Circular Electron Positron Collider

PFA Oriented ECAL Simulation and Optimization for the CEPC

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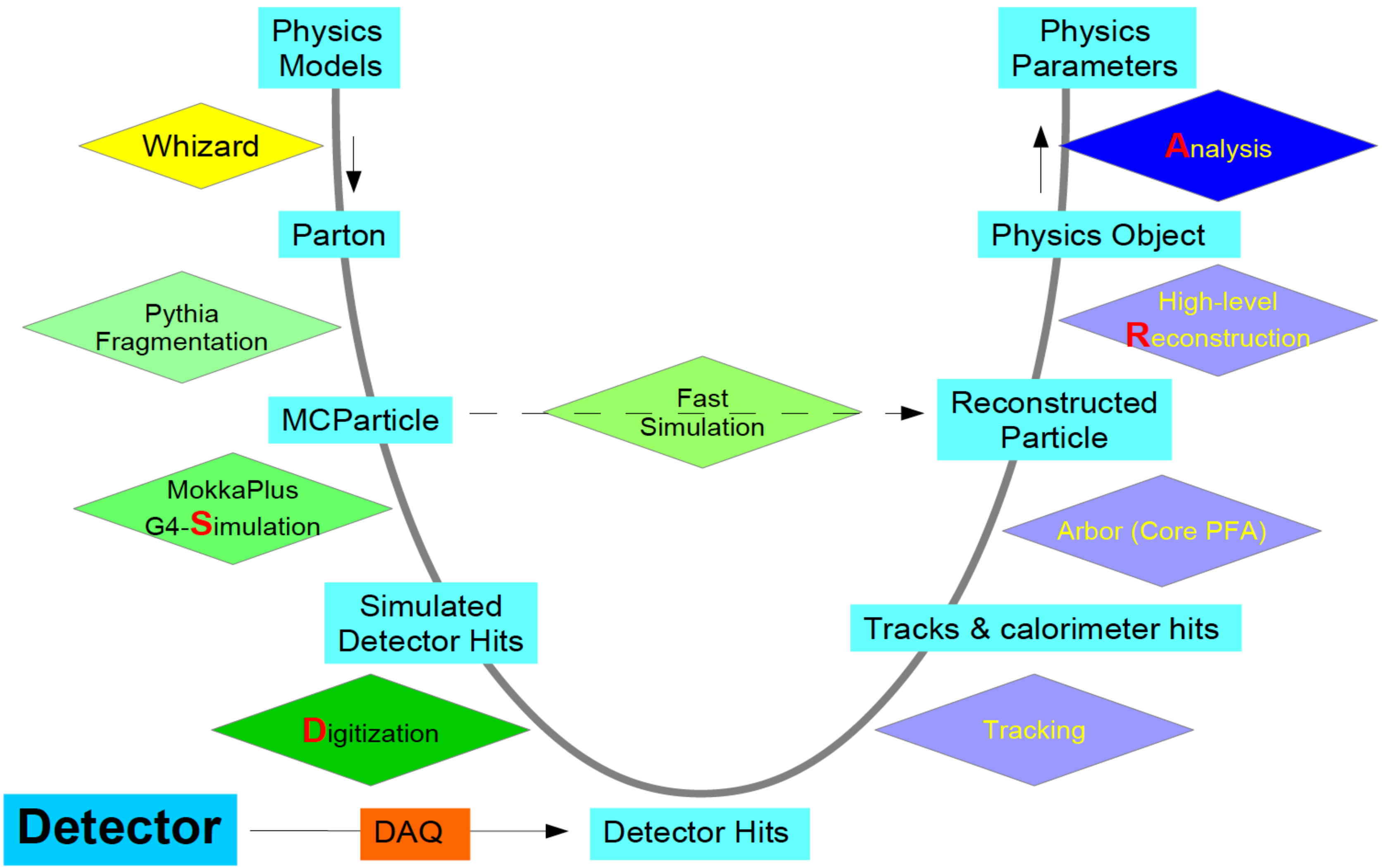
Outline

- Tools:
  - Simulation: Software chain & Geometries
- Optimization of ECAL Geometry
  - Cell Size & Photon Shower Separation
  - Longitudinal Structures & EM Energy Measurements
- Summary

CEPC Full Simulation Software

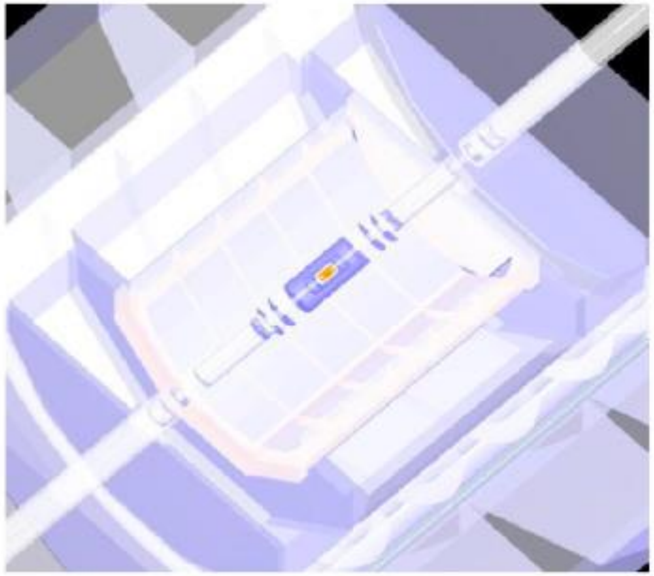


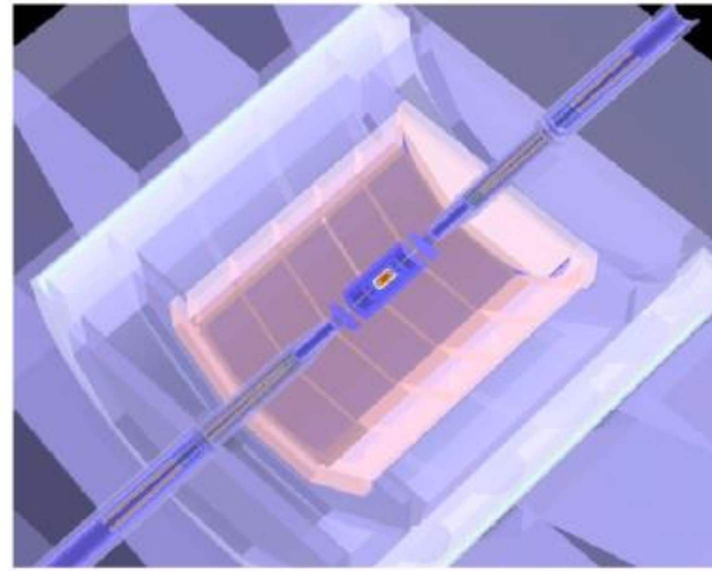
CEPC Detector Model

- **CEPC_V1: baseline in CEPC preCDR**
- **CEPC_V4: baseline for CEPC CDR （APODIS）**

