PULSTAR Utilization and Irradiation Testing Capabilities for Advanced Reactor Research

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Nuclear Reactor Program

UNC System Board of Governors Center

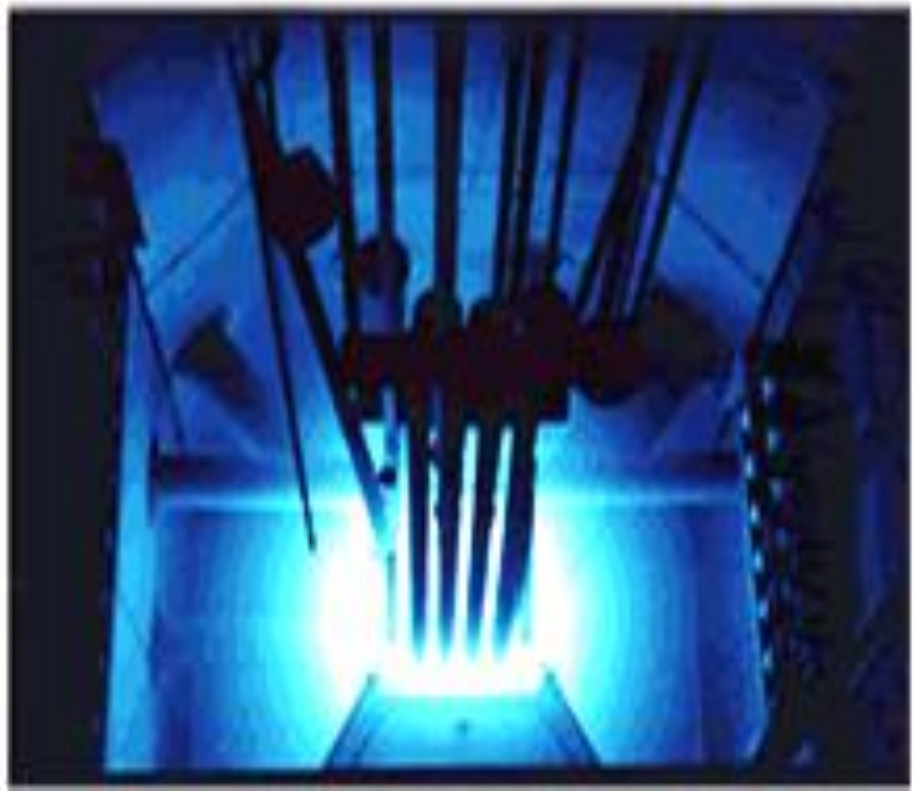
- **Education / Training**
  - Provide a hands-on understanding of the physics and operations of nuclear reactors to the next generation of nuclear engineers
  - Serve as a multi-disciplinary education center in the area of radiation physics applications
  - Provide training in support of nuclear power development

- **Scientific applications and research**
  - Develop state-of-the-art facilities for understanding and applying the principles of radiation interaction with matter
    - Includes in-pool and ex-pool studies

- **Outreach, extension and service**
  - Support the national infrastructure through the use of nuclear methods in various aspects including medical and industrial

PULSTAR Reactor

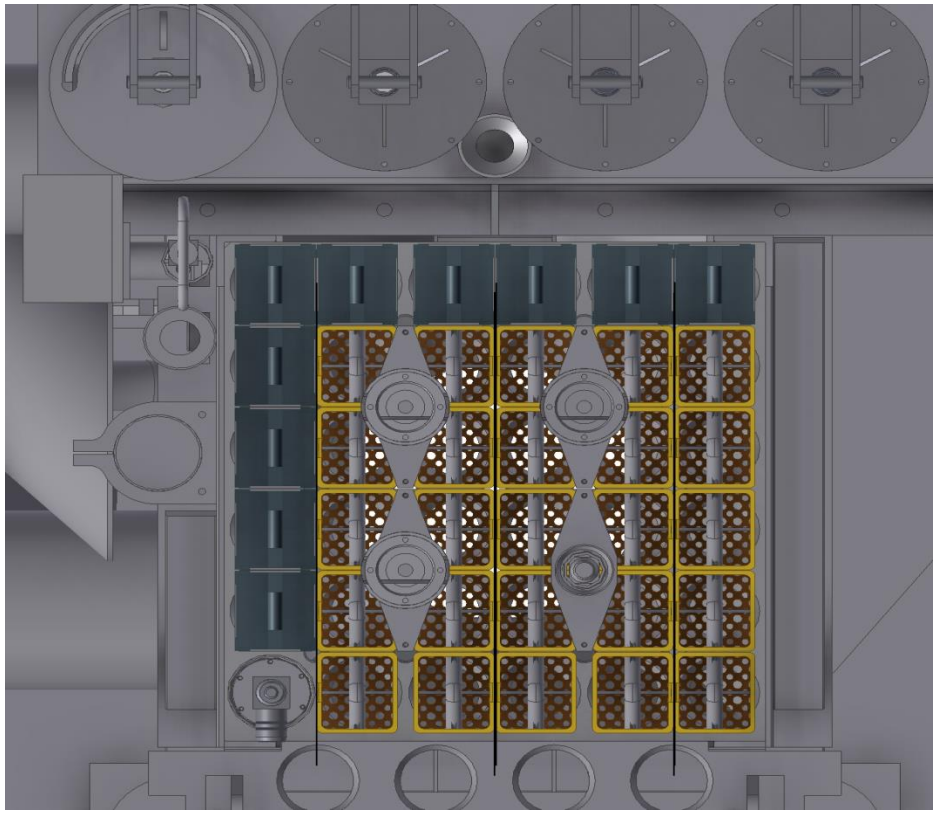
- 1-MW power
  - Upgrade to 2-MW
- Open pool/tank
- Light water moderated and cooled



