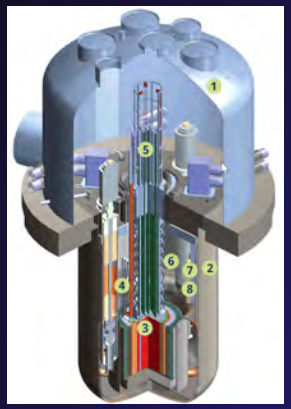


MCNP6

Los Alamos
NATIONAL LABORATORY
EST. 1943

Delivering science and technology
to protect our nation
and promote world stability

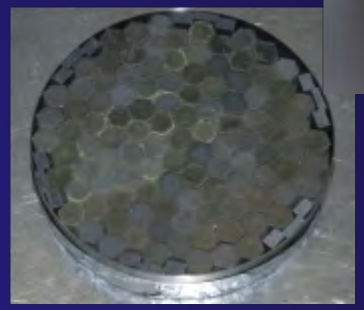
Overview of LANL Capabilities for Adv Reactor Community

- **Los Alamos has rich legacy of supporting nuclear energy missions**
  - We see our role as supporting NRIC by providing value-added research, development and prototyping of advanced reactor components
- **Nuclear 'Fuel' Materials Synthesis and Fabrication of Fuel prototypes**
  - Scope: Synthesis, processing, properties and characterization; LEU/dU ceramics, U-Pu-Halides.
  - For certain fuel types fabrication, at LANL and transport to testing site may not be straight forward (LANL will work with hosting organization to standup facilities)
- **Non-nuclear specialized materials and prototypes**
  - Scope: established as part of NE Microreactor Program and NASA
- **Integrated Nuclear Measurements**
  - Scope: Small-scale low power nuclear demonstrations and measurements

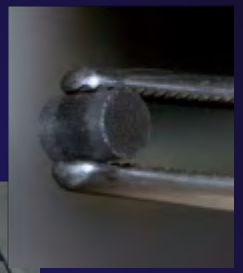
Some Actinide Ceramic Pellets Produced at LANL

UN pellets produced for SP-100 National Assembly Test core

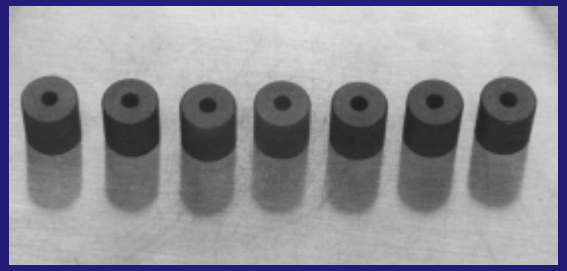
Np-MOX pellets



Hexagonal PuO_2 Pellets



MAMOX Pellet

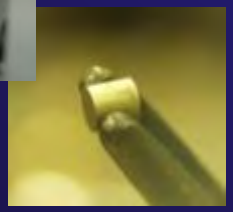


Annular UN Pellets

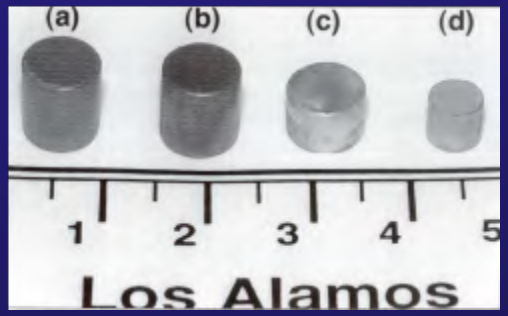
UPu Carbide

UN/U_3SI_2

MA Nitride



IMF Nitride



$(Pu,U,Zr,Ca)O_2$ CERCER Pellets

80/20 MOX Pellet

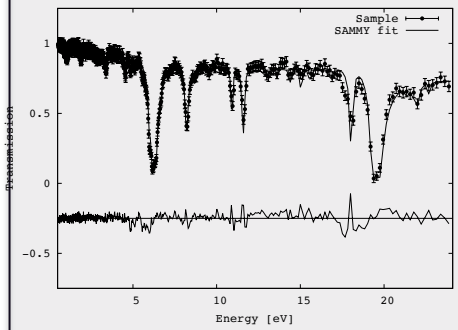
Authorization Basis of FRL

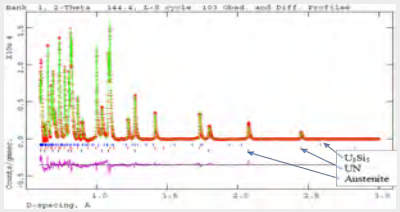
- **Depleted Uranium (dU)**
  - Primary isotope for materials research and development
  - 50 kg annual throughput
- **Low-enriched Uranium (LEU)**
  - FRL is a primary fabrication facility for AFC
  - ≤20% U-235 for TREAT/ATR/HFIR irradiations under AFC, NASA and industry
- **Highly-enriched Uranium (HEU)**
  - Future ATR irradiations may seek more sophisticated enrichment within rodlet; currently authorized to 27% enrichment
- **Thorium-232**
  - Included in original authorization request
  - Small R&D Thorium efforts
- **Low dose neutron-irradiated materials**

