Fermilab

U.S. DEPARTMENT OF ENERGY Office of Science

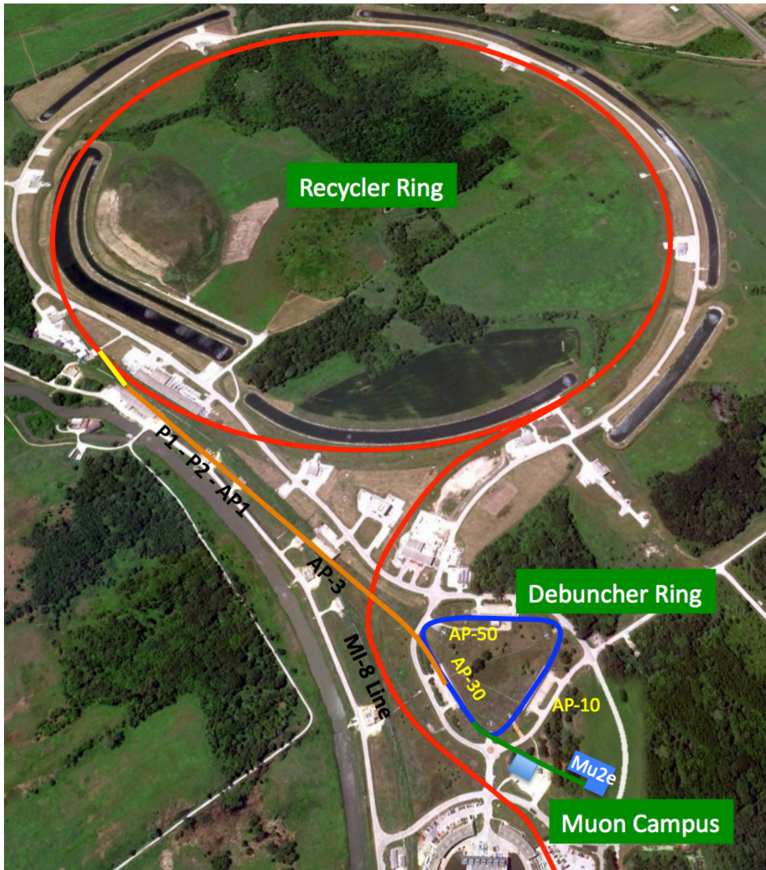
Mu2e Overall Project Scope and Cost Estimate Development

Ron Ray
Mu2e Project Manager
8/26/2014

Introduction

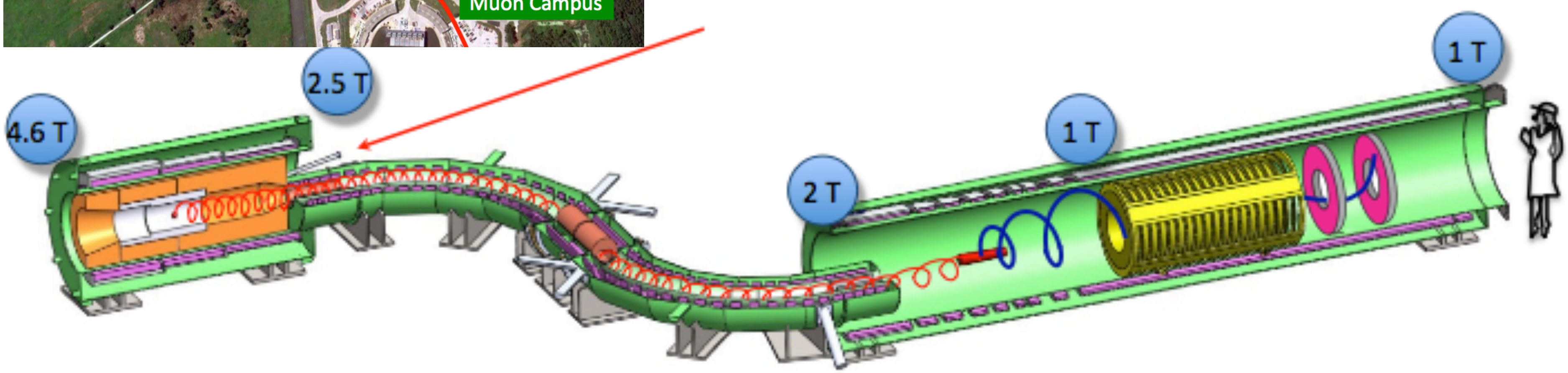
- Mu2e will be the world's most sensitive search for *Charged Lepton Flavor Violation*
- This would be a major discovery on par with the discovery of quark mixing and neutrino oscillations.
- Search is motivated by the same physics considerations that motivate searches for new physics at the LHC
  - Mu2e is sensitive to the same physics as the LHC, but in a complementary way.
  - Mu2e is also sensitive to new physics beyond the reach of the LHC
- Guidance from the recent P5 prioritization panel was unambiguous – "Complete the Mu2e Project."

