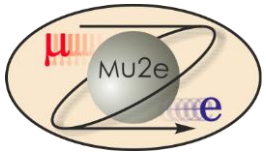
Fermilab

U.S. DEPARTMENT OF ENERGY Office of Science

Mu2e WBS 5 Muon Beamline

Mu2e Independent Cost Estimate

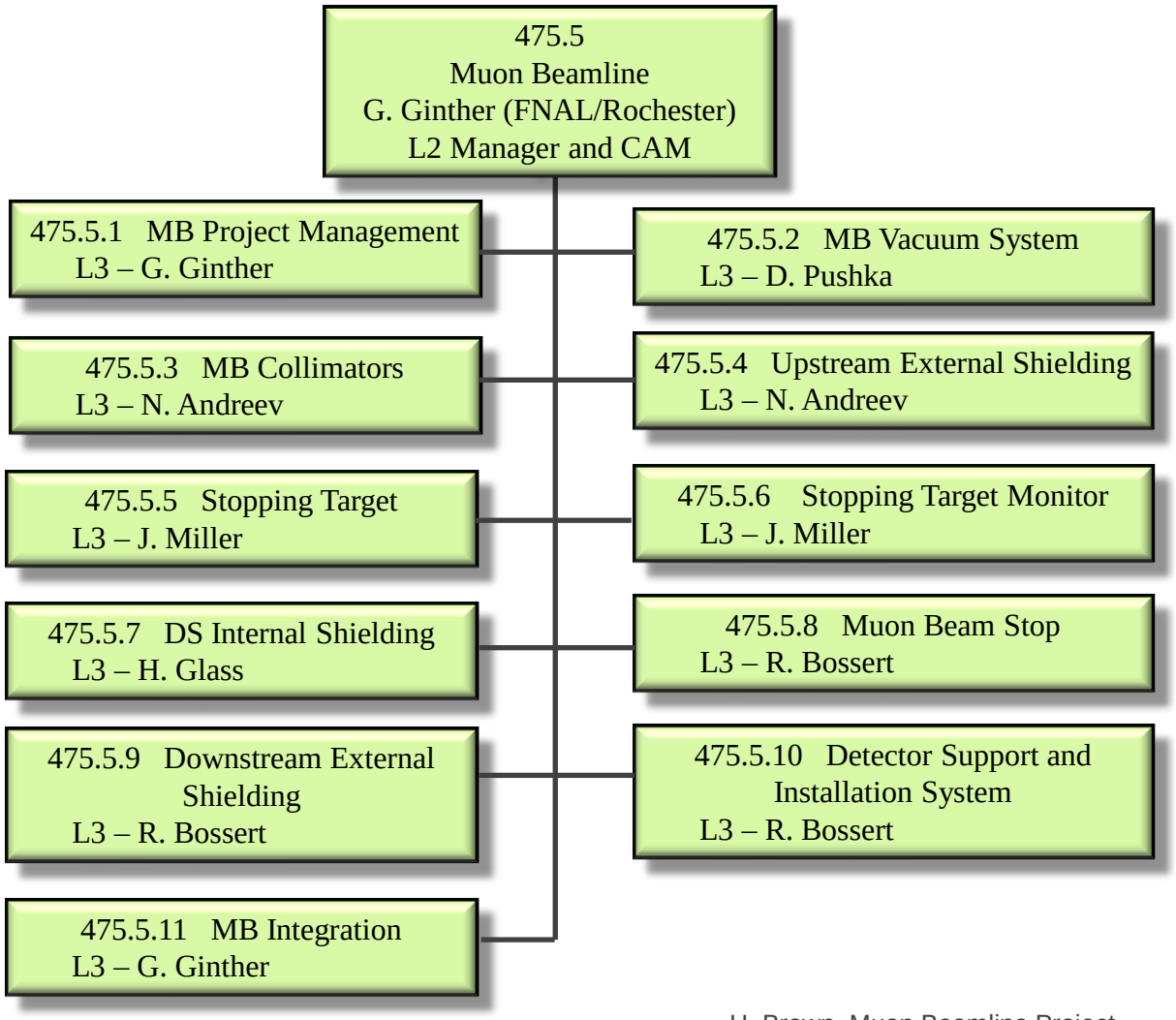


George Ginther

Mu2e Muon Beamline Level 2 Project Manager

8/26/2014

Muon Beamline Organization



- H. Brown Muon Beamline Project Controls Specialist

- J. Brandt, G. Gallo, S. Krave, and B. Woods are providing significant additional engineering
- York is contributing to the vacuum system
- Boston University is involved in stopping target and stopping target monitor
- NIU involved in the Muon Beam Stop and Detector Support and Installation System
  - D. Hedin and physics students
  - N. Pohlman and engineering students (currently L. Martin and U. Okafor)
- Accelerator Physics Center contributing to MARS simulation effort
- Mu2e collaboration continues to make crucial contributions to development primarily through simulations studies
  - Neutron task force
  - Caltech, Fermilab, LBNL, NIU, Rice, UC Irvine, Virginia, York

