Status of ECAL Optimization Study

Ji-feng Hu, Jing Li,
Prof. Hai-jun Yang, Liang Li
INPAC, SJTU

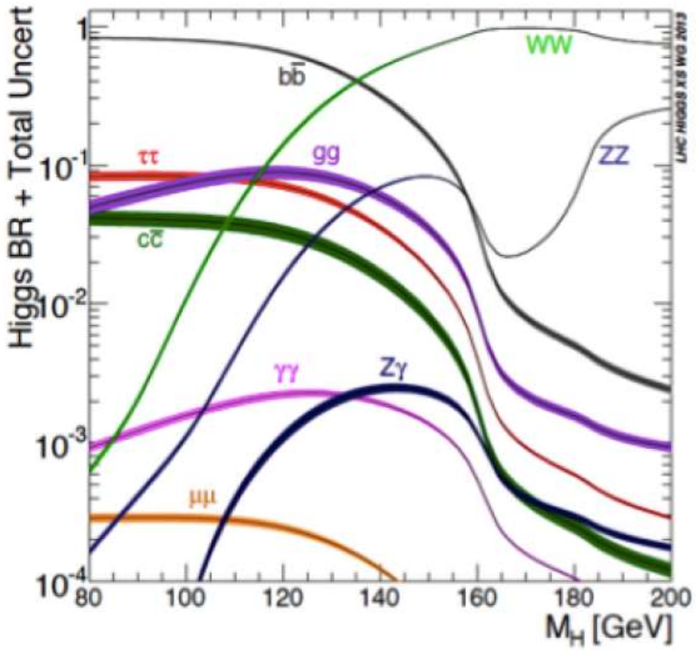
Outline

- Why ECAL optimization matters?
- How to make optimizations
- Preliminary results
  - Basic performance
  - Physics benchmarks
- To do list

Why ECAL optimization matters?

- *Both physics goals and budgets require geometry optimization.*

过程	截面	事例数（亮度$5ab^{-1}$）
	希格斯玻色子产生截面（fb）	
$e^+e^- \to ZH$	212	1.06×10^6
$e^+e^- \to \nu\bar{\nu}H$	6.72	3.36×10^4
$e^+e^- \to e^+e^-H$	0.63	3.15×10^3
总计	219	1.10×10^6
	背景过程截面（pb）	
$e^+e^- \to e^+e^-$（Bhabha）	25.1	1.3×10^8
$e^+e^- \to qq$	50.2	2.5×10^8
$e^+e^- \to \mu\mu$(或者$\tau\tau$)	4.40	2.2×10^7
$e^+e^- \to WW$	15.4	7.7×10^7
$e^+e^- \to ZZ$	1.03	5.2×10^6
$e^+e^- \to eeZ$	4.73	2.4×10^7
$e^+e^- \to e\nu W$	5.14	2.6×10^7



- *ECAL and HCAL are two essential components for gamma/lepton/jets reconstruction and identification.*

Software Version and Samples

- Software versions,
  - Simulation: Mokka-08-03 revised
  - Reconstruction: Arbor_KD_3.3 plus track-related processors
  - Digitization : G2CDArbor
- Samples,
  - e^{-}/γ single particle, energy@5,10,20,50,100 GeV
  - $ee \rightarrow ZH \rightarrow ll\gamma\gamma@\sqrt{s} = 250\ GeV$, 1000 Events
  - $ee \rightarrow ZH \rightarrow ll\ l\nu qq@\sqrt{s} = 250\ GeV$, 1E5 Events
- Geometry: cepc_v1 using SiW in ECAL,
  - Cell size @ 1X1, 5X5, 10X10, 20X20 mm
  - Number of layers @ 16, 20, 26, 30
  - fixed total material.
  - other sub-detectors taken by default.

ECAL and HCAL Simulation Chains

Mokka-08-03 (SimCalorimeterHit)

- *CEPC_v1*
- *New plugin for recording energy deposit in non-sensitive region.*

Digitization in G2CDArbor (CalorimeterHit)

- Energy threshold 50 keV, to be checked
- Linear response only now.
- Simple digitization, re-calibration coefficients for non-default geometry.
- *Emulated digitization models are under development.*

Reconstruction in Arbor_KD_v3.3 (LICH) (lepton Identification)

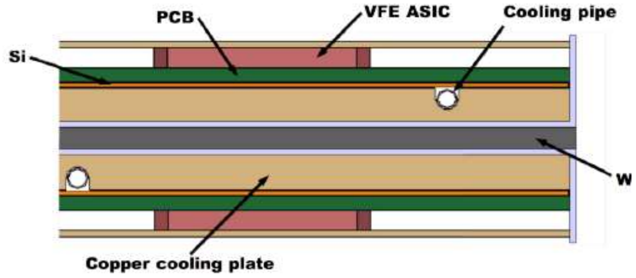
- Default tracking and clustering
- Some new parameters for Arbor thresholds at different geometry setups.

