

Radiation Shielding Design Analysis for the Ring to Second Target Beam Transport at the Spallation Neutron Source Second Target Station

Wouter C. de Wet, PhD

dewetwc@ornl.gov

Accelerator Design and Technology

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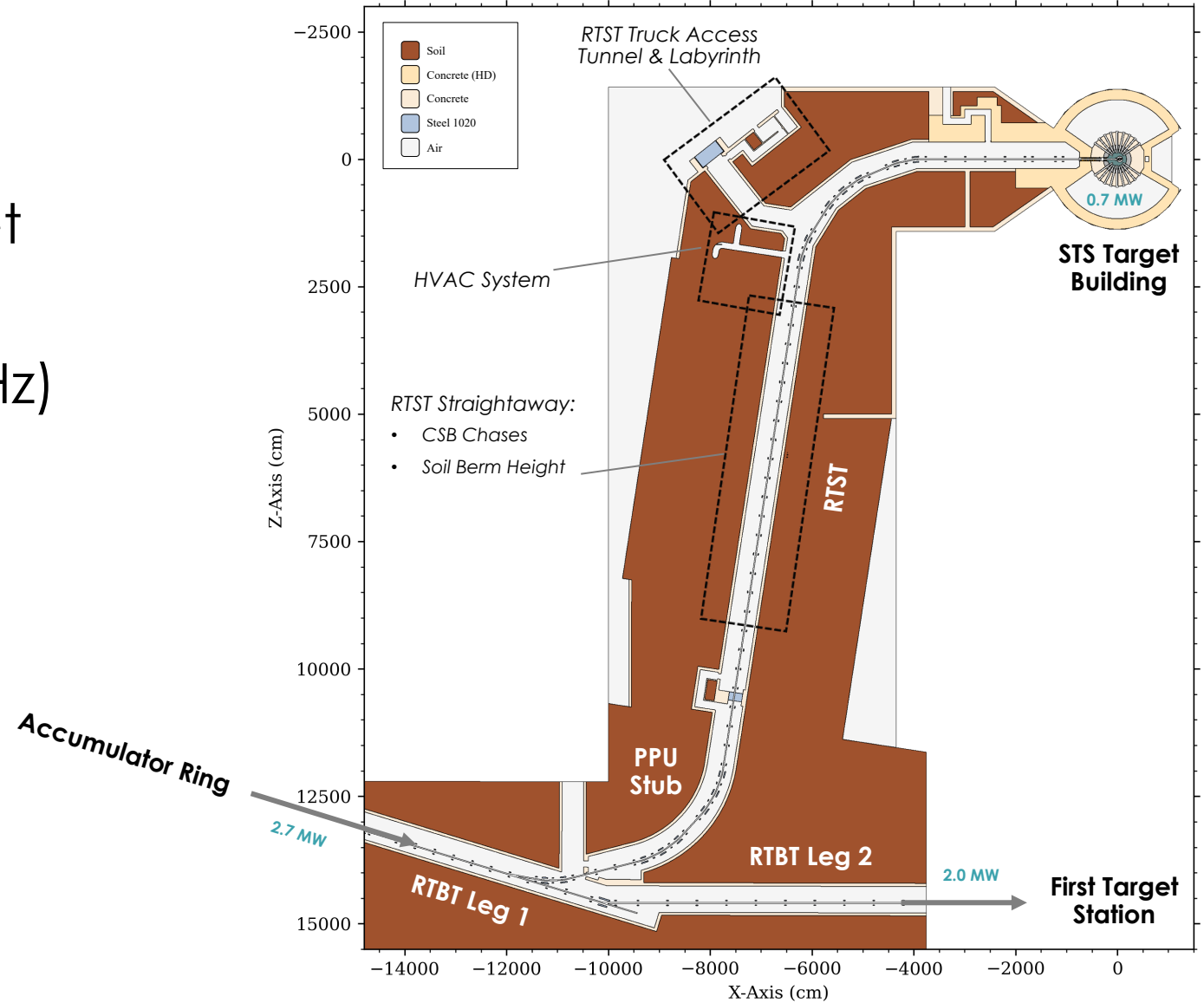
Outline

- Introduction to Second Target Station Project - RTST
- Shielding Design Guidance
- Radiation Transport Methodology
- Analysis 1: Truck Access Tunnel & Labyrinth
- Analysis 2: HVAC Ducts
- Analysis 3: Soil Berm and Electrical Chases

STS-RTST Overview

- RTST - Ring to Second Target Beam Transport
- Beam Power is 700 kW (15 Hz)
- Proton Energy is 1.3 GeV
- Total Length is ~220 m
- 56 Quadrupole Magnets
- 15 Dipole Magnets

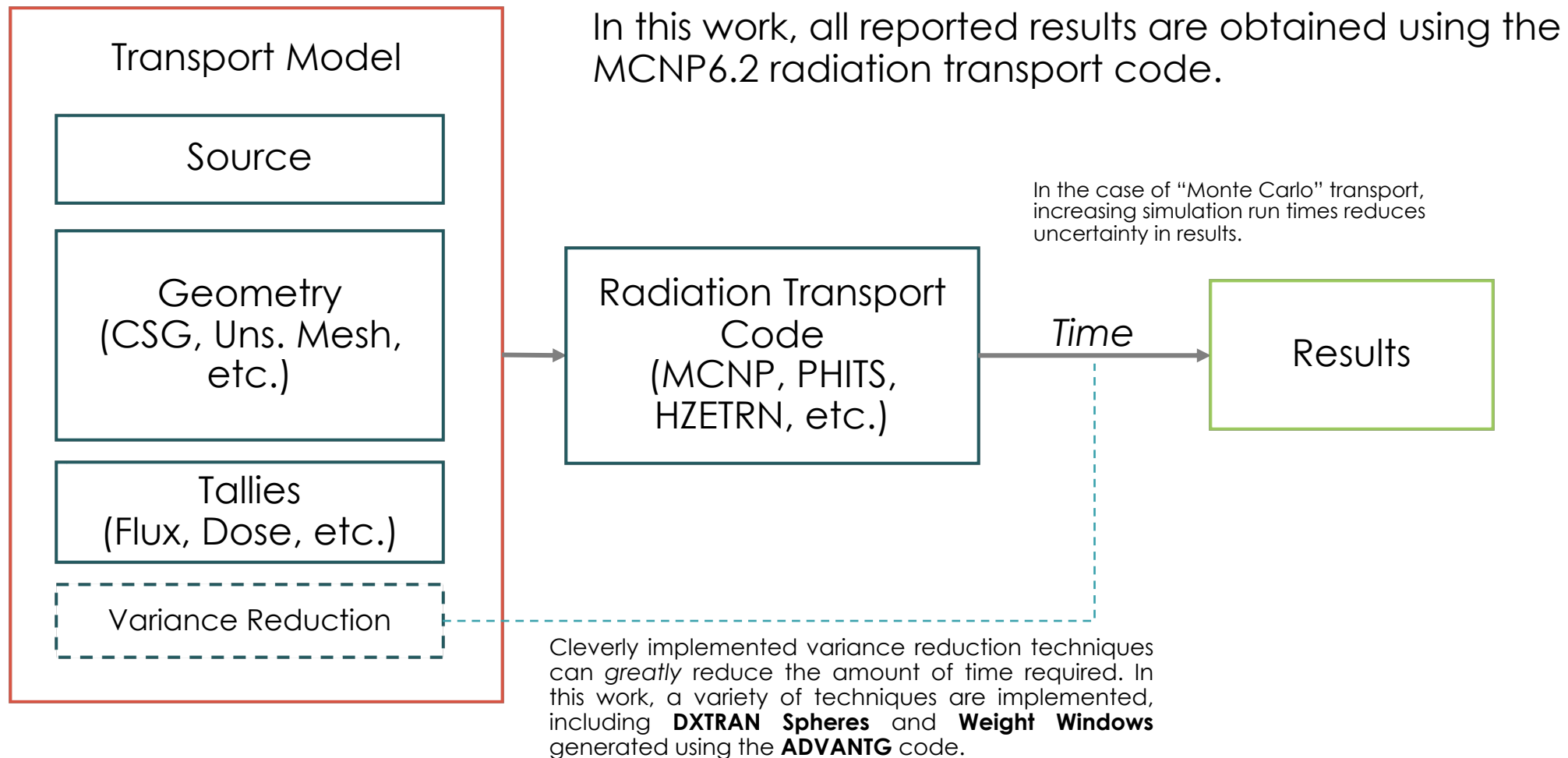
STS Accelerator Geometry



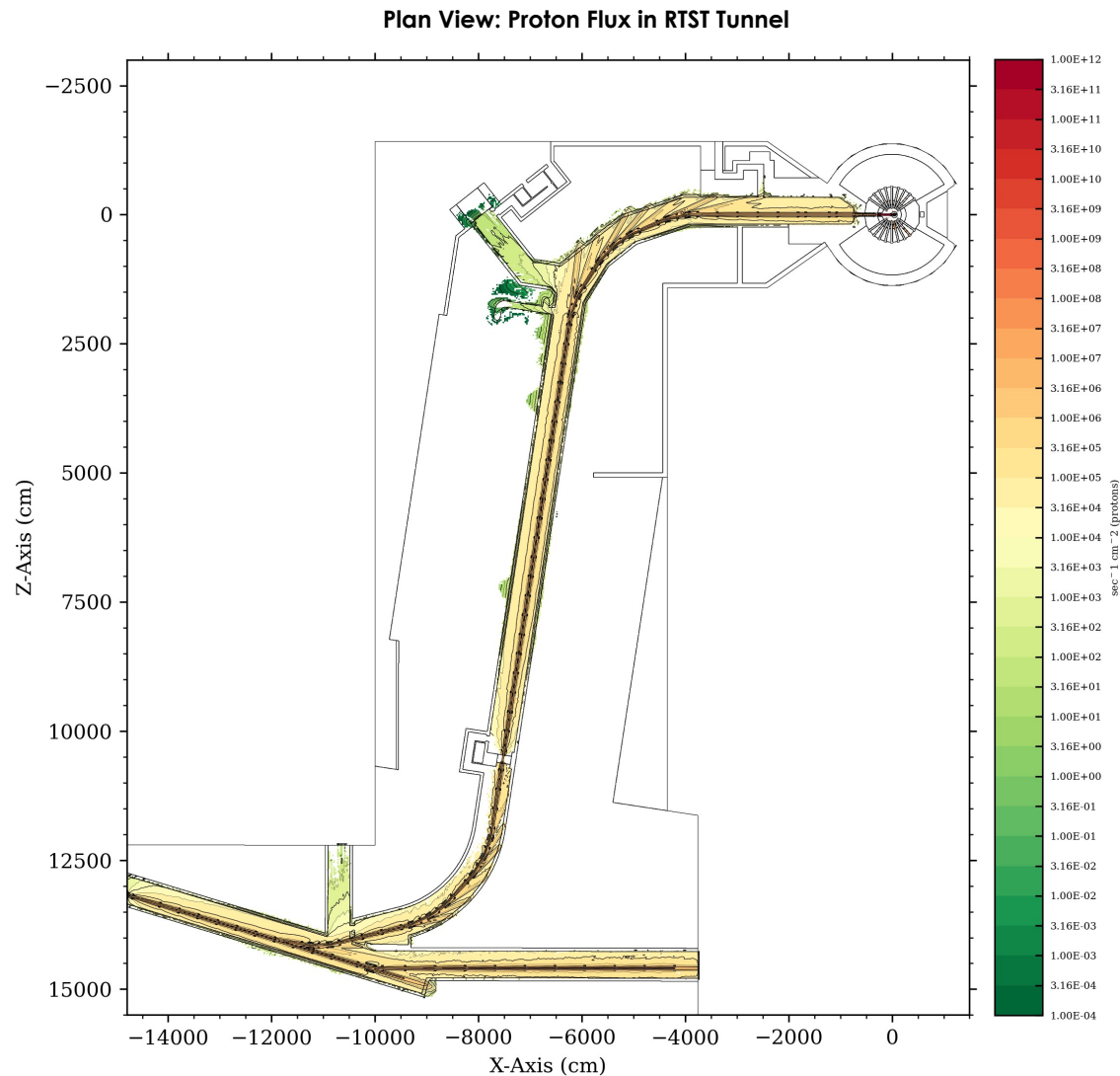
Shielding Design Guidance

- Dose rates in generally occupied regions should be <0.25 mrem/hr during normal operations
- Requirement begins 30 cm from shielding surface
- Exceptions possible for regions in which continuous occupation not plausible

