Circular Electron Positron Collider

PFA Oriented ECAL Simulation and Geometry Optimization for the CEPC

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On behalf of CEPC Software and Calorimeter Working Group

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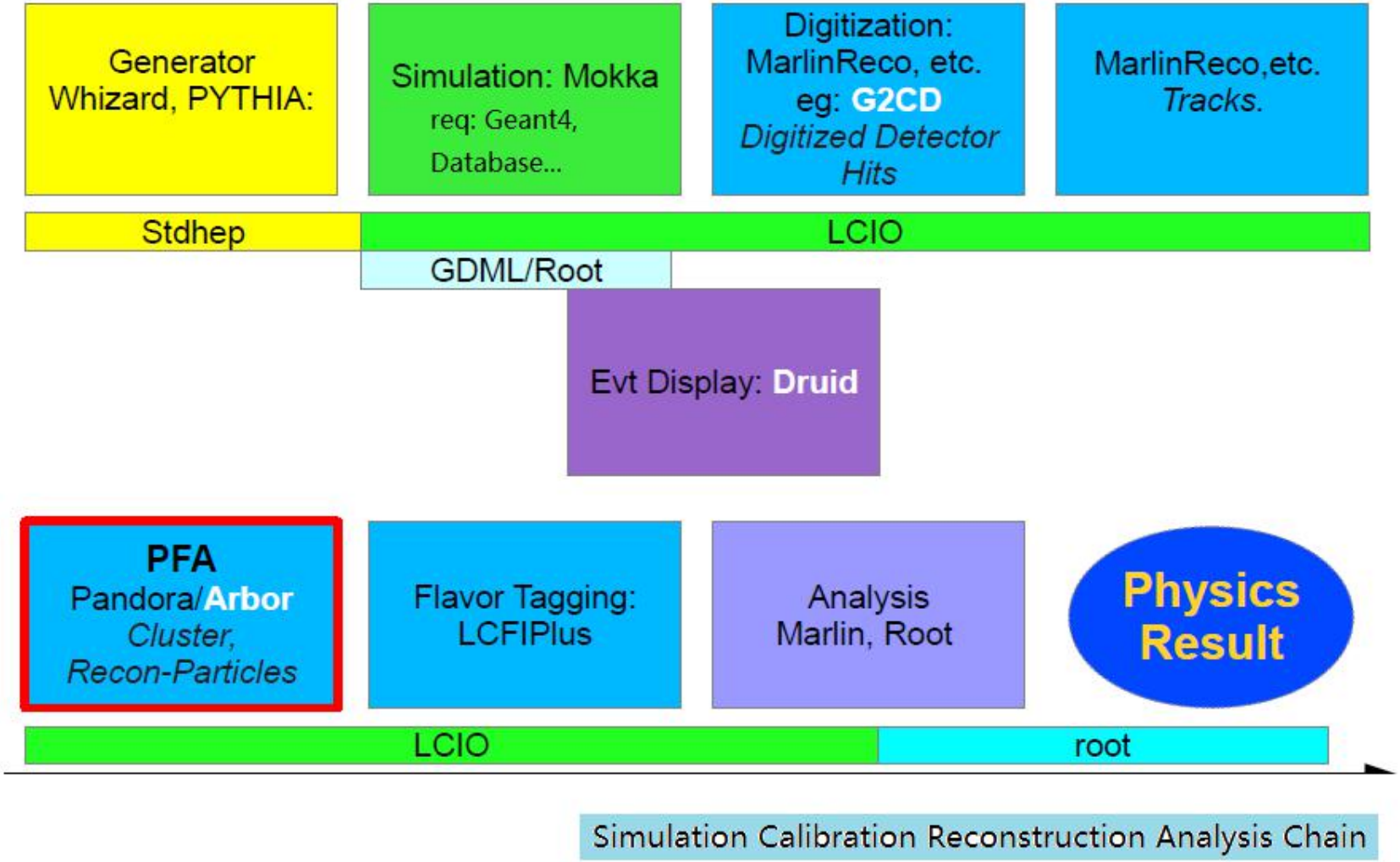
Outline

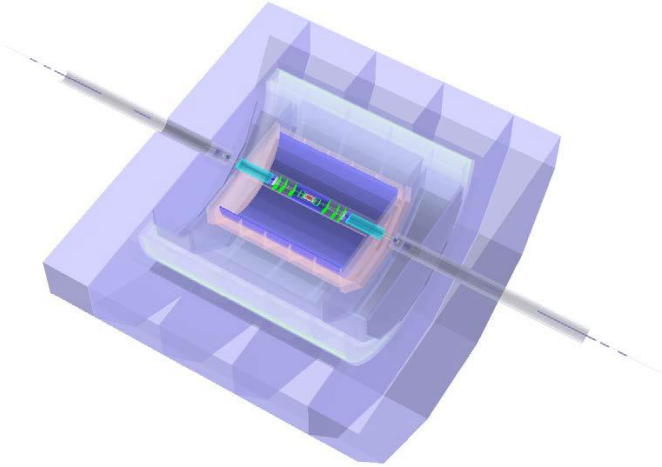
- Tools:
  - Simulation: Software setup & Geometries
  - Reconstruction: ArborPFA
- Optimization of ECAL Geometry
  - Cell Size & Photon Shower Separation
  - Longitudinal Structures & EM Energy Measurements
    - Absorber thickness
    - Number of ECAL layers
- Summary and Plan

CEPC Full Simulation Software

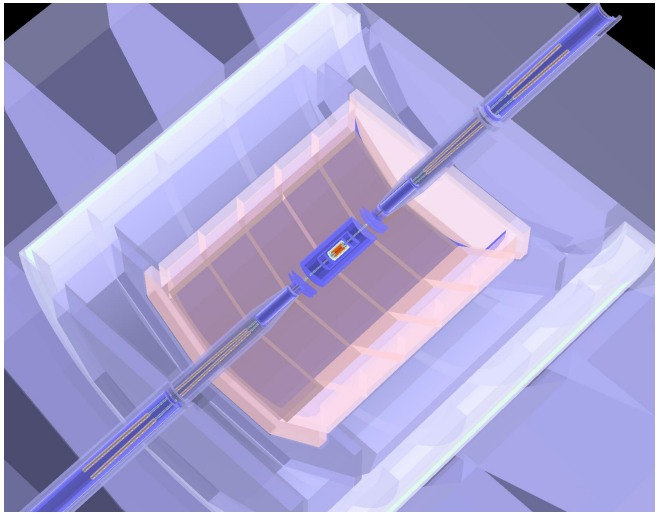


CEPC Detector Model

Sub-detector	CEPC_v1	CEPC_v4
Tube & Mask	Single pipe	New MDI design—doubly pipe
Lcal	R: 60 mm ~ 172 mm	R: 30 mm ~ 100 mm
VXD	16mm/62.5mm, 37mm/125mm, 58/125mm	Same as CEPC_v1
FTD	220mm, 371.3mm, 645mm, 846mm, 1057.5mm	220mm, 371.3mm, 643mm, 844mm, 925mm
SIT & SET	153mm, 300mm, 1811mm, 1813.5mm	Same as CEPC_v1
TPC	Sensitive Radius: 384mm ~ 1718mm	Same as CEPC_v1
Ecal	R: 1843mm ~ 2028mm; Z: 2450mm ~ 2635mm; Cell size: 5.0833mm Rin_endcap: 226.8 mm	Cell size: 10.1667mm Rin_endcap: 245 mm
Hcal	R: 2058mm ~ 3385.53mm; Cell size: 10.408 mm; 48 layers	R: 2058mm ~ 3143.43mm; Z: 2650mm ~ 3736.43mm; 40 layers
Yoke	Rin = 4415(barrel), 300(endcap)	Rin = 4174(barrel), 300(endcap) (240 for MDI)
Field	3.5 T	3.0 T



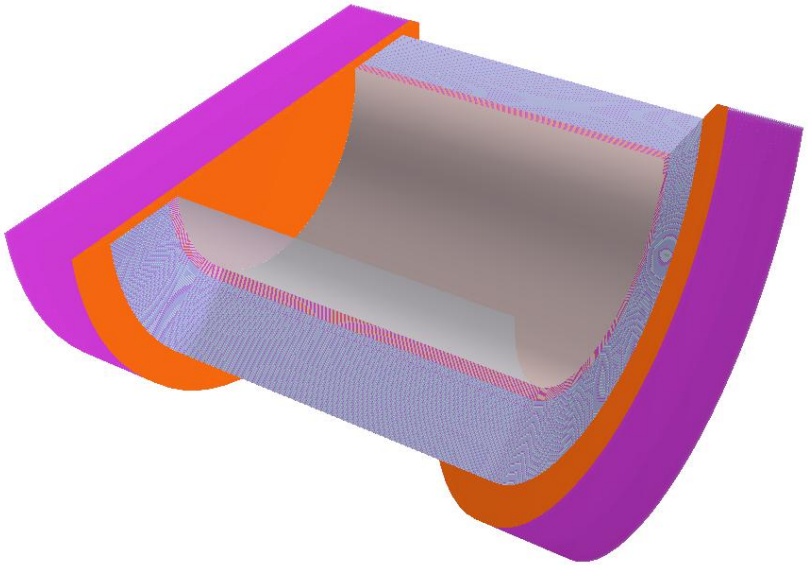
CEPC_v1



CEPC_v4

Smaller BField (3.5 → 3T), Thinner HCAL (48 → 40Layers),MDI/Yoke System, etc.

