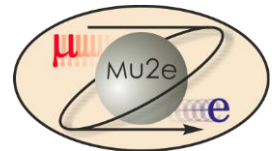




Mu2e Tracker

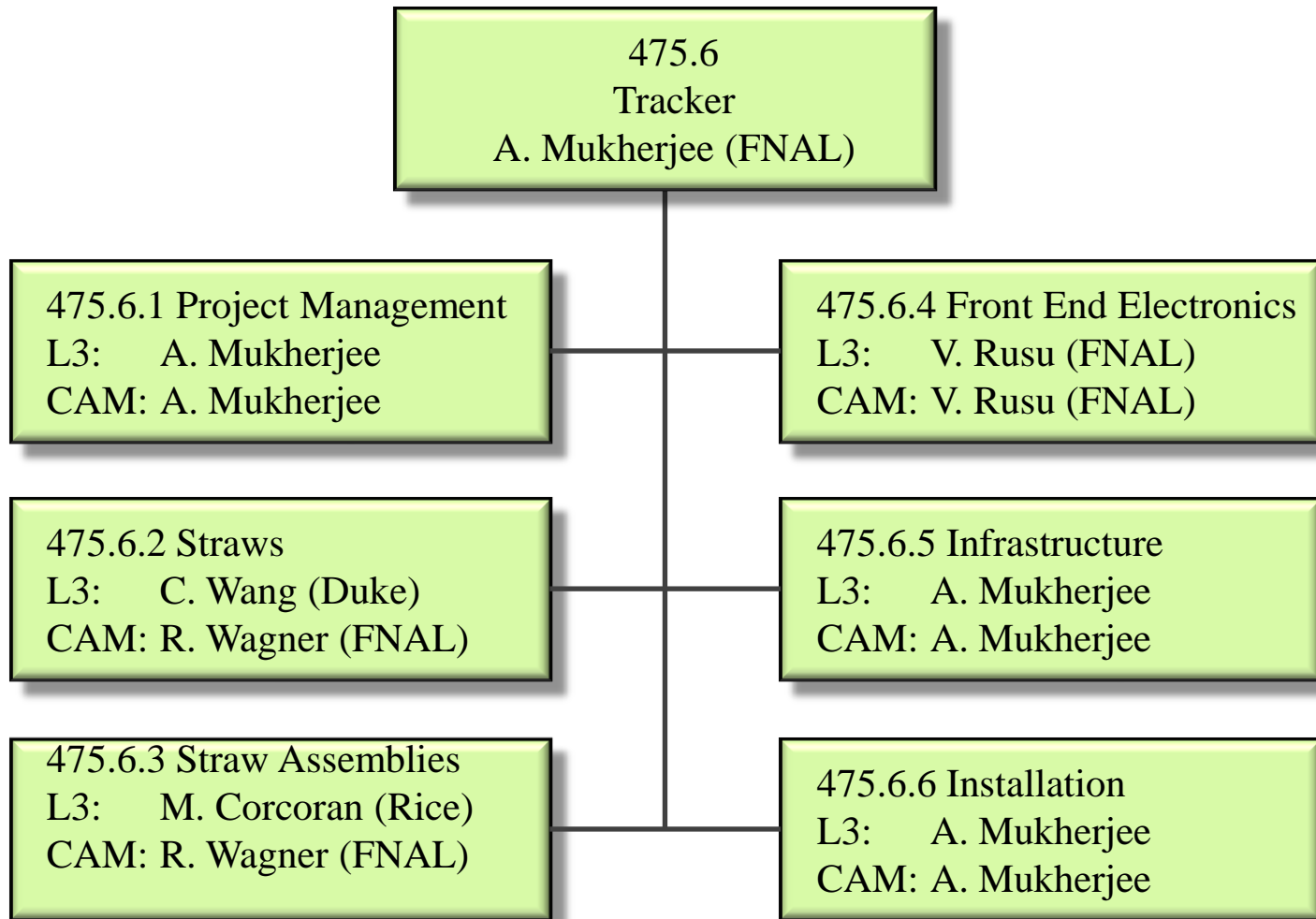
Aseet Mukherjee
Tracker L2 Manager
21 Oct 14



Tracker Team

- Aseet Mukherjee – L2 Manager
 - Started work at Fermilab in 1986 working on CDF's Run-I tracker (CTC), a $\sim 3\text{m} \times 3\text{m}$ cylindrical drift chamber.
 - Co-leader with Bob Wagner for construction of CDF's Run-II tracker (COT), a $\sim 3\text{m} \times 3\text{m}$ cylindrical drift chamber.
 - Worked on pattern recognition and fitting software for CTC; slow controls, calibration, monitoring, and maintenance for both trackers.
- Bob Wagner – Deputy Manager
 - Worked on design and construction of CTC
 - Co-leader for construction of COT.
 - Leader for construction of vertex drift chamber (VTX) for CDF Run-I
 - Worked on calibration, monitoring, and maintenance of all three drift chambers.

Organization



Requirements

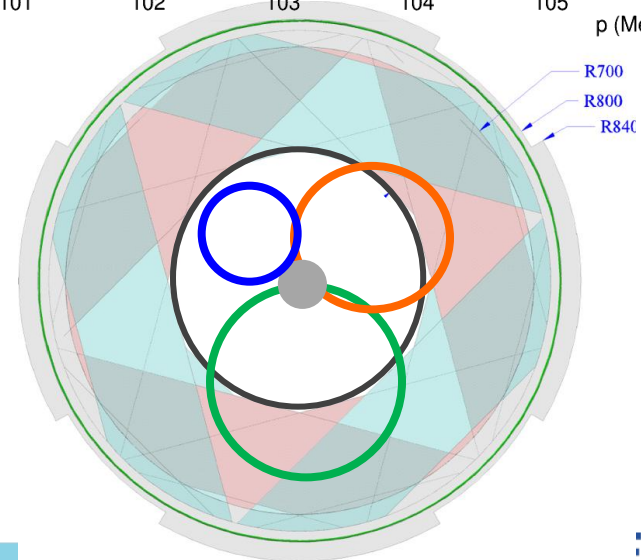
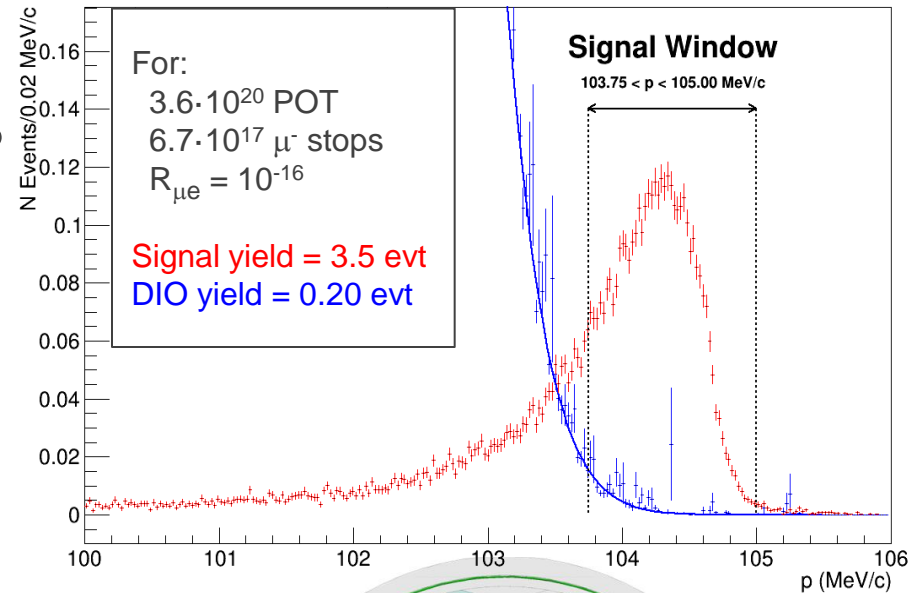
Mu2e Document

