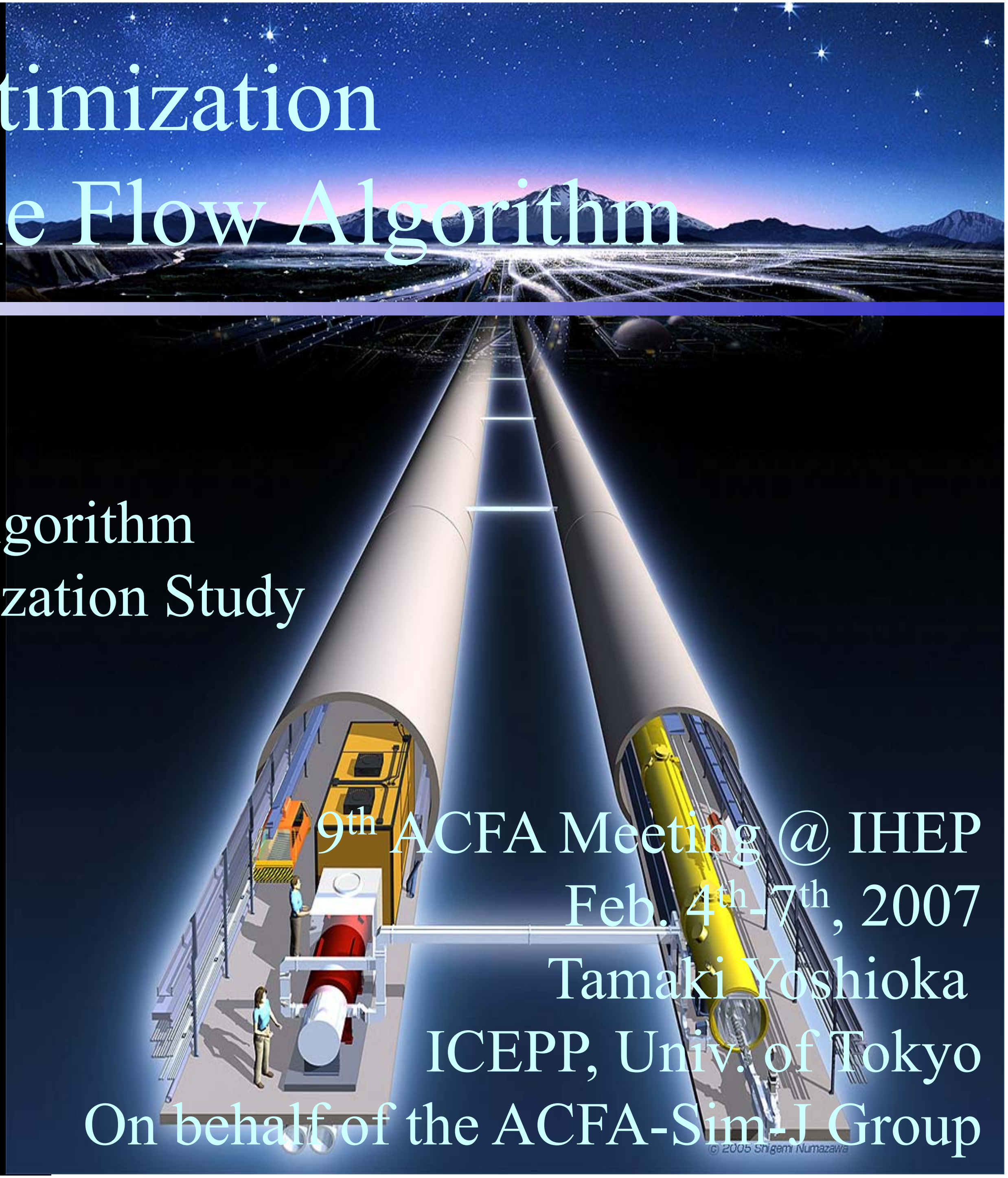
Detector Optimization using Particle Flow Algorithm



Contents

9th ACFA Meeting @ IHEP
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Tamaki Yoshioka
ICEPP, Univ. of Tokyo
On behalf of the ACFA-Sim-J Group

Introduction

- Most of the important physics processes to be studied in the ILC experiment have multi-jets in the final state.
  → **Jet energy resolution is the key in the ILC physics.**

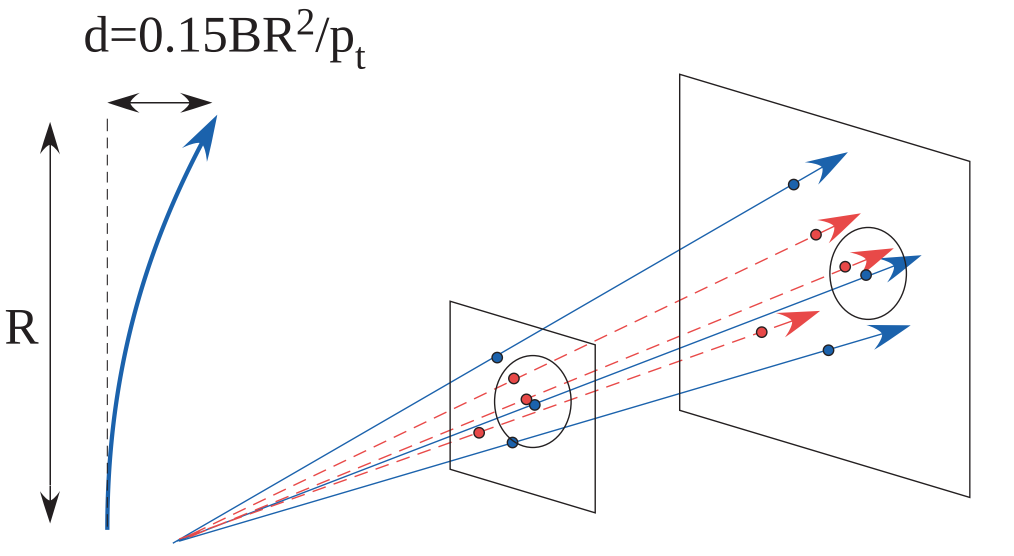
- The best energy resolution is obtained by reconstructing momenta of individual particles avoiding double counting among Trackers and Calorimeters.
  - Charged particles (~60%) measured by Tracker.
  - Photons (~30%) by electromagnetic CAL (ECAL).
  - Neutral hadrons (~10%) by ECAL + hadron CAL (HCAL).

  → ***Particle Flow Algorithm (PFA)***

- In this talk, general scheme and performance of the GLD-PFA, using the GEANT4-based full simulator (Jupiter), will be presented.

GLD Detector Concept

- To get good energy resolution by PFA, separation of particles (reducing the density of charged and neutral particles at CAL surface) is important.



