# Mu2e WBS 5.10 Detector Support and Installation System Director's CD-2 Review

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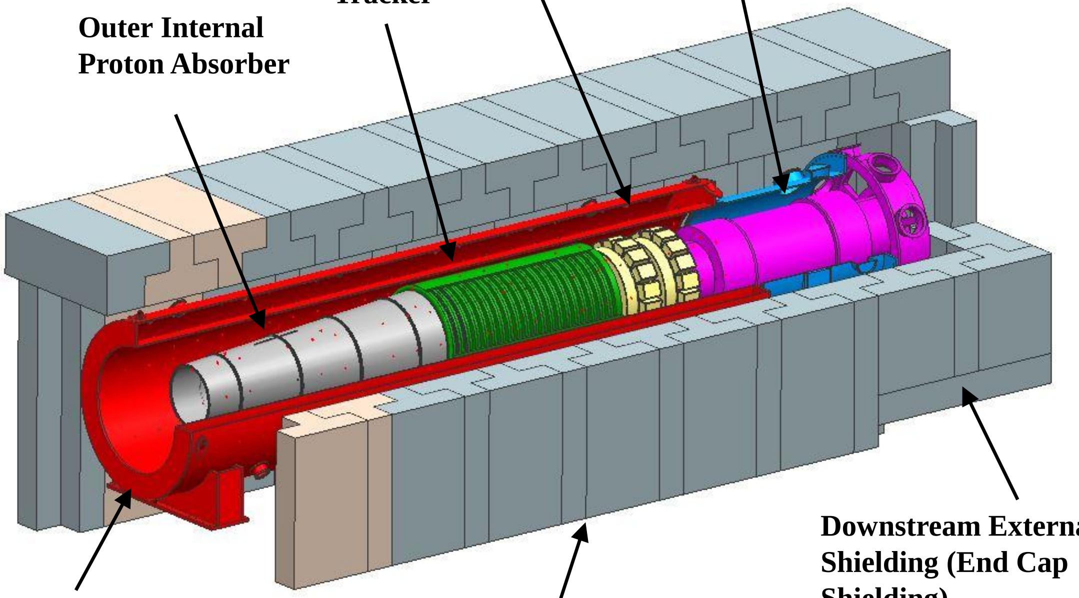
7/8/2014

# 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, and Muon Beam Stop 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

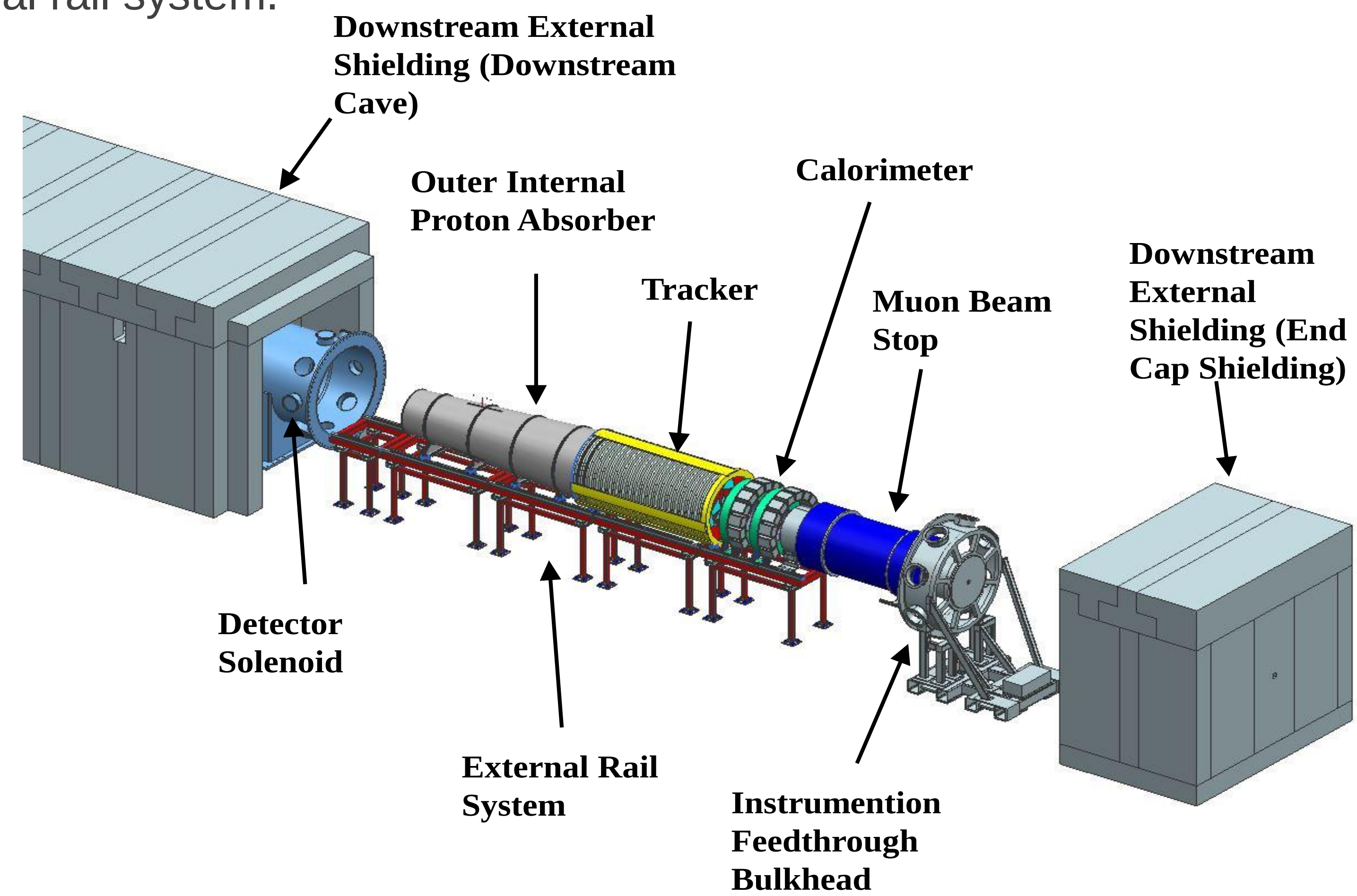
Physics requirements dictate the overall size, location and placement accuracy for the individual components within the DS bore. Components will be aligned to a set of fiducials which are positioned with respect to the center of the solenoid geometric bore.

