LCDROOT and GEANT4

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Introduction

- We have developed a simulation and analysis package based on ROOT.

  → LCDROOT
- For detailed detector study, GEANT4 has been implemented in LCDROOT.
- In this talk, I will introduce what we can do with LCDROOT.

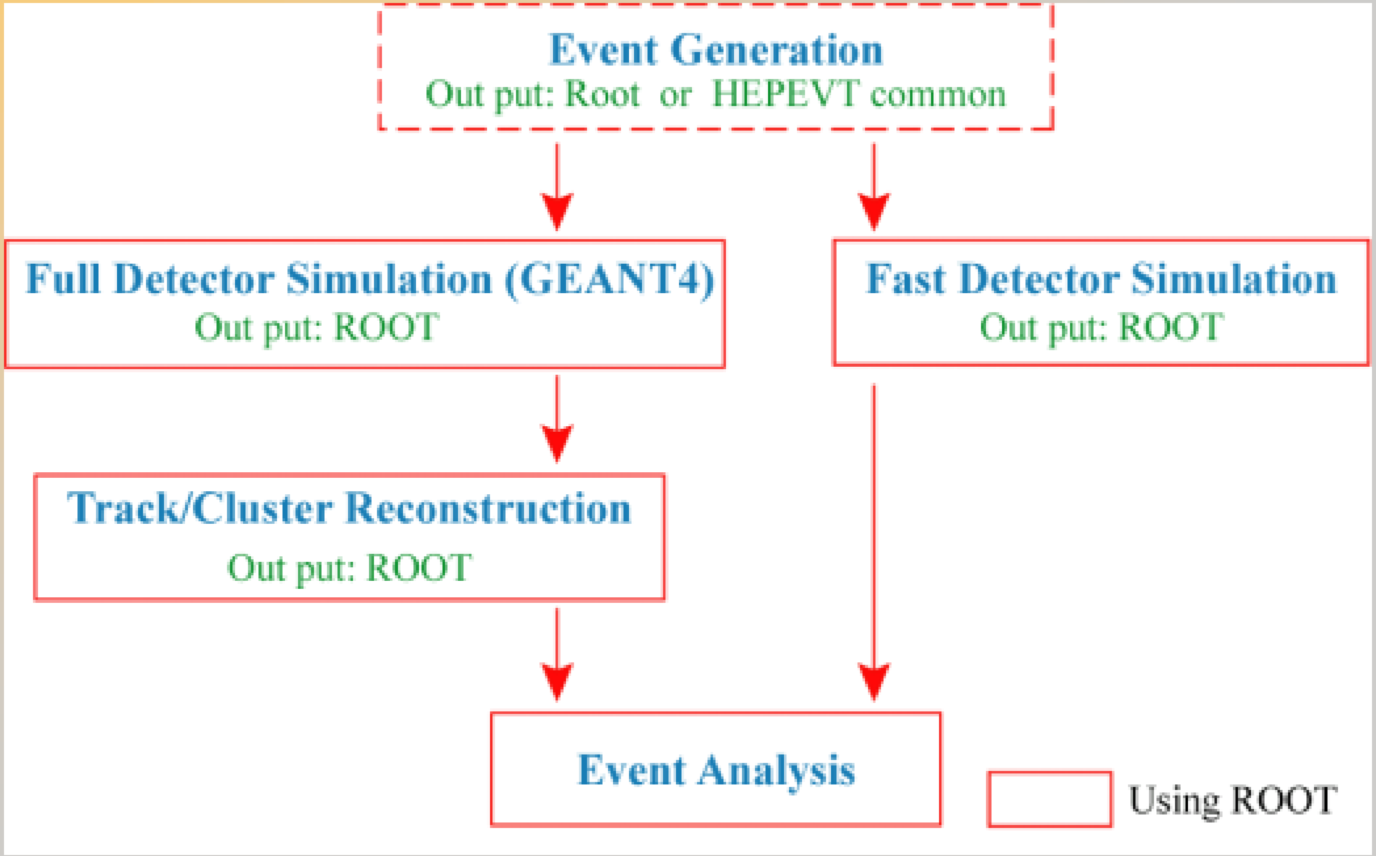
Topics of Discussion

- LCDROOT analysis flow
- Generator
- Fast simulation
- Full simulation
- Reconstruction
- Analysis
- Summary and future plan

Supported plat form

- Linux (RedHat7.X)
- SunOS
- Windows
- (MacOS X)

LCDROOT analysis flow



Generator

- PANDORA (C++) by M. Peskin with PYTHIA/TAUOLA interface (M. Iwasaki)

  Include beam polarization, beamstrahlung, ISR

  Can directory handle in LCDROOT

  → main generator of LCDROOT

  new version of Pandora2.3 will be implemented soon.

Generator (cont.)

- PYTHIA6.2 is implemented. (new)
- Herwig6.5 is implemented. (new)
- ISAJET7.48 is implemented. (new)
- Output: ROOT or STDHEP
  Or can be directly linked to FastMC

Fast Simulation

- Track
  - Smear & bend charged particles
  - Set 5 parameter error matrix (B.Schumm)
- Cluster
  - Smear particle position and energy
  - Cluster merging (for granularity study)
- Output : ROOT file format

Full simulation

- For detailed detector study, we provide GEANT4 full simulation environment.
- Currently there are two executables for the full simulation depending on input file format (ROOT or STDHEP).
- Output : ROOT file format

Detector geometry

- Detector geometry must be flexibly set.

  → We do not want to make executables detector by detector.