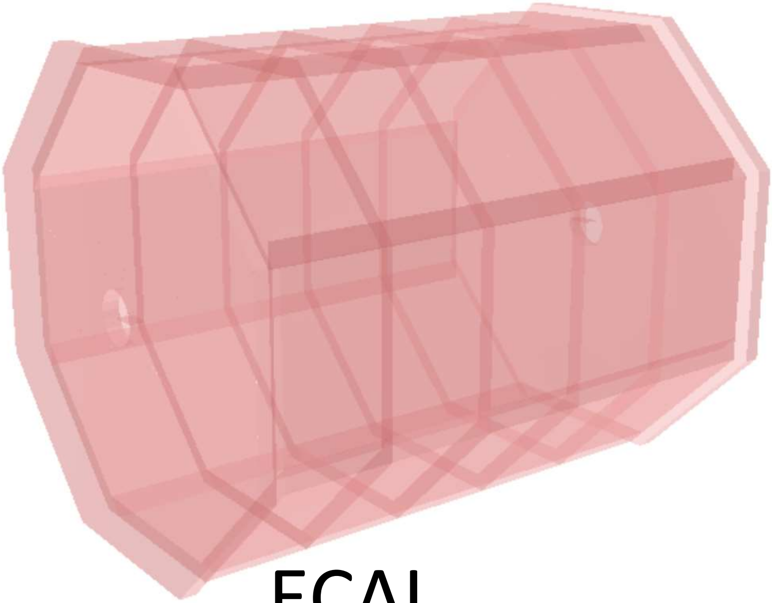
Analysis

- Z, best combination of two leptons.
- H, two most energetic neutral particles.

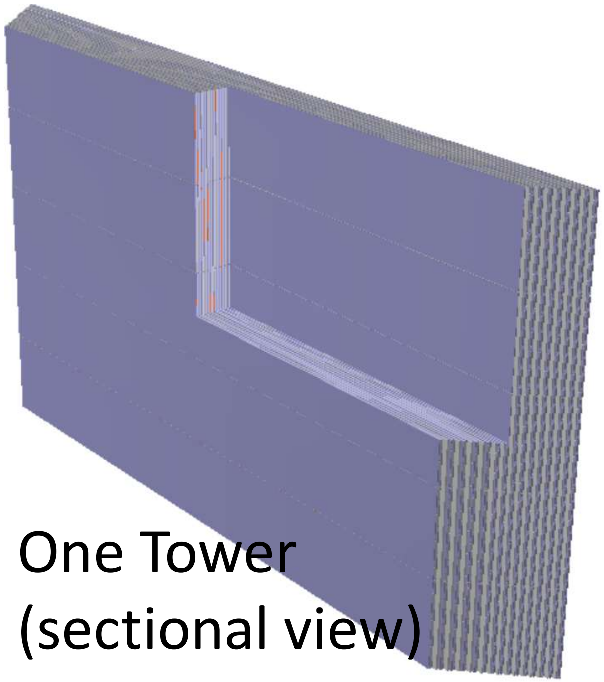
ECAL Setup

Parts	Thickness (mm)	Absorber (mm)	Dimension (mm)	Cell size (mm^2)
Barrel	5.25 (L0-19) 7.35 (L20-29)	2.1 4.2	R, 1843 -2028 Z, 0.00-2350	5.08x5.08
Endcap	5.25 (L0-19) 7.35 (L20-29)	2.1 4.2	R, 226.8-2088 Z, 2450-2635	5.08x5.08





