SiD DBD Tracking Performance

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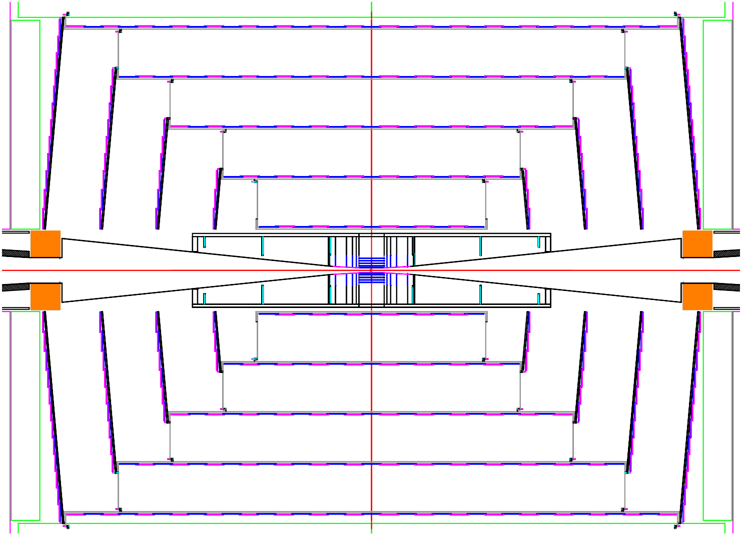
Simulation Model (sidloi3)

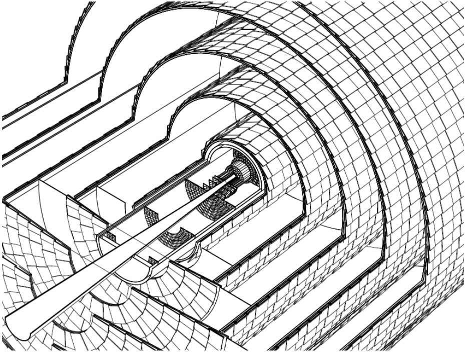


Simulation Model (sidloi3)

- All silicon tracker for highest single point resolution
- Low number of layers to minimize material budget
- Vertex detector and main tracker designed as integral system to provide 10 hits throughout the acceptance
- Pixelized vertex detector
  - 5 barrel layers + 4 endcap disks + 3 forward disks
  - 20 µm pitch
- Main tracking detector
  - 5 barrel layers + 4 disks (stereo strips)
  - 25 µm strip pitch
  - 50 µm read-out pitch
  - 100 mm strip length

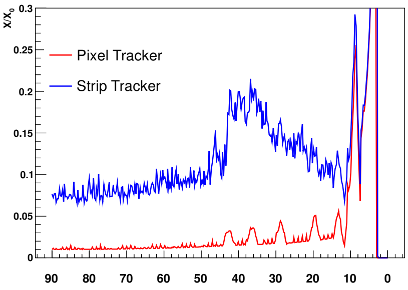
Improvements since the LOI

- Detector model
  - Replace cylindrical tracker geometry with layers made of modules
  - Additional material through overlapping modules
  - Readout, cabling and support structures included
- Digitization (SiSim)
  - Realistic charge simulation
  - Nearest neighbor clustering
- Track finding (SeedTracker)
  - Improved performance by pre-caching variables and introducing additional break conditions

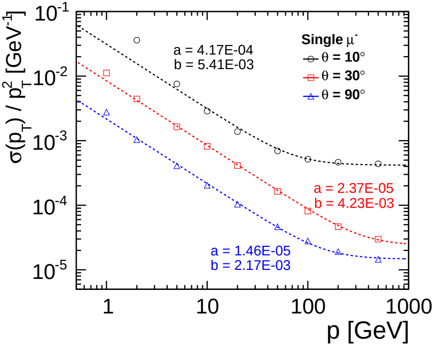


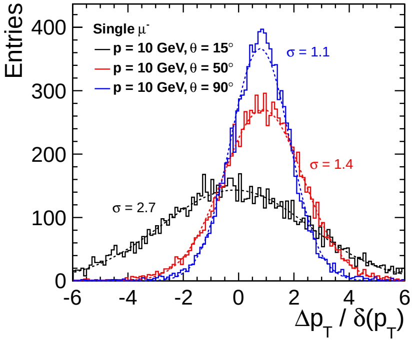
Material Budget

- Vertex detector total at $\theta = 90^\circ$:
  $\sim 9\%\,\mathrm{X}_0$
- Tracker total at $\theta = 90^\circ$:
  $\sim 1.5\%\,\mathrm{X}_0$
- Material budget per layer
  - Vertex barrel: 0.11% X_0
  - Vertex endcap: 0.11% X_0
  - Forward disk: 0.11% X_0
  - Tracker barrel: 0.51% + 0.48% X_0
  - Tracker endcap: 0.64% + 0.5% X_0