Requirements

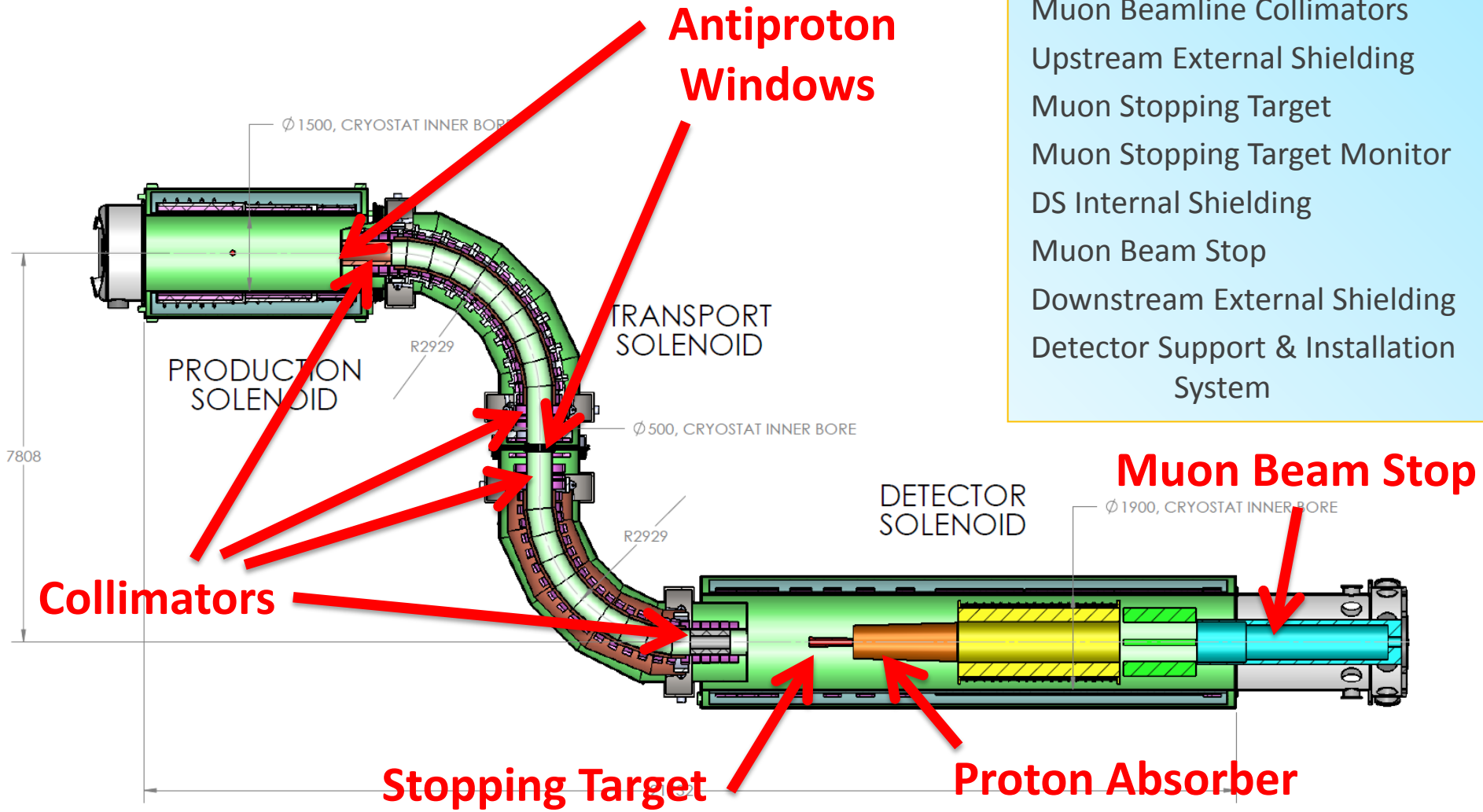
WBS 5 Muon Beamline has a diverse set of responsibilities aimed at supporting efficient and reliable detector operation

The Muon Beamline scope is documented in the WBS dictionary (Mu2e-doc-4300) and is driven by requirements documents that are under Configuration Management.

• Science Requirements for the Mu2e Experiment	Mu2e-doc-4381
• Muon Beamline Vacuum System	Mu2e-doc-1481
• Muon Beamline Collimators	Mu2e-doc-1044
• Upstream External Shielding	Mu2e-doc-1506
• Muon Stopping Target	Mu2e-doc-1437
• Muon Stopping Target Monitor	Mu2e-doc-1438
• Detector Solenoid Internal Shielding	Mu2e-doc-1439
• Muon Beam Stop	Mu2e-doc-1351
• Downstream External Shielding	Mu2e-doc-1371
• Detector Support and Installation System	Mu2e-doc-1383

Muon Beamline Orientation

- Muon Beamline Vacuum System
- Muon Beamline Collimators
- Upstream External Shielding
- Muon Stopping Target
- Muon Stopping Target Monitor
- DS Internal Shielding
- Muon Beam Stop
- Downstream External Shielding
- Detector Support & Installation System

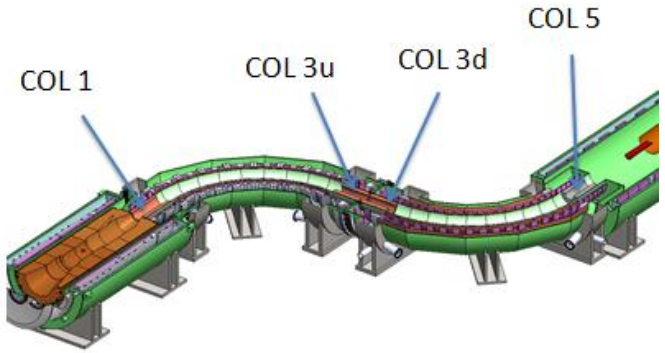


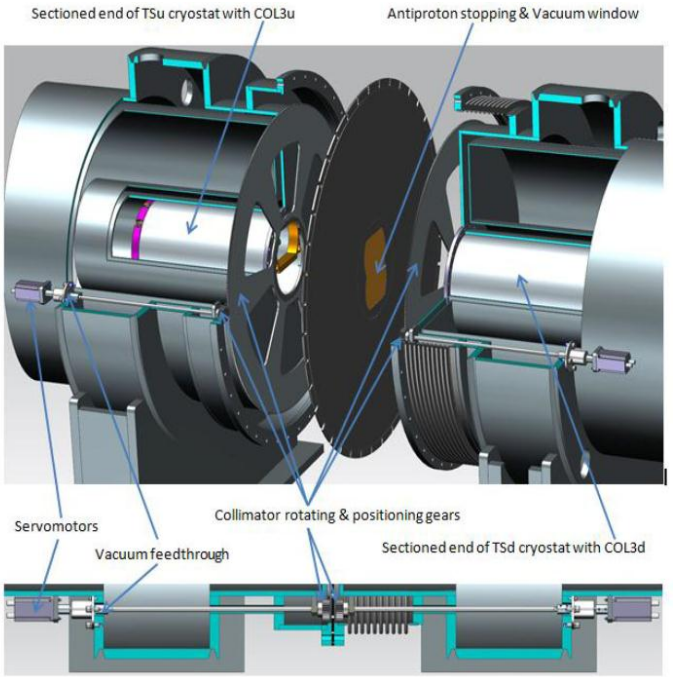
WBS 475.05.02 Muon Beamline Vacuum System

