SiD Tracking Simulation: Status and Plans

Richard Partridge

for the SiD Tracking Group

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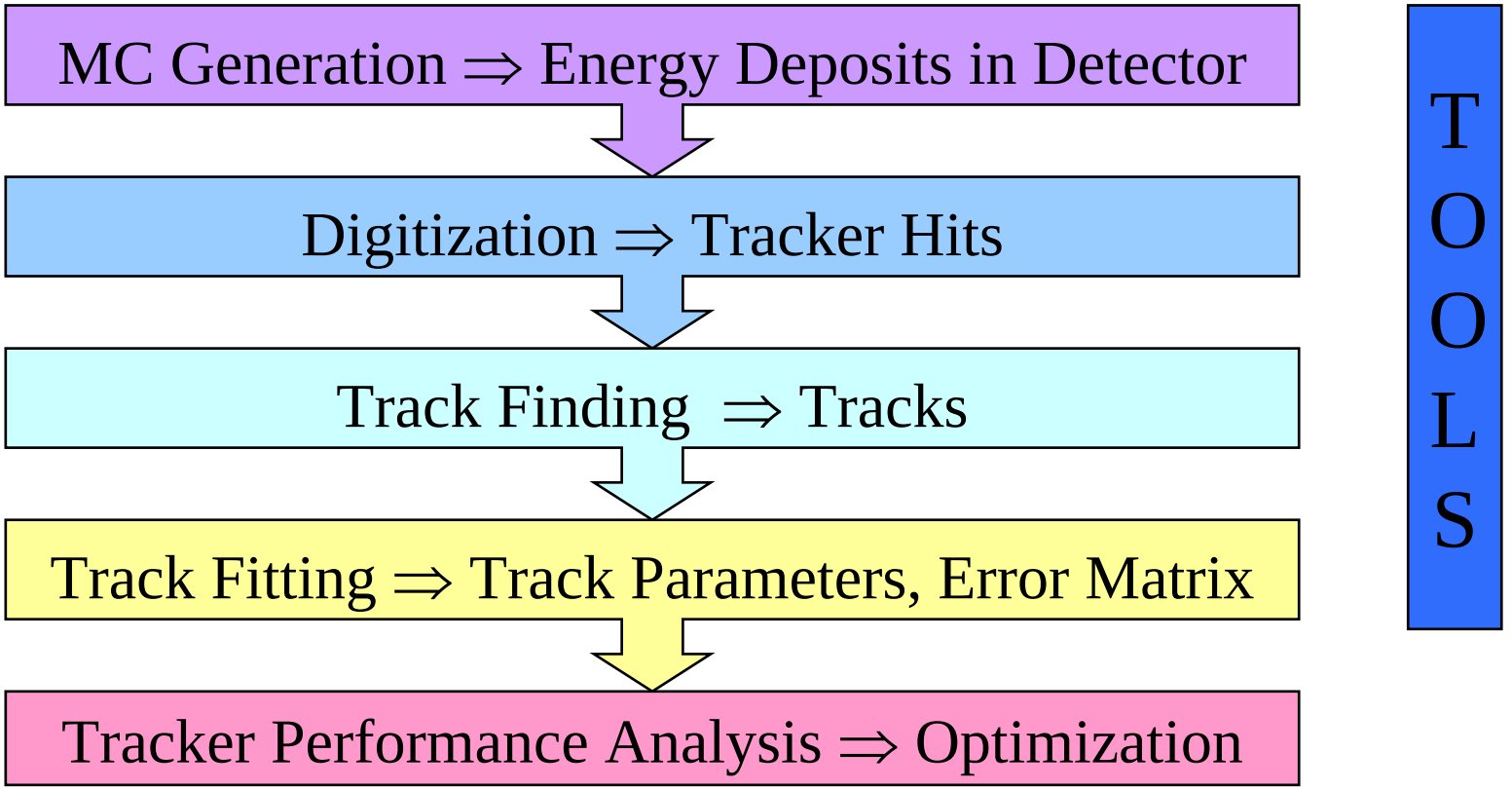
Tracking Simulation

