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# High Temperature Hydride Moderators

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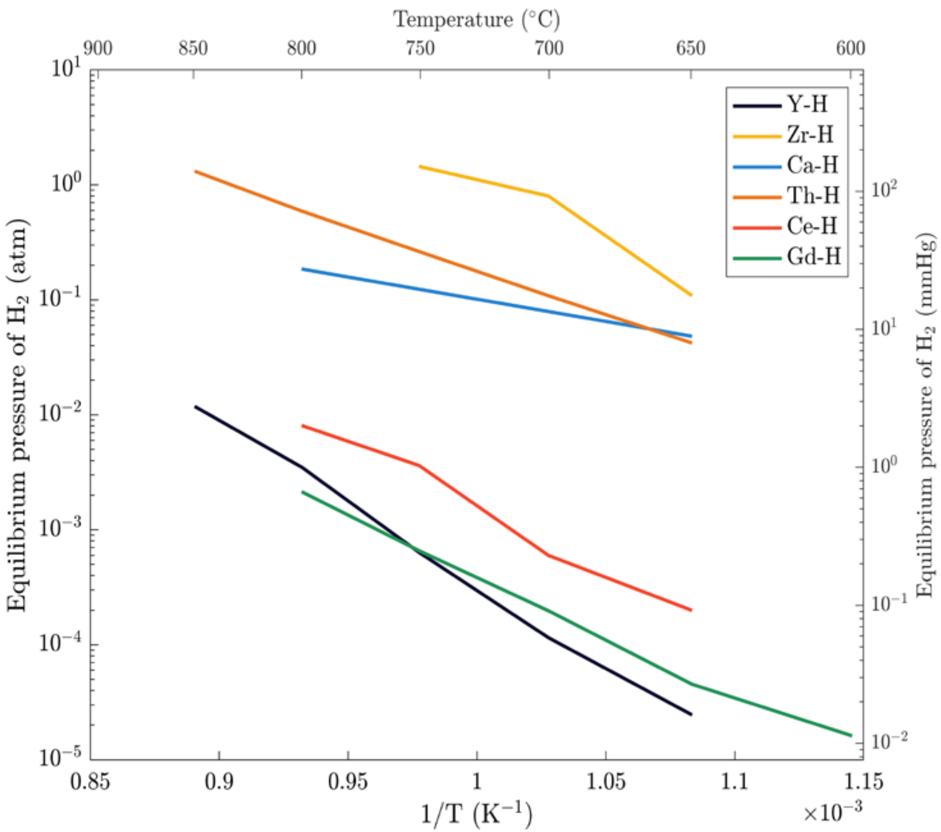
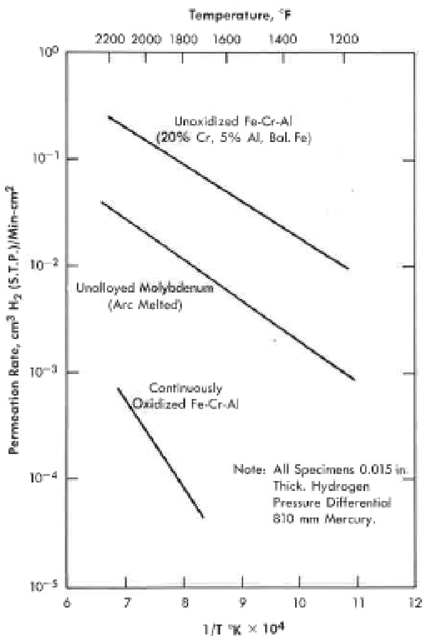
# High Temperature Moderators for Microreactors

- Moderators could result in improving economics and transportability in certain scenarios
  - Likely to reduce HALEU requirements
  - Thermally stable n-shielding
- R&D Interests
  - Synthesize and characterize alloys that improve economics
  - Neutron irradiation and swelling
  - Diffusion and migration
  - Cladding and interface enginnering
  - S(a,b) and neutronic data
  - Criticality benchmark



