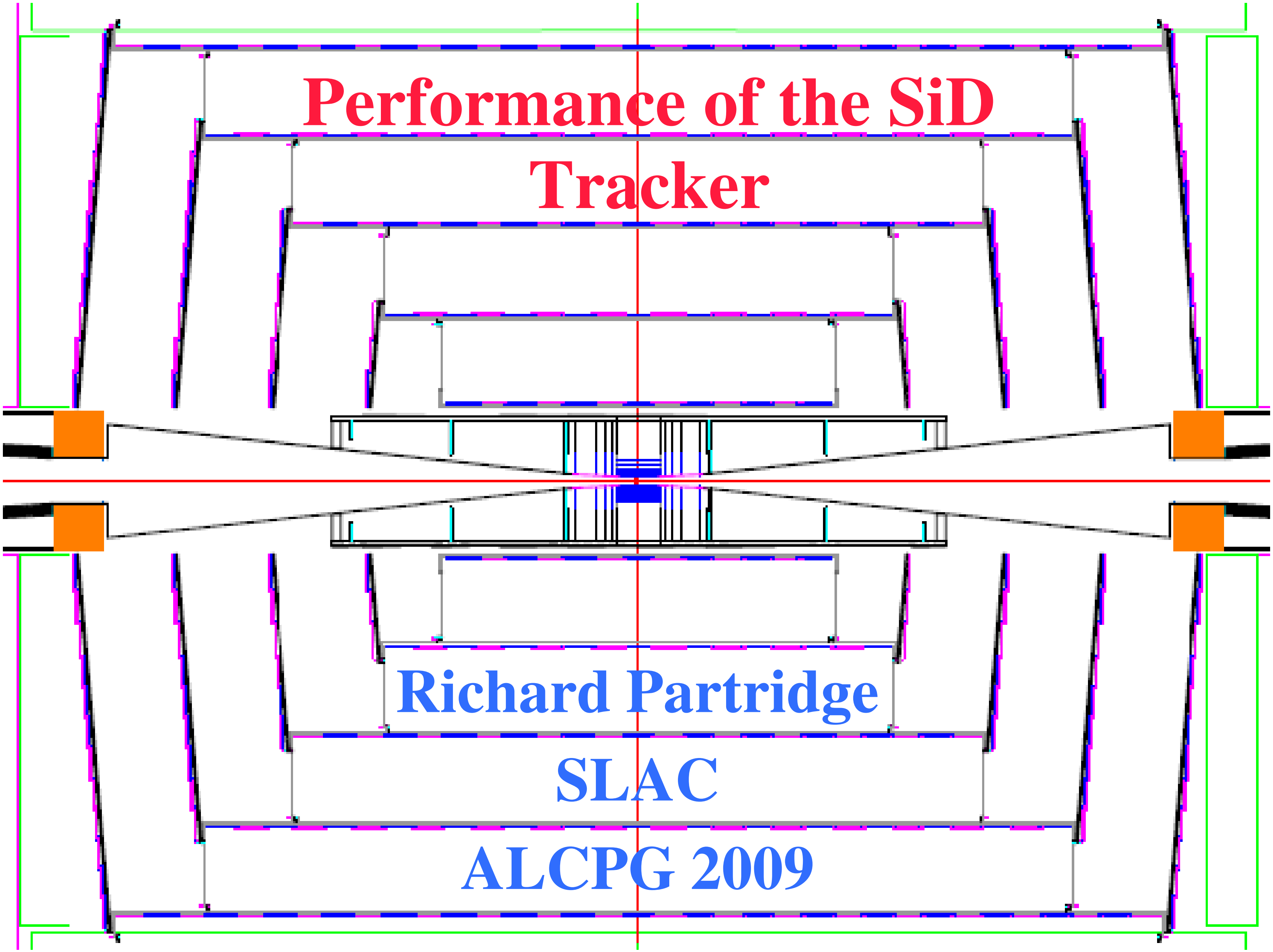
Performance of the SiD Tracker



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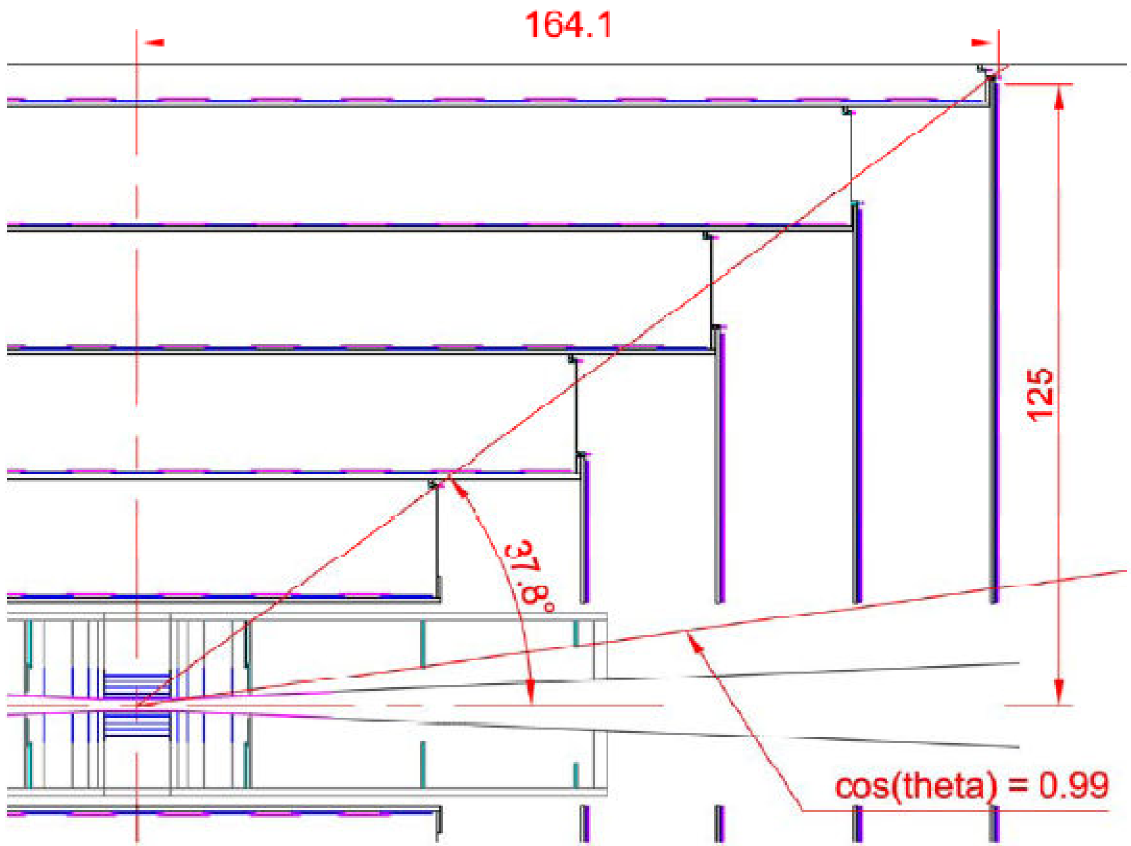
Overview

