Fermilab

Mu2e WBS 5.3 Collimators
DOE CD-2/3b Review

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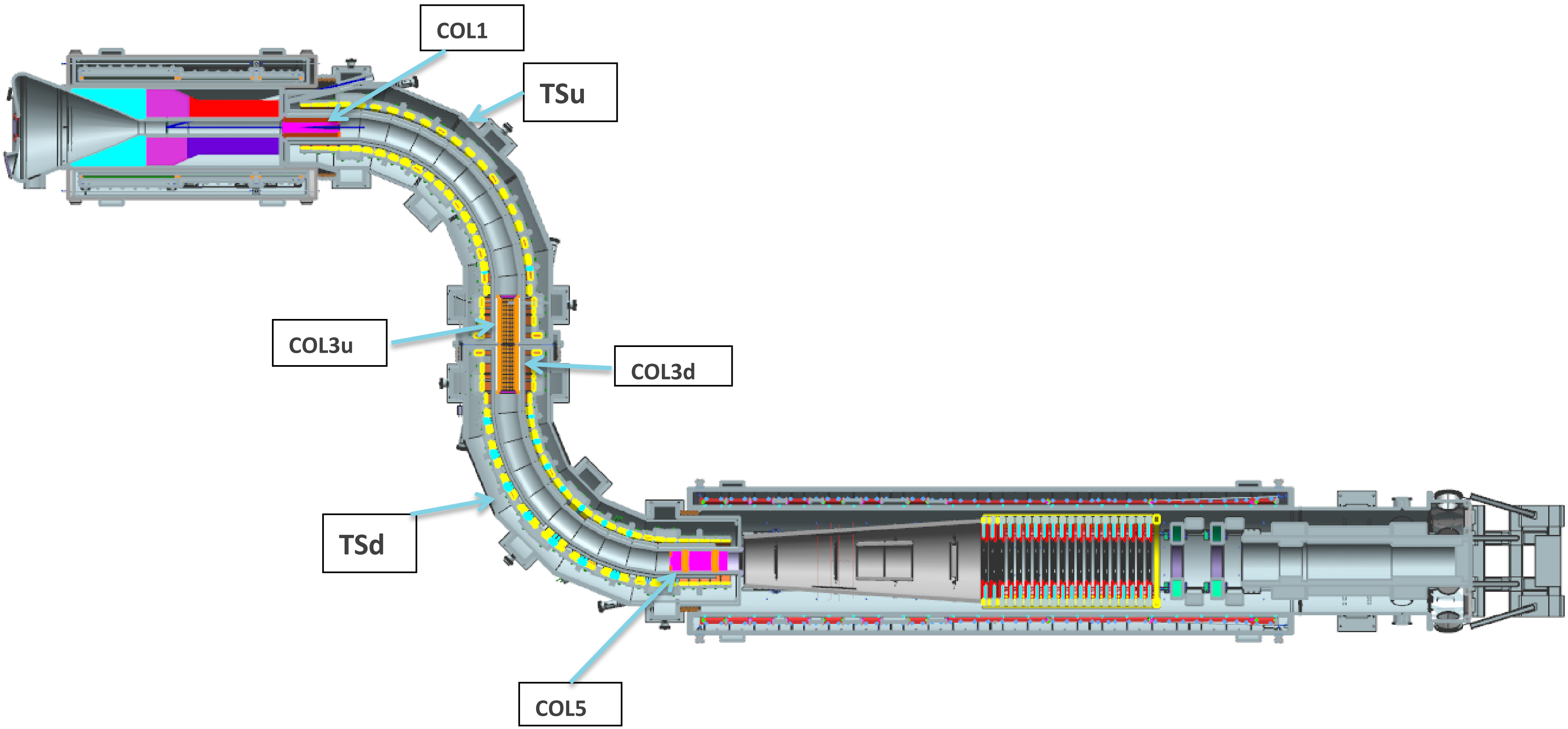
10/21/2014

Requirements

- The muon beamline collimators filter the beam as it passes through the Transport Solenoids (TSu and TSd), selecting muons of the desired charge and momentum range to optimize the probability of their capture in the muon stopping target



Requirements

- Muon's selection is achieved by a vertical offset of the aperture in the two central collimators (COL3u and COL3d) with respect to the horizontal center plane to take advantage of "curvature drift" in the two TS bends formed by the two toroidal sections. In this curved B-field negatively charged particles are deflected upward in the first curved section and pass through the offset central collimator aperture and are deflected back onto the nominal beam line in the second curved section.

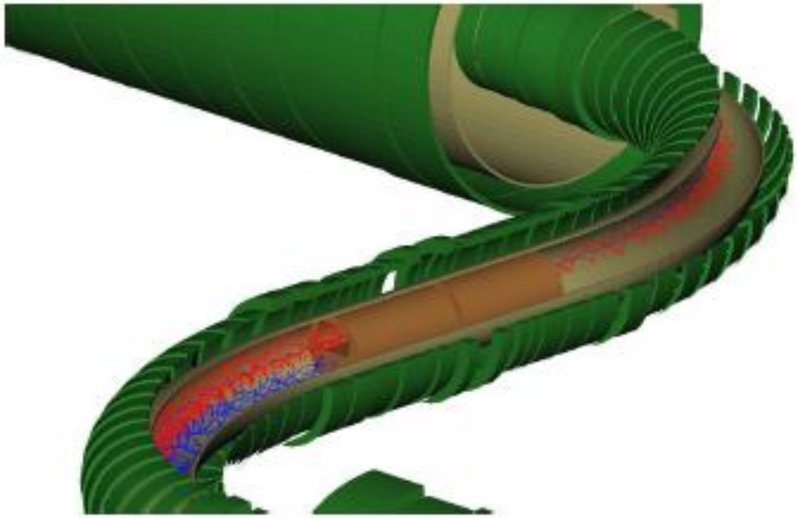
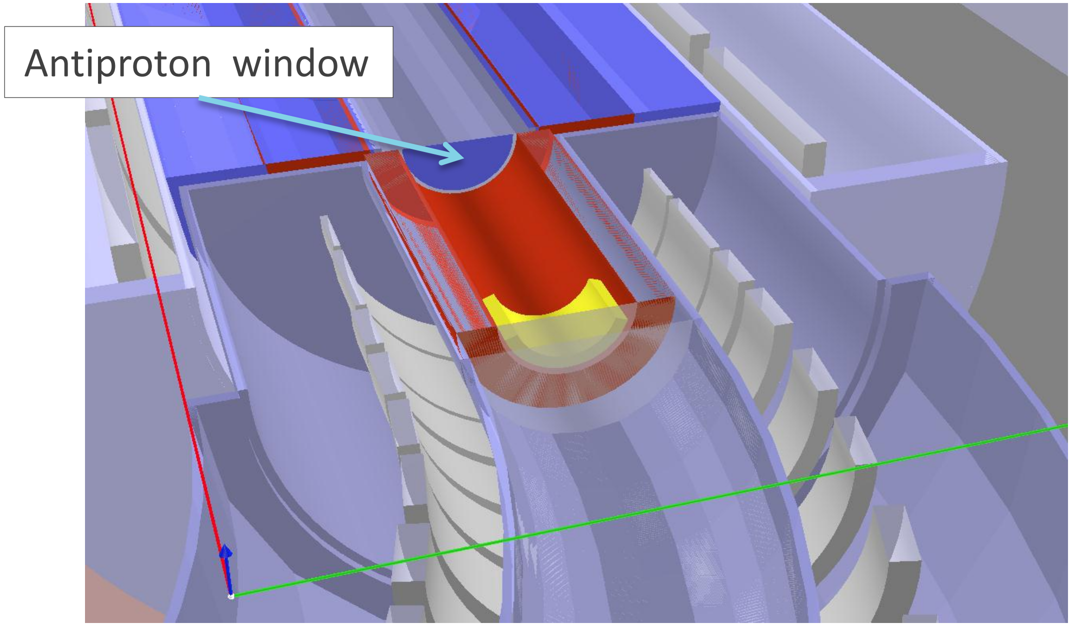


Figure 2.5: Cutaway view of the Transport Solenoid in the region of the asymmetric collimator. The upper spiraling negative muons (red) pass through, the lower positive muons (blue) are stopped.