The support system must:

- provide the ability to move the interior DS components out of and back into the DS bore within the specified accuracy requirements (e.g, for servicing).
- provide a path within the DS bore for routing of the electrical cables and cooling tubes from the devices to the back of the 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.

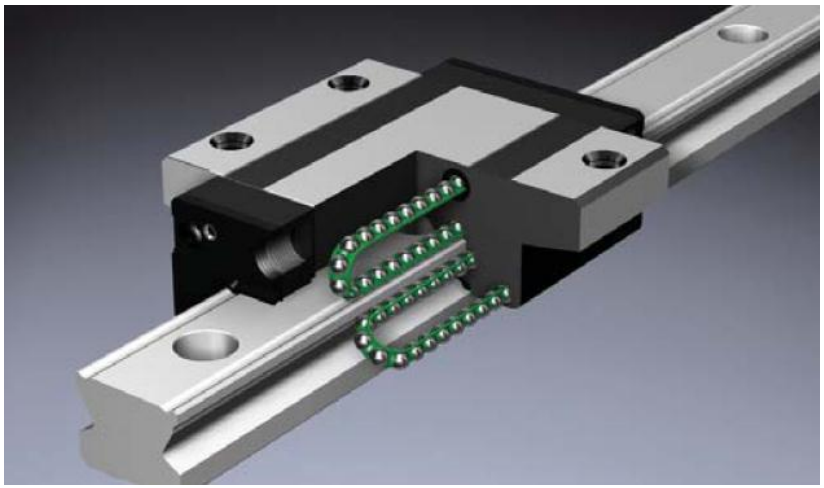
# Design

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



# Design

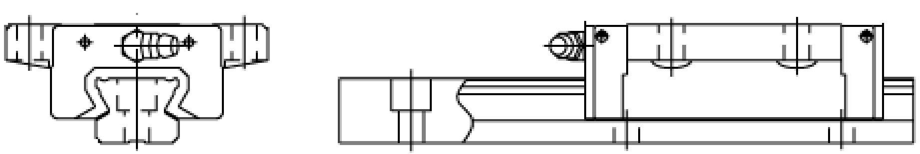
The rails and bearing blocks rails are made of non-magnetic stainless steel. Bearing blocks are made exclusively of non-magnetic components.