CEPC Simplified Geometry



- **Goal:**
  to understand the ultimate clustering performance & set reference for geomtry defect impacts study.

- calorimeter only
- ideal geometry(Cylindrical barrel layer).
- totally homogeneous, with no geometry defects
- easily modified

```
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/Mokka/init/globalModelParameter SiCalYCellSize  5
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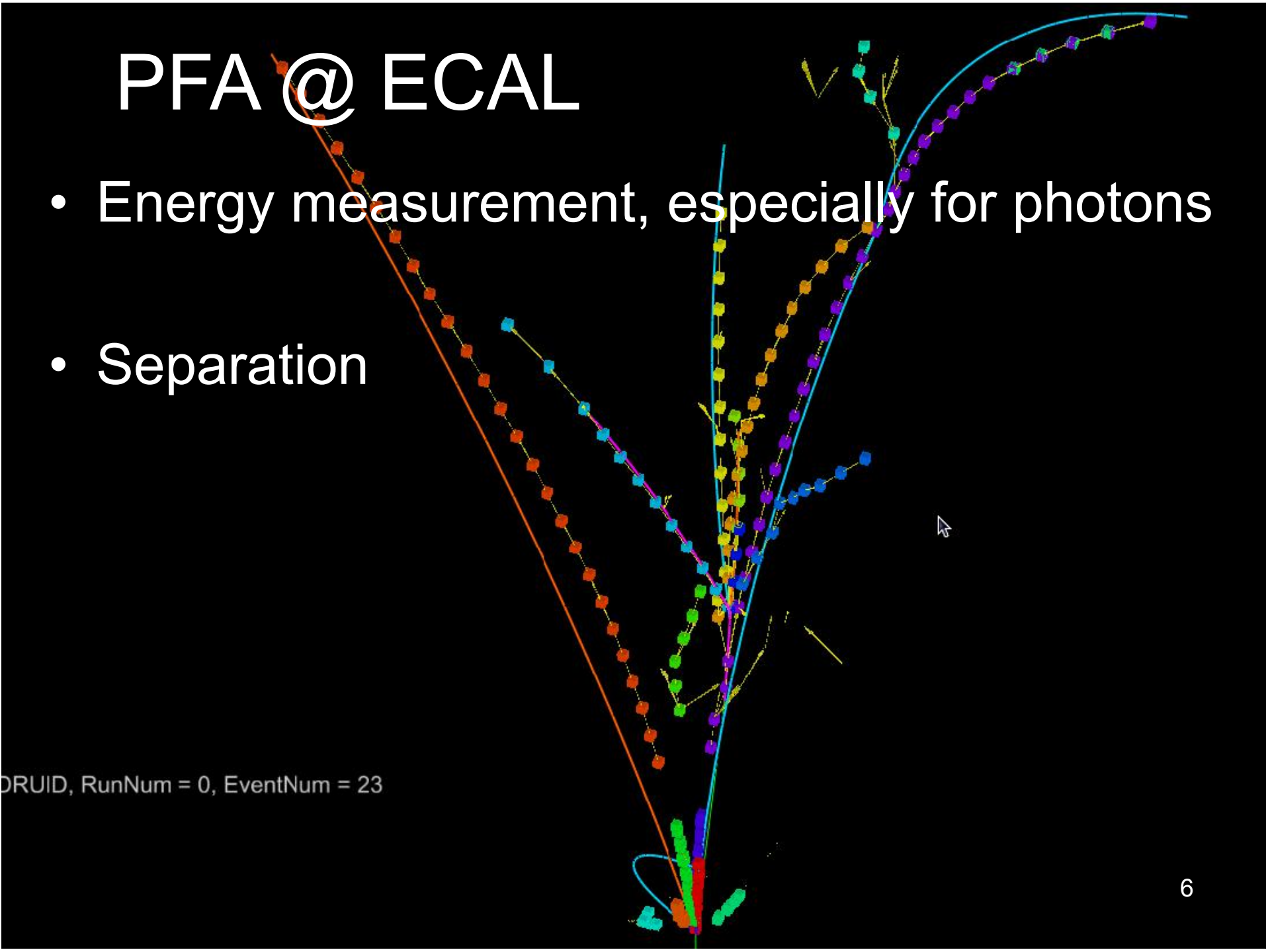
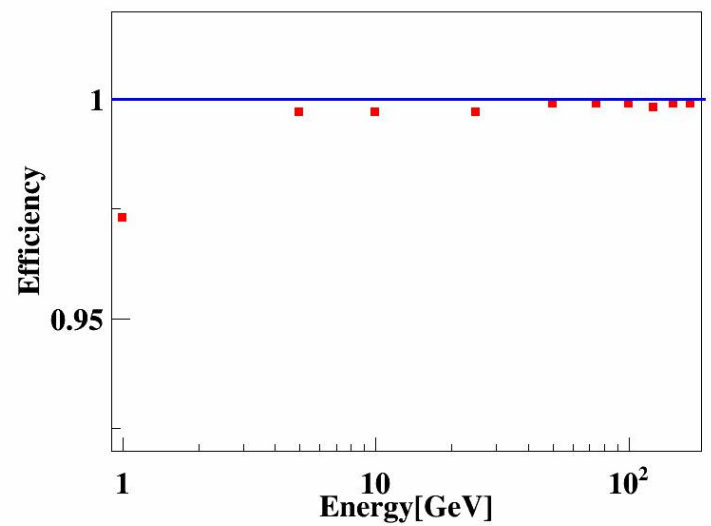
PFA @ ECAL

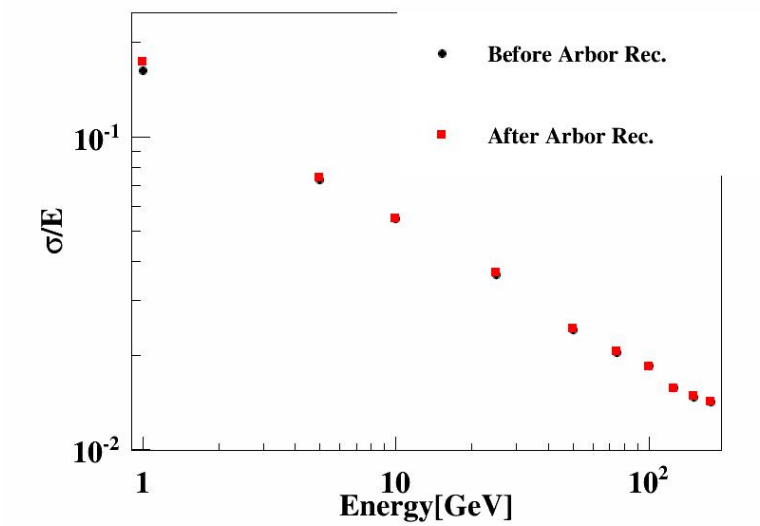
- Energy measurement, especially for photons
- Separation



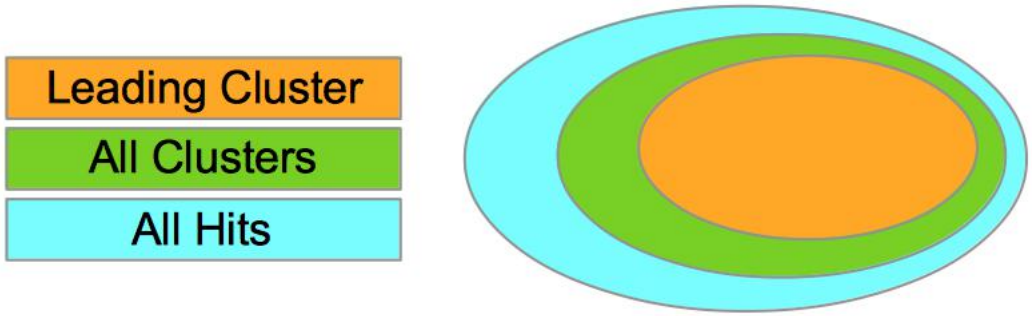