- Design and fabricate the equipment to pump down and maintain the muon beamline vacuum space at appropriate operating pressures to facilitate proper beamline operation, appropriate target lifetime and detector performance
  - 475.05.02.01 Production Solenoid Enclosure ($419k)
  - 475.05.02.02 Detector Solenoid Enclosure ($1146k)
  - 475.05.02.03 Solenoid Cryostat Interconnect Components ($394k)
  - 475.05.02.04 External Vacuum System Components ($1076k)
  - 475.05.02.05 Monitoring, Controls and Interlocks ($221k)
  - 475.05.02.06 Vacuum System Management ($99k)

WBS 475.05.03 Muon Beamline Collimators

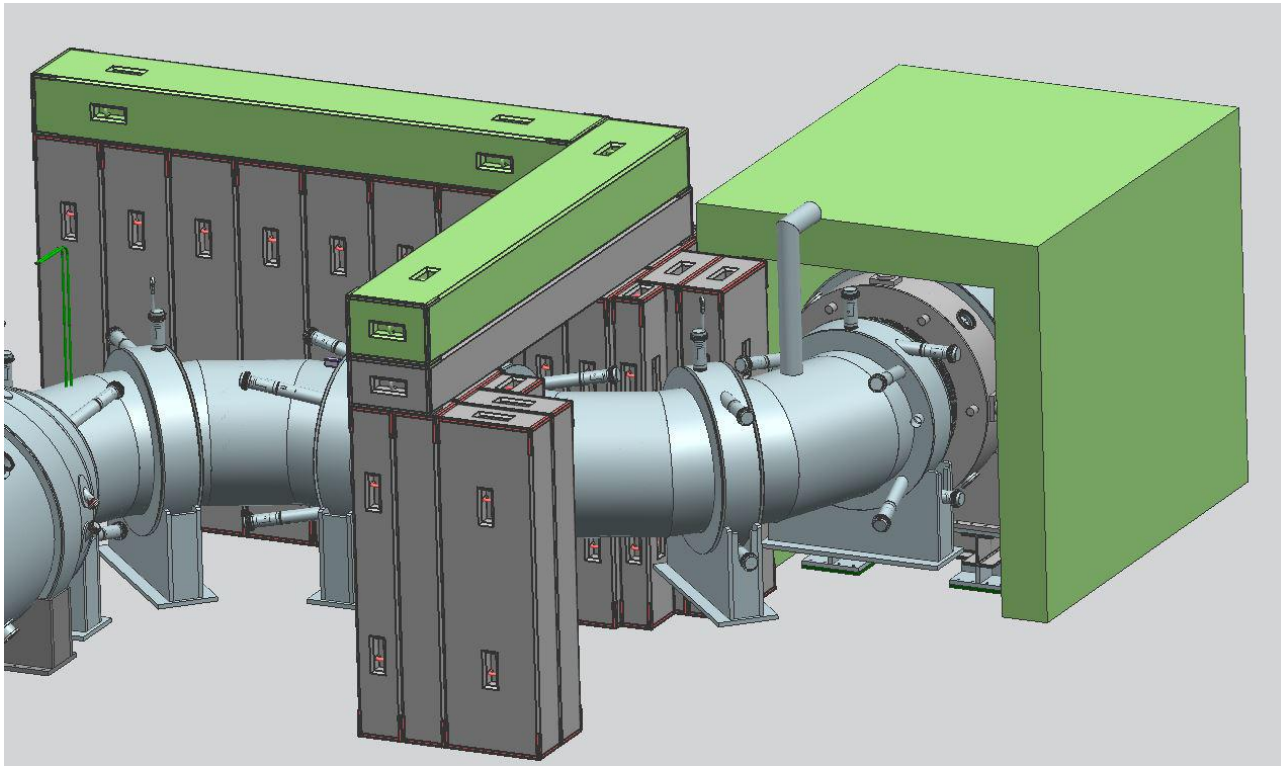
- Design and fabricate the devices in the muon beamline to protect the Transport Solenoid coils as well as the detectors while allowing efficient passage of the desired beam particles, and install the collimators in the Transport Solenoid
  - 475.05.03.01 TS1 Collimator (COL1) COL1 Antiproton Stopping Window ($437k)
  - 475.05.03.02 TS3 Collimators (COL3u and COL3d) and Antiproton Stopping Window Assembly ($680k)
  - 475.05.03.03 TS5 Collimator ($274k)





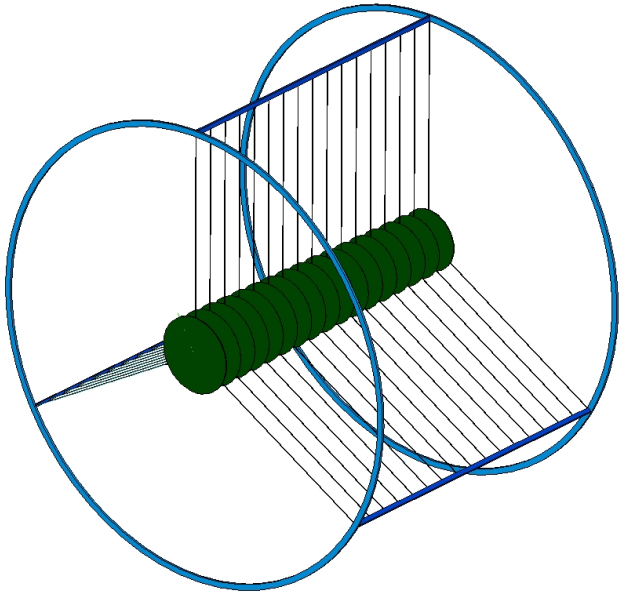
WBS 475.05.04 Upstream External Shielding

- Design and fabricate the shielding to reduce the particle flux from the Production Solenoid and Upstream Transport Solenoid region incident upon the Mu2e detectors in the Mu2e experiment hall (1982k$)
  - Reduce beam related background rates
  - 90 ton concrete cave surrounding Production Solenoid
  - 242 tons high density and 48 tons normal density concrete to isolate production region from detector hall



