SUPPLEMENTAL SHIELDING CALCULATION OF BMIT SOE-1 AT THE CANADIAN LIGHT SOURCE

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Outline

- Introduction
- Present Shielding at BMIT SOE-1
- Why the Supplemental Shielding Calculation?
- Approximations and Program Used
- Calculations and Measurements
- Conclusion and Recommendation
- Acknowledgements

Introduction-
Canadian Light Source (CLS)

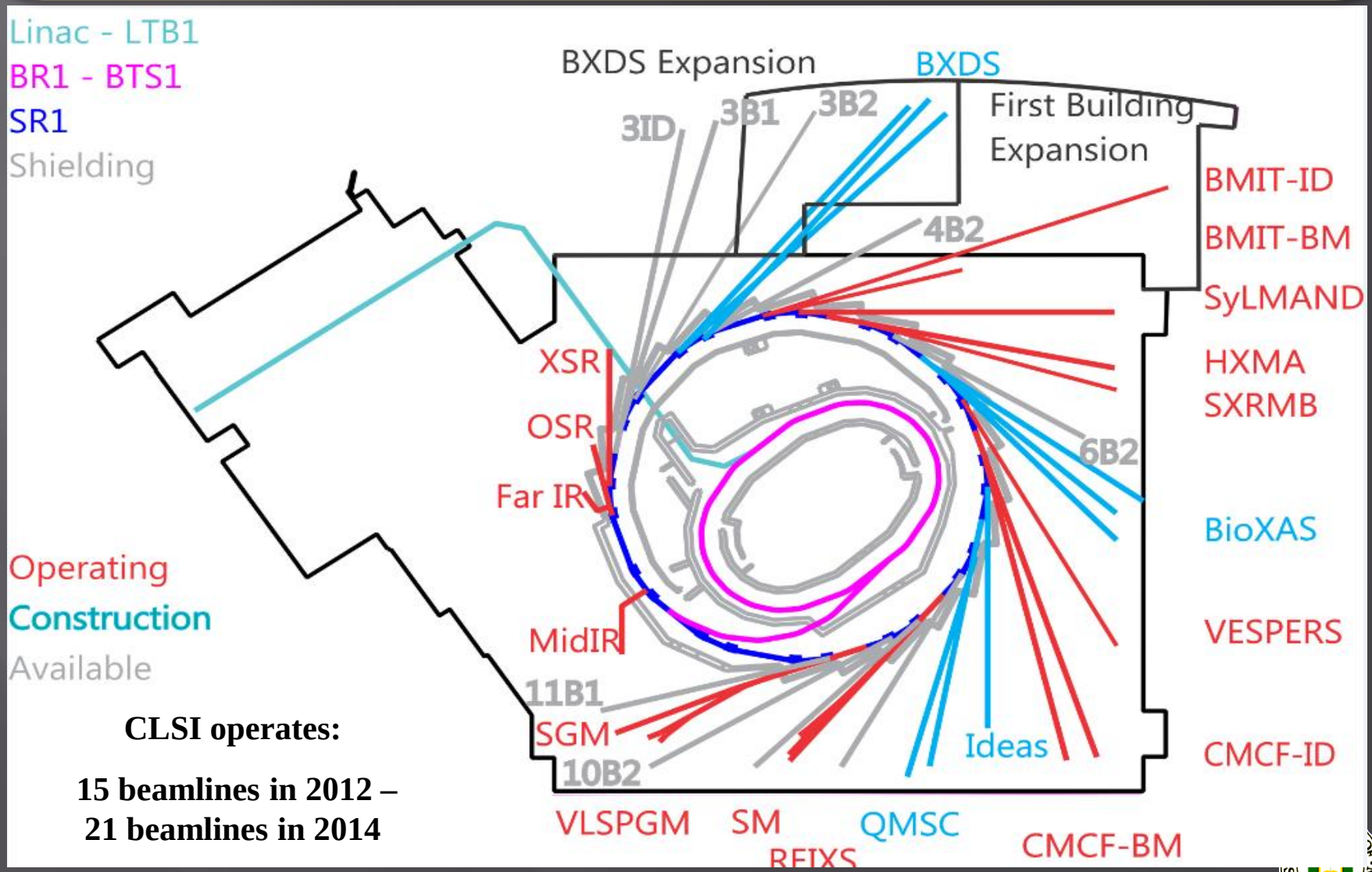
- 3rd Generation Synchrotron Facility
- Ring Energy/Current: 2.9GeV/500 mA
- Phase I beamlines: 7, mainly insertion device (ID) beamlines
- Phase II beamlines: 8, mainly bending magnet (BM) beamlines
- Phase III beamlines: 6, planned, 3 currently under construction
- 15 beamlines in 2012, 21 beamlines by 2014

Introduction-
Biomedical Imaging and Therapy (BMIT) Facility

- ~1100 m^2 addition with
  - 2 beamlines, 3 experimental end stations
  - Biological / specimen preparation areas
  - Human Preparation Area
  - Animal Preparation Area
  - Control / Visualization Area

- Human preparation areas separated from animal preparation areas
  - Separate air handling for human subject areas and animal prep areas
  - Separate human (with ambulance capability) and animal entrances

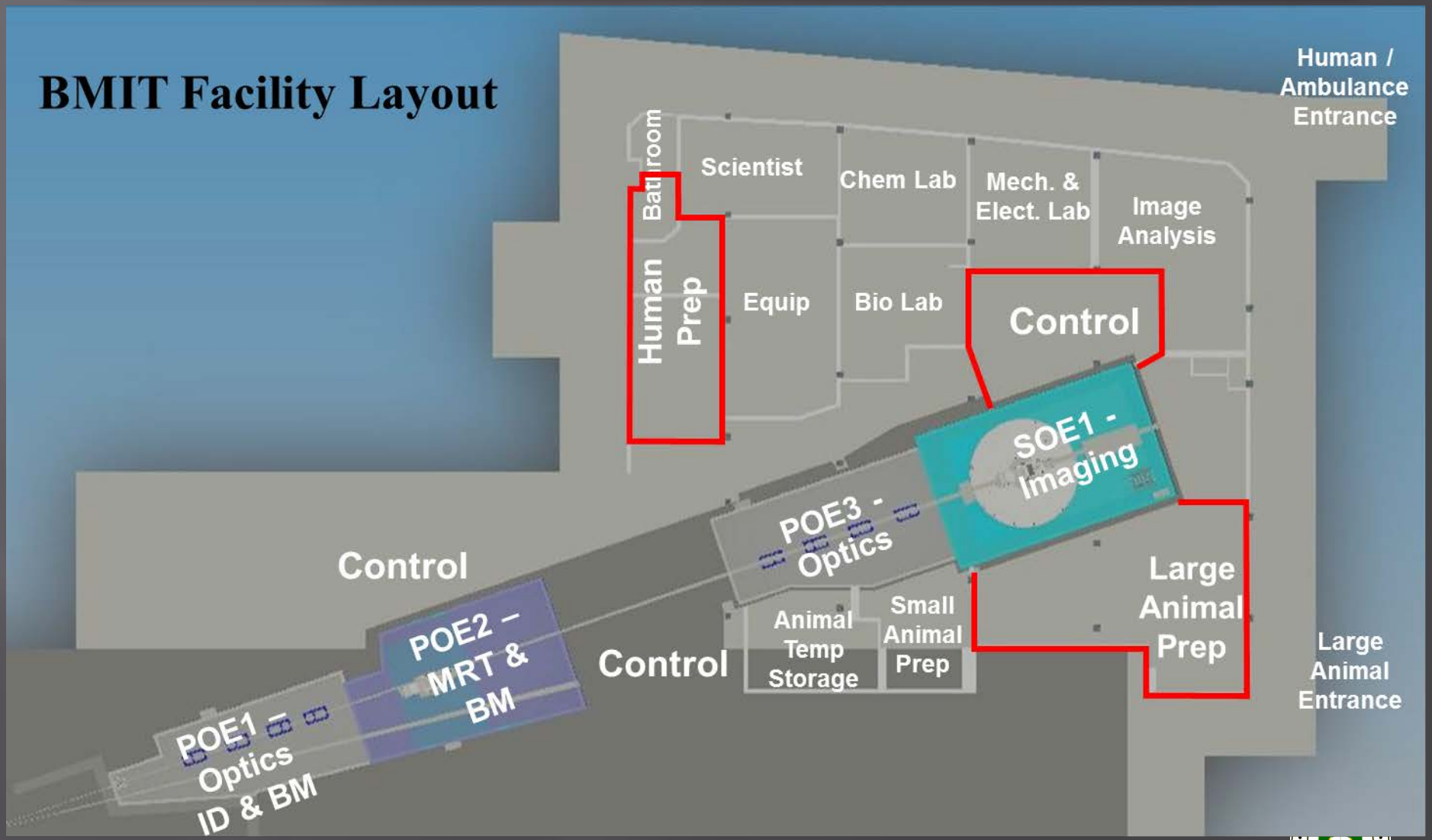
Introduction-
Biomedical Imaging and Therapy (BMIT) Facility