Mu2e Project Scope

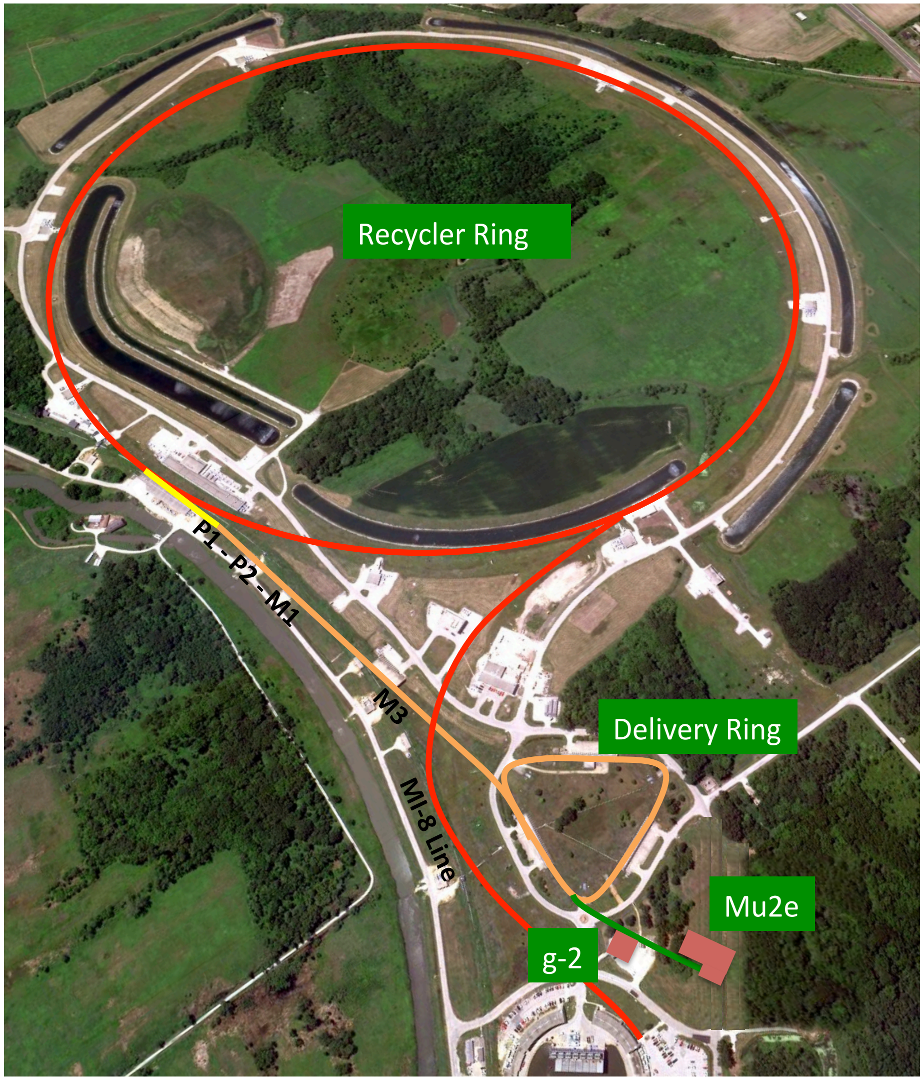


Mu2e Project scope includes

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



Beam Delivery

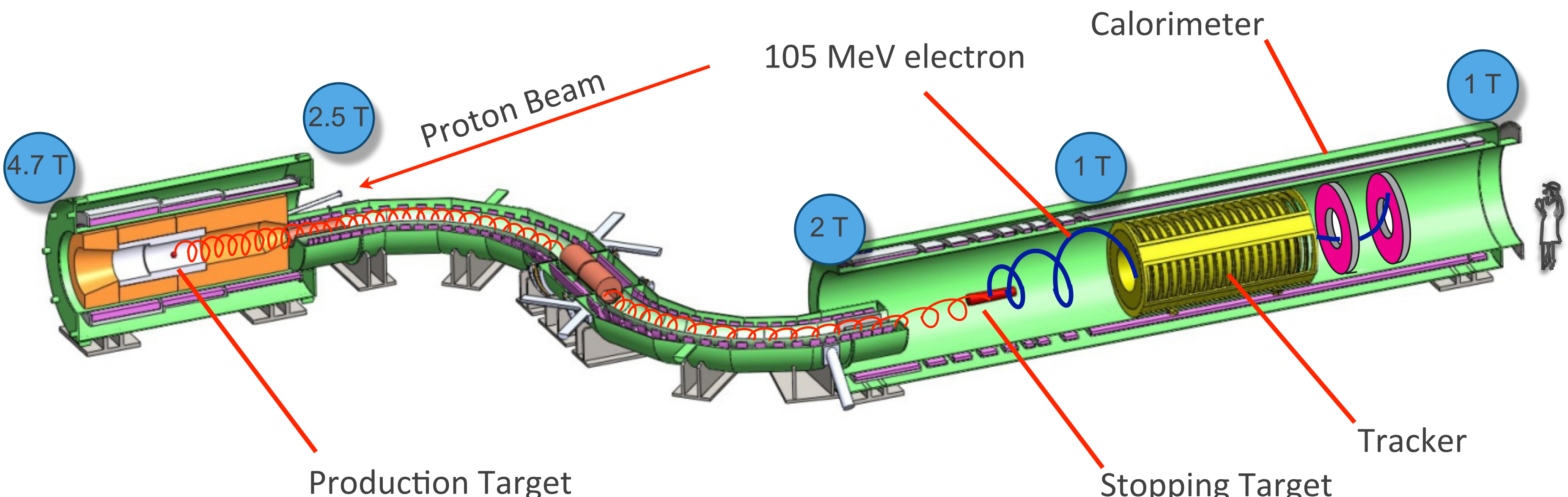


- We make muons by directing 8 GeV protons on to a target.
- Batches of protons from the Booster are transported through existing beamlines to the Recycler Ring where they are re-bunched and transported to the Delivery Ring through existing transport lines.
- Beam is slow extracted from Delivery Ring 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



Additional Contributions to Mu2e

- Mu2e is one element of an integrated Muon Program
- The Mu2e and Muon g-2 Projects depend on off-project upgrades to the accelerator complex and infrastructure, a llection of activities called the Muon Campus Program.
- Muon Campus common projects r Mu2e and g-2
  - MC1 building houses power supplie inction system and cryo plant – 100% complete
  - Beam Transport Accelerator Improveme
  - Cryo Facility AIP – 50% complete
  - Delivery Ring AIP – 10% complete
  - Recycler Ring RF AIP – 15% complete
  - Beamline Enclosure General Plant Project (GPP) – Constructio
  - Muon Campus Infrastructure GPP
- In-kind contribution from INFN for significant part of calorimeter and contributions to solenoid R&D.
- Off project work tracked in Mu2e schedule via milestones.

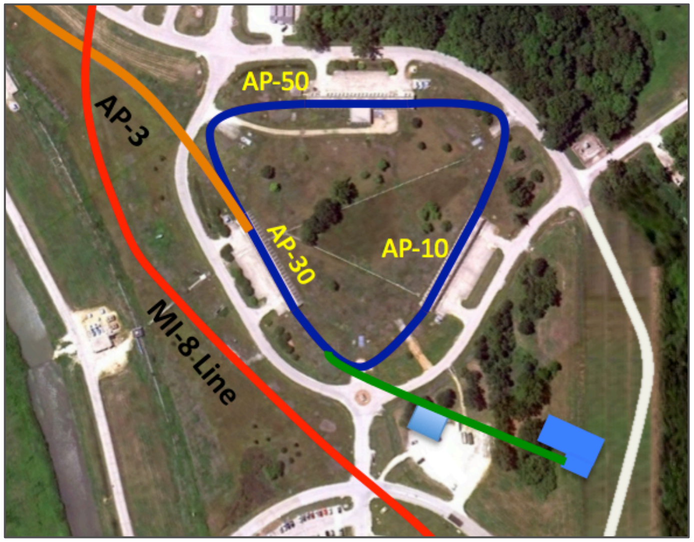
Muon Campus Common Projects Managed by Mary Convery. Required by g-2 long before they are needed by Mu2e.

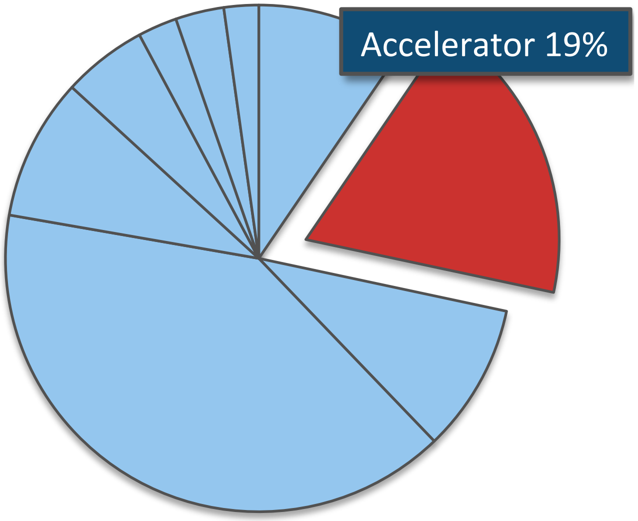
Envisioned Muon Campus

WBS 2 - Mu2e Accelerator

Provide 8 kW beam of 8 GeV protons to the Mu2e detector

- 475.2.1 Accelerator Project Management ($3469k)
- 475.2.3 Instrumentation and Controls ($2407k)
- 475.2.4 Radiation Safety Improvements (($2021k)
- 475.2.5 Resonant Extraction System ($5480k)
- 475.2.6 Delivery Ring RF System ($2600k)
- 475.2.7 External Beamline ($5903k)
  - Significant use of repurposed magnets
- 475.2.8 Extinction Systems ($3179k)
- 475.2.9 Target Station ($10,551k)
- Significant interface to Muon Campus AIPs and GPPs.

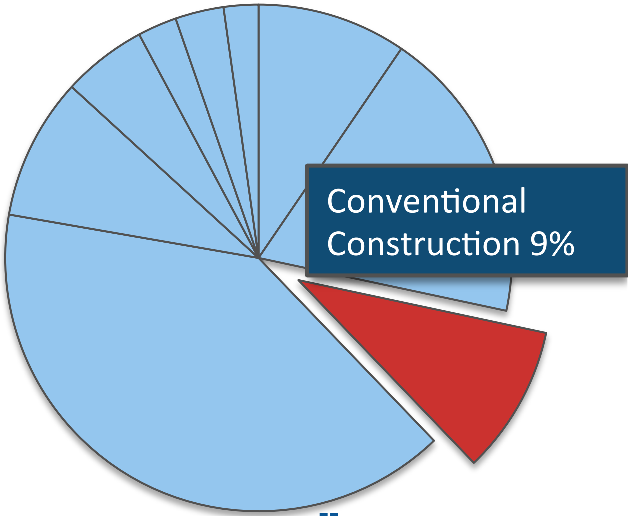




WBS 3 - Conventional Construction

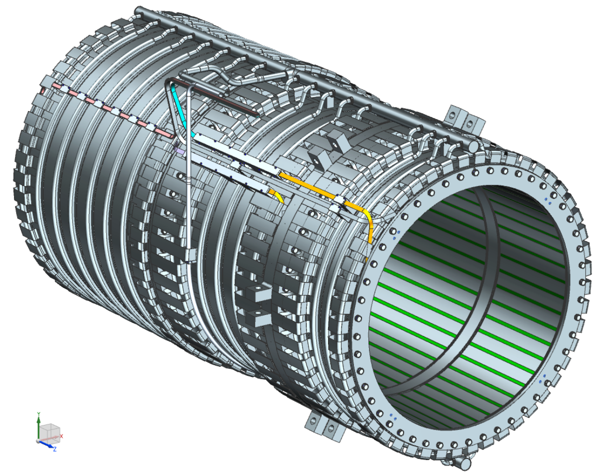
Facility to house Mu2e experiment and supporting infrastructure

- Conceptual Design ($433k)
- Preliminary/Final Design ($2365k)
- Construction Phase Oversight ($2485)
- Construction ($14,941k)
  - Underground enclosure to house detector
  - Surface building for infrastructure
- Project Close ($369k)
- Interface to Muon Campus Beamline Enclosure GPP and MC-1 Building.

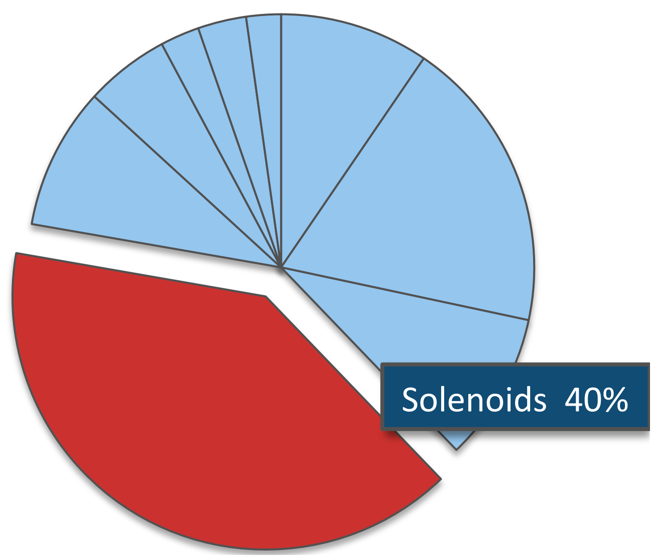


WBS 4 Solenoids

Provide magnetic field configuration necessary to capture pions, form a secondary muon beam, reject backgrounds and precisely momentum analyze electrons.



