Fermilab

Mu2e CD-2 Review: WBS 5.7 DS Internal Shielding

Henry Glass
L3 Manager, WBS 475.05.07
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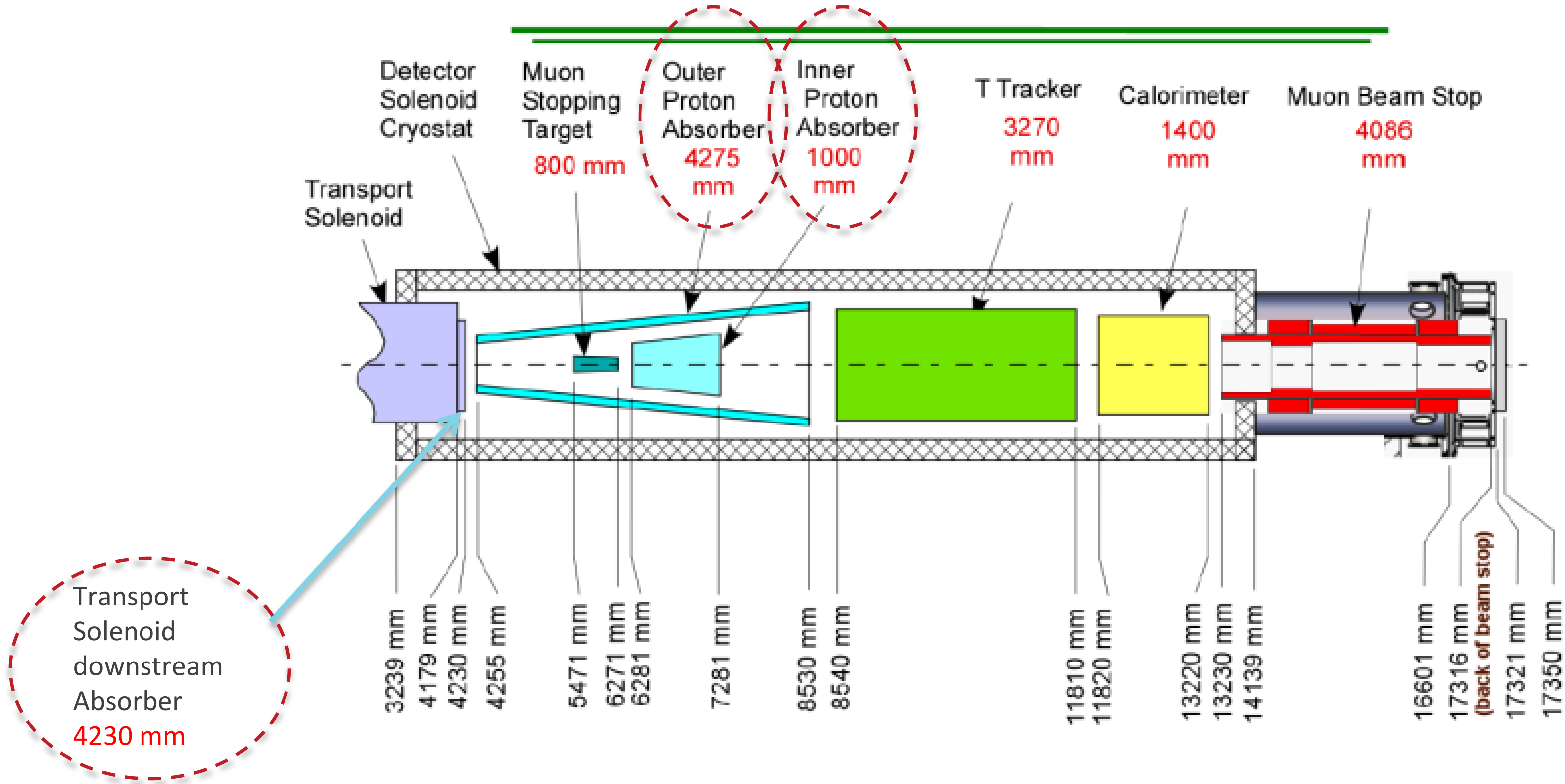
Requirements

- Four physics requirements:
  1. Reduce the background rates at the tracker sufficiently for reliable reconstruction of electron tracks.
  2. Minimize the energy loss and multiple scattering of electrons within the acceptance of the tracker including those that pass through the inner proton absorber and its supports.
  3. Minimize muons stopping on the proton absorber.
  4. Minimize contributions to the background rates in the calorimeter.
- Requirements satisfied by three passive shielding components that absorb protons and neutrons; designs shown in following slides

