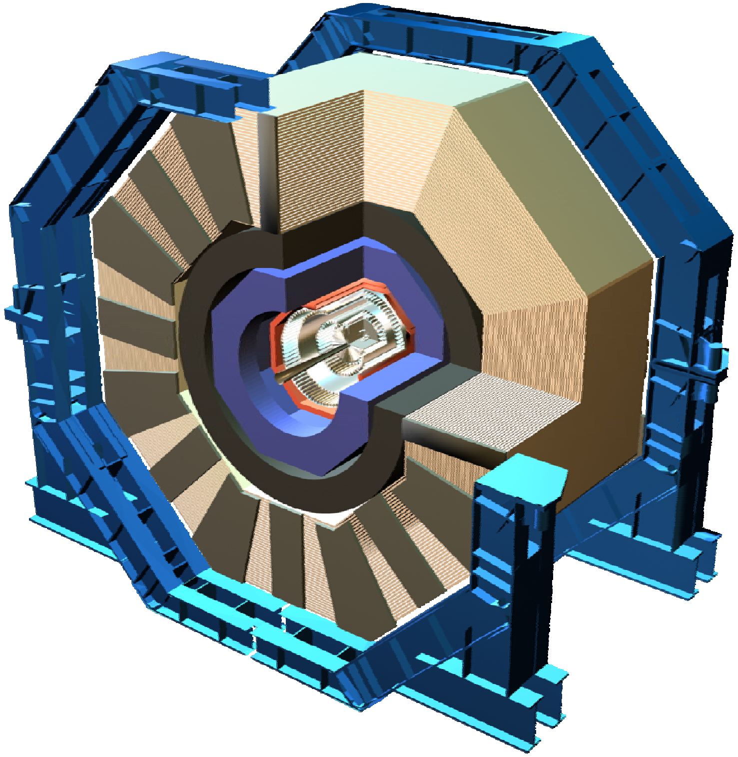
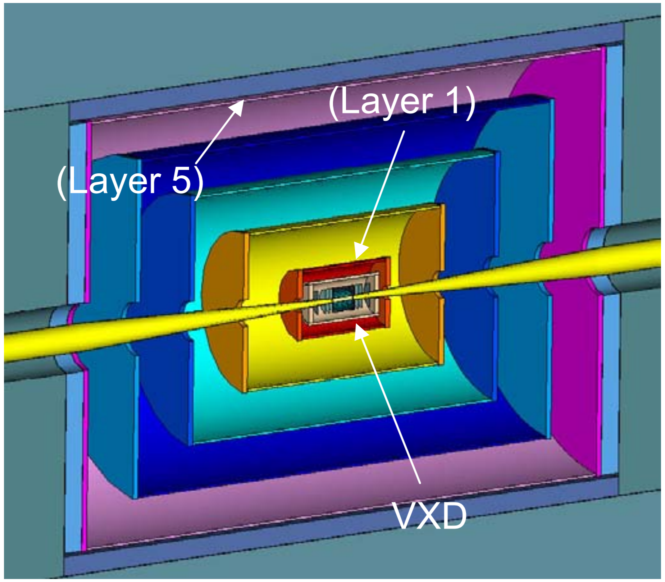
The Vertex Detector in the SiD Concept



Bill Cooper

Fermilab



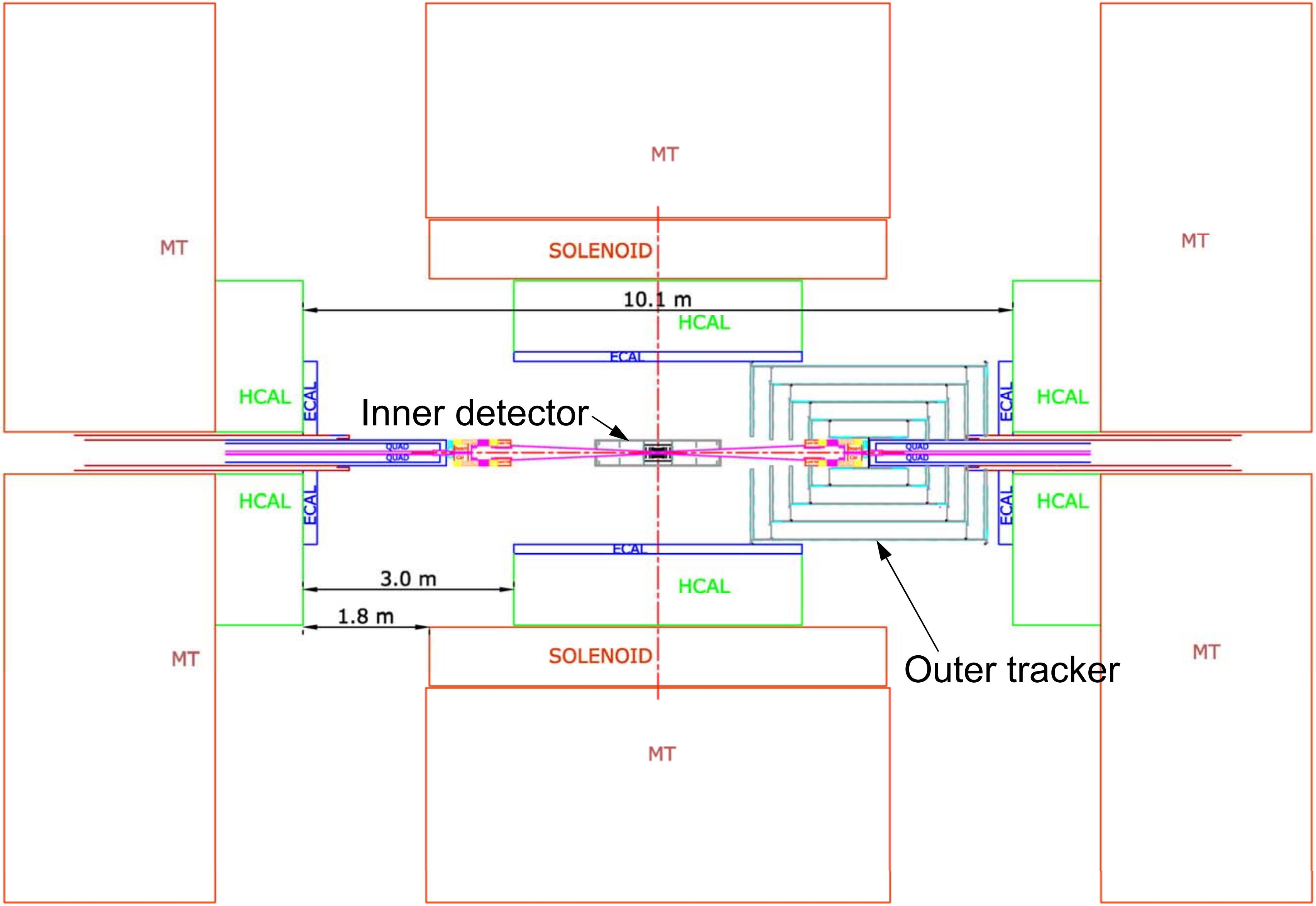
Introduction

- SiD is a closely integrated detector.
  - Designs of the outer tracker and the vertex detector have been developed which include provisions for accessing and servicing the vertex detector.
- The vertex detector mechanical design is strongly dependent upon sensor technologies.
  - We do not know which sensor technology will be most appropriate when a choice must be made.
  - To make progress, we have developed a design based upon specific assumptions regarding the sensors. Those assumptions will be described.
- Features of the design which was developed will be described.
  - Mechanical support structures
  - Number of radiation lengths
  - VXD cooling will be described in a later talk.
- Work remains, but we think the design is realistic.