Radiation Transport Methodology



Transport Sources



- Linear beam losses along active transport lines
 - Assume 1 W/m of beam
 - 1.3 GeV protons
 - Lost protons placed in beam tube walls
- Backscatter from primary beam
 - 700kW primary beam on tungsten target
 - 1.3 GeV protons

Transport Tallies

- MCNP6 TMESH
 - 25 cm rectilinear mesh
- 3 Particle Species
 - Protons
 - Neutron
 - Photons
- Quantities
 - Flux
 - Dose Rate
 - Exposure contributions calculated via whole-body external exposure effective dose rate flux-to-dose conversion factors.

Analysis 1

Truck Access Tunnel & Labyrinth

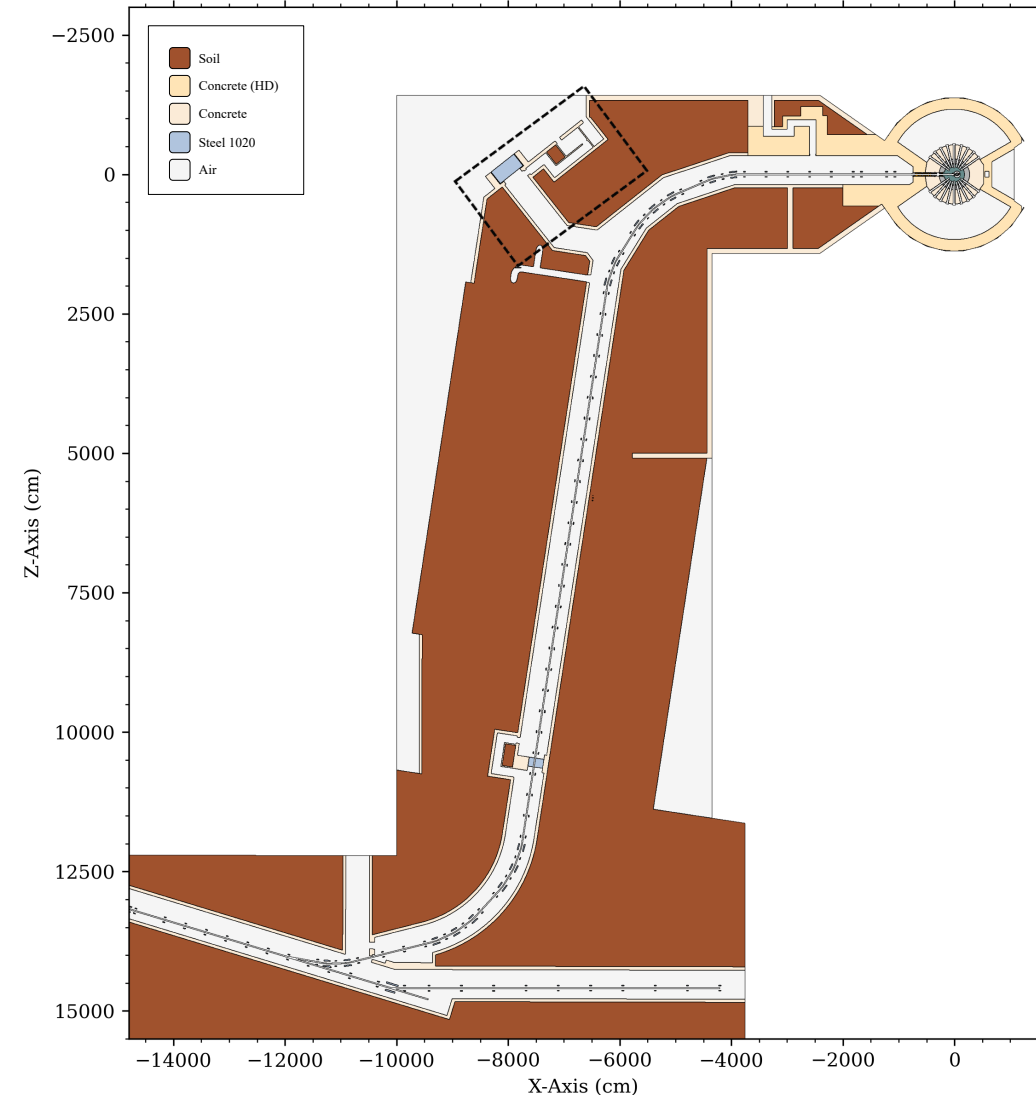
Truck Access Tunnel

- Source: 1 W/m beam losses in RTBT, RTST, and 1 MW primary beam-on-target backscatter.
- Region: RTST Truck Access Tunnel and Labyrinth.

Objective

Determine if dose rates in occupied regions outside of Truck Access Tunnel and Labyrinth are <0.25 mrem/hr during normal operations.

STS Accelerator Geometry



Truck Access Tunnel Continued

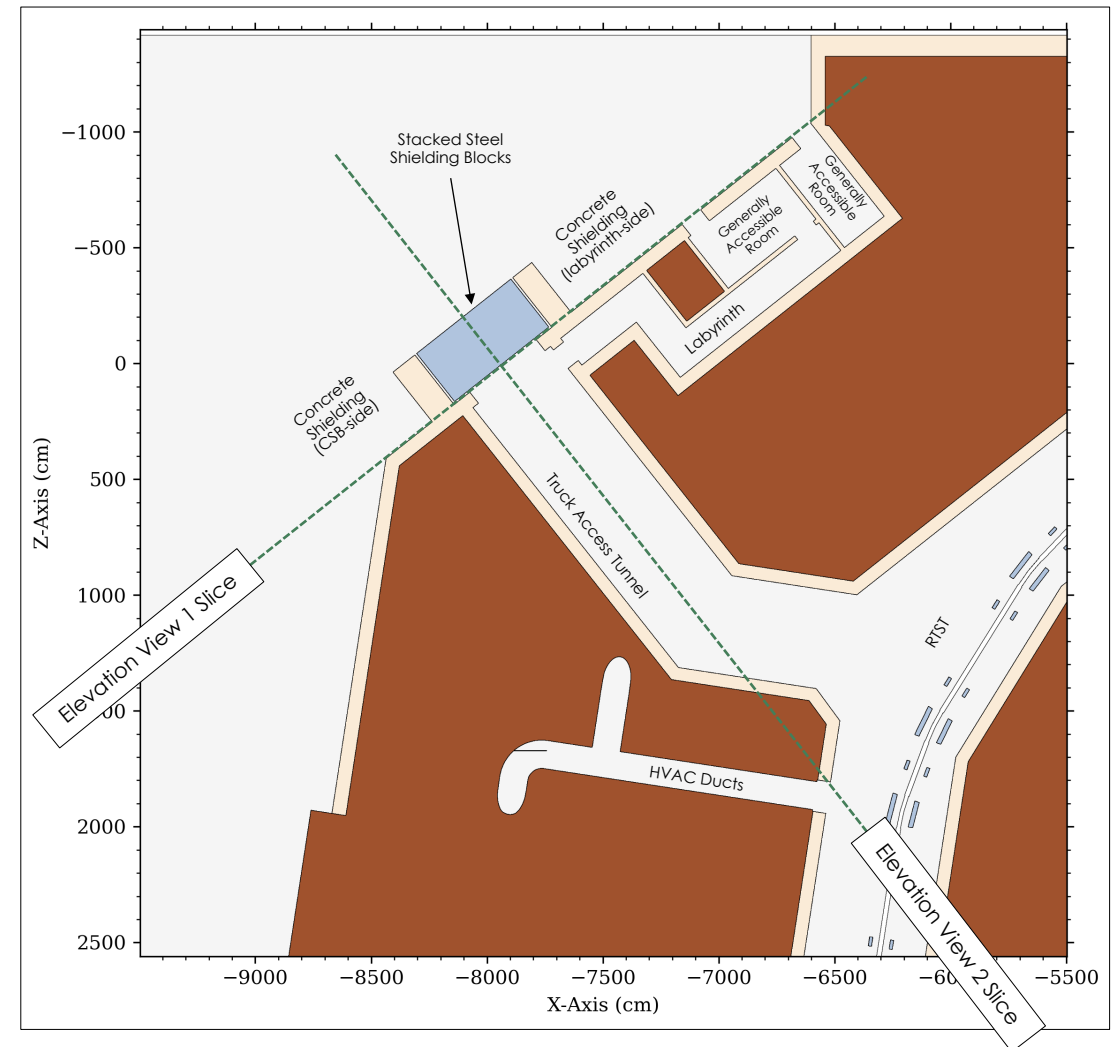
Material Specifications

- Soil, $\rho_{\text{bulk}} = 1.931 \text{ g/cm}^3$, (21% H₂O content)
- Concrete, $\rho = 2.339 \text{ g/cm}^3$
- Steel, $\rho = 7.039 \text{ g/cm}^3$
- Air, $\rho = 0.0011988 \text{ g/cm}^3$

Elevation Views

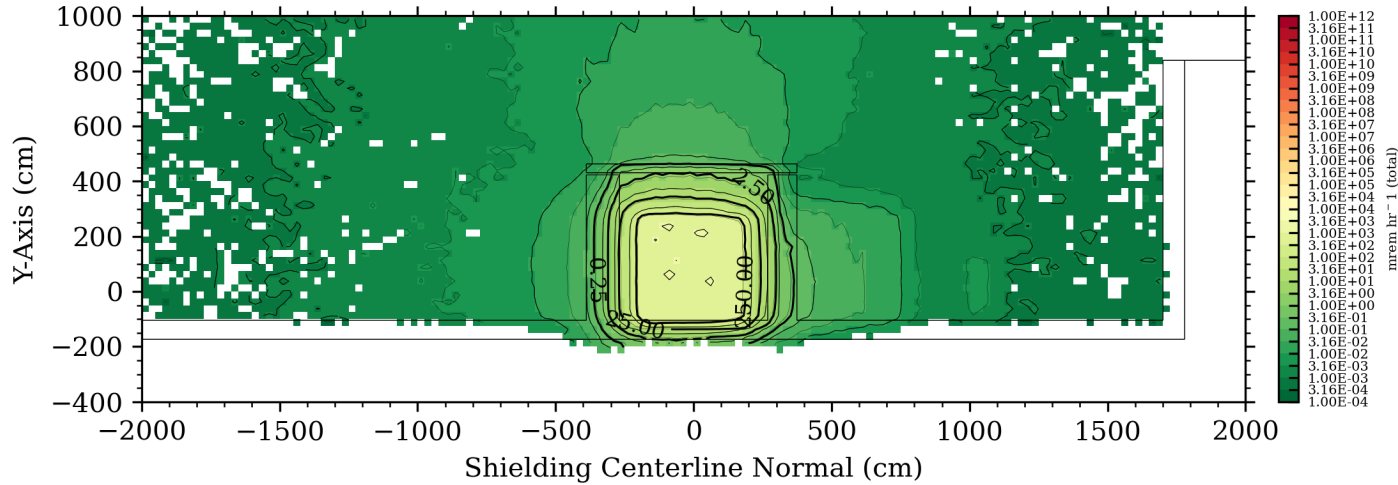
- Elevation View 1 Slice is perpendicular to the truck access tunnel centerline and parallel with the interior face of the stacked steel shielding.
 - Slice is intentionally placed in the gap between the exterior wall of the truck access tunnel and interior face of the stacked steel shielding mass.
- Elevation View 2 Slice is directly along the truck access tunnel centerline.

