27ID-HEX Beamline Shielding Design Analysis

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Outline

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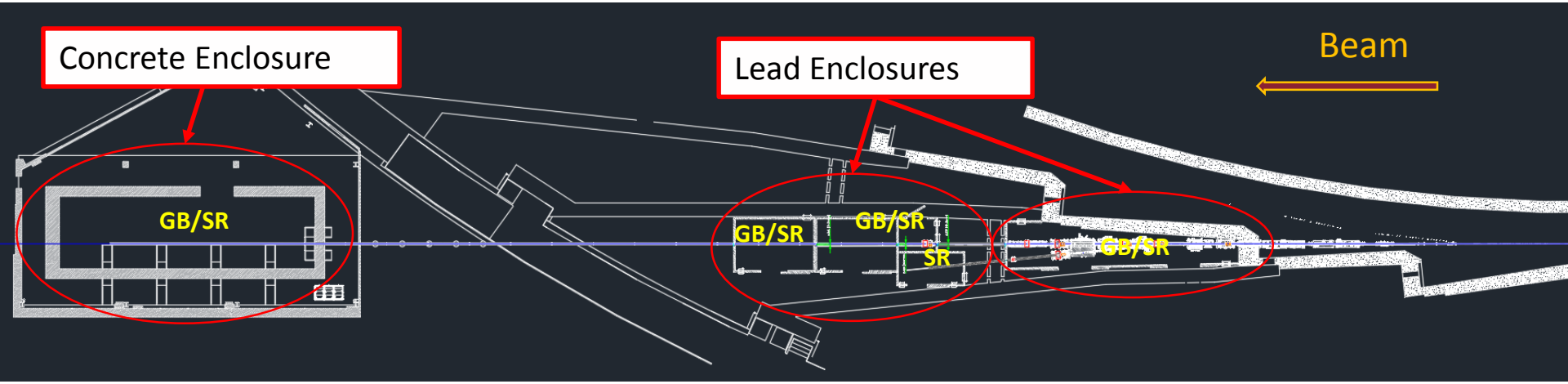
- Gas Bremsstrahlung Analysis
- Synchrotron radiation Analysis
  - White Beam Enclosures
  - Monochromatic Beam Enclosures
- Conclusions/Remarks
- Ongoing/Future Work

Introduction: 27ID-HEX Shielding Design

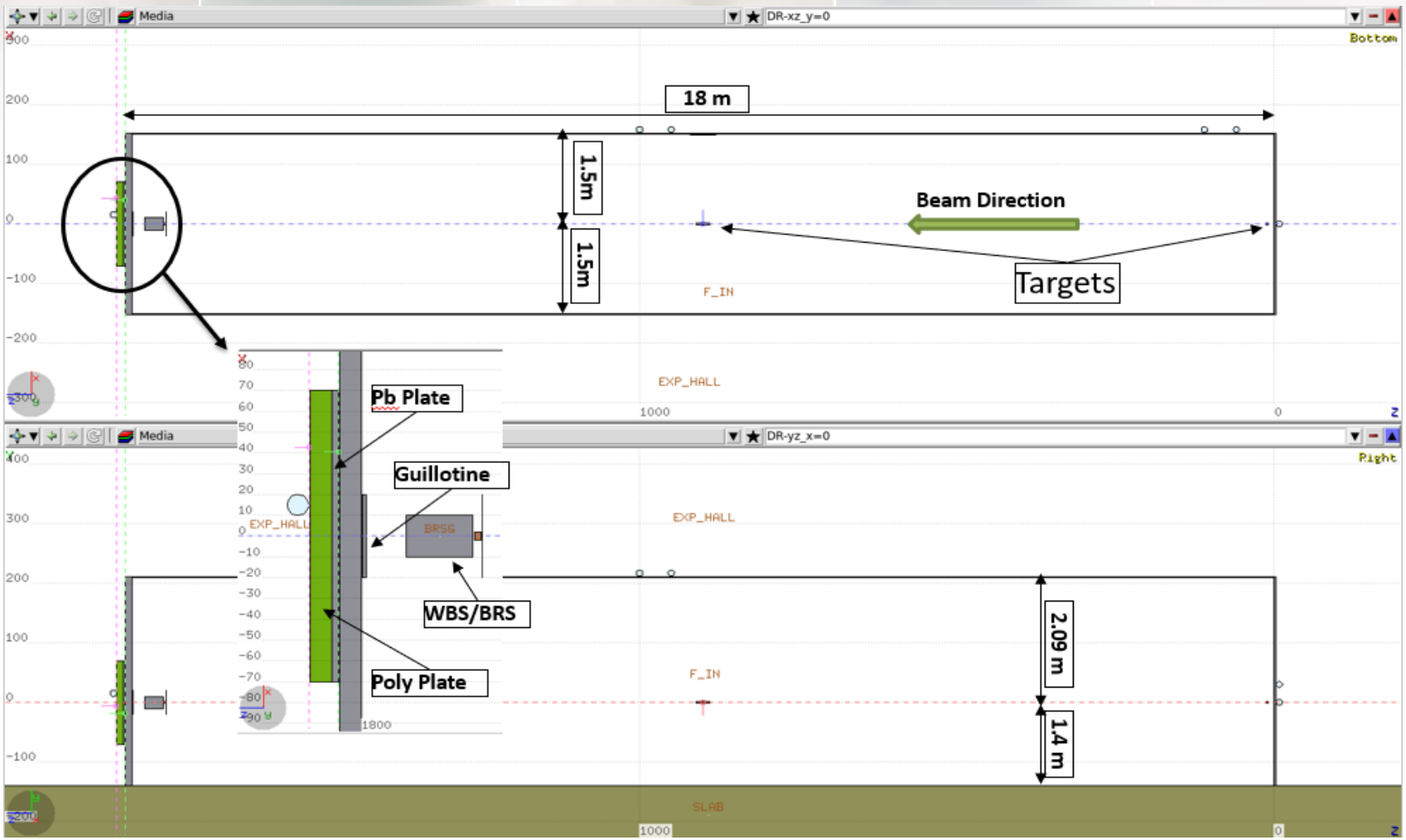
- Radiation Sources Considered:
  - Gas Bremsstrahlung [GB] (interaction of stored electrons with residual gas molecules)
  - Synchrotron Radiation [SR] (Super Conducting Wiggler SCW70)
- Codes used: FLUKA (Monte Carlo Code) & STAC8 (Analytical Code) - Both used extensively in radiation analyses of 17 NSLS-II beamlines (EPUs, IVUs, Damping Wigglers, 3PW, BM) – to date all measured dose rates around beamline enclosures are undistinguishable from BG.
- Dose Criteria:
  - < 0.05 mrem/h (occupied areas on the experimental floor) [as per shielding design guidelines]
  - < 25 mrem per year to any individual not involved in the operation of the facility.
- Focus of this Talk: Shielding design of 27ID-HEX enclosures walls and roof using generic approach - Details of beamline components or ray tracings were not finalized at the time of analysis.
- RSC Review of enclosure shielding conducted on October 23, 2018 with no issues.
- Ongoing and future shielding design work
  - Transport pipes and interface to enclosure walls
  - Validation of Enclosure/Labyrinths/Penetrations/Doors (preliminary/final) design once submitted by contractor
  - Validation of enclosure shielding once beamlines components and ray tracings are finalized.
  - Top-Off simulations.