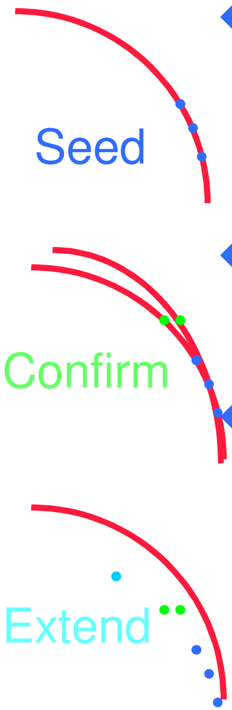
- SiD has an all-Silicon Tracker
  - 5 barrel + 7 disk pixel inner vertex detector
  - 5 barrel (axial strip) + 4 disk (stereo strip) outer detector
  - ~10 precision hits per track



Measuring Tracker Performance

- This talk focuses on the tracker performance reported in the SiD Letter of Intent
- Performance was determined using detailed simulation of the SiD tracker using GEANT to simulate detector response
- For LOI, SiD modeled tracker as cylinders and disks
  - "Virtual Segmentation" used to divide cylinder/disk into individual sensors
  - "Planar Detector" with individual silicon sensors and detailed simulation of charge deposition / hit clustering has recently been made available
- Track finding code (seedtracker) used to reconstruct tracks
  - Results presented here only use information from the tracker – see Dima Onoprienko's talk for Calorimeter Assisted Tracking
- All software (except for GEANT) is based on the Java-based lcsim software distribution

SeedTracker Algorithm



- Track finding begins by forming all possible 3 hit track seeds in the three "Seed Layers"
  - Brute force approach to finding all possible track seeds
- Require the presence of a hit in a "Confirmation Layer"
  - Significantly reduces the number of candidate tracks to be investigated
- Add hits to the track candidate using hits on the "Extension Layers"
  - Discard track candidates with fewer than 7 hits (6 hits for barrel only tracks)
  - If two track candidates share more than one hit, best candidate is selected
- Upon each attempt to add a hit to a track candidate, a helix fit is performed and a global χ^2 is used to determine if the new track candidate is viable

Track Finding Strategy

- The user interacts with the track reconstruction program by specifying one or more "strategies"
- For the LOI, we used strategies that required:
  - At least 7 hits on the track
    - Only 1 hit per layer
    - Special barrel only strategy with 6 hits used to pick up low-p_T particles in the central region
  - $p_T > 0.2$ GeV
  - r - ϕ and s - z impact parameter cuts $|d_0| < 1$ cm and $|z_0| < 1$ cm
  - $\chi^2 < 50$ ($\chi^2 < 25$ for 6-hit barrel only strategy)
- "Strategy Builder" used to find optimized sets of seed and confirm layers used for efficient track finding
- Unless otherwise noted, tracking performance results that follow are for *tt* events at $E_{cm} = 500$ GeV

