Attachment B

USI Screening Checklist

A) USI Screening Purpose: ☒ **Proposed Activity** ☐ **Existing Condition**	**B) Description of Proposed Activity/Discovered Condition and Sponsor/Condition Owner:** Review of Shielding Analysis of the 22BM-FISMET Beampipe Penetration / Dr. M. Benmerrouche
C) USI Screening Outcome: ☒ **No potential USI** ☐ ***Potential USI***	**USI Screening Performed by/Date:** Steve Moss 10/10/18 Steve Moss / October 10, 2018 The following answers are based on NSLSII-ESH-TN-282, which determined the need for supplemental shielding in the region of the beampipe penetration for 22-BM FIS/MET Beamline, to maintain compliance with NSLS-II Shielding Policy. The shielding has been installed and is under configuration control.

Qualified Screener answers the following questions; if:

- Any question is answered yes (i.e., "Y"), check "Potential USI" box in Part C, above.
- If all questions are answered no (i.e., "N"), check "No potential USI" box in Part C, above.

Does the proposed change or discovered condition impact or potentially impact:

1) The personnel protection system (PPS)?
Examples: Access doors, fencing, hutches, accelerator enclosures, software change, hardware modifications that are not, "replacement-in-kind."

☐Y or ☒N

2) ODH Monitoring System?
Examples: Hutch ODH monitors, filling station ODH monitors.

☐Y or ☒N

3) Radiation Safety Component?
Examples: Shielding, earthen berms, hutches, concrete walls, beam shutters, scatter shields, burn-through devices, exclusion zones, labyrinths, beam stops, beam masks, collimators, hutch guillotine and beam transport pipes.

☐Y or ☒N

4) Area radiation monitoring system or components?
Examples: Changing instrument position or use of a new type of instrument used for area radiation monitoring, alarms and controls.

☐Y or ☒N

5) Radiological source terms identified in the SAD?

Examples: New insertion devices, change to the maximum synchrotron energy or accelerated charge values, accelerator modifications that are not "replacement-in-kind."

☐Y or ☒N

6) Critical devices
Examples: Safety shutters, dipole magnets, top-off apertures.

☐Y or ☒N

7) PS operating organization?
Examples: Control room operators, support staff responsible for PPS, radiation monitoring or shielding configuration management.

☐Y or ☒N

8) Operational safety limits described in the Authorization Basis Documents?
Examples: Maximum current, beam energy, pulse rate.

☐Y or ☒N

Forward the completed form to the Authorization Basis Manager

NSLSII-ESH-TN-282 October 2018

Shielding Analysis of the 22BM-FIS/MET Beampipe Penetration

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Office of Science, Office of Nuclear Physics

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NSLS II TECHNICAL NOTE BROOKHAVEN NATIONAL LABORATORY	NUMBER **NSLSII-ESH-TN-282**
AUTHORS: M. Benmerrouche	DATE 10/09/2018
Shielding Analysis of the 22BM-FIS/MET Beampipe Penetration	

1. INTRODUCTION

The purpose of this report is to determine the shielding required, both on the inside and outside of the penetration through the storage ring shielding, which is required for the FIS/MET beamlines IR beampipe. The aim is to ensure that the dose rates in the occupied areas near the penetration comply with the NSLS-II shielding policy [1] for both normal and abnormal beam loss conditions. In this report, ambient dose equivalent rates are reported in units of mrem/h.

