SNS Improvements Aided by J-PARC Collaboration

Mark Lyttle

Section Head
Neutron Technologies Engineering

Oak Ridge National Laboratory, USA

Contents

- Overview of the SNS facility, recent power upgrade, and Second Target Station (STS)
- Operating power and production ramp-up plans and status
- Overview of target and moderator system upgrades and status
- The Moderator Test Station project
- Current and future SNS and J-PARC target system collaboration opportunities

Spallation Neutron Source (SNS) in the US hosts a pulsed neutron source similar to J-PARC MLF

Second Target Station accelerator stub complete, design on track

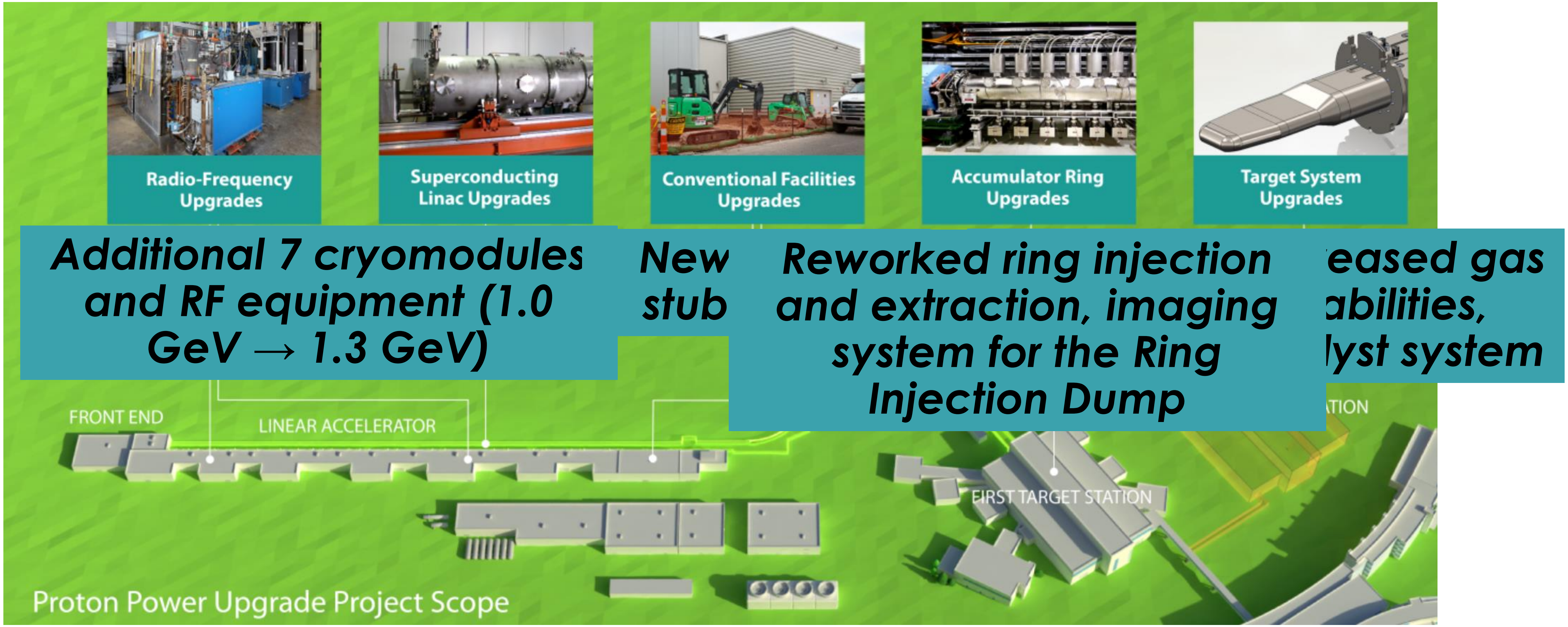
Tunnel completed to connect the accelerator to the future second target station

Future Second Target Station

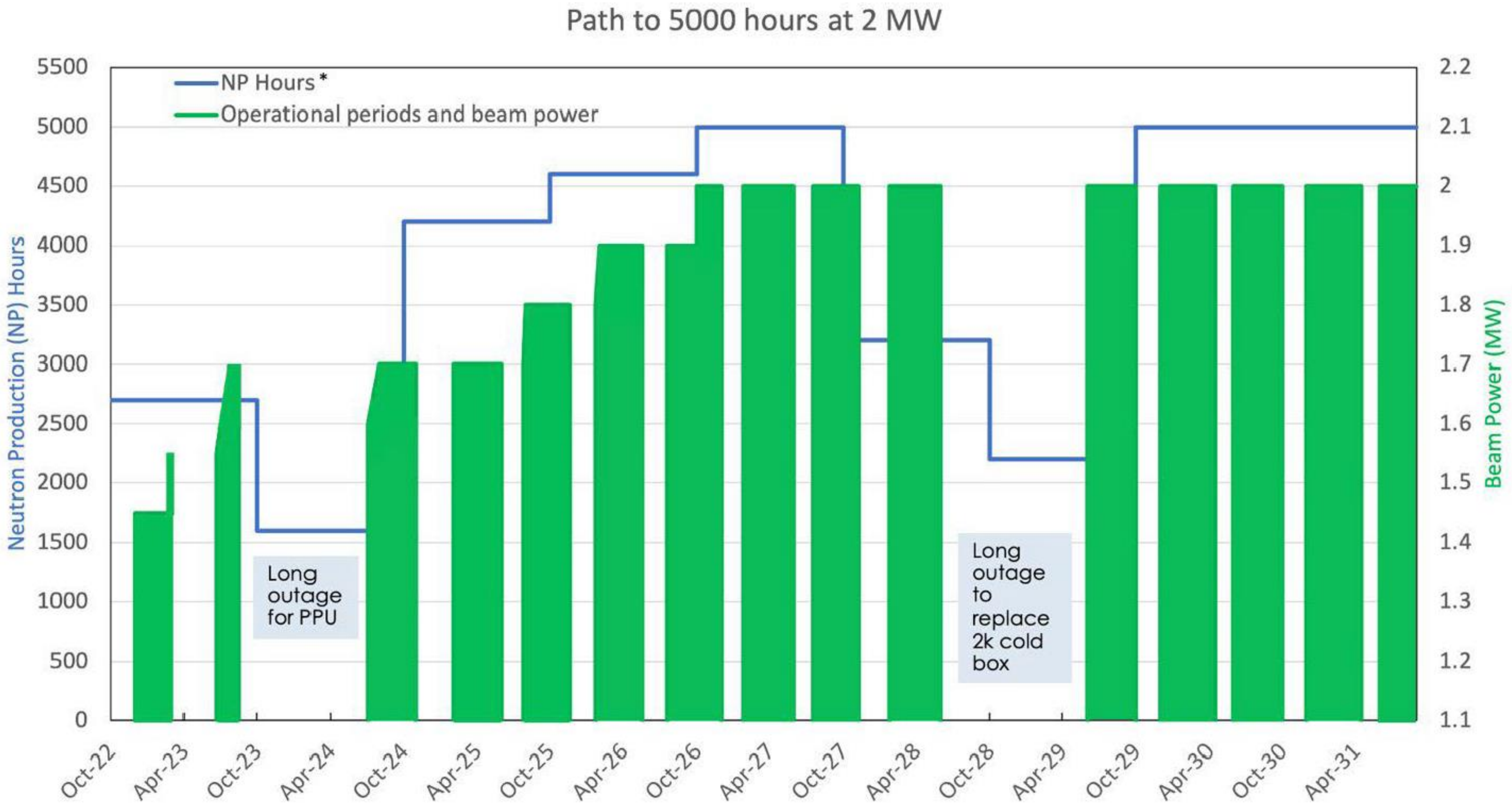
The target station will used a rotating tungsten target, with a goal for early science in 2034

Proton Power Upgrade project completed, doubling the power capability of the accelerator and upgrading the target systems.

