Mu2e Tracker

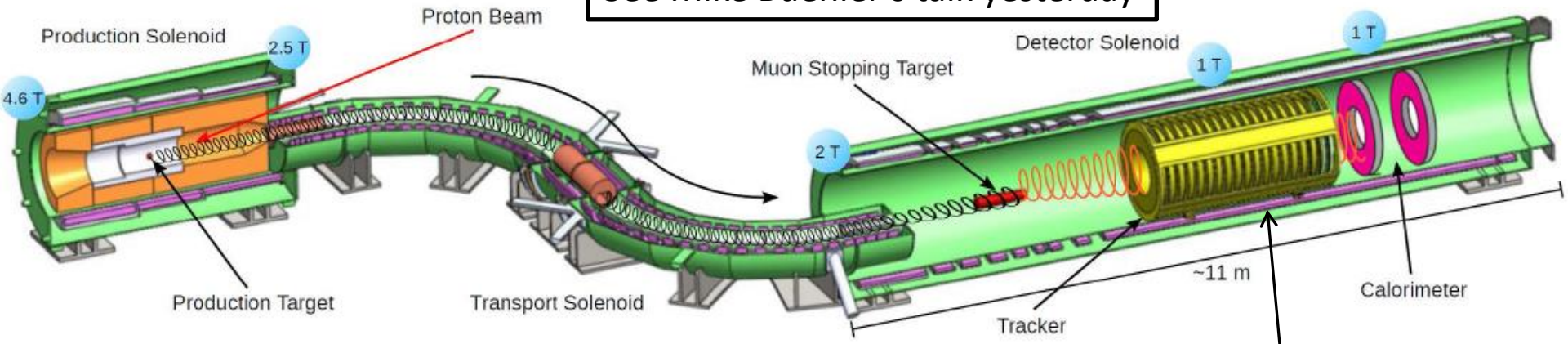
Overview & Progress

James L. Popp – For the Mu2e Tracker Group

August 5, 2015

The Mu2e Muon Beamline

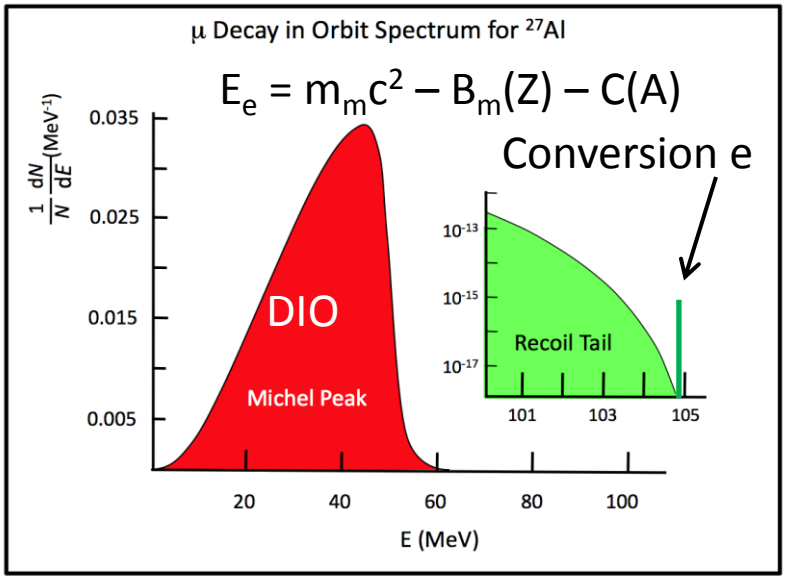
See Mike Buehler's talk yesterday

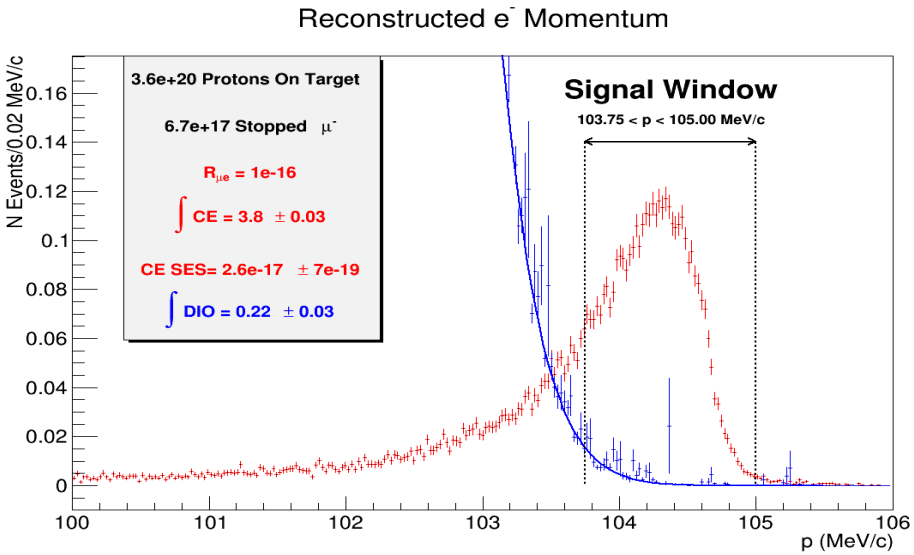


The primary detector for the experiment

- Production Solenoid
  - 8 GeV p beam (8.3 kW) strikes pion production target (tungsten, 160 mm long, 63 mm dia.)
  - Pions decay to muons & gradients in B field push particles to the right
- Transport Solenoid
  - Toroidal B field & collimators perform sign and momentum selection
  - Produce mostly mu-minus with optimum momenta to stop in secondary target
- Detector Solenoid