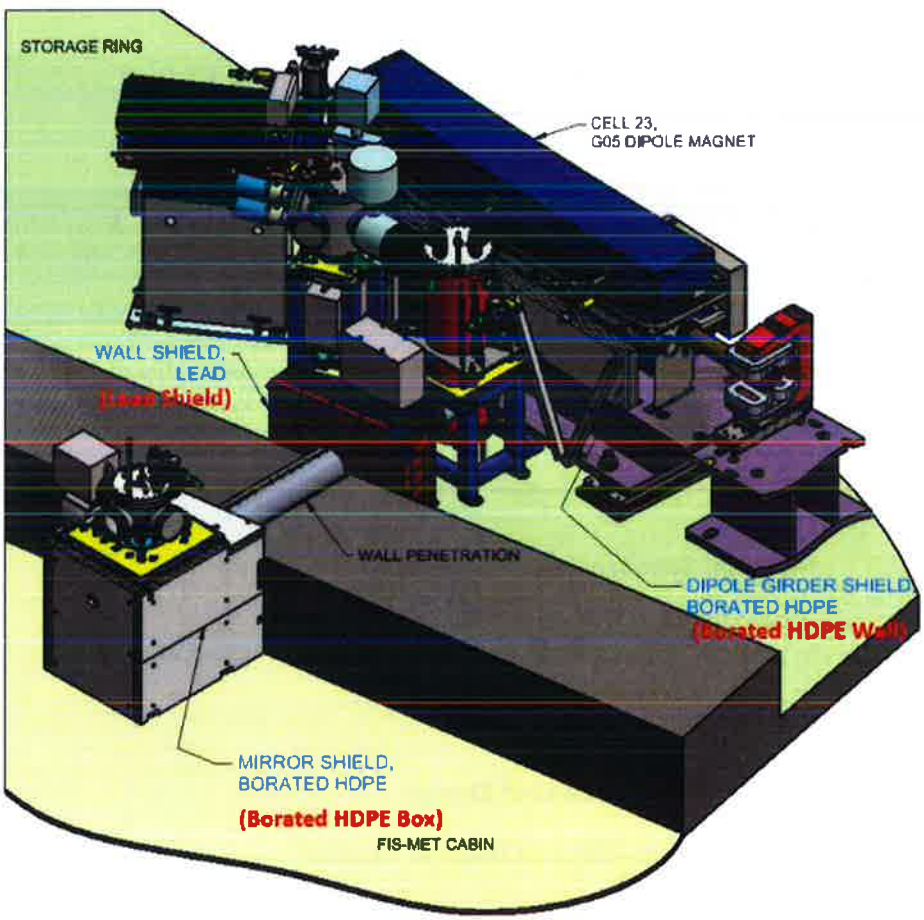


Figure 1: The layout of FIS/MET showing the beamlines components inside the storage ring tunnel and some components at the exit of the penetration. The storage ring shielding outer wall is shown horizontally, cut-away at the height where the IR beampipe passes through. The additional installed shielding is labeled in red.

Figure 1 shows the 22BM-FIS/MET IR beamlines components that are inside the storage ring tunnel and some components near the exit the penetration for the IR beampipe. The additional shielding that was required to meet the NSLS-II shielding policy [1] consist of the Borated High-Density Polyethylene (HDPE) wall, Lead Shield, and Borated HDPE box, which are labeled in red.

2. RADIATION SHIELDING ANALYSIS

The beam loss scenarios that were considered to estimate dose rates in the occupied areas near the penetration for the IR beampipe and to determine if additional shielding is required included the following:

1. Gas Bremsstrahlung and Synchrotron Radiation striking upstream components in the 23-ID Front End (FE) and components inside the IR dipole vacuum chamber.

2. Mis-steered injected beam (fault condition) striking the IR dipole vacuum chamber, Mirror M1 inside the vacuum chamber, and the quadrupole upstream of the vacuum chamber.

3. Routine stored electron beam losses.

4. Mis-steered injected beam (fault condition) striking components along the 23-ID FE.

In scenario 1 of the GB and SR, the leakage radiation is expected to be negligible. As an example, Figure 2 shows the total ambient dose rate distribution inside and outside of the storage ring tunnel, near the IR beamline penetration when the GB strikes mirror M1 inside the IR dipole vacuum chamber. As shown in Figure 2(d) the amount of radiation leakage is negligible, leading to ambient dose rates of less than 0.001 mrem/h with no additional shielding required.

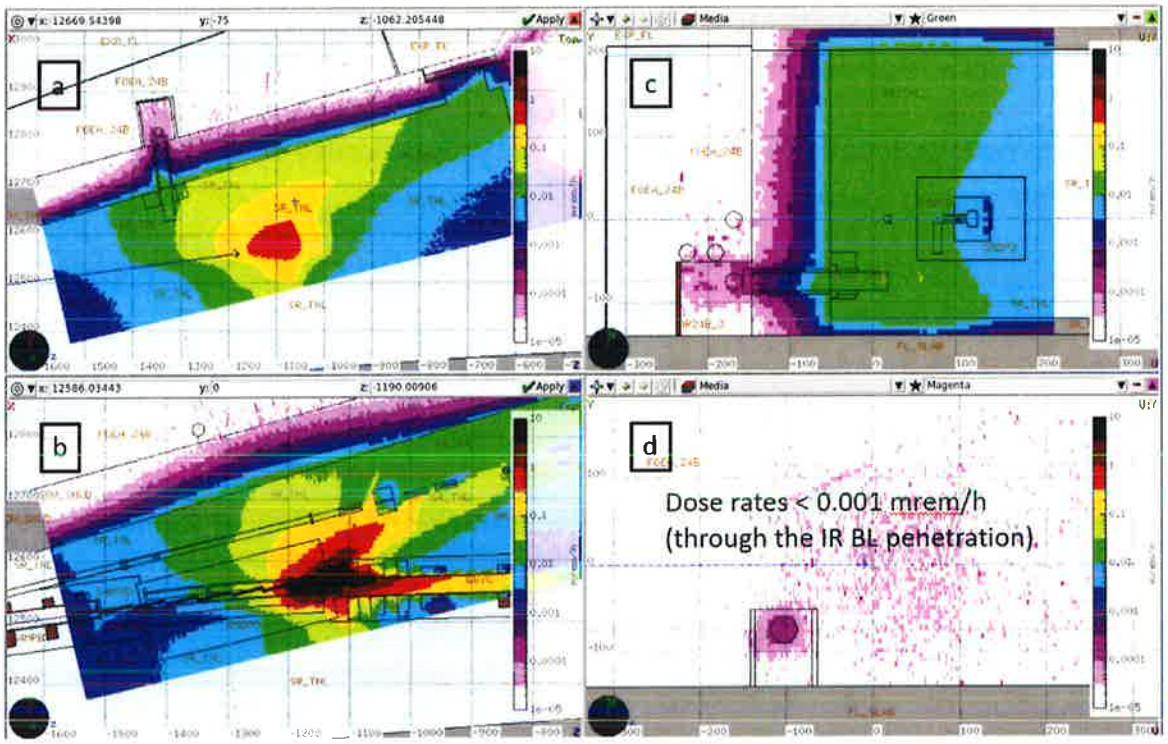


Figure 2: The total dose distributions (mrem/h) inside the storage ring tunnel and outside near the penetration for the IR beampipe. In this case, GB strikes the mirror M1 inside the IR dipole chamber. The left figures show a plan view at the elevation of the penetration of the IR beam pipe (a) and electron orbit (b). Figure (c) shows the elevation view through the center of the penetration and Figure (d) shows the total ambient dose rates at the exit of the IR beampipe penetration.