Hitachi Plastic Mold Steel

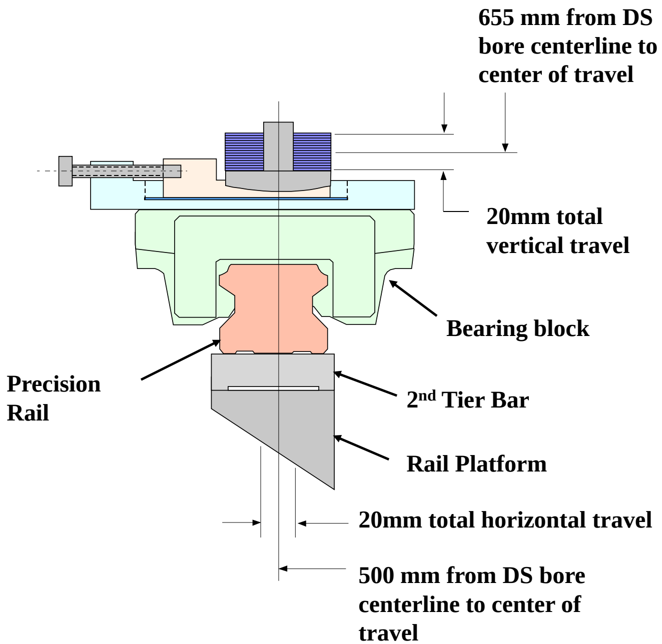
**HPM75**

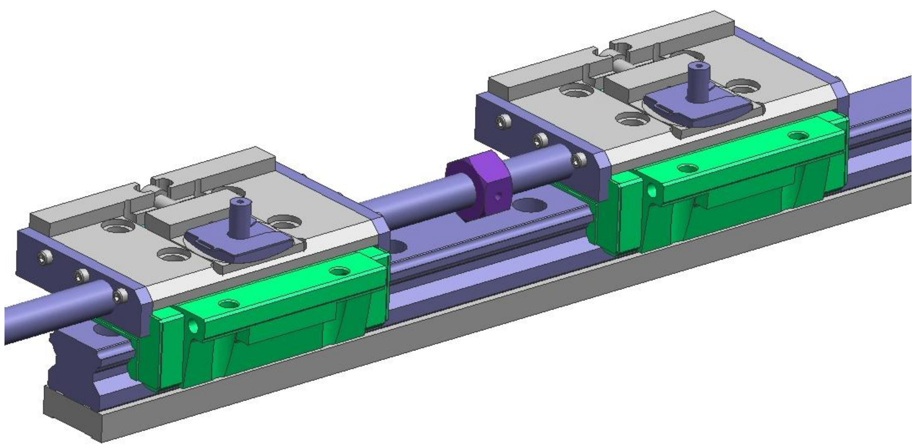
- Hardenable to 40-45 HRC
- Non-magnetic, permeability (μ) is 1.01



# Design

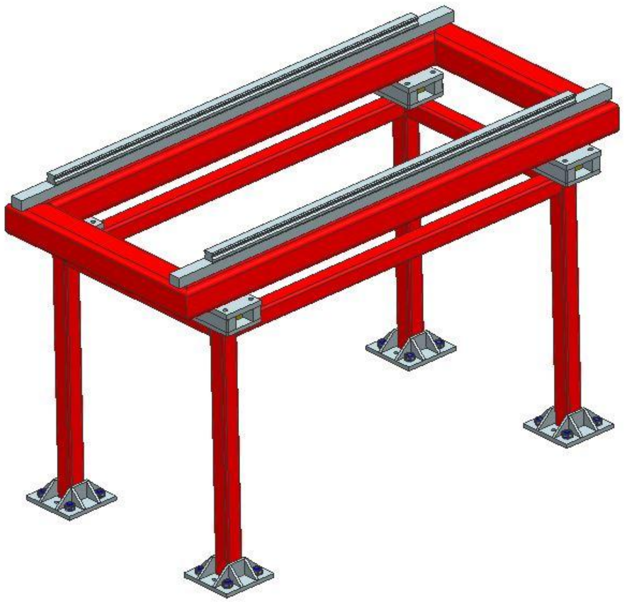
Vertical and lateral adjustment of components will be done using adjustment mechanisms as shown below.  The rails will be attached to stainless steel support platforms that are welded onto the inside wall of the DS cryostat.  The rails and the cryostat wall will support the weight of each component, allowing all alignment criteria to be achieved.  All components will be attached longitudinally and secured to the IFB.  The rails and bearings are made exclusively of non-magnetic components.

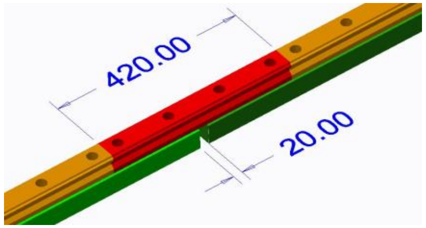


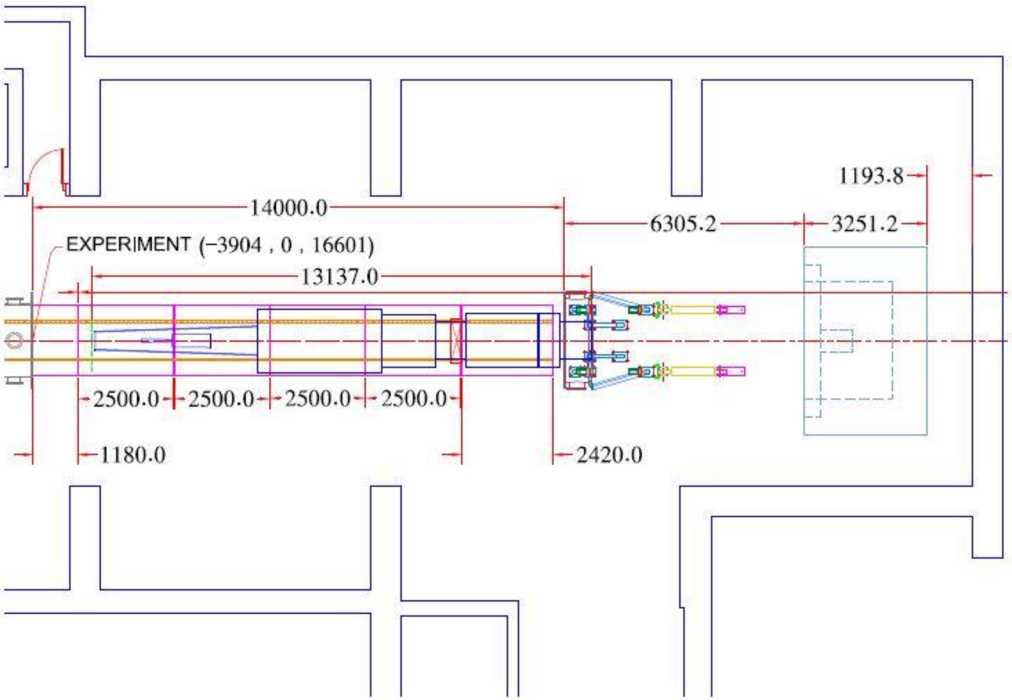



# Design

The external rail system will consist of several removable stands.  They will be temporarily installed as the internal DS components are extracted from the installation position and removed as the "detector train" is reinserted.

