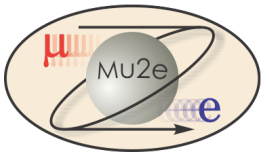
Fermilab

U.S. DEPARTMENT OF ENERGY Office of Science

Logistics for Mu2e Director's CD-2/3 Review



R. Ray
Mu2e Project Manager
7/8/2014

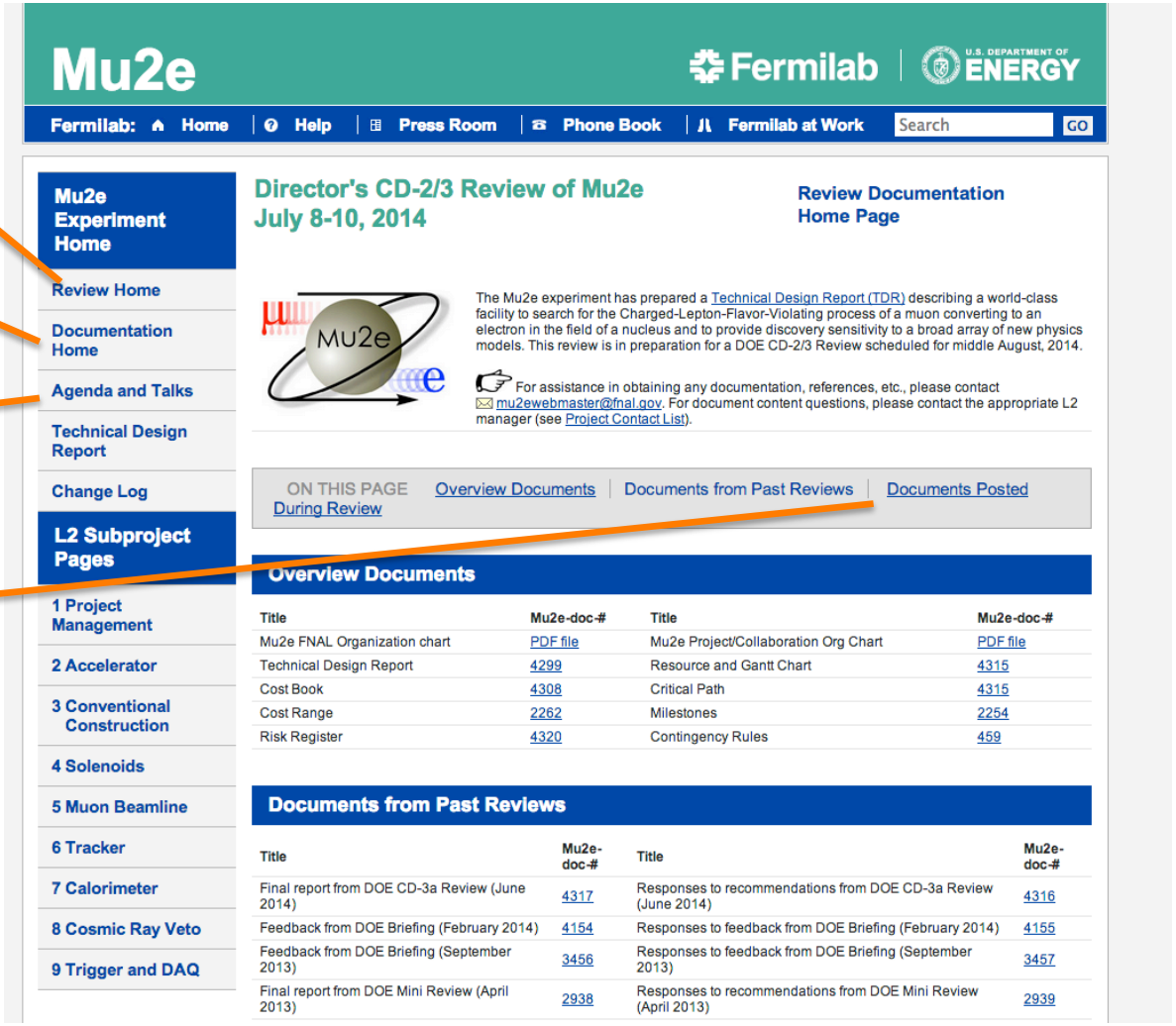
Mu2e Review Page

Takes you to Dean's Review Page

Brings you back to this page

Takes you to Indico site Where talks are posted

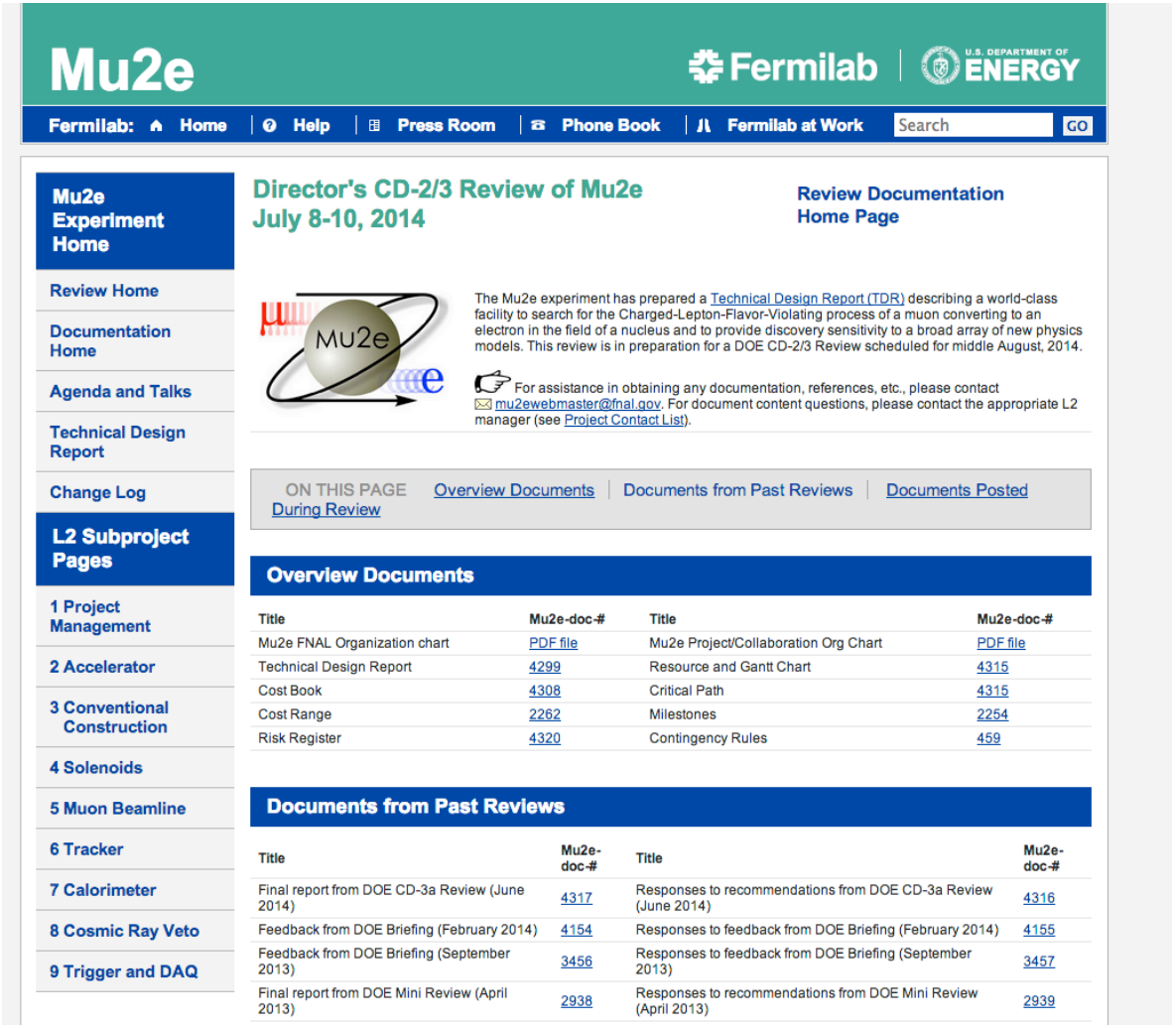
Where we'll post additional stuff as review evolves



Mu2e Review Page

http://mu2e.fnal.gov/public/project/reviews/cd2dir-review/cd2dir-index.shtml

A link to the relevant documentation for each L2 sub-project

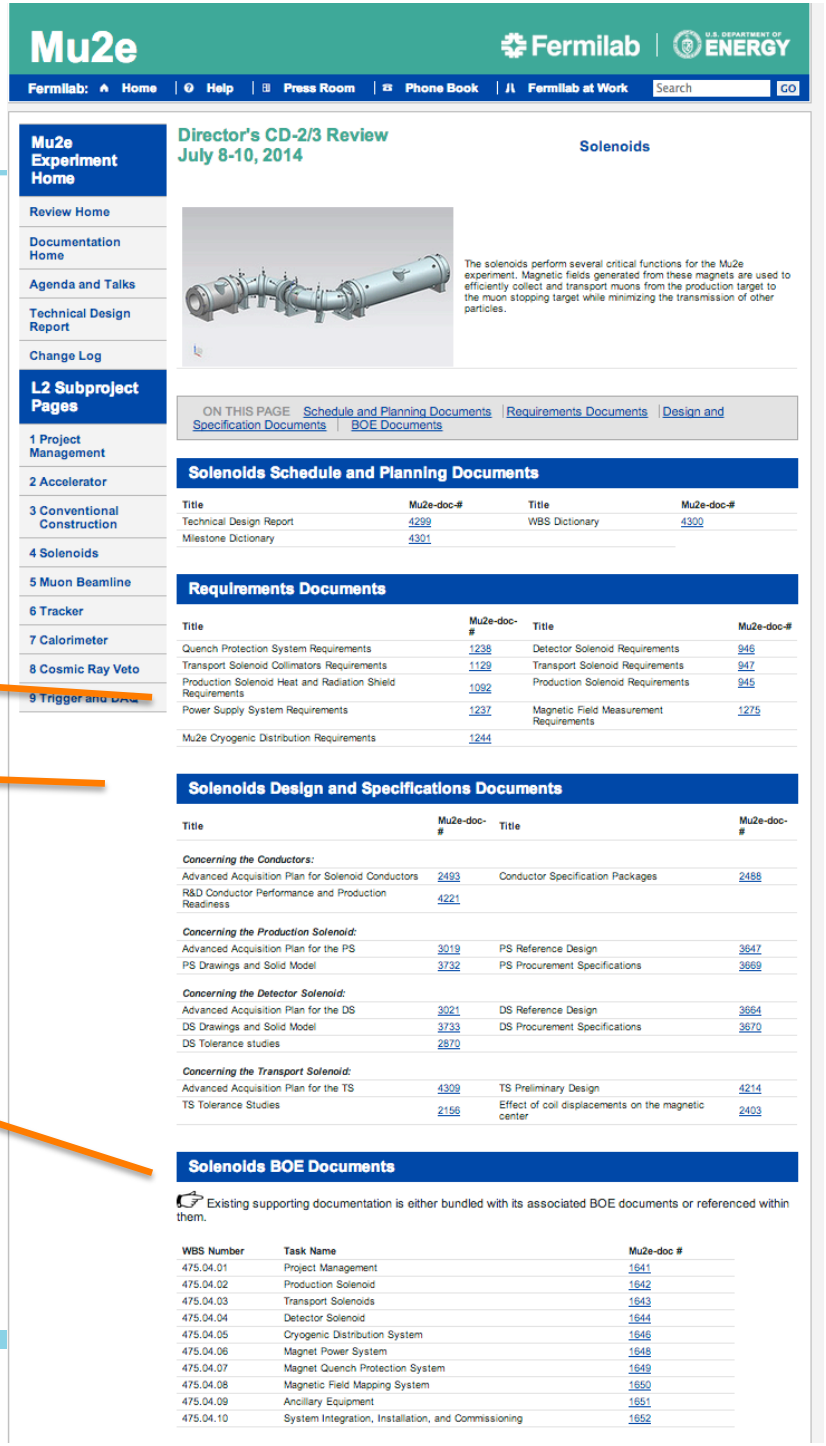


L2 Example: Solenoids

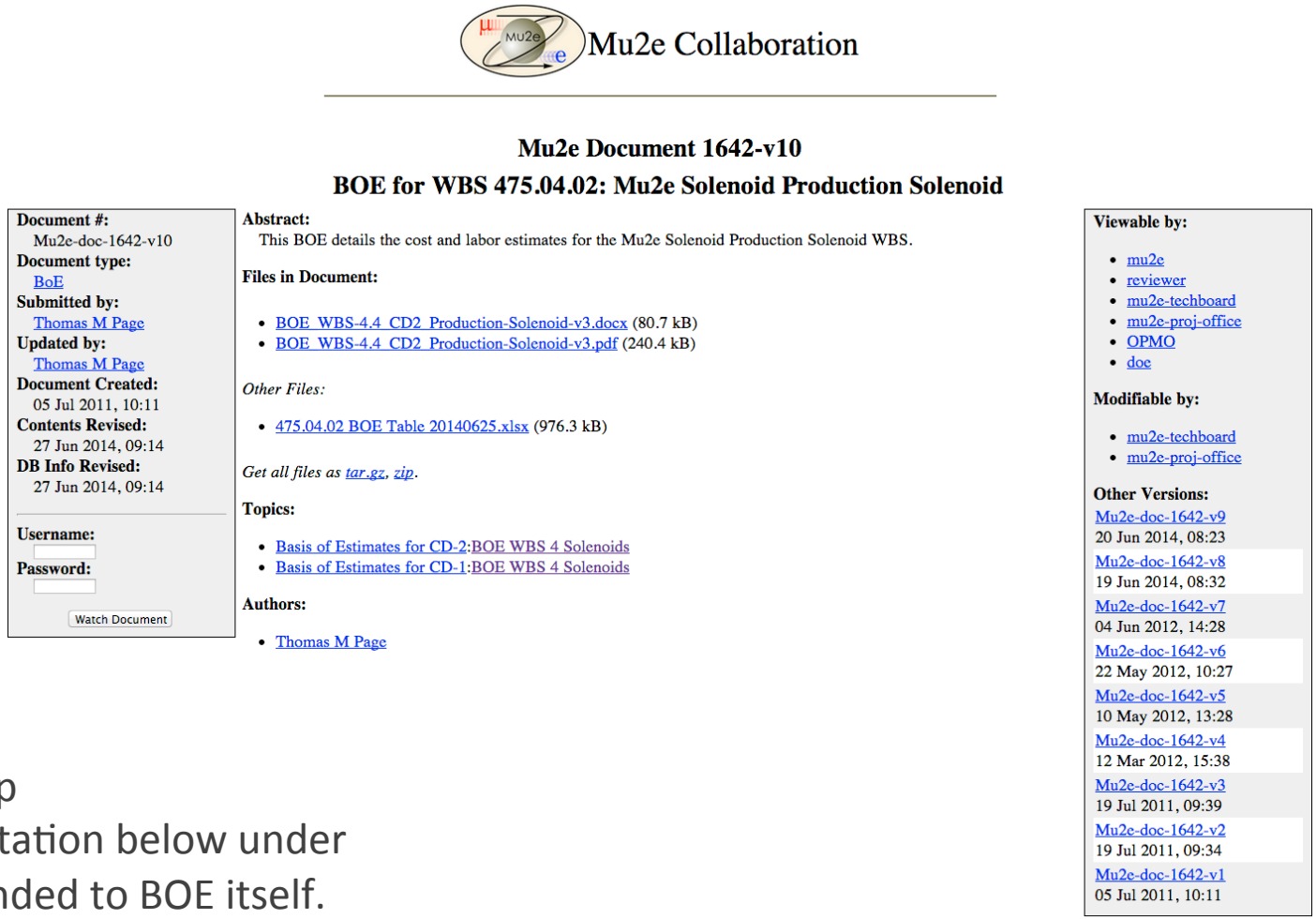
Requirements

Design and Specifications

BOEs



BOE Example



Mu2e Collaboration

Mu2e Document 1642-v10

BOE for WBS 475.04.02: Mu2e Solenoid Production Solenoid

Document #:
Mu2e-doc-1642-v10
Document type:
BoE
Submitted by:
Thomas M Page
Updated by:
Thomas M Page
Document Created:
05 Jul 2011, 10:11
Contents Revised:
27 Jun 2014, 09:14
DB Info Revised:
27 Jun 2014, 09:14

Username:
Password:
Watch Document

Abstract:
This BOE details the cost and labor estimates for the Mu2e Solenoid Production Solenoid WBS.

Files in Document:

- BOE_WBS-4.4_CD2_Production-Solenoid-v3.docx (80.7 kB)
- BOE_WBS-4.4_CD2_Production-Solenoid-v3.pdf (240.4 kB)

Other Files:

- 475.04.02 BOE Table 20140625.xlsx (976.3 kB)

Get all files as tar.gz, zip.

Topics:

- Basis of Estimates for CD-2:BOE WBS 4 Solenoids
- Basis of Estimates for CD-1:BOE WBS 4 Solenoids

Authors:

- Thomas M Page

Viewable by:

- mu2e
- reviewer
- mu2e-techboard
- mu2e-proj-office
- OPMO
- doe

Modifiable by:

- mu2e-techboard
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Other Versions:
Mu2e-doc-1642-v9
20 Jun 2014, 08:23
Mu2e-doc-1642-v8
19 Jun 2014, 08:32
Mu2e-doc-1642-v7
04 Jun 2012, 14:28
Mu2e-doc-1642-v6
22 May 2012, 10:27
Mu2e-doc-1642-v5
10 May 2012, 13:28
Mu2e-doc-1642-v4
12 Mar 2012, 15:38
Mu2e-doc-1642-v3
19 Jul 2011, 09:39
Mu2e-doc-1642-v2
19 Jul 2011, 09:34
Mu2e-doc-1642-v1
05 Jul 2011, 10:11

BOE itself is at the top
Supporting documentation below under "other files" or appended to BOE itself.

Cost Book and Gantt Chart

- Gantt Chart
  - Gives numbers as supplied from the BOEs and entered into P6
    - Hours for labor
    - FY14 $ for materials
    - Specify the resource type
- Cost Book
  - Gives total cost for each WBS item
    - Starts from the estimates in the BOEs
      - Hours for labor
      - FY14 $ for materials
    - Assigns $ values to labor resources
      - By resource type
    - Is escalated and fully burdened
  - Only Fermilab labor shows-up in Labor column
    - Univ. labor shows-up in M&S or is uncosted

Gantt Chart Example

External Beamline Safety System Total Loss Monitoring		**1344.50**	**10/14/13 A**	**2/26/19**				
47502.04.03.2.001000	Prepare documentation of TLM design features	5.00	10/14/13 A	10/18/13 A	47502.01.02.00100	ACWP	C	Engineering Physicist 10
47502.04.03.2.001010	Disseminate External Beamline TLM design. Publish documentation	5.00	10/23/13 A	10/29/13 A	47502.04.03.2.001	ACWP	C	Engineering Physicist 5
47502.04.03.2.001020	Develop the plan of using TLMs in External Beam Line Enclosure	15.00	10/1/15	10/21/15	FY16B02, 47502.04.05.00101 47502.07.01.00601 47502.04.01.00103 47502.01.02.00100	2120	C	Engineering Physicist 15
47502.04.03.2.001030	Final Shop Drawing of External Beamline Safety System TLM (Post CD-2; PED)	50.00	10/23/18	1/9/19	47502.04.02.1.001 47502.04.03.2.001 47502.04.03.2.001 47502.04.02.1.001 47502.04.02.1.001	2120	K	Engineering Physicist 123
47502.04.03.2.001040	Complete Procurement of Materials and Service for Electrical SubContractor	5.00	1/9/19	1/16/19	47502.04.03.2.001	2120	C	Accelerator Systems Specialist 2; Construction Coordinator 16
47502.04.03.2.001050	Complete Procurement of Materials and Service for Electrical SubContractor (M&S)	5.00	1/9/19	1/16/19	47502.04.03.2.001	2120	C	M&S Standard with Base Year FY14 15605
47502.04.03.2.001060	Complete Procurement of Materials and Service for Electrical SubContractor (Obligation)	1.00	1/9/19	1/10/19	47502.04.03.2.001	Obligation	C	M&S Standard with Base Year FY14 15605
47502.04.03.2.001070	Complete Procurement of Materials and assemble TLM End Caps	1.00	1/16/19	1/17/19	47502.04.03.2.001 47502.04.03.2.001 47502.04.03.2.001	2120	C	M&S Standard with Base Year FY14 100; Accelerator Systems Specialist 1; Electrical Interlock Technician 2

Activity ID

Activity Name

Docdb # for BOE

PMT Code

Resources

Cost Book Example

Fermilab labor in hours. Matches number in P6 and BOE

Labor hours for contractors and non-Fermi institutions. Matches number in P6 and BOE

M&S in FY14 dollars. Matches number in P6 and BOE

Activity ID and Name

Mu2e Cost Book CD-2 Directors Review

WBS	BoE Labor Hours	BoE Non-Fermi Hours	BoE M&S	B A C	Estimate Uncertainty	Total	Contingency on remaining costs
47502.03.03.2.001120 Purchase BLM Ion Chambers			12,600	16,112	3,222	19,335	20.0%
47502.03.03.2.001140 Assemble BLM Ion Chambers	300			34,635	8,659	43,294	25.0%
47502.03.03.2.001150 Leakage Test BLM Ion Chambers	30			3,463	866	4,329	25.0%
47502.03.03.2.001160 Radiation Test BLM Ion Chambers	60			7,860	1,965	9,825	25.0%
47502.03.03.2.001170 Install Service Buliding Hardware	30			3,463	866	4,329	25.0%
47502.03.03.2.001180 Install Tunnel Hardware	30			3,578	894	4,472	25.0%
47502.03.03.2.001190 Req prep parts for Cabling	8			971	243	1,214	25.0%
47502.03.03.2.001200 Purchase Cable Hardware			4,950	6,330	1,266	7,596	20.0%
47502.03.03.2.001210 Pull Cables		256		31,886	6,377	38,263	20.0%
47502.03.03.2.001220 Terminate Cables	12			1,385	346	1,732	25.0%
47502.03.03.2.001230 Test Cables	12			1,385	346	1,732	25.0%
47502.03.03.2.001240 Finalize readback software	80			11,867	2,967	14,833	25.0%
47502.03.03.2.001250 Test Finished System	60			12,163	3,041	15,203	25.0%
47502.03.03.2.001260 Commission BLM System	60			12,163	3,041	15,203	25.0%
47502.03.03.2.001270 Document BLM System	40			7,849	1,962	9,812	25.0%
475.02.03.04 Technical Documentation	1,855			290,032	71,863	361,894	24.8%
47502.03.04.001030 Prepare for CD-2/3 reviews	40			6,143	1,229	7,371	20.0%
47502.03.04.001055 Controls and Instrumentation Support 2014	184			28,256	7,064	35,320	25.0%

Cost Book Example (cont)

Budget At Completion (BAC) is the total cost of labor and M&S, burdened and escalated. Number produced in COBRA.

Estimate uncertainty on this activity, in burdened, escalated dollars

Total = sum of BAC and Estimate Uncertainty.

% Contingency on the work remaining. Contingency on completed work is 0.