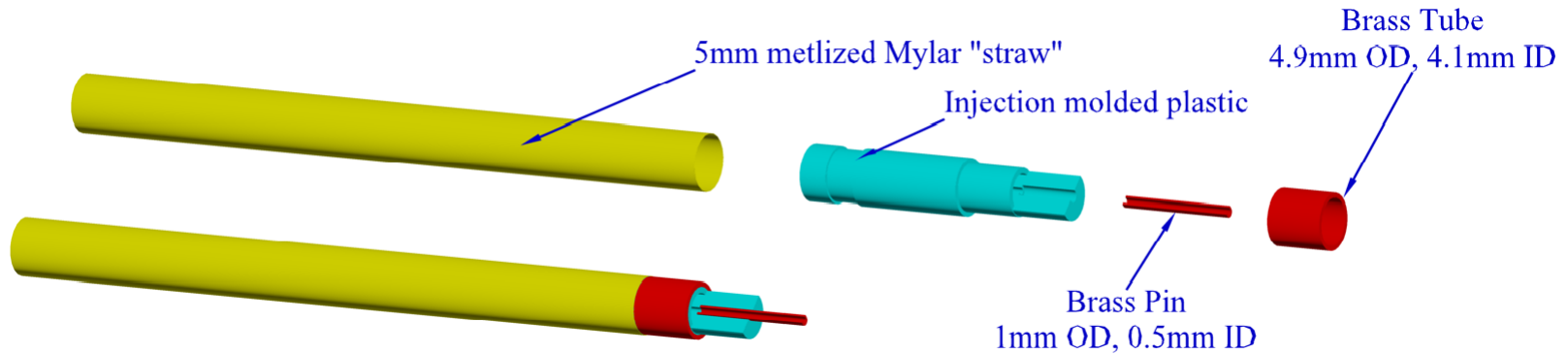
Science Driven Requirements	4381
Requirements for the mu2e Tracker Front End Electronics	3879
Tracker Requirements Document	732

Requirements

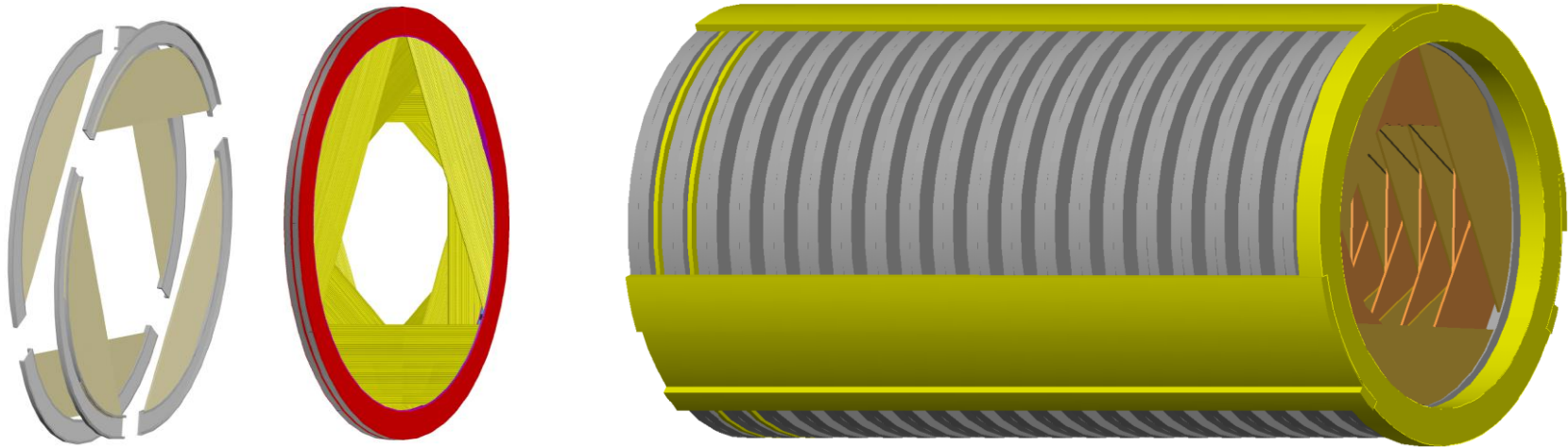
- Blind to low energy background electrons
- Adequate resolution
- Efficient for signal
- **$r < 380\text{mm}$**
“No” mass (vacuum)
- **$380 < r < 700\text{mm}$**
Low mass detector
- **$r > 700\text{mm}$**
Support structure

Reconstructed e^- Momentum



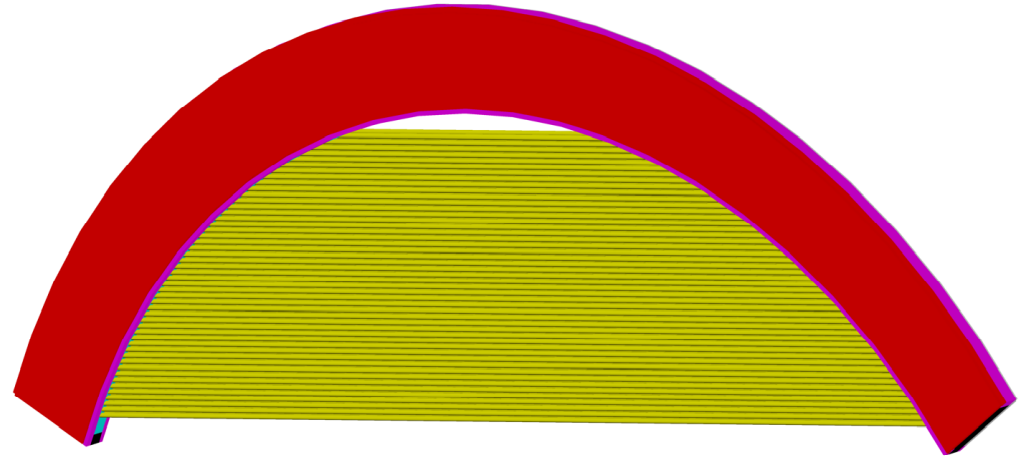
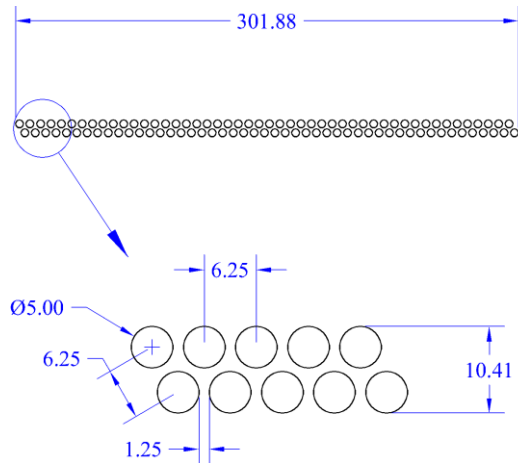


- L3: C. Wang (Duke)
CAM: R. Wagner (FNAL)
- 5 mm OD metalized Mylar[®] straws, 15 μ m wall
 - Mylar for higher yield and modulus (compared to Kapton)
 - Aluminum on inner and outer surface
 - Gold on inner surface
- 25 μ m gold plated tungsten sense wire



- L3: M. Corcoran (Rice) CAM: R. Wagner (FNAL)
- 96 straws form a panel (120° arc)
- 6 panels form a self supporting ring called a plane
- Two planes, with a small gap, form a station
12 rotations, pattern set to optimize stereo reconstruction
- 18 stations form the tracker

