Status of SiD Tracking Software

Tim Nelson

SLAC

Tasks to be done

- Port Nick's digitization code to org.lcsim
- Port Nick's pattern recognition and tracking code to org.lcsim
- Extend Nick's Fitter to include endcap layers
- Port Bruce's strip digitization code to org.lcsim
- Update Bruce's strip digitization code for short ladders
- Develop clustering algorithm for strip tracker
- Develop stand-alone outer tracker pattern recognition and track finder
- Determine z segmentation in barrel
- How many layers are sufficient for robust tracking?
- Do we need stereo readout in the barrel?
- Determine technology for forward region
- Quantify VXD tracking efficiency when backgrounds are added
- Quantify tracking performance in dense jets
- Study of occupancies as a function of various disk-tiling geometries
- Quantify number of ghost hits for various geometries
- Quantify fake track rate
- Stand-alone tracking studies for outer tracker
- K_s reconstruction
- Quantify p_T-resolution, notably in the forward region
- Uniformity of the magnetic field
- .....

Many of these things existed in old framework (hep.lcd) but are needed in new framework (org.lcsim) in order to make progress

Proposal

- Port Nick's tracking algorithm to org.lcsim — Rich Partridge
- Once ported:
  - 1) Review by simulation group to make code compatible with org.lcsim framework — Norman
    2) Debug, tune and optimize code to obtain same results as obtained in lcd.hep framework — UCSC
    3) Based on the same code, develop alternative tracking algorithm — Rich Partridge
  - 4) ftf (finder) — Norman
- Port ccd simulation to org.lcsim — Nick
- Develop digitization code for OT — Tim
- Cluster finding, verification of performance — Tim, Bruce
- Segmentation, stereo — .....
- Segmentation, stereo (forward) — porting: Norman
- Develop OT pattern recognition code — Tim
- Track fitting
  - Port sldfit to org.lcsim — Nick
  - develop Kalman filter (own development or trf) — Steve
- Garfield development — Dima

- Timetable: end of October for first pass ?

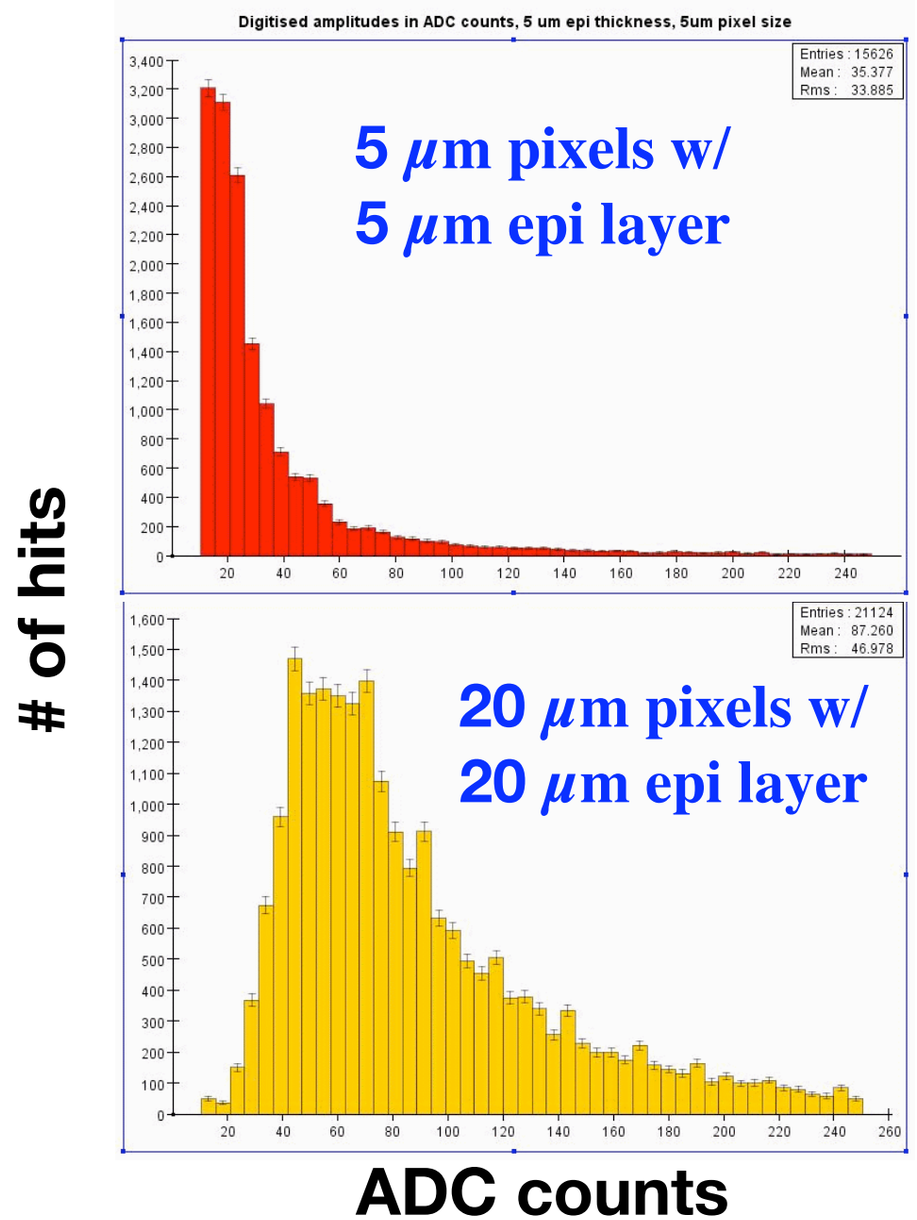
A very ambitious plan ... *some real progress*