As another example, Figure 3 shows the total ambient dose rates distribution inside and outside of the storage ring tunnel, near the IR beamline penetration, when the GB strikes the bending magnet photon shutter located upstream of the 23-ID FE. As in the previous case, the amount of radiation leakage is negligible, leading to ambient dose rates of less than 0.001 mrem/h (see Figure 3(d)) and therefore no additional shielding is required.

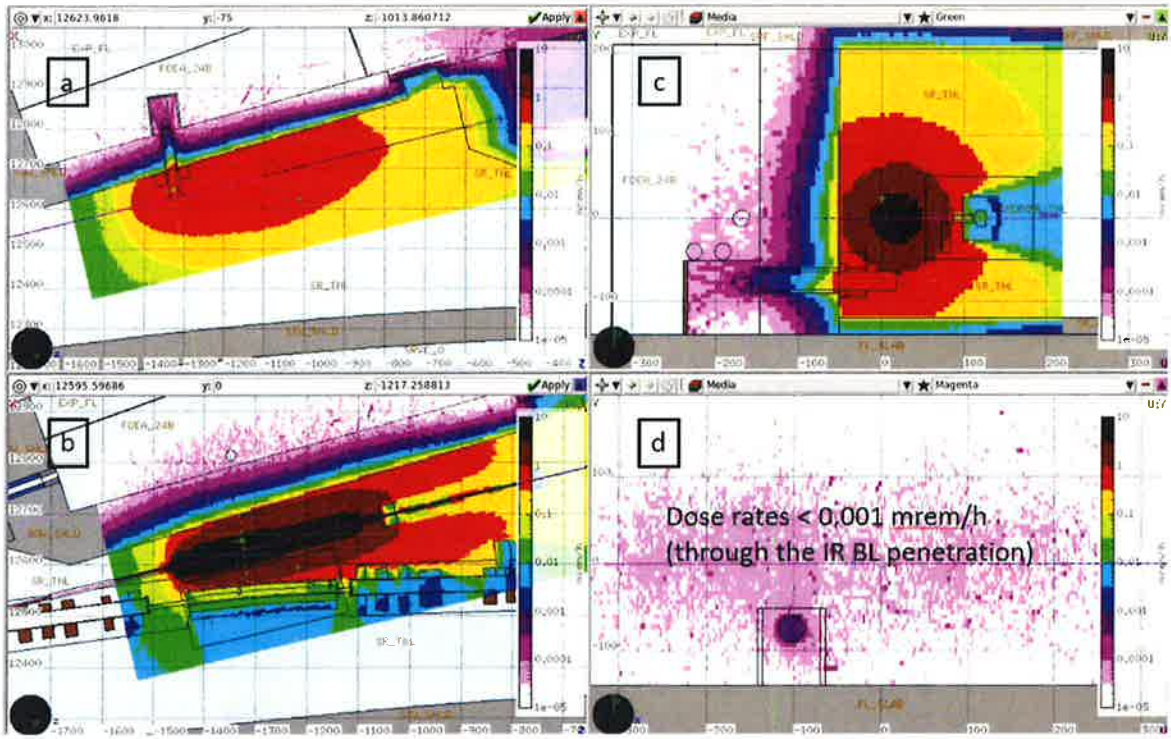


Figure 3: Same as Figure 2 but with GB striking the bend magnet photon shutter located at the upstream end of the 23ID FE.

In scenario 2, mis-steered beam striking storage ring components near the penetration of the IR beam pipe is considered in detail, because the amount of radiation leakage through the penetration can be significant compared to the cases of GB and SR. In all FLUKA simulations for scenario 2, a pencil beam of 3 GeV electrons is assumed for the electron beam and the results are normalized to a booster to storage ring injection charge rate of 15 nC per second. As per the NSLS-II Shielding Policy [1], the radiation dose criteria for the fault conditions considered below should be below 100 mrem/h. As it will be shown, additional shielding will be required for these fault conditions to keep the ambient dose rates below 100 mrem/h. The following cases were considered:

1. Electrons mis-steered on the inboard side of the IR dipole vacuum chamber
2. Electrons mis-steered on the outboard side of the IR dipole vacuum chamber
3. Electrons mis-steered into the M1 mirror inside the IR dipole vacuum chamber
4. Electrons mis-steered on the last quadrupole on girder 4 just upstream of the IR dipole vacuum chamber

FLUKA simulation results will be shown for cases 1 and 3 and a summary of the dose rates results will be given for all cases. Figure 4 shows the total ambient dose rates distribution inside and outside the storage ring tunnel near the IR beamline penetration when the

electron beam is mis-steered toward the inboard side of the IR dipole vacuum chamber. In this simulation the only shielding that is included is the Borated HDPE box located at the exit of the penetration for the IR beam pipe. Clearly, the total dose rates exceed 100 mrem/h immediately above the box and exceed 1000 mrem/h inside the box. The neutron contribution to the total ambient dose rate is given in Figure 4(d), which also exceeds 100 mrem/h/.

