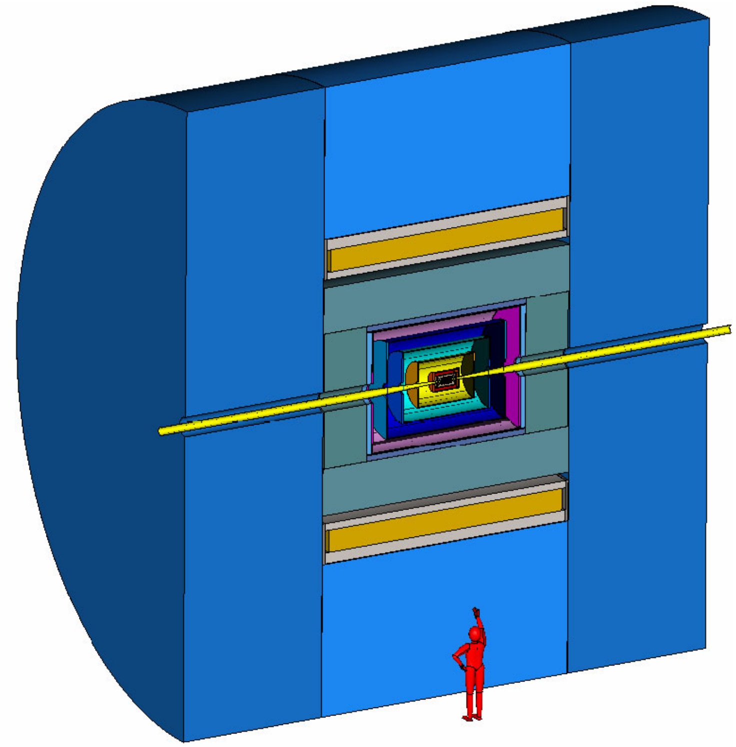
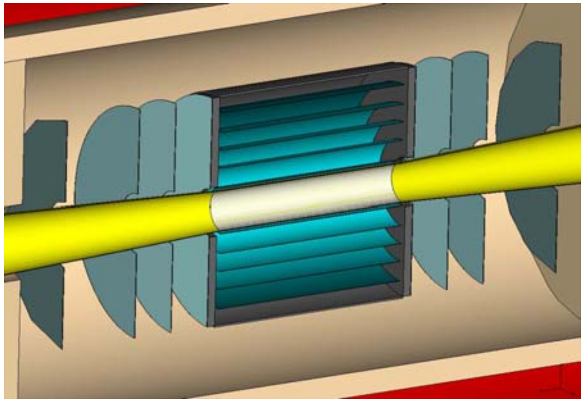
Design and Performance of Silicon Tracking in SiD



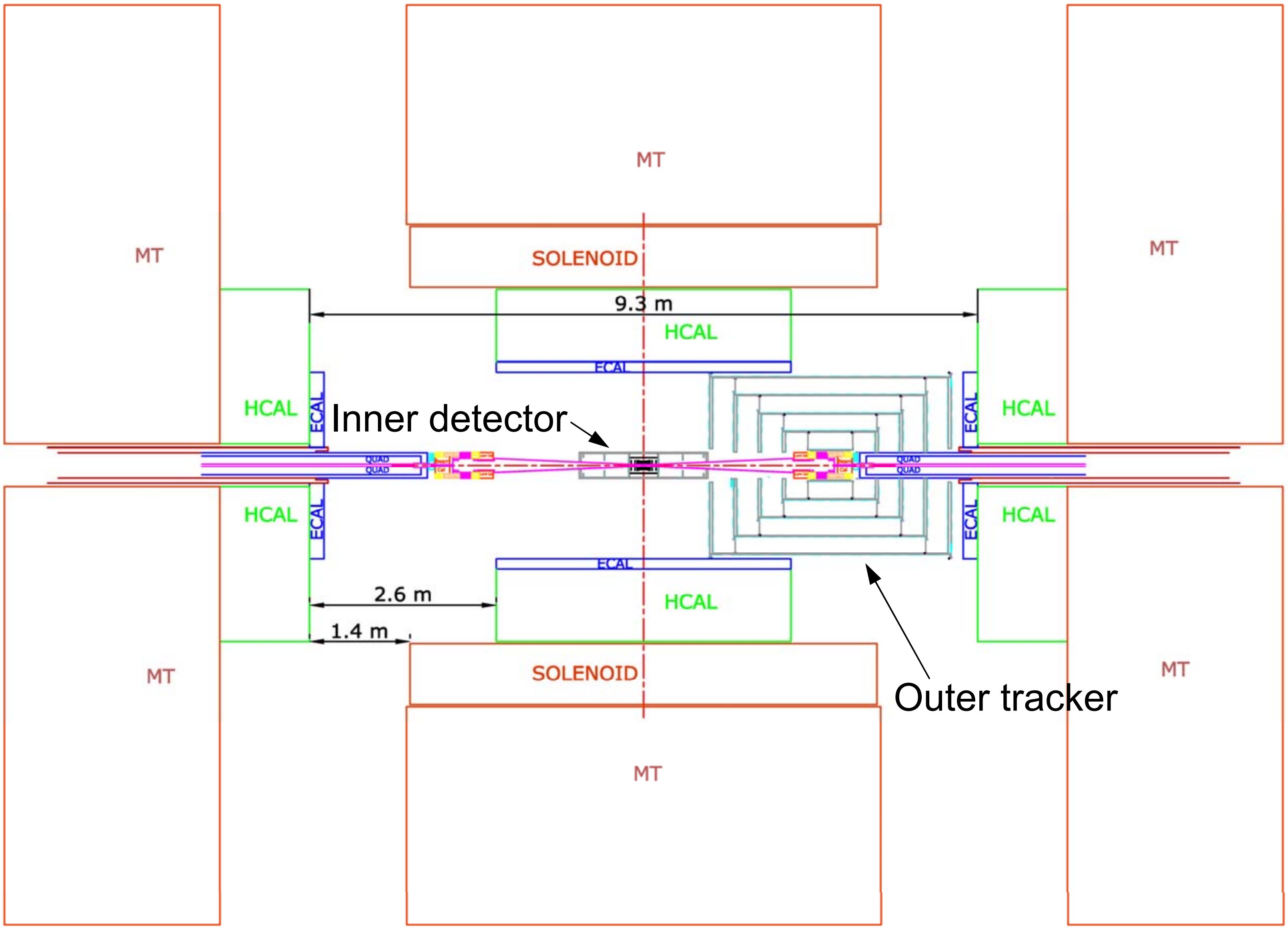
Bill Cooper
Fermilab



Overall Detector and Silicon Tracking

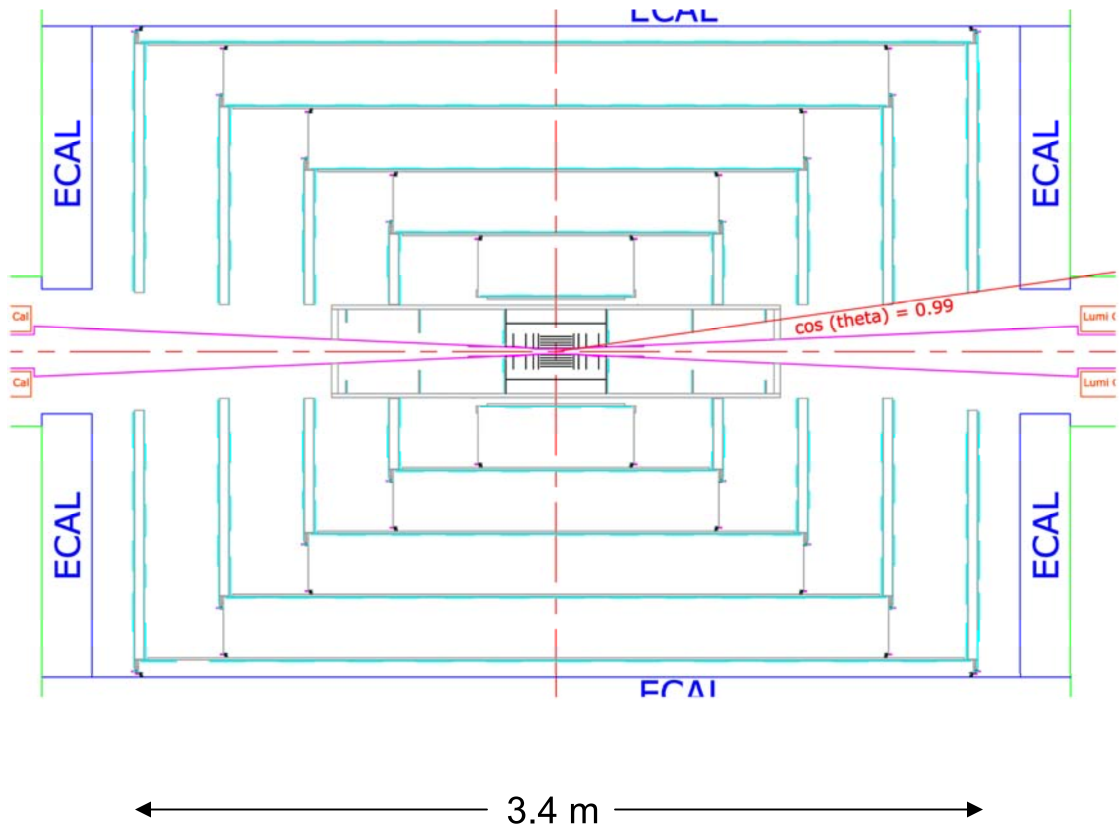
- An integrated detector design for ILC depends critically on the Particle Flow Algorithm (PFA), which is used to measure jet energies and uses all parts of the detector.
  - The detector should be hermetic.
- Tracking inboard of calorimetry is separated into an inner vertex detector and an outer silicon tracker.
  - The vertex detector finds tracks and vertices and makes initial measurements of momenta.
  - The outer tracker increases the precision with which momenta are measured and links tracks to calorimetry and the muon system.
  - A solenoid immediately outside the central calorimeter provides a 4 T to 5 T magnetic field for momentum measurements.
- During servicing of silicon tracking, the endcaps are opened, the inner vertex detector and beam pipe remain fixed, and the outer silicon tracker rolls longitudinally.