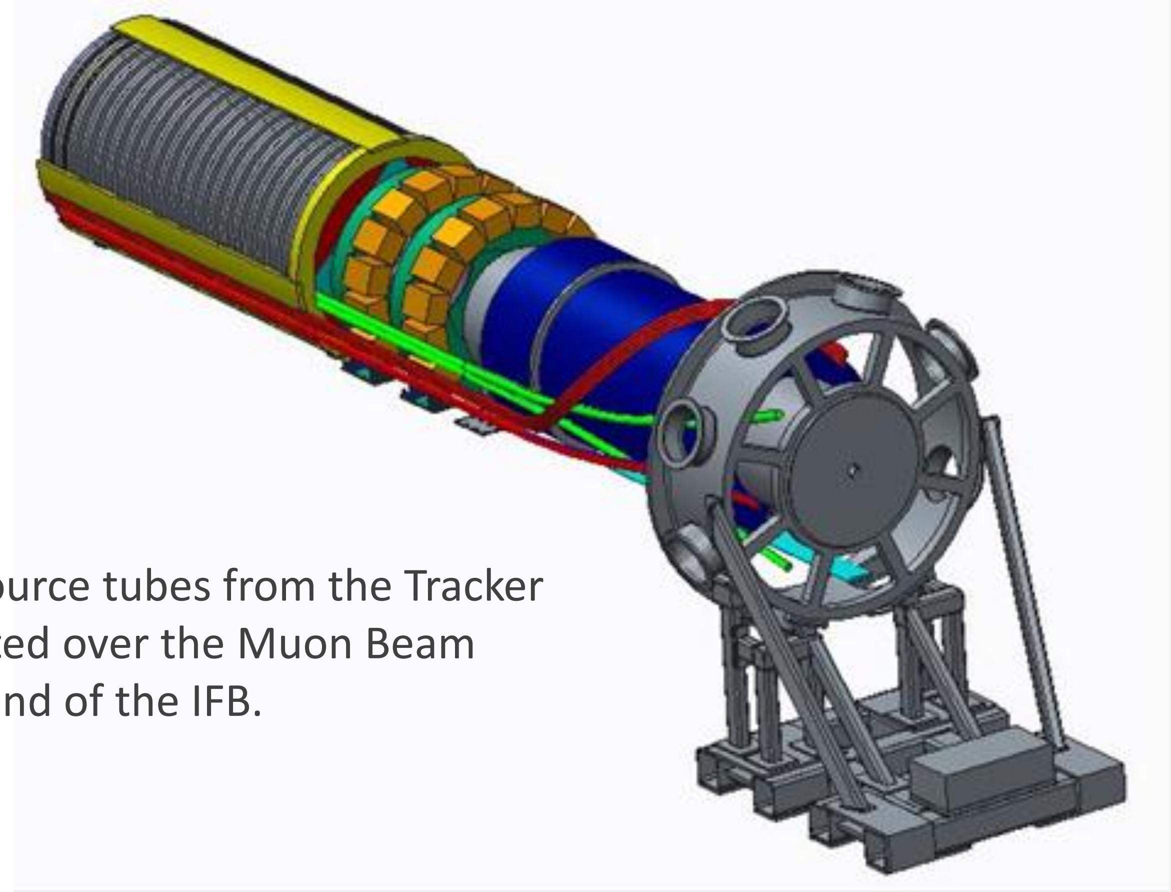




# Design

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.

# Changes since CD-1

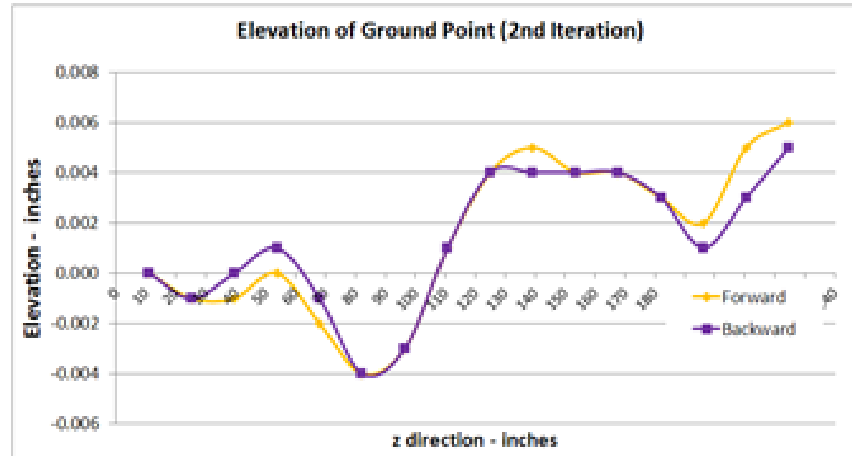
- Development of 2nd tier bars in rail alignment system based upon experience with rail system mock-up
- Refined external rail supports design
  - Fewer individual stands should reduce installation/alignment time
  - Reduced footprint will allow better access to detector train but requires additional floor track plates
- Preliminary design of detector support adjustment mechanism
- Include bore heaters and associated instrumentation to reduce temperature variation inside warm bore
- Revisit tolerance specifications for positioning of detector elements to optimize cost/performance
- Revised stay-clear areas within bore for components based upon elimination of internal neutron shielding.
- Implemented alternate method of Muon Beam Stop support, allowing less stress on internal system and longer external stands.