CLSI operates:

15 beamlines in 2012 –
21 beamlines in 2014

Introduction-
Biomedical Imaging and Therapy (BMIT) Facility



Introduction-
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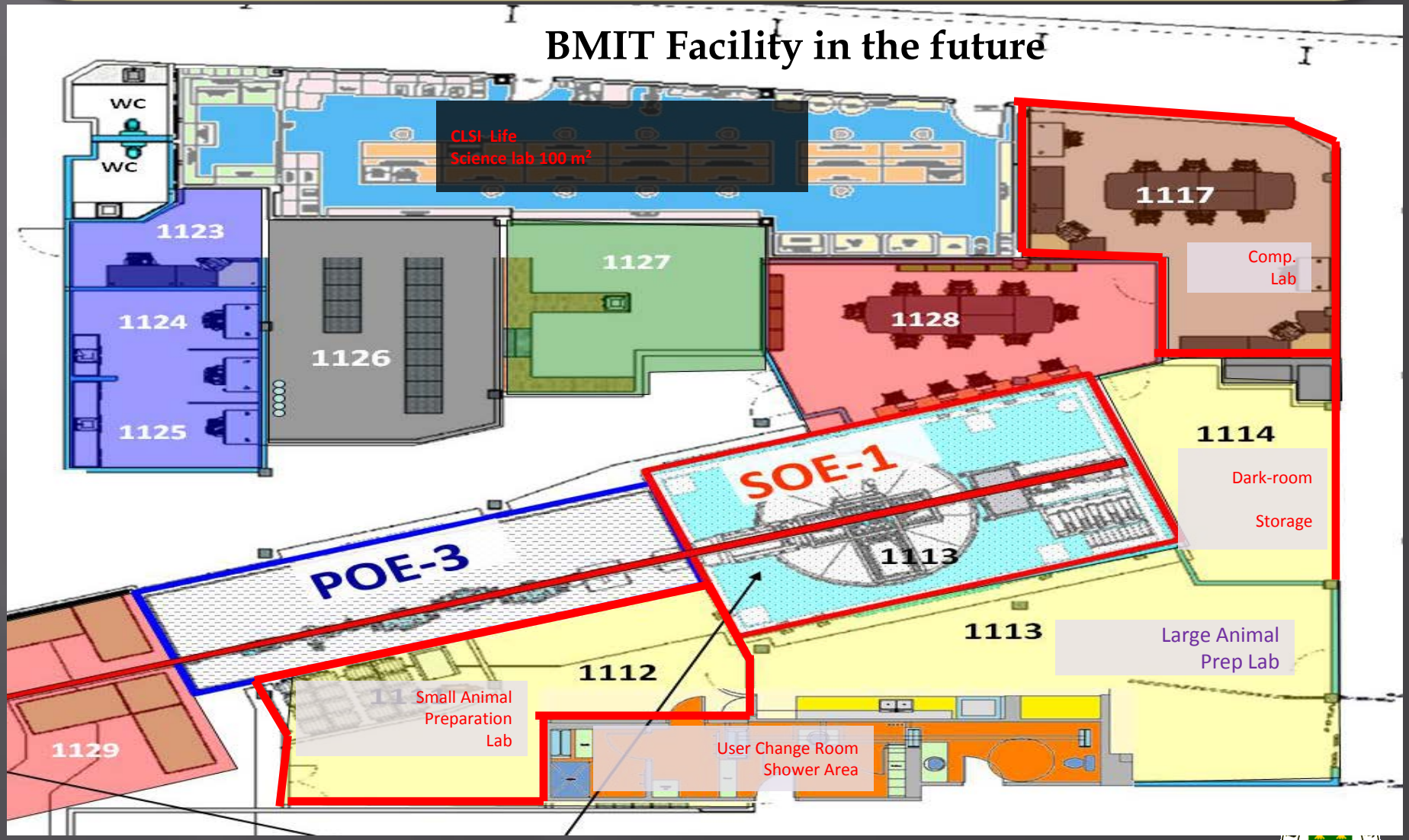

Introduction-
Biomedical Imaging and Therapy (BMIT) Beamlines

- Phase II beamlines:
  - Bending Magnet (BMIT-BD) 05B1-1: operational
  - Insertion Device (BMIT-ID) 05ID-2: superconducting wiggler, under commissioning

- Superconducting Wiggler Specifications:

Parameter	Value	Unit
Magnetic Field, B_0 (max)	4.3	T
Critical Energy, E_C (max)	24	keV
Period Length, λ_0	4.8	cm
Deflection Parameter, K (max)	19.3	K/γ ~3.4 mrad
Photon Range	0.1-0.6	Å
Energy Range	20-100+	keV
N (full + half field)	25 + 2	periods
Peak Power Density [a]	40.1	W/mm^2

[a] @ 26.5 meters (500 mA, 2.9 GeV)