Mu2e Cost Book CD-2 Directors Review

WBS	BoE Labor Hours	BoE Non-Fermi Hours	BoE M&S	B A C	Estimate Uncertainty	Total	Contingency on remaining costs
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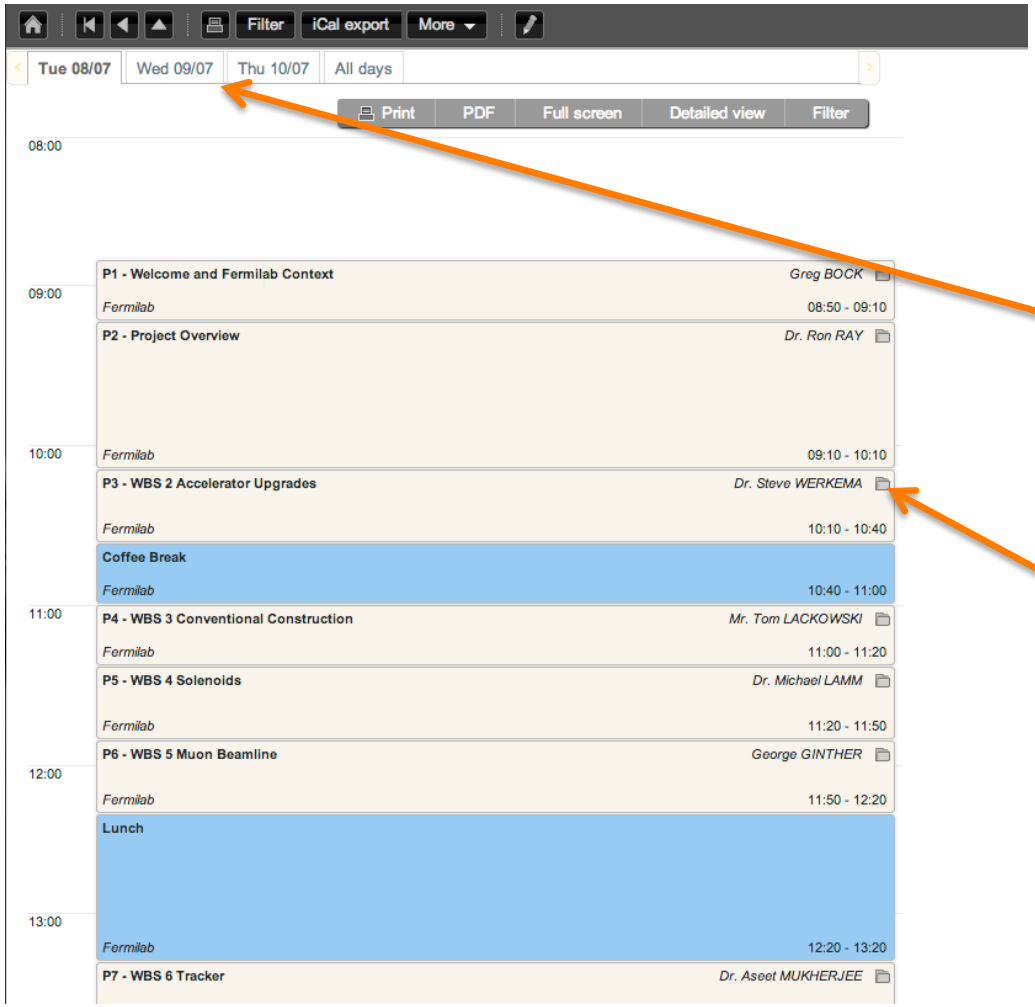
47502.03.04.001055 Controls and Instrumentation Support 2014	184			28.256	7.064	35.320	25.0%

Indico Page

https://indico.fnal.gov/conferenceDisplay.py?confId=8683#20140708

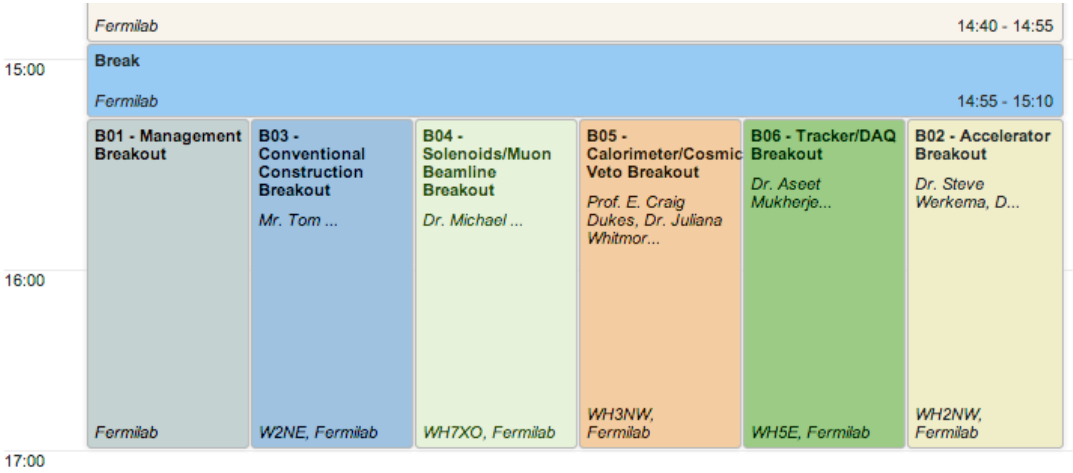


Presentations are linked to Indico page

Click here to navigate between days

Click here to open talk

Indico Page



Contribution details

15:10 B01-1 Schedule Methodology
Presenter(s): David LEEB *(Fermi National Accelerator Laboratory)*
Location: Fermilab

15:15 B01-2 Risk Analysis
Presenter(s): Mike DINNON *(Fermilab)*
Location: Fermilab

15:20 B01-3 ES&H
Presenter(s): Ms. Adrienne HAHN *(Fermilab)*
Location: Fermilab

15:25 B01-4 Uncosted Scientific Effort
Presenter(s): Dr. Douglas GLENZINSKI *(Fermilab)*
Location: Fermilab

15:30 B01-5 Procurement
Presenter(s): Steve GAUGEL *(Fermilab)*
Location: Fermilab

15:35 B01-6 Status of Recommendations
Presenter(s): Dr. Douglas GLENZINSKI *(Fermilab)*
Location: Fermilab

15:40 B01-7 Lessons Learned
Presenter(s): Dr. Ron RAY *(Fermilab)*
Location: Fermilab

15:45 B01-8 KPPs and Off-Project Installation

Breakout sessions loaded with talks, but agenda is free-form. Agenda and presentations tailored to reviewers needs.

Getting Help


For assistance in obtaining any documentation, references, etc., please contact
mu2ewebmaster@fnal.gov. For document content questions, please contact the appropriate L2 manager (see Project Contact List).

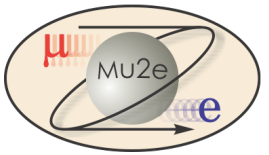
Look for this symbol.

Available from every page in Documentation Site, usually at the bottom.

Fermilab

U.S. DEPARTMENT OF ENERGY Office of Science

Mu2e Project Overview



Ron Ray
Mu2e Project Manager
7/8/2014

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 performed resulting in a Total Project Cost of $271M.
- Requesting CD-2 approval this summer along with CD-3 approval for the Mu2e Detector Hall and some parts of the accelerator system.
  - ESAAB for CD-3a long-lead procurement of superconducting cable scheduled for July 10

Tailoring Strategy

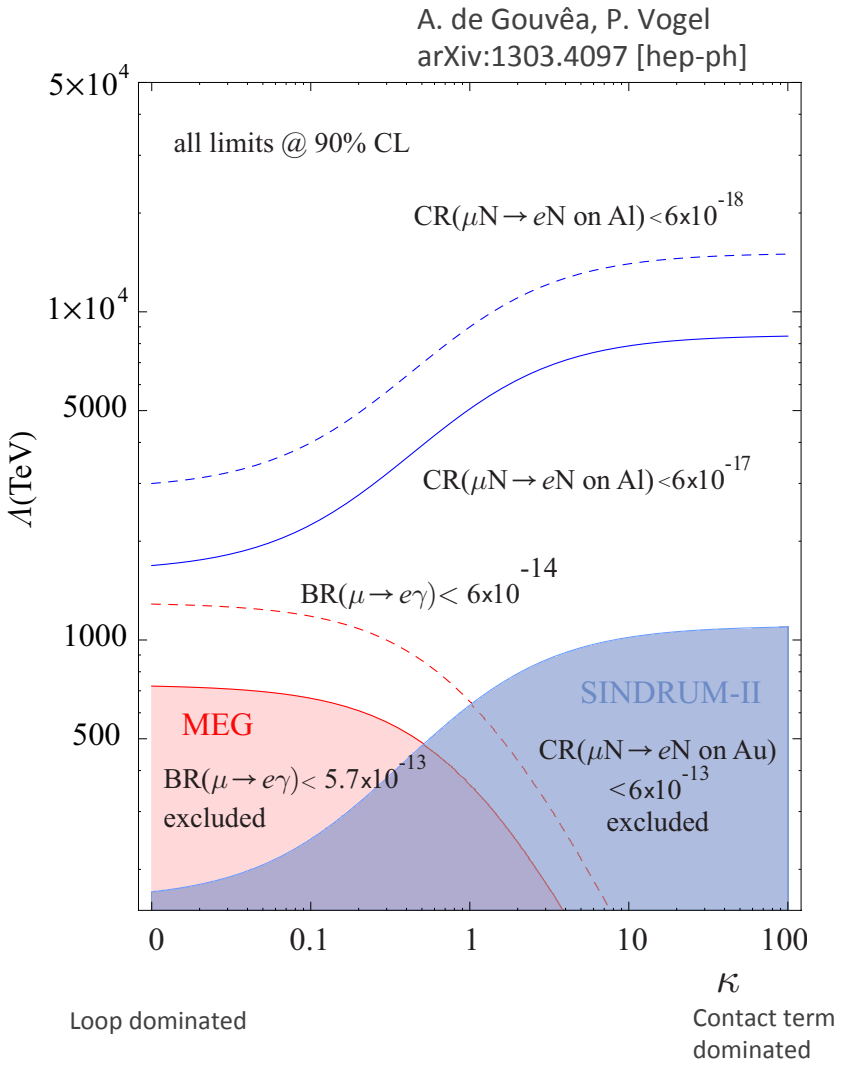
- CD-3a for long-lead solenoid conductor
  - Review held June 10, 2014
  - ESAAB scheduled for July 10, 2014
- CD-2 and CD-3 for the Detector Hall and parts of the accelerator
  - This Review
- Series of CD-3 mini reviews as other systems complete designs, pass internal design and construction readiness reviews.
  - Maximally flexible strategy suggested by DOE OPA
  - Driven by the long shadow of the solenoids that could require everything else to hibernate while waiting for designs to be completed in a traditional CD-3 strategy.

Mu2e in a Nutshell

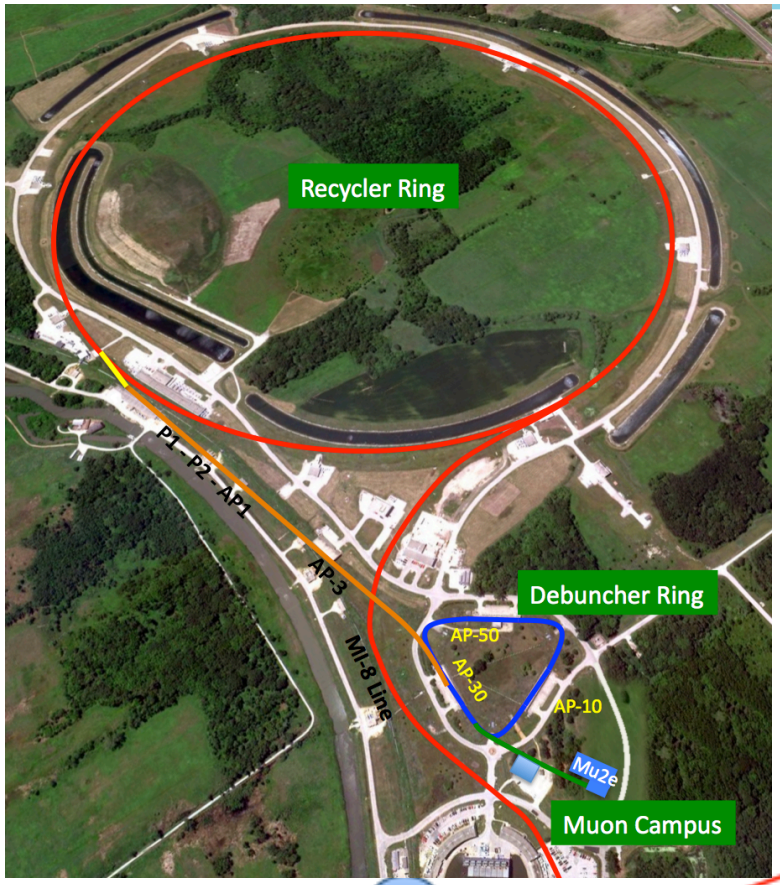
- Mu2e is a search for Charged Lepton Flavor Violation (CLFV) via the coherent conversion of $\mu^- N \rightarrow e^- N$
  - Most new physics models so far postulated provide new sources of flavor phenomena
  - Observation is unambiguous evidence for new physics.
- Target sensitivity has great discovery potential
  - Goal: Single-event-sensitivity of 2.5 x 10^{-17} (relative to ordinary μ capture)
  - Goal: <0.5 events background
    - Yields Discovery Sensitivity for all rates > few 10^{-16}
    - Factor of 10,000 more sensitive than existing measurement.
- Quark flavor is violated. Neutrino flavor is violated.
  - Both implied something profound about the underlying physics
  - Both garnered Nobel Prizes
- Mu2e enables a search for charged lepton flavor violation with unprecedented precision that could prove to be equally profound.

Science drivers

- Explore the unknown, new particles, interactions and physical principles (in the new P5 framework).
- Broad discovery sensitivity across all categories of new physics models
- Sensitivity to 10,000 TeV, well beyond any imaginable accelerator
- Sensitive to new physics at LHC energies that is suppressed by small mixing angles, loop factors
- Sensitive to new physics at 10 TeV, beyond reach of LHC but within reach of 100 TeV pp collider.

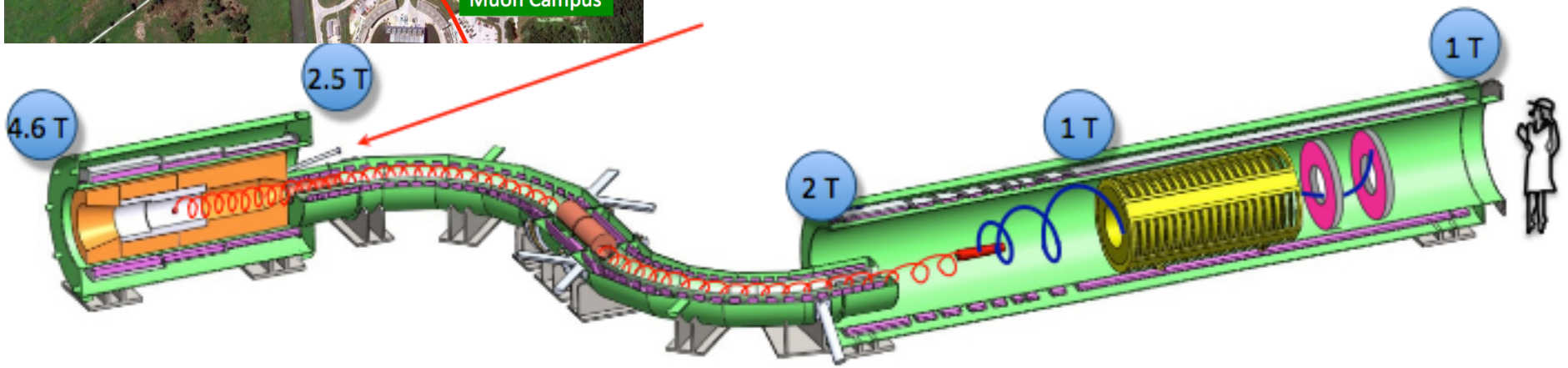


Mu2e Project Scope



Mu2e Project scope includes

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



Mu2e Collaboration

Laboratori Nazionali di Frascati
INFN Genova
INFN Lecce and Università del Salento
INFN Lecce and Università Marconi Roma
INFN Pisa
Universita di Udine and INFN Trieste/Udine

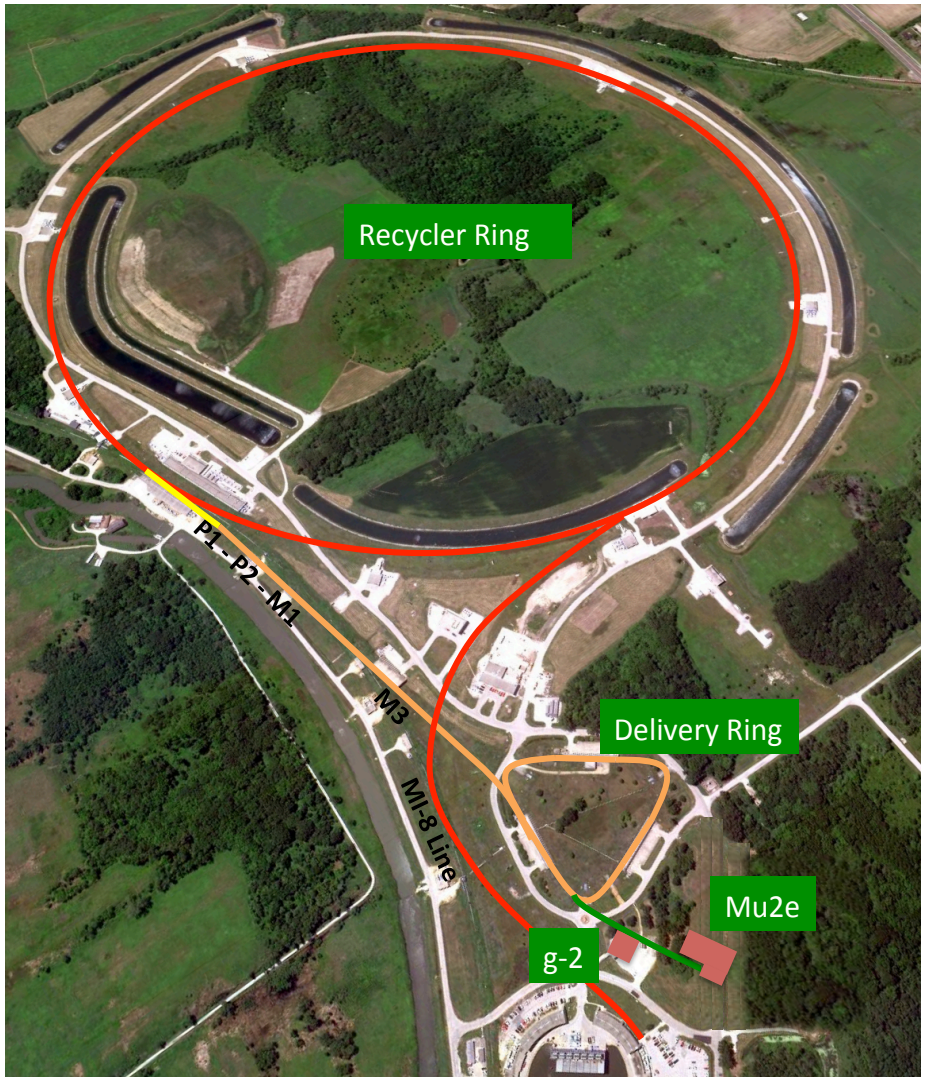
Joint Institute for Nuclear Research, Dubna
Institute for Nuclear Research, Moscow

Boston University
Brookhaven National Laboratory
Lawrence Berkeley National Laboratory
University of California, Berkeley
University of California, Irvine
California Institute of Technology
City University of New York
Duke University
Fermi National Accelerator Laboratory
University of Houston
University of Illinois
Lewis University
University of Massachusetts, Amherst
Muons Inc.
Northern Illinois University
Northwestern University
Pacific Northwest National Laboratory
Purdue University
Rice University
University of Virginia
University of Washington

How Does the Experiment Work?

What Drives the design?

Beam Delivery

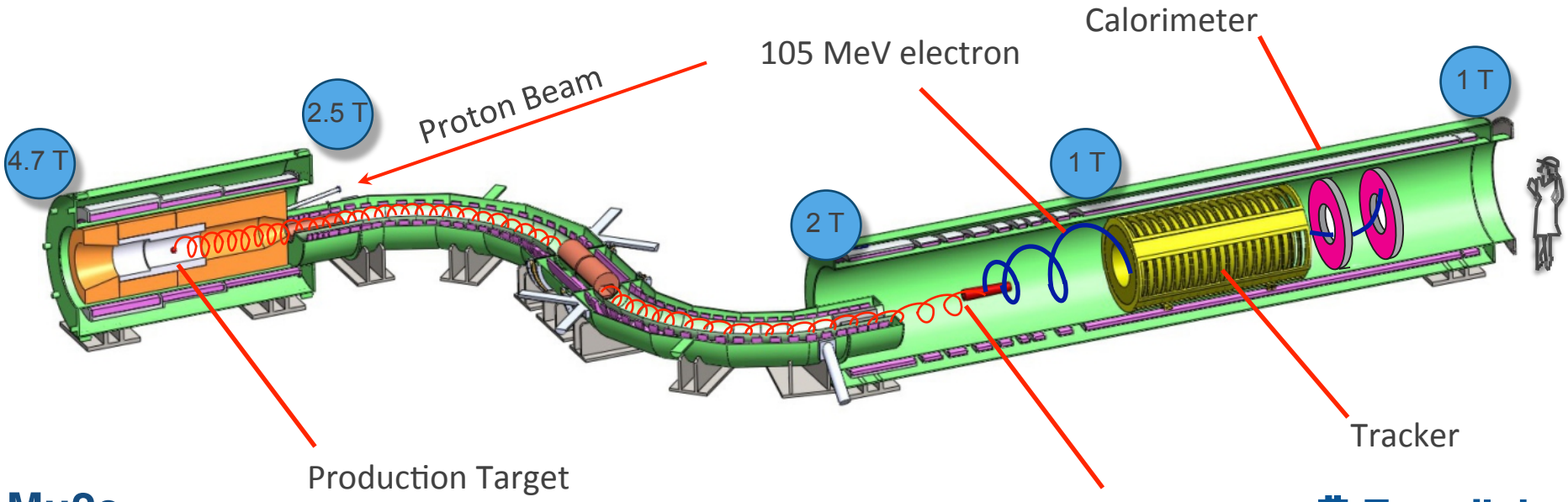


- We make muons by directing 8 GeV protons on to a target.
- Batches of protons from the Booster are transported through existing beamlines to the Recycler Ring where they are re-bunched and transported to the Delivery Ring through existing transport lines.
- Beam is slow extracted from Delivery Ring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

Mu2e Apparatus

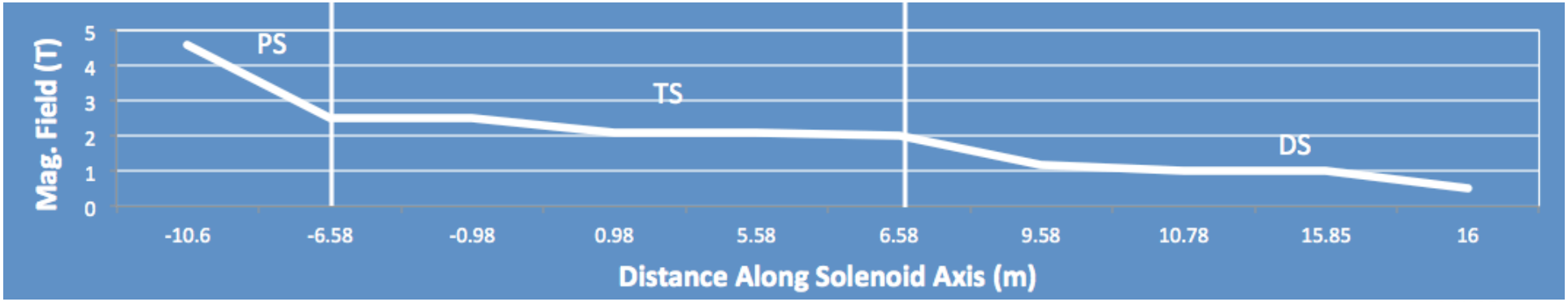
- Solenoids capture pions, form secondary muon beam, preserve timing structure, provide magnetic field for momentum analysis and help to reject backgrounds
  - Most efficient way of producing an intense, low energy muon beam
- 2 targets
- Tracker – Straw tubes
- Calorimeter – BaF2 crystals
- Cosmic Ray Veto – Scintillator, WLS fibers, SiPMs
- Stopping Target Monitor – Crystal
- Warm bore of solenoids evacuated to 10^{-4} to 10^{-5} Torr.

