Status of SiD Tracking Software

Richard Partridge

Boulder Simulation Workshop

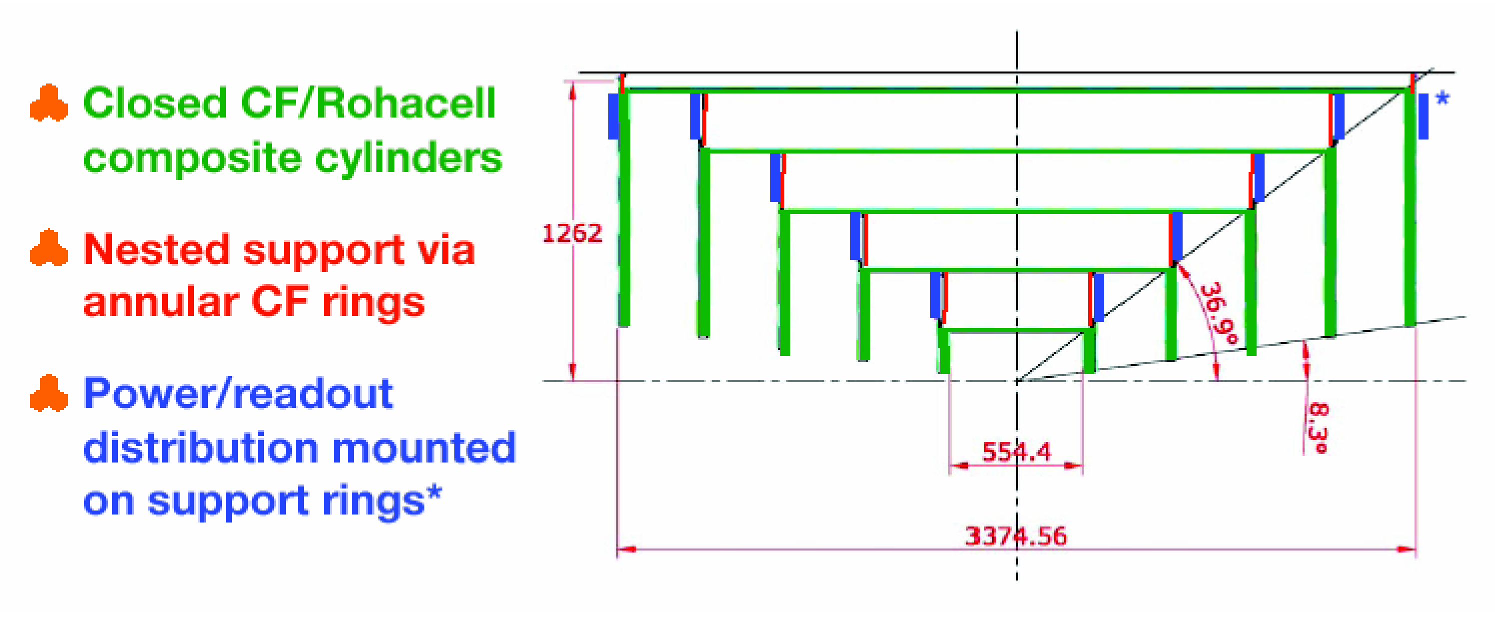
January 9 - 11, 2006

Silicon Tracking Goals

- Develop a realistic baseline tracker design, including required mechanical supports, readout electronics, etc.
- Optimize the baseline design of the tracker using realistic MC simulations of ILC events
- Demonstrate that the tracker can efficiently and precisely reconstruct tracks for ILC physics processes
- Demonstrate that the tracker has required performance for energy flow algorithms