Often quoted "Figure of Merit"

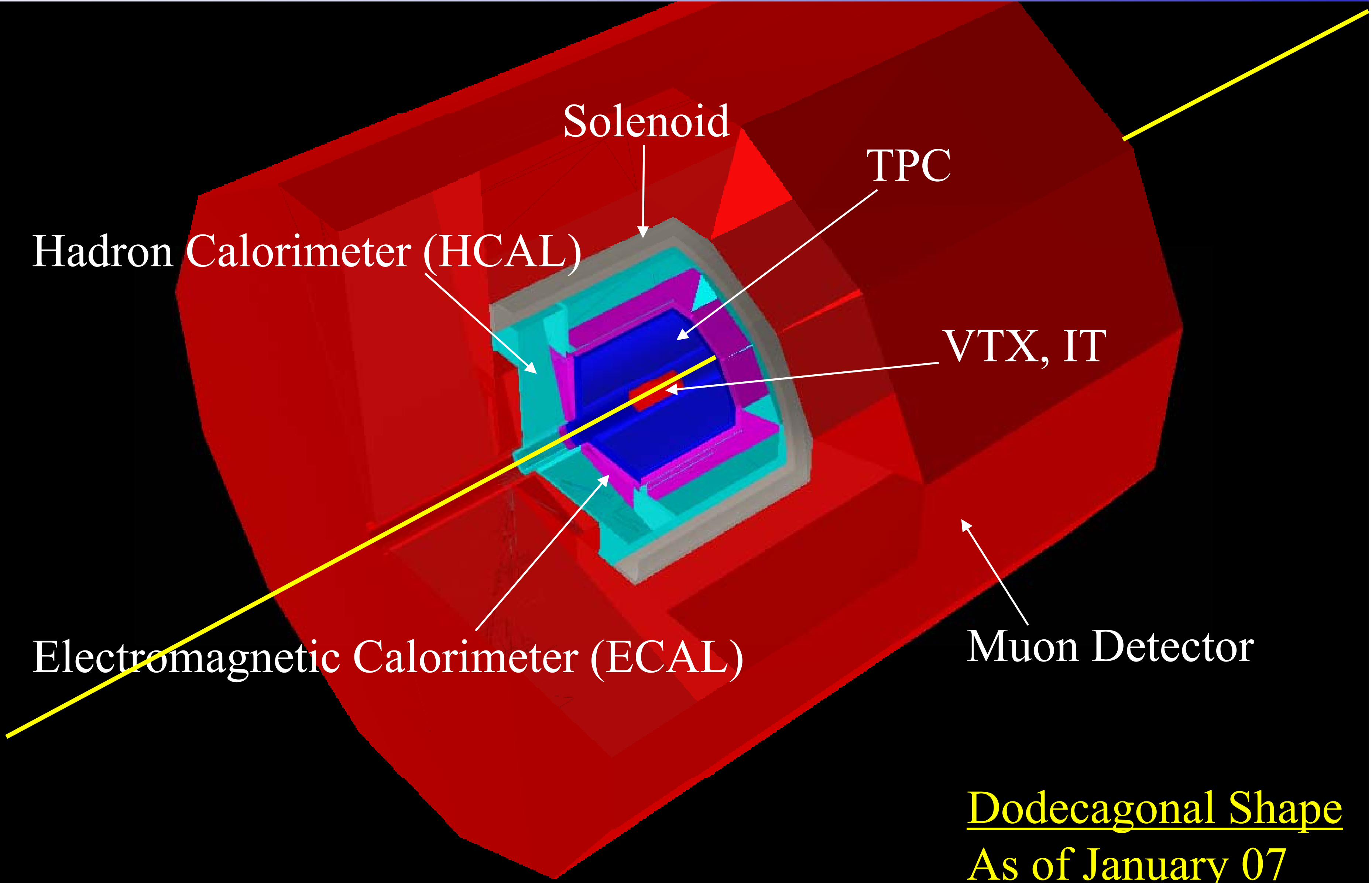
$$\frac{BR^2}{\sqrt{\sigma^2 + R_M{}^2}}$$

B : Magnetic field
R : CAL inner radius
σ: CAL granularity
R_M : Effective Moliere length

- ***GLD concept***

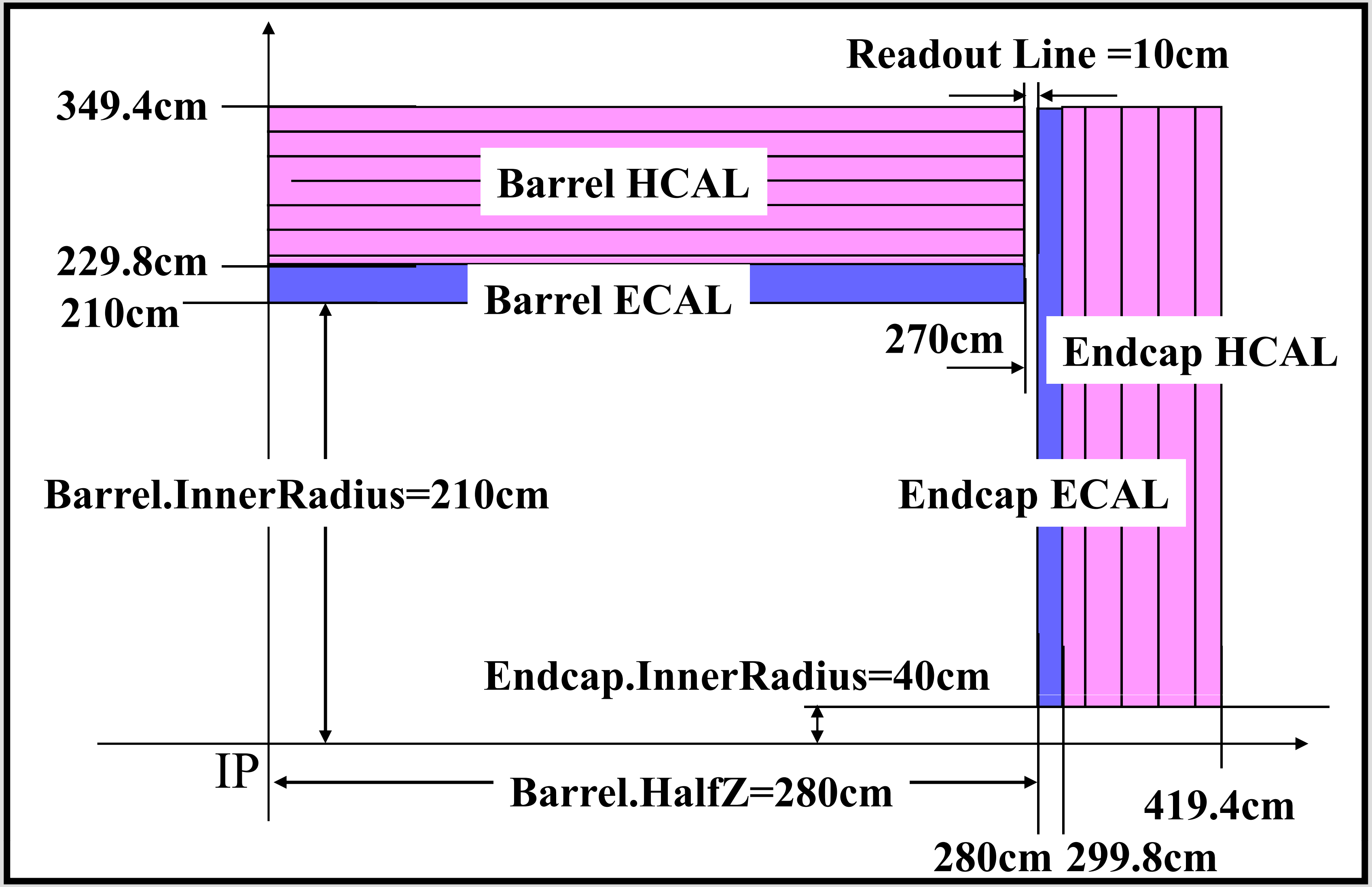
1. Large inner radius of ECAL to optimize the PFA.
2. Large tracker for excellent dp_t/p_t^2 and pattern recognition.
3. Moderate B field (~3T).

