Fermilab

U.S. DEPARTMENT OF ENERGY Office of Science

Mu2e WBS 5.2 Muon Beamline Vacuum CD-2 Director's Review

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7/8/2014

Requirements

- Required vacuum level:
  - PS + TSu; 1 x 10^{-5} torr.
  - DS + TSd; 1 x 10^{-4} torr.
- Required vacuum pump down time:
  - PS + TSu; approximately 100 hours.
  - DS + TSd; approximately 100 hours.
- Required magnetic field for high vacuum pumps:
  - PS + TSu; approximately 500 Gauss.
  - DS + TSd; approximately 600 Gauss.
- Required magnetic field for backing and roughing vacuum pumps:
  - PS + TSu; approximately 100 Gauss.
  - DS + TSd; approximately 100 Gauss.
- Required pre-operational cleanliness for vessels:
  - PS + TSu; standard high vacuum cleaning and degreasing
  - DS + TSd; standard high vacuum cleaning and degreasing

Requirements

- Required operational cleanliness:
  - PS + TSu; minimize, but not eliminate vacuum pump oil back-streaming.
  - DS + TSd; minimize, but not eliminate vacuum pump oil back-streaming
- Appropriate windows and access ports must be provided as part of the enclosure for the Production Solenoid
- Appropriate window, ports and feedthroughs must be provided as part of the enclosure for the Detector Solenoid
- Vacuum lines (and other services) should be located to minimize penetrations in the detector shielding
  - Penetrations to the transport and detector solenoids should if at all possible come through the bottom, and if they cannot be through the bottom, then they should be away from the target region. In no cases should they penetrate the top.

Design

- Conceptual designs for the PS end cap, the VPSP and the IFB are largely unchanged from CD-1.
- Changes to the vessels will be made as part of the next design iteration. Specifically:
  - The PS shape will be changed to use conventional pressure vessel design details.
  - The VPSP will have nozzles changed to better match the pump orientation and maximize conductance.
  - The IFB will be analyzed to evaluate the shape with respect to the vacuum loading.

Design

- A remotely located large diffusion pump connected by a large diameter, high vacuum will evacuate the PS.
- Two directly mounted smaller diffusion pumps will evacuate the DS.
- Roughing pumps will also serve as the backing pumps for the diffusion pumps.
- Roughing systems will be tied together and roughing will be performed slowly to minimize the differential pressure across the anti-proton stopping window at the TSu/TSd interface.
- A first draft of the written interlock description has created.
- A P&ID has been created.

Design

- For the PS, where a remotely located large diffusion pump connected by a large diameter, high vacuum will evacuate the PS:
  - Diffusion pump is located in the remote handling room where the radiation exposure is lessened.
  - Current design has two diffusion pumps, one to use, one as a hot stand-by unit.
  - Pumping capacity limited by the conductance of the high vacuum line between the PS and the diffusion pumps.
    - Operating both pumps will have little affect on increasing the pumping speed.
  - Diffusion pumps are fitted with cold traps to reduce the oil back-streaming into the PS to improve cleanliness.

Design

- For the DS, where two close coupled diffusion pumps mounted on the VPSP will evacuate the DS:
  - Diffusion pumps are located inside the shielding.
  - Current design has two diffusion pumps, both in use.
  - Current design has two ports for additional pumps if required.
  - Pump size limited by the available space between the VPSP and the shielding.
  - Diffusion pumps are fitted with cold traps to reduce the oil back-streaming into the DS to improve cleanliness.

Changes since CD-1

- Considered magnetic field as a design input to the vacuum pumping system.
  - Changed to diffusion pumps.
- Used outgassing rates from published literature for surfaces consistent with anticipated conditions.
- Vacuum requirements in the PS region increased (a higher quality, lower pressure level) due to primary target lifetime concerns.
- By-pass lines around the anti-proton stopping window at the TSu/TSd interface eliminated as they would not serve to protect the anti-proton stopping window in the event of a vacuum window failure in the PS.

