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Shielding Requirements for the LCLS Project (Title I)

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Brief Summary: This specification describes radiation shielding requirements for the Title I design of the Conventional Facilities of LCLS.

Keywords: Shielding, radiation

Key WBS#'s: 1.9

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Shielding requirements for the LCLS project (Title 1)

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Beam parameters used in the calculations:

Electron beam: 15 GeV, 2 kW (unless specified).
Spontaneous X-ray: Spectrum provided by Roman Tatchyn. The average power up to the 180th harmonic is 2.78 W (2.73×10^{14} photons/s). The critical energy is 140 keV. The following beam parameters were used to calculate the spectrum:14.35 GeV, 0.95 nC/pulse, 120 Hz, e-beam power of 1.6 kW, and 4000 periods in undulator (120 meter).
Free electron laser: Not included because the energy of the FEL is only 8.2 keV.

BTH Head House (see Figure 1 provided by David Saenz on April 5):

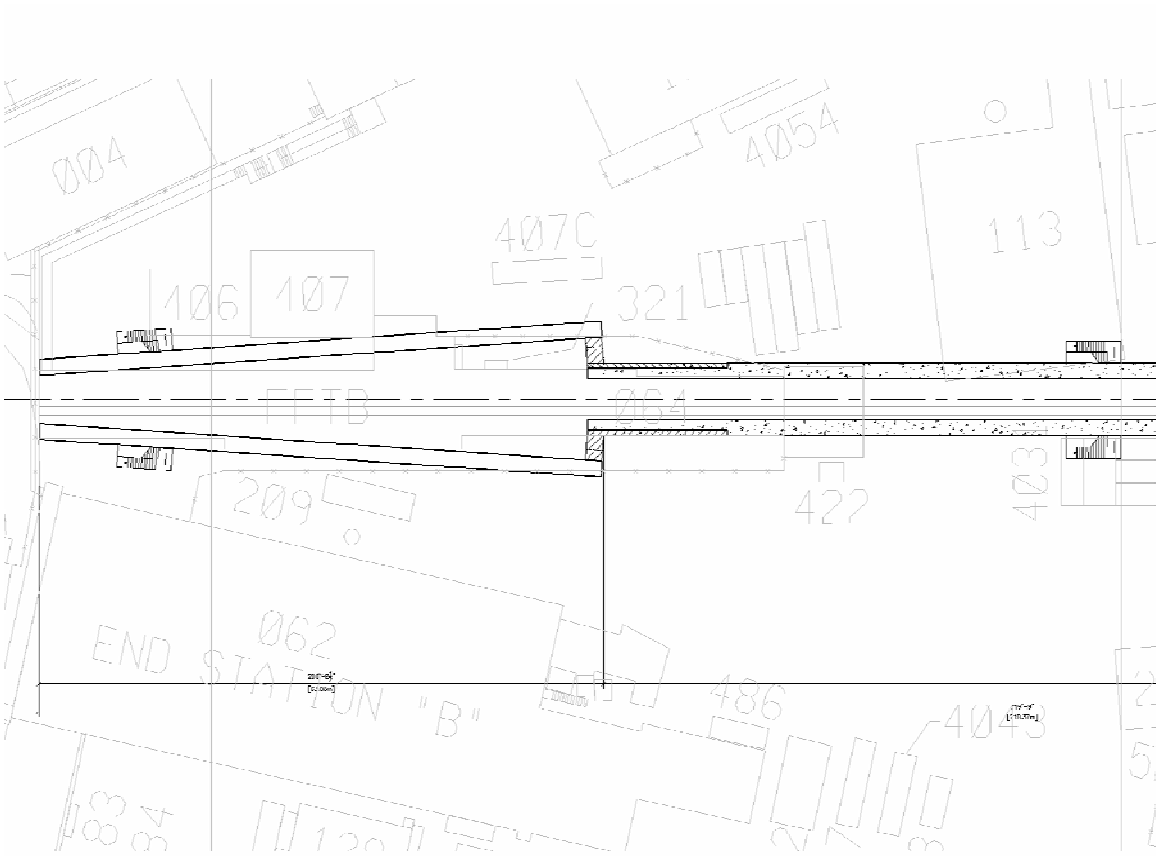

Figure 1 BTH head house and BTH tunnel

Beam losses: 5 W is lost at any point in one of six beam lines.
Requirements: 72 to 67 inches concrete on the sides as the distance to the BSY wall increases from 0 m to 63 m.
Non-occupied area on the roof: 43 inches concrete.
Occupied area on the roof: 63 inches concrete.