Critical 1972

PULSTAR Reactor

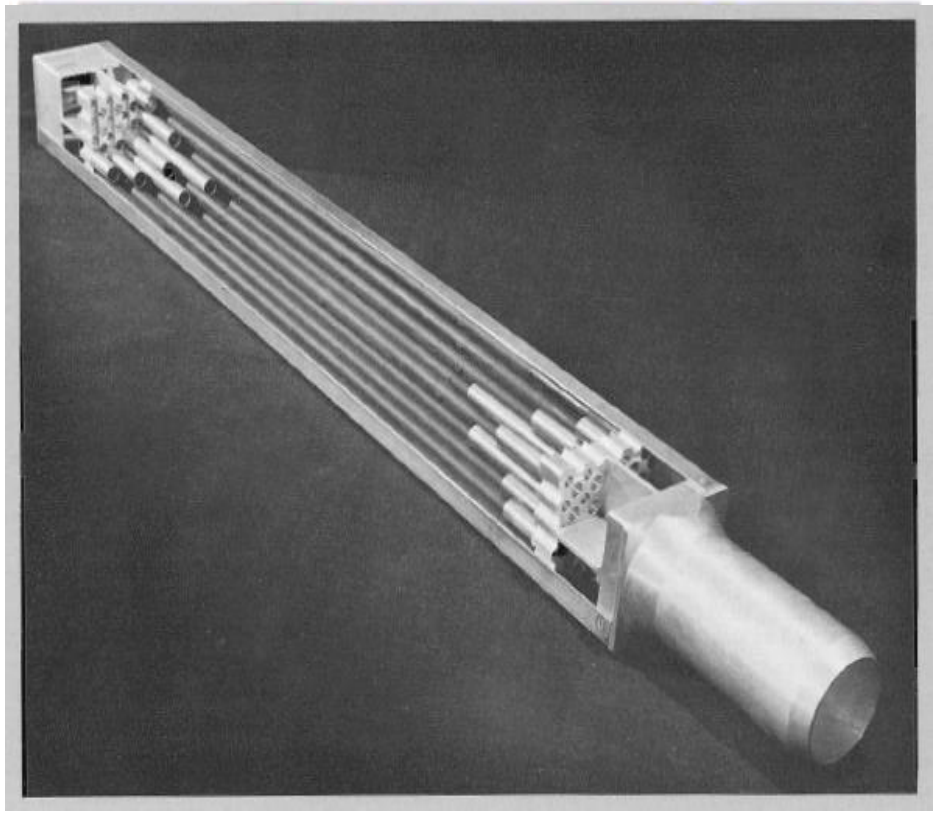
- 1-MW power
  - Upgrade to 2-MW
- Open pool/tank
- Light water moderated and cooled
- 5 x 5 array of fuel assemblies
- 5 x 5 array of pins



Critical 1972

PULSTAR Reactor

- 1-MW power
  - Upgrade to 2-MW
- Open pool/tank
- Light water moderated and cooled
- 5 x 5 array of fuel assemblies
- 5 x 5 array of pins
- Sintered UO_2 pellets
- 4% and 6% enriched