- 30% beam energy increase, 50% beam current increase
- 2 MW to First Target Station
- 0.7 MW for Second Target Station



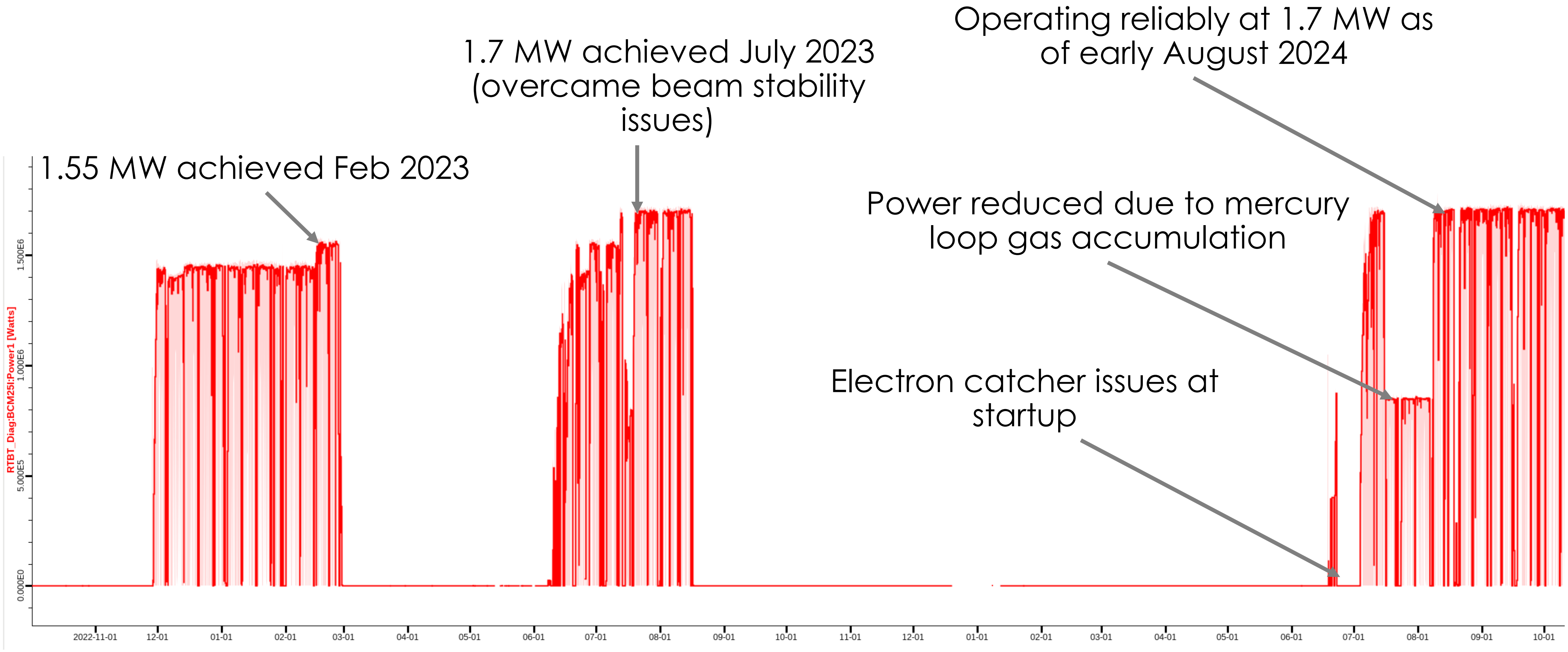
SNS is ramping up to 2MW operations and 5000 neutron production hours per year.



After 2 MW achieved, next goal is shift to 45 Hz operation

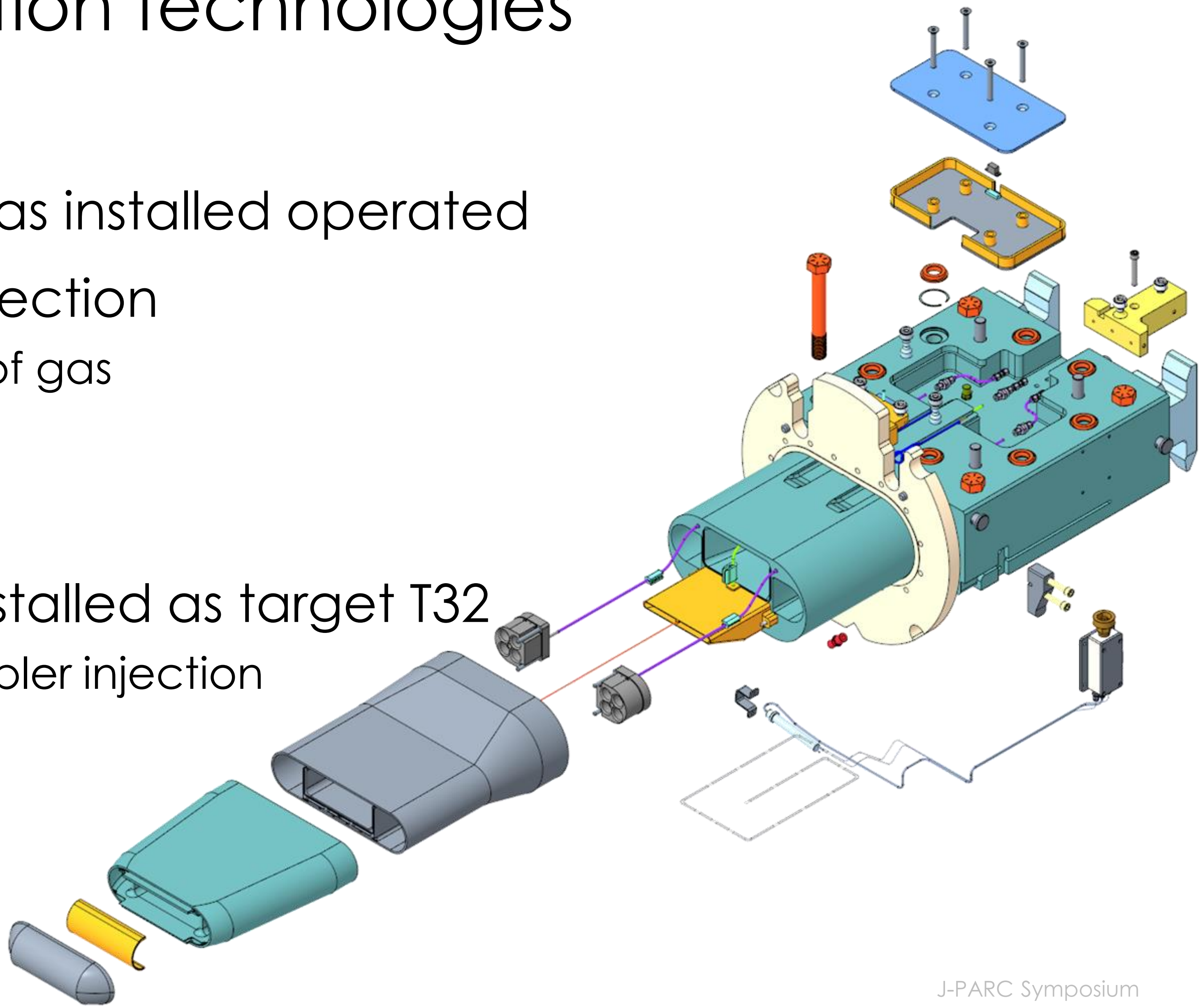
- Change will bring SNS close to J-PARC levels of energy per pulse
  - SNS pulse energy levels
    - 1.4 MW at 60 Hz = 23 kJ
    - 1.7 MW at 60 Hz = 28 kJ <- We are here
    - 2 MW at 60 Hz = 33 kJ
    - 2 MW at 45 Hz = 44 kJ
  - J-PARC pulse energy levels
    - 1 MW at 25 Hz = 40 kJ
- Different SNS beam energy (1.3 GeV) compared to J-PARC (3 GeV) and beam profiles lead to different peak mercury pressure (40 MPa for 1 MW at J-PARC, 34 MPa for 2 MW at SNS)

