Evolution of the Design of a Silicon Tracker for the Linear Collider

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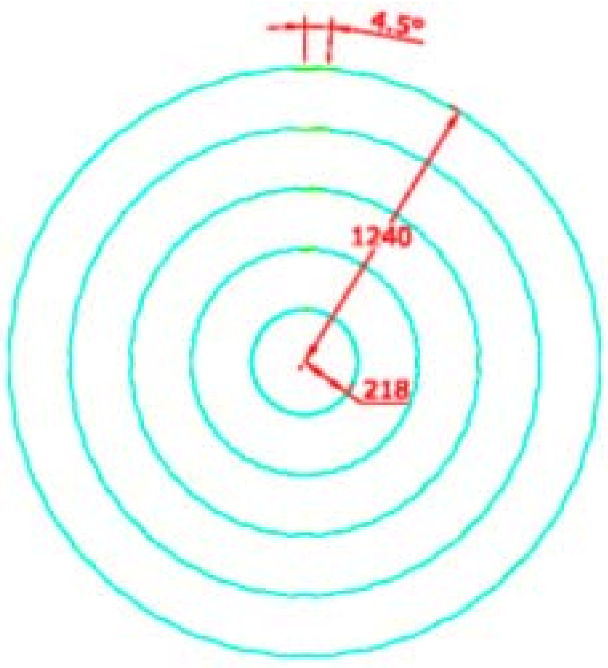
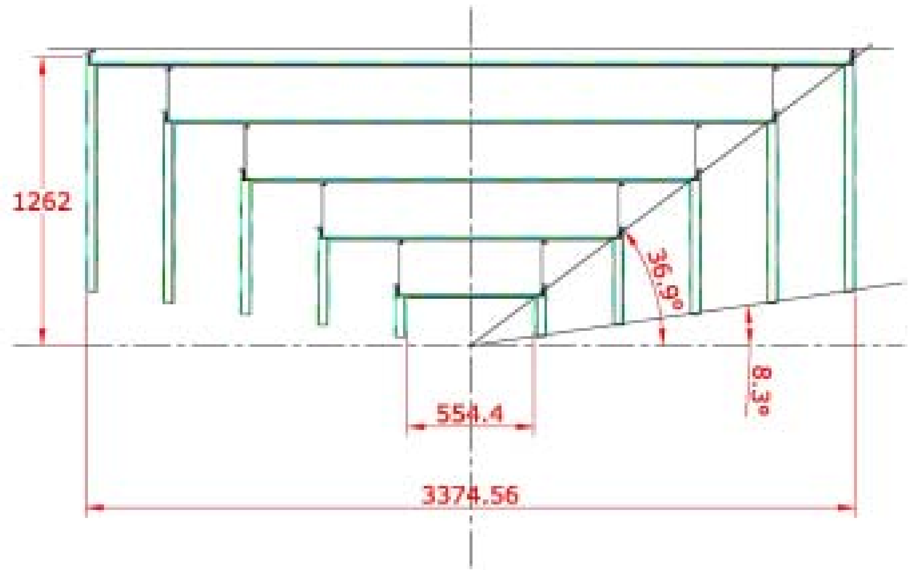
Fermilab

Overall Geometry for the Design Presented in Victoria

- Barrels
  - Five barrels
  - Measure Phi only
  - Eighty-fold phi segmentation
  - Barrel lengths increase with radius
  - Maximum active radius = 1.240 m
  - Minimum active radius = 0.218 m
  - Maximum active length = 3.307 m

- Disks
  - Five double-disks per end
  - Measure R and Phi
  - Disk radii increase with Z
  - Maximum active radius = 1.262 m
  - Minimum active radius = 0.041 m
  - Maximum Z (active) = 1.687 m
  - Minimum Z (active) = 0.282 m





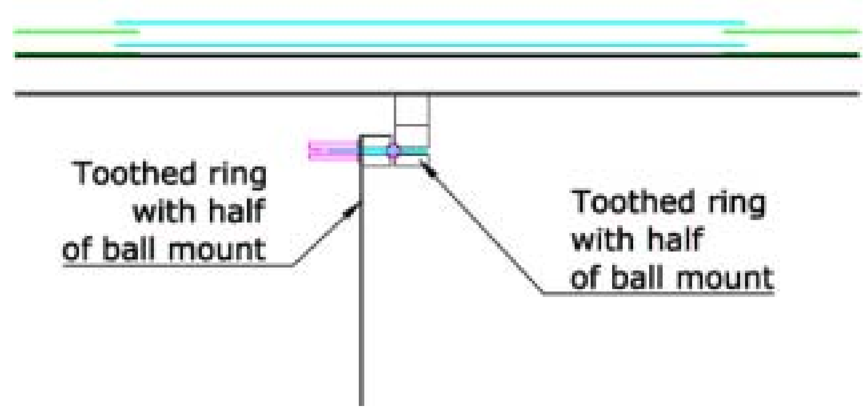
Sensor and Chip Counts (Victoria Design)

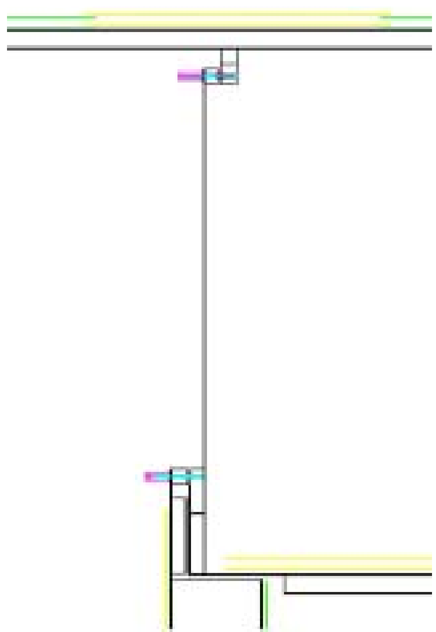
Barrels (Layer)	Sensors	Active area (m^2)	Chips	Disks (Sum of two ends)	Sensors	Active area (m^2)	Chips
1	640	1.72	1920	1Phi + 1R	100	0.70	1140
2	960	4.11	5760	2Phi + 2R	280	2.93	4240
3	1440	9.15	12960	3Phi + 3R	640	6.75	9600
4	1920	16.26	23040	4Phi + 4R	960	12.17	16160
5	1920	19.50	28800	5Phi + 5R	1440	19.16	23840
Sum	6880	50.73	72480	Sum	3420	41.71	54980
Barrels + both sets of end disks					10300	92.44	127460