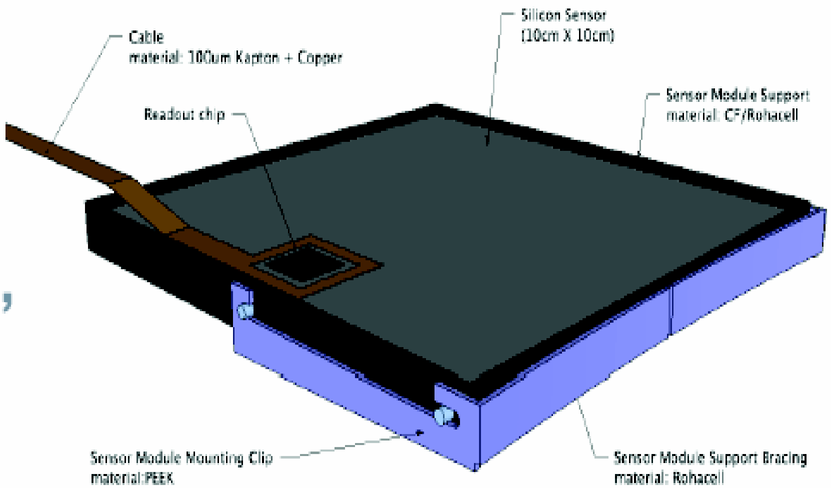
Baseline Tracker Design

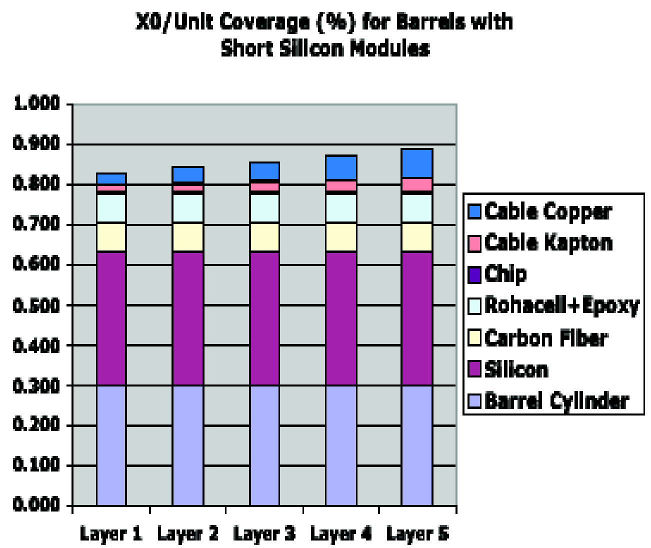
- Central: 5 axial silicon strip layers mounted on carbon fiber / Rohacell foam cylinders
- Forward: 5 disks with stereo strip pairs
- Implemented in org.lcsim framework
  - » Simulation model includes estimated readout material



