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12ID SMI Beamline Radiation Shielding Analysis	

Introduction

The NSLS-II Beamline Radiation Shielding Policy has been stated as follows in reference 1: Radiation exposure to staff and users resulting from National Synchrotron Light Source II (NSLS-II) operations must comply with Brookhaven National Laboratory (BNL) and Department of Energy (DOE) radiation requirements and must be maintained as low as reasonably achievable (ALARA). Per the Photon Sciences Shielding Policy (PS-C-ASD-POL-005), in continuously occupied areas during normal operation the dose rate is ALARA, and shall be < 0.5 mrem/h (based on occupancy of 2000 hours/year) or less than 1 rem in a year.

For a fault event, the dose shall be < 20 mrem in a non-radiation controlled area and < 100 mrem in a radiation controlled area. Although the experimental floor is initially designated as a radiation controlled area, it is hoped that in the future, it can be declared a non-radiation controlled area. As such, beamlines should be shielded such that in the event of a fault, the total dose, integrated over the duration of the fault, is < 20 mrem.

In this report the recommended shielding is based on calculations to achieve dose rates less than 0.05 mrem/hr in continuously occupied areas and less than 0.5 mrem/hr on contact with the downstream wall of the First Optical Enclosure (FOE) [2] during normal operations.

Beamlines are required to shield against the two primary sources of radiation, the primary gas bremsstrahlung (GB) and the synchrotron beam, as well as the secondary radiation resulting from the scattering of these two primary beams by the beamline components and/or air. The shielding requirements for the FOE are dominated by the scattering of the primary bremsstrahlung and not the synchrotron beam. Guidelines for the NSLS-II Beamline Radiation Shielding Design are also provided in reference 1. These guidelines were used to determine the thickness of the FOE walls as well as dimensions of the supplementary shielding required to reduce the dose on the downstream FOE walls. The shielding recommended for the lateral and roof panels is generally sufficient for most white beam component configurations. However, the recommended as-built shielding for the downstream FOE wall may not be sufficient to protect against secondary gas bremsstrahlung (SGB) and additional shielding is usually necessary.

The radiation shielding analysis for the Soft Matter Interfaces (SMI) beamline (12ID-SMI) is documented in this technical note. The goal of the simulations documented here was to estimate the radiation dose levels generated inside and outside the beamline shielded enclosures during normal operations and some fault conditions, thus evaluating the efficiency of the as-designed shielding.

The layout of the SMI beamline is shown in Figure 1.1, excerpted from the Beamline Ray Trace Layout [PD-SMI-RAYT-0001]. The ray trace drawings list the major components in the beamline and provide their positions. Beam is shown traveling from right to left. For shielding analysis, this information in addition to the geometries and materials of the components and shielding are collected into an input document, included herein as Appendix 1.

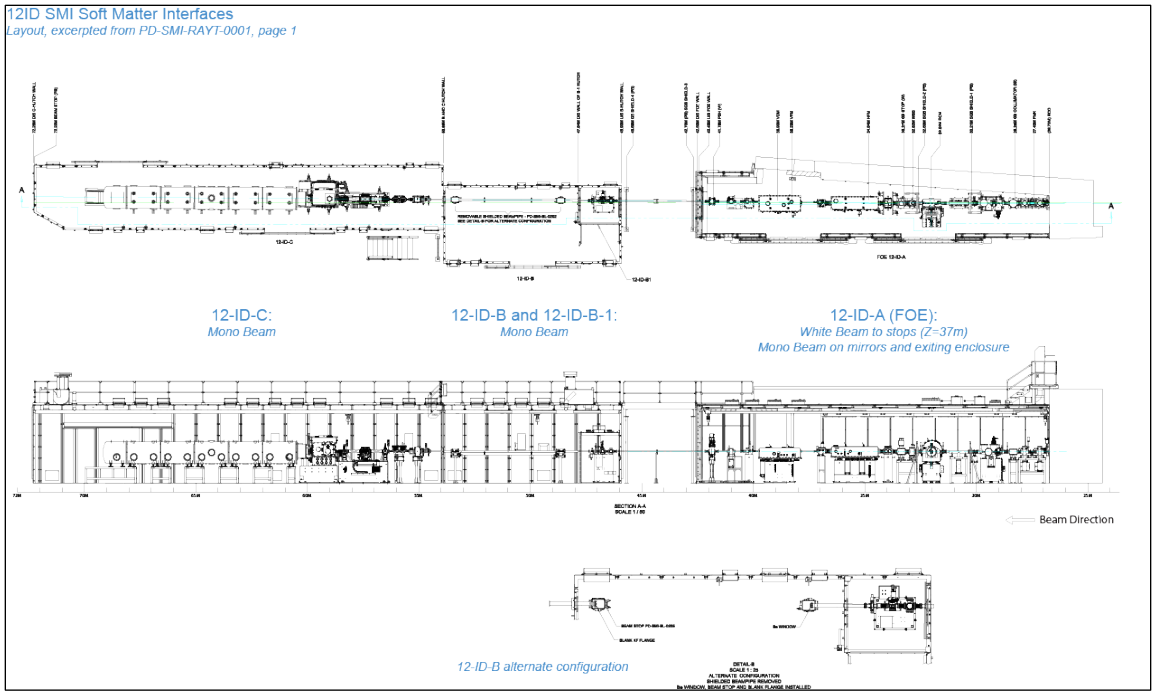


Figure 1.1: 12ID-SMI Layout from PD-SMI-RAYT-0001, sheet 1. Annotations in blue identify the enclosures: 12-ID-A, the First Optics Enclosure (FOE); 12-ID-B and 12-ID-B-1, the future/diagnostics hutch and optics closet respectively; and 12-ID-C, the Experimental End Station.

The remainder of this document is organized as follows.

Section 2 describes the model generated for FLUKA analysis of primary gas bremsstrahlung (GB) and secondary gas bremsstrahlung (SGB) in 12-ID-A, using NSLS-II source parameters, and all SMI shielding and optical components as-installed taking into account bench and installation survey report data.

Section 3 presents the FLUKA simulation results. The analysis finds that bremsstrahlung radiation is stopped by shielding at or before the 12-ID-A downstream wall, making GB/SGB analysis of the mono beam transport pipe and enclosures unnecessary.

Section 4 describes analysis of the synchrotron radiation, considering white beam from the in-vacuum undulator source up to the white beam stop located in the middle of the FOE, and monochromatic beam through the transport pipe and downstream enclosures, which can be interlocked into two distinct shielding configurations for diagnostic and experimental operating modes.

Section 5: Summary.

Section 6: References.

Section 7: Acknowledgments.

2. Description of the FLUKA model

At NSLS-II undulator beamlines such as 12ID-SMI, FOE shielding is designed for primary radiation and thermal management. The white beam components disperse the primary bremsstrahlung without significant energy loss; thereby greatly increasing the angular range of very high-energy bremsstrahlung photons. It is necessary to intercept this secondary bremsstrahlung before it hits the downstream FOE wall. The design of the 12ID-SMI beamline includes additional shielding in order to reduce the dose on the downstream wall.

As recommended by reference 1 Appendix A we use the "custom GB generator based on an analytic representation of the source's energy spectrum, which was scaled in intensity in accordance with the experimental estimates of total GB power. This custom source assumes a 1/E energy spectrum dependency, with a maximum energy of 3GeV, and generates internally the corresponding probability density function from analytical descriptions".

The NSLS-II primary gas bremsstrahlung (GB) source parameters are summarized in Table 1.

Table 1: NSLS-II primary bremsstrahlung source parameters

Electron energy	3 GeV
Stored current	500 mA
Length of ID straight section	15.5 m
Pressure in straight section	1 ntorr

The beam is normalized at 17μW incident power, for the long (15.5m) straight. This value corresponds to the estimated bremsstrahlung power generated by a 500mA electron beam of 3GeV, assuming that the vacuum in the straight sections is better than 10^{-9} Torr. The bremsstrahlung source file is kept in the NSLS-II Radiation Physics Folder.

Based on 12ID-SMI ray tracings primary GB will interact with some of the components per the descriptions in Appendix 1. The areas of the components irradiated by the primary GB are shown in each subsection of Section 3 which describes the results of the primary GB striking each component. Only areas illuminated by the primary GB per the ray tracing were sampled for analysis. The simulations performed to confirm the adequacy of the FOE shielding and radiation safety components are presented in Table 2. Components referenced in Table 2 are described in more detail further below and in Appendix 1.

The 12ID beamline FLUKA model includes the FOE roof, sidewalls, downstream wall, ratchet wall, and long wall of the storage ring. The FOE is lined with Pb: lateral walls 18mm, roof 10mm, and downstream wall 50mm. See Appendix 1 for more details. A prototype FLUKA input file is kept in the NSLS-II Radiation Physics Folder.

The 12ID-SMI beamline has been installed with an IVU23 source canted inboard, and has dual aperture masks and wide beam stops in the Front End and the FOE to accommodate a future source to be canted outboard. Hence, in general, components are not symmetrical about the straight centerline. Our analysis uses a coordinate system with Z axis along the straight centerline. In Appendix 1, component X,Z coordinates are referenced from the center of the straight. In the FLUKA models, the Z coordinate has an offset of 2671.7 cm setting the origin at the ratchet wall. In the Appendix 1 input tables and in the FLUKA model, the X axis is horizontal with positive sense outboard, and the Y axis is vertical with positive up. Y=0 at the orbit height.

Table 2: List of FLUKA simulations

Component / Report Section	Simulation GB incident on the:	Position of GB source (cm)	
1 / 3a	Dual Aperture Fixed Mask (DAFM)	X Y Z	7.49 0 2740.6
2 / 3b	Gas Bremsstrahlung Collimator (GBC)	X Y Z	8.53 1.8 2824.8
3 / 3c	Horizontal Slits, position 4	X Y Z	-1.31 0.555 2902.7
3 / 3c	Horizontal Slits, position 5	X Y Z	-1.31 -0.555 2895.3
4 / 3d	Vertical Slits	X Y Z	-2.235 1.25 2922.7
5 / 3e	Pinhole Mask, Position 2	X Y Z	6.3 0 3006.8
5 / 3e	Pinhole Mask, Position 5	X Y Z	-0.7 0 3006.8
6 / 3f	Dual Crystal Monochromator (DCM)	X Y Z	-1.9 -0.8 3198.05
7 / 3g	White Beam Stop (WBS), OBC	X Y Z	7.5 0 3282.2
7 / 3g	White Beam Stop (WBS), Position 5	X Y Z	-0.21 2.6 3282.2
8 / 3h	Gas Bremsstrahlung Shield (GBS), OBU	X Y Z	9.168 1.2 3326.8

Figure 2.1 shows the beamline components in the FOE as drawn from the FLUKA model. Note that the monochromatic beam is redirected multiple times, by the vertical bounce monochromator and the horizontal and vertical focusing and deflection mirrors. Small components such as slit jaws in the mono beam paths do not all intercept the same X and Y planes and some of them cannot be seen in the view shown. Views confirming all aspects of the model have been generated for review by the 12ID-SMI Lead Beamline Scientist and Beamline Mechanical Engineer.

The 12ID-SMI is a canted dual beam beamline. As such there is an Outboard (O/B) and an Inboard (I/B) beam within the beam pipe and for each fixed component. The I/B beam will be the first to be commissioned. There are four fixed components in the model that can receive the direct GB radiation. All of these components are designed for the dual beam operations. There are four movable components which are only for the I/B beam. The movable components are only included in

the model when analysis consists of the GB interactions with those components. For the analyses of the GB radiation interacting with the fixed components the movable components are removed from the calculation. Also included in the model are two lead shields, one upstream of the double crystal monochromator (DCM) and one downstream of the DCM. Beyond the beam stops there are three mirrors, a photon shutter, a guillotine and a lead shielded pipe exiting the FOE. The side walls, roof and back wall are standard NSLS-II designs lined with 1.8, 1.0, and 5.0 cm of lead, respectively. The FOE for 12ID is extends beyond the ratchet wall so there is a short side wall on the I/B side of the FOE, lined with lead that is 1.8 cm in thickness.

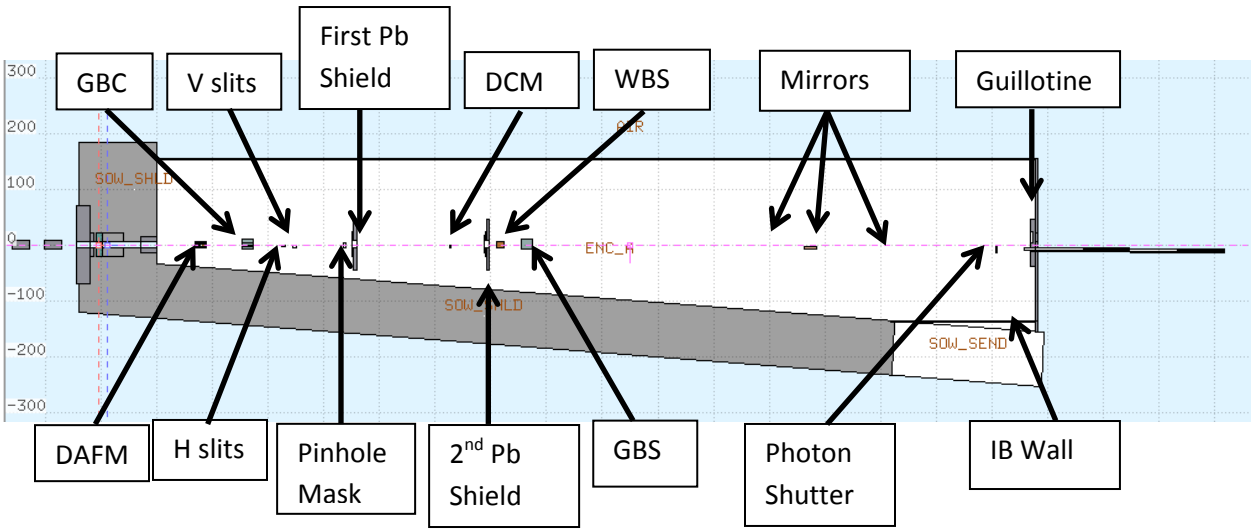


Figure 2.1: The components of the FOE in the FLUKA model.

3. Results for primary Gas Bremsstrahlung (GB) simulaitons.

The main shielding requirement for the FOE is from primary Gas Bremsstrahlung radiation originating from the storage ring's electron beam interacting with residual gas in the storage ring. This paths of this radiation are determined by ray tracing of the GB through and around the beam line components. The results of the ray tracing are included in Appendix 1. The analysis approach was to place the GB beam at various locations within the area covered by the irradiation. Short analyses with FLUKA were performed and irradiation spots that resulted in the highest radiation doses at the roof, side wall and back wall were selected for longer analyses. None of the interactions resulted in significant dose in or around the beam pipe leaving the FOE or at the FOE I/B wall. Hence the results of those analyses are not shown here. All simulations include the installed Secondary GB Shields.

3a. GB on the Dual Aperture Fixed Mask (DAFM)

For the analyses on the DAFM five positions were used as are shown in Figure 3.a.1. The results of the analyses are summarized in Table 3.a.1. When the GB strikes the DAFM, none of the positions resulted in dose rates that exceeded 0.04 mrem/hr on the roof, at either side wall and back wall. For the presentations here, none of the cases of GB striking any component led to a significant radiation dose at the short I/B side wall. For all cases SW refers to the O/B side wall.

Table 3.a.1 dose rate (mrem/hr) calculated for the GB striking 5 positions on the DAFM

DAFM	BW	Roof	SW
OBC	<0.01	0.03	0.03
OBU	<0.01	0.04	0.03
Pos 2	<0.01	0.02	0.04
Pos 3	<0.01	0.02	0.04
Pos 7	0.03	0.03	0.03

The dose distributions within the FOE for the GB striking the DAFM on the OBC (O/B beam, vertical center of the GB) position are shown in Figure 3.a.2 for the top view and Figure 3.a.3 for the side view. The position of interaction is x=7.49 cm, y=0 cm, and z=2740.6 cm. These two figures demonstrate minimal dose rate downstream of the interaction and that the shielding performs well. The dose distribution for the roof at contact is shown in Figures 3.a.4 and 3.a.5. This figure demonstrates the maximum dose rate on the roof is expected to be 0.03 mrem/hr. Likewise Figures 3.a.6 and 3.a.7 shows the dose distribution along the O/B side wall and the maximum dose rate is 0.03 mrem/hr. At the back wall, the dose rate is negligible and is not shown.

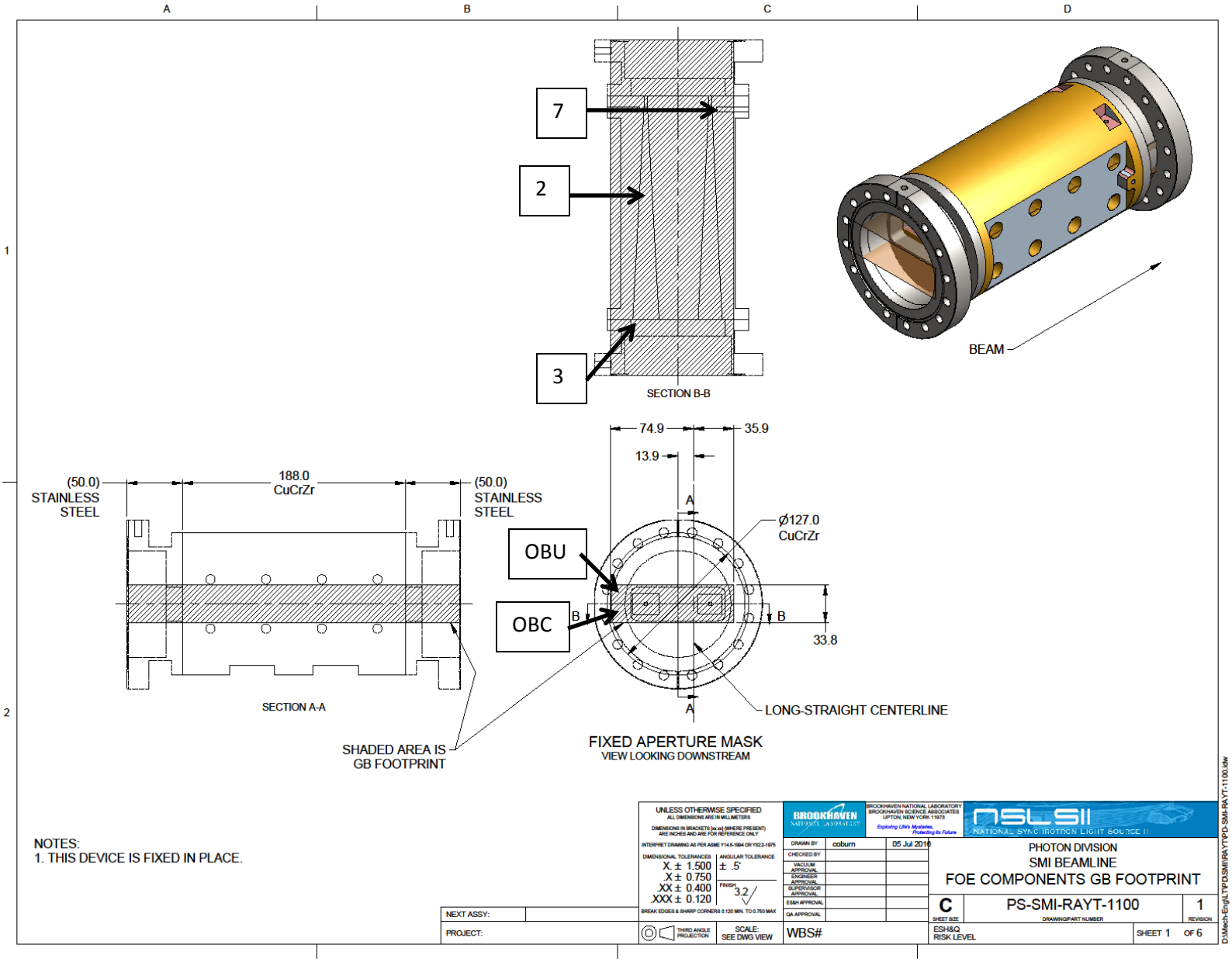


Figure 3.a.1. Five selected positions for analysis of GB on the DAFM

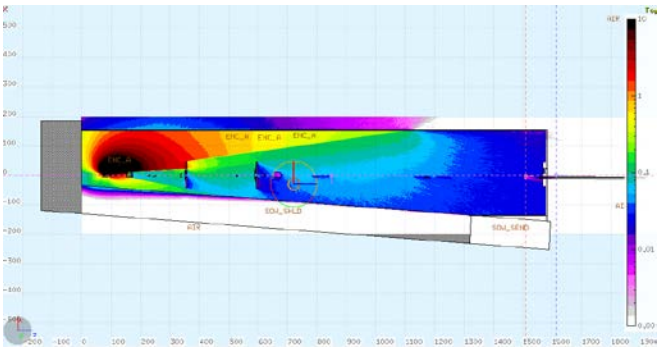


Figure 3.a.2: Dose distribution from the GB striking the OBC position - top view

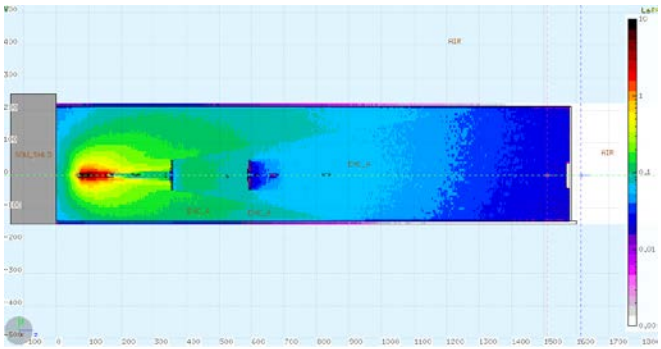


Figure 3.a.3: Dose distribution from the GB striking the OBC position - side view

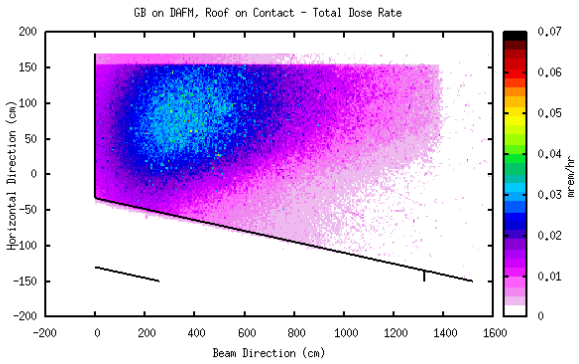


Figure 3.a.4: Radiation dose distribution on the roof on contact.

