The SiD Silicon Tracker for the ILC

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for the SiD Tracking Group

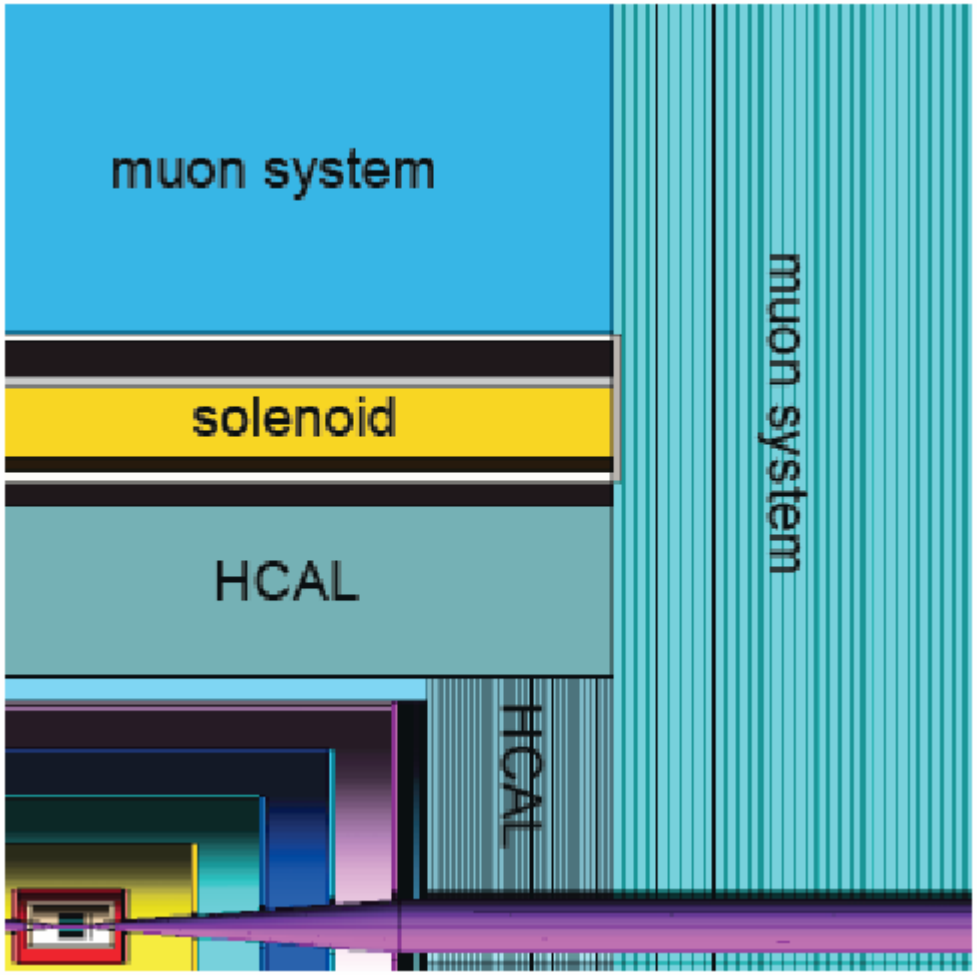
Talk Outline

- Tracking in the SiD Concept
- Tracker Design
- Tracker Performance

The SiD Concept

Defining Features of SiD

- Si pixel vertex detector
  - Best possible flavor tagging and pattern recognition
- Si strip tracker
  - Highest precision tracking to measure charged particles
- Si/W EM calorimeter
  - Finest possible segmentation to identify/measure photons
- High field solenoid (5T)
  - Smallest possible vertex detector inner radius
  - Improves charged particle momentum resolution



Tracking in the SiD Design Concept

- Of the four ILC detector concepts, SiD is the only one to adopt an all-silicon tracker

Why did we do this?

- Silicon provides the best resolution:
  - in position – ~7 μm hit resolution
  - in time – single bunch resolution
  - in 2-hit resolving power – typically a few strips (~150 μm??)
  - in track reconstruction for a given tracker volume
- Silicon trackers are inherently stable devices
  - Geometry of strips on sensor is precisely known
  - Good mechanical stability for supporting structures possible
- Compact tracking volume reduces detector costs
  - It is clear that detector cost will be constrained
  - M. Briedenbach SiD cost model: total detector cost scales as $R^{1.2}_{tkr}$

Context and Focus

- Several talks have already presented considerable material on tracking at the ILC
  - Marty Briedenbach gave SiD overview
  - Jim Brau previously covered the vertex detector
  - Bruce Schumm covered physics motivation and rationale for Si tracking
  - Several talks on pixel technologies that may be important for SiD
- Focus of this talk is to describe the SiD tracker baseline design
  - The baseline design has been developed within the SiD tracking group and represents a starting point to begin the process of optimizing the design
  - In many areas, there are alternative ideas / technologies that people are thinking about
  - We need R&D on technologies and detailed simulation of the design that can quantify performance of the baseline and alternatives to optimize the design
  - Lots of room for good ideas and contributions! Send me email if you would like to get involved.