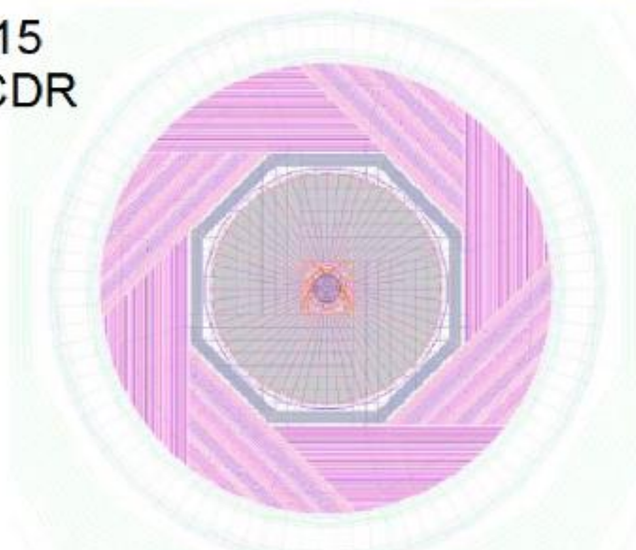
	CEPC_v1 (~ ILD)	APODIS (Optimized)	Comments
Track Radius	1.8 m	>= 1.8 m	Requested by Br(H->di muon) measurement
B Field	**3.5 T**	**3 T**	**Requested by MDI**
ToF	**-**	**50 ps**	**Requested by pi-Kaon separation at Z pole**
ECAL Thickness	84 mm	84(90) mm	84 mm is optimized on Br(H->di photon) at 250 GeV; 90mm for bhabha event at 350 GeV
ECAL Cell Size	5 mm	10 mm	Passive cooling request ~ 20 mm. 10 mm should be highly appreciated for EW measurements – need further evaluation
ECAL NLayer	30	30	Depends on the Silicon Sensor thickness
HCAL Thickness	**1.3 m**	**1 m**	-
HCAL NLayer	**48**	**40**	Optimized on Higgs event at 250 GeV; Margin might be reserved for 350 GeV.

CEPC_V1 vs CEPC_V4

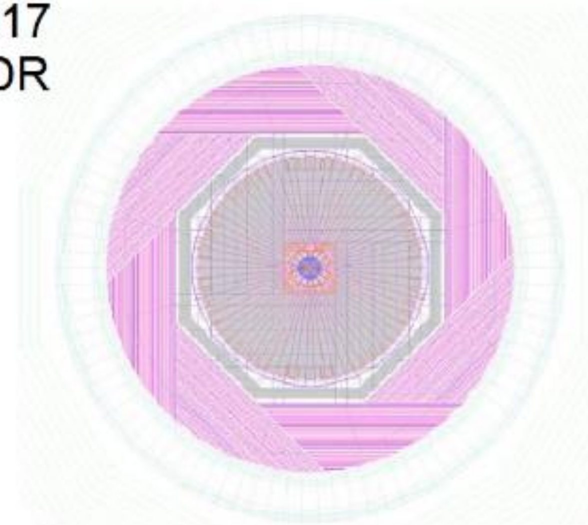




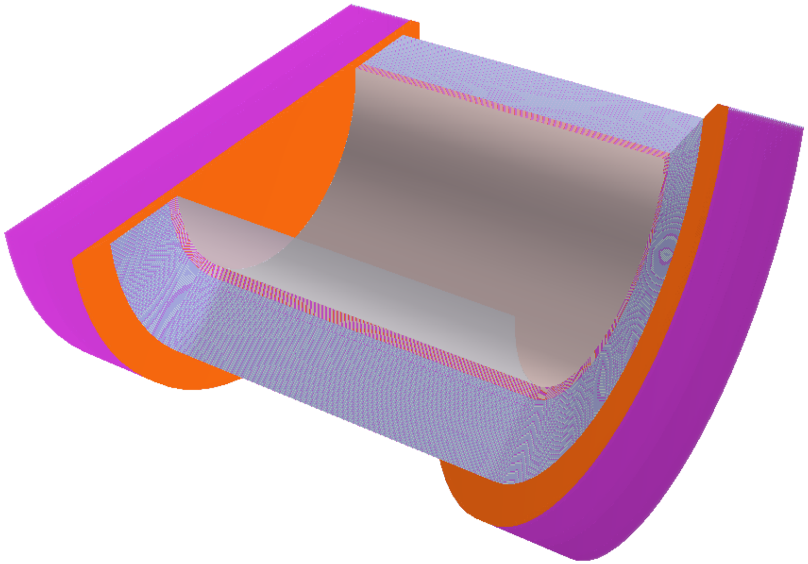
2015
PreCDR



2017
CDR



CEPC Simplified Geometry



- calorimeter only
- ideal geometry(Cylindrical barrel layer).

Advantages:

- easily modified
- no geometry defects
- totally homogeneous

```
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/Mokka/init/globalModelParameter world_box_hy 100000
/Mokka/init/globalModelParameter world_box_hz 250000
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/Mokka/init/globalModelParameter SiCalYCellSize  5
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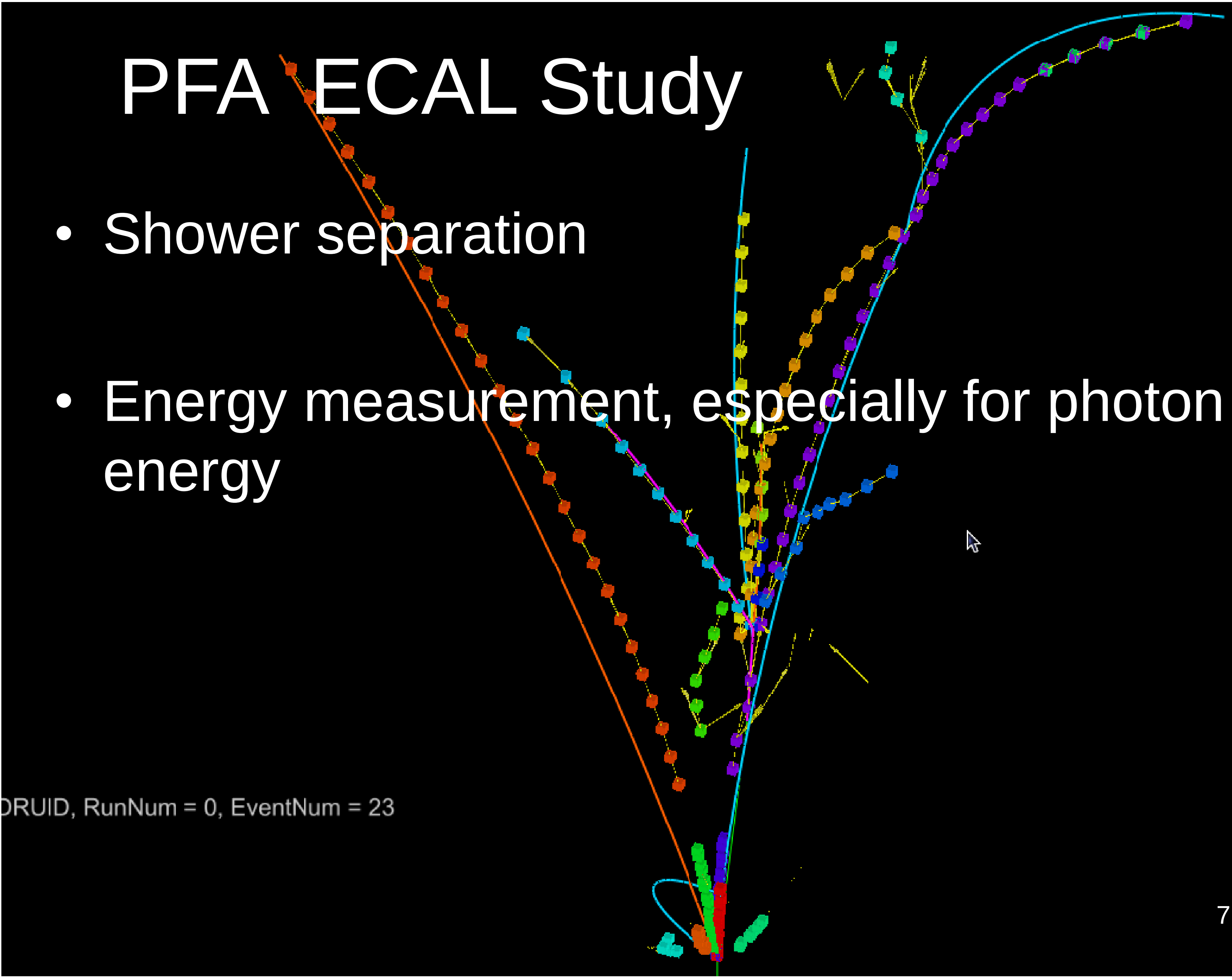
PFA ECAL Study

- Shower separation
- Energy measurement, especially for photon energy



ECAL geometry optimization

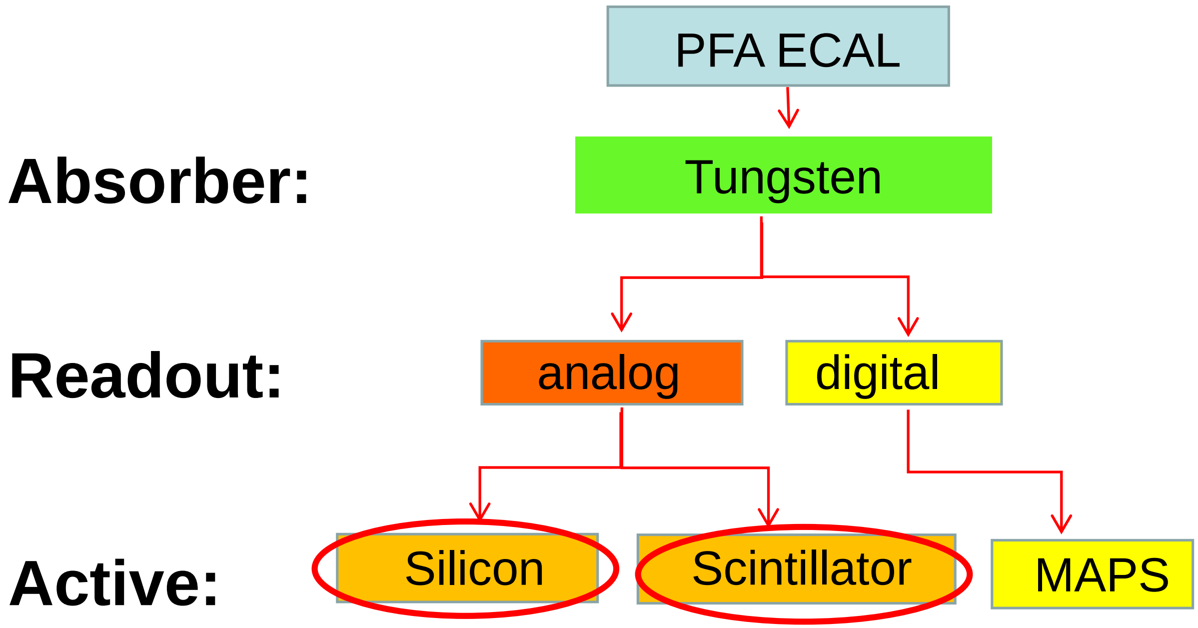
- Transverse:
  - Cell Size

  photon shower separation, with physics benchmark of Br(tau->X)

- Longitudinal
  - Total Absorber Thickness
  - Number of Layers & Sensor Thickness

  photon energy resolution

CEPC PFA ECAL Options



Differences for ScECAL geometry optimization:

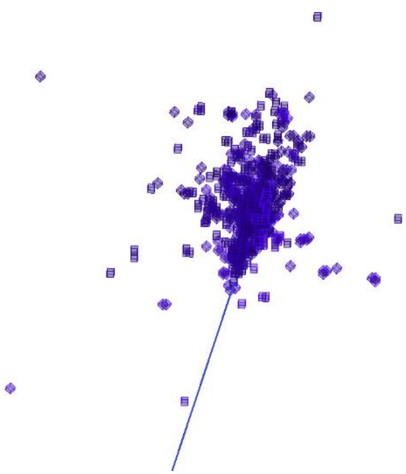
- Scintillator sensor (~2 mm) is thicker than Silicon (~0.5 mm)