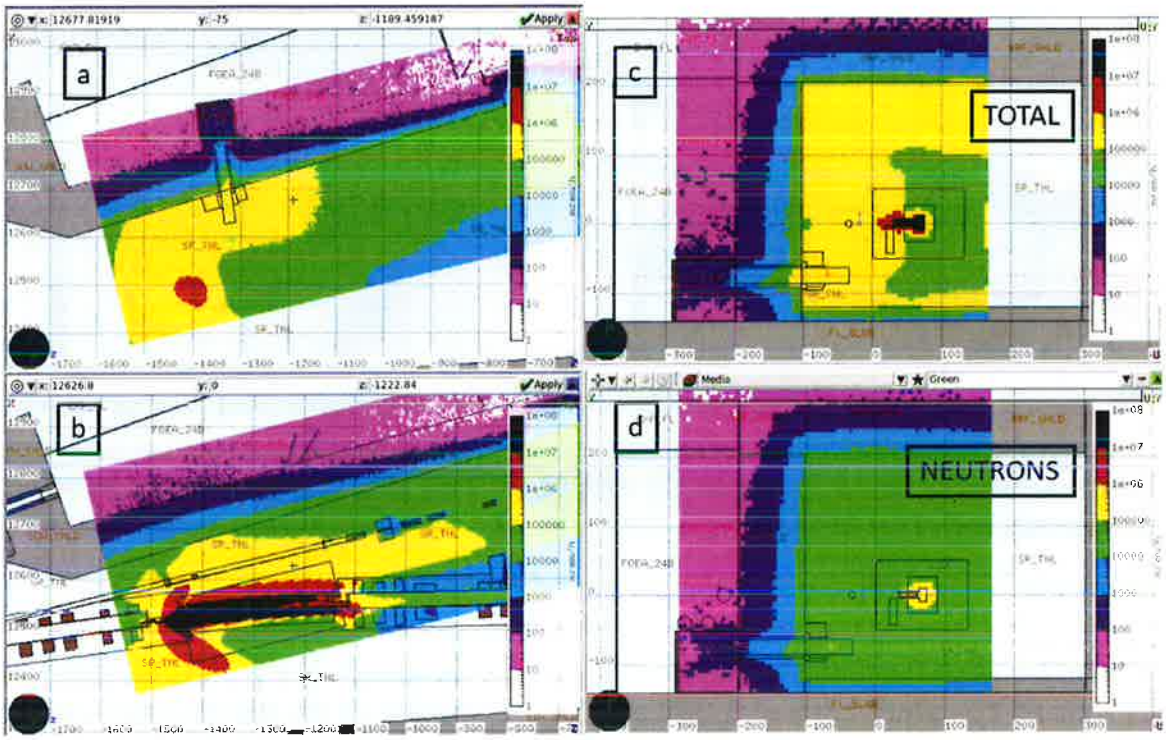


Figure 4: The total dose distributions (mrem/h) inside the storage ring tunnel and outside near the penetration for the IR beampipe. In this case, mis-steered electron beam strikes the inboard side of the IR dipole vacuum chamber. The Borated HDPE box shielding is included in the simulation. The left figures show a plan view at the elevation of the penetration of the IR beam pipe (a) and electron orbit (b). Figures (c) and (d) show the total and neutrons ambient dose rates respectively at an elevation view through the center of the penetration.

Figure 5 shows the total ambient dose rates distribution inside and outside of the storage ring tunnel, near the IR beamline penetration when the electron beam is mis-steered toward the inboard side of the IR dipole vacuum chamber with the Borated HDPE box and the Borated HDPE wall shields included in the simulation. The total dose rate distribution at the exit of the penetration has reduced in extent compared to the case with only the Borated HDPE box and is below 1000 mrem/h inside the box. The total ambient dose rate still exceeds 100 mrem/h immediately above the Borated HDPE box. The neutron contribution to the total ambient dose rates are given in Figure 5(d), which are now below 100 mrem/h outside of the Borated HDPE box.