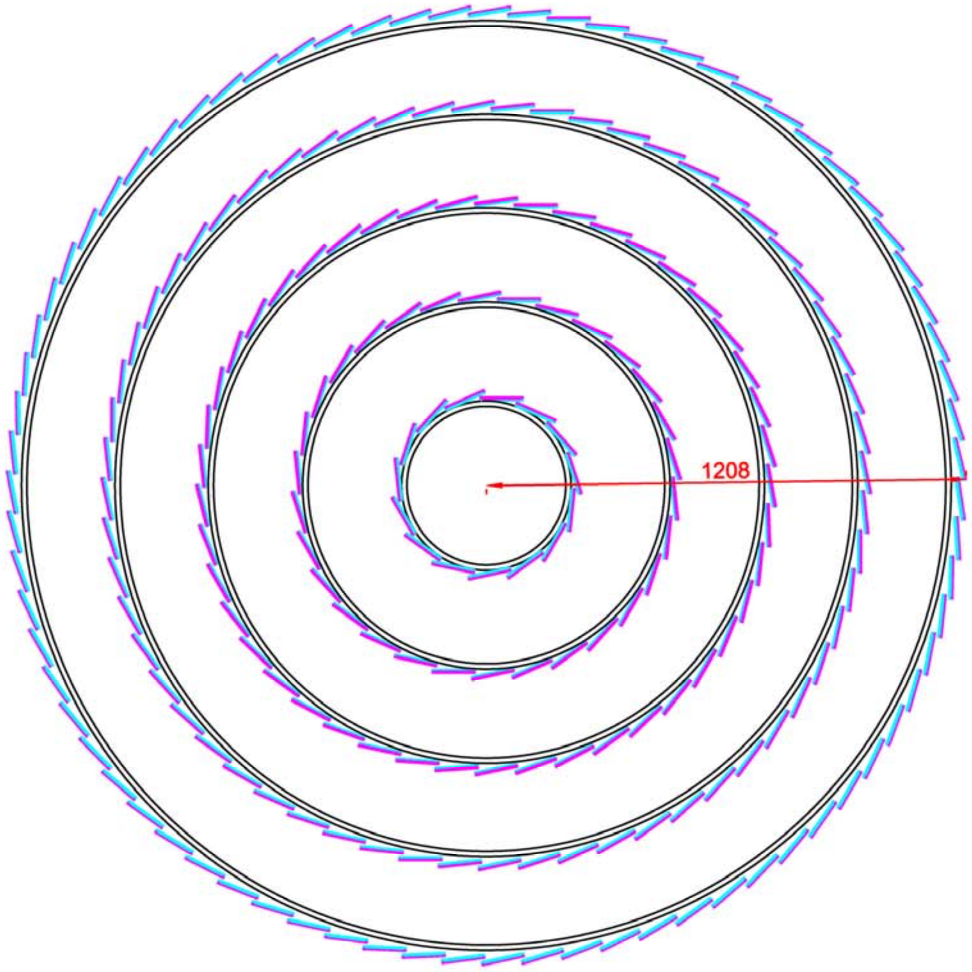
Sensor Modules and Material Estimate

- Outer surfaces of cylinders tiled with small (~10cm×10cm), low-mass, sensor modules
  - single-sided in barrel (r-ϕ)
  - double-sided in disks **(??)**
- Modules are primarily silicon with minimal support. Readout material minimized.