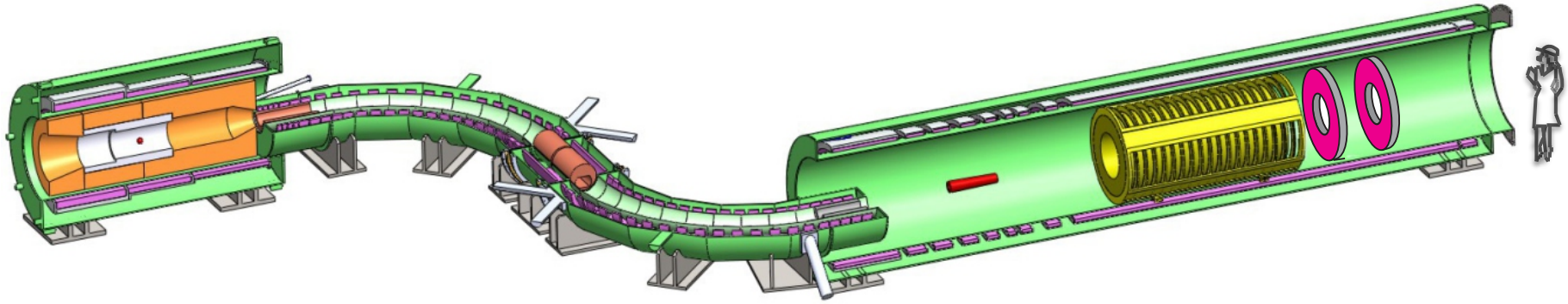
Cosmic Ray Veto and Stopping Target Monitor not shown



Mu2e Apparatus

Magnetic Field Profile – Driven by the science requirements

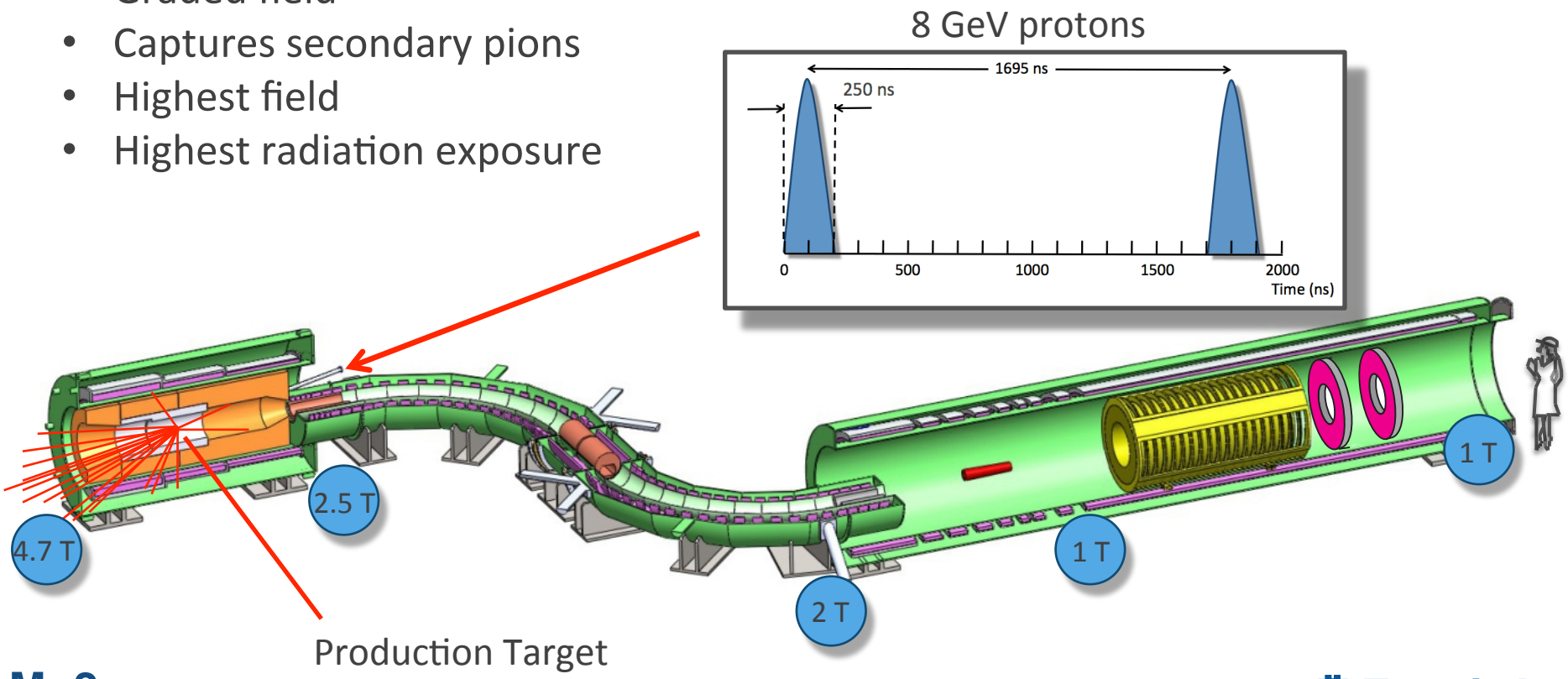




Mu2e Apparatus

Production Solenoid

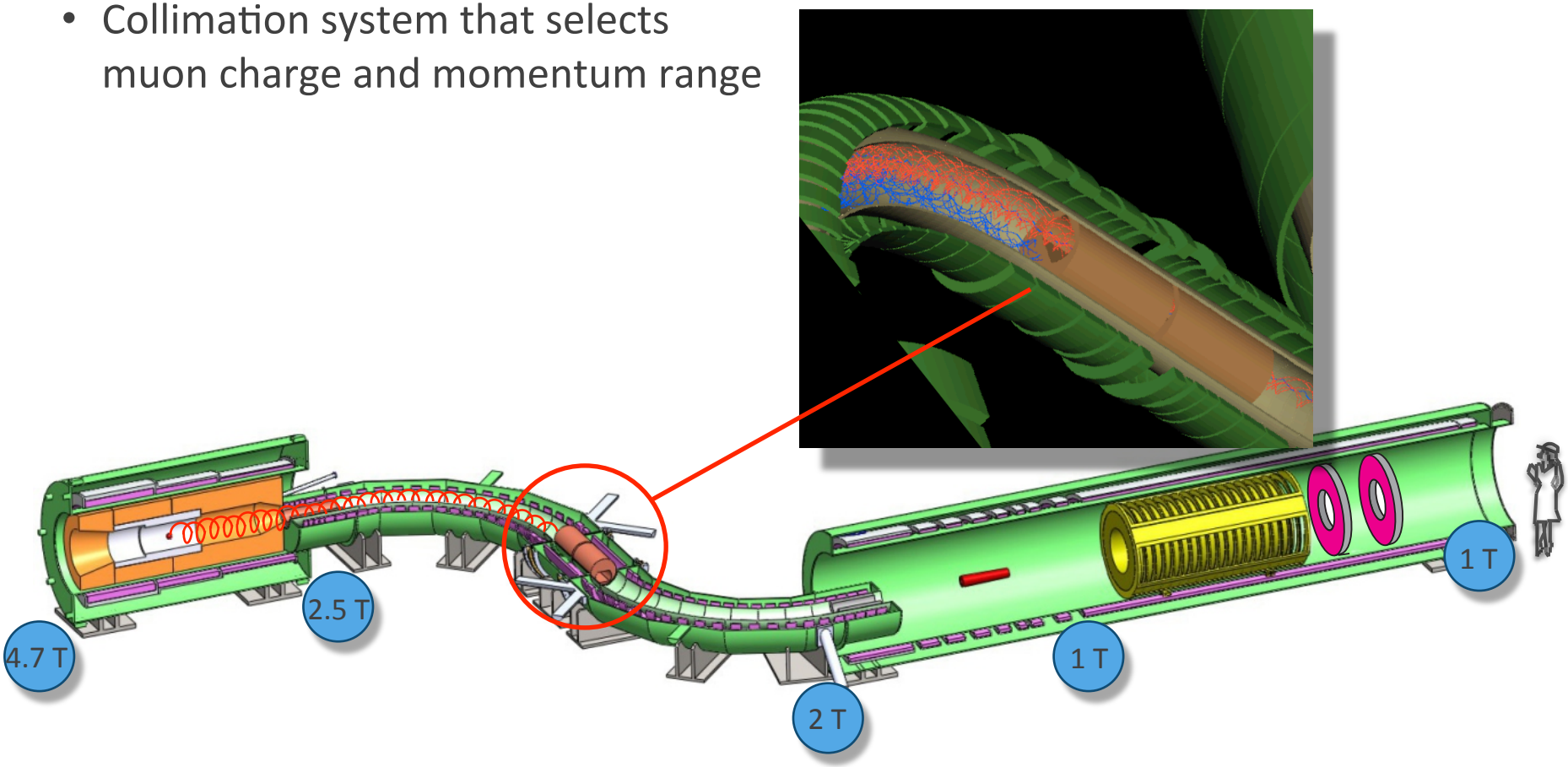
- Production target
- Graded field
- Captures secondary pions
- Highest field
- Highest radiation exposure



Mu2e Apparatus

Transport Solenoid

- Collimation system that selects muon charge and momentum range

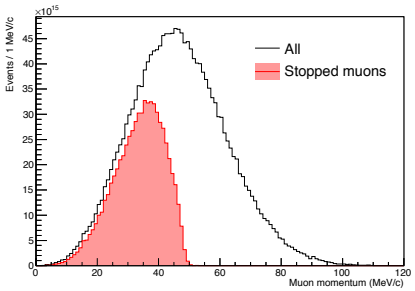


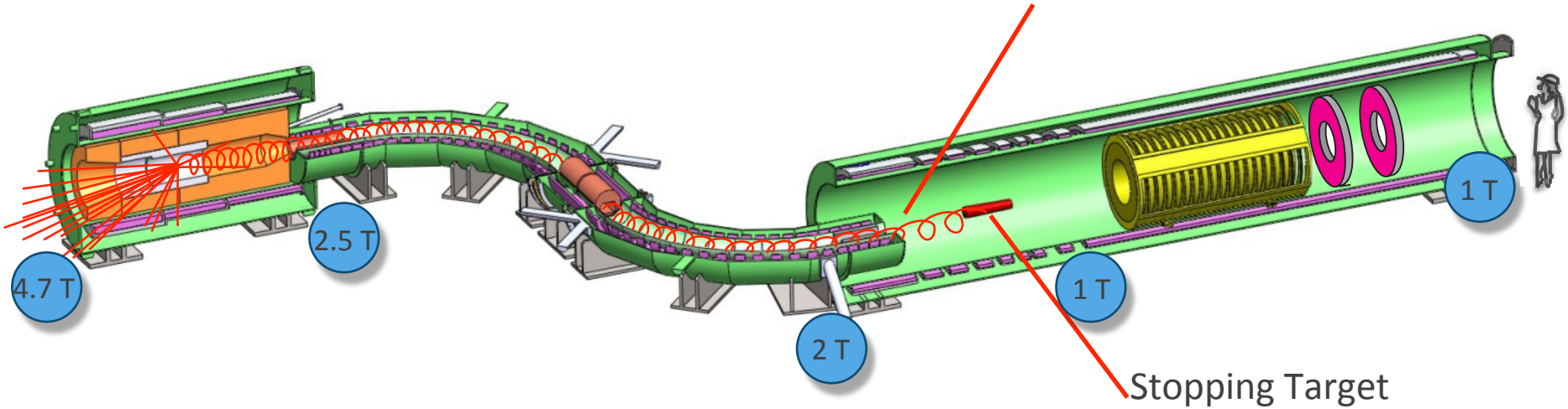
Mu2e Apparatus

Transport Solenoid

- Collimation system selects muon charge and momentum range
- Pbar window in middle of central collimator
- Directs 10^{10} Hz of μ^- to stopping target

40 MeV/c μ^-

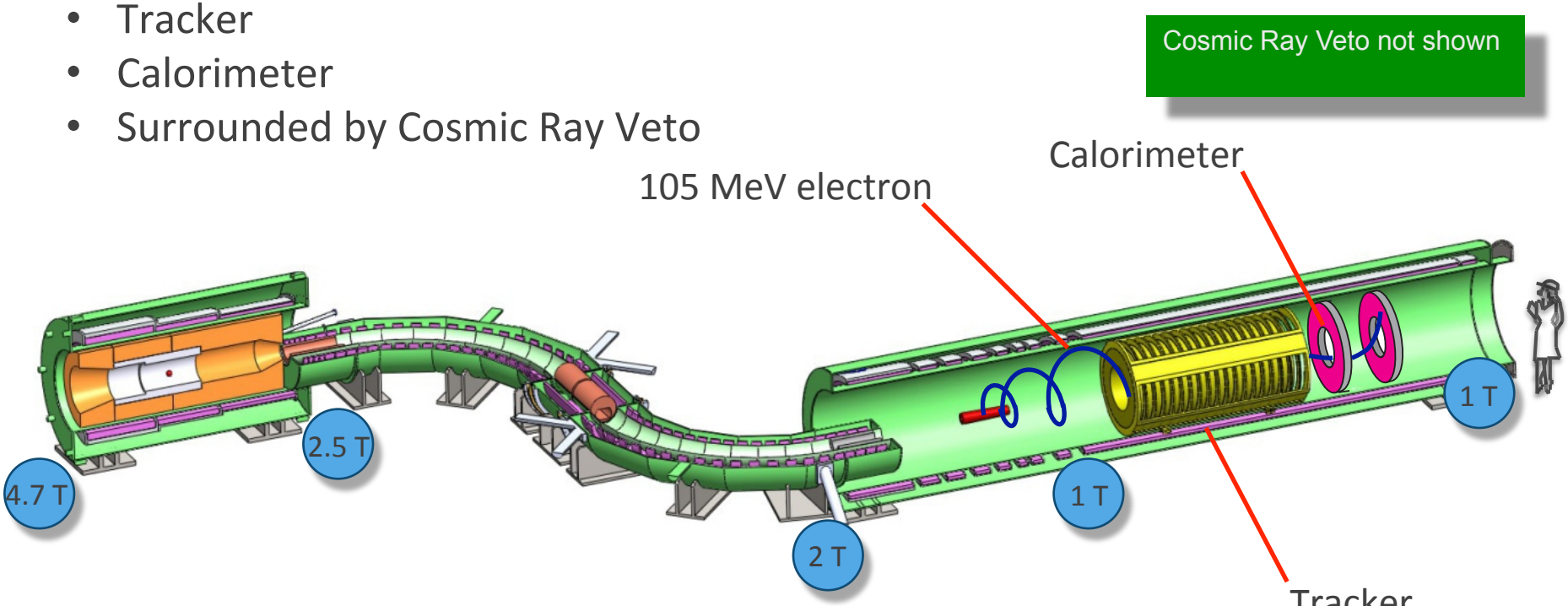




Mu2e Apparatus

Detector Solenoid

- Graded field upstream for acceptance and background suppression
- Uniform field downstream for momentum analysis
- Muon stopping target
- Tracker
- Calorimeter
- Surrounded by Cosmic Ray Veto

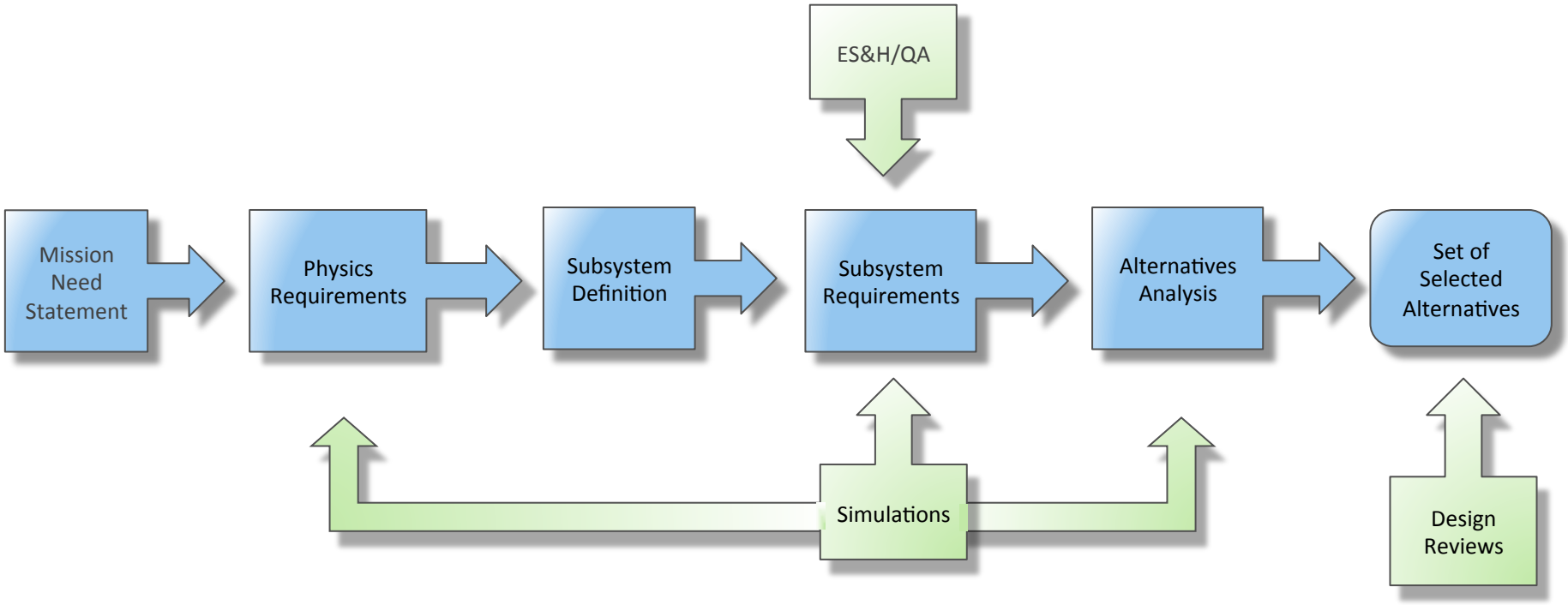


Requirements Management

Topic	Document Database Number
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
Tracker	Mu2e-doc-732
Calorimeter	Mu2e-doc-864
Cosmic Ray Veto	Mu2e-doc-944
Calibration	Mu2e-doc-1182
Trigger and DAQ	Mu2e-doc-1150

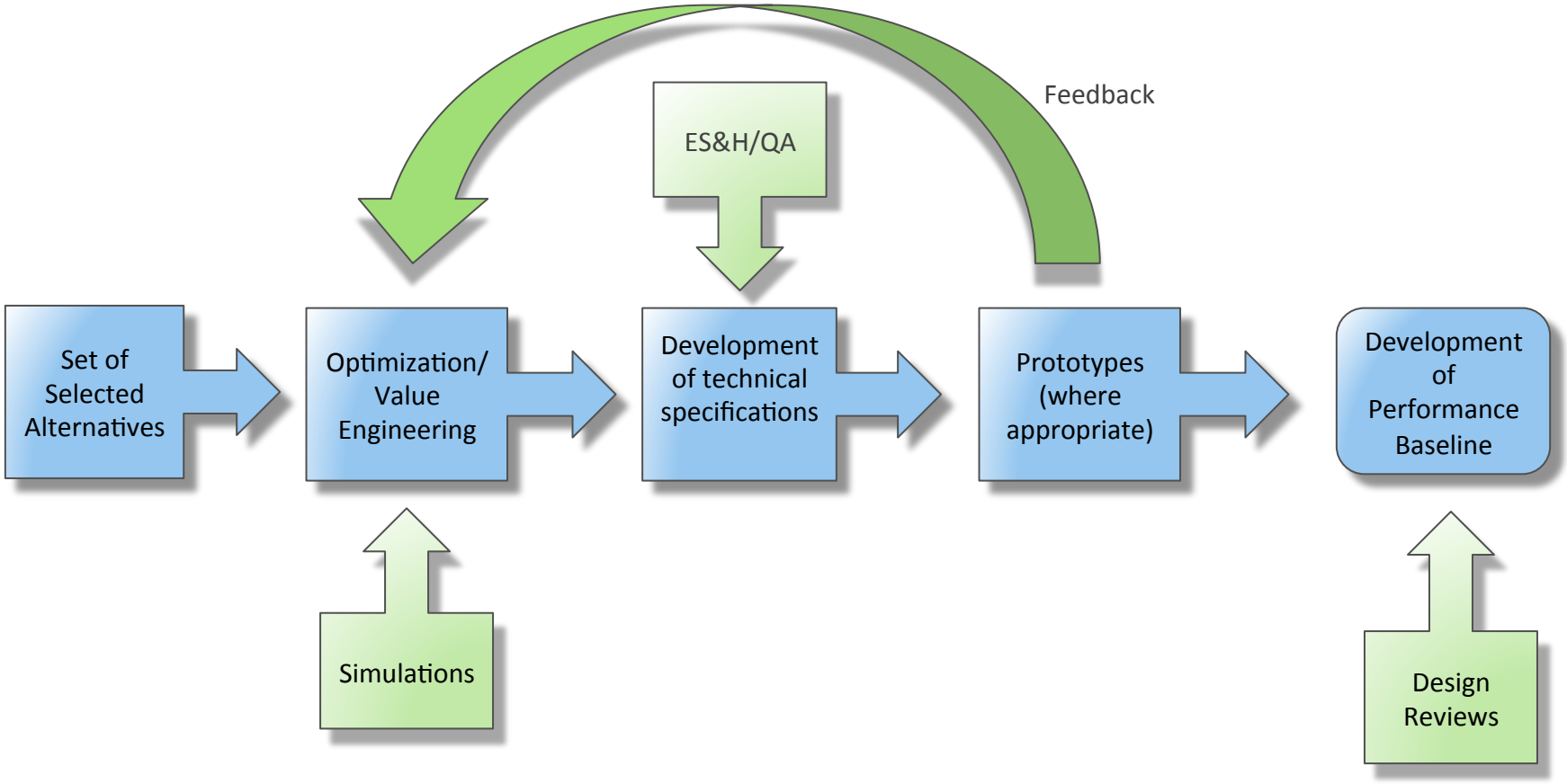
- Requirements necessary to execute the experiment have been developed primarily by the Collaboration
- Under configuration management on docdb.
- Electronically signed by responsible parties. Automatic notification if document is changed.
  - Part of Configuration Management.
- Signed version is the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

Design Development

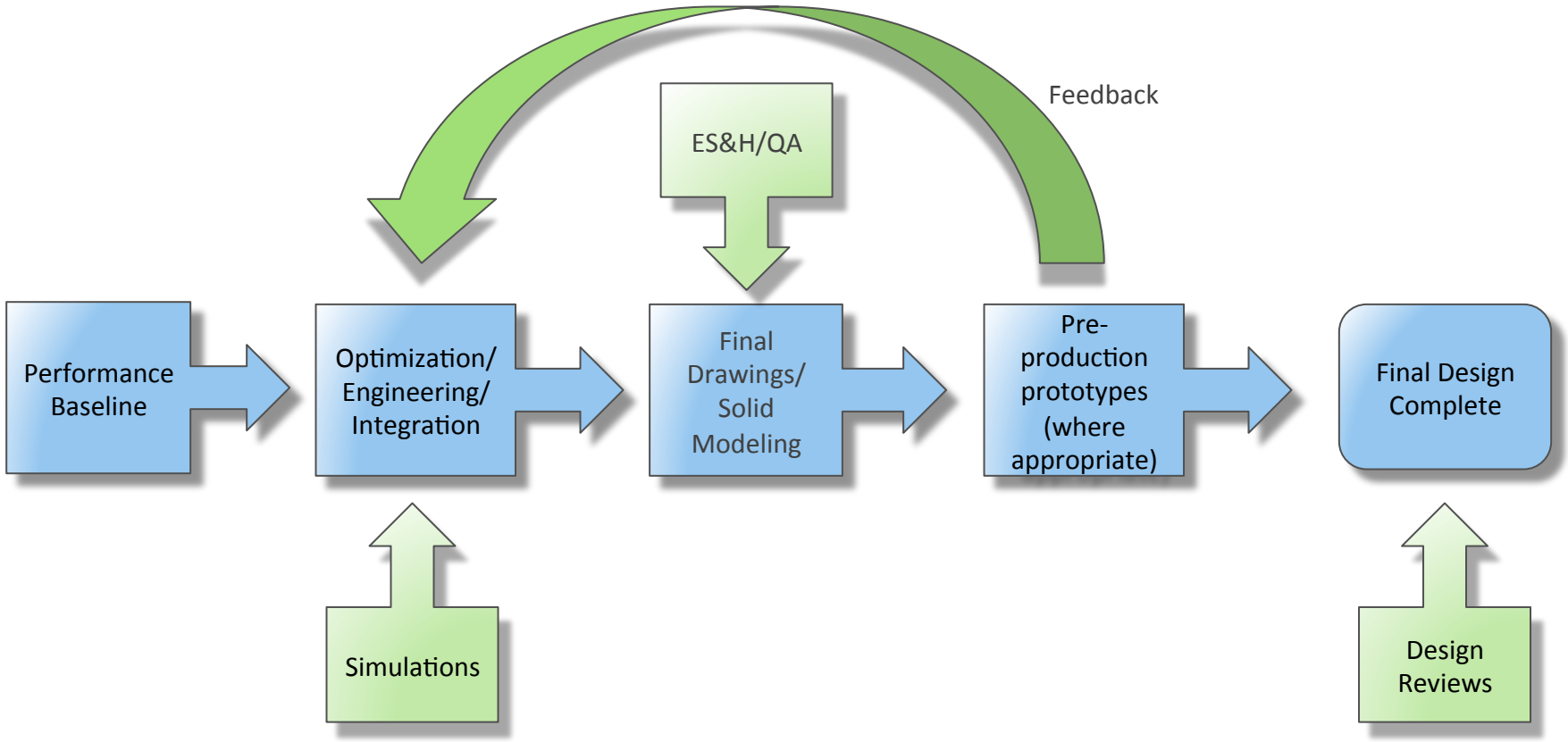


A set of technical alternatives was selected as the result of the conceptual design validated at CD-1.