  - Muons captured in Coulomb orbits in aluminum stopping target foils
  - Muons either: Decay in orbit, capture on nucleus, may convert directly to electron
  - **Mu2e will directly measure conversion electrons with unprecedented sensitivity**

Requirements

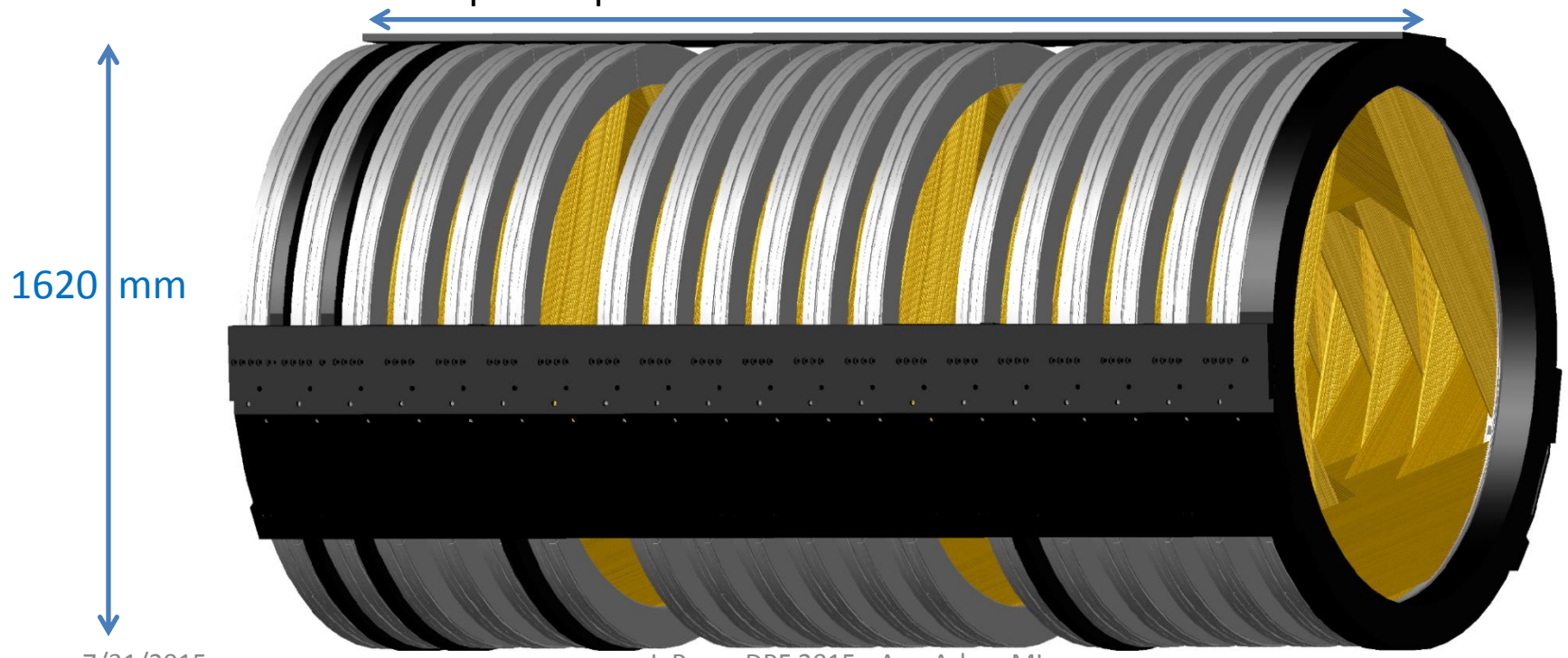




- Blind to DIO (muon decay in orbit)
  - r < 380 mm, no mass
    - Completely bypass muon beam
  - 380 < r < 700 mm, low mass
  - r > 700 mm
    - support structure
    - front end electronics
  - $B_m(Z)$ = muon binding energy
  - C(A) = nuclear recoil energy
- Resolution
  - Momentum tails matter
  - Gaussian fit to high end
    - At 105 MeV/c, σ < 180 keV/c
  - Dominated by multiple scattering