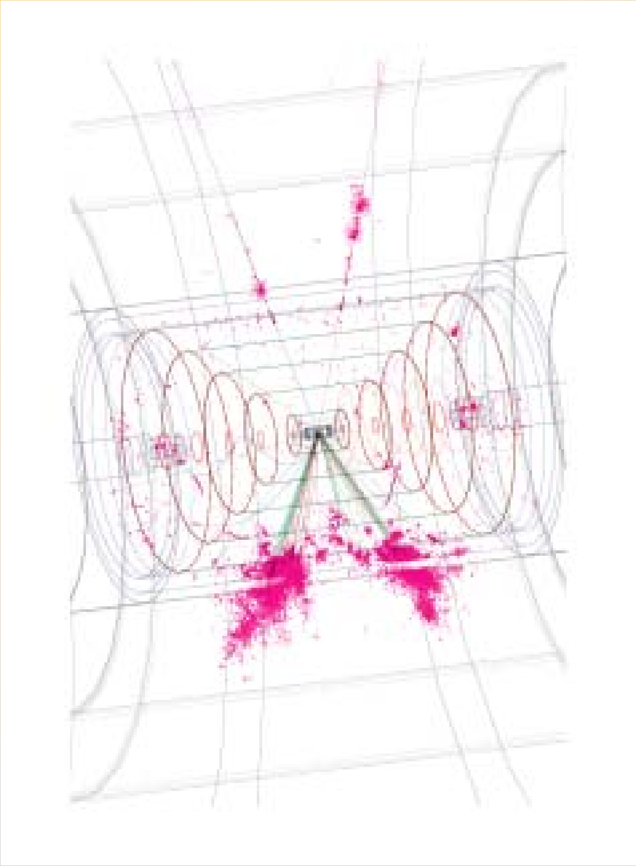
- Current solution is XML.

  XML is a text file and easily change detector geometry.

An example of XML file

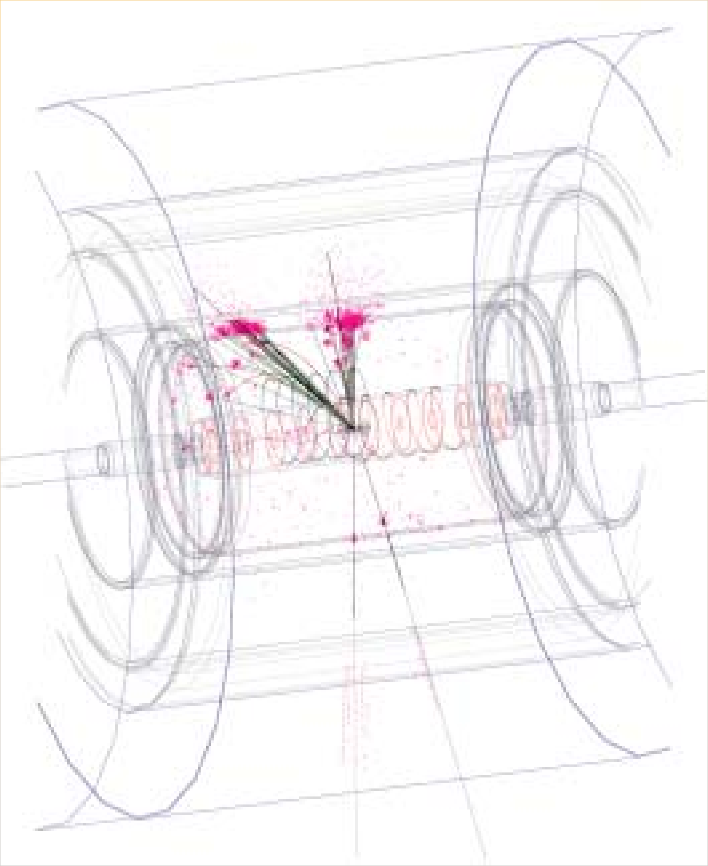
```xml
<volume id="EM_BARREL" rad_len_cm="0.7248" inter_len_cm="0.028" >
   <tube>
     <barrel_dimensions inner_r = "127.0" outer_z = "210.0" />
     <layering n="30">
       <slice material = "W" width = "0.25" />
       <slice material = "Si" width = "0.04" sensitive = "yes" />
       <slice material = "G10" width = "0.2" />
       <slice material = "Air" width = "0.01" />
     </layering>
     <segmentation cos_theta = "840" phi = "1680" />
  </tube>
  <calorimeter type = "em" />
</volume>

<volume id="HAD_BARREL" rad_len_cm="1.133" inter_len_cm="0.1193">

   <tube>
     <barrel_dimensions inner_r = "153.0" outer_z = "312.0" />
     <layering n="34">
       <slice material = "Stainless_steel" width = "2.0" />
       <slice material = "Polystyrene" width = "1.0" sensitive = "yes" />
     </layering>
     <segmentation cos_theta = "600" phi = "1200" />
  </tube>
  <calorimeter type = "had" />
</volume>
```

Event display (SDMar01)



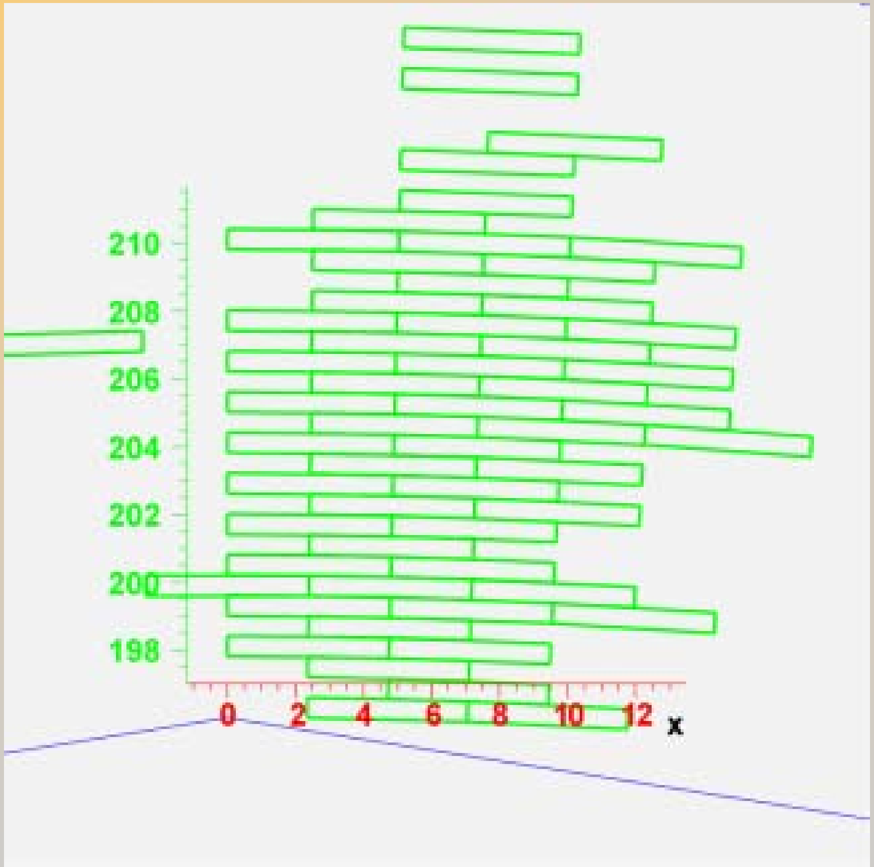
- ee→ZH;Z→μμ
- VXD:CCD
- Tracker: Silicon strip
- Magnet: 5Tesla
- EM Calorimeter: Si+W
- HAD Cal: Stainless+Scintillator

