First experiences with ILD-FCC and full reco chain in key4hep

$e^+e^- \to \tau\bar{\tau}$ @ 91.2 GeV

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Plan de Recuperación, Transformación y Resiliencia
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GVA NEXT Fondos Next Generation en la Comunitat Valenciana
Gen-T
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Disclaimer: first experience with the tools, so… lots of codex stuff!

Human input from Daniel Jeans and Olmo Arquero. Thanks!

Outline

- **Framework, tools, generator**
- **Looking at the generator level**
- **Efficiency of reconstruction PFOs**
  - For every generator particle (status=2), is there a PFO ?
- **PFO Particle ID performance**
  - For every reconstructed PFO (with MC truth linked) is the PID correct?

Part 1 -
Framework, tools, generator

Samples

- **Central samples from FCC, stdep.**
  - https://fcc-physics-events.web.cern.ch/fcc-ee/gen/winter2023/not-defined/stdhep
  - wzp6_ee_tautau_ecm91p2
  - Gaussian beams → WHIZARD ISR → hard $e^+e^- \to \tau^+\tau^-$ LO process → PYTHIA6 FSR/hadronization → STDHEP

WHIZARD $e^+e^- \to \tau^+\tau^-$	
Generator	**WHIZARD 3.0.3**
Process	$e^+e^- \to \tau^+\tau^-$
Matrix element	LO
\sqrt{s}	**91.2 GeV**
Beam energy spread	**Gaussian · 0.132% / beam**
ISR	WHIZARD · recoil scheme
Final-state shower	PYTHIA6 · FSR ON
Shower ISR	OFF (Pythia)
Hadronization	**PYTHIA6 · ON**
Generator output	STDHEP

Software

SIM/RECO software		
Key4hep release	**2026-08-21**	/cvmfs/sw-nightlies.hsf.org/key4hep/releases/2026-08-21/x86_64-almalinux9-gcc14.2.0-opt/key4hep-stack/2026-08-21-5qmpe6/setup.sh
Platform	x86_64-almalinux9-gcc14.2.0-opt	
Detector model	**ILD_FCCee_v01**	
ILDConfig	production configuration snapshot, Aug. 2026	279b180a88597e45dfaf84f35d1b8b5358300079
MarlinReco	**v1.38.1**	fe8e9e2d08b47048e639c072b7bce97f9847f7d1

Software - DDSIM

```
ddsim \
  --steeringFile ddsim_steer.py \
  --compactFile "$COMPACT_FILE" \
  --inputFiles "$LOCAL_INPUT" \
  --outputFile "$SIM_FILE" \
  --numberOfEvents "$N_EVENTS" \
  --crossingAngleBoost 15.e-3
```

steering

```
Detector              ILD_FCCee_v01
Simulation            DD4hep / ddsim / Geant4

Physics list          QGSP_BERT
Range cut             0.1 mm
Minimum kinetic E     1 MeV

Geant4 decays         disabled
Saved process         Decay

Crossing-angle boost 15 mrad
```

Software - Reco

```
k4run ILDReconstruction.py \
  --detectorModel=ILD_FCCee_v01 \
  --inputFiles="$SIM_FILE" \
  --outputFileBase="$OUTPUT_BASE" \
  --num-events=-1
```

```
EDM4hep SIM
    ↓
Tracker digitisation
TrackingDigi_FCCeeMDI
    ↓
Track reconstruction
TrackingReco_FCCeeMDI
Clupatra + ConformalTracking
    ↓
Calorimeter digitisation / reconstruction
    ↓
PandoraPFA
    ↓
PandoraPFOs
    ↓
EDM4hep REC
```

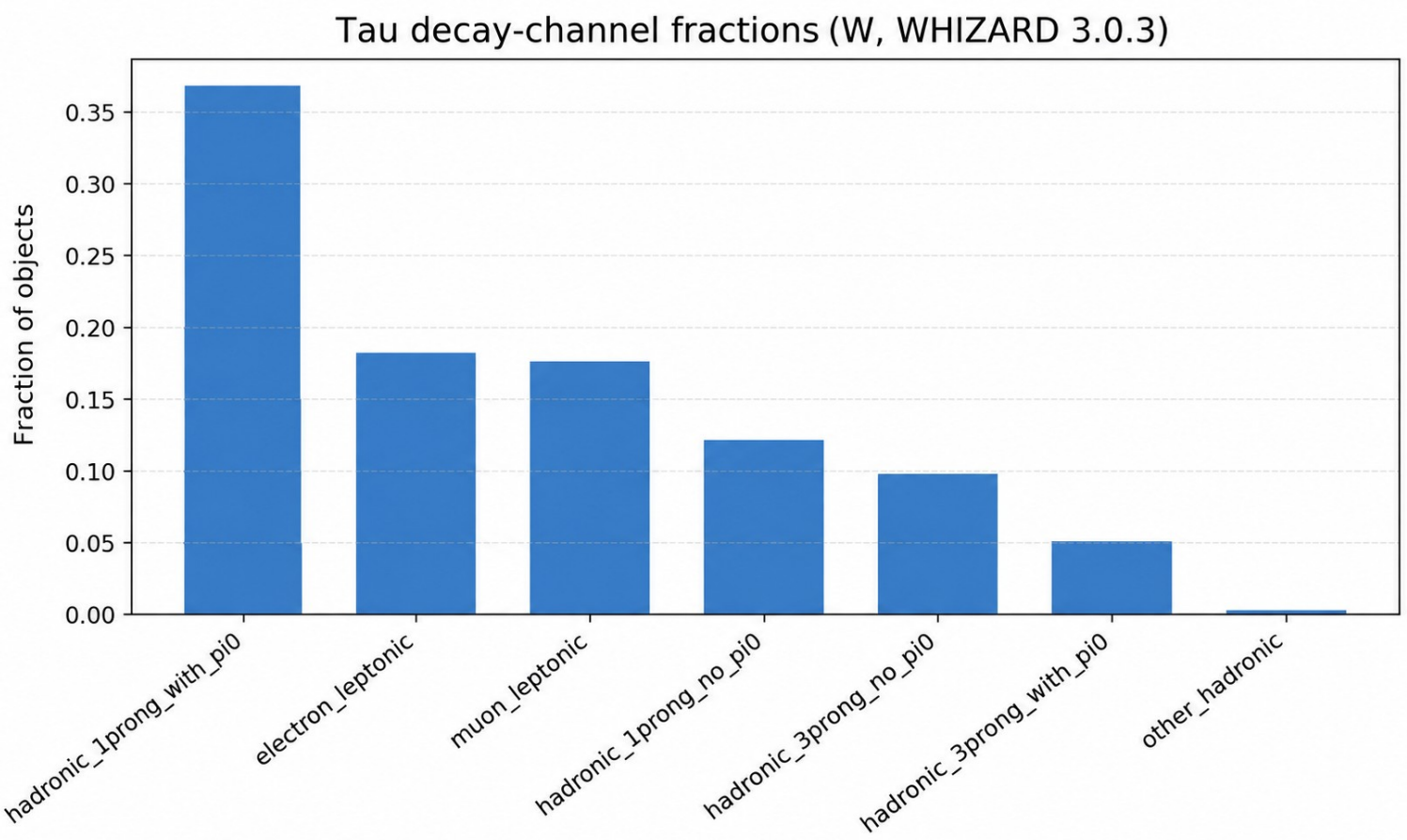
▷ **What about truth-PFO linking ?**

- It was missing in my first in the REC files.
- Added afterwards with REC-only RecoMCtruthLinker