Gas Bremsstrahlung Analysis

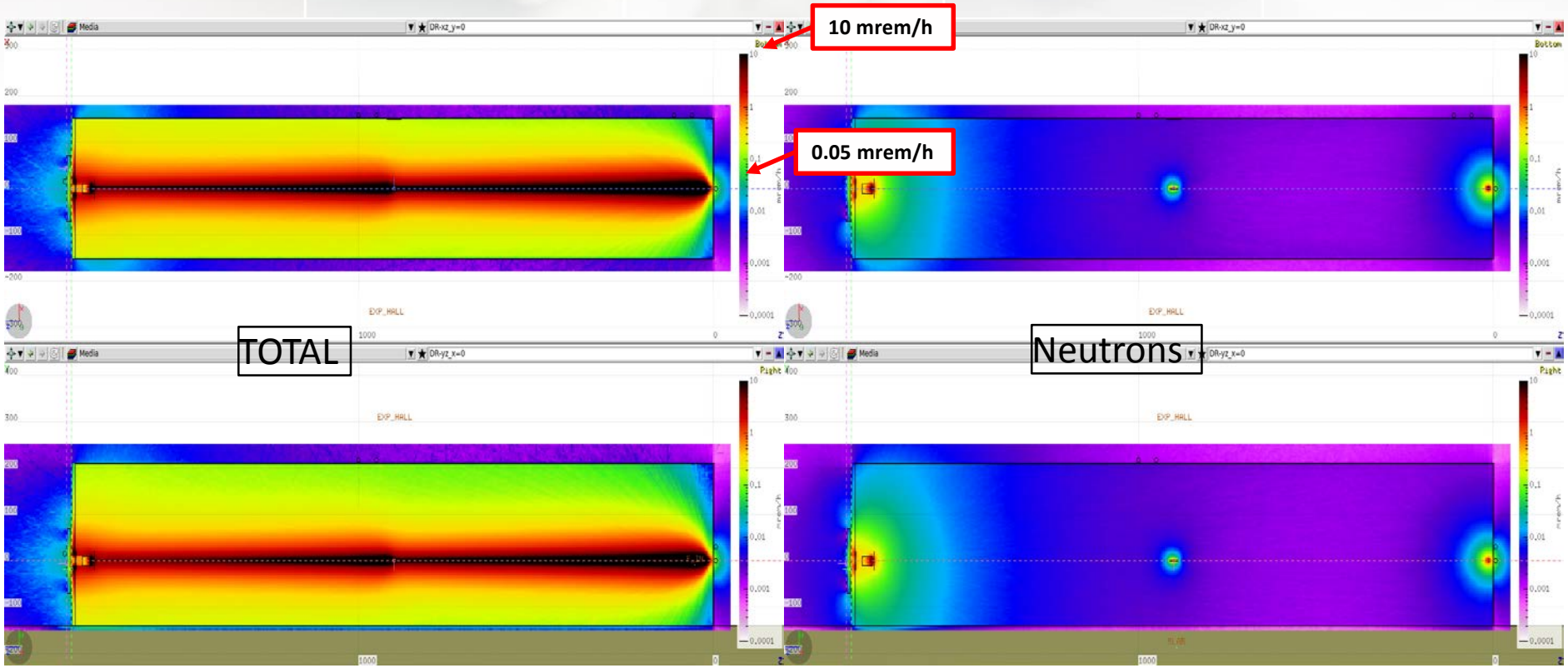
- Assumptions:
  - Source: 1 ntorr residual gas pressure , 15.5 m straight Section, GB Power of 17 µW (500 mA Stored Beam Current)
  - Use FLUKA source routine to sample from GB spectrum (1/E)
  - FLUKA 3D geometry of rectangular enclosure (18m, 3m, 6m and 19m long for white beam enclosures A, C, D/E, and F respectively and 5m long for monochromatic beam enclosure B)
    - Will show results for 18m Pb enclosure and 19 m concrete enclosure
  - No details of beamline components or ray tracings available at the time when simulations were carried out.
    - Perform generic analysis with standard Cu and Si targets
    - Bremsstrahlung stop and white beam stop positioned 50 cm from D/S wall
    - Beamline components other than Si optics and copper masks/stops/slits may require further study
  - No apertures (e-g Masks, GB stop) or Penetrations (e-g: labyrinths/transport pipe) considered
  - Various configurations were simulated that included Cu and Si targets placed at different locations inside each beamline enclosure, varying the length of the Cu target and using either short or long Si targets with different orientations to the beam direction.
  - The thickness of the downstream wall and combination of additional local shielding were also varied.

FLUKA Model for the Lead Enclosure

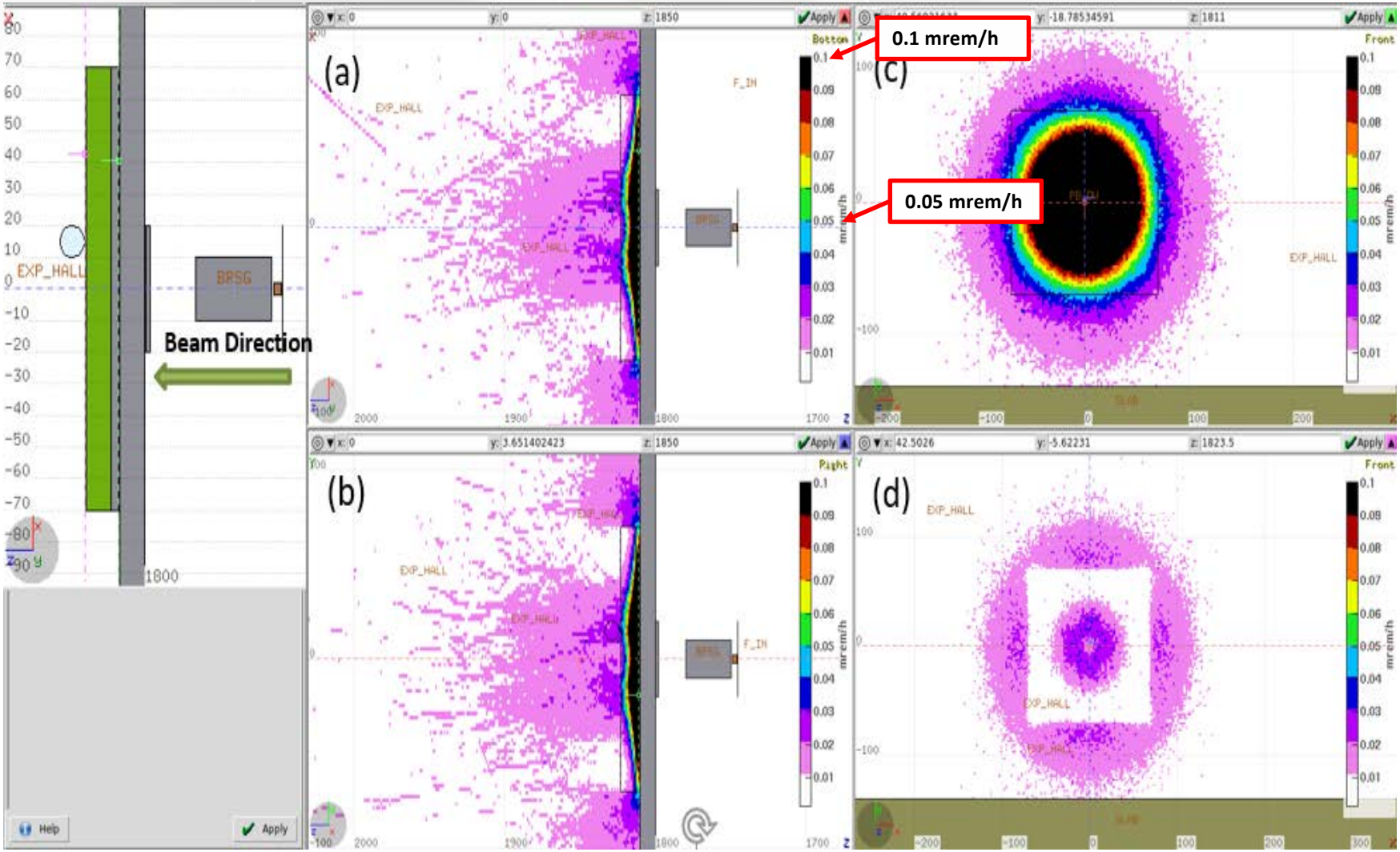


Lead walls and roof: DW (10 cm), LW (2 cm), UW (2 cm), Roof (1 cm)
Guillotine: 2cm [40x40 cm^2], Pb Plate: 3 cm [140x140 cm^2], Poly Plate: 10cm [100x100 cm^2]
BRS: R=10 cm/L=30 cm, WBS: R=2 cm/L=3cm @ 50cm from D/S wall
Targets: Cu [R=2cm/L=3cm] @ z=10cm from U/S wall, Si [4x4 cm^2 , L=20cm] @ middle of enclosure

