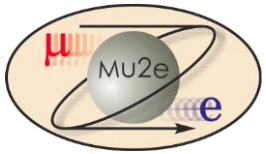
Fermilab

WBS 475.04.08 Field Mapping System



Michael Tartaglia

L3 for Magnetic Field Mapping

DOE CD-2 Review

October 21-24, 2014

Solenoid Team

- Mike Tartaglia – L3 Manager for Field Mapping System
  - 18 years in TD magnet test operations, magnetic measurement and analysis
  - TD Test & Instrumentation Department Head since May 1, 2014
- Team
  - Marc Buehler, Associate Scientist in Magnet Systems Dept.
    - And students
  - Mau Lopes, Associate Scientist in Magnet Systems Dept.
    - And students
  - Charles Orozco, Co-op Mechanical Engineer
  - Konstantinos Vellidis, Guest Engineer

Requirements

- Field Mapping System Requirements – Docdb#1275
- In Summary:
  - Verify that the solenoid system meets all magnetic field requirements (Docdb #1266)
  - Monitor fields in critical regions of the muon beamline during solenoid operation
  - Obtain precision field maps of the DS spectrometer and calorimeter regions at nominal & calibration operating currents

Requirements

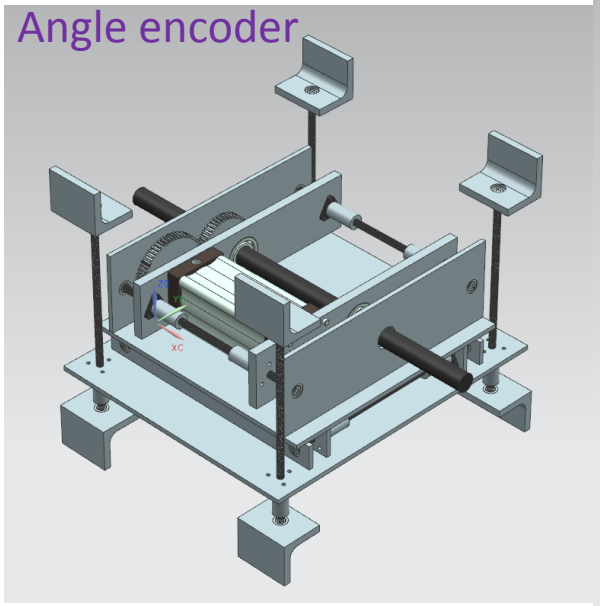
- In Greater Detail:
  - Map {Bx,By,Bz} along DS bore (0<R<70cm)
    - DS-only during commissioning – QA check of DS magnetic field
    - Final magnetic configuration; DS at reduced currents (calibration settings)
    - Most demanding – precise tracker region requires dB/B~10^{-4}
  - Map {Bz,Br} and {dBz/dz} in PS along HRS bore (limited to R<17cm)
    - PS-only during commissioning – QA check of PS magnetic field, HRS permeability
    - Final magnetic configuration (all solenoids powered)
  - Map {Bz} into PS/TS1 and DS/TS5 collimators (limited to R<15cm)
    - Final magnetic configuration; TS adjustments and trim power supply settings
  - Monitor {B} in DS spectrometer region during Mu2e operation
  - Monitor {Bz} and {dBz/dz} along TS1, TS3u, TS3d, TS5 collimators (R~15cm)
    - Measure straight section continuous negative gradients, final magnetic configuration
  - Perform Electron Source Test (off project)
    - Map electron transport through TS, final magnetic configuration

Design

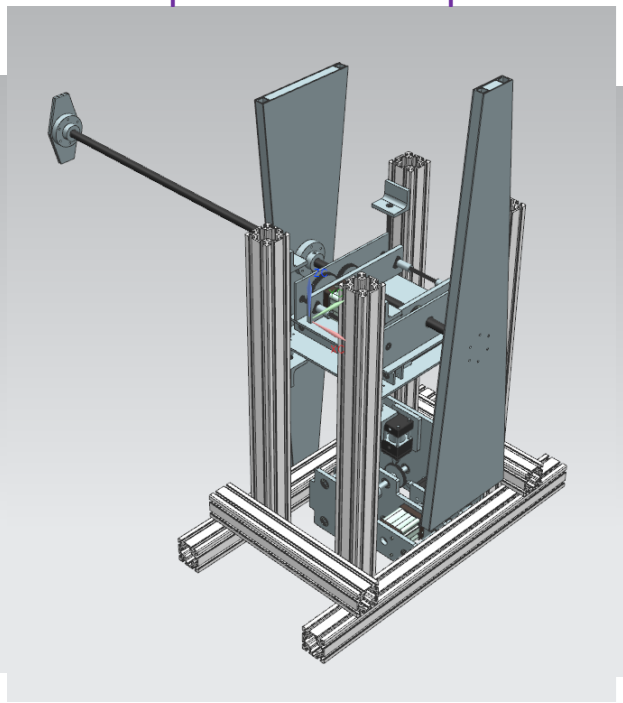
- DS Field Mapper
  - Probe positioning mechanism, similar to CMS solenoid mapper
  - Axial motion along precise DS detector support rails
  - Modern calibrated 3D Hall probes at fixed $\{R_i\}$ on rotating “propellers”
    - Shaft extension to map into TS5 collimator