Event display (LDMar01)



- ee→ZH ; Z→μμ
- VXD: CCD
- Tracker: TPC
- Magnet: 3Tesla
- EM Cal.: Pb+Scintillator
- HAD Cal.: Pb+Scintillator

Staggered geometry



10GeV photon
EM calorimeter

Full reconstruction

- Track

  Tracks are found with cheater algorithm

  (gather hits which are from the same particle)

  then fit using Kalman filtering (next slide).

- Cluster

  Make clusters with Cheater Algorithm

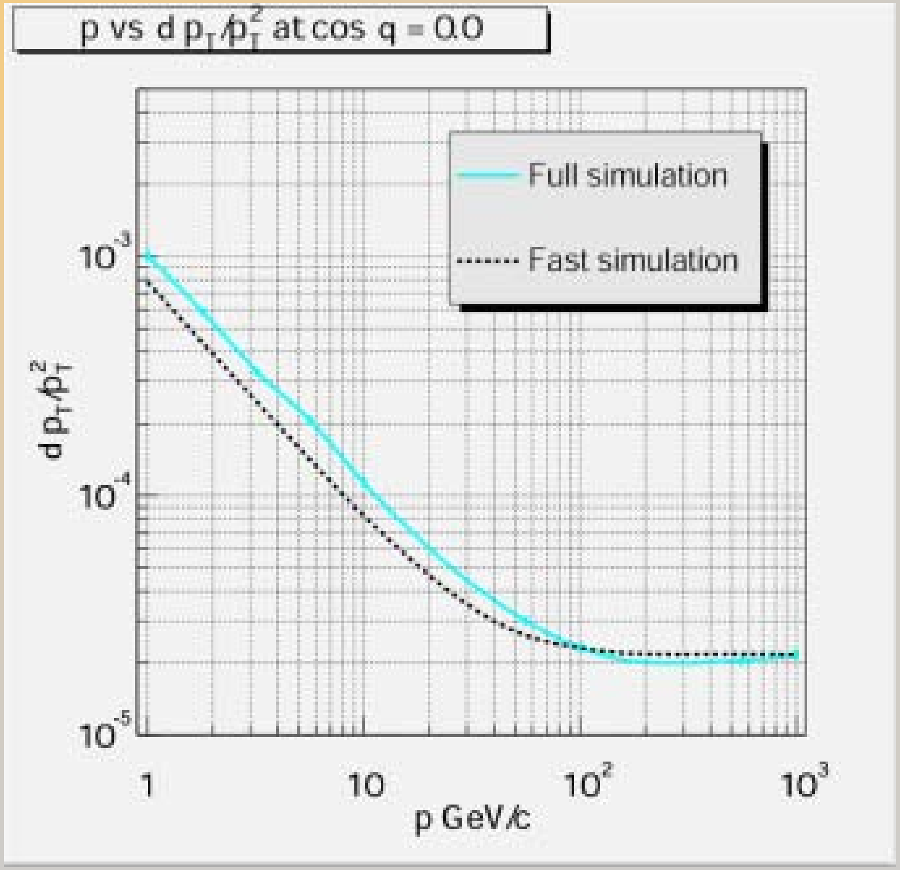
  (gather hits which are from the same particle)

  Local neighborhood algorithm

Kalman filter track fit

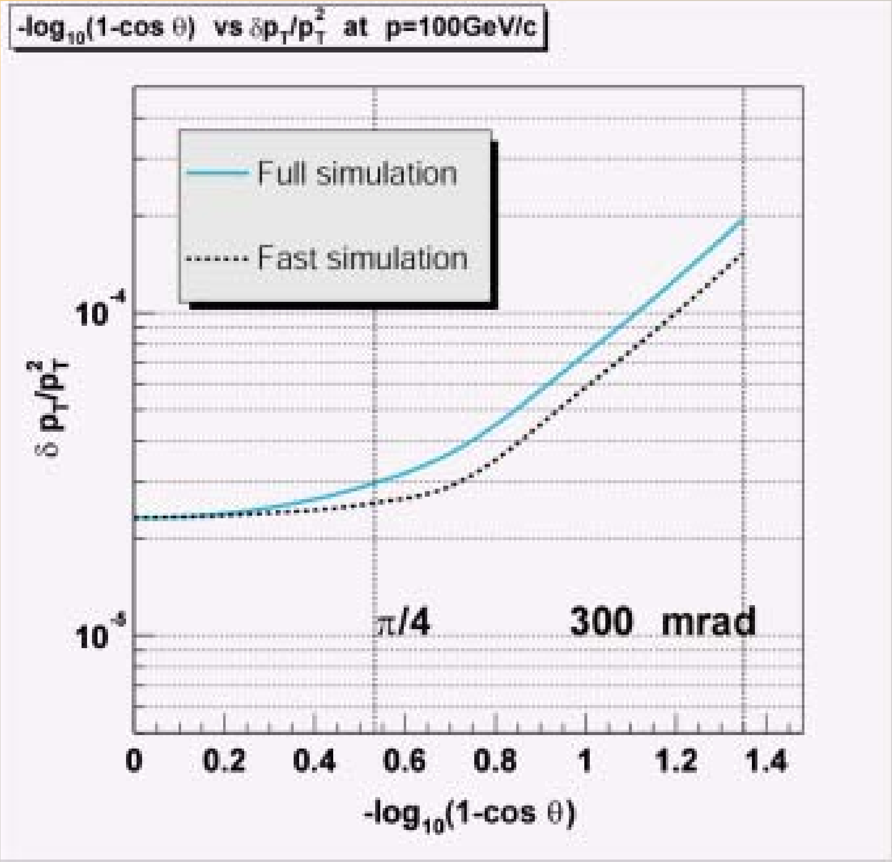
- Need to study non-gaussian effects from multiple scattering and energy loss.
- Track fitting with Kalman filter is implemented for LCDROOT, taking care of these effects.

