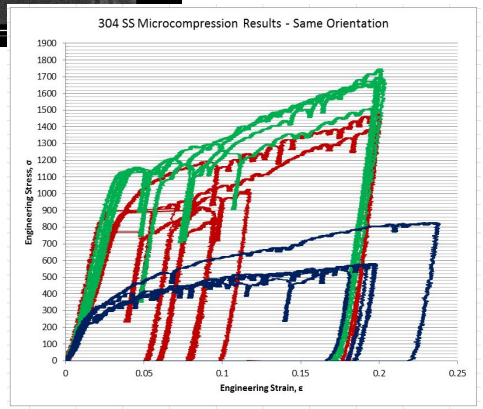
Impact of U-232 doping to improve enriched uranium detectability

UCB Student: Hi Vo
UCB Advisor: Peter Hosemann

NNSA-Relevant Outcomes
Measuring mechanical properties of micrometer size particles to gain insights into material history

Hi is currently a staff member at LANL



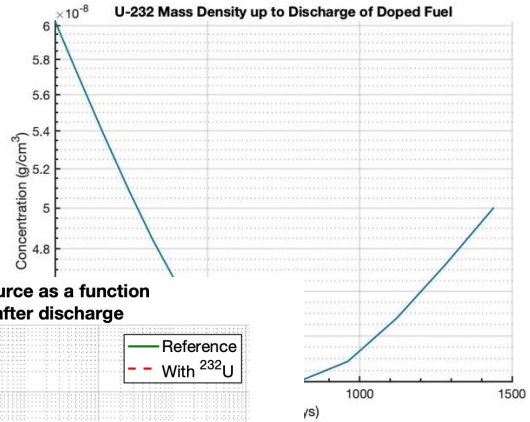


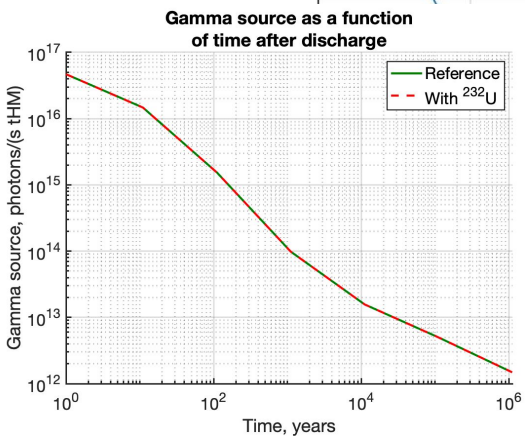
UCB Student: Samuel Varghese
UCB Advisor: Massimiliano Fratoni

NNSA-Relevant Outcomes

Data of needs for advanced reactors
Repatriation of HEU and Pu from Japan (NA-23 program)

