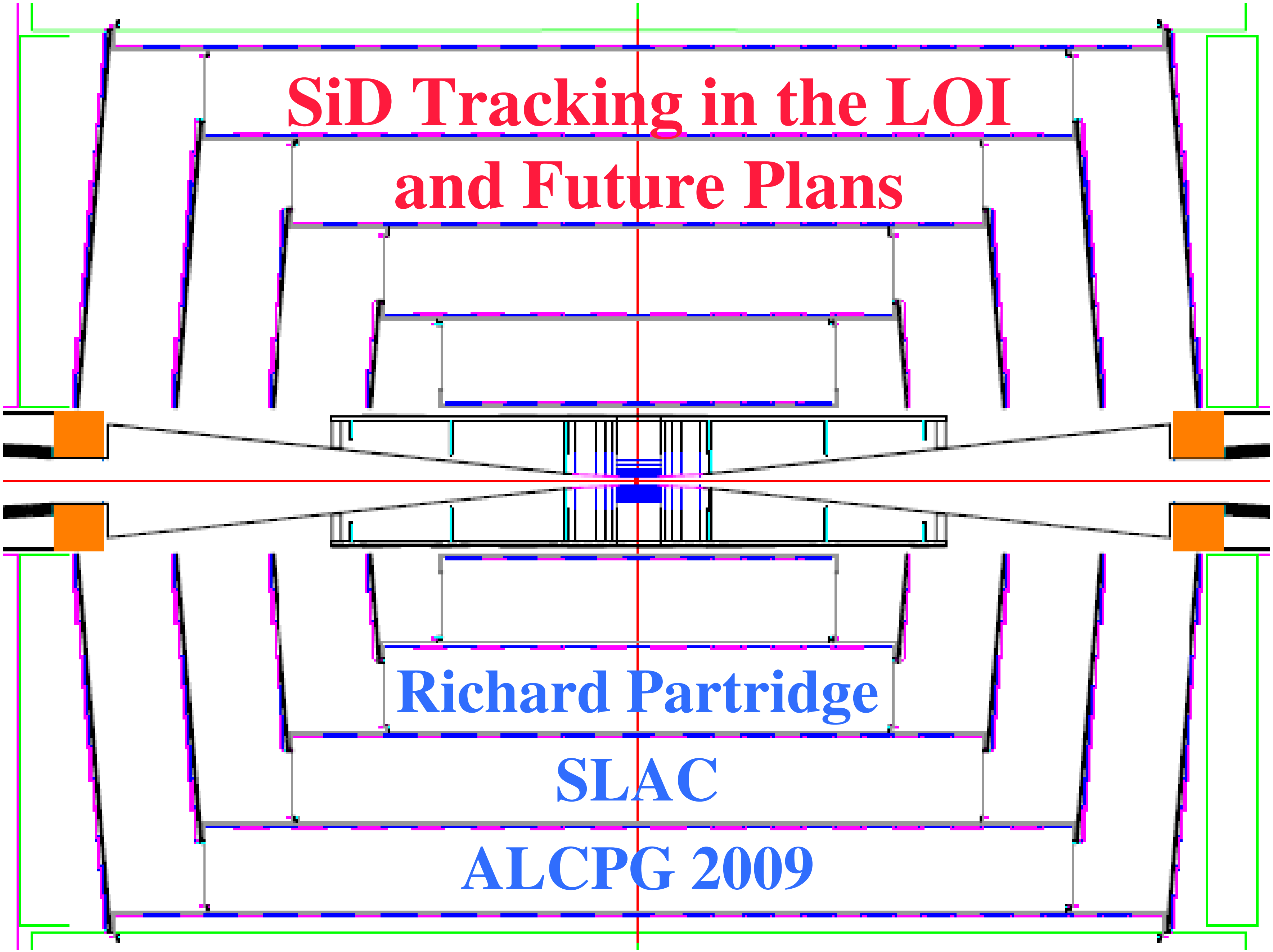
SiD Tracking in the LOI and Future Plans



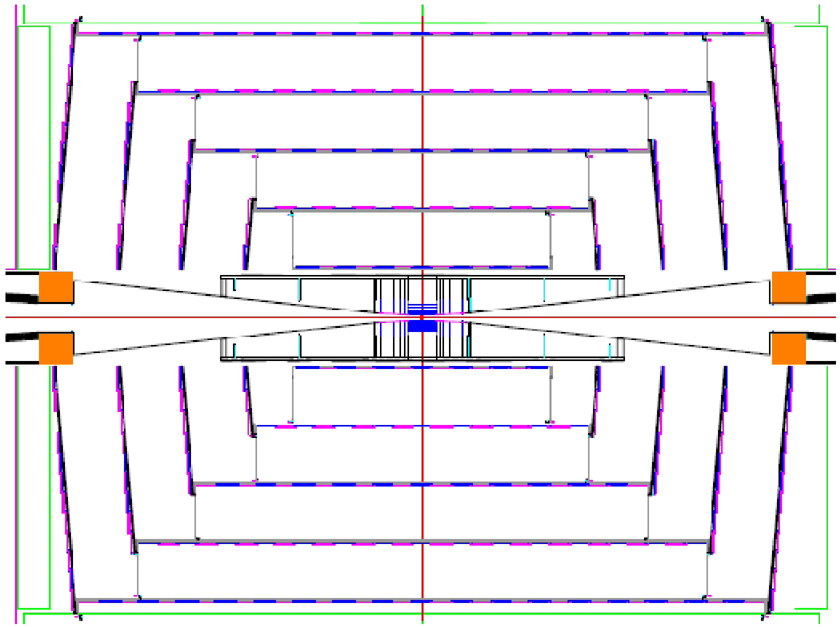
Richard Partridge

SLAC

ALCPG 2009

Overview

- LOI shows good tracking performance for baseline SiD tracker
  - 5 barrel + 7 disk pixel inner vertex detector
  - 5 barrel (axial strip) + 4 disk (stereo strip) outer detector
  - ~10 precision hits per track