Part 2 -
Monte Carlo Simulation

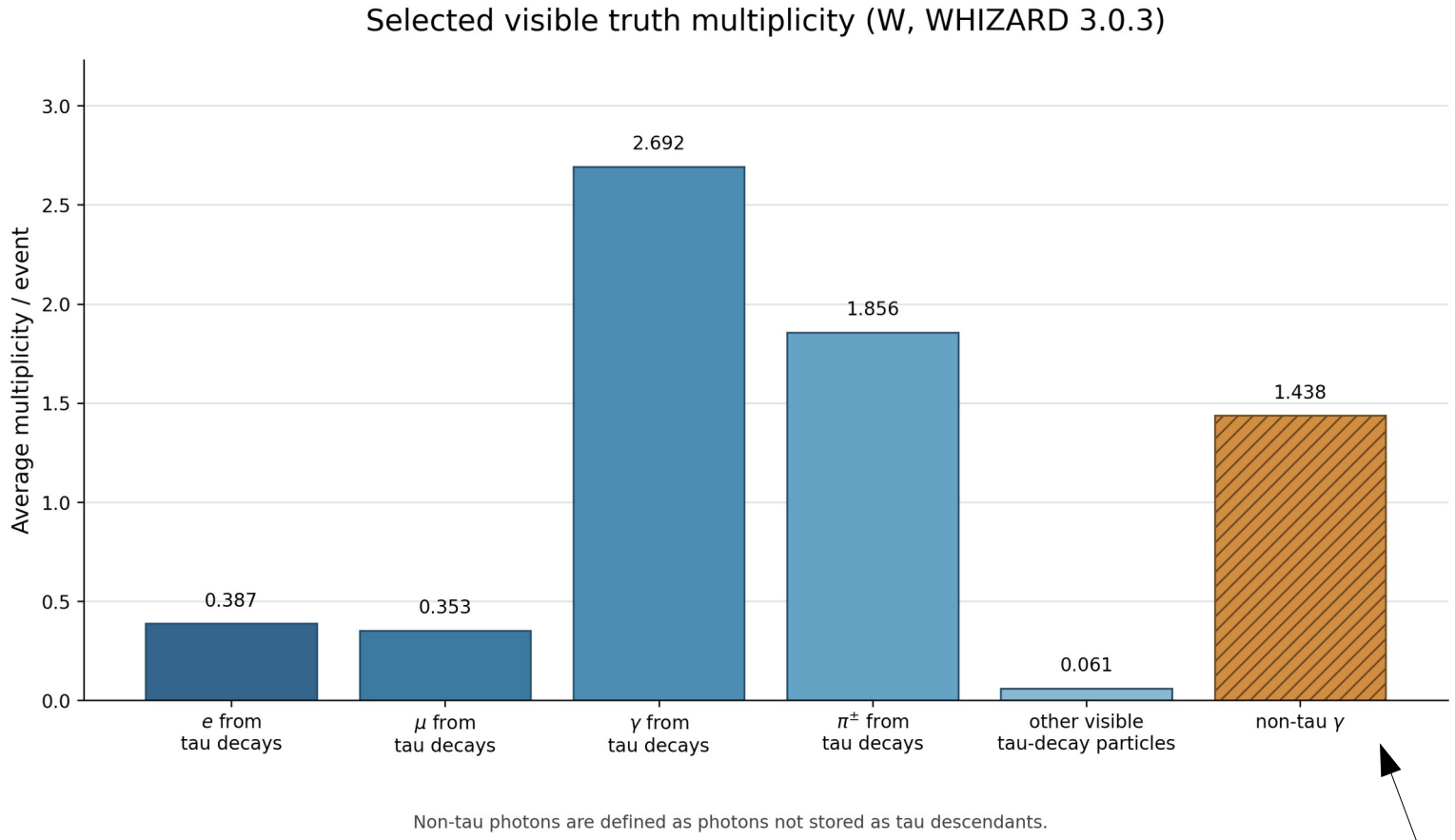
MC truth: decay channels

- Decay channels



MC truth: multiplicity of final state particles

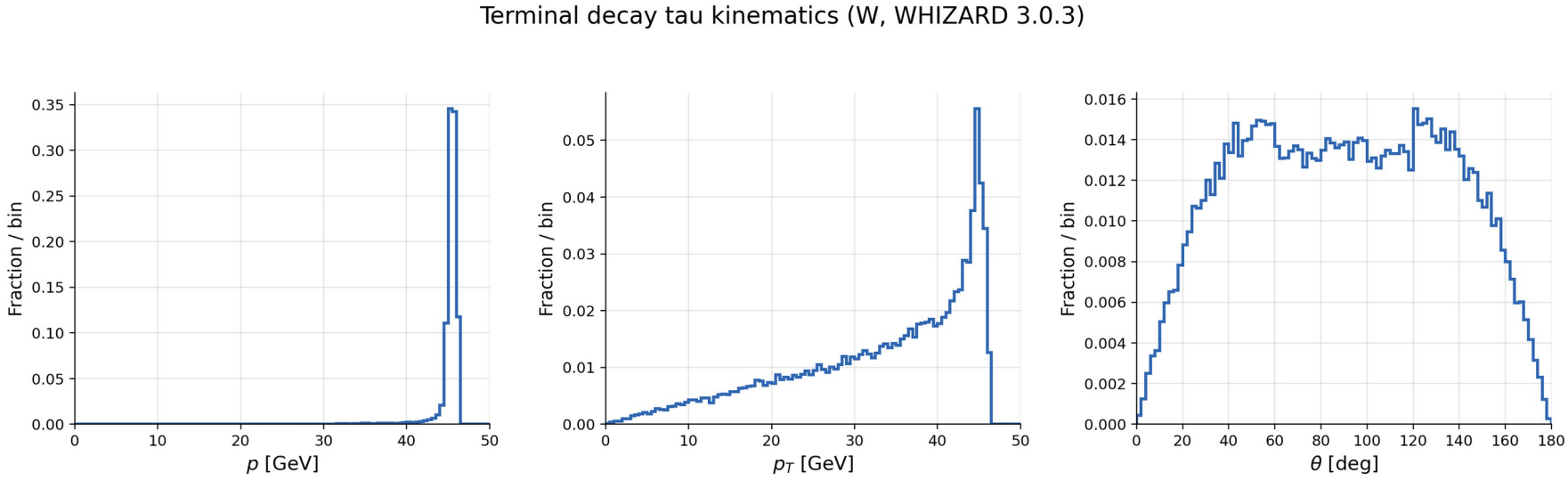
- **Final particle multiplicity**



ISR ?

MC truth: undecayed taus

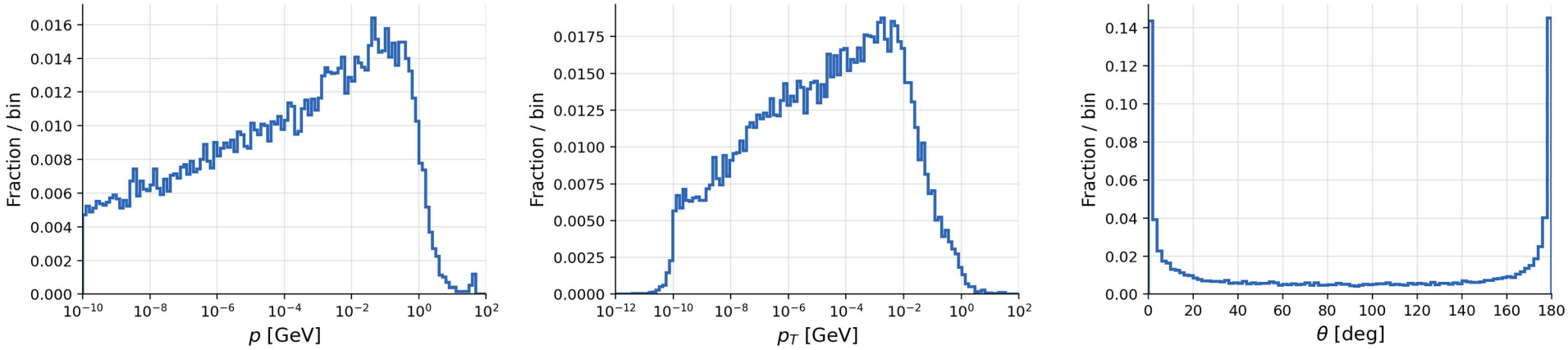
- **Kinematics of (undecayed) taus**



MC truth: final state particles

- **Non-tau photons (ISR?)**

Non-tau photon kinematics (W, WHIZARD 3.0.3)