Critical 1972

Nuclear Reactor Program

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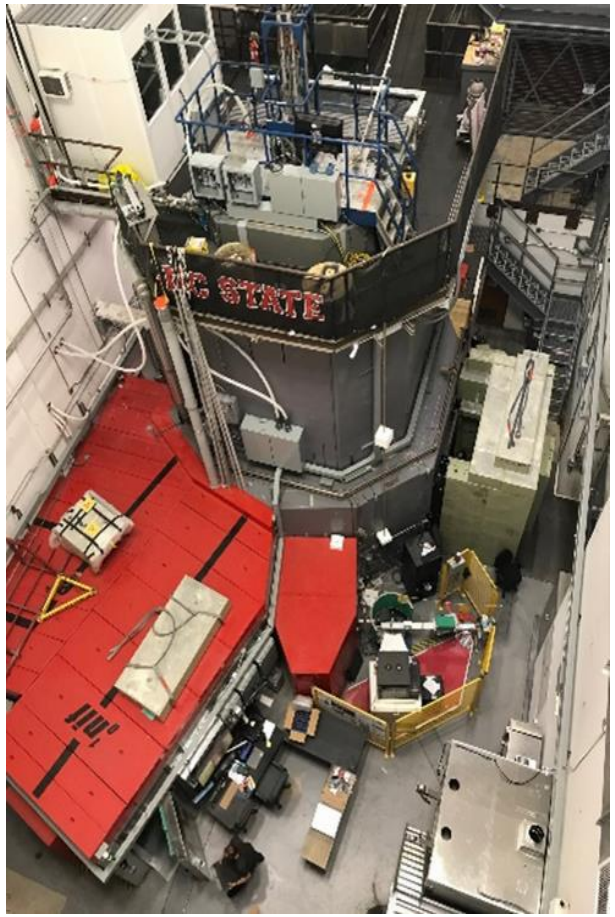
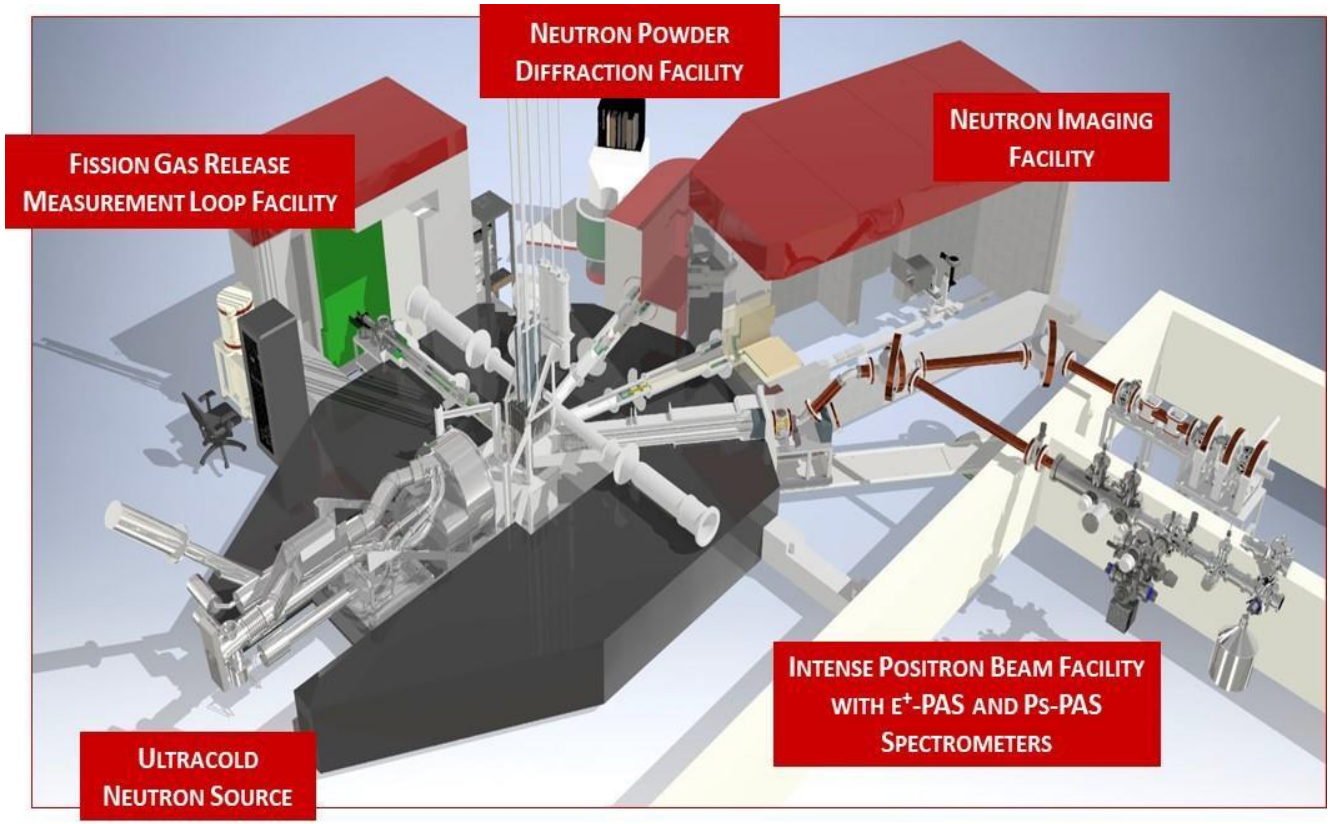
2024



PULSTAR 1-MWth Reactor

DOE NSUF partner

NSF RTNN partner



$60M investment in infrastructure

Advanced Reactor Research

- Advanced Testing Environments
  - Fuel Irradiation
  - Elevated Temperatures
  - Molten Salts
- Advanced Analytical Techniques
  - Fission Gas Release and Assay
  - Laser Induced Breakdown Spectroscopy
- PIE Capabilities
  - Positron Annihilation Lifetime Spectroscopy
  - Neutron Powder Diffraction
  - Gamma Spectroscopy and Spectrometry
  - Hot Cell

Fuel Irradiation

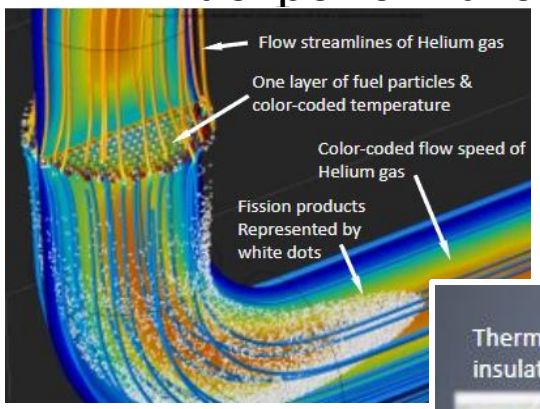
- Proposed Advanced Reactor Fuels:
  - Nitrides
  - Carbides
    - TRISO
  - Fueled Molten Salt (liquid)
- Understudied when compared to traditional materials (eg. UO2)

