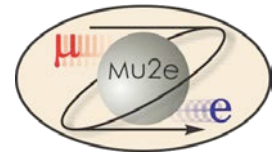




U.S. DEPARTMENT OF
ENERGY Office of
Science

Solenoids

Mu2e Independent Cost Estimate

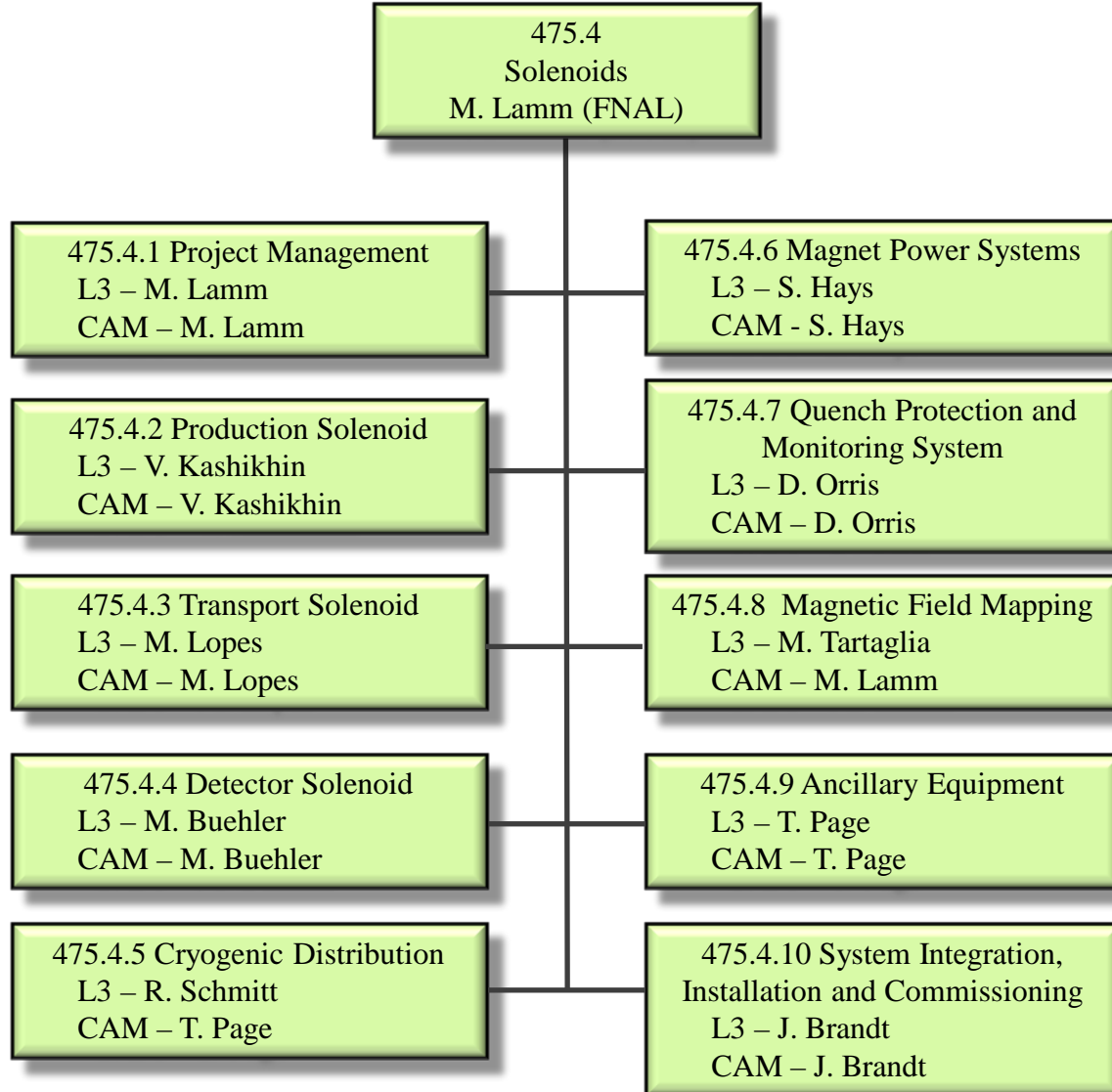


M. Lamm

Mu2e L2 Manager for Solenoids

8/26/2014

L2 Solenoid Organization



Requirements

The Mu2e Solenoids are driven by 8 requirements documents that are under Configuration Management.