Plan View 1: Truck Access Region Geometry



Elevation View 1, Concrete Shielding & Lintel

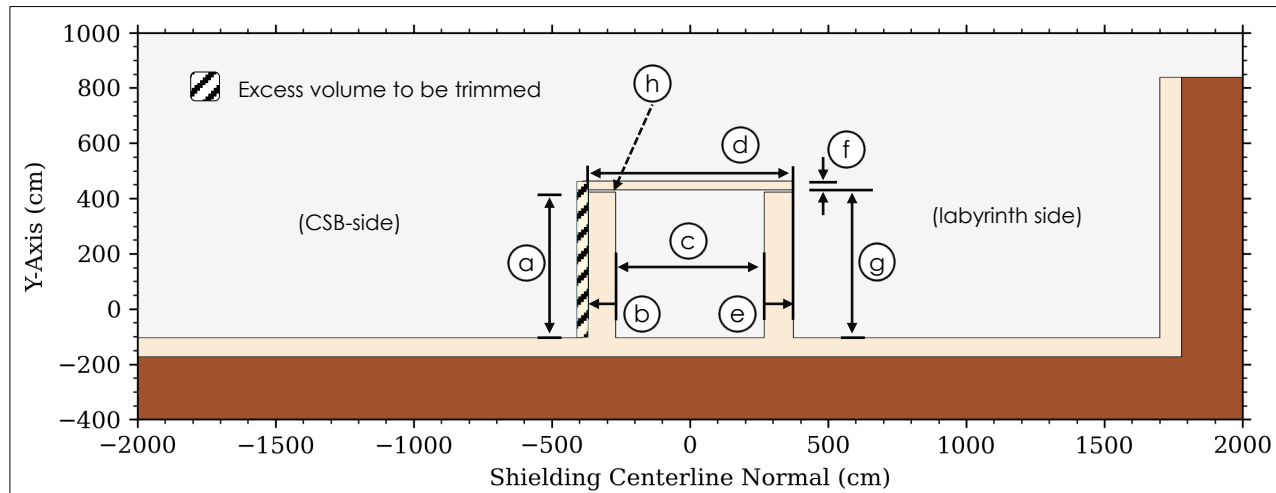
Elevation View 1: Total Dose Rate (1W/m Beam Losses & Target Backscatter)



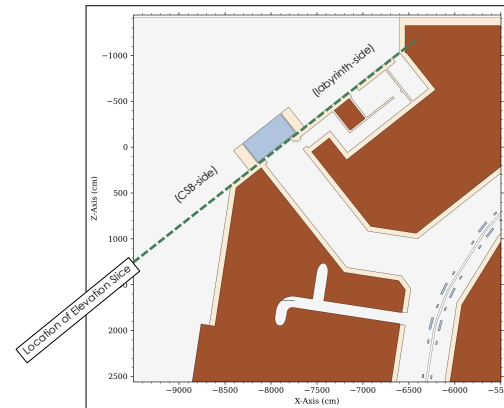
Dimension(s)

- (a) 528.3 cm — Height of concrete shielding from tunnel floor.
- (b) 110.0 cm — Required width of concrete shielding (CSB-side).
- (c) 538.32 cm — Interior spacing between concrete shield walls.
- (d) 733.32 cm — Full width of concrete lintel (outer concrete extents).
- (e) 85.0 cm — Required width of concrete shielding (labyrinth-side).
- (f) 30.5 cm — Height of concrete lintel.
- (g) 537.3 cm — Concrete lintel distance from tunnel floor.
- (h) 9.0 cm — Vertical gap between concrete lintel and walls.

Elevation View 1: Geometry

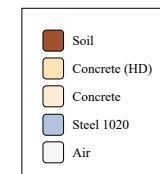


Plan View



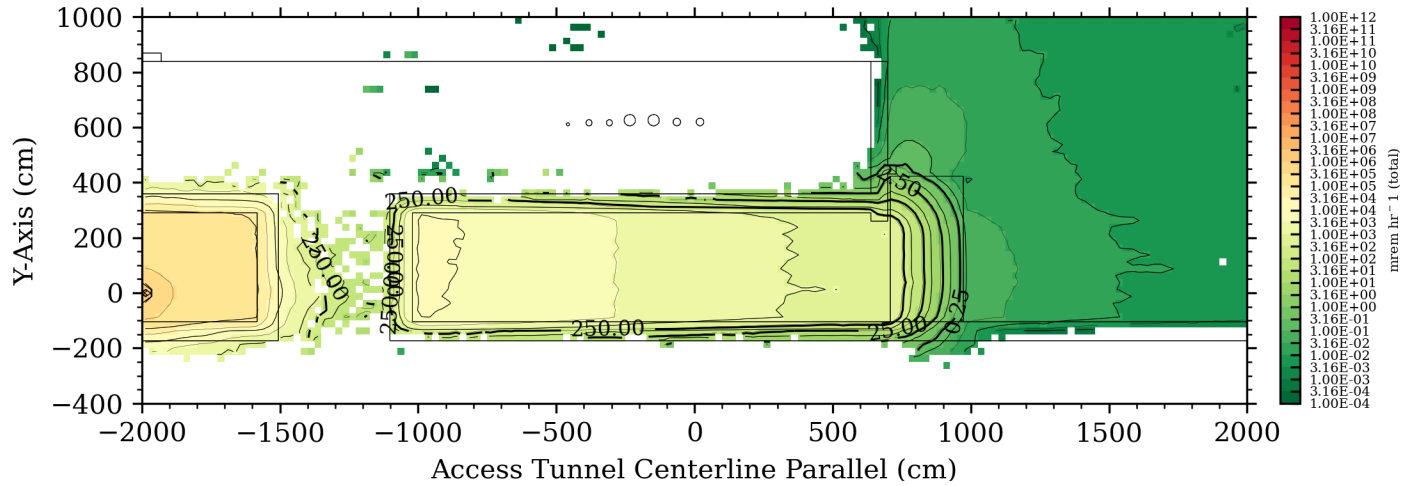
Notes

- Concrete inner walls are equidistant from the steel shielding centerline. In other words, midpoint of **c** lies directly along the truck access tunnel centerline.
- Gap **h** is not necessary. It may be filled by increasing **a** to match **g**. It may not be removed by decreasing **g** to match **a**.

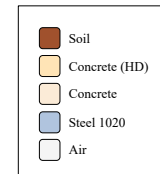


Elevation View 2, Steel Shielding Centerline & Lintel

Elevation View 2: Total Dose Rate (1W/m Beam Losses & Target Backscatter)



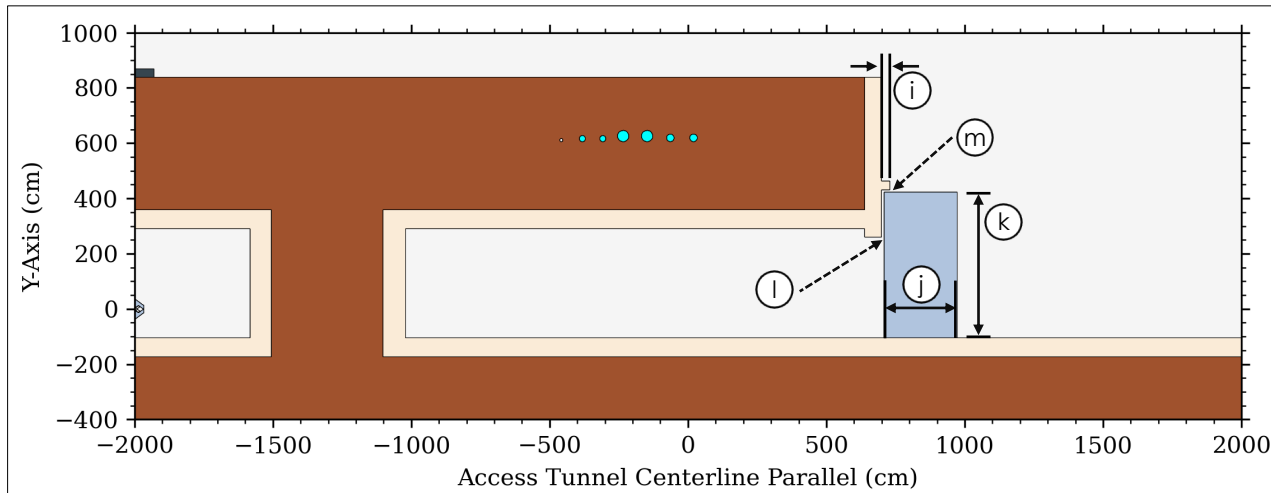
- (i) 30.5 cm — Concrete lintel depth.
- (j) **245.0 cm** — Required depth of stacked steel shielding.
- (k) 528.3 cm — Height of stacked steel shielding.
- (l) 9.0 cm — Gap between truck access tunnel exterior wall and interior face of stacked steel shielding blocks.
- (m) 9.0 cm — Gap between concrete lintel and stacked steel shielding.



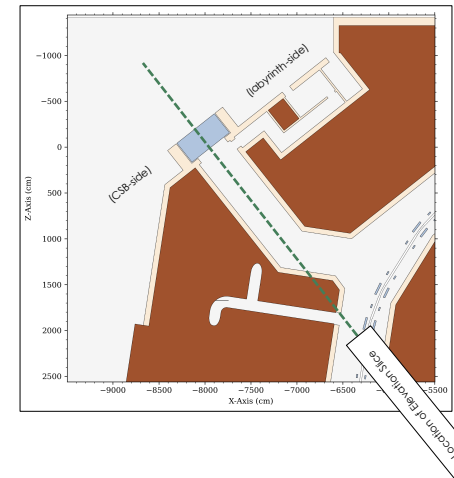
Notes

- There is no gap between the underside of the stacked steel shielding blocks and the tunnel floor/road elevation. Blocks will sit directly on the ground.
- Dose rates streaming through HVAC ducts exceeding 0.25 mrem/hr on left side of plots are for the first design iteration and are no longer relevant.