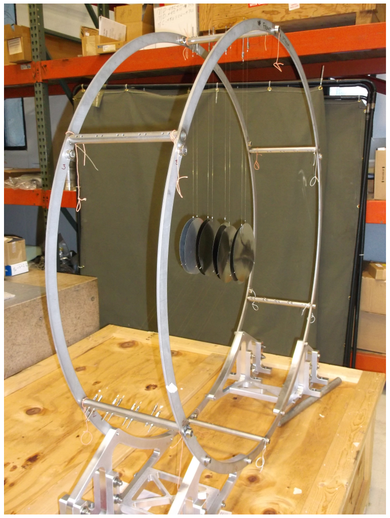
- 475.4.1 Project Management ($3465k)
- 475.4.2 Production Solenoid ($14,682k)
  - Fabrication cost based on competitive bid process. Working to put P.O. in place
- 475.4.3 Transport Solenoid ($23,826k)
- 475.4.4 Detector Solenoid ($16,001k)
  - Fabrication cost based on competitive bid process. Working to put P.O. in place
- 475.4.5 Cryogenic System ($11,544k)
- 475.4.6 Magnet Power System ($1495k)
- 475.4.7 Magnet Quench protection System ($2912k)
- 475.4.8 Magnetic Field Mapping System ($1048k)
- 475.4.9 Ancillary Equipment ($959k)
- 475.4.10 System Integration, Installation and Commissioning ($5135k)

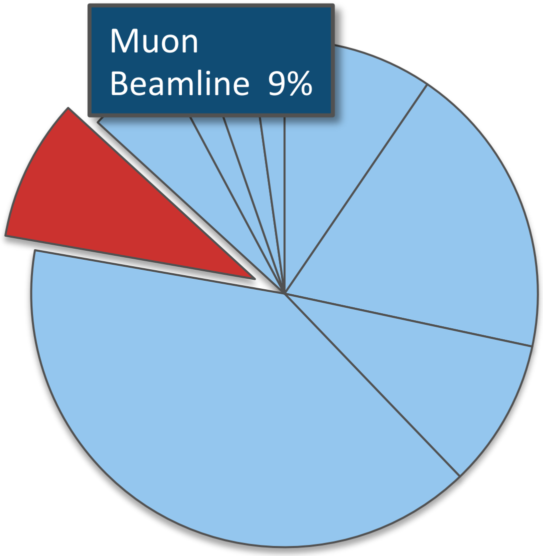


WBS 5 Muon Beamline

Components necessary to form the muon beam, stop muons and shield the rest of the detector from the byproducts.

- 475.5.1 Project Management ($3136k)
- 475.5.2 Vacuum System ($3354k)
- 475.5.3 Collimators ($1392k)
- 475.5.4 Upstream External Shielding ($1982k)
- 475.5.5 Stopping Target ($180k)
- 475.5.6 Stopping target Monitor ($343k)
- 475.5.7 Detector Solenoid Internal Shielding ($392k)
- 475.5.8 Muon Beam Stop ($781k)
- 475.5.9 Downstream External Shielding ($3392k)
- 475.5.10 Detector Support Structure ($2469k)
- 475.5.11 Systems Integration ($334k)

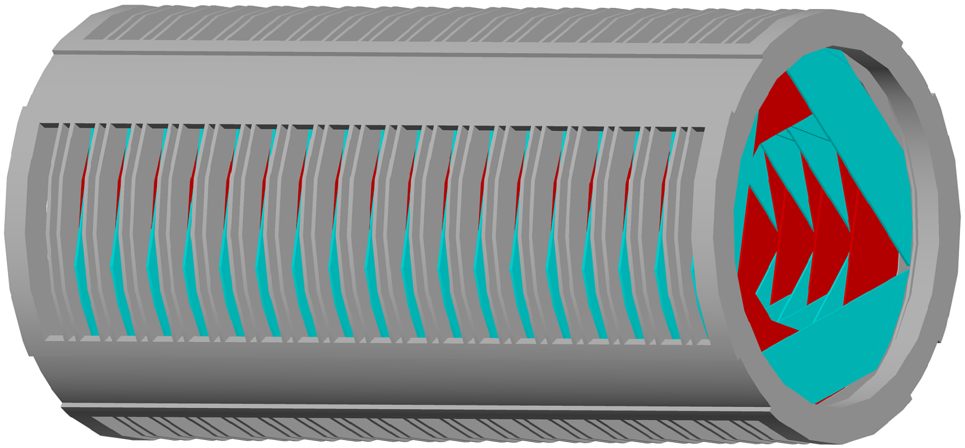


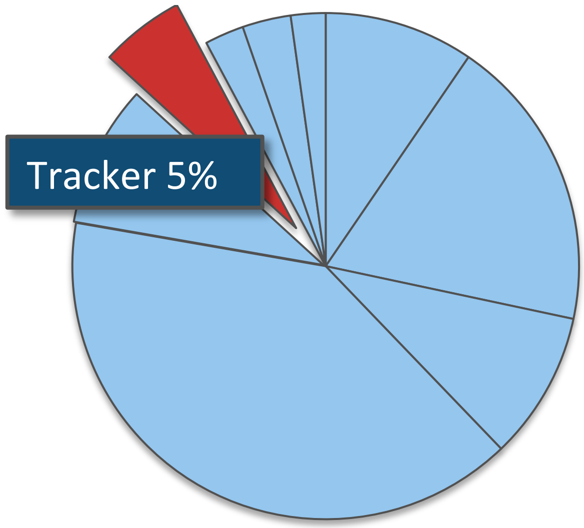


WBS 6 Tracker

Measure the trajectory of electron tracks with 21,000 straw drift tubes

- 475.6.1 Project Management ($1820k)
- 475.6.2 Straws ($1313)
- 475.6.3 Straw Assemblies ($3629k)
- 475.6.4 Front End Electronics ($2253k)
- 475.6.5 Infrastructure ($943k)
- 475.6.6 Detector Assembly and Installation ($70k)

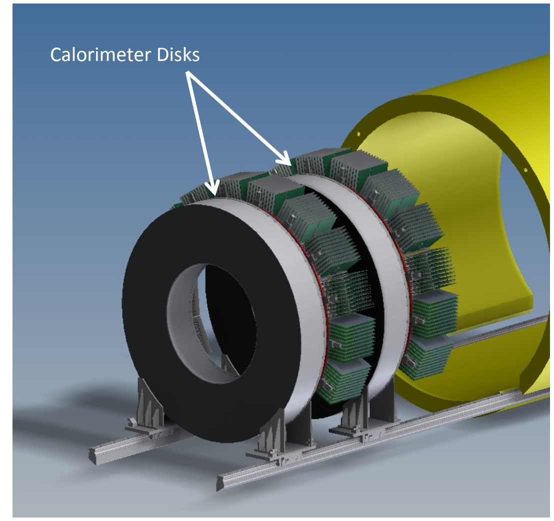


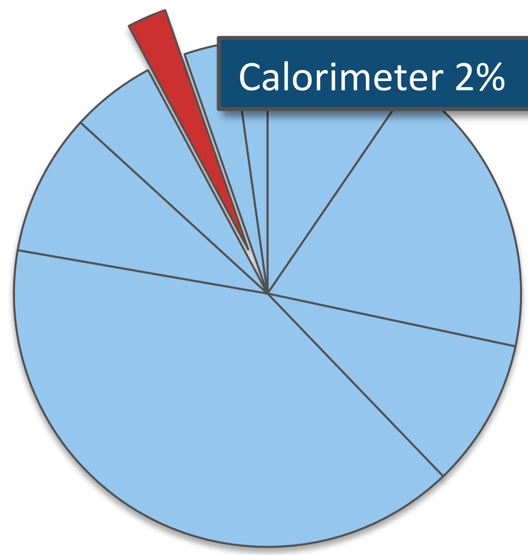


WBS 7 - Calorimeter

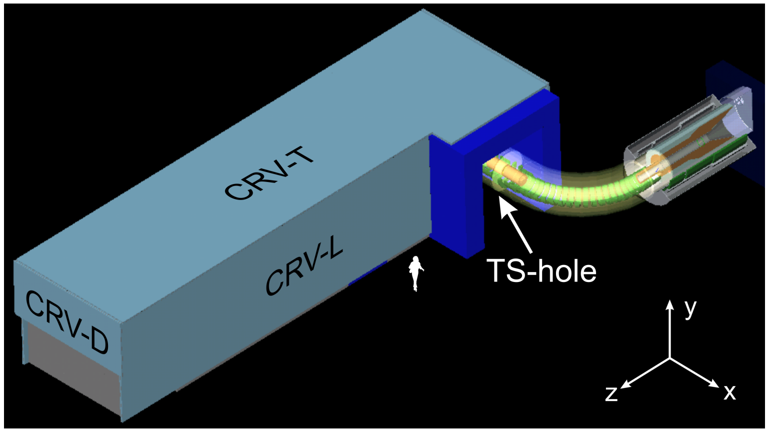
Measure the energy, position and timing of electrons

- 475.7.1 Project Management ($269k)
- 475.7.2 Crystals ($3125k)
- 475.7.3 Mechanical Support ($162k)
- 475.7.4 Photosensors ($1088k)
- 475.7.5 Digitizer ($108k)
- 475.7.6 Calibration Systems ($720k)
- 475.7.7 Power ($4k)
- 475.7.8 Installation ($315k)
- Significant in-kind scope provided by INFN
- DOE contribution is
    - 2/3 of crystals
    - 1/2 of photosensors
    - 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



