OAK RIDGE National Laboratory

The SNS Moderator Test Station

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Spallation Neutron Source

Oak Ridge National Laboratory

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U.S. DEPARTMENT OF ENERGY

Moderator Test Station at SNS

- We will build a Moderator Test Station at SNS with significantly different optimization than most small neutron source facilities
- SNS and HFIR are very large scale neutron facilities - almost any experiment *using* neutrons is better done at SNS or at HFIR
- The SNS Beam Test Facility (with “spare” RFQ and front end) is fixed
  - Limited choices allow us to focus our optimization on the application
- Leverage experience at other facilities (LENS, Hokkaido, etc.) to optimize a single neutron beamline for moderator characterization
  - No need to compromise that main goal to serve multiple goals
  - Less need to worry about “low flux” - we're always going to be low relative to SNS!
- Describe concept, show justifying moderators, underscore efficiency in access and in neutron usage

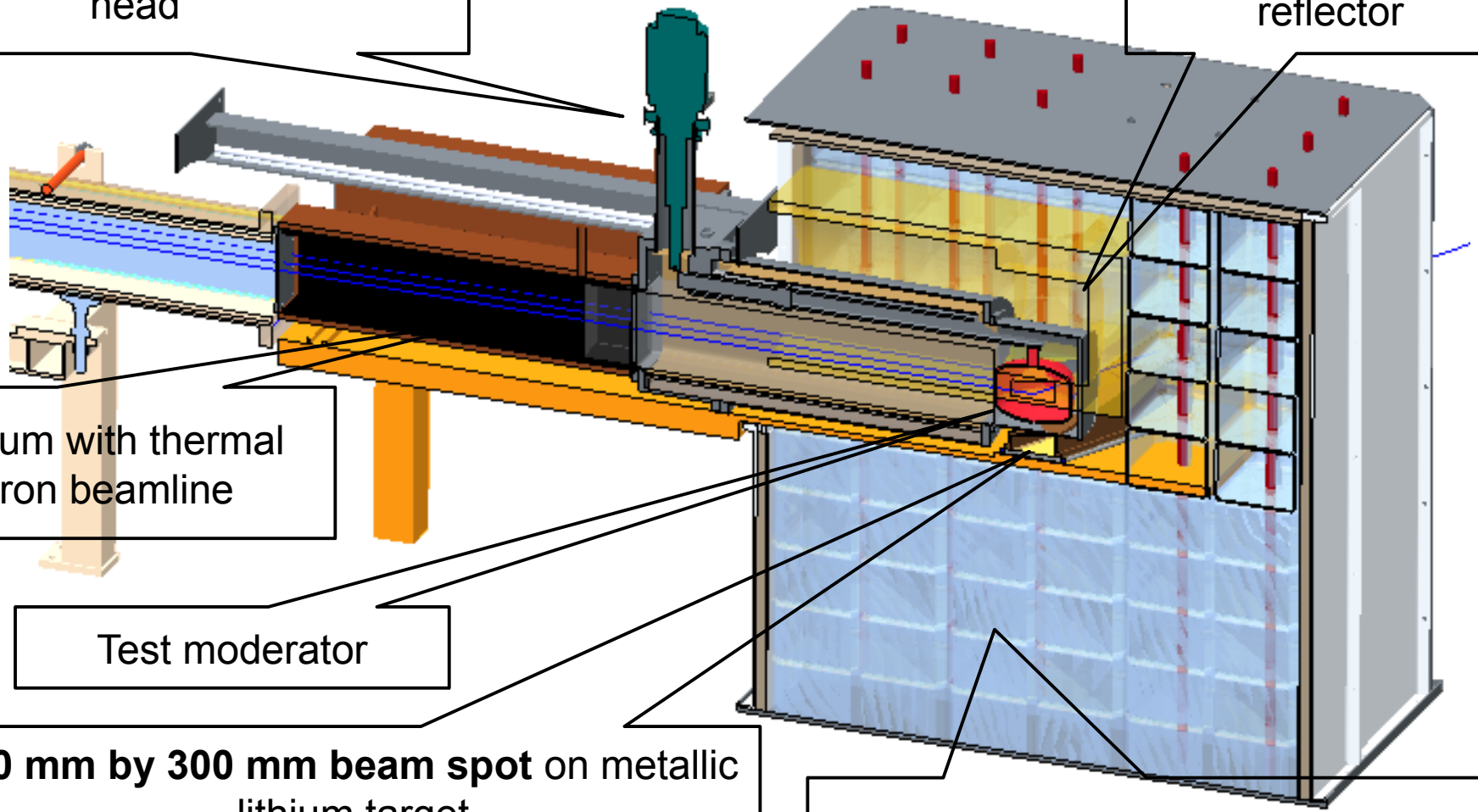
Moderator Test Station Concept

- Leverage SNS RFQ test station (the BTF)
  - 2.5 MeV protons, 50 mA peak, up to 60 Hz, up to 1 ms
  - Proton energy, peak current, maximum rep-rate are not free variables
- Use a LEBT-style proton chopper; choose from 0.5 to 10+ μs proton pulse
- Add a neutron producing target; 3E10 n/s at 75 W from p(^{7}Li,n)
  - Lithium is most prolific target at 2.5 MeV proton energy
  - Maximum neutron energy of 0.8 MeV reduces shielding and activation
  - 75 W over an 80 mm by 300 mm footprint compatible with edge-cooled backing plate
- Provide large volume space for test moderator
  - Can't do 10 cm high by 16 cm diameter elsewhere, or filters, or ...
  - Wing configuration is prototypic and allows small view / high brightness
- Optimize single neutron beamline for moderator characterization

