WBS 5.8 Muon Beam Stop
Mu2e CD-2 Review

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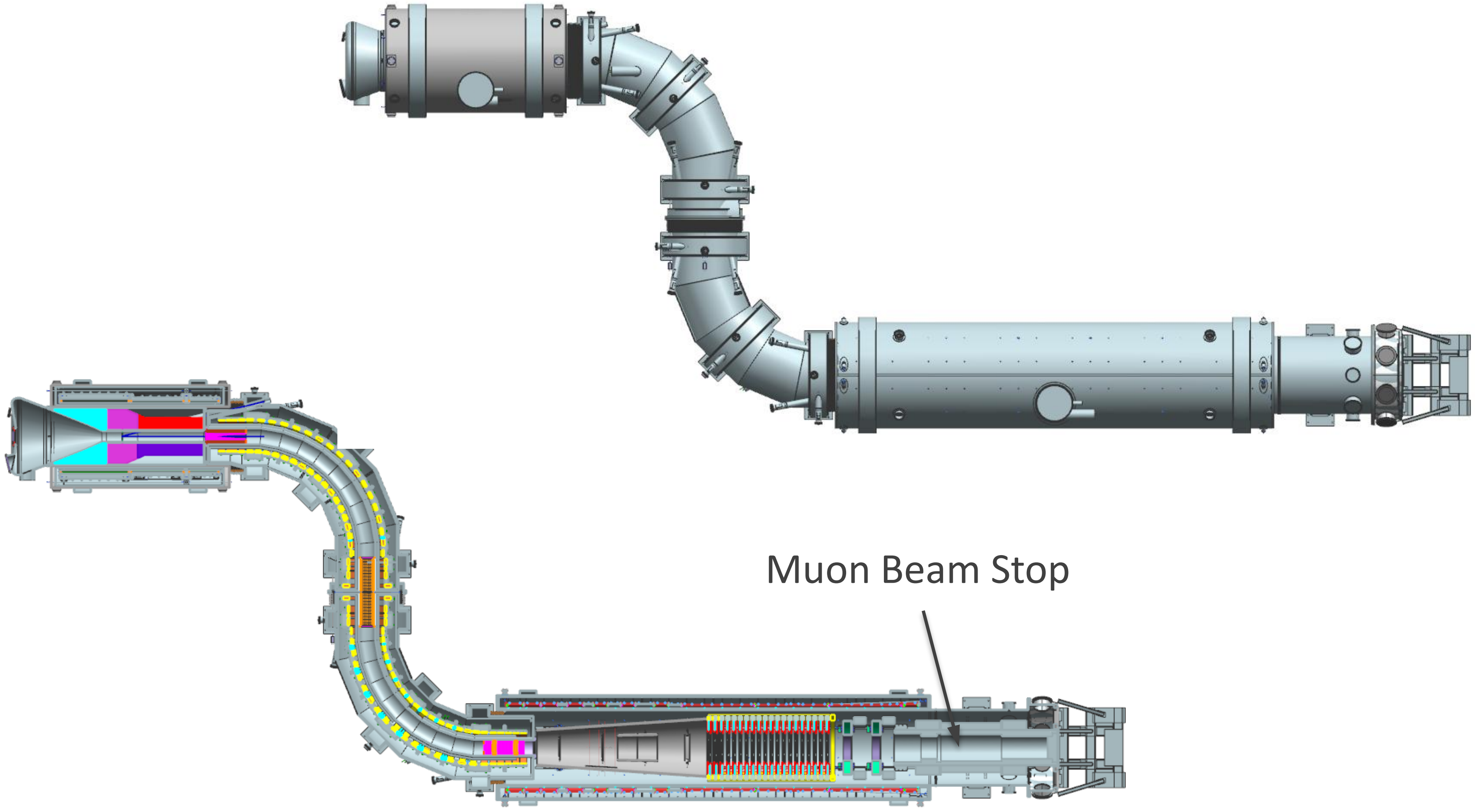
10/21/2014

Overview of the Orientation:



Requirements

The Muon Beam Stop (MBS) will be located within the bore of the Detector Solenoid (DS). It is designed to absorb beam particles, which consist mainly of electrons and muons, that reach the downstream end of the solenoid, while minimizing the background to the surrounding detectors resulting from muon decays and captures in the beam stop.

The Mu2e Muon Beam Stop requirements and specifications are documented in Mu2e-doc-1351.

Requirements

Physics Requirements

- Shielding should ensure that the rate seen by the CRV from particles originating in the MBS should not be larger than the rate from the stopping target. Satisfying this requirement is the joint performance of the MBS and the Downstream External Shielding.
- Backsplash particles from the MBS should not produce delayed signals that could be mistaken for conversion electrons in the Tracker.
- The MBS should not produce secondary particles with a larger radiation impact on the calorimeter than those that arise from the stopping target.
- A clear line-of-sight is required from the muon stopping target, through the muon beam stop to the muon stopping target monitor, which is to be located well downstream of the MBS.

Requirements

Mechanical Requirements

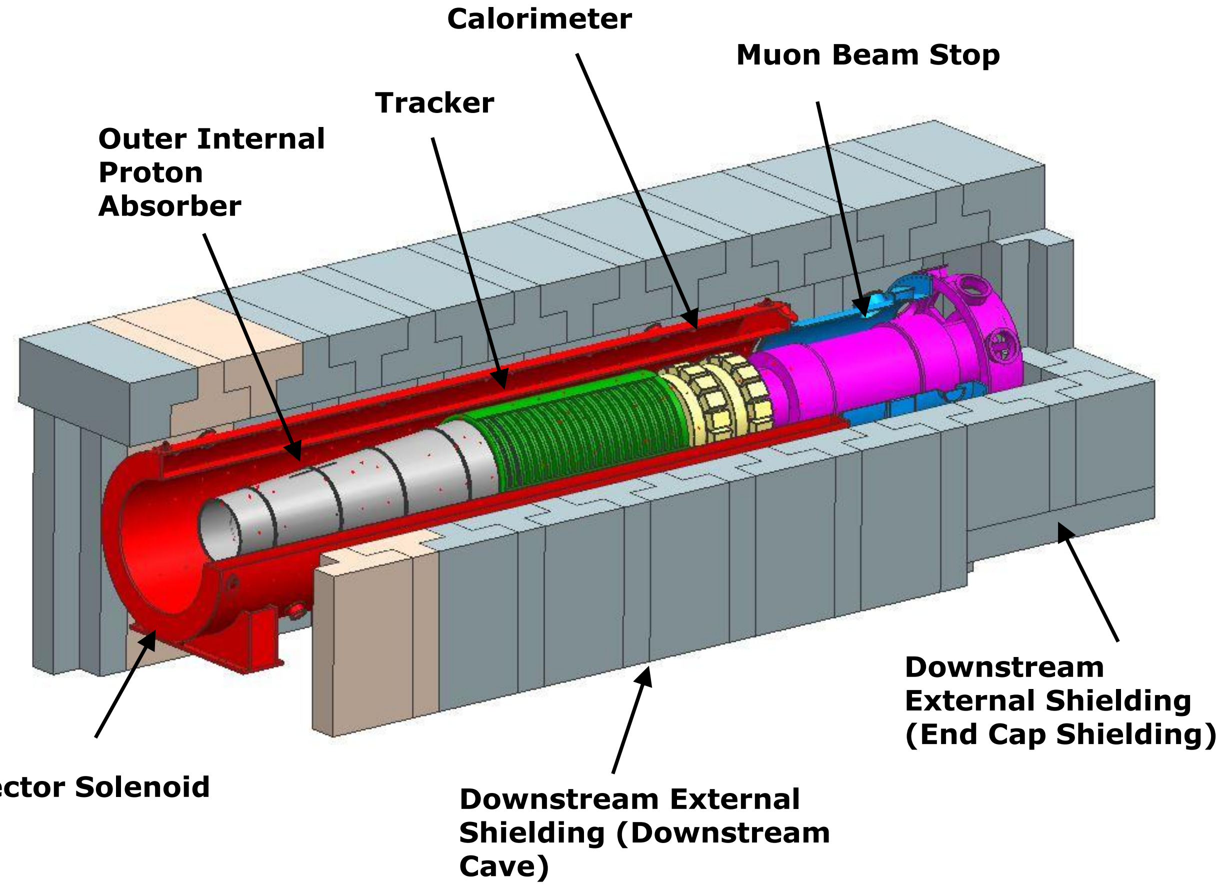
- The Beam Stop and support structure must be designed to accommodate and support cabling, cooling tubes and source tubes from the Tracker and Calorimeter.

- Total mass of the Beam Stop must be accomodated by the load specifications of the DS internal bore.

- The Beam Stop must provide a connection between the IFB (Instrumentation Feed Through Bulkhead) and the other internal detector components which will allow a longitudinal position reproducibility within 1 mm.

