Mu2e Tracker Straws

Chiho Wang
Straws L3 Manager
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Outline

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

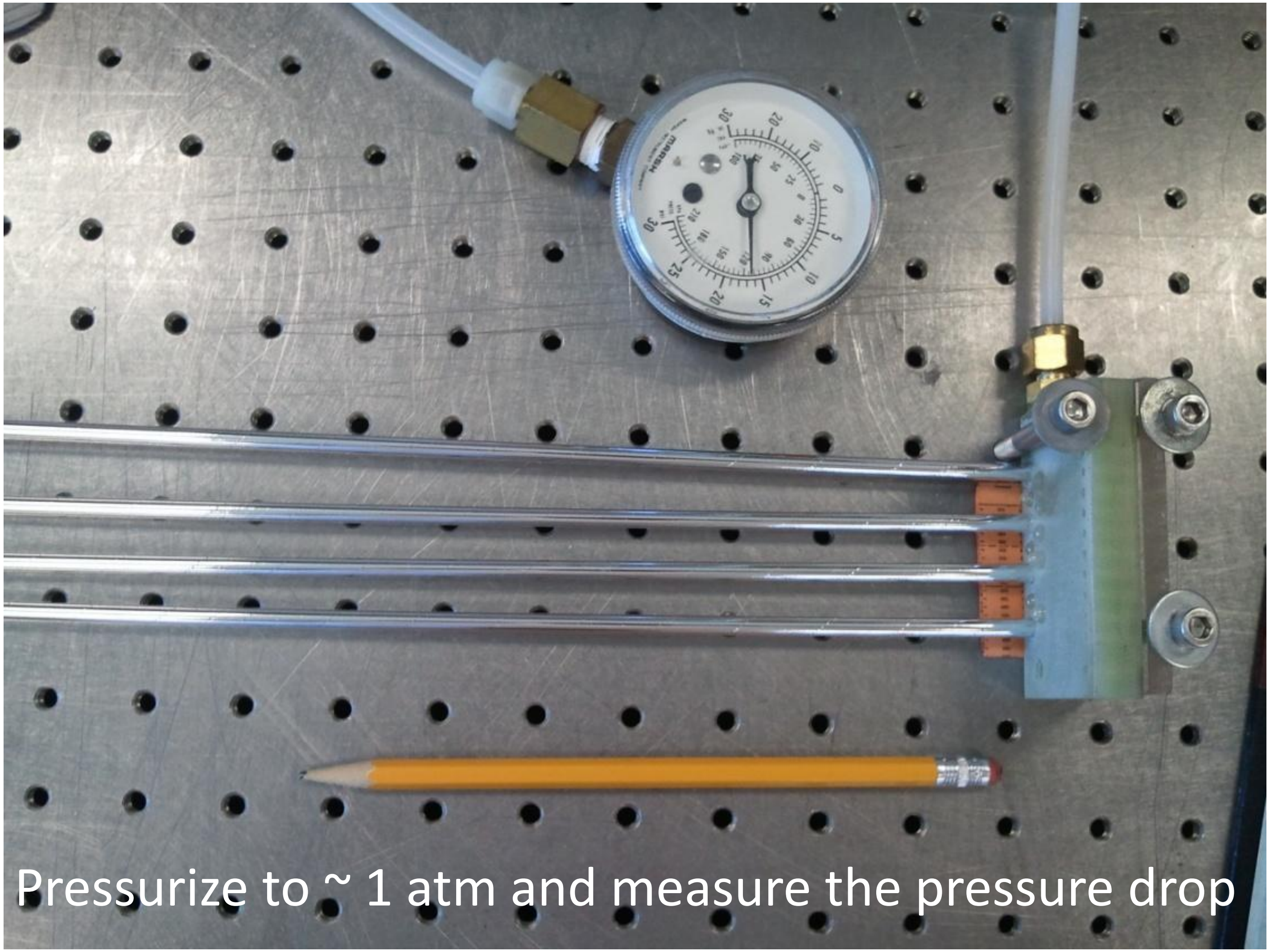
Straw requirements

- 5mm 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.

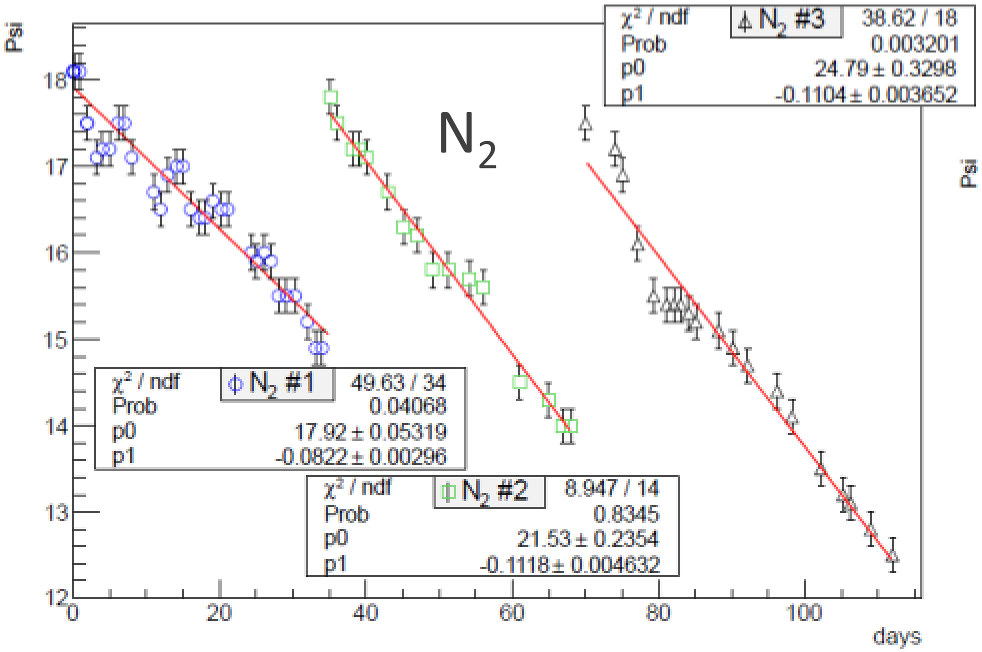
Straw properties

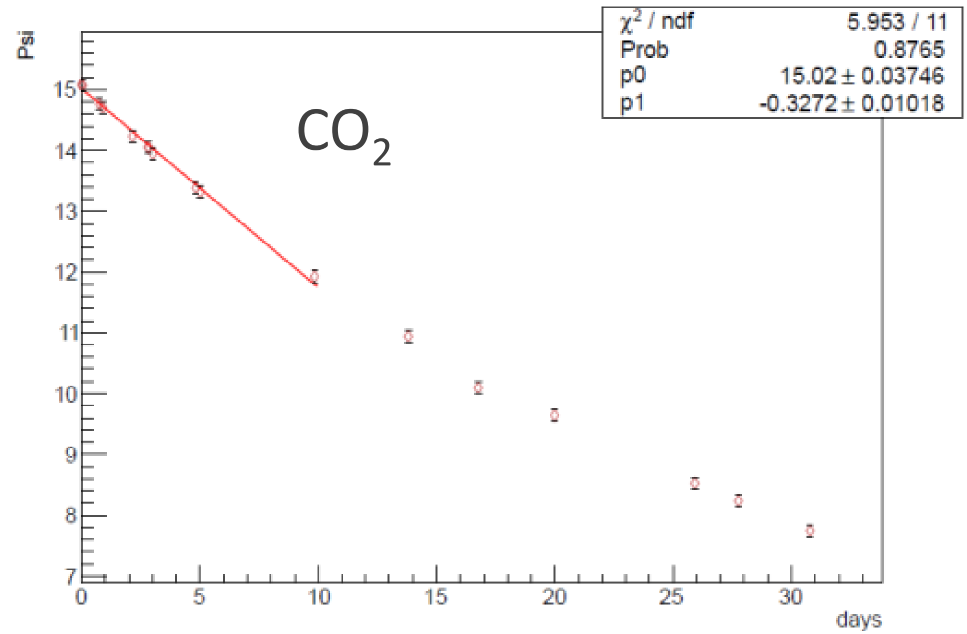
- Destructive tests:
  - Pressure: sustained 60 psi (10 min.). Destroyed ≥ 70 psi
  - Stretch: sustained 1.6 kg (2 yrs.). Destroyed ≥ 2.9kg
- Mechanical:
  - Linear density: 0.34±0.01 g/100cm
  - Wall thickness: 15μm
    - Derived from linear density, assuming Mylar density 1.39g/cm^3, and same for the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

