Geant4 application for future linear collider detector studies

Toshinori Abe & Masako Iwasaki

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Many thanks Dr. Asai for his kind help

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  (by Dr.Iwasaki)
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Introduction

- 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.
- We used to use GISMO, but now switch to GEANT4

Detector geometry

- **Detector geometry must be flexibly set.**

  → We do not want to make executables detector by detector.
- **Current solution is XML.**

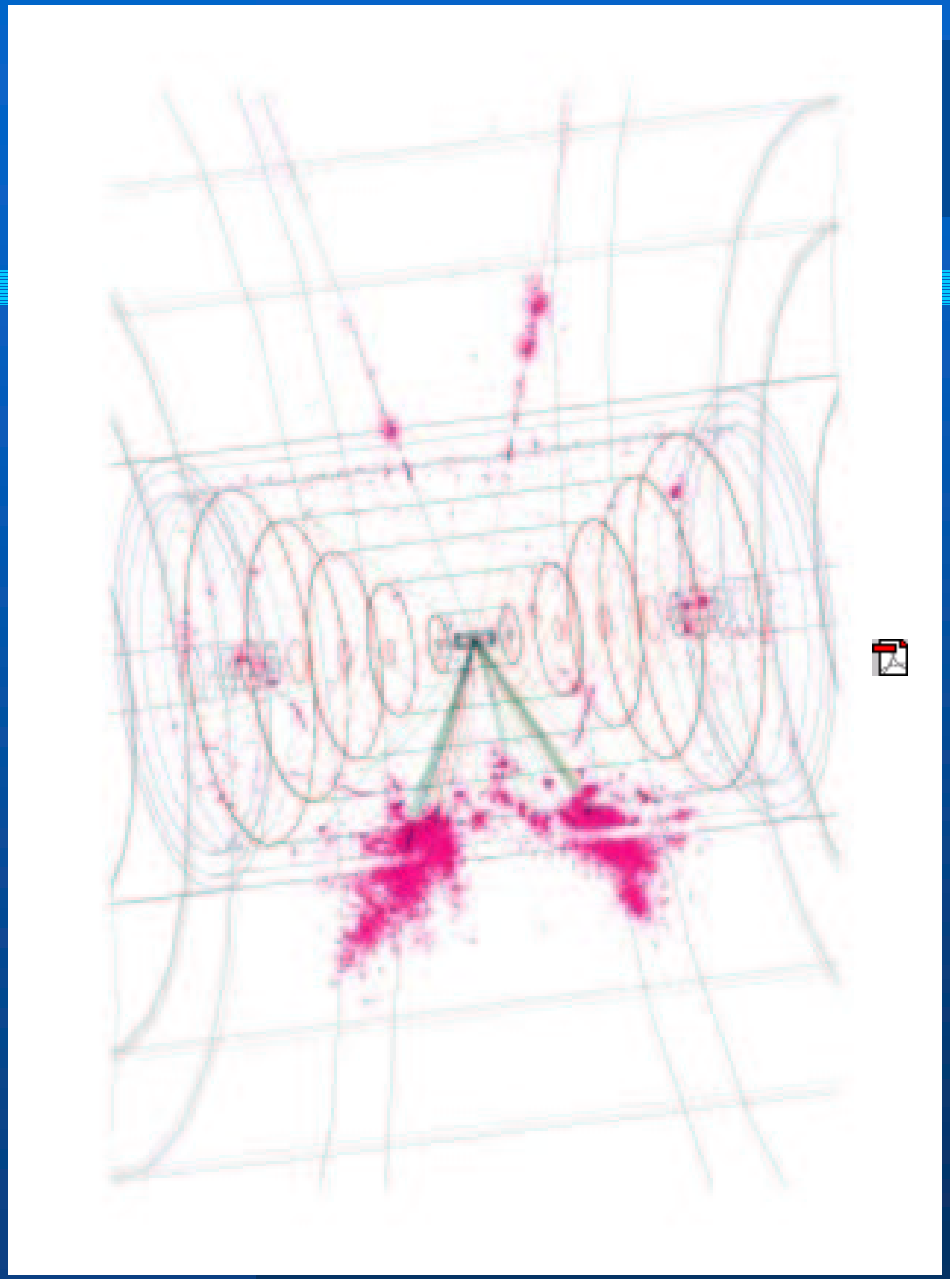
  XML is a text file and easily change detector geometry.

An example of XML file

```
<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>
```



ee→ZH ; Z→μμ (with SD)

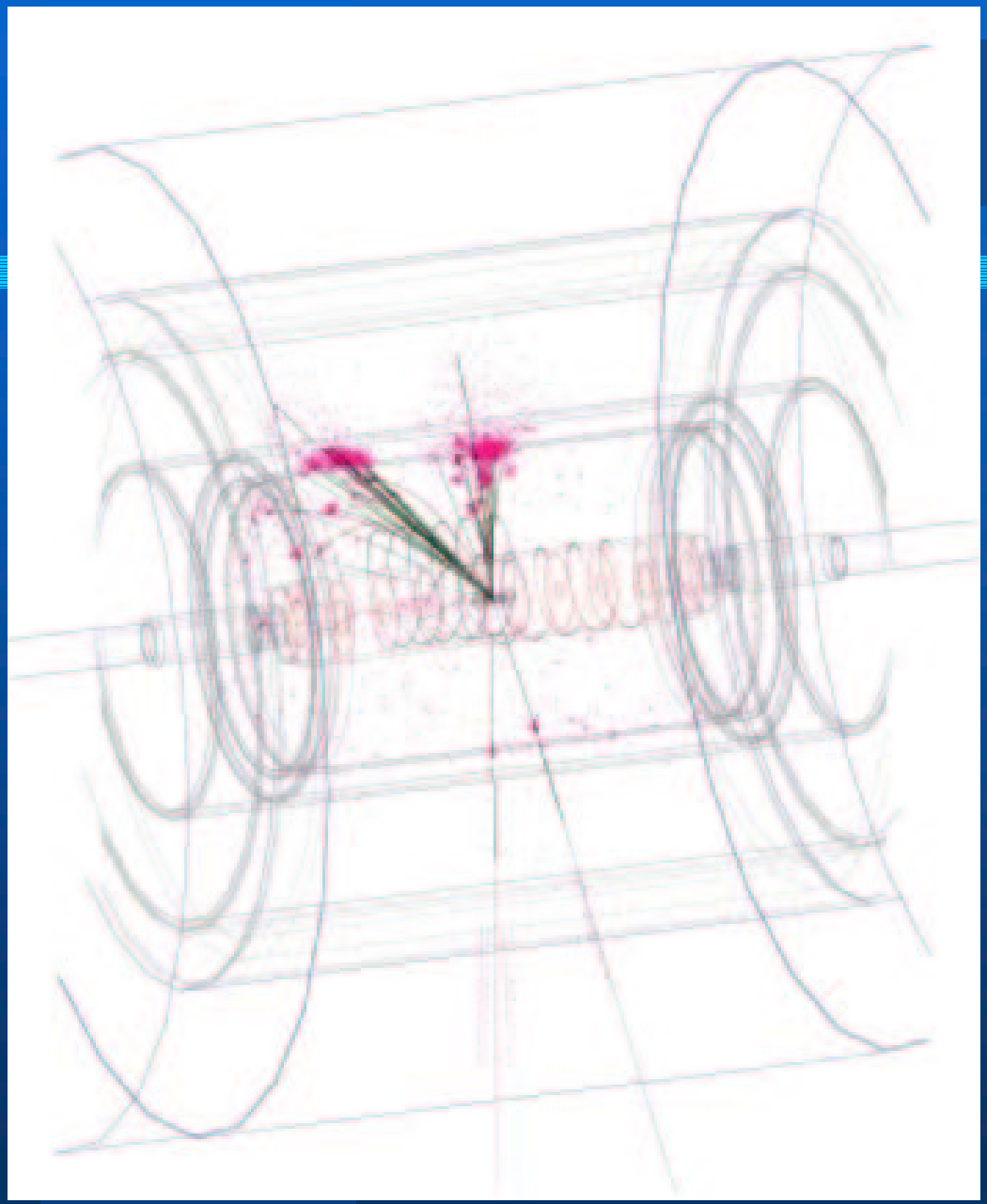
VXD:CCD

Tracker: Silicon strip
(5layers)

