Neutron Source Developments

AAC 2012

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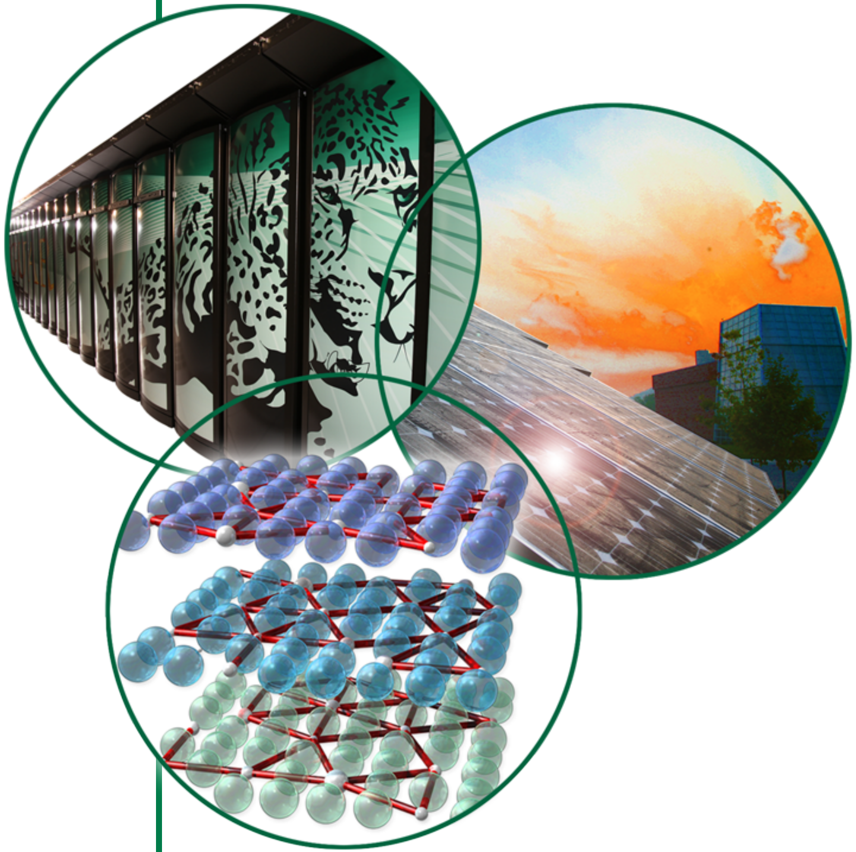


Outline

- SNS Moderator Performance:
  - Present measurements/predictions
- Aluminum Proton Beam Window:
  - Impact on target operations
  - Impact on neutron performance
- Next IRP:
  - Goals: improvements of brightness of coupled moderator, reduced waste, and concept for disposal
  - Neutronics design calculations
  - Engineering design

Outline (cont)

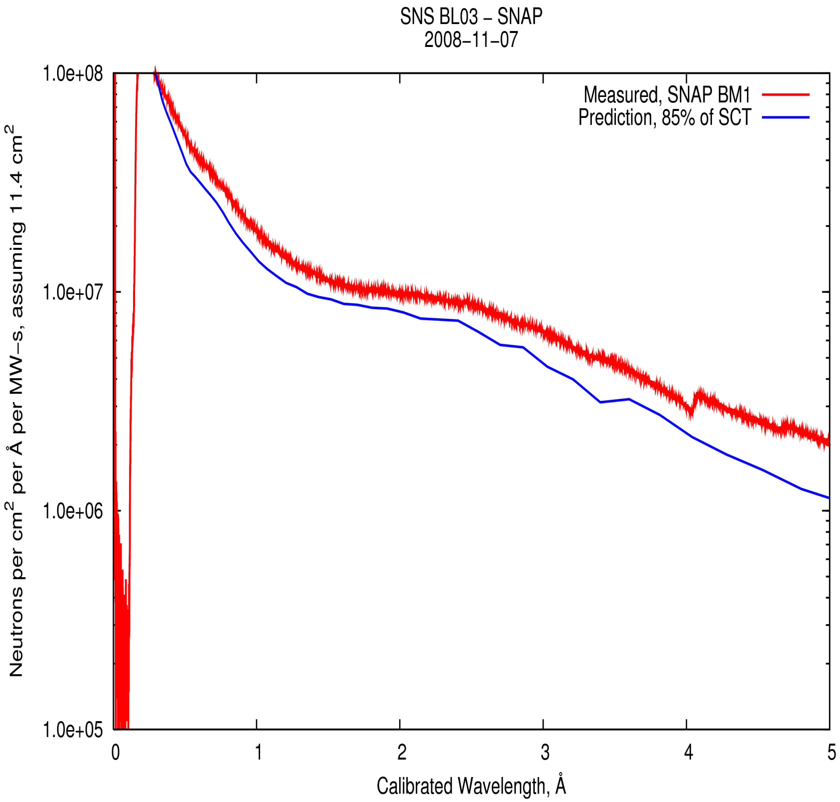
- Advanced moderator:
  - Experiments and preliminary results
  - Simulation capabilities
  - Future activities

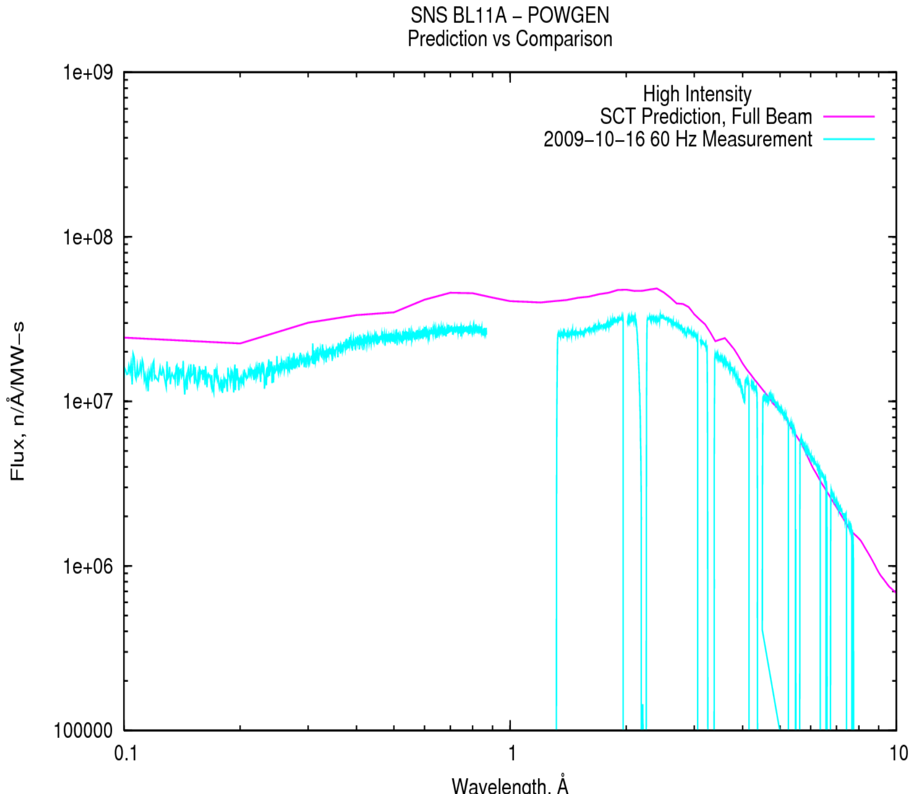
Moderator Neutron Performance

- Performance measurements performed on demand
  - No complete set of data from all beam lines available
- Performance measurement are complicated by in-beam optical components
  - Measurements done at guide exits or instrument sample locations
  - Need to simulate beamline to obtain an un-skewed comparison
- We believe simulations predict within 10-20%

TU Moderator: Decoupled & poisoned hydrogen

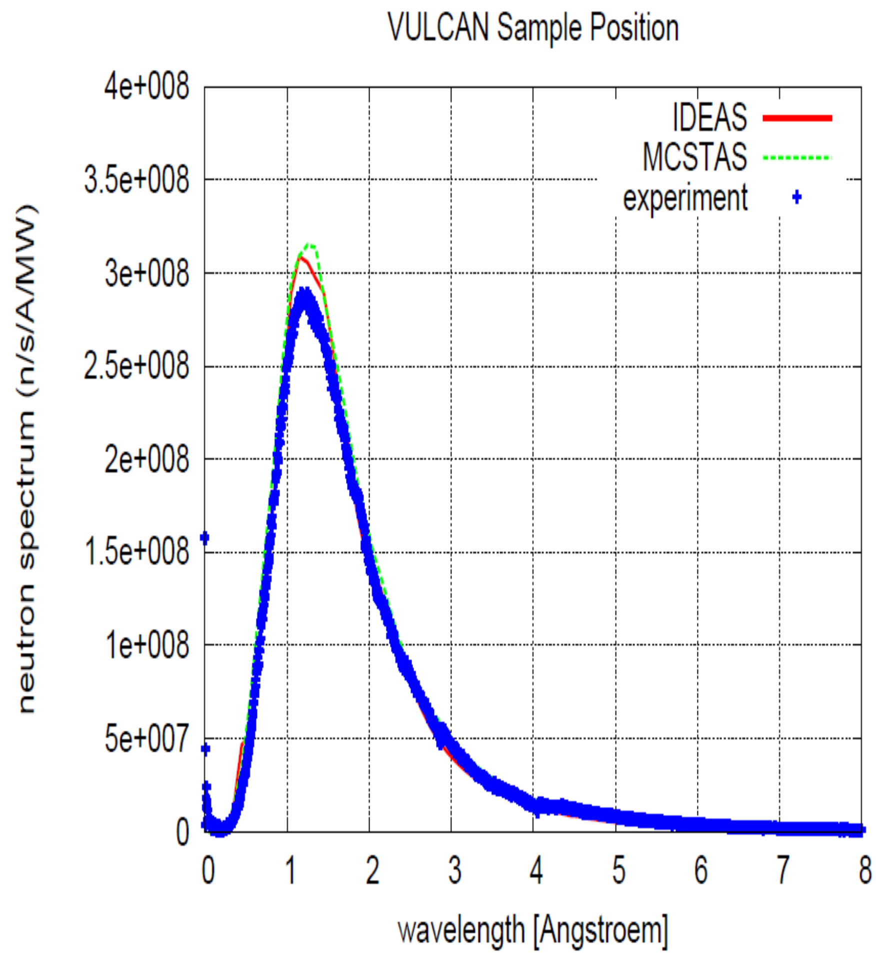
- Top upstream moderator (hydrogen)
- Within 20% after correcting for IRP light water cooling instead of heavy water cooling