Geometry in Jupiter

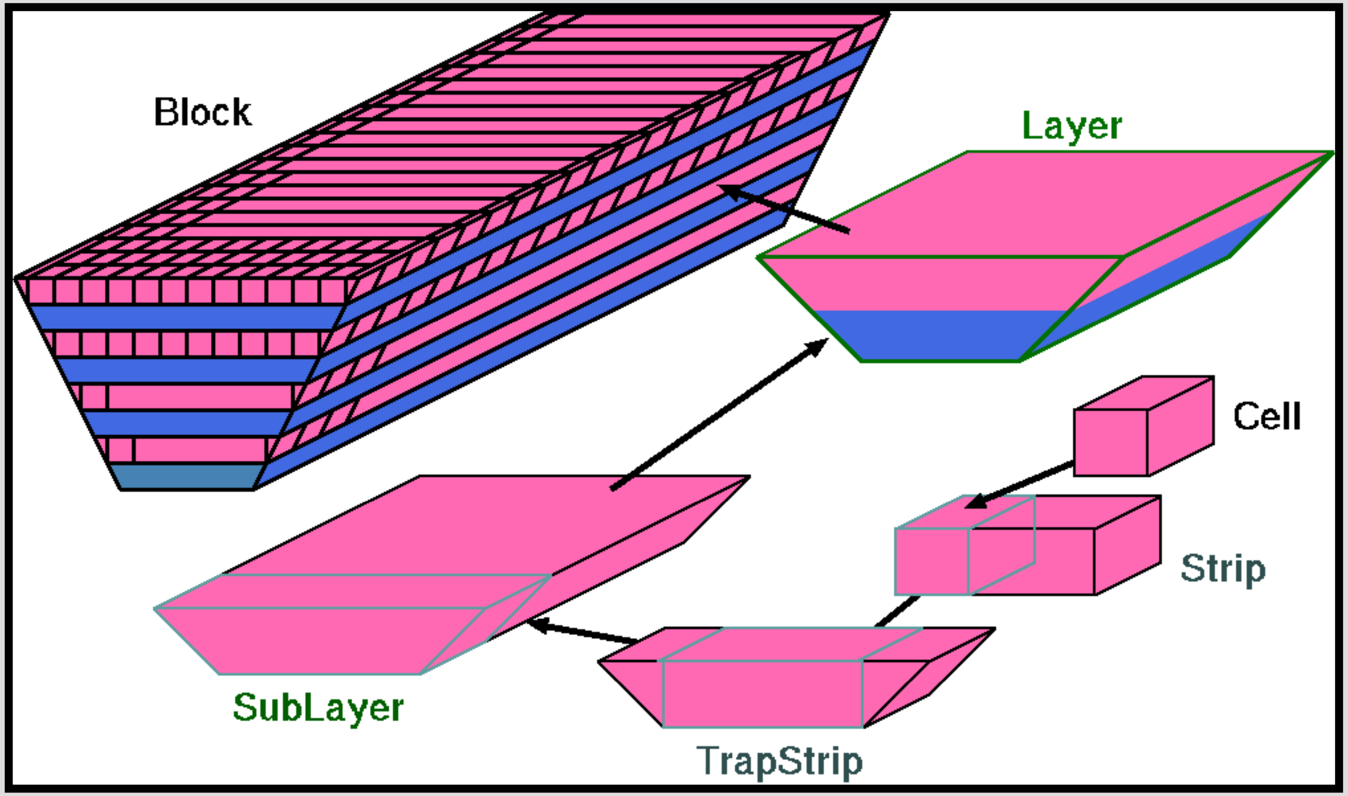


Dodecagonal Shape
As of January 07

Calorimeter Geometry in Jupiter



Calorimeter Structure



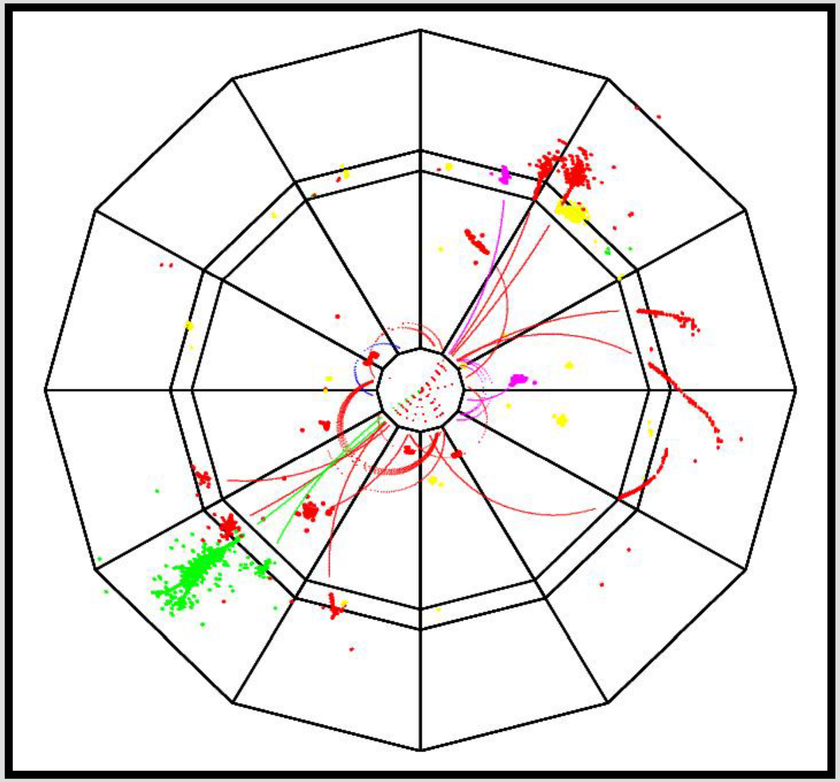
Active Layer

Absorber

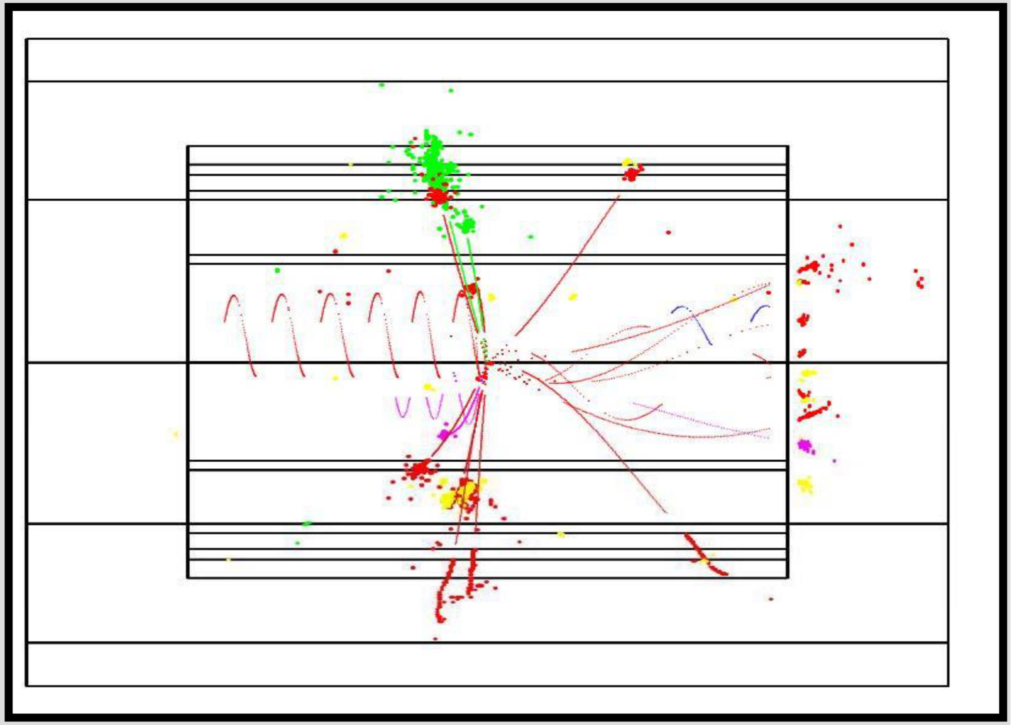
Current cell size : 1x1cm Can be changed.

ECAL	HCAL
W/Scinti./Gap	Fe/Scinti./Gap
3/2/1 (mm) x 33 layers	20/5/1 (mm) x 46 layers

Z-pole Event Display



End View



Side View