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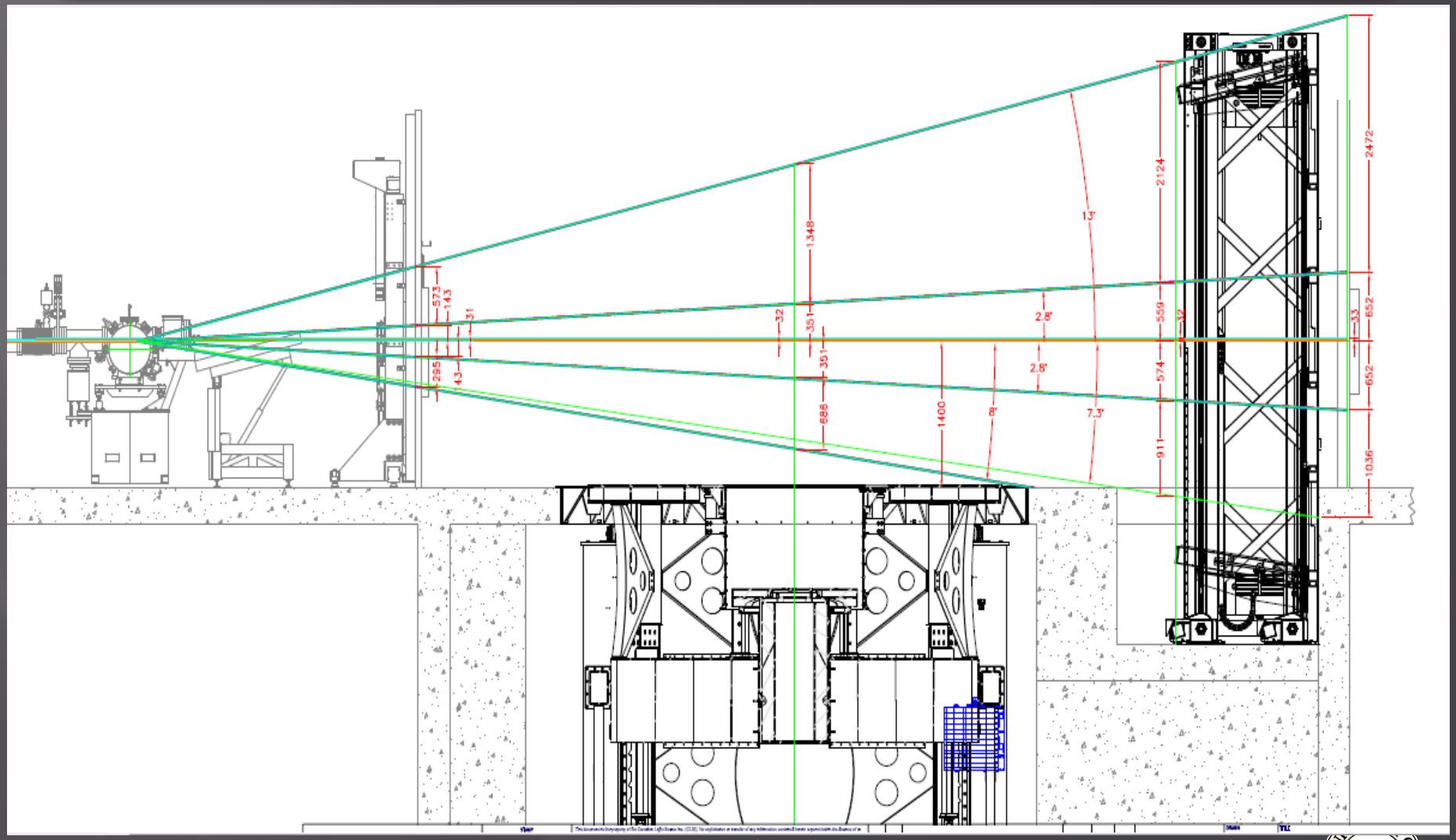
Introduction-
Biomedical Imaging and Therapy (BMIT) Capabilities

- Imaging:
  - ✓ Conventional Absorption Imaging
  - ✓ K-edge Subtraction Imaging (KES)
  - ✓ Phase Contrast Imaging
    - •Propagation Based Phase Contrast
    - •Analyzer Based Imaging /Diffraction Enhanced Imaging (ABI/DEI)
    - •Grating Interferometry Imaging (in progress for BMIT)
  - ✓ Computed Tomography Imaging (CT)
  - ✓ Combinations: DEI CT, KES CT, Phase CT
- Therapy:
  - ✓ Microbeam Radiation Therapy (MRT)
  - ✓ Synchrotron Stereotactic Radiotherapy (SSRT)

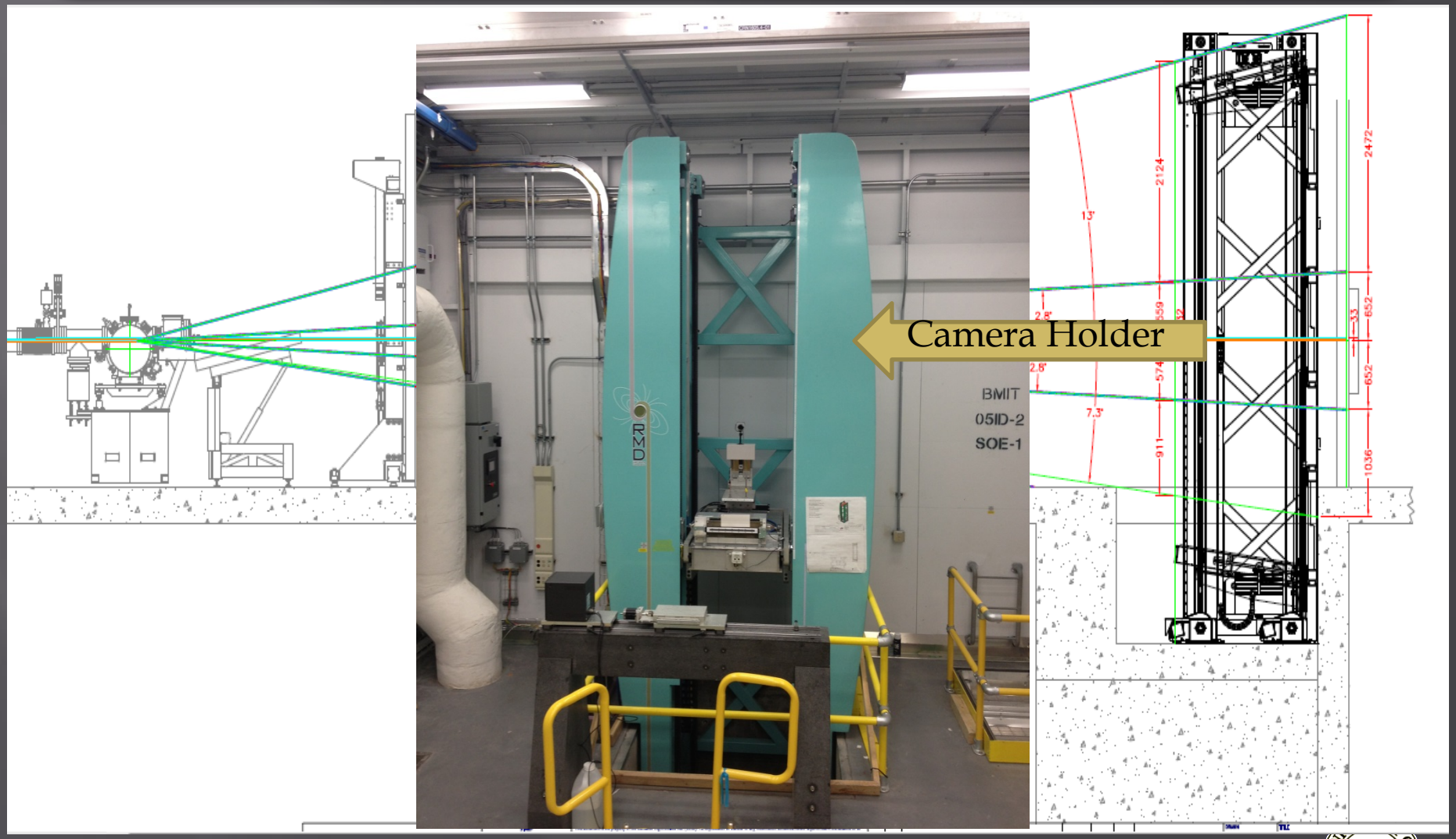
Introduction-
Biomedical Imaging and Therapy (BMIT) SOE -1