SNS power ramp to 1.7 MW



2 MW target module design operated successfully, incorporating gas injection technologies pioneered at J-PARC.

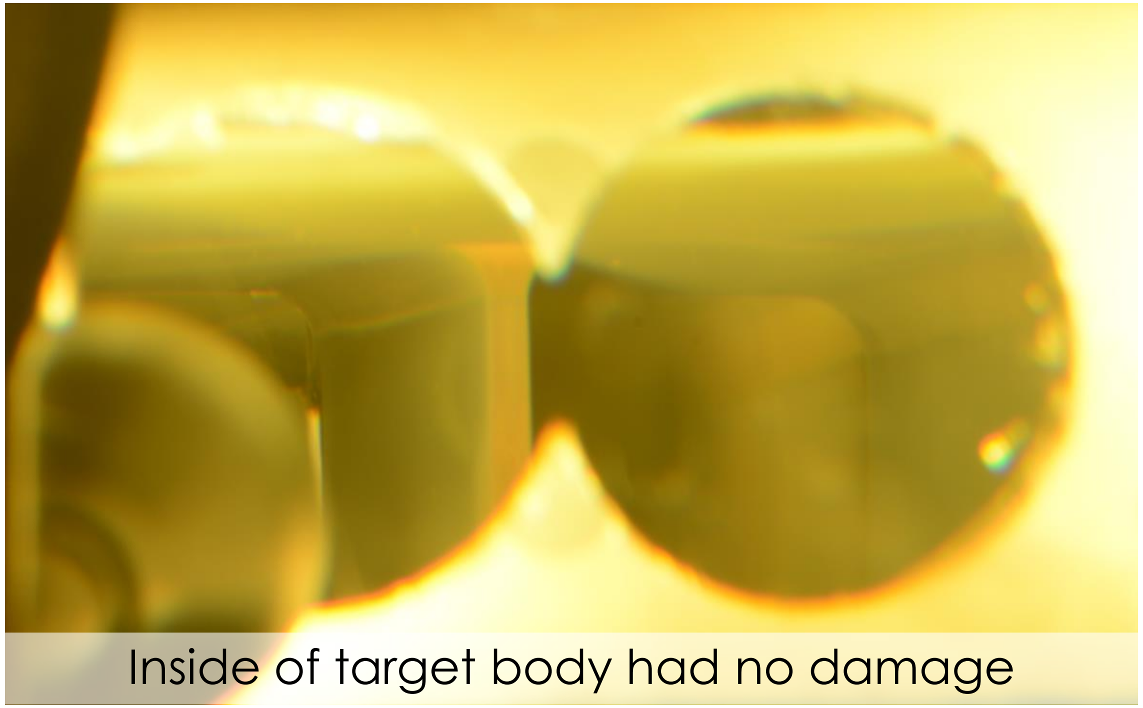
- 2 MW target module design was installed operated
- Target did not use nose gas injection
  - This supply makes large bubbles of gas
  - We do <u>not</u> expect a gas wall
- Operated until August 2023
- Another 2 MW target is now installed as target T32
  - Both nose injection and swirl bubbler injection are functioning



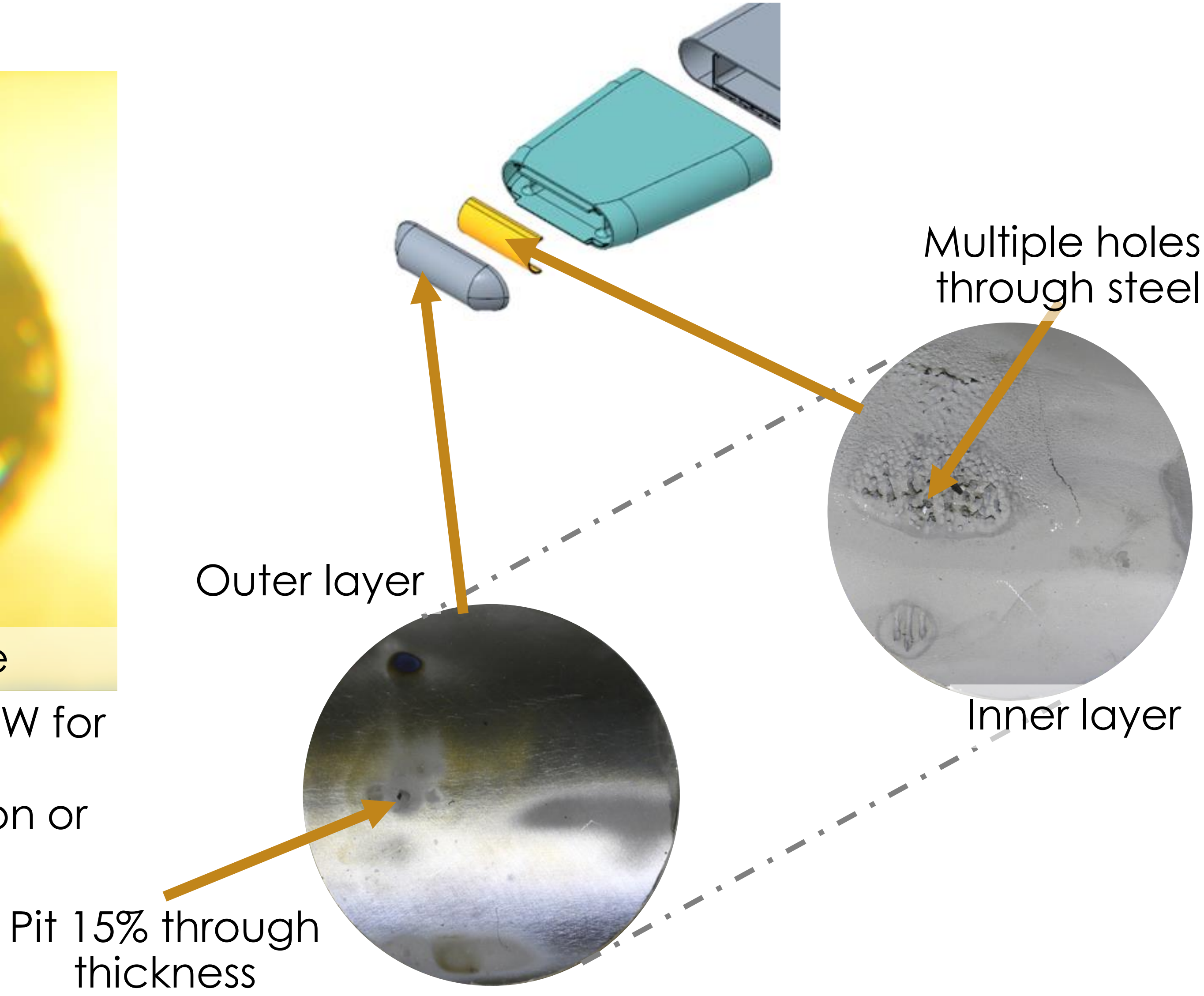
SNS contacts: Drew Winder and Kevin Johns