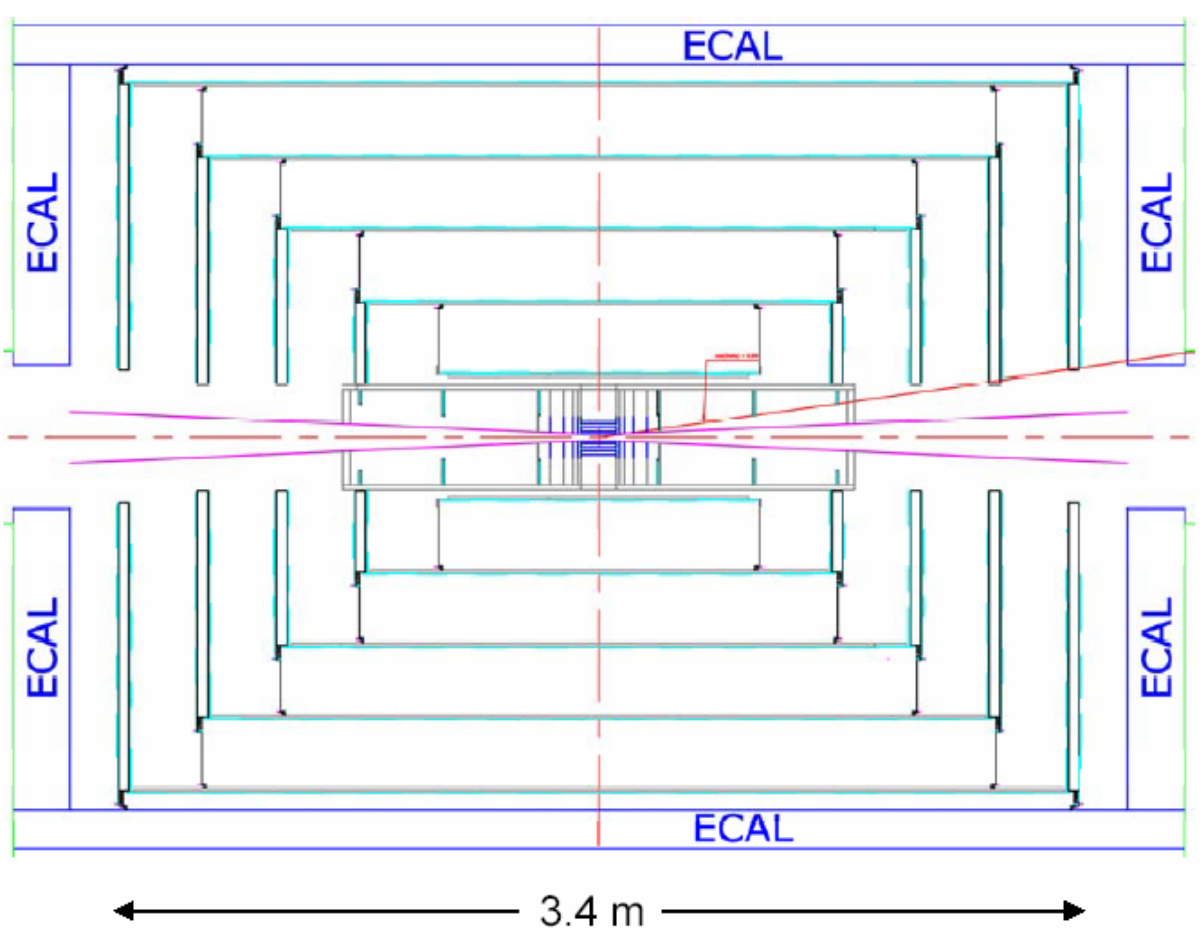
Baseline Tracker Layout

Outer Tracker

- Silicon strips
- 5 barrel layers
- 4 disks per end
- Supported by ECAL

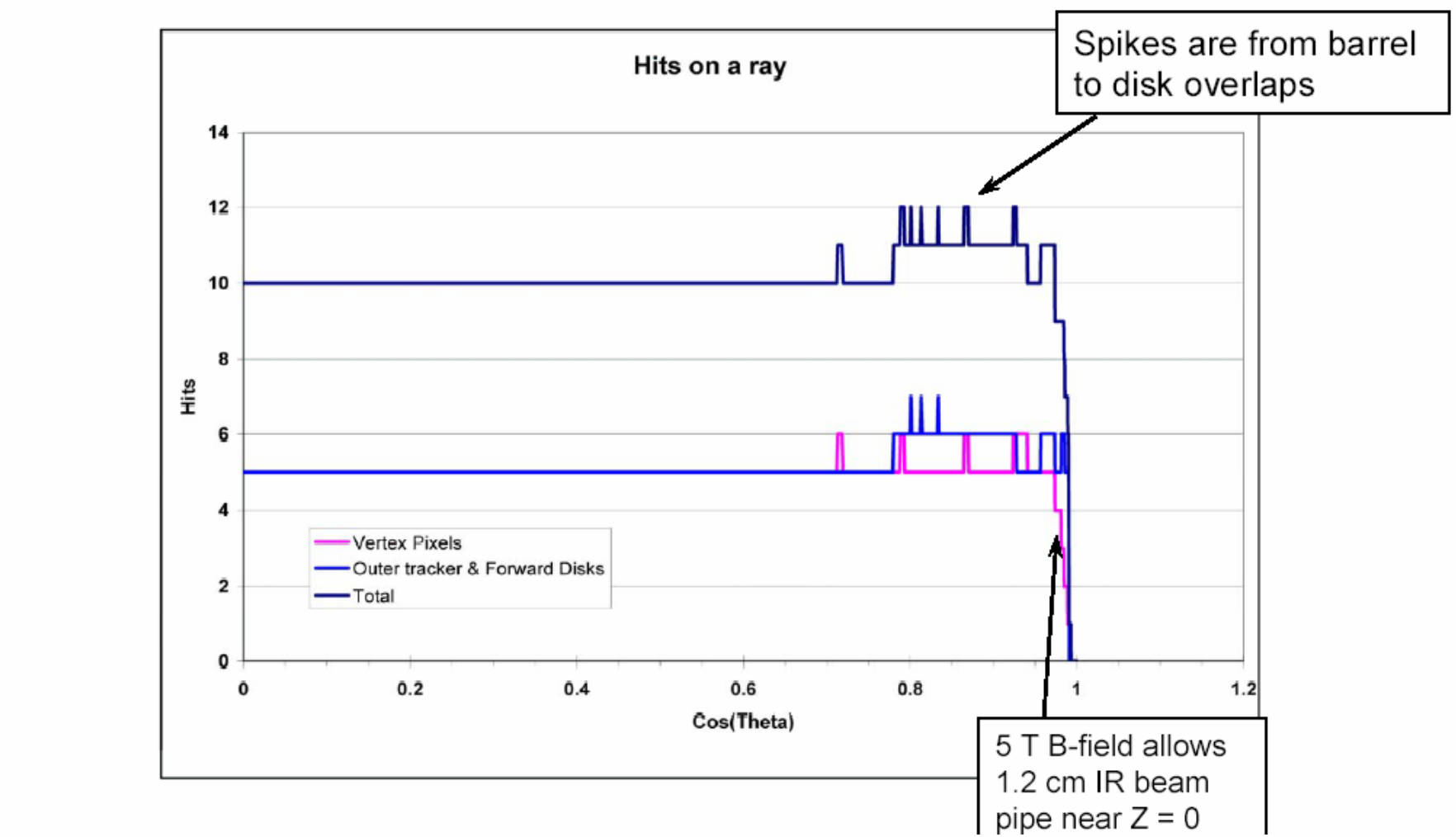
Vertex Detector

- Silicon Pixels
- 5 barrel layers
- 7 disks per end
- Supported by beam pipe