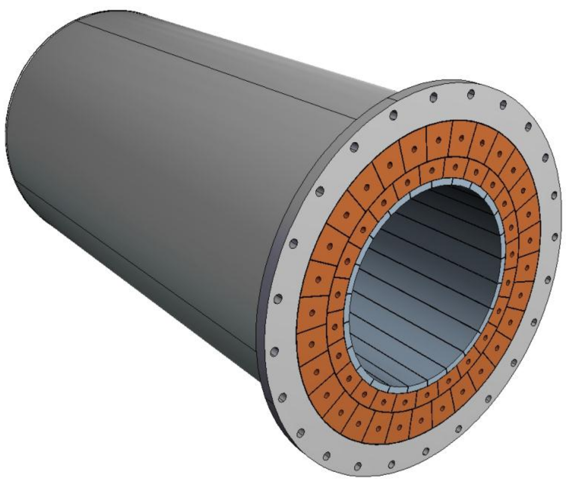
Requirements

- Antiprotons (p-bar), if allowed to continue on to the muon stopping target, would produce a serious physics background. There are several ways to decrease p-bar induced backgrounds. The Mu2e approach is to introduce two thin windows in the transport solenoid region. The windows need to be thick enough to reduce the probability for p-bar passage through the windows but also thin enough to not substantially decrease the muon yield. First window is located on upstream end of COL1 and must not limit vacuum pumping of TS bore. Second antiproton window is between COL3u and COL3d in middle of TS (see slide 7).
- Recent efforts to further suppress antiproton transmission incorporated an additional 20cm long arc of graphite (yellow) at the downstream end of COL1 as illustrated below

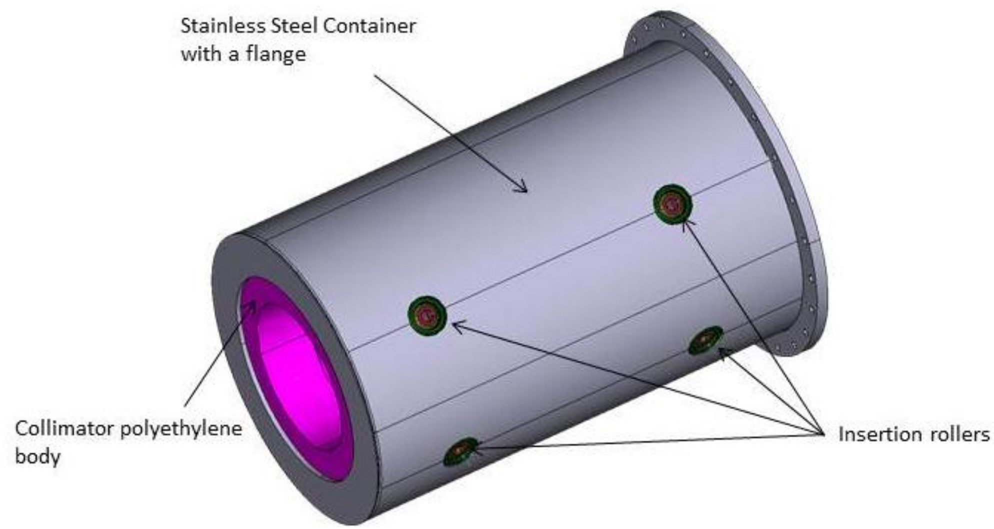


Design

- **There are two types of collimator assembly configurations:**
- **First type - stationary collimator**: COL1 and COL5, specified collimator material will be assembled into stainless steel containers which serve as the housings for the collimator and includes insertion rollers to facilitate installation in the TS bore.



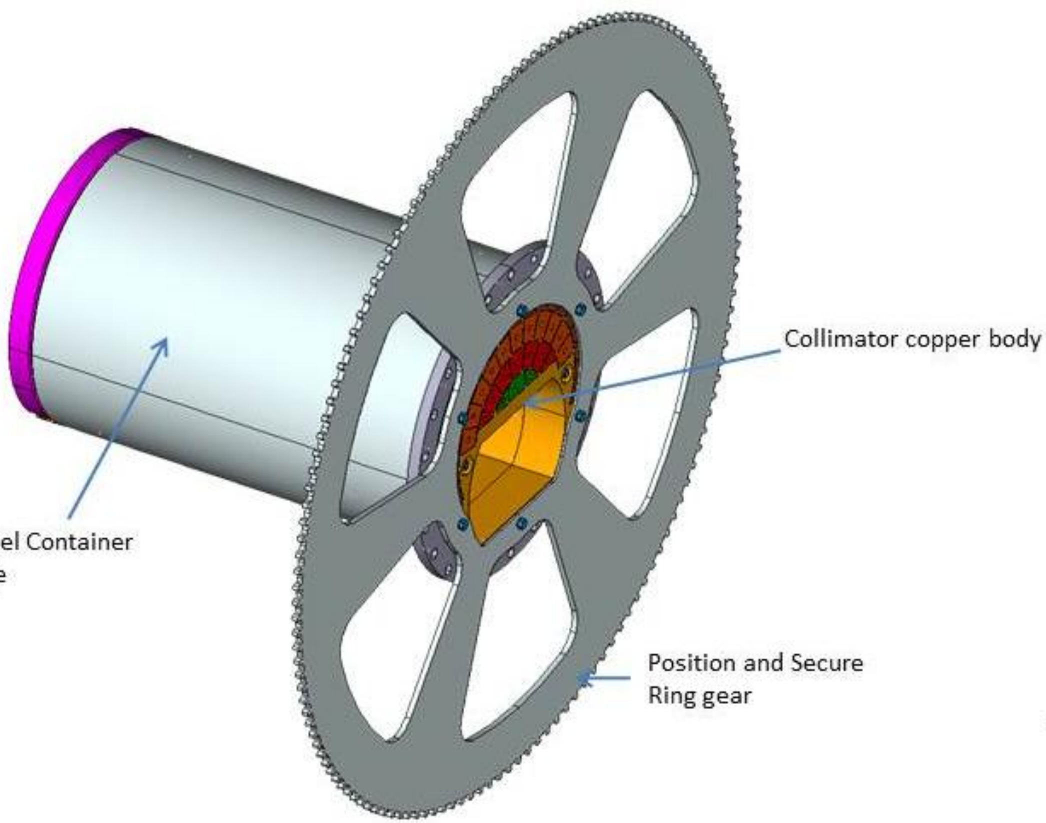
View of the COL1 as seen from the upstream end, illustrating the individual copper pieces inserted into the stainless steel housing and the segmented innermost graphite layer.



View of COL5 as seen from below, highlighting the insertion rollers embedded in the stainless steel collimator housing.

Design

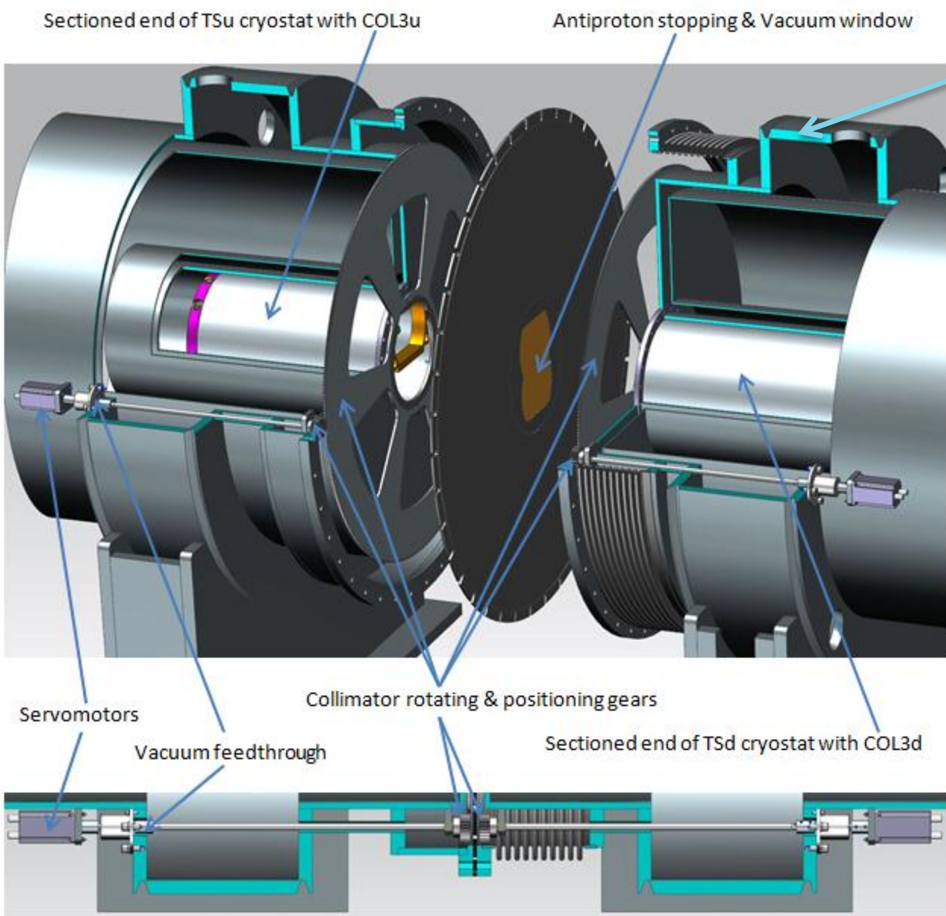
- **Second type - rotatable collimators: COL3u and COL3d**



