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Fakultät Physik
Université Clermont Auvergne
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Study of electroweak observables in the heavy flavour sector at FCC-ee

$$D^0 \rightarrow \pi^0\pi^0 \rightarrow 4\gamma$$

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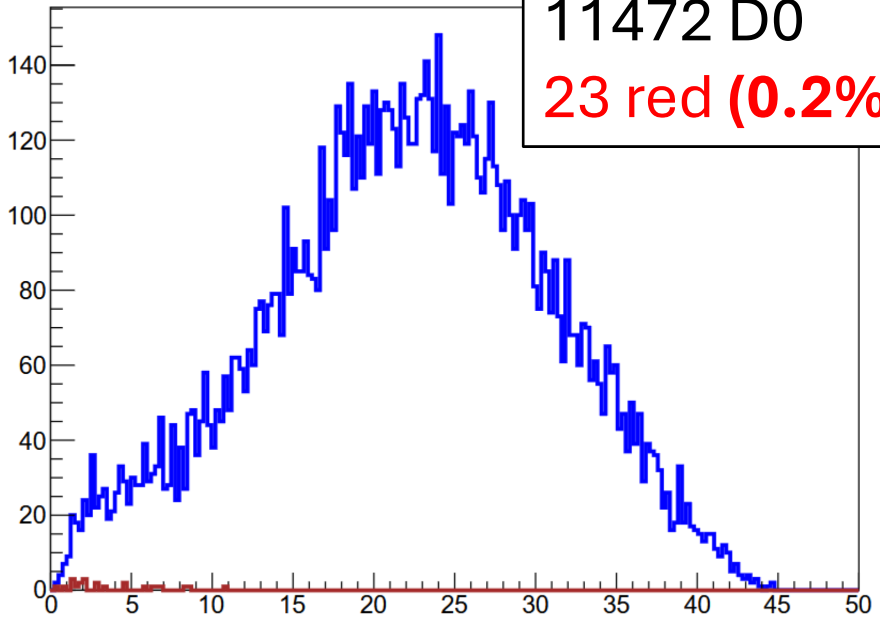
D0 populations in the samples