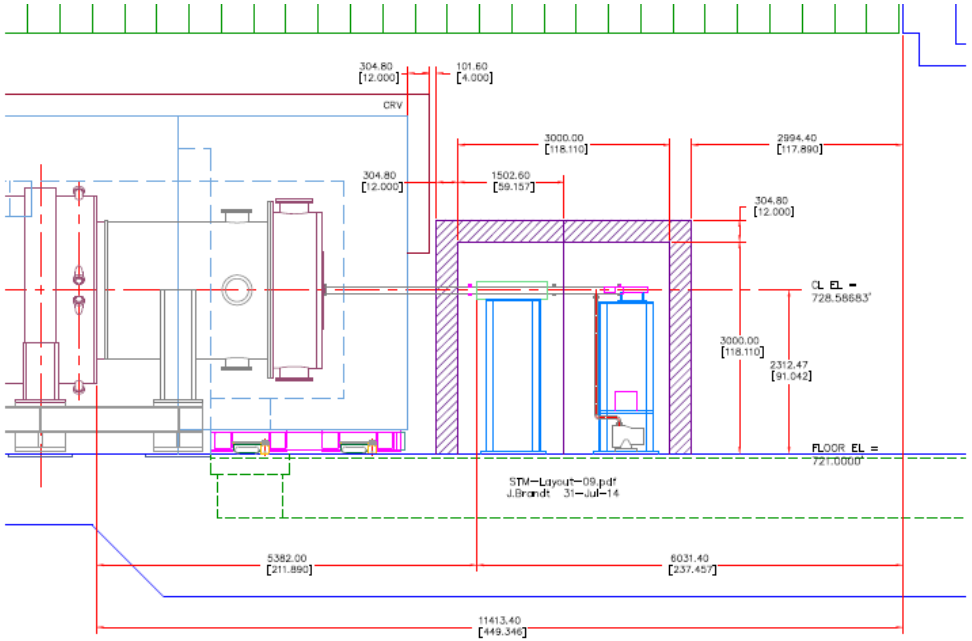
WBS 475.05.05 Muon Stopping Target

- Design and fabricate the target for the muon beam (180k$)
  - Target is designed to efficiently stop muons in the incident beam while minimizing the loss of potential signal electrons generated by the conversion of stopped muons into electrons in the nuclear field of the target atoms
  - The frame necessary to support the target is within the scope of this WBS.
  - Seventeen 200μm thick aluminum disks
    - Diameter from 16.6 cm to 13.1 cm
  - Tungsten wire supports



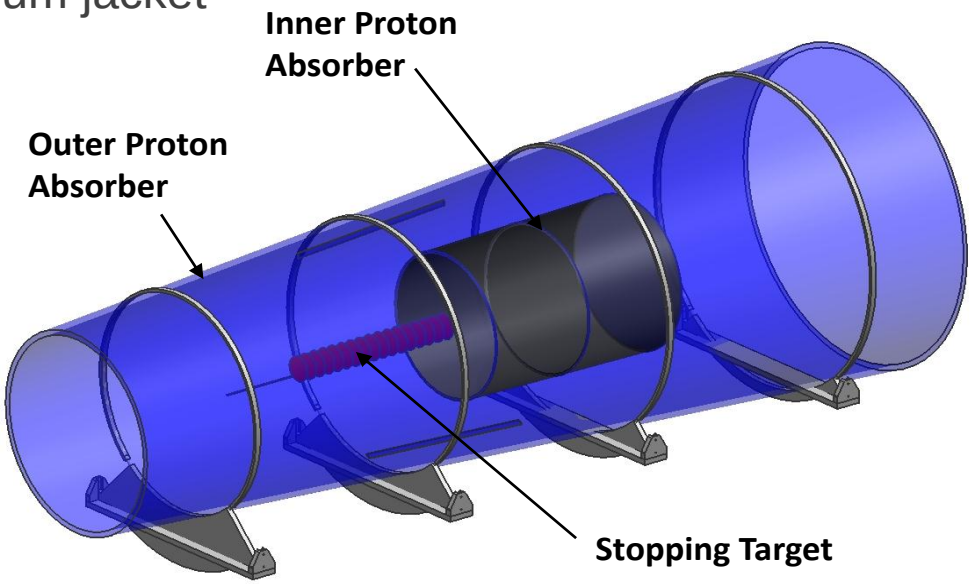
WBS 475.05.06 Muon Stopping Target Monitor

- Design and fabricate the equipment to monitor the rate of muons stopping in the stopping target, providing the normalization for the Mu2e experiment (343k$)
- Stopping Target Monitor is a germanium detector monitoring delayed photons from the de-excitation of ^{27}Mg created by muon capture on aluminum
- Germanium detector located outside vacuum volume downstream in low mag field region
- Sweeping magnet
- Beam shutter protects detector from beam flash
- Additional shielding surrounding detector



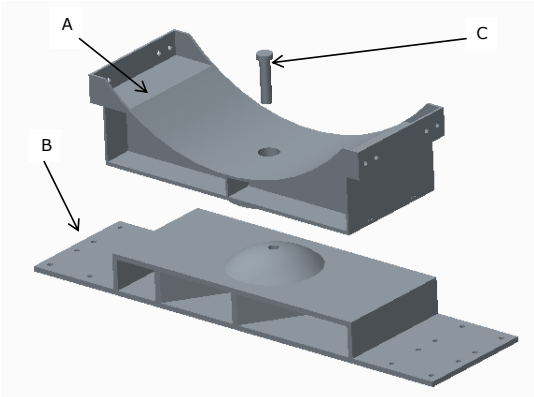
WBS 475.05.07 Detector Solenoid Internal Shielding