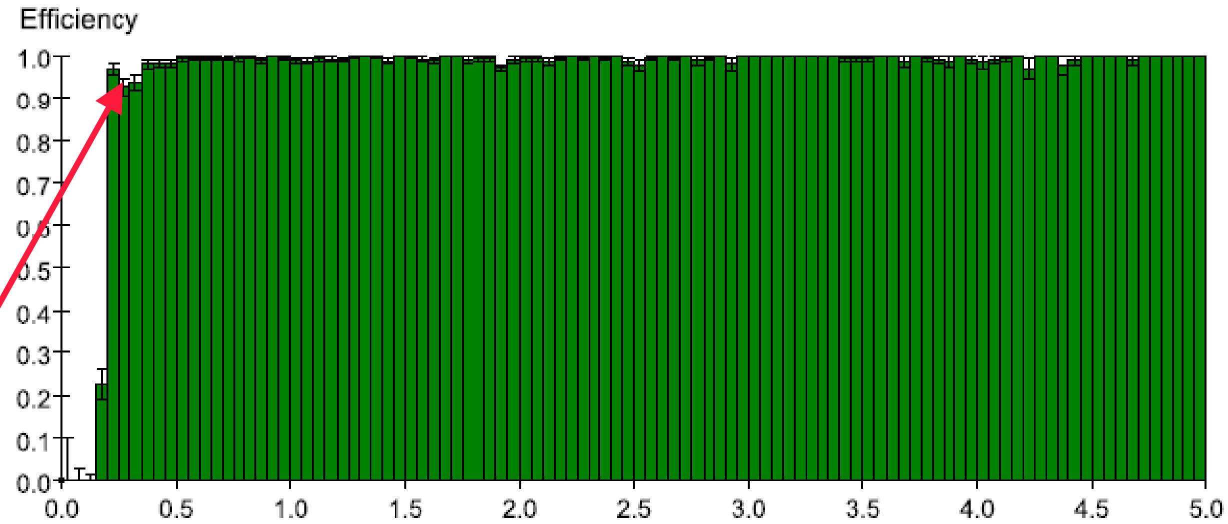


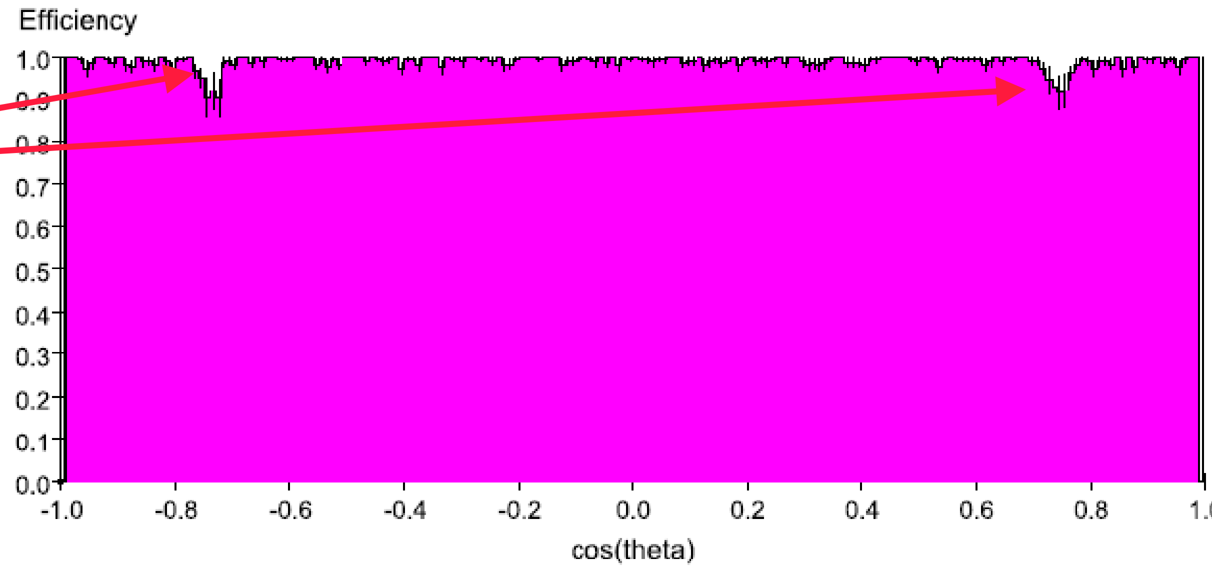
Goals:

- Provide quick review of LOI performance studies
- Describe new efforts to improve fidelity of tracking simulations

Tracking Efficiency vs p_T, $\cos(\theta)$

- Generally find high tracking efficiency for tracks with:
  - $p_T > 0.2$ GeV
  - $|\cos(\theta)| < 0.99$

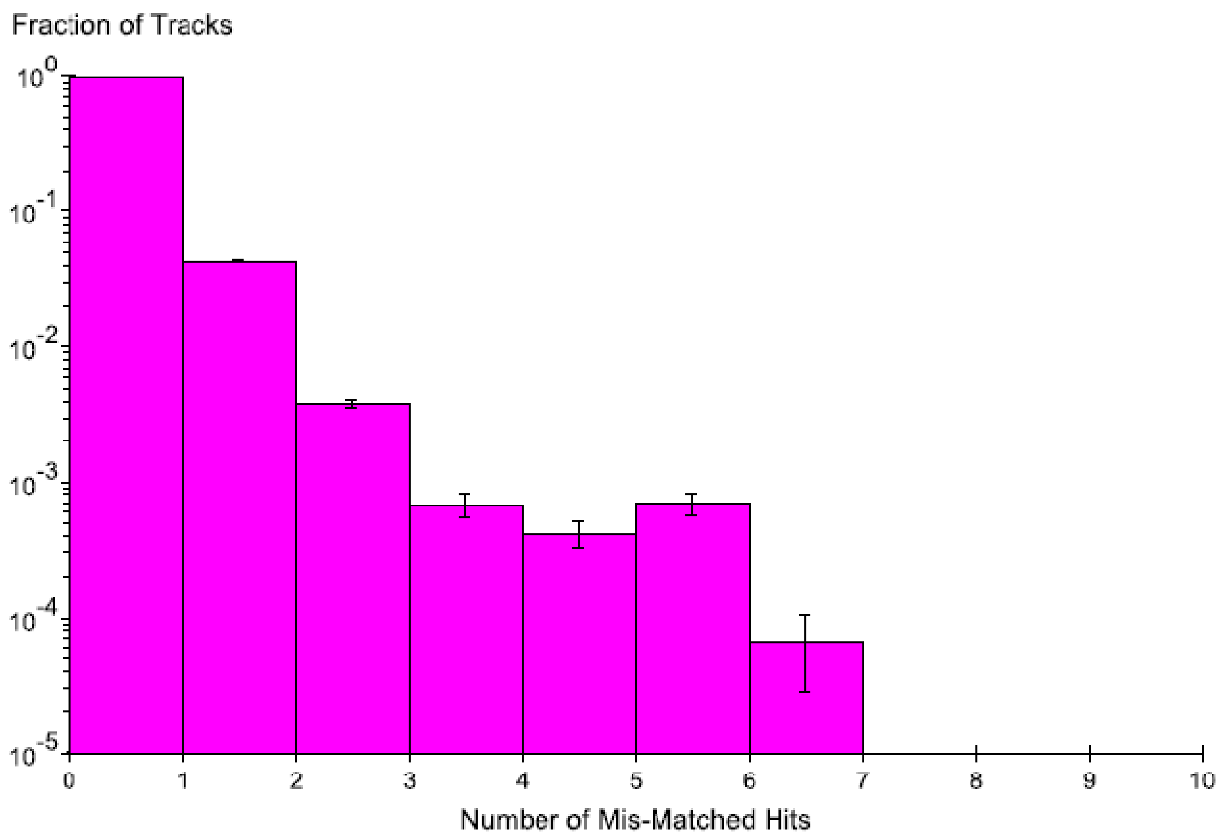




Dip in efficiency for low-p_T tracks in barrel/endcap transition region is an artifact that will be eliminated in future studies