Straw leak measurement 1



Straw leak measurement 1



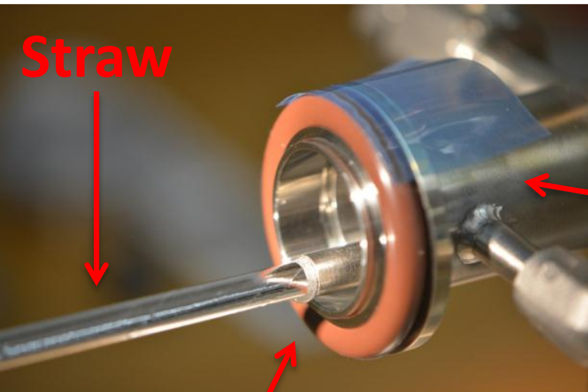


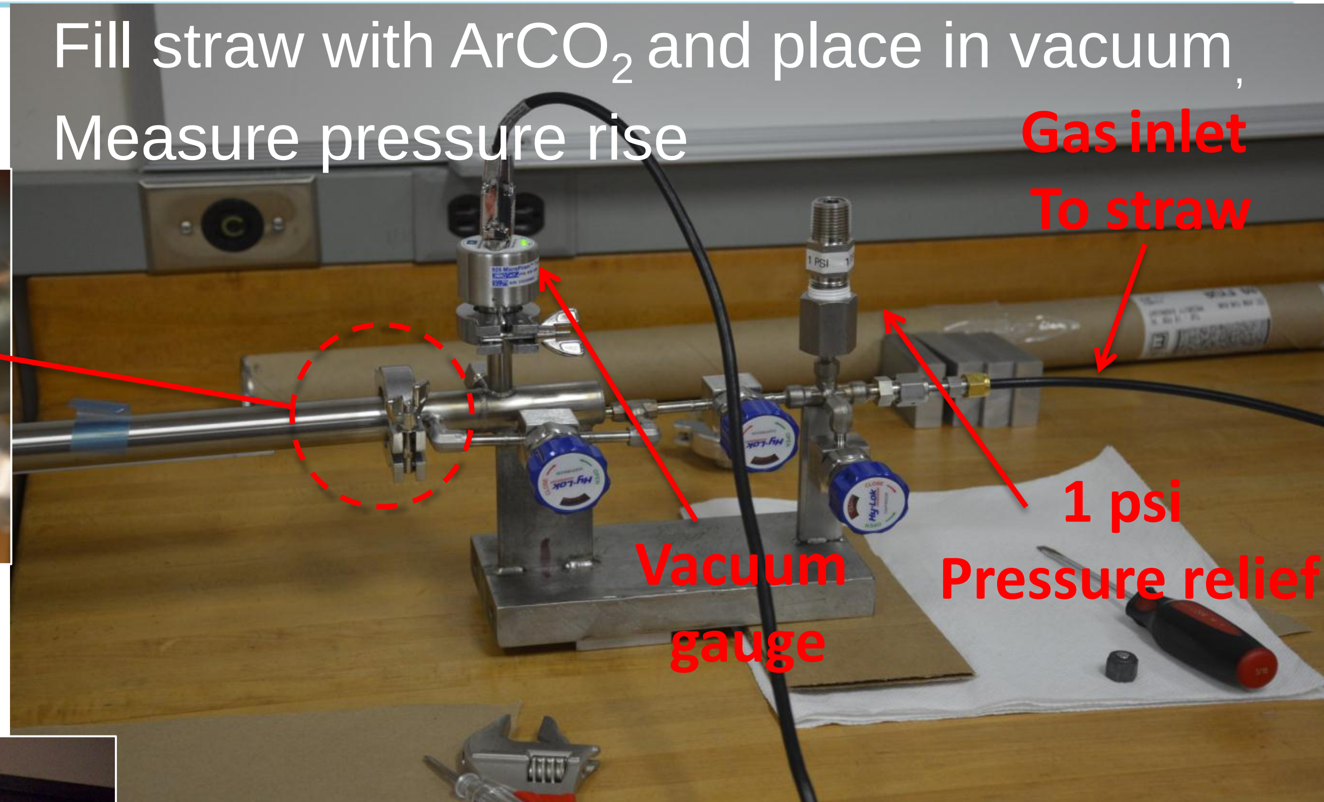
- N_2 leak rate =0.095±0.026 psi/day
- CO_2 leak rate =0.36±0.06 psi/day
- Assume Ar leak rate similar to N_2 , and straw volume ~ 0.3 m^3, estimated Ar(80%)CO(20%) leak rate ~ 2ccm / tracker volume

Straw leak measurement 2

Fill straw with $ArCO_2$ and place in vacuum,

Measure pressure rise

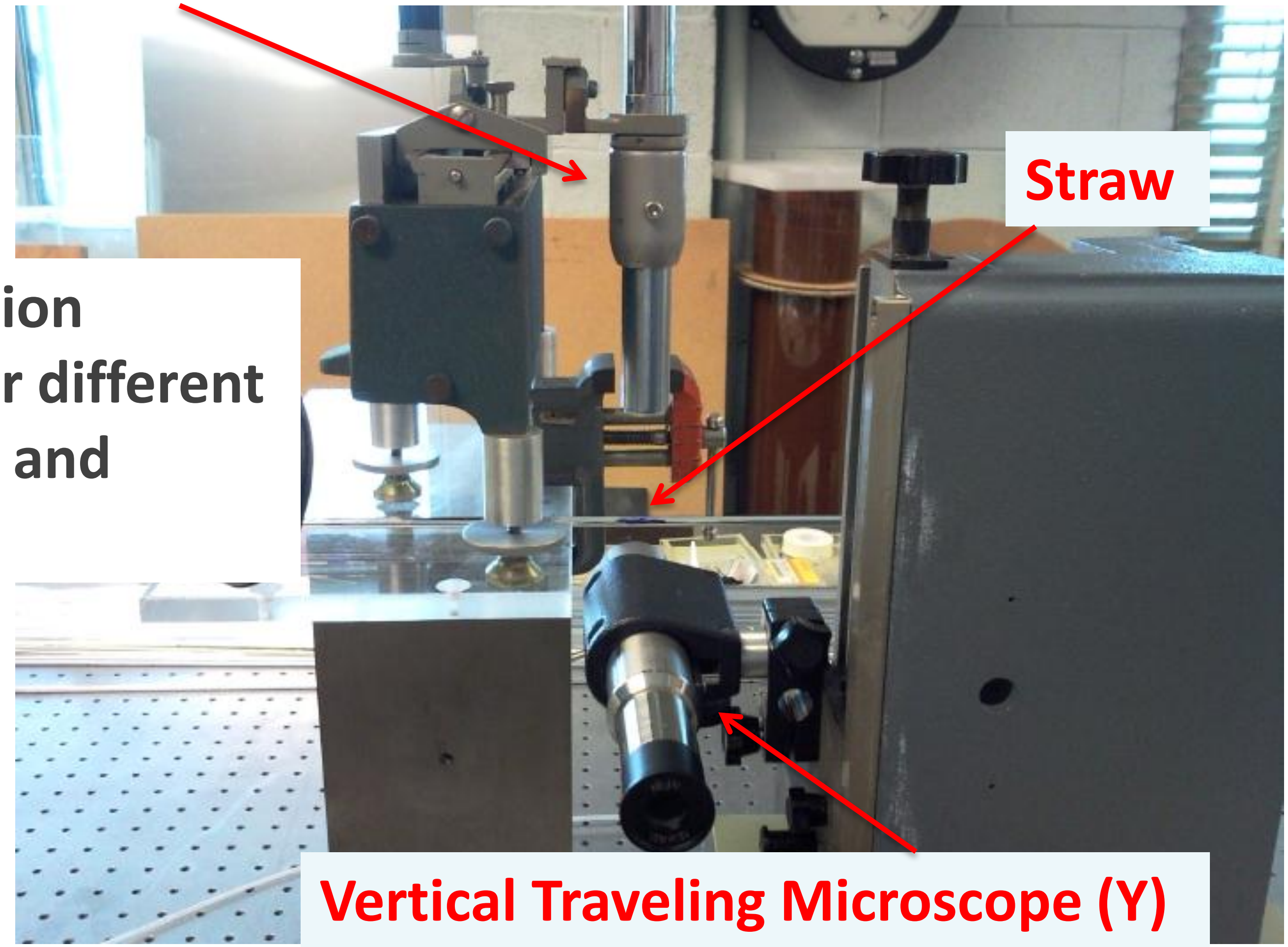




- Tested 10x 129cm straws
- Averaged leak rate = 3.6×10^{-4}ccm/straw
- ~ 4 ccm / tracker volume