Reconstruction

- Detector response: turning SimTrackerHits into TrackerHits
  - Segmentation of cylinders and disks into individual readout modules
  - Simulation of charge deposition in silicon
  - Digitization/clustering of hits
- Track Finding
  - VTX-seeded
  - ECAL-seeded
  - Standalone
  - Global
- Track Fitting
  - SLD Billoir-fitter
  - Kalman fitter
  - Weight-matrix fitter

CCD Simulation for VXD

- A package for simulation of CCD existed in old hep.lcd (N. Sinev)
- Captures basic features of individual CCD hits as function of sensor design
- This code has now been ported to org.lcsim



Tracker Segmentation

Silicon layers are defined as continuous cylinders and disks in geometry description for GEANT4:

simulation of readout segmentation left for reconstruction phase

- Some basic tools exist for tracker segmentation (N. Graf), but implementation still incomplete:
  - For Si simulation: ability to take a GEANT-produced SimTrackerHit and get from it the ID# of the readout segment (module) that was hit
  - For reconstruction: ability to take the ID# and get from it all the geometry information about that module

➡ **each reconstruction algorithm must deal with this in own way creating**

- **problems for comparing algorithms**
- **problems comparing module designs / tiling schemes**
- **impossible to compare ghosting in double-sided stereo arrangements**

Silicon Simulation

Currently, GEANT4 energy depositions (SimTrackerHits) are turned into silicon hits (TrackerHits) by the application of Gaussian smearing: ignores important effects that distinguish designs

- **impact of S/N (strip length, sensor/chip design, etc...) on efficiency**
- **impact of S/N on resolution**
- **impact of B-field on resolution**
- **effect of merged clusters on resolution and tracking confusion**

A simulation of the physics of charge generation and deposition on silicon strips is required to capture all of these effects