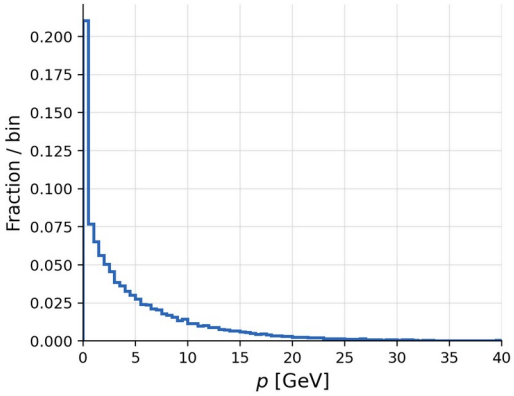


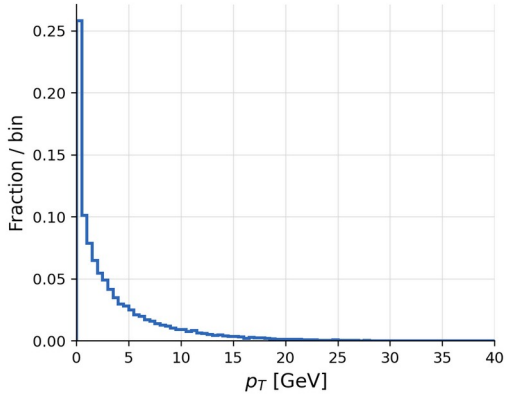
Non-tau photons are defined as photons not stored as tau descendants.

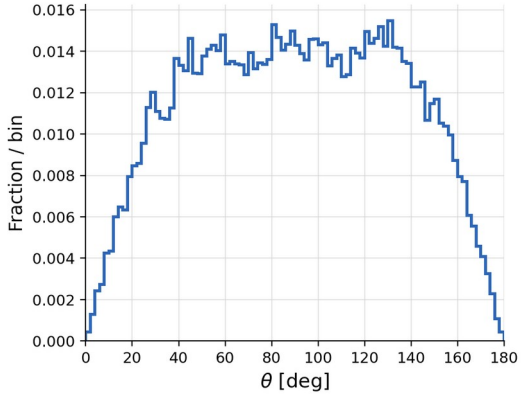
Very low energetic and/or forward

MC truth: final state particles

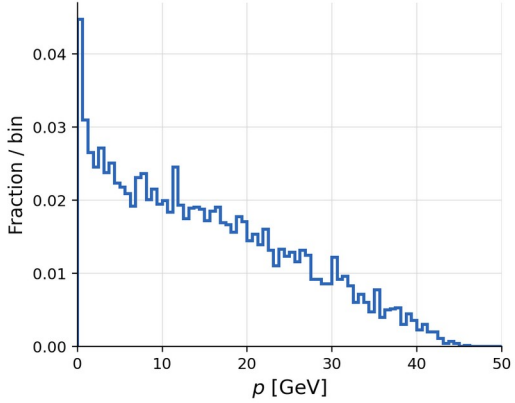
Photon truth from tau decays (W, WHIZARD 3.0.3)

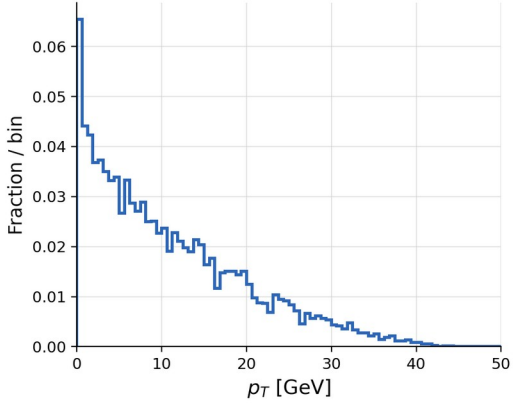


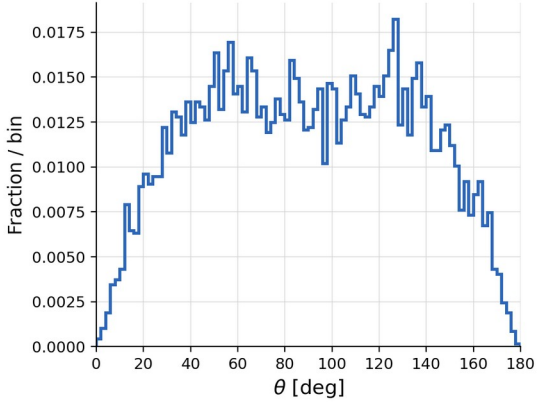




Electron truth from tau decays (W, WHIZARD 3.0.3)