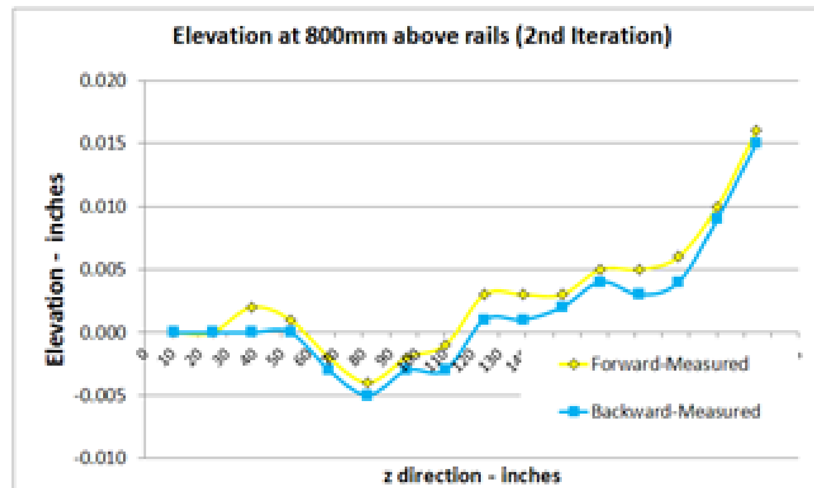
# Value Engineering since CD-1

- 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 test space availability for servicing detectors.

# Remaining work before CD-3

- 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 2$^{nd}$ 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 will rely about the following tools :

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

# Risks

Schedule risk

– 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

Technical risk

- Detector components move after installation, due to forces generated by the magnetic field or other changes in the operating environment, causing misalignment.

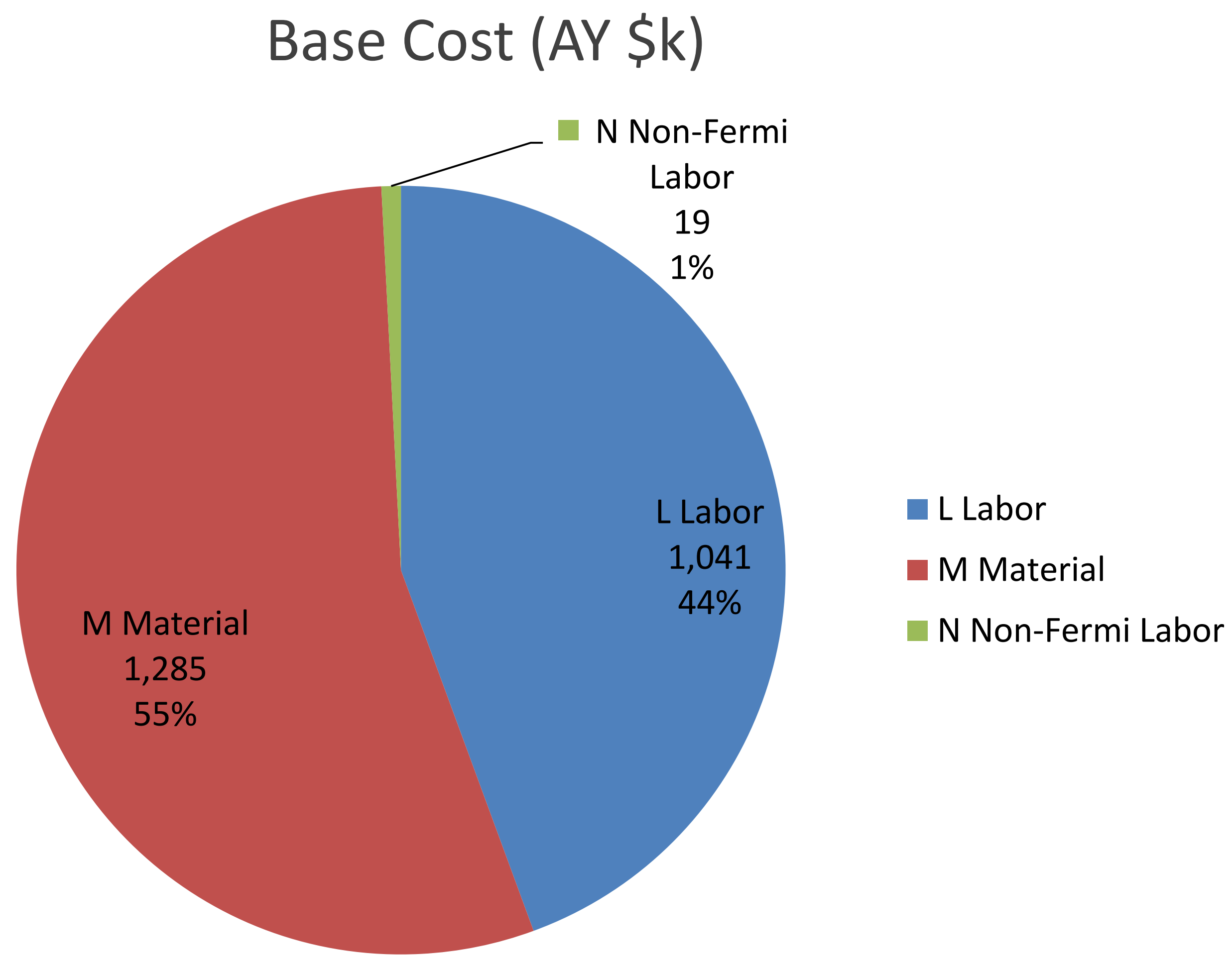
- Primary mitigation is to complete FEA calculations of all forces and stresses expected within the bore area during operation.
- Also instrumentation of tracker to monitor orientation.
- Note: After mitigation, the residual technical risk must be transferred since it can only be realized beyond the project horizon.