  - Total thickness (2mm*30 > 0.5mm*30). Previous talk shows the simulation results on longitudinal structure.
  - Moliere radius (~24 mm > ~19mm) -> Negligible Impact for small cell size.

The results are based on the SiECAL, similar results have been achieved with ScECAL

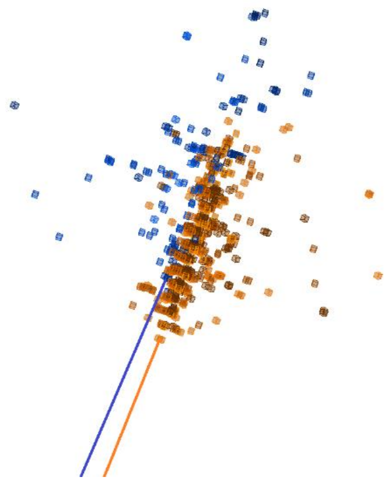
Nearby EM-Shower Separation

Lots of nearby EM-showers exist in jets, the separation and reconstruction of them are important for some physics objecsts.

The reconstruction efficiency of two parallel 5 GeV photons was studied. The distance between these two photons ranges from 1mm to 80mm.

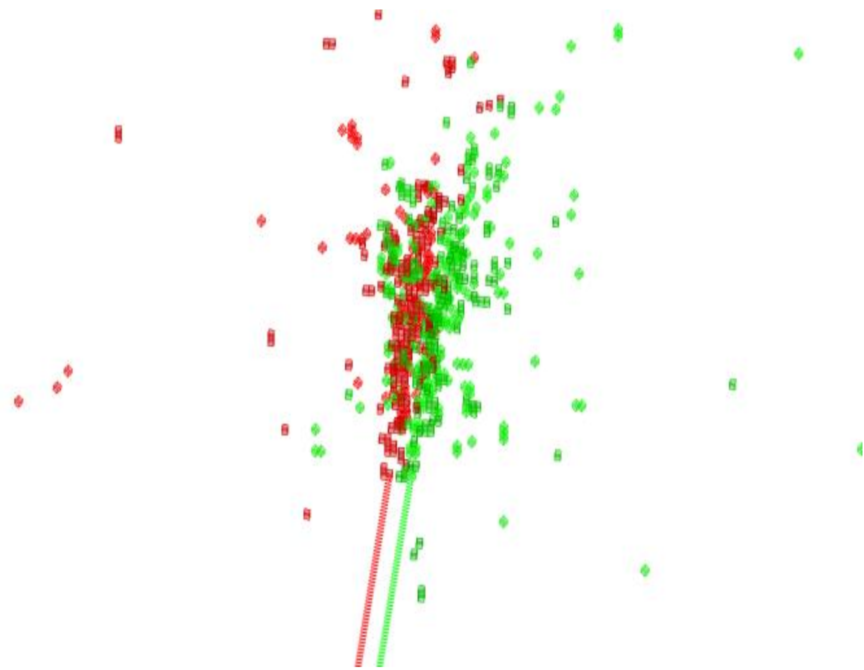


failed



failed

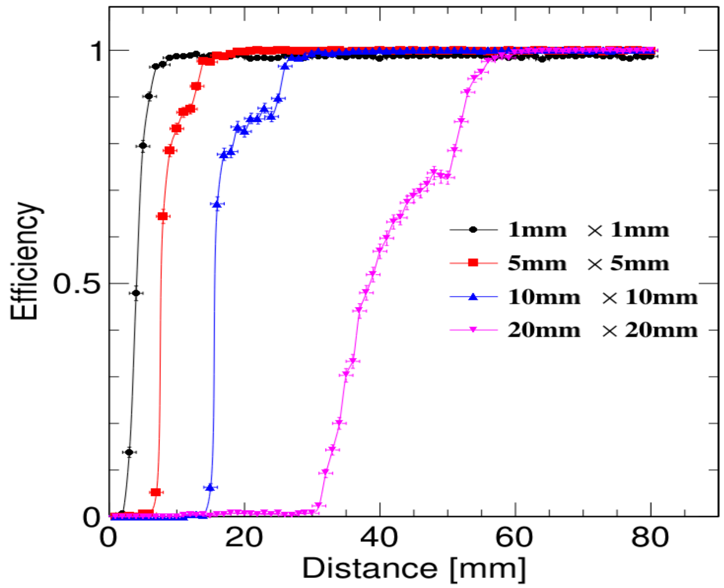
($E_{\text{blue cluster}} \approx 1/6E_{\text{orange cluster}}$)

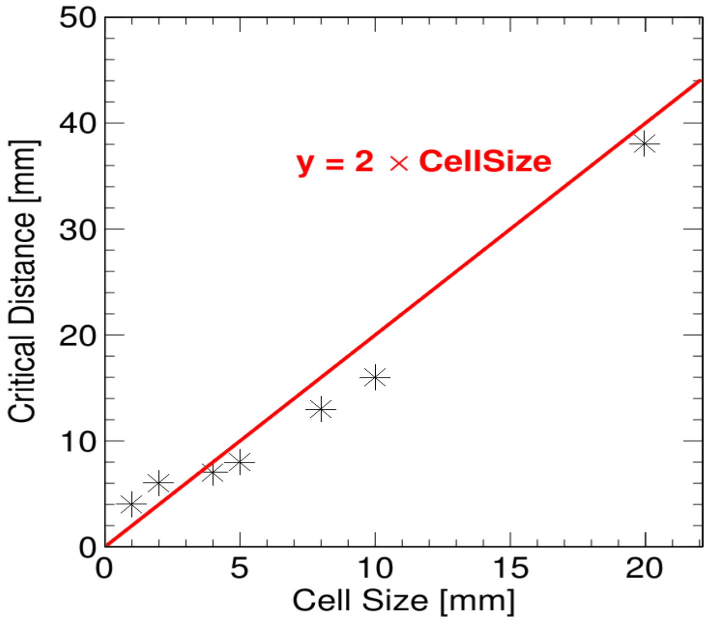


succeeded

$1/3E_{All}<E_{photon1}<2/3E_{All}$ && $1/3E_{All}<E_{photon2}<2/3E_{All}$: succeeded

Nearby EM-Shower Separation



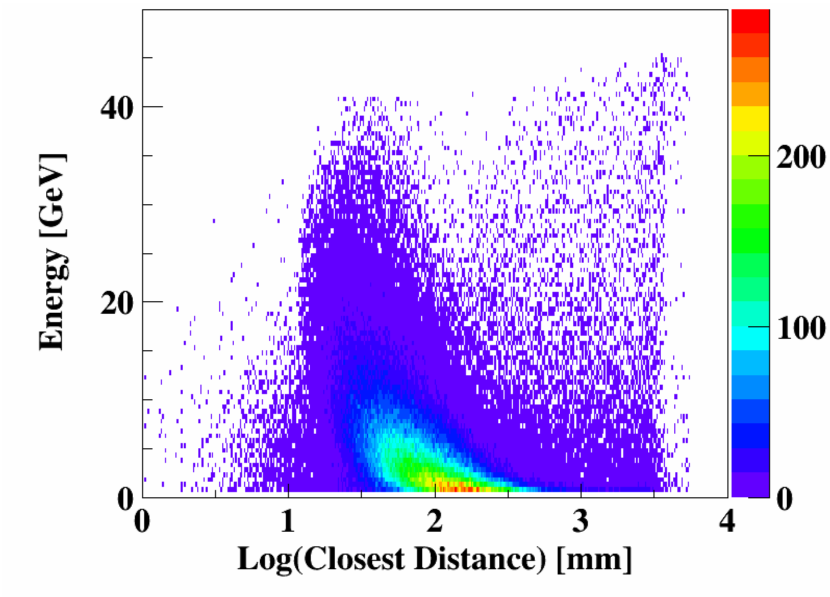


Efficiency with differrent cell size was checked