Magnet: 5Tesla

EM Calorimeter:
Si+W
5x5mm^2
R=127cm

HAD Calorimeter:
Stainless Steel
+ Scintillator
1x1cm^2
R=143cm



ee→ZH ; Z→μμ (with LD)

VXD:CCD
Tracker: TPC
Magnet: 3Tesla
EM Calorimeter:
Pb+Scintillator
5x5cm^2
R=200cm
HAD Calorimeter:
Pb+Scintillator
20x20cm^2
R=250cm

GEANT4 application for LCD

- We use GEANT4.4.0 and ROOT3.2.7.
- Input generator data is ROOT file format or STDHEP format.
- Output data (hits,…) is written in ROOT file format.
- The application program works on various computer plat forms (Linux, SunOS, Windows).

Event generation time

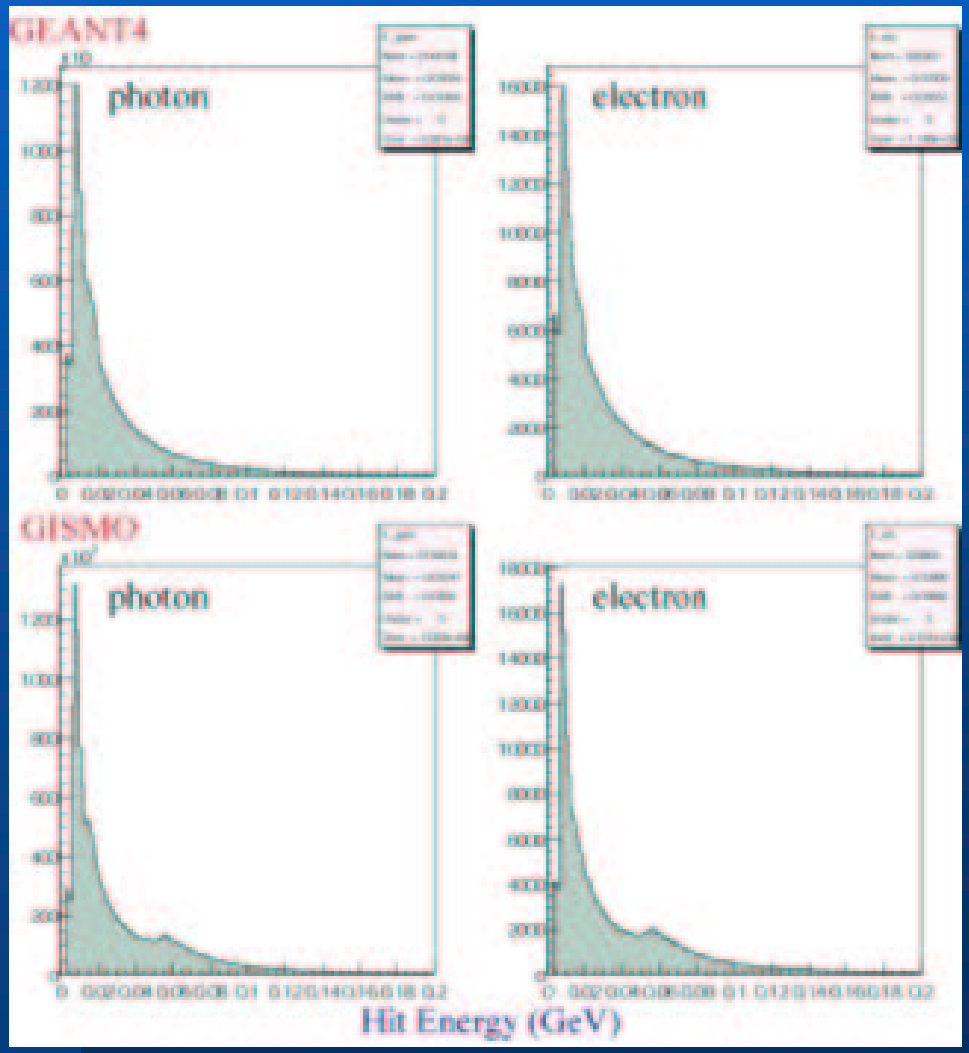
- Generate ee→tt @ Ecm=500 GeV
- Computer: RedHat7.2+733MHz CPU

  SD: ~ 1mim/event

  LD: ~ 3mim/event

Comparison between GEANT4 and GISMO (by Dr.Iwasaki)

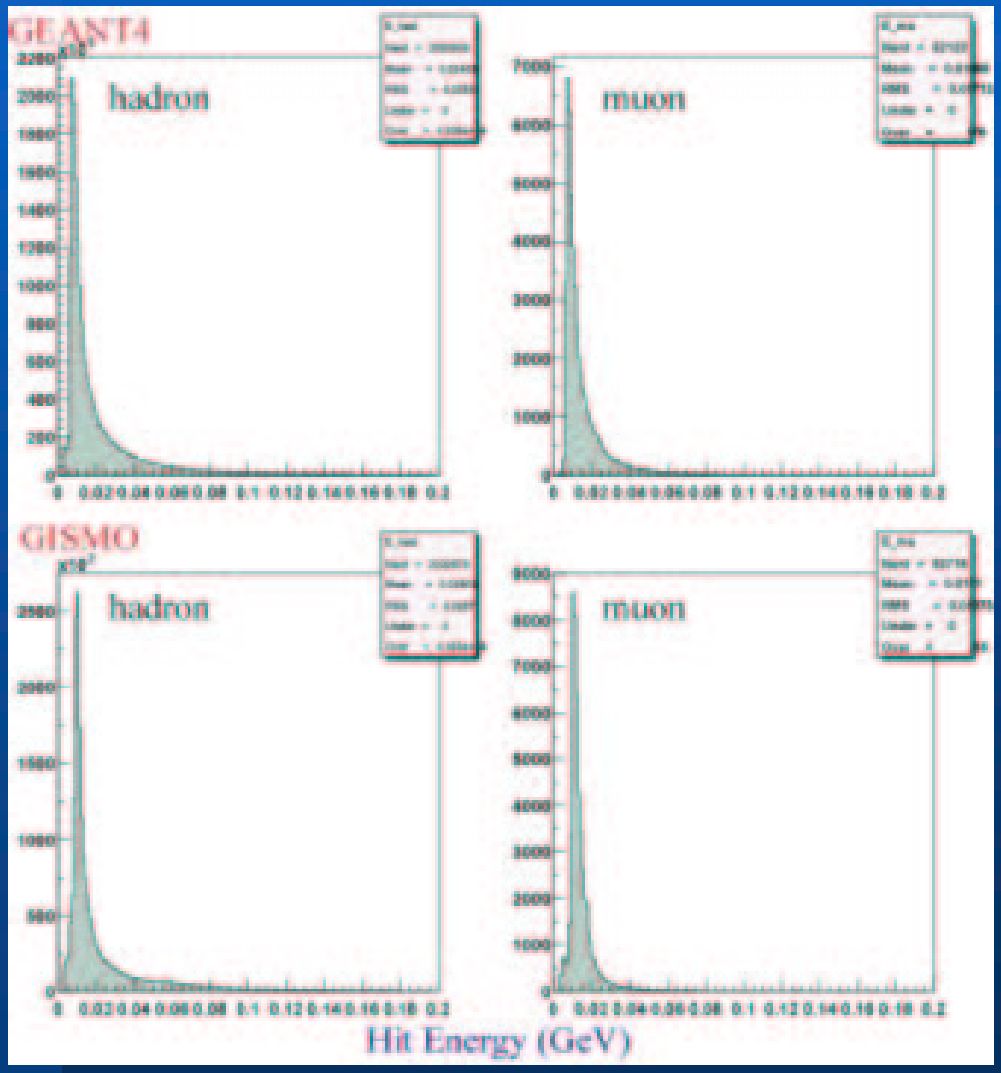
EM Hit Energy (e & photon, SD)