Design

- Three components of DS Internal Shielding

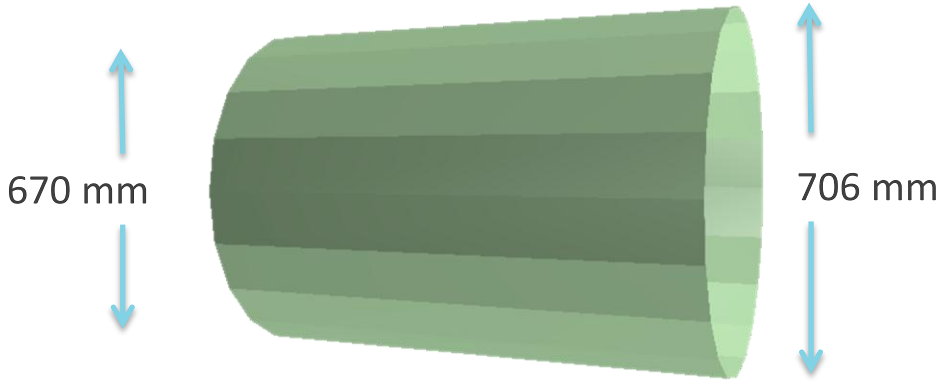


TSdA Design

- Transport Solenoid downstream absorber (TSdA):
  - Disk shaped, center hole allows muon beam to pass through
  - 50 mm thickness
  - Nominal material: borated polyethylene
  - Reduces hit rate in tracker by ~30% (simulation)
  - No significant technical issues

IPA Design

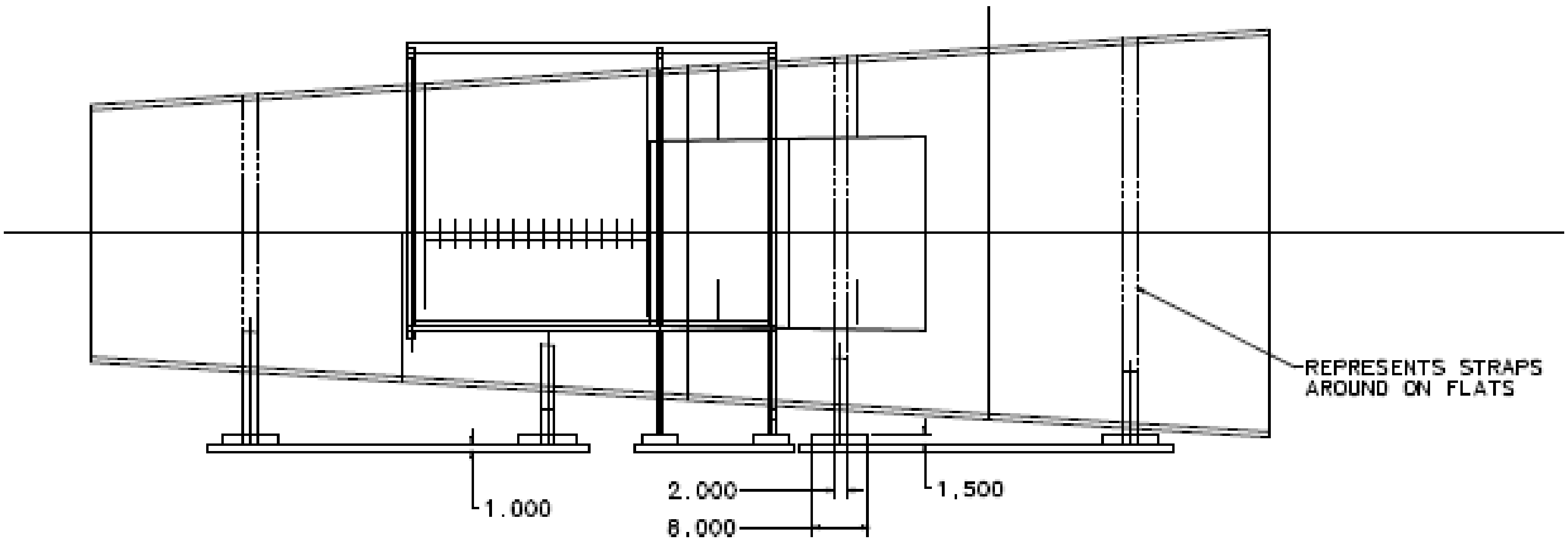
- Inner Proton Absorber (IPA):
  - Conical frustum, 0.5 mm thickness, 1.0 m length
    - Sufficiently thin to minimize scattering and energy loss of conversion electrons
    - No stopping muons
  - Low-Z materials required
  - Mechanical stability requirements best met using carbon fiber
  - Support and align using 6.0 μm tungsten wires; support from OPA wall
  - Plan to build and monitor a prototype to refine design



