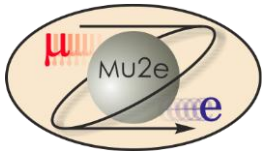
Fermilab

Mu2e Tracker Straws



Chiho Wang
Straws L3 Manager
10/22/2014

Outline

- Straw requirements
- Straw property measurements
- Straw assembly components and procedures
- Cost

Straw requirements

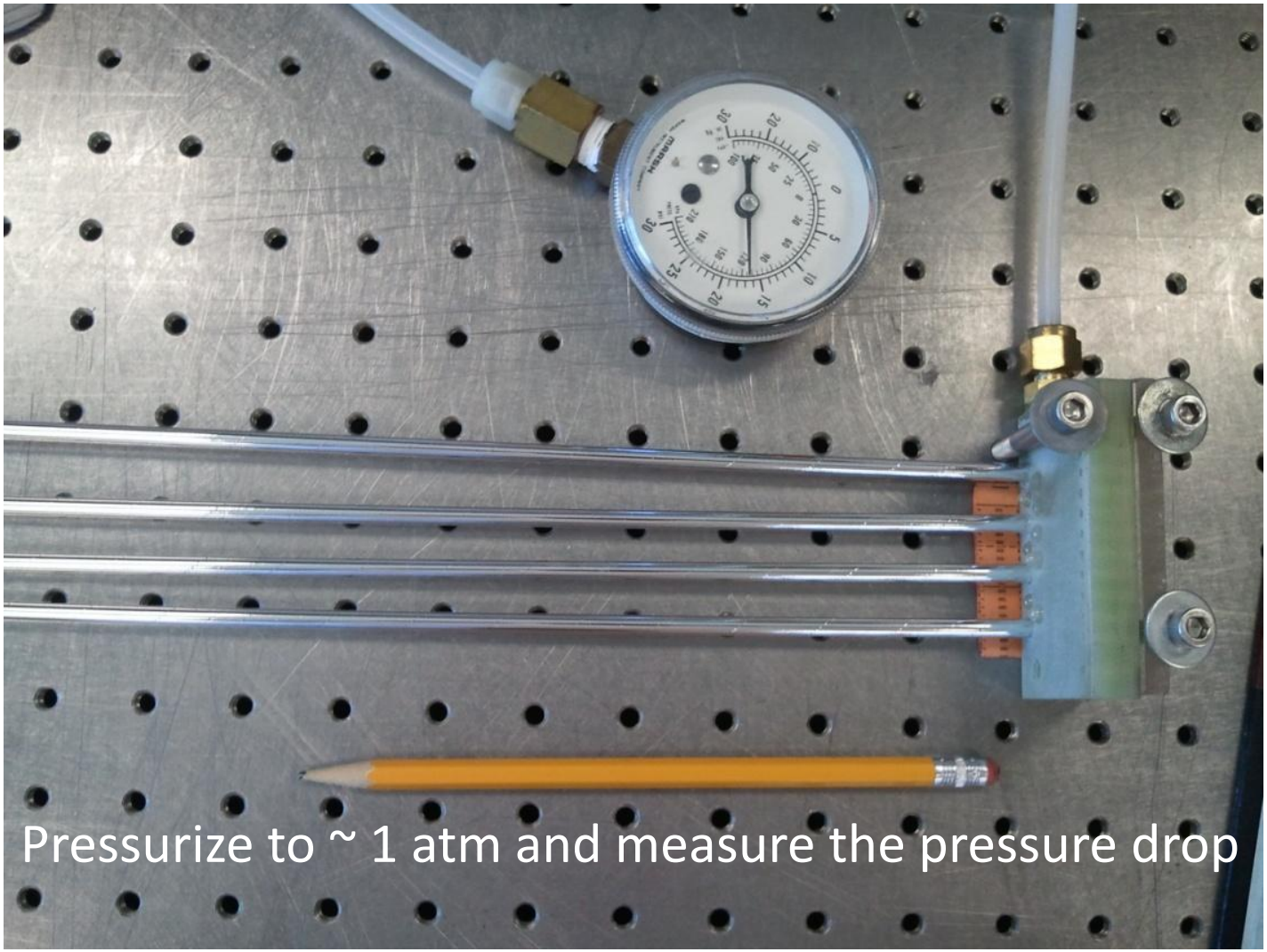
- 5 mm ID metalized Mylar tube cathode.
- Minimal material
  - 6 μm Mylar + 3 μm adhesive + 6 μm Mylar double helical wrap
  - Inner wall coating: 500Å Al + 200Å Au
  - Outer wall coating: 500Å Al
- Operates in vacuum
  - Sustains > 1 atm pressure difference
  - Leak rate < 7 ccm / detector volume
- Stability
  - Straw straightness: max. transverse deviation/sagging < 300 μm for HV stability.
    - Longitudinal tension is applied to keep straw straight.
    - Initial tension need to be higher to counter for material relaxation over time (creep).
  - Sustains radiation over the life time of operation.

Straw properties

- Destructive tests:
  - Pressure: sustained 60 psi (10 min.). Destroyed ≥ 70 psi
  - Stretch: sustained 1.6 kg (2 yrs.). Destroyed ≥ 2.9 kg
- Mechanical:
  - Linear density: 0.34±0.01 g/100cm
  - Wall thickness: 15 μm
    - Derived from linear density, assuming Mylar density 1.39 g/cm^3, and same for the polyester based adhesive.
  - Spring constant: 0.891 cm/kg/100cm
- Electrical:
  - Cathode resistance: 120 Ω/100cm