Detector Open with Full Access to Inner Detector



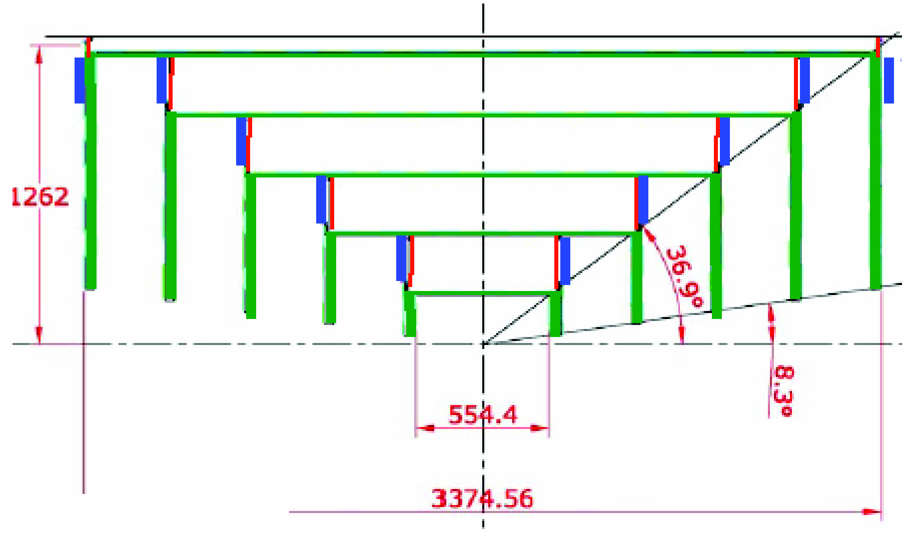
Silicon Tracking Layout

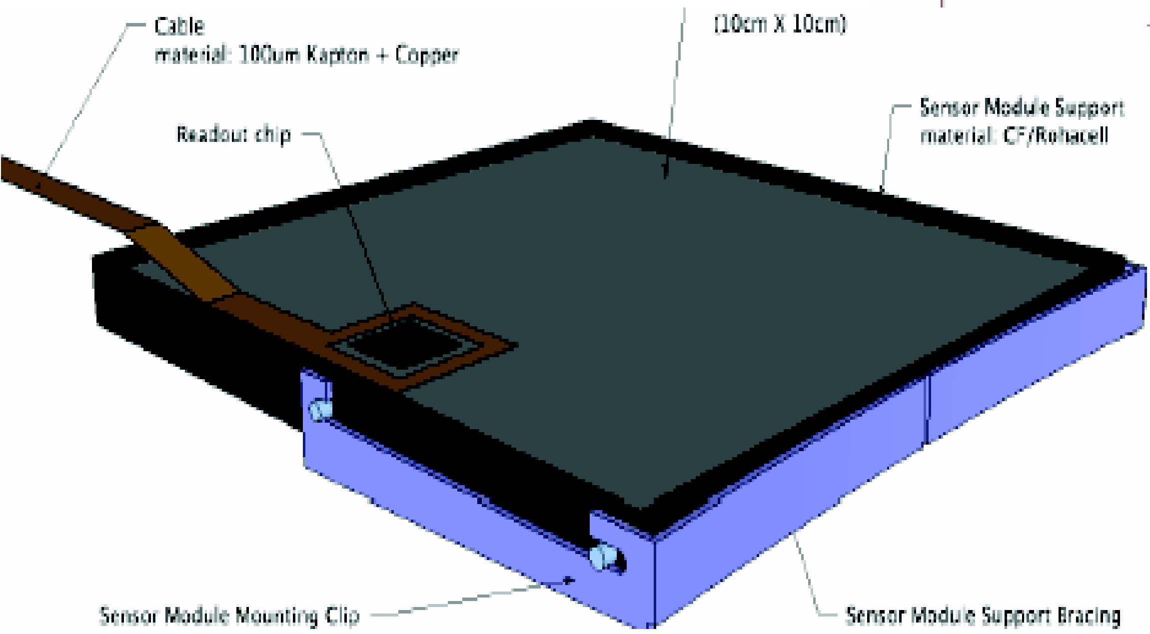
- Outer tracker
  - 5 barrel layers
  - 5 disks per end
  - OR = 1.25 m
  - IR = 0.2 m
    - May need to adjust inner radius to accommodate beam-line elements
  - Supported from ECAL
- Inner detector
  - VXD
    - 5 barrel layers (may increase to 6)
    - 4 disks per end
  - Additional “forward” disks
  - Supported from conical portions of beam pipe



Outer Tracker as Modeled in SiD_{00}

- Closed CF/Rohacell cylinders
- Nested support via annular rings
- Power/readout motherboard mounted on support rings

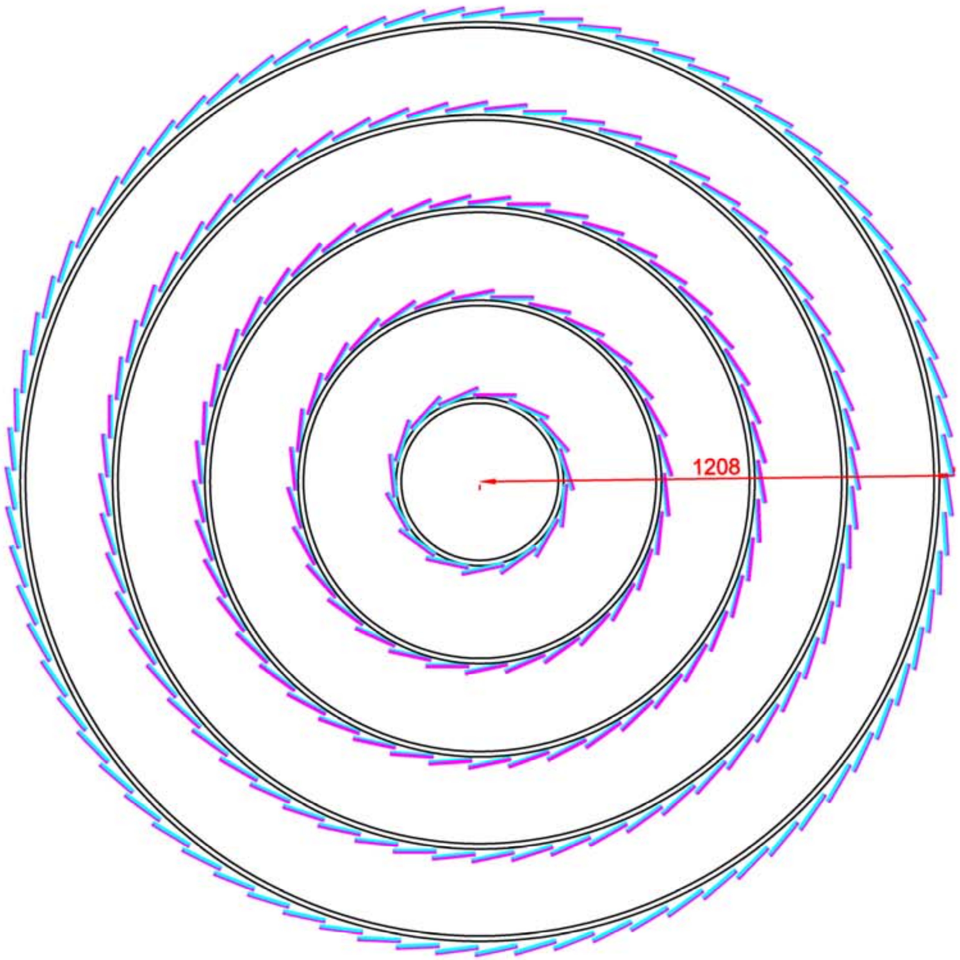




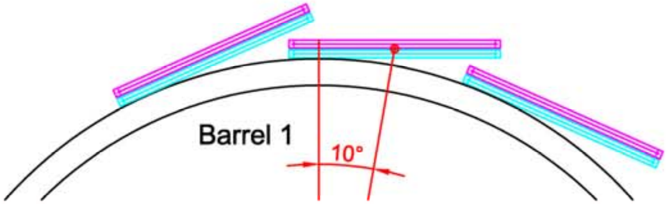
- Cylinders tiled with 10x10cm sensors with readout chip
- Single sided (ϕ) in barrel
- R, ϕ in disks
- Modules mainly silicon with minimal support (0.8% X_0)
- Overlap in *phi* and *z*