ECAL

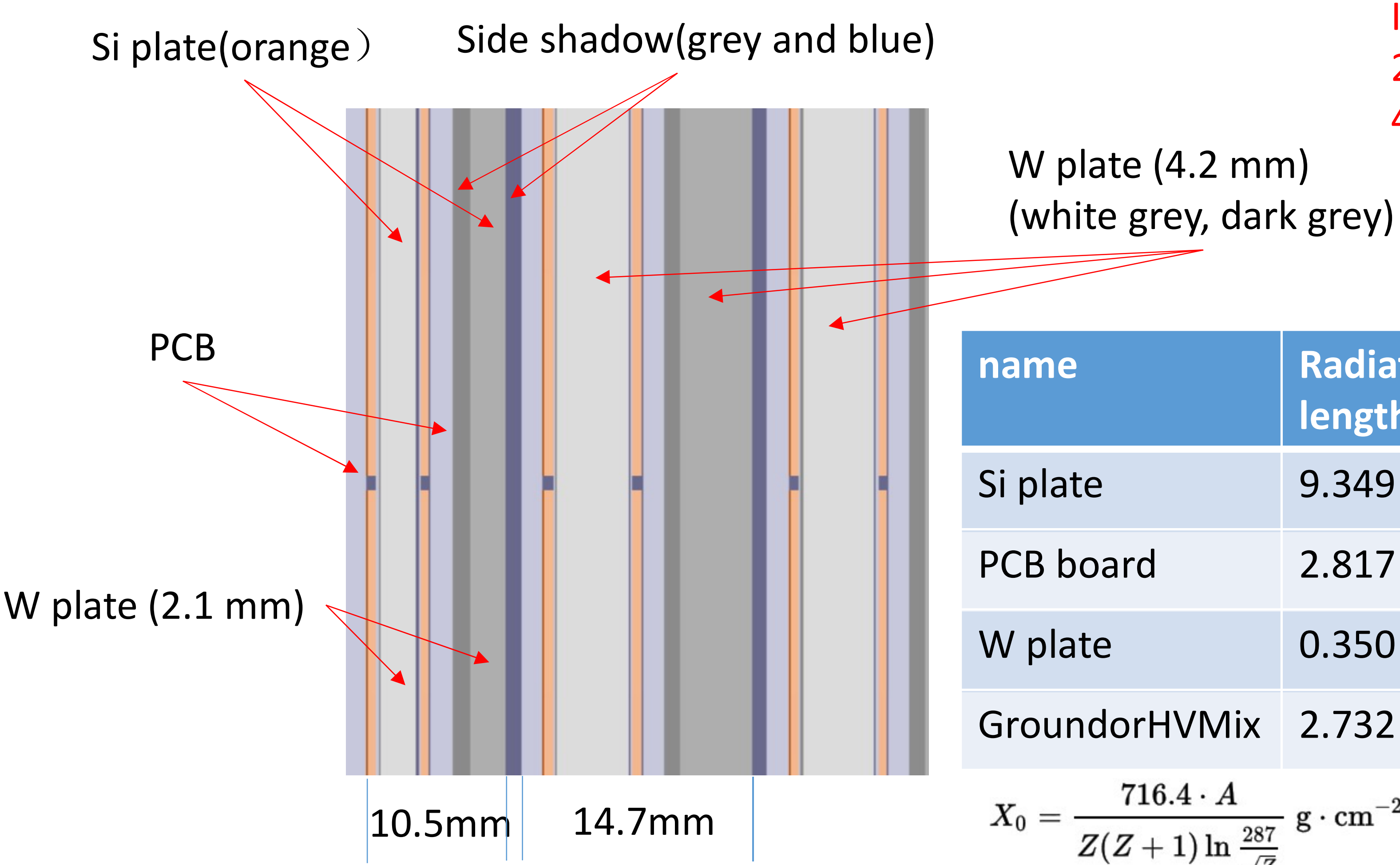


One Tower
(sectional view)

One tower
(side view)

Zoom in Side View (ROOT Geo)

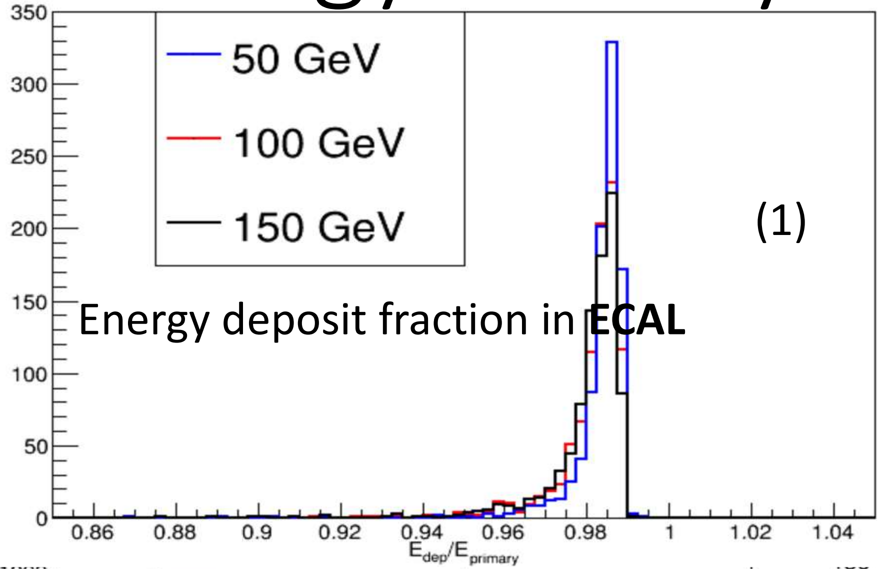
Illustration:
2 thin layers
4 thick layers.

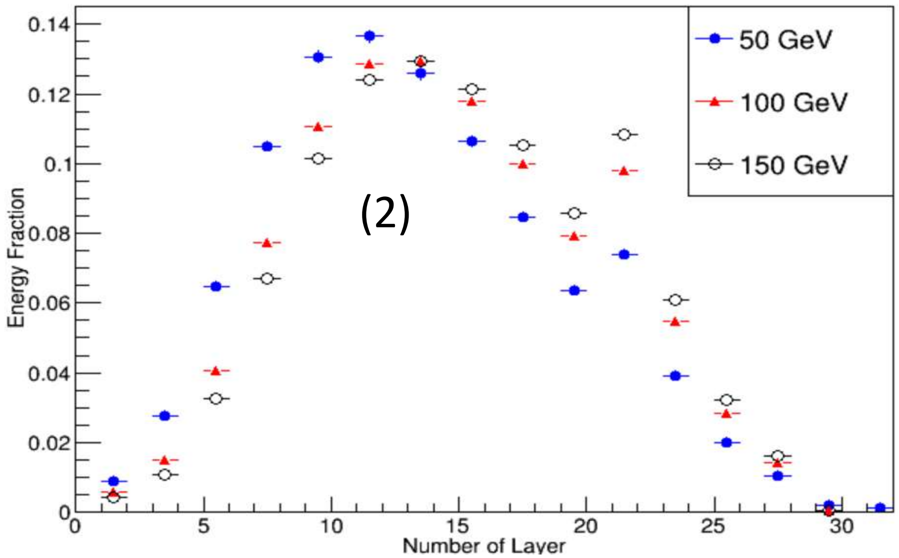


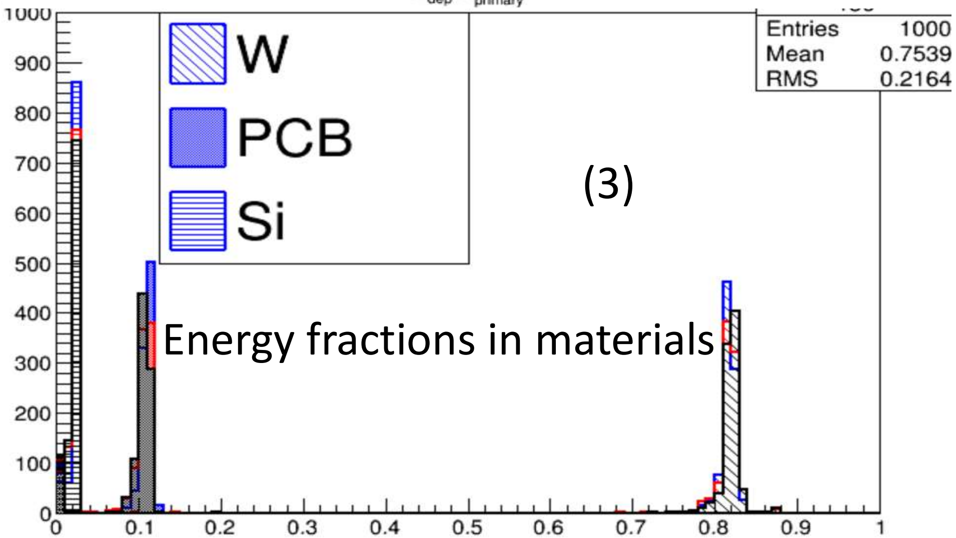
name	Radiation length (cm)
Si plate	9.349
PCB board	2.817
W plate	0.350
GroundorHVMix	2.732