OPA Design

- Outer Proton Absorber (OPA)
  - Also conical frustum, 20 mm thickness, ~4.3 m length, ~300 kg
  - Outside muon beam and CE trajectories
  - Nominal material is 5% borated polyethylene
  - Made in two longitudinal sections to allow access to and support of the stopping target
  - Slots cut into OPA will allow for tungsten support wires to be strung between stopping target and support frame
  - OPA supported by stainless steel cradles

Proton Absorber / Stopping Target Assembly

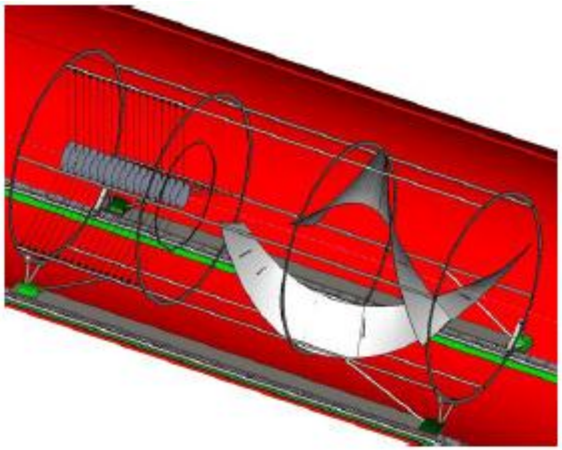


Improvements since CD-1

- IPA length reduced by 50%
- OPA is new item;
- TSdA is also new, for neutron absorption

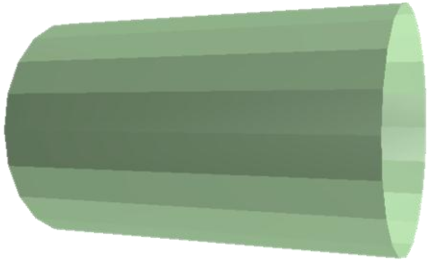
Downselects

- IPA geometry: conical frustum selected over blade design



Blade – not selected – does not work with cosmic muon calibration scheme

Conical 1.0 m length selected (vs 2.0 m length)