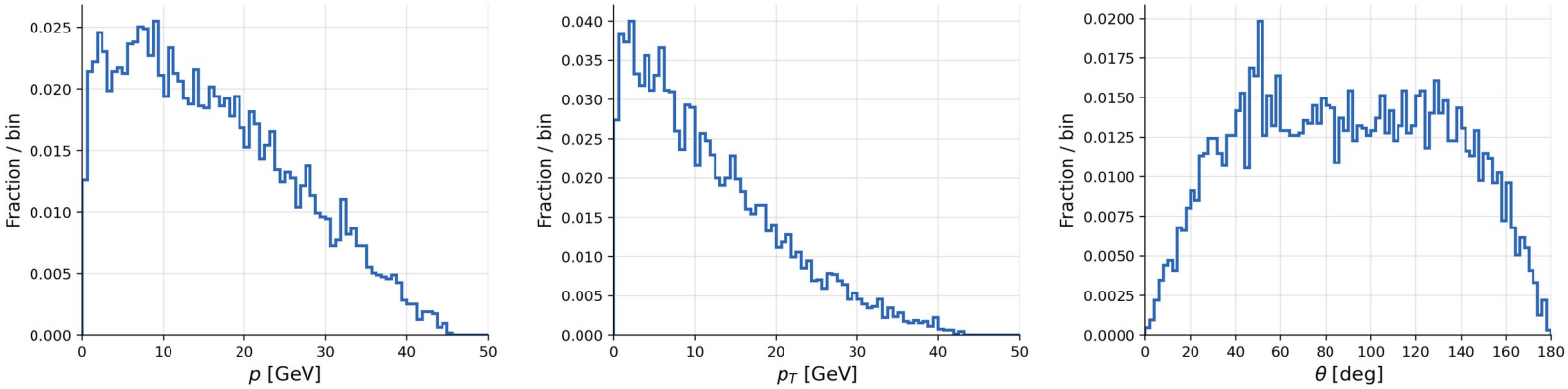




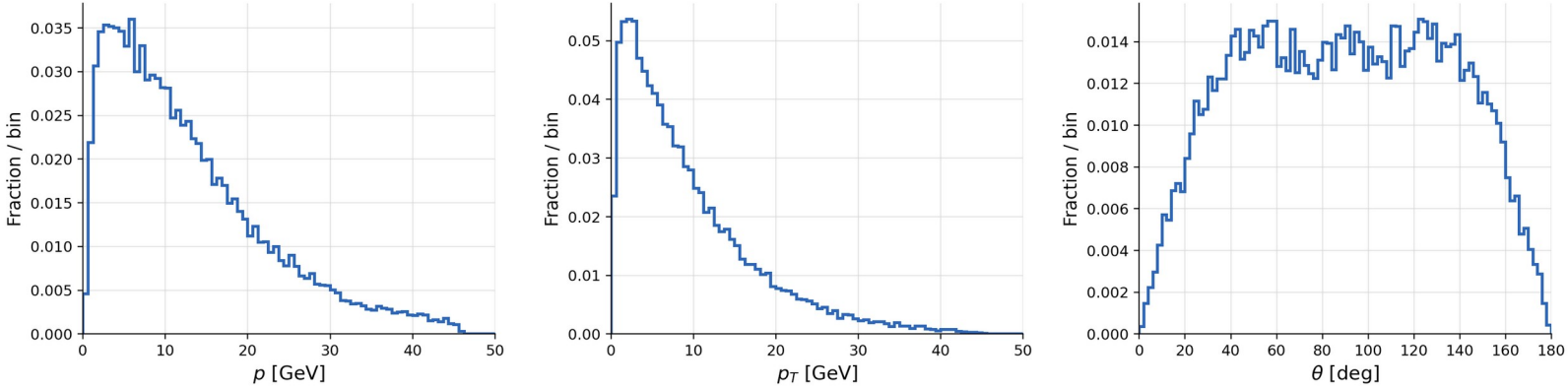


MC truth: final state particles

Muon truth from tau decays (W, WHIZARD 3.0.3)



Charged-pion truth from tau decays (W, WHIZARD 3.0.3)



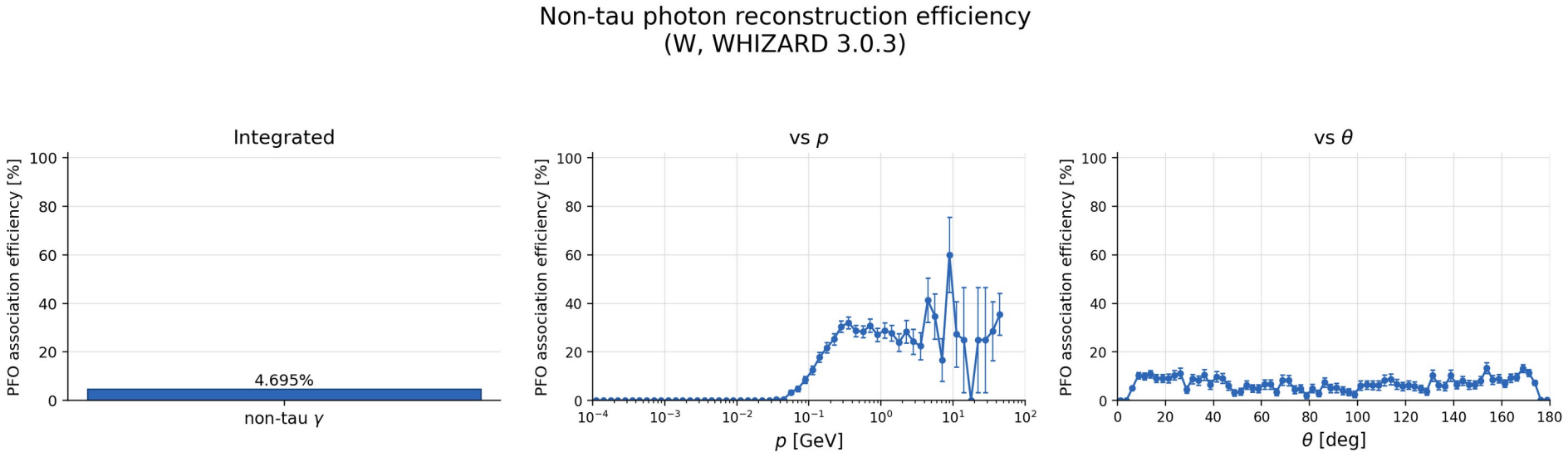
Part 3 -
Efficiency of PFO reconstruction

Efficiency of reconstruction of particles

- For:
  - Muons, charged pions, electrons, photons with generationStatus==1 (final decay products)
  - and ISR photons
- we check if a PFO is reconstructed and associated to it.

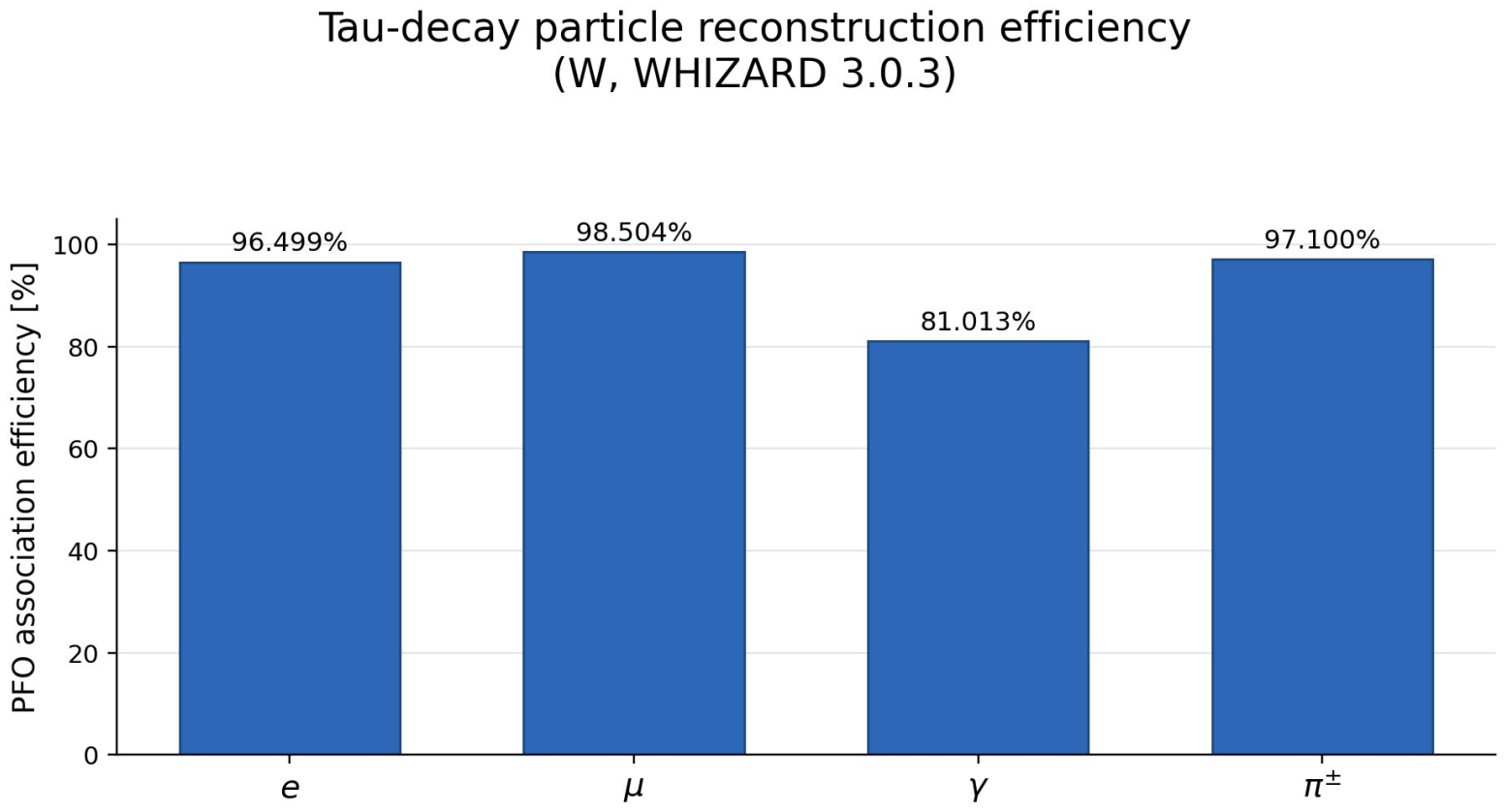
- Note: PFO association is truth-based and ancestry-aware
  - PID is not used in the matching.