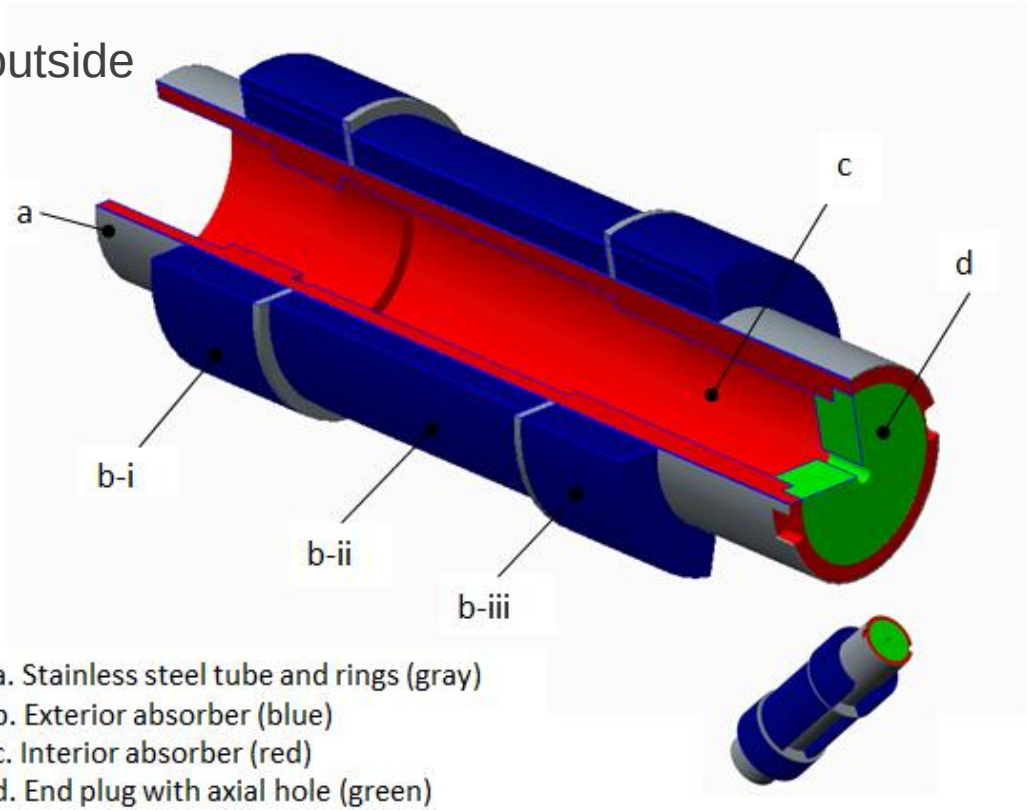
- Design and fabricate the shielding surrounding the muon stopping target. This shielding reduces rates in the tracker and the cosmic ray veto to facilitate efficient detector performance (392k$)
  - 50 mm thick borated polyethylene covering the downstream end of the Transport Solenoid cryostat vacuum jacket
  - Inner Proton Absorber
    - 0.5 mm thick
  - Outer Proton Absorber
    - 20 mm thick
    - Borated polyethylene
    - ~700 lbs
  - Support structure



WBS 475.05.08 Muon Beam Stop

- Design and fabricate muon beam stop, which absorbs the beam particles that pass through the target, minimizing the backgrounds in the detectors (781k$)
  - Stainless steel tube supporting polyethylene both inside and outside
  - Hole in the downstream end for line of sight to the muon stopping target monitor
  - ~5 tons of stainless steel and polyethylene
  - Mounting fixtures

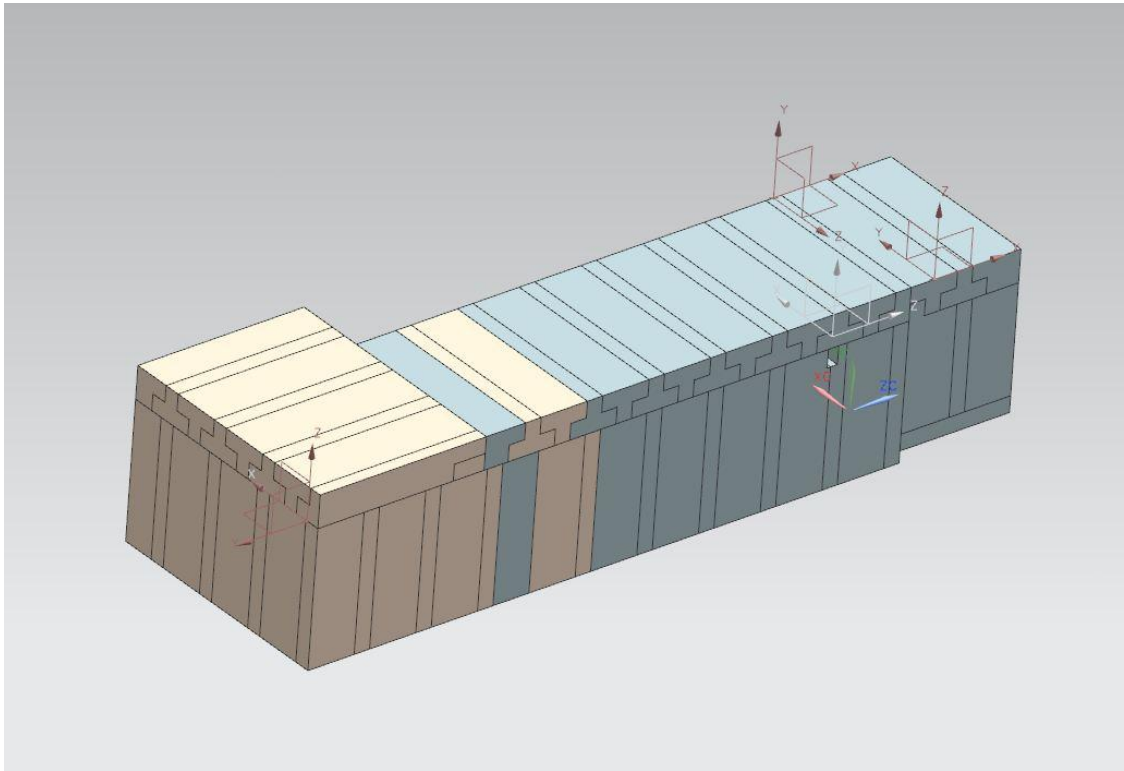




a. Stainless steel tube and rings (gray)
b. Exterior absorber (blue)
c. Interior absorber (red)
d. End plug with axial hole (green)

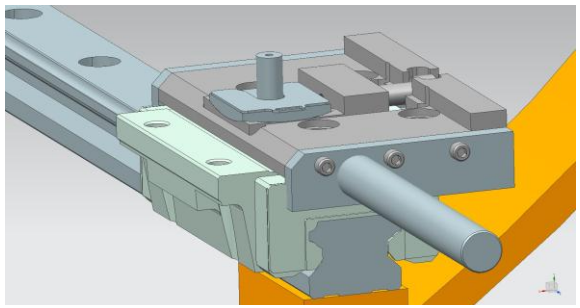
WBS 475.05.09 Downstream External Shielding