T. K. Nelson, SLAC

Outer Tracker with a Single Type of Module



Sensors:
Cut dim's: 104.44 W x 84 L
Active dim's: 102.4 W x 81.96 L
Boxes:
Outer dim's: 107.44 W x 87 L x 4 H
Support cylinders:
OR: 213.5, 462.5, 700, 935, 1170
Number of phi: 15, 30, 45, 60, 75
Central tilt angle: 10 degrees
Sensor phi overlap (mm):
Barrel 1: 5.3
Barrel 2: 0.57
Barrel 3: 0.40
Barrel 4: 0.55
Barrel 5: 0.63
Cyan and magenta sensors and boxes are assumed to be at different Z's and to overlap in Z.
Within a given barrel, cyan sensors overlap in phi as do magneta sensors.



Beam Pipe

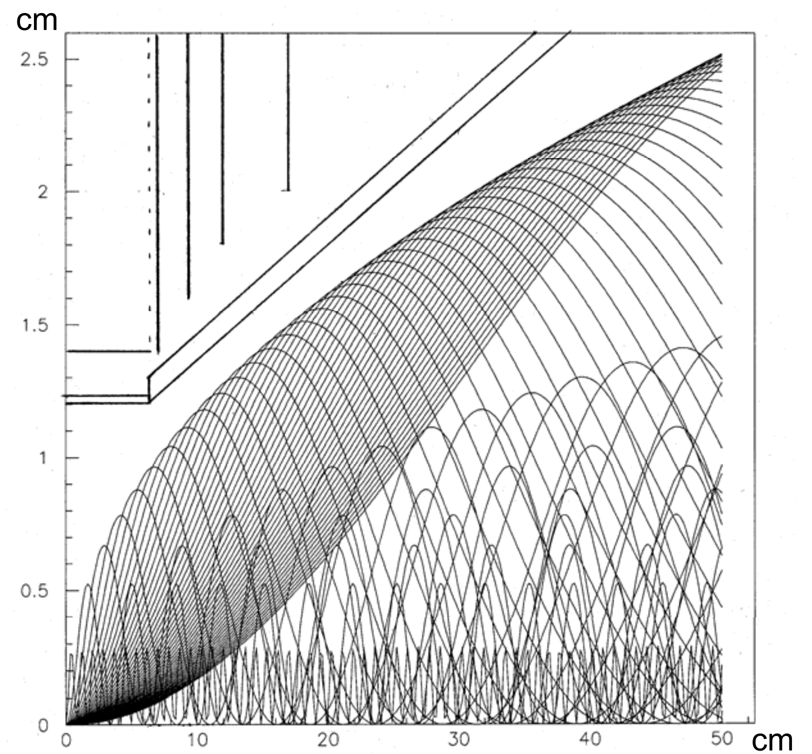
- An all-beryllium beam pipe was assumed for design purposes.
  - Portions of cones could be SS.
- Avoidance of pair backgrounds leads to a conical beam pipe shape beyond the central region.
- sidaug05 assumes a beam pipe inner radius of 1.2 cm within the region Z = ±6.251 cm. Beryllium wall thickness = 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.

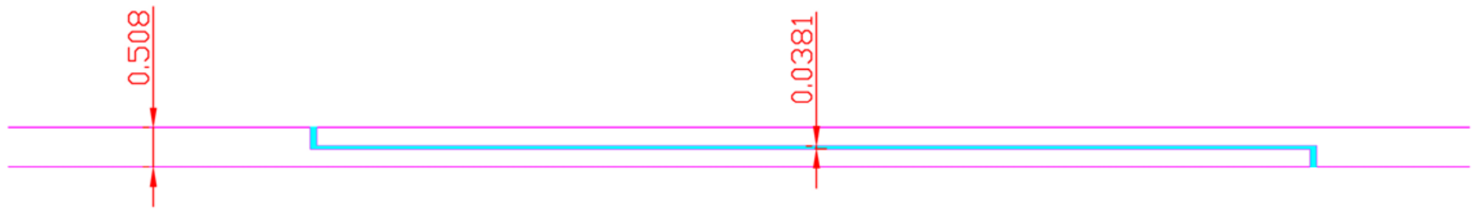
Takashi Maruyama

500 GeV Nominal 5 Tesla + 20 mrad xing

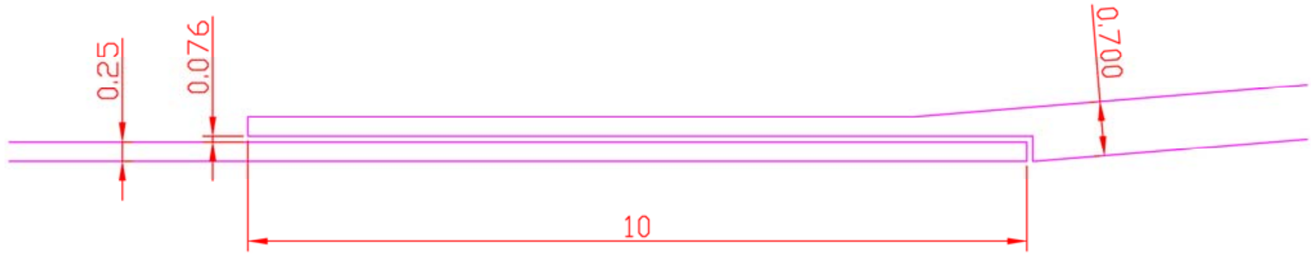


Beam Tube Joints

- Brush-Wellman Electrofusion developed a proprietary electron beam brazing technique for beryllium to beryllium joints. The braze material is thought to be aluminum.
- Joint concept for 1.16" OD (14.7 mm OR) DZero beam pipe:

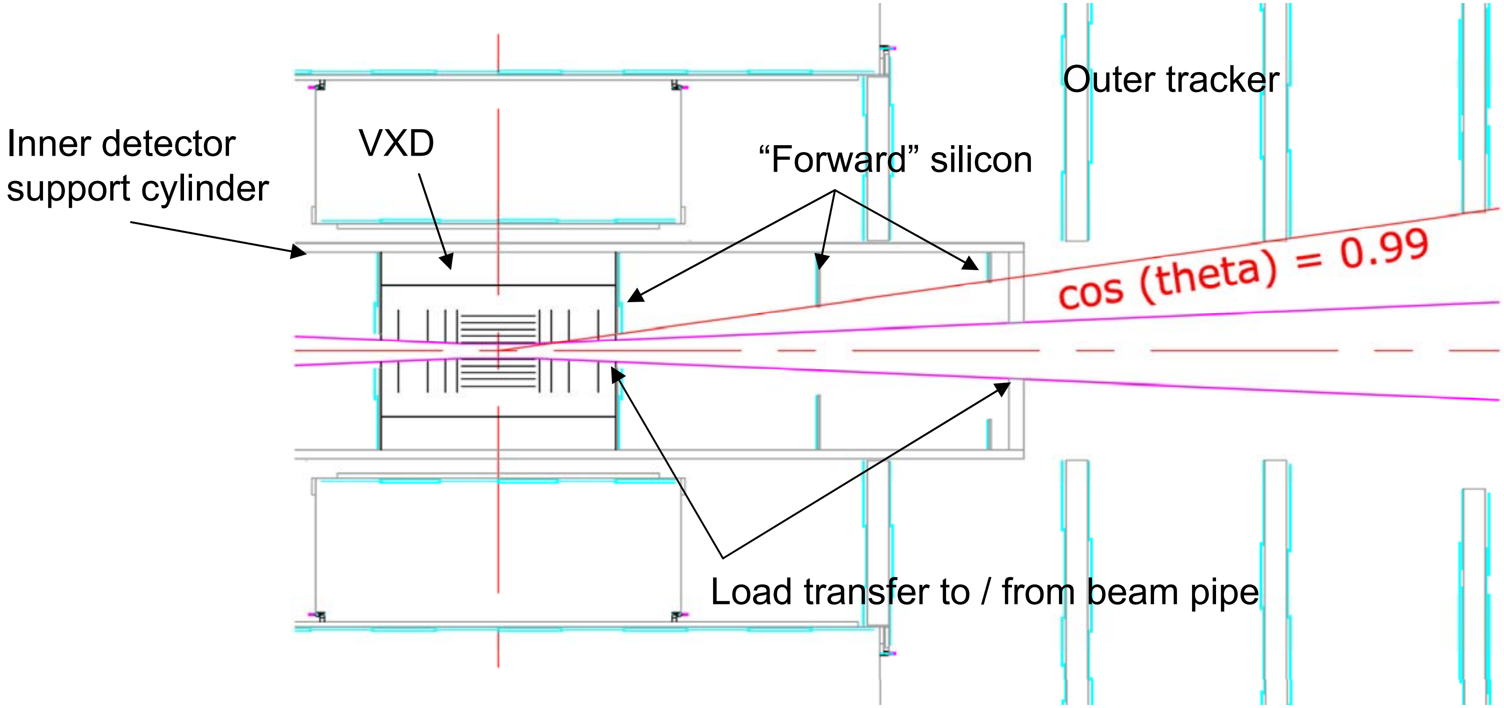


- Similar concept for ILC (note that sidaug05 assumed 0.4 mm, rather than 0.25 mm in the straight portion):



Concept of Inner Detector (VXD) Support

- To allow installation on the beam pipe, the inner detector and its support structures are based upon half-cylinders.
- Outer support half-cylinders could be thermally insulating
  - Detector elements are supported from those half-cylinders.
- Support half-disks couple to the beam pipe at approximately Z = ± 0.2 m and Z = ± 0.9 m and aid in maintaining beam pipe straightness.
- To reduce material, many of the support structures could be strut-like.

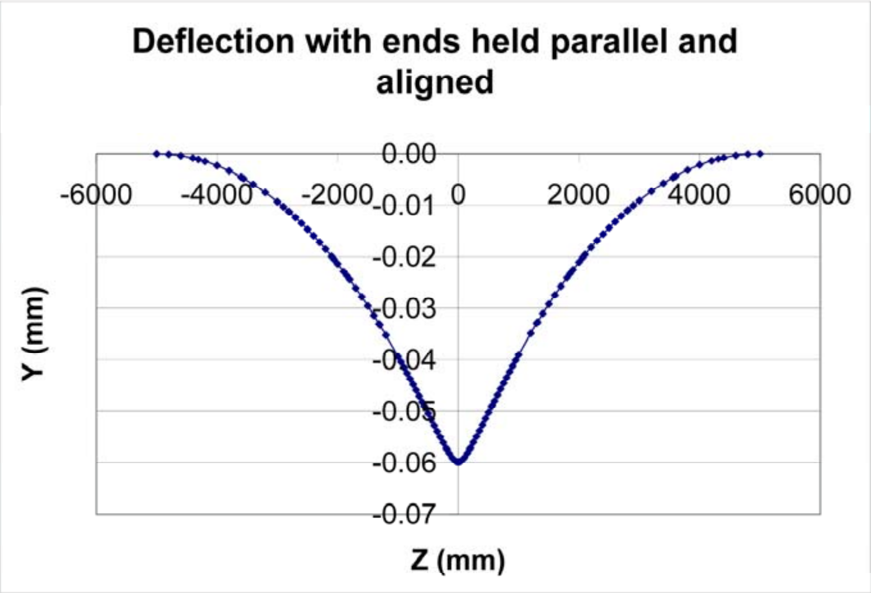


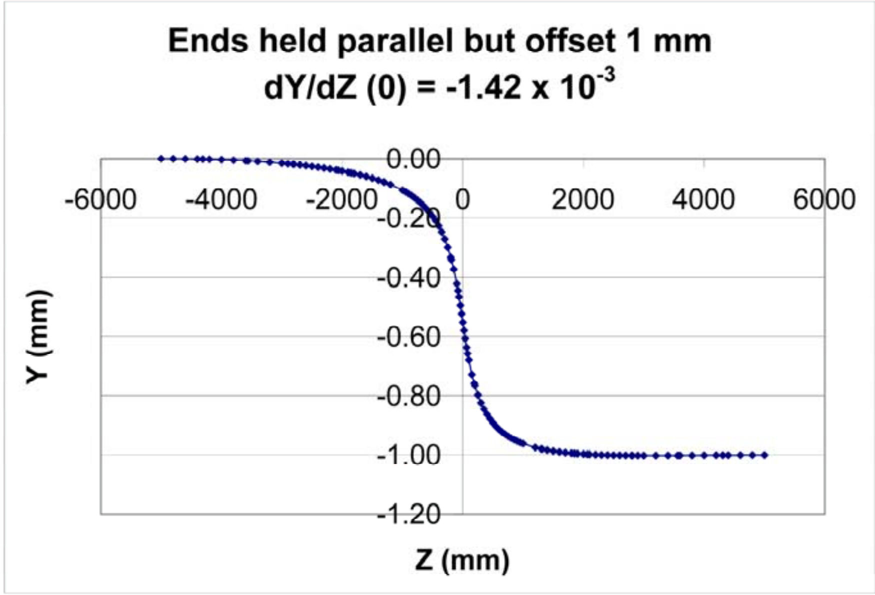
Beam Pipe Deflections

- A wall thickness of 0.25 mm was assumed in the central, straight portion.
- The radius of conical portions was assumed to increase with dR/dZ = 17/351.
  - Wall thickness in the conical portions was chosen to correspond to collapse at slightly over 2 Bar external pressure.
- An inner detector mass of 500 g was assumed to be simply supported from the beam pipe at Z = ± 900 mm.

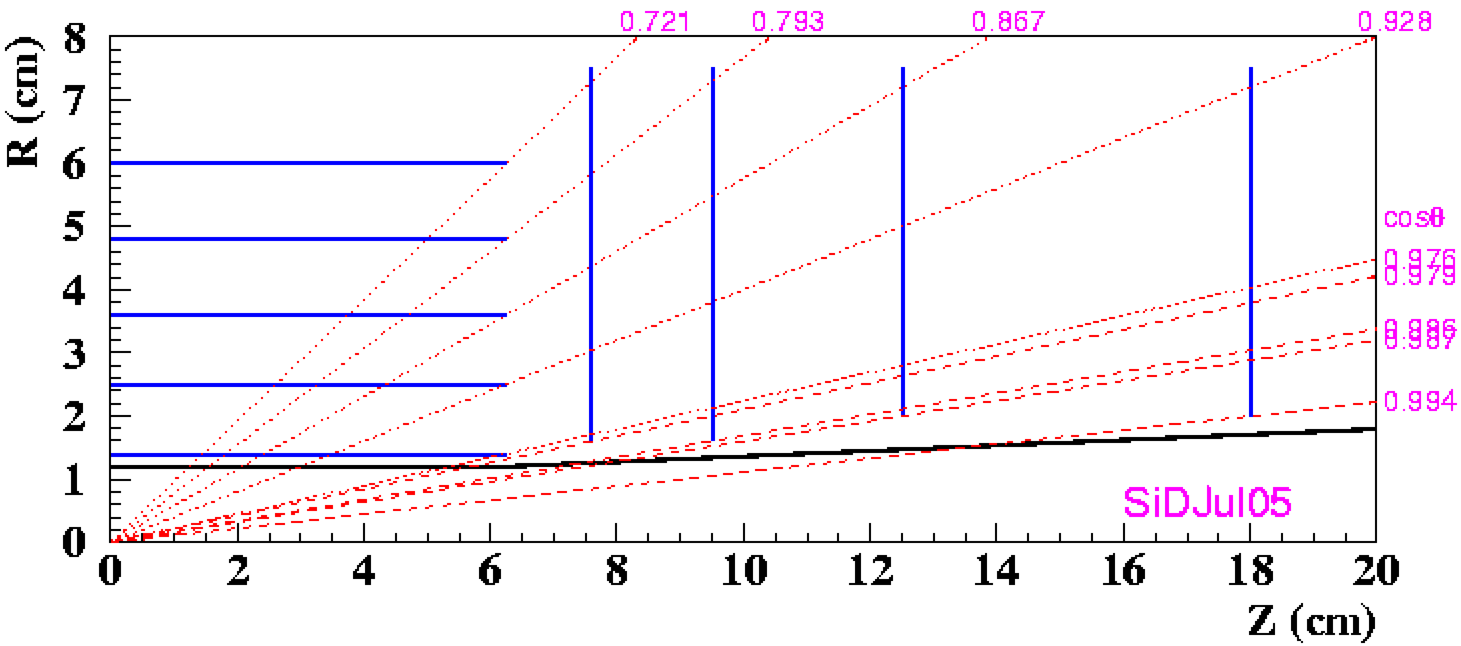
Inner detector weight contributes ~ 0.008 mm.