Momentum resolution

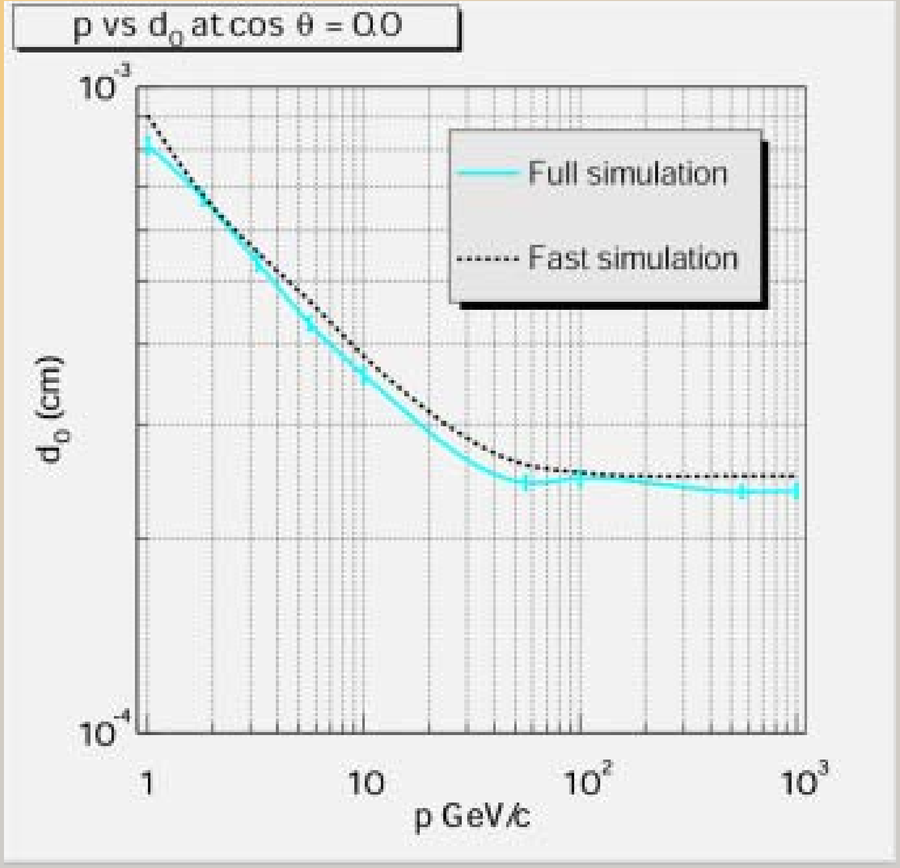


SDMar01

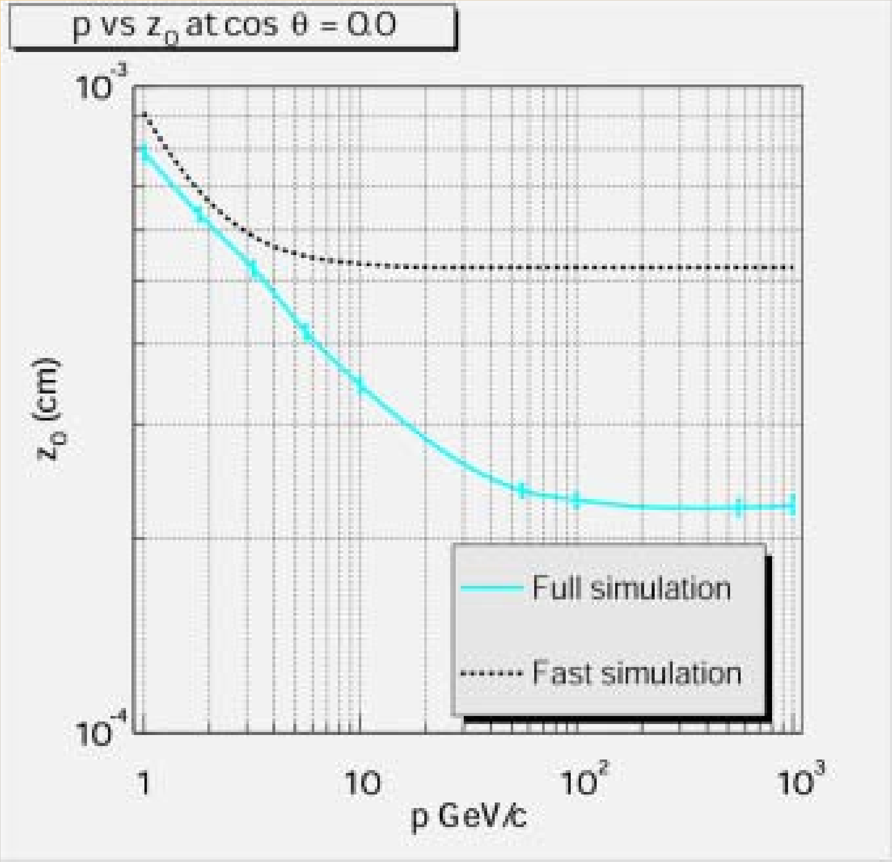
Momentum resolution 2



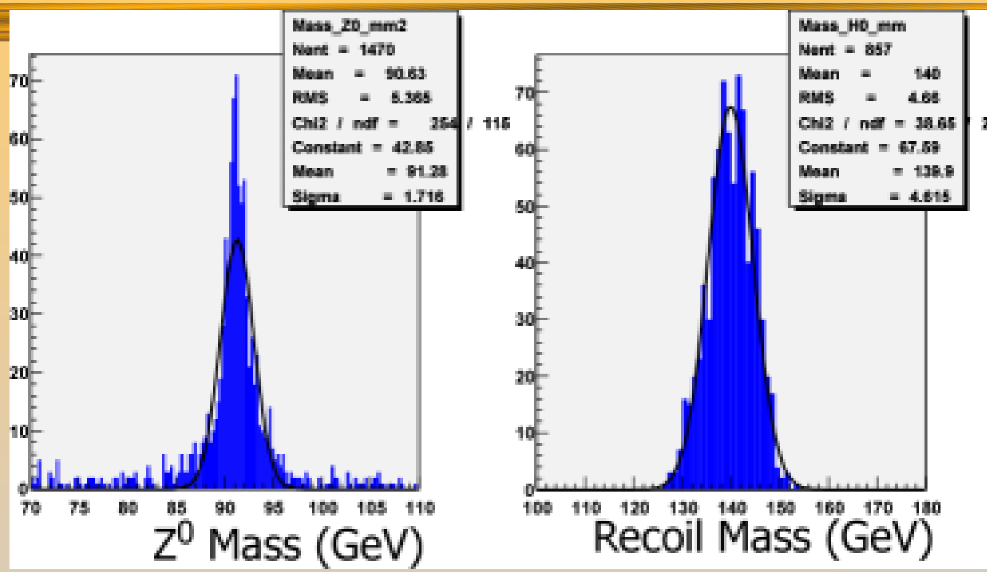
Impact parameter resolution 1



Impact parameter resolution 2



Recoil Higgs mass resolution



by M.Iwasaki

	Reconstructed Z^0 mass	Recoil H^0 mass	
$Z^0 \rightarrow \mu^+\mu^-$ mode	91.3±1.27 GeV	139.9±4.63 GeV	(FASTMC)