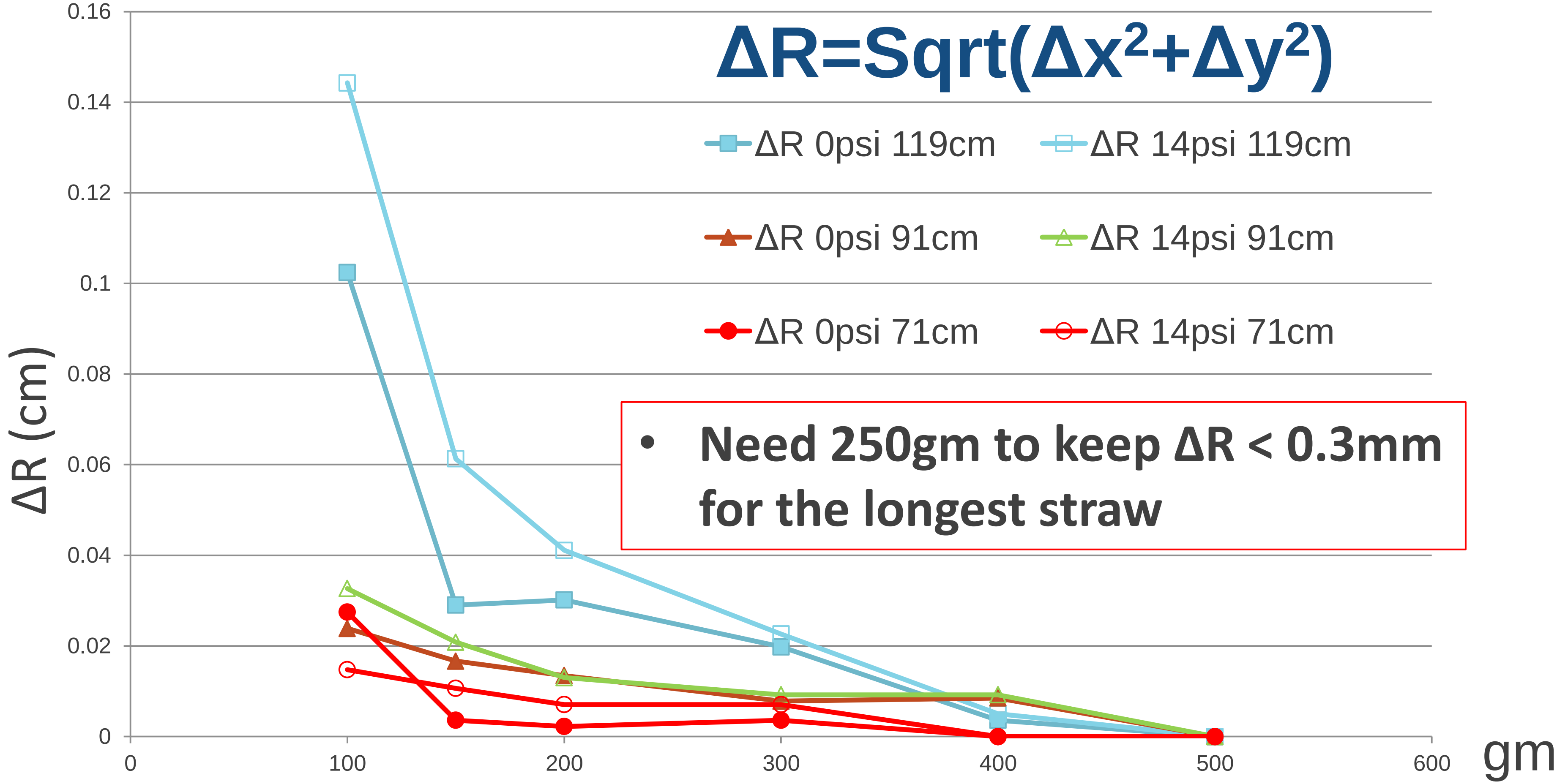
Straw straightness measurement

To determine the required straw tension



Straw deviation measured for different straw length and tension.

Straw straightness measurement

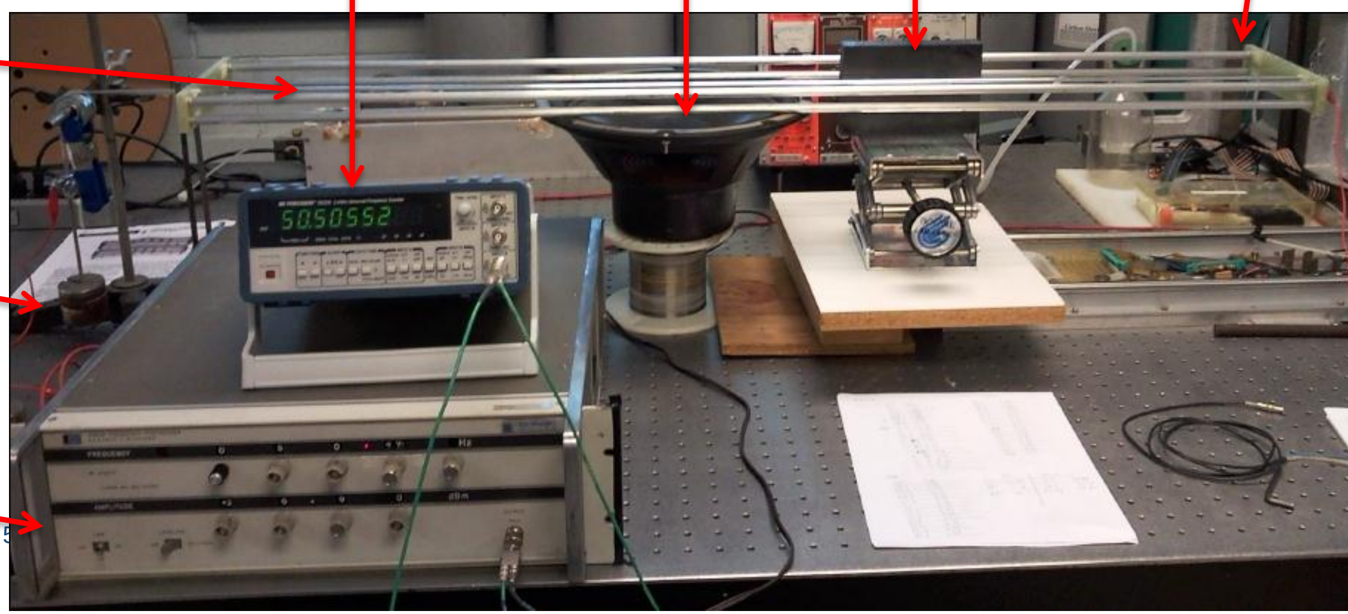


- **Need 250gm to keep ΔR < 0.3mm for the longest straw**

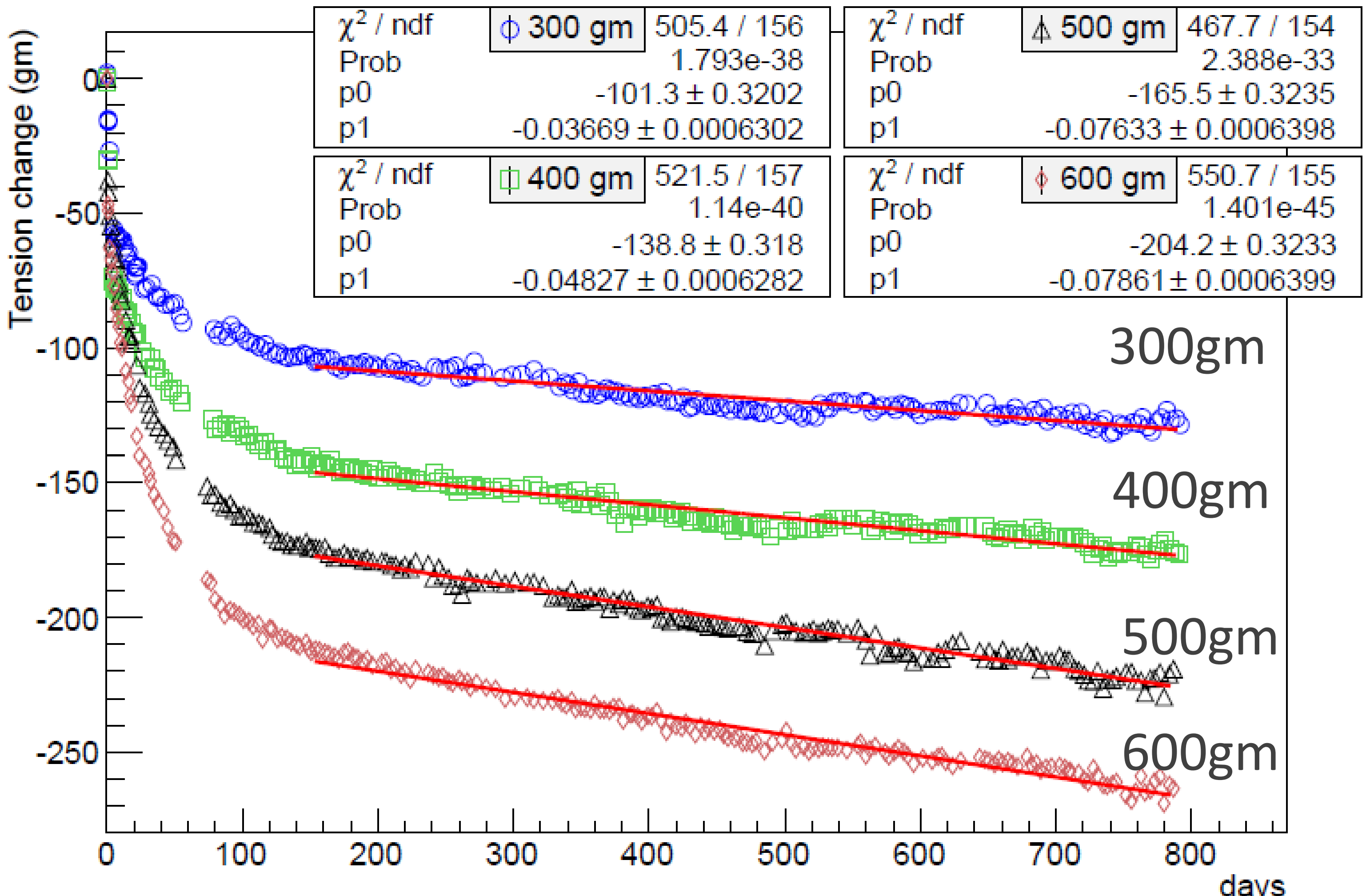
Mid point deviation, relative to the highest tension (500g)