Photon Energy Measurement by ArborPFA



Photon shower energy collection efficiency



Photon energy resolution before and after reconstruction

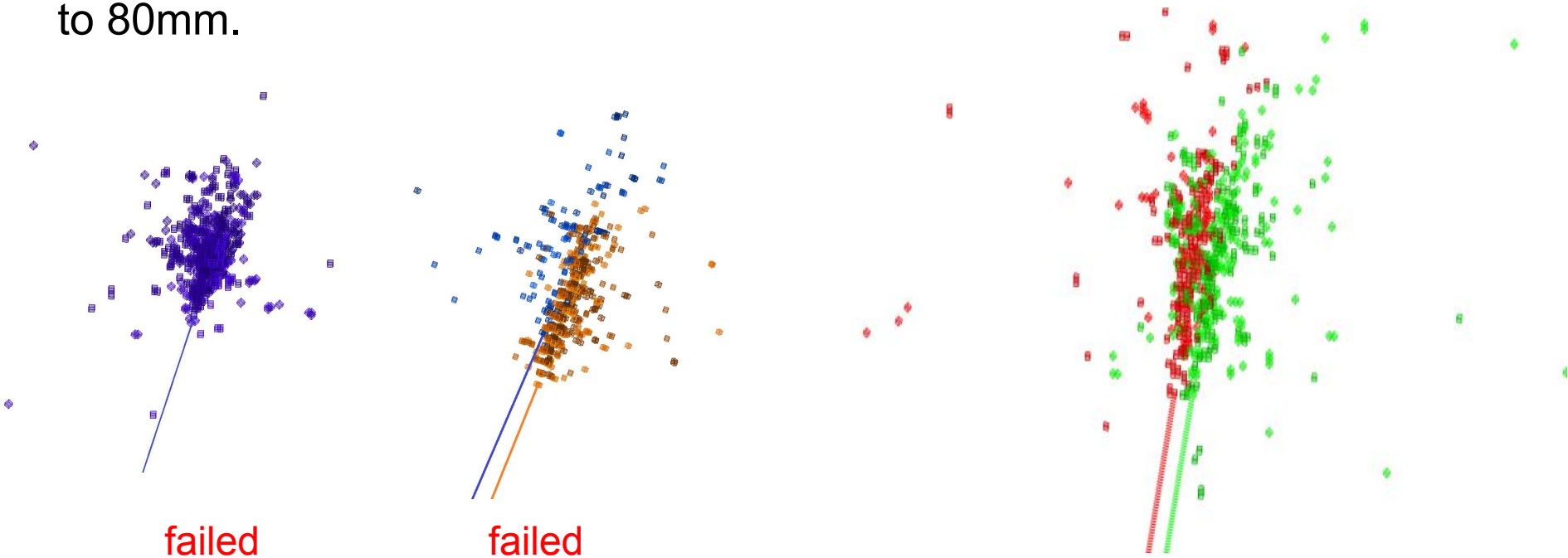


Efficiency
= LC Energy/total hit energy

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



failed

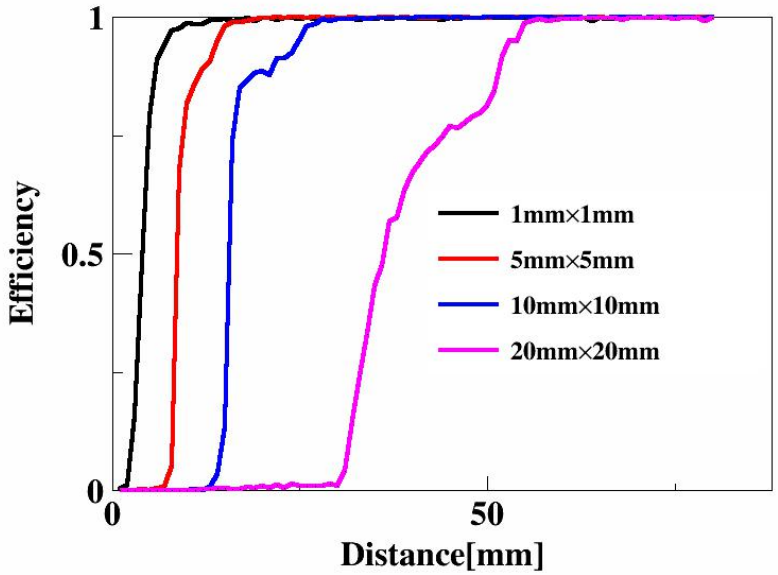
failed

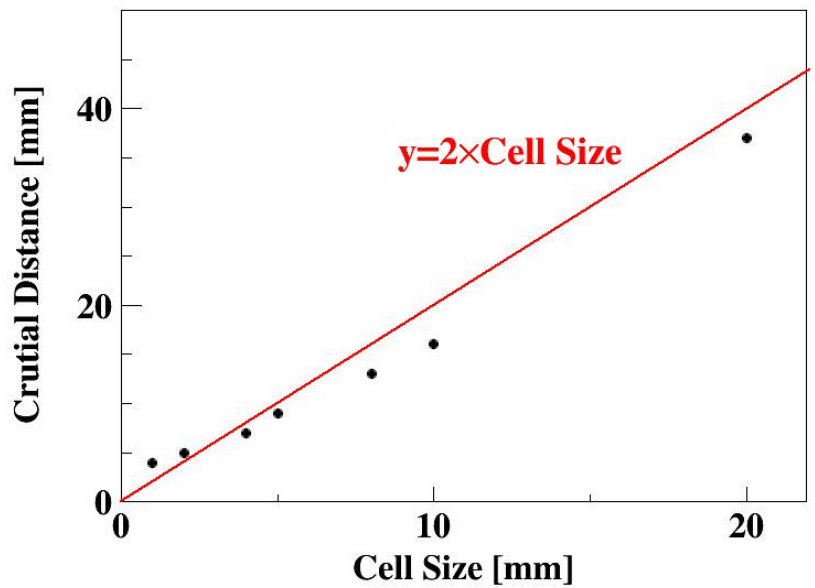
($E_{blue\ cluster} \approx 1/6 E_{orange\ cluster}$)

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

ECAL geometry optimization

- Transverse:
  - Cell Size

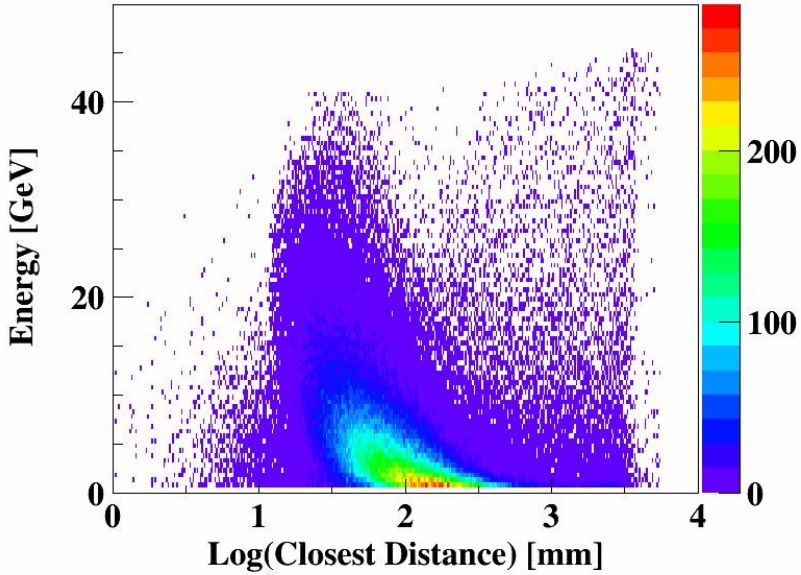
  photon separation, with physics benchmark of Br(tau->X)