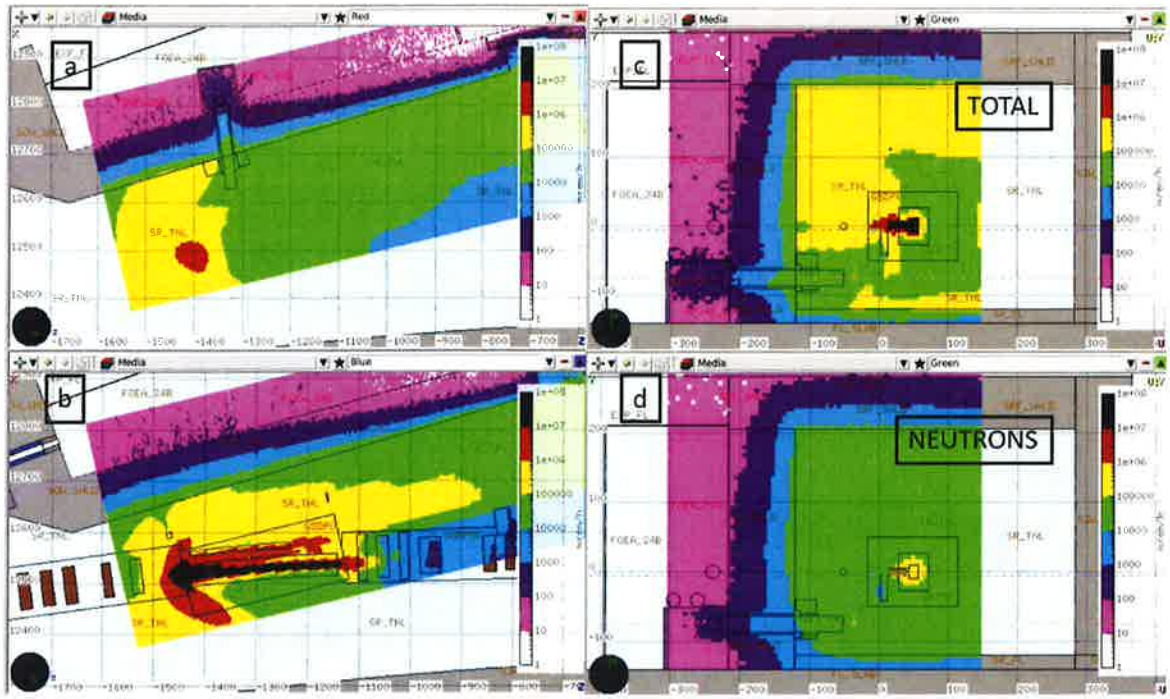


Figure 5: Same as Figure 4 but with both the Borated HDPE box and the Borated HDPE wall near the IR dipole chamber shielding included in the simulation.

Figure 6 shows the total ambient dose rates distribution inside and outside the storage ring tunnel, near the IR beamline penetration, when the electron beam is mis-steered toward the inboard side of the IR dipole vacuum chamber, with the Borated HDPE box, the Borated HDPE wall and the lead shield at the entrance of the penetration included in the simulation. The total dose rates distribution at the exit of the penetration has reduced in extent compared to the case with only the Borated HDPE box and the Borated HDPE wall, and is contained well within the Borated HDPE box. The total ambient dose rates are now below 100 mrem/h outside the Borated HDPE box. The neutrons contribution to the total ambient dose rates is given in Figure 6(d) and are similar to the case with the Borated HDPE box and the Borated HDPE wall.

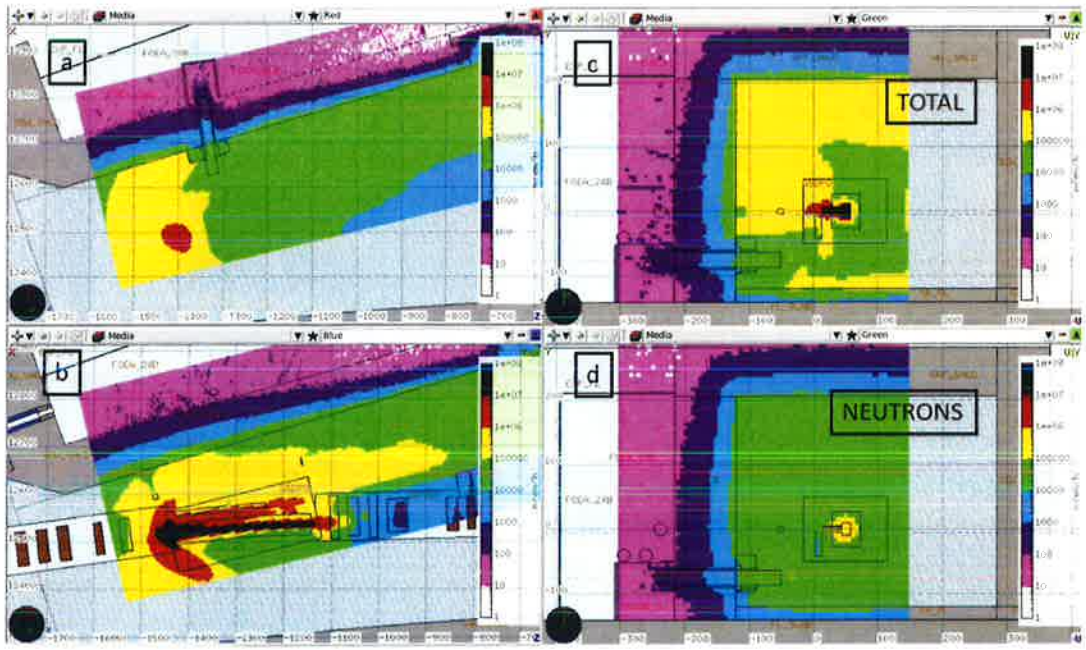


Figure 6: Same as Figure 4, but with the Borated HDPE box and the Borated HDPE wall near the IR dipole chamber and the lead shields included in the simulation.

The total ambient dose rates for case 3, where electrons are mis-steered into the M1 mirror, inside the IR dipole vacuum are given in Figure 7. In these plots the Borated HDPE box, Borated HDPE wall and lead shield are all included in the simulation. The total ambient dose rates are below 100 mrem/h outside the Borated HDPE Box. The neutrons contribution to the total ambient dose rates is given in Figure 7(d) and are similar to the case with Borated HDPE box and Borated HDPE wall.

