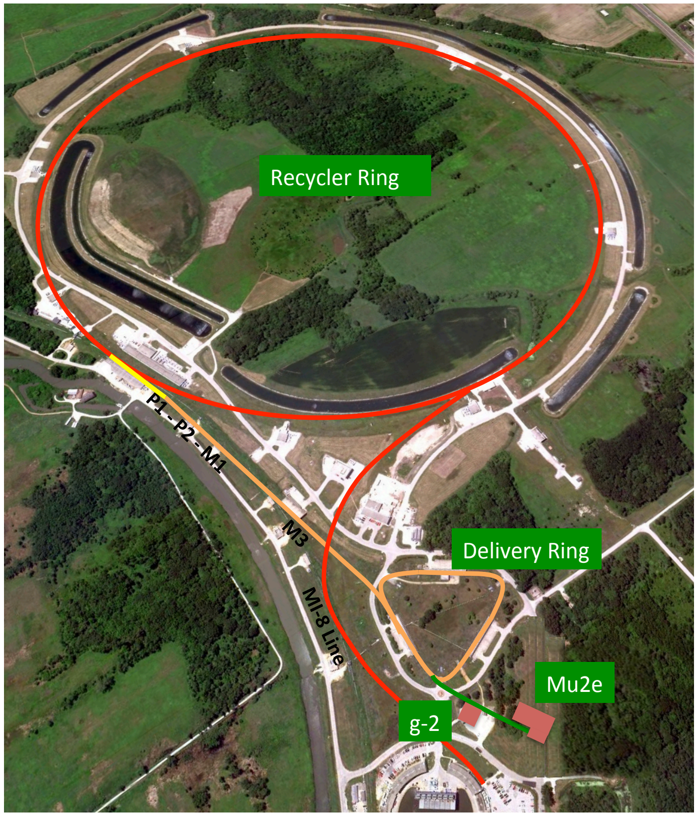
Mu2e Project Overview

Ron Ray
Mu2e Project Manager
10/21/2014

Introduction

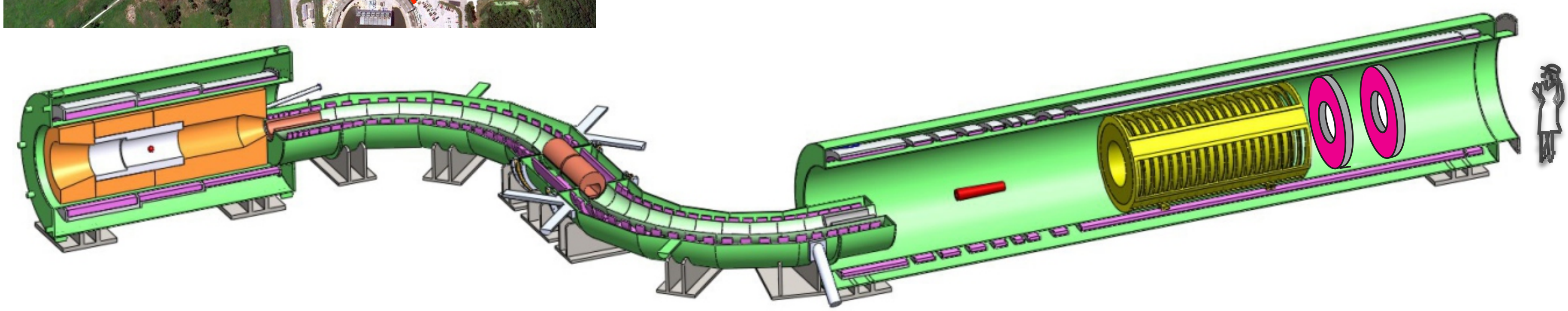
- Mu2e is a compelling discovery experiment with sensitivity to a broad range of new physics
  - Reach extends to 10^4 TeV, beyond the reach of any current or planned accelerator.
- Synergistic part of the overall muon program at Fermilab
- Full cost, schedule and risk analysis has been developed resulting in a Total Project Cost of $271M, matching the funding profile from OHEP.
- Requesting CD-2 approval for full Project along with CD-3b approval for the Mu2e Detector Hall and the Transport Solenoid Modules.

Mu2e Project Scope



Mu2e Project scope includes

- New building to house experiment
- Modifications/additions to accelerator complex
- Mu2e apparatus
  - Superconducting Solenoids
  - Tracker
  - Calorimeter
  - Cosmic Ray Veto (not shown)
  - DAQ



Additional Contributions to Mu2e

The scope required for Mu2e to become a functioning experiment comes from several sources

- Mu2e Project
- NOvA Project
  - MI-8 connection to Recycler and Recycler Injection Kicker
- Muon Campus common projects needed for both Mu2e and g-2
  - MC1 building houses power supplies for Mu2e beamline, extinction system and cryo plant
  - Beam Transport Accelerator Improvement Project (AIP)
  - Cryo Facility AIP
  - Delivery Ring AIP
  - Recycler Ring RF AIP
  - Beamline Enclosure General Plant Project (GPP)
  - Muon Campus Infrastructure GPP
- In-kind contribution from INFN for significant part of calorimeter and contributions to the solenoids
- Off project work tracked in Mu2e schedule via external milestones.

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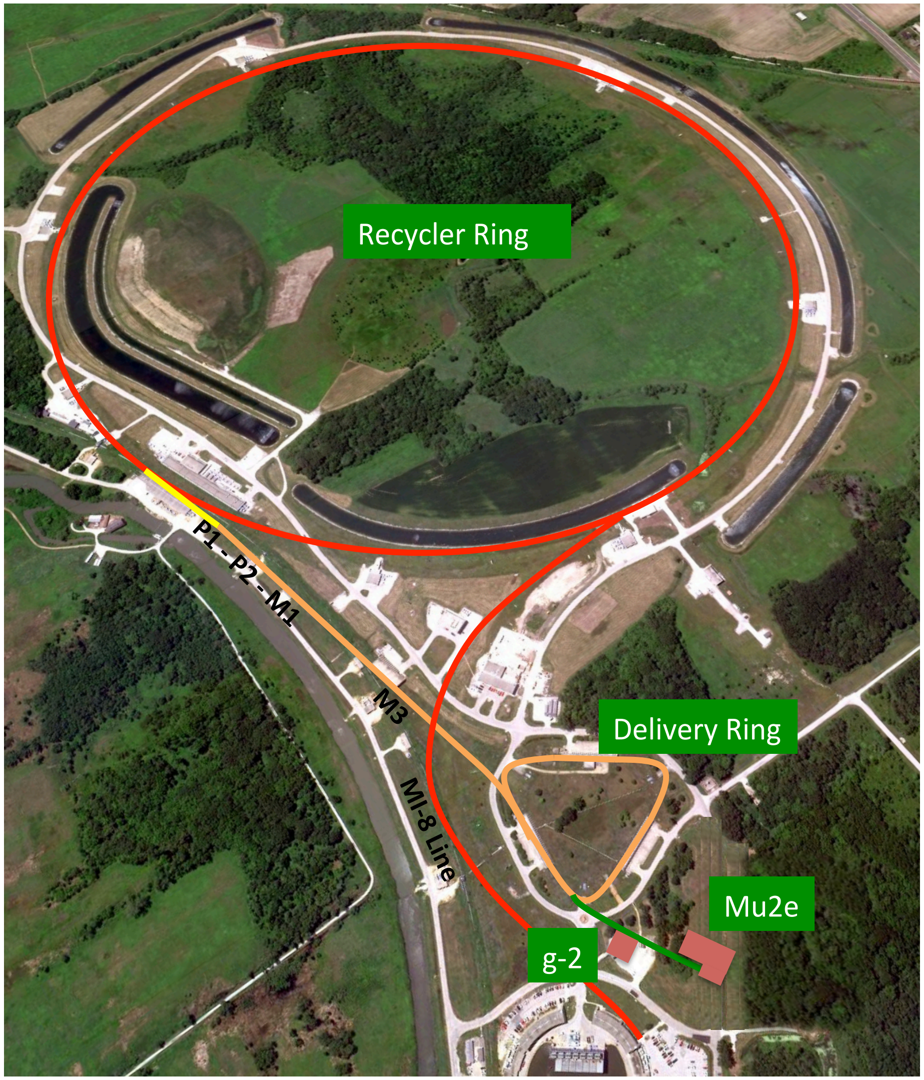
Muon Campus Common Projects managed by Mary Convery. Required by g-2 long before they are needed by Mu2e.

How Does the Experiment Work?

What Drives the design?

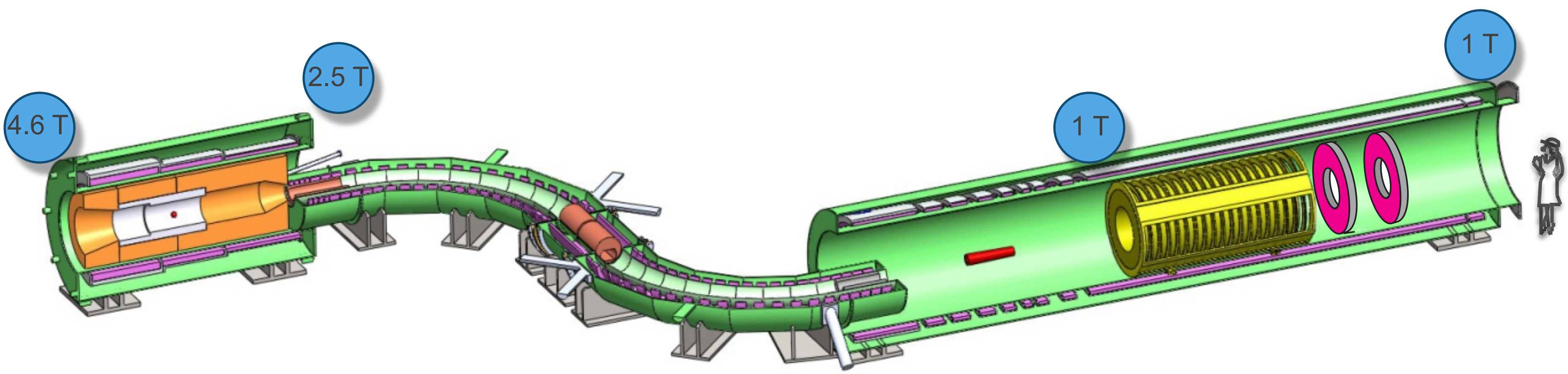
Beam Delivery



- We make muons by directing 8 GeV protons on to a target.
- Batches of protons from the Booster are transported through existing beamlines to the Recycler Ring where they are re-bunched and transported to the Delivery Ring through existing transport lines.
- Beam is slow extracted from Delivery Ring in microbunches of ~ 10^7 protons every 1694 ns through a new external beamline to the Mu2e production target.
- An *extinction system* removes residual protons between microbunches.
- Mu2e can run simultaneously with NOvA and Booster Neutrino Program.

Mu2e Apparatus

- Solenoids capture pions, form secondary muon beam, preserve timing structure, provide magnetic field for momentum analysis and help to reject backgrounds
  - Most efficient way of producing an intense, low energy muon beam



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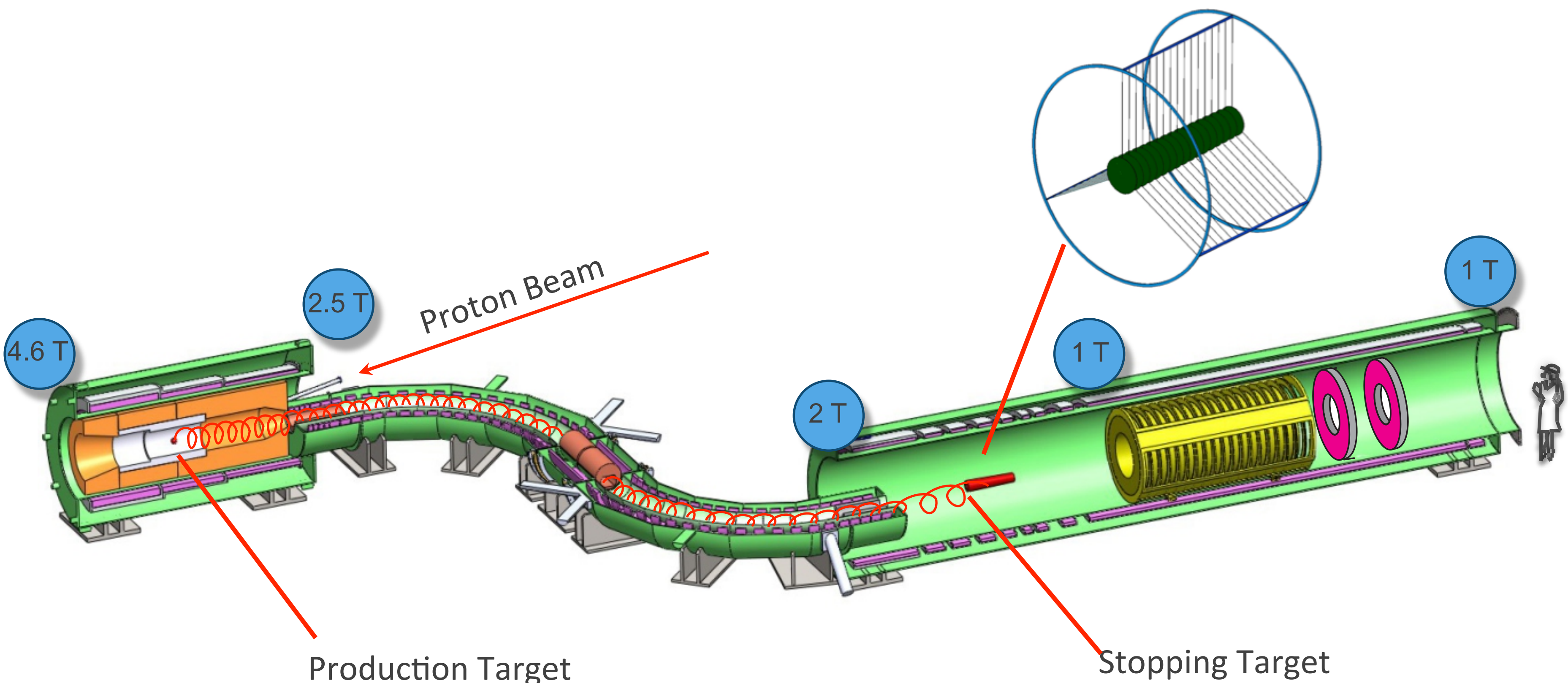

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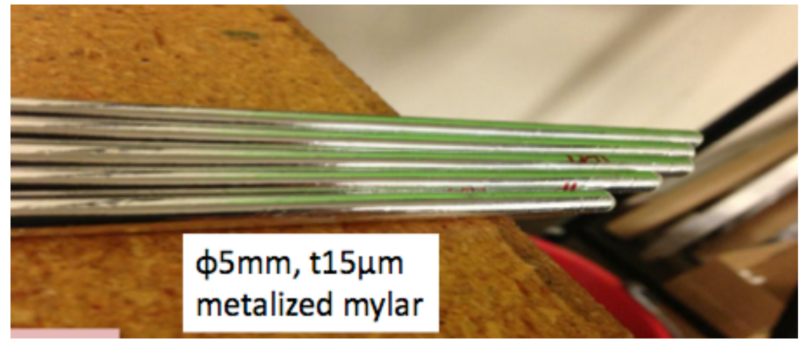
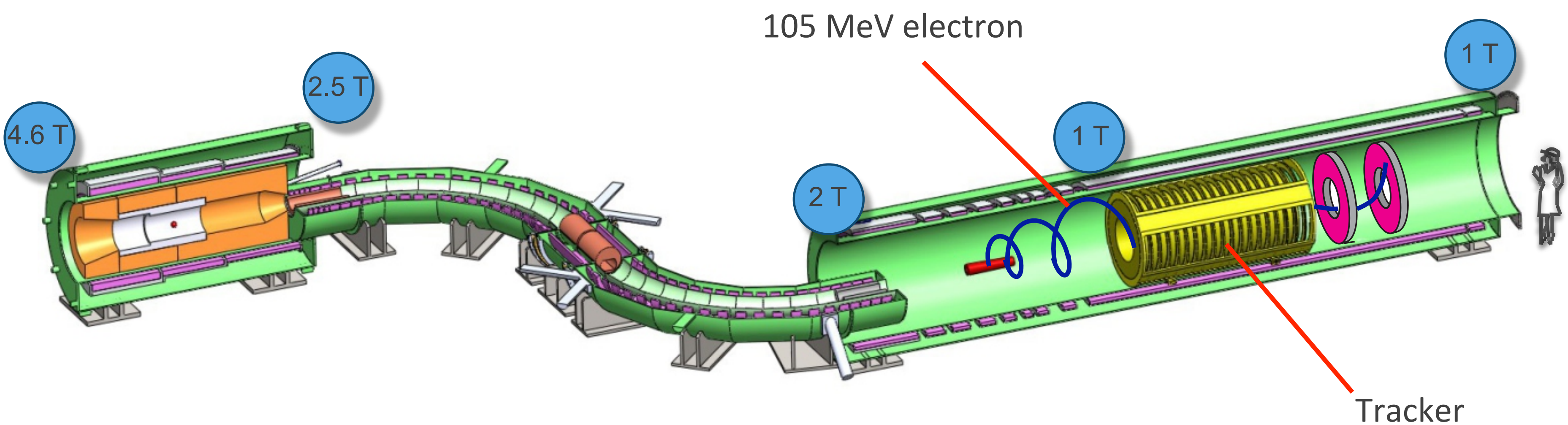
- Tracker – Straw tubes





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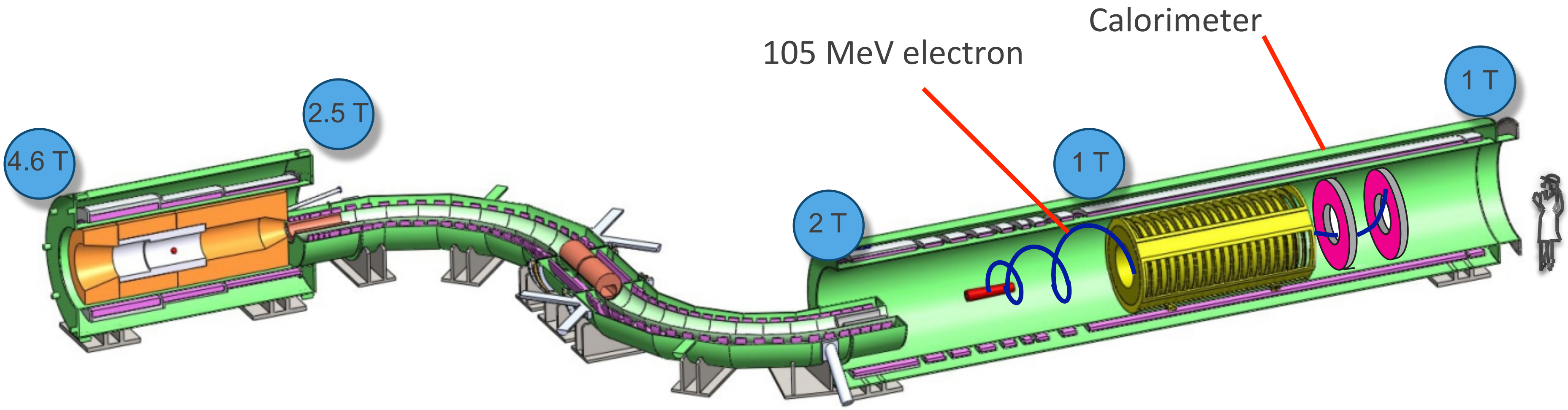

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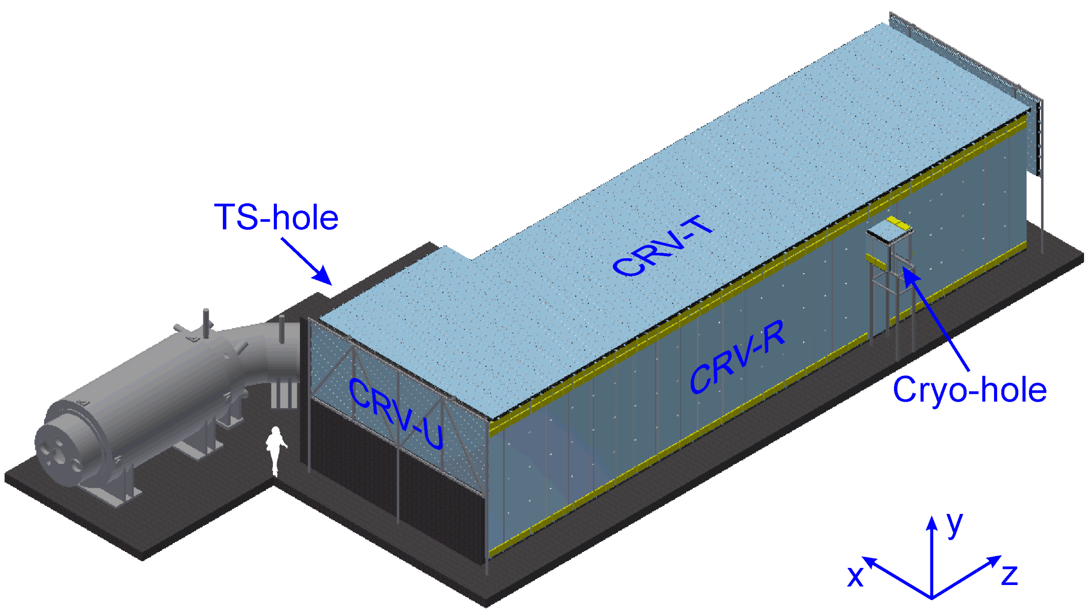

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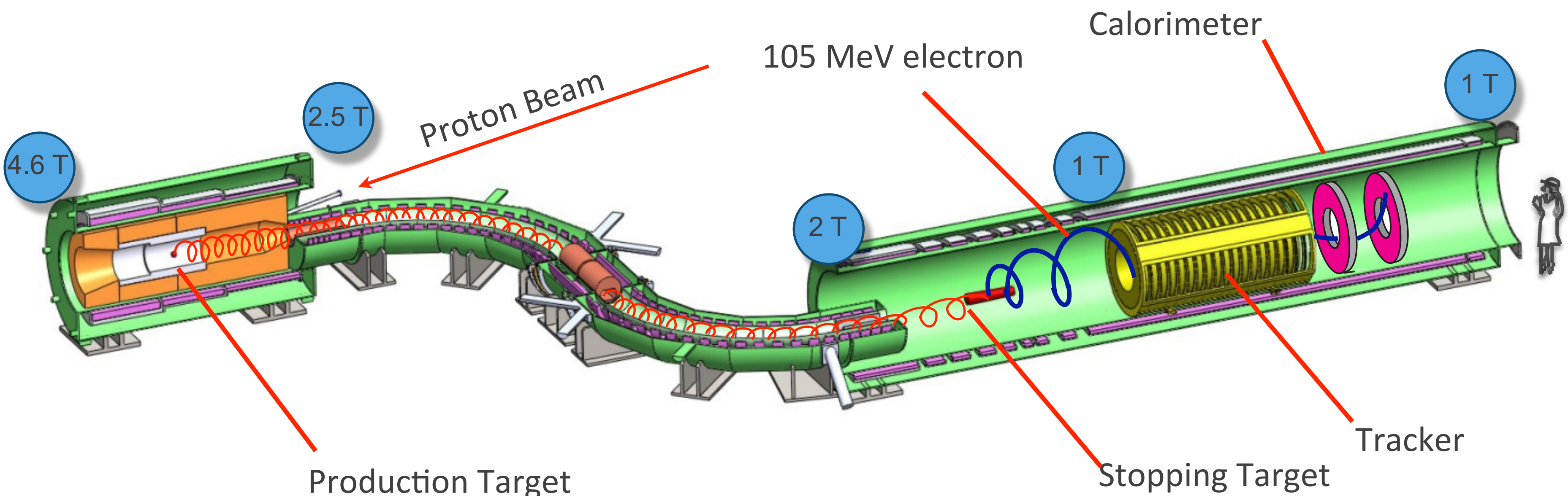
- Warm bore of solenoids evacuated to 10^{-4} to 10^{-5} Torr.