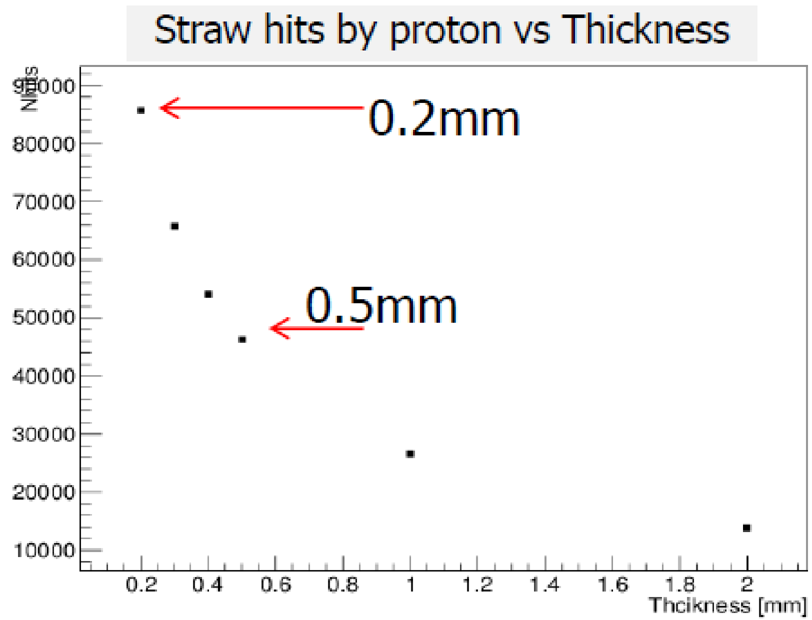


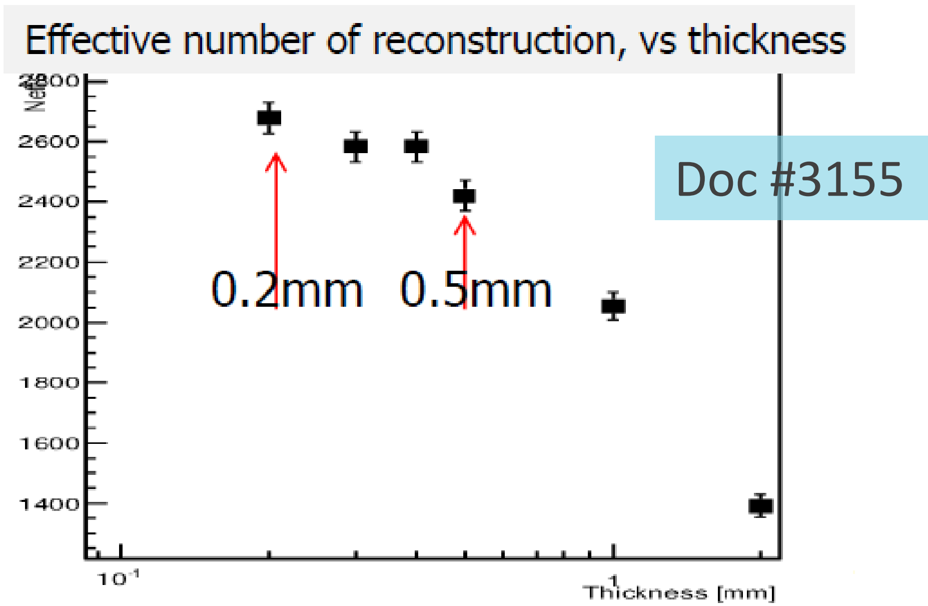
Performance

- Geometries of OPA and IPA are being optimized by simulation (M.J. Lee, LBNL: preliminary simulation details in docDB #3155 – choice of radius, thickness, slope…)
- TSdA
  - reduces neutron contribution to tracker hit rate by ~30% (D. Brown, DocDB #3479),
  - reduces neutron contribution to hit rate on disk 1 of calorimeter by ~15% (B. Echenard DocDB #3498)

Performance improvements via simulation

Example: IPA thickness optimization
- left plot: tracker proton hits vs thickness
- right plot: reconstructed CE's vs thickness





Integration and Interfaces

- External interfaces to Solenoids, Tracker, Calorimeter
- DS internal shielding has internal interfaces to stopping target, Detector support structure, downstream vacuum
- Integration and interfaces addressed via
  - WBS Dictionary and interface documents
  - Muon beamline meetings
  - Detector simulation meetings
  - Formal signoff between responsible parties for external interfaces

Remaining work prior to fabrication

- Complete simulations and studies to optimize proton absorber design
  - Verify material choices
  - Validate negligible impact of slots in OPA
  - Complete design / implement support structure
- Build IPA prototype
- Optimize fabrication technique for OPA

Quality Assurance

- Quality Assurance relies upon the following tools :
  - Fermilab Quality Assurance Manual
  - Fermilab Engineering Manual
  - Mu2e Quality Assurance Program
  - Documented engineering calculations and drawings
    - reviewed, approved and released
  - Verification of physics simulations
  - Prototypes will be tested for many months to verify long-term viability
  - Components received from vendors will be inspected for conformance to specifications
    - Dimensions of each internal shielding component will be verified

Risks

- IPA: material does not maintain its desired shape.
  - Solution: investigate use of support ribs

- OPA: Cost for Vendor to form borated polyethylene into required shape may be high.
  - Considering alternative materials: simulations using standard lower-cost HDPE are being run now
  - Conduct in-house tests on forming borated polyethylene

ES&H

- To perform muon beamline activities safely will require appropriate planning (JHA), attention to ES&H considerations and FESHM and FRCM requirements
  - Accessing confined space FESHM 5063
  - Crane, hoist, and forklift use FESHM 5021
  - Fall Hazards FESHM 5066
  - Magnetic fields FESHM 5062.2
  - Electrical hazards FESHM 5042
  - Radiation hazards FRCM
    - Activation by beam
  - And possibly ODH
    - FESHM 5064