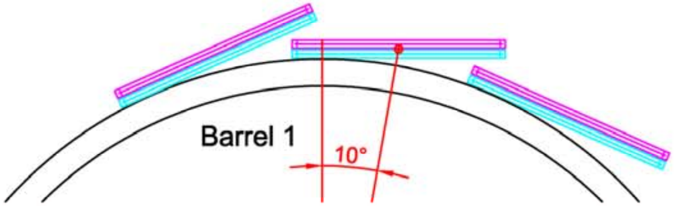




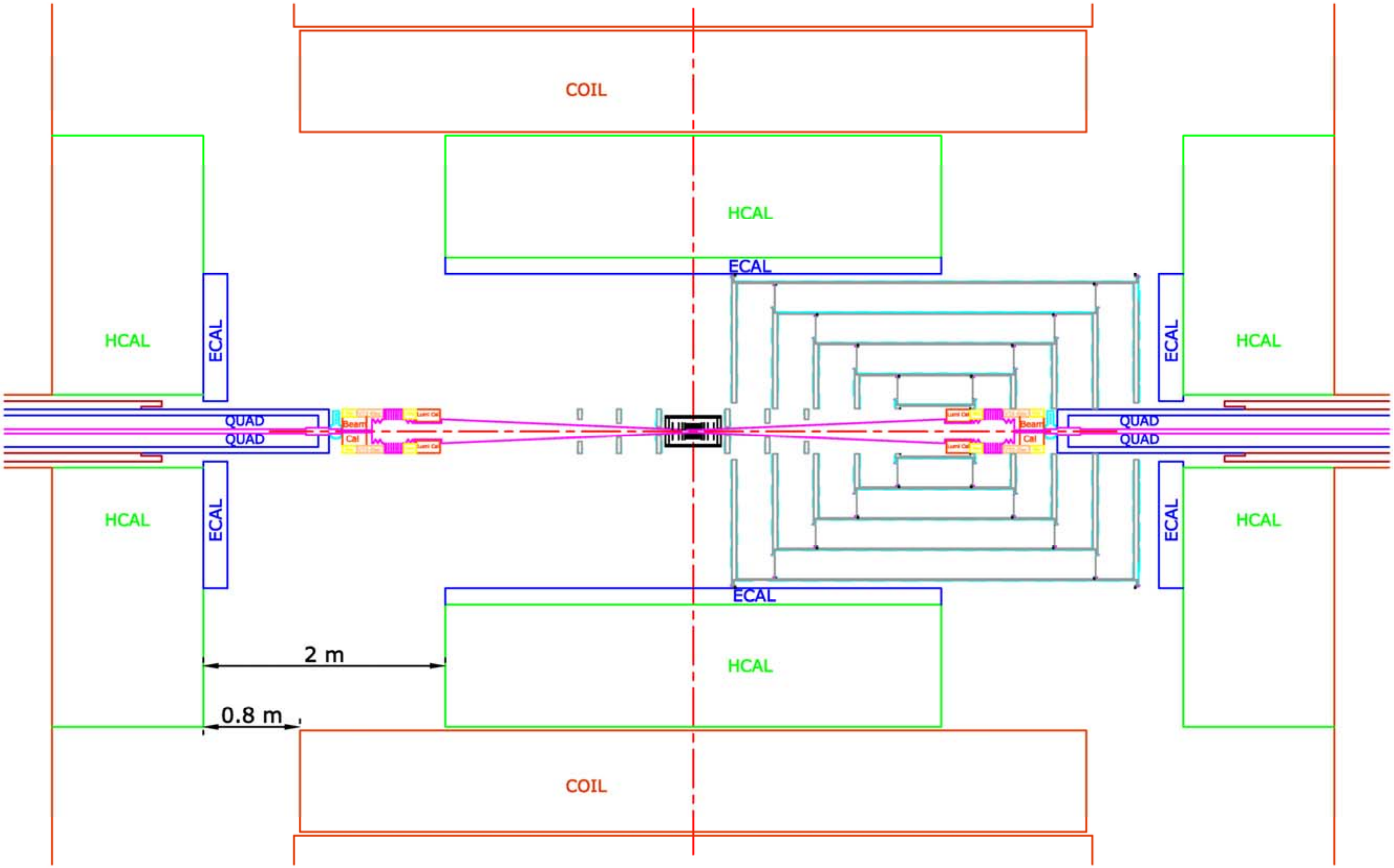
Layout of Outer Tracker Barrels



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.