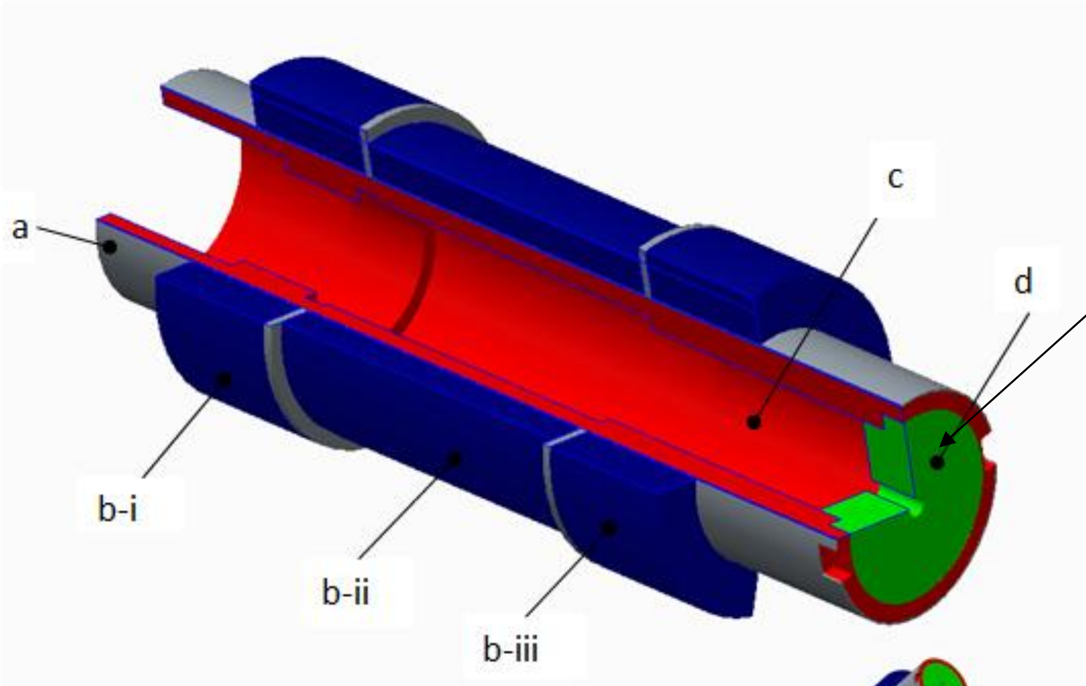
Design

The Muon Beam Stop will be located within the bore of the Detector Solenoid, and will be located longitudinally between the IFB and the Calorimeter.



Design

This preliminary design of the MBS consists of several concentric cylindrical structures of stainless steel and high density polyethylene.



a. Stainless steel tube and rings (gray)
b. Exterior absorber (blue)
c. Interior absorber (red)
d. End plug with axial hole (green)

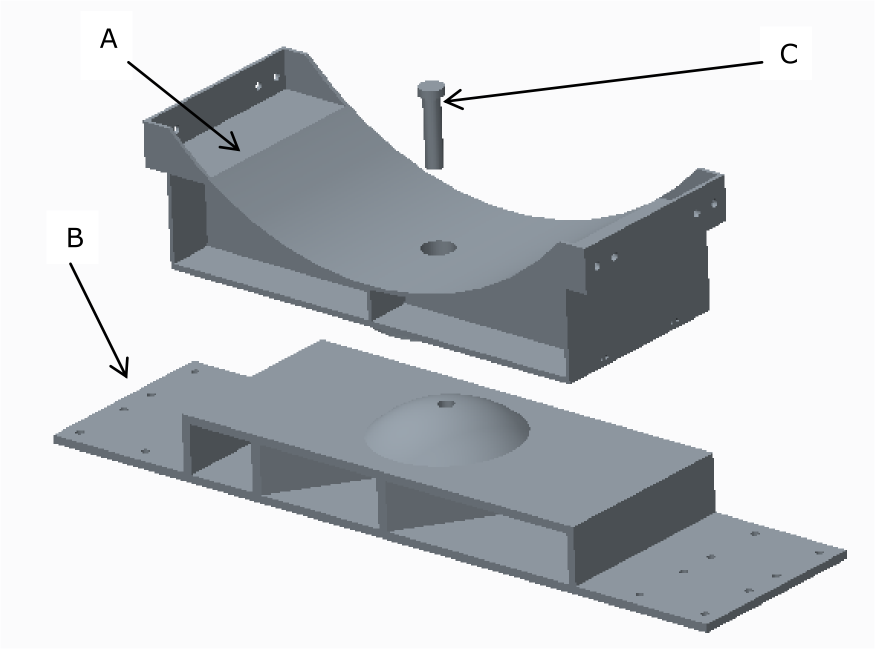
The poly end plug contains an 80mm diameter hole to allow line-of-sight from the stopping target to the stopping target monitor.

Some areas of polyethylene are cut away to allow space for support structures, cooling tubes and source tubes to and from the detectors.

Design

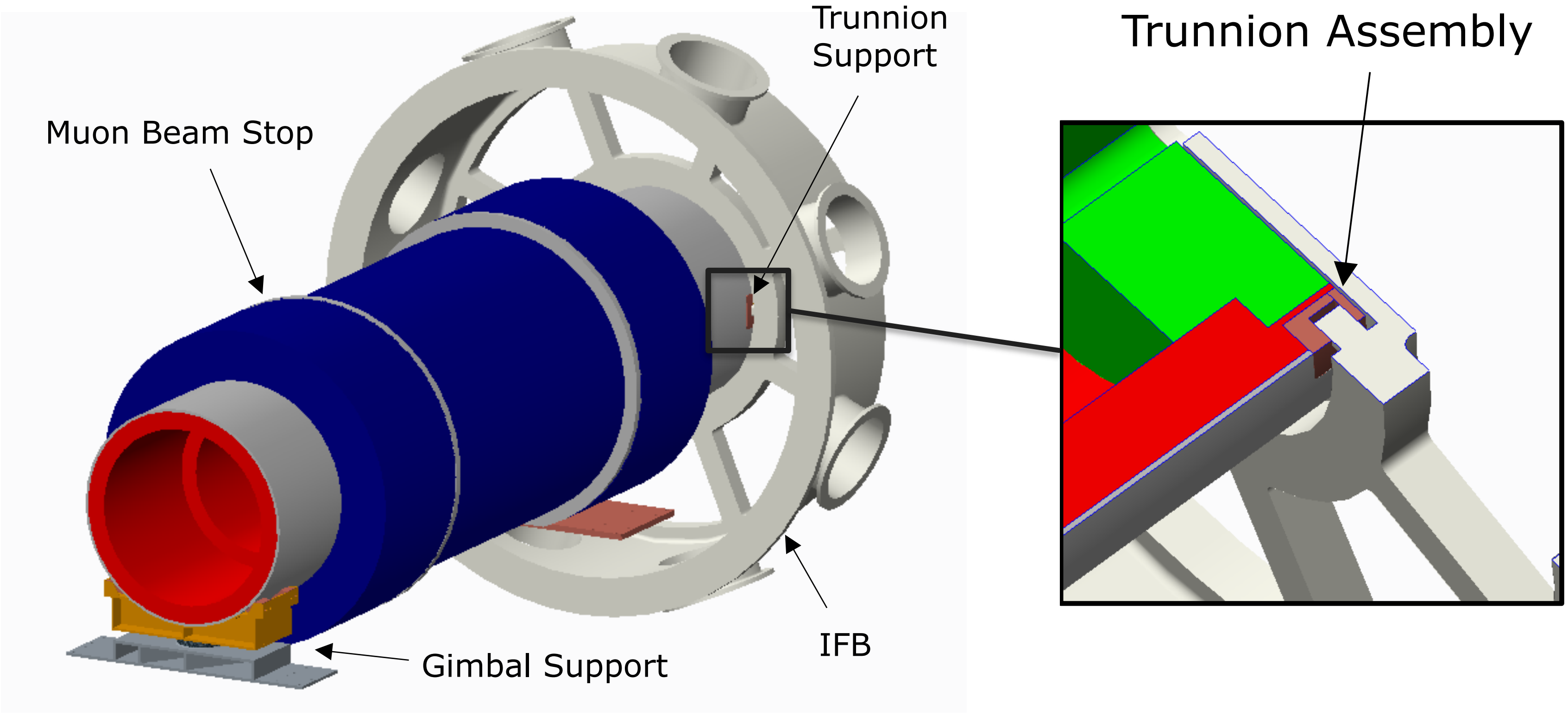
The beam stop is supported on the internal rail system by a “gimbal support” on the upstream end   It is supported on the downstream end by the IFB through a “trunnion assembly”.

The 3-part gimbal support allows the upstream end of the MBS to remain accurately placed on the rails while still accommodating the larger movement of the downstream end during detector train insertion and extraction.