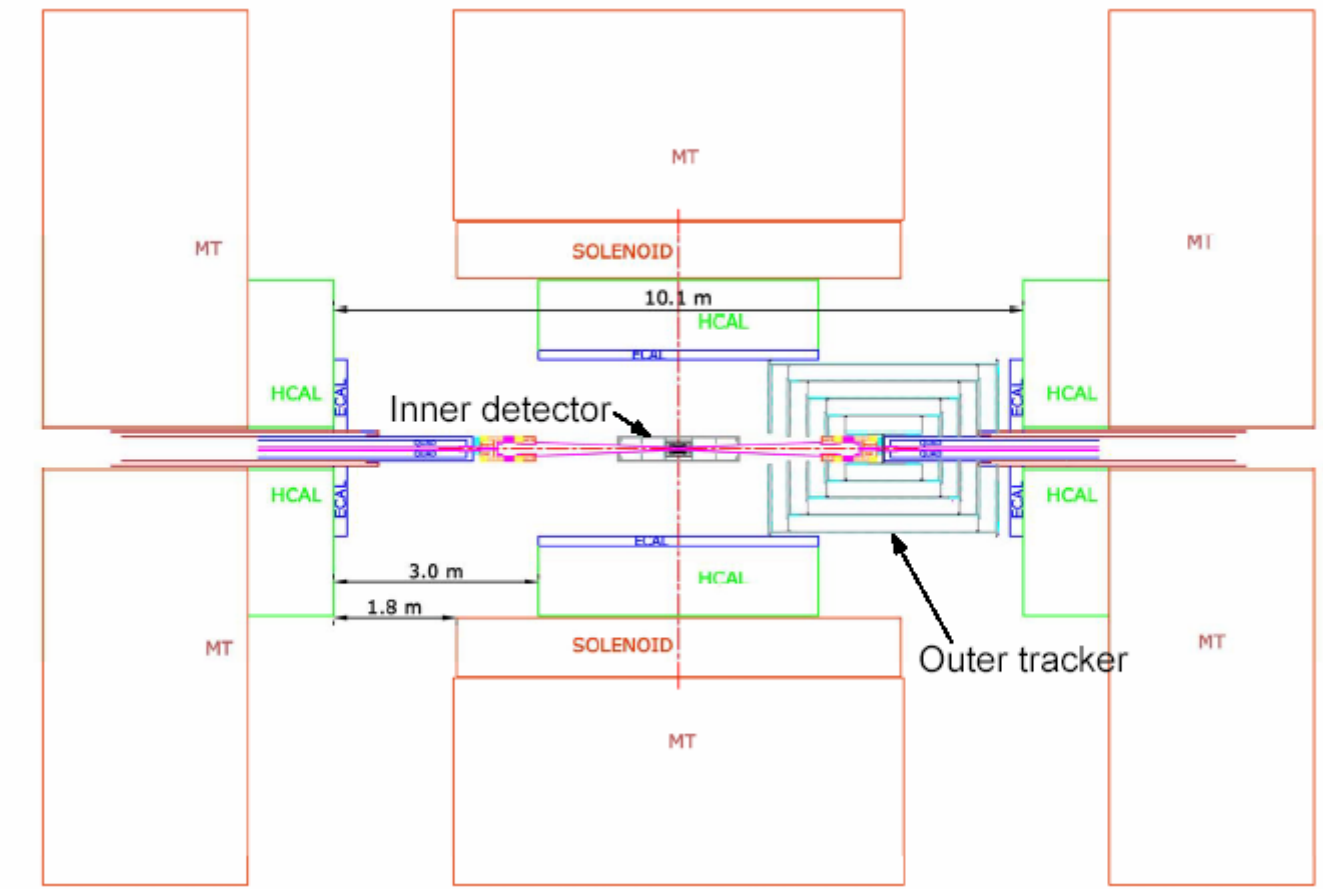
Solid Angle Coverage

- Full coverage for $|\cos\theta| < 0.99$ (10 hits typical)

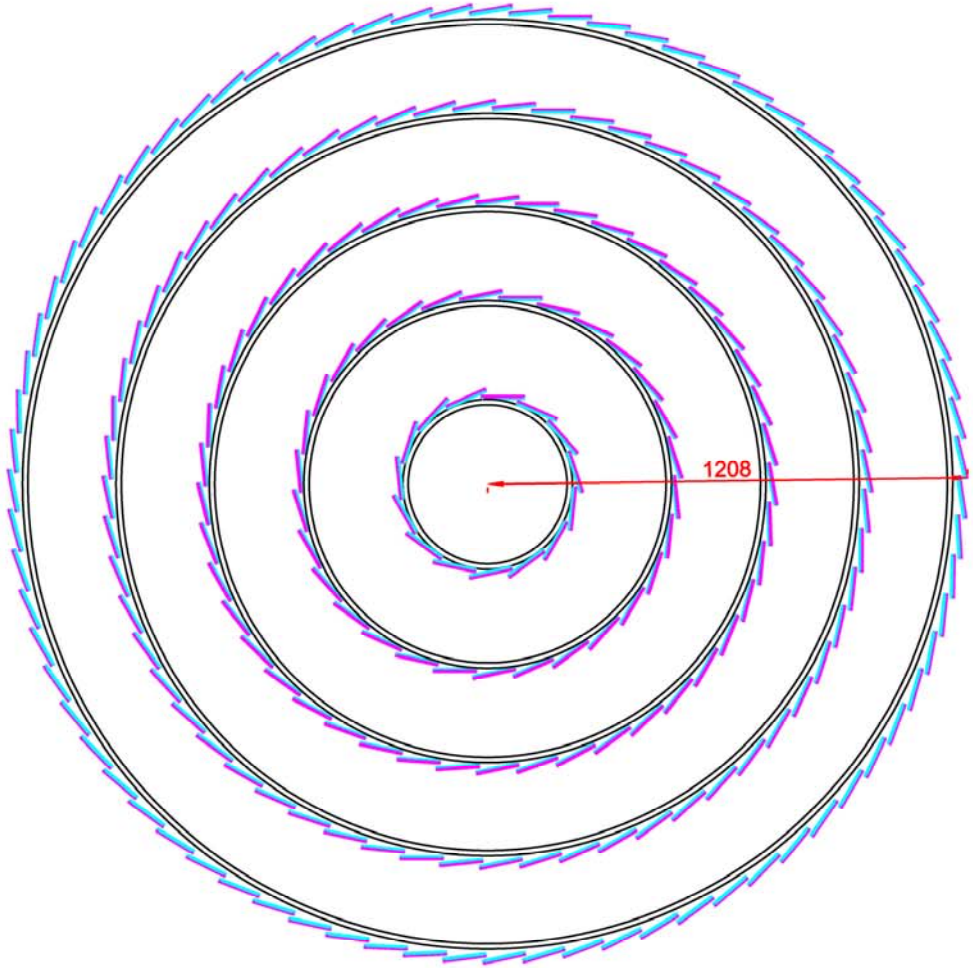


Access to Vertex Detector

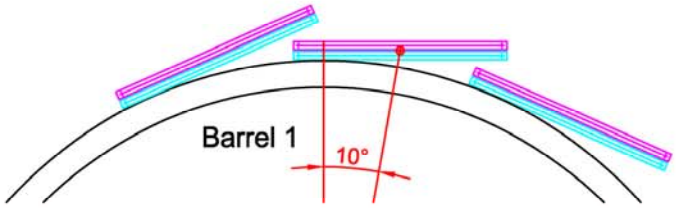
- Providing access to vertex detector constrains outer tracker to r > 20 cm