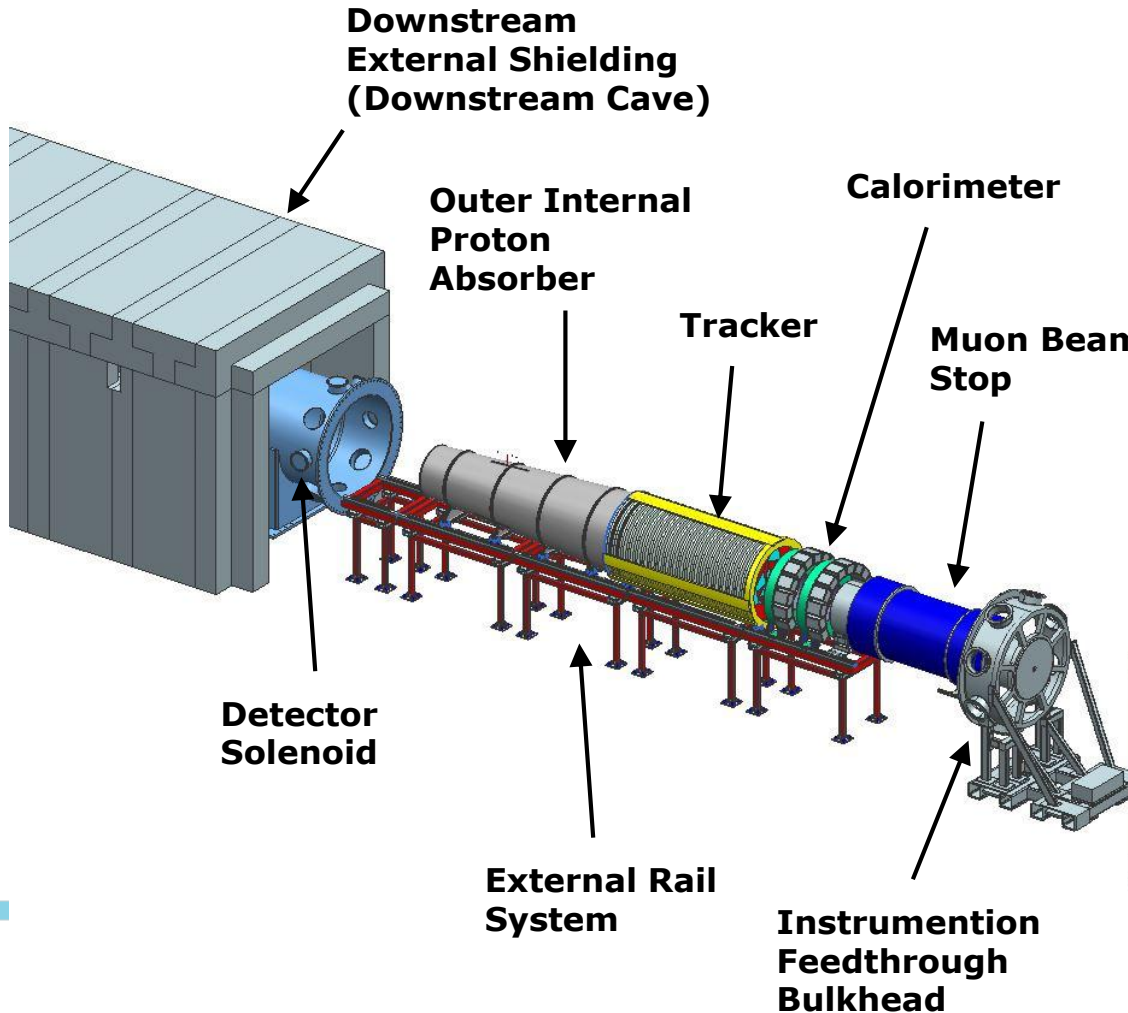
- Design and fabricate the shielding to reduce the particle flux from the Downstream Transport Solenoid region and the Detector Solenoid region incident upon the Mu2e cosmic ray veto detectors in the Mu2e experiment hall (3392k$)
  - Reduce beam related background rates on cosmic ray veto so that the detector can provide the necessary discrimination against cosmic ray induced background sources
  - T block downstream cave and independent end cap shielding
  - 409 tons high density (barite) concrete
  - 430 tons normal density concrete



WBS 475.05.10 Detector Support and Installation System

- Design, fabricate and install the equipment to support and align the detectors inside the Detector Solenoid bore, as well as to facilitate extraction and insertion of the detectors for servicing (2470k$)
  - Includes rails mounted inside the Detector Solenoid bore
  - Bearing blocks, alignment mechanism
  - External stands and supports





Muon Beamline Project Risks

- Muon-138 Detector installation takes longer than anticipated
  - Probability Moderate Risk Impact $400k
  - 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
- Muon-147 Degrader required for calibration
  - Probability Moderate Risk Impact $250k
  - Could also impact design of Detector Solenoid internal shielding
- Muon-146 Rate exceeds muon stopping target monitor capability
  - Probability Moderate Risk Impact 200k$
  - Primary mitigations rely upon ongoing simulation efforts and test beam activities