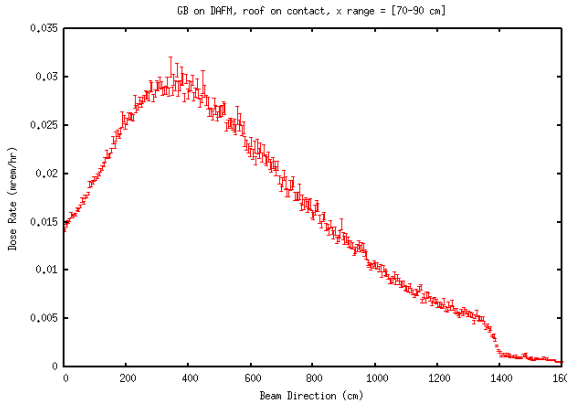


Figure 3.a.5: Radiation dose distribution on the roof on contact for an x range of 70 and 90 cm. The maximum is 0.03 mrem/hr.

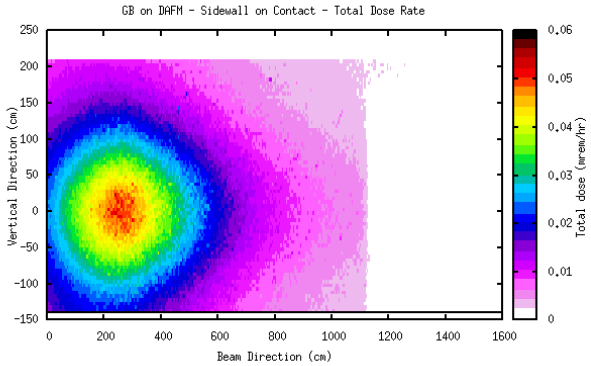


Figure 3.a.6: Radiation dose distribution at the side wall on contact.

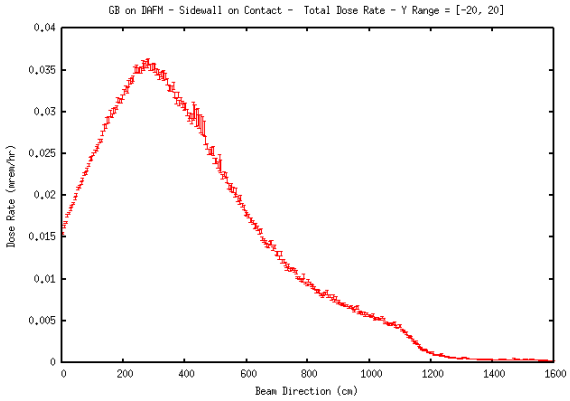


Figure 3.a.7: Radiation dose distribution on the side wall on contact for a y range of -20 and +20 cm. The maximum dose rate is 0.3 mrem/hr.

3.b. GB on the Gas Bremsstrahlung Collimator (GBC)

Four positions were analyzed for the Gas Bremsstrahlung Collimator are shown in Figure 3.b.1 and the summary of the analyses are shown in Table 3.b.1. All of the positions analyzed were within the targeted dose rate on contact. The highest dose rate outside the FOE occurred when the beam was incident on the O/B edge at the upper corner of the beam spot (OBU). The coordinates of this interaction point are x= 8.53 cm, y= 1.8 cm, z= 2824.8 cm. The results of those analyses for that position are presented in Table 3.b.1 and Figures 3.b.2 through 3.b.7. From Figures 3.b.2 and 3.b.3, there is minimal dose beyond the second lead shield so no results will be shown for the back wall nor for the short IB wall beyond the ratchet wall.

Table 3.b.1: Summary of Total Radiation dose rates for the GBC

GBC	BW	Roof	SW
OBC	<0.01	0.02	0.04
OBU	<0.01	0.03	0.04
C	<0.01	0.03	0.04
UC	<0.01	0.03	0.03

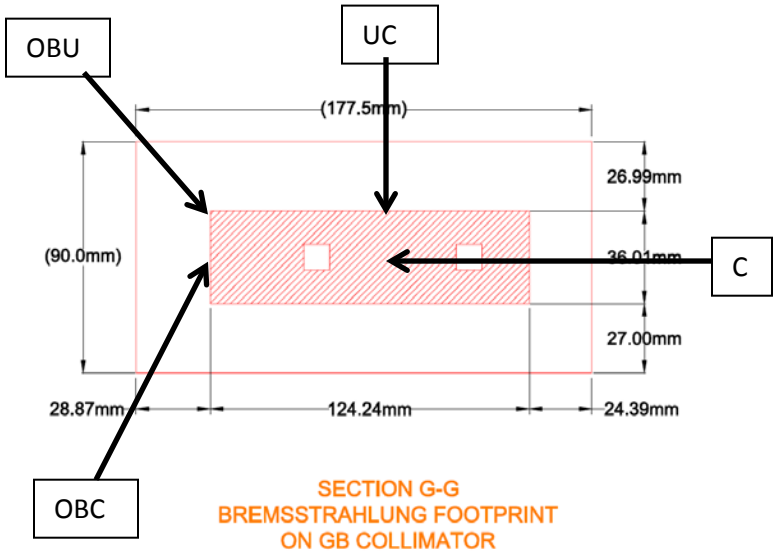


Figure 3.b.1: Four Selected Positions for the GB Collimator

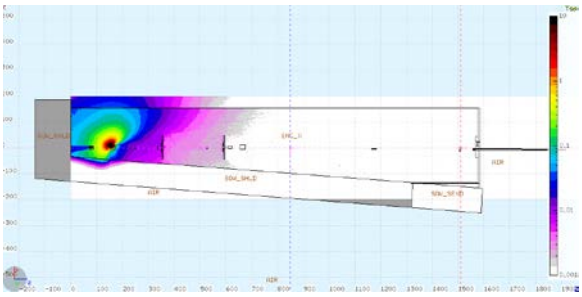


Figure 3.b.2: Dose distribution from the GB striking the OBU position - top view

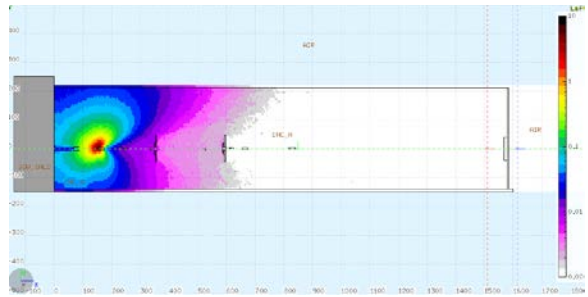


Figure 3.b.3: Dose distribution from the GB striking the OBU position - side view

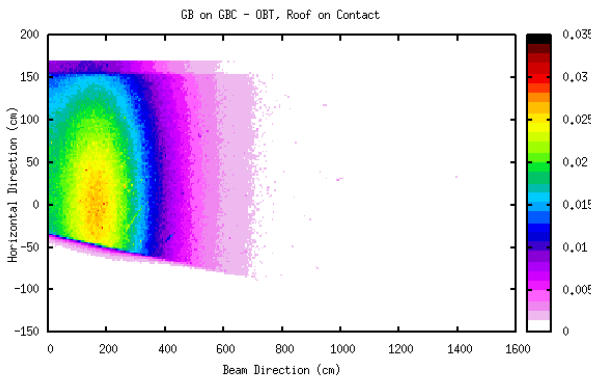


Figure 3.b.4: Radiation dose Distribution on the roof on contact

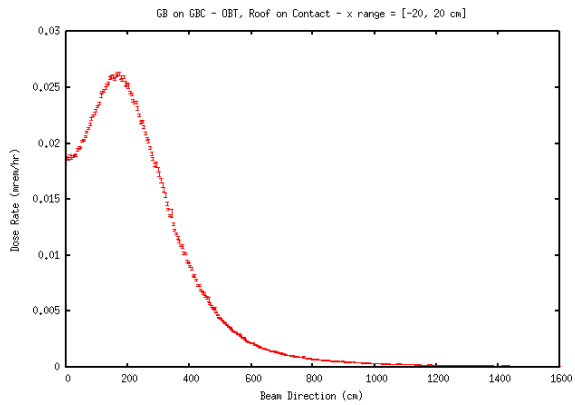


Figure 3.b.5: Radiation dose Distribution on the roof on contact for an x range of -20 and +20 cm. The maximum is 0.03 mrem/hr.

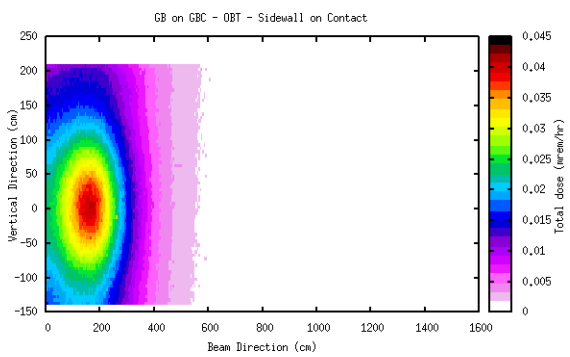


Figure 3.b.6: Radiation dose Distribution at the side wall on contact

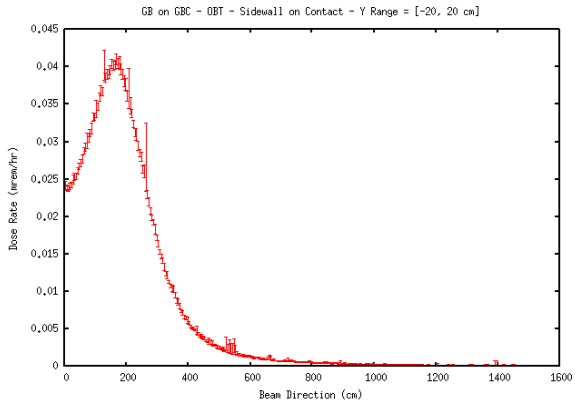


Figure 3.b.7: Radiation dose Distribution on the side wall on contact for a y range of -20 and +20 cm. The maximum dose Rate is 0.04 mrem/hr on contact.

3.c. GB on the Horizontal Slits.

The horizontal slits are movable and retractable items in the beamline. For the analyses of the GB on the DAFM and GBC, these slits, along with the following Vertical slits and Pinhole collimator are removed from the calculation. They are only included as scattering sources and hence are included here. Figure 3.c.1 shows the Ray Tracing analyses for the GB on the Horizontal Slits and the points that were analyzed. Table 3.c.1 shows the summary results of the analyses. The results indicate there are positions on the Horizontal Slits where the GB striking them produce higher dose rates considerably than the other interaction points considered before. The results shown here will be from positon 4 (x= -1.31 cm, y= 0.555 cm, z= 2902.7 cm) for the roof and sidewall and from positon 5 for the back wall (x= -1.31cm, y= -0.555 cm, z= 2895.3 cm). Figure 3.c.2 and Figure 3.c.3 show the top and side views of the dose distributions in the FOE. They demonstrate that for a few cases the radiation propogates along an unintended path inside the aperture of the SGB shield.

Table 3.c.1. Summary Results of the Analyses of the GB on the Horizontal Slits

Horizontal Slits	BW	Roof	SW
Pos 1	0.3/0.11 at 30 cm	0.04	0.025
Pos 2	0.4/0.16 at 30 cm	0.03	0.03
Pos 4	0.035	0.02	0.02
Pos 5	0.4/0.16 at 30 cm	0.03	0.05

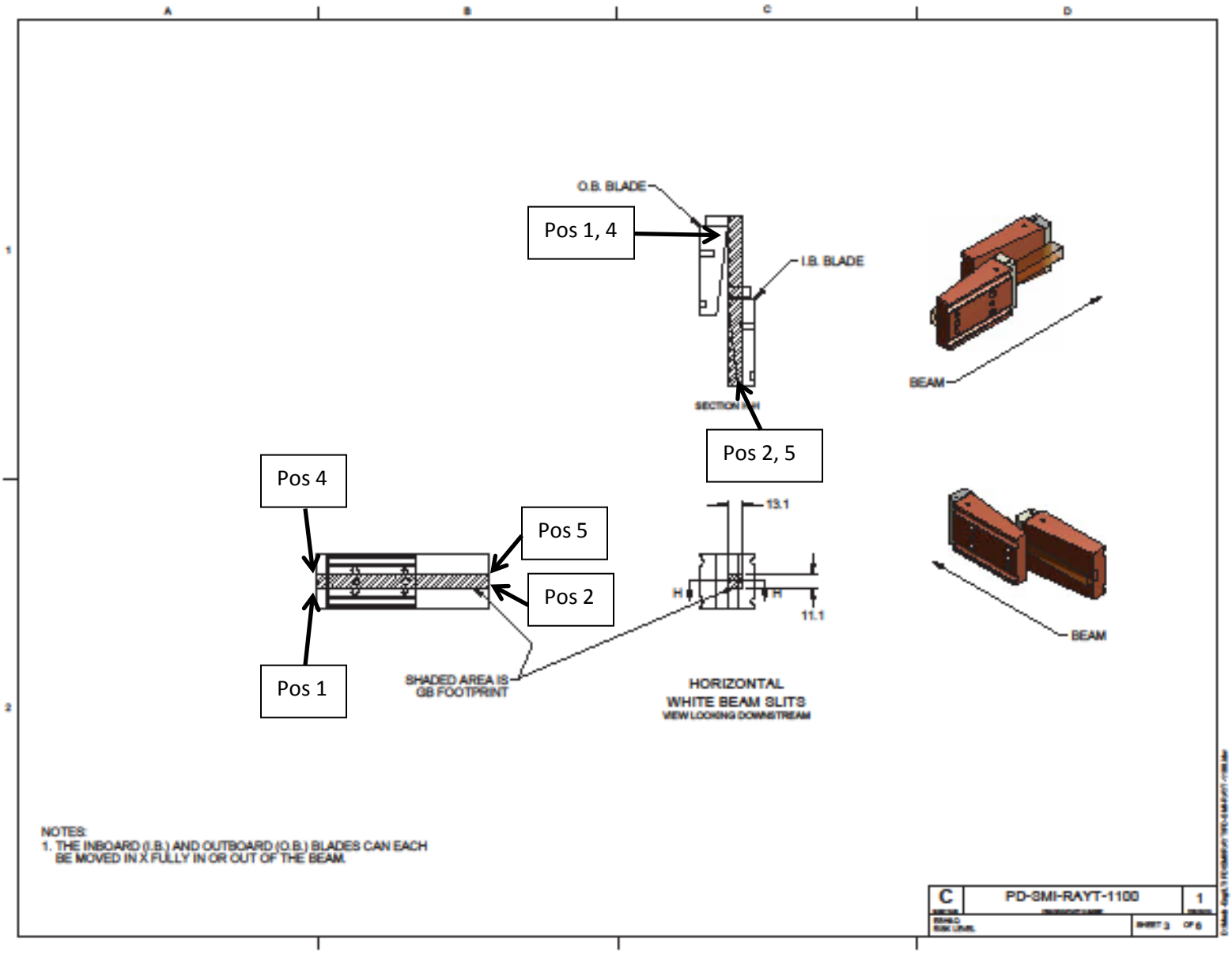


Figure 3.c.1: Positons on the Horizontal slits for the analyses.

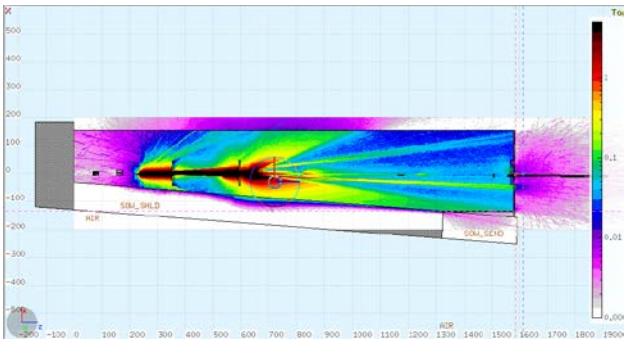


Figure 3.c.2: Dose distribution from the GB striking Position 5 - top view

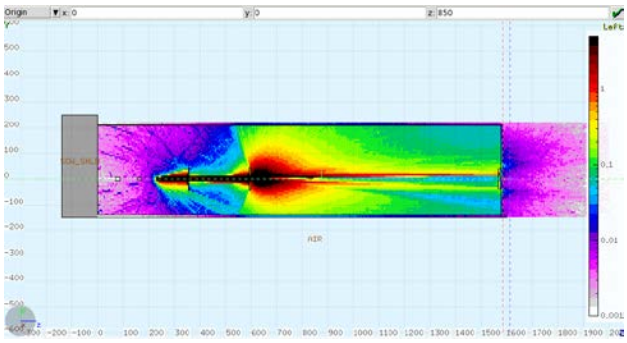


Figure 3.c.3: Dose distribution from the GB striking Position 5 - side view

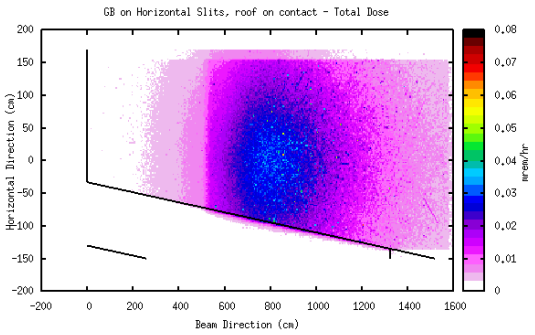


Figure 3.c.4: Radiation dose distribution on the roof on contact.

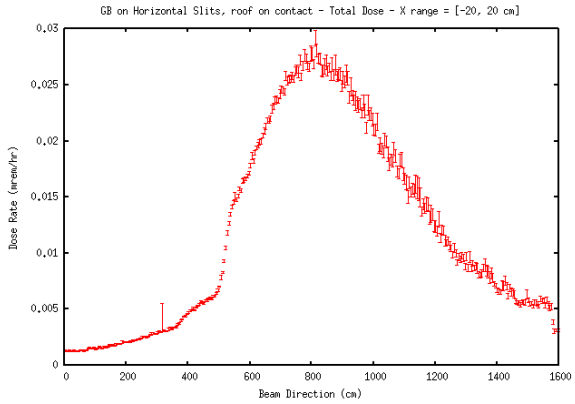


Figure 3.c.5: Radiation dose distribution on the roof on contact for an x range of -20 and +20 cm. The maximum is 0.04 mrem/hr.

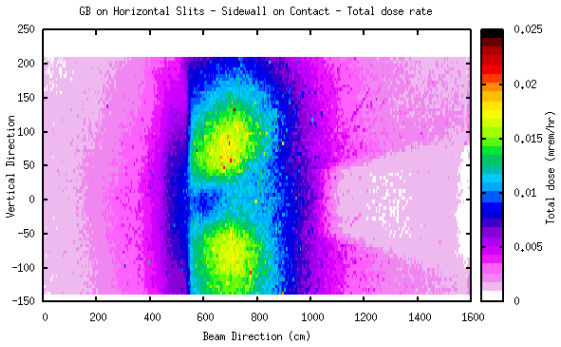


Figure 3.c.6: Radiation dose distribution at the side wall on contact.

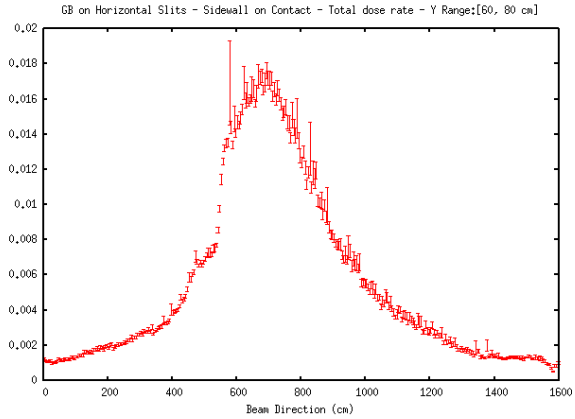


Figure 3.c.7: Radiation dose distribution on the side wall on contact for a y range of 60 and 80 cm. The maximum dose rate is 0.02 mrem/hr on contact.

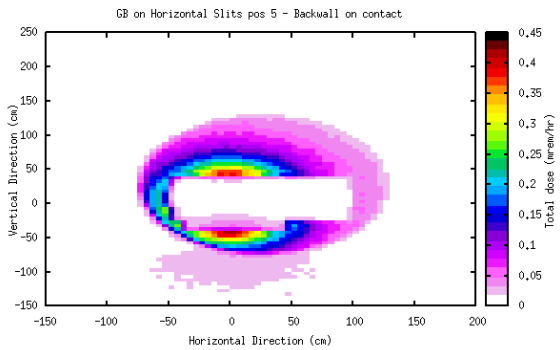


Figure 3.c.8: Radiation dose distribution at the back wall on contact.