Layout of Outer Tracker Barrels

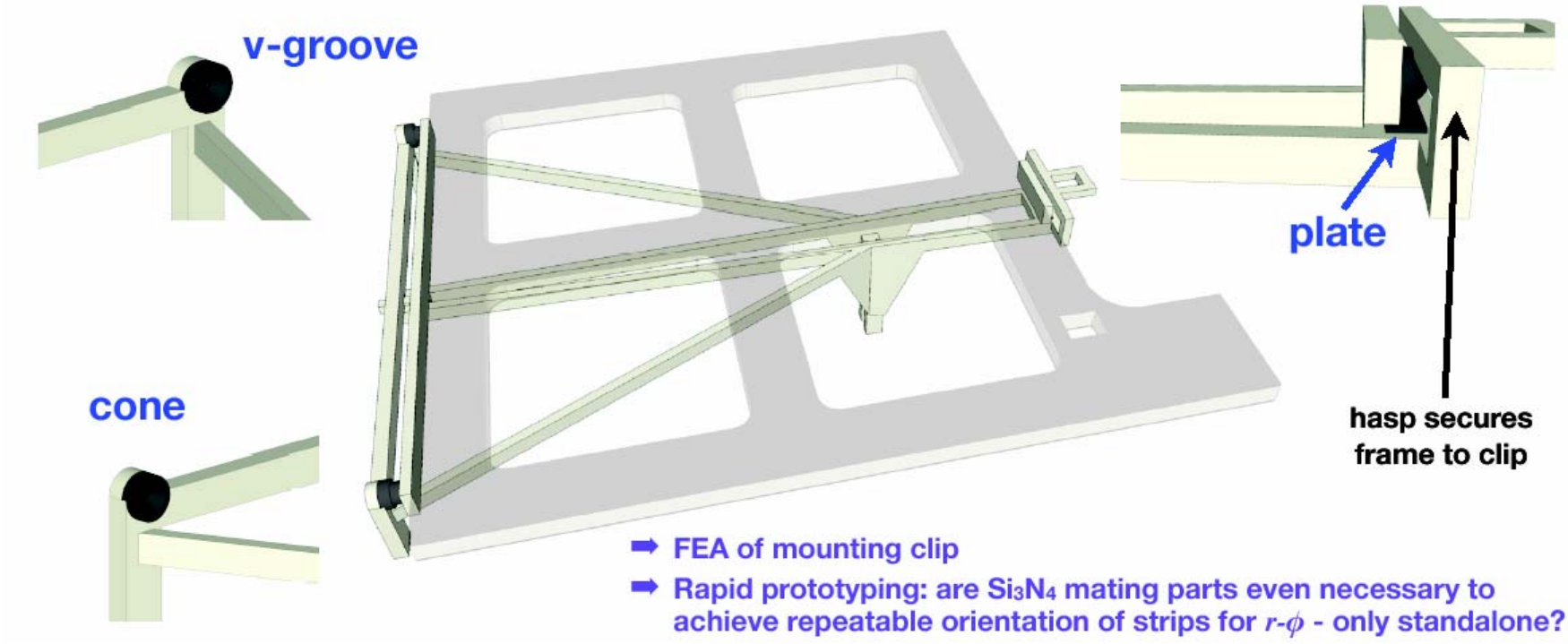


Sensors:
Cut dim's: 104.44 W x 84 L
Active dim's: 102.4 W x 81.96 L
Boxes:
Outer dim's: 107.44 W x 87 L x 4 H
Support cylinders:
OR: 213.5, 462.5, 700, 935, 1170
Number of phi: 15, 30, 45, 60, 75
Central tilt angle: 10 degrees
Sensor phi overlap (mm):
Barrel 1: 5.3
Barrel 2: 0.57
Barrel 3: 0.40
Barrel 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.



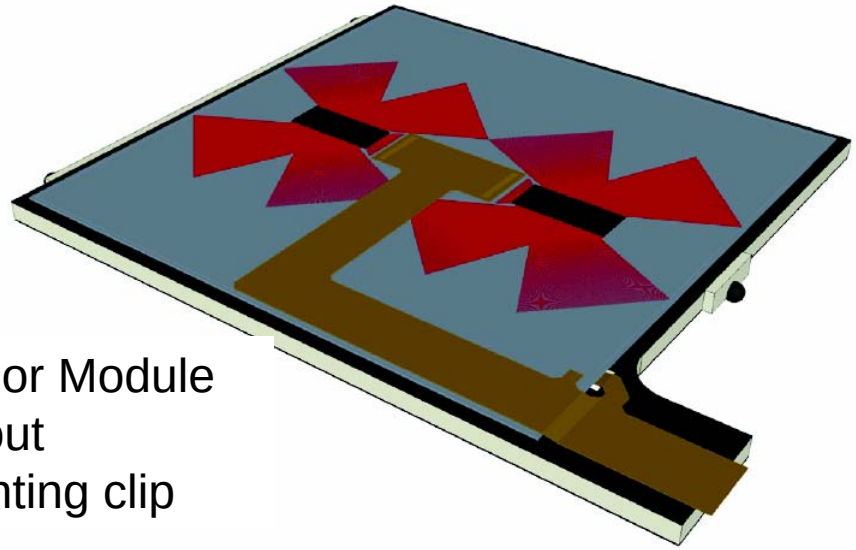
Sensor Module Supports

- Sensor modules are mounted on support cylinders
  - Support cylinders provide overall mechanical stability
  - Constructed using carbon fiber + Rohacell foam + carbon Fiber sandwich
- Modules are attached to support cylinder using a mounting clip with 3-point support



