Date: October 10, 2017

To: RSC, C. Cullen, K. Kusche, and M. Palmer

From: D. Beavis

Subject: Change in ATF Exit Labyrinth and Removal of Obsolete Beam Stops

ATF requested that guidance be provided so that the obsolete beam dumps be removed and a labyrinth constructed to protect the east exit gate. In addition, ATF would like to move the beam line 1 (BL1) vertical beam dump 3 feet downstream, change the 20° bend direction at the end of BL2 to the opposite direction, and operating the two dipoles in BL2 on separate power supplies. A summary of the desired changes are:

- Remove obsolete beam dumps
- Install a shield wall to form a labyrinth for the east gate and reduce direct dose
- Operate the two dipoles in BL2 on separate Power supplies, including mis-matched magnet current for some experiments will be conducted.
- Flip the 20 degree bend at the end of BL2 to the west rather than the east.
- Move the beam dumps for both beam lines.

Simple analysis was conducted using formulas for dose rates, shielding attenuation and outputs from existing MCNPX results for ATF. As this analysis was done quickly to provide guidance additional analysis is required to ensure the design is adequate; not all issues were examined for the changes. The design relies on two important aspects:

1. The shielding added in the recent past to the exterior of ATF
2. The chipmunk at the east gate was upgraded to be alarming and interlocking.

A layout with these changes and the obsolete beam stops is shown in Figure 1. The old BL2 beam dump forms a labyrinth for radiation created upstream in both beam lines. This obsolete beam dump also shields the east door from radiation from the BL2 beam stop and scrapping in the downstream end of BL2. The old BL3 beam dump and BL2 beam dump form a shield wall for radiation scattered off the end wall, rear ceiling, and rear west wall. These functions must be taken into account for the new design.

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1 This move is not possible with the forward portions of the obsolete BL2 beam dump.
2 There was not sufficient time to “properly” analyze all the changes, but I like to see accelerator facilities improved for experimental purposes and radiation protection. I notified the ATF staff to RS LOTO EH beam off and that they could start the changes assuming someone else would conduct additional checks on the analysis.
The history of the dump shielding is not known to the author. A guess would be that the initial obsolete BL2 dump was extended after initial operations. Pb was probably added to the gate exit area, and the ploy and Pb wall to provide additional shielding from losses in the beam lines, mainly BL2 and BL3. It is also guessed that the row of Pb in BL2 from the last dipole to the beam stop was added to reduce the radiation at the east gate.

Figure 1: Plan view of ATF Experimental Hall (EH) with BL2 20 degree bend in the opposite direction. BL1 has the vertical dipole moved downstream 3 feet. The obsolete beam dumps are shown at the end of EH.

The removal of the obsolete beam dumps was suggested as an option when the exterior shielding was added to upgrade the ATF ASE parameters in Jan. and Feb. of this year. A preliminary configuration of the new design is shown in Figure 2. The parameters given to ATF that appear to satisfy the necessary radiation issues are:

- Construct the wall with at least 18 inches of heavy concrete. A density of 3.85 g/cc was used in the analysis. The main issue in the forward direction is photons and not neutrons. Thicker is “better” but it eats up the floor space and does not appear to be necessary. CosC shielding blocks are being considered for the construction.
- The wall should be nine feet long, which is almost to the zero degree maxis of BL2 before the last bending magnet. There was not sufficient time to examine if the wall could be as short as 6 feet. The length needs to be long enough to prevent high intensity forward shine from the last dipole in the “wrong” polarity.
- The interface to the east shielding wall has conduits etc and the main blocks will need to start a few inches away. The gap should be sealed in a reasonable manner, but this gap does not shine on the gate but rather the end wall shielding which would have to scatter
to the gate. Labyrinth formulas or other methods should be used to estimate the leakage at the interface.

- Vertical seams between blocks should not be much of an issue if the blocks are well placed. As noted above the small seam will shine onto the end wall shielding and then need to reflect scatter to the gate.

- Horizontal seams can allow the leakage radiation to be transported directly to the gate. To reduce the leakage the horizontal seams should be kept as far from the beam mid-plane as possible. Depending on the width of a seam they can be filled with thin Al of steel shims as was done for ERL. A band of Pb could also be placed over seams to reduce the photons, if necessary. As was done at LVTF. The radiation from the horizontal seam to the gate would likely be a narrow vertical band that not be detected by the gate chimpmunk. A calculation or some scattering material on the seam should be considered.