Servicing

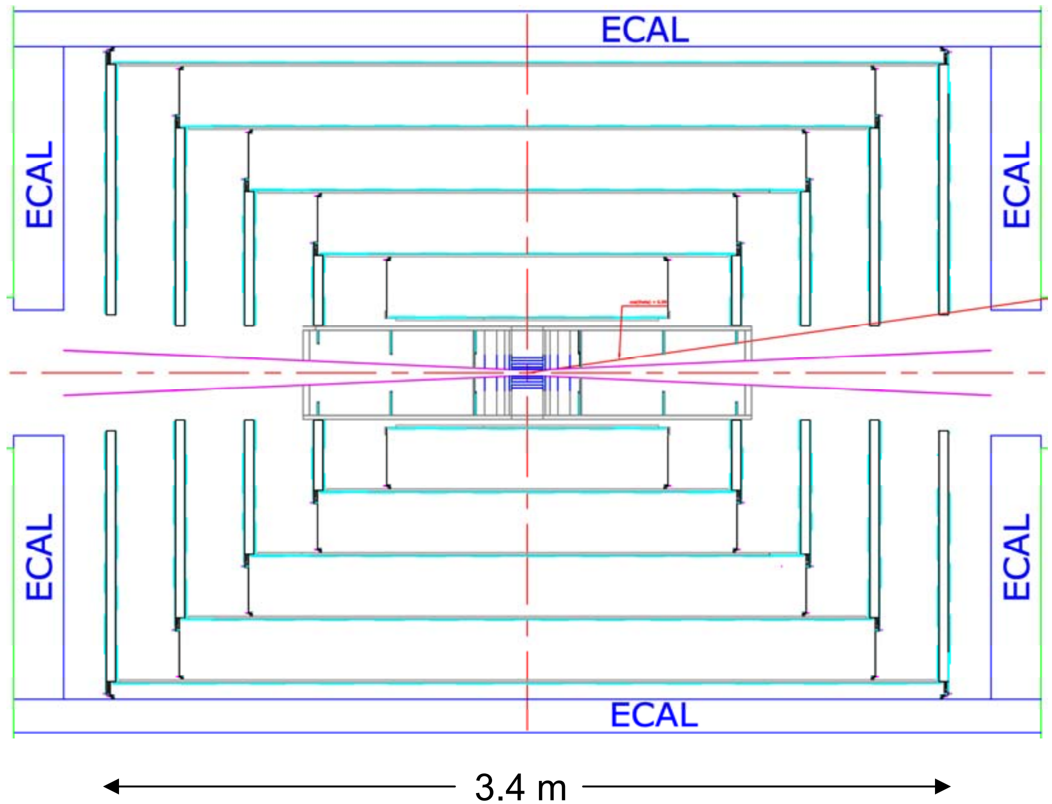
- During servicing, the end-caps are opened.
  - That allows cables and services to be disconnected.
- The silicon outer tracker is moved longitudinally.
  - Portions of the outer silicon tracker can be serviced in that configuration.
- The vertex detector and beam line elements remain fixed.
  - That minimizes disturbances to beam line elements, but does require that appropriate support has been included in their design.
  - The vertex detector is supported from the beam pipe.
  - In that configuration, vertex detector elements can be serviced, or even replaced.
- This approach to servicing sets constraints on the boundary between the outer silicon tracker and vertex detector elements.
  - During servicing, some beam line elements are located within the boundaries of the outer silicon tracker.
  - Adequate clearances must be maintained.
    - Outer tracker to beam line elements
    - Vertex detector elements to outer tracker

Detector Open / Full Access to Inner Detector



Silicon Tracking Layout (In Progress)

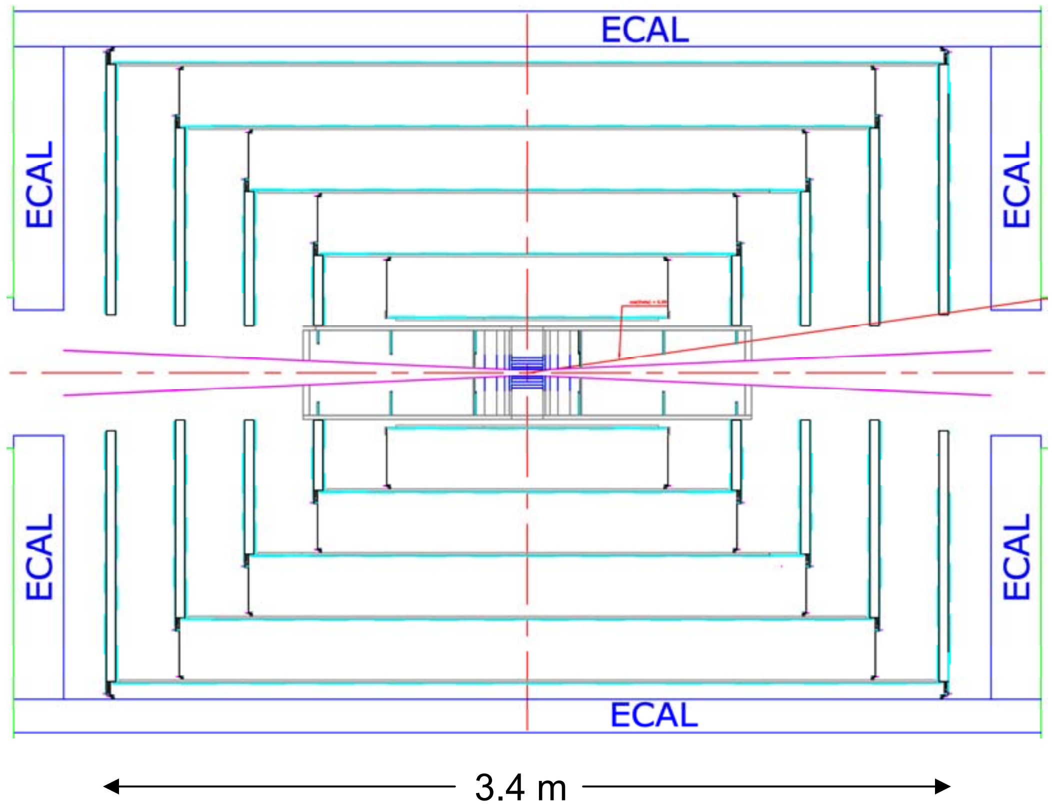
- Outer tracker (micro-strips)
  - 5 barrel layers
    - Measure R-Phi
  - 4 disks per end
  - OR = 1.25 m
  - IR = 0.2 m
  - Supported from ECAL
- Inner detector
  - VXD (pixels)
    - 5 barrel layers
    - 4 disks per end
  - Three additional "forward" disks extend angular coverage of the outer tracker to cos(θ) = 0.99
  - Supported from conical portions of beam pipe



- Lengths of outer tracker barrels have been adjusted to reduce the extent to which material aligns with a ray from the origin.
- Outer tracker disks could be shallow cones to increase stiffness in Z while reducing material.