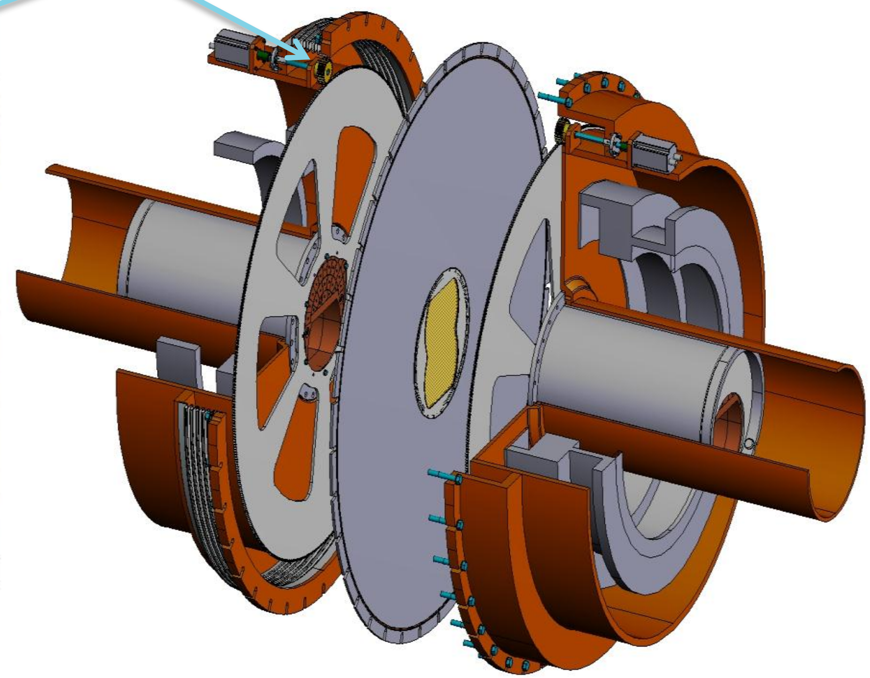
A large gear will be attached to the inner housing of collimators to provide easy azimuthal rotation of the inner housing, containing the copper body of collimator, with respect to the outer container which will be attached to the TS cryostat flange.
Collimator will be rotated by 180 degree during the detector calibration and afterwards turned back to nominal position.

Improvements since CD-1

Preliminary Design of TS3 Collimators



Different TS cryostat design and adaptation of Collimator part for it.



CD-1 Design of TS3 Collimators

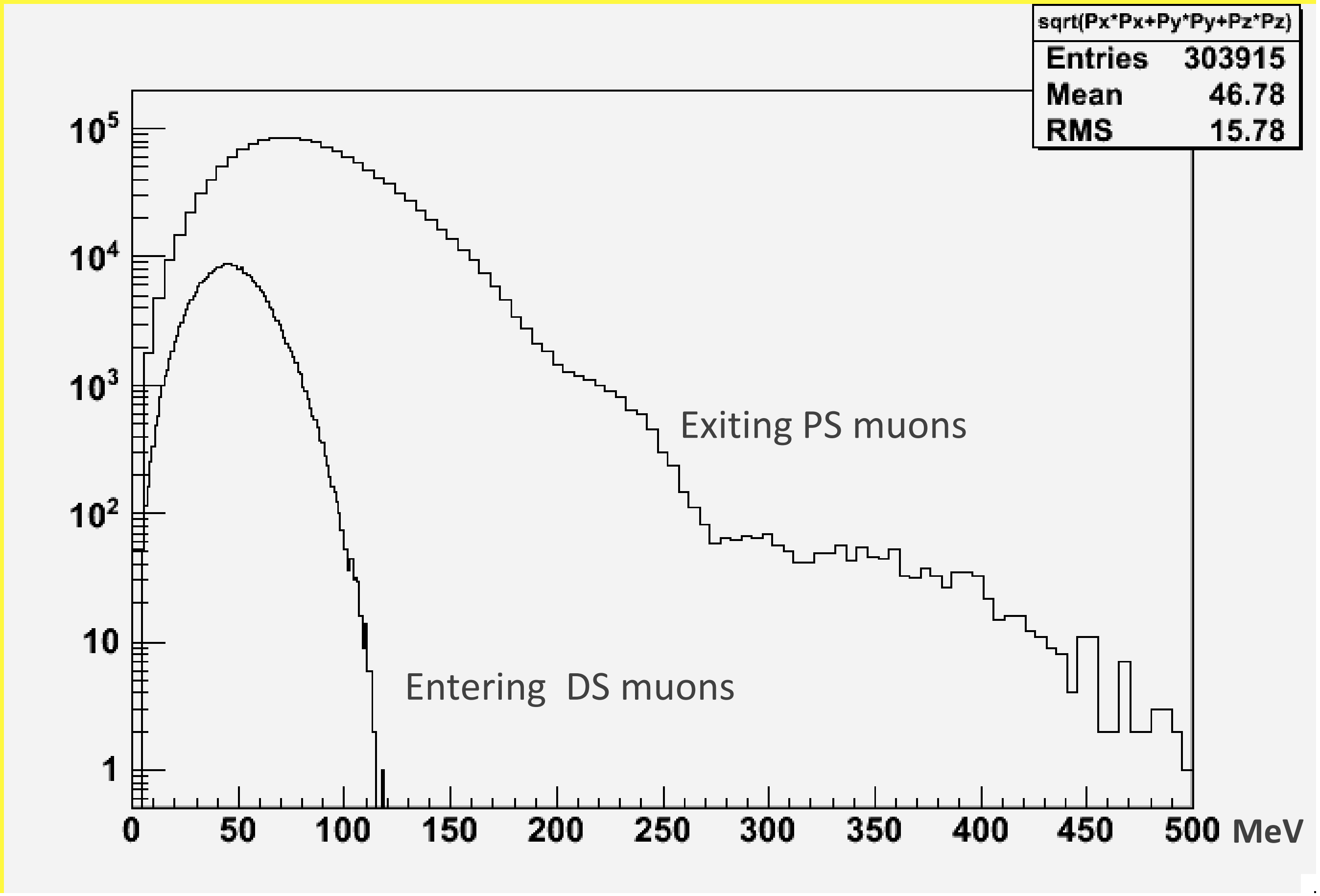
Value Engineering since CD-1

- Integration of magnetic mapping instrumentation inside all collimators
- Instrumentation/ports to verify COL3u and COL3d orientation
- Optimization of Collimator Drive/rotate system design for new TS cryostat design

Downselects

- Explored and eliminated poly liner within TS warm bore
- Confirmed copper as the material of choice for COL3
- Confirmed poly as the material of choice for COL5

Performance



Negative Muon Flux Exiting PS and Entering Detector

Remaining work prior to fabrication

- Verify final material choices
- Design COL1 antiproton window
- Finalize COL3u/COL3d interface region
- Complete integration of magnetic field mapping instrumentation into collimators

Integration and Interfaces

- Collimators have external interfaces to Accelerator, Solenoids, and CRV
- Internal interfaces to
  - Muon beamline vacuum system
  - Upstream external shielding
  - Stopping target monitor
  - Downstream external shielding
- Integration and interfaces addressed via
  - WBS dictionary and interface documents
  - Muon beamline meetings
  - Mechanical and electrical integration meetings
  - Formal signoff between responsible parties for all external interfaces will be required as part of the final design

Quality Assurance

Quality Assurance in the Collimator system efforts relies upon the following tools :

- Fermilab Quality Assurance Manual
- Fermilab Engineering Manual
- Documented engineering calculations and drawings reviewed, approved and released
- Verification of physics simulations
  - Comparisons between MARS and GEANT4
- Documentation of procedures
- Delivered materials will be inspected for conformance to the specifications

Risks

- Anti-proton stopping window at the TSu/TSd interface will be made from a beryllium plate whose thickness is 0.2 mm in center line of window and linearly increasing to 1.3mm on outer window border at distance of 150mm .
- This window will absorb the anti-protons in the middle of TS3 and must be designed to be replaced.
- This window serves as a vacuum separator in the middle of the beamline to prevent radioactive molecules migrating down stream into the detector solenoid. It will be challenging to keep equal pressure on both sides of this window-membrane if some vacuum leak will opened in the beamline.
- All above concerns present the risks that are being mitigated during design development of TS3 Collimator System, intended to support (relatively) easy replacement of the window.
  - the vacuum system will regulate pressure differential across the window.

ES&H

- HAZARDOUS MATERIAL
  - ANTIPROTON WINDOW AT THE TSU/TSD INTERFACE MAY BE BERYLLIUM
- CRANE, HOIST AND FORKLIFT USE
  - The collimators are heavy objects, so during installation special care should be taken to follow Fermilab safety procedures for working with lifting equipment.
- RADIATION HAZARDS
- MAGNETIC FIELDS
- ELECTRICAL HAZARDS
- CRYOGENIC HAZARDS