Sensor Modules

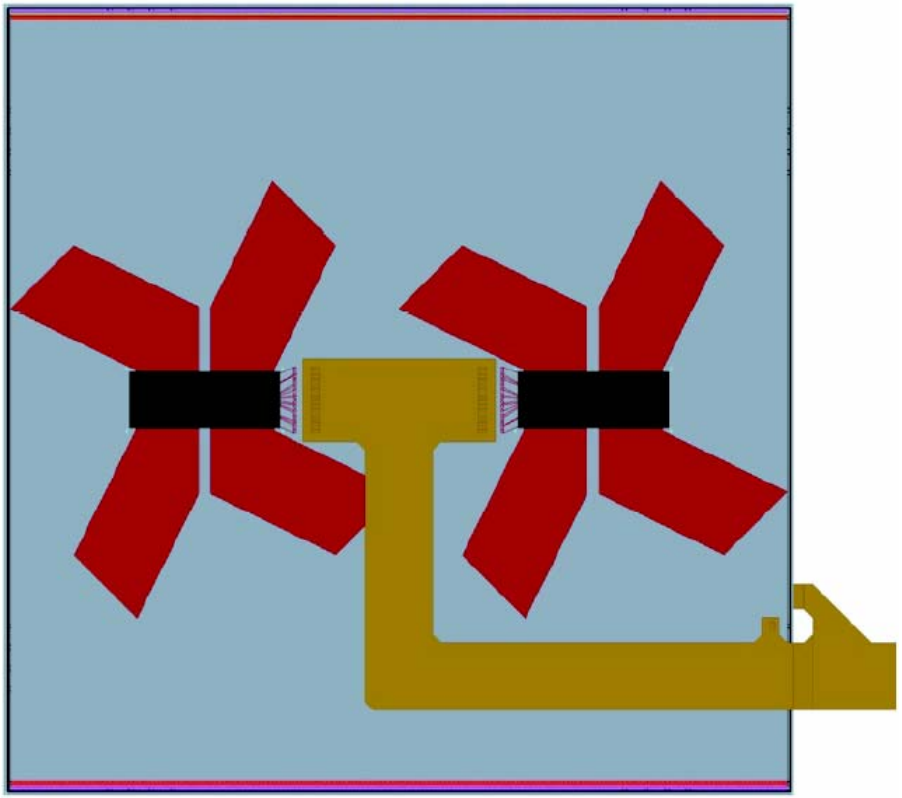
- Modules overlap in both ϕ and z coordinates to minimize gaps, assist in alignment
- Modules can have either one or two sensors mounted on module frame
- Baseline design has one sensor/module
  - Vertex detector serves as primary source of 3D pattern recognition
  - Outer tracker provides precise momentum measurement and resolves ambiguities, fakes



Sensor Module without mounting clip

Strip Sensors

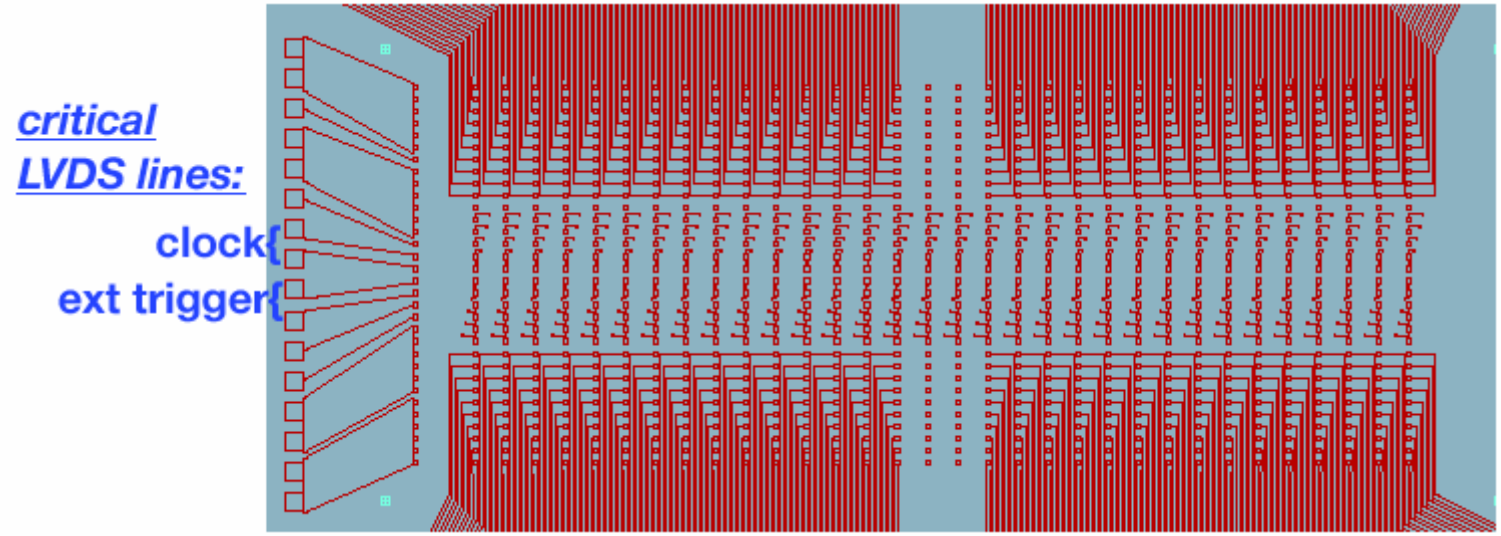
- Single-sided p on n sensors
- AC coupled, polysilicon bias R's
- 93.5 mm square
- 25 μm strip pitch
- 50 μm readout pitch
- 1840 readout strips
- Two KPiX readout chips bump bonded to sensor
- Readout cable signals wire-bonded to sensor
- Double metal layer used to route strip and readout cable signals



