Collimators and Transport Solenoid Shielding Reference Design

Document No: **MECO-MUB-03-002**	Created: **4/23/2003**	Page: **1** of **12**
	Modified: **10/13/03**	Version: **1.01**

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Abstract

This document provides the requirements and basic design parameters for the four collimators located inside the warm bore of the Transport Solenoid. The collimators primarily serve to filter the muon beam, selecting muons of the correct charge and momentum range to optimize stopping probability while eliminating all other particles to the greatest extent possible. The first collimator in the upstream portion of the TS also serves to shield the first several TS coils from radiation emanating from the production region. This document also includes a description of additional shielding inserts within the warm bore of the TS to limit the coil radiation loads associated with neutral particles and with back splash off of the front face of the central collimator.

History of Changes			
Rev. No.	Date	Sections	Description of changes
1.00	4/23/03	All	Initial version containing a few mechanical parameters and some 3D CAD modeling sketches.
1.01	10/13/03	All	Revised to include additional shielding in the upstream TS to limit the radiation load on the upstream TS coils. Changed cryostat inner wall thickness to 2 cm as part of that shielding. Now includes beam-heating estimates from some elements.

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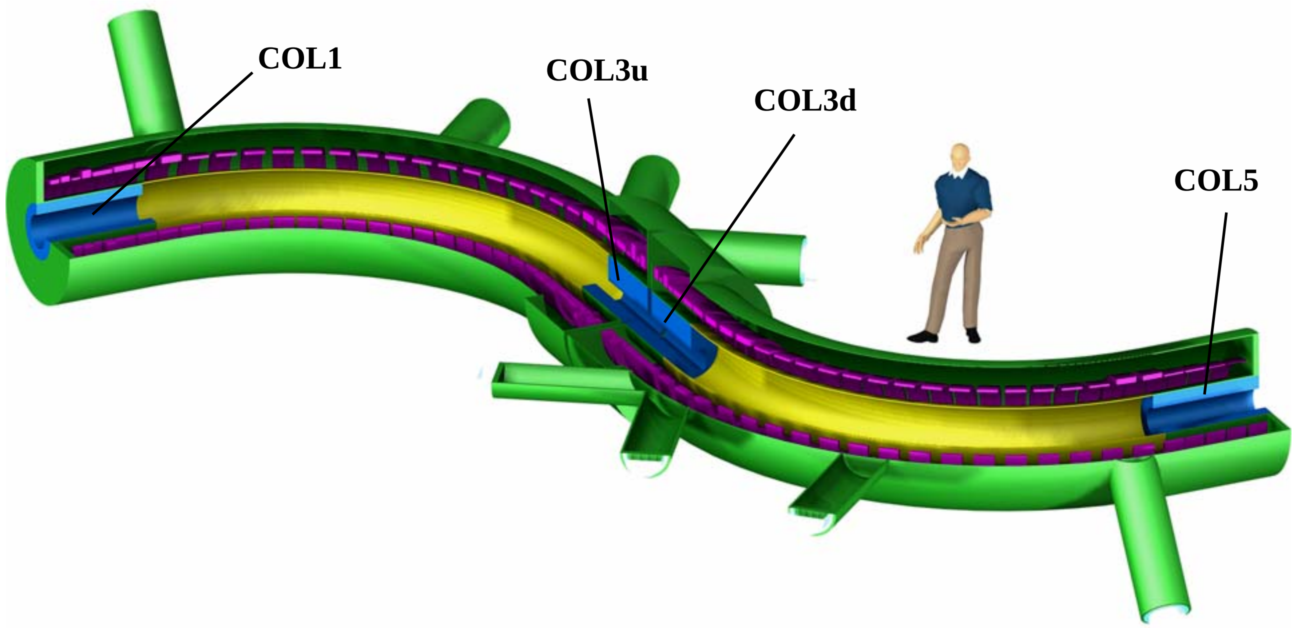

Figure 1.1 – Overview of the collimators (blue) positioned within the warm bore of the Transport Solenoid cryostats (green). The additional shielding elements in the upstream (TSu) region required for limiting radiation load on the TS coils are not shown in this figure.

1. INTRODUCTION

The collimators filter the beam as it passes through the Transport Solenoid (TS), selecting muons of the correct charge and momentum range to optimize the probability of their capture in the stopping target foils. This selection is achieved by offsetting the aperture of the two central collimators vertically with respect to the beamline to take advantage of "curvature drift" in the two TS bend sections. Curvature drift causes particles to drift upward or downward depending upon the charge of the particle. Negatively charged particles are deflected downward in the first bend section, and pass through the offset central collimator aperture, and are deflected back onto the nominal beam line in the second bend section, while positively charged particles are driven upward in the first bend and stop in the central collimator. The extent of a particle's vertical displacement in the central TS is momentum dependent, thus the size and location of the vertical aperture also momentum select the beam.