Tracking Philosophy

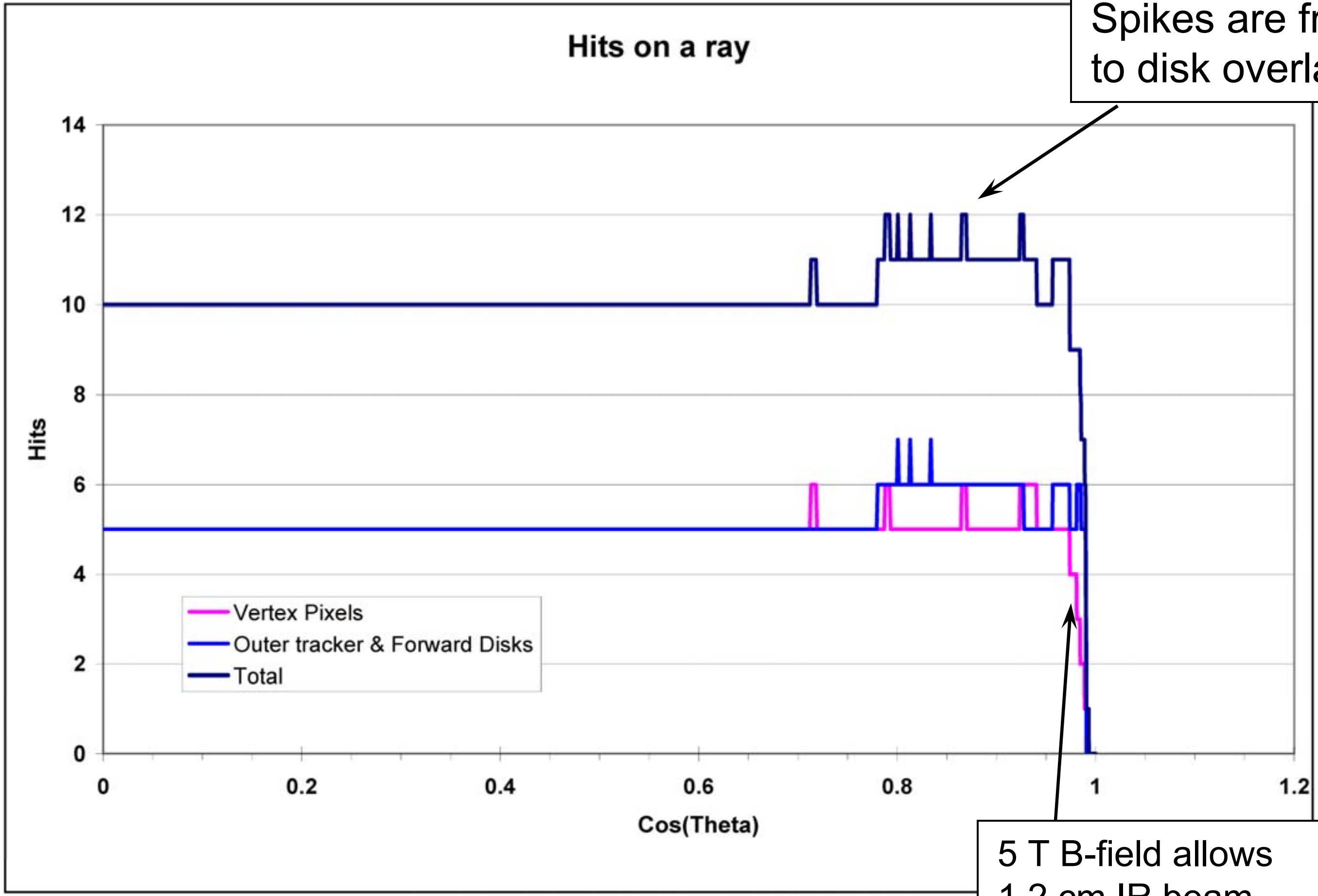
- Vertex detector
  - Provides high-precision measurements of tracks and vertices
  - ~ 3 µm vertex resolution
  - Provides an initial measurement of momentum
- Outer silicon detector
  - Measures P_T
  - In combination with a track direction from the vertex detector, provides P
  - Connects tracks to calorimetry



- Calorimetry
  - Measures E
  - PFA to improve resolution
  - Allows tracking backward into outer tracker

Tracking Philosophy

- Disks extend outer tracker and vertex detector coverage in forward and backward directions.
- Geometry has been chosen to provide full overlap for straight rays.



Spikes are from barrel to disk overlaps

5 T B-field allows 1.2 cm IR beam pipe near Z = 0

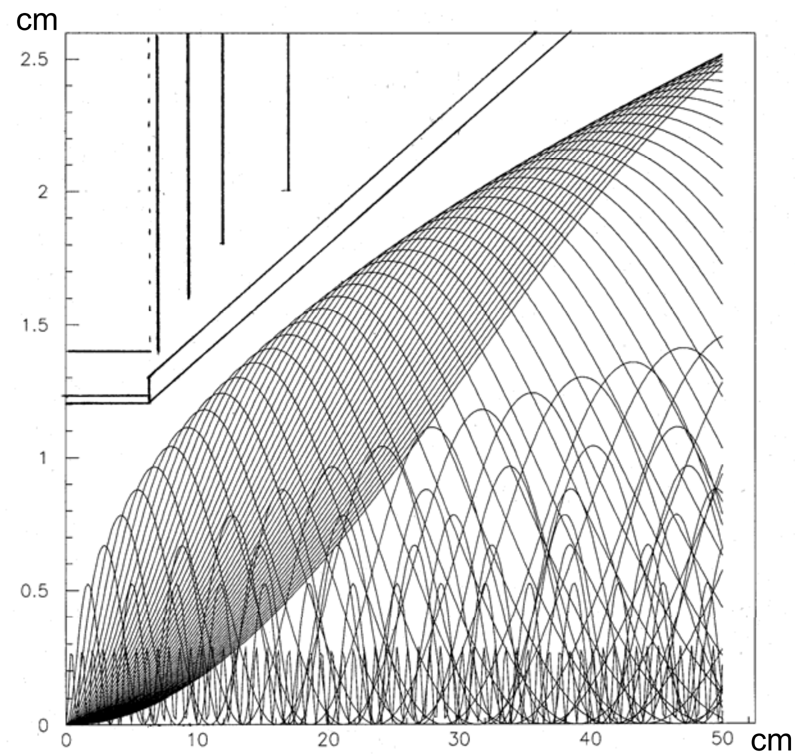
Beam Pipe

- An all-beryllium beam pipe was assumed for design purposes.
  - Portions of cones could be SS.
- Avoidance of pair backgrounds leads to a conical beam pipe shape beyond the central region.
- sidaug05 assumes a beam pipe inner radius of 1.2 cm within the region Z = ±6.251 cm. Beryllium wall thickness = 0.04 cm.
  - Sonja Hillert and Chris Damerell have stressed the importance silicon at a small radius.

  http://nicadd.niu.edu/cdsagenda//askArchive.php?base=agenda&categ=a0562&id=a0562s4t2/moreinfo#262
- Beam pipe liners are under study.
  - sidaug05 assumes a 0.0025 cm titanium shield in the central region and 0.0075 cm titanium shields in the conical regions to absorb low energy (<50 keV) photons and fluorescent x-rays. Tungsten masks were assumed in the conical regions, but consequences of tungsten weight will need to be examined.