$$X_0 = \frac{716.4 \cdot A}{Z(Z+1)\ln\frac{287}{\sqrt{Z}}}\ \mathrm{g\cdot cm^{-2}}$$

Energy Density Function

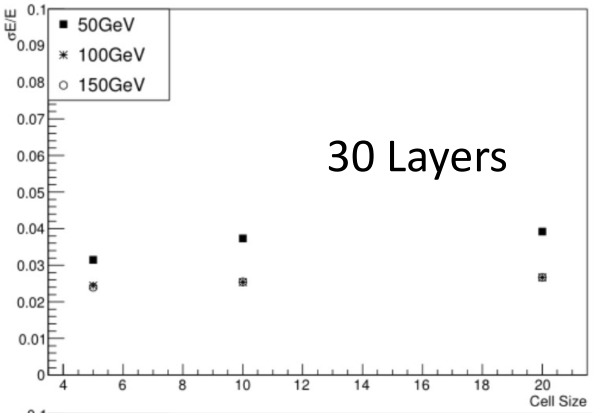


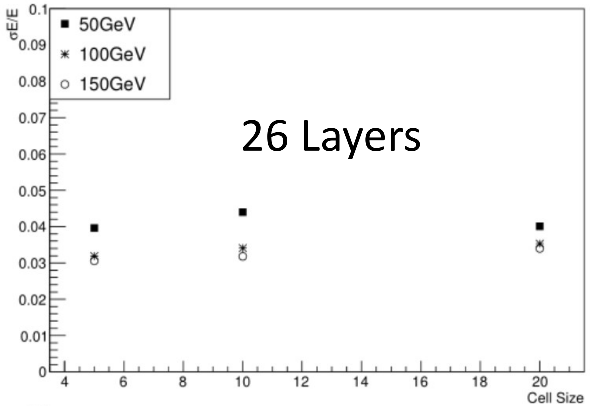


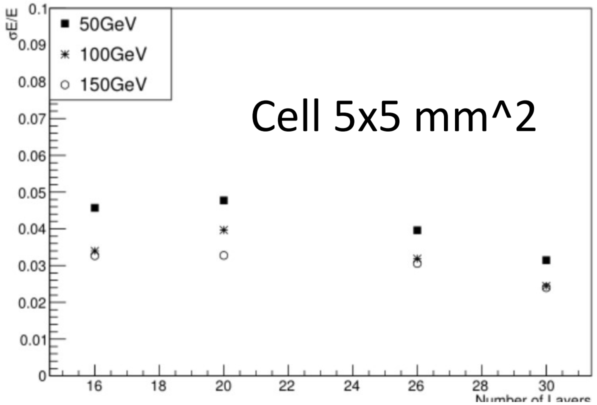


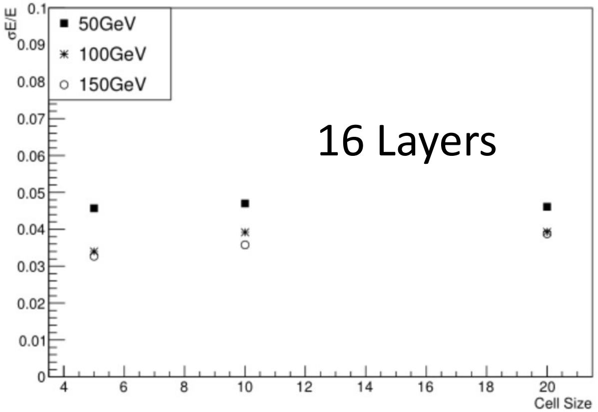
- (1) 99% energy of incident photon will be deposited in ECAL.
- (2) the turn point is due to thick layers.
- (3) W plates absorb ~82% energy of photons.

