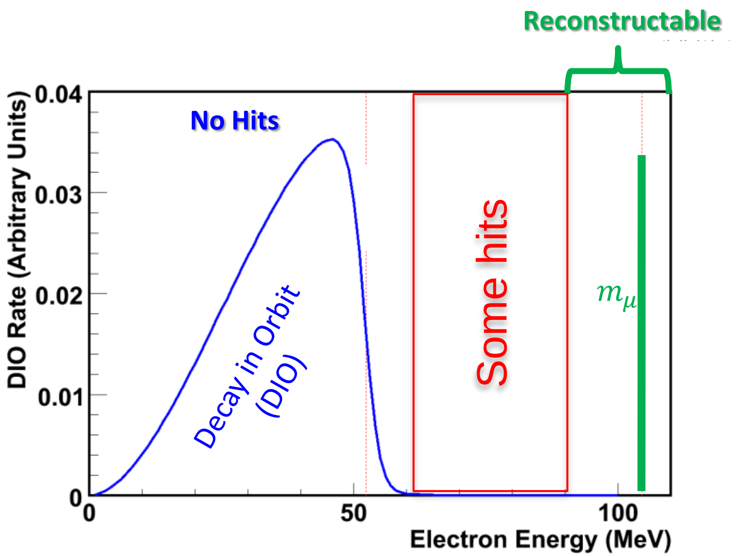
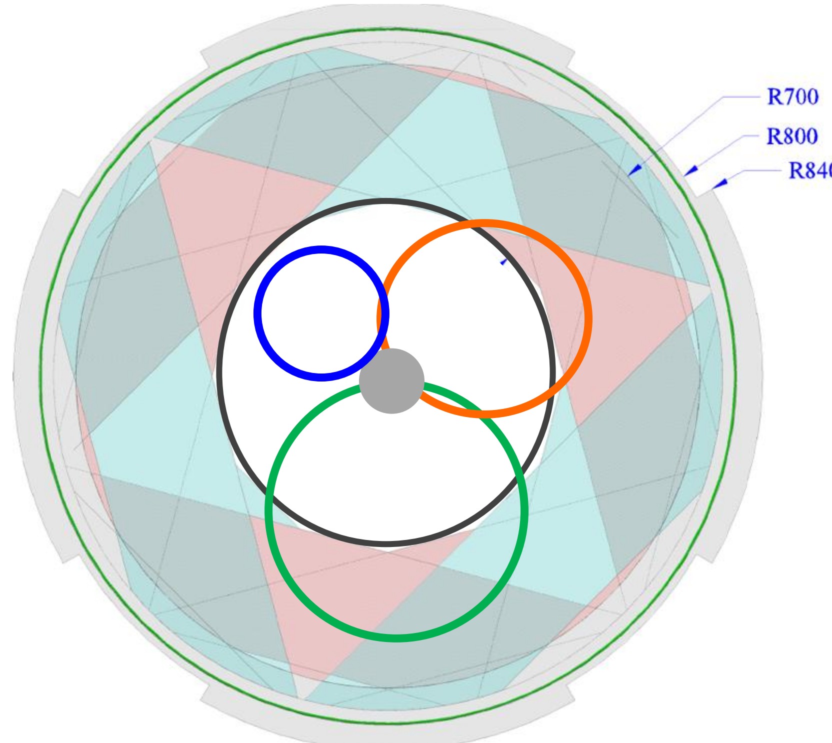
Mu2e Tracker

Aseet Mukherjee
Tracker L2 Manager
7/8/2014

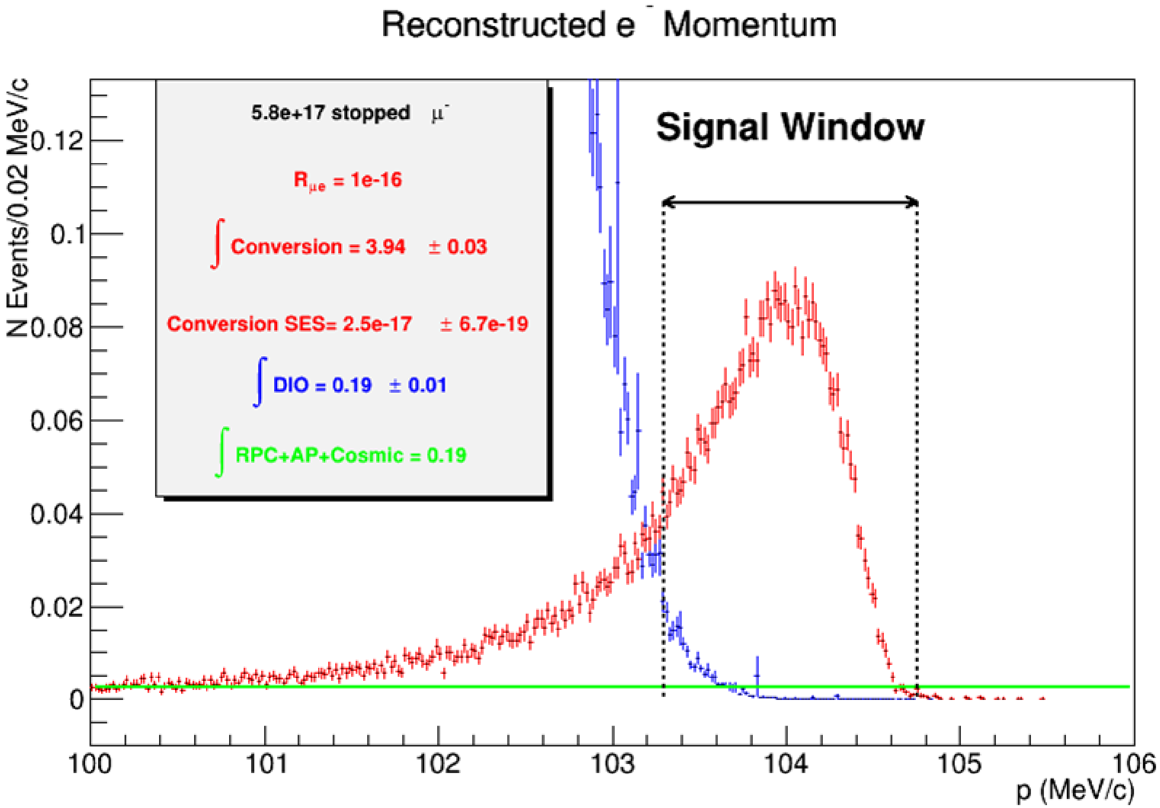
Requirements





- Blind to DIO
  - **r<380mm:** "No" mass (vacuum)
  - **380<r<700mm:** Low mass detector
  - **r>700mm:** Support structure