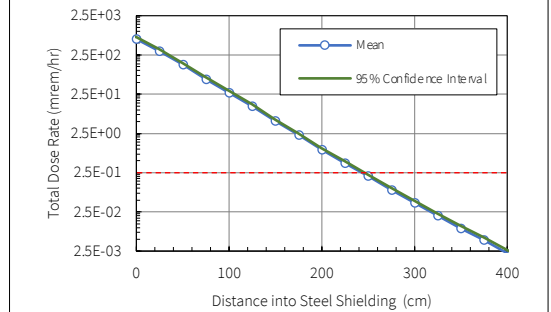
Elevation View 2: Geometry



Plan View

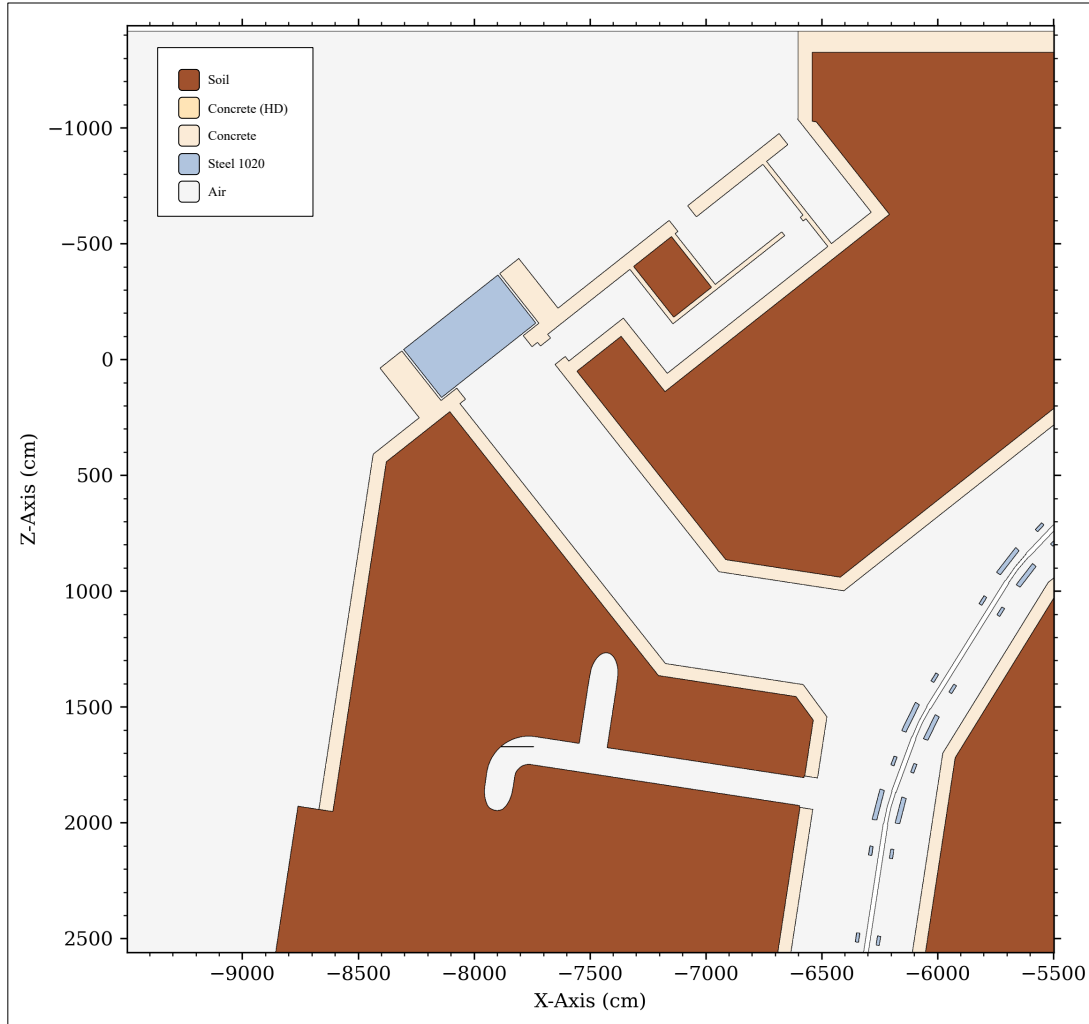


Steel Shielding Dose Rate vs. Depth

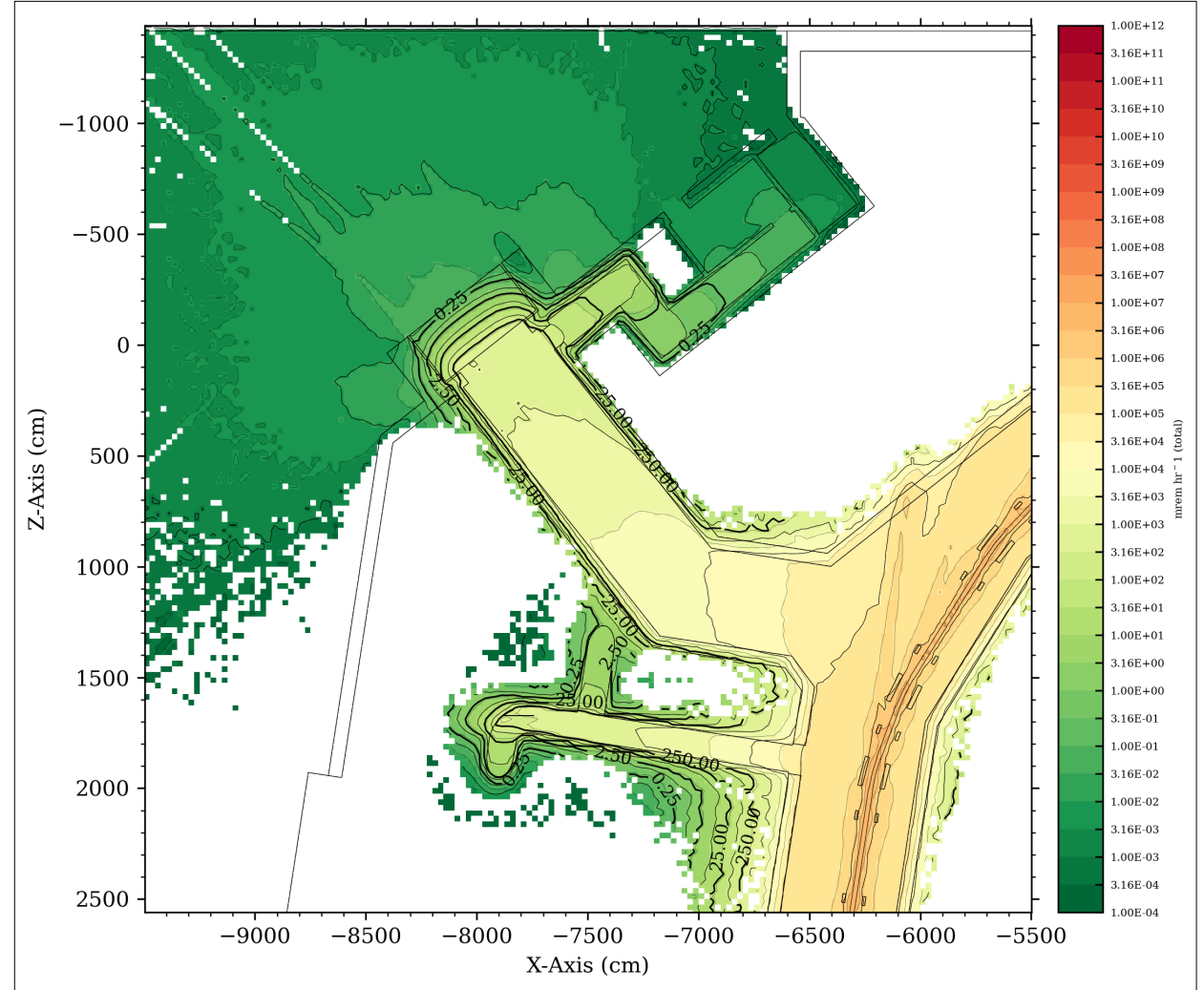


Plan View 1, Truck Access Shielding & Labyrinth

Plan View 1: Geometry

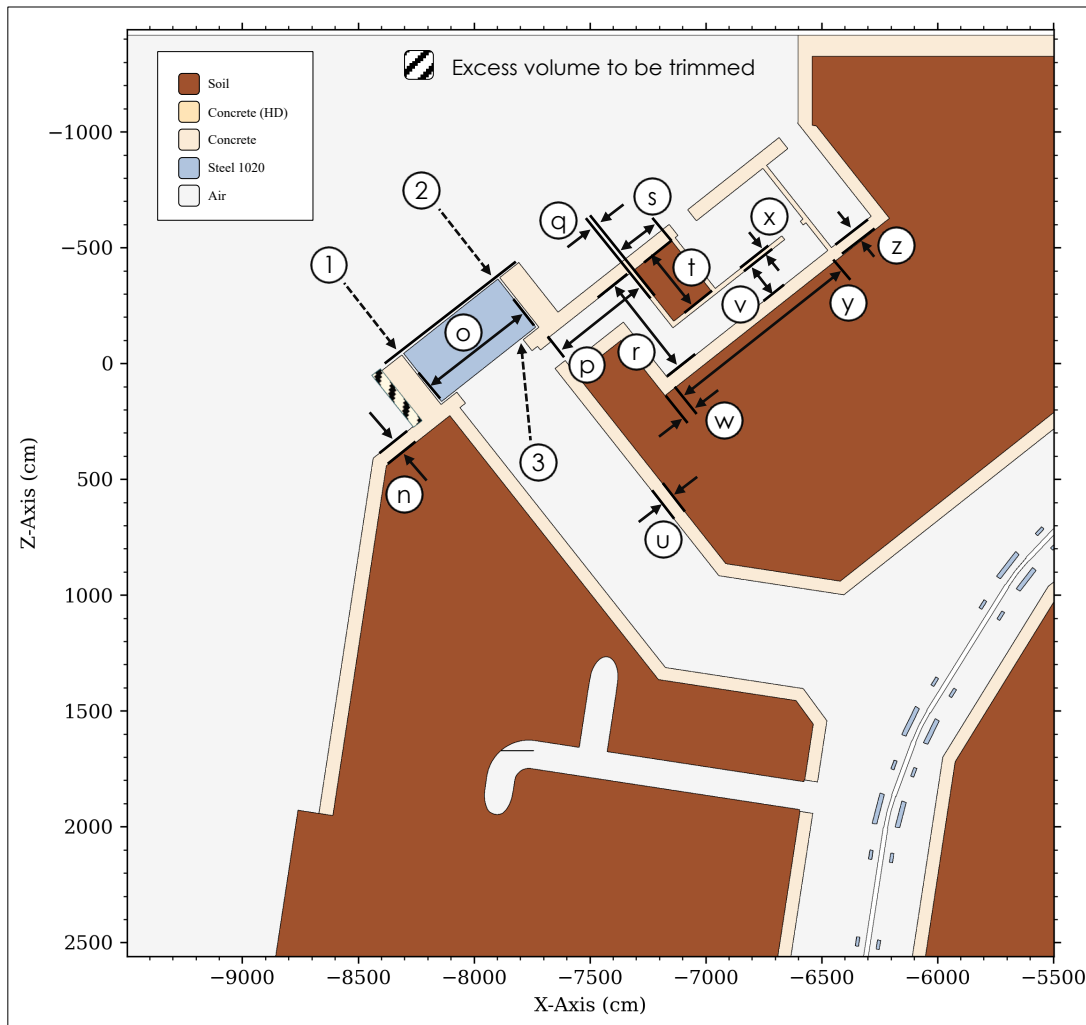


Plan View 1: Total Dose Rate (1W/m Beam Losses & Target Backscatter)