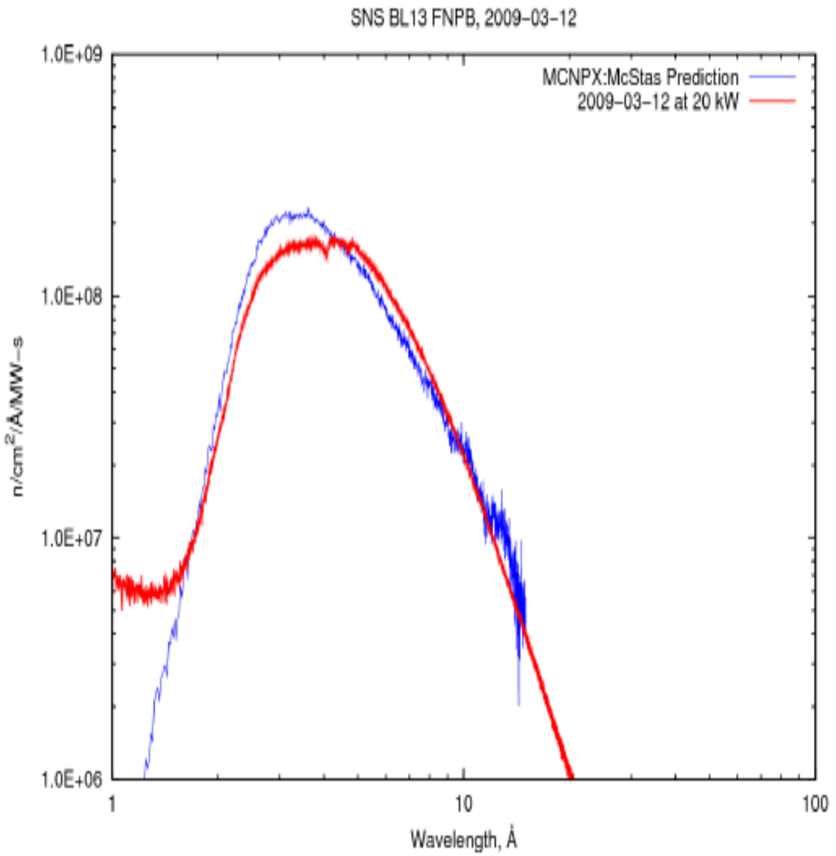
BU Moderator: Decoupled Ambient Water

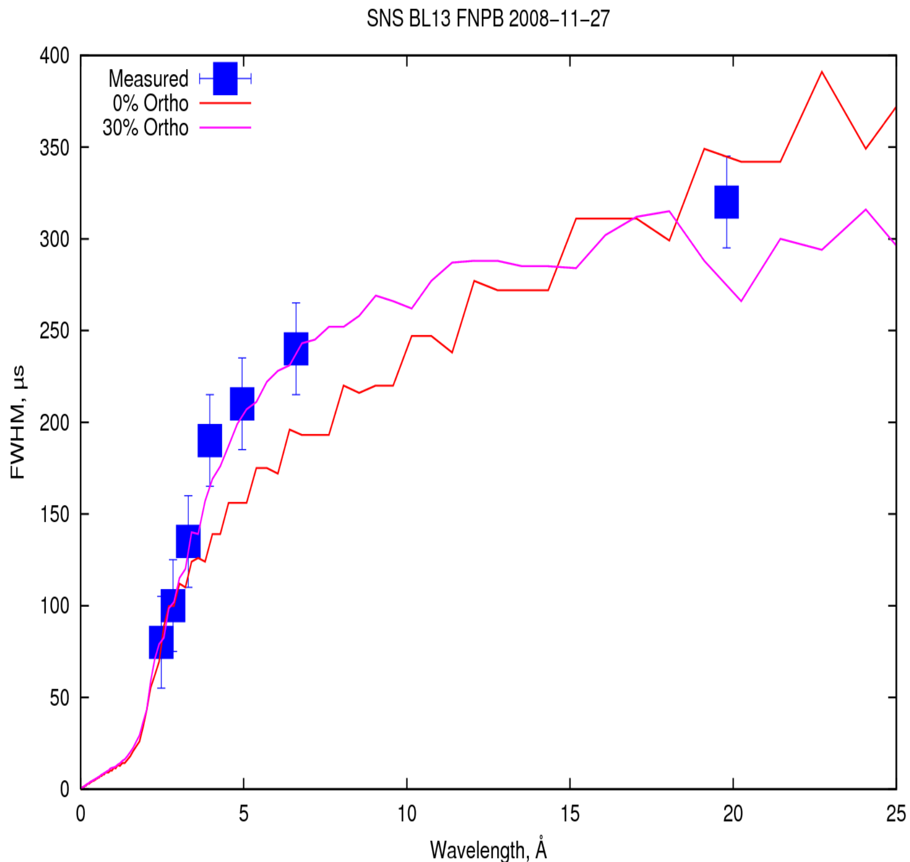
Measured at VULCAN sample position



BD Moderator: Coupled Hydrogen

- After moderator repair of the hydrogen feedline extending it into moderator vessel
- Measured at FNPB: indication of significant ortho fraction



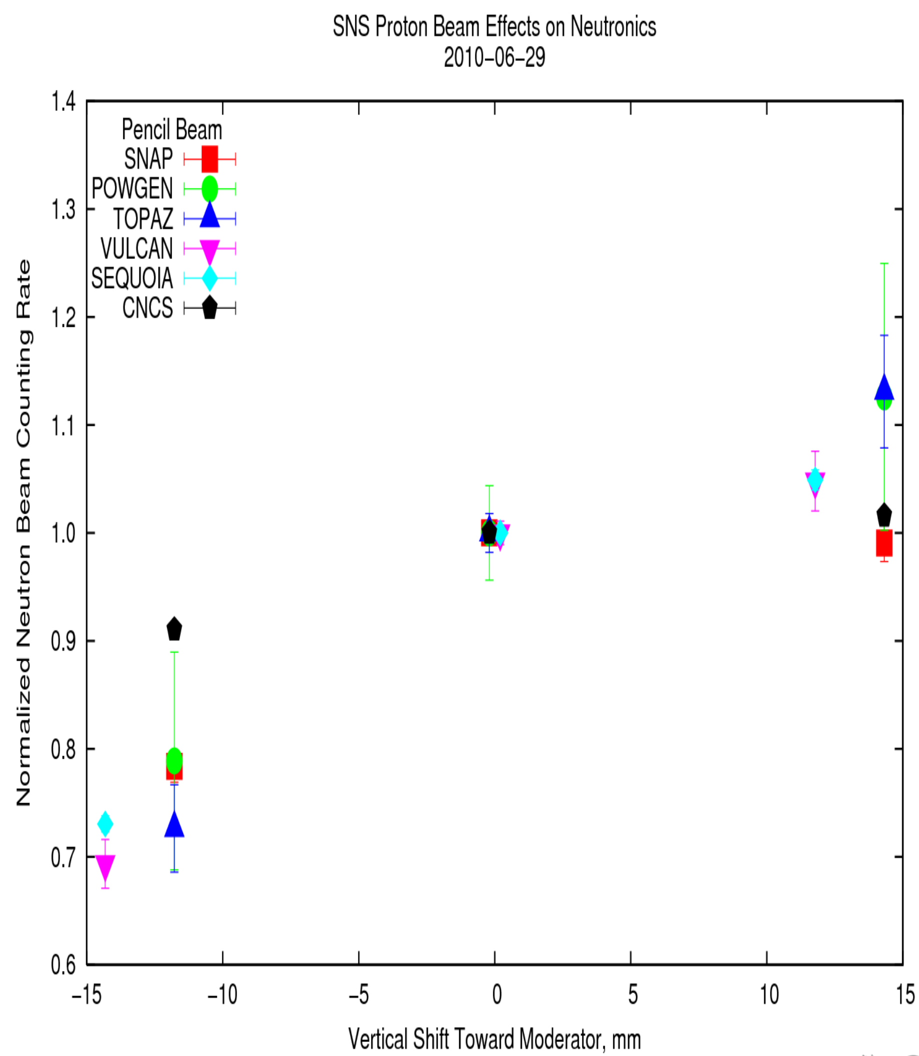


Neutron Performance Sensitivity due to off-center Proton Beam

- Target Imaging System calibrated during AP time of 29 June 2010
  - Involves running pencil beams as well as nominal beams at different locations across target face to calibrate light output per proton
- We simultaneously measured neutron spectra and background levels on several scattering instruments in order to characterize the sensitivity to proton beam configuration
  - TU: SNAP (03), POWGEN (11a), TOPAZ (12)
  - BU: VULCAN (07), SEQUOIA (17)
  - TD: CNCS (05)
  - Covered every viewed moderator face except for BD