ISR photons:



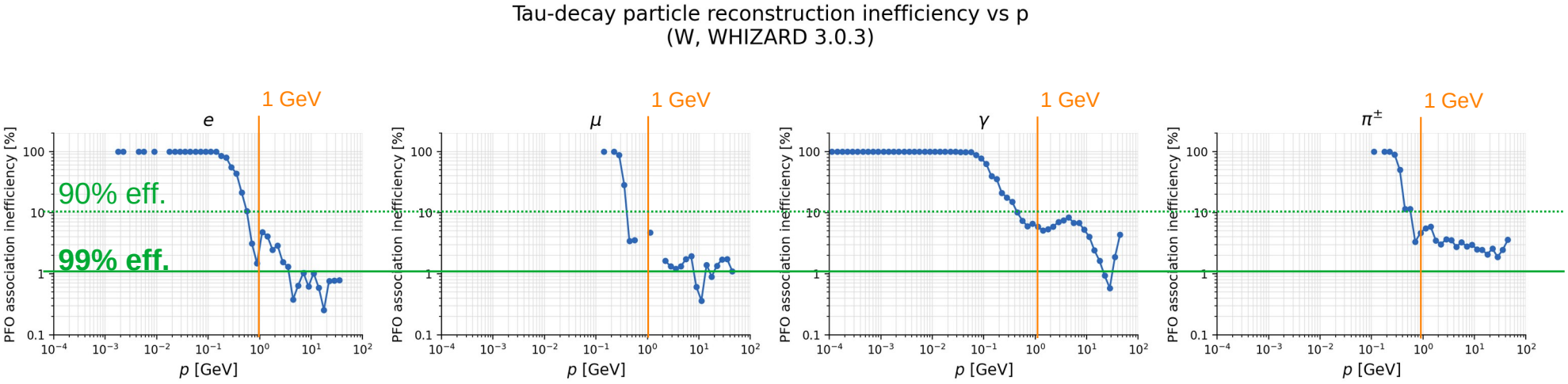
Truth-based, ancestry-aware PFO association; PID not required. Non-tau means not stored as a tau descendant.

Decay products



Truth-based, ancestry-aware PFO association; PID not required.

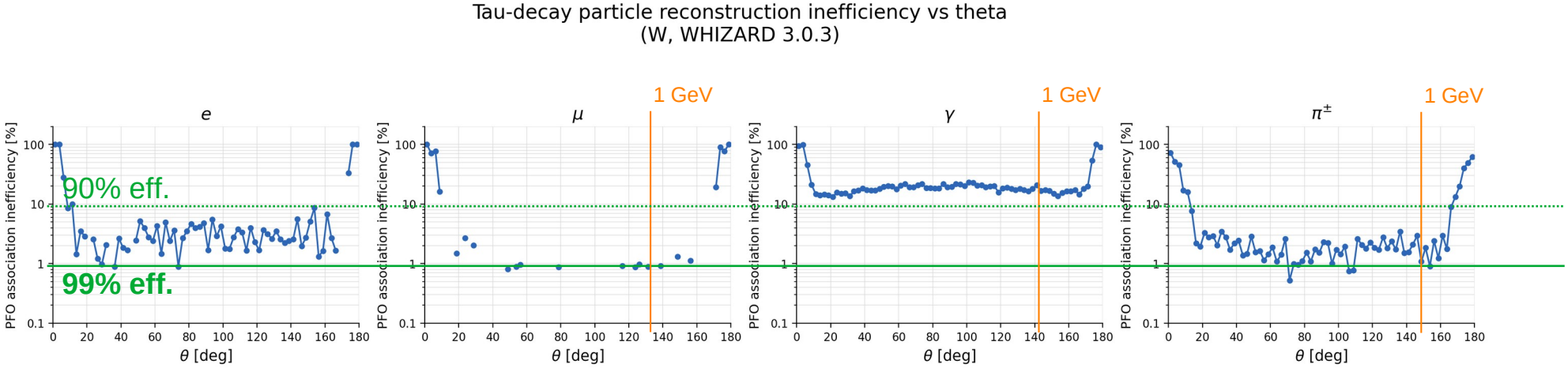
Decay products



Truth-based, ancestry-aware PFO association; PID not required.

