WBS 5.10 Detector Support and Installation System
Mu2e CD-2 Review

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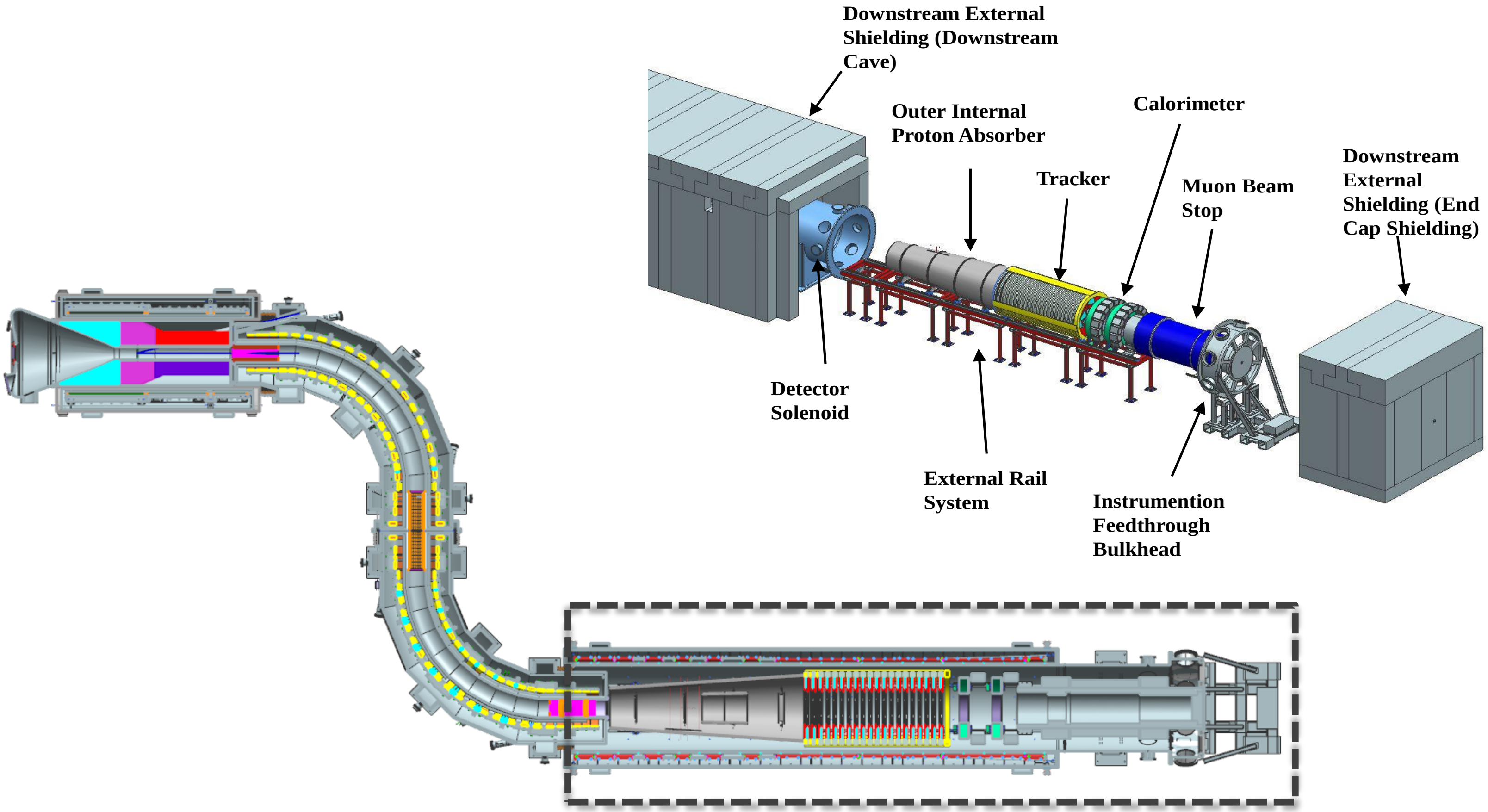
10/21/2014

Overview of the Orientation

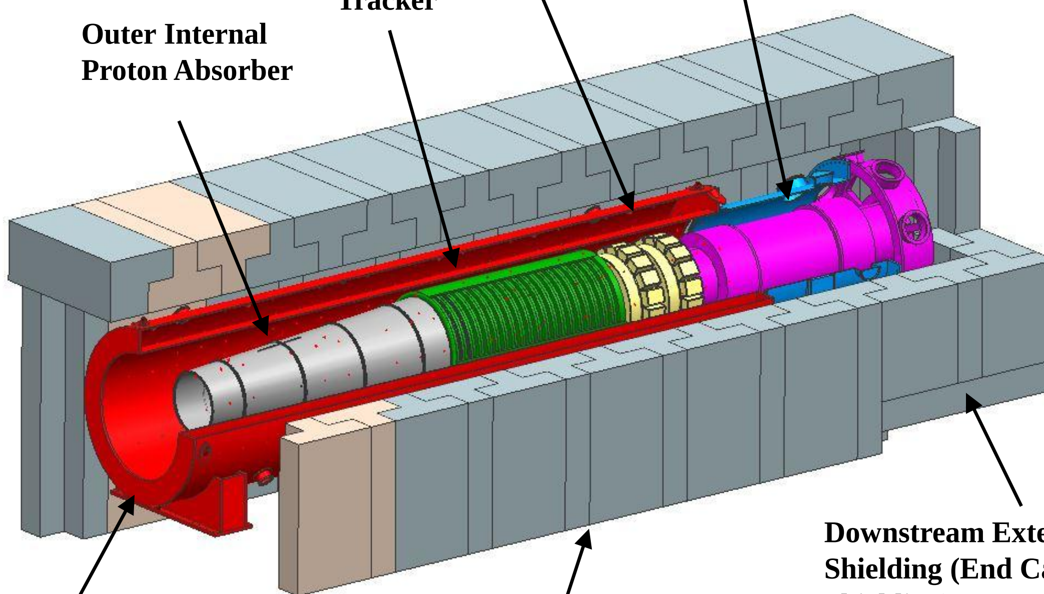
The detector support and insulation system is located within the interior of the Detector solenoid (DS) and the Vacuum Pump Spool Piece (VPSP). It also includes an external “staging area” to support the components when removed for maintenance.



Requirements

- The Detector Support Structure is required to transport and align components within the Detector Solenoid warm bore. The Muon Stopping Target, Proton Absorbers, Tracker, Calorimeter, Muon Beam Stop and associated instrumentation and services must be transported accurately and safely into position and aligned with respect to the standard Mu2e coordinate system.

The Mu2e Detector Support and Installation System requirements and specifications are documented in Mu2e-doc-1383.



Requirements

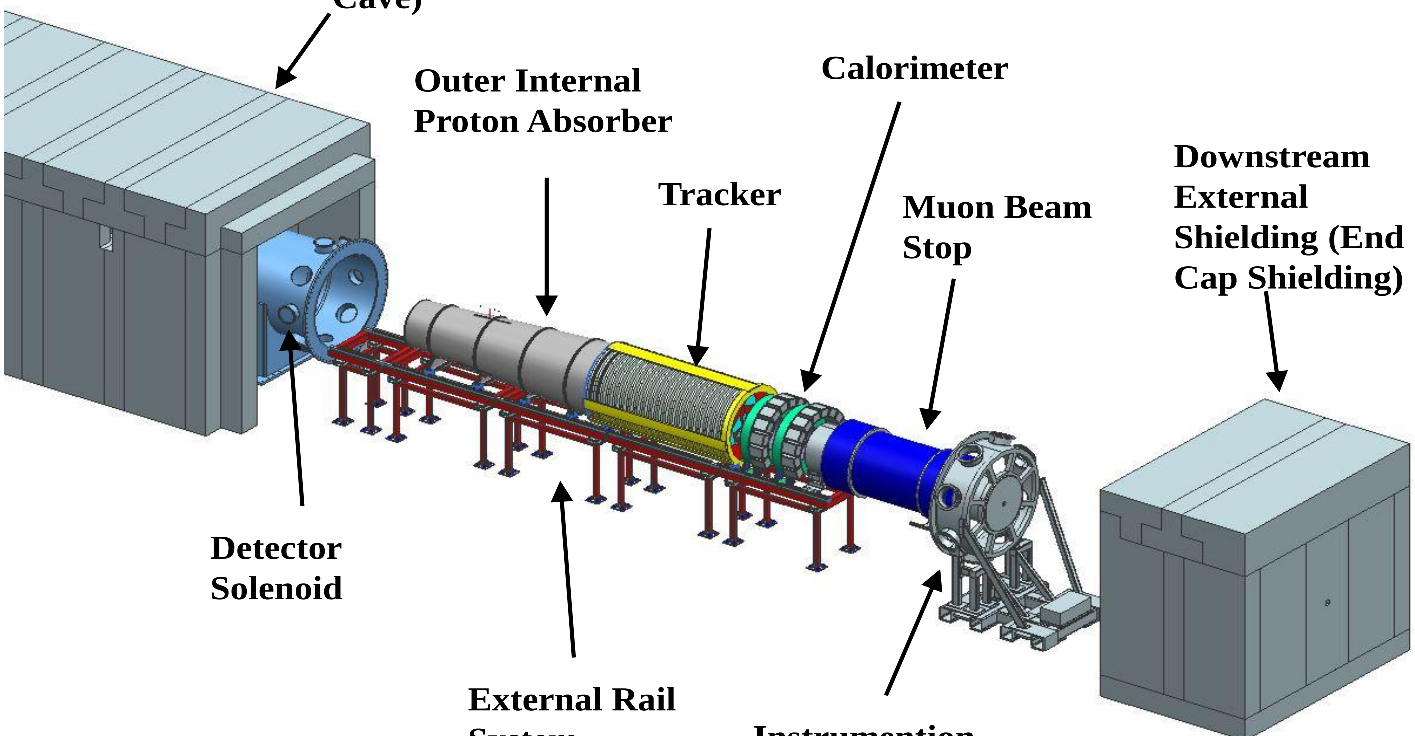
Physics requirements dictate the overall size, location and placement accuracy for the individual components within the DS bore. Components will be aligned to a set of fiducials which are positioned with respect to the center of the solenoid geometric bore.

The support system must:

- provide the ability to move the detector train out of and back into the DS bore within the specified accuracy requirements (e.g, for maintenance).
- provide a path within the DS bore for routing of the electrical cables and cooling tubes and other services from the devices to the back of the Instrumentation Feedthrough Bulkhead (IFB).
- provide support for the magnetic field mapping system.
- not impede particle trajectories or lead to an enhancement of detector rates or physics background as a result of interacting particles.
- support downstream end of muon beam stop.
- provide a temporary enclosure for the component train while stationed outside the DS bore.
- Provide space for routing of cables and tubes from the calorimeter and tracker inside the DS to the "electronics and mechanical rooms" through a trench in the floor.