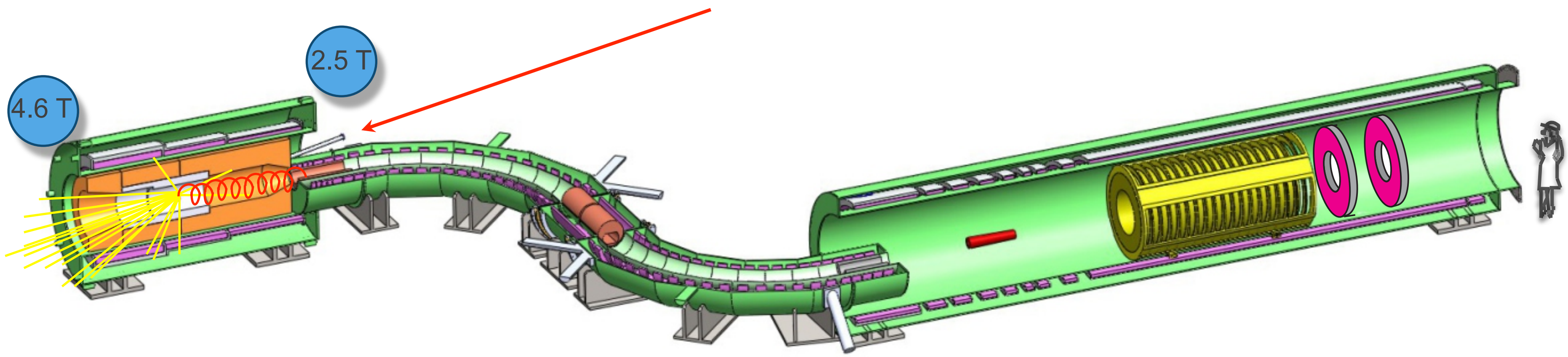
Cosmic Ray Veto and Stopping Target Monitor not shown



Mu2e Apparatus

Production Solenoid

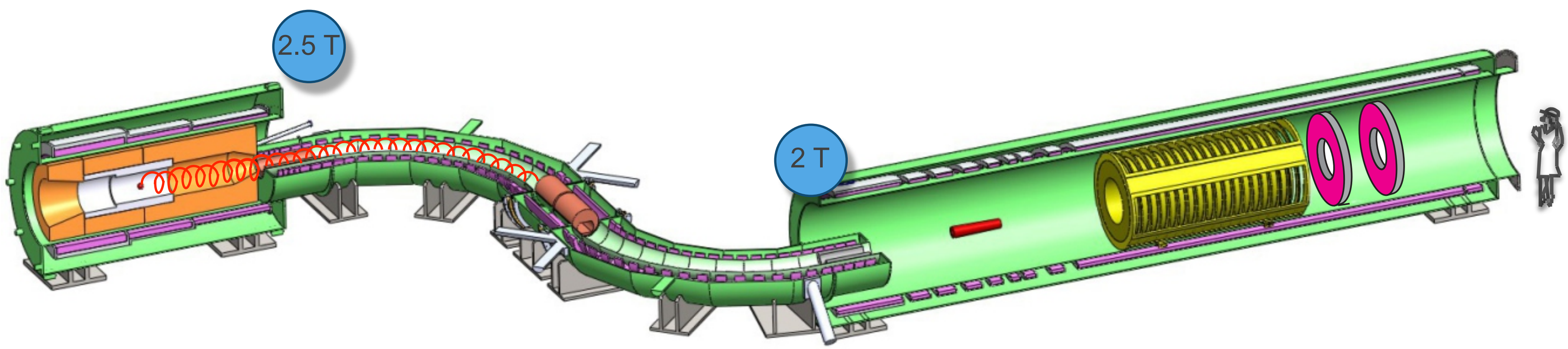
- Houses Production Target
- Inner bore lined with a bronze and water heat and radiation shield to limit radiation damage
- Captures pions and accelerates them towards the other solenoids



Mu2e Apparatus

Transport Solenoid

- Collimation system selects muon charge and momentum range
- Pbar window in middle of central collimator



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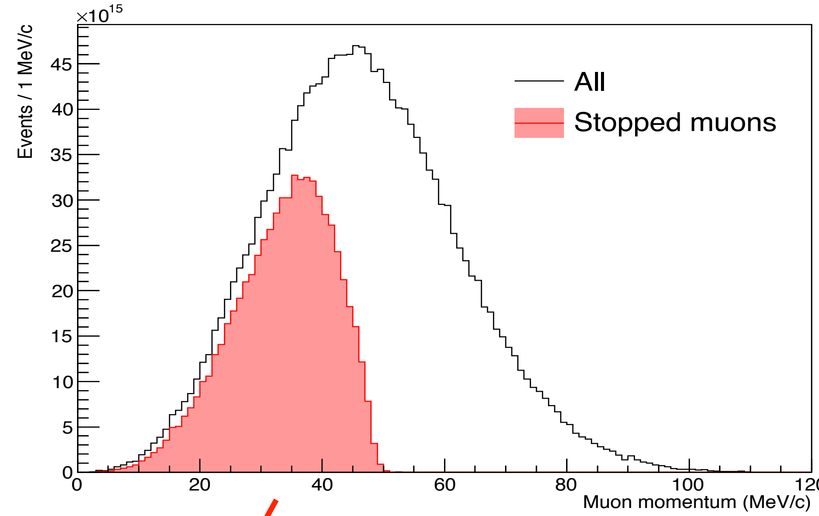
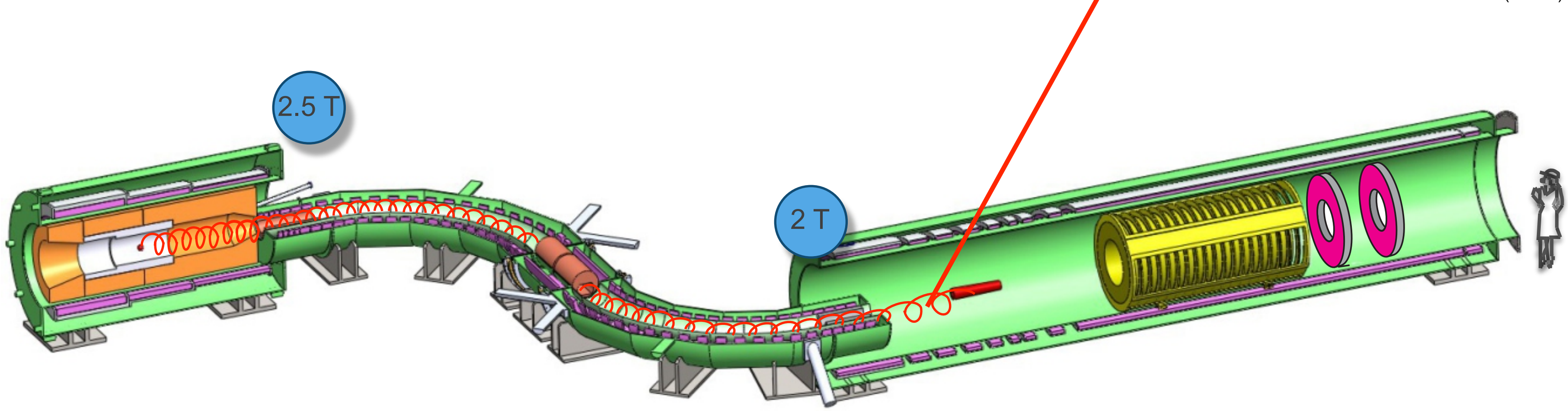
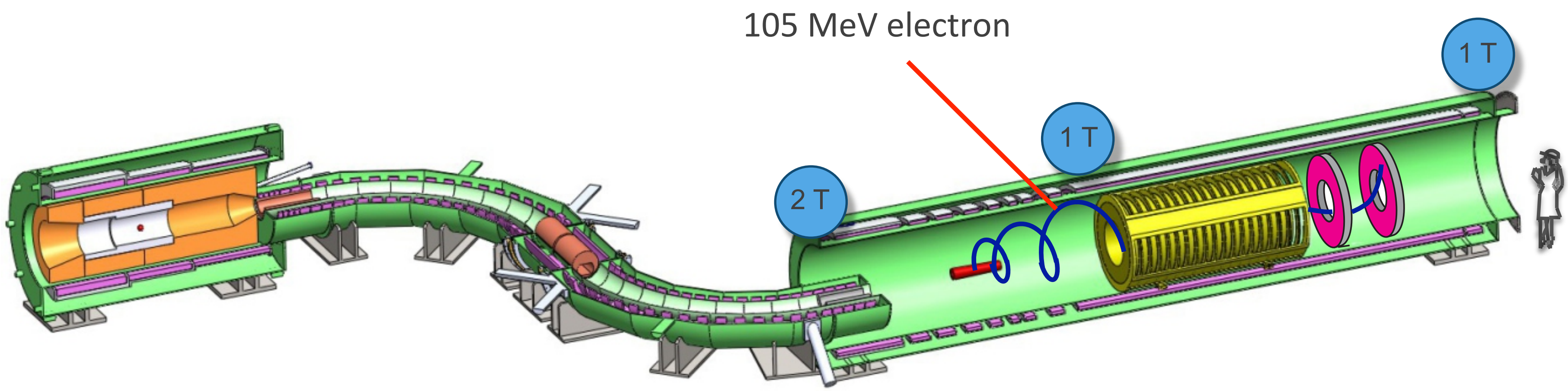




Mu2e Apparatus

Detector Solenoid

- Graded upstream field to improve acceptance and reject backgrounds
- Uniform field downstream for momentum analysis



Design Drivers

- High level requirements are driven by the science
  - Background rejection
  - High efficiency reconstruction of conversion electrons
- Discussed extensively in TDR Chapter 3
  - Physics requirements listed at end of Chapter 3.
    - These are the requirements that must be met to reject backgrounds to the required level and achieve the target sensitivity.
  - The physics requirements flow down to the Project subsystem requirements and design.

Requirements Management

Topic	Document Database N
Science Driven Requirements	Mu2e-doc-4381
Proton Beam	Mu2e-doc-1105
Extinction	Mu2e-doc-1175
Extinction Monitoring	Mu2e-doc-894
Production Target	Mu2e-doc-887
Heat and Radiation Shield	Mu2e-doc-1092
Proton Beam Absorber	Mu2e-doc-948
Conventional Facilities	Mu2e-doc-1088
Production Solenoid	Mu2e-doc-945
Transport Solenoid	Mu2e-doc-947
Detector Solenoid	Mu2e-doc-946
Cryoplant	Mu2e-doc-1509
Cryo Distribution	Mu2e-doc-1244
Quench Protection	Mu2e-doc-1238
Solenoid Power System	Mu2e-doc-1237
Magnetic Field Mapping	Mu2e-doc-1275
Stopping Target	Mu2e-doc-1437
Stopping Target Monitor	Mu2e-doc-1438
Transport Solenoid Collimators	Mu2e-doc-1129
Muon Beam Stop	Mu2e-doc-1351
Vacuum System	Mu2e-doc-1481
Proton Absorber	Mu2e-doc-1439
Neutron Absorbers	Mu2e-doc-1371
Muon Beamline Shielding	Mu2e-doc-1506
Detector Support and Installation System	Mu2e-doc-1383
Pbar Window	Mu2e-doc-941
Tracker	Mu2e-doc-732
Calorimeter	Mu2e-doc-864
Cosmic Ray Veto	Mu2e-doc-944
Calibration	Mu2e-doc-1182
Trigger and DAQ	Mu2e-doc-1150

- Requirements necessary to execute the experiment have been developed primarily by the Collaboration
- Under configuration management.
- Electronically signed by responsible parties. Automatic notification if document is changed.
  - Part of Configuration Management.
- Signed version is the official document.

Integration

- Integration is required to bring component subsystems together into a single functioning system.
  - Must be built into the design process from the beginning.
- Integration is achieved in Mu2e via meetings, documentation, 3D drawings and agreements between responsible parties.
- Completed, agreed upon interfaces are part of the final design of a system.
  - In Mu2e, final designs include signed interface agreements.
- For the preliminary design we require that each subsystem have a document that identifies and defines each interface, both internal and external.
- More detail in plenary talk by K. Krempetz (Project Engineer) later today.

Example – CRV Interface Document

CRV is ready for CD-2, so they have a document that identifies and describes all interfaces (docdb# 1551)

Mu2e Project Document No.1551
Cosmic Ray Veto Interface Specifications

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3. EXTERNAL INTERFACES

Item	*Interface*	*Description*	*Owners*	*Reference Documents/ Drawings*
108.03.2.1	Scintillator Extrusions to Muon Beamline	Muon beamline shielding must be sufficient to keep radiation levels to below 1 kGy at scintillator extrusions.	475.08.03 475.05.09	
108.04.2.1	Fibers to Muon Beamline	Muon beamline shielding must be sufficient to keep radiation levels to below 1 kGy at fibers.	475.08.04 475.05.09	
108.05.2.1	Photodetector to Muon Beamline	Muon beamline shielding must be sufficient to keep radiation levels to below 1E10 n/cm^2 at the photodetectors.	475.08.05 475.05.09	
108.06.2.1	Electronics Mu2e building	The readout and power cables from the front-end boards must be routed to the readout controllers situated in the electronics room by cable trays installed in the detector hall. Power supplies for the readout controllers will be placed in the electronics room, adjacent to the readout controllers. The electrical distribution system should provide adequate power for the CRV electronics.	475.08.06 475.03	
108.06.2.2	Electronics Trigger and DAQ	The front-end board readout controllers must communicate with the DAQ and slow control system to allow data to be taken from the CRV and controls to be sent to the CRV front-end electronics. The DAQ must provide a clock with 1 ns timing resolution for the front-end boards.	475.08.06 475.09	

Example – Conventional Construction Interface Document

Conventional Construction has a final design, so we have signed agreements between all responsible parties. Owners and relevant drawings referenced (docdb #1537 – linked to Review page)

Item	***Interface***	***Description***	***Owners***	***Reference Documents/ Drawings[2]***
103.06.2.15	Mechanical Room	Space/room is needed for vacuum pumps, and detector/electronic cooling. Utility chase and penetrations are provided. Proper sealing of penetration are needed to be provided by user.	WBS475.03/ &WBS475.05, &WBS475.06, &WBS475.07, &WBS475.09 &OFF 475	A-3, M-5, M-7, M-8, M-9, M-21
103.06.2.16	Solenoid Support	Track Plates are provided to transport and support the solenoid system. Each solenoid will be mounted to a support frame. This frame will transfer the loads from the cryostat to the Mu2e building floor. Clearance around this frame is required for the CRV and shielding. Base plates anchored to the mat foundation resists the solenoid loadings. The flatness requirement and installation tolerance of the steel plate and surrounding concrete is specified at half mill tollerance.	WBS475.03/ WBS475.04	SC-29 TO SC-33
103.06.2.17	Diagnostic Abort	MC Beamline Enclosure project constructs the Abort system, comprised of cast in place concrete and place steel core. The abort was designed by WBS475.02 and will be installed under the MC Beamline Enclosure project 6-10-22.	WBS475.03/ WBS475.02	6-10-22/SC-20

Example – Conventional Construction Interface Document

103.6.2.1	1537v15 (cert)	Interface CF: NEPA/Environment	approved
103.6.2.2	1537v15 (cert)	Interface CF: ESH&Q	
103.6.2.3	1537v15 (cert)	Interface CF: Access Roads, Parking and Hardstand	
103.6.2.4	1537v15 (cert)	Interface CF: Utilities-DWS	
103.6.2.5	1537v15 (cert)	Interface CF: Utilities-ICW	
103.6.2.6	1537v15 (cert)	Interface CF: Utilities-CHW	approved
103.6.2.7	1537v15 (cert)	Interface CF: Utilities-LCW	approved
103.6.2.8	1537v15 (cert)	Interface CF: Utilities-San	approved
103.6.2.9	1537v15 (cert)	Interface CF: Utilities-Nat Gas	approved
103.6.2.10	1537v15 (cert)	Interface CF: Utilities-FIRUS	approved
103.6.2.11	1537v15 (cert)	Interface CF: Utilities-Electric	approved
103.6.2.12	1537v15 (cert)	Interface CF: High Bay Area	approved
103.6.2.13	1537v15 (cert)	Interface CF: Solenoid Power Supply Room	approved
103.6.2.14	1537v15 (cert)	Interface CF: DAQ Rack Room	approved
103.6.2.15	1537v15 (cert)	Interface CF: Mechanical Room	approved
103.6.2.16	1537v15 (cert)	Interface CF: Solenoid Support	approved

Web-based approval system set up by Configuration Manager (H. Glass)

40 Interface agreements for Conventional Construction

Example – Conventional Construction Interface Document

103.6.2.1	1537v15 (cert)	Interface CF: NEPA/Environment	approved
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103.6.2.3	1537v15 (cert)	Interface CF: Access Roads, Parking and Hardstand	approved
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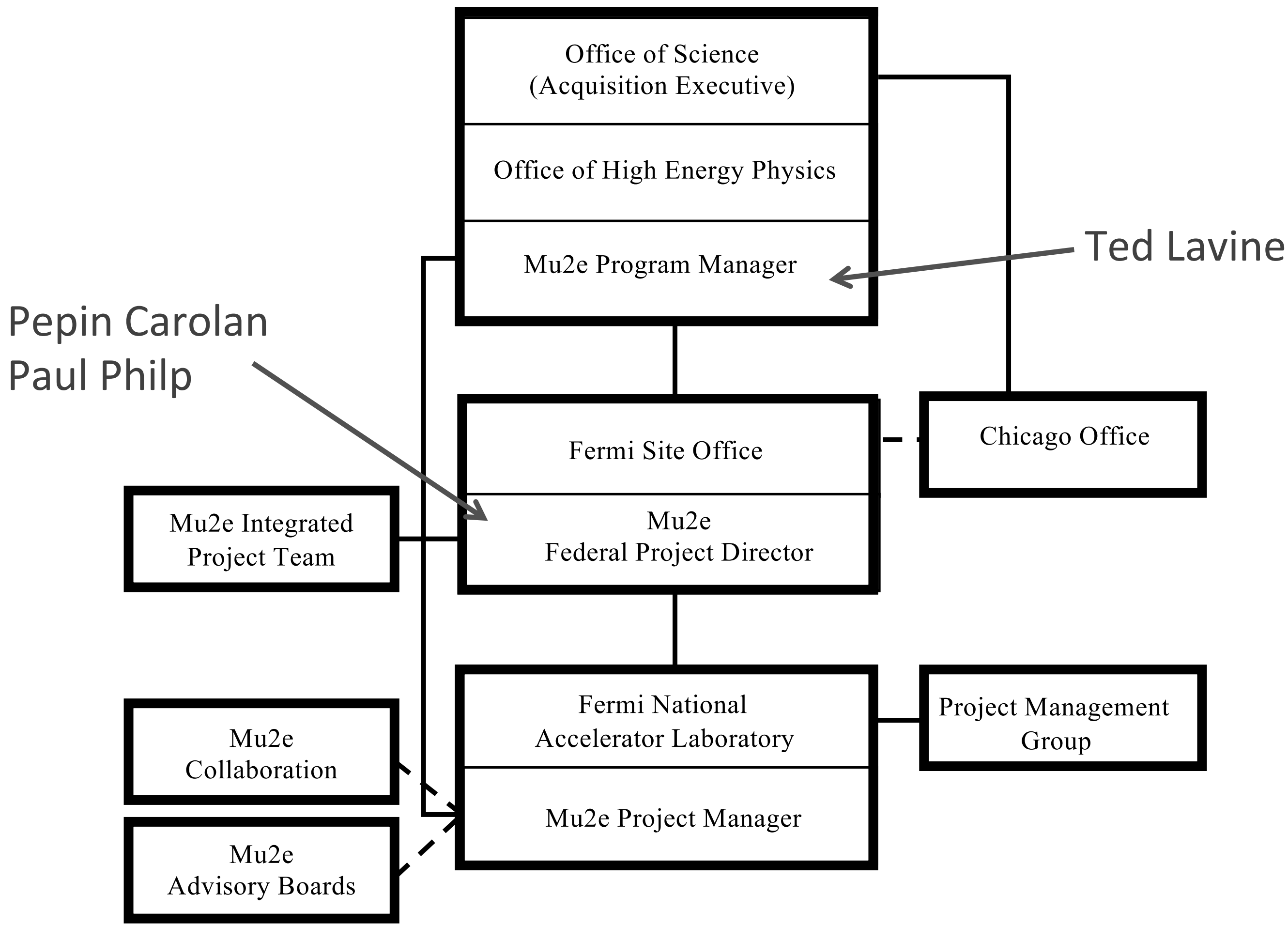
103.6.2.9	1537v15 (cert)	Interface CF: Utilities-Nat Gas	approved
103.6.2.10	1537v15 (cert)	Interface CF: Utilities-FIRUS	approved
103.6.2.11	1537v15 (cert)	Interface CF: Utilities-Electric	approved
103.6.2.12	1537v15 (cert)	Interface CF: High Bay Area	approved
1			approved
1			approved
1			approved
1			approved

First Name	Last Name	Signoff Status	Signoff Date
Dee	Hahn	signed	2014-09-29
Thomas	Lackowski	signed	2014-10-02

Management and Organization



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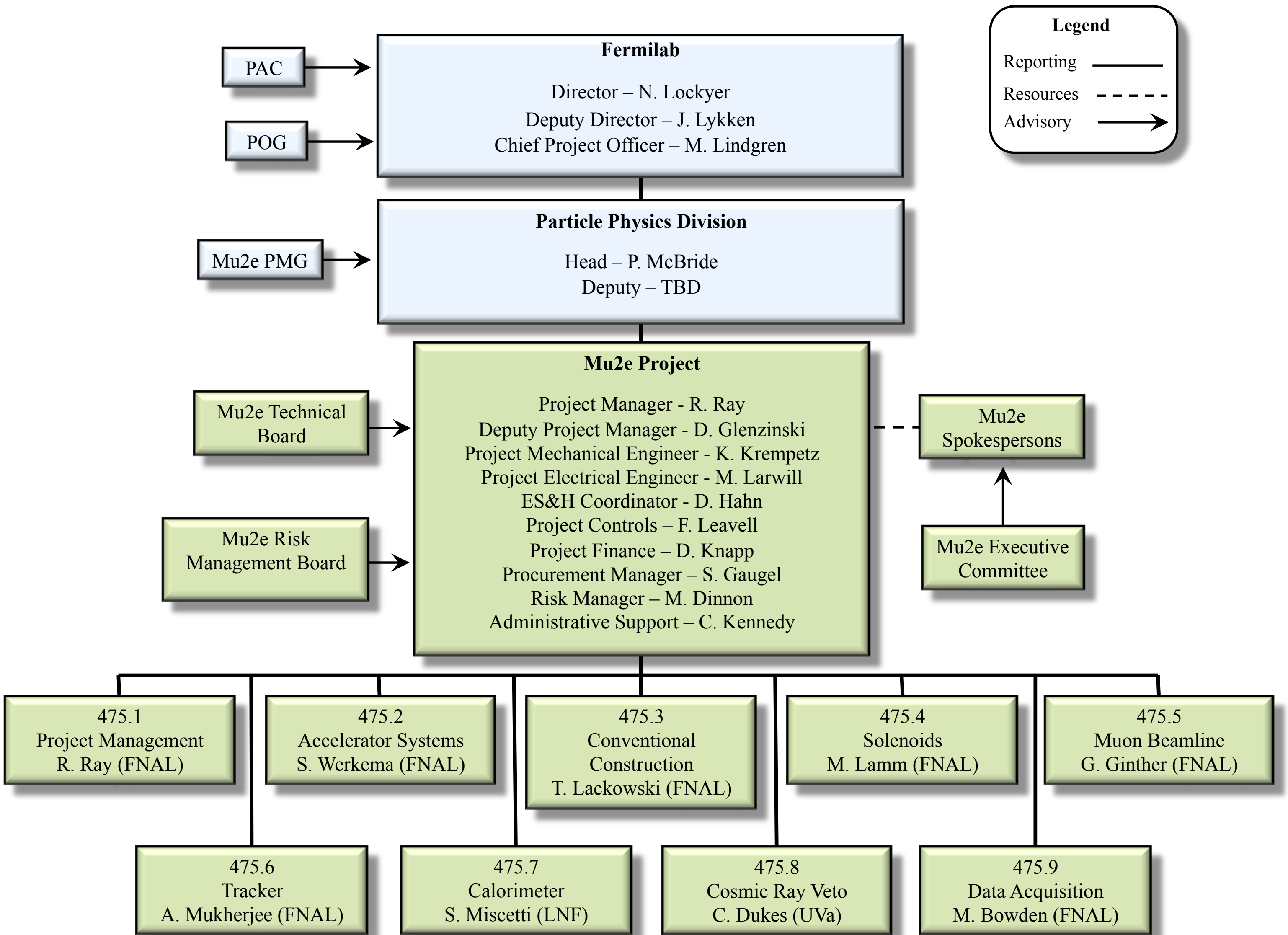

