Photons study

CEPC Physics Performance Wednesday Working Meeting

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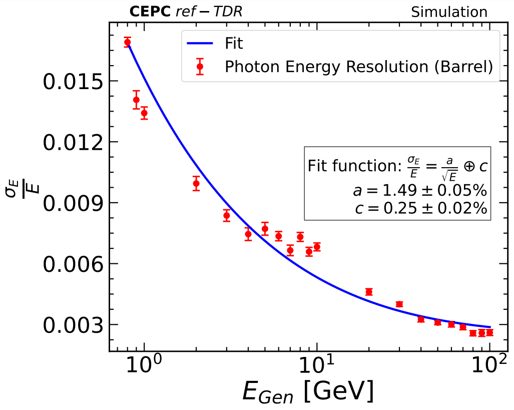
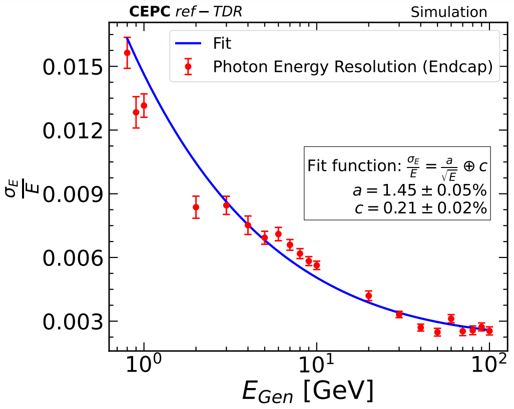
Energy Resolution relative to E_{gen}^{γ}: Barrel v. Endcap

In the barrel:



In the endcap:



Few discrepancies for points not fitted well due to the gaps impact (dead material alongside both θ and Φ)

Endcap results similar to barrel: only γ entering ECAL after shower used for fitting, resolution not related to amount of material in front of the Endcap.

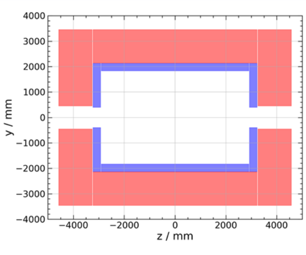
Reconstruction efficiency relative to E^{γ}_{gen}: Corrected

Corrected formula for calculating reconstruction efficiency (only accounting unconverted γ-still working on converted photons)

Previous formula: $Efficiency = \frac{Non-zero\ leading\ energy\ PFO\ in\ each\ event}{All\ truth\ particles(photons)}$,

New formula: $Efficiency = \frac{Leading\ energy\ PFO\ in\ same\ event\ as\ truth\ particle\ considered}{All\ truth\ particles(photons)\ in\ barrel\ or\ endcap}$

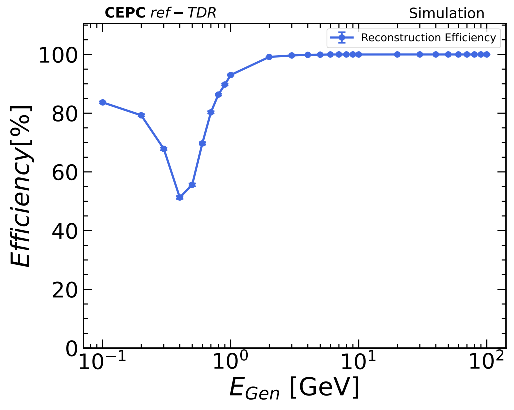
All truth particles in barrel or endcap region defined by this condition:
R > 1830mm(barrel) or |z|>2930mm(endcap)



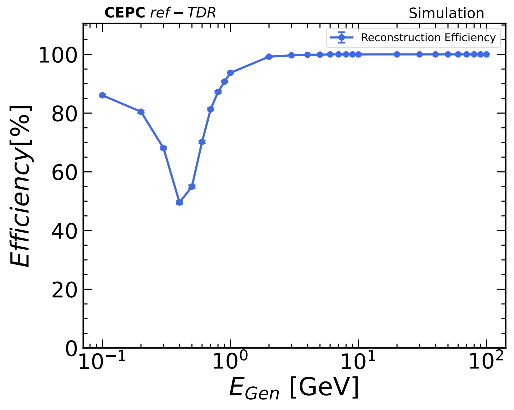

```
// Check if photon is unconverted
bool isUnconverted = !(std::hypot(Truth_EPx[truthPhotonIdx], Truth_EPy[truthPhotonIdx]) < 1830 &&
                      Truth_EPz[truthPhotonIdx] < 2930 && Truth_EPz[truthPhotonIdx] > -2930);
```