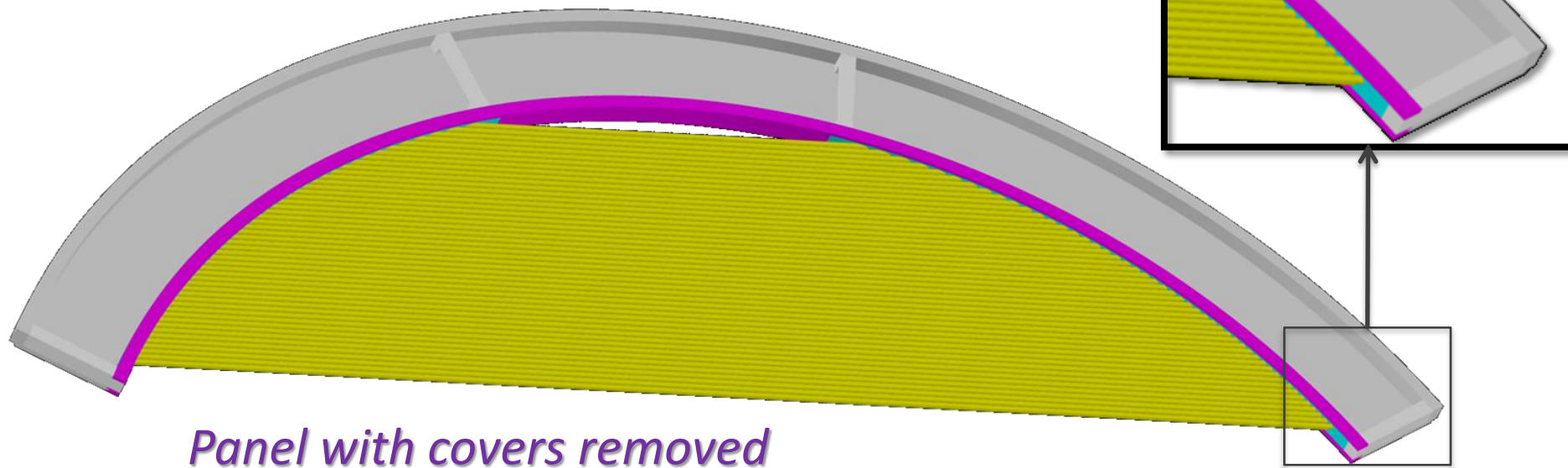
Panel



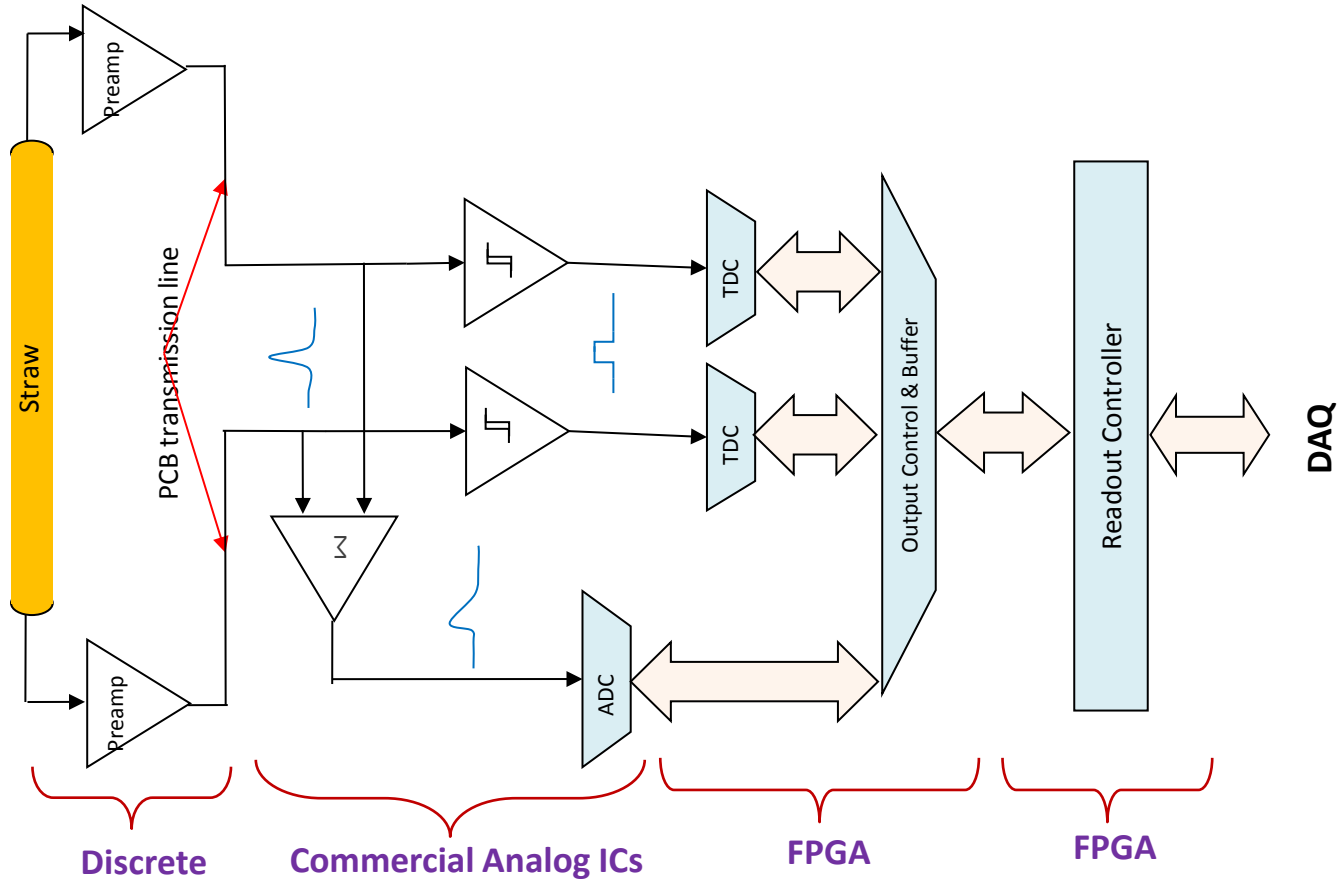
- 96 straws of varying length form a *panel*
 - Staggered pattern to improve efficiency and resolve left/right ambiguity
 - Gap between straws to allow for expansion when operating in vacuum
- Panel frame encloses front end electronics

Gas Manifold

- Changed since CD1 (was all metal)
- 3D printed plastic with holes for straws: cyan. 2 pieces
- Stainless steel reinforcement: magenta. 3 pieces
- Everything else aluminum: grey. 6 pieces



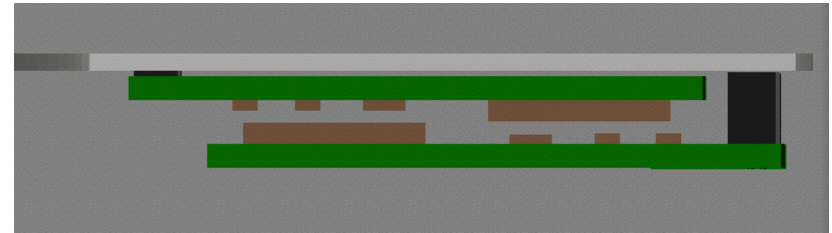
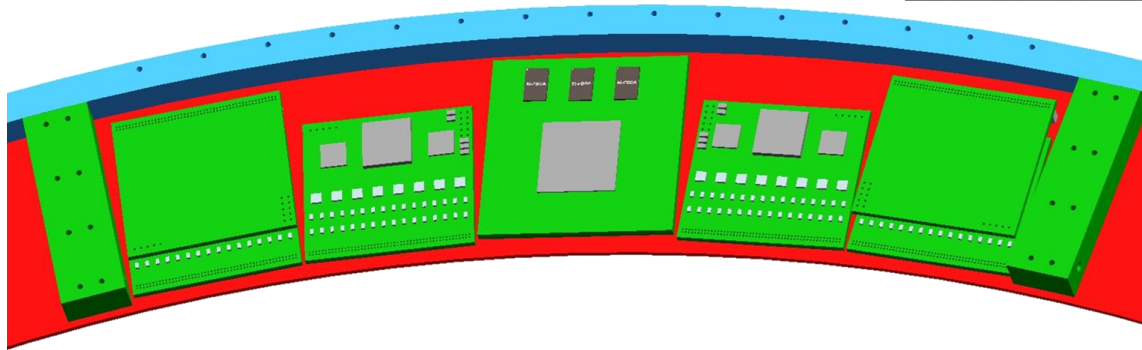
Panel with covers removed



- L3 & CAM: V. Rusu (FNAL)

