OAK RIDGE National Laboratory

Neutron shielding and transport calculations for the post-beryllium replacement HFIR cold guide hall

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U.S. DEPARTMENT OF ENERGY

This research used resources at the Spallation Neutron Source, a DOE Office of Science User Facility operated by the Oak Ridge National Laboratory.

Outline

HBRR introduction

Computational needs and workflow

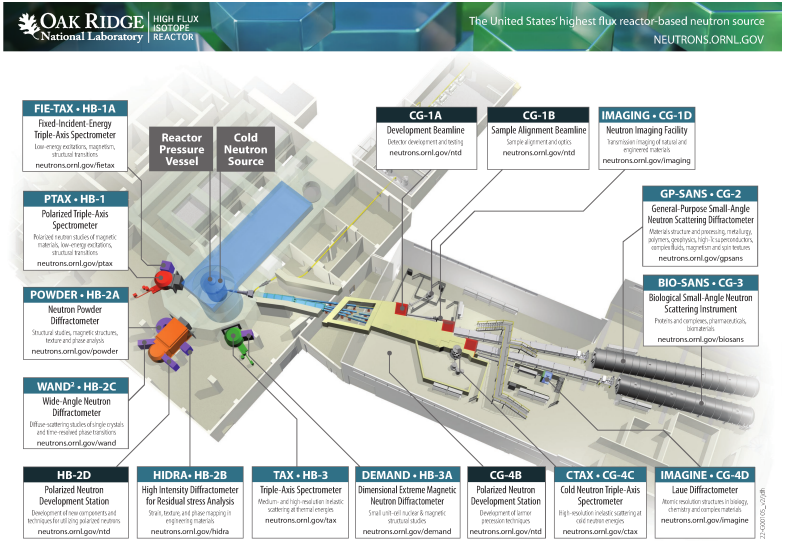
Examples and calculations

Conclusion

High Flux Isotope Reactor at ORNL

HFIR

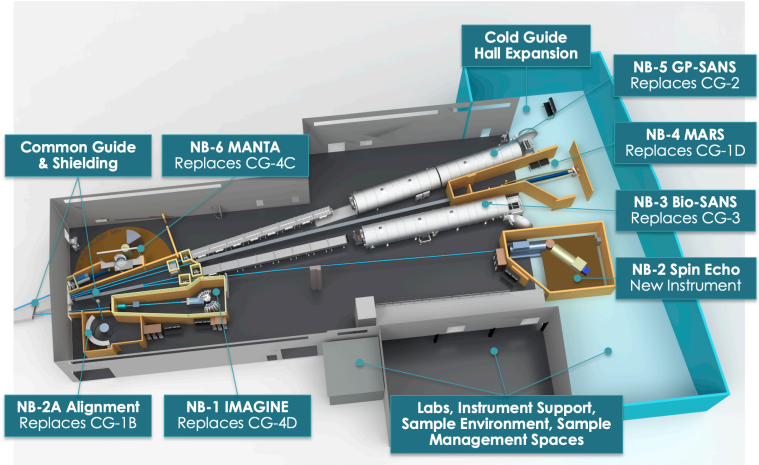
- 85 MW reactor based neutron source
- 3 thermal beams, 1 cold source
- Replacement of beryllium reflector planned for 2028



HFIR post HBRR

HFIR

- Planned for 2028
- Newly optimized beamline configuration
- New shielding configuration, secondary shutters, velocity selectors.



Computational needs

McStas

- Scattering instrument design and optimization process uses the fast ray tracing code McStas
  - sample oriented physics only
- Large set of neutron beamline components
  - Supermirror guides. velocity selectors, monochromators

MCNP

- General purpose radiation transport code
  - Detailed physics and data tables
  - Shielding can be modeled in detail
- Extensions for neutron beamline components
  - Supermirror guides, velocity selectors, single crystal scattering, small angle neutron scattering

Unifying McStas and MCNP models

Ability to work from the same base model in McStas and MCNP (and CAD software).

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MCNP geometry writer script requirements

Requirements

- The primary routines should be facility agnostic.
  - No hard coded values or assumptions.
  - Facility specific information should be in a pre-processor.
- Ability to read IGES from McStas2CAD script.
  - A pre-processor script reads the IGES archive file and generates Geomwriter input.
  - Assumptions can be made about the dimensions of guide units, and generation of arms, transformations, and tallies.
- Quickly incorporate changes from upstream.
  - The pre-processor reads the IGES zip and uses information from previous reads.
- Ability to merge with an existing MCNP model.
  - An existing MCNP model (cells, surfaces, materials) should be importable and mutable.
- Placing objects relative to other objects.
  - Mimics the arm component from McStas for specifying secondary coordinate systems.