θ drive: 270° continuous air motor, geared 360° motion

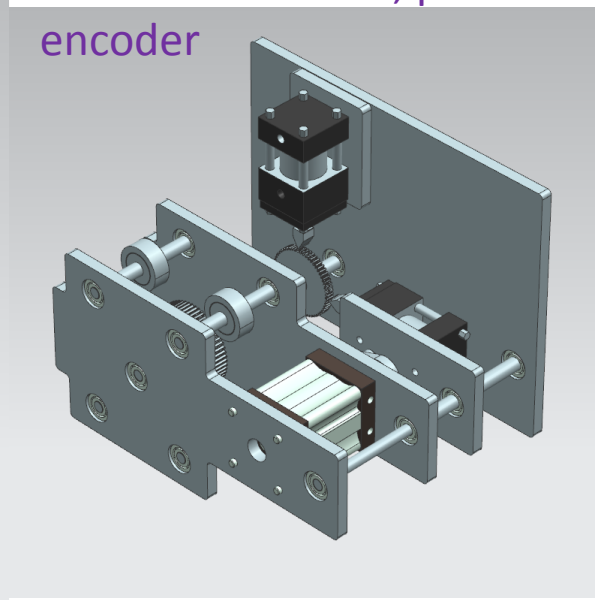
Angle encoder



Fixed position NMR probes



Z drive: stepper air motor, piezo control valves toothed drive belt, position encoder



Design

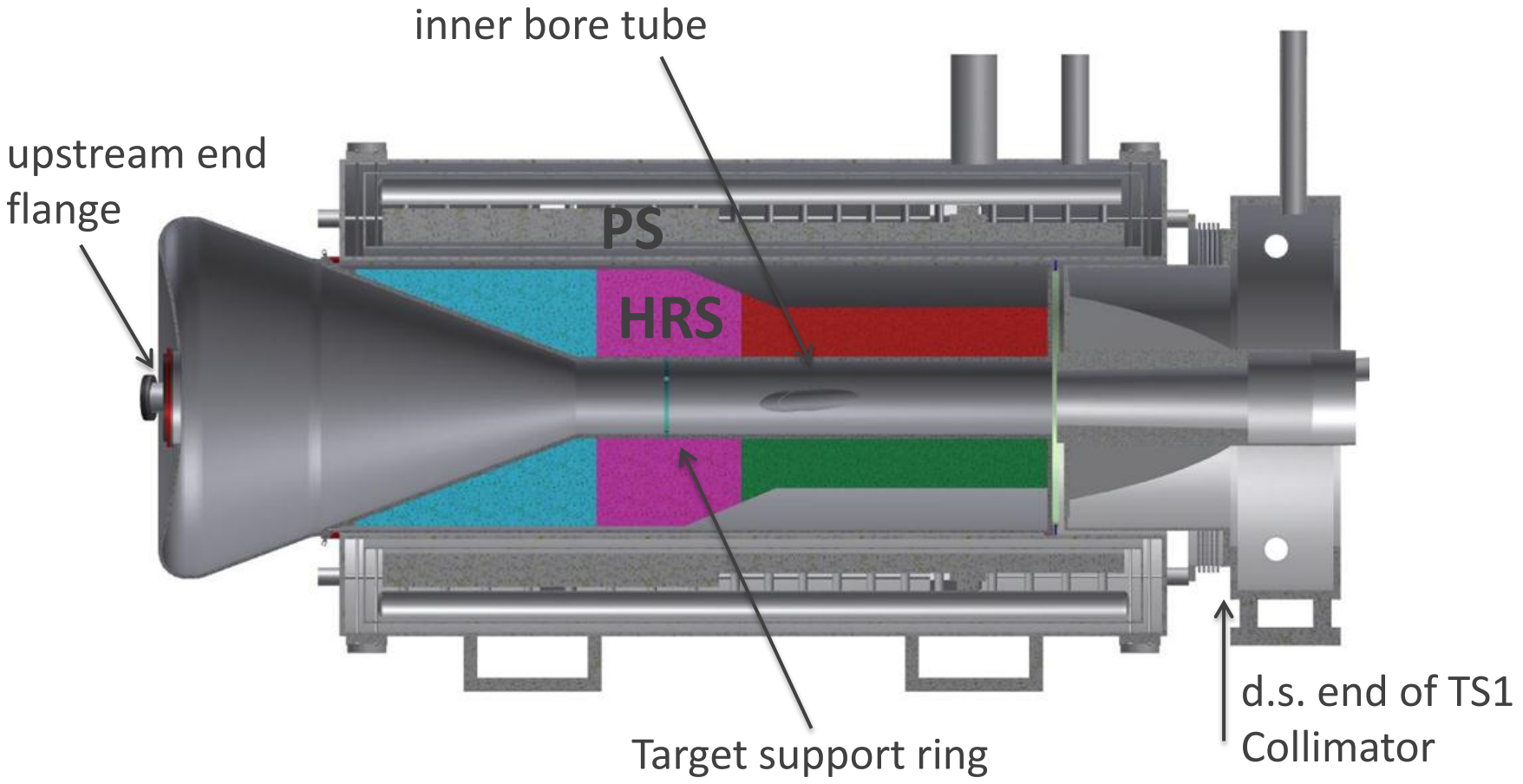
- DS Field Mapper Status
  - 3D model, bill of materials ~complete
  - Developing preliminary drawings
- Field Mapper DAQ and Controls
  - New FNAL/TD Magnet Measurement System
    - Configurable, Extensible, Modern Software Architecture
    - Software framework & component developments are advanced
    - Utilize mostly commercial off-the-shelf components
      - PXIe, NI, Labview; Metrolab NMR
    - Hall and NMR prototype (calibration) system testing started
  - Detailed instrumentation design will begin soon
    - Readiness for CD-3

