Straw Tube Detectors @Duke

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Outline

- Solenoid Detector Collaboration Straw Tracker @SSC
- ATLAS Transition Radiation Tracker (TRT) @LHC
- Mu2e Straw Tracker @FNAL
- DUNE Straw Tube Detector (STT) for Same Axis Near Detector
- FCCee straw tracker

SDC Straw Tracker (1989 - 1993) @SSC

- 4 mm diameter Kapton straws (30 μm thick)
- Straw tubes were inside a carbon fiber shell (4 meters long)
- Duke was scheduled to construct ~1/2 to 1/3 of the modules
- Design and R&D
  - Straw end-plates where straws are terminated and interfaced with electronics
  - Helical wire-support design
  - Wire-joint
  - Aging test
- Constructed 4 meter long two full size modules (out of 4) and beam tested @BNL

SSC SDC TDR @1992- straw tracker (2 x 4 meter long – x & u)

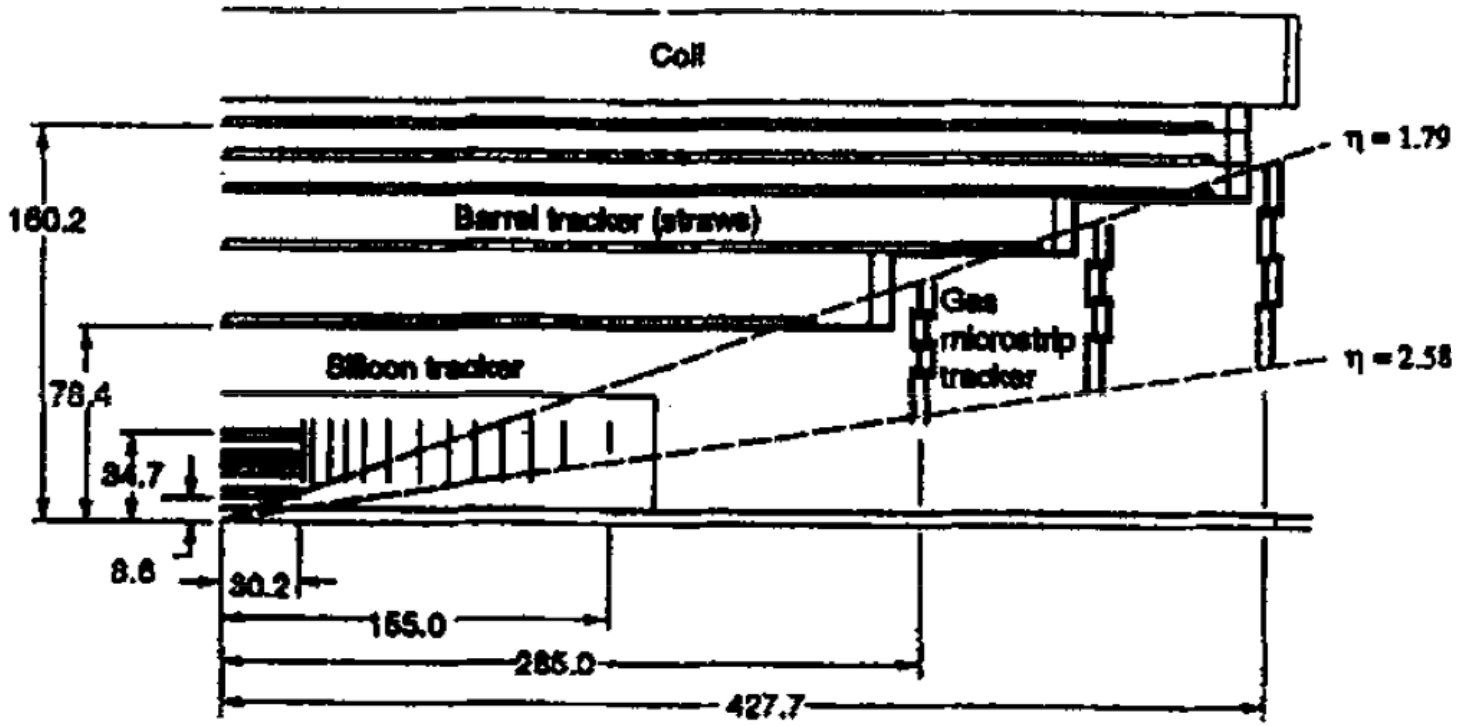


Fig. 1. A transverse view of a quarter section of the tracker. Dimensions are in centimeters.