This plots should be redone with a meaningful cut in theta acceptance

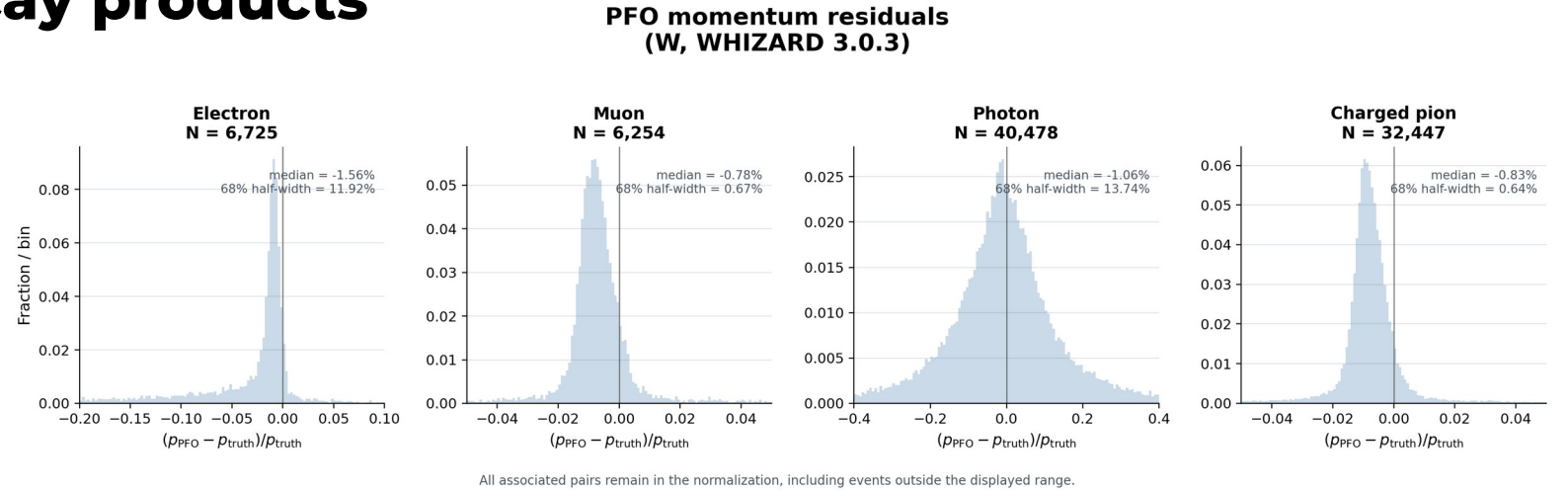
Decay products

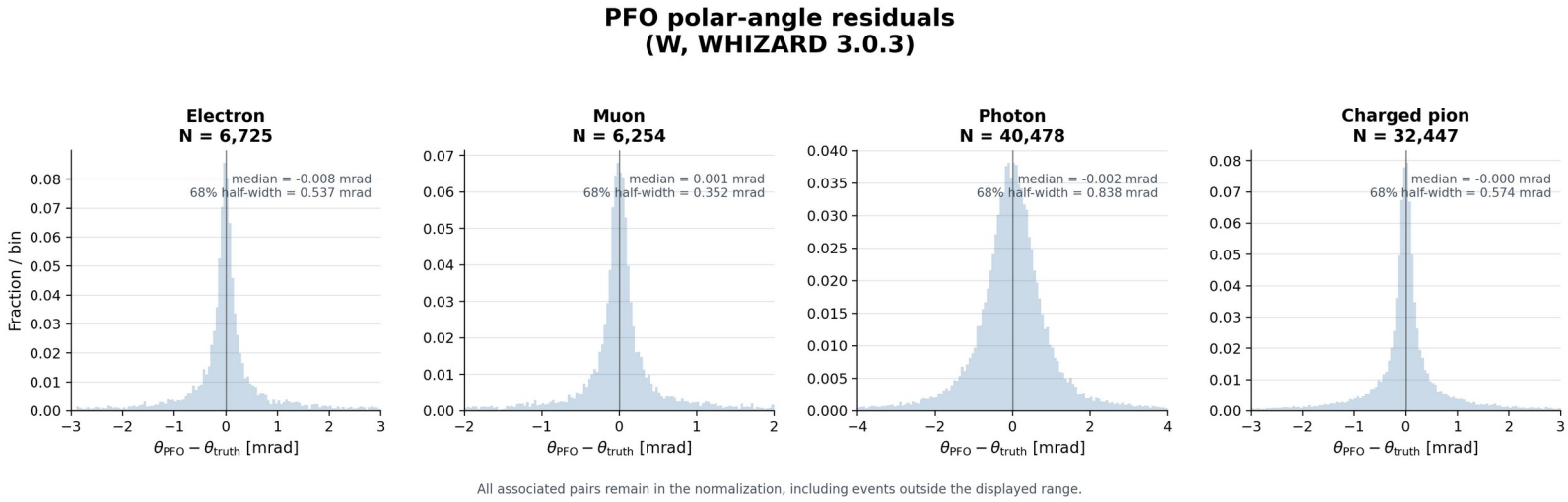


Truth-based, ancestry-aware PFO association; PID not required.

This plots should be redone with a meaningful cut in mom. acceptance

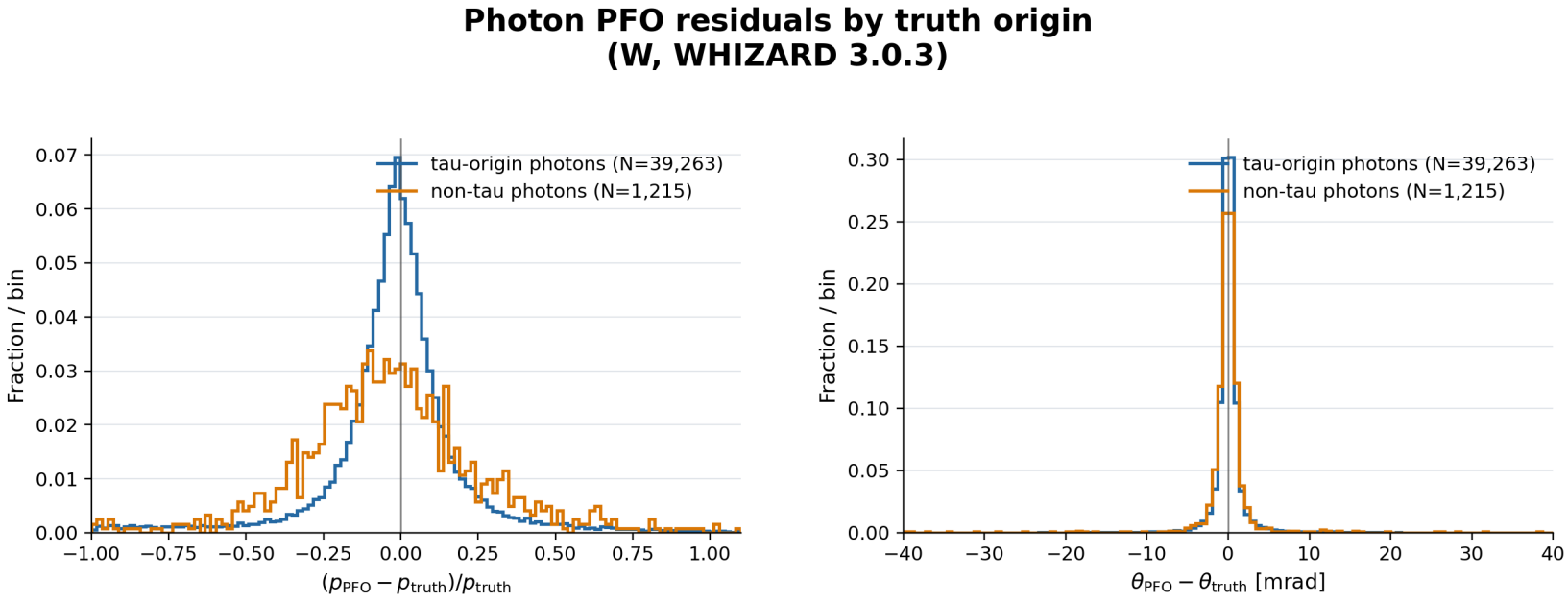
Decay products





This plots should be redone with a meaningful cut in mom/angles. acceptance

Photons



Each origin category is independently normalized to all its associated photon pairs.

This plots should be redone with a meaningful cut in mom/angles. acceptance

Part 4 -
PID efficiency and migration

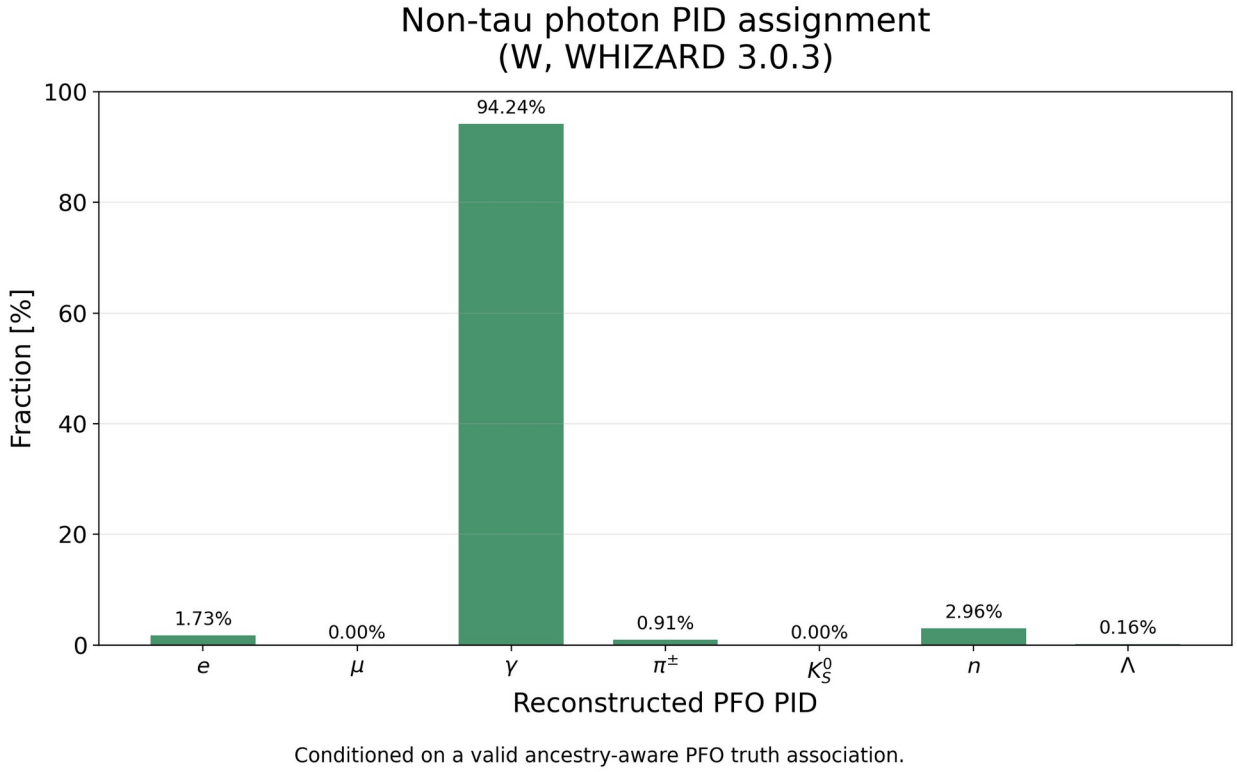
PFO PID efficiency

- **Truth association** used for PID
  - Each reconstructed PFO is linked back through the MC history to the nearest *statusGen==2 Mcparticle*.
  - This recovers cases where the direct truth link points to an intermediate or secondary MC particle.
  - I call this **“ancestor-link”**

- **PFO sample used for the PID eff.**
  - 99.71% of reconstructed PFOs obtain an ***ancestor-link.***
  - The remaining 0.29% are excluded from the PID study.