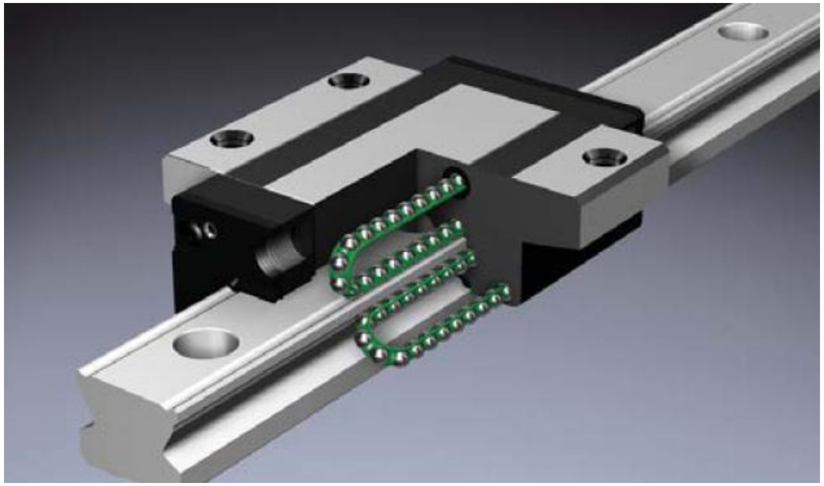
Design

Two separate rail systems will be implemented, the “internal” and “external” systems. Once transported, the alignment of all detector train components will be maintained by the internal rail system.



Design

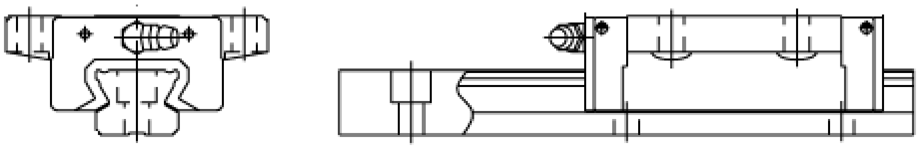
The internal rails are made of non-magnetic stainless steel. Bearing blocks are made exclusively of non-magnetic components.



Hitachi Plastic Mold Steel

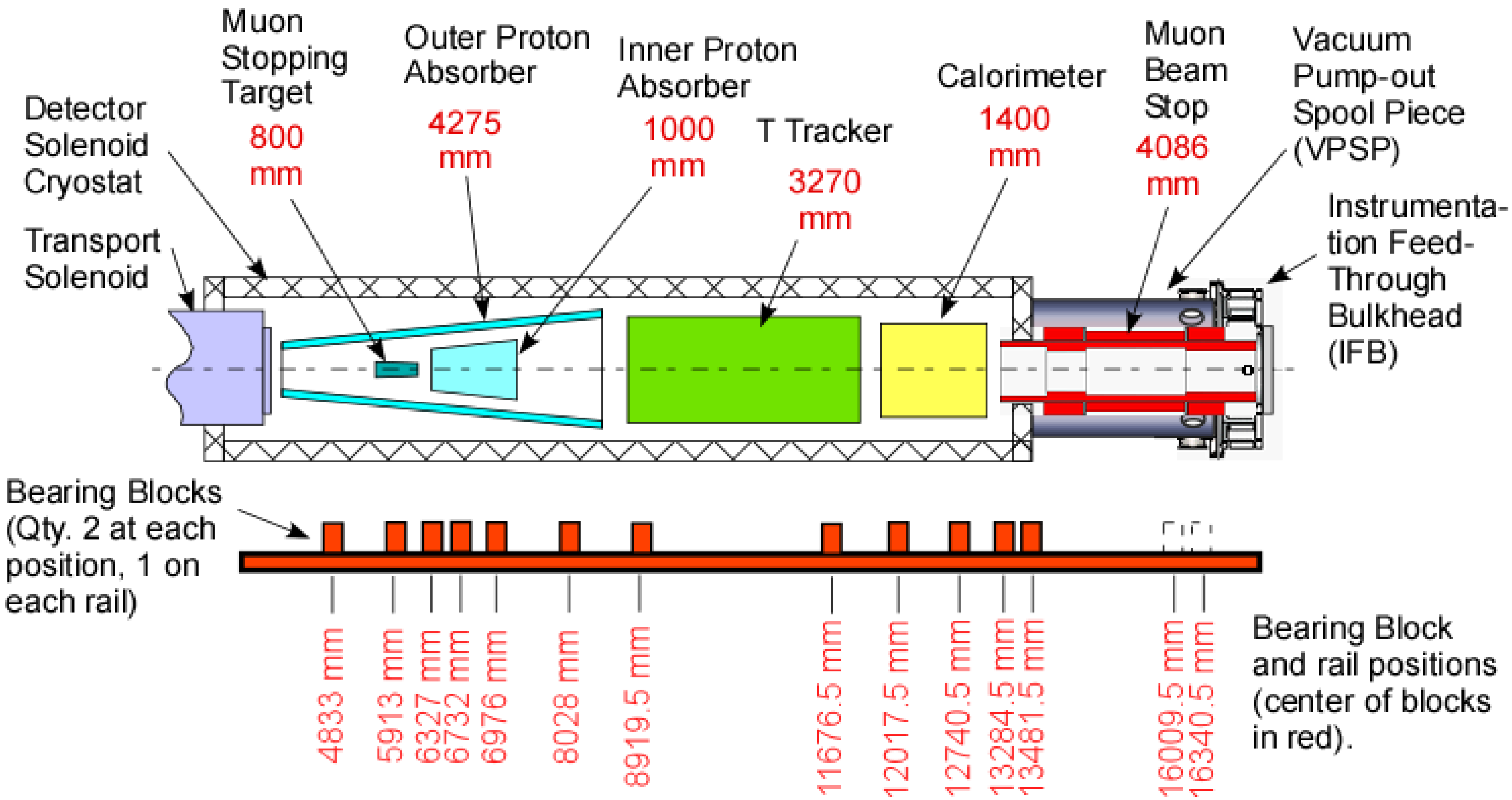
HPM75

- Hardenable to 40-45 HRC
- Non-magnetic, permeability (μ) is 1.01



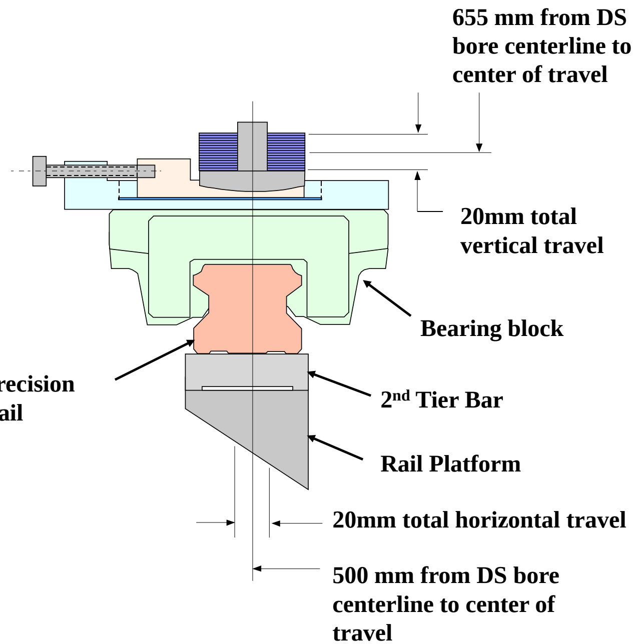
Design

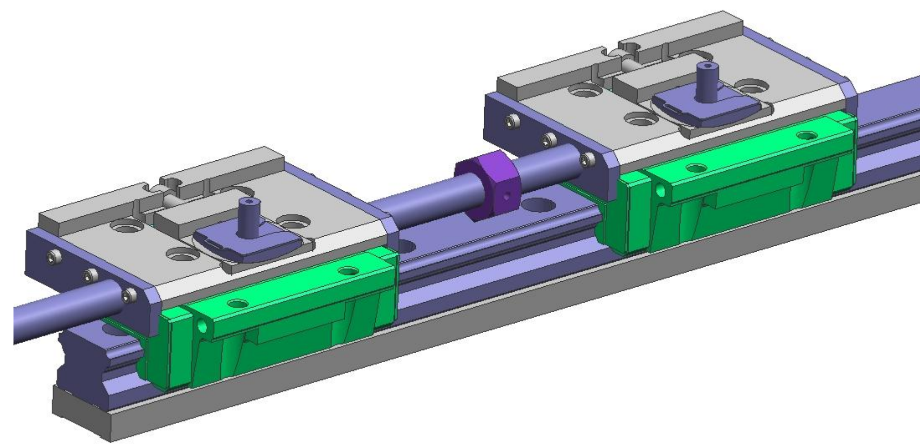
Illustration showing components within the DS bore and the position of the bearing blocks when all components are installed.



Design

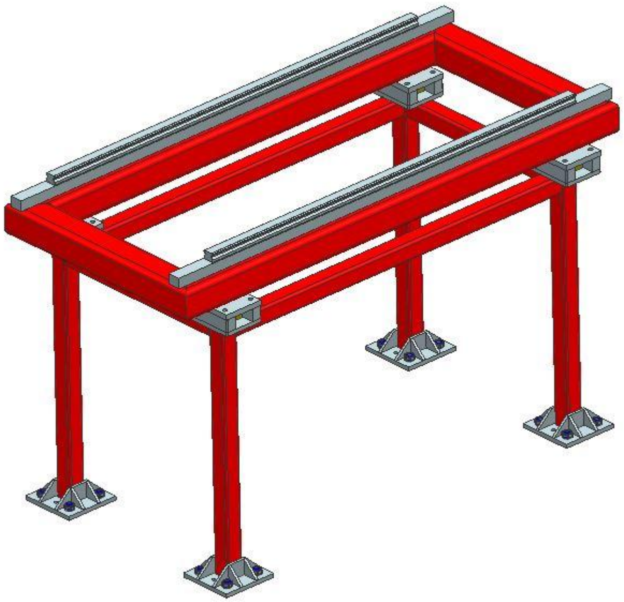
Vertical and lateral alignment of components will be done using adjustment mechanisms as shown below. The rails will be attached (through 2nd-tier bars) to the stainless steel support platforms that are welded onto the inside wall of the DS cryostat. The rails and the cryostat wall will support the weight of each component, allowing all alignment criteria to be achieved. All components will be attached longitudinally and secured to the IFB.