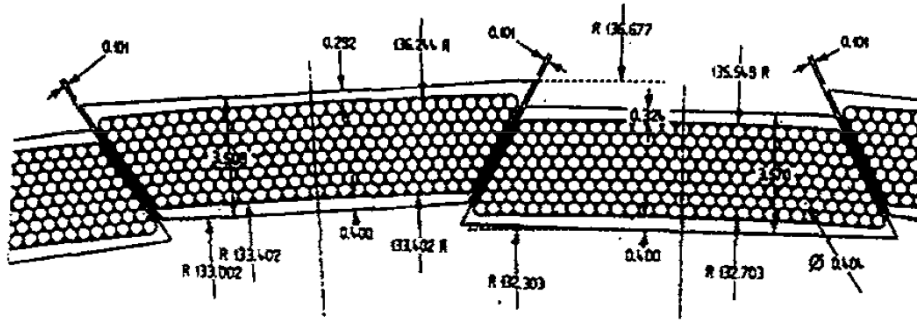
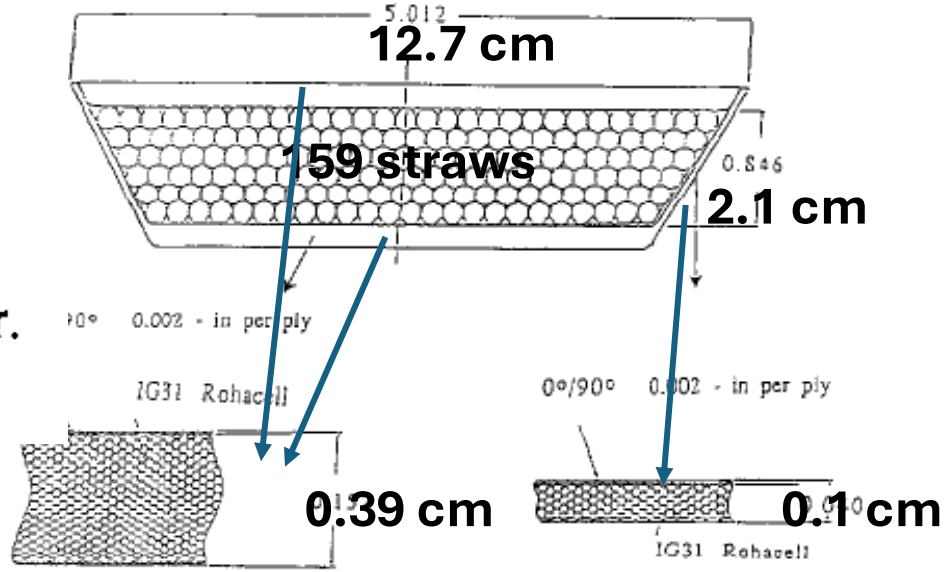
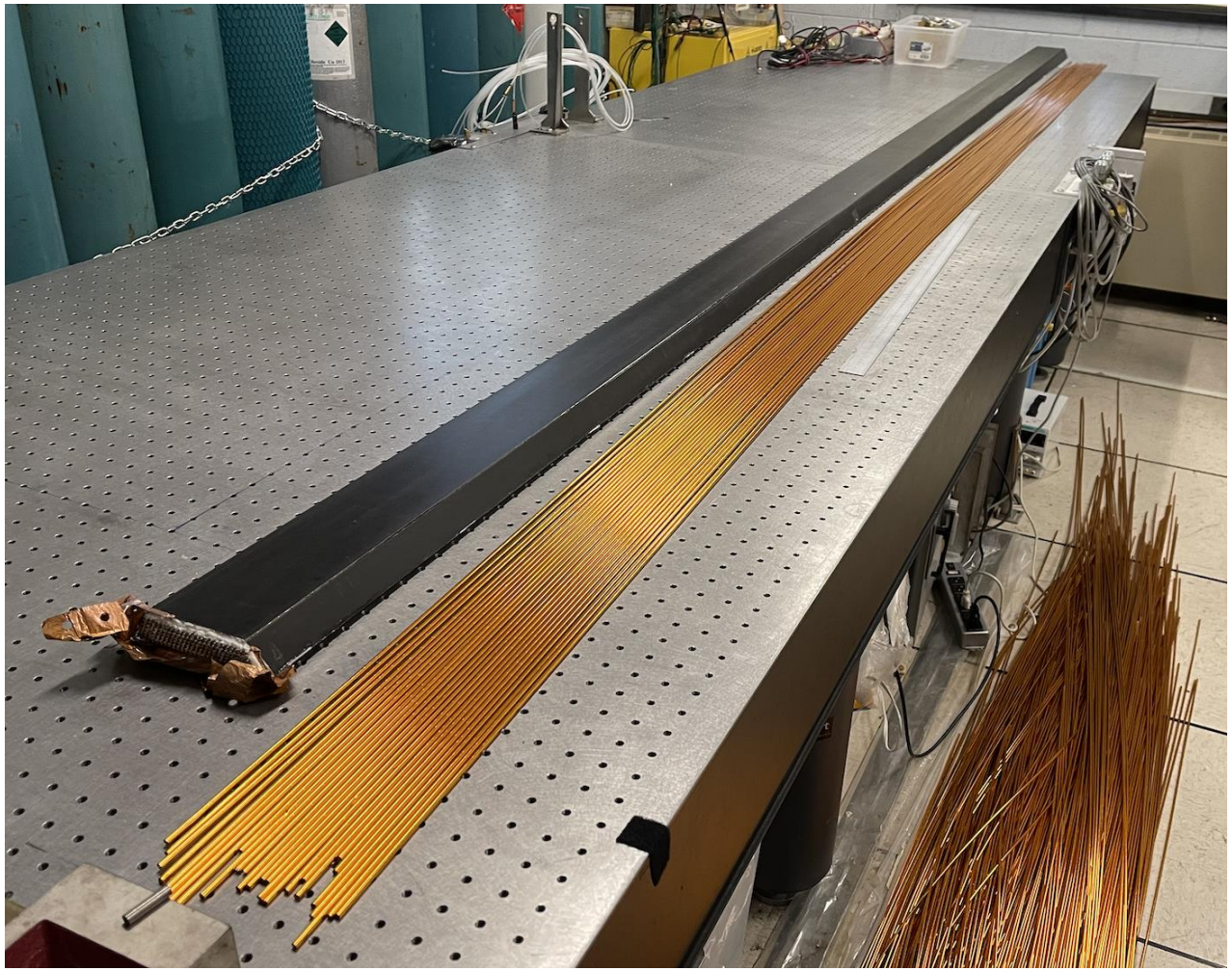
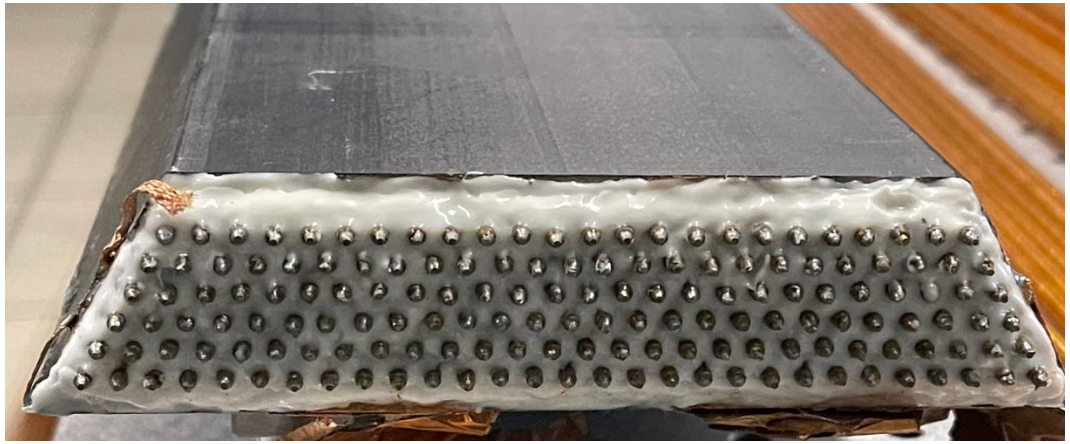


Fig. 3. Detail of the axial modules, showing the eight layers of straws.



SDC straw tracker





ATLAS Barrel TRT (1995 –)

- Joined ATLAS after SSC termination
- Many SDC straw tracker designs were adapted
- Duke constructed ~1/2 modules (out of 96 + spares)
- Has been in operation since ~2010