- Science Driven Requirements Mu2e-doc-4381
- Production Solenoid Requirements Mu2e-doc-945
- Detector Solenoid Requirements Mu2e-doc-946
- Transport Solenoid Requirements Mu2e-doc-947
- Power Supply System Requirements Mu2e-doc-1237
- Quench Protection Requirements Mu2e-doc-1238
- Cryo Distribution Requirements Mu2e-doc-1244
- Magnetic Field Mapping Requirements Mu2e-doc-1275

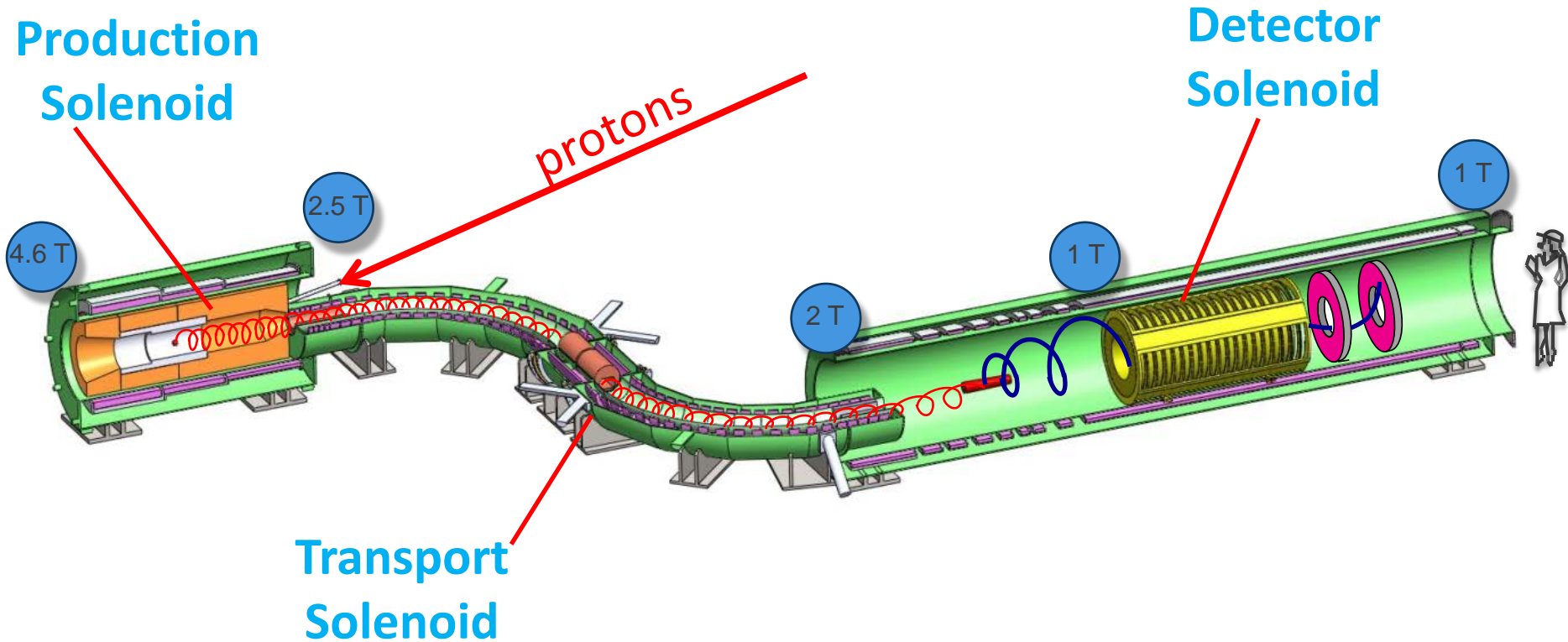
Scope

Provide integrated magnetic system for Mu2e experiment including required support infrastructure and interfaces to the Muon Campus. Primary Deliverables:

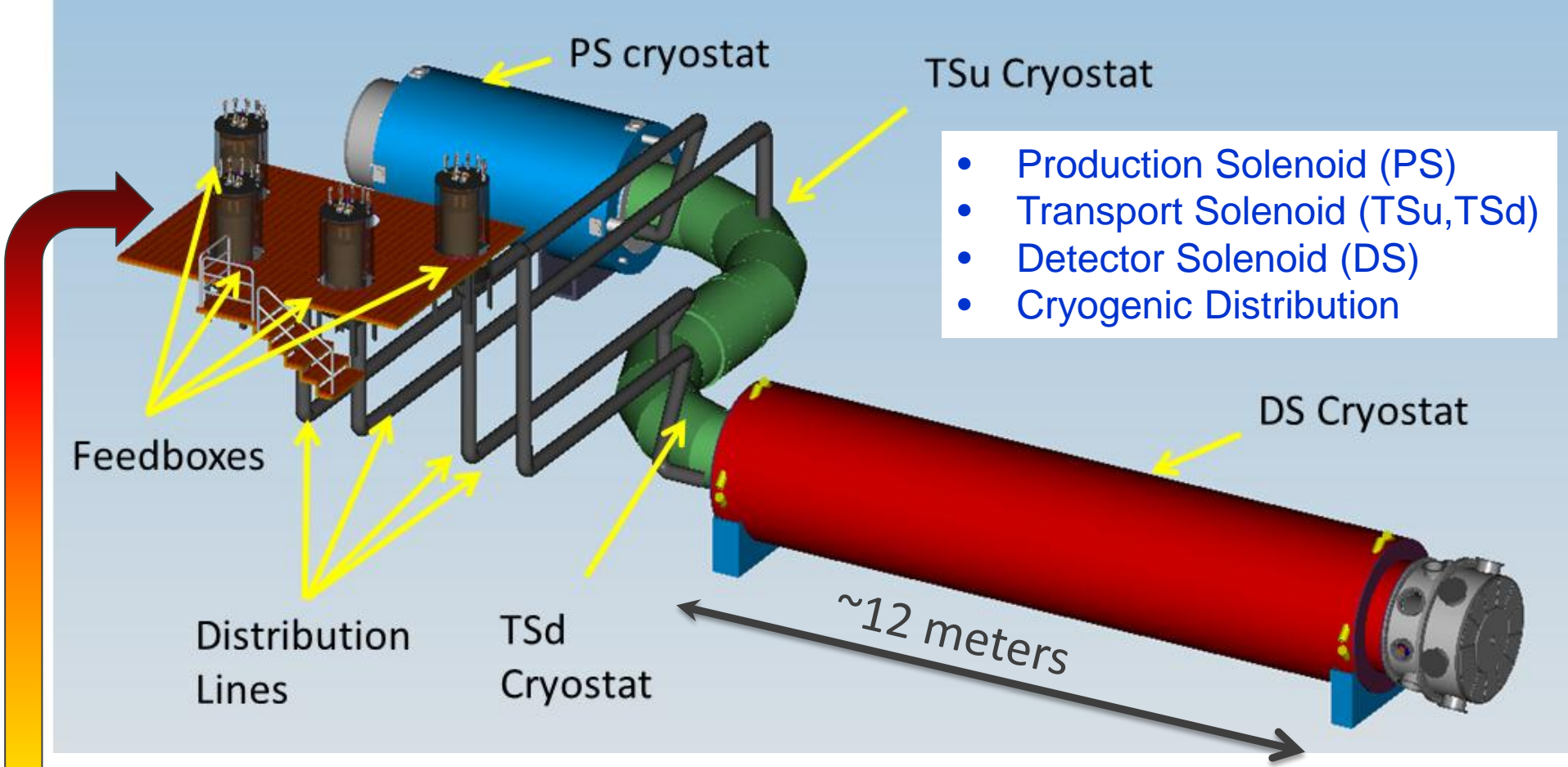
- Three superconducting solenoids
 - Production Solenoid
 - **Transport Solenoid**
 - **Detector Solenoid**
- ...and support infrastructure
 - Cryogenic Distribution System
 - Power Supply System along with magnet controls and monitoring
 - Magnetic Field Mapping System
 - **Installation and Commissioning of these deliverables**

Mu2e Solenoid System

- Three solenoids provide magnetic field for experiment



Mu2e Solenoid Scope



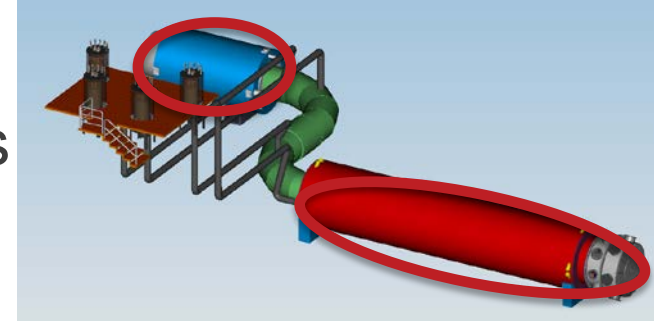
- Cryo distribution box
- Power Supply/Quench Protection