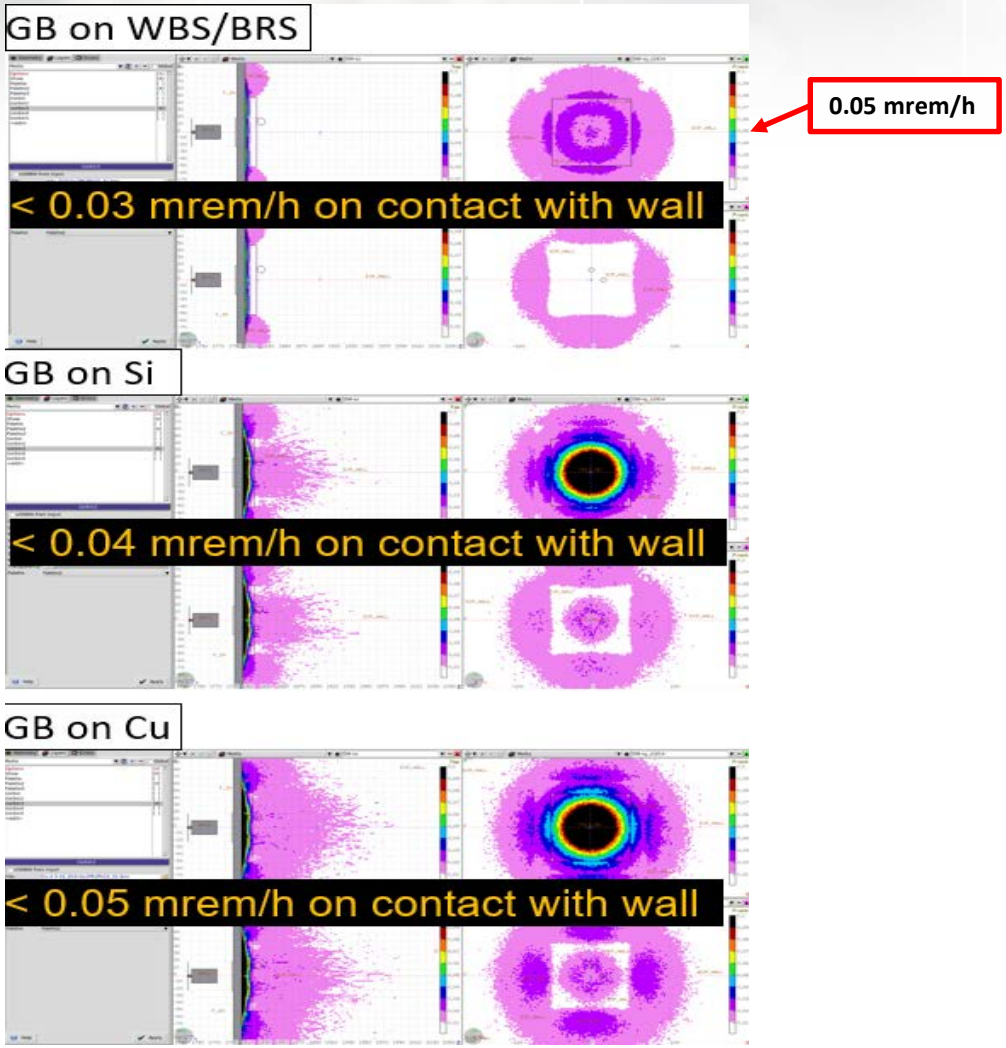
Ambient Dose rates (mrem/h)
27ID-A Enclosure



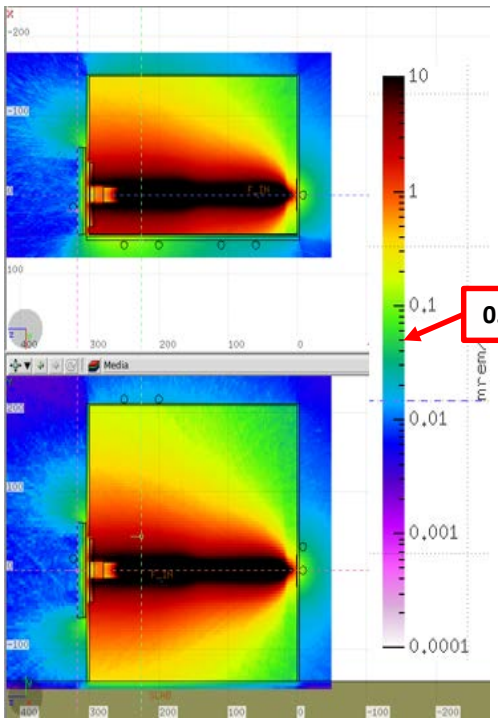
Total Ambient Dose rates (mrem/h)
27ID-A Enclosure D/S Wall