Takashi Maruyama

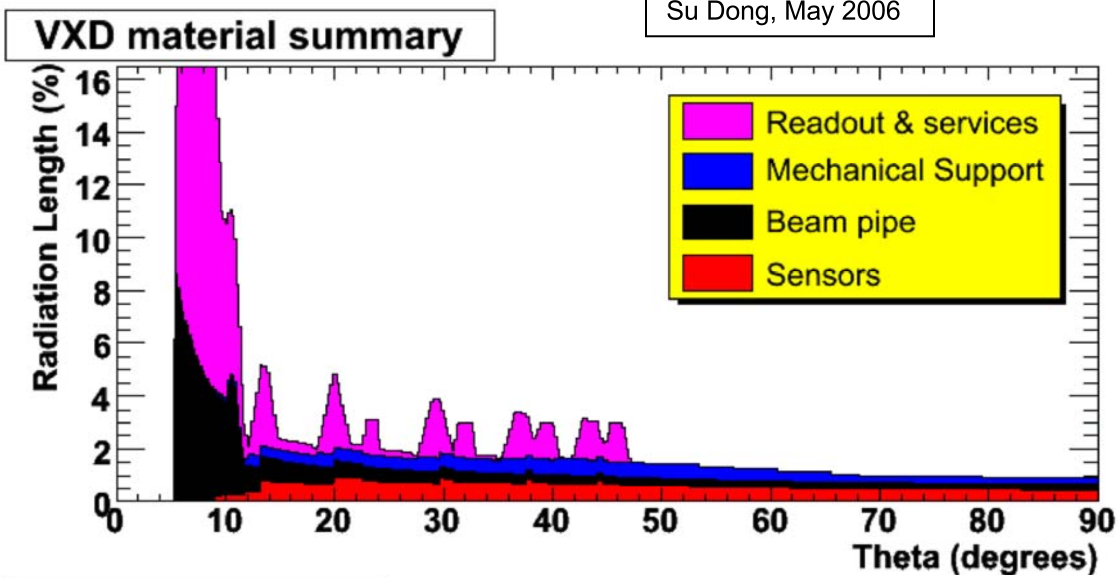
500 GeV Nominal 5 Tesla + 20 mrad xing



VXD Material

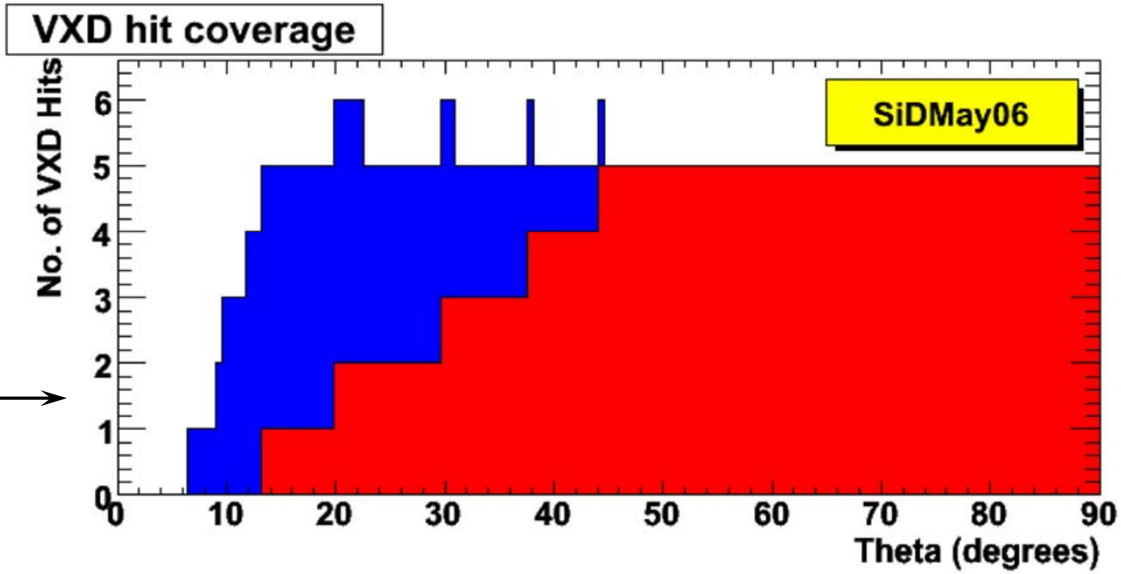
- Assumptions (partial):
  - 100 µm sensor thickness
  - 50 µm epoxy
  - 260 µm CF with ¾ of area removed
  - 400 µm beam pipe wall (central region)
  - 25 µm Ti beam pipe liner