OAK RIDGE National Laboratory

Post irradiation examination of 2 MW target showed damage only at the beam center

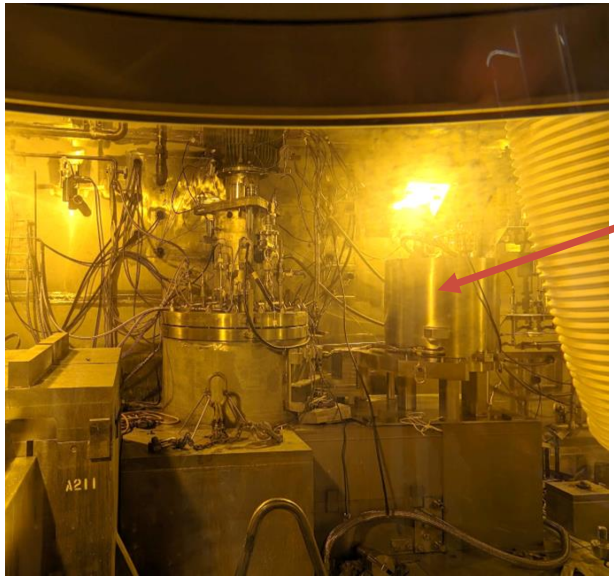

Inside of target body had no damage

The first 2MW target operated above 1.4 MW for 2737 hours and above1.7 MW for 538 hours (total of 4388 MW-hrs.) without nose injection or increased gas injection rate.



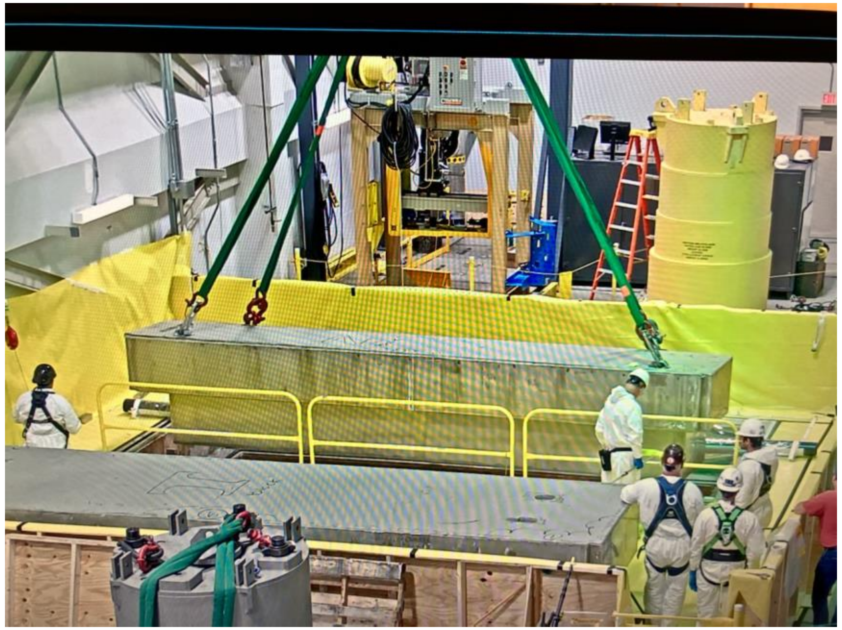
SNS contact: David McClintock

Mercury loop improvements incorporated to allow for nose injection and higher helium gas injection rates.



Mercury overflow tank installed next to the mercury pump

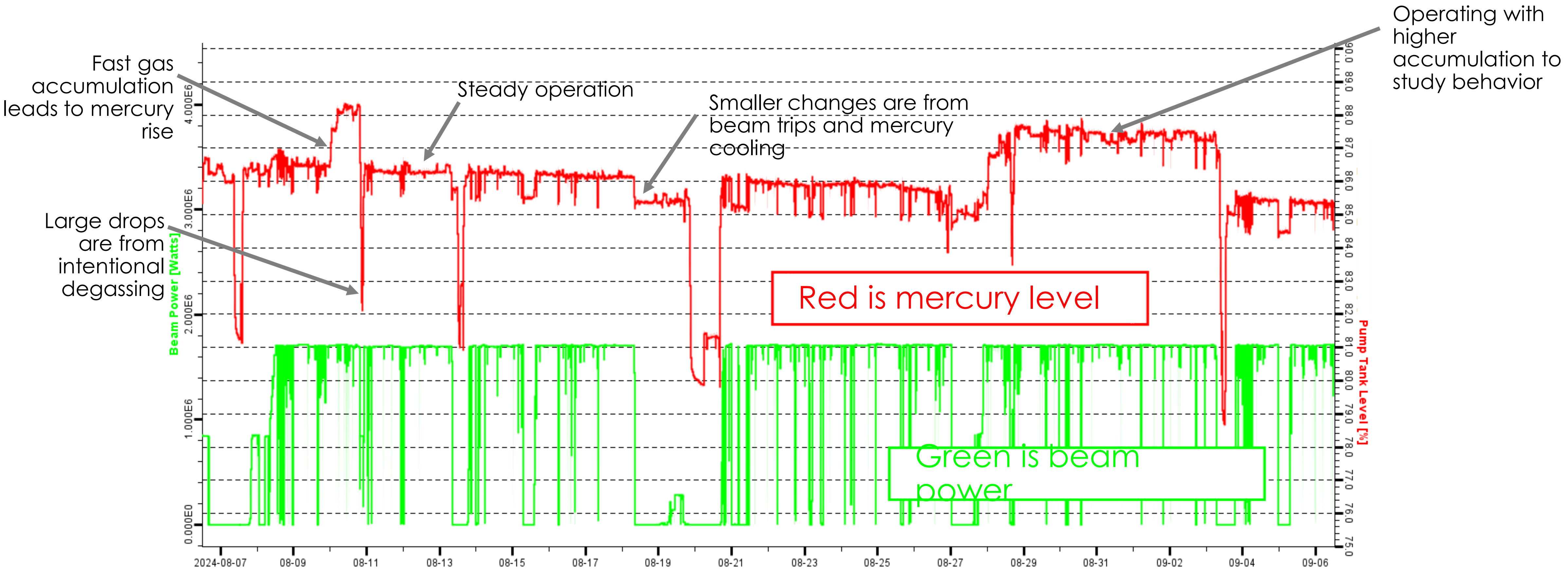
A new mercury overflow tank (left and top right) and vent line/shield block assembly (lower right) installed.



Installation required removal of the hot cell roof beams, a first for SNS.

SNS contacts: Drew Winder and Ryan Schultz

Despite the loop improvements, SNS is struggling with gas accumulating in the mercury loop.



SNS contact: Drew Winder

Influenced by J-PARC, a parahydrogen catalyst system is installed and operating in the liquid hydrogen moderator loops.