At large distance, the reconstruction efficiency converges to 1
At very closed by distance, the reconstruction efficiency drops significantly

The critical separation distance is defined as the distance with which the successful reconstruction efficiency is 50%.

Nearby Photon Showers in Physics Objects

Z->tau tau
(at Zpole Energy)



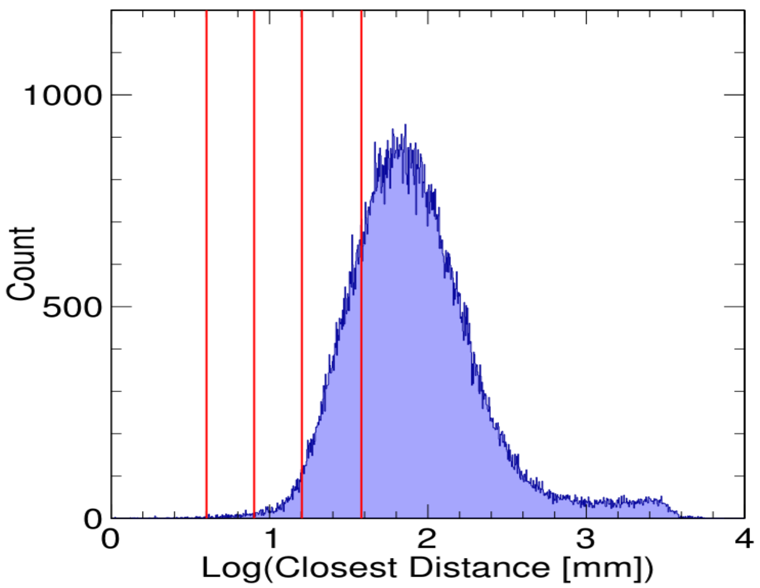
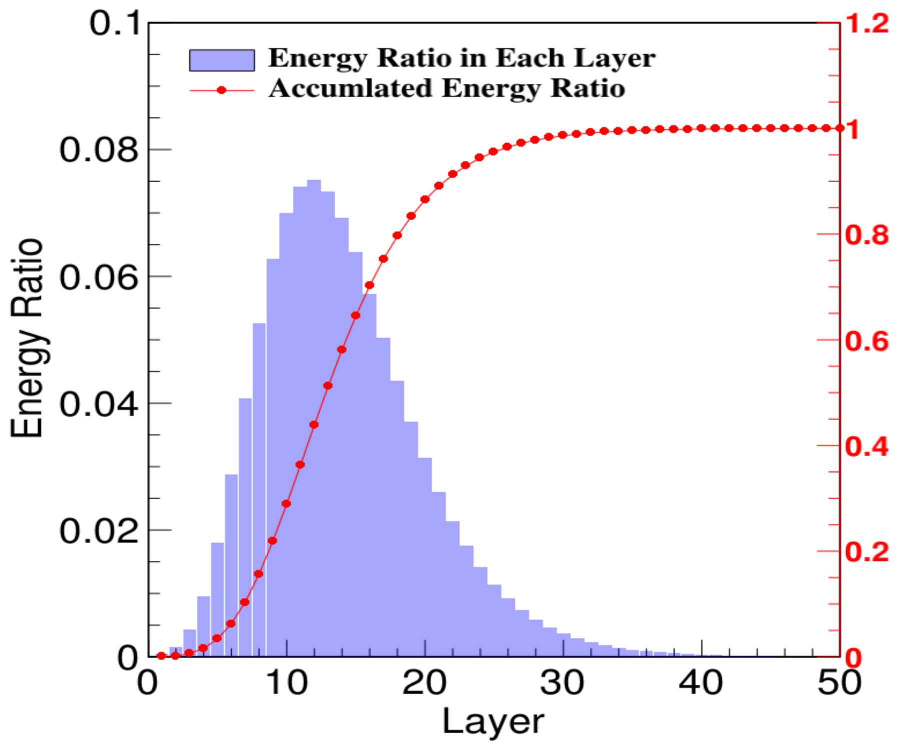


Table 2. Percentages of photons that would be polluted by neighbor particles

Cell Size	Critical Separation Distance with Arbor	Percentage of $Z \rightarrow \tau^+\tau^-$
1 mm	4 mm	0.07%
5 mm	8 mm	0.30%
10 mm	16 mm	1.70%
20 mm	38 mm	19.6%

At least ~10mm×10mm effective cell size

Study on ECAL Absorber Thickness



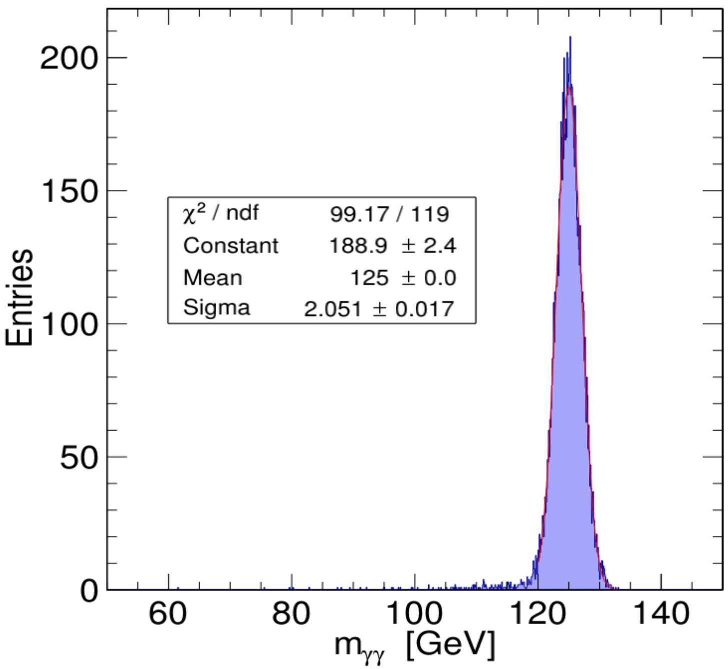
80-90mm Total Tungsten Thickness is resonable

175GeV photon shower energy deposit in each 1mmW (0.35X_0)

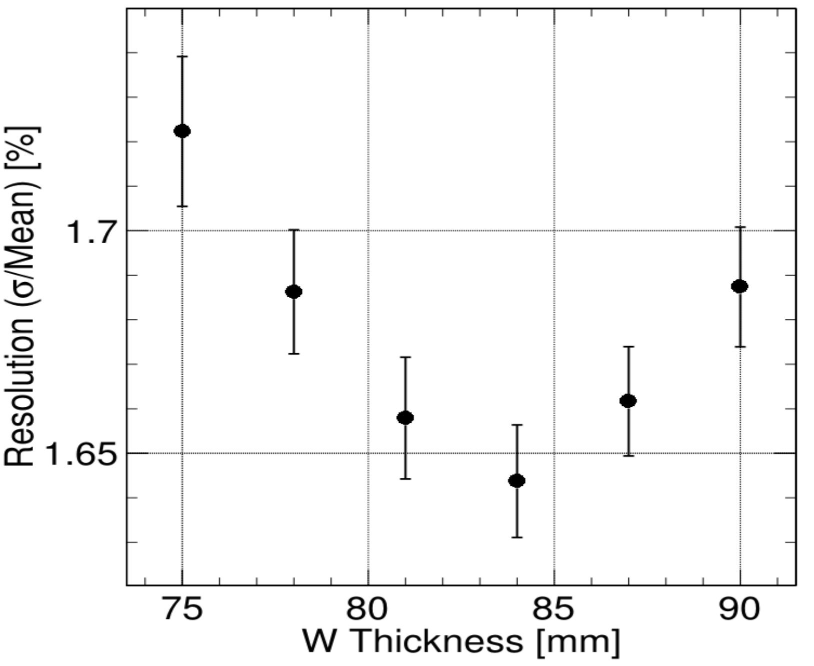
	95mm W	90mm W	85mm W	80mm W
175GeV	99.0%	98.6%	97.9%	96.9%
