Run 2b Silicon Mechanical Design and Status

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Introduction

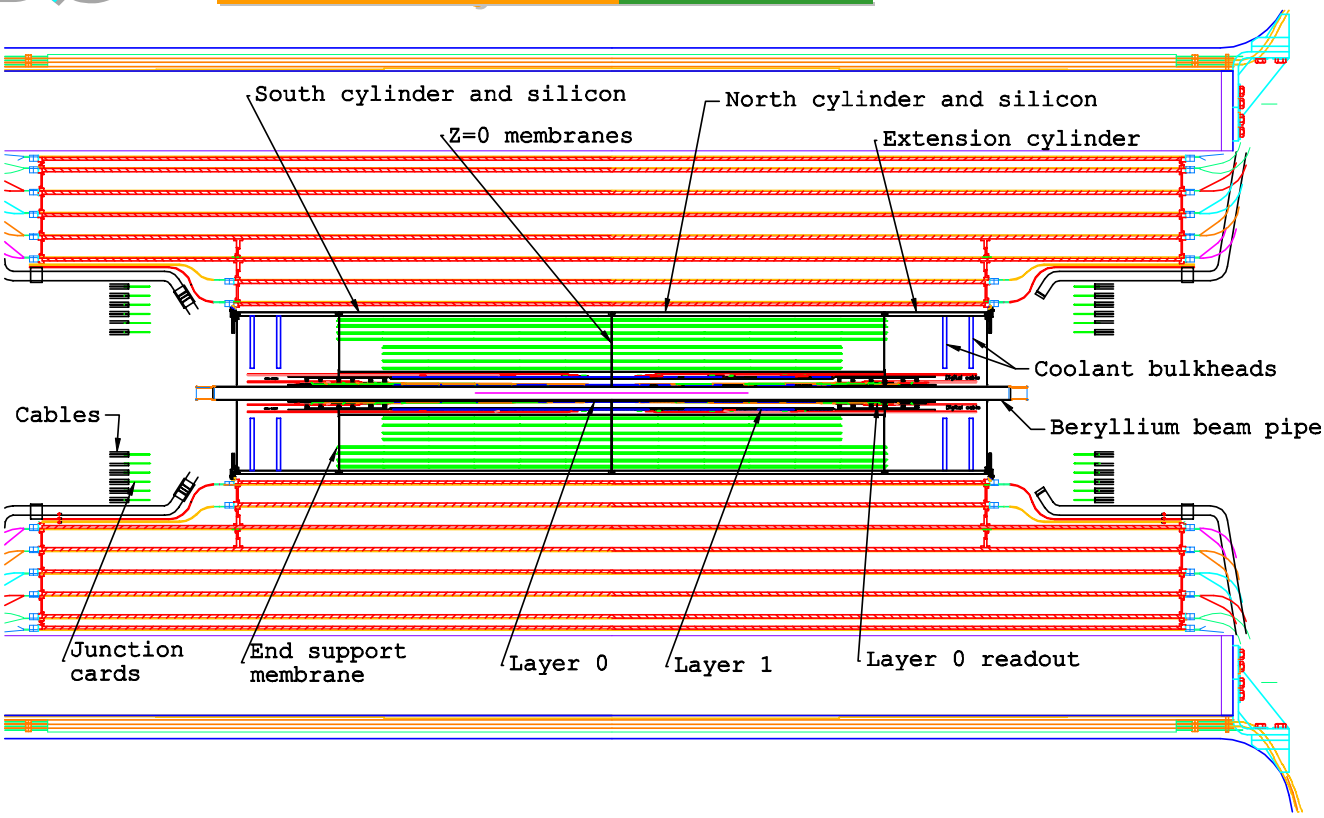
- The TDR provided good motivation for making design decisions.
- Many university and laboratory people have worked together to develop a solid design.
- We are proceeding to work on design details and the details of fabrication techniques.

- Outline
  - **Design features**
  - **Overall layout**
  - **Layers 0-1**
  - **Layers 2-5**
  - **Finite element analyses**
  - **Beam pipe**
  - **Radiation lengths of material**
  - **Summary**

Design features

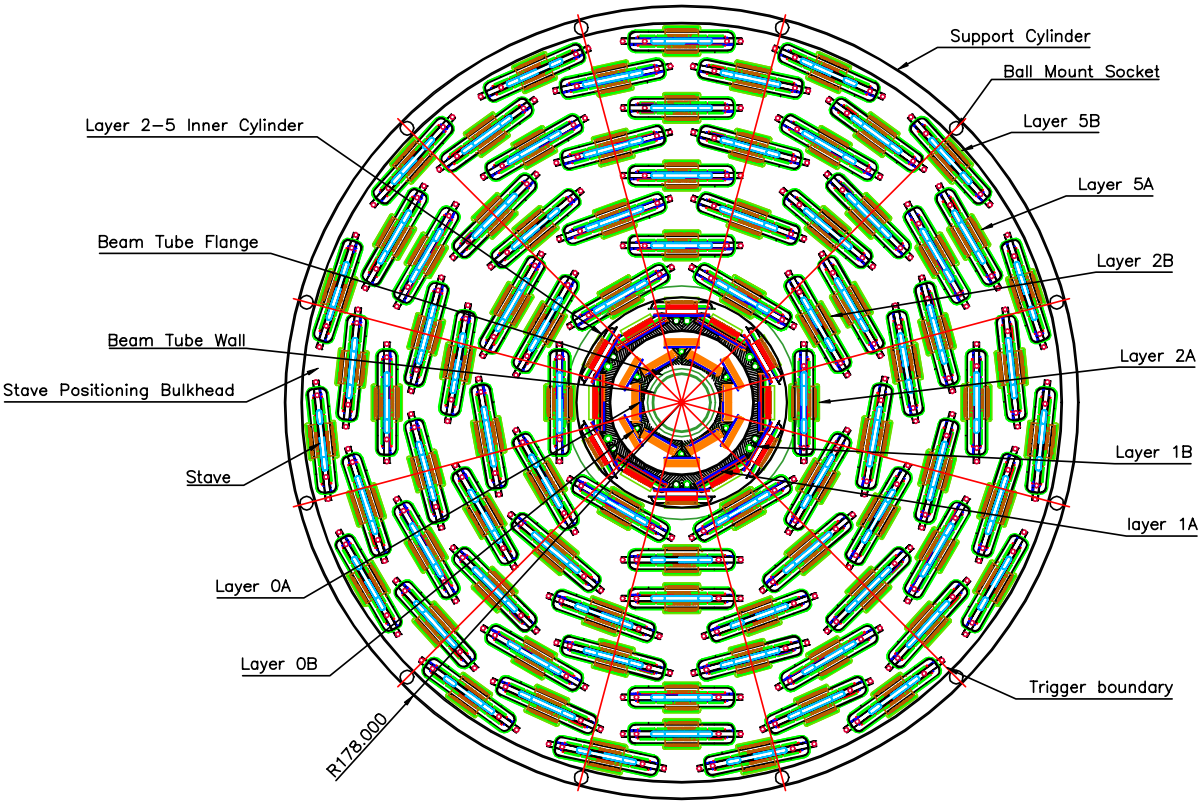
- The design allows the D0 detector to remain in the collision hall during Run 2b installation.
  - The end calorimeters roll open 39". Silicon has been split into identical north and south assemblies to allow each assembly to be installed through the available opening while providing ample space for services at its outer end.
  - Assemblies can be installed from the either the north or the south. To take advantage of collision hall access paths, we plan to install from the north.
- The six layer silicon tracker is separated into two radial groups.
  - Allows fabrication of inner and outer layers in parallel
  - Allows the inner layers to be serviced (or replaced) with the detector in the collision hall
  - Inner layers: Layers 0 and 1
    - » Axial readout only
    - » Mounted on integrated support
    - » Assembled into one unit
    - » Designed for V_{bias} up to 1000 V
    - » -20° C coolant
  - Outer layers: Layers 2-5
    - » Axial and small angle stereo readout
    - » Stave support structure
    - » Designed for V_{bias} up to 300 V
    - » -10° C coolant
- Employ single sided silicon only with 3 sensor types
  - 2-chip wide for Layer 0
  - 3-chip wide for Layer 1
  - 5-chip wide for Layers 2-5

Overall layout: Plan view



- Populated lengths based upon expected luminous region
  - Layers 0-1: 96 cm
  - Layers 2-3: 100 cm
  - Layers 4-5: 120 cm
- North and south support structures are aligned at SiDet before silicon installation. They will be joined into a single unit during installation at D0.
- Extension cylinders connect the main cylinders to the ends of fiber tracker barrel 1.
  - That allows better coordinate measuring machine access for measurements of positions of silicon structures.
- Reproducible ball mounts join cylinder sections.