Plan View 1, Truck Access Shielding & Labyrinth

Plan View 1: Geometry



Dimension(s)

- Ⓝ 60.96 cm — Truck Access Tunnel outer concrete wall thickness.
- Ⓞ **528.3 cm** — Width of stacked steel shielding blocks. Does not include the 5.0 cm gaps on either side between the interior faces of concrete shielding walls and steel mass.
- Ⓟ 452.12 cm — Length of first hallway in Truck Access Tunnel labyrinth (width is 147.32 cm).
- Ⓠ 20.32 cm — Truck Access Tunnel labyrinth concrete wall thickness surrounding inner soil shielding mass.
- Ⓡ 452.12 cm — Length of second hallway in Truck Access Tunnel labyrinth (width is 152.4 cm).
- Ⓢ 208.28 cm — Truck Access Tunnel labyrinth inner soil shielding mass thickness in the dimension perpendicular to the Truck Access Tunnel centerline.
- Ⓣ 279.4 cm — Truck Access Tunnel labyrinth inner soil shielding mass thickness in the dimension parallel to the Truck Access Tunnel centerline.
- Ⓤ 55.88 cm — Truck Access Tunnel concrete wall thickness.
- Ⓥ 152.4 cm — Width of third hallway in Truck Access Tunnel labyrinth.
- Ⓦ 55.88 cm — Truck Access Tunnel labyrinth concrete wall thickness.
- Ⓧ 20.32 cm — Truck Access Tunnel labyrinth interior concrete wall thickness.
- Ⓨ 883.92 cm — Length of third hallway in Truck Access Tunnel labyrinth.
- Ⓩ 55.88 cm — Truck Access Tunnel labyrinth concrete wall thickness.
- ① **5.0 cm** — Gap between concrete shielding wall (CSB-side) and stacked steel shielding mass.
- ② **5.0 cm** — Gap between concrete shielding wall (labyrinth-side) and stacked steel shielding mass.
- ③ **9.0 cm** — Gap between stacked steel shielding blocks and Truck Access Tunnel outer wall.

Analysis 2

HVAC Supply and Return Ducting

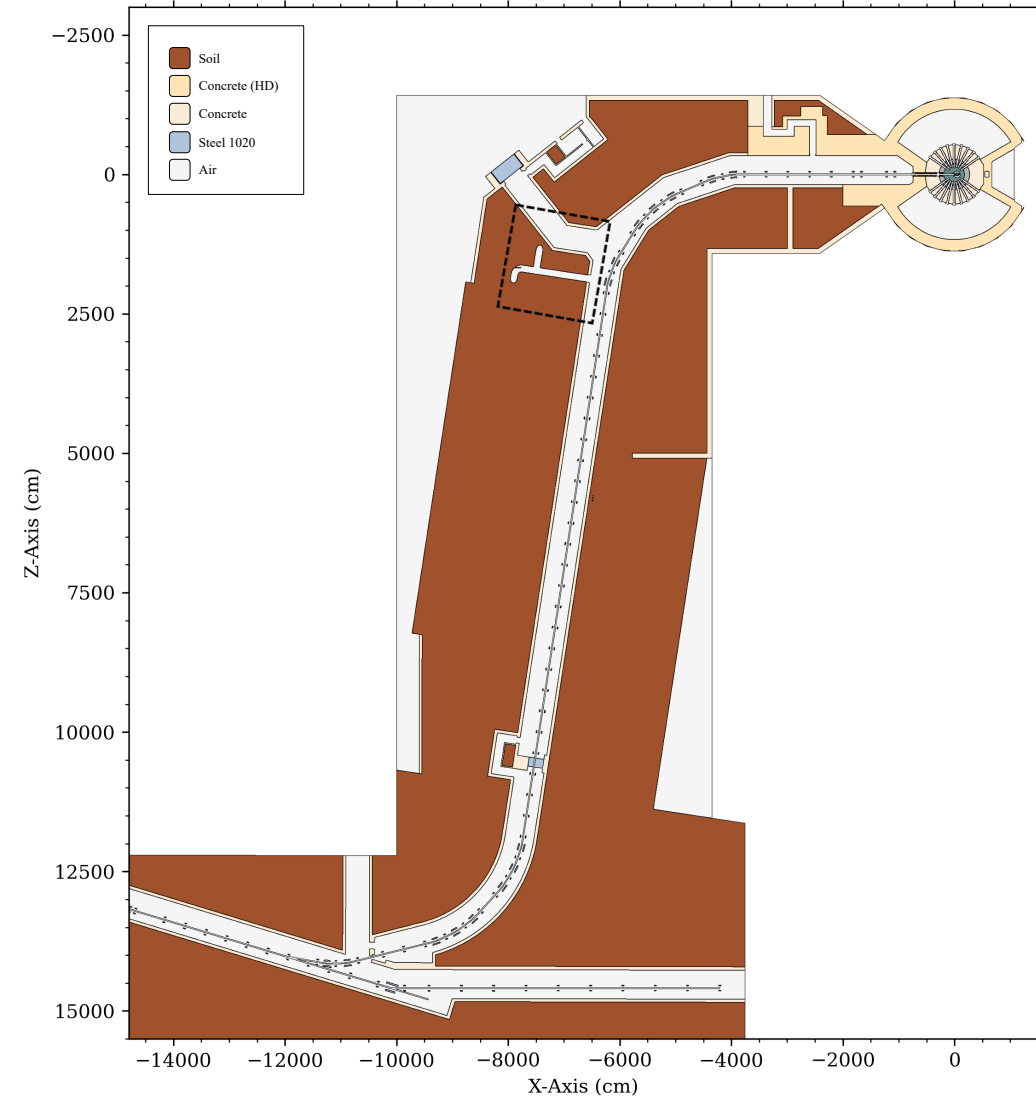
HVAC Supply and Return Ducting

- Source: 1 W/m beam losses in RTBT, RTST, and 1 MW primary beam-on-target backscatter.
- Region: HVAC ducts just upstream of the beam-right bend between CSB and RTST Truck Access Tunnel.

Objective

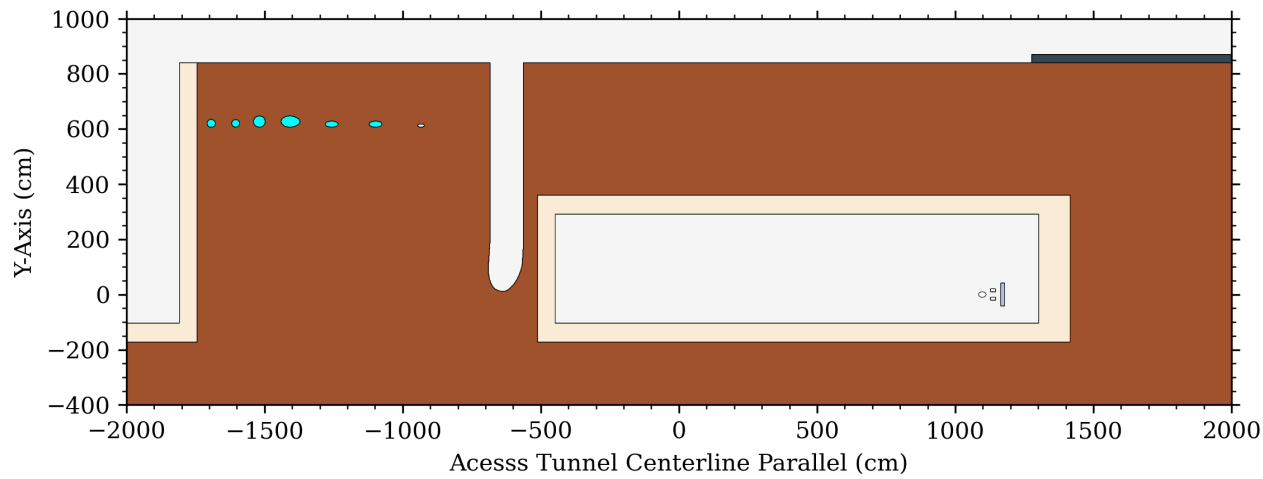
Determine if dose rates in occupied regions on berm surface outside HVAC ducts are <0.25 mrem/hr during normal operations.