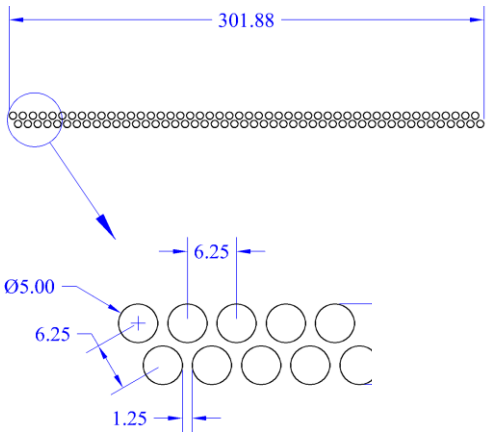
Baseline Design

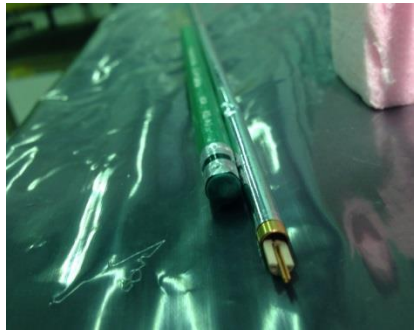
- Wound Mylar® straw drift tubes – operated in vacuum
  - Inside: layer of aluminum with gold layer on top, Outside: layer of Al
    - Au-plated tungsten sense wire
    - 20736 straws filled w/Ar:CO_2 mixture (80:20) at 1 atm
  - Measure
    - Drift time (max 50 ns) for track distance from the wire: res. < 200 microns
    - Read out both ends wire, use pulse timing to determine position along wire: res. ~30 mm
  - 18 stations: 2 planes per station

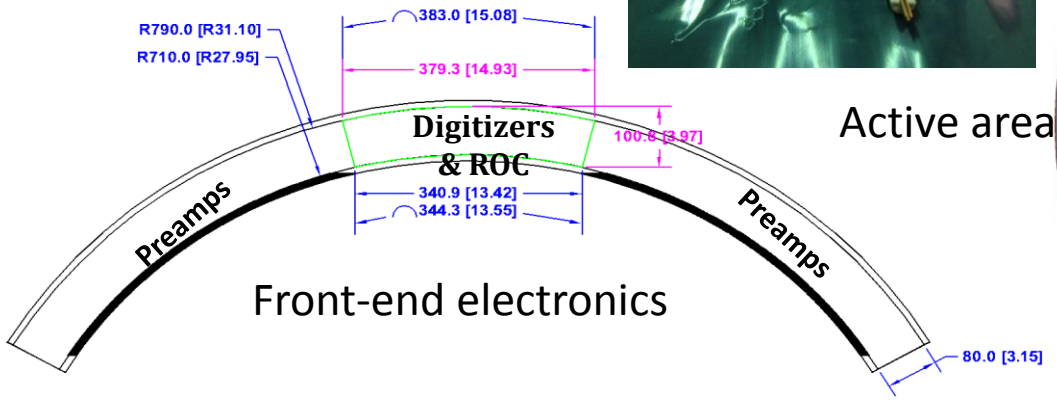


Straw Planes

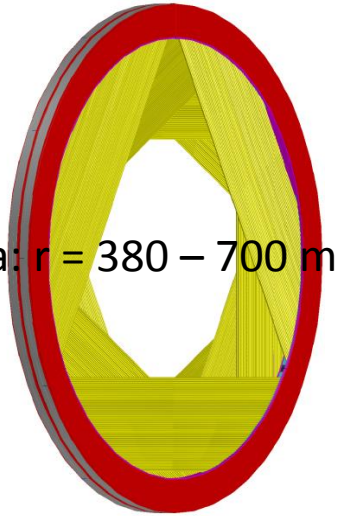
- Each plane has 2 circular rings
  - Plane has 6 panels, a panel has two straw layers
    - Each layer has 48 straws
    - **15 micron straw wall – we are pushing the state-of-the-art here**
  - Circular rings rotated 30 deg for stereo
  - Straw lengths: 430 mm – 1200 mm, dia. 5.0 mm
  - Sense wire: 25 micron, gold-plated tungsten