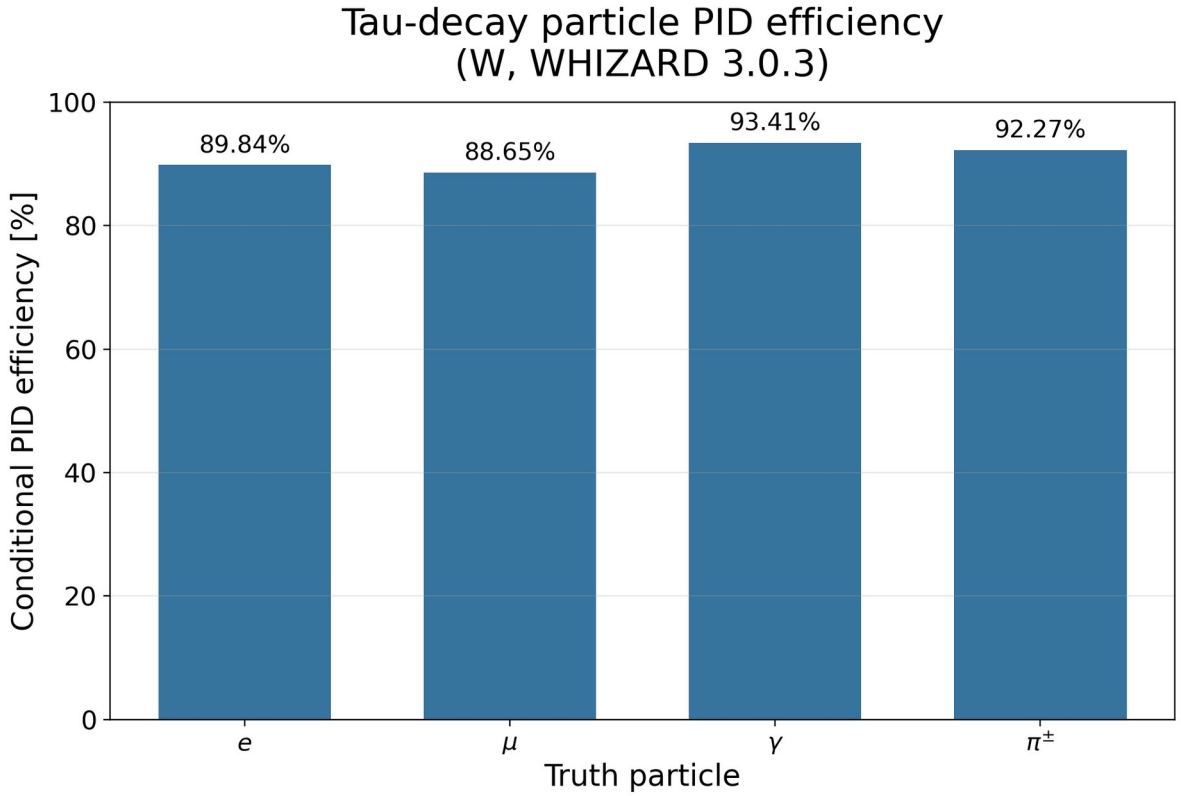
  - *For comparison: with the direct link, 79.98% of PFOs were already linked directly to a statusGen==2 Mcparticle.*

PFO PID efficiency - ISR



This plots should be redone with a meaningful cut in mom./angle acceptance

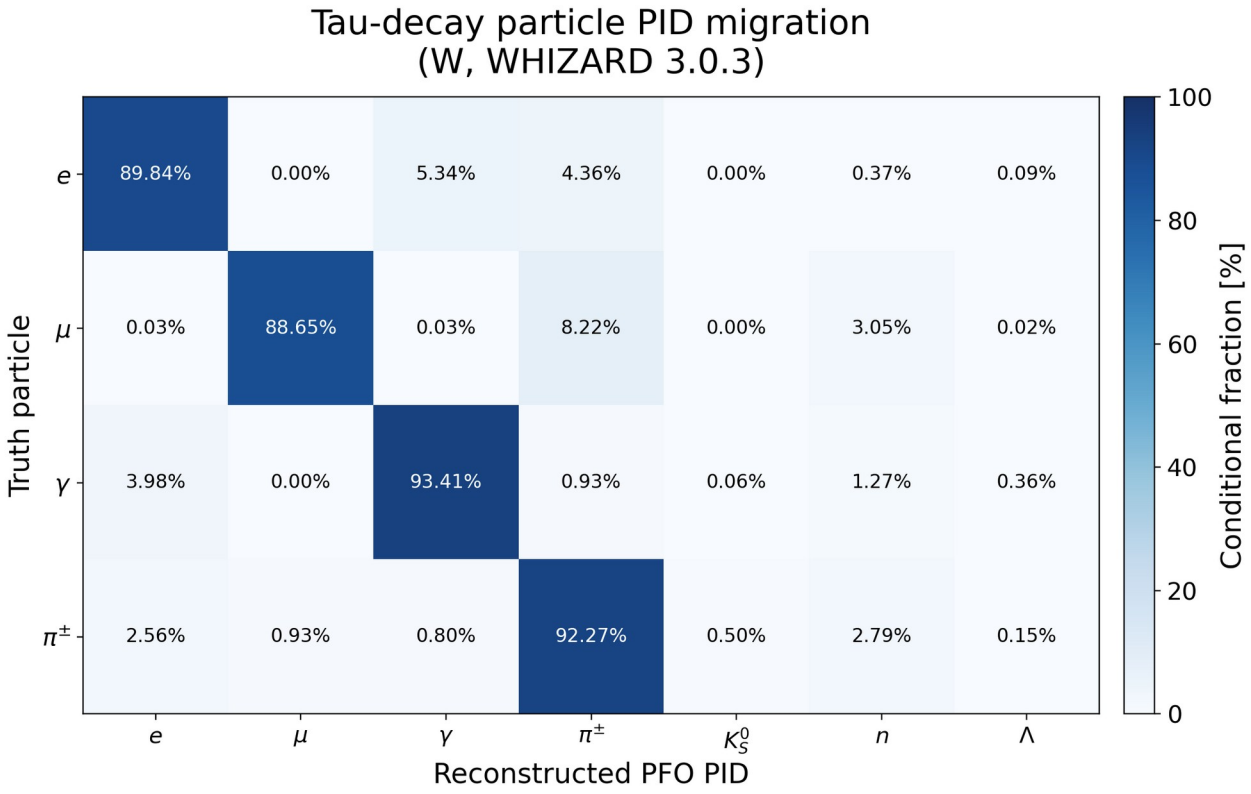
PFO PID efficiency



Conditioned on a valid ancestry-aware PFO truth association.