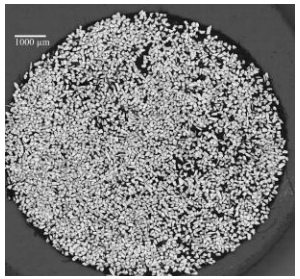
- License Amendment 20 (2023)
  - Fission rates up to 2E9 fissions/s
  - Allows for vented fuel experiments

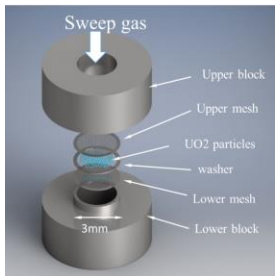
Example – Fission Gas Release

Impetus

- Intergranular fission gas transport phenomena
- Measure release of FP gases from bare fuel particles
- Improve understanding of FP impact on fuel performance

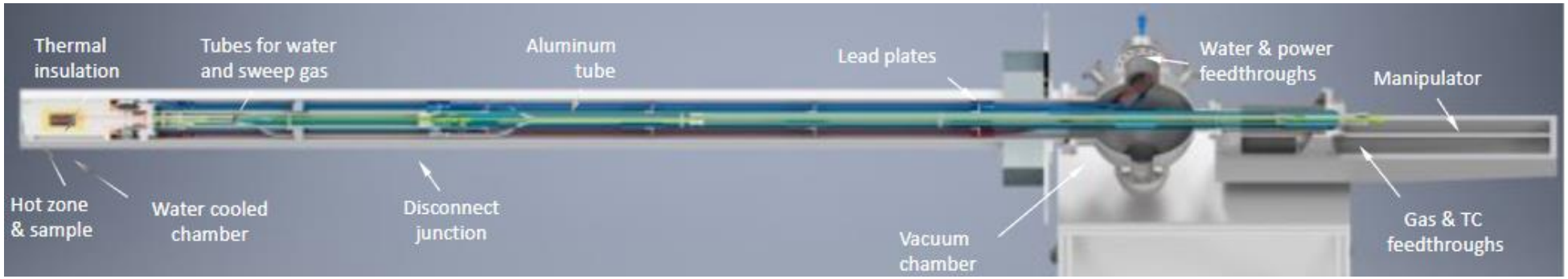






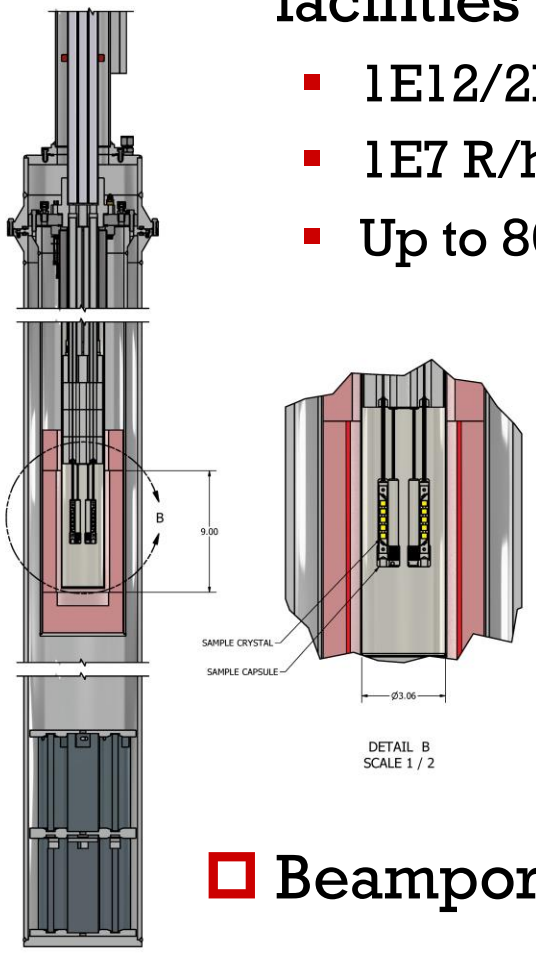
Facility Design

- Material agnostic; can test many different fuel designs
- Sample temperature controlled up to 1000 C

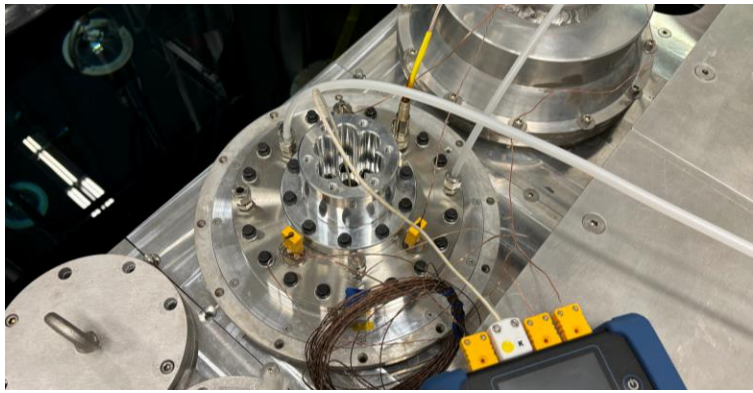


Temperature Controlled Environments

- Materials properties change depending on temperature
  - Physical and crystallographic phase transitions
  - Conductivity
  - Microstructure and chemical stability
- Radiation effects on materials can be highly temperature dependent
  - Interaction cross sections
  - Defect mobility
- Sensor and Instrument Performance Characterization