120GeV	99.2%	98.8%	98.2%	97.3%
45GeV	99.4%	99.1%	98.7%	98.1%

vvHiggs->diphoton Reconstruction

the reconstruction accuracy is mainly decided by the photon energy resolution because the spatial resolution is negelectable.

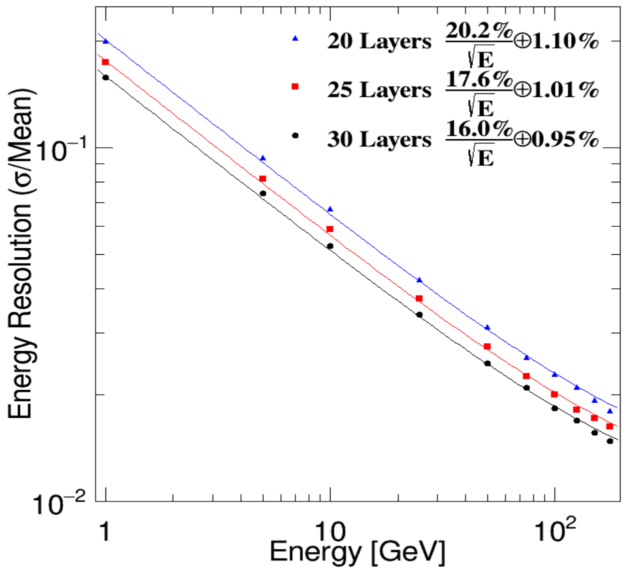


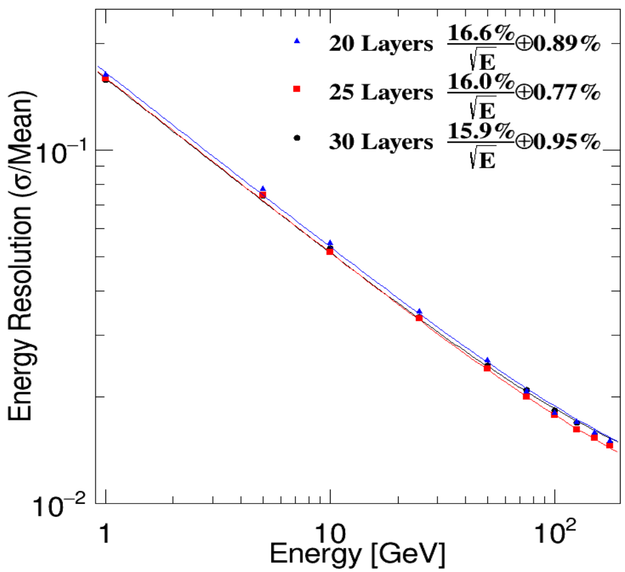
30layers ECAL with
2.8mmW+0.5mmSi in each layer



resolution(σ/mean) with different total tungsten thickness

Photon energy resolution at different ECAL layer number





0.5mm thick silicon in each layer

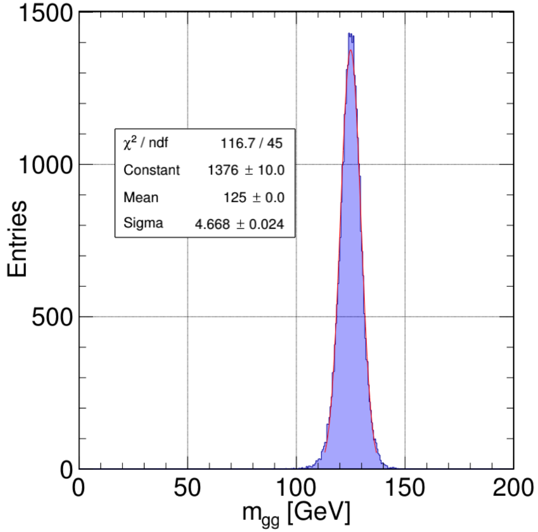
less layer gets worth photon energy resolution, due to the less sensor/absorber ratio

thicker sensor can compensate photon energy resolution

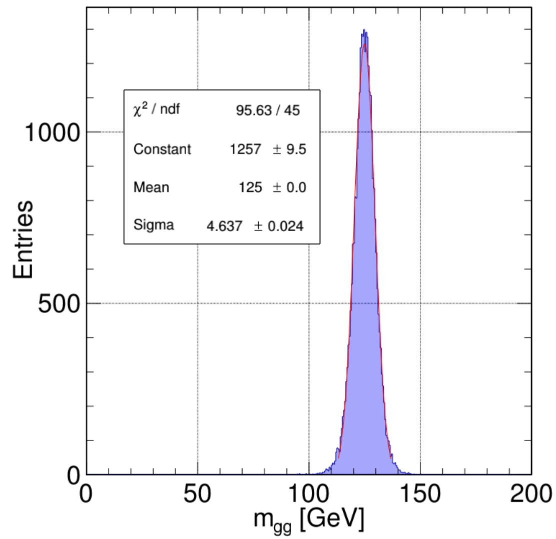
30layers 0.5mm silicon
25layers 1mm silicon
20layers 1.5mm silicon

CEPC Detector Model Results

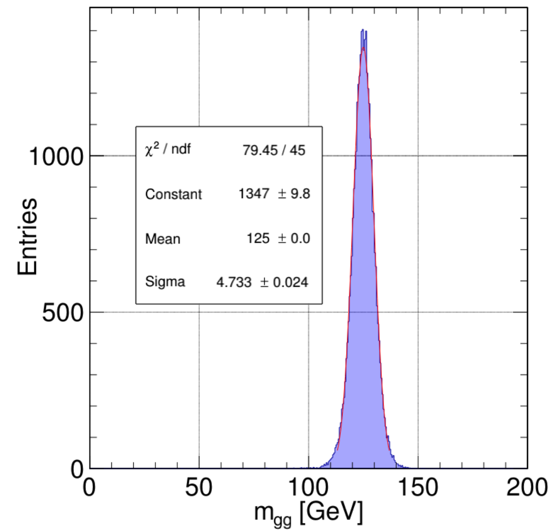
vvHiggs->gluon gluon



0.5mm Si, 30 layers



1mm Si, 25 layers



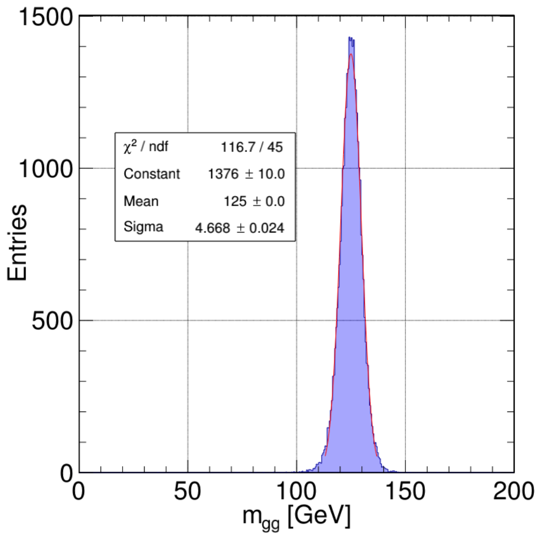