Digitizers

*Digitizers and ROC
(inner ring suppressed)*

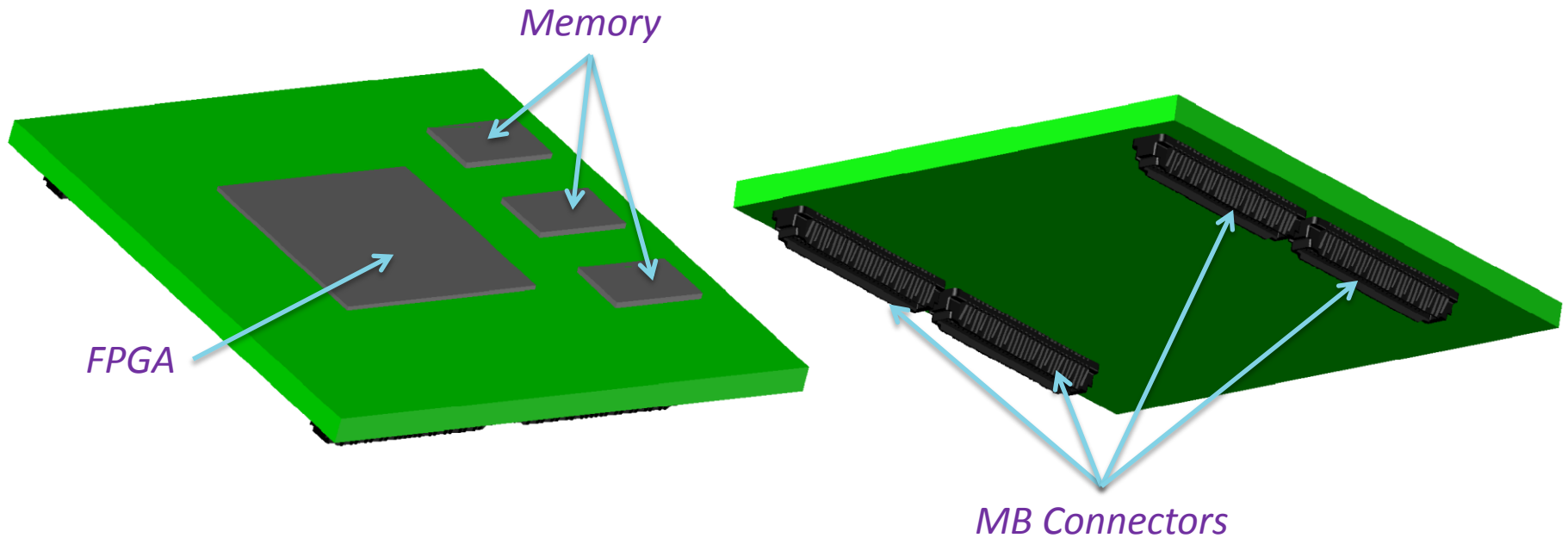


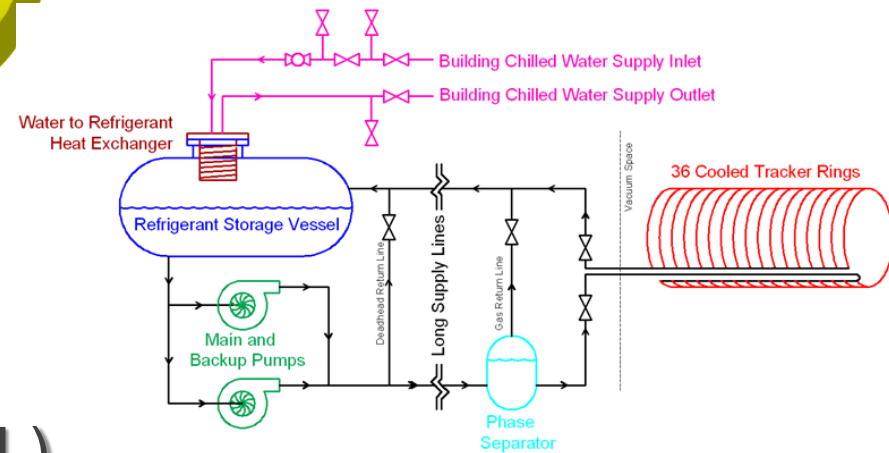
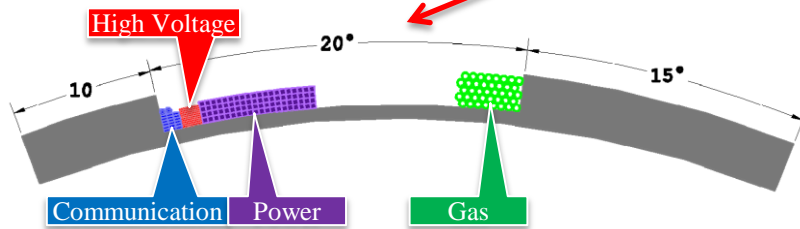
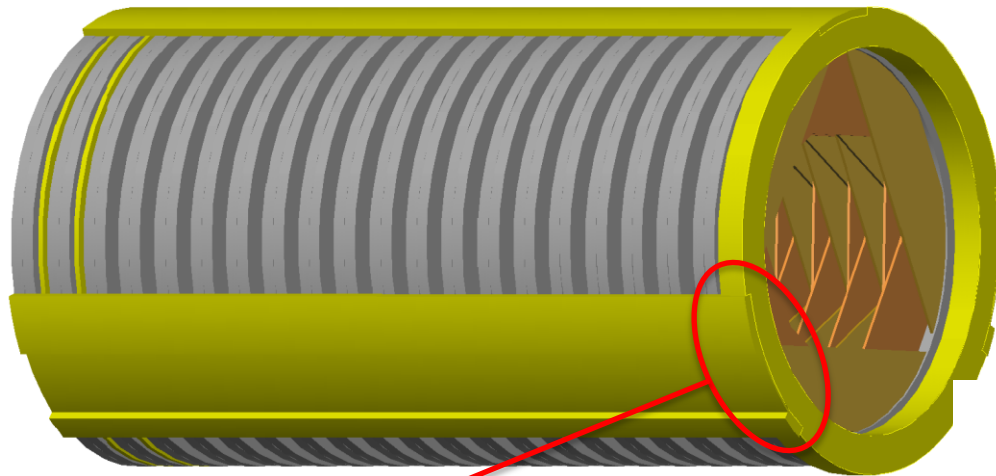
*Edge view of digitizer
boards with overlapping*

- Change since CD1: All commercial, off the shelf parts
- Tight fit, but it does fit
- Design complete
(subject to value engineering as new parts become available)
- Quotes for parts, boards, assembly

Readout Controller

- Work is being done by Fermilab and U. of Houston
- Preliminary designs exist.
 - 1st iteration: Over-size boards with many test features
 - Next iteration: Reduce size. Conceptual layout exists