- Interface to roof shielding does not have to be too elaborate. If it is necessary to avoid the direct shine to the gate near the ceiling several layers of shielding material could be shimmed to be in contact with the roof shielding and other layers to avoid lower seams. The thickness can be less in effective attenuation than the main wall.

Figure 2: Preliminary layout used to consider the issues. The shielding is 2 feet thick and 6.2 feet long. This is not the shield that this report recommends but was a starting point.

The analysis of P.K. Job and W.R. Casey for NSLS-II was used to estimate photon and neutron source terms and attenuation for shielding materials. The attenuation lengths for photons, Giant

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3 The shielding over the top of the gate area was not examined to see if the ceiling height changes.

Dipole Resonance (GDR) neutrons, and High Energy Neutrons (HEN) are given in the Table 1. Only heavy concrete and Pb was used in the analysis\(^5\) for ATF simple.

**Table 1: Shielding Materials and Parameters\(^6\) used from Footnote 4**

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Shielding Material</th>
<th>Density in (g/cc)</th>
<th>Attenuation length (g/cm(^2))</th>
<th>Attenuation length (cm(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photons</td>
<td>Light Concrete</td>
<td>2.35</td>
<td>49</td>
<td>20.9</td>
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<tr>
<td></td>
<td>Heavy concrete</td>
<td>3.85</td>
<td>50</td>
<td>13</td>
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<tr>
<td></td>
<td>Pb</td>
<td>11.35</td>
<td>25</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Poly</td>
<td>1.01</td>
<td>70</td>
<td>69.3</td>
</tr>
<tr>
<td>GDR</td>
<td>Light concrete</td>
<td>2.35</td>
<td>40</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Heavy concrete</td>
<td>3.85</td>
<td>45</td>
<td>11.7</td>
</tr>
<tr>
<td></td>
<td>Pb</td>
<td>11.35</td>
<td>161</td>
<td>14.2</td>
</tr>
<tr>
<td></td>
<td>poly</td>
<td>1.01</td>
<td>6.3</td>
<td>6.2</td>
</tr>
<tr>
<td>HEN</td>
<td>Light concrete</td>
<td>2.35</td>
<td>65</td>
<td>27.6</td>
</tr>
<tr>
<td></td>
<td>Heavy concrete</td>
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<td>75</td>
<td>19.5</td>
</tr>
<tr>
<td></td>
<td>Pb</td>
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<td>191</td>
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<tr>
<td></td>
<td>poly</td>
<td>1.01</td>
<td>62</td>
<td>61</td>
</tr>
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</table>

The goal of the analysis is to ensure that routine operations will not cause the east gate chipmunk to alarm or interlock. Beam faults that can create excessive radiation at the gate must not exceed the guidance for using one fail-safe radiation detector for protection and to ensure the dose in a large beam loss event meets the C-AD shielding policy. The neutron and photon dose will be evaluated for several running conditions. Some of the analysis will depend on resigned beam stops at the end of the beam lines.

The neutron dose rates at a foot for are estimated to be 48,000 mrem/hr for GDRs and 8,000 mrem/hr for HEN at a foot for 5 Watts of continuous beam loss. The closest source to the gate is estimated to be 11.3 feet at the end of BL1. The neutron dose rates with a 45 cm heavy concrete wall\(^7\) are 8 mrem/hr for GDR neutrons and 6 mrem/hr for HEN. This is an extreme fault and the chipmunk at the gate would provide protection. The BL1 dump would need to provide at least a factor of 10 attenuation for the neutrons to achieve 0.7 mrem/hr at the gate. Additional reduction would be appropriate for ALARA. ATF has not operated at the ASE limits; if this is done then one may what to consider the location of the sources, local shielding, and reposting the area near the gate. For typical ATF operations the dose rate will be less than 0.1 mrem/hr for the neutrons.

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5 Poly was used to estimate the effectiveness of the present obsolete beam dump for BL2. The poly in the table is for non-borated poly and the poly at ATF may have boron.

6 The density of AGS concrete of 3.85 was used to scale the attenuation. The attenuation of heavy concrete wfor HEN was a guess. Other materials and information are given in the NSLS-II note.