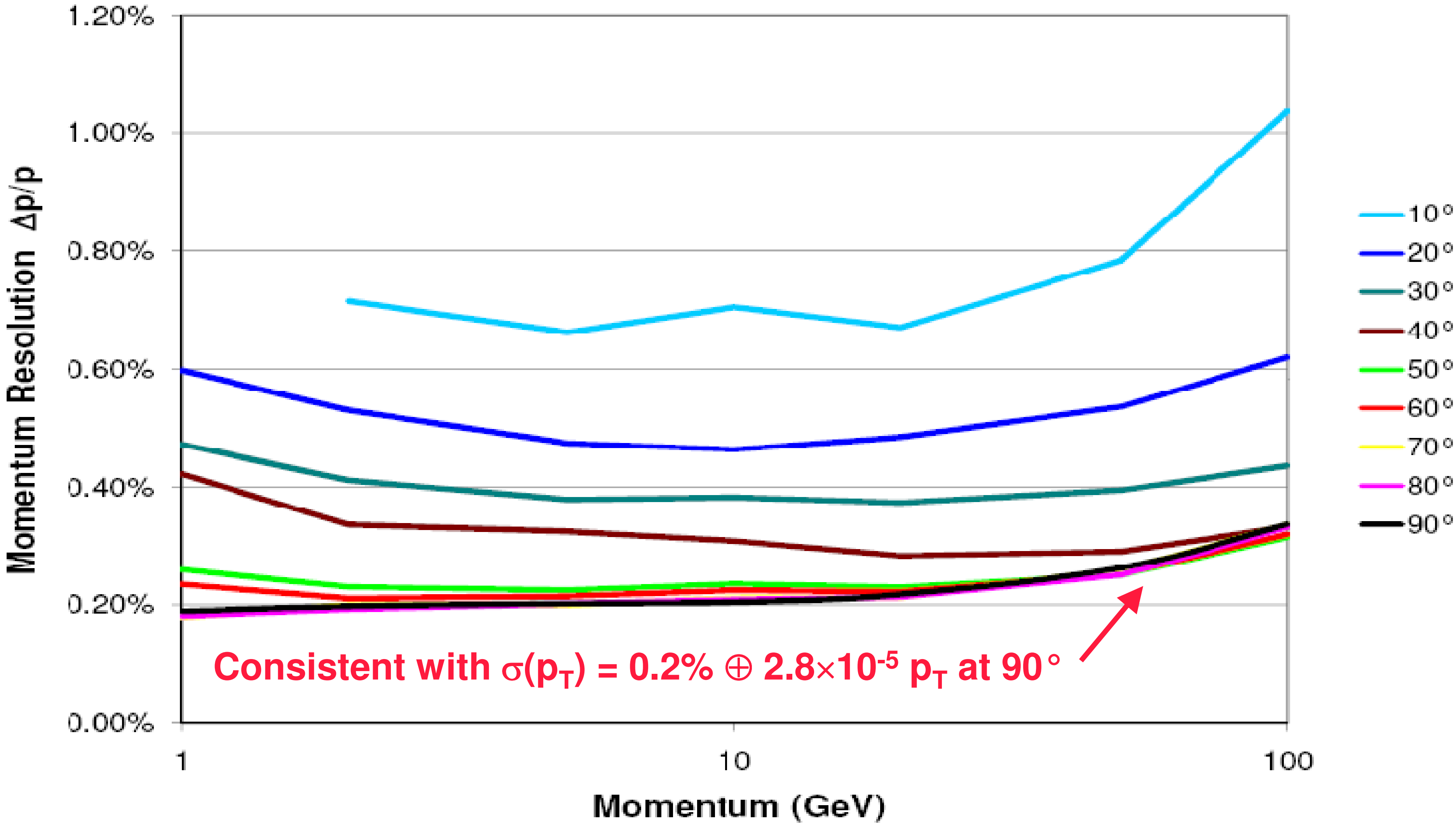
Comparison with MC Truth

- We identify which MC particles are associated with each hit
- Assign track to the MC particle that contributes the most hits
- Find how many hits on the track are from other MC particles
- >99% of tracks have ≤1 mis-assigned hits, ~0.07% fake tracks