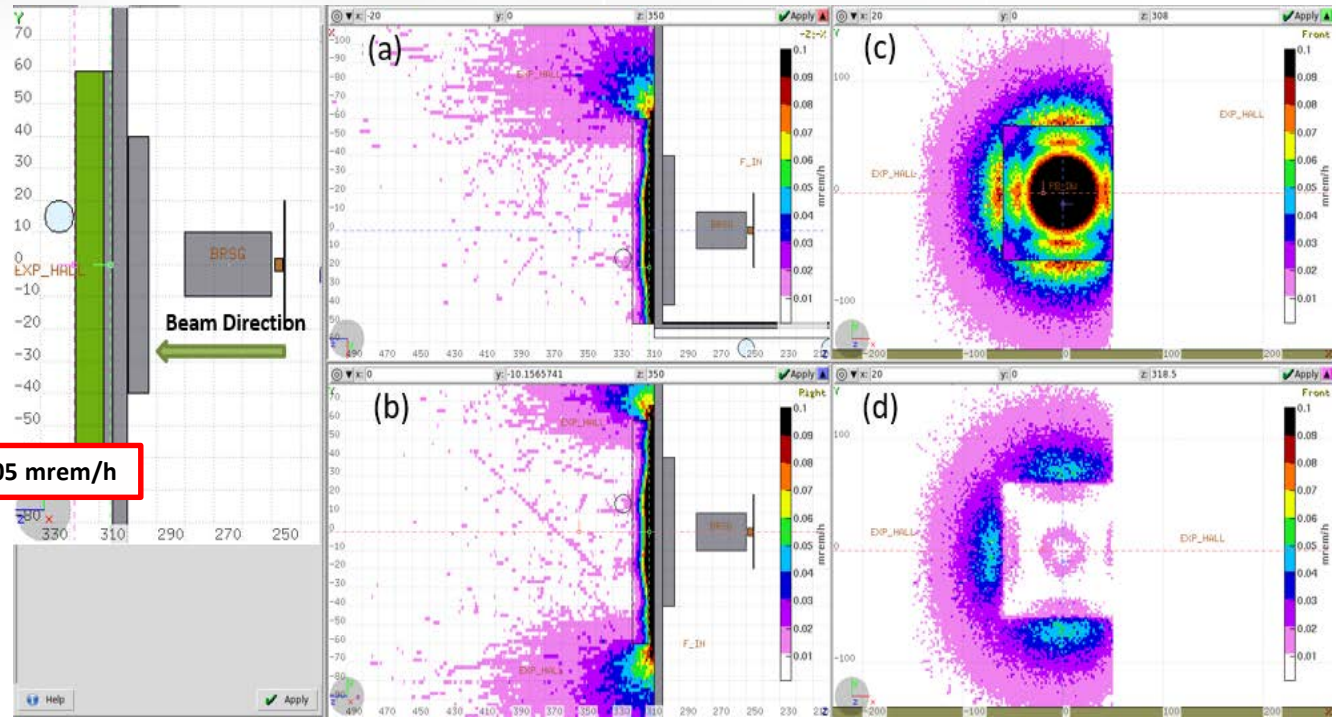


Total Ambient Dose rates (mrem/h) 27ID-A Enclosure D/S Wall



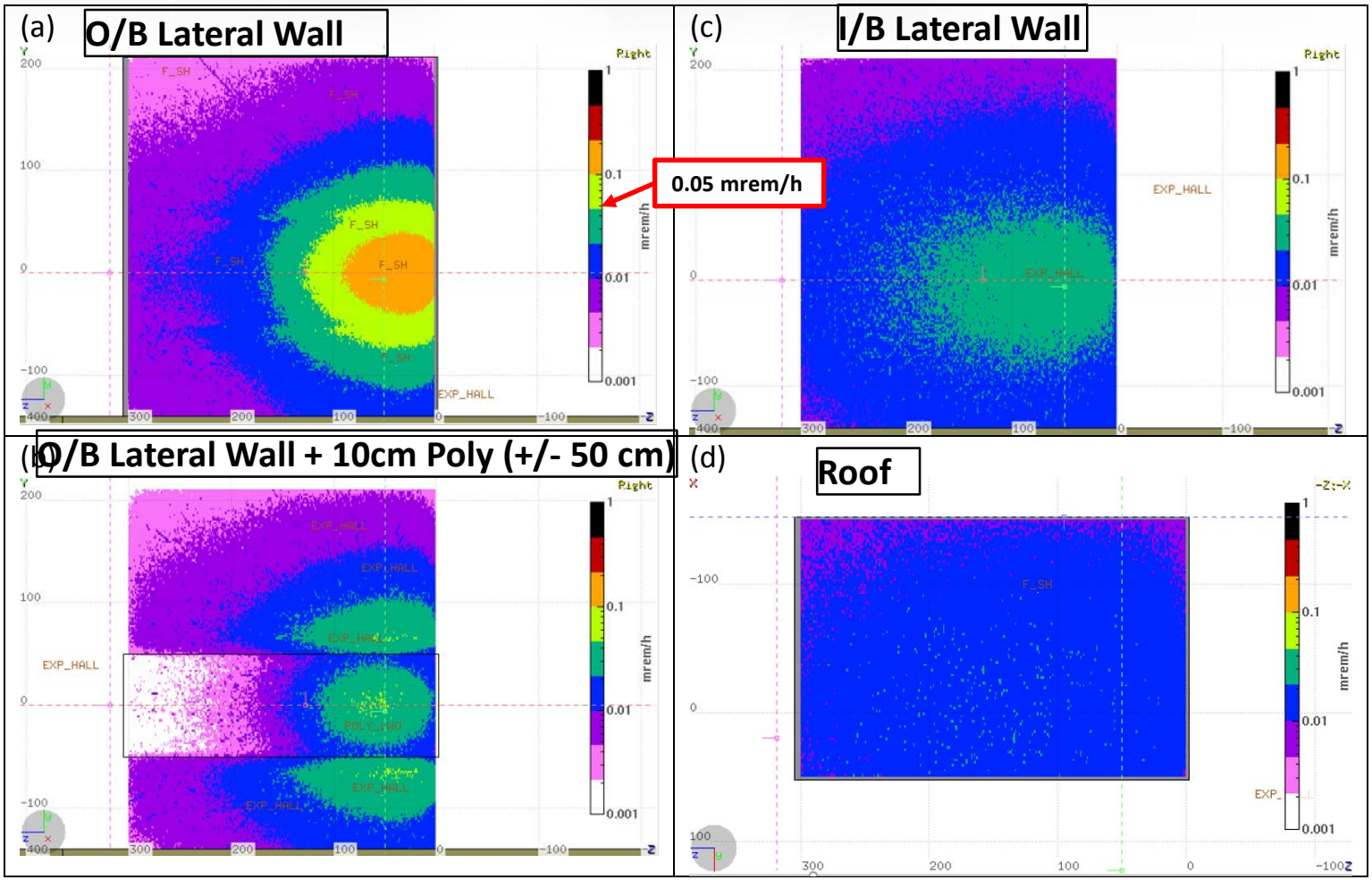
Ambient Dose rates (mrem/h) 27ID-C Enclosure – D/S wall



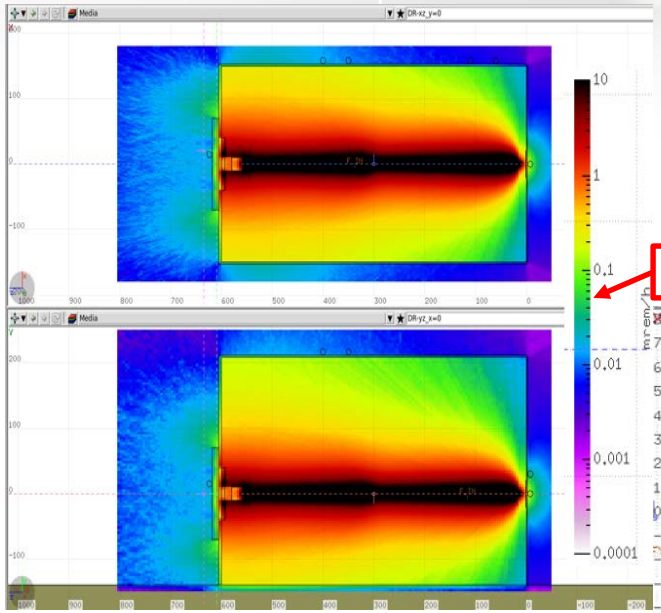


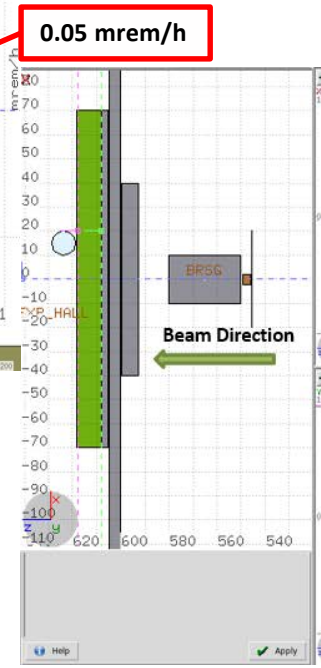
Small amount of radiation leaks just outside the lead plate that amounts to approximately 0.08 mrem/h which slightly exceeds the dose criteria. However, the spatial extent of this dose rate is localized and drops to below 0.05 mrem/h at the surface of the poly plate.