Cost Table

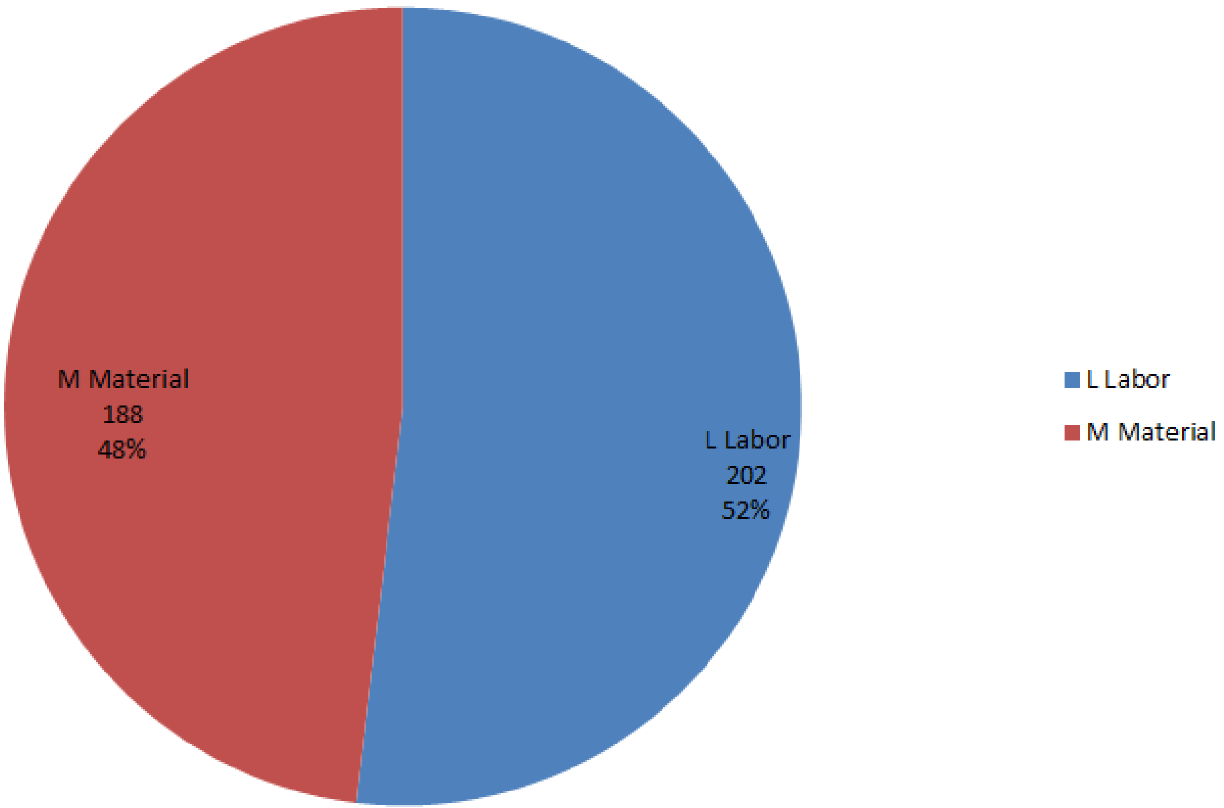
WBS 5.7 Detector Solenoid Internal Shielding

Costs are fully burdened in AY k$

	Base Cost (AY K$)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining budget)	% Contingency (on remaining budget)	Total Cost
475.05 Muon Beamline						
475.05.07 Detector Solenoid Internal Shielding						
475.05.07 Detector Solenoid Internal Shielding	188	202	390	119	35%	509
Grand Total	188	202	390	119	35%	509