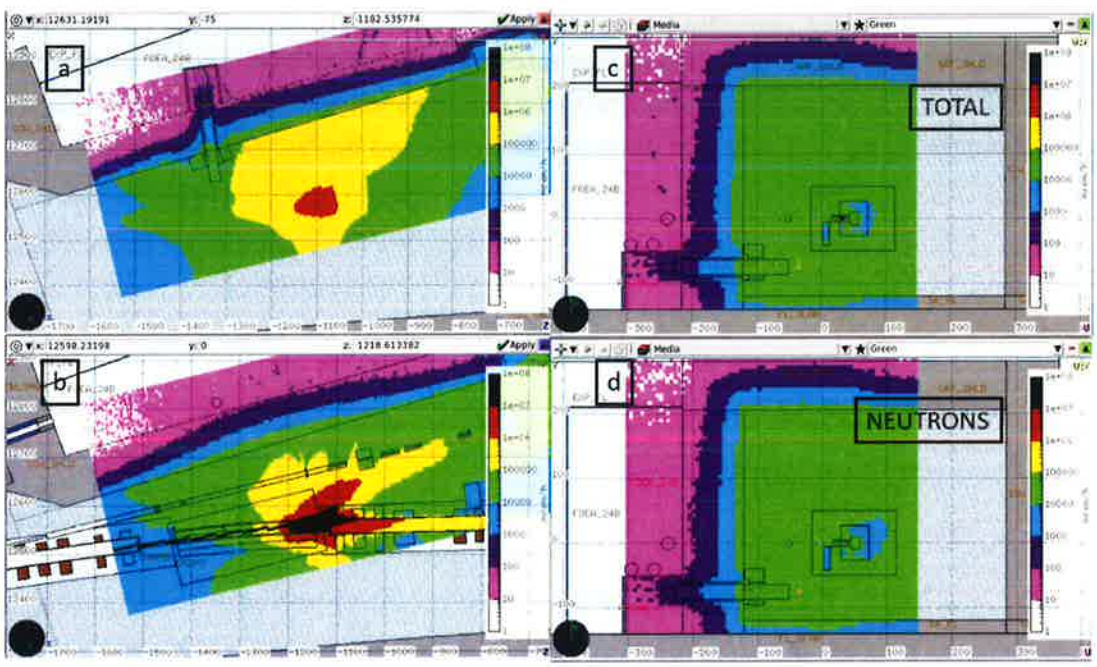


Figure 7: Same as Figure 6 but with electrons mi-steered into the M1 mirror located inside the IR dipole vacuum chamber.

In Table 1, the total ambient does rates are given at 4 detectors locations as illustrated in Figure 8. Detector DSW3 is inside the Borated HDPE Box and is not directly accessible to people, while detectors DSW2 and DSW4 are immediately outside the Borated HDPE Box and can be accessible to people. Detector DSW1 is positioned at electron beam orbit height. The total ambient dose rates for the four electron beam mis-steering scenarios are given in Table 1 at the four detectors location. The highest ambient does rates are obtained when the mis-steered electron beam strikes the outboard side of the dipole vacuum chamber. Clearly, the Borated HDPE Box is not enough to keep the total ambient dose rates below 100 mrem/h. However, with the Borated HDPE Wall, Lead Shield and Borated HDPE Box in place, the total ambient dose rates should be below 100 mrem/h and therefore comply with the NSLS-II shielding policy [1] for fault conditions.

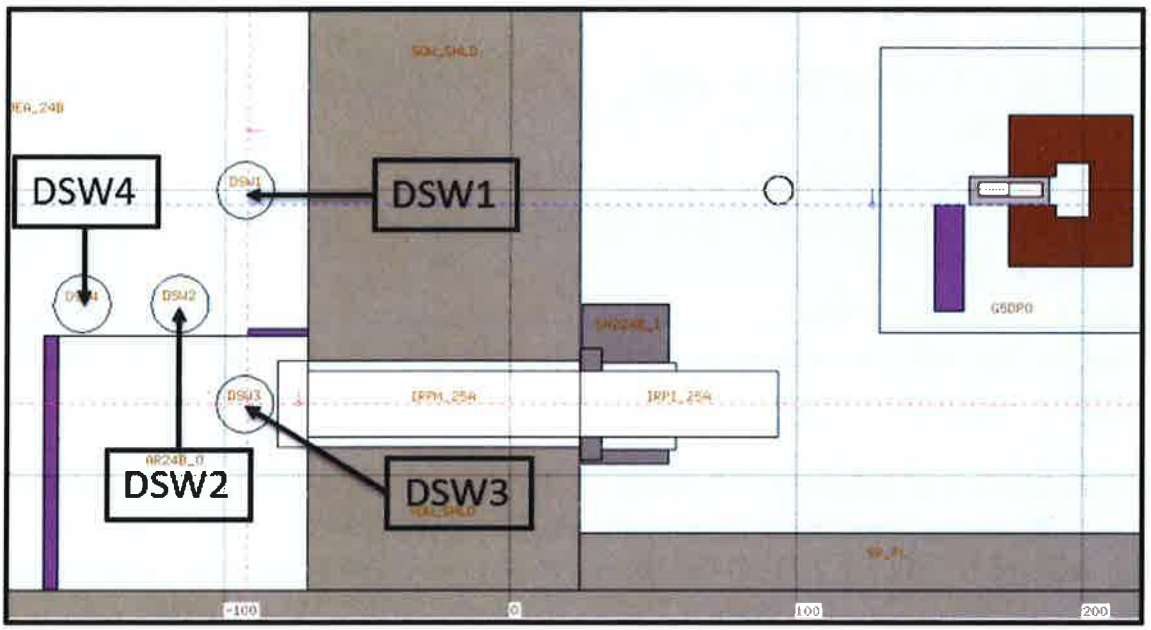


Figure 8: Locations of the detectors used for scoring the radiation dose inside and outside the Borated HDPE Box.