TRT end plate

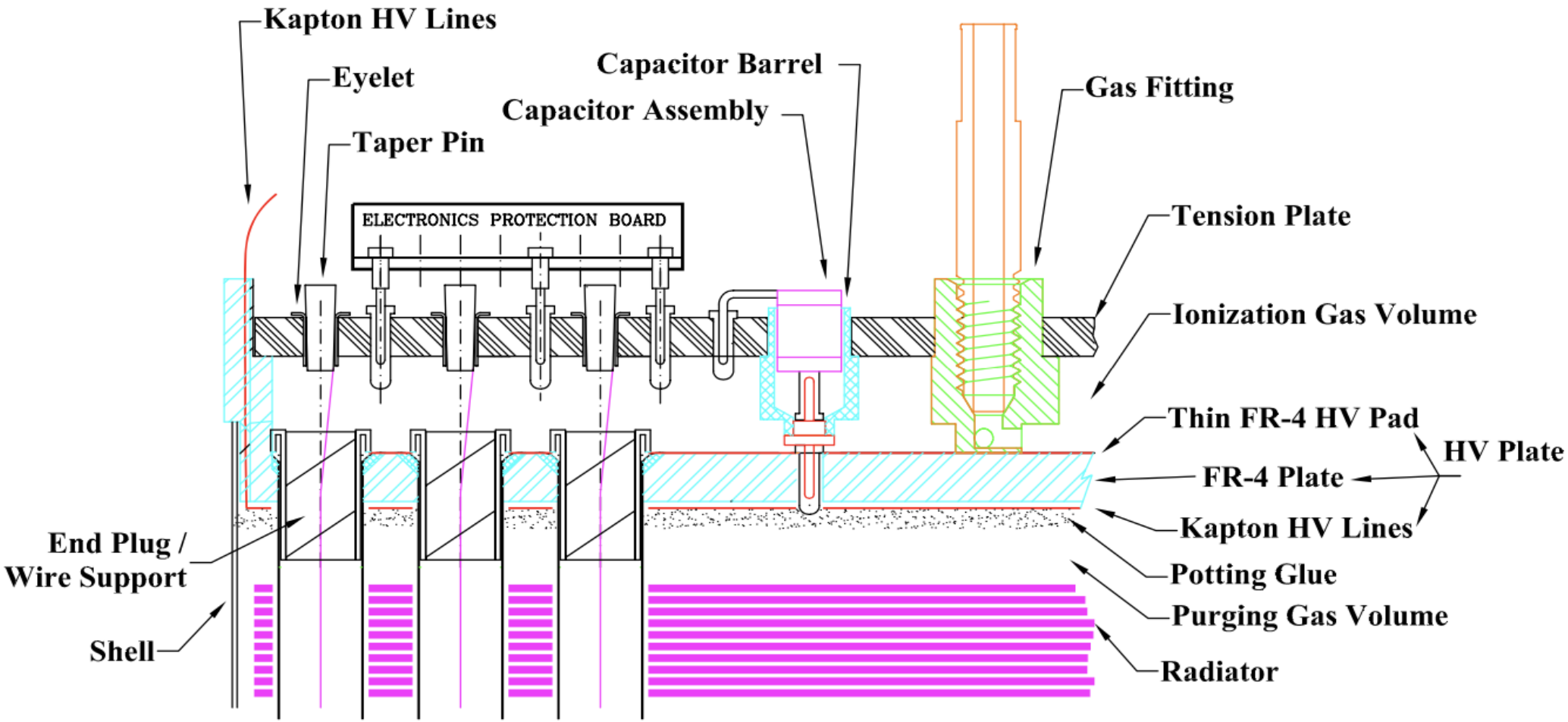


Figure 8. Tension plate and HV plate at module end.

Wire-support – Helical hole

- Support wire every ~ 100 cm with < 100 μm accuracy wrt the straw center
  - Tension .vs electrostatic force
- Do not interfere with gas flow
- re-restring

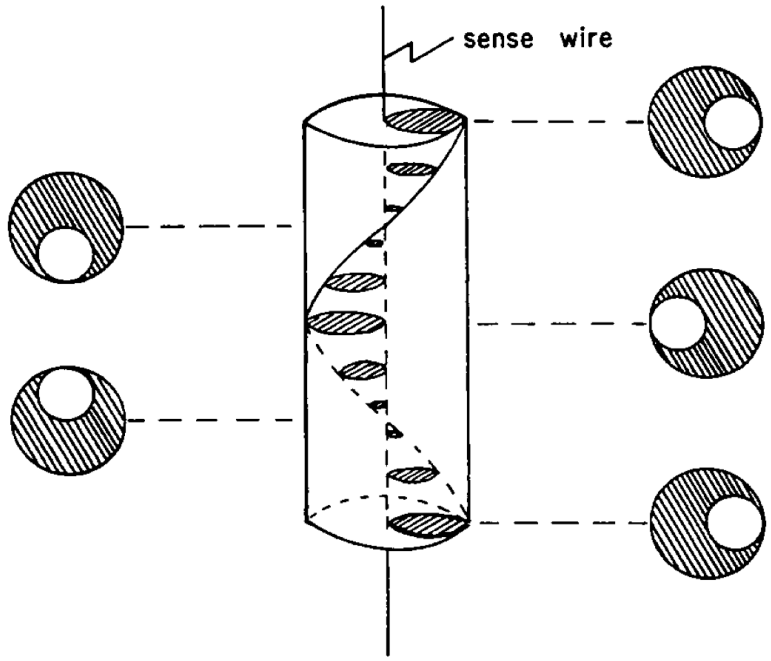
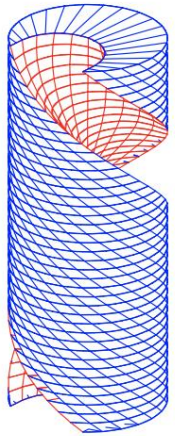
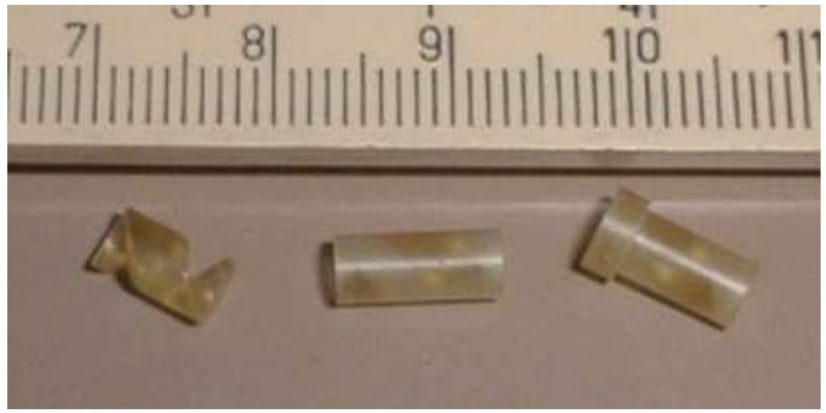
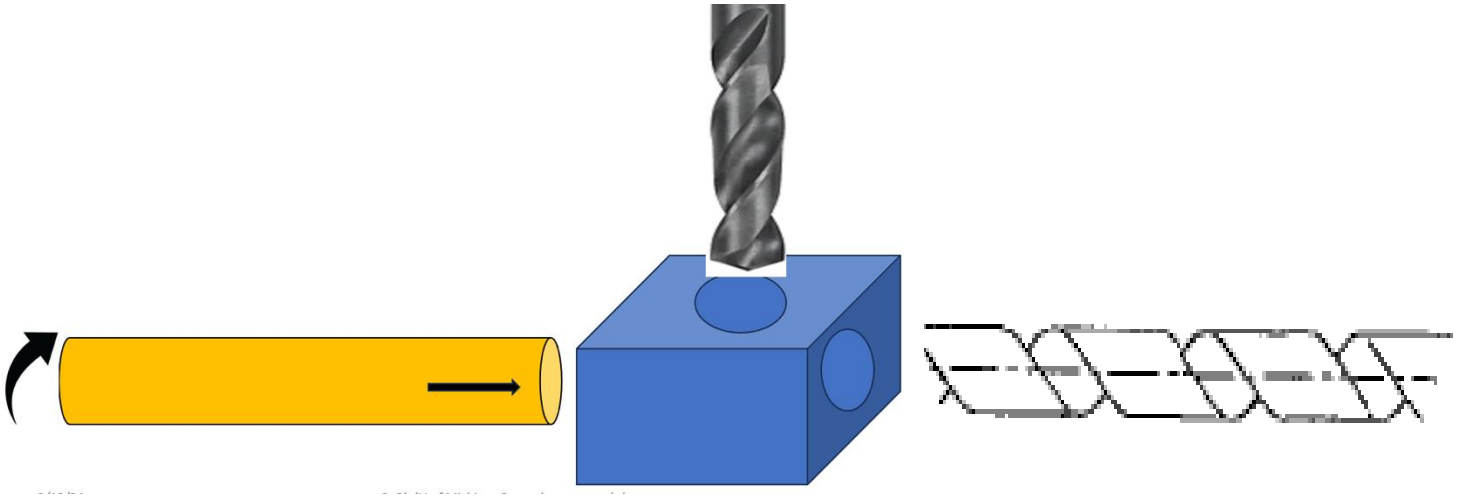


