SNS Accelerator Advisory Committee
Oak Ridge, TN
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Neutron Source Development

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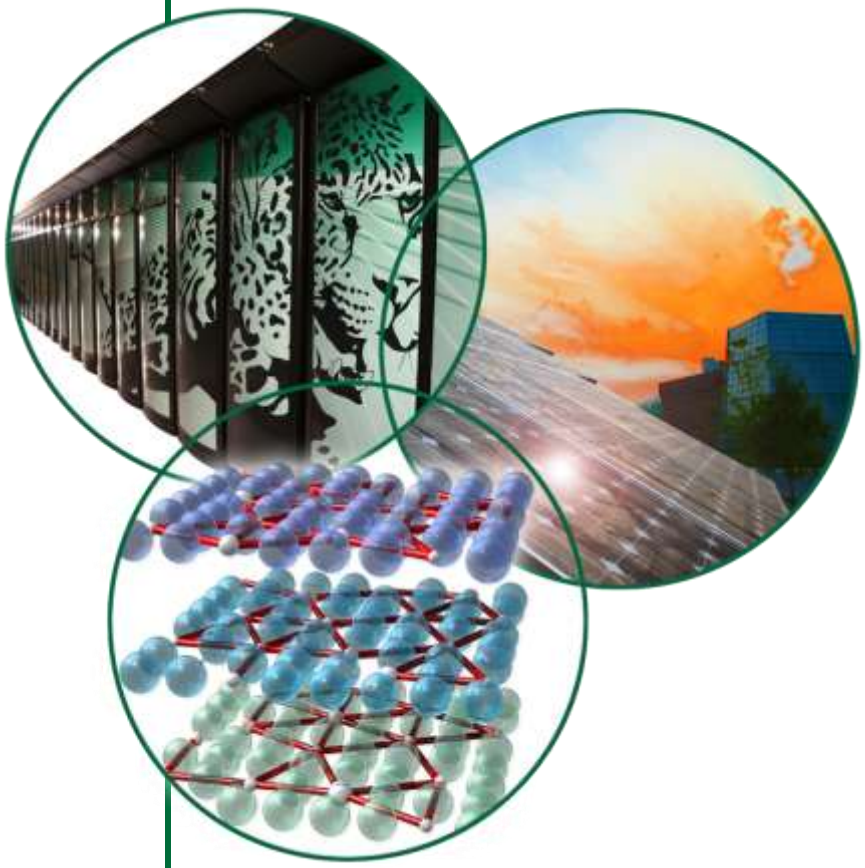


U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Response to action item 2324

- **"Although the expectation is that the fix of the lower cryogenic moderator will alleviate the problem for the medium term future, it remains to be seen to what beam power, and whether the spring will last or break from vibrations and fatigue at the low temperatures. In any case, it would be prudent to accelerate the manufacturing of the spare reflector plug, for which a contract has recently been awarded."**

Response:

The moderator fix has been working well up to 1 MW. Procurement is proceeding for the second inner reflector plug and delivery is scheduled for August 2010.

Neutron source development at SNS

- Target devel
- HE

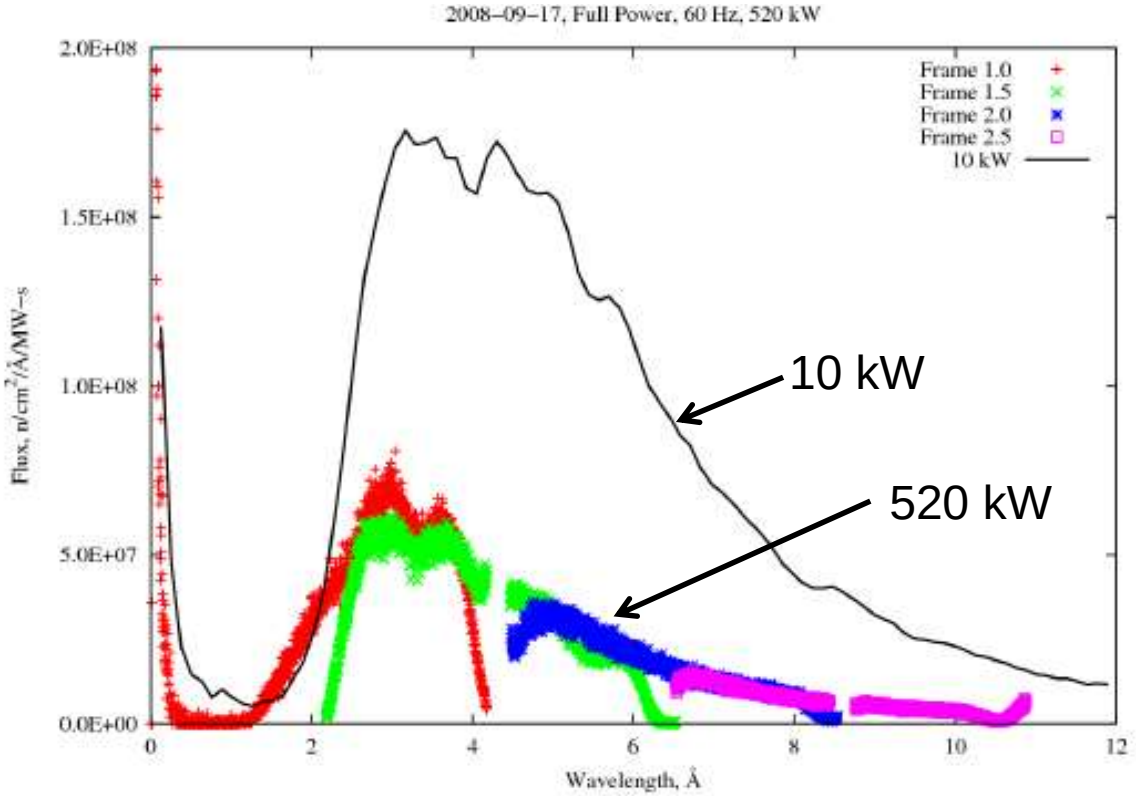
Covered by Bernie in next talk

- Moderator and reflector development
- Neutronics

Topics

- Bottom downstream moderator repair
- Recent work on the cryomoderator system
- Plans for the next generation Inner Reflector Plug (IRP)
- Advanced moderator progress