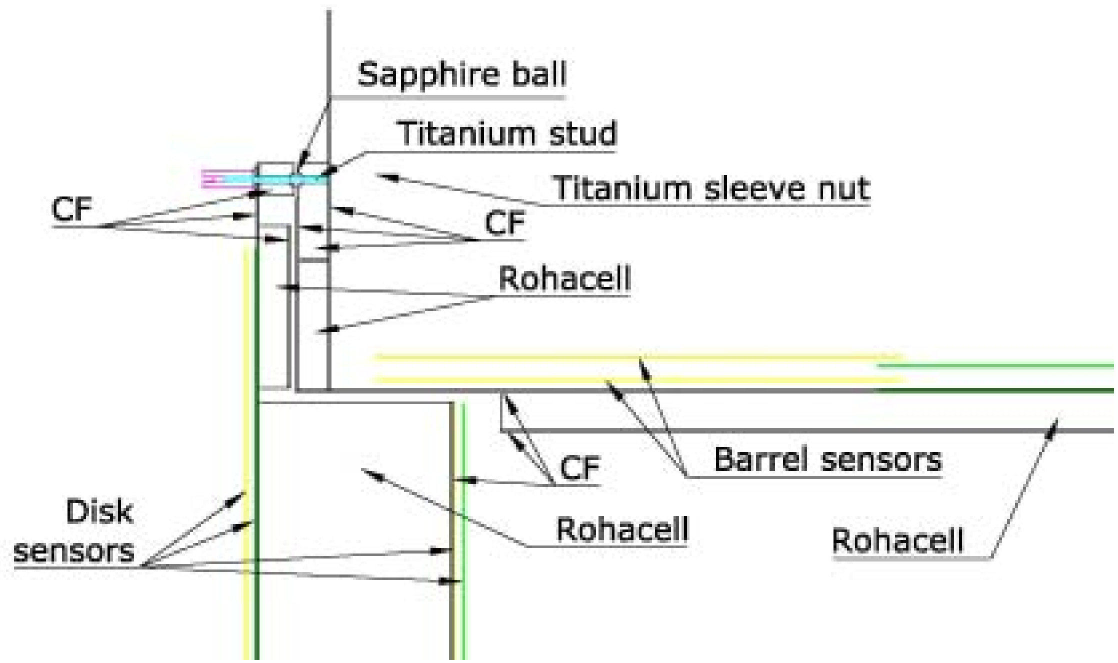
- >16 million channels
- Chip counts, based upon 128 channels per chip, may seem high, but are consistent with a pitches of 50 - 60 μm, trace lengths of 100 – 140 mm, and no ganging of sensors.
- Chips with 1024 channels are being designed.
  - That would impact azimuthal segmentation, particularly for the barrels at smaller radius.
- Dry gas (air) cooling is assumed.
  - For 290 watts removed (consistent with air cooling), that corresponds to 18 μwatts per channel → power cycling.

Connections among Barrel and Disk Assemblies

- Disk to barrel connections are critical in this design. One end is shown.
  - At the other end, the stud is attached to the disk in order to allow the connection to be completed. Barrels are clocked during installation to allow teeth to pass one another.
  - An option with both disk layers outboard of the associated cylinder end is under consideration.