Submission to Hamamatsu planned for this fall

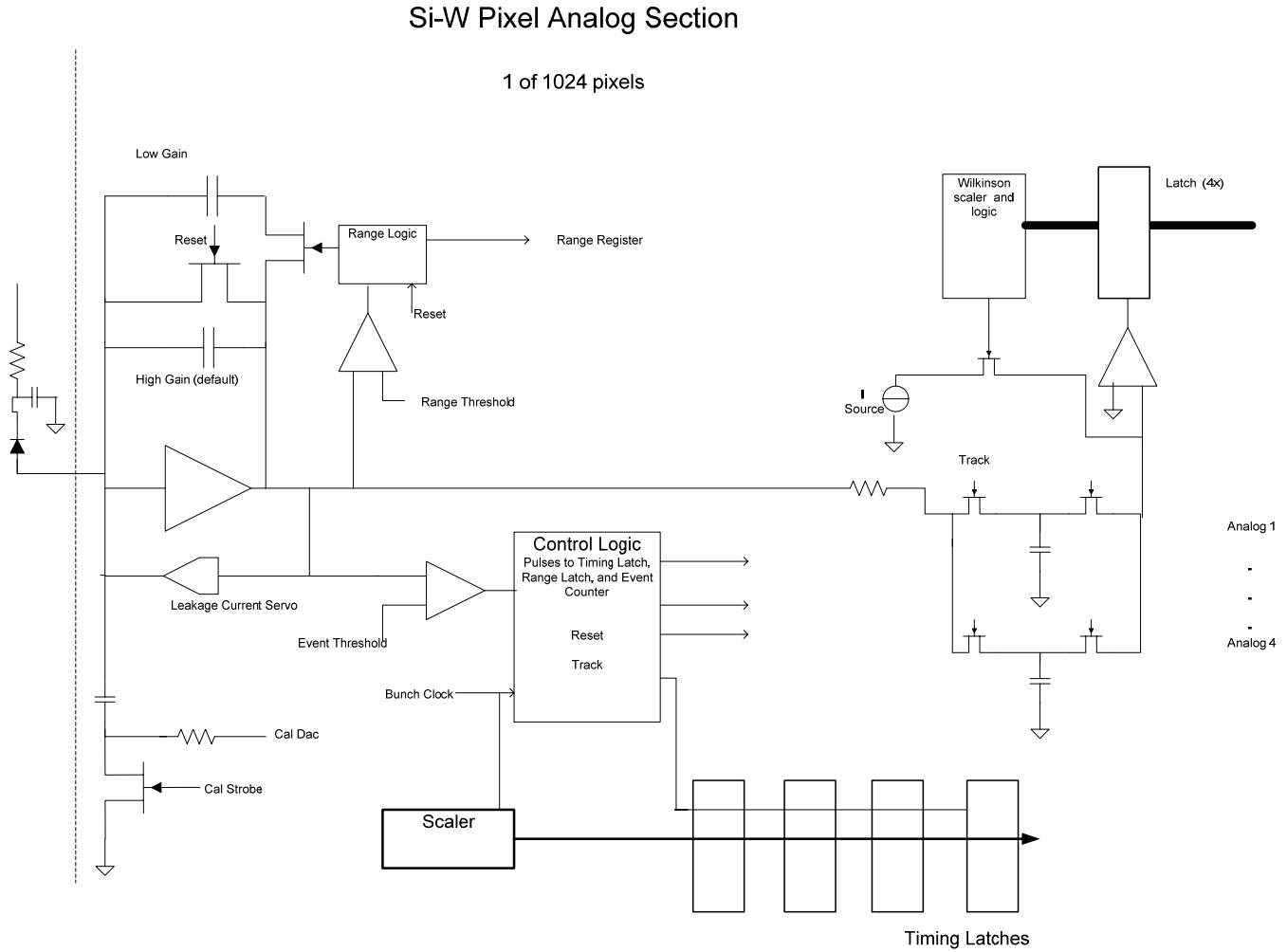
Double Metal Routing

- Plan to first try bonding KPiX, readout chip directly to sensor
- One concern is clock coupling into strips under clock lines
  - Clock lines are synchronous and balanced, so it should be OK
  - Backup plan is to introduce a small hybrid between sensor and KPiX
- Groups of neighboring strips routed to rows of neighboring pins, nearest neighbor readout logic being added to KPiX