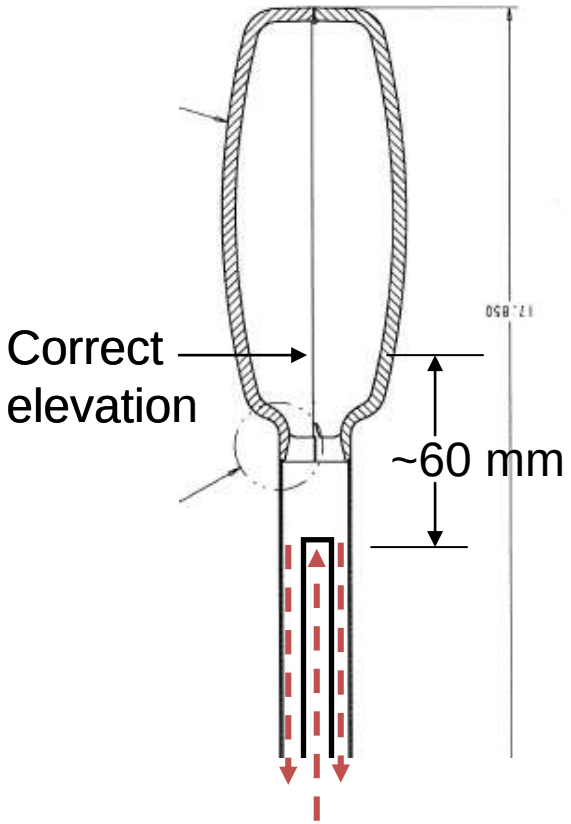
Bottom downstream coupled hydrogen-2008



- **Bottom downstream moderator**
  - **hydrogen, but upside down**
- **Loss of neutrons with increasing beam power**
- **What's going on?**

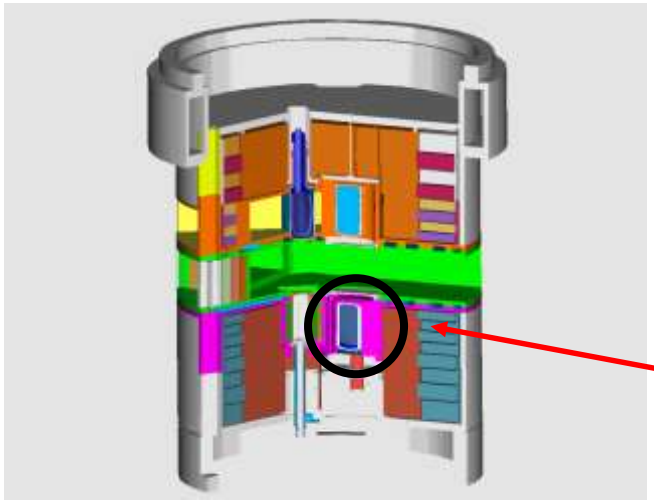
Inlet piping was too short

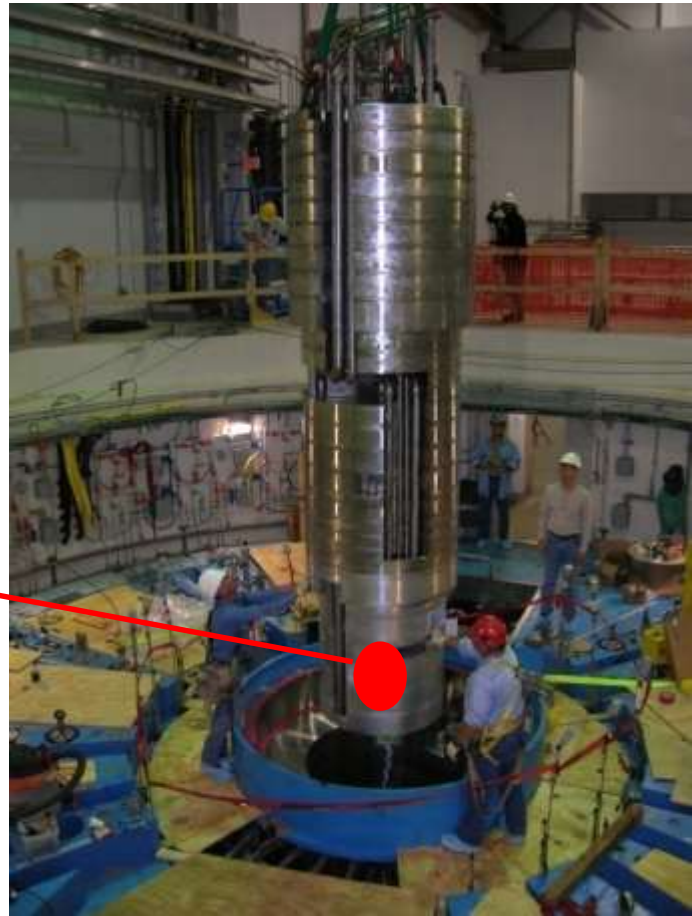
- Transfer lines and moderator were constructed by two separate companies
- Changes during construction did not propagate to second company
- End result: like blowing air into a straw that sits outside a coke bottle
- Moderator needs a stent!