Reconstruction efficiency relative to E^{γ}_{gen}:Corrected

Previously:

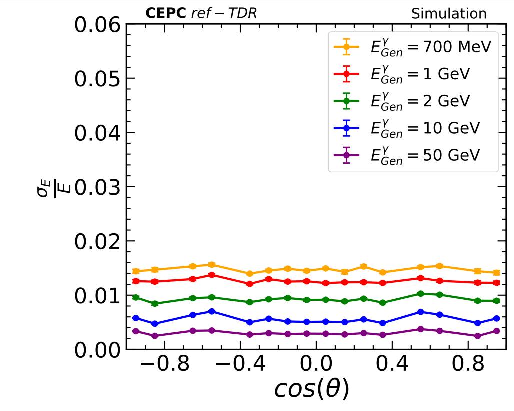


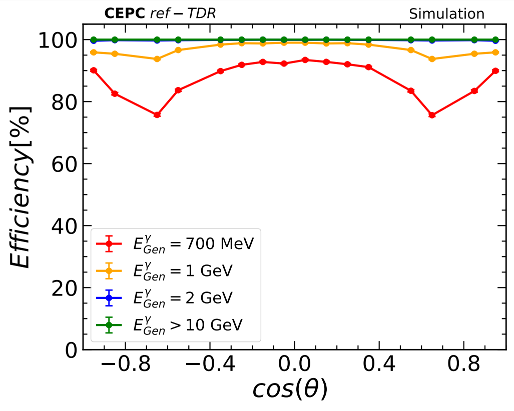
After correction



No big change (few percents) at low energies

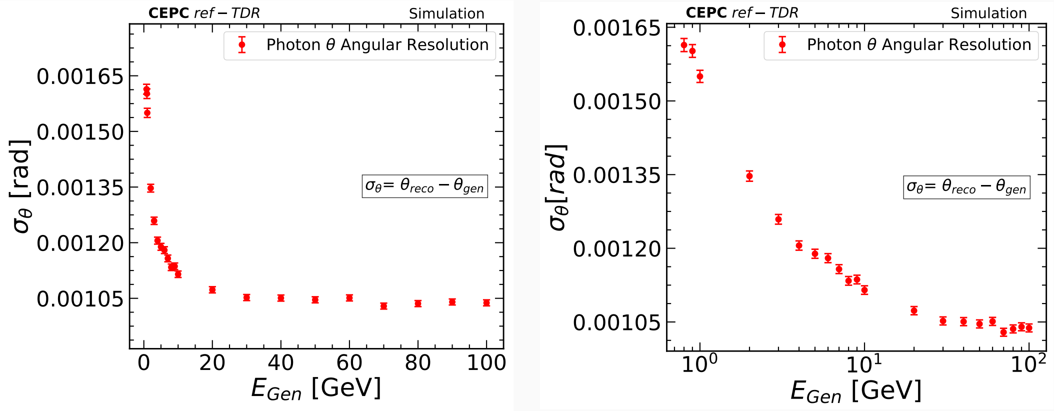
Energy Resolution & Reconstruction efficiency relative to $cos(\theta)$





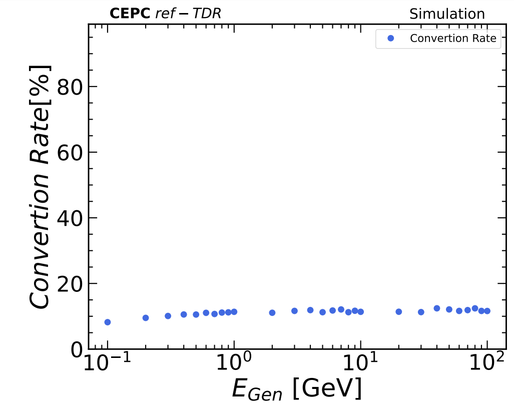
Added curves for energies (2 GeV, 700 MeV)

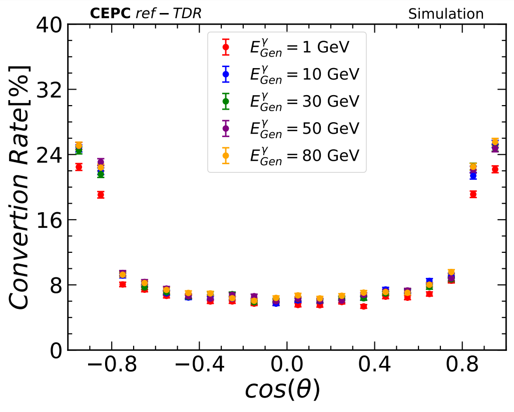
θ Angular Resolution relative to E^{γ}_{gen}