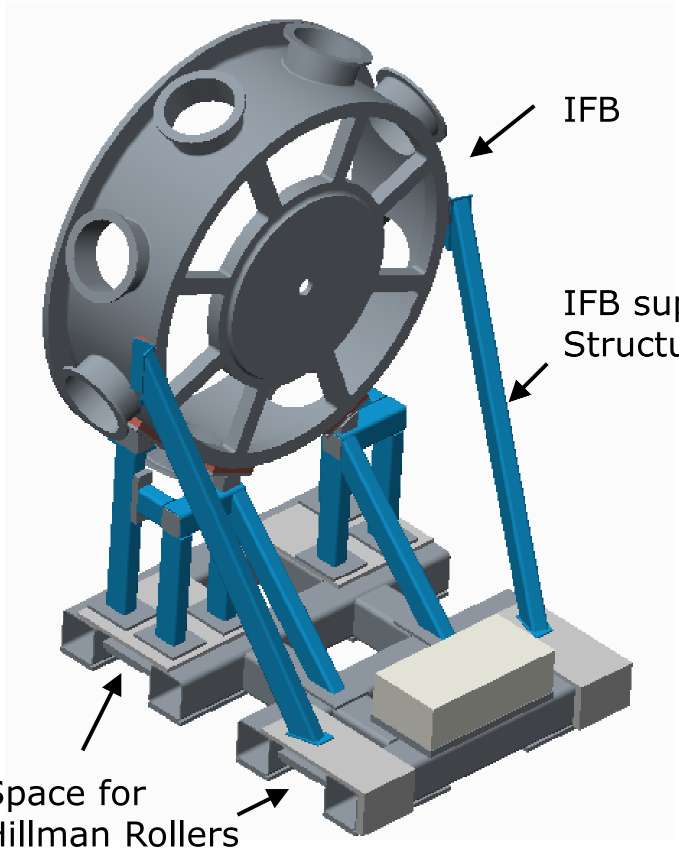
Design

On the downstream end, the trunnion attaches to the IFB, which is supported independently of the rest of the internal detector components.



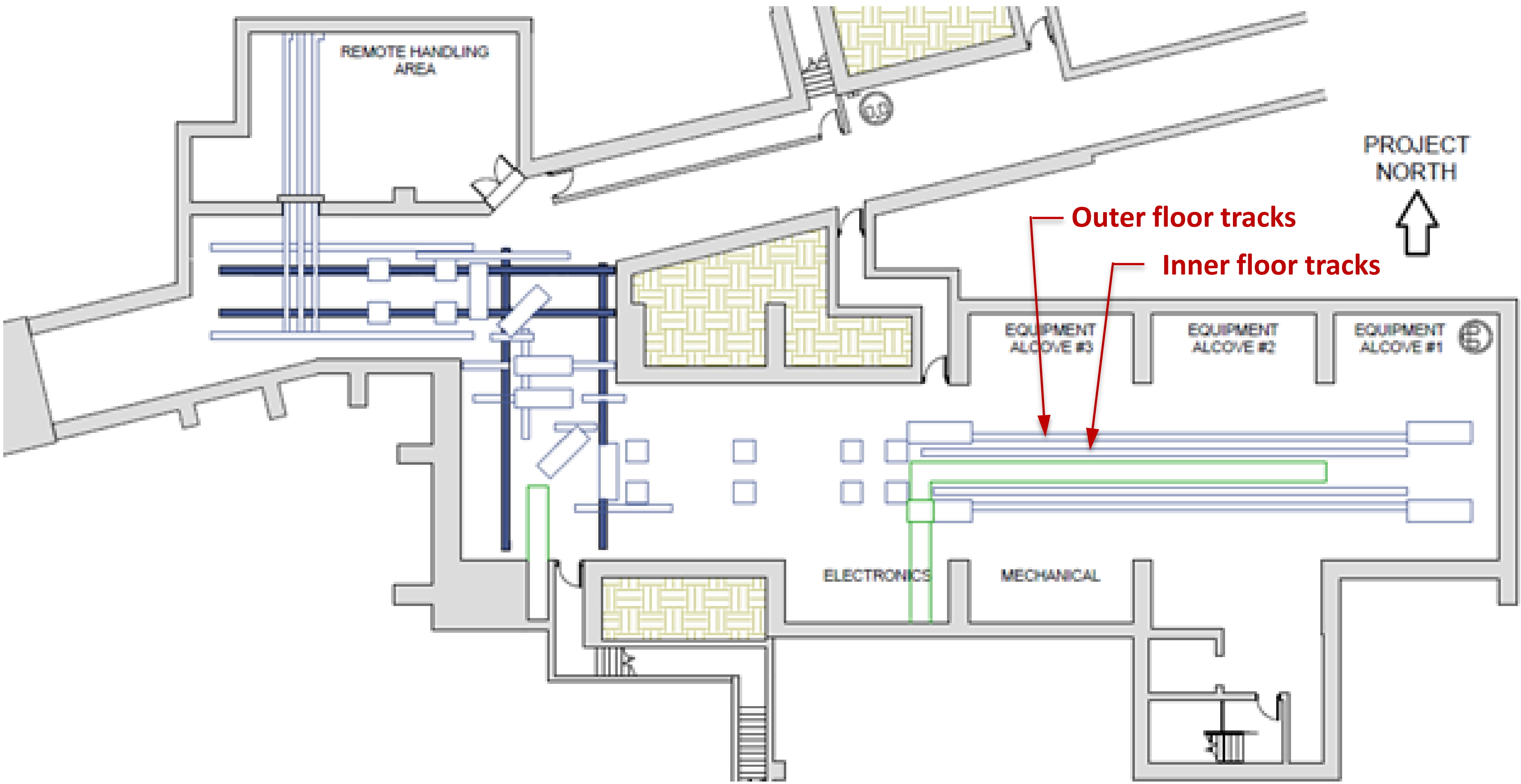
Design

The trunnion attaches to the IFB, which is supported separately from the rest of the internal detector components, and rides on Hilman rollers, on a separate floor track.



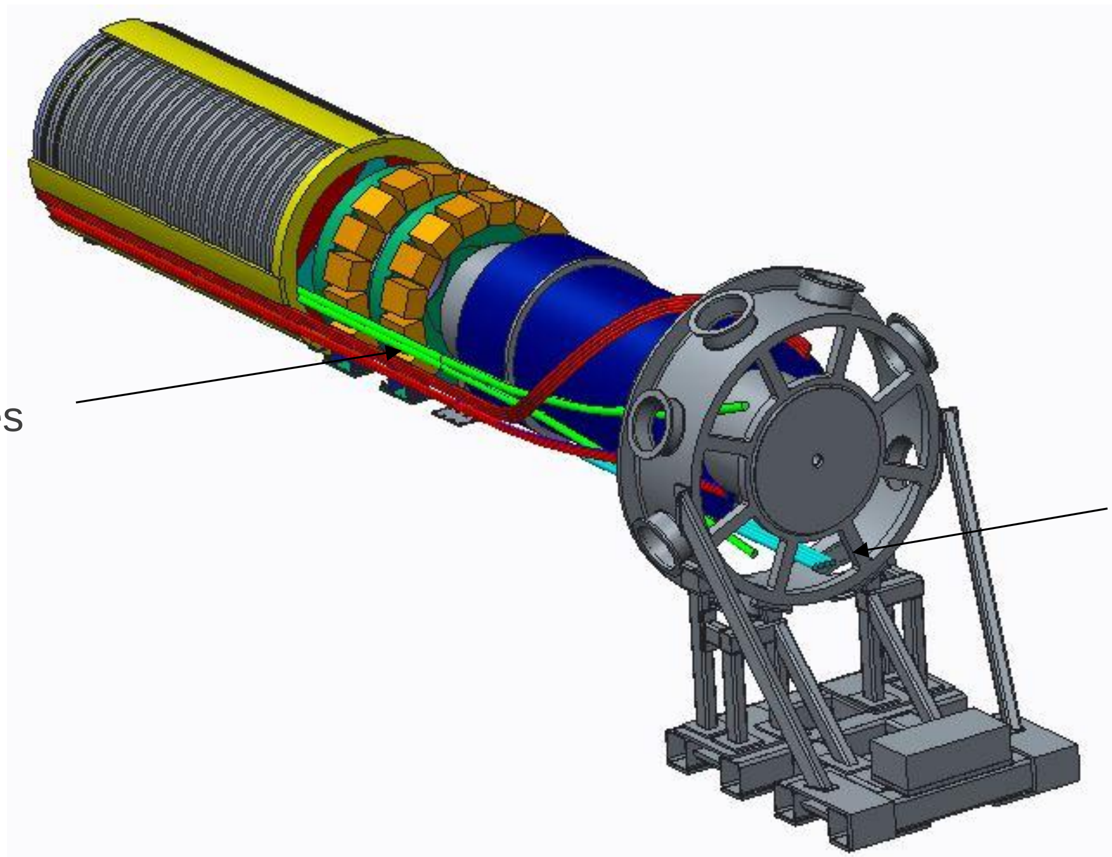
Design

Floor Track Plate Layout



Design

The Muon Beam Stop must accommodate the cables, cooling tubes and source tubes from the calorimeter and the tracker, which will extend over the length of the MBS and be terminated at, and permanently attached to, the IFB.