Maximum stress ~ 20 MPa





SiD Vertex Detector Geometry (SiDAug05)



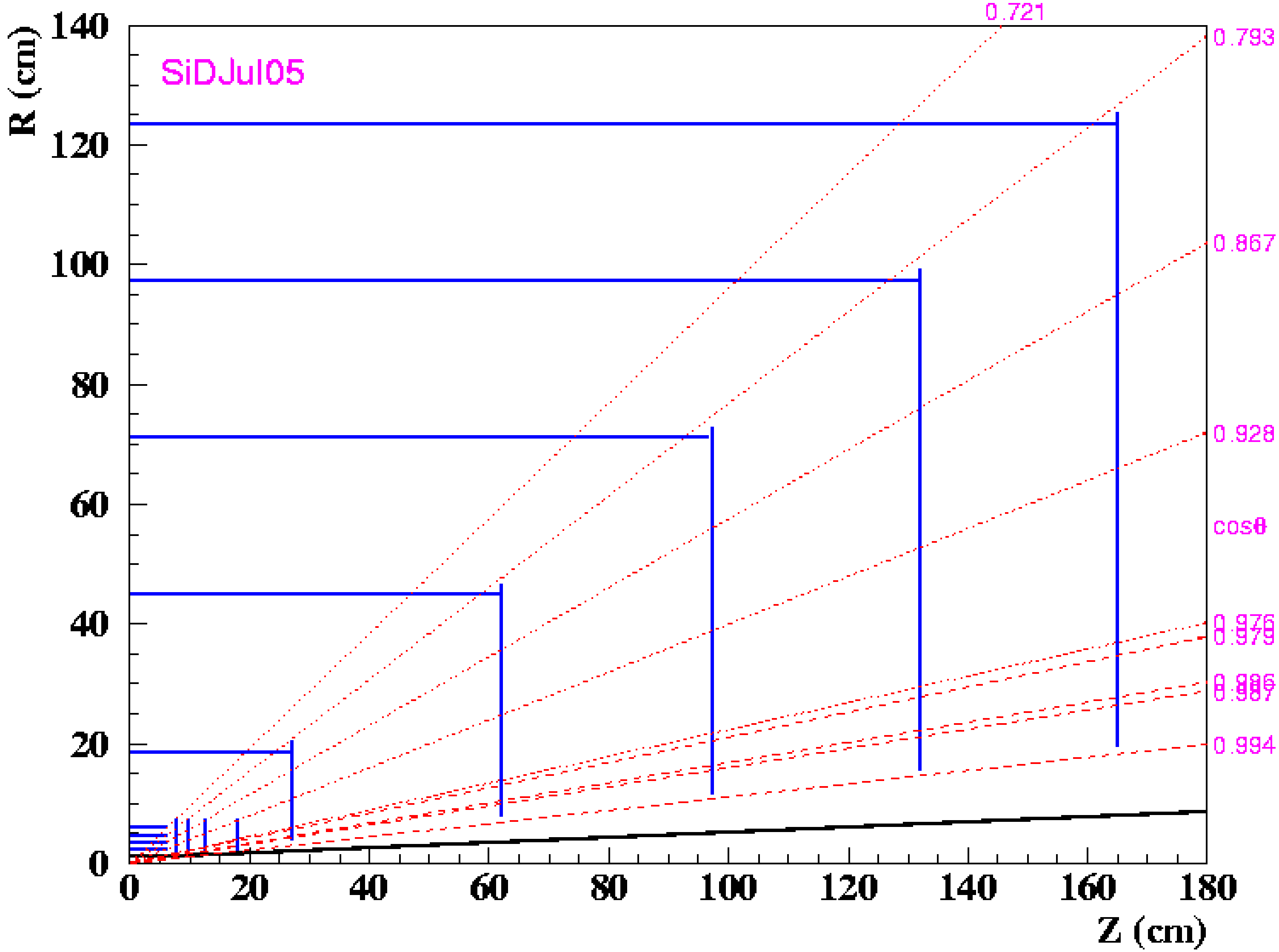
5 barrel layers

4 end disks

Aimed to get good 5 hit coverage at all angles for self tracking
Many issues for cosθ>0.98
Sensors are generic pixels of 20x20x20 μm^3