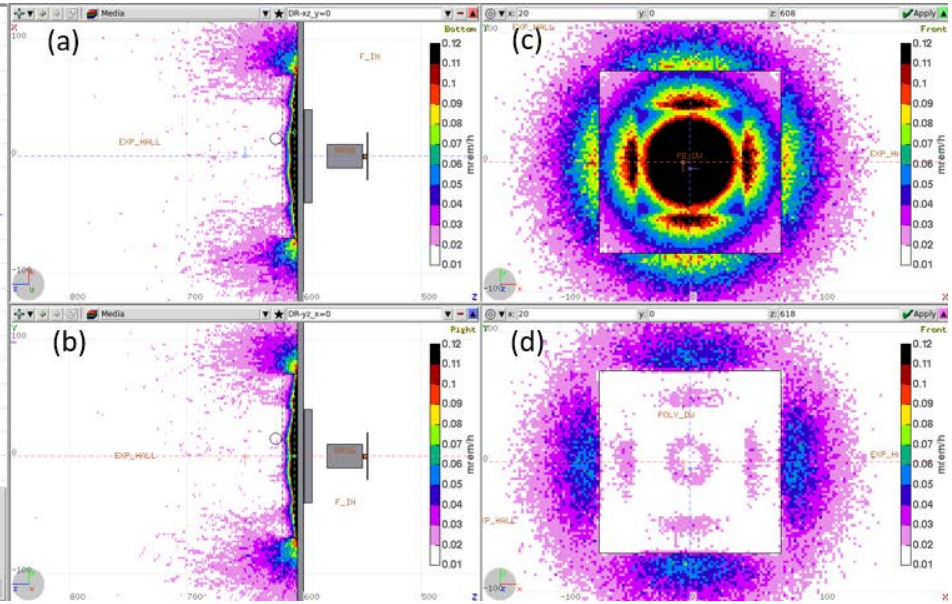
Ambient Dose rates (mrem/h)
27ID-C Enclosure – Lateral walls & Roof



Ambient Dose rates (mrem/h) 27ID-D/E Enclosure – D/S wall

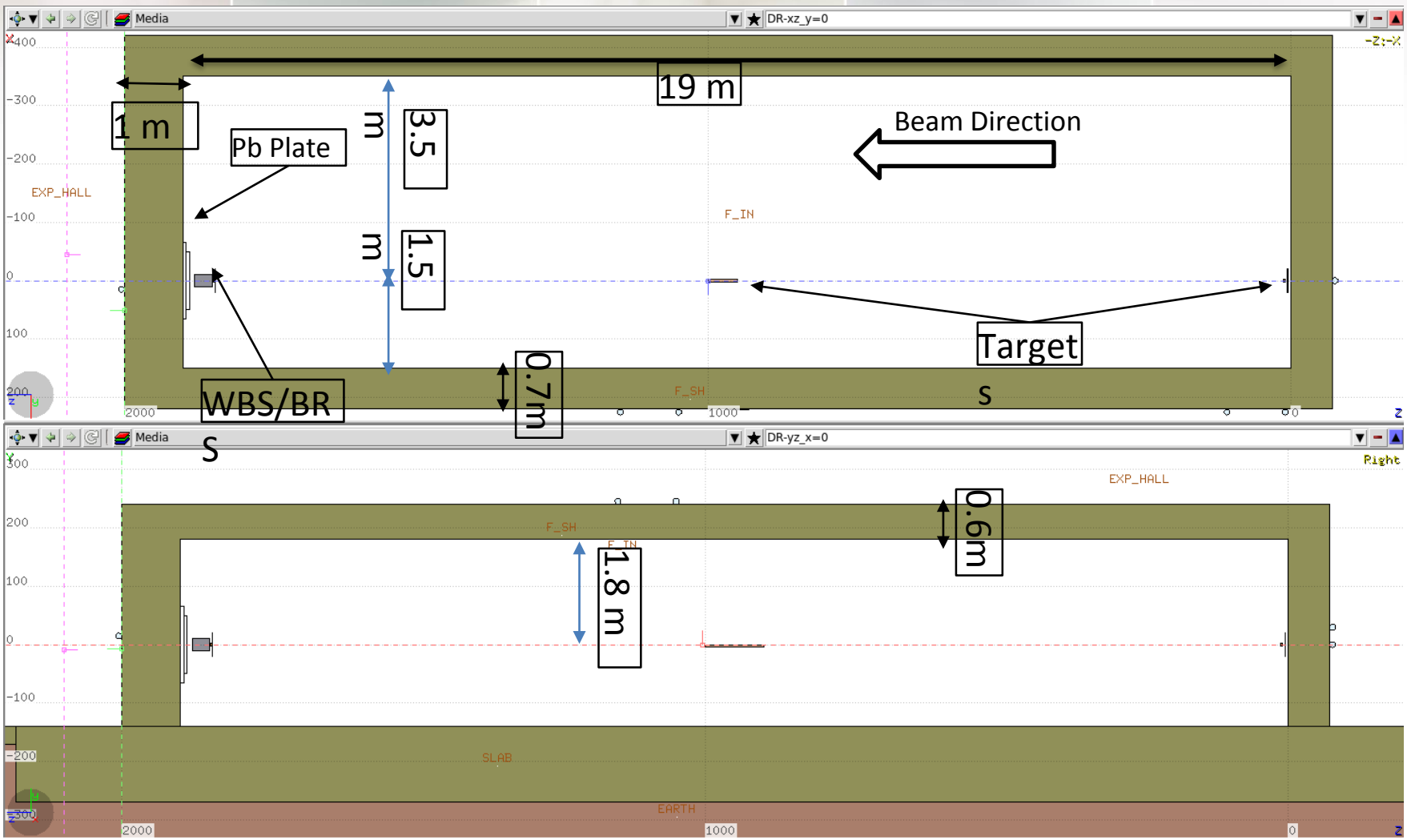






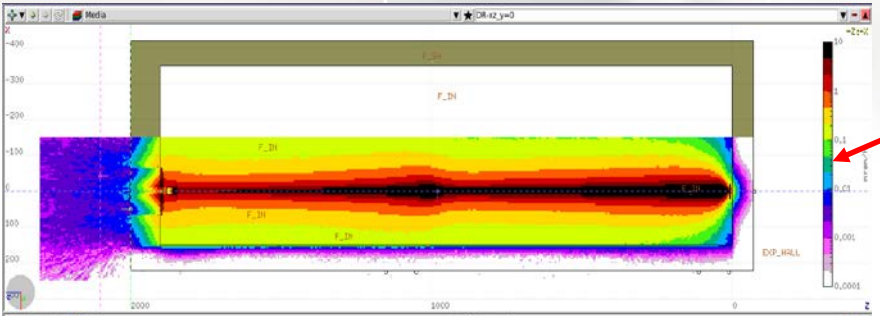
Small amount of radiation leaks just outside the lead plate that amounts to approximately 0.09 mrem/h which slightly exceeds the dose criteria. However, the spatial extent of this dose rate is localized and drops to below 0.05 mrem/h at the surface of the poly plate.