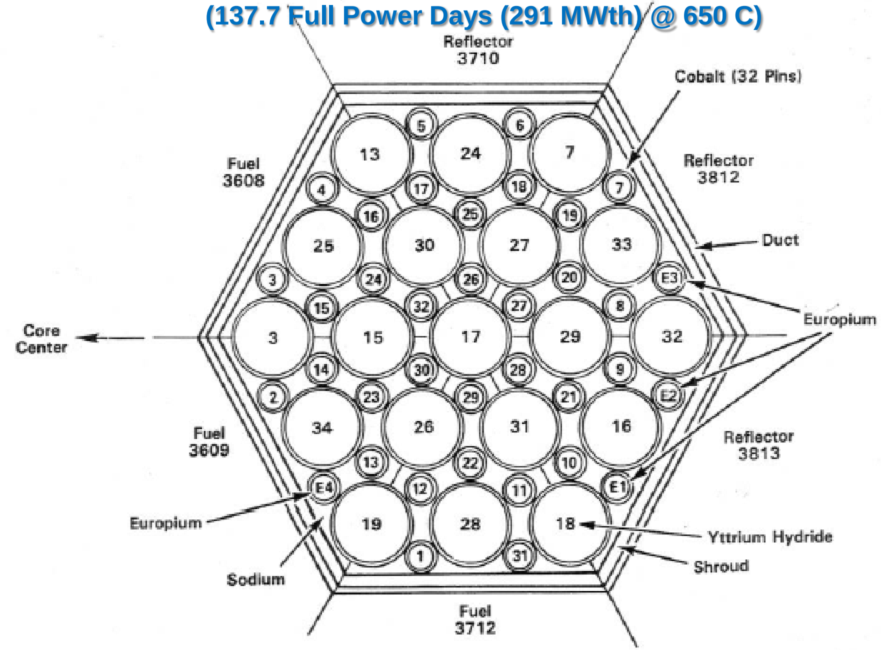
# Yttrium-Hydrogen System – historical data

**Hydrogen Permeation through Clad**




**Fast Reactor Use of $YH_{1.8}$**

(137.7 Full Power Days (291 MWth) @ 650 C)




Analysis and Results of a Hydrogen-Moderated Isotope Production Facility in the FFTF, D. W. Wotten et al (1989)

# Directly-hydrided material was brittle, air-stable solid that was able to be dry machined

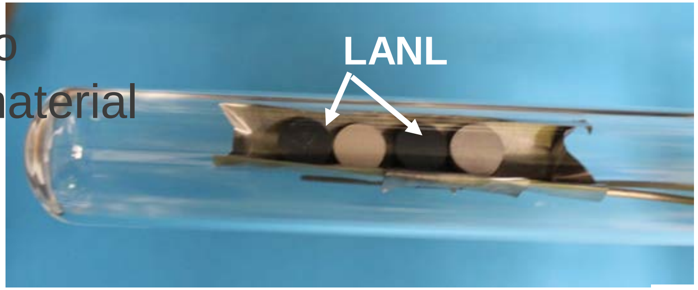
Examples of directly-hydrided $YH_2$

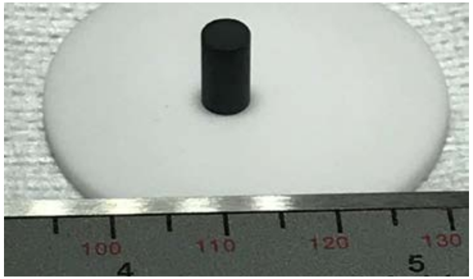

1” diameter cylinder showing example of dry machining

Some cracking occurred during synthesis, but most pieces were machined without additional fracture