	91.3±1.72 GeV	139.9±4.61 GeV	(GEANT4)
$Z^0 \rightarrow e^+e^-$ mode	91.2±1.45 GeV	139.9±4.63 GeV	(FASTMC)
	90.8±1.94 GeV	141.3 ±5.56 GeV	(GEANT4)

Analysis

- We have several useful analysis tools for future linear collider studies

  Jet Finder … (Durham, Jade, Jade-E)

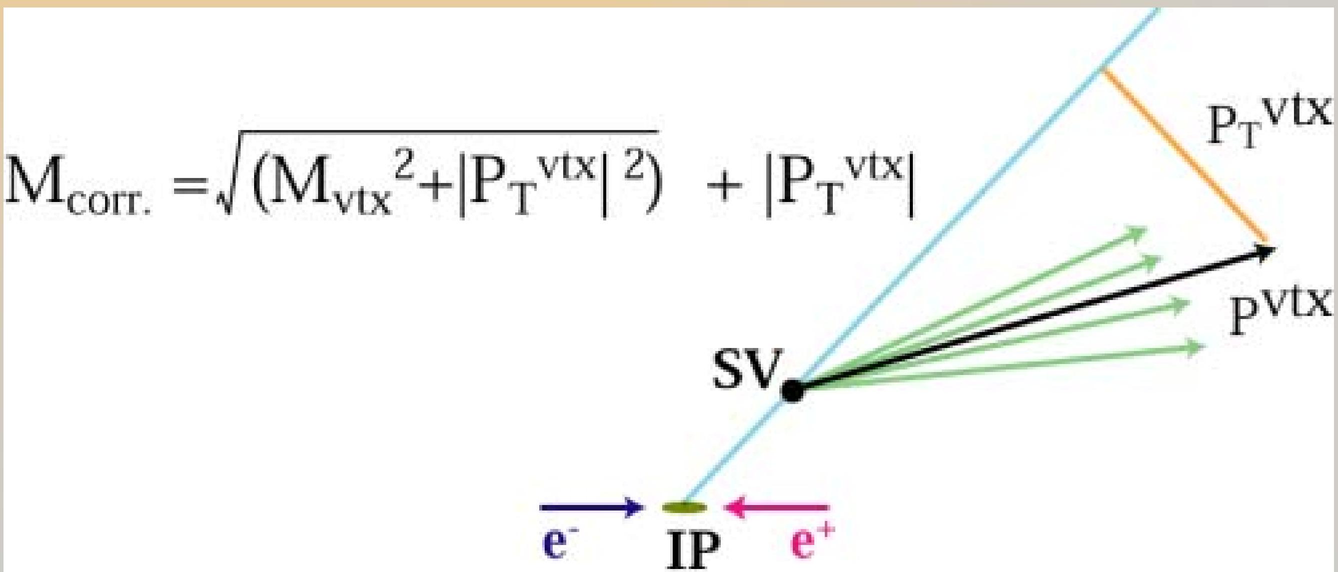
  Thrust Finder

  Particle extrapolator (for energy flow)