End of the flared sections of BTH Head Hall (endplug):

Beam losses: 2 kW, 15 GeV hits the endplug in an accident case.
Requirements: 8″ iron + 7' concrete endplug.

BTH tunnel (see Figure 1):

Beam losses: 5 W is lost at any point in a single 0^0 line.
Requirements: 72 inches on the sides.
Requirements for the roof are the same as BTH house.

Bridge over the BTH (see Figure 2):

Beam losses: 5 W is lost at any point.
Requirements:

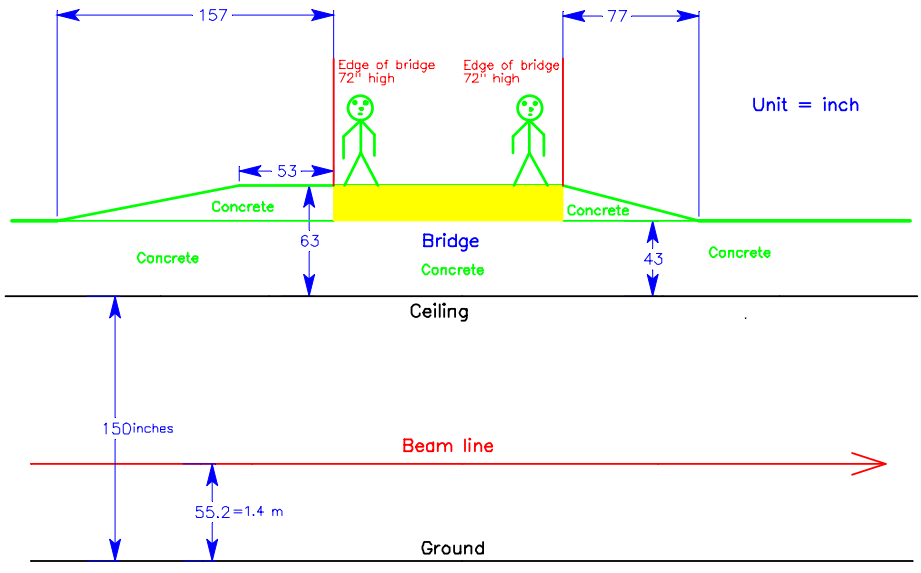

Figure 2 Bridge over the BTH

B131 corner (see Figure 3):

Beam losses: 5 W is lost at any point in a single 0^0 line.
Requirements:

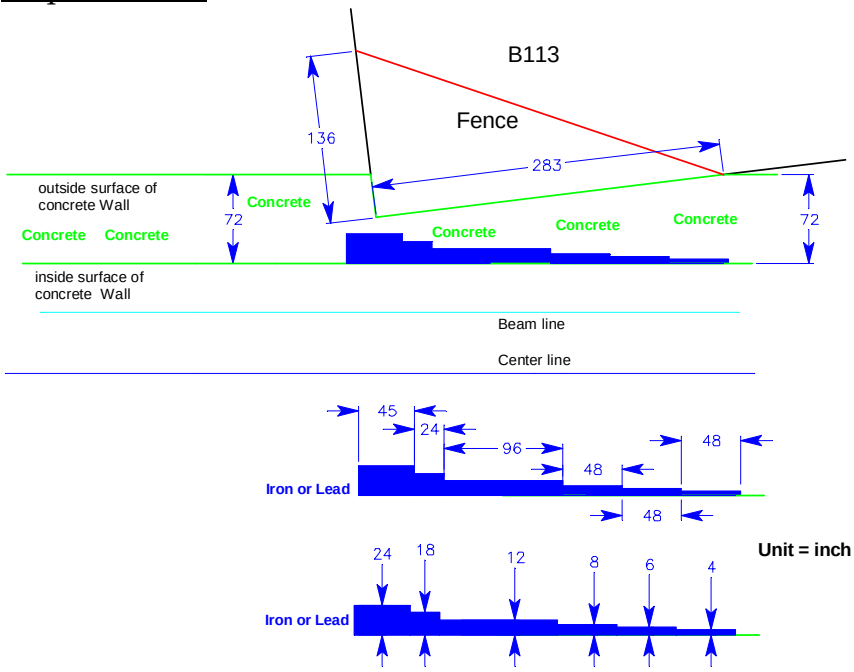

Figure 3 Shielding for B113

Maze to BTH tunnel (see Figure 4):