- Z → qq (uds) @ 91.2GeV, tile calorimeter, 1cm x 1cm tile size

Particle Flow Algorithm for GLD

Flow of GLD-PFA

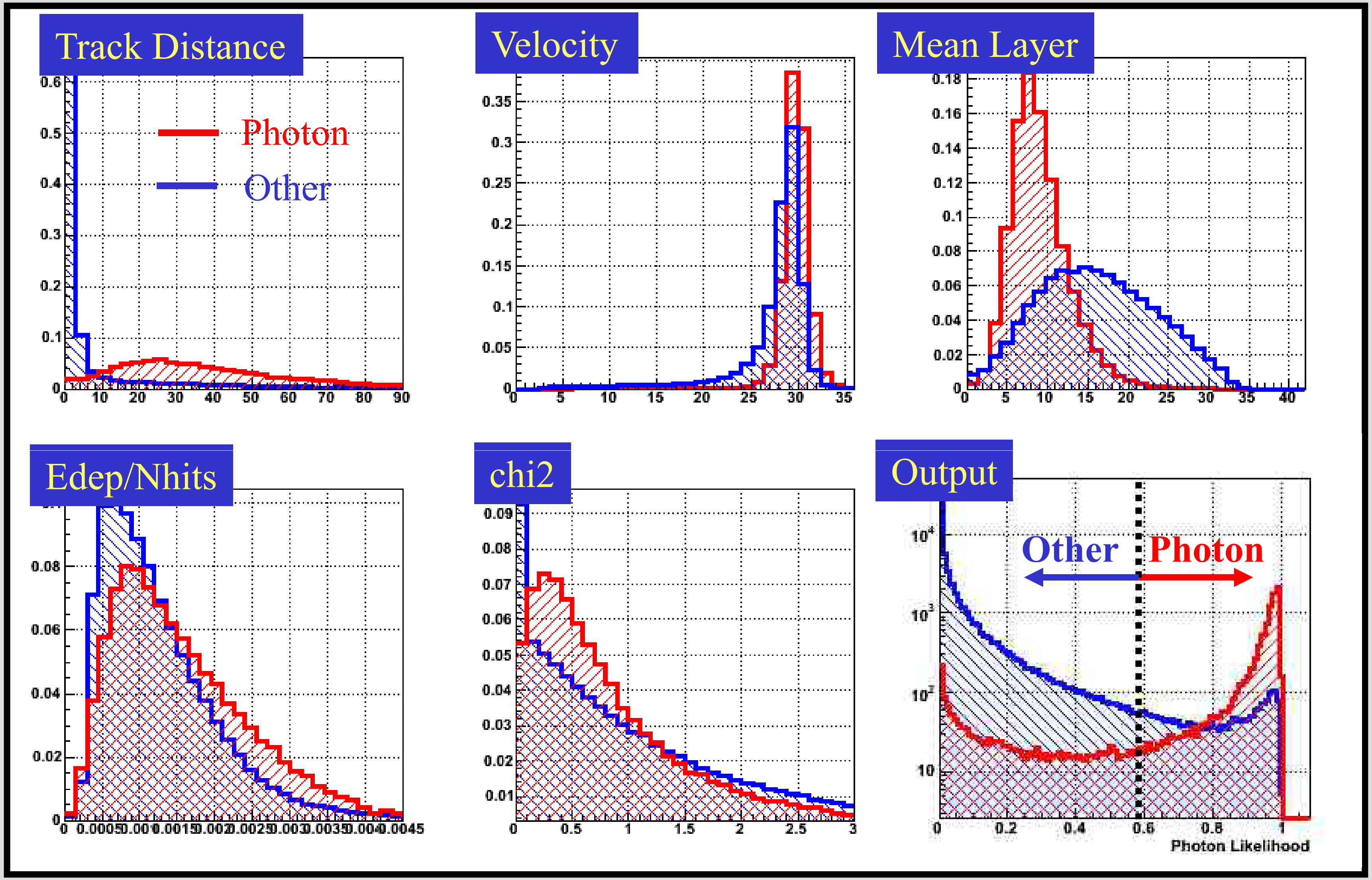
1. Photon Finding
2. Charged Hadron Finding
3. Neutral Hadron Finding
4. Satellite Hits Finding

*Satellite hits = calorimeter hit cell which does not belong to a cluster core

Note : Monte-Carlo truth information is used for muon and neutrino.

Photon Likelihood

- Five variables are selected to form the photon likelihood function.