Photon θ angular resolution almost as expected: expecting around 0.045° or 0.000785 rad (approximation from ECAL shower position reso. around 1/10*15mm = 1.5mm)

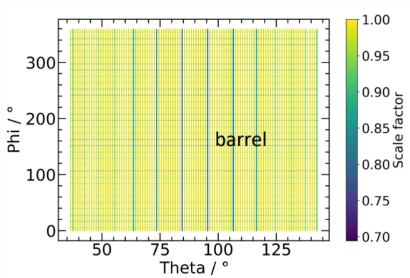
Convertion Rate relative to $cos(\theta)$

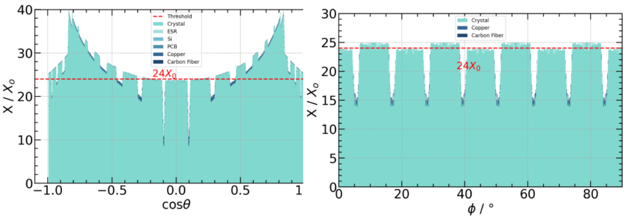




3 points in the region ($0.75<|cos(\theta|)<0.85$ = 0.775, 0.8, 0.825) to be added in order to have a clearer look at the evolution of the convertion rate: samples being generated 10k events per point to harmonize with rest of plot

Gap impact study and calibration





Gap impact study to correct energy peak of PFO to truth for different energy and angle (module boundaries)

Diphoton channel: Selection package for $q\bar{q}\gamma\gamma$ sub-channel

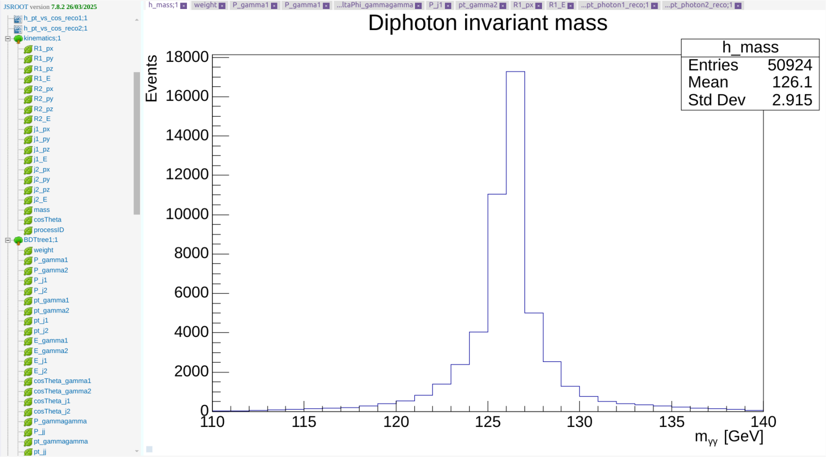
```
===== Event Selection Summary =====
Total events processed: 99800
Exclusive 2 jets and 2 photons: 80254 (80.4148%)
E_y1 > 25 GeV: 79199 (98.6854%)
35 GeV < E_y2 < 95 GeV: 70811 (89.409%)
cos(theta_yy) > -0.95: 68894 (97.2928%)
cos(theta_jj) > -0.95: 67432 (97.8779%)
pT_y1 > 20 GeV: 63573 (94.2772%)
pT_y2 > 30 GeV: 60151 (94.6172%)
110 GeV <m_yy < 140 GeV: 59062 (98.1896%)
E_yy > 120 GeV: 58850 (99.6411%)
Pass photon-jet angular cut: 50924 (86.5319%)
Final selected events:       50924 (51.0261%)
```

Table 2. Selection criteria and corresponding efficiencies in the $q\bar{q}\gamma\gamma$ channel. $\gamma1(\gamma2)$ is defined as the photon with lower (higher) energy, $\cos\theta_{\gamma\gamma}(\cos\theta_{jj})$ is the polar angle of the di-photon (di-jet) system, and $\min|\cos\theta_{\gamma j}|$ is the minimum $\cos\theta$ of the photon-jet pairs.