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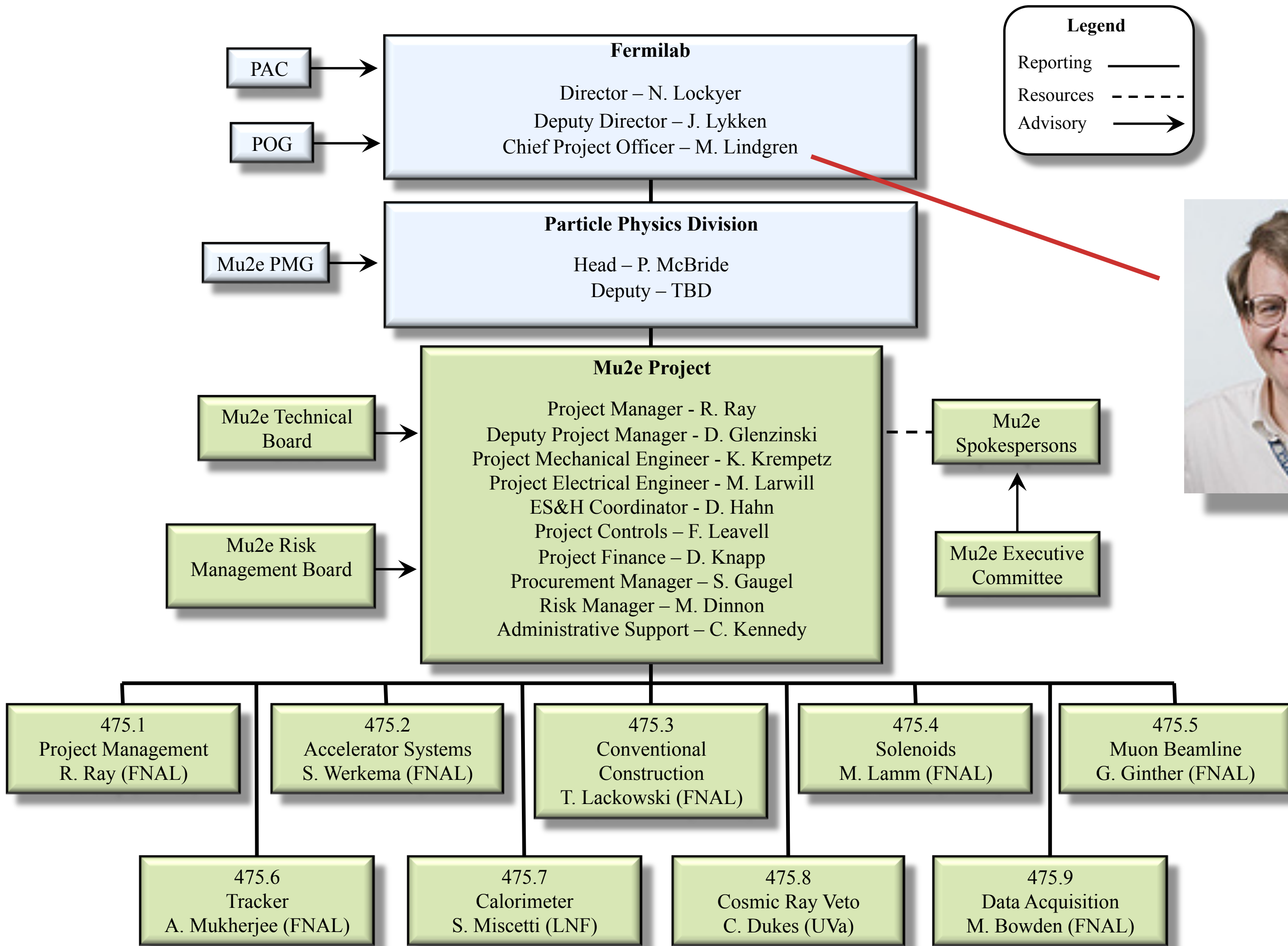
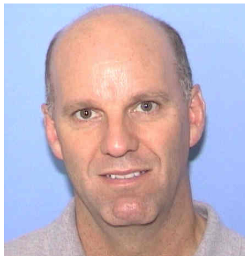


L2 Managers





1
Project Management
R. Ray
FNAL

2
Accelerator
S. Werkema
FNAL

3
Conventional Construction
T. Lackowski
FNAL

4
Solenoids
M. Lamm
FNAL

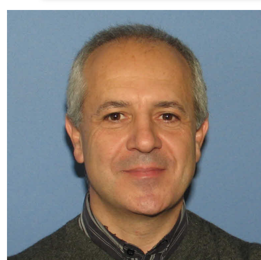
5
Muon Beamline
G. Ginther
FNAL

6
Tracker
A. Mukherjee
FNAL

7
Calorimeter
S. Miscetti
Frascati

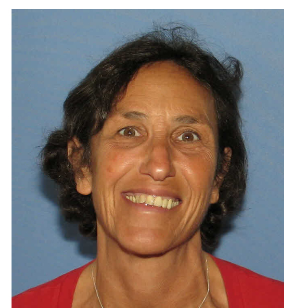
8
Cosmic Ray Veto
C. Dukes
UVa.

9
Trigger and DAQ
M. Bowden
FNAL

Project Office

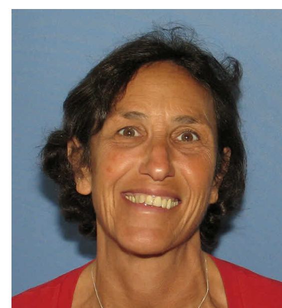
Ron Ray	PM
Doug Glenzinski	Deputy PM - outgoing
Kurt Krempetz	Project Mechanical Engineer/ Systems Integration
Marcus Larwill	Project Electrical Engineer/ Systems Integration
Fran Leavell	Lead Project Controls
David Leeb	Project Controls
Halley Brown	Project Controls
Mike Gardner	Project Controls
Dale Knapp	Financial Officer
Dee Hahn	ES&H Coordinator
Cindy Kennedy	Admin support
Steve Gaugel	Procurement Manager
Mike Dinnon	Risk Management
Hank Glass	Configuration Management
Eric James	Installation and Integration Coordinator
Dervin Allen	Installation and Integration Floor Manager



Project Office

- Ron Ray — PM
- Julie Whitmore — Deputy PM - incoming
- Kurt Krempetz — Project Mechanical Engineer/ Systems Integration
- Marcus Larwill — Project Electrical Engineer/ Systems Integration
- Fran Leavell — Lead Project Controls
- David Leeb — Project Controls
- Halley Brown — Project Controls
- Mike Gardner — Project Controls
- Dale Knapp — Financial Officer
- Dee Hahn — ES&H Coordinator
- Cindy Kennedy — Admin support
- Steve Gaugel — Procurement Manager
- Mike Dinnon — Risk Management
- Hank Glass — Configuration Management
- Eric James — Installation and Integration Coordinator
- Dervin Allen — Installation and Integration Floor Manager




ESH&Q

- Fermilab and Mu2e Project firmly committed to safety and quality.
- Safety integrated into Lab management at all levels.
  - Project embedded in Lab's line Management
- Oversight by Lab ESH&Q organization as well as by Division & Section ES&H organizations
- Project ES&H coordinator – Dee Hahn
- Integrated Safety Management Plan developed (docdb 785)
- Hazard Analysis Report including evaluation and mitigation of safety risks developed and posted (docdb 4229)
- NEPA approval obtained in 2012 (docdb 2274)
- Preliminary Shielding Assessment approval (docdb 4313)
- Preliminary approval of Total Loss Monitors (TLM) as a credited safety system (docdb 4132)
- Quality Assurance Program (docdb 677)
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> - Dedicated ES&H talk by D. Hahn in Management Breakout
> - Dedicated QA talk by D. Glenzinski in Management Breakout

Cost and Schedule

Cost Methodology

General Procedure

- Activity-based RLS. M&S, labor hours, resources and durations established at activity level.
- Estimators instructed to use 85% C.L. base estimates
- Estimate uncertainty is added to each activity based on the level of design maturity.
- A statistical evaluation of the cost associated with risk exposure adds additional contingency to the Project

TPC = base estimate +
100% estimation uncertainty +
statistical evaluation of risks at 80% C.L.
+ application of burdening and escalation

WBS Dictionary

- WBS defines Project Scope
- Dictionary describes Scope, objective, deliverables and assumptions for each Control Account.
- Describes activities that make up the Control Account.

Control Account	WBS Name	WBS Extended Definition
475.02.05	Resonant Extraction System	**Cost Account Manager: V. Nagaslaev** **A. Technical Objective** The technical objective is to design, manufacture, and install the systems necessary for the resonant extraction of beam from the Delivery Ring synchrotron. **B. Scope of Work Statement** • General engineering design of the Delivery Ring resonant extraction system. • Design, manufacture, and installation of the resonant extraction electrostatic septum modules (two modules) and power supply. • Design, procurement, and installation of the resonant extraction tune quadrupole magnets and power supplies. • Design, manufacture, and installation of the resonant extraction harmonic sextupole magnets and power supplies. • Design, procurement/manufacture, and installation of the resonant extraction dynamic bump magnets and power supplies. • Design, manufacture, and installation of the RF knock out (RFKO) kicker and power supply. • Design, manufacture, and installation of the resonant extraction fast feedback devices and electronics. **C. Deliverables** • Two resonant extraction electrostatic septum modules and power supply installed plus two spare ESS modules (one spare of each type). • 3 CQA tune quadrupole magnets and power supplies. • 7 ISA harmonic sextupole magnets (6 + 1 spare) and power supplies. • RFKO kicker and power supply. • 4 NDB dynamic bump dipole magnets and power supplies. • Wall current monitor and associated feedback electronics.

BOEs

- Support the resources, cost, effort and durations in P6
- Include
  - Definition of scope covered
  - Supporting documents
  - Assumptions

Mu2e **BASIS of ESTIMATE (BoE)**	**Date of Estimate:** 6 / 26 / 2014 **Revision Date:** **Prepared by:** Julie Whitmore **Contributing:** Paul Rubinov, Yuri Oksuzian, Craig Dukes **Docdb #:** 3912

WBS number: 475.08.05.02 **Control Account:** 475.08.05 **WBS Title:** Photodetector Quality Assurance Design and Fabrication

WBS Dictionary Definition: This set of activities includes the labor and materials necessary to design and produce the Quality Assurance SiPM testing fixture for evaluating the SiPMs. The QA tester is needed to test a 10% sample of the production devices before accepting the SiPMs from the vendor. The production SiPMs are then sent to UVA for mounting on counter motherboards. There are a total of 18,816 SiPMs needed for CRV module production with an additional 1,526 SiPMs needed for spare modules. A total of 20,000 SiPMs are needed for production, including wastage, and radiation/longevity acceptance testing. In addition, a total of 5,000 spares will be needed. The cost for these spare devices and the labor for the 10% acceptance testing are off-project.

Supporting Documents (including but not limited to):
see Electronic docdb file referenced above for supporting documentation.
#862 includes the parameters for the CRV system.
#3911 Includes information on the Photodetector Procurement
Vendor summary of invoices for prototype QA jig materials and eng/tech effort to date.
P6 schedule spreadsheet corresponding to this BOE (Excel)

Quality Control Process Applied by: E. Craig Dukes **Date:** 6/26/14

Assumptions:
- BOE only covers activities from the baseline date of May 1, 2014 onward. Activities prior to the baseline date are entered into the schedule as actuals with 0% contingency.
- Costs are in 2014 dollars and do not include indirects.
- Durations are in working days.
- 1 FTE = 1768 hours for an average year. P6 uses the actual calendar for each year with the exact number of workdays.
- SiPMs are fabricated in industry.
- SiPMs are characterized using a custom testing tester (see WBS 475.05.02). Devices will be shipped to UVa for assembly onto SiPM counter motherboards (see WBS in CRV Electronics)

Currently Assigned Personnel

L2 Manager – E.C. Dukes
Deputy L2 Manager – J. Whitmore
L3 Manager – J. Whitmore

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BOEs

- Resources
- Hours
- M&S costs
- Estimate type/ contingency
- Durations at 85% C.L.

Task 475.8.5.2.1050 Fabricate QA prototype tester – M&S

M&S cost for prototype tester.

M&S Cost	$8000	Cost for tester chassis and misc electronics components
Duration	60 days	M&S purchases for rebuild after prototype design changes.
Estimate Type	Advanced	Contingency of 20% based on contingency rule M3. M&S based on fabrication of boards with similar design.

Task 475.8.5.2.1055 Fabricate QA prototype tester – remaining - FNAL

Labor for FNAL electrical engineer and technicians to procure components, fabricate, assemble and test the QA tester. Parts procurement, board layout/design, and board assembly is nearly completed. Tester assembly and testing is not.

Total Labor	292 hours	
Electrical Design Engineer	100 hours	Engineering estimate based on previous experience testing similar items. Assumes EE working 3 months at 0.25 FTE.
Engineering Physicist	80 hours	Engineering estimate based on previous NIU experience.
Electrical Drafter	40 hours	Engineering estimate based on previous board layout work.
Electrical Technician	8 hours	Engineering estimate based on previous experience procuring parts.
Electrical Assembly Technician	24 hours	Engineering estimate based on previous board assembly work.
Electronics Technician	40 hours	Engineering estimate based on previous NIU experience. Assumes 3 month at 10% FTE.
Duration	60 days	Assumes 3 months of above eng/tech effort.
Estimate Type	Preliminary	Contingency of 35% based on contingency rule L4.

Task 475.8.5.2.1062 Fabricate QA prototype tester – Labor – NIU remaining

Labor for NIU undergraduate student to write software for QA SiPM tester.

M&S	$16,131	595 Hours software support remaining. Engineering estimate based on similar projects.
Duration	162 days	Assumes student working for 4 FTE months.
Estimate Type	Conceptual	Contingency of 50% based on contingency rule L5. Higher end of range due to inexperienced student labor.

Task 475.8.5.2.1065 Fabricate QA dark box – Labor - NIU

Labor for NIU electrical technicians to design, procure components, and fabricate temperature stabilized dark box for testing prototype, pre-production, and production SiPMs.

Mechanical Engineer – Northern Ill Univ	120 h	Engineering estimate based on similar projects with large modifications.
Duration	30 days	Assumes tech working for 0.75 FTE month.
Estimate Type	Conceptual	Contingency of 50% based on contingency rule L5. Higher end of range due to design immaturity.

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BOEs

Often include supporting details

<u>Details of the Base Estimate</u>

The activities covered in this BOE include M&S purchases, procurement activities related to the M&S, and labor associated with producing a Quality Assurance tester for the Cosmic Ray Veto photodetectors. M&S estimates are based on previous experience with fabricating prototype testers used at NIU for the proton tomography project.

The plan for SiPM Quality Assurance testing is to measure the I-V curves of 10% of the 20,000 production SiPMs. This SiPM QA testing procedure has been used previously on a joint NIU/FNAL proton tomography project with a SiPM test facility at NIU. SiPMs for the Fall 2013 FNAL beam test were also tested at this facility. Based on the experience from that facility, a stand-alone test tester has been designed that does not require the additional support infrastructure (power supplies, picoammeter, etc.) that the NIU test stand needs to test the SiPMs.

The QA testing box is a stand-alone tester that will be used to simultaneously apply bias voltages to 32-SiPMs, measure the currents of each SiPM, and send the data off to a PC via a USB connection. The 32 SiPMs are mounted in a reusable waffle-pack fixture, with electrical connections to each surface mount SiPM being made by elastometric ZEBRA connectors. The SiPMs fixture will be placed in a temperature stabilized dark box.

A prototype of the QA tester is being developed and will be used to test the initial 320 SiPMs for radiation damage studies. Modifications to the final production design will come from experience with that prototype tester and dark box. The production tester will be built by Fermilab. NIU is responsible for producing the temperature controlled dark box. Production SiPMs will be tested at NIU with NIU undergraduates. Ten percent of the SiPMs will be QA tested before accepting the production devices.

Estimate SiPM Tester jig Labor and M&S

This document summarizes the labor and M&S for fabricating the SiPM tester jig that Fermilab is developing. It does not include the cost for the dark box that NIU is developing. The documentation includes a summary of the labor from the initial development of the prototype SiPM tester jig. Also attached is a parts list for the prototype jig. The total amount for the components is ~$8k. We assume that this is the cost for the components for the production testers.

Labor summary:
Estimate for remaining development work is based on the actuals from the initial development work.
Prototype jig
Fabrication
FNAL Electrical Design Engineer (David Huffman + Mark Kozlovsky) – 100 hours
FNAL Engineering Physicist (Paul Rubinov) – 80 hours
FNAL Electrical Drafter (Nina Moibenko) – 40 hours
FNAL Electrical Technician (Johnny Green) – 8 hours
FNAL Elec Assembly Technician (Paula Lippert) – 24 hours
FNAL Electronics Technician (Merle Watson) – 40 hours

Production Jig
Fabrication
FNAL Electrical Design Engineer (David Huffman + Mark Kozlovsky) – 55 hours
FNAL Engineering Physicist (Paul Rubinov) – 40 hours
FNAL Electrical Drafter (Nina Moibenko) – 40 hours
FNAL Electrical Technician (Johnny Green) – 24 hours

FNAL Electrical Assembly Technician (Paula Lippert) – 32 hours

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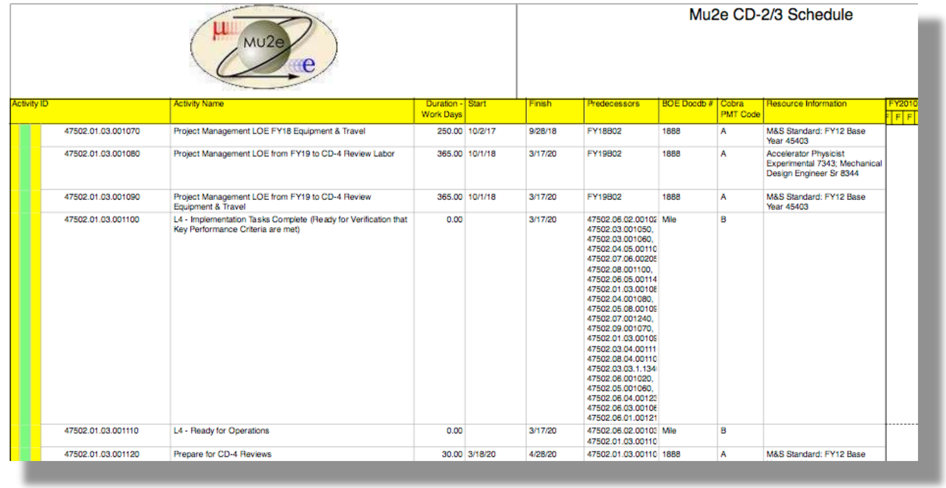
Resource Loaded Schedule

- Activity based RLS contains
  - 6885 activities
  - 4806 Work Packages
    - 3600 current budget
    - 815 contracted labor/material purchases
    - 391 obligations
  - 74 Control Accounts and 30 CAMs
  - 1100 milestones
  - 224 Constraints
    - 7 are accelerator shutdowns
    - 7 are Muon Campus milestones
    - 199 are reporting milestones
- Critical Path, Near Critical Path and sub-project Critical Paths all identified using the RLS.
- Work schedule, obligations, resource profiles are derived from the RLS


Mu2e CD-2/3 Schedule

Activity ID	Activity Name	Duration - Work Days	Start	Finish	Predecessors	BOE Docdb #	Cobra PMT Code	Resource Information
47502.01.03.001070	Project Management LOE FY18 Equipment & Travel	250.00	10/2/17	9/28/18	FY18B02	1888	A	M&S Standard: FY12 Base Year 45403
47502.01.03.001080	Project Management LOE from FY19 to CD-4 Review Labor	365.00	10/1/18	3/17/20	FY19B02	1888	A	Accelerator Physicist Experimental 7343; Mechanical Design Engineer Sr 8344
47502.01.03.001090	Project Management LOE from FY19 to CD-4 Review Equipment & Travel	365.00	10/1/18	3/17/20	FY19B02	1888	A	M&S Standard: FY12 Base Year 45403
47502.01.03.001100	L4 - Implementation Tasks Complete (Ready for Verification that Key Performance Criteria are met)	0.00		3/17/20	47502.06.02.0010[illegible] 47502.03.001050, 47502.03.001060, 47502.04.05.0011[illegible] 47502.07.06.0020[illegible] 47502.08.001100, 47502.06.05.0011[illegible] 47502.01.03.0010[illegible] 47502.04.001080, 47502.05.08.0010[illegible] 47502.07.001240, 47502.09.001070, 47502.01.03.0010[illegible] 47502.03.04.0011[illegible] 47502.08.04.0011[illegible] 47502.03.03.1.134[illegible] 47502.06.001020, 47502.05.001060, 47502.06.04.0012[illegible] 47502.06.03.0010[illegible] 47502.06.01.0012[illegible]	Mile	B	
47502.01.03.001110	L4 - Ready for Operations	0.00		3/17/20	47502.06.02.0010[illegible] 47502.01.03.0011[illegible]	Mile	B	
47502.01.03.001120	Prepare for CD-4 Reviews	30.00	3/18/20	4/28/20	47502.01.03.0011[illegible]	1888	A	M&S Standard: FY12 Base

Rates and Assumptions

- Schedule trued-up with actuals through end of April 2014 and statused through September 2014.
- Estimate developed in FY14$
- One person-year = 1768 hours
  - 52 weeks x 40 hrs/week x 0.85
- Applied burdening rates are based on where work is being done
  - Every Division/Section at Fermilab has different overhead rates.
  - Every Mu2e institution has their own rates.
  - Rates are subject to change.
- Average salary rates are used for each distinct resource
- Escalation rates for M&S, Labor.

Escalation

	FY15	FY16	FY17	FY18	FY19	FY20	FY21
Labor	2.7%	2.8%	3.0%	3.1%	3.3%	3.4%	3.5%
M&S	1.9%	1.9%	2.0%	2.0%	2.0%	2.0%	2.0%

- Labor and M&S rates from Fermilab Budget Office.
  - Use information from the Congressional Budget Office (CBO) annual pricing forecast done each February
  - CFO and Budget office interpret trends in prices and normalize for lab expectations and DOE funding constraints
- Risk Registry addresses risk that commodities (steel, aluminum, copper, gold) escalate faster than inflation (docdb 3845).

Contingency

- Contingency is the combination of Estimate Uncertainty and risk exposure.
- Estimate Uncertainty is based on maturity of design.
- Estimate Uncertainty Rules for labor and M&S posted on review web site (docdb 459).
  - Standard rules, similar (or identical) to those used by other Fermilab Projects
    - Do not reflect risk.
- Risk was addressed in a quantitative analysis process using a Monte Carlo
  - Primavera Risk Analysis Tool used to validate cost and schedule risk.