Assembly Process

Assembly of the MBS will take place in several steps to facilitate fit between sections. A brief summary of the assembly process follows:

1. Order 316L stainless steel tube assembly. The stainless steel tube can be manufactured with ID tolerance of +/- 4mm and wall thickness tolerance of +/- 0.5mm .
2. Fully anneal stainless tube assembly.
3. Receive and inspect the stainless steel tube assembly.
4. Using measured dimensions of stainless steel tube, update the specifications of the HDPE and order HDPE parts. Parts are expected to be made from 2 inch thick rings, and will be pinned to each other. The center external ring will need to be made of two pieces and attached by HDPE pins or welded at assembly.
5. Receive the polyethylene pieces and inspect.
6. Install polyethylene pieces into stainless steel tube at Fermilab.

Installation Sequence

A brief summary of the MBS installation sequence follows:

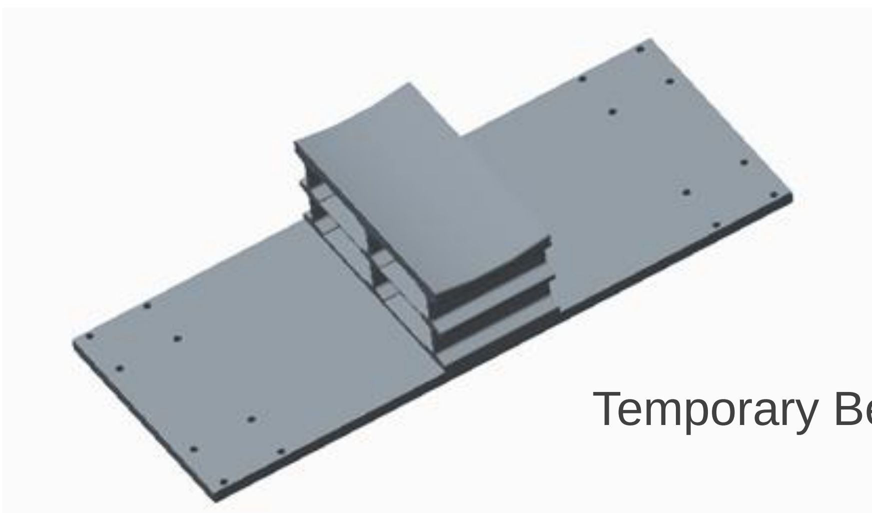
1. Install the external rail system downstream of the Detector Solenoid.
2. Lower the beam stop onto the external stands. The MBS will be entirely supported by the rail system, using the gimbal support on the upstream end and the temporary support on the downstream end.
3. Roll the MBS into the installed position and measure the position with respect to the DS geometric bore.
4. Adjust the position if necessary using shims. Roll back in to verify the position, and roll out into the "maintenance" position.
5. Individually position and adjust the calorimeter, tracker, and other components in the detector train, beginning with the downstream-most component (the calorimeter). Connect each component to the next-most-downstream component in the detector train axially, after being measured.
6. Roll IFB into position with respect to the MBS and attach the trunnion to the MBS trunnion bracket.
7. Roll the temporary support downstream, off the external rail stand, lower and remove.
8. Attach the cooling tubes and cables to the calorimeter and tracker and route them past the MBS to the IFB (tubes and cables will be partially supported by the MBS).
9. Connect all cables from the floor trench to the IFB.
10. After completion of the KPPs, roll the component train, including the IFB, into position and close the vacuum system

Improvements since CD-1

- Optimizing design to enhance performance
  - An extensive series of simulations
  - Lead has been eliminated
  - Mass has increased, with more polyethylene
- Support of downstream end transferred from rails to enclosure
  - Reduces number of individual external stands required in detector support and installation system

Value Engineering since CD-1

Redesign of support system to allow downstream end of MBS to be supported by IFB allows simplification of the external support system, but requires an additional temporary support for the downstream end of the MBS prior to transferring the load to the IFB.



Temporary Beam Stop Support

Performance

- Preliminary design of the beam stop and the end cap shielding satisfy the performance criteria, however, optimization continues in an attempt to enhance the margin.
- New support system satisfies the vertical, lateral, and longitudinal criteria for placement
- Mass of MBS does not exceed the maximum load specification for the DS bore, although some structural calculations are still pending
- Configuration of MBS and supports allow for routing of services to and from Tracker and Calorimeter

Remaining work before Fabrication

- Continue simulations to establish final geometry and optimize material selections.
- Test “gimbal-trunnion” support system on rail system mockup.
- Continue and document all structural calculations.

- Complete layout and design of cable and tube routing along the MBS.
- Refine and complete documentation of Installation procedure

Quality Assurance

- Quality Assurance in the Muon Beam Stop efforts rely upon the following tools :
  - Fermilab Quality Assurance Manual
  - Fermilab Engineering Manual
  - Documented engineering calculations and drawings
    - reviewed, approved and released
  - Verification of physics simulations
    - Comparisons between MARS and GEANT4
  - Prototypes and mockups as appropriate
  - Documentation of procedures
  - Delivered materials will be inspected for conformance to the specifications

Risks

There are no moderate or high risks which involve the Muon Beam Stop.

There is a low risk that the fit of the polyethylene parts into and over the stainless tube is not adequate to allow the structure to be assembled. This will be mitigated by ordering the stainless steel structural member first, and using the measured values to specify the sizes of the HDPE parts. If time does not allow this to be done, careful tolerances and inspection of the parts before arrival will mitigate this risk.

There is a low risk that the “gimbal and trunnion” assembly, which is meant to allow for any variations in movement of the IFB on Hilman rollers does not work as planned. This risk will be mitigated by a test of the system on an existing rail system mockup.

There also is a low risk that the weld between the stainless structural tube and the reinforcing rings will have a magnetic permeability higher than the requirements specify. This will be mitigated by annealing the tube prior to assembly, as well as performing tests on weld samples with the materials before manufacturing, and testing the MBS welds for permeability as part of the incoming inspection process.

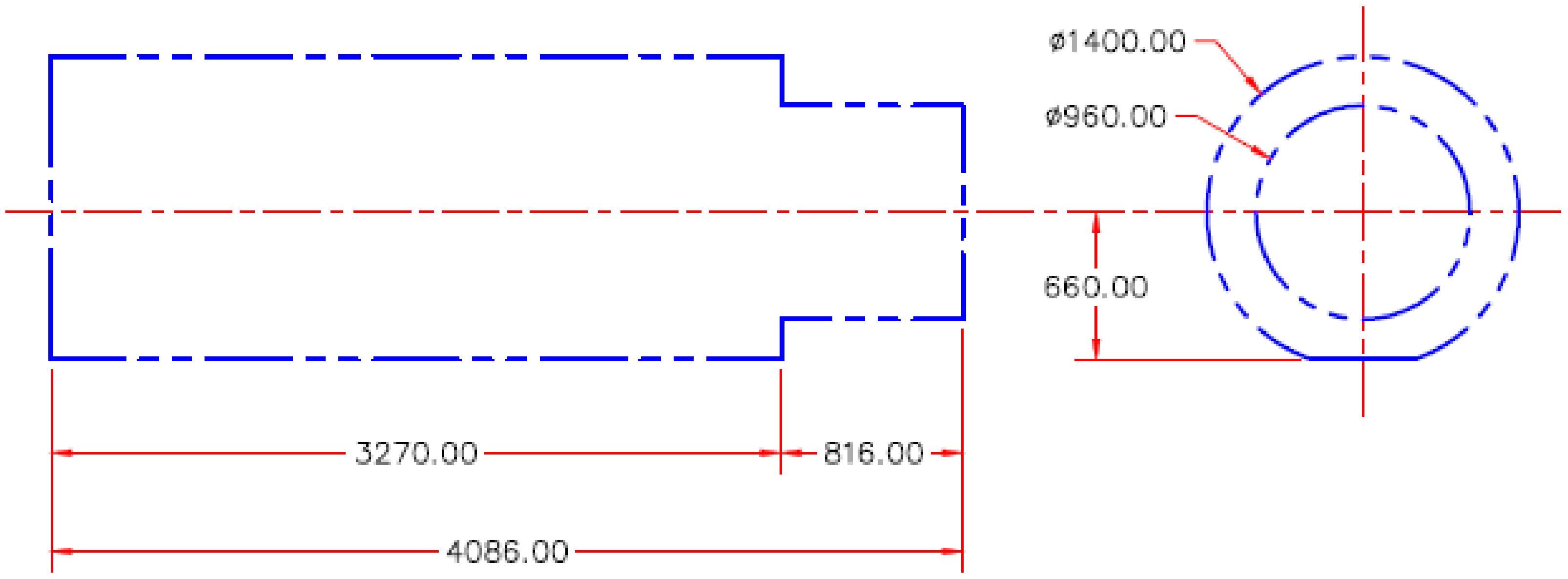
Integration and Interfaces

- The Muon Beam Stop has external interfaces to the Tracker, Calorimeter, and the Detector Solenoid.
- Internal interfaces with the Vacuum System, Stopping Target, Stopping Target Monitor, Internal Shielding, Detector Support and Installation System, and Downstream External Shielding
- Formal sign-off between owners of all external interfaces as part of final design requirements.
- Interfaces understood and under control.
- Muon Beamline personnel participate in bi-weekly integration meetings