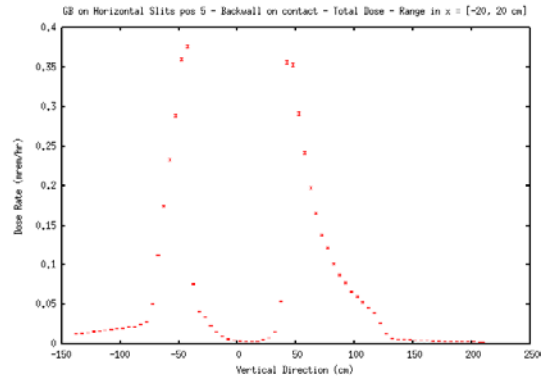


Figure 3.c.9: Radiation dose distribution at the back wall between x=[-20, 20 cm] on contact. The maximum dose rate is 0.4 mrem/hr on contact.

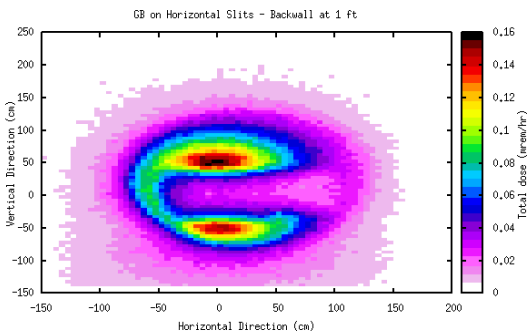


Figure 3.c.12: Radiation dose distribution at the back wall at 30 cm.

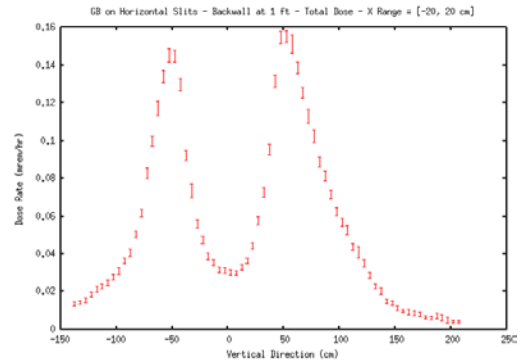


Figure 3.c.13: Radiation dose distribution at the back wall between x=[-20, 20 cm]on contact. The maximum dose rate is 0.16 mrem/hr at 30 cm.

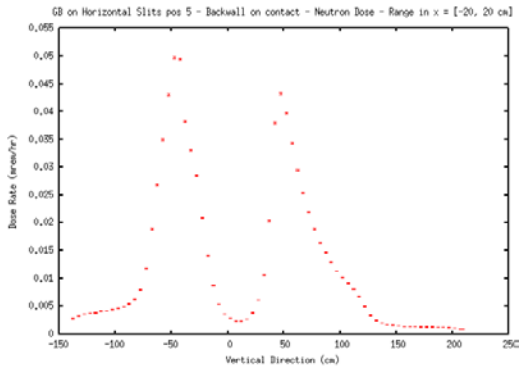


Figure 3.c.14: Neutron dose distribution at the back wall between x=[-20, 20 cm] on contact.

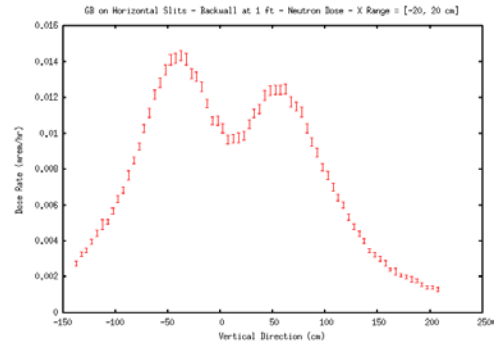


Figure 3.c.15: Neutron dose distribution at the back wall between x=[-20, 20 cm] at 30 cm.

3.d. GB on the Vertical Slits.

As with the horizontal slits, the vertical slits are moveable and are analyzed only as GB interaction components. Figure 3.d.1 shows the four points used for the analyses and Table 3.d.1 shows a summary of the data. From Table 3.d.1 The GB interacting on the Vertical slits results in dose rates below the limits. For this report only the results from position 5 (x= -2.235 cm, y= 1.25 cm, z= 2922.7 cm) will be presented. The top and side views of the radiation dose rate within the FOE show that for the specific location of position 5, some of the radiation goes through the lead shielding and around the GB shield.

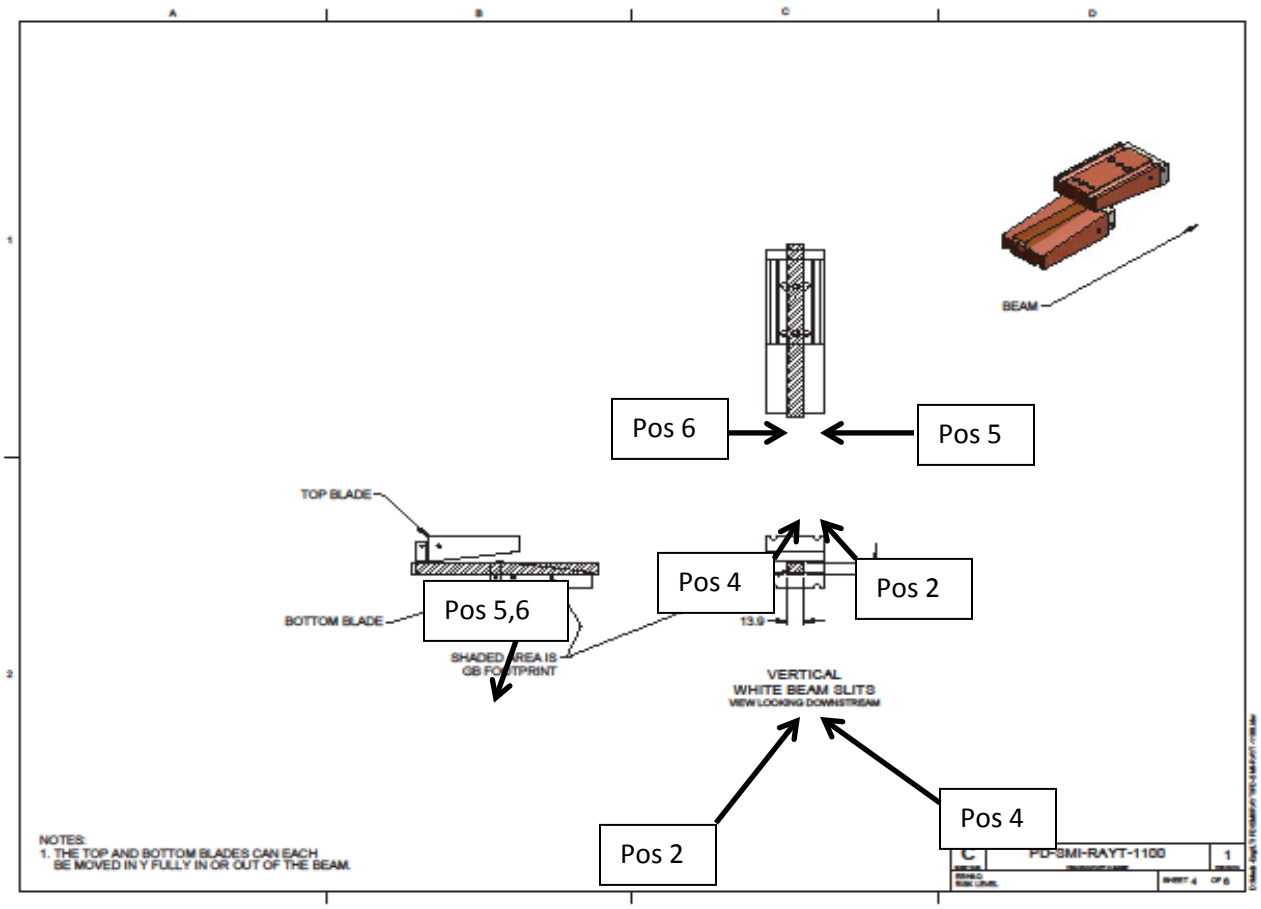


Figure 3.d.1: Positions on the Vertical Slits Analyzed for this report.

. **Table 3.d.1: Summary of GB on the Vertical Slits**

Vertical Slits	BW	Roof	SW
Pos 2	0.03	.03	.03
Pos 4	0.03	.025	.03
Pos 5	0.06/0.01 at 30cm	.025	.02
Pos 6	0.04	.03	.03

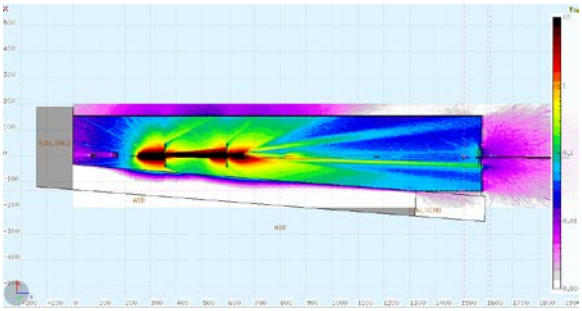


Figure 3.d.2: Dose distribution from the GB striking Position 5 - top view

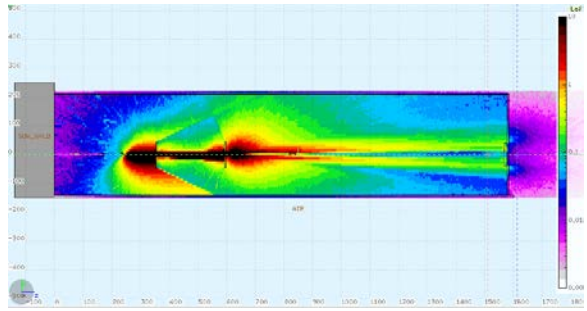


Figure 3.d.3: Dose distribution from the GB striking Position 5 - side view

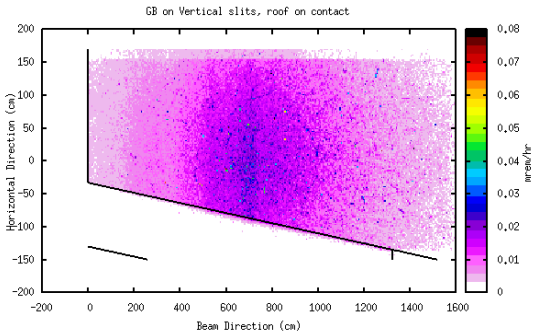


Figure 3.d.4: Radiation dose distribution on the roof on contact.

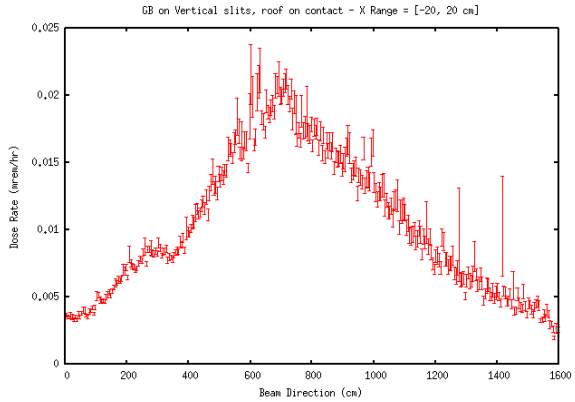


Figure 3.d.5: Radiation dose distribution on the roof on contact for an x range of -20 and +20 cm. The maximum is 0.025 mrem/hr.

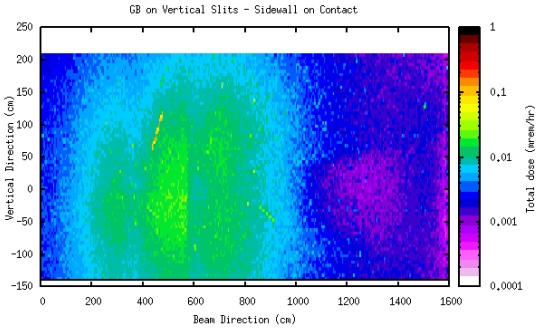


Figure 3.d.6: Radiation dose distribution at the side wall on contact.

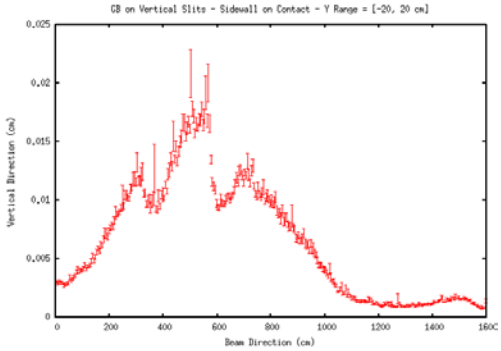


Figure 3.d.7: Radiation dose distribution on the side wall on contact for a y range of -20 and +20 cm. The maximum dose rate is 0.2 mrem/hr on contact.

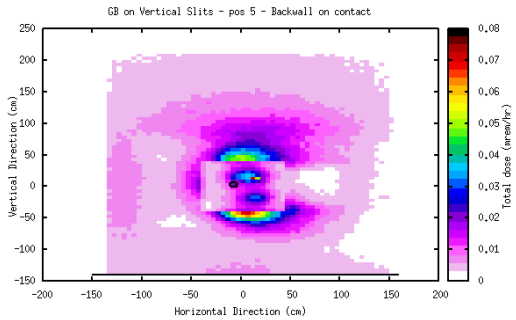


Figure 3.d.8: Radiation dose distribution at the back wall on contact

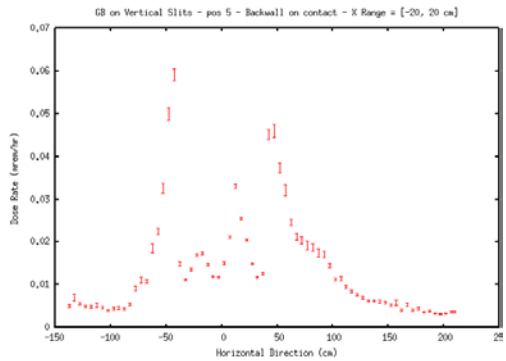


Figure 3.d.9: Radiation dose distribution at the back wall between x=[-20, 20 cm] on contact. The maximum dose rate is 0.06 mrem/hr on contact.

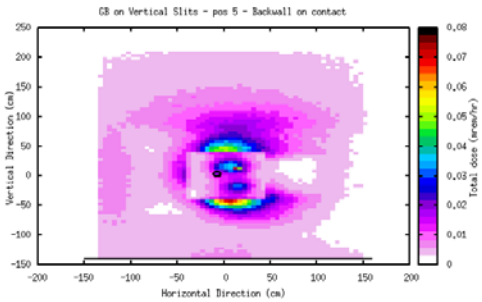


Figure 3.d.10: Radiation dose distribution at the back wall on contact.

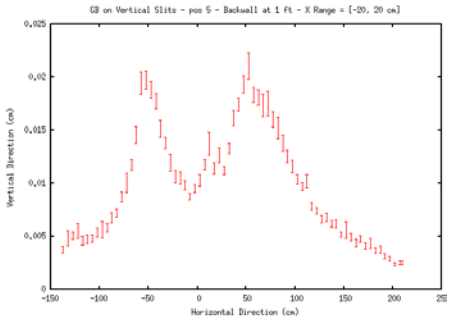


Figure 3.d.11: Radiation dose distribution at the back wall between x=[-20, 20 cm] at 30 cm. The maximum dose rate is 0.055 mrem/hr.

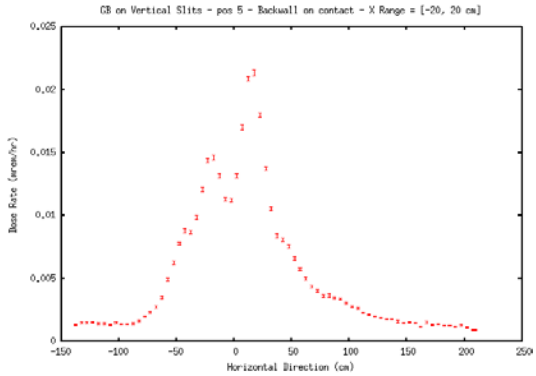


Figure 3.d.12: Neutron dose distribution at the back wall between x=[-20, 20 cm] on contact.

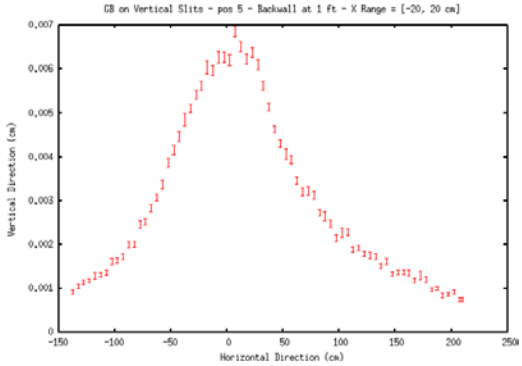


Figure 3.d.13: Neutron dose distribution at the back wall between x=[-20, 20 cm] at 30 cm.

3.e. GB on the Pinhole Mask.

As with the horizontal and vertical masks, the Pinhole Mask is a moveable item and hence is included only as an interaction device for the GB analyses. As such the mask was modeled strictly as a cylinder of copper. The interaction points studied for this report are shown in Figure 3.e.1 and a summary of the results is shown in Table 3.e.1. For this report the results from the GB striking Pos 2 (x= 6.3 cm, y= 0 cm, and z= 3006.8 cm) will be presented for the roof and side wall and from pos 5 (x= -0.7 cm, y= 0 cm, z= 3006.8 cm) for the back wall.

Table 3.e.1: Summary of GB analyses on the Pinhole Mask.

Pinhole Mask	**BW**	**Roof**	**SW**
Pos 1	0.06/0.04 at 30 cm	0.05	0.05
Pos 2	0.025	0.025	0.04
Pos 5	0.07/.02 at 30 cm	0.03	0.04
Pos 6	0.025	0.03	0.04

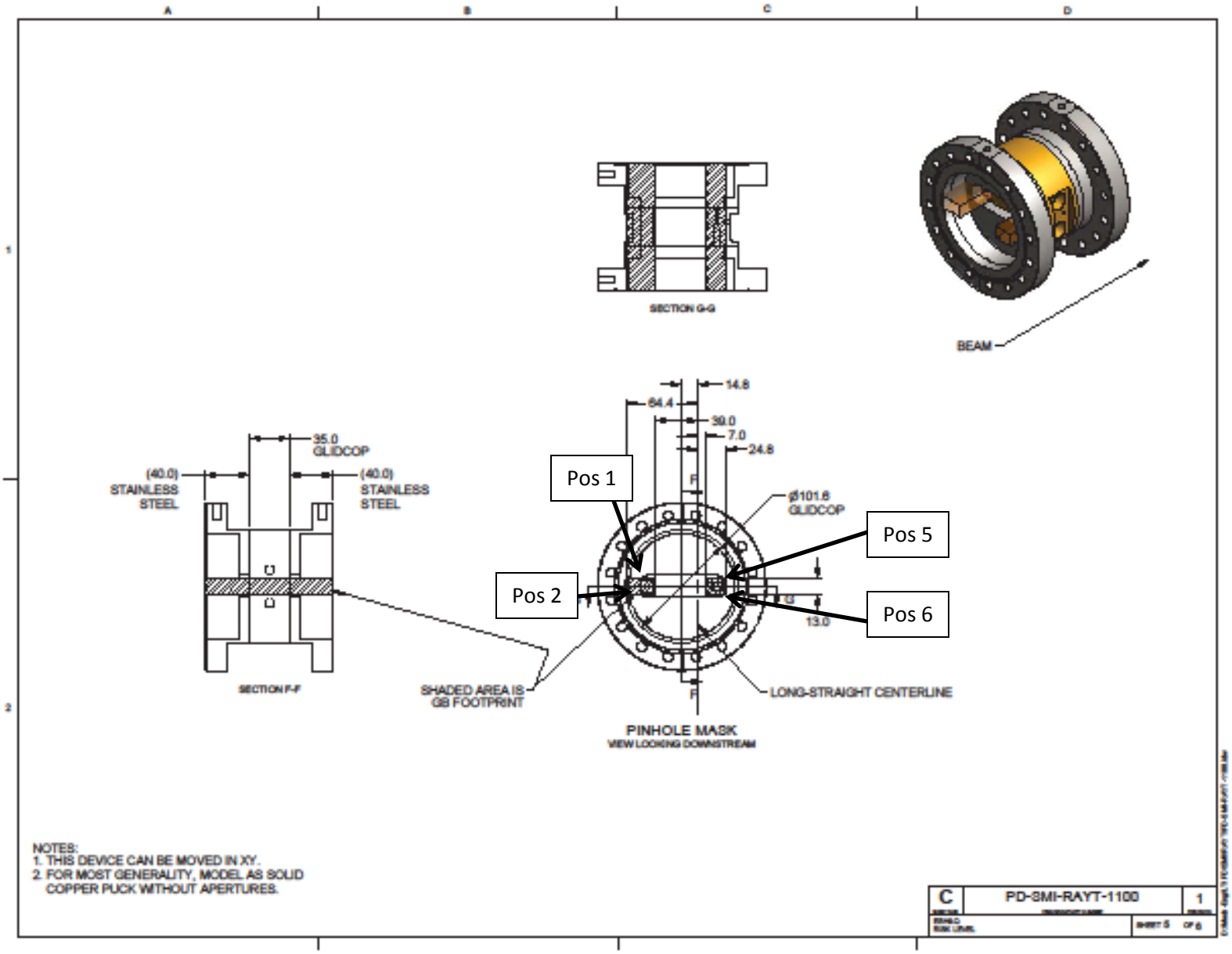


Figure 3.e.1: Positions on the Pinhole Mask Analyzed for this report.