Value Engineering since CD-1

- No formal value engineering exercises have been performed.
- However, in developing the P&ID, design decisions have been made to select the most cost effective solutions while meeting the requirements.

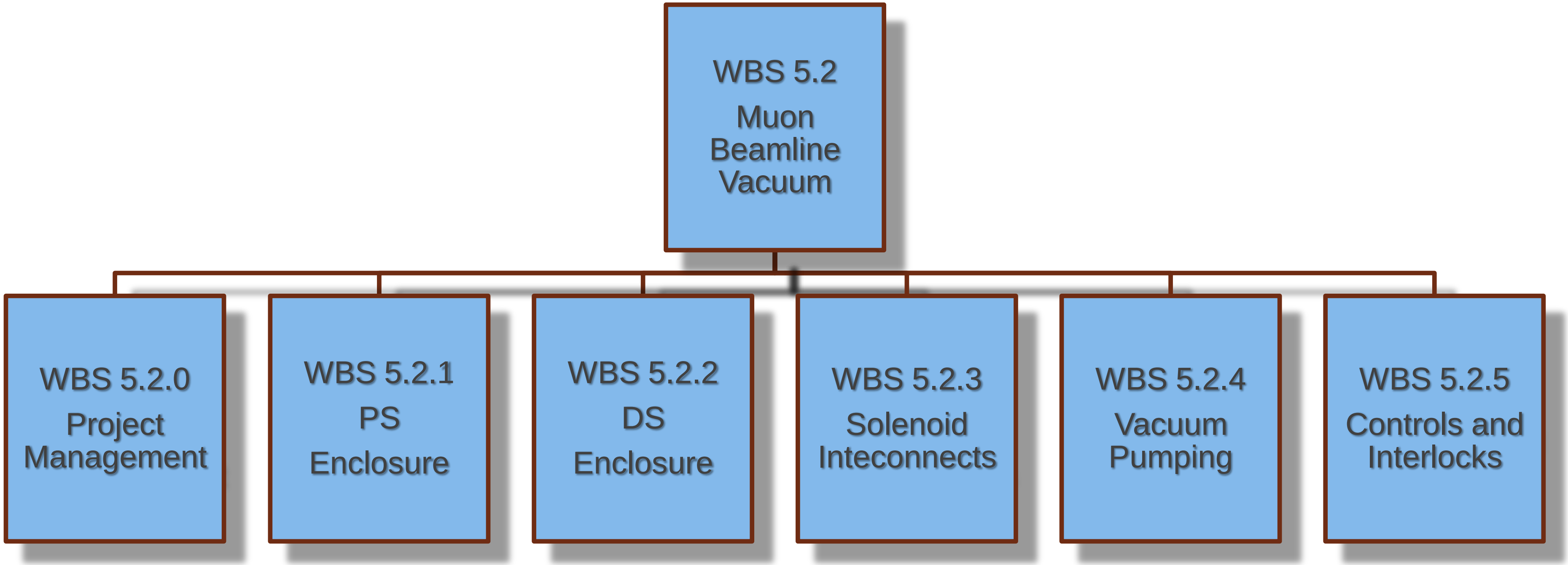
Performance

- Gas loads used as inputs to the pumping system design are:
  - PS + TSu; 0.9468 torr-l/sec.
  - DS + TSd; 32.06 torr-l/sec.
- Pressures achieved at 10 hours of high vacuum pumpings are:
  - PS + TSu; 5 x 10^{-5} torr
  - DS + TSd; 6 x 10^{-4} torr

Remaining work before CD-3

- Prepare FESHM 5033 vessel calculations for the three vessels and the PS evacuation line which are part of this system:
  - Productions Solenoid End cap (PS)
  - Vacuum Pump Spool Piece (VPSP)
  - Instrumentation Feed Through Bulkhead (IFB)
  - PS high vacuum evacuation line
- Modify conceptual designs shown as required to meet safety requirements.
- Prepare FESHM 5033.1 vacuum window calculations for all thin windows not already covered as part of the vessels.
- Generate purchase specification (including drawings) for the PS, VPSP, and IFB.
- Generate design documentations for all portions of the system per chapter 4 of the Engineering Manual and have reviewed per chapter 5.