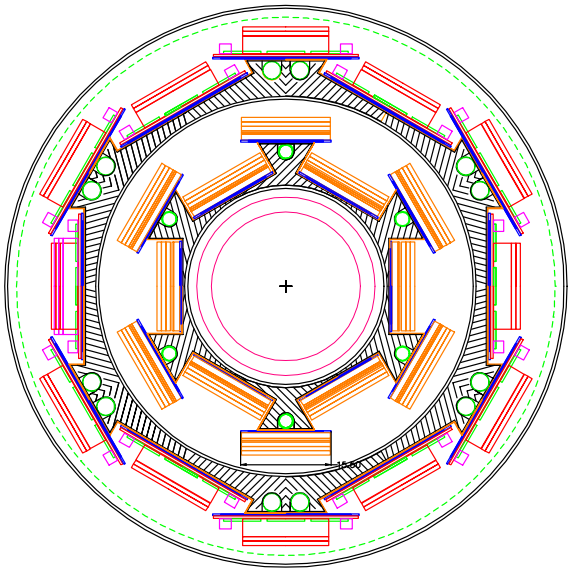
Overall layout: End view

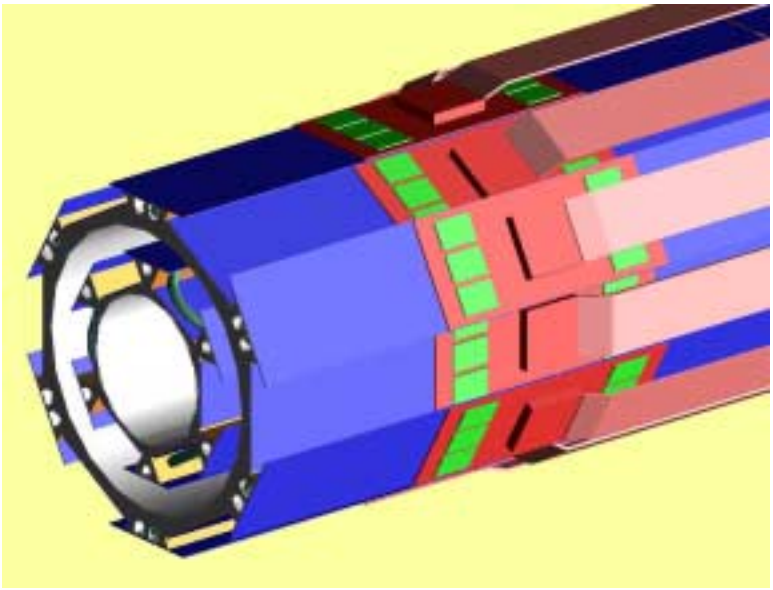


- The geometry allows a 12-sector trigger structure.
  - Half the layer 3-5 staves are shared between sectors.
  - 99.6% acceptance for 1.5 GeV/c and an impact parameter of 2 mm
- Thin bulkheads position staves within layers 2-5.
- The layer 2-5 bulkheads support layers 0-1.
- Support cylinder outer radius = 178 mm.
- No element is supported from the beam pipe. The beam pipe is inserted after all silicon is installed at D0.

Layers 0 and 1

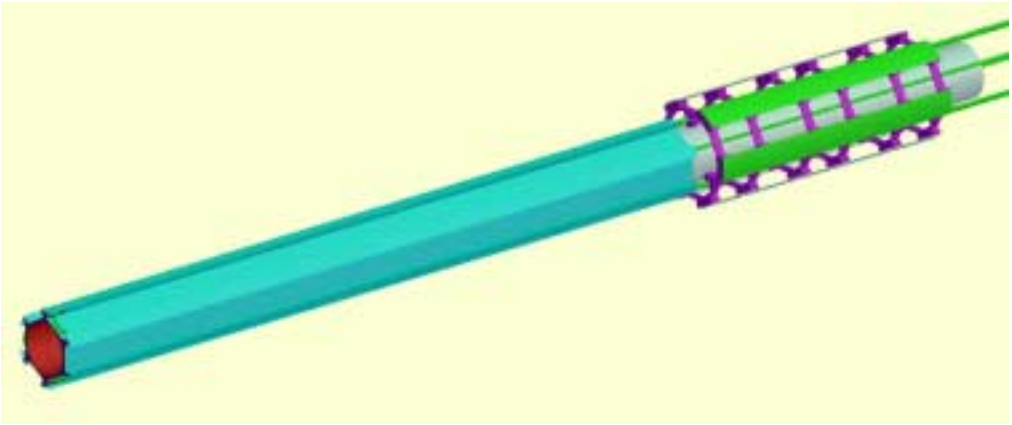
- 12, 12-fold geometry
- Layer 0:
  - 2-chip wide x 79.4 mm long sensors
  - 25 μm trace pitch, 50 μm readout pitch
  - Hybrids at the end connected to sensors with analogue cables
  - Two SVX chips per sensor
  - Axial readout only
- Layer 1:
  - 3-chip wide x 79.4 mm long sensors
  - 29 μm trace pitch, 58 μm readout pitch
  - Hybrids on-board
  - 6-chip hybrid readout services two sensors
  - Axial readout only



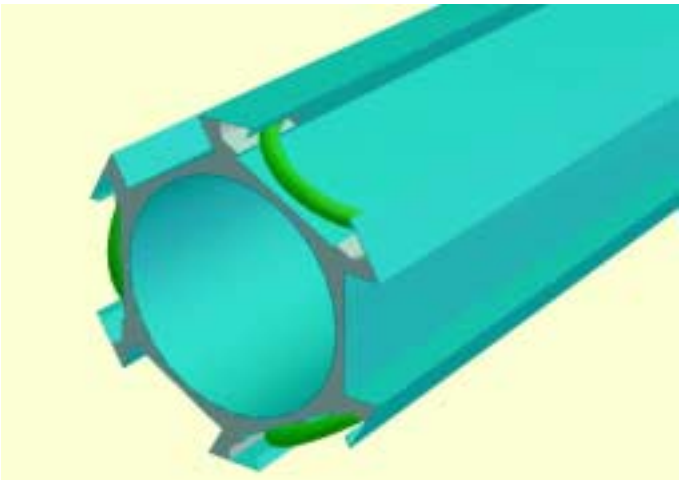


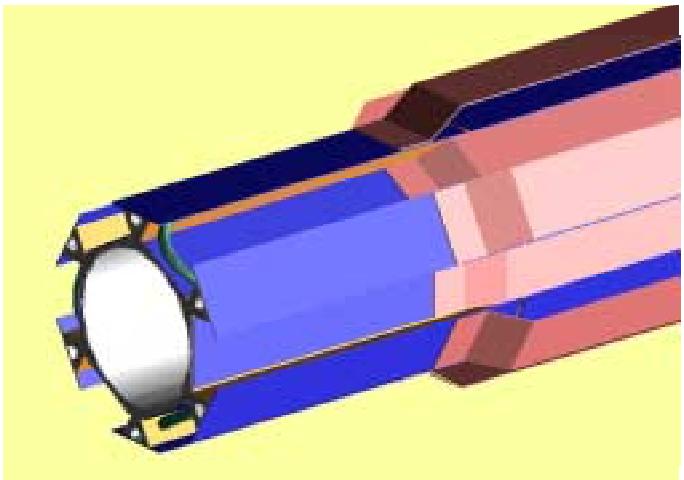
Layer 0 support

- 12-fold crenellated geometry
- Carbon fiber lined with carbon foam
- Integrated cooling
- R_{in} = 16.75 mm
- Sensor radii = 17.80 mm, 24.65 mm