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

  photon energy resolution

Nearby Photon Showers in Physics Objects

Z->tau tau
(at Zpole Energy)



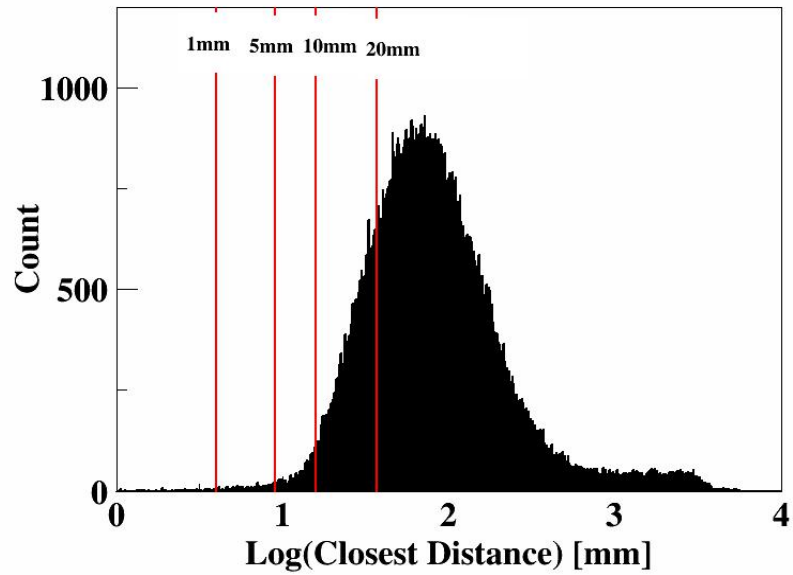
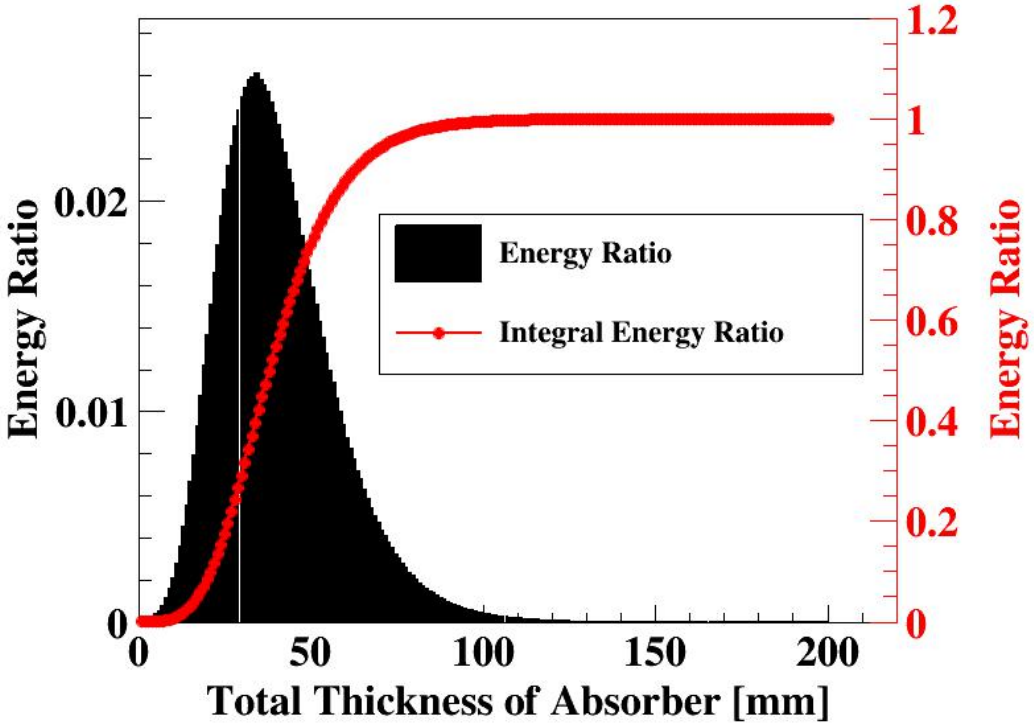


Table 2. Percentage of photons that would be polluted by neighbor particle

Cell Size	Crucial Separation Distance with Arbor	Percentage of H→ $\gamma\gamma$		Percentage of Z→ $\tau\tau$
		≥30GeV	≤30GeV	
1mm	4mm	0%	0.06%	0.068%
5mm	9mm	0.007%	0.352%	0.388%
10mm	16mm	0.097%	1.12%	1.70%
20mm	37mm	0.404%	6.41%	18.6%

At least ~10mm×10mm effective cell size

Study on ECAL Absorber Thickness



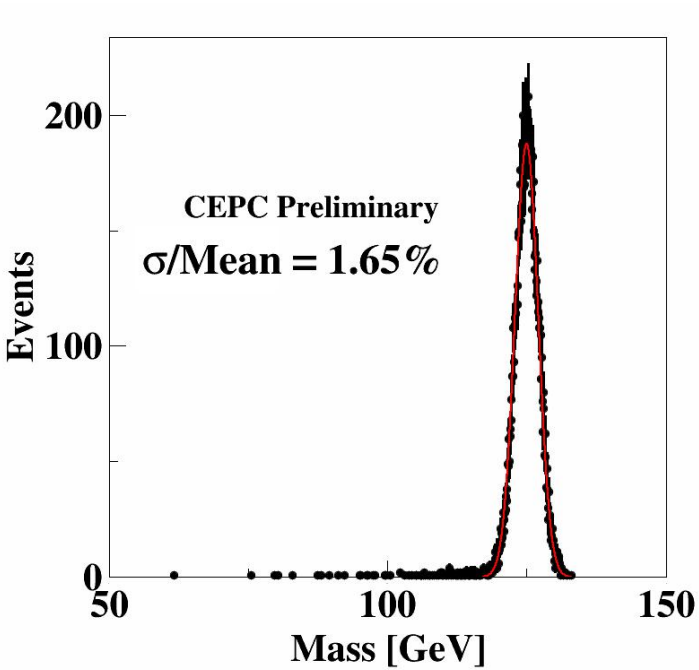