Mis-steered electron beam incident on	Total Ambient Dose Equivalent Rate at 4 detectors inside the FIS/MET Cabin near the penetration (mrem/h)			
	DSW1	DSW2	DSW3	DSW4
Mirror M1 with BP Box	43.30	67.90	245.97	85.59
Mirror M1 with BP Box, BP Wall and Pb Shield	43.29	47.04	188.20 **(0.23)**	50.04
Dipole VC I/B with BP Box	84.53	157.44	737.41	206.31
Dipole VC I/B with BP Box, BP Wall and Pb Shield	82.84	75.08	159.07 **(0.19)**	61.98
Dipole VC O/B with BP Box	72.74	264.90	1544.82	312.96
Dipole VC O/B with BP Box, BP Wall and Pb Shield	57.80	64.17	201.98 **(0.25)**	59.25
G4 Quadrupole with BP Box	28.38	33.44	142.58	45.07
G4 Quadrupole with BP Box, BP Wall and Pb Shield	27.82	28.92	88.66 **(0.11)**	35.77

Table 1: Total ambient dose rates for the four electron mis-steering conditions. VC: Vacuum Chamber, I/B: inboard, O/B: outboard, BP: Borated HDPE. See Figure 1 for shielding locations. The numbers in parentheses are for electron beam routine losses.

The numbers in parentheses are for scenario 3, where electron beam routine losses are assumed at 1.1 nC/min and are obtained by multiplying the dose rates for electron mis-steering conditions by 0.12%. The NSLS-II shielding policy [1] for normal beam losses requires dose rates to be kept below 0.5 mrem/h and as shown in Table 1, total ambient does rates (highlighted in green) for the four beam loss cases are below 0.5 mrem/h.

Finally, we consider scenario 4 where injected electrons could be transported down the FE of 23-ID and strike FE components. As an example, Figure 9 shows the total ambient dose rates distribution inside and outside of the storage ring tunnel near the IR beampipe penetration, when the injected electron beam strikes the FE slits. As shown in Figure 9(d) the amount of radiation leakage is negligible leading to ambient dose rates of less than 10 mrem/h with no additional shielding required.

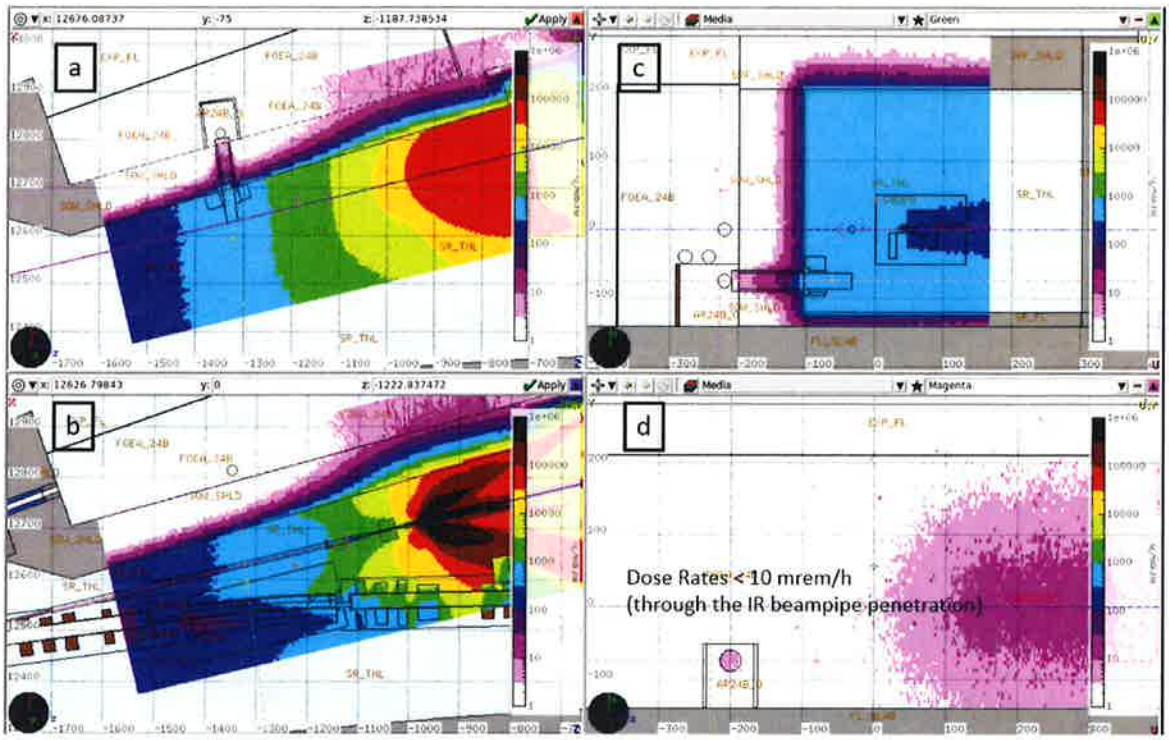


Figure 9: The total dose distributions (mrem/h) inside the storage ring tunnel and outside near the penetration for the IR beampipe. In this case, mis-steered electron beam strikes components in the FE of the 23-ID beamline. The left figures show a plan view at the elevation of the penetration of the IR beampipe (a) and electron orbit (b). Figure (c) shows the elevation view through the center of the penetration and Figure (d) shows the total ambient dose rates at the exit of the IR beampipe penetration.

