BNL-210972-2019-TECH

NSLSII-ESH-TN-138

SRX 5ID Radiation Shielding Analysis

Z. Xia,

August 2014

Photon Sciences

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC), Basic Energy Sciences (BES) (SC-22)

DISCLAIMER

NSLS II TECHNICAL NOTE BROOKHAVEN NATIONAL LABORATORY	NUMBER NSLSII-ESH-TN-138
AUTHORS: Z. Xia	DATE 8/7/2014
5-ID SRX Beamline Radiation Shielding Analysis	

1. Introduction:

This note documents the radiation shielding analysis of Submicron Resolution X-ray Spectroscopy (SRX, 5 ID) beamline at 500 mA, including Gas Bremsstrahlung (GB) and Synchrotron Radiation (SR). Figure 1 shows the layout of SRX, which uses an in vacuum undulator (IVU21) source.

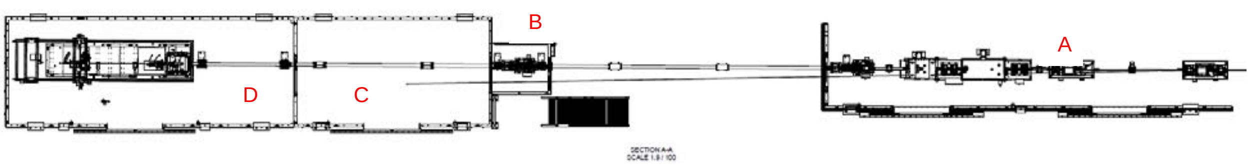

Figure 1 SRX layout

2. GB Shielding Calculation

For the evaluation of the GB shielding requirements, the undulator source is assumed to have a 15.5-m-long air section at 10^{-9} torr. The FLUKA simulation uses a 1/*k* energy spectrum (with *k* denoted as the photon energy) from 10 keV up to 3 GeV [1], and the FLUKA results are normalized to the power of 17 µW, which is the GB source for 3 GeV, 500 mA electron beams at 1 ntorr of Storage Ring Vacuum [2]. The First Optical Enclosure (FOE) shielding is dominated by GB. The FOE lateral panel is made of 18 mm Pb, roof 6 mm Pb and downstream wall 50 mm Pb.

The main scatterers considered in the Secondary Gas Bremsstrahlung (SGB) shielding analysis are (from downstream to upstream): white beam stop, mirror and white beam slits. The SRX FLUKA geometry is shown in Figure 2 and main parameters are listed in Table 1.