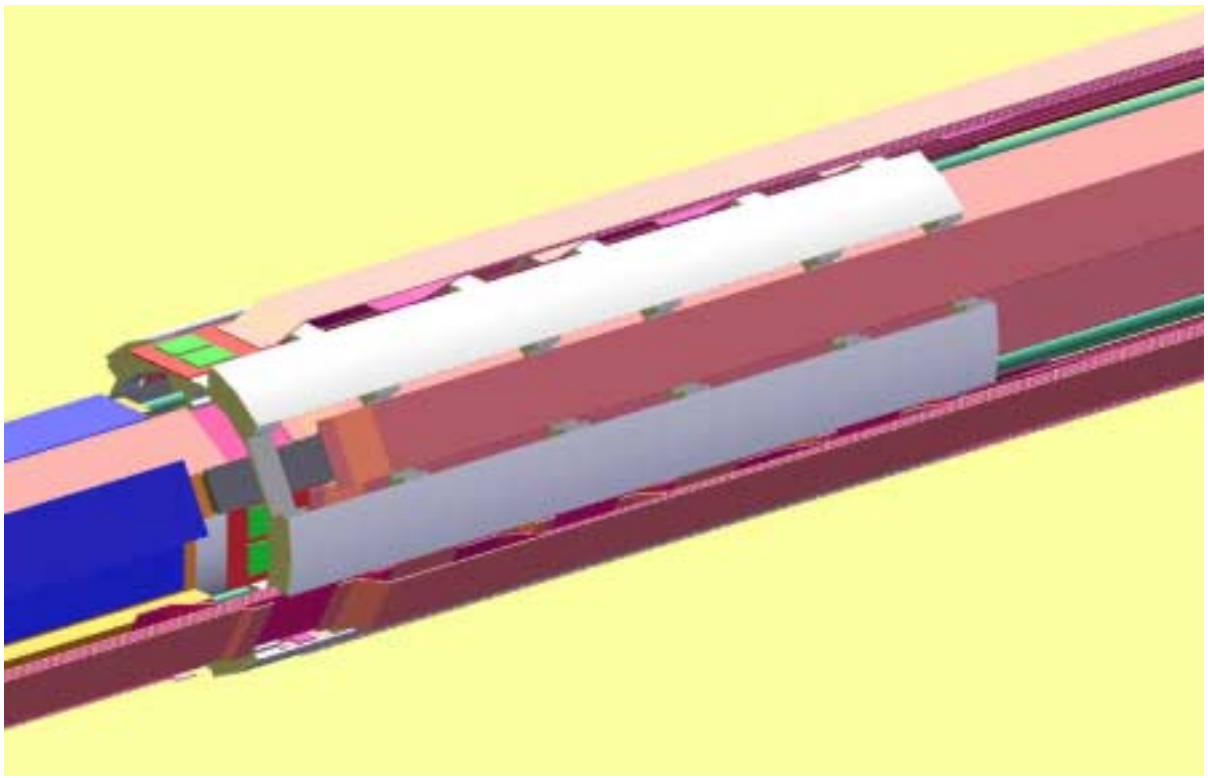
L0 mechanical structure



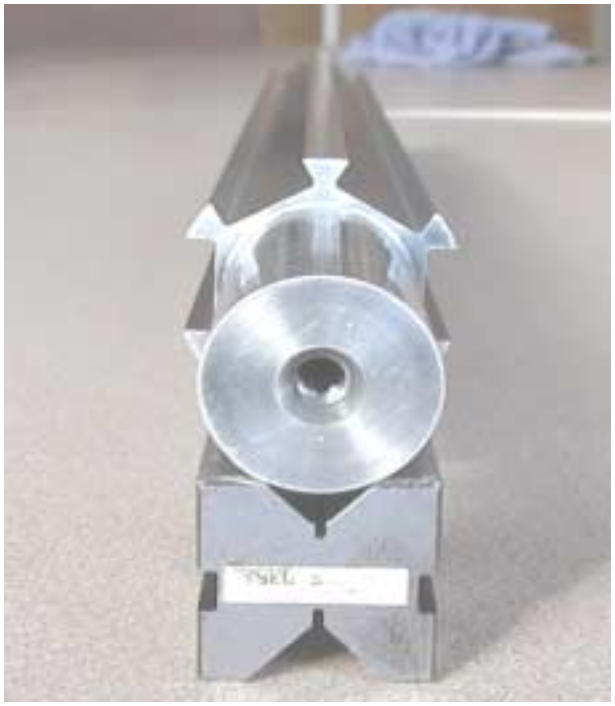


Layer 0 support

- Hybrids are off board
  - Analogue cables carry signals
  - 2-chip hybrids
  - Staggered in z for 6 readouts per end per phi-sector
- Six support rings
- Space is extremely tight