Moderator Test Station Goals

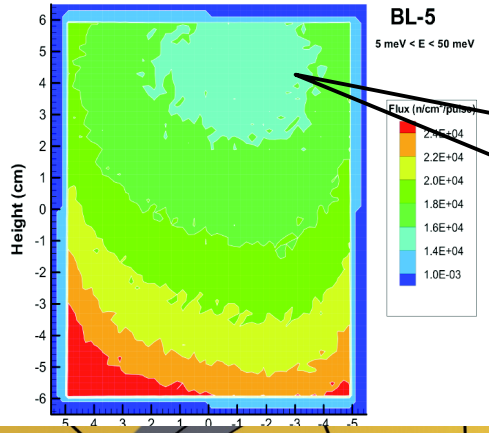
- **Demonstrate performance characteristics / advantages of advanced moderators in prototypical configurations**
- Wing-type, not slab-type test moderator configuration
  - All production scale sources have used wing moderators
  - “High-brightness” gains apply only to wing moderators
- Accommodate large moderator assemblies
  - Deep moderators don't fit in current test facilities
  - Reflector-filters also don't fit in current test facilities
  - Fancy optics, reflector fitting, aren’t an option in current test facilities
- Ensure reproducible intensity and (when desired) complete decoupling

MTS Moderator / Neutron Beamline

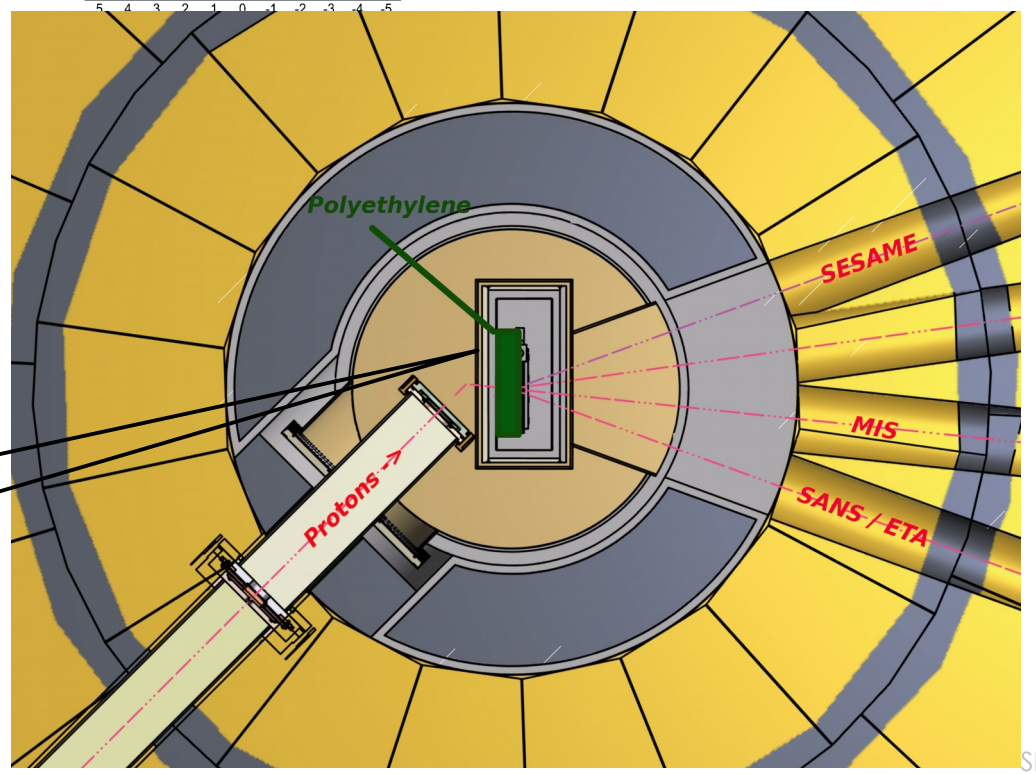


MTS Needs to Use Wing Configuration

- Demonstrate performance advantages of advanced moderators in prototypical configurations
- **Wing-type, not slab-type**
  - All current short pulsed sources have used wing moderators exclusively
  - Many aspects of “high-brightness” moderators apply only to wing moderators
- Must accommodate large moderator assemblies