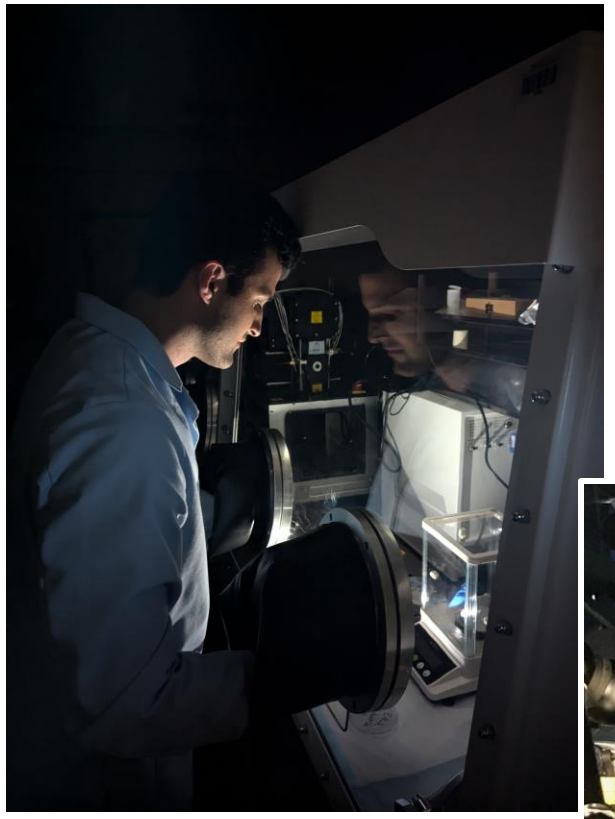
- Near-core irradiation facilities
  - 1E12/2E11 nv (Th/F)
  - 1E7 R/hr gamma
  - Up to 800 C



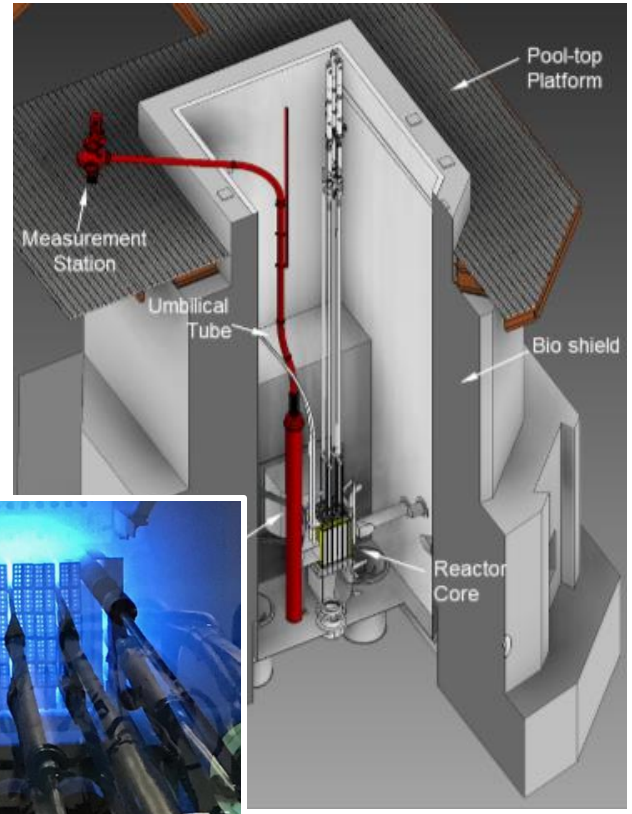
- Beamport Facilities

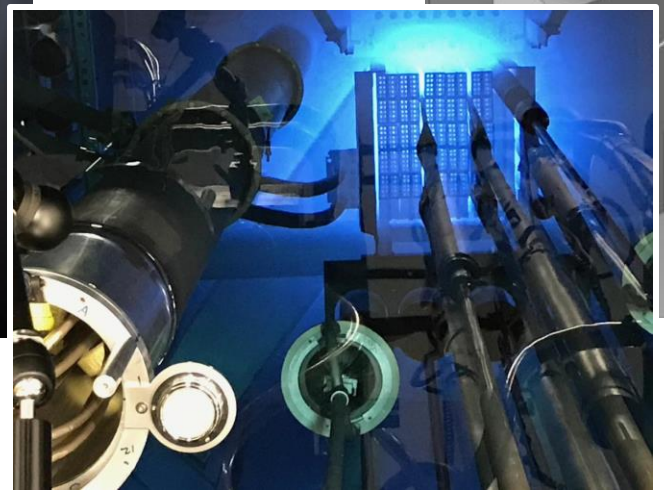
Molten Salt Environments

- Complex Environment
  - Intense radiation fields
  - Uncommon corrosion environment (ideal conditions are anerobic)
  - Elevated temperatures
- Building test MSRs is high-risk
  - How to emulate environment using research reactors?
- Near-Core mixed radiation fields