$e^+e^- \rightarrow cc$

- **Last time:**



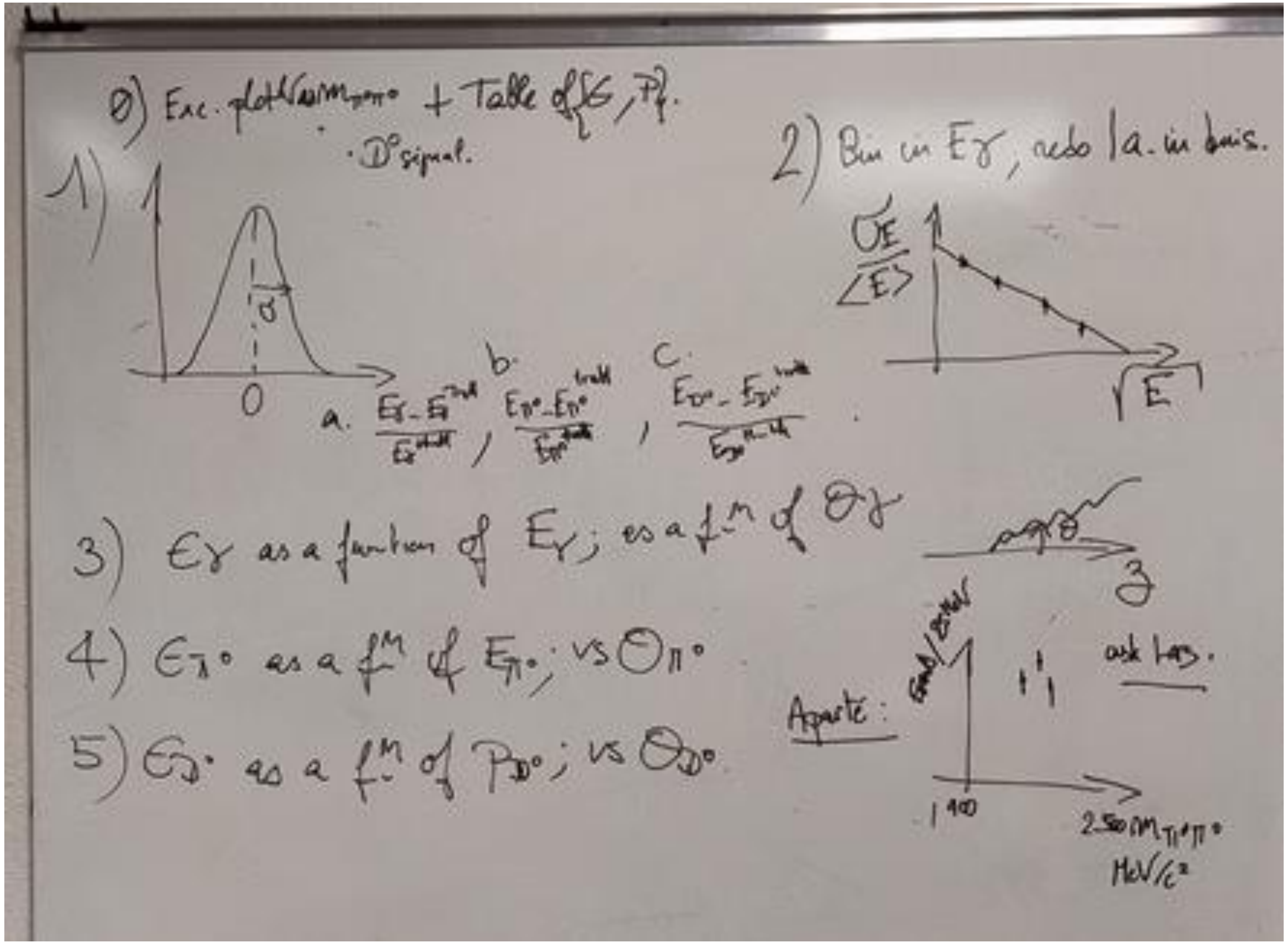
10k events
11472 D0
23 red **(0.2%)**

- **Re-run with higher event number:**

100k events
115k D0
493 red
(0.43 +/- 0.02) %

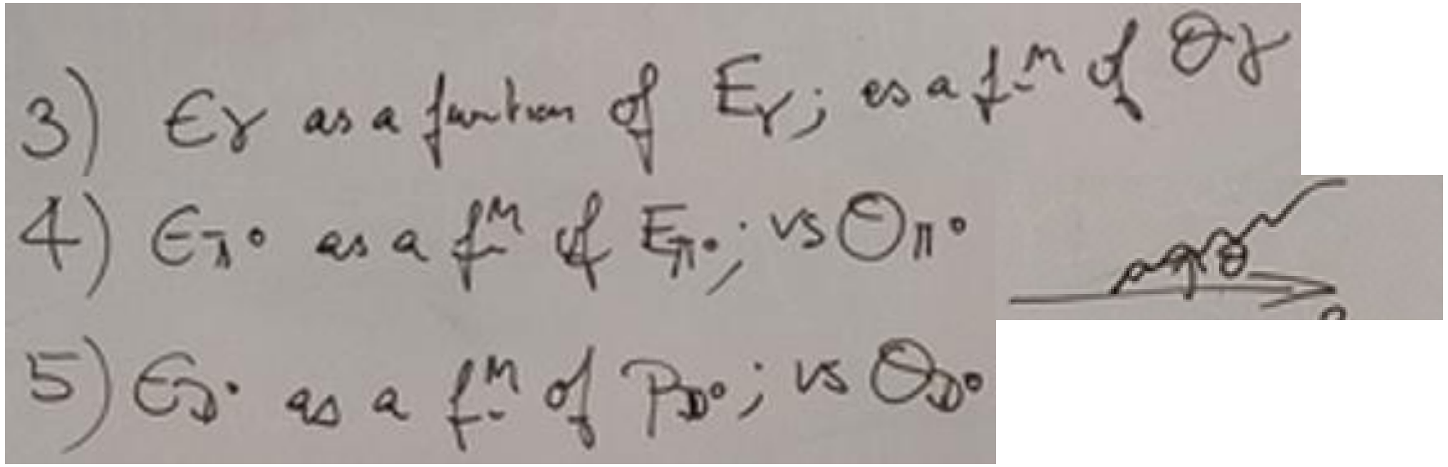
250k events
286k D0
1179 red
(0.411 +/- 0.012) %

Picture of the whiteboard (next steps)

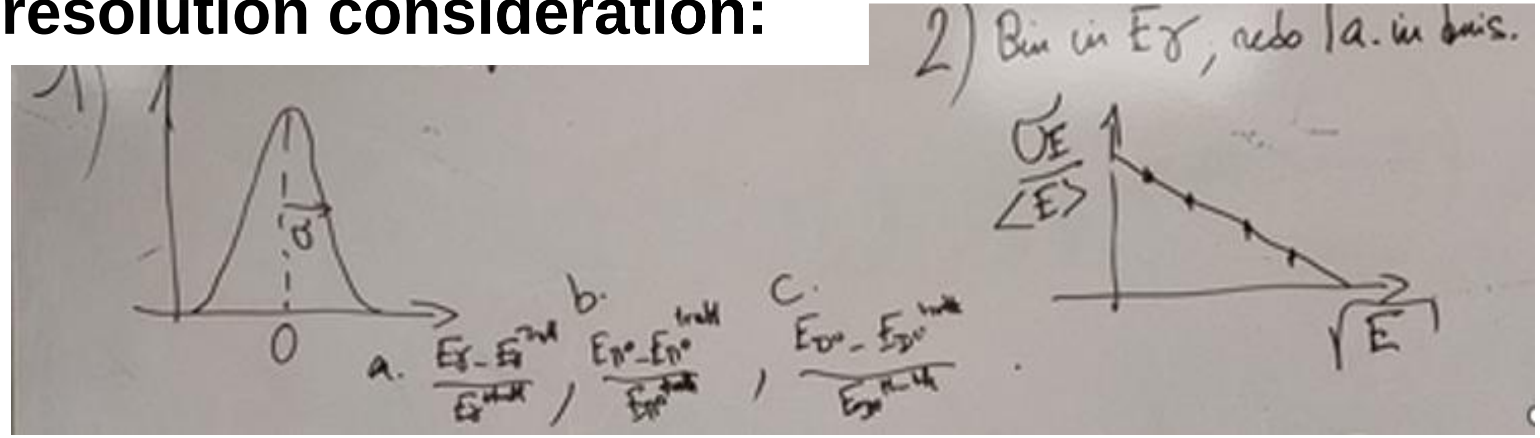


Picture of the whiteboard (next steps)

