# VXD Mechanical R&D at the University of Washington

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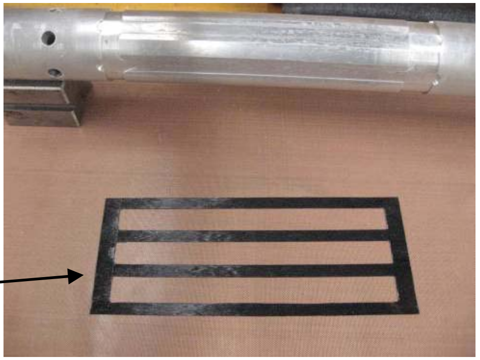
LCRD in conjunction with Fermilab, SLAC

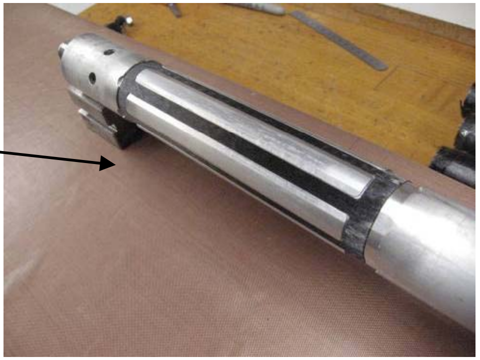
# University of Washington - ILC detector R&D

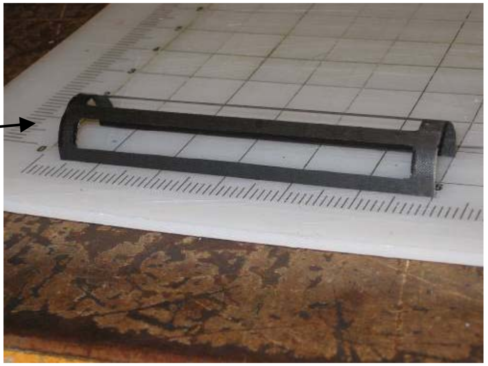
- The Seattle group is working with Fermilab on the carbon-fiber mechanical support structures
  - Develop techniques for fabricating and handling thin-walled carbon fiber structures
  - Prototypes of carbon-fiber support structures
  - Various tooling for attaching support membranes to support structure and mounting silicon wafers on support structure
  - FEA analysis of mechanical and thermal behavior
  - Measurement of material properties of carbon-fiber lay-ups
- Fabricated and delivered to Fermilab
  - Three prototype half-shell structures for evaluation, testing and developing silicon mounting procedures
  - Assembly mandrel, end ring glue fixture and vacuum chuck for precision placement of silicon

# Support Structure Proof of Concept

- A simple mandrel was made to develop fabrication techniques for the proposed carbon fiber structure
  - Material is pre-laminated on a flat surface. Then the windows are cut out leaving the frame.
  - The pre-laminate is then layed up onto the mandrel, loaded into a vacuum bag, and cured in an autoclave.
  - Removing the cured part from the mandrel without breaking it is a delicate procedure, but we demonstrated that this could be done reliably.