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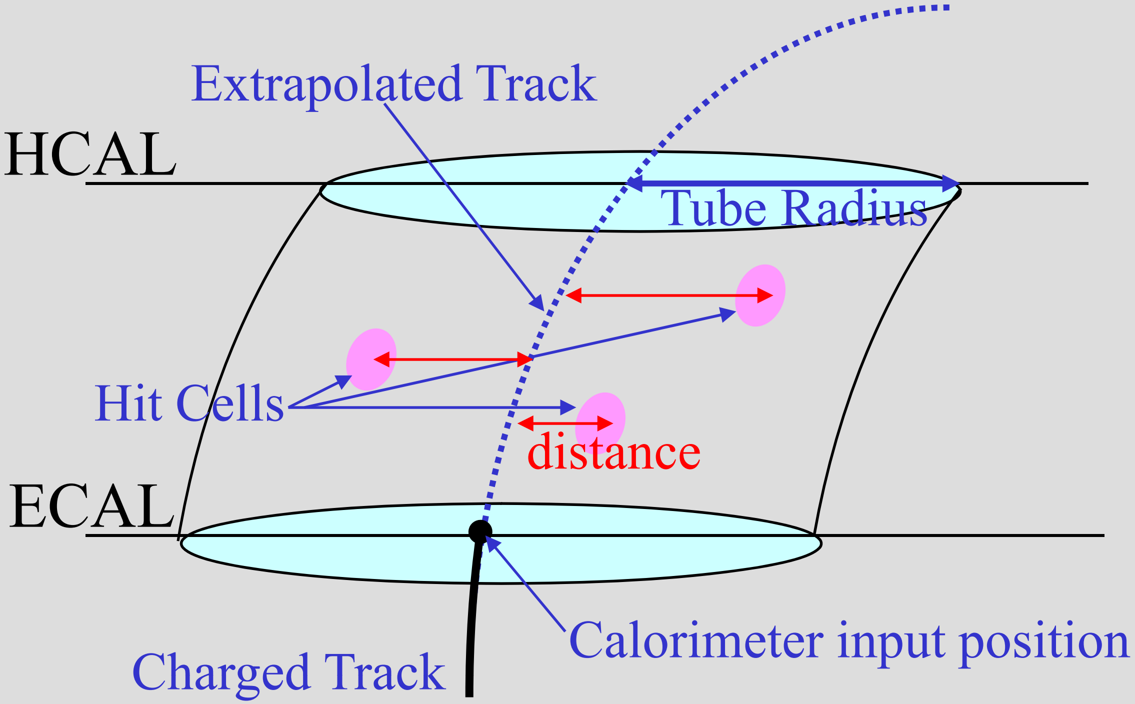
Charged Hadron Finding

- ***Basic Concept*** :
  Extrapolate a charged track and calculate a distance between a calorimeter hit cell and the extrapolated track. Connect the cell that in a certain tube radius (clustering).



- Calculate the distance for any track/calorimeter cell combination.

- Tube radius for ECAL and HCAL can be changed separately.

Particle Flow Algorithm for GLD

Flow of GLD-PFA

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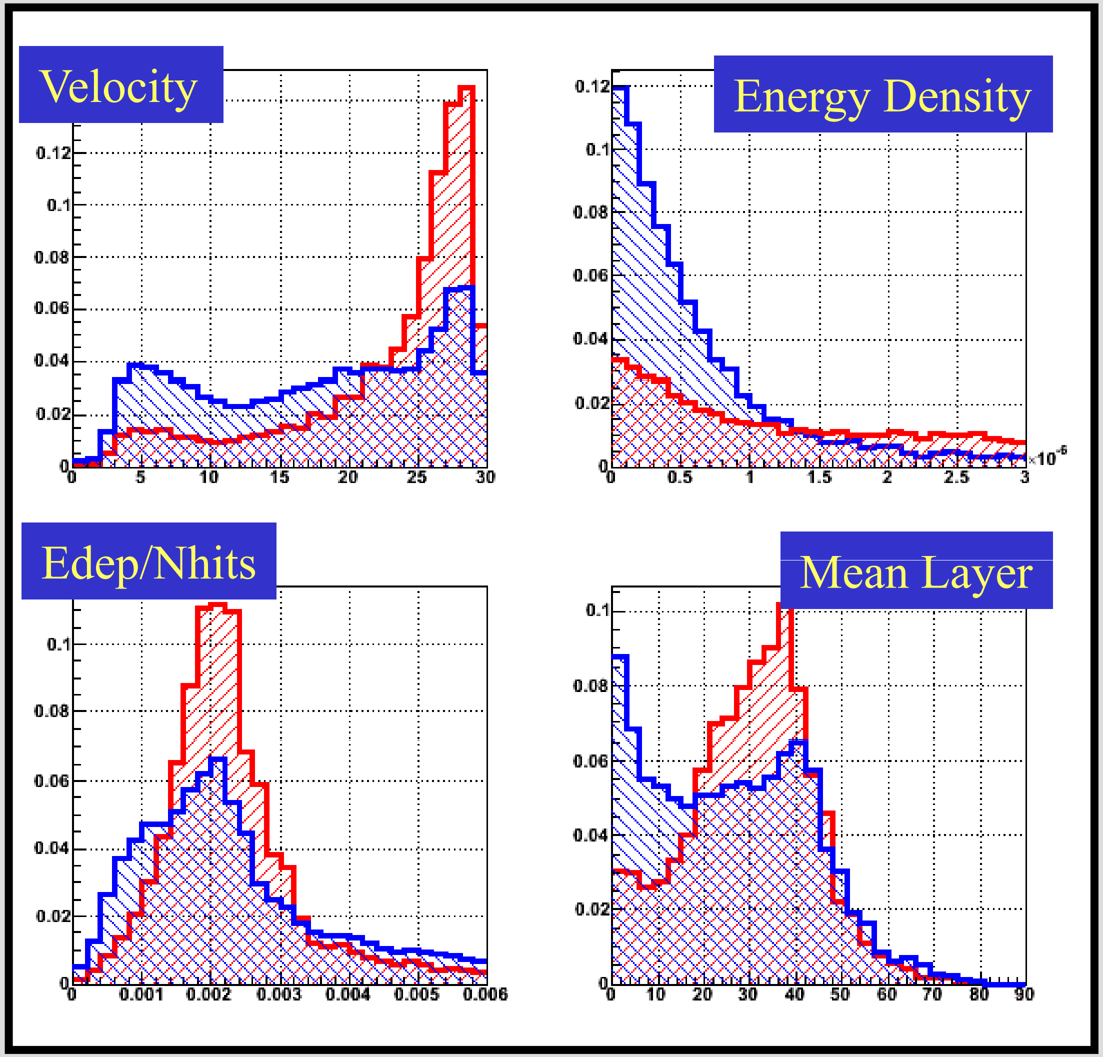
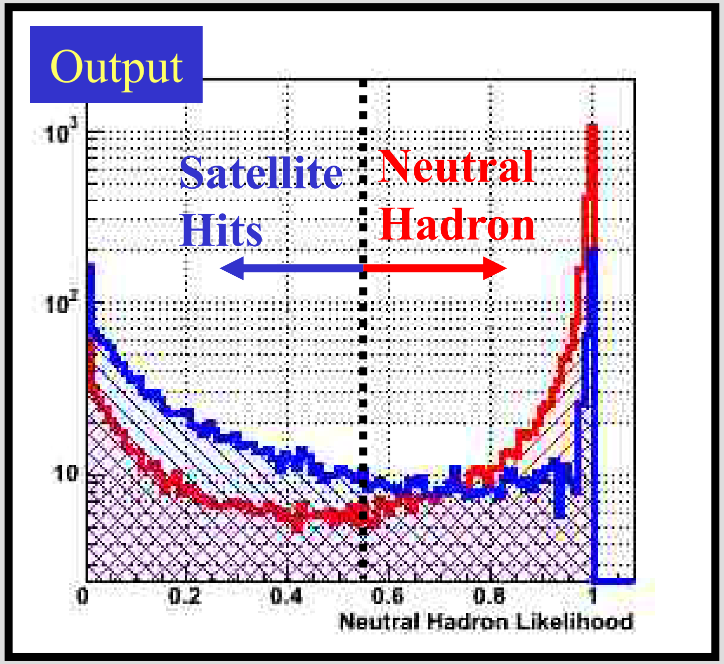
Neutral Hadron Likelihood