Fermilab Estimate Uncertainty Rules

M&S

Code	Type of Estimate	Contingency %	Description
M&S Guidelines			
M1	Existing Purchase Order	0%-15%	Items that have been completed or obligated. Non-zero contingency may be appropriate in some cases because of potential changes that may occur over the life of the procurement.
M2	Procurements for LOE / Oversight work	0%-20%	M&S items such as travel, software purchases and upgrades, computers, etc. estimated to support LOE efforts and other work activities.
M3	Advanced	10%-20%	Items for which there is a catalog price or recent vendor quote based on a completed or nearly completed design or an existing design with little or no modifications and for which the costs are documented.
M4	Preliminary	20%-40%	Items that can be readily estimated from a reasonably detailed but not completed design; items adapted from existing designs but with moderate modifications, which have documented costs from past projects. A recent vendor survey (e.g., budgetary quote, vendor RFI response) based on a preliminary design belongs here.
M5	Conceptual	40%-60%	Items with a documented conceptual level of design; items adapted from existing designs but with extensive modifications, which have documented costs from past projects
M6	Pre-Conceptual - Common work	60%-80%	Items that do not have a documented conceptual design, but do have documented costs from past projects. Use of this estimate type indicates little confidence in the estimate. Its use should be minimized when completing the final estimate.
M7	Pre-Conceptual - Uncommon work	80%-100%	Items that do not have a documented conceptual design, and have no documented costs from past projects. Its use should be minimized when completing the final estimate.
M8	Beyond state of the art	>100%	Items that do not have a documented conceptual design, and have no documented costs from past projects. Technical requirements are beyond the state of the art.

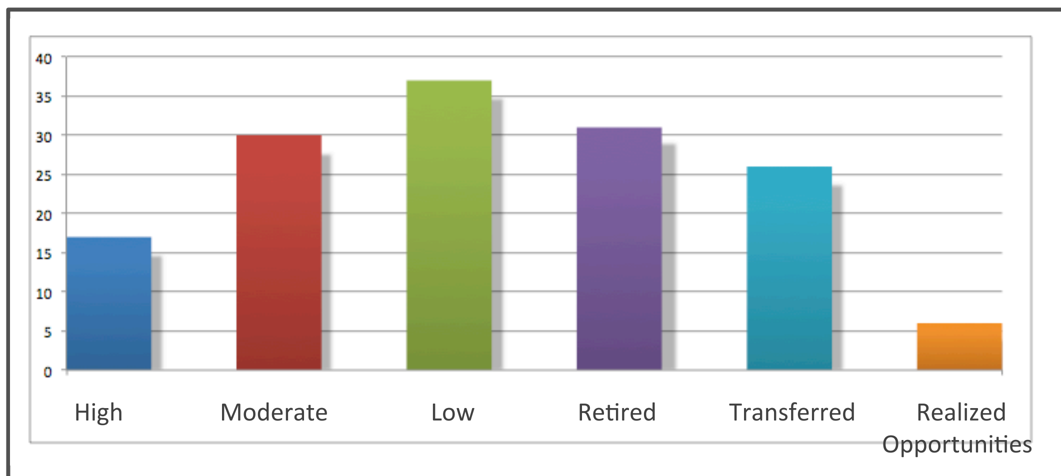
Fermilab Estimate Uncertainty Rules

Labor

Code	Type of Estimate	Contingency %	Description
LABOR Guidelines			
L1	Actual	0%	Actual costs incurred on activities completed to date.
L2	Level of Effort Tasks	0%-20%	Support type activities that must be done to support other work activities or the entire project effort, where estimated effort is based on the duration of the activities it is supporting.
L3	Advanced	10%-25%	Based on experience with documented identical or nearly identical work. Development of activities, resource requirements, and schedule constraints are highly mature. Technical requirements are very straightforward to achieve.
L4	Preliminary	25%-40%	Based on direct experience with similar work. Development of activities, resource requirements, and schedule constraints are defined at a preliminary (beyond conceptual) design level. Technical requirements are achievable and with some precedent.
L5	Conceptual	40%-60%	Based on expert judgment using some experience as a reference. Development of activities, resource requirements, and schedule constraints are defined at a conceptual level. Technical requirements are moderately challenging.
L6	Pre-conceptual	60%-80%	Based only on expert judgment without similar experience. Development of activities, resource requirements, and schedule constraints are defined at a pre-conceptual level. Technical requirements are moderately challenging.
L7	Rough Estimate	80%-100%	Based only on expert judgment without similar experience. Development of activities, resource requirements, and schedule constraints is largely incomplete. Technical requirements are challenging.
L8	Beyond state of the art	>100%	No experience available for reference. Activities, resource requirements, and schedule constraints are completely undeveloped. Technical requirements are beyond the state of the art.

Risk Management

- Project risks documented in risk registry
- Risks continuously monitored. Living document.
  - Monitor, mitigate and retire risks as part of design and implementation process.
- Actively managing 84 risks
  - 69 Threats
  - 15 Opportunities
  - 31 risks retired
  - 6 opportunities realized at a savings of $1.7M
  - > $8.5M spent to mitigate risks
    - Included in Project baseline cost.



Largest Remaining Risks

Risk							Post-mitigation							
Risk ID	Risk Form DocDb #	Type	Title	Date of Risk	Mitigation Cost (Included in baseline)	Category	Probability	Schedule-Delays Level 3 Milestone or Project Critical Path by X Days	Cost	Technical	ES&H	Score	Owner	Point estimate (cost k$)
ACCEL-020	3333	Threat	Cannot use TLMs to control beam losses.	FY15-FY19		Current Risk	L	N	VH	N	N	H	T. Leveling	$ 2,000
ACCEL-151	3833	Threat	Redesign the Remote Handling System for Water cooled target	FY16-FY18	$ 100,000	Current Risk	VL	N	VH	M	N	H	M.Campbell, R.Coleman	$ 3,300
CAL-108	3347	Threat	INFN cannot deliver full in-kind scope.	FY16-FY20		Current Risk	L	N	N	VH	N	H	R. Ray	$ -
CONST-049	3351	Opportunity	Conventional construction bids are lower than estimated cost.	FY15		Current Risk	M	N	VH	N	N	H	T. Lackowski	$ (1,200)
PM-010	3366	Threat	Increase in Fermilab overhead rates	FY16-FY20		Current Risk	M	N	VH	N	N	H	Ron Ray	$ 1,500
PM-153	3844	Opportunity	Commodity prices decrease	FY16-FY18		Current Risk	L	N	VH	N	N	H	Ron Ray	$ (1,173)
PM-154	3845	Threat	Commodity prices escalate faster than inflation	FY16-FY18		Current Risk	L	N	VH	N	N	H	Ron Ray	$ 1,173
SOL-070	3368	Threat	Interface problems with the solenoids.	FY17-FY20		Current Risk	L	H	VH	N	N	H	M. Lamm	$ 1,000
SOL-155	3954	Opportunity	Cryo Distribution Box Funded by Cryo AIP	FY15-FY17		Current Risk	M	VH	VH	N	N	H	M. Lamm	$ (2,500)
ACCEL-015	3331	Threat	Injection damper required for Delivery Ring	FY16-FY19		Current Risk	L	N	N	VH	N	H	J. Morgan	$ 185
CAL-148	3834	Threat	solid state photodetector that is blind to longer wavelengths	FY15	$ 100,000	Current Risk	M	M	N	H	N	H	D. Hitlin	$ -
SOL-183	4568	Threat	TS Magnet fabrication failure due supplied process or component	FY20	$ 200,000	Current Risk	M	L	M	N	N	H	M.Lamm	$ 620
ACCEL-200	4589	Threat	Need to add new power supplies to the beam line.	FY15-FY16	20,000	Current Risk	M	VL	H	VL	N	H	D. Still	$ 400
MUON-138	3360	Threat	Detector installation takes longer than expected.	FY19		Current Risk	M	M	H	N	N	H	G. Ginther	$ 400
SOL-148	3837	Threat	Production Solenoid must be installed through PS hatch using a large rented crane.	FY18-19		Current Risk	M	N	H	N	N	H	T. Page	$ 300
TRACK-169	4444	Threat	Background levels >4x expectation necessitate additional Tracker stations	FY15		Current Risk	M	N	H	M	N	H	A. Mukherjee	$ 1,000
TRIG-128	3393	Threat	Insufficient manpower for DAQ software.	FY17-FY20		Current Risk	M	N	H	N	N	H	M. Bowden	$ 500

Risk Management

- High and Moderate Risks have detailed individual risk forms describing the risk and mitigation strategies.

Mu2e Risk Form

Risk Identifier: Ron Ray **Risk Owner:** Ron Ray

Risk ID: PM-010 **Risk Type:** THREAT

Date: 9/20/2013 **Date revised:** 8/15/14

Risk Title: Increase in Fermilab overhead rates

Risk Description: Fermilab overhead rates have been increasing in recent years. We will use this data to estimate increases in future years. If the increases are greater than our estimates we will have a shortfall. We are particularly vulnerable to this because of our large percentage of Fermilab labor.

Detailed Risk Cause: Base support for Fermilab decreases causing overhead rates to increase faster than our estimates.

Detailed Risk Effect: Cost increase

WBS Affected: all labor activities

Other WBS Affected:

Actual Start Date (when available from schedule)	Actual Finish Date (when available from schedule)
FY16	FY20

Initial Risk Analysis – (description of selection of impacts and probability, text length commensurate with risk complexity): All Fermilab labor has overheads applied. The overhead varies depending on the organization where the work is done. Overheads have been going up in recent years and there is a risk that they will continue to rise.

Initial Risk Probability and Impact scores selected from Mu2e Risk Management Plan (Mu2e-doc-461) Tables 1 and 2

Initial Probability (VH,H,M, L,VL)	Initial Schedule Impact (Delays Level 3 milestone or project critical path by) in days (VH,H,M,L,VL)	If HIGH SCHEDULE IMPACT, Upper Bound of Current Schedule Impact (Days)	Initial Cost Impact (VH,H,M,V,VL)	If HIGH COST IMPACT, Upper Bound of Current Cost impact ($)	Initial Scope Impact (VH,H,M,L,VL)	Initial ES&H and Quality Impact (VH,H,M,L,VL)
H	N		VH	Unbounded	N	N

Exposure (What the risk will cost when it occurs): Overhead rates are adjusted at the beginning and end of each fiscal year. Changes at the end of the FY are retroactive to the beginning of the year. The risk continues until Project completion and can happen over-and-over again but the financial impact diminishes each year as less Project Labor remains into the future that could be subject to increased overheads.

Initial Risk Mitigation Plan considered in the Initial Risk Analysis and included in the Base Plan Cost and Schedule: Add contingency specifically to cover higher overheads. Make sure adequate contingency exists year-by-year to cover retroactive changes.

Base Plan Mitigation Cost ($)	Base Plan Mitigation Cost Uncertainty ($)	Start and Finish Dates or Description of Current Mitigation Plan Duration
0	0	Accept Risk

New Mitigation Plan or Additional Risk Mitigation Measures Description:

Response Type (Accept, Reduce, Avoid, Transfer)	New or Additional Mitigation Cost Range ($) Low Bound	Upper Bound	Schedule impact of undertaking the mitigation plan – delays Level 3 milestone or project critical path (Days) Lower Bound	Upper Bound	Probability of plan failing to achieve expected mitigation (H,MH,ML,L)
Accept	0	0	None	None	

Residual/Current Risk Probability and Impact Scores:

Residual/ Current Probability (VH,H,M, L,VL)	Residual Schedule Impact (Delays Level 3 milestone or project critical path (Days) (VH,H,M, L,VL)	If HIGH SCHEDULE IMPACT, Upper Bound of Residual Schedule Impact (Days)	Residual Cost Impact (VH,H,M, L,VL)	If HIGH COST IMPACT, Upper Bound of Residual Cost Impact ($)	Residual Scope Impact (VH,H,M, L,VL)	Residual ES&H and Quality Impact (VH,H,M, L,VL)
M	N		VH	Unbounded	N	N

Additional Notes: Analysis of historical data in spreadsheet posted with this form on docdb results in a 90% C.L. cost of \$1447k. Round up to \$1500k. Analysis is summarized below.

Point estimate (cost k$)	Point Estimate (schedule-days)	Point estimate (probability)	EXPECTATION VALUE IN k$	EXPECTATION VALUE IN Days
$1500k	0	50%	$750	0

Analysis of Risk

The Fermilab Financial Section has provided historical data for overhead rates, going back to 2007. The individual components, plotted in Figure 1a are:

- *PS* - Program Support for AD, CD, PPD and TD
- *CSS* – Common Site Support
- *TSCS* – Technical and Scientific Common Support
- *G&A* – General and Administrative.

Overhead rates for AD, CD, PPD and TD are obtained by combining the Divisional Program Support rate with CSS, TSCS and G&A. For example:

AD Overhead rate = (1+PS)(1+CSS)*(1+TSCS)*(1+G&A) - 1.*

Overhead rates for other organizations are obtained in the same way, but without the Program Support component. The historical overall rates for the various Divisions and Sections are shown in Figure 1b.

To evaluate the risk to the Mu2e project from potential increases in overhead rates, we have evaluated low, medium and high scenarios as follows:

Accelerator Division Program Support (AD PS) – Steadily decreasing from FY08 to FY13, but a significant jump in FY14. In a band between 28% and 35% for the last 6 years. Currently at 34%. Assume:

- Low: 28%
- Medium: 30%
- High: 35%

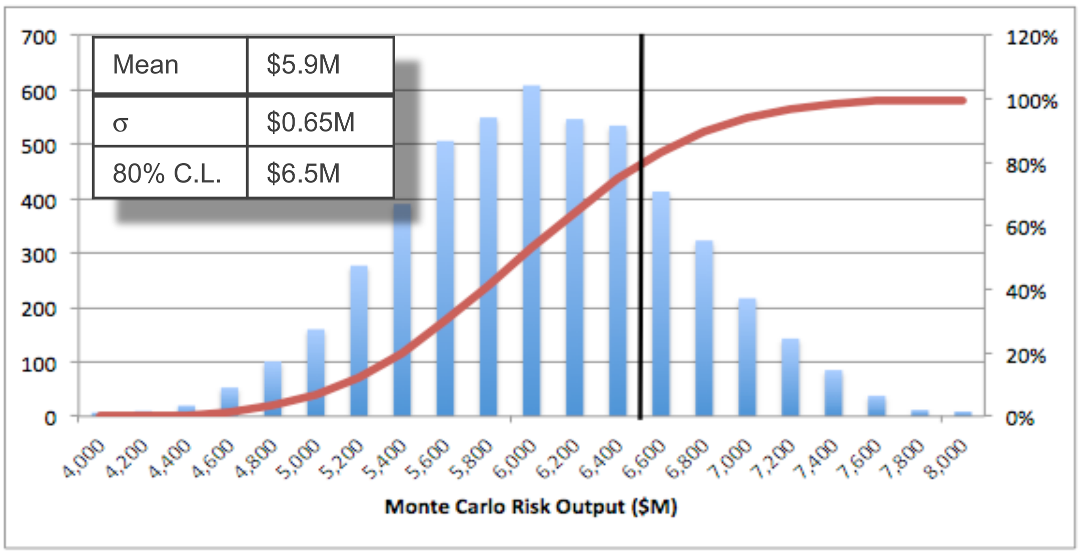
Computing Division Program Support (CD PS) - Steadily decreasing over the past 4 years. In a band between 9% and 13% for the last 5 years. Currently at 11.3%. Assume:

- Low: 9%
- Medium: 11%
- High: 13%

Particle Physics Division Program Support (PPD PS) – In a band between 12% and 18% for the past 8 years. Currently at 17.5%. Assume:

Risk Analysis

- Monte Carlo performed on Risk Register to determine cost at 80% C.L.
- Schedule risks included and costed in analysis
  - Cost associated with schedule risks determined using PRA
    - Uses schedule logic and correlations
  - PRA analysis of overall schedule risk consistent with 24 months of float added to end of schedule.



Mean	$5.9M
σ	$0.65M
80% C.L.	$6.5M

L2	80% C.L. Risk
Project Management	$1265
Accelerator	$814
Conventional Construction	($637)
Solenoids	$3455
Muon Beamline	$468
Tracker	$556
Calorimeter	$51
Cosmic Ray Veto	$318
DAQ	$244
Total	$6534k

Total Project Cost

Fully burdened AY $k

(Values in AY $k)	Performed	ETC	Contingency EU + Risk	% Cont on ETC	Total
Project Management	9,565	11,104	2,125	19%	**22,794**
Accelerator	11,790	29,016	9,433	33%	**50,239**
Conventional Construction	2,642	18,603	2,825	15%	**24,070**
Solenoids	16,743	71,225	24,322	34%	**112,290**
Muon Beamline	4,406	15,161	5,922	39%	**25,490**
Tracker	2,941	8,582	3,760	44%	**15,283**
Calorimeter	522	4,406	1,164	26%	**6,092**
Cosmic Ray Veto	1,543	5,229	1,963	38%	**8,735**
Trigger & DAQ	1,829	2,971	1,207	41%	**6,007**
Total	**51,982**	**166,296**	**52,722**	**32%**	**271,000**

Total Project Cost

(Values in AY $k)	Performed	ETC	Contingency	% Cont	Total
Project Management	9,565				
Accelerator	11,790				
Conventional Construction	2,642				
Solenoids	16,743				
Muon Beamline	4,406				
Tracker	2,941				
Calorimeter	522				
Cosmic Ray Veto	1,543				
Trigger & DAQ	1,829				
Total	**51,982**	**166,296**	**52,722**	**32%**	**271,000**

DOE ICE performed over past 2 months validated our base cost estimates.

"The ICE Team recommends no adjustments to the cost estimate for BOP direct costs. The cost estimate is complete. The level of detail and backup information is impressive. The strength of the BOP cost estimate lies in the planning and definition of the work to be performed for each WBS activity. Likewise, materials and supplies (M&S) are very well identified. Quotes and purchase orders are available for all large procurements."

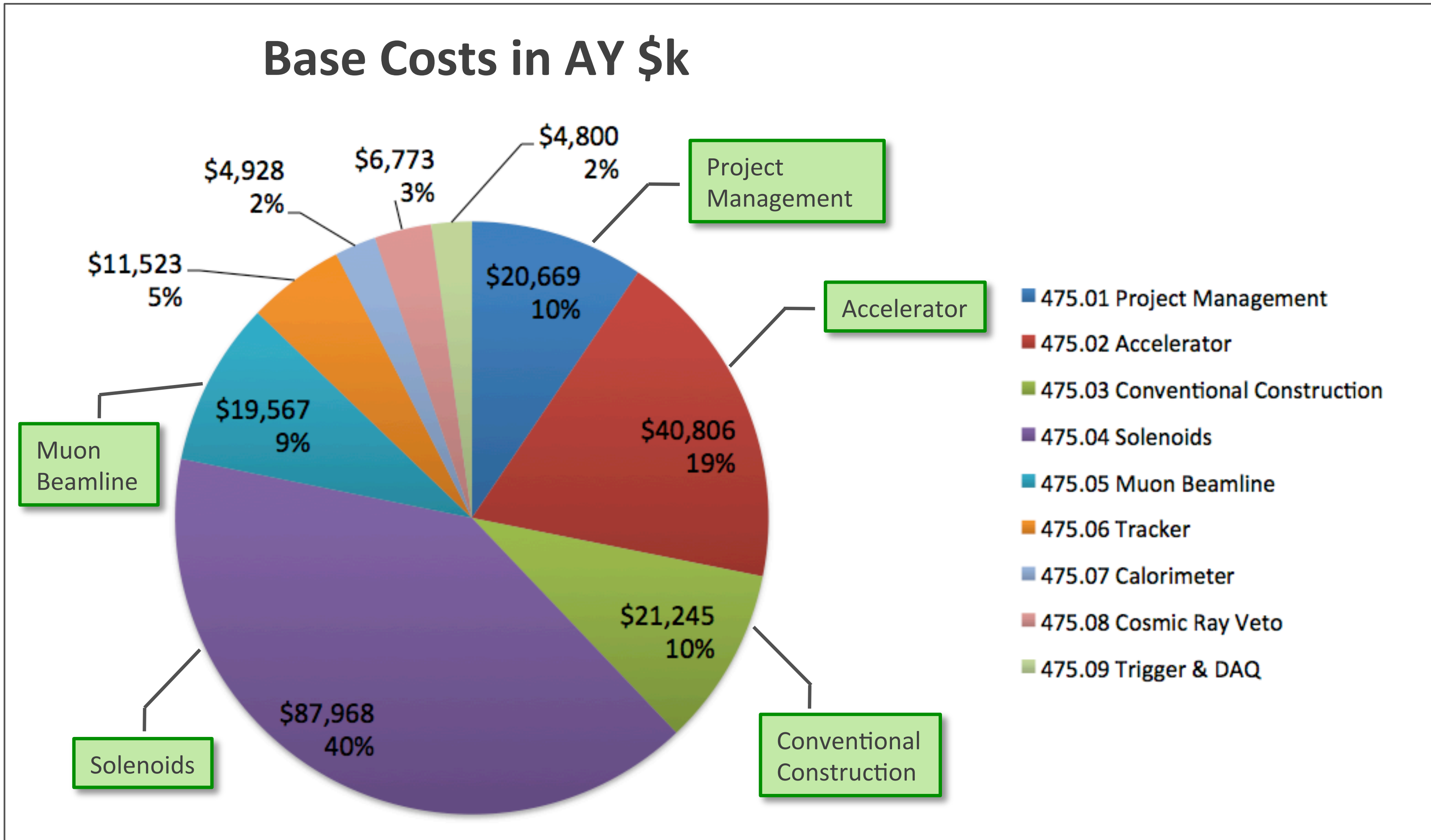
Contingency

- Overall contingency of 32% on cost to go, but risk is not evenly distributed
- $39M of Project Management costs spread throughout the Project
  - $24M cost-to-go
  - Primarily LOE based on assigned personnel and well established need, so contingencies are low
    - Example: I'm assigned at 100%. No contingency.
    - We do have a risk that more Project Management might be needed.
  - Conventional Construction is a big ticket item with low risk that is well understood. Similar to other recent construction on site. We have a bid that we are about to turn into a PO. Cost known.
- If we exclude PM costs and contingency, the contingency on the remaining cost-to-go is 35%.
- If we exclude PM and Conventional Construction, the contingency on the remaining "technical scope" of the Project is 37%.