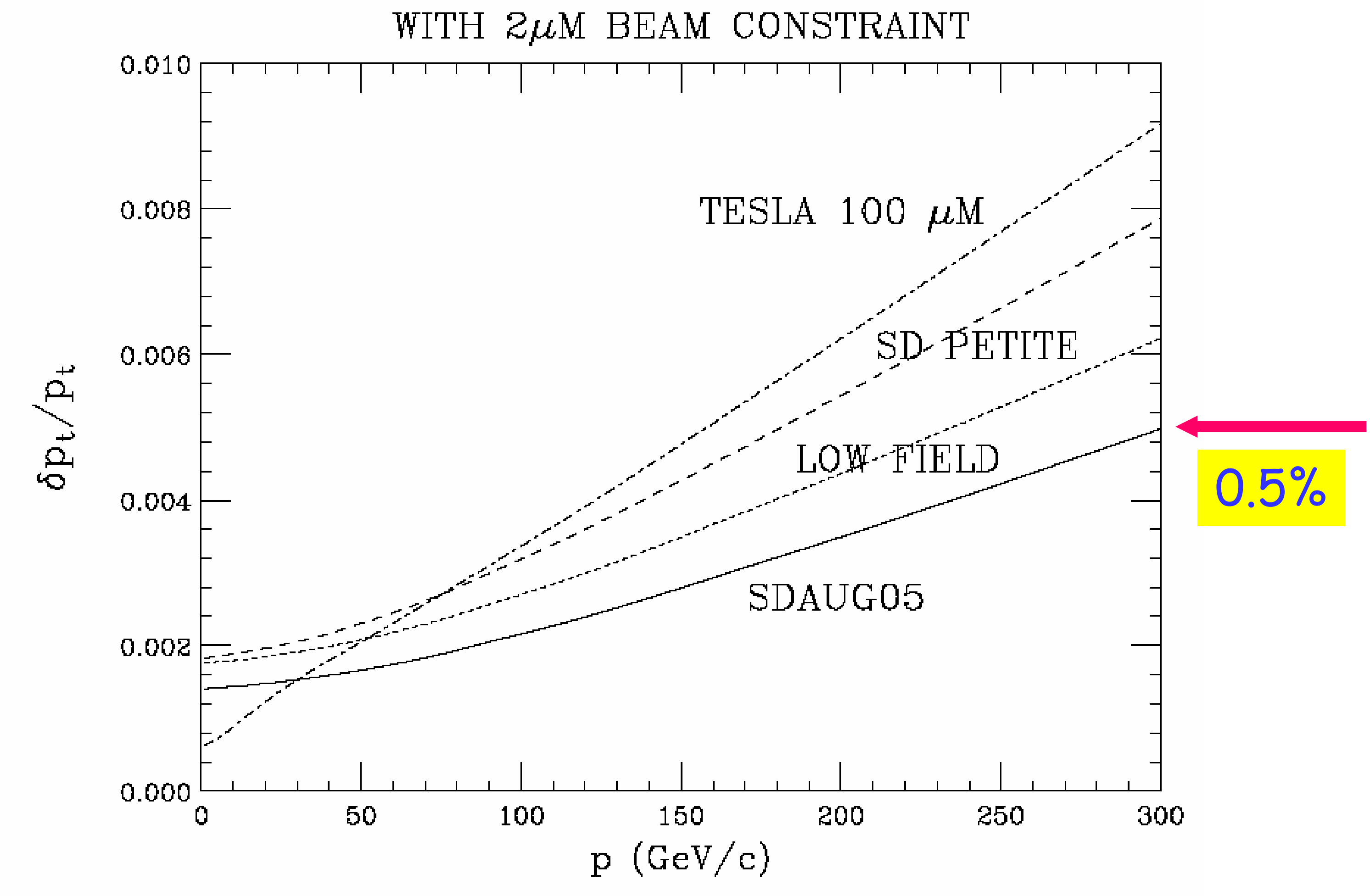


Access to Vertex Detector



Baseline Design Momentum Resolution

- Calculate from expected hit resolution (90° tracks)



Design Optimization

- Our approach to design optimization is largely focused on answering 5 "Critical Questions":

1. Develop a baseline design for the forward direction
2. Does the baseline design find tracks well? Is the performance robust in the presence of machine and physics backgrounds?
3. Does the tracker design need to become more complicated than the baseline design?
4. Can decays in flight be detected efficiently? Is this an important capability?
5. Demonstrate (if true) the need to minimize tracker material to minimize multiple scattering.