Integration and Interfaces

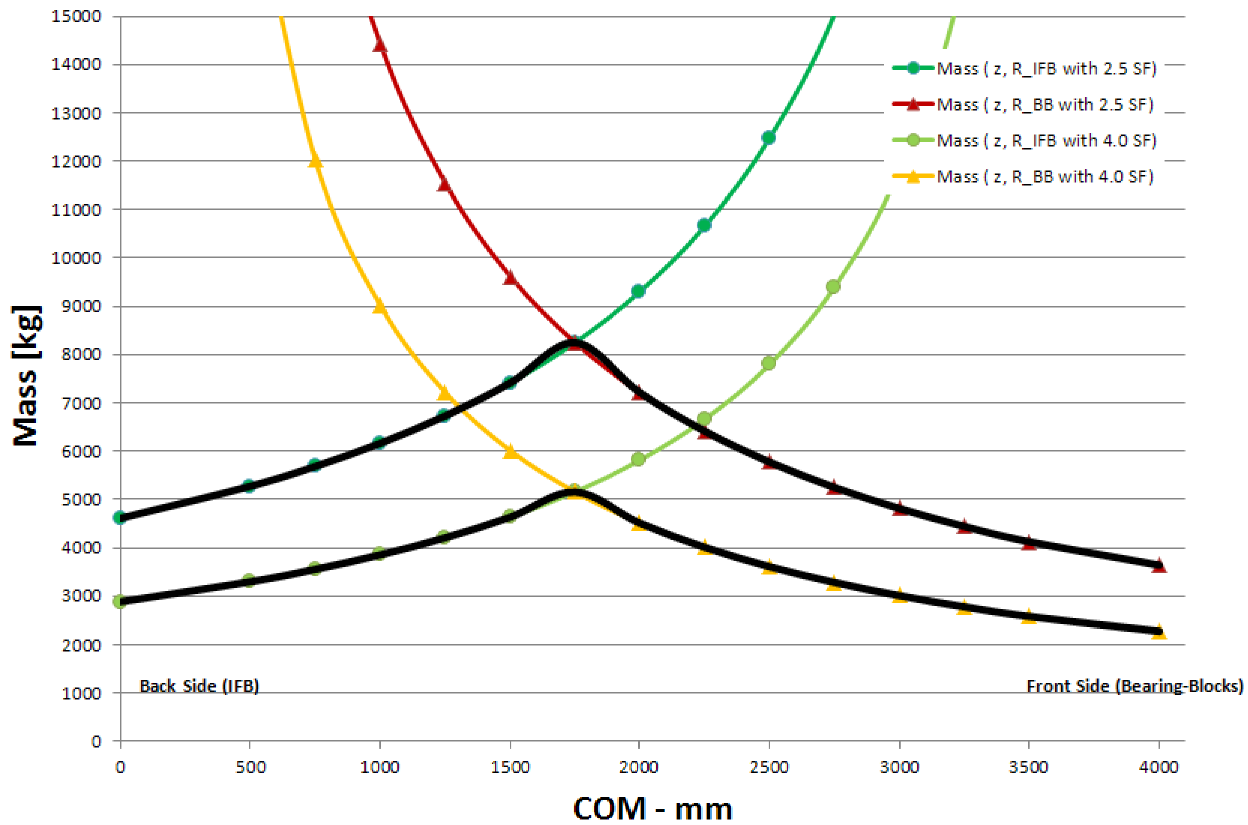
- In particular, important interfaces involve:
  - the support of the Muon Beam Stop by the Detector Support and Installation System on the upstream end and by the “trunnion” connection to the Instrumentation Feedthrough Bulkhead on the downstream end.
  - the cabling and cooling tube routing from the tracker and calorimeter to the electronics and mechanical rooms, which traverse the outside surface of the Muon Beam Stop.
  - The DS vacuum pump-out ports located in the VPSP are within the longitudinal space of the MBS. The MBS must not impede the pumping capacity.
  - Line-of-sight for the Muon Stopping Target monitor must not be impeded by the MBS.

Integration and Interfaces



The MBS must conform to a specific maximum “envelope” to provide clearance on the exterior surface for cables and tubes, longitudinal space for other components and space for support mechanisms. The “flat” on the bottom allows external stands to be extracted during installation.

Integration and Interface



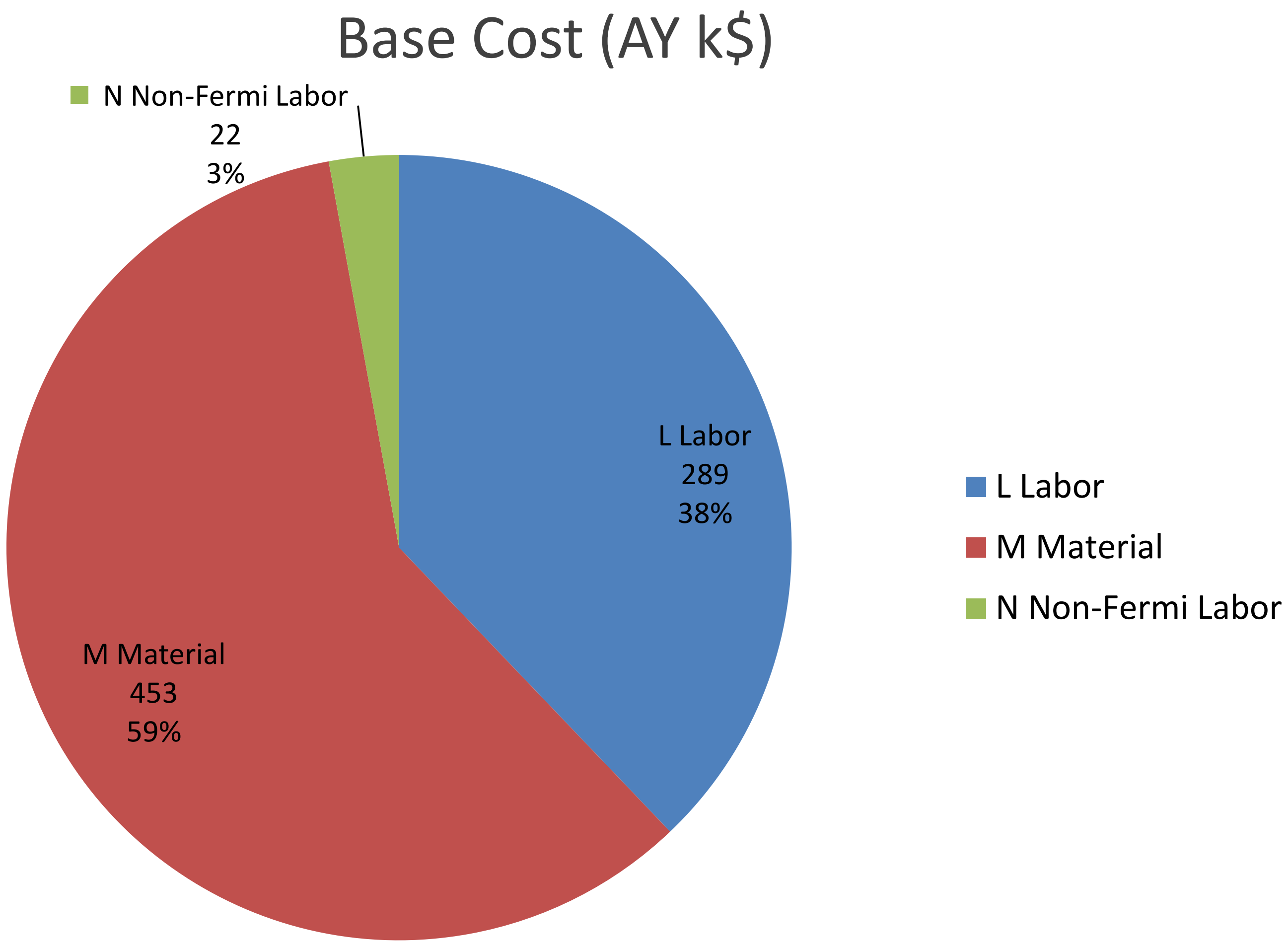
The MBS must conform to specific requirements regarding maximum weight and position of the center of mass, to avoid violating the load requirements of the bearing/rail assembly or the trunnion mechanism, as shown above.