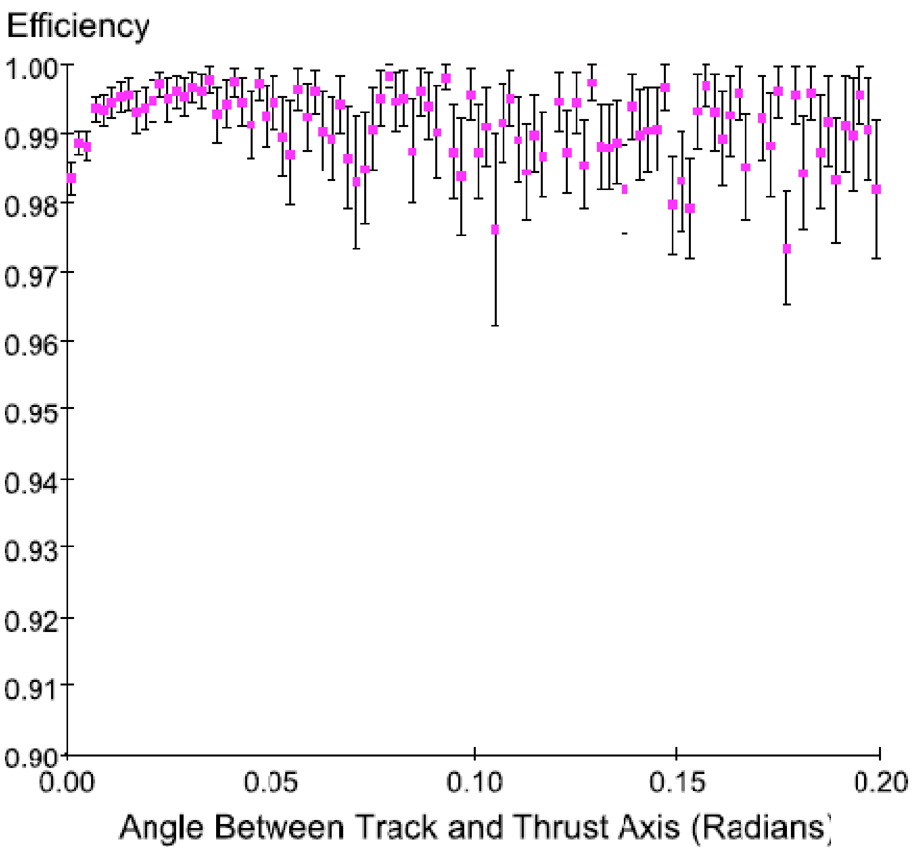
Momentum Resolution

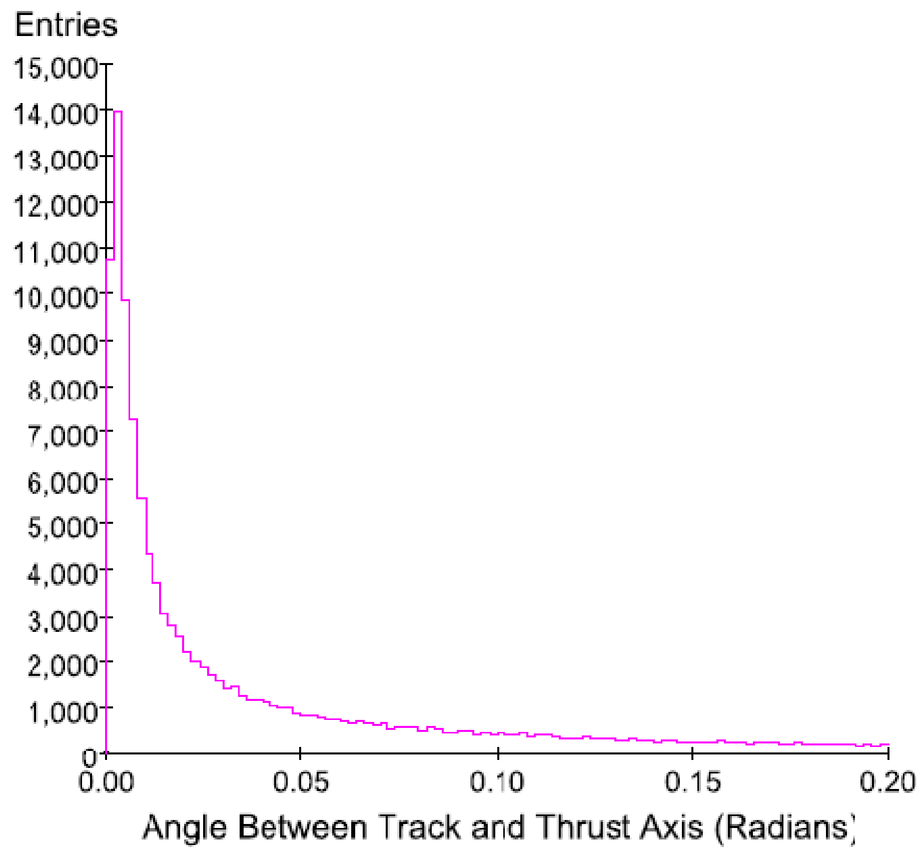
- Good momentum resolution everywhere!



Tracking Efficiency in Core of Jets

- Look at tracking efficiency vs angle between track and thrust axis for 1 TeV *qq* events
- See high tracking efficiency even in core of high energy jets





SiD Tracking Road Map

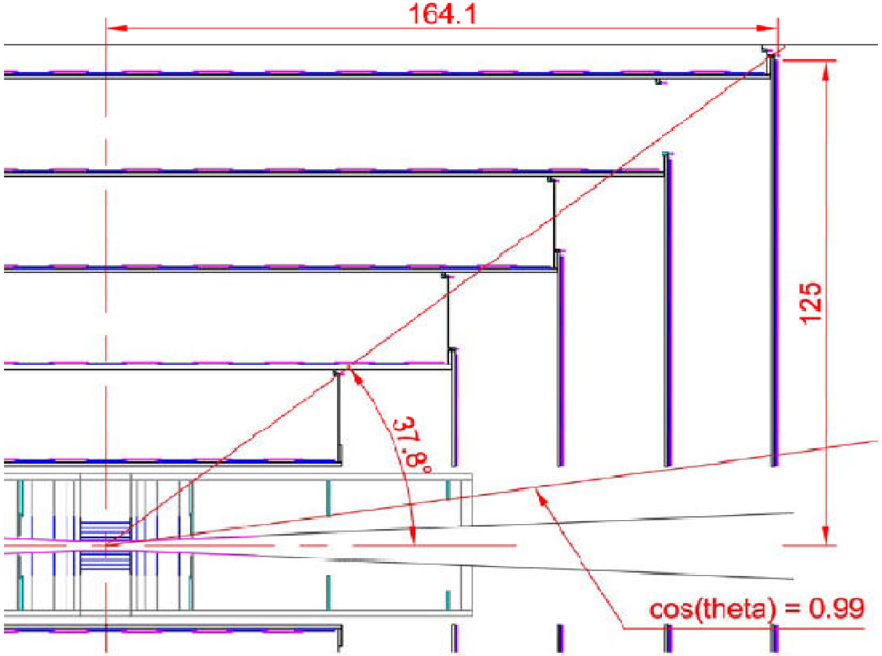
LOI Implementation

- Include all active and dead material in tracker geometry
- Virtual segmentation divides cylinders / disks into sensors
- No overlapping sensors, gaps
- No charge deposition modeling
- Simple clustering to make hits
- 3D stereo hits formed for forward disks including ghost hits
- SeedTracker and Calorimeter Assisted Tracking algorithms
- Simple helix fitter used for pattern recognition and final track fit (no multiple scattering correlations, circle + s-z fits)