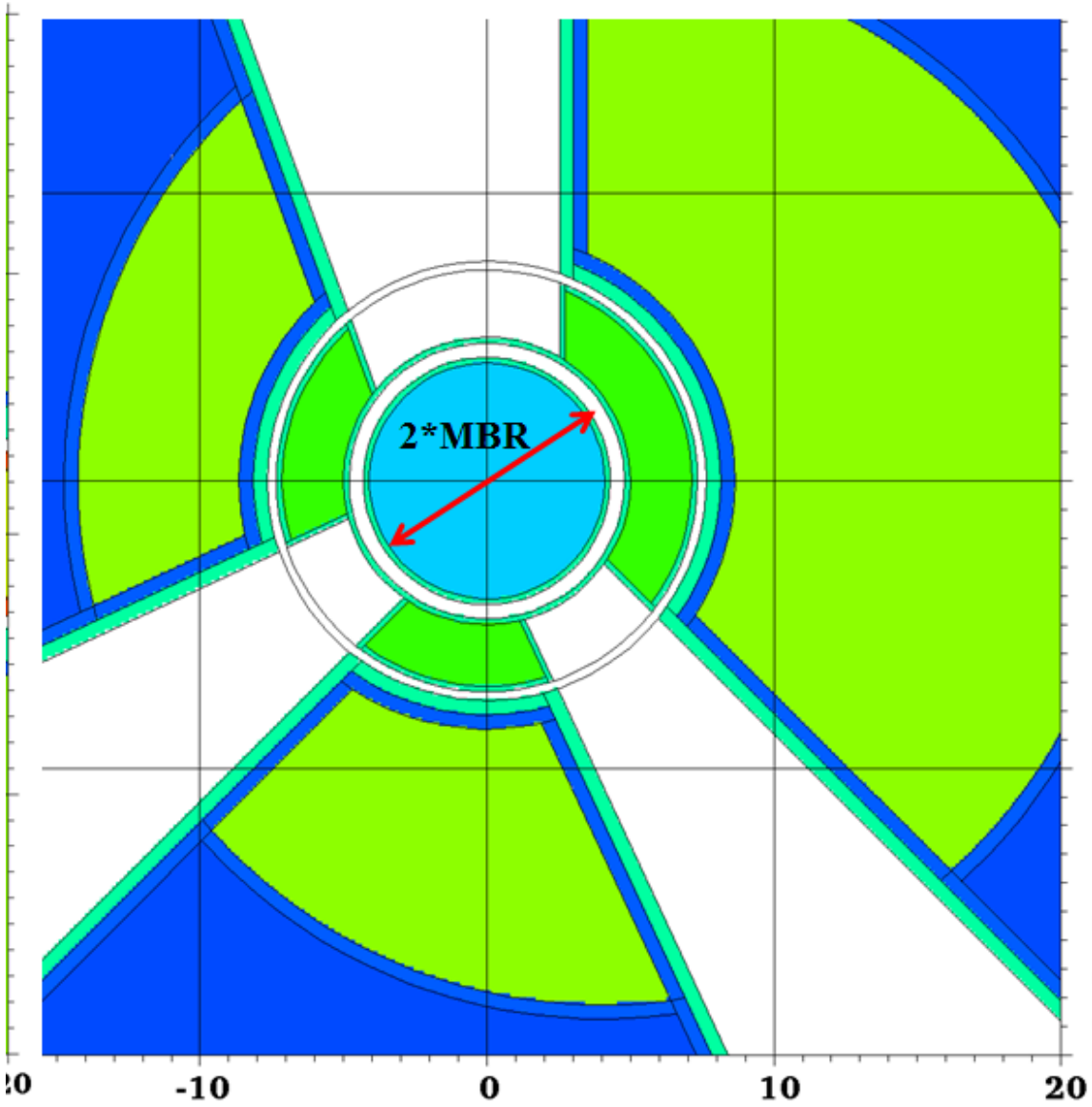
High-brightness moderator removes the dimmer portion, but only for a wing moderator