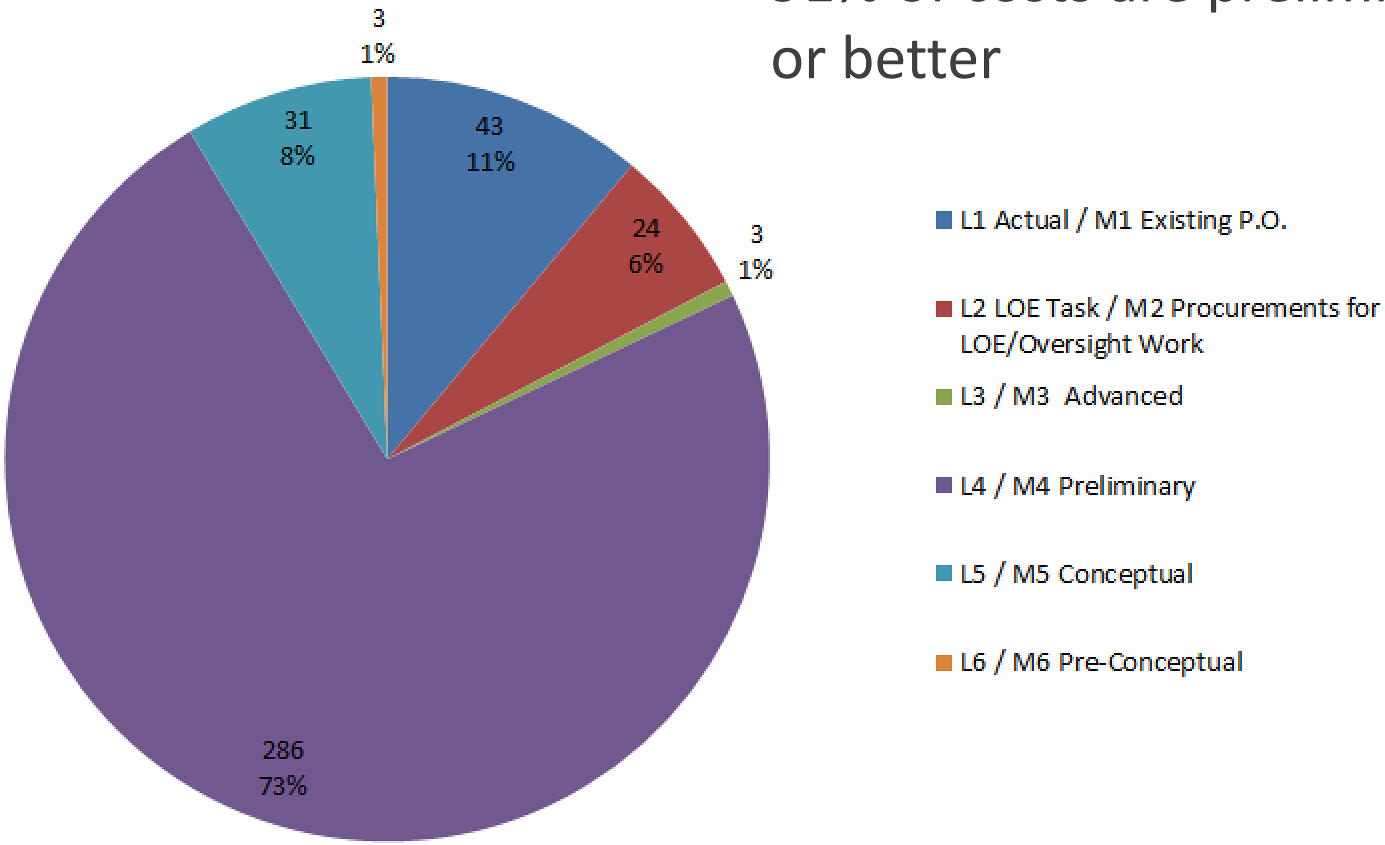
475.05.07 Detector Solenoid Internal shielding