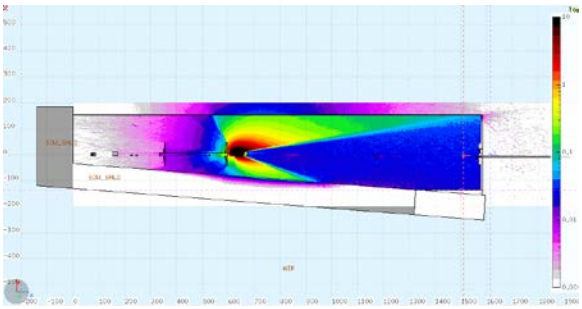


Figure 3.e.2: Dose distribution from the GB striking Position 2 - top view

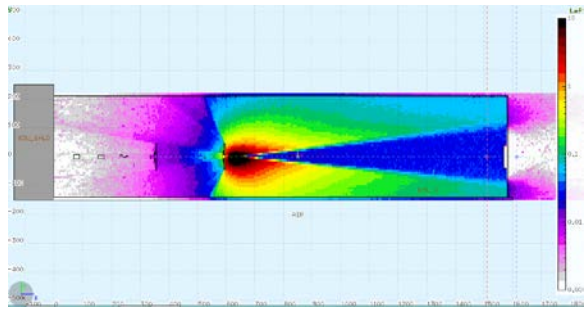


Figure 3.e.3: Dose distribution from the GB striking Position 2 - side view

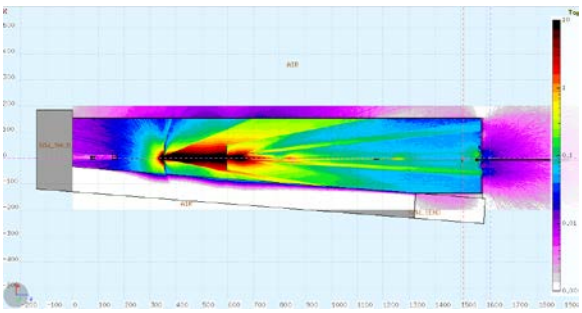


Figure 3.e.4: Dose distribution from the GB striking Position 5 - top view

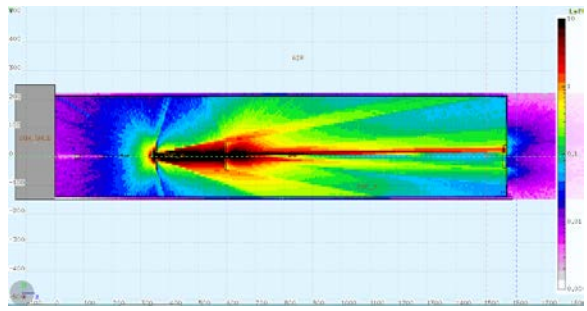


Figure 3.e.5: Dose distribution from the GB striking Position 5 - side view

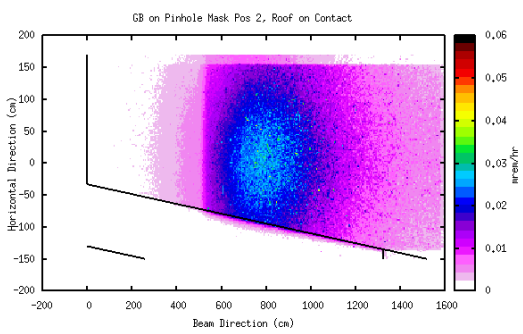


Figure 3.e.6: Radiation dose distribution on the roof on contact

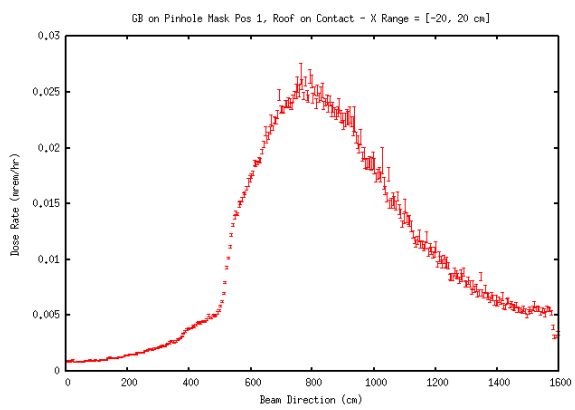


Figure 3.e.7: Radiation dose distribution on the roof on contact for an x range of -20 and +20 cm. The maximum is 0.04 mrem/hr

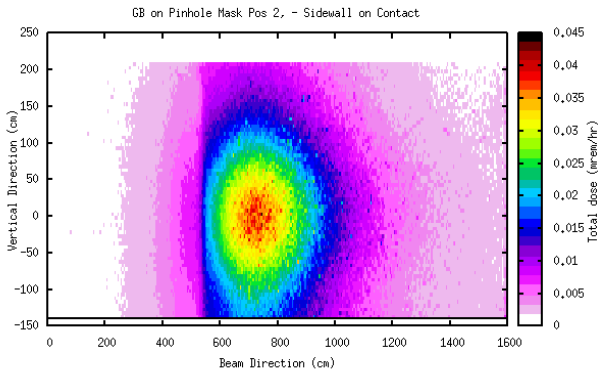


Figure 3.e.8: Radiation dose distribution at the side wall on contact.

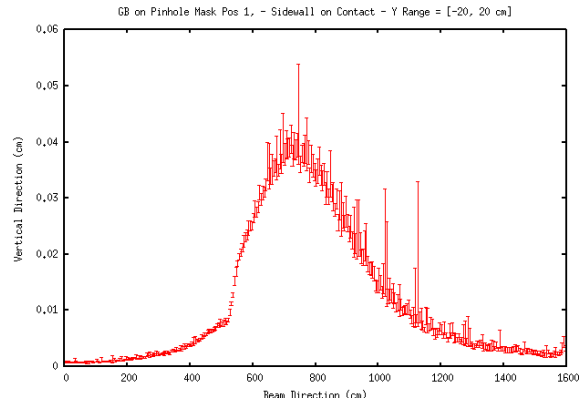


Figure 3.e.9: Radiation dose distribution on the side wall on contact for a y range of -20 and +20 cm. The maximum dose rate is 0.04 mrem/hr on contact.

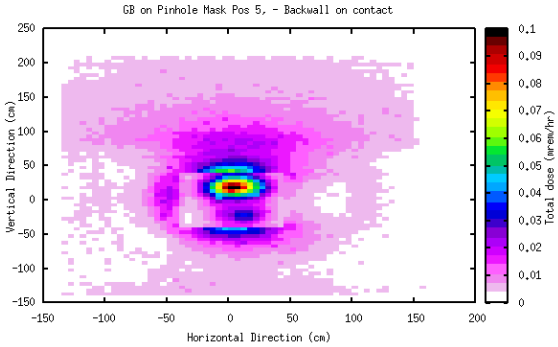


Figure 3.e.10: Radiation dose distribution at the back wall for Position 5 on contact.

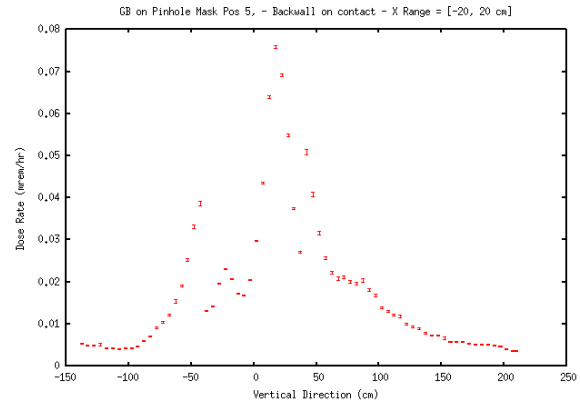


Figure 3.e.11: Radiation dose distribution at the back wall between x=[-20, 20 cm] on contact. The maximum dose rate is 0.11 mrem/hr on contact.

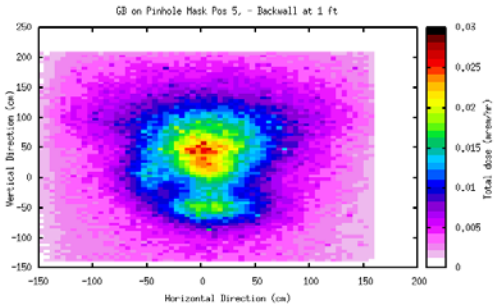


Figure 3.e.12: Radiation dose distribution at the back wall at 30 cm.

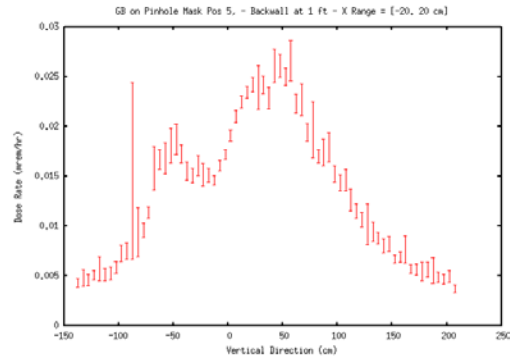


Figure 3.e.13: Radiation dose distribution at the back wall between x=[-20, 20 cm] at 30 cm. The maximum dose rate is 0.03 mrem/hr.

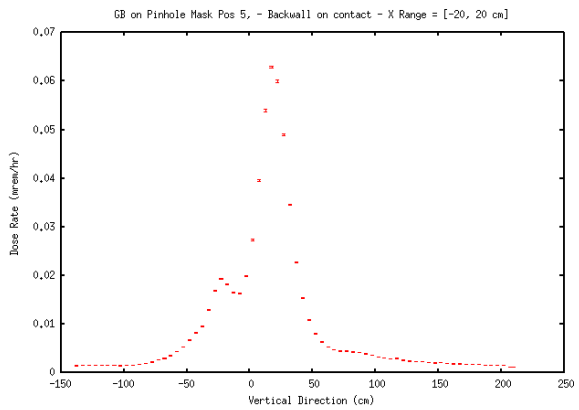


Figure 3.e.14: Neutron dose distribution at the back wall between x=[-20, 20 cm] on contact; maximum value is 0.09.

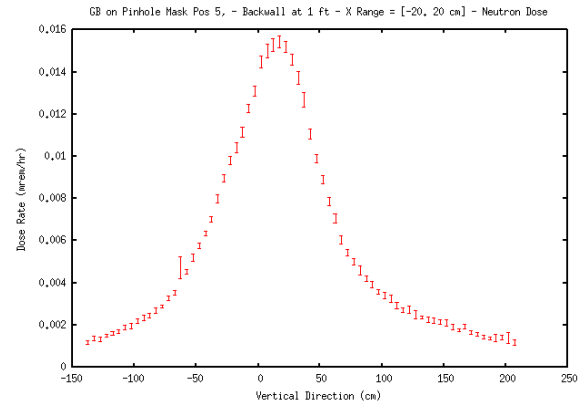


Figure 3.e.15: Neutron dose distribution at the back wall between x=[-20, 20 cm] at 30 cm; maximum dose rate is 0.016 mrem/hr.

3.f. GB on the Dual Crystal Monochromator (DCM)

The DCM is a rotatable device which is always in the beam while the beam line is being used. Figure 3.f.1 shows five locations on the DCM that were analyzed for the GB interactions. The DCM is a piece of silicon sandwiched between two pieces of copper. The GB strikes part of the copper on each side. Table 3.f.1 provides the summary of the GB analyses when it strikes each of the five points shown in Figure 3.f.1. The results from the GB striking the Lower Center of the DCM are presented (x= -1.9 cm, y= -0.8 cm, z=3198.05 cm). As with the horizontal slits, the angles are such that the residual radiation can pass through the lead shielding and under and around the GB stop.

Table 3.f.1: Summary of GB analyses on the DCM.

DCM	BW	Roof	SW
OBC	0.025	0.03	0.03
OBU	0.025	0.03	0.03
C	0.025	0.03	0.03
UC	0.03	0.04	0.03
LC	0.16/0.12 at 30cm	0.025	0.03

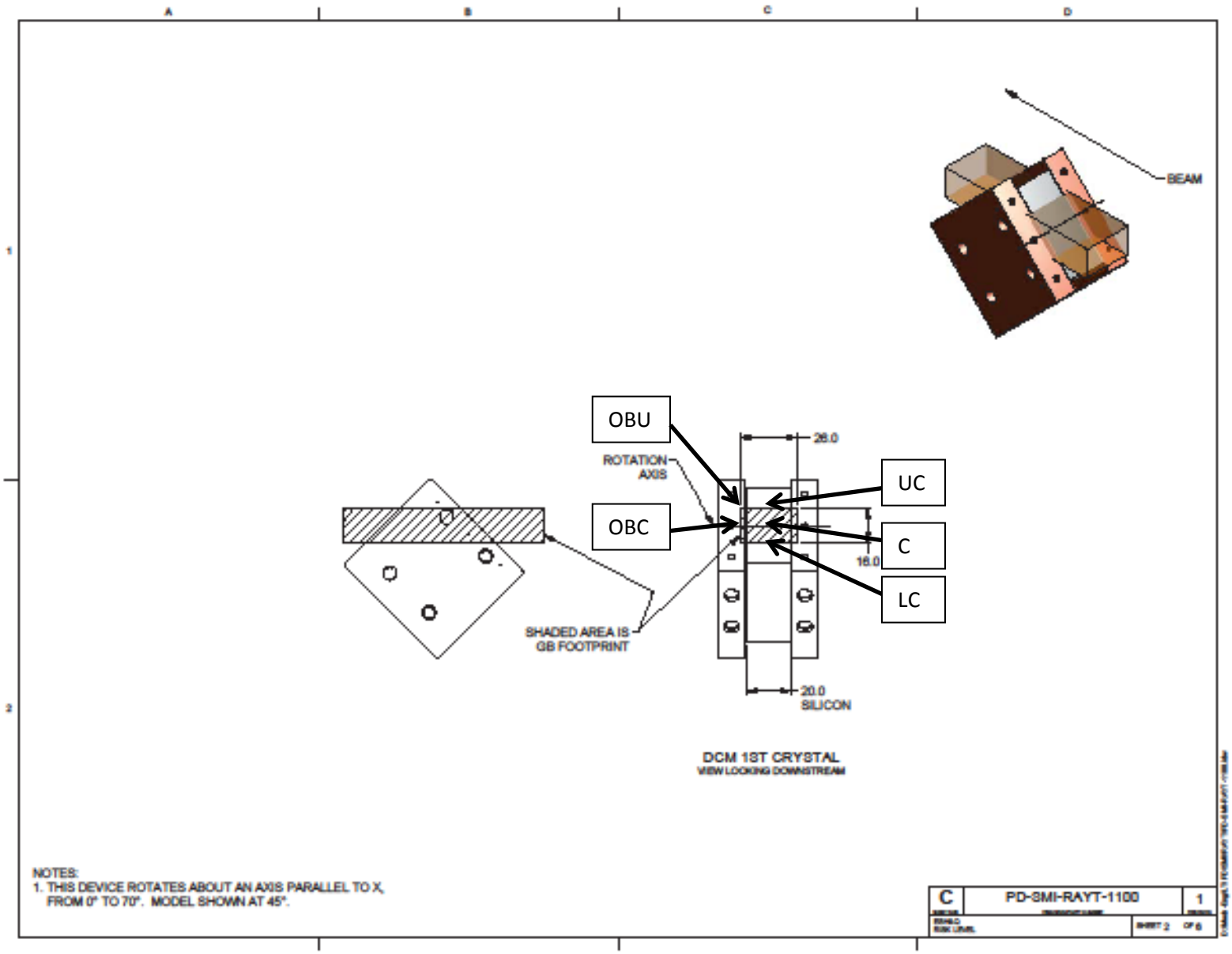


Figure 3.f.1: Location of five positions on the DCM that were analyzed for the GB interactions.

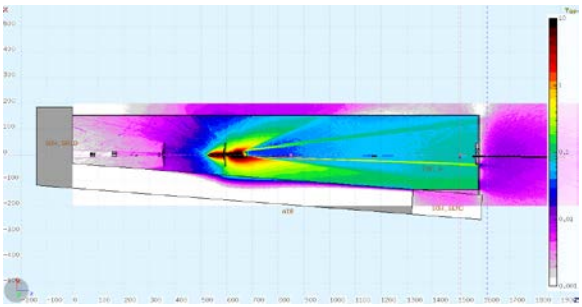


Figure 3.f.2: Dose distribution from GB striking the LC position - top view

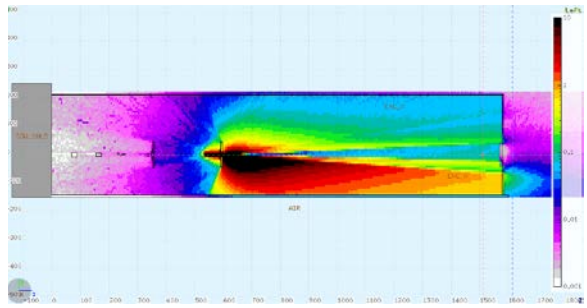


Figure 3.f.3: Dose distribution from GB striking the LC position - side view

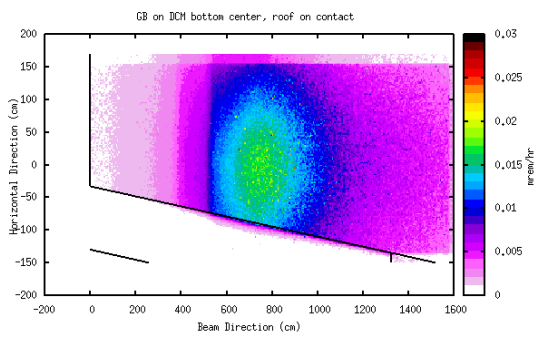


Figure 3.f.4: Radiation dose distribution on the roof on contact

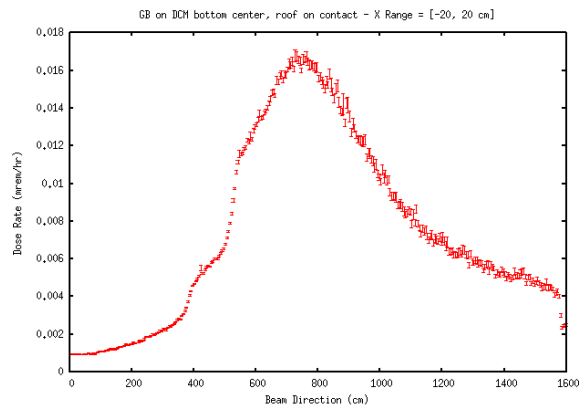


Figure 3.f.5: Radiation dose distribution on the roof on contact for an x range of -20 and +20 cm. The maximum is 0.03 mrem/hr

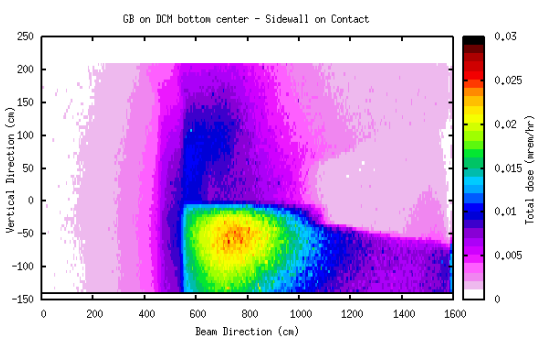


Figure 3.f.6: Radiation dose distribution at the side wall on contact

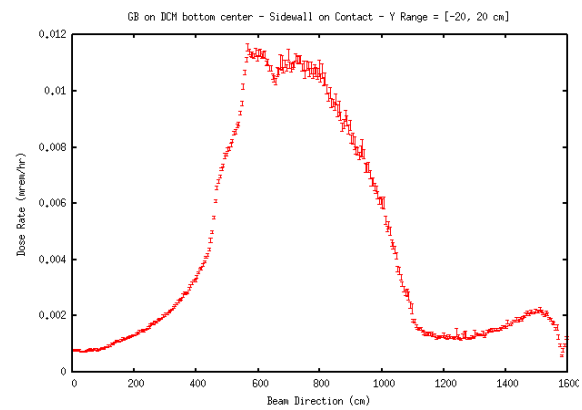


Figure 3.f.7: Radiation dose distribution on the side wall on contact for a y range of -20 and +20 cm. The maximum dose rate is 0.03 mrem/hr on contact.

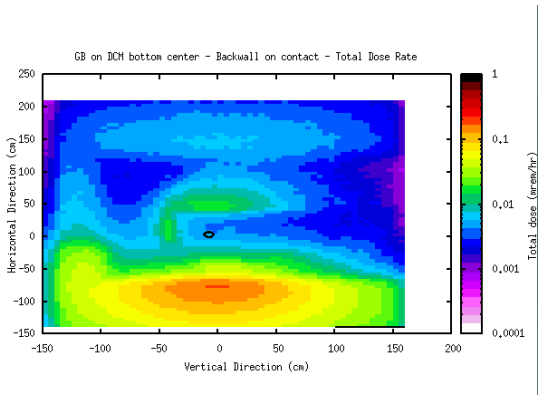


Figure 3.f.8: Radiation dose distribution at the back wall on contact.