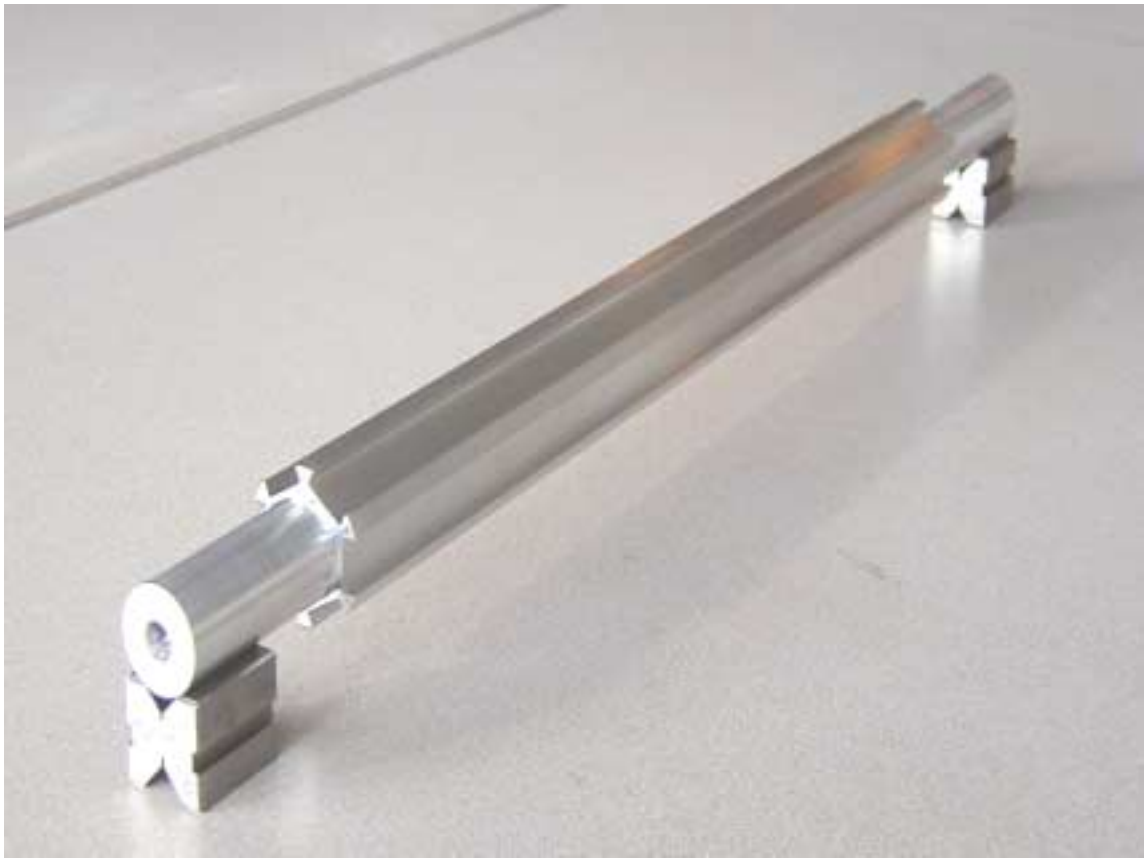


Prototype Layer 0 Castellated Mandrel



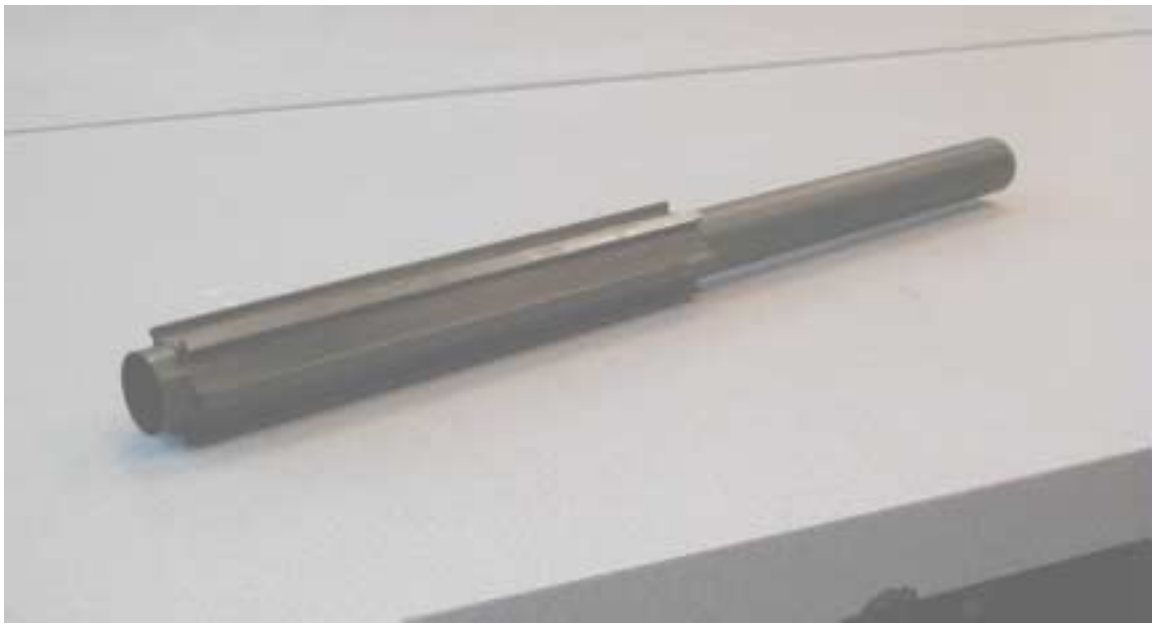
- Castellated mandrel for outer shell.
- Cylindrical mandrel for inner shell.

Henry Lubatti
November 7, 2001



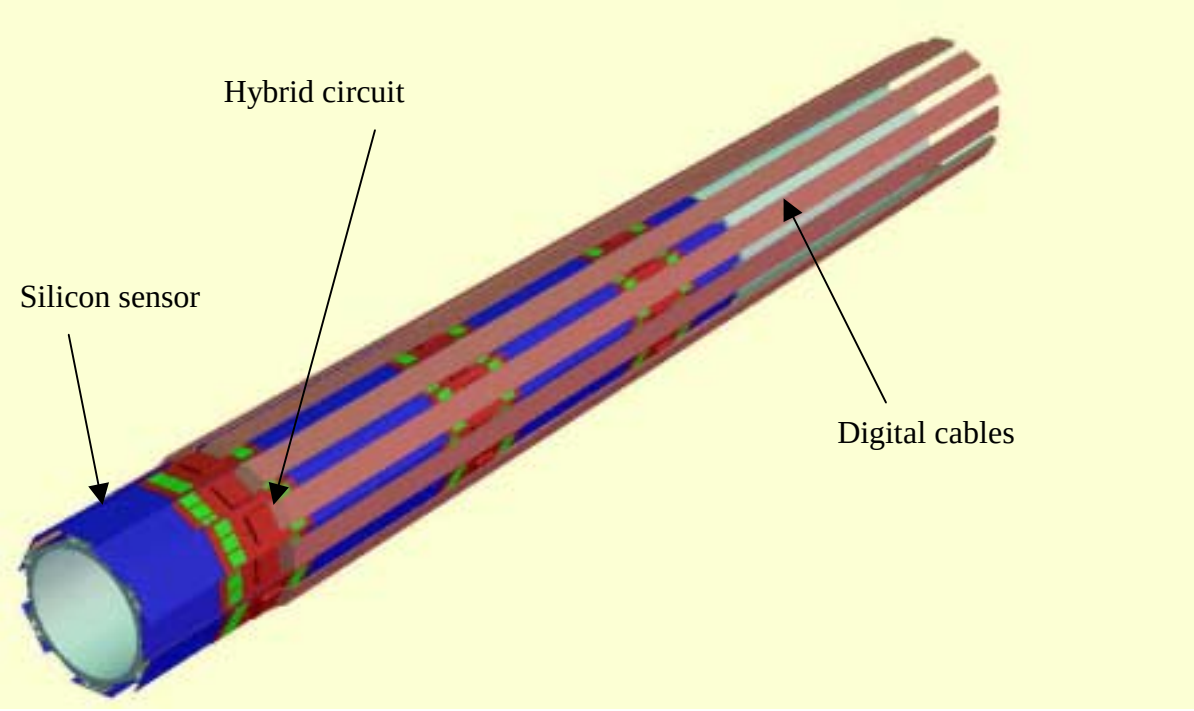
Layer 0 prototype castellated cylinder and inner cylinder

- Fabricated by University of Washington during the past week.



Layer 1 support

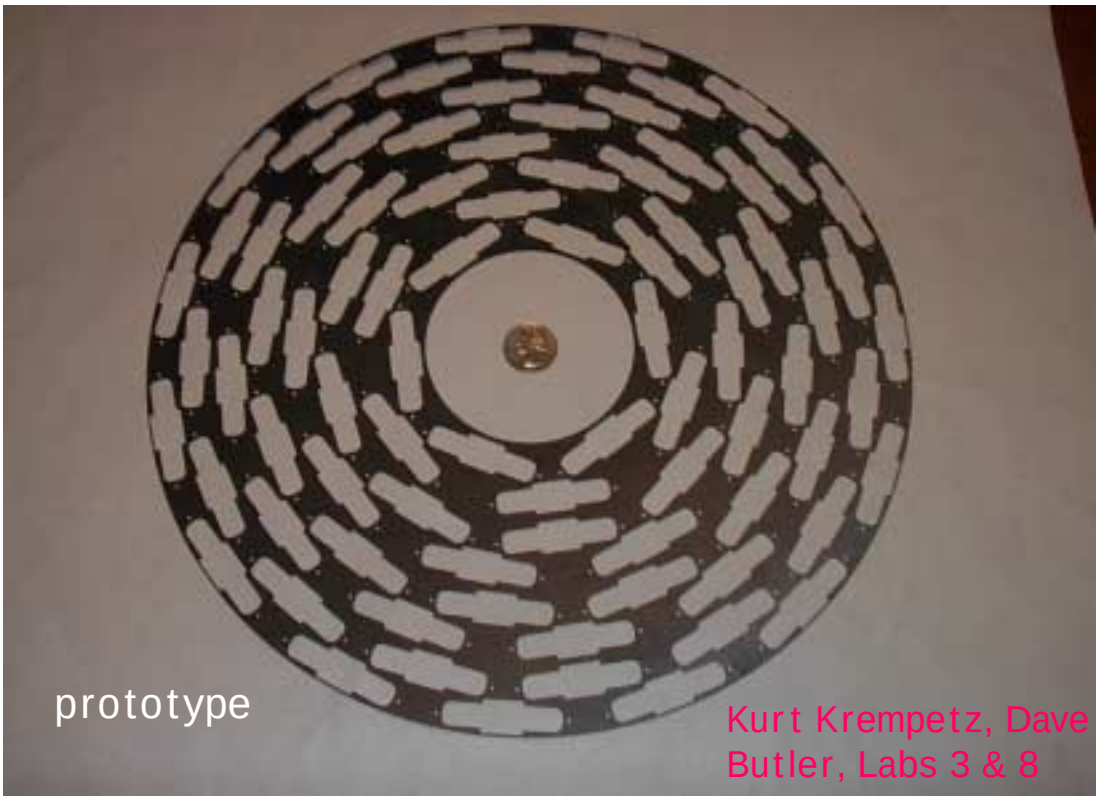
- 12-fold crenellated geometry
- Carbon fiber lined with carbon foam
- Integrated cooling
- Hybrids are mounted on silicon
- Layer 1 space is also tight
- R_{inner} = 32 mm
- R_{outer} = 45 mm (46 mm stay-clear boundary)
- Sensor radii = 34.80 mm, 39.05 mm



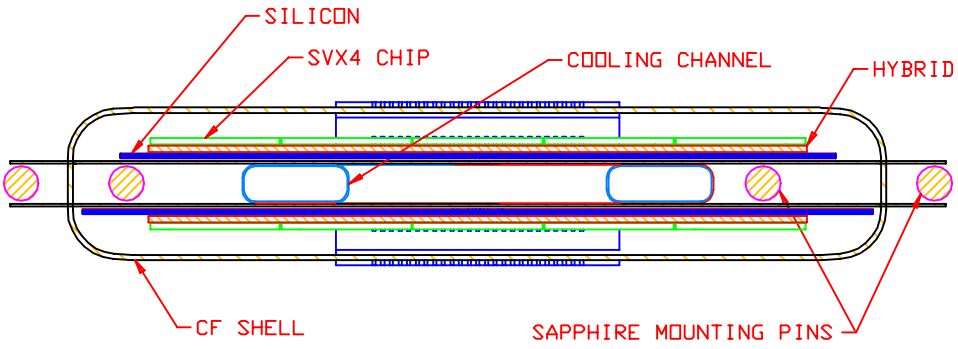
L1 assembly complete with silicon sensors, hybrids and digital cables.