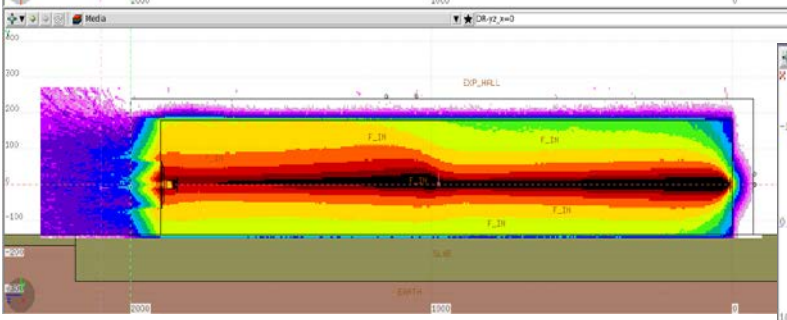
FLUKA Model for the Lead Enclosure

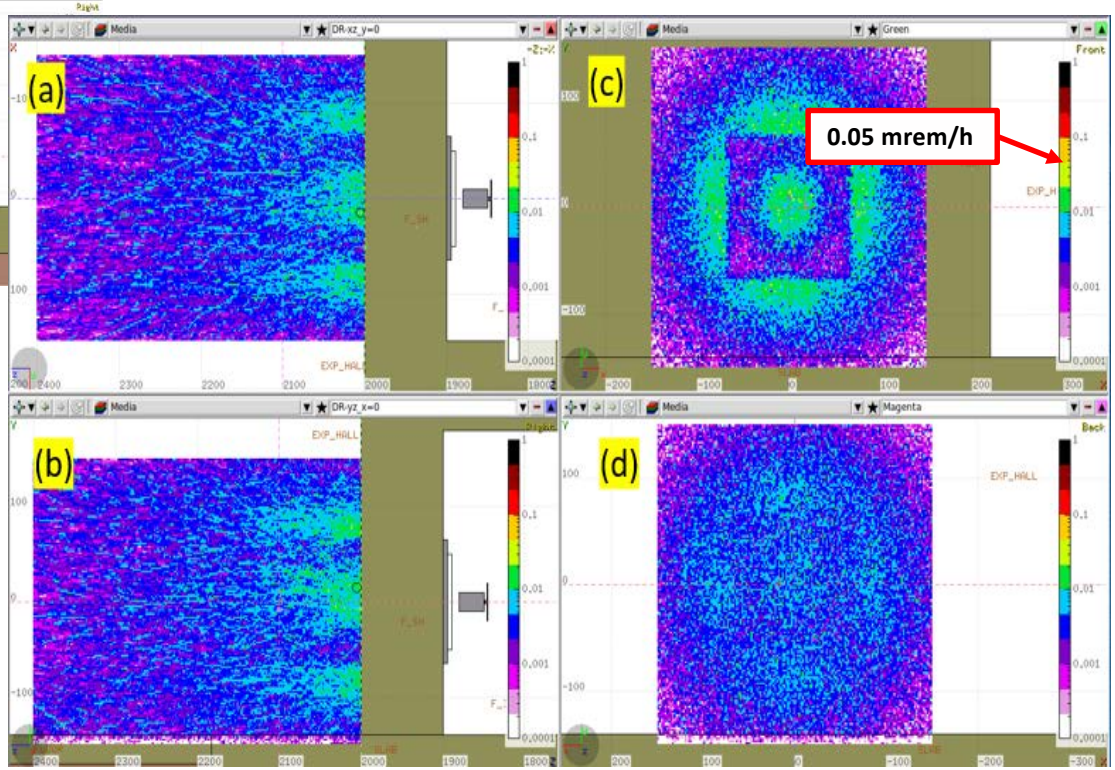


Concrete Walls and roof: DW (100 cm), LW (70 cm), UW (70 cm), Roof (60 cm)
Pb Plate: 5 cm [130cm x 130cm]
BRS: R=10 cm/L=30 cm, WBS: R=2 cm/L=3cm @ 50cm from D/S wall
Targets: Cu [R=2cm/L=3cm] @ z=10cm from U/S wall, Si [4x4 cm^2 , L=20cm] @ middle of enclosure

Ambient Dose rates (mrem/h)
27ID-F Concrete Enclosure – D/S wall





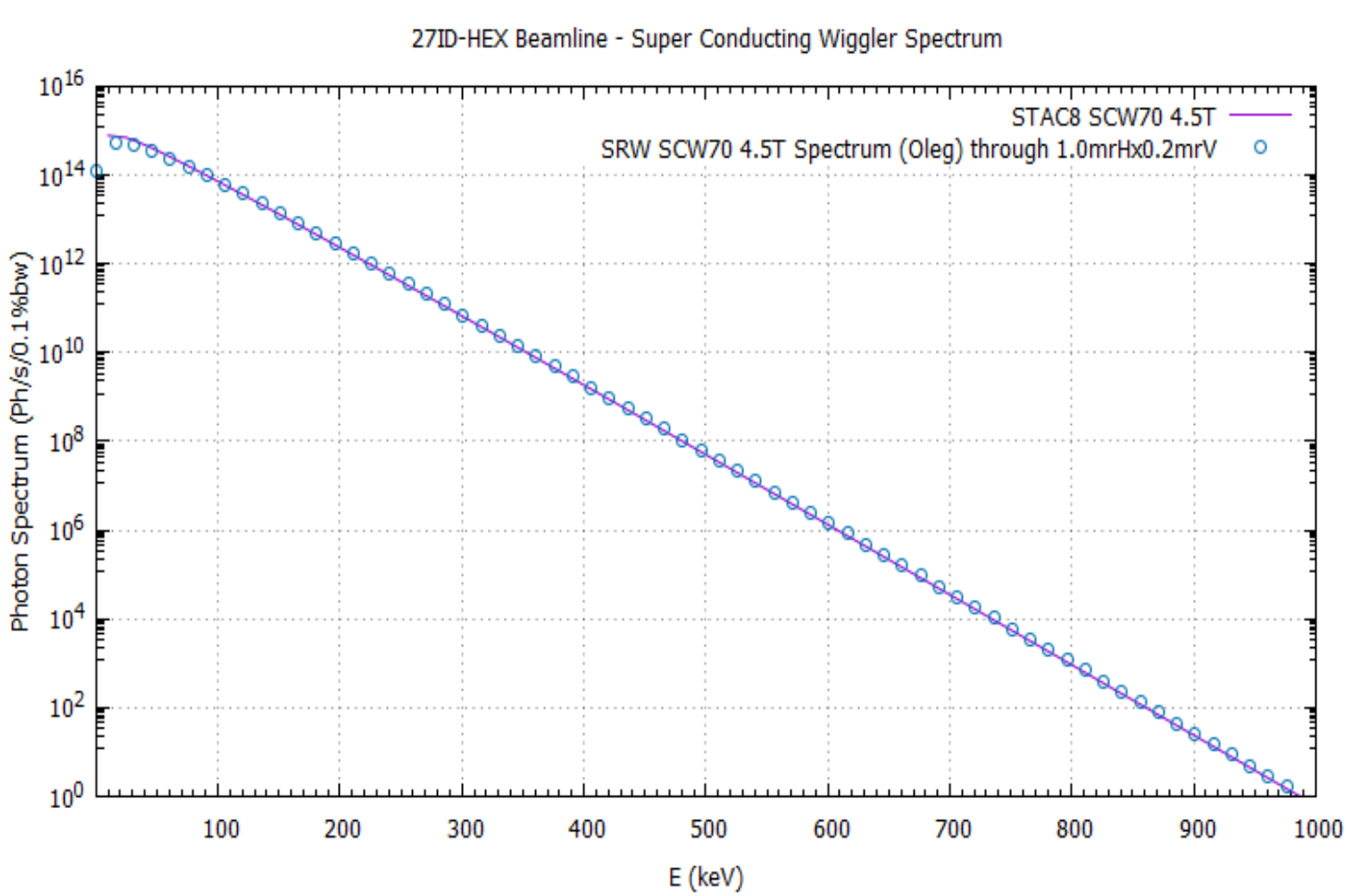


Total ambient dose rates are approximately 0.02 mrem/h on contact and below 0.01 mrem/h @ 1m away from the D/S wall.