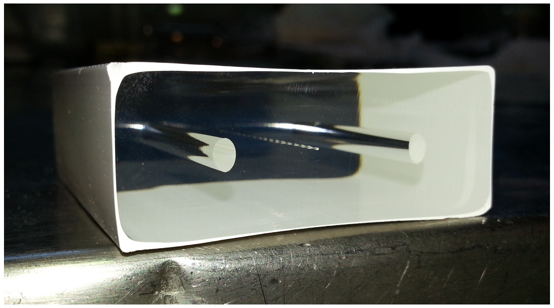


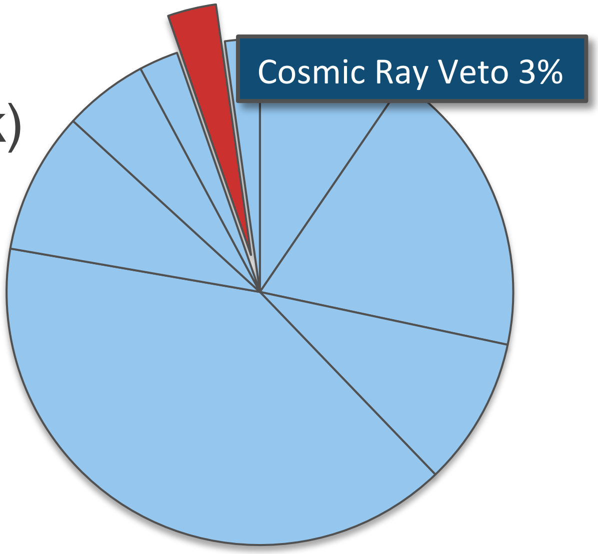
WBS 8 - Cosmic Ray Veto



Veto cosmic rays that can mimic the physics signal

- 475.8.1 Project Management ($450k)
- 475.8.2 Mechanical Design ($139k)
- 475.8.3 Scintillator Extrusions ($1023k)
- 475.8.4 Fibers ($455k)
- 475.8.5 Photodetectors ($766k)
- 475.8.6 Electronics ($1728)
- 475.8.7 Module Fabrication ($1474)
- 475.8.8 Detector Assembly and Installation ($206k)
- 475.8.9 Conceptual Design ($522k)

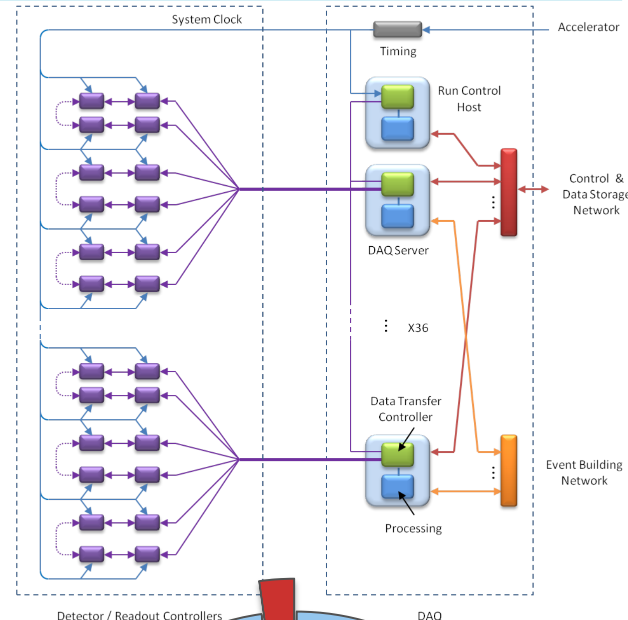


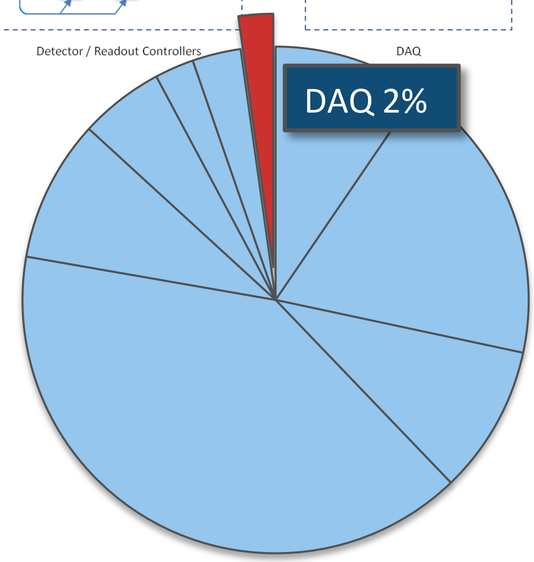


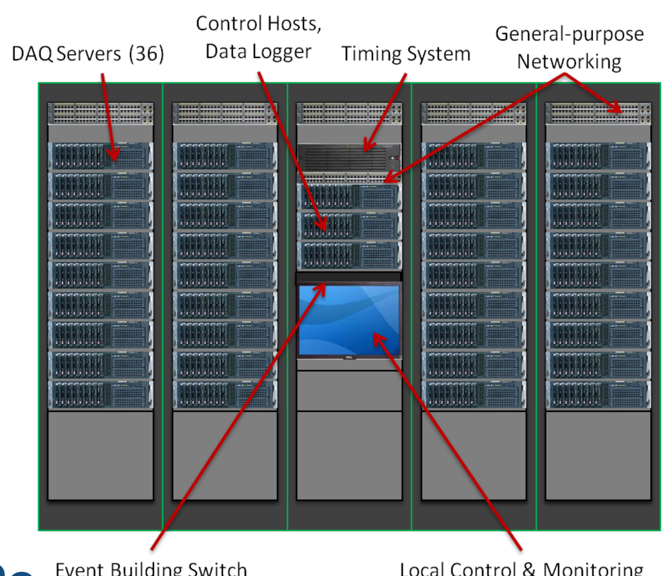
WBS 9 – Data Acquisition (DAQ)

Collect, assemble and record data from ~550 detector sources

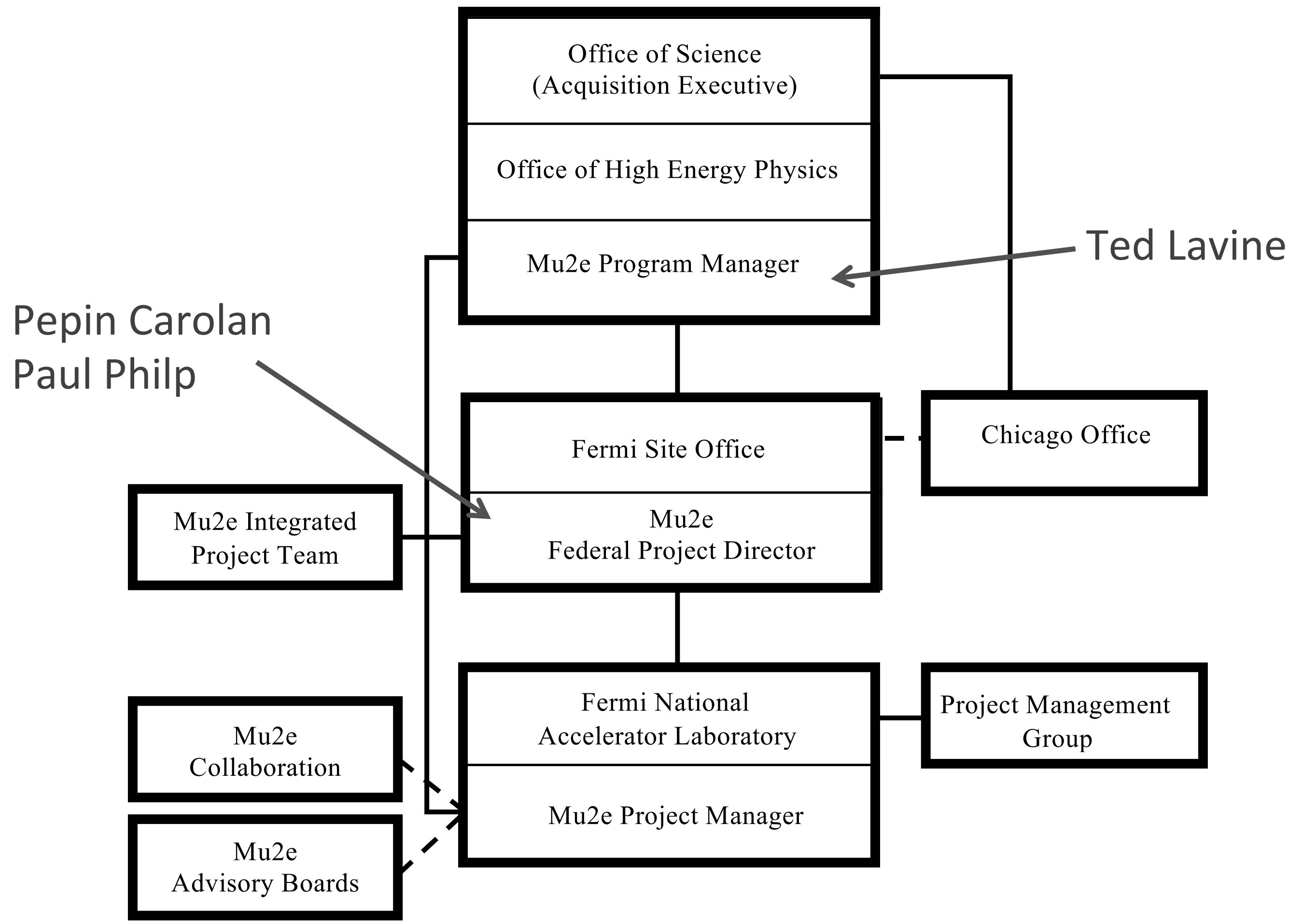
- WBS 475.9.1 Project Management ($1165k)
- WBS 475.9.2 System Design and Test ($361k)
- WBS 475.9.3 Data Acquisition ($1825k)
- WBS 475.9.4 Data Processing ($858k)
- WBS 475.9.5 Controls and Networking ($581k)