Complete workflow

McStas2CAD

- Utilizes McStas trace functionality to produce ASCII IGES file of the geometry of a beamline model.

Pre-processor

- For each `.zip` file:
  - process the log file
  - process all guides
  - generate `.off` files for stitching
  - process velocity selectors
  - utilize "cut" dictionary
- Produces input for Geomwriter.

Auxiliary files

- Existing MCNP models for import, `.off` and `.stl` files for arbitrary cells.
- Grid structure for large cells.

Geomwriter

- Workflow allows for swapping beamlines in and out of model by commenting out lines.
- Processes input as ASCII plain text line-by-line.
- Geomwriter checks all non-mirror surfaces for redundancy.

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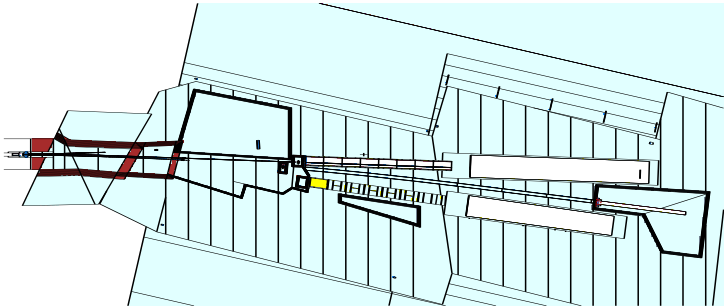
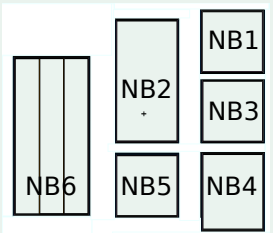
Complete HFIR CGH model



Model generation

- 60 minutes to generate - 7529 cells, 23945 surfaces, 231485 lines
- Loading the model in MCNP takes minutes, reasonable run time.

Beamlines



- NB1 - Imagine
- NB2 - Spin Echo
- NB3 - Bio-SANS
- NB4 - MARS
- NB5 - GP-SANS
- NB6 - Manta

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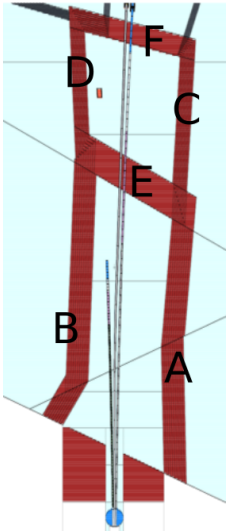
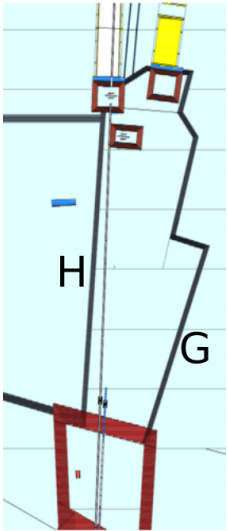
Shielding geometry





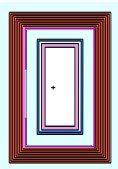
Existing shielding walls

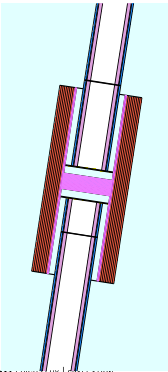
- A,B: 76.2cm (30in)
- C,D: 50cm (19.7in)
- E: 105cm (41.3in)
- F: 70cm (27.6in)
- Barytes concrete

New common shielding

- Inside new CGH, housing secondary shutters and velocity selectors.
- G,H: 20cm (7.9in)
- HD concrete

Guide and secondary shutter geometry





Construction

- Guides are build from McStas2CAD description of interior and expanded along surface normals from IGES to construct glass, vacuum, and casing.
- Shutter is located relative to a guide segment and surrounded by lead tube.