Straw creep measurement

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

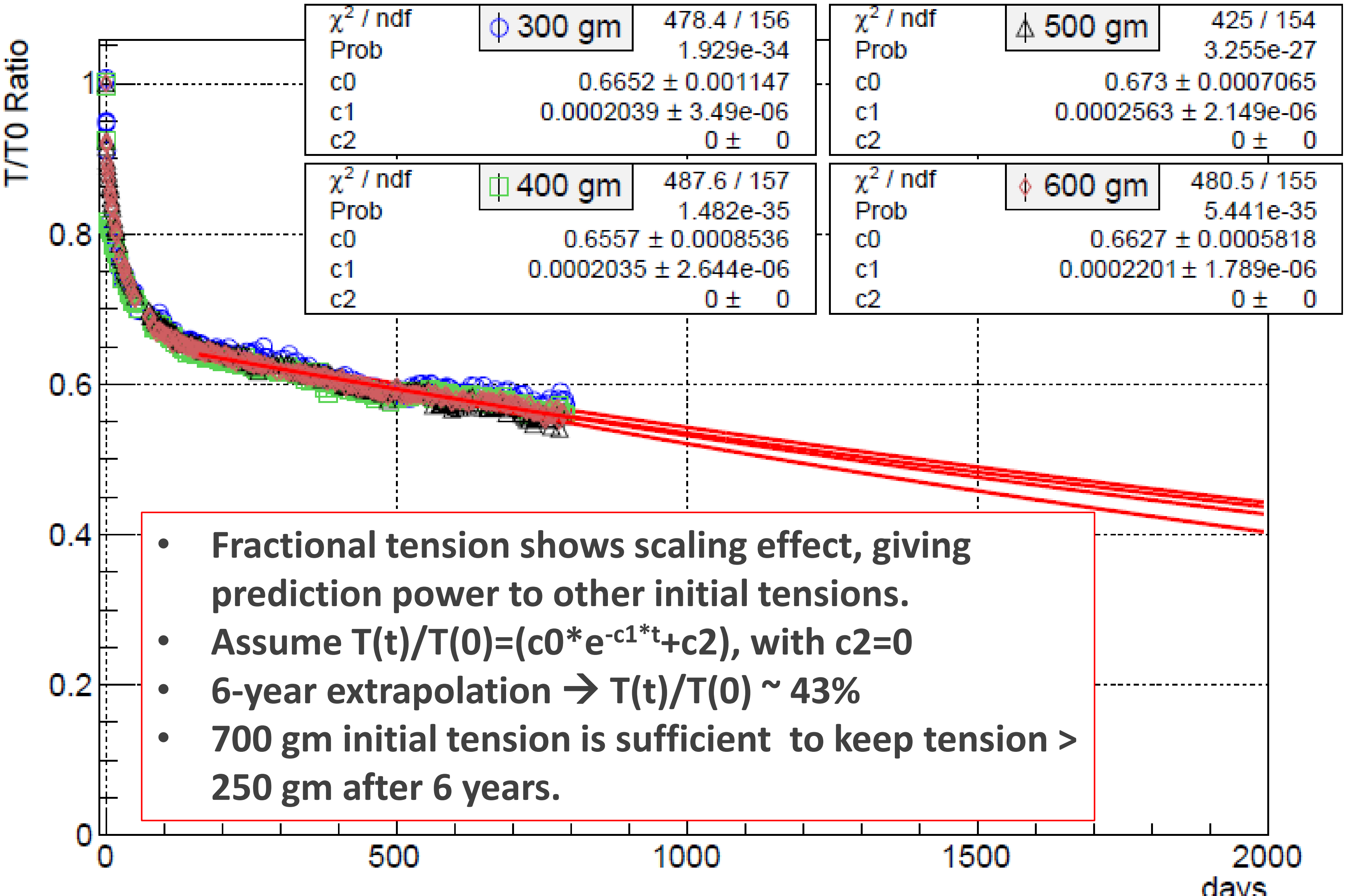


Straw creep measurement



(corrected for temperature & humidity variation)

Straw creep measurement



- **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 gm initial tension is sufficient to keep tension > 250 gm after 6 years.**

Radiation aging study

- 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 Fe55 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 110cm:

			Gain(x)/Gain(110cm)		
Period	Charge (mC/cm)	Current (nA/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 balanced 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