- BMIT Secondary Optical Enclosure -1 (SOE-1):
  - Is the last hutch of the BMIT Beamlines
  - Is a monochromatic beam experimental hutch
  - Monochromatic beam supplied by the Insertion Device-the superconducting wiggler
  - Dimensions L x W x H are: 10.53m x 6m x 5m

Introduction-
Biomedical Imaging and Therapy (BMIT) SOE -1



Introduction-
Biomedical Imaging and Therapy (BMIT) SOE -1



Introduction-
Biomedical Imaging and Therapy (BMIT) SOE -1

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Present Shielding at BMIT SOE - 1

- The shielding is done against:
  - ✓ Scattered monochromatic beam from the CT or KES monochromator
  - ✓ The direct CT and KES beams on the downstream wall (End Wall)

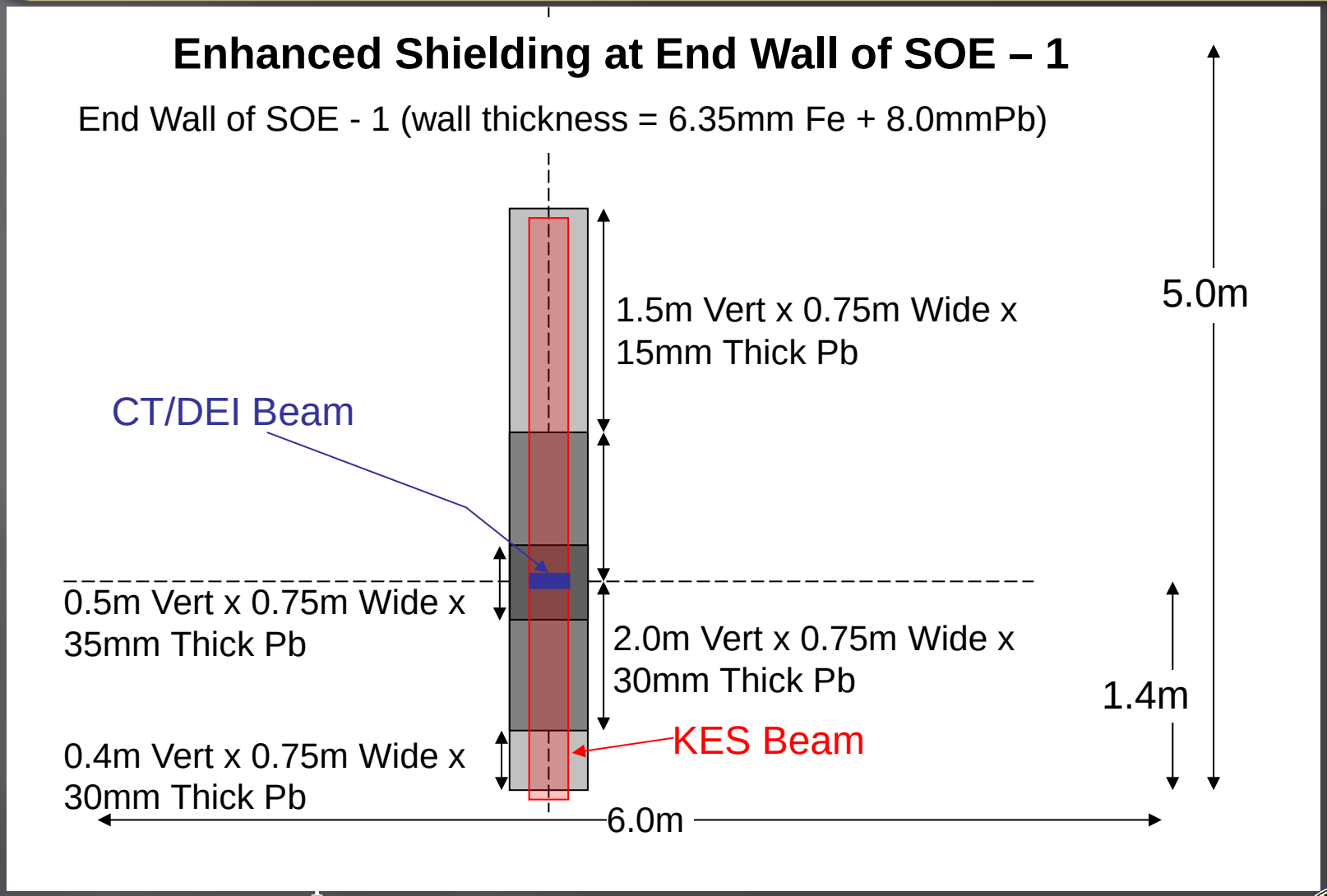
CT and KES Monochromators are in the Primary optical Enclosure-3 (POE-3) Hutch

Present Shielding at BMIT SOE - 1

Side Wall Thickness		Roof Wall Thickness		End Wall Thickness	
Fe (mm)	Pb (mm)	Fe (mm)	Pb (mm)	Fe (mm)	Pb (mm)
6.35	8	6.35	8	6.35	8*

* Enhanced shielding on downstream wall of SOE-1: additional 35mm thick Pb 0.5m high 0.75m wide strip centered at 1.4m on ID beam, 30mm thick Pb 2m high 0.75m wide strip centered at 1.4m on ID beam center and additional 15mm thick Pb 0.75m wide strip extending to floor and above 30mm Pb to a height of 3.9m from experimental floor

Present Shielding at BMIT SOE - 1



Why the Supplemental Shielding Calculation?

- Radiation levels above the expected (< 1μGy/hr) were measured recently at the End Wall of SOE-1
- Increment in radiation levels attributed to scattered white beam by the KES monochromator (a single crystal monochromator) in POE-3 into SOE-1
- Though this is peculiar to the BMIT beamline, it may not be uncommon for beamlines that use single crystal monochromators

Approximations and Program Used

- Only Compton scattering is responsible for beam scattering
- The incident beam is assumed to be scattered from a point source rather than an extended source
- Only single scattering is considered; dose contribution from re-scattering is not considered (i.e. build-up effect is ignored)

Approximations and Program Used (contd.)