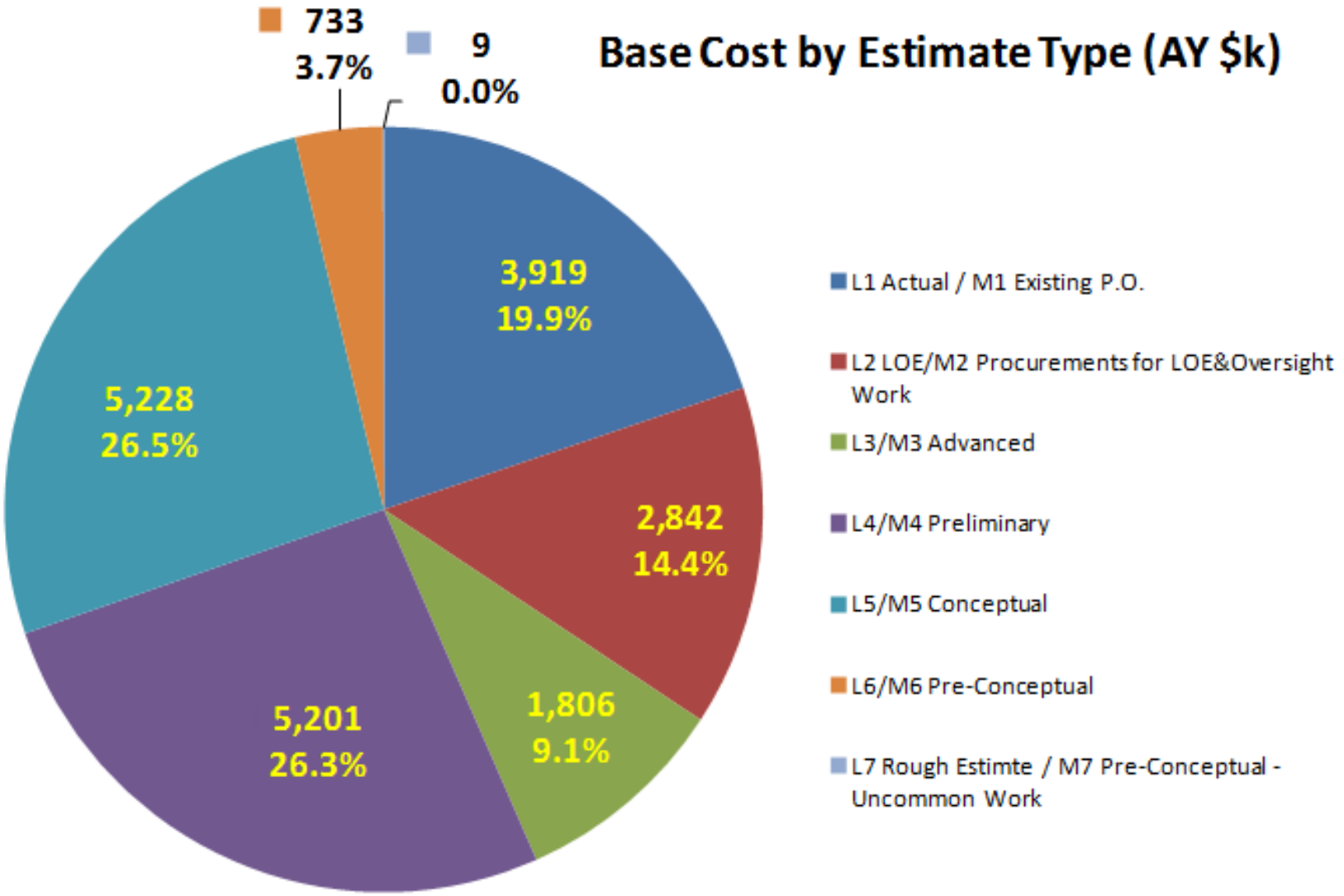
Muon Beamline Cost Table

475.05 Muon Beamline

Costs are fully burdened in AY $k

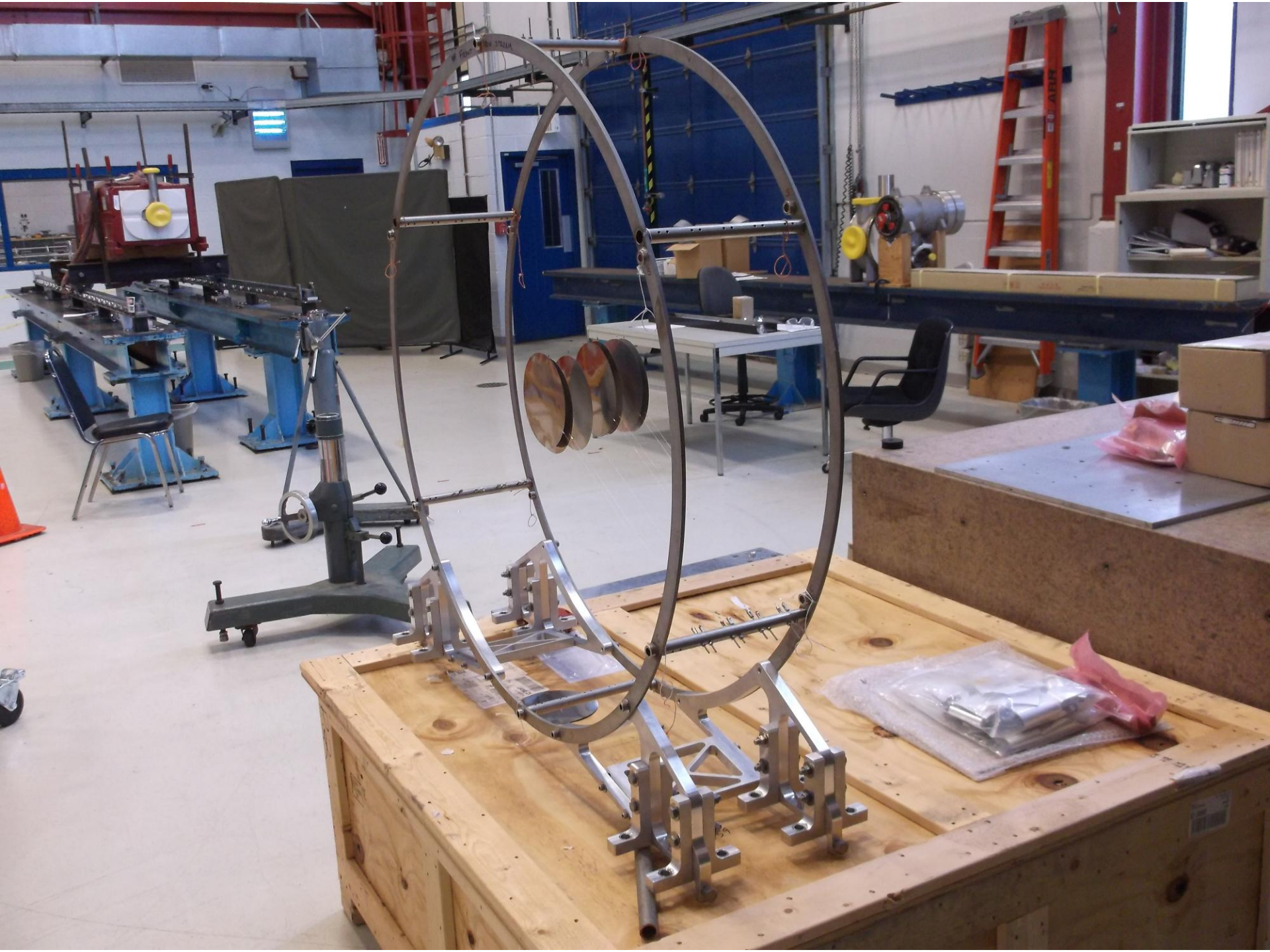
	M & S	Labor	Base Cost	Estimate Uncertainty	% Contingency on ETC	Total
475.05.01 Muon Beamline Project Management	71	3,065	3,136	160	6%	3,296
475.05.02 Vacuum System	2,077	1,277	3,354	1,209	38%	4,563
475.05.03 Collimators	747	644	1,392	524	41%	1,916
475.05.04 Upstream External Shielding	1,368	614	1,982	812	46%	2,795
475.05.05 Stopping Target	61	120	180	67	39%	247
475.05.06 Stopping Target Monitor	193	149	343	189	55%	532
475.05.07 Detector Solenoid Internal Shielding	189	203	392	120	34%	512
475.05.08 Muon Beam Stop	481	300	781	225	36%	1,006
475.05.09 Downstream External Shielding	2,541	851	3,392	1,378	45%	4,770
475.05.10 Detector Support Structure	1,427	1,043	2,470	650	31%	3,120
475.05.11 Systems Integration, Test & Analysis	27	307	334	169	54%	502
475.05.13 Muon Beamline Conceptual Design/R&D	107	1,873	1,980			1,980
475.01.99 Risk Based Contingency				499		499
Total	9,290	10,447	19,737	6,001	38%	25,739