Requirements

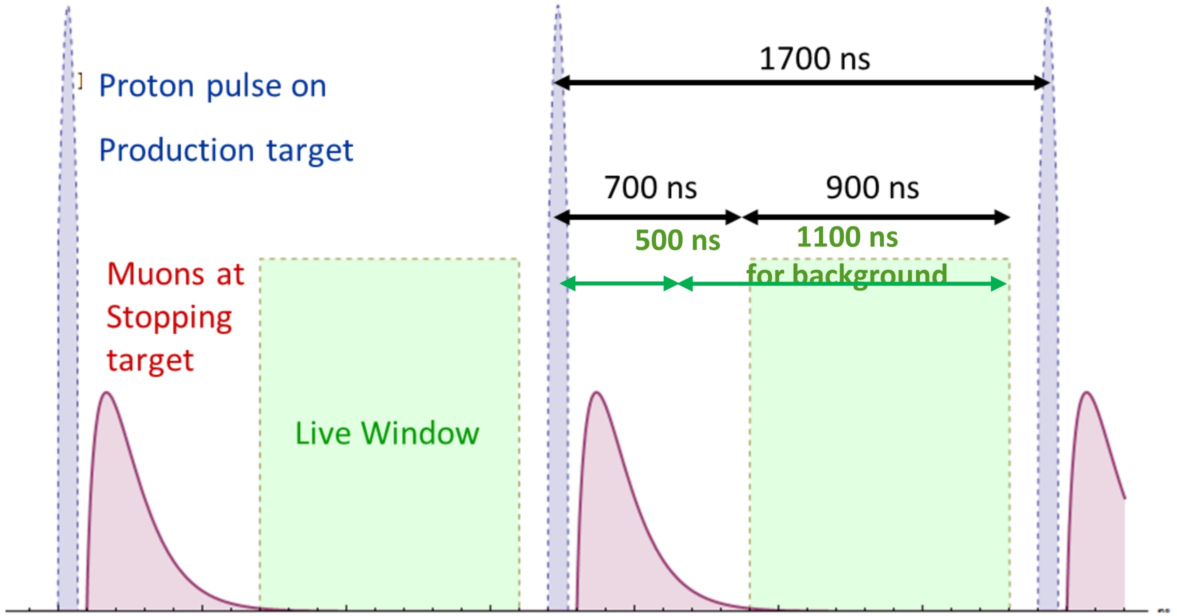


- Resolution

Tails matter, but using simple Gaussian

σ<180 keV/c at 105 MeV/c

Requirements



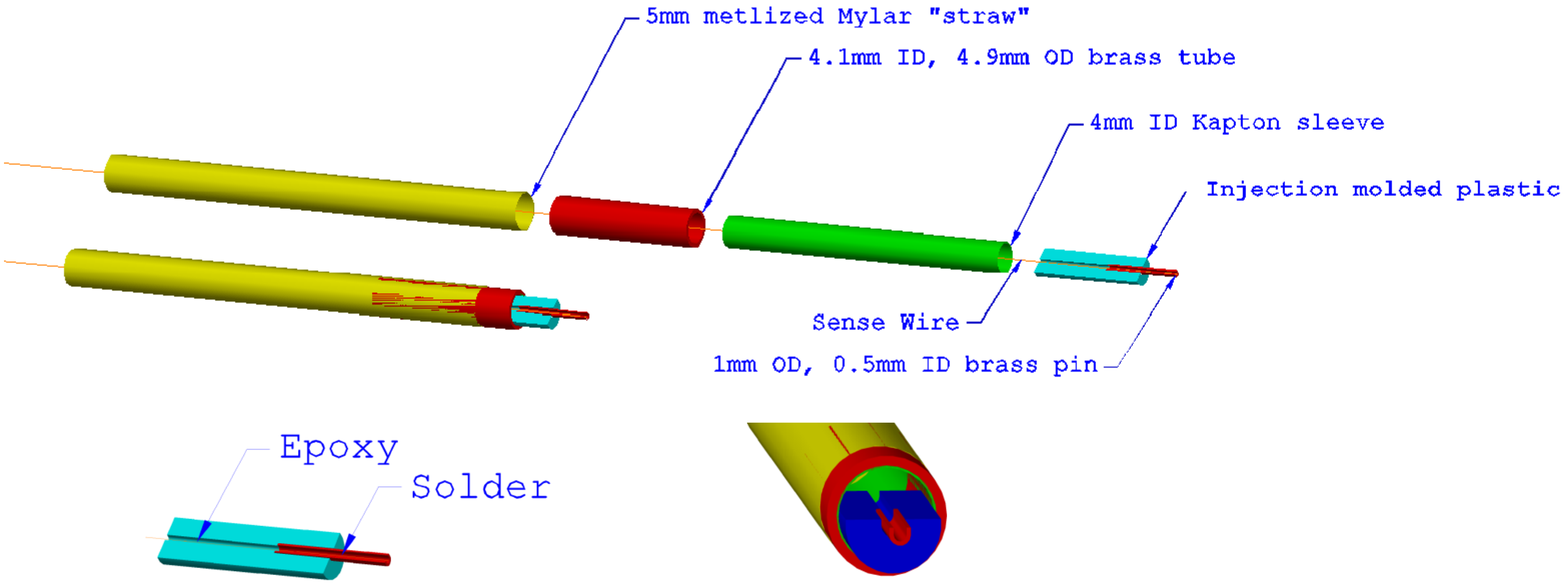
- Timing
  - Take data 500ns after proton pulse at full intensity. *Highest rate straws: 5 MHz (average over livetime)*
  - 300ns after proton pulse at reduced intensity for calibration

Requirements

- Particle ID
  - dE/dx (pulse height) for p/e separation per hit
- Reliability
  - Operate in ambient vacuum
  - Leak rate <7 ccm

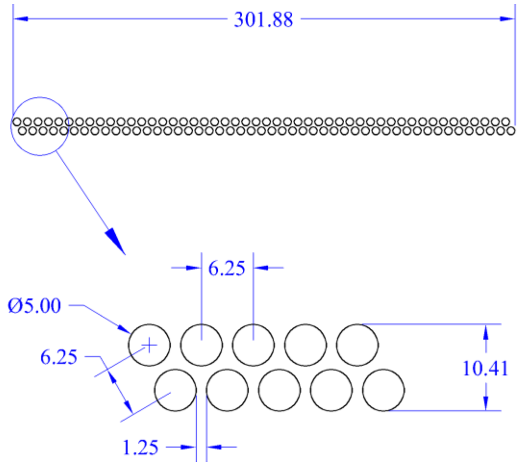
More complete requirements found in document 732

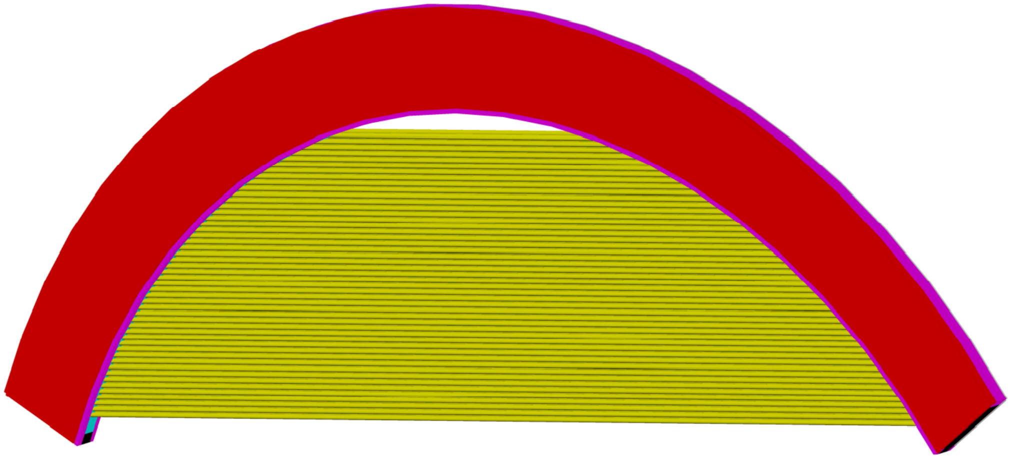
Design: Straw



- 5 mm OD metalized Mylar® straws, 15µm wall
  - Mylar for higher yield and modulus (compared to Kapton)
  - Aluminum on inner and outer surface
  - Gold on inner surface
- 25 µm gold plated tungsten sense wire