# ES&H

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

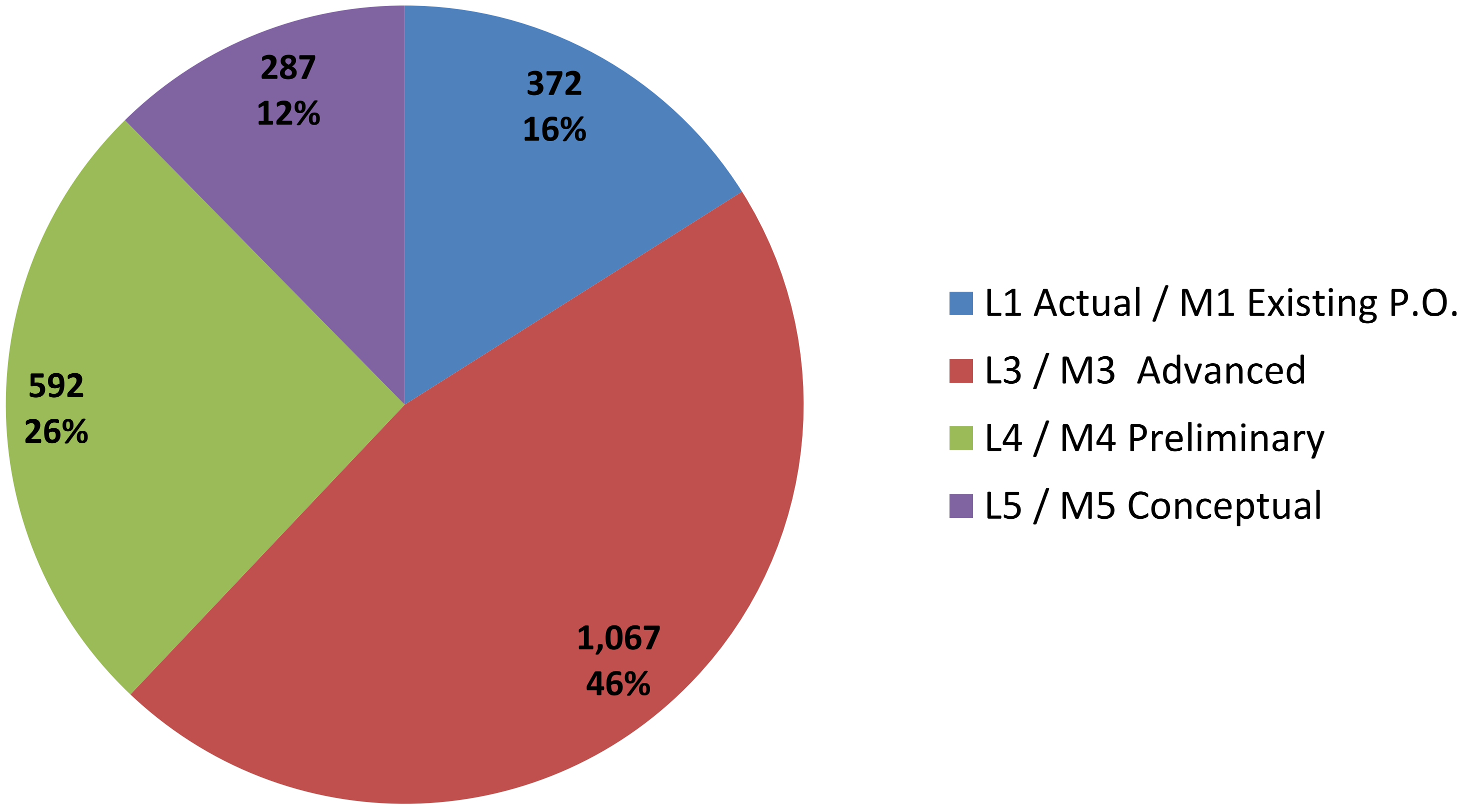
- Accessing confined space FESHM 5063
- Possible use of lead (hazardous materials)  FESHM 5052.3
- Crane, hoist, and forklift use FESHM 5021
- Fall Hazards FESHM 5066
- Magnetic fields FESHM 5062.2
- Electrical hazards FESHM 5042
- Fire hazards
- Hydraulic and perhaps pneumatic systems (and potential stored energy)
- Radiation hazards
- Hazardous waste
- Cable Trays  FESHM 5043
- And possibly ODH FESHM 5064