- Four variables are selected to form the NHD likelihood function.





— Neutral Hadron

— Satellite Hits

Particle Flow Algorithm for GLD

Flow of GLD-PFA

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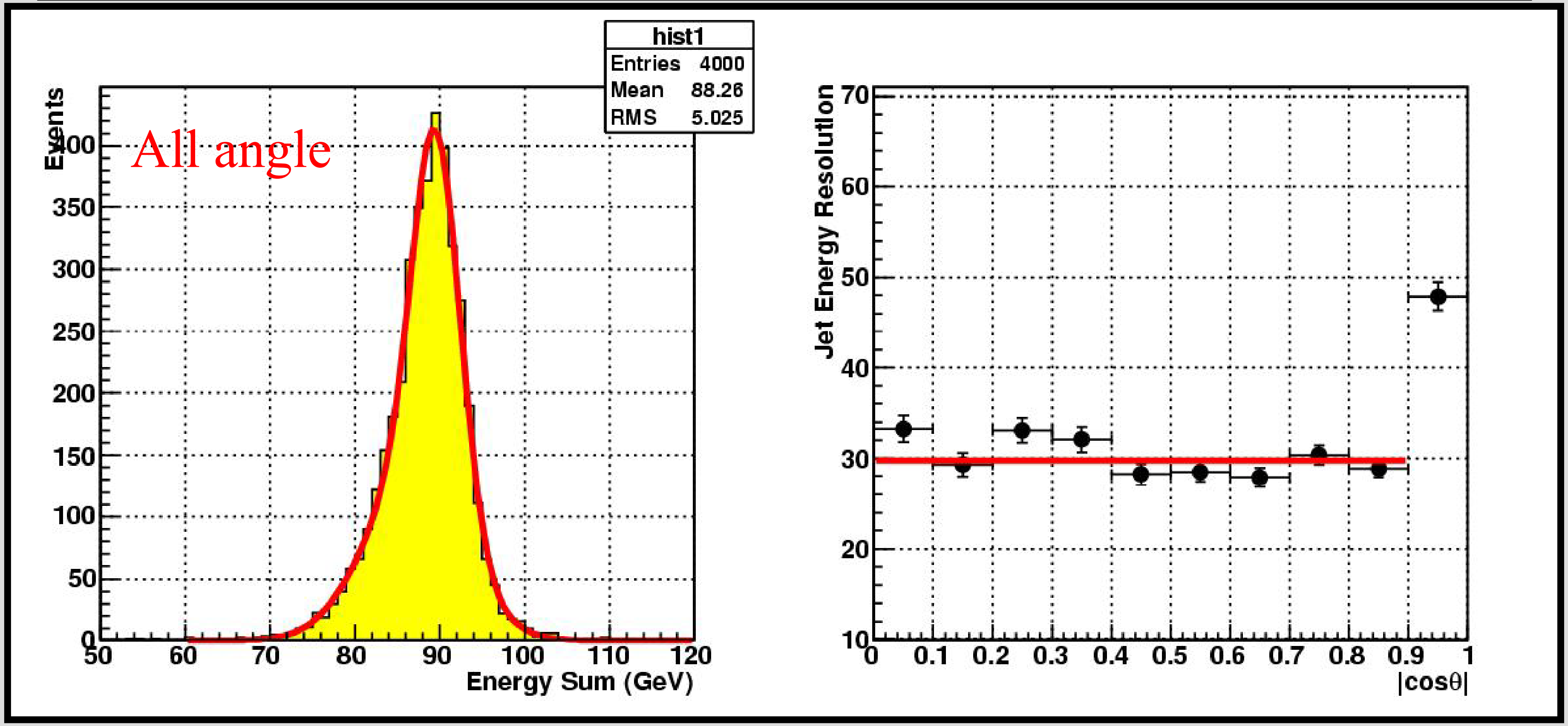
Jet Energy Resolution (Z-pole)

- Z → uds @ 91.2GeV, tile calorimeter, 1cm x 1cm tile size



- Almost no angular dependence : ~30%/√E for |cosθ|<0.9.
- cf. 60 %/√E w/o the PFA (sum up the calorimeter energy)

Jet Energy Resolution (Z-pole)