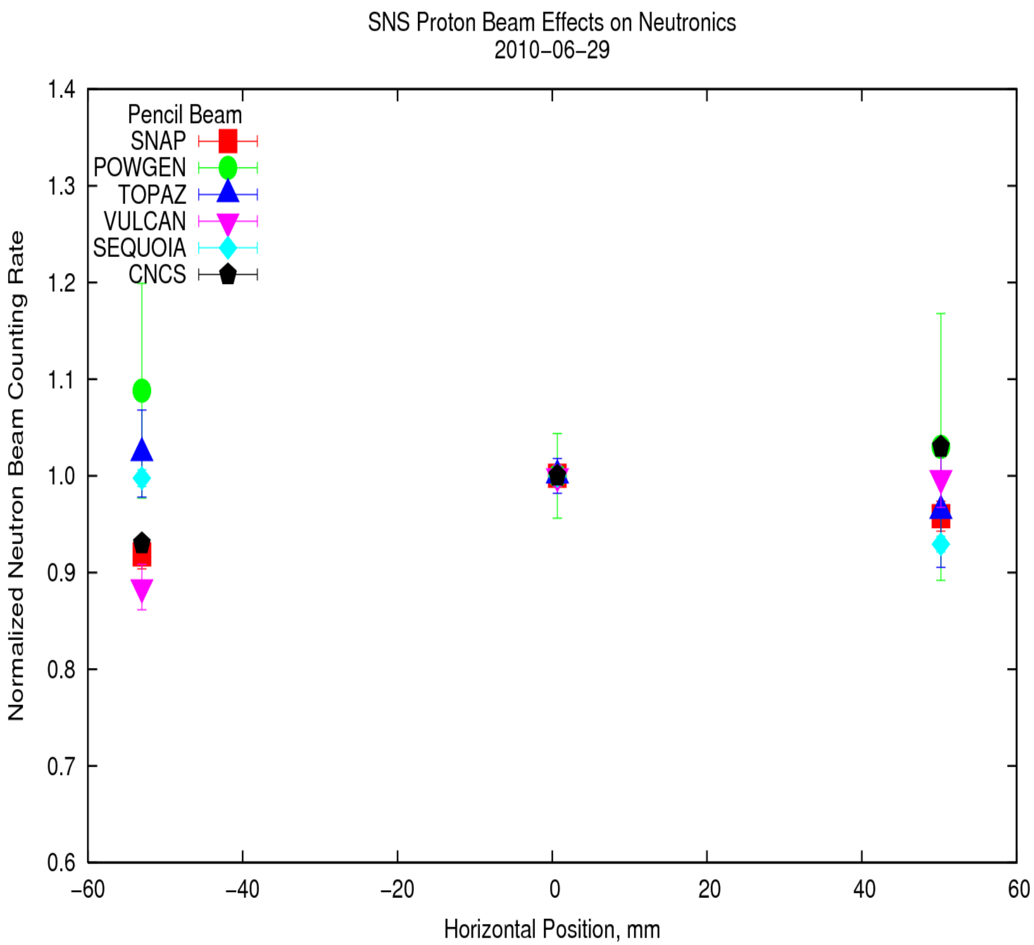
Pencil Beam Vertical Scan:

- **Moving away from moderator penalizes beamlines more than moving toward the moderator:**
  - **Loss about 20% per cm away**
  - **Gain about 5% per cm toward**
- **Effect seems to be similar for beamlines sharing moderator**
- **Effect is stronger for upstream moderators**
  - **Could not include BD moderator**
- **Figure shows vertical *shift* toward relevant moderator**



Pencil Beam Horizontal Scan:

- Horizontal shift shows smaller variation
  - ~10% for 50 mm offset; much greater than would be possible within the OE or on the basis of target lifetime constraints
- Horizontal scan performed only with pencil beam
- In addition to the variation being small, most were not statistically significant
  - Runs were mostly 2 minutes each

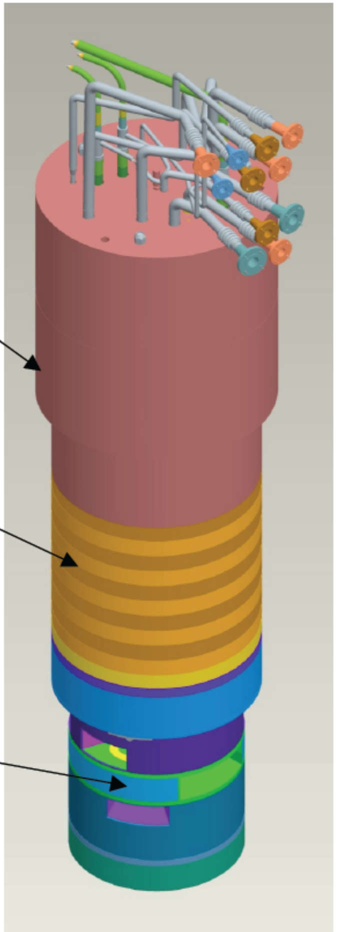


We continue with measurements as part of instrument support as opportunities arise.

Spare Inner Reflector Plug

Spare IRP Assembly

- Upper IRP
  - Passively cooled shielding
- Intermediate IRP
  - Actively cooled shielding
- Lower IRP
  - Actively cooled shielding
  - Integrated moderators
  - Be reflector
  - Moderator beam tubes
  - Target opening



- Physics design is identical to the first IRP
- Shielding is improved and water cooling routing is simplified
- Extensive Delays have been encountered with Spare IRP procurement – 6061-T6 EB welding of moderator and lower IRP components
- Delivery expected summer, 2012

Next generation Inner Reflector Plug (IRP)

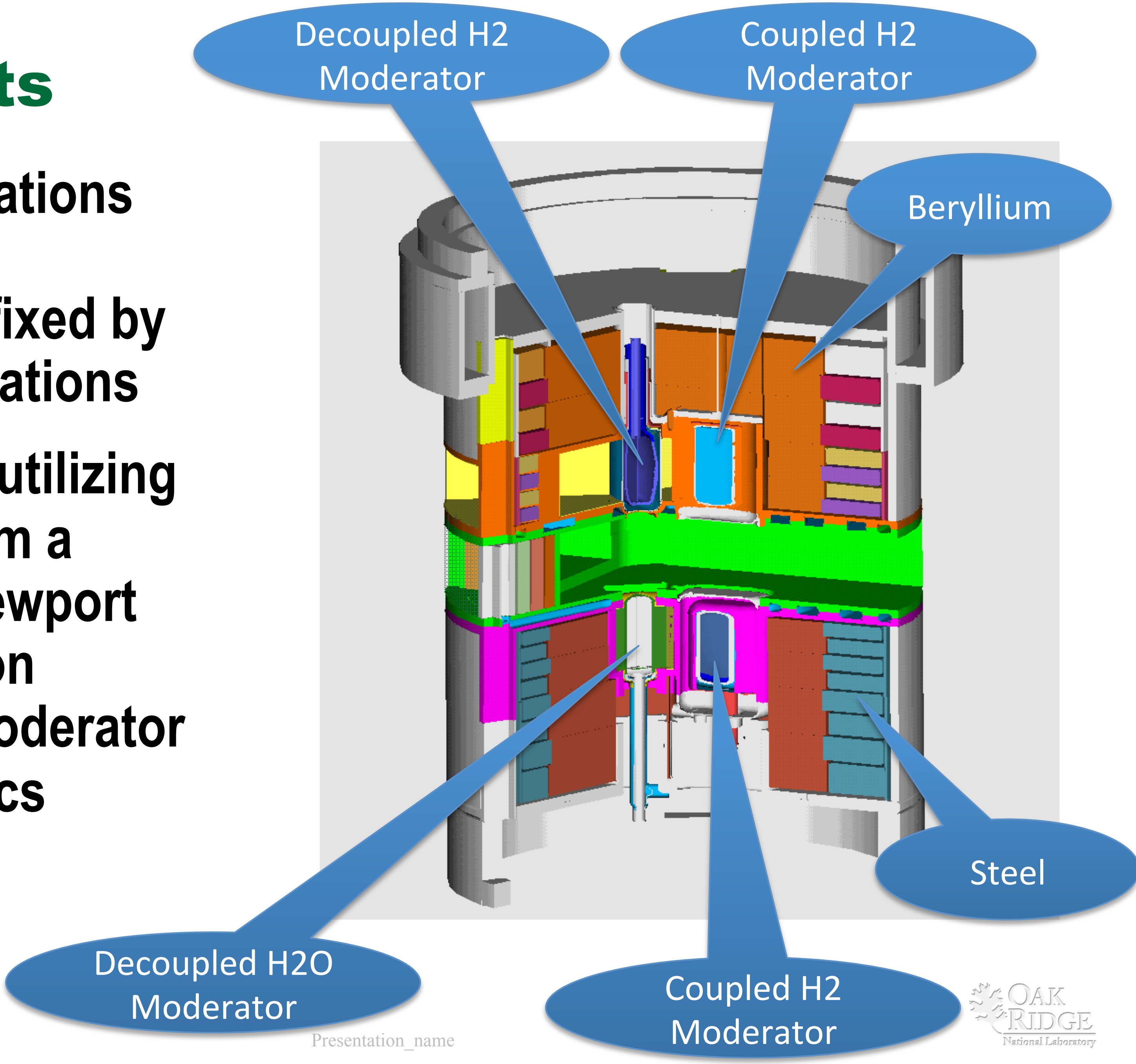
- **SNS IRP has limited life (30,000 MW-hours as designed)**
  - Current operation has been ~12000 MW-hours
  - At 1 MW operation and 5,000 hours per year, that is ~4 years from now
  - Procurement takes ~2 years, and awarding a contract may take 0.5 years
- **Less than 2 years to have a design, drawing package, and ready to go out for bids**

Next generation IRP: Design Goals

- **Increase lifetime from 6 MW-years to 8 MW-years**
  - Change to Cd poison and increase decouplers and liners
- **Increase performance of upstream moderators by 10%**
- **Increase performance of downstream moderators by 30%**
  - Requires an ortho to para convertor, which also improves resolution of Basis, CNCS, etc.
- **Improved waste handling**
  - Current IRP will not fit in TN-RAM cask without being cut into pieces
  - Create a two-piece IRP composed of a inner-inner plug containing the moderators and the beryllium (lifetime limiting components) and the steel shielding as outer-inner component with increased lifetime of 40-50 MW-years.