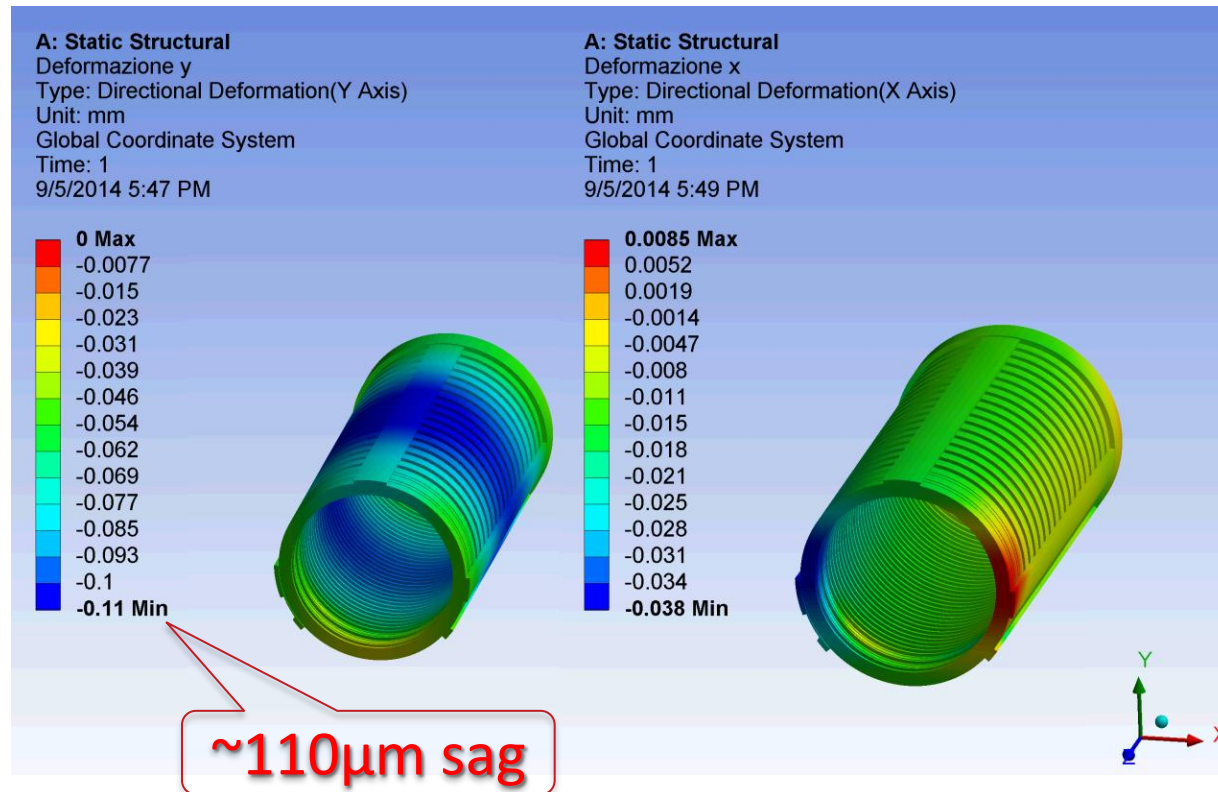




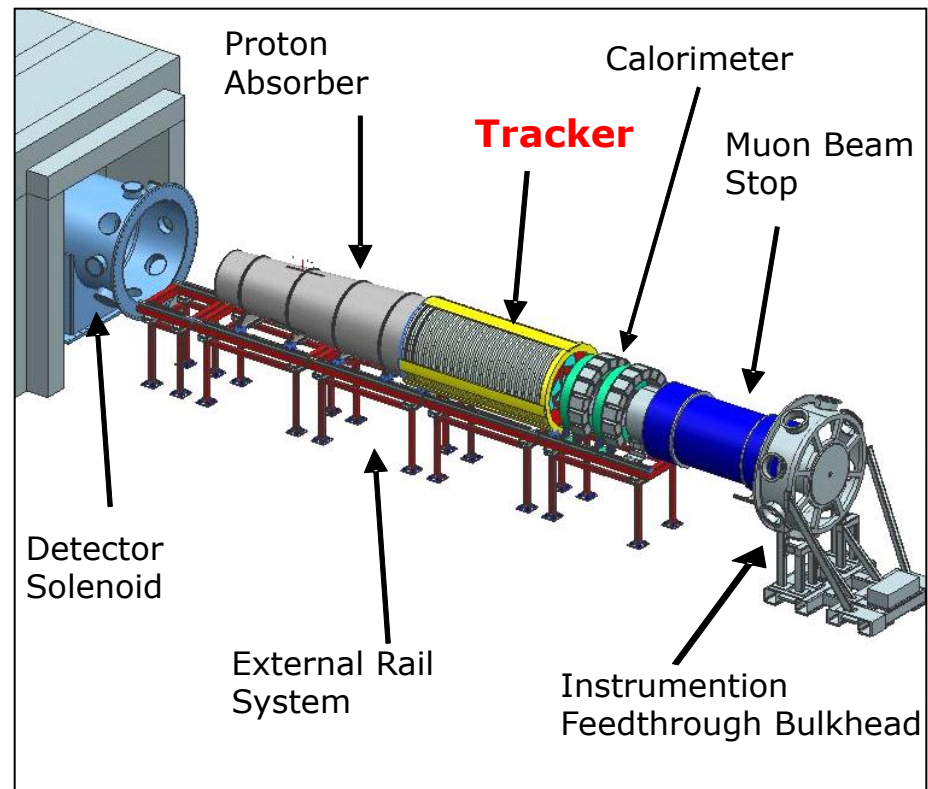
- L3 & CAM: A. Mukherjee (FNAL)
- Utilities run along support beams
- Cooling runs around each plane

Support Structure

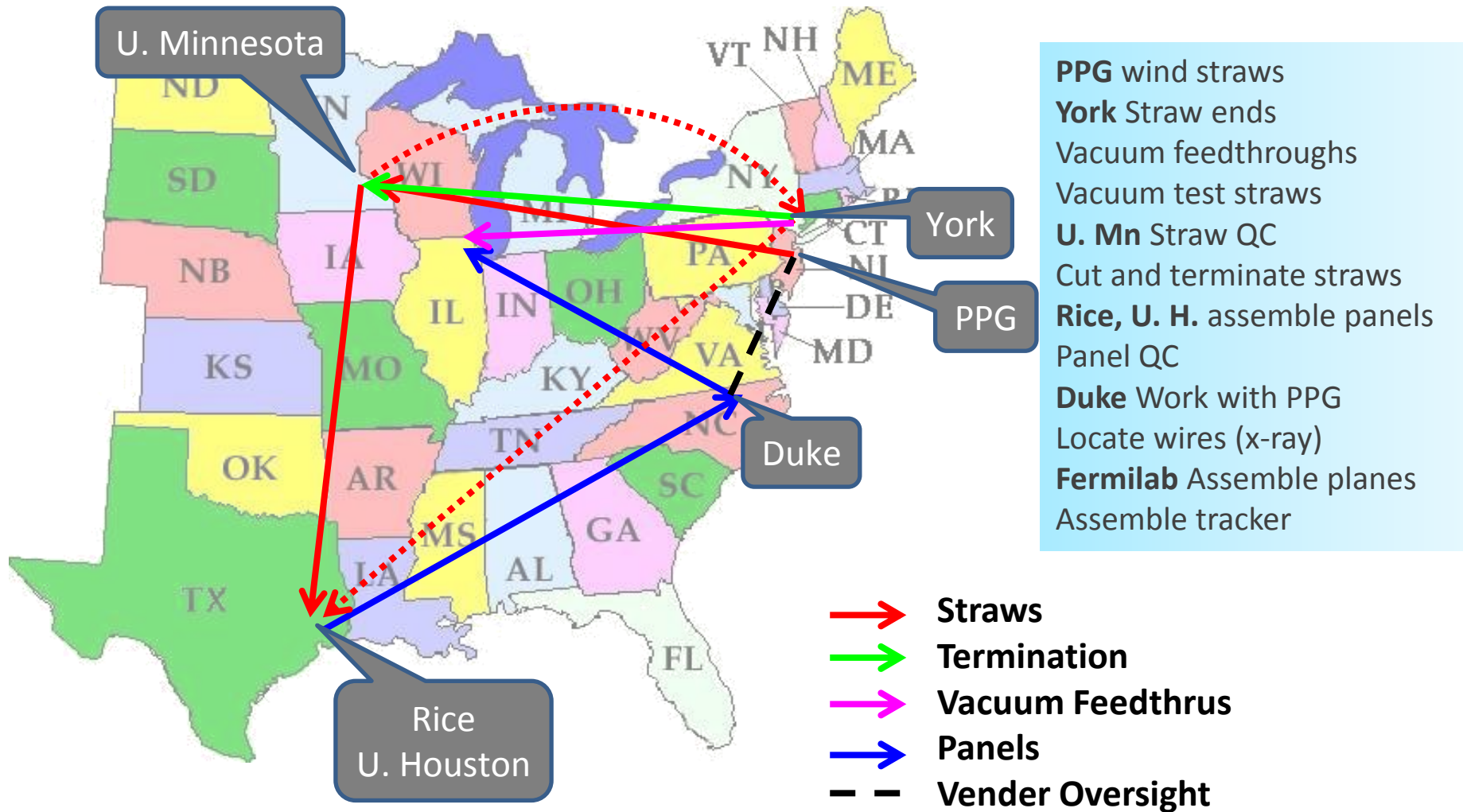
- Preliminary design complete
- All aluminum gives acceptable deflection (were considering stainless steel at CD1)



- L3 & CAM: A. Mukherjee (FNAL)
- Work with muon beamline (475.05) to install detector on rails
- Post-installation optical survey
- Route cables through DS
- Test connections



Parts Flow



Improvements Since CD-1

- Composite gas manifold using 3D printing technology
 - Lower cost than drilling holes in metal
 - Insulating... don't need to add Kapton sleeves
 - Special features can be added at no added cost
 - Simplify preamp connection
 - Build in epoxy application features
- Digitizers with all off-the-shelf parts
- All-aluminum support structure
- More details in breakout talks

Integration and Interfaces

- External Interfaces
 - Muon Beamline
 - Conventional Construction
 - Calorimeter
 - DAQ
- Internal Interfaces
 - Straws \leftrightarrow FEE, Straw Assemblies
 - FEE, Straw Assemblies \leftrightarrow Infrastructure
 - Straw Assemblies, Infrastructure \leftrightarrow Installation
- Documented in docdb-1562 and 3545
- Participation in bi-weekly integration meetings
- Formal sign-off between owners of all external interfaces as part of final design requirements
- Interfaces understood and under control.

Quality Assurance

- Straw material tested by supplier for conductivity and adhesion of metal to Mylar[®]
- 100% testing of straws for leak rate and electrical conductivity before being assembled into panels
- Tension measurement of straws and wires during panel assembly and before panels are assembled into planes
- X-ray scan of wire positions within panel
- Vacuum testing of panels before assembly into planes
- Work in progress on database, bar coding, etc.