80-90mm Total Tungsten Thickness is resonable

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

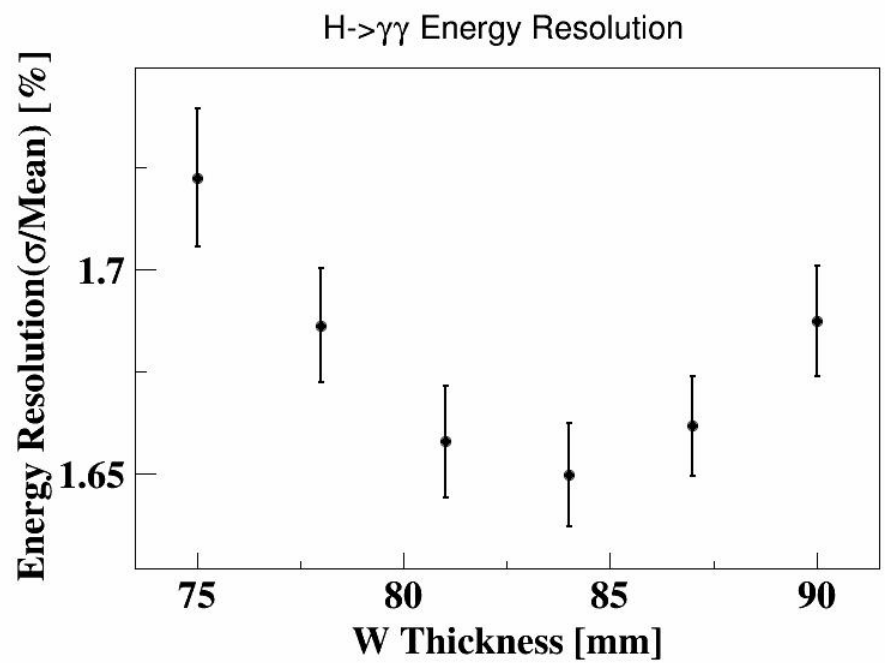
	95mm W	90mm W	85mm W	80mm W
175GeV	99.0%	98.6%	97.9%	96.9%
120GeV	99.2%	98.8%	98.2%	97.3%
45GeV	99.4%	99.1%	98.7%	98.1%

vvHiggs->diphoton Reconstruction

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

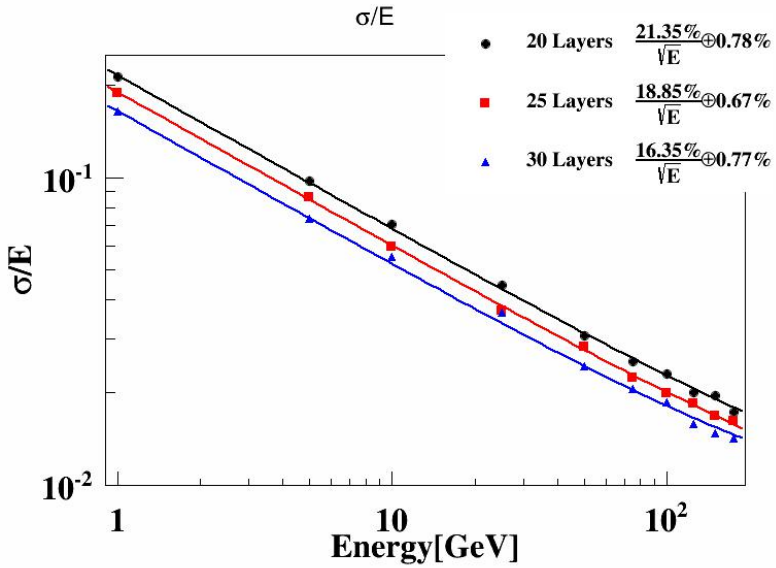


30layers ECAL with
2.8mmW+0.5mmSi in each layer



resolution(σ/mean) with different total tungsten thickness

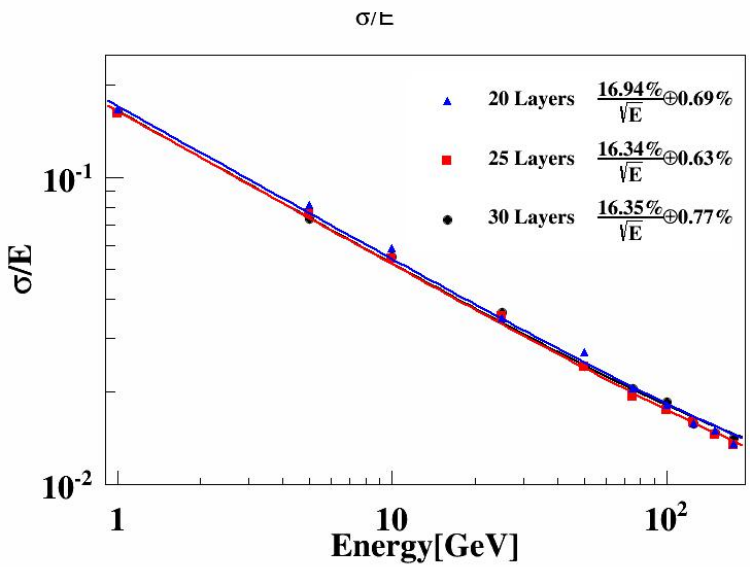
Photon energy resolution at different ECAL layer number, and Silicon sensor thickness



0.5mm thick silicon in each layer