Organizational Breakdown



Quality Assurance

- Procured vessels and pipe (PS, VPSP, IFB, vacuum lines) will be helium mass spectrometer (HMS) leak tested to verify the specified leak rate is achieved prior to installation.
- HMS leak testing will be repeated after installation to locate leaks should the system not pump down as the calculations predict.

Risks

- Major risks include:
  - Outgassing rates that exceed the values used to size the vacuum pumping equipment
  - Leak rates that exceed the values used to size the vacuum pumping equipment
  - Building and shielding size limitations that preclude installing larger capacity pumps and evacuation lines
- Mitigation strategies include:
  - Reducing surface area of vacuum space
  - Reducing materials in the vacuum space
  - Waiting a longer time for the outgassing to decay before achieving the required vacuum level.
  - Repairing leaks.

Risks

- Cost/schedule impacts if these risks are realized:
  - If an external leak is causing the vacuum to remain too high, it will take some time to locate and repair the leak.
  - If an internal leak (perhaps from the tracker) is causing the vacuum to remain too high, it will take some time to locate and repair the leak or add more pumps to compensate for the leak.
  - Will increase labor costs for the effort to locate and repair the leak or procure and install more pump capacity.

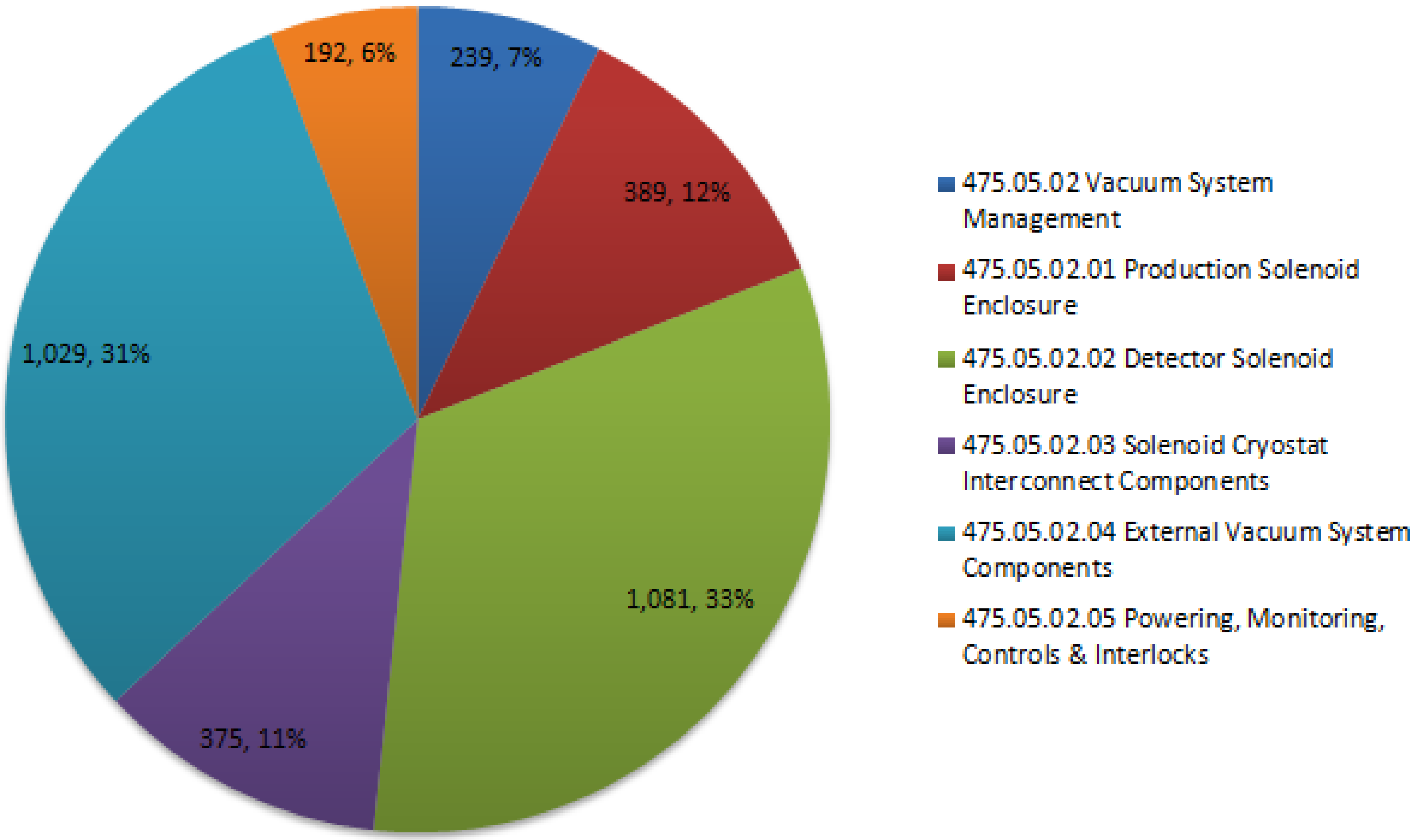
- Minor risks include vessels that do not pass the pre-installation helium leak test initially and require repair.
  - May not affect the overall schedule so long as the vessel procurements are not on the critical path.