Vacuum vessel holding three catalyst beds

Welded 10-liter iron oxide catalyst bed

Catalyst bed retention elements

Cerafelt

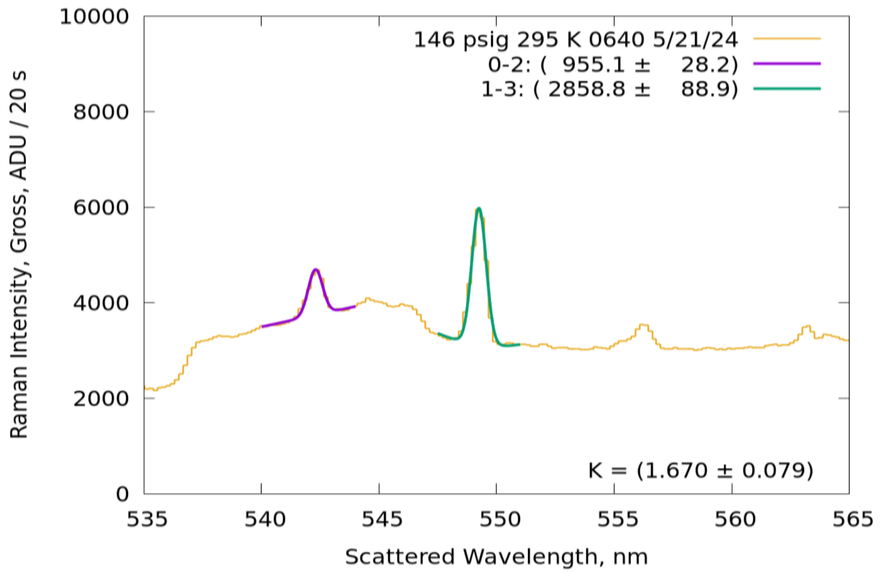
Mesh screen

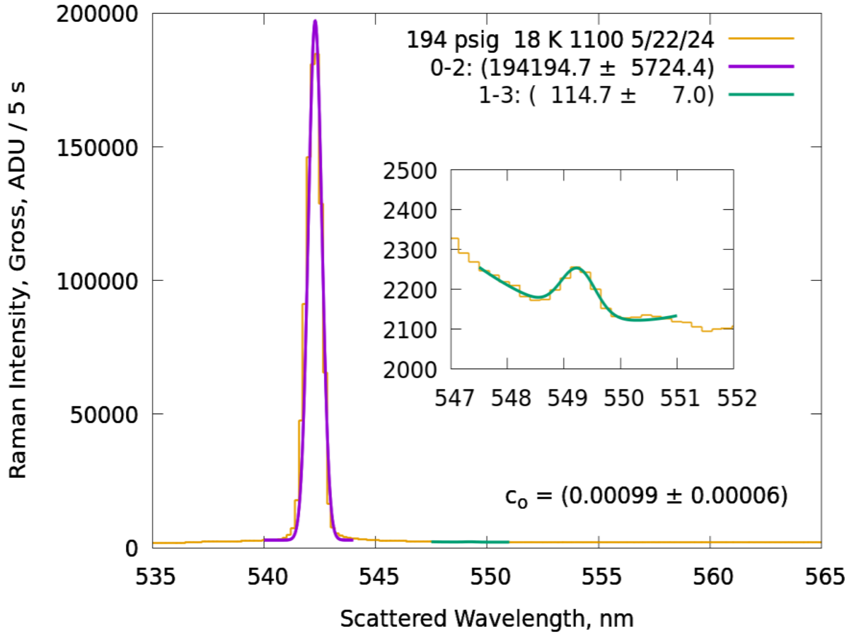
Perforated plate

SNS contact: Brian DeGraff

In-situ Raman spectroscopy gives real-time ortho-para fraction measurement capability.

- Spectra at room temperature during hydrogen fill operation provides ample signal to support calibration with 30 second measurement at 100 mW (top graph)
- Spectra at low temperature (18 K) is far stronger, limiting integration to 5 s, but still enabling adequate view of orthohydrogen peak (bottom graph)

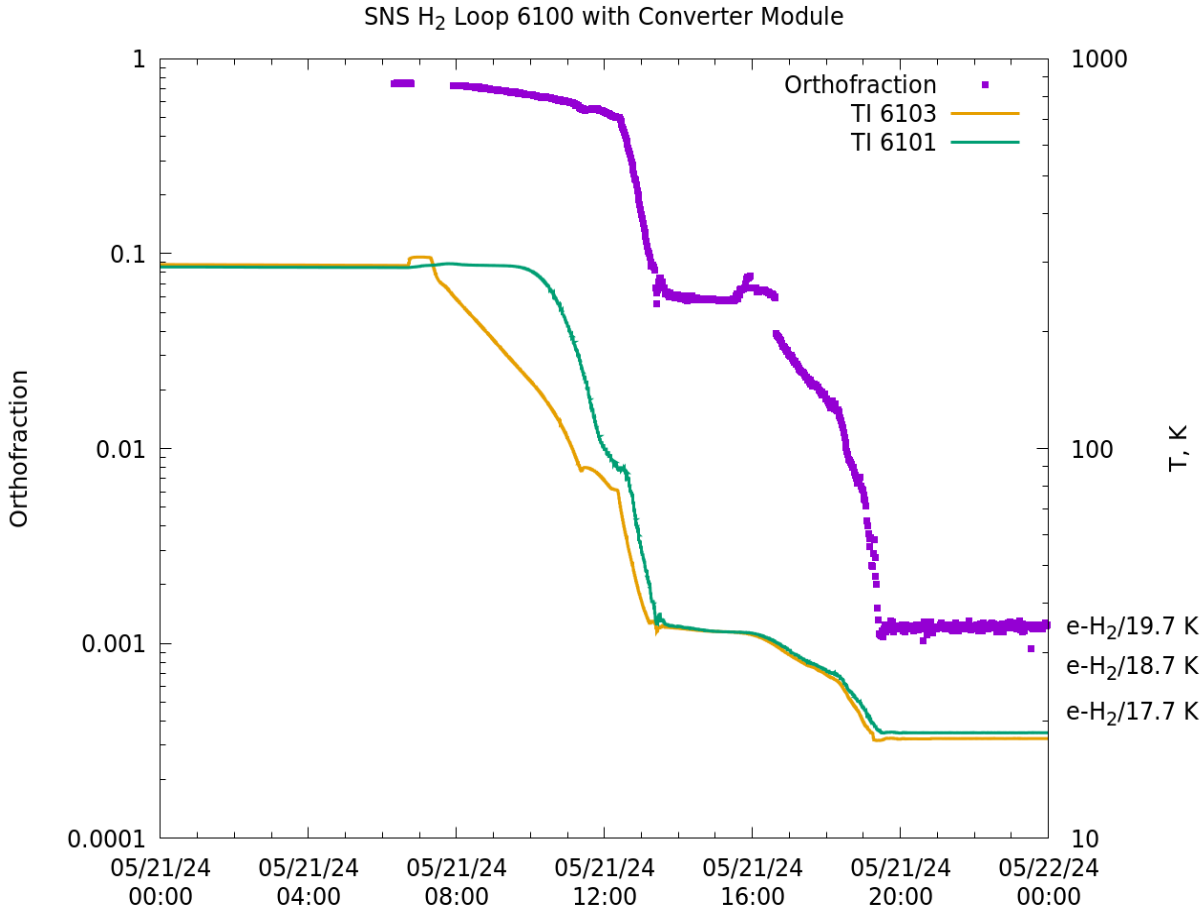




SNS contact: Erik Iverson

Hydrogen Cooldown

- The apparent ortho-fraction falls from 75% to values consistent with thermodynamic equilibrium quickly – a response time less than minutes responding to temperature changes.
- Catalyst system is a success – rapid relaxation to effective equilibrium, facilitating stable performance at minimal orthohydrogen levels



SNS contact: Erik Iverson

Cadmium electroplating to replace metal arc spraying is showing promising results for applying thick (>1.4mm) neutron decoupler coatings.