Design

- PS Field Mapper
  - Hall probes to measure field strength and axial gradient
    - Will be calibrated in Tevatron Dipole to 5 T
  - Probe positioning mechanism still very preliminary
    - Following evolution of PS bore (HRS=heat & radiation shield)
    - Utilize linear guide supported by HRS bore and upstream flange
    - Cantilevered section downstream of target support ring
      - Extends map into TS1 collimator
    - External Z-drive system & encoder
    - Azimuthal positioning with non-magnetic rotary piezo stage
  - Detailed mechanical design to begin soon
  - Same Control & Instrumentation as DS
    - Tailored interface boxes and separate cabling

Design

- PS Field Mapper
  - PS with Heat & Radiation Shield

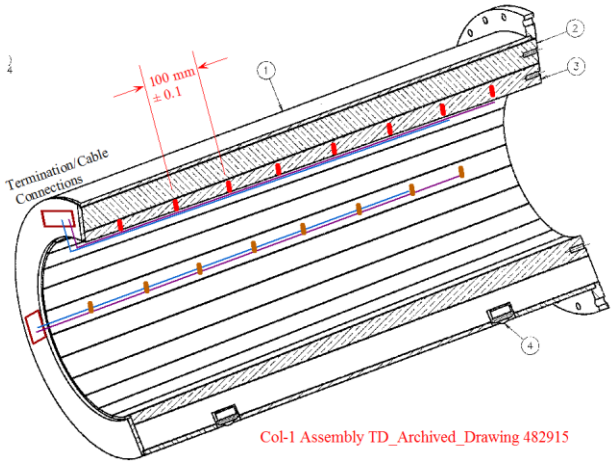


Design

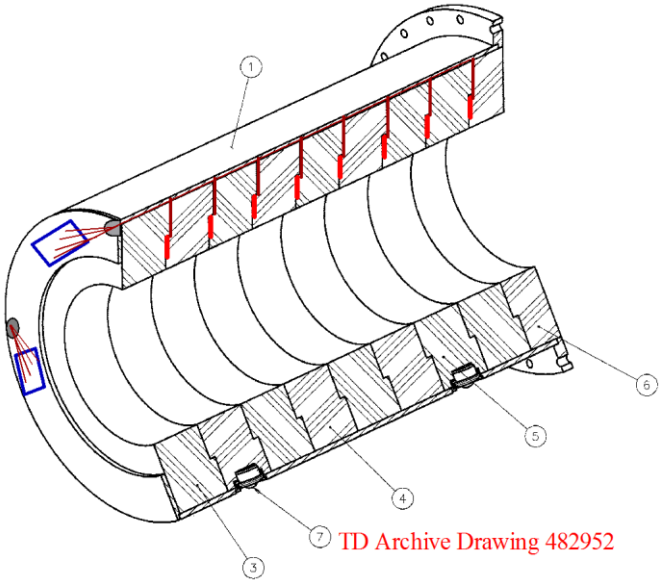
- In-Situ Sensors
  - NMR probes in DS spectrometer region
    - Mounted to inner bore (fixed positions to detect field changes)
      - In place during field mapping
    - Mounted to tracker frame ends (distinguish position changes)
      - Re-use probes from DS field mapper
    - Same electronics used during DS field mapping
  - Hall probes in TS Collimators [Now part of “TS Instrumentation”]
    - This is the only viable approach to check TS3 straight regions
    - Expect to map TS1 & TS5; these sensors monitor changes over time
    - 1D Hall probes (& RTDs) embedded in collimators (3 designs)
      - after epoxy-impregnated construction in precisely spaced pre-machined slots
    - Read out by multiplexed instrumentation system (all magnet sensors)
      - Working on wiring and signal feed-through design details

Design

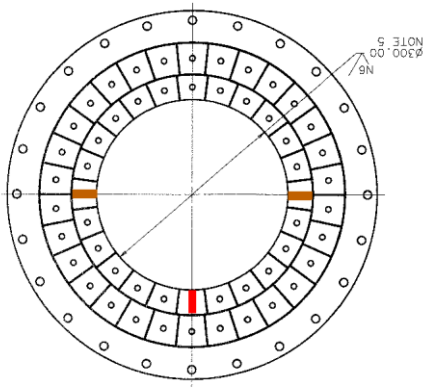
- TS Collimator In-Situ Sensors

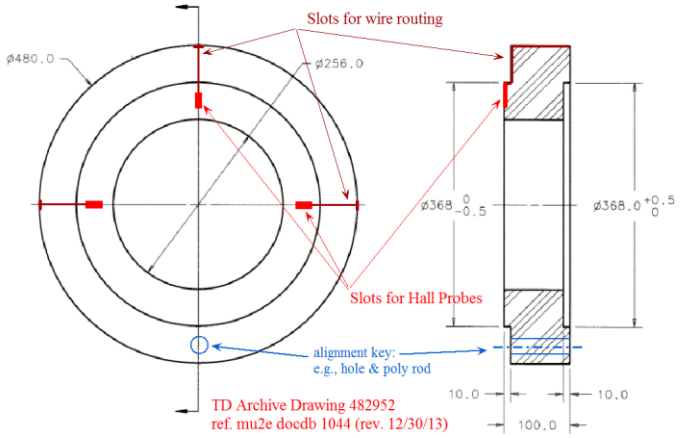


TS1 Collimator



TS5 Collimator





Design

- Electron Transport Test
  - Off project; design & cost studied under Field Mapping WBS
  - Validate transport from primary target region through TS1,3,5 collimators to stopping target in “final magnetic configuration”