Fig. 3. Duke wire support design. A helical hole is made inside a plastic cylinder.



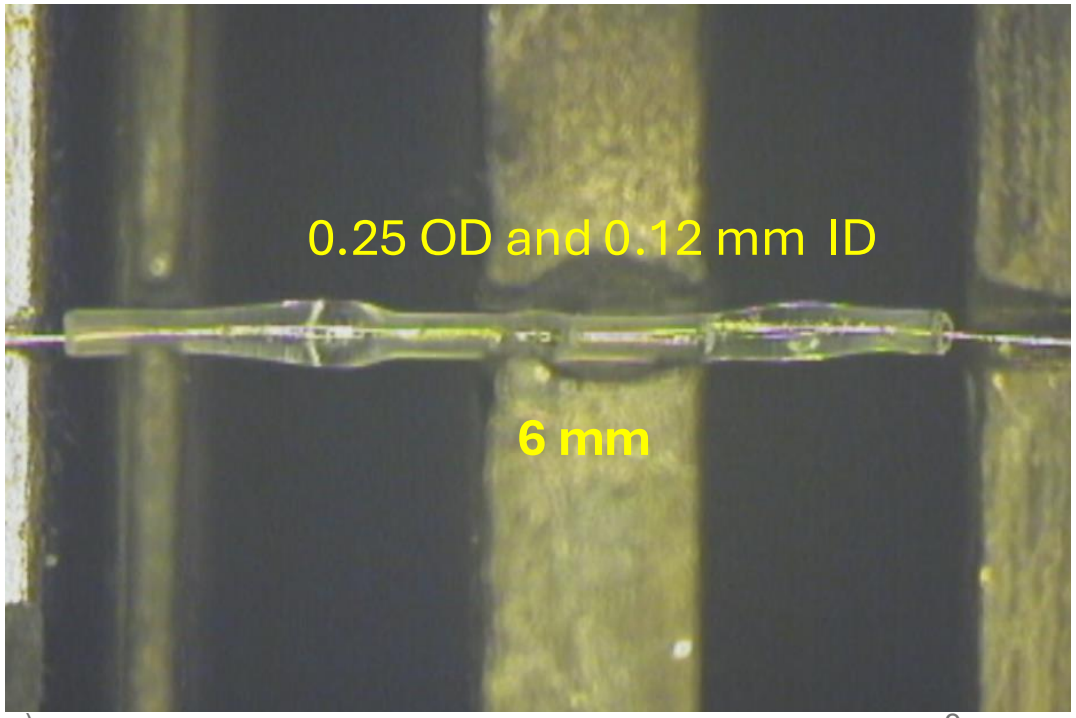




Wire-joint (EN-1, Borosilicate Sealing Glass)

- Break wire and connect with an insulator to isolate two sides
  - Left and right sides can be read out independently decreasing the occupancy by 1/2
  - Insulator : Low melting temperature glass tube 6 mm long, 0.25 mm OD and 0.12 mm ID.
  - Two wires are inserted, and the glass is melted
  - Not by friction, but chemical interaction between tungsten and glass

- All Barrel TRT wires have one or two wire-joints. In case of two wire-joints, there is a dead region
- Rad hard