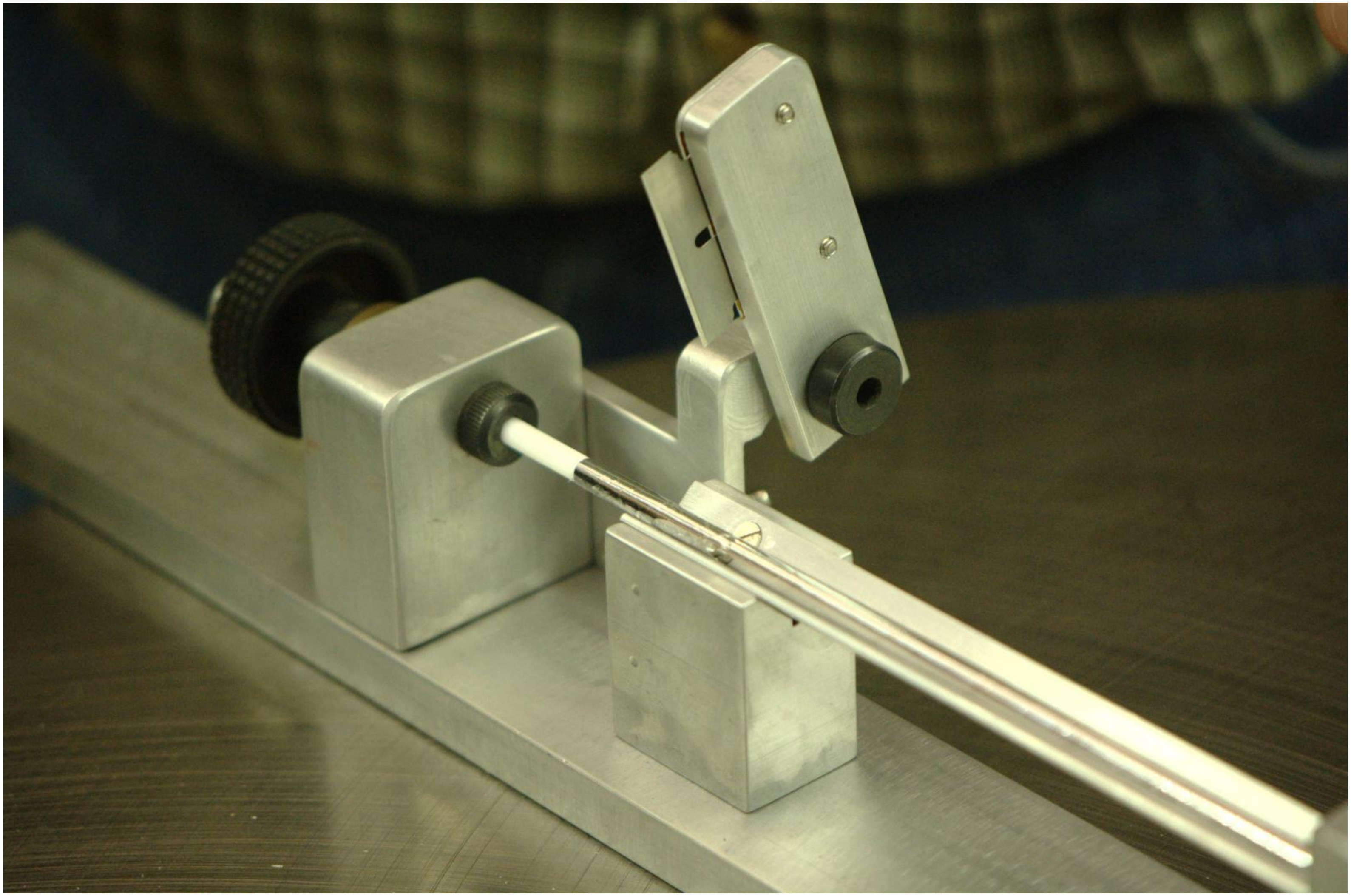
Straw property summary

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

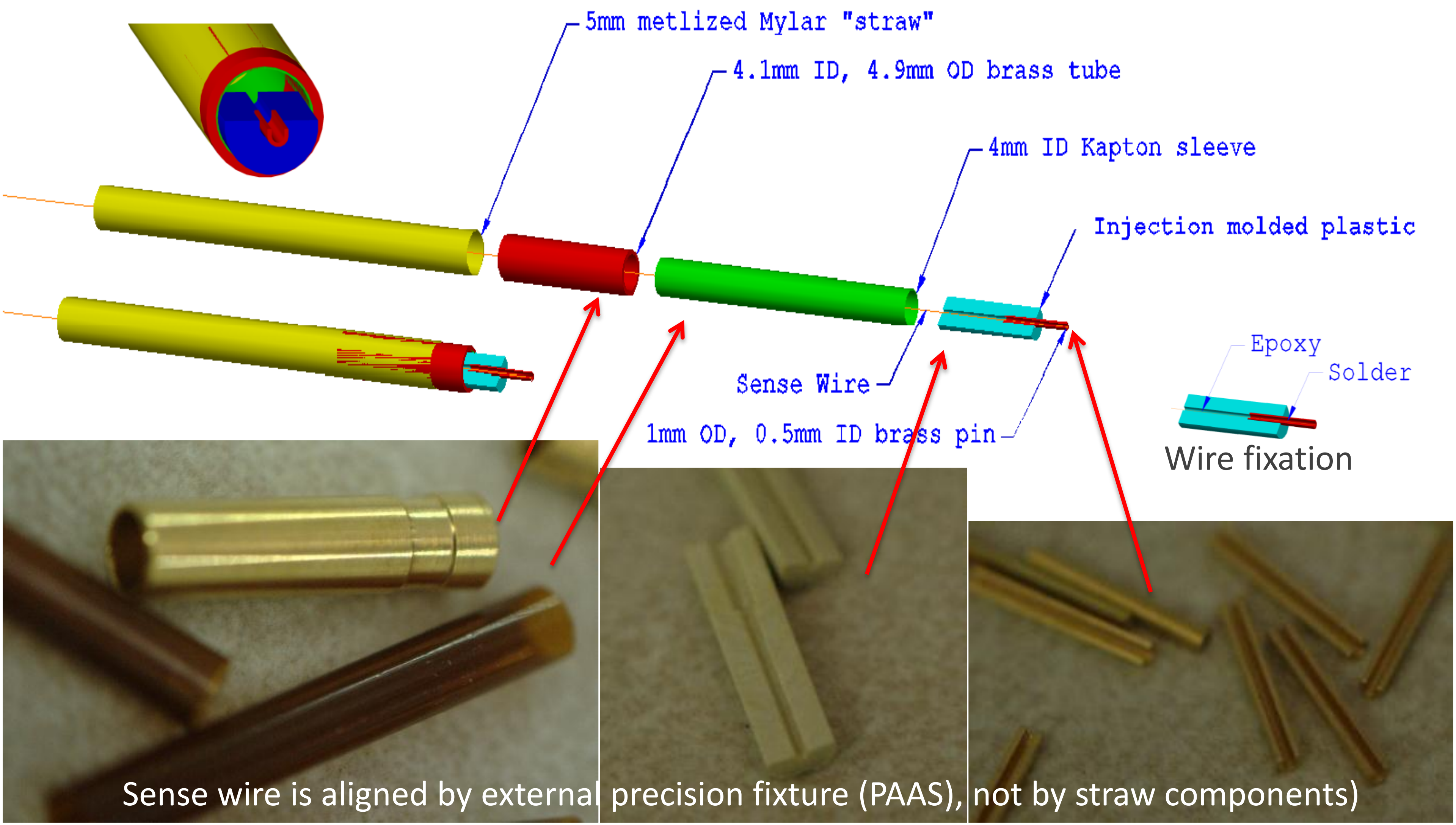
Straw assembly

- 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

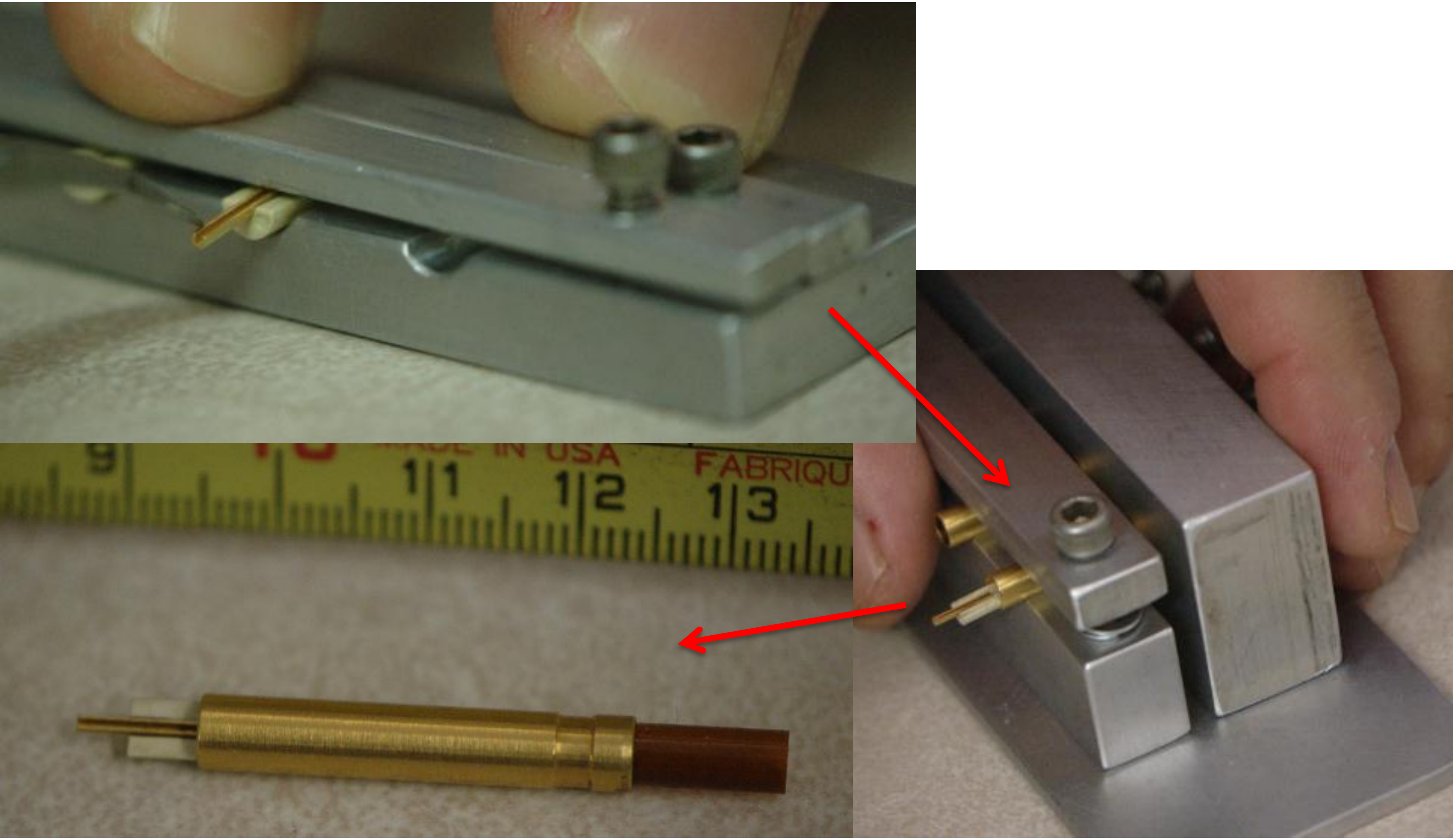


Straw sub-assembly



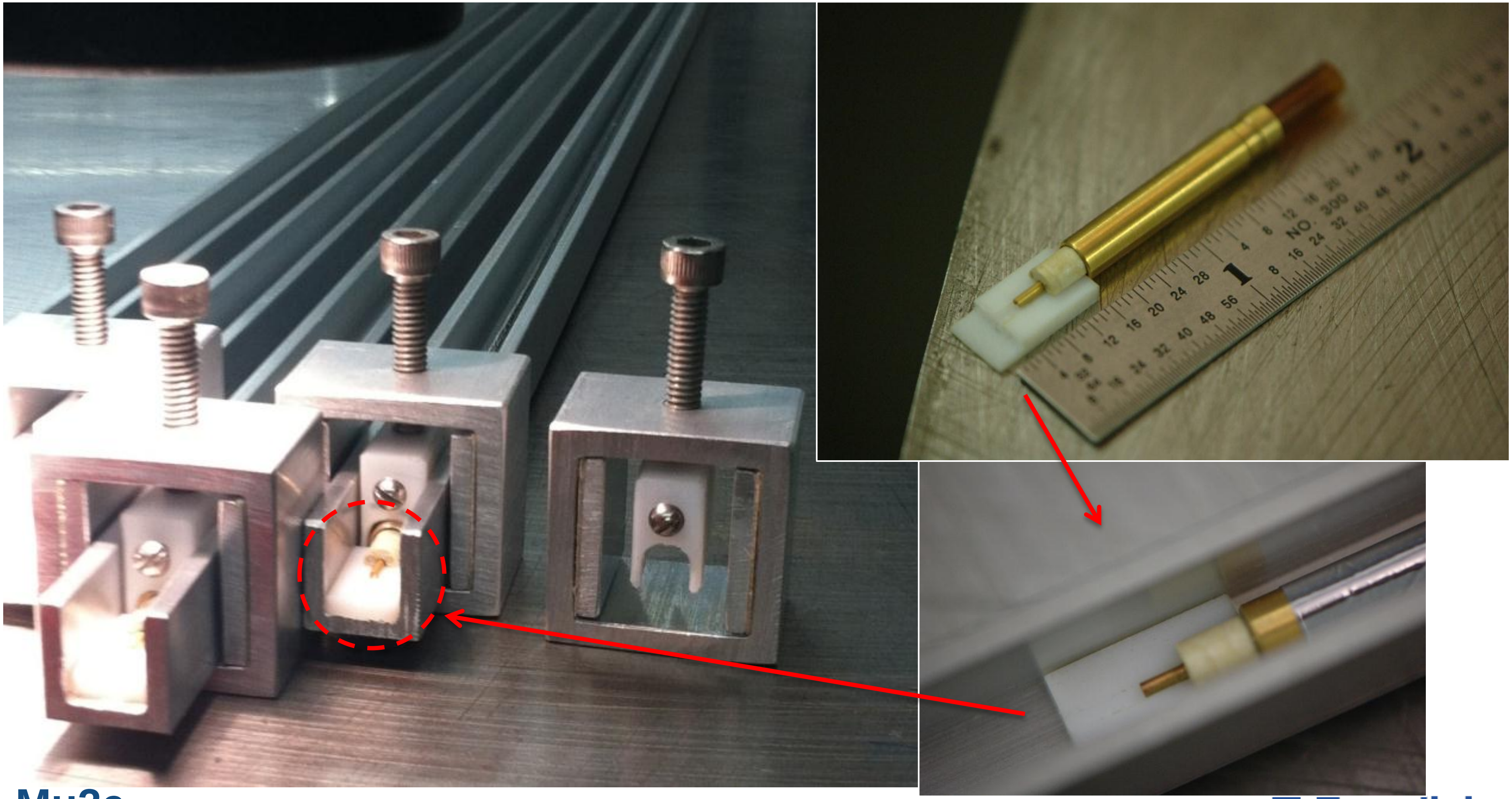