ES&H

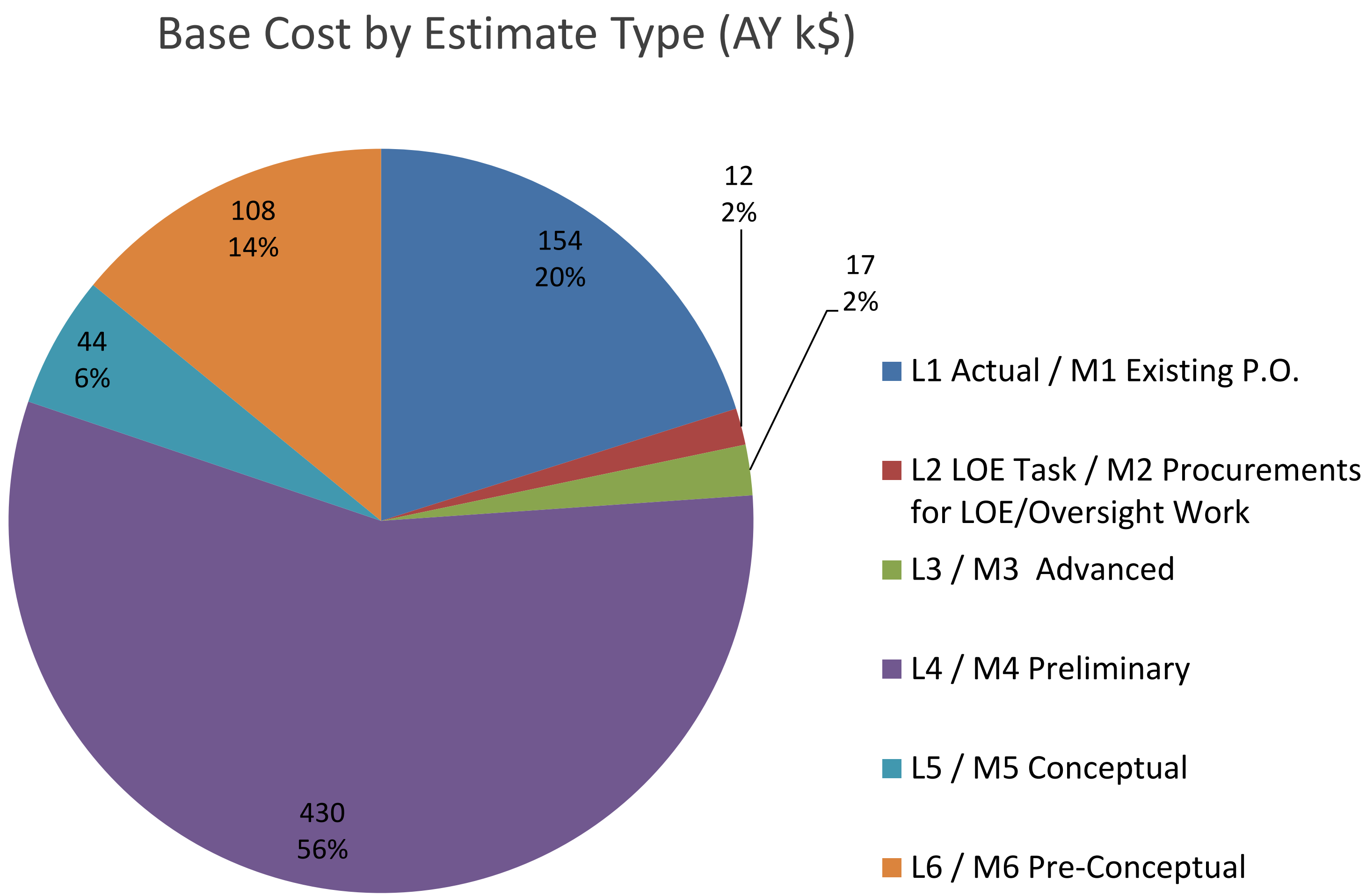
To perform Muon Beam Stop activities safely will require appropriate planning (JHA), attention to ES&H considerations and FESHM and FRCM requirements

- Accessing confined space FESHM 5063
- Crane, hoist, and forklift use FESHM 5021
- Fall Hazards FESHM 5066
- Magnetic fields FESHM 5062.2
- Electrical hazards FESHM 5042
- Fire hazards
- Hydraulic systems (and potential stored energy)
- Radiation hazards FRCM
  - Activation by beam
- And possibly ODH
  - FESHM 5064