STS Accelerator Geometry

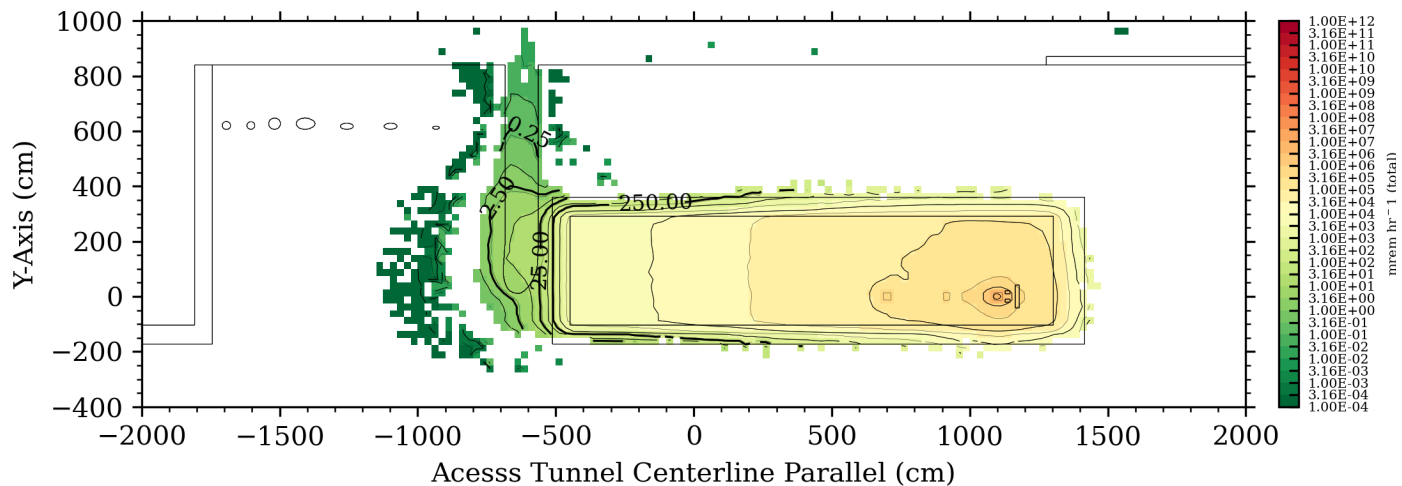


HVAC Supply and Return Ducting

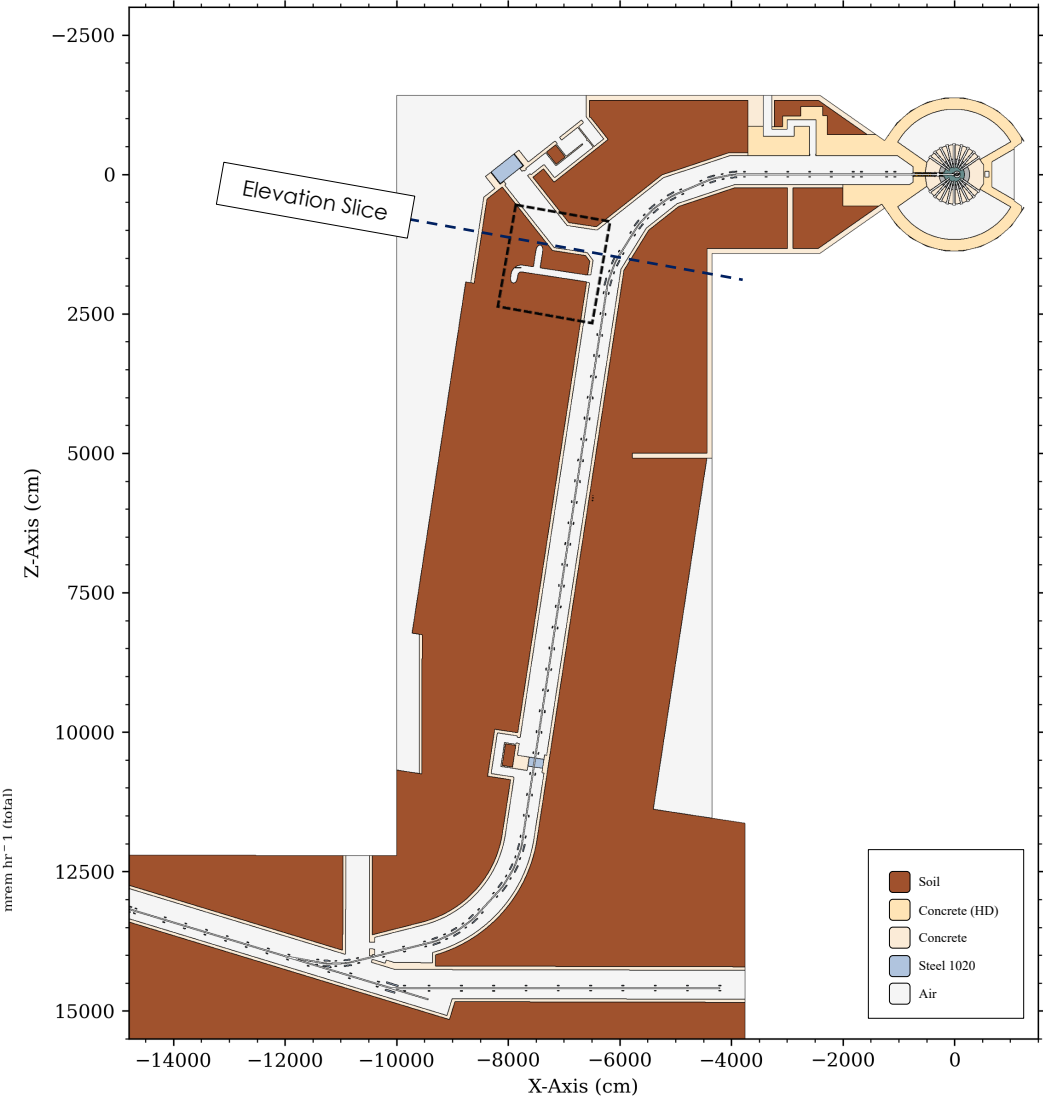
Elevation Slice Geometry



Total Dose Rate, mrem/hr

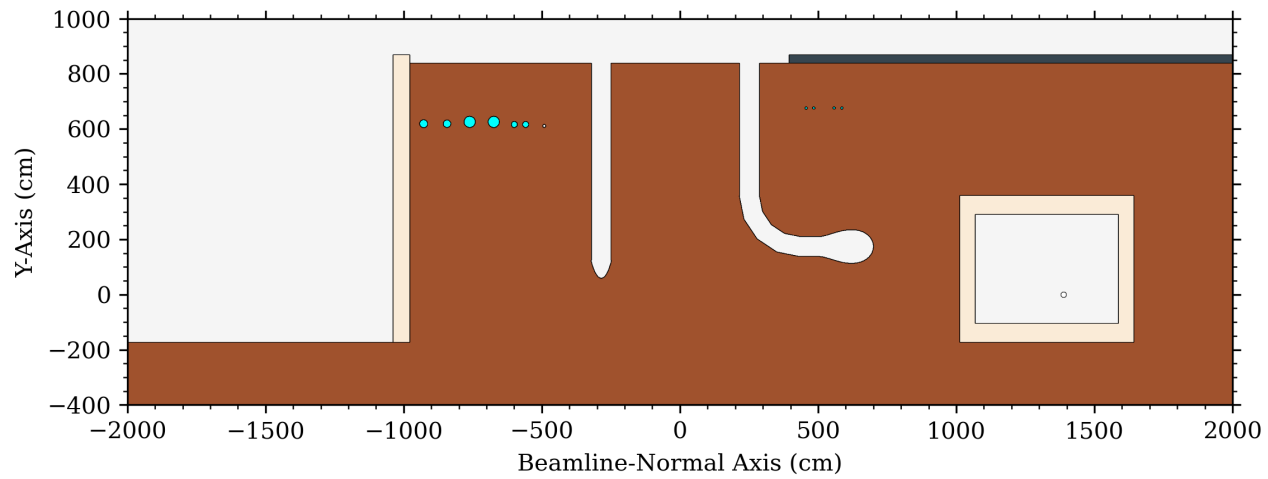


STS Accelerator Geometry

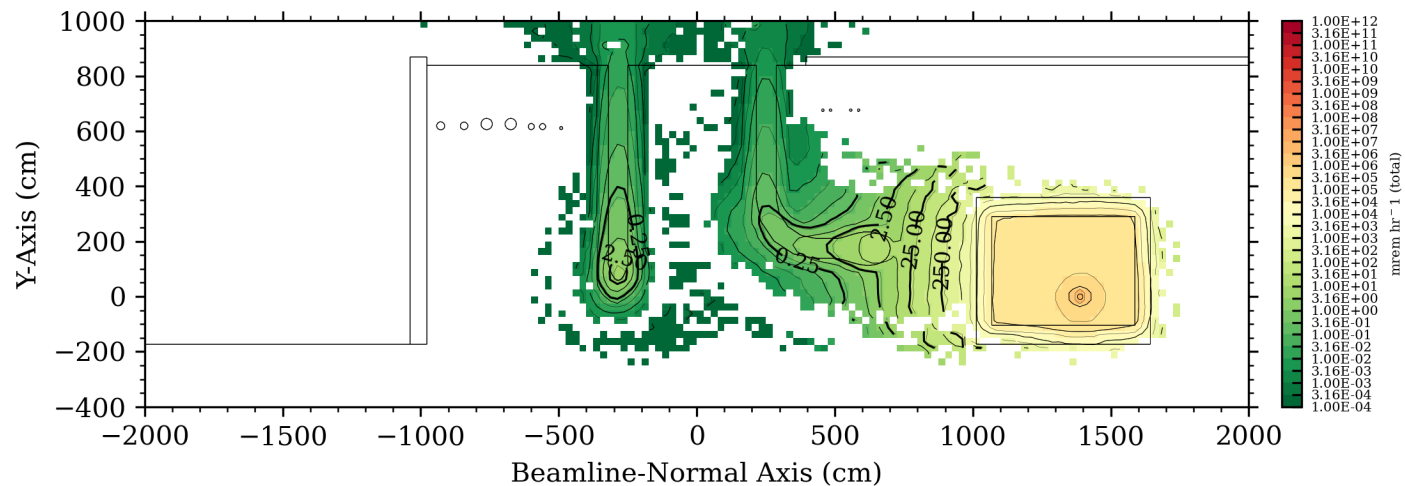


HVAC Supply and Return Ducting

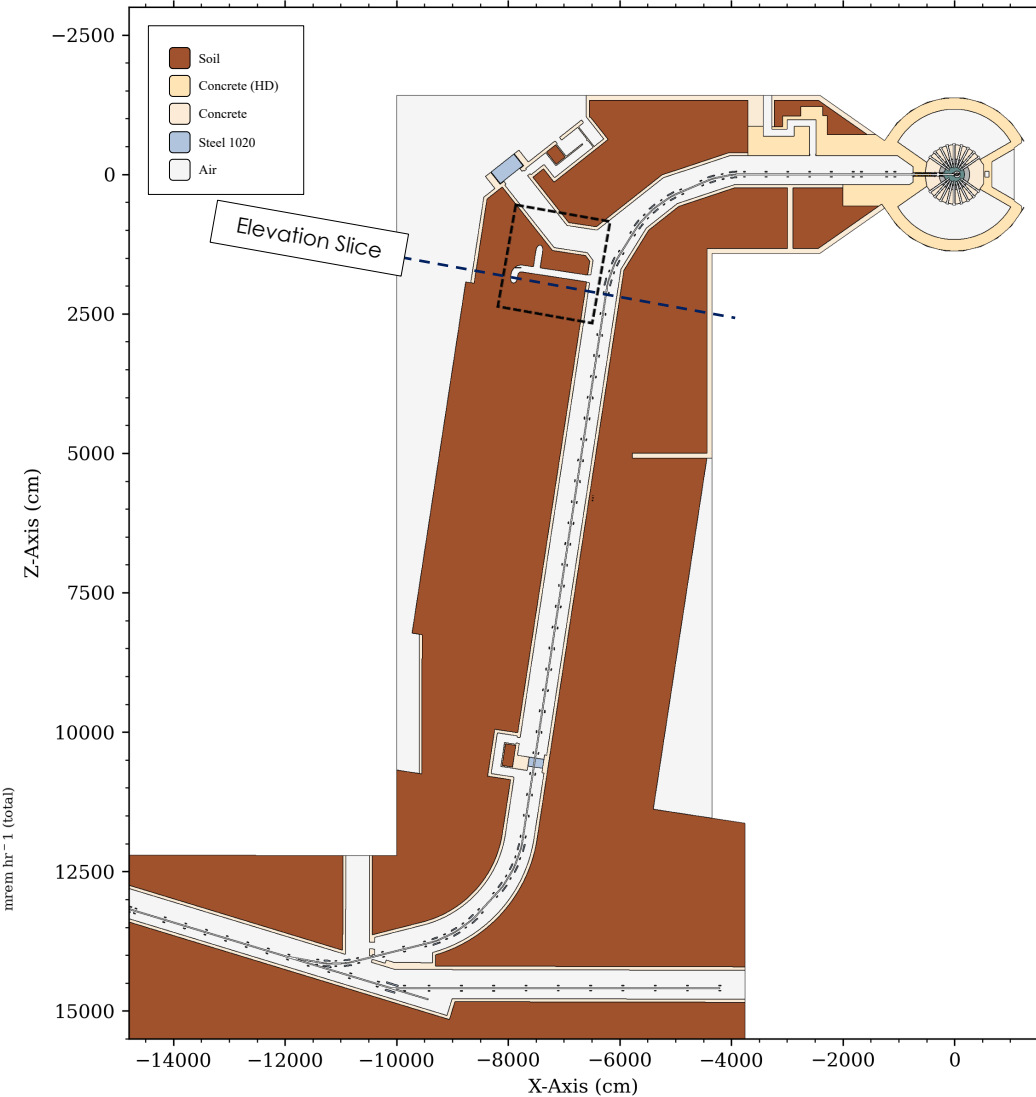
Elevation Slice Geometry



Total Dose Rate, mrem/hr



STS Accelerator Geometry



Analysis 3