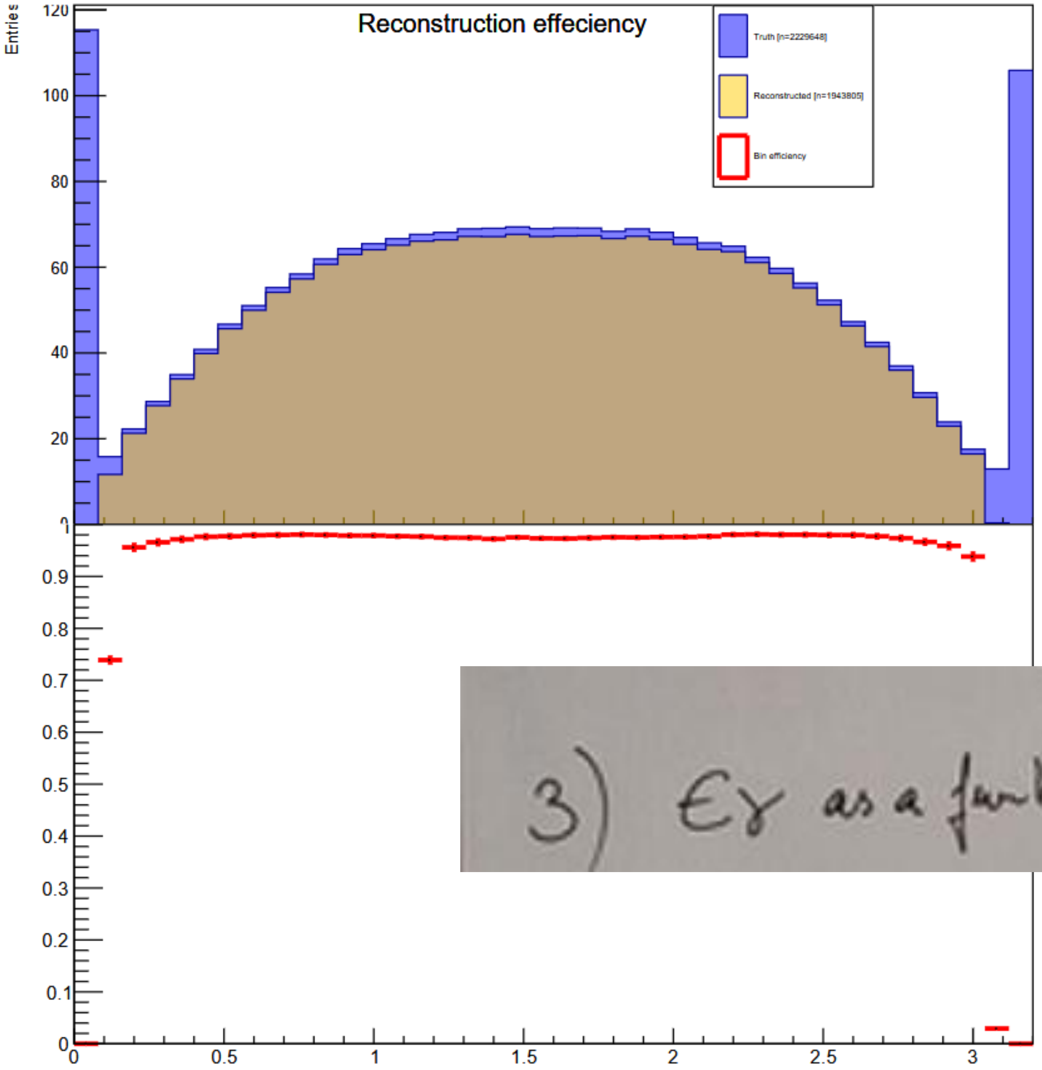
- **Efficiency consideration:**

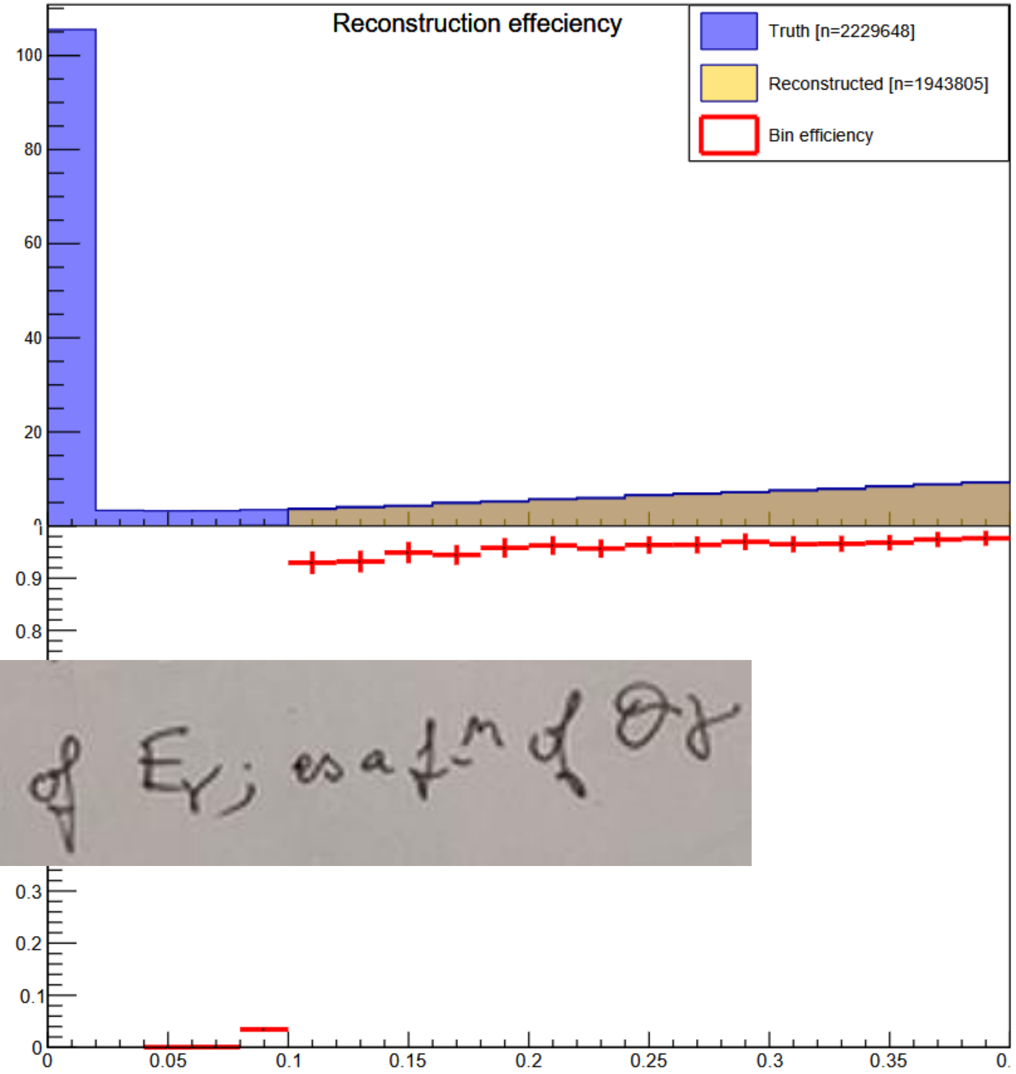


- **Energy resolution consideration:**



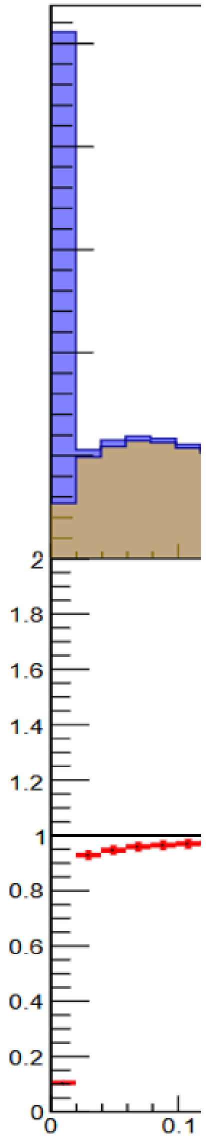
Reconstruction effeciency vs. photon angle