In addition to the role of beam filter, the upstream collimator serves to protect the first several TS coils from radiation originating in the production target. This shielding is further enhanced by the addition of several toroidal sections fitted within the TSu to ameliorate the effects of neutral particles from the production target and secondary production on the front face of COL3u due to the impact of positive particles that the central collimator is designed to stop.

2. REQUIREMENTS

2.1 Beam Filtering

Detail our requirements for suppression of positives and selecting the required negative muon momentum range at the entrance to the Detector Solenoid. For engineering purposes assume that the present shielding provides sufficient filtering to meet the physics requirements

2.2 Support off of the Transport Solenoid cryostat

Each collimator and all supplemental shielding is supported in its location by the inner wall of the TS cryostat.

2.3 Maximum Instantaneous Power Dissipation At Any Position Within the Transport Solenoid Coils

The shield shall limit the instantaneous local heating in the Transport Solenoid coils due to radiation originating in the production target to less than 5 μW/gm at any point within the coil volume.

2.4 Maximum Total Power Dissipation Within the Transport Solenoid Cold Mass

The shield shall limit the total steady-state power dissipation in the cold mass of the Transport Solenoid to less than ?? W.

2.5 Alignment

TBD.

2.6 Cooling

The heat loads are quite modest in comparison to those in the Production Solenoid. Thus, it may be sufficient to rely upon radiative heat transfer to the actively cooled regions to maintain the temperature of the TS shielding elements.

3. DESIGN

One important note at the outset: in order to supplement the shielding of all of the coils in the upstream TS (TSu), the current simulation assumes that the TSu inner cryostat wall is 2 cm thick, rather than the 1 cm listed in MIT's Conceptual Design Report. The additional centimeter is added inside the warm bore, thus the revised warm bore of TSu is 24 cm. For manufacturing convenience, this document assumes that the TSd inner bore will also be reduced to 24 cm so that the two toroidal inner cryostat pipes will be identical.

3.1 Component Volumes from the Physics Simulation

Dimensions are given in cm and angles are in degrees. The volume names from the simulation code are given in parentheses and labeled in Figure 1.1.

Collimator in the First (Highest Field) TSu Straight Section (COL1)

This consists of a cylindrical outer shell with a conical section removed. It is coaxial with Production Solenoid.

Position of Center	Inner Radius @ -z end	Inner Radius @ +z end	Outer Radius	Length	Material
(390.4, 0.0, -345.4)	15.0	17.0	24.0	100.0	Cu

Collimators in Central TSu Straight Section (COL3u)

The cross-section of this collimator is shown in Figure 3.1. The collimator is coaxial with the x-axis in the Standard MECO Coordinate System [1].

Position of Center	Outer Radius	Length	Material
(42.5, 0.0, 0.0)	24.0	80.0	Cu

Collimators in Central TSu Straight Section (COL3d)

The cross-section of this collimator is shown in Figure 3.1. The collimator is coaxial with the x-axis in the Standard MECO Coordinate System.