Cost Distribution by Resource Type

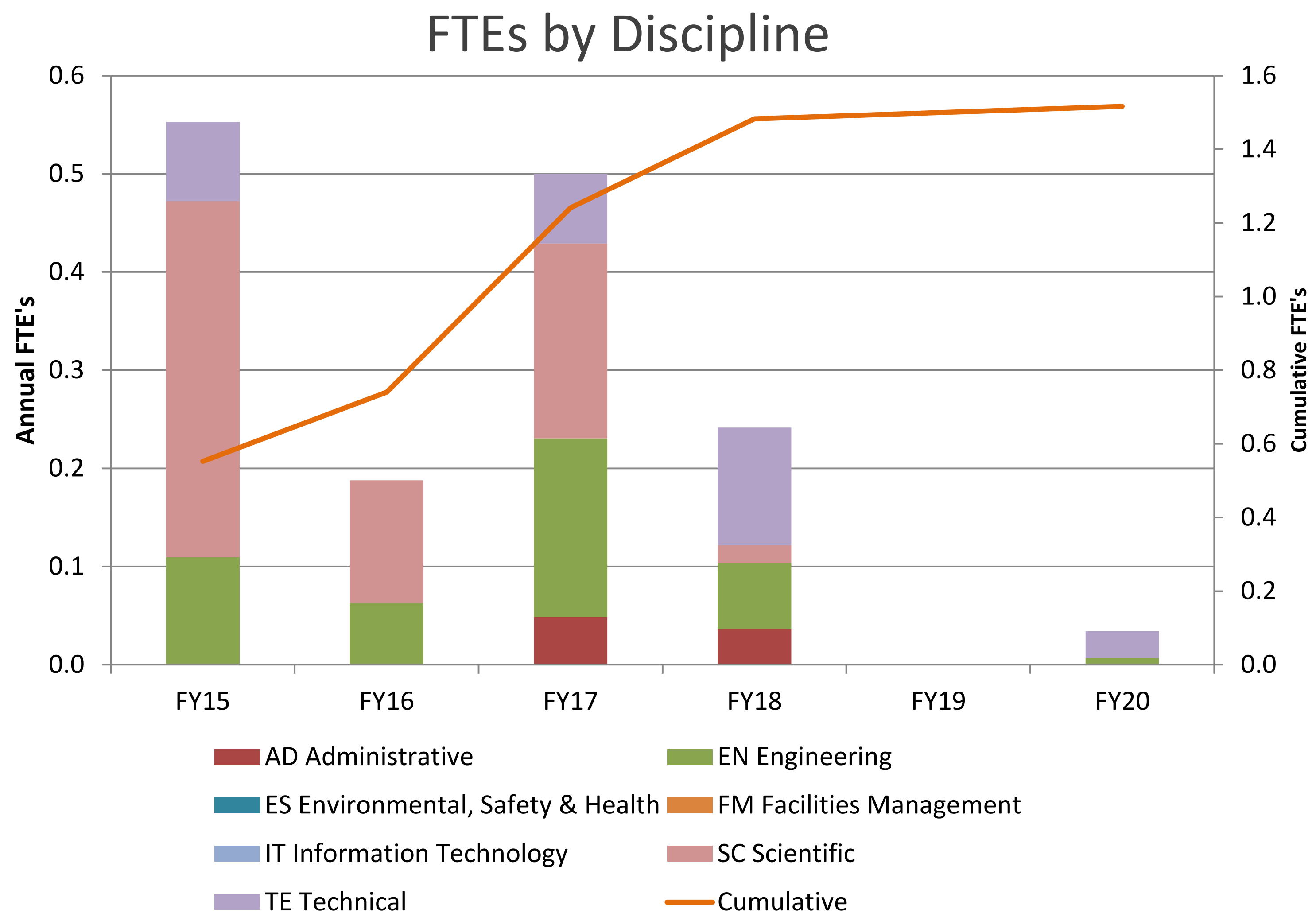


Quality of Estimate



80% at preliminary design level or better

Labor Resources



Cost Table

WBS 5.8 Muon Beam Stop

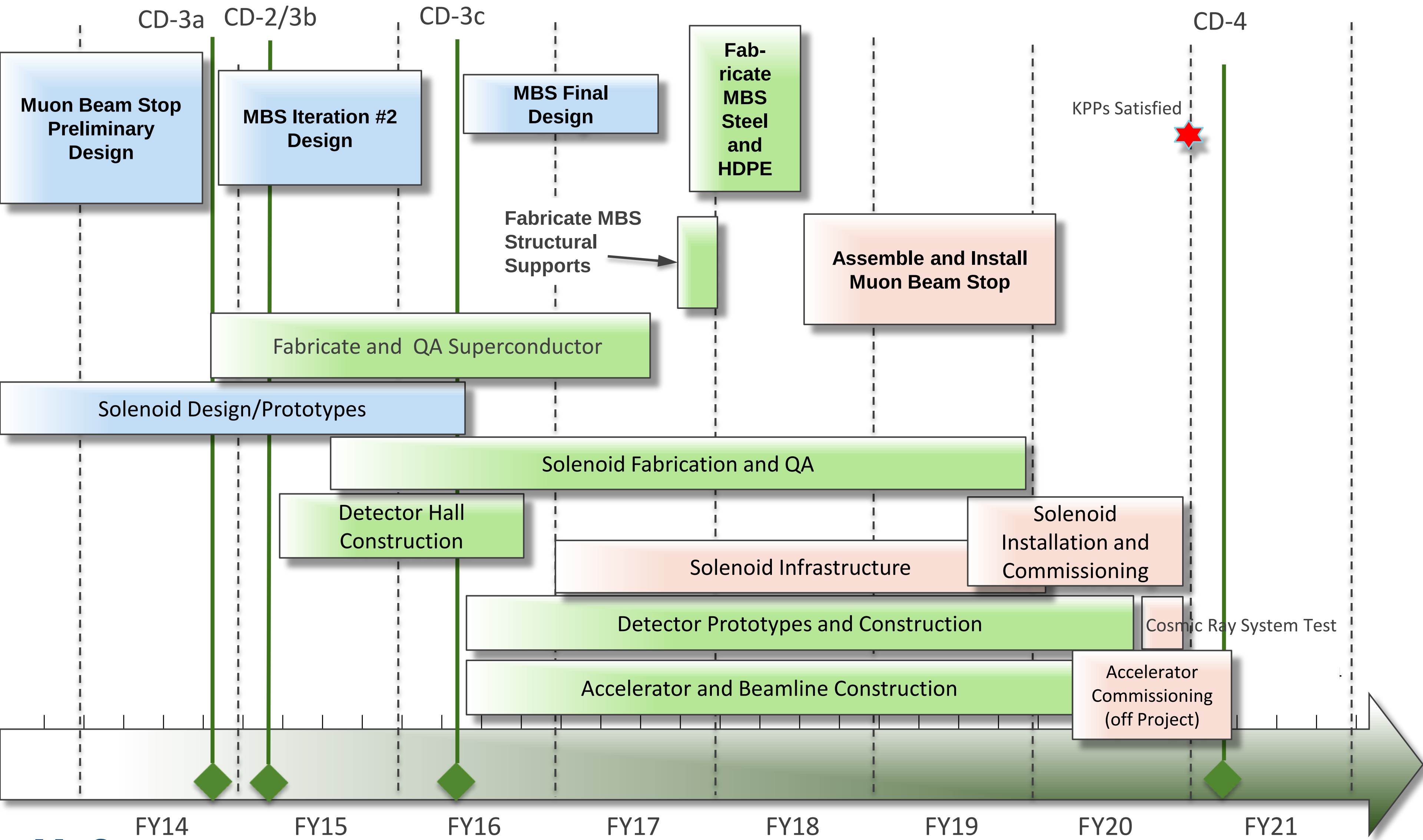
Costs are fully burdened in AY k$

	Base Cost (AY K$)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining budget)	% Contingency (on remaining budget)	Total Cost
475.05 Muon Beamline						
475.05.08 Muon Beam Stop						
475.05.08 Muon Beam Stop	475	289	764	219	37%	983
Grand Total	475	289	764	219	37%	983

Major Milestones

Activity ID	Milestone Name	Milestone Date
47505.8.001675	Muon Beam Stop 2^{nd} iteration design complete	November 09, 2015
47505.8.001844	Muon Beam Stop ready for CD 3c Review	December 11, 2015
47505.8.001845	CD 3 Approval Muon Beam Stop.	February 23, 2016
47505.8.031010	All Muon Beam Stop Components at FNAL	April 11, 2018
47505.8.031040	Muon Beam Stop ready for CD-4	November 13, 2019

Schedule



CD-3a
CD-2/3b
CD-3c
CD-4
Muon Beam Stop Preliminary Design
MBS Iteration #2 Design
MBS Final Design
Fab-ricate MBS Steel and HDPE
KPPs Satisfied
Fabricate MBS Structural Supports
Assemble and Install Muon Beam Stop
Fabricate and QA Superconductor
Solenoid Design/Prototypes
Solenoid Fabrication and QA
Detector Hall Construction
Solenoid Installation and Commissioning
Solenoid Infrastructure
Detector Prototypes and Construction
Cosmic Ray System Test
Accelerator and Beamline Construction
Accelerator Commissioning (off Project)
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Summary

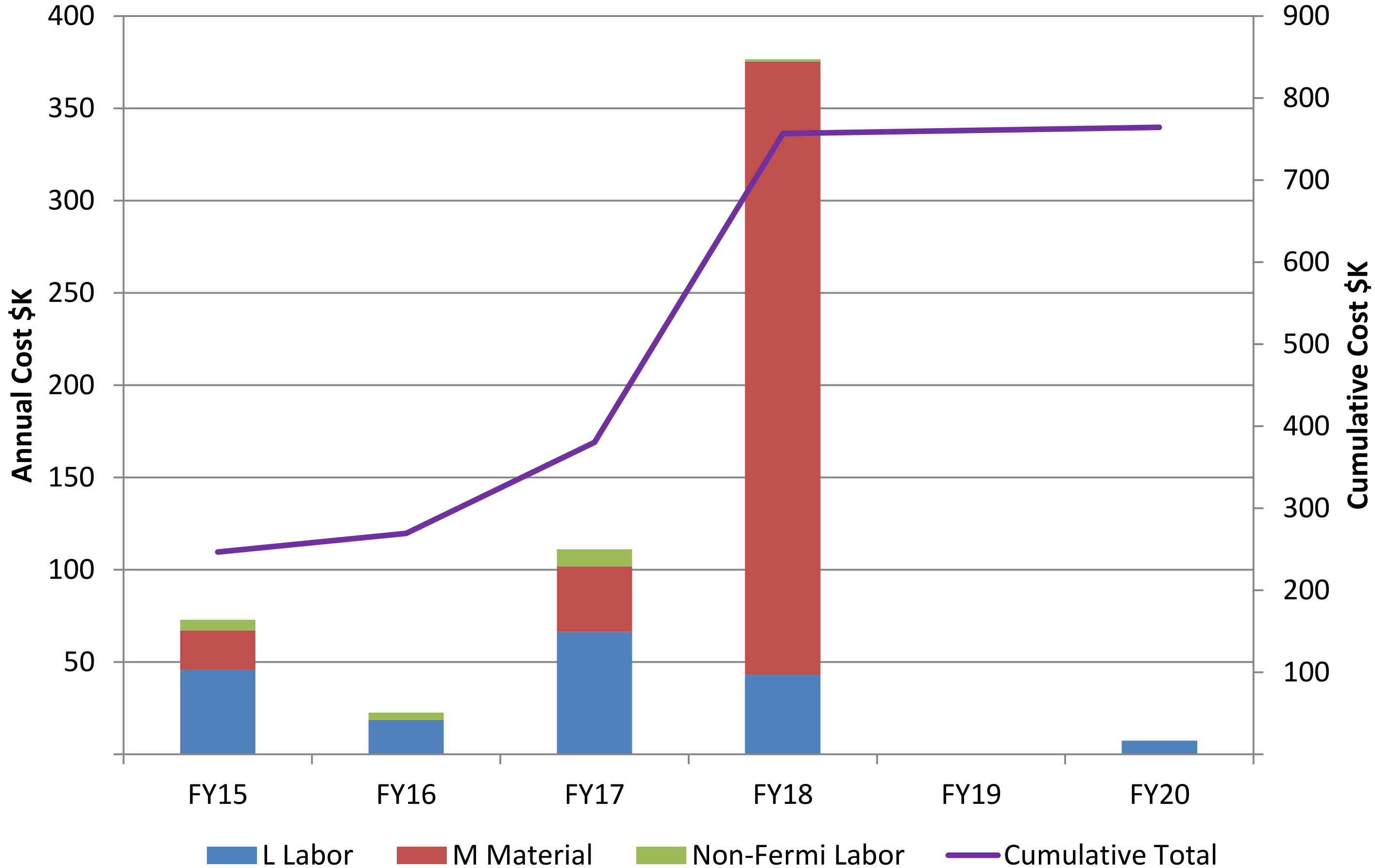
- Have made substantial progress since CD-1
  - Simulations verify that preliminary design of MBS meets the requirements
  - Design has been significantly refined/optimized
    - MBS Materials (eliminated boron, eliminated lead)
    - Gimbal-Trunnion support system
    - Cable and tube routing scenario