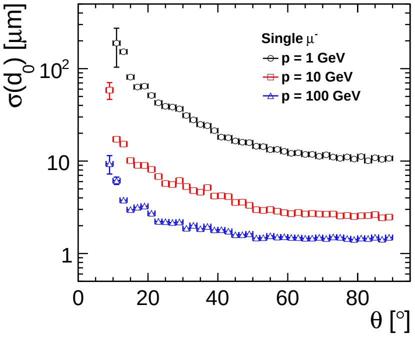
Momentum Resolution (p_{T})

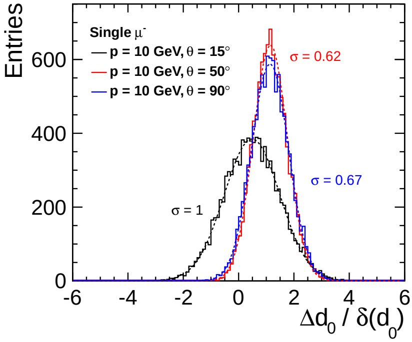




- Dashed line: fit to $\sigma(p_{\mathrm{T}})/p_{\mathrm{T}}^2 = a \oplus b/\left(p \sin\theta\right)$
- Reach $\sigma(p_{\mathrm{T}})/p_{\mathrm{T}}^2 < 5 \times 10^{-5}\,\mathrm{GeV}^{-1}$ for $\theta > 30^\circ$ and $p > 100\,\mathrm{GeV}$
- Charge dependend bias in p_{T} reconstruction
- Transverse momentum uncertainty underestimated by up to a factor of 2

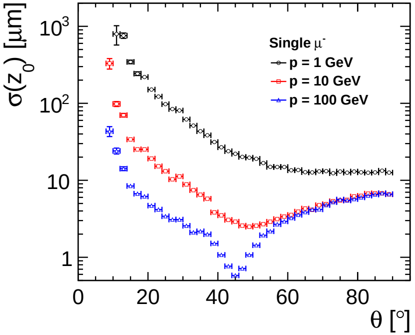
Impact Parameter Resolution (d_0)

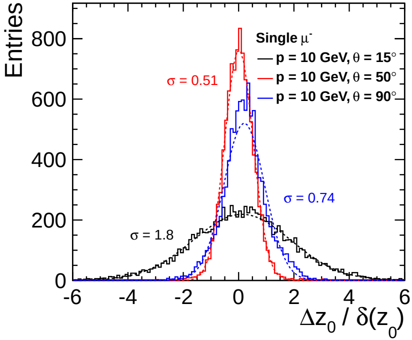




- Reach 10 µm resolution for 1 GeV tracks
- $\mathcal{O}(\mu m)$ resolution for high momentum tracks
- Charge dependend bias in d_0 reconstruction in forward region
- Fit overestimates d_0 uncertainty

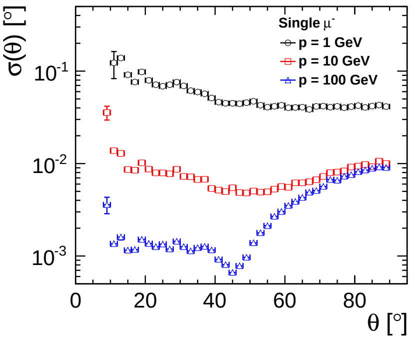
Impact Parameter Resolution (z_0)

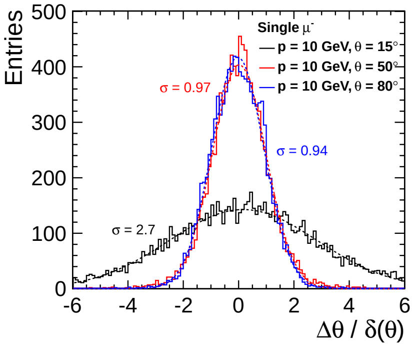




- $\mathcal{O}(10\,\mu\text{m})$ resolution for low momentum tracks
- Resolution limited in central region by straight line fit in current track fitting algorithm

Polar Angle Resolution (θ)

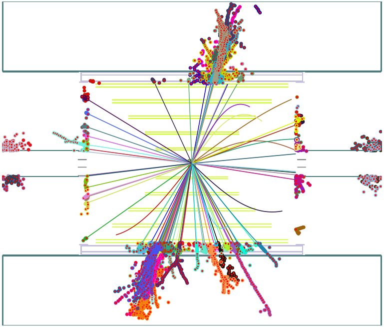




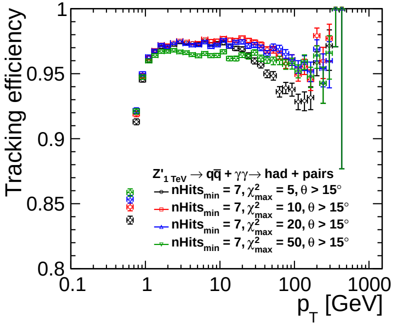
- Only use 3D hits in straight line fit: limited lever arm in central region (use vertex only)