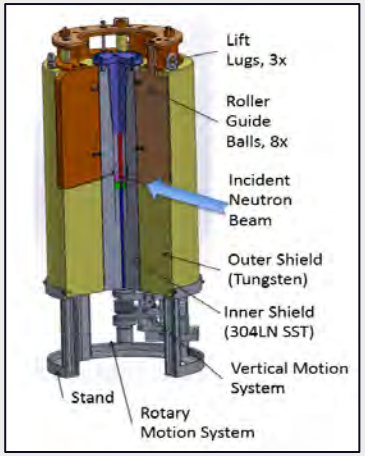
Current maximum capacity is 10's of kg of LEU 'ceramic' fuel. Possible to increase authorization to 100 kg/yr with limited investment

Pillars of ANDE/APIE at LANL

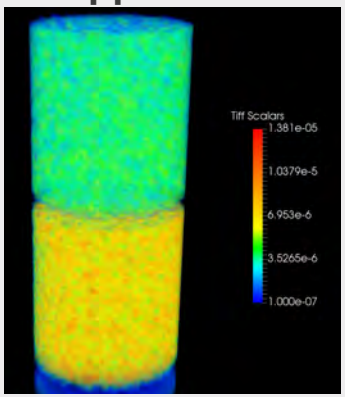
Method Development

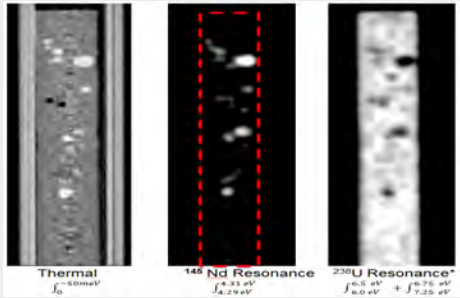


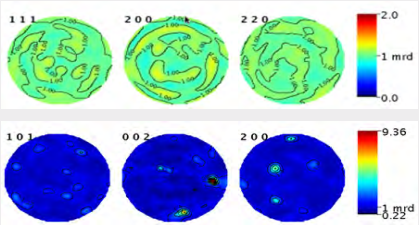




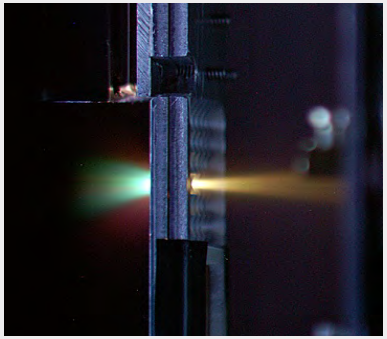
Demonstration & Application

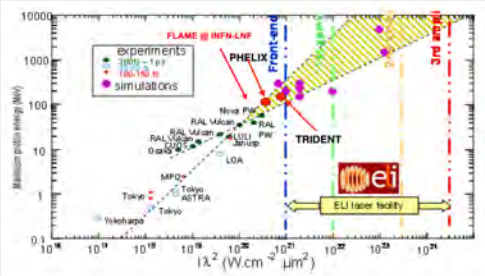






Develop Pool-side Capability