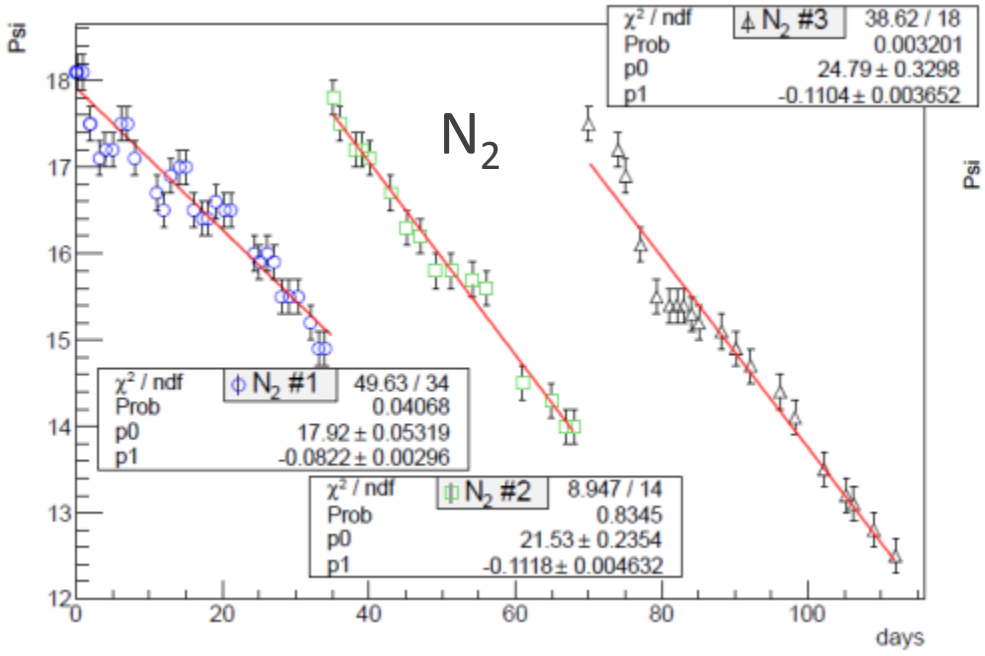
Straw leak measurement 1

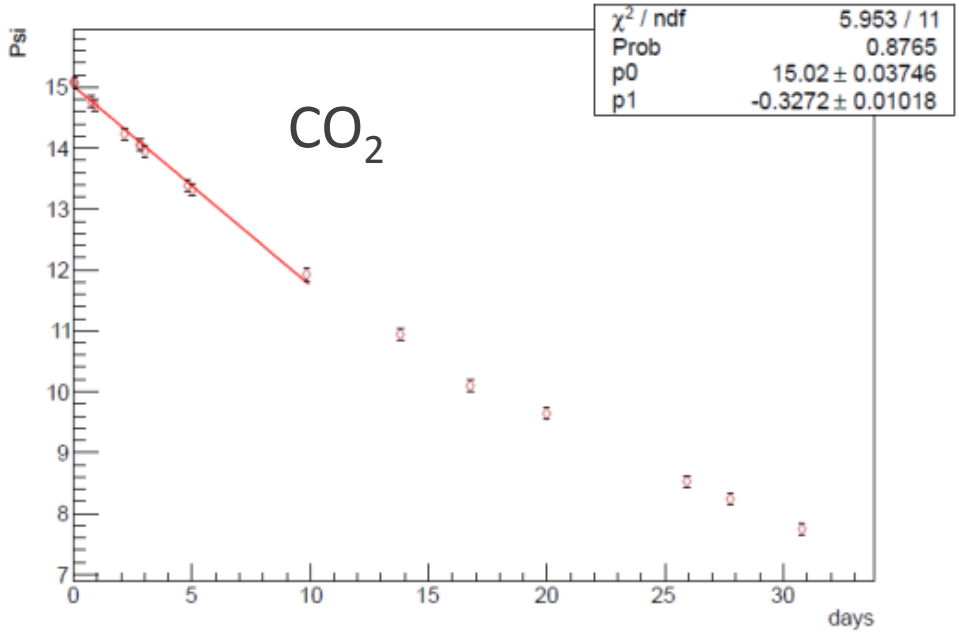
Duke *C. Wang, S. Oh*



Straw leak measurement 1

Duke *C. Wang, S. Oh*

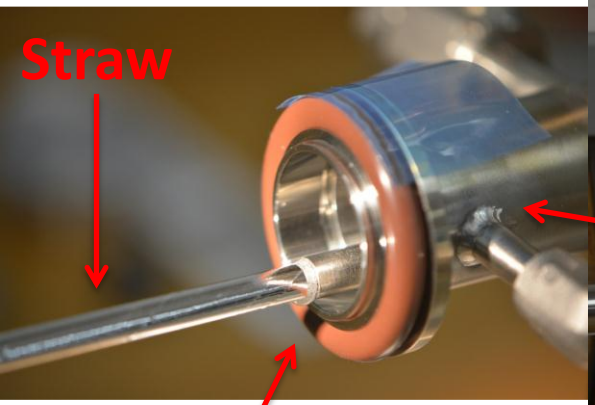


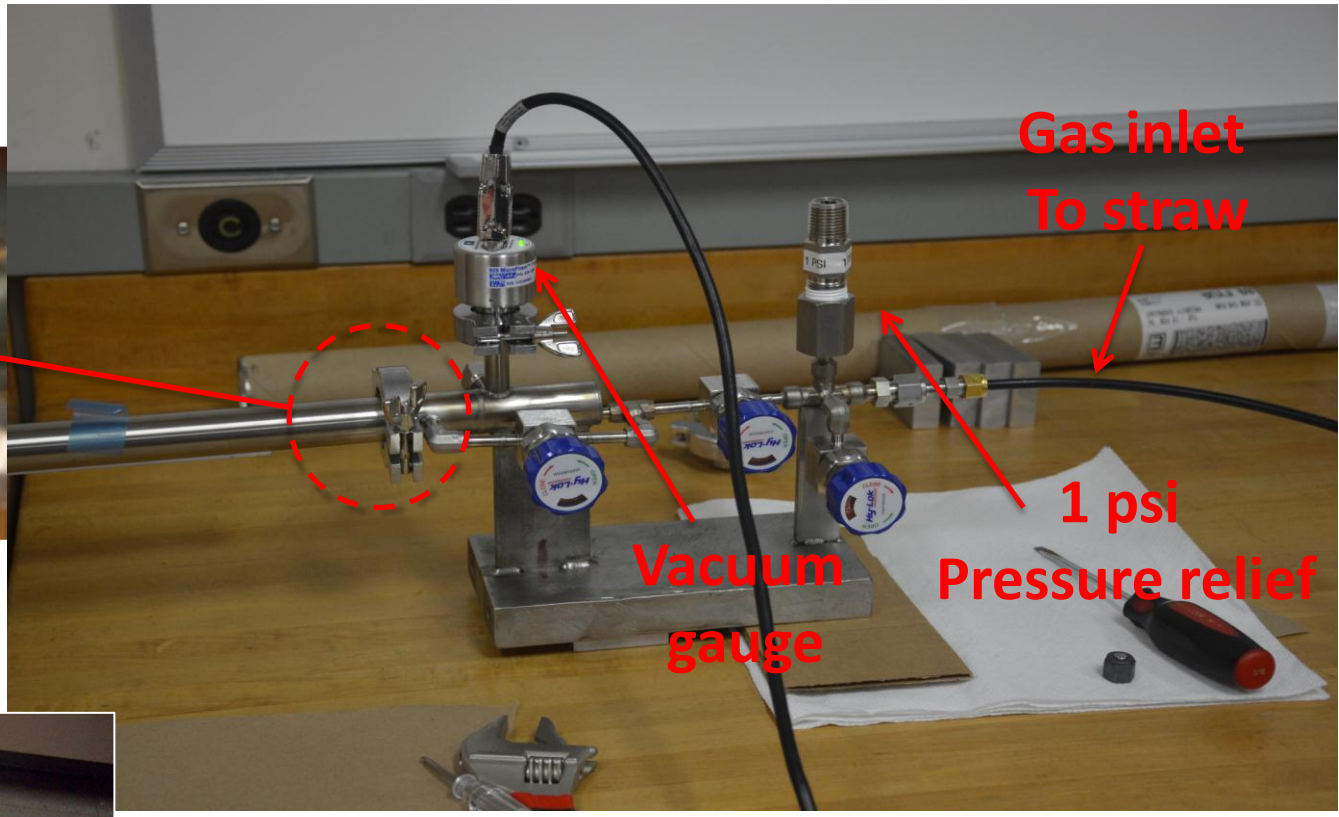


- N_2 leak rate =0.095±0.026 psi/day
- CO_2 leak rate =0.36±0.06 psi/day
- Assume Ar leak rate similar to N_2 , and straw volume ~ 0.3 m^3, estimated Ar(80%)CO(20%) leak rate ~ 2 ccm / tracker volume

Straw leak measurement 2

York *J. Popp, K. Lynch*

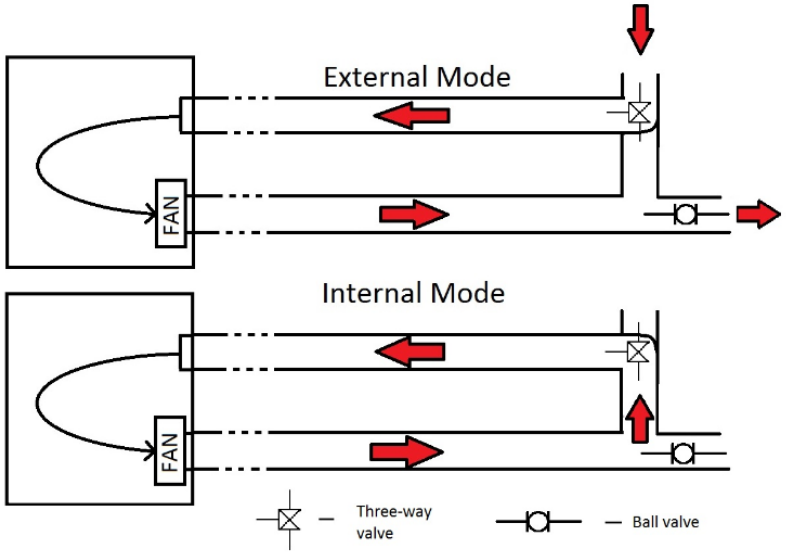


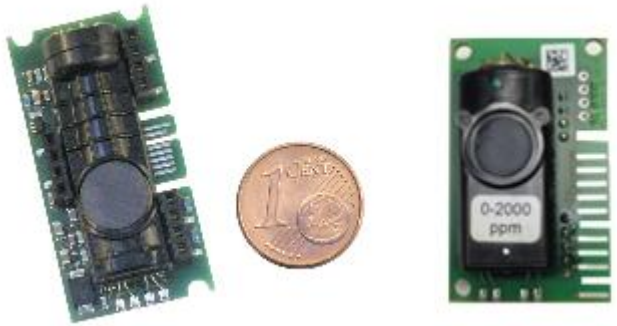


- Tested 10 × 129cm straws
- Early results ≲ 4 ccm / tracker volume
- Improvements underway

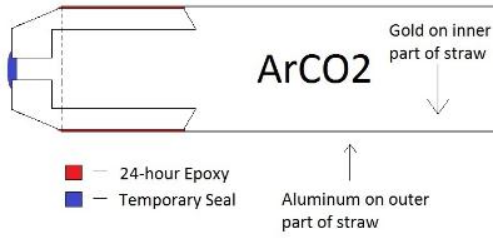
Straw leak measurement 3

Rice *D. Rivera, M. Corcoran*





EE891 and EE892 CO2 sensor



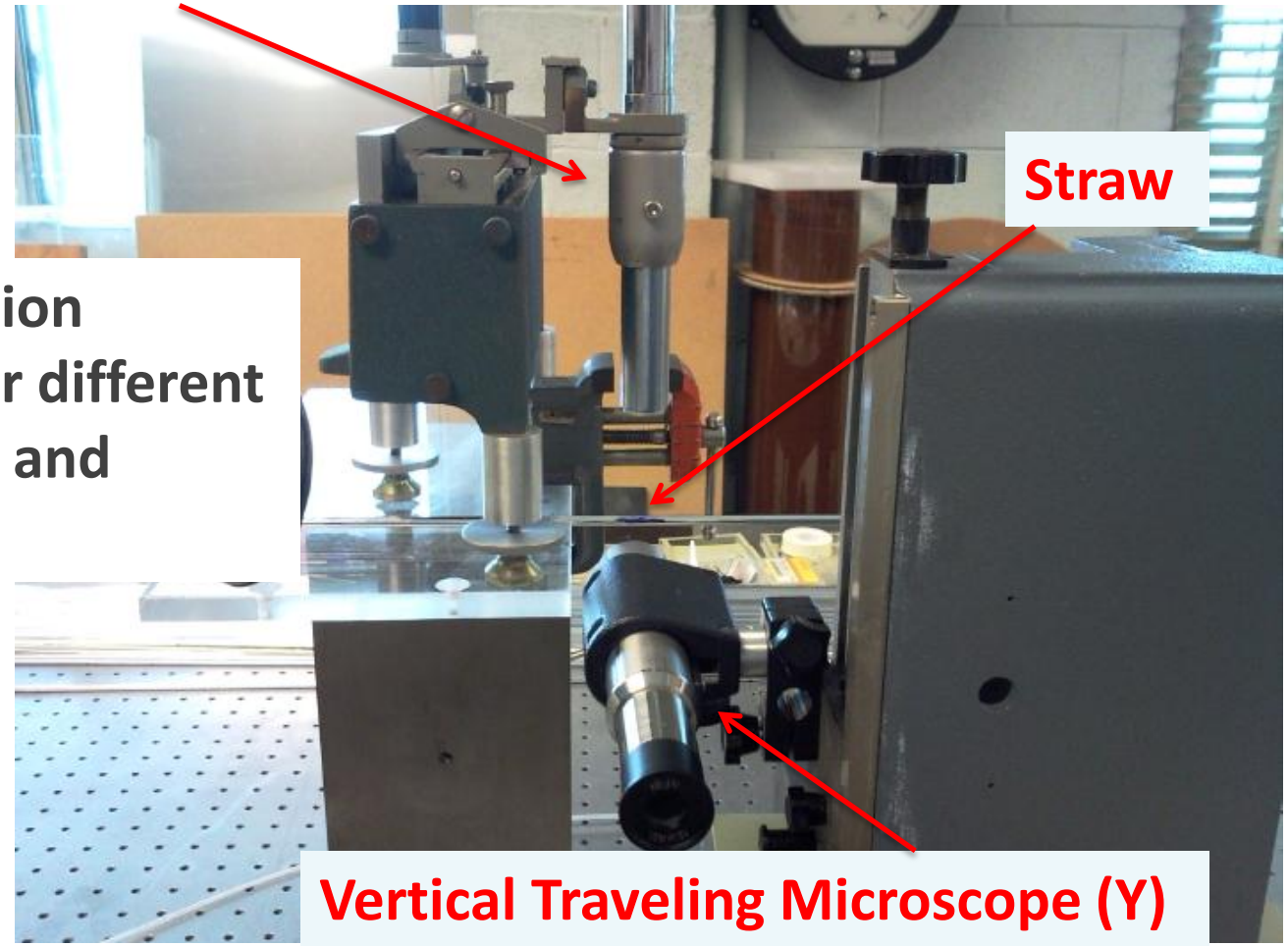
- Tested 119 ×129cm straws
- Averaged leak rate = $5 \cdot 10^{-5}$ ccm/straw
- ~1 ccm for tracker volume