$E_{GEANT4} < E_{GISMO}$ (~10%)

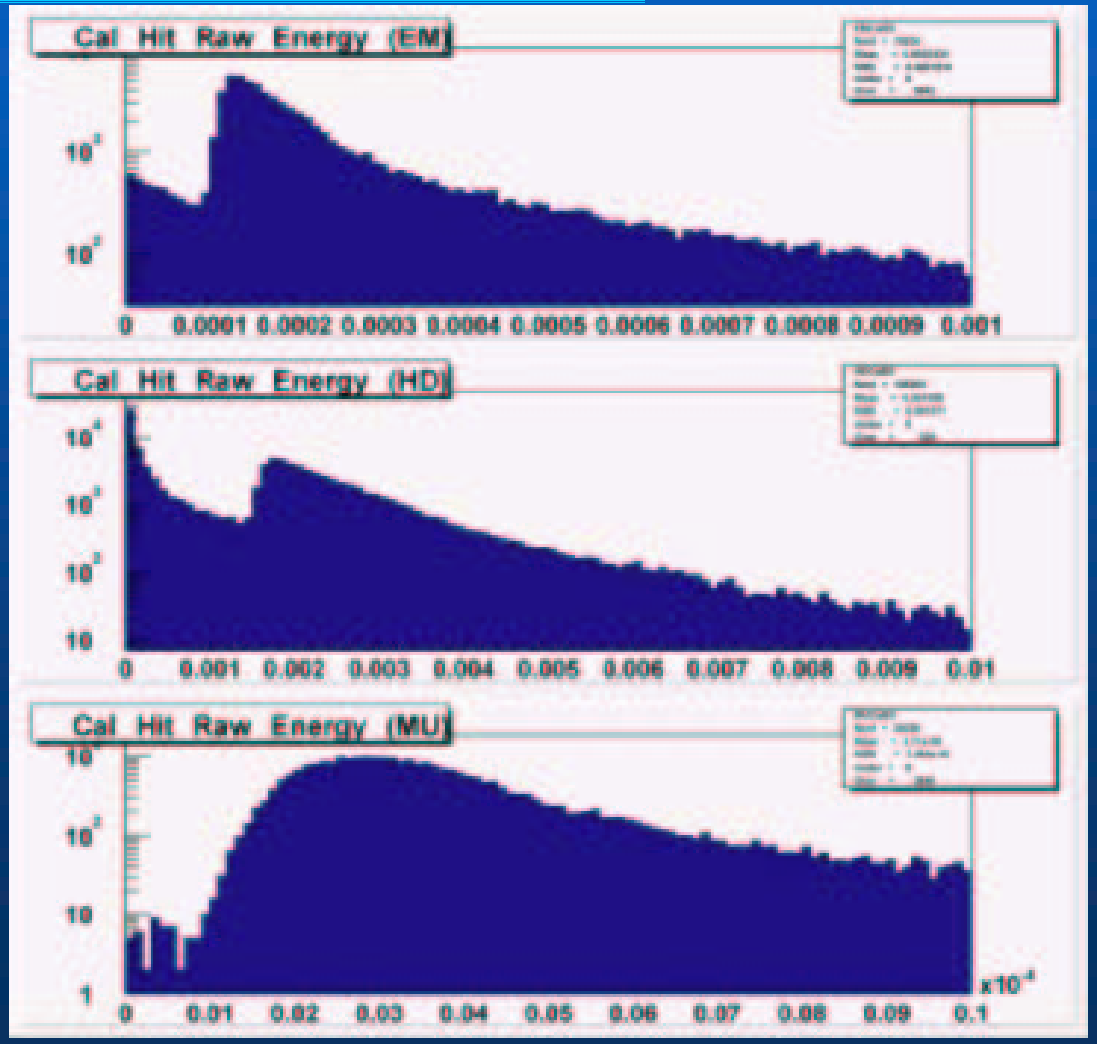
(Use same energy scale)

EM Hit Energy (π & μ, SD)