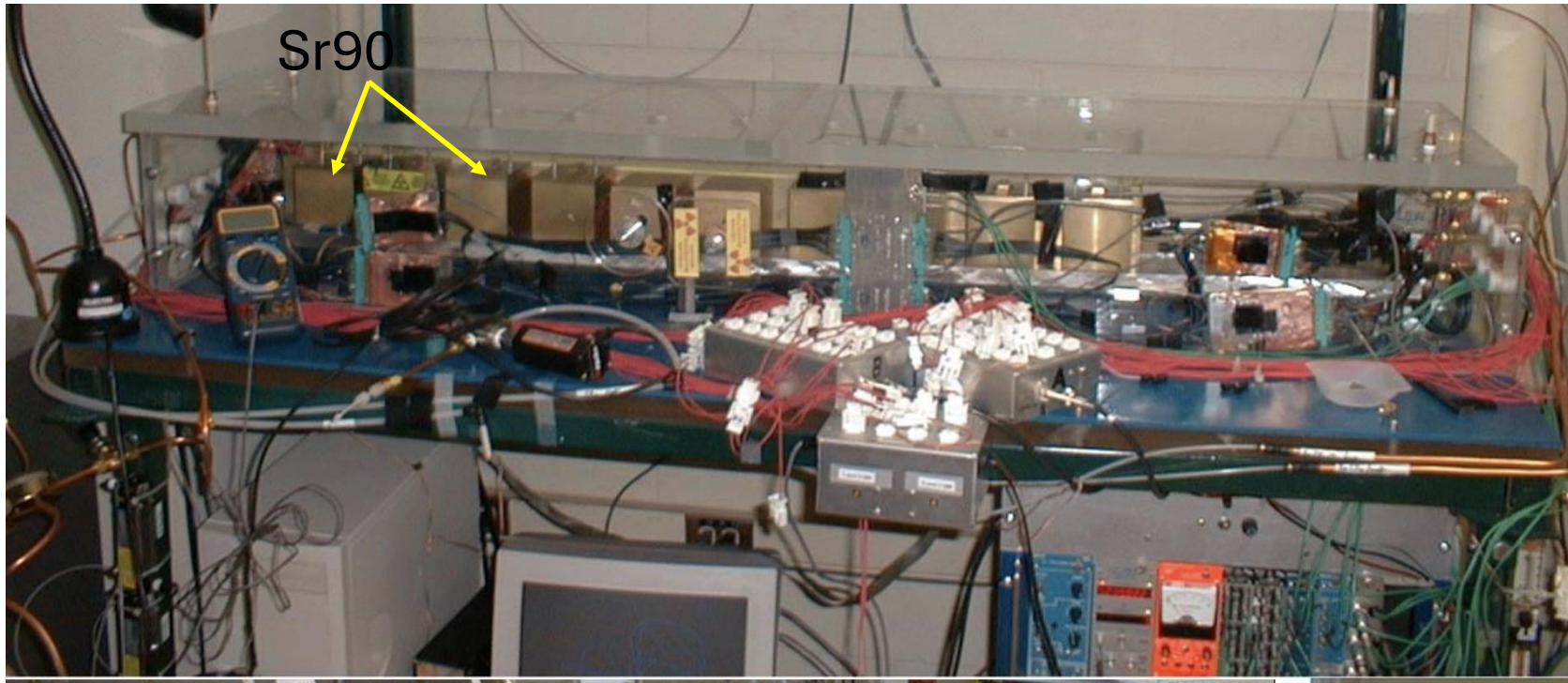
Aging Test

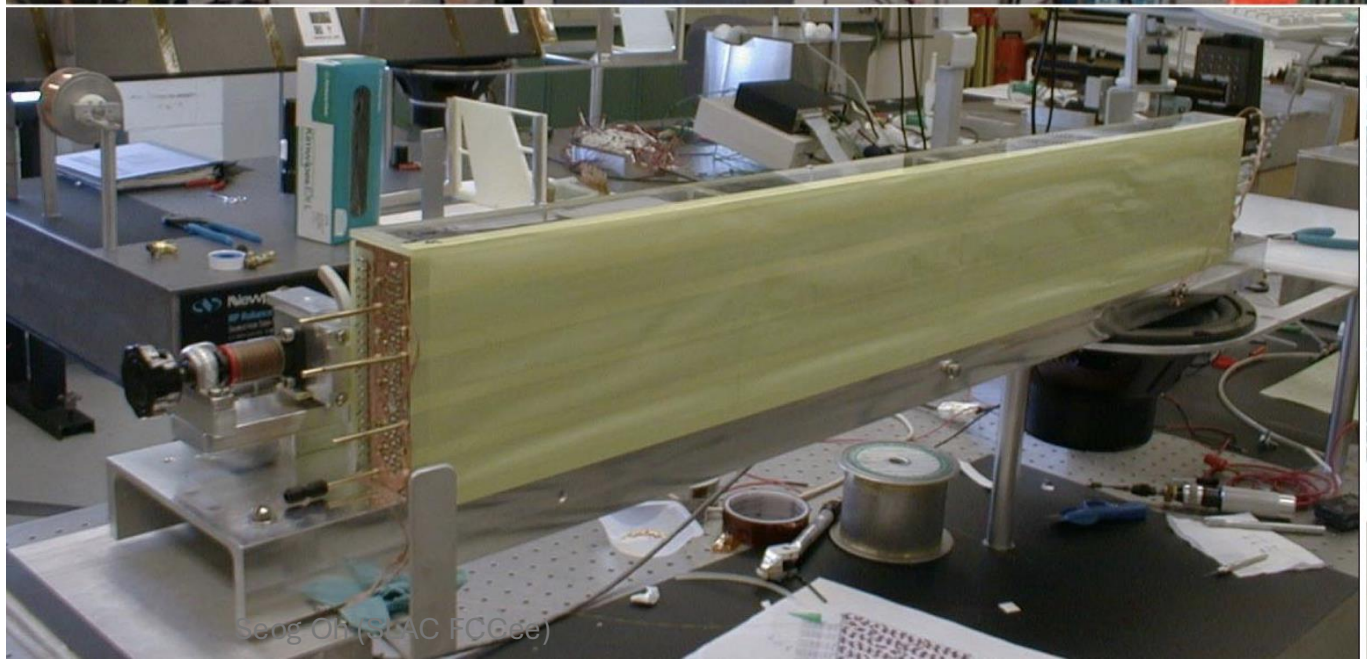
-200 mCi Sr^{90}

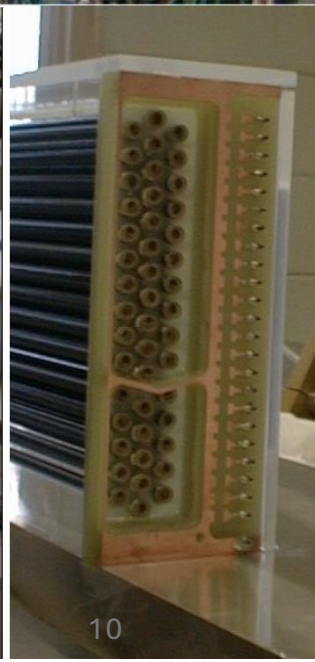
2 x 50 mCi + 10 x 10mCi

-Fe55 for gain

-Enclosed for Humidity control



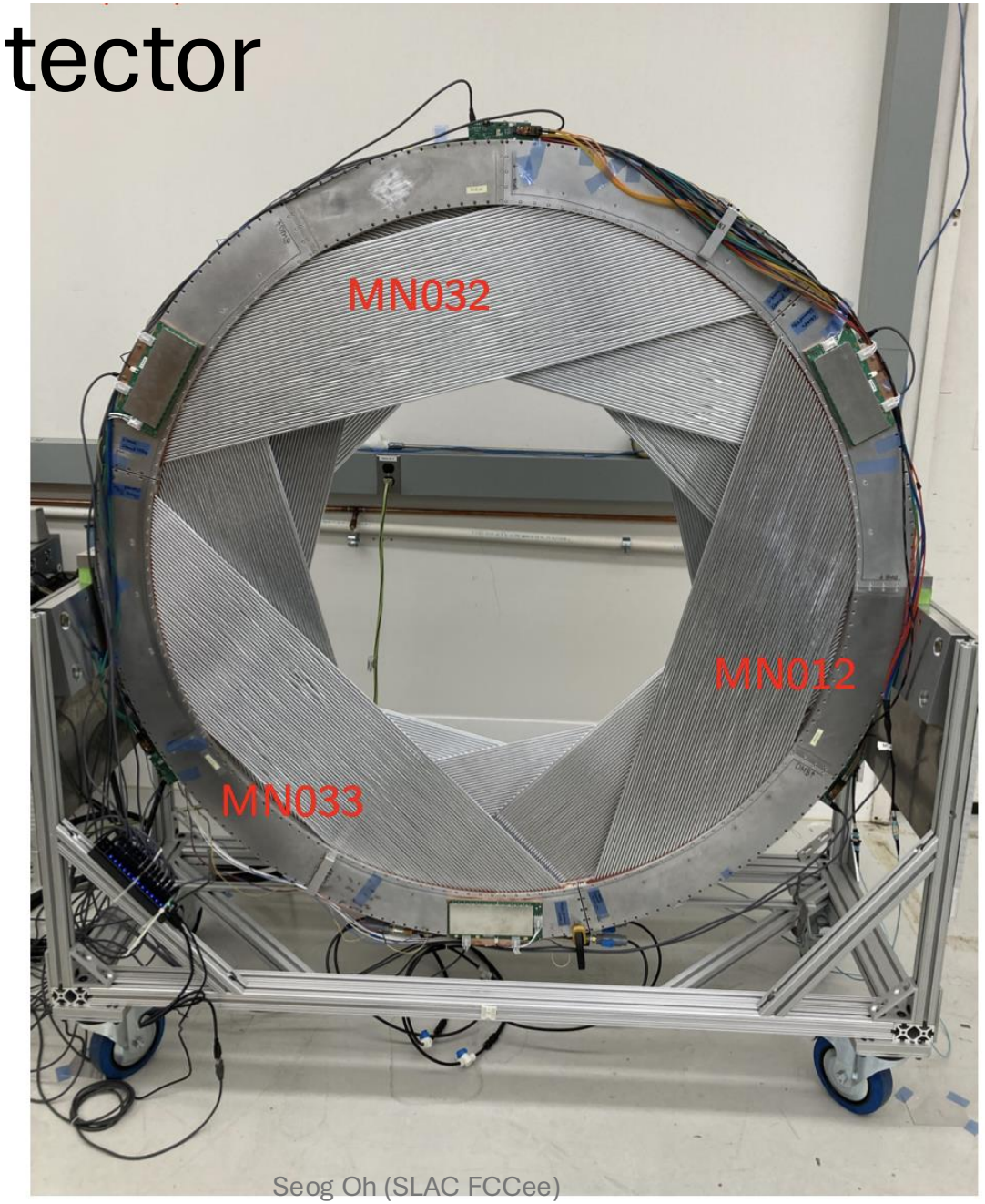




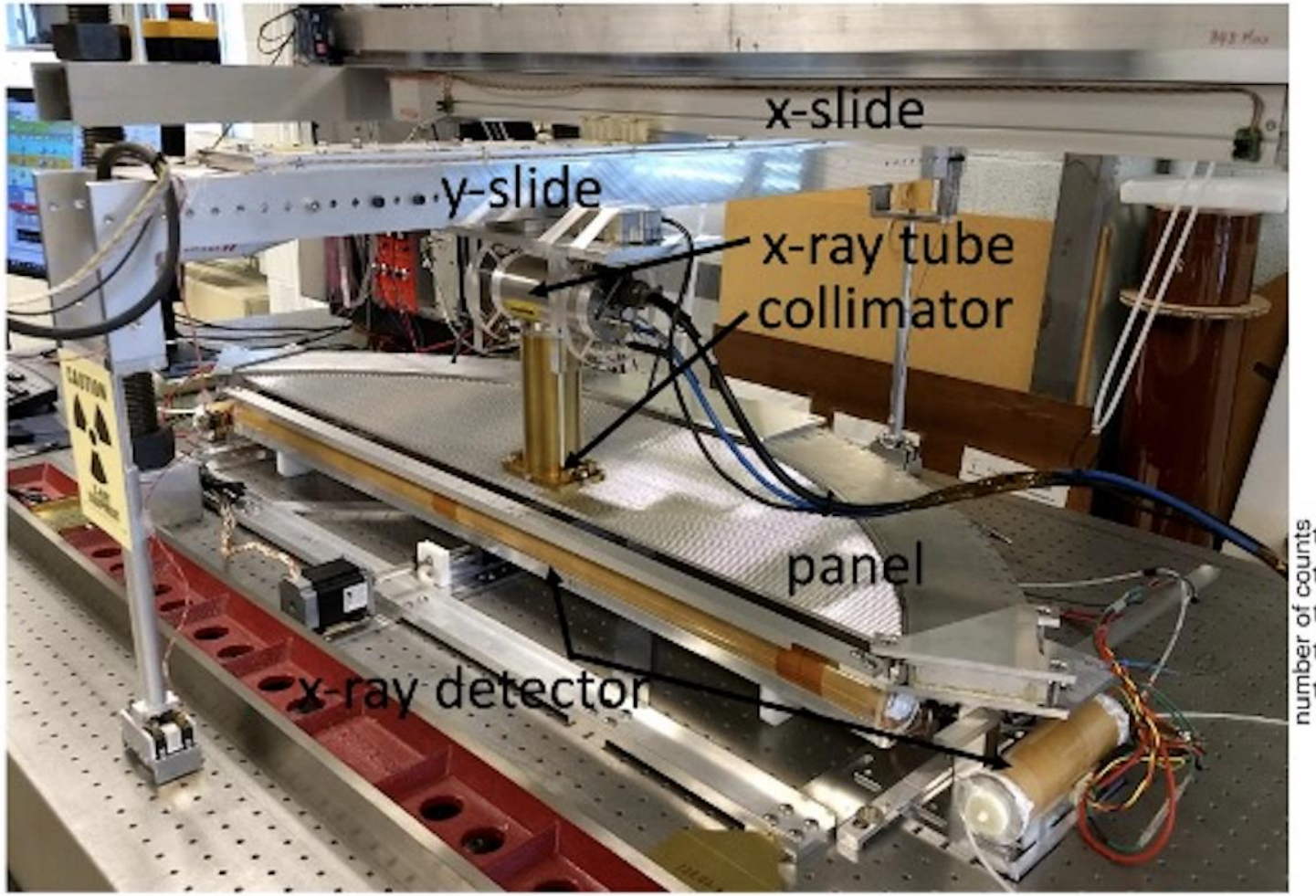
Mu2e Straw Detector (2010-)

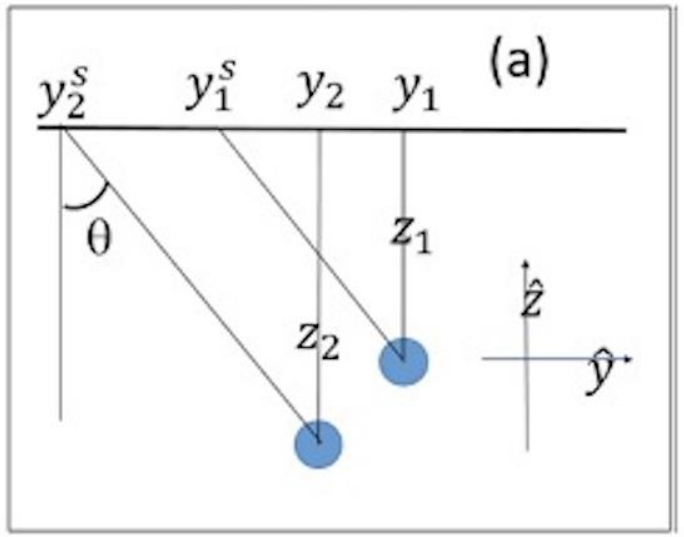
- Searching for muon conversion to electron in nuclear field.
- Duke has been a part of straw tracker collaboration since 2010.
- The panel construction was finished in 2023, and assembly and installation are in progress. Data taking starts in a couple of years.
  - 5 mm diameter mylar straw tubes with 16 μm thickness
- Duke contribution
  - Prepare module (panel) components
  - X-ray scanner to map wire and straw position
  - Straw tube relaxation (creep) measurement.
    - Straw tubes are tensioned to 700 gf before gluing to the frame