The problem

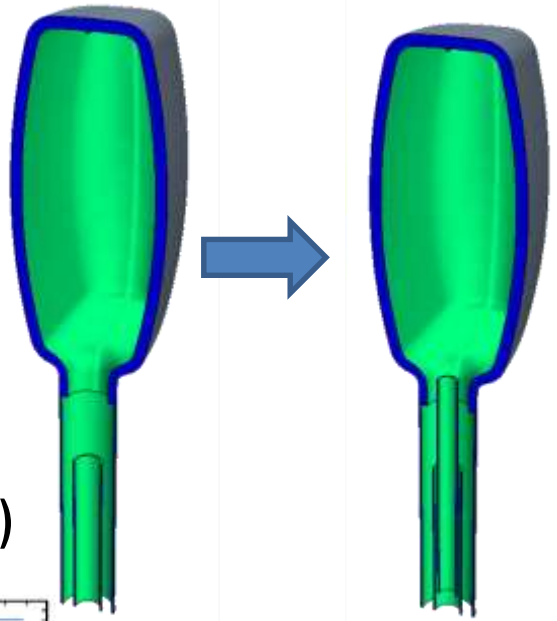
- From the access point to the moderator is ~50 feet
- Inner diameter of the concentric pipe in <0.4”
- Need enough hydrogen flow to cool moderator vessel

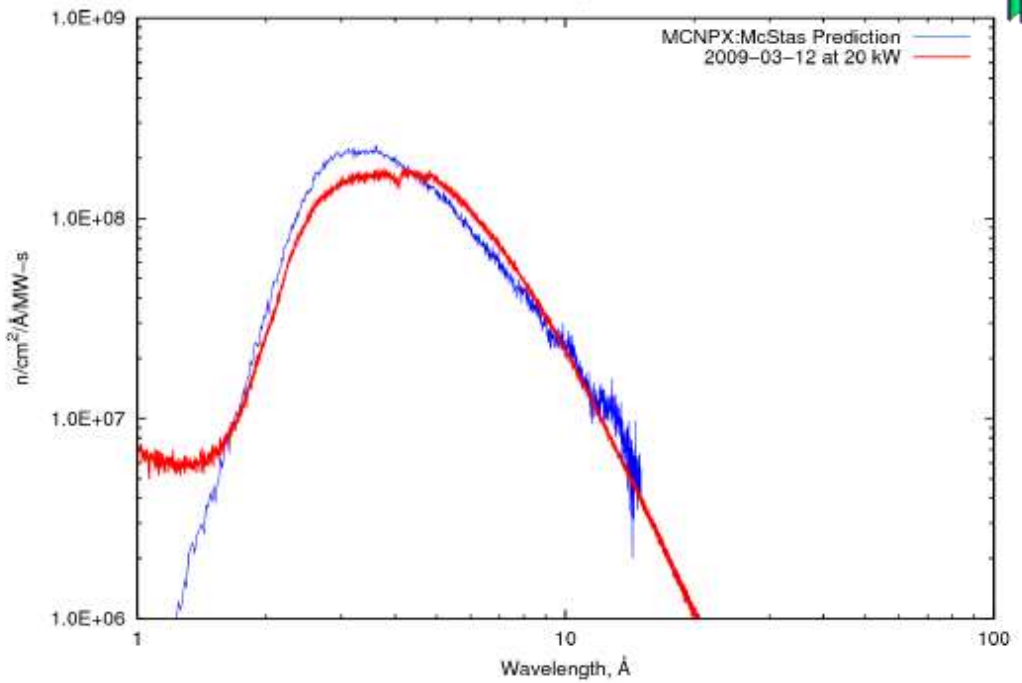




Repair was successful

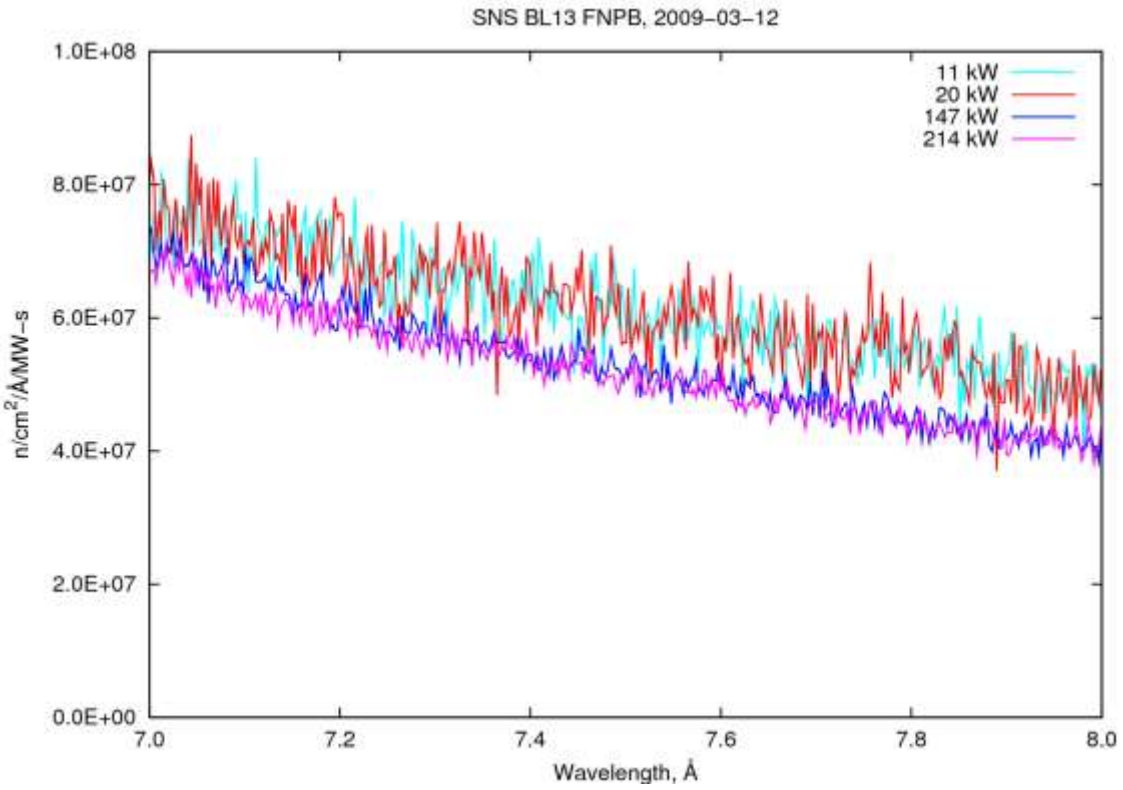
- Bottom downstream moderator repaired
  - Hydrogen feedline extended into moderator vessel
  - Spring deployment - the final chapter (http://www.youtube.com/watch?v=EwUNiOZpMOU)
  - Full flux provided to BLs 13-15 (FNPB, NSE, and HYSPEC)