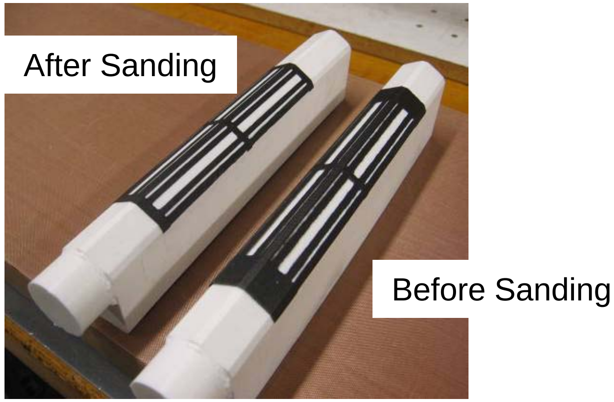






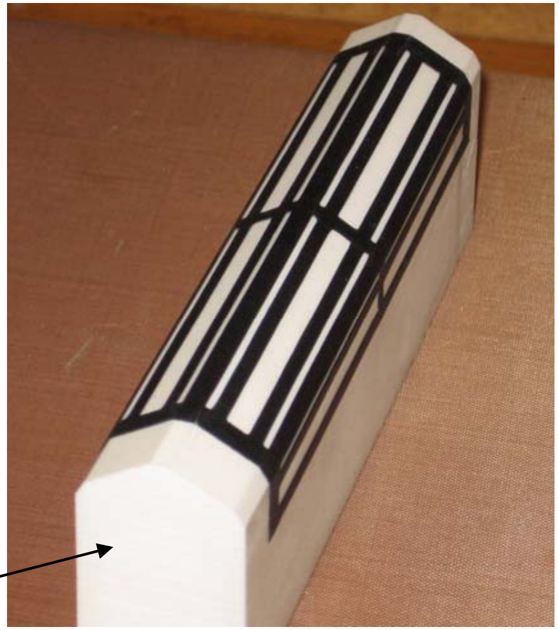
# Layer 1 Prototype Support Structures

- **Fabrication techniques and mandrel design were refined for production of the prototypes**
  - **Windows are hand cut from the flat, uncured material using an aluminum template.**
  - **After curing, the window edges are cleaned up with fine sandpaper.**
  - **The ends are left long to maintain structural integrity during removal from the mandrel and while sanding the window edges.**
  - **A belt sander is used for the final operation of cutting the ends to length.**



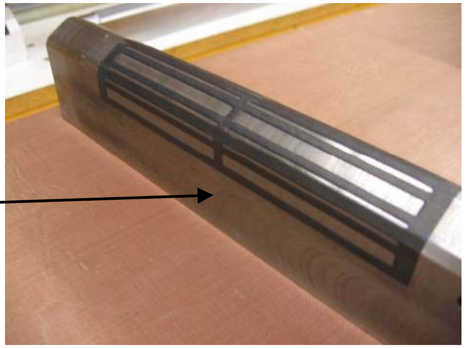

# Layer 1 Prototype Support Structures

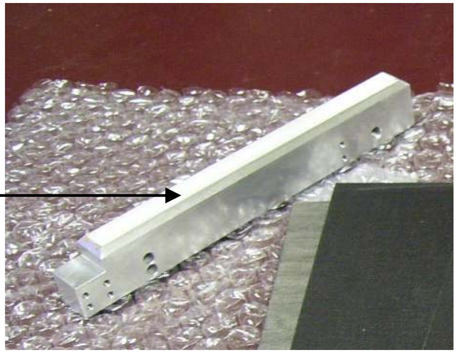
- Three structures have been fabricated.
  - Fiber orientation is [0,90,90,0].
  - K13C2U material.
- Parts are delicate but reasonably robust if handled properly.
- Each structure is shipped with a handling mandrel (polyurethane castings of the lay-up mandrel).
- End-rings have been installed at Fermilab on one structure.

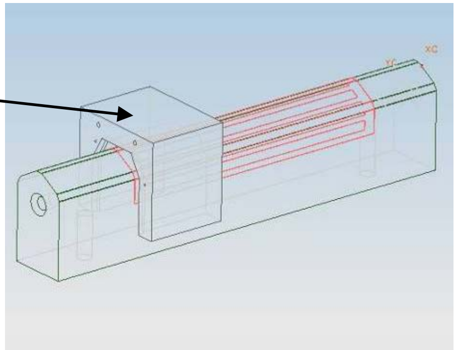


# Tooling

- **Two identical steel mandrels were CNC machined.**
  - One mandrel is used in Seattle for carbon fiber lay-up.
  - The second mandrel is used at Fermilab as an assembly fixture, and for mounting silicon.
- **A vacuum chuck with a porous ceramic surface was fabricated. The chuck will be used to place silicon.**
- **Fixtures (2) for positioning of the end-rings during glue-up to support structure were machined. Fixtures are also used as support structure thickness gauges.**