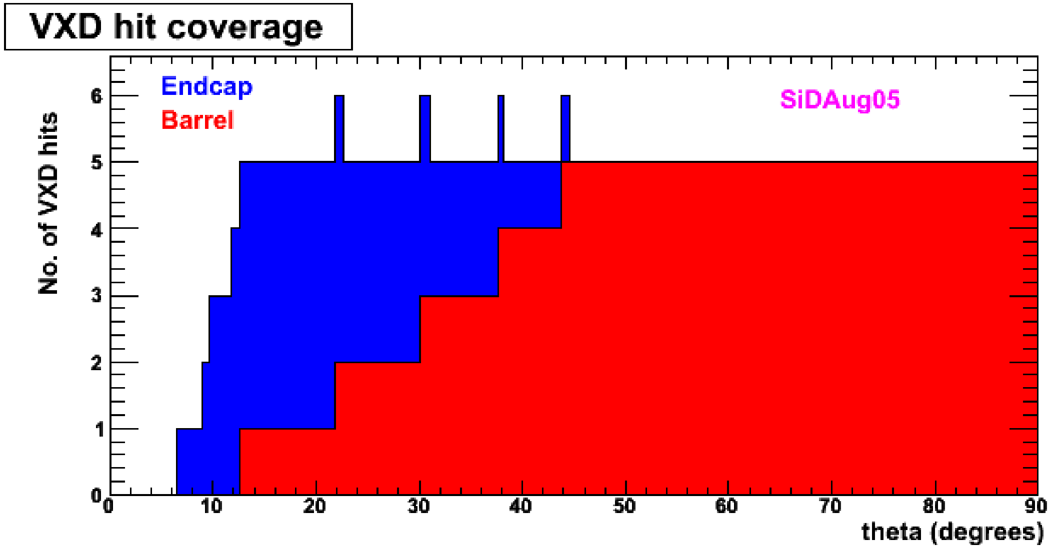
Su Dong, SLAC, Snowmass 2005

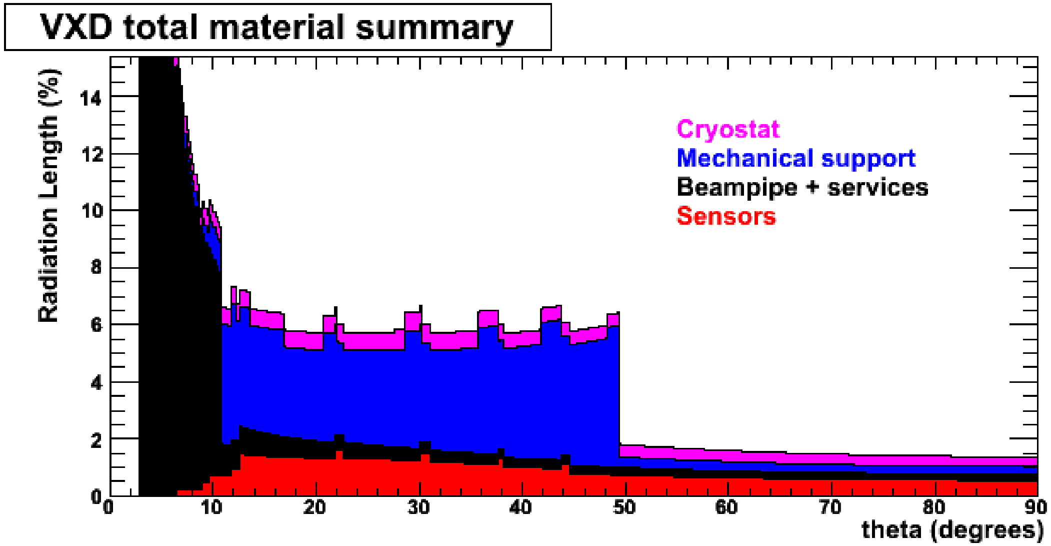
Tracker+VXD matching



VXD Hits and Material

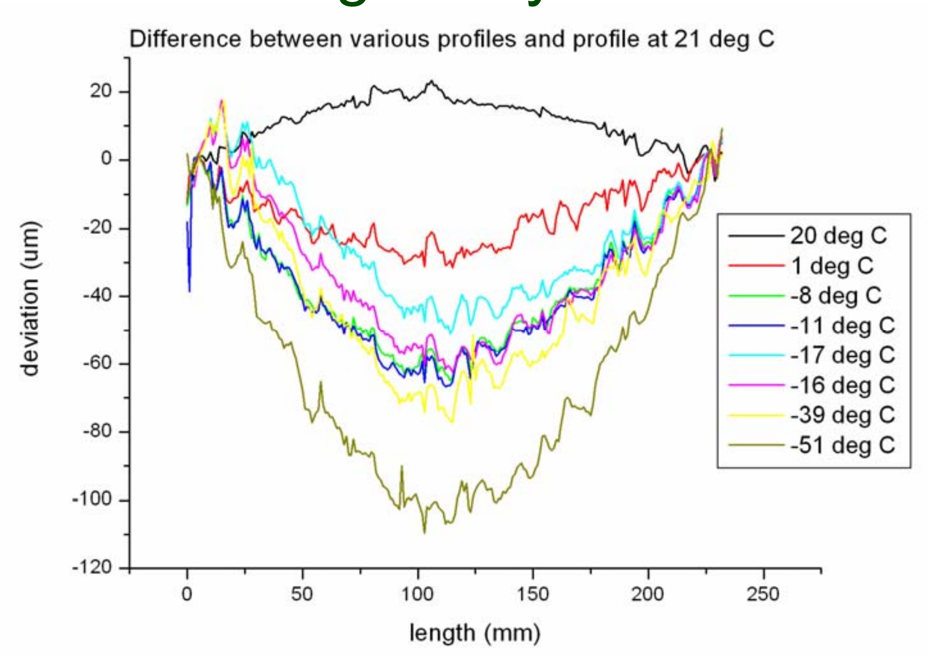
- Overlaps between VXD barrels and disks have been chosen to provide good hermeticity.
- We are only beginning work on mechanical support structures and expect to investigate:
  - material selection
  - removal of unnecessary material, particularly in support disks
  - thermal and vibrational stability.
- We hope that the 6% in the forward region can be reduced to 3% - 4%.



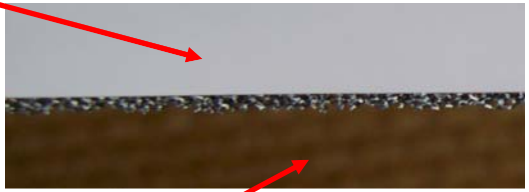


VXD "Ladder" Tests with SiC Foam

Thin glue layer



20 µm silicon

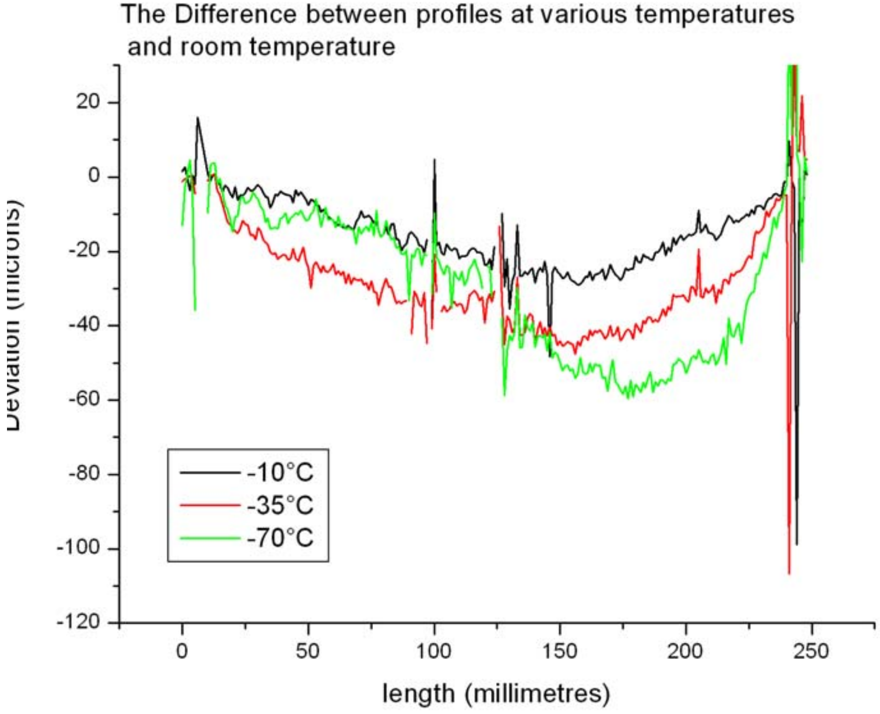


1.5 mm silicon carbide

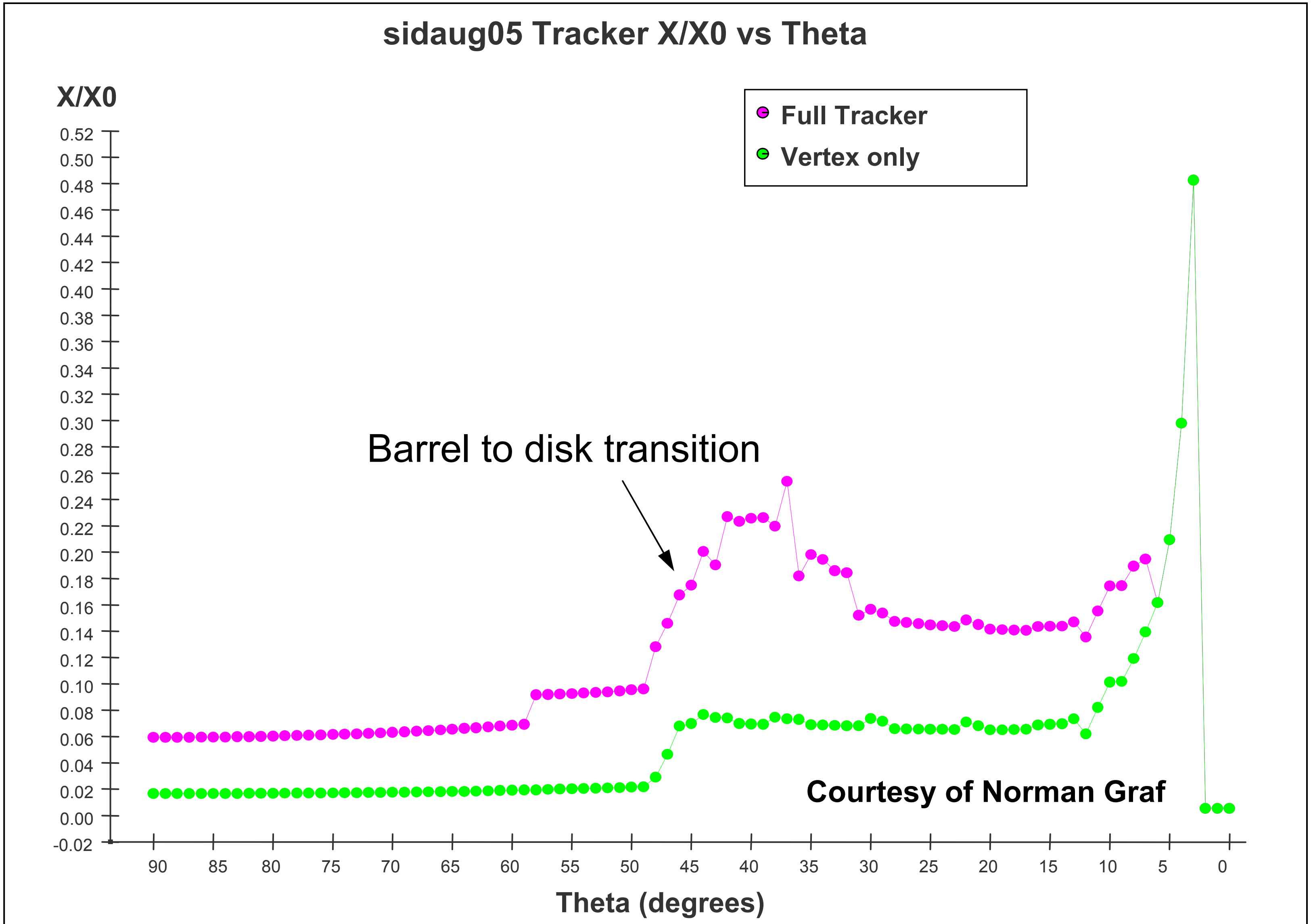
- 8% Silicon Carbide
  - Single-sided
  - 0.14% X0
  - 3-4% believed possible

LCFI:
J. Goldstein
S. Worm

Glue "pillars"