Slab configuration can't demonstrate high-brightness

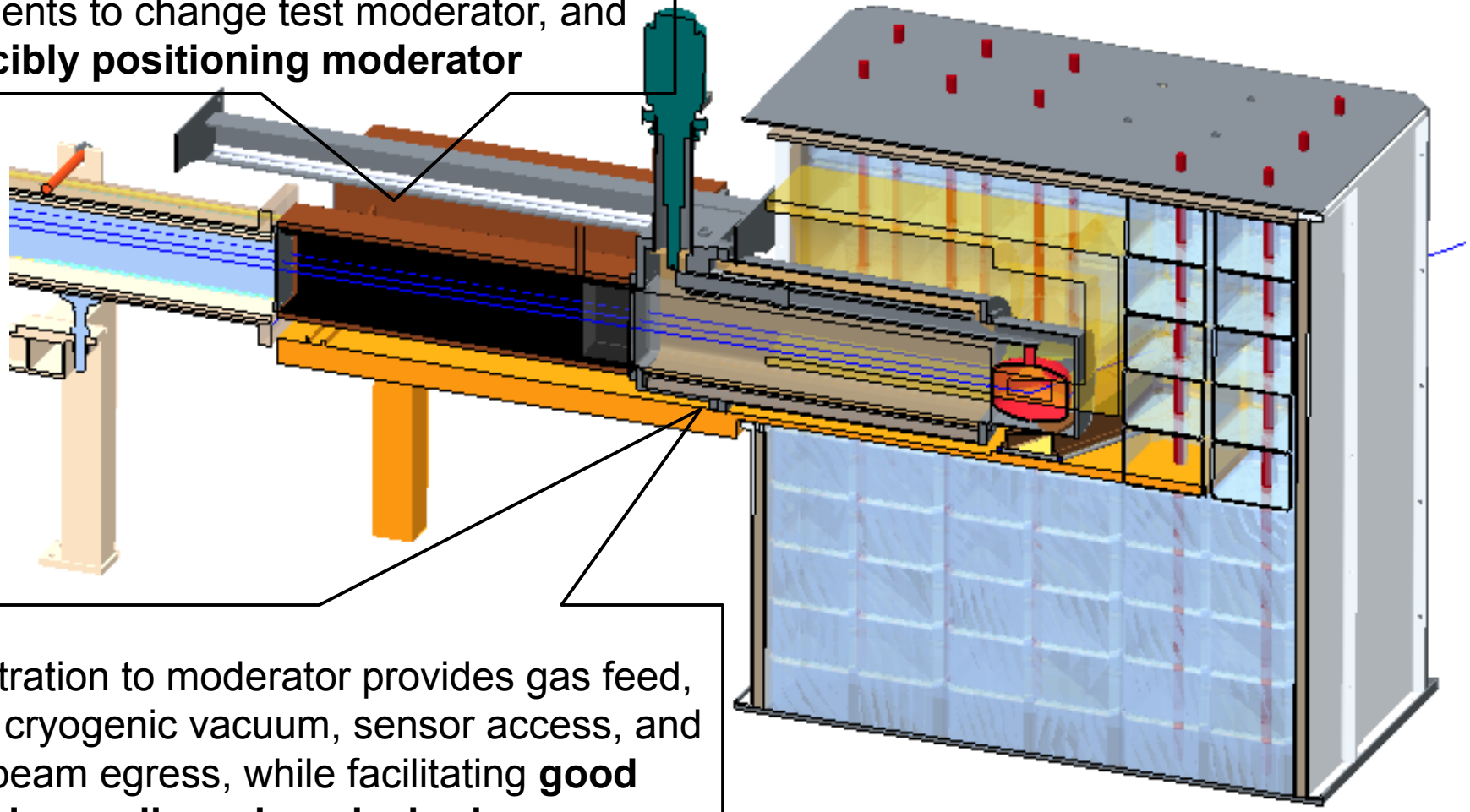
MTS Needs to Allow Large Moderators

- Demonstrate performance advantages of advanced moderators in prototypical configurations
- Wing-type, not slab-type
- **Must accommodate large moderator assemblies**
  - Optimized high-brightness moderator may be 12+ cm diameter
  - Some versions as large as 20 cm diameter
  - Current test facilities limit us to around 8 cm depth
  - Tube moderators? Single-crystal reflector-filters? etc.



MTS Moderator / Neutron Beamline

Moderator / beamline assembly extracts along beamline on track, eliminating shield unstacking or crane requirements to change test moderator, and **reproducibly positioning moderator**

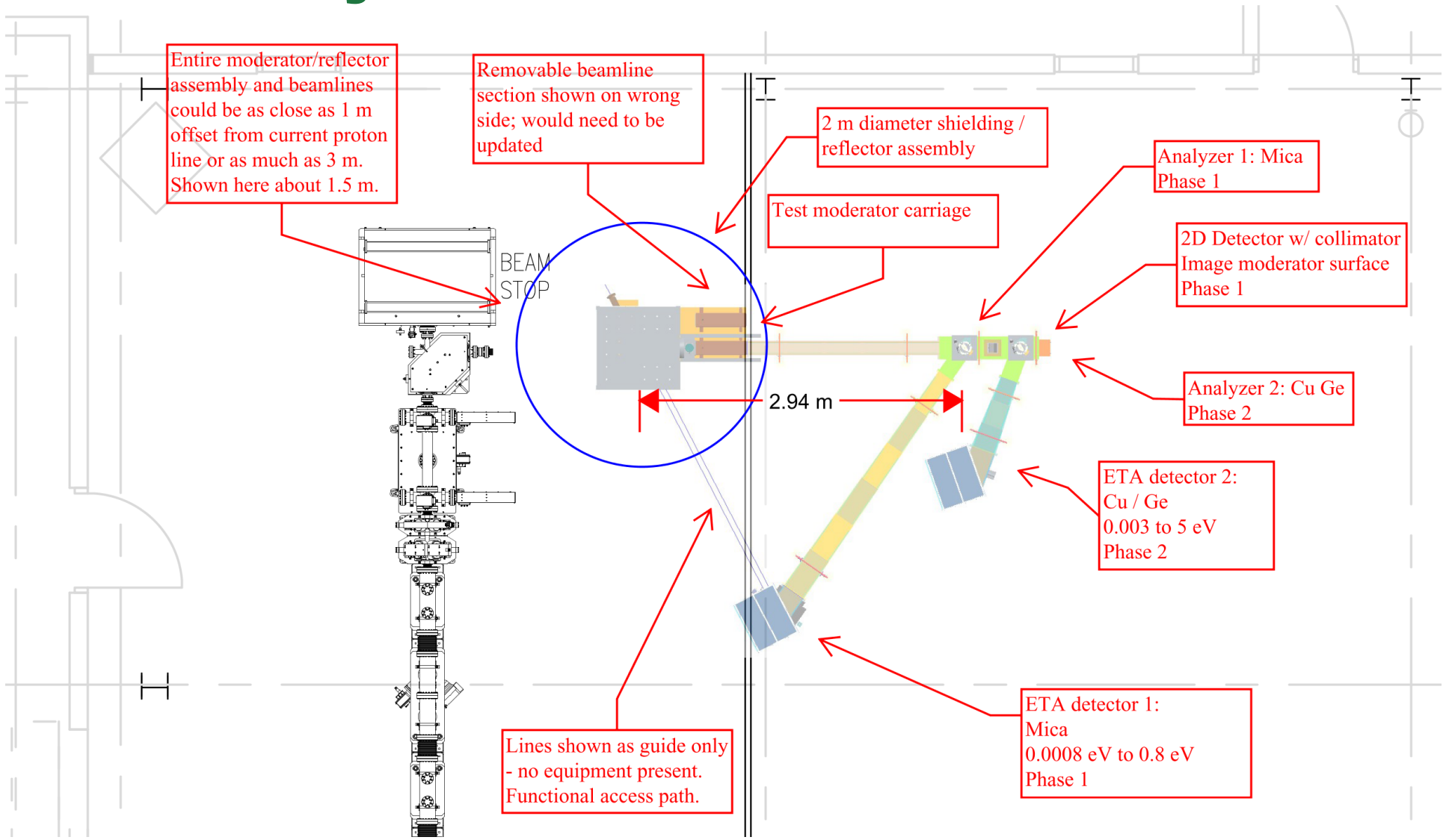


Single penetration to moderator provides gas feed, thermal link, cryogenic vacuum, sensor access, and neutron beam egress, while facilitating **good decoupling when desired**