ES&H

- FESHM (the Fermilab Environment, Safety and Health Manual) includes chapters which directly apply to the vacuum vessels and vacuum windows used on this system.
- Engineering notes will be necessary to show vessels meet the requirements.
- These engineering notes also provide a quality assurance that the designs will safely hold vacuum and will not collapse.

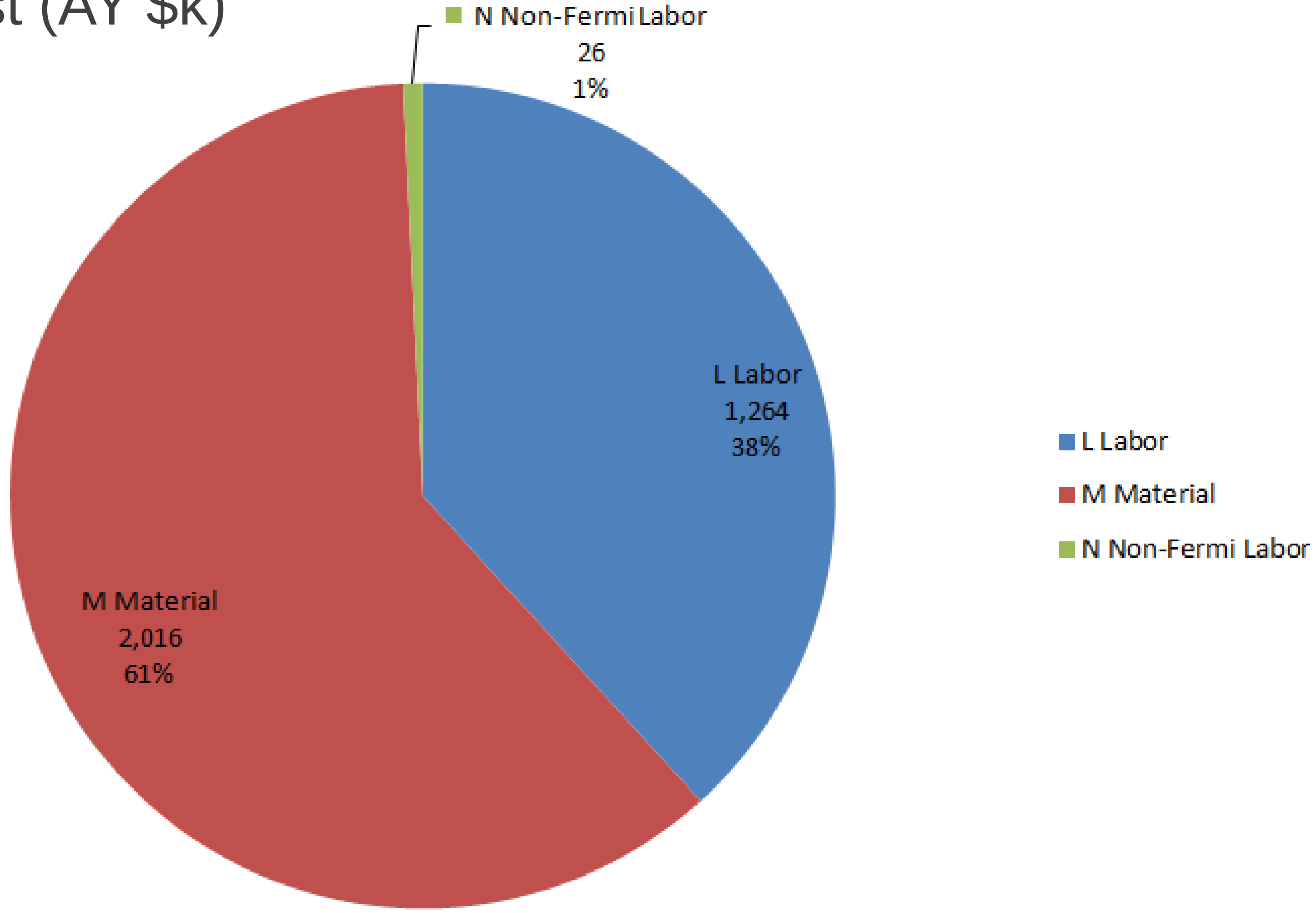
Cost Distribution by L4

- Base Cost by L4 (AY $k)