Straw straightness measurement

To determine the required straw tension

Duke *C. Wang, S. Oh*

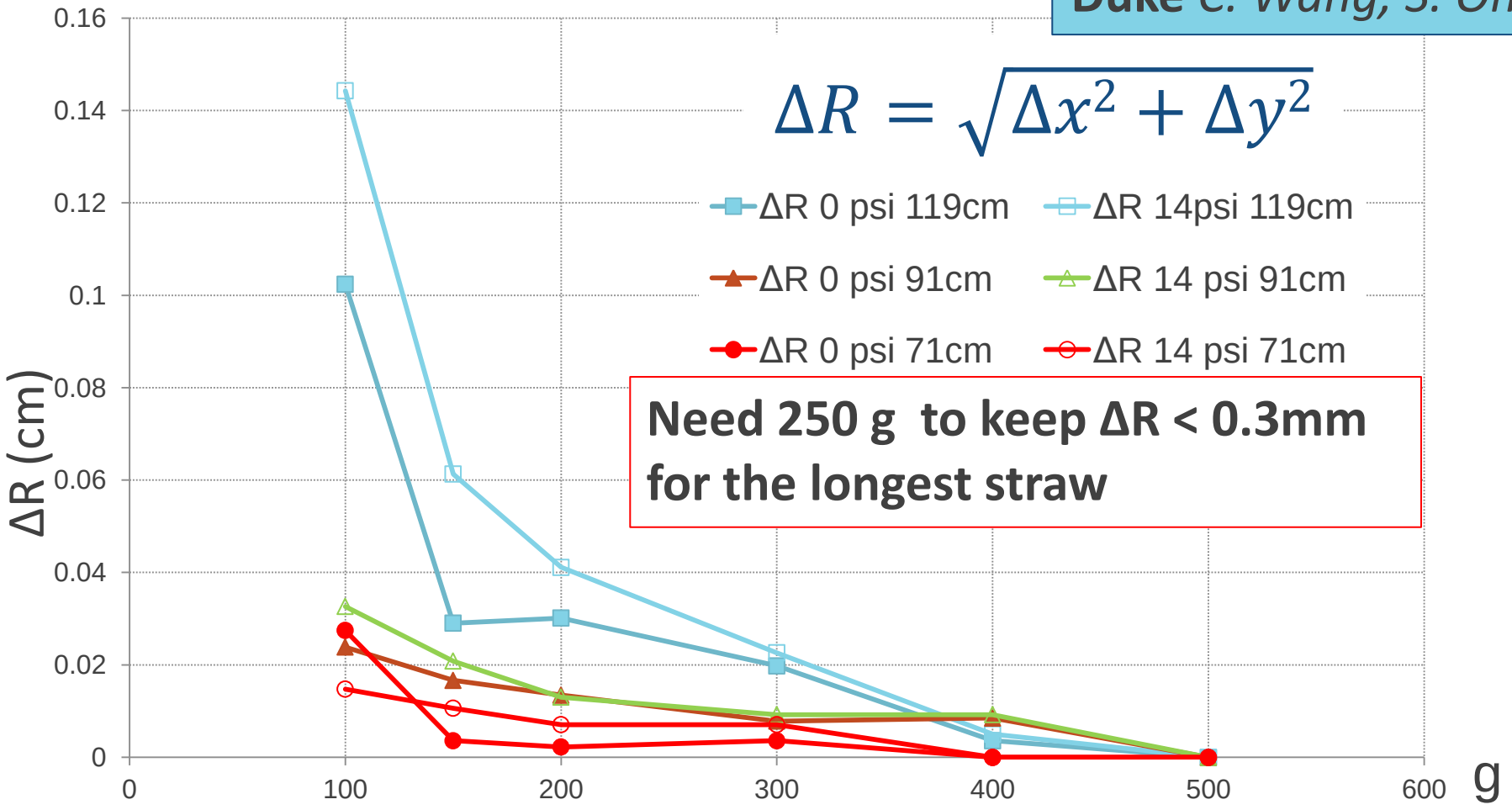
Horizontal Traveling Microscope (X)



Straw deviation measured for different straw length and tension.

Straw straightness measurement

Duke *C. Wang, S. Oh*

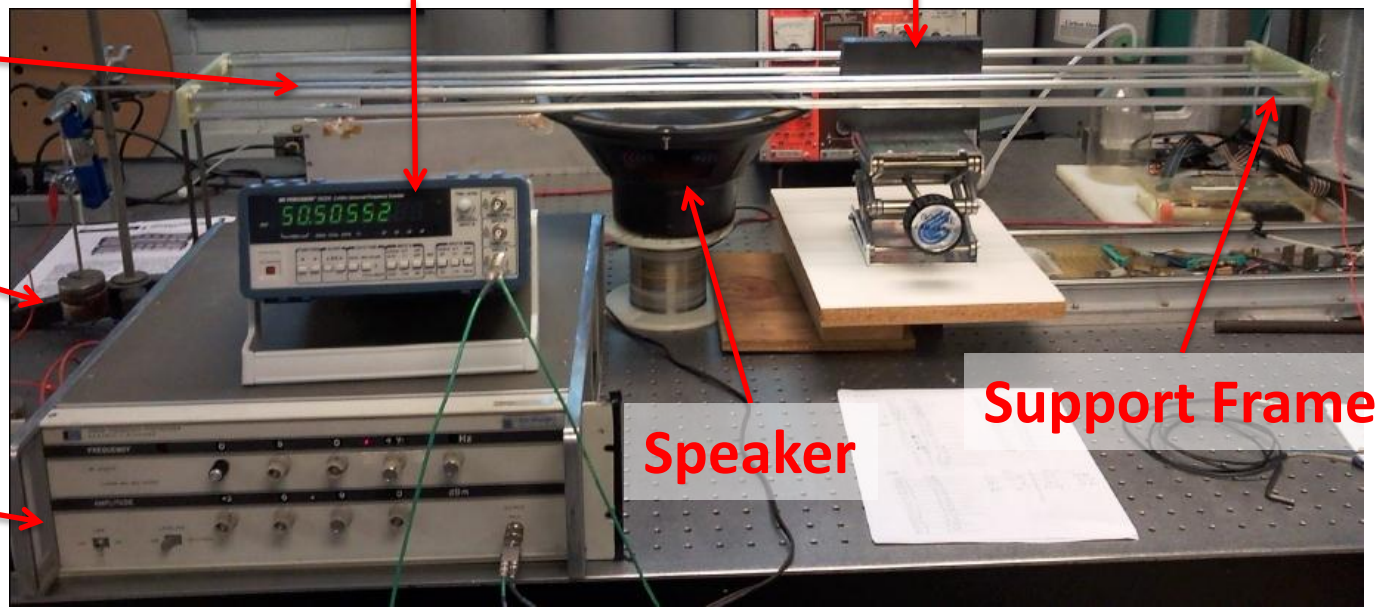


Mid point deviation, relative to the highest tension (500g)