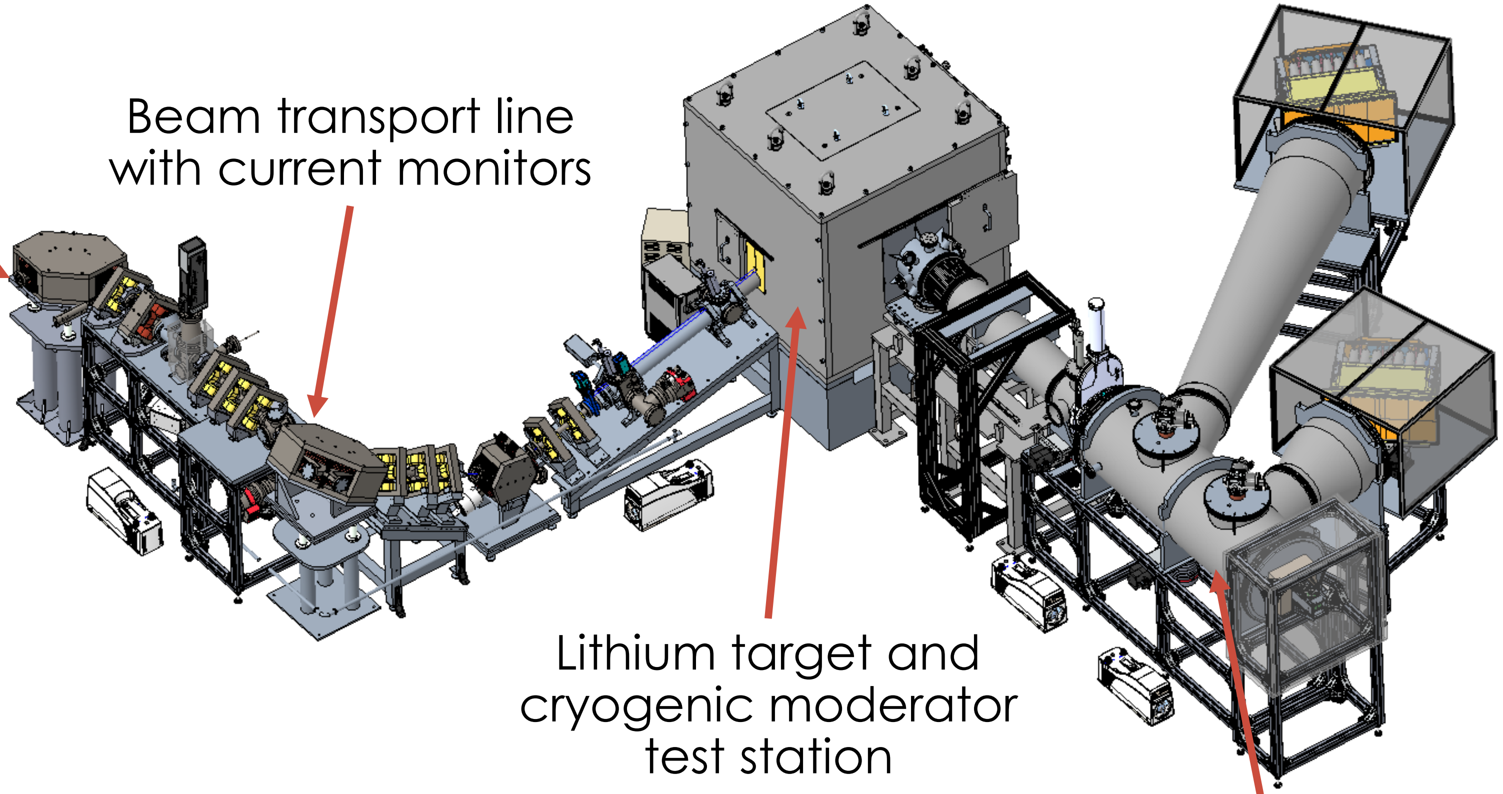
SNS ambient moderator in cadmium electrolytic solution

Initial testing had good adhesion, but excessive porosity

Addition of circulation and agitation system in the electrolyte bath resulted in good adhesion and density

SNS contact: Doug Armitage

Moderator Test Station (MTS) for studying advanced moderator concepts is under design.