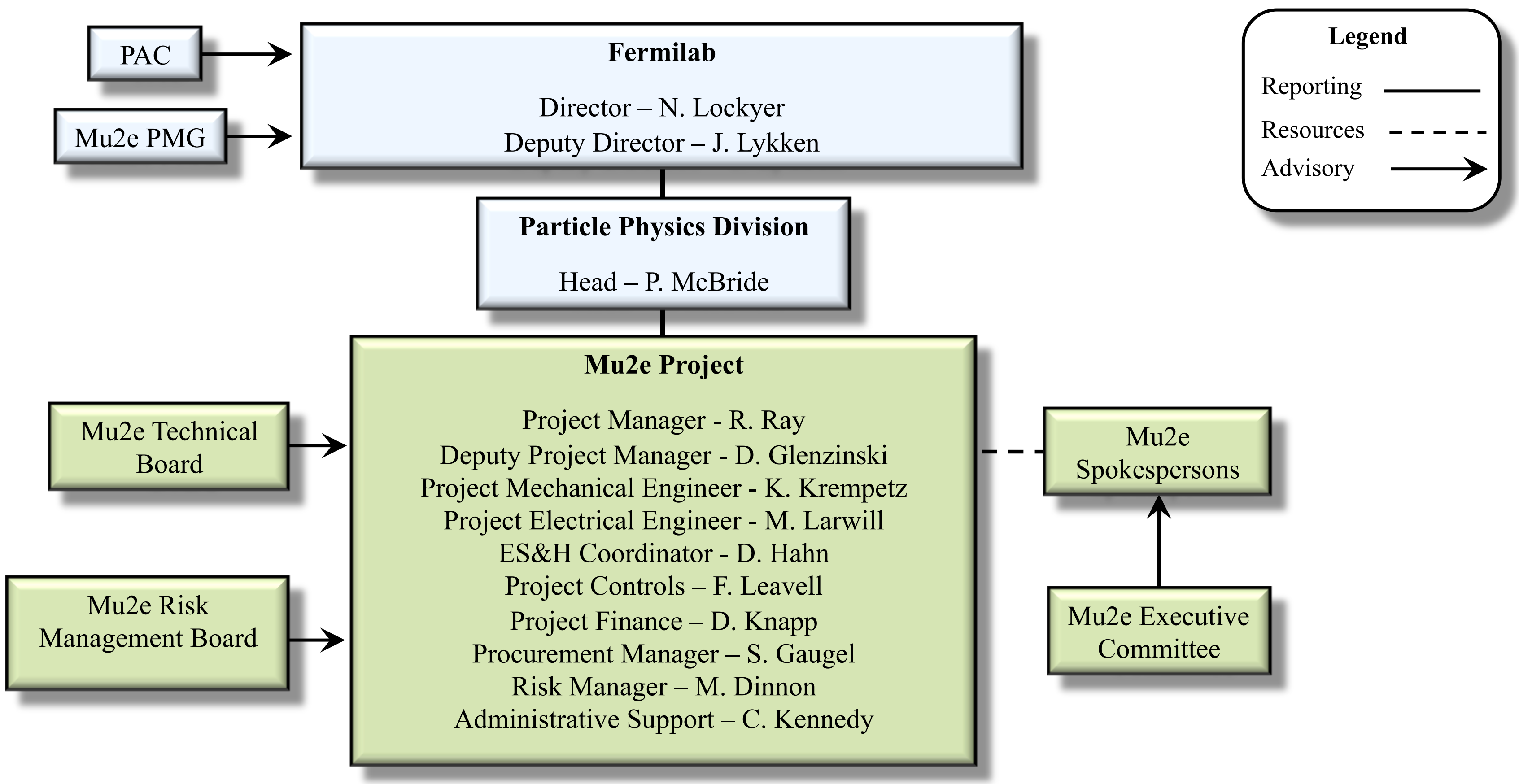




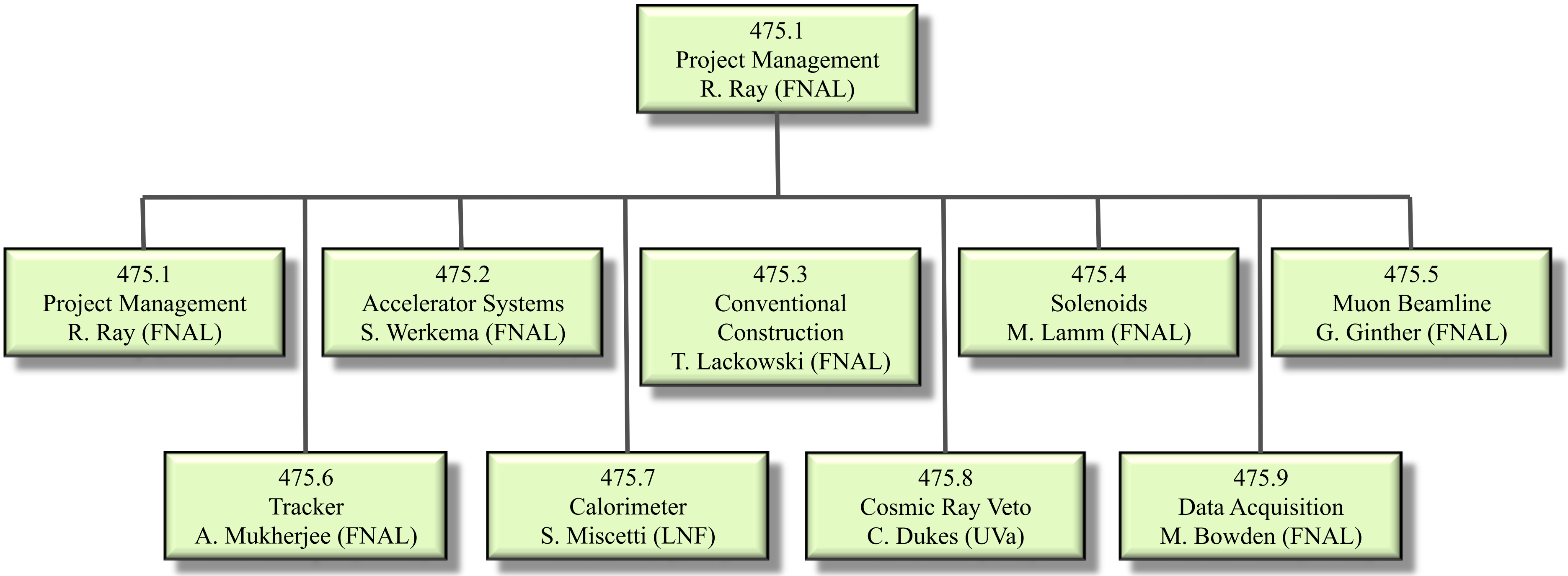
Management and Organization of Mu2e



Management and Organization



Mu2e 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





Cost and Schedule

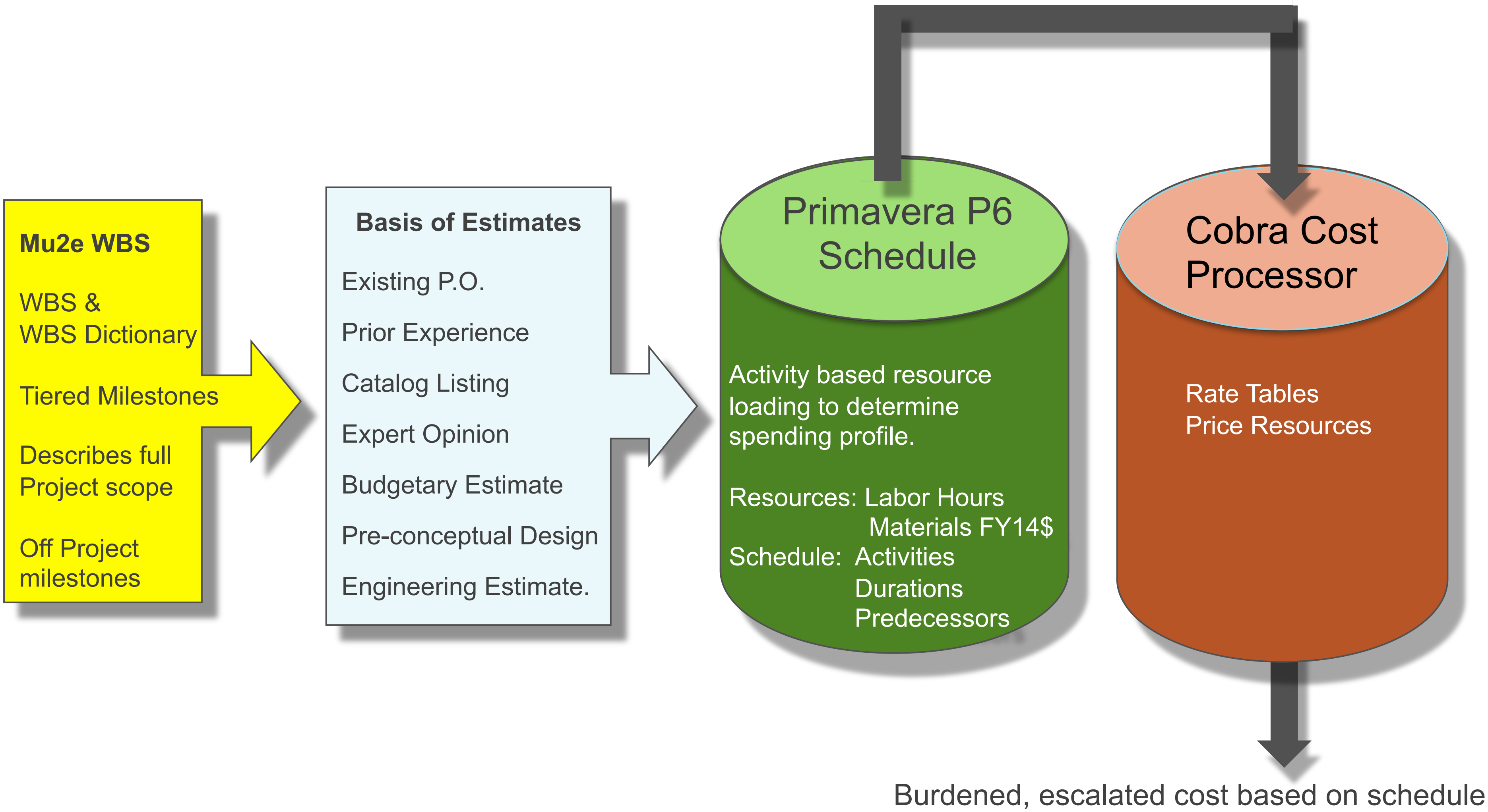
Cost Methodology

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

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BOEs

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

Task 475.8.7.4.1040 Fabricate Electronics Prototype Modules – M&S

The extrusions, fiber, and SiPMs come from 8.3, 8.5, and 8.5 respectively. The cost for materials is expected to be $5,100 per module -- $2,500 for Al, $2000 for fiber guide bar and SiPM manifolds (55$ per di-counter pair, (16.5+11)*2=55), and $600 for epoxy. We estimate the cost for the Al roughly scaling the 475.8.7.4.1010 estimate by area and accounting for the increased thickness of obsorber**.** We conservatively estimate 30% of the epoxy required for the larger module, and 40% of the AL cost of the longer module – since the AL cost does not directly scale with length (the thickness has also been increased). Two modules will be produced to test the side module-mounting scheme, access to the counter motherboards, and schemes by which modules are clamped together. They will also serve as a test bed for electronics. Quotes exist for epoxy, fiber guide bar, SiPM manifolds, and similar Aluminum purchases have recently been made so we assign a 25% contingency based on rule M4.

Module Materials	$10,200	See attached quotes for small FGB and manifold.
Ship to Fermilab	$600	Based on cost for test-beam prototype experience
---------		
M&S Cost	$10,800	Total of list above
Duration	44 days	9 weeks
Estimate Type	Preliminary	Contingency of 25% based on contingency rule M4.

Task 475.8.7.4.1050 Fabricate Electronics Prototype Modules – Labor

This will presumably go much smoother than the mechanical prototype. We estimate that this will take full-time effort for 6 weeks of a Virginia technician (240 hours) to build both modules. This estimate is based on experience with the test-beam prototype module. We assign a 40% uncertainty based on rule L4.

Technician Leader - Virginia	240 hr	Based on test-beam prototype experience
Undergrad Student (Scientist) – Univ. of Virginia	80 hr	
Duration	44 days	9 weeks
Estimate Type	Preliminary	Contingency of 40% based on contingency rule L4.

Task 475.8.7.4.1060 Design and Fabricate Pre-production Prototype Shipping Crates and End Caps – M&S

Each shipping crate will be approximately 3 feet wide by 20 feet long by 3 feet tall and weigh up to 4,000 lbs. They will be built from plywood, 4"x4" x 8' timbers, 2"x4" x8' lumber and screws. Strapping materials are also required. Prototype module end caps will be fabricated to protect the sensitive manifolds on the end of each fiber. Crate and end cap design exists and a quotes is attached to this BOE. We assign a 40% contingency based on rule M4.

M&S Cost	$2000	Crate and Materials
Duration	15 days	3 week
Estimate Type	Preliminary	Contingency of 40% based on contingency rule M4.