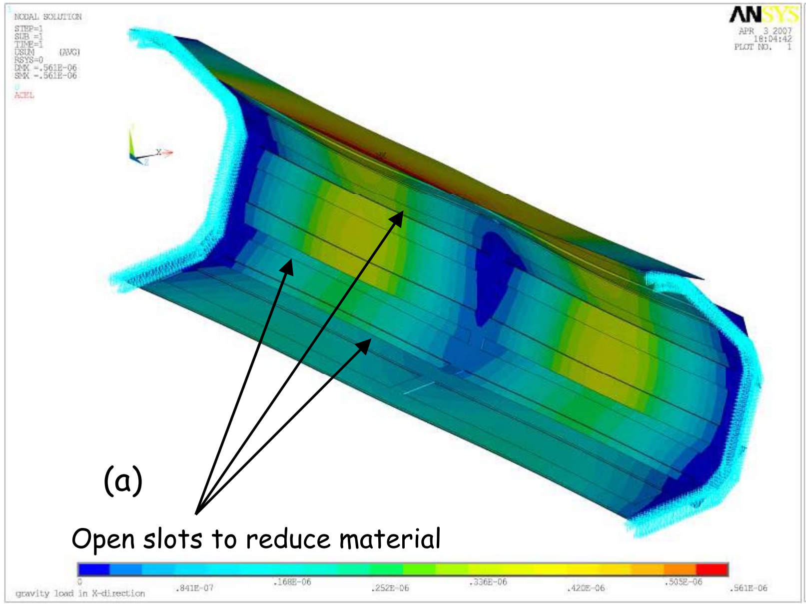


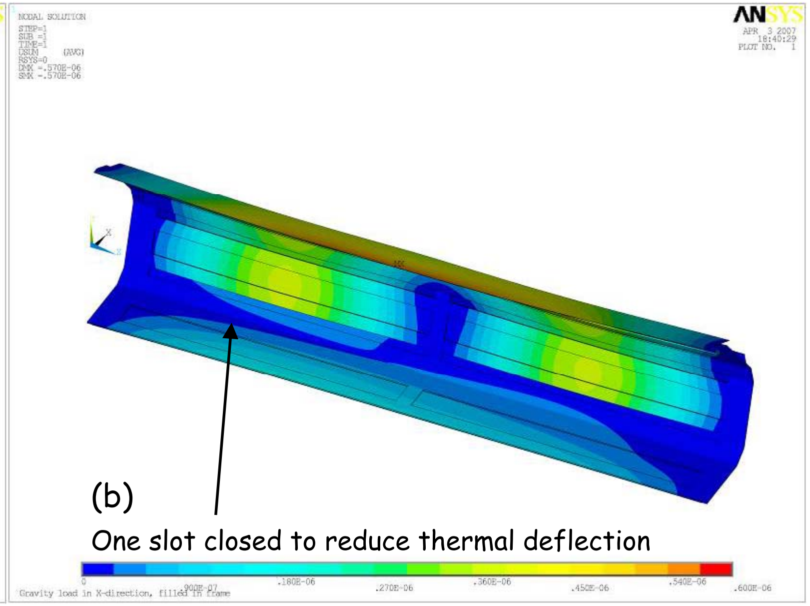


# FEA Studies

This work has the aim of understanding how to optimize the geometry of the carbon fiber/epoxy composite frame to minimize deflection due to gravity and temperature changes.

This model uses a 4-layer (0,90,90,0 degree) lay-up. The gravitational deflections of two slightly different structures are:



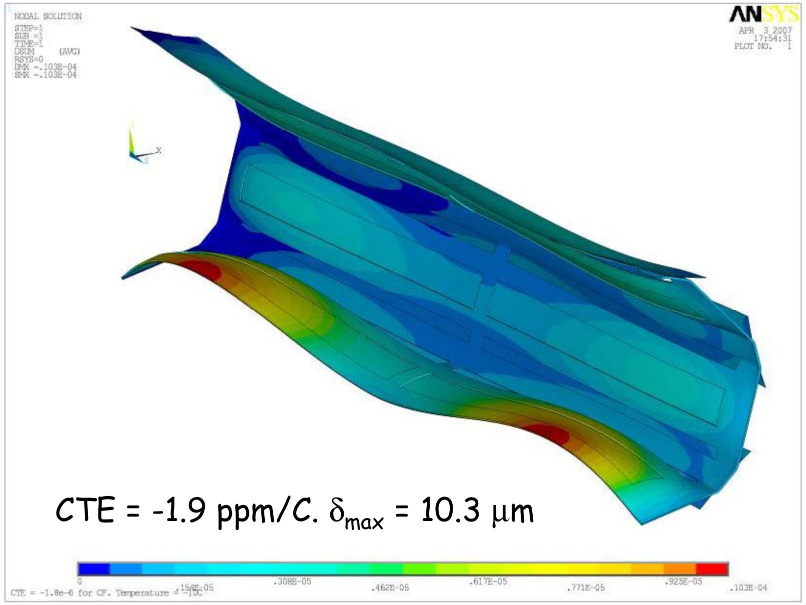




The maximum deflection vector is about 0.6 $\mu$m in each case.