Layers 2-5

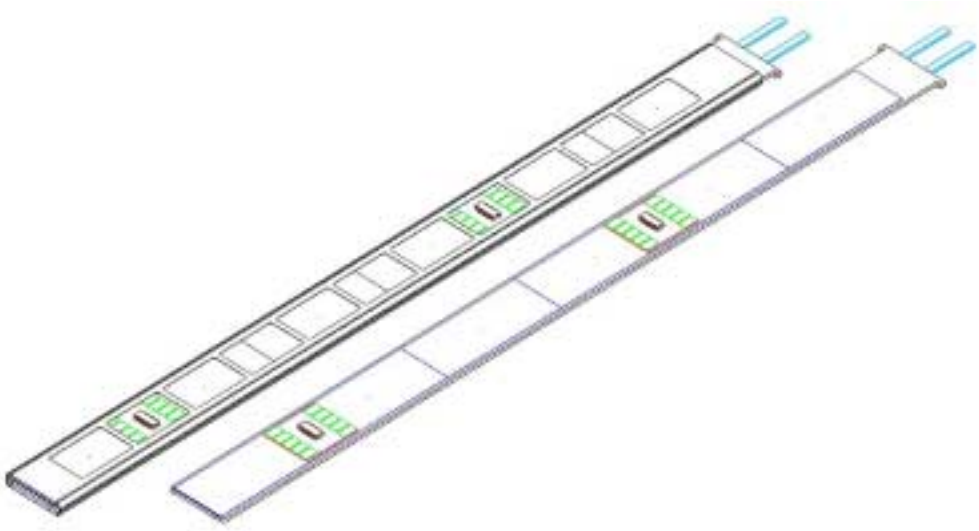
- 12, 18, 24 and 30-fold geometry
- All four layers:
  - 5-chip wide x 100 mm long sensors
  - 30 μm trace pitch, 60 μm readout pitch
  - Hybrids on-board
  - 10-chip hybrid readout
  - Stereo and axial readout in separate sub-layers
  - Stereo angle obtained by rotating sensor
- Staves
  - Readout modules are assembled into staves
  - Staves are positioned with carbon-fiber bulkheads
  - Staves are five sensors long in layers 2-3 and six sensors long in layers 4-5.



Stave Structure



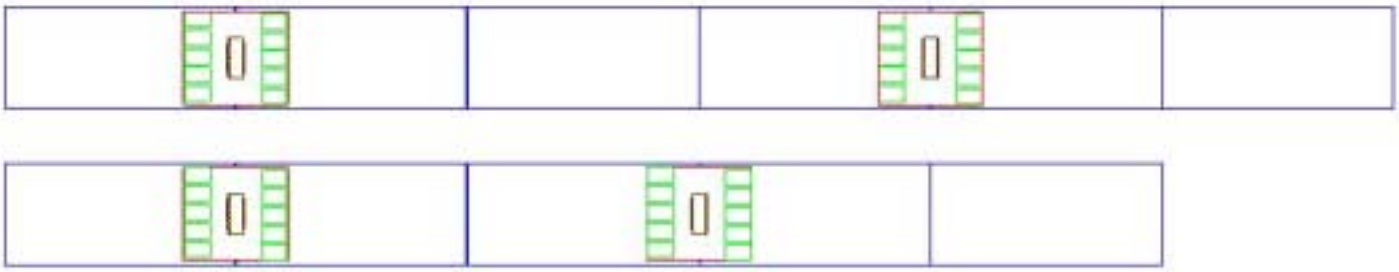
- Stave is doublet structure of four readout modules
  - Two layers of silicon
    - » Axial and stereo
    - » Two readout modules each
  - Separated by PEEK cooling lines
  - Total of 168 staves
- Stave has carbon fiber cover
  - Protects wirebonds
  - Provide support for digital cables
  - Provides mechanical stiffness
- Staves are positioned at ends by carbon fiber bulkheads



Ganging and longitudinal segmentation

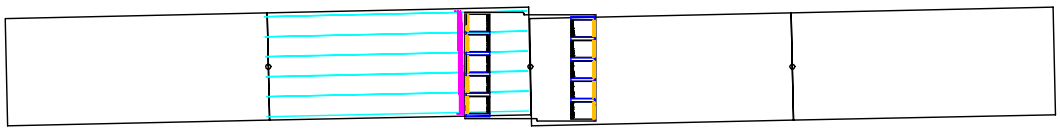
- Layers 1-5
  - Each hybrid is double-ended.
  - Sensors are ganged to one another to form sensor modules.
  - A sensor module is connected to each end of a hybrid.
- Sensor ganging
  - Layers 4-5:
    - » 100-100 200-200 ganging
  - Layers 2-3:
    - » 100-100 100-200 ganging
  - Layers 0-1:
    - » None: All sensors are read out individually