Beam losses: 5 W is lost at any point in a single 0^0 line.
Requirements: see Figure 4 in red.

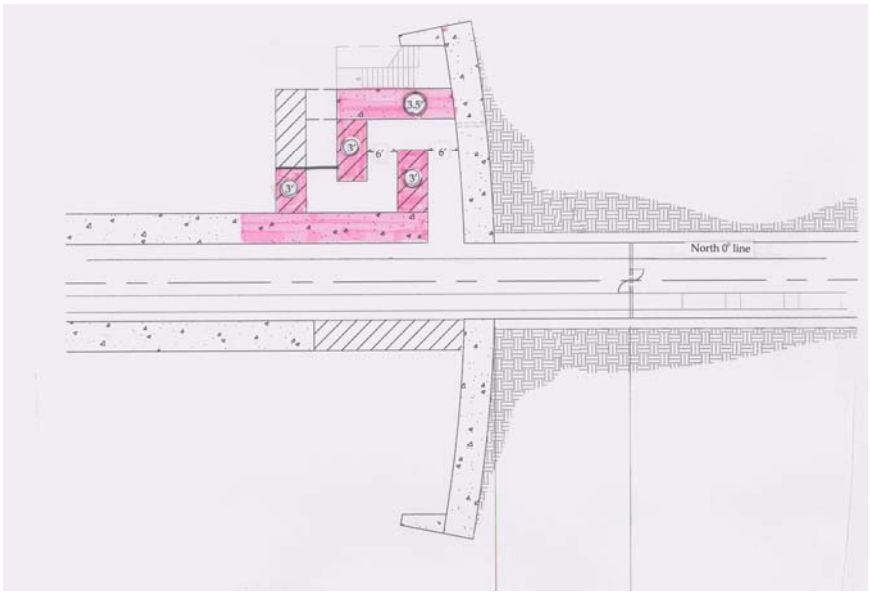

Figure 4 Maze to BTH tunnel

Single beam dump (SBD):

Beam losses: 2 kW parks on the SBD.
Requirements: 4′ lead plug behind the SBD. 10″ iron on the side.

Tune-up stopper:

Beam losses: 167 W (10 Hz) parks on the tune-up stopper.
Requirements: Lead collimator downstream of the tune-up stopper (5′ long, 0.25″ ID, 12″ OD). 13 feet earth on the sides and 10.5 feet earth on the roof without local shielding. 8″ iron on the side of the stopper.

E-beam dump:

Beam losses: 2 kW parks on the e- beam dump.

Requirements: Above the dump, 2 feet iron + 3 feet concrete, 2 feet concrete roof of the tunnel, 6′ earth above the roof. 8″ iron and 3′ concrete in the forward direction. 3′ concrete below the dump. The distance from the tunnel floor to the center of the dump is 1 m. The bend angle is 5^{o}.

Muon shielding (see Figure 5):

Beam losses: 30 W is lost at any point between the end of the undulator and the end of the dump magnets in the 0^0 direction.

Requirements:
3′ long toroidal magnetic spoiler is located downstream of the dump magnets. The outside diameter of the spoiler is 24″, the inside diameter is 0.6″ including the current winding. (The distance from the front face of the spoiler to the Near Hall is 50 m). A 3′ thick iron muon shield which fills the tunnel is located downstream of the electron dump. The beam hole through the muon shield is 3 cm diameter. (The distance from the front face of the muon shield to the Near Hall is 33 m). 4′ iron and 3′ concrete is used as the up-beam wall of the first Near Hall hutch.

Maze to the e- dump and Front End (see Figure 5):

Beam losses in the Dump line: 30 W is lost near the passage way of the maze.