- Cost estimates for the Muon Beam Stop have been completed.
  - 80% of cost understood at preliminary design level or better

- Risks are understood and mitigated to the extent possible.
- Interfaces are identified and resource needs are understood.
- The Muon Beam Stop is ready for CD2

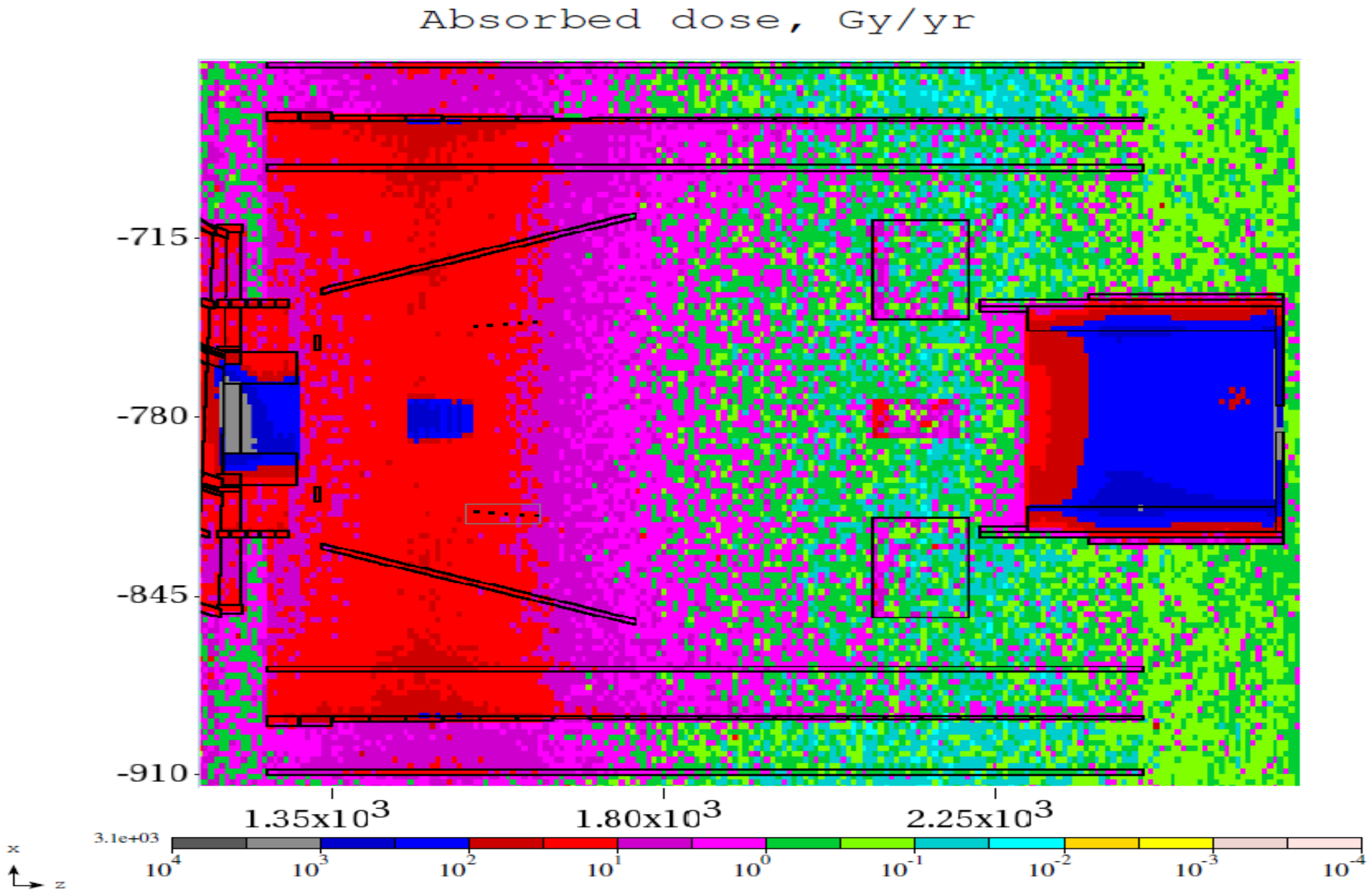
Backup Slides

Backup Slide



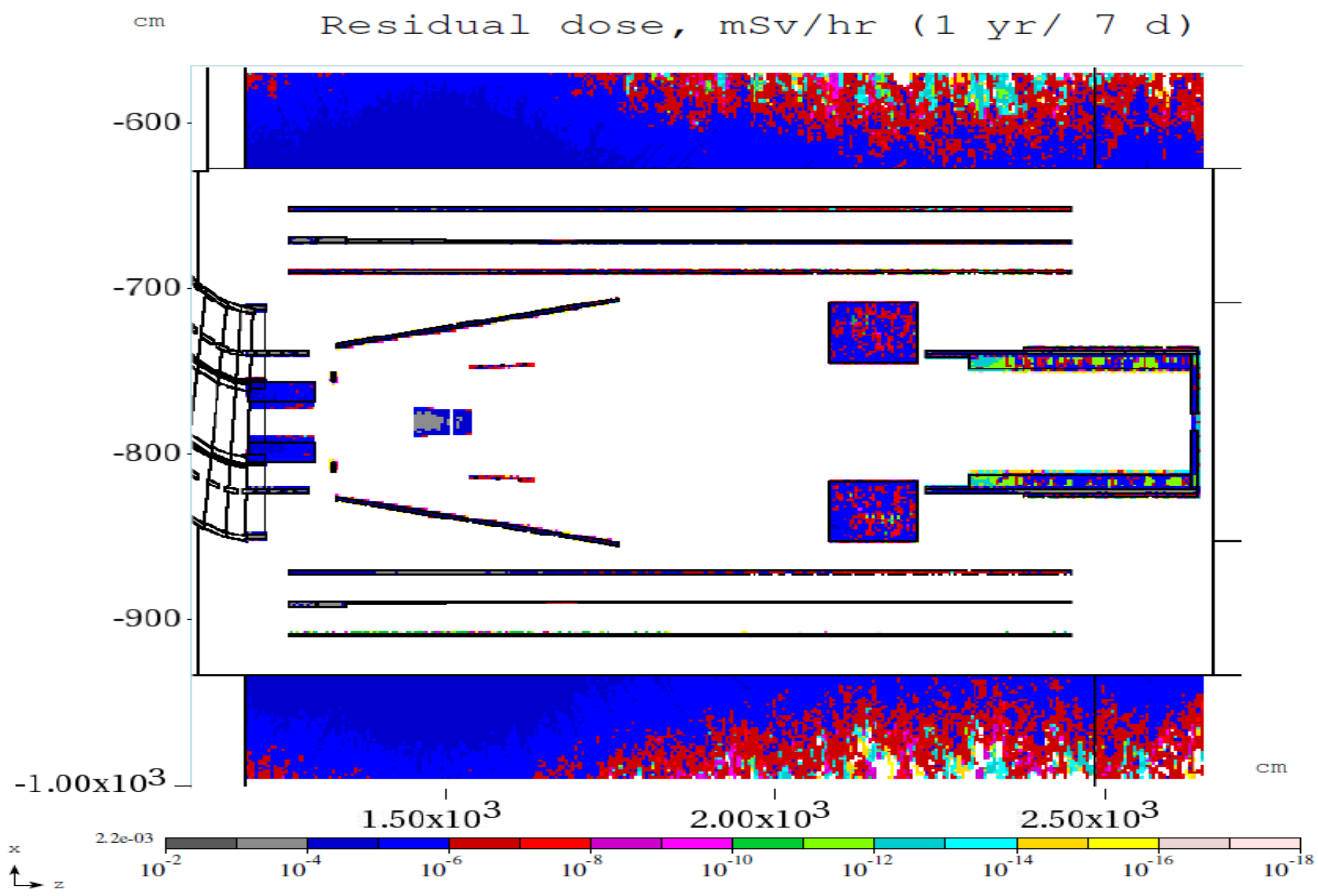
Backup Slide

Absorbed dose in DS, Gy/yr



Backup Slide

Residual dose in DS, mSv/hr



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