Straw creep measurement

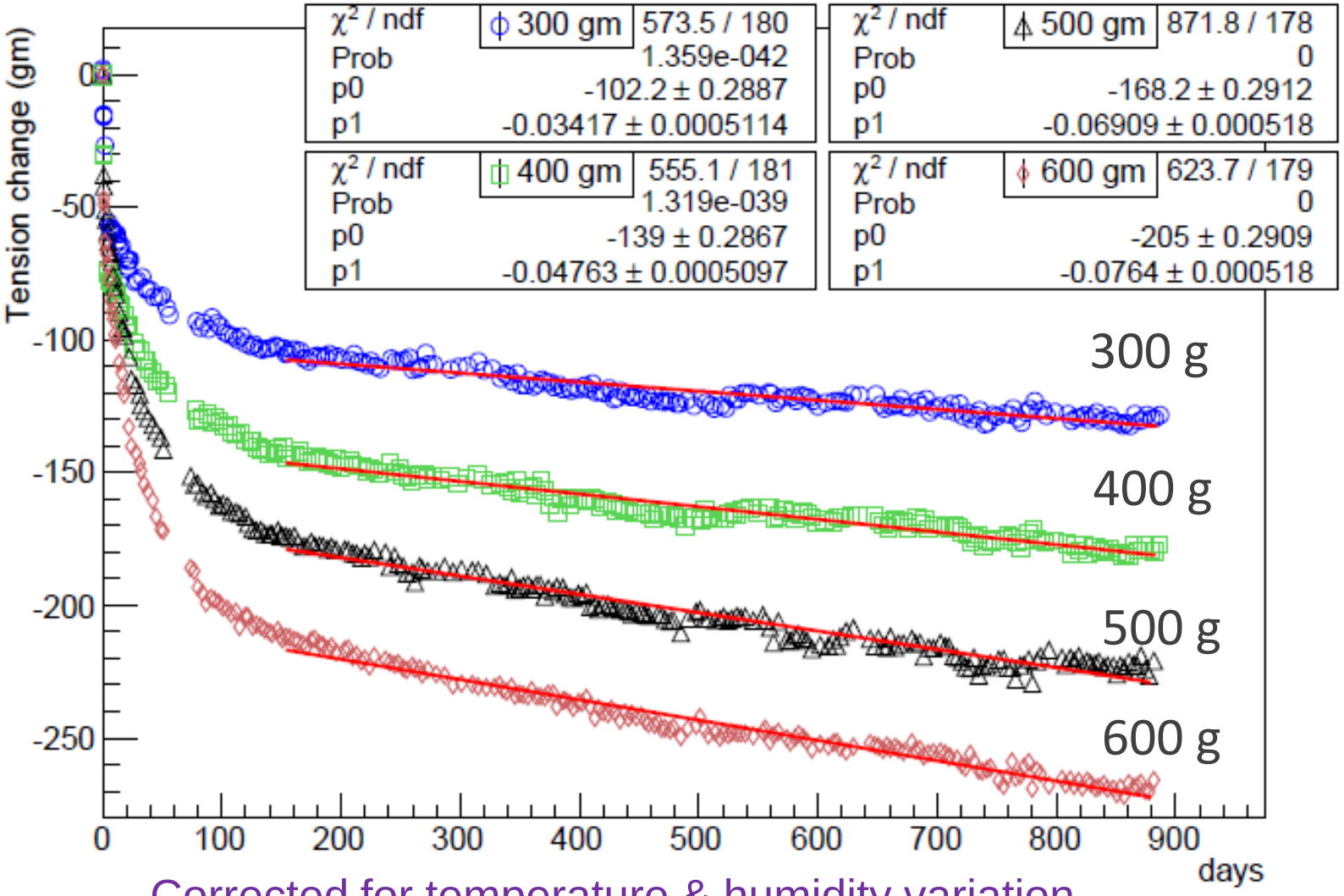
Duke *C. Wang, S. Oh*

- Glue straws on a support frame (120 cm) with tensions:
  300 g, 400 g, 500 g, 600 g.
- Measure straw tension by resonant frequency as a function of time.



Straw creep measurement

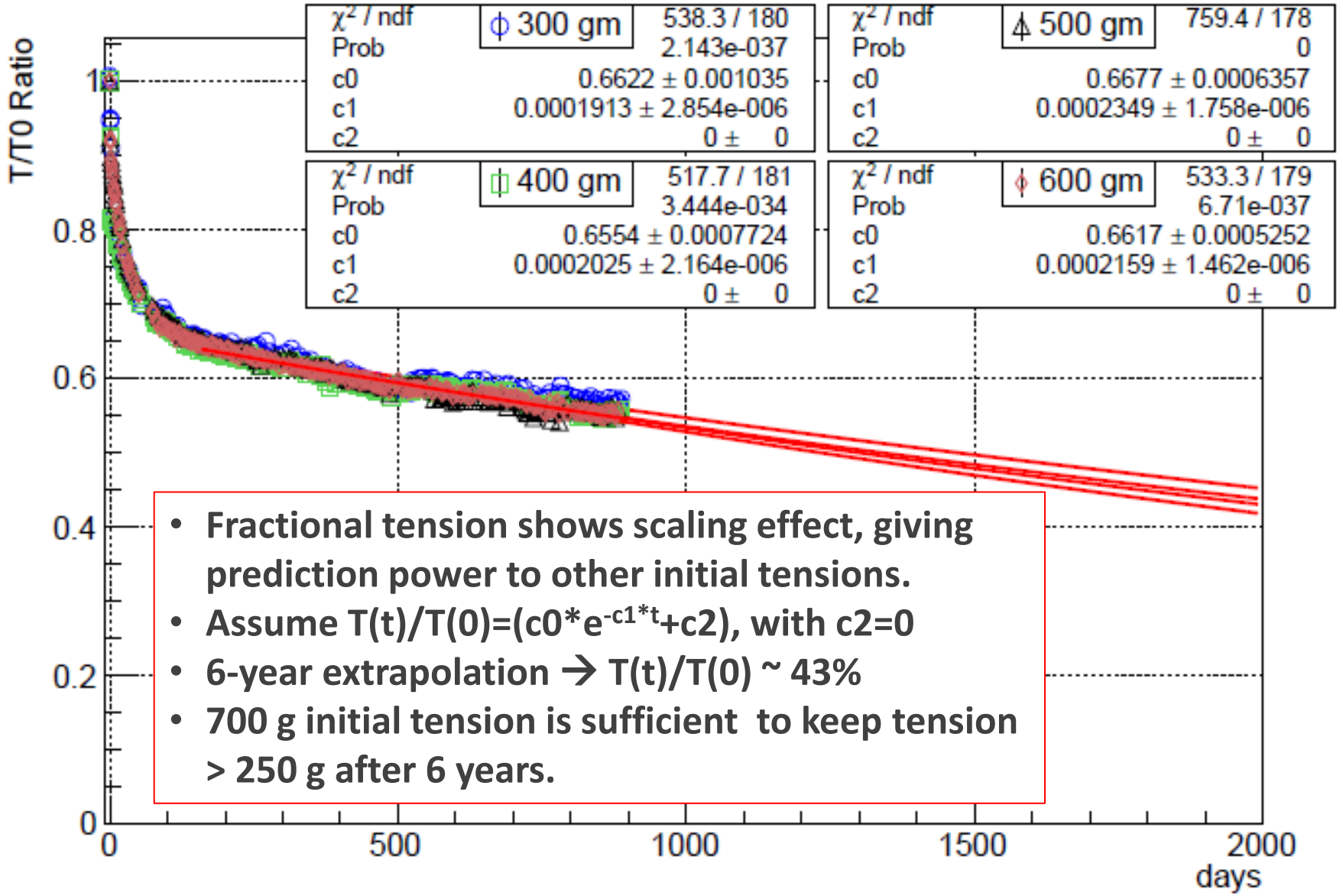
Duke *C. Wang, S. Oh*



Corrected for temperature & humidity variation

Straw creep measurement

Duke *C. Wang, S. Oh*



- **Fractional tension shows scaling effect, giving prediction power to other initial tensions.**
- **Assume $T(t)/T(0)=(c0*e^{-c1*t}+c2)$, with c2=0**
- **6-year extrapolation → T(t)/T(0) ~ 43%**
- **700 g initial tension is sufficient to keep tension > 250 g after 6 years.**

Radiation aging study

Fermilab *R. Wagner*

- A single straw detector, constructed with relevant components, was operated under Sr^{90} irradiation.
- Expected total dose (including beam flash) of 0.9 C/cm was irradiated.
- Gain change monitored by Fe^{55} peak amplitude.
- Observed no measurable degradation in gain or cathode resistivity

Fractional gain change over 3 irradiation periods.
Measured at 3 locations from downstream.
Referenced to un-irradiated point at 110 cm:

Period	Charge (mC/cm)	Current (nA/cm)	Gain(x)/Gain(110 cm) p1 (7cm)	p2 (37cm)	p3 (67cm)
1	120	18	0.979	0.982	0.994
2	120	36	1.010	1.009	1.002
3	670	70	0.994	0.990	0.983
Total	910		±2%		

- Gas flow rate = 2 vol/hr/m
- 20±0.02% CO_2 with balance Ar
- Airgas "primary standard" grade. Purity 99.99% with individual impurities below:

Contaminant	Max. Concentration (ppm)
Carbon Monoxide	10
Hydrogen	10
Nitrogen	20
Oxygen	10
Total Halogens	10
Total Hydrocarbons	10
Water	10

Straw property summary

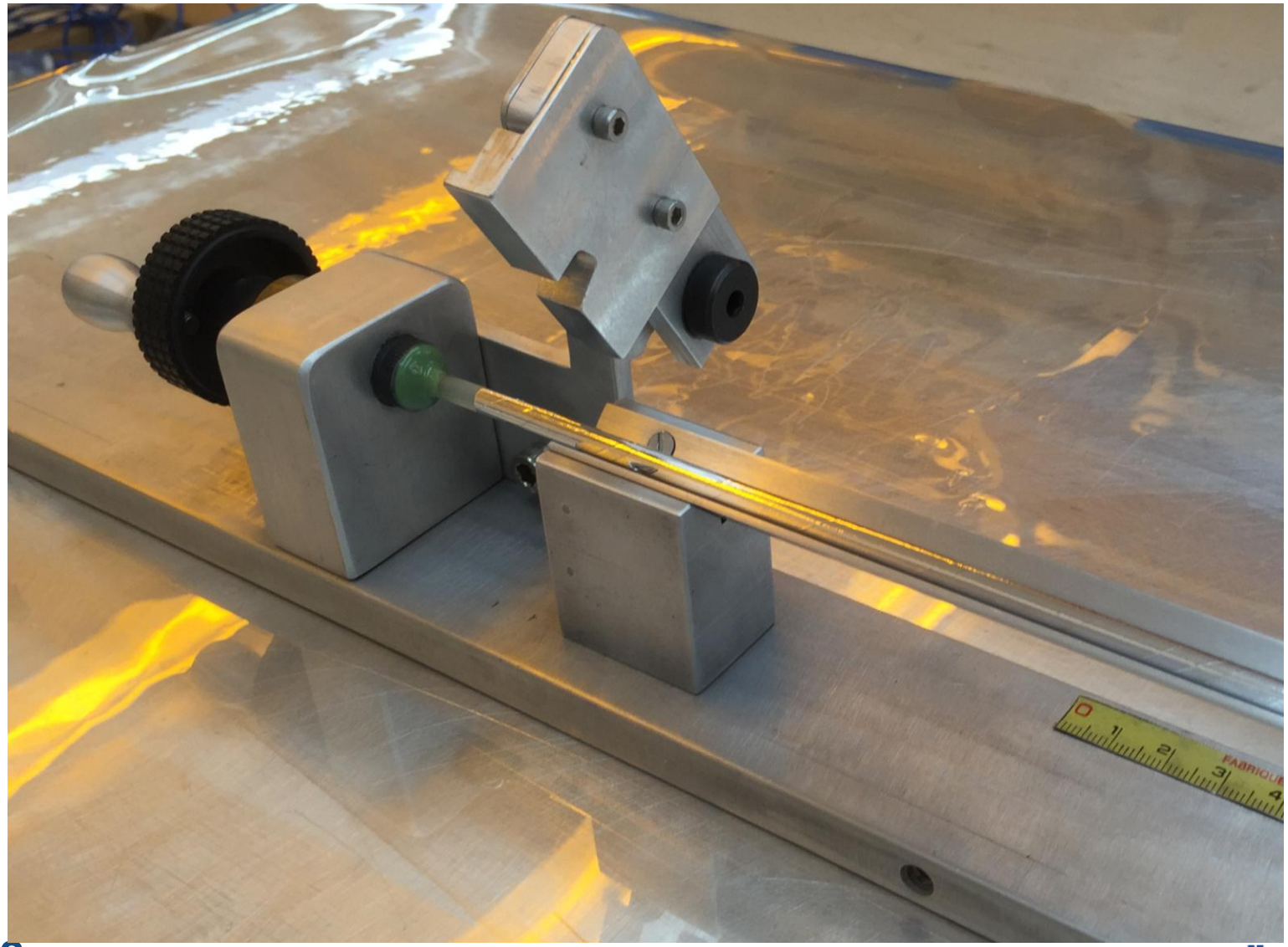
- Straw is robust and has no problem operating in vacuum. The burst pressure exceeds 60 psi and is well above 14 psi.
- Straw leak rate of $\lesssim$4 ccm is within acceptable range of 7 ccm
- 700 g initial tension is needed to keep straw tension above 250 g after 6 years, which is needed to keep straw straightness within $\pm$0.3 mm for HV stability.
- Straw can sustain tension > 1.6 Kg and is well above the needed 700 g initial tension.
- No measurable degradation in gain after expected dosage of radiation.