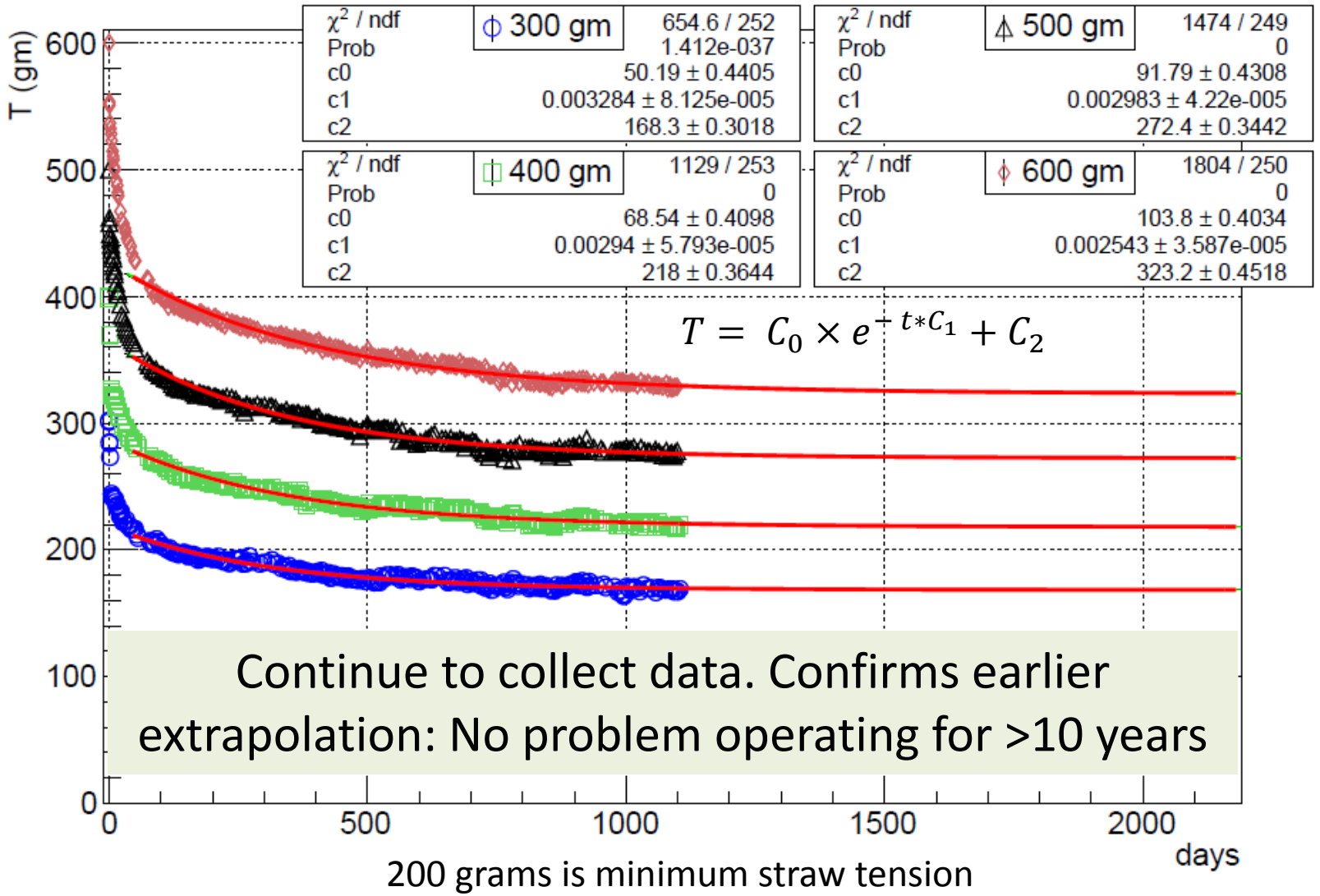


Front-end electronics



Active area: r = 380 – 700 mm

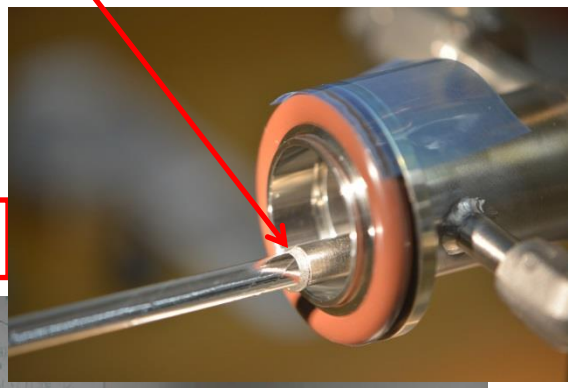
Stress Relaxation

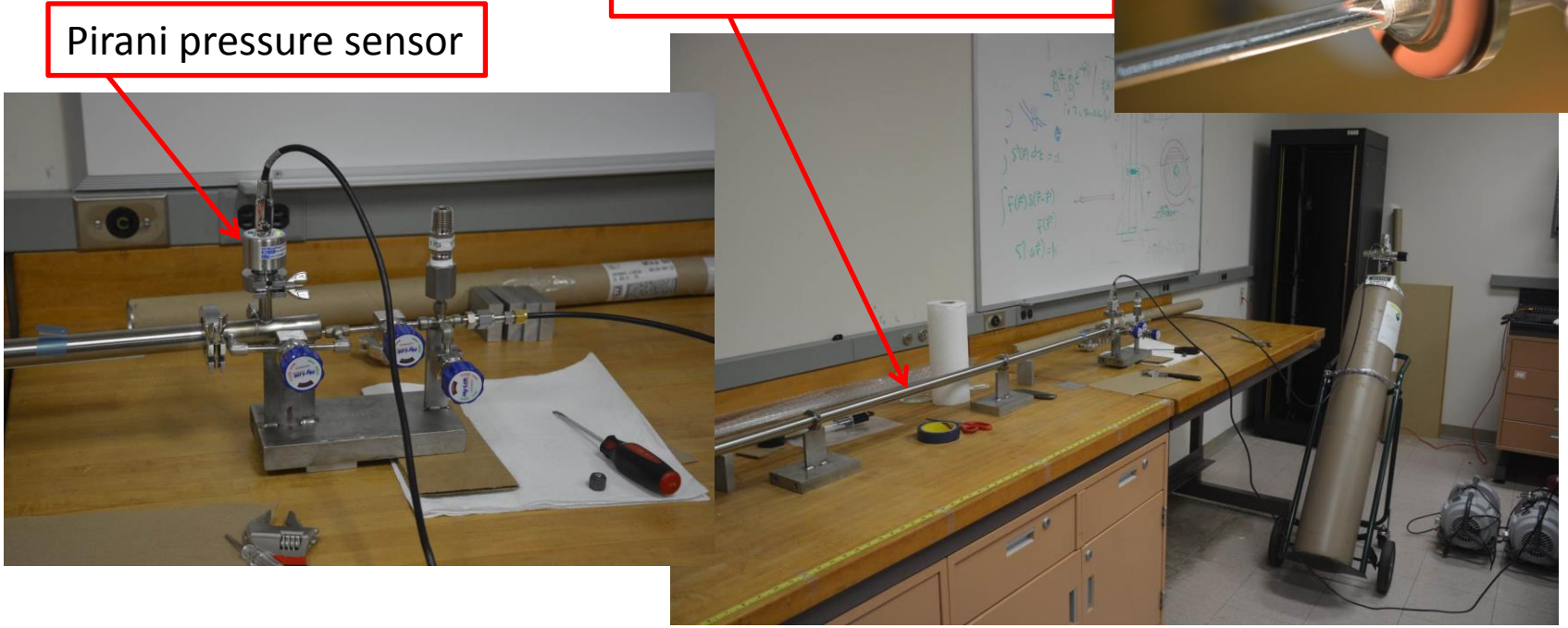


200 grams is minimum straw tension

