

# $Z \rightarrow \tau\tau$ . Reconstruction and preliminary tau polarization studies at FCCee. ILD vs CLD



ILD meeting at CERN 15-09-2026

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Project PID2024-158190NB-C22  
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# Introduction

CLD and ILD are detectors designed for future colliders. ILD originally for linear colliders. For this work using the adapted FCC version.

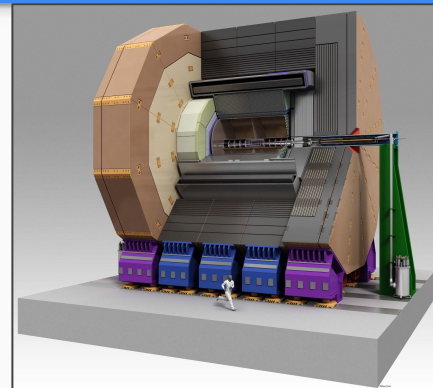
## Shared foundations:

- Same solenoid field.
- Vertex detector and LumiCal identical.
- Nearly identical HCAL.

## The main difference, the tracker:

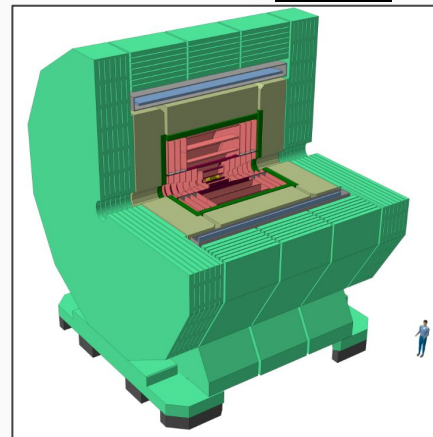
- CLD -> Silicon tracker.
- ILD -> TPC-based tracker. IT adapted from CLD. Silicon Inner Tracker and External Tracker.
- Some differences in ECAL granularity and distribution.

Same detection concept (precision vertexing + PFA calorimetry) but two tracking approaches: silicon (CLD) vs gaseous tracking (ILD).



ILD schematic view

Behnke, T. et al. (2013). ILC Technical Design Report, Volume 4: Detectors. International Linear Collider.



CLD schematic view

Bacchetta, Nicola et al - arXiv:1911.12230LCD-Note-2019-001

# Methodology

## Generation:

- Pythia 8.3, sqrt(s) 91.188 GeV, FCCee winter 2023 configuration
- Geant4: FTFP\_BERT (CLD) / QGSP\_BERT(ILD); range cut 0.7 / 0.1 mm
- **CLD\_o2\_v06** / **ILD\_FCCee\_v01** geometry.

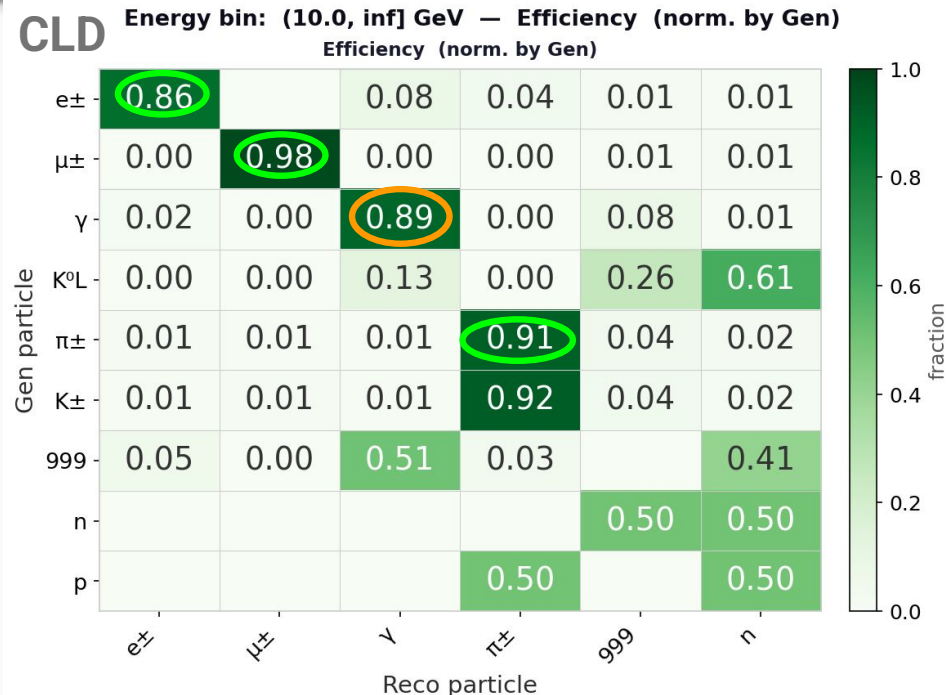
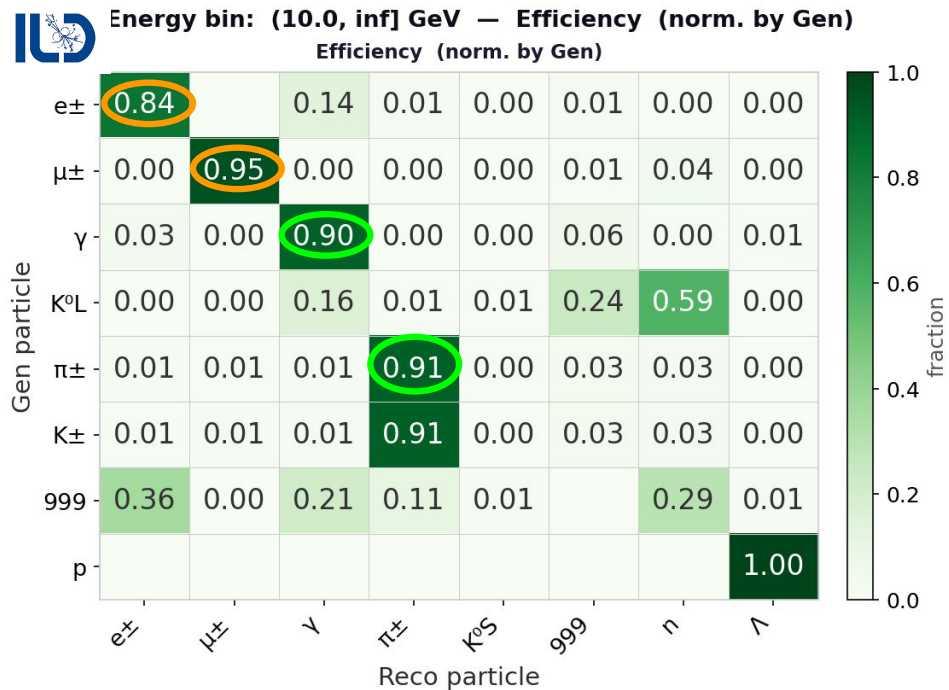
## Reconstruction: PandoraPFA.

Evaluation of the reconstruction, figures of merit:

- **Matching method** -> closest with  $dR < 0.1$  rad (no Truth-Reco link in ILD@FCC).
- **Efficiency** -> all reco particle matched divided by n gen (per particle and energy bin)
- **Purity** -> for “fakes” (reco fakes), using reco energy for binning.

**Tested on 2M events  $e^+e^- \rightarrow Z \rightarrow \tau^+\tau^-$  FullSim (~1.5M for ILD)**

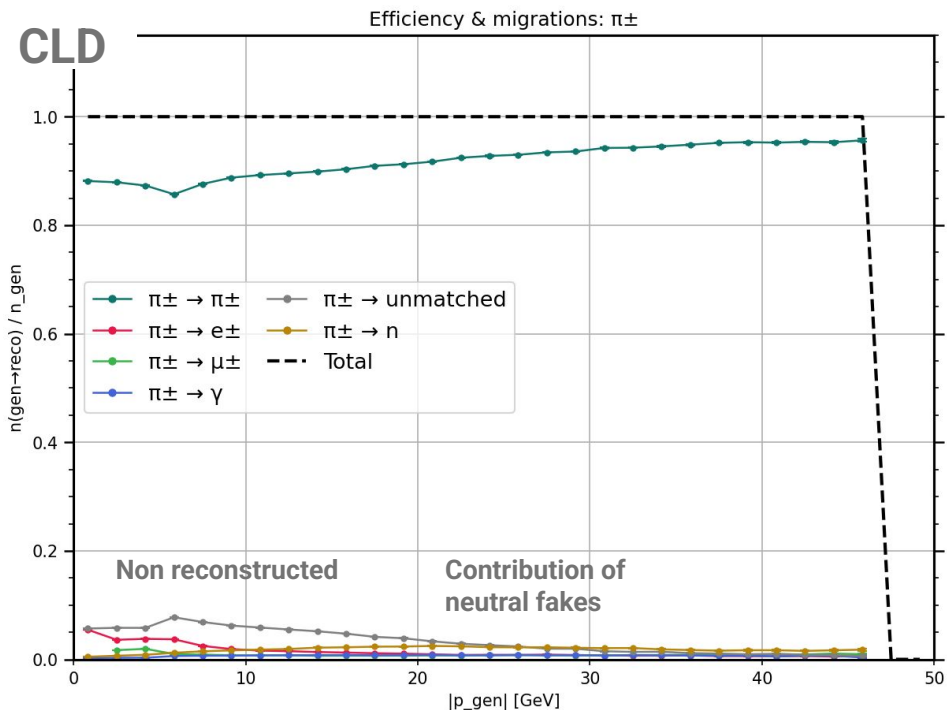
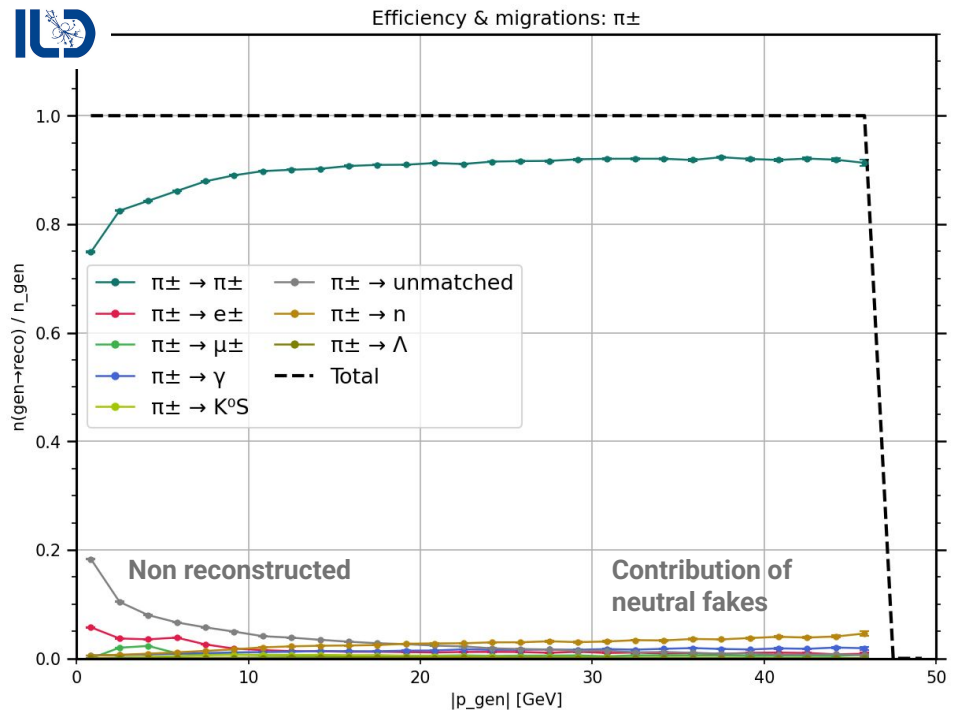
# Overall Efficiency (>10GeV)



General efficiency, with a cut in gen energy of 10GeV (to avoid low energy effects):

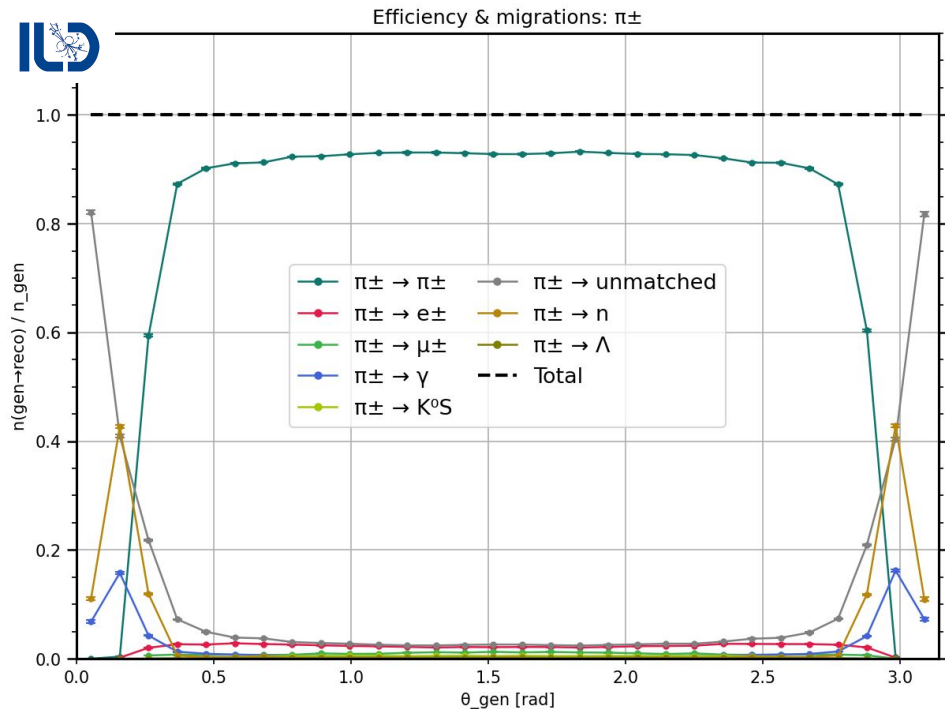
→ **ILD and CLD are equal in terms of efficiency.** Worse case for both detectors are electrons, with <90% eff.

# Pion efficiency by $P_{\text{gen}}$

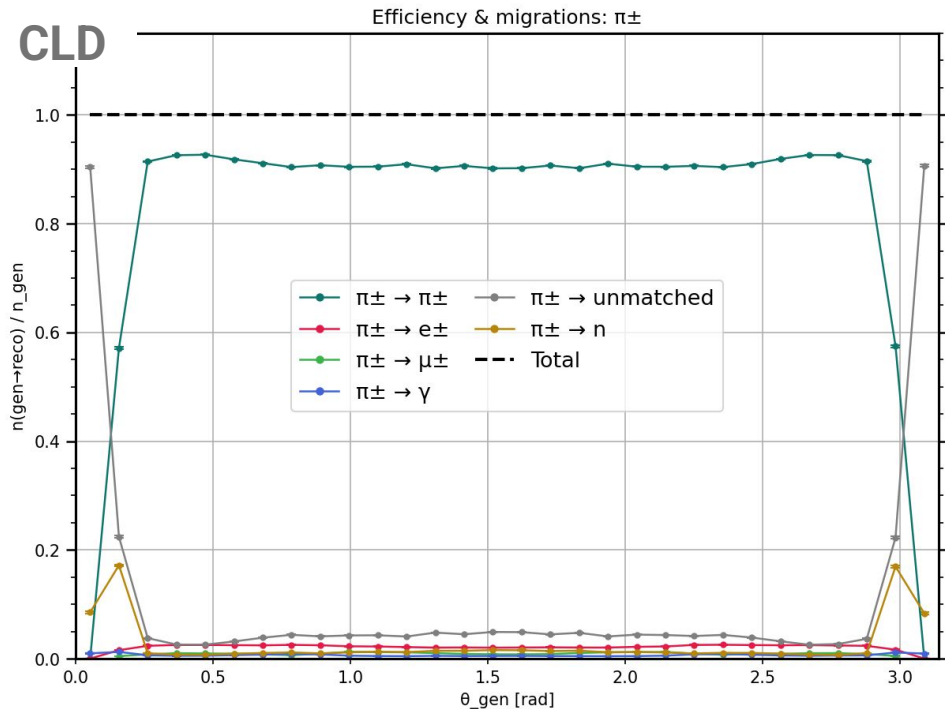


ILD presents a more stable tendency, while CLD achieved a higher efficiency in high P. **Principal degradation sources for both detectors are missing and neutral fakes.** This degradation is mainly in low momentum range (<10GeV ILD and <20GeV CLD).

# Pion efficiency by $\theta_{\text{gen}}$



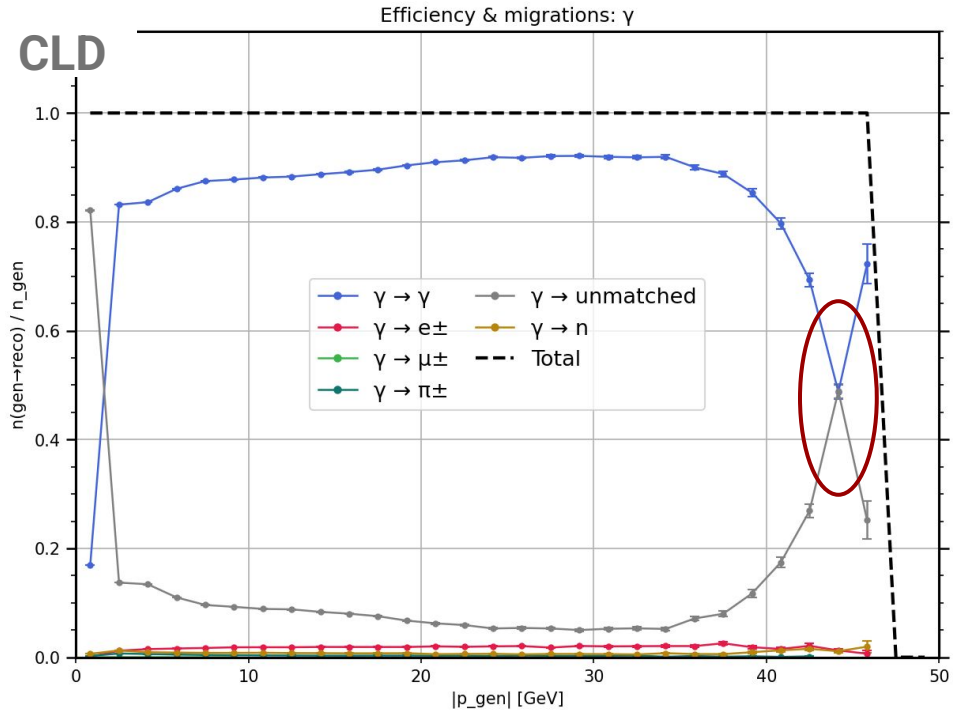
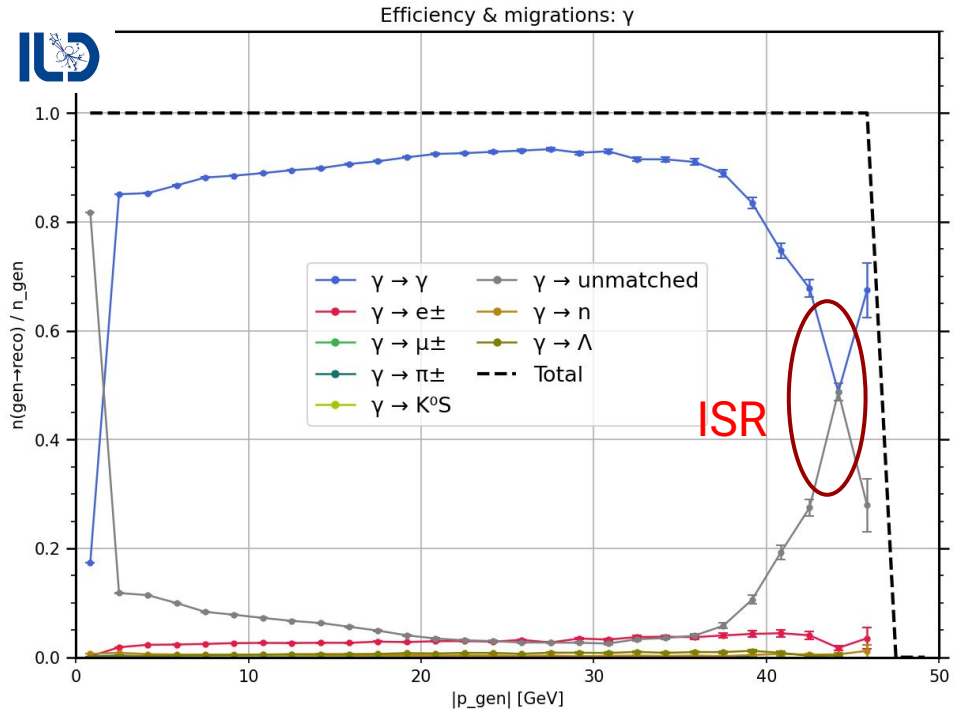
CLD



Reconstruction dependence on theta shows edge effect, and a slightly decrease in efficiency in the central part of the detector for CLD.