Position of Center	Outer Radius	Length	Material
(-42.5, 0.0, 0.0)	24.0	80.0	Cu

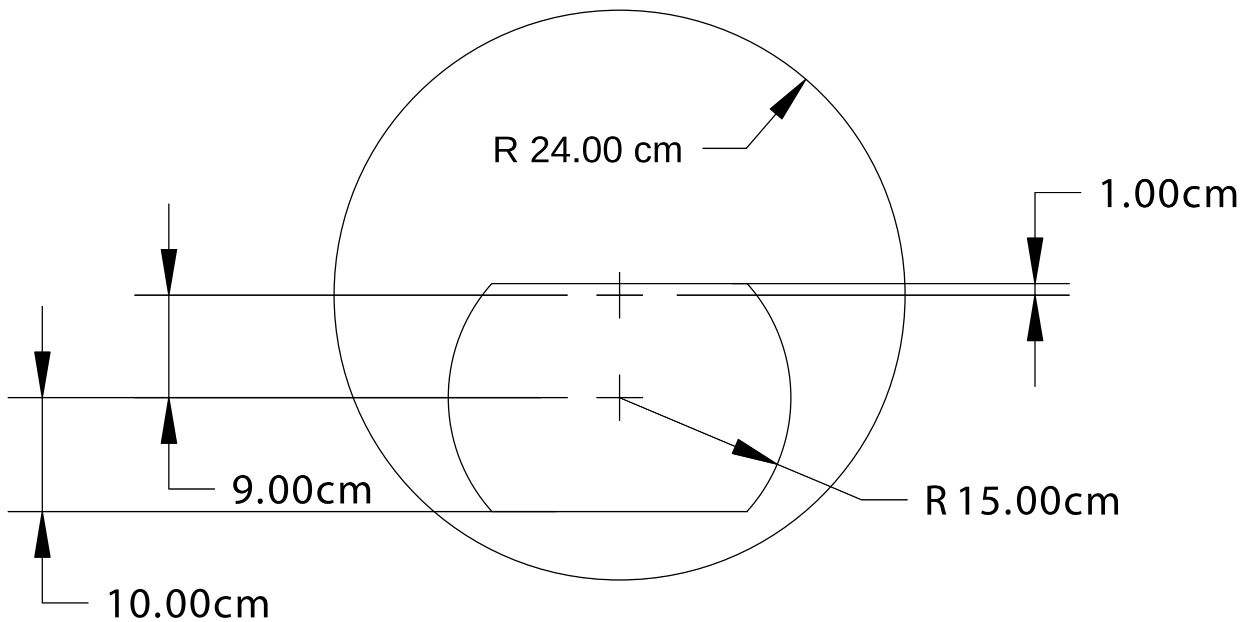

Figure 3.1 – Cross-sectional view of the central collimators COL3u and COL3d. Note that the outside radius of this collimator is reduced to 24 cm to accommodate a thicker inner cryostat wall relative to the design in the previous version.

Collimator in the Last (Lowest Field) TSd Straight Section (COL5)

This consists of a cylindrical shell that is coaxial with Detector Solenoid.

Position of Center	Inner Radius	Outer Radius	Length	Material
(-390.4, 0.0, 343.0)	12.8	24.0	100.0	Cu

Additional shielding in the TSu

There are six sections of copper affixed to the inner cryostat wall in the TSu region to reduce the impact of ionizing radiation on the coils. Each of these pieces is described in terms of the angular range it occupies within the TSu and the range of radii as measured from the centerline of the TS. See Figure 3.2 for an illustration of the components' locations. Cross-sectional views are provided in Figure 3.3 through Figure 3.5.

Section	θ Range	ϕ Range	Inner Radius	Outer Radius	Material
S1	(0.0, 36.72)	(0.0, 180.0)	20.0	24.0	Cu
S2	(13.16, 26.08)	(0.0, 90.0)	18.0	20.0	Cu
S3	(36.72, 72.75)	(0, 360.0)	22.0	24.0	Cu
S4	(36.72, 56.24)	(0.0, 180.0)	20.0	22.0	Cu
S5	(50.91, 72.75)	(-70.0, 30.0)	20.0	22.0	Cu
S6	(72.75, 90.0)	(0.0, 360.0)	20.0	24.0	Cu