Straw Gas Leak/Permeation Tests

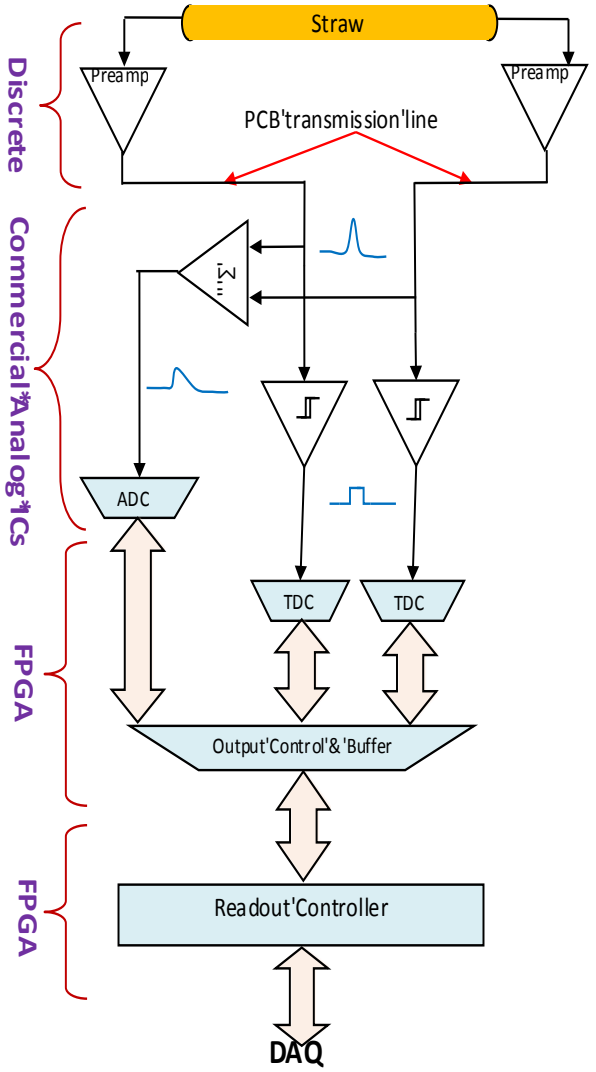
- See next talk: Dan Ambrose
  - Accelerated tests: CO_2 sensors
  - Vacuum tests: turbo + roots pump





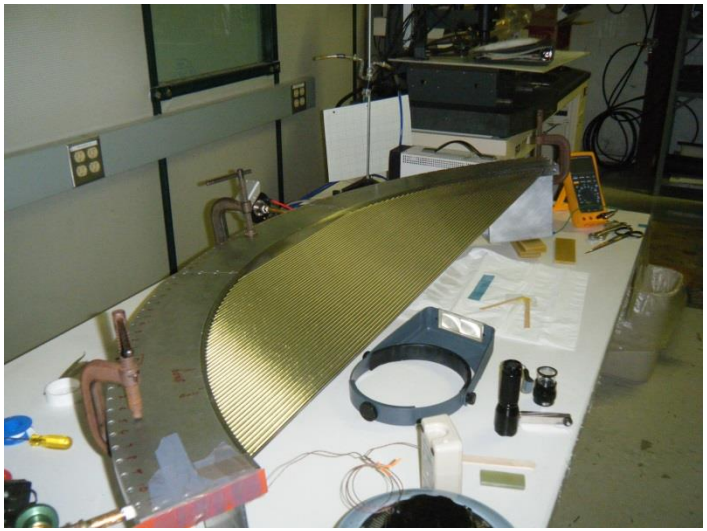
Front End Electronics

- Digitizers & zero-suppression logic located on detector to minimize vacuum penetrations
- Electronics tests underway
- ADC to do Particle ID
  - For example, to reject protons from muon capture on the nucleus in stopping target