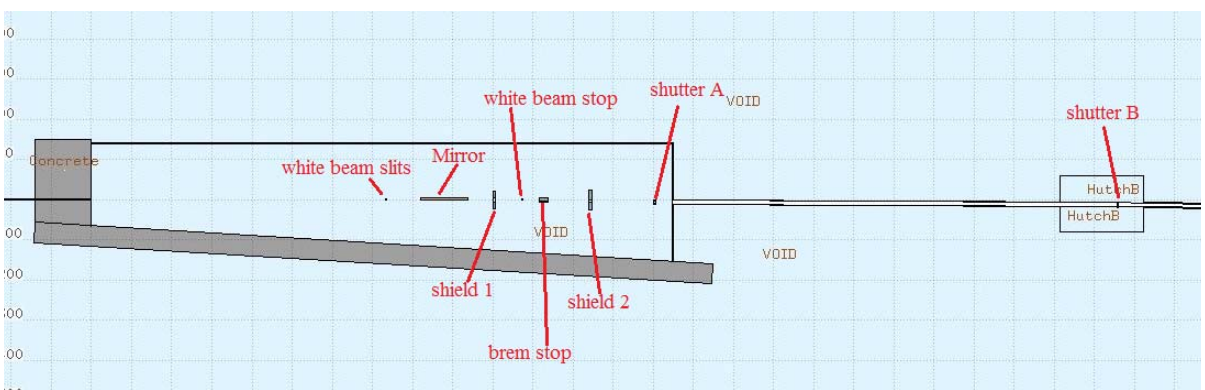

Figure 2 Main scatterers, collimators and shields

Table 1 Z locations and dimensions of main scatterers and shields

Scatterers	Upstream Z location (Distance from straight section center)	Dimensions	Material
White beam slits	3278.53 cm	1” cubic (optimum target)	Copper
Mirror	3366.1 cm	5 cm × 8 cm × 120 cm L (rotate 0.2 degree)	Silicon
White beam stop	3619.63 cm	1” cubic (optimum target)	Copper
Shields	Upstream Z location (Distance from straight section center)	Dimensions	
Shield 1	3548.8 cm	43.18 cm × 39.37 cm × 5.08 cm thick (aperture radius: 5.75 cm)	Tungsten
Bremsstrahlung stop	3664.2 cm	11 cm × 9 cm × 20 cm thick (aperture: 1.5 cm ×1.5 cm)	Tungsten
Shield 2	3787 cm	Radius 25.4 cm × 7.62 cm thick (aperture: Radius 4 cm)	Tungsten
Shutter	3949.2 cm	12.5 cm × 15 cm × 3.8 cm thick (aperture: 4 cm × 2.5 cm)	Tungsten

2.1 White beam stop as scattering target

White beam stop is immediately followed by a bremsstrahlung stop in SRX FOE. The dose rates on lateral wall and roof are always < 0.05 mrem/h for SRX beamline based on FLUKA calculations (with or without SGB shields). In this note, the dose rate on beam plane is plotted.

Figure 3 shows the dose rate from white beam stop scatterer (simulated by a 1 inch Cubic Cu target). The dose rates in all occupied area are < 0.05 mrem/h (including downstream of FOE area and surface of transport pipe).

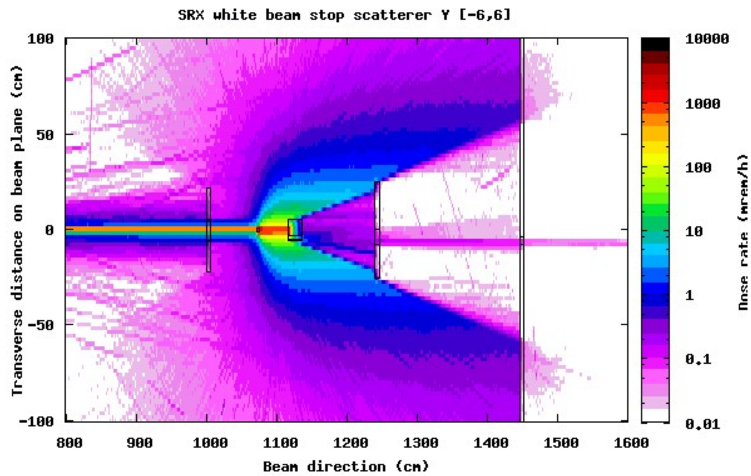

Figure 3 SRX white beam stop scatterer, dose rate on beam plane

2.2 Mirror as scattering target

SRX has a 120 cm long silicon mirror (rotated 0.2 degree), kicking beam inboard. The dose rates on beam plane are plotted for “Shutter Open” and “Shutter Closed” scenarios.

2.2.1 Shutter (in hutch A) closed, Mirror scatterer (without lead around transport pipe)

Figure 4 shows the dose rate on beam plane from mirror scatterer with shutter A closed.