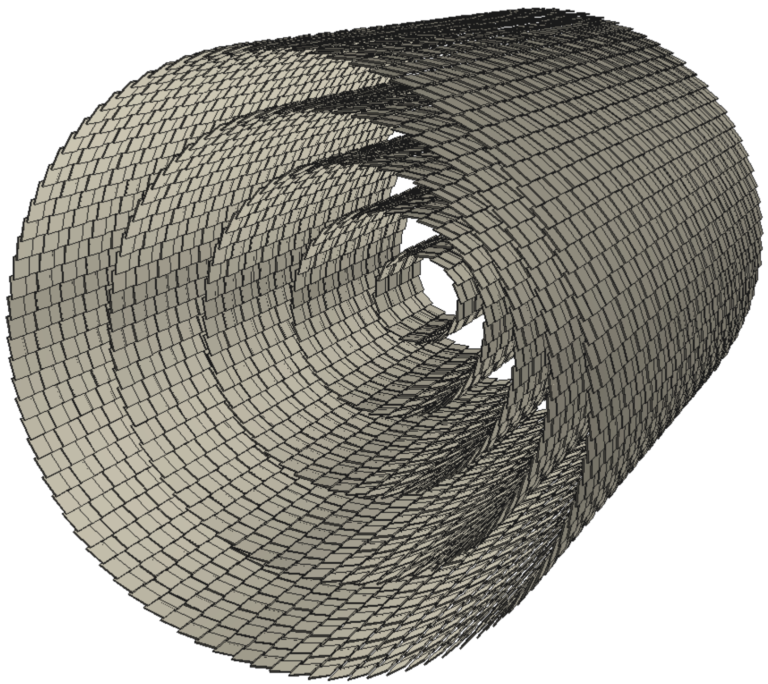
Post-LOI Goal

- Update material as needed to reflect changes in tracker design
- Individual planar sensors to match detailed geometry
- Overlapping sensors, realistic gaps
- Realistic charge deposition
- Improved clustering / hit making
- 3D stereo hits formed for forward disks including ghost hits
- Incremental improvements in algorithms – no big changes
- Continue to use simple helix fitter for pattern recognition, long term goal is to implement a Kalman filter for final track fit

Switch to Planar Geometry



LOI geometry consisted of cylinders and disks with virtual segmentation



New geometry models each silicon sensor – SiD has rectangular detectors in barrel, trapezoidal detectors in endcaps

Richard Partridge

Compact XML Description

- Simple but versatile description of geometry
  - Barrel geometry with overlapping sensors

```
<layer module="SiTrackerModule_Layer1" id="1" vis="SiTrackerBarrelLayerVis">
  <barrel_envelope inner_r="215.075" outer_r="245.0" z_length="578 * 2" />
  <rphi_layout phi_tilt="0.17506" nphi="20" phi0="0." rc="216.355 + 5.0" dr="0.0" />
  <z_layout dr="4.0" z0="512.128" nz="13" />
</layer>
```

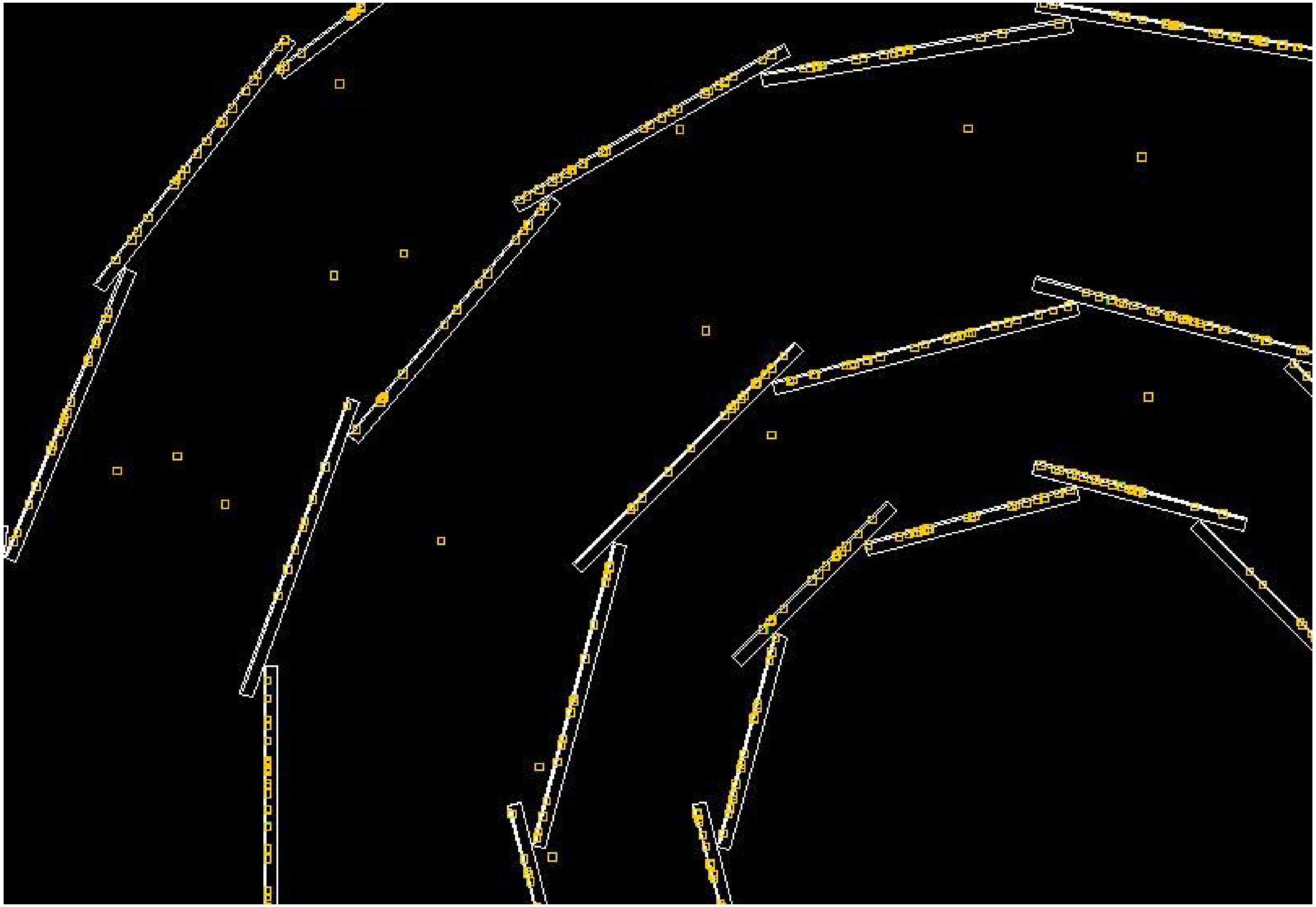
  - Endcap geometry with rings of sensors

```
<layer id="1">
  <ring r="256.716" zstart="787.105+1.75" nmodules="24" dz="1.75" module="Module1" />
  <ring r="353.991" zstart="778.776+1.75" nmodules="32" dz="1.75" module="Module1" />
  <ring r="449.180" zstart="770.544+1.75" nmodules="40" dz="1.75" module="Module1" />
  </layer>
```