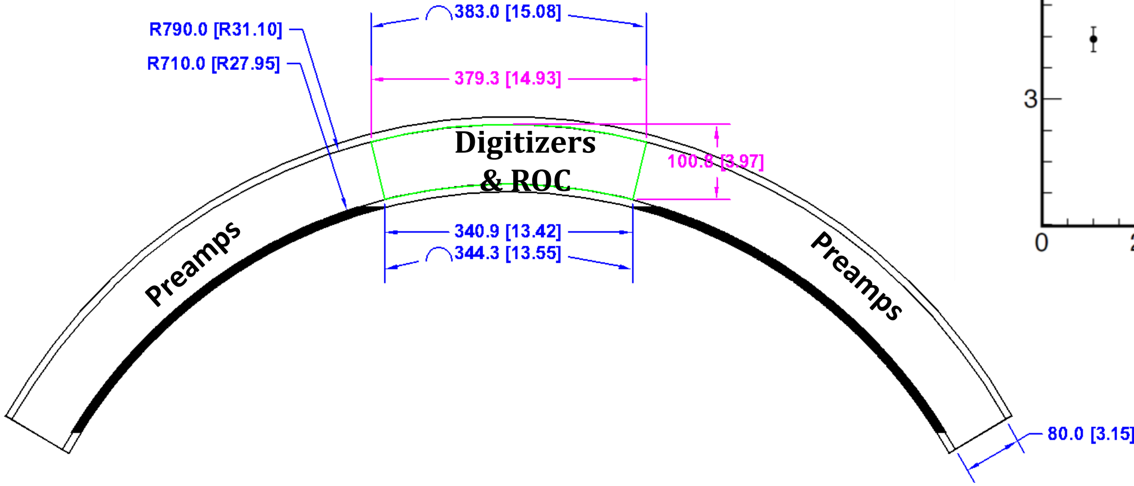
Design: Panel

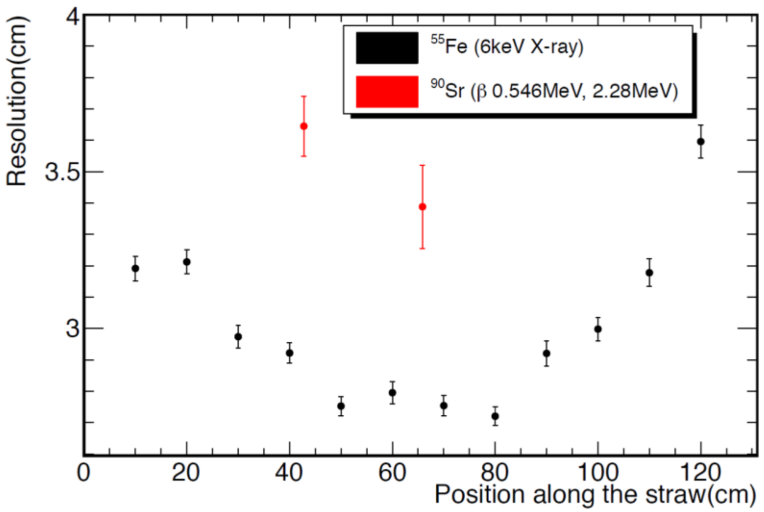




- 96 straws of varying length form a ***panel***
  - Staggered pattern to improve efficiency and left/right ambiguity resolution
  - Gap between straws to allow for expansion
- Panel frame encloses front end electronics

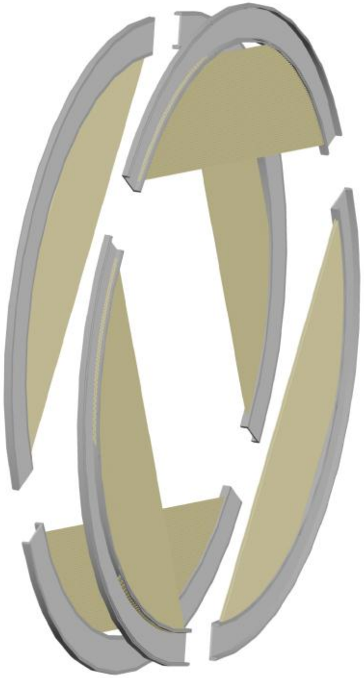
Design: Panel

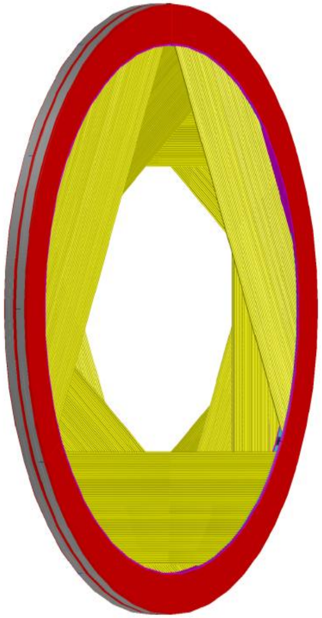




- Panel structure encloses front end electronics
- O-ring and screwed-down cover for gas seal
- Read out straws from both ends for time division
  Measure position along wire by propagation time