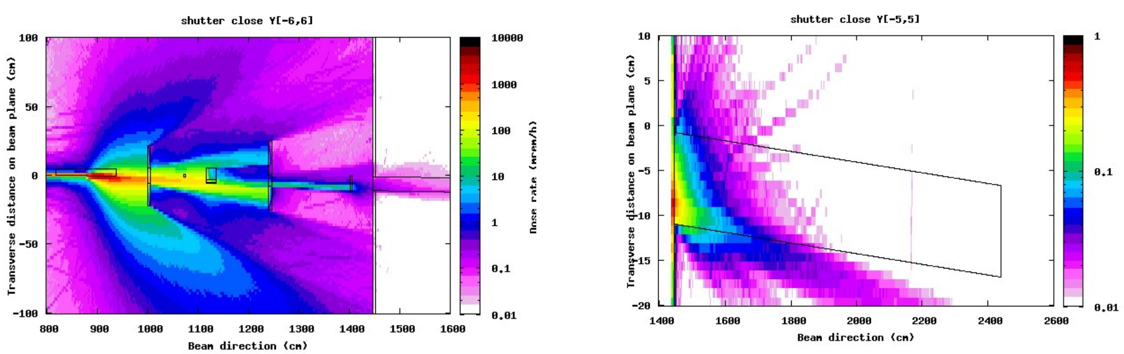

Figure 4 Mirror scatterer, dose rate on beam plane with shutter (in hutch A) CLOSED

As shown in Figure 4, the dose rate is < 0.5 mrem/h on contact of wall or pipe and decreases to < 0.05 mrem/h at 30 cm. Note in practice the dose rate around the pipe is much lower due to the 5 mm lead wrap around the transport pipe.

2.2.2 Shutter (in hutch A) open, Mirror scatterer (with 5 mm lead around transport pipe)

Figure 5 shows the dose rate with "shutter open" scenario. As shown in figure 5, with 5 mm lead around the transport pipe, the dose rate is < 0.05 mrem/h in all occupied area.

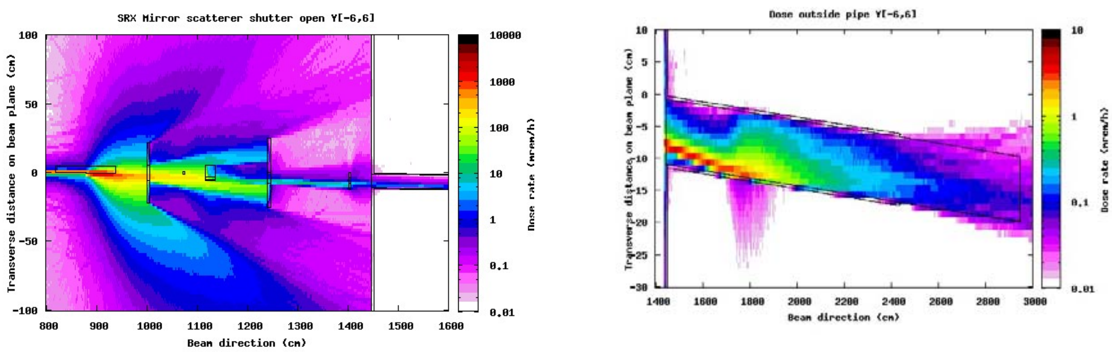

Figure 5 Mirror as scatterer, dose rate on beam plane with shutter (in hutch A) OPEN

Figure 6 is the same figure as figure 5 (right) with a different scale (starting at 0.05 mrem/h). It is seen the radiation is well contained in the pipe and the dose rate downstream of Hutch B is ~ 0.06 mrem/h. Considering hutch C pipe is wrapped by 5 mm lead too, the dose rate is acceptable in all occupied areas in this scenario.