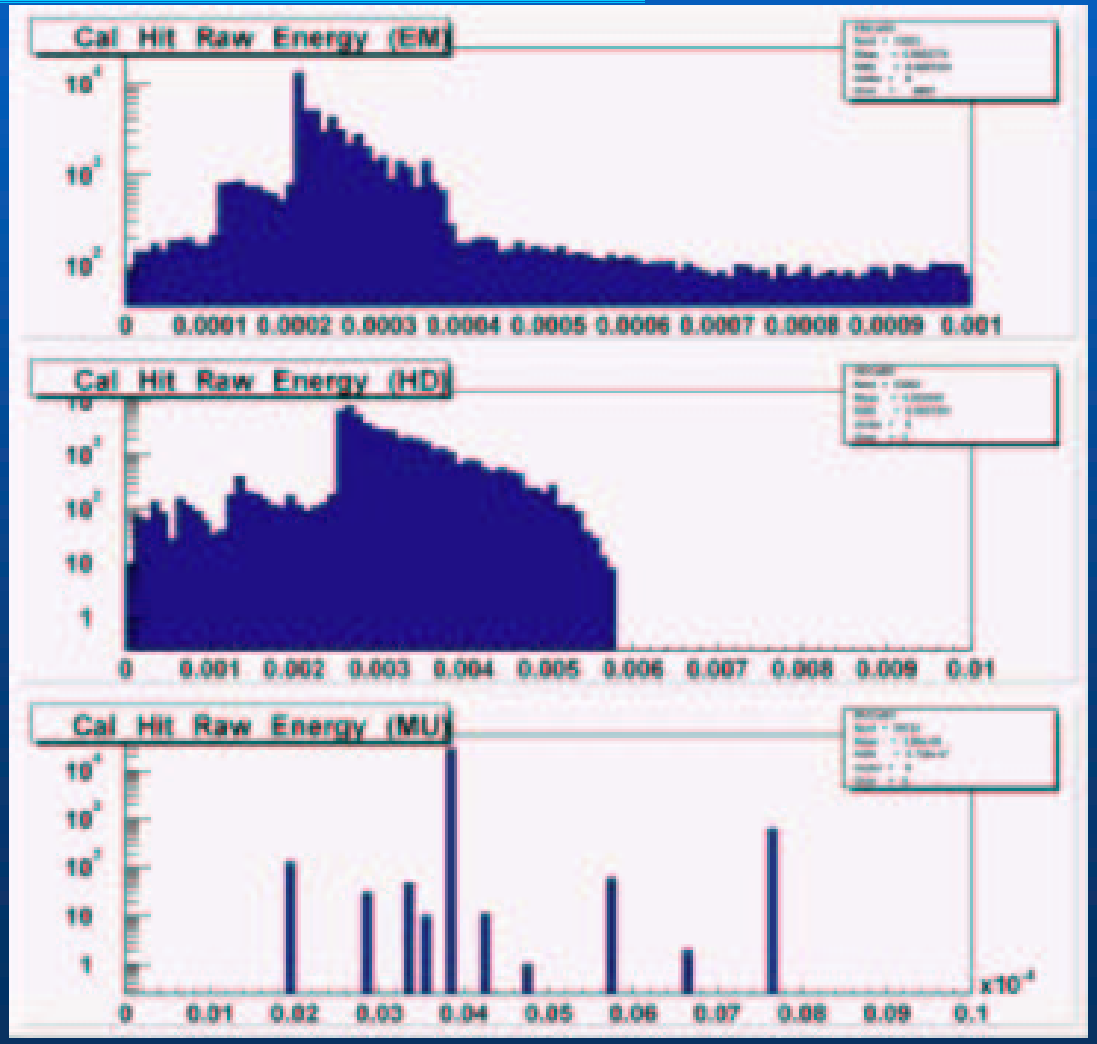


GISMO …
less high energy tail

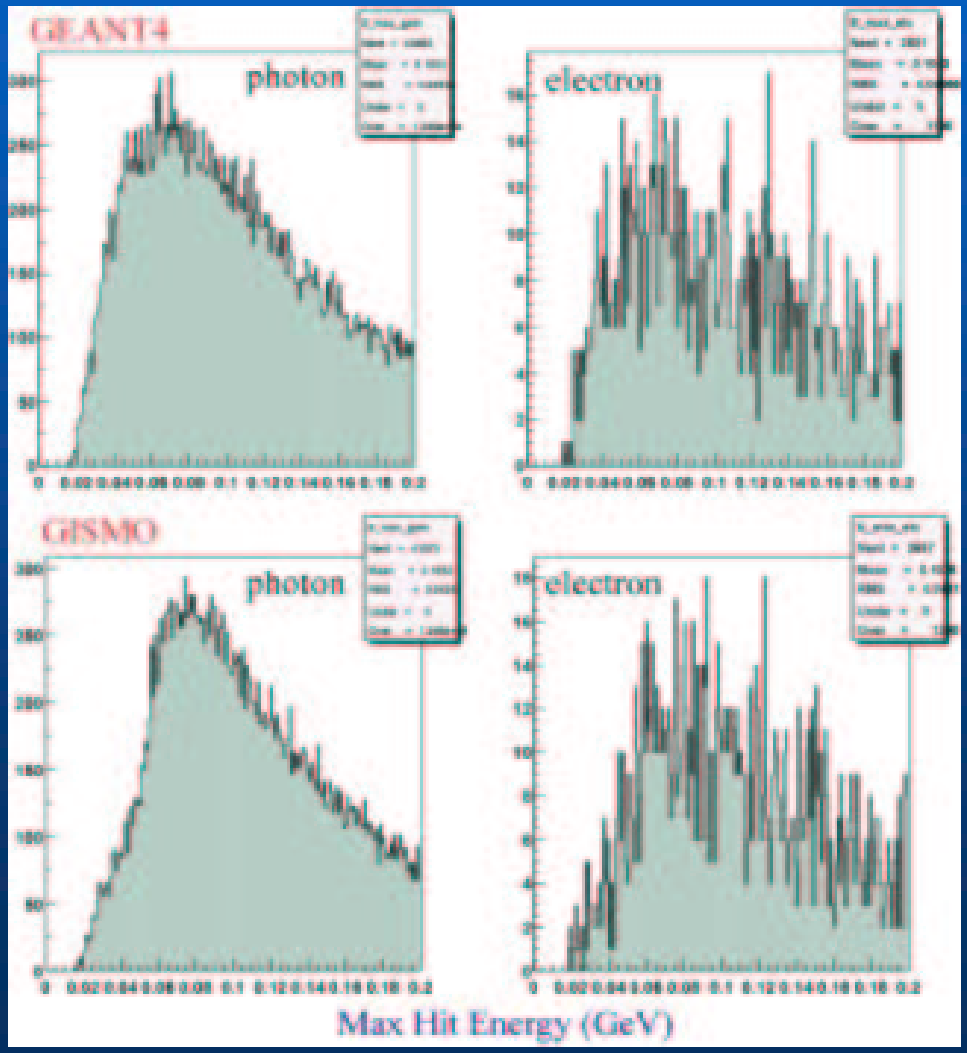
Hit Energy (Z→μμ, SD, Geant4)



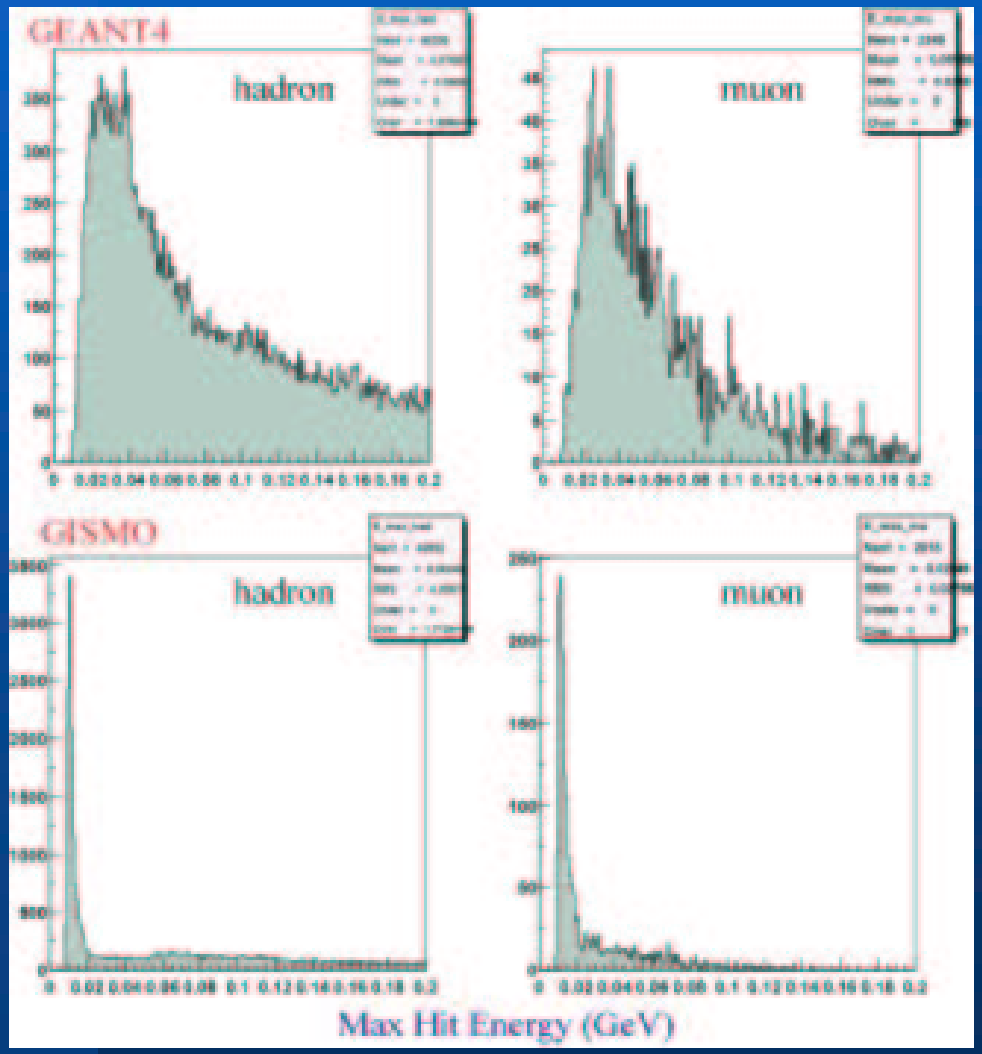
Hit Energy (Z→μμ, SD, Gismo)



Max. hit energy in a cluster (e & photon, SD)



Max. hit energy in a cluster (π & μ, SD)