Su Dong, May 2006



Barrel layers only

Barrels plus disks

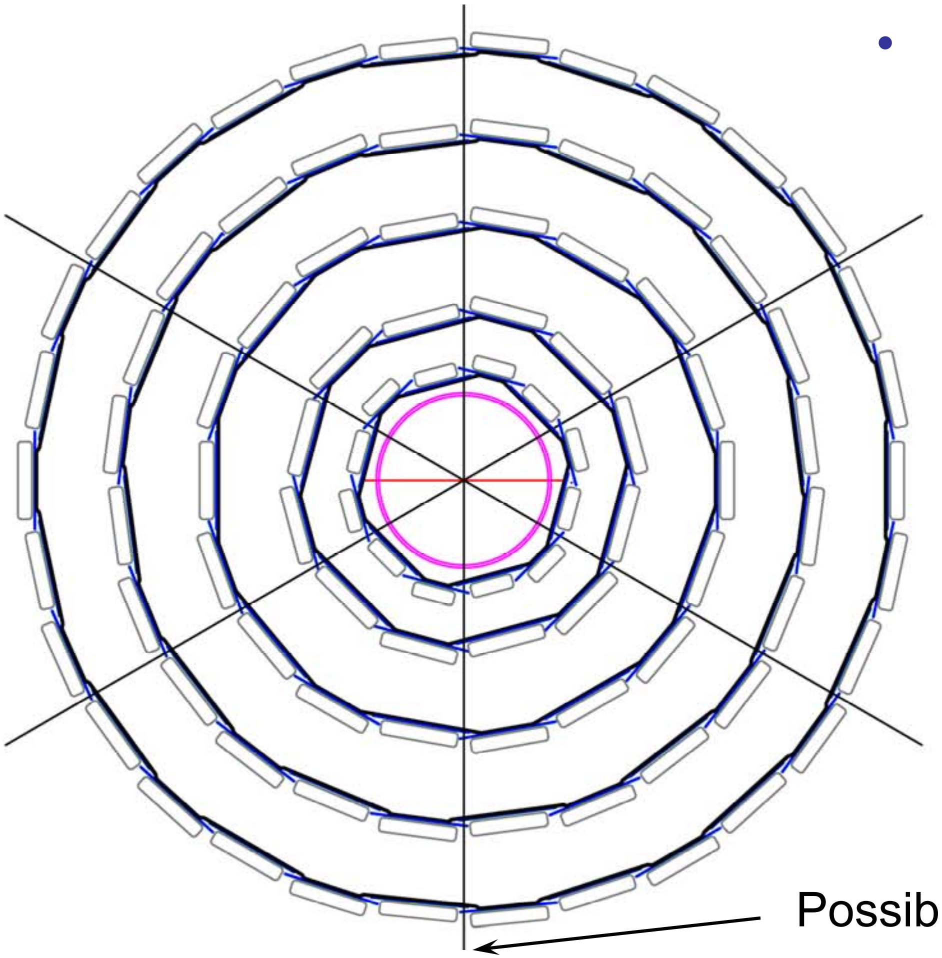


cm

VXD Barrel End View

- 2 types of sensors
- A and B sub-layer geometry

- 6-fold symmetry
- To reduce mass, barrel layers are glued to form a unit.
- Up to 15 sensors per unit



Sensors:
IR_A = 14, 22, 35, 47.6, 60 mm
IR_B = 15.15, 23.13, 35.89, 48.41, 60.77 mm
Active widths: 9.1, 13.3 mm
Cut widths: 9.6, 13.8 mm
Beam pipe IR: 12 mm
Beam pipe OR: 12.4 mm
March 3, 2006

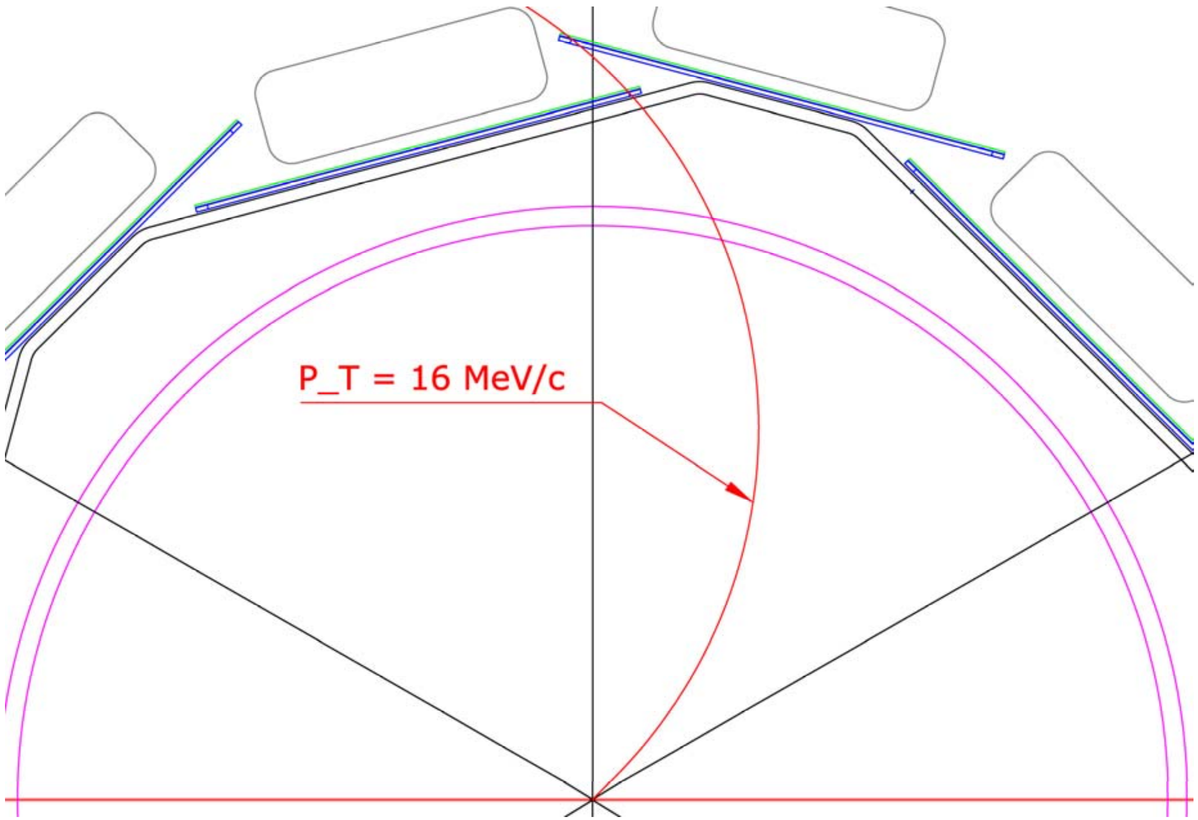
Oblong boxes are openings in end rings and end membranes for cables, optical fibers, and air flow.

Splitting into two halves allows assembly about the beam pipe.