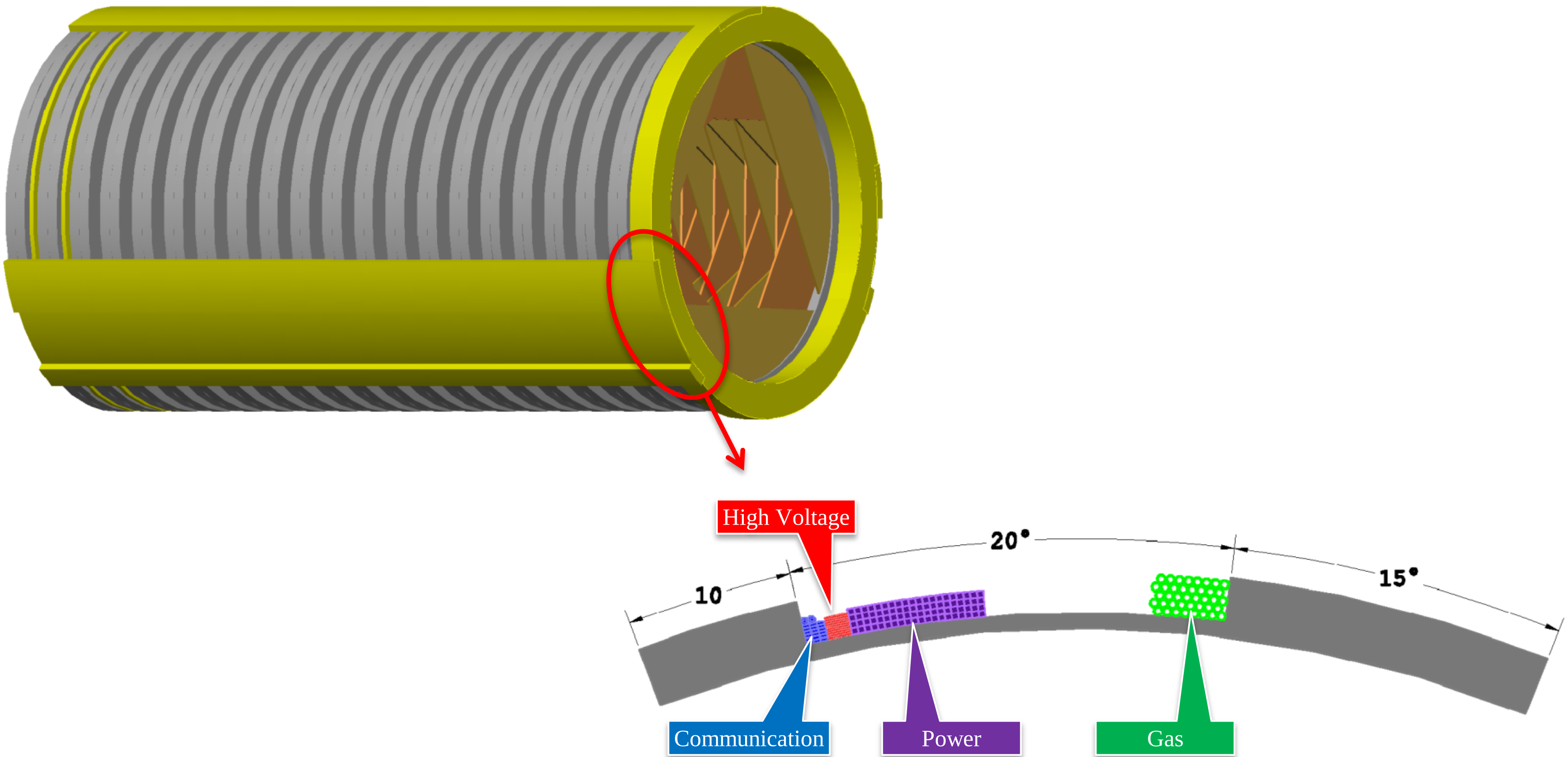
Design: Plane, Station





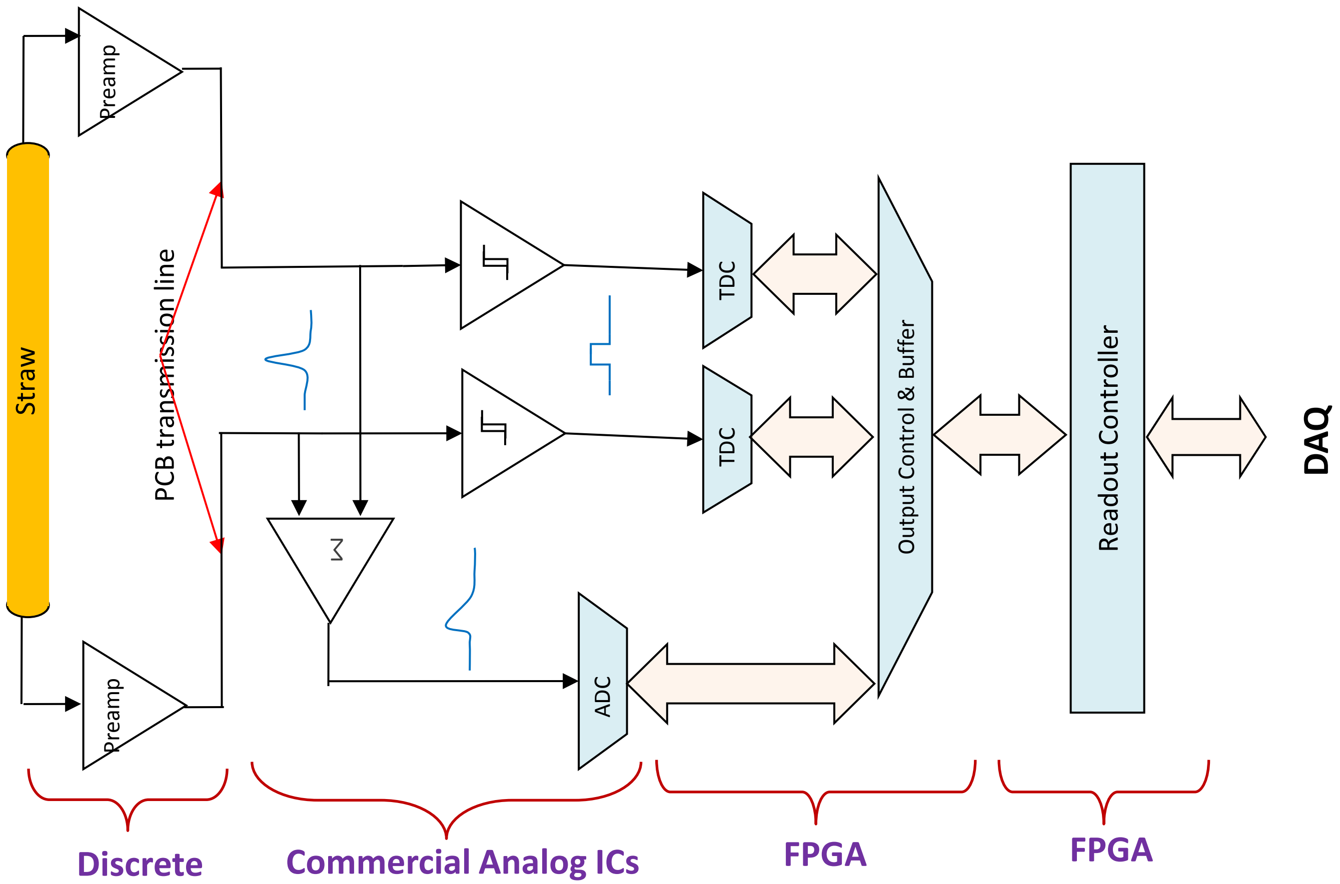
- 6 panels form a self supporting ring called a plane
  - 30º rotation between sides for stereo and for mechanical strength
- Two planes, with a small gap, form a station

Design: Full Tracker



- 20 stations with horizontal support beams form the tracker
- Support beams also carry utilities

Design: Readout



Material and Work Flow

1. Material from Sheldahl to PPG.
   Winding done by PPG
2. Straws from PPG to York
   Test, cut, terminate
3. Straws from PPG & Gas manifold parts from Fermilab to Rice.
   Rice & U. Houston Assemble panels
4. Completed panels to Duke
   Wire position scan
5. Panels sent to Fermilab
   Assemble Tracker

Changes since CD-1

- Expanded radially from 800 to 810mm
  - Span of gas manifold goes from 100 to 110mm
    - Thicker support elements
    - Can use lower cost aluminum and plastic
  - Increased space for electronics
- Panel construction
  - Combine aluminum, stainless steel, and 3D printed plastic to reduce cost
- Plane Construction
  - Found 30º rotation gives improved stereo performance

Changes since CD-1

- Number of stations
  - Found 20 stations gives excellent performance
- 3 beam support (was 4)
  - All cabling, gas… on lower beams
  - Allows easier removal of planes for repair
- Revised stiffener ring geometry to leave more room for calorimeter
- Front End Electronics
  - Commercial, off the shelf components

Value Engineering since CD-1

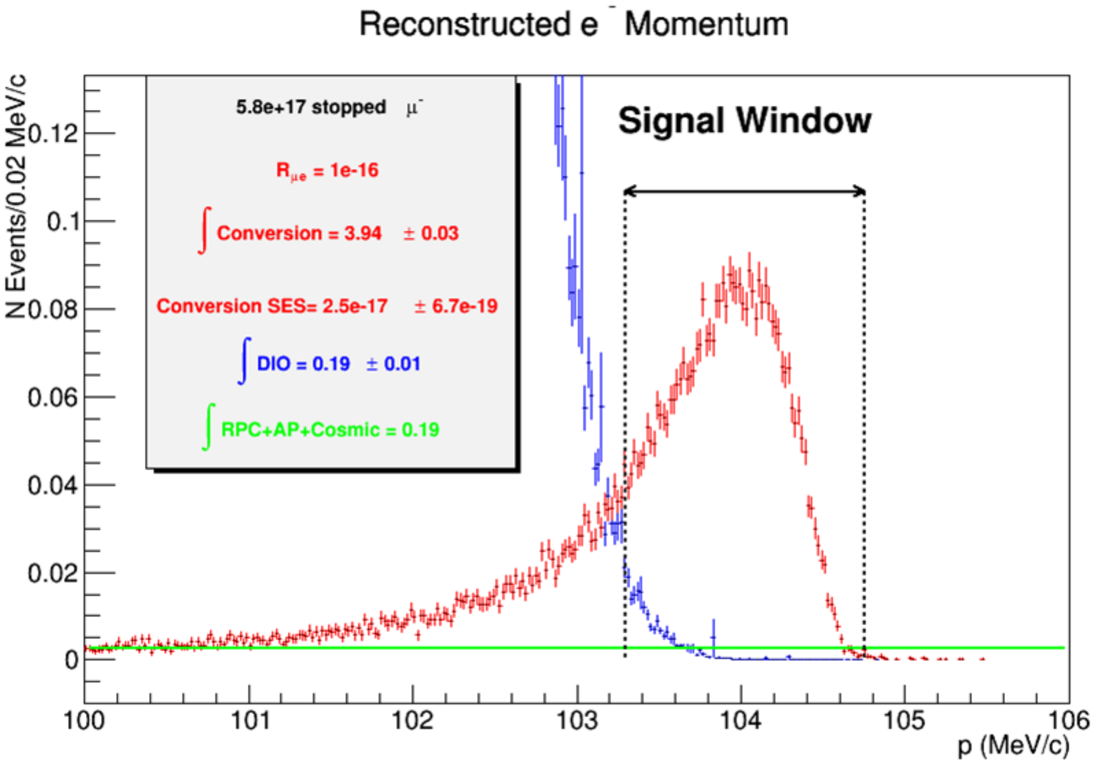
- Most changes since CD-1 are part of value engineering
  - Panel Frame Construction
  - Number of Stations
  - Front end electronics

Downselects

- Front end 100% COTS (no ASIC)
  - Reduces schedule uncertainty
  - Lower contingency
  - Greater benefits from Moore's Law