Next IRP: constraints

- Viewport locations and sizes of moderators fixed by beamline locations
- Instruments utilizing neutrons from a particular viewport must agree on change of moderator characteristics



Next gen. IRP: Decoupled Moderators

- Veined or checker-board poison did not provide improvements over the poison plate design.
- Decoupled moderators are optimized to intensity at cost of increased pulse width or vice versa by the moderator thickness: instruments are happy with present compromises or have conflicting wishes.

➢ No change in decoupled moderator geometries

- The only change will be the replacement of the gadolinium poison material by a cadmium

➢ Gains of 5-15% in neutron brightness is expected by the poison material change including a lifetime extension of 1 year.

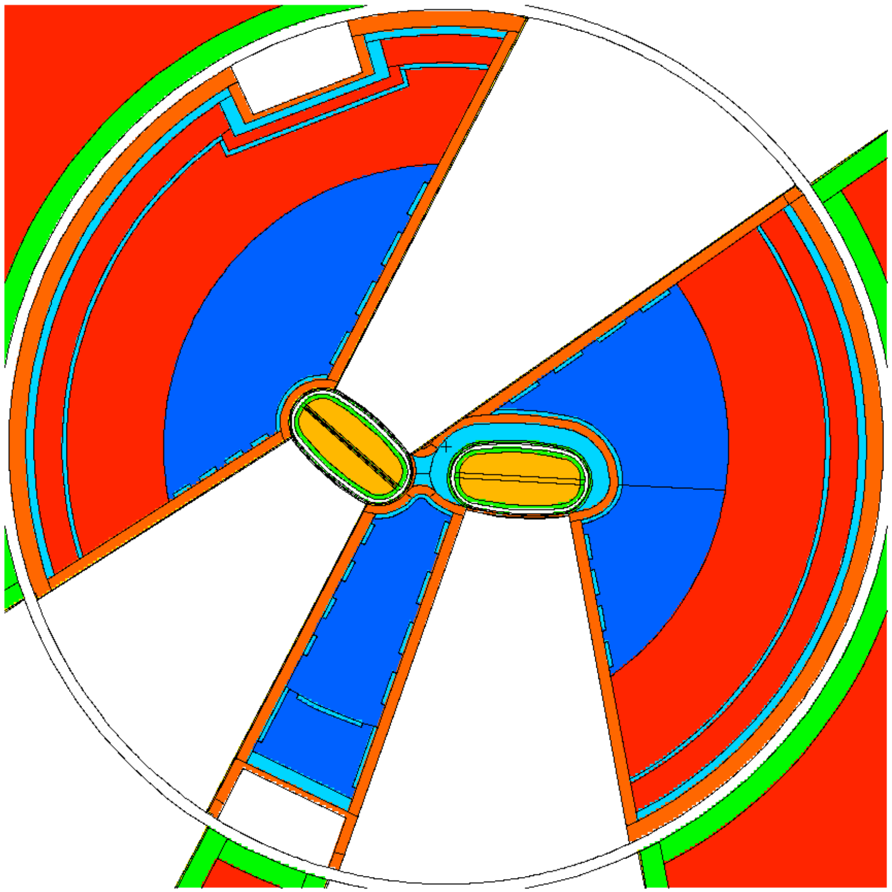
Next gen IRP: Coupled H2 moderators

- The thickness was chosen to 5 cm to make the brightness insensitive to changes in the ortho/ para ratio.
- With the commitment to implement a catalyst driving the H2 to the para state, we can gain intensity by increasing the thickness to 10-12 cm.

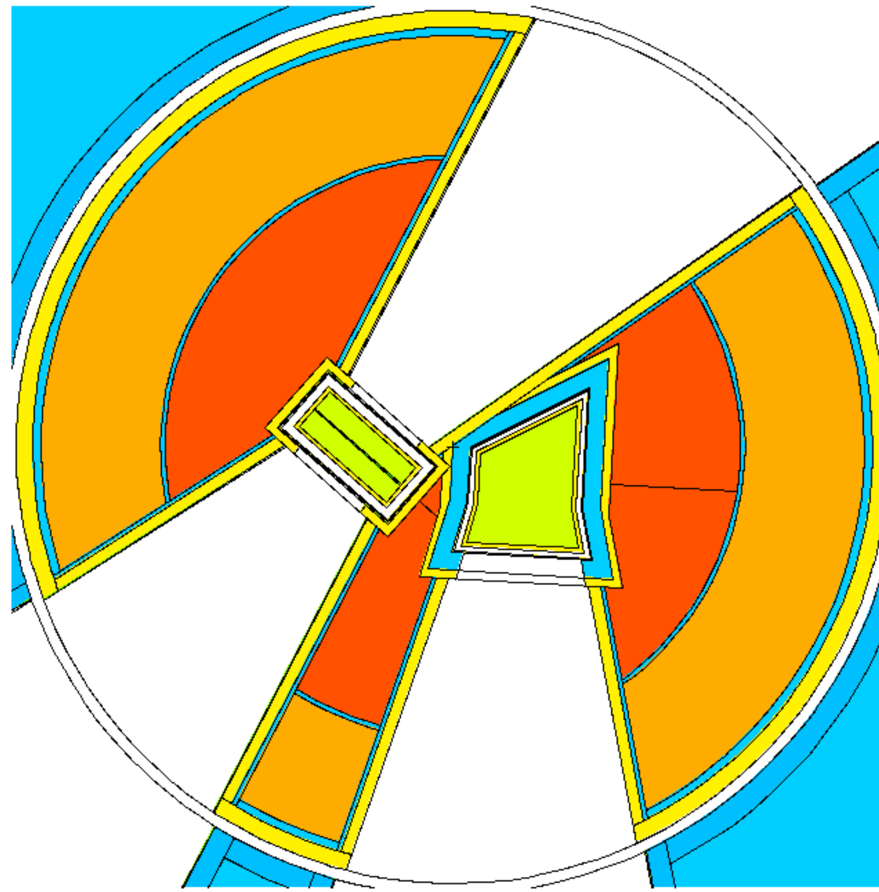
Add graph intensity vs thickness for differnet ortho/pra ratiosn