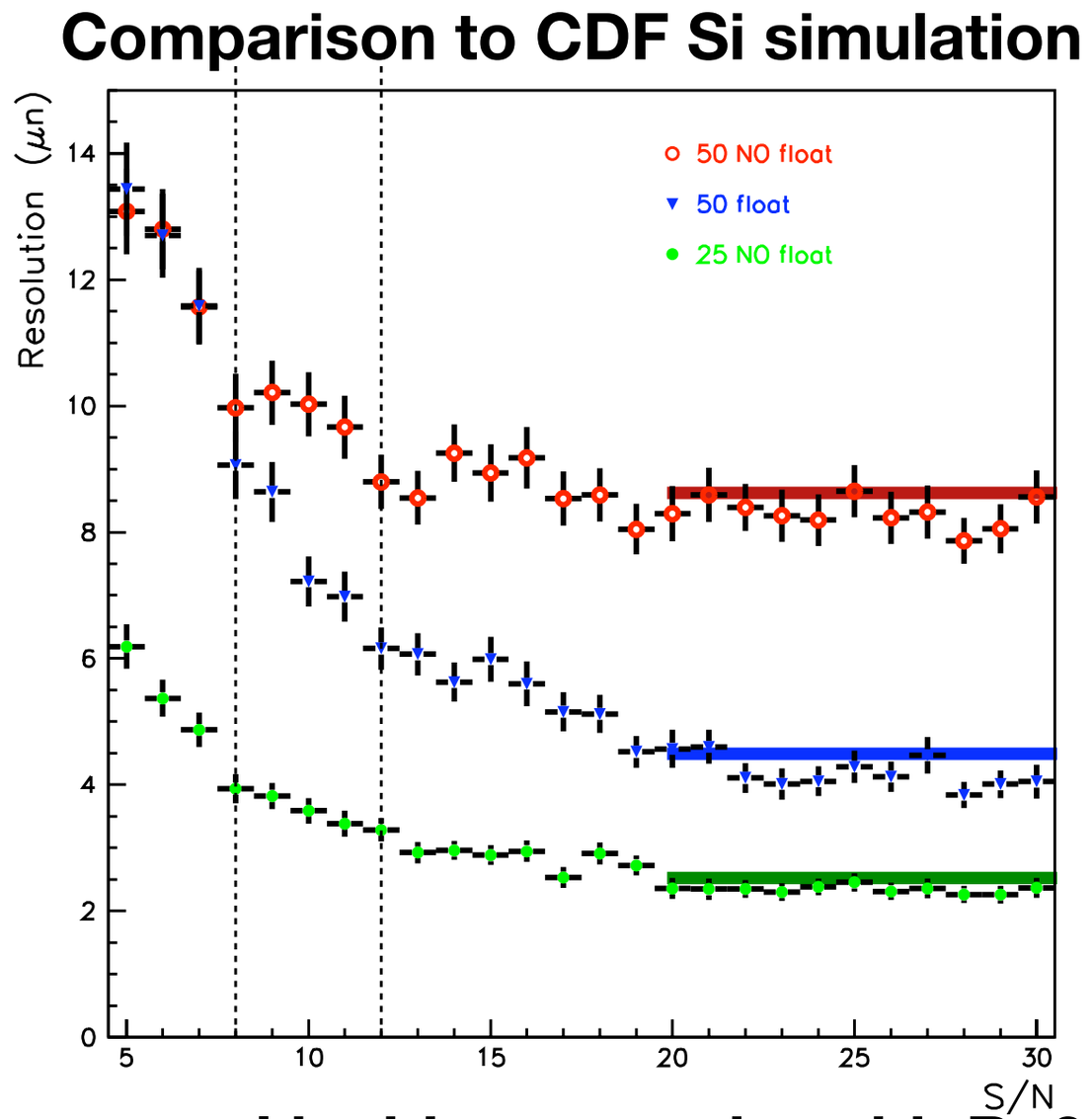
Improved Silicon Simulation

New package for detailed simulation of silicon strips (T. Nelson)

- Still debugging but some components now validated
- Need to integrate this tool with existing simulation code
  - want to use generic digitization tools
  - need richer output from GEANT4
- Results of letting GEANT4 handle short-range delta-ray production look encouraging

"GEANT4 is like a car you can start by fiddling with the radio."