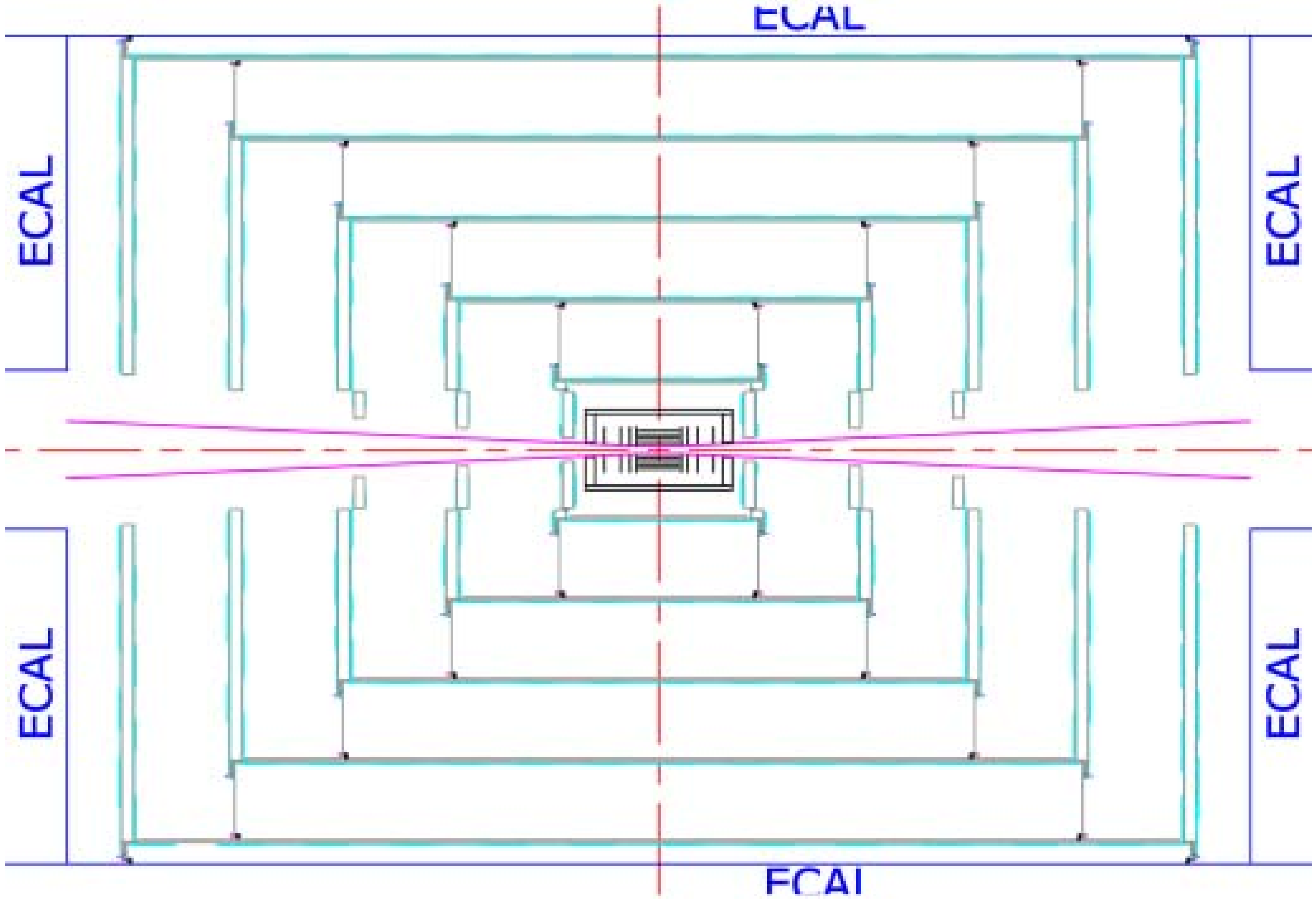






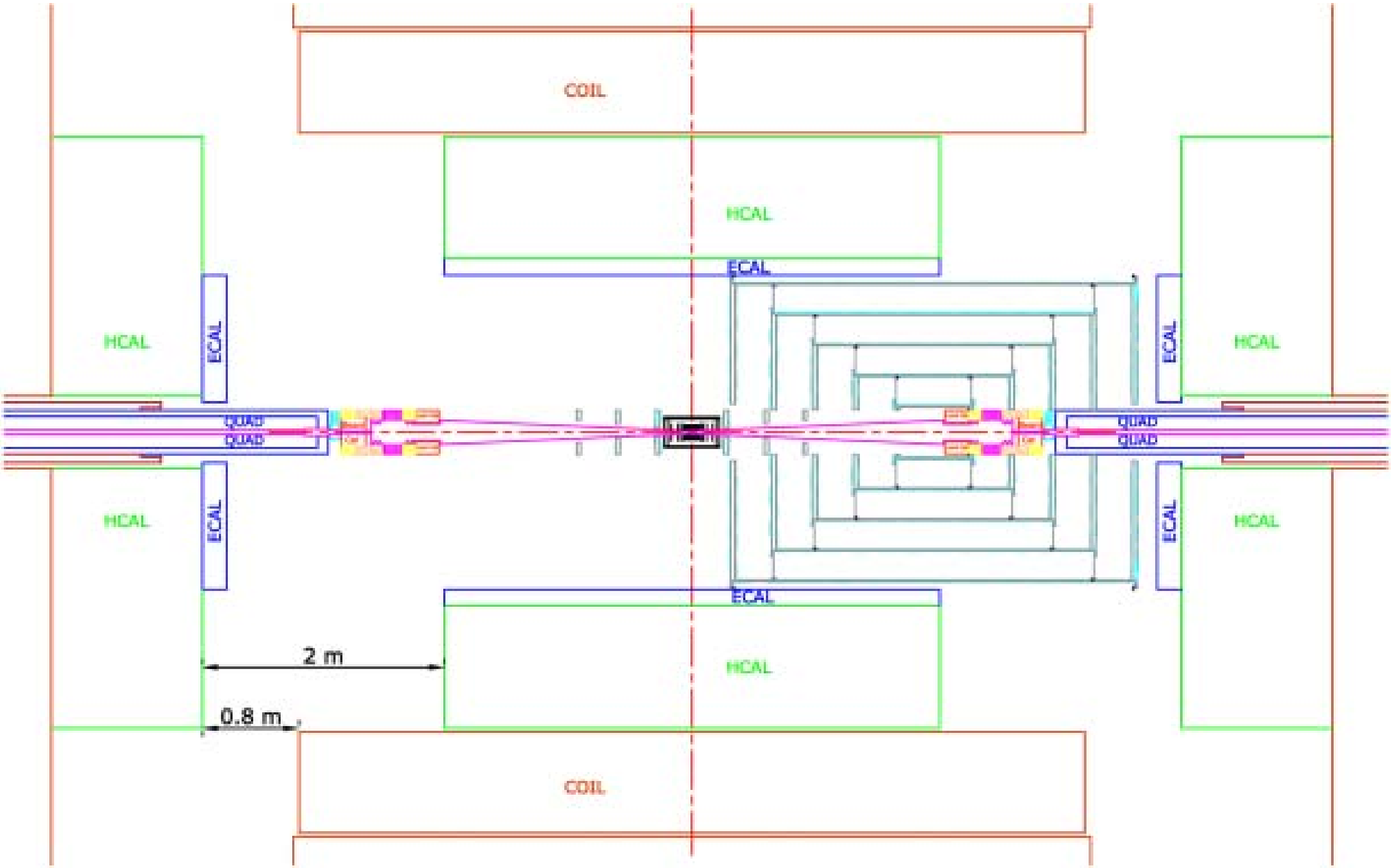
Developments Since Victoria

- The outer silicon tracker has been separated into a portion supported from the ECAL and a portion supported from the beam pipe to allow servicing of the VXD.
- Overlap between smaller and larger disk portions is provided by offsetting the portions at smaller radius towards Z = 0.