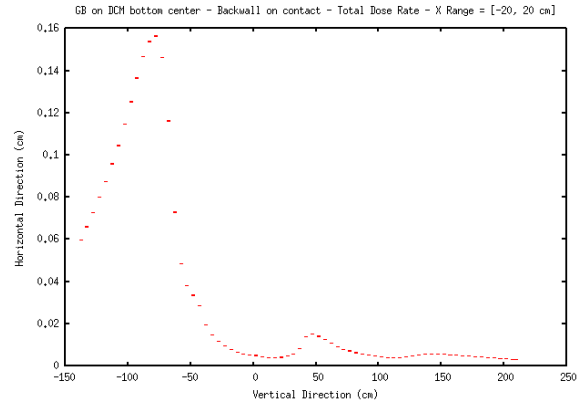


Figure 3.f.9: Radiation dose distribution at the back wall between x=[-20, 20 cm] on contact. The maximum dose rate is 0.16 mrem/hr on contact.

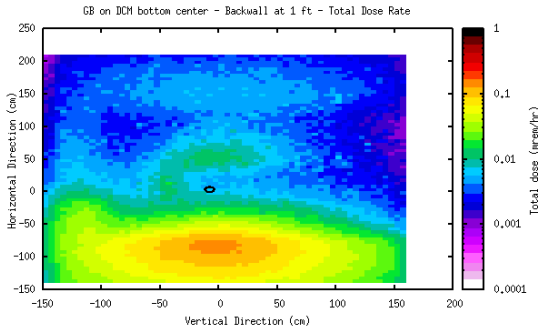


Figure 3.f.10: Radiation dose distribution at the back wall at 30 cm.

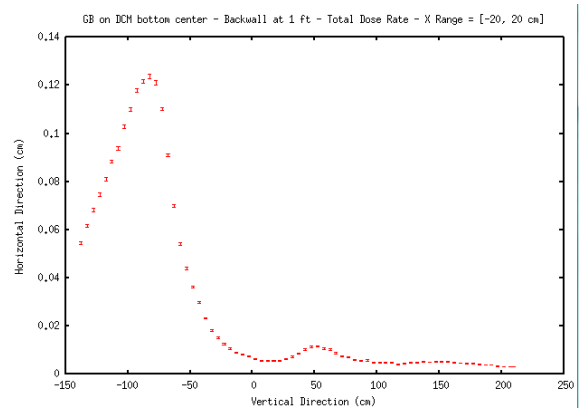


Figure 3.f.11: Radiation dose distribution at the back wall between x=[-20, 20 cm] at 30 cm. The maximum dose rate is 0.12 mrem/hr.

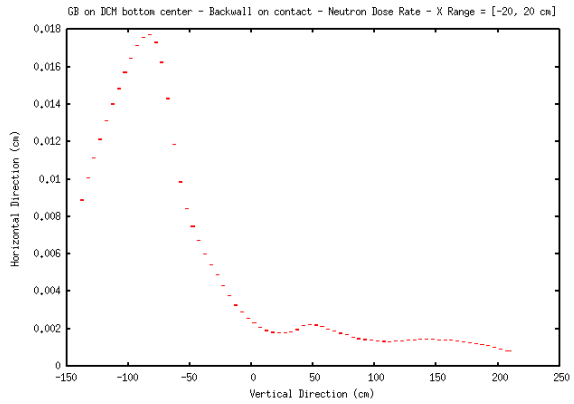


Figure 3.f.12: Neutron dose distribution at the back wall between x=[-20, 20 cm] on contact.

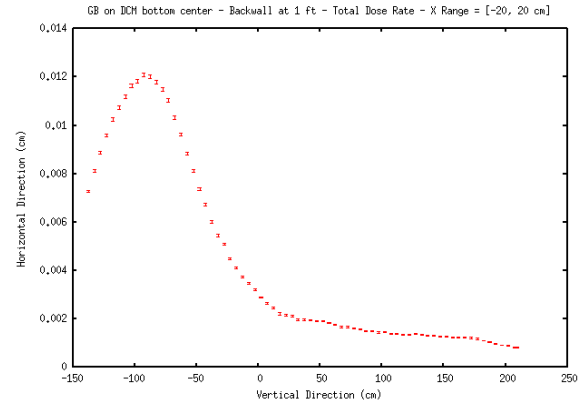


Figure 3.f.13: Neutron dose distribution at the back wall between x=[-20, 20 cm] at 30 cm.

3.g. GB on the White Beam Stop (WBS)

The WBS is a fixed device which stops any radiation that is not offset vertically by the DCM. It is a block of copper with a wedge shaped top. Figure 3.g.1 shows five locations on the WBS that were analyzed for the GB interactions. The GB strikes part of the copper on each side. Table 3.g.1 provides the summary of the GB analyses when it strikes each of the five points shown in Figure 3.g.1. The results presented will be for the OBC (x= 7.5 cm, y= 0 cm, z= 3282.2 cm) except for the roof which the results from position 5 for the roof.

Table 3.g.1: Analysis of GB on five locations on the WBS

WBS	BW	Roof	SW
OBC	0.11/0.06 at 30 cm	0.01	0.04
OBU	0.06/0.02 at 30 cm	0.04	0.04
Pos 3	0.06/0.02 at 30 cm	0.04	0.04
Pos 4	0.05	0.05	0.05
Pos 5	0.09/0.04 at 30 cm	0.05	0.05

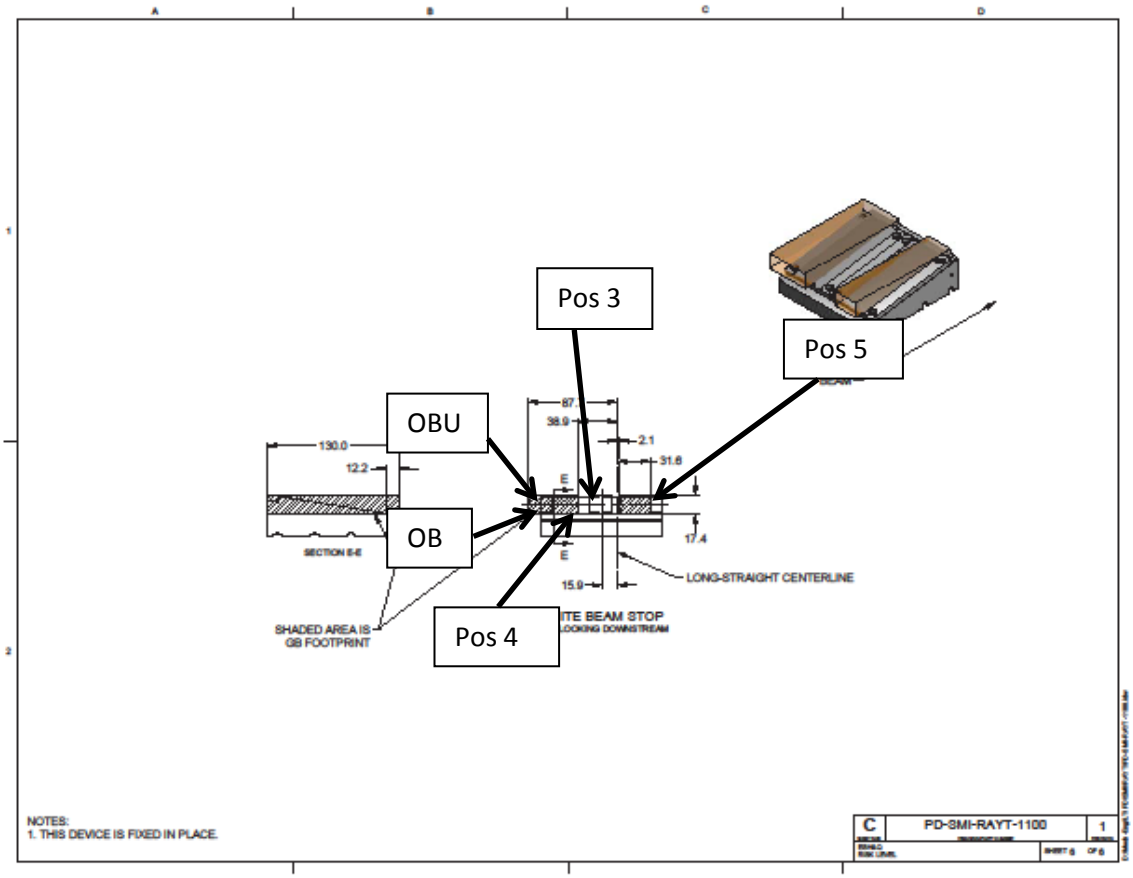


Figure 3.g.1: Five positions on the WBS used for the GB analyses.

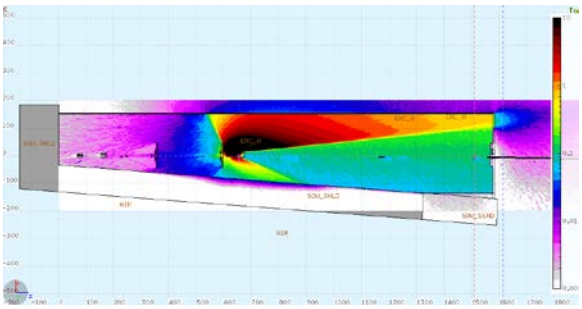


Figure 3.g.2: Dose distribution from GB striking the OBC position - top view.

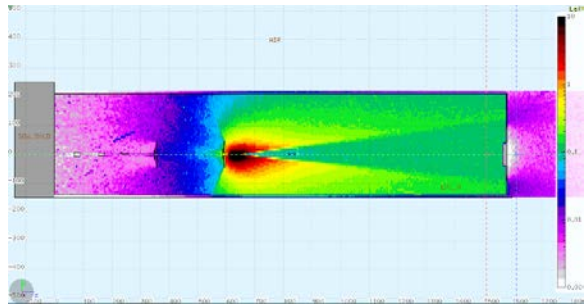


Figure 3.g.3: Dose distribution from GB striking the OBC position - side view.

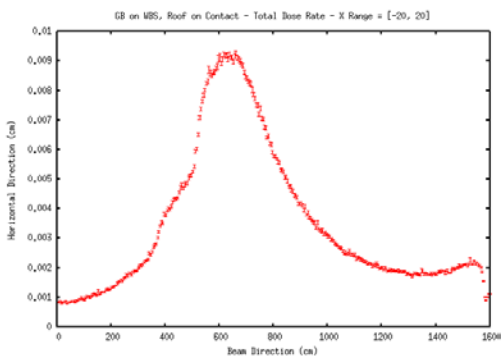


Figure 3.g.4: Radiation dose distribution on the roof on contact.

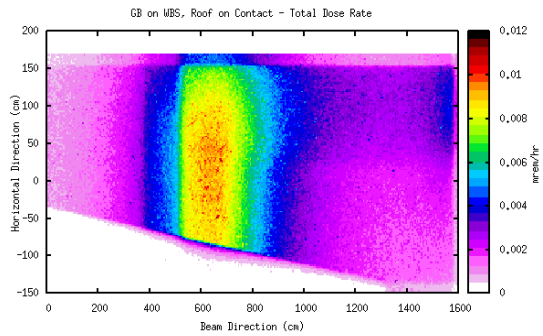


Figure 3.g.5: Radiation dose distribution on the roof on contact for an x range of -20 and +20 cm. The maximum is 0.01 mrem/hr.

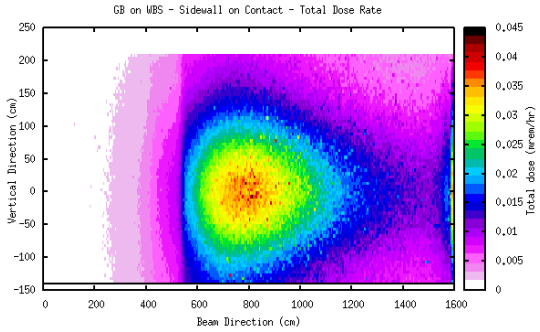


Figure 3.g.6: Radiation dose distribution at the side wall on contact.

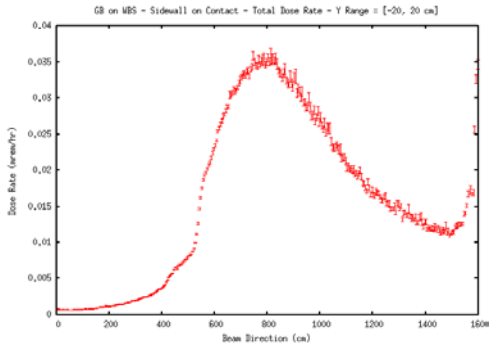


Figure 3.g.7: Radiation dose distribution on the side wall on contact for a y range of -20 and +20 cm. The maximum dose rate is 0.04 mrem/hr on contact.

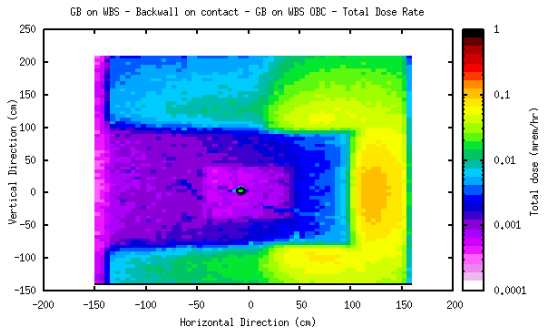


Figure 3.g.8: Radiation dose distribution at the back wall on contact.

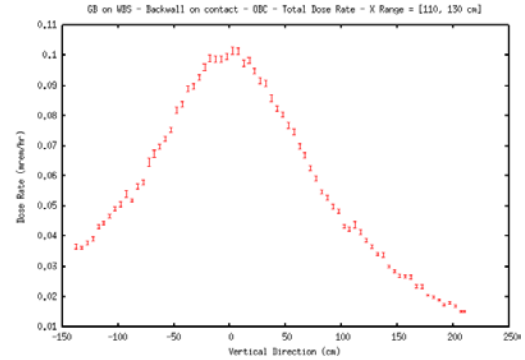


Figure 3.g.9: Radiation dose distribution at the back wall between x=[110, 130 cm] on contact. The maximum dose rate is 0.11 mrem/hr on contact.

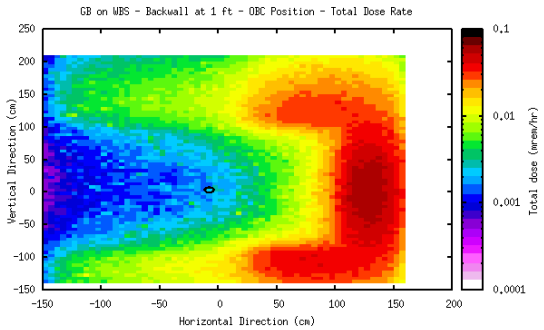


Figure 3.g.10: Radiation dose distribution at the back wall at 30cm.

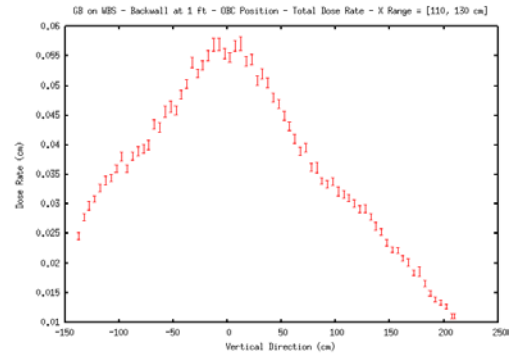


Figure 3.g.11: Radiation dose distribution at the back wall between x=[110, 130 cm] at 30cm. The maximum dose rate is 0.06 mrem/hr at 30cm.

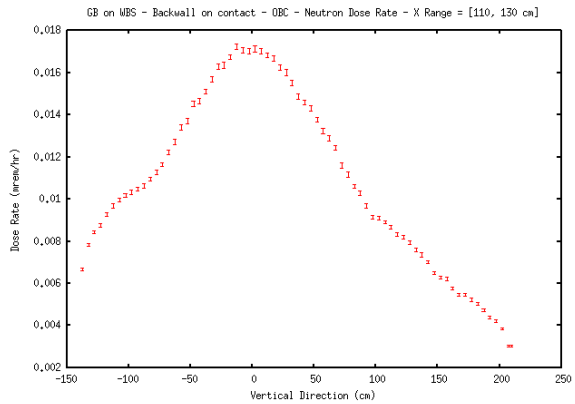


Figure 3.g.12: Neutron dose rate (Max. 0.018) distribution at the back wall on contact.

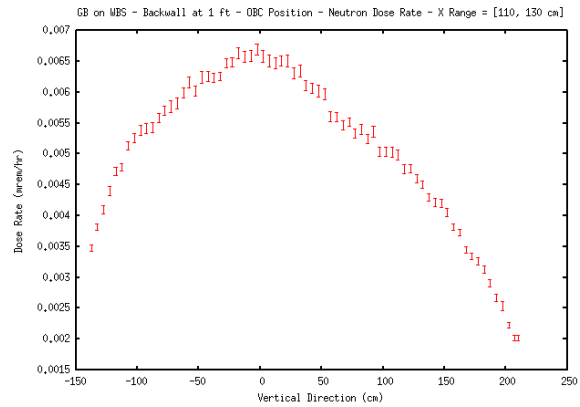


Figure 3.g.13: Neutron dose rate (Max. 0.007) distribution at the back between x=[110, 130 cm] wall at 30 cm.

3.h. GB on the Gas Bremsstrahlung Stop (GBS)

The GBS is a fixed device that is designed to stop the GB radiation from passing downstream within the FOE. It consists of a tungsten block of copper with two slits in it for the synchrotron radiation to pass through it. Figure 3.h.1 shows four locations on the GBS that were analyzed for the GB interactions and table 3.h.1 provides the summary of the GB analyses when it strikes each of those four points shown. The results presented will be for the OBU (x= 9.168 cm, y= 1.2 cm, z= 3326.8). All of the results are within the target dose rate.

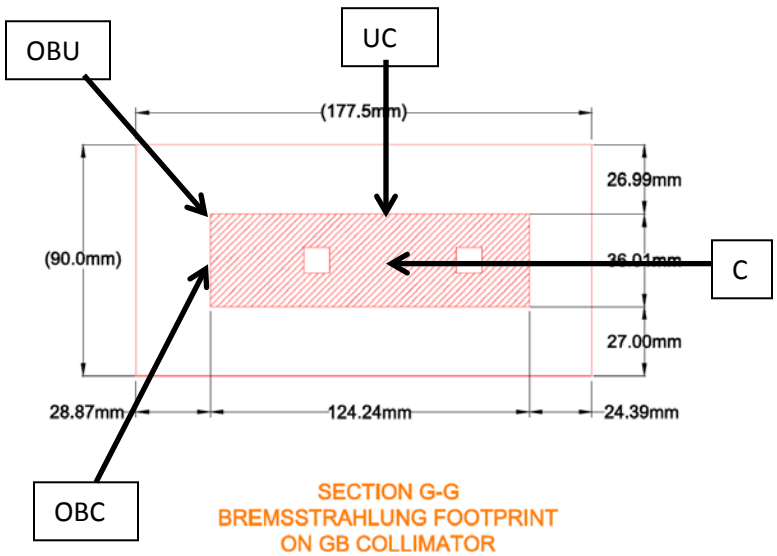


Figure 3.h.1: Four Selected Positions for the GB Collimator.

Table 3.h.1: Analysis of GB on five locations on the GBS

GBS	BW	Roof	SW
OBC	<0.01	0.03	0.045
OBU	<0.01	0.025	0.045
Center	<0.01	0.03	0.03
UpperCenter	<0.01	0.03	0.03

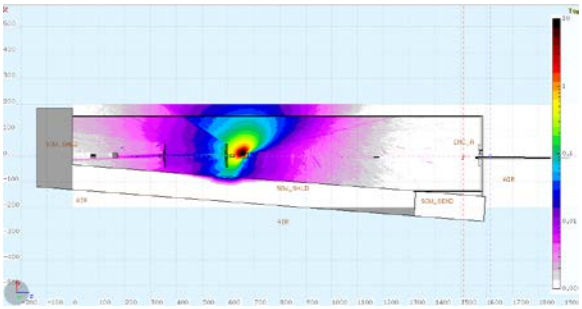


Figure 3.h.2: Dose distribution from GB striking the OBU position - top view.

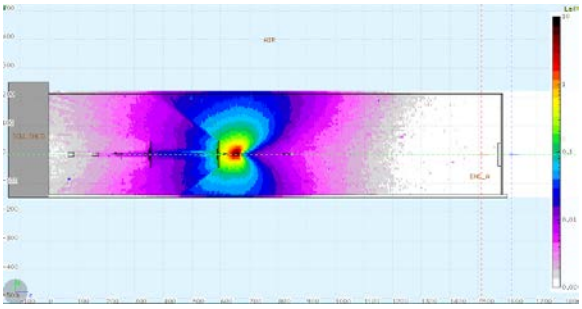


Figure 3.h.3: Dose distribution from GB striking the OBU position -- side view.

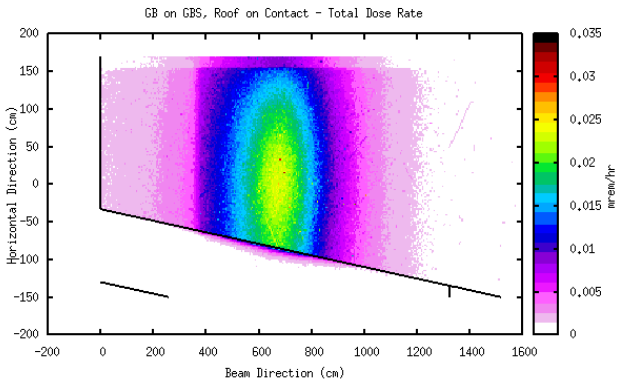


Figure 3.h.4: Radiation dose distribution on the roof on contact.