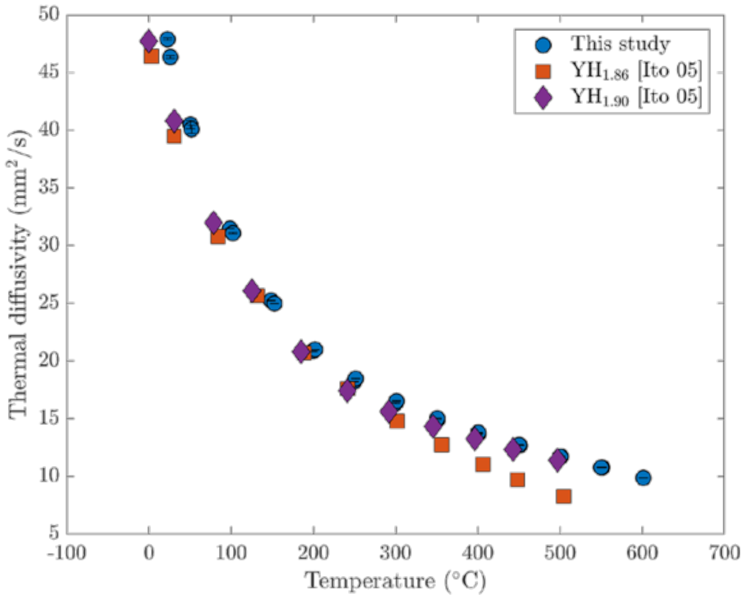
# High-density pellets show the feasibility of using powder metallurgy to produce near net-shape $YH_2$

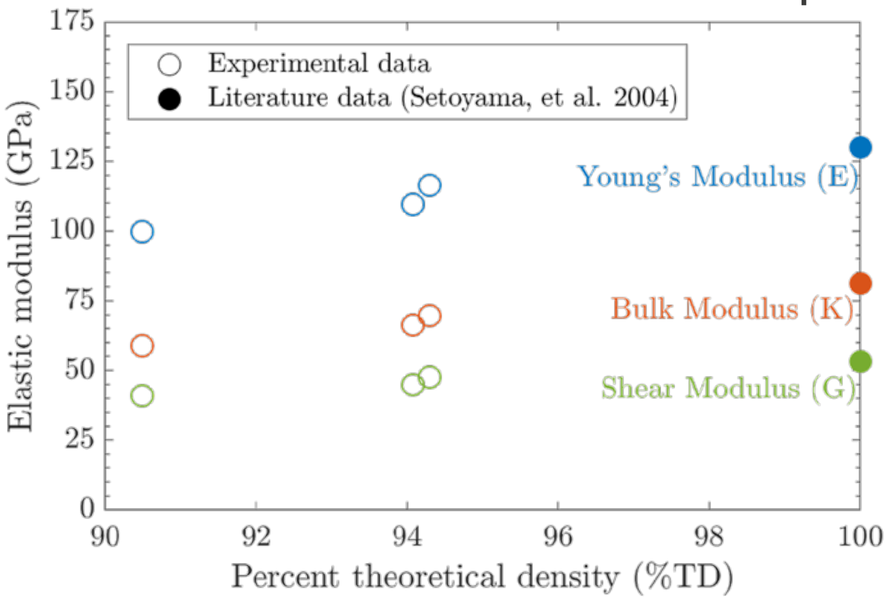
- Process has been refined to produce 93 – 98% dense material
- Properties consistent with literature