- Field Mapping
- Ancillary Equipment
- Installation and commissioning

WBS 475.4.2 Production Solenoid (PS)

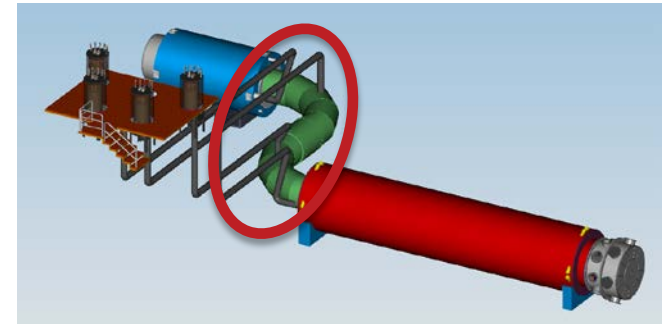
WBS 475.4.4 Detector Solenoid (DS)

- Design and fabricate (PS/DS)
 - Large superconducting electro-magnets
- Largest estimate at completion elements
 - Superconductor (\$2.3M/\$2.1M)
 - Final Design by Vendor (\$1.9M/\$2.3M)
 - Tooling by Vendor(\$1.9M/\$1.9M)
 - Fabrication by Vendor(\$5.0M/\$6.7M)
- Basis of Estimate
 - Actual Vendor quotes account for ~86% of scope
 - Engineering estimates mostly on in house preliminary design labor for remaining elements, based on application of similar technology in other Fermilab magnet projects include our own experience with Mu2e conceptual design



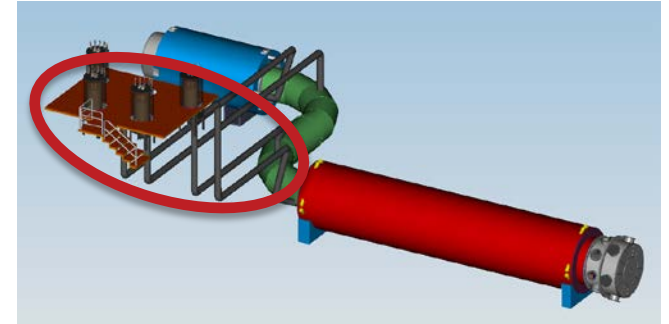
WBS 475.4.3 Transport Solenoid (TS)

- Design and fabricate the Transport Solenoid
 - Large superconducting electro magnet
 - Components fabricated in industry, final assembly and test at FNAL
- Estimate at completion by Level 4
 - 475.04.03.01 Superconductor (\$4,659k)
 - 475.04.03.02 Cold Mass Components (\$7,880k)
 - 475.04.03.03 Cryostat Components (\$3,210k)
 - 475.04.03.04 Magnet Assembly (\$3,842k)
 - 475.04.03.05 Support Structure (\$434k)
 - 475.04.03.06 Interconnects (\$340k)
 - 475.04.03.07 Test Cryostat (\$3,462k)
- Basis of Estimate
 - Vendor RFI's for coil modules (largest single TS cost)
 - Engineering estimates based on application of similar technology in other Fermilab magnet construction projects



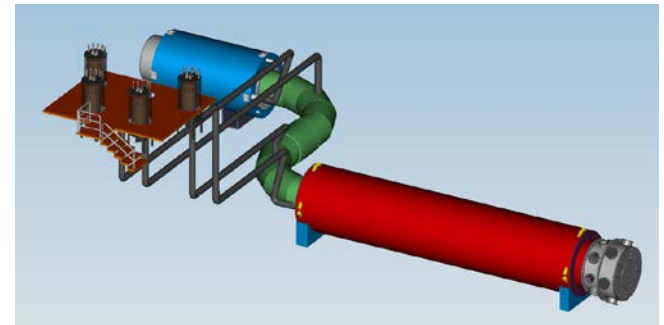
WBS 475.4.5 Cryogenic Distribution

- Design and fabricate the Mu2e Cryo system
 - Major support infrastructure for large superconducting magnets
- Estimate at completion by Level 4
 - 475.04.05.01 Power leads (\$652k)
 - 475.04.05.02 Cryogenic Feed Boxes (\$4,822k)
 - 475.04.05.03 Cryogenic Transfer Lines (\$1,037k)
 - 475.04.05.04 Cryogenic Interconnects (\$551k)
 - 475.04.05.05 Insulating Vacuum (\$1,902K)
 - 475.04.05.07 Cryogenic Distribution Box (\$2,328k)
- Basis of Estimate
 - Components are very similar to systems designs for other Fermilab Cryogenic Distribution systems
 - Engineering estimates based on application of similar technology in other Fermilab cryogenic construction projects