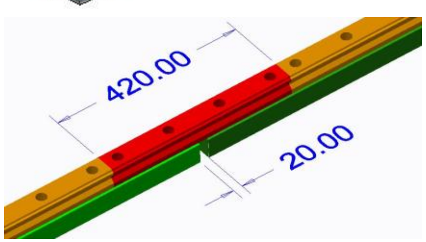


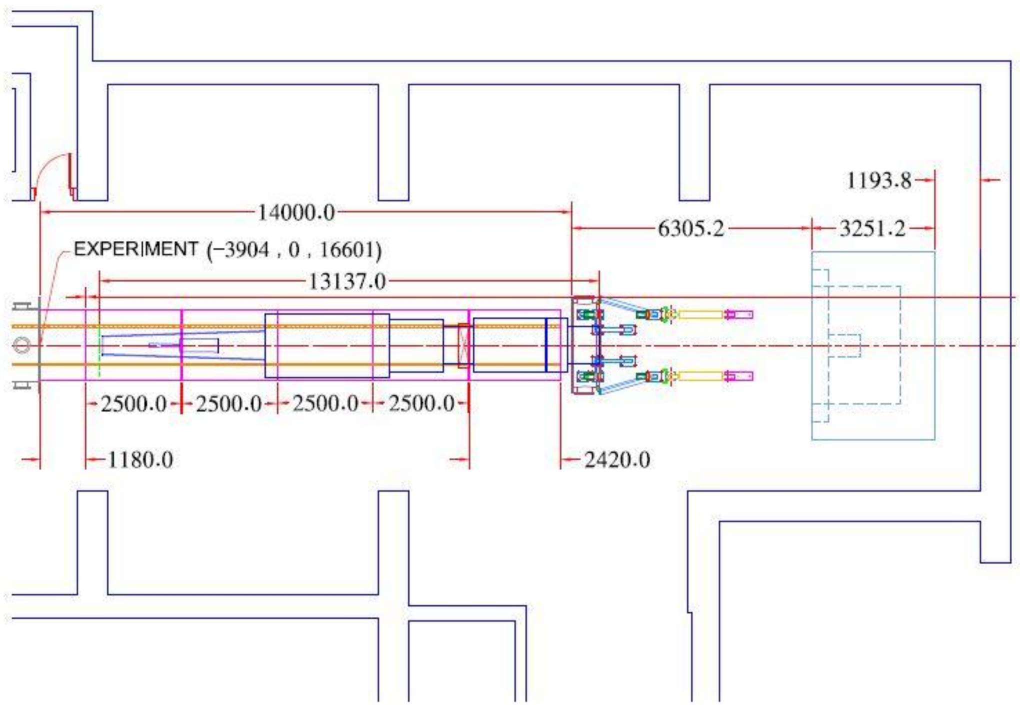


Design

The external rail system will consist of six removable stands. They will be temporarily installed in sequence as the detector train is extracted from the installed position, and removed as the “detector train” is reinserted.

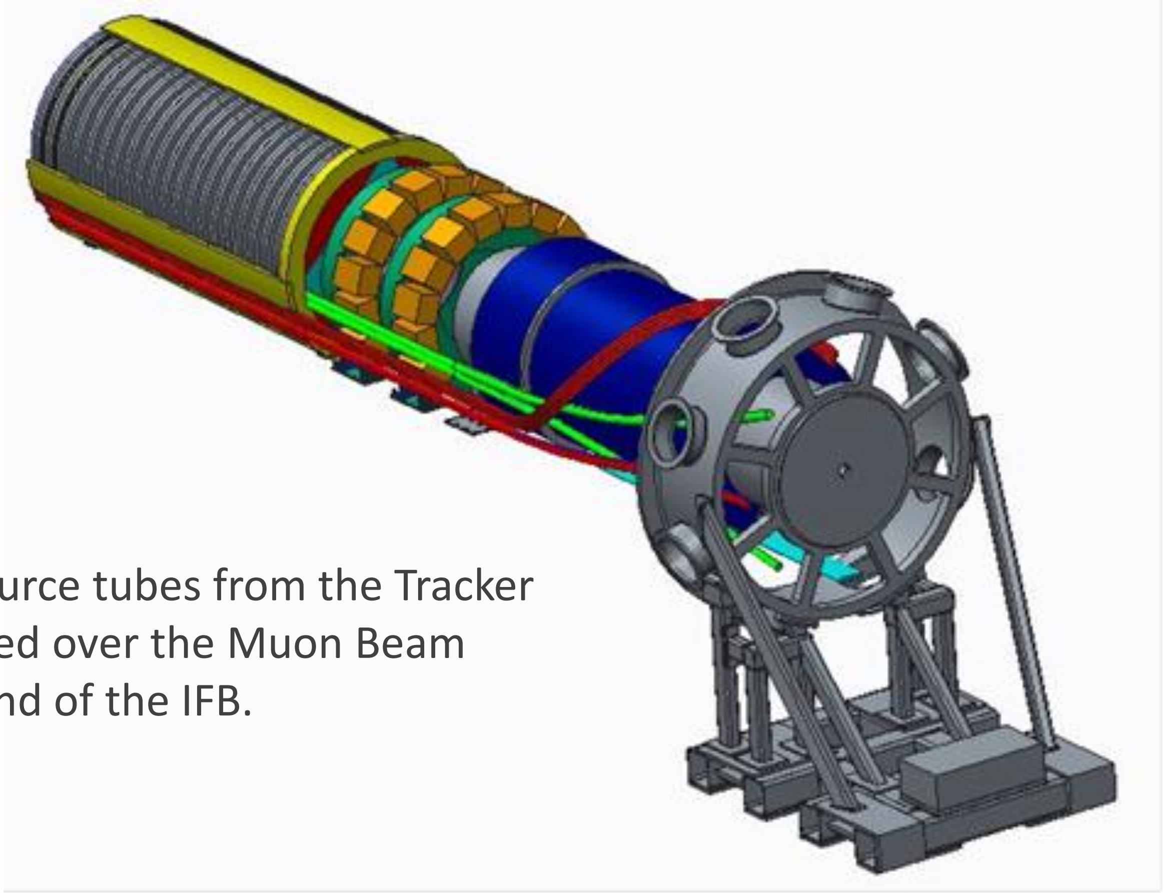






Design

The muon beam stop is the most downstream component within the DS. It will be attached directly to the IFB and supported on the downstream end by the IFB support.



Cables, cooling tubes and source tubes from the Tracker and Calorimeter will be routed over the Muon Beam Stop and pass through the end of the IFB.

Installation Sequence

A brief summary of the installation process follows:

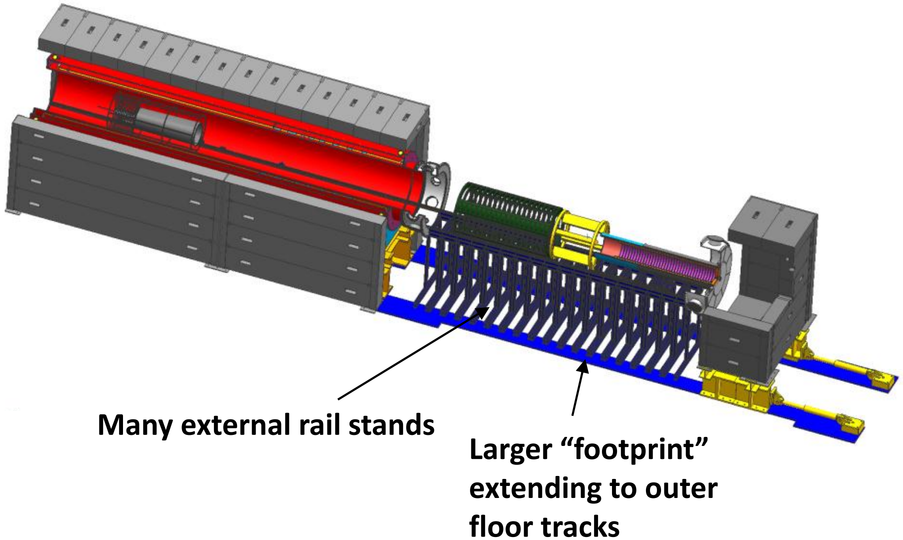
1. Measure the geometric bore of the Detector Solenoid with respect to fiducials placed within the detector hall.
2. Measure the rail platform surfaces.
3. Machine the second tier bars based on the rail platform measurements and install the second tier bars .
4. Verify the alignment of the resulting rail system.
5. Install the external rail system relative to the internal rail system, starting with the stand closest to the Detector Solenoid. The top section of each stand will be aligned using leveling jacks and bolted to the lower portion, creating a permanent assembly. The top sections will have been previously constructed, measured and shimmed to ensure that the rails conform to a plane.
6. Complete the initial installation. Each individual detector component will be lowered onto the external rail system, rolled into the DS bore and placed into its approximate final longitudinal position, starting from the downstream end of the detector train. Each component will be individually measured in X, Y, and Z with respect to the geometric bore of the detector solenoid, comparing targets placed on the component structures to the initial measurements of the DS bore. Several steps may be required to achieve the alignment criteria for each component.

Installation Sequence (continued)

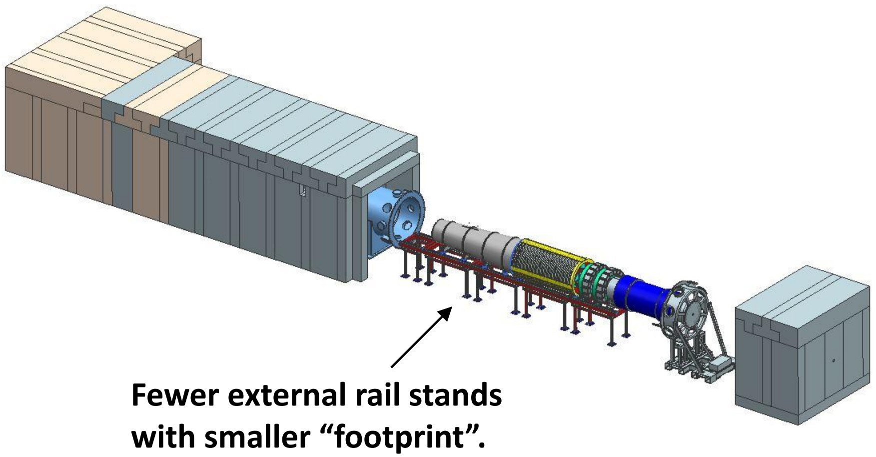
7. Couple the detector train components with axial couplers to form the downstream part of the detector train. Repeat as each element is aligned. Once all elements of the detector train are coupled, a final measurement will be done, and this value will be considered the "initial installation position" (Table 4 in docdb 1383).
8. After the initial installation has been completed, the detector train can be rolled out of and back into the initial position on the rails. The rail system maintains the appropriate level of reproducibility (Table 5 in docdb 1383) each time the components are extracted and re-inserted.
9. Following installation, the DS magnetic field will be mapped with respect to the DS cryostat. These measurements can be used to assess the magnetic center of the DS and can be compared to the measurements of the DS bore geometry (but the intent is to align detector components to the geometric center of the DS bore).
10. Once the detector train is aligned on the external rails, mate it to the IFB (removing the temporary downstream MBS support).
11. Connect and terminate the cables and cooling systems to the tracker and calorimeter, and to the connectors on the inside surface of the IFB.
12. Connect cables and tubes from the floor trench to the outside surface of the IFB and verify functionality.
13. Roll the component train into the DS bore and close the vacuum system.
14. Roll the End Cap Shielding into place, closing the Downstream External Shielding.