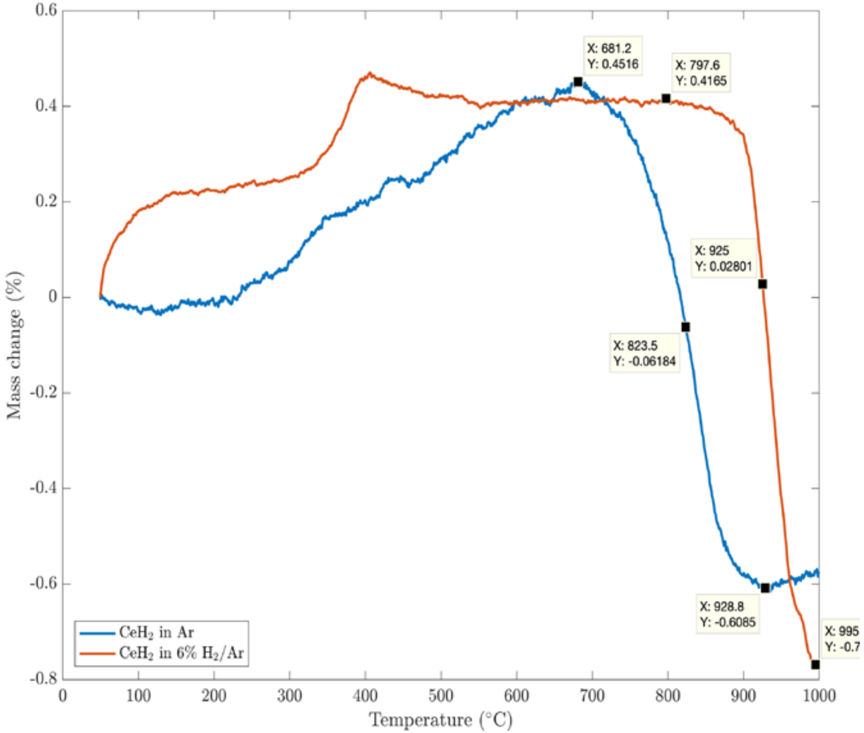



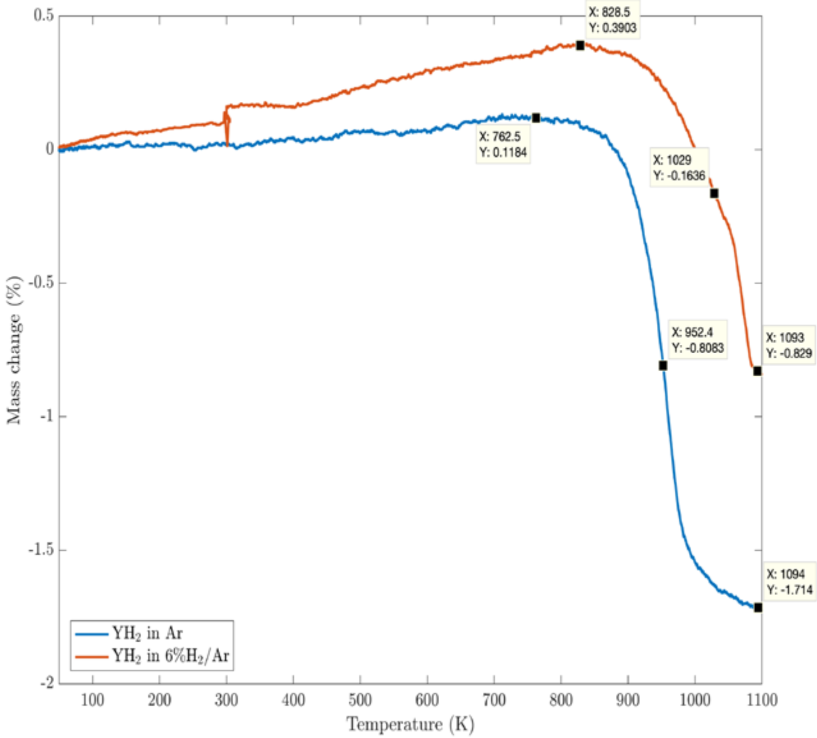
94% TD sintered pellet



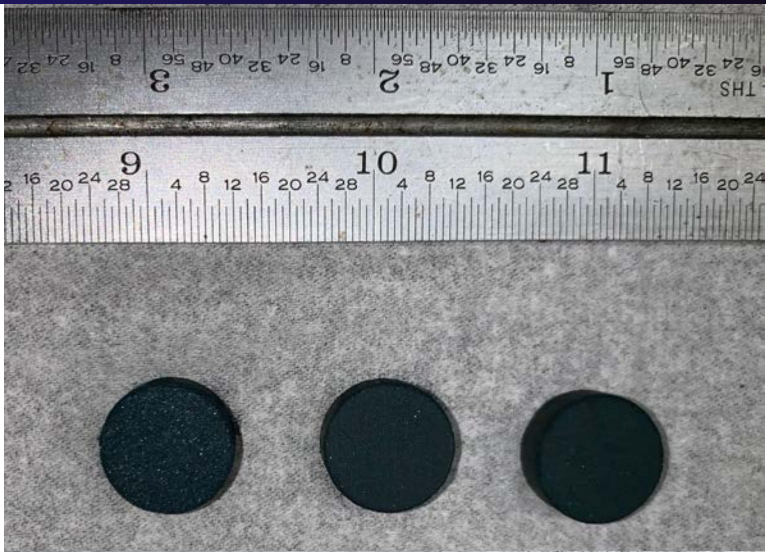
# Stability of two Hydride components (Y-H & Ce-H)