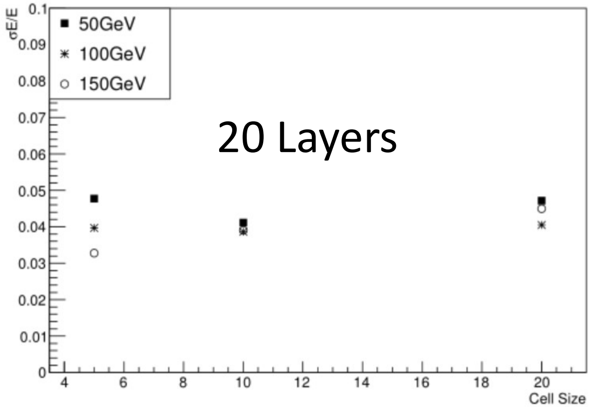
Relative Energy Resolution

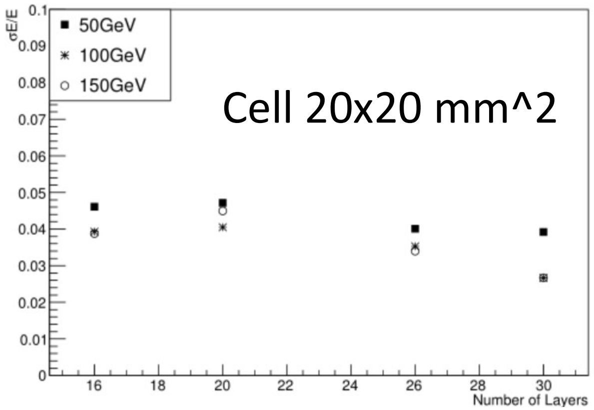






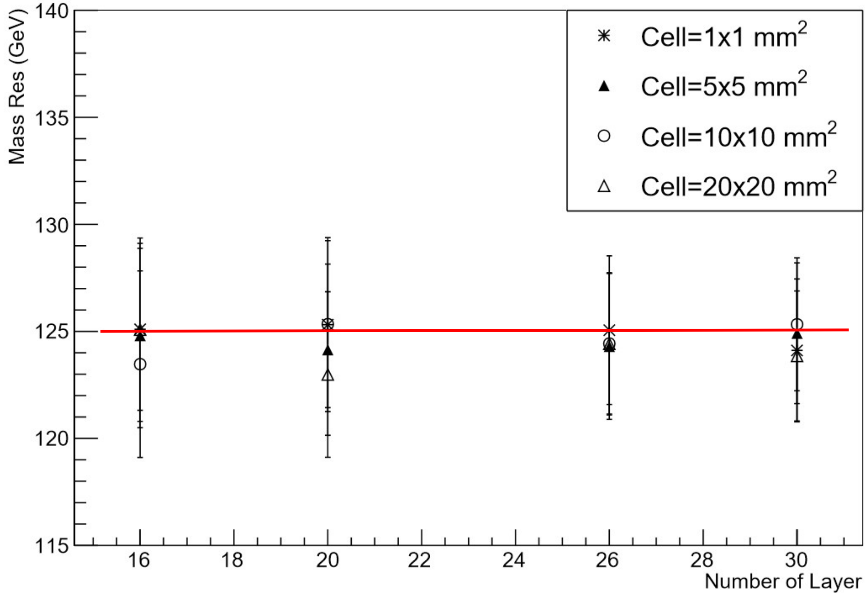


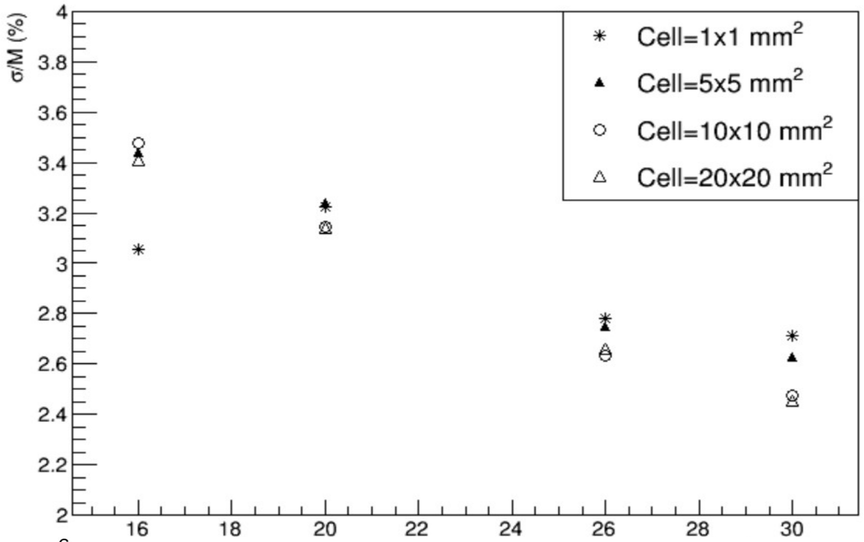


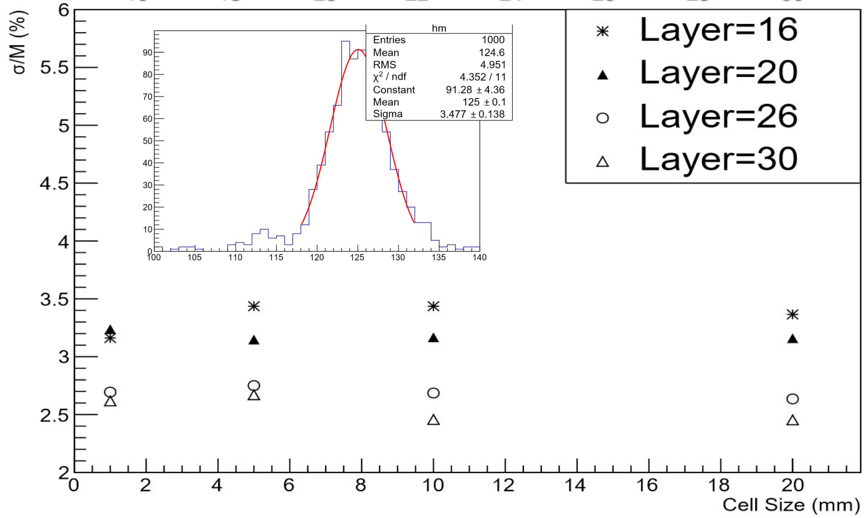


- More layers, better energy resolution
- Energy resolution almost is independent of cell size.

Test of Higgs->$\gamma\gamma$







- Z reconstructed by two charged leptons
- Higgs by the most energetic two neutral particles.
- Background not yet investigated.
- Higgs invariant mass fitted with a Gaussian
- Energy re-calibration at different geometry.
- Some new parameters values for Arbor.