    - Position source near primary target position
      - Few-MeV Beta or Electron Conversion Source
      - Re-use PS field mapping device to move the source
      - Need components to allow rough evacuation of Muon Beamline
    - Detect electrons at downstream positions
      - Thin Scintillator tiles with on-board SiPM detectors (& electronics?)
      - Study detected position versus start position
        - Simulation in progress to define detector segmentation
      - Step 1: Detect at TS3 pbar-window gap (test TSu transmission)
      - Step 2: remove TS3 detector, detect at DS stopping target
    - Detailed studies and simulations in progress

Changes since CD-1

- Production Solenoid/TS1 Collimator
  - No longer mapping the PS full aperture
    - Heat & Radiation Shield will now be an integral part of PS
    - Field mapping only in limited aperture of the HRS bore
    - Target support ring ~17 cm radius
  - Bkgd Simulations → new pbar window requirement
    - upstream of TS1 Col ⟶ could impact TS1 mapping
    - Looking at timing and method of this material installation
    - Electron Source Test could also be affected
- In-Situ Hall Probes
  - Collimator instrumentation is TS responsibility

Value Engineering since CD-1

- Control and DAQ Readout Same Controls and DAQ Readout System will be utilized for both DS and PS (map one at a time; tailored interface boxes and software configurations)
- PS field map Hall Probe positioning device will also be used to position the Electron Source in the e-SourceTest
- In-Situ Hall probe readout system will be common with all other magnet sensors
- Same NMR probes and instrumentation will be used both for mapping and in-situ monitoring of DS field

Downselects

- Electron Source Test at CD-1 considered using low energy electron gun array, vs radioactive source on positioning stage
  - Few MeV Beta or Conversion source has several advantages