Development of Performance Baseline



Development of Final Design

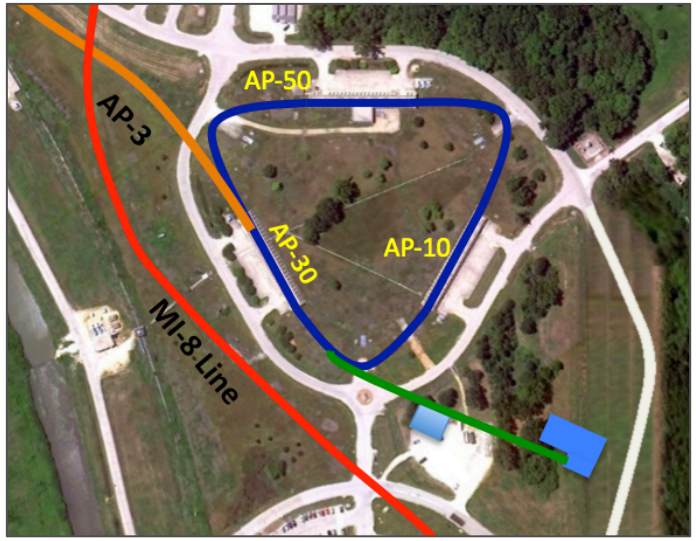


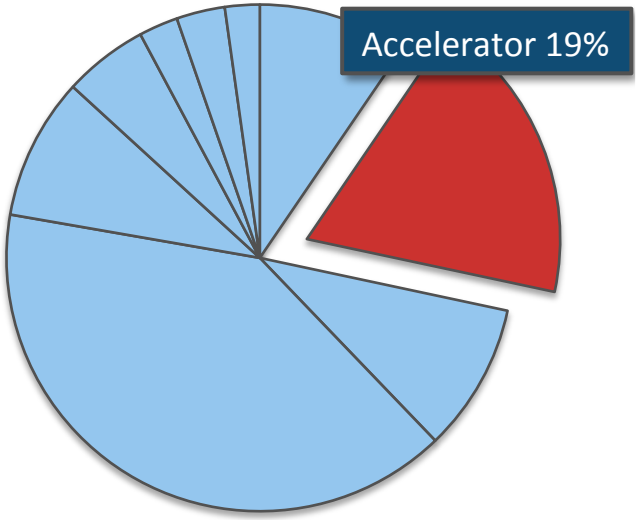
Validation of pre-production prototypes for detector systems, using final parts, required before production may begin.

Project Scope

WBS 2 - Mu2e Accelerator

- Delivery Ring RF System
  - Same RF cavities used in Recycler RF system.
- Resonant Extraction System
- External Beamline
  - Recycled Accumulator magnets
- Extinction System
- Extinction Monitoring
- Production Target
- Heat and Radiation Shield to protect Production Solenoid
- Proton Beam Absorber
- Radiation Safety
- Instrumentation and Controls
- Significant interface to Muon Campus AIPs and GPPs.

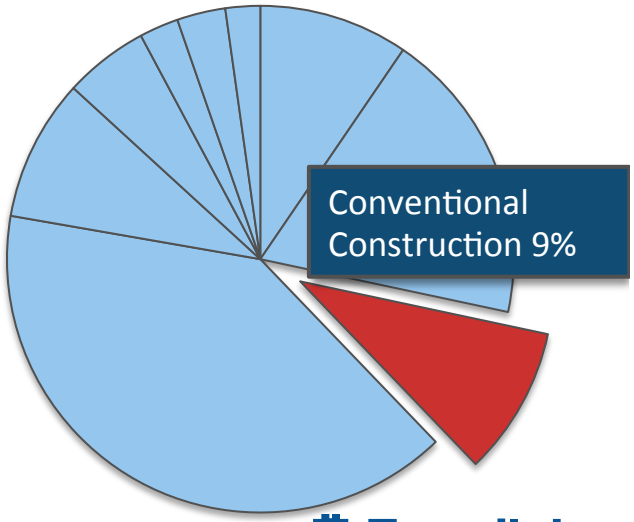




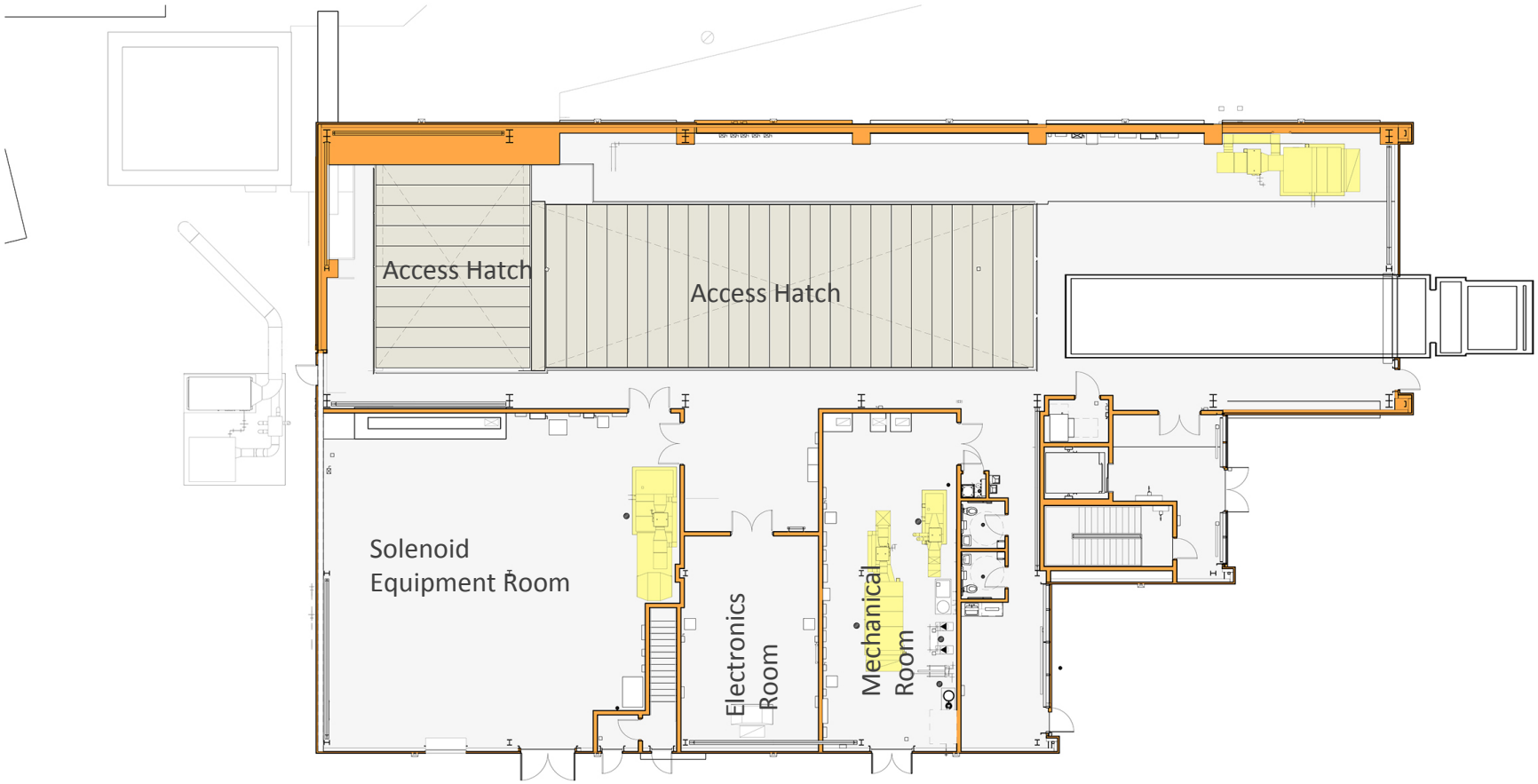
WBS 3 - Conventional Construction

Conventional Construction scope includes

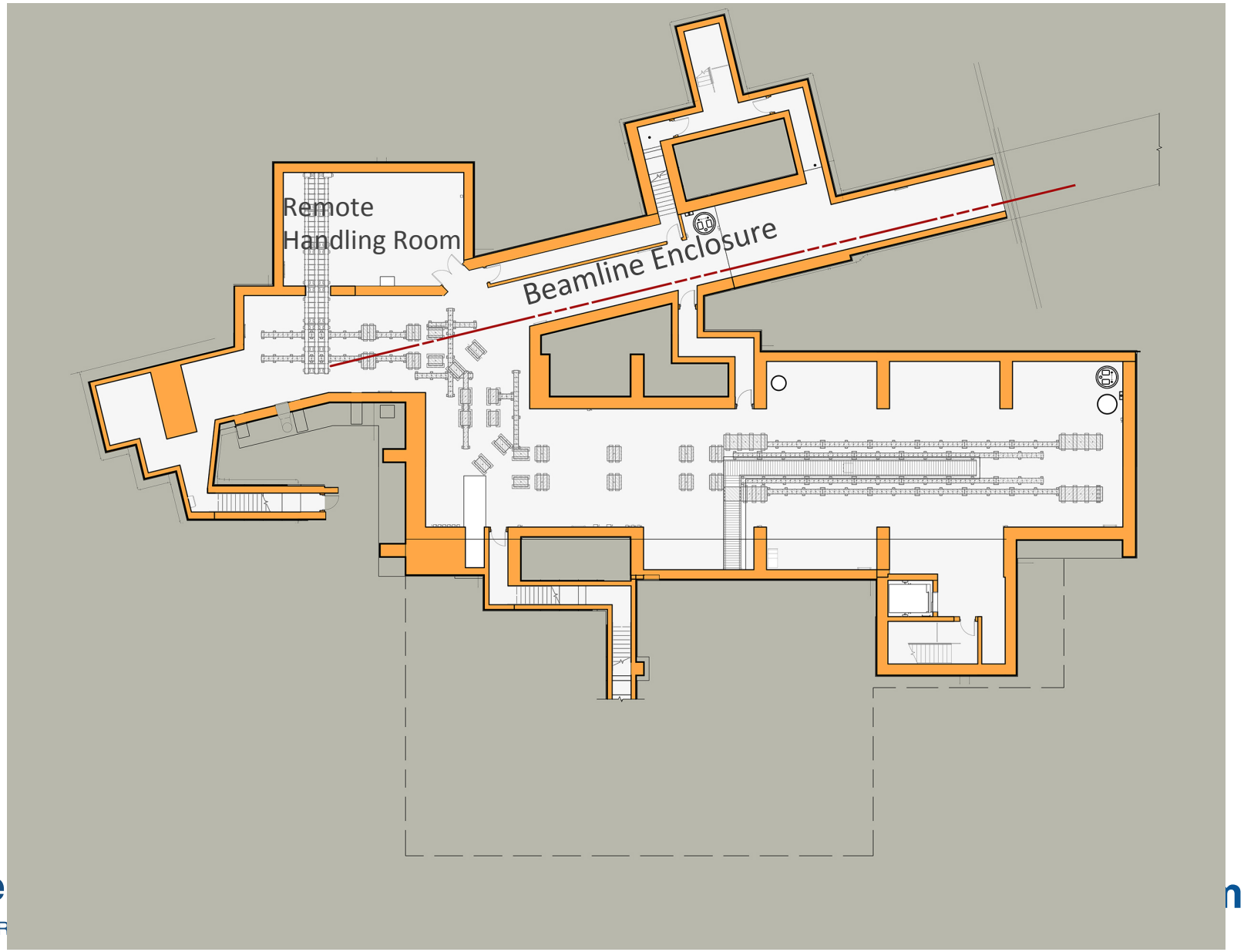
- Mu2e Detector Hall
  - Underground enclosure to house detector
  - Surface building for infrastructure
- Delivery Ring power and ventilation upgrades/ reconfiguration.
- Interface to Muon Campus Beamline Enclosure GPP and MC-1 Building.



Surface Building

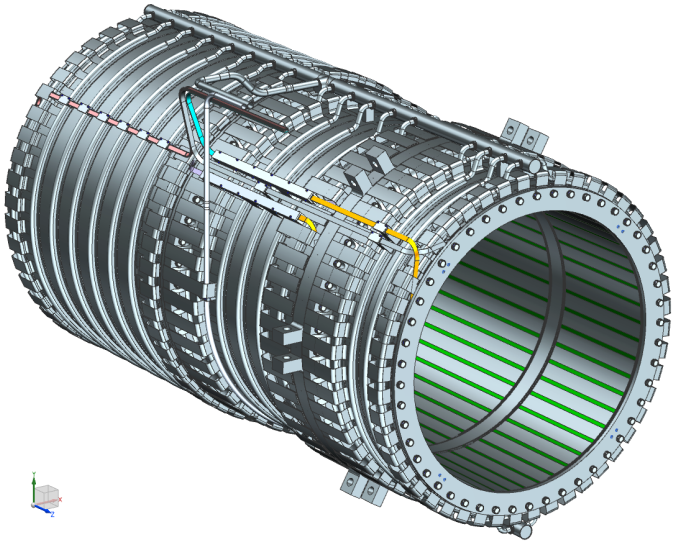


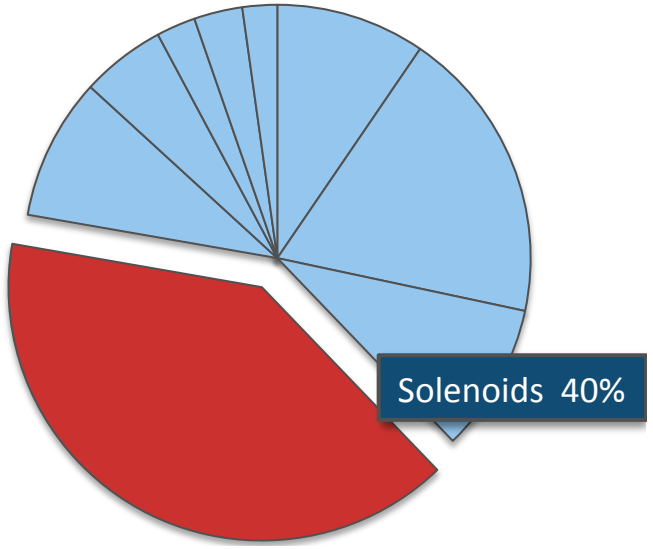
Detector Enclosure



WBS 4 - Solenoids

- Solenoids drive the cost and the schedule
  - On or near the critical path for entire duration of Project.
- System includes solenoids, infrastructure, installation, commissioning, field mapping equipment.
- Solenoid conductor being procured based on CD-3a authorization.
  - P.O.s in place
  - ESAAB scheduled for July 10.
- Evaluation of bids for final design/build of PS and DS complete.
  - Putting P.O. in place. Costs known. Consistent with CD-1 estimates.
- Significant contribution from INFN Genoa to TS R&D and QA of production conductor.

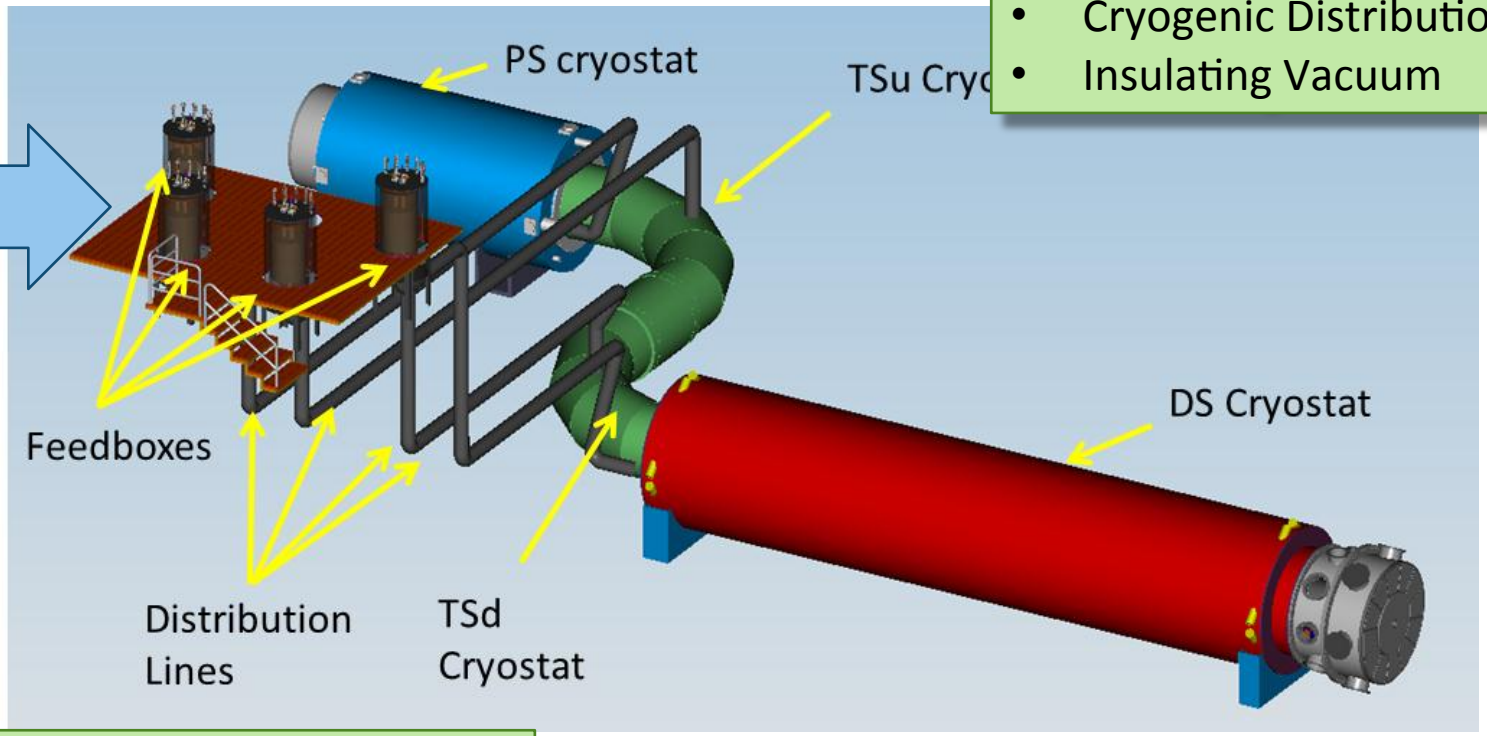




Solenoids

~65/35 of Base Cost Solenoids/Infrastructure

- Production Solenoid (PS)
- Transport Solenoid (TS)
- Detector Solenoid (DS)
- Cryogenic Distribution
- Insulating Vacuum

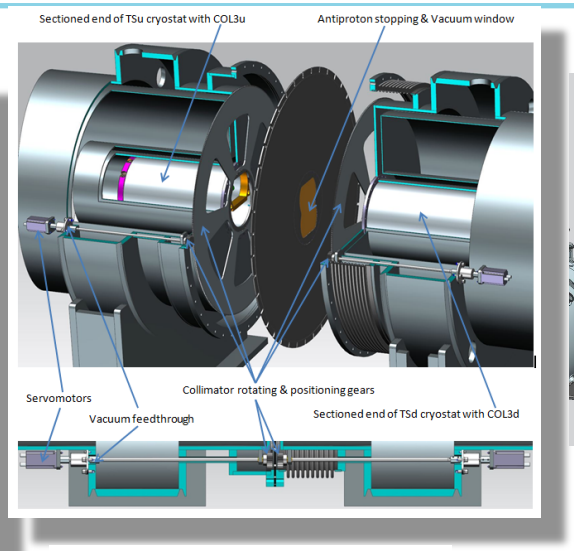


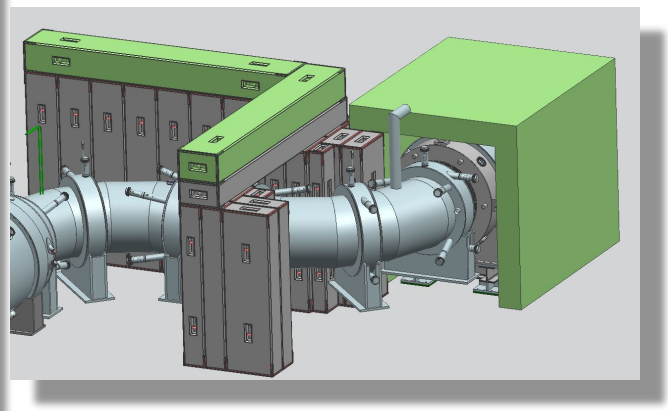
- Power Supply
- Quench Protection

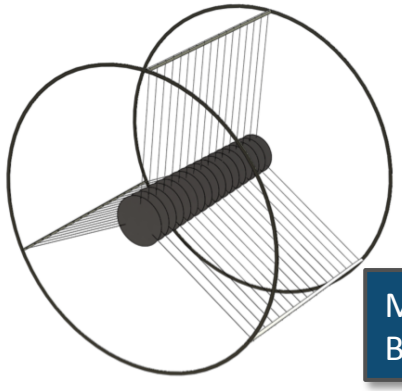
- Field Mapping
- Ancillary Equipment
- Installation and commissioning

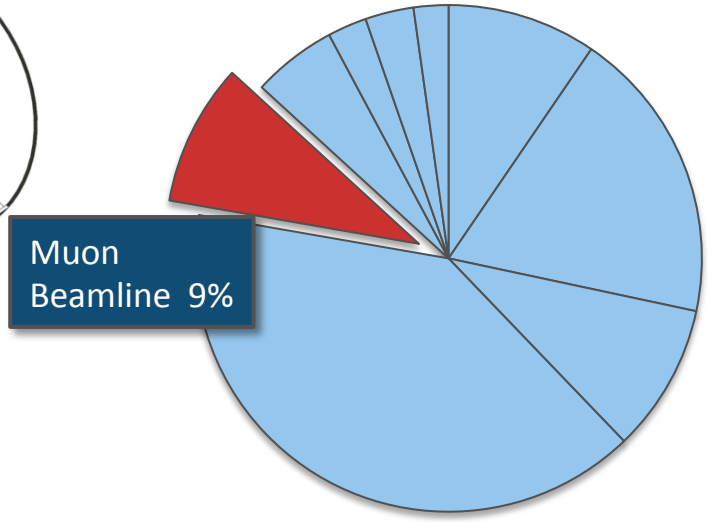
WBS 5 - Muon Beamline

- Vacuum System
- Collimators
- External Shielding
- Stopping Target
- Stopping Target Monitor
- DS Internal Shielding
- Muon Beam Stop
- Detector Support and Installation System
- Muon Beamline interfaces to nearly every other system.