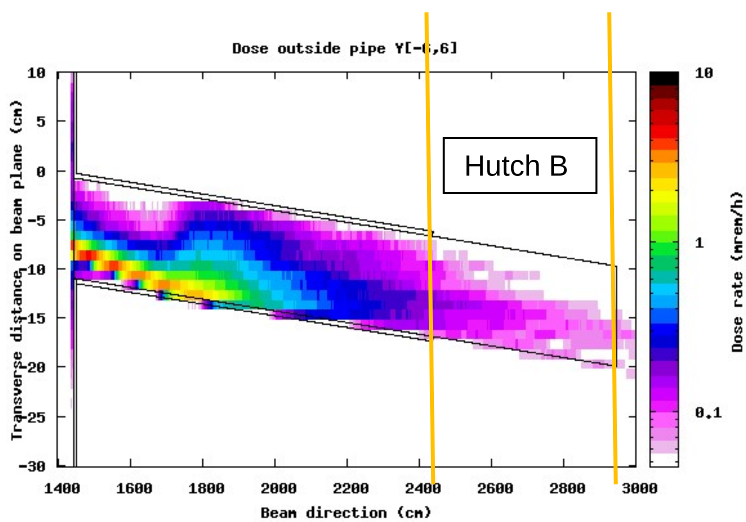

Figure 6 Mirror scatterer, shutter A OPEN, dose rate around transport pipe and in Hutch B

2.3 White beam slits as scattering target

White beam slits are located upstream of mirror, which are simulated by a 1 inch Cu cubic in FLUKA calculation. The dose rates on beam plane are plotted for “Shutter Open” and “Shutter Closed” scenarios.

2.3.1 **Shutter (in hutch A) closed, white beam slits scatterer**

Figure 7 shows the dose rate on beam plane. On the FOE downstream wall, the dose rate is < 0.5 mrem/h on contact and decrease to < 0.05 mrem/h at 30 cm.

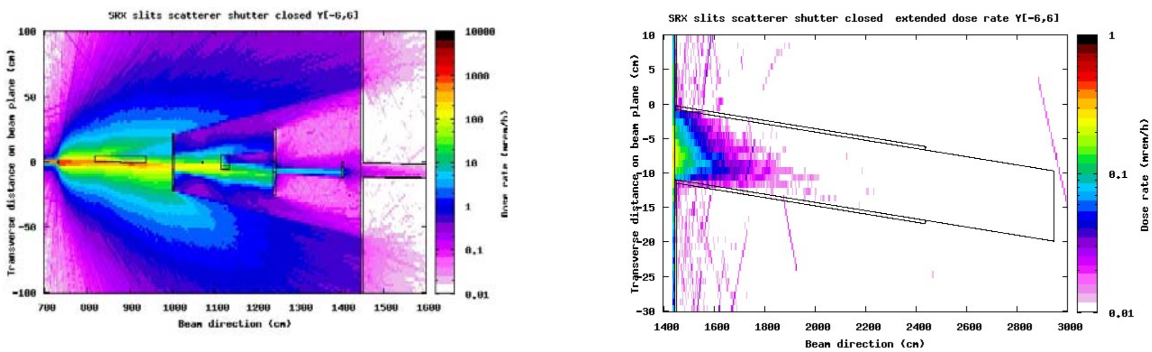

Figure 7 White beam slits scatterer, dose rate on beam plane with shutter (in hutch A) CLOSED

2.3.2 **Shutter (in hutch A) open, white beam slits scatterer**

Hutch D is only occupied when hutch B shutter is closed. Figure 8 shows the dose rate with hutch B shutter closed. As shown in Figure 8, the dose rates downstream of hutch B (including inside hutch C and D) are negligible.