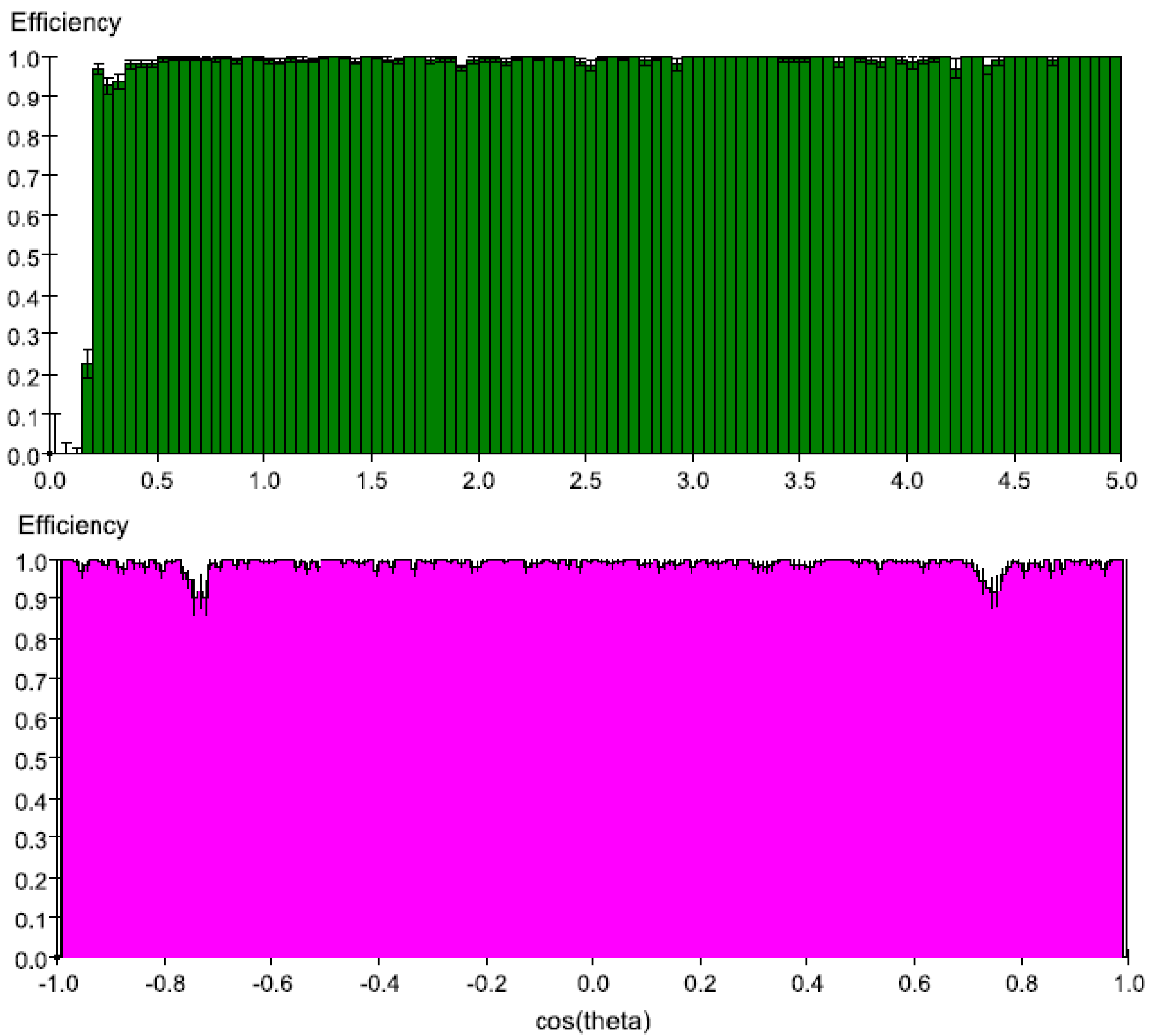
Tracking Efficiency

- Track reconstruction algorithm has >99% efficiency for "findable" tracks that pass momentum and impact parameter cuts and have at least 6 hits

Selection	Selection Efficiency	Cumulative Efficiency
All Tracks	-	100%
$p_T \geq 0.2$ GeV	$(93.54 \pm 0.11)\%$	$(93.54 \pm 0.11)\%$
$N_{hit} \geq 6$	$(90.91 \pm 0.13)\%$	$(85.04 \pm 0.16)\%$
Seed Hits Present	$(99.78 \pm 0.02)\%$	$(84.85 \pm 0.17)\%$
Confirm Hit Present	$(99.95 \pm 0.01)\%$	$(84.84 \pm 0.17)\%$
$\|d_0\| \leq 1$ cm	$(99.80 \pm 0.02)\%$	$(84.65 \pm 0.17)\%$
$\|z_0\| \leq 1$ cm	$(99.69 \pm 0.03)\%$	$(84.39 \pm 0.17)\%$
Track Reconstruction	$(99.32 \pm 0.04)\%$	$(83.81 \pm 0.17)\%$

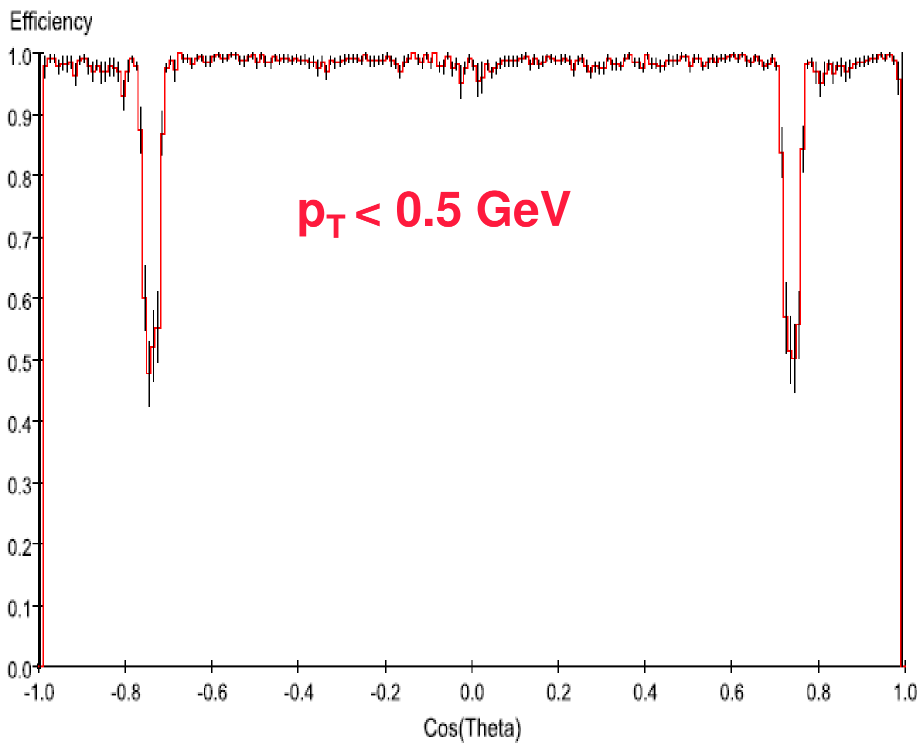
Tracking Efficiency vs p_T, cos(θ)