Analysis Logic of Higgs→WW

Package provided by Libo liao

Revising some over counting in loops.

Revising some MC truth matching.

Switch to PFOs exported by LICH.

ArborPFOs *[FSR correction]*
- ArborPFOs
- FsrArborPFOs

Z Tag *[the least mass difference]*
- PFOs of Z candidates
- The other PFOs

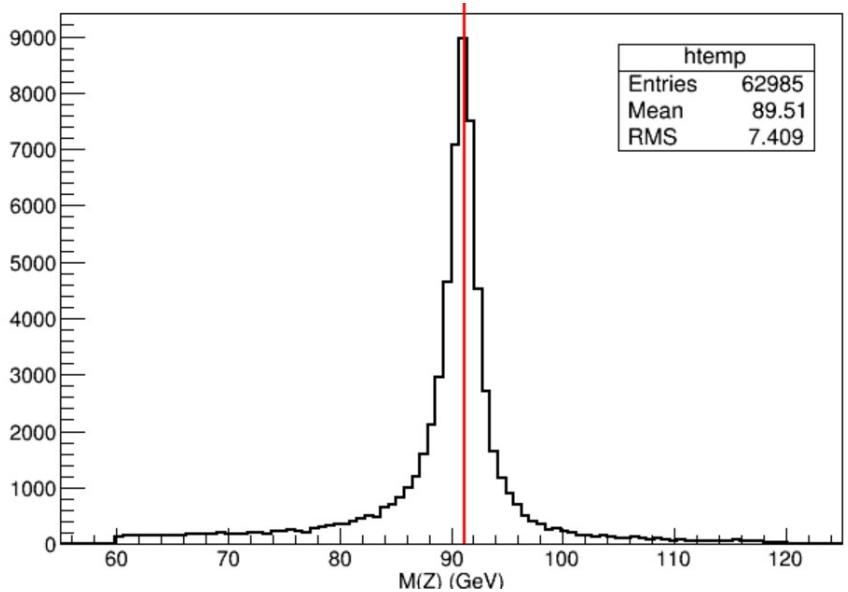
Isolated lepton Tag *[no any charged found within a cone angle]*
- Isolated leptons
- The other PFOs

Vertex, JetClustering and FlavorTag
- Refined Jets

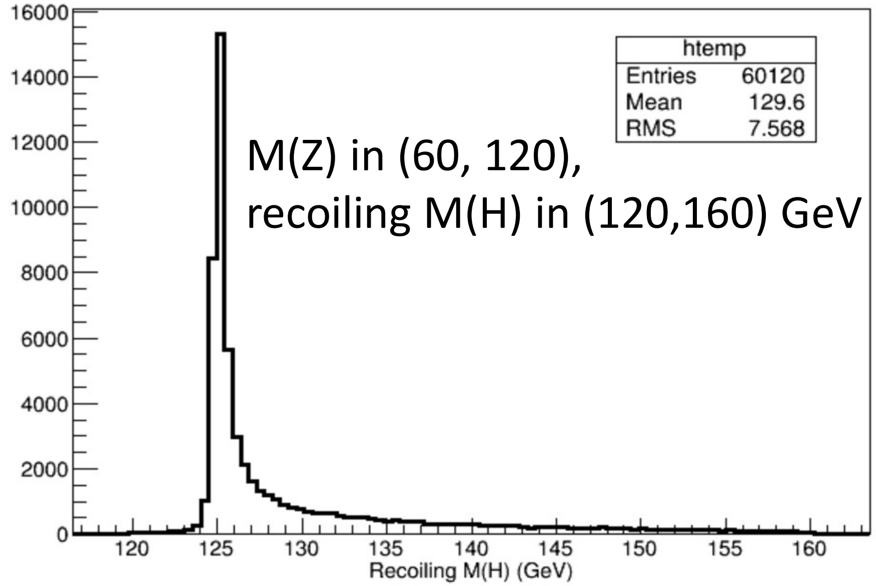
1. LcfiplusProcessor weights
/lcfiweights/d0prob_zpole.root
/lcfiweights/z0prob_zpole.root
2. LICH weights
/new_1pfo/