Next IRP: Coupled H2 moderators

Present design

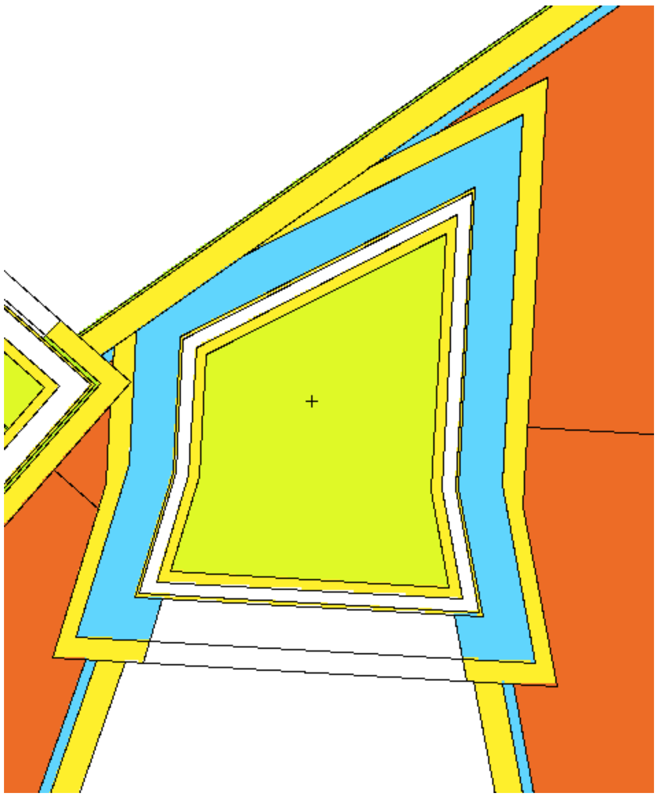


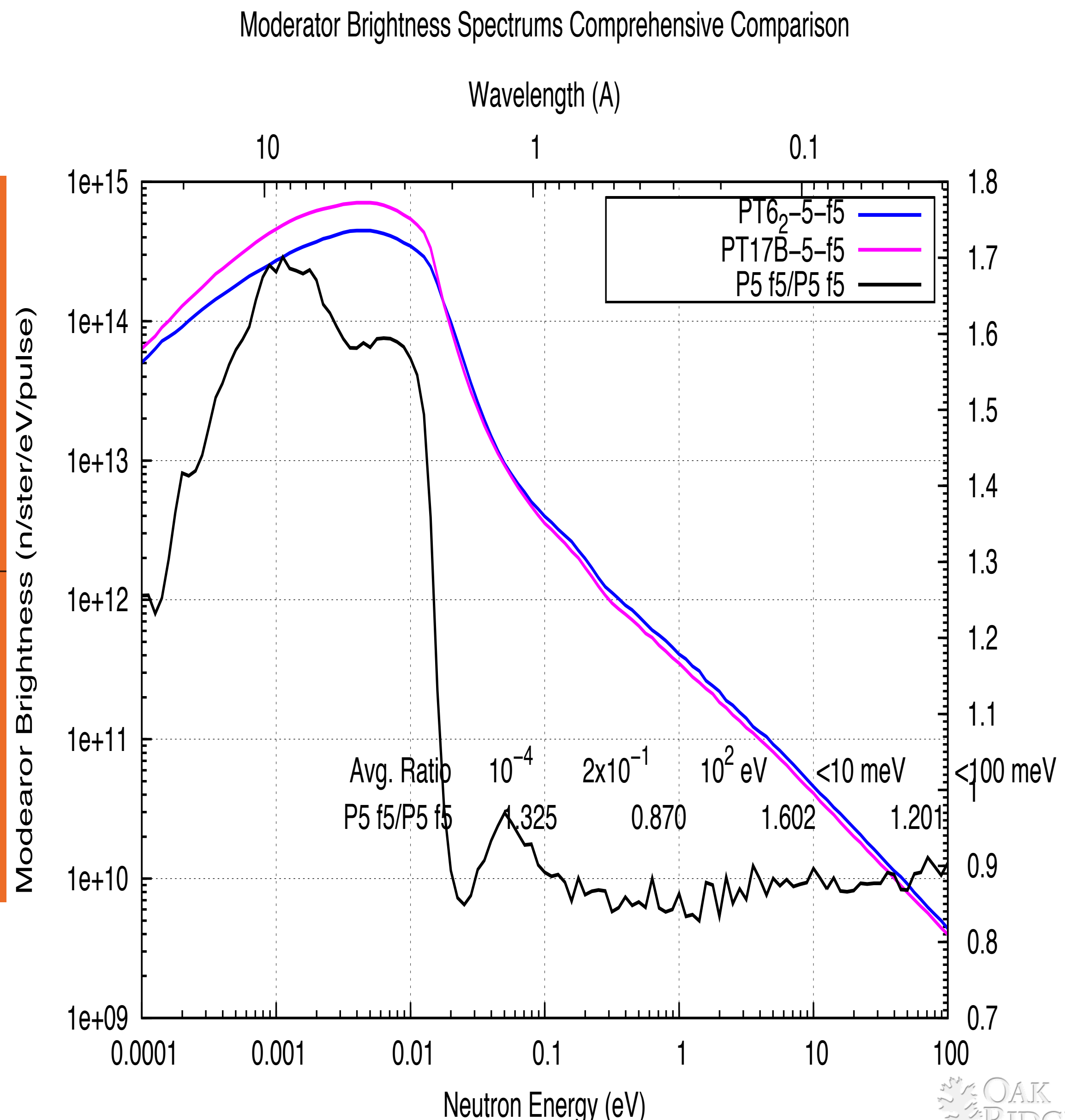
Next design (idealized)



Next IRP: Coupled H2 moderators

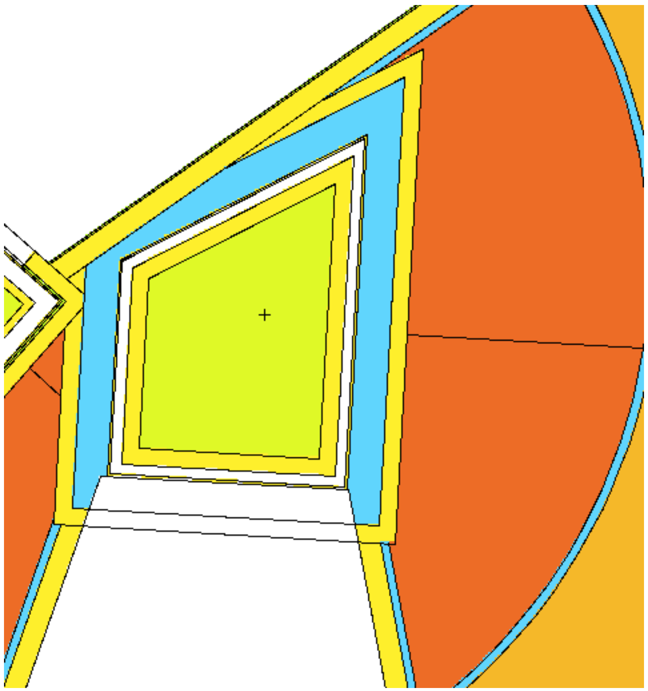
Idealized geometry

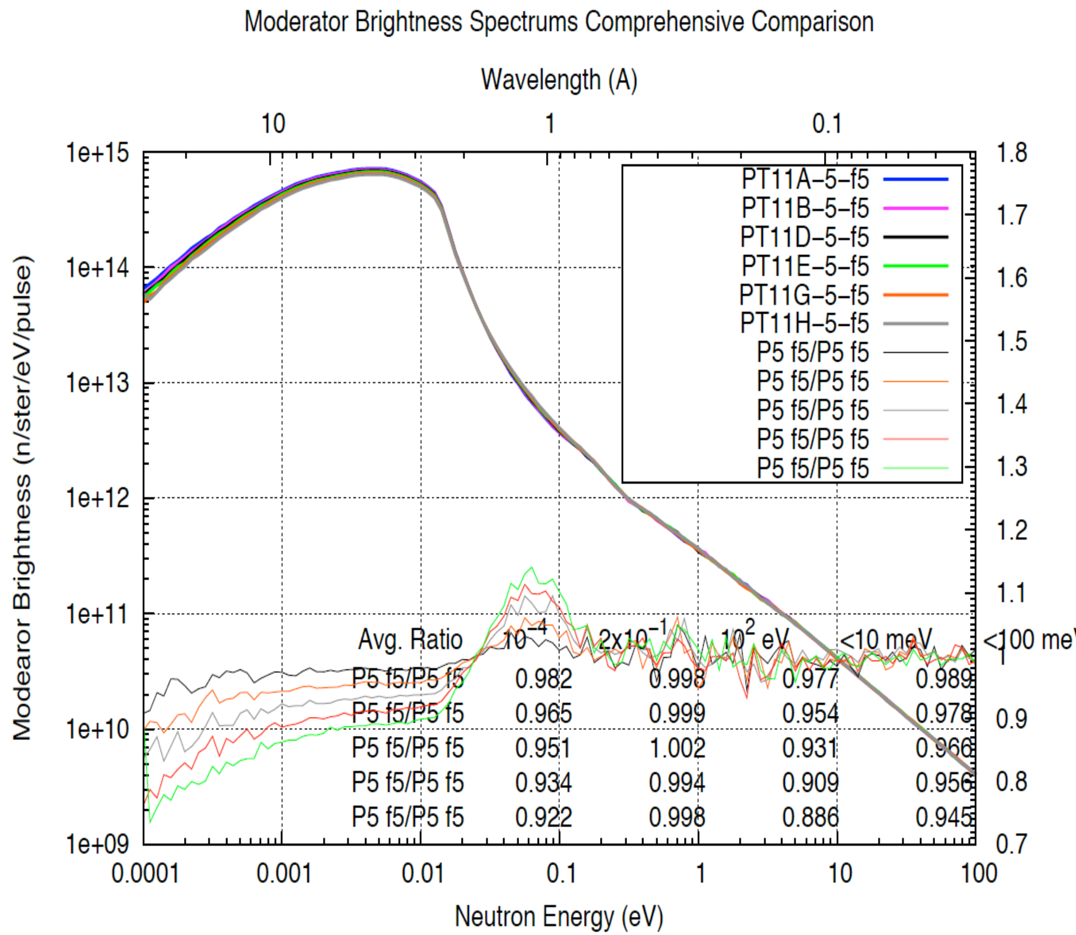




Next IRP: Coupled H2 moderators

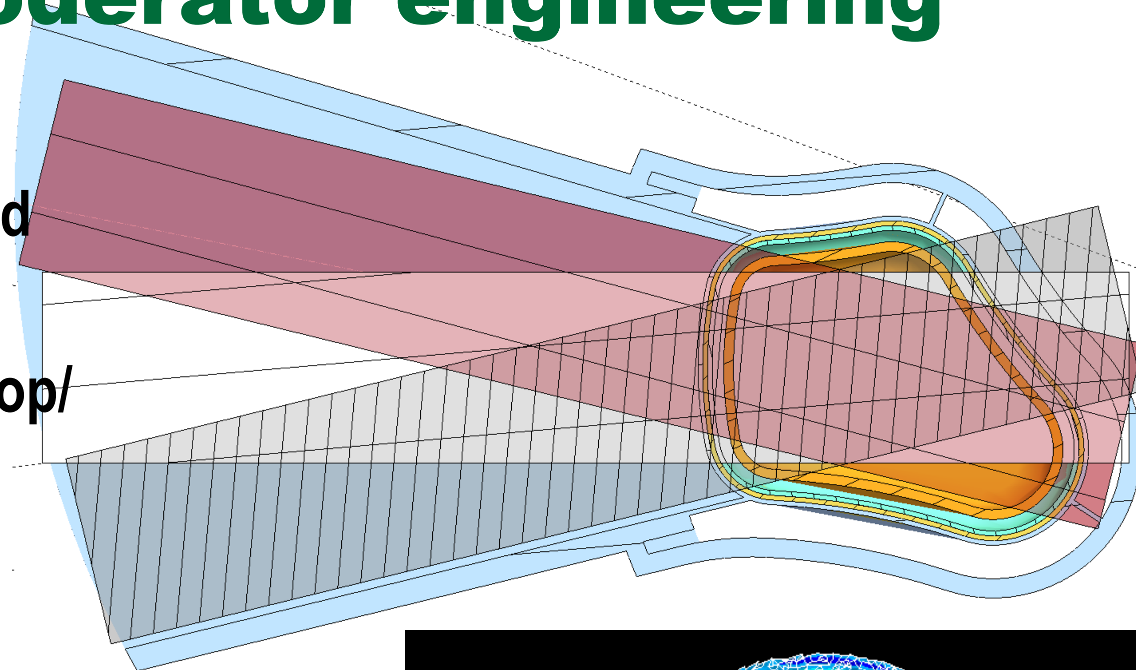
- **Variation of H2-vessel thickness 5-10 mm**