# Scale up of sintering process

- $YH_2$ pellets pressed at increasing pressures (0-200 MPa) to establish a density vs consolidation pressure curve
- 12 $YH_2$ pellets were pressed in a 15 mm diameter die to 75 MPa.
  - Fabricated with -325 mesh powder or -200/+325 powder
- Additional $YH_2$ pellets were pressed with a die lubricant to improve the integrity of the pellets.
- A sintering furnace to scale up production rate has been installed

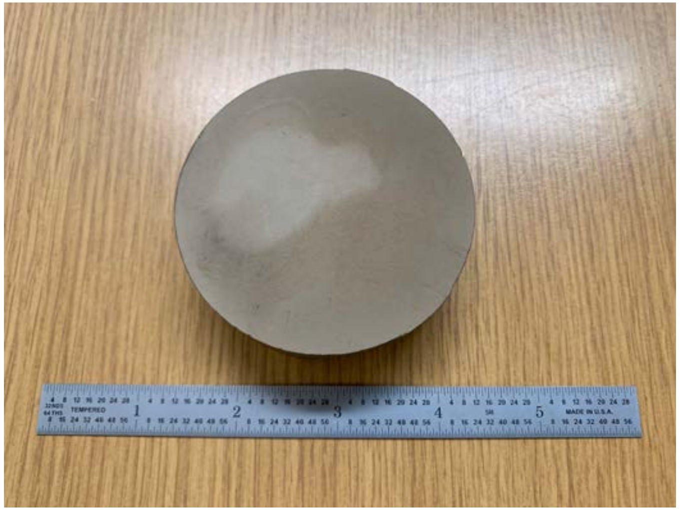


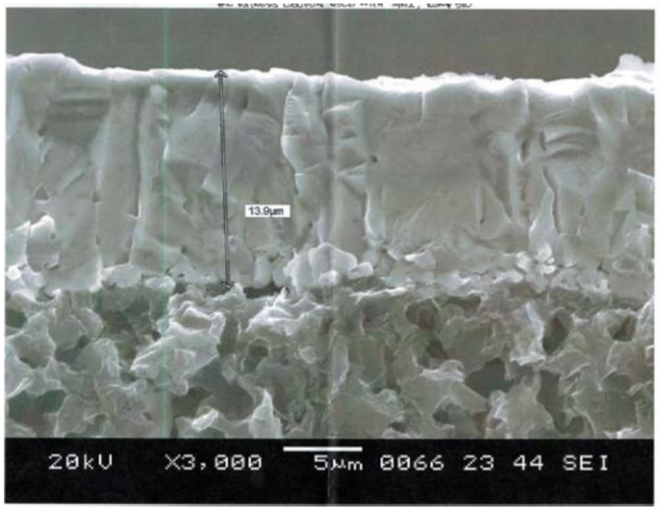
# TZM cladding progress for ATR Irradiation

- TZM tubing 15 mm diameter with 0.5 mm wall thickness has been procured.
- TZM caps were fabricated for the tubing. These caps are punched from sheet stock into a U shape press fit cap.
- Diffusivity of hydrogen through TZM is being studied. Plug type TZM caps were fabricated to join TZM tubing with stainless steel tubing.