Layers 4-5



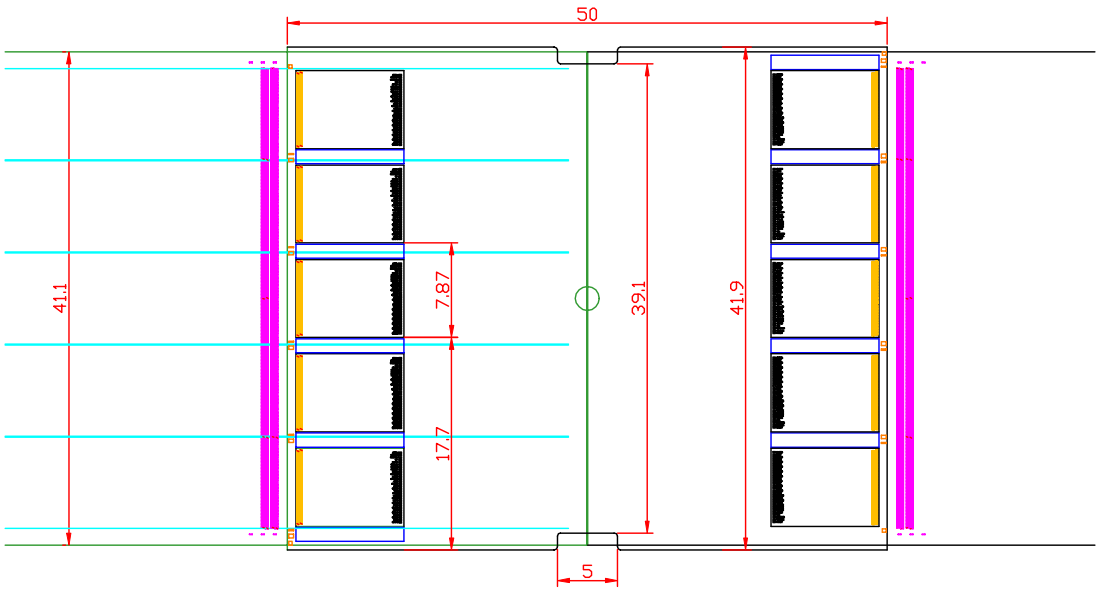
Layers 2-3

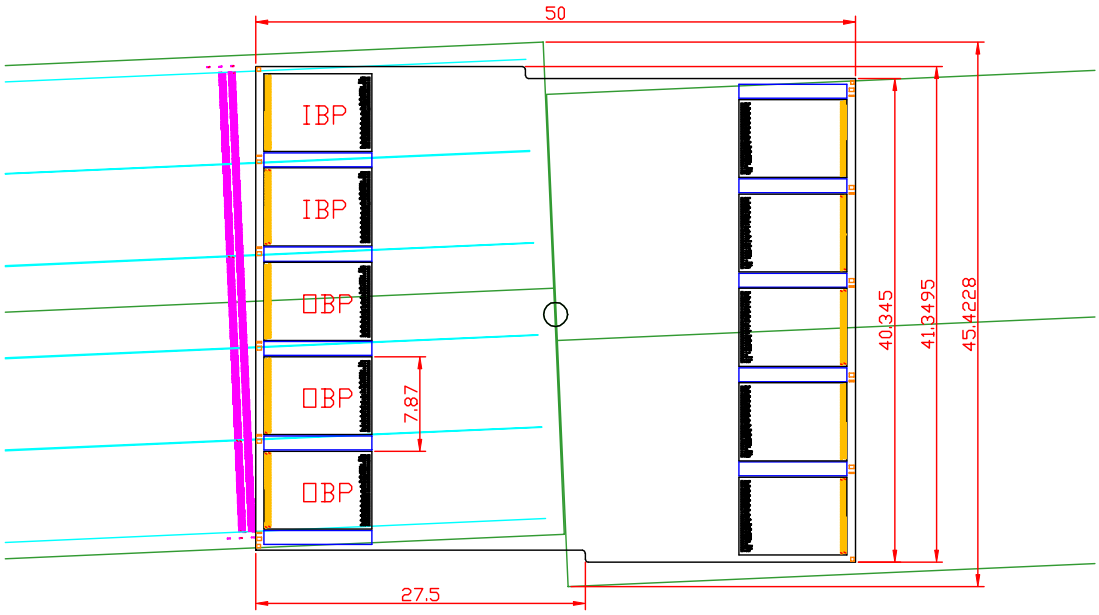
- Stereo angles are obtained by rotating a sensor gang
  - 1.25^{o} for 200 mm gang length
  - 2.5^{o} for 100 mm gang length



Sensor to hybrid connections

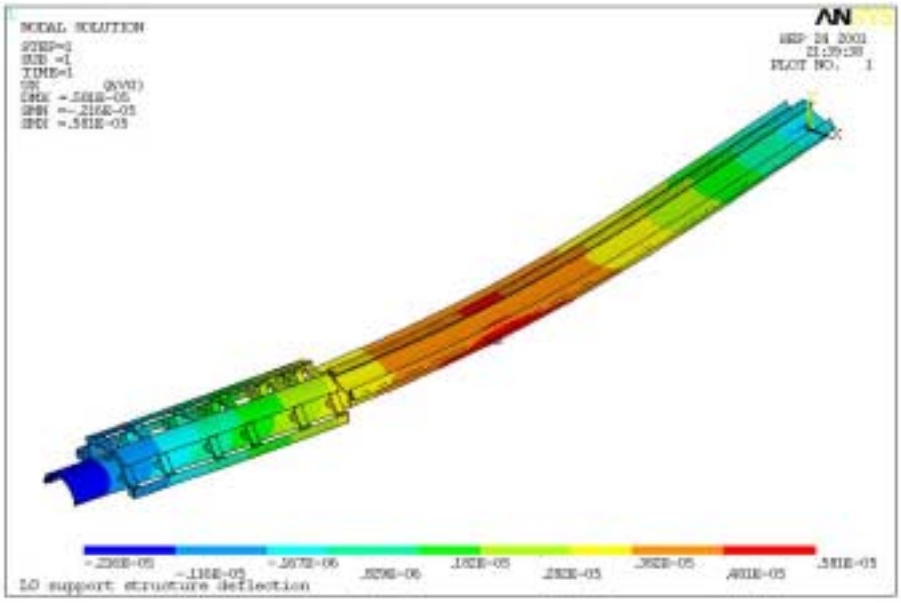
- We want one sensor for both axial and stereo.
- Wire bond lengths and angles are critical.
- Hybrid and sensor bond pad layouts have been developed to accomplish that.





Finite element analysis (FEA)

- Layer 0 maximum gravitational deflection = 5.8 μm.



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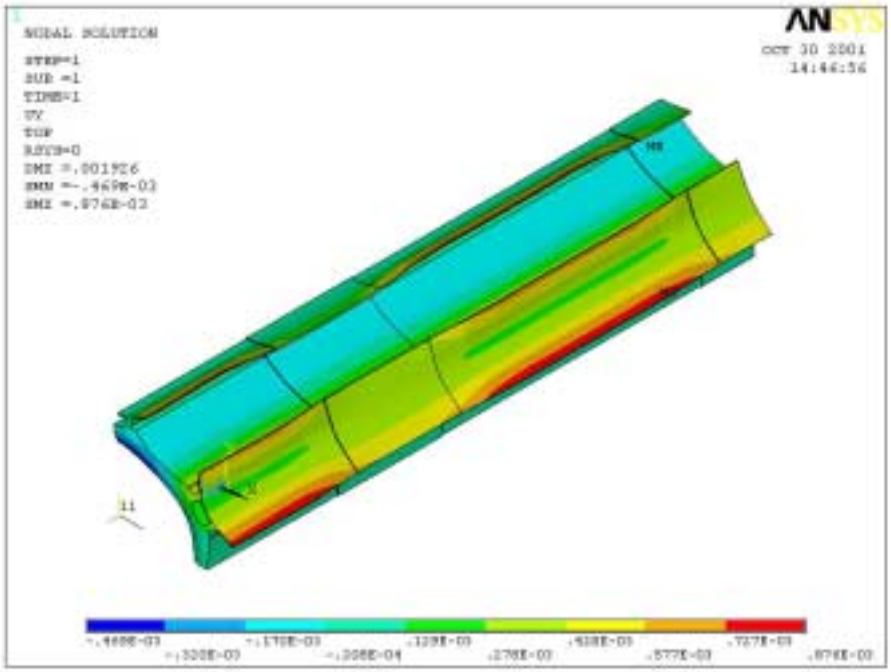
- Layer 1 maximum gravitational deflection = 1.4 μm.



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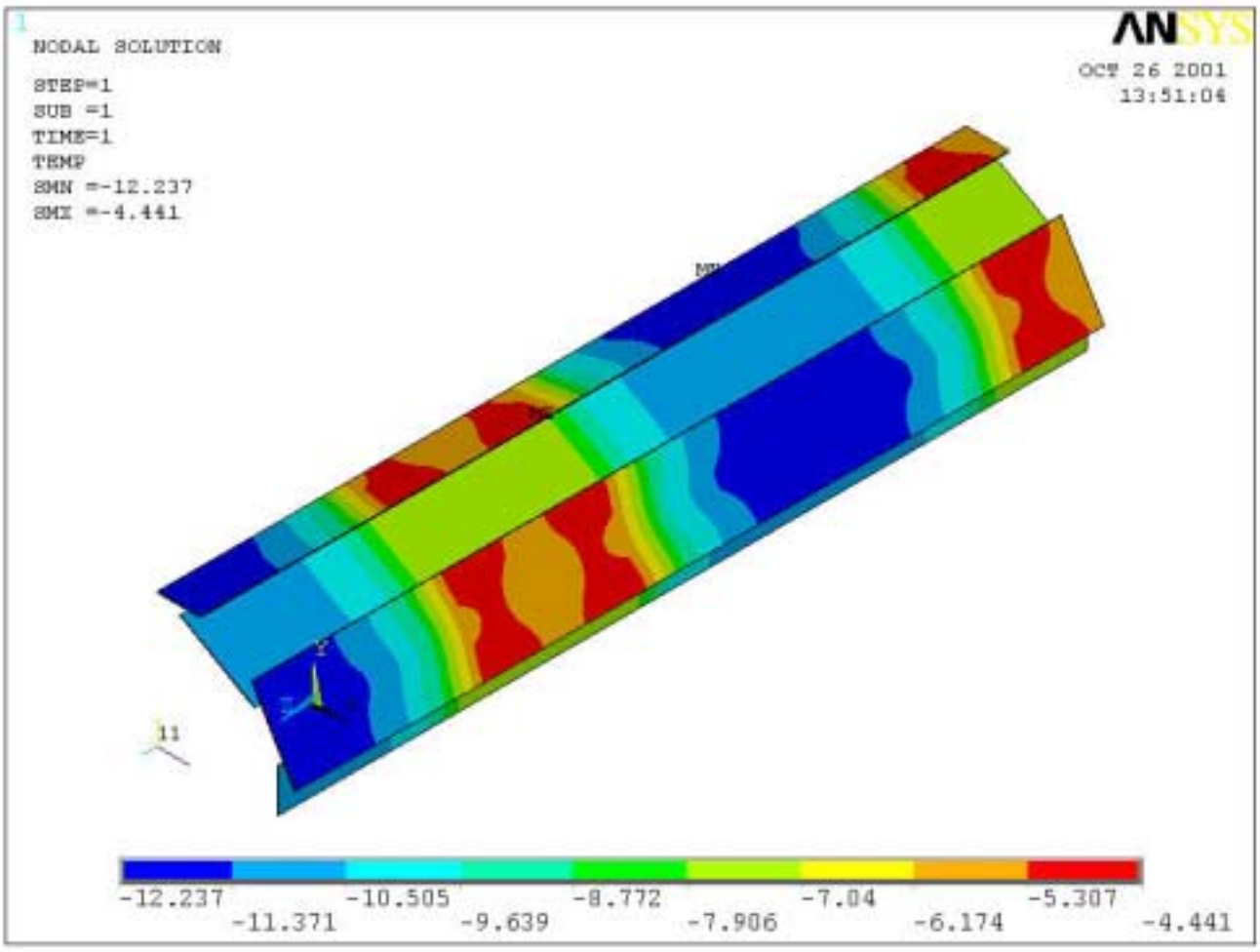
FEA: Layer 1 temperature distribution