Dimensions

- Borofloat glass: 0.6 cm
- Vacuum: 0.4 cm
- Steel casing: 0.3 cm

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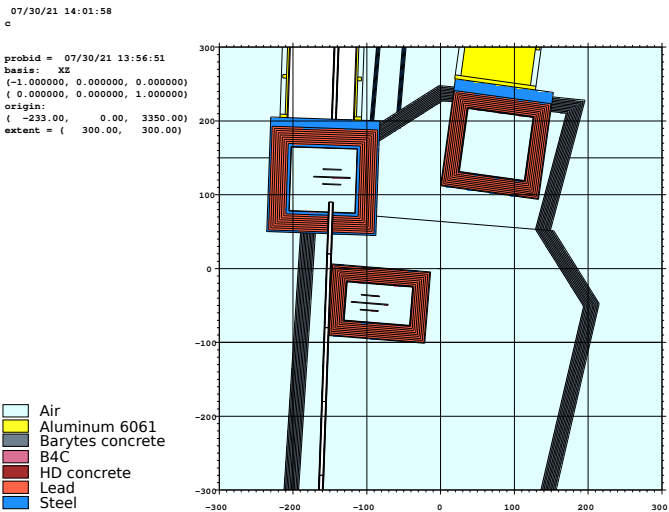
Velocity selectors



Velocity selector boxes

- Box dimensions from `.off` and placed at locations given in McStas2CAD output, relative to arms.
- Boxes are 0.5cm B4C, 1cm steel, 20cm lead, 1cm steel (inside $\rightarrow$ outside) in layered onions.

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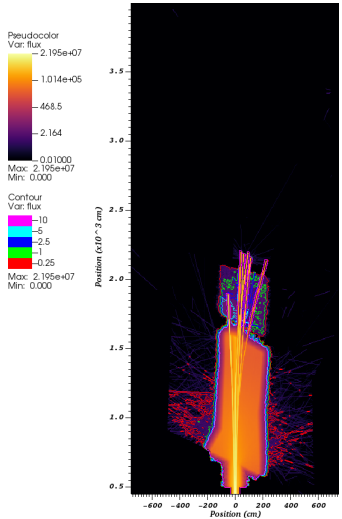
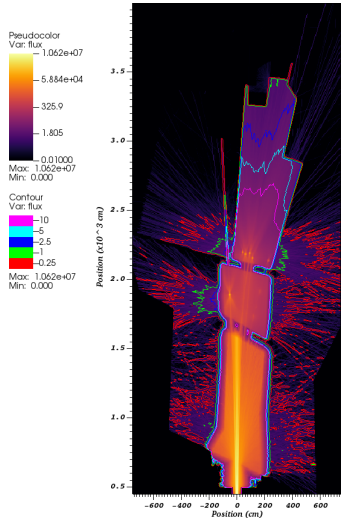
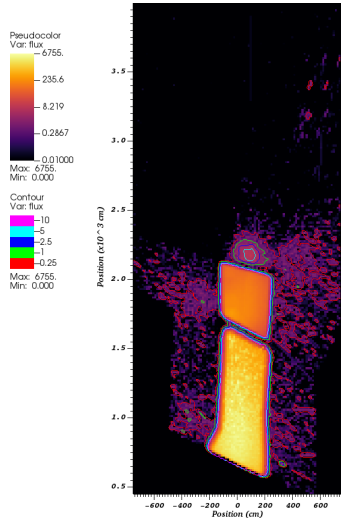
All closed - With Lead and B4C



Neutron dose (mrem/hr)



Gamma dose (mrem/hr)



Above common roof

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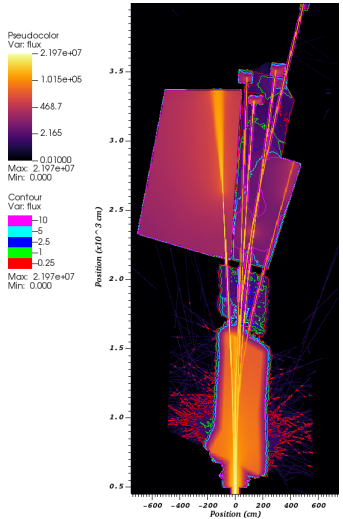
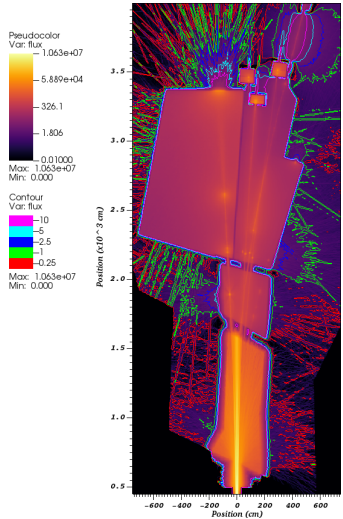
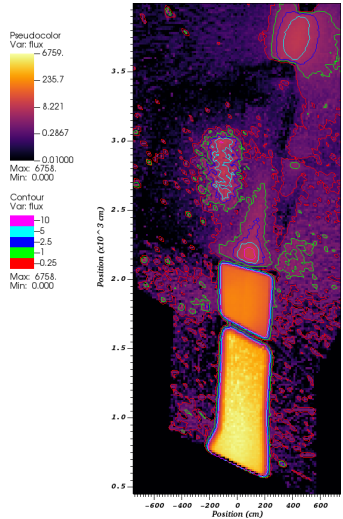
All open - With Lead and B4C