Risks and Opportunities

- 10 current risks in risk registry
 - 8 threats, all mitigated to the extent possible
 - 2 Very Low probability
 - 4 Low probability
 - 2 Medium probability
 - 2 opportunities
 - 1 Medium probability
 - 1 High probability
- Detailed mitigation plans documented and linked from Risk Register (docdb-4320)
- All risks understood and under control

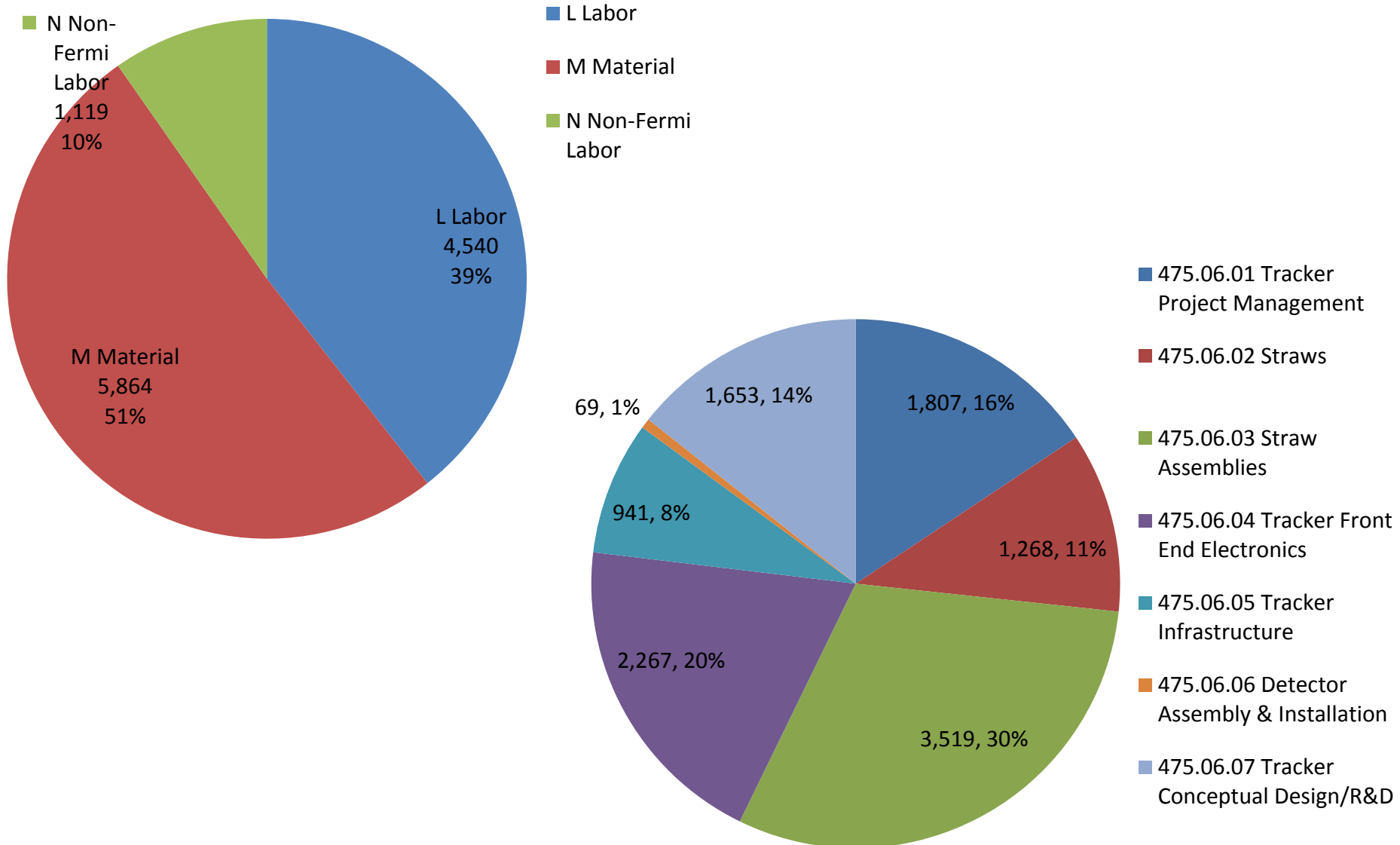
- X-ray machine at Duke
 - Procedures in place from ATLAS TRT construction
- Gas (Ar:CO₂) is non-flammable and non-toxic. Tracker volume less than one compressed gas cylinder.
- Radioactive sources are widely used at Fermilab. All applicable safety rules will be followed.
- High voltage is moderate by Fermilab standards: 1500V, <1mA and ~10mJ stored energy on any one line
- Power is from 48V supplies which have passive (limited capacity) and active (monitor and trip) current limit
- No unusual toxic or hazardous materials used
 - Extensive experience with epoxy at all participating institutions

Cost Table

	Base Cost (AY K\$)			Estimate Uncertainty (on remaining costs)	% Contingency on ETC	Total Cost
	M&S	Labor	Total			
475.06 Tracker						
475.06.01 Tracker Project Management	28	1,779	1,807	250	20%	2,057
475.06.02 Straws	1,200	69	1,268	429	38%	1,697
475.06.03 Straw Assemblies	2,708	811	3,519	1,493	47%	5,012
475.06.04 Tracker Front End Electronics	1,676	591	2,267	643	32%	2,910
475.06.05 Tracker Infrastructure	374	567	941	352	38%	1,293
475.06.06 Detector Assembly & Installation		70	69	37	53%	106
475.06.07 Tracker Conceptual Design/R&D	999	654	1,653			1,653
475.06.99 Risk Based Contingency				556	-	556
Grand Total	6,983	4,540	11,523	3,760	44%	15,283