# Diffusion Barrier Coatings

- Graphite samples have been CVD coated with ZrC (~25 micron thickness). TZM sheet has been cut and cleaned. Diffusion couple samples will be tested at 800C to study carbon diffusion into the TZM
- A multilayer coating for the TZM tubing is being developed. Expected to consist of a plated bond coating, getter layer and diffusion barrier layer. Candidate materials include Ni, Cr, Mo, Zr, Al2O3 and AlN.





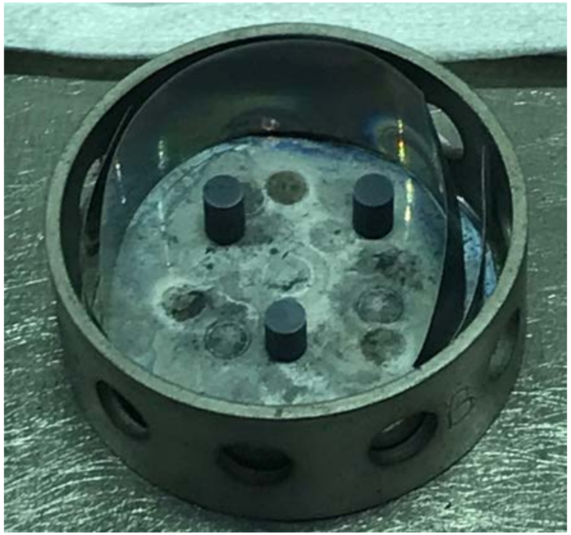
# Future work will focus on process refinement, scaling, and evaluating hydrogen migration

- Focus on production of high-density $YH_2$ pellets refining sintering process to prevent formation of impurity phases

- Shift to production of larger pellets and more complex geometries in-line with reactor designs

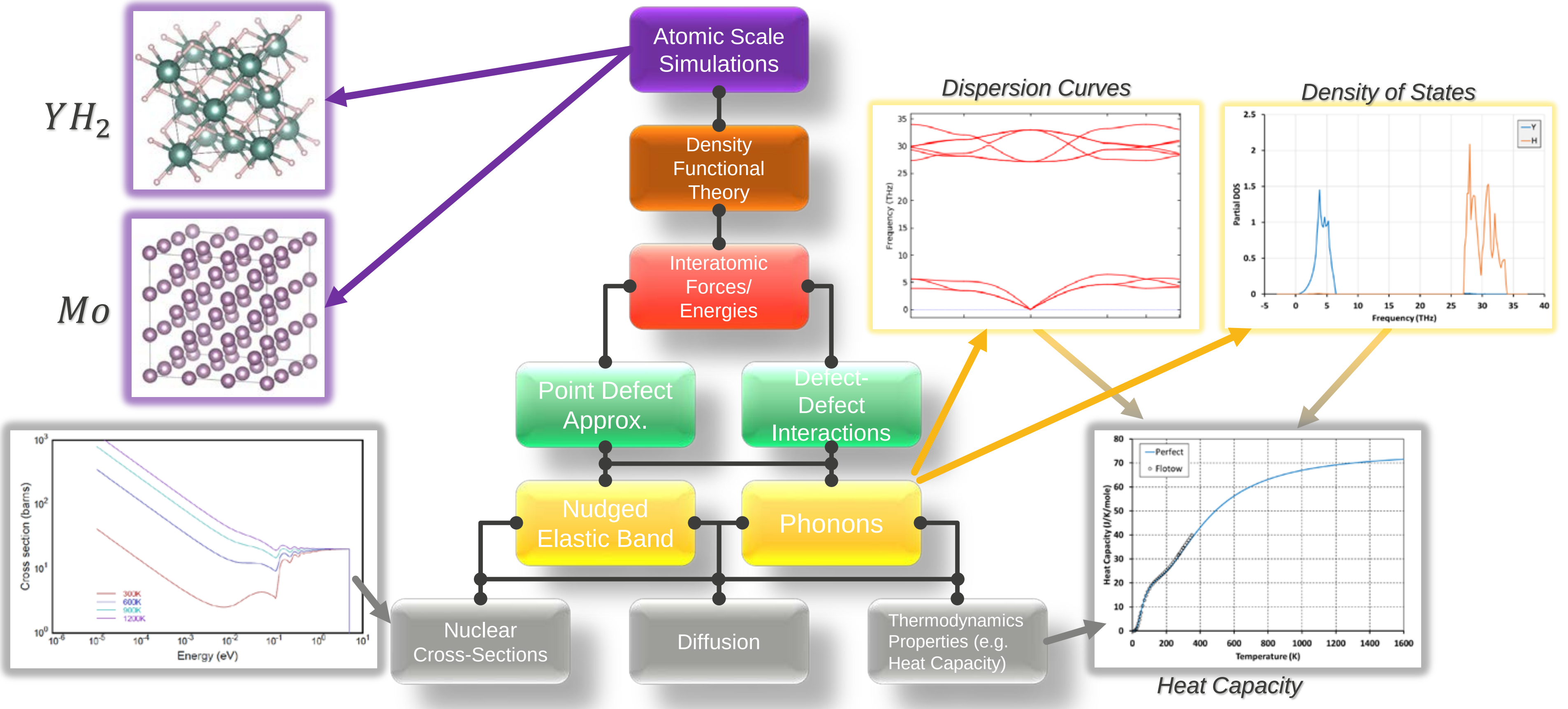
- Populate property databases for fuel performance codes