- Program used for the calculations of the radiation dose and required shielding is written in Interactive Data Language (IDL)

- Is similar to other programs such as STACK8 - partly derived from the program PHOTON

- The written program can also be used to calculate the radiation dose to a subject within the hutch during experiments

Measurements and Calculations - Measurements

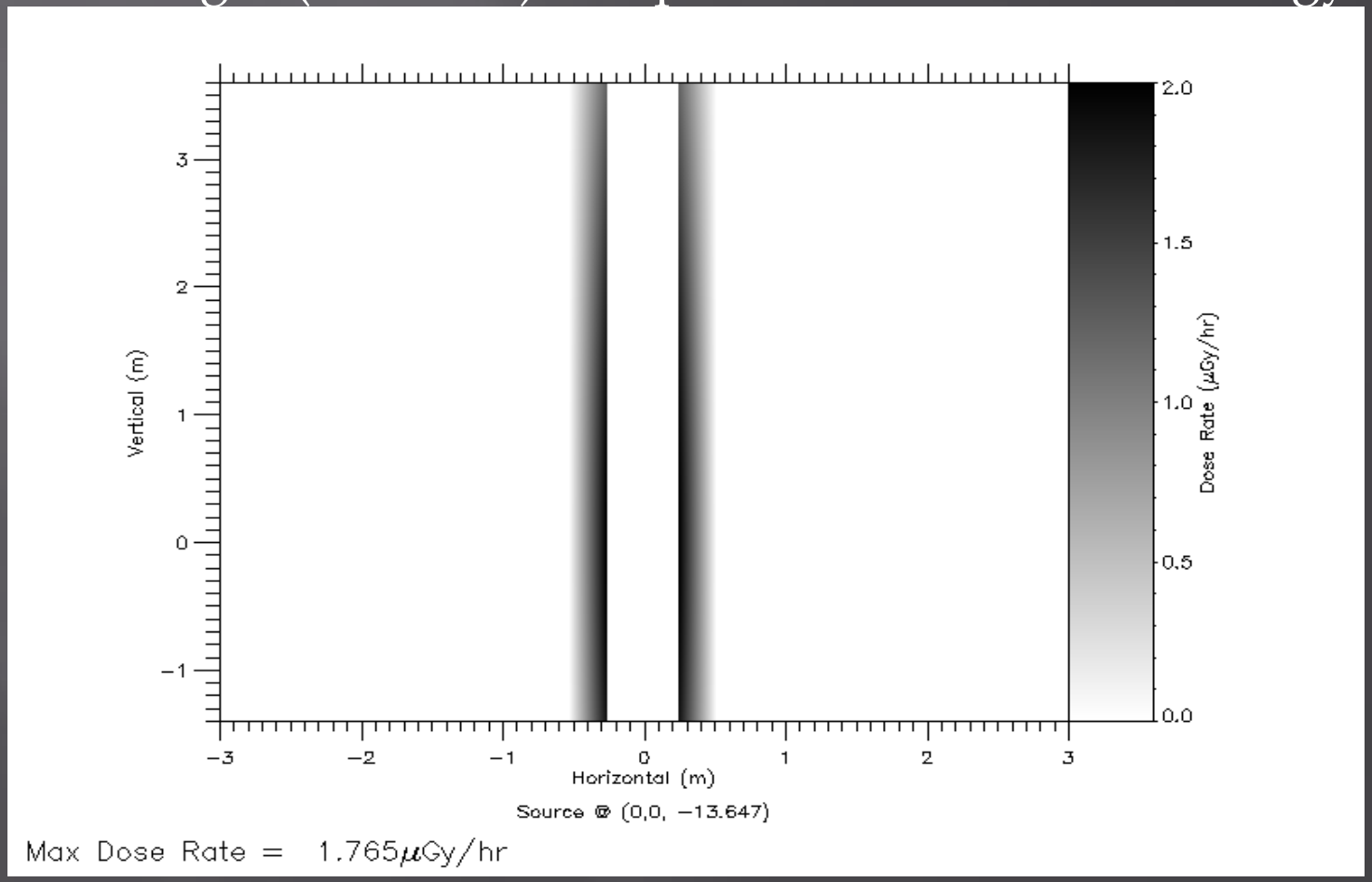
Performed by CLS Health, Safety and Environment Team: Wiggler field (4.1 T), Ring current (0.250A)

Beam Energy (keV)	Vertical Position Above the Floor (m)	Dose Rate (μSv/hr)
20	4.00 (i.e., 2.6 above beam)	1.46 ± 20%
33	3.15 (i.e., 1.75 above beam)	0.40 ± 20%
112	1.90 (i.e., 0.5 above beam)	0.66 ± 20%

Recommended horizontal width enhanced shielding, 50cm, implemented 75cm. The measurements were taken at vertical positions on the outside edge of the enhanced shielding, which is 0.375 m from beam center. No radiation was measured coming through the enhanced shielding.

Measurements and Calculations - Calculations

Performed using soe_end_wall.pro written in IDL:
Wiggler field (4.1 T), Ring current (0.250A), Scatter material (Si), Scatter length (0.214 cm) computed based on beam energy (20 keV)