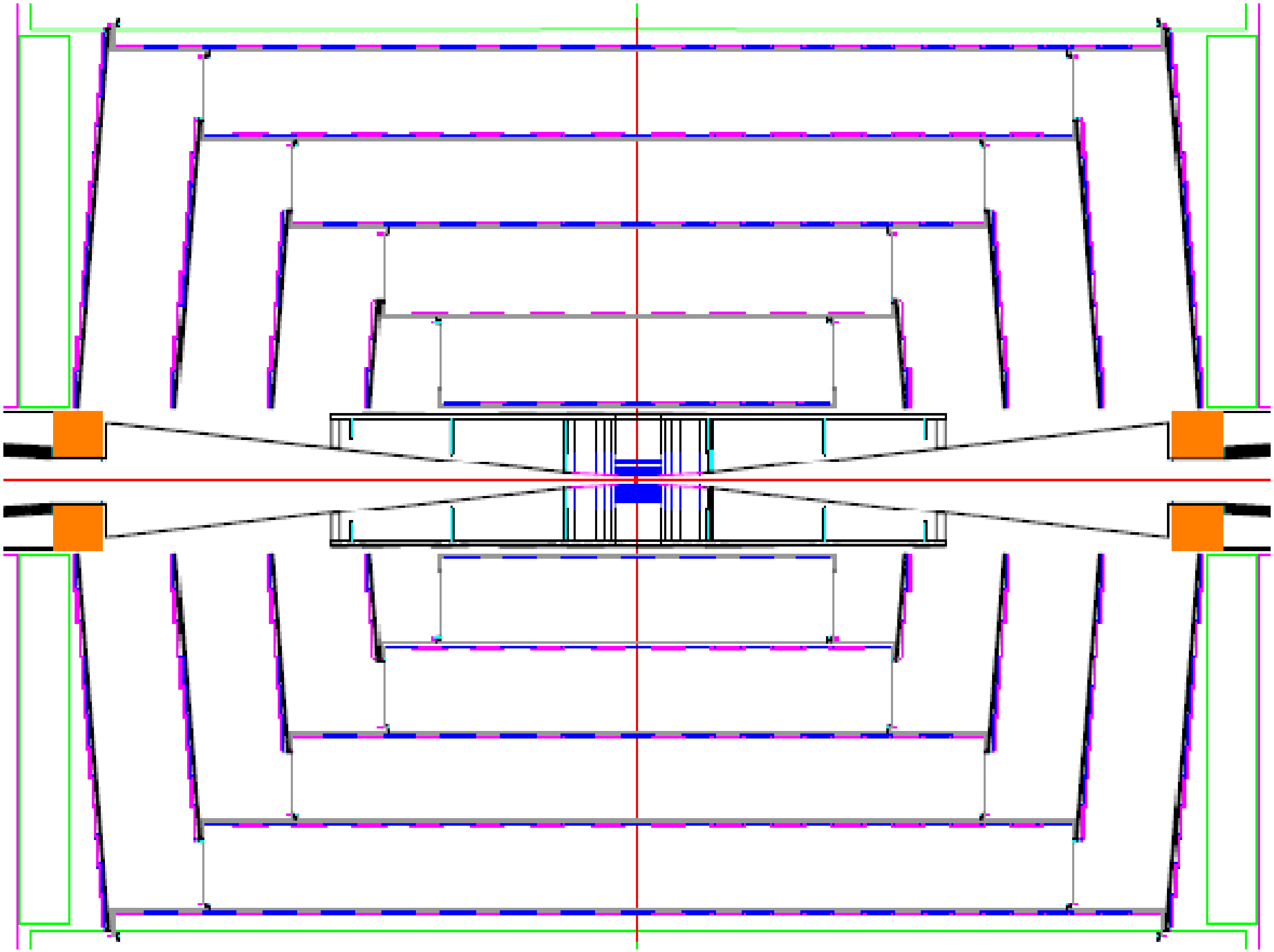
- Additional XML blocks define module geometry, layering, and materials

Realistic Detector Geometry

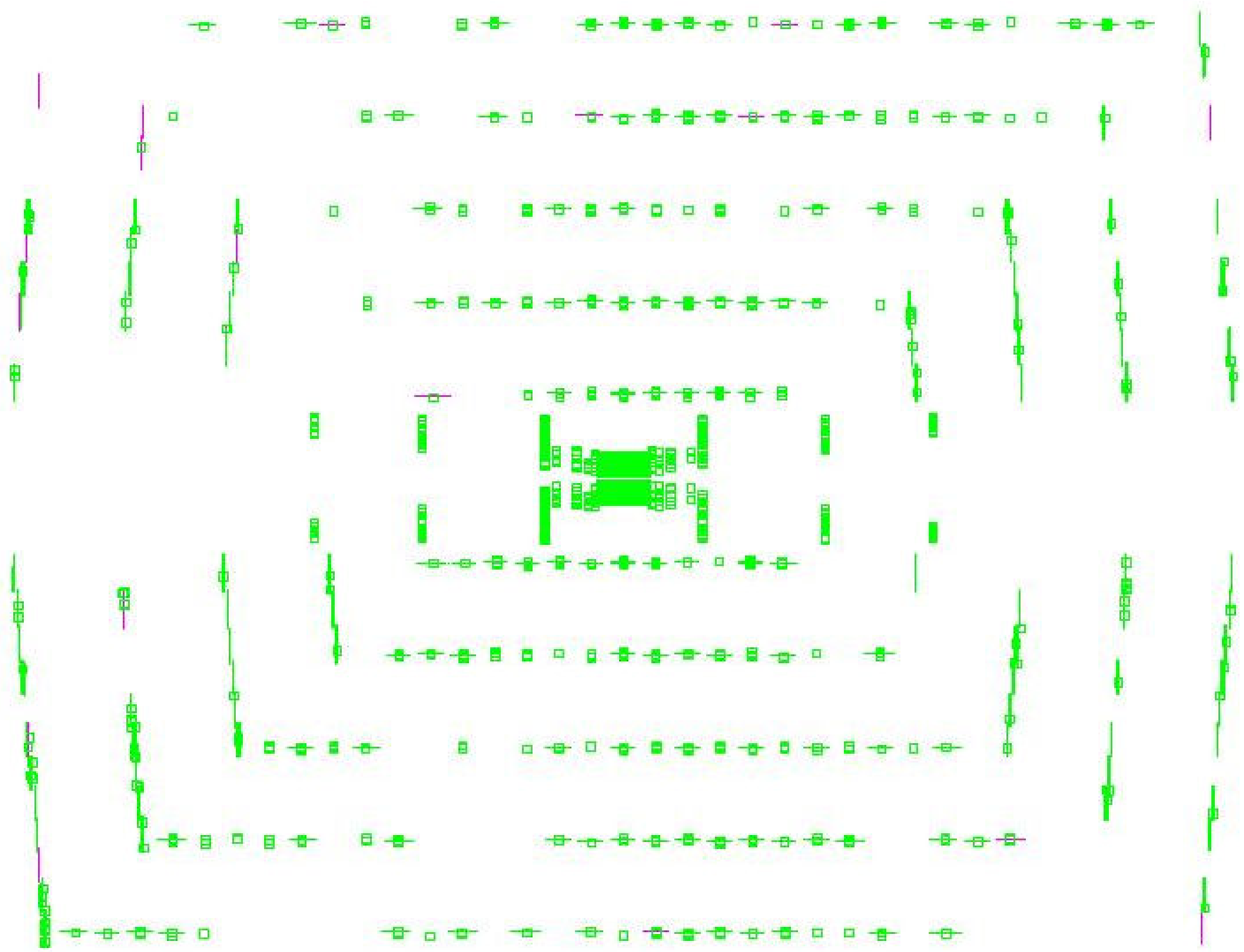
- Blow-up of vertex detector showing hits on planar sensors