Power dependence for coupled hydrogen

- Flux degradation at higher beam powers is on the order of 10-15%
- Is this a hint of an ortho/para effect?
- Or is it a temperature/hydrogen density effect?



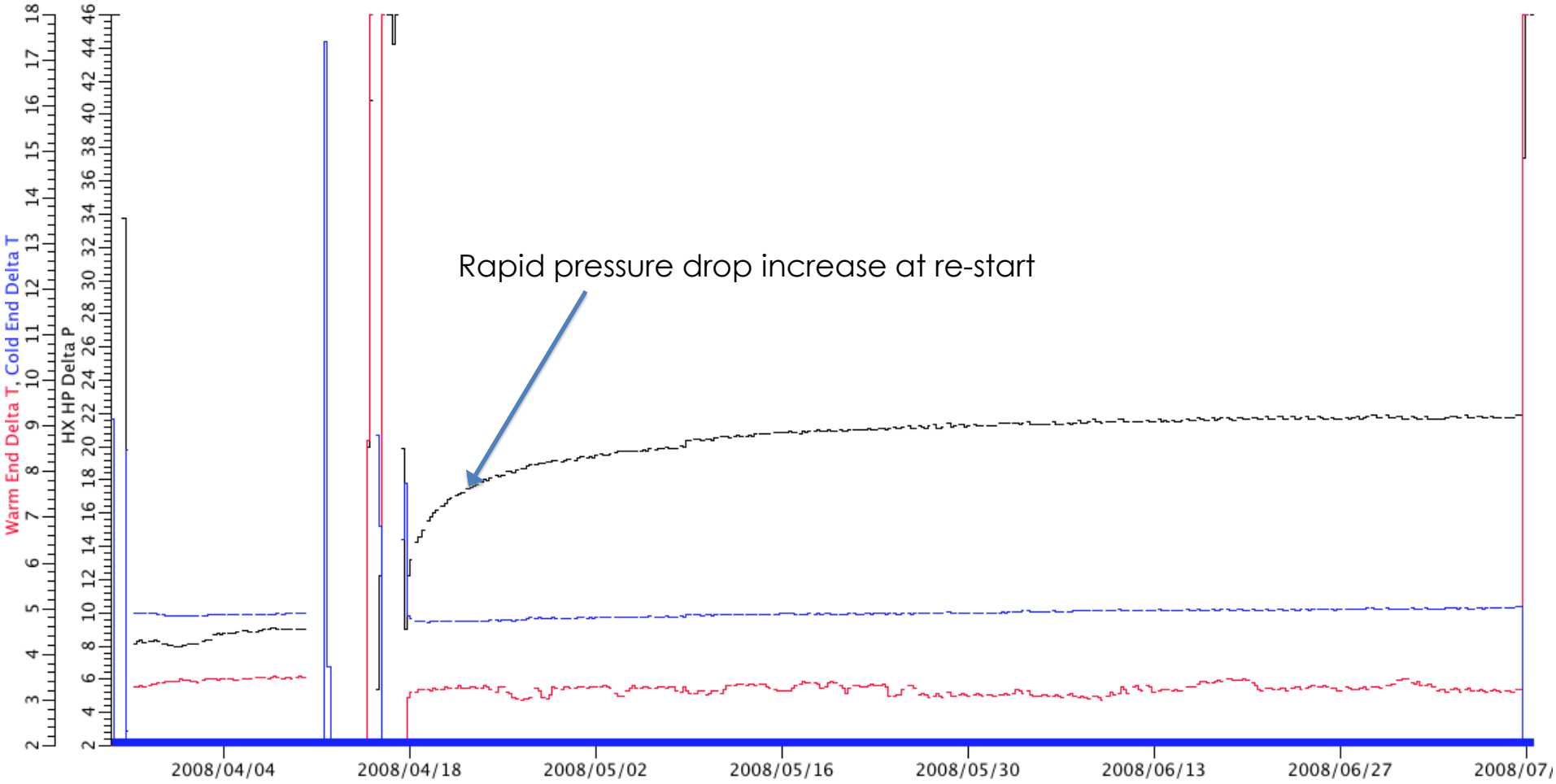
Helium Refrigeration System Degradation

- After 2 years of successful stable operation, the system began to show symptoms of a slow refrigeration capacity degradation
  - First evident in a operation cycle where the suction pressure was increased from 30 to 35 psig
- Initial fear: flow induced instability
  - Although there is no basis for such a conclusion, the trend was unmistakably similar
- When the system was warmed up and re-started due to insufficient capacity, the suction pressure was returned to 30 psig
  - A return to 30 psig did not correct the trend