Improvements Since CD-1

- Development of 2nd tier bars in the rail alignment system based upon experience with rail system mock-up
- Refined external rail supports design
  - Fewer individual stands facilitate more efficient installation/alignment and extraction.
  - Reduced footprint will allow better access to detector train but requires additional floor track plates (which are now in the civil construction plans).



CD-1 design



CD-2 design

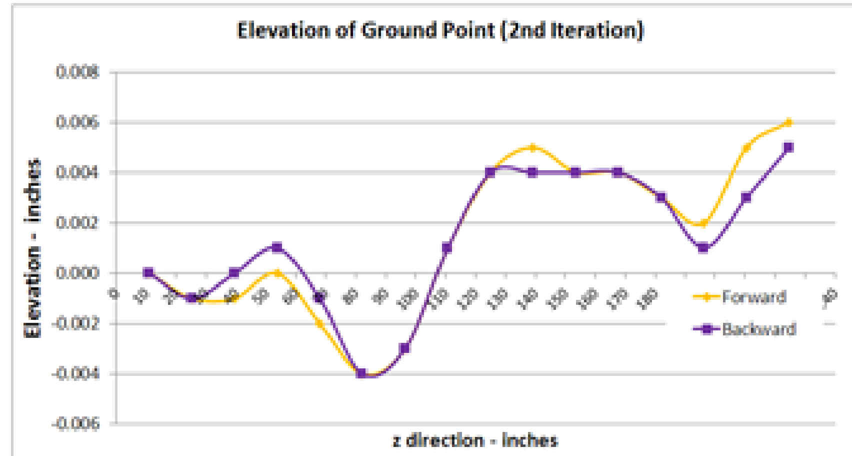
Improvements Since CD-1

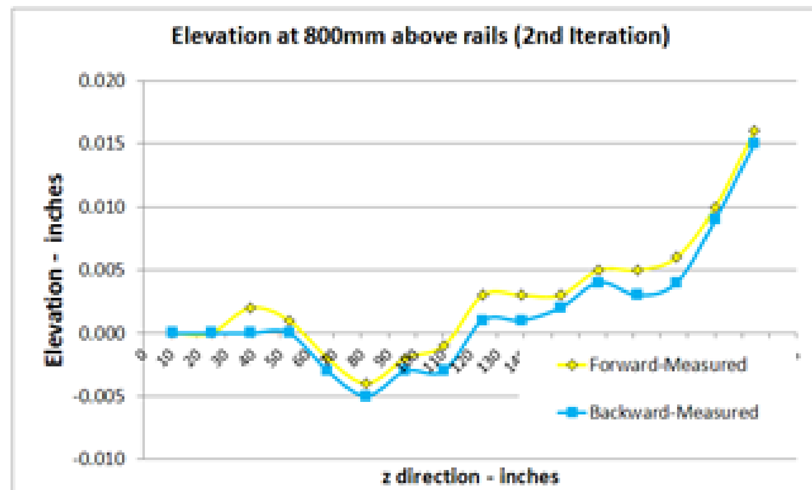
- Preliminary design of detector support adjustment mechanism
- Include bore heaters and associated instrumentation to reduce temperature variation inside the warm bore
- Revisit tolerance specifications for positioning of detector elements to optimize cost/performance
- Revised stay-clear areas within the DS bore for components based upon refined support system and elimination of internal neutron shielding.
- Implemented alternate method of Muon Beam Stop support, allowing less stress on the internal system and longer external stands (for more efficient insertion /extraction sequence)
- Added temporary enclosure to protect components during maintenance.

Value Engineering since CD-1

- Refined dimensional requirements for placement of components to reduce installation time.
- Redesigned the support system for the Muon Beam Stop, reducing the number of external stands.
- Developed 2nd tier bar system, reducing shimming and installation time.

Performance





- Studies at rail system mockup indicate that position measurements are reproducible to with ±25mm at seven meters from the laser tracker as measured via the laser tracker
- Reproducibility degrades as a function of distance from the laser tracker.
- The laser tracker device uncertainty is expected to be ±50mm at 10 meters.

Performance

- Mockup tested with loads up to 5000 kg (beam stop or tracker size), maintains coefficient of friction of under .005 with expected deflections.
- Mockup currently being used to evaluate space availability for servicing detectors.

Remaining work before Fabrication

- Complete testing of installation system at mockup.
  - Test external rail system
  - Test “trunnion” system of support for Muon Beam Stop
  - Assess space available for servicing detectors
  - Test component adjustment mechanisms
  - Prototype 2nd tier bar system
  - Complete measurements of, and document deflections of components on rails
- Complete FEA of deflections
- Refine assessment of thermal issues within bore
- Complete weld studies
- Refine cable/services management plans

Quality Assurance

Quality Assurance in the detector support system efforts rely upon the following tools :

- Fermilab Quality Assurance Manual
- Fermilab Engineering Manual
- Documented engineering calculations and drawings
    - reviewed, approved and released
- Physics simulations
- Prototypes and mockups as appropriate
- Documentation of procedures
- Delivered materials will be inspected for conformance to the specifications

Risks

- Detector installation takes longer than anticipated
  - Primary mitigation is to continue refining the installation plan to account for new information and additional insights
  - Plan for parallel installation activities where and as resources permit
    - For example, take measurements for 2nd tier rails prior to delivery of DS to the Mu2e hall

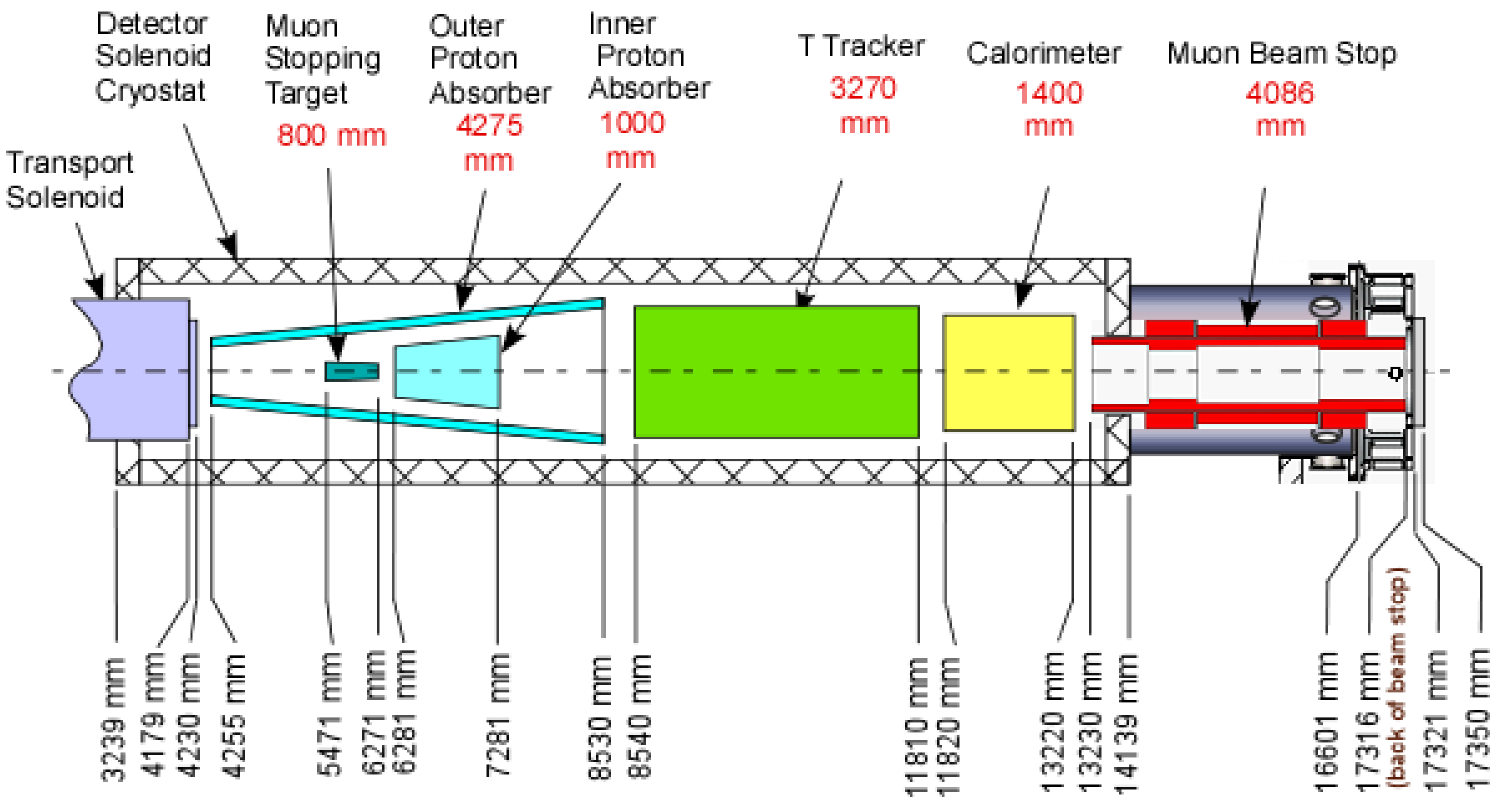
- Detector components move after installation, due to forces generated by the magnetic field or other changes in the operating environment, causing misalignment.
  - Primary mitigation is to complete FEA calculations of all forces and stresses expected within the bore area during operation.
  - Also instrumentation of tracker to monitor orientation.
  - Note: After mitigation, the residual mitigated risk must be transferred since it may only be realized beyond the project horizon.