- Tracking simulation is a multi-layered effort



Tools – MC Generation

- Starting point: COMPACT XML file to specify geometry

```
<detector id="13" name="TrackerBarrel" type="MultiLayerTracker"  readout="TkrBarrHits">
  <layer id="1" inner_r = "20.000*cm" outer_z = "26.7*cm">
   <slice material = "PEEK" thickness = "0.02*cm" />
   <slice material = "Rohacell31" thickness="0.14*cm" />
   <slice material = "Epoxy" thickness="0.0175*cm" />
   <slice material = "CarbonFiber" thickness=".016*cm" />
   <slice material = "Silicon" thickness = "0.03*cm" sensitive = "yes" />
   <slice material = "Silicon" thickness = "0.00048*cm" />
   <slice material = "Kapton" thickness = "0.0038*cm" />
   <slice material = "Copper" thickness = "0.00038*cm" />
  </layer>
```

- Relatively easy to change tracker geometry!
- Simulation package (SLIC) produces a “SimTrackerHit” when a particle deposits energy in a sensitive layer
- MC Generation tools are mature and stable

Tools - Hit Digitization

- Detector hits are not created during GEANT simulation
  - » Allows readout segmentation to be changed without re-running GEANT

To form hits:

- Charge deposition
  - » Turn energy deposits into charge on nearby strips
  - » Include Lorentz angle, diffusion, capacitive coupling, noise
- Readout Segmentation and Clustering
  - » Map strip charges onto the readout segmentation
  - » Sum charges when multiple particles produces charge on the same strip
  - » Find clusters of strips and form “TrackerHit” with hit position and error

Tools - Track Finding

Several approaches being taken in track finding:

- Conformal Mapping
  - » Conformal mapping of circular trajectory to a straight line
  - » Current package works from 3D hits – needs strip digitization + ghosting
  - » Results presented in tracking meetings for forward tracking
- Vertex Seeded Tracking
  - » Find track seed in vertex tracker and pick up hits in outer tracker
  - » Results presented in tracking meetings using MC truth for vertex seeds
- Calorimeter Seeded Tracking (Garfield)
  - » Find MIP stubs in calorimeter and pick up hits in outer tracker
  - » Can be used to find long-lived secondaries (K_S, Λ, etc.)
- Stand-alone Outer Tracking
  - » Find track candidates using outer barrel tracker

Tools - Track Fitting

Goals:

- Given a collection of hits, find the helix that best fits the hits
- Determine the error matrix for the helix parameters
- Provide the ability to swim the track parameters, error matrix to any point on the track (e.g., production vertex, calorimeter entrance, etc.)

Approaches:

- Weight Matrix
  - » Performs a χ^2 fit of hits to a helix including multiple scattering correlations
- Kalman Filter
  - » Uses Kalman Filter to adapt trajectory for observed multiple scattering

Tools - Who is Doing What?

Task	People
CCD Digitization	Nick Sinev
Strip Digitization	Tim Nelson
Conformal Map Tracking	Norman Graf
Vertex Seeded Tracking	Fred Blanc, RP, Steve Wagner
Calorimeter Seeded Tracking	Dima Onoprienko, Eckhard Von Toerne
Stand Alone Outer Tracking	Tim Nelson
Weight Matrix Fitter	Nick Sinev
Kalman Filter Fitter	Fred Blanc, Norman Graf

Tool Status

Tool	Variant	Status
MC Simulation	SLIC	Released
Digitization	Pixel (CCD) Digitization	Released
	Strip Charge Deposition	Complete
	Strip Readout Segmentation	In Progress
Track Finding	Conformal Map Tracking	Released*
	Vertex Seeded Tracking	In Progress
	Calorimeter Seeded Tracking	Released*
	Stand Alone Outer Tracking	Released*
Track Fitting	Weight Matrix Fitter	Complete
	Kalman Filter Fitter	In Progress**

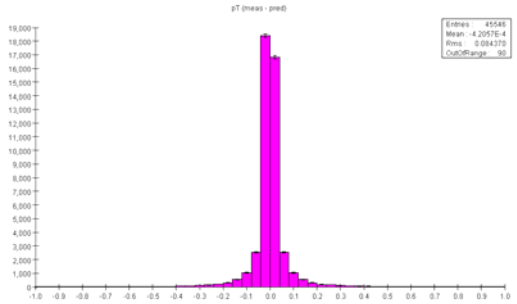
* Currently uses smeared hits ** Complete for Conf. Map Tracking