Glovebox labs for sample prep and non-irradiation studies

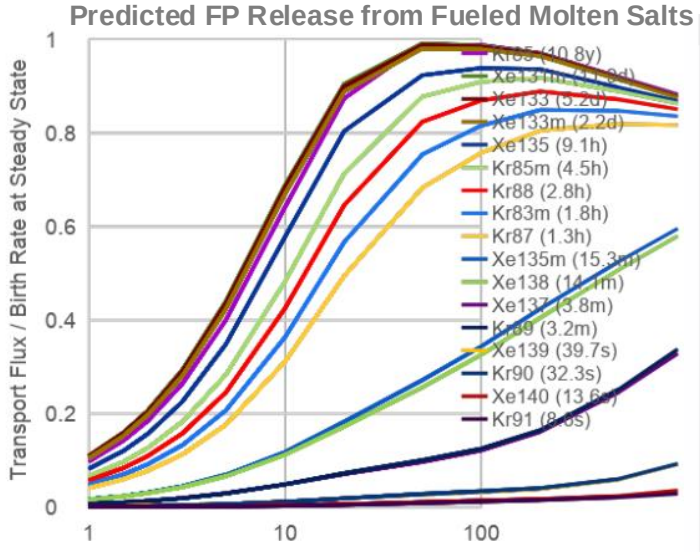


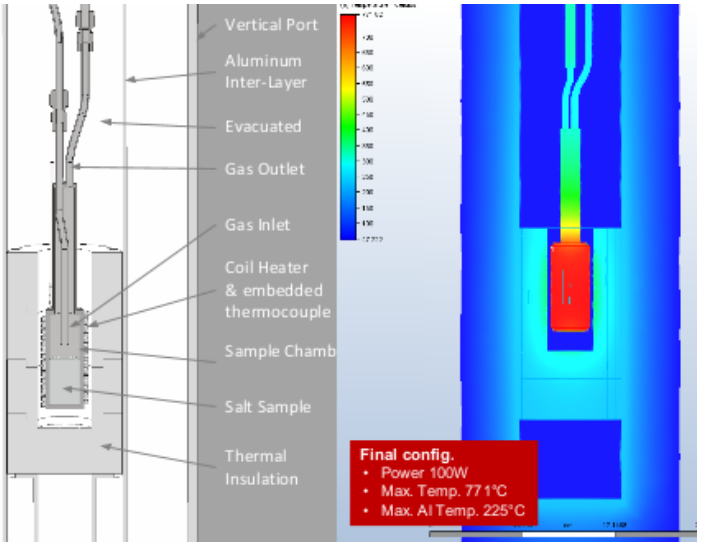


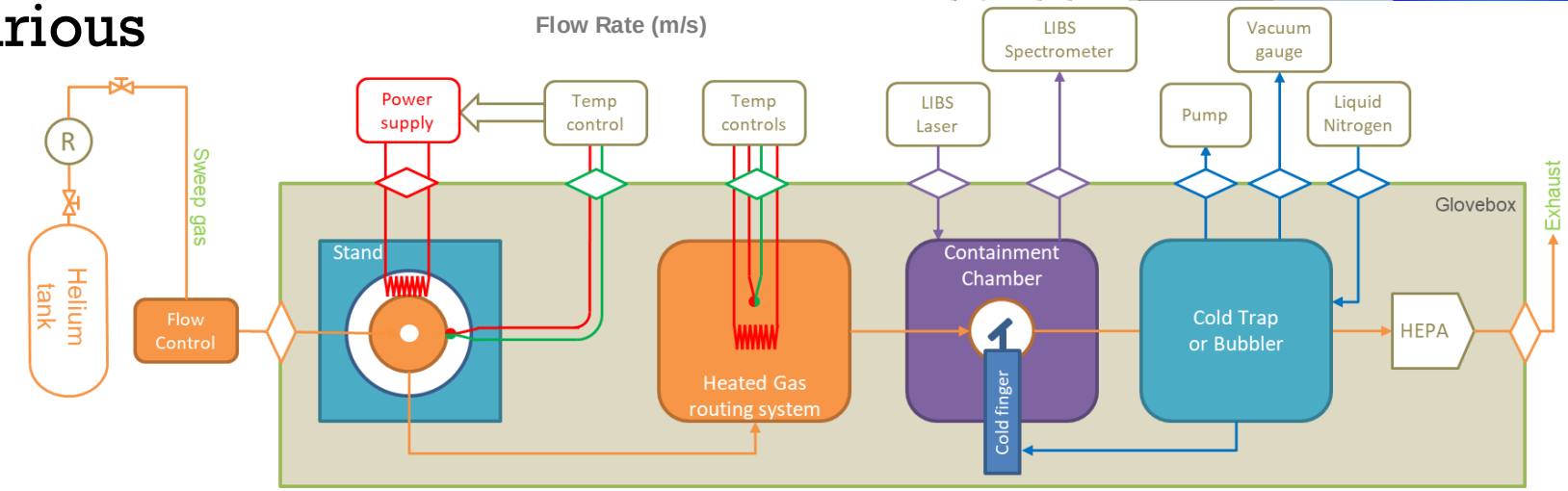
Standpipe installed adjacent to reactor core