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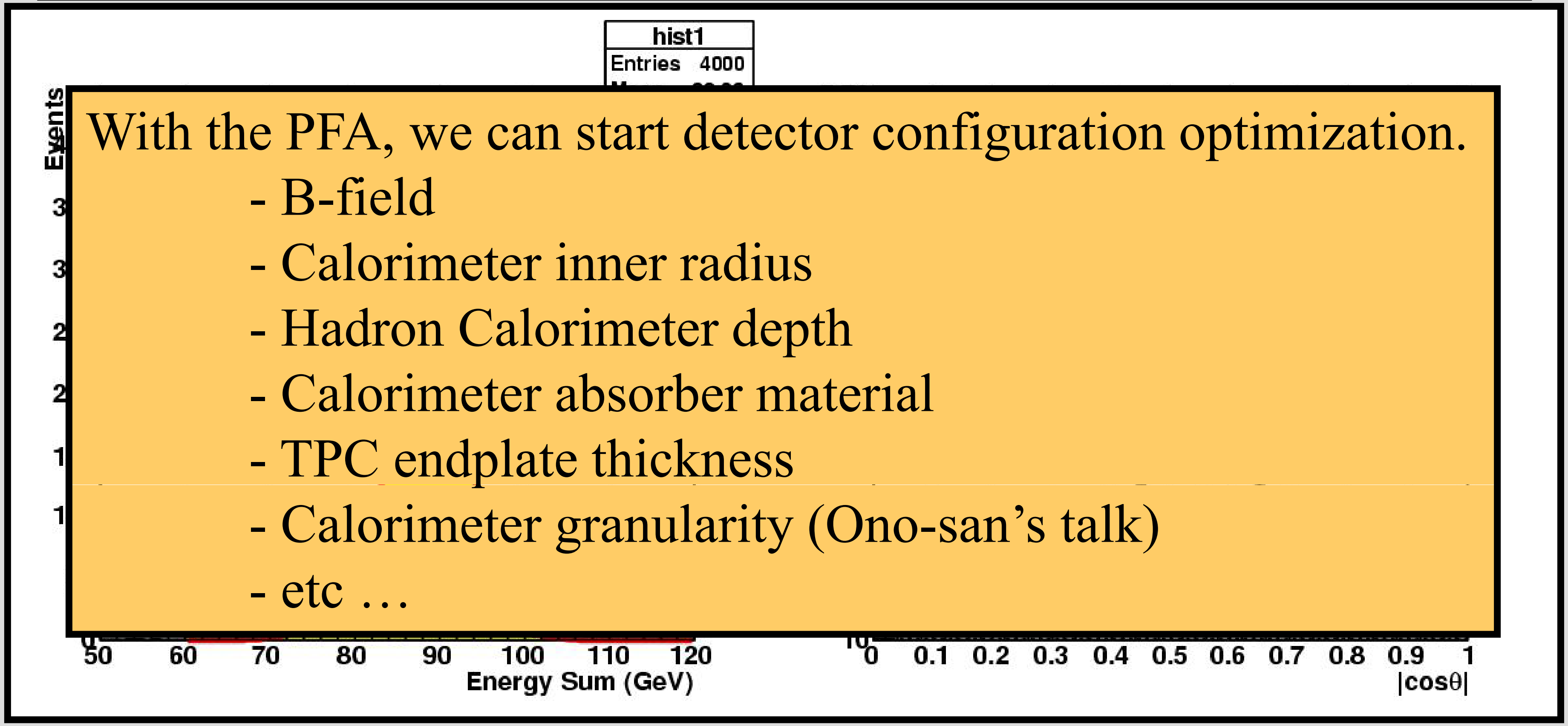


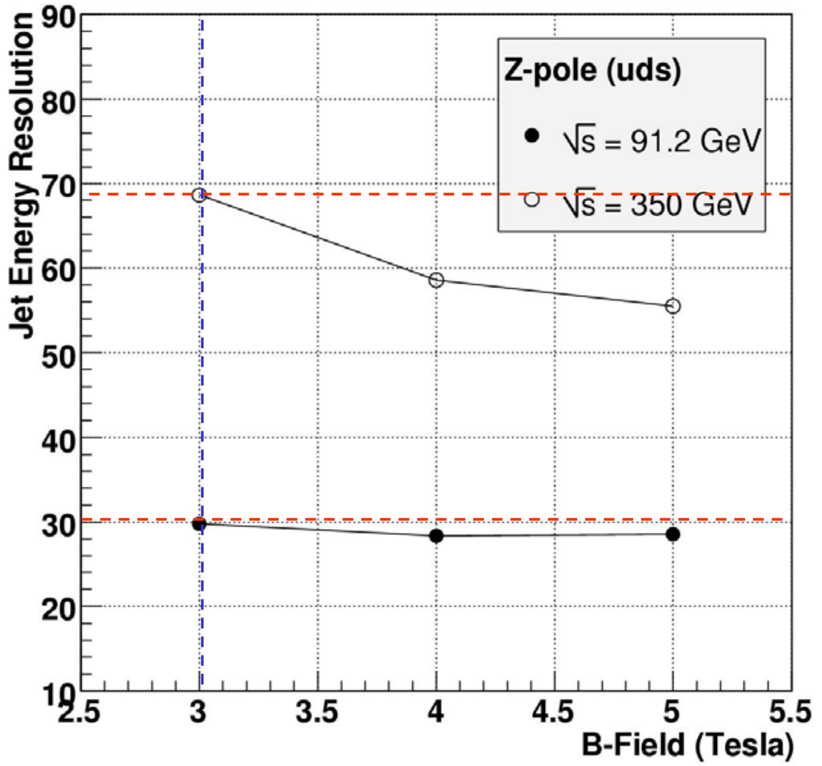
With the PFA, we can start detector configuration optimization.

- B-field
- Calorimeter inner radius
- Hadron Calorimeter depth
- Calorimeter absorber material
- TPC endplate thickness
- Calorimeter granularity (Ono-san’s talk)
- etc …

- Almost no angular dependence : ~30%/√E for |cosθ|<0.9.
- cf. 60 %/√E w/o the PFA (sum up the calorimeter energy)

B-field Dependence

- B-field dependence of the PFA performance is studied.
  Default B-field = 3 Tesla, 1cm x 1cm cell size.



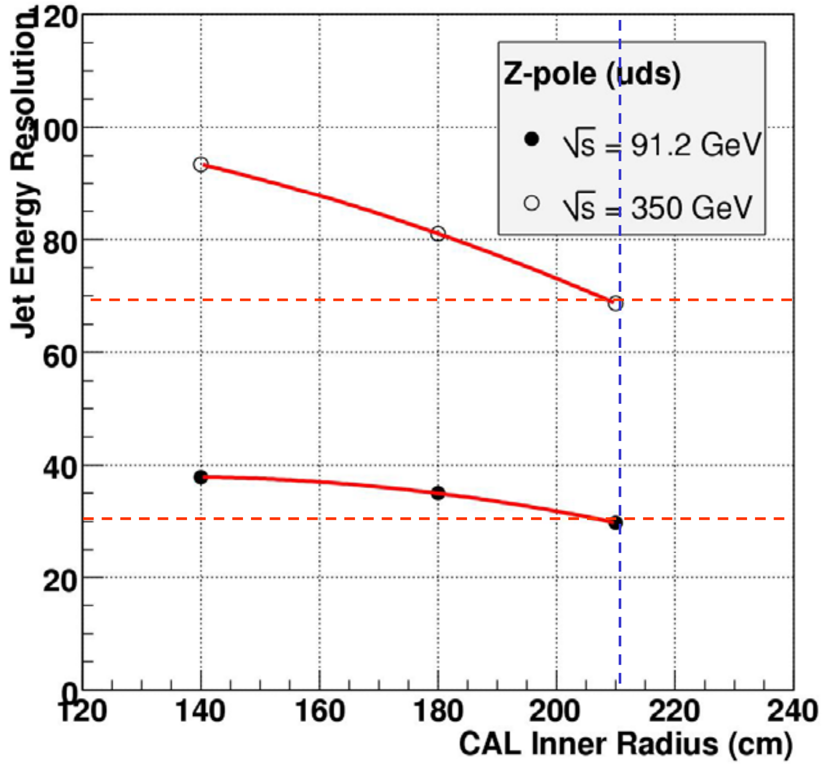
- Higher magnetic field gives better PFA performance as expected.
- 5 Tesla case does not improve PFA performance very much.