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

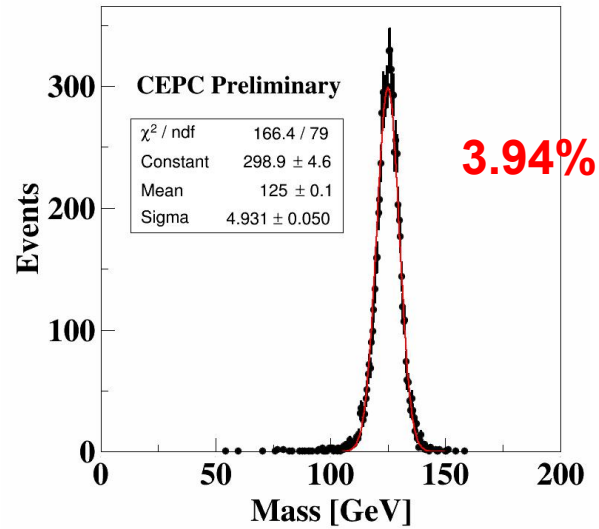
thicker sensor can compensate photon energy resolution



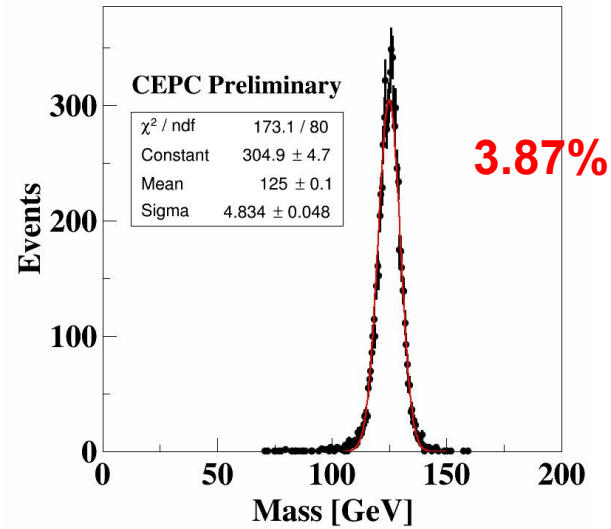
30layers 0.5mm silicon
25layers 1mm silicon
20layers 1.5mm silicon

CEPC Detector Model Results

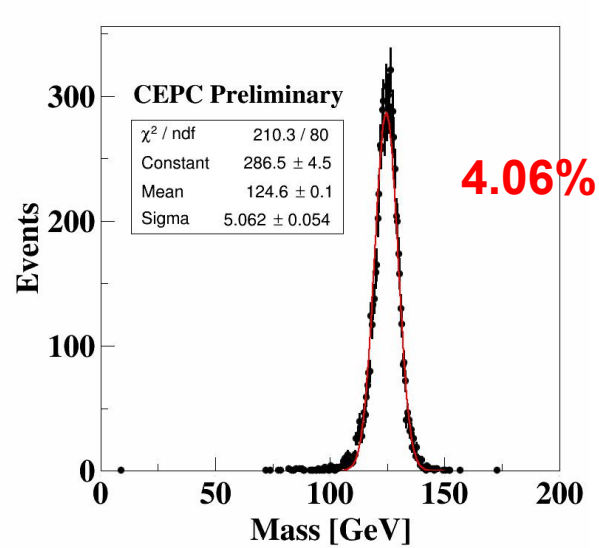
vvHiggs->gluon gluon



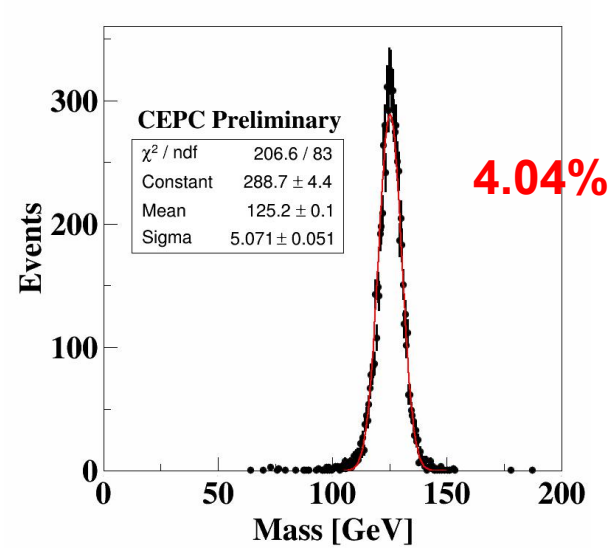
0.5mmSi, 30Layers



1mmSi,30Layers



1mmSi,20Layers



1.5mmSi,20Layers

Summary

- Dedicated Software tools has been established, for detailed optimization studies

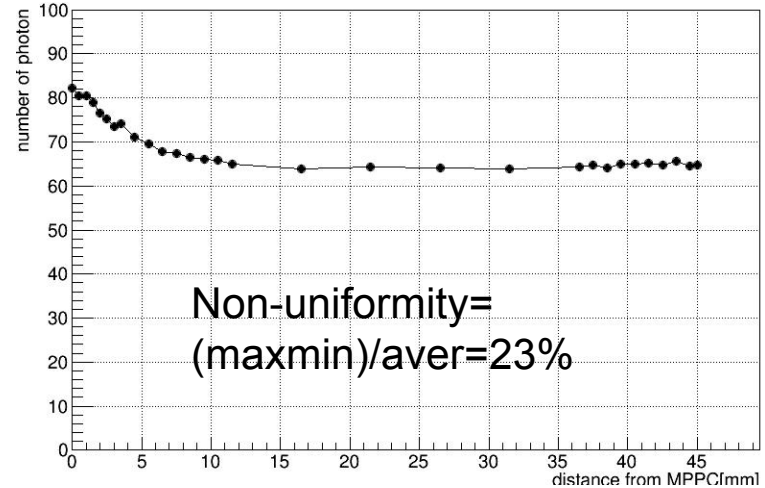
- Recommended ECAL Geometry for CEPC