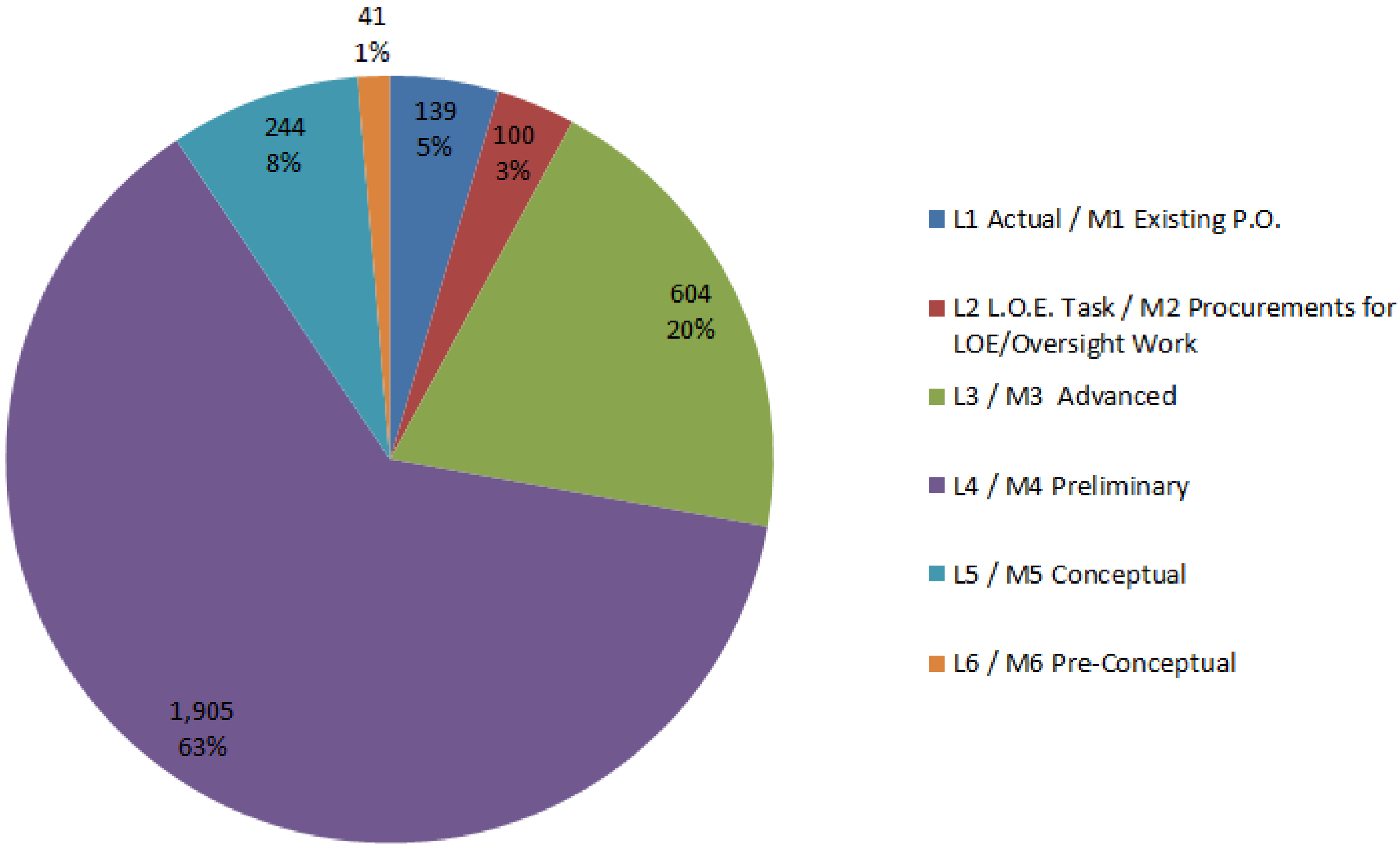
Cost Distribution by Resource Type

- Base Cost (AY $k)