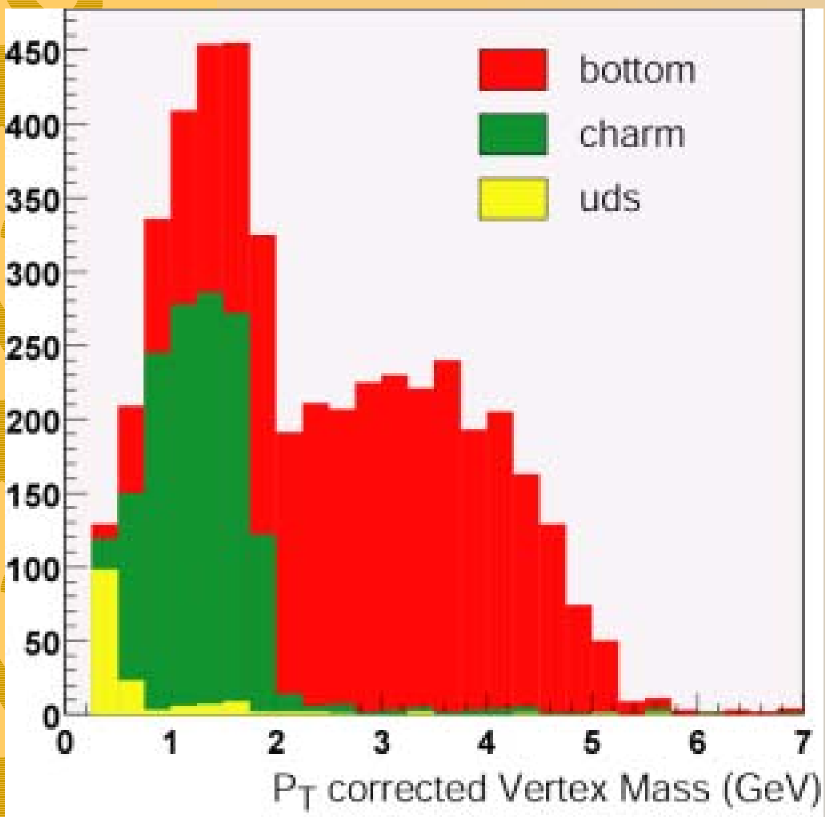
  Vertex Finder and Flavor tagging

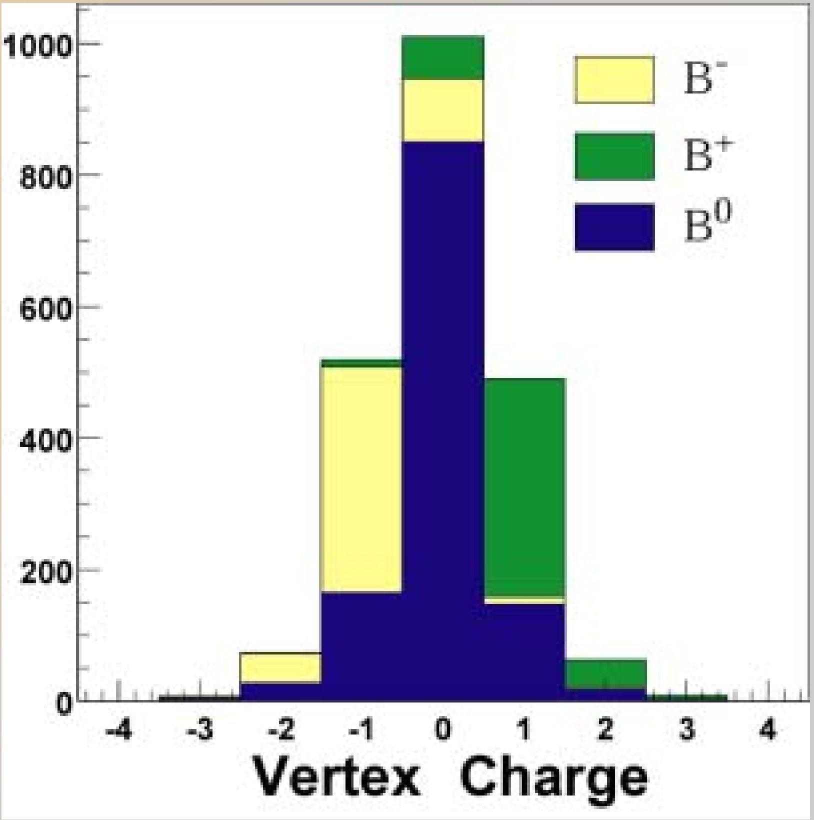
Vertex finder

- SLD's unique topological vertex finder + mass tag
  D.J.Jackson NIM A388, 247 (1997)
  SLD collaboration PRL 80, 660 (1998)