KPiX Readout Chip

- Provides readout of up to 4 hits in bunch train

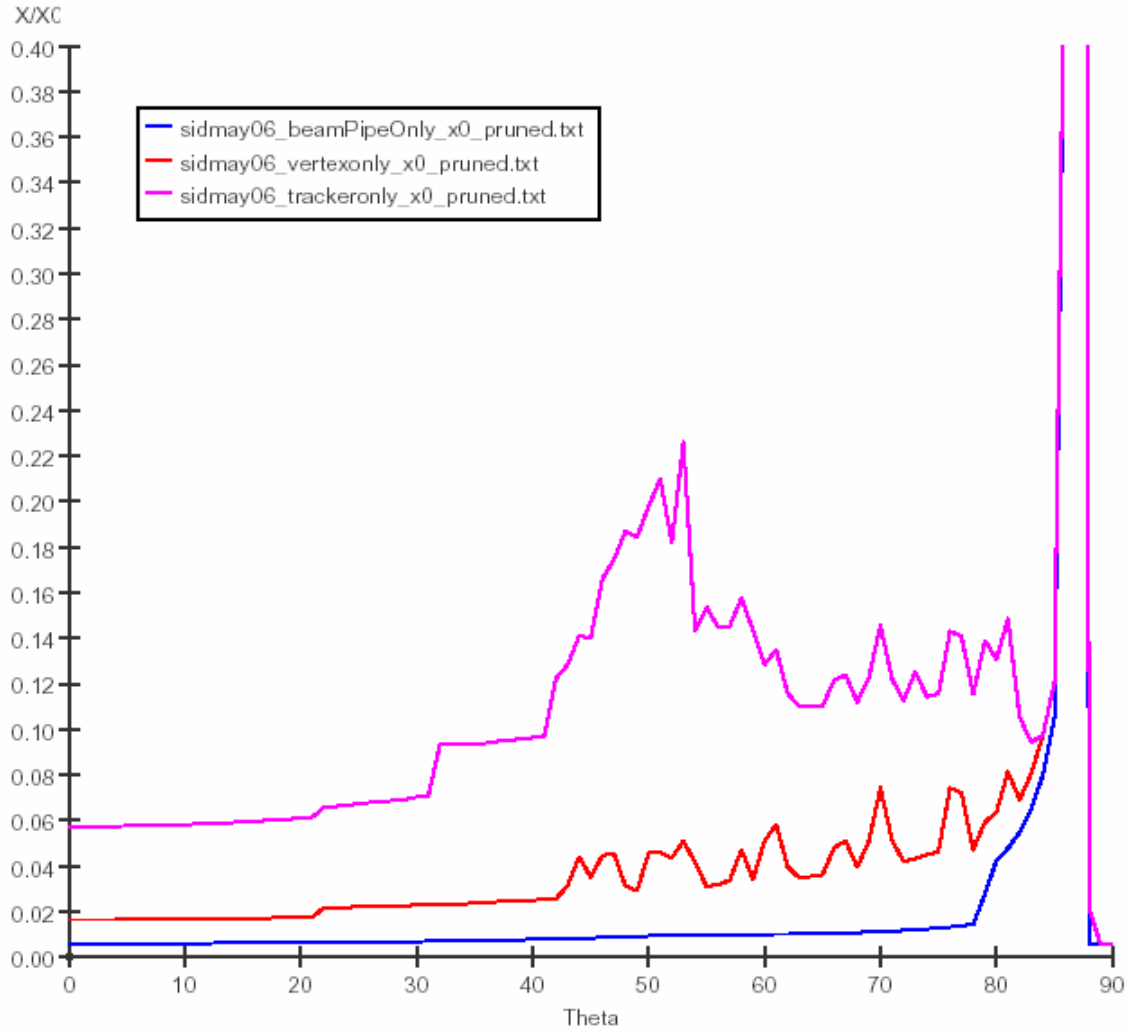


Forward Disks

- Forward disk design is much less developed than barrel design
- Expect many of the barrel features to carry over
  - Modules mounted on carbon fiber + Rohacell foam supports
  - KPiX readout mounted on sensors, all sensors read out individually
- One difference: baseline design has two sensors per disk to provide 3D space point measurements
- Baseline geometry of sensors has not been decided
  - Square sensors with 90° stereo
  - Hexagonal sensors with 60° stereo (e.g., disk 1 with x-u, 2 with x-v, etc.)
  - Wedges with strips parallel with sensor edges
- Need to study tracking performance in simulations to make a sensible choice