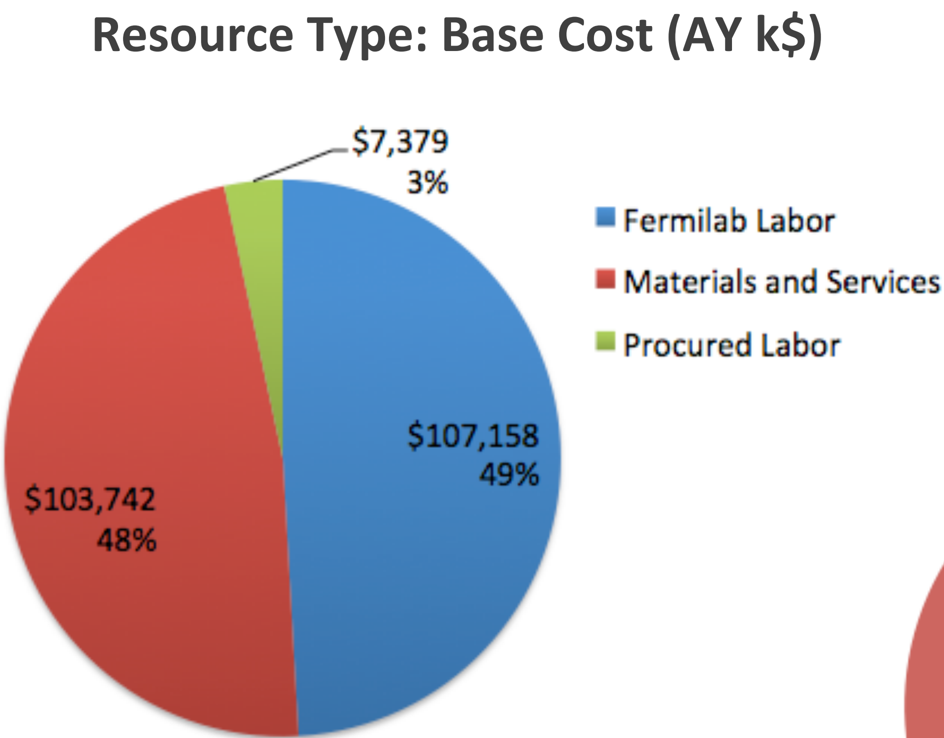
Scope Contingency

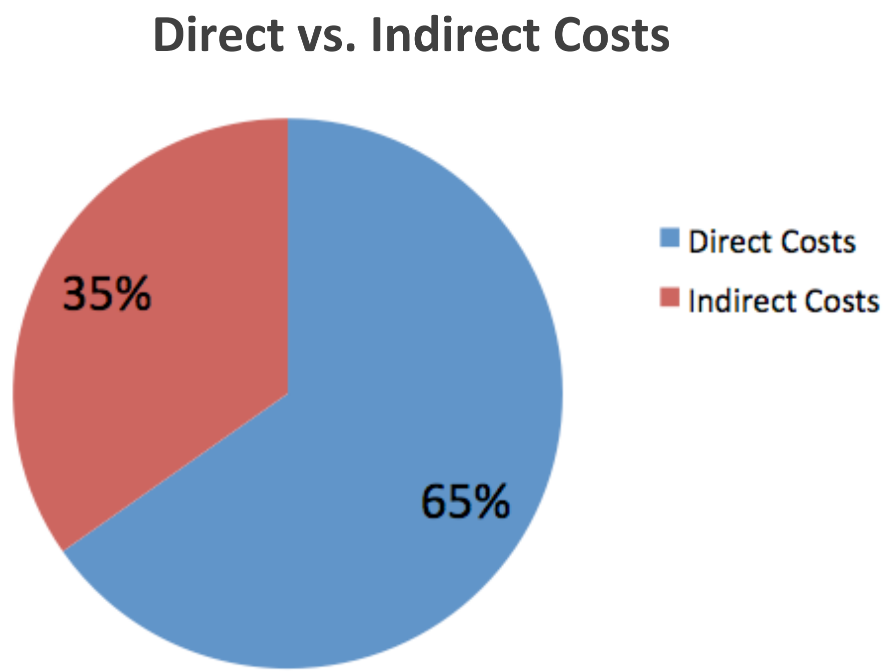
- By running at 5x lower beam power we could eliminate ~$3M of heavy concrete shielding around the TS and DS.
  - Shielding is purchased late in project
  - Shielding could be added later.
- The second calorimeter disk could be eliminated, deferred or provided by another agency or International partner. Saves ~$4M while reducing acceptance by ~40%.
  - Second disk could be added later.
- We are pursuing additional opportunities that, if realized, would effectively increase available contingency
  - other agencies provide some part of existing scope
  - move more work from Laboratory to University groups
- Potentially an additional $10M in contingency is possible
- Active management of scope contingency as we retire risks and re-evaluate opportunities could free up more.
- More detail in Management Breakout

Cost Breakdown by L2



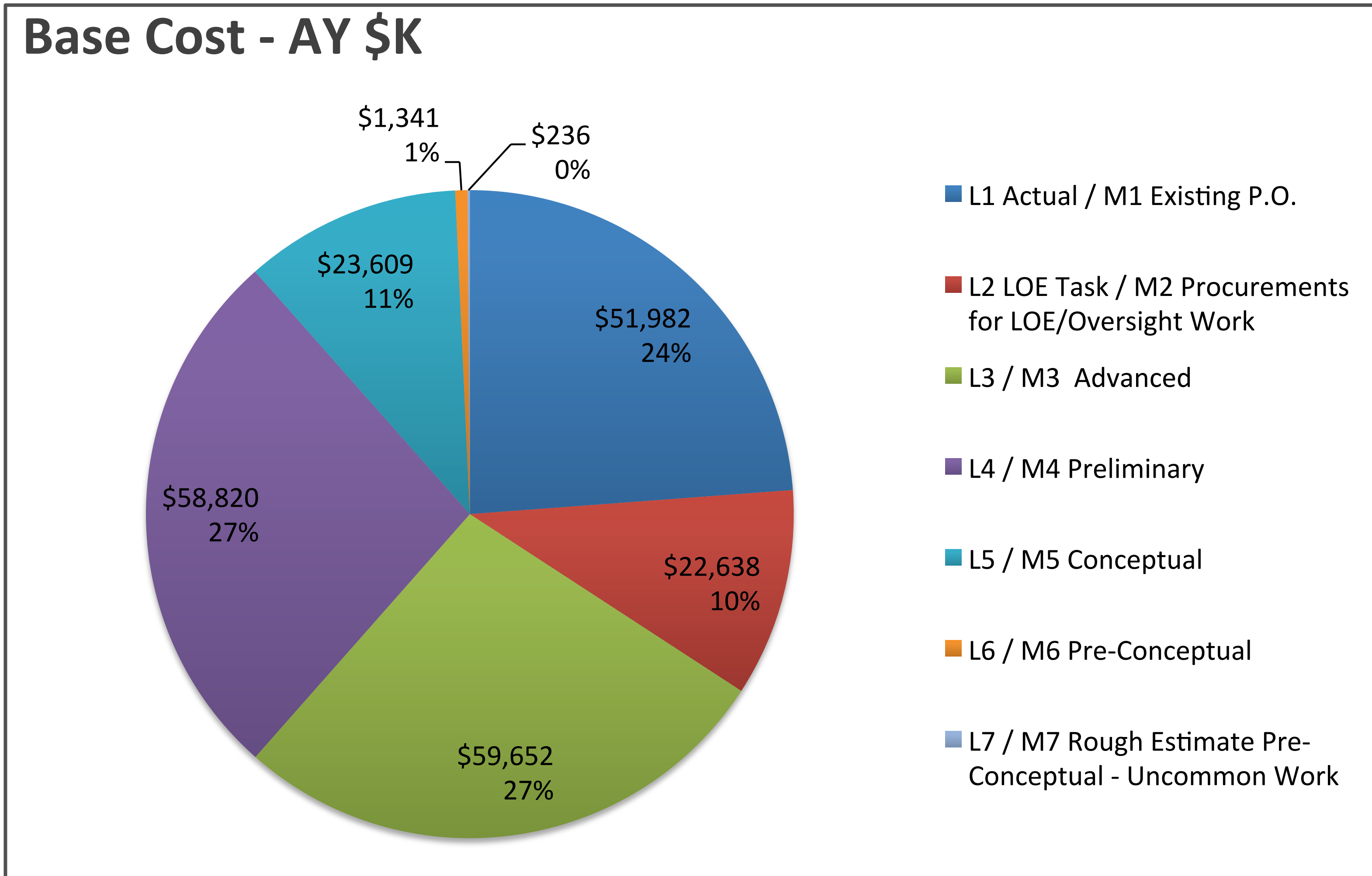
Cost Breakdown





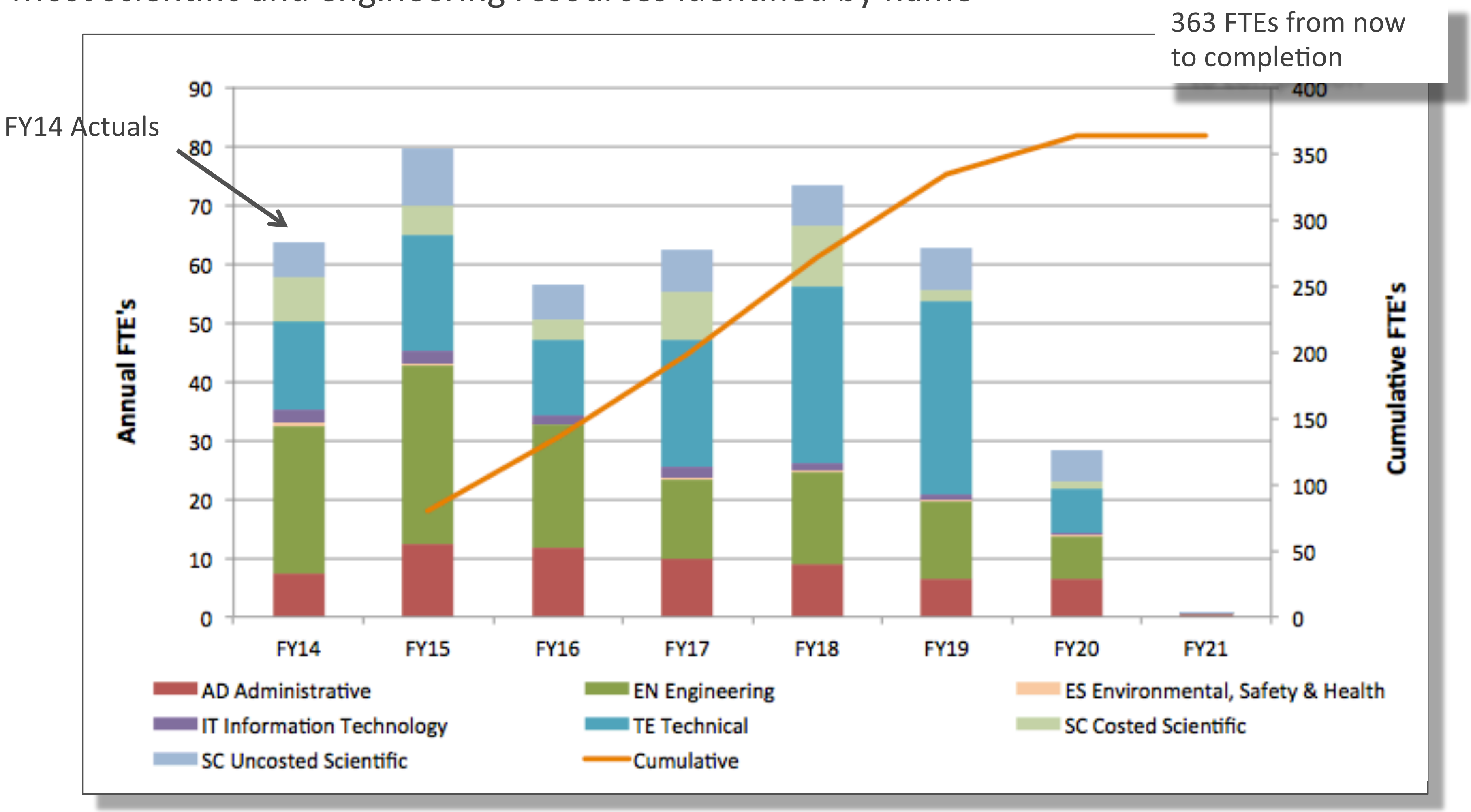
Quality of Estimate

88% of cost at or beyond Preliminary level

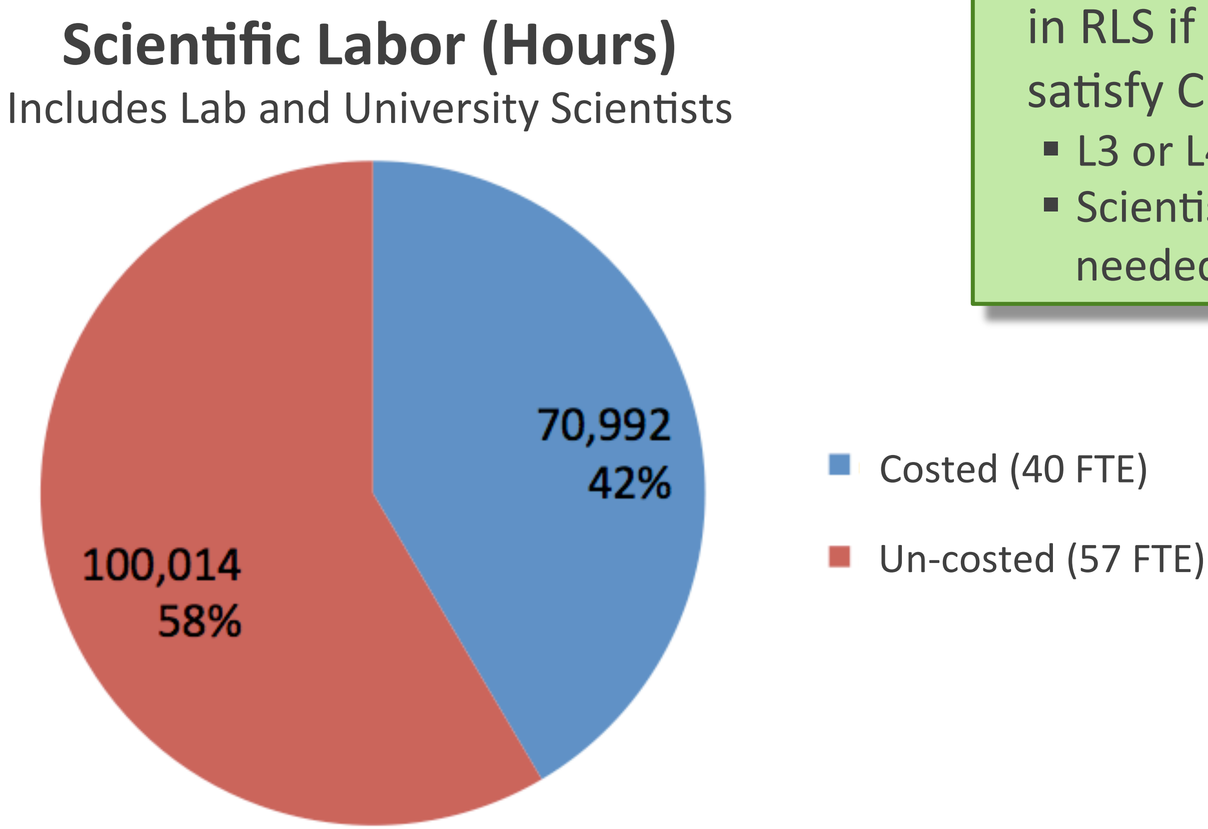


Labor Resources

Agreement with Fermilab Divisions for required resources in FY15
Most scientific and engineering resources identified by name



Scientists

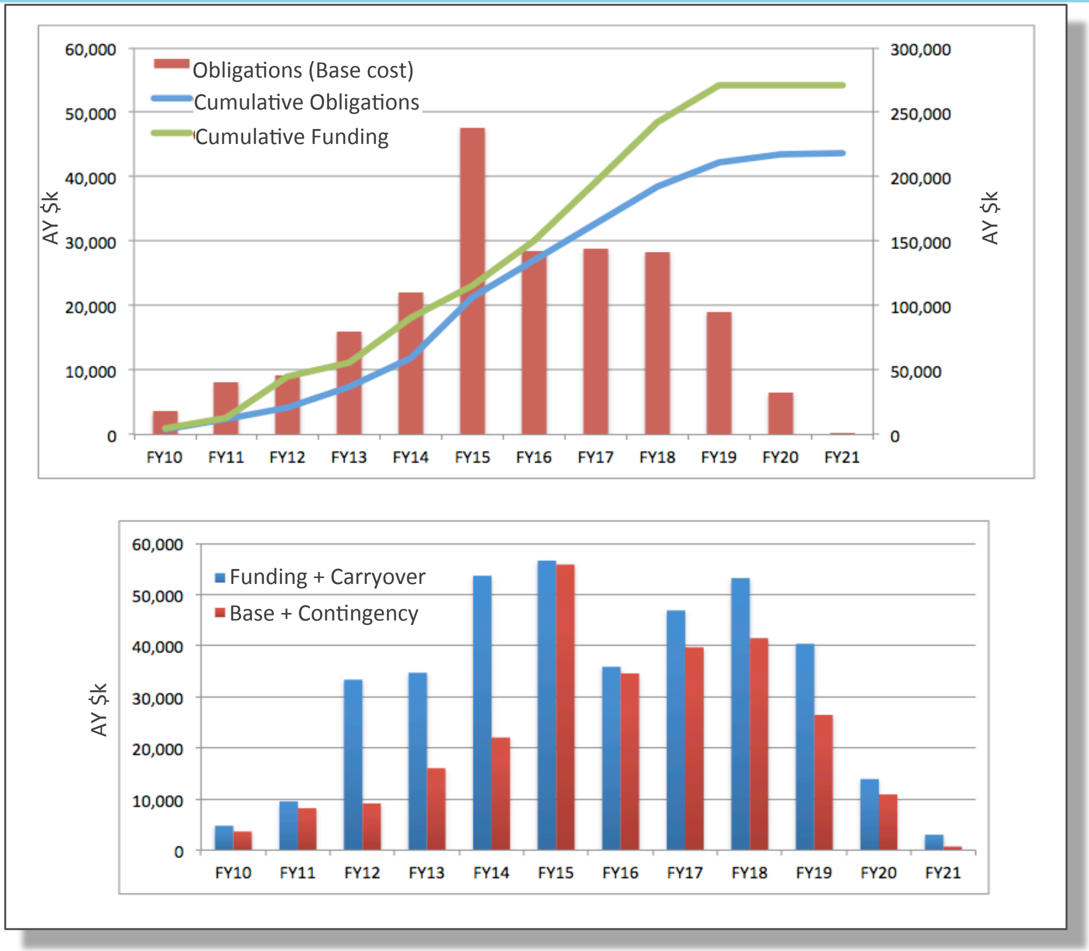


- Un-costed scientists are included in RLS if they are required to satisfy CD-4
  - L3 or L4 managers
  - Scientists performing simulations needed for design.

Resource Availability

- Significant Fermilab resources required for success of Project, particularly for Solenoids, Accelerator, Muon Beamline.
  - Have generally been successful in securing needed resources, but not always.
    - Lots of other projects at Fermilab, sometimes with competing needs
  - Occasionally have to look outside the Lab for resources. We have been very successful in doing this when necessary.
    - RAL
    - Bartoszek Engineering
    - Argonne cryo group
    - New cryo hires
- Lab Management is working hard to understand resource needs, level resources and establish well communicated priorities – One of CPOs primary responsibilities.

Obligation and Funding Profile



Fiscal Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
OPC - R&D	0.5	0.5	1	2.5								4.5
OPC - Design	4.3	7.9	7									19.2
TEC - PED			24	8	15							47
TEC - Construction					20	25	35.1	45.6	46	28.6		200.3
Total Project Cost	4.8	8.4	32	10.5	35	25	35.1	45.6	46	28.6	0	271

Degree of Project Definition

- No unique definition
- Based on DOE Cost Estimating Guide we have a Class 2 estimate for which engineering should be 30 - 70% complete.
  - "Class 2 estimates are generally prepared to form a detailed contractor control baseline against which all Project work is monitored."
- We looked at the number of performed design hours (engineers, designers, drafters, scientists) compared to the entire design process. Contract engineering included.
  - Design is not necessarily a linear process.
  - Based on this metric, the design process is 58% complete when weighted by cost.

L2	Project Definition
Accelerator	77%
Conventional Construction	100%
Solenoids	55%
Muon Beamline	43%
Tracker	60%
Calorimeter	40%
Cosmic Ray Veto	66%
DAQ	60%
Total	**58%**

Tailoring Strategy

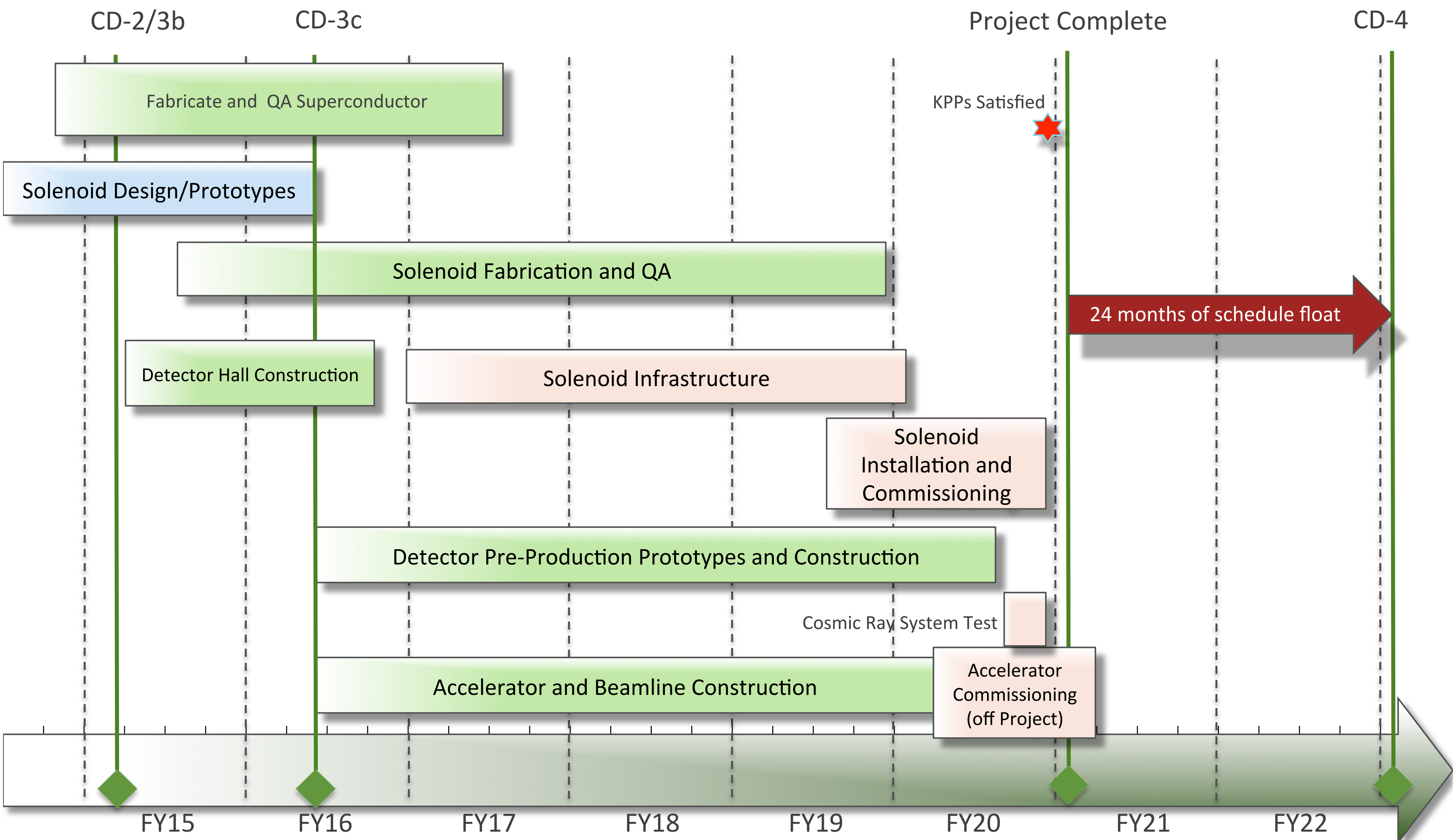
- CD-3a for long-lead solenoid conductor
  - Granted July 10, 2014
- CD-2 for entire Project and CD-3b for the Detector Hall and Transport Solenoid Modules
  - This Review
- CD-3c approval in mid FY16.
  - Timed to keep the solenoids moving on a technically limited schedule since they define the critical path.
  - Most final designs will be complete by CD-3c, but a few will not.
    - The designs that are not complete will be well along and the risk associated with the remaining design is small.
  - Final Design Plan is available on the Review web page.

CD Milestones

Major Milestone Events	Preliminary Schedule
CD-0 (Approve Mission Need)	1st Qtr, FY10 (A)
CD-1 (Approve Alternative Selection and Cost Range)	4th Qtr, FY12 (A)
CD-3a (Approve Start of Long-lead Procurement)	4th Qtr, FY14 (A)
CD-2 (Approve Performance Baseline)	1st Qtr, FY15
CD-3b (Start of Phased Construction/Fabrication)	1st Qtr, FY15
CD-3c (Approve Start of Construction)	2d Qtr, FY16
Key Performance Parameters Satisfied	1st Qtr, FY21
CD-4 (Includes 24 months of programmatic float)	1st Qtr, FY23

- CD date is defined as official sign-off.