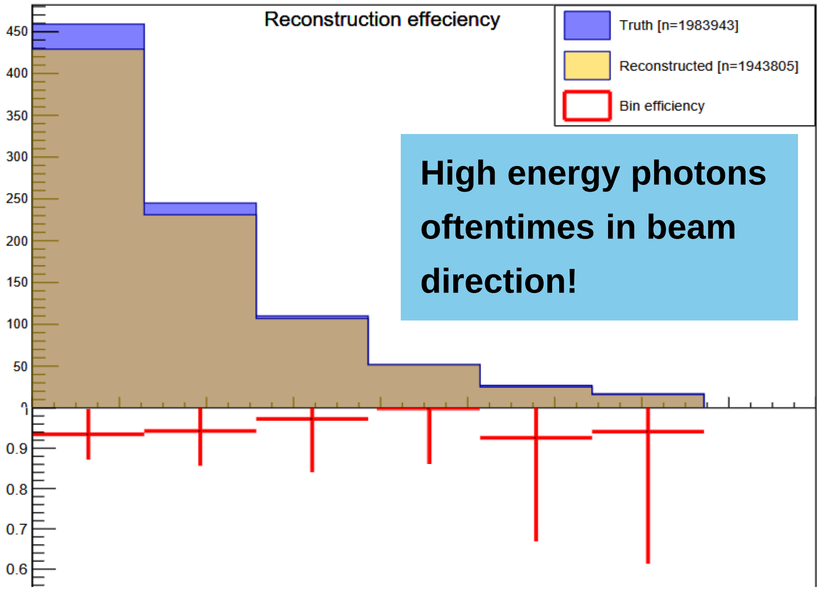


3) ε_γ as a function of E_γ; as a f^n of θ_γ

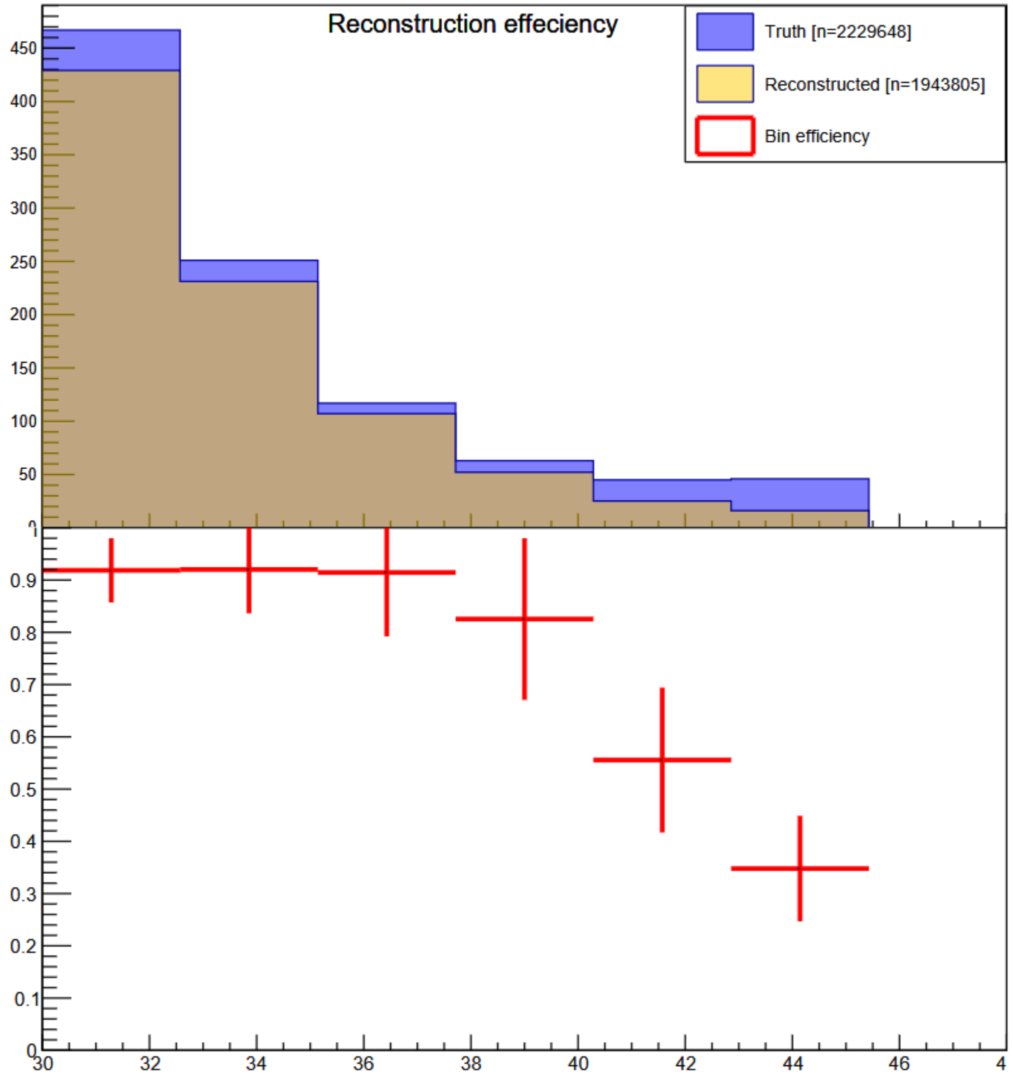
Reconstruction effeciency vs. photon energy



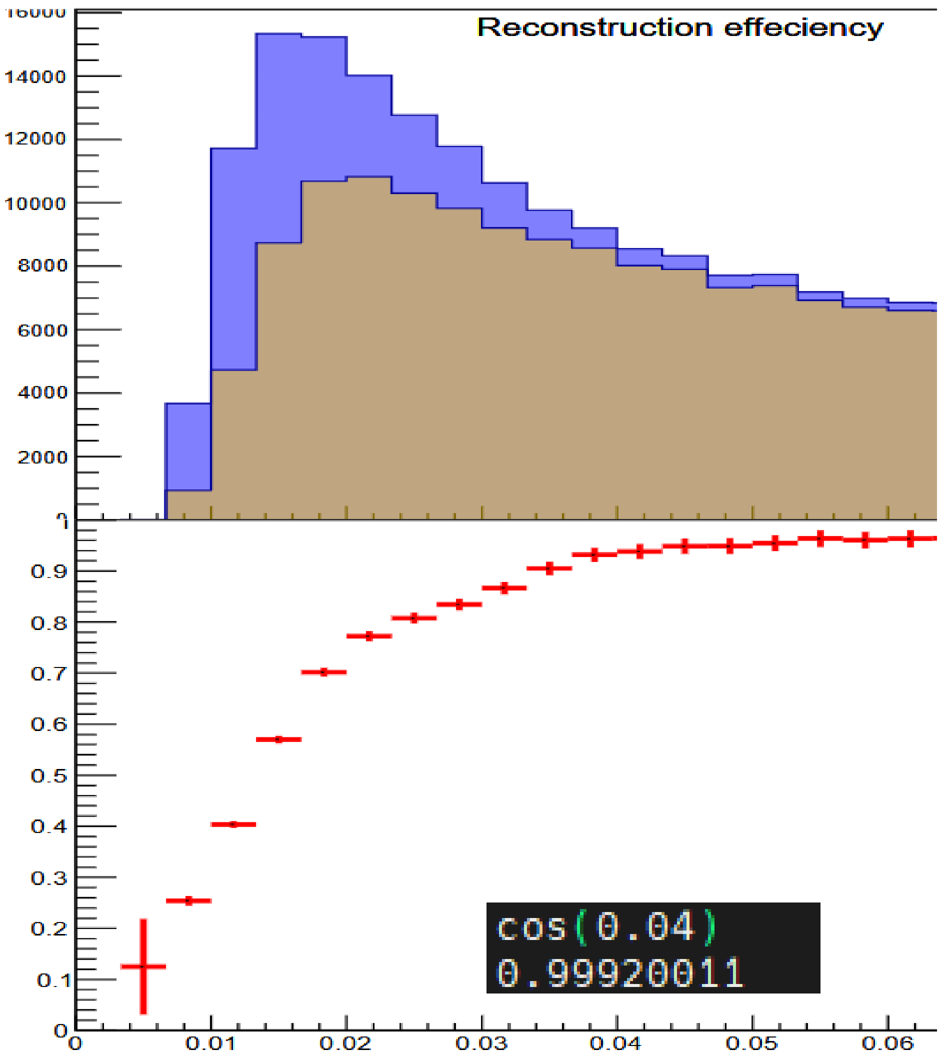
- Reconstruction effeciency shrinks for **low** and **high energy** photons



High energy photons oftentimes in beam direction!