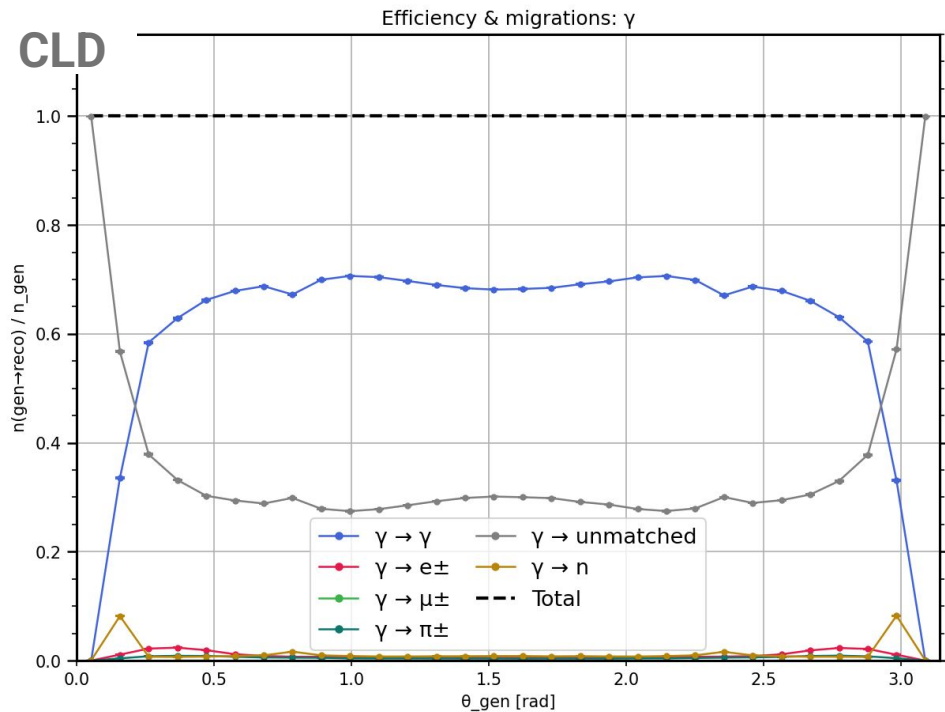
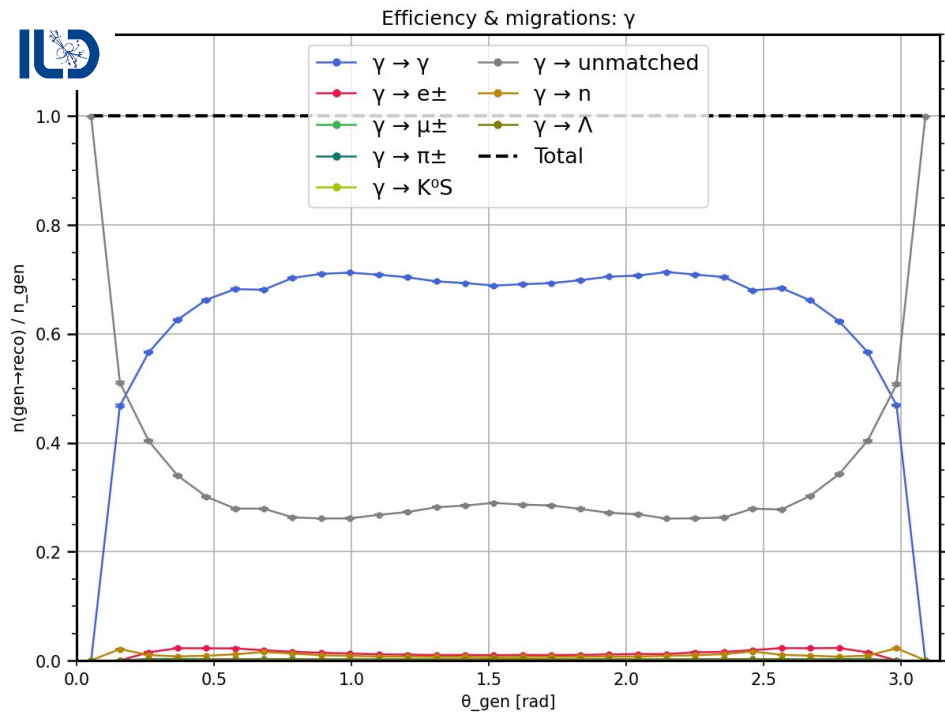
➔ Confusion with neutrals dominate the edges in ILD. For CLD, it's distributed across the whole range.

# Photon efficiency by $P_{\text{gen}}$



→ Both detector show same behaviour (non reconstructed photons as main source of eff. loss).  
While ILD next confusion source are electrons, in CLD is distributed among fake neutral and electrons.

# Photon efficiency by $\theta_{\text{gen}}$



Same behaviour. Neutral fakes are in theta extreme values.

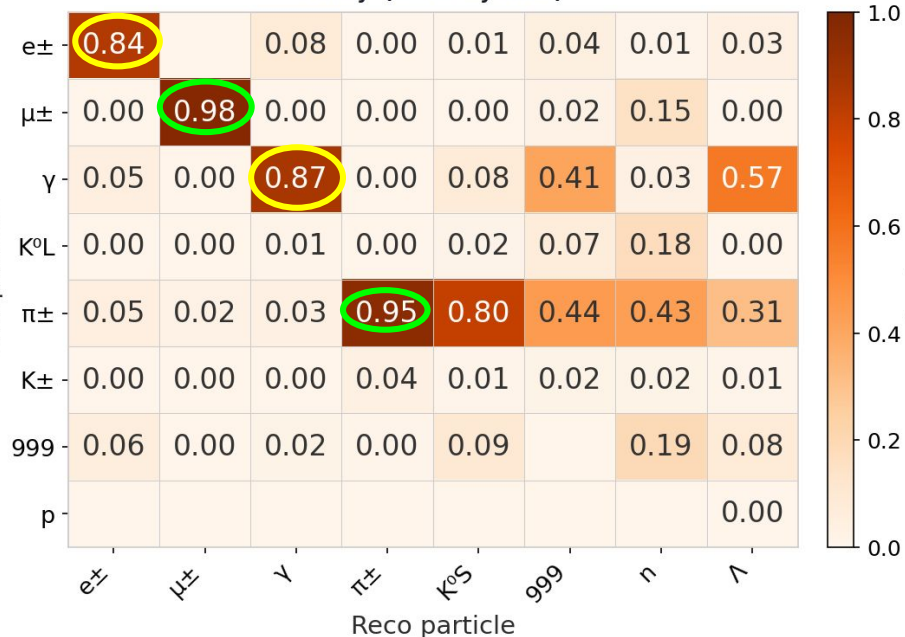
# Purity by particle type (>10GeV)



Energy bin: (10.0, inf] GeV — Purity (norm. by Reco)

Purity (norm. by Reco)

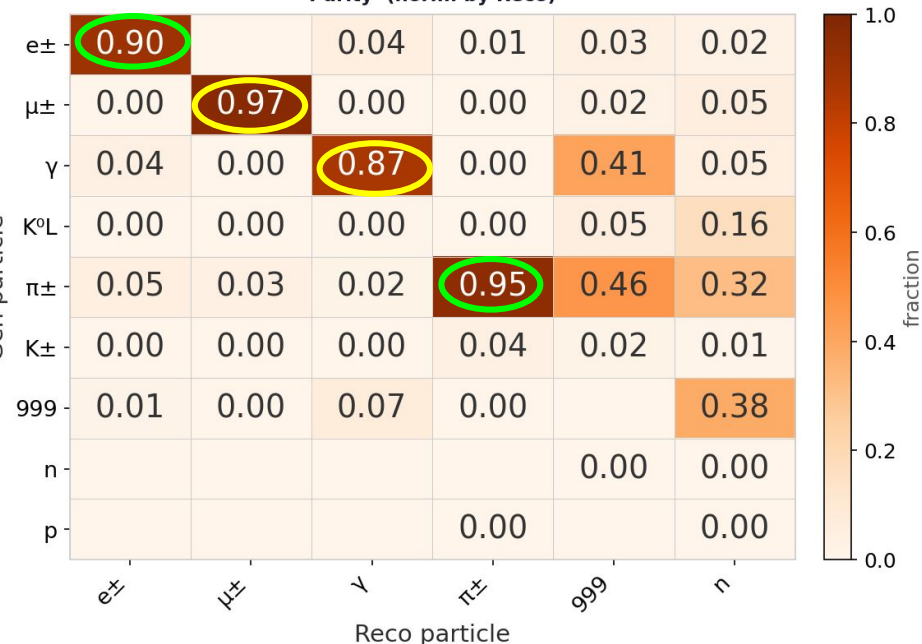
Gen particle



Energy bin: (10.0, inf] GeV — Purity (norm. by Reco)

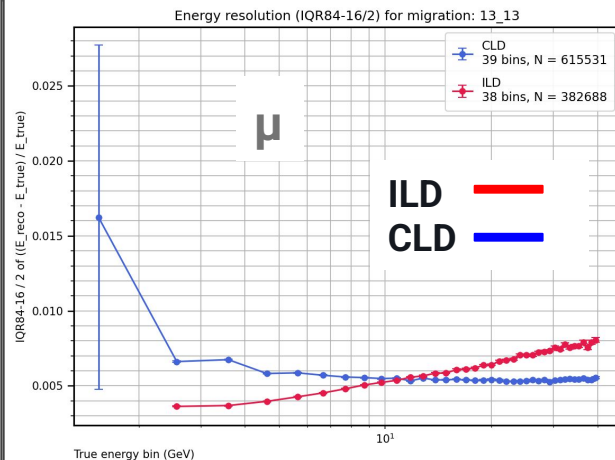
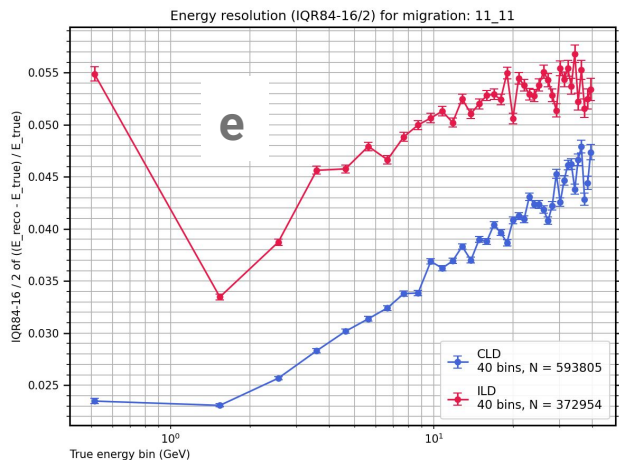
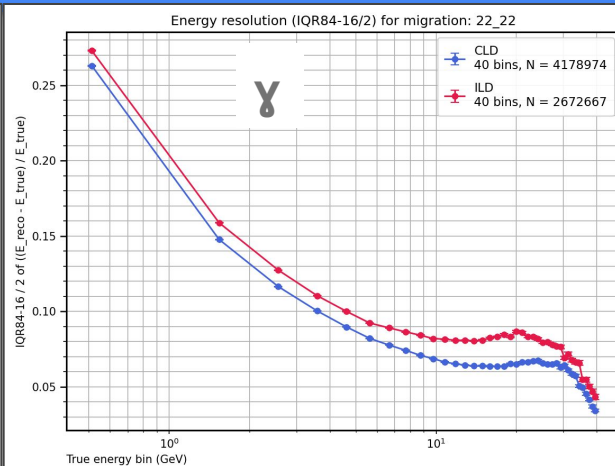
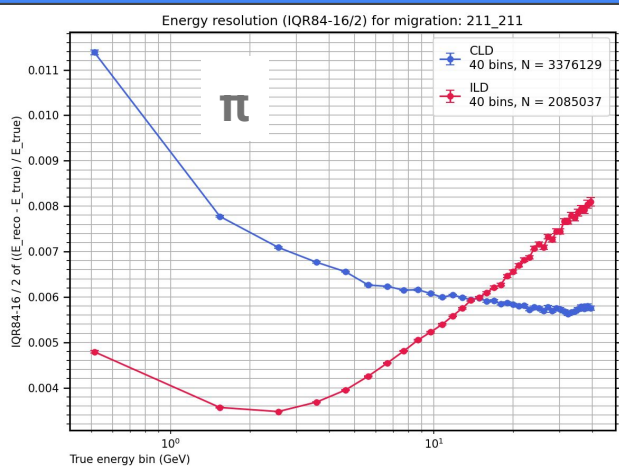
Purity (norm. by Reco)

Gen particle



ILD reconstruction show a higher rate of fakes (worse purity) with electrons (84% vs 90% with CLD). The rest of the particles have similar purities.

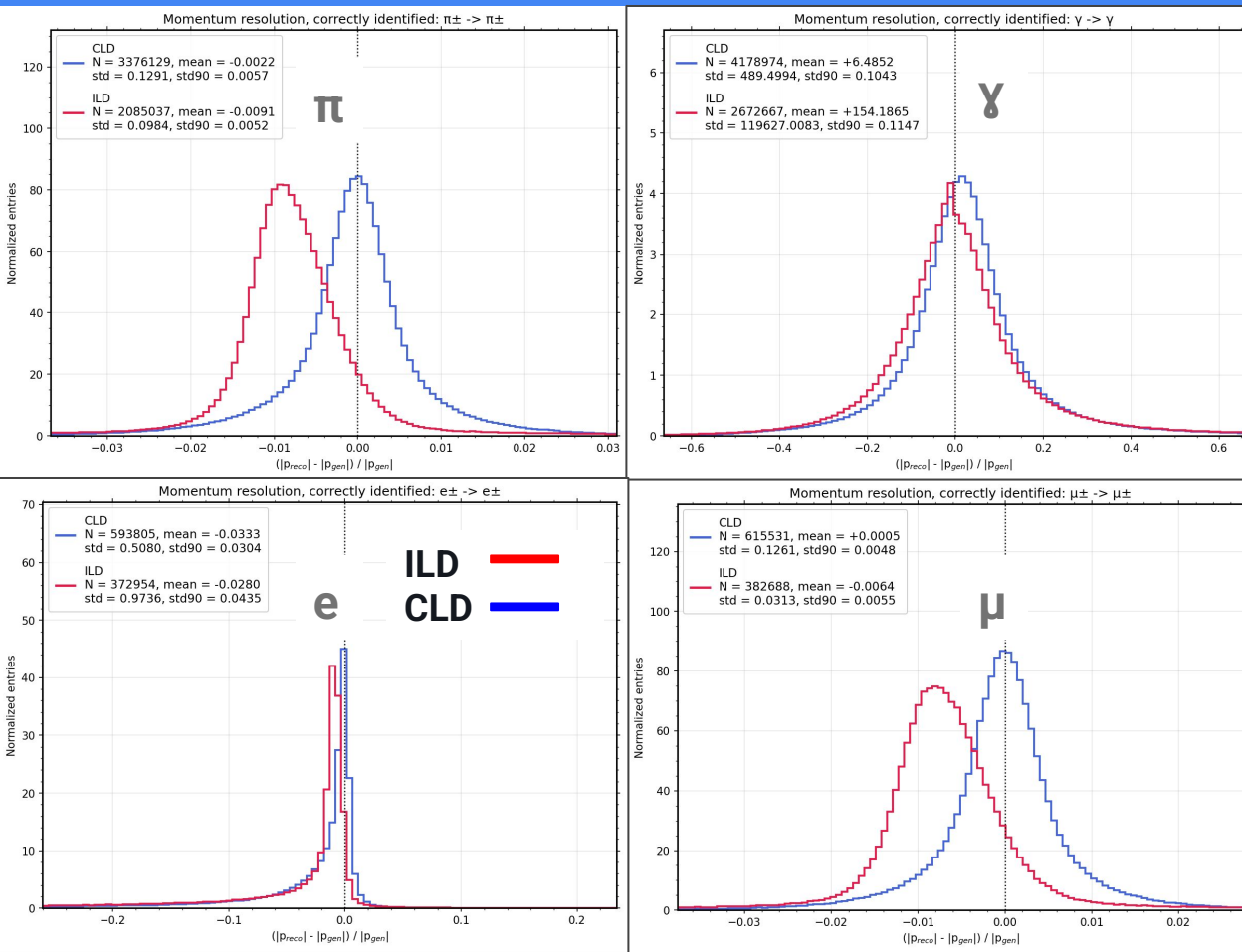
# Energy Resolution vs True Energy (Using IQR 84-16)



**Remark:** ILD tracking algorithm is not yet optimized for FCC-ee, so it's normal to have discrepancies with charged particles.

→ CLD shows a better resolution in general, except for low energy pions ( $P < 10$  GeV) where ILD presents better results.

# Overall momentum resolution distribution



In general, **ILD** shows displaced distribution (underestimation) in momentum resolution, specially for pions and muons.

Electron resolution present a x10 spread compared to pions and muons. Need to look in depth.

*Again, remark the non final status of the track fitting algorithm for ILD.*

# Tau Reconstruction

# Tau Reconstruction - Polarization Analysis

Based on:

- $\tau$  decays **experimental signature**.
- P4, PID & charge of reconstructed particles.

**Leptonic decays:**

- if  $\mu \Rightarrow \tau \rightarrow \mu \nu \nu$
- If  $e \Rightarrow \tau \rightarrow e \nu \nu$

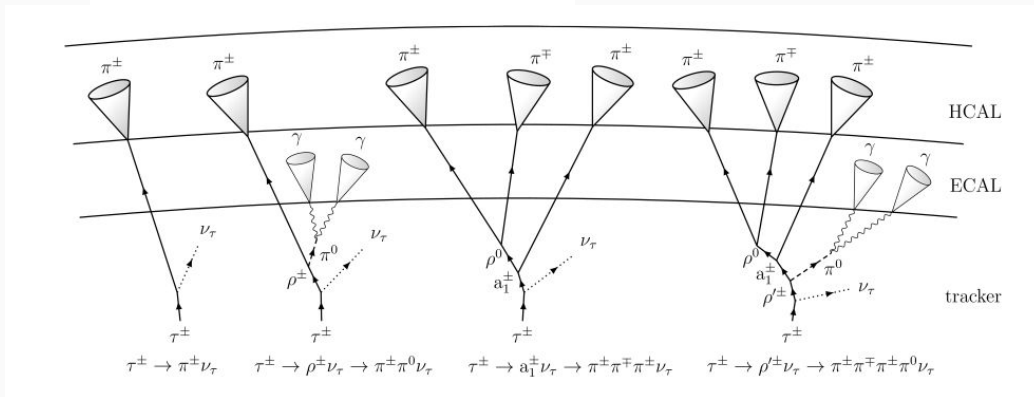
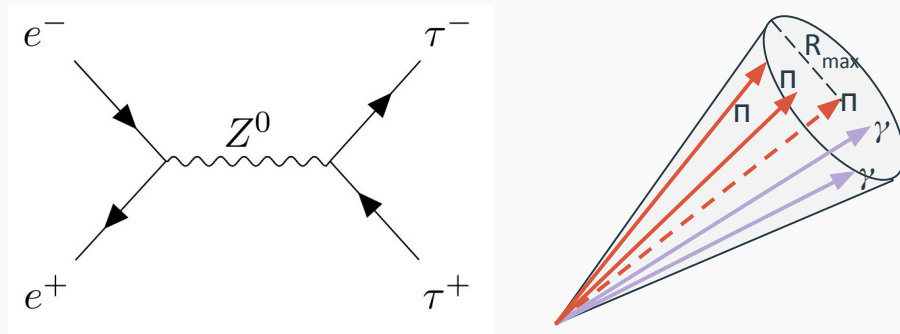
**Hadronic decays** (using  $\pi^\pm$  as seed):

- Single  $\pi^\pm \Rightarrow \tau \rightarrow \pi \nu$
- $\pi^\pm + \gamma \Rightarrow \tau \rightarrow \pi N \pi^0 \nu$   
( $N \approx n^0 \gamma / 2$ , rounding up)
- $3\pi^\pm \Rightarrow \tau \rightarrow \pi \pi \pi \nu$
- $3\pi^\pm + \gamma \Rightarrow \tau \rightarrow \pi \pi \pi \pi N \pi^0 \nu$