Straw assembly

- After a straw is received from manufacturer it needs to go through QC procedures and get assembled into a straw sub-assembly. These procedures include:
  - Visual inspection
  - Continuity check (measure resistance)
  - Leak test
  - Cut to length
  - Assemble/Attach end pieces
- A QA/QC data base is being developed to track/link component data.

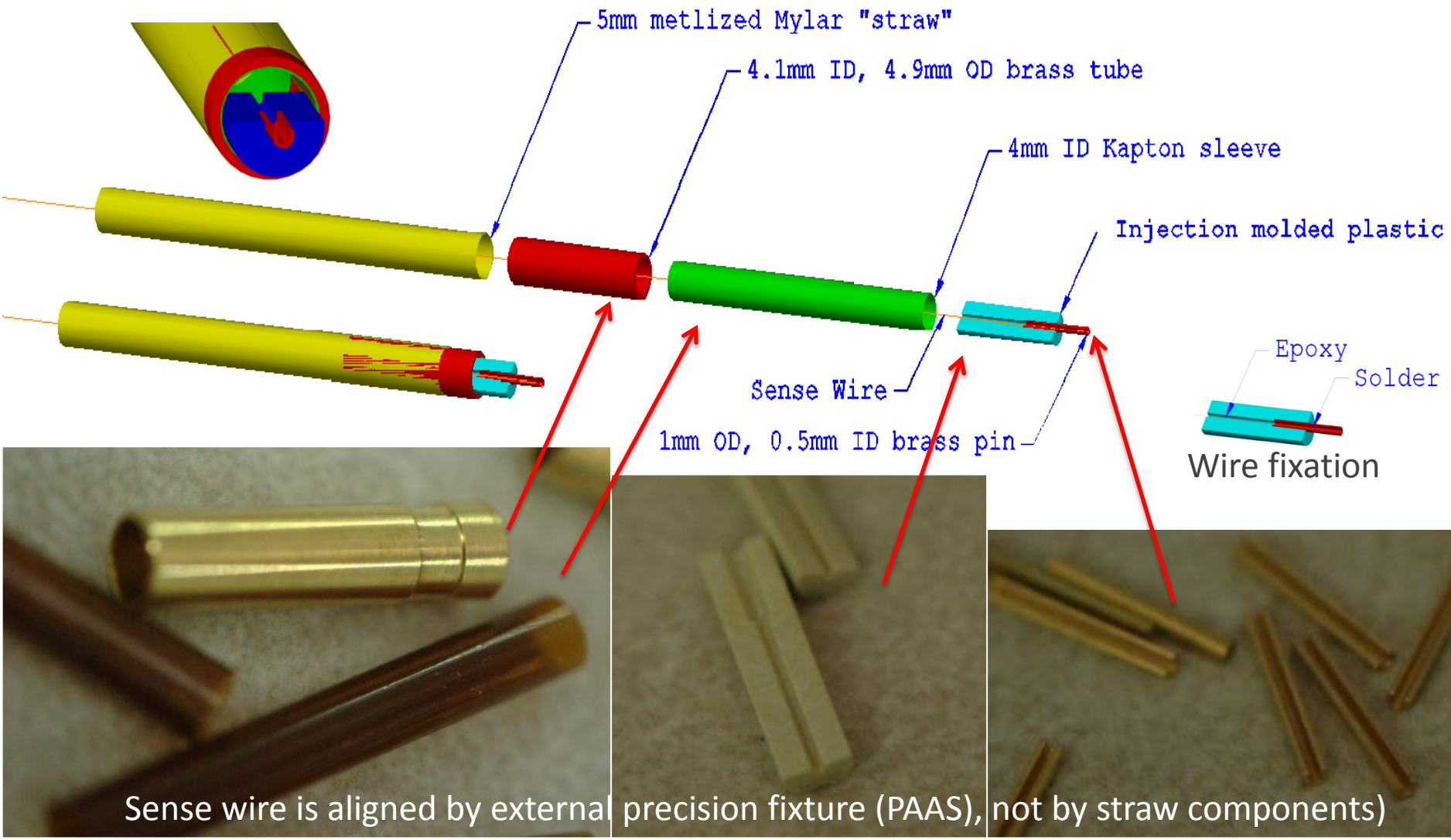
Straw cutter

Fermilab *R. Wagner*



Straw sub-assembly

Fermilab *R. Wagner, A. Mukherjee*

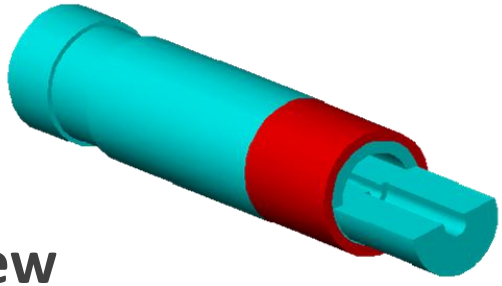


Sense wire is aligned by external precision fixture (PAAS), not by straw components)

Straw Termination

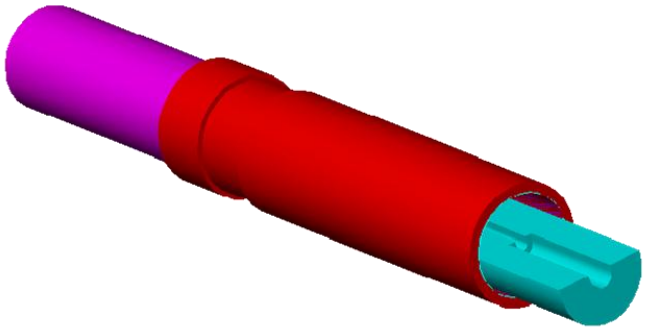
Fermilab *R. Wagner, A. Mukherjee*

- Simulation studies show it is *not* necessary to deaden straws near gas manifold



New

- 3piece construction
- Mostly plastic
  Lighter & cheaper

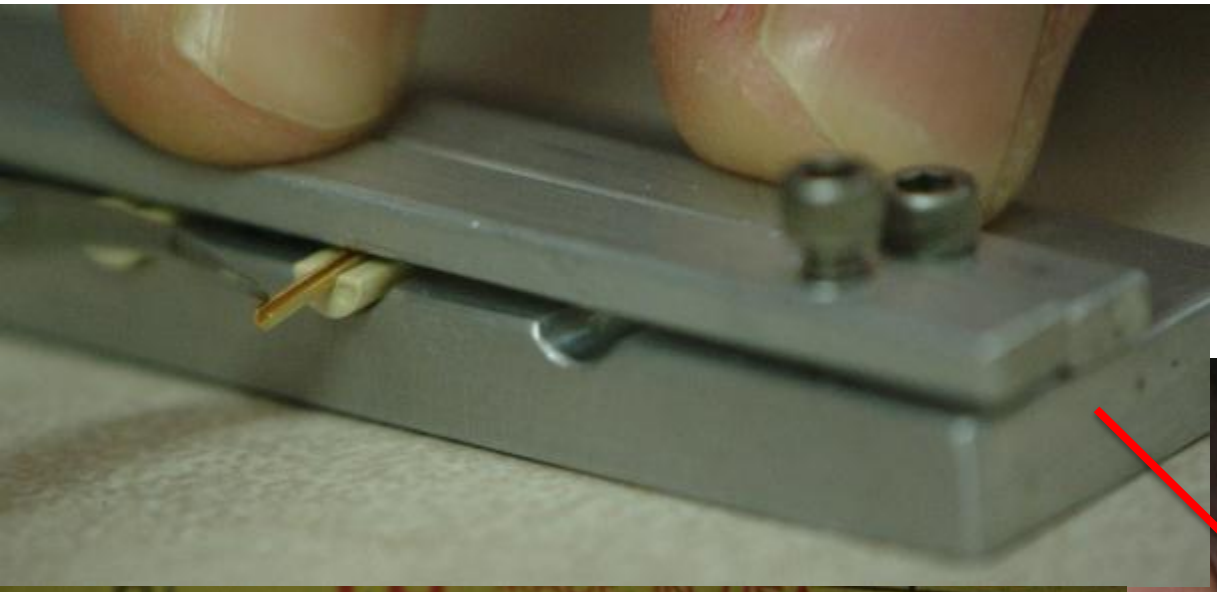


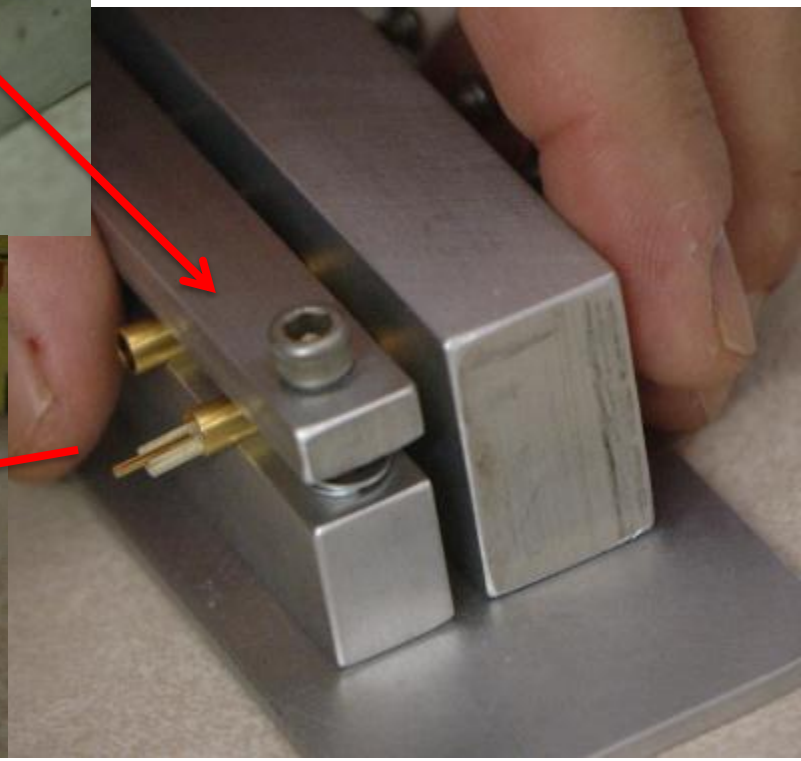
Old

- 4 piece construction
- Kapton sleeve trimmed to deaden ~1 cm past manifold
- Mostly brass