Angle of a photon pair from a pion

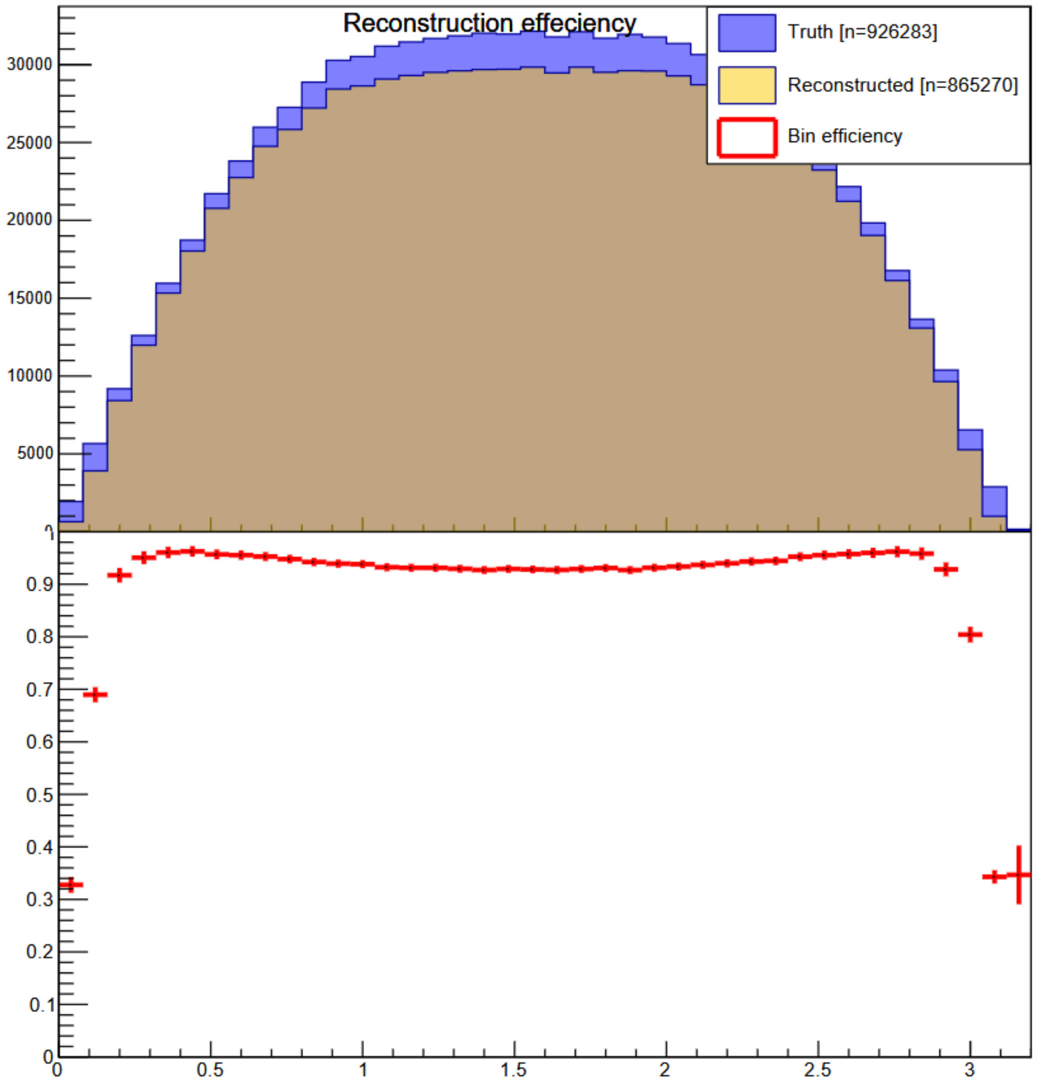


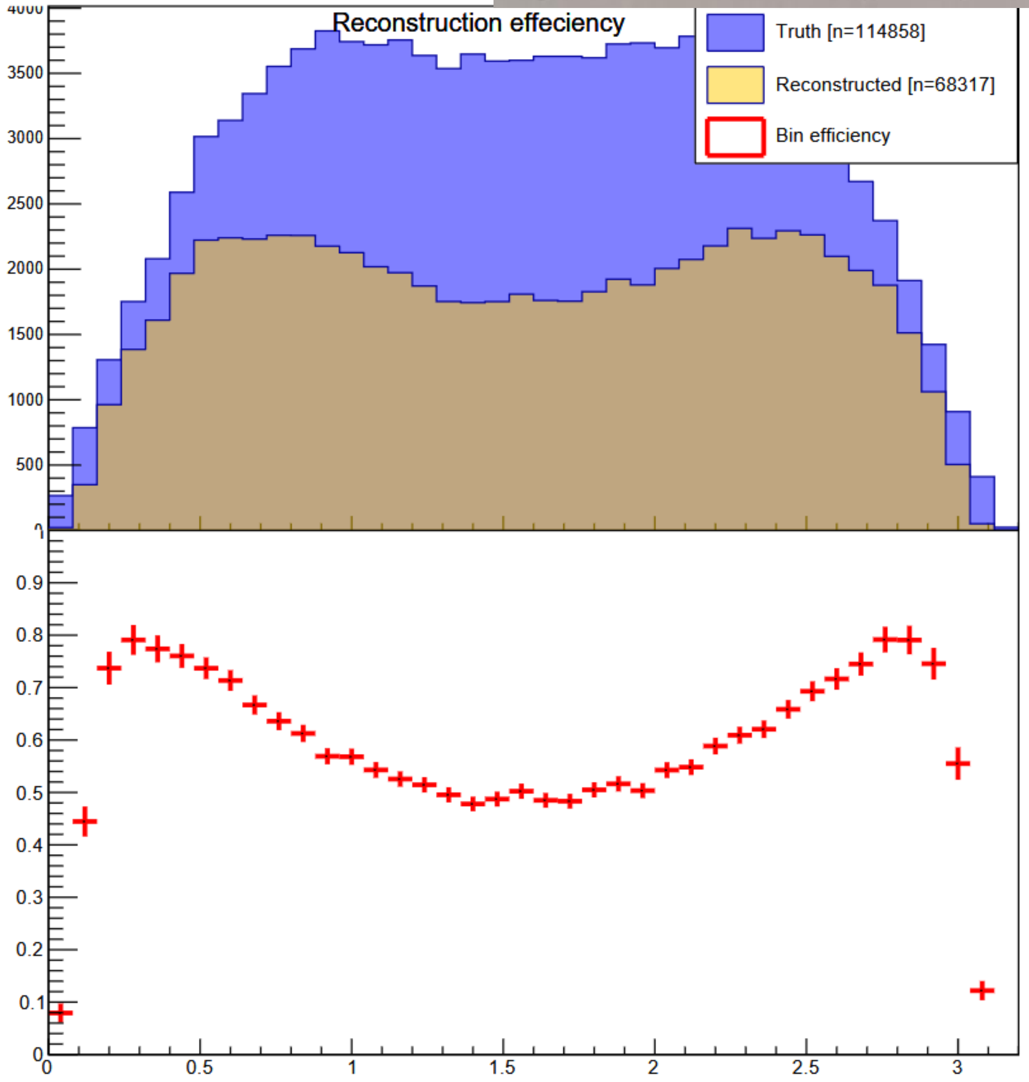
- The **smaller** the **angle**, the **greater** the **boost** of the decay
- Photons with a very **small angle** are **likely** to hit the **same detector element**