Sam is currently an intern at LLNL

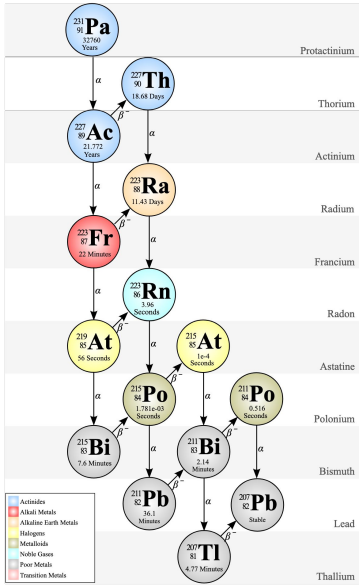


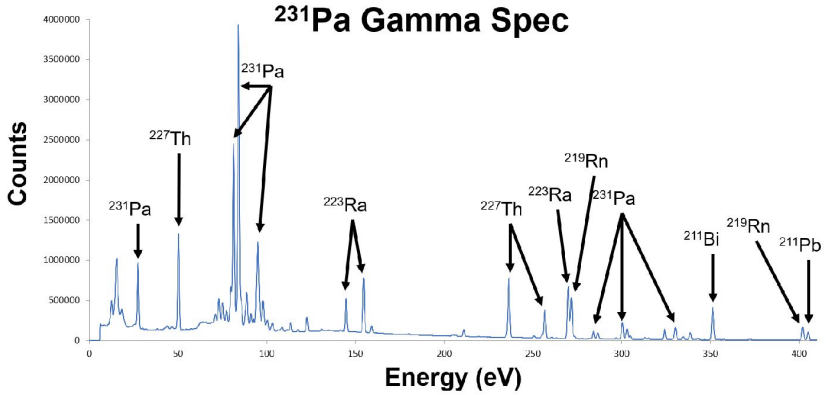


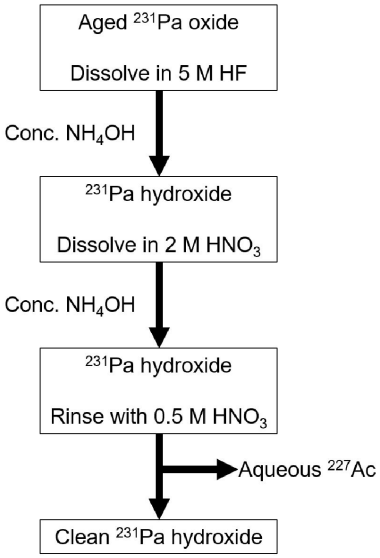
Actinide Detection and Separation

- UCB Advisor: **R. Abergel**
- Postdoc: **A. Gaiser** (Berkeley, moving to faculty position at U. Mich / FRIBE)
- Collaboration with SNL: **D. Farley** and **E. Uribe**

Laying the groundwork for Pu/U and Th/Pa separations technologies that will be relevant for online reprocessing of fissile materials in molten salt directly applicable to Molten Salt Reactor (MSR) development. Purification of legacy Pa-231 materials followed by sample spikes in various salt environments for characterization. The goal is for this work to move from chemistry to the engineering focus, with the goal to setup a salt loop with actinides.





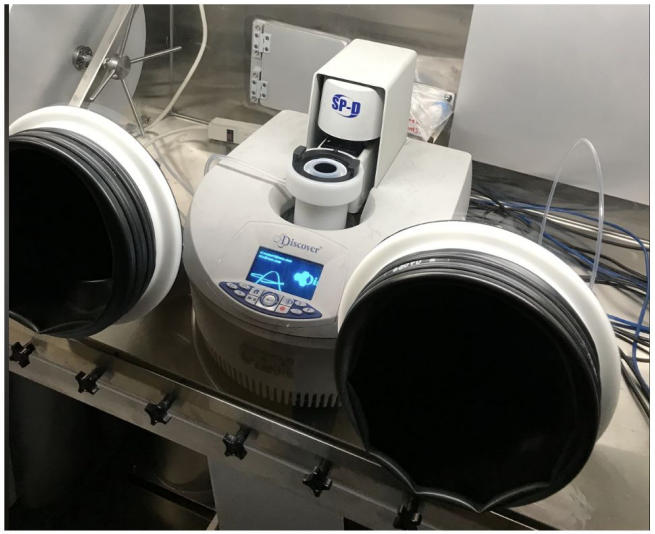


Chemical Analysis and Chemical Sensors for Molten Salts

Student: **Sasha Kennedy**
UCB Advisor: **Raluca O. Scarlat**
LANL Mentor: **Marisa Monreal**

Relevance and long-term goals: Detect signatures of activity at fuel cycle facilities and sites of advanced reactors. For example, the impact of air ingress on speciation and, consequently, solubility and volatility of actinides and fission products, and the ability to detect a breach of containment, which may signal material diversion. Electrochemical techniques can lend themselves to development of chemical sensors that are robust, that could be distributed, and that can also be portable. Applications can range to detection of redox potential, oxide content, or concentration of a specific species, to detection of air ingress via process monitoring, or other deviations from normal process operation.