**No background (Zqq, Bhabha...).**

**No low BR decays identification.**

**Invisible energy is ignored.**

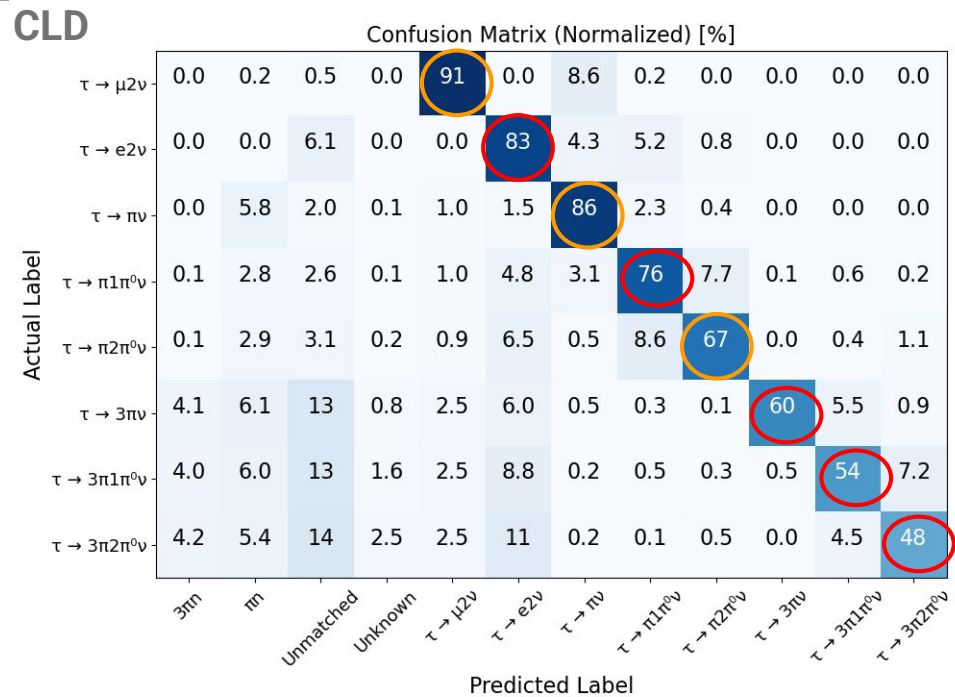
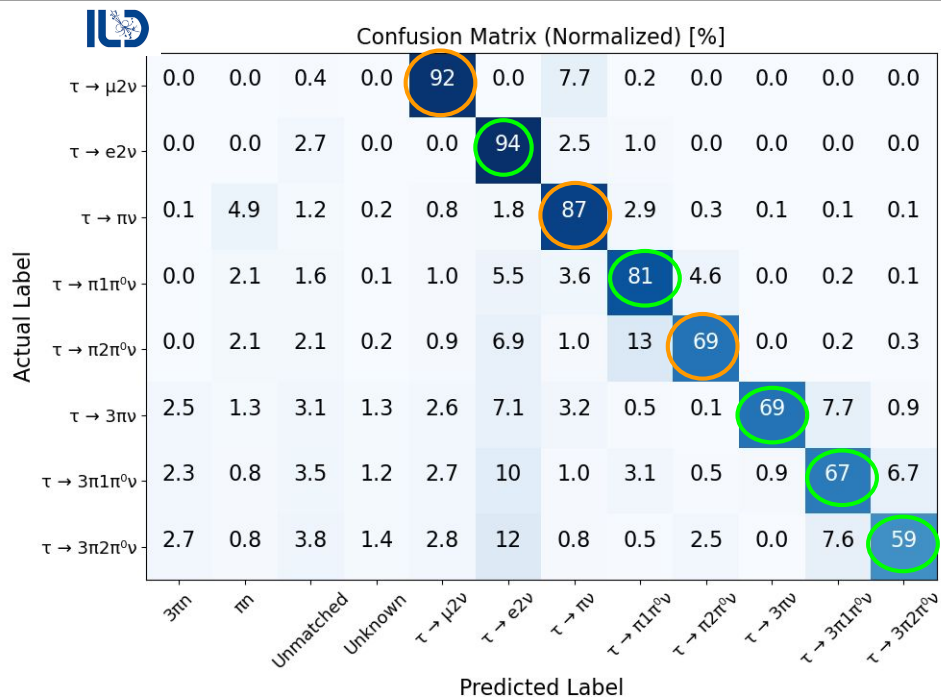


**New:** FSR correction for decay with photons (see backup).

[Github Repo](#)

**Currently, reconstruction is the main challenge ([Tau reconstruction - Laurits](#))**

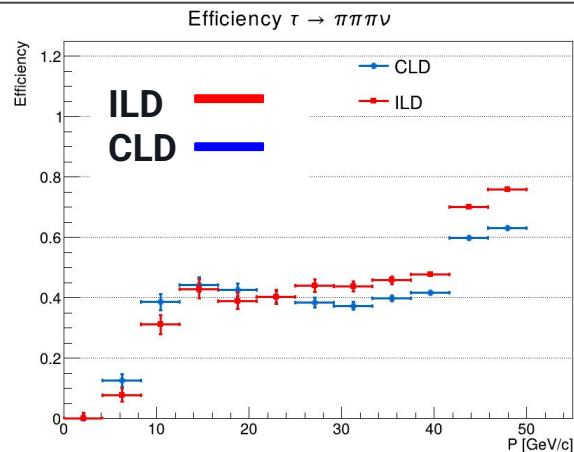
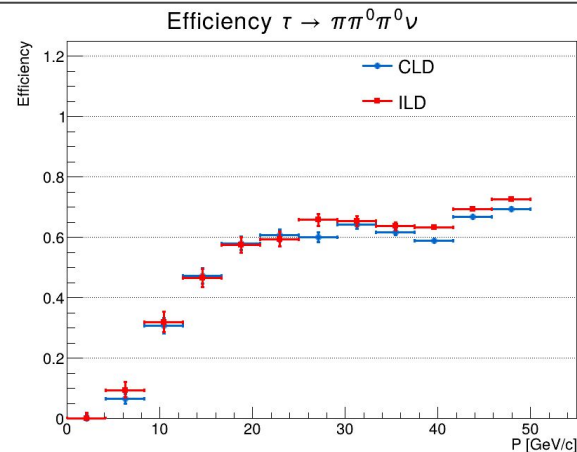
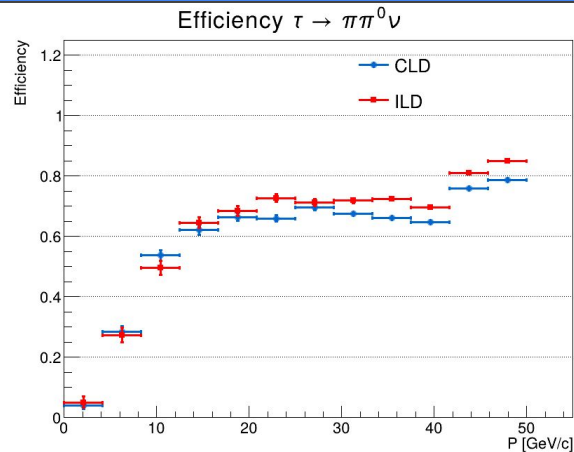
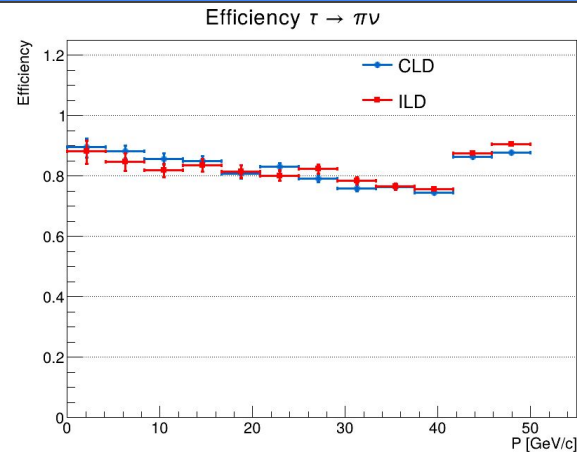
# Tau Reconstruction. Confusion matrix per decay.



→ ILD results in a **better tau reconstruction efficiency** (wo/ compromising purity, see backup).

This is particularly important in decays involving more than one charged pion.

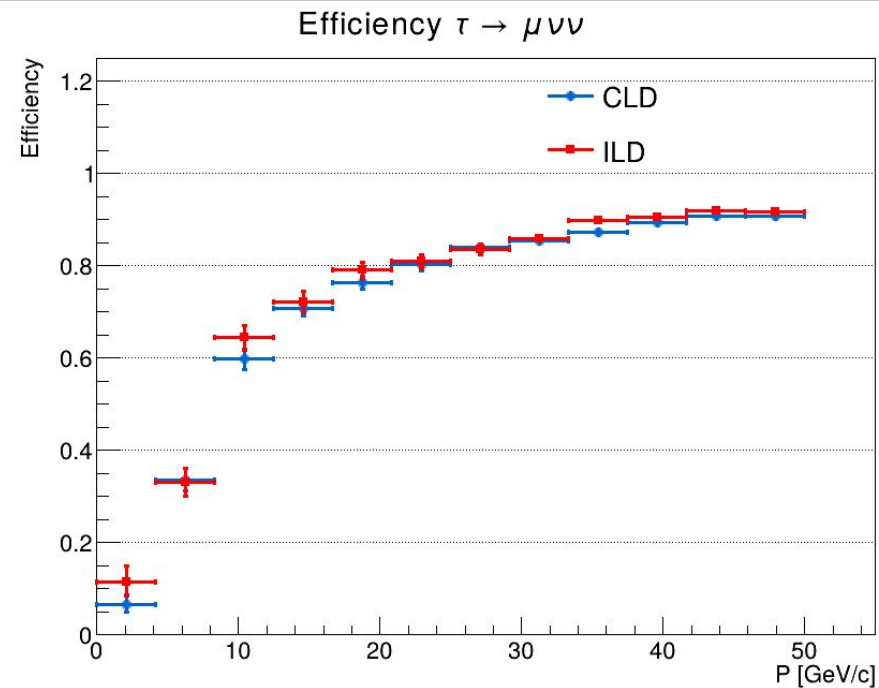
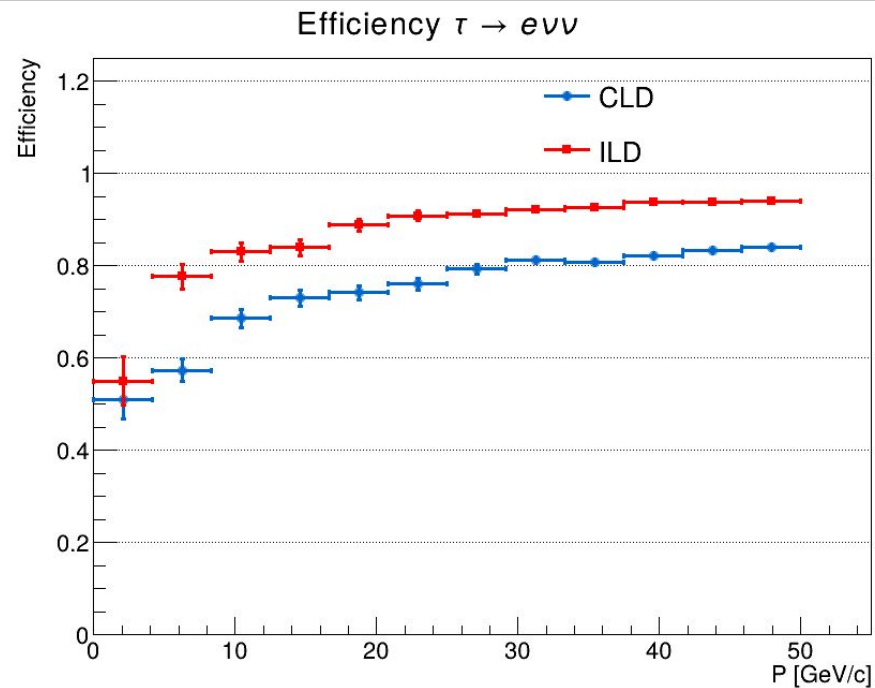
# Tau Reconstruction. Efficiency for hadronic decays



Tau efficiency is low in general for both methods (especially at low energy when photons get implied), but **ILD** gets better efficiency in rho and  $a_1$  decays.

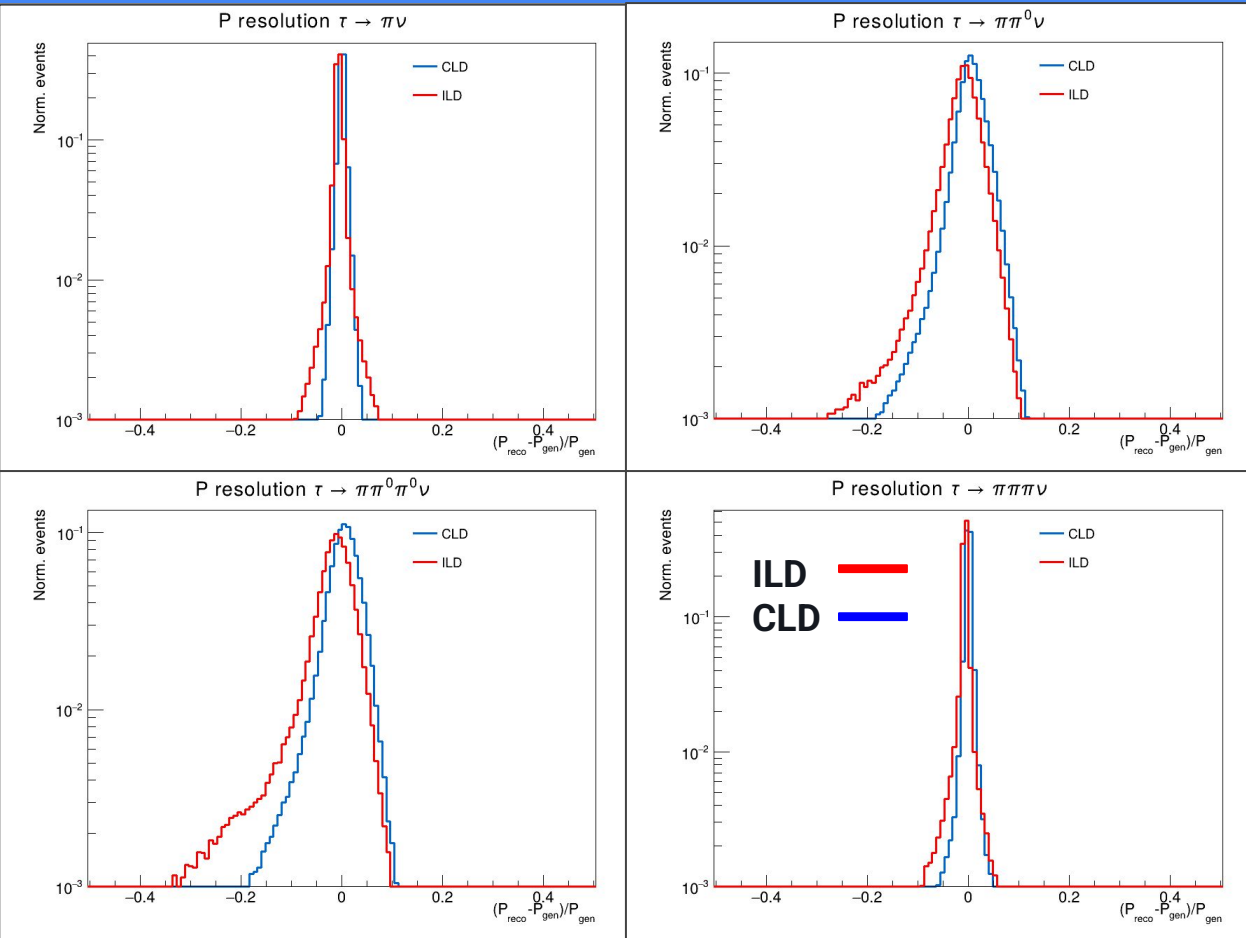
The **most sensitive case is  $a_1 \rightarrow \pi\pi\pi$** , where **ILD** clearly improves the efficiency from  $\sim 25\text{GeV}$ .

# Tau Reconstruction. Efficiency comp. for leptonic decays



For leptonic decays **ILD** improves the efficiency of electronic decay. Muon decay is similar between models.

# Tau Reconstruction - Resolution by decay



- Regarding resolution, **CLD** is better in every case (as expected from the particle level results).
- $a_1 \rightarrow \pi\pi\pi$  is the case where both detectors get similar resolution.

# Polarization

# Rho + lepton (cuts from CLD optimal fit)

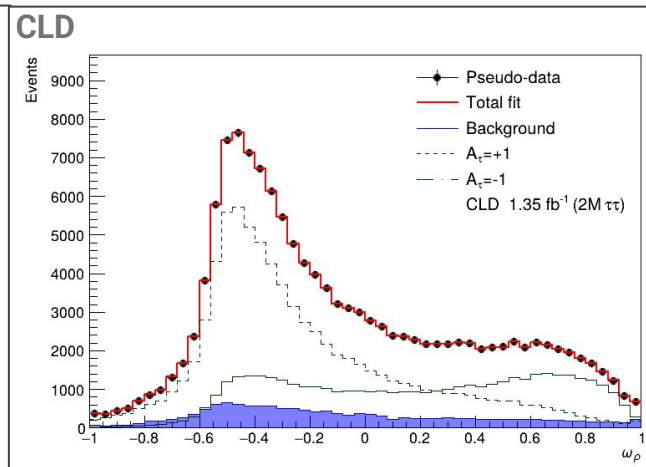
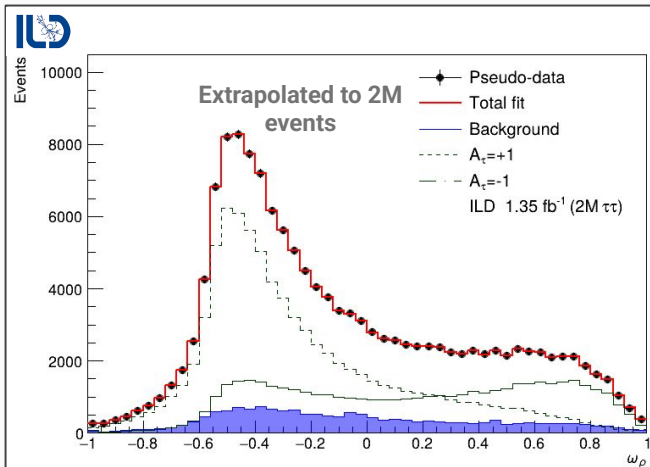
Re-weighting method using correlation between the two taus.

See this [presentation](#).

This method has been **calibrated for CLD**. Same optimal cuts are applied here to ILD.

| Cut (min-max)                      | $\rho$ channel |
|------------------------------------|----------------|
| Meson $p$ (GeV/c)                  | 2.0 – 45.57    |
| Lepton $p$ (GeV/c)                 | 10.0 – 41.16   |
| Meson-Lepton angle (rad)           | 3.06 – 5.00    |
| $\cos \theta_{\rho}^{\text{reco}}$ | <0.95          |

- Very similar results.
- Fit errors slightly larger with ILD.



| Parameter                    | Generated value | ILD                 | CLD                 | Rel. diff. error (ILD-CLD)/CLD |
|------------------------------|-----------------|---------------------|---------------------|--------------------------------|
| $\mathcal{A}_{\tau}$         | 0.14955         | $0.1495 \pm 0.0075$ | $0.1494 \pm 0.0074$ | +0.2%                          |
| $\mathcal{A}_e$              | 0.14955         | $0.1491 \pm 0.0096$ | $0.1493 \pm 0.0097$ | -0.7%                          |
| $g_V/g_A$                    | 0.07520         | $0.0749 \pm 0.0049$ | $0.0751 \pm 0.0050$ | -0.7%                          |
| $\sin^2 \theta_{\text{eff}}$ | 0.2312          | $0.2313 \pm 0.0013$ | $0.2312 \pm 0.0013$ | -0.7%                          |

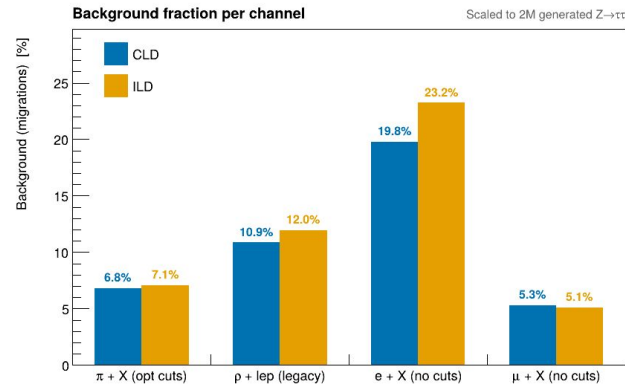
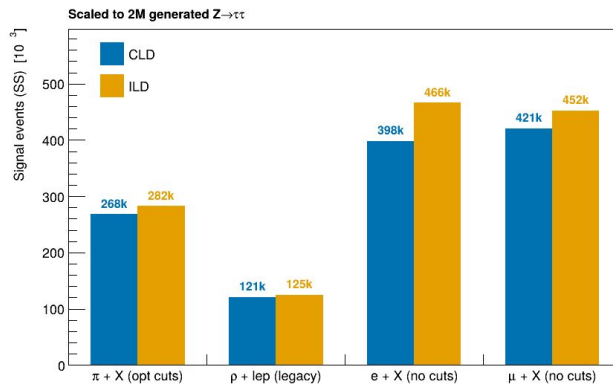
# Polarization, summary

- Different fit cases have been explored.
- For pion decay, ILD fit error is larger.
- ILD dominates error in  $\rho$ , e and  $\mu$  decays.