Integration and Interfaces

- The Detector Support and Installation System has external interfaces to the Tracker, Calorimeter, Solenoids, Trigger & DAQ, and Conventional Construction.
- Internal interfaces with the Vacuum System, Stopping Target, Stopping Target Monitor, Internal Shielding, Muon Beam Stop, and Downstream External Shielding
- In particular, important interfaces include
  - the alignment and insertion of all components within the DS bore.
  - the Muon Beam stop connection to, and support from, the IFB
  - the cabling and cooling tube routing from the tracker and calorimeter to the electronics and mechanical rooms
- 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

Interfaces/Stay Clear Areas

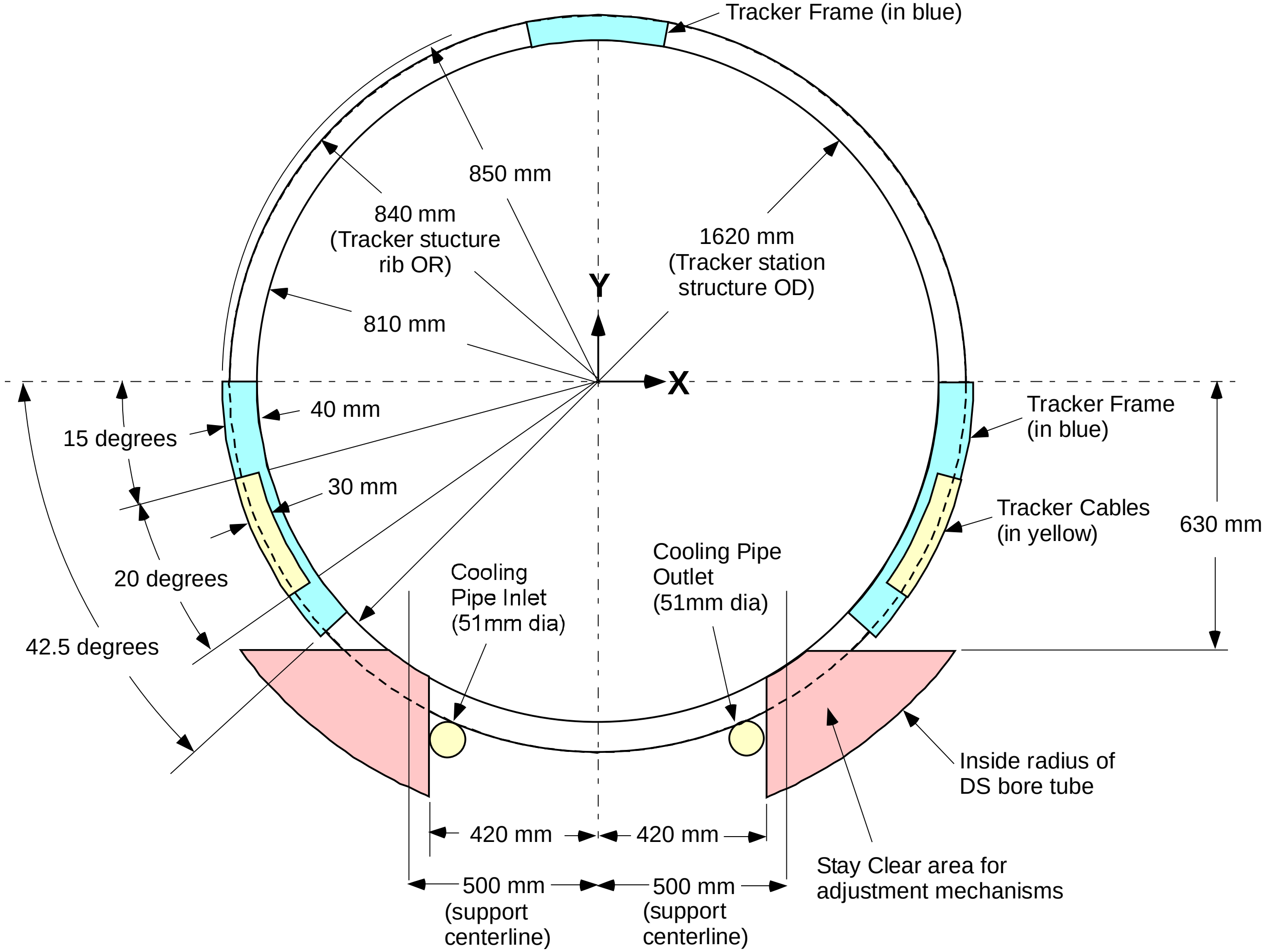
The longitudinal and lateral positions of each component, as well as the "stay clear" areas for components, cables and cooling tubes are defined within WBS 5.10.



Reference: R. Bossert and G. Ginther, Stay Clear Areas within DS Bore", Mu2e docdb 4128.

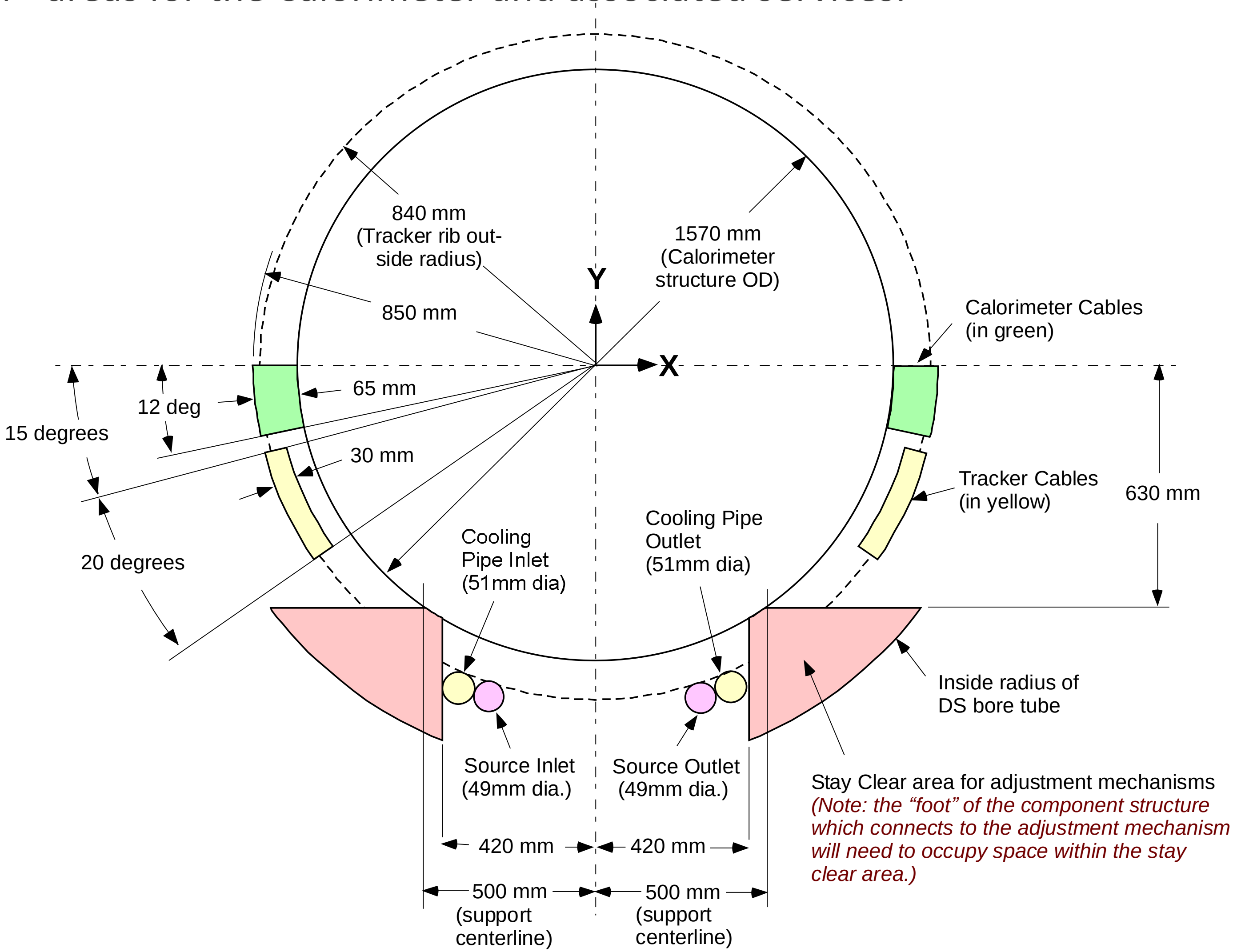
Interfaces/Stay Clear Areas

“Stay Clear” areas for the Tracker and associated services.



Interfaces/Stay Clear Areas

"Stay Clear" areas for the Calorimeter and associated services.