Microwave Digestion for Elemental Analysis Method Development

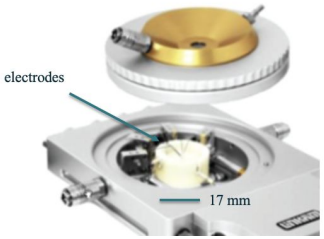


Optical Spectroscopy

1000 °C Optical Cell
with electrochemical probes

compatible with:

In-glove-box optical microscope
Raman
UV-Vis with Optical Fiber Connectors
GCMS Gas Analysis and Gas Control

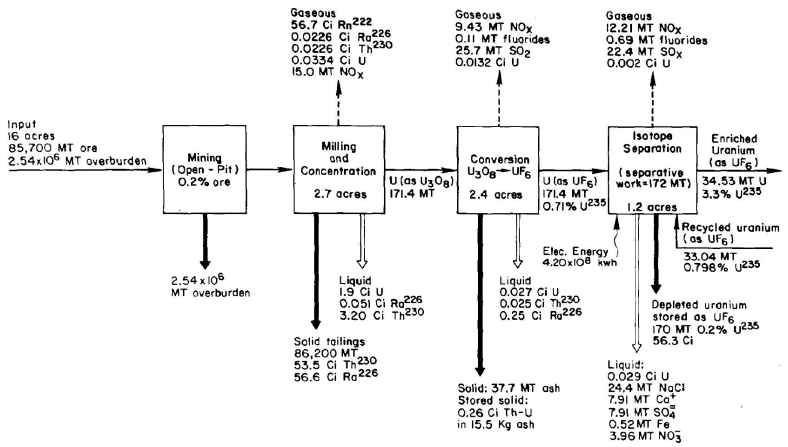


Building on the legacy of Thomas Pigford, founder of the Nuclear Engineering department at UCB and author of the 1981 book "*Nuclear Chemical Engineering*," we intend to develop a new undergraduate course in nuclear chemical engineering. The course includes engineering processes of the front-end and back-end of the fuel cycle, and environmental processes of isotope transport, reaction and separation, including advance reactor fuel cycles and medical isotope production.

The course would be suitable for junior, senior undergraduate student and graduate students in nuclear engineering, and also of relevance to material science and chemical engineering. (e.g. MSE 120, Minerals Production currently includes a short module on uranium mining.)

Example Topics, as illustrated in Pigford (1981)

CONTENTS



NUCLEAR CHEMICAL ENGINEERING AND NUCLEAR ENGINEERING

Dr. K. Czerwinski

Professor. Experimental efforts focus on evaluating the chemical forms and molecular structure of compounds containing radioelements.

Dr. D. Koury

Research Professor. High-temperature materials science: diffusion interactions of simulated metallic nuclear fuel and cladding materials. Microscopy and X-ray diffraction analysis

Dr. F. Poineau

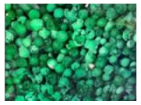
Associate Professor. Expertise in technetium and actinides chemistry and characterization of radioelement compounds through XAFS spectroscopy.

Dr. A. Gelis

Associate Professor- Director Radiochemistry Program. Solution based actinide separations and speciation, microfluidic separations and characterization, isotope separations

Harry Jang (Fellow) Preparation uranium microspheres as targets for medical isotopes production and alternative nuclear. Developed a new method uranium fluoride microsphere preparation.

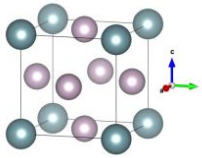
Academic Advisor: **F. Poineau**
Lab interaction : **LANL-2021 summer internship (mentor: A. Pugmire)**



UF_4 microspheres

Josephine Libero (Affiliate) Preparing new actinide-transition metal alloys for metallic used fuel characterization. Work provides data to monitor burn-up for safeguard applications, simplify reprocessing and develop new waste forms.