Remaining work before CD-3

- Complete preliminary designs
- Complete preliminary design drawings
- Complete final designs
- Complete final design drawings

Quality Assurance

- All mechanical components & materials will be inspected, and tested for magnetic properties (proximity to NMR in calibration magnet) for conformance with specifications
- All Hall probes & electronics will be calibrated to the required level over the specified operating range; probe tilt angles and sensitivity to temperature variations will be measured
- Multiple probes provide redundancy for cross-checks; NMR probes provide absolute field at reference points
- Metrology will be used to determine the precise probe positions: for internal alignment, adjustment, and motion
- Entire system will be assembled, bench- and field- tested well in advance of solenoid cryogenic and powered operations
- Data analysis tools will be developed and ready to allow rapid evaluation of data quality during the field mapping operations

Risks

- No major risks have been identified with field mapping

ES&H

- ES&H issues associated with Field Mapping System and Operation:
  - DS confined space: access to DS bore is required for installation and removal of Field Mapper Z-drive belt
  - During cryogenic operations: ODH conditions may apply within regions of the Mu2e Hall
  - During magnet powered operations: high magnetic field hazard will apply within some regions of the Mu2e Hall
  - Electron Source Test: training in proper handling and storage of radioactive source (beta or electron conversion) will be needed

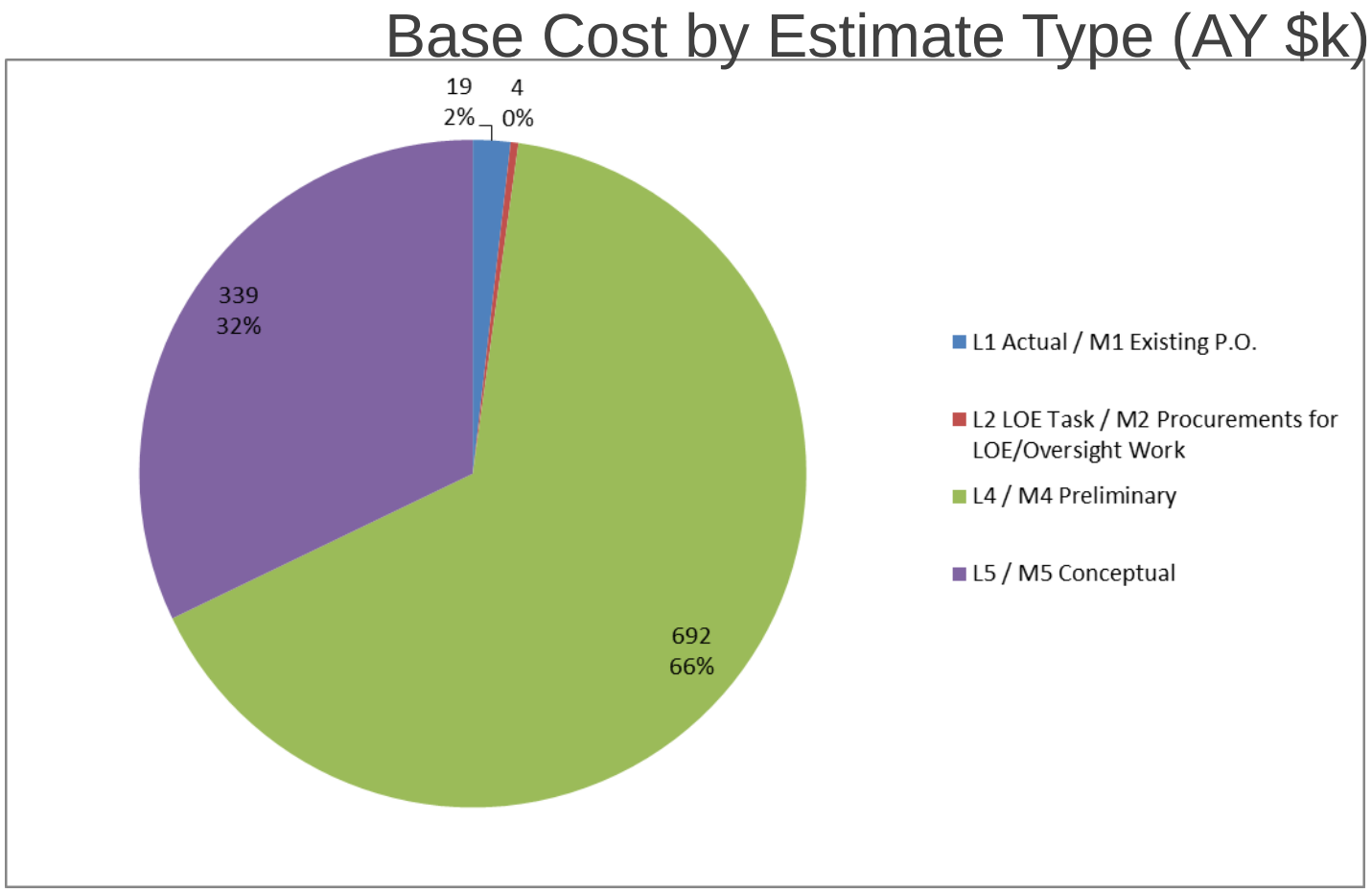
Major Milestones

- 475.04.08 Field Mapping System
  - 001170 Final Design of Magnetic Field Mapping System Complete
  - 001310 Vendor for magnetic field mapping system purchased parts selected
  - 001360 PO issued for magnetic field mapping system purchased parts

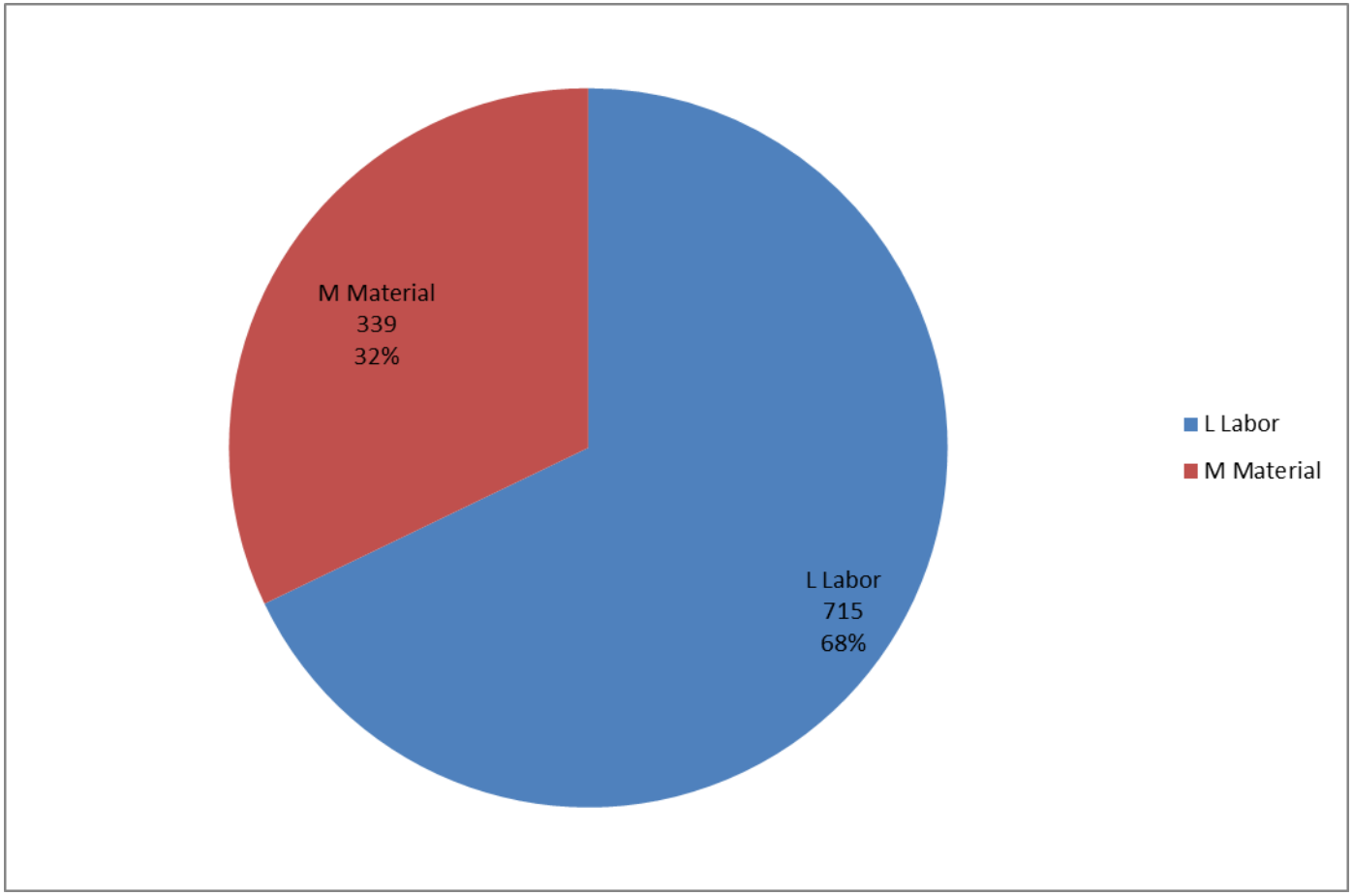
Cost Table

	Base Cost (AY K$)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining costs)	% Contingency on ETC	Total Cost
475.04.08 Magnetic Field Mapping System						
475.04.08 Magnetic Field Mapping System	339	715	1,053	448	43%	1,501
Grand Total	339	715	1,053	448	43%	1,501