Sense wire is aligned by external precision fixture (PAAS), not by straw components)

Assembly jigs for assembling end pieces

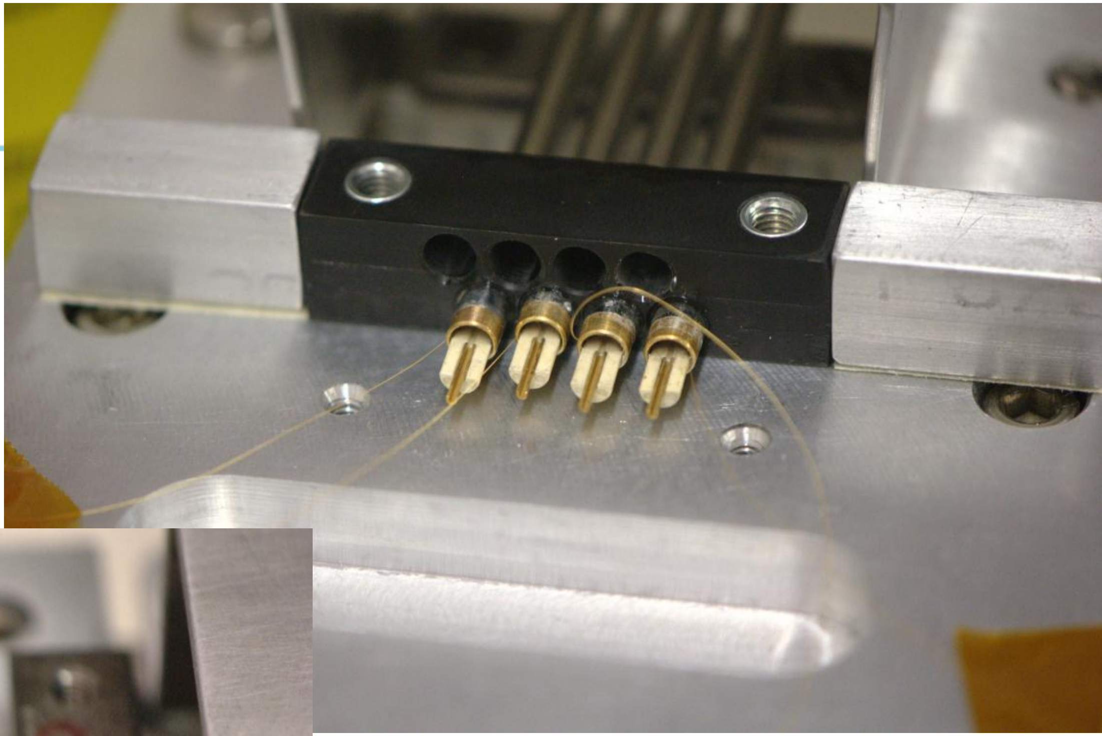


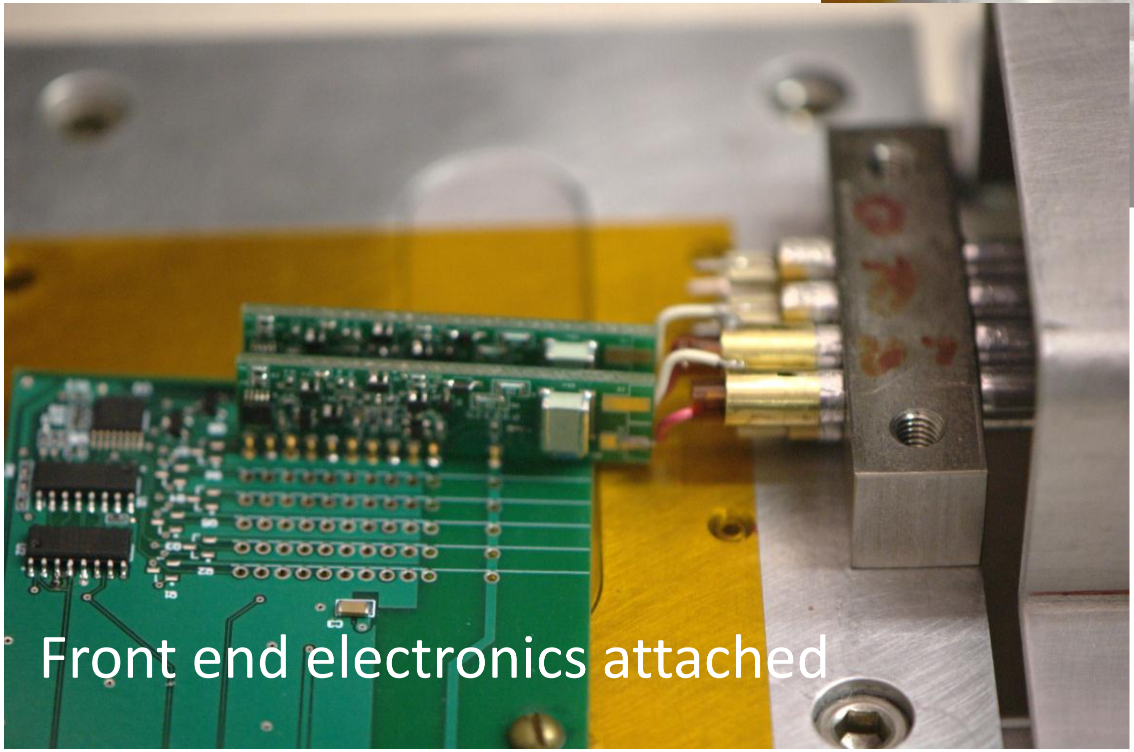
Assembly jigs for gluing end pieces to straw

- Orient end pieces on both end of the straw to the same direction and glue to straw with conductive glue.