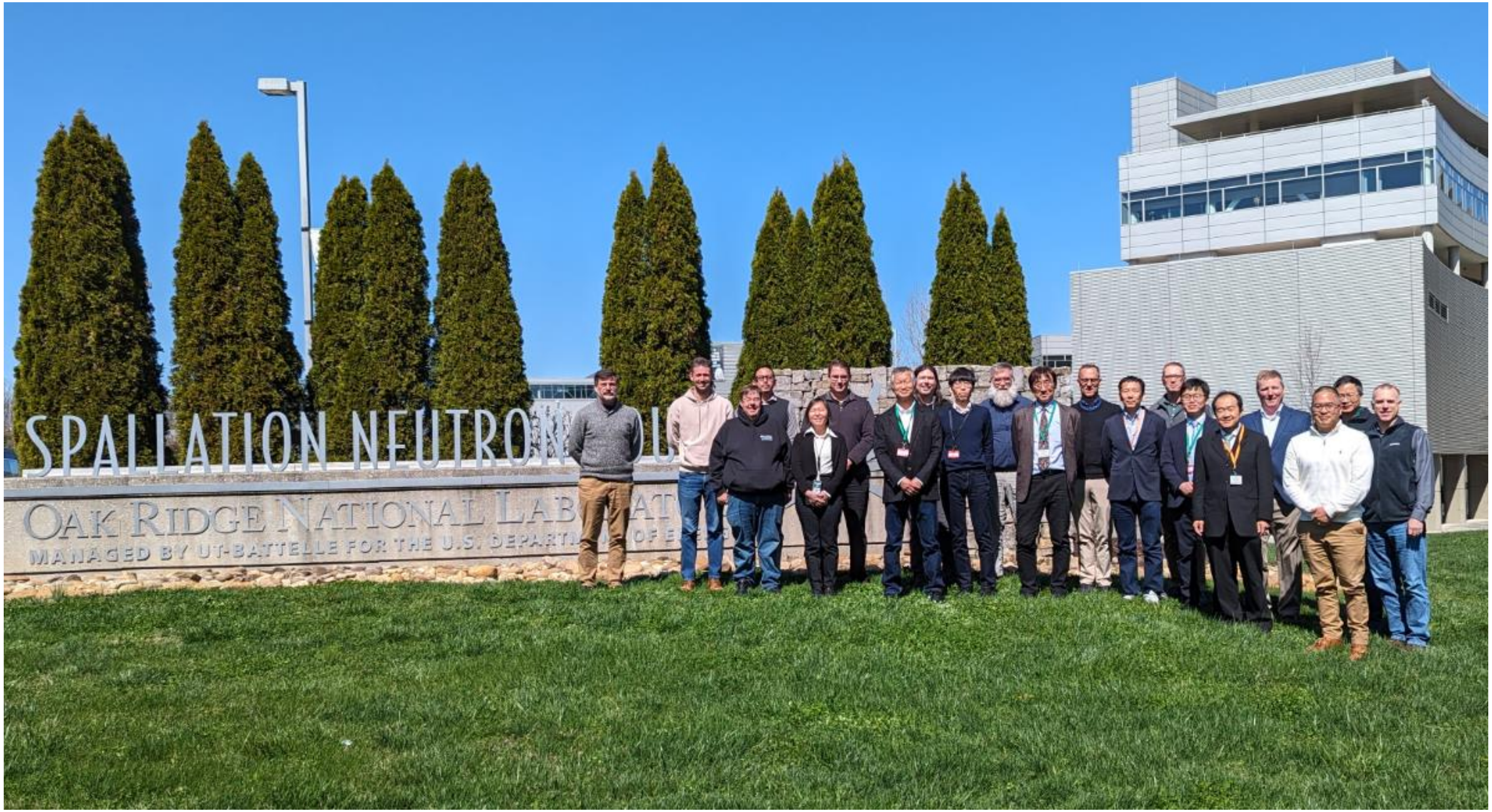


SNS contacts: Kevin Johns and Erik Iverson

J-PARC/SNS collaboration on Target systems has been hugely beneficial to both facilities, with many more opportunities in the future, including:

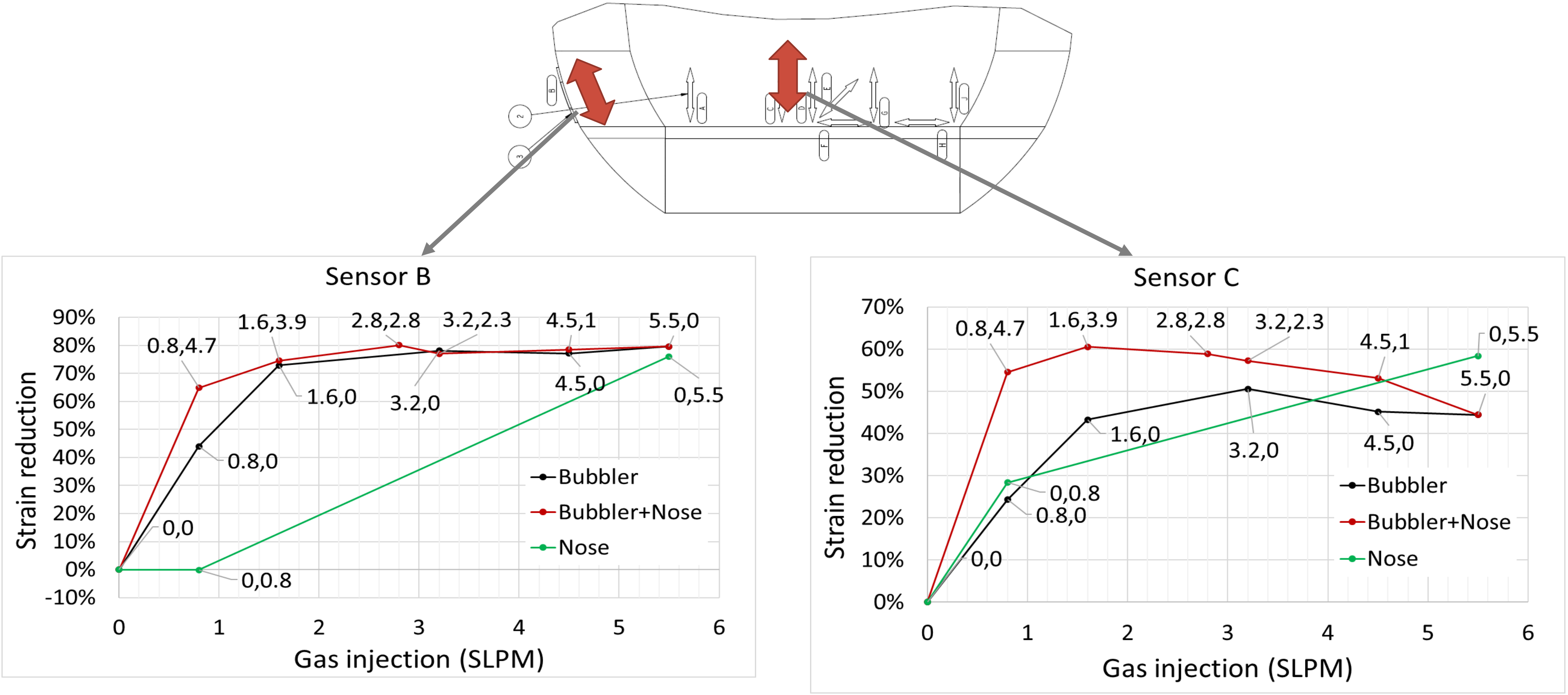
- Shared operations and maintenance experience
- Development and characterization of advanced materials for moderators, decouplers, poisons, and targets
- Development and characterization of advanced moderator geometries
- Development of design tools and techniques for multi-phase, high-power targets
- Development of manufacturing techniques and technologies for target system components

Questions?


SPALLATION NEUTRON
OAK RIDGE NATIONAL LAB
MANAGED BY UT-BATTELLE FOR THE U.S. DEPART

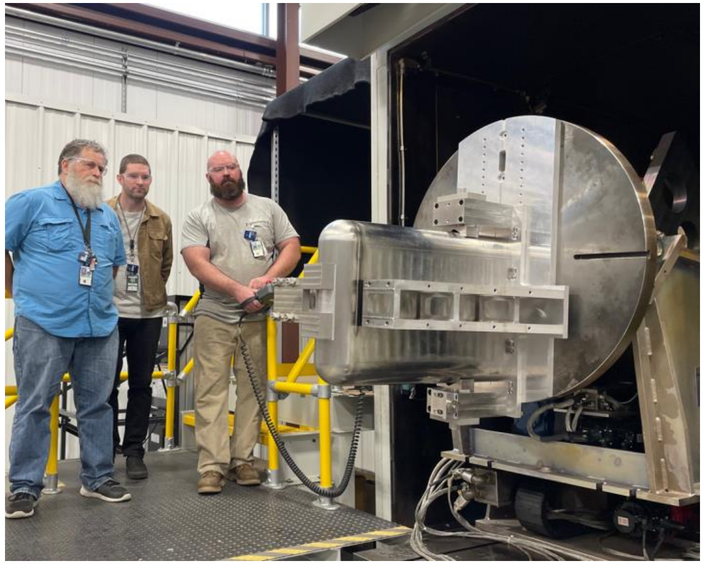
Backup slides

Strain measurements show the nose injector is effective at the injection site and center of the target.