Investigation

- A close examination of the last two years of operation revealed the pressure drop across the high pressure side of the HX and the adsorber had increased significantly
  - Previous horizontal HX runs never exhibited such a high pressure drop yet the runs were never stable
  - The first vertical operational cycle was stable and had the lowest pressure drop across the HX and adsorber
- The second run was abbreviated by a failure of the bulk oil separator
  - This failure resulted in a total loss of helium flow thus the cold box remained cold
- It is suspected that during the bulk oil separator repair, air cryo-pumped back into the cold HX
  - This suspicion is validated by an observation of a noticeable increase in the pressure drop across the HX and adsorber in the first day that the refrigerator was restarted

HX Performance During Interrupted Run



Gross Contamination

- Increase in pressure drop across the HX and adsorber would seem to imply that a significant amount of contamination had accumulated
- Subsequent warm up cycles would transport any trapped contaminates throughout the HX and to the adsorber
  - Gross contamination could easily overwhelm the adsorber
- If not properly regenerated, the adsorber would no longer function properly
- Close observation of subsequent runs throughout the 2 year period indicate very slow capacity degradation that worsened from run to run
  - Consistent with system contamination that moves throughout the system unaided by a saturated adsorber

Inadequate Adsorber Regeneration

- One of the various theories that was explored when the HX was horizontal was tower water instability in the after cooler HX
- To address this potential concern, the after cooler HX was connected to the chilled water supply
  - This modification did not improve the capacity degradation, however, the modification was left in place
- Operating the after cooler HX at chilled water temperatures results in a helium supply temperature of ~45F
- The "warm" gas from the compressor is circulated through an embedded coil in the adsorber charcoal bed during regeneration
  - At 45F the adsorber is NEVER above the dew point and as such any moisture that has become trapped is not released
- Furthermore, the HX never being brought above the dew point could also hold some level of moisture on its abundant surfaces

Path Forward

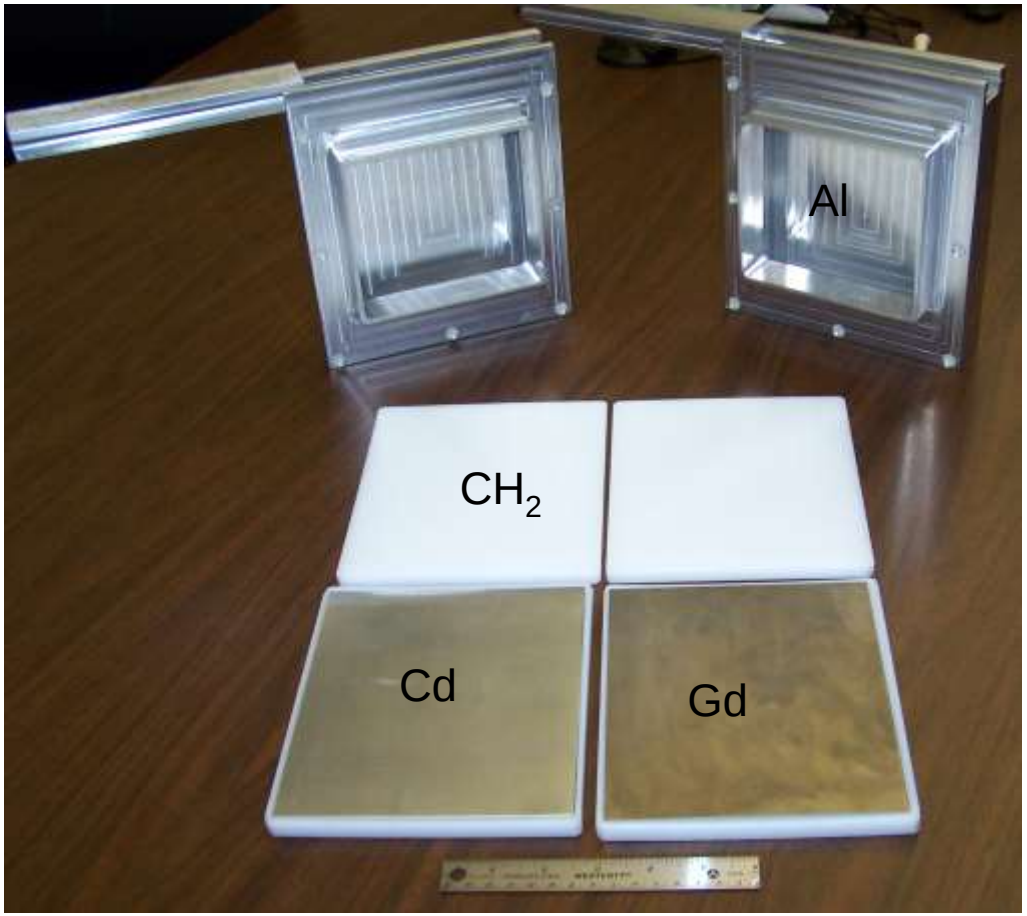
- At the conclusion of the last production run, the chilled water valves were pinched in an effort to elevate the helium supply temperature during the regeneration cycle
  - This was closely observed using a RGA and it was clear that a large quantity of water was released from the adsorber at elevated temperatures
  - An inline supplemental gas circulation heater is being installed in the adsorber regeneration circuit
- Differential pressure gauges were also temporarily installed and indicated that pressure drop across the high pressure stream is roughly evenly divided between the HX and the adsorber
- The HX was derimed for several days using warm N2
- Once the system has been completely recovered, it will be cooled down briefly for a couple of times
  - After each brief cool down, the adsorber will be isolated and properly regenerated at elevated temperature
  - These short runs will serve as a means of purifying the helium
- The system will then be operated at normal operating conditions but at 40 psig suction pressure for as long as possible
  - HX pressure drop and temperature differentials will be closely monitored for any indication of capacity degradation