A 2x4 prototype



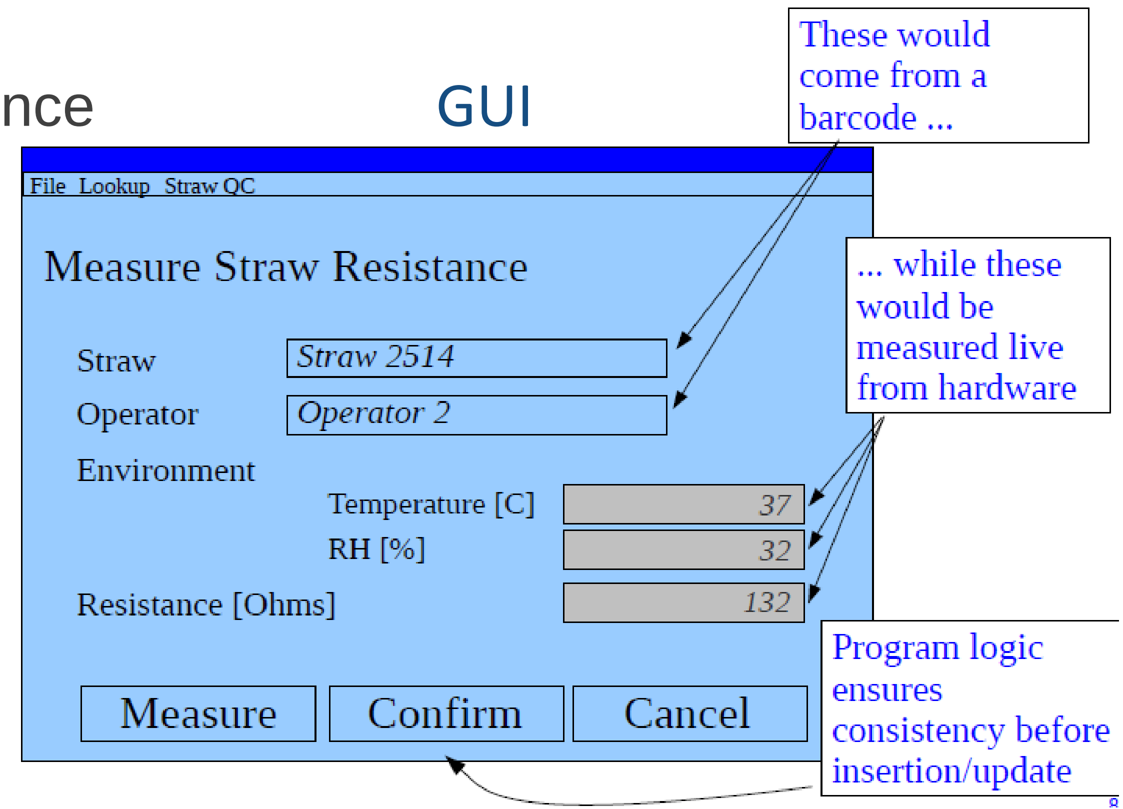


QA/QC data base

- RDBMS
  - Open source
  - Multimaster replication
  - Input programming language independence

  →MariaDB (formerly MySQL)

GUI

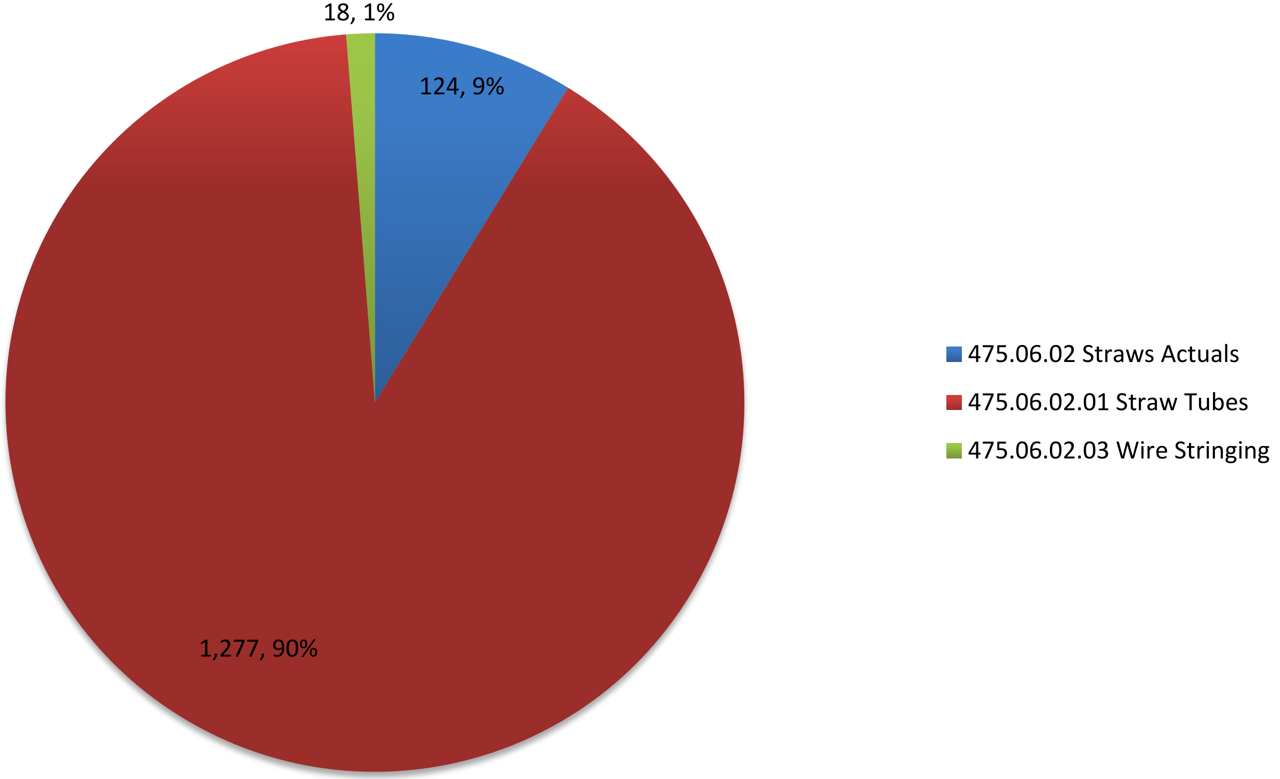


Straw assembly summary

- 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 2x4 prototype is completed with front end electronics attached.
- A QA/QC data base is being implemented for production process.