Example – Molten Salt Gas Sweep

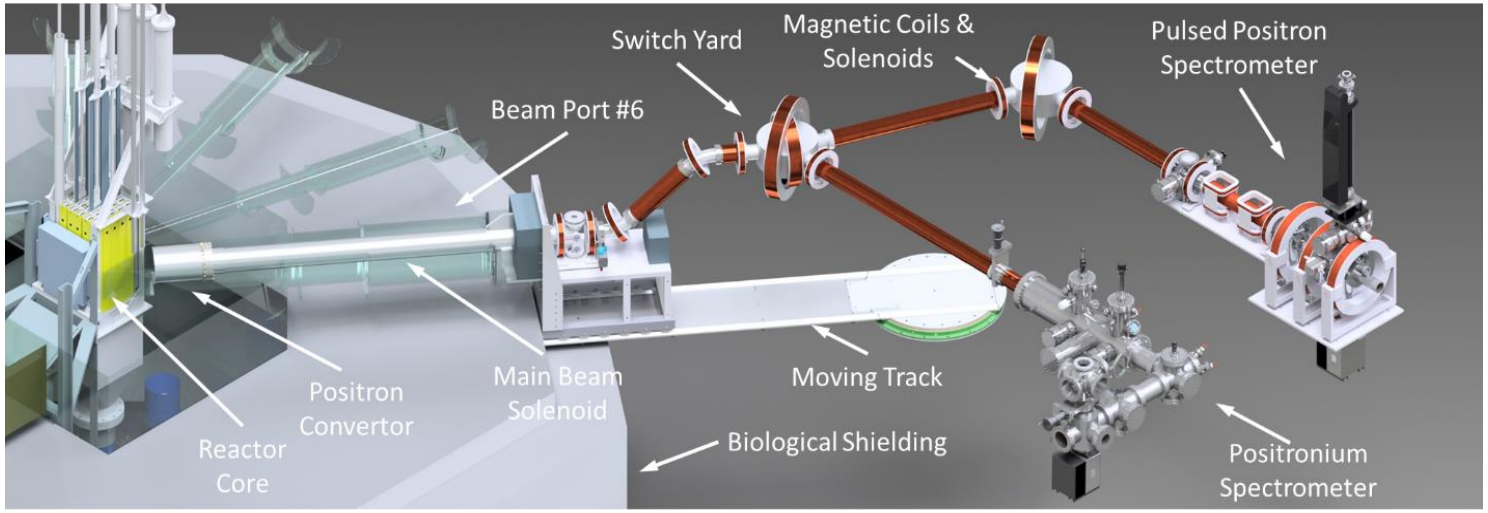
- **Facility Design**
  - Release and transport of fluoride volatiles and tritium from molten salts
  - Regional temperature control
  - Inert gas sweep with flow control and measuring
- **Compatibility with various analytical systems**
  - Gamma spectroscopy
  - LIB spectroscopy
  - Tritium monitoring

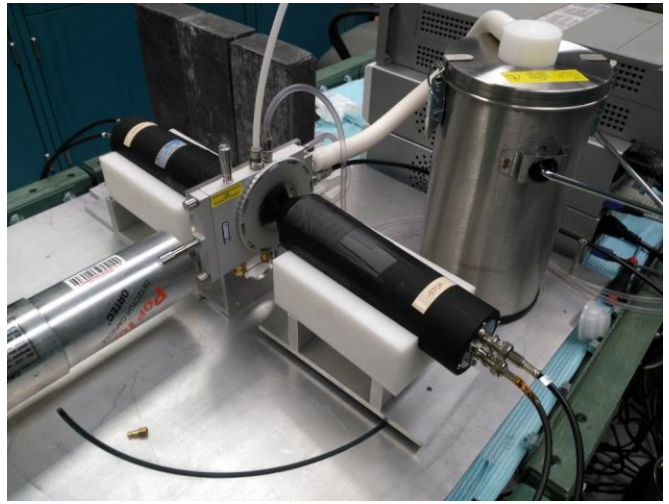




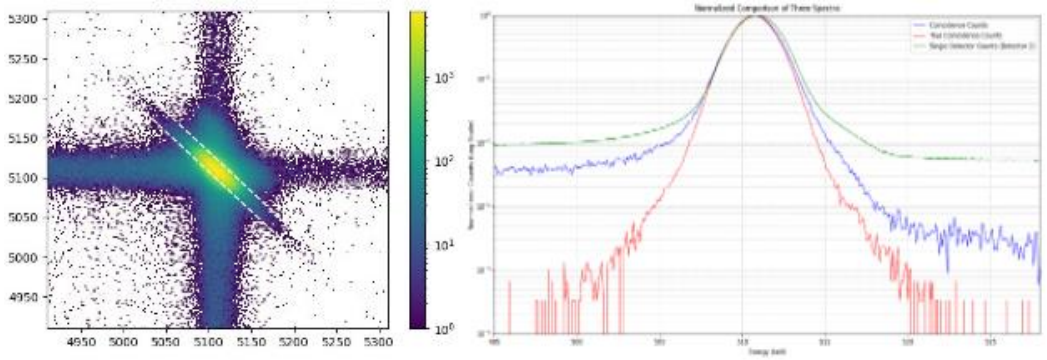


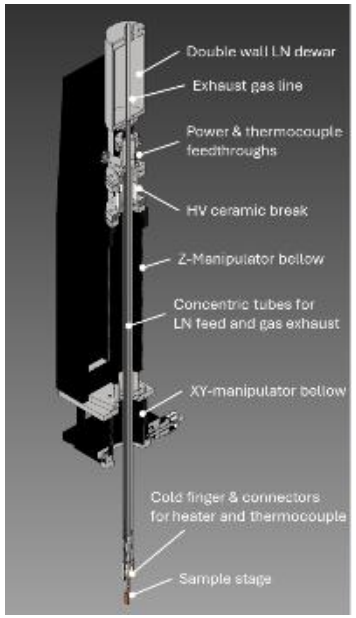
Intense Positron Beam Facility





- Greater than 10^8 e+/s
- Defect analysis on soft matter, semiconductors, metals, etc.
- PALS and CDBS analysis