7 This is for the wall thickness of 45 cm. The actual path would likely reduce the dose rates by a factor of 2.
Neutron can also irradiate the gate by scattering off the shielding walls. Assuming a source at least 10 feet from the end wall the dose rate using albedo coefficients is estimated to 25 mrem/hr for a full beam loss. The chipmunk or local shielding can provide the necessary protection. For the BL2 beam stop at the end of the transport an attenuation of 200 would be desirable to reduce the dose rate below 0.1 mrem/hr at the gate. The present beam stop does not have this amount of neutron shielding since the beam is typically less than 0.1 Watts and the obsolete beam stops provide shielding.

The beam stops at the end of BL1 and BL2 will be moved and rebuilt. New criteria should be used for the stops including a limit on energy and beam power. Otherwise the chipmunk at the gate will alarm or interlock on excessive radiation not allowing experiments to operate as designed. The large angle photons have a dose rate (footnote 4) of 1.39 mrem-m²/J . For 5 watts of electron beam this can be converted to 250,000 mrem/hr at a foot. The worst case would appear to be just upstream of beam stop in BL2 with a distance of approximately 18 feet and an angle of about 45 degrees through the shield wall. A full beam fault would create 6 mrem/hr at the gate.

The dose rate at smaller angles can be higher. The forward radiation for thick targets is 100-1000 times higher. Faults with a dose rate of 600 to 6000 mrem/hr at the gate will be terminated in a short period of time when detected by the chipmunk. A simple analysis was conducted for the FFAG test this year in BL1. The analysis assumed that 5 Watts of 85 MeV electrons strike a Pb block where the density and radius was varied. The concrete end wall allowed scattering towards the gate. For 4 cm of Pb with a radius of 20 cm the dose rate at the gate was 300 mrem/hr with an equal mix of neutrons and photons.

An estimate was conducted for the dose reflection off the end wall to the gate for BL2. Figures 19 and 20 of Jan. 17, 2017 memorandum was used to estimate the scattered radiation from the end wall. 250 MeV electrons struck a 10 cm thick Pb shield in front of a light concrete shield wall. The Pb was 200 cm in front of the wall and it is assumed that the beam axis is 16 feet from the gate to approximate BL2. The dose rate at the gate for a circular disc centered on the BL2 axis with radius 30 cm was 3.5 mrad/hr. An annular region from 150cm to 180 cm produced a dose of 1.6 mrad/hr at the gate, assuming that the center of the annular region could be used for the distance. Additional areas were not calculated but the dose rate at the gate would be expected to be about 20 mrad/hr.

The beam stops at for BL1 and BL2 will need to be rebuilt. The stops may need to be improved to reduce the neutrons, especially for BL2. The issues of ground activation and skyshine should be considered. The building roof and the concrete floor form a credible cap to prevent leachate from reaching the groundwater. It may be desirable to add more shielding under the dump to remove the need of considering the concrete floor a cap. Removable soil samples could be placed under the beam stops to obtain empirical data. The results would need to be reduced to take into account the 1 foot of concrete. Skyshine form ATF is monitored by 3 TLDs. No detectable 8

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8 Usually not recommended.
9 D. Beavis, May 3, 2017; http://www.c-ad.bnl.gov/esfd/RSC/Memos/05_03_17_ATF.pdf
skyshine has been detected at adjacent facilities. Both skyshine and ground activation are guidelines are yearly standards so short operations at high intensity does not impact the results. However, operations at the ASE limit for an entire year could cause a substantial increase. Another means is to develop an operating scenario and monitor that it is not exceeded. For RHIC operations these types of issues were addressed with a conservative operating scenario, but not operating machine continuously at the ASE limit for the year.

The report\textsuperscript{11} on the design of an ATFII beam stop could be used to examine some of the issues for the ATF beam stop. This report is not appropriate for the floor beam dump in BL1. The analysis in the ATF SAD should be reviewed to examine the potential ground activation.

The side wall of Pb along the transport from the last BL2 bending magnet to the beam stop may be obsolete. As discussed above this was likely an afterthought when photon dose was detected at the east gate. However, some Pb is needed to ensure mis-tuned beam has sufficient material to initiate scattering.

The RSC meeting\textsuperscript{12} that discussed the ASE changes did not have time to address issues of hold points while the designs are verified with routine operations and a limited set of beam fault studies. The changes being made for December should be incorporated into the review.

\textsuperscript{11} H. Seymour and K. Yip, August 16, 2016; \url{http://www.c-ad.bnl.gov/esfd/RSC/Memos/seymour_hannah_report.pdf}

\textsuperscript{12} RSC Meeting of Feb. 14, 201; \url{http://www.c-ad.bnl.gov/esfd/RSC/Minutes/02_14_17Minutes.pdf}