-Jeremy McCormick

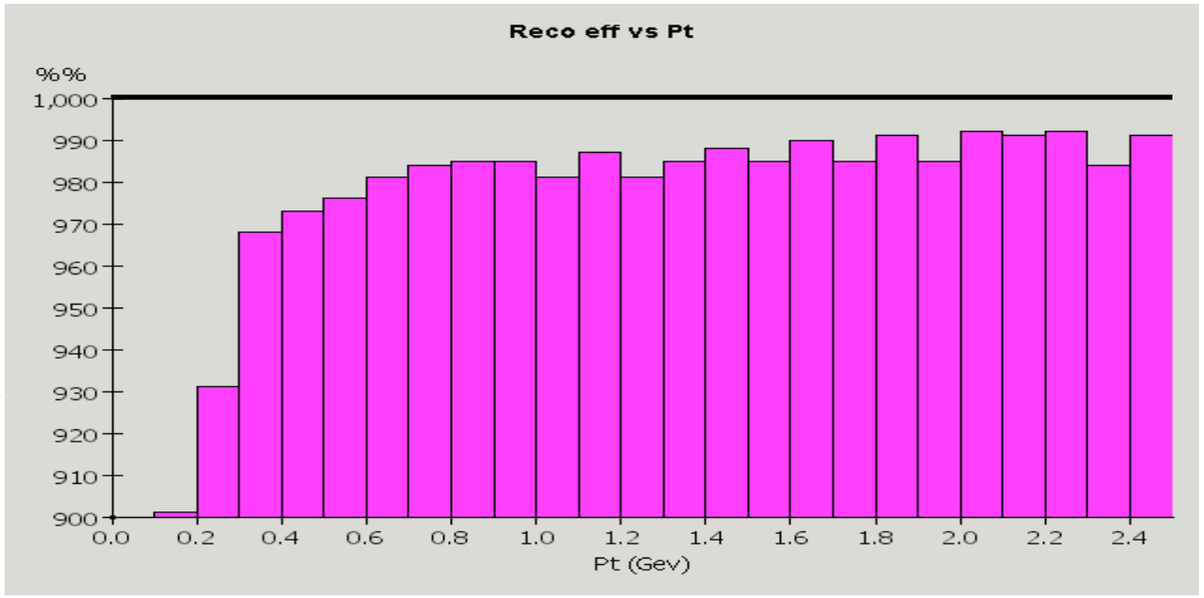


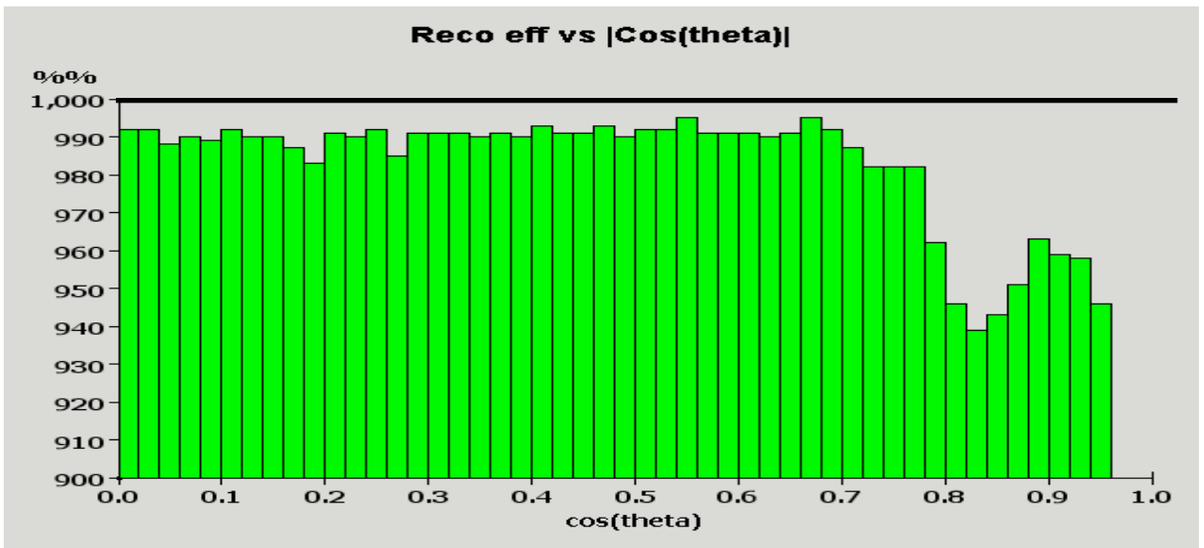
Track Finding

A key assumption of SiD tracking:
VXD is the primary tracking device for pattern recognition

- Code developed in old framework (hep.lcd) for VXD-seeded tracking (N. Sinev)
- Need to port this code to org.lcsim (R. Partridge)
- **Some infrastructure now in place: hopeful for progress by Boulder**

This is a critical task that still must be completed





Calorimeter-seeded Tracking

What happens if tracks originate beyond inner layers of VXD?

GarfieldTracking (D. Onoprienko) uses track stubs in ECAL to seed tracking in the tracker

Port from hep.lcd to org.lcsim is complete and code checked in: no results or further development yet

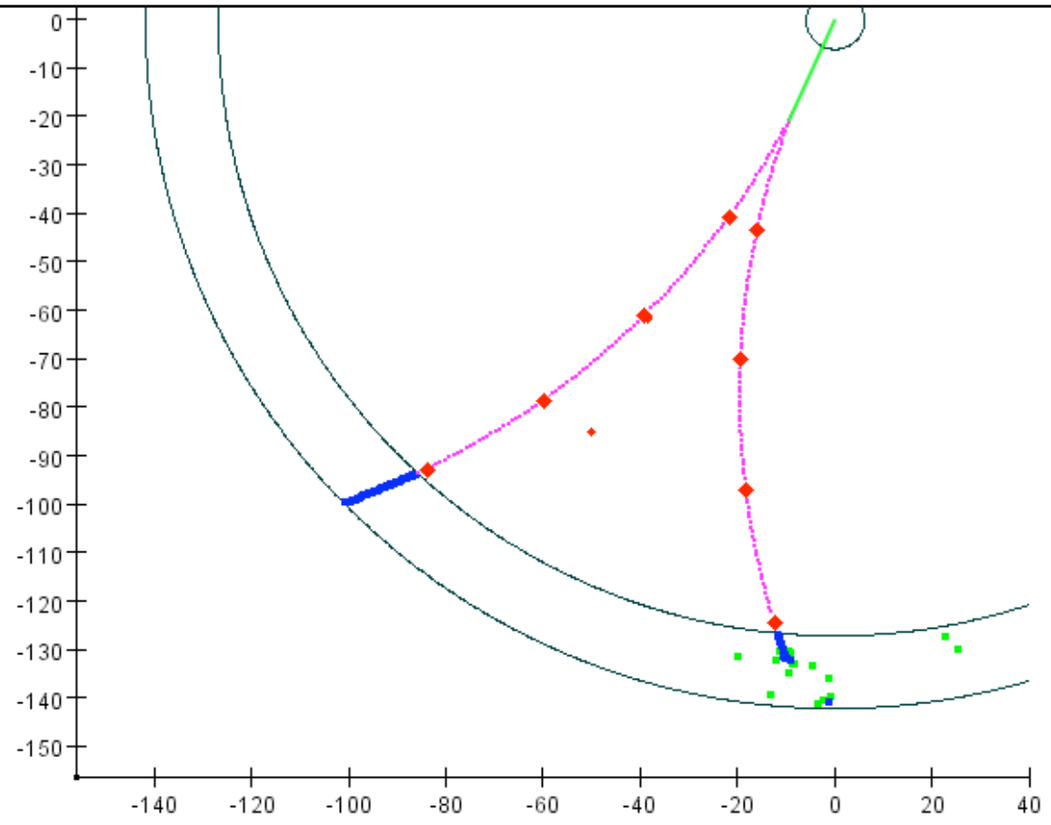
With the current version, we reconstruct