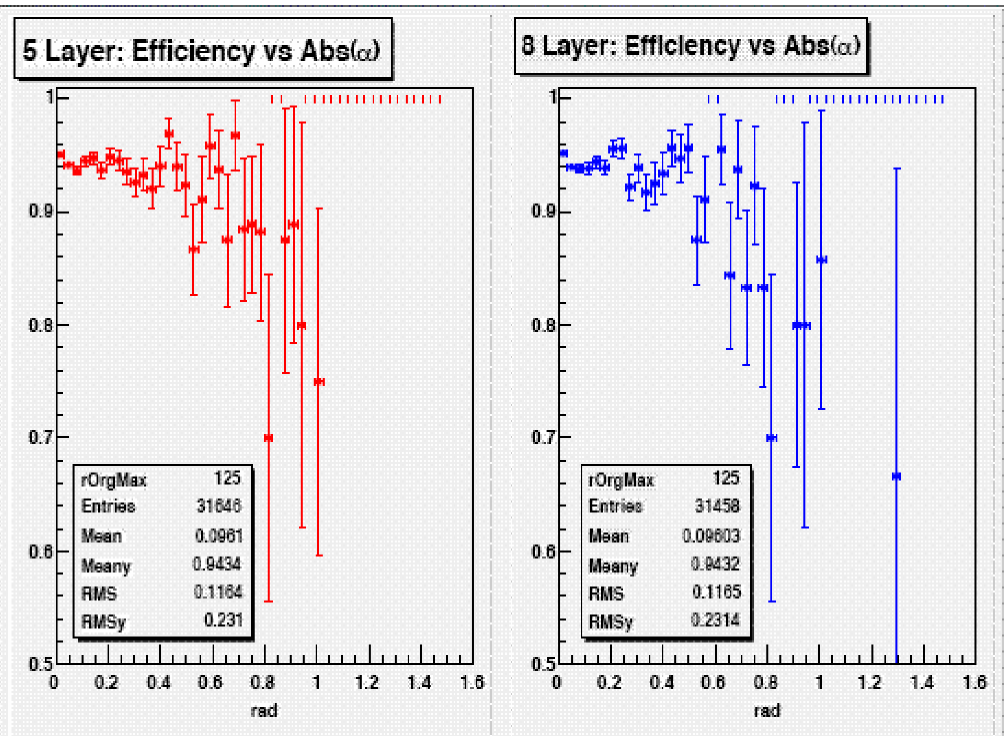
A Partial List of Questions

- What strip orientations should be employed in the forward disks
- Should the r < 20 cm region be entirely pixels?
- What is the tracking efficiency (overall, forward, core of jets, etc.)?
- What are the rates for fake/mis-measured tracks?
- How many crossings can the pixel detectors integrate over?
- How deep do the strip readout buffers need to be?
- Do we need stereo layers in the barrel strip tracker? Which layers?
- Do we have enough/too many layers?
- Do we need to fill the gap between the vertex and strip detectors?
- Can we efficiently find long-lived decays (K_S, Λ, long-lived b decays)?
- What is the impact of inefficiency/fakes on PFA/physics measurements?
- What is the impact of options that add material (stereo, more layers) on PFA/physics measurements?