# Cost Distribution by Resource Type

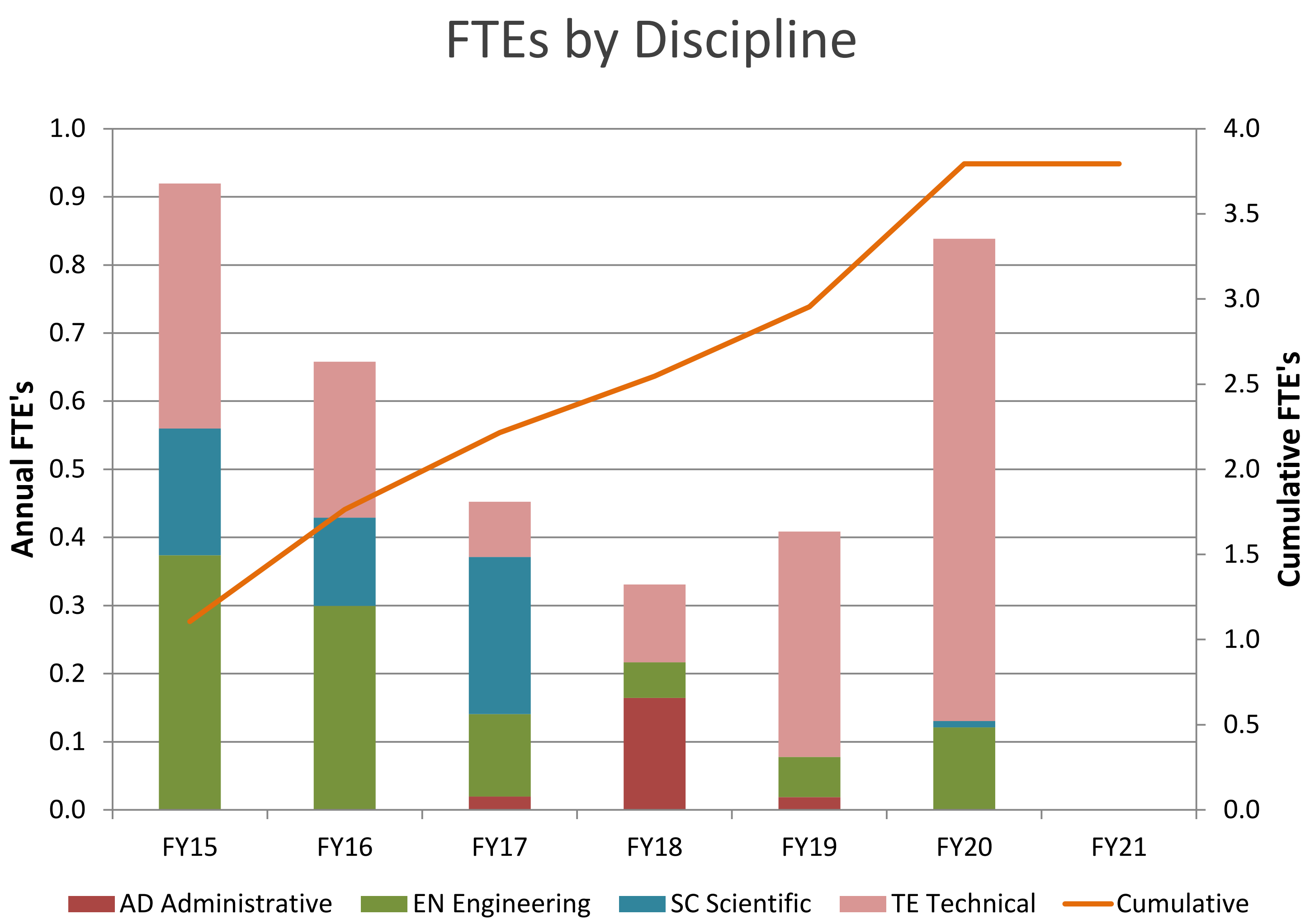


# Quality of Estimate

Base Cost by Estimate Type (AY$k)