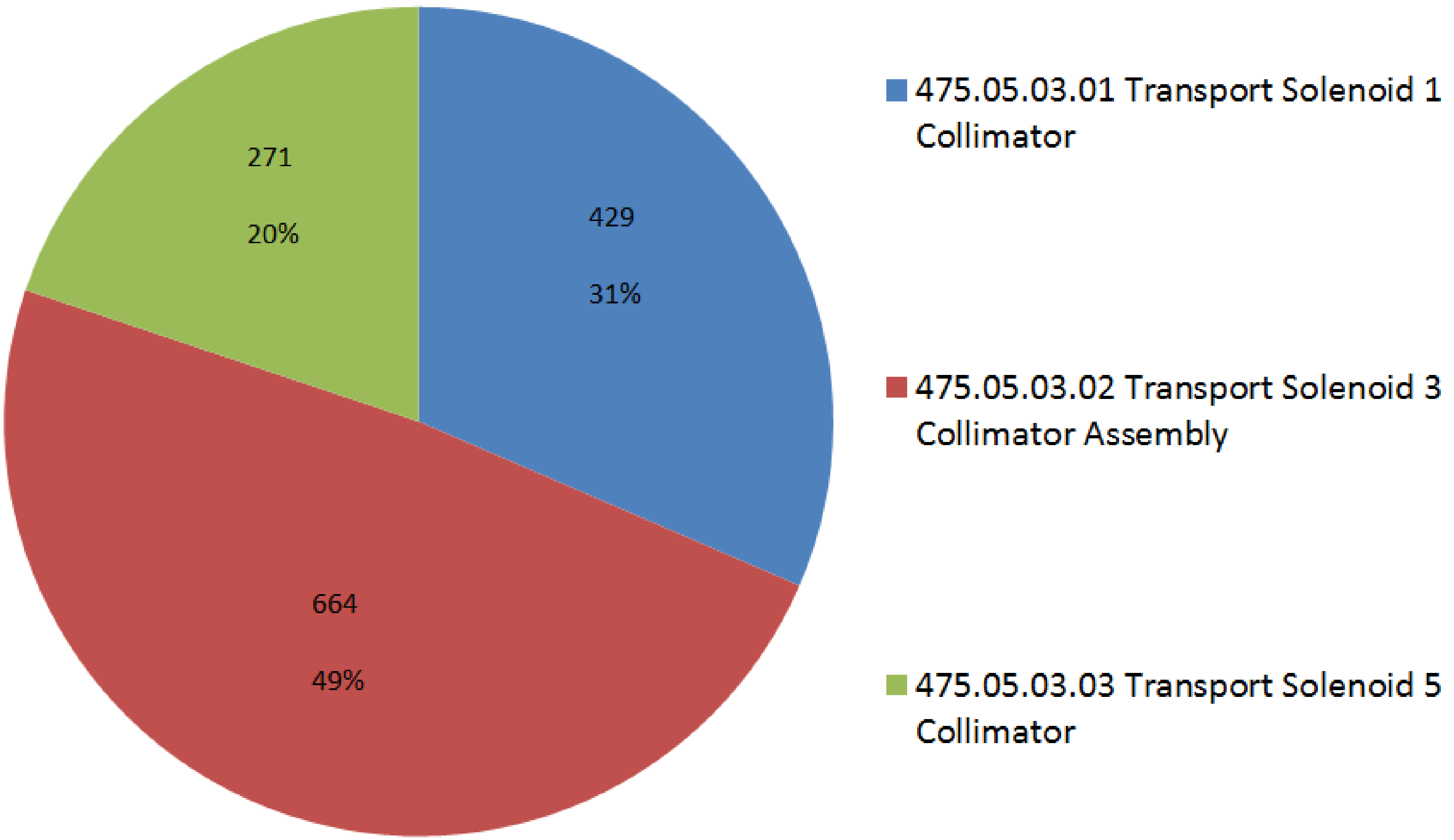
Cost Table for 475.05.03 Collimators

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						
475.05.03 Muon Beamline Collimators						
475.05.03.01 Transport Solenoid 1 Collimator	190	240	429	213	59%	642
475.05.03.02 Transport Solenoid 3 Collimator Assembly	394	270	664	226	38%	890
475.05.03.03 Transport Solenoid 5 Collimator	153	118	271	89	38%	360
Grand Total	737	628	1,364	527	44%	1,891

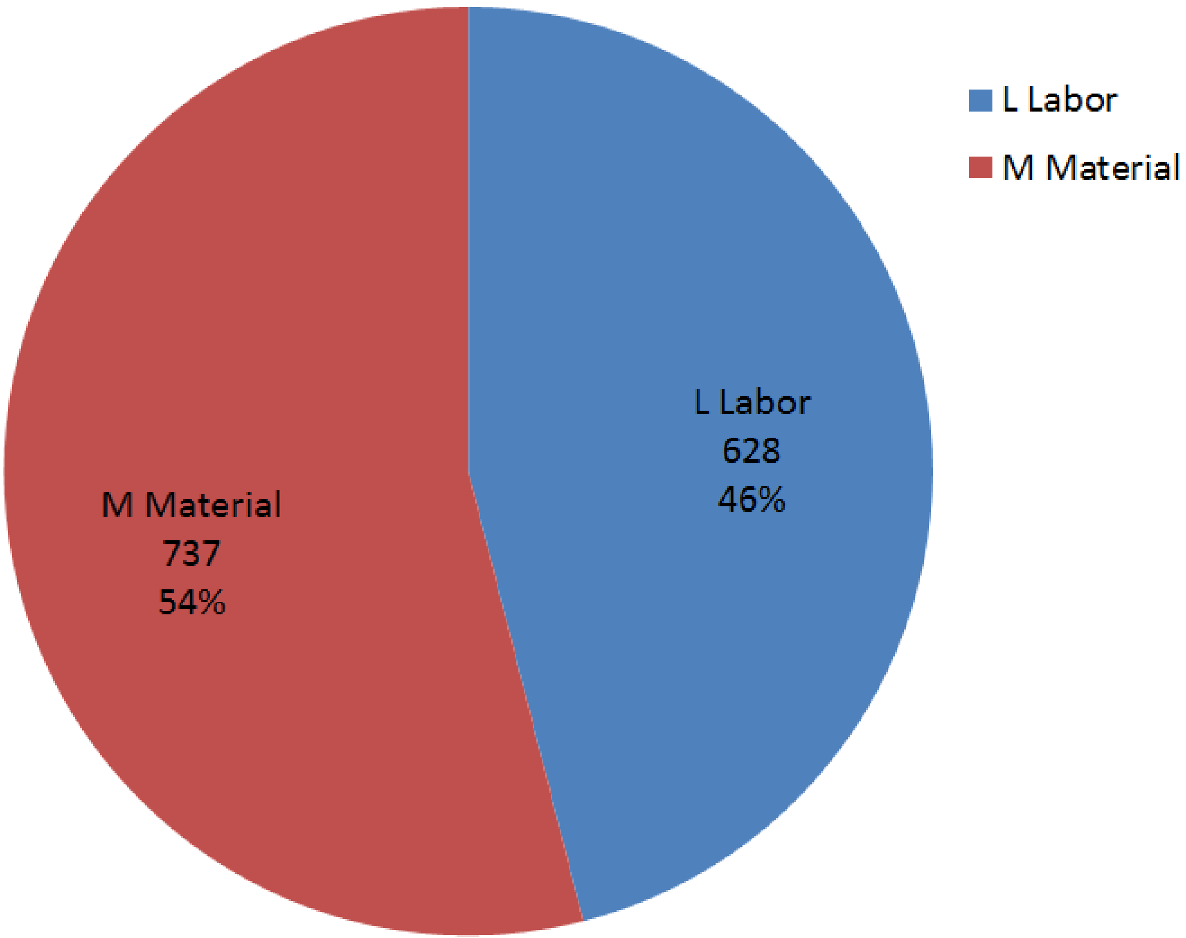
Cost Distribution for 475.05.03 Collimators