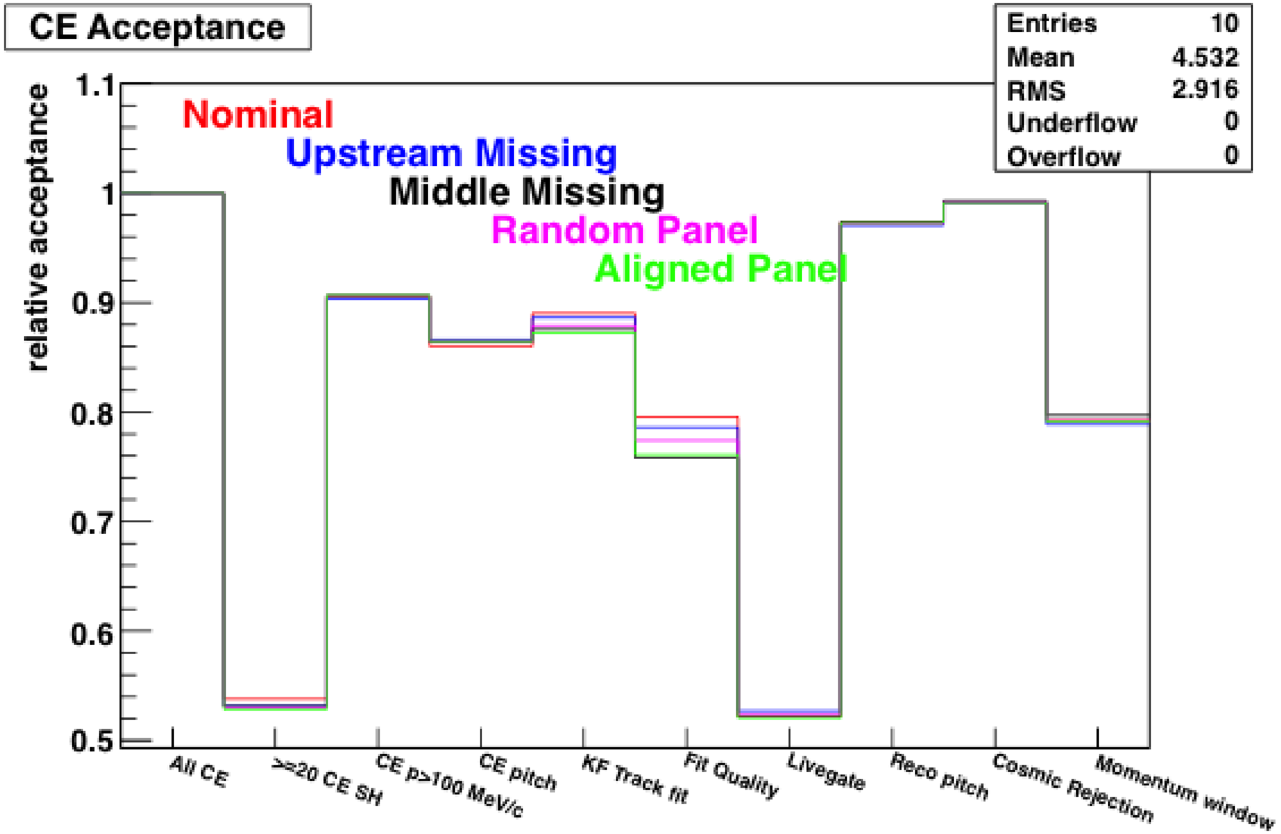
Performance

- Resolution
  - Meets the simple Gaussian approximation requirement on σ
  - Meets the SES requirement



Performance

- Robustness
  - Functions with good efficiency and resolution with ~1000 dead straws



Remaining work before CD-3

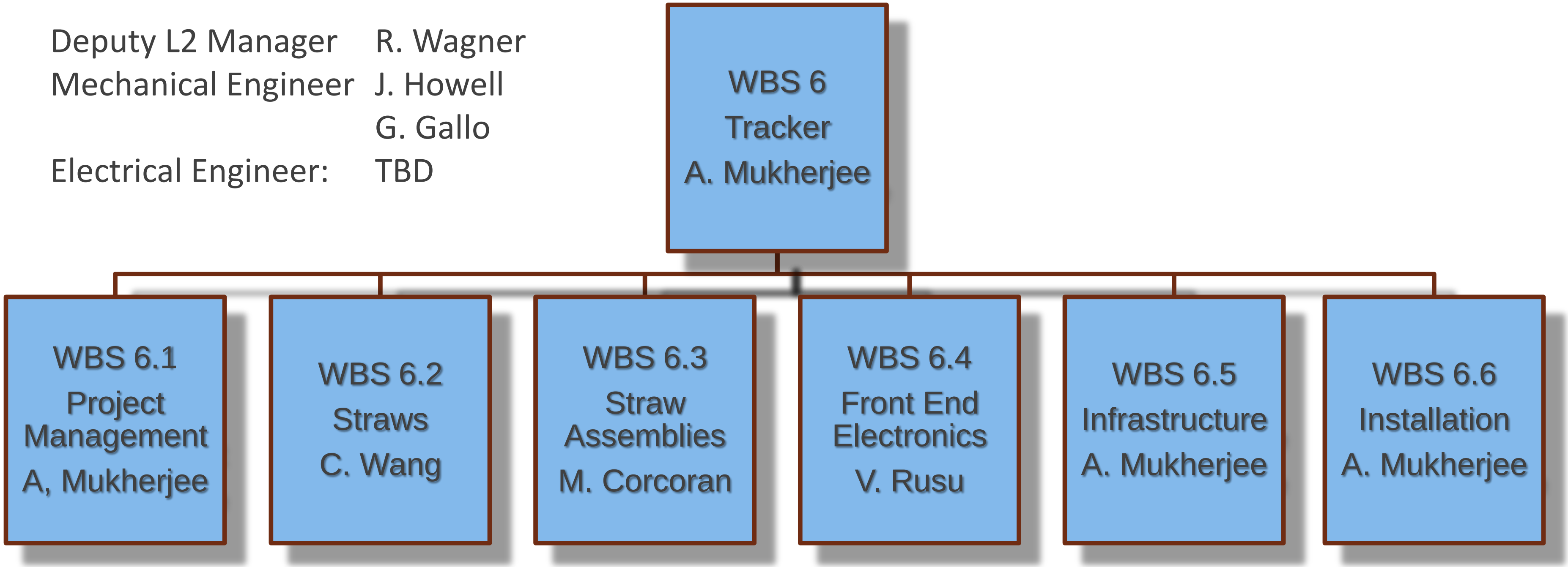
- Complete and test 1st panel
  - All metal frame
  - Testing includes operating in vacuum
  - Define parameters to enter into QC database
  - Test bed for electronics
- Complete and test 2nd panel
  - Composite frame
  - Refine parameters to enter into QC database
- Complete and test 1st plane
  - 6 panels
  - Refine assembly procedure
  - Test for ground loop or other coherent noise issues

Remaining work before CD-3

- Design assembly fixtures
  - Panels to plane
  - Planes into full tracker
- Refine survey and installation
- Test outgassing from cabling, including optical fibers
- Test for electrical breakdown around Townsend regime

Organizational Breakdown

Deputy L2 Manager R. Wagner
Mechanical Engineer J. Howell
G. Gallo
Electrical Engineer: TBD



Quality Assurance

- **Single Straws.** Each straw remains in a bar-coded storage tube from the first test till it is installed in a panel
  - Leak test each straw
    May switch to spot-checking if failure rate remains very low
  - End-to-end resistance check
  - Record straw and wire tension over time
- **Panel.** Each panel is bar-coded.
  - Locate all wires relative to survey monuments using X-ray
  - Leak test all panels
    May test in batches – multiple panels in vacuum vessel – if failure rate is low
- **Completed Tracker**
  - Optical survey of panel positions