~ 25 % of all K_S^0 decaying into charged pions

~ 40 % of K_S^0 with Pt > 1 GeV

~ 46 % of charged pions from K_S^0 (~ 61 % with Pt > 1 GeV)

and there are obvious ways to improve it.

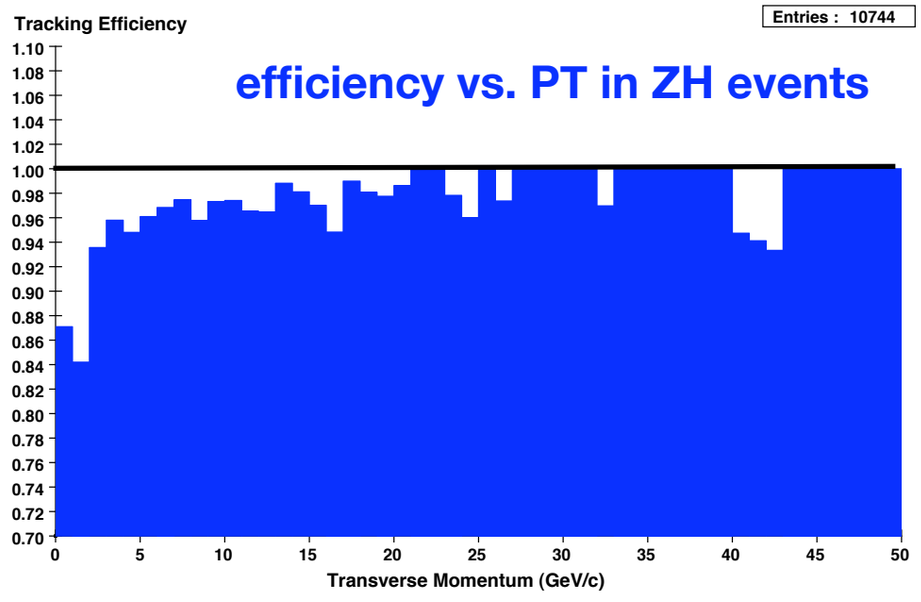


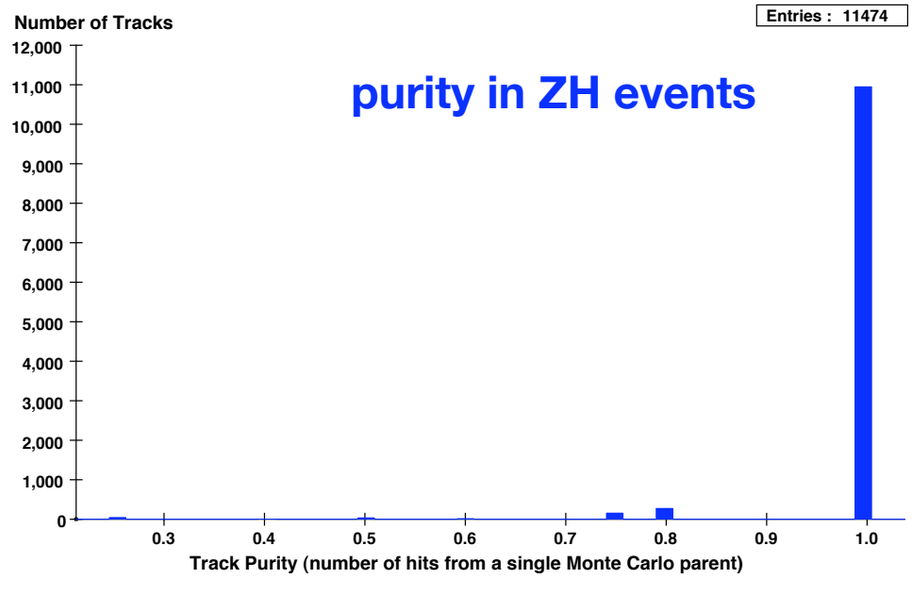
Outer Tracker Standalone

Can tracking work without VXD?

A new outer-tracker-only algorithm developed in org.lcsim (T. Nelson)