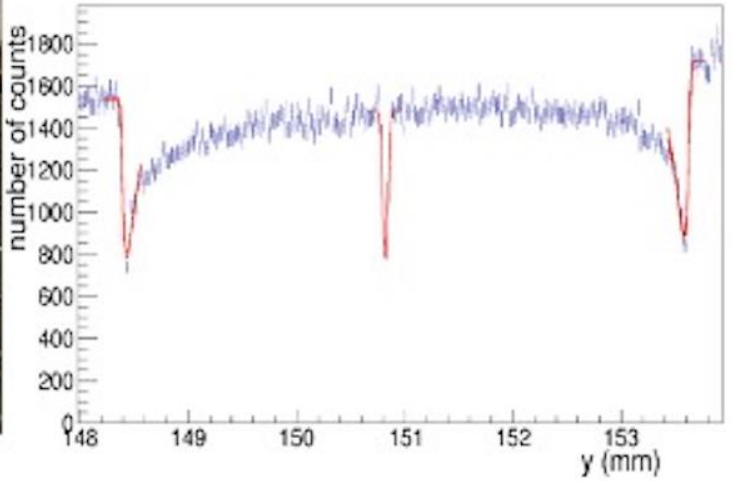
Mu2e Straw Detector



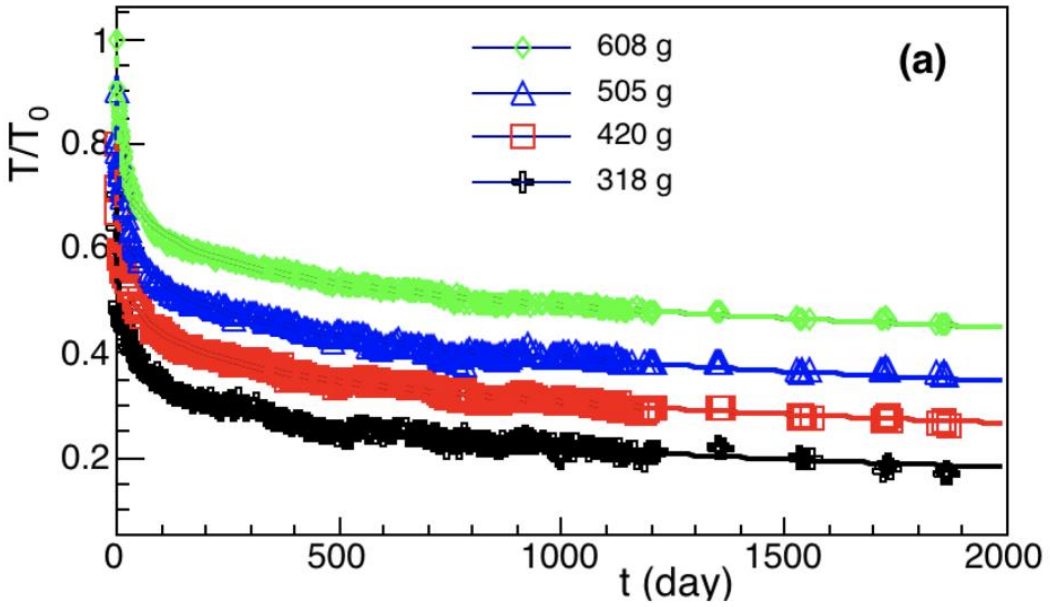
X-ray scanner : three-dimensional measurement with 5 (15) μm accuracy

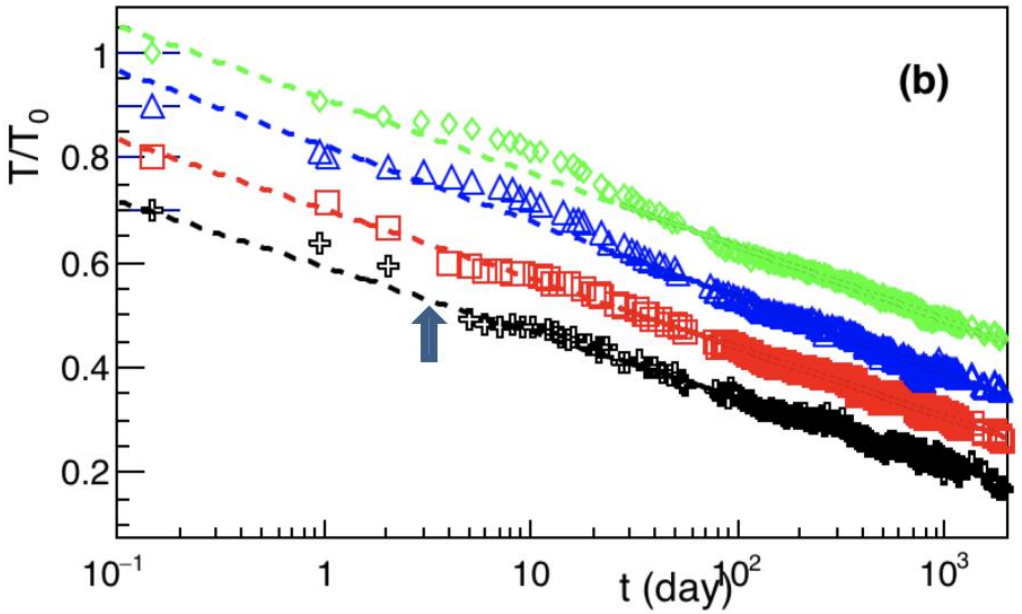






Relaxation measurement (5 yr)