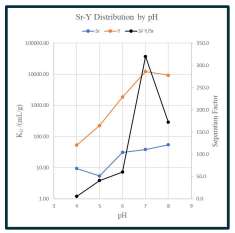
Academic Advisor: **D. Koury**
Lab interaction : **LLNL-2022 summer Internship**



UTc_3 Structure

Logan Smith (Affiliate) Developing methods for the separation of radionuclides for medical applications (i.e., ^{90}Y and ^{225}Ac).

Academic Advisor: **A. Gelis**
Lab interaction : **LLNL-2022 summer internship (mentor: M. Mitchell)**



Separation $^{90}Sr/^{90}Y$"

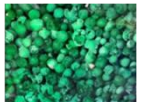
UNLV

NUCLEAR CHEMICAL ENGINEERING AND NUCLEAR ENGINEERING

Harry Jang (Fellow) Preparation uranium microspheres as targets for medical isotopes production and alternative nuclear. Developed a new method uranium fluoride microsphere preparation. This work on UF_4 microsphere can lead to the formation of oxide or metallic U particles and can enable processes for applications to TRISO fuel, or novel U metal particle based fuel. This work can link with the ^{232}U effort through understanding the uranium speciation during the material synthesis and will provide a baseline for the incorporation of ^{232}U into novel fuel forms.

Academic Advisor: **F. Poineau**

Lab interaction : **LANL-2021 summer internship (mentor: A. Pugmire)**

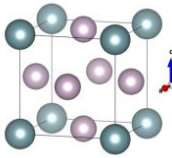


UF_4 microspheres

Josephine Libero (Affiliate) Preparing new actinide-transition metal alloys for metallic used fuel characterization. Work provides data to monitor burn-up for safeguard applications, simplify reprocessing and develop new waste forms. Josie is evaluating alloys of U with fission elements, particularly Tc. She has evaluated Re and Tc alloys with U. For U nuclear fuels, understanding the intermetallic U-Tc species formed can help inform burnup and can be coupled to the behavior of ^{232}U added to metallic fuel as a marker.

Academic Advisor: **D. Koury**

Lab interaction : **LLNL-2022 summer Internship**

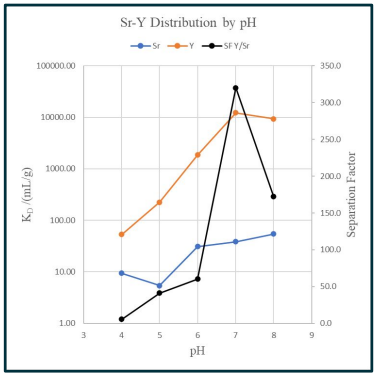


UTc_3 Structure

Logan Smith (Affiliate) Developing methods for the separation of radionuclides for medical applications (i.e., ^{90}Y and ^{225}Ac). While these efforts may not be directly coupled to isotopes produced in the fission process, i.e., ^{225}Ac, the applications developed with the separation chemistry and technology application can be applied to fission products, actinides, and isotopes from neutron reactions. This includes the microfluidics technology which can exploit these separation methods.