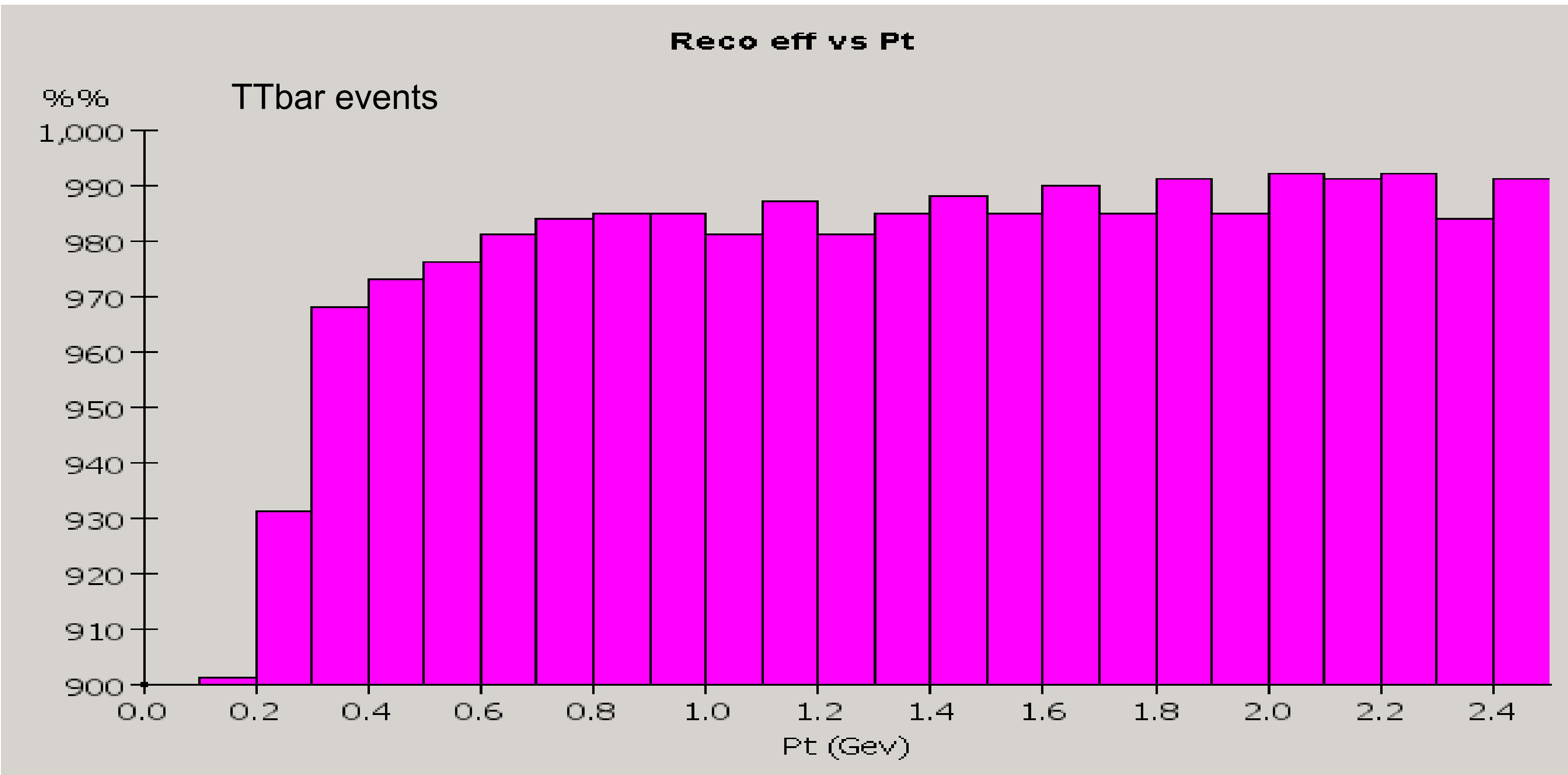
August 2005 SiD Simulation



Track Reconstruction Efficiency

- VXD-based tracking algorithms developed by N. Sinev
  - Outgrowth of earlier work by H. Videau and M. Ronan
- Start with hits in 3 VXD layers plus a very loose IP constraint, then require at least 4 VXD hits.
- Extrapolate to silicon micro-strips and add hits

http://nicadd.niu.edu/cdsagenda//askArchive.php?base=agenda&categ=a0562&id=a0562s1t1/moreinfo#256,1,SiD tracking using VXD as a primary tracking device



Pt Resolution in the Central Region

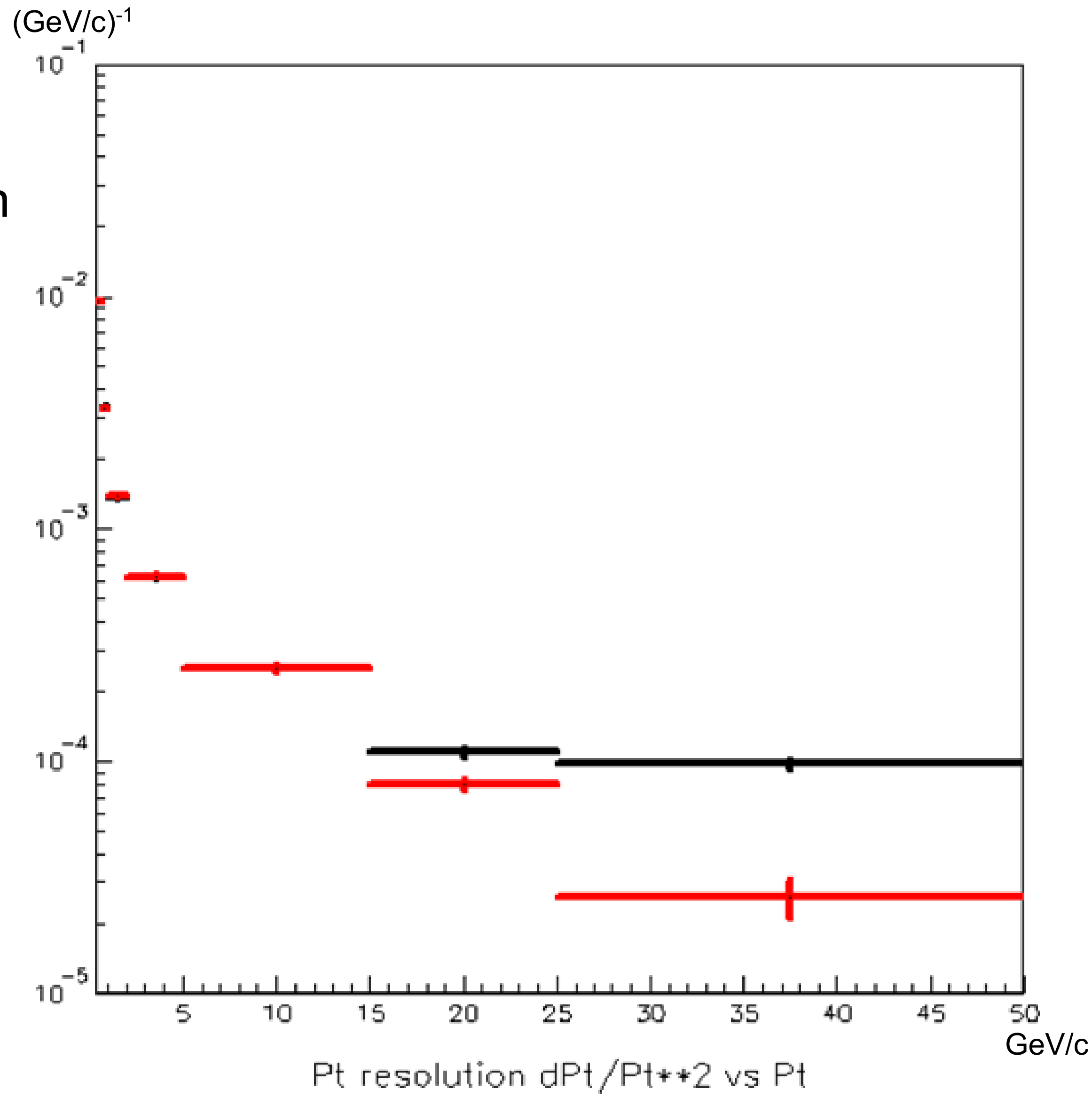
August 2005

VXD-based reconstruction algorithm

Fitting remains to be implemented in the disks, so only barrel tracks are included.

Black: reconstructed tracks

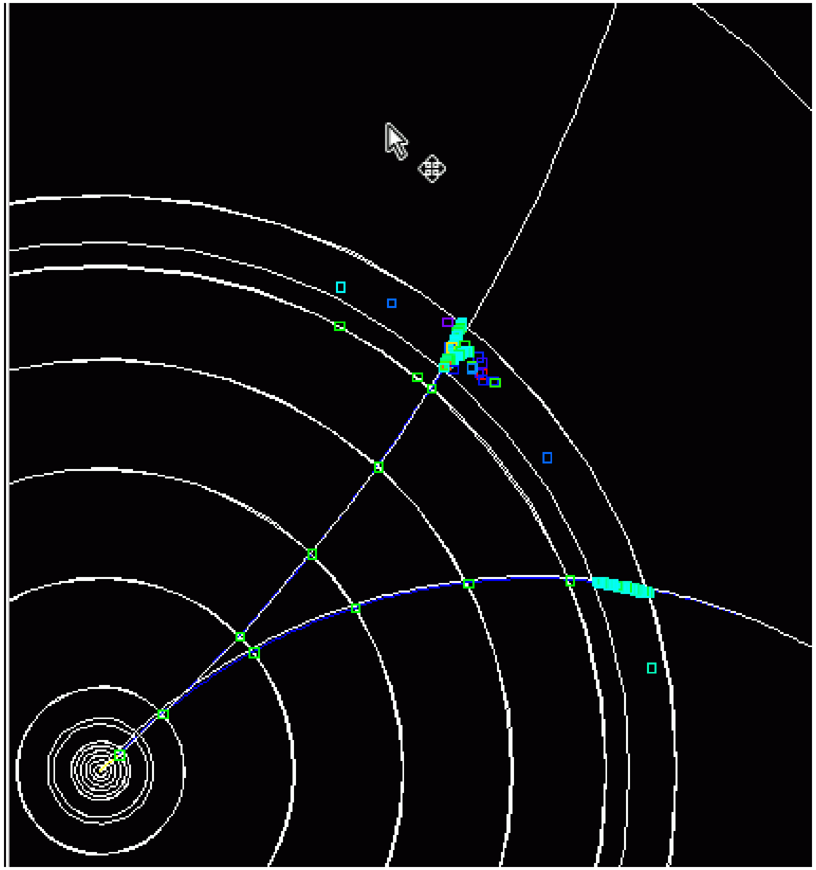
Red: after fitting which includes outer tracker hits

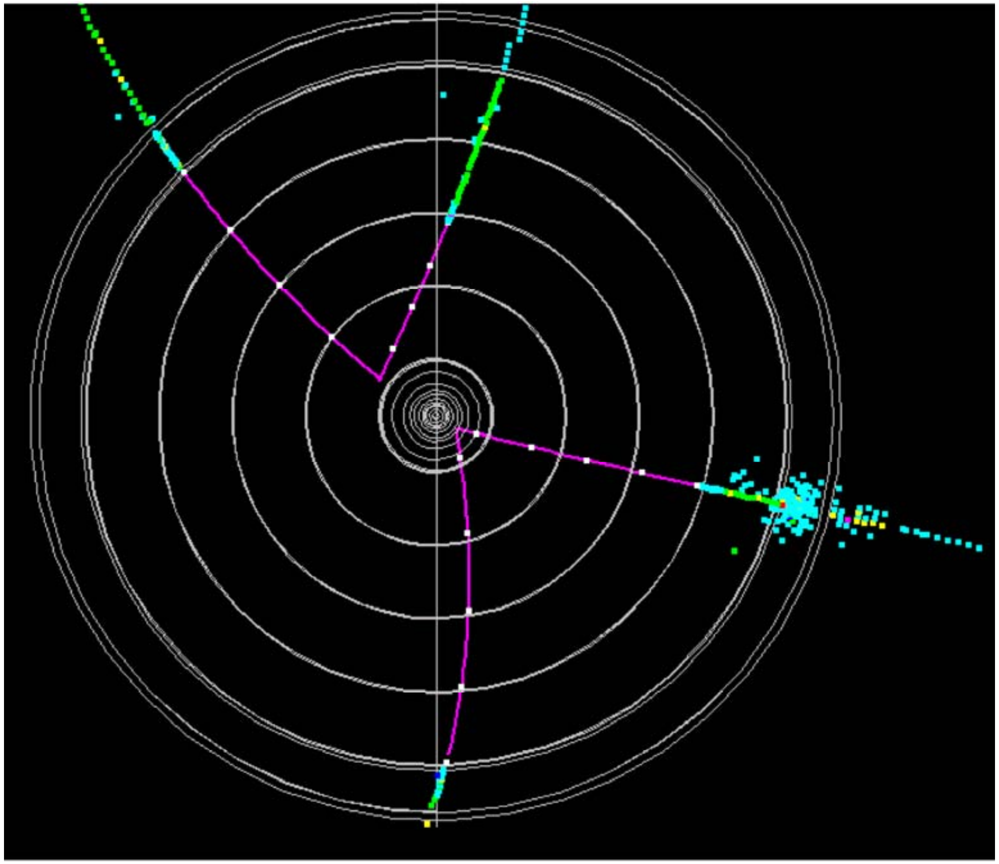


Nick Sinev, U. Oregon

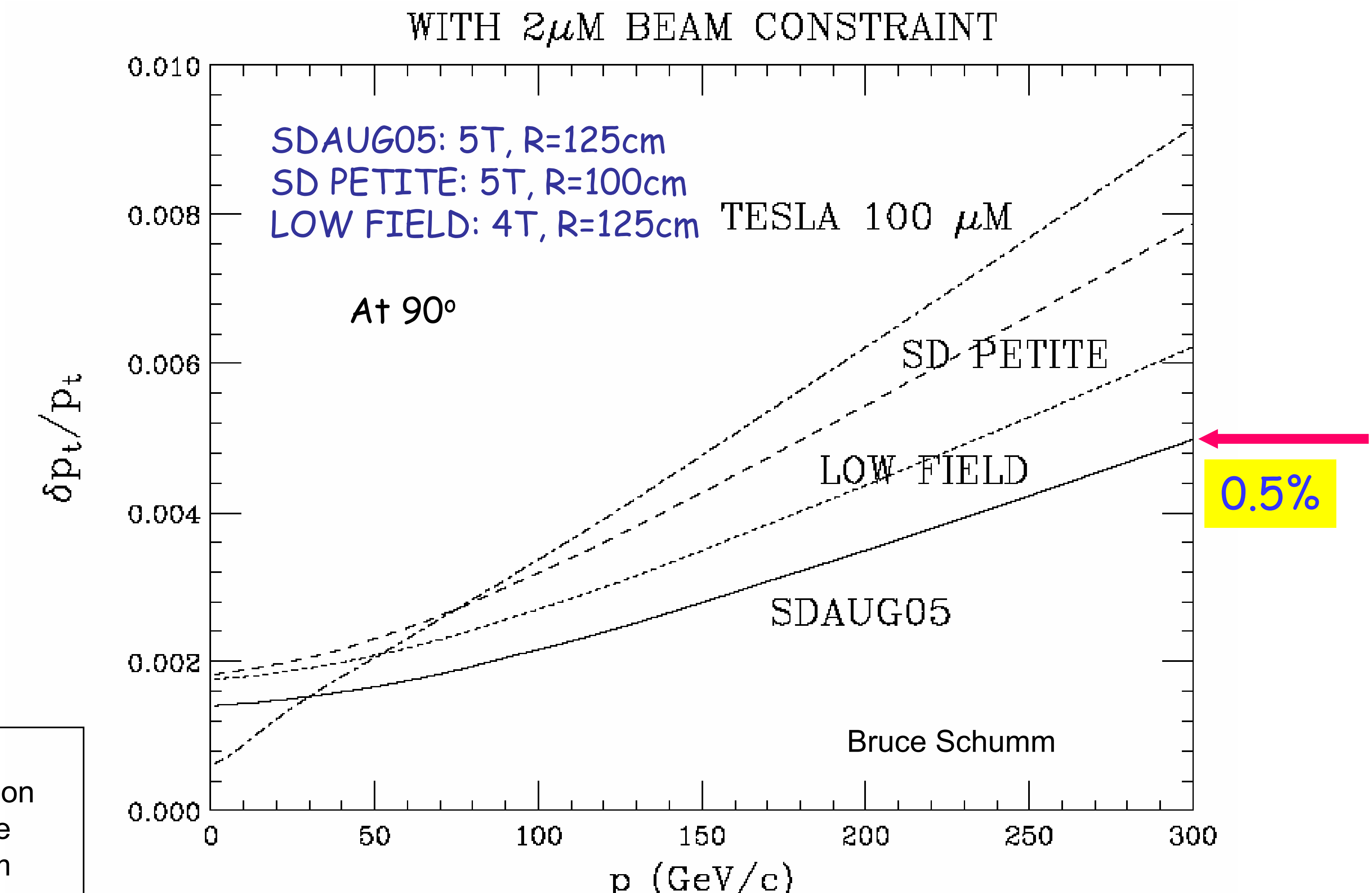
Tracking from Outside Inward

- Dmitry Onoprienko has been developing algorithms for finding tracks starting from ECAL.
- Particularly helpful for decays outside VXD





Tracker Momentum Resolution



Analytic calculation by Bruce Schumm (UCSC).

In Summary

- Realistic layouts have been developed for silicon tracking.
- The designs are hermetic.
- Designs take into account mechanical support and servicing issues.
- While we hope to make improvements, material budgets are understood.
- Tracking designs have been incorporated in simulations.
- Initial studies indicate excellent track reconstruction efficiencies and excellent precision of track momentum measurements.