- Base Costs in AY k$



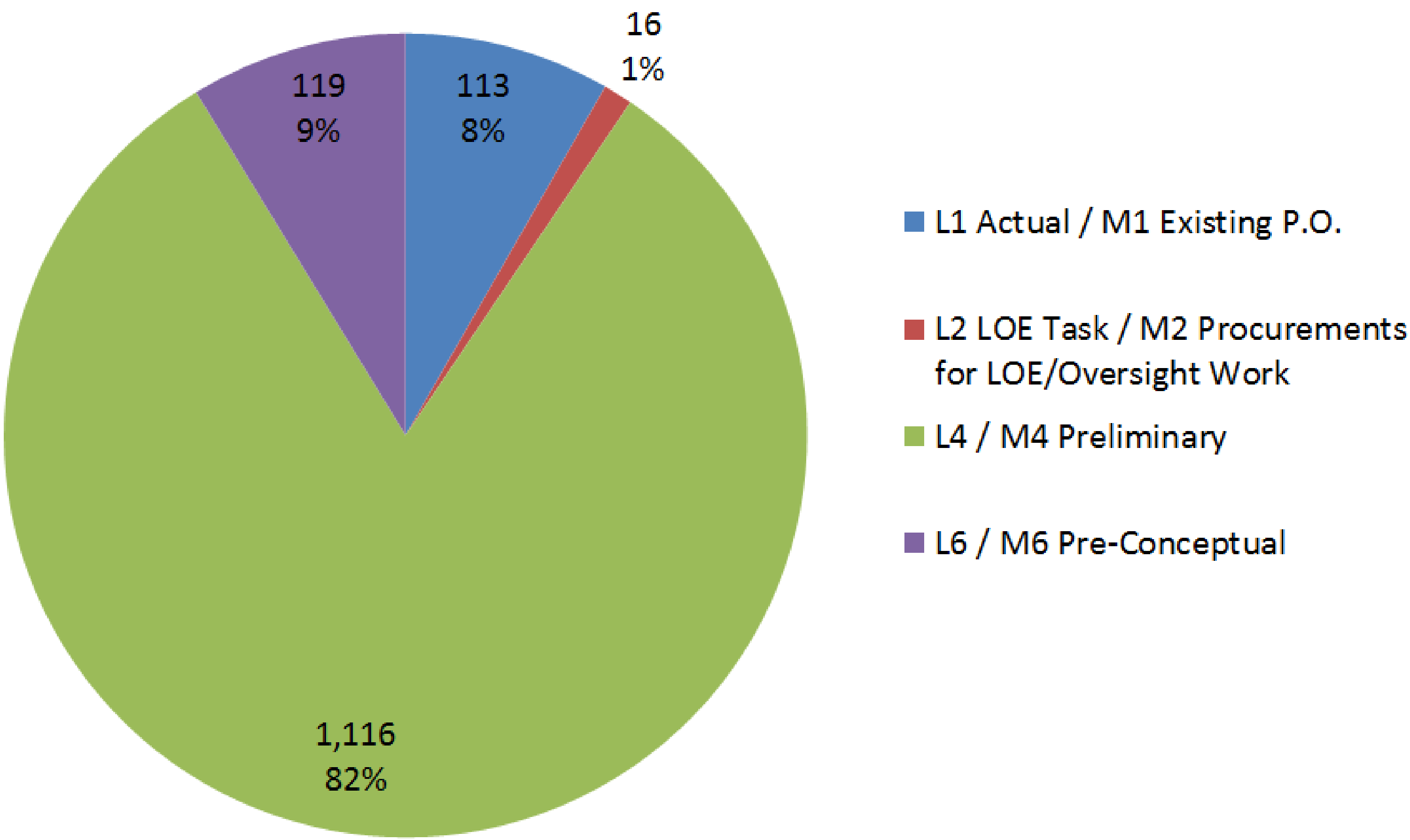
Cost Distribution by Resource Type

- Base Costs in AY k$



Quality of Estimate

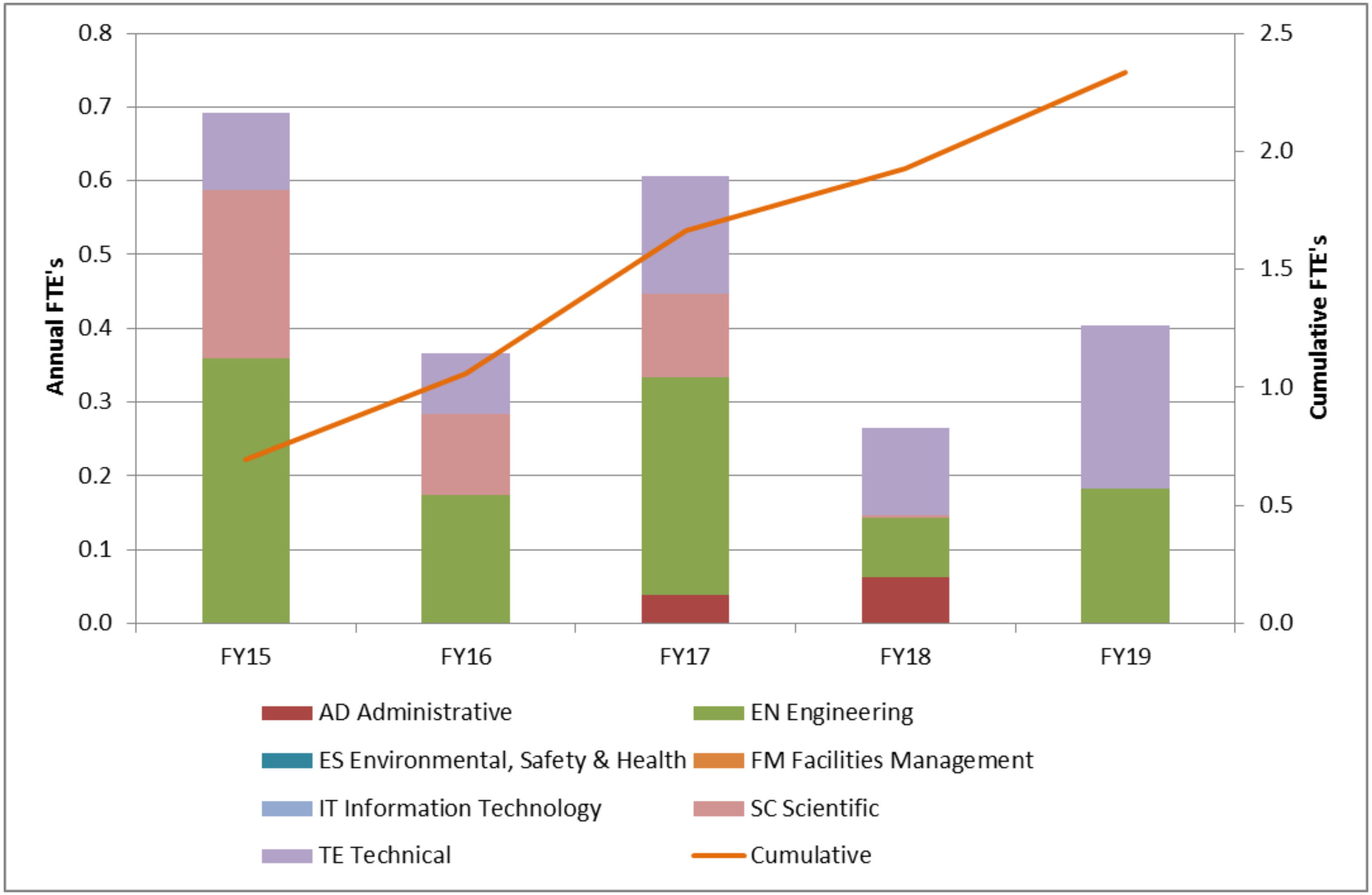
- Base Costs in AYk$



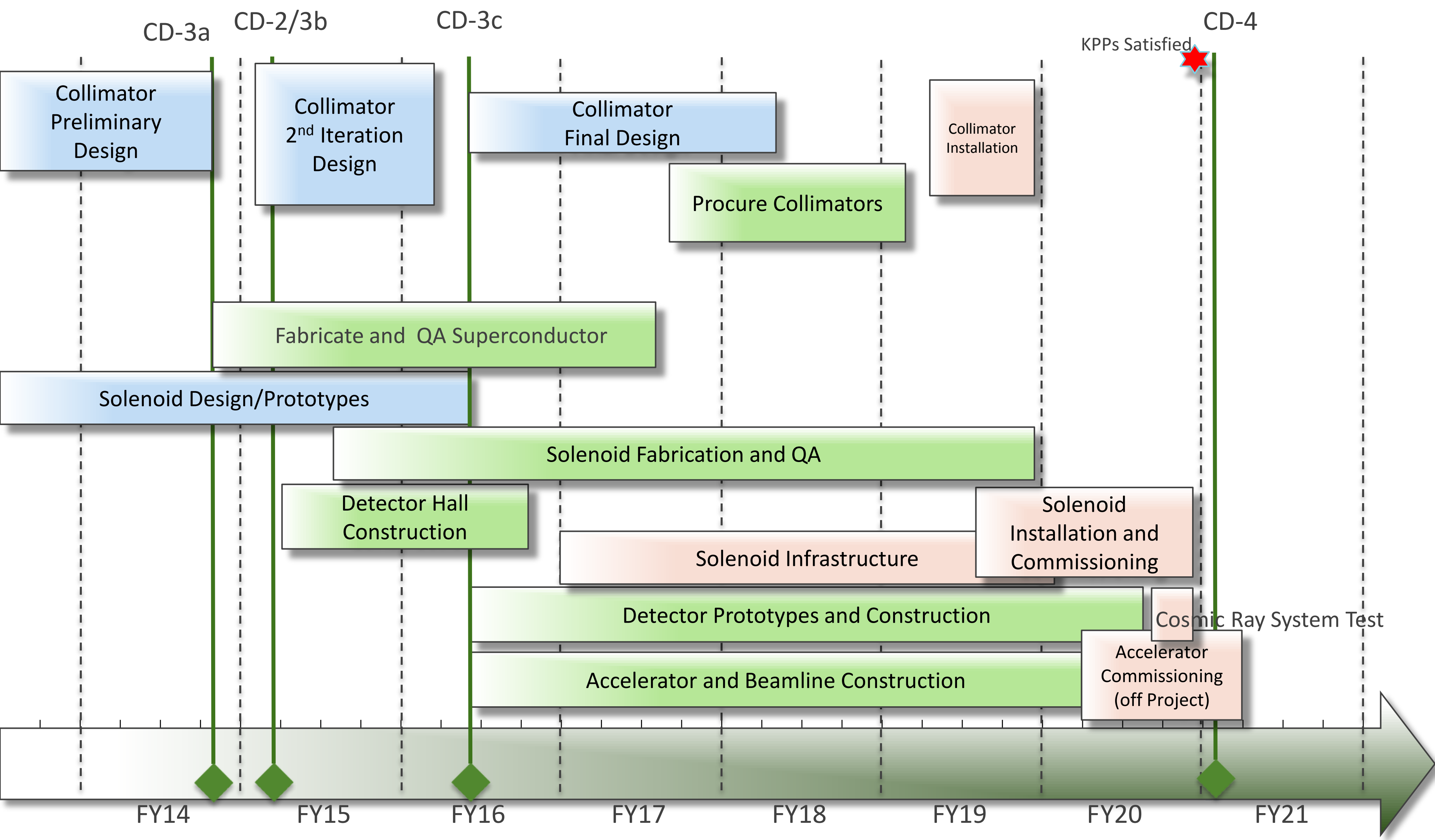
- 91% of costs at the preliminary design level or better