1.5mm Si, 20 layers

Table 1. Resolution of reconstructed Higgs boson mass through $\nu\nu Higgs, Higgs \rightarrow gluons$ events using different longitudinal structures at CEPC_v1 geometry.

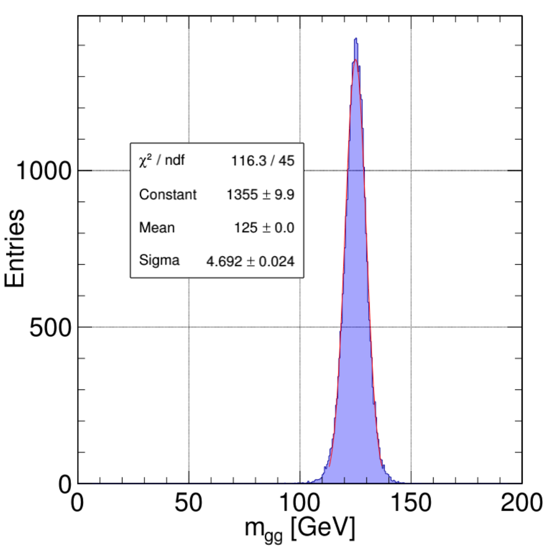
Layer number	Silicon sensor thickness	Higgs boson mass resolution (Statistic error only)
30	0.5 mm	3.74 ± 0.02 %
25	1 mm	3.71 ± 0.02 %
20	1.5 mm	3.78 ± 0.02 %

CEPC Detector Model Results

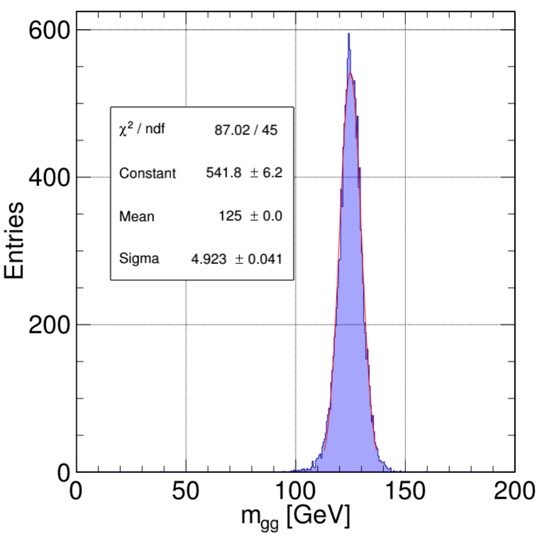
vvHiggs->gluon gluon



0.5mm Si, 30 layers
5mm*5mm



1mm Si, 25 layers
10mm*10mm



1.5mm Si, 20 layers
20mm*20mm

Cell Size (mm^2)	5×5	10×10	20×20
BMR	3.74 ± 0.02 %	3.75 ± 0.02 %	3.93 ± 0.02 %

Summary on ECAL Geometry Optimization

- ~10mm*10mm or smaller cell size is needed for EM shower seperation in tau jets.

- Total Tungsten thickness should be 80-90mm.

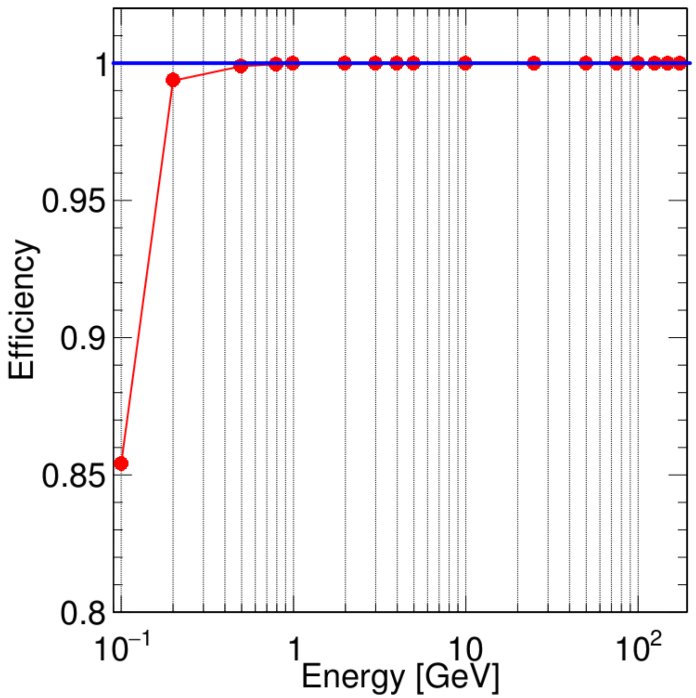
- <30 layers is feasible, if thicker sensor can be used to conpensate photon energy resolution loss.