Assembly jigs for assembling end pieces

Fermilab *R. Wagner*

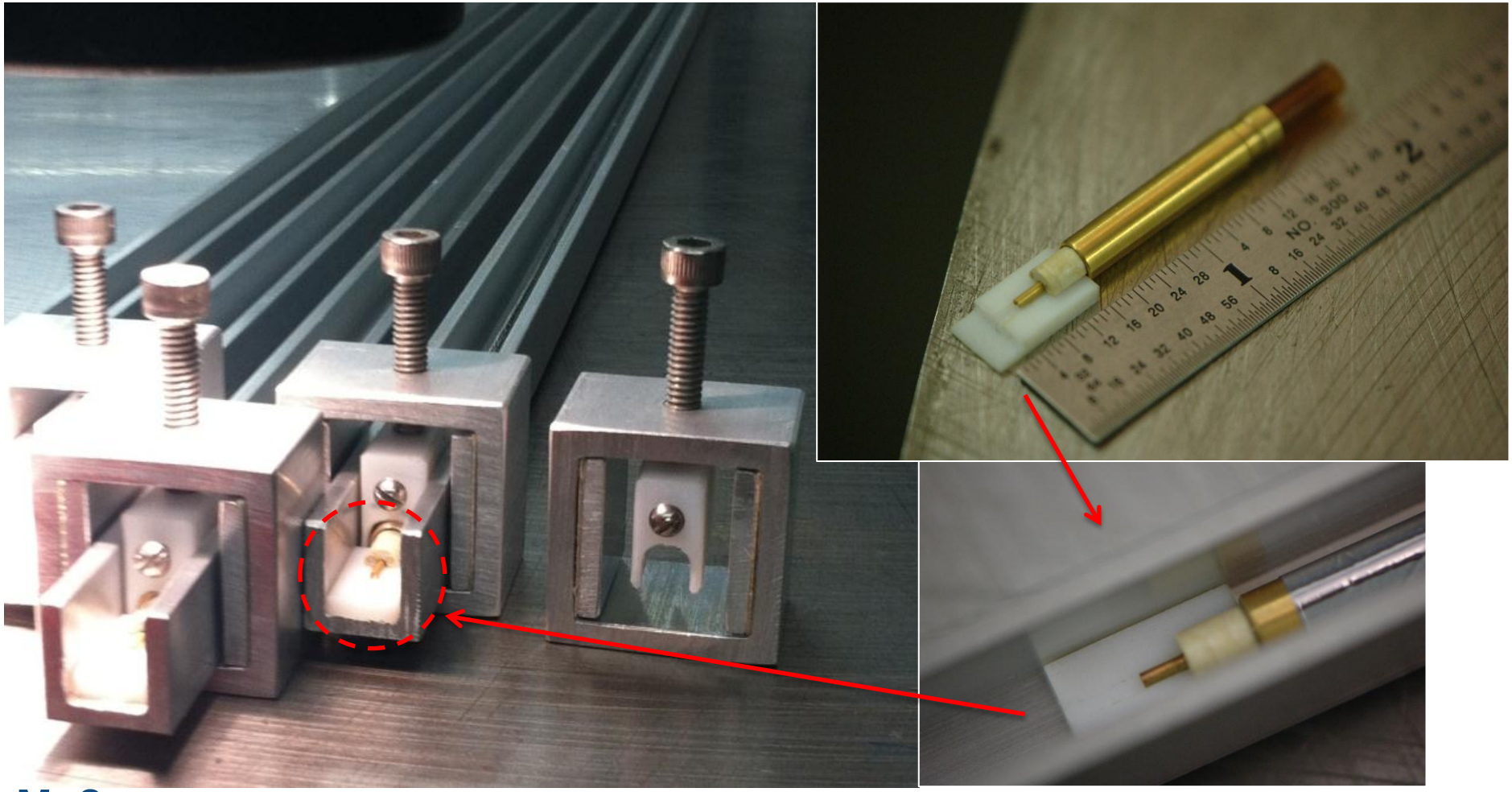




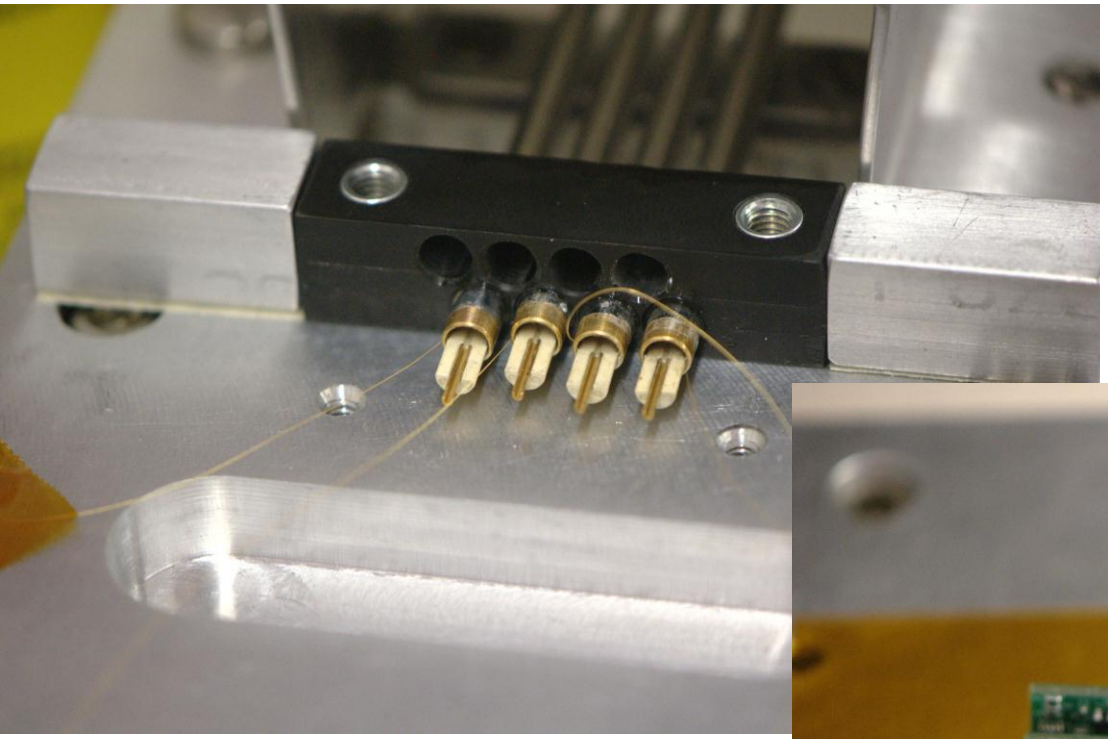
Assembly jigs for gluing end pieces to straw