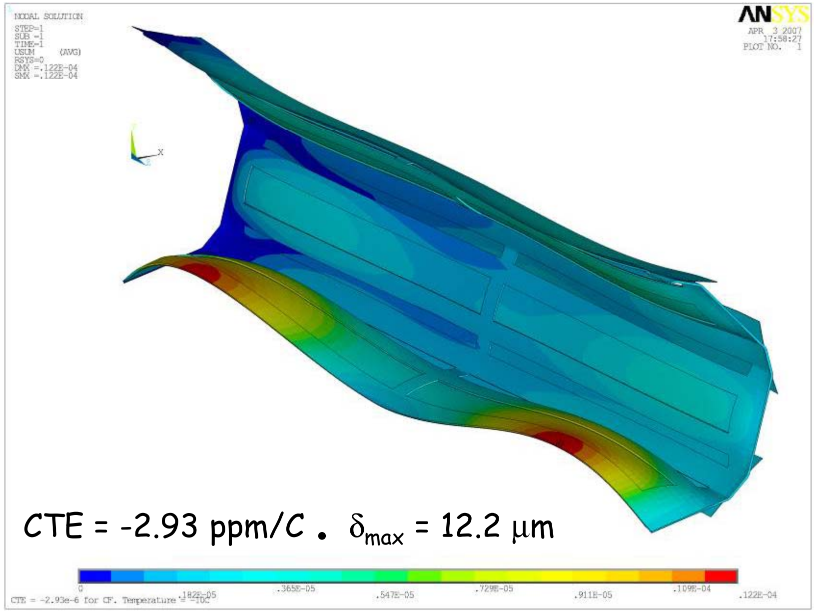
# FEA Studies

Because of the large temperature change between curing the composite at room temperature and its operation at, say, -10 C, it is expected that thermal deflections will be significant because of the CTE difference between the carbon fiber composite and the silicon sensors. The CTE of the composite is not well known, therefore results are given here for two different CTE values (-2.93 ppm/K and -1.9 ppm/K).

The first structure shown has open areas intended to reduce the material used to a minimum:



CTE = -1.9 ppm/C. $\delta_{max}$ = 10.3 μm

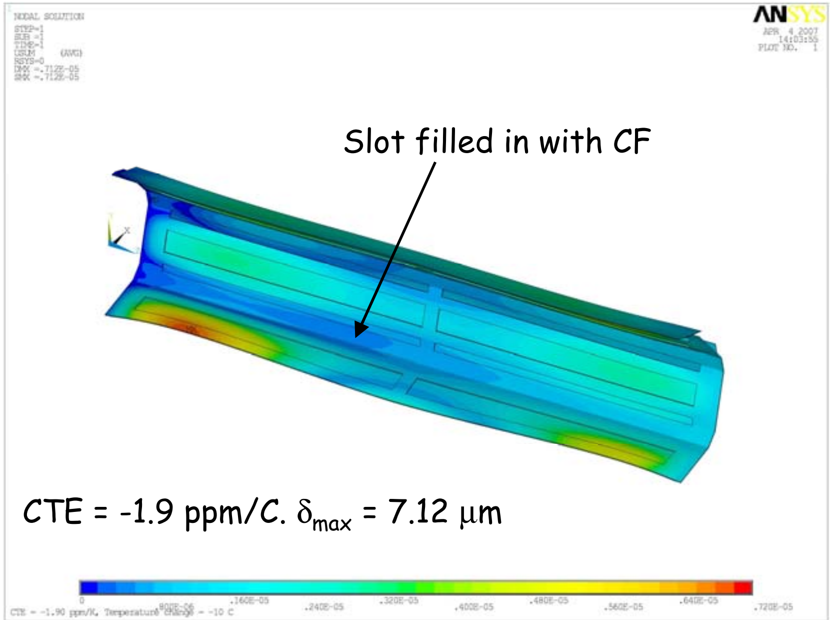


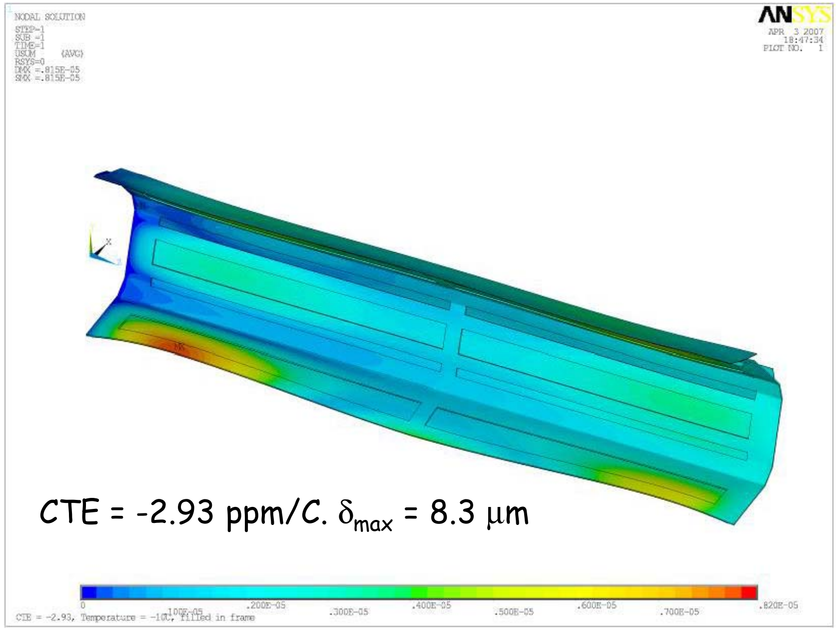
CTE = -2.93 ppm/C . $\delta_{max}$ = 12.2 μm