→ Due to low momentum tracks?

Ecm	3 Tesla	4 Tesla	5 Tesla
91.2	29.8±0.4	28.4±0.3	28.6±0.3
350	68.7±1.1	58.5±1.0	55.5±0.9

ECAL Radius Dependence

- ECAL inner radius dependence of the PFA performance is studied.
  Default Radius = 210 cm, 1cm x 1cm cell size.

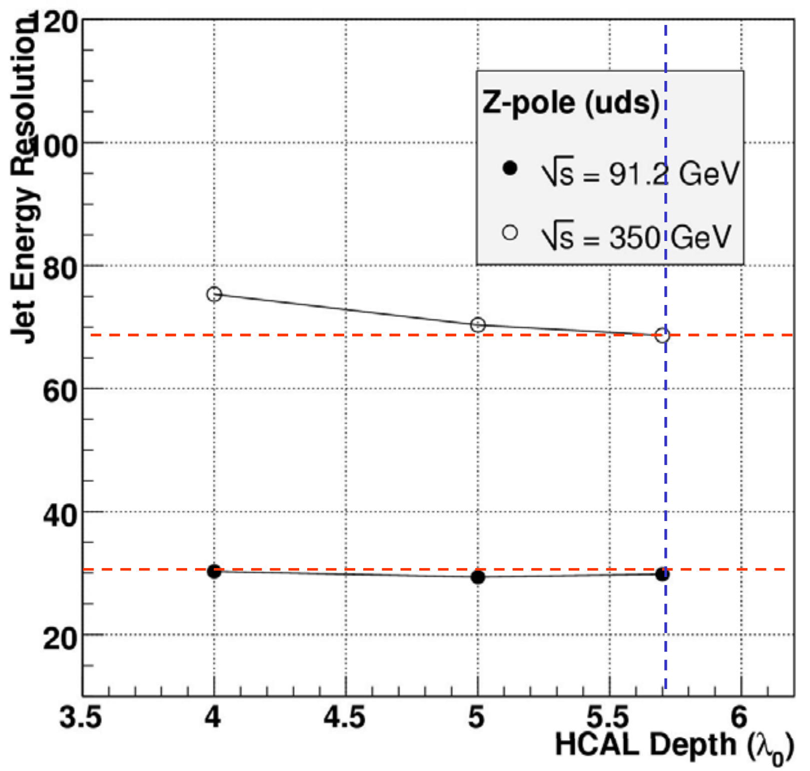


- Larger calorimeter radius gives better PFA performance as expected.
- PFA performance depends on the CAL radius squared.

Ecm	140 cm	180 cm	210 cm
91.2	37.9 ± 0.4	35.0 ± 0.4	29.8 ± 0.4
350	93.4 ± 1.5	81.0 ± 1.3	68.7 ± 1.1

HCAL Depth

- HCAL depth dependence of the PFA performance is studied.
  Default thickness = 5.7 λ0, 1cm x 1cm cell size.

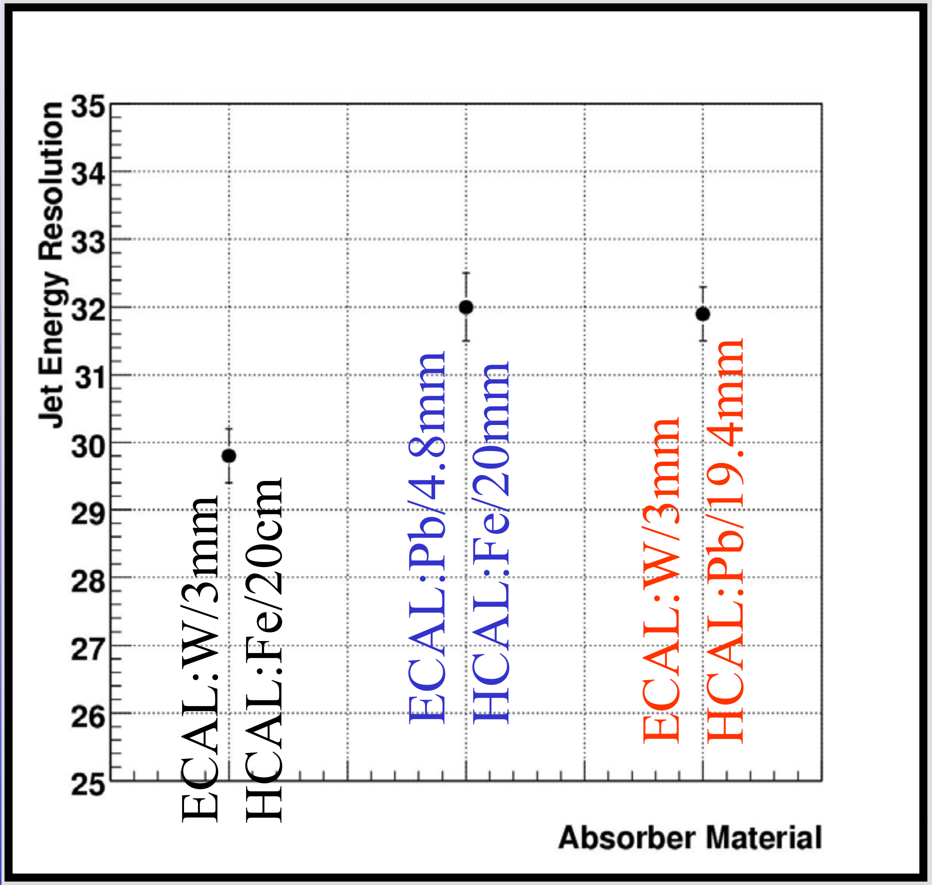


- Thinner HCAL gives worse PFA performance due to shower leakage.
- 5λ0 HCAL does not degrade PFA performance so much even for Ecm = 350GeV.

Ecm	140 cm	180 cm	210 cm
91.2	37.9±0.4	35.0±0.4	29.8±0.4
350	93.4±1.5	81.0±1.3	68.7±1.1

Absorber Material

- CAL absorber material dependence of the PFA performance is studied. Default = W ECAL, Fe HCAL, 1cm x 1cm cell size.



- The absorber thickness is adjusted so that the total radiation (interaction) length become the same as that of default configuration.
- Pb ECAL and/or HCAL are comparable to default.

Default	Pb ECAL	PbHCAL
29.8 ± 0.4	32.0 ± 0.5	31.9 ± 0.4

Summary

- Realistic PFA has been developed using the GEANT-4 based full simulator of the GLD detector.
- Jet energy resolution is studied by using Z→qq events. ILC goal of 30%/√E has been achieved in the barrel region of the Z-pole events.
- PFA performance with various GLD configuration has been studied.

  → High B-field/Large Calorimeter gives better performance as expected.

  → PFA performance of Pb calorimeter is comparable to that of default configuration.