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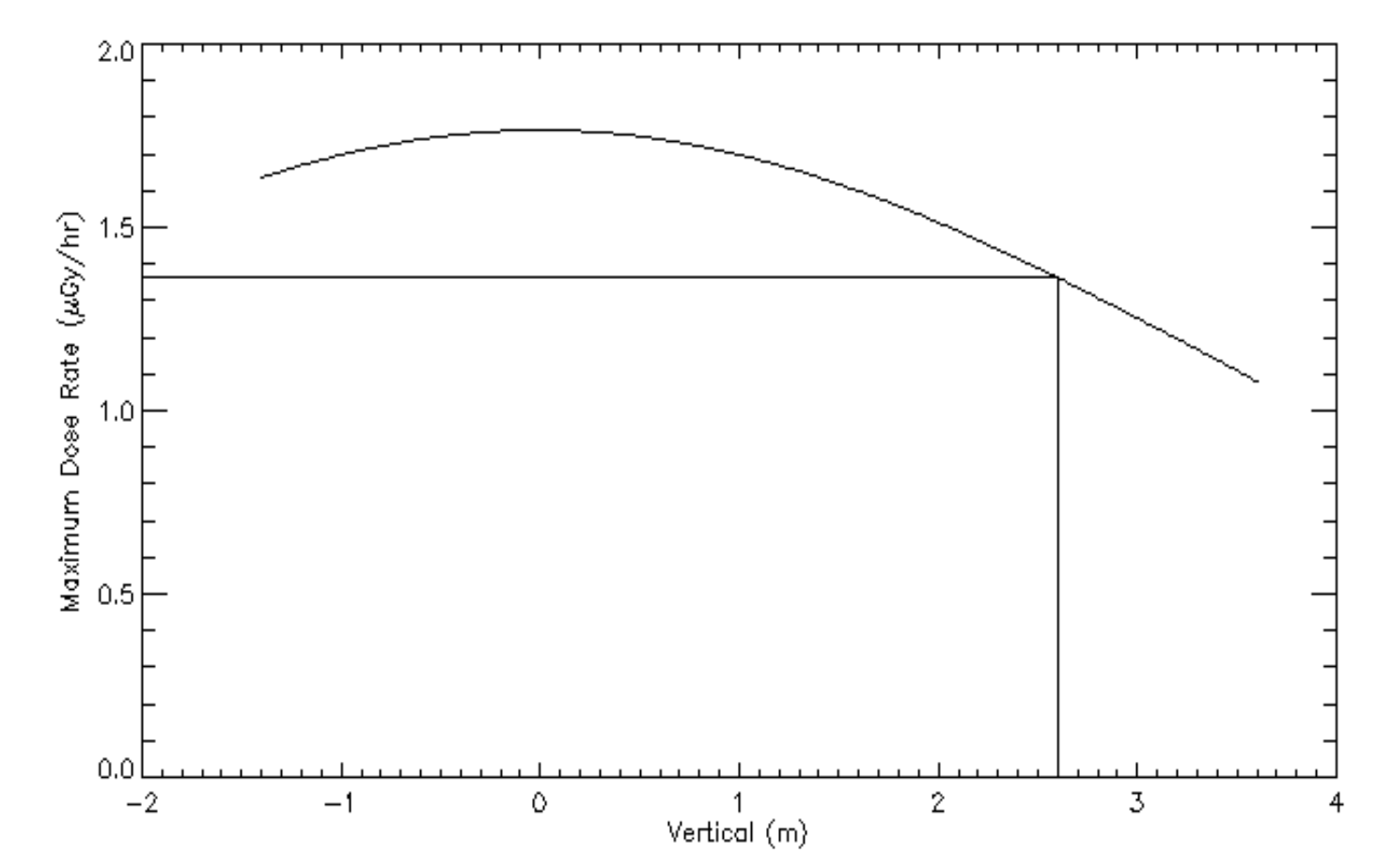
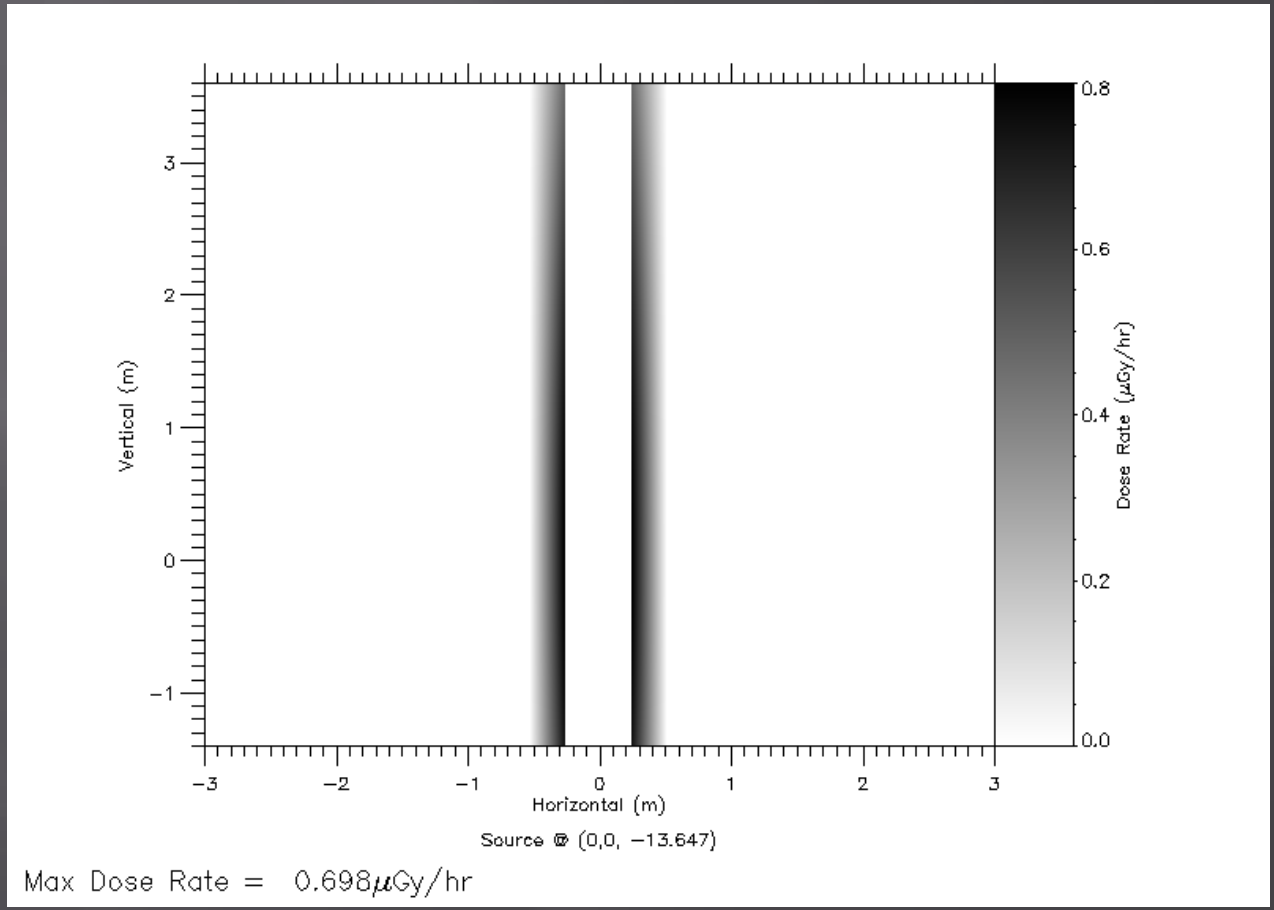


1.36μGy/hr at a vertical height of 2.6m above beam

Measurements and Calculations - Calculations

Performed using soe_end_wall.pro written in IDL: Wiggler field (4.1 T), Ring current (0.250A), Scatter material (Si), Scatter length (0.211 cm) computed based on beam energy (33 keV), 0.8 cm of Pb, 1.635 cm of Fe