Quality Assurance

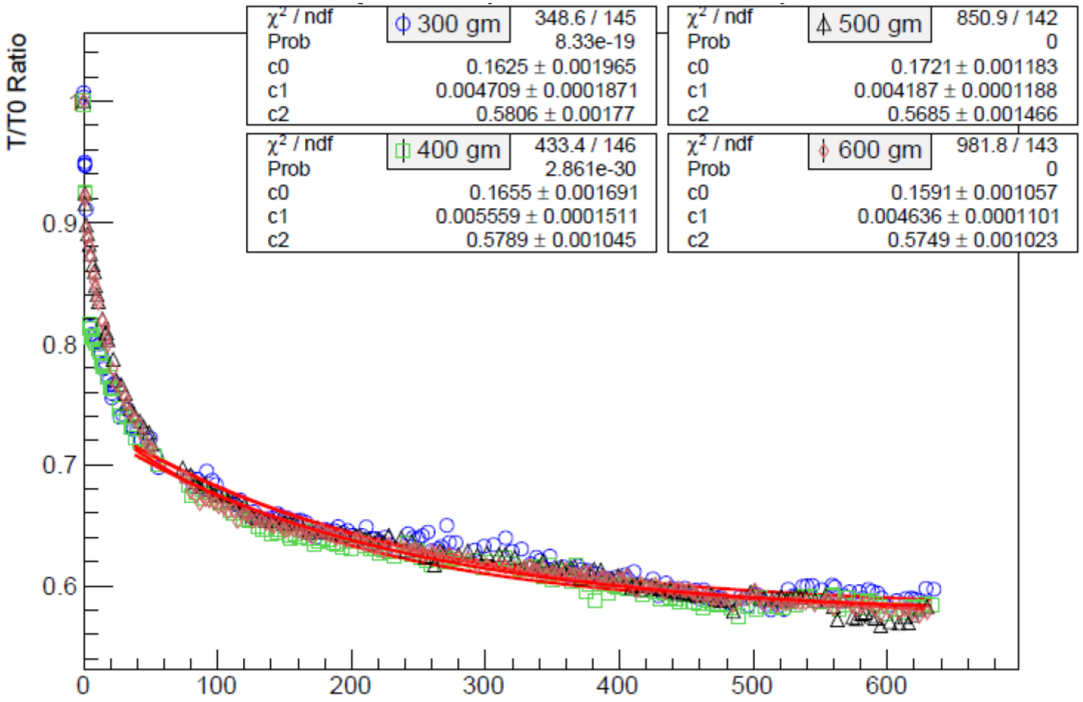
- **Preamps**
  - Bench test with pulser and high voltage
  - Test HV disconnect circuit on subset
    Destructive to disconnect… needs repair after test
- **Digitizers & ROC**
  - Bench test with pulser and built-in pattern generators
- **Monitoring**
  - Pressure and multiple temperature monitors in each panel
  - Precision electronic level and Hall probes to monitor detector orientation

Risks

- TRACK-097 Catastrophic Failure
  - Probability: Very low
  - Impact: High, on cost and schedule
  - Mitigation
    - Natural disaster (flood, fire, tornado, …): None
    - Over-pressure: Multiple relief valves (or bubblers), segmentation of gas system (each station fed separately)
    - Over-heating: Multiple sensors and interlocks

Risks

- TRACK-139 Mylar Creep
  - Probability: Low
  - Impact: Medium, on cost, schedule, and performance
  - Mitigation: Add one or more intermediate supports
    Conceptual design exists, will pursue if ongoing tests indicate a problem



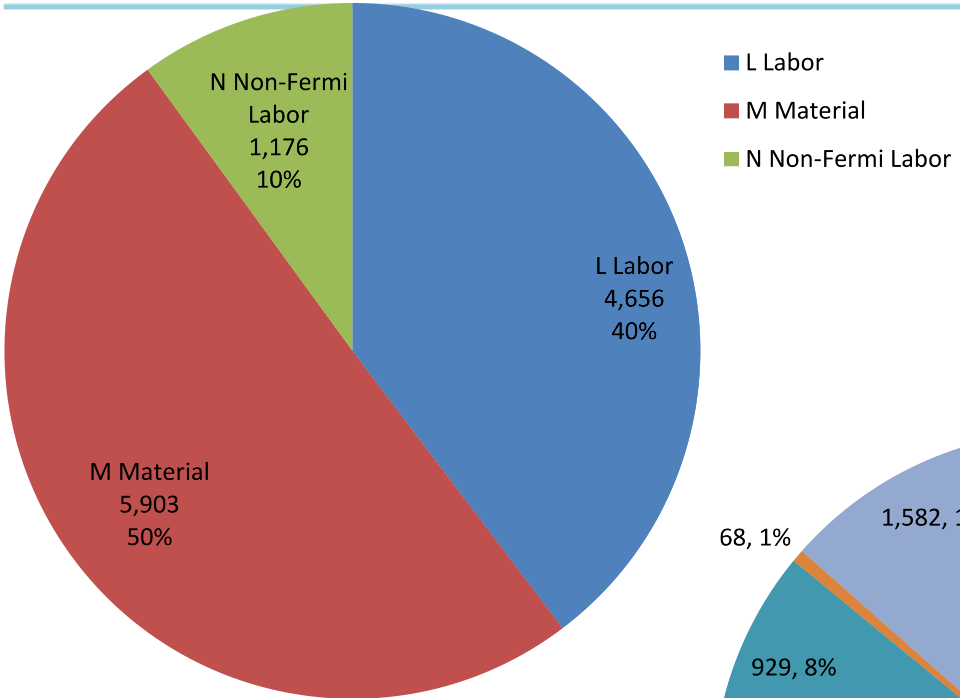
ES&H

- There are no unusual ES&H issues
  - Gas (Ar:CO_2) is non-flammable and non-toxic
  - Total detector gas volume is <1000L, less than a single compressed gas cylinder. Not a serious ODH issue.
  - 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 (bound on capacity) and active current limitation
  - No toxic or hazardous materials used
    - Epoxy is used but there is extensive experience with this at all participating institutions

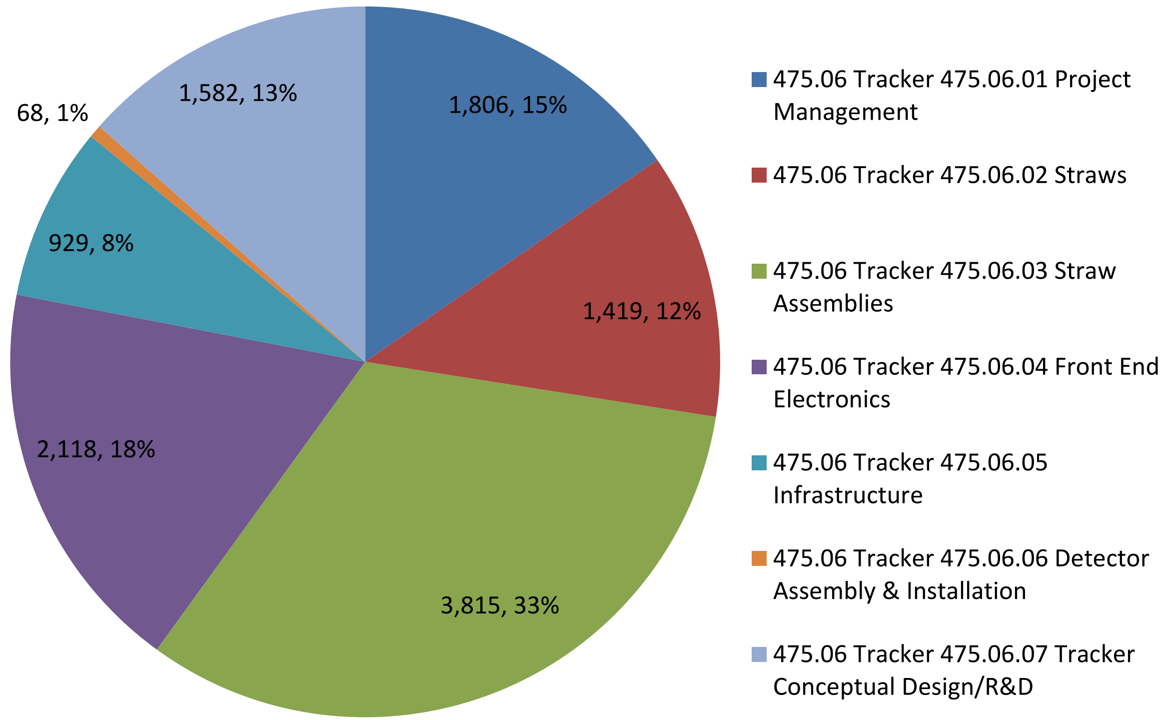
Cost Table

	Base Cost (AY k$)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining costs)	% Contingency on ETC	Total Cost
475.06 Tracker						
475.06.01 Project Management	21	1,785	1,806	253	19%	2,059
475.06.02 Straws	1,354	65	1,419	488	38%	1,908
475.06.03 Straw Assemblies	2,991	824	3,815	1,495	42%	5,310
475.06.04 Front End Electronics	1,414	703	2,118	641	33%	2,759
475.06.05 Infrastructure	372	557	929	347	38%	1,276
475.06.06 Detector Assembly & Installation		68	68	36	53%	104
475.06.07 Tracker Conceptual Design/R&D	928	654	1,582		0%	1,582
475.06.99 Risk Based Contingency				651		651
Grand Total	7,080	4,656	11,736	3,912	43%	15,648