Possible clam-shell split line

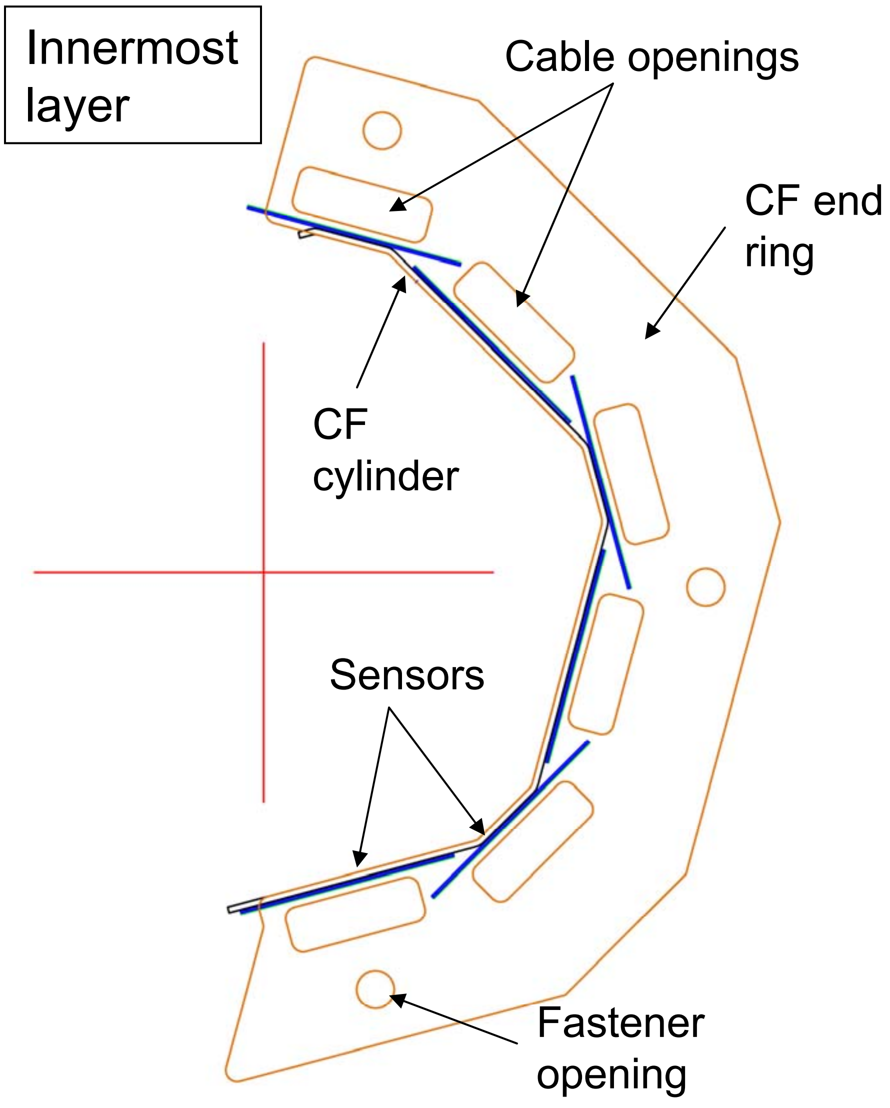
VXD Barrel End View

- Control of “ladder” thickness allows barrel sensors to provide overlap to quite low momentum and to preserve good acceptance for tracks originating away from the beam line.



Barrel Layers

- Sensors are supported from and glued to a carbon fiber (CF) shell.
- Each barrel layer includes a CF end ring, which controls out-of-round distortions.
- Openings provide cable, optical fiber, and dry gas passages.
- Other openings to reduce mass and adjust gas flow would be added.
- End membranes connect one layer to the next to form a half-barrel.
- To control material, the use of fasteners has been limited.
  - Three fasteners per end ring

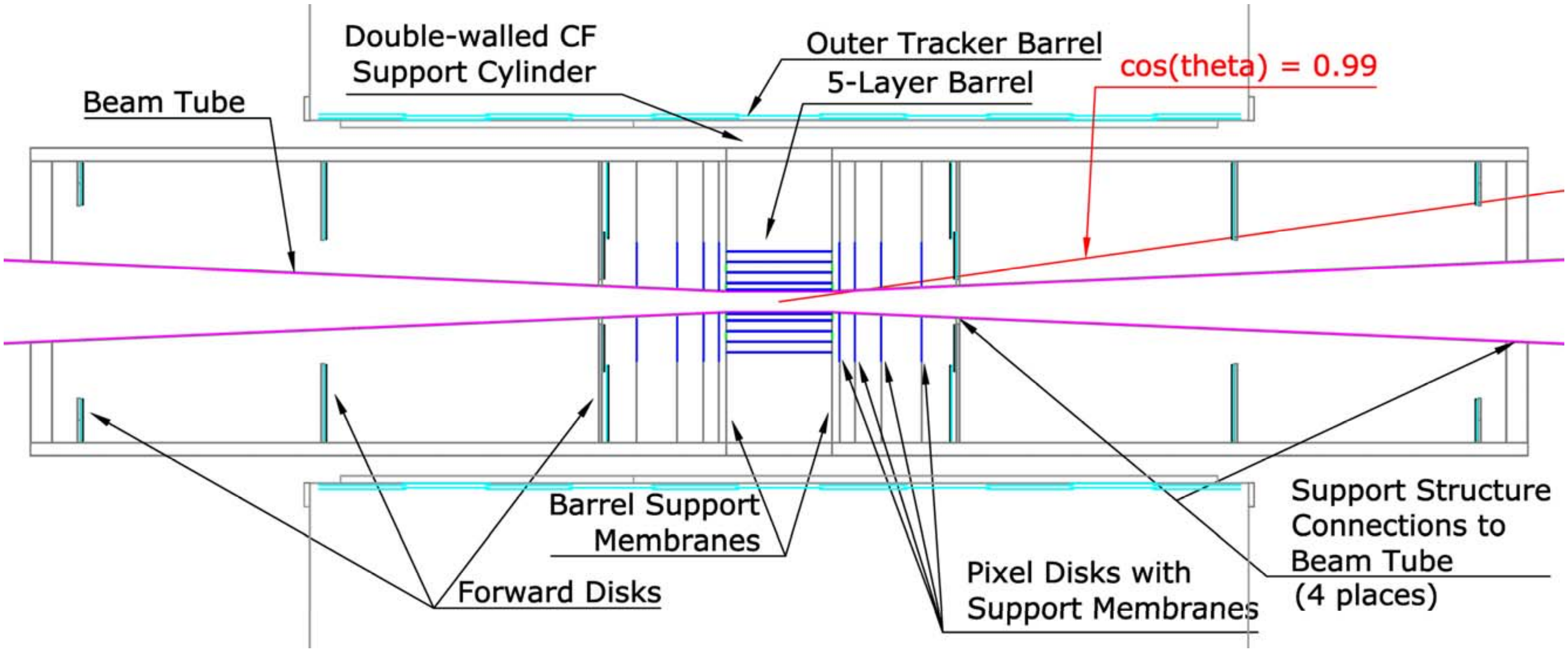


Sensor Assumptions

- VXD pixel size = 20 µm x 20 µm x 20 µm (or less) in the central pixel region
  - Provides good resolution and pattern recognition with five layers
  - Forward disks may have a coarser granularity
- Sensors are cooled by forced flow of dry gas.
  - Limits the number of radiation lengths
- To minimize Phi gaps between sensors, we assumed the following.
  - Sensor boundaries about active area are 0.25 mm wide.
  - Sensor thickness, including readout, is 0.15 mm.
  - The gap from the physical edge of one sensor to the surface of the next is 0.5 mm.
    - Of the 0.5 mm, we think 0.25 mm is needed. Portions of sensors could extend into the other 0.25 mm.
- To eliminate the need for barrel sensor-sensor longitudinal overlap, we assumed 125 mm long sensors (6" technology).
- We assumed that sensors are flat as fabricated and do not need to be flattened by support structures.
  - According to Ron Lipton, MIT Lincoln Labs have produced such sensors in a thickness range of 0.05 to 0.10 mm