Except for muon channel, ILD presents a larger BG contribution, but it also recovers more signal events.

Fit error comparison (2M  $\tau$  extrapolated) —  $\sin^2\theta_{\text{eff}}$  generated = 0.2312

| Parameter                           | $\pi + X$<br>(opt. cuts)                       | $\rho + \text{lep}$<br>(legacy cuts)          | e + X<br>(no cuts)                            | $\mu + X$<br>(no cuts)                        |
|-------------------------------------|------------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| $\sigma(\mathcal{A}_\tau)$          | ILD: 0.0061<br>CLD: 0.0047                     | ILD: 0.0075<br>CLD: 0.0074                    | ILD: 0.0094<br>CLD: 0.0097                    | ILD: 0.0078<br>CLD: 0.0081                    |
|                                     | <b><math>\Delta\text{rel: } +30.8\%</math></b> | <b><math>\Delta\text{rel: } +0.2\%</math></b> | <b><math>\Delta\text{rel: } -2.4\%</math></b> | <b><math>\Delta\text{rel: } -4.2\%</math></b> |
| $\sigma(\mathcal{A}_e)$             | ILD: 0.0075<br>CLD: 0.0064                     | ILD: 0.0096<br>CLD: 0.0097                    | ILD: 0.013<br>CLD: 0.013                      | ILD: 0.011<br>CLD: 0.011                      |
|                                     | <b><math>\Delta\text{rel: } +17.7\%</math></b> | <b><math>\Delta\text{rel: } -0.7\%</math></b> | <b><math>\Delta\text{rel: } -0.7\%</math></b> | <b><math>\Delta\text{rel: } -4.3\%</math></b> |
| $\sigma(g_V/g_A)$                   | ILD: 0.0038<br>CLD: 0.0033                     | ILD: 0.0049<br>CLD: 0.0050                    | ILD: 0.0063<br>CLD: 0.0063                    | ILD: 0.0052<br>CLD: 0.0054                    |
|                                     | <b><math>\Delta\text{rel: } +17.7\%</math></b> | <b><math>\Delta\text{rel: } -0.7\%</math></b> | <b><math>\Delta\text{rel: } -0.7\%</math></b> | <b><math>\Delta\text{rel: } -4.3\%</math></b> |
| $\sigma(\sin^2\theta_{\text{eff}})$ | ILD: 0.00095<br>CLD: 0.00081                   | ILD: 0.0013<br>CLD: 0.0013                    | ILD: 0.0016<br>CLD: 0.0016                    | ILD: 0.0013<br>CLD: 0.0014                    |
|                                     | <b><math>\Delta\text{rel: } +17.7\%</math></b> | <b><math>\Delta\text{rel: } -0.7\%</math></b> | <b><math>\Delta\text{rel: } -0.8\%</math></b> | <b><math>\Delta\text{rel: } -4.3\%</math></b> |



# Conclusions and next steps

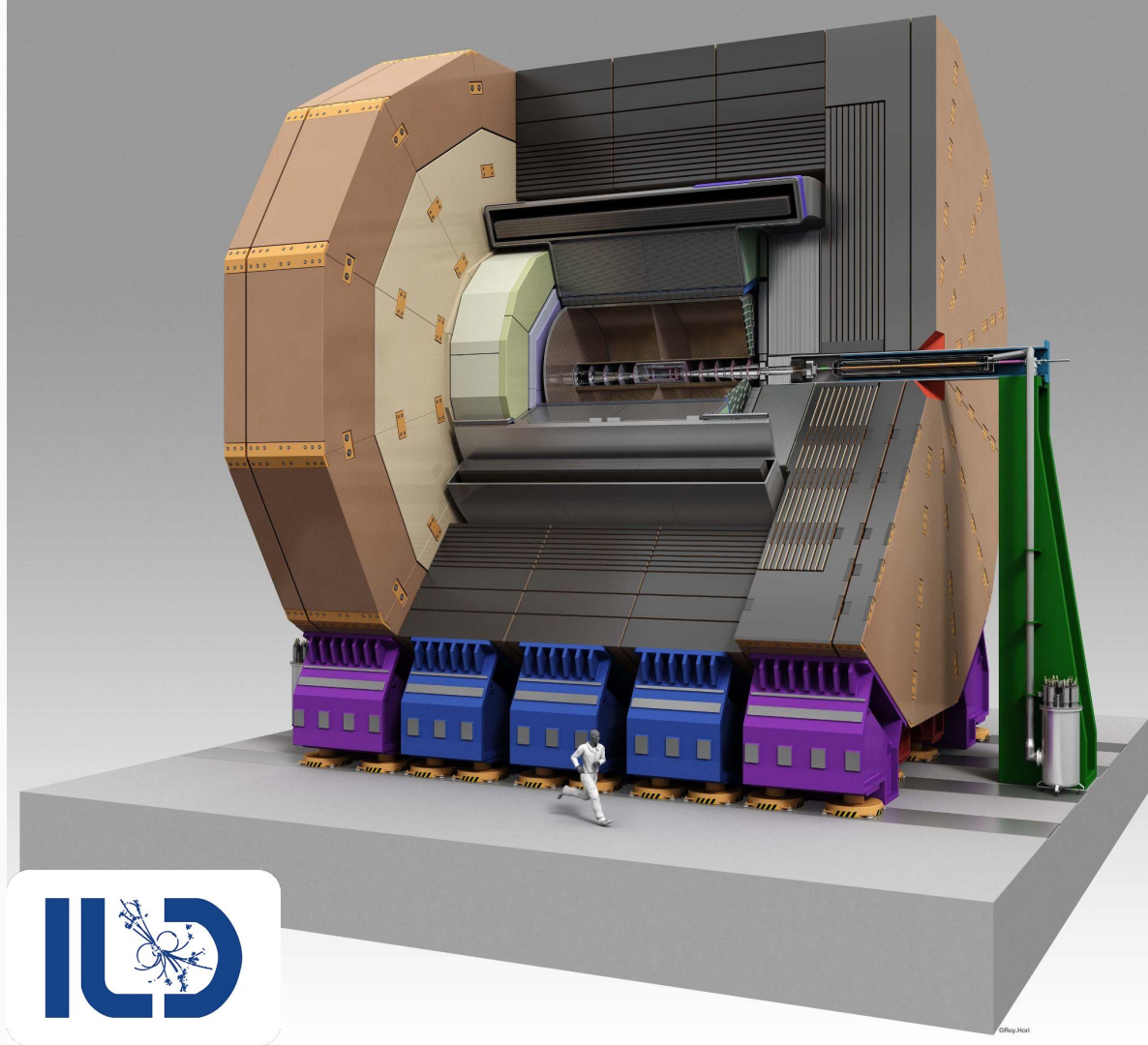
In this work **ILD** and **CLD** are compared in the context of Full Simulation FCCee  $Z \rightarrow \tau^+ \tau^-$ .

- This preliminary comparison show very similar performances at particle level:
  - **Similar efficiencies and purities** for the analyzed particles (note that this sample has almost no neutrons).
  - **Compatible resolution**, non comparable now because of the status of ILD reconstruction.
- At tau reconstruction level, ILD improves the efficiency for almost every decay.
  - Three pions and electron decays are the most affected, with a ~10% increase.
- **Polarization analysis results in similar fits for both detectors.**
  - Depending on the decay one detector is better. Need to study pion decay.

## Next steps:

- Optimize tau reconstruction for ILD (now the applied cuts are customized for CLD).
- **Extend polarization analysis to  $a_1 \rightarrow \pi\pi\pi$**  (now possible with the statistics).
- Repeat the analysis with optimized version of tracking fitting.
- Compare with others generators (KKMCee or Whizard, WIP)

Thanks  
for your  
attention



**BACKUP**

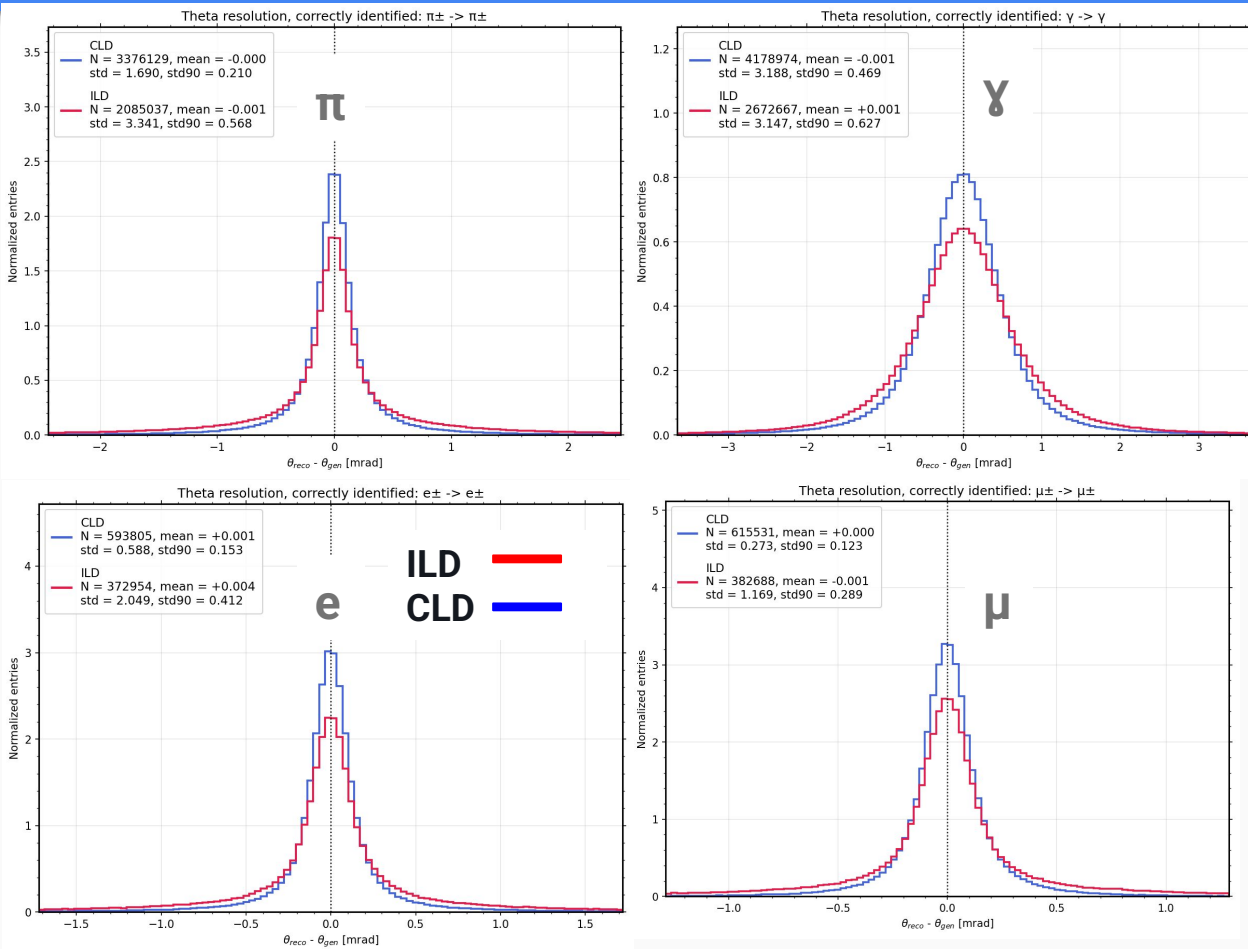
# Particle Reconstruction (PandoraPFA)

## Stack configuration

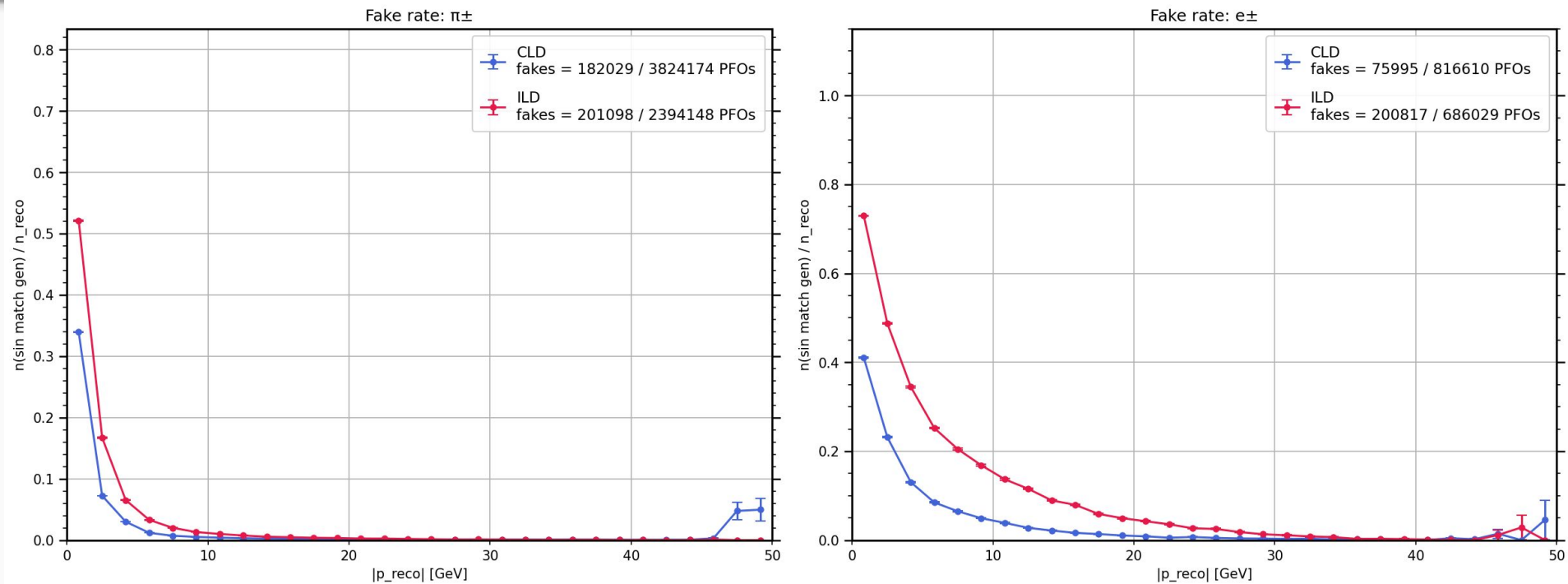
CLD: Pythia 8.311, simulating  $e^+e^- \rightarrow Z \rightarrow \tau^+\tau^-$  at  $\sqrt{s} = 91.188$  GeV. FCC-ee winter2023 setup (p8\_ee\_Ztautau\_ecm91.cmd). DDSim/Geant4 11.2.2 - CLD\_o2\_v06 model from k4geo v0.21 - FTFP\_BERT physics list w/ 0.7 mm production range cut. 30 mrad beam crossing angle. Reconstruction with CLDConfig through k4MarlinWrapper 0.9 - PandoraPFA 4.3.1 particle flow. **Key4hep 2024-10-03 release.**

ILD: Same hardprocess, centre-of-mass energy and beam-spot parameters. ILD\_FCSee\_v01 model from k4geo v0.24. Simulation used the QGSP\_BERT physics list with a 0.1 mm. Reconstruction was performed with ILDConfig (commit e859eaf) k4MarlinWrapper v00-14 - PandoraPFA 4.11.2. **Key4hep 2026-04-08 release.**

# Overall angular resolution distribution



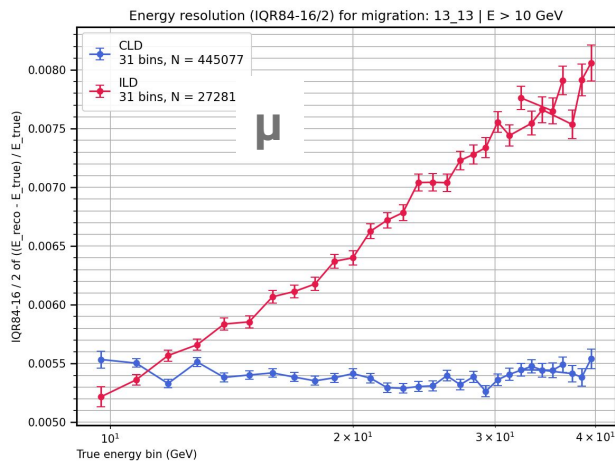
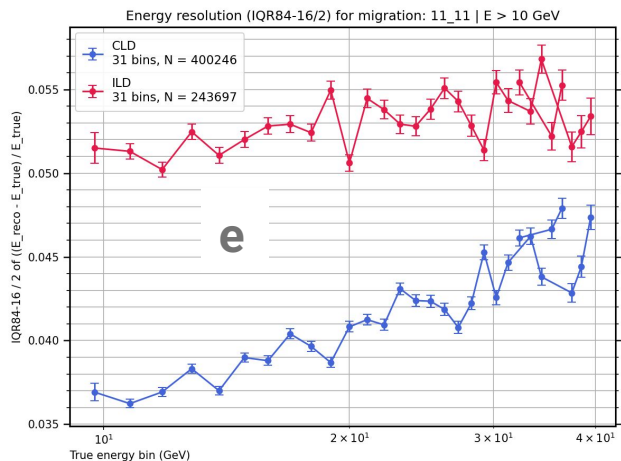
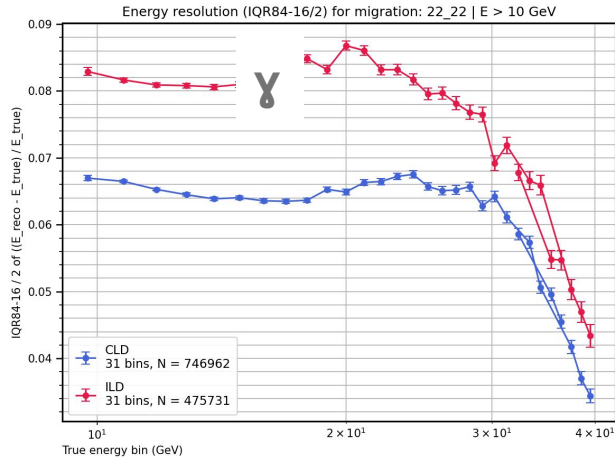
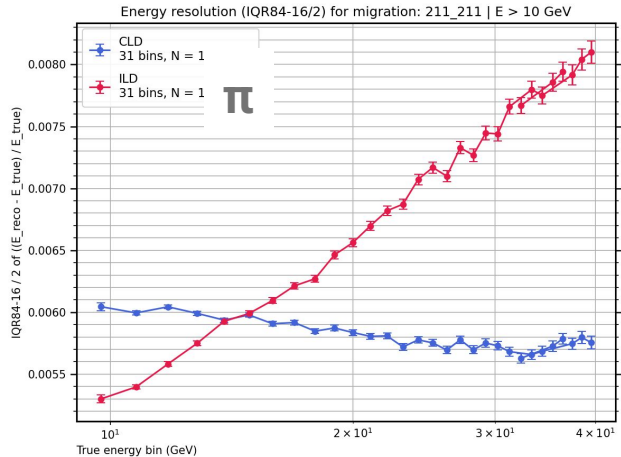
# Fake rate for pions and electrons by $P_{\text{reco}}$



ILD present more fakes at  $P < 10/20$  GeV

- Fake rate “yield” ->  $\frac{\# \text{fakes}}{(\# \text{events} * \text{bin width})}$

# Energy Resolution E>10GeV



Differences increase with energy for pions and muons, while remain constant for photons and electrons.