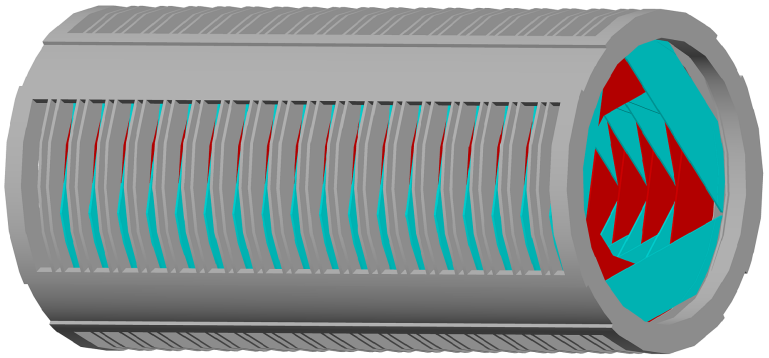


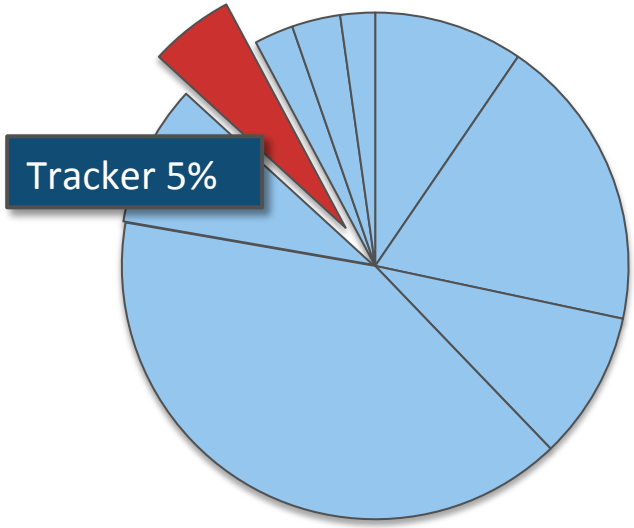




WBS 6 - Tracker

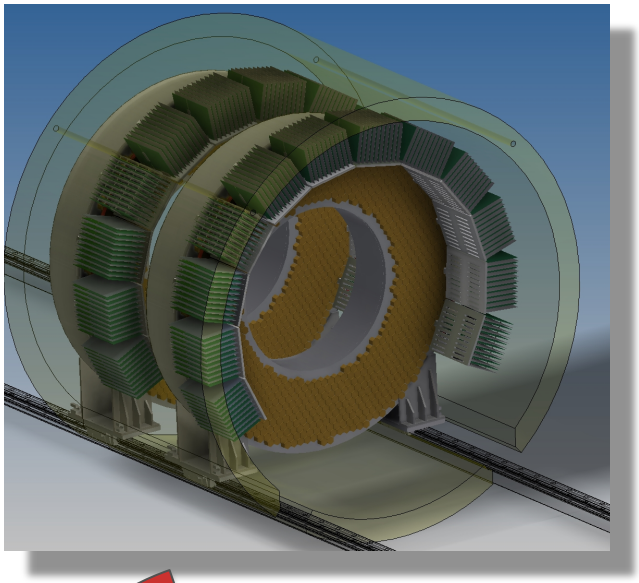
- 23,040 thin wall (15 μm) straws (5 mm diameter) distributed over 20 stations.
  - Thin walls to minimize multiple scattering.
  - Operates in 10^{-4} Torr vacuum and 1 Tesla magnetic field.
- Each straw outfitted with
  - 2 preamps
  - 2 TDCs (time division)
  - 1 ADC (differentiate protons from electrons)
  - Addressable fuse to disable straw
- Operation in vacuum requires cooling system
- Gas system (Ar: CO_2)

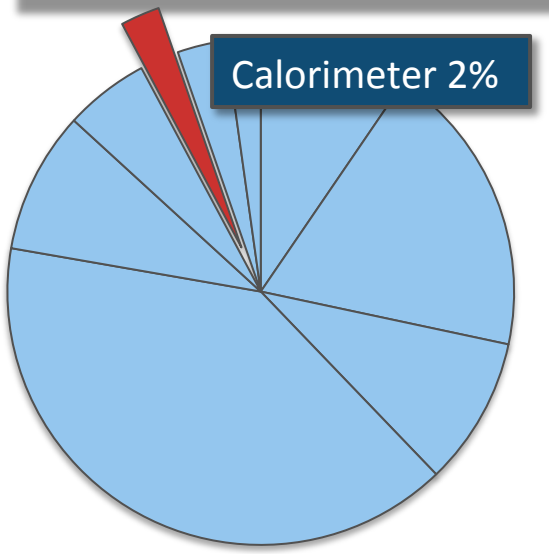




WBS 7 - Calorimeter

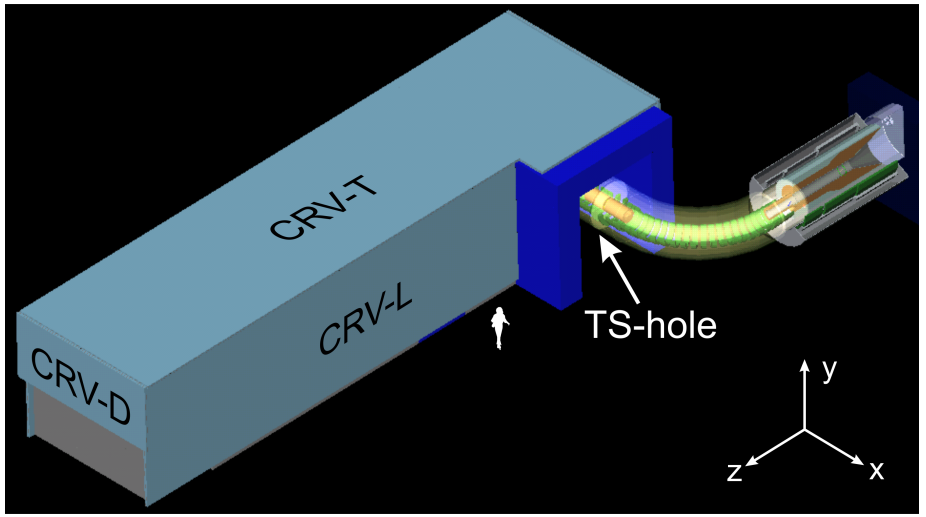
- Significant in-kind scope provided by INFN
- 1860 BaF_2 crystals arranged in 2 disks.
  - Operates in 10^{-4} Torr vacuum and 1 T field.
- Each crystal read out by
  - 2 UV-extended, solar-blind APDs to take advantage of fast component at 220 nm.
- Carbon Fiber mechanical support system
- Flasher system
- Source calibration system
- DOE contribution is
  - 2/3 of crystals
  - 1/2 of APDs
  - Source Calibration system – Recycled from BaBar
  - 50% of installation and commissioning labor
- INFN provides balance of crystals, APDs and installation labor plus
  - Mechanical support
  - Front end electronics and digitizers
  - Laser calibration system

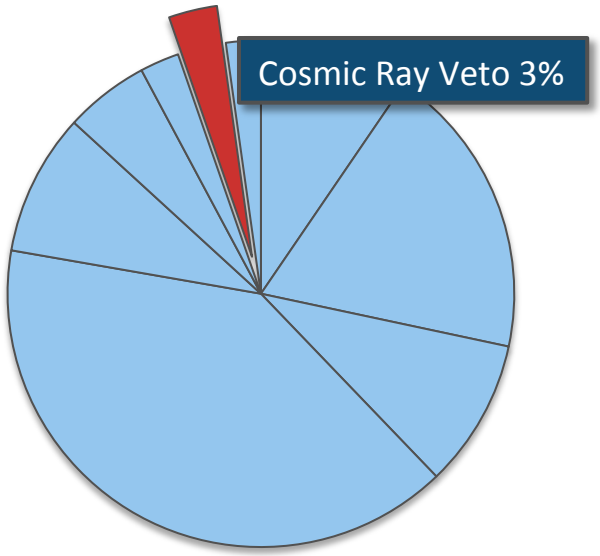




WBS 8 - Cosmic Ray Veto

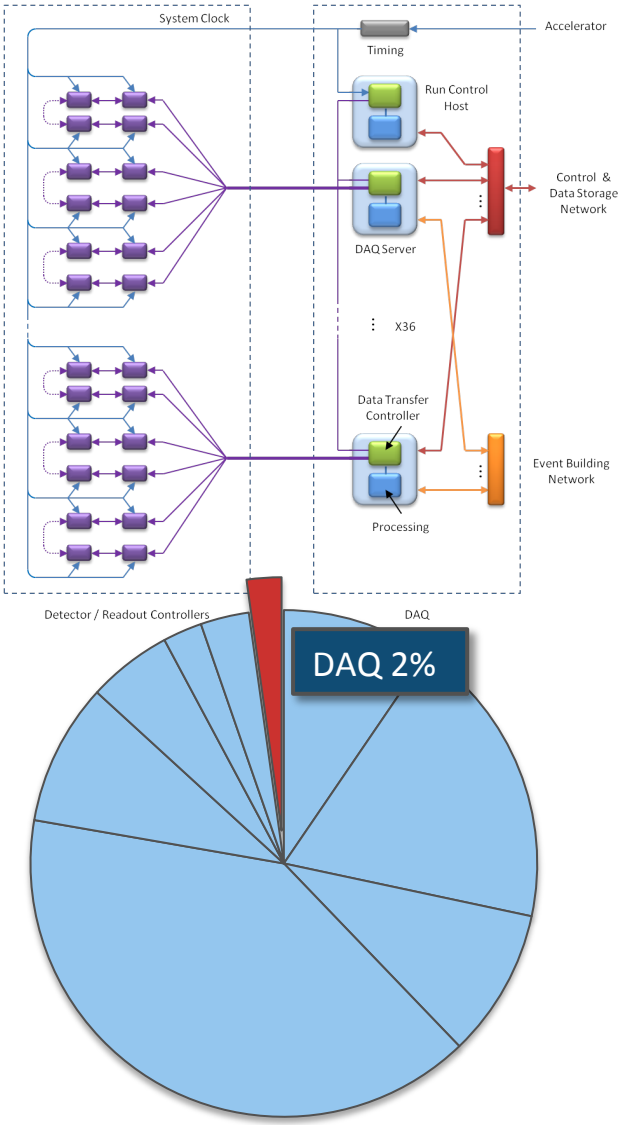
- Nearly hermetic veto on top and sides of DS and half of TS with 0.9999 overall efficiency.
- 4 layers of extruded scintillator
  - 5152 counters
  - Up to 4.7 m long
  - 1248 m^2
  - 50 km of WLS fiber
  - Read out with SiPMs
- Shielding of neutrons from production target, stopping target collimators and beam stop required.
  - Intense μ^- beam is a significant source of neutrons when they are captured.





WBS 9 - DAQ

- Collect and assemble data from ~550 detector sources
- Provide online filtering to reduce data rate by ~x100.
- Streaming Architecture. Data is zero-suppressed, transferred off the detector, assembled and then analyzed in a single processor.
- Slow controls interface to detector.
- Primarily off-the-shelf components, but a significant amount of software.
  - Leverages existing ART and ARTDAQ platforms developed to support NOvA, Mu2e and other future Fermilab programs.



Additional Contributions to Mu2e

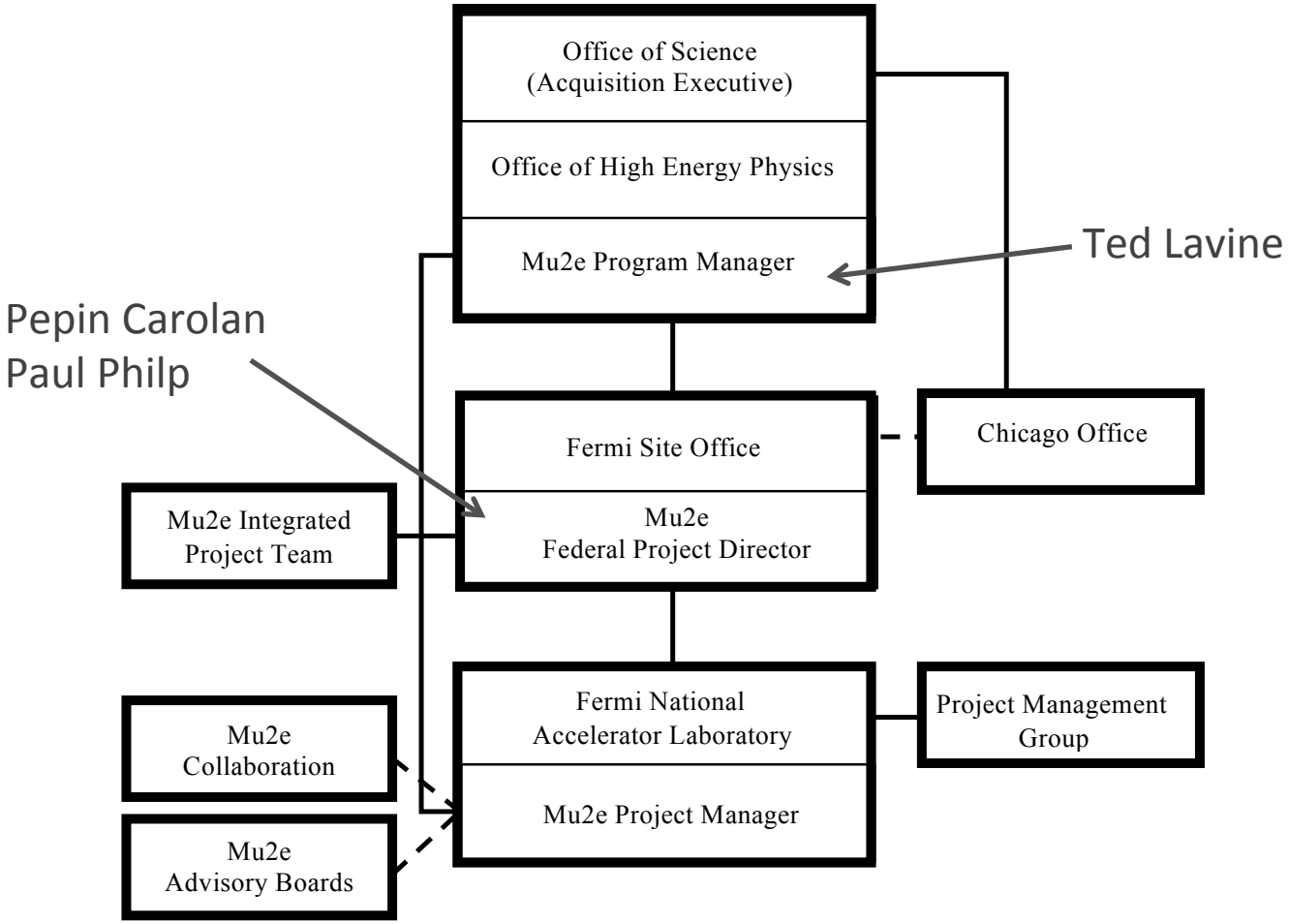
The scope required for Mu2e to become a functioning experiment comes from several sources

- Mu2e Project
- NOvA Project
  - MI-8 connection to Recycler and Rec… …ker
- Muon Campus common projects ne… …d g-2
  - MC1 building houses power supplies for … …d cryo plant
  - Beam Transport Accelerator Improvement Proj…
  - 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 milestones.

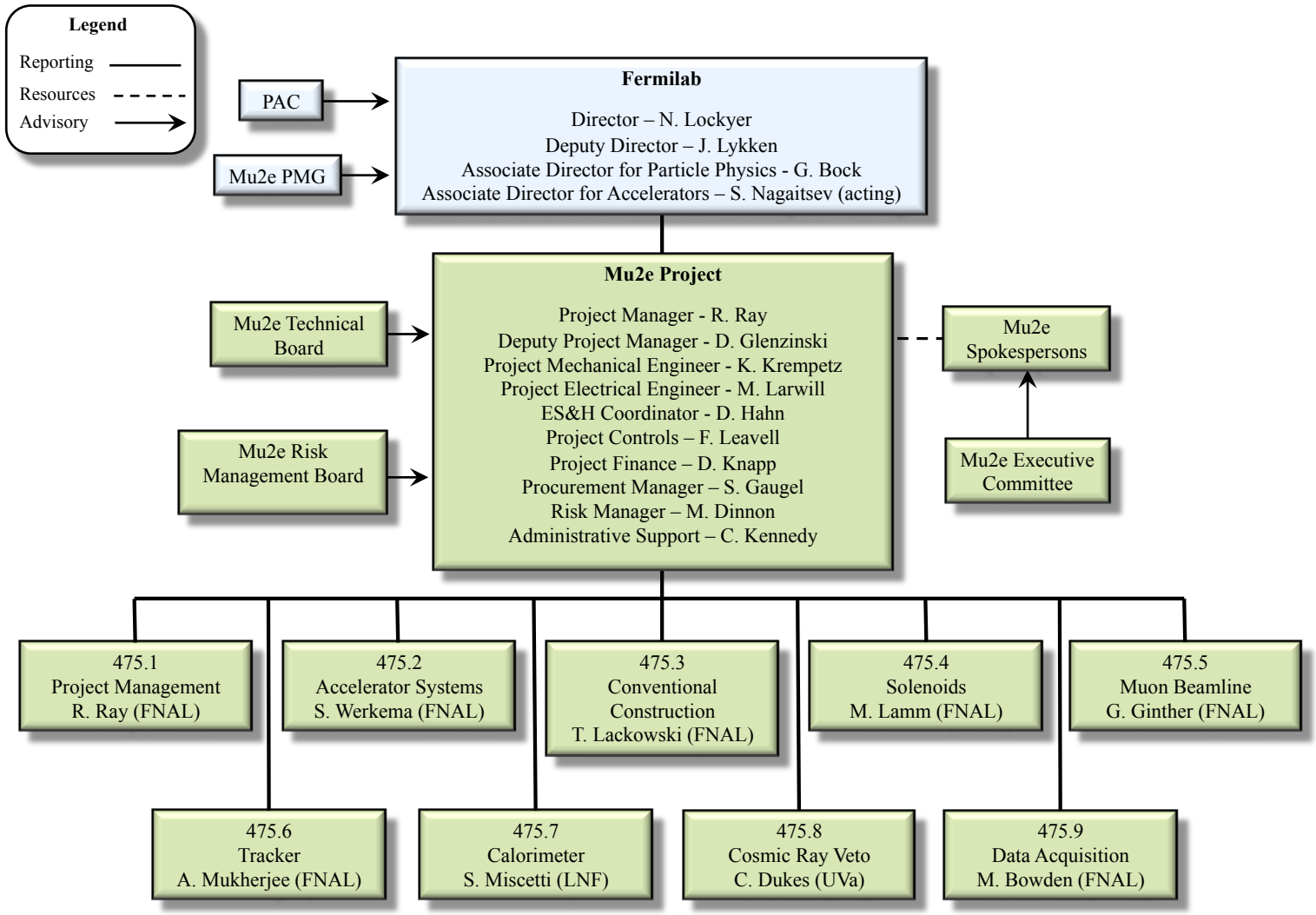
Muon Campus Common Projects Managed by Mary Convery. Required by g-2 long before they are needed by Mu2e.