Selections	Higgs signal	$q\bar{q}\gamma\gamma$ background
Exclusive 2 jets and 2 photons	85.56%	69.57%
$E_{\gamma1} > 25$ GeV	100.00%	2.35 %
$E_{\gamma2} \in [35, 95]$ GeV	98.37%	35.33%
$\cos\theta_{\gamma\gamma} > -0.95$	95.20%	68.01%
$\cos\theta_{jj} > -0.95$	90.86%	85.54%
$pT_{\gamma1} > 20$ GeV	93.42%	56.94%
$pT_{\gamma2} > 30$ GeV	93.25%	54.54%
$m_{\gamma\gamma} \in [110, 140]$ GeV	97.50%	21.14%
$E_{\gamma\gamma} > 120$ GeV	99.47%	98.41%
$\min|\cos\theta_{\gamma j}| < 0.9$	71.67%	48.05%
Total eff	44.08%	0.01%
Yields in 5.6 ab^{-1}	766.64	26849.38

Efficiencies higher than previously, need cross-check with Fangyi to confirm (use different selections or maybe just better reconstruction in TDR software)

Diphoton channel: BDT trees



2 BDT trees created for training and validation (split 50-50)

Invariant mass distribution seems to need recalibration (means @ 126.1 GeV): to be fitted using DSCB after cross-check

Diphoton channel: Selection package for $\mu^+\mu^-\gamma\gamma$ sub-channel

```
===== Event Selection Summary =====
Total events processed: 10000
Exclusive 2 muons and 2 photons: 7841 (78.41%)
E_y > 35 GeV: 7768 (99.069%)
|cos(theta_y)| > < 0.9: 6693 (86.1612%)
10 GeV < pT_y1 < 70 GeV: 6655 (99.4322%)
30 GeV < pT_y2 < 100 GeV: 6579 (98.858%)
110 GeV <m_yy < 140 GeV: 6477 (98.4496%)
85 GeV < m^recoil_yy < 105 GeV: 5378 (83.0323%)
125 GeV < E_yy < 145 GeV: 5369 (99.8327%)
Final selected events:       5369 (53.69%)
```

Table 3. Selection criteria and corresponding efficiencies in the $\mu^+\mu^-\gamma\gamma$ channel. $\gamma 1(\gamma 2)$ is defined as the photon with lower (higher) energy; $M_{\gamma\gamma}^{\text{recoil}}$ is the recoil mass of the di-photon system in CEPC $\sqrt{s} = 240$ GeV : $\left(M_{\gamma\gamma}^{\text{recoil}}\right)^2 = \left(\sqrt{s} - E_{\gamma\gamma}\right)^2 - p_{\gamma\gamma}^2 = s - 2E_{\gamma\gamma}\sqrt{s} + m_{\gamma\gamma}^2$.

Selections	Higgs signal	$\mu^+\mu^-\gamma\gamma$ background
Exclusive 2 muons and 2 photons	70.18%	5.18%
$E_\gamma > 35$ GeV	99.21%	8.39%
$\lvert\cos\theta_\gamma\rvert < 0.9$	83.79%	38.14%
$pT_{\gamma 1} \in [10, 70]$ GeV	99.84%	86.30%
$pT_{\gamma 2} \in [30, 100]$ GeV	99.96%	95.59%
$m_{\gamma\gamma} \in [110, 140]$ GeV	98.08%	37.62%
$M_{\gamma\gamma}^{\text{recoil}} \in [85, 105]$ GeV	80.12%	21.29%
$E_{\gamma\gamma} \in [125, 145]$ GeV	99.88%	95.86%
Total eff	45.69%	0.01%
Yields in 5.6 ab^{-1}	39.32	2662.77

Efficiencies higher than expectations for this sub-channel as well

Diphoton channel: Selection package for $\nu\bar{\nu}\gamma\gamma$ sub-channel

```
===== Event Selection Summary =====
Total events processed: 9019
Inclusive 2 photons: 7304 (80.9846%)
E_y > 30 GeV: 7272 (99.5619%)
|cos(theta_y)| < 0.8: 5406 (74.3399%)
pT_y > 10 GeV: 5406 (100%)
M_missing > 60 GeV: 5143 (95.135%)
110 GeV < m_yy < 140 GeV: 5345 (103.928%)
125 GeV < E_yy < 145 GeV: 5117 (95.7343%)
Final selected events:      5117 (56.7358%)
```

Table 4. Selection criteria and corresponding efficiencies in the $\nu\bar{\nu}\gamma\gamma$ channel. M_{missing} is the missing mass calculated from the total visible objects.