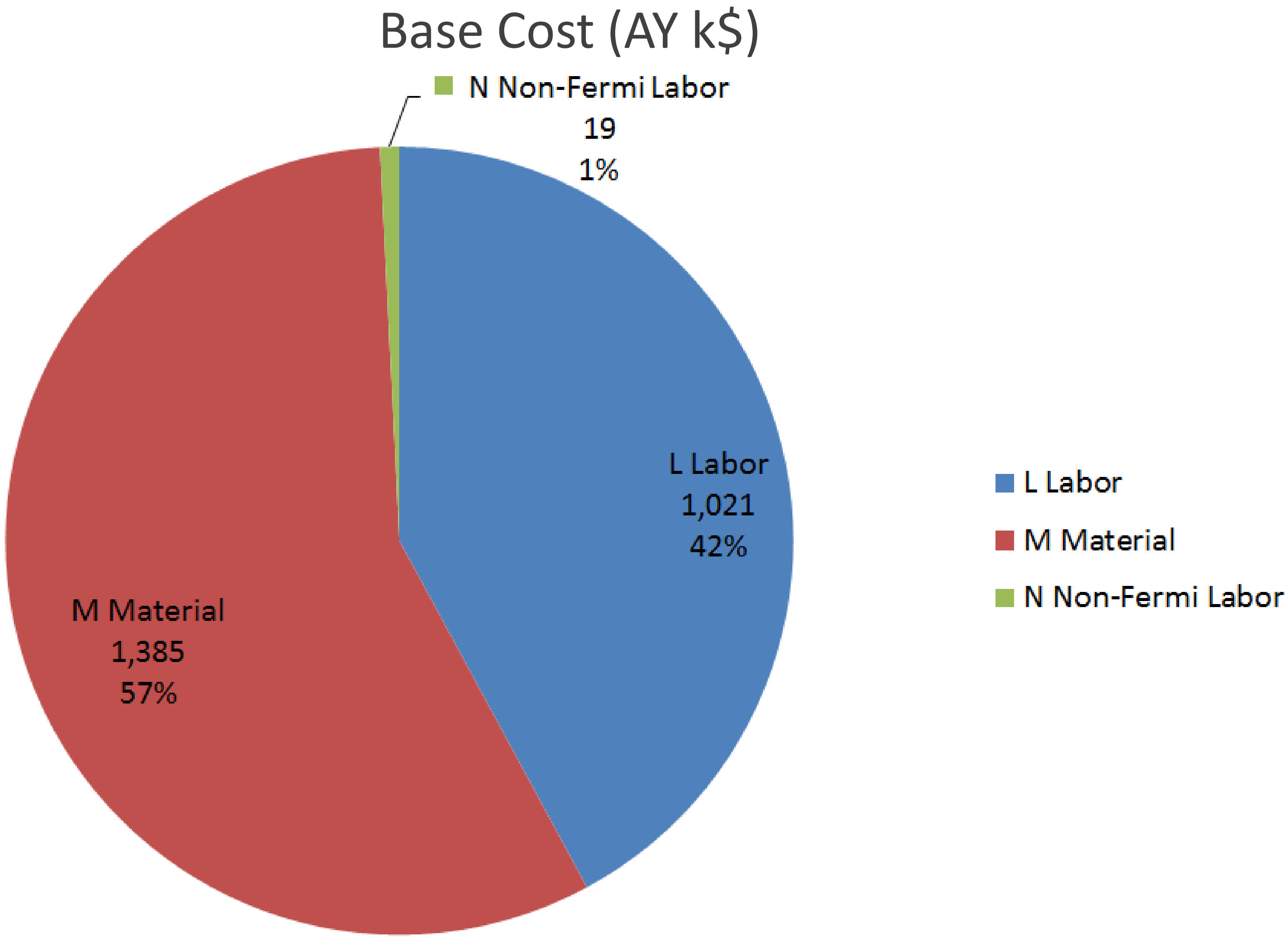


ES&H

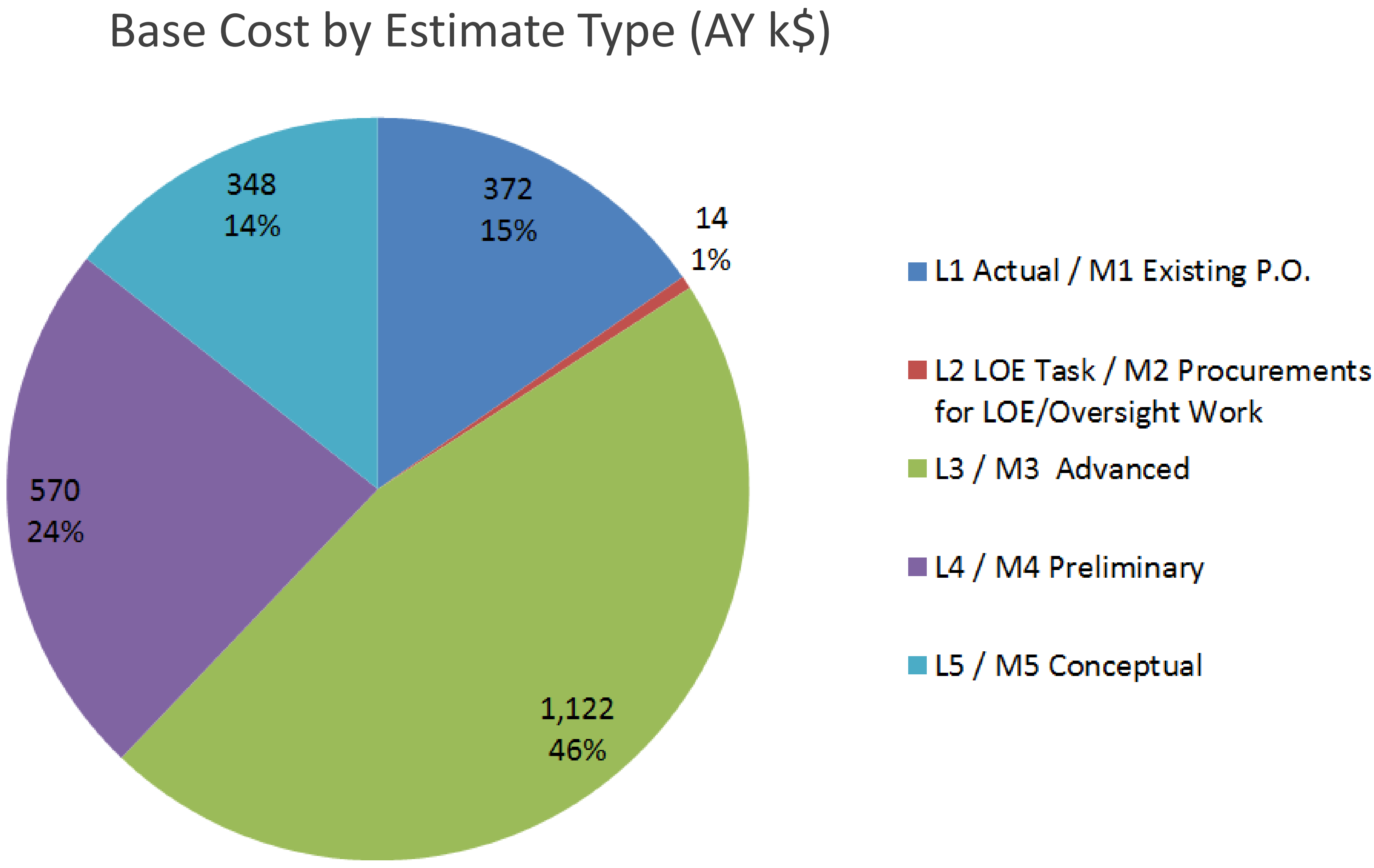
To perform component installation activities safely will require appropriate planning (JHA), attention to ES&H considerations and FESHM and FRCM requirements

- 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
- Cable Trays FESHM 5043
- And possibly ODH FESHM 5064