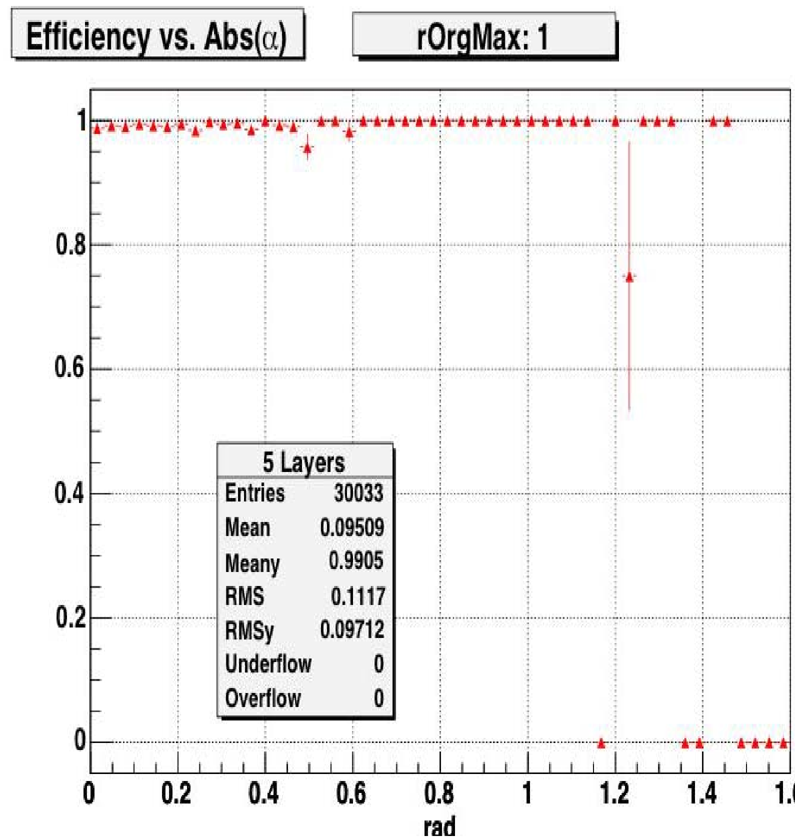
Some Encouraging Indications

- A variety of SiD tracking studies were performed using hep.lcd framework

All Tracks



Tracks originating inside beam pipe



Limitations of hep.lcd work

- SiD has moved to org.lcsim – need to port hep.lcd codes
- Vertex seeded tracking insensitive to design of outer tracker
- Tracker and/or calorimeter seeded algorithms needed to find long-lived tracks
- Hits for strip tracker were smeared MC hits – need true digitization code to get realistic hits

Tracking Simulation in org.lcsim

- Vertex detector hit digitization
  - Port of hep.lcd CCD digitization largely complete (Nick Sinev)
- Strip detector hit digitization
  - Charge deposition model largely complete (Tim Nelson)
- Track finding algorithms
  - 3D Seeds (RP)
  - Calorimeter seeded tracking algorithm largely ported (Dmitri Onoprienko, Eckhard von Toerne)
  - Stand-alone strip tracking (Tim Nelson)
  - Local track finding using TRF (Norman Graf)
  - Conformal mapping algorithm (Norman Graf)
- Track fitting, error estimation
  - Port of weight-matrix based fitter largely complete (Nick Sinev)
  - Kalman fitter (Norman Graf, Fred Blanc/Steve Wagner)

Seed Tracking Algorithm in hep.lcd

- Look at all combinations of hits in 3 vertex detector layers within fixed angle cuts
- Helix formed for each combination using the three r-ϕ measurements and inner+outer z measurements
- Check validity of helix
  - » Momentum cut
  - » Distance of Closest Approach (DCA) cut
  - » Require z measurement for middle layer to be on helix
- Swim track to other vertex/strip layers and find associated hits
- Check for duplicate track (>1 hit in common), pick better track (more hits, or better χ^2 if equal number of hits)
- Iterate using other layer combinations for seeds

Seed Tracking for org.lcsim

- Goal: port functionality of hep.lcd algorithm to org.lcsim
- Allow more general specification of tracking “scenarios”
  - » Each scenario specifies 3 layers to use in forming seed
  - » Seed layers can be from any layer with 3D measurements
  - » Allow seed layers to be in strip tracker by combining stereo layers pairs to form true and ghost 3D hits
  - » Each scenario specifies cuts on p_T, DCA, χ^2, minimum # layers, etc.
- Minimize/generalize parameters
  - » Example: limit hits considered in forming seeds to those that are within p_T, DCA cuts instead of angle cuts
  - » Example: use measurement resolution from the trackerhit and expected multiple scattering based on material traversed rather than parameterized resolutions in forming χ^2
- Status: helix finding largely done, need to swim to other layers and pick up additional hits, perform triage

Summary

- Baseline tracker design is implemented in org.lcsim
- Digitization code is fairly advanced
  - » CCD digitization largely complete
  - » Charge deposition model for strips largely complete, need to form hits
- A number of tracking algorithms are in various stages of development
  - » Inside out, outside in, strip-only, local tracking, etc.
- Fitting and error matrix code in progress
  - » Weight-matrix approach largely complete
  - » Kalman fitting under development
- Early results indicate that ~10 measurements with superb resolution/two hit resolution are sufficient to find tracks and reject backgrounds in the linear collider environment