Management and Organization

Management and Organization

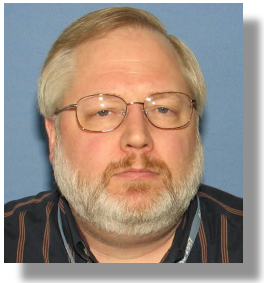


Management and Organization



L2 Managers

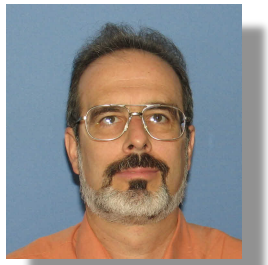
1
Project Management
R. Ray
FNAL



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

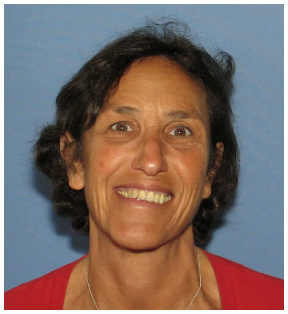
7
Calorimeter
S. Miscetti
Frascati

8
Cosmic Ray Veto
C. Dukes
UVa.

9
Trigger and DAQ
M. Bowden
FNAL

Project Office

- Ron Ray — PM
- Doug Glenzinski — Deputy PM
- 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



Lab Framework

Lab framework supports the successful execution of Projects

- Lab-wide Integrated Safety Management
- Lab-wide approach to Quality Assurance
- Lab-wide uniform approach to Project Controls and use of certified Earned Value Management System (EVMS)
- Project Management Group (PMG) oversees all Projects in a uniform manner.
- Monthly Project Oversight Group (POG) brings Project Managers, Directorate and Line Managers together to discuss common issues and concerns.
  - Shared experience
  - Lessons Learned

Communications

- Laboratory and DOE Management
  - Monthly Program Oversight Group (POG)
  - Monthly Project Management Group (PMG)
  - Weekly Integrated Project Team (IPT)
  - Semi-annual meetings with Divisions/Sections to discuss resource needs
- Project
  - Weekly Technical Board Meetings
  - Weekly/bi-weekly meetings of L2 Subsystems
  - Bi-weekly Integration Meetings
- Collaboration
  - Weekly meetings and monthly updates from Project Manager
  - Week-long Collaboration Meetings every 4 months
  - Weekly Simulation Meeting

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 appointed – Dee Hahn.
- Integrated Safety Management Plan developed (Mu2e-doc-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 TLMs as a credited safety system (docdb 4132)
- Quality Assurance Program (docdb 677)
- Custom QA/QC plan tailored to each L2 subsystem discussed in TDR subsystem chapters
- Extensive QA plan developed for solenoid conductor

Cost and Schedule

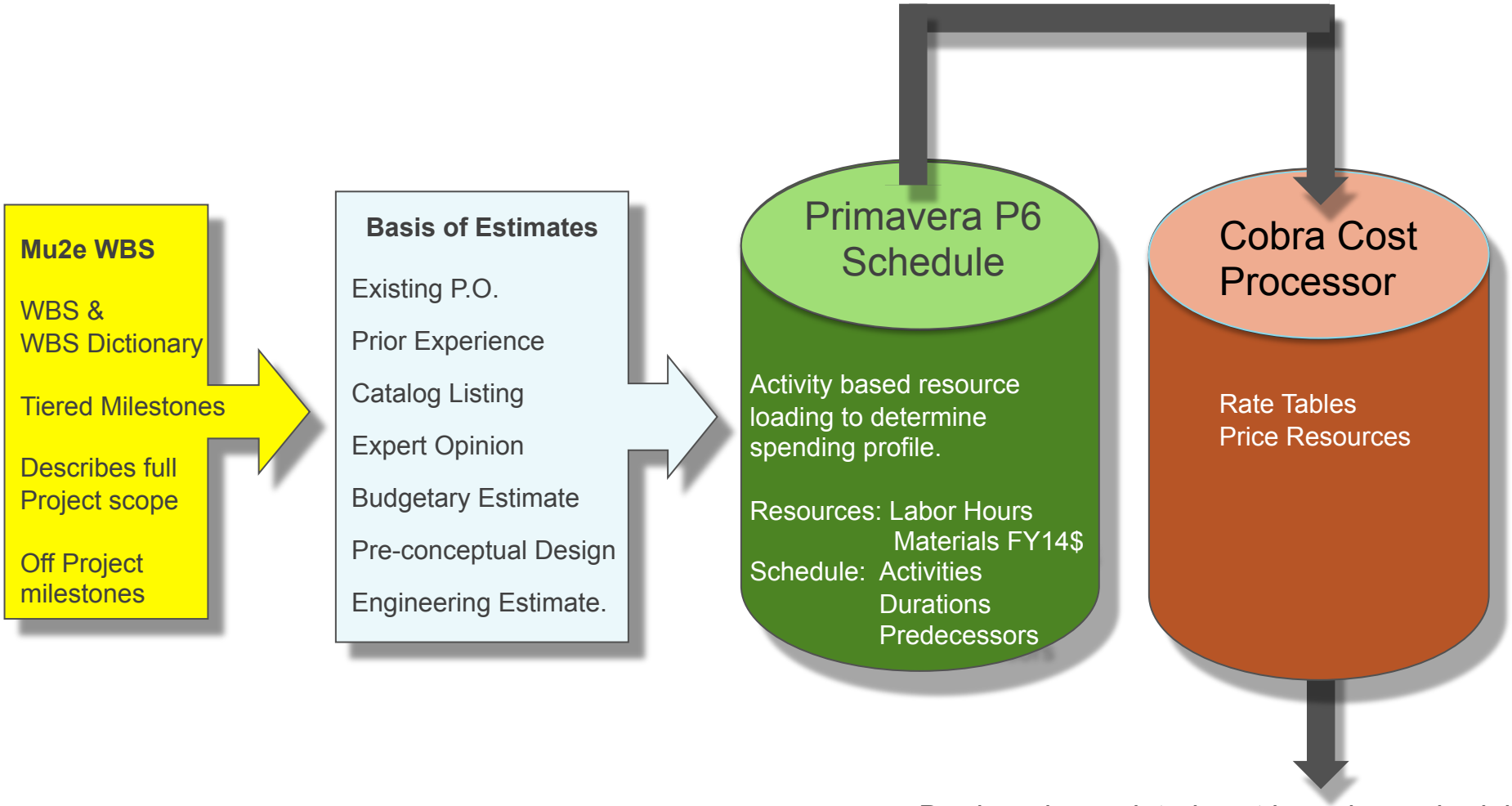
Cost Methodology

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 +
90% C.L. cost associated with risks
+ application of burdening and escalation

Cost and Schedule Development



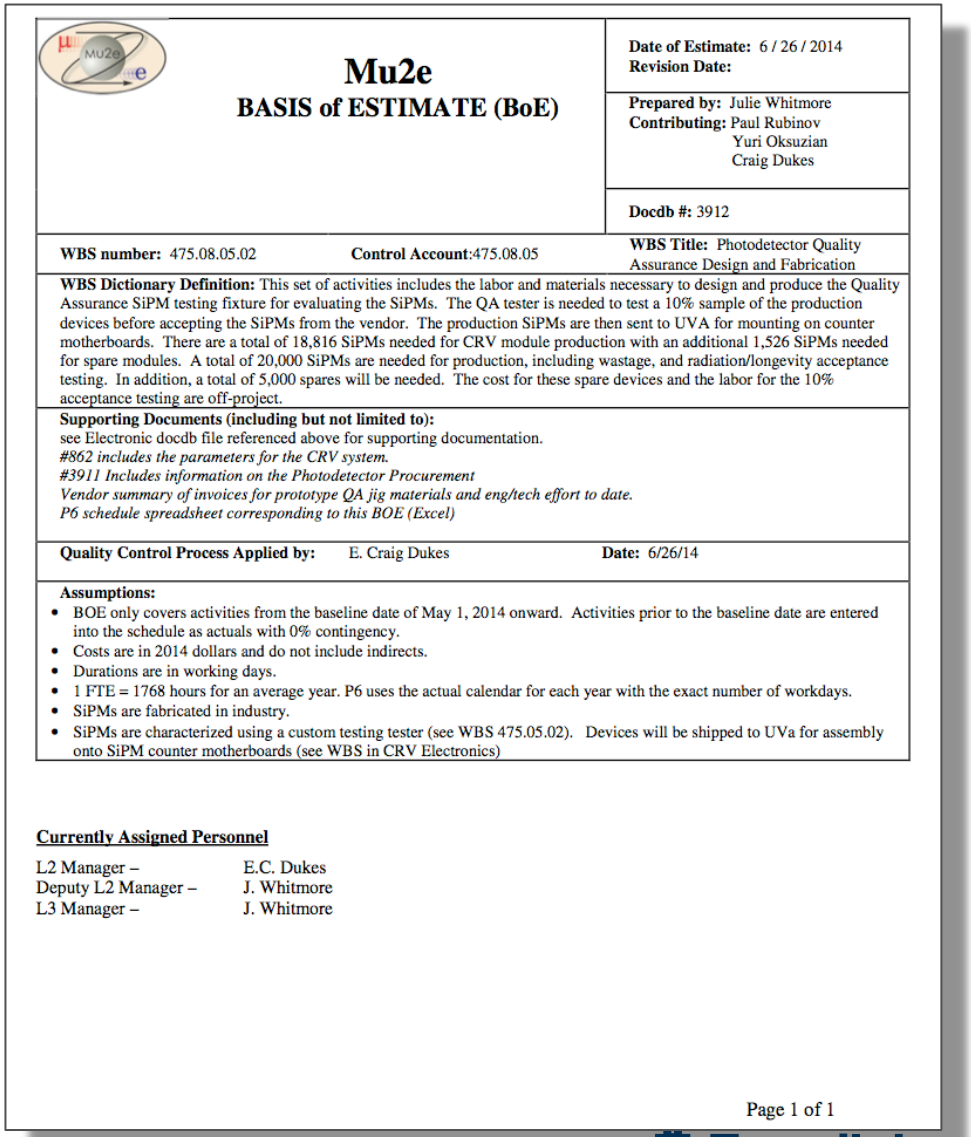
WBS Dictionary

- 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 costs 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

Page 1 of 1

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.

Page 3 of 3

BOEs

Often include supporting details

Details of the Base Estimate

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

Page 7 of 7

BOEs

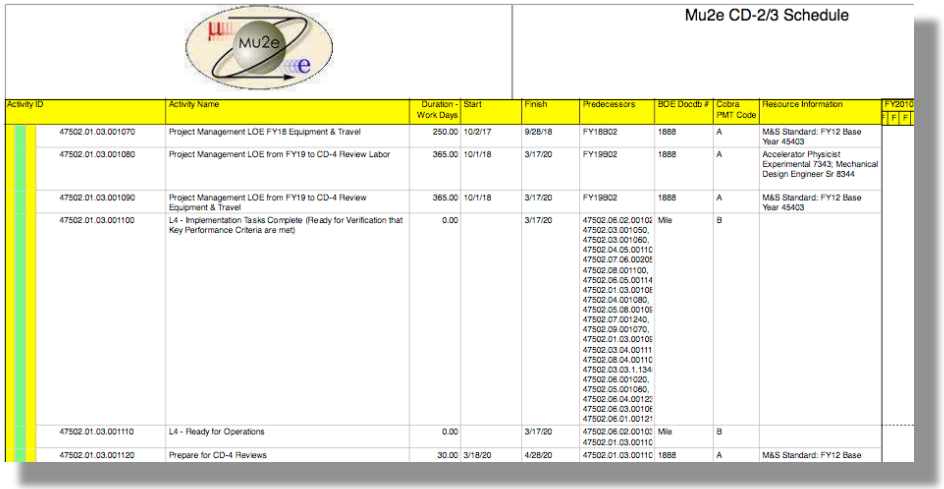
Listing of catalog prices

SiPM_IVMS parts costs

Description	cost	Total
		$7,987.97
ghielectronics__display_req2410.pdf	$199.90	
newark_SiPM_IVMS_TQ2_req2408.pdf	$25.50	
digikey_Web ID 50336149 Access ID 67167_req2402	$36.00	
advanced metalcraft_IVMS--panels_req2401.pdf	$174.00	
mcmaster_FHS440_req2397.pdf	$11.06	
advanced metalcraft_IVMS-brackets-panels_req2396.pdf	$138.00	
advanced metalcraft_IVMS-brackets-panels_req2377.pdf	$894.00	
arrownac_quote_SiPM_IVMS_purchase_req2376.pdf	$221.99	
mouser_SiPM_IVMS_purchase_req2375.pdf	$364.17	
Digi-Key_Web ID- 49895085-Access ID-17304_req2374.pdf	$593.72	
newark_SiPM_IVMS_purchase_req2373.pdf	$625.75	
hammond BUF13-12019M_req2372.pdf	$147.70	
samtec_connector_req2309.pdf	$120.80	
newark_80condFlat_req2371.pdf	$180.00	
coastal_q61718_sipm_ivms_req2358.pdf	$1,231.50	
Future_sstpad5_req2335.pdf	$189.00	
PSUI_traco_TEN-5_0511_req2310.pdf	$93.18	
acopian_PS and sockets_req2329.pdf	$1,830.00	
newark_enclosure_1402KV_req2320.pdf	$187.08	
ghi_elect_modules_req2317.pdf	$619.20	
avnet_connectors_req2311.pdf	$105.42	

Resource Loaded Schedule

- Activity based RLS contains
  - 6022 activities
  - 4324 Work Packages
    - 3212 current budget
    - 758 contracted labor/material purchases
    - 354 obligations
  - 74 Control Accounts and 30 CAMs
  - 494 milestones
  - 25 Constraints
    - 8 are completed activities/milestones
    - 8 are Muon Campus milestones



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	47502.06.02.00102 47502.03.001050, 47502.03.001060, 47502.04.05.00110 47502.07.06.00208 47502.08.001100, 47502.06.05.00114 47502.01.03.00108 47502.04.001080, 47502.05.08.00109 47502.07.001240, 47502.09.001070, 47502.01.03.00105 47502.03.04.00111 47502.08.04.00110 47502.03.03.1.134 47502.06.001020, 47502.05.001060, 47502.06.04.00123 47502.06.03.00106 47502.06.01.00121	Mile	B	
47502.01.03.001110	L4 - Ready for Operations	0.00		3/17/20	47502.06.02.00100 47502.01.03.00110	Mile	B	
47502.01.03.001120	Prepare for CD-4 Reviews	30.00	3/18/20	4/28/20	47502.01.03.00110	1888	A	M&S Standard: FY12 Base

- Estimate Uncertainty is assessed at the activity level.
- Critical Path, Near Critical Path and sub-project Critical Paths all identified.
- Work schedule, obligations, resource profiles are derived from the RLS
- CD-2 date fixed. Other CD dates float.

Rates and Assumptions

- Schedule trued-up with actuals through end of April, 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 and Construction.

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%
Civil Construction	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%

- Labor and M&S rates from Fermilab Financial Office.
- Construction rates from Jacobs Engineering.
- Rates subject to change.
- Risk Registry addresses risk that commodities (steel, aluminum, copper, gold) escalate faster than inflation.

Estimate Uncertainty

- Contingency is the combination of estimate uncertainty and risk exposure.
- Estimate Uncertainty Rules for labor and M&S posted on review web site (Mu2e-doc-459)
  - Standard rules, similar (or identical) to those used by NOvA, g-2 LBNE, MicroBooNe, etc.
    - Do not reflect risk.
- Risk was addressed in a quantitative analysis process using a Monte Carlo
  - Similar approach from g-2 and Mu2e
  - Primavera Risk Analysis Tool used to confirm cost and schedule risk analysis.

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

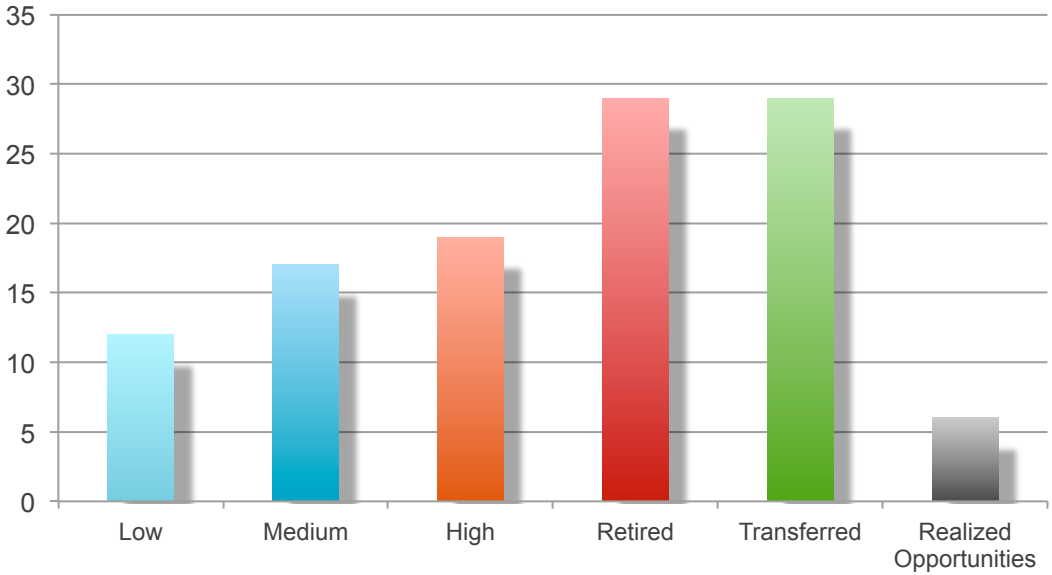
Code	Type of Estimate	Contingency %	Description
LABOR Guidelines			
L1	Actual	0%	Actual costs incurred on activities completed to date.
L2	Level of Effort Tasks	0%-20%	Support type activities that must be done to support other work activities or the entire project effort, where estimated effort is based 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.

Primary Estimate Sources

1. Project Management
   - Primarily LOE assigned personnel and experience from other Projects.
2. Accelerator
   - In house expertise and experience. Lessons Learned from NOvA.
3. Conventional Construction
   - In house expertise and experience including recent MC-1 building.
4. Solenoids
   - P.O.s/quotes for cost drivers. In-house experience and engineering estimates for labor.
5. Muon Beamline
   - In-house engineering estimate
6. Tracker
   - Experience from CDF tracker, ATLAS straws. In-house engineering estimates. COTS parts for electronics.
7. Calorimeter
   - Experience from KLOE and BaBar. Crystal costs based on vendor quotes and R&D purchases.
8. Cosmic Ray Veto
   - In-house experience with scintillator extrusions (NuMI, T2K, Minerva) and vendor quotes for SiPMs.
9. DAQ
   - In-house experience and scaling from NOvA actuals.

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 48 risks
  - 58 retired or transferred
- Since CD-1
  - 29 risks retired
  - 6 opportunities realized at a savings of $1.7M
  - >$6M spent to mitigate risks

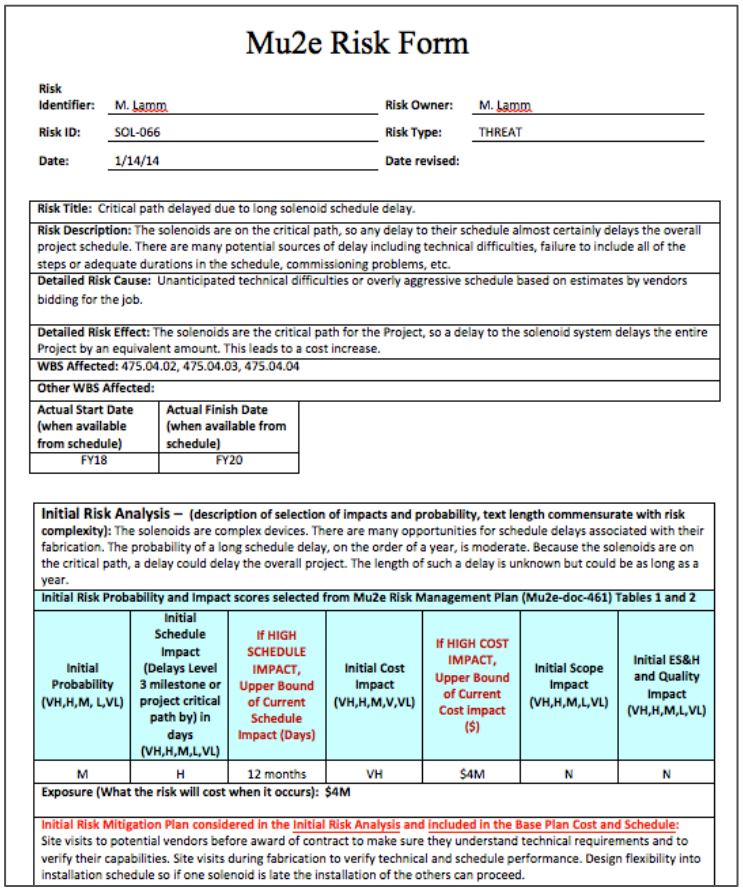


Largest Remaining Risks

Risk						Post-mitigation						
Risk ID	Risk Form DocDb #	Type	Title	Date of Risk	Mitigation Cost (Included in baseline)	Probability	Cost	Technical	ES&H	Score	Risk Owner	Point estimate (cost k$)
SOL-157	4225	Threat	PS conductor first article does not meet specifications	FY15-FY16	$ 400,000	M	VH	M	N	40	M. Lamm	$ 2,000
PM-010	3366	Threat	Unexpected increase in Fermilab overhead rates	FY14-FY19		M	VH	N	N	40	Ron Ray	$ 1,000
CAL-108	3347	Threat	INFN cannot deliver full in-kind scope.	FY14-FY19		M	VH	H	N	40	R. Ray	$ 1,000
ACCEL-151	3833	Threat	Redesign the Remote Handling System for Water cooled target	FY14-FY17	$ 100,000	L	VH	M	N	24	M.Campbell, R.Coleman	$ 3,300
CONST-050	3352	Threat	Conventionl construction bids exceed estimated cost.	FY14		L	VH	N	N	24	T. Lackowski	$ 1,200
MUON-138	3360	Threat	Detector installation takes longer than expected.	FY19		M	H	N	N	24	G. Ginther	$ 400
PM-154	3845	Threat	Commodity prices escalate faster than inflation	FY15-FY17		L	VH	N	N	24	Ron Ray	$ 1,024
SOL-066	3367	Threat	Critical path delayed due to solenoid schedule delay.	FY18-FY20	$ 20,000	M	VH	N	N	24	M. Lamm	$ 1,384
SOL-070	3368	Threat	Interface problems with the solenoids.	FY14-FY19		L	VH	N	N	24	M. Lamm	$ 1,000
SOL-080	3372	Threat	Insufficient testing of DS and/or PS at Vendor	FY18-FY20	$ 50,000	L	VH	N	N	24	M. Lamm	$ 2,000
SOL-148	3837	Threat	Production Solenoid must be installed through PS hatch using a large rented crane.	FY18-19		M	H	N	N	24	T. Page	$ 300
TRIG-128	3393	Threat	Insufficient manpower for DAQ software.	FY14-FY19		M	H	N	N	24	M. Bowden	$ 500
VETO-164	4258	Threat	More CRV coverage is needed.	FY14-FY15		H	VL	N	N	24	C. Dukes	$ 60

Risk Management

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



Mu2e Risk Form

Risk Identifier: M. Lamm | **Risk Owner:** M. Lamm

Risk ID: SOL-066 | **Risk Type:** THREAT

Date: 1/14/14 | **Date revised:**

Risk Title: Critical path delayed due to long solenoid schedule delay.

Risk Description: 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.

Detailed Risk Cause: Unanticipated technical difficulties or overly aggressive schedule based on estimates by vendors bidding for the job.

Detailed Risk Effect: The solenoids are the critical path for the Project, so a delay to the solenoid system delays the entire Project by an equivalent amount. This leads to a cost increase.

WBS Affected: 475.04.02, 475.04.03, 475.04.04

Other WBS Affected:

Actual Start Date (when available from schedule)	Actual Finish Date (when available from schedule)
FY18	FY20

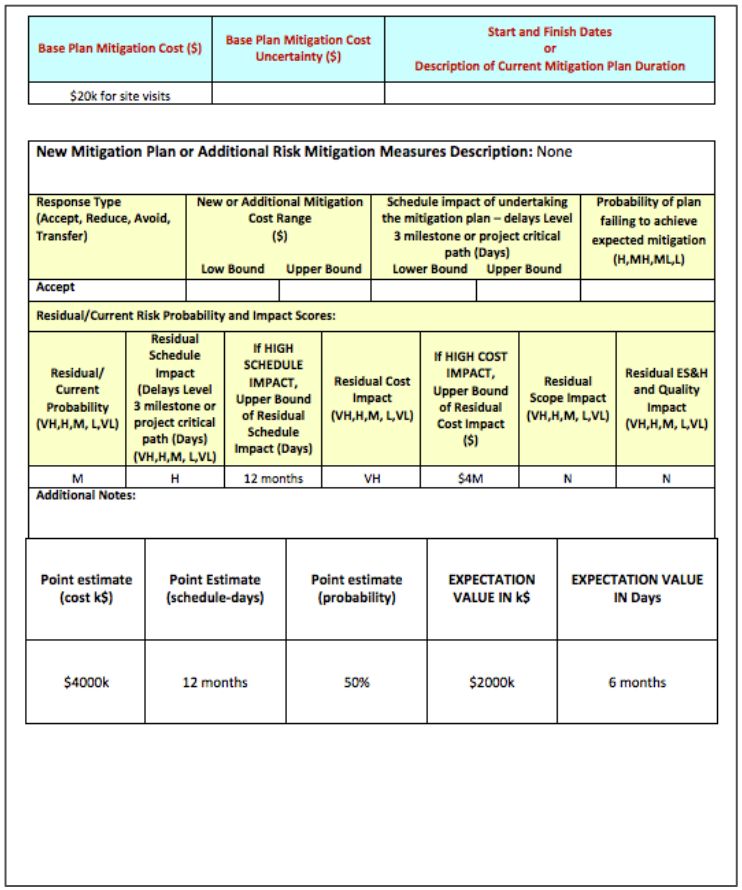
Initial Risk Analysis – (description of selection of impacts and probability, text length commensurate with risk complexity): The solenoids are complex devices. There are many opportunities for schedule delays associated with their fabrication. The probability of a long schedule delay, on the order of a year, is moderate. Because the solenoids are on the critical path, a delay could delay the overall project. The length of such a delay is unknown but could be as long as a year.