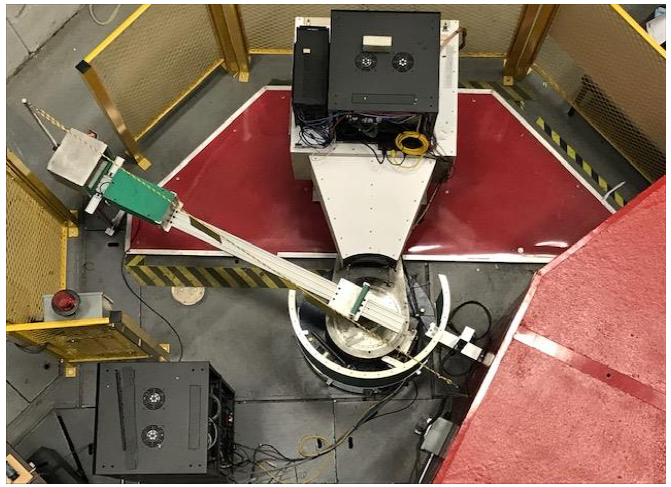
Neutron Scattering – Powder Diffraction

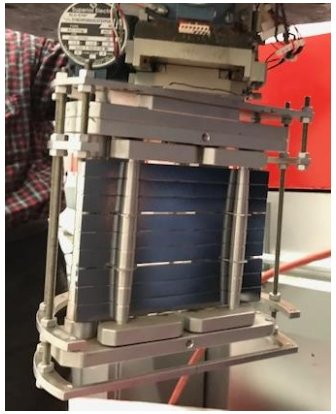
NPDF Facility Upgrades – Dual Purpose:

- Diffraction Measurements:

  15 New Position Encoding Modules (PEM) – improved diffraction measurement resolution $\Delta d/d$ of 2.9×10^{-3} for ϕ3mm holder

- Transmission Measurement Capabilities:
  - Monochromator capable of providing beam wavelengths of 1.085 Å, 1.180 Å, 1.479 Å, and 1.762 Å
  - Can install sample heaters or cryogenic apparatus to control temperature



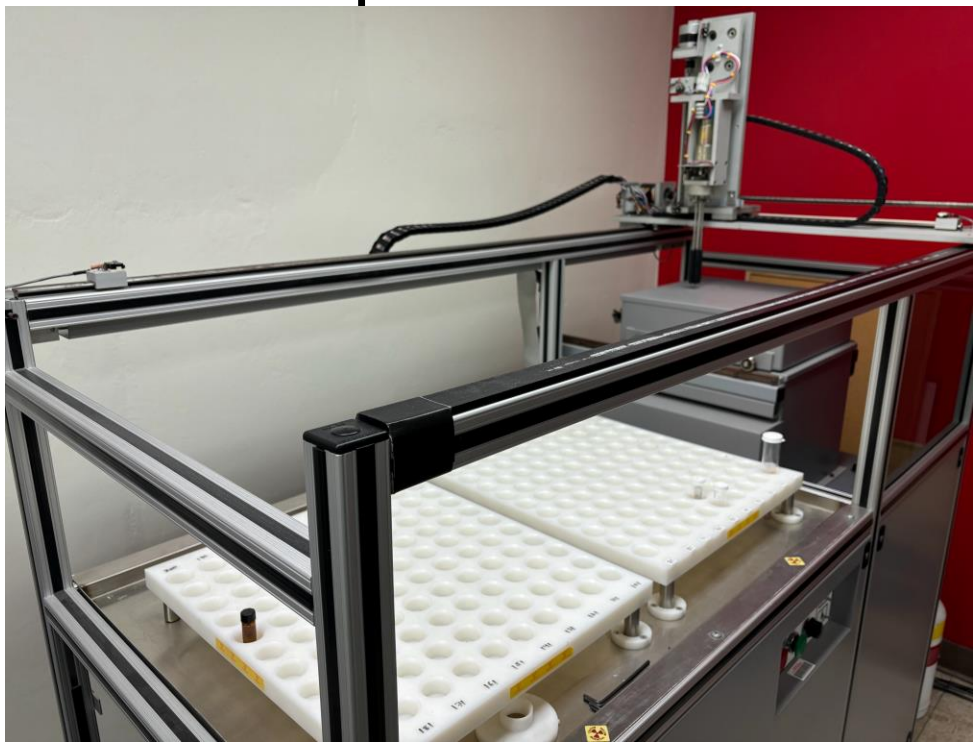


Additional Capabilities

PULSTAR Hot Cell Facility

- Equivalent 6-Inch Lead Shielding
- Post-irradiation material handling and processing

Gamma Spec. and NAA



- Gamma spec. labs with special-purpose measurement stations (eg. PN transfer for short-lived species)
- QMS Based on ISO/IEC 17025 & ISO 9001

Summary

- PULSTAR Reactor
  - Mission
  - Reactor and Facilities
- Advanced Reactor Research
  - Fueled Irradiation Experiments
  - Temperature Controlled Facilities
  - Molten Salt Reactor Environments
- PIE Capabilities
  - Positron Beam
  - Neutron Powder Diffraction
  - Gamma Spectroscopy and Spectrometry
  - Hot Cell

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Thank You

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