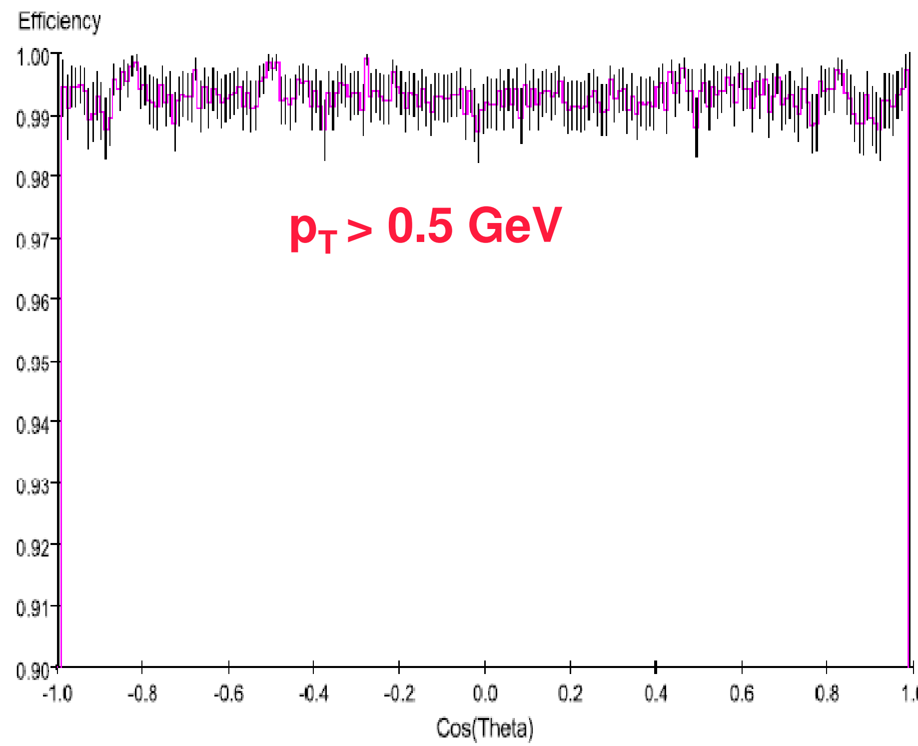
- Generally find high tracking efficiency for tracks with:
  - $p_T > 0.2$ GeV
  - $|\cos(\theta)| < 0.99$



Efficiency at Barrel / Endcap Transition

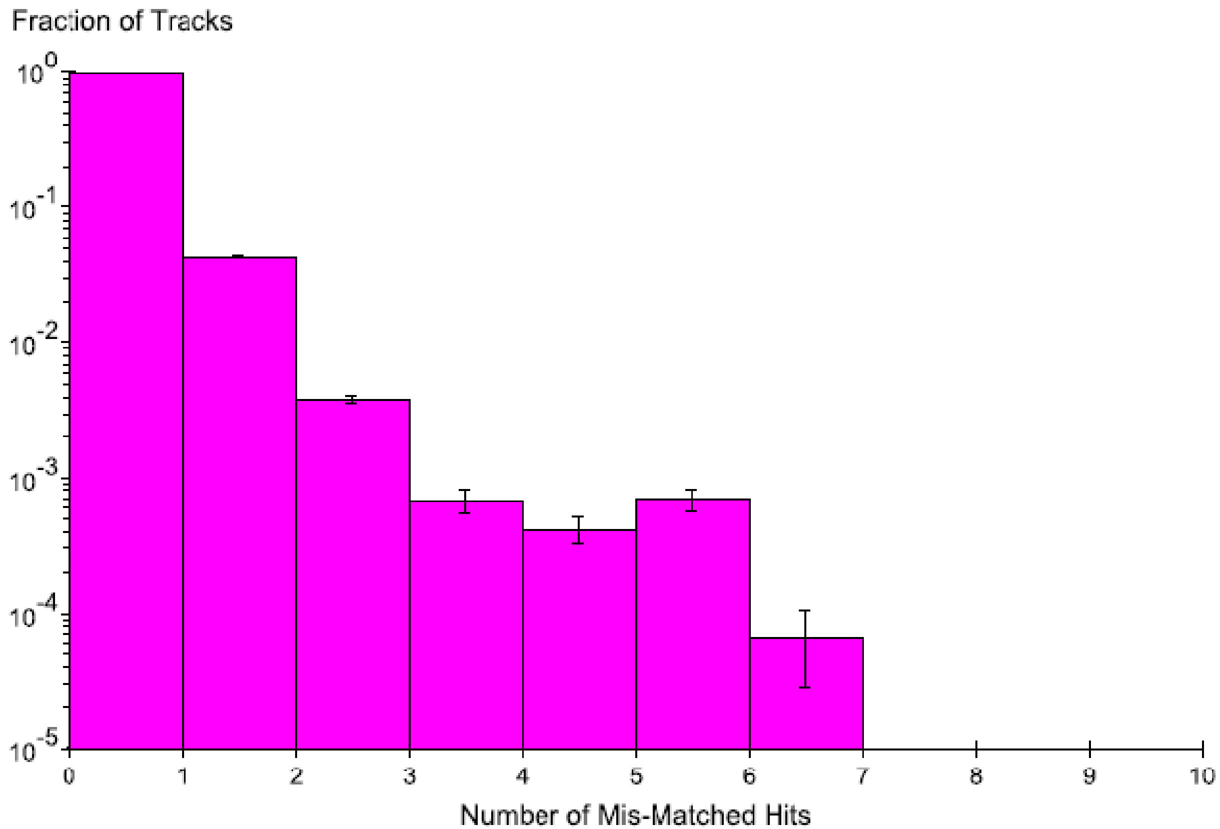
- Observe a drop in efficiency for low p_T tracks in the barrel / endcap transition region
  - Believed to be due to tracks that curl by >180° between barrel and disk layers
  - Expect that further optimization of strategies / tracking algorithm will eliminate this dip