- Orient end pieces on two ends
- Glue to straw with conductive glue

Fermilab *R. Wagner*

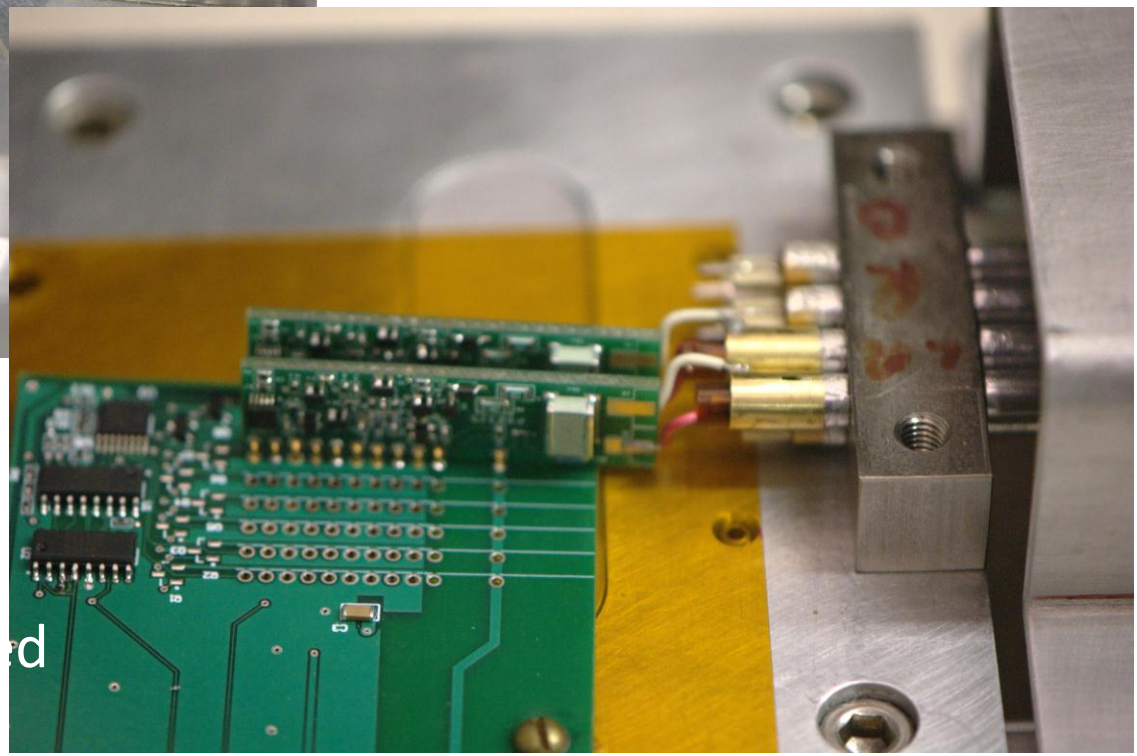


A 2x4 prototype



Fermilab

R. Wagner, V. Rusu

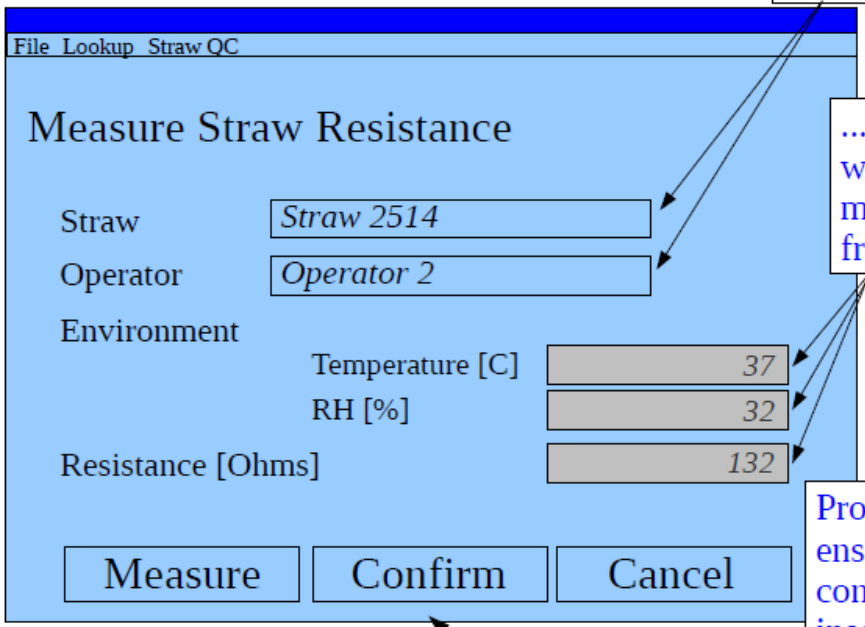


QA/QC data base

- Use a RDBMS
  FNAL supports PostgreSQL
- Barcode users & most parts
  Straws via their storage tubes
- QC and construction steps recorded in DB
- Leverage NOvA software experience and barcode readers, but write new software interface

Rice *M. Corcoran*
York *K. Lynch*

GUI



These would come from a barcode ...

... while these would be measured live from hardware

Program logic ensures consistency before insertion/update

Straw assembly summary

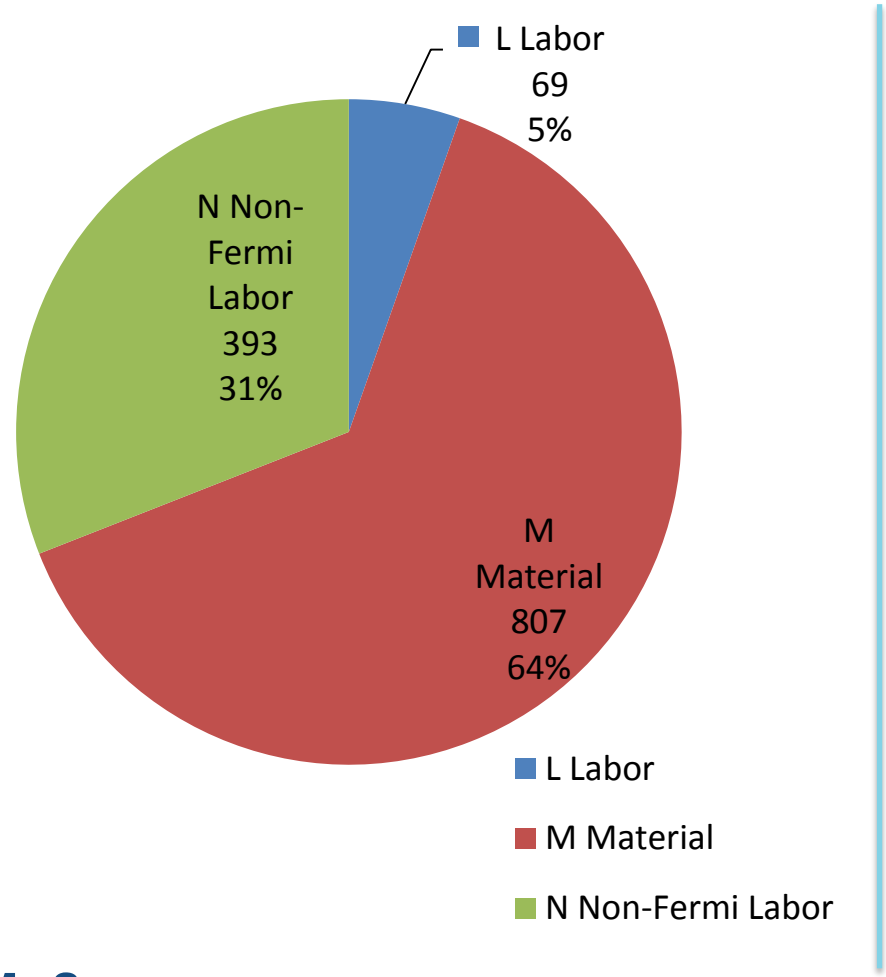
- Straw end components had been manufactured and tested.
- Assembly tools and test equipment for straw assembly procedures were developed and functional.
- Using the material and tools developed, a 2×4 prototype is completed with front end electronics attached.
- A QA/QC data base is being implemented for production process.

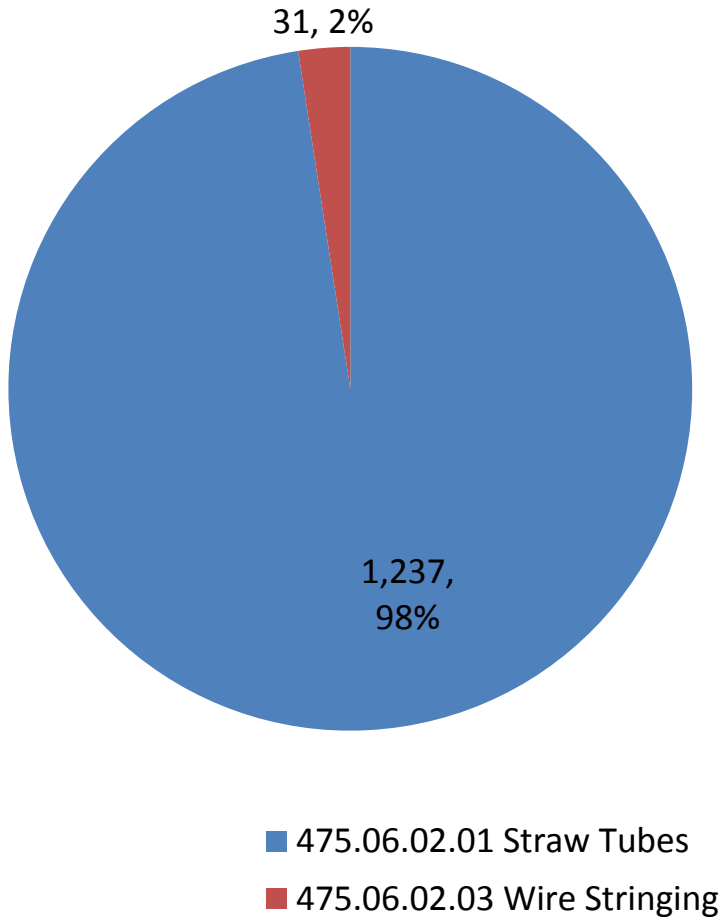
Cost Table

	Base Cost (AY K$)			Estimate Uncertainty (on remaining costs)	% Contingency on ETC	Total Cost
	M&S	Labor	Total			
475.06 Tracker						
475.06.02 Straws						
475.06.02.01 Straw Tubes	1,170	67	1,237	425	38%	1,662
475.06.02.03 Wire Stringing	29	2	31	4	21%	35
Grand Total	1,200	69	1,268	429	38%	1,697