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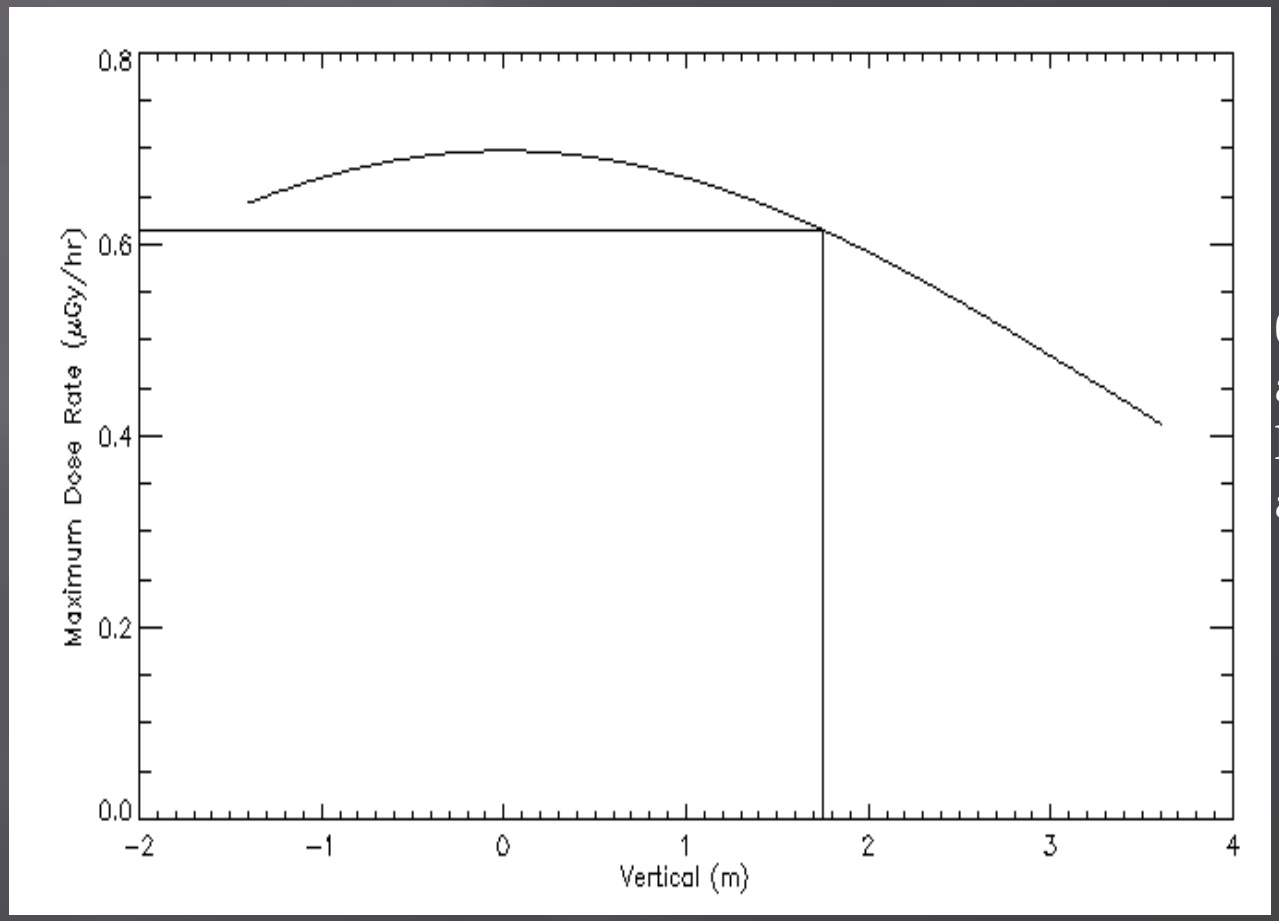
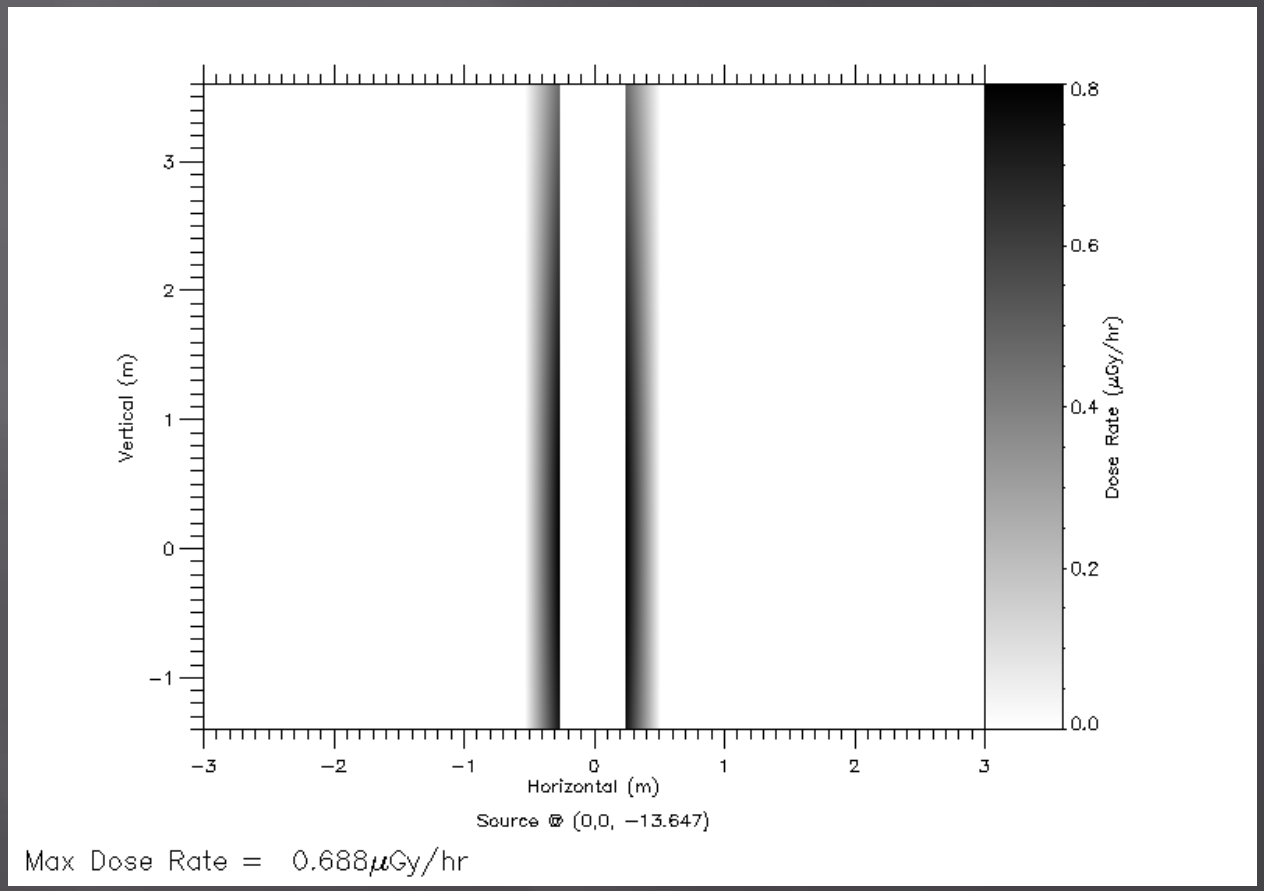


0.62μGy/hr at a vertical height of 1.75m above beam

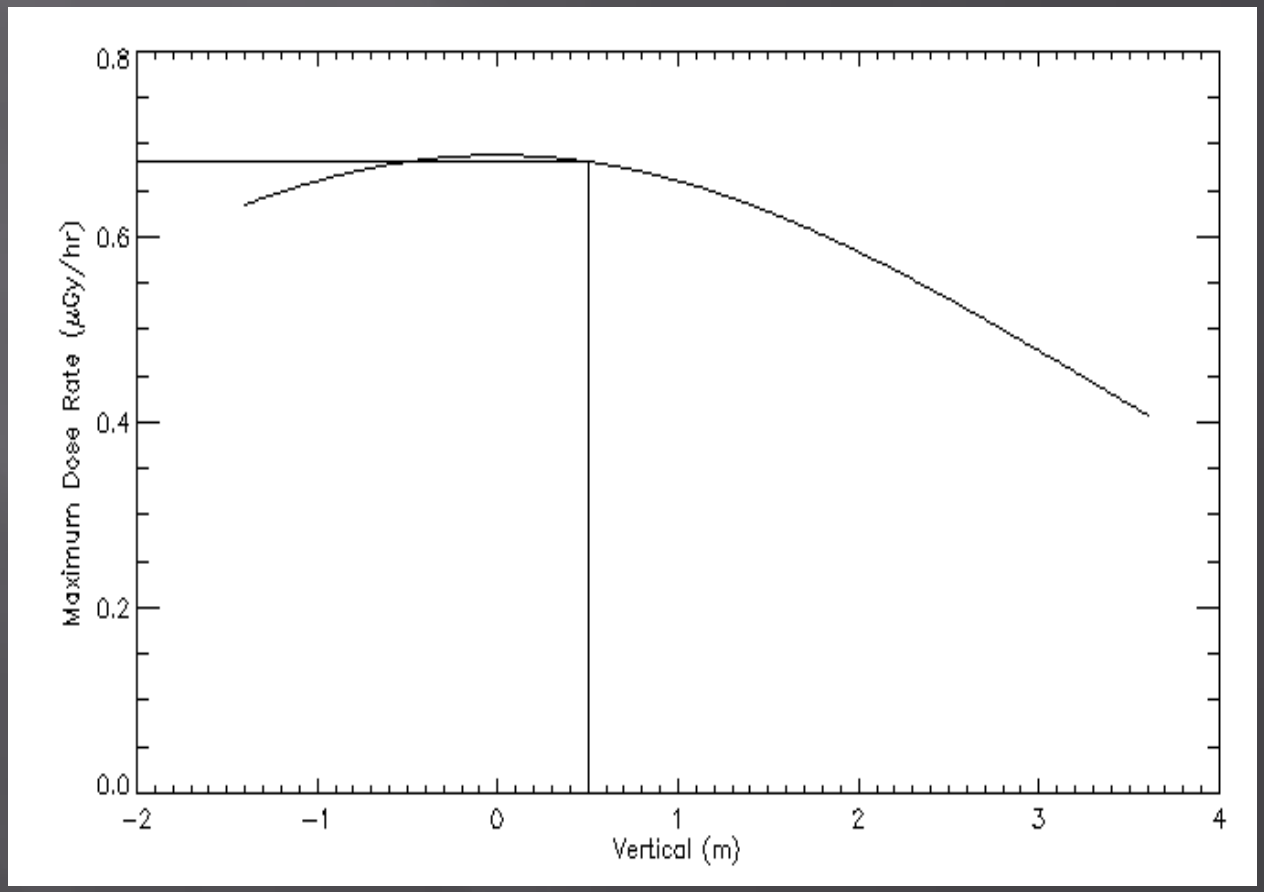
Measurements and Calculations - Calculations