Beam losses in the Front end: Spontaneous X-ray hits a mirror, and the high-energy bremsstrahlung of 540 mW hits a BCS copper stopper. 540 mW is from the calculations performed for 2002 LCLS Lehman review assuming that 167 W (10 Hz) hits an X-ray monitor in the last section of the undulator.

Requirements: see Figure 4; the maze wall is 2′ concrete.

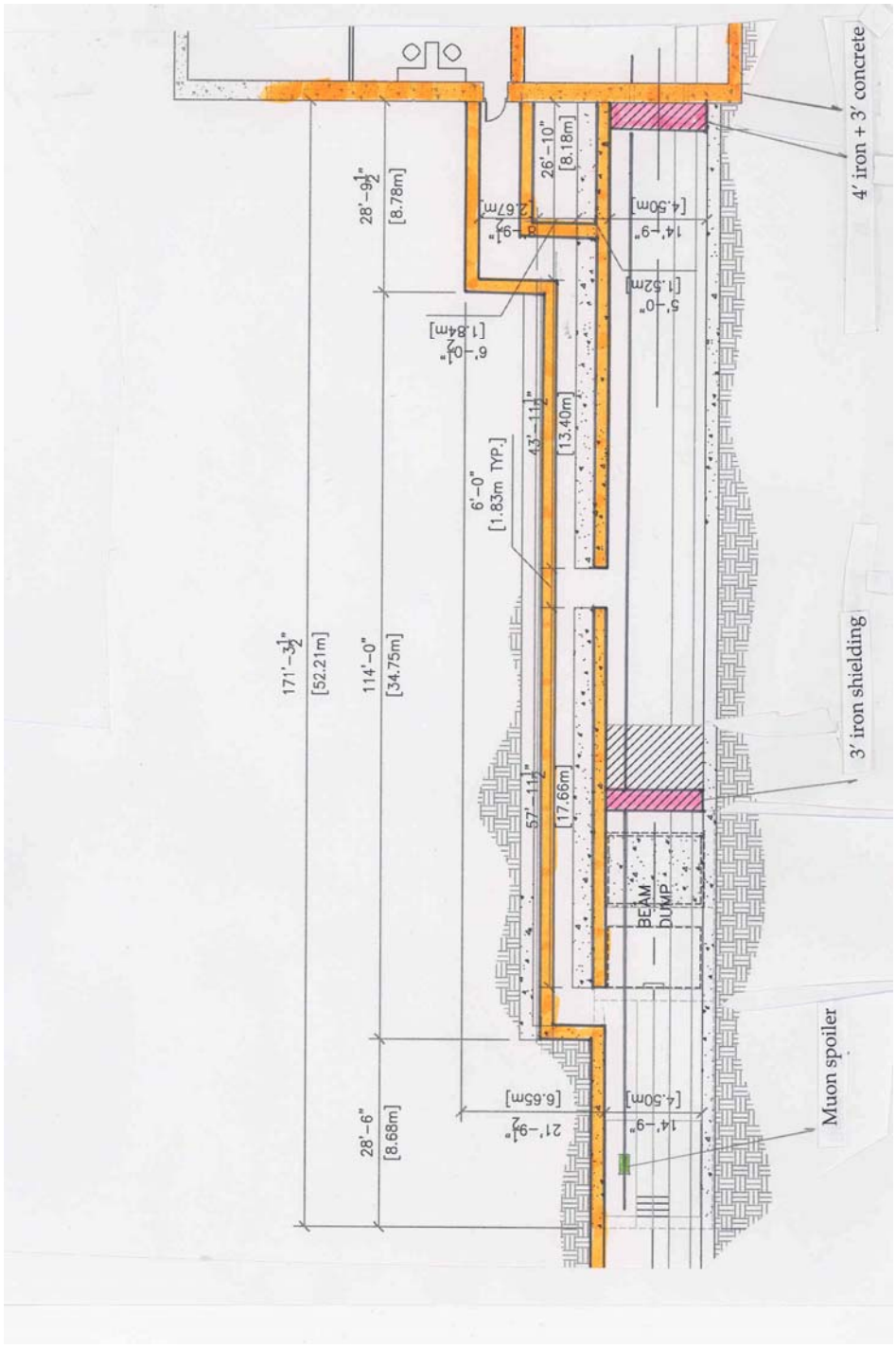

Figure 5 Muon shielding and the maze to the dump line and Front End

Near Hall hutch (see Figure 6 provided by David Saenz on April 5):