Neutron dose (mrem/hr)



Gamma dose (mrem/hr)



Above common roof

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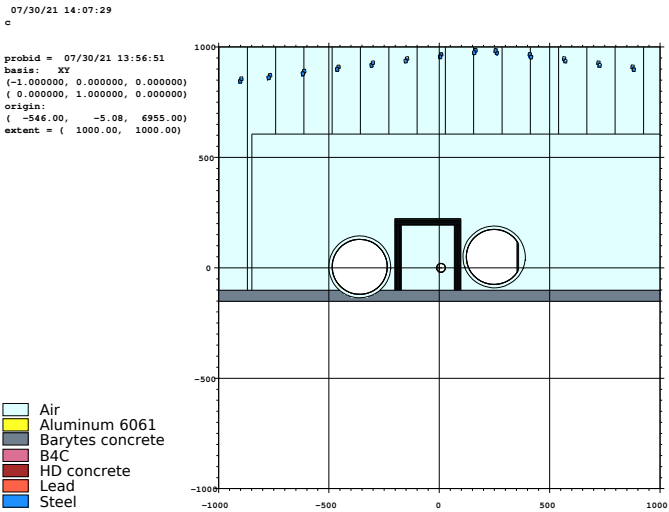
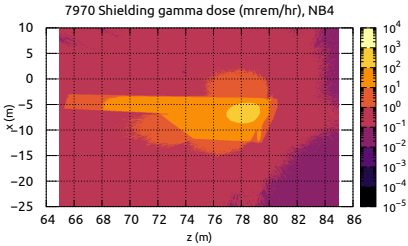
NB4 Cave Roof



Cave shielding

- Barytes concrete 30cm thick and 3m tall on inside.
- 3m tall on the inside, 30cm section above is switched to air for “no roof” calculations, tally region is immediately above 30cm section.

NB4 above roof dose



Requirements

- There is a planned personnel accessible mezzanine above NB4.
- Low background at the NB3 and NB5 (SANS instruments).

Implications

- Without a roof, this region would be above 100 mrem/hr gamma and above 10 mrem/hr neutron.
- A roof will be required for NB4.

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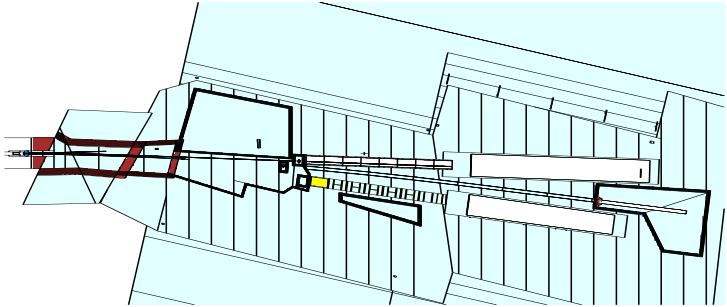
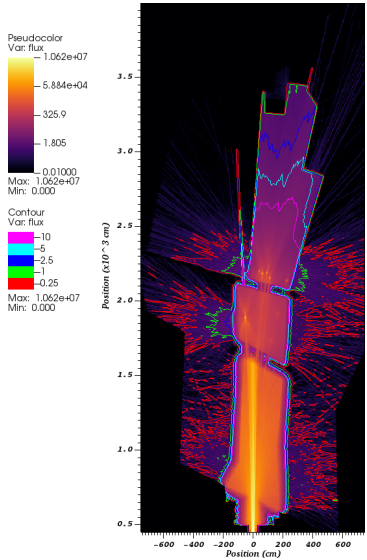
Conclusions





Conclusions

- Successful use of McStas2CAD output for MCNP guide network model building.
- In progress work on multiple aspects of the post HBRR HFIR Cold Guide Hall.

Thank you!