Higgs→WW→lvqq

100000 events

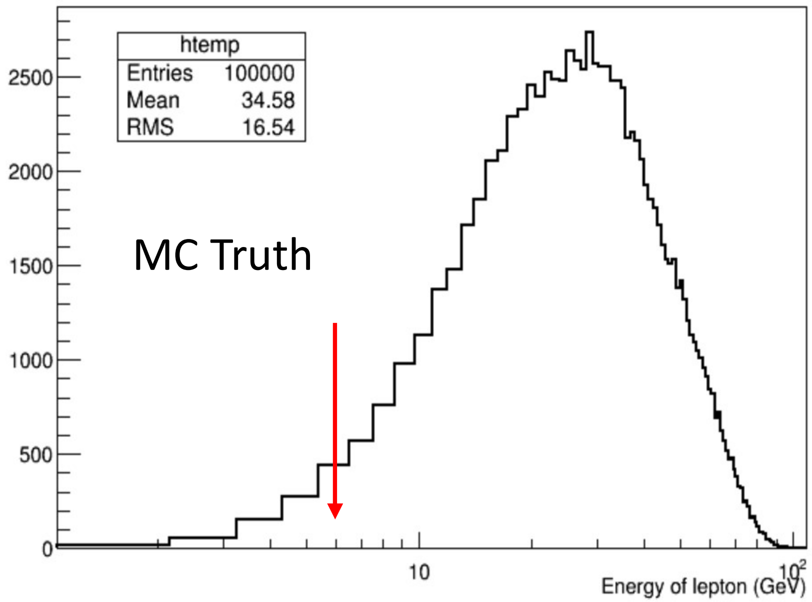


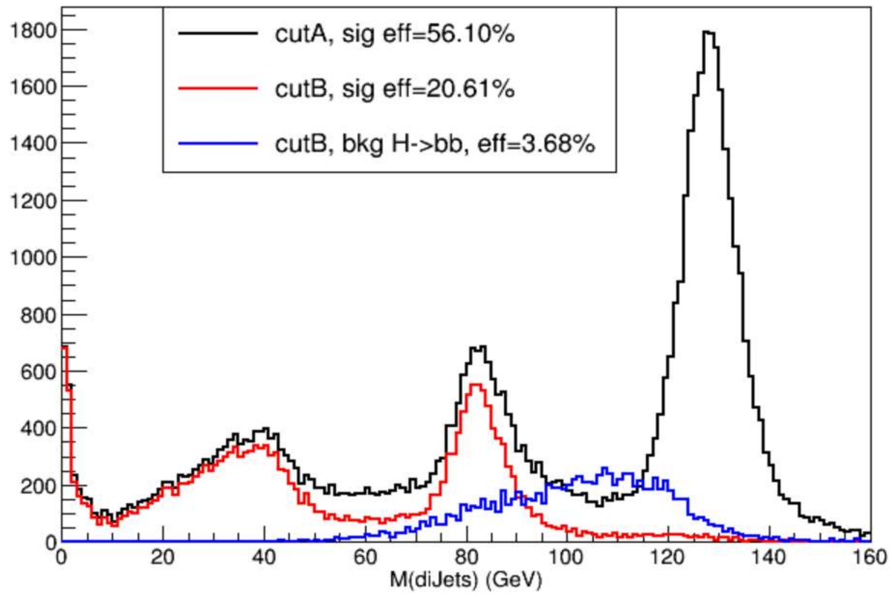
M(Z) in (60, 120) GeV



- (Left), Z mass, (red) line indicates the nominal mass.
- (Right), the recoiling mass, $M = \sqrt[2]{E^2 - (\vec{p}_{l1} + \vec{p}_{l2})^2}$, lepton 1 and lepton 2 are coming from Z.

Background Suppression





- Cut A, M(Z) in (68.98, 113.38) GeV, approximately within 3 sigma region of Z pole mass. Recoiling M(H) within (120, 160) GeV, Angle of two jets >0;
- Cut B, cut A plus number of isolated lepton >=1, its energy >5 GeV (energy threshold needs be discussed).
- Other backgrounds are under investigation.

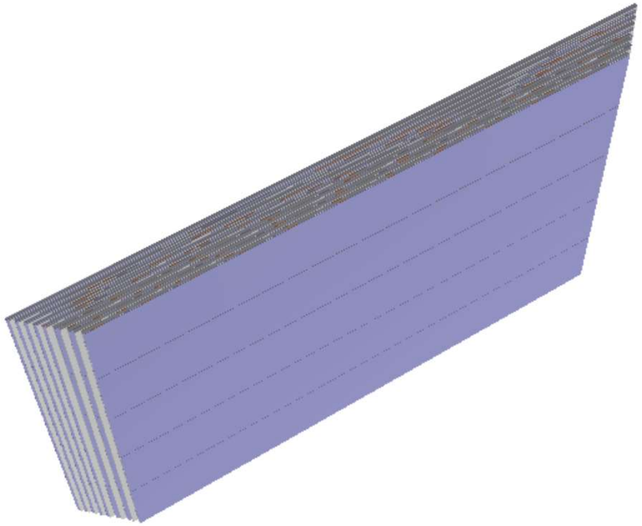
Summary

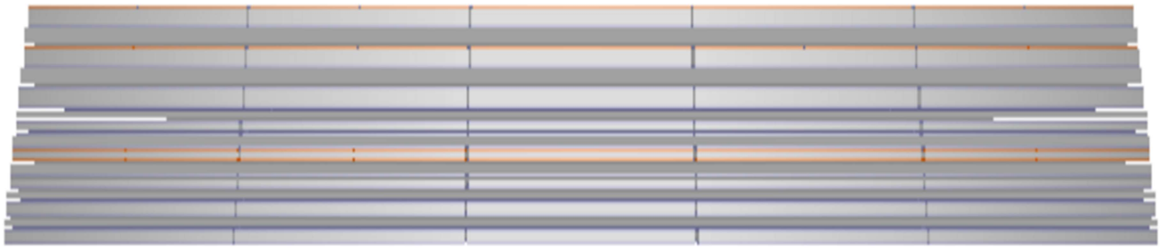
- SiW ECAL optimization was preliminarily studied.
  - 4 X 4 combinations of geometry were tested.
  - Physics channels of Higgs→γγ, WW are being thoroughly investigated
  - Conclusions will be made after fine digitization development.
- To do list,
  - Jet Energy Resolution in HCAL
  - Benchmark of H->WW with background analysis.