Labor Resources by FY

- FTE's by Discipline for 475.05.03 Collimators



Schedule


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

Milestones

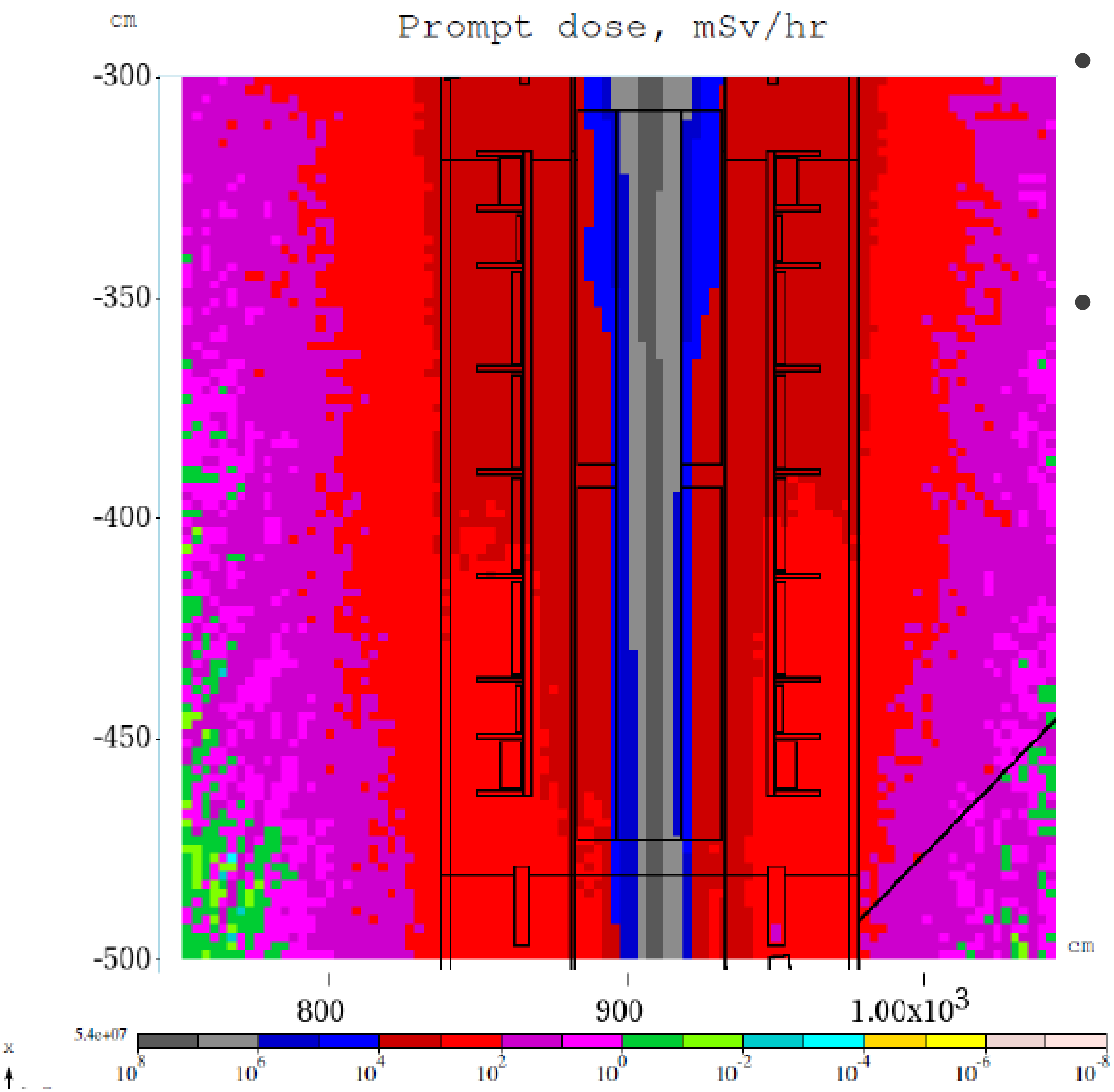
47505.3.3.001200	T5 - Transport Solenoid 5 Collimator 1st Iteration Preliminary Design Complete	6/26/2014
47505.3.000900	T5 - Collimators ready for Director's CD2 Review	7/7/2014
47505.3.000905	T5 - Collimators ready for DOE CD2 Review	10/13/2014
47505.3.2.001275	T5 - TS3 Collimators 2nd iteration design complete	6/23/2015
47505.3.2.001355	T5 - TS3 Collimators ready for CD-3 Review	7/27/2015
47505.3.3.001265	T5 - 2nd iteration Design TS5 Collimator Complete	8/31/2015
47505.3.3.001353	T4 - TS5 Collimator ready for CD-3 Review	10/1/2015
47505.3.1.001265	T5 - TS1 Collimator 2nd iteration Design Complete	10/23/2015
47505.3.000940	T5 - Collimators ready for CD-3 Review	11/24/2015
47505.3.1.001390	T5 - TS1 Collimator ready for CD-3 Review	11/24/2015
47505.3.000950	T5 - Collimators CD-3 approval	2/24/2016
47505.3.2.001345	T5 - TS3 Collimators ready for fabrication	6/8/2017
47505.3.1.001370	T5 - TS1 Collimator ready for fabrication	10/16/2017
47505.3.2.021009	T5 - TS3 pbar window Components at Fermilab	12/26/2017
47505.3.3.001340	T5 - TS5 Collimator ready for fabrication	2/7/2018
47505.3.2.041010	T5 - All Transport Solenoid 3 Collimator Components at FNAL	3/5/2018
47505.3.2.011018	T5 - TS3 Collimators at Fermilab	3/6/2018
47505.3.2.011019	T5 - TS3 Collimators Ready for Installation	4/3/2018
47505.3.1.001445	T5 - TS1 Collimator at Fermilab	7/12/2018
47505.3.1.001495	T4 - TS1 Collimator ready for Installation	8/2/2018
47505.3.1.001510	T5 - TS1 Collimator pbar window at Fermilab	8/10/2018
47505.3.3.001444	T5 - TS5 Collimator at Fermilab	10/25/2018
47505.3.3.001515	T5 - TS5 Collimator ready for Installation	11/8/2018
47505.3.1.001560	T5 - TS1 Collimator ready for CD-4	1/22/2019
47505.3.000960	T5 - TSu Collimator Installation complete	1/28/2019
47505.3.2.041075	T5 - TS3 Collimators Installed	8/30/2019
47505.3.000970	T5 - TSd Collimator Installation complete	9/6/2019
47505.3.2.041090	T5 - TS3 Collimators ready for CD-4	9/6/2019
47505.3.000980	T5 - MB Collimators Ready for CD-4	9/9/2019
47505.3.3.001535	T5 - TS5 Collimator Installed	9/9/2019
47505.3.3.001540	T5 - TS5 Collimator ready for CD-4	9/9/2019

Summary

- A preliminary design of the muon beamline collimators which addresses the requirements has been completed
  - Requirements & Specifications have been completed for 2nd iteration of the preliminary design of the TS collimators, Doc-db1044
  - 3-D models of the preliminary design of the TS collimators have been developed
- Cost estimates for the collimators are complete
  - 91% of costs at the preliminary design level or better
  - Risks are understood and being mitigated to the extent possible solutions
- Interfaces are identified and resource needs are understood
- Muon Beamline collimators are ready for CD-2