  - ~10mm*10mm or smaller cell size is needed for EM shower seperation in tau jets.
  - Total Tungsten thickness should be 80-90mm.
  - <30 layers is feasible, if thicker sensor can be used to conpensate photon energy resolution loss.

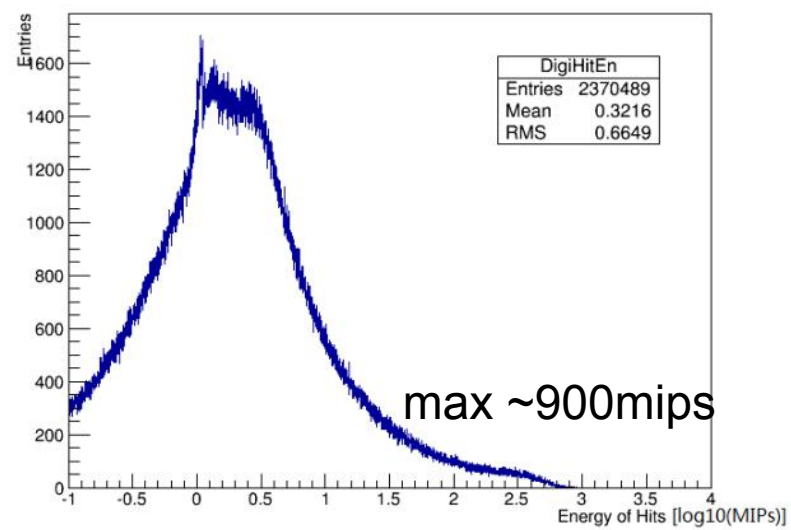
Next

- Reconstruction optimization at different geometries

- Development & Validation of Digitization algorithms, Proper modelling of detector response

- Clarify the physics requirements to the sub-detectors & recommed optimize designes to the sub-detector studies

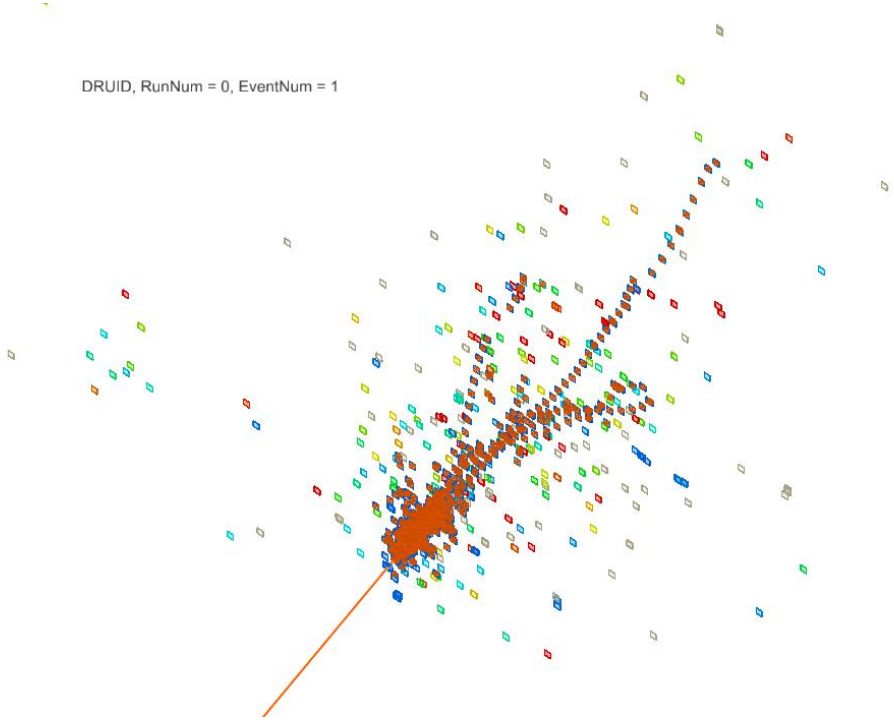




vvHiggs->γγ Events
5mm*45mm*2mm
plastic scintillator cell

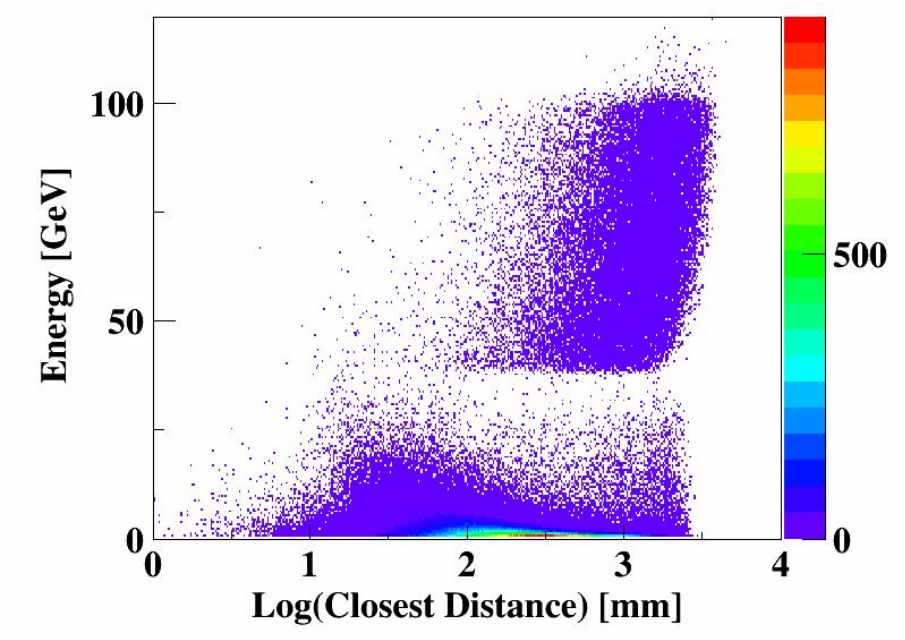