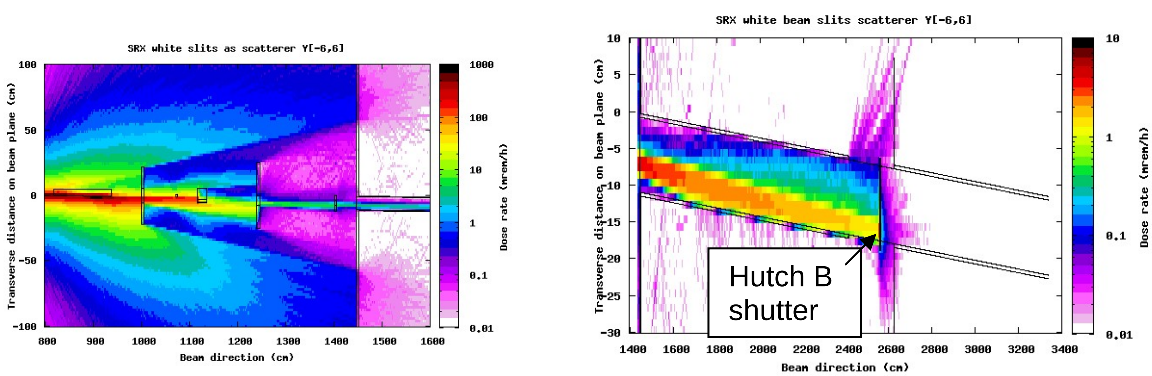

Figure 8 White beam slits scatterer, dose rate on beam plane with shutter (in hutch A) CLOSED

When hutch B shutter is open, the direct SGB leakage from white beam slits will be stopped by shutter B plates (size: 125 mm H × 150 mm V) [3]. The aperture size in shutter B is 40 mm H × 25 mm V at the center. Only tertiary GB scattering will travel through the shutter aperture further to hutch C and D, which is not a concern (hutch C transport pipe is wrapped by 5 mm Pb and hutch D is not occupied).

3. SR Shielding Calculation

The SRX 5ID beamline uses an IVU 21 source and the parameters are listed in Table 2.

Table 2 Source Parameters for IVU 21 [4]

Source	**Max. source opening**	**No. Of periods**	**Max. B_{eff} (T)**	**Period (mm)**	**Length (m)**	**E_c (keV)**	**Total power (kW)**
IVU 21	1.0 mrad-H	72	0.97	21	1.5	5.8	4.3

3.1 FOE wall / roof for white beam

The FOE shielding is dominated by GB. The dose rate from SR is negligible on lateral and downstream walls with current FOE shielding.

3.2 Transport pipe

The SRX transport pipe is a 4 inch diameter stainless steel pipe wrapped by 5 mm lead. In the shielding calculation, beam is assumed to be 1 inch to pipe and the wrapped lead is assumed to be 3 mm. The calculation was done conservatively for 10 m compressed air by STAC 8 for the maximum monochromatic energy and bandwidth (25 keV and 0.1% bandwidth). The calculation considered up to 3^{rd} harmonics (75 keV).With platinum coated mirror at 0.14 degree to the incident beam, the dose rate is negligible (< 0.001 mrem/h) outside of the transport pipe.

3.3 Monochromatic hutches

3.3.1 Mono hutch lateral wall and roof

The lateral and downstream panels of SRX mono hutches are made of 6 mm stainless steel (SS). The roof is made of 6 mm stainless steel (note the calculation is done with 3 mm SS). The minimum distance between the scattering point to the side wall and the roof is 0.702 m and 0.868 m [5] (in hutch 5ID-B). The dose rates on the lateral wall and roof are listed in Table 3. The scattering target in the calculation is assumed to be a 10 cm radius, 2 cm thick Silicon disk, tilted at 0.155 degree to the incident beam.

Table 3 Maximum dose rate on lateral wall and roof

	Distance	Shielding	Dose rate (mrem/h)
Lateral wall	0.702 m	6 mm SS	0.003
Roof	0.868 m	3 mm SS	0.01

3.3.2 Mono hutch downstream wall

A mono beam stop (305 mm × 305 mm × 25 mm thick PB) is installed around the beam center in hutch D (similar or larger size lead guillotine around beam pipe in Hutch B and C) to prevent the monochromatic beam from direct hitting the downstream wall. Table 4 lists the dose rates on hutch D downstream wall. Note the downstream wall shielding calculation takes credit of FOE fixed mask, which decreases SR fan size to 0.11 mradH.