Cost Breakdown

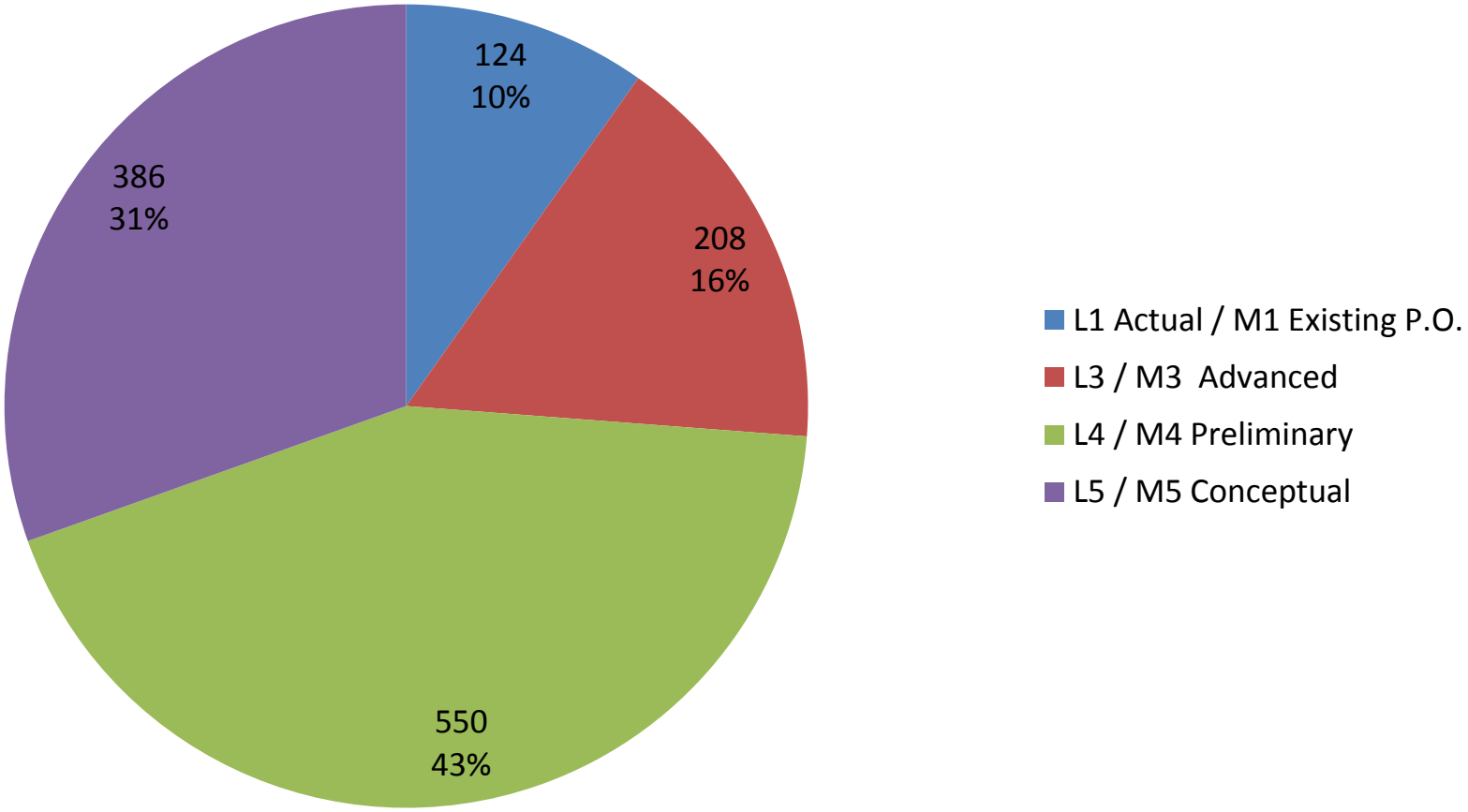
Base Cost (AY K$)





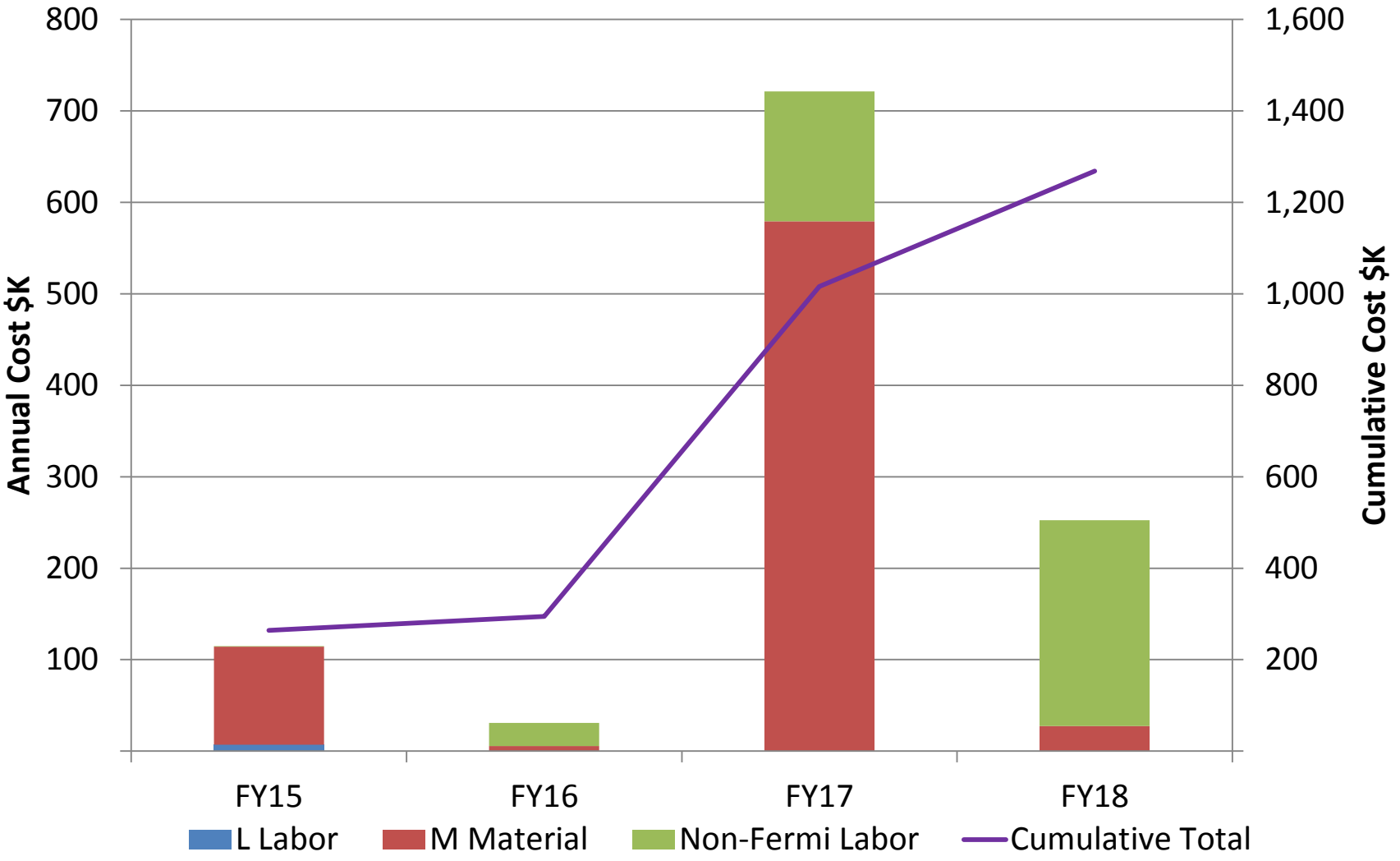
Quality of Estimate

Base Cost (AY K$)



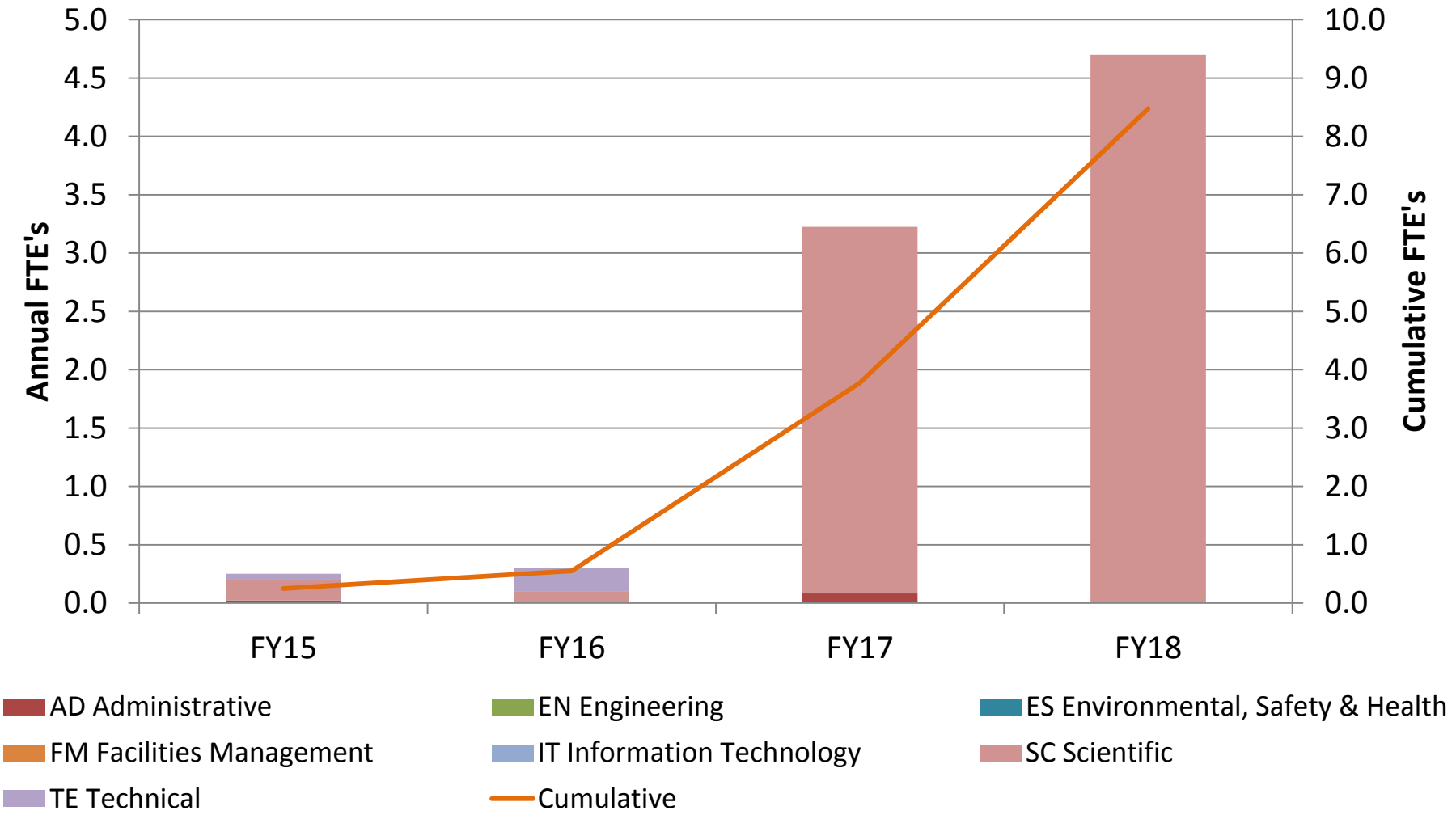
Labor & Material by FY

Base Cost (AY K$)



Labor Resources by FY

FTEs by Discipline



Conclusion

- Detecting elements of the tracker: straws and straw-end components are manufactured and tested.
- Straw tube is robust and leak tight, and exceeds the requirements to operate in vacuum for 6 years.
- Assembly procedures and assembly tooling are realized and exercised.
- A QA/QC data base is being implemented.
- Ready for CD-2