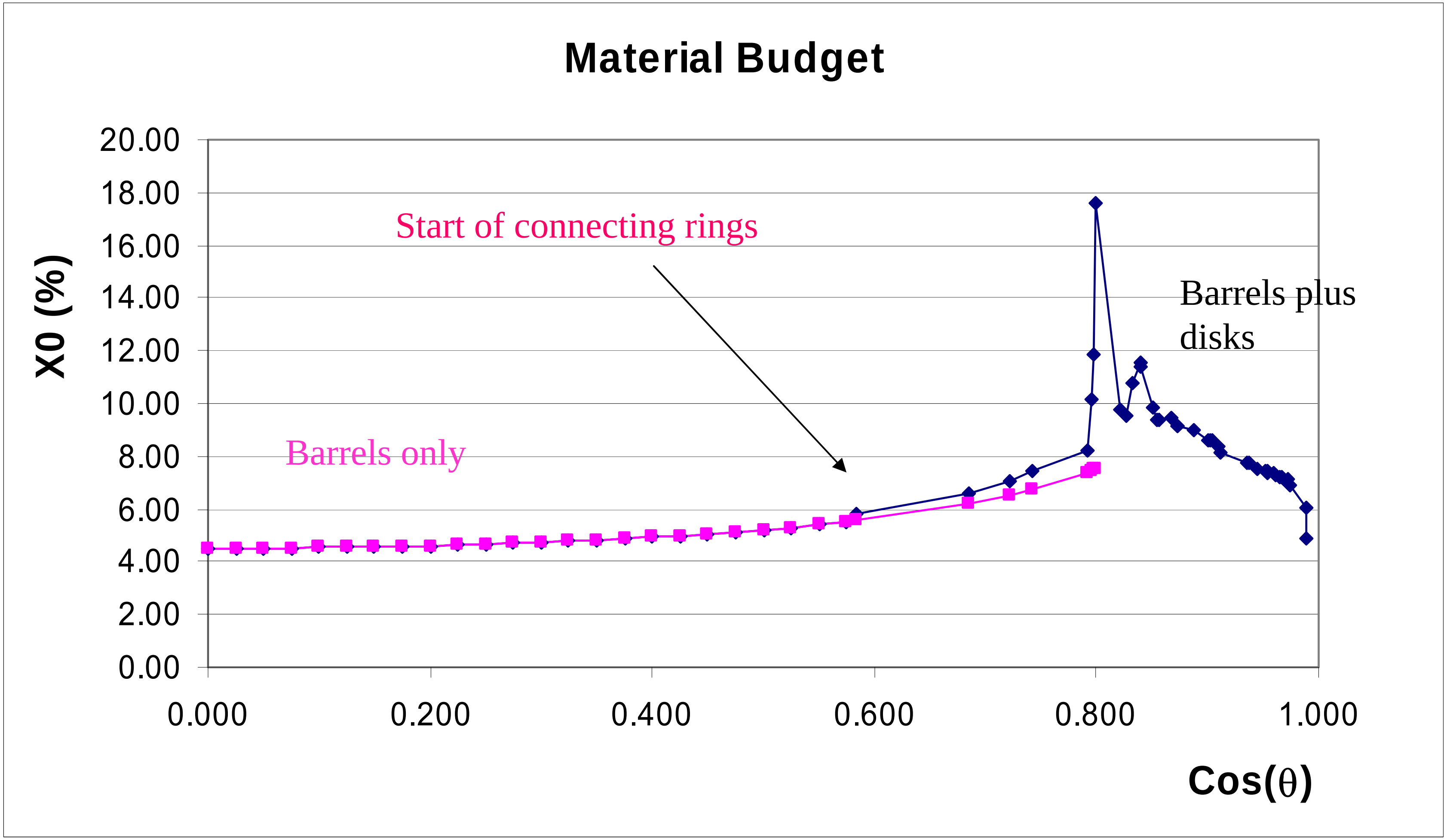


Developments Since Victoria

- The outer tracker is moved longitudinally (in either direction) for VXD servicing while the VXD and beam line elements remain stationary.
  - Quadrupoles and associated details are not current.



Radiation Lengths for the Victoria Design (Marcel Demarteau)



- Beam pipe, VXD, optical transceivers, and associated fibers are not included.
- 0.8% of a radiation length per layer is comparable to the BaBar silicon tracker

Babar Silicon Tracker

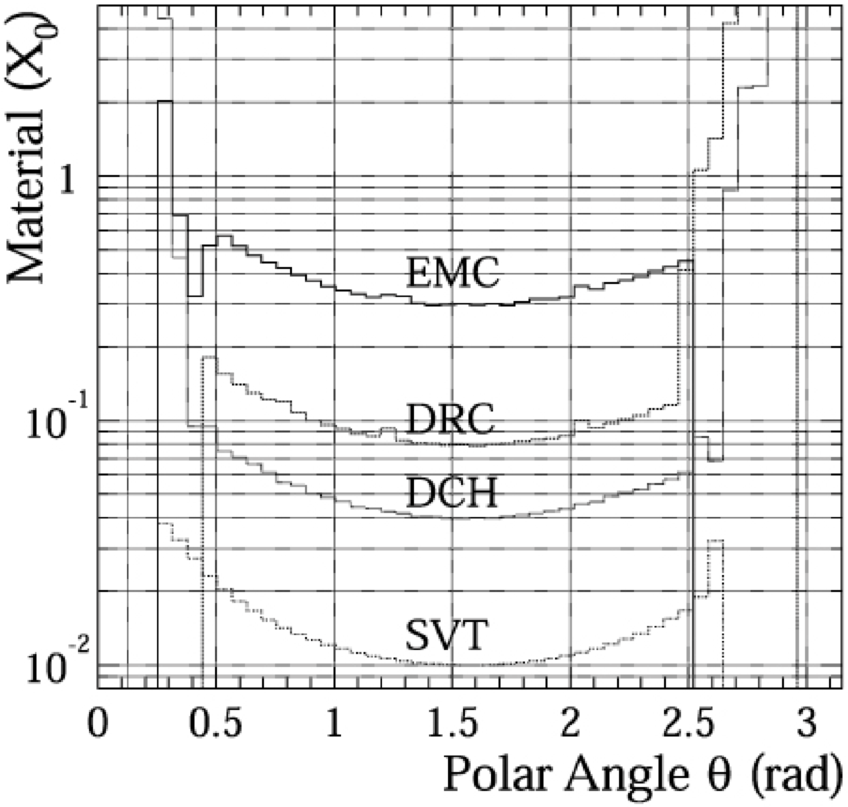
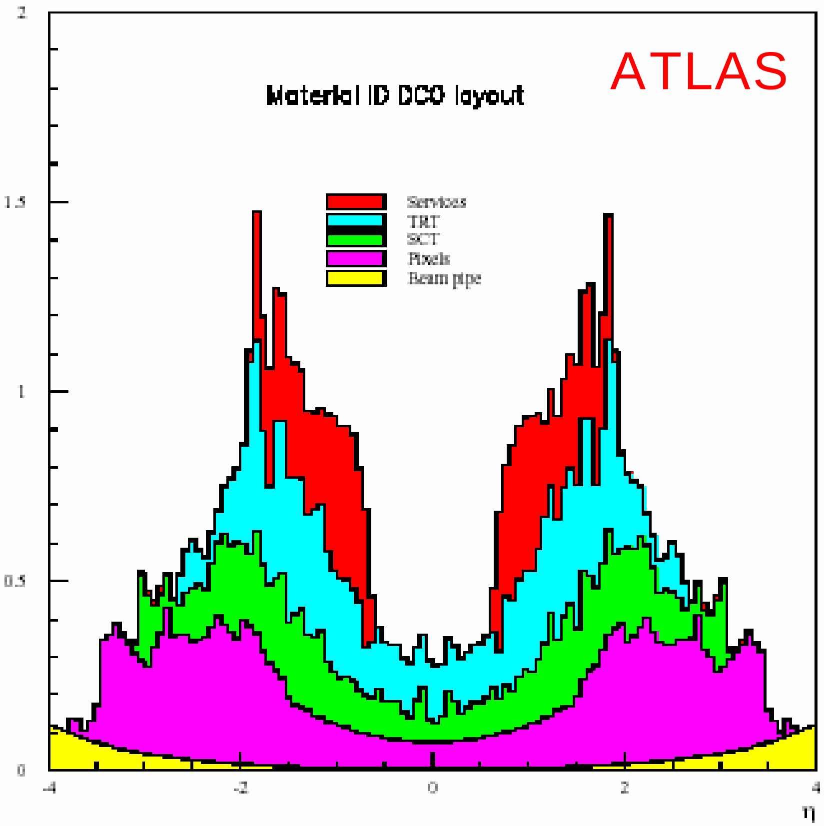
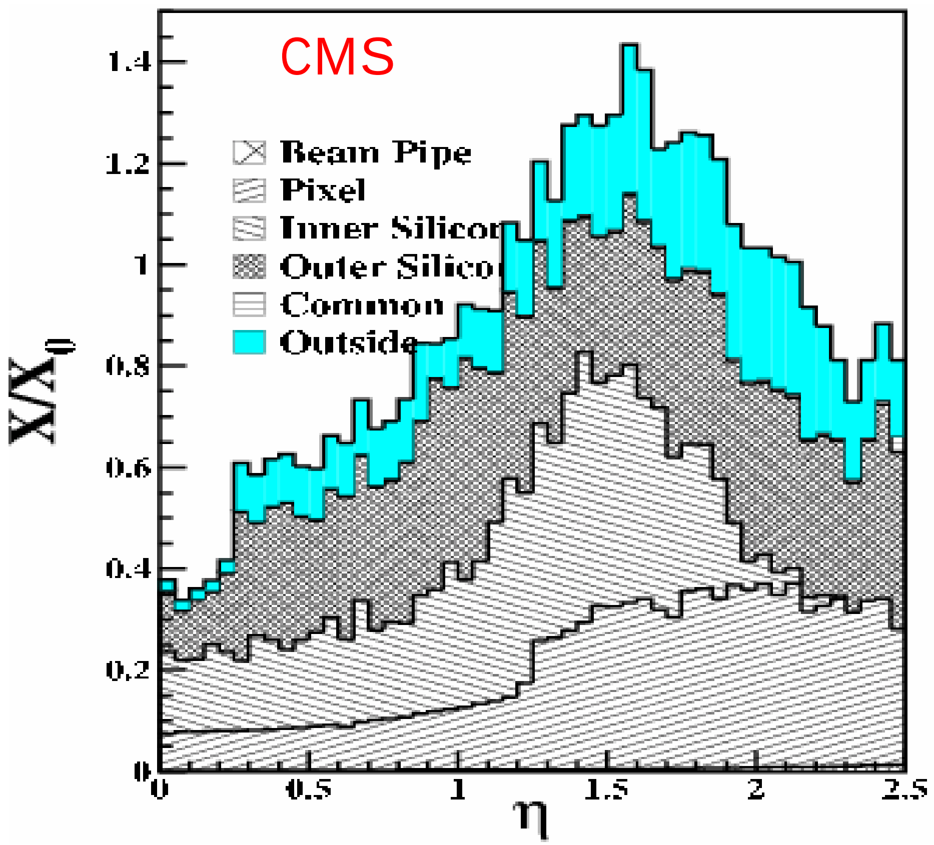