# Absolute PID (>10GeV)



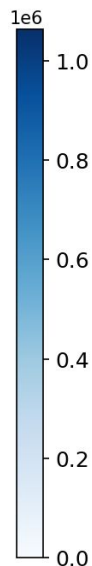
Energy bin: (10.0, inf] GeV — Absolute counts

Absolute counts

Gen particle

|           |         |         |         |           |       |        |        |       |
|-----------|---------|---------|---------|-----------|-------|--------|--------|-------|
| $e^\pm$   | 243,697 |         | 42,173  | 2,375     | 56    | 2,894  | 441    | 191   |
| $\mu^\pm$ | 5       | 272,818 | 734     | 434       | 2     | 1,512  | 10,489 | 3     |
| $\gamma$  | 14,576  | 3       | 475,731 | 503       | 526   | 29,946 | 2,116  | 3,208 |
| $K^0_L$   | 25      | 6       | 3,386   | 146       | 107   | 4,958  | 12,408 | 14    |
| $\pi^\pm$ | 14,429  | 6,274   | 16,606  | 1,063,768 | 5,470 | 32,165 | 30,620 | 1,746 |
| $K^\pm$   | 321     | 502     | 646     | 43,403    | 42    | 1,339  | 1,250  | 37    |
| 999       | 16,487  | 81      | 9,809   | 4,955     | 650   |        | 13,539 | 439   |
| p         |         |         |         |           |       |        |        | 1     |

Reco particle



CLD

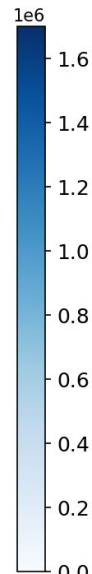
Energy bin: (10.0, inf] GeV — Absolute counts

Absolute counts

Gen particle

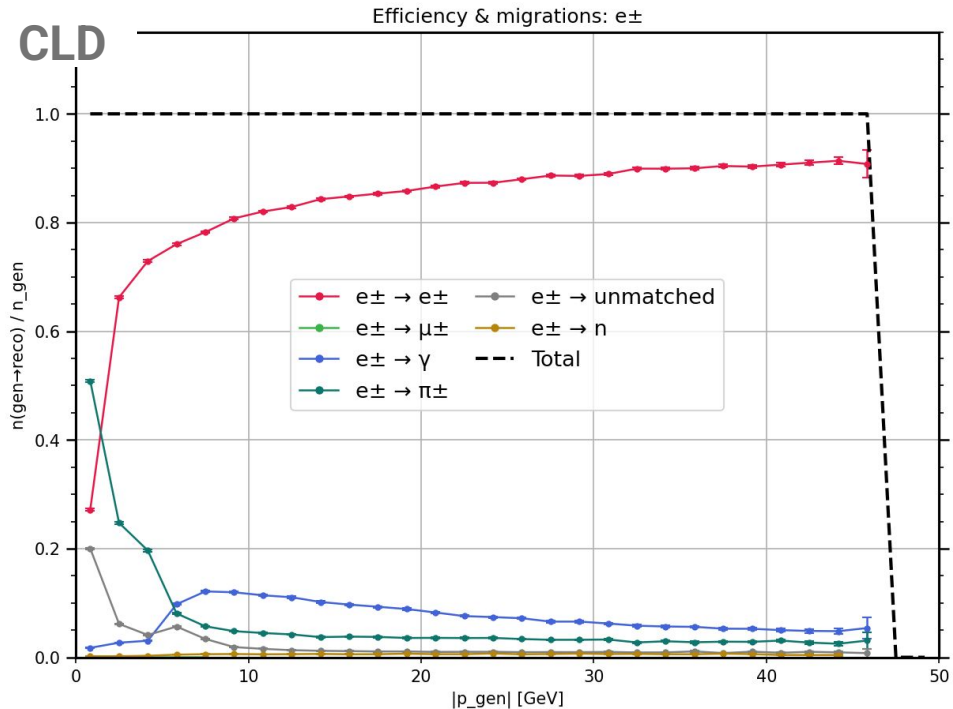
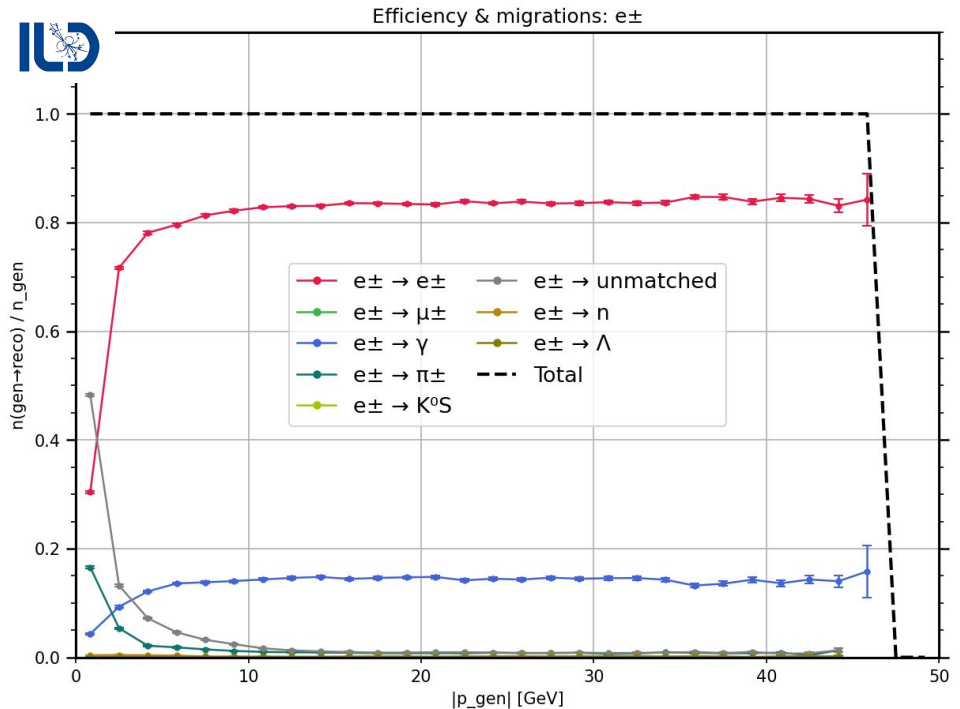
|           |         |         |         |           |        |        |        |  |
|-----------|---------|---------|---------|-----------|--------|--------|--------|--|
| $e^\pm$   | 400,246 |         | 38,487  | 16,524    | 5,051  | 2,752  |        |  |
| $\mu^\pm$ | 13      | 445,077 | 24      | 870       | 3,199  | 6,493  |        |  |
| $\gamma$  | 15,754  | 1       | 746,962 | 2,440     | 65,967 | 6,056  |        |  |
| $K^0_L$   | 15      | 2       | 4,209   | 106       | 8,550  | 20,232 |        |  |
| $\pi^\pm$ | 21,410  | 13,621  | 14,109  | 1,700,367 | 73,567 | 39,173 |        |  |
| $K^\pm$   | 565     | 934     | 475     | 68,919    | 2,734  | 1,300  |        |  |
| 999       | 5,860   | 25      | 58,751  | 3,821     |        |        | 46,868 |  |
| n         |         |         |         |           | 1      | 1      |        |  |
| p         |         |         |         | 1         |        | 1      |        |  |

Reco particle



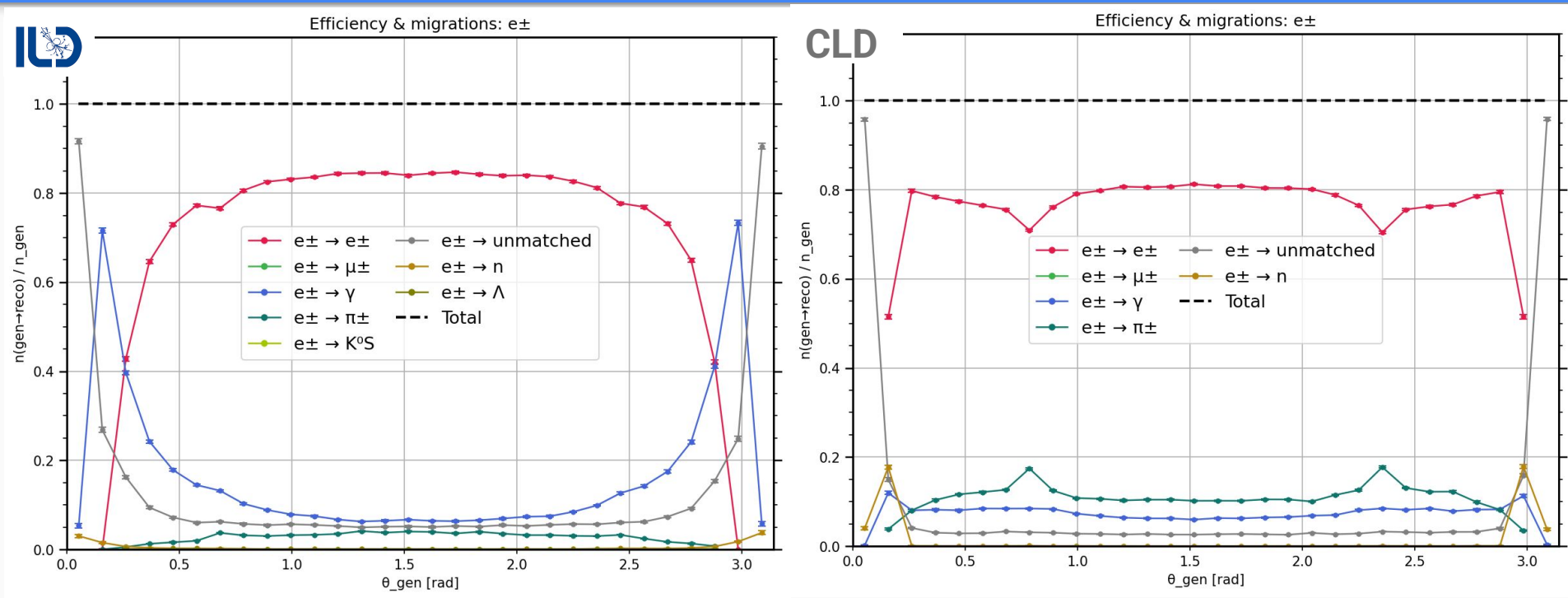
Fakes in ILD are relevant with electrons (~2-4 times CLD). In CLD, neutral fakes dominate.

# Electron efficiency by $P_{\text{gen}}$



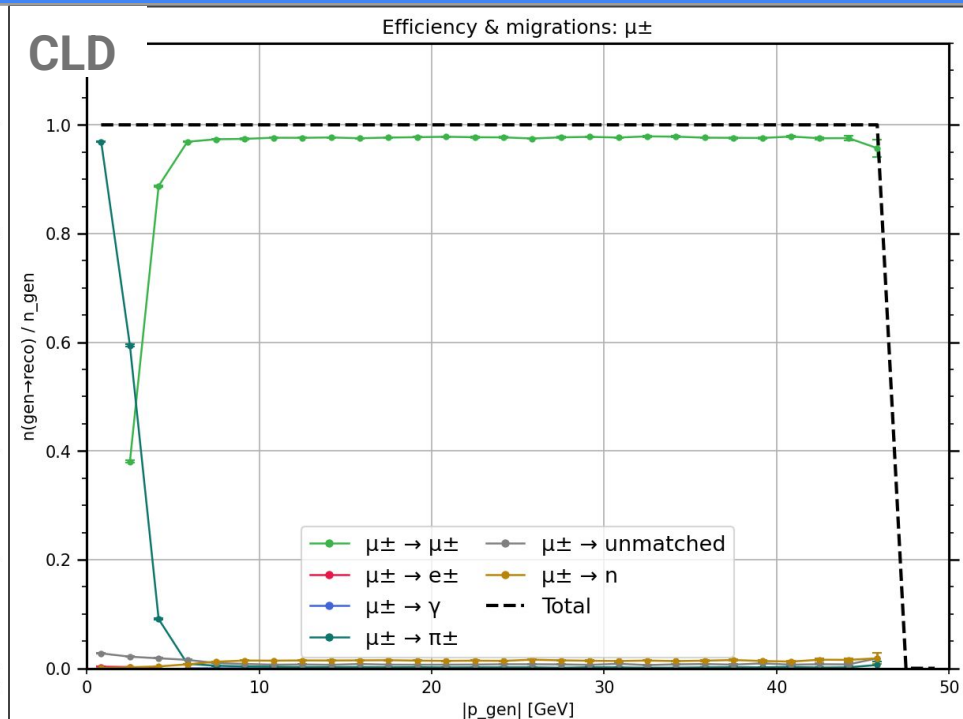
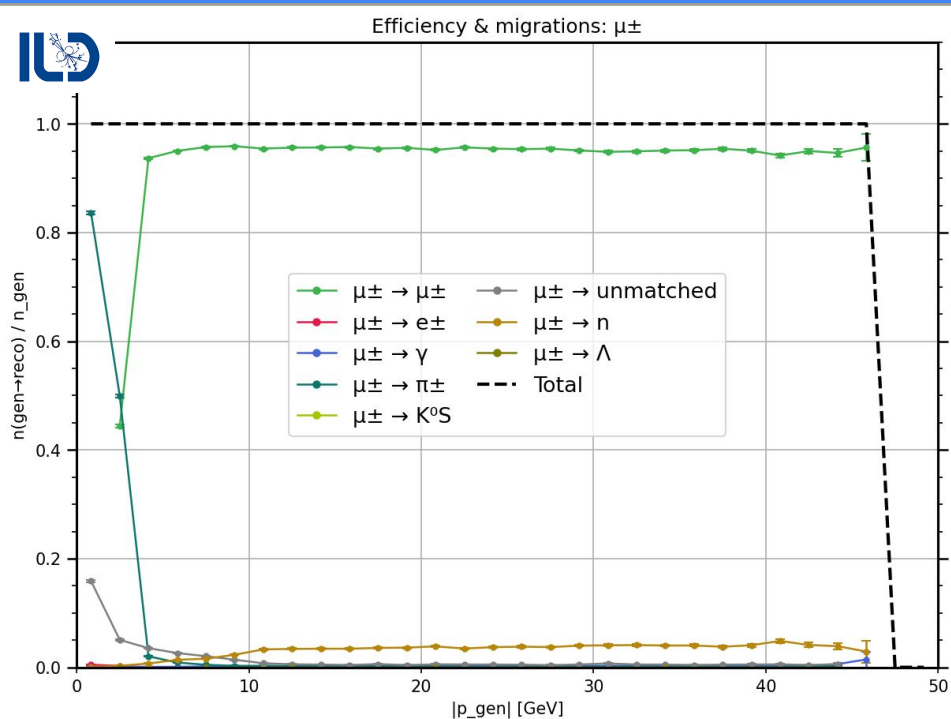
For **electrons** ILD is slightly better in 0-20 GeV. Then BG dominated by photon migration, and CLD presents slightly better results.

# Electron efficiency by $\theta_{\text{gen}}$



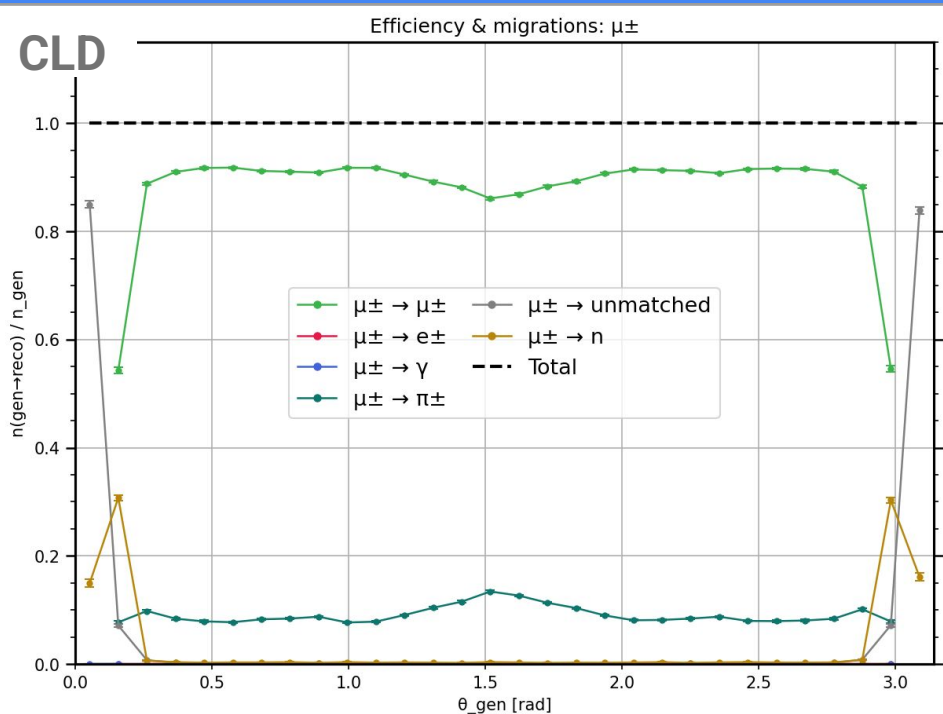
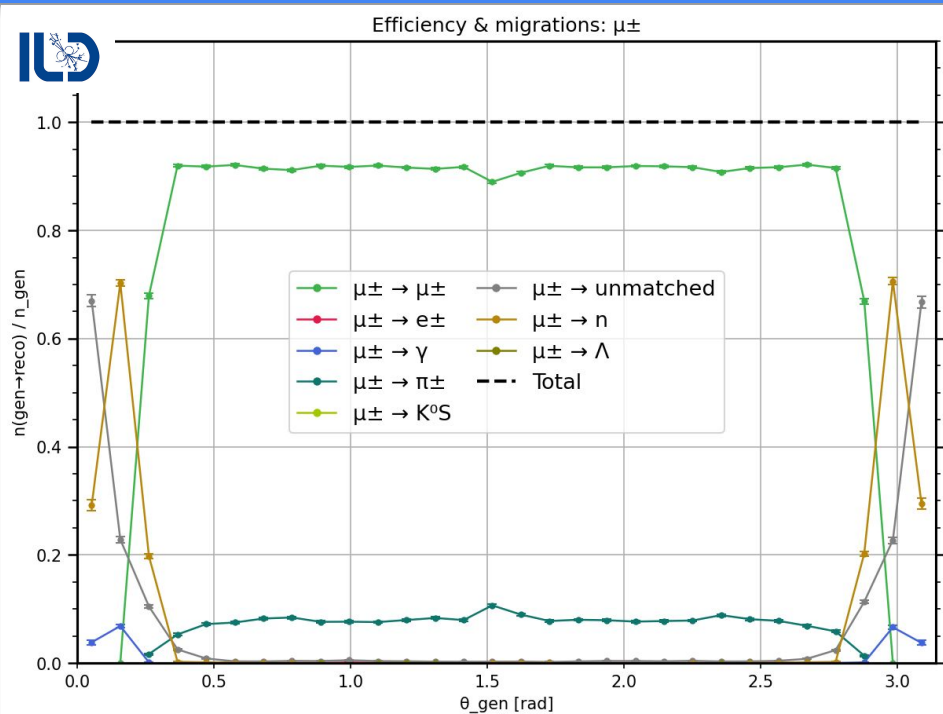
Same edge effects for ILD (dominating photon fakes), but for CLD it show 2 symmetrical valleys  $\sim 0.8$  rads and  $\sim 2.3$  rads, caused by pion fakes.

# Muon efficiency by $P_{\text{gen}}$



Non negligible confusion with neutrals (Both ILD and CLD).

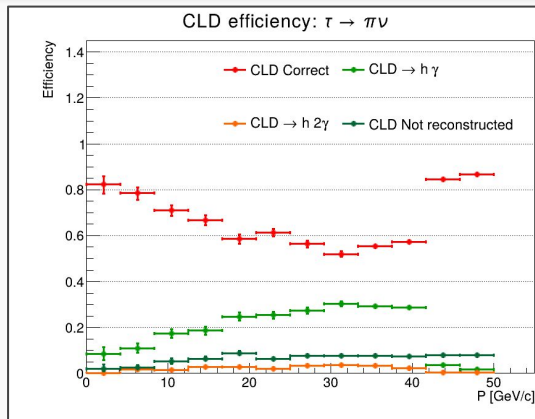
# Muon efficiency by $\theta_{\text{gen}}$



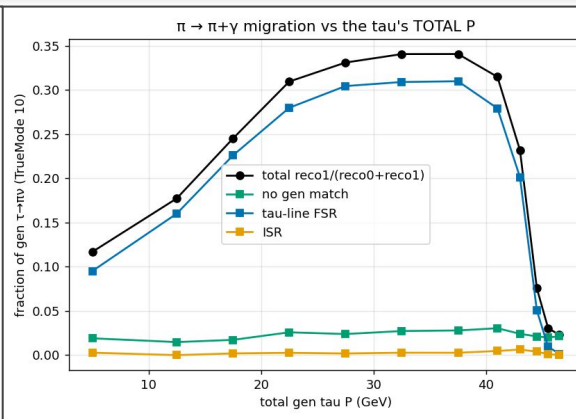
While confusion with neutrals in ILD is present in certain theta ranges, in CLD is distributed in all the range.