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

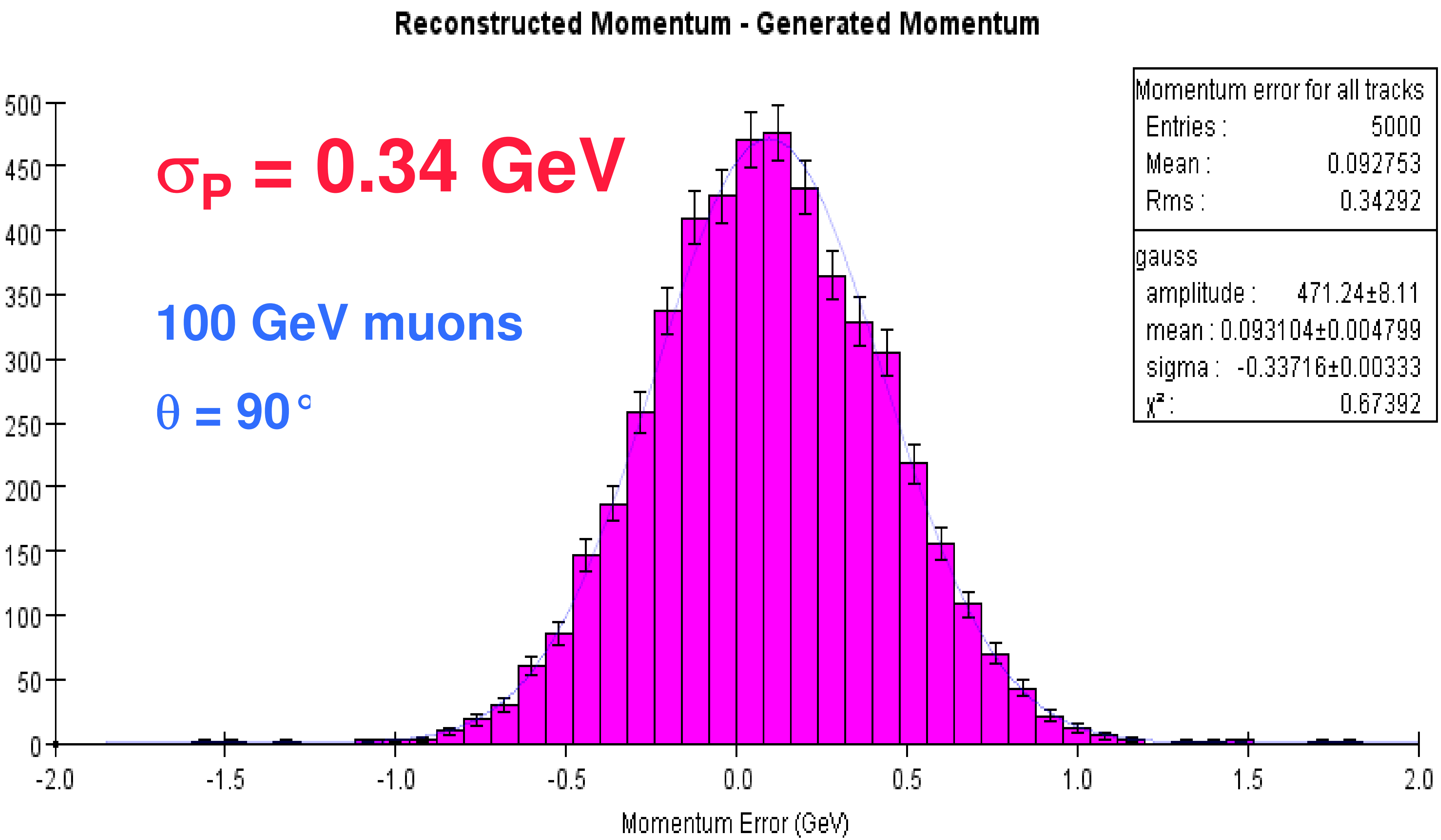


Momentum Resolution

$\sigma_P = 0.34$ GeV