Figure 3. Amount of material (in units of radiation lengths) which a high energy particle, originating from the center of the coordinate system at a polar angle θ, traverses before it reaches the first active element of a specific detector system.

- Babar: 5 layers of double-sided Si
- Stays below 4% at normal incidence traversing SVT; average of 0.8% X_0 per layer
- Ref: The BaBar Detector, NIM A479: 1-116, 2002

For comparison, material budget in LHC experiments



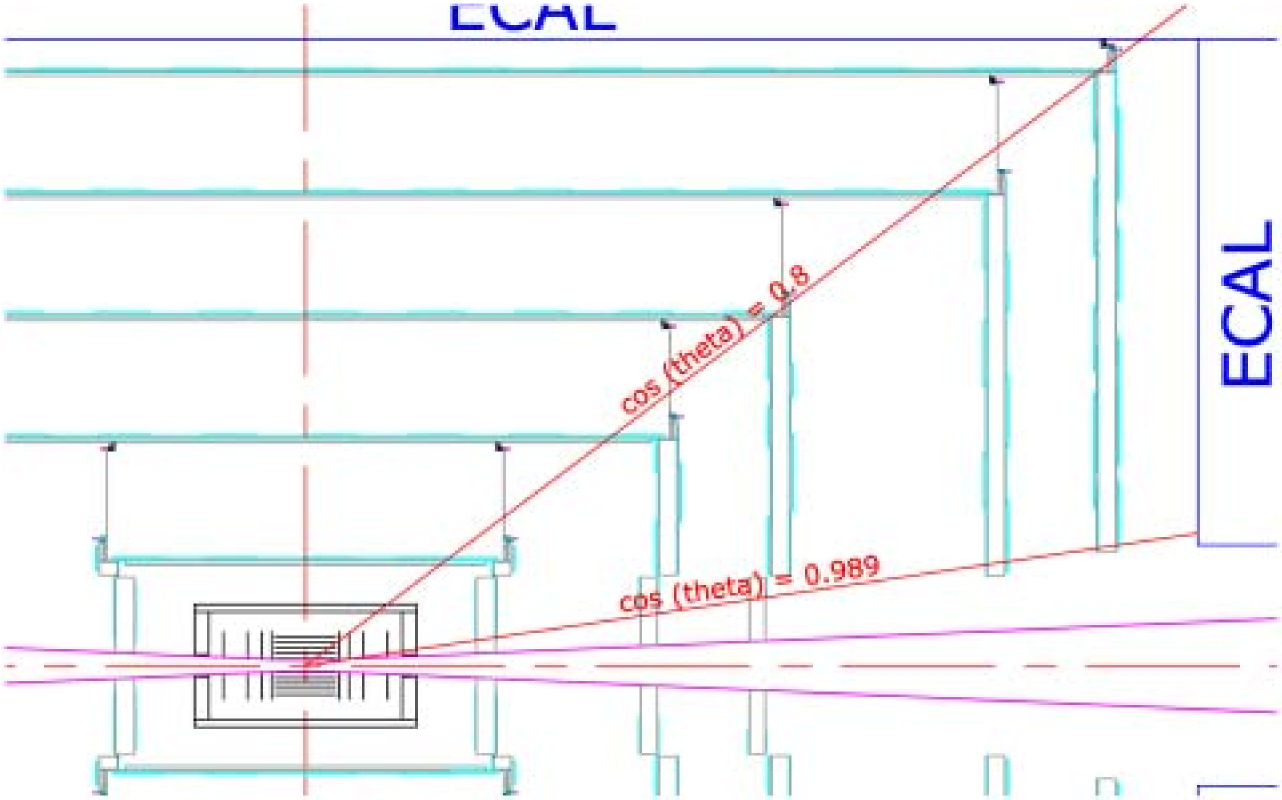


Starts at about 30% X0, including transition radiation tracker

Starts at about 35% X0 (~27% X0 excluding pixel detector)

Modifications to Control Projective Geometry

- Two measures reduce the effects of projective barrel and disk mechanical connections:
  - CF connecting disks have spokes rather than being continuous.
  - Ball mounts and spokes are not aligned in azimuth from layer to layer.
- Two other measures could be implemented:
  - One additional sensor in barrels 1, 2, and 4 (each side of Z = 0), as shown below
  - Openings cut in projective regions of the support cylinders.