WBS 475.4.10 System Integration, Installation and Commissioning

- We are responsible for the installation and commissioning of the solenoid deliverables
- We are responsible for the internal integration of solenoid component and co-responsible for all interfaces to experiment
- Estimate at completion: \$5,135K
 - Predominately Labor
- Basis of Estimate
 - Developed in close collaboration with those responsible for the solenoid deliverables and the L2's for Muon Beamline and Civil Construction
 - Engineering estimates based on extensive experience from other Fermilab magnet construction projects



Largest Solenoid Risks

As listed in the Mu2e Risk Register

SOL- 157: PS conductor (made by a third party vendor) first article does not meet specifications

- While we are utilizing proven existing technology and have made prototypes of each of the Mu2e conductor, PS conductor is the most challenging to build
- Schedule delay because first production article of the PS conductor does not meet specifications. This would require another iteration that could take up to a year
 - Risk Impact: \$2000k.
 - Probability: Moderate
- Mitigation: We work closely with the vendor to ensure success. We will require a 100m prototype to demonstrate that the process has converged followed by a first article production length. Once these are approved we will move to full production.

Solenoid Risks Continued...

SOL- 066: Critical path delayed due to long solenoid schedule delay.

- The solenoids are on the critical path, so any delay to their schedule almost certainly delays the overall project schedule. There are many potential sources of delay including technical difficulties, failure to include all of the steps or adequate durations in the schedule, commissioning problems, etc.
 - Risk Impact: \$2000k.
 - Probability: Moderate
- Mitigation: Site visits to potential vendors before award of contract to make sure they understand technical requirements and to verify their capabilities. Site visits during fabrication to verify technical and schedule performance. Design flexibility into installation schedule so if one solenoid is late the installation of the others can proceed.

Solenoid Risks Continued...

SOL- 080: Insufficient testing of DS and/or PS at Vendor

- The selected solenoid vendor plans to do a cold test at liquid helium temperatures. However, because of the significant infrastructure required to test at full power, vendor contract does NOT require DS and PS site full power test. If serious problem is uncovered at Fermilab, magnet would be send back to vendor and disassembled
 - Risk Impact: \$2000k.
 - Probability: Low
- Mitigation: Thorough testing of conductor prior to fabrication. Significant safety margin built into design. Independent design reviews and formation of an independent Solenoid Acquisition Oversight Committee. Detailed in-process QA/QC program. Require vendor to produce a practice coil to validate fabrication design. Site visits prior to bid award to validate vendor capabilities and during fabrication to ensure execution of QC program. Note we are discussing with vendor about the cost of performing full power test at site.

Solenoid Risks continued

SOL- 070: Interface problems with the solenoids.

- The assembled solenoids must function as an integrated magnetic system. The solenoids will all be built by different vendors. Poorly specified interface requirements could lead to mechanical interface problems or to the wrong field configurations in the interface regions.
 - Risk Impact: \$1000k.
 - Probability: Low-Moderate
- Mitigation: Work with vendors to understand how to best specify and manage interfaces and maintain constant and effective communication during the design and construction phases with all concerned parties. Since we are building the TS, include tolerance matching (mechanical and magnetic) into the design.