Planning for the next generation IRP

- Current IRP is designed for 6 MW-years
  - This summer will reach the equivalent of ~1 MW-year
  - Detailed design & fabrication takes ~3 years
  - If changes are desired, need to understand them ***this year***
- Changes come in 3 basic types
  - Improve performance
  - Improve cost & manufacturability
  - Improve handling/waste stream

Changing The Moderator Poison Can Impact Operations

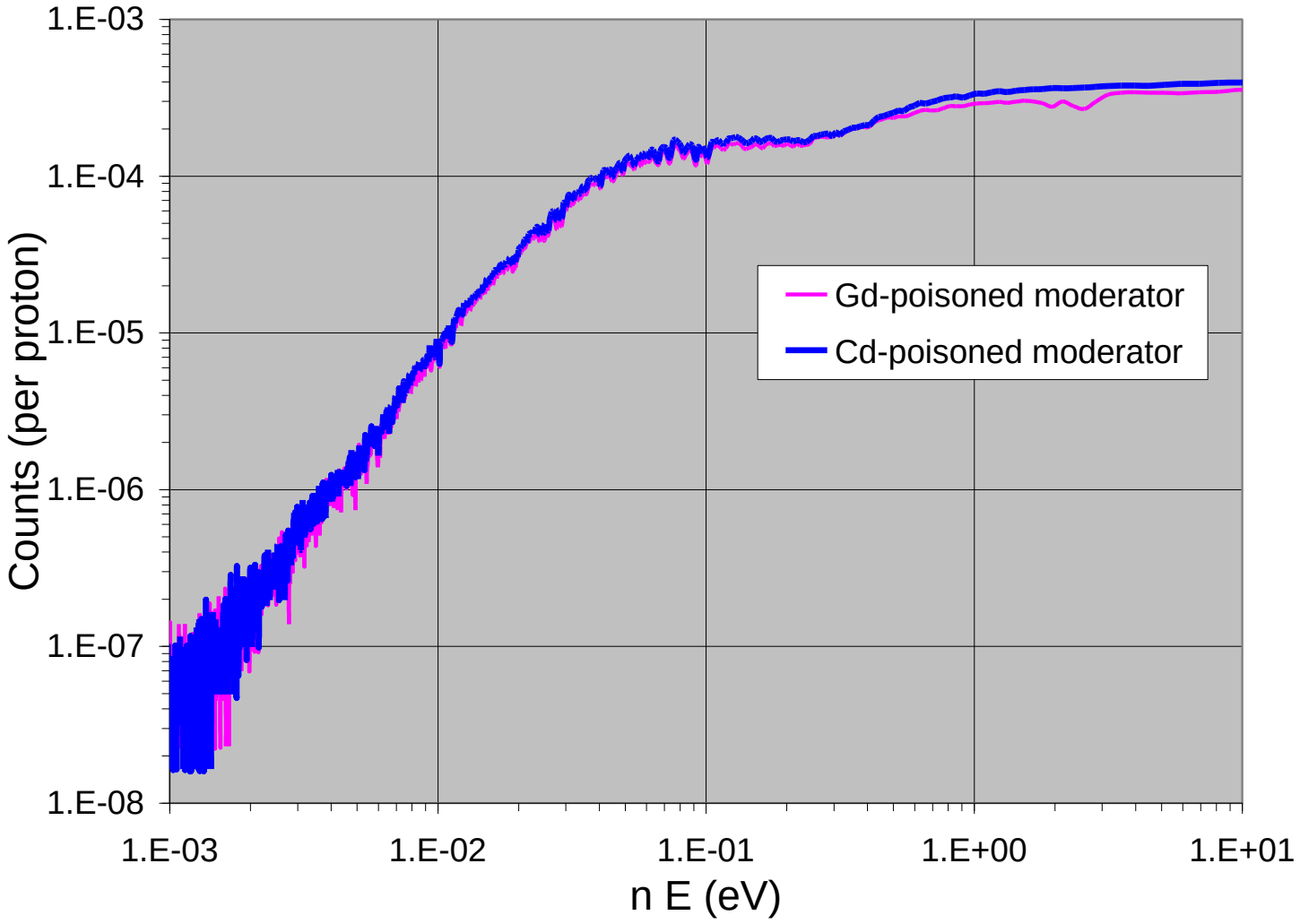
- **Inner reflector plug lifetime is dominated by the moderator poison plate burnup**
- **Changing the moderator poison material from Gd to Cd can:**
  - **Lengthen lifetime of IRP from 6 MW-years to 8 MW-years**
  - **Reduce operating cost ~$10M over life of facility (two IRPs)**
  - **Reduce outage time and personnel dose**
  - **No impact on performance**
- **Concerns:**
  - **High energy gamma background**
  - **Unexpected performance impact**
- **Experiment completed at LENS in 2008**



Moderators before Cd coating

Improves cost and handling

Verification of Cd poison performance



Measured spectra of Gd- and Cd- poisoned moderator

“Inner” inner reflector plug

- Lifetime is limited by radiation damage and burnup in a small area of the IRP
- Does it make sense to further sub-divide the IRP?
  - Reduces cost of each future replacement
    - May save $20M over life of facility
  - Engineering (cooling system) is complex
  - Reduces waste from facility
    - Additional savings from waste disposal