MTS Typical Moderator Characterization

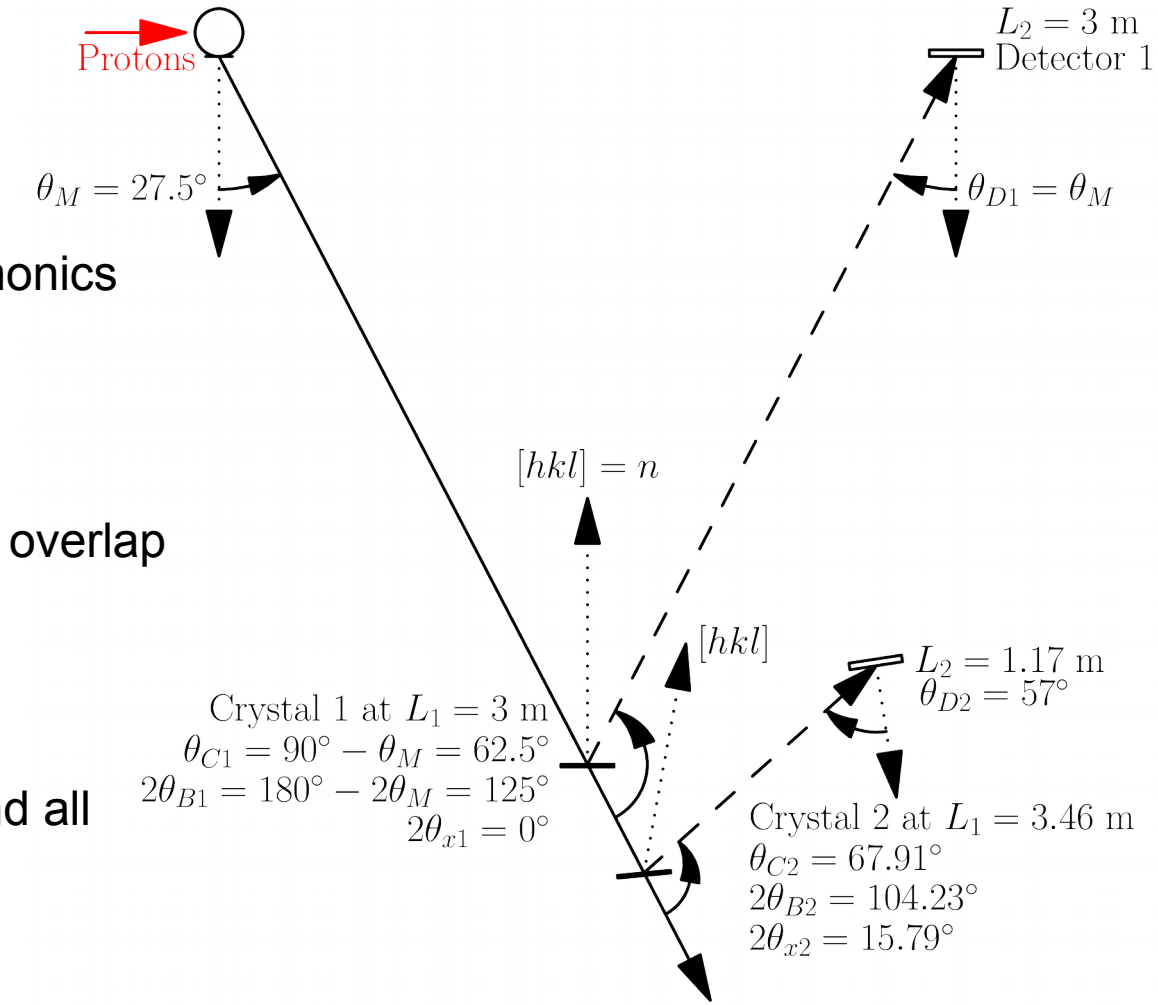
- Energy spectrum; <0.1 meV to >10 eV
  - Simple time-of-flight measurement, both low-efficiency and high-efficiency in-beam detectors, including single-pulse
  - Flight path length of ~2 m or greater required
- Energy-dependent brightness across moderator; 1 meV to 1 eV
  - Pinhole or eggcrate collimators with 2D detector
- Energy-dependent emission time distribution; 0.3 meV to 3 eV
  - Time-focused crystal analyzers; 0.3 meV to ~3 eV requires two separate analyzer arms, but also makes it easy to check resolution effects
  - Flight path lengths of ~6 m total, short pulse required