The maximum deflection vector for a 10C delta T goes from 12.2 to 10.3 μm with this change in CTE. For reference the CTE for silicon is 2.49 ppm/K

# FEA Studies

To reduce the deflection, one of the open areas in the carbon fiber frame was filled in:

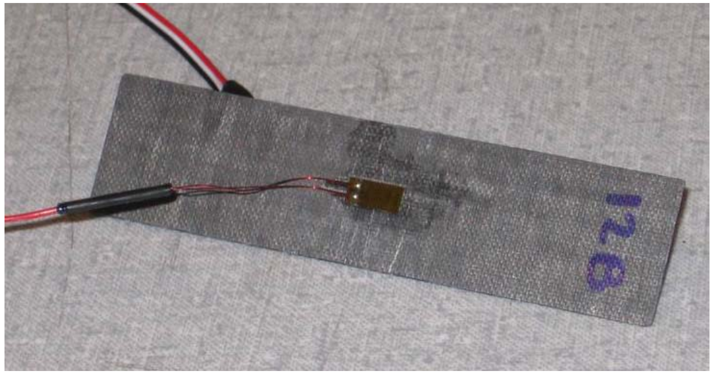


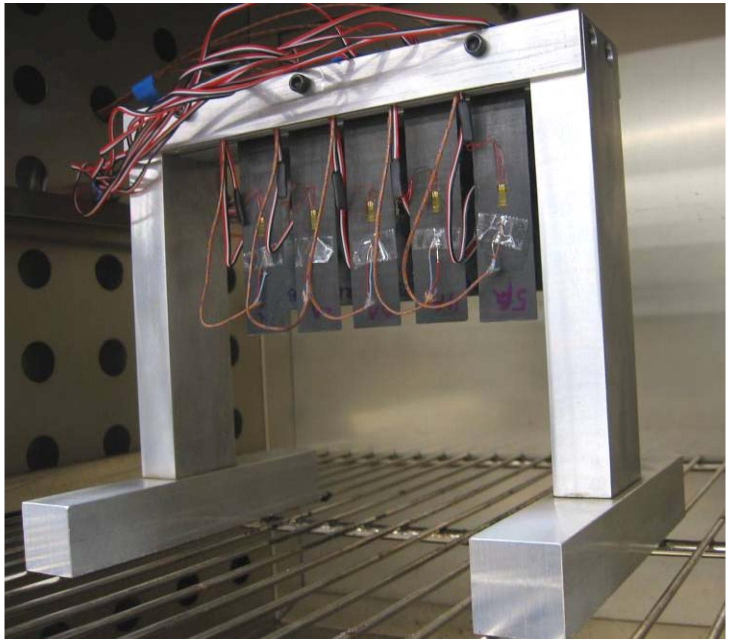




For this modified structure the maximum deflection vector goes from 8.2 to 7.12 $\mu$m with this change in CTE. For reference the CTE for silicon is 2.49 ppm/K

# Measurements of Carbon Fiber Properties

- **Coefficient of Thermal Expansion measurements of [0,90,90,0] specimens.**
  - **Test method: Measurement Group Tech Note TN-513-1.**
  - **CTE measured using strain gages mounted front and back on flat coupons.**
  - **Coupons mounted in rack and placed in lab oven.**
  - **Thermocouples taped to each CF coupon.**
  - **Strain and temperature are monitored through temperature excursions from 25°C - 70°C, in 5 degree increments.**
  - **Dwell time at each increment is 15 minutes minimum.**



# Measurements of Carbon Fiber Properties

- Results of Seattle Measurements
  - Average CTE of 5 coupons = -1.9E-6/°C
  - Standard Deviation = 0.1E-6/°C
  - Predicted CTE for [0,90,90,0] layup using Composite Pro is -1.95E-6/°C
- These results do not agree with CTE value found at Fermilab through different methods. More study is needed.