- Planned neutron diffraction and imaging to measure hydrogen self-diffusion

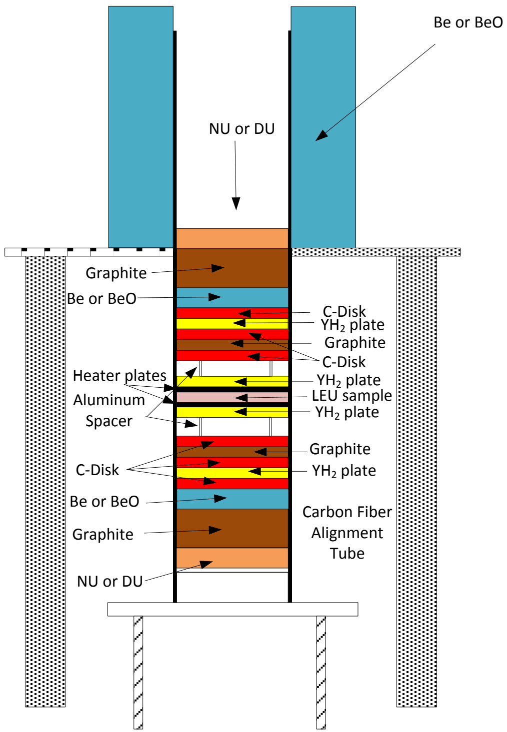


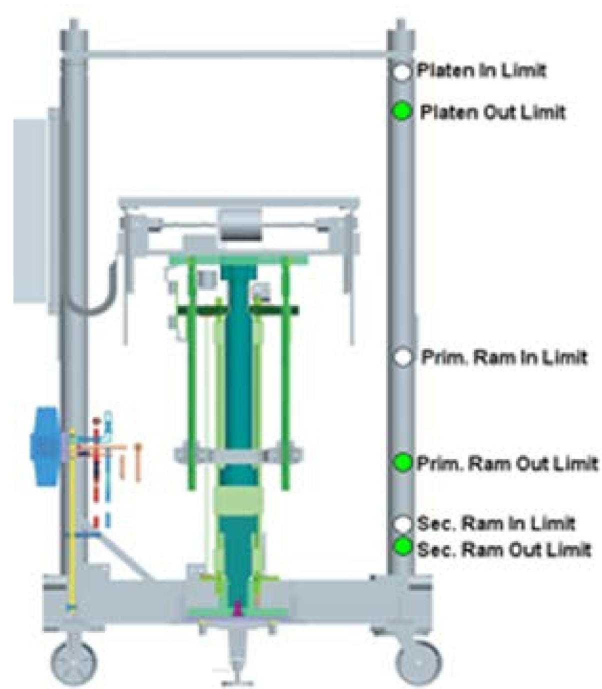
98%-dense $YH_2$

# First Principle Quantum Mechanical Simulations



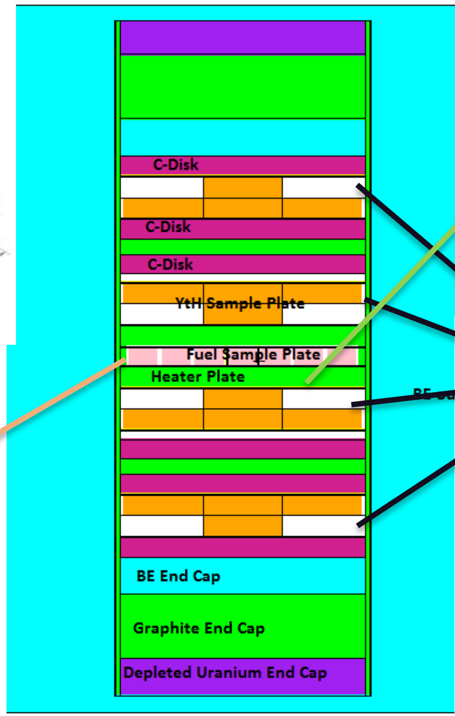
# Experimental Set Up for Hydride Benchmark

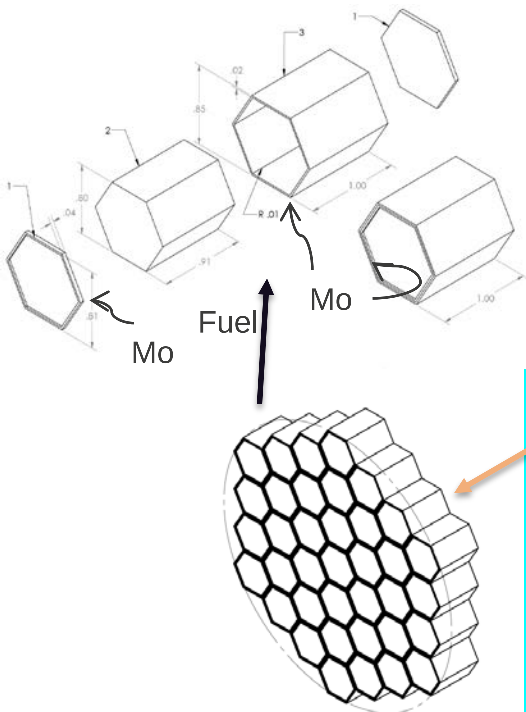


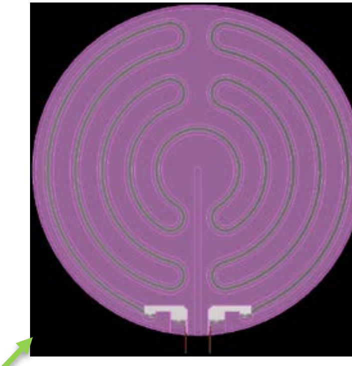
# Hydride Benchmark: Validation of Neutron Kinetics

## Configuration #5

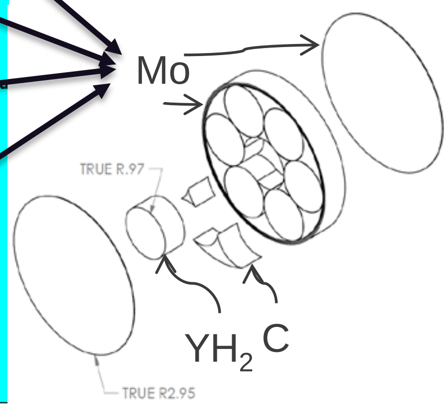



**19%-LEU Sample Plate (Micro-engineered Fuel)**



**Graphite Heater for localized heating**




**$YH_{1.85}$ Plate (Spectral shifting)**

# Hydride Benchmark: Test Matrix

Series of 5 configurations of to allow for understanding of separate effects