Brightness at 1 meV reduced about 1.5%/mm

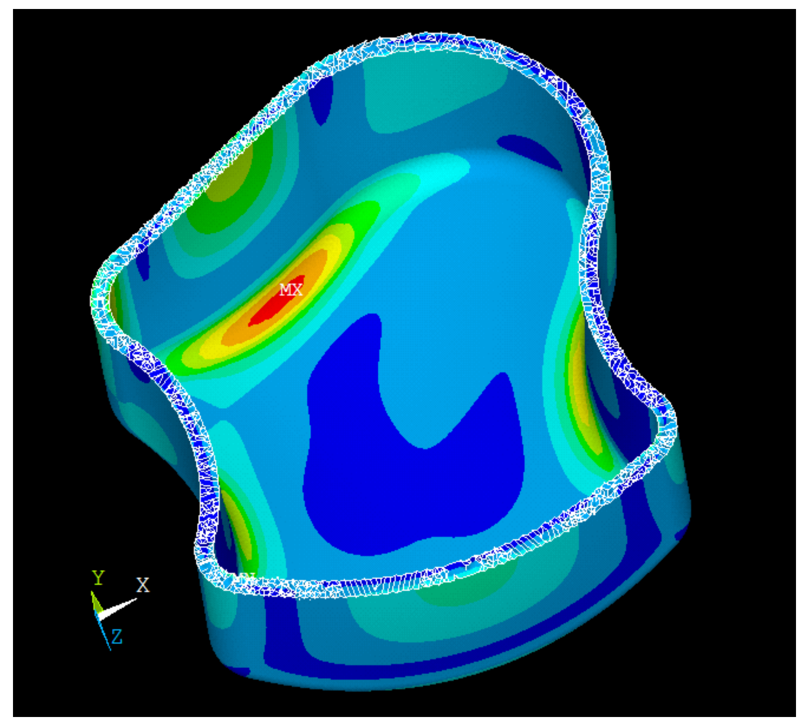
Coupled H2 moderator engineering



Engineering reality:

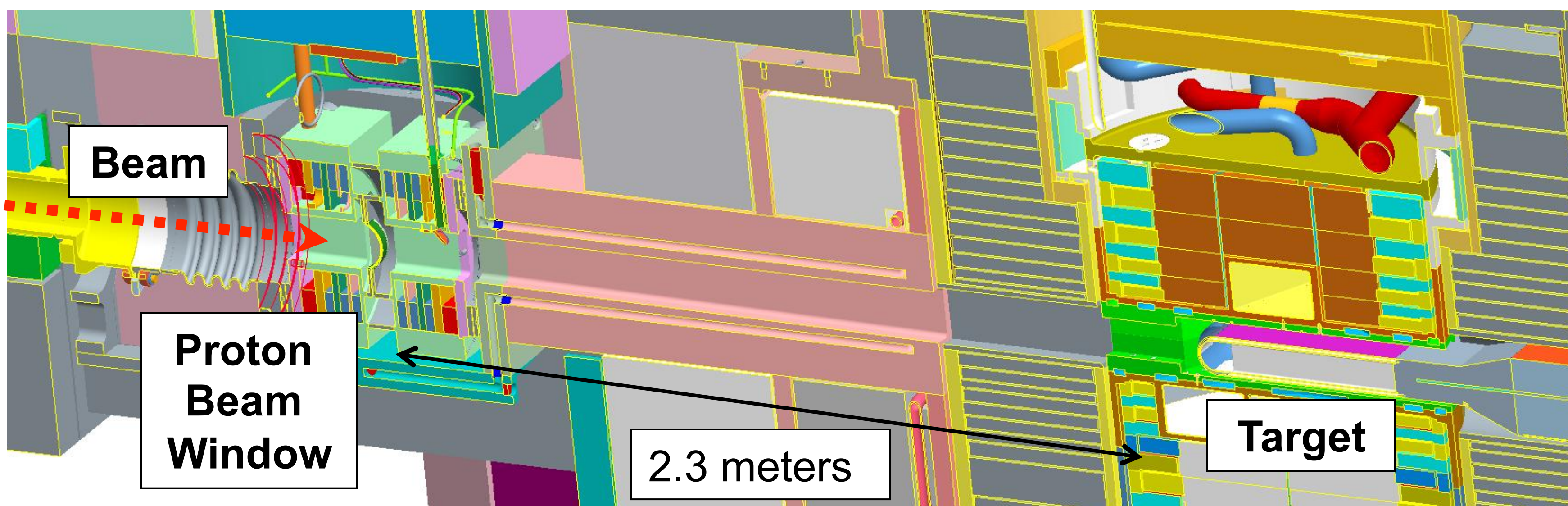
- Curved walls and rounded edges to reduce stress
- Supply lines connect at top/bottom
- Flow diverters may be needed
- Thermal expansion calls for positioning tolerances
- Fabrication constraints

Iterations between neutronics and engineering analyses coming up



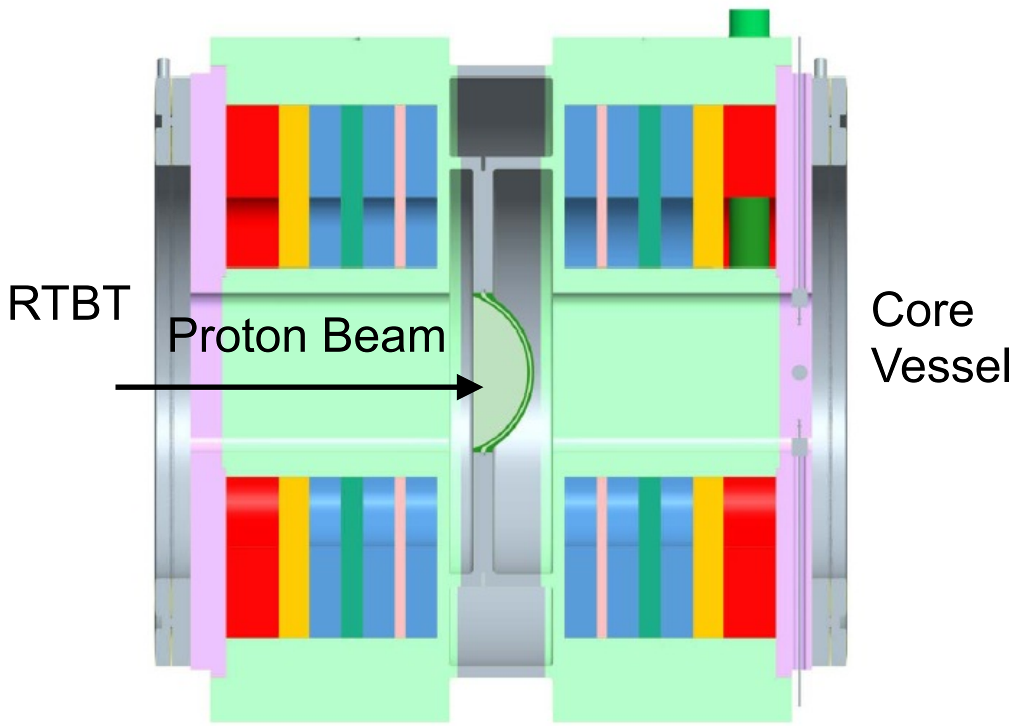
Proton Beam Window (PBW) Assembly

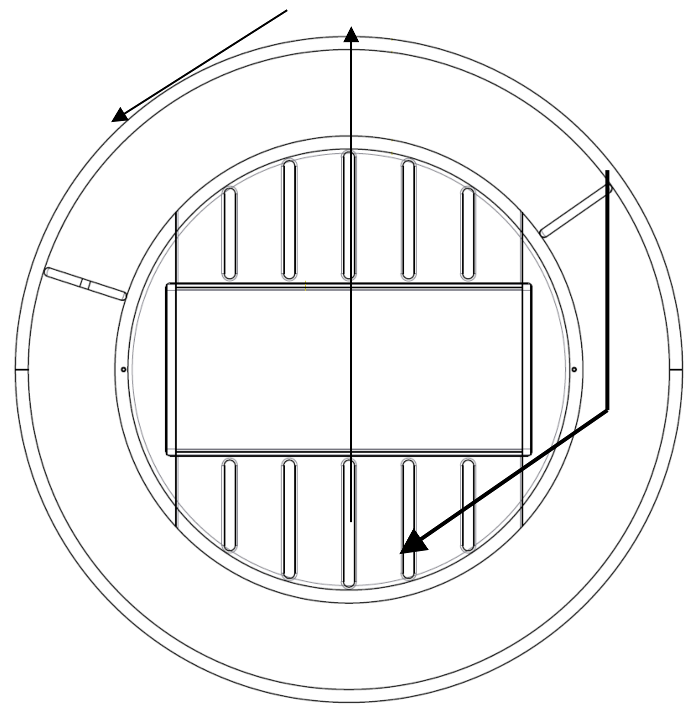
- Separate high vacuum of accelerator from helium environment of core vessel
- Allow proton beam of up to 2MW to pass through window
- Shield surrounding assemblies from particles from scatter and spallation occurring in window
- Houses halo thermocouples and target imaging system hardware for beam diagnostics