- Distribution by resource type (Labor / Material)   AY k$

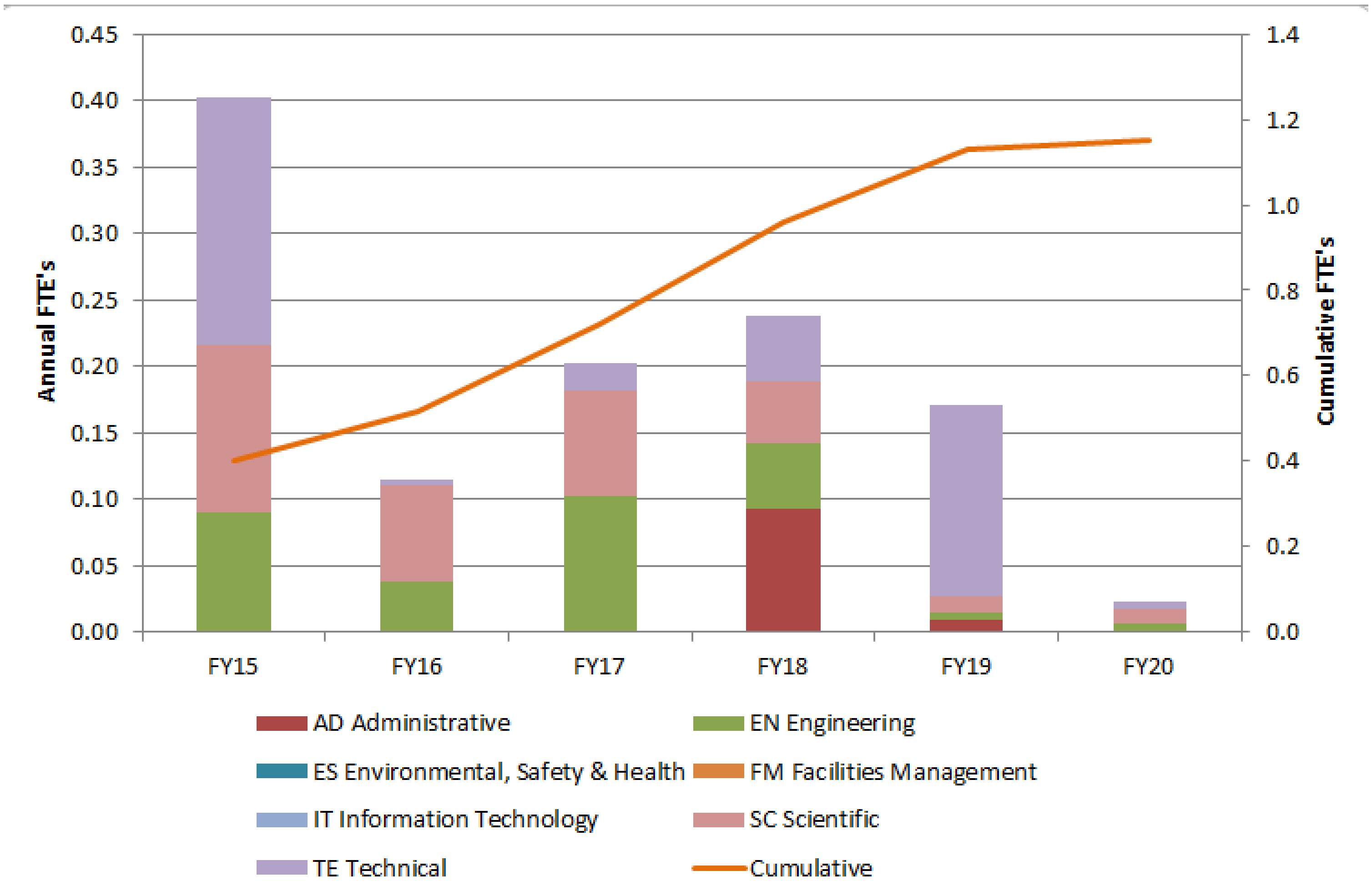


Quality of Estimate (AY k$)