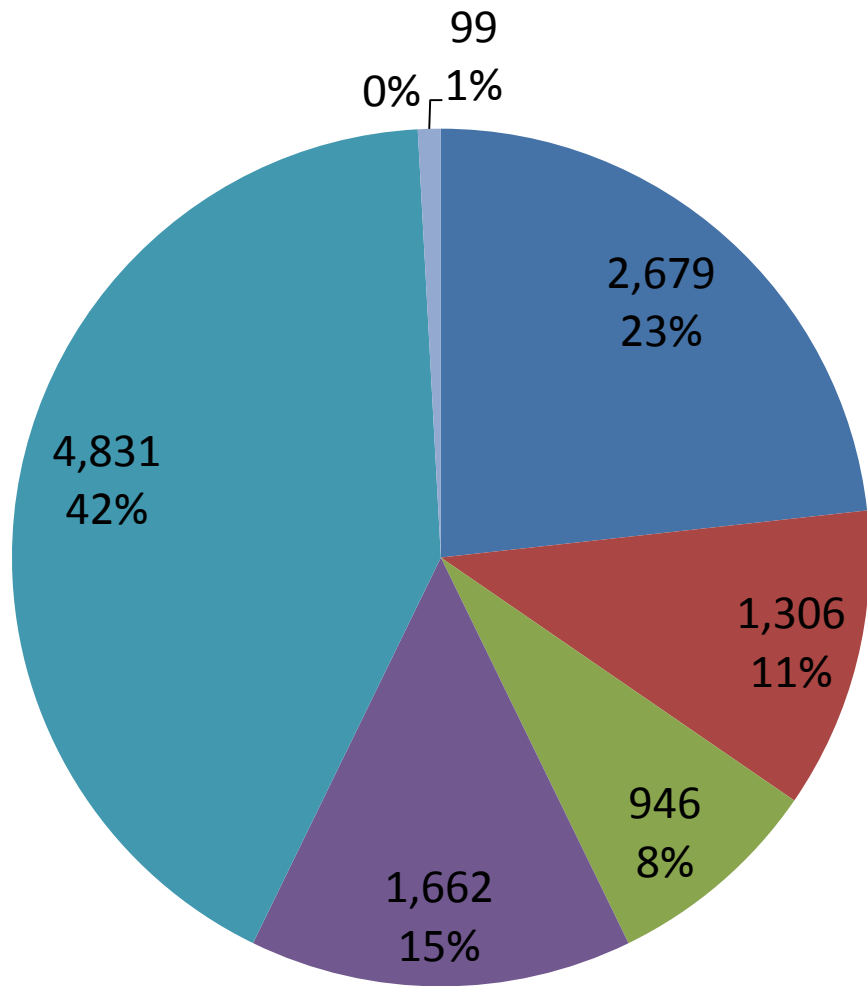
Cost Breakdown

Base Cost AY K\$



Quality of Estimate

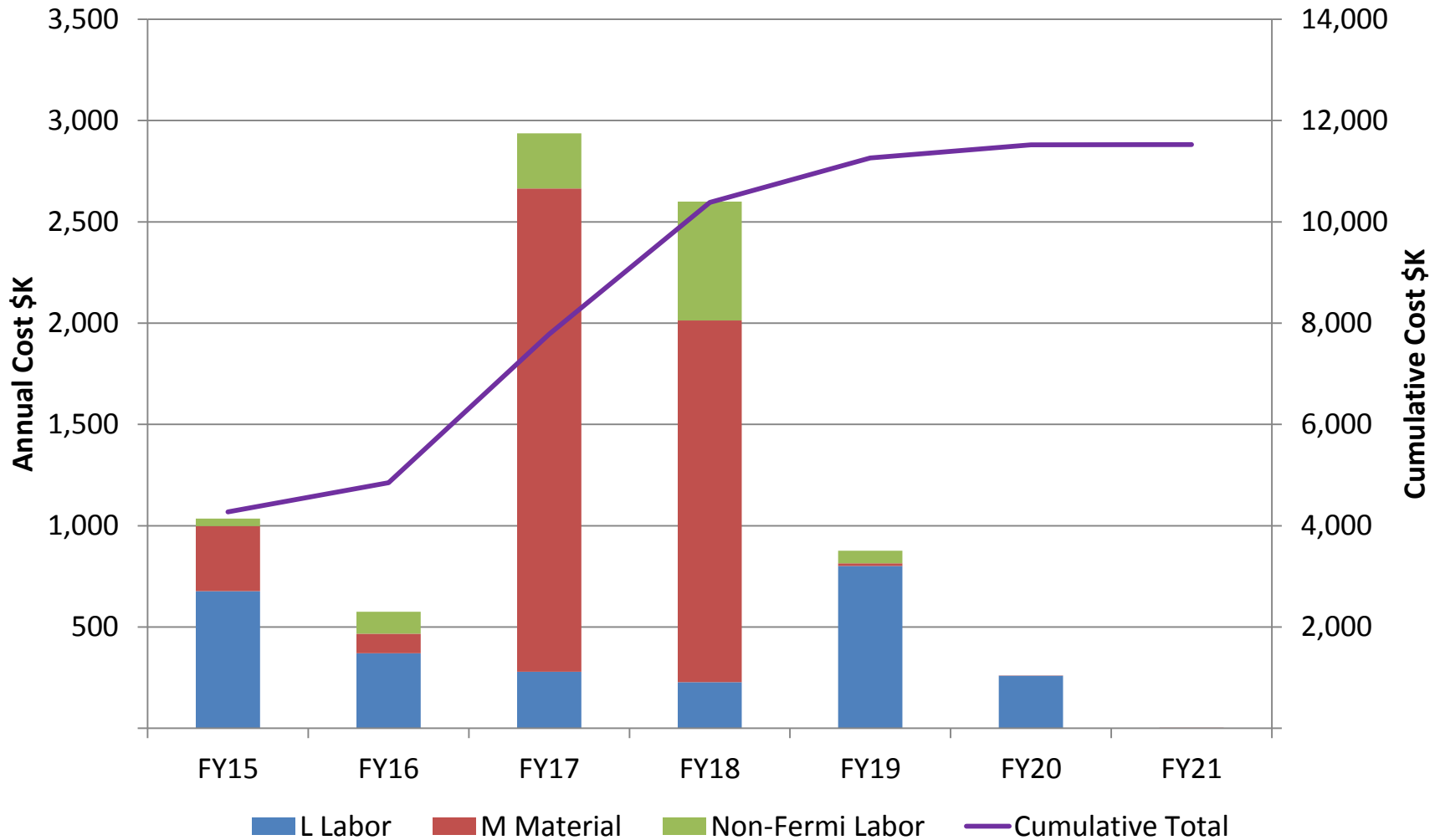
Base Cost AY K\$



- L1 Actual / M1 Existing P.O.
- L2 LOE Task / M2 Procurements for LOE/Oversight Work
- L3 / M3 Advanced
- L4 / M4 Preliminary
- L5 / M5 Conceptual
- L6 / M6 Pre-Conceptual
- L7 / M7 Rough Estimate Pre-Conceptual - Uncommon Work

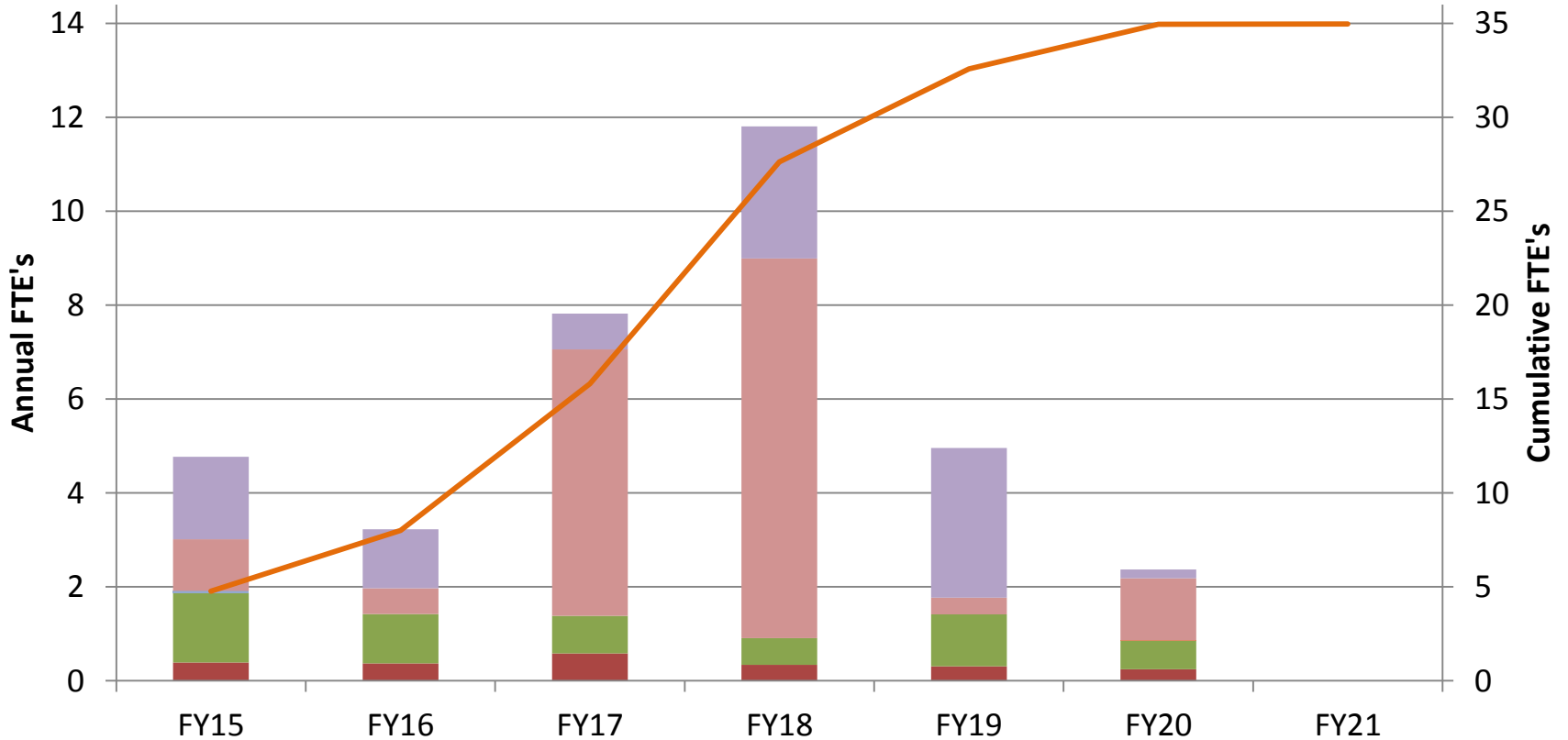
Labor & Material by FY

Base Cost AY K\$



Labor Resources by FY

FTEs by Discipline



- AD Administrative
- FM Facilities Management
- TE Technical

- EN Engineering
- IT Information Technology
- Cumulative

- ES Environmental, Safety & Health
- SC Scientific

Milestones

L4 and L5 with **corrections** that were not noticed in time for this review

7/20/15 Single Panel Prototype Evaluation Complete (formerly said “Plane”)