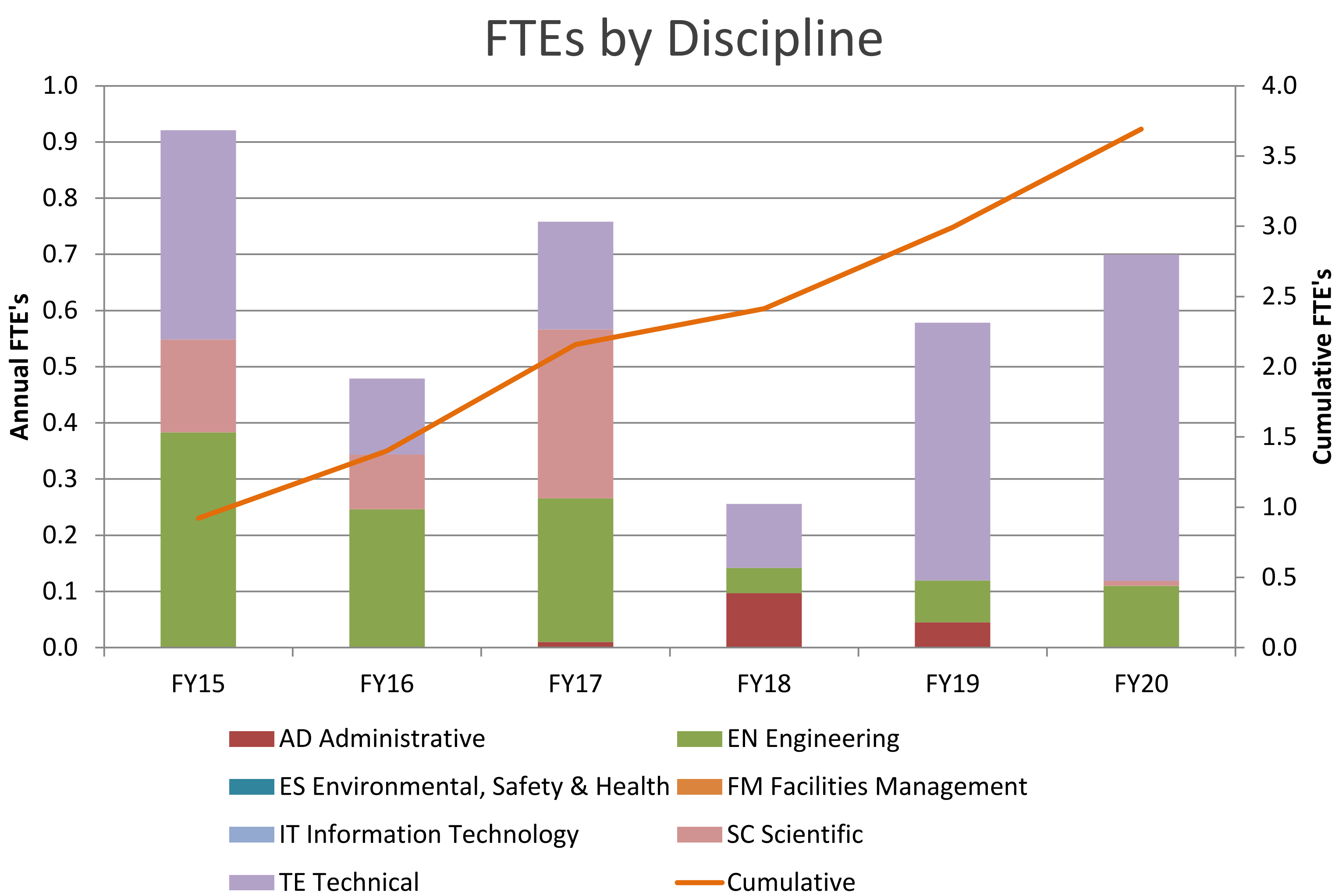
Cost Distribution by Resource Type



Quality of Estimate



Labor Resources



Cost Table

WBS 5.10 Detector Support and Installation

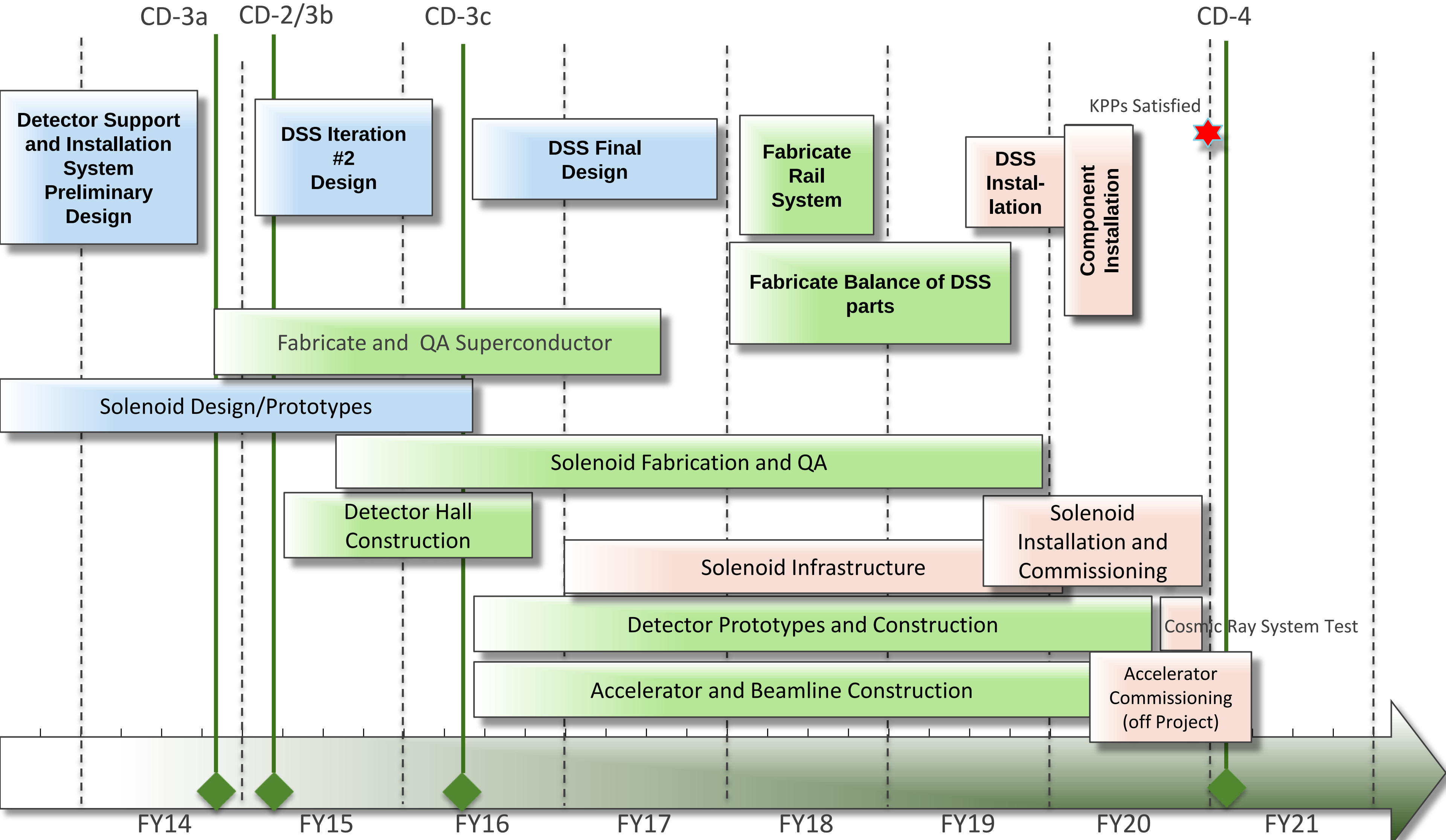
Costs are fully burdened in AY k$

	Base Cost (AY K$)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining budget)	% Contingency (on remaining budget)	Total Cost
475.05 Muon Beamline						
475.05.10 Detector Support and Installation System						
475.05.10 Detector Support and Installation System	1,404	1,021	2,425	644	32%	3,069
Grand Total	1,404	1,021	2,425	644	32%	3,069

Major Milestones

Activity ID	Milestone Name	Milestone Date
47505.10.001755	Detector Support and Installation system 2nd iteration design complete	November 20, 2015
47505.10.001946	Detector Support and Installation System ready for CD 3c Review	December 08, 2015
47505.10.001947	CD 3 Approval Detector Support and Installation System	February 23, 2016
47505.10.011005	Advanced Procurement Plan for Rail System Fabrication Complete	September 08, 2017
47505.10.011060	Vendor for Rail System Fabrication Selected	September 29, 2017
47505.10.031040	Detector Support and Installation System Components at Fermilab	July 01, 2019
47505.10.041248	Test Insertion Complete	Feb 21, 2020
47505.10.041290	Detector and Installation System Ready for CD-4	March 20, 2020

Schedule



CD-3a
CD-2/3b
CD-3c
CD-4
Detector Support and Installation System Preliminary Design
DSS Iteration #2 Design
DSS Final Design
Fabricate Rail System
DSS Instal-lation
Component Installation
KPPs Satisfied
Fabricate Balance of DSS parts
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
    - Designs have been significantly refined/optimized
    - Preliminary designs meet the requirements
    - Implementation of Mockup has been very instructive

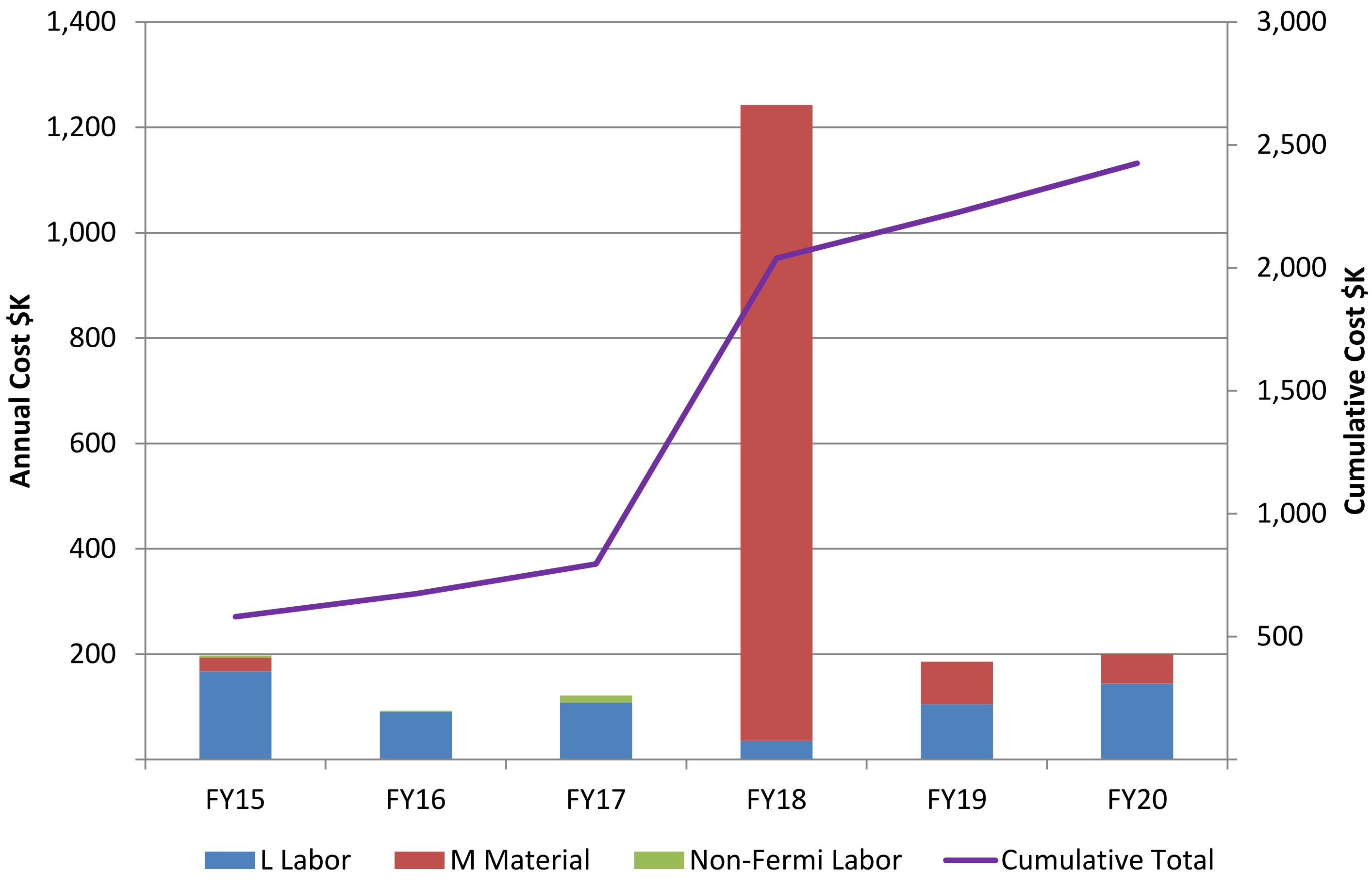
- Cost estimates for Detector Support and Installation System have been completed.
    - 86% of cost understood at preliminary design level or better

- Risks are understood and mitigated to the extent possible.
- Interfaces are identified and resource needs are understood.
- Detector Support and Installation System is ready for CD2

Backup Slides

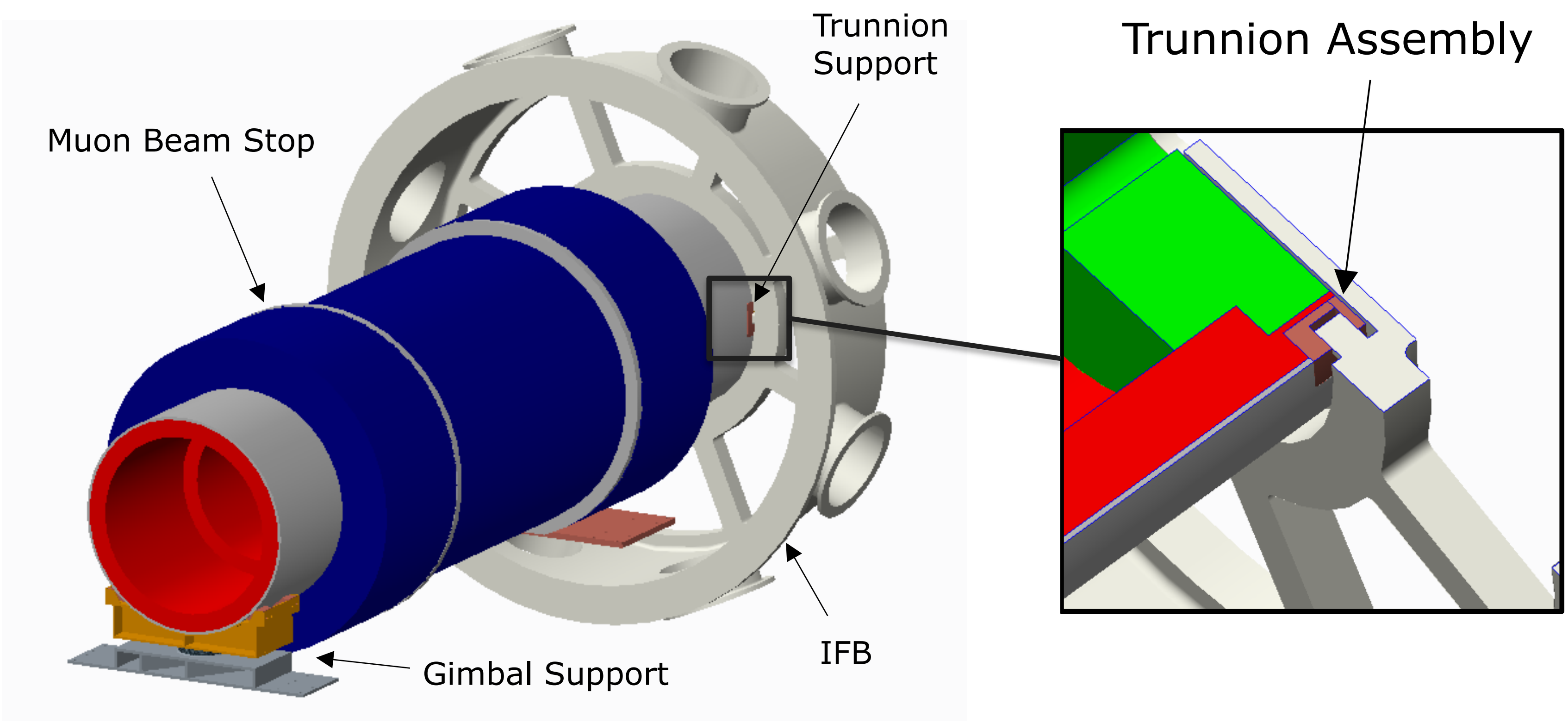
Backup Slide

Labor/Material Breakdown (AY k$)