Task 475.8.7.4.1070 Design and Fabricate Pre-production Prototype Shipping Crates and End Caps– Labor

The mechanical prototype modules will be shipped to Fermilab so that additional studies of handling and mounting the modules can be conducted. Module end caps will be designed to protect the sensitive manifolds on the end of each fiber. Depending on end cap design shipping crates may not be necessary and this could save thousands of dollars on crating materials and personnel effort. This quote is based on experience from shipping the test-beam prototype to Fermilab. We assign a contingency of 40% based on L4.

Technician Leader - Virginia	80 hr	Based on test-beam prototype experience.
Undergrad Student (Scientist) – Univ. of Virginia	40 hr	
Duration	15 days	3 weeks
Estimate Type	Preliminary	Contingency of 40% based on contingency rule L4.

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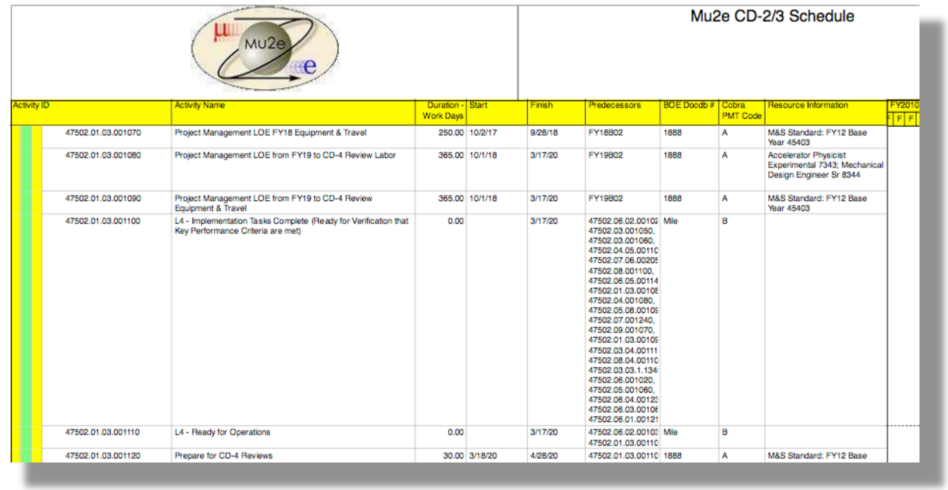
Resource Loaded Schedule

- Activity based RLS contains
  - 6920 activities
  - 4771 Activities with budget
    - 3458 Labor and non-P.O. purchases
    - 873 contracted labor/material purchases
    - 394 obligations
  - 71 Control Accounts and 30 CAMs
  - 765 milestones
  - 23 Constraints
    - 7 are Muon Campus milestones
    - 6 are accelerator shutdowns



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, 47502.03.001050, 47502.03.001060, 47502.04.05.0011, 47502.07.06.0020, 47502.08.001100, 47502.06.05.0011, 47502.01.03.0010, 47502.04.001080, 47502.05.08.0010, 47502.07.001240, 47502.09.001070, 47502.01.03.0010, 47502.03.04.0011, 47502.08.04.0011, 47502.03.03.1.134, 47502.06.001020, 47502.05.001060, 47502.06.04.0012, 47502.06.03.0010, 47502.06.01.0012	Mile	B	
47502.01.03.001110	L4 - Ready for Operations	0.00		3/17/20	47502.06.02.0010, 47502.01.03.0011	Mile	B	
47502.01.03.001120	Prepare for CD-4 Reviews	30.00	3/18/20	4/28/20	47502.01.03.0011	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

Rates and Assumptions

- Schedule trued-up with actuals through end of April, 2014.
- Estimate developed in FY14$. COBRA escalates to AY$.
- 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.

Uncosted Resources

Some resources that contribute to Mu2e are funded outside of the Project

- ES&H – Funded through overhead. Independence is central to the importance of their oversight role.
- Procurement – Funded through overhead
- University scientists, Post docs and grad students – Funded through Base HEP Research Program
- Scientists from other Labs – Funded through base program
- Scientists from Fermilab who are not engaged in management or work on the accelerator.
  - Rules for uncosted scientists posted on ICE Review web site (docdb#763, 764).
- Resources funded by agencies other than DOE
  - For Mu2e this means INFN. No NSF contributions to the Project.

University Resources

- Engineers, designers, technicians and undergraduates at Universities are funded by the Project.
- Statements of Work are developed and Purchase Orders to Universities are generated for the scope of work described in the SOW.
- This work is developed as labor with university resources in P6, but costed as M&S in COBRA.