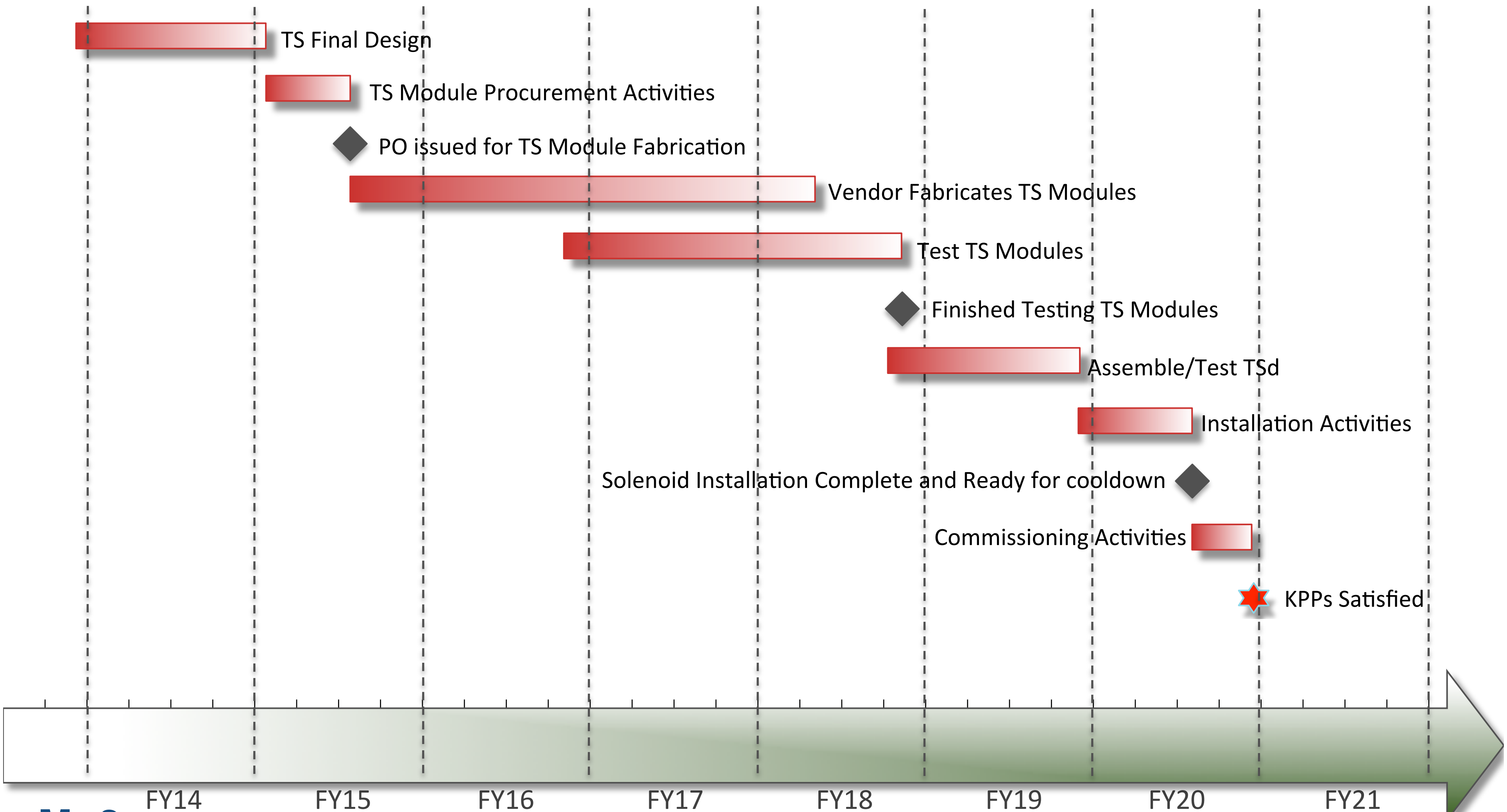
Schedule



CD-2/3b
CD-3c
Project Complete
CD-4
Fabricate and QA Superconductor
KPPs Satisfied
Solenoid Design/Prototypes
Solenoid Fabrication and QA
24 months of schedule float
Detector Hall Construction
Solenoid Infrastructure
Solenoid Installation and Commissioning
Detector Pre-Production Prototypes and Construction
Cosmic Ray System Test
Accelerator and Beamline Construction
Accelerator Commissioning (off Project)
FY15
FY16
FY17
FY18
FY19
FY20
FY21
FY22

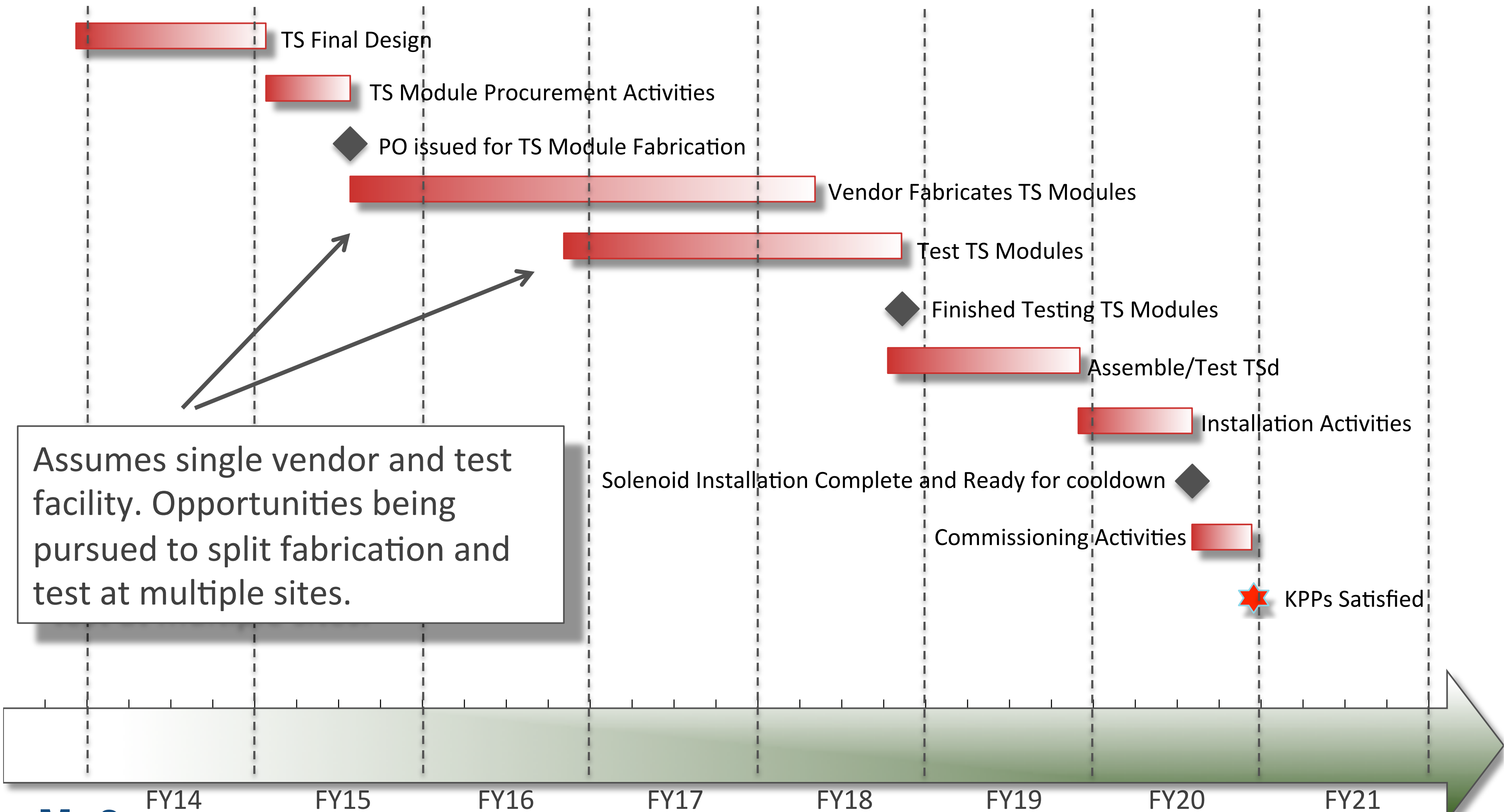
Critical Path

Detailed Gantt Chart of critical path posted on Review web page



Critical Path

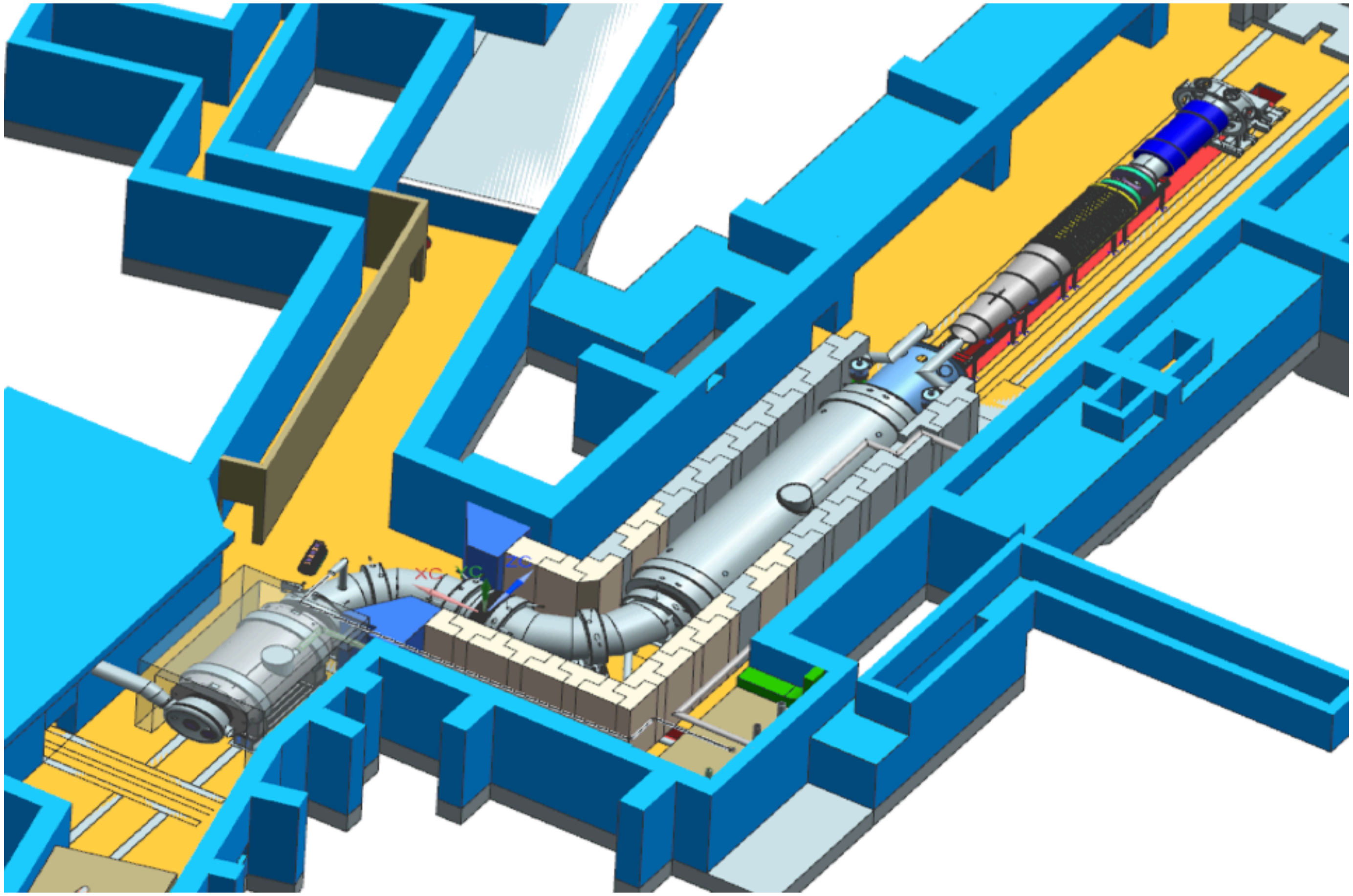
Detailed Gantt Chart of critical path posted on Review web page



CD-3b Request – Detector Hall

- We are requesting CD-3b for the Mu2e Detector Hall and the Transport Solenoid Modules.
- Recommendation from DOE CD-1 Review to accelerate procurement of building
  - "Consider accelerating the start of civil construction to take advantage of the recent aggressive construction market conditions"
    - We have bids on the detector hall from a well known contractor at a good price, so this strategy has worked.
- Detector Hall Design is 100% complete.
- 100% drawings from the A&E completed several months ago
- Interfaces defined and signed off
- Bids in hand
- Ready to go.

CD-3b Request – Detector Hall

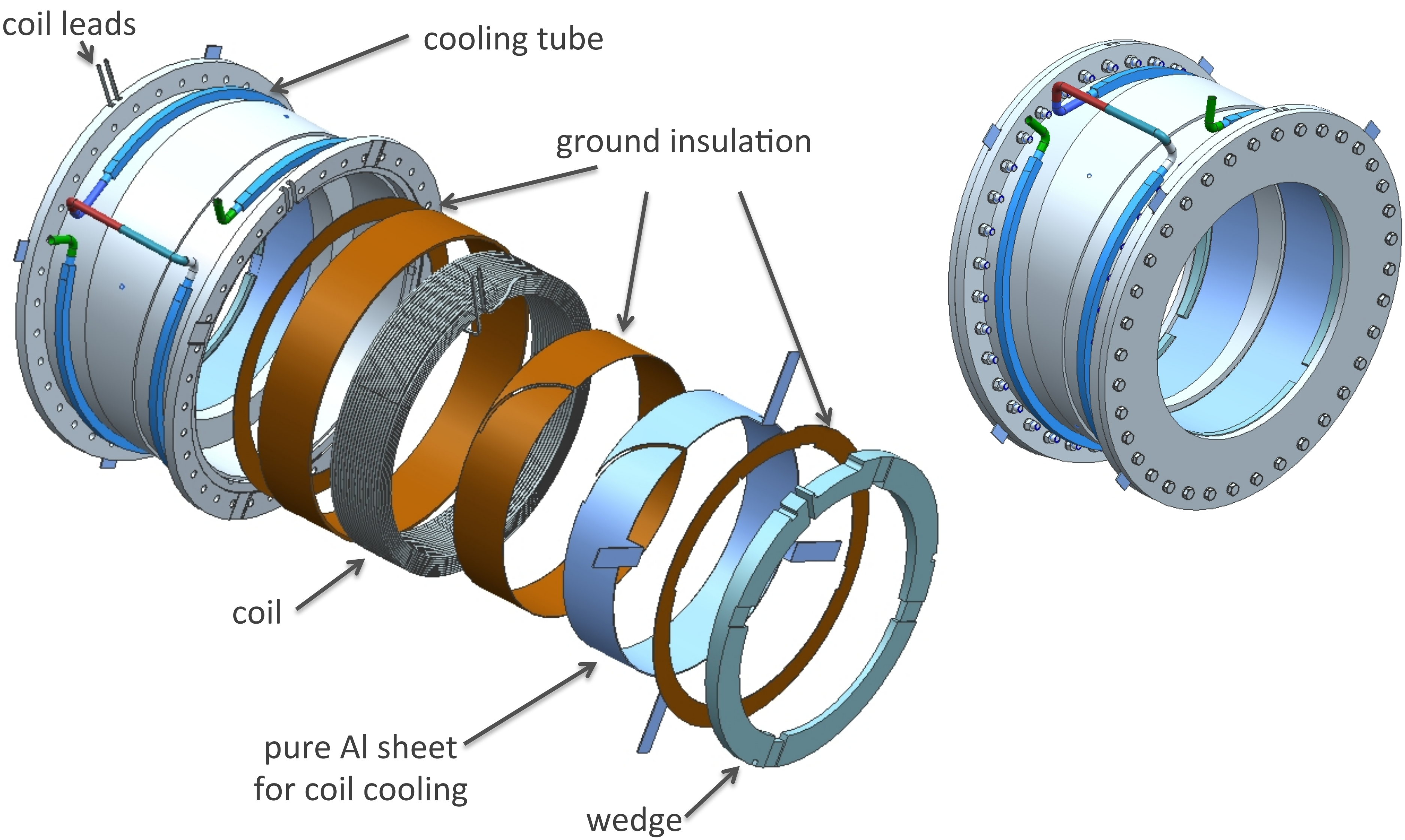


- Building interfaces well understood.
- Solenoid dimensions stable for several years.
- Confident that this is the building we need.

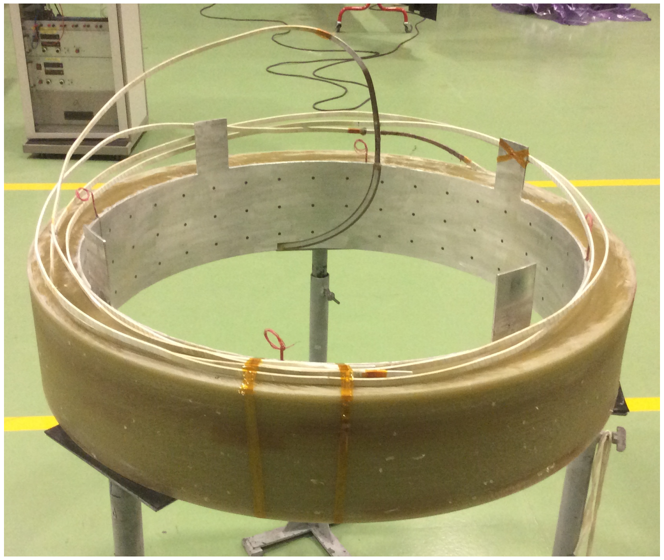
CD-3b Request – TS Modules

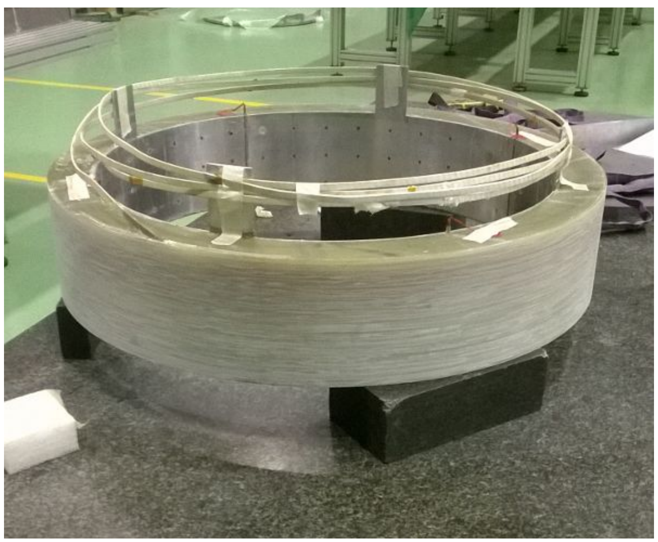
- TS Modules are on the critical path.
  - Delay of TS Modules to CD-3c delays the overall Project by 10 months
- TS Module design 90% complete. 70% of drawings complete.
  - List of remaining drawings presented in Solenoid Breakout
- 2 TS conductor coils inserted inside an aluminum shell.
  - 27 Modules in all
  - Natural extension of CD-3a decision that approved procurement of long-lead conductor. TS conductor fabrication currently underway.
- Remaining TS Module design work well understood.
- Overall solenoid designs stable
- Risk on remaining design work is low.
- Nearly complete prototype module. Detailed test plan.
- See M. Lopes' breakout talk

CD-3b Request – TS Modules

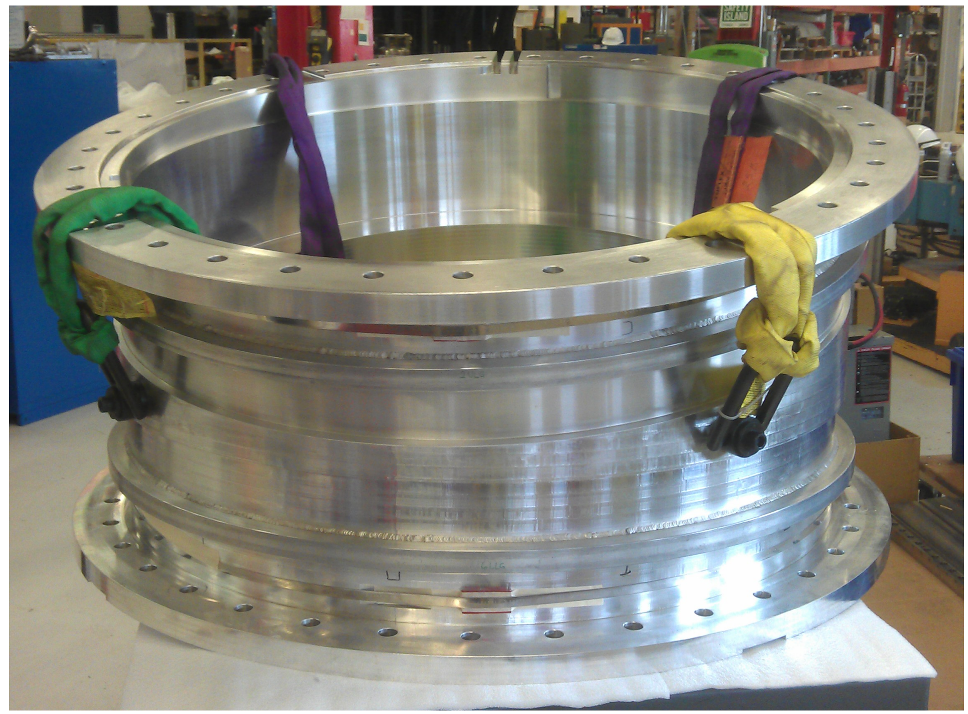


CD-3b Request – TS Modules

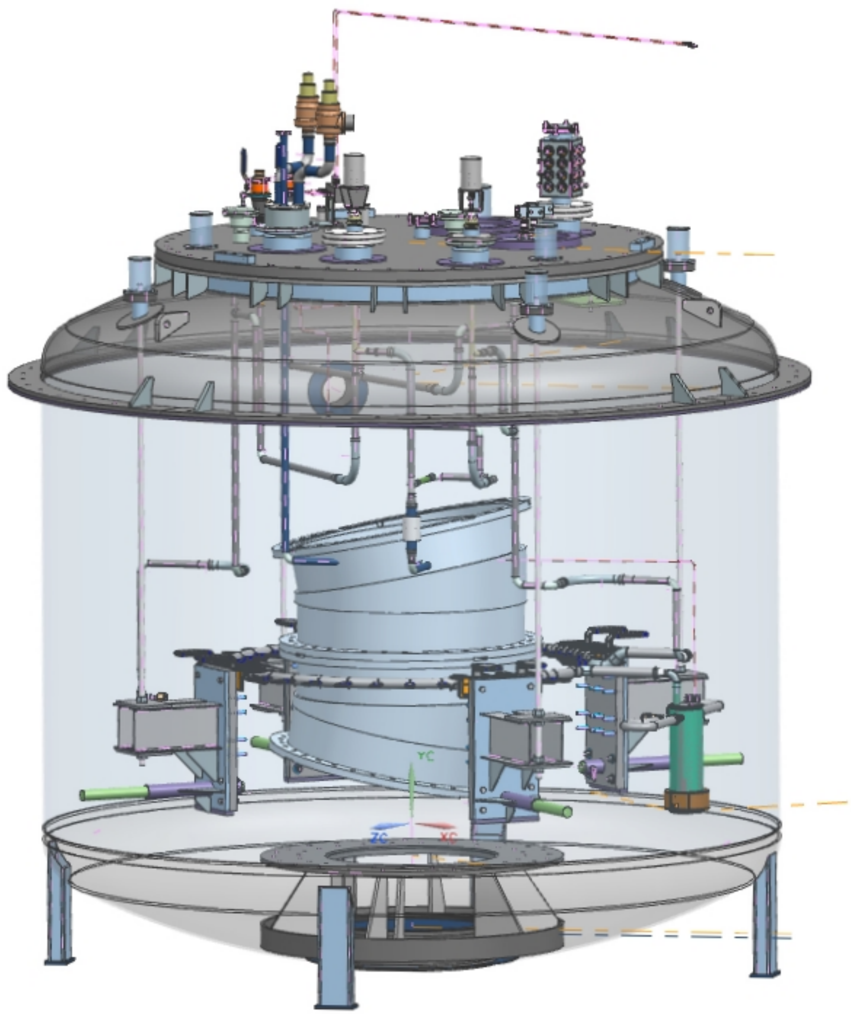




- Two coils are inserted into an aluminum shell to form a module.
- INFN collaborating on prototype.