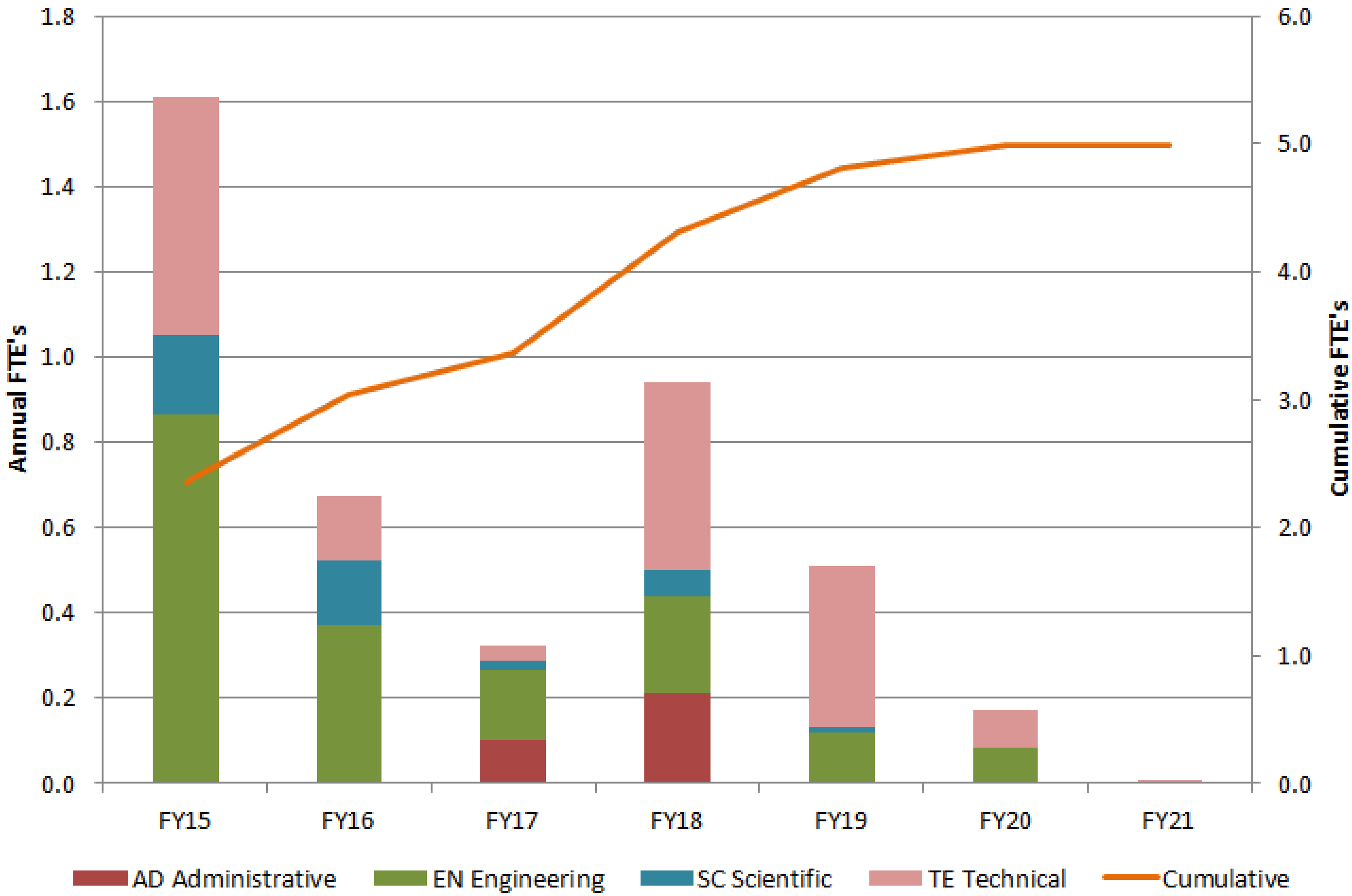
Quality of Estimate

- Base Cost by Estimate Type (AY$k)



Labor Resources

- FTEs by Discipline