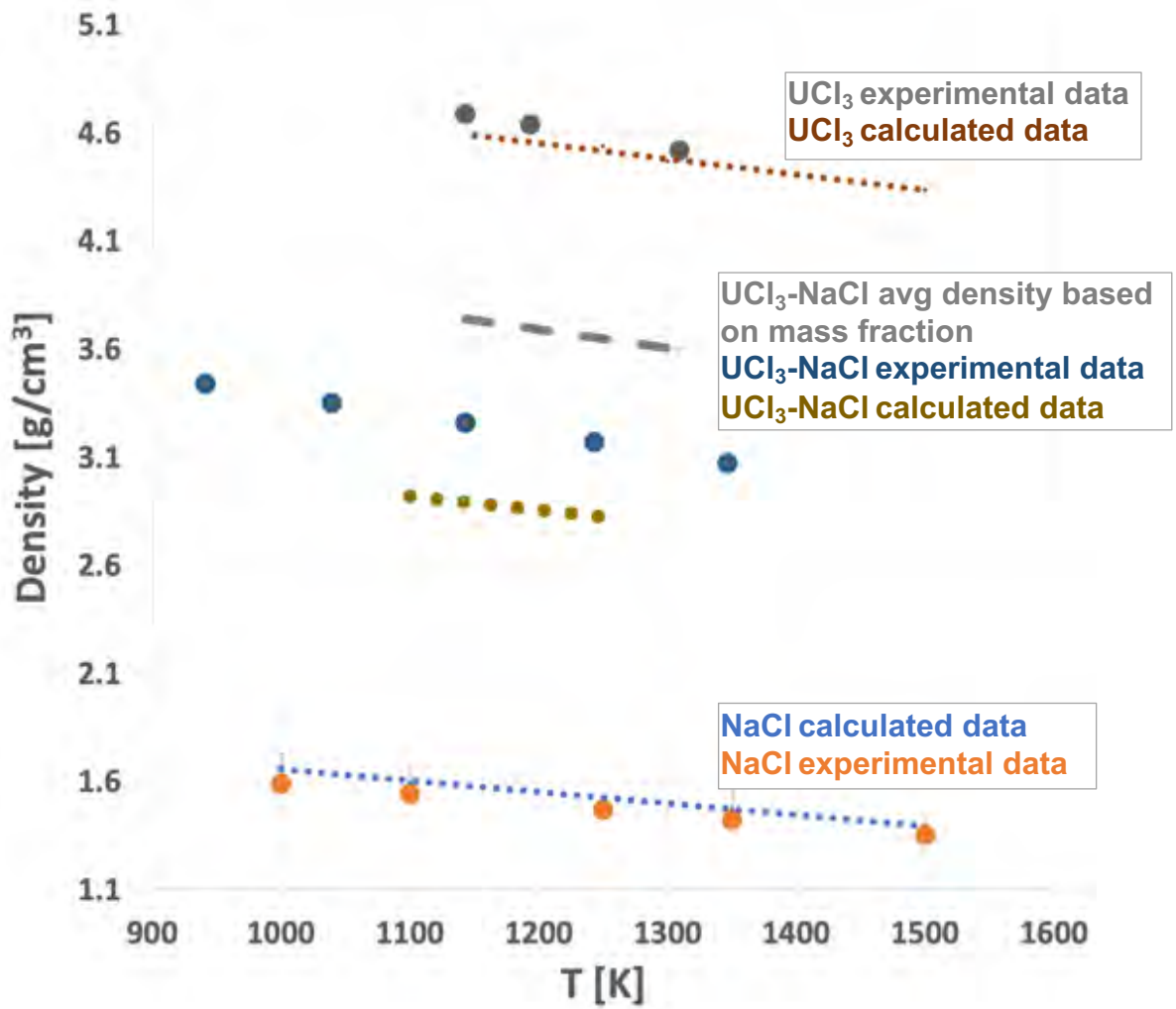


Synthesis, Properties, and Corrosion Characteristics of Molten Fuel Salts

- **Speciation and Impurity Chemistry Cyclic Voltammetry**
  - –Square Wave Voltammetry
- **Corrosion and Materials Evaluation**
  - –Cyclic Potentiodynamic Polarization
  - –Static and pseudo-dynamic exposure
- **Actinide Chloride Synthesis**
  - –UCl_3, UCl_4, $ThCl_4$, $PuCl_3$

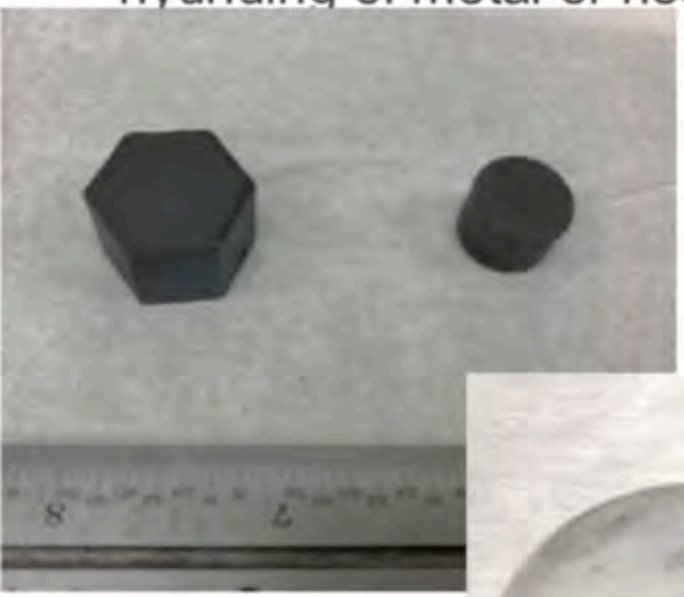
Integrating Modeling with Empirical Density Results