# Optimization for pi decay

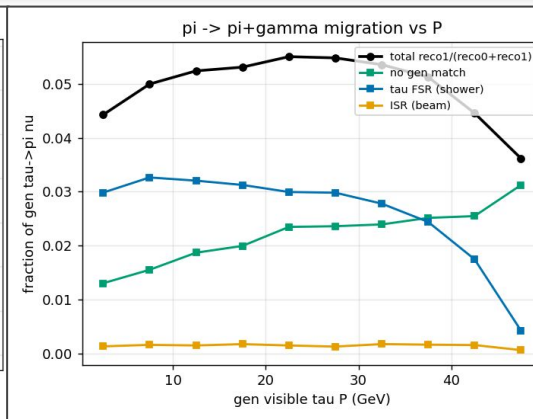
# Motivation



Low eff in 20-40 GeV.



Origin by Tau P



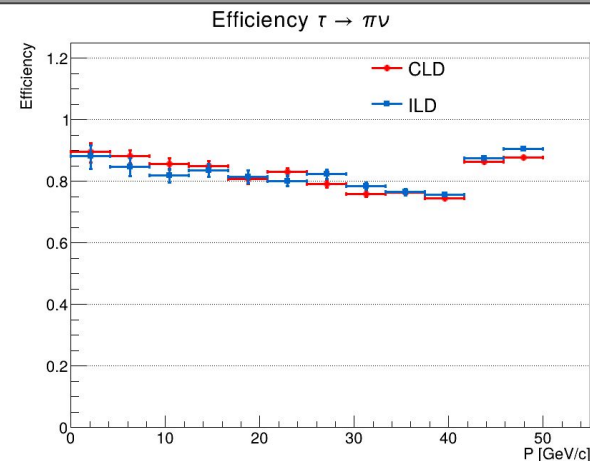
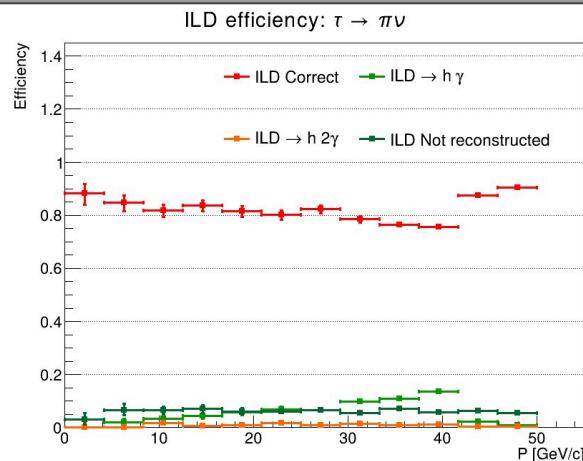
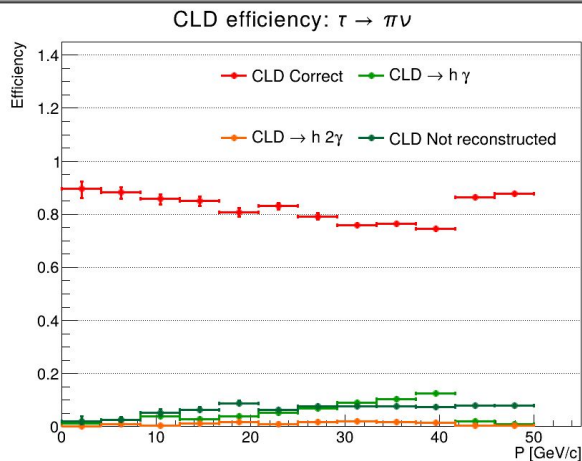
Origin by Tau visible P

The migration is mainly caused by tau FSR photons (photon next to pion in the reconstruction cone).

**Claude Opus 5** was used for **exploring the origin and selection cuts**.

→ **Simplified prompt:** "Given the Root file with the information of all the particles, find the cuts that mitigate the FSR effect in the pion decay, while preserving photon coming from neutral pions."

# The result



The selection consist in a selection of photons depending on the best pair-mass (close to neutral pions), and then a rejection using  $P_\gamma / P_\pi < 0.05$  or  $P_\gamma > 2.0$  GeV AND  $m(\pi+\gamma) > 1.2$  (see backup for pseudo-code).

**The previous selection solve the confusion of the decay by ignoring the extra photons.**

# The solution

Photon selection can be improved using (1) the mass of the  $\pi^0$  to select extra photons and (2,3) cut in fraction carried by the photon and the relation with the rho mass.

recoverPionFromExtraPhoton — runs AFTER the tau cone is built

Applies only if:

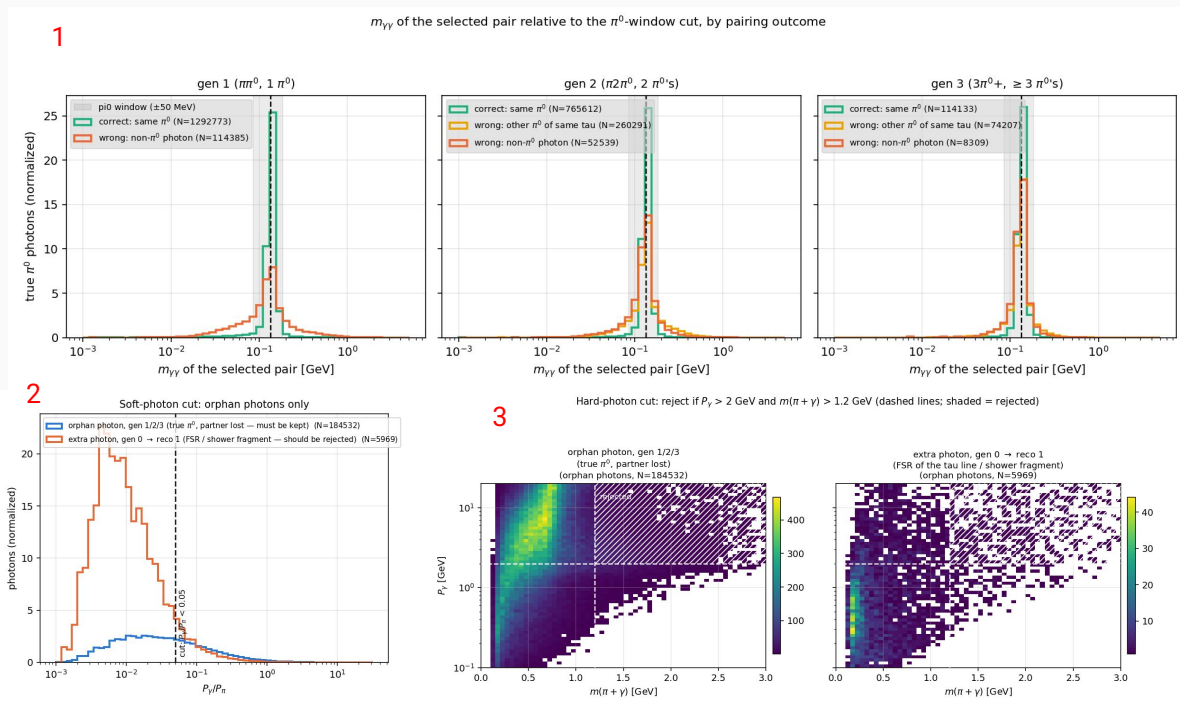
- 1-prong (1 charged pion)
- 0 neutrons
- $\geq 1$  photon in cone

For each photon pair:

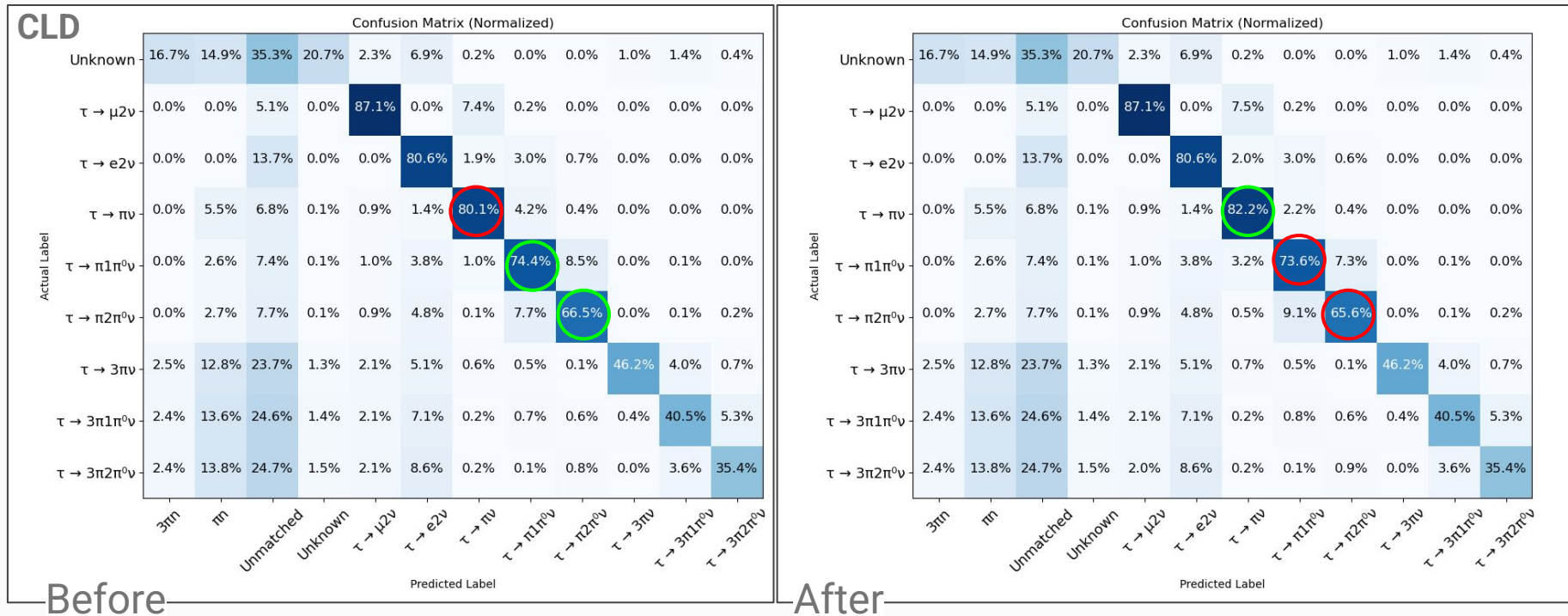
**if  $m(\gamma\gamma) \approx m(\pi^0)$  (within 0.05 GeV)** <sup>1</sup>  
 → both photons PROTECTED (never removed)

For each remaining (unpaired) photon:

**if  $P_\gamma / P_\pi < 0.05$**  <sup>2</sup>  
 → REMOVE (soft shower fragment)  
**else if  $P_\gamma > 2.0$  GeV AND  $m(\pi+\gamma) > 1.2$  GeV** <sup>3</sup>  
 → REMOVE (hard FSR-like photon)  
 else  
 → KEEP

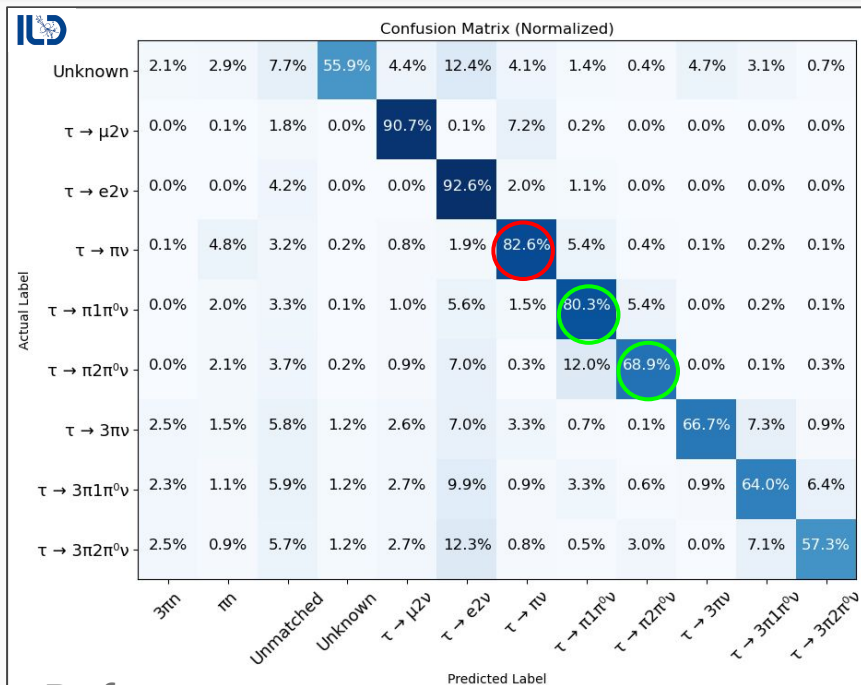


# The result

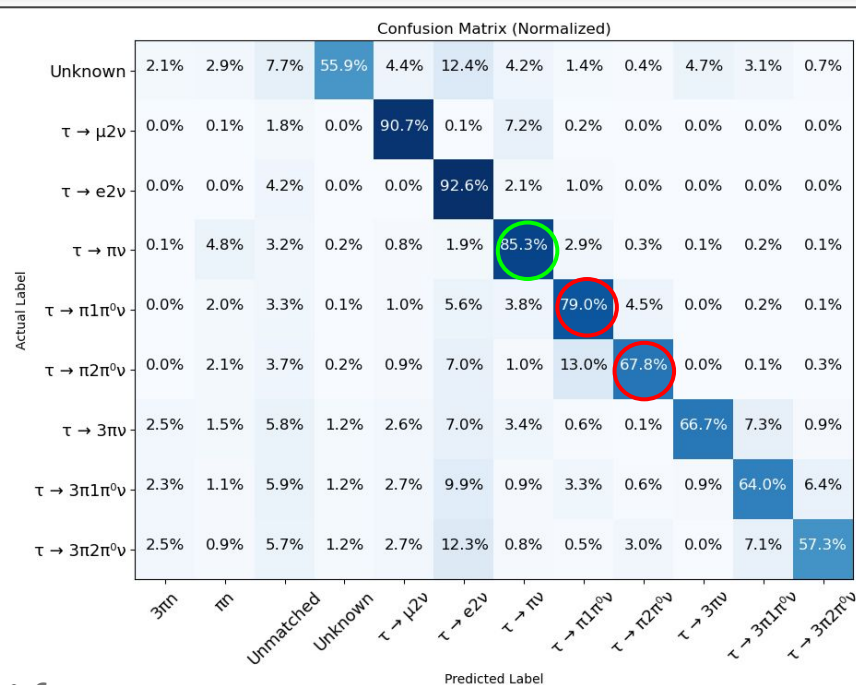


Other decays are affected by this cut, slightly reducing the efficiency.

# The result



Before



After

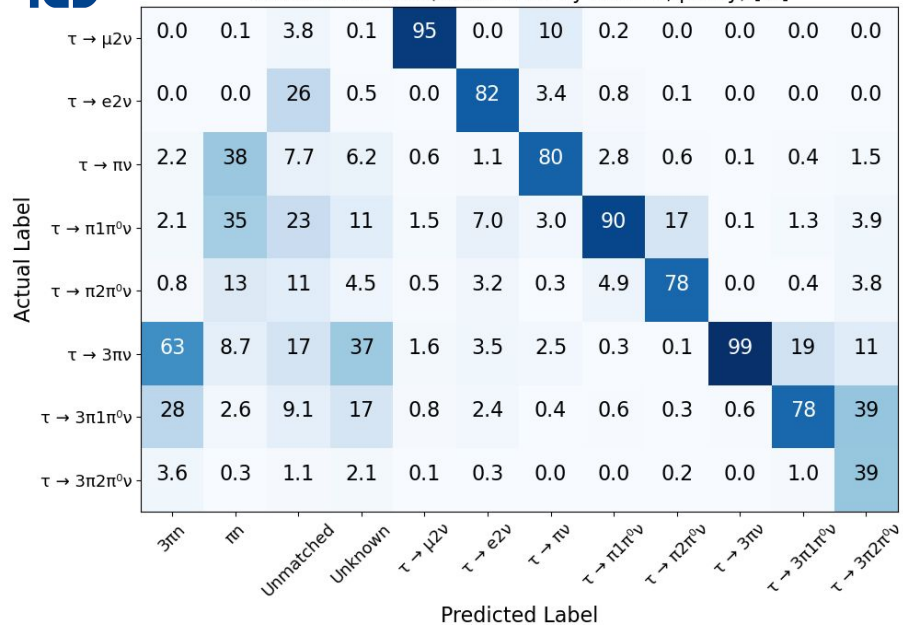
Other decays are affected by this cut, slightly reducing the efficiency.

# Tau Reconstruction

# Purity by reconstructed tau decay

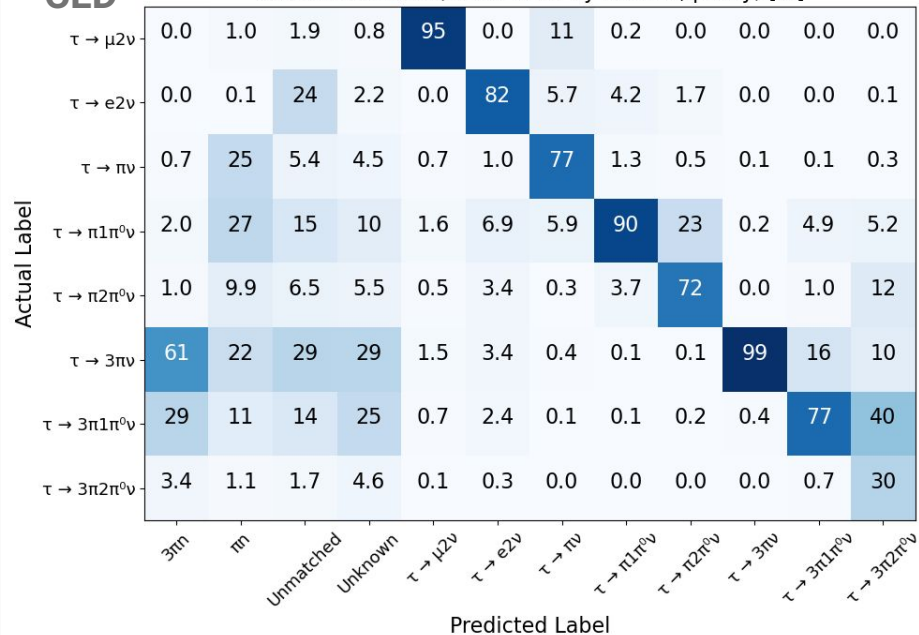


Confusion Matrix (Normalized by column, purity) [%]



CLD

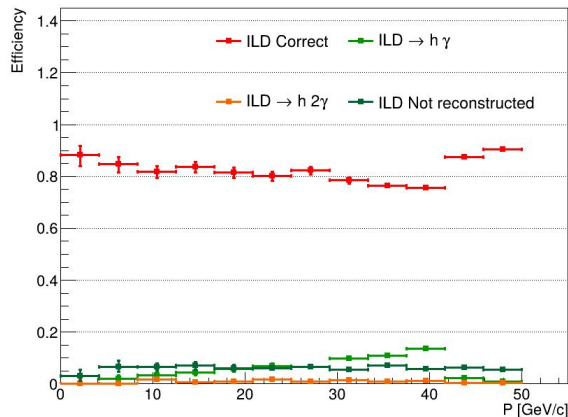
Confusion Matrix (Normalized by column, purity) [%]



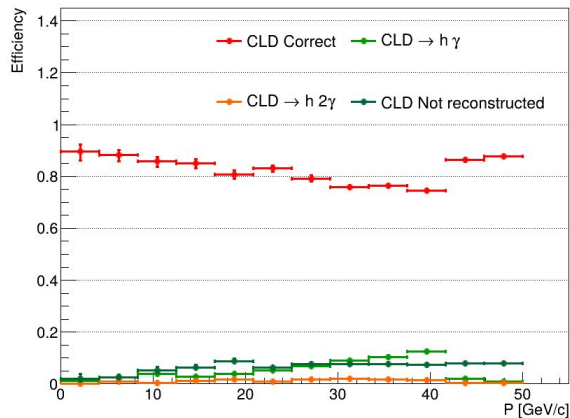
Very similar results, ILD slightly better than CLD.