This plots should be redone with a meaningful cut in mom./angle acceptance

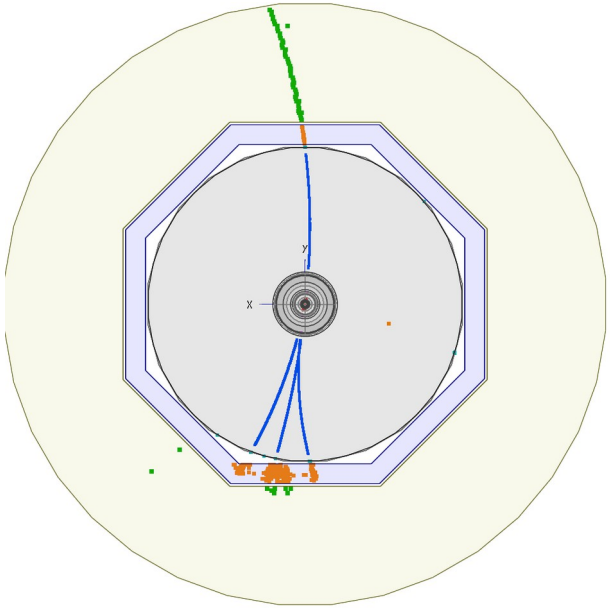
PFO PID efficiency



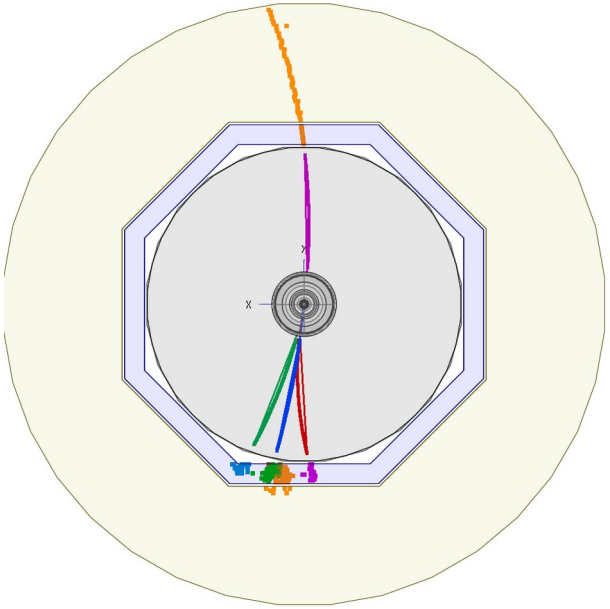
PID evaluated only for PFOs with a valid ancestry-aware truth association.

This plots should be redone with a meaningful cut in mom./angle acceptance

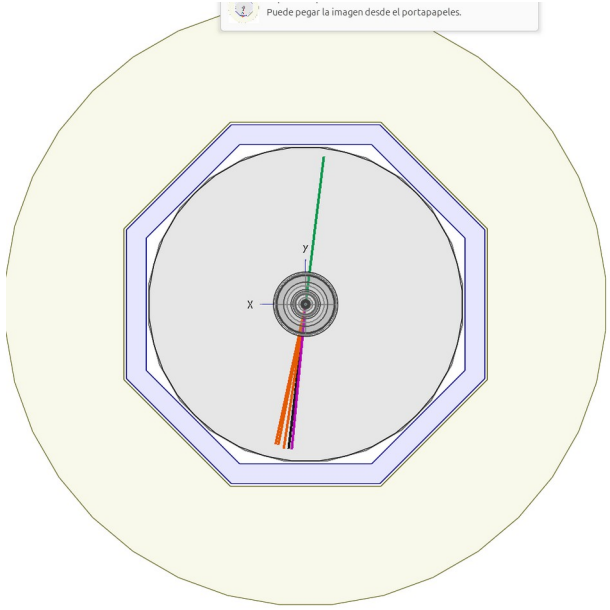
Extra -



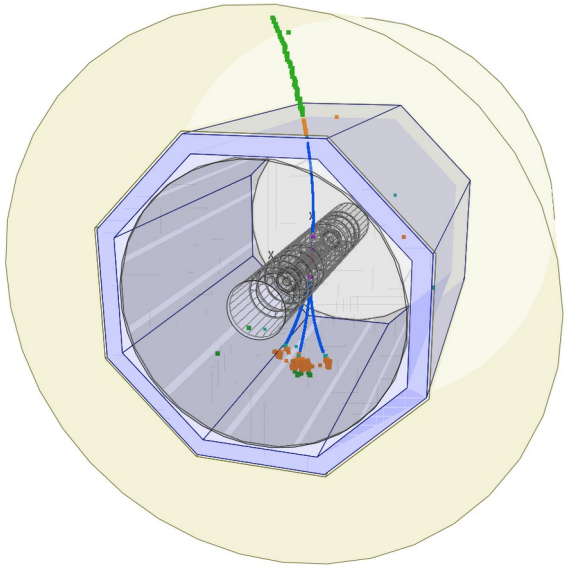
hits



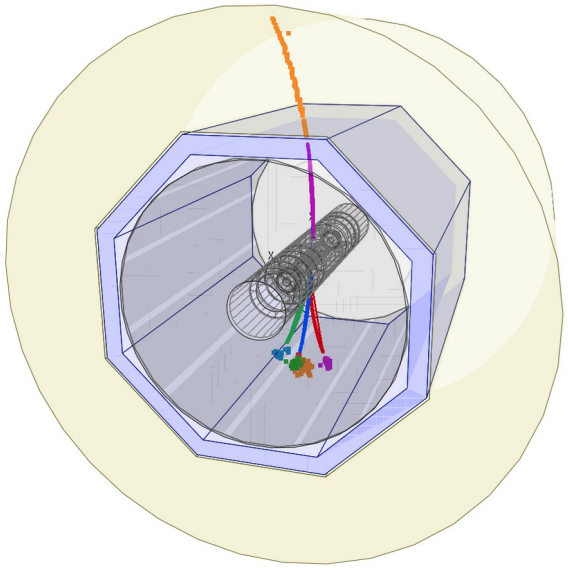
tracks/clusters



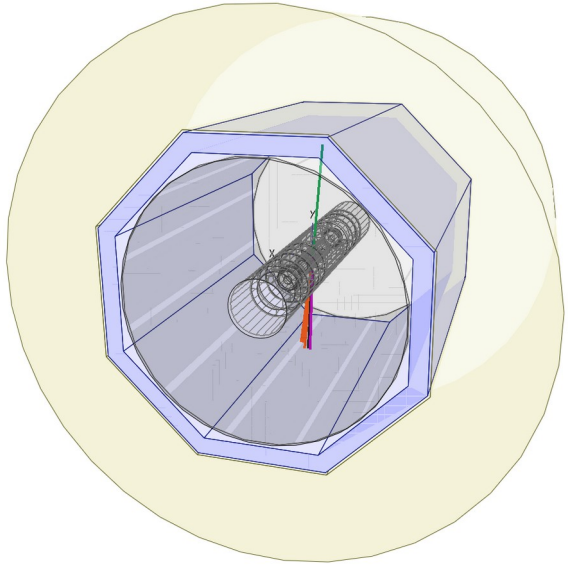
PFOs



hits



tracks/clusters



PFOs

Summary next steps

- This is my first approach to the tau-tau samples and ILD reco in key4hep
- No big surprises / issues found.
- Some preliminary performance plots shown today with only few observables and few particles studied
  - A more comprehensive approach should be followed
  - Also preliminary comparisons between W+P6, Pythia8, KKMCee (not shown here)

- ILD reco (and geo) is in continuous evolution
  - (I) Should keep (better) track of it

- Physics goal
  - Integrate this effort with other ongoing activities on tau-tau for FCC. Under discussion.