SiD LOI Geometry – CAD Drawing



SiD LOI Geometry – Event Display



New Hit Digitization

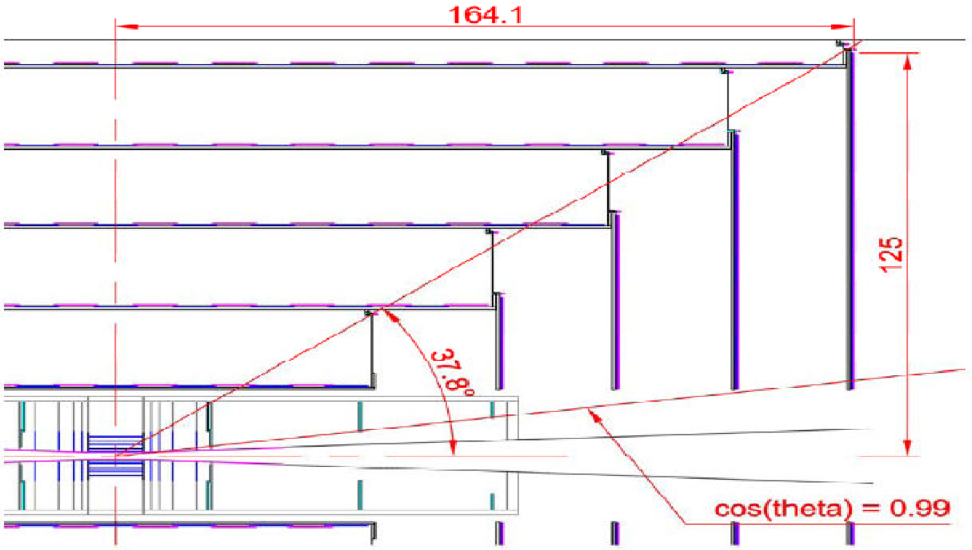
- Charge deposition for strip detectors based on CDF Si sensor simulation algorithm implemented by Tim Nelson
  - Track sub-divided into segments
  - Each segment drifted to sensor electrodes accounting for Lorentz angle
  - Charge for segment divided among electrodes accounting for diffusion
  - Charge transferred from sensor electrodes to readout electrodes as established by a charge transfer matrix – provides way to include capacitive coupling to intermediate and neighbor
- Charge deposition for pixel detectors can use either the strip simulation algorithm or a detailed modeling using electric field maps developed by Nick Sinev
- Strip/pixel charges clustered by a nearest neighbor algorithm
  - Hash maps used to achieve approximately linear scaling of clustering time with number of hits, even with large numbers of hits
- Form tracker hits from clusters with expected hit errors

Track Finding

- No significant changes to track finding algorithm
  - See LOI and RP talk at 2008 LCWS for details of tracking algorithm
- Some structural/implementation changes to improve tracking performance, especially with large numbers of hits
  - Using lcsim software to study sATLAS tracker upgrade with ~2M hits/xing
- To run tracking with the new geometry and digitization code required a new set of strategies
  - Strategies used to guide track reconstruction
  - Specify p_T and impact parameter constraints and χ^2 cuts
  - Specify layers to be used for a given strategy and role of each layer (seed, confirm, or extend)
- Used strategy builder on a high-p_T muon sample to automatically construct strategies

Strategy Builder

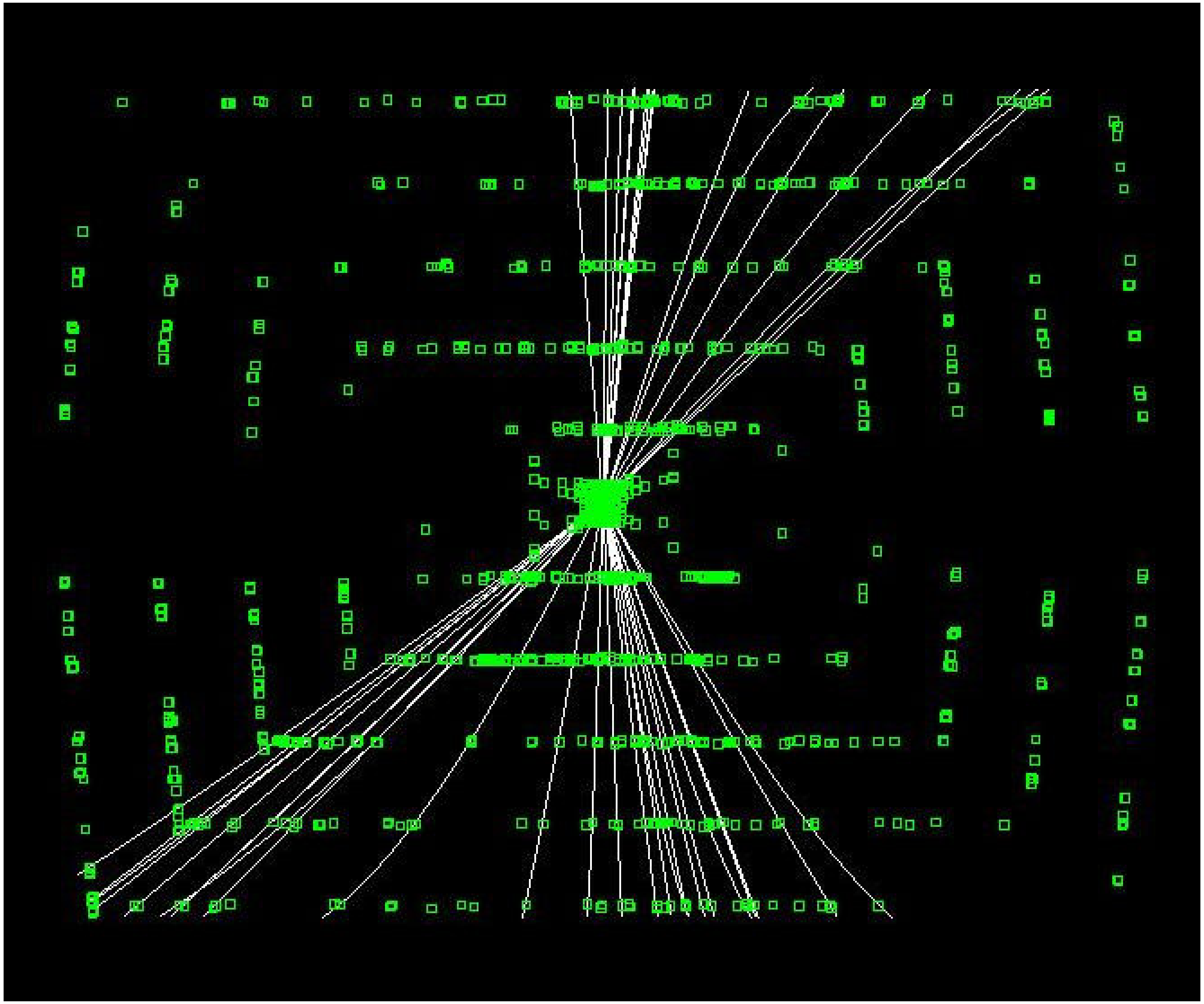
- Finding an optimal set of strategies that provides complete coverage turns out not to be so easy
  - Many distinct sets of layers are required, especially in the forward region
  - Requires carefully examining possible track paths looking for coverage holes
  - Typically need ~20 strategies to have full coverage for baseline tracker design to find ≥7 hit tracks with $p_T > 1.0$ GeV for 100% detector efficiency
- Strategy list needs to be re-optimized whenever:
  - Change detector geometry
  - Change helix cutoffs
  - Change number of hits required