Quality of Estimate

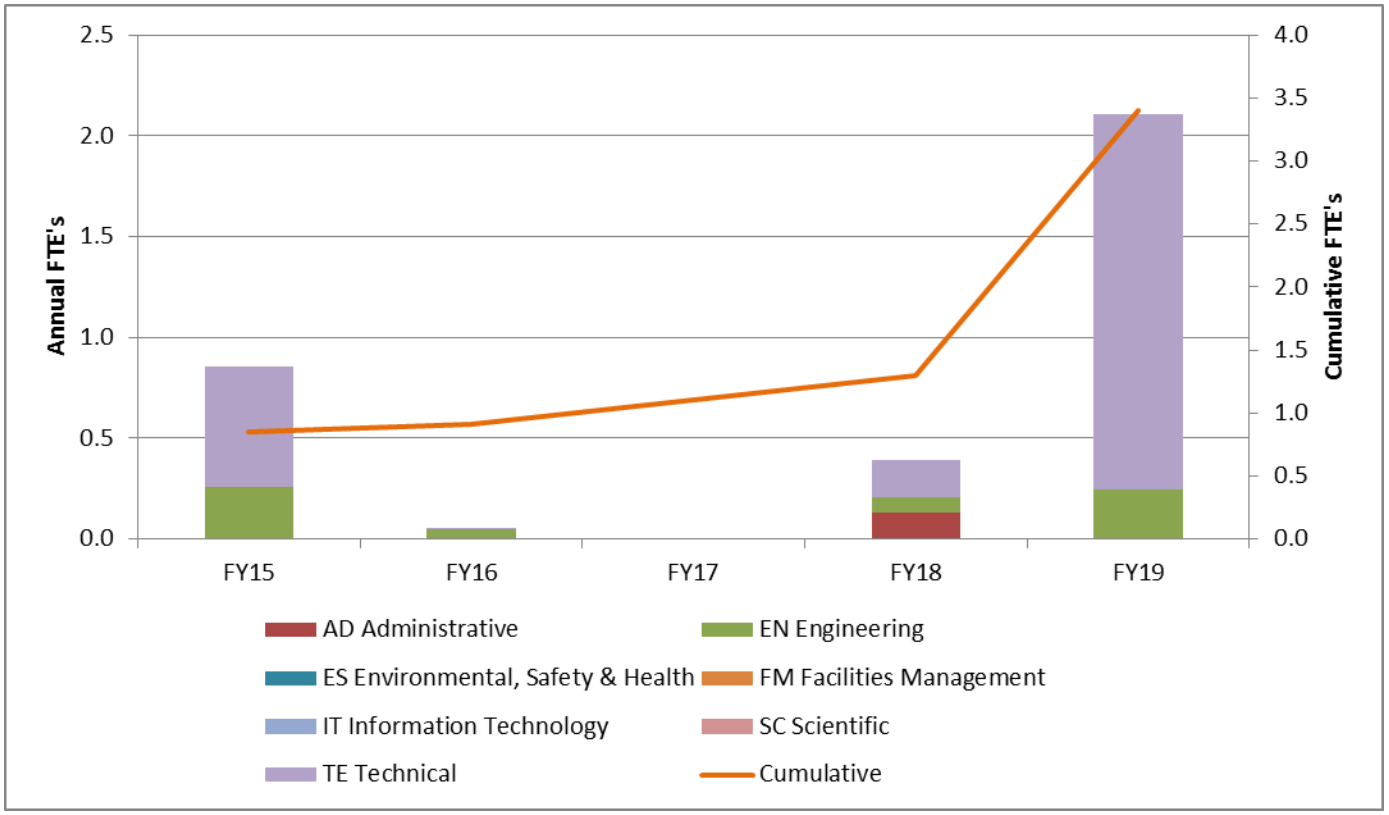


Resource Type

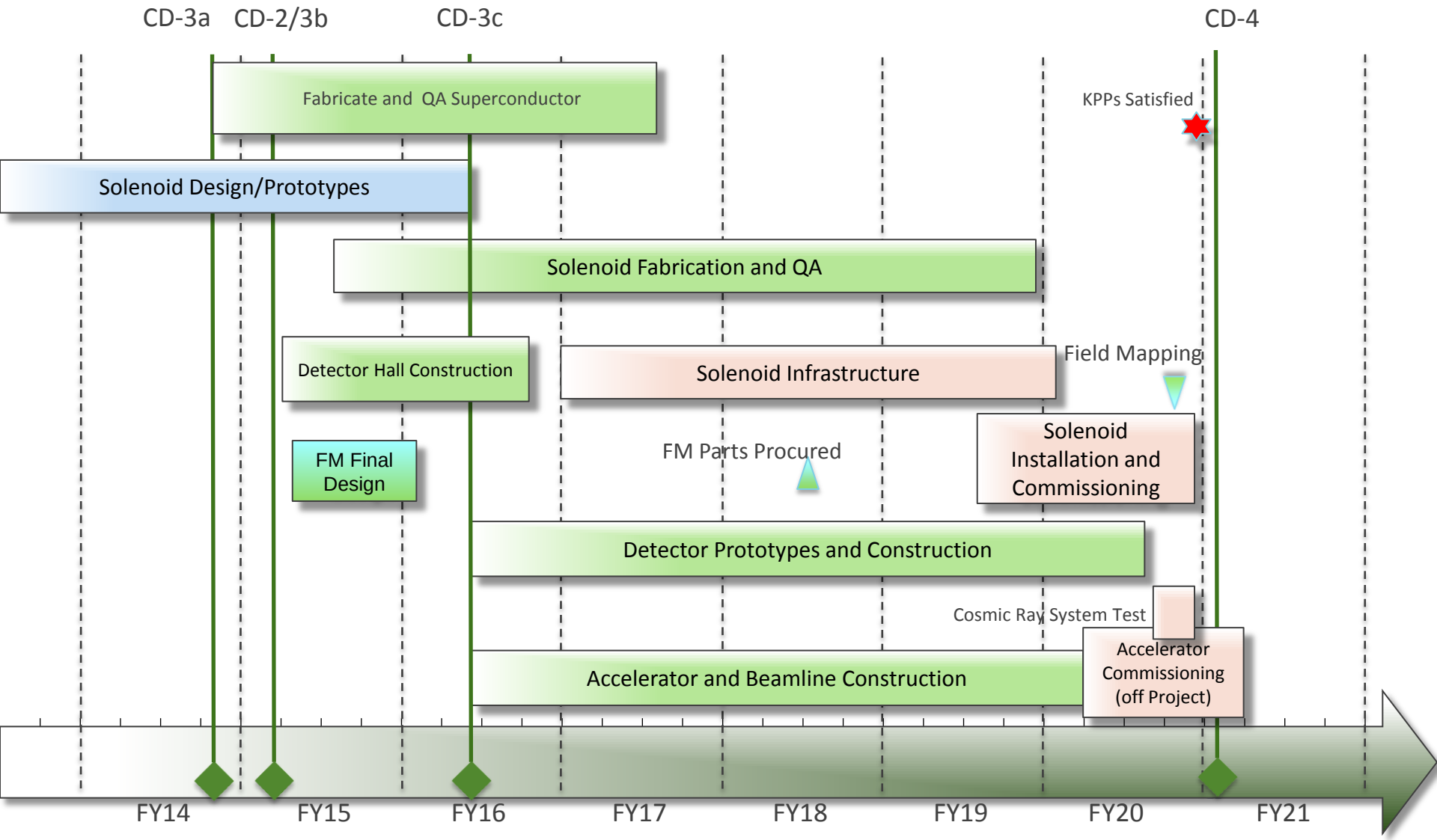


Labor Resources by FY

FTEs by Discipline



Schedule


CD-3a
CD-2/3b
CD-3c
CD-4
Fabricate and QA Superconductor
KPPs Satisfied
Solenoid Design/Prototypes
Solenoid Fabrication and QA
Detector Hall Construction
Solenoid Infrastructure
Field Mapping
FM Final Design
FM Parts Procured
Solenoid Installation and Commissioning
Detector Prototypes and Construction
Cosmic Ray System Test
Accelerator Commissioning (off Project)
Accelerator and Beamline Construction
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Summary

- Field Mapping System preliminary design is in progress
  - Mapping is not on the critical path
    - In-situ sensors needed at end of TS construction
    - Other Mapping activities happen during Solenoid commissioning
  - DS is the most important, is the most advanced
    - Next focus on the daq & controls
  - PS Mapper
    - mechanical design following DS mechanical completion
- Field Mapping System is ready for CD2