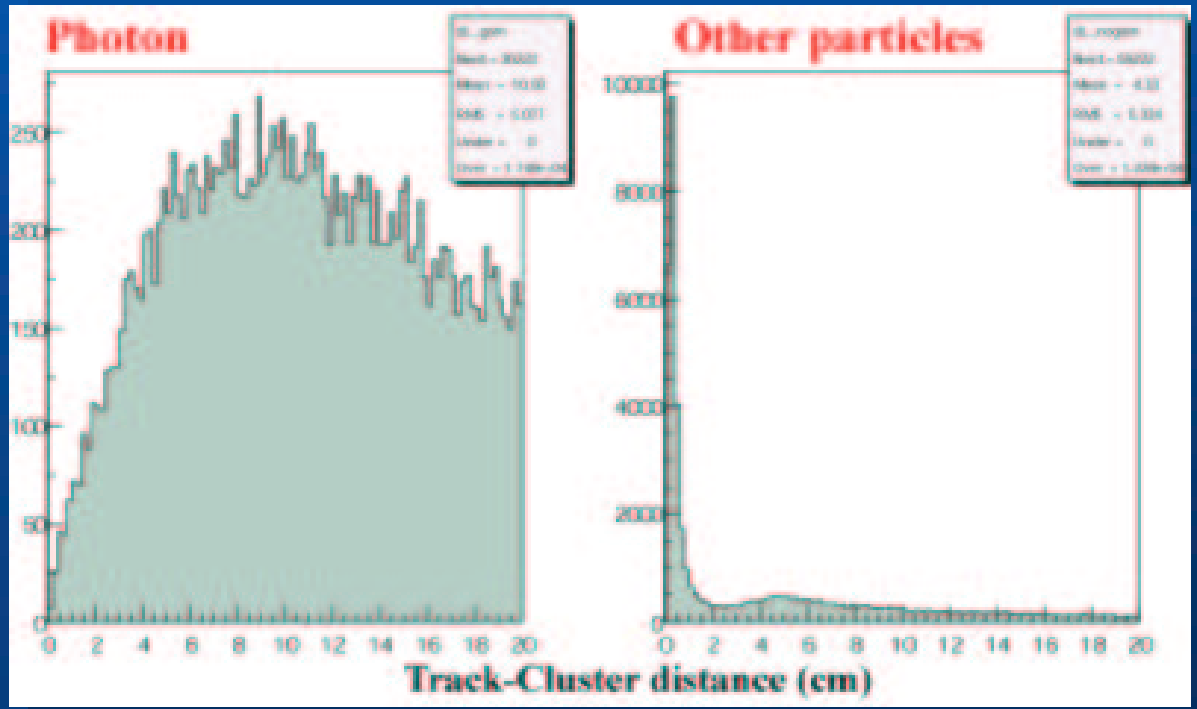


GISMO/GEANT4 quite different shape…
need more study in future

Photon reconstruction (by Dr.Iwasaki)

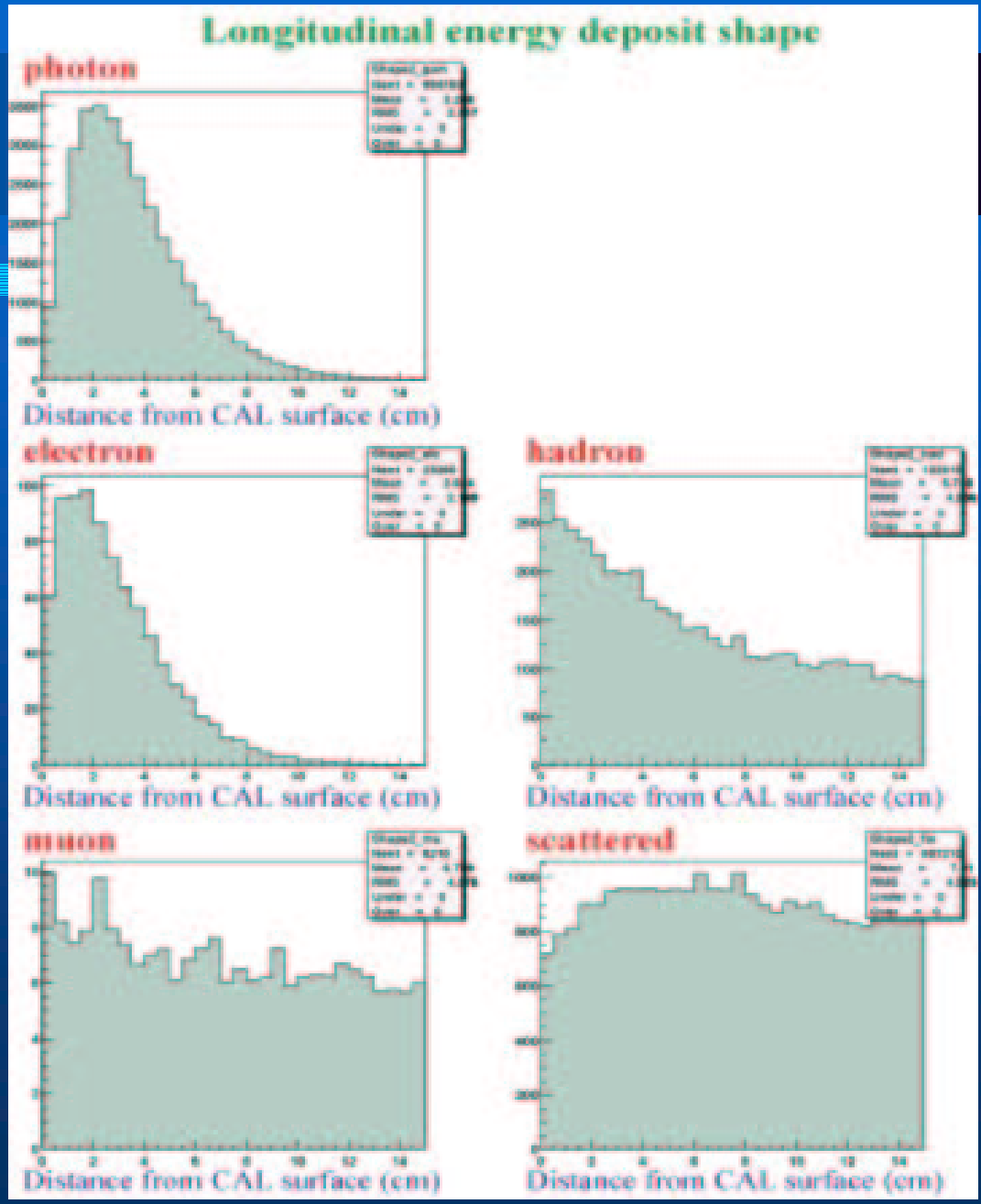
γ selection by transverse information

- **Extrapolate charged tracks to the cluster radius.**
- **Associate the nearest track to the cluster.**