- First pass works only in barrel, assumes tracks come from IP
- Efficiency in mid-to-high 90's for P_T>2 GeV
- Purity (average fraction of hits originating from a single track) >98%
- **Efficiency vs. purity degrades significantly with longer modules**



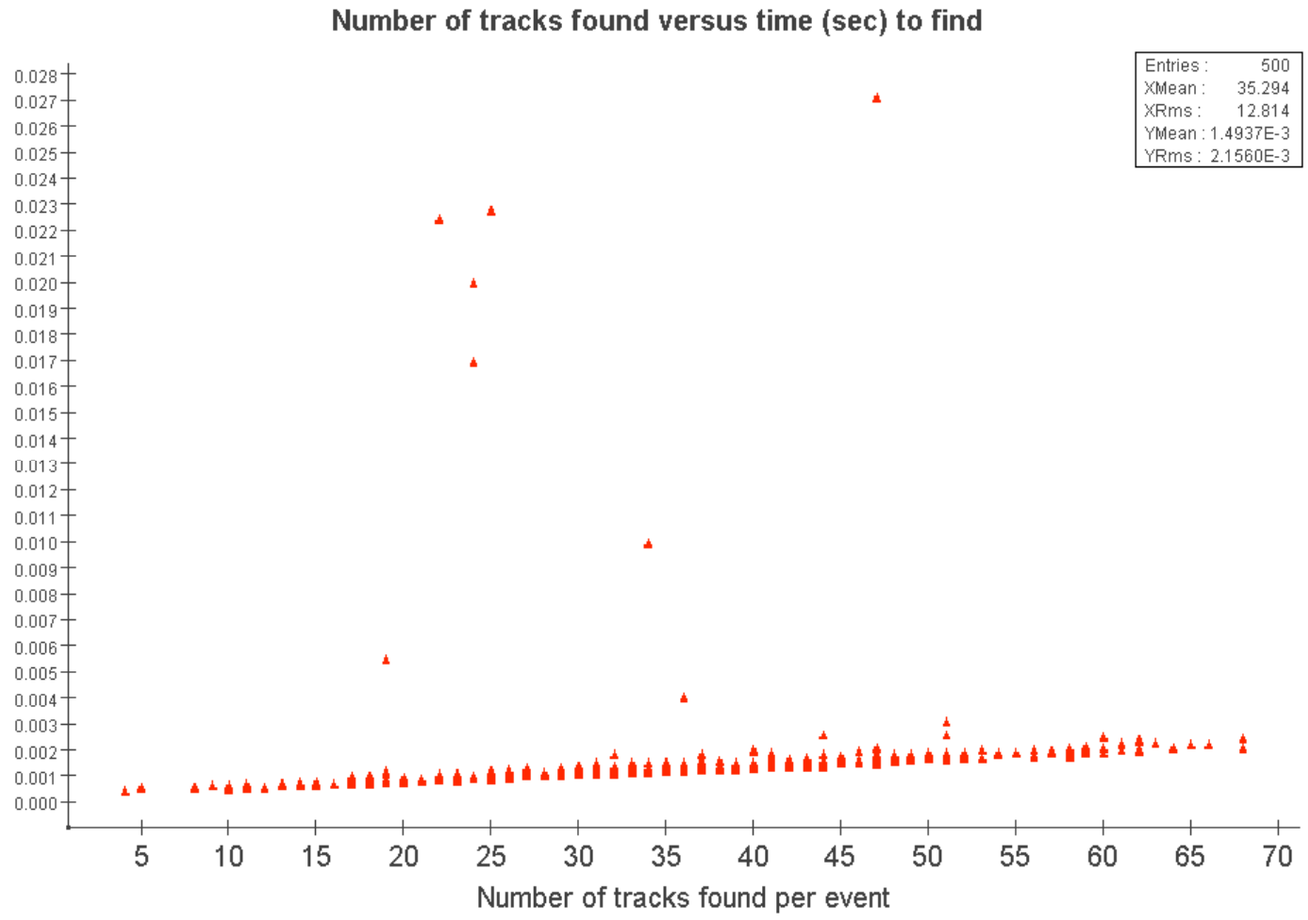


Global Track Finding

A way to use VXD and outer tracker in a more integrated fashion?