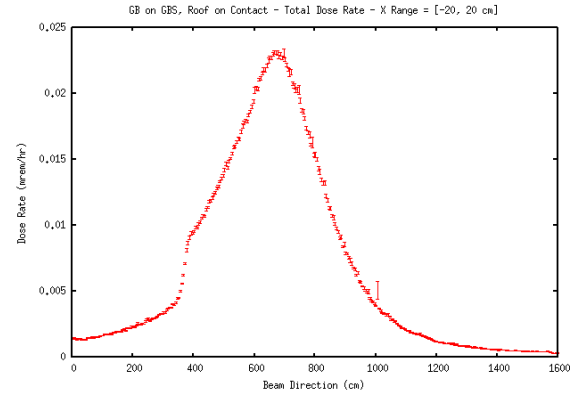


Figure 3.h.5: Radiation dose distribution on the roof on contact for an x range of -20 and +20 cm. The maximum is 0.025 mrem/hr.

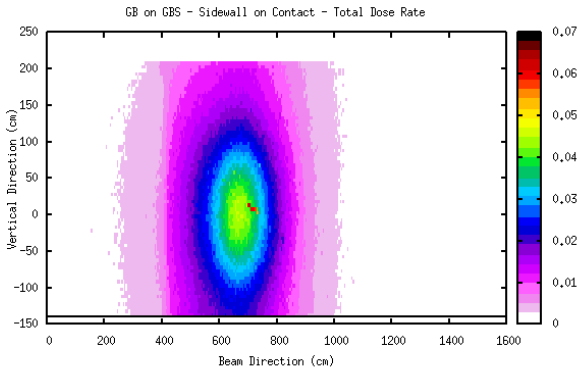


Figure 3.h.6: Radiation dose distribution at the side wall on contact.

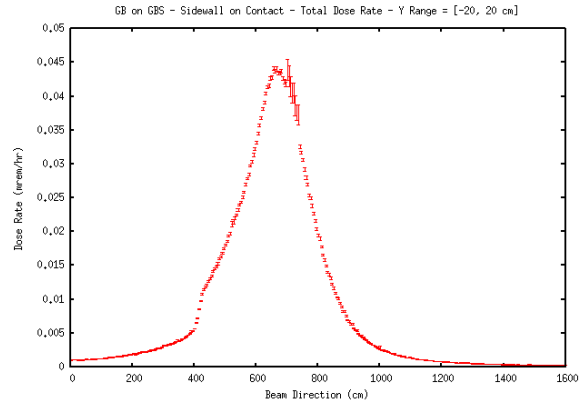


Figure 3.h.7: Radiation dose distribution on the side wall on contact for a y range of -20 and +20 cm. The maximum dose rate is 0.045 mrem/hr on contact.

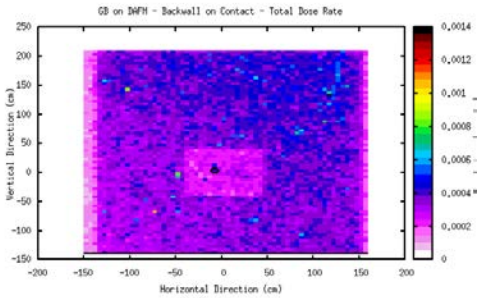


Figure 3.h.8: Radiation dose distribution at the back wall on contact. Maximum dose rate is <0.01 mrem/hr.

3.i. Final Survey

After the FLUKA simulations were completed a final survey of the 12ID-SMI FOE was completed. This survey showed the second lead shield was positioned 0.22 cm horizontally from the position assumed for the simulations. Three GB scatter locations were selected to determine whether the actual shield position would impact the results. The results are presented in Table 3.i and they indicate no significant difference in the calculated dose rate from the second lead shield being in either position.

Table 3.i

	DCM/LC		Hslits/pos2		Vslits/pos6	
	orig	final	orig	final	orig	final
Roof	0.017	0.017	0.025	0.025	0.022	0.022
Side Wall	0.012	0.012	0.02	0.02	0.018	0.018
Back Wall	0.16	0.16	0.37	0.36	0.1	0.1

4. Synchrotron Radiation Calculations

In the analysis of the synchrotron radiation, we consider white beam from the in-vacuum undulator source up to the white beam stop located in the middle of the FOE, and monochromatic beam through the transport pipe and downstream enclosures, which can be interlocked into two distinct shielding configurations for diagnostic and experimental operating modes.

12ID-SMI source parameters are given in Table 4.1. BSA document NX-C-XFD-RSI-001 (Version 5, 25 Nov. 2013) identifies the source and period length (In-Vacuum Undulator with 23mm period, IVU23), and the maximum field strength. Number of periods is obtained from Final Design Review documentation of BSA Contract 227859. The maximum horizontal source opening is obtained from Front End ray trace drawing SR-FE-IVU12-1001 Rev B. The NSLS-II stored electron beam parameters of Table 1 (Section 2 herein) have been used to calculate the critical energy and the total integrated power.

Table 4.1: Source parameters used for 12ID-SMI synchrotron calculations.

Source	Max. Source opening	No. of periods	Max. B_{eff} (T)	Period (mm)	E_c (keV)	STAC 8 Total Power (kW) @ 500mA
IVU23	0.5 mrad-H	116	0.95	23	5.7	7.5

The analytic code STAC8 [3] was used to calculate the ambient dose equivalent rates in the occupied areas outside beamline enclosures and transport pipes. The build-up factor in shielding was included in the calculation. However, the effect of SR polarization was not considered leading to the same shielding requirements for the lateral wall and roof provided the distance from the scatter target to dose point is the same. The shielding calculations assume that the bremsstrahlung has been completely stopped in the 12ID-SMI FOE.

Operating cases which could be considered as outside previously reviewed envelopes, along with one beam mis-steering case which is a plausible error condition, are labeled at their scattering target positions by numbers 1 through 6 in Figure 4.1. Figure 4.2 shows more detail for the cases in the B and B-1 hutches, where the canted beam path set targets at X values different from the straight centerline that defines X=0 in our coordinate system. These cases are considered in Section 4.a through 4.f herein. The first case, involving synchrotron white beam, uses STAC8 calculated spectrum up to maximum photon energy of 500 keV.

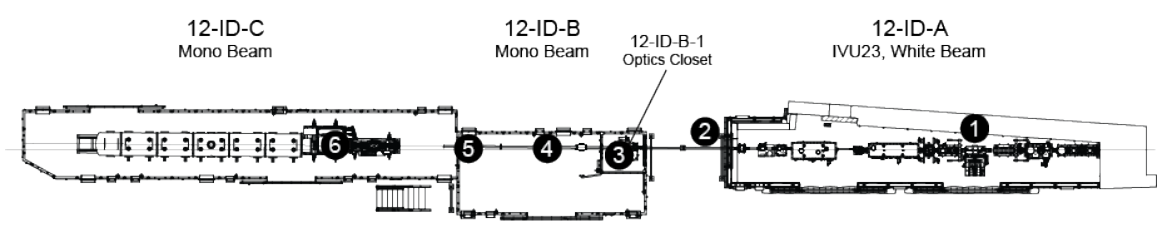


Figure 4.1. Graphical index of the list of operating cases. Numbered labels indicate the scattering target locations and are discussed in sections 4.a through 4.f

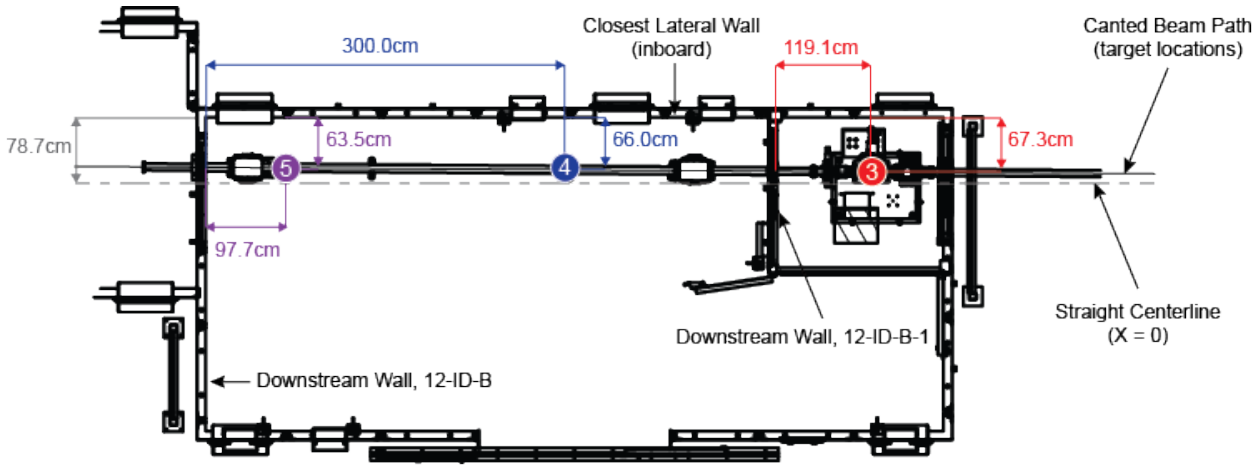


Figure 4.2. Illustration of the distances from target locations 3, 4, and 5 (red, blue, and purple respectively) to the inboard (closest) lateral wall and the downstream wall in 12-ID-B and 12-ID-B-1. Beam comes from the right. The canted beam path places targets further inboard than the straight centerline.

Cases in the mono beam end-stations involve reflections from the 3 Pt coated mirrors at incident angle of 0.18 degrees (most conservative assumption for high energy harmonics): horizontal focusing, vertical focusing, and vertical deflection [4]. The monochromatic energies and bandwidths are the same considered in [5] and are listed in Table 4.2 and the corresponding photon fluxes from zero, single, double, and triple mirror reflections.

Table 4.2: Monochromatic beam energies, bandwidths and corresponding photon flux at 500 mA including fluxes from single, double and triple mirror reflections.

Monochromatic Beam Energies (keV)	Bandwidths (keV)	Ph/s @ 500 mA	Ph/s @ 500 mA 1 Pt Mirror @ 0.18 deg	Ph/s @ 500 mA 2 Pt Mirrors @ 0.18 deg	Ph/s @ 500 mA 3 Pt Mirrors @ 0.18 deg
22.00	2.200E-03	3.792E+13	3.043E+13	2.442E+13	1.960E+13
66.00	5.300E-04	2.275E+09	4.654E+06	9.521E+03	1.948E+01
88.00	5.300E-04	4.247E+07	2.539E+04	1.518E+01	9.076E-03
110.00	1.300E-04	1.950E+05	4.605E+01	1.088E-02	2.569E-06
154.00	4.000E-05	2.341E+01	1.396E-03	8.324E-08	4.964E-12

4.a White beam at the double crystal monochromator (DCM) in 12-ID-A (Location 1)

The scattering target is assumed to be a silicon disk of 10 cm radius and 2 cm thick tilted at 0.155 degree with the respect to the incident beam [6]. The position of the scatter target is assumed to be located at SMI DCM approximately 1050.9 cm from the FOE downstream wall, 155.1 cm from the lateral wall (outboard) and 210.0 cm from the roof. Results are shown in Table 4.3.

Table 4.3: SR shielding design requirements for 12ID-SMI FOE.

	Distance (cm)	Required Shielding	Ambient Dose rate (mrem/h)
Lateral wall	155.1	5 mm Pb	0.0115
Roof	210.0	4 mm Pb	0.0411
Downstream Wall (> 1°)	1050.9	6 mm Pb	0.0418

The results show that the shielding thicknesses required for the gas-bremsstrahlung will largely shield for the scattered white beam radiation. Therefore the existing shielding thicknesses of the FOE walls and roof as given in Appendix 1 are more than adequate to meet the shielding design goal of 0.05mrem/h.

4.b Mono beam at shielded transport in walkway – error condition (Location 2)

After a single reflection from the Pt coated mirror, the monochromatic beam impinges on the pipe (5 mm Lead wrapped around a 2 mm thick steel pipe) at 4.6 mrad grazing angle. The effective shielding thickness through the transport pipe for this mono beam mis-steering case is 5 mm (Pb)/4.6E-03 = 1087 mm which is equivalent to 1087/14 ~ 78 monochromatic photon shutters. Therefore radiation dose are negligible for this case.

4.c Mono beam, 3 mirror reflections at 0.18°, at slit in 12-ID-B-1 (Location 3)

The scattering target is assumed to be a tungsten disk of 5 cm diameter and 0.2 cm thickness oriented normal to the incident beam [4]. Distances from the inboard lateral wall, roof, and downstream wall are tabulated below. The dose rates in the occupied areas on contact with the enclosure walls and roof are negligible.

Table 4.4: Maximum dose rate on lateral wall, roof and downstream wall.

	Distance (cm)	Existing Shielding	Ambient Dose rate (mrem/h)
Lateral wall	67.3	6 mm Fe	< 0.001
Roof	81.0	6 mm Fe	< 0.001
Downstream Wall (> 1°)	119.1	6 mm Fe	< 0.001

4.d Mono beam, 3 mirror reflections at 0.18°, at sample in 12-ID-B (Location 4)

The scattering target is assumed to be a silicon disk of 5 cm diameter and 0.2 cm thickness. Two operating cases can be envisioned, one with the sample oriented normal to the incident beam and one at grazing incidence [4]. Distances from the inboard wall, roof, and downstream wall are tabulated below. In either orientation of the target, the dose rates in the occupied areas on contact with the enclosure walls and roof are negligible.

Table 4.5: Maximum dose rate on lateral wall, roof and downstream wall.

	Distance (cm)	Existing Shielding	Ambient Dose rate (mrem/h)
Lateral wall	66.0	6 mm Fe	< 0.001
Roof	247.0	6 mm Fe	< 0.001
Downstream Wall (> 1°)	300.0	6 mm Fe	< 0.001

4.e Mono beam, 3 mirror reflections at 0.18°, at removable beam stop block 12-ID-B (Location 5)

The scattering target is a lead block of dimensions X=19.4cm, Y=21.2cm, and Z=2.5cm as given in Table 2 of Appendix 1. Beam strikes the block at normal incidence. Distances from the inboard wall, roof, and downstream wall are tabulated below. The dose rates in the occupied areas on contact with the enclosure walls and roof are negligible.

Table 4.6: Maximum dose rate on lateral wall, roof and downstream wall.

	Distance (cm)	Existing Shielding	Ambient Dose rate (mrem/h)
Lateral wall	63.5	6 mm Fe	< 0.001
Roof	247.0	6 mm Fe	< 0.001
Downstream Wall (> 1°)	97.7	6 mm Fe	< 0.001

4.f Mono beam, 3 mirror reflections at 0.18°, at sample in 12-ID-C (Location 6)

The scattering target is assumed to be a silicon disk of 5 cm diameter and 0.2 cm thickness. Two operating cases can be envisioned, one with the sample oriented normal to the incident beam and one at grazing incidence. Since lateral wall distances are > 100 cm , roof distance is 247.0 cm, and downstream wall distance is > 1300 cm, doses are less than was the case for the same sample in case 4.d at Location 4 and therefore negligible.

5. Summary and Conclusions

For SMI, as for other beamlines at the NSLS-II, the shielding requirements are driven by gas bremsstrahlung (GB) radiation striking components in the First Optical Enclosure (FOE) and by "topoff" radiation. The calculated dose rate for the GB striking the components are presented in this Tech Note and the results from the "topoff" radiation are the subject of a subsequent Tech Note. There are eight components of the SMI beamline that can be struck with GB radiation, as listed in Table 5.1 and each component was modeled with the GB interacting at multiple locations. The locations that resulted in the highest levels of radiation were selected for further analyses. A total of 25 locations were selected for the analyses presented in this report. A summary of the maximum calculated dose rates from these 25 locations are presented in Table 5.1 for the GB striking each component that could have direct interactions with the GB.

Table 5.1: Summary of FLUKA simulations

		Maximum dose rate (mrem/hr)		
	Simulation GB incident on the:	Roof on Contact	Sidewall on Contact	Backwall on Contact/@30 cm
1	Dual Aperture Fixed Mask (DAFM)	<0.05	<0.05	<0.05
2	Gas Bremsstrahlung Collimator (GBC)	<0.05	<0.05	<0.05
3	Horizontal Slits	~0.05	<0.05	~0.4/~0.16
4	Vertical Slits	<0.05	<0.05	~0.06/<0.05
5	Pinhole Mask	~0.05	~0.05	~0.07/<0.05
6	Dual Crystal Monochromator (DCM)	<0.05	<0.05	~0.16/~0.12
7	White Beam Stop (WBS), OBC	~0.05	~0.05	~0.11/~0.06
8	Gas Bremsstrahlung Shield (GBS), OBU	<0.05	<0.05	<0.05

Of the eight components studied here, four are movable, the Horizontal Slits, the Vertical Slits, the Pinhole Mask and the DCM, and the other four are fixed. For the transport of the GB radiation, only the DCM was included since the other items can be completely removed from the beam path. The DCM changes angle, but is always in the beam. The slits and the Pinhole Mask were included in the model as scattering points only.

The dose rates for the roof and side wall on contact never exceeded 0.05 mrem/hr but in several instances, the dose rate at the back wall exceeded 0.05 mrem/hr on contact but was within 0.5 mrem/hr. As far as the GB interactions are concerned, there is no indication of any additional shielding for the 12ID-SMI FOE.

Based on the STAC8 calculations, the dose rates outside the enclosures and beam transport pipe are consistent with the NSLS-II shielding policy for normal operating conditions as well as mis-steering monochromatic beam events.

All shielding simulations should be validated by comparisons with measurements of the dose rates near the walls of the FOE, the beam transport pipe and the mono beam enclosures during commissioning.

6. References

[1] LT-C-ESH-STD-001, Guidelines for the NSLS-II Beamline Radiation Shielding Design, November 7, 2014.

[2] NSLS-II Issue and Decision Paper: ALARA Analysis for Installations of Secondary Bremsstrahlung Shields in the First Optics Enclosure, R. Lee, PS-C-ESH-STD-005 (06/01/2016).

[3] Y. Asano and N. Sasamoto, "Development of shielding design code for synchrotron radiation beamline," Radia. Phys. Chem. 44 (1994) 133. Y. Asano, "A study on radiation shielding and safety analysis for a synchrotron radiation beamline," JAERI-Research-2001-006, March 2001.

[4] Private communication with E. DiMasi.

[5] Z. Xia, "SMI 12-ID-B Hutch Design Shielding Review", Radiation Safety Memo dated May 13, 2014. NSLS-II Tech Note 147.

[6] Z. Xia and W.-K. Lee, "Attenuation of Scattered Monochromatic Synchrotron Radiation in Iron and Lead", NSLS-II TN145 (09/16/2014). See page 26.

7. Acknowledgements

E. DiMasi (SMI Beamline Lead Scientist), D. S. Coburn (SMI Beamline Mechanical Engineer), and Christopher J. Stelmach (NSLS-II Design Engineer) contributed to this report.

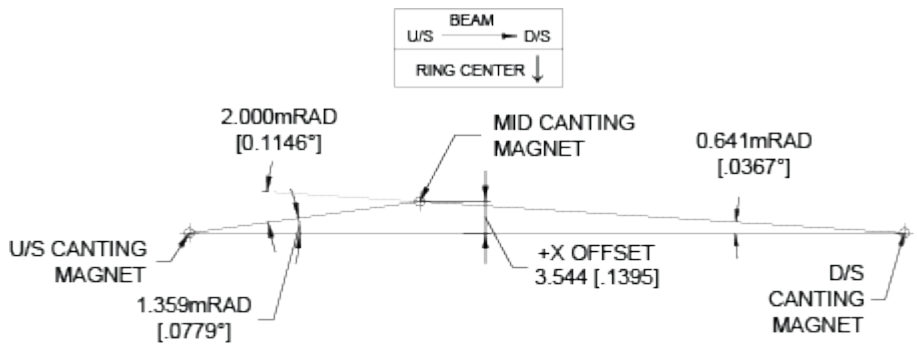
APPENDIX 1

12ID, Soft Matter Interfaces (SMI) Beamline Model Input: 22 July 2016

Coordinate system

The Z axis lies along the long straight centerline. The positions (Z coordinates) of the components are defined with respect to the center of the straight. SMI is an asymmetrically canted beamline with the installed 2.8m IVU23 source d/s canted i/b, and provisions for a future upgrade with a 1.5m source u/s canted o/b.

Installed IVU23 reference: SR-ID-SMI-IVU-1000 Rev.B. Figure below shows detail of canting angles from that document. The installed IVU23 is located at Z=0.600m. Reference the 12-ID front end raytracing, SR-FE-IVU12-1001 Rev.B for Front End coordinates and components. For 12-ID synchrotron and GB fans, reference beamline raytracing, PD-SMI-RAYT-0001.

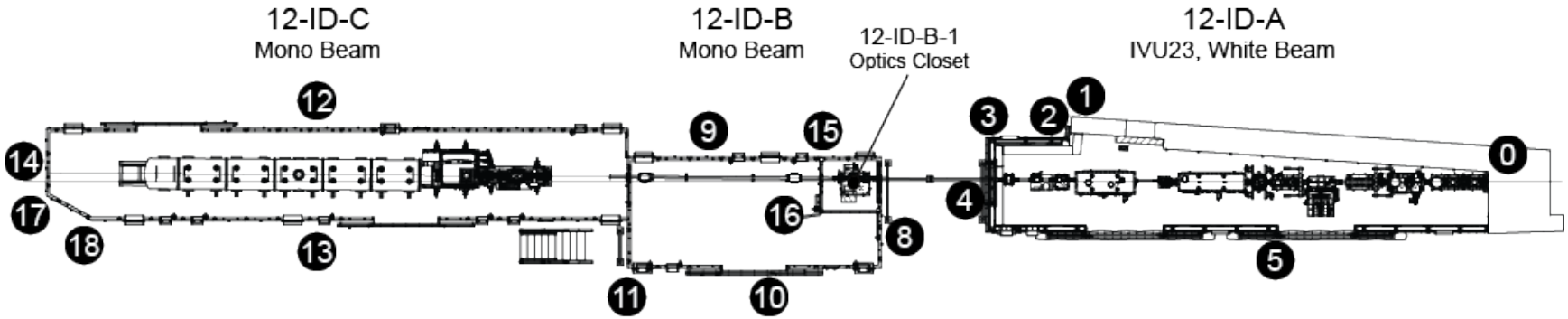


DETAIL E - CANTING ANGLE SCHEMATIC
SCALE: NONE
NOTE: ANGLES ARE NOT TO SCALE AND SHOWN FOR ILLUSTRATION ONLY

The 12ID 2.8m IVU23 source is identical to the source for beamlines 4ID and 16ID, modeled by NSLS-II.