Quality of Estimate



WBS 5 Muon Beamline Summary

- WBS 5 Muon Beamline has a diverse set of responsibilities aimed at supporting efficient and reliable Mu2e detector operation
- We are in the process of refining and optimizing the design of the various muon beamline elements
  - Including value engineering
- Estimates for Muon Beamline are complete and documented
  - Estimates primarily by seasoned engineers (with relevant experience) based upon current design and incorporating input from previous experience as well as vendor quotes
  - 70% of cost at the Preliminary Design level or higher
- Risks identified and mitigated where possible. Cost set aside as contingency to cover residual risks where appropriate.
- Anticipate that many major WBS 5 procurements will be scheduled towards the end of the project

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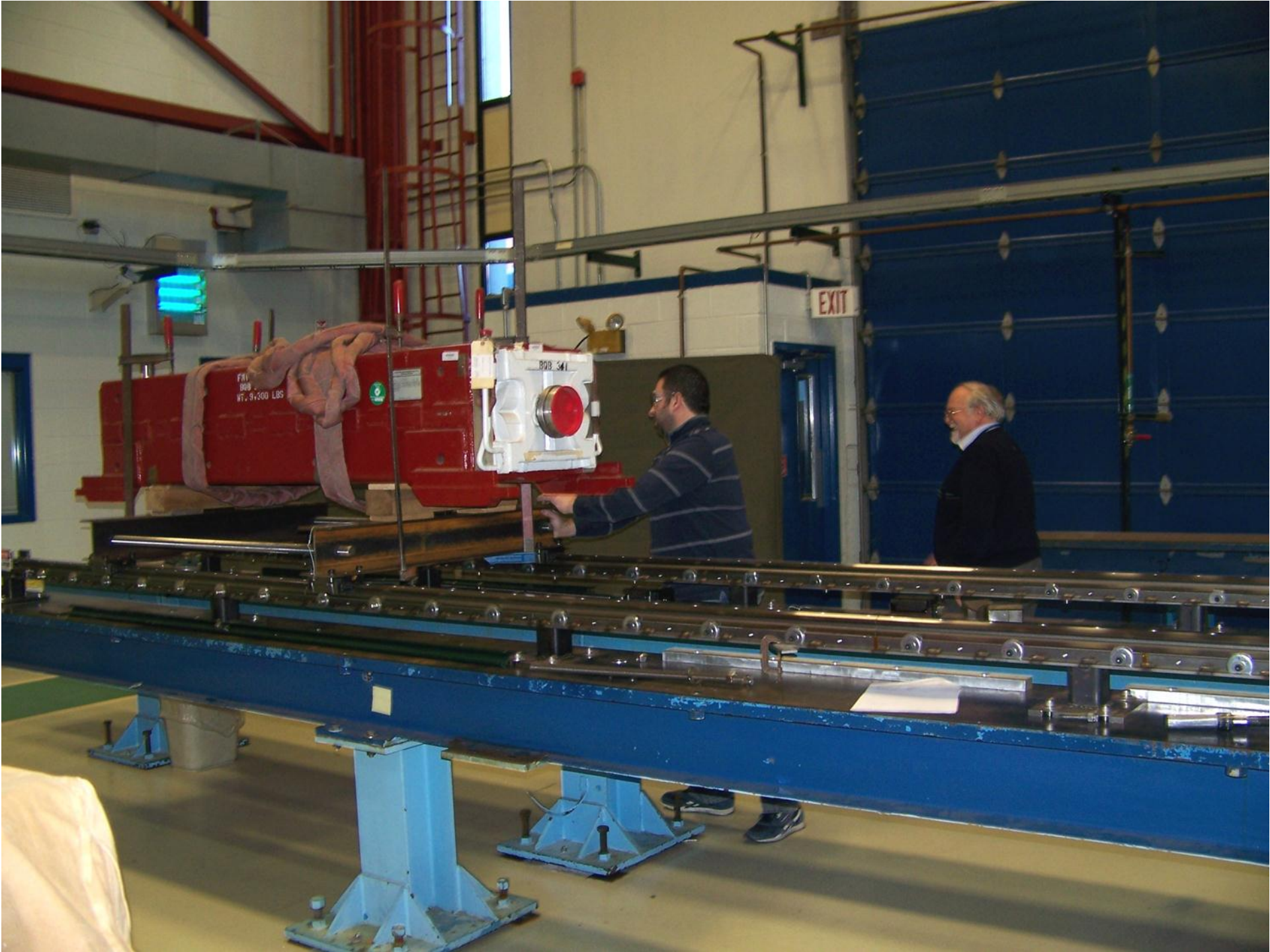
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