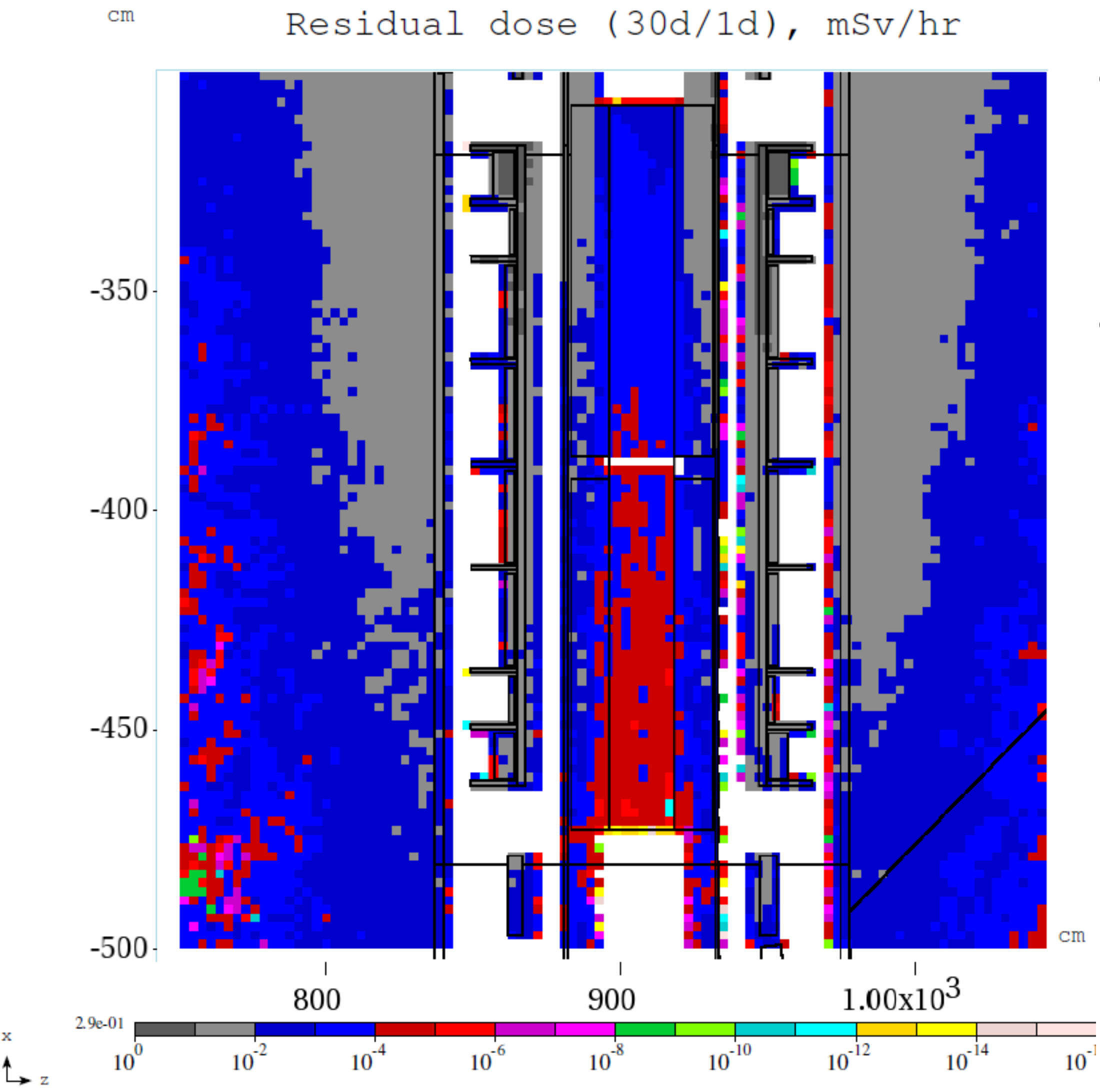
Backup slides

Radiation levels around COL3u and COL3d



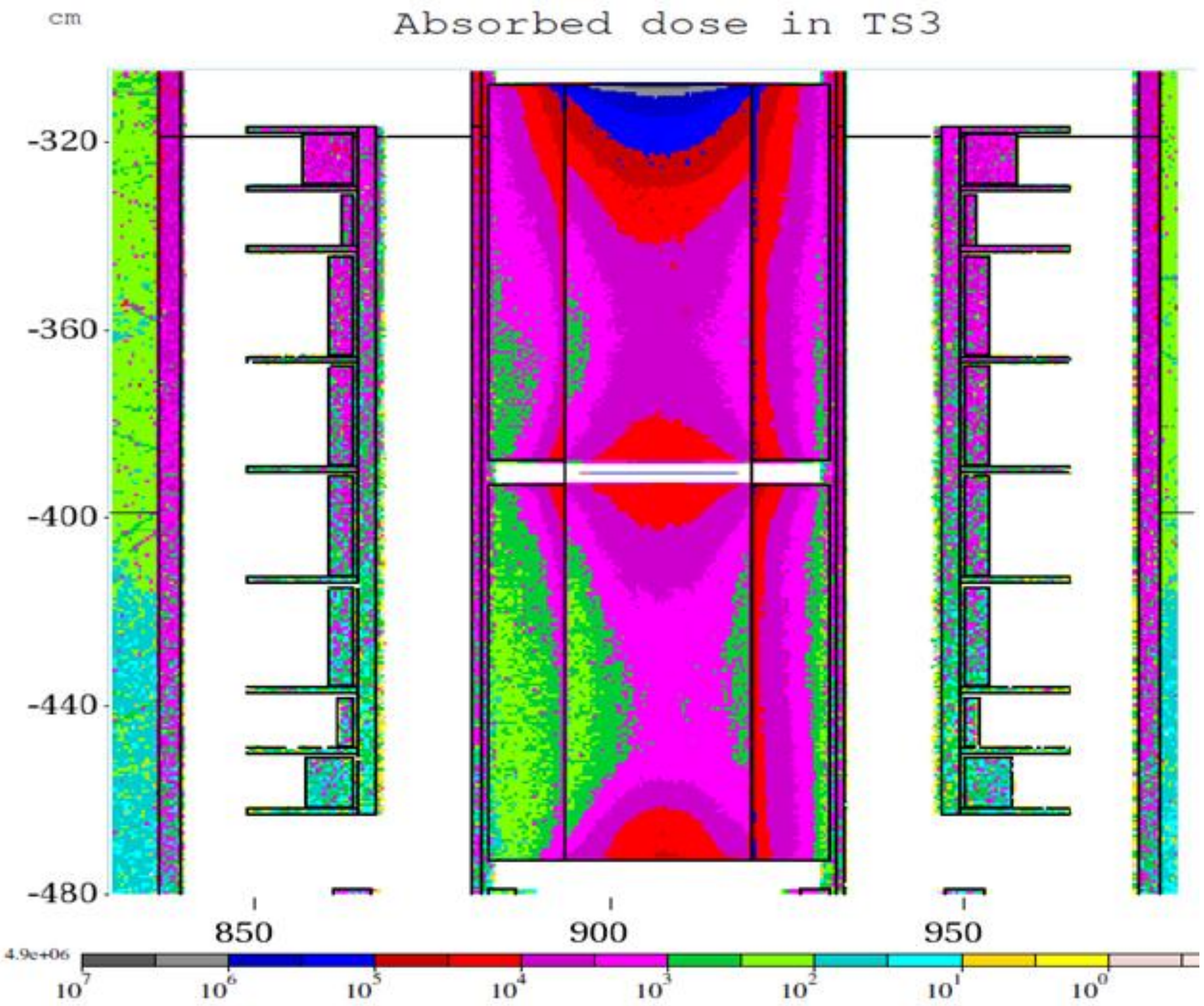
- Results from MARS simulations (docdb 3237)
- Prompt dose rates at outside surface of TS cryostat in vicinity of COL3u and COL3d is ~10^3 mSv/hr

Residual Dose Rates



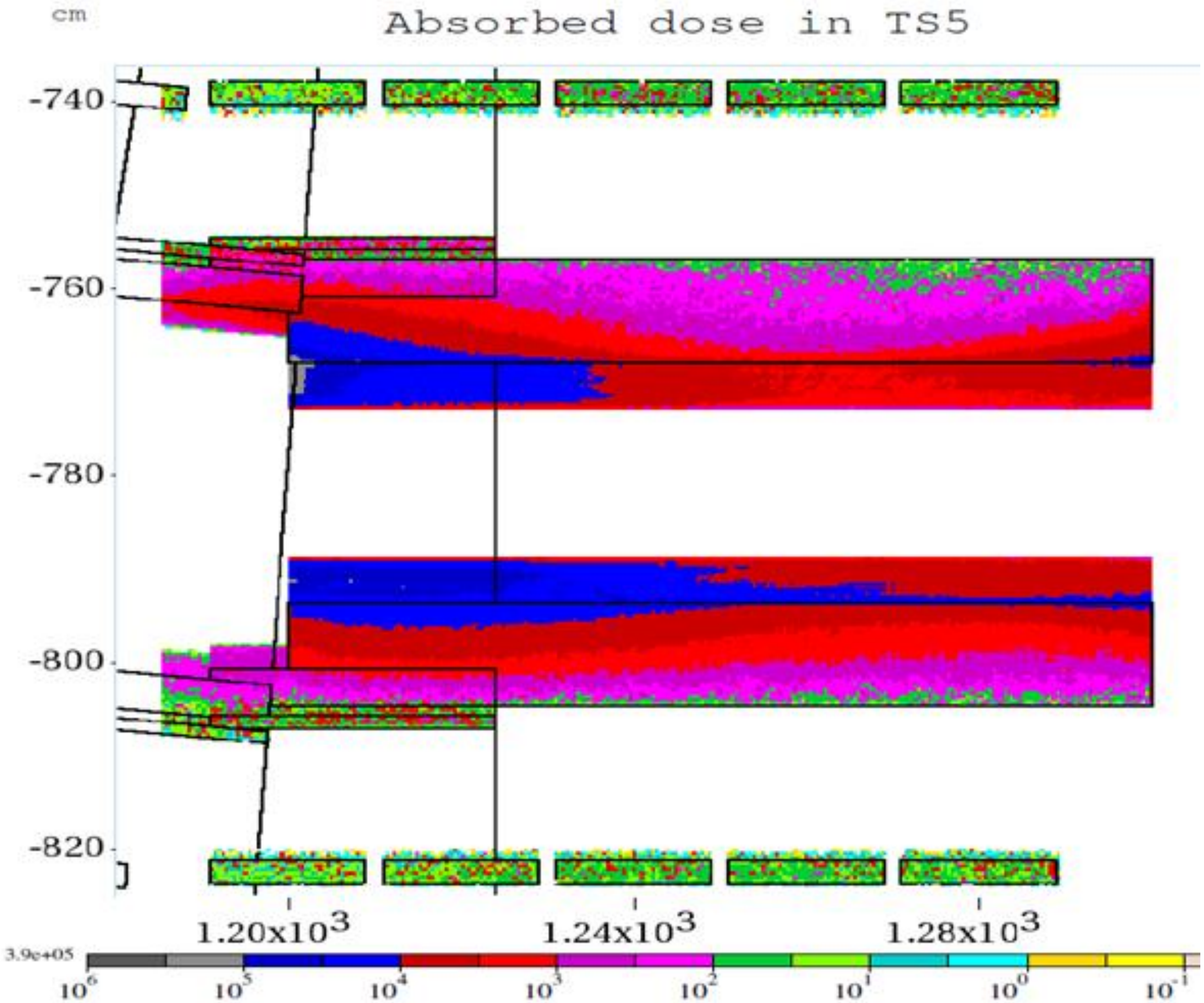
- Results from MARS simulations (docdb 3237)
- Residual dose rates outside of TS cryostat around COL3u and COL3d after one year of running at nominal beam power and 7 days of cooldown <10^{-1} mSv/hr