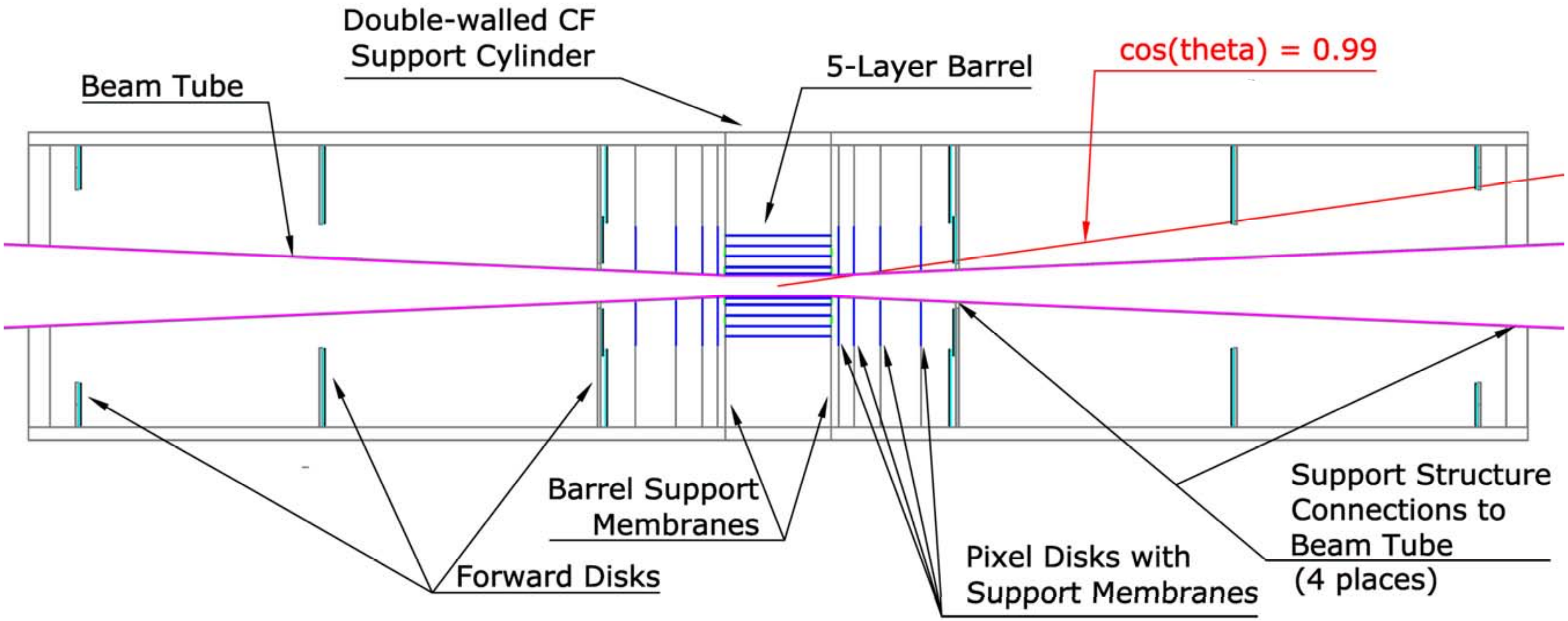
VXD Elevation View

- 5-layer pixel barrel: Z = ±62.5 mm; 14 mm < R < 61 mm
- 4 pixel disks per end: Z = ± 72, ± 92, ± 123, ± 172 mm; R < 71 mm
- 3 forward disks per end: Z = ± 208, ± 542, ± 833 mm; R < 166 mm
  - Could be pixels or pairs of micro-strips
- Coverage extends to cos(theta) = ± 0.99.



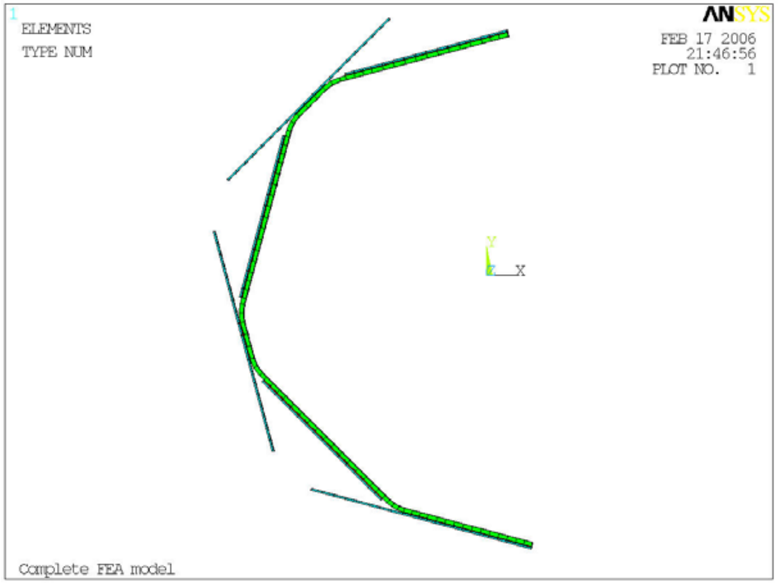
VXD Elevation View

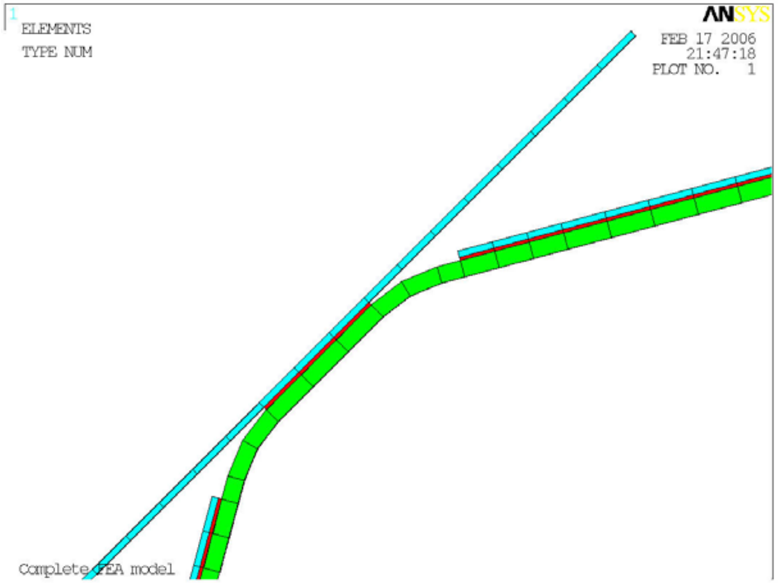
- Outer split cylinders couple to the beam tube at Z = ± 214 and ± 882 mm, are supported by the beam tube, and stiffen it.
- High modulus CF has been assumed for most support structures.
  - Typical thickness, 0.26 mm, assumes 4 layers of pre-preg.
  - In many places, average thickness can be substantially reduced by cutting holes.
- CF membranes support the barrel and disks.