Academic Advisor: **A. Gelis**

Lab interaction : **LLNL-2022 summer internship (mentor: M. Mitchell)**



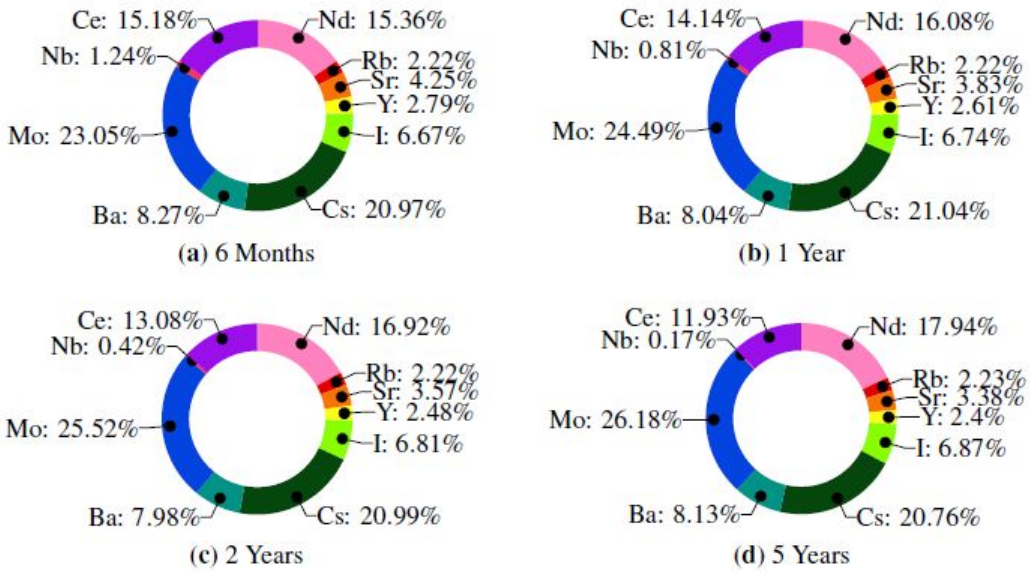
Separation $^{90}Sr/^{90}Y$"

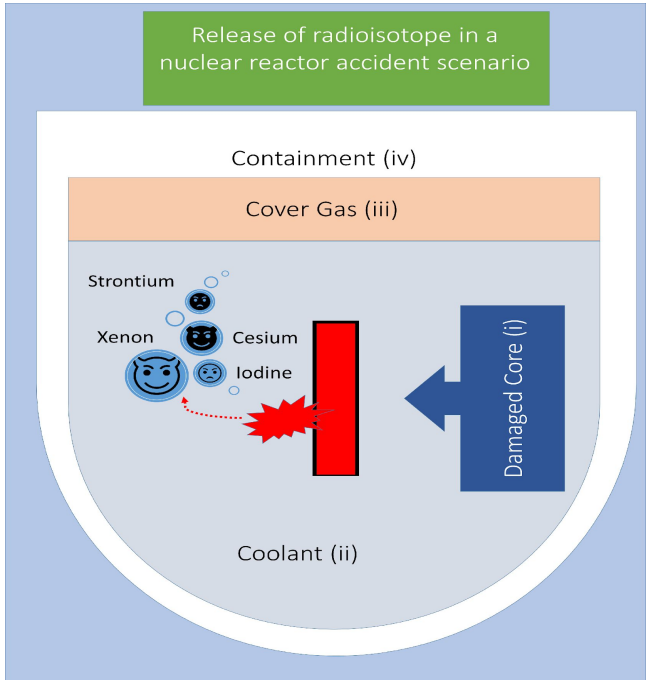
Fission product inventory in Lead-cooled Fast Reactors (LFRs)

Student: Jake Noltensmeyer, MSc, NE
Advisor: Osman Anderoglu
Lab Mentor: TBD

Relevance:
Radioisotope production in LFR. Planned NSSC work: behavior of some of the fission products (FP) in Pb over the summer.

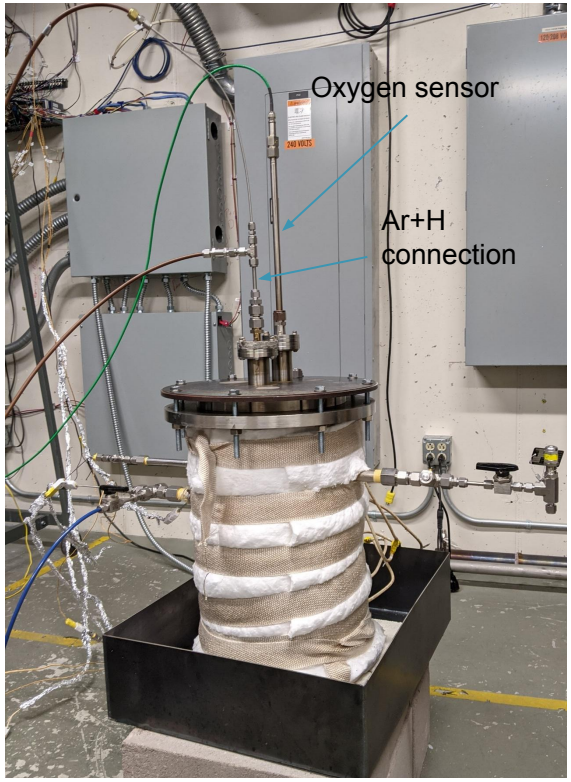
Some of the radioisotopes are volatile at LFR operating temperatures.
Parametric Study of Initial Conditions for Lead Fission Product Solubility