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)
M	H	12 months	VH	$4M	N	N

Exposure (What the risk will cost when it occurs): $4M

Initial Risk Mitigation Plan considered in the Initial Risk Analysis and included in the Base Plan Cost and Schedule: 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.



Base Plan Mitigation Cost ($)	Base Plan Mitigation Cost Uncertainty ($)	Start and Finish Dates or Description of Current Mitigation Plan Duration
$20k for site visits		

New Mitigation Plan or Additional Risk Mitigation Measures Description: None

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					

Residual/Current Risk Probability and Impact Scores:

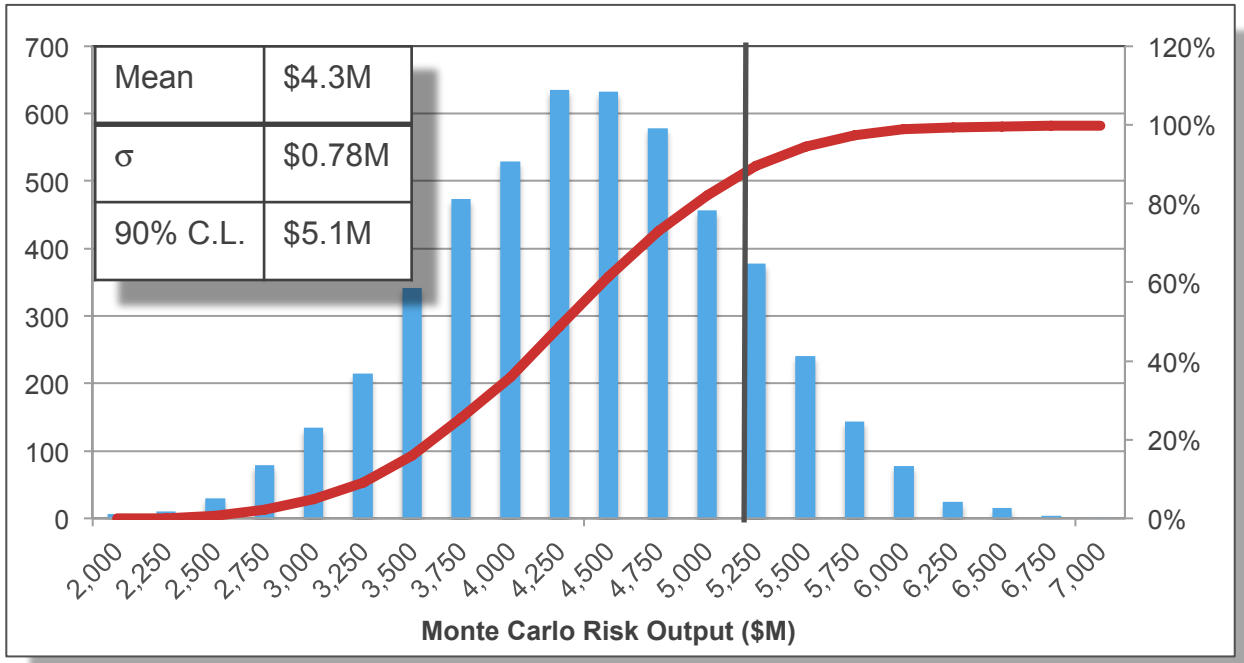
Residual/ Current Probability (VH,H,M, L,VL)	Residual Schedule Impact (Delays Level 3 milestone or project critical path (Days) (VH,H,M, L,VL)	If HIGH SCHEDULE IMPACT, Upper Bound of Residual Schedule Impact (Days)	Residual Cost Impact (VH,H,M, L,VL)	If HIGH COST IMPACT, Upper Bound of Residual Cost Impact ($)	Residual Scope Impact (VH,H,M, L,VL)	Residual ES&H and Quality Impact (VH,H,M, L,VL)
M	H	12 months	VH	$4M	N	N

Additional Notes:

Point estimate (cost k$)	Point Estimate (schedule-days)	Point estimate (probability)	EXPECTATION VALUE IN k$	EXPECTATION VALUE IN Days
$4000k	12 months	50%	$2000k	6 months

Risk Analysis

- Monte Carlo performed on Risk Register to determine cost at 90% C.L.
- Schedule risks included and costed in analysis
  - Cost associated with schedule risks determined using PRA
  - PRA analysis of overall schedule risk consistent with 24 months of float added to end of schedule.
    - Project Office costed for 24 months of float.

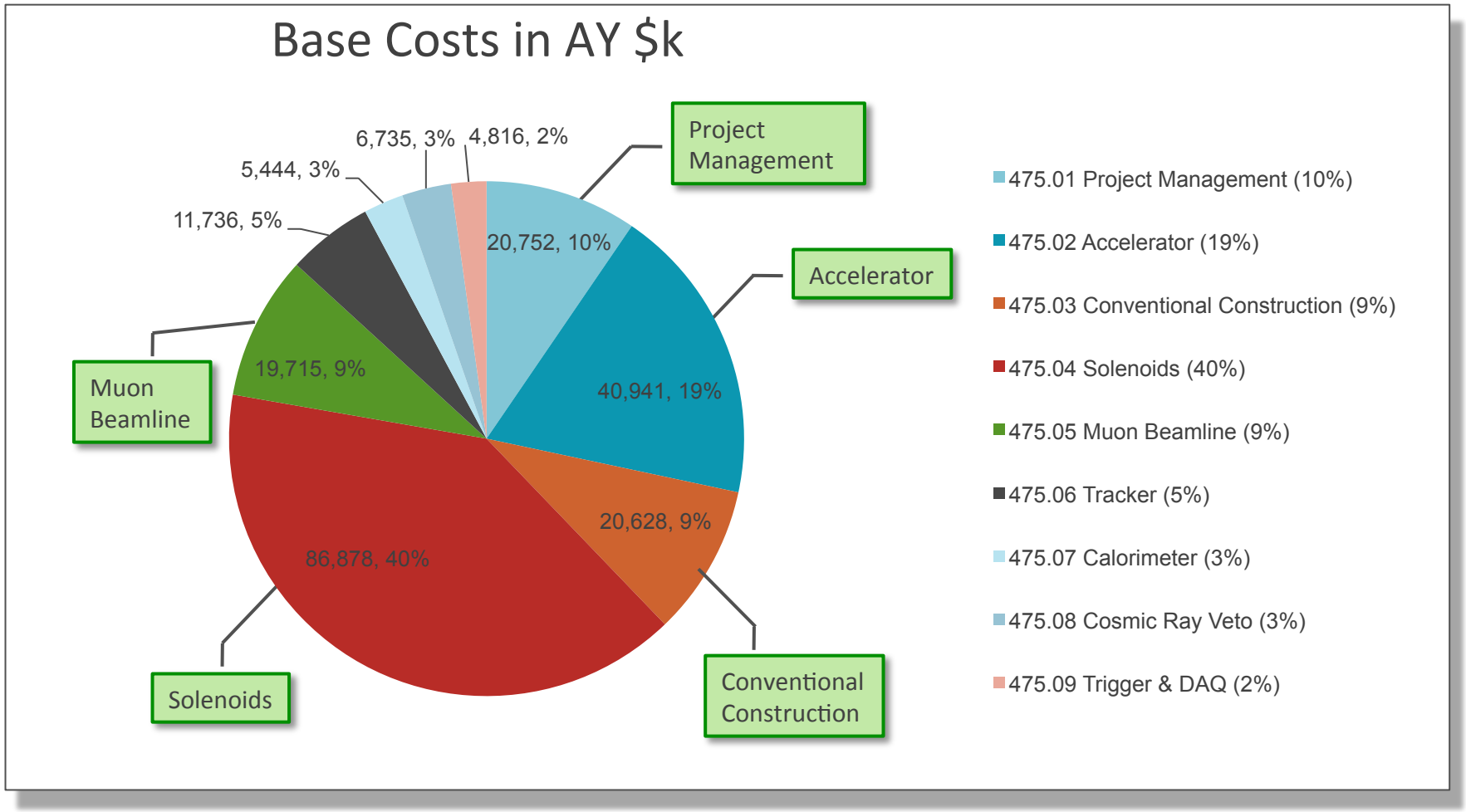


L2	90% C.L. Risk
Project Management	$1208
Accelerator	$982
Conventional Construction	($510)
Solenoids	$1196
Muon Beamline	$499
Tracker	$651
Calorimeter	$523
Cosmic Ray Veto	$323
DAQ	$273
Total	$5145

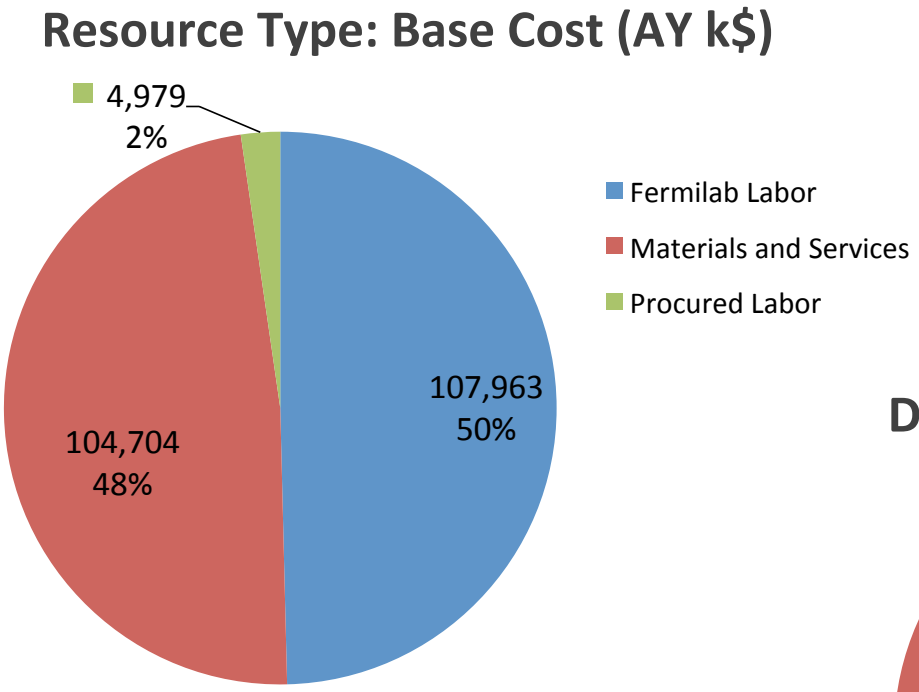
Total Project Cost

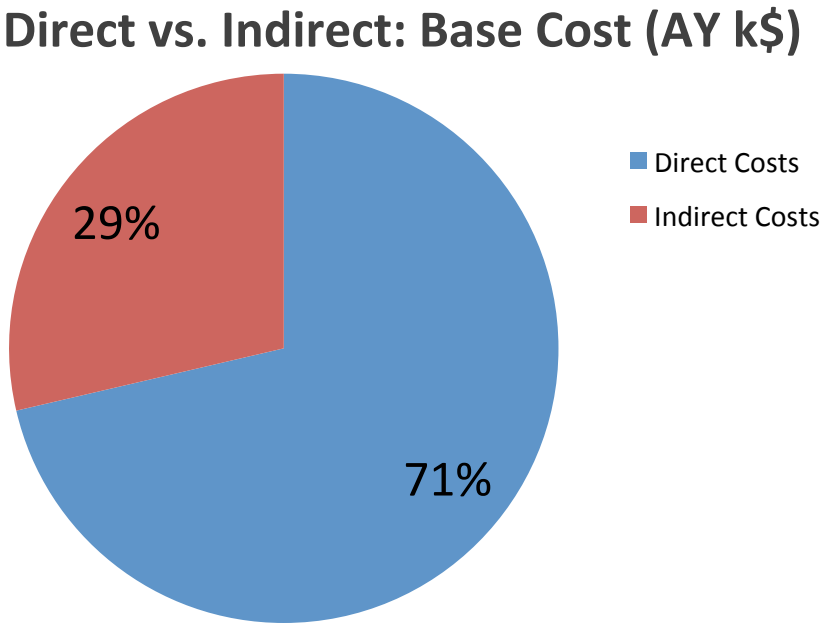
(Values in AY $k)	Performed	ETC	Contingency EU + Risk	% Cont on ETC	Total
Project Management	8,458	12,294	2,071	17%	22,823
Accelerator	10,315	30,627	9,726	32%	50,668
Conventional Construction	2,274	18,354	3,183	17%	23,811
Solenoids	15,285	71,593	23,208	32%	110,086
Muon Beamline	4,039	15,676	5,993	38%	25,708
Tracker	2,610	9,126	3,912	43%	15,648
Calorimeter	164	5,280	1,898	36%	7,342
Cosmic Ray Veto	1,262	5,472	1,955	36%	8,690
Trigger & DAQ	1,506	3,310	1,243	38%	6,059
Total	**45,913**	**171,733**	**53,190**	**31%**	**270,836**

Cost Breakdown by L2

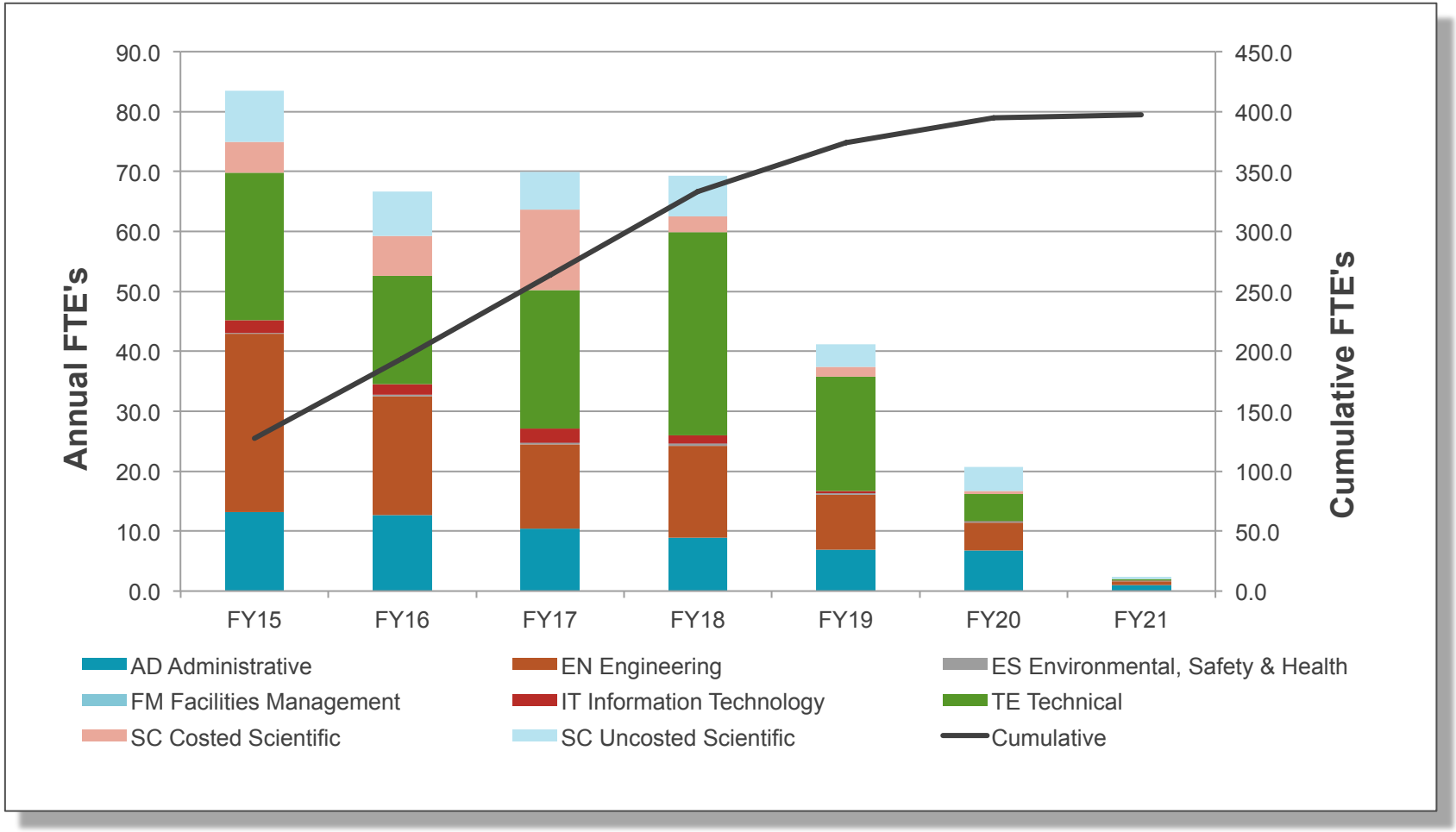


Cost Breakdown

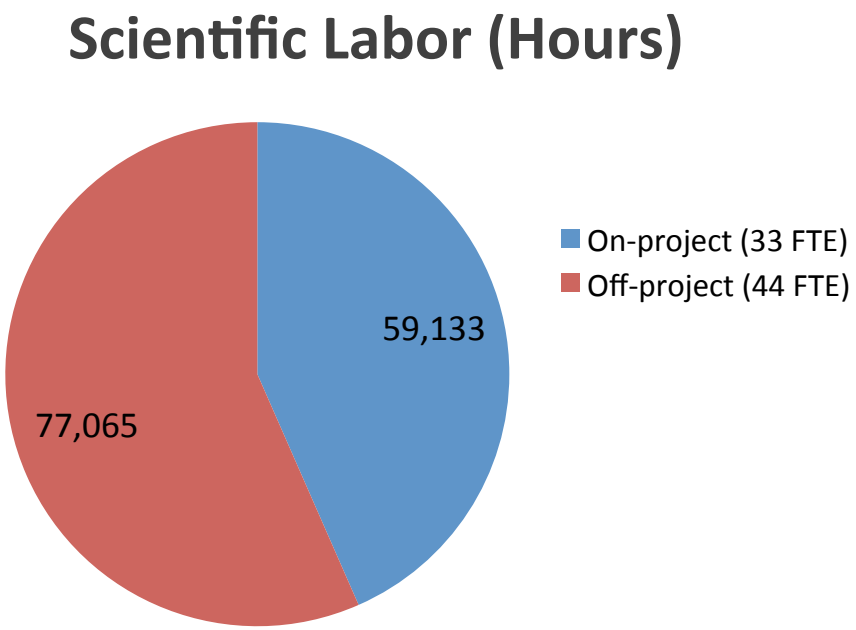




Labor Resources



Scientists

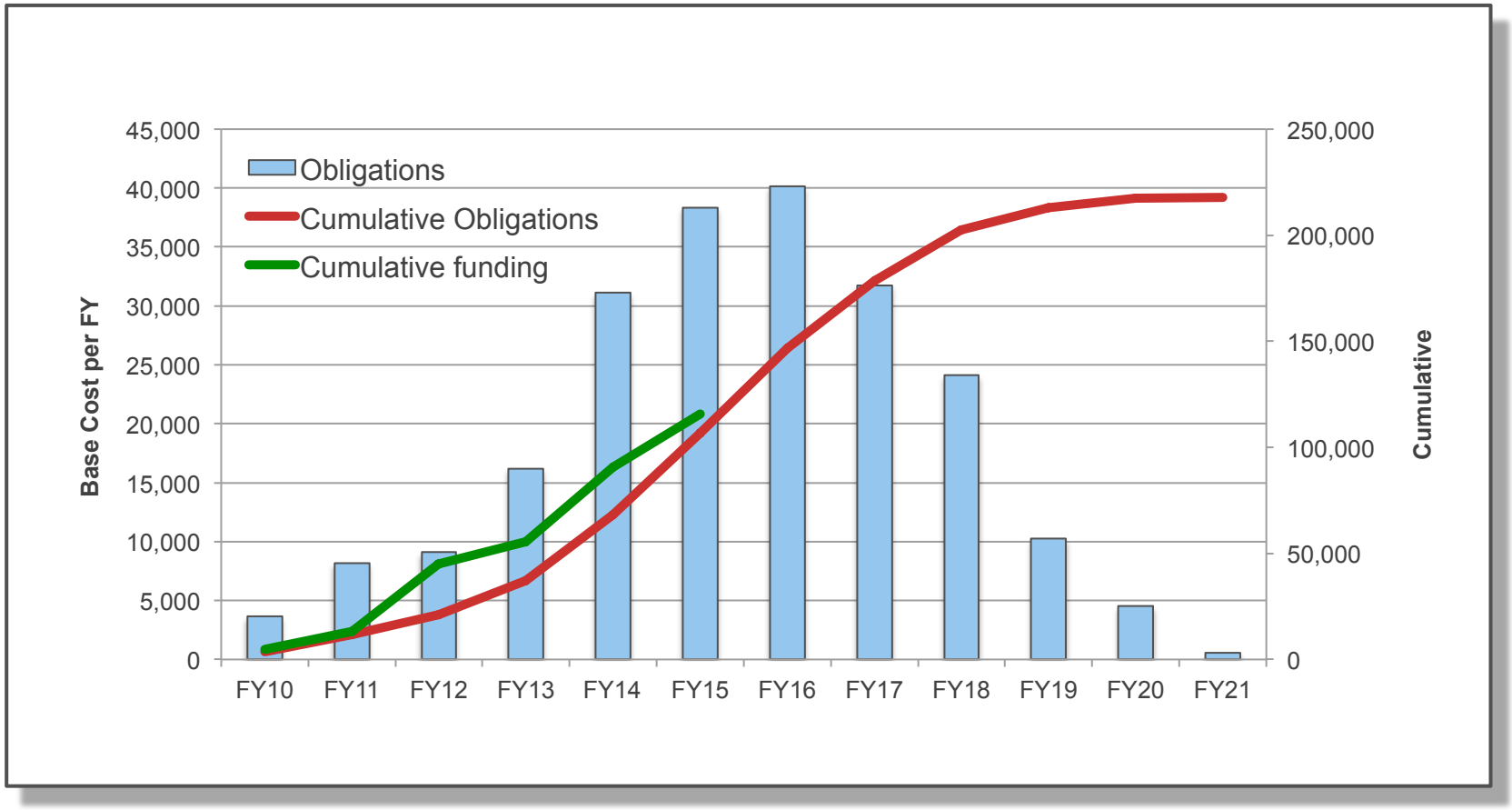


- $13.7M Total for on-project scientists from project inception.
- Uncosted scientists are included in RLS if they are required to satisfy CD-4
  - L3 or L4 managers
  - Simulations needed for design.