Absorbed Dose in COL3u and Col3d



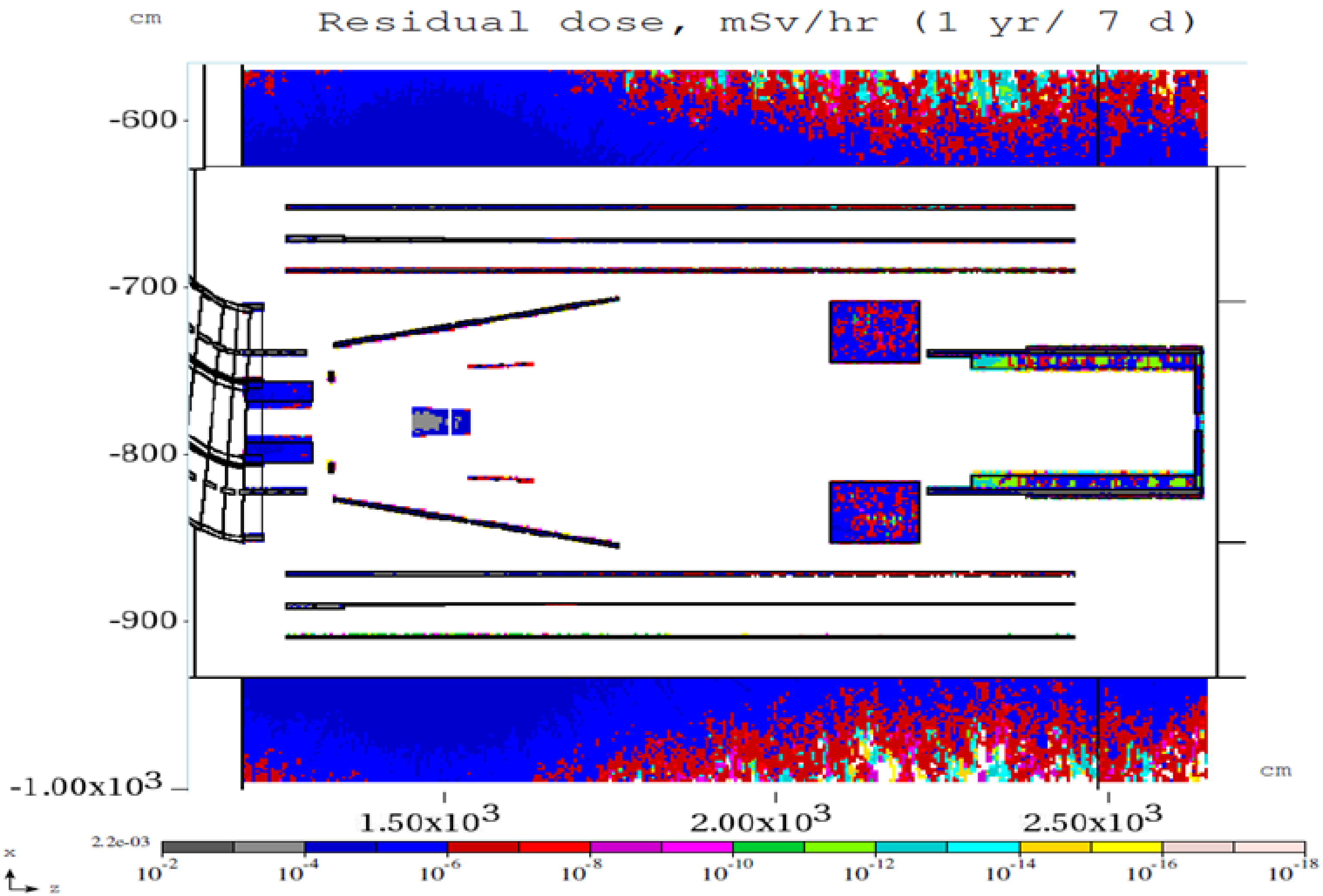
- Results from MARS simulations (docdb 3593)
- Peak dose at the upstream end of COL3u is ~0.5 MGray per year

Absorbed Dose in COL5



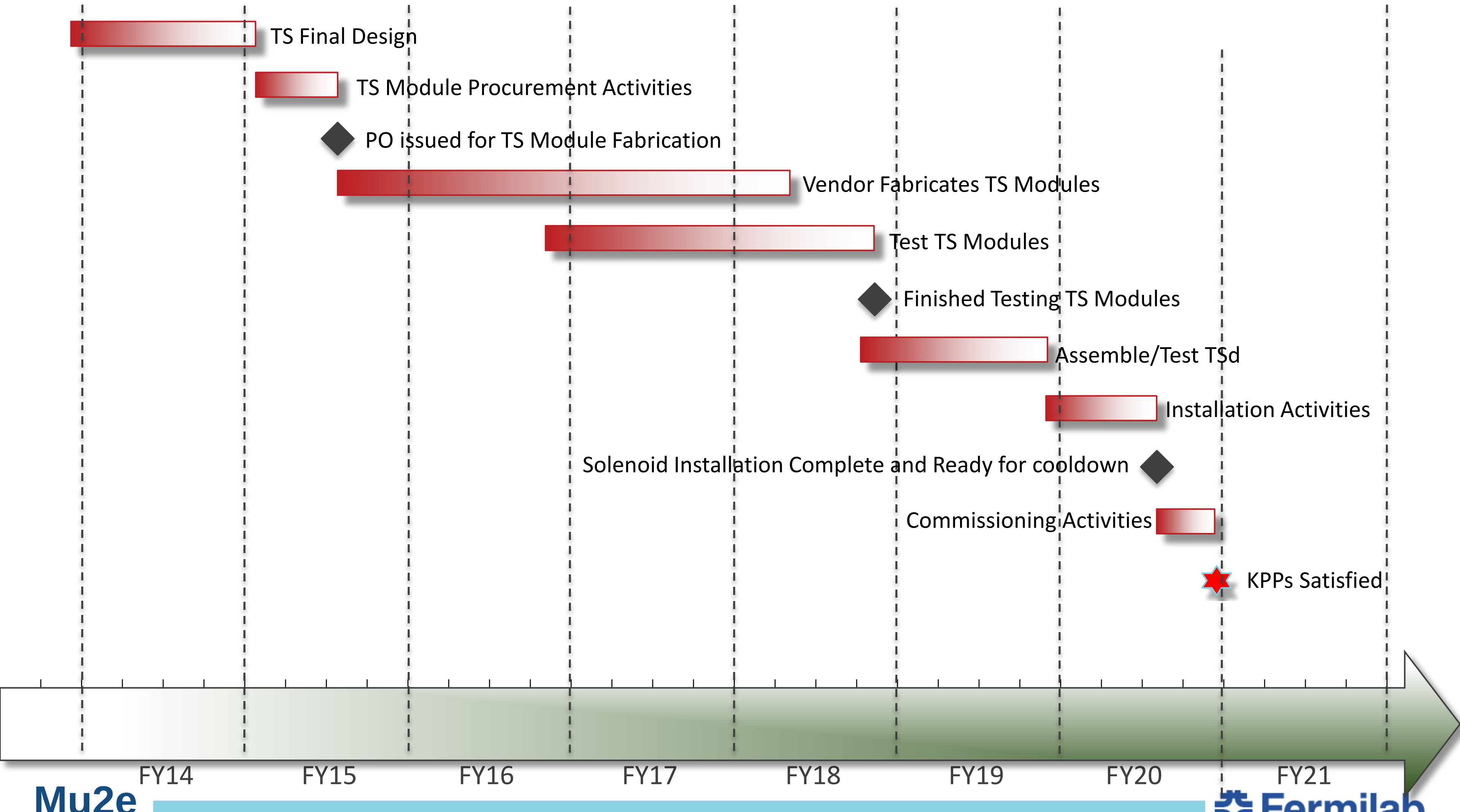
- Results from MARS simulations (docdb 3593)
- Peak dose is ~0.2MGray per year at the upstream end of COL5

Residual Dose Rates



- Results from MARS simulations (docdb 3593)
- Residual dose rates around COL5 after one year of running at nominal beam power and 7 days of cooldown <10^{-4} mSv/hr

Critical Path



Labor and Material per Fiscal Year

- Base costs in AYk$