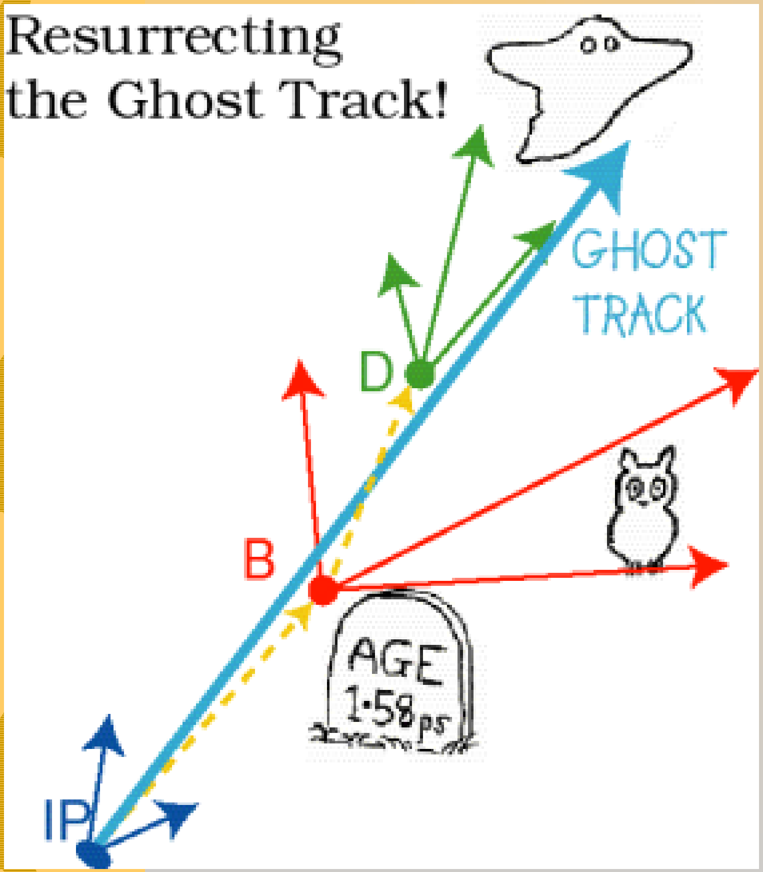


Vertex finder



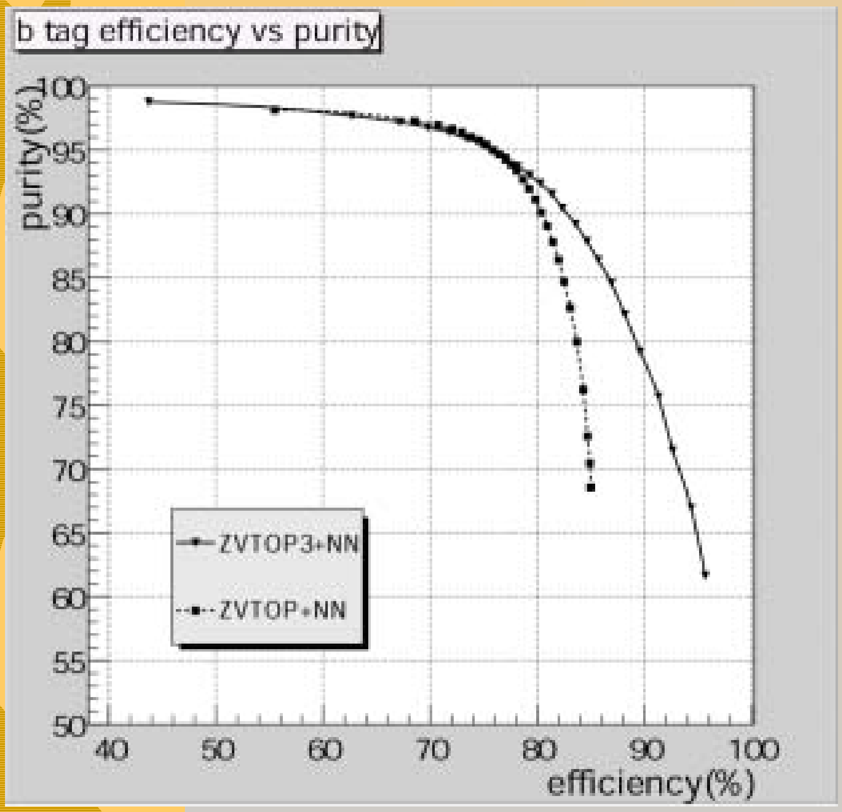


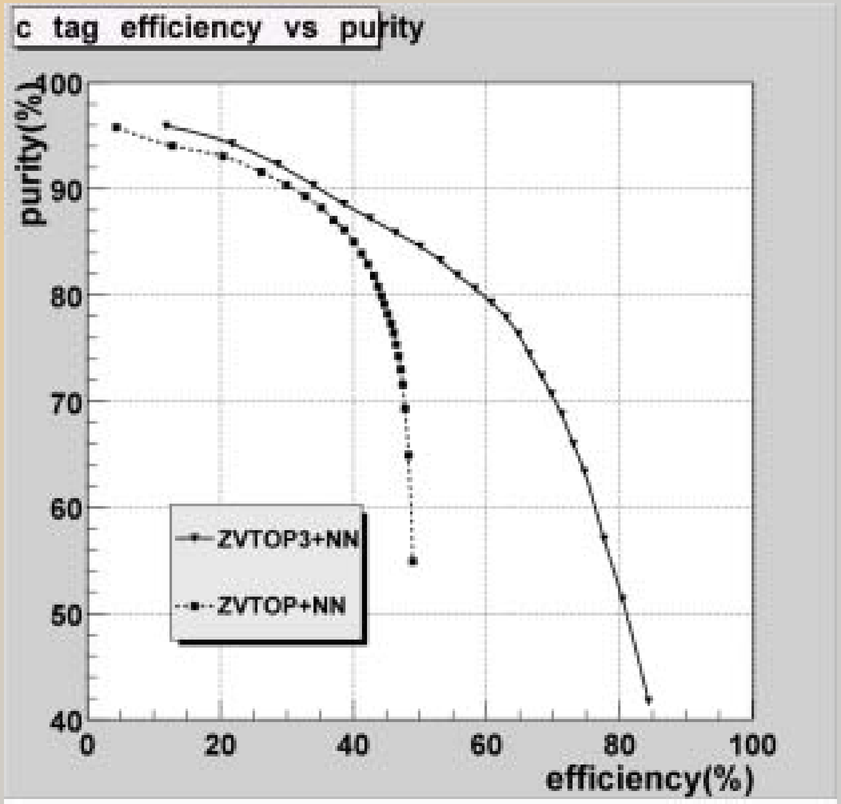
Ghost track algorithm



- Ghost-track vertex finding algorithm implementation
- Use straightness of b-decay chain

H.F. jet tag with N.N.