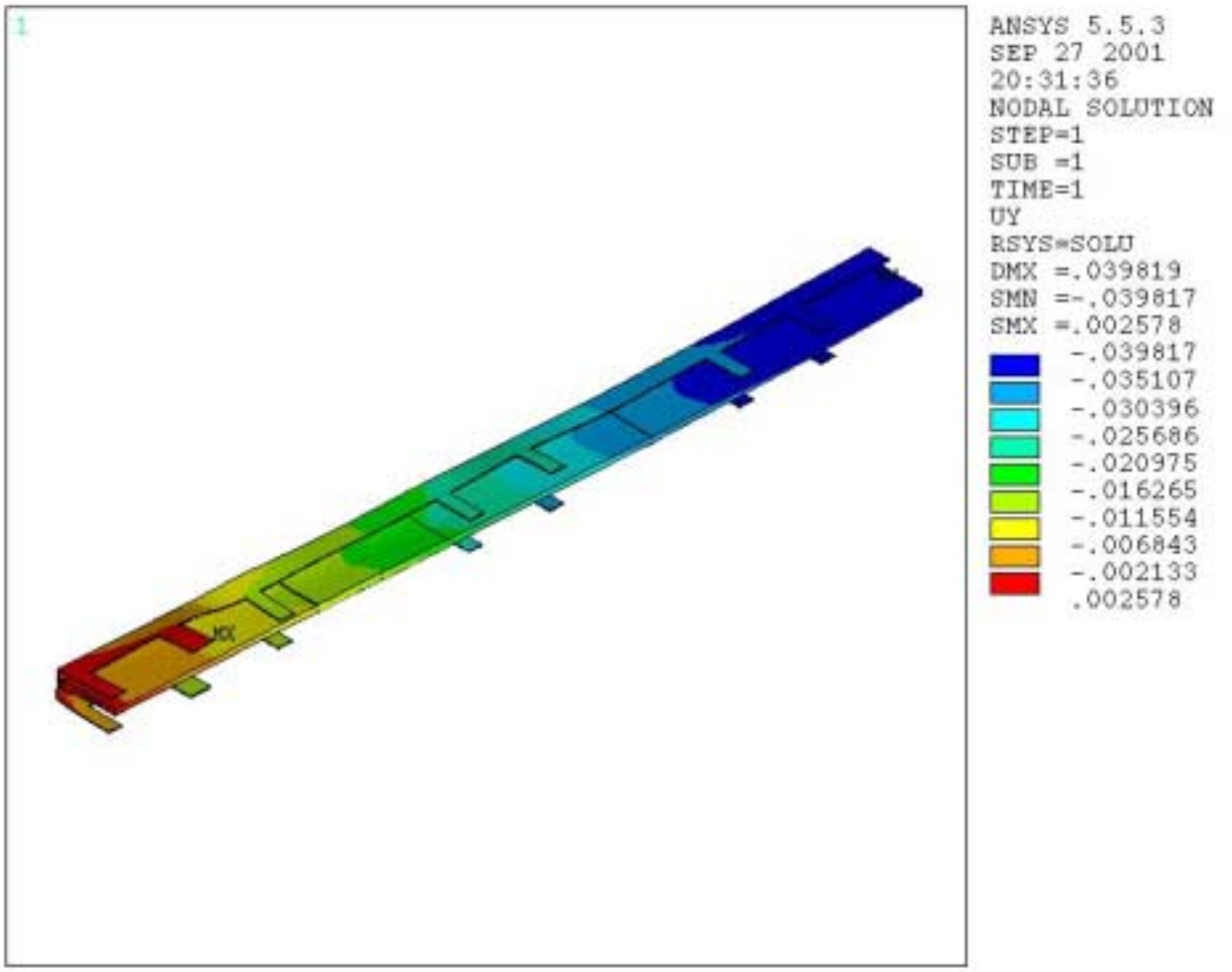
-14.5° C coolant

Maximum silicon temperature = -4.4° C.



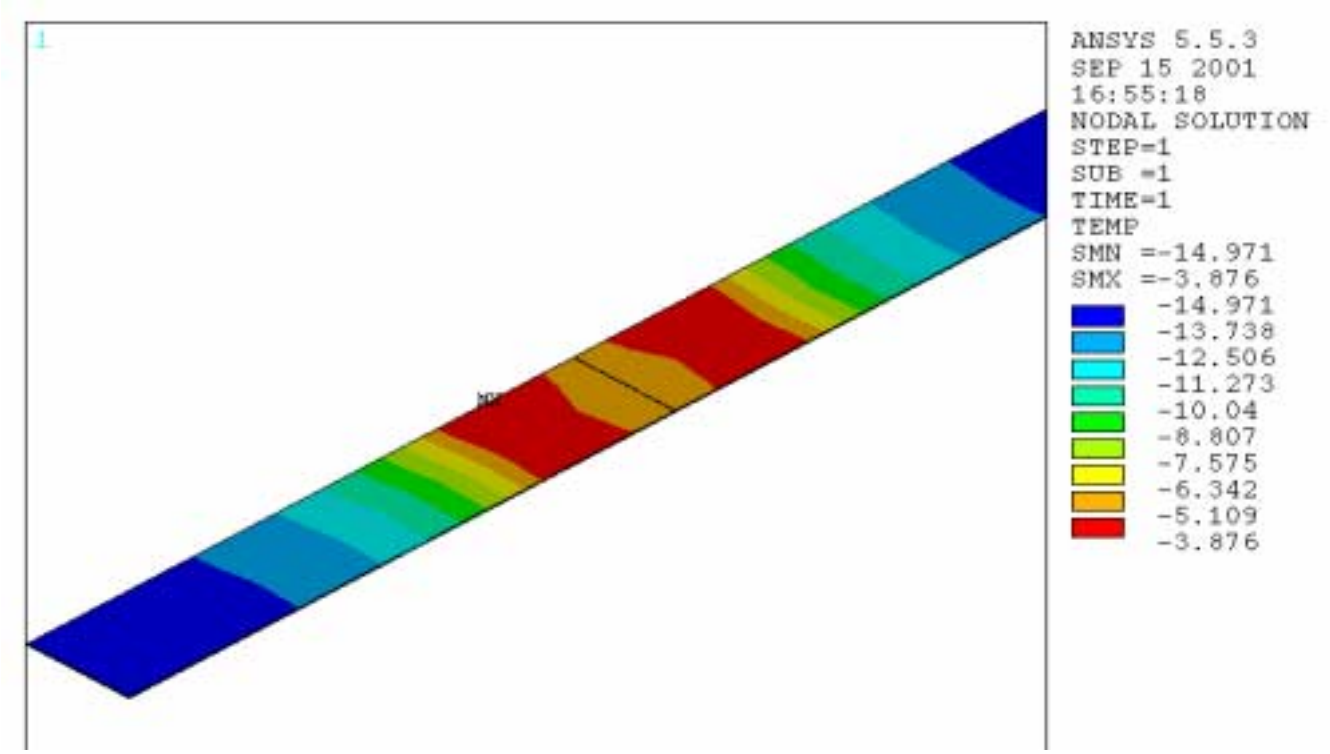
FEA: Stave gravitational deflection

Sagitta = 12.4 μm



FEA: Stave temperature distribution

- Layer 2-5 temperature with –15° C coolant. Tmax = -3.9° C.