Improves cost and handling

Increase size of coupled hydrogen moderators

- J-PARC colleagues have demonstrated the performance of large volume coupled parahydrogen moderators
  - We want to capitalize on this success
- Maintaining parahydrogen is critical
  - Current moderators are sized to minimize the impact of orthohydrogen
- Must be able to ***measure*** the ortho/parahydrogen ratio
  - Raman spectroscopy tests were conducted last week at LENS
- Must be able to ***control*** the ortho/parahydrogen ratio
  - Developing a cryomoderator laboratory for this and other tests

Cryomoderator laboratory

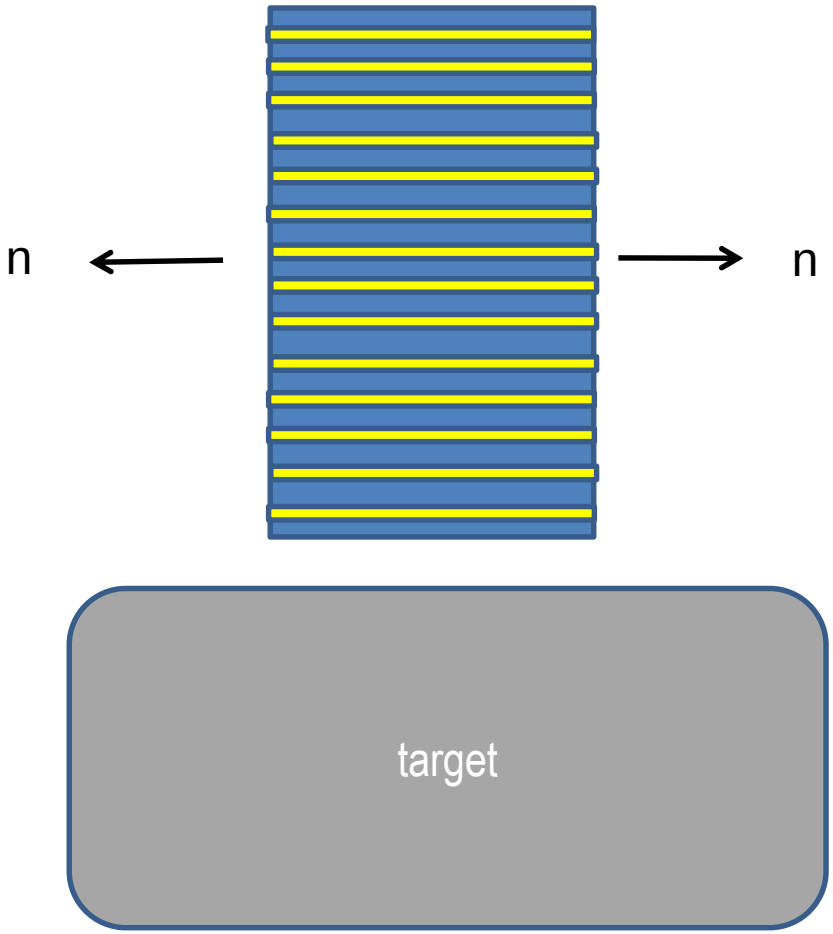
- In the cryomoderator laboratory we can:
  - Test the efficiency of catalysts
  - Test the ruggedness of advanced moderator concepts
  - Test moderator designs without traveling offsite
  - Perform flow visualization tests
  - Test control logic changes before implementing them on the operating system, avoiding downtime
  - Explore failure mechanisms of probes (Si diodes)
  - Test alternate control algorithm (P vs T) which should improve system operations

Advanced moderator concept

- Unique idea from Stuart Ansell utilizing single crystals
  - Initially could not calculate the performance, but proved it worked on an instrument at ISIS
  - Quick test at LENS validated the ISIS test
- Collaboration between SNS and ISIS
  - Stuart is on sabbatical at SNS for roughly one year
  - Together we will:
    - Develop a computational capability to predict performance
    - Perform two experiments at LENS to measure performance
      - First experiment scheduled for late March/early April

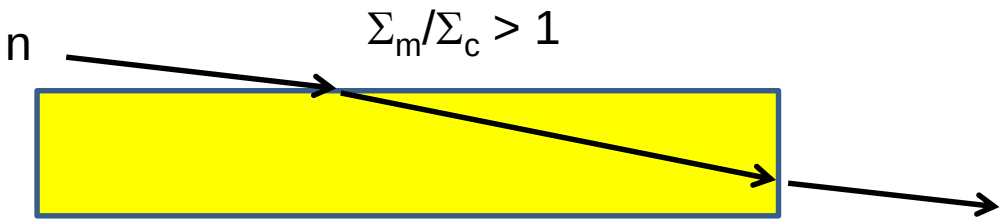
Single crystal moderator

- Created as layers of single crystals in a moderating material
  - Initial tests used poly (effectively water)
  - Does it work for a non-moderating fluid like parahydrogen?
- There are two components to the gains:
  - reflective/refractive
    - More efficient extraction
  - degenerate
    - Inverse of a Laue pattern