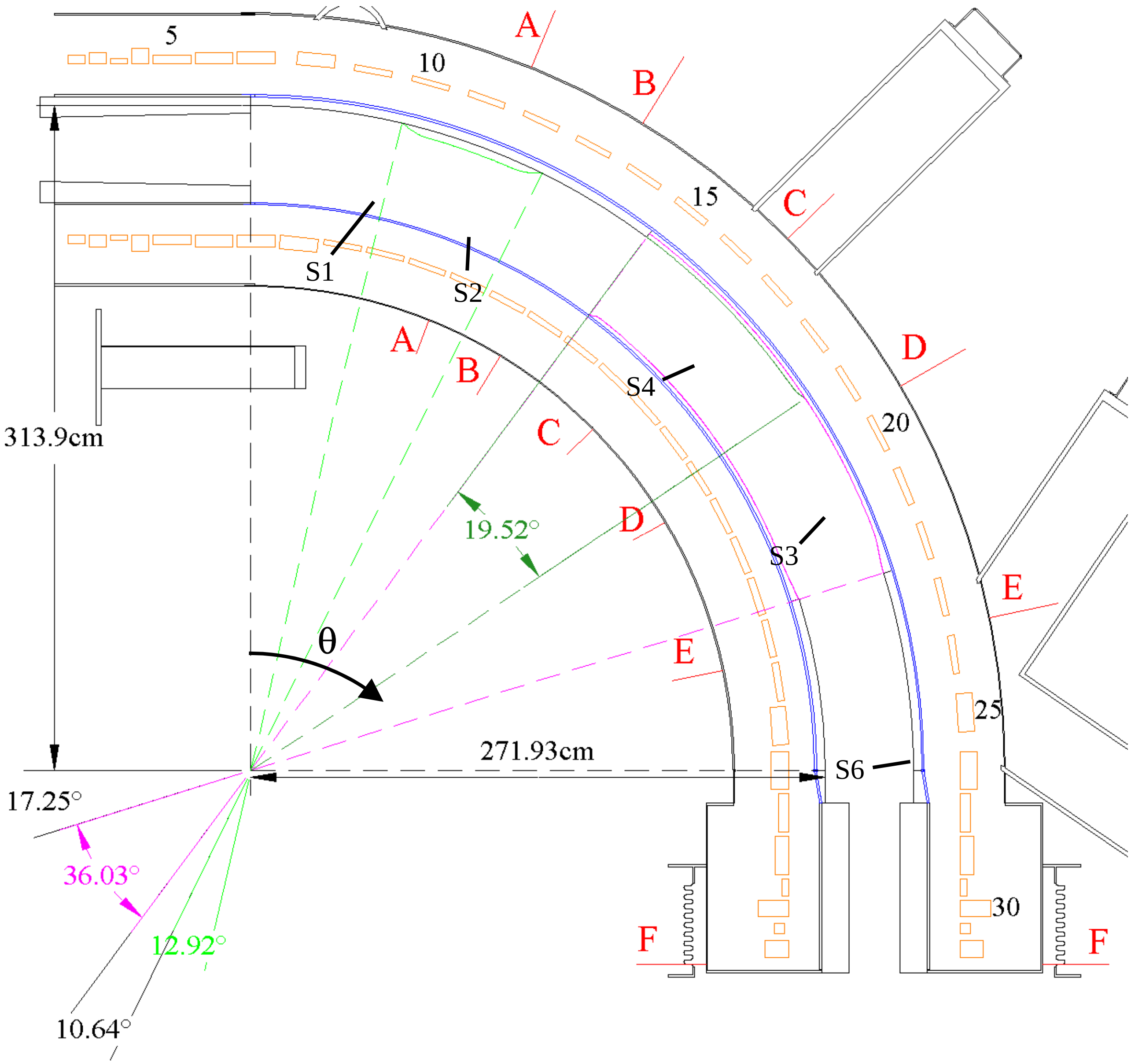

Figure 3.2 – Overview of the additional radiation shielding within the upstream TS. The S5 section does not intersect the horizontal plane through the TS central axis and thus does not appear here. For convenience the TS coil numbers are labeled on the figure as well.

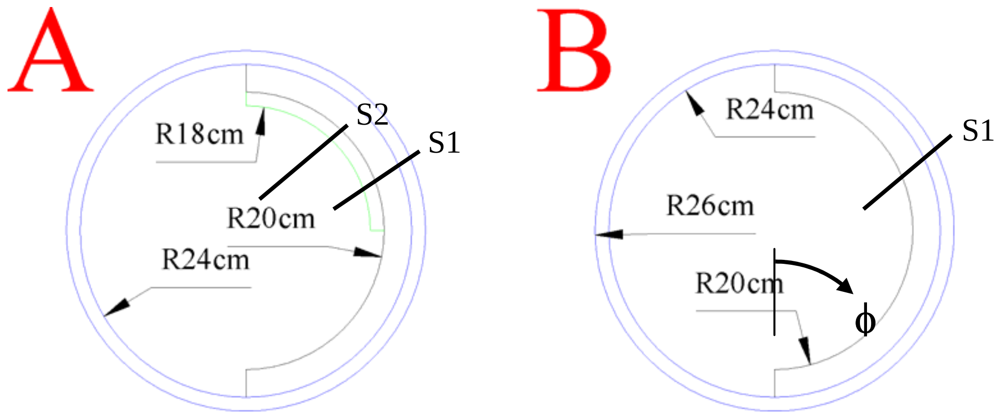

Figure 3.3 – "A" and "B" cross-section views of the TSu shielding looking generally toward the PS. The outer ring is the TS inner cryostat wall.