Performed using soe_end_wall.pro written in IDL: Wiggler field (4.1 T), Ring current (0.250A), Scatter material (Si), Scatter length (0.208 cm) computed based on beam energy (112 keV), 0.8 cm of Pb, 1.635 cm of Fe



Measurements and Calculations - Calculations

Performed using soe_end_wall.pro written in IDL: Wiggler field (4.1 T), Ring current (0.250A), Scatter material (Si), Scatter length (0.208 cm) computed based on beam energy (112 keV), 0.8 cm of Pb, 1.635 cm of Fe



0.68μGy/hr at a vertical height of 0.5m above beam

Measurements and Calculations - Calculations Versus Measurements

Beam Energy (keV)	Vertical Position Above the Floor (m)	Measured Dose Rate (µSv/hr)	Calculated Dose Rate (µSv/hr)
20	4.00 (i.e., 2.6 above beam)	1.46 ± 20%	1.36
33	3.15 (i.e., 1.75 above beam)	0.40 ± 20%	0.62
112	1.90 (i.e., 0.5 above beam)	0.66 ± 20%	0.68

Measurements and Calculations - Calculations for Supplemental shielding

Scatter length (0.50 cm), Scatter material (Si), Wiggler field (4.3T),Ring current (0.500A), 0.635 cm of Fe

Lead Thickness (cm)	Max Dose Rate (μGy/hr)
0.8	14.38
1.0	4.93
1.2	1.90
1.4	0.79
1.6	0.36

Conclusion and Recommendation

- Based on our calculations, a lead thickness of 1.6cm (16.0mm) reduced the dose rate at BMIT SOE-1 End Wall to the target value: < 1μGy/hr

- Since there is currently 8.0mm of Pb at the SOE-1 End Wall, we recommend an additional 8.00 mm of Pb shielding to be added in order to reduced the observed high dose rate to the target value

Reference

Shielding Estimate for the BioMedical Imaging and Therapy Beamline,
26.2.35.1 – Rev. 0
Date: 2007-03-20
Dean Chapman

Acknowledgements

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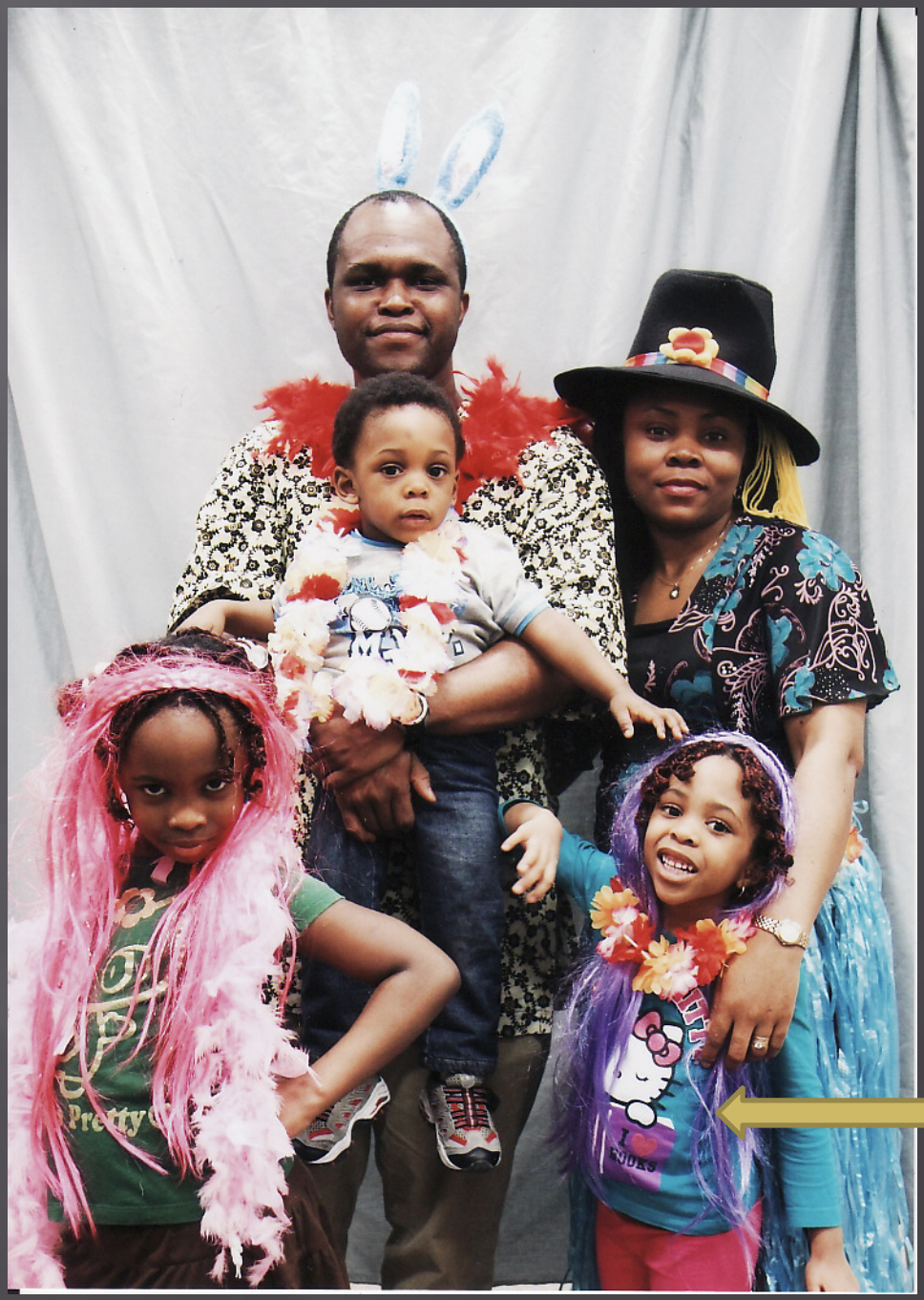
Canada

Thanks for the attention.



Is 5 years old today

Thanks for the attention.