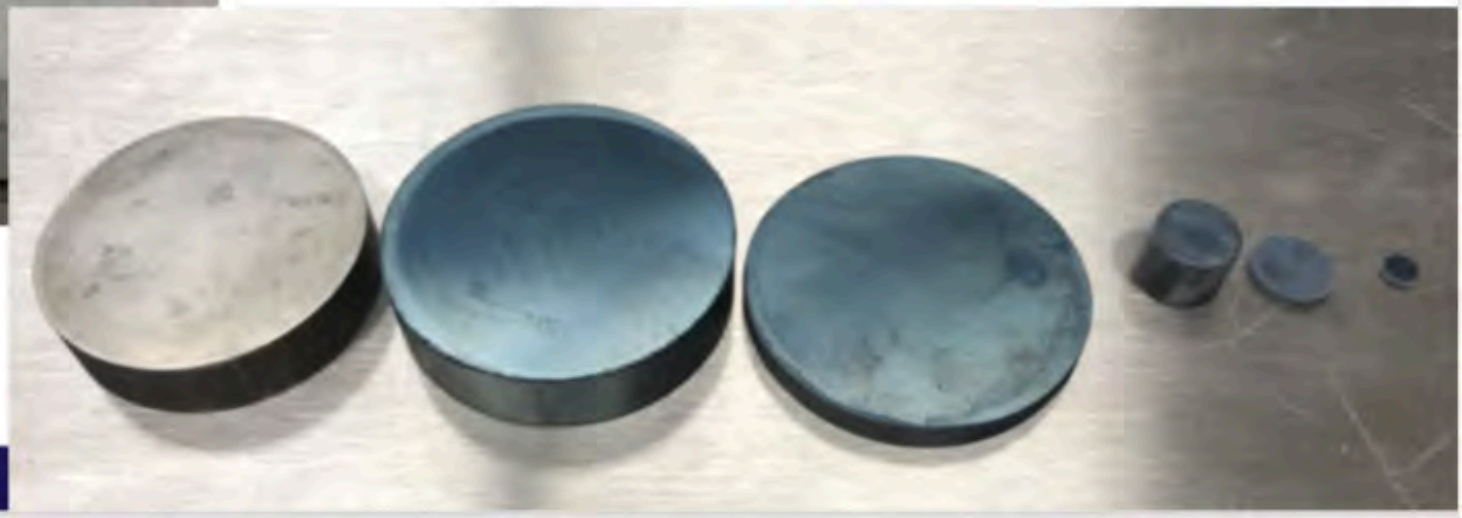
- Top and bottom sets of data: pure UCl_3 and NaCl
  - Modeling data close to experimental data
- Center set of data: 28 mol% UCl_3 in NaCl
  - Experimental data (blue dots) *lower* than simple average density based on mass fraction (gray trace)
  - Modeling data not as close for mixture as for pure systems; required incorporation of Van der Waals interactions and magnetism
  - These observations are prompting the next stages of our research!



Hydride moderators

- Fabrication of hydrides possible through direct hydriding of metal or near net shape powder metallurgy process