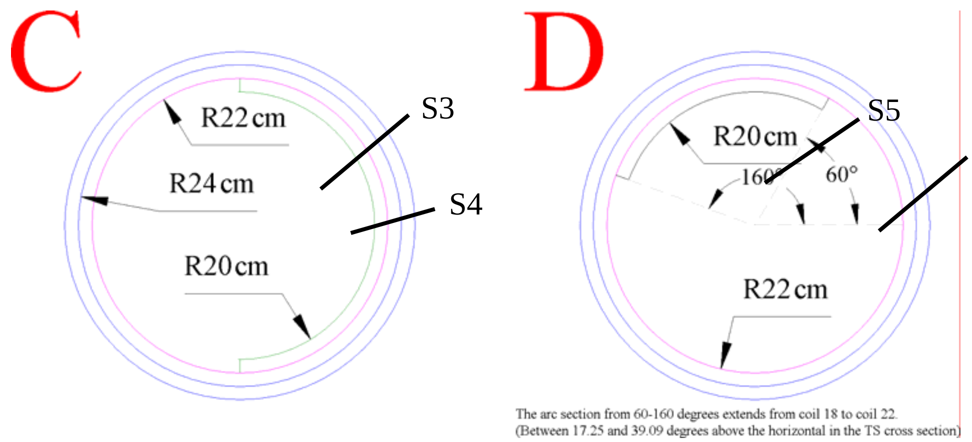

Figure 3.4 – "C" and "D" cross-section views of the TSu shielding looking upstream.

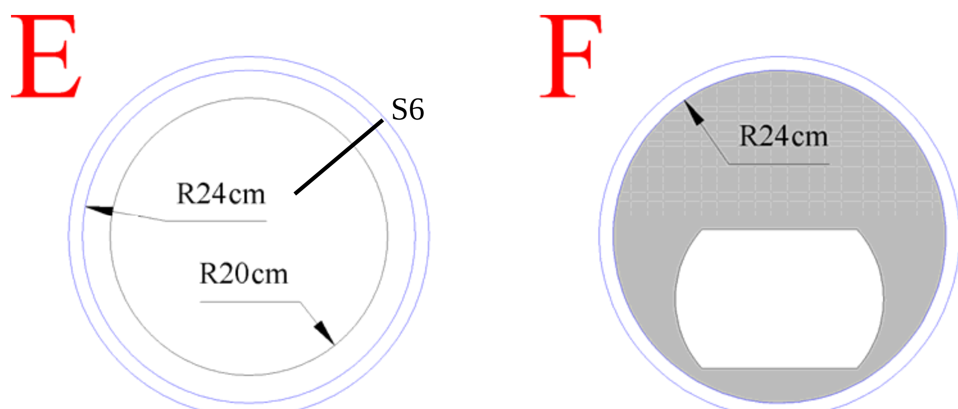

Figure 3.5 – "E" and "F" cross-section views of the TSu shielding. The latter is detailed in Figure 3.1 above.