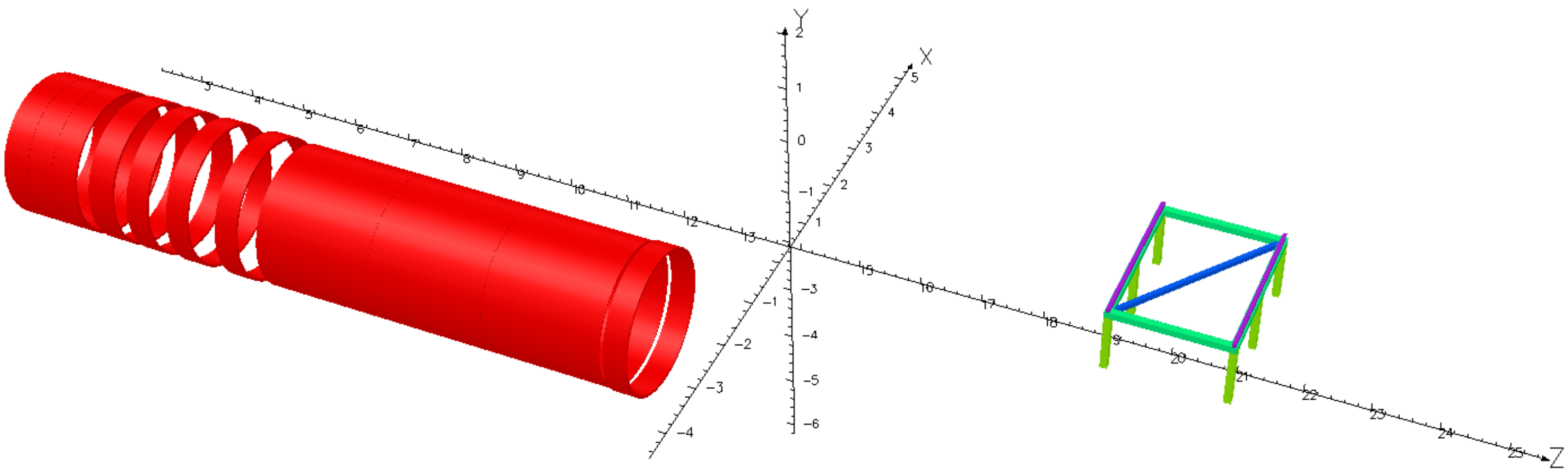


Backup Slide

Details of the "trunnion" connection between the beam stop and the IFB.



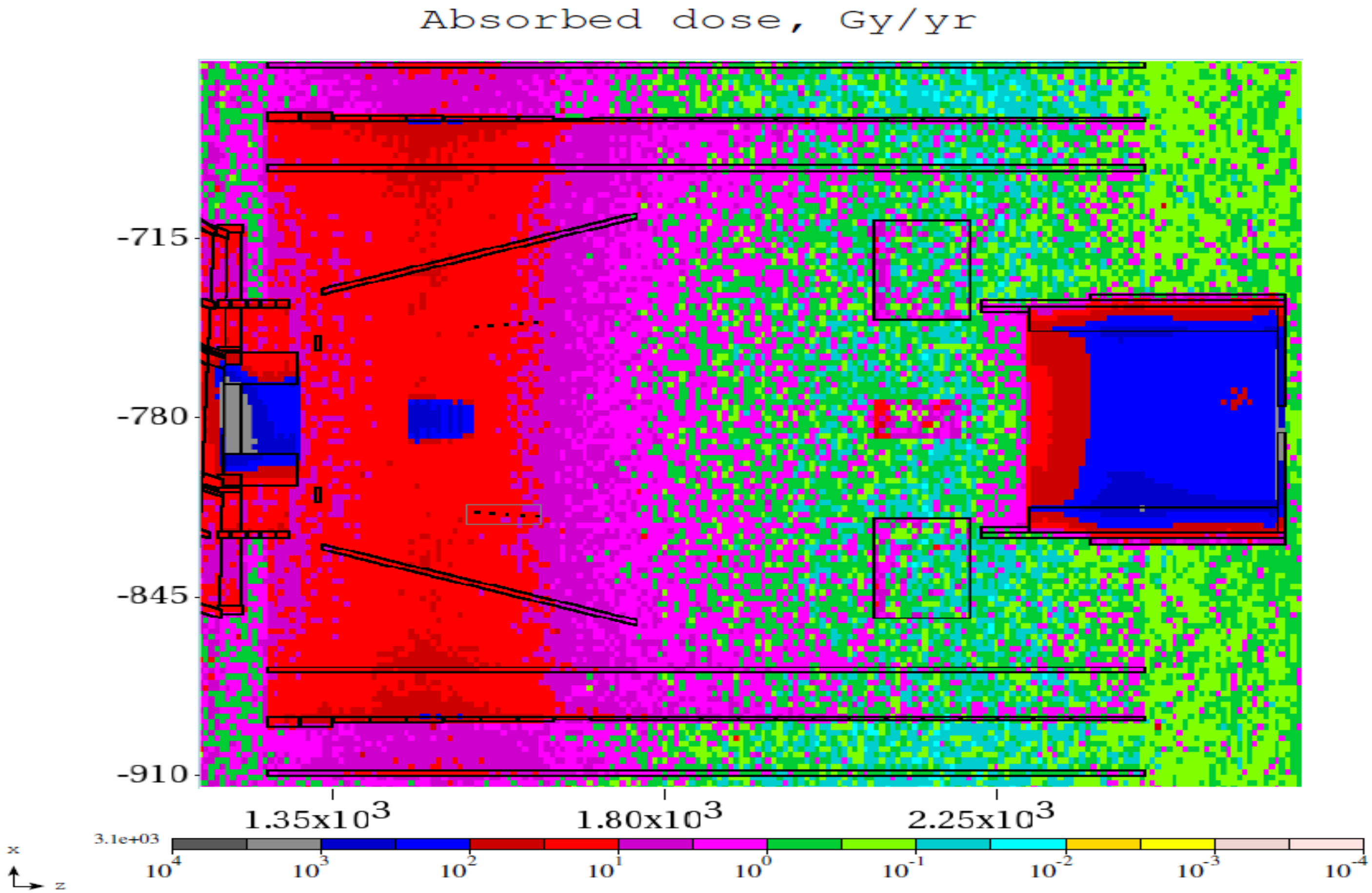
Backup Slide



Total forces on the coils	Fx (N)	Fy (N)	Fz (N)
Analytical solution	0	0	-48
FEM non-magnetic material solution	0	0	-48
FEM magnetic material (default BH curve) solution	-12	-11	13
Difference	-12	-11	61

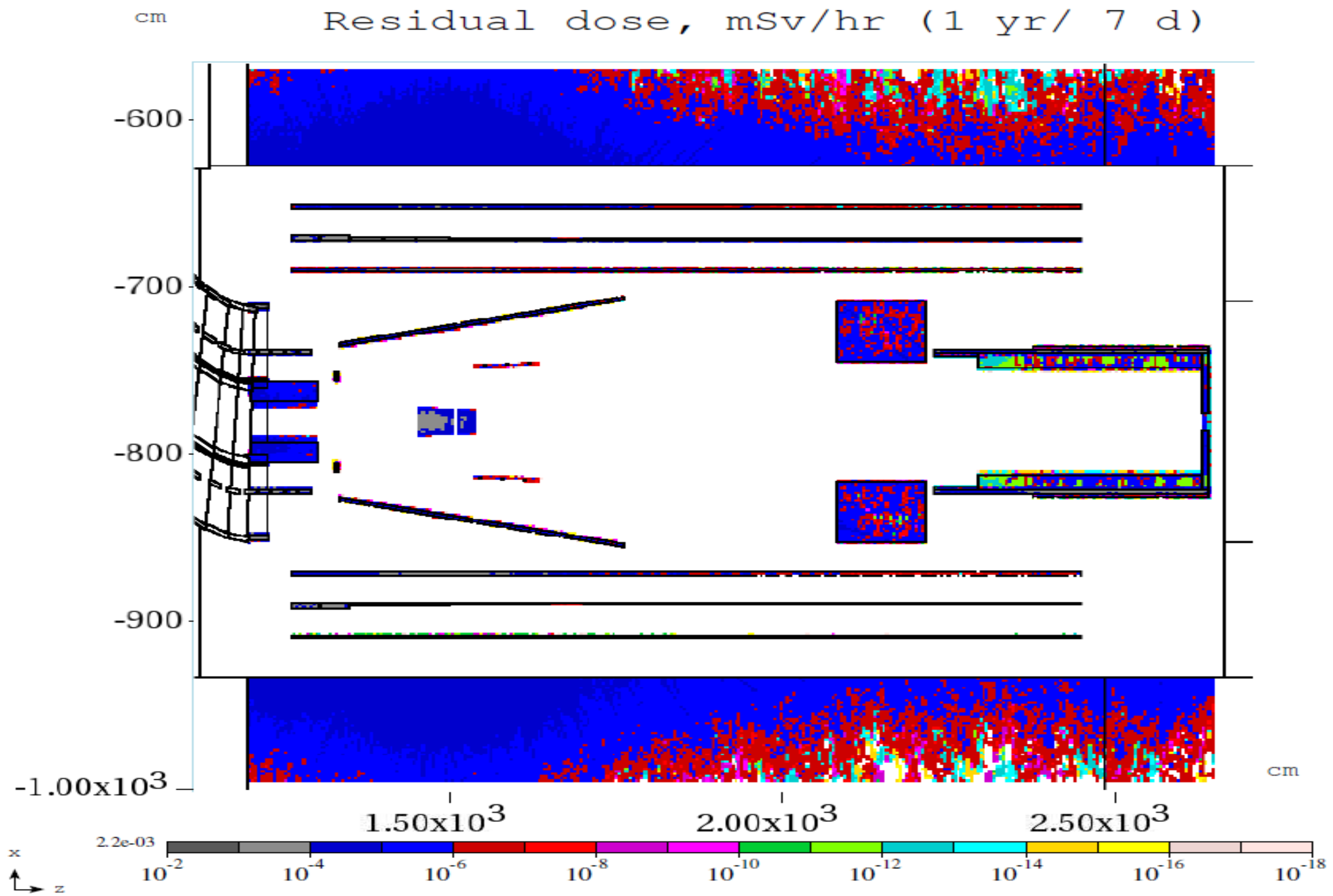
Backup Slide

Absorbed dose in DS, Gy/yr



Backup Slide

Residual dose in DS, mSv/hr



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