Selections	Higgs signal	$\nu\bar{\nu}\gamma\gamma$ background
Inclusive 2 photons	85.51%	0.34%
$E_{\gamma\gamma} > 30$ GeV	99.81%	20.13%
$\lvert\cos\theta_\gamma\rvert < 0.8$	70.48%	11.56%
$pT_\gamma >$ GeV	99.97%	99.26%
$M_{\text{missing}} > 60$ GeV	98.17%	99.71%
$m_{\gamma\gamma} \in [110, 140]$ GeV	97.51%	22.86%
$E_{\gamma\gamma} \in [120, 150]$ GeV	99.16%	99.58%
Total eff	57.08%	0.002%
Yields in 5.6 ab^{-1}	335.89	3640.20

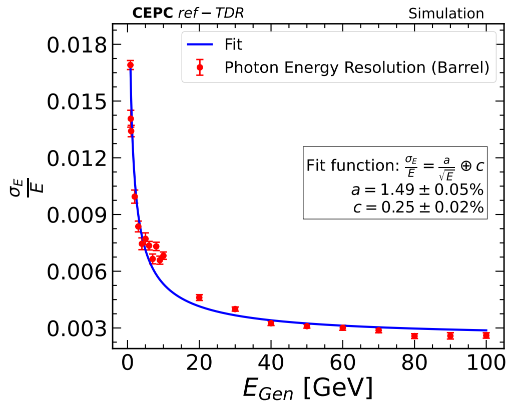
Efficiencies close to expectations, much cleaner sub-channel

Thank you!

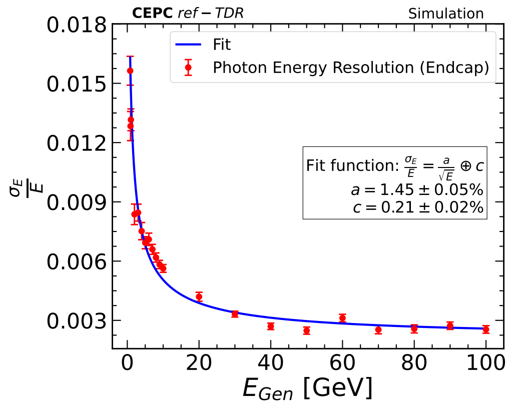
Back-up

Back-up

In the barrel:

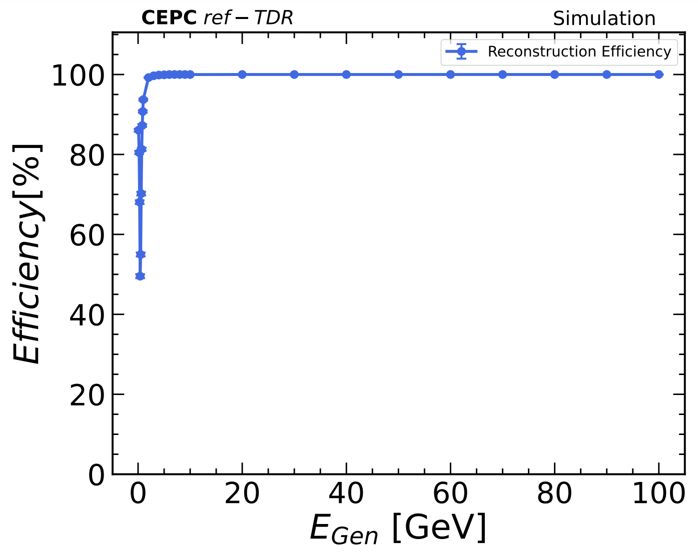


In the endcap:



Linear axis plots

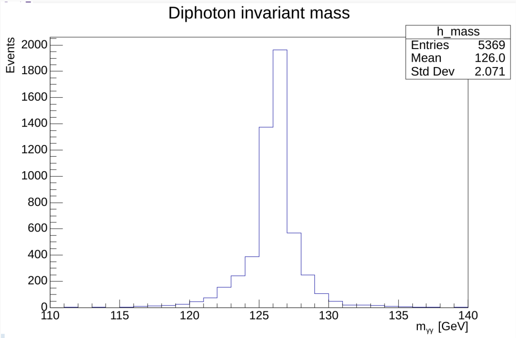
Back-up



CEPC *ref − TDR*
Simulation
Reconstruction Efficiency
100
80
60
40
20
0
0
20
40
60
80
100
Efficiency[%]
E_{Gen} [GeV]

Back-up

$\mu^+\mu^-\gamma\gamma$ sub-channel:



$m_{\gamma\gamma}$ distribution histograms before fitting

$\nu\bar{\nu}\gamma\gamma$ sub-channel