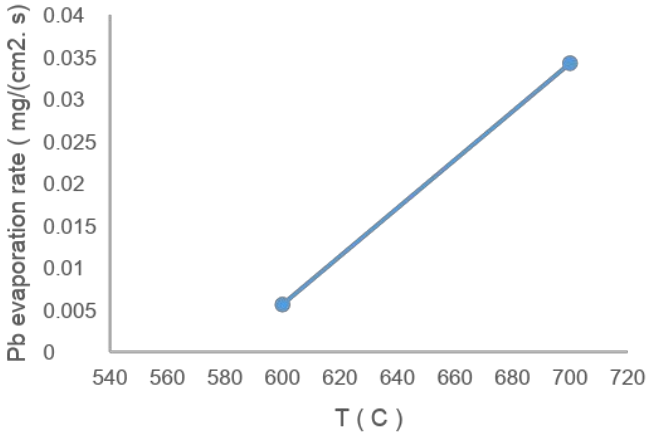




Fission product inventory in Lead-cooled Fast Reactors (LFRs)

Experimental set up





Pb evaporation rate was measured up to 700C. Oxide formation can inhibit evaporation and therefore oxygen control is one of the key parameters for evaporation.

We use an electrochemical method to measure oxygen concentration in pure Pb and this is one of the most critical aspects.

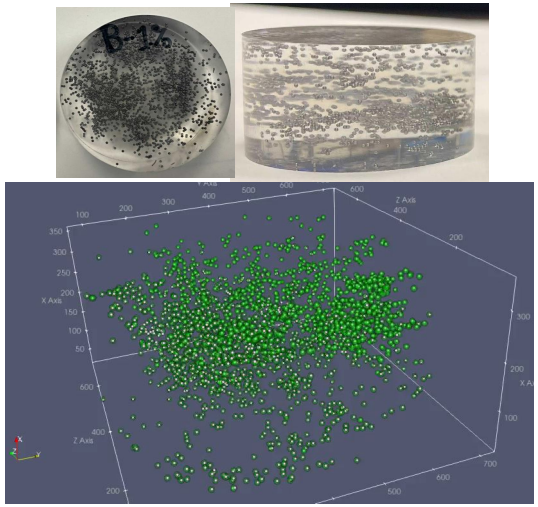
Real-time feature selection and classification

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

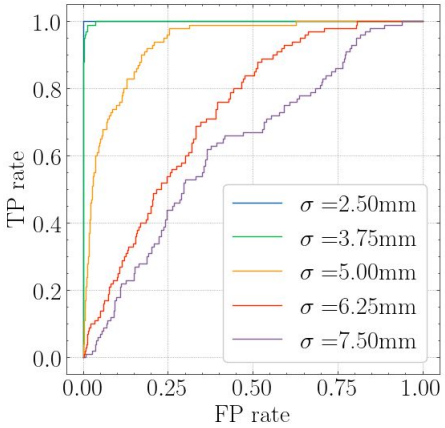
National Lab Collaborator: to be identified

Ph.D. Student: John Leland
Starting in Fall 2022
Faculty Advisor: Dr. Angela Di Fulvio

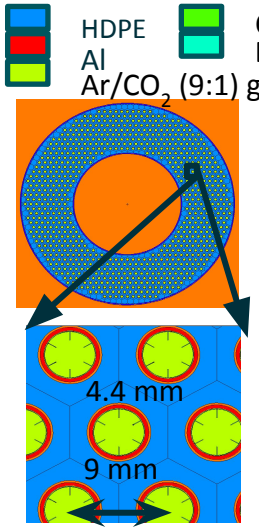
Goal: We propose to apply software and hardware that we have developed to track TRISO-fueled pebble in pebble bed reactors for material accountancy and safeguards of emerging fuel cycles.