Synchrotron Radiation Analysis

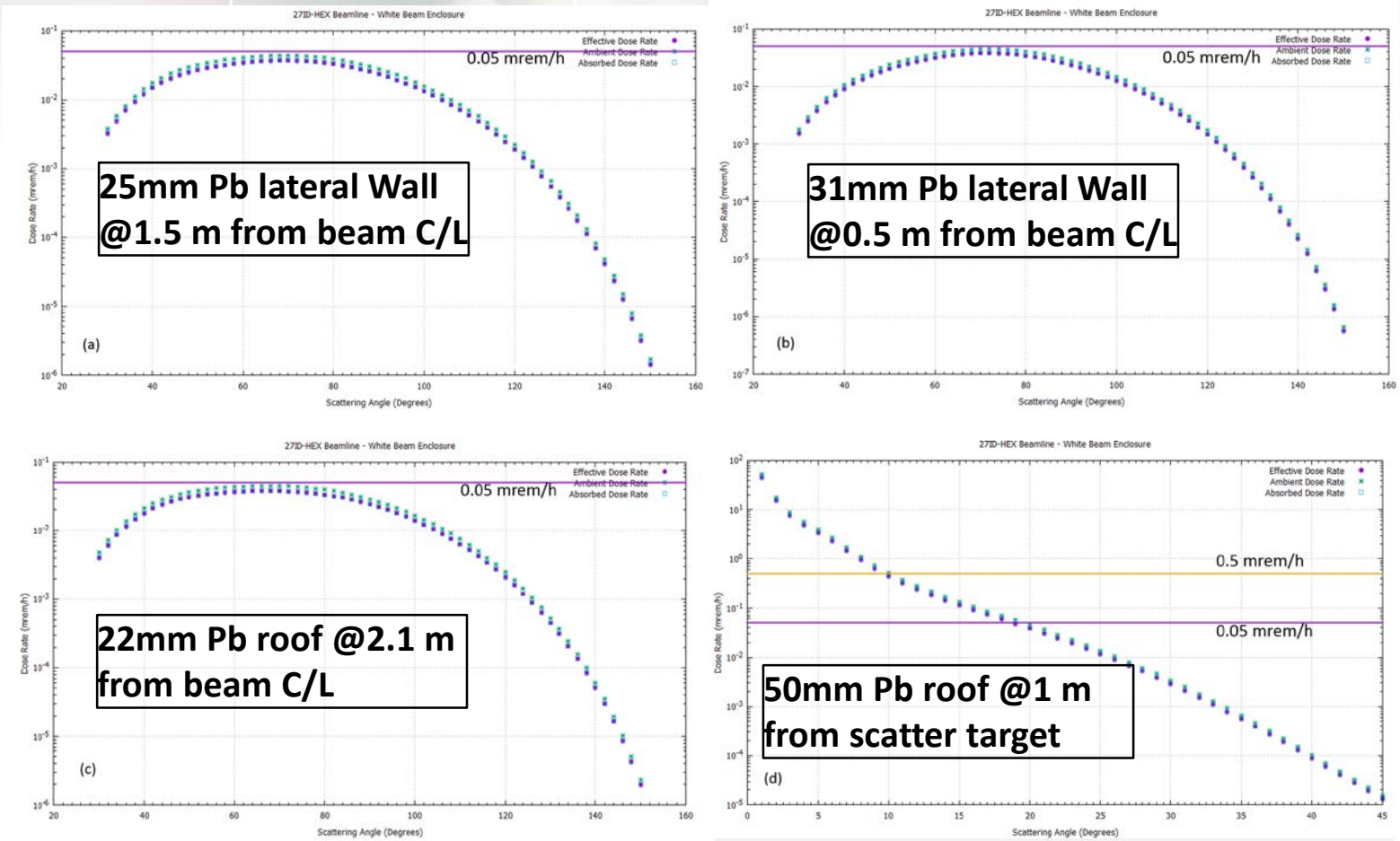
- The 27-ID (HEX) beamline is a Superconducting Wiggler (SCW70) source and the calculations are based on the following accelerator and insertion device parameters:
  - Electron Energy: 3 GeV
  - Stored beam Current: 500 mA
  - SCW70:
    - Period Length: 70 mm
    - Number of Poles: 29
    - Max magnetic Field: 4.5 T
  - Horizontal Fan entering the enclosures
    - 27ID-A, 27ID-C, 27ID-D and 27ID-E: 1.4 mradH
    - 27ID-F: 1.0 mradH
    - 27ID-B: 0.2 mradH
- STAC8 analytical code used to calculate ambient dose rates taking into account build-up factor in the shielding material.

27ID SCW Spectrum



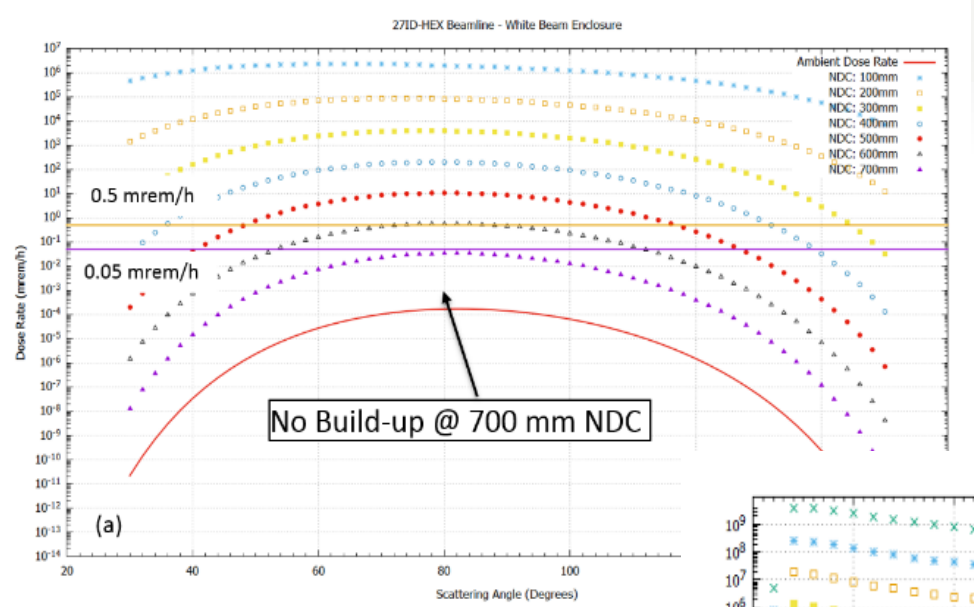
The SCW70 spectrum calculated with STAC8 agrees very well with the calculated spectrum using a separate code SRW (Oleg)

Photon dose rates (mrem/h) on contact with the white beam enclosure walls and roof as a function of the scattering angle

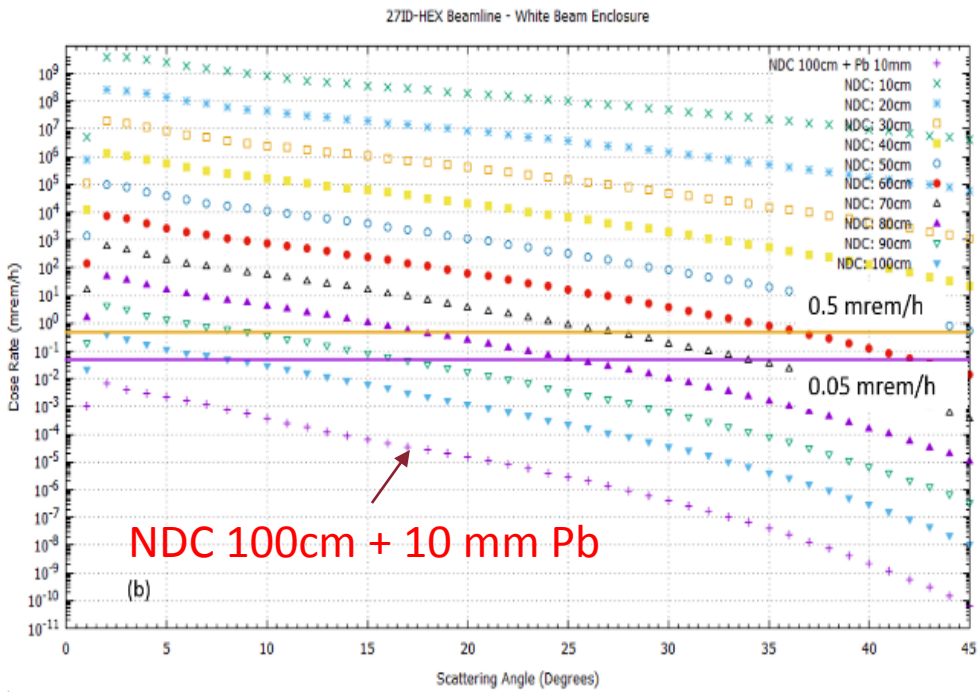


A thickness of 5 cm of lead will keep the ambient dose rates below 0.05mrem/h, except for forward scattering angles below approximately 20 degrees. Below 20 degrees the thicker 10 cm Pb downstream wall of 27ID-A enclosure and additional shielding on the downstream wall of 27ID-C, D, E enclosures which consist of a 3 cm Pb plate and 7 cm Pb guillotine will reduce ambient dose rates below 0.05 mrem/h in the forward direction.