100 GeV muons

$\theta = 90°$

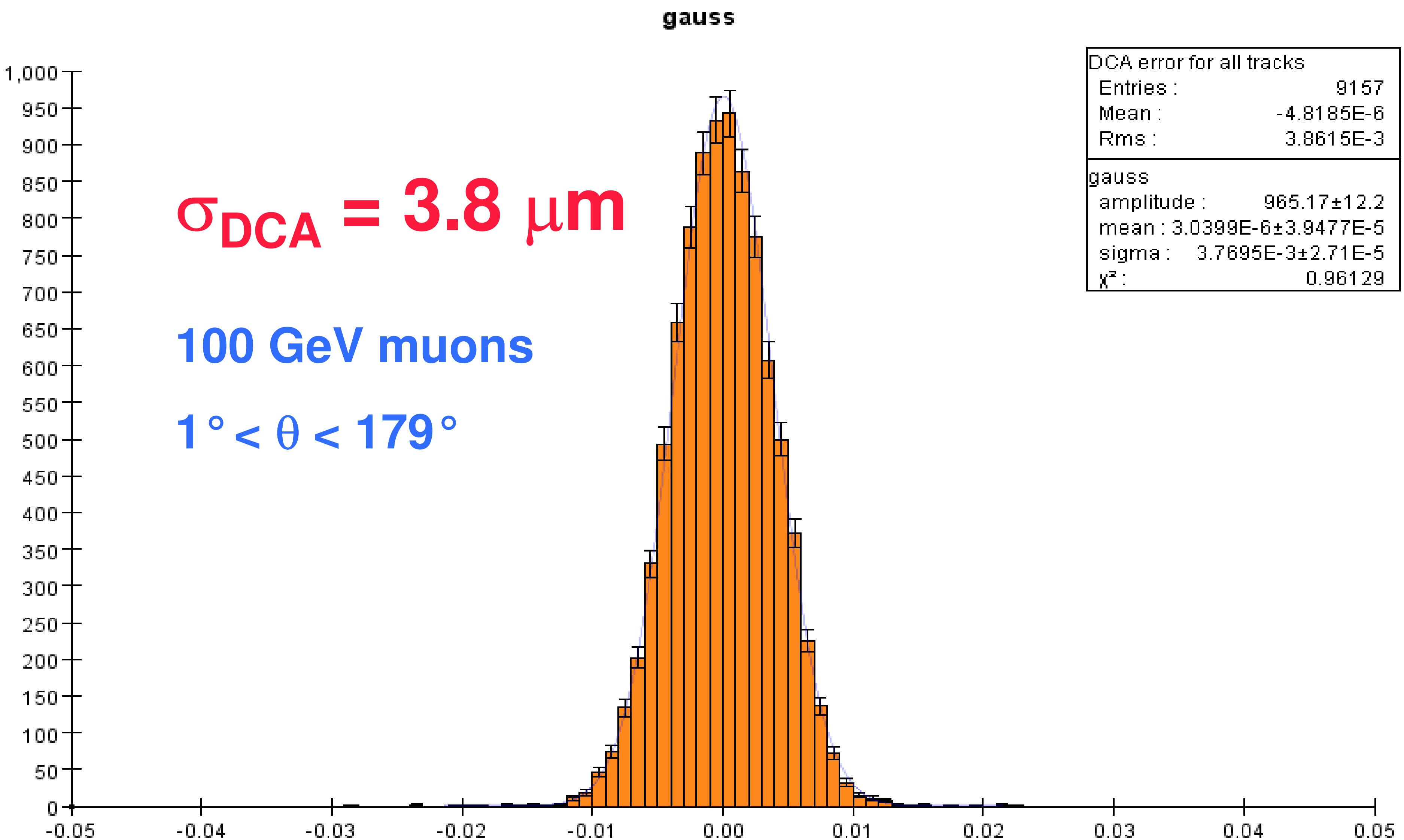


DCA Resolution

σ_{DCA} = 3.8 μm

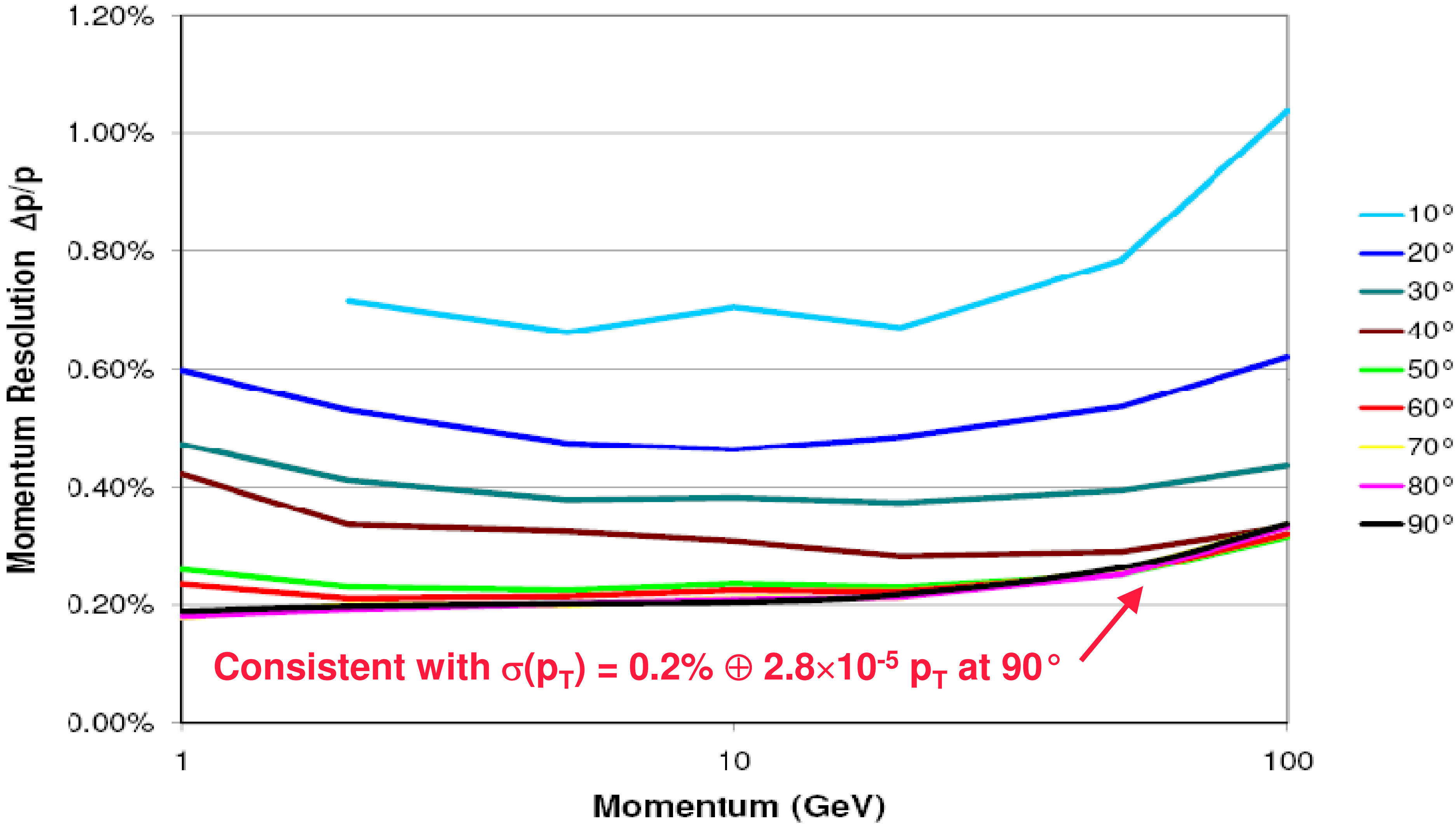