MTS Details: Layout at extended BTF

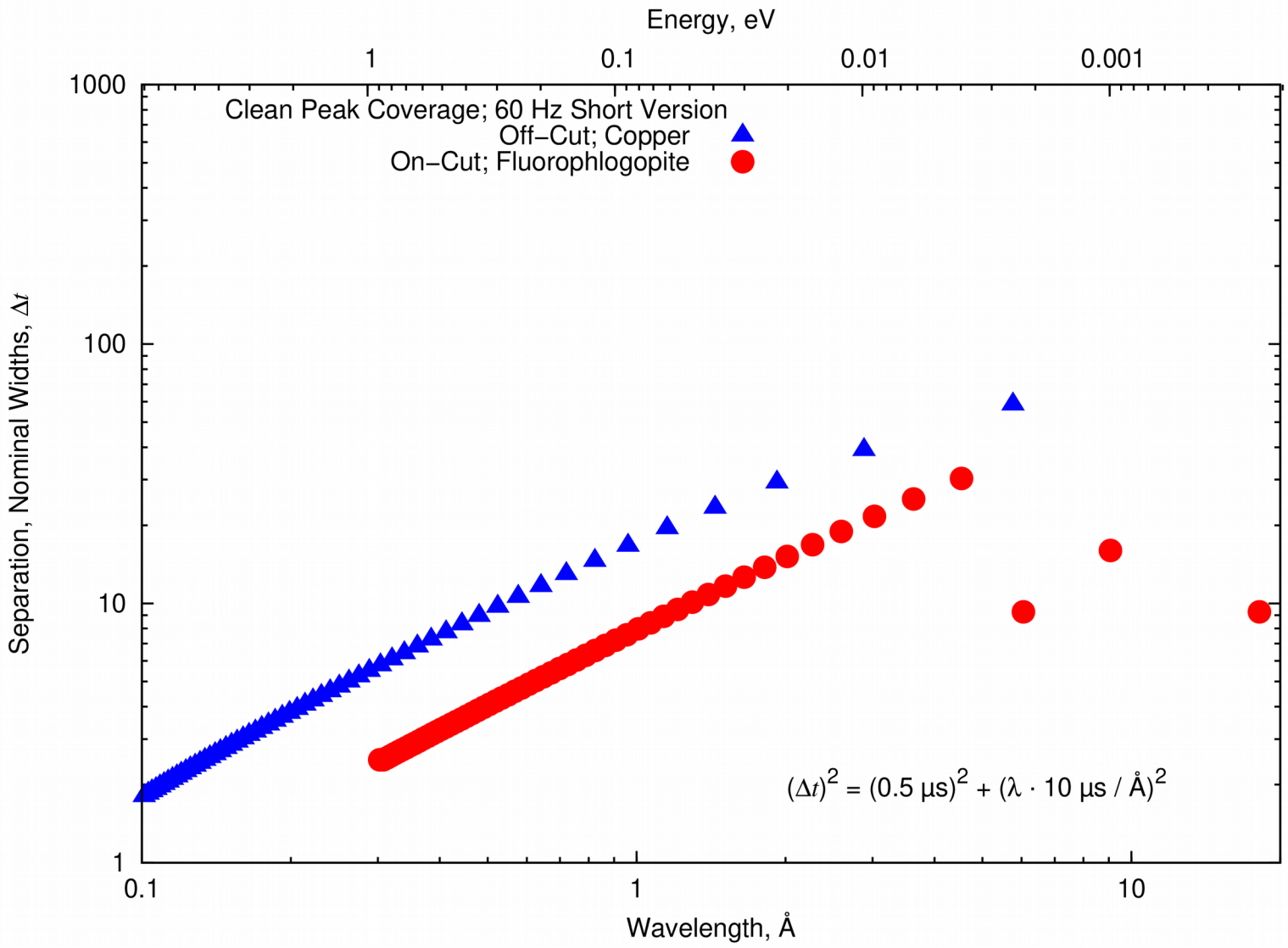


MTS Details: Time-Focused Analyzers

- Symmetric (on-cut) analyzer array:
  - Synthetic Fluorophlogopite
  - Symmetric flight path arms
  - 00n series provides 18.1 Å first-order and all harmonics
  - 3 m primary and secondary flight paths
  - Detector, analyzer, and moderator all parallel
  - Frame overlap at 60 Hz intersperses but does not overlap
- Asymmetric (off-cut) analyzer array:
  - Copper cut for 221, using 111
  - nnn series provides 5.77 Å first-order reflection and all harmonics
  - 3.46 m / 1.17 m flight paths
  - Detector at oblique angle to beam



MTS ETD Analyzer Energy Coverage



MTS Performance Estimate

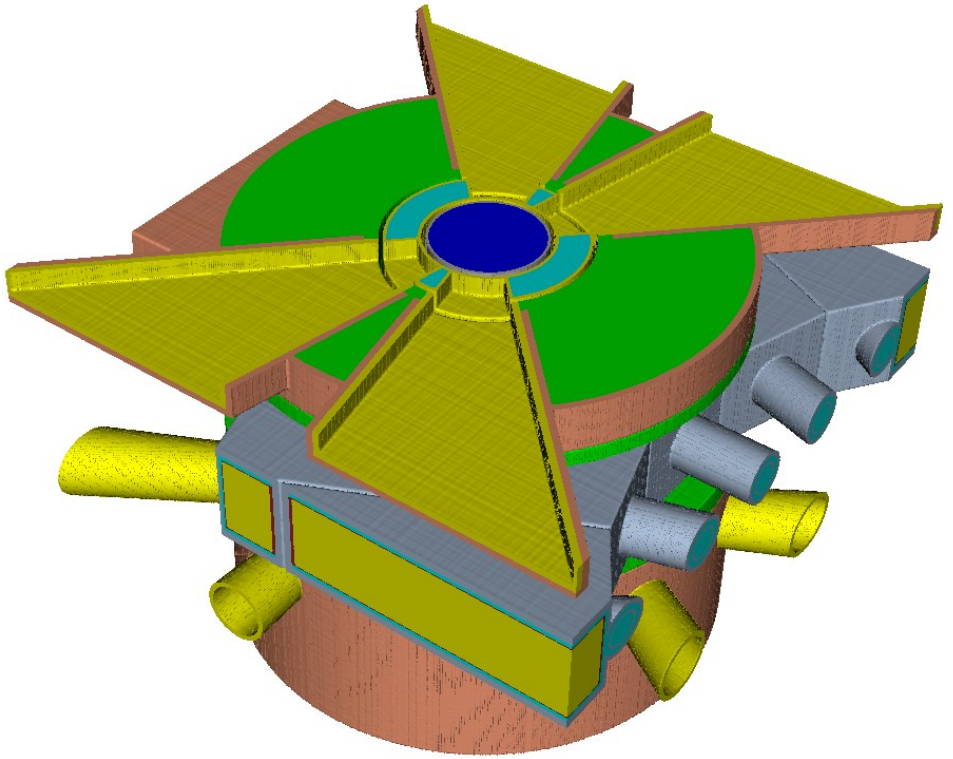
- Lower moderator brightness as compared to LENS
  - 50 mA vs 16 mA (3); 13 μs vs 13 μs (1)
  - 2.5 MeV p(^{7}Li,n) vs 13 MeV p(Be,n) (0.02)
  - Primary source strength around 200 times lower than LENS for shorter pulse operation, 15 times lower for comparable pulse
  - Better thermalization factor from lower neutron energy
  - Wing versus slab moderator configuration
- Larger acceptance into emission time measurement systems
  - Two 400 cm^2 analyzers vs one 18 cm^2 analyzer
  - Shorter primary flight paths (3 & 3.4 m vs 8.5 m)
  - Large area detectors capturing all analyzed beam
  - Factor 300 increased **efficiency** over LENS
- Comparable experiments have factor 20 increase in countrate, or better pulse shape experiment (no deconvolution) with comparable countrate