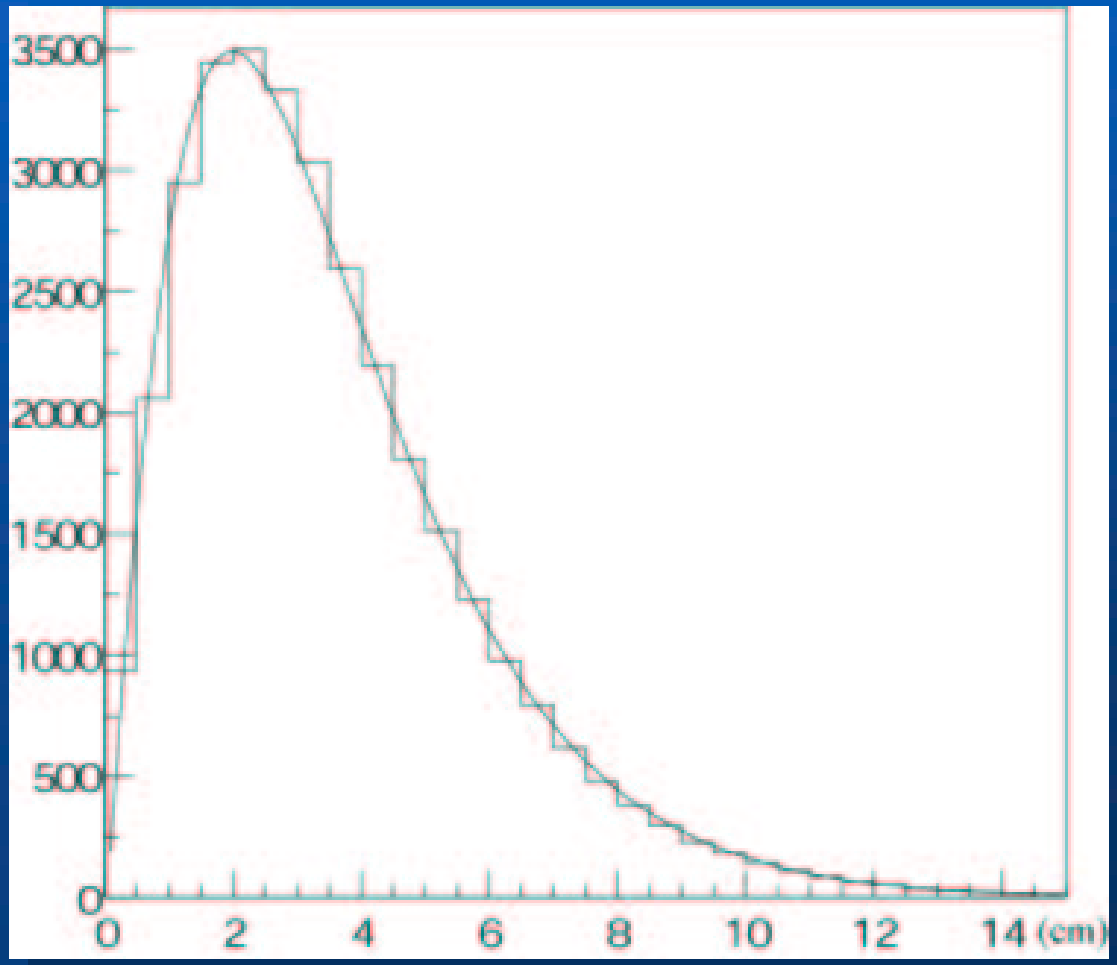
γ selection:
Π=48%
ε=98%

γ selection by longitudinal information



γ selection by longitudinal information (cont.)

We determine the longitudinal γ shape by fitting.

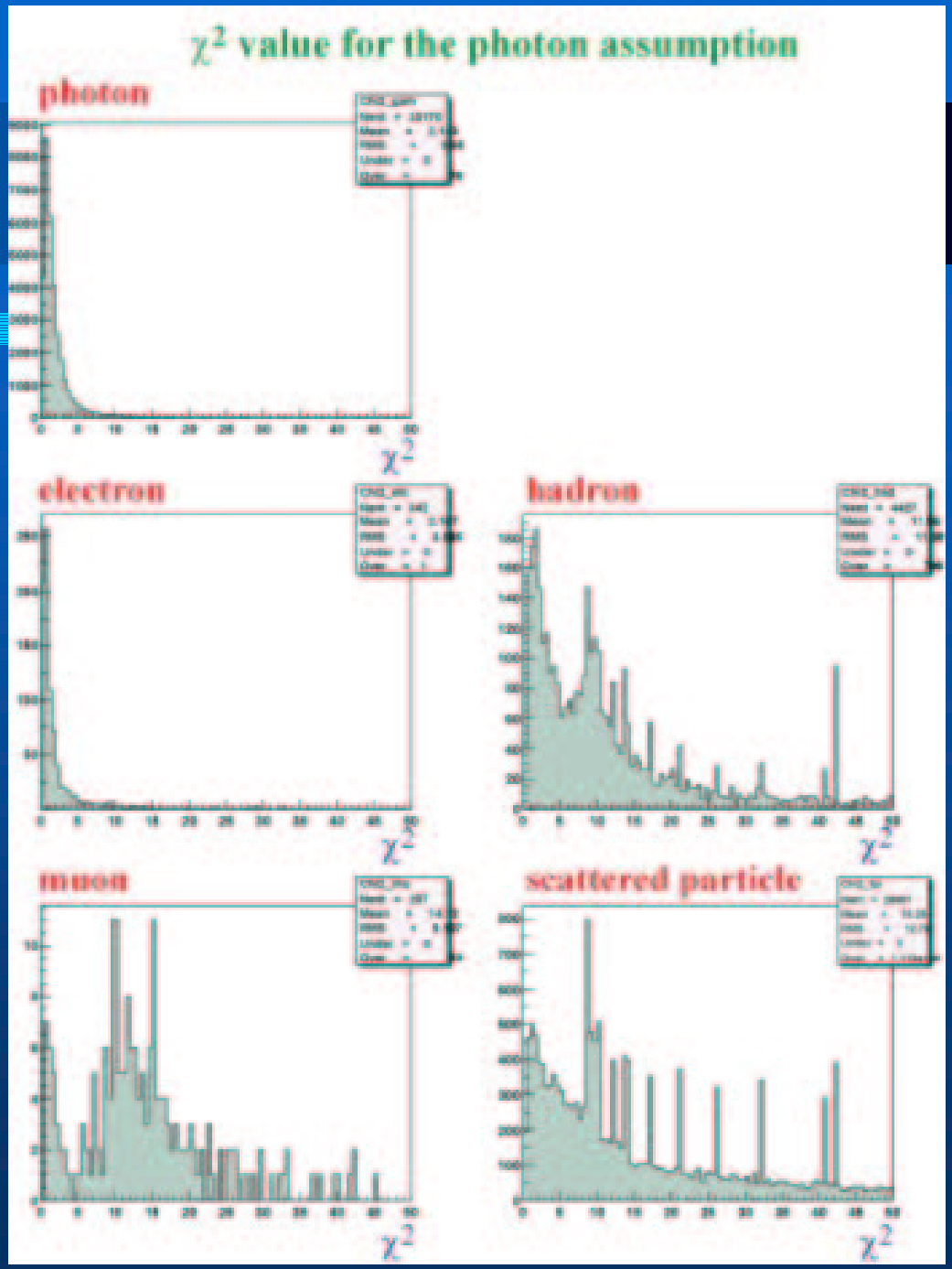


χ^2 for the γ assumption

- **Overall γ selection performance with other selection:**

  Π=85%

  ε=85%



Mass reconstruction (no kin. con.)