Beam losses: Spontaneous X-ray hits a mirror, and the high-energy bremsstrahlung of 12 mW hits a copper PPS stopper. 12 mW is from the calculations performed for 2002 LCLS Lehman review assuming that 20 W is lost inside a collimator upstream of the undulator. A collimator with aperture of 0.5 cm is located after the undulator.

Requirements: 2 feet concrete wall on the north side, 4" iron local shielding after PPS stopper, 3 feet concrete wall down beam, 3 feet concrete on the roof.
3 feet concrete wall on the north side of the reflect mirror tank.

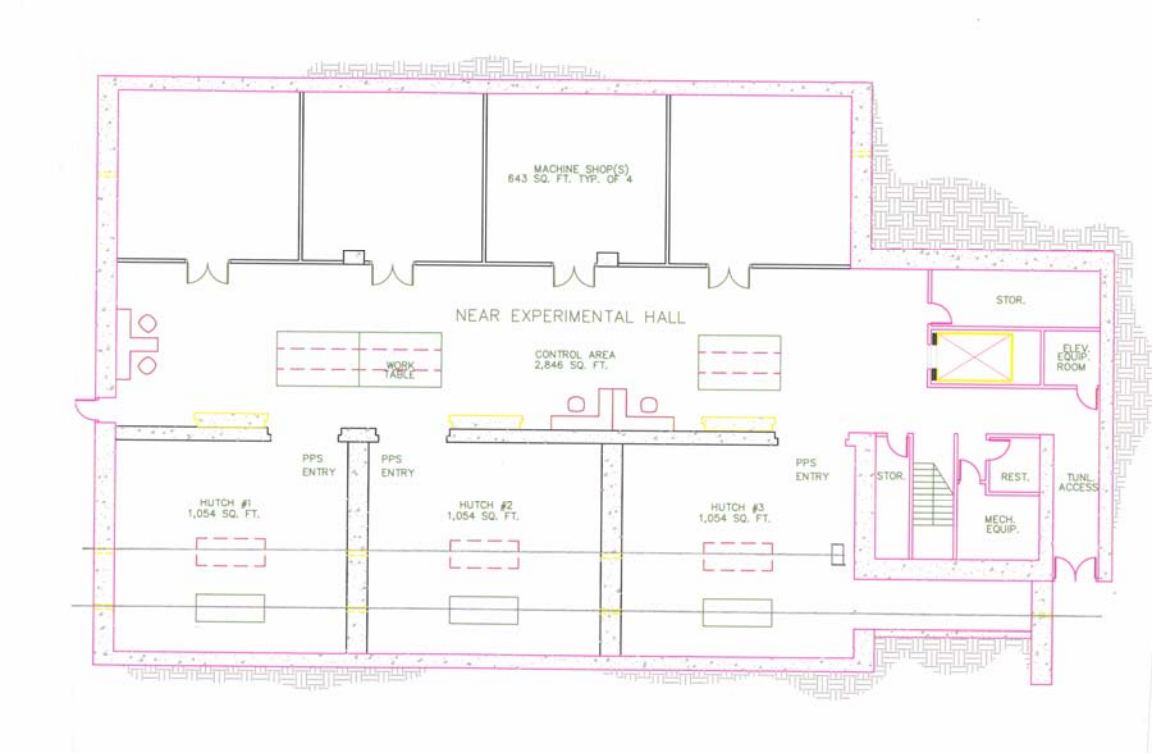

Figure 6 Shielding requirement for Near Hall

Far Hall 0^0 hutch (see Figure 7 provided by David Saenz on April 5):

Beam losses: As the same as the Near Hall.

Requirements:
2 feet concrete wall on the sides, 3 feet concrete wall down beam with 4" iron local shielding and a photon dump**.** 2 feet concrete on the roof**.** Figure 7 does not reflect the shielding requirements as mentioned above.