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 money set aside because of 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 other projects
    - Do not reflect risk.
- Risk was addressed in a quantitative analysis process using a Monte Carlo
  - 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

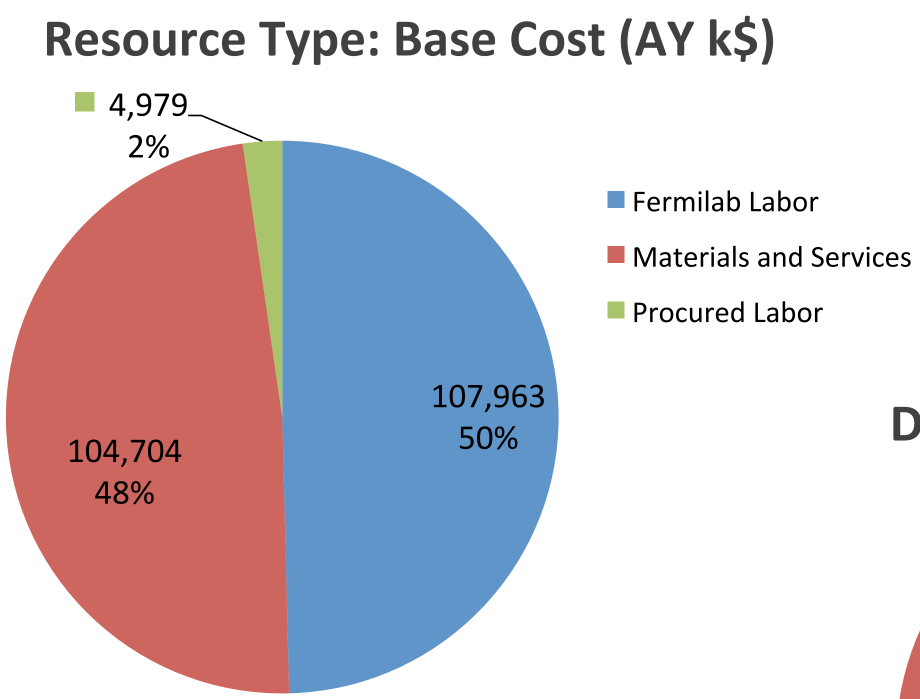
Labor

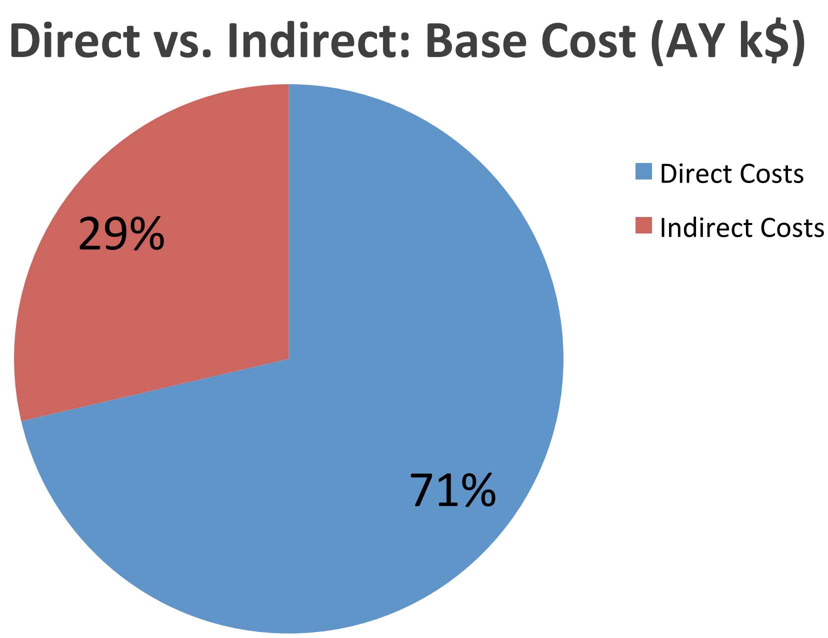
Code	Type of Estimate	Contingency %	Description
LABOR Guidelines			
L1	Actual	0%	Actual costs incurred on activities completed to date.
L2	Level of Effort Tasks	0%-20%	Support type activities that must be done to support other work activities or the entire project effort, where estimated effort is based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

Total Project Cost

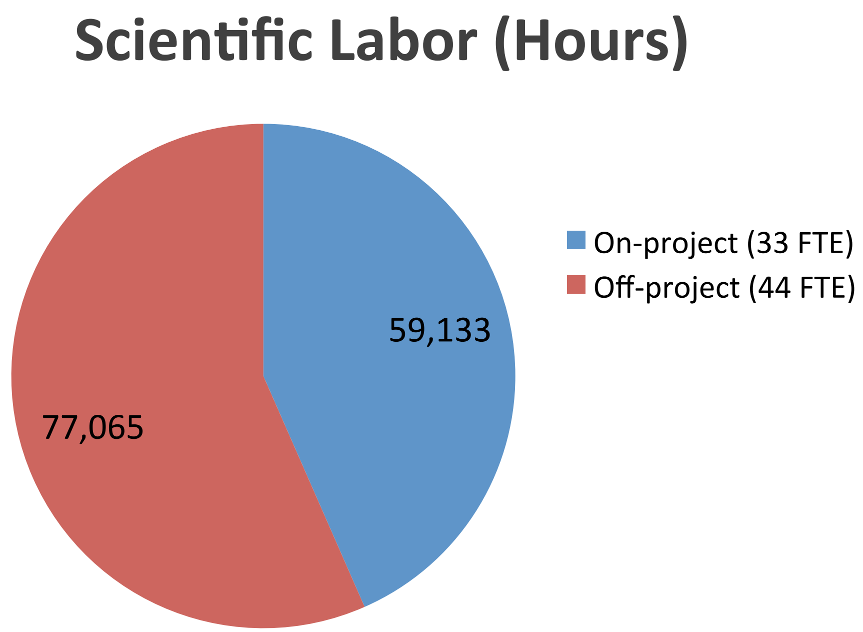
(Values in AY $k)	Performed through April 2014	ETC	Contingency EU + Risk	% Cont. on ETC	Total
Project Management	8,458	12,241	2,070	17%	22,770
Accelerator	10,053	30,604	9,534	31%	50,192
Conventional Construction	2,274	18,319	3,180	17%	23,772
Solenoids	14,823	72,274	22,717	31%	109,814
Muon Beamline	3,919	15,819	6,001	38%	25,739
Tracker	2,608	9,073	3,821	42%	15,502
Calorimeter	135	5,657	1,628	29%	7,421
Cosmic Ray Veto	1,235	5,530	1,961	35%	8,726
Trigger & DAQ	1,506	3,284	1,233	38%	6,023
Total	**45,012**	**172,801**	**52,146**	**30%**	**269,959**