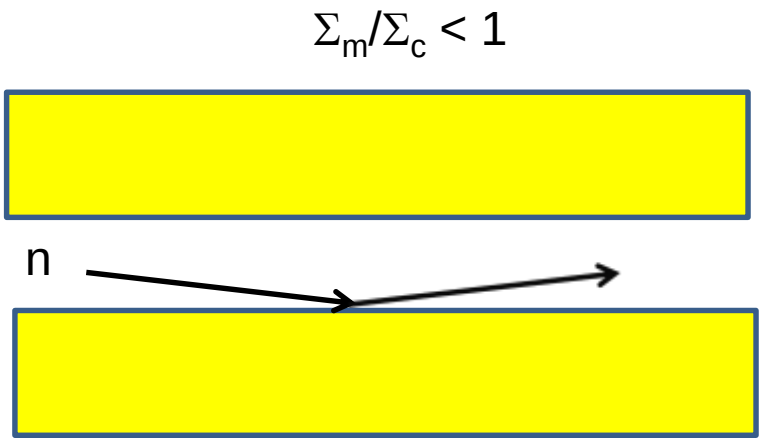


Refractive/reflective gain

- For moderating media, use roughened (nonreflective) surfaces
  - Neutrons that normally would scatter in the medium will now transport through the crystals

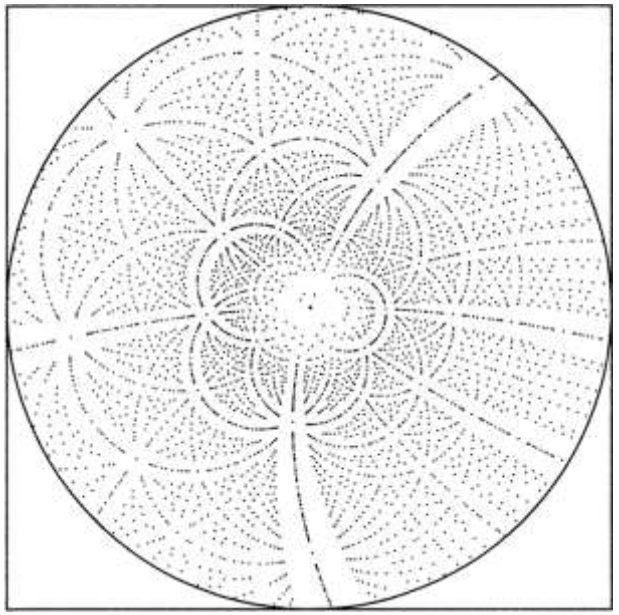


- For non-moderating media, use reflective surfaces
  - Neutrons streaming in the wrong direction are given additional chances to illuminate a neutron guide



Degenerate gain

- When a stationary crystal is illuminated with a beam of neutrons from a continuum of wavelengths, a Laue diffraction pattern is formed
- Is there a set of conditions by which this process can be reversed?
  - Neutrons at various wavelengths and angles in a diffuse source (moderator) are focused into a beam
  - Can we even calculate/scope the possibility???

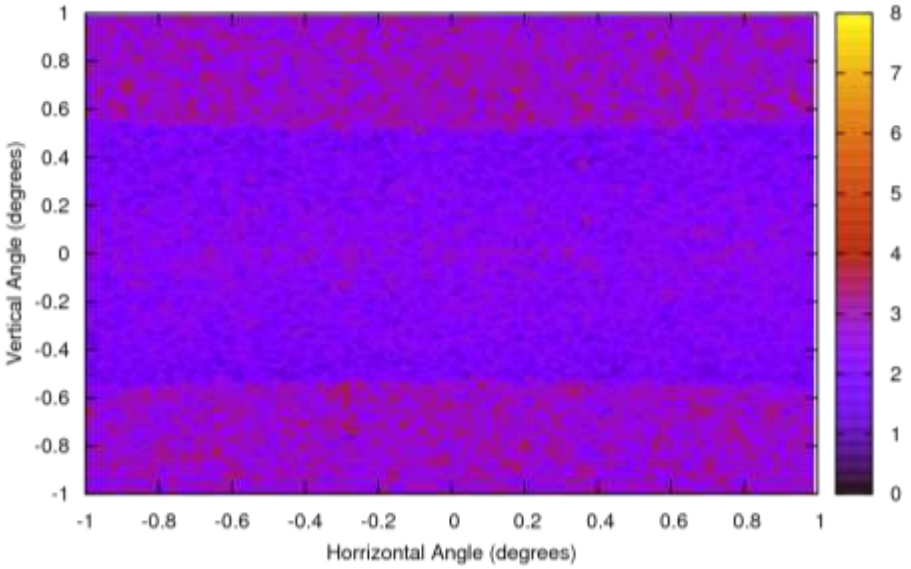


Calculated Laue diffraction pattern

Initial experiment

- Tests are planned for both moderating (water) and non-moderating (parahydrogen) fluids
- Will use Si (111) for this test
  - Inexpensive, readily available
- Ability to "aim" moderator is important
- Ability to measure hydrogen ortho/para ratio is important

Calculated Ratio of Silicon/Poly
to Poly moderator
2 Å neutrons, detector at 10 m



Summary

- Neutron source development is focused on the system performance, lifetime, and maintainability/operability
- CMS operations are improving
  - BD moderator repair was successful and measurements showed expected neutron brightness
  - Recent instability was correctly diagnosed as contamination
    - Procedures are being revised to prevent future contaminate events
  - Tests are underway to demonstrate performance at design suction pressure corresponding to full power operations
- Establishing a moderator lab is important for both operations and moderator development

Summary (cont.)

- Redesign of the IRP is currently underway
  - Focus is not only on performance, but also on extending lifetime, reducing cost, and reducing waste stream
  - Expect to complete conceptual design this year
- Collaboration with ISIS on crystal moderator concept is moving quickly
  - Stuart is working on the theory and helping design experiments
  - First experiment is planned for March/April
  - Expected gain is a factor of > 3 (refraction/reflection only)
  - Full experiment planned for fall