Back Up

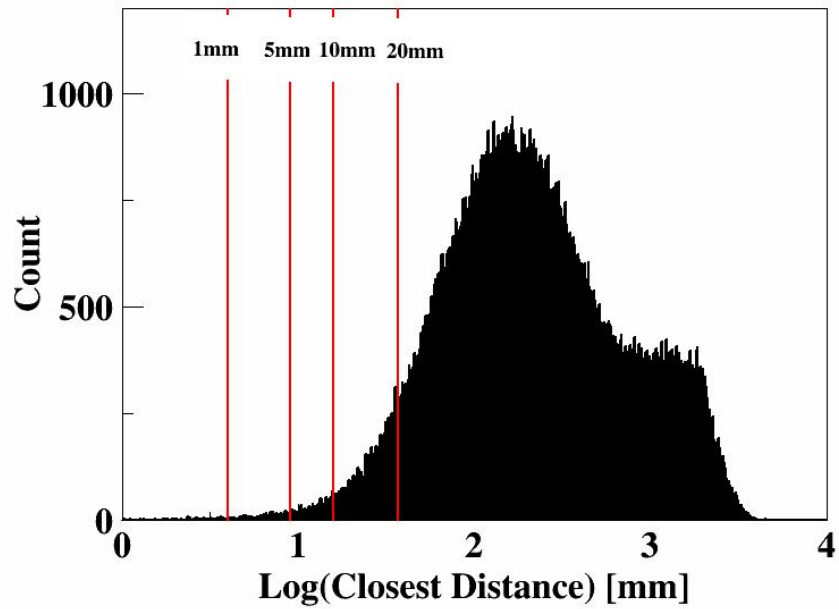
Photon Reconstruction by ArborPFA



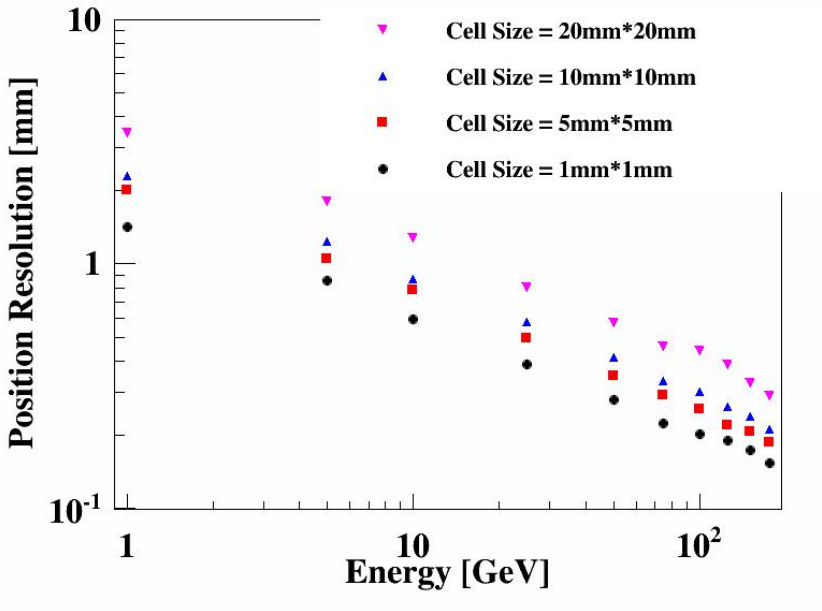
Nearby Photon Showers in Physics Objects

qq H->γγ

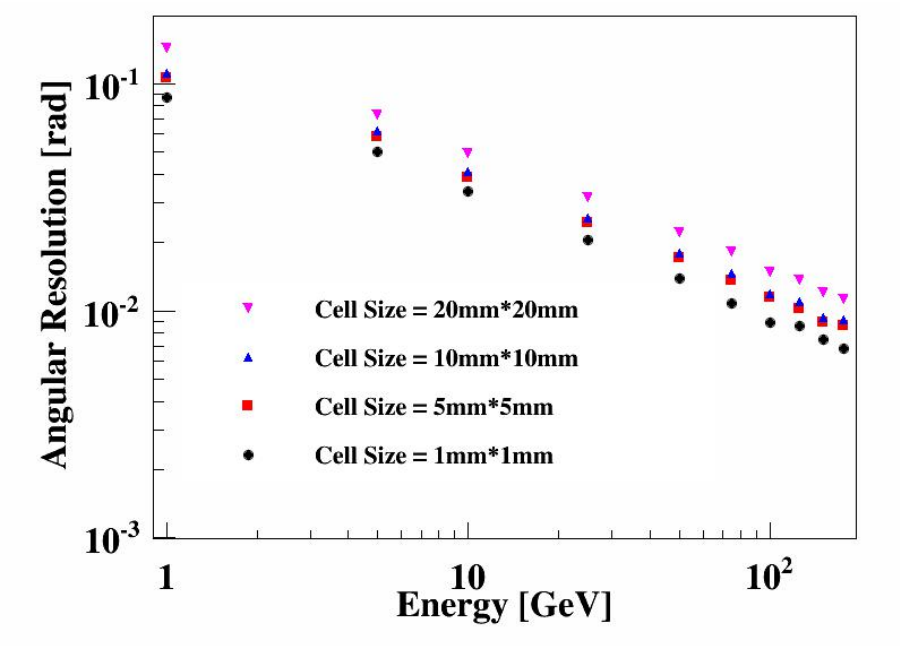




Photon Spatial Resolution

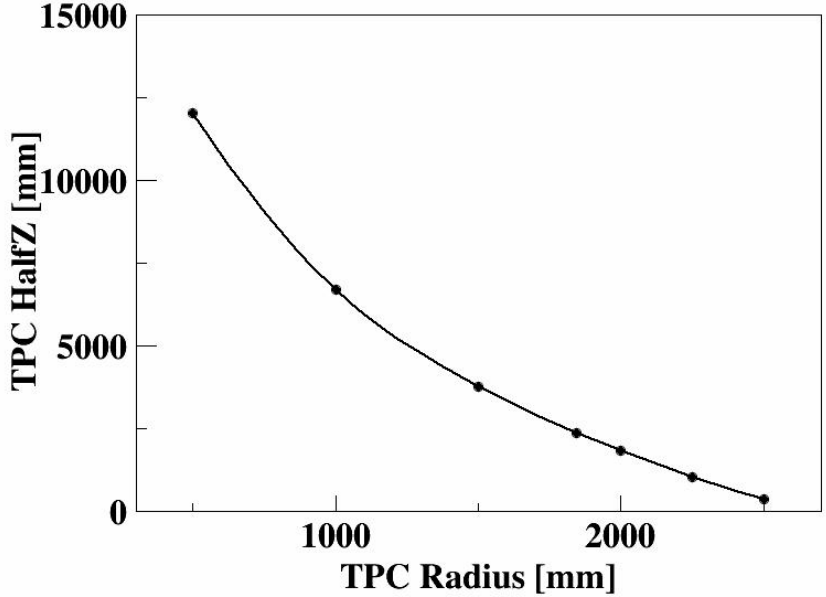


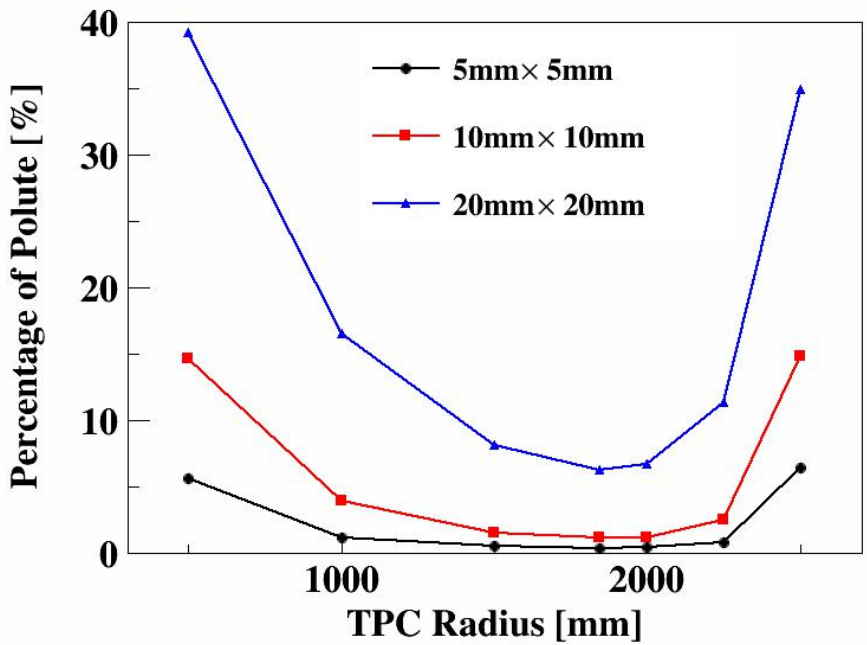
Position Resolution



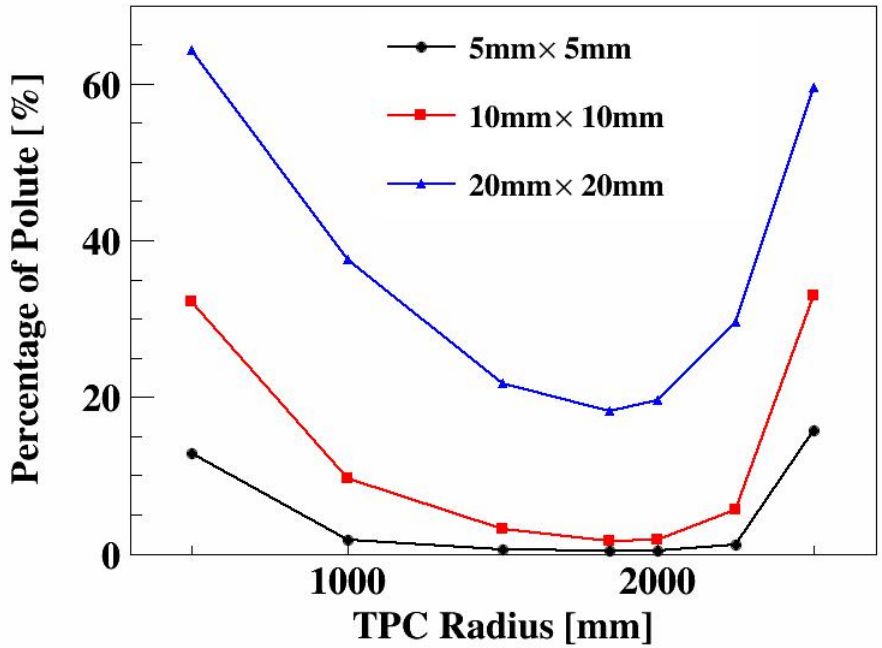
Angular Resolution

ECAL R-Z



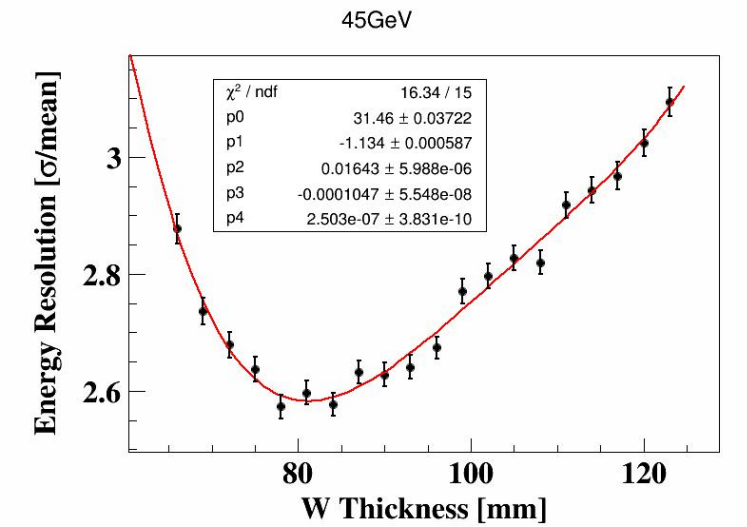


qq H->γγ

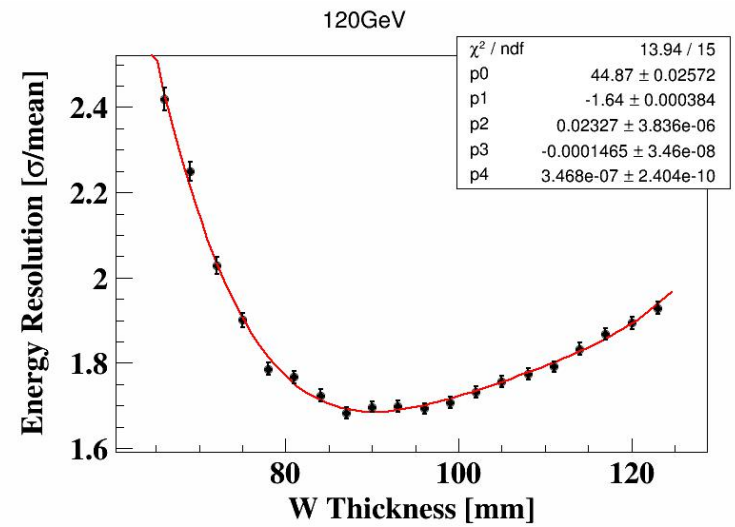


Z->tau tau

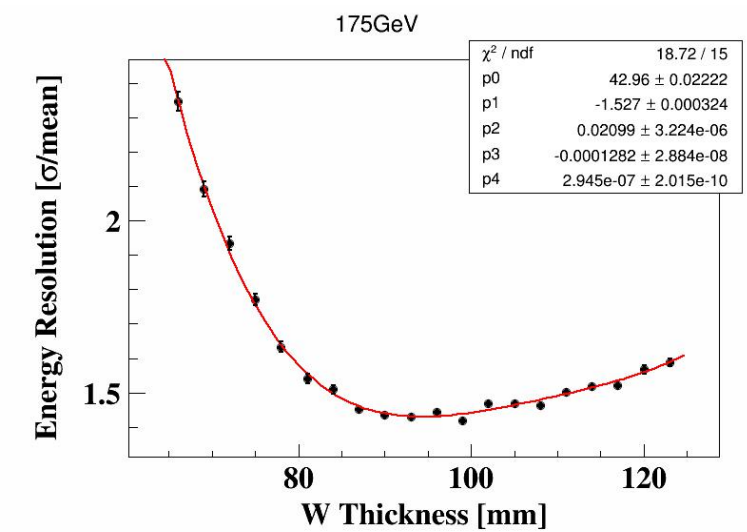
Phton energy resolution with different absorber thickness



45GeV



120GeV



175GeV