MTS Neutronic Efficiency

- What matters (here) is “neutrons counted” (in unspecified phase space)
  - Part of that phase space includes setup time, measurement time
- ~~Make more neutrons (we’re not doing this...)~~
- Count more of the neutrons we make - efficiency in performance
  - Dedicated, short beamline beam means larger acceptance and broader bandwidth into emission time analyzer: **factor 300 increased efficiency** over current (general purpose) beamline configurations
  - Dedicated, short beamline means larger beams into in-beam (monitor) detectors resulting in **factor 10 increased efficiency** over current (general purpose) beamline configurations, plus better detector options
- Make neutrons more easily - efficiency in use
  - Reduced yield and energy means smaller shielding, which means easier access to change moderators, which means more experiments
  - Reduced yield and energy means lower activation, which means easier / faster access to change moderators, which means more experiments

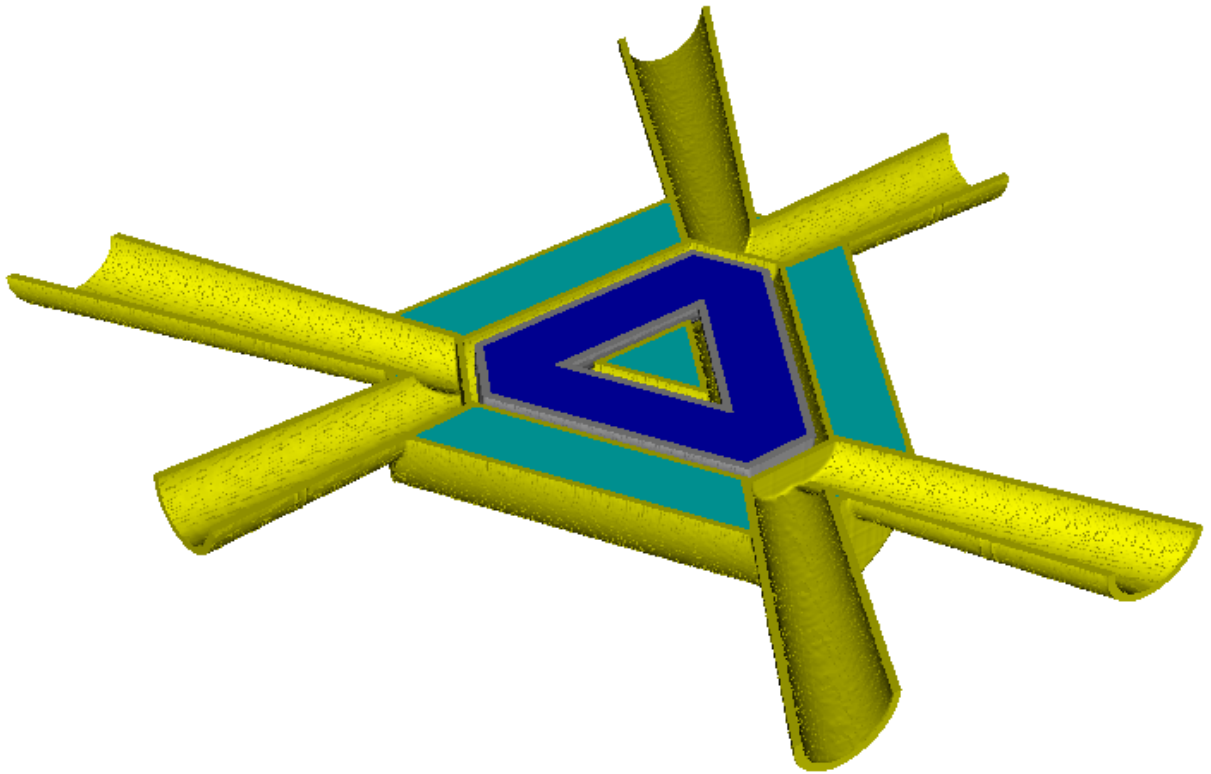
MTS Payoff - Second Target Station I

- Advantages of STS project derive from high brightness moderators
  - Moderator “imaging”, e.g., JPARC, demonstrates brightness distribution across moderator surface, supporting low dimensional concepts as effective, but the specific details matter
- STS cylindrical moderator is 3 cm tall, 8 cm diameter
  - Could almost go in LENS, but not with water premoderator
  - Need to demonstrate brightness enhancement and test orthohydrogen sensitivity