Cost Table

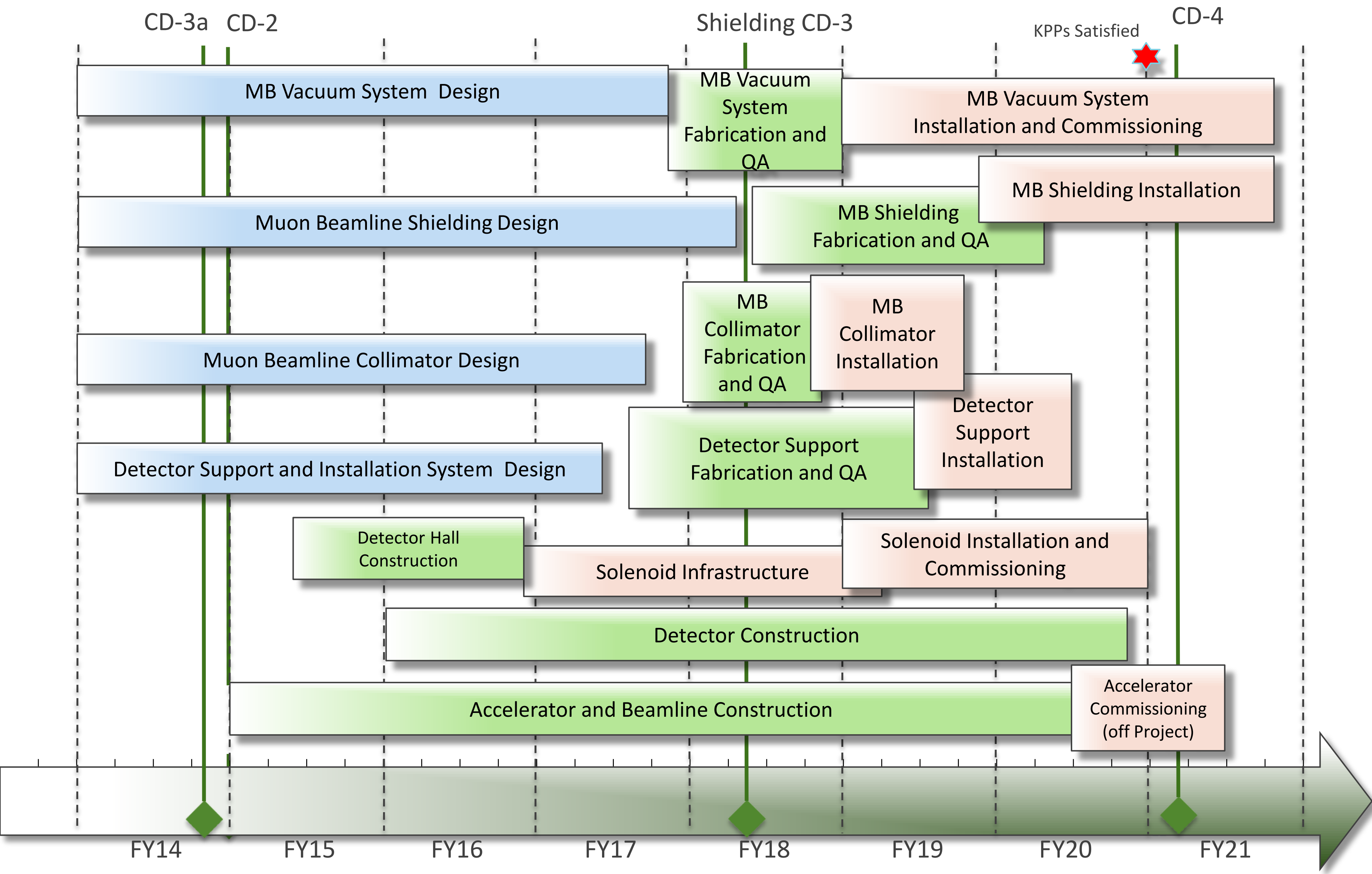
- WBS 5.2 Muon Beamline Vacuum System
  - Costs are fully burdened in AY $k