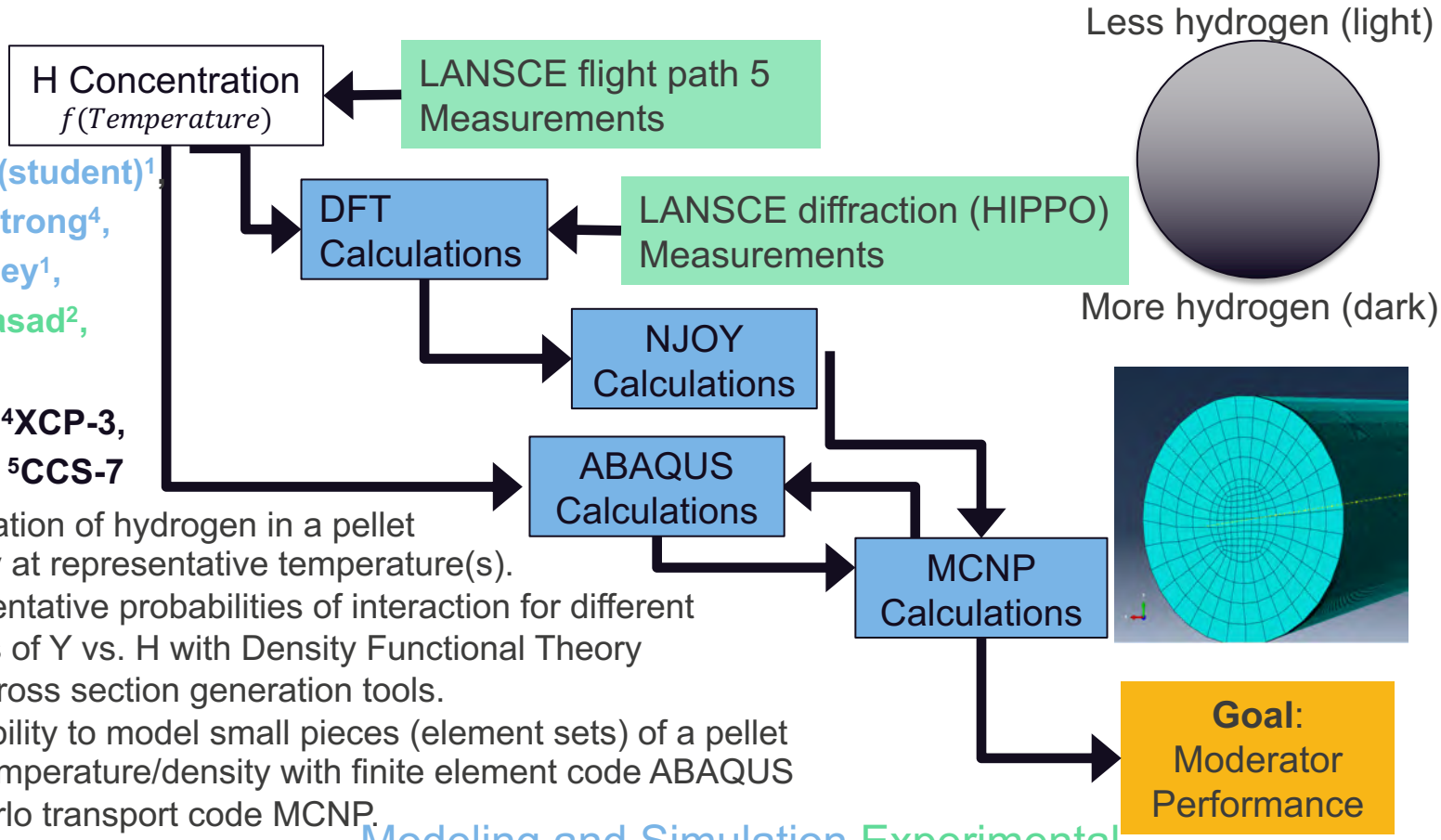




LDRD Director's Initiative Project: Experiment/Simulations to

- Sven Vogel[2],
- Alex Long[2],
- Vedant Mehta (student)[1],
- Jerawan Armstrong[4],
- Gregg McKinney[1],
- Aditya Shivprasad[2],
- Erik Luther[3],

[1]NEN-5, [2]MST-8, [4]XCP-3, [3]SIGMA-1/2, and [5]CCS-7

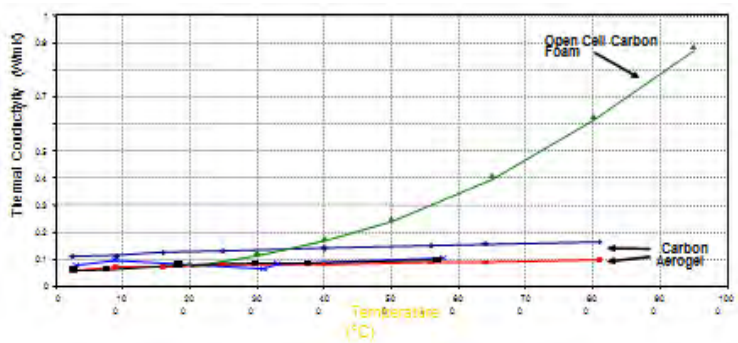


1. Determine location of hydrogen in a pellet experimentally at representative temperature(s).
2. Create representative probabilities of interaction for different concentrations of Y vs. H with Density Functional Theory (DFT)/NJOY cross section generation tools.
3. Develop capability to model small pieces (element sets) of a pellet with distinct temperature/density with finite element code ABAQUS and Monte Carlo transport code MCNP.

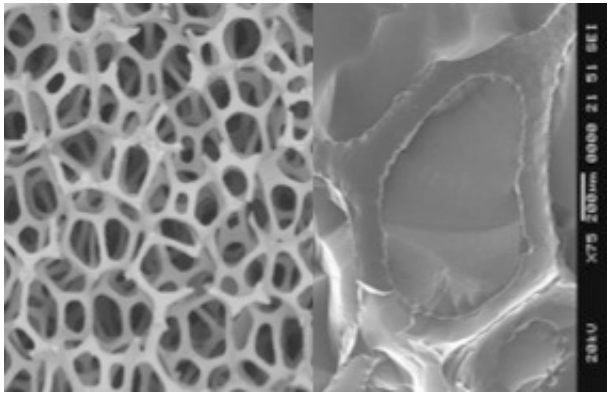
Modeling and Simulation Experimental

Insulator materials

- **Hierarchically porous, low density SiC and ZrC via an aerogel infiltration process:**
  - Macroporous reticulated foams infiltrated with carbon aerogel.
  - coated with SiO_2 or ZrO_2, composites then heated to produce carbides.