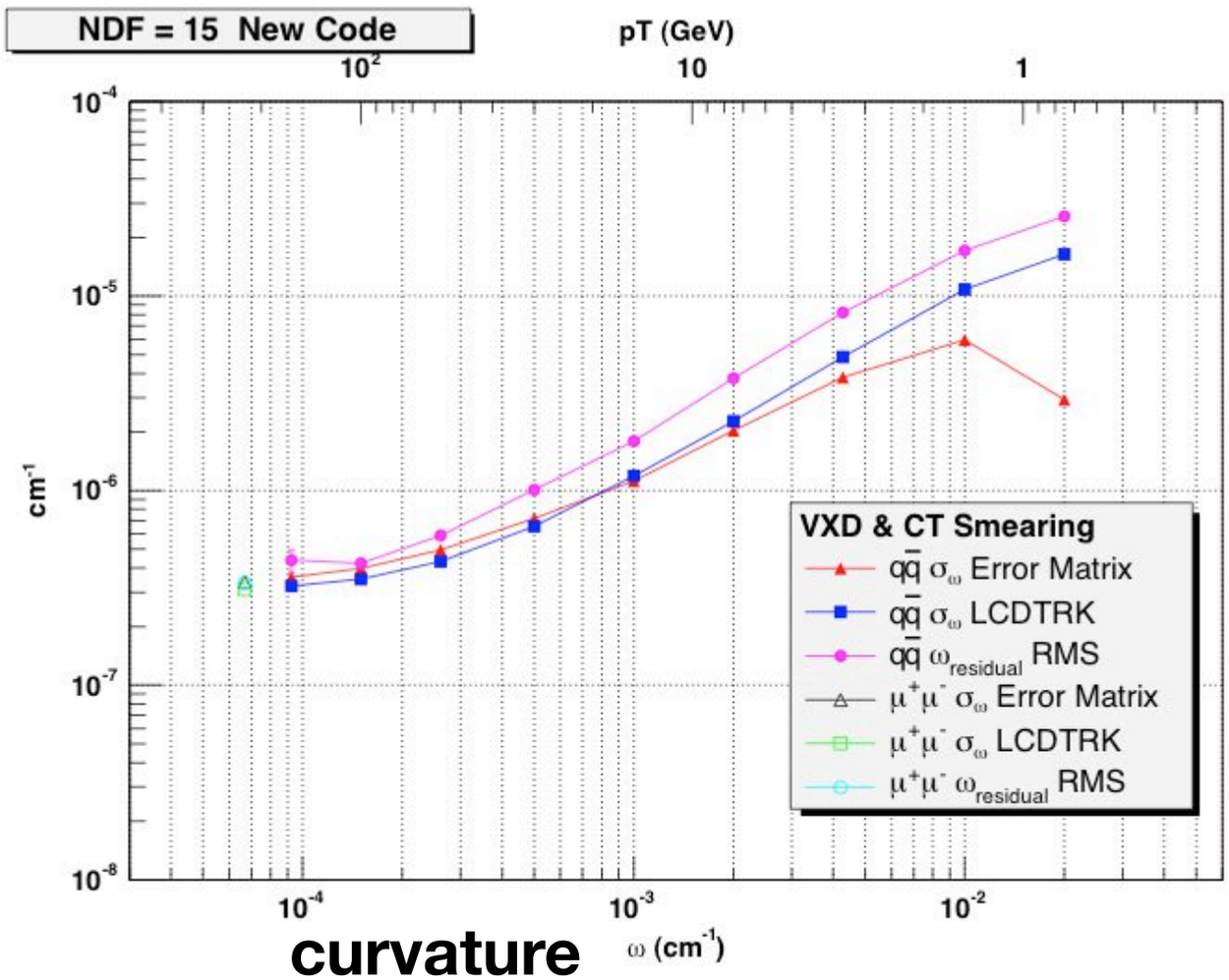
FTF (fast track finder): conformal mapping track finding algorithm (N. Graf)

- first looks at speed look encouraging
- event displays look reasonable
- **More results soon**