	Base Cost (AY k$)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining costs)	% Contingency on ETC	Total Cost
475.05 Muon Beamline						
475.05.02 Vacuum System						
475.05.02 Vacuum System Management		239	239	33	33%	272
475.05.02.01 Production Solenoid Enclosure	211	178	389	176	45%	565
475.05.02.02 Detector Solenoid Enclosure	829	252	1,081	406	38%	1,486
475.05.02.03 Solenoid Cryostat Interconnect Components	115	260	375	122	32%	497
475.05.02.04 External Vacuum System Components	829	200	1,029	356	35%	1,385
475.05.02.05 Powering, Monitoring, Controls & Interlocks	57	135	192	82	43%	274
Grand Total	2,041	1,264	3,305	1,174	37%	4,480

Major Milestones

- Engineering notes for the vacuum vessels completed and submitted for review.
- Vacuum equipment purchase requisitions submitted for Mu2e management approval.

Schedule



CD-3a
CD-2
Shielding CD-3
KPPs Satisfied
CD-4
MB Vacuum System Design
MB Vacuum System Fabrication and QA
MB Vacuum System Installation and Commissioning
Muon Beamline Shielding Design
MB Shielding Fabrication and QA
MB Shielding Installation
Muon Beamline Collimator Design
MB Collimator Fabrication and QA
MB Collimator Installation
Detector Support and Installation System Design
Detector Support Fabrication and QA
Detector Support Installation
Detector Hall Construction
Solenoid Infrastructure
Solenoid Installation and Commissioning
Detector Construction
Accelerator and Beamline Construction
Accelerator Commissioning (off Project)
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Summary

- Upstream Muon Beamline will need to be evacuated to a pressure of less than 10^{-5} torr to support efficient primary target operation
- Downstream Muon Beamline will need to be evacuated to a pressure of less than 10^{-4} torr to support detector operation

- Much design work remains to be performed
- Nearly all of the remaining design work is similar to work previous performed.