91% of costs are preliminary or better



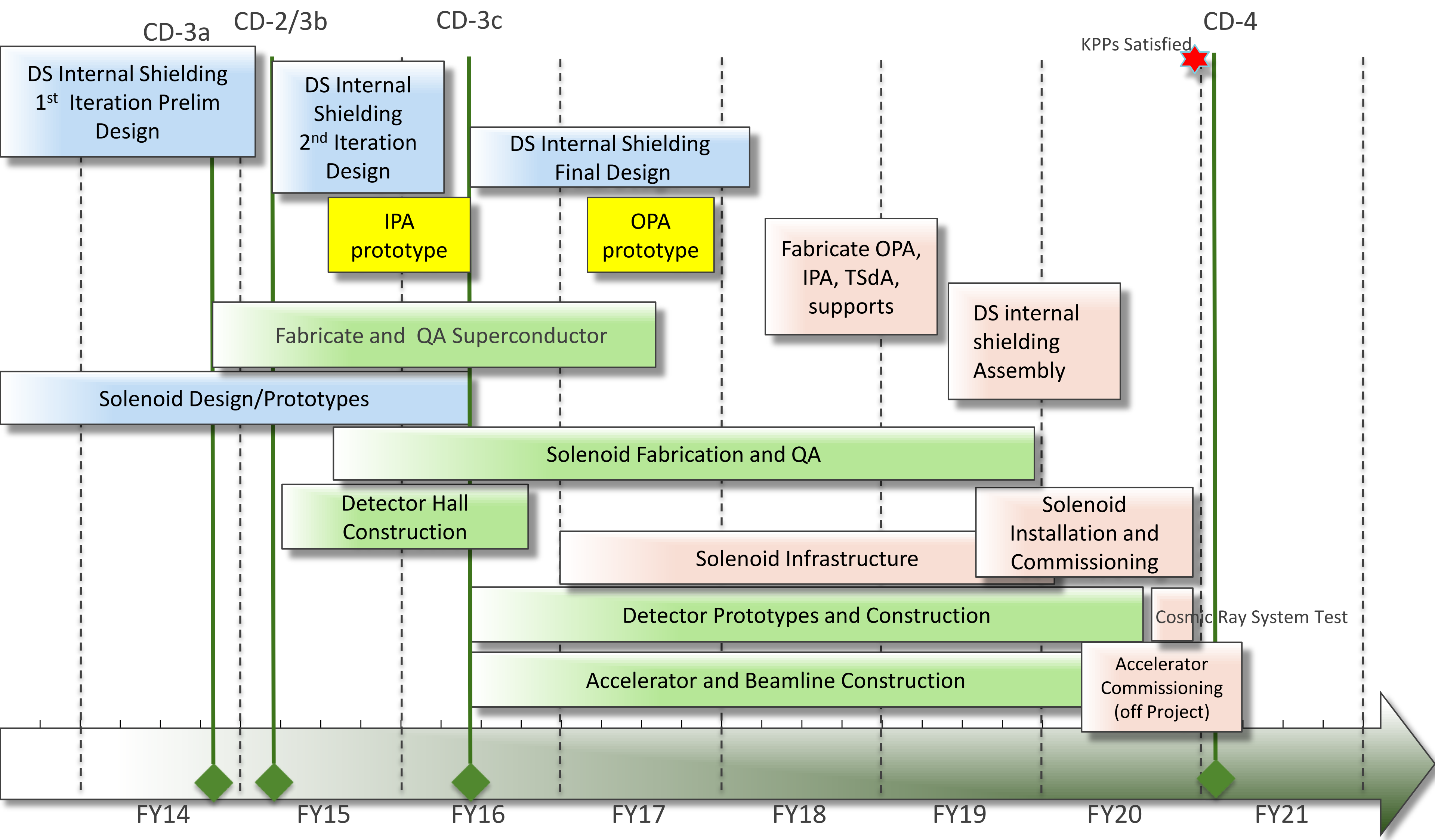
FTEs by Discipline



Major Milestones – DS Internal Shielding

- T5 – 2nd Iteration Design Complete – 11/23/15
- T5 – Ready for CD-3 Review – 12/9/15
- T5 – CD-3 Approval – 2/23/16
- T5 – Ready for fabrication – 1/26/18
- T5 – Proton Absorber components inspected at FNAL – 11/9/18
  - T4: 1/9/19*
  - T3: 2/11/19*
  - T2: 5/9/19*
- T5 – Ready for CD-4 – 11/21/19

Schedule, DS internal shielding



Summary

- Proton absorbers reduce rate of protons reaching tracker, fully satisfying requirements
- Solution is three independent passive absorbers (OPA, IPA, TSdA); TSdA additionally absorbs neutrons, thus reducing backgrounds for both tracker and calorimeter
- Interfaces identified
- Resource needs understood
- Ready for CD-2

Backup…

L3 Manager's Previous Experience

- Stony Brook research assistant, Fermilab Expt 605, 1980-85: detector system development, PhD 1985.
- The Aerospace Corporation, 1985-89: Manager, Advanced Applications, Image Exploitation Dept. Managed staff in image processing tasks.
- Fermilab, 1990-present. Currently Applied Scientist II
  - Main Injector, 1990-97: responsible for magnetic field measurements. Test program supervisor; measurement probe design
  - Manager of permanent magnet measurements, Recycler, 1996-99.
  - Deputy Dept. Head, Magnet Test Facility, 1991-2005. Explained to various bosses how to use Excel. Also supervised scientists in magnetic measurements group.
  - Pierre Auger Observatory, 1999-2013. Project Office jack-of-all-trades: Cost & Schedule Officer; web master; supervisor of summer students / teachers…
  - Fermilab Holometer, 2010-present. Optical simulations; laser safety.
  - Mu2e, 2012-present. Configuration Manager / change control. L3 Manager, Muon Beamline / DS internal shielding.

Labor Resources by FY (AY k$)