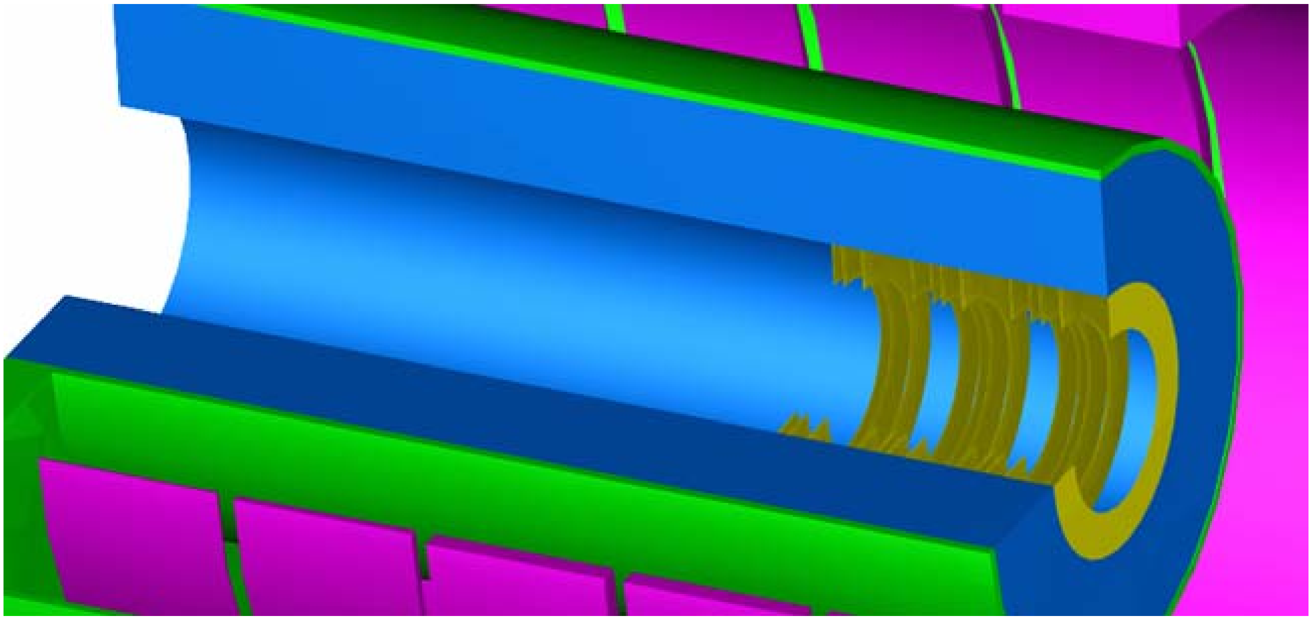

Figure 3.6 – Detail view of COL5 showing the thin annular foils (yellow) positioned at the upstream end of the collimator.

Thin Foils Within Collimator COL5 (CTA5, CTB5, CTC5, CTD5)

These are a series of thin annular foils within the downstream collimator COL5 as shown in Figure 3.6. These serve to reduce rates in the Tracker.

Position of Center	Inner Radius	Outer Radius	Thickness	Material
(-390.4, 0.0, 293.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 298.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 300.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 301.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 303.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 308.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 310.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 311.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 313.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 318.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 320.0)	8.5	12.8	0.006	Cu
(-390.4, 0.0, 321.0)	8.5	12.8	0.006	Cu

3.2 Mechanical Properties

Table 3.1 below lists the masses of the collimators. X lists the expected heat load at the nominal beam intensity for several TS volumes. The latter values are derived from [2].

Table 3.1 – Estimated masses of each of the shield components used in the physics simulation

Volume Name	Mass (kg)	Center of Gravity (cm)
COL1	900	(390.4, 0.0, 343.3)
COL3u	1012	(42.5, 3.5, 0.0)
COL3d	1012	(-42.5, 3.5, 0.0)
COL5	1298	(-390.4, 0.0, 343.0)

Table 3.2 – Expected radiation heat load in TS collimator and shielding volumes from [2].

Volume Name	Heat Load (W)
COL1	96.0
TSu Inner Cryostat Wall	4.0
S1	16.1
S2	6.0
S3	12.2
S4	9.3
S5	10.6
S6	13.4

3.3 Installation and Removal

A partial plan for installation of the collimators is shown in the Solenoid System CDR [3]. Additional details for installation of supplemental shielding remain TBD.

4. INTERFACES

4.1 Mounting on the TS inner cryostat walls

4.2 Installation during TS onsite assembly

4.3 Allowance for installation/removal of the Anti-proton Stopping Window

5. PERFORMANCE

5.1 Transport Solenoid Coil Heat Load

The heating of the TS coils and other structures due to primary radiation from the production target and secondary production on the collimators has been estimated [4]. The results are summarized here in Table 5.1. The total expected heat load on the TS coils for nominal operations is 3.0 W.

Table 5.1 – Estimated radiation heat loads in the Transport Solenoid coils during nominal operations using the shielding described in this document.

TS Coil #	Heat Load (W)	TS Coil #	Heat Load (W)	TS Coil #	Heat Load (W)
1	0.18	**11**	0.07	**21**	0.05
2	0.19	**12**	0.10	**22**	0.06
3	0.17	**13**	0.12	**23**	0.07
4	0.21	**14**	0.10	**24**	0.06
5	0.26	**15**	0.08	**25**	0.09
6	0.23	**16**	0.08	**26**	0.12
7	0.14	**17**	0.08	**27**	0.07
8	0.15	**18**	0.06	**28**	0.05
9	0.06	**19**	0.06	**29**	0.02
10	0.06	**20**	0.05	**30**	0.01

6. REFERENCES

1. M. Hebert, *The MECO Standard Coordinate System*, MECO-Standards-03-001 (2003)
2. V. Tumakov, *Beam Energy Deposition in Different Parts of Experimental Setup*, MECO112, University of California, Irvine (2003)
3. Massachusetts Institute of Technology Plasma Science and Fusion Center, *MECO Superconducting Solenoid System Conceptual Design Report*, (2002) http://meco.ps.uci.edu/MIT_MECO_CDR.pdf
4. V. Tumakov, *Energy Deposition in TS Coils*, MECO110, University of California, Irvine (2003)