100 GeV muons

1° < θ < 179°



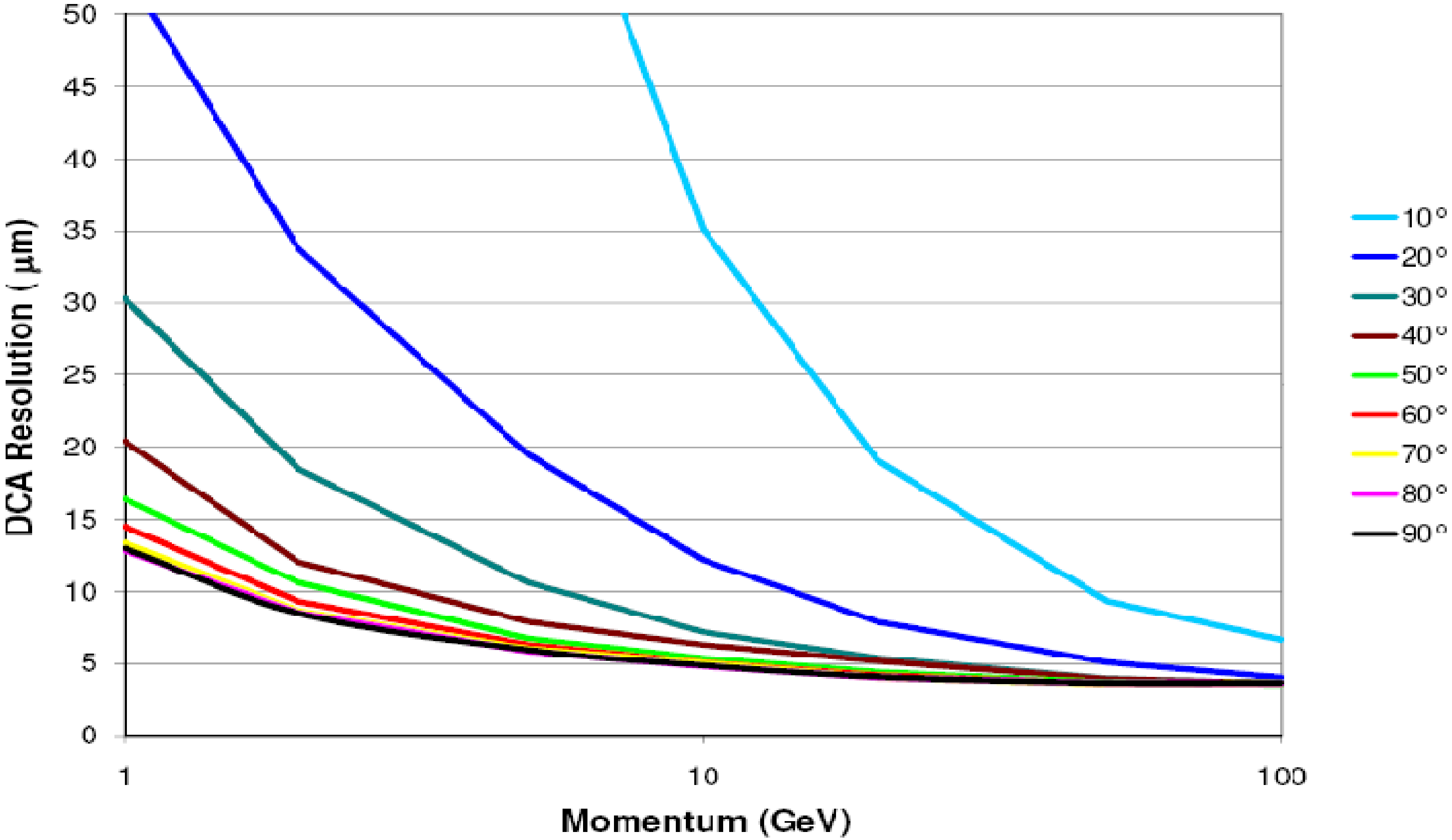
Momentum Resolution

- Good momentum resolution everywhere!