Track Fitting

- Track fitter in hep.lcd was SLD-originated Billoir fitter (N. Sinev)
- Behavior studied in great detail (B. Schumm, UCSC): some minor anomalies in comparing reported errors to expected errors to residuals
- Not being ported to org.lcsim



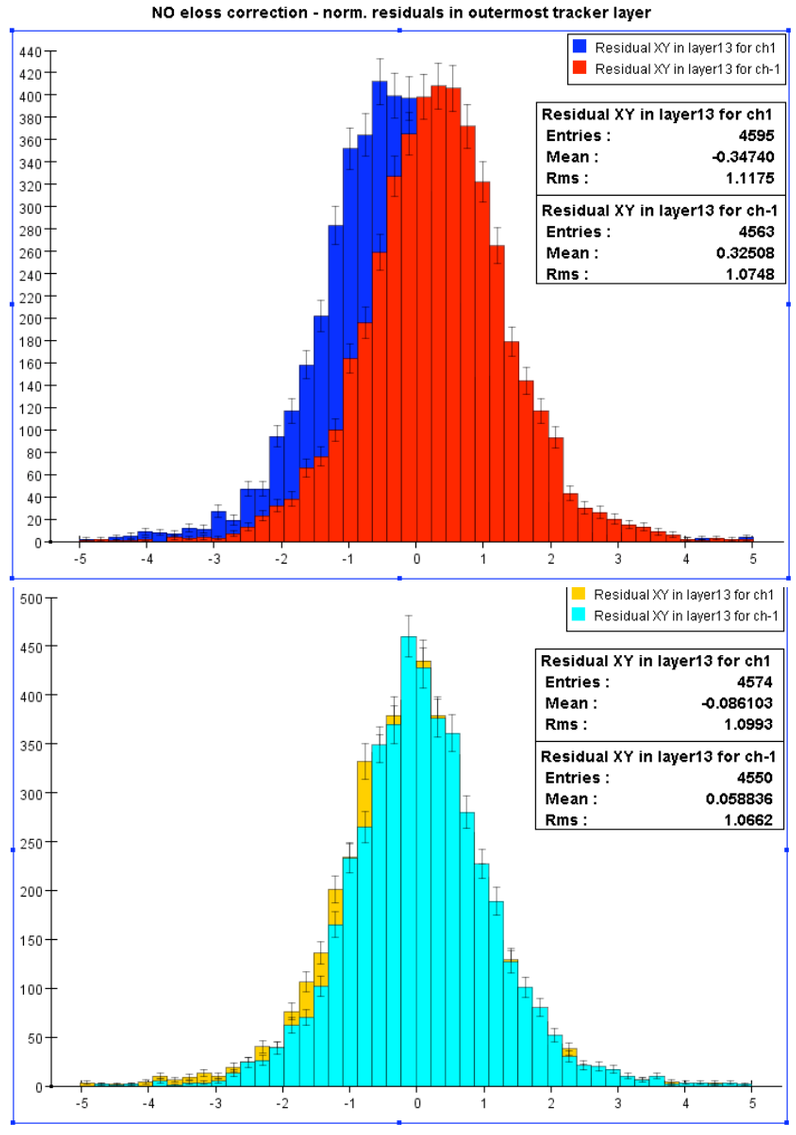
Weight-matrix Fitter

- New fitter developed in org.lcsim (N.Sinev)
- Properly accounts for material effects
- Some mysteries not understood
  - a bug in this code?
  - GEANT4 problem?

w/o eloss correction

w/ eloss correction

# of tracks



Normalized residual for +/- tracks

Kalman Fitter

- Basic components of Kalmen fitter (trf) present in org.lcsim for some time (N. Graf)
- Not yet fully implemented/working

A Few Words About Benchmarking

Physics is the ultimate arbiter, but...

Need to develop a standard set of intermediate performance benchmarks for comparing designs

- $\sigma_{P_T}(P_T, \theta_{detector})$ - **this is reasonably well understood**
- $\varepsilon(P_T, \theta_{detector}, d_0, \theta_{jet}, \text{backgrounds})$ - **some understanding of this in central, little in forward**
- fake tracks (rates and failure mechanisms) - **only very rough understanding so far**

Focus for future must be on understanding tracking efficiencies and fakes, especially in forward region

Conclusions

- Some significant progress since Snowmass on making org.lcsim usable for the full range of SiD tracking studies: not nearly what we were shooting for
- For Detector Outline, we have a good handle on resolutions, reasonable confidence in good efficiency and purity
- We do not yet have all the tools to optimize the SiD design, but hope to have them soon
- Expect more progress on several fronts by Boulder sim/reco workshop: several individuals seem to have planned busy holidays!