# Efficiency by P and $\theta$ for $\pi$ decay.

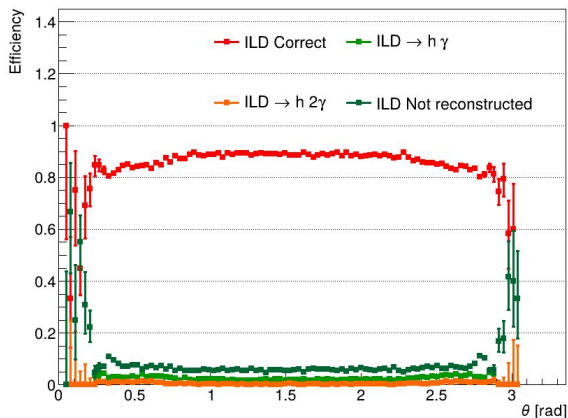
ILD efficiency:  $\tau \rightarrow \pi\nu$



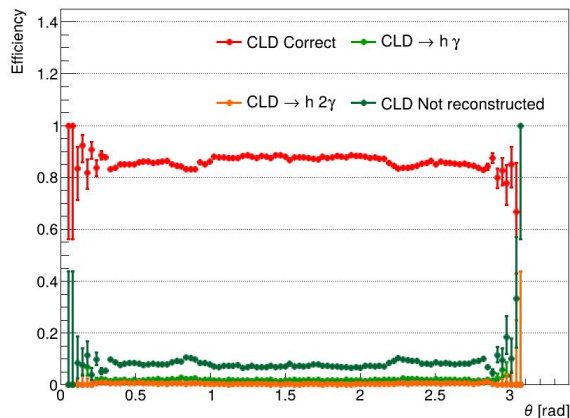
CLD efficiency:  $\tau \rightarrow \pi\nu$



ILD efficiency:  $\tau \rightarrow \pi\nu$

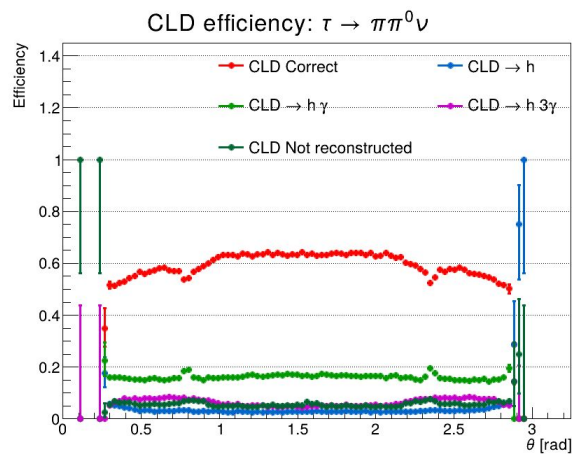
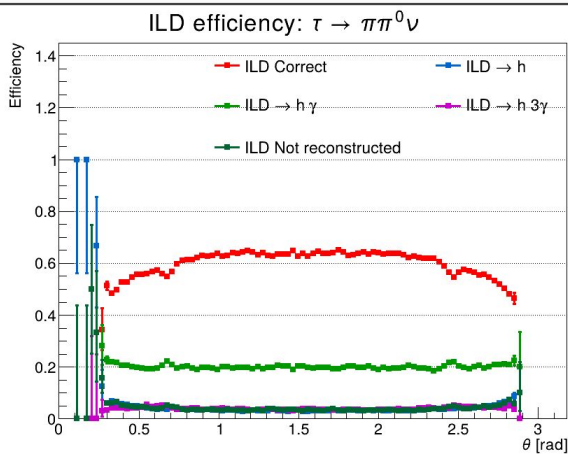
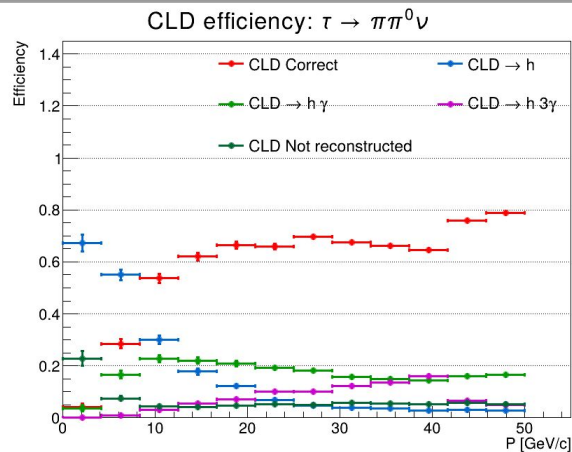
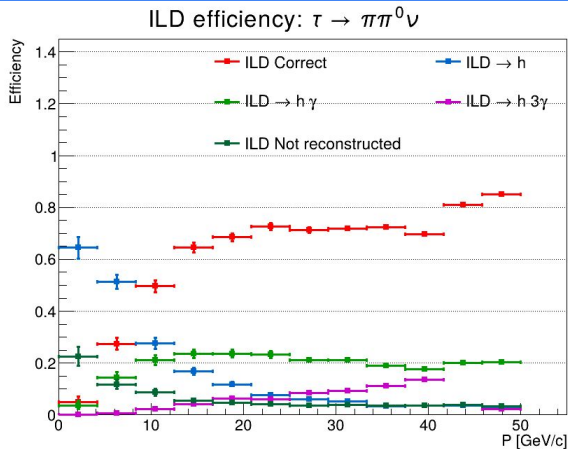


CLD efficiency:  $\tau \rightarrow \pi\nu$



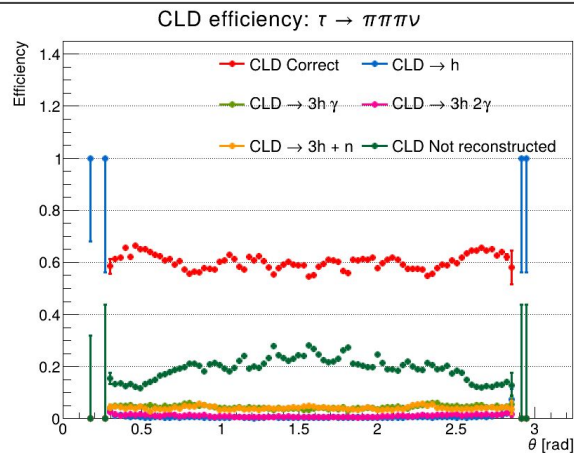
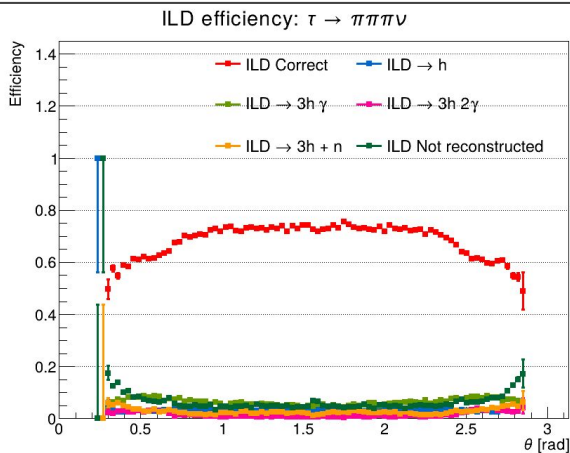
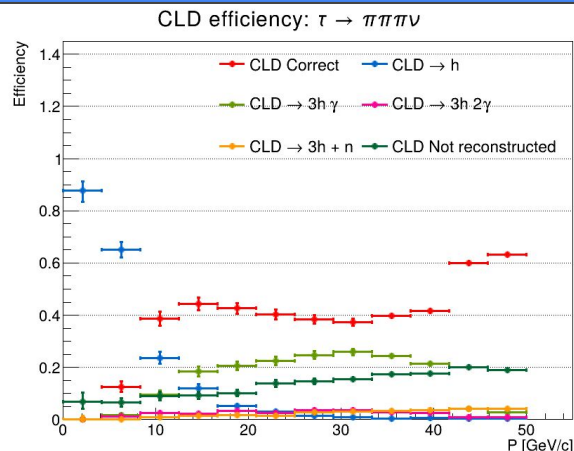
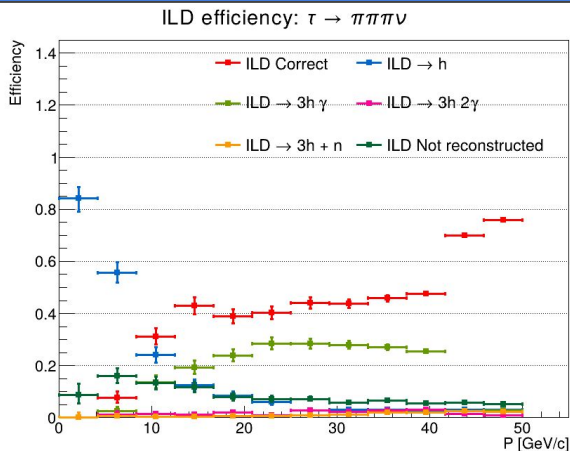
**Main contribution to efficiency loss in pion decay is the presence of a photon that comes mainly from FSR. Next is non reconstructed taus.**

# Efficiency by P and $\theta$ for $\pi\pi^0$ decay



Similar to the pi decay, the rho decay show migrations going to h-gamma (loss of a photon) and h-3gamma (excess in one photon)

# Efficiency by P and $\theta$ for $\pi\pi\pi$ decay

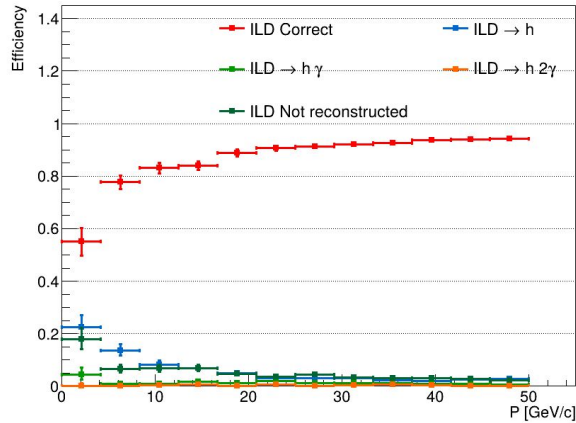


Low energy is dominated by the lack of pions (only one of three is reconstructed).

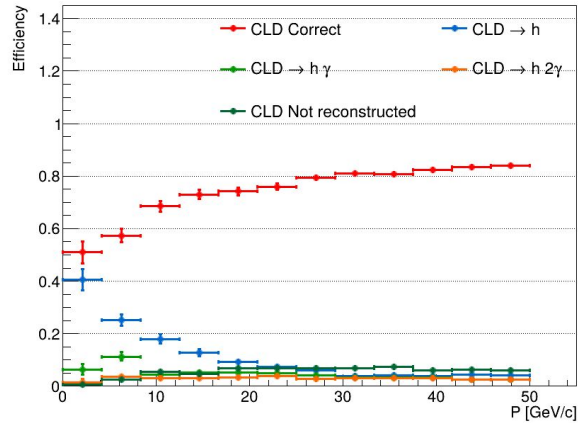
Here CLD show an increase in “not reconstructed” migration (non-tau cases, two pions). The next contribution is the presence of an extra photon.

# Efficiency by P and $\theta$ for e decay

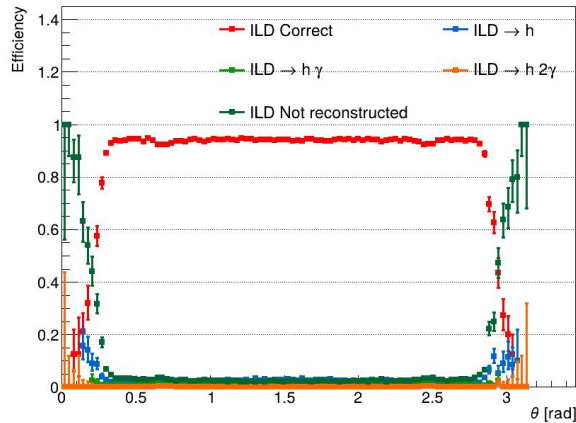
ILD efficiency:  $\tau \rightarrow e\nu\nu$



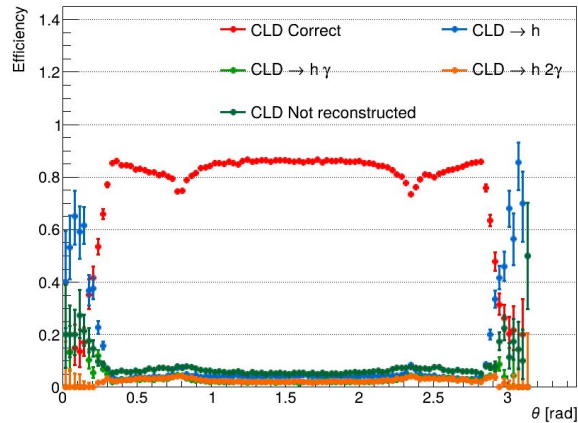
CLD efficiency:  $\tau \rightarrow e\nu\nu$



ILD efficiency:  $\tau \rightarrow e\nu\nu$



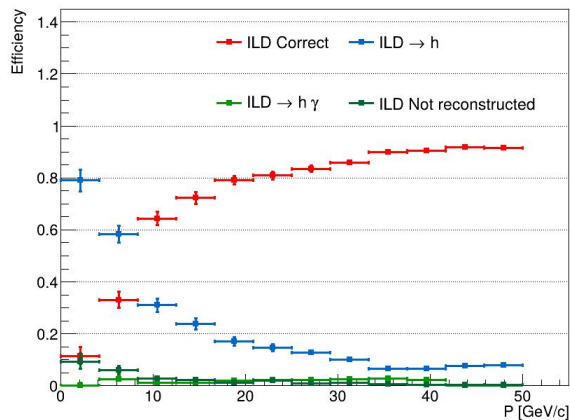
CLD efficiency:  $\tau \rightarrow e\nu\nu$



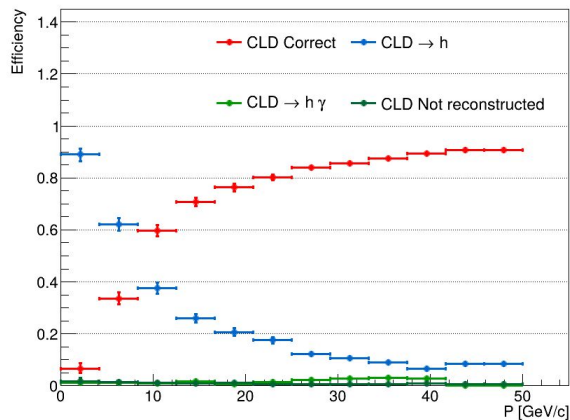
Electron efficiency is good in general (slightly better for ILD).

# Efficiency by P and $\theta$ for $\mu$ decay

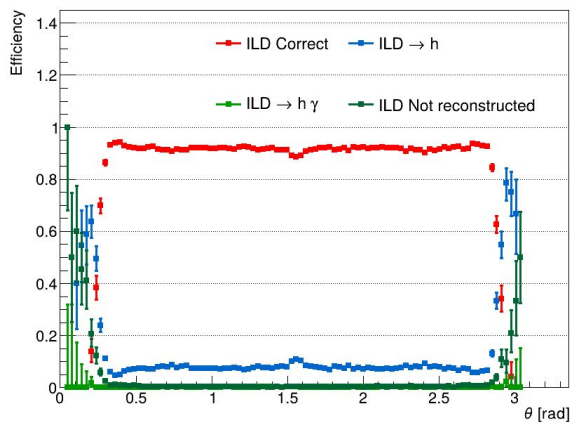
ILD efficiency:  $\tau \rightarrow \mu \nu \nu$



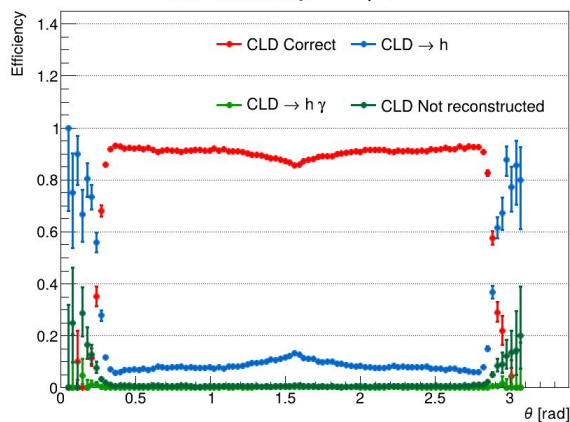
CLD efficiency:  $\tau \rightarrow \mu \nu \nu$



ILD efficiency:  $\tau \rightarrow \mu \nu \nu$

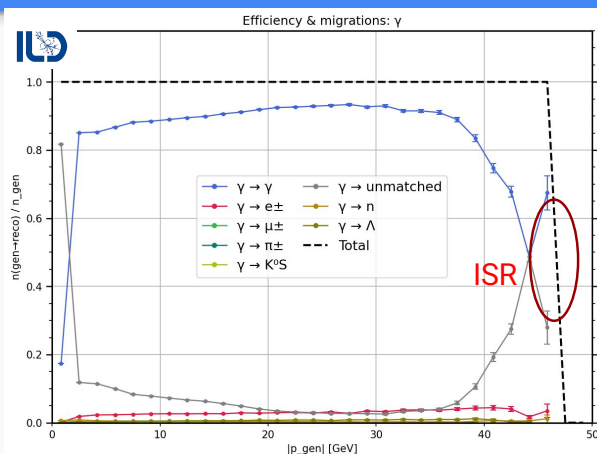


CLD efficiency:  $\tau \rightarrow \mu \nu \nu$



Muon efficiency is good from 20~25 GeV. At lower energies, is dominated by charged hadron confusion.

# No reconstructed photons $P \sim 45$ GeV angle distribution

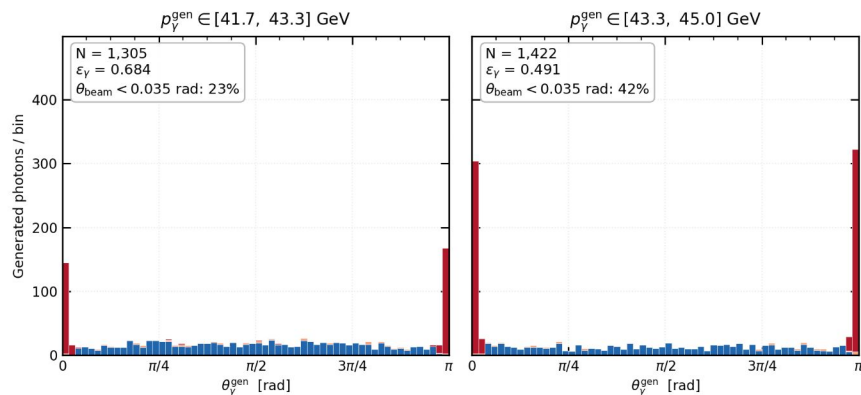


Theta distribution of photons in the low efficiency and adjacent bins (ILD, Ztt, 2M events).