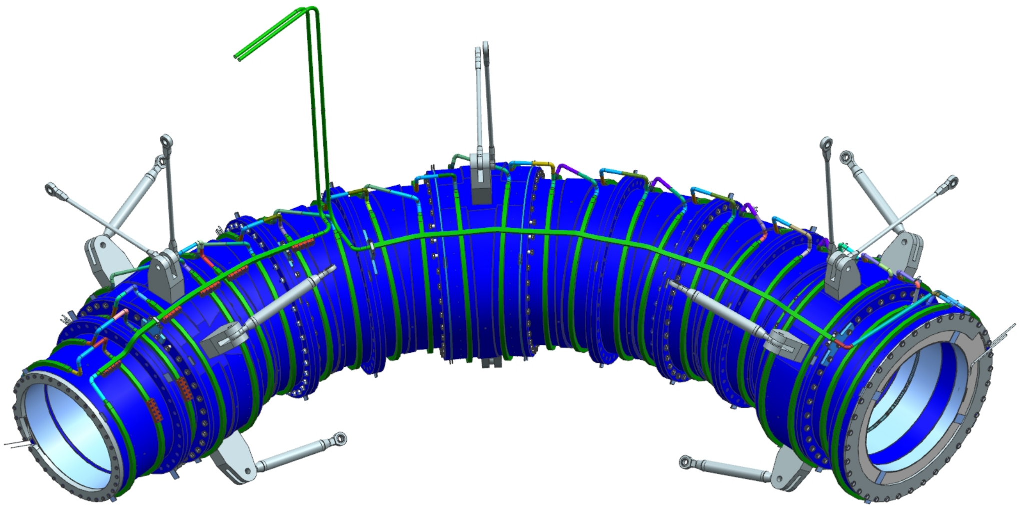


CD-3b Request – TS Modules



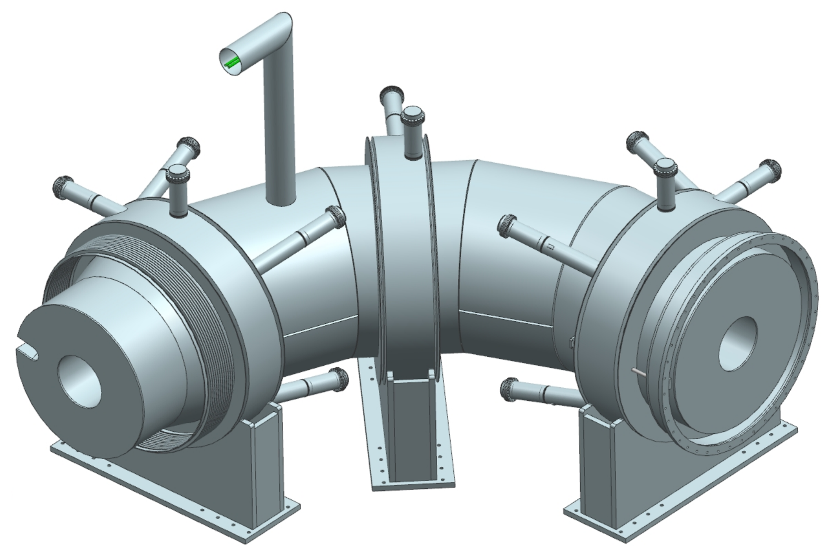
Modules are fully tested in test cryostat at Fermilab.

CD-3b Request – TS Modules



Modules are assembled into cold mass

Assembled cold mass is installed in cryostat.



CD-3b Request

	Base Cost	Contingency	Total
Detector Hall	$13M	$2.4M	$15.4M
TS Modules	$5.9M	$3.0M	$8.9M
Total	**$18.9M**	**$5.4M**	**$24.3M**

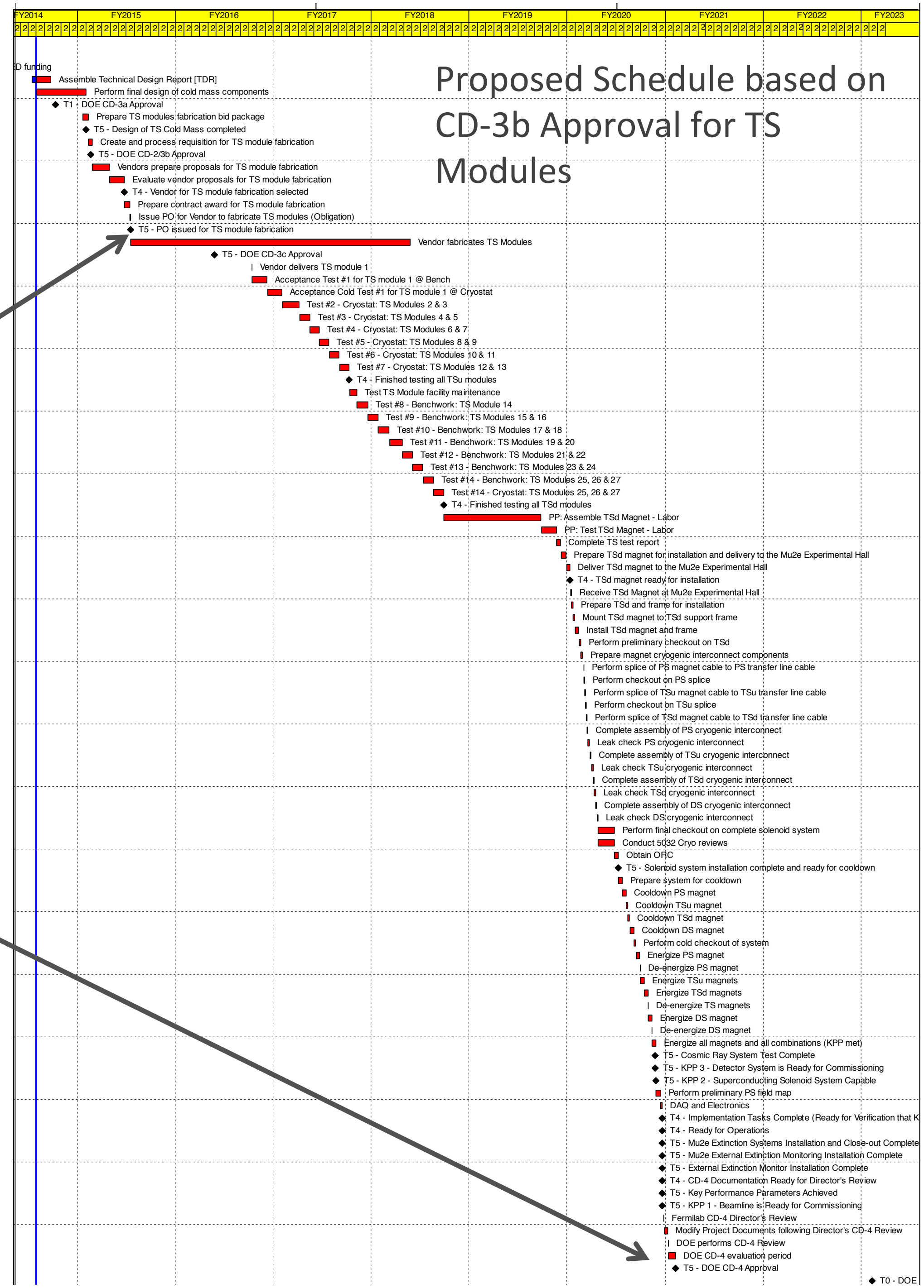
- We have the money in hand to make these purchases. We just need the authority to proceed.
  - Want to proceed immediately on Detector Hall.
  - Need PO in place for TS Modules by April to maintain schedule.

Proposed Baseline Schedule

Proposed Schedule based on CD-3b Approval for TS Modules

Issue PO for TS Modules in April 2015, based on CD-3b approval

Project Complete in November, 2020

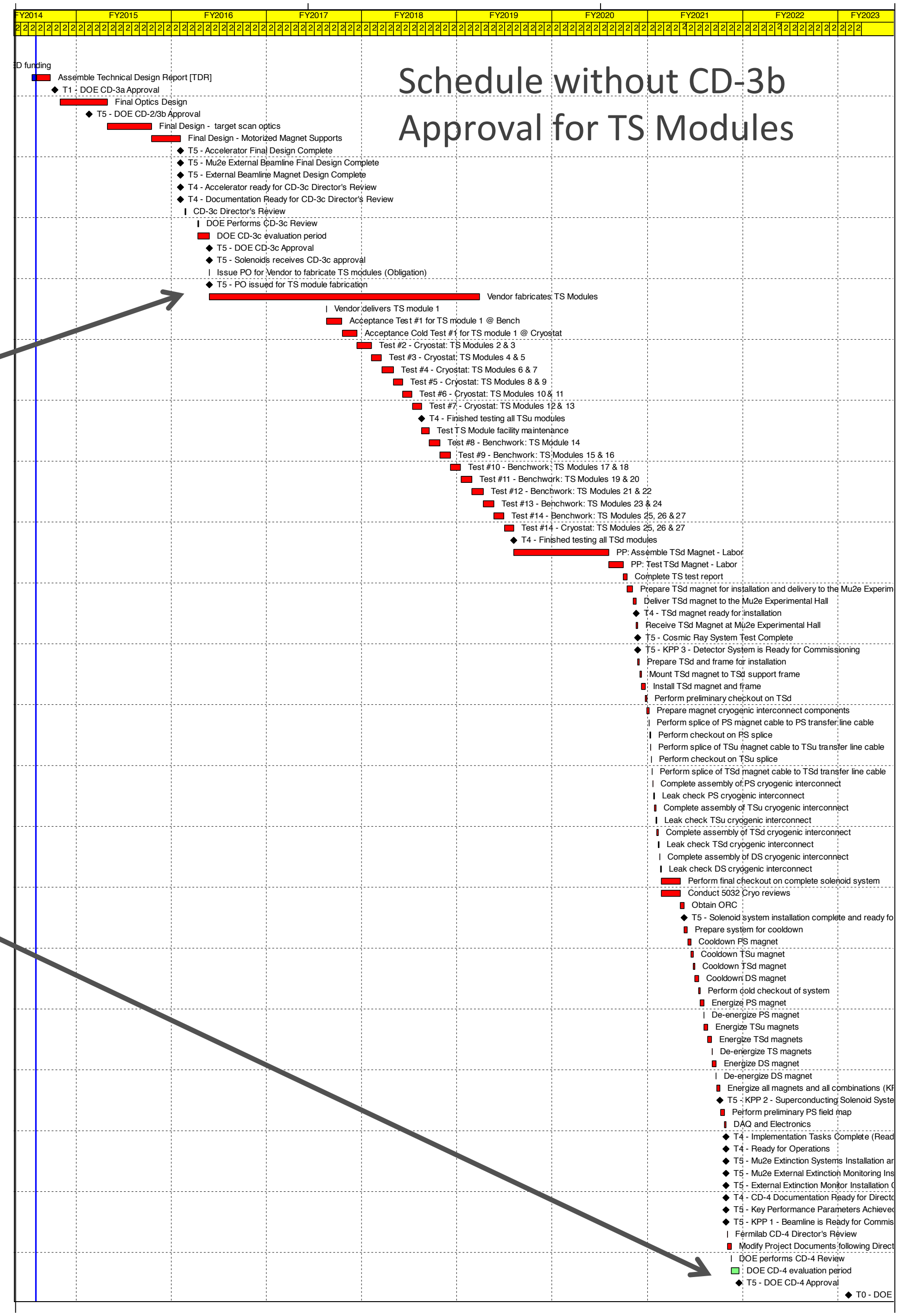


Impact of delaying TS Modules to CD-3c

Issue PO for TS Modules in Feb. 2016, based on anticipated CD-3c approval

Project Complete in September 2021, 10 months later.

- Increased cost
- Competition from Japan



Status of Recommendations

Review	Total no.	Open
Director's pre-CD-2/3b review	53	3
DOE CD-3a review	2	1
DOE Briefing (Feb2014)	3	0
DOE Briefing (Sep2014)	1	0
DOE mini-review (Apr2013)	1	0
DOE mini-review (Nov2012)	3	0
DOE-CD-1 review	24	1
Director's pre-CD-1 review	49	0
Independent Design Review	48	0

- 184 Recommendations/Action Items total.
- 179 Closed. 5 Open.
- Detailed talk in Management Breakout.

KPPs

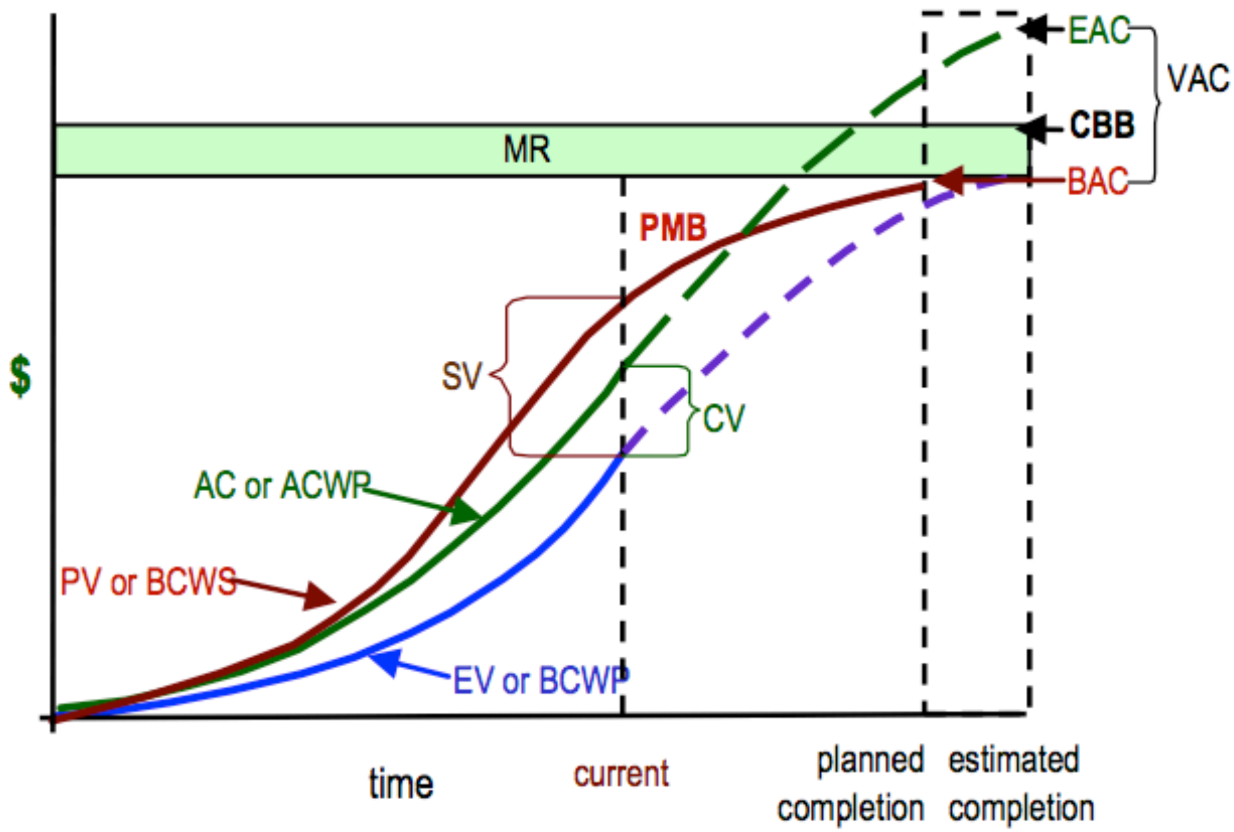
Key Parameters	Threshold Performance	Objective Performance
Accelerator	All accelerator components, RF and resonant extraction components are installed and tested at specified voltages and currents. The production target and support hardware is complete, delivered to Fermilab and ready for installation. Heat and Radiation Shield is installed in Production Solenoid. Shielding designed for 1.5 kW operation delivered to Fermilab and ready for installation	Protons are delivered to the diagnostic absorber in the M4 beamline. Shielding designed for 8 kW operation delivered to Fermilab and ready for installation.
Superconducting Solenoids	The Production, Transport and Detector Solenoids have been cooled and powered to the settings necessary to take physics data.	The Production, Transport and Detector Solenoids have been cooled and powered to their nominal field settings.
Detector Components	Cosmic ray tracks are observed in the Tracker, Calorimeter and a subset of the Cosmic Ray Veto and acquired by the Data Acquisition System after they are installed in the garage position behind the DS. The balance of the CRV counters are at Fermilab and ready for installation.	The cosmic ray data in the detectors is acquired by the Data Acquisition System, reconstructed in the online processors, visualized in the event display and stored on disk.

Objective KPPs are preferred outcome and are costed.

Threshold KPPs still allow for good physics

Details in Management Breakout

EVMS



EAC
VAC
CBB
MR
BAC
PMB
$
SV
CV
AC or ACWP
PV or BCWS
EV or BCWP
time
current
planned completion
estimated completion

EVMS

- All CAMS have received EVMS training.
- Have been statusing the schedule since January
- Most statusing is done face-to-face between CAM and Project Controls leads.
- Cost and schedule trued up to actuals through April.
- Cost Performance Reports generated for April - September and included in Monthly Reports (available from Review web page).

EVMS – Report by L2 - June through Sept

June 30, 2014
Currency in: $K

Work Package.WBS (2)	Current Period							Cumulative to Date									At Complete				
	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	SPI	CPI	BAC	EAC	VAC	% Spent	% Complete
475.01 Project Management	217	217	202	0	0%	15	7%	8,893	8,893	8,866	0	0%	27	0%	1.00	1.00	20,669	20,647	21	43%	43%
475.02 Accelerator	747	689	330	(58)	-8%	359	52%	11,122	10,858	10,712	(265)	-2%	145	1%	0.98	1.01	40,806	40,437	369	26%	27%
475.03 Conventional Construction	87	80	25	(7)	-8%	55	68%	2,458	2,421	2,337	(37)	-1%	84	3%	0.99	1.04	21,245	21,124	121	11%	11%
475.04 Solenoids	325	171	382	(155)	-48%	(212)	-124%	15,488	15,650	15,747	162	1%	(97)	-1%	1.01	0.99	87,968	88,276	(309)	18%	18%
475.05 Muon Beamline	147	116	111	(31)	-21%	5	5%	4,290	4,142	4,136	(148)	-3%	7	0%	0.97	1.00	19,567	19,525	42	21%	21%
475.06 Tracker	135	67	72	(67)	-50%	(5)	-7%	2,931	2,762	2,864	(168)	-6%	(102)	-4%	0.94	0.96	11,523	11,598	(75)	25%	24%
475.07 Calorimeter	71	49	6	(23)	-32%	43	88%	276	396	211	120	43%	185	47%	1.43	1.88	4,928	4,831	96	4%	8%
475.08 Cosmic Ray Veto	165	78	72	(87)	-53%	6	8%	1,570	1,389	1,380	(181)	-12%	8	1%	0.88	1.01	6,773	6,727	45	21%	21%
475.09 Trigger & DAQ	83	80	72	(2)	-3%	9	11%	1,684	1,663	1,653	(21)	-1%	10	1%	0.99	1.01	4,800	4,781	20	35%	35%
Total	**1,977**	**1,547**	**1,272**	**(430)**	**-22%**	**276**	**18%**	**48,712**	**48,174**	**47,906**	**(538)**	**-1%**	**267**	**1%**	**0.99**	**1.01**	**218,278**	**217,947**	**331**	**22%**	**22%**

July 31, 2014
Currency in: $K

Work Package.WBS (2)	Current Period							Cumulative to Date									At Complete				
	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	SPI	CPI	BAC	EAC	VAC	% Spent	% Complete
475.01 Project Management	231	231	223	0	0%	8	4%	9,124	9,124	9,089	0	0%	35	0%	1.00	1.00	20,669	20,639	29	44%	44%
475.02 Accelerator	395	549	433	154	39%	116	21%	11,517	11,406	11,146	(111)	-1%	261	2%	0.99	1.02	40,806	40,178	627	28%	28%
475.03 Conventional Construction	71	72	51	1	2%	21	29%	2,529	2,493	2,388	(36)	-1%	105	4%	0.99	1.04	21,245	21,106	139	11%	12%
475.04 Solenoids	767	383	885	(383)	-50%	(502)	-131%	16,254	16,033	16,632	(221)	-1%	(599)	-4%	0.99	0.96	87,968	88,425	(457)	19%	18%
475.05 Muon Beamline	72	94	93	22	30%	1	2%	4,362	4,236	4,228	(126)	-3%	8	0%	0.97	1.00	19,567	19,586	(19)	22%	22%
475.06 Tracker	97	56	72	(41)	-42%	(16)	-29%	3,027	2,818	2,936	(209)	-7%	(118)	-4%	0.93	0.96	11,523	11,585	(62)	25%	24%
475.07 Calorimeter	80	46	6	(34)	-43%	40	87%	356	442	217	85	24%	225	51%	1.24	2.04	4,928	4,745	182	5%	9%
475.08 Cosmic Ray Veto	165	62	100	(102)	-62%	(38)	-61%	1,735	1,451	1,481	(284)	-16%	(30)	-2%	0.84	0.98	6,773	6,640	133	22%	21%
475.09 Trigger & DAQ	80	71	63	(9)	-12%	7	10%	1,764	1,734	1,717	(30)	-2%	17	1%	0.98	1.01	4,800	4,836	(36)	36%	36%
Total	**1,957**	**1,564**	**1,927**	**(393)**	**-20%**	**(363)**	**-23%**	**50,669**	**49,738**	**49,833**	**(931)**	**-2%**	**(95)**	**0%**	**0.98**	**1.00**	**218,278**	**217,741**	**537**	**23%**	**23%**

August 31, 2014
Currency in: $K

Work Package.WBS (2)	Current Period							Cumulative to Date									At Complete				
	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	SPI	CPI	BAC	EAC	VAC	% Spent	% Complete
475.01 Project Management	221	221	244	0	0%	(23)	-10%	9,345	9,345	9,332	0	0%	12	0%	1.00	1.00	20,669	20,668	1	45%	45%
475.02 Accelerator	386	204	313	(182)	-47%	(109)	-53%	11,904	11,611	11,459	(293)	-2%	152	1%	0.98	1.01	40,806	40,257	549	28%	28%
475.03 Conventional Construction	68	80	26	13	19%	55	68%	2,596	2,574	2,414	(23)	-1%	160	6%	0.99	1.07	21,245	21,080	165	11%	12%
475.04 Solenoids	386	199	388	(187)	-48%	(189)	-95%	16,640	16,232	17,020	(408)	-2%	(788)	-5%	0.98	0.95	87,968	88,585	(617)	19%	18%
475.05 Muon Beamline	52	74	104	22	42%	(31)	-42%	4,414	4,310	4,332	(104)	-2%	(22)	-1%	0.98	0.99	19,567	19,632	(65)	22%	22%
475.06 Tracker	104	55	63	(49)	-47%	(8)	-15%	3,131	2,873	2,999	(258)	-8%	(126)	-4%	0.92	0.96	11,523	11,589	(66)	26%	25%
475.07 Calorimeter	56	39	2	(17)	-30%	37	96%	412	481	218	69	17%	262	55%	1.17	2.20	4,928	4,700	228	5%	10%
475.08 Cosmic Ray Veto	117	37	45	(80)	-69%	(8)	-23%	1,851	1,488	1,526	(363)	-20%	(38)	-3%	0.80	0.98	6,773	6,591	182	23%	22%
475.09 Trigger & DAQ	76	55	72	(22)	-28%	(18)	-32%	1,841	1,789	1,789	(52)	-3%	(1)	0%	0.97	1.00	4,800	4,826	(25)	37%	37%
Total	**1,465**	**963**	**1,257**	**(502)**	**-34%**	**(294)**	**-31%**	**52,134**	**50,701**	**51,090**	**(1,433)**	**-3%**	**(389)**	**-1%**	**0.97**	**0.99**	**218,278**	**217,928**	**351**	**23%**	**23%**