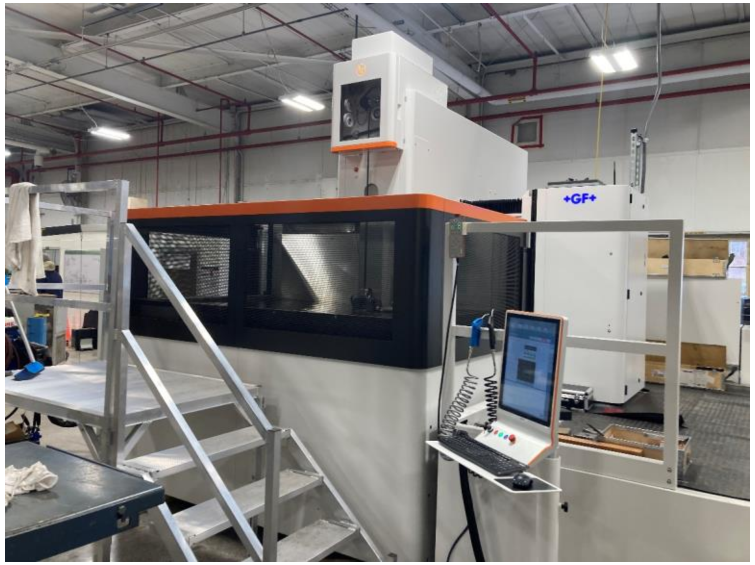


SNS contact: Hao Jiang

ORNL has invested heavily in manufacturing capabilities for targets and reflector plugs.



First water-cooled shroud weld performed on ORNL electron beam welder



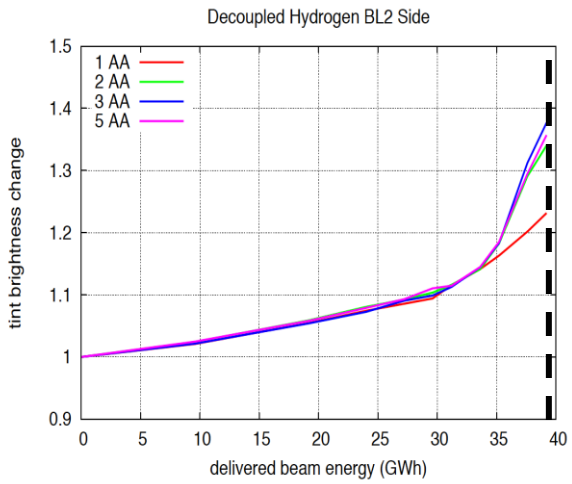
Extensive plunge and wire electric discharge machining (EDM) capabilities

New machining capabilities include large format 5-axis machining and cadmium machining capabilities

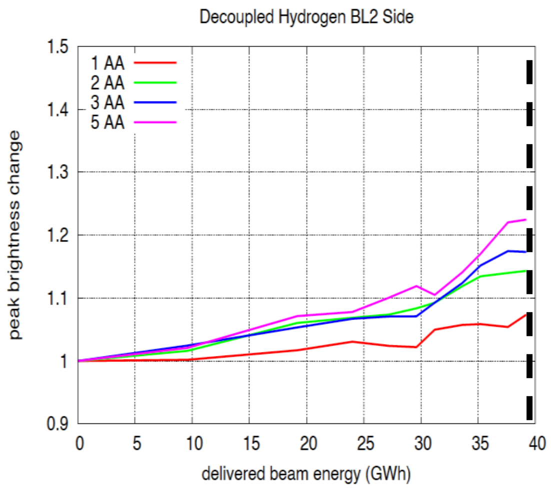
SNS contact: Hyon Ko

The second SNS inner reflector plug (IRP-2) is operating beyond its design life due to delays in manufacturing.

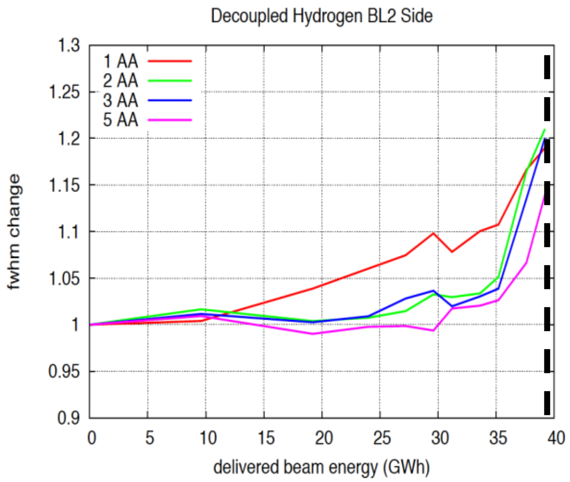
- 28 GWh design life vs. planned 40 GWh operations life
- Beginning to see effects of poison and decoupler burnup on the top upstream and ambient moderators
- More frequent instrument calibrations are required



tint brightness



peak brightness



FWHM pulse

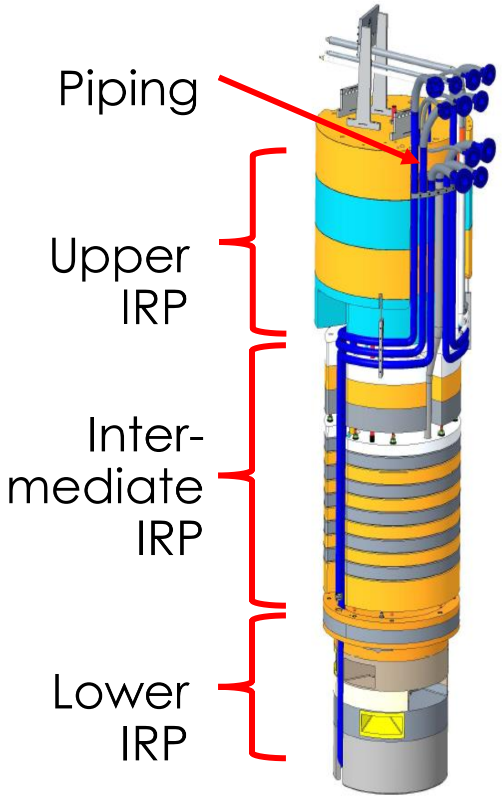
Decoupled poisoned hydrogen moderator

SNS contacts: Franz Gallmeier and Wei Lu

IRP-3 must be delivered in August of 2025 for installation beginning in November of 2025.

- Final assembly to begin Nov. 2024
- Issues during manufacturing include:
  - Damage to moderator housing during electron beam weld
  - High leak rates and cracking in various aluminum welds
  - Nested hydrogen piping bending issues required a redesign
  - Delamination of metal arc spray cadmium and aluminum coatings

The Lower IRP, which contains the moderators and reflectors, is the last major component before final assembly.

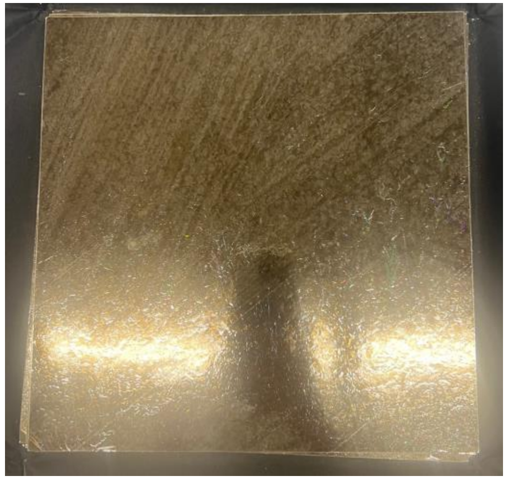


SNS contact: Hyon Ko

MTS design status and technical developments

- Conceptual design complete, preliminary design underway
  - Preliminary design completes by end of 2024
  - Final design completes by mid-2025
  - Installation and commissioning in 2026-2027
- Target
  - Thin film lithium deposition with overcoat being developed with ORNL energy storage and conversion experts
- Analyzer arrays
  - Material selection, characterization, and optimization
  - natural phlogopite (mica crystal) chosen material; exploring elastic deformation to achieve required crystal plan orientations

Lithium coating test coupons



Mica analyzer crystal

SNS contacts: Kevin Johns and Erik Iverson