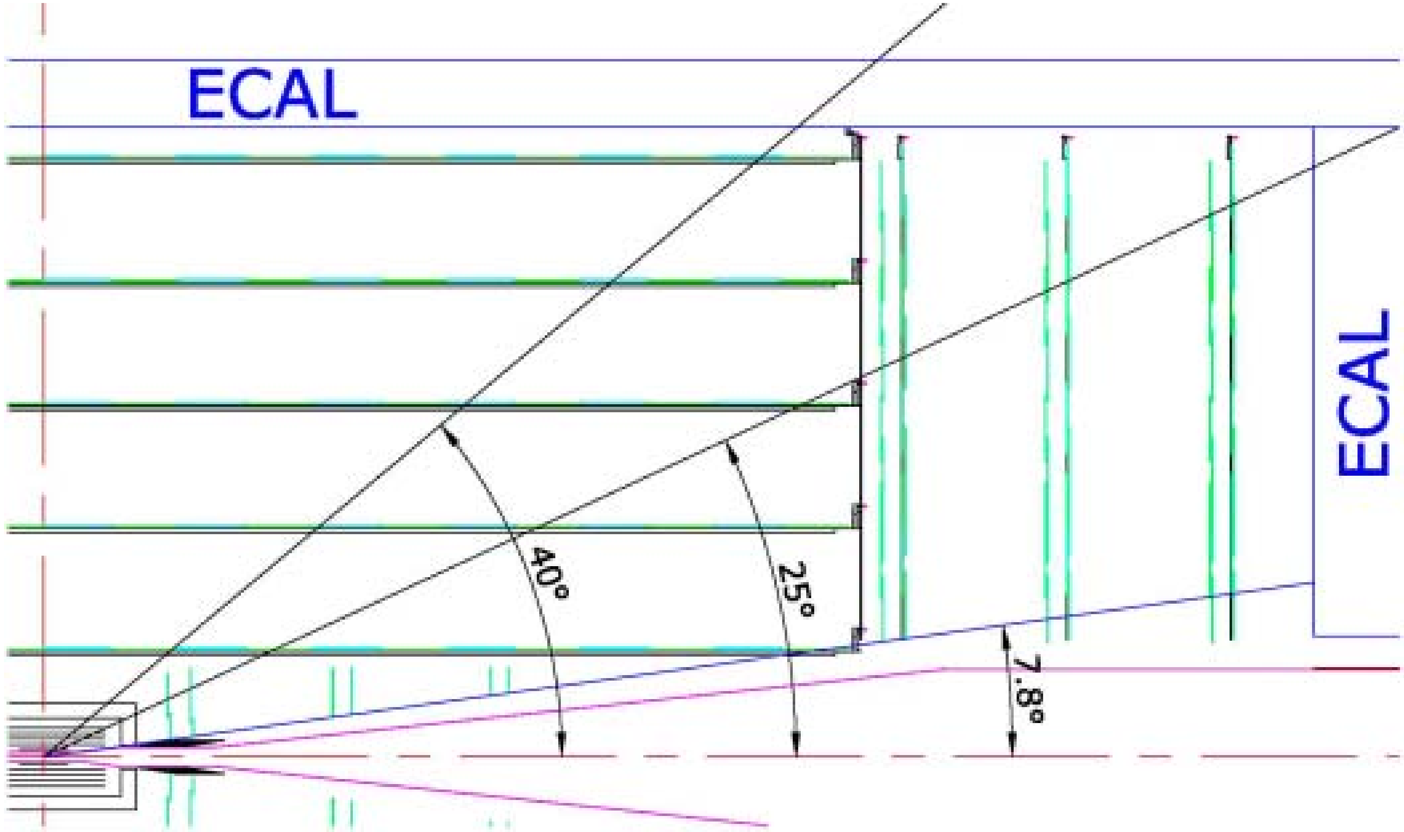


Geometry Choices under Consideration

- Number of barrel (disk) layers
  - Adequate momentum resolution is achieved with 5 layers plus the vertex chamber.
  - Does stand alone tracking for decays outside the vertex chamber require more disk and barrel layers?
  - Up to 10 layers have been suggested.
- Number of layers with stereo
  - The Victoria design assumed no stereo in the barrels.
    - Each sensor would be individually read out. Then knowing the sensor in which a hit occurred would provide limited z information.
  - The design assumed ~ 90^o degree stereo in the disks.
    - Except at the innermost radii, occupancies are low (a few %).
    - Individual read out of each sensor limits the number of ghosts.
  - Are additional stereo layers needed?
- Should all barrels have the same length?
- Simulation studies have been started to answer these questions.

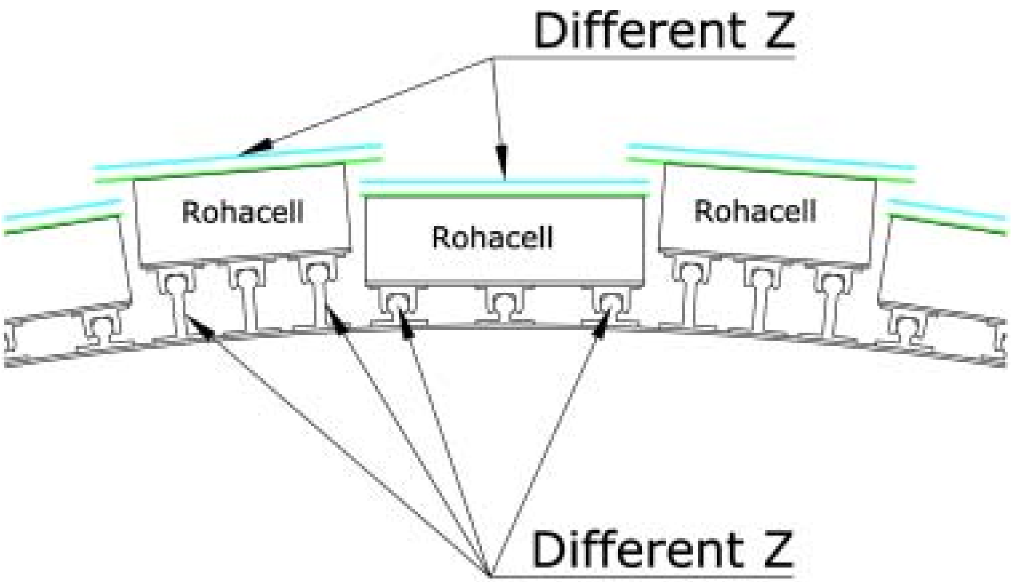
Long Ladders

- Long ladders offer the potential for less power dissipation and a reduction in the number of radiation lengths associated with readout and cabling.
  - More consistent with disks at the ends of a barrel region
- S/N and low incidence angles near barrel ends could be issues.
- Chip design to obtain a favorable S/N is under investigation.