# Labor Resources



# Cost Table

WBS 5.10 Detector Support and Installation

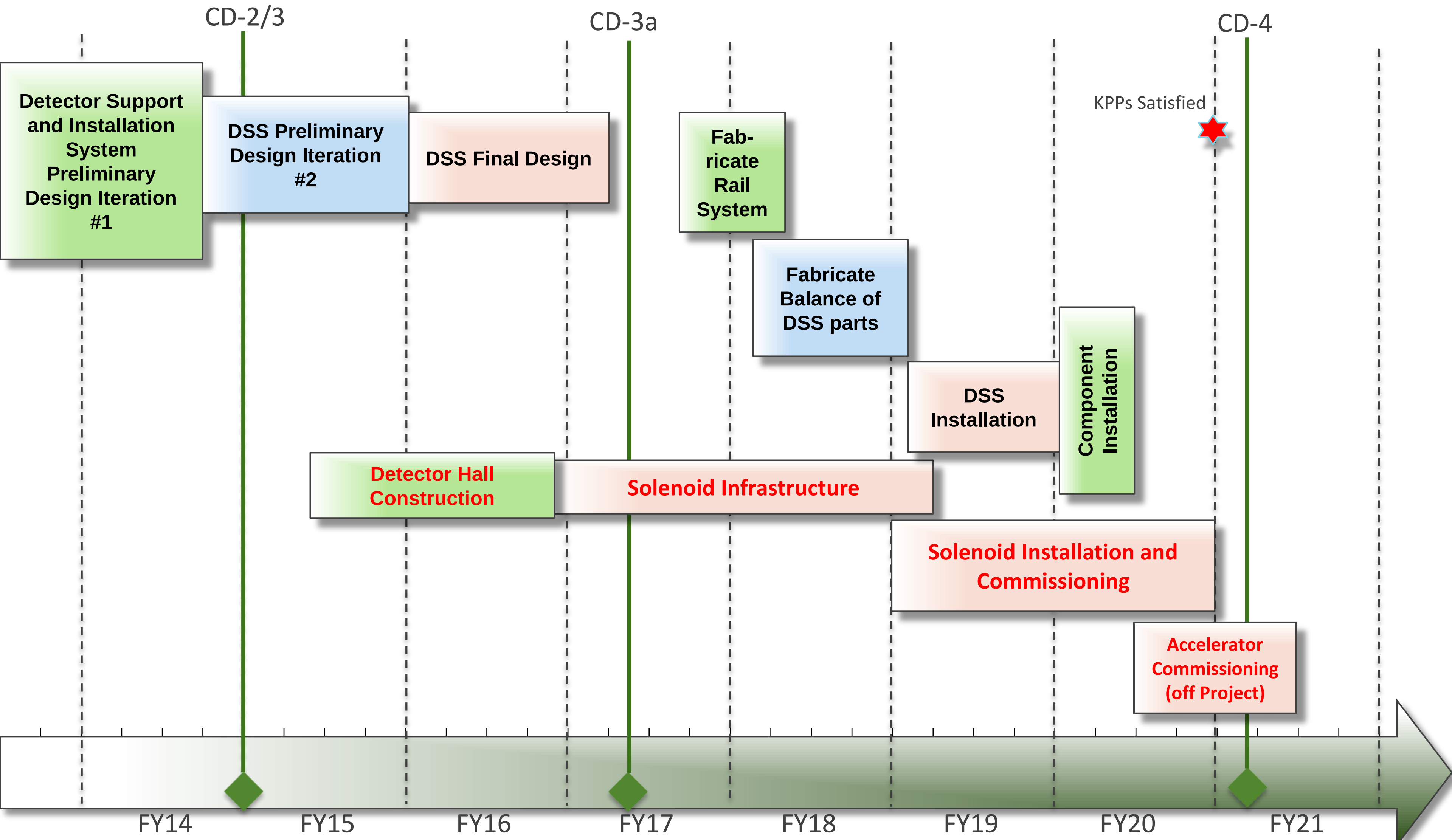
Costs are fully burdened in AY k$

| | Base Cost (AY k$) | | | | | |
|---|---|---|---|---|---|---|
| | M&S | Labor | BAC | Estimate Uncertainty (on remaining costs) | % contingency on ETC | Total |
| 475.05 Muon Beamline | | | | | | |
| 475.05.10 Detector Support Structure | 1,304 | 1,041 | 2,344 | 620 | 31% | 2,965 |
| **Grand Total** | **1,304** | **1,041** | **2,344** | **620** | **31%** | **2,965** |

# Major Milestones

| Activity ID | Milestone Name | Milestone Date |
|---|---|---|
| 47505.10.001946 | Detector Support Structure ready for CD 3a Review | March 16, 2017 |
| 47505.10.001947 | CD 3a Approval Detector Support Structure. | March 30, 2017 |
| 47505.10.011005 | Advanced Procurement Plan for Rail System Fabrication Complete | April 03, 2017 |
| 47505.10.011060 | Vendor for Rail System Fabrication Selected | April 24, 2017 |
| 47505.10.041248 | Test Insertion Complete | Feb 07, 2020 |
| 47505.10.041290 | Detector and Installation System Ready for CD-4 | March 13, 2020 |

# Schedule



CD-2/3
CD-3a
CD-4
Detector Support and Installation System Preliminary Design Iteration #1
DSS Preliminary Design Iteration #2
DSS Final Design
Fab-ricate Rail System
Fabricate Balance of DSS parts
DSS Installation
Component Installation
KPPs Satisfied
Detector Hall Construction
Solenoid Infrastructure
Solenoid Installation and Commissioning
Accelerator Commissioning (off Project)
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

# Summary

- Have made substantial progress since CD-1
  - Many designs have been significantly refined/optimized
  - Preliminary designs meet the requirements

- Implementation of Mockup has been very instructive.

- Still several substantial tasks to complete
  - Complete all tests of installation system on mockup.
  - Complete FEA including deflections and thermal issues.
  - Complete design of thermal measurement and control systems.
  - Complete weld studies
  - Refine cable/services management plans in conjunction with Tracker and Calorimeter.

# Backup Slide

## Labor/Material Breakdown