Current SNS PBW Design

- Inconel 718 window between 316 SS shield blocks
- Approximate lifetime of 7500 hours at 1 MW





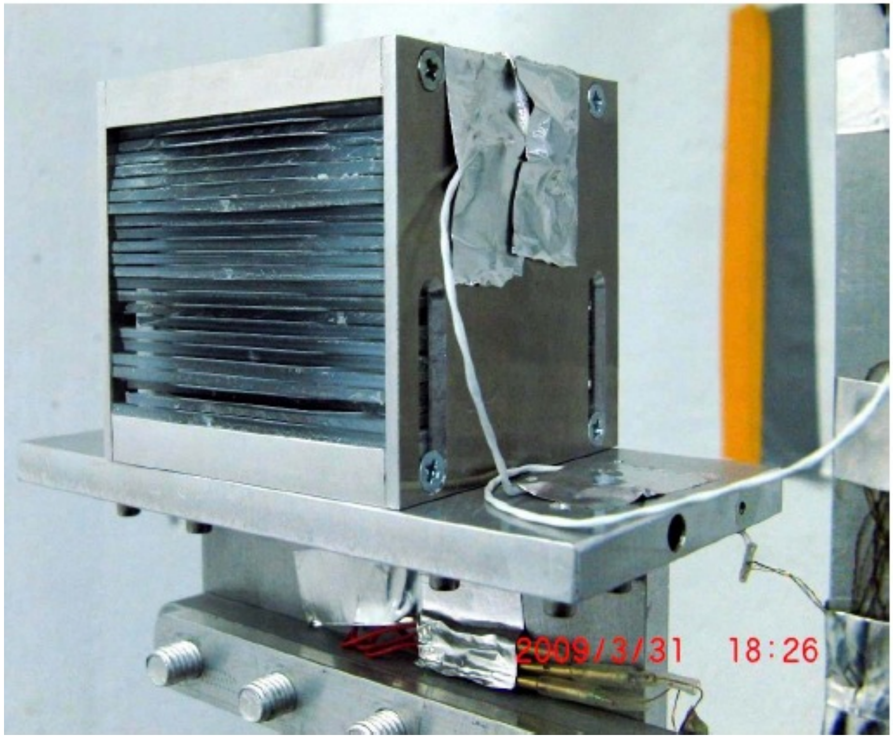
Motivation for Aluminum PBW

- Increased PBW lifetime – estimated at 15000 hrs @ 1MW
  - Rough estimate based on SINQ target 4 safety hull
- Increased neutronic performance – estimated 3-5% increase compared to current Inconel 718 window
- Decreased heating in PBW and shield blocks – estimated 33% and 45%, respectively, of heating for current window
- Higher thermal conductivity and lower energy deposition and stiffness lead to lower thermal stress levels

Engineering details will be given by Peter Rosenblad

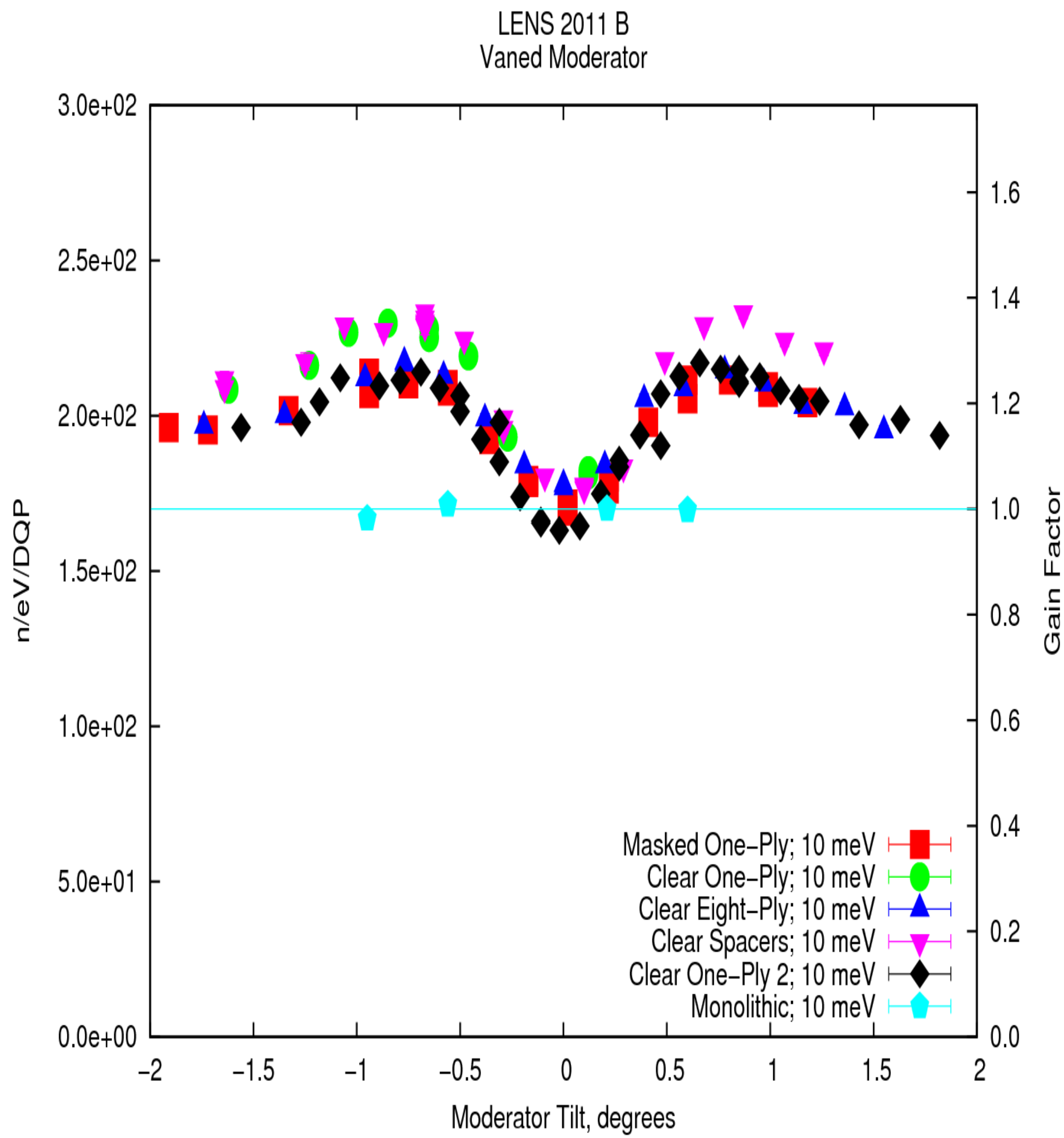
Directional moderators

- More neutrons in the direction of the beamline (or guide)
- Active program with Lens
- ILL effort on diamond nanoparticles may be combined with crystals
  - Working on collaboration to perform joint experiment at Lens

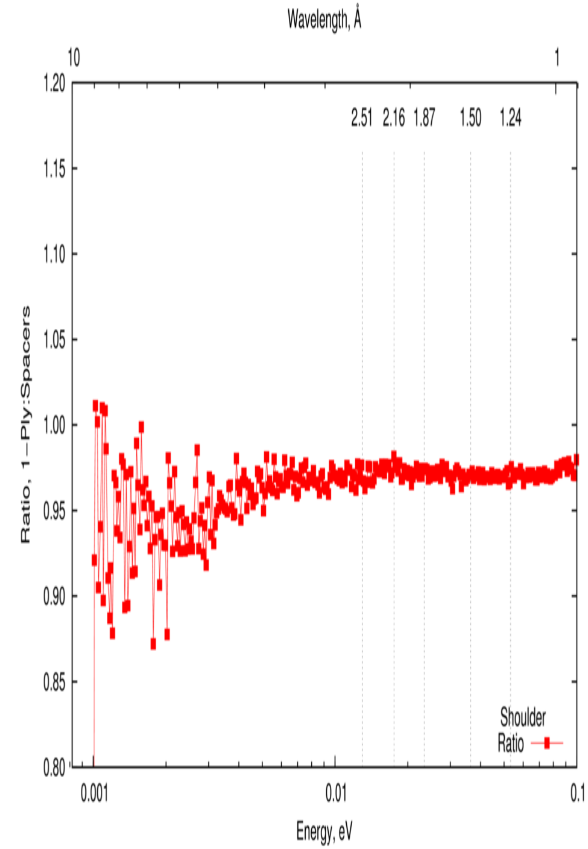


Directional Moderator Experiments:

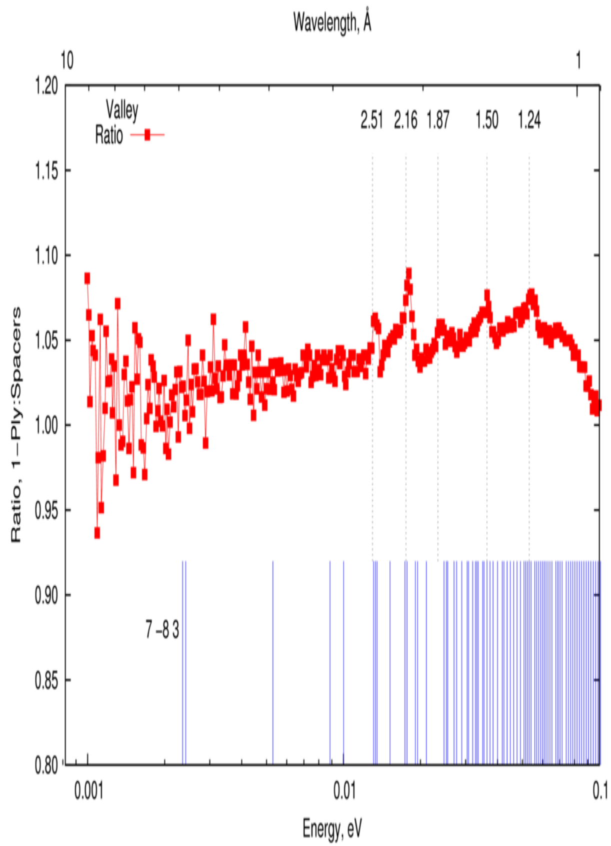
- Neutron Emission at different angles with regard to surface normal of moderator stack
- 30% gain at 0.7 degree tilt from PE/Si stacks of 0.7/2mm layer thicknesses
- 35% gain at 0.7 degree tilt from PE/void gap stacks of 0.7/2mm layer thicknesses



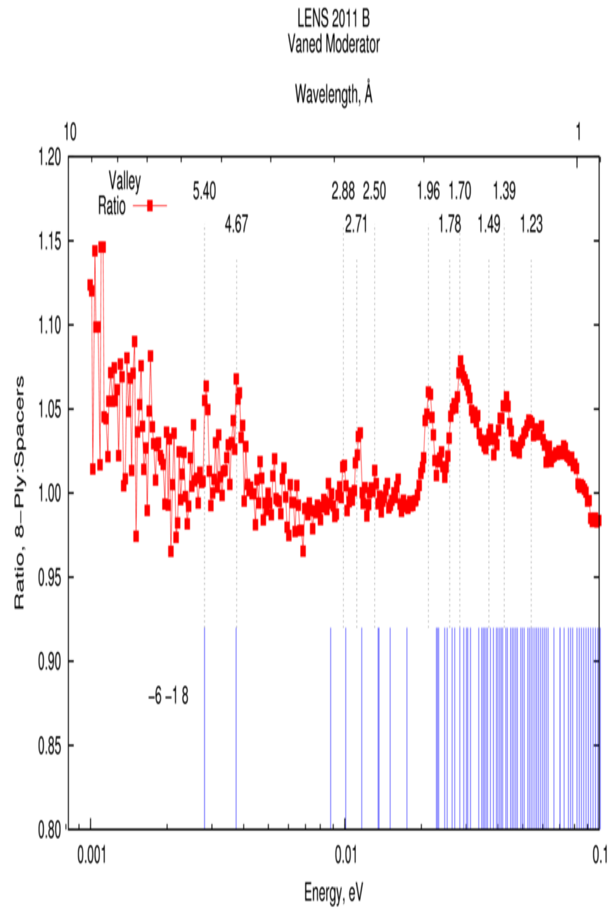
Directional Moderator Experiments:



Shoulder 1-ply Si



Valley 1-ply Si



Valley 8-ply Si

Gains due to Bragg diffraction effects are demonstrated at 0 degree moderator tilt but not at 0.7 degree tilt with the silicon vein structures

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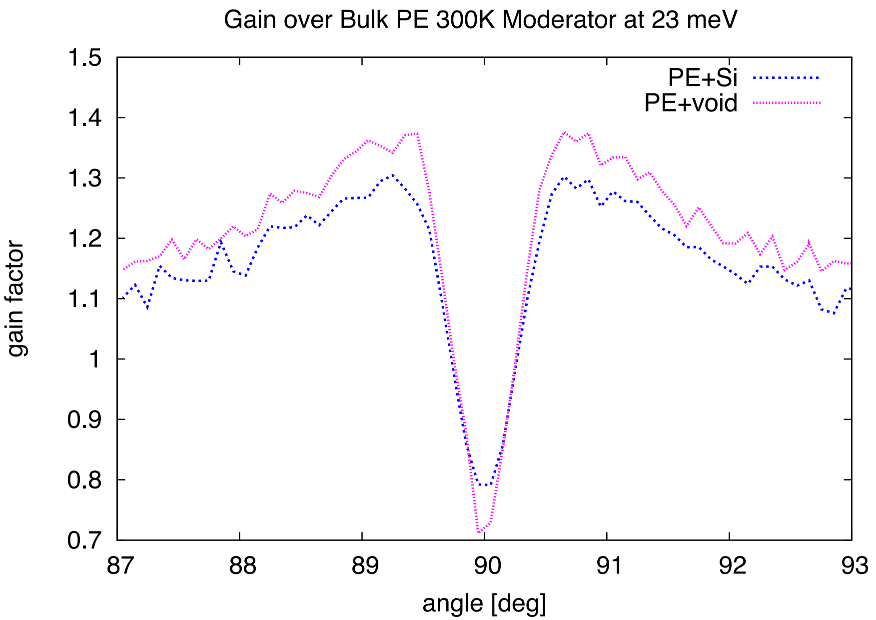
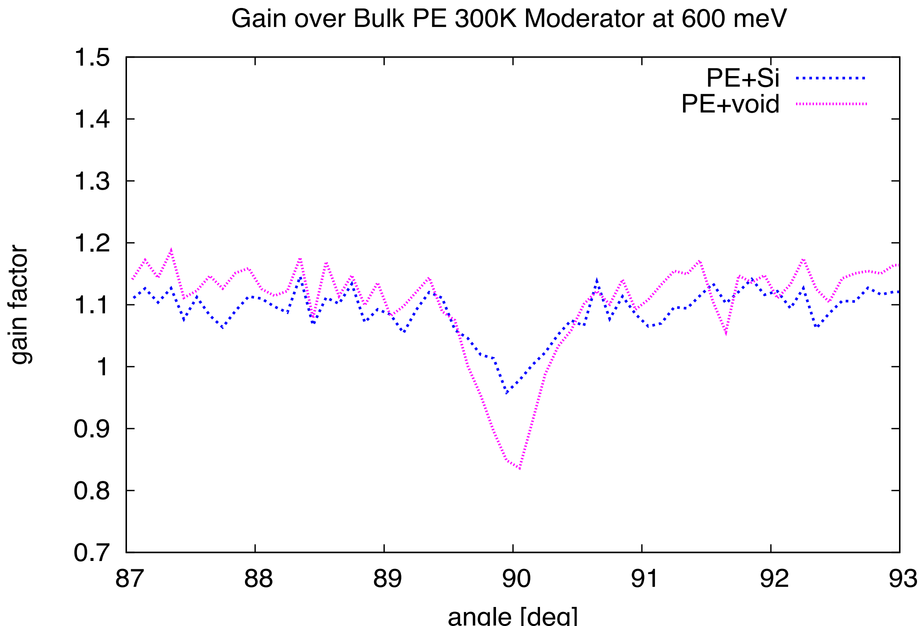
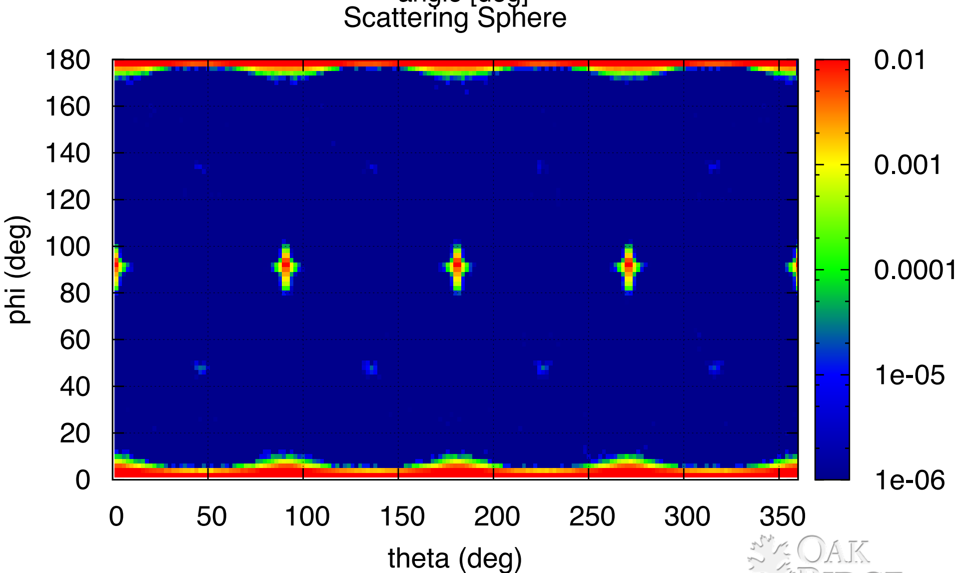
Directional Moderator: Simulations





Part of the Directional Moderator LDRD is the creation of tools (MCNPX) for simulating such effects:

- Neutron refraction and reflection at material interfaces
- Single crystal scattering effects



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Directional Moderator: Future Activities

- Conduct another experiment campaign with cold moderators
- Perform simulation of experiment with new toolset
- Publish