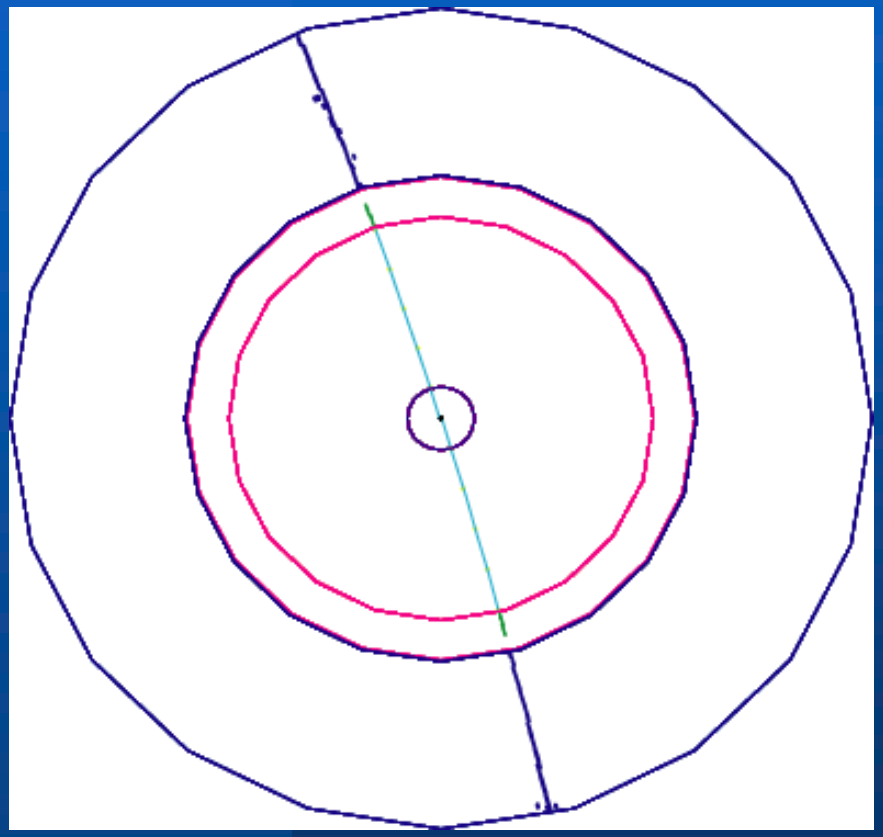
GEANT4	W mass	error	Top mass	error
Track + γ	67.1±15.9 GeV	(28%)	141.0±33.5	(24%)
Track + γ (true)	70.2±16.9	(24%)	147.0±31.7	(22%)
Track + γ (true) + h^0(true)	77.2±15.1	(20%)	159.7±30.7	(19%)

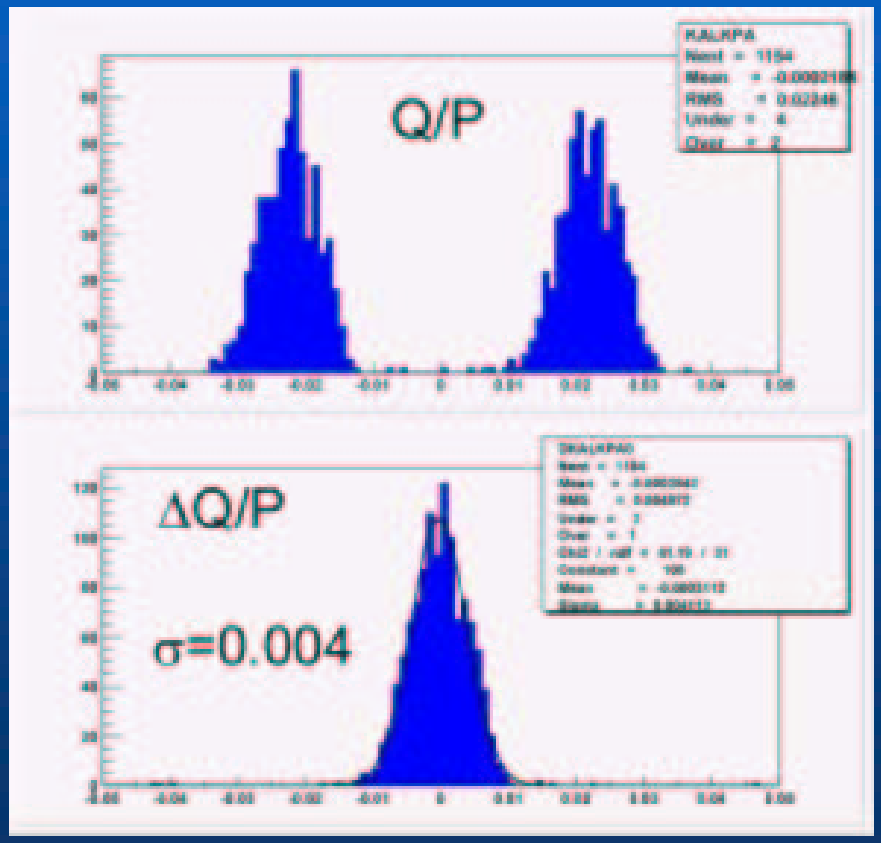
- True-γ/selected-γ difference … 2~4%
  →very good γ selection performance
- Adding the neutral hadron clusters
  →can improve mass resolution 3~4%

Calorimeter tracking

- Fine granularity of SD calorimeter (5X5mm^2) makes enable tracking.
- Calorimeter may help track finding with tracking device and can significantly contribute to physics analysis (GMSB,…)
- We have checked the tracking performance using $Z \rightarrow \mu\mu$ and single photon events.