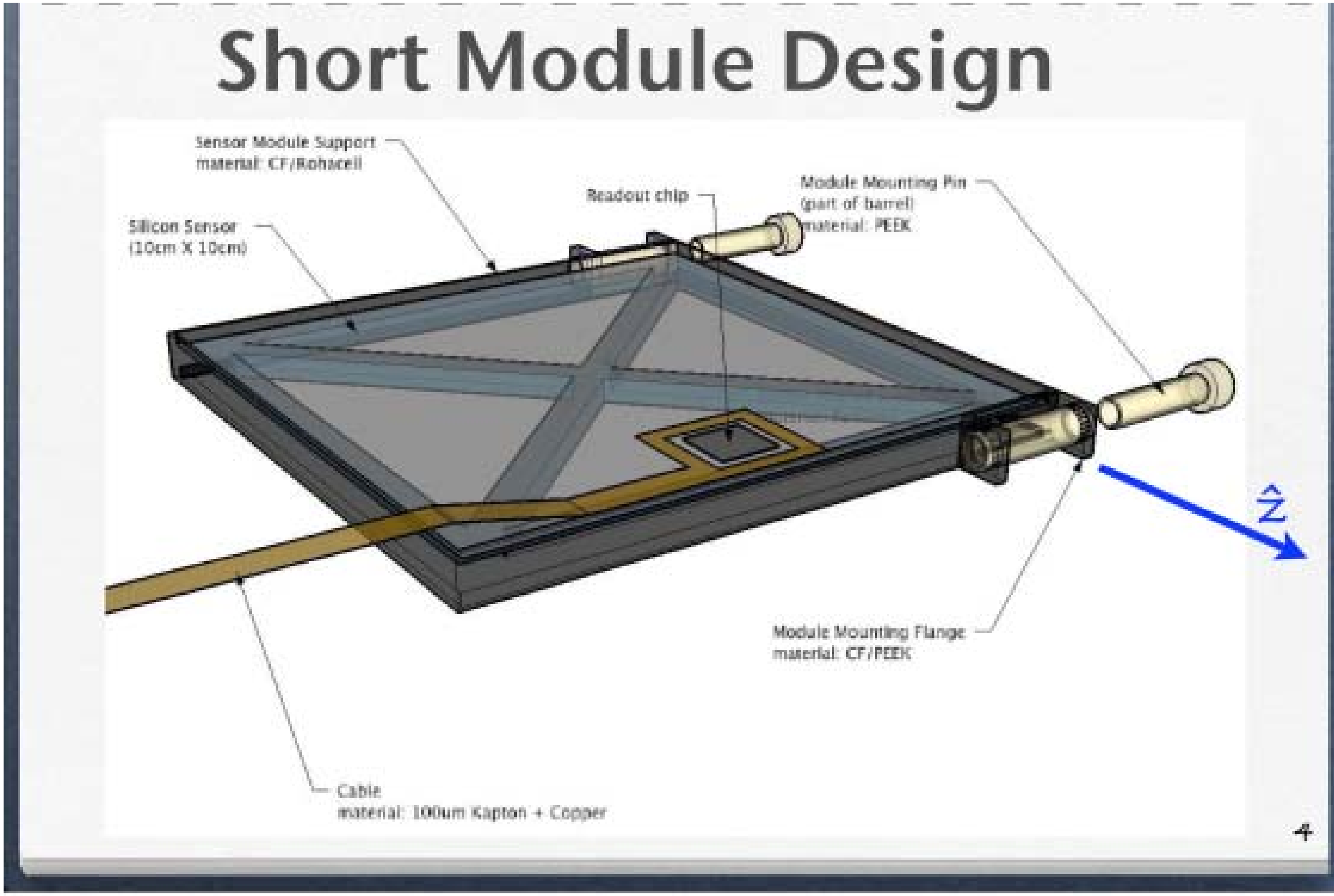
One Approach for Multi-Sensor Ladders

- Sensor – Rohacell – CF Sandwich
- CF and Rohacell would likely be narrower and shorter than the region covered by sensors.
  - That allows overlap in Phi and Z.
- CF (and Rohacell) need not be "solid". Holes could be cut so that a significant fraction of the area covered is free of CF (Rohacell).
- Three point ball and socket mounting (parts and photo from Kurt Krempetz)



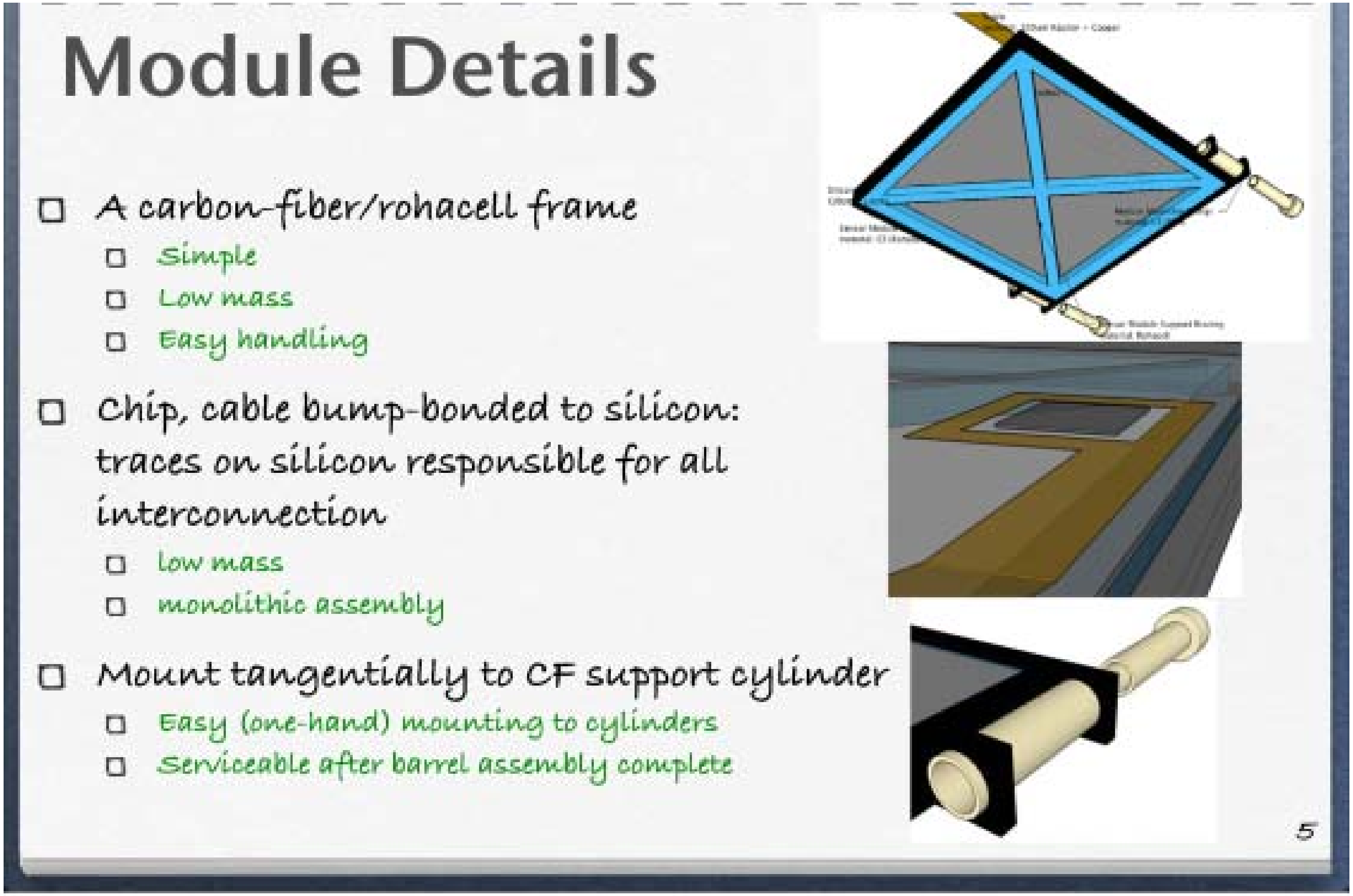
Proposal for Single Sensor Modules, Tim Nelson (SLAC)