P0 & D0 Effeciency

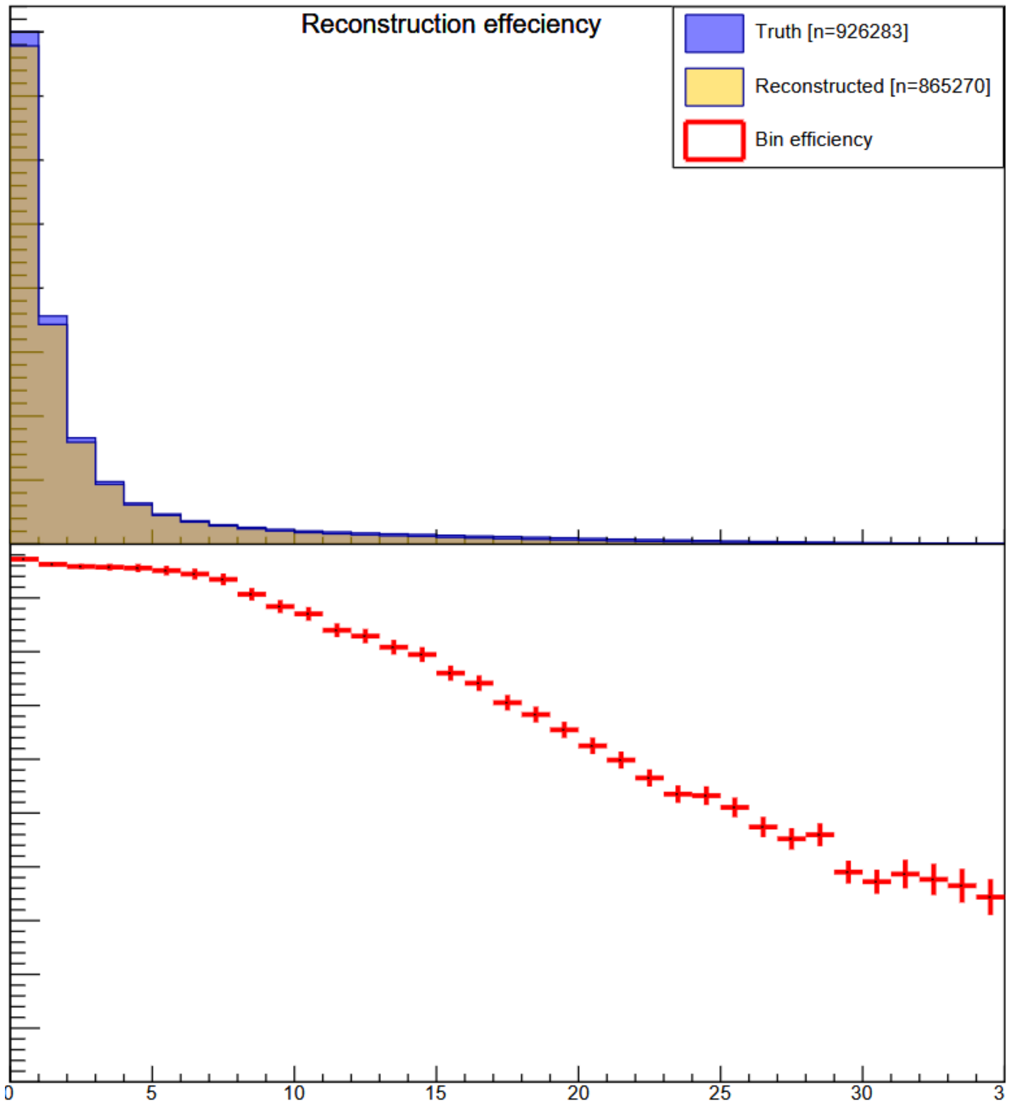
4) ϵ_{π^0} as a f^n of E_{π^0}; vs Θ_{π^0}

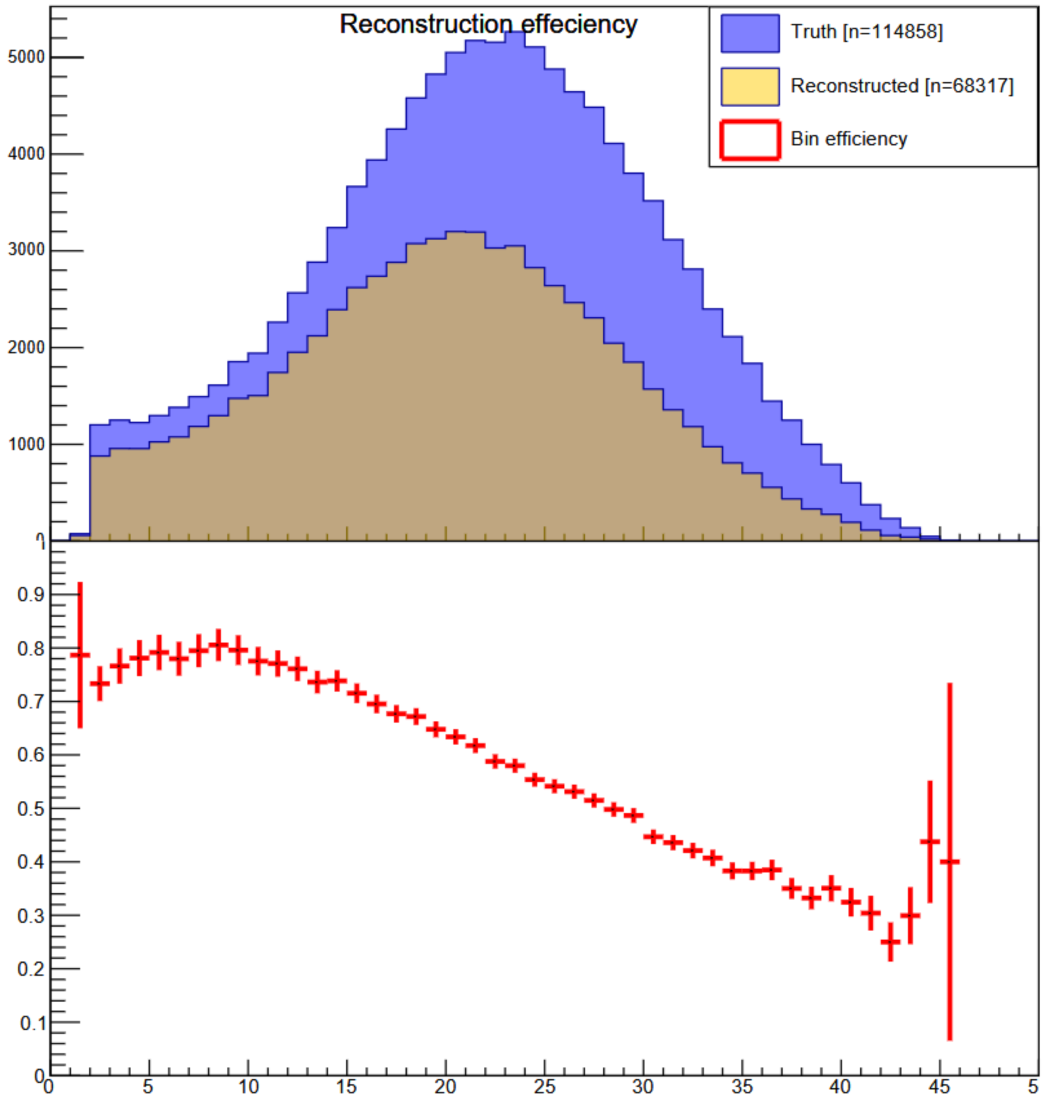
5) ϵ_{D^0} as a f^n of P_{D^0}; vs Θ_{D^0}