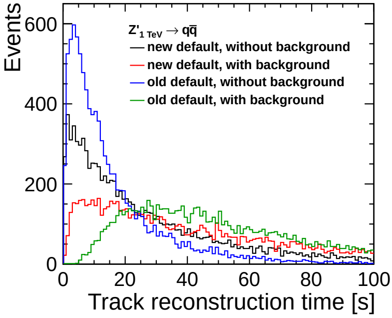
Di-Jet Sample

- Di-jet events decaying at rest with $m = 1\,\mathrm{TeV}$
- Most challenging topology because of highest local occupancies
- Include 1 BX beam related background (ILC DBD $\sqrt{s} = 1\,\mathrm{TeV}$)
  - Incoherent pairs ($\sim$ 400k particles / BX)
  - $\gamma\gamma \rightarrow$ hadrons (4.1 events / BX)



Strategy Optimization



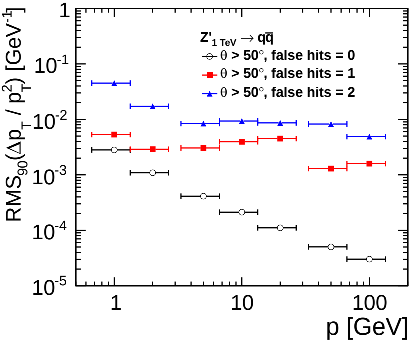


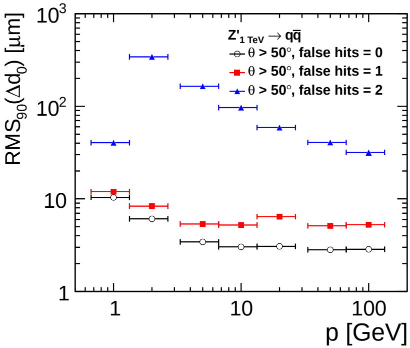
- Re-train strategies in presence of backgrounds
- No seeding in two innermost vertex layers to reduce track candidates
- Choose χ^2 cut as tight as possible without affecting efficiency

Tracking Efficiency Definition

- Tracking efficiency $= \frac{\#\text{reconstructed tracks}}{\#\text{findable mc particles}}$
- Truth matching based on number of contributed hits
- Generic findable definition (used for SiD and ILD in CDR studies)
  - Charged particle
  - Origin of particle $< 50\,\text{mm}$ from IP
  - Distance traveled along path $> 50\,\text{mm}$
  - Signal particle (no pairs or $\gamma\gamma \rightarrow$ hadrons)

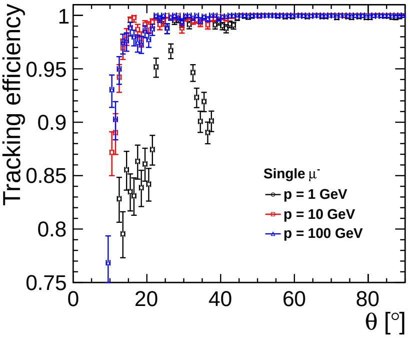
Track Quality Cut

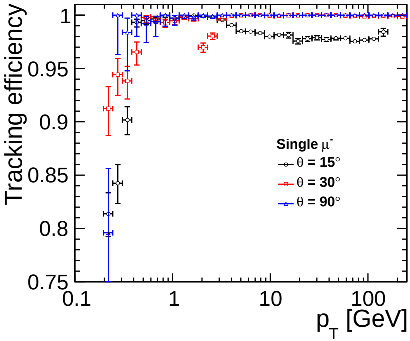




- Low total number of hits requires very high purity
- One or more falsely assigned hits results in bad track reconstruction
- Require not more than one false hit for track counted in efficiency

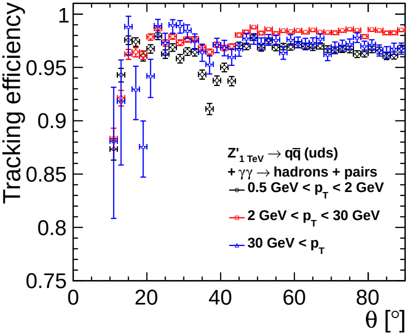
Tracking Efficiency (Single particles)