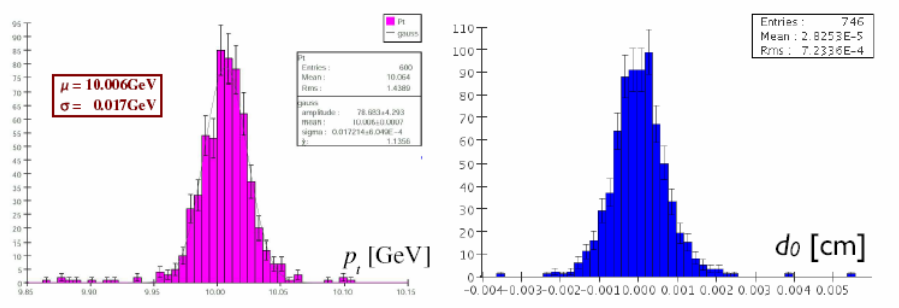
Near-Term Tool Milestones

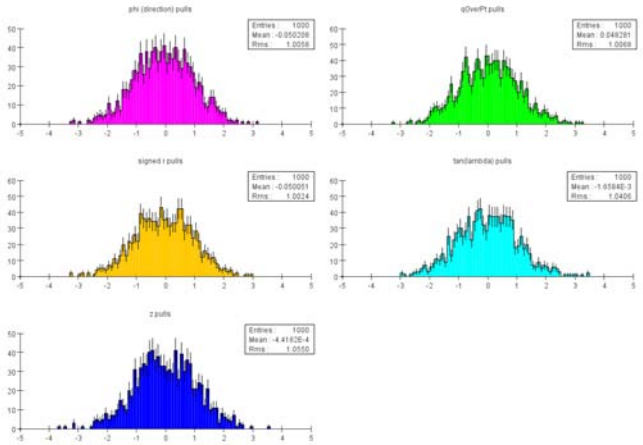
Milestone	Completion
Reconstruction of Vertex Seeds	July
Vertex Seeded Tracking using Reconstructed Vertex Seeds	August
Hit Digitization for Barrel Strips	September

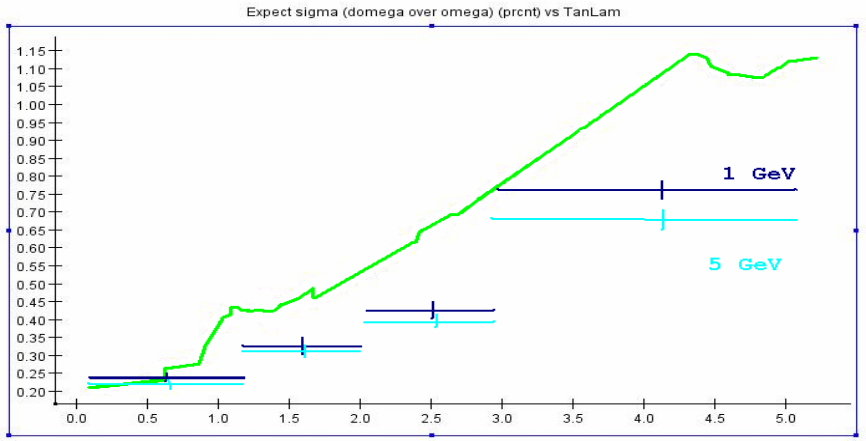
Tracking Analysis

- Use tracking tools to characterize / optimize tracker design
- Some preliminary results shown at VLCW06









- Much more to do…

Tracking Characterization

- Study rudimentary tracking performance measures that characterize tracker performance
- Largely independent of physics process
- Provides most direct feedback for tracker optimization
- Track Resolution
  - » pT, direction, impact parameters in bend and non-bend planes
- Tracking Efficiency
  - » pT dependence, polar angle dependence, jet core vs isolated track
- Fake track rates
  - » pT dependence, polar angle dependence, jet core vs isolated track
- Effect of backgrounds on tracker performance
  - » Produce high occupancy at low radius
  - » Potential impact on tracking performance, readout electronics design

Optimization of Tracking Geometry

- Software framework is designed to allow study of detector variations with full simulation / reconstruction
- Tracking routines make use of geometry information used to generate events, so extensive tuning / coding is (hopefully) not required

Some pertinent questions:

- Does the baseline design have the right number of layers?
- Is an equal radial spacing of barrel layers optimal?
- Are we able to adequately project out from the vertex detector to the first layer of the outer tracker?
- Is the barrel / disk transition optimally located?
- Is there sufficient / excessive overlap of sensors?