RTST-to-CSB Concrete Chases

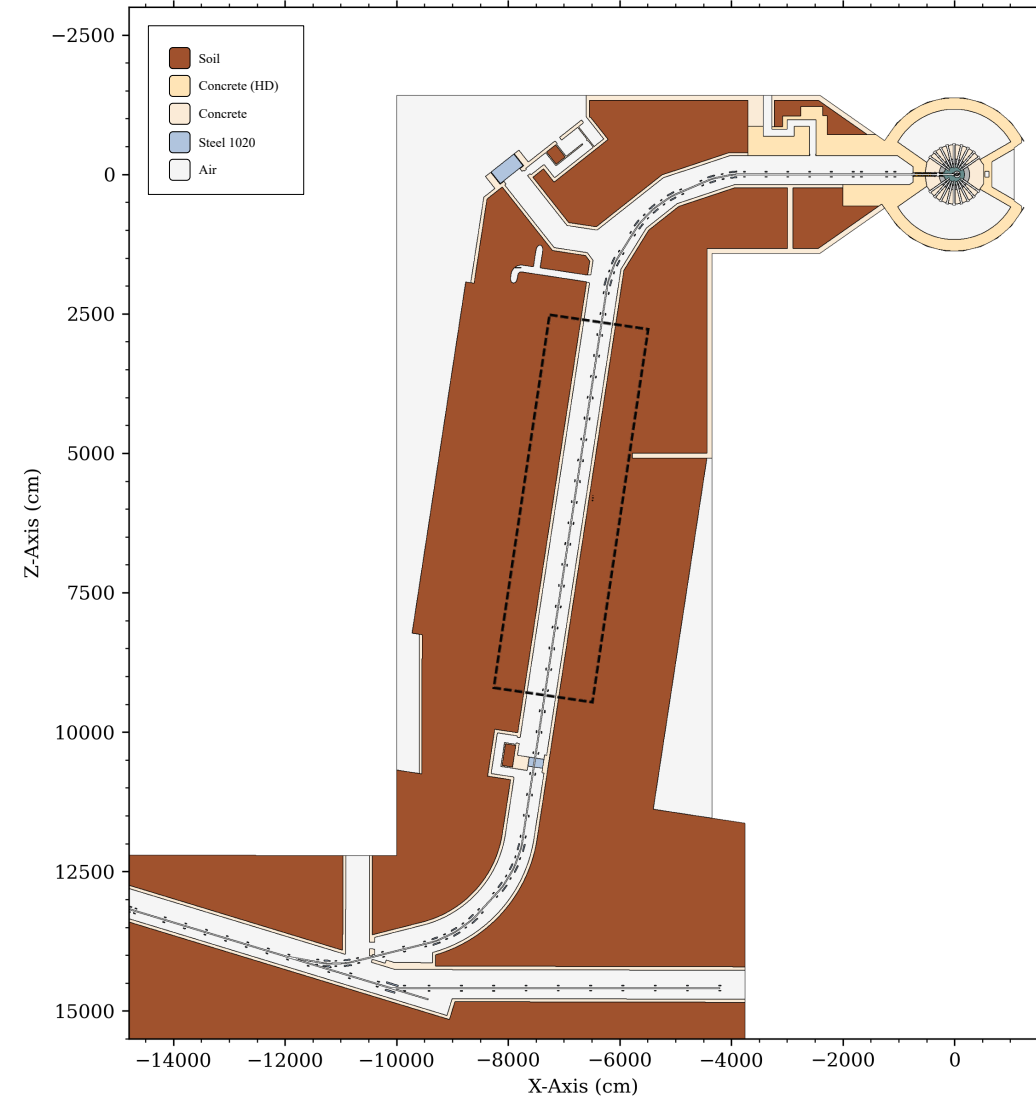
RTST-to-CSB Concrete Chases

- Source: 1 W/m beam losses in RTBT, RTST, and 1 MW primary beam-on-target backscatter.
- Region: Concrete chases inside the soil berm above the RTST tunnel.
- Berm thickness is ~530 cm.

Objective

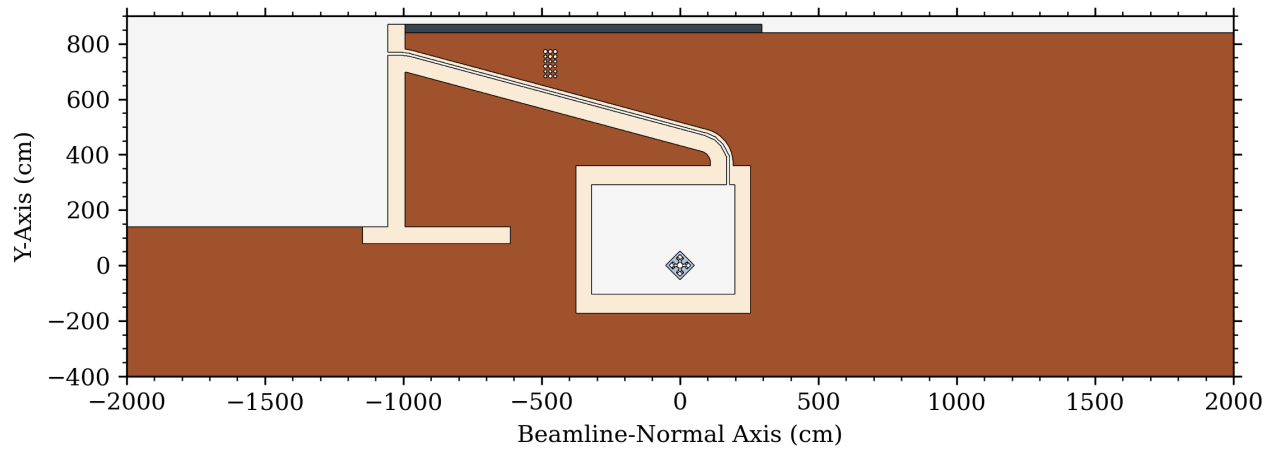
Determine if dose rates in occupied regions on berm surface and inside CSB due to streaming through concrete chases are <0.25 mrem/hr during normal operations.