Thermal conductivity of carbon foams.



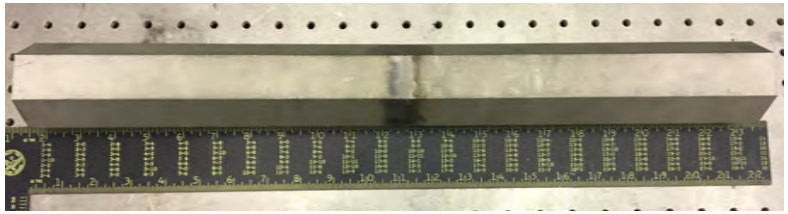
L, RVC; R, RVC with aerogel. RVC pore diam. ~0.5mm.

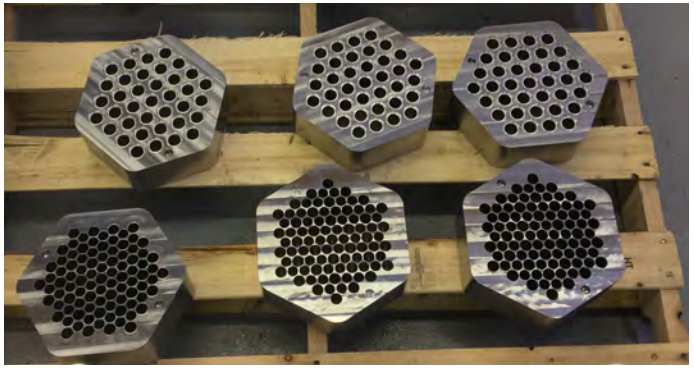
Monolithic test articles for nonnuclear heat pipe and heat exchanger experiments.

- **Goals:**
  - Demonstrate use of additive manufacturing for fabrication of test articles.
  - Fabricate a test article longer than 20” long to contain a single heat pipe. Fuel rods will be simulated with cartridge heaters.
  - Demonstrate joining techniques for individual pieces.

Heat pipes on order

These two sections were built with AM.



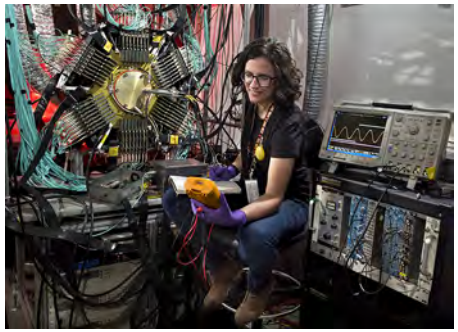


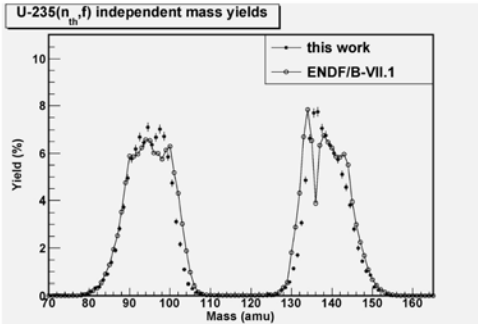
Pictures Courtesy of Colt Montgomery, Michael Brand, John Carpenter, and Amber Black, SIGMA-2

Integral Measurements

Differential Measurements

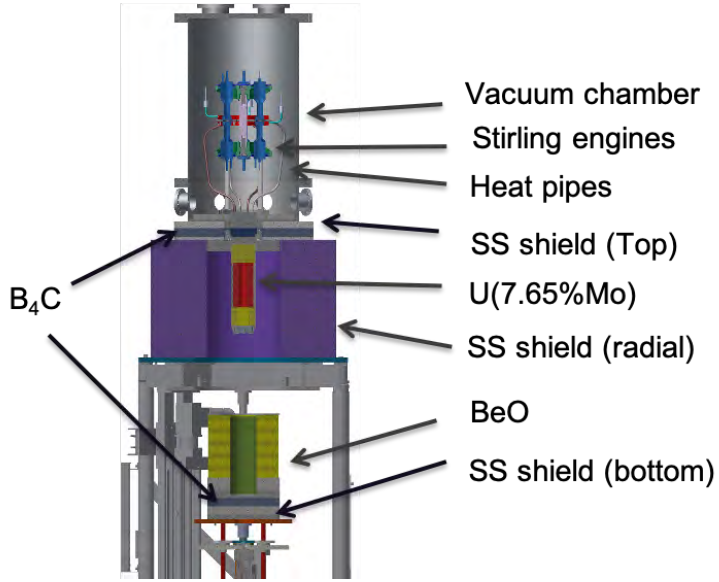
- Measuring nuclear data, fundamental physics
- ORNL/LANL