September 30, 2014
Currency in: $K

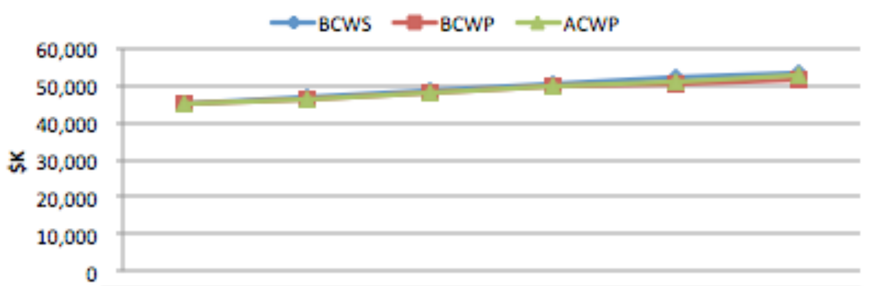
Work Package.WBS (2)	Current Period							Cumulative to Date									At Complete				
	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	SPI	CPI	BAC	EAC	VAC	% Spent	% Complete
475.01 Project Management	221	221	158	0	0%	63	28%	9,565	9,565	9,490	0	0%	75	1%	1.00	1.01	20,669	20,600	69	46%	46%
475.02 Accelerator	302	179	154	(123)	-41%	26	14%	12,206	11,790	11,612	(416)	-3%	178	2%	0.97	1.02	40,806	40,830	(24)	28%	29%
475.03 Conventional Construction	65	68	25	4	6%	43	63%	2,661	2,642	2,439	(19)	-1%	203	8%	0.99	1.08	21,245	21,055	190	12%	12%
475.04 Solenoids	291	511	860	220	75%	(349)	-68%	16,931	16,743	17,880	(188)	-1%	(1,137)	-7%	0.99	0.94	87,968	89,129	(1,161)	20%	19%
475.05 Muon Beamline	69	96	50	27	39%	46	48%	4,483	4,406	4,382	(78)	-2%	24	1%	0.98	1.01	19,567	19,567	0	22%	23%
475.06 Tracker	107	69	57	(39)	-36%	12	18%	3,238	2,941	3,056	(296)	-9%	(114)	-4%	0.91	0.96	11,523	11,579	(56)	26%	26%
475.07 Calorimeter	52	41	101	(11)	-20%	(59)	-142%	464	522	319	58	12%	203	39%	1.12	1.64	4,928	4,763	165	7%	11%
475.08 Cosmic Ray Veto	111	56	130	(55)	-50%	(74)	-134%	1,962	1,543	1,656	(419)	-21%	(112)	-7%	0.79	0.93	6,773	6,640	133	25%	23%
475.09 Trigger & DAQ	76	40	39	(36)	-47%	2	4%	1,917	1,829	1,828	(88)	-5%	1	0%	0.95	1.00	4,800	4,800	(0)	38%	38%
Total	**1,294**	**1,281**	**1,572**	**(13)**	**-1%**	**(291)**	**-23%**	**53,428**	**51,982**	**52,662**	**(1,446)**	**-3%**	**(680)**	**-1%**	**0.97**	**0.99**	**218,278**	**218,961**	**(683)**	**24%**	**24%**

Earned Value Report for September by Control Account

Mu2e Project
September 30, 2014
Currency in: $K

	Current Period							Cumulative to Date									At Complete				
Control Account	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	SPI	CPI	BAC	EAC	VAC	% Spent	% Complete
475.01.02 Project Office Conceptual Design (Post CD-0: OPC)	31	31	2	0	0%	29	94%	4,832	4,832	4,688	0	0%	144	3%	1.00	1.03	4,951	4,806	144	98%	98%
475.01.03 Project Office Preliminary & Final Design Phase to CD-2/3	190	190	156	0	0%	34	18%	4,733	4,733	4,802	0	0%	(69)	-1%	1.00	0.99	4,733	4,802	(69)	100%	100%
475.01.04 Project Office Implementation & Close-out to CD-4	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	10,985	10,991	(6)	0%	0%
475.02.01 Project Management	39	39	14	0	0%	25	64%	1,157	1,157	1,219	0	0%	(62)	-5%	1.00	0.95	3,568	3,650	(82)	33%	32%
475.02.03 Instruments and Controls	6	6	10	0	0%	(5)	-79%	390	399	391	9	2%	8	2%	1.02	1.02	2,225	2,138	88	18%	18%
475.02.04 Radiation Safety and Improvments	4	5	4	1	18%	1	18%	342	328	376	(14)	-4%	(48)	-15%	0.96	0.87	2,021	2,067	(47)	18%	16%
475.02.05 Resonant Extraction System	54	31	52	(22)	-42%	(21)	-68%	1,139	962	896	(177)	-16%	66	7%	0.84	1.07	5,527	5,537	(10)	16%	17%
475.02.06 Rings RF	3	3	(2)	0	0%	5	175%	260	260	277	0	0%	(18)	-7%	1.00	0.94	1,806	1,826	(20)	15%	14%
475.02.07 External Beamline	74	3	19	(70)	-95%	(15)	-441%	972	864	861	(108)	-11%	3	0%	0.89	1.00	7,240	7,223	16	12%	12%
475.02.08 Extinction Systems	45	54	18	9	20%	36	66%	845	774	727	(71)	-8%	47	6%	0.92	1.07	3,027	3,045	(18)	24%	26%
475.02.09 Target Station	78	38	38	(40)	-51%	(0)	-1%	2,055	2,001	1,820	(55)	-3%	181	9%	0.97	1.10	10,346	10,298	48	18%	19%
475.02.10 Accelerator Conceptual Design/R&D (OPC)	0	0	(0)	0	0%	0	-	5,045	5,045	5,045	0	0%	0	0%	1.00	1.00	5,045	5,045	0	100%	100%
475.03.01 Conv.Constr. Conceptual Design	0	0	0	0	0%	(0)	-	537	537	537	0	0%	(0)	0%	1.00	1.00	537	537	(0)	100%	100%
475.03.02 Conv.Constr. Preliminary/Final Design	65	68	25	4	6%	44	64%	2,124	2,105	1,902	(19)	-1%	203	10%	0.99	1.11	2,255	2,064	192	92%	93%
475.03.03 Conv.Constr. Construction Phase Oversight	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	2,485	2,485	0	0%	0%
475.03.04.01 Mu2e Detector Service Building & Hall Fixed Price	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	12,968	12,968	0	0%	0%
475.03.04.02 Delivery Ring Upgrades	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	353	353	0	0%	0%
475.03.04.03 Fermi Procured Items and T&M	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	1,892	1,894	(1)	0%	0%
475.03.04.04 Absorber Fabrication	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	275	275	0	0%	0%
475.03.04.05 Building Controls	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	112	112	0	0%	0%
475.03.05 Conv.Constr. Project Close	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	367	367	0	0%	0%
475.04.01 Solenoids Project Management	24	24	61	0	0%	(37)	-158%	1,086	1,086	1,098	0	0%	(12)	-1%	1.00	0.99	3,456	3,470	(14)	32%	31%
475.04.02 Production Solenoid	1	0	460	(1)	-90%	(460)	-524955%	1,550	1,549	1,732	(1)	0%	(183)	-12%	1.00	0.89	15,391	15,575	(185)	11%	10%
475.04.03 Transport Solenoids	195	402	265	207	106%	137	34%	5,196	4,953	5,362	(242)	-5%	(409)	-8%	0.95	0.92	23,856	24,296	(440)	22%	21%
475.04.04 Detector Solenoid	2	20	(8)	19	1217%	28	138%	929	958	1,378	29	3%	(421)	-44%	1.03	0.69	15,901	16,339	(438)	8%	6%
475.04.05 Cryogenic Distribution System	44	53	72	8	19%	(20)	-38%	1,044	1,068	1,082	24	2%	(14)	-1%	1.02	0.99	11,643	11,619	24	9%	9%
475.04.06 Magnet Power System	7	0	1	(7)	-100%	(1)	-	282	276	268	(6)	-2%	8	3%	0.98	1.03	1,514	1,509	5	18%	18%
475.04.07 Quench Protection and Monitoring System	6	6	16	(1)	-9%	(10)	-175%	420	410	467	(10)	-2%	(57)	-14%	0.98	0.88	2,942	3,006	(64)	16%	14%
475.04.08 Magnetic Field Mapping System	1	0	0	(1)	-95%	(0)	-147%	24	21	38	(3)	-13%	(17)	-82%	0.87	0.55	1,053	1,071	(18)	4%	2%
475.04.09 Solenoids Ancillary Equipment	0	0	(0)	(0)	-100%	0	-	0	18	1	17	3724%	17	97%	38.24	35.67	988	966	22	0%	2%
475.04.10 Solenoids System Integration, Installation & Commissioning	11	7	(3)	(4)	-40%	9	138%	373	375	425	3	1%	(50)	-13%	1.01	0.88	5,195	5,250	(56)	8%	7%
475.04.11 Solenoids Conceptual Design/R&D (OPC)	0	0	(5)	0	0%	5	-	6,029	6,029	6,028	0	0%	1	0%	1.00	1.00	6,029	6,028	1	100%	100%
475.05.01 Muon Beamline Project Management	37	37	16	0	0%	20	55%	724	724	681	0	0%	43	6%	1.00	1.06	3,314	3,272	42	21%	22%
475.05.02 Vacuum System	5	35	7	30	564%	28	80%	288	249	206	(39)	-14%	43	17%	0.86	1.21	3,313	3,276	37	6%	8%
475.05.03 Collimators	5	3	10	(2)	-38%	(7)	-214%	170	172	154	2	1%	18	10%	1.01	1.11	1,364	1,348	17	11%	13%
475.05.04 Upstream External Shielding	9	10	5	1	10%	5	47%	283	267	252	(17)	-6%	14	5%	0.94	1.06	1,973	1,964	9	13%	14%
475.05.05 Stopping Target	0	0	0	0	0%	(0)	-	10	10	12	0	0%	(2)	-20%	1.00	0.83	178	181	(2)	7%	6%
475.05.06 Stopping Target Monitor	0	0	(0)	(0)	-100%	0	-	18	3	0	(15)	-85%	2	88%	0.15	8.25	334	332	2	0%	1%
475.05.07 DS Internal Shielding	1	1	(1)	(1)	-49%	1	221%	48	47	49	(0)	-1%	(2)	-4%	0.99	0.96	390	391	(2)	13%	12%
475.05.08 Muon Beam Stop	6	4	11	(2)	-34%	(7)	-175%	174	171	197	(3)	-2%	(26)	-15%	0.98	0.87	764	795	(31)	25%	22%
475.05.09 Downstream External Shielding	2	1	(3)	(1)	-68%	4	657%	359	358	400	(1)	0%	(42)	-12%	1.00	0.89	3,367	3,412	(45)	12%	11%
475.05.10 Detector Support Structure	2	1	4	(1)	-51%	(3)	-409%	383	383	421	(1)	0%	(38)	-10%	1.00	0.91	2,425	2,466	(41)	17%	16%
475.05.11 Muon Beamline Systems Integration	3	6	0	3	100%	5	93%	46	42	30	(3)	-8%	13	30%	0.92	1.43	164	150	14	20%	26%
475.05.13 Muon Beamline Conceptual Design/R&D (OPC)	0	0	(1)	0	0%	1	-	1,980	1,980	1,979	0	0%	1	0%	1.00	1.00	1,980	1,979	1	100%	100%
475.06.01 Tracker Project Management	13	13	4	0	0%	8	65%	539	539	484	0	0%	54	10%	1.00	1.11	1,807	1,753	54	28%	30%
475.06.02 Straws	5	2	23	(3)	-67%	(22)	-1323%	149	132	245	(17)	-11%	(113)	-86%	0.89	0.54	1,268	1,386	(118)	18%	10%
475.06.03 Straw Assemblies	37	39	12	3	8%	27	70%	401	323	417	(78)	-19%	(93)	-29%	0.81	0.78	3,519	3,623	(104)	11%	9%
475.06.04 Tracker Front End Electronics	45	15	22	(30)	-67%	(6)	-43%	441	273	213	(168)	-38%	59	22%	0.62	1.28	2,267	2,158	109	10%	12%
475.06.05 Tracker Infrastructure	8	0	(1)	(8)	-100%	1	-	56	22	40	(34)	-61%	(18)	-81%	0.39	0.55	940	934	7	4%	2%
475.06.06 Detector Assembly & Installation	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	70	70	0	0%	0%
475.06.07 Tracker Conceptual Design/R&D (OPC)	0	0	(4)	0	0%	4	-	1,653	1,653	1,656	0	0%	(3)	0%	1.00	1.00	1,653	1,656	(3)	100%	100%
475.07.01 Calorimeter Project Management	1	1	(1)	0	0%	2	236%	119	119	123	0	0%	(4)	-4%	1.00	0.96	269	273	(4)	45%	44%
475.07.02 Crystals	16	12	3	(4)	-23%	9	74%	36	33	46	(2)	-7%	(13)	-40%	0.93	0.72	2,612	2,617	(5)	2%	1%
475.07.03.02 Radiation & Temperature Monitoring David Hitlin	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	162	162	0	0%	0%
475.07.04 Photodetectors	19	10	89	(10)	-49%	(80)	-815%	136	107	98	(29)	-21%	9	9%	0.79	1.10	748	730	18	13%	14%
475.07.05 Electronics	0	0	9	0	0%	(9)	-	108	108	48	0	0%	59	55%	1.00	2.23	108	48	59	100%	100%
475.07.06 Calibration System	16	19	(0)	3	16%	19	100%	66	155	3	89	135%	152	98%	2.35	48.12	718	620	98	1%	22%
475.07.07 Calorimeter Power	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	4	4	0	0%	0%
475.07.08 Calorimeter Installation	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-	308	309	(1)	0%	0%
475.08.01 Cosmic Ray Veto Project Management	5	5	50	0	0%	(45)	-985%	94	94	171	0	0%	(76)	-81%	1.00	0.55	445	521	(76)	33%	21%
475.08.02 Cosmic Ray Veto Mechanical Design	4	4	14	0	0%	(10)	-231%	75	75	70	0	0%	5	7%	1.00	1.07	138	138	(0)	51%	54%
475.08.03 Scintillator extrusions	0	0	23	0	0%	(23)	-	226	201	143	(25)	-11%	58	29%	0.89	1.40	1,029	971	58	15%	20%
475.08.04 Cosmic Ray Veto Fibers	7	1	13	(6)	-90%	(12)	-1737%	25	16	29	(10)	-38%	(14)	-87%	0.62	0.54	462	474	(11)	6%	3%
475.08.05 Photodetectors	35	25	(1)	(10)	-29%	26	105%	372	310	295	(62)	-17%	15	5%	0.83	1.05	769	714	55	41%	40%
475.08.06 Cosmic Ray Veto Electronics	54	2	60	(52)	-96%	(58)	-2436%	418	150	262	(268)	-64%	(112)	-75%	0.36	0.57	1,720	1,662	58	16%	9%
475.08.07 Cosmic Ray Veto Module Fabrication	6	19	(26)	13	199%	45	238%	218	164	150	(54)	-25%	14	9%	0.75	1.10	1,490	1,437	53	10%	11%
475.08.08 Detector assembly and installation	0	0	(1)	0	0%	1	-	23	23	33	0	0%	(11)	-46%	1.00	0.68	208	219	(11)	15%	11%
475.08.09 Cosmic Ray Veto Conceptual Design/R&D (OPC)	0	0	(1)	0	0%	1	-	511	511	503	0	0%	8	2%	1.00	1.02	511	503	8	100%	100%
475.09.01 TDAQ Project Management	10	10	6	0	0%	4	41%	661	661	660	0	0%	0	0%	1.00	1.00	1,165	1,166	(1)	57%	57%
475.09.02 TDAQ System Design and Test	0	0	(0)	0	0%	0	-	294	294	294	0	0%	0	0%	1.00	1.00	361	361	0	81%	81%
475.09.03 Data Acquisition	38	24	32	(14)	-37%	(8)	-34%	595	578	586	(17)	-3%	(8)	-1%	0.97	0.99	1,831	1,845	(15)	32%	32%
475.09.04 Data Processing	16	3	(2)	(13)	-81%	5	153%	213	170	160	(44)	-21%	10	6%	0.79	1.06	860	843	17	19%	20%
475.09.05 Controls and Networking	13	4	3	(9)	-71%	1	29%	153	126	128	(27)	-17%	(1)	-1%	0.83	0.99	583	584	(1)	22%	22%
Total	**1,294**	**1,281**	**1,572**	**(13)**	**-1%**	**(291)**	**-23%**	**53,428**	**51,982**	**52,662**	**(1,446)**	**-3%**	**(680)**	**-1%**	**0.97**	**0.99**	**218,278**	**218,961**	**(683)**	**24%**	**24%**

Overall Performance



	4/30/14	5/31/14	6/30/14	7/31/14	8/31/14	9/30/14
BCWS	45,004	46,735	48,712	50,669	52,134	53,428
BCWP	45,004	46,626	48,174	49,738	50,701	51,982
ACWP	45,004	46,635	47,906	49,833	51,090	52,662

	4/30/14	5/31/14	6/30/14	7/31/14	8/31/14	9/30/14
SPI	1.00	1.00	0.99	0.98	0.97	0.97
CPI	1.00	1.00	1.01	1.00	0.99	0.99

Tools are all in place and working

CD-2 Requirements

CD-2 Requirements

	CD-2--APPROVE PERFORMANCE BASELINE	SC-2
PRIOR TO CD-2--PRELIMINARY DESIGN	Approve updated Acquisition Strategy if changes are major	SC-1 with SC-28 concurrence
	Establish a Performance Baseline (PB)	FPD
	Approve updated PEP	SC-2
	Prepare a Baseline Fund. Profile & reflect in budget docs. & PEP. Consider full funding if TPC < $50M	SC-2
	Approval of Long-Lead Procurement	SC-2
	Develop Project Management Plan, if applicable	N/A
	Complete Preliminary Design	Project
	Incorporate High Perf. & Sustainable Bldg. & Sustainable Environmental Stewardship	Project
	Conduct a Preliminary Design Review	Team external to project
	Complete Preliminary Design Report	Project
	Perform Baseline Validation Review	ICE by OECM with OPA
	Conduct a Project Definition Rating Index analysis as part of an EIR	N/A
	Conduct a Technical Readiness Assessment & develop a Technical Maturation Plan	N/A
	Employ an EVMS compliant with ANSI/EIA-748A, or as defined in the contract	Contractor
	Prepare a Hazard Analysis Report	Site Office or Lab
	Continue with Quality Assurance Program	Site Office or Lab
	Conduct Preliminary Security Vulnerability Assessment, if necessary	Site Office or Lab
	Issue Final NEPA determination (i.e., FONSI)	SC-1 or Site Office
	Update budget documents and Exhibit 300 if applicable	SC-AD

http://science.energy.gov/~/media/opa/pdf/processes-and-proceduresProject_Decision_Matrix_11_2010_n.pdf

CD-2 Requirements

- Acquisition Strategy
  - Document complete and signed (Mu2e-doc-1074)
- Establish a Performance Baseline
  - Cost, schedule, scope and scope contingency defined.
- Approve Updated PEP
  - Mature draft exists (Mu2e-doc-1172)
- Approval of Long-Lead Procurement
  - CD-3a granted July 10, 2014
- Complete Preliminary Design
  - Design documented in TDR (Mu2e-doc-4299)
- Incorporate High Performance & Sustainable Environmental Stewardship
  - Comply with DOE Guiding Principles (Mu2e-doc-2005)
  - High Performance and Sustainability Checklist (Mu2e-doc-2081)
- Conduct a Preliminary Design Review
  - Director's Review, IDR, this review.

CD-2 Requirements

- Complete Preliminary Design Report
  - TDR (Mu2e-doc-4299)
- Perform Baseline Validation Review
  - ICE performed over past 2 months. Draft report issued.
- Employ an EVM System
  - Mu2e is in compliance with Fermilab certified EVM System. Tools and processes in place. Reports for April - September generated.
- Prepare a Hazard Analysis Report
  - Mu2e-doc-4229 – See D. Hahn's Management breakout talk.
- Continue with QA Program
  - Rigorous QA program for solenoid conductor in place and serves as an example for the rest of the Project.
- Conduct Preliminary Security Vulnerability Assessment
  - Mu2e-doc-676. Theft, vandalism, computer security are the primary issues.
- Issue Final NEPA determination
  - Categorical Exclusion obtained in June, 2012 (Mu2e-doc-2274).

Additional Requirements for CD-3

	CD-3--APPROVE START OF CONSTRUCTION	SC-2
PRIOR TO CD-3--FINAL DESIGN	Approve updated CD-2 Project Documentation (PEP, AS, PDS, etc) if major changes	Reviewed by SC-28 Approved by SC-2
	Complete Final Design	Project
	Incorporate High Performance & Sustainable Bldg. & Sustainable Env. Stewardship	Project
	Conduct a Final Design Review	Team external to project
	Complete Final Design Report	Project
	Employ a certified EVMS compliant with ANSI/EIA-748A, or as defined in the contract	Certified by SC-28
	Execution Readiness Review	ICE by OECM if warranted or IPR by OPA
	Conduct a Technology Readiness Assessment, where significant CTE modification occurs	N/A
	Update the Hazard Analysis Report	Site Office or Lab
	Prepare Construction Project Safety and Health Plan	Site Office or Lab
	Update the Quality Assurance Program	Site Office or Lab
	Finalize the Security Vulnerability Assessment Report, if necessary	Site Office or Lab

Final Design

- 100% design completed for Conventional Construction
  - Details in Conventional Construction Breakout
- TS Module design 90% complete. 70% of final drawings complete.
  - Prototype module nearly complete
    - Test plan in place
  - Internal design review scheduled
  - Readiness Review in early 2015
  - Issue P.O. in April 2015 to maintain schedule.
  - Detailed TS Module presentation in Solenoid Breakout

Summary/Charge Questions for CD-2

1. Do the proposed technical design and associated implementation approach satisfy the performance requirements? How has the project team ensured that the subsystems will be fully integrated? Are CD-4 goals reasonable and well defined?

- Technical design at or beyond Preliminary design stage for vast majority of components.
  - Design satisfies requirements (see following talks from L2 Managers)
  - Integration incorporated into design process. Integration team in place. Signed agreements between responsible parties required as part of final design.
  - KPPs developed in consultation with OHEP. Define CD-4 requirements. Threshold and Objective KPPs defined. Threshold KPPs produce good physics. (See Management breakout)

2. Is the cost estimate and schedule consistent with the plan to deliver the technical scope? Is the contingency adequate for the risk?

- Comprehensive RLS has been constructed consistent with Fermilab standards including the certified EVM System.
  - Overall contingency of 32%. 37% contingency on technical scope.
    - Have identified scope contingency that could further increase contingency, if necessary.

Summary/Charge Questions for CD-2

3. Are the management structure and resources adequate to deliver the proposed technical scope within the baseline budget and schedule as specified in the PEP?

- Lab management reorganized to better support Projects
- Mature, experienced Project team in place and functioning.
- Resource needs understood. Most resources required for FY15 identified by name.

4. Is the documentation required by DOE Order 413.3B for CD-2 complete?

- CD-2 documentation is complete

5. Are ES&H aspects being properly addressed given the Project's current stage of development?

- ES&H embedded into all aspects of Lab/Project work (see management Breakout)

6. Has the Project responded satisfactorily to the recommendations from the previous independent project review?

- Have positively responded to recommendations from all previous reviews (see Management Breakout)

Summary/Charge Questions for CD-3b

7. Is the detailed design sufficiently mature so that the Project can continue with procurement and fabrication? Has there been adequate progress on the long-lead procurement activities approved under CD-3a?

- Conventional Construction design 100% complete. Interfaces defined, understood and signed off by all owners.
- TS Module design
  - 90% complete.
  - Drawings 70% complete.
  - Prototype module nearly complete. Detailed test plan in place for prototype Good progress on solenoid conductor authorized by CD-3a.
  - Much more detail in Solenoid Breakout

8. Is the documentation required by DOE Order 413.3B for CD-3b complete?

- Documentation is complete.

Summary

- We are ready for CD-2!
- The Detector Hall and TS Modules are ready for CD-3!