- Note the beam direction
- The pigtail connects to a bus cable, which allows natural multiplexing of sensors



Proposal for Single Sensor Modules, Tim Nelson (SLAC)

- Sensors are overlapped in azimuth following a spiral geometry
- Lorentz drift is accommodated by the mounting angle (adopted as part of the baseline geometry)



Finite Element Analysis

- Initial FEA of the outer support barrel indicates that maximum deflection with fully constrained ends is small, = 14 µm.

OR=1233mm, L=3559mm

Barrel Wall:

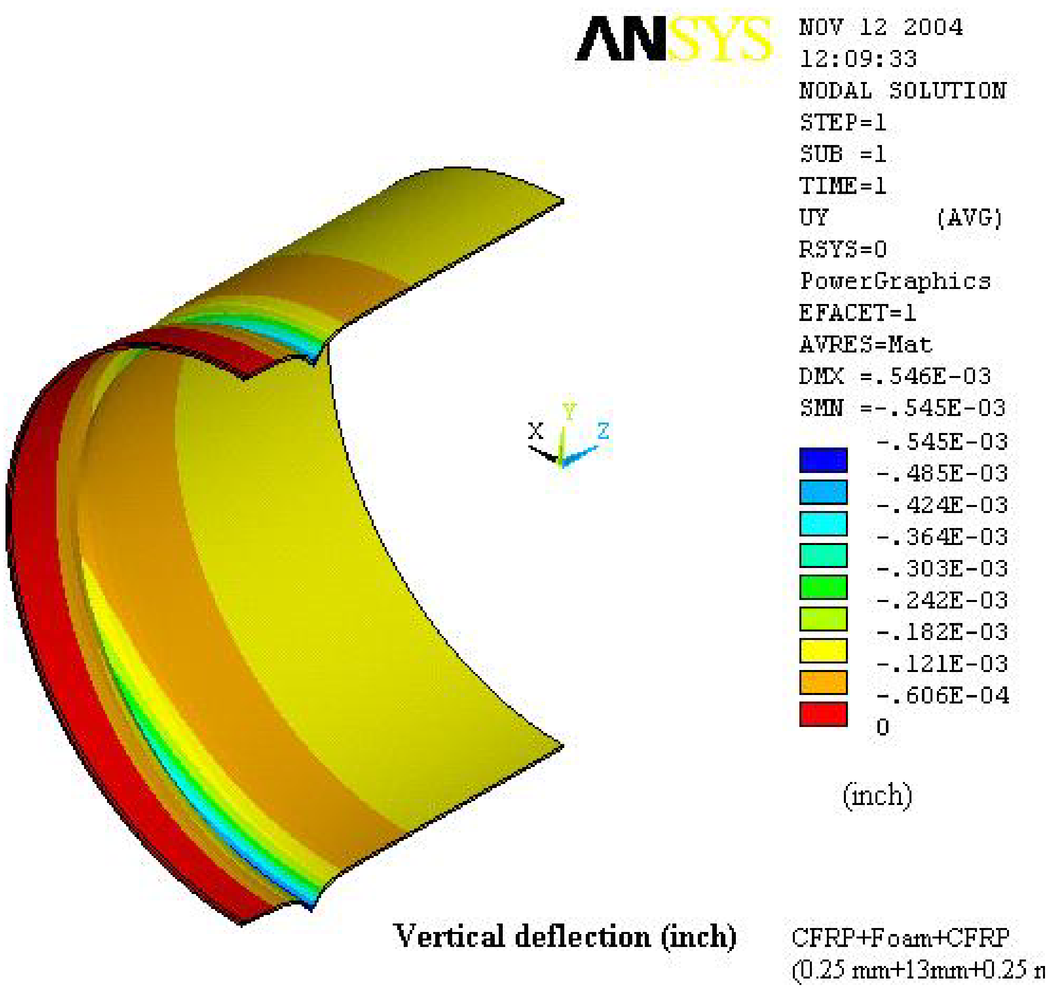
- 2 skins of .25mm quasi-isotropic carbon fiber lay-up, sandwiched about 13 mm of Rohacell 31 foam

Unidirectional Carbon Fiber:

- Modulus=724MPa (105msi)
- Resin Content RC=40%
- Net modulus = 165MPa (24msi)

Two applied loads:

- Barrel 5 weight, including the silicon on barrel 5
  - Circumferentially and longitudinally uniform load of 44,196g (~97 lb)
- Barrel 4-1 weights including silicon and the 4 silicon disks attached to those barrels
  - Circumferentially uniform load of 100,600g (~222 lb) concentrated at Two Z-locations



In Conclusion

- Steady progress has been made on designs and design constraints.
- Designs have been updated.
  - Adjustments to barrel lengths to distribute material at barrel – disk connections
  - Separation of disks into inner and outer portions to allow VXD servicing
  - Barrel sensor angles adjusted to compensate for the Lorentz angle
- Simulations have been started to understand:
  - Barrel and disk numbers, lengths, and locations
  - The extent to which stereo tracking is needed
  - Tracking with and without the use of the vertex chamber
  - The effects of material.
- Module designs have been proposed for the barrel sensors
- Initial finite element analysis of barrel support cylinders indicates deflections are acceptable.
- The development of VXD mechanical designs which are integrated with those of the outer silicon tracker has just begun.