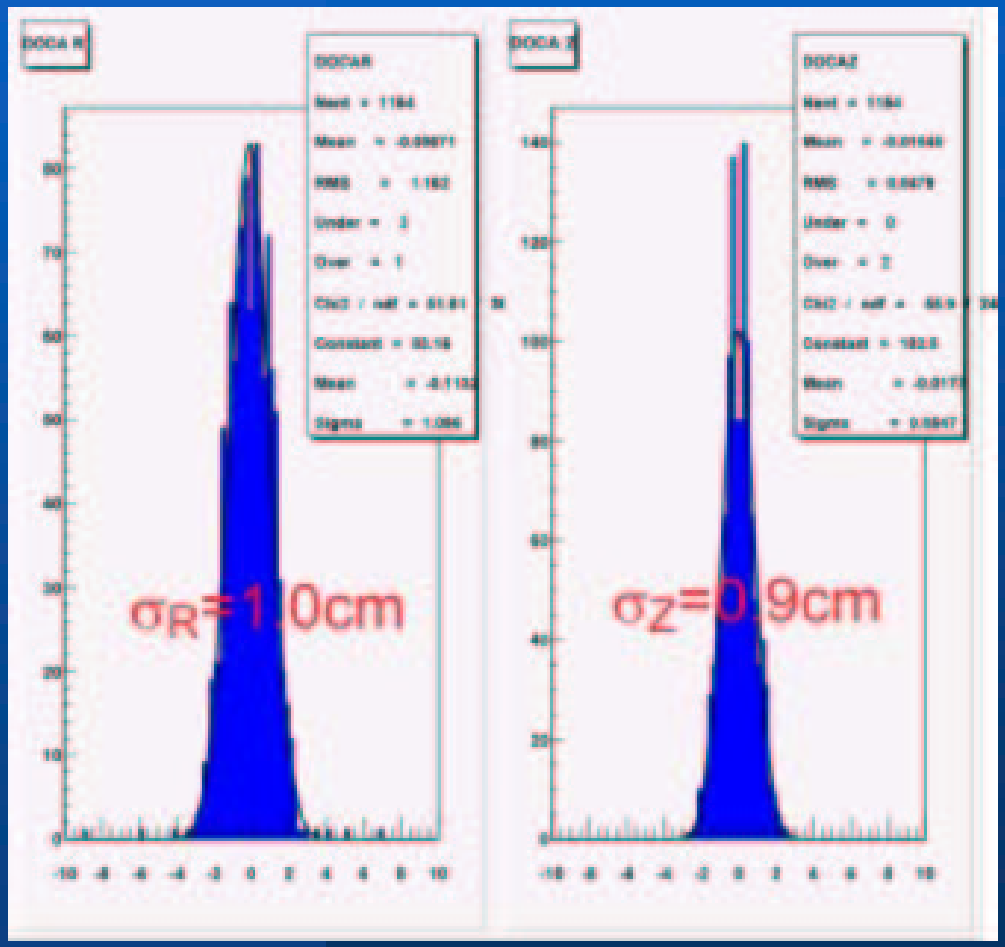
Charge separation





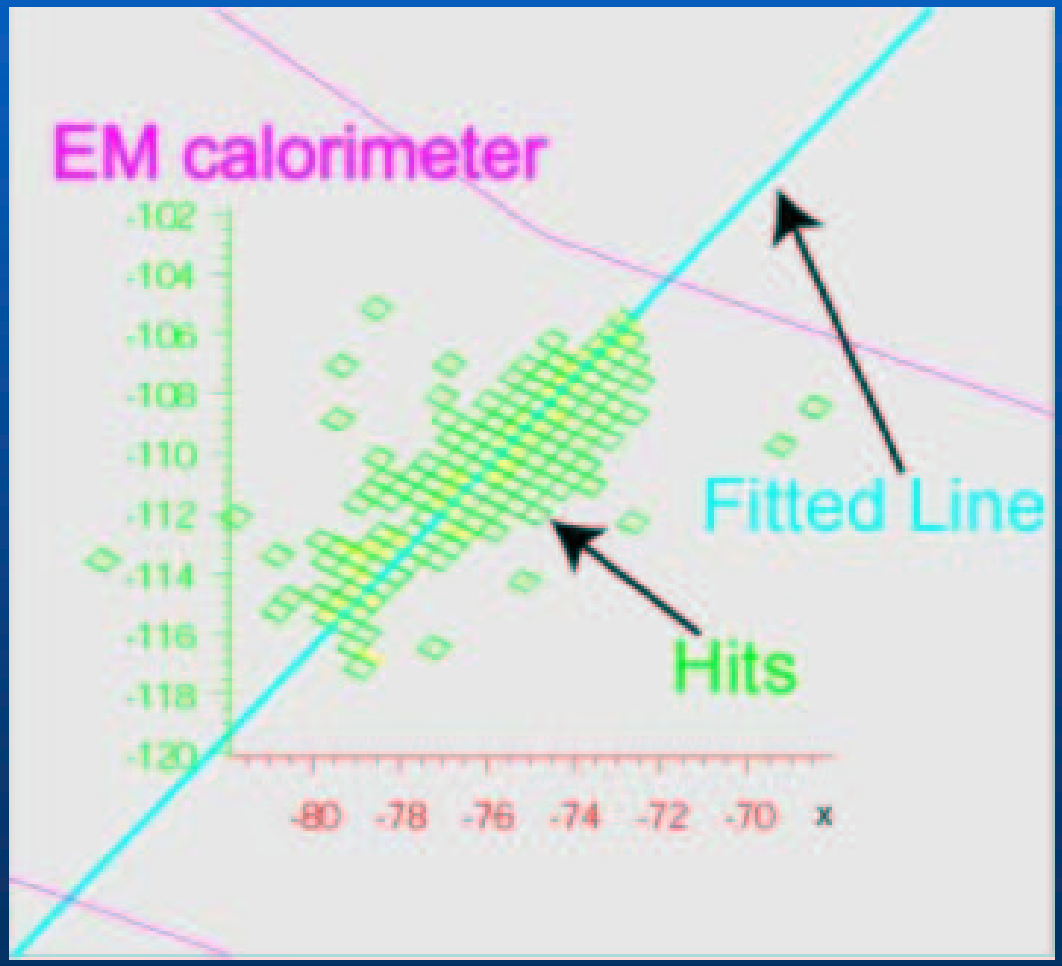
- **Sample is Z→μμ @ Ecm=91.26GeV**

Impact parameter resolution

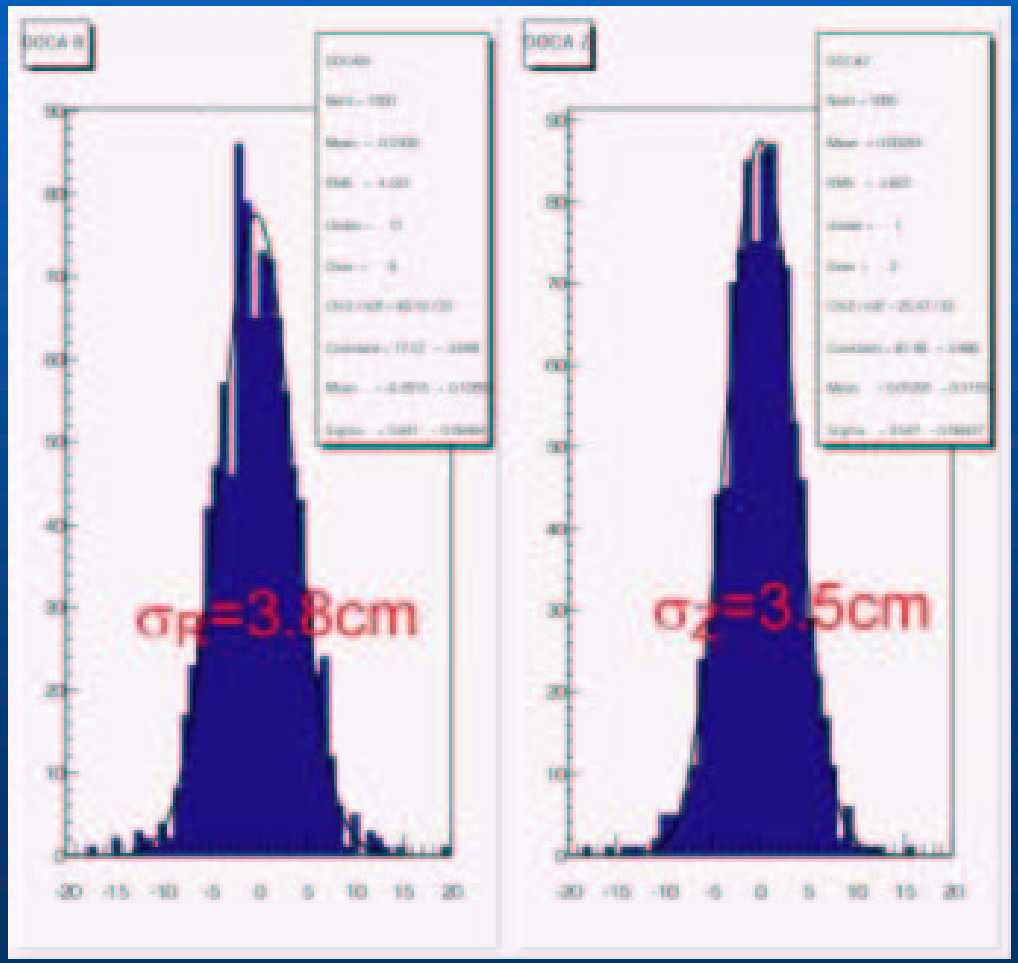


- **Impact parameter and momentum resolution must improve when the tracks link to hits in outer layer of tracking device.**

Line fitting of photon clusters



DOCA resolution



10GeV gamma from I.P.

Summary

- LCD Geant4 works with XML detector file on various computer plat forms.

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

- Significant difference in hadron and muon hits between GEANT4 and GISMO.
- Current SD detector design gives very good photon reconstruction.
- Calorimeter tracking is promising for SD.

Future plan

- Implementation of Norman's "generic hit output" idea.
- Make GEANT4 plug-in for ROOT.
- Support of SIO output format.

Request to GEANT4

- Please support various platforms (HP-UX, AIX,…)
- Please allow optimization flag for Windows

Detector designs

29 cm Al

120x

Λ =~6

2 mm scint
8 mm Pb

40x

X_0=~28
Λ =~1

1 mm scint
4 mm Pb

LD

r

coil

40 cm Al

34x

Λ =~4

HAD
Cal

1 cm scint
2 cm Stainless_steel

30x

X_0=~21
Λ =~0.8

EM
Cal

0.1mm Air
2 mm G10
0.4 mm Si
2.5 mm W

SD