STS Accelerator Geometry

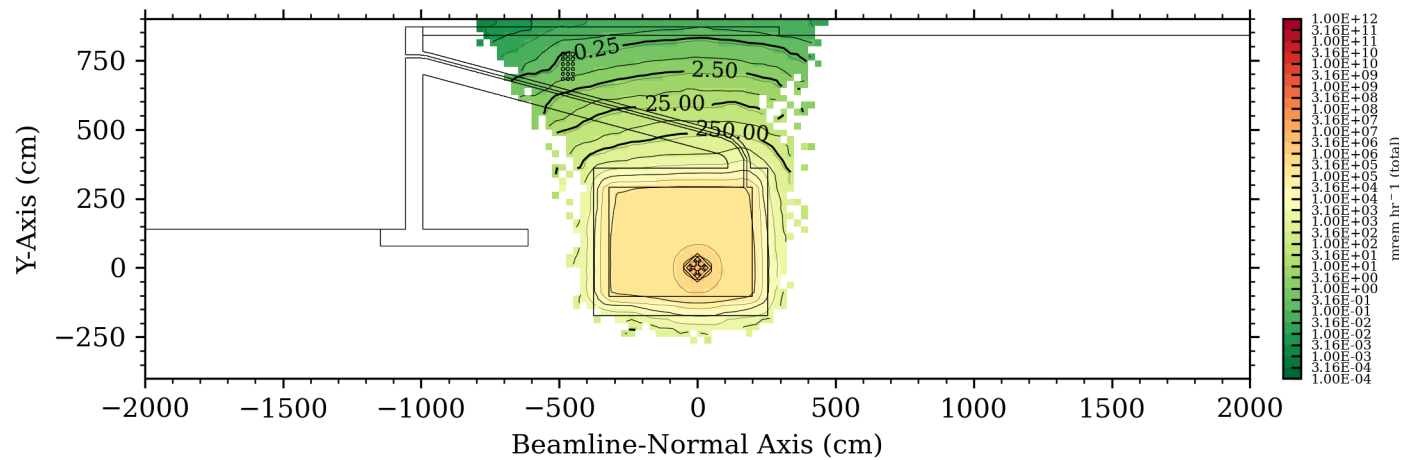


RTST-to-CSB Concrete Chases

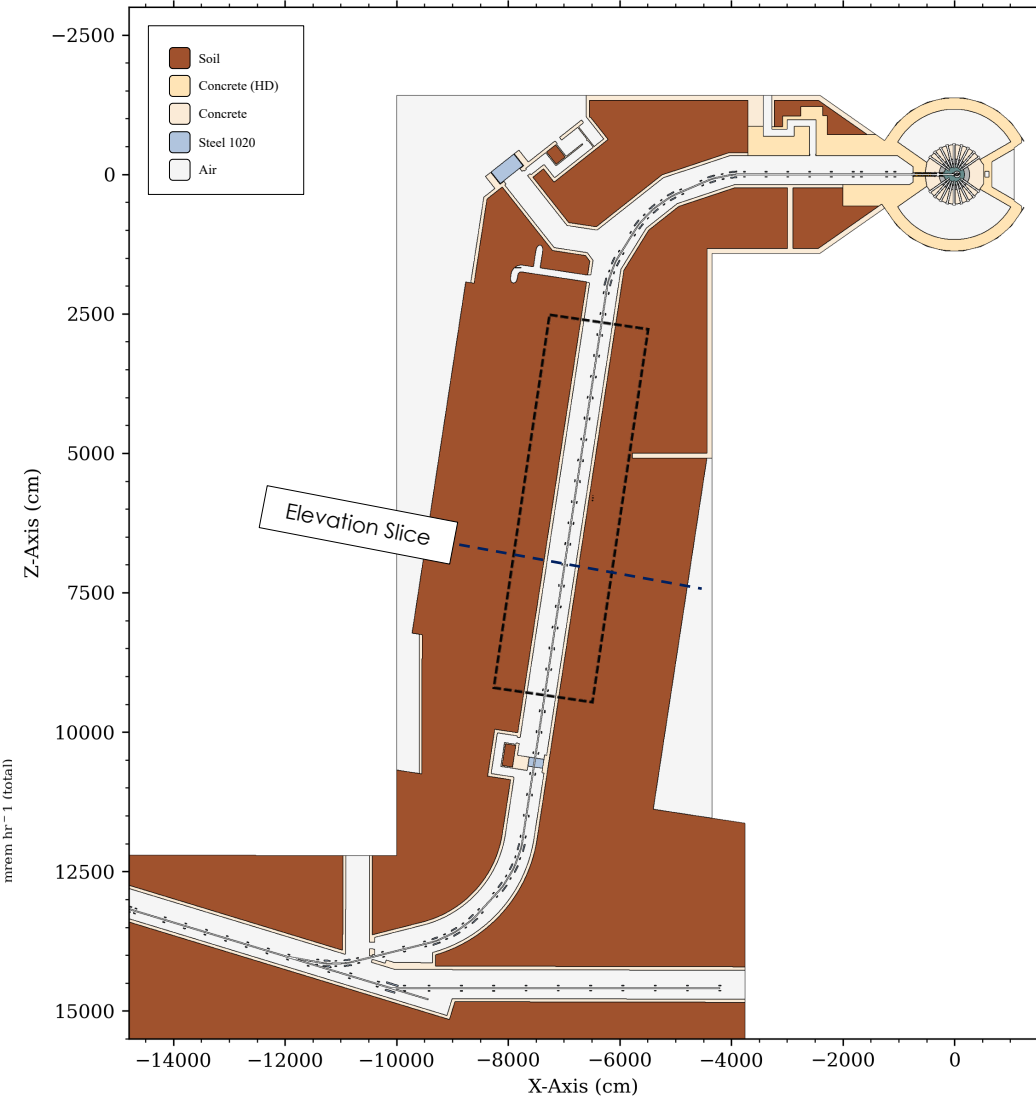
Elevation Slice Geometry



Total Dose Rate, mrem/hr

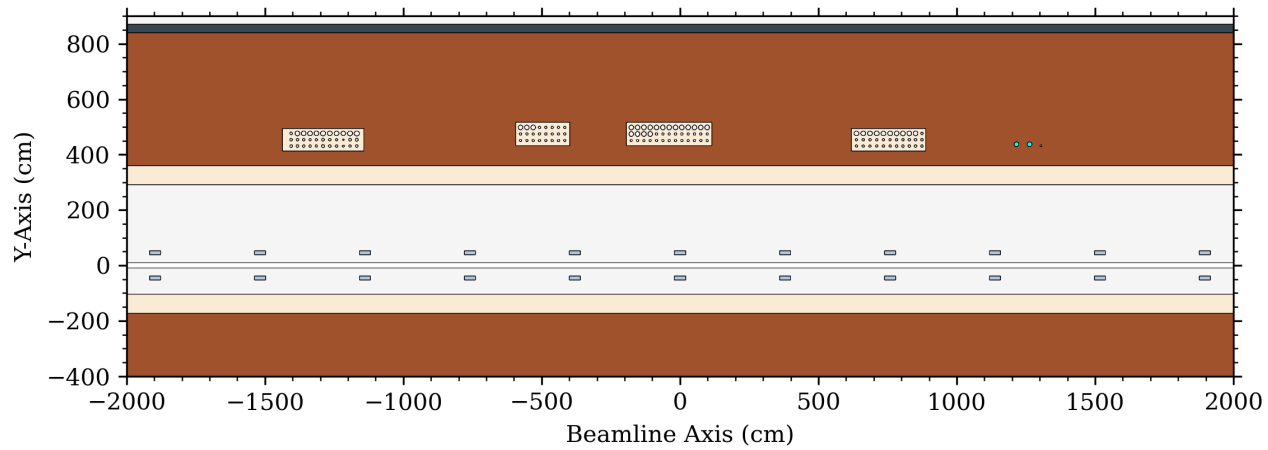


STS Accelerator Geometry

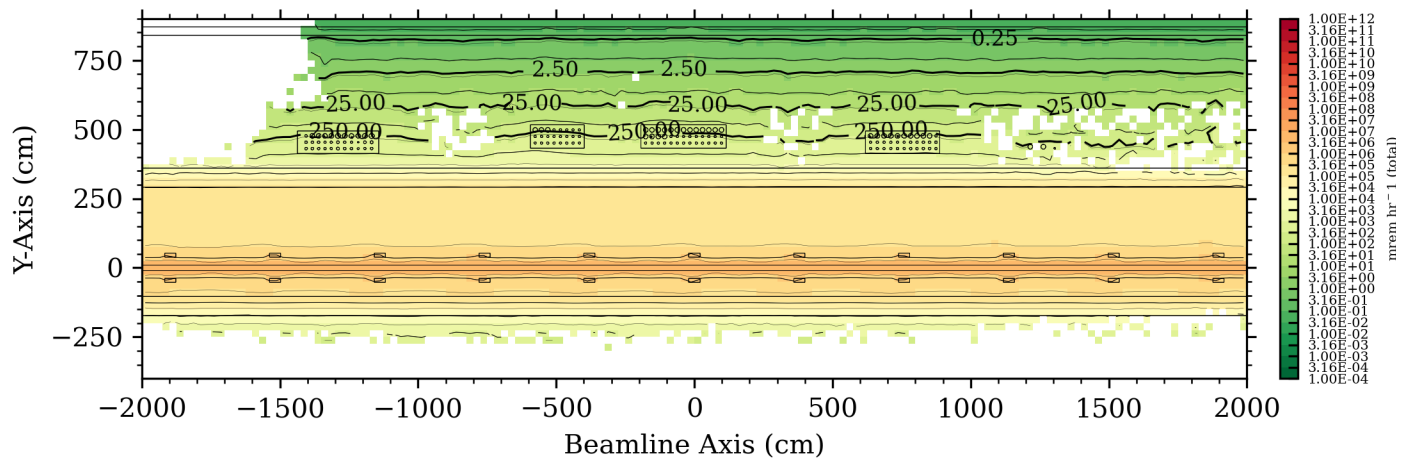


RTST-to-CSB Concrete Chases

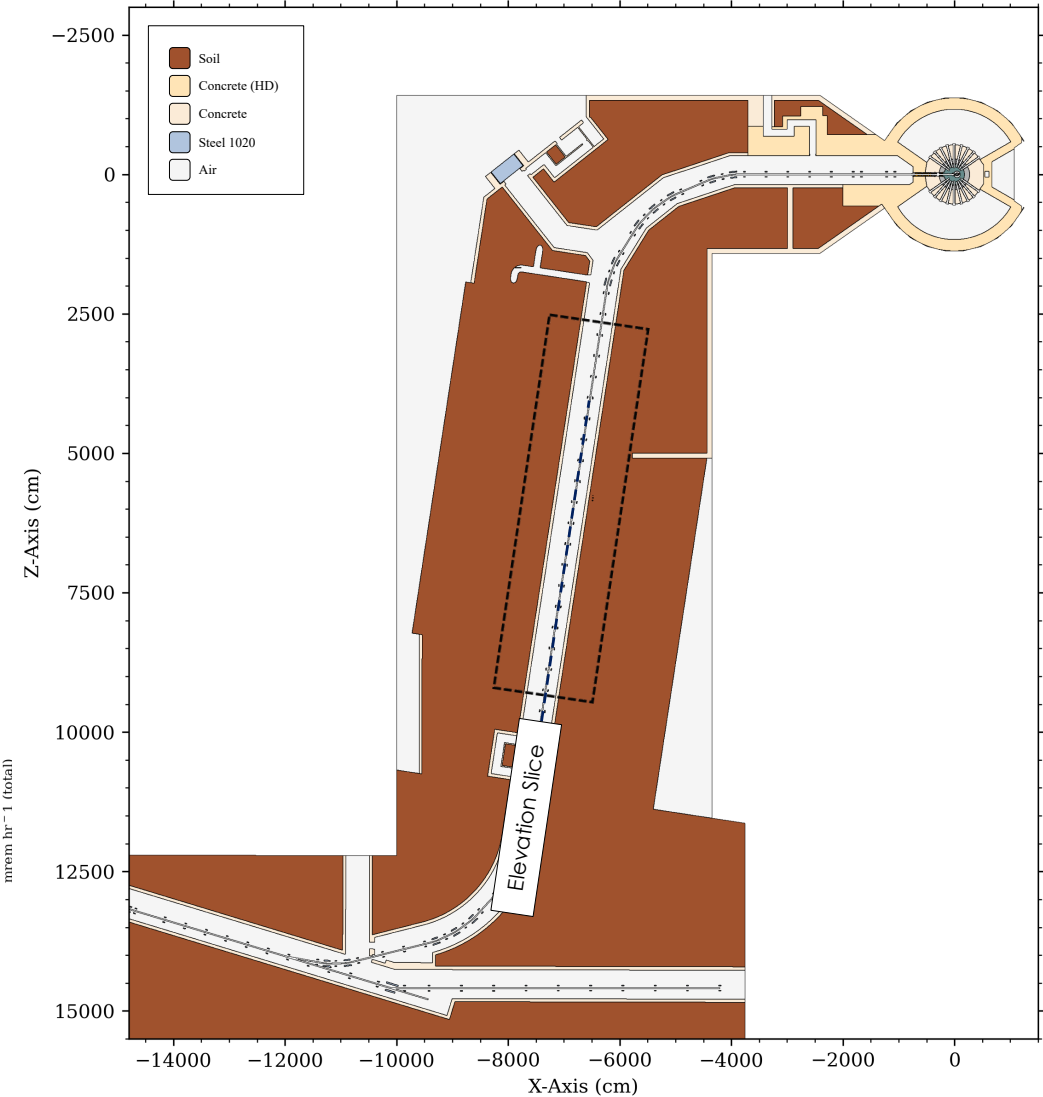
Elevation Slice Geometry



Total Dose Rate, mrem/hr



STS Accelerator Geometry



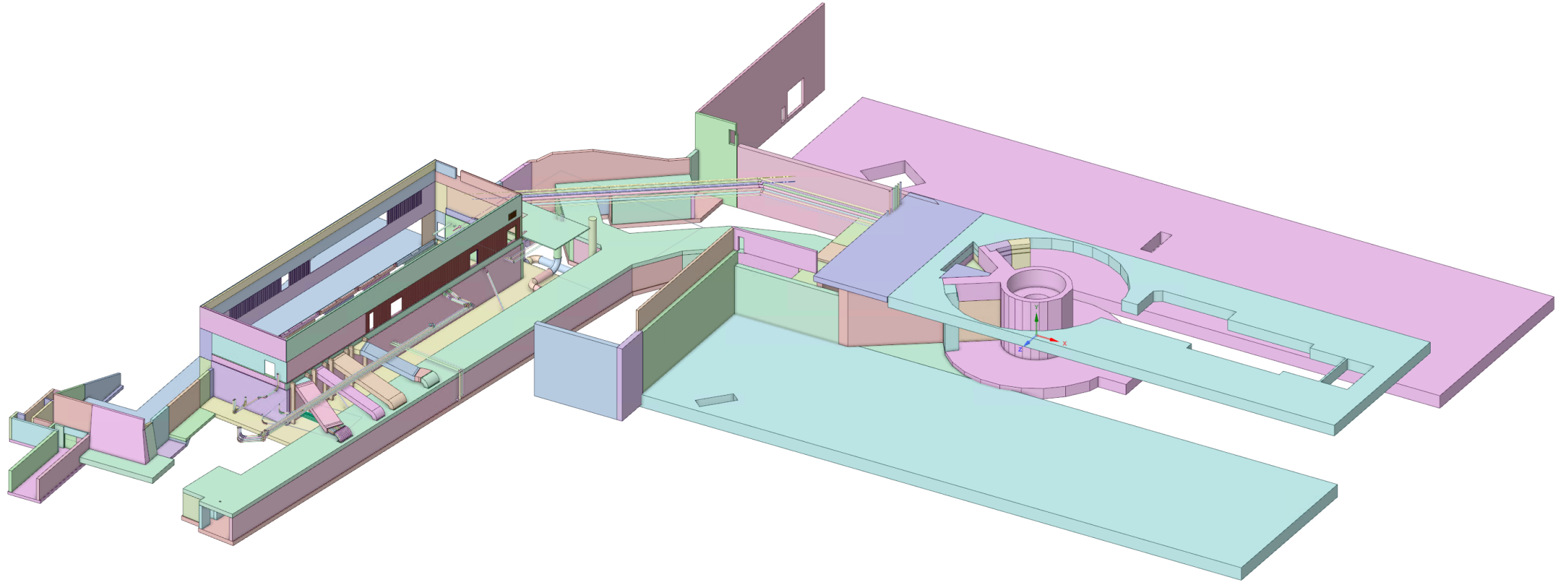
Summary

- Second Target Station RTST tunnel shielding design includes a multitude of smaller independent designs.
- These major component designs are demonstrated to meet their intended shielding design requirements during continuous operation of the RTST beamline:
 - Truck Access Tunnel & Labyrinth
 - HVAC Ducts
 - Soil Berm and Electrical Chases

Questions?

Backup Slides

RTST Geometry



RTST Geometry (slightly closer)