Table 4 SRX dose rate on Hutch D downstream wall (mono beam 25 keV with 0.1% bandwidth up to 3rd harmonics)

	Dose rate (mrem/h)
Area covered by mono beam stop (< 8.7 degree)	<0.001
Area outside of mono beam stop coverage (> 8.7 degree)	0.01

4. 50 mA commissioning analysis

Figure 9 shows the dose rate at 50 mA without installing the SGB shields (shield 1 and shield 2 in Table 1).

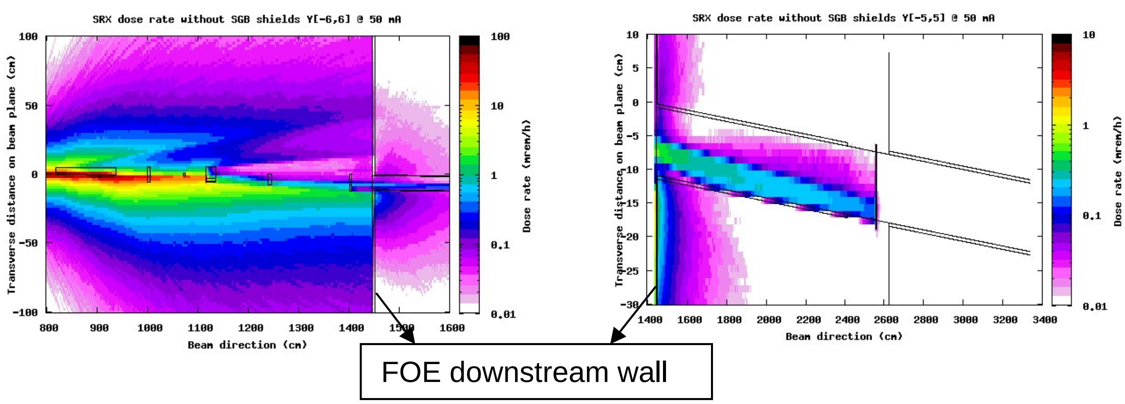

Figure 9 SRX dose rate without SGB shields installed at 50 mA

As shown in Figure 9, a 2 meter long exclusion zone (+/- 1 meter around beam center) downstream of FOE is needed for 50 mA commissioning if the SGB shields are not installed for SRX.

5. Conclusions:

For 500 mA operation, with the two proposed SGB shielding from SRX (shield 1 and shield 2 in Table 1), the radiation level meets NSLS-II shielding policy.

1) The surface dose rate on FOE downstream wall is < 0.5 mrem/h, which decreases to < 0.05 mrem/h at 30 cm distance.
2) The dose rate in other occupied areas is < 0.05 mrem/h.

A 2 meter long × 2 meter wide exclusion zone is needed downstream of SRX FOE for 50 mA commissioning if the SGB shields are not installed. All SGB shields must be installed before the electron current goes up.

During SRX design review, shield 2 in table 1 (Z ~ 38 m) was changed from 3” thick tungsten to 4” Pb (dimensions stay the same). The purpose of shield 2 is to block scattered radiation at small angles. From previous calculation [6], the required lead thickness is 9 cm at these angles, so 4” Pb is sufficient in this case. All shielding will need to be verified by radiation survey during commission. If a radiation leakage is observed during the measurement, shielding shall be installed to mitigate the radiation level outside of the enclosure to acceptable level.

Reference:

[1] J.Donald Cossairt, Fermilab-TM-1834, Radiation Physics for Personnel and Environmental Protection, Revision 11, November 2011.
[2] P.K. Job, Shielding Guidelines for Secondary Bremsstrahlung at NSLS-II Beamlines with Mirror as the First Optical Element, September 11, 2012.
[3] Private communication between Y. Yuan and Z. Xia.
[4] Email from J. Thieme to Z. Xia.
[5] Email from Y. Yuan to Z. Xia
[6] W. Lee, PPT, “RadiationShieldingUpdate_March282014”, slide 15.