Integral Measurements

- Low power tests (10 to 100 kWt)
- Void/Temp coefficients
- Self-regulation measurements
- Control system qualification

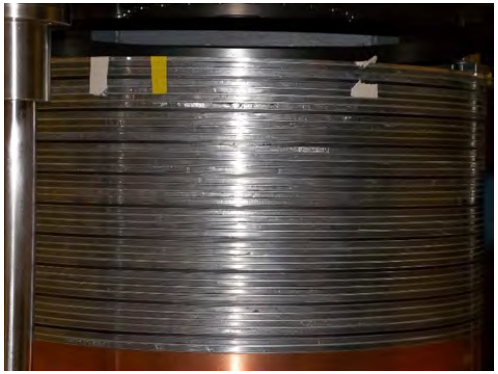


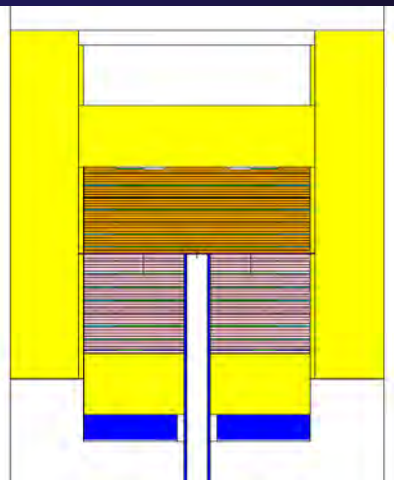
Large Scale Tests

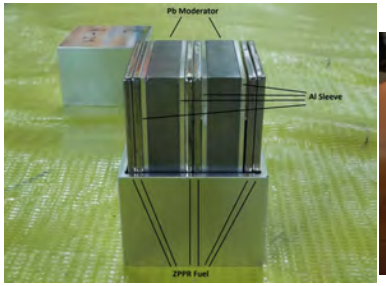
- High power demonstrations
- NRIC/INL

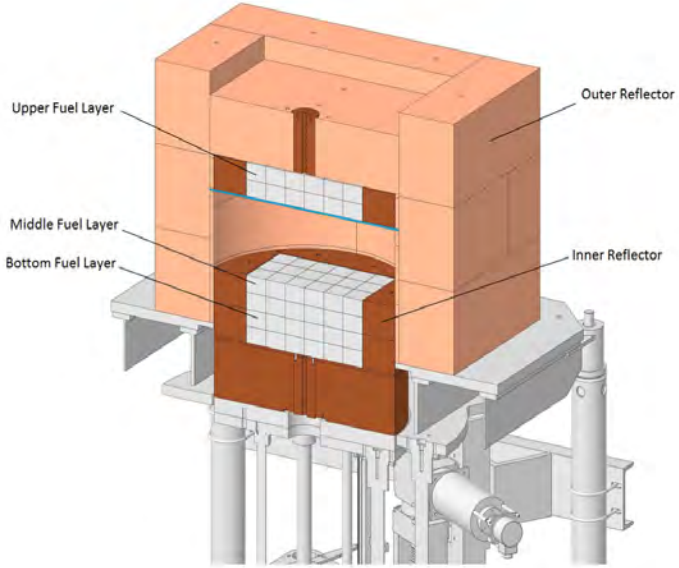
Lead (Pb) Void Coefficient Measurements

- **Recent lead (Pb) measurements**
  - No intermediate-energy Pb benchmarks exist!
  - JAEA was very interested in performing such measurements
    - For applications with future ADS systems
  - Three experimental series (each with multiple configurations) were performed.
    - HEU: “Jemima” plates (~21 kg of HEU) with lead matrix material and Cu reflector.
    - HALEU: “Jemima” plates (~21 kg of HEU) and Nat U plates (to give “effective” enrichment of ~21%) with lead matrix material and Cu reflector.
    - Pu: ZPPR fuel plates (3” x 2” x 0.25”) and lead plates with Cu reflector.
  - Coming to ICSBEP “soon”.