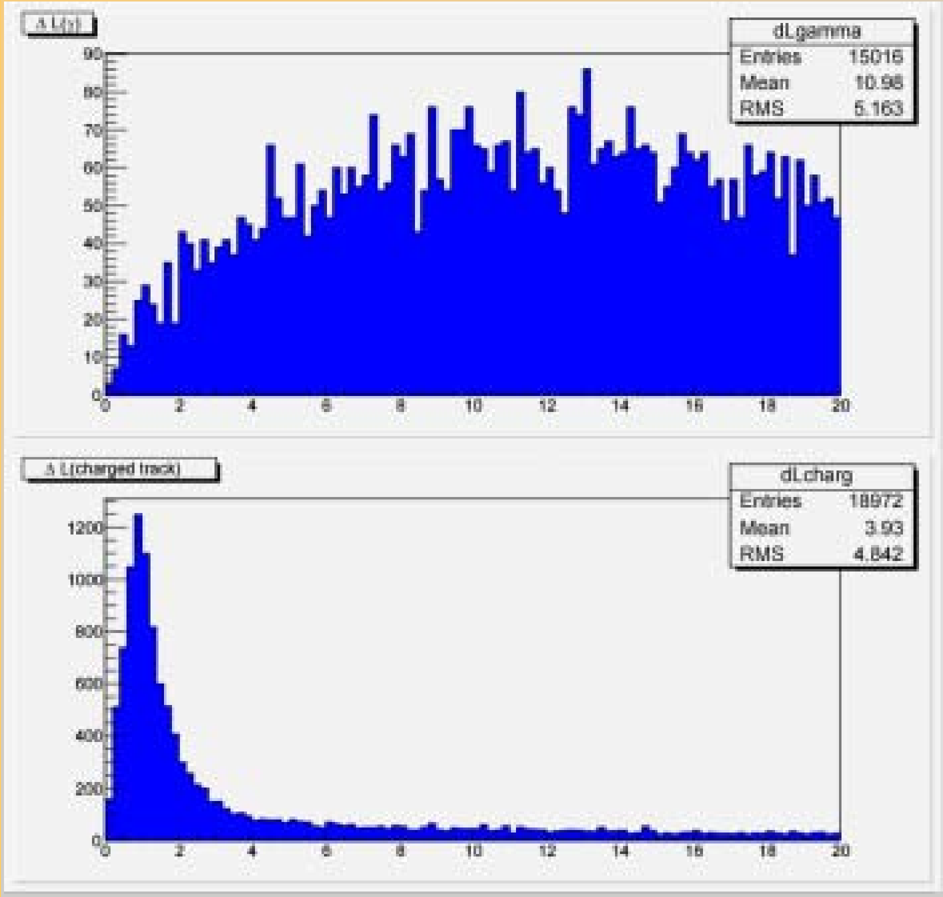




Enegy flow analysis

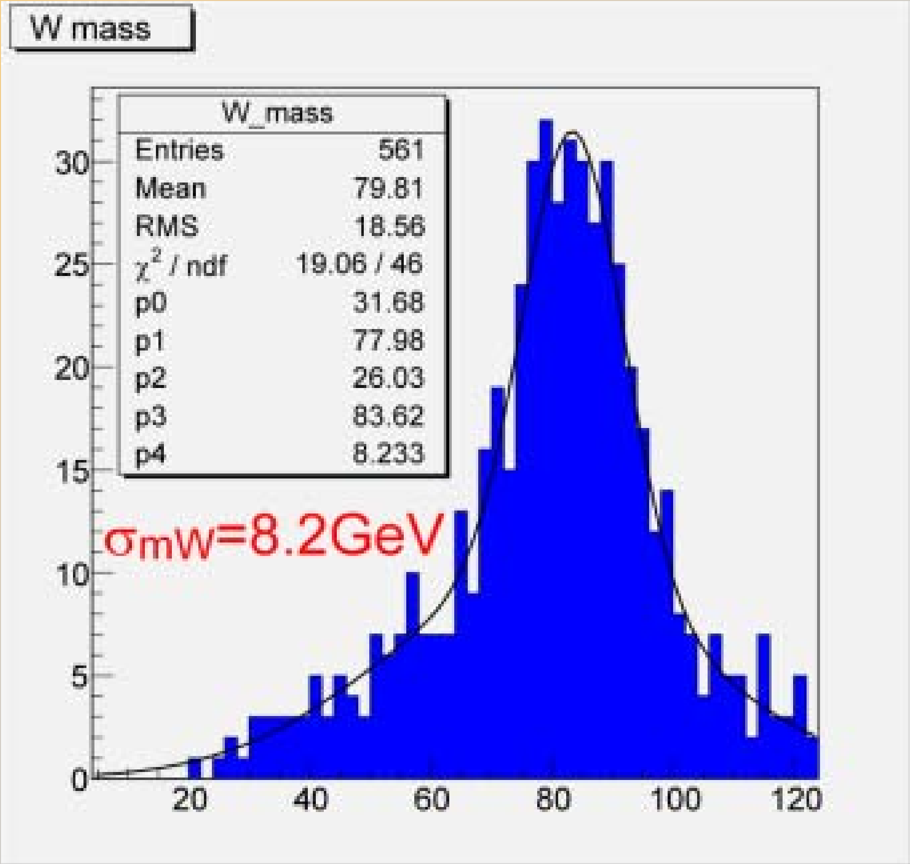
- Requirements from future linear collider
  →very good jet energy resolution
  →needs energy flow method
  typical multi-jet event
  chrg. part. carry 64% E→ tracker
  photon carry 25% E→EM cal.
  neut. Had. carry 11% E→HAD cal.
- Calorimeter must be optimized for energy flow.
  → need detailed detector study.

Track extrapolator



- Reconstructs jets from tracks + neutral clusters
- Select neutral clusters by seeing track-cluster matching

W mass reconstruction



Summary

- We have developed simulation/analysis tools for the future Linear Collider experiments
- The simulation/analysis tools based on ROOT

  → work well!
- There is a LCD Root web page!

  http://www-sldnt.slac.stanford.edu/nld/New/Docs/LCD_Root/root.htm

Future plan

- LCDROOT is under huge changing.
  Use ROOT classes as possible.
  (ex. XML→TGeomXXX classes)
- Track finder
- Beam backgrounds (ROOT format) by GEANT4 are expected to be implemented for JLC, NLC, TESLA, and CLIC configuration.