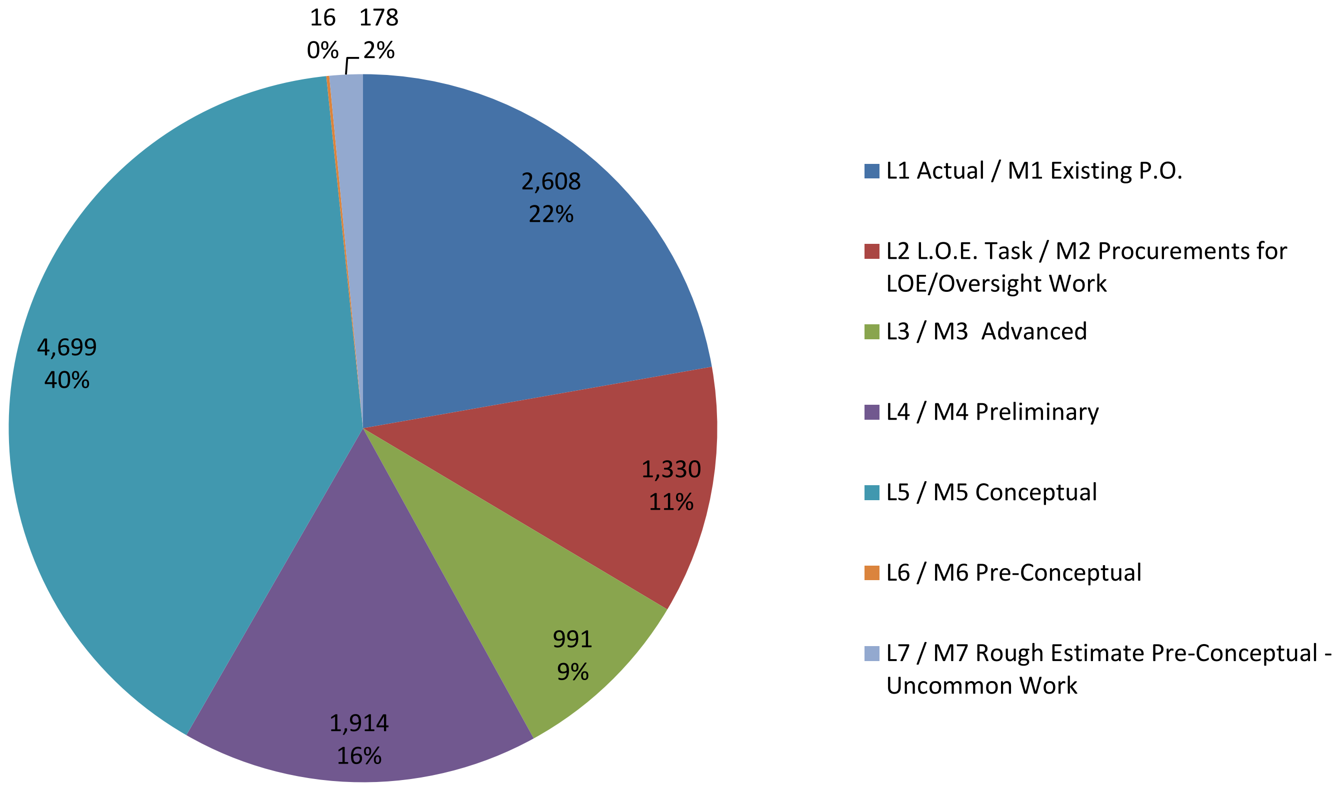
Cost Breakdown



AY K$

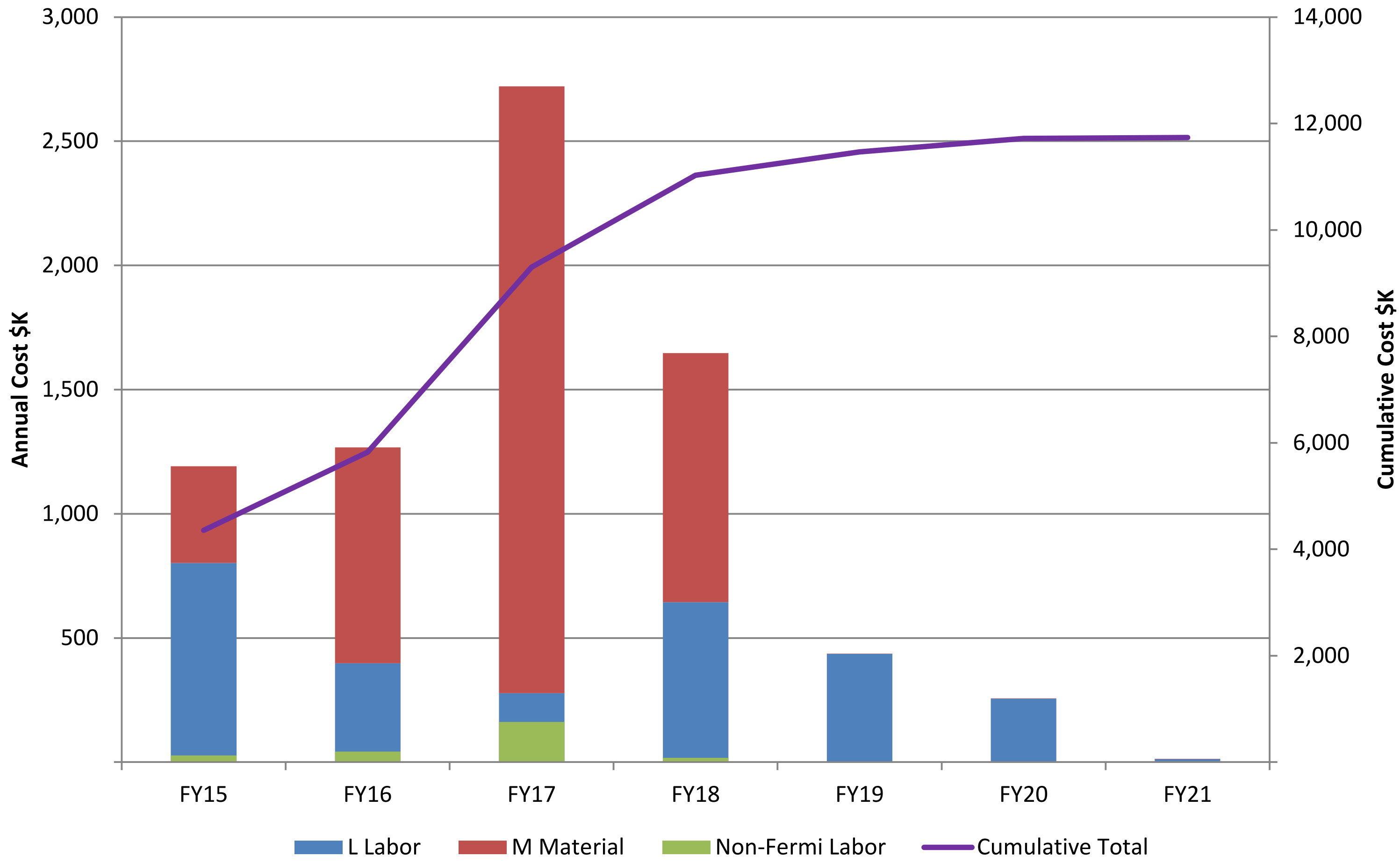


Quality of Estimate

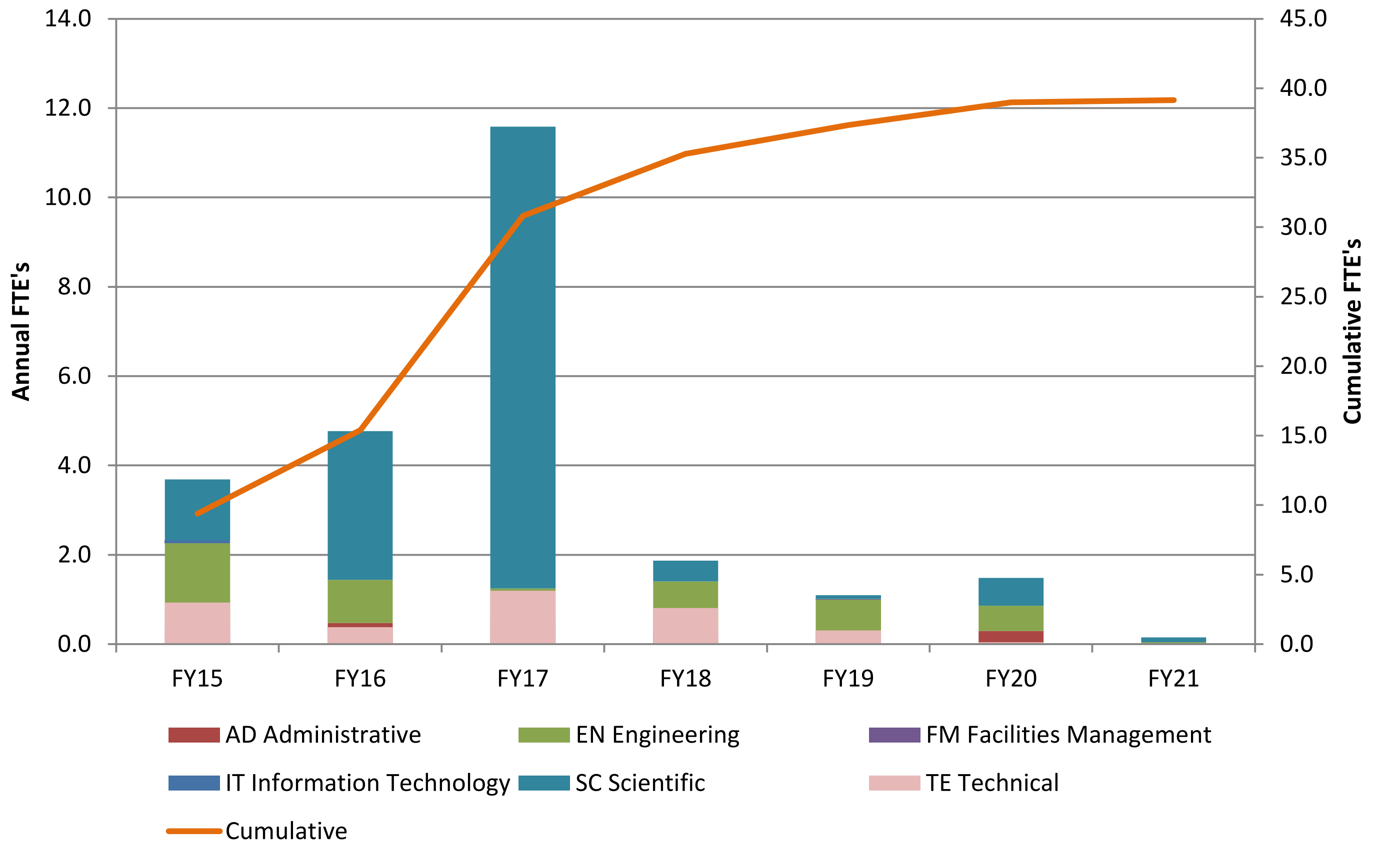


AY K$

Labor & Material by FY



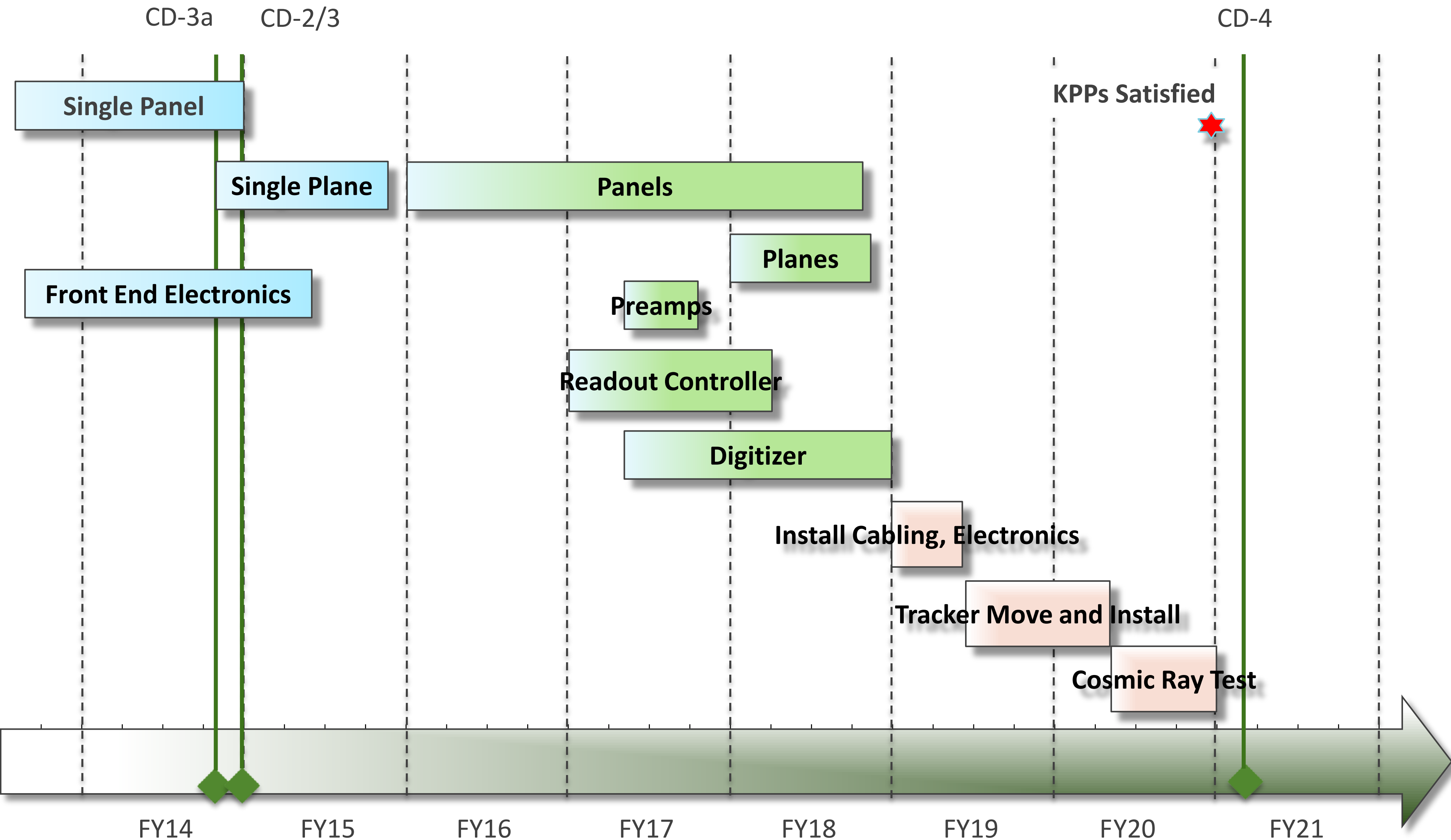
Labor Resources by FY



Major Milestones

- Single Panel prototype evaluation complete enough for TDR Chapter
- Single Plane Prototype Evaluation Complete
- Final Design Tasks Complete
- Implementation Tasks Complete (Ready for Verification that KPP are met)
- Ready for Operations

Schedule


CD-3a
CD-2/3
CD-4
KPPs Satisfied
Single Panel
Single Plane
Panels
Planes
Front End Electronics
Preamps
Readout Controller
Digitizer
Install Cabling, Electronics
Tracker Move and Install
Cosmic Ray Test
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Summary

- Manufacture and QC of straws well defined
- Straw assembly procedures being tested now
  - Panel late FY14
  - Plane test late FY15
- Design and analysis of full tracker support and assembly under way
- Front end electronics technology chosen
  - Preliminary version of preamps, digitizers, ROC exist
  - Mother board design in progress
- Key elements of infrastructure defined
  - Cooling
  - Readout cables
  - LV distribution via DC-DC convertors
- Final assembly and installation being worked out with Muon Beamline
- Ready for construction starting FY16