Beamline Enclosures

SMI brings white beam into the First Optics Enclosure, Hutch 12-ID-A. All GB is expected to be stopped and shielded in 12-ID-A. SMI uses monochromatic beam in Hutches 12-ID-B and 12-ID-C, as shown below.



Beamline enclosure information is provided for the modeling of white synchrotron beam, mono synchrotron beam, primary GB, and seconday GB in 12-ID-A, and mono synchrotron beam in 12-ID-B and 12-ID-C.

Inside 12-ID-B is an “Optics closet” with interlocked doors. This enclosure designated 12-ID-B-1 is also to be analyzed for mono beam shielding as described further below. Guillotines and inboard beam penetrations are tabulated with the beamline transport pipe. Outboard beam penetrations are plugged with shielding equivalent to the respective wall shielding. Beam stops are tabulated with the components.

Table 1. Beamline Enclosures

Wall	Position (mm)	Thickness	Material
(0) Ratchet Wall U/S I/B corner	X= -331 Z=26717	n/a	n/a
(1) D/S End of 12-ID-A Ratchet Wall	X= -1491 Z=39993	n/a	n/a
(2) U/S End of 12-ID-A Inboard Wall	X= -1351 Z= 39993	18 mm	Lead
(3) D/S End of 12-ID-A Inboard Wall	X= -1351 Z= 42500		
(4) Plane of 12-ID-A Downstream Wall	Z= 42500	50 mm	Lead
(5) Plane of 12-ID-A Outboard Wall	X= 1532	18 mm	Lead
(6) FOE Roof relative to orbit plane	Y > 2100	10 mm	Lead
(7) All Floors relative to orbit plane	Y= -1400	n/a	n/a
(8) Plane of 12-ID-B Upsteam Wall	Z= 46000	6 mm	Steel
(9) Plane of 12-ID-B Inboard Wall	X= -787	6 mm	Steel
(10) Plane of 12-ID-B Outboard Wall	X= 2713	6 mm	Steel
(11) Plane of shared wall (-B D/S, -C U/S)	Z= 54000	6 mm	Steel
(12) Plane of 12-ID-C Inboard Wall	X= -1688	6 mm	Steel
(13) Plane of 12-ID-C Outboard Wall	X= 1212	6 mm	Steel
(14) Plane of 12-ID-C Downstream Wall	Z= 72362	6 mm	Steel
(15) Plane of 12-ID-B-1 Closet D/S Wall	Z= 47950	6 mm	Steel
(16) Plane of 12-ID-B-1 Closet O/B Wall	X= 953	6 mm	Steel
(17) Chamfer Coordinate	X= 430 Z=72362	6 mm	Steel
(18) Chamfer Coordinate	X= 1212 Z=70940	6 mm	Steel

(19) 12-ID-B, 12-ID-C ceiling rel. to orbit	Y > 2500	6 mm	Steel
(20) 12-ID-B-1 ceiling rel. to orbit plane	Y > 835	6 mm	Steel

Beam Transport

SMI has standard fixed shielded beampipe (steel tubing with wrapped lead shielding) in the walkway between 12-ID-A and 12-ID-B-1 (Fixed Shielded Beam Pipe A). SMI has constructed two different configurations to bring beam into and through 12-ID-B, via the Optics Closet 12-ID-B-1. Pipe sections are joined within shielded boxes equivalent to the shielding of the pipes.

In the Standard Configuration, beam travels into 12-ID-B-1, interacts with optical components, and from there through Fixed Shielded Beam Pipe B, Removable Shielded Beam Pipe, and Fixed Shielded Beam Pipe C. These three beam pipes bring beam from 12-ID-B-1, through 12-ID-B, to 12-ID-C. Experiments are performed in 12-ID-C, with 12-ID-B-1 and 12-ID-C interlocked. Analysis must show that it is safe to walk into 12-ID-B, just as if one walks in any experimental floor walkway.

In the Diagnostic Configuration, the Removable Shielded Beam Pipe is un-installed. In a downstream location in 12-ID-B along the inboard beam path, a Removable Beam Stop Block is installed. Diagnostic experiments are performed in 12-ID-B, with 12-ID-B-1 and 12-ID-B interlocked. Analysis must show that it is safe to walk into 12-ID-C, just as if one walks downstream of any operating experimental hutch.

Table 2. Beamline Transport Pipes

Component	**Location (mm)**	**Apertures or dimensions (mm)**	**Material**
Fixed Shielded Beam Pipe A	U/S penetration center (12-ID-A): X= -72.6, Y= 29.4, Z= 42500 D/S penetration center (12-ID-B): X= -96.9, Y= 29.4, Z= 46000	Inner Diameter: 68	Shielding: 5 mm Lead + 2mm steel tubing

Guillotine, 12-ID-A D/S Wall	Stack of movable lead sheets: Top edge: Y= 400.4 Bottom edge: Y= -399.6 I/B edge: X= -384 O/B edge: X= 456 Penetration location: I/B: X= -72.6, Y= 29.4 O/B: X= 143.1, Y= 29.4 (plug) Penetration diameter: 68	Thickness: 100. Note: Holes in fixed walls of the hutch, per as-built inspection: I/B: X= -76.9, Y= 38 O/B: X=138.8, Y= 35 Diameter: 178 (both)	Material: Lead
Fixed Shielded Beam Pipe B	U/S penetration (12-ID-B-1): X= -110.4, Y= 29.4, Z= 47950 D/S penetration (shield box): X= -114.0, Y= 29.4, Z= 48477	Inner Diameter: 68	Shielding: 5 mm Lead + 2mm steel tubing
Removable Shielded Beam Pipe	U/S penetration (shield box): X= -114.0, Y= 29.4, Z= 48477 D/S penetration (shield box): X= -146.7, Y= 29.4, Z= 53199	Inner Diameter: 68	Shielding: 5 mm Lead + 2mm steel tubing

Fixed Shielded Beam Pipe C	U/S penetration (shield box): X= -146.7, Y= 29.4, Z= 53199 D/S penetration (shield box): X= -152.3, Y= 29.4, Z= 54000	Inner Diameter: 68	Shielding: 5 mm Lead + 2mm steel tubing
Removable Beam Stop Block	Location of center of U/S face: X= -146.6, Y= +5.65, Z= 53023	Dimensions: 194(X) ×212(Y) ×25(Z)	Material: Lead
12-ID-C Beam Stop (standard)	Location of center of U/S face: X= -277, Y= 37	Dimensions: 300(X) ×300(Y) ×25(Z)	Material: Lead

12-ID-A Beamline Components

Beamline components are tabulated here for 12-ID-A, pertinent to Synchrotron white beam/max fan, primary GB, and secondary GB analysis. See figure below and Table 3. See also NSLS-II Tech Note 147 (2014). The Z axis lies along the long straight centerline. The positions (Z coordinates) of the components are defined with respect to the center of the straight.

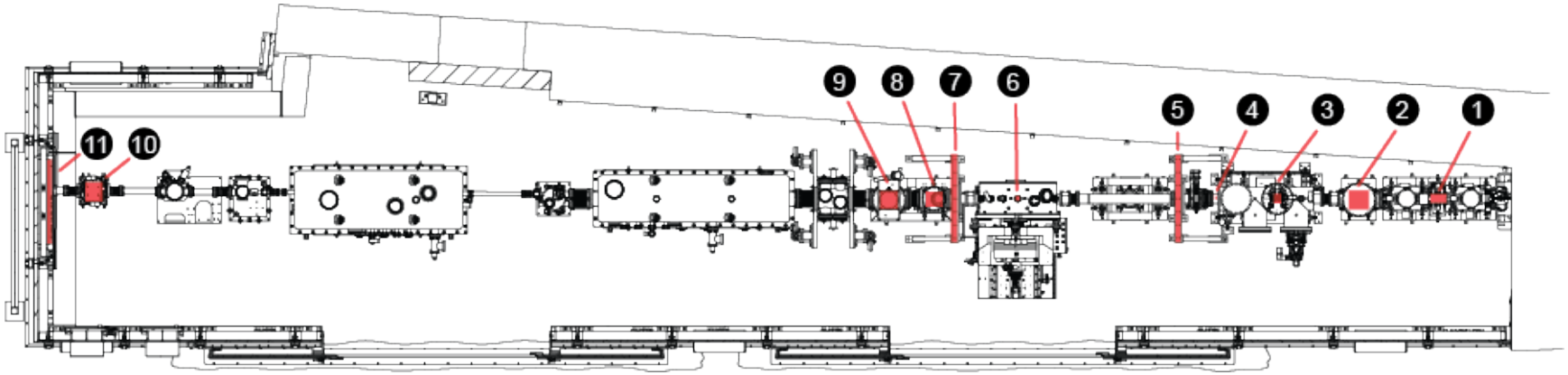


Table 3. Beamline Components and SGB shields. Further info is given in figures and comments following.

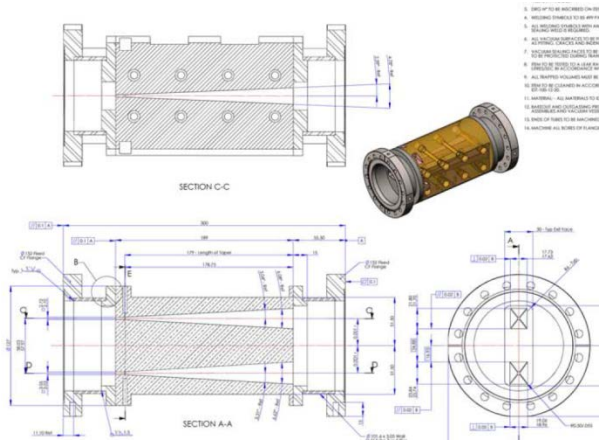
Component	Location Z of Upstream Face (mm)	Dimensions		X,Y Location (mm)	Material	Associated Drawings
		Outer dimensions (W)×(H)×(L)(mm)	Aperture (W)x(H) or (Diameter)(mm)			
(1) Dual Aperture Fixed Mask	27406	Cylinder w/ axis along Z: Dia. 127 Length 188	Two tapered apertures, asymmetric. Size U/S: I/B: 21.8(X)× 17.8(Y) O/B: 23.8(X)× 19.0(Y) Size D/S: I/B: 2.7(X)× 2.7(Y) O/B: 3.2(X)× 3.1(Y)	Block center: X= 13.9, Y= 0 I/B aperture center loc U/S: X= -14.9, Y= 0 O/B aperture center loc U/S: X= 42.7, Y= 0 I/B aperture center loc D/S: X= -15.1, Y= 0 O/B aperture center loc D/S: X= 43, Y= 0	CuCrZr (Copper)	PD-SMI-BL-LAY-1011, PD-SMI-BL-LAY-1015. Apertures from presurvey report
(2) Bremsstrahlung Collimator	28248	177.50mm (X) × 90mm (Y) × 206mm (Z)	Two rectangular apertures I/B: 10mm(X) × 10mm(Y) O/B: 10mm(X) × 10mm(Y)	Block center: X= 25.5, Y= 0 I/B aperture center loc: X= -15.4 , Y= 0 O/B aperture center loc: X= 43.9, Y= 0	Tungsten	PD-SMI-BL-LAY-1012, PD-SMI-BL-LAY-1016 Apertures checked by survey
(3a) White Beam Slit (H,I/B)	28953	Model blade as 25mm(X) × 50mm(Y) × 80mm(Z)	n/a	Block center: X= -15.4, Y= 0	Glidcop (Copper)	See details below

(3b) White Beam Slit (H, O/B)	29018	Model blade as 25mm(X) × 50mm(Y) × 80mm(Z)	n/a	Block center: X= -15.4, Y= 0	Glidcop (Copper)	See details below
(3c) White Beam Slit (V, top)	29213	Model blade as 50mm(X) × 25mm(Y) × 80mm(Z)	n/a	Block center: X= -15.4, Y= 0	Glidcop (Copper)	See details below
(3d) White Beam Slit (V, bot)	29153	Model blade as 50mm(X) × 25mm(Y) × 80mm(Z)	n/a	Block center: X= -15.4, Y= 0	Glidcop (Copper)	See details below
(4) Pinhole Aperture	30068	Cylinder w/ axis along Z: Dia. 101.6 Length 35	Apertures not to be modeled.	Block center: X= 14.8, Y= 0	Glidcop (Copper)	See details below
(5) SGB Shield 1	30212	see description below	130mm (Dia.)	Aperture and lead square center: X= 14.9, Y= 0	lead	PD-SMI-BL-0203, PD-SMI-BL-LAY-1020
(6) DCM crystal	31991	20mm(X) × 50mm(Y) × 48mm(Z)	n/a	Block center: X= -19, Y= -25	silicon, sand-wiched between Cu plates	See details below
(7) SGB shield 2	32596	see description of (5)	130mm (Dia.)	Aperture and lead square center: X= 15.7, Y= 12.5	lead	PD-SMI-BL-0204, PD-SMI-BL-LAY-1020
(8) White Beam Stop	32822	120mm (X) × 40mm (Y) × 130mm (Z)	n/a	Center of rectangular block to model: X= 15.9, Y= 9	Glidcop (Copper)	PD-SMI-BL-LAY-1019, PD-SMI-BL-LAY-1013

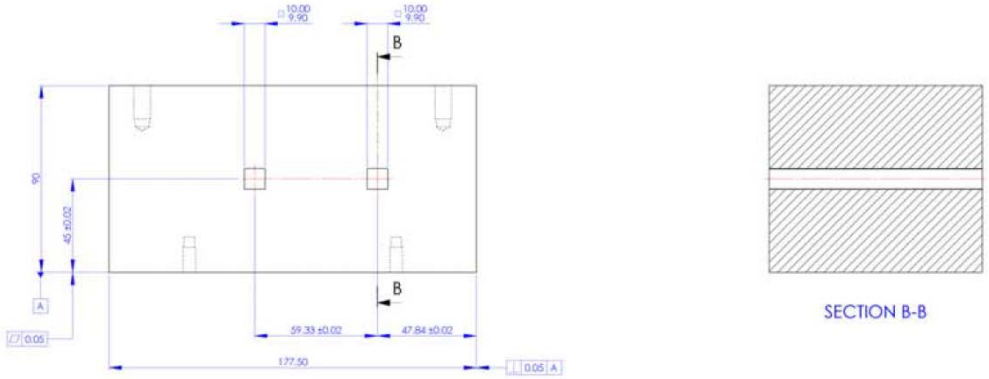
(9) GB Stop	33268	177.5 (X) × 78 (Y) × 206 (Z)	Two rectangular apertures I/B: 10mm(X) × 6mm(Y) O/B: 10mm(X) × 6mm(Y)	Block center: X= 28.2, Y= 3 I/B aperture center: X= -18.6, Y= 25 O/B aperture center: X= 50.6, Y= 25	Tungsten	PD-SMI-BL-LAY-1019, PD-SMI-BL-LAY-1013
(10) Photon Shutter	41779	NSLS-II standard mono beam shutter	One of the 4 Tungsten blocks: 125(X) × 150(Y) × 38 (Z)	Aperture: 40(X) × 25(Y) Block center: X= -67.6, Y= 29.4	Tungsten	per spec, as-built, and instal-lation
(11) Guillotine	42400 (u/s face)	840(X)× 800 (Y) × 50 (Z)	See description below and Table 2 regarding beam penetrations and construction	Block center: X= 36, Y= 0.4	Lead	per spec, as-built, and instal-lation
Downstream wall, directly adjacent to guillotine	42500	See line (4) Table 1	Outboard Penetration: 178 (Dia.) Plug in o/b penetration: 165 (Dia.) Thickness 50 (Z)	O/B Penetration location: X= 130, Y= 29.4 Plug location: X= 130, Y= 17	Lead	per spec, as-built, and instal-lation

Detailed descriptions follow.

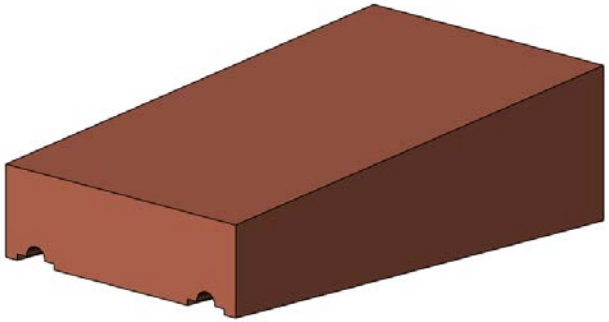
(1) <u>Dual Aperture Fixed Mask</u>. Synchrotron white beam mask, dual aperture. Expect SGB at angles < 8° from this component to be captured by GB Collimator (component 2) or SGB Shield 1 (component 5). Image shown below is a detail from bench survey drawing PD-SMI-BL-LAY-1011 Rev A (in review). PD-SMI-BL-LAY-1015 Rev A is the installation layout drawing (released).



(2) <u>Bremmstrahlung Collimator</u>. Primary GB collimator, dual aperture. Image shown below is a detail from the bench survey drawing PD-SMI-BL-LAY-1012 Rev A (in review). PD-SMI-BL-LAY-1016 Rev A is the installation layout drawing (released).

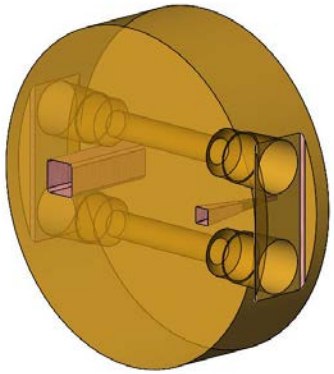


(3) White Beam Slits. Copper alloy blades can be inserted fully into beam path and can be modeled as rectangular solids. Vertical (V) versus horizontal (H) blades are oriented at 90° angles to each other, which we expressed in the X×Y×Z block sizes in Table 3. We expect SGB at angles < 8° from this component to be captured by SGB Shield 1 (component 5). Note that a movable slit is not considered an x-ray mask.

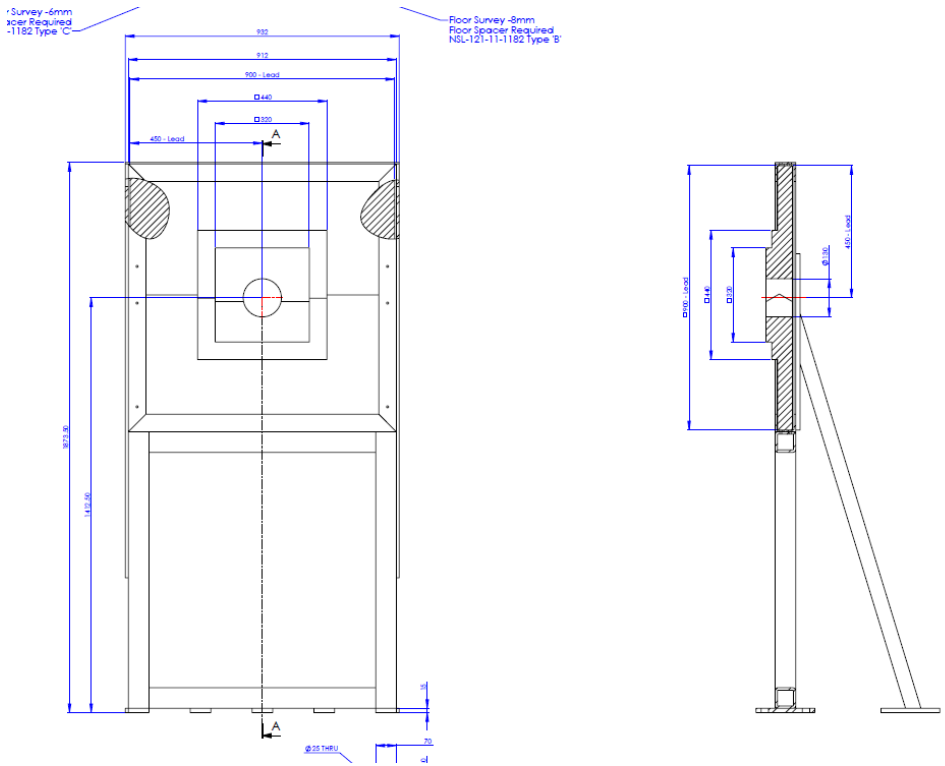


(4) Pinhole Aperture. Copper alloy disc with very small x-ray apertures, can be inserted fully into beam path and can be modeled as a solid copper disk (see figure below). This component was modeled in Tech Note 147 for SGB. Note that a movable aperture is not considered an x-ray mask.

NOTE: COMPONENT NOT INSTALLED FOR IRR AT SMI. SGB COMPUTATION IS FOR FUTURE CONFIGURATION.



(5) <u>SGB Shield 1</u>. Designed to capture secondary GB, this is a stack of square lead sheets centered with each other (location of center in Table 3) and with a round central aperture (diameter in Table 3). The lead is 90mm thick within a 320mm × 320mm square; 70mm thick within the surrounding 440mm × 440mm square; and 50mm thick in the surrounding 900mm × 900mm square. Image shown below is a detail from the vendor item drawing PD-SMI-BL-LAY-0203 Rev A (in review). PD-SMI-BL-LAY-1020 Rev A is the installation layout drawing (in work). Component (7), SGB Shield 2, is the same structure at a shifted location in X,Y,Z.