- Strategy Builder automates creation of optimized strategy list

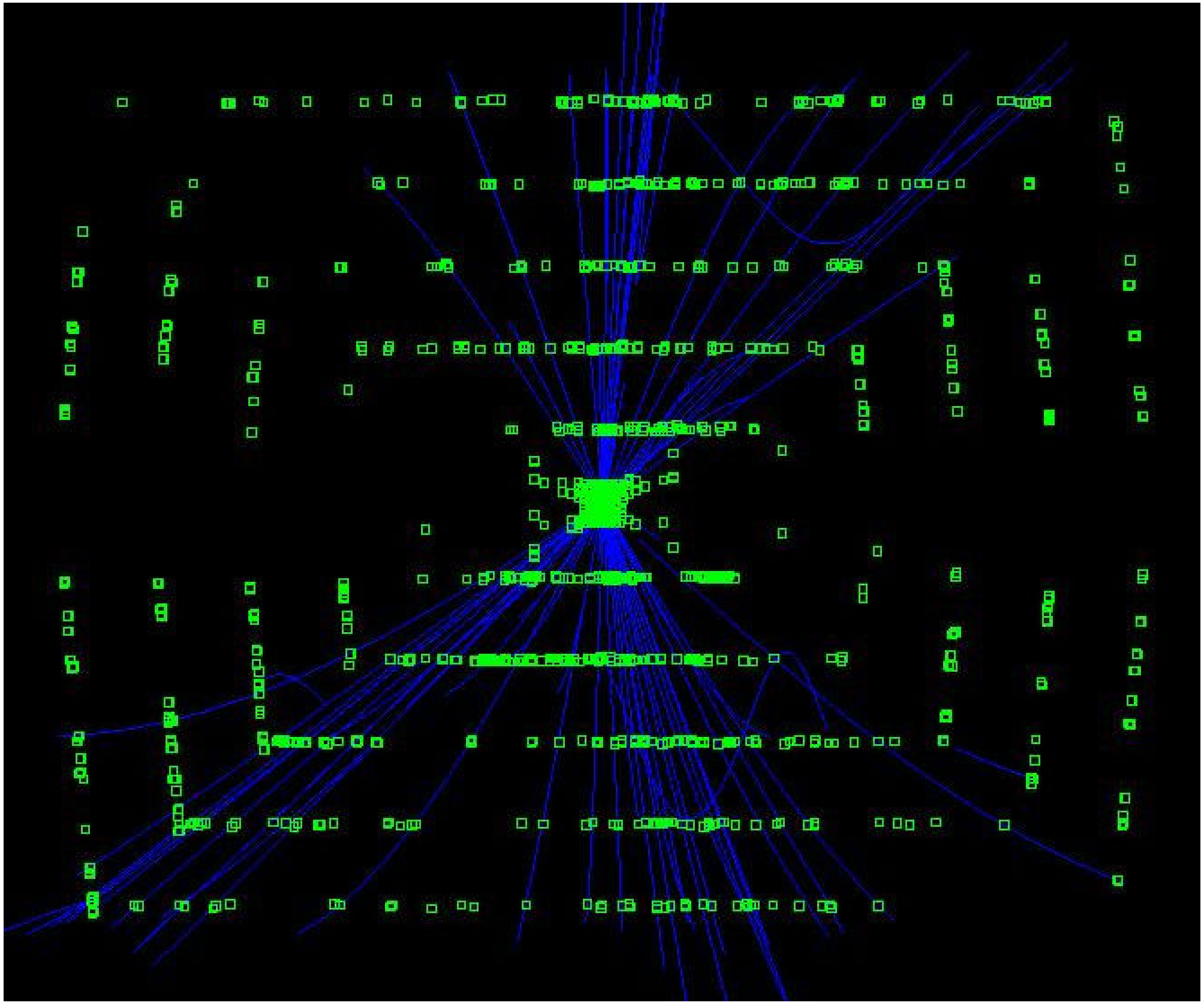
Track Reconstruction

- Reconstructed tracks for a typical *tt* event at E_{CM} = 500 GeV



Compare to MC Generated Tracks

- Generated tracks for a typical *tt* event at E_{CM} = 500 GeV



Summary

- SiD has characterized tracking performance using detailed GEANT simulations with full track reconstruction
- >99% tracking efficiency for findable tracks
  - Findable tracks in this study have $p_T > 0.2$ GeV, <1 cm impact parameter
- High tracking efficiency over full solid angle
  - Tracking coverage extends to $|\cos(\theta)| \sim 0.99$
  - Uniform efficiency except for dip in efficiency for low p_T tracks at barrel-disk transition – further work needed here
- <1% of tracks have >1 mis-assigned hit, fake rate ~ 0.07%
- Excellent track parameter resolution
- Excellent tracking performance maintained in core of high energy jets and in events with 10x expected background
- First try at reconstructing tracks using planar sensor geometry and detailed hit digitization looks promising