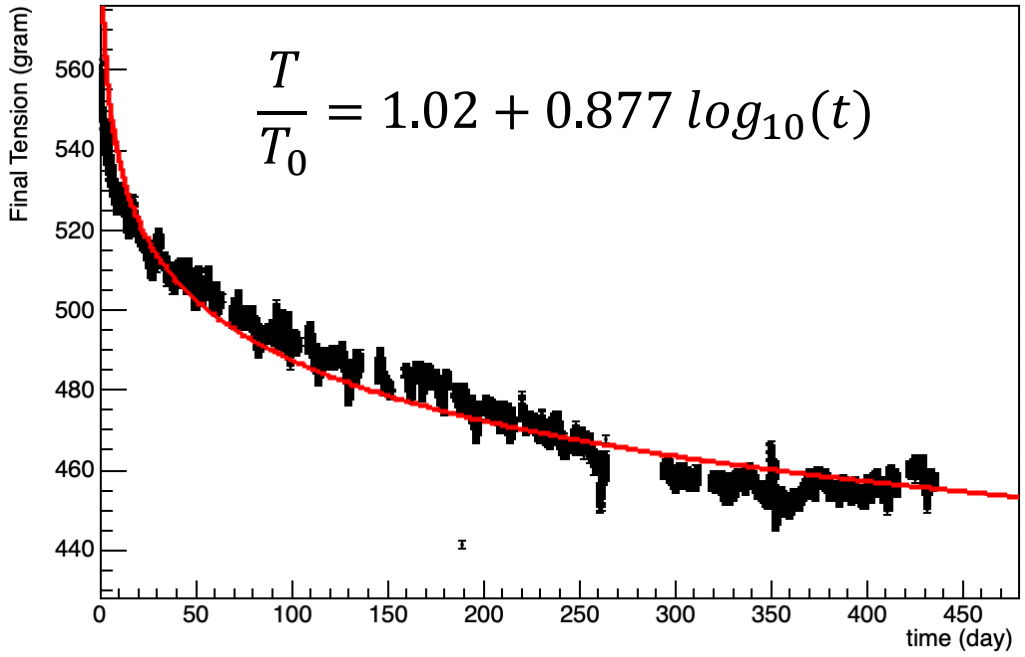


- Straws are tensioned and fixed at both ends. Tension is measured vs. time.
- ~ 5 years of data
- $T/T_0 = D_1 + D_2 \log_{10}(t)$

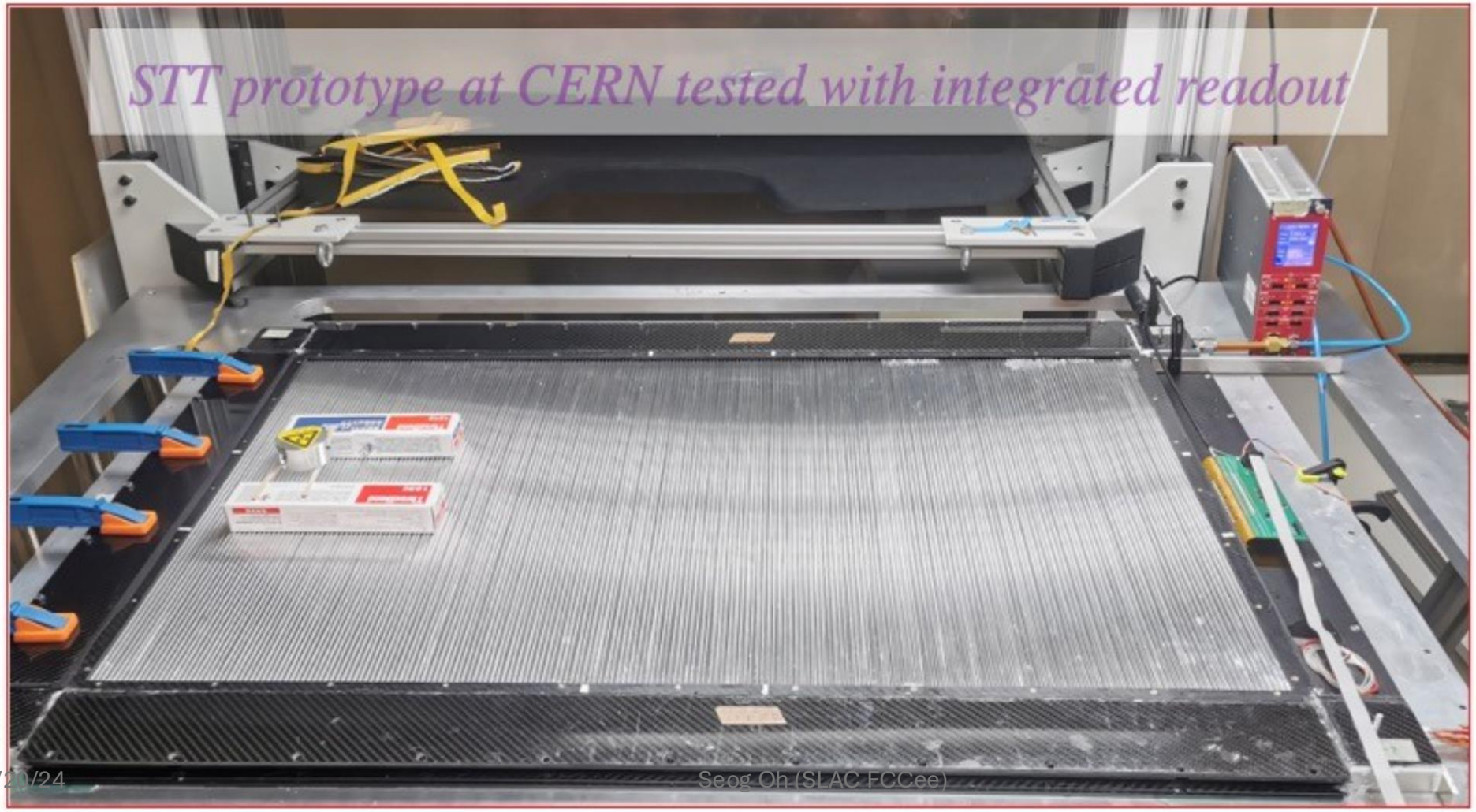
Initial Tension (g)	D_1	D_2
318	0.90 ± 0.01	-0.126 ± 0.001
420	0.91 ± 0.01	-0.133 ± 0.001
505	0.94 ± 0.01	-0.149 ± 0.001
608	0.92 ± 0.01	-0.145 ± 0.001
Average	0.92 ± 0.01	-0.138 ± 0.005

STT (Straw tube tracker) for DUNE same axis near detector (2021 -)

- We are in designing and prototyping stage.
  - 5 mm diameter mylar straw tubes with 20 μm thickness.
- Contribution
  - Design
  - Characterization of straw tubes – mechanical/electrical
  - Straw tube relaxation measurement
    - The straw tubes are pressurized (2 atm relative) before gluing to the frame for tension.



(2023) 1 m by 0.8 m prototype : two x-layers and two y-layers
(2025) 4 m by 3 m full size prototype



FCCee Straw Tube R&D

- Straw bundling
- This is to reduce material (with less supporting frames)
- We have some experience in bundling straw tube for strength.
- We still have several hundreds of SDC straw tubes (4 meter long), which is about the length of proposed FCCee straw tube detector
- We propose to bundle ~ 200 straw tubes.
- After bundling, various mechanical properties will be measured. And compare to FEA calculation.
- If the bundle is “stable”, a few straw tubes will be strung to operate.

- x and u bundle with SDC straw tubes
- 75 straws tubes per bundle
- Length: 1 meter
- Operational