3. SUMMARY AND CONCLUSION

The radiation shielding analysis of the IR FIS/MET beampipe penetration has been carried out with FLUKA Monte Carlo radiation transport code. The analysis indicates the need for additional shields to conform to the NSLS-II Radiation Shielding Policy [1]. The additional shielding consists of a Borated HDPE Wall near the IR dipole vacuum chamber (Drawing No. SR-FE-SHLD-0130), a lead shield at the entrance of the IR beampipe penetration (Drawing No. SR-FE-SHLD-0110), and a Borated HDPE box at the exit of the IR beampipe penetration (Drawing No. SR-FE-SHLD-0160). The shielding has been installed and is under configuration control.

4. REFERENCES

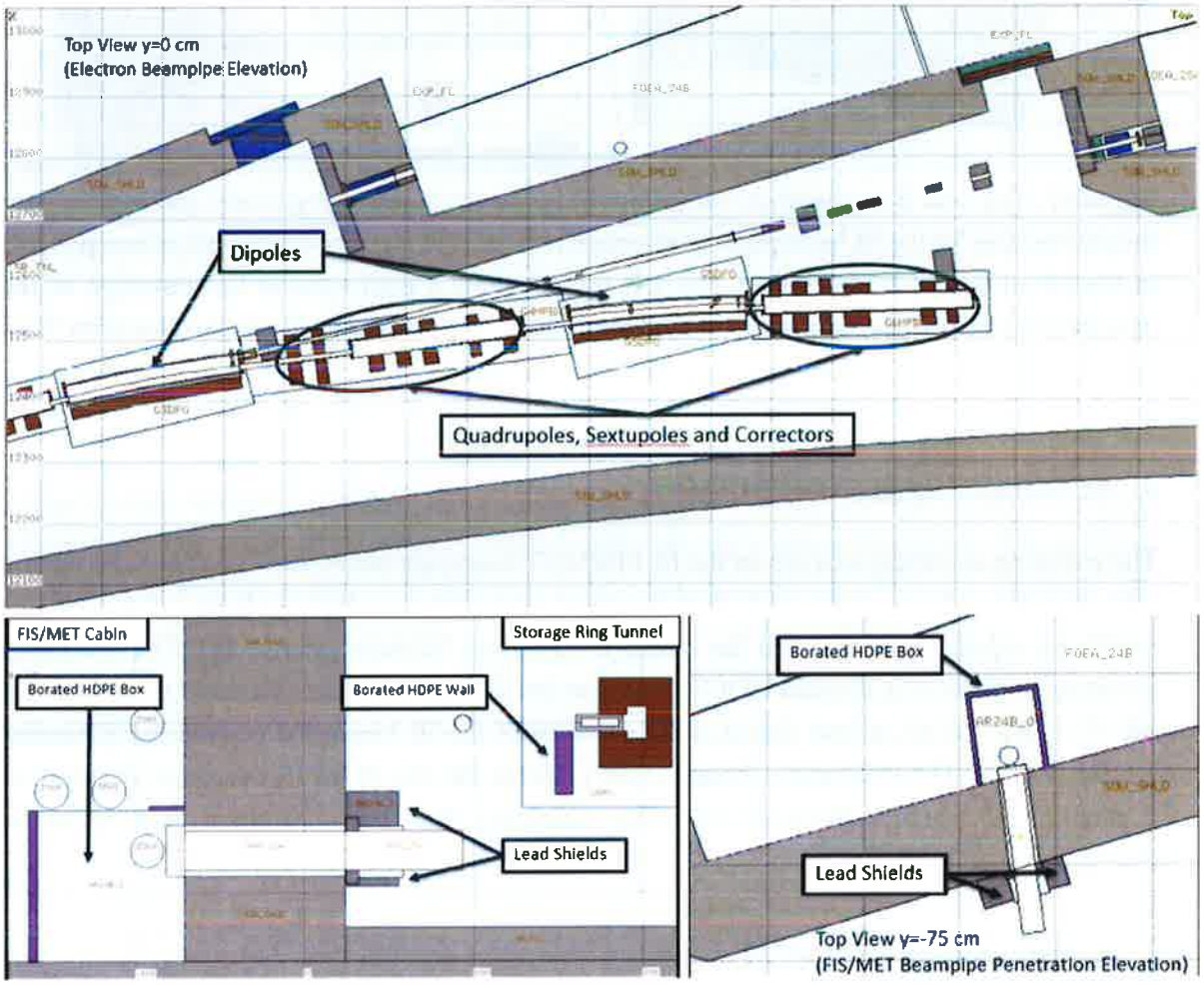
[1] Photon Sciences Shielding Policy, PS-C-ASD-POL-005, March 26, 2014.

APPENDIX 1

The FLUKA model used for this study was built based on the following engineering drawings

1. SR-SHLD-LAY-2000 Rev.1
2. SR-FE-SHLD-0130 (Borated HDPE near the dipole chamber)
3. SR-FE-SHLD-0110 (lead at the entrance of the penetration)
4. SR-FE-SHLD-0160 (Borated HDPE box at the exit of the penetration)
5. SR-FE-EPUN1-1101 (CSX Front End, Ray Trace Drawing)
6. SR-FE-EPUN1-1100 (CSX Front End, Assembly Drawing)

Additional information by the NSLS-II Design Engineer Mark Breitfeller and included shielding, exit absorber, IR dipole vacuum chamber, stick absorber, mirror M1 and Bending Magnet Photon Shutter.



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