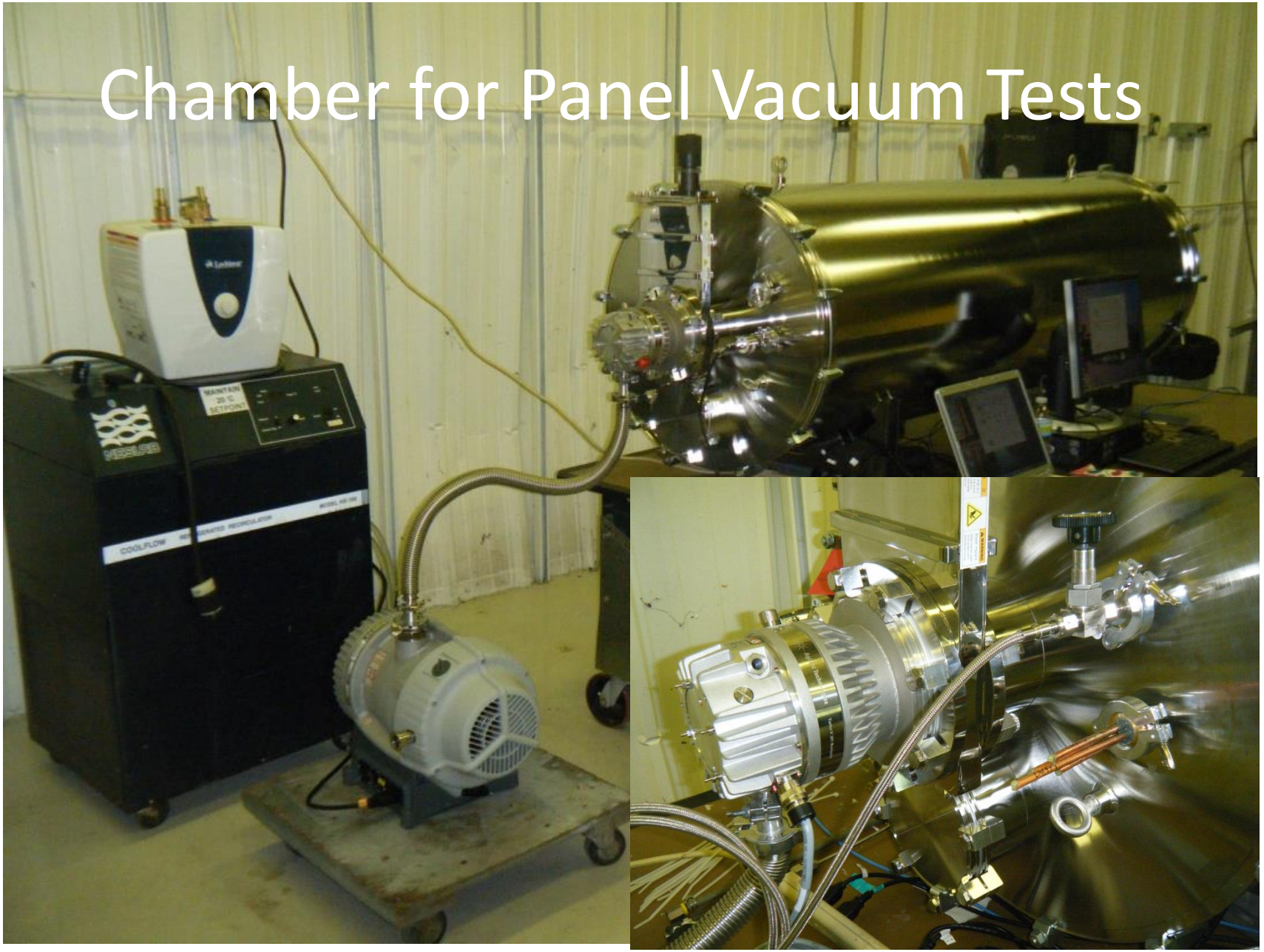


Current Panel Prototype 1.5

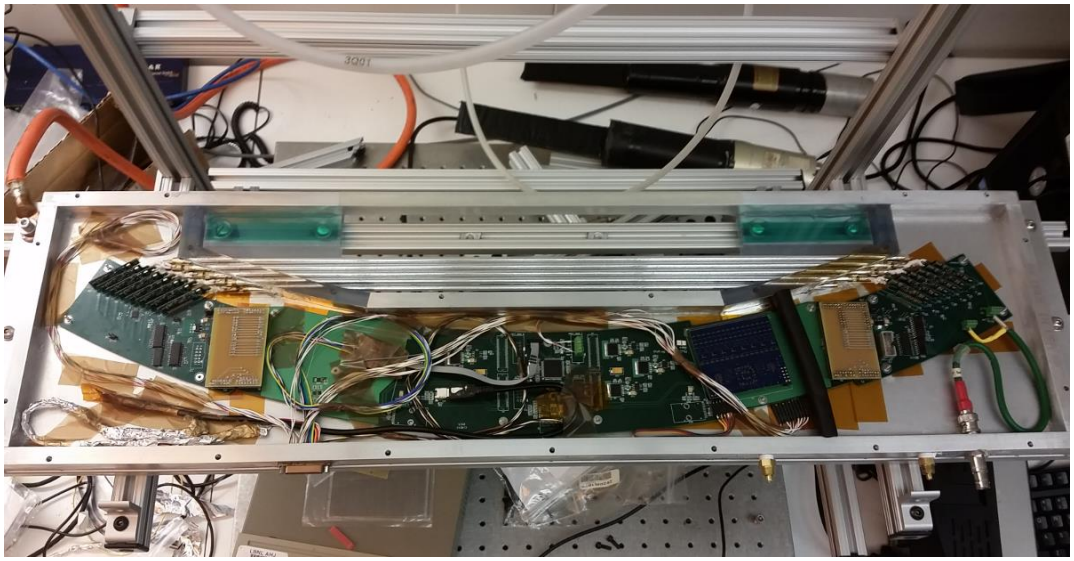
- Version 1.5
  - First leak test of manifold, straws + terminations as a single unit
  - Trouble-shooting manifold cover leaks
- Begin vacuum leak testing when
  - panel gas seal problem resolved
  - vacuum chamber & feedthroughs will be ready soon