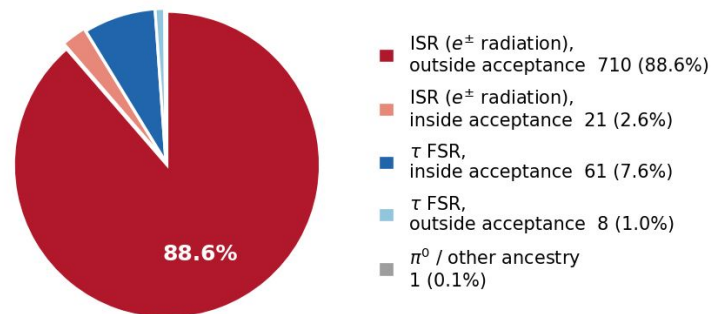
The distribution shows the increase of non-reconstructed low theta photons at  $\sim 44$  GeV

ILD  $Z \rightarrow \tau^+ \tau^-$ , full simulation

reconstructed as  $\gamma$  reconstructed, wrong PID not reconstructed

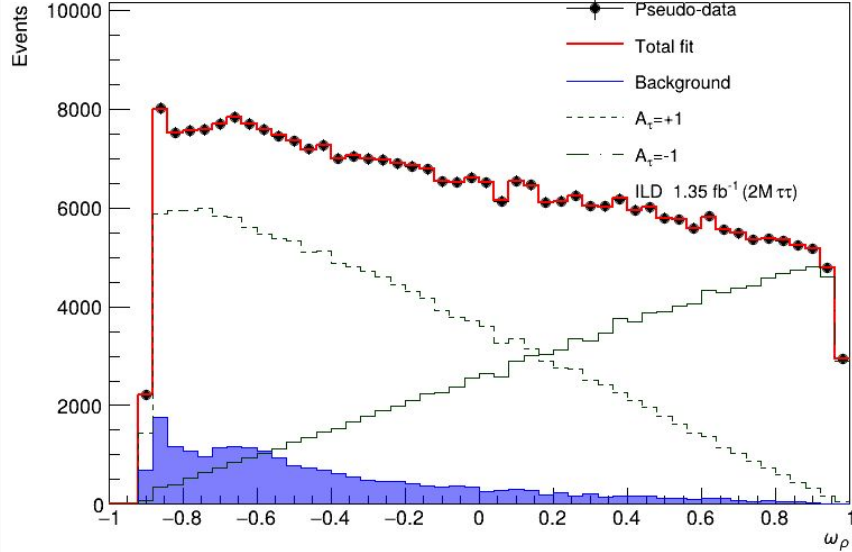


Origin of the photons not reconstructed in the efficiency dip,  
 $p_\gamma^{\text{gen}} \in [43.3, 45.0]$  GeV

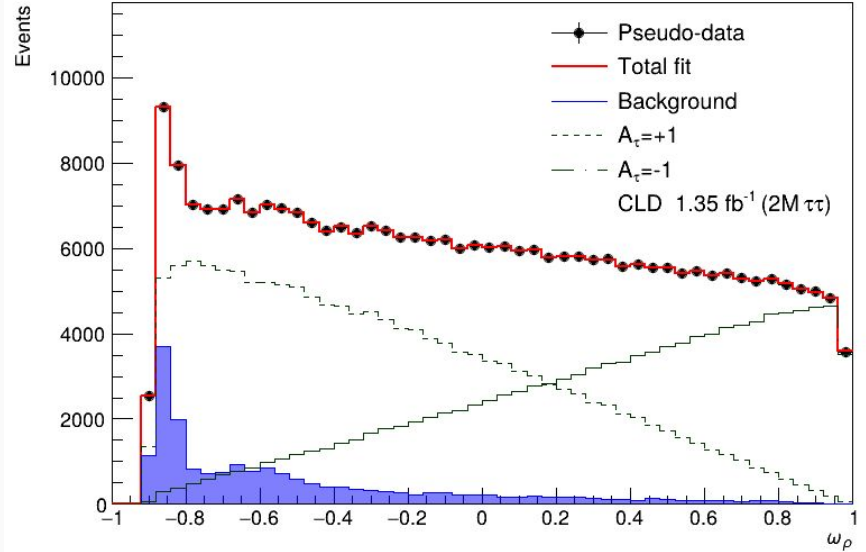


# Tau Polarization

# pion + X (Optimal cuts -WIP-)

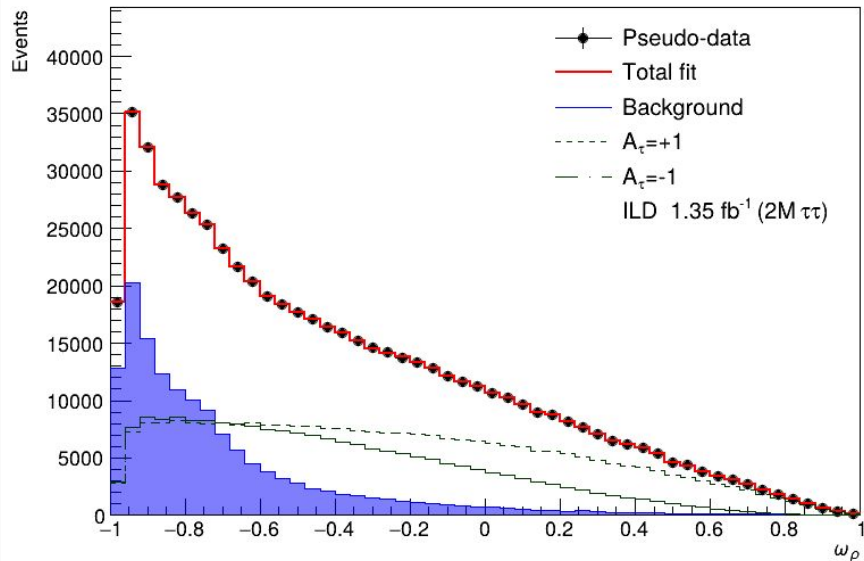


## CLD

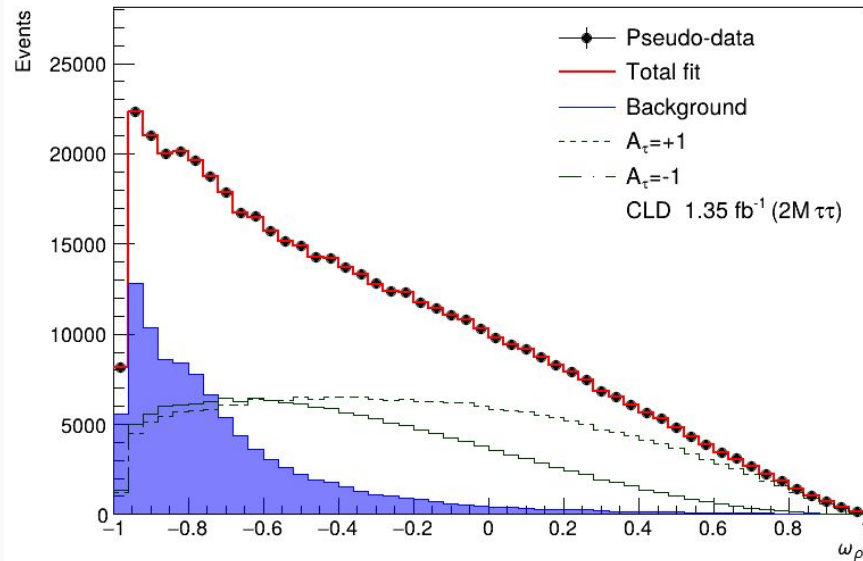


| Parameter            | Generated value | ILD                   | CLD                   | Rel. diff. error<br>(ILD-CLD)/CLD | Dev. ILD       | Dev. CLD       |
|----------------------|-----------------|-----------------------|-----------------------|-----------------------------------|----------------|----------------|
| $\mathcal{A}_\tau$   | 0.14955         | $0.1495 \pm 0.0061$   | $0.1496 \pm 0.0047$   | +30.8%                            | -0.01 $\sigma$ | +0.01 $\sigma$ |
| $\mathcal{A}_e$      | 0.14955         | $0.1494 \pm 0.0075$   | $0.1494 \pm 0.0064$   | +17.7%                            | -0.02 $\sigma$ | -0.03 $\sigma$ |
| $g_V/g_A$            | 0.07520         | $0.0751 \pm 0.0038$   | $0.0751 \pm 0.0033$   | +17.7%                            | -0.02 $\sigma$ | -0.03 $\sigma$ |
| $\sin^2\theta_{eff}$ | 0.2312          | $0.23122 \pm 0.00095$ | $0.23122 \pm 0.00081$ | +17.7%                            | +0.02 $\sigma$ | +0.03 $\sigma$ |

# electron + X

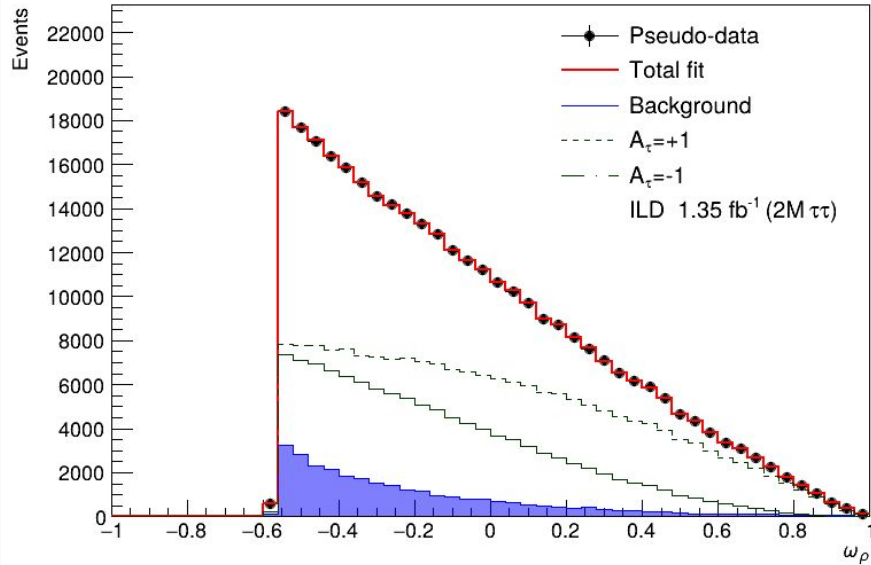


## CLD

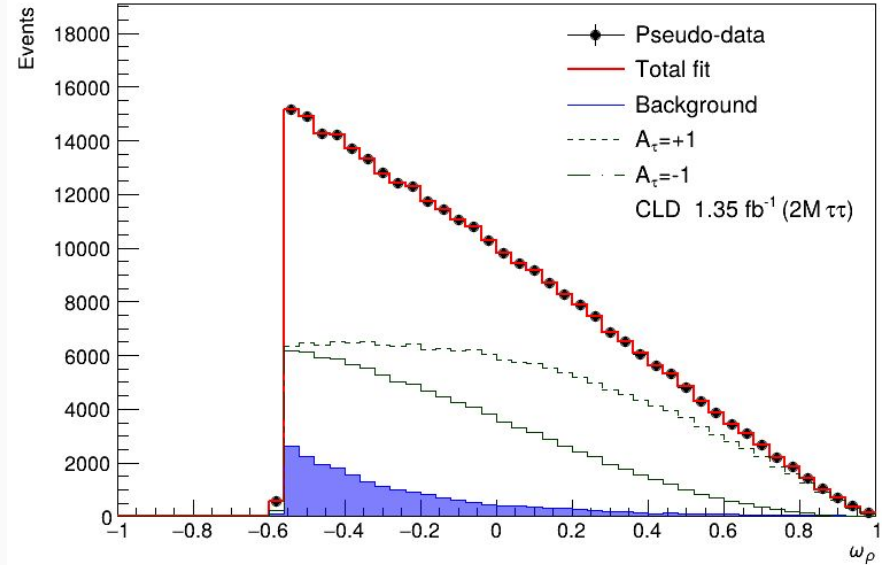


| Parameter                    | Generated value | ILD                 | CLD                 | Rel. diff. error<br>(ILD-CLD)/CLD | Dev. ILD       | Dev. CLD       |
|------------------------------|-----------------|---------------------|---------------------|-----------------------------------|----------------|----------------|
| $\mathcal{A}_\tau$           | 0.14955         | $0.1495 \pm 0.0094$ | $0.1496 \pm 0.0097$ | -2.4%                             | $-0.01 \sigma$ | $+0.00 \sigma$ |
| $\mathcal{A}_e$              | 0.14955         | $0.150 \pm 0.013$   | $0.149 \pm 0.013$   | -0.7%                             | $-0.00 \sigma$ | $-0.01 \sigma$ |
| $g_V/g_A$                    | 0.07520         | $0.0752 \pm 0.0063$ | $0.0752 \pm 0.0063$ | -0.7%                             | $-0.00 \sigma$ | $-0.01 \sigma$ |
| $\sin^2 \theta_{\text{eff}}$ | 0.2312          | $0.2312 \pm 0.0016$ | $0.2312 \pm 0.0016$ | -0.8%                             | $+0.00 \sigma$ | $+0.01 \sigma$ |

# electron + X ( $e P > 10\text{GeV}$ )

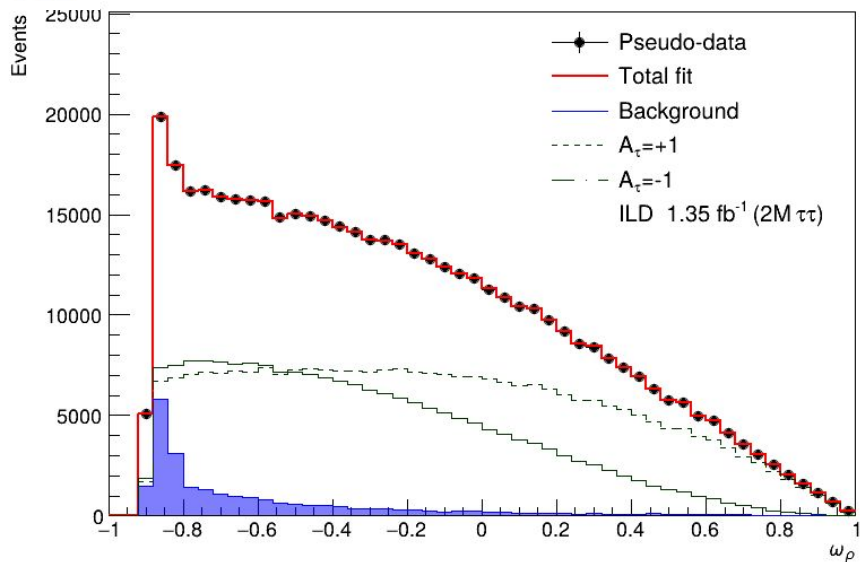


## CLD

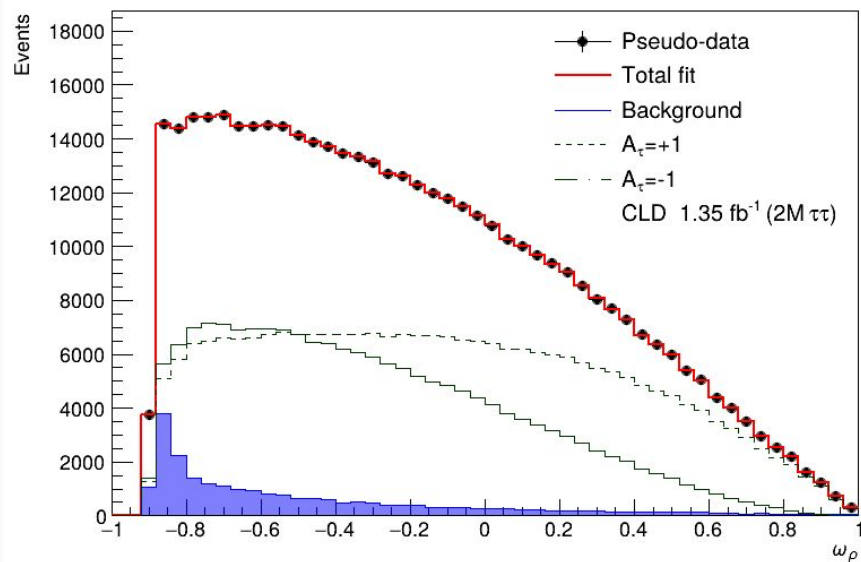


| Parameter                    | Generated value | ILD                 | CLD                 | Rel. diff. error<br>(ILD-CLD)/CLD | Dev. ILD       | Dev. CLD       |
|------------------------------|-----------------|---------------------|---------------------|-----------------------------------|----------------|----------------|
| $\mathcal{A}_\tau$           | 0.14955         | $0.150 \pm 0.015$   | $0.150 \pm 0.014$   | +2.2%                             | -0.00 $\sigma$ | -0.00 $\sigma$ |
| $\mathcal{A}_e$              | 0.14955         | $0.149 \pm 0.019$   | $0.149 \pm 0.018$   | +5.2%                             | -0.00 $\sigma$ | -0.01 $\sigma$ |
| $g_V/g_a$                    | 0.07520         | $0.0752 \pm 0.0096$ | $0.0751 \pm 0.0091$ | +5.2%                             | -0.00 $\sigma$ | -0.01 $\sigma$ |
| $\sin^2 \theta_{\text{eff}}$ | 0.2312          | $0.2312 \pm 0.0024$ | $0.2312 \pm 0.0023$ | +5.1%                             | +0.00 $\sigma$ | +0.01 $\sigma$ |

# muon + X

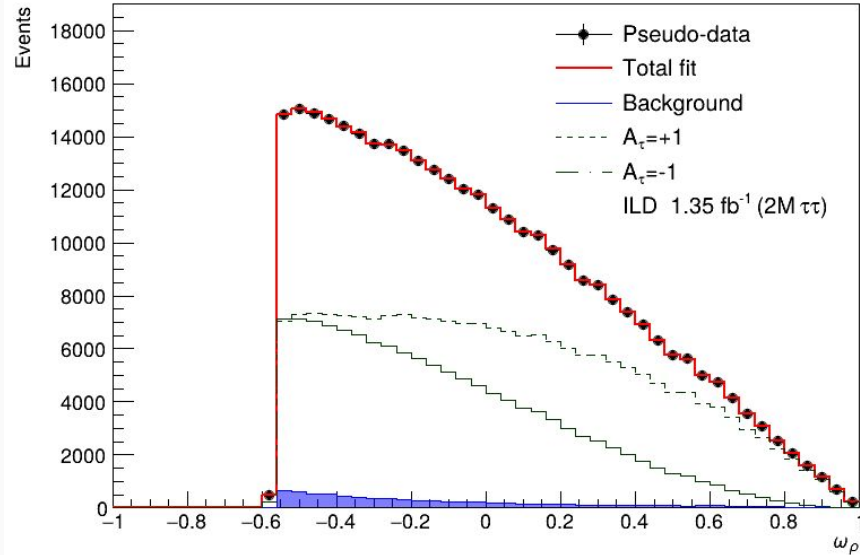


## CLD

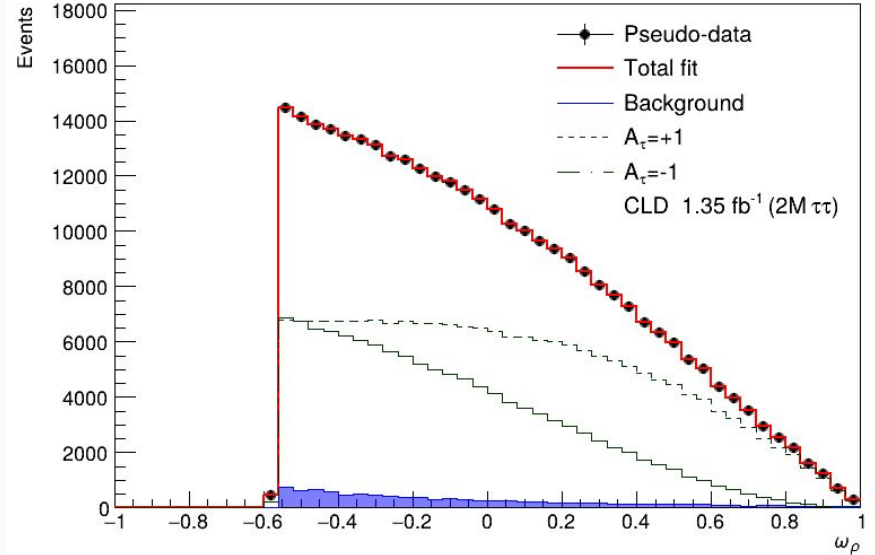


| Parameter                    | Generated value | ILD                 | CLD                 | Rel. diff. error<br>(ILD-CLD)/CLD | Dev. ILD       | Dev. CLD       |
|------------------------------|-----------------|---------------------|---------------------|-----------------------------------|----------------|----------------|
| $\mathcal{A}_\tau$           | 0.14955         | $0.1495 \pm 0.0078$ | $0.1496 \pm 0.0081$ | -4.2%                             | $-0.01 \sigma$ | $+0.01 \sigma$ |
| $\mathcal{A}_e$              | 0.14955         | $0.149 \pm 0.011$   | $0.149 \pm 0.011$   | -4.3%                             | $-0.03 \sigma$ | $-0.03 \sigma$ |
| $g_V/g_A$                    | 0.07520         | $0.0751 \pm 0.0052$ | $0.0750 \pm 0.0054$ | -4.3%                             | $-0.03 \sigma$ | $-0.03 \sigma$ |
| $\sin^2 \theta_{\text{eff}}$ | 0.2312          | $0.2312 \pm 0.0013$ | $0.2312 \pm 0.0014$ | -4.3%                             | $+0.03 \sigma$ | $+0.03 \sigma$ |

# muon + X (muon P > 10GeV)



CLD



| Parameter                    | Generated value | ILD                 | CLD                 | Rel. diff. error<br>(ILD-CLD)/CLD | Dev. ILD       | Dev. CLD       |
|------------------------------|-----------------|---------------------|---------------------|-----------------------------------|----------------|----------------|
| $\mathcal{A}_\tau$           | 0.14955         | $0.1495 \pm 0.0094$ | $0.1496 \pm 0.0096$ | -2.0%                             | $-0.00 \sigma$ | $+0.00 \sigma$ |
| $\mathcal{A}_e$              | 0.14955         | $0.149 \pm 0.013$   | $0.149 \pm 0.013$   | -3.8%                             | $-0.02 \sigma$ | $-0.02 \sigma$ |
| $g_V/g_A$                    | 0.07520         | $0.0751 \pm 0.0062$ | $0.0751 \pm 0.0064$ | -3.8%                             | $-0.02 \sigma$ | $-0.02 \sigma$ |
| $\sin^2 \theta_{\text{eff}}$ | 0.2312          | $0.2312 \pm 0.0016$ | $0.2312 \pm 0.0016$ | -3.8%                             | $+0.02 \sigma$ | $+0.02 \sigma$ |