MTS Payoff - Second Target Station II

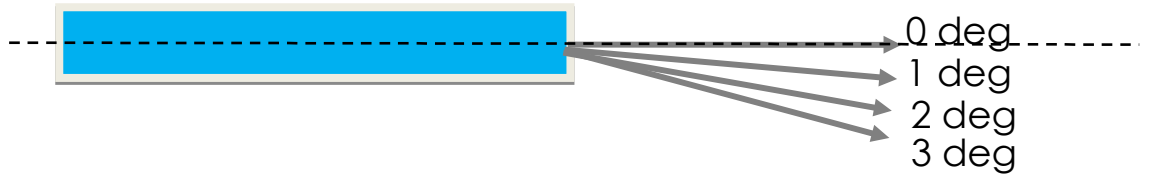
- Challenges of high brightness moderators include alignment requirements
  - High brightness moderators require significantly tighter guide-moderator alignment
- STS tube moderators are 3 cm diameter and ~15-20 cm long, in an arrangement around 20 cm diameter
  - No chance to fit into existing test facilities
  - Need to assess sensitivity to alignment of tube axis and guide axis

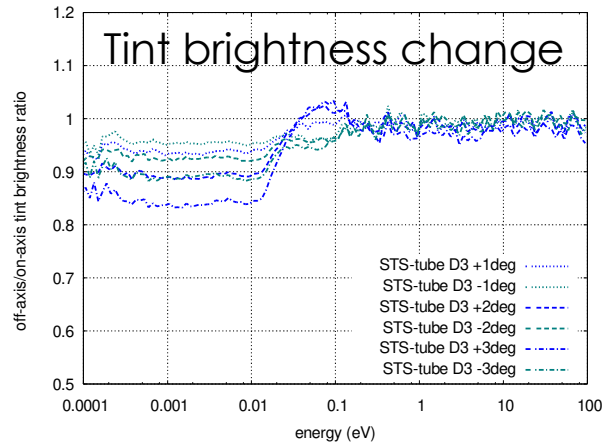


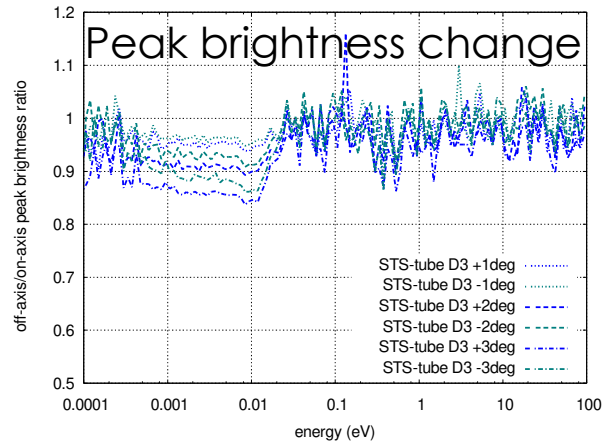
How must we aim our optics using Tube Moderators?

Sensitivity of off-axis beam extraction:

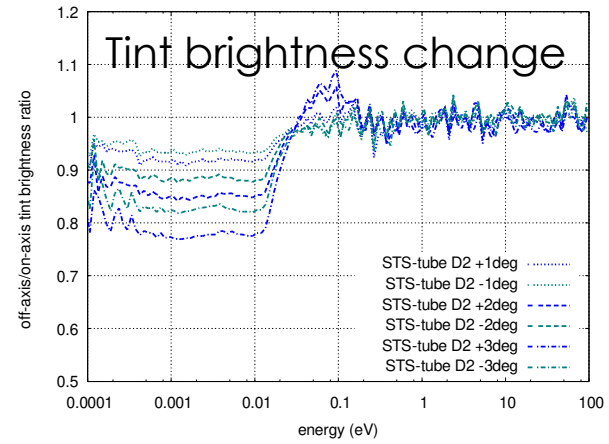
- 3-cm-diameter tube moderator:
  - 1 degree off axis costs about 5%

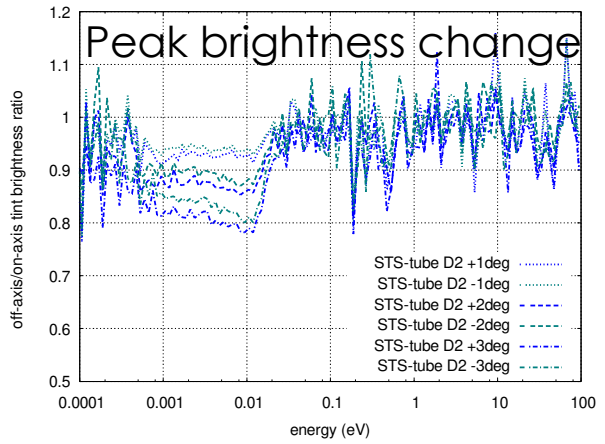






- 2-cm-diameter tube moderator
  - 1 degree costs 7-8%





Summary

- The SNS Moderator Test Station will permit characterization of high-brightness parahydrogen cylinder and tube moderators in prototypical wing configuration, supporting the STS concept
- Along the way we'll develop a capability to explore and characterize advanced moderator configurations that exceeds any facility currently available
- Targeted optimization will let us improve the measurement time to characterize a moderator at LENS with two orders of magnitude lower primary source intensity (and even lower shielding requirements)
- Improved characterization concepts will let us do so over a larger energy range, with more certain and better understood instrument characteristics