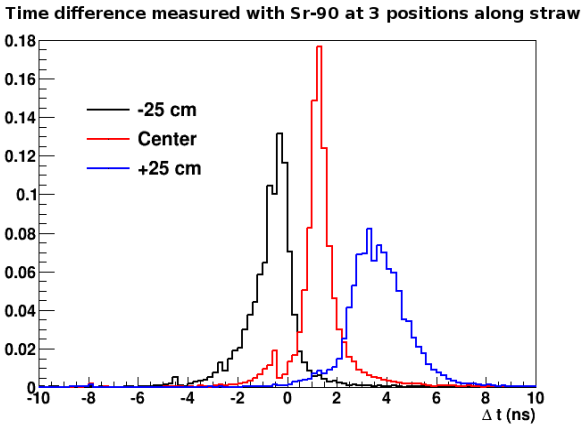


Chamber for Panel Vacuum Tests



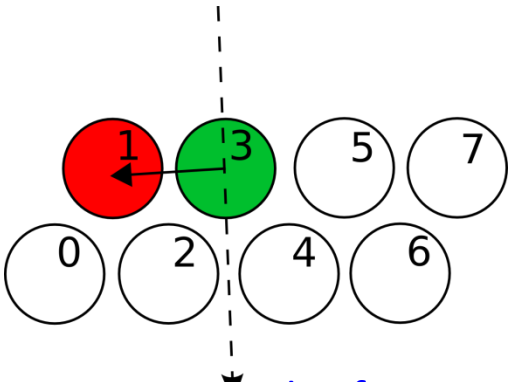
Tracker Prototype Chamber Electronics



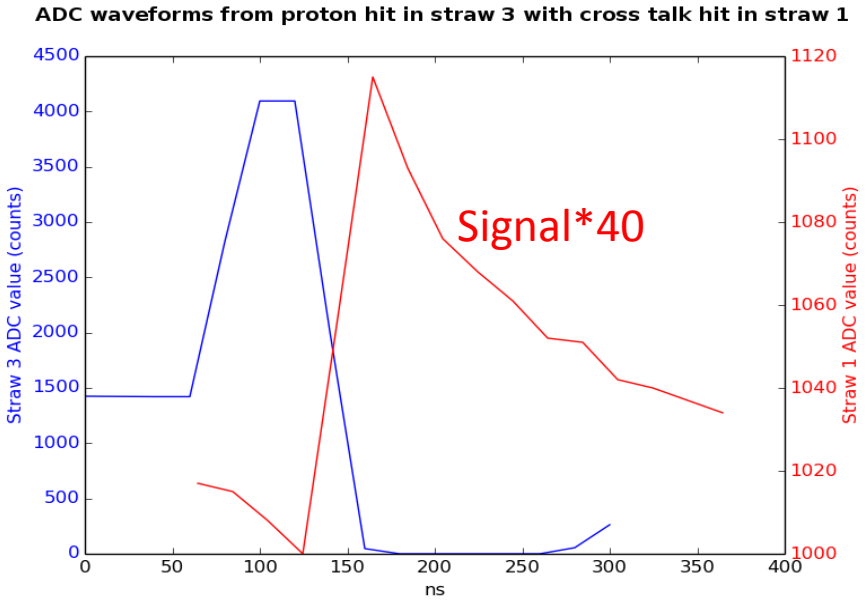


- Shortest 8 straws of one panel
  - Further electronics tests
- Compact and mobile for beam tests, etc.
- Measured ~4.5 cm position resolution along straw using Sr-90 source
  - As tests continue we are confident that design resolution will be attained

Measured rate of cross talk using LBL 88 inch cyclotron proton beam



A proton pulse from capture saturates straw a channel



- In worst case 25% of proton hits produced a cross talk hit
  - Cyclotron simulates protons from **muon capture on nucleus**
- This study gives an upper limit on the relative loss in conversion electron (acceptance times efficiency) from these additional background hits of 0.62%
  - Additional studies are planned

Summary

- Mu2e requires a low-mass tracker that can operate in vacuum
- The Mu2e baseline design
  - straw tube tracker, 15 μm thick straw walls, 5 mm diameter, dual-ended readout
- Developed 15 μm straws and demonstrated that their mechanical and gas permeability properties meet Mu2e requirements
- Preliminary designs of the tracker, supports, electronics, and services exist
  - built a single-panel prototype that will soon be tested in vacuum
  - built small scale prototypes to use in beam tests
  - the measured electronics performance and cross talk are satisfactory
- The final design of the tracker will be ready for CD-3 in 2016