X-ray computed tomography of mockup fuel compact with reconstructed and segmented kernels



Receiver Operating Characteristic (ROC) curve of pebble identification algorithm based on the X-ray CT

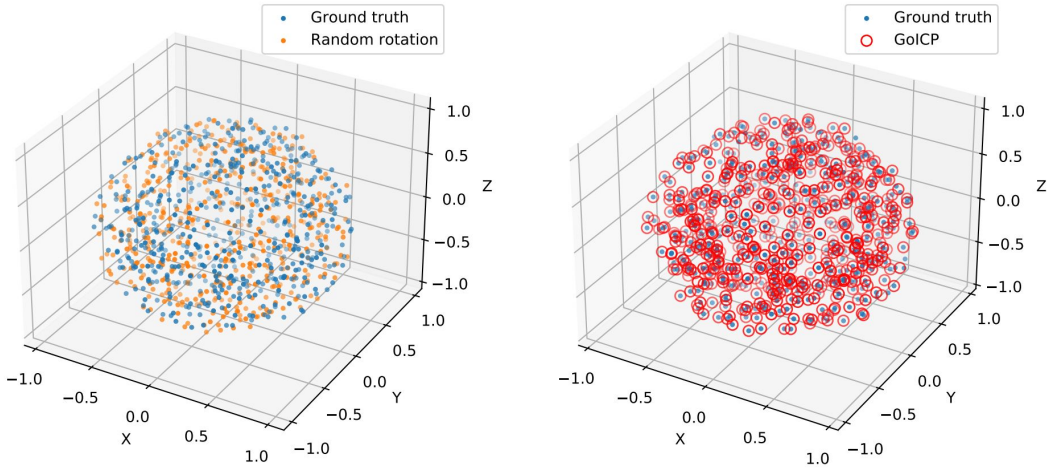


Boron-coated straw based multiplicity counter with short die-away time and minimized gamma-ray sensitivity

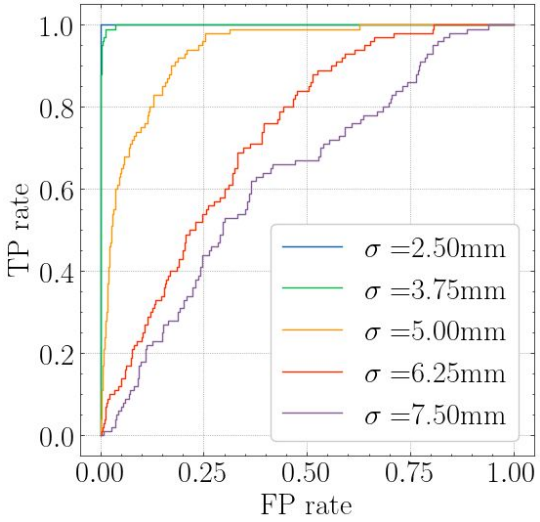
Real-time feature selection and classification

Goal: We propose to apply software and hardware that we have developed to track TRISO-fueled pebble in pebble bed reactors for material accountancy and safeguards of emerging fuel cycles.

We tested 100 fuel pebbles with random rotations and increasing Gaussian noise levels. We achieved a classification ratio (correctly identified pebbles/total number of pebbles) of 100%. The algorithm is robust against high noise level (15% of pebble radius).



Identification of a randomly rotated pebble.



Receiver operating characteristic curves at different noise levels.

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Acknowledgements

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number **DE-NA0003996.**