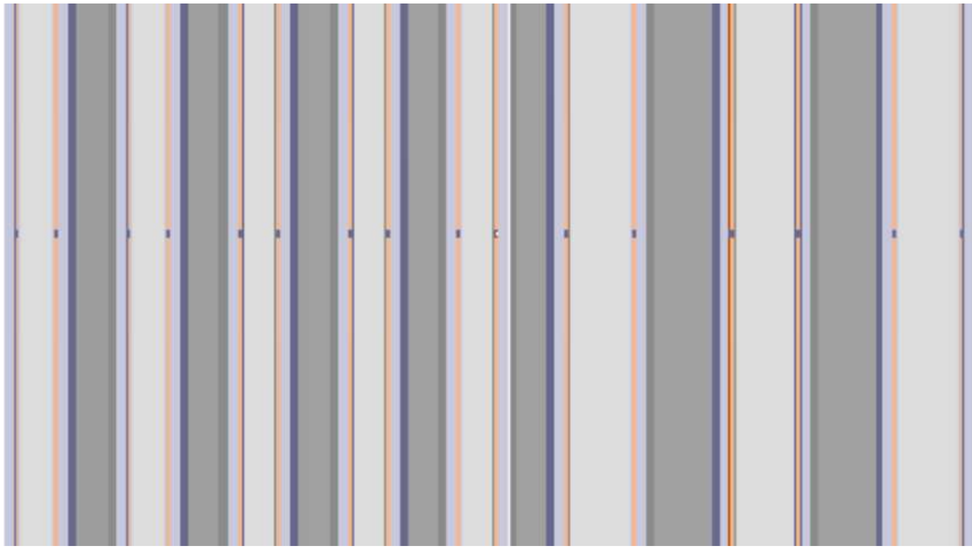
Acknowledge

Thanks to Man-qi Ruan, Gang Li, Li-bo Liao, Dan Yu, Shi Chen, Bing Liu, Chen-dong Fu etc. for their helpful discussions and supports.

ECAL Geometry (16 Layers)

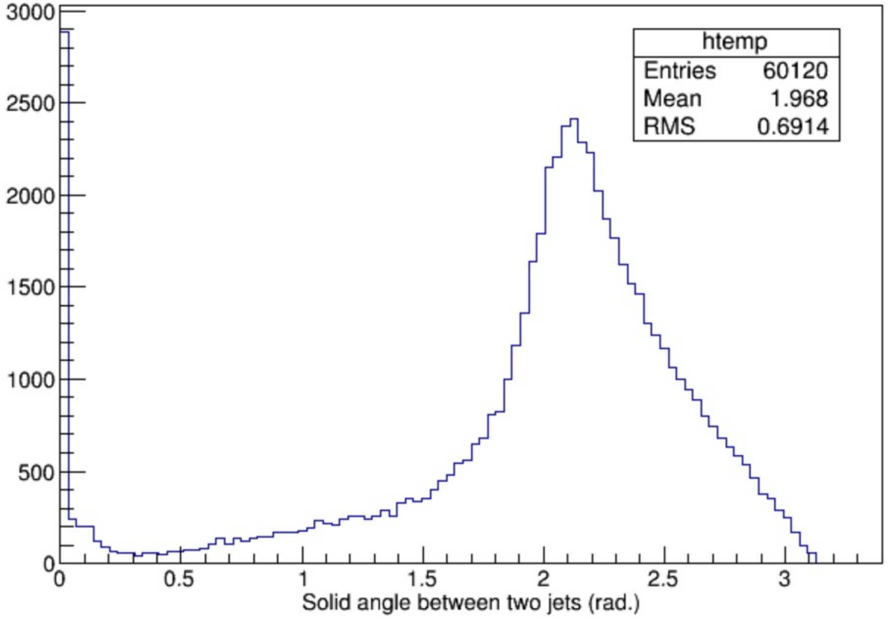


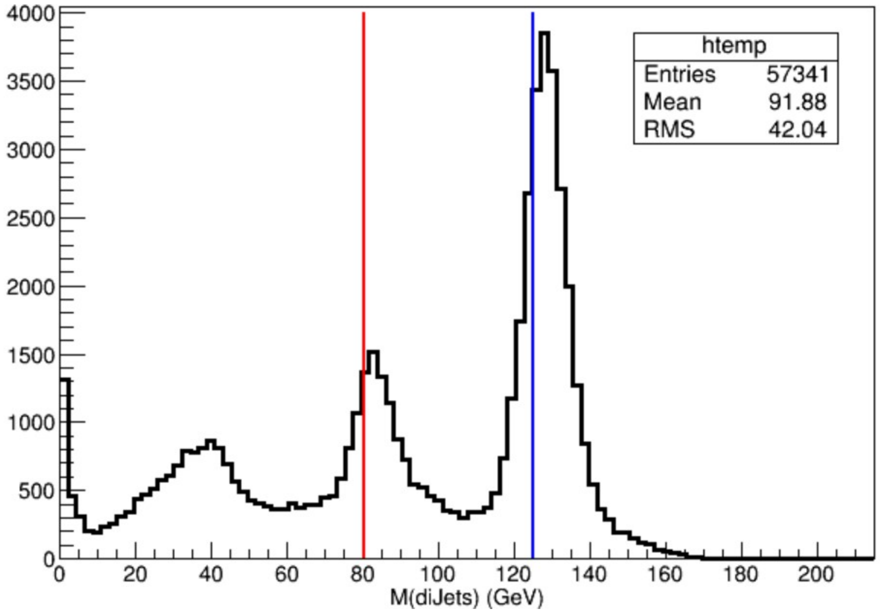




- Si fixed,
- Thicker W plate (7.98mm)

Di-jets Mass





M(Z) in (60, 120) GeV,
recoiling M(H) in (120,160) GeV and
Solid angle > 0

- (Left) Solid angle between two jets.
- (Right) Invariant mass of di-jets. (red) line indicates W nominal mass, (blue) line the Higgs nominal mass. The Higgs peak is contributed by the leading lepton of virtual W decays mixing in jets reconstruction. Higgs and real W peak mass are a little larger than their nominal mass, which tells not well fined calibration.

Zoom in Side View （ROOT Geo)