- Paper: *Particle Flow Oriented Electromagnetic Calorimeter Optimization for the Circular Electron Positron Collider, JINST, March 2018*

Thanks for your attention!!

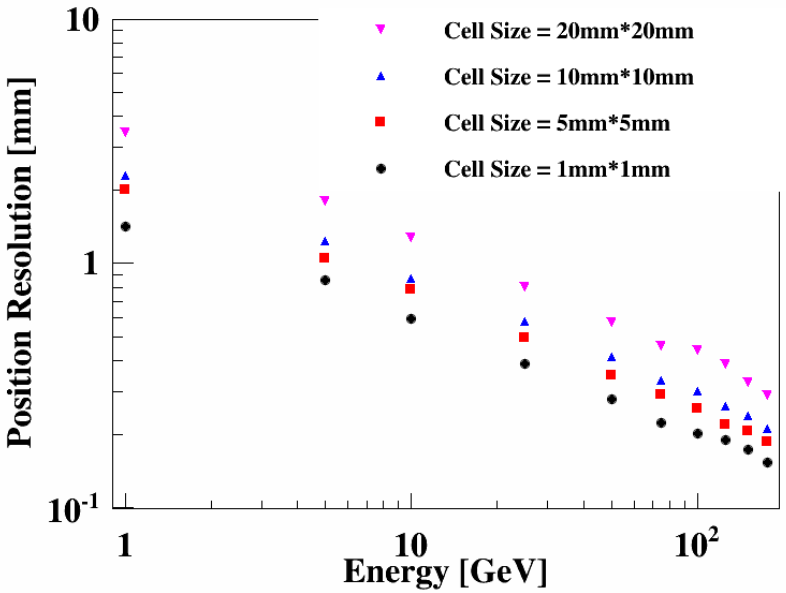
Back Up

Finding Efficiency on Photon Reconstruction by ArborPFA

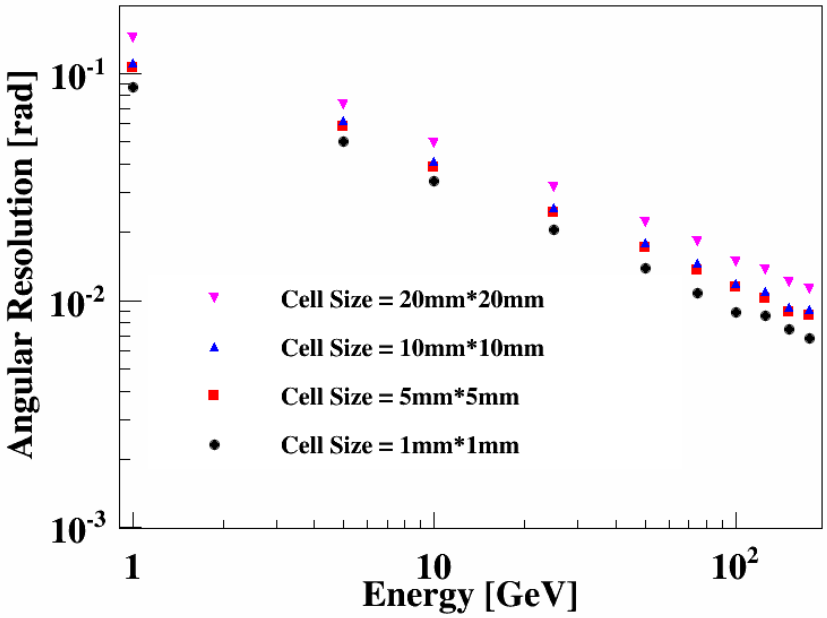


Good performance on photon shower energy collection and energy measurement !!

Photon Spatial Resolution

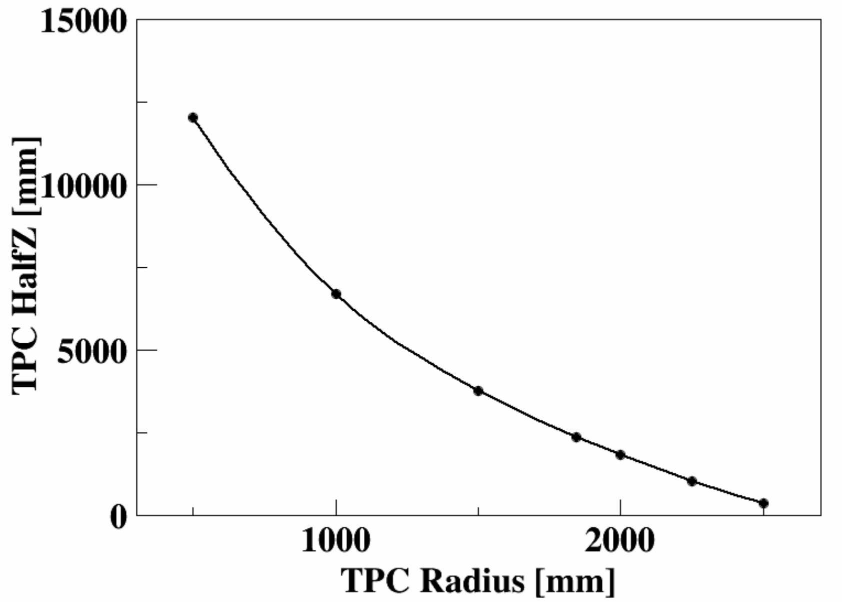


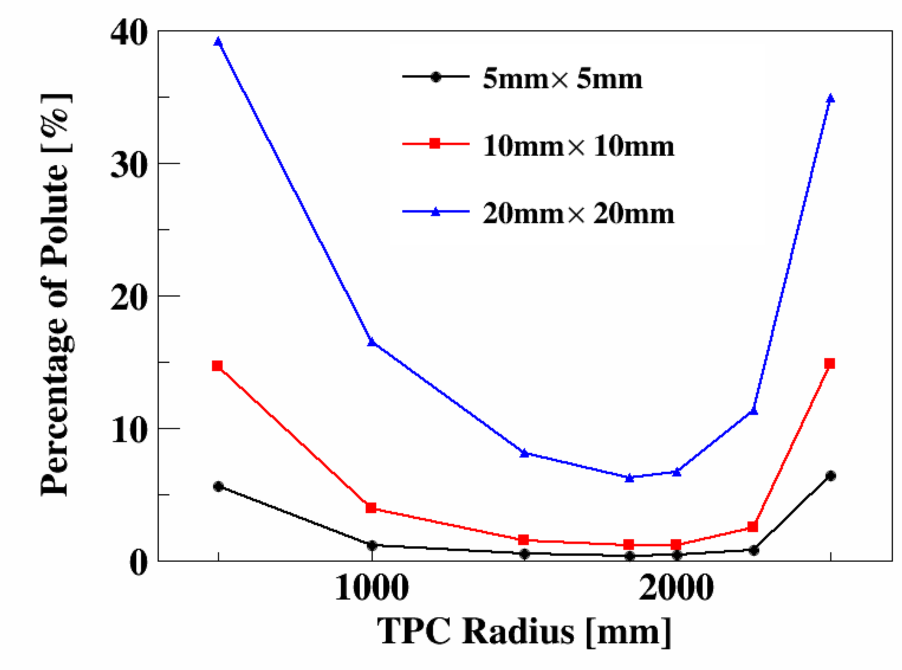
Position Resolution



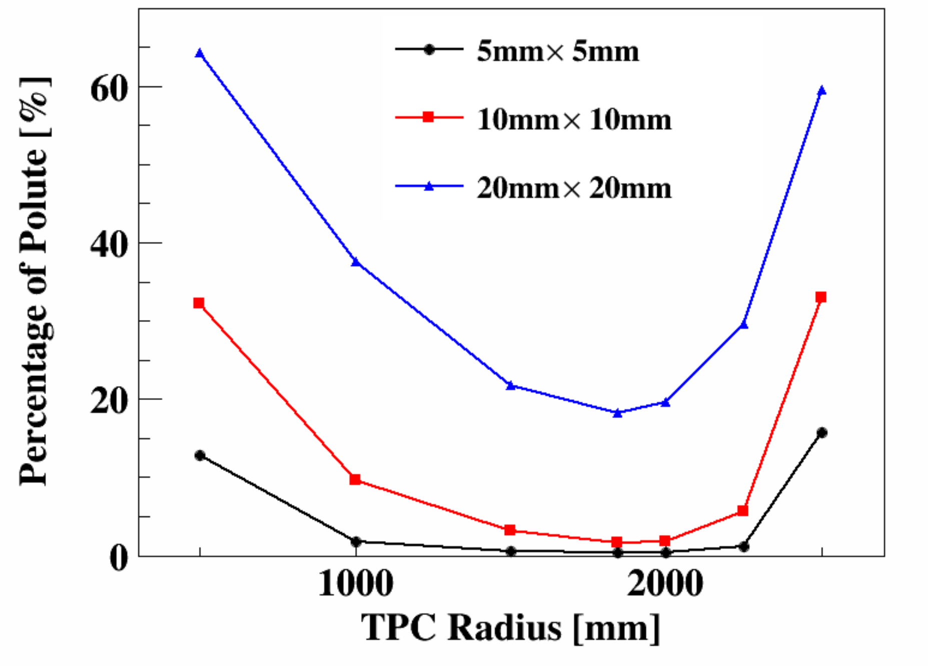
Angular Resolution

ECAL R-Z



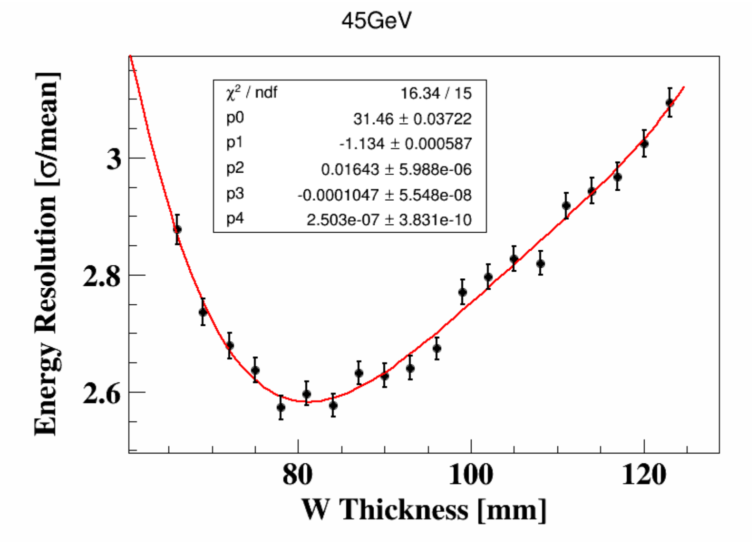


qq H->γγ

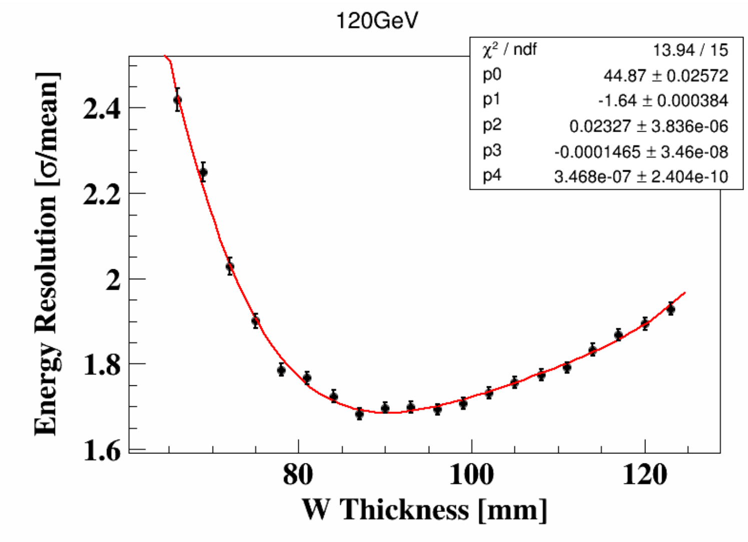


Z->tau tau

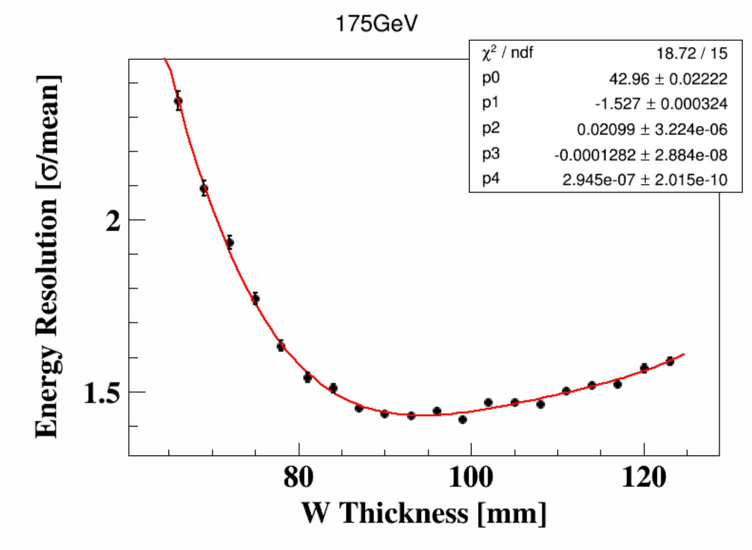
Phton energy resolution with different absorber thickness



45GeV



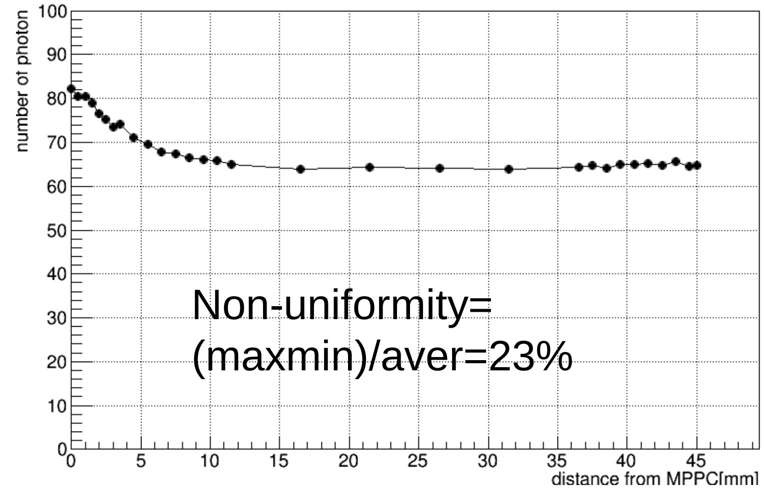
120GeV



175GeV

Digitization for ScW ECAL

- Nonhomogeneity
- Saturation
- etc..



vvHiggs->γγ Events
5mm*45mm*2mm
plastic scintillator cell