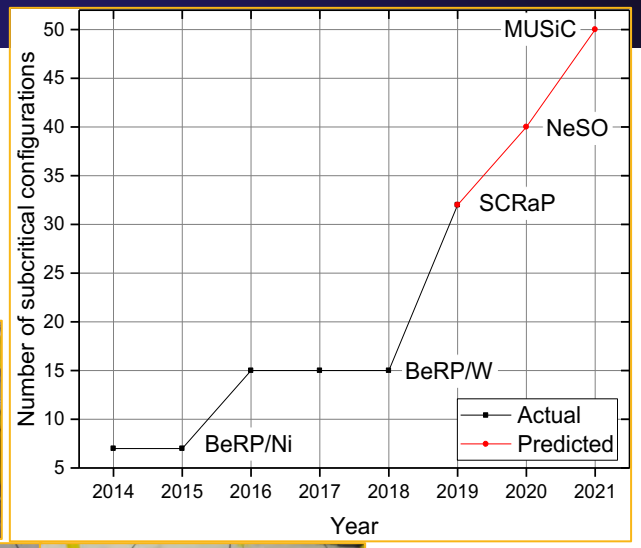


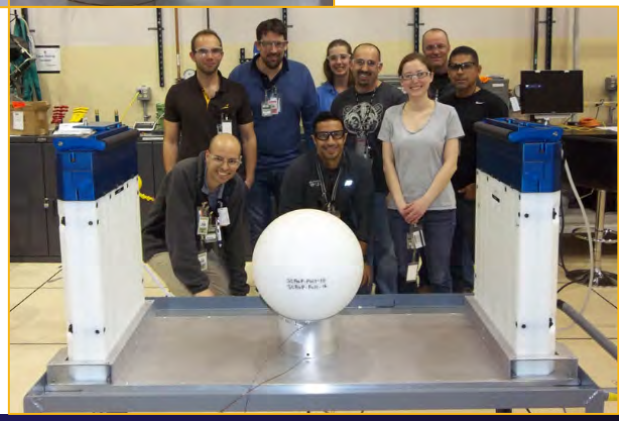




Recent Subcritical Experiments

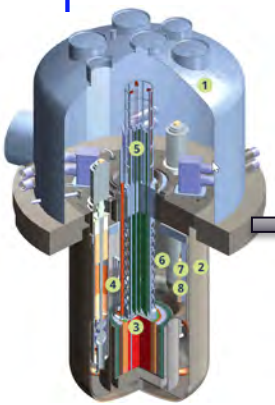
- **Growing dataset of neutron multiplication benchmarks experiments/evaluations**
  - Culmination of several years of sub-critical experiment research
  - Goal is to validate nuclear data and computational methods
- **BeRP-Ni (published in 2014)**
  - Executed in 2012, ICSBEP evaluation published in 2014
- **BeRP-W (published in 2016)**
  - Sub-critical tungsten-reflected α-phase Pu
  - Executed in 2012, ICSBEP evaluation published in 2016
- **SCRαP (published in 2018)**
  - Sub-critical copper/poly-reflected α-phase Pu
  - Executed in 2016, ICSBEP evaluation published in 2018





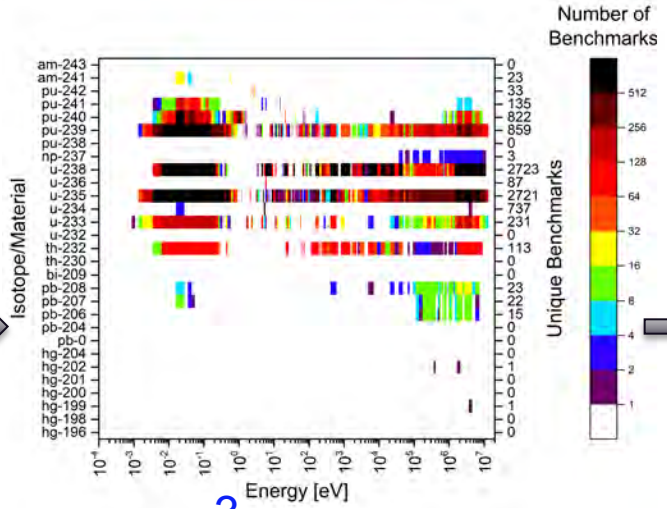
Designing critical experiments

1



2

$$S_{k,x} = \frac{dk/k}{dx/x} = -\frac{\langle \psi^{\dagger}, (\Sigma_x - S_x - k^{-1}F_x)\psi \rangle}{\langle \psi^{\dagger}, k^{-1}F\psi \rangle}$$



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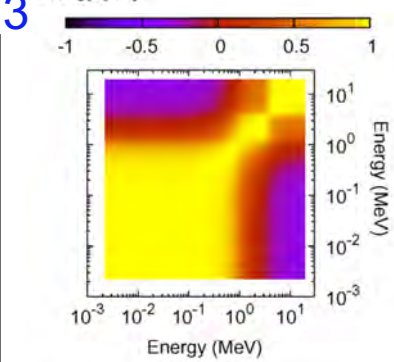

FIG. 6: Correlation matrix for the capture cross section of $n+^{235}U$.

4

1: **Generate model** (Monte Carlo or deterministic) of application for radiation transport simulations.
2: Perform cross-section **sensitivity simulations**.
3: Perform a **gap analysis** to investigate if similar benchmarks exist.
4: Perform **optimization** to design new experiments that are more sensitive to the application than existing benchmarks.