Cost Breakdown





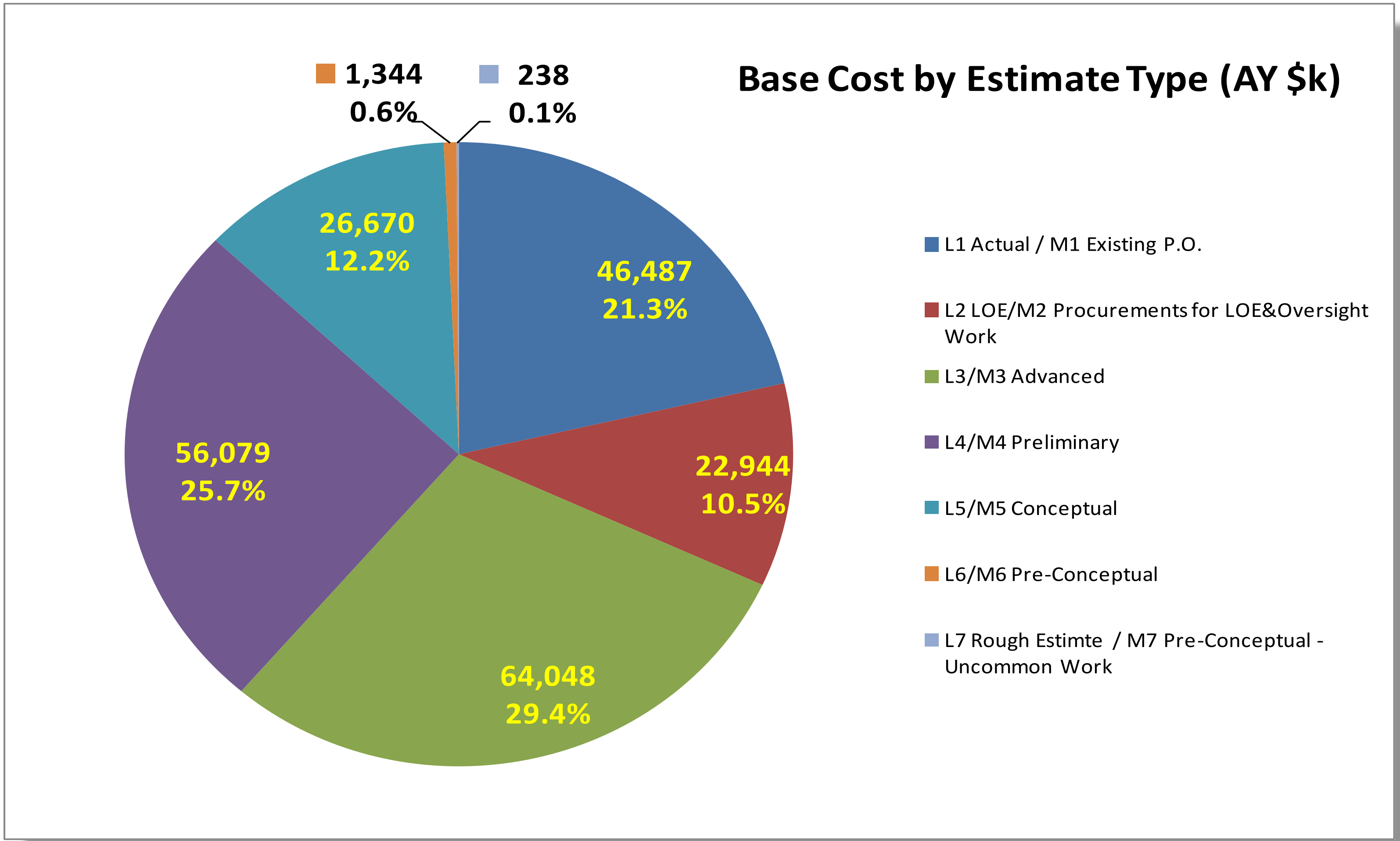
Scientists



- $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.

Quality of Estimate

88% of cost at or beyond Preliminary Design

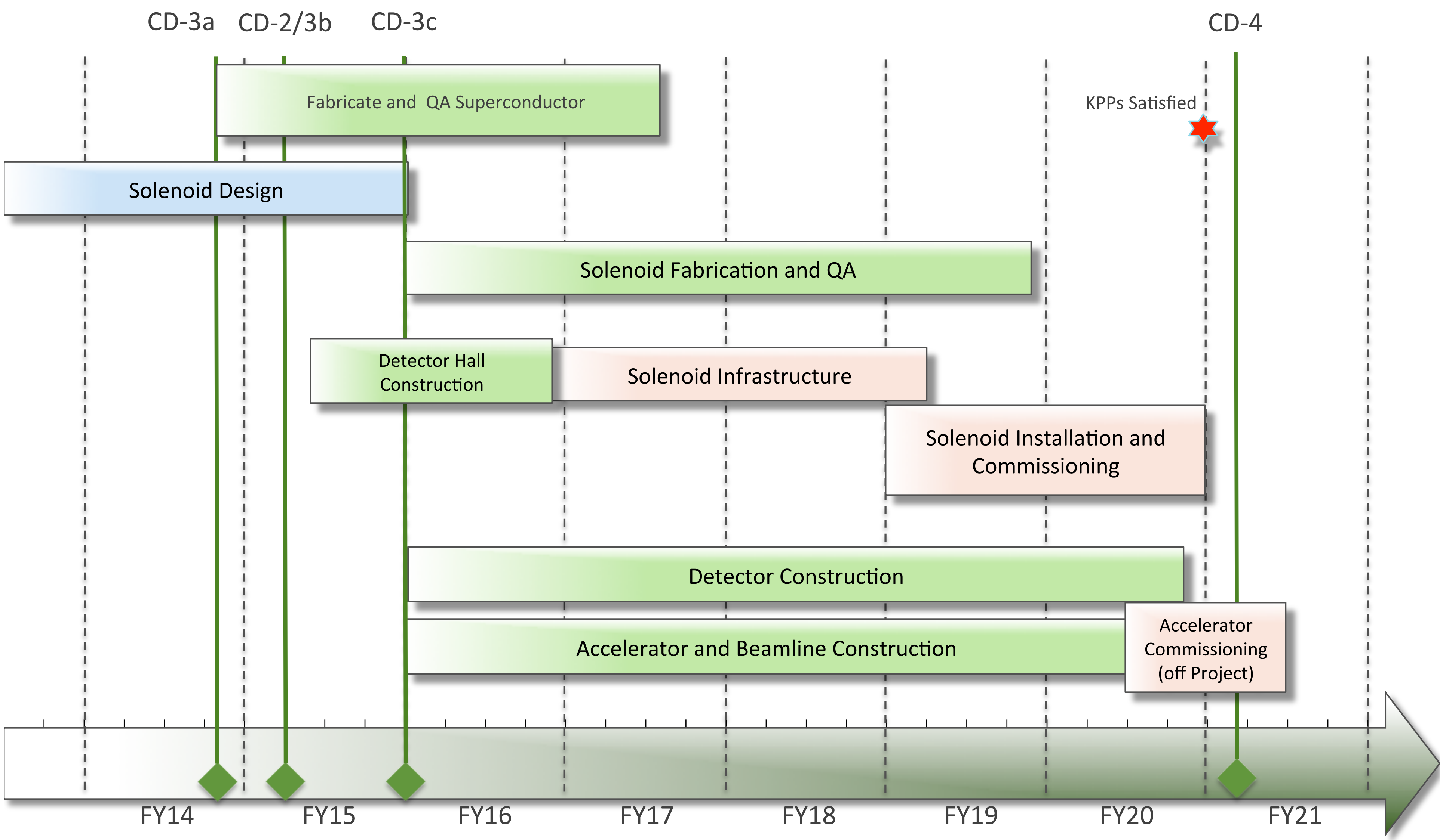


Degree of Project Definition

- 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%

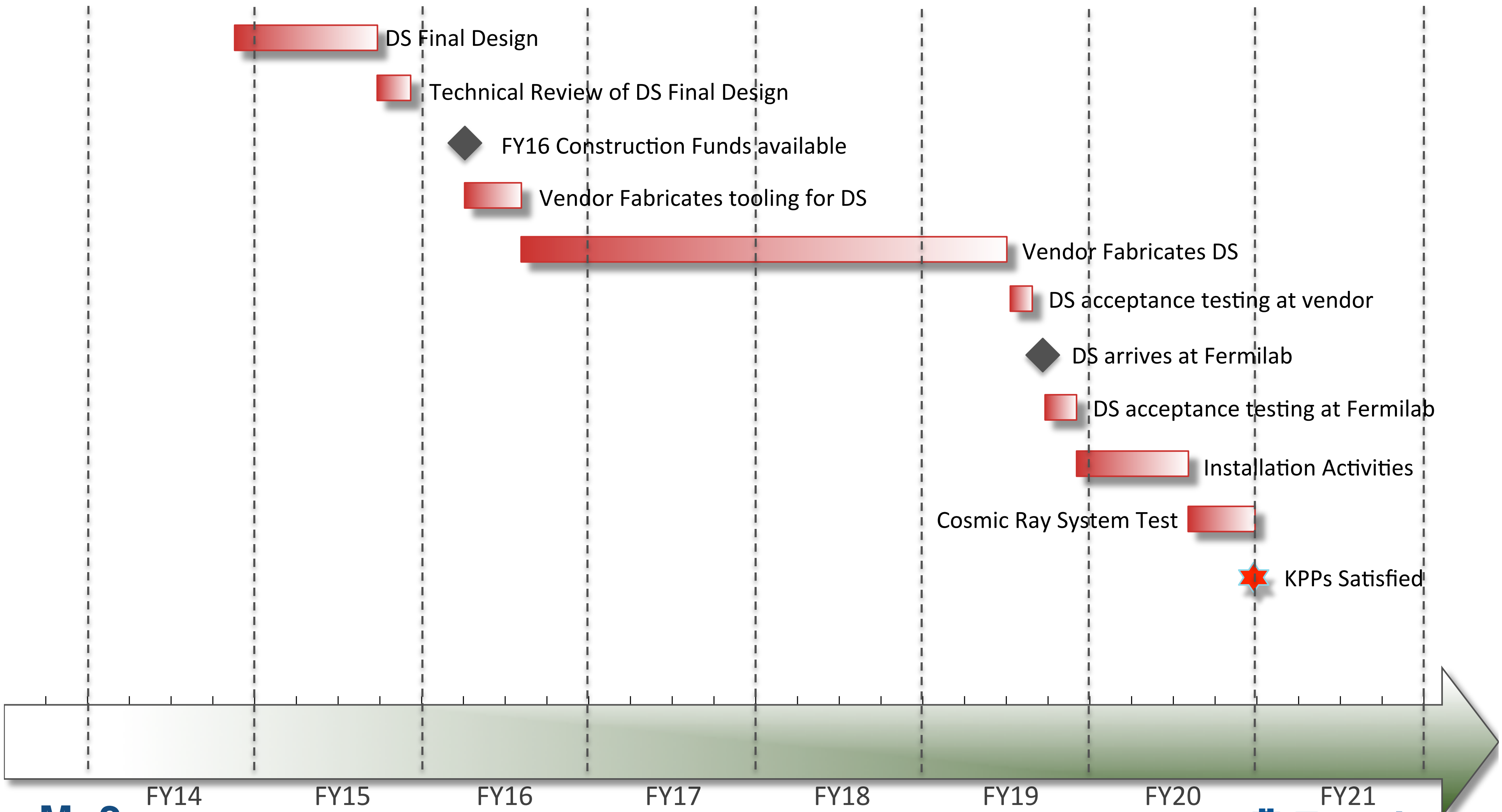
Schedule



CD-3a
CD-2/3b
CD-3c
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



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.