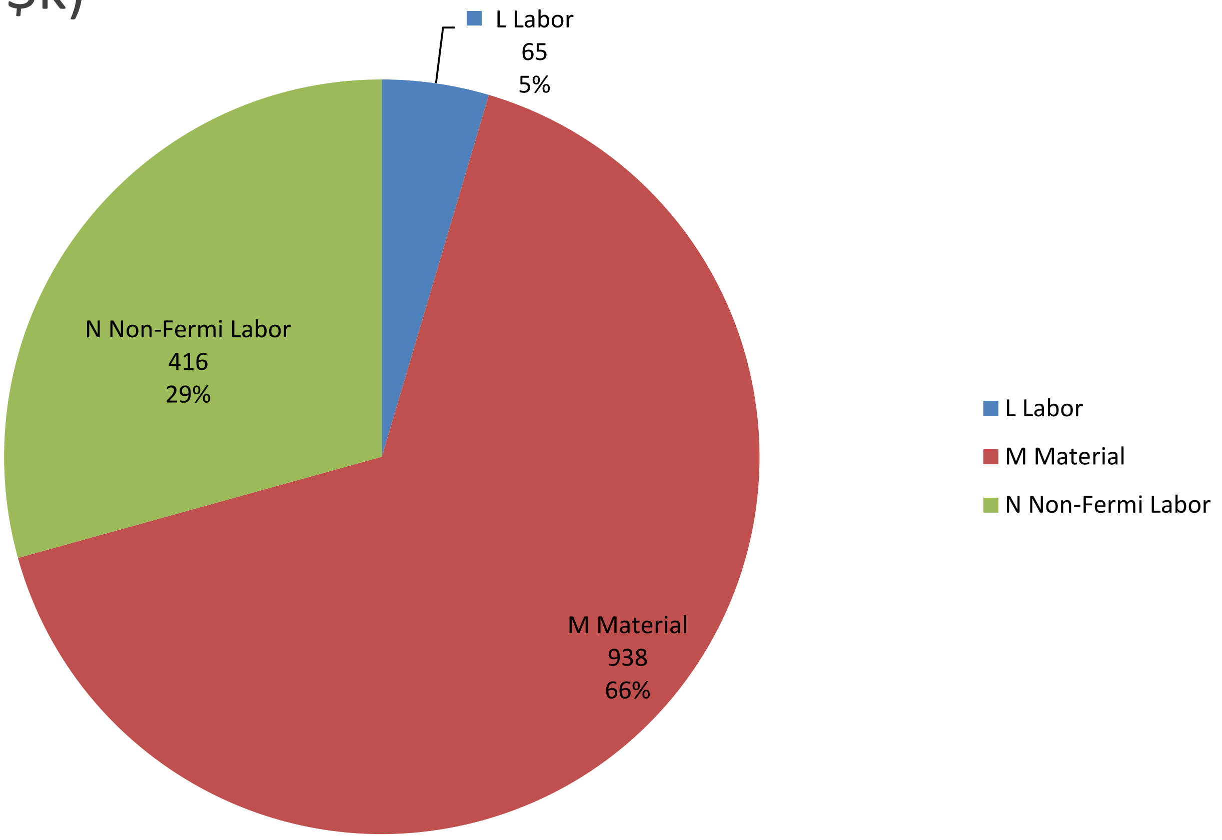
Cost Distribution by L4

Base Cost by L4 (AY $k)



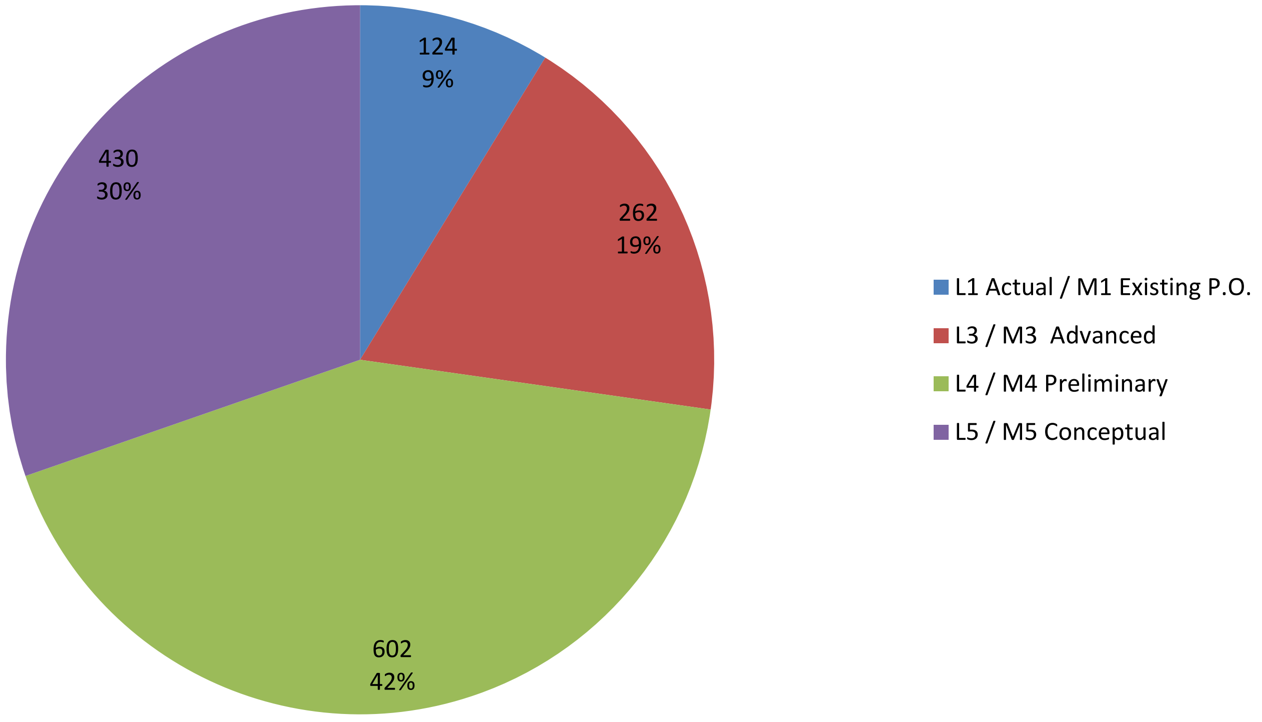
Cost Distribution by Resource Type

Base Cost (AY $k)

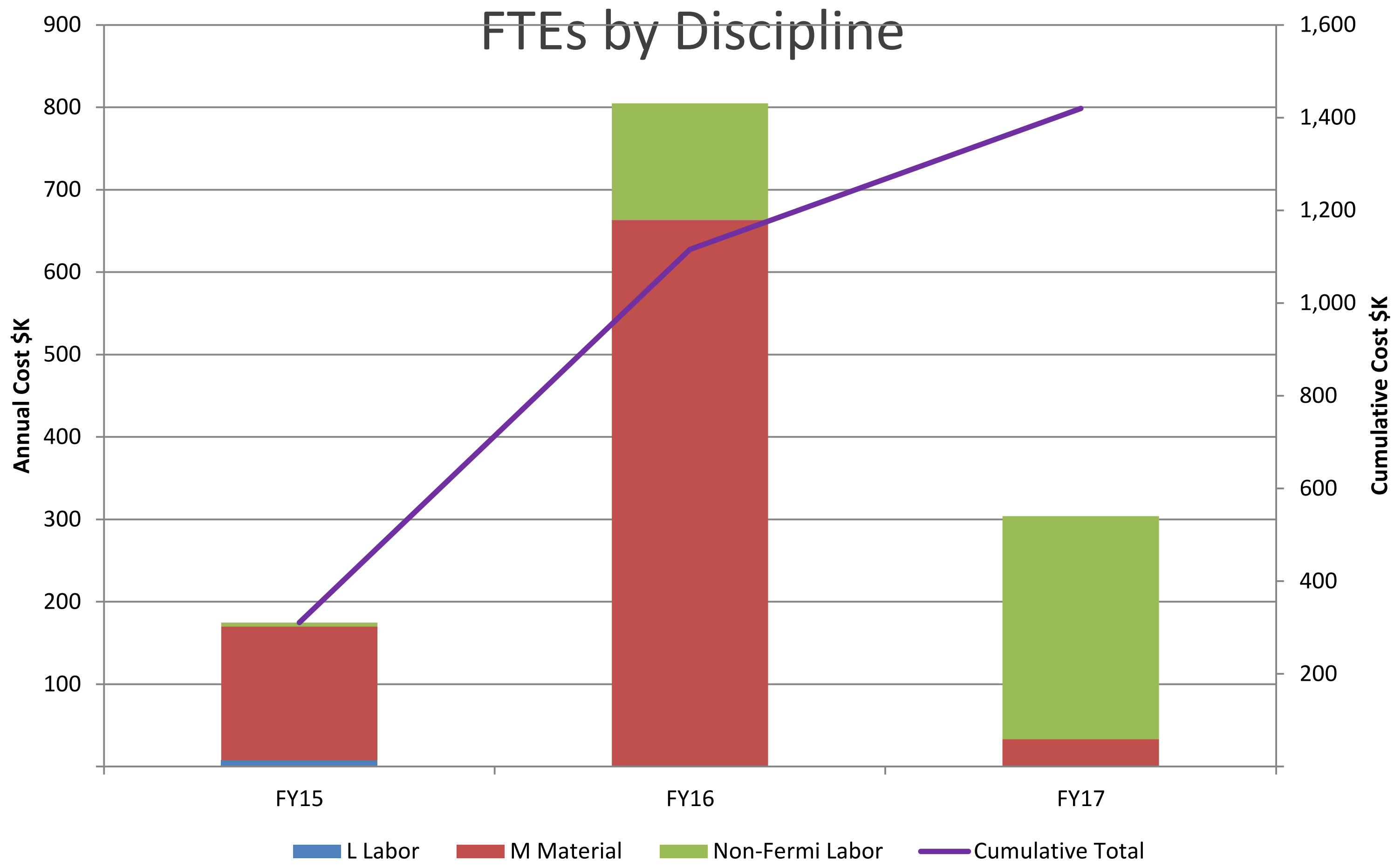


Quality of Estimate

Base Cost by Estimate Type (AY$k)



Labor Resources



Cost Table

Costs are fully burdened in AY $k

	Base Cost (AY $)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining costs)	% Contingency on ETC	Total Cost
475.06 Tracker						
475.06.02 Straws						
475.06.02 Straws	75	49	124			124
475.06.02.01 Straw Tubes	1,262	16	1,277	486	38%	1,763
475.06.02.03 Wire Stringing	18		18	3	15%	20
Grand Total	1,354	65	1,419	488	38%	1,908

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.
- Cost is better estimated.