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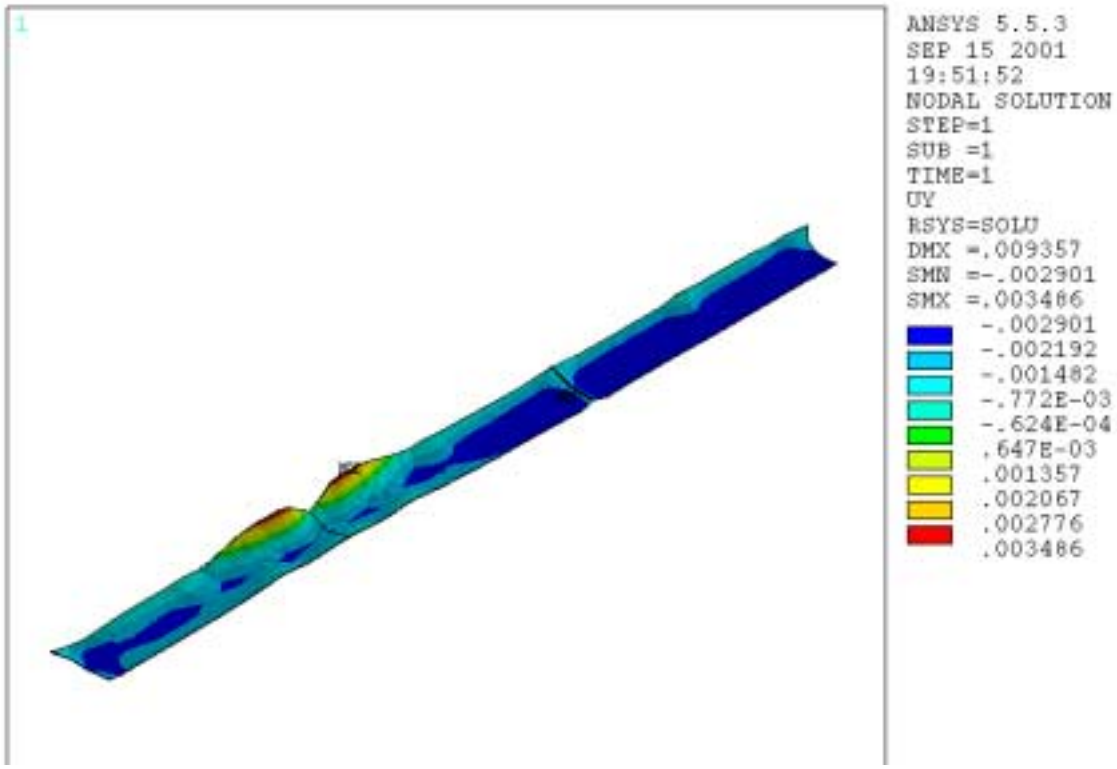
FEA: Stave thermal bowing

- Layer 4-5 thermal bowing out of plane with –15° C coolant (mm). Range = +3.5 / -2.9 µm.



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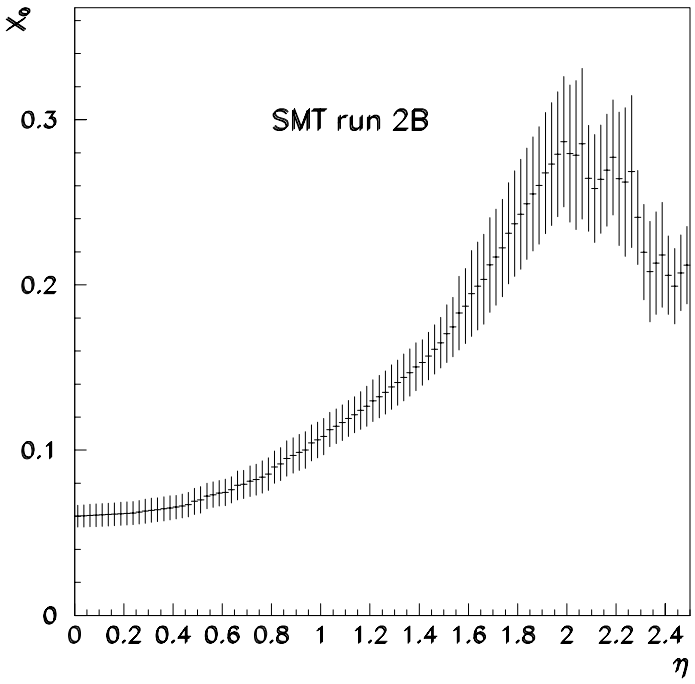
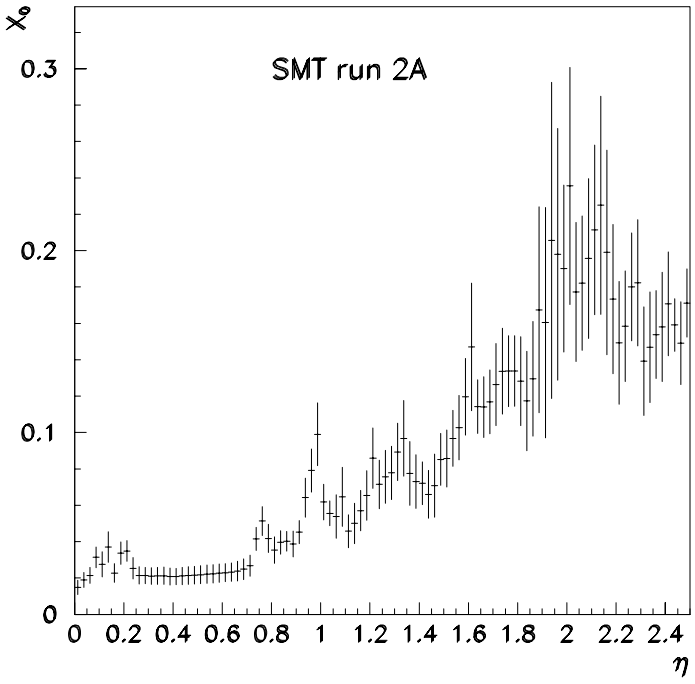
Beam pipe

- Drawings are complete and procurement specifications have been written for a 72” (1829 mm) long beryllium beam pipe.
- CDF and D0 have reached preliminary agreement on beryllium sections
  - Outside diameter = 29.464 mm.
  - Wall thickness = 0.508 mm.
- No longitudinal joint (which contributes substantial material in Run 2a). The pipe sections are expected to be made by blind boring into billets and joined by electron beam welding. EBW procedures were developed for LHC experiments.
- Some concerns regarding higher brittleness of billet material. (Most previous beam pipes have been made from rolled sheet).
- Short stainless steel sections with flanges at each end.
- The three beryllium sections span 1746 mm.

Radiation lengths (Preliminary)





Preliminary study from Flera Rizatdinova and Lisa Chabalina. Some Run 2b material remains to be added: foam, cooling tubes, supports at high η.

Run 2b has 6 axial measurements and 4 stereo measurements or 10 measurement surfaces.

Run 2a has 4 axial measurements and 4 stereo measurements in central barrels or 8 measurement surfaces.

The number of radiation lengths in Run 2b is higher because of the use of single-sided silicon,

but the smaller radius of the inner layers and limited material before them improves impact parameter resolution (later talk).

Summary

- The overall geometry has been established.
- Prototyping has begun on:
  - Stave positioning bulkheads
  - Stave carbon-fiber structures
  - Cooling passages
  - Layer 0 support structures
- Mechanical design work is nearly complete for:
  - Layer 1 hybrid modules (ready to order prototypes)
  - Layer 2-5 hybrid modules
  - Layer 0 sensors (prototype sensors ordered)
  - Layer 1 sensors (ready to order prototypes)
  - Layer 2-5 sensors
- Initial FEA studies have been made of:
  - Layer 0 and 1 gravitational deflections
  - Layer 1 temperature distribution
  - Layer 1 thermal distortion
  - Stave gravitational deflection
  - Stave temperature distribution
  - Stave thermal distortion
- The beryllium beam pipe design is complete and ready for beam pipe procurement.
- As detector designs are documented on engineering drawings, emphasis will shift to the design of fabrication and assembly fixtures.