See Doug Glenzinski's Management breakout talk for more details

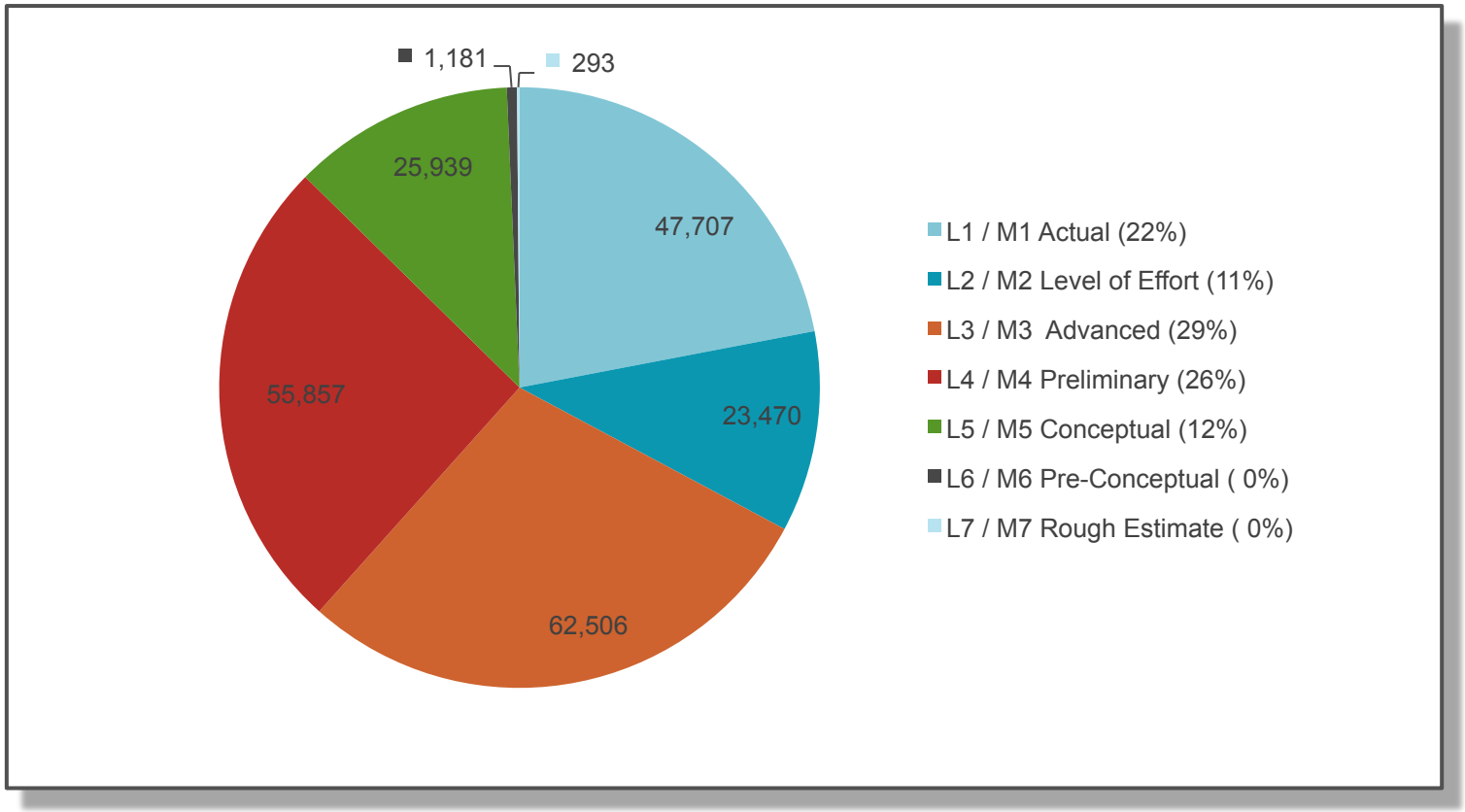
Obligation and Funding Profile

Expecting a funding profile soon.



Quality of Estimate

88% of cost at or beyond Preliminary design



Degree of Project Definition

- No unique definition
- Based on DOE Cost Estimating Guide we have a Class 2 estimate with engineering that is 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.
  - Design is not necessarily a linear process.
  - Based on this metric, the design process is 56% complete.

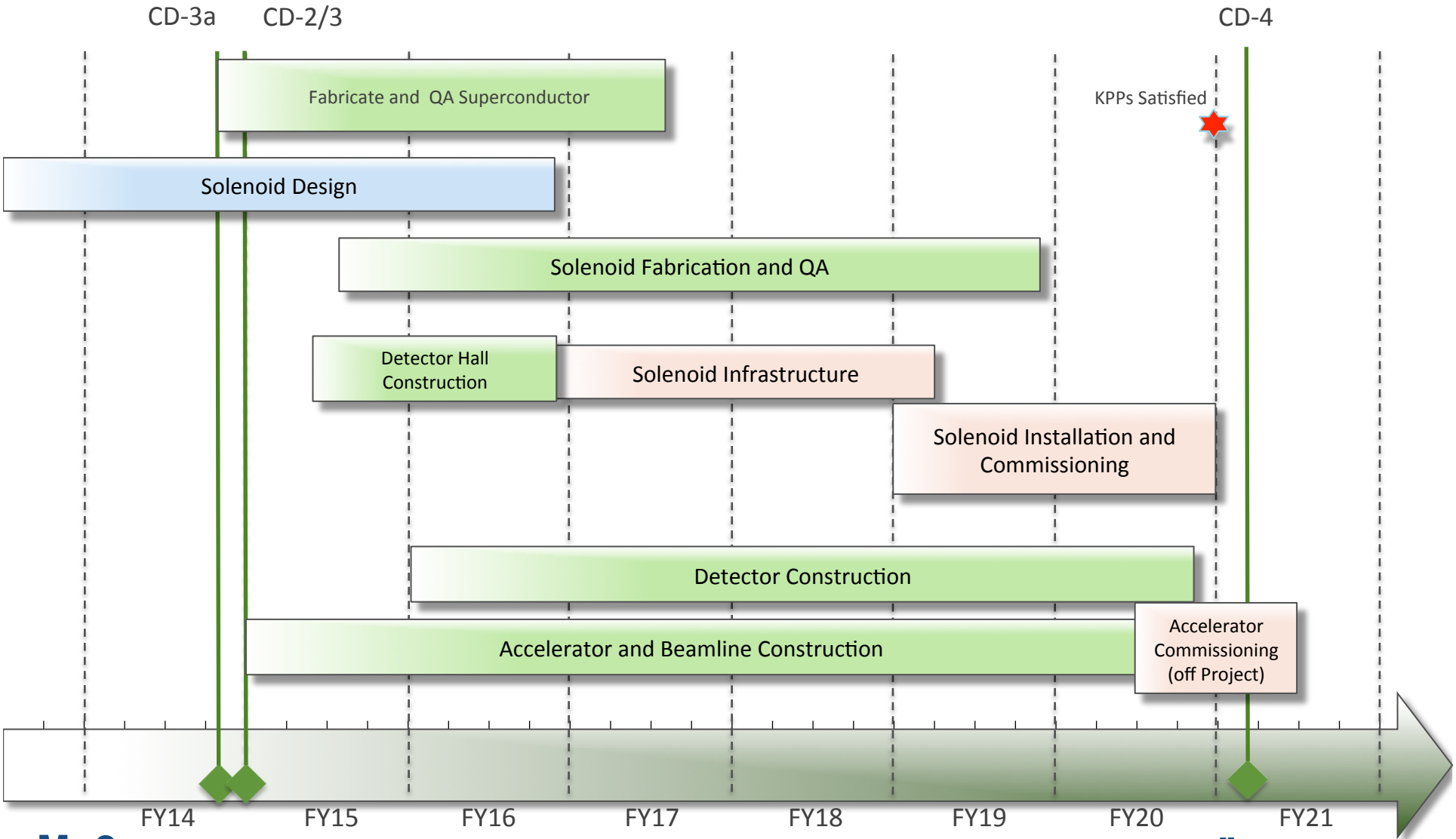
L2	Project Definition
Accelerator	55%
Conventional Construction	100%
Solenoids	55%
Muon Beamline	40%
Tracker	40%
Calorimeter	40%
Cosmic Ray Veto	55%
DAQ	60%
Total	56%

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
CD-2 (Approve Performance Baseline)	4th Qtr, FY14
CD-3 for Detector Hall	4th Qtr, FY14
CD-3 Mini Reviews	FY15 – FY17
Key Performance Parameters Satisfied	1st Qtr, FY21
CD-4 (Includes 24 months of programmatic float)	1st Qtr, FY23

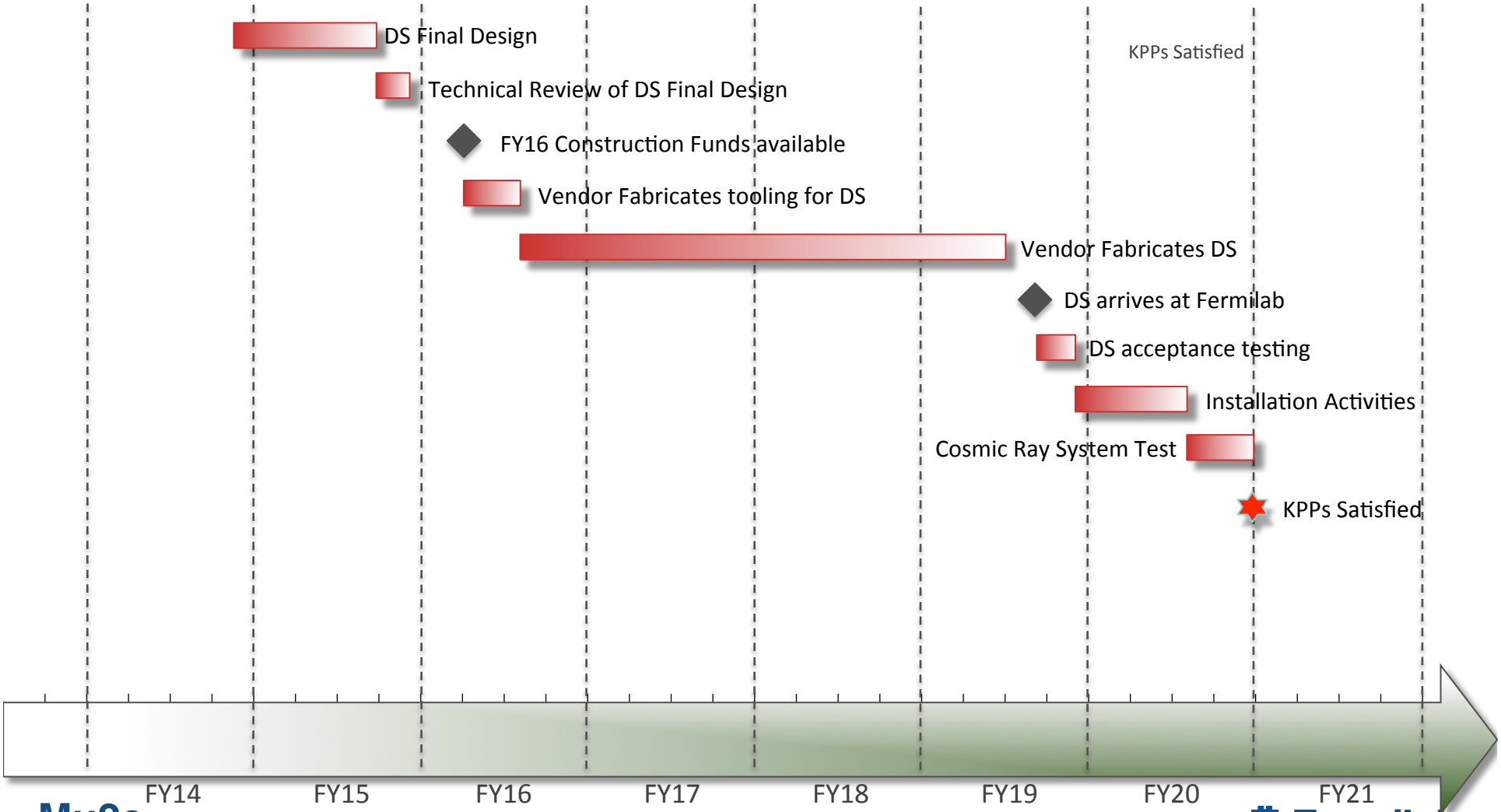
- CD-2 date fixed in schedule. Other CD dates float and are determined by predecessors.
- CD date is defined as official sign-off.

Schedule

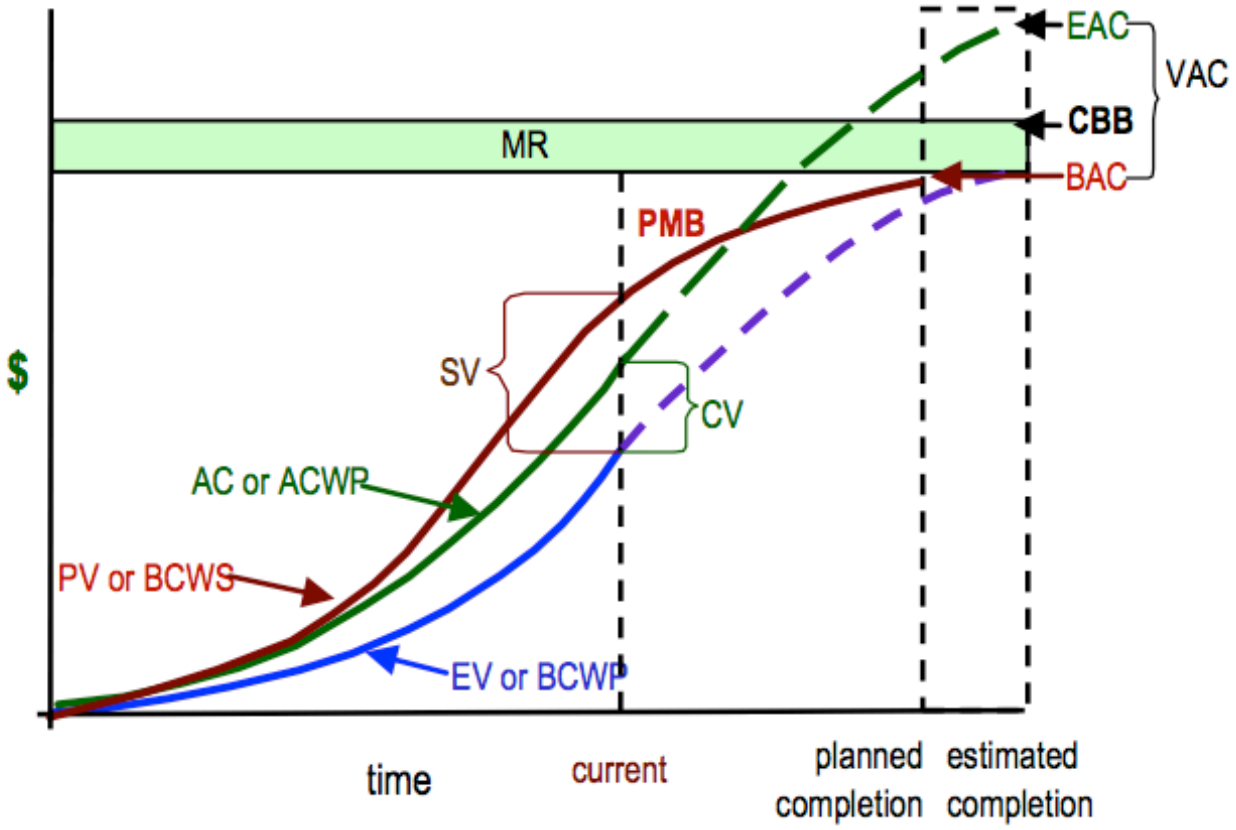

CD-3a
CD-2/3
CD-4
Fabricate and QA Superconductor
KPPs Satisfied
Solenoid Design
Solenoid Fabrication and QA
Detector Hall Construction
Solenoid Infrastructure
Solenoid Installation and Commissioning
Detector Construction
Accelerator and Beamline Construction
Accelerator Commissioning (off Project)
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Critical Path

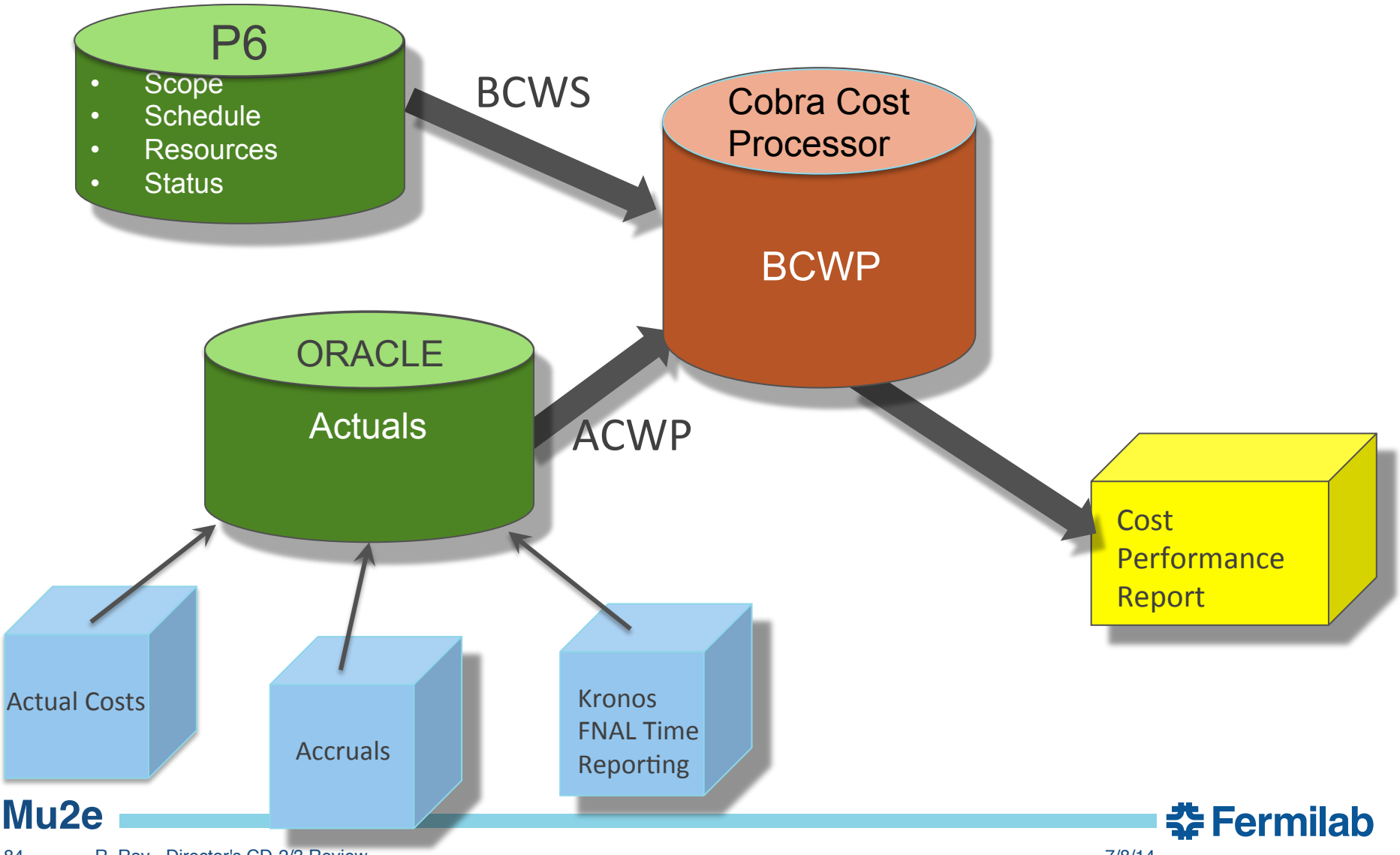
Detailed Gantt Chart of critical path posted on Review web page



EVMS


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

Monthly Reporting



EVMS

- Have been statusing the schedule since January
- Most statusing is done face-to-face between CAM and Project Controls leads.
- Baseline was frozen 2 weeks ago.
- Cost and schedule trued up to actuals through April.
- Cost Performance Reports generated for April and May and included in Monthly Reports (available from Review web page)
  - Will generate June before DOE Review.
- Not as far along on this as we would like but our P6 schedule is fully EVMS compliant, the tools and procedures are in place and we will have a full ramp-up prior to the DOE Review.

EVMS – May Report by L2

Report: **Mu2e_Earned Value** - Project Stoplight metrics

Project: **MU2E** - Mu2e
Status Date: 05/31/2014

Mu2e
May 31, 2014
Currency in: $K

	Current Period							Cumulative to Date								
Work Package.WBS (2)	**Budget**	**Earned**	**Actuals**	**SV ($)**	**SV (%)**	**CV ($)**	**CV (%)**	**Budget**	**Earned**	**Actuals**	**SV ($)**	**SV (%)**	**CV ($)**	**CV (%)**	**SPI**	**CPI**
475.01 Project Management	217	217	205	0	0%	12	6%	8,676	8,676	8,663	0	0%	12	0%	1.00	1.00
475.02 Accelerator	563	351	337	(212)	-38%	14	4%	10,608	10,396	10,382	(212)	-2%	14	0%	0.98	1.00
475.03 Conventional Construction	97	68	38	(29)	-30%	30	44%	2,371	2,341	2,312	(29)	-1%	30	1%	0.99	1.01
475.04 Solenoids	611	520	542	(92)	-15%	(22)	-4%	15,434	15,342	15,365	(92)	-1%	(22)	0%	0.99	1.00
475.05 Muon Beamline	259	109	106	(150)	-58%	3	3%	4,177	4,028	4,025	(150)	-4%	3	0%	0.96	1.00
475.06 Tracker	95	16	184	(79)	-83%	(168)	-1061%	2,703	2,624	2,792	(79)	-3%	(168)	-6%	0.97	0.94
475.07 Calorimeter	54	174	70	120	221%	104	60%	189	309	205	120	63%	104	34%	1.63	1.51
475.08 Cosmic Ray Veto	223	57	74	(166)	-74%	(17)	-30%	1,457	1,292	1,309	(166)	-11%	(17)	-1%	0.89	0.99
475.09 Trigger & DAQ	95	76	76	(19)	-20%	1	1%	1,602	1,583	1,582	(19)	-1%	1	0%	0.99	1.00
Total	**2,214**	**1,587**	**1,631**	**(627)**	**-28%**	**(44)**	**-3%**	**47,218**	**46,591**	**46,635**	**(627)**	**-1%**	**(44)**	**0%**	**0.99**	**1.00**
Management Reserve																
TAB																

At Complete				
BAC	**EAC**	**VAC**	**% Spent**	**% Complete**
20,752	20,744	8	42%	42%
40,941	40,848	93	25%	25%
20,628	20,598	30	11%	11%
86,878	87,057	(179)	18%	18%
19,715	19,681	34	20%	20%
11,736	11,901	(165)	23%	22%
5,444	5,464	(20)	4%	6%
6,735	6,635	99	20%	19%
4,816	4,796	20	33%	33%
217,645	**217,726**	**(81)**	**21%**	**21%**
0	0			
217,645	217,726			

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 defined. Need a funding profile followed by resource leveling
- Approve Updated PEP
  - Updated draft exists (Mu2e-doc-1172)
- Approval of Long-Lead Procurement
  - CD-3a ESAAB scheduled for July 10
- 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
  - This week

CD-2 Requirements

- Complete Preliminary Design Report
  - TDR (Mu2e-doc-4299)
- Perform Baseline Validation Review
  - ICE/ICR scheduled for July 22-24
- Employ an EVM System
  - Tools and processes in place. Reports for April and May generated. Schedule being statused. Actuals brought into schedule.
- 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

Complete a Final Design

- 100% designs completed for
  - Mu2e building (see Tom's talk)
  - Accelerator Instrumentation and Controls (see Steve's talk)
  - Radiation Safety (see Steve's talk)
  - Delivery Ring RF (see Steve's talk)

Summary

- Mu2e target sensitivity has great discovery potential, directly addresses one of the P5 physics drivers and is complementary to present/future collider programs.
- Technical design is at or beyond the Preliminary design stage for vast majority of components.
- Comprehensive RLS has been constructed consistent with Fermilab standards including the certified EVM System.
- We are ready for CD-2!
- The Detector Hall is ready for CD-3!