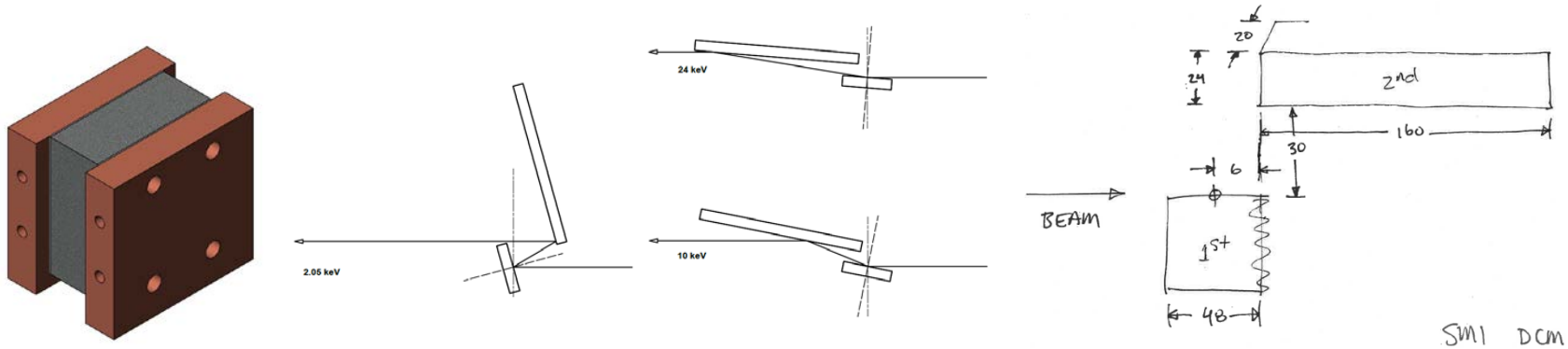
(6) <u>DCM Crystal.</u> In the pciture, the silicon crystal is gray and the sandwiching copper cooling blocks are copper colored. The X-ray beam at Y=0 is aligned with the top face. In the picture at left, Y=up and the beam travels from foreground-left to background-right, between the copper blocks.

Dimensions are given in Table 3 for orientation zero degrees rotation about X axis.

The location of the rotation axis is on the top face, midpoint in Z. The full motion range is -3° to 75° (bounce up direction). In the calculation of Tech Note 147, the crystal model was rotated to 45° to present the maximum target to incident GB.

The copper plates were disregarded. It is not possible to drive part of the copper into the GB path in SMI's case because the X translation is impossible with the vessel bolted closed. This info is included for completeness. Dimensions of the copper blocks: 12(X) × 55(Y) × 59(Z).

Update: Note rotation is lefted handed about an axis parallel to X and located at center of top face.

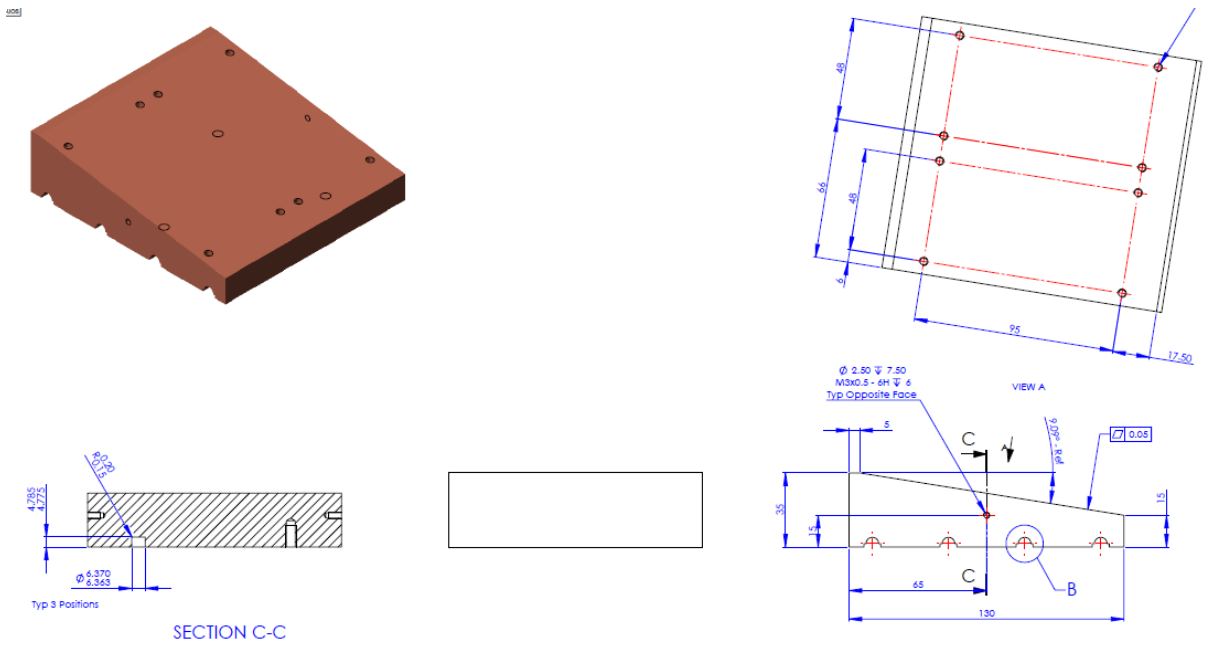


More info: center schemes show angles of working geometries with beam coming from the right at different energies. The crystal assembly rotates about the 1st crystal rotation axis, and the vertical beam offset is 25mm, maintained by a variable crystal gap. (Disregard the crystal aspect ratios in the middle sketch.) The accurate geometry (as-built) is shown at right, note that the "30mm" vertical <u>gap</u> separation is variable.

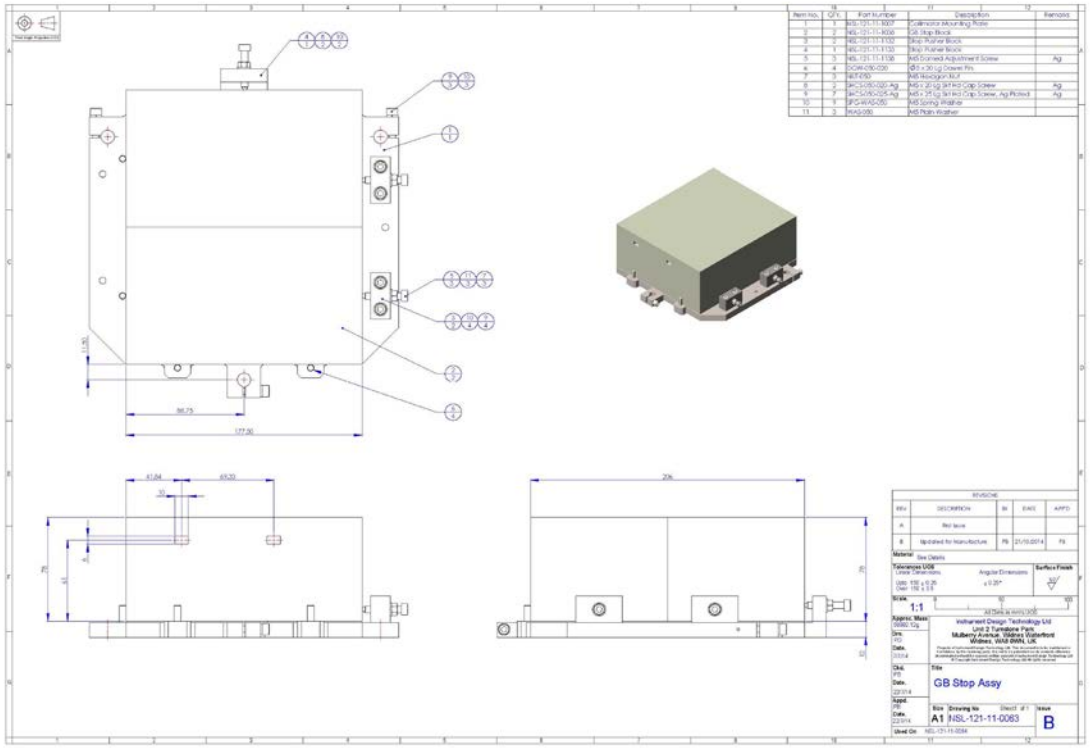
Equation for rotation of crystals at angle θ: <u>gap</u> = 25mm × sinθ / sin(2θ). At θ = 45° the <u>gap</u> = 17.7mm.

(7) <u>SGB Shield 2</u>. Designed to capture secondary GB, this component has dimensions identical to SGB Shield 1 (component 5). The vendor item drawing is PD-SMI-BL-LAY-0204 Rev A (in review). PD-SMI-BL-LAY-1020 Rev A is the installation layout drawing (in work).

(8) <u>White Beam Stop</u>. Synchrotron white beam stop, beam incident on sloped surface with reflection upwards. Expect SGB at angles < 8° from this component to be captured by GB Stop (component 9). Image shown below is a detail from bench survey drawing PD-SMI-BL-LAY-1019 Rev A (in review). PD-SMI-BL-LAY-1013 Rev A is the installation layout drawing (in review). In Table 3, the X,Y locations are referencd to the U/S face, bottom edge, center. The component also has a few-mm-thick copper plate mounted on top to create the removable phosphor surface. We included the additional plate in the volume of the simplified rectangular block model in Table 3.



(9) <u>Bremmstrahlung Stop</u>. Primary GB stop, dual aperture for mono beam to pass. Image shown below is a detail from the bench survey drawing PD-SMI-BL-LAY-1019 Rev A (in review). PD-SMI-BL-LAY-1013 Rev A is the installation layout drawing (in review).

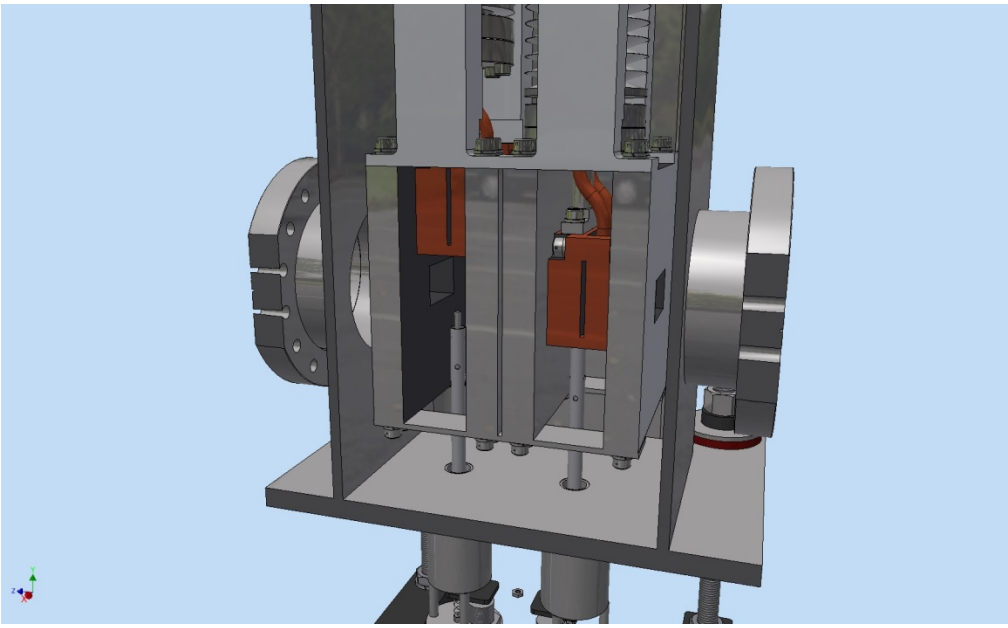


(10) <u>Photon Shutter</u>. The standard NSLS-II mono beam photon shutter (PD-COM-PSH-1000) is shown below. SMI's model has aperture 40mm(X) × 25mm(Y). In the picture, beam travels from right to left. There are four co-aligned Tungsten plates with rectangular apertures. A copper block moves into the X-ray beam path in the "closed" configuration. Copper blocks move together but this picture shows the left block "open" and right block "closed". Table 3 gives the installed X,Y position of the center of the tungsten block aperture.

NSLS-II shielding calculations can be performed with shutter closed and open to determine doses captured by the copper as a shielding element, versus SGB scattering from the copper, captured by hutch shielding D/S.

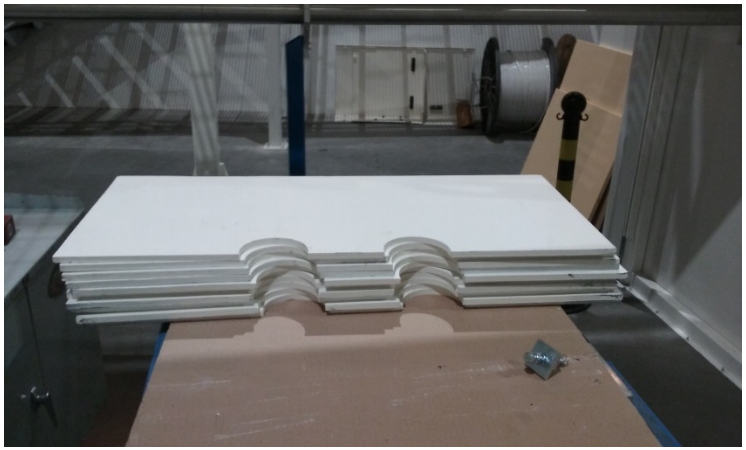
This memo does not provide all the component dimensions. We prefer it be checked how this component is treated for other beamlines. See drawing PD-COM-PSH-1000. *** NOTE 31 May 2016. PD-COM-PSH-1000 does not match vendor model.

Update: per Vinita, the photon shutter is modeled as a single tungsten block of the given dimensions and aperture.



(11) <u>Guillotine</u>. The dimensions in Table 3 give 50mm lead thickness for the guillotine and disregards the details at the apertures. Photos of the dis-assembled guillotine are shown below.

The thickness of the lead sheet stack is actually 100mm. 50mm was the spec and 50mm is the depth of the plug that fits into the apertures, both the inboard one with the pipe and the stopped one outboard. If the shielding is marginal at 50mm thickness, we should look at an analysis of 100mm thickness excepting within a 100mm diameter at each penetration. This 100mm diameter is smaller than the plug sizes of 165mm (O/B) to 178mm (I/B) provided in the plane of the wall (O/B) or packed around the transport pipe (I/B).



Final remarks on Fluka calculations:

NSLS-II Tech Note 147 details preliminary GB and SGB calculation made in 2014 per the 12-ID-A design. Secondary scatterers that were considered were the Pinhole Aperture (4) and the DCM 1st crystal (6). The Fixed Mask (1), White Beam Slits (3), and White Beam Stop (8) can be assessed by examination of raytracing.

Note Fluka can be done with an aperture in place of the mono beam pipe exiting the 12-ID-A hutch.

12-ID Monochromatic Beam Components

In the following we assume that all white beam and GB are stopped by the intended components and shielding within 12-ID-A. When preliminary analyses were made, scattering of mono beam from optical components in 12-ID-A and 12-ID-C had been considered to be exempt from re-calculation due to the standard large distance to the hutch walls and standard wall shielding.

12-ID-B and 12-ID-B-1 require mono beam calculations for the following reasons:

- The correct IVU23 source had not been modeled at the time of calculations in 2014
- Credit had not been taken for decreased flux of higher harmonics due to the mirrors in 12-ID-A that steer mono beam into 12-ID-B and 12-ID-B-1
- Non-standard inboard wall of 12-ID-B-1 and 12-ID-B is less than 1000mm from the beam path where scatterers may be placed

See BSA Document NX-C-XFD-MEM-SMI-025 Version 1 for mirror angle analysis, confirmed later by raytracing.

- Per conversation with Zhong Zhong, 6 June, it will not be necessary to analyze mono beam intensities at the shielded beam pipes. This will be documented at the RSC meeting 21 June.

Notes from RSC’s Preliminary Review of SMI Raytracing, 21 June 2016

1. SMI is ready to finalize the raytracing for release.

2. SMI shall defend W mask clearances of 24mm to fan edge, using documented tolerances

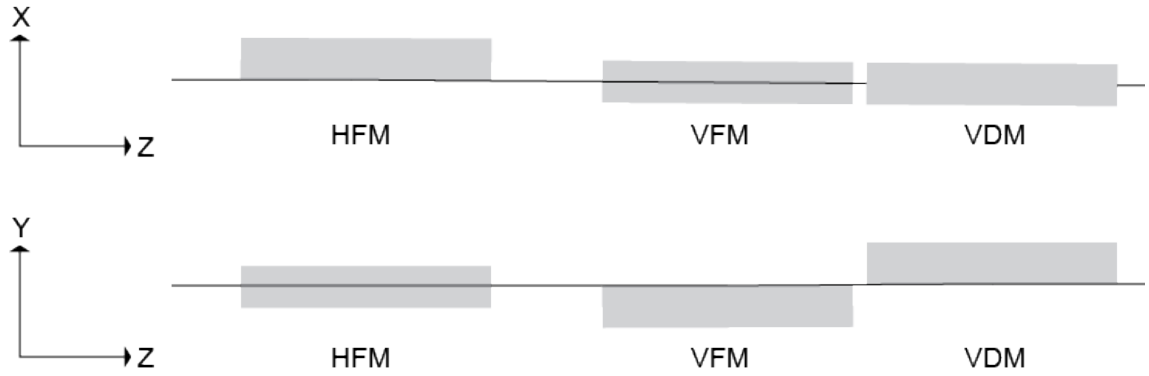
3. Grazing angle of mono beam in beam transport pipe is not concerning, long path attenuates all radiation

4. Tech Note 147 was reviewed by Wah-Keat Lee and per email dated 22 June 2016, realistic bandwidths, mirror reflections, and scaling, the other items addressed in TN147 such as B inboard wall distance, pose no risks and require no re-evaluation.

5. SMI is ready to begin the analysis report and complete the Fluka simulations

Monochromatic Beam Focusing and Deflecting Mirrors in the FOE

Mirrors are located downstream of White Beam and GB Stops. Details included here for completeness.



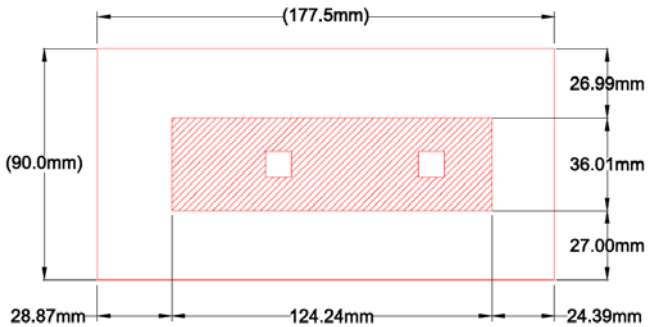
Relative layout of the Horizontal Focusing Mirror (HFM), Vertical Focusing Mirror (VFM), and Vertical Deflecting Mirror (VDM) are shown (not to scale; beam comes from left). Mirrors are solid Silicon blocks with thin metal coatings and limited motions about the nominal positions. Dimensions and coordinates are as follows. The rotation is about the beam reflection location. The monochromatic beam footprint extends the length of the mirror. Per the beamline raytracing, all excursions of the mirrors reflect the max fan of the mono beam within the confines of shielding and stops. Mirrors can be removed from the mono beam by retraction of up to 3mm along X (HFM) or Y (VFM, VDM). Mirrors can be moved parallel to their reflecting planes ±12mm. Mono beam cannot hit any metal holder or frame of the mirrors. Radius of the focusing surface of HFM and VFM is variable between 2km and flat, and does not afffect beam steering in any way. The VDM is flat.

Table 4. Mirror dimensions and coordinates

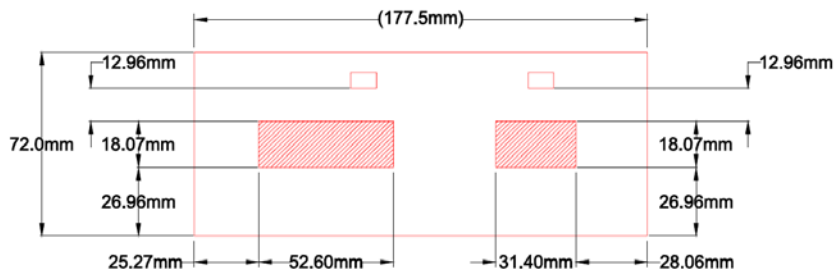
Component	Beam Reflection Location (mm)	Dimensions (mm)	Rotation
HFM	Center of inboard face; X= -19.7, Y= 25, Z= 34838	X= 35, Y= 46, Z= 600	About Y -0.217°
VFM	Center of top face; X= -43.6, Y= 25, Z= 38287	X= 28, Y= 46, Z= 500	About X -0.180° About Y -0.397°
VDM	Center of bottom face; X= -48.4, Y= 29.4, Z= 38993	X= 40, Y= 40, Z= 410	About X -0.180° About Y -0.397°

GB fan illumination areas on FOE components

PD-SMI-RAYT-0001-RevA: Below, screenshots from beamline raytrace, GB fan on primary GB components



SECTION G-G
BREMSSTRAHLUNG FOOTPRINT
ON GB COLLIMATOR



SECTION H-H
BREMSSTRAHLUNG FOOTPRINT
ON GB STOP

PD-SMI-RAYT-1100-Rev1: See Beamline Raytracing for GB fan on optical components