Forward Tracker Design

- Ideally, a group would take “ownership” of the forward tracker design
- The pair background, decreasing lever arm make this a challenging region for tracking

Many open questions:

- Sensor shape: Square? Wedge? Hexagon? Other?
- Strip orientation: x, y? Also u, v? small angle stereo? r, ϕ?
- How many layers? Where are they?
- What is the smallest sensible tracking angle?
- Is occupancy acceptable for KPix design?
- Should we have forward pixel disks at low radius?
- How are the sensors supported?

Long-Lived Secondary Tracking

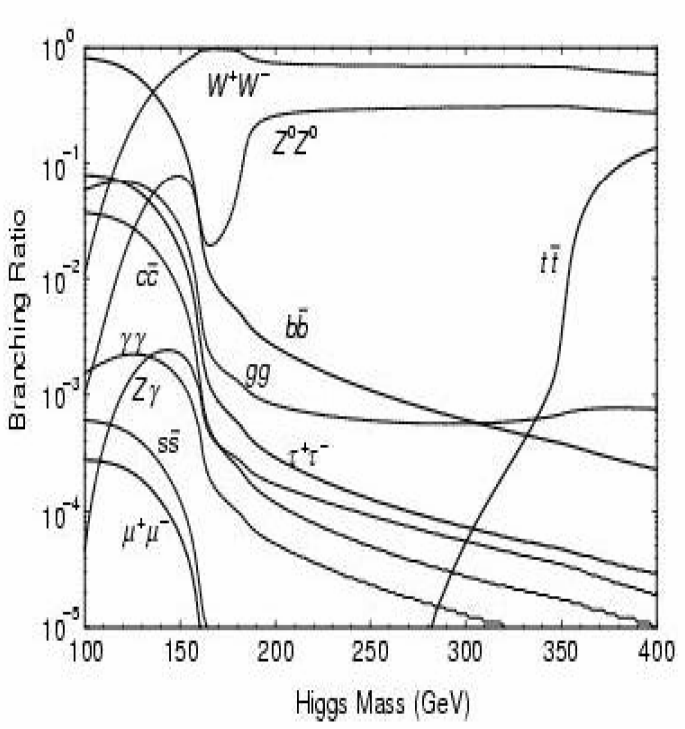
- K_S, Λ will typically decay outside the vertex detector
- Boosted B mesons sometimes have large decay lengths also
- Simulations in hep.lcd framework typically found 5% tracking inefficiency due to non-prompt tracks
- In baseline design, barrel region has only axial strips
  - » Only coarse measurement in r-z plane from readout segmentation
  - » Poor precision in track polar angle, r-z impact parameter

To be studied:

- Calorimeter seeded tracking performance / optimization
- Improvement from having >0 stereo barrel layers
- Physics impact of not reconstructing long-lived secondaries

Heavy Flavor Identification

- Efficient identification of b and c quarks is a critical requirement to meet ILC physics goals
- Example: Higgs branching ratios
- Need to optimize tracking for heavy quark tagging efficiency
- Requires secondary vertexing code
  - » ZVTop has been ported to org.lcsim



To be studied:

- Characterize tagging performance
- Dependence on inner radius
- Optimal radii and length of layers

Physics Benchmarking

- Tracker performance potentially impacts a wide variety of physics processes
- ILC physics performance is the ultimate goal of the design optimization
- Benchmarks will be important in the comparison of the SiD concept and brand X

Some possible benchmarks:

- pT resolution as it affects the Higgs recoil mass resolution
- Higgs branching ratio precision (tagging efficiency / fakes)
- Impact of material on PFA jet energy resolution
- Need a good benchmark for forward tracking performance!

Who is Doing What?

Task	People
Tracking Characterization	Bruce Schumm + students
Tracker Geometry Optimization	?
Forward Tracker Design	?
Long-Lived Secondaries	Dima and Eckhard? Others?
Heavy Flavor Identification	Caroline Milstene
Physics Benchmarking	?

Summary

- A plan for developing tracking tools was generated at Snowmass
- There has been progress in all areas, but in many cases the rate of progress has been slow
- We are getting close to having all the pieces in place, commitments have been made to complete these efforts
- While there will be continuing development of the tools, our greatest need is for people to get involved in the tracking analysis and tracker optimization
- This is the fun part!
- If you are interested in getting involved, please get in touch with Marcel or myself