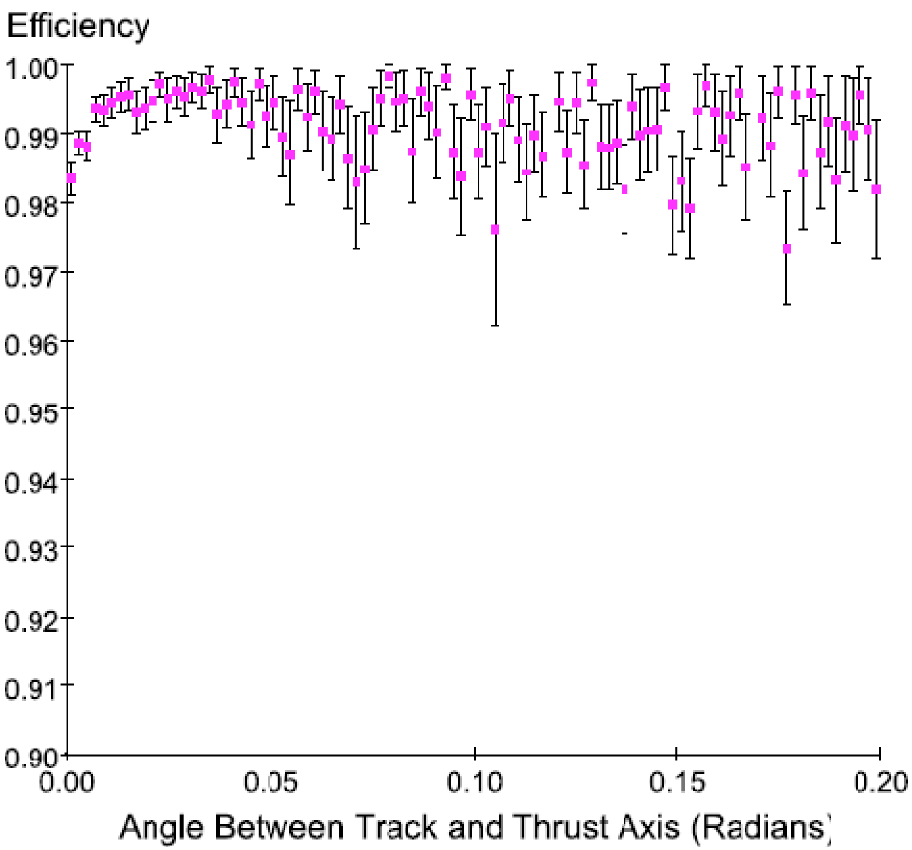
Impact Parameter Resolution

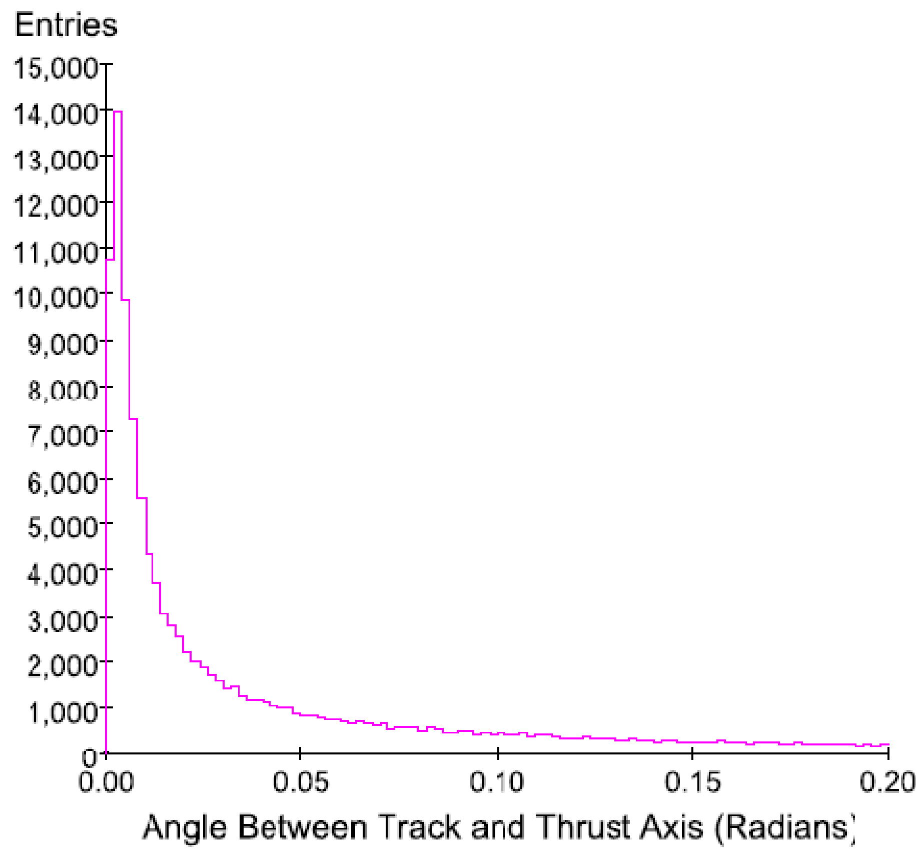
- 4 um impact parameter resolution at high momentum



Tracking Efficiency in Core of Jets

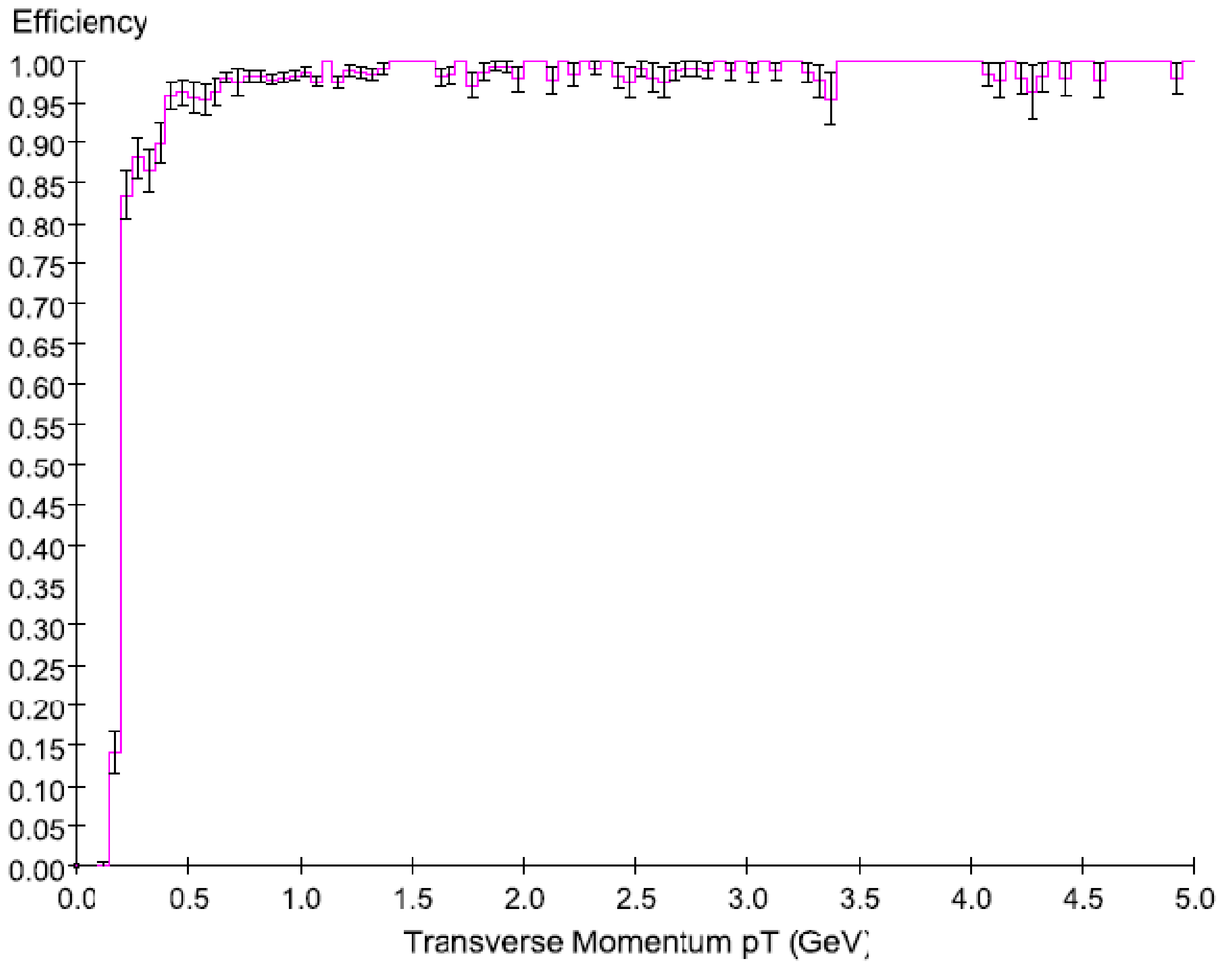
- Look at tracking efficiency vs angle between track and thrust axis for 1 TeV *qq* events
- See high tracking efficiency even in core of high energy jets





Tracking Efficiency with Backgrounds

- High tracking efficiency for *bb* events at 500 GeV with background from 10 beam crossings overlaid (10x baseline)



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 momentum and impact parameter resolution
- Excellent tracking performance maintained in core of high energy jets and in events with 10x expected background