Decrease for high energies





What are we able to reconstruct?

$$D^0 \to \pi^0\pi^0 \to 4\gamma$$

100%

97.66%

```
Decay D0
    1.0     pi0  pi0        PHSP;
Enddecay
Decay anti-D0
    1.0     pi0  pi0        PHSP;
Enddecay
End
```

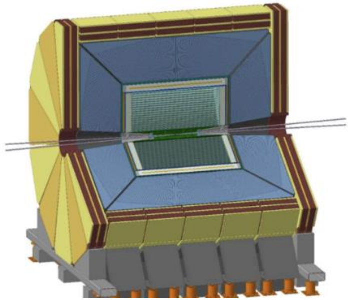
π^0 DECAY MODES

For decay limits to particles which are not established, see the appropriate Search sections (A^0 (axion) and Other Light Boson (X^0) Searches, etc.).

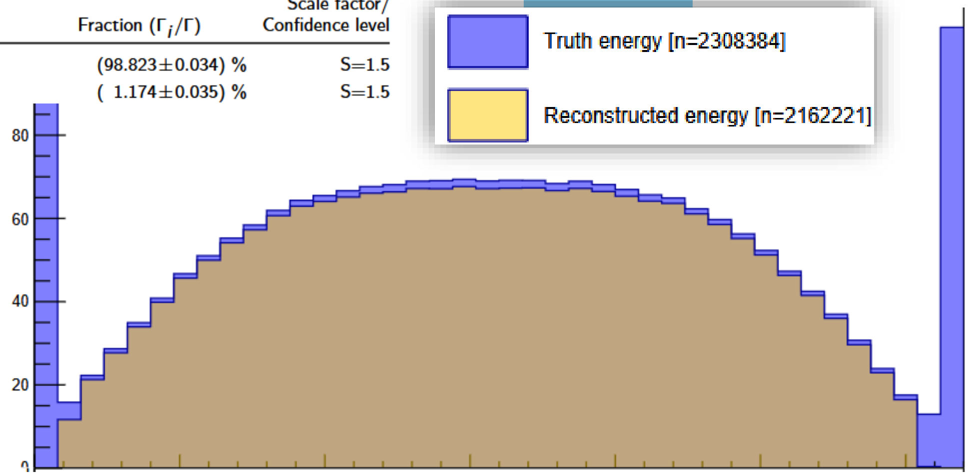
Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
2γ	(98.823 ± 0.034) %	S=1.5
$e^+e^-\gamma$	(1.174 ± 0.035) %	S=1.5

D^0 DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
	Pionic modes		
Γ_{141}	$\pi^+\pi^-$	$(1.454\pm0.024)\times10^{-3}$	S=1.4
Γ_{142}	$2\pi^0$	$(8.26\pm0.25)\times10^{-4}$	



93.67%



Photon angle

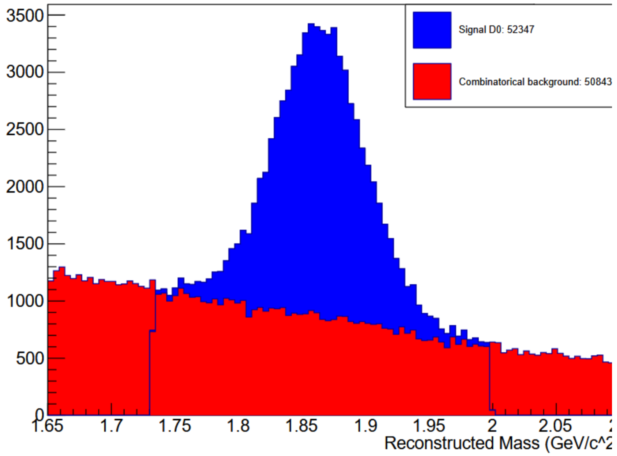
.root

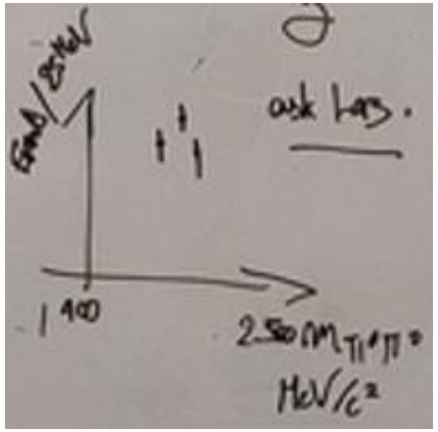
91.47%

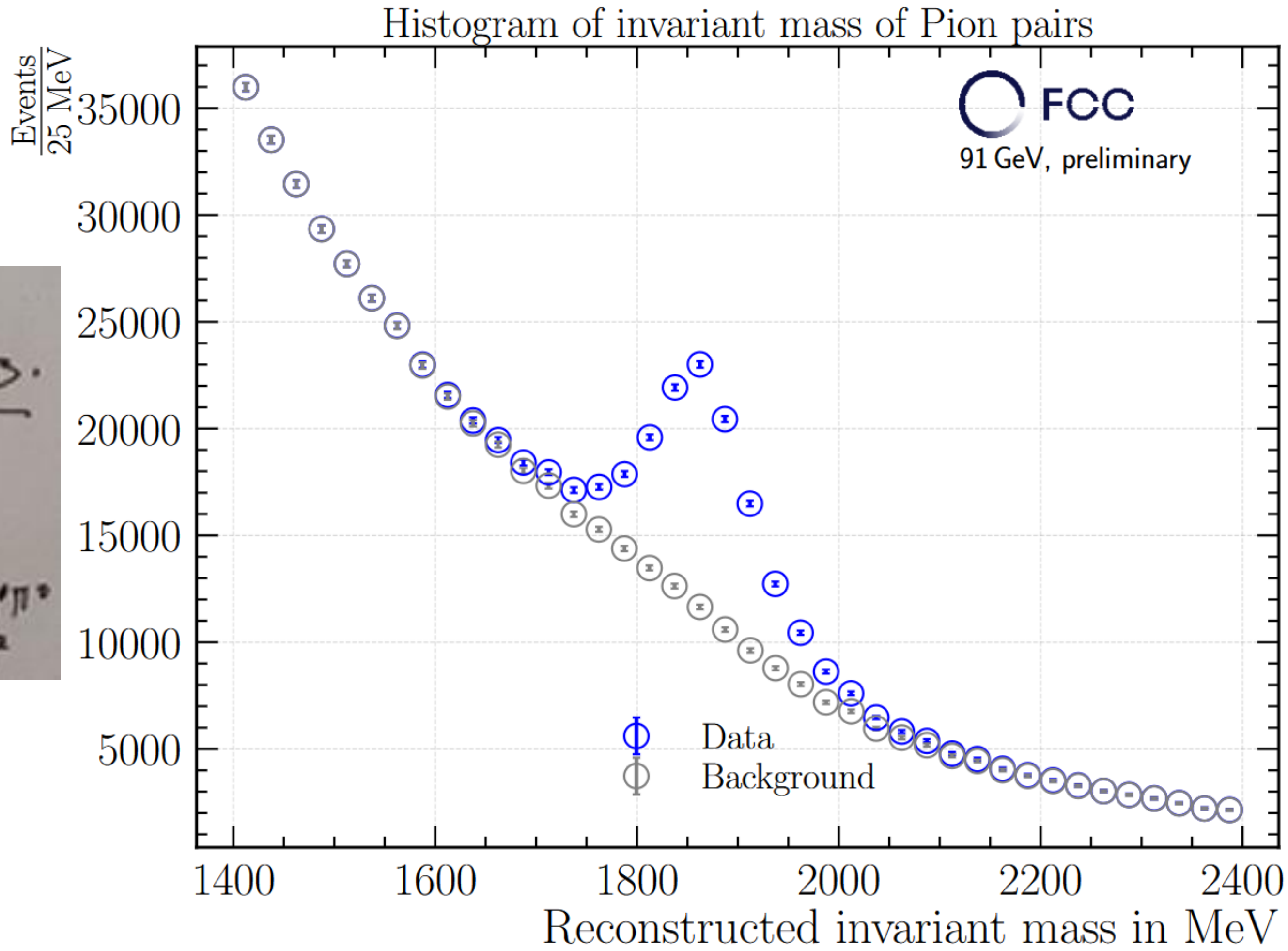
- Includes cases where photons share clusters, requiring advanced reconstruction algorithms