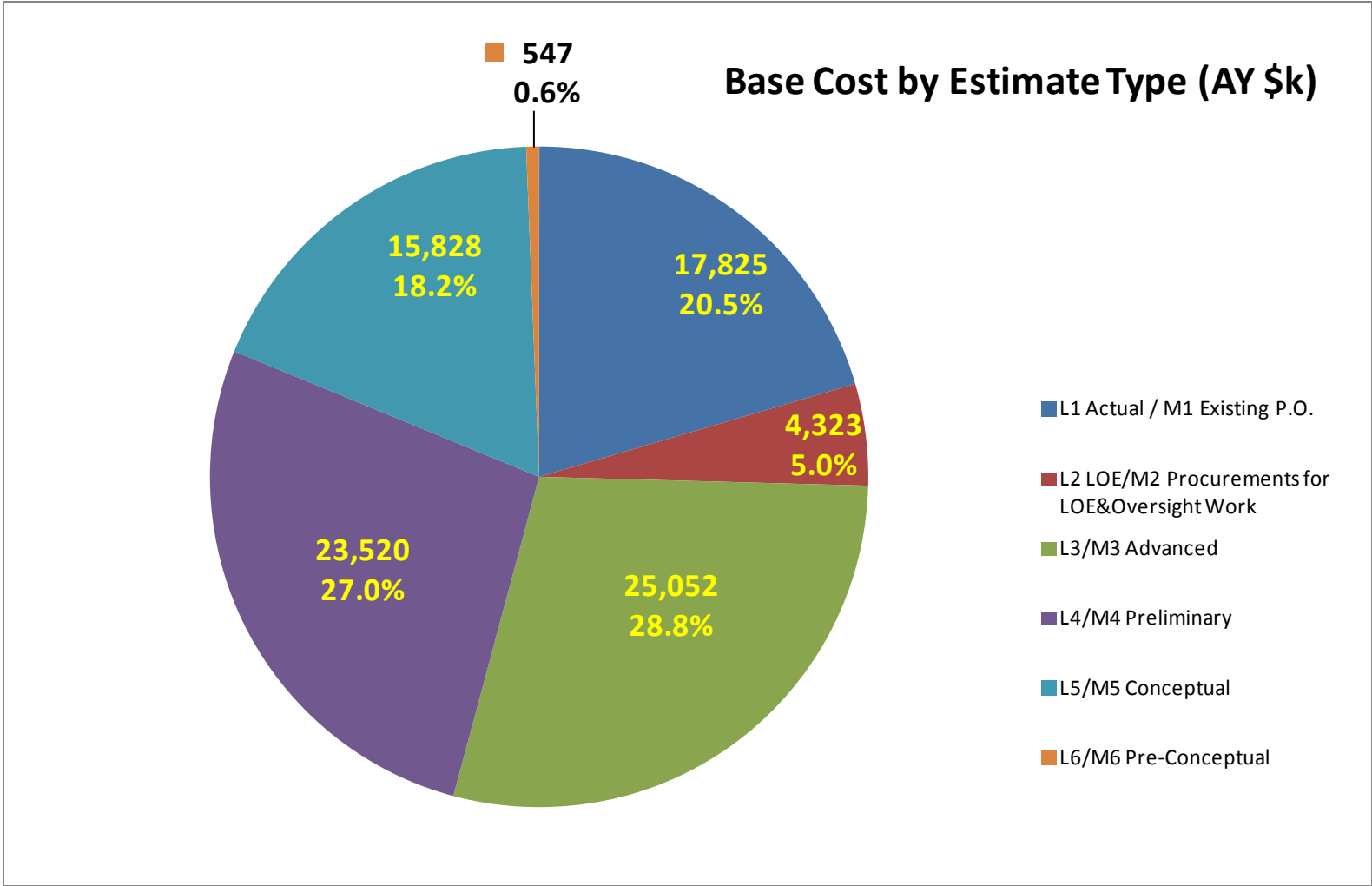
Solenoid Costs by L3's

Costs are fully burdened
in AY \$k

475.04 Solenoids

	M & S	Labor	Base Cost	Estimate Uncertainty	% Contingency on ETC	Total
475.04.01 Project Management	610	2,855	3,465	501	20%	3,966
475.04.02 Production Solenoid	12,357	2,325	14,682	2,287	17%	16,970
475.04.03 Transport Solenoids	12,445	11,381	23,826	8,039	41%	31,865
475.04.04 Detector Solenoid	13,830	2,171	16,001	2,632	17%	18,633
475.04.05 Cryogenic System	5,191	6,353	11,544	3,993	37%	15,537
475.04.06 Magnet Power System	901	594	1,495	385	31%	1,880
475.04.07 Magnet Quench Protection System	734	2,178	2,913	980	39%	3,892
475.04.08 Magnetic Field Mapping System	339	710	1,048	446	43%	1,494
475.04.09 Ancillary Equipment	306	653	959	410	43%	1,369
475.04.10 System Integration, Installation and Commissioning	541	4,594	5,135	1,848	39%	6,982
475.04.11 Solenoids Conceptual Design/R&D	680	5,349	6,029			6,029
475.04.99 Risk Based Contingency				1,196		1,196
Total	47,934	39,162	87,097	22,717	31%	109,814

Quality of Estimate



Summary

- Estimates for Mu2e Solenoids are complete
 - 80% of cost understood at the Preliminary Design level or higher
- Risks understood, mitigated where possible. Cost set aside as contingency to cover residual risks.
- Estimates are traceable
 - Comprehensive set of BOEs and backup information developed