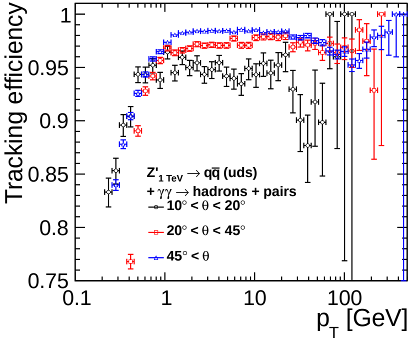




- Very high efficiency ($>> 99\%$) for single particles with $p_{\mathrm{T}} > 2\,\mathrm{GeV}$ and $\theta > 20^\circ$
- Inefficiencies in very forward region $\theta < 20^\circ$
- Inefficiencies in barrel endcap transition region for low momentum particles

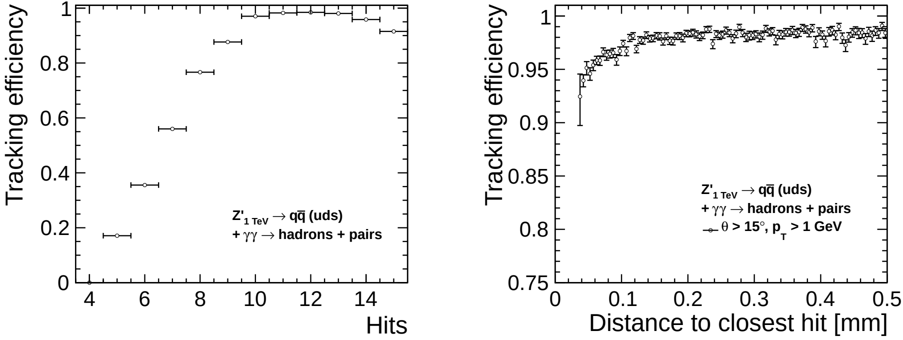
Tracking Efficiency





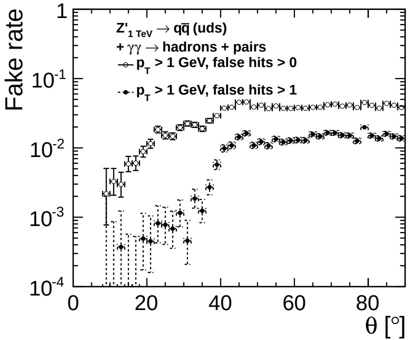
- Very high efficiency for particles of 1–30 GeV: $> 98\%$
- Lower efficiency in transition region: higher material and confusion by ghost hits
- Lower efficiency for very high momenta: high local occupancy in centre of jets

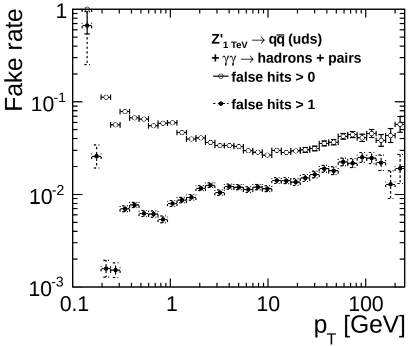
Tracking Efficiency



- Excellent tracking efficiency for particles that leave at least 10 layers
- Lower efficiency for curlers and at limit of acceptance
- Tracking efficiency limited by single-point resolution in dense environments (other hits closer than 100 μm)

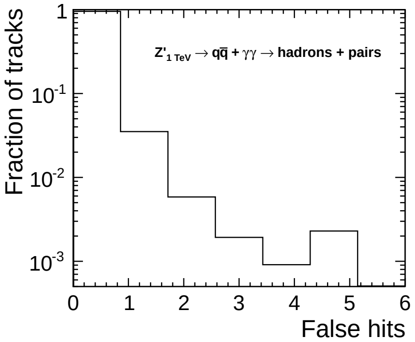
Fake Rate

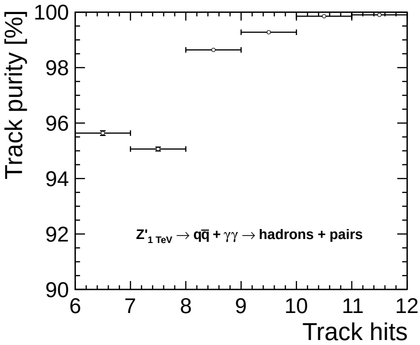




- Define fake tracks as non-pure tracks
- Fake rate in central region $\mathcal{O}(1\%)$
- Significantly lower fake rates in pixel-only forward region

Track Purity





- Less than 1% of reconstructed tracks with more than 1 falsely assigned hit
- Track purity of $> 98.5\%$ for tracks with 8 or more hits

Conclusion

- Realistic simulation model with layers made of individual modules
- Momentum resolution goal reached
- Impact parameter resolution goal reached
- High tracking efficiency $> 98\%$
- Tracking robust in presence of beam-related backgrounds (1BX incoherent pairs and $\gamma\gamma \rightarrow$ hadrons)
- Track finding / fitting algorithm should be replaced with Kalman filter