In future compare to this value?!

Aparte:



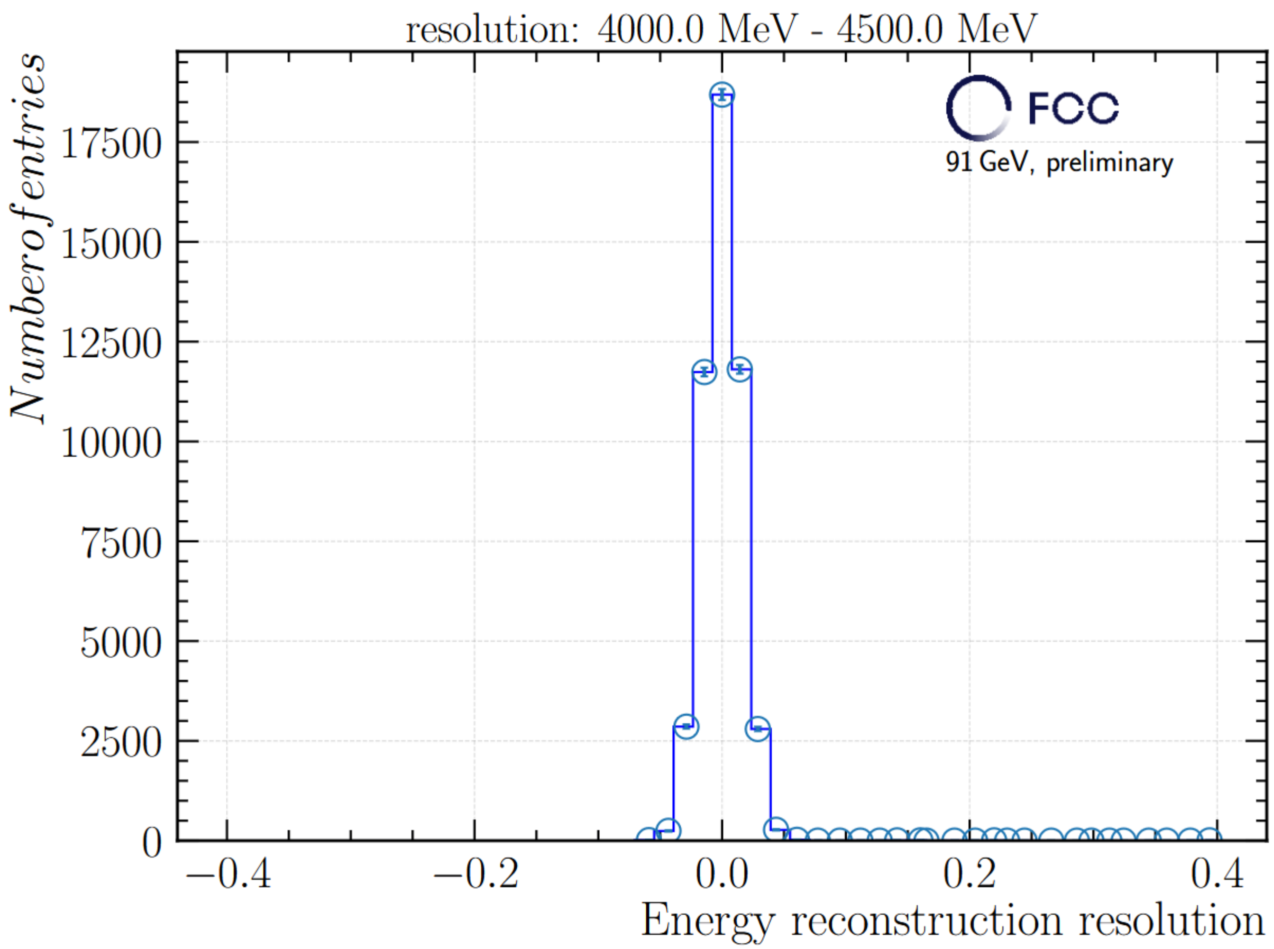


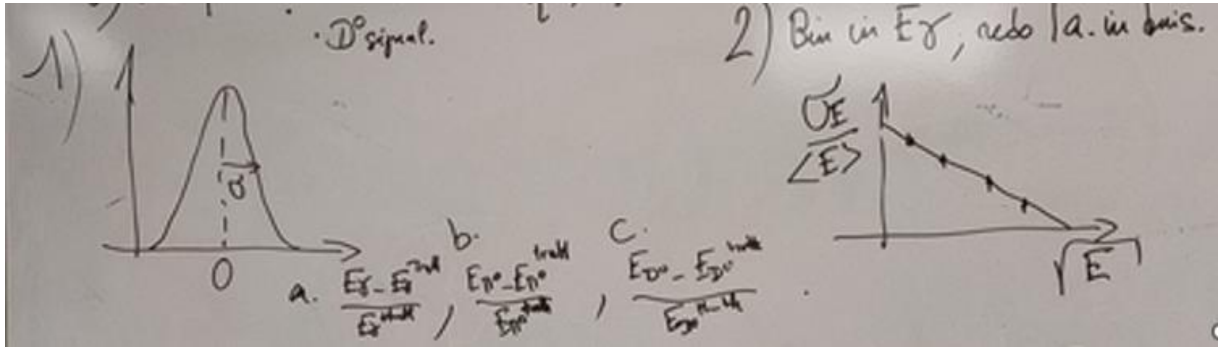