Finite Element Analysis (FEA)

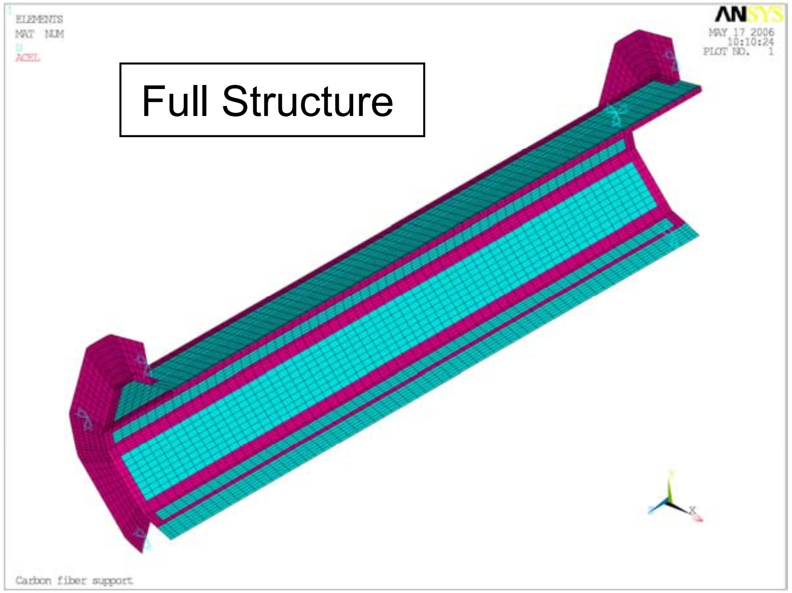
- An initial model was developed by Colin Daly (University of Washington) to represent the barrel 1 carbon fiber (CF) support structure, sensors, and epoxy which holds sensors in place.
- All sensors are on the outer surface of the carbon fiber (CF).
- A & B layers have been placed leaving 0.54 mm from the edge of an A-layer sensor to the surface of a B-layer sensor.
- All barrel 1 sensors are shown 9.6 mm wide (9.1 mm active).
- B-layer sensors overhang CF ~3.3 mm.

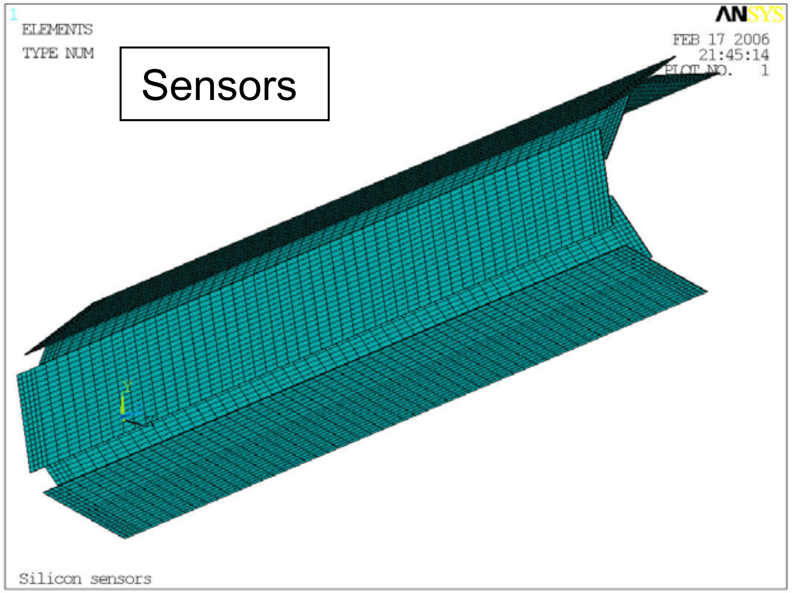




FEA of Innermost Barrel

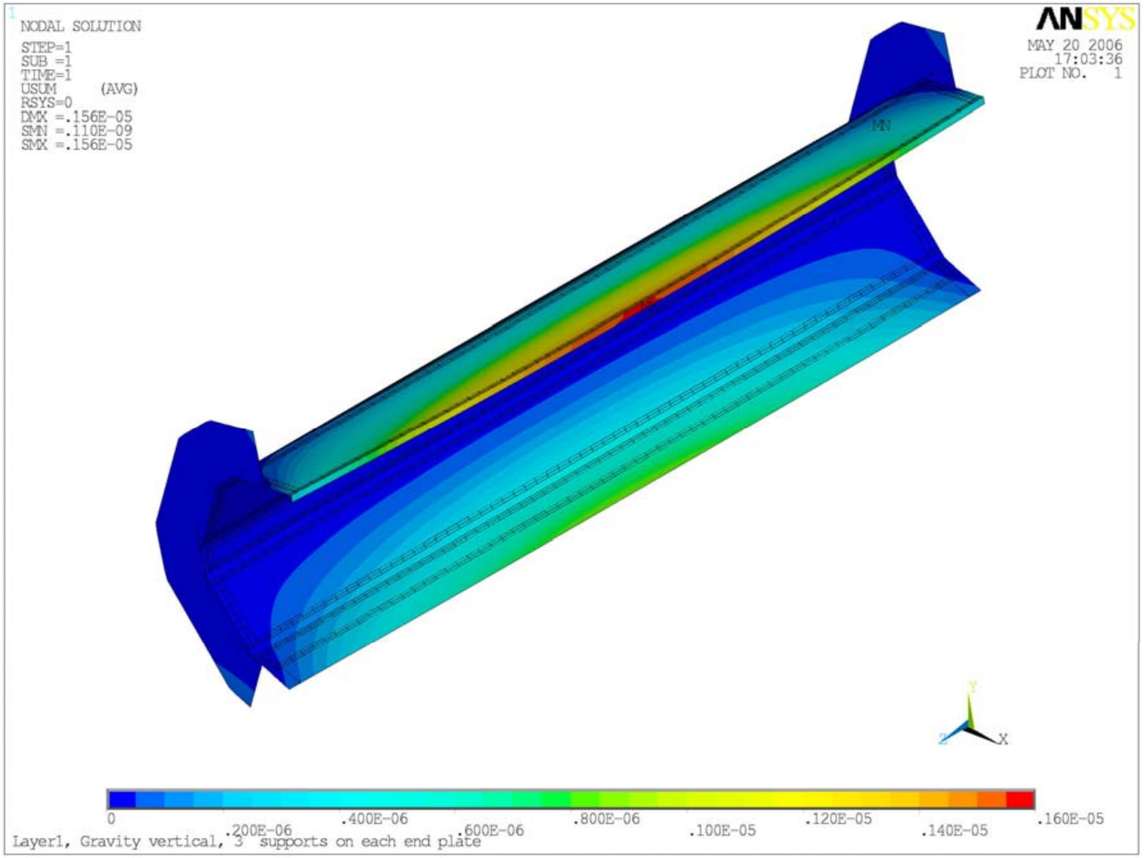
- Thicknesses:
  - CF:
    - 3 (had been 4) layers K13C
    - Each 0.065 mm thick
    - 0^o, 90^o, 0^o lay-up
  - Sensors: 0.100 mm
  - Epoxy: 0.050 mm
- Overall length was taken to be 125 mm
  - The present design assumes 125 mm long sensors and 126 mm long CF
- Elements to represent end rings are included.





Gravitational Deflections

- Maximum deflection = 1.6 µm with gravity acting vertically.
- Deflection had been 15 µm for a 165 mm long structure with 4 laminate layers



Summary

- Mechanical design features of the outer silicon tracker have been extended to the vertex detector.
- A design based largely upon carbon fiber support structures has been developed.
  - That design is intended to be suitable for sensor operation at > -10^{o} C.
- Feasibility of the design depends upon sensor developments.
  - We expect to follow developments and to take them into account.
- An initial FEA model has been developed for barrel sensor structures.
  - Gravitational deflections for 125 mm barrel sensors are small.