10/1/16 Single Plane Prototype Evaluation Complete

6/5/17 Production Straws ready for assembly

6/13/17 LV power supplies received

7/13/17 Production preamps tested

10/30/17 All panels complete and tested

5/23/18 Straw Assemblies Complete

7/6/18 LV System installed

7/20/18 Cooling system installed and tested

7/24/18 Gas System Installed and Tested

8/31/18 HV system installed

2/25/19 Electronic Installation Complete

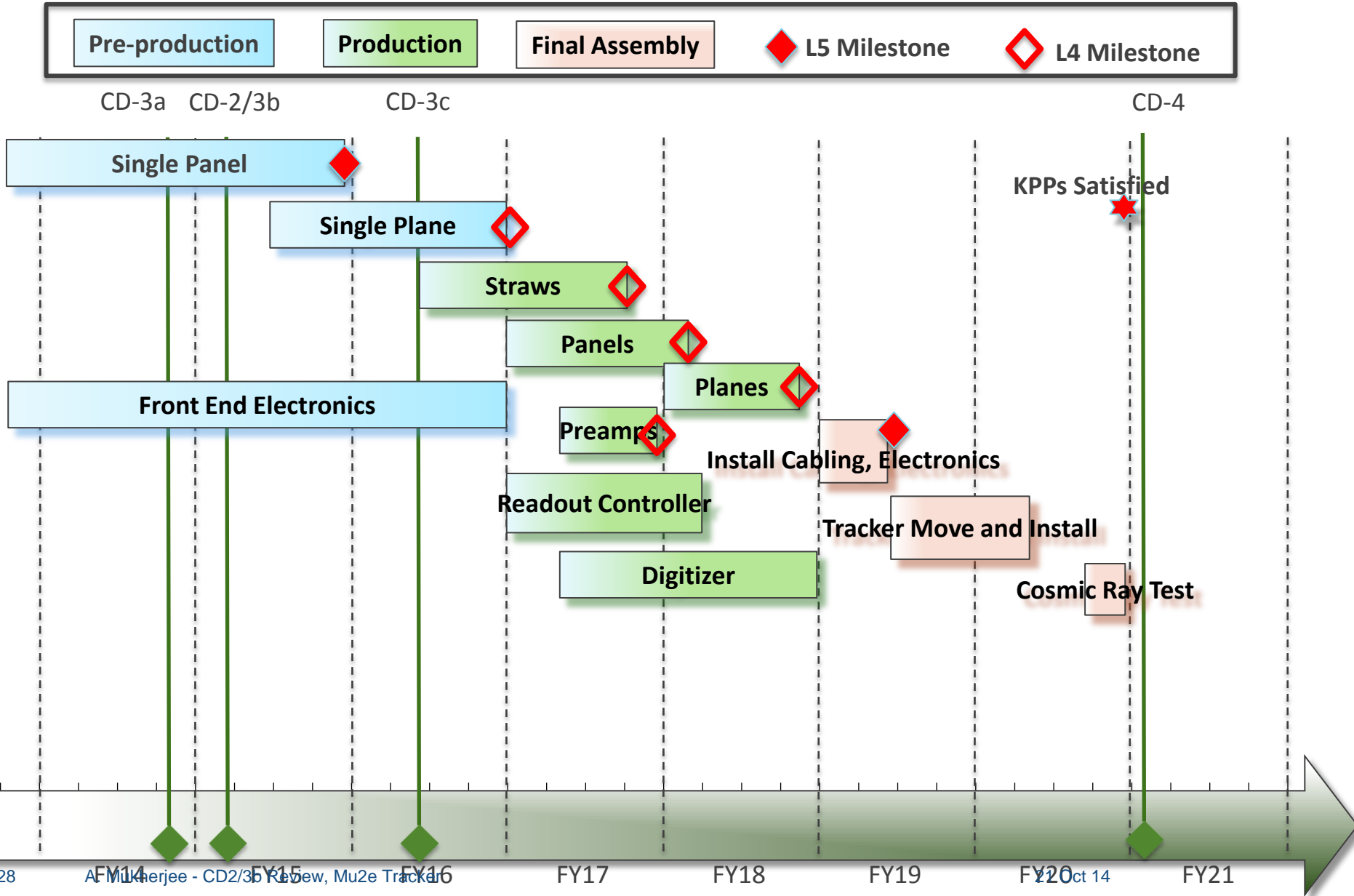
2/25/19 Implementation Tasks Complete

(Ready for Verification that Key Performance Criteria are met)

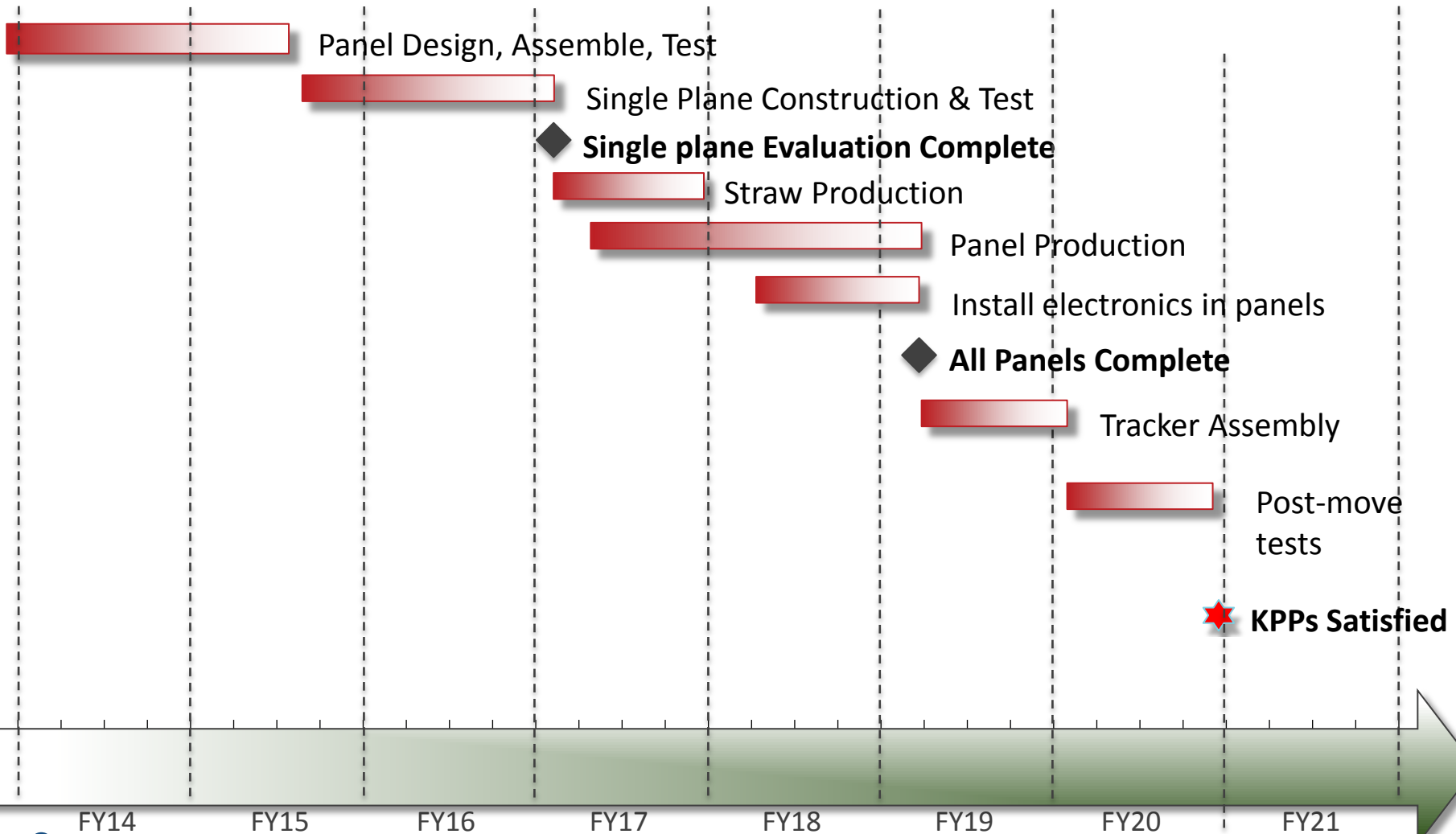
4/10/20 Ready for Cosmic Ray Test

10/15/20 Ready for Operations

Schedule



Critical Path



Summary

- Design satisfies requirements: resolution, efficiency, and reliability
- Cost estimates complete
 - 99% is at Conceptual or higher
 - 57% is at Preliminary or higher
 - Risks are understood and mitigated to the extent possible
- Interfaces have been identified and defined
- Needed resources identified, within Fermilab and from collaborating institutions
- ES&H incorporated into the plans

Tracker is ready for CD-2