Ambient dose equivalent rates on the exterior of the lateral and downstream walls of 27ID-F enclosure as a function of the scattering angle for various thickness of the concrete



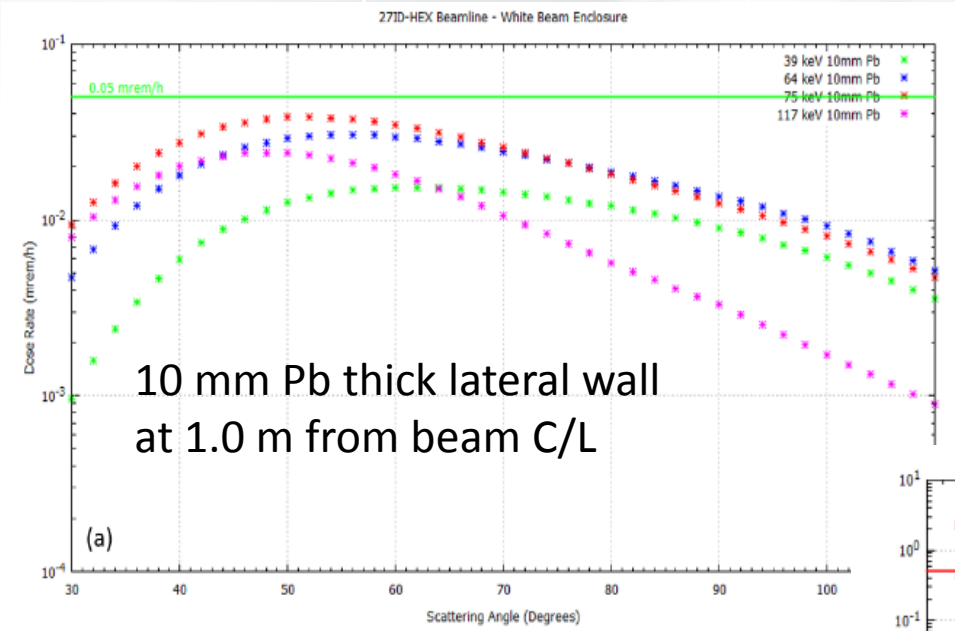
Ambient dose rates are underestimated by over two orders of magnitude without build-up factors in the concrete stressing the importance of build-up in the concrete



27ID-F Concrete Enclosure Roof, I/B wall and U/S wall

- The requirement for the roof is 60 cm thick concrete assuming a 10% occupancy on the roof of the satellite building (lower dose rates for building maintenance staff) and 20% occupancy on the roof of the 27ID-F enclosure for NSLS-II staff.
  - It is planned to restrict access to the enclosure roof since any equipment requiring routine maintenance will not be located on the roof.
- The shielding requirements for the inboard lateral wall and upstream wall are 64 cm and 65 cm respectively but it is planned to construct these with the same thickness as the outboard lateral wall.

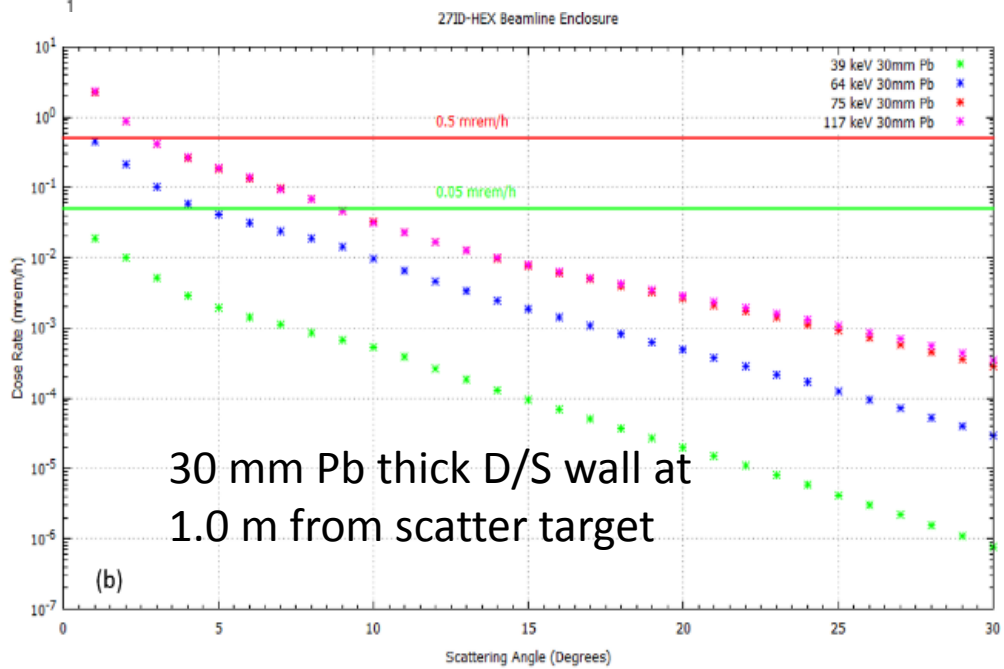
Photon dose rates on contact with the walls of 27ID-B enclosure as a function of the scattering angle and for four operational monochromatic beam energies.



For the D/S wall, forward scattering angles below approximately 10 degrees require additional shielding. Below 10 degrees the monochromatic beam stop (30 cm x 30 cm) that is 35mm Pb thick will keep ambient dose rates below 0.05 mrem/h in the forward direction.

The ambient dose rates were calculated for the 4 operational energies of the 27-ID-HEX beamline corresponding to 39, 64, 75 and 117 keV, including higher harmonics (no mirrors D/S of SBM).

The minimum required thickness for the roof was calculated to be 8 mm Pb



Conclusions/Remarks

- A detailed shielding analysis has been carried out for the new NSLS-II 27ID-HEX beamline. Since the beamline components layout and ray tracing drawings have not yet been finalized, the shielding analysis followed a generic approach using standard scatter targets.
- The shielding requirement specified should keep the radiation dose to personnel as low as reasonable achievable and in compliance with the NSLS-II shielding policy.
- Shielding requirements for the downstream wall of both concrete and Lead white beam enclosures is primarily determined by GB scattering off beamline components.
- Shielding requirements for the lateral wall, upstream wall and roof is dominated by white beam synchrotron radiation scattering off beamline components.
- Build up factors in the concrete shielding is very important and was considered in the analysis.
- The shielding requirements should be validated once the beamline components and penetrations through the walls and roof are finalized – additional localized shielding may be required.
  - Additional neutron shielding may be required for thick scatter targets located near upstream wall or lateral wall (e-g: 27ID-C enclosure).
- Special attention should be given to
  - Penetrations needed for beam transport pipes and associated interface to the enclosure walls to minimize radiation leakage.
  - Design of the Labyrinths
  - Lead enclosure interface to the concrete floor (floor shine) and concrete walls.

Ongoing and future shielding design work

- Beam transport pipes and interface to enclosure walls
- Validation of Enclosure/Labyrinths/Penetrations/Doors (preliminary/final) design once submitted by contractor
- Validation of enclosure shielding once beamlines components and ray tracings are finalized.
- Top-Off simulations.

THANK YOU FOR YOUR ATTENTION