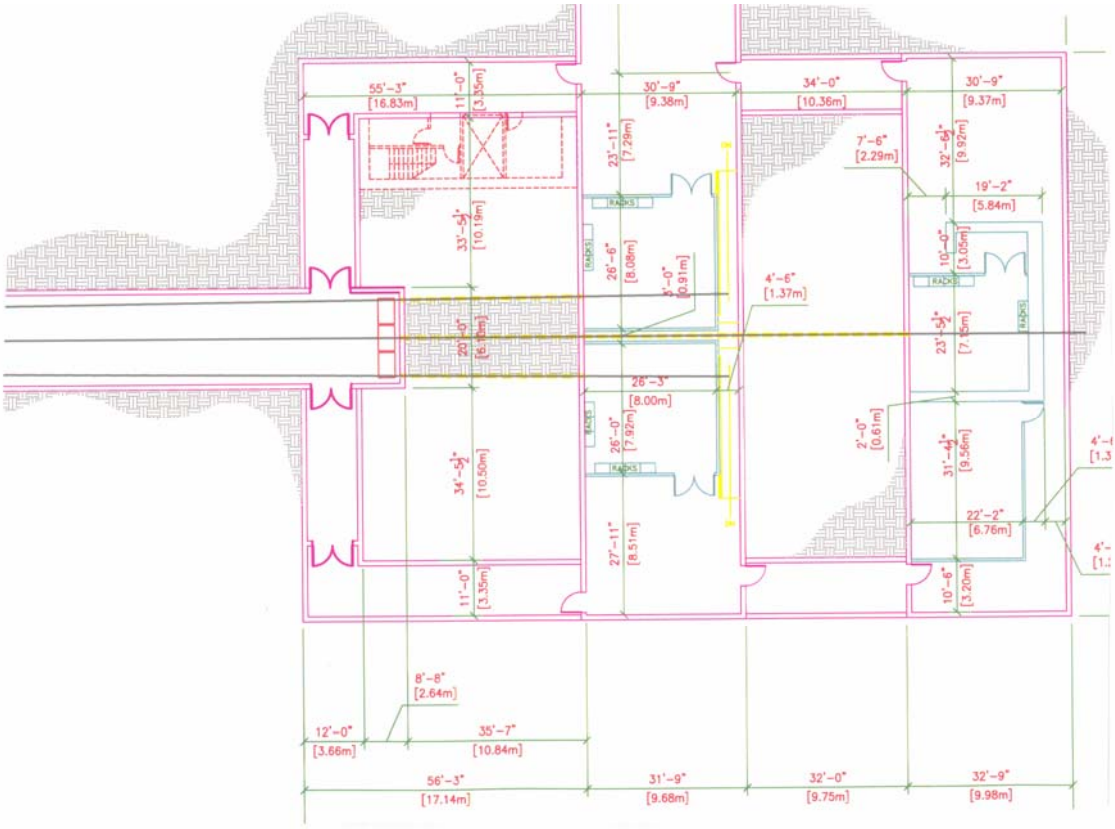

Figure 7 Shielding requirement for Far Hall

Far Hall off-side hutches:

Beam losses: Scattered and reflected spontaneous X-ray from a mirror located in the last Near Hall hutch hits a mirror inside the off-side hutch.

Requirements:
6 mm of iron or 1.2 mm of lead or 8.2 cm of concrete on the sides,
2 mm of lead in the down-beam wall with a thick plate (1 m × 1 m × 70 mm iron or 9 mm lead) and a photon dump in place. 1.0 mm of lead on the roof

Appendix

Per John Galayda's request RP studied shielding requirements for the following beam parameters:
Electron beam: 28 GeV, 5 kW.
Spontaneous X-ray: Scaled spectrum using 28 GeV, e-beam power of 5 kW.

Preliminary results indicate that no major additional shielding will be needed for the electron beam transport enclosures (Head House, BTH Tunnel, e- Dump, Muon shielding). However, magnetized spoilers and local shielding may need to be added down-beam of radiation sources. Since the critical energy of the spontaneous X-ray radiation will increase when the electron energy increases, both the Near Hall and the Far Hall would require thicker wall shielding.