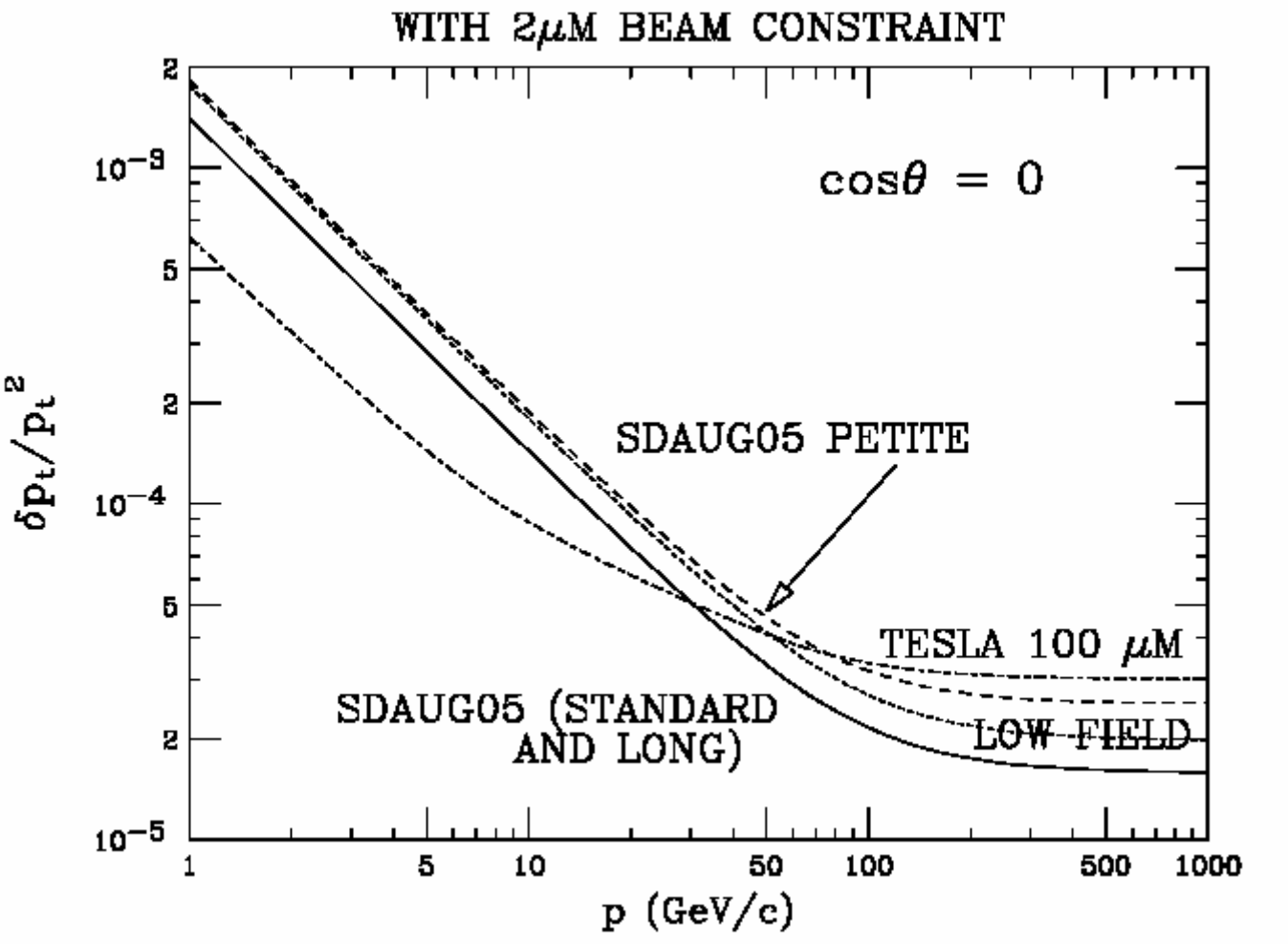
Material Estimate

- Considerable emphasis on minimizing material in tracker



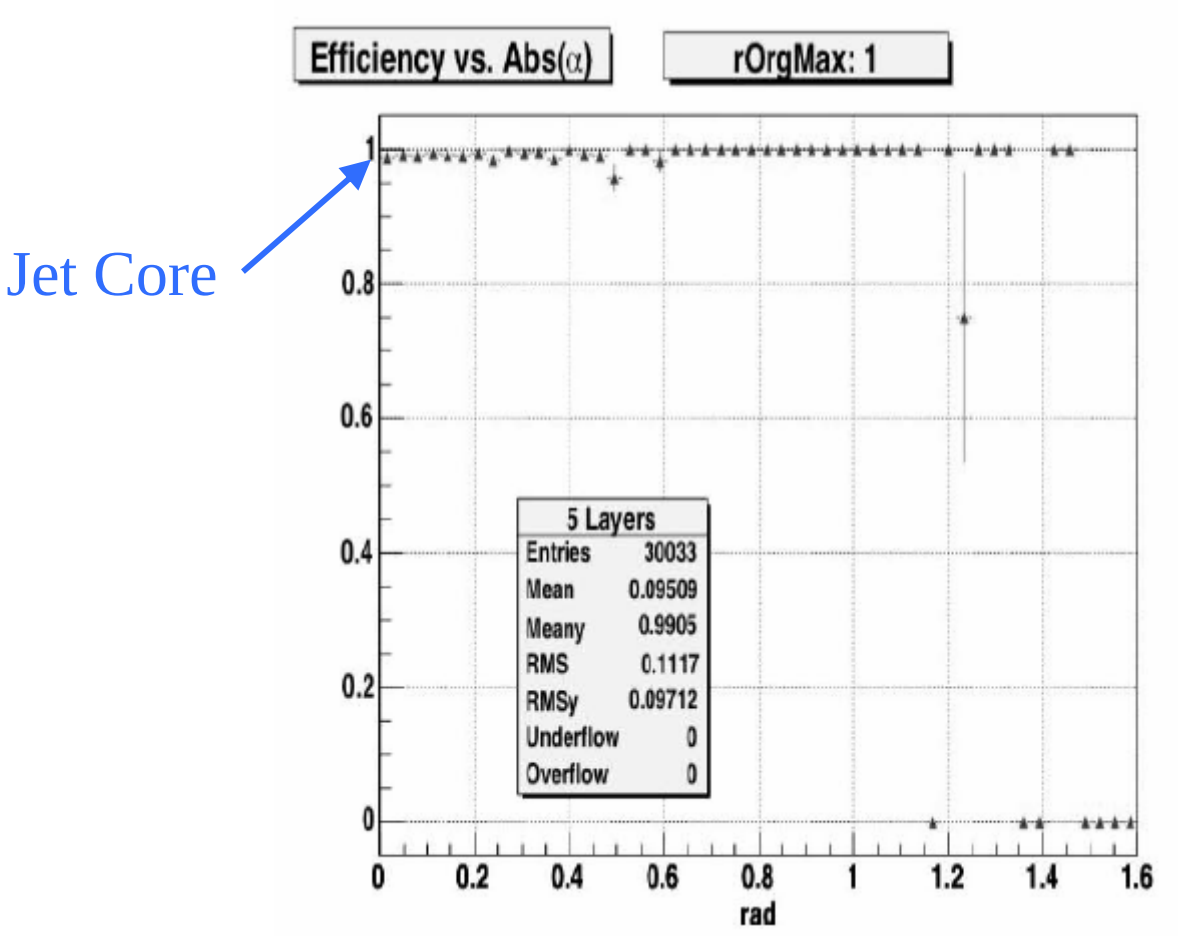
Tracking Resolution

- Excellent momentum resolution (~0.2% for $1 < p_T < 100$ GeV)



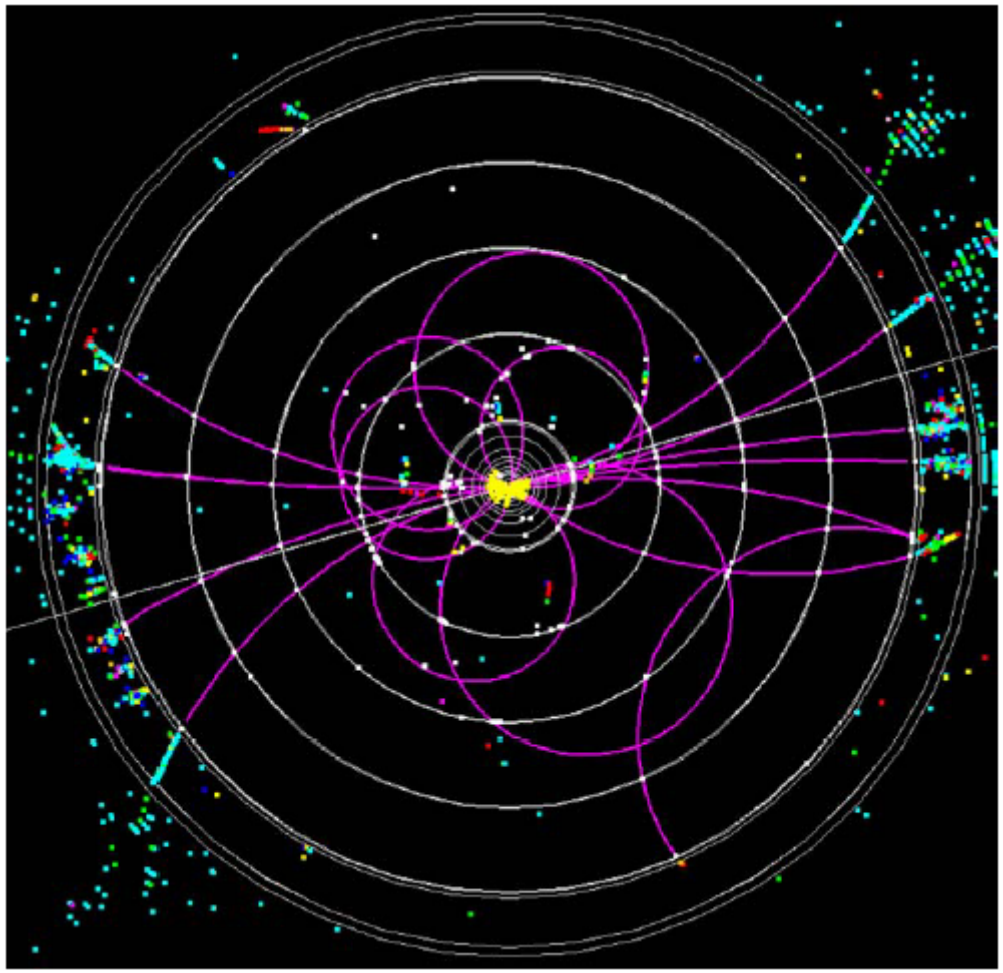
Tracking Efficiency

- Excellent tracking efficiency even in the core of jets for tracks originating within 1 cm of the IP



Calorimeter Seeded Tracking

- Use fine-grained SiW calorimeter to seed tracks originating away from the IP



Conclusions

- Silicon tracker is a key and distinguishing feature of SiD
- Baseline design is well advanced in barrel tracker
- Expect to have module prototypes next year
- A similar level of detail is needed for the forward disks
- Simulation results are promising
  - Excellent resolution and efficiency for tracks originating near IP
  - Calorimeter can help with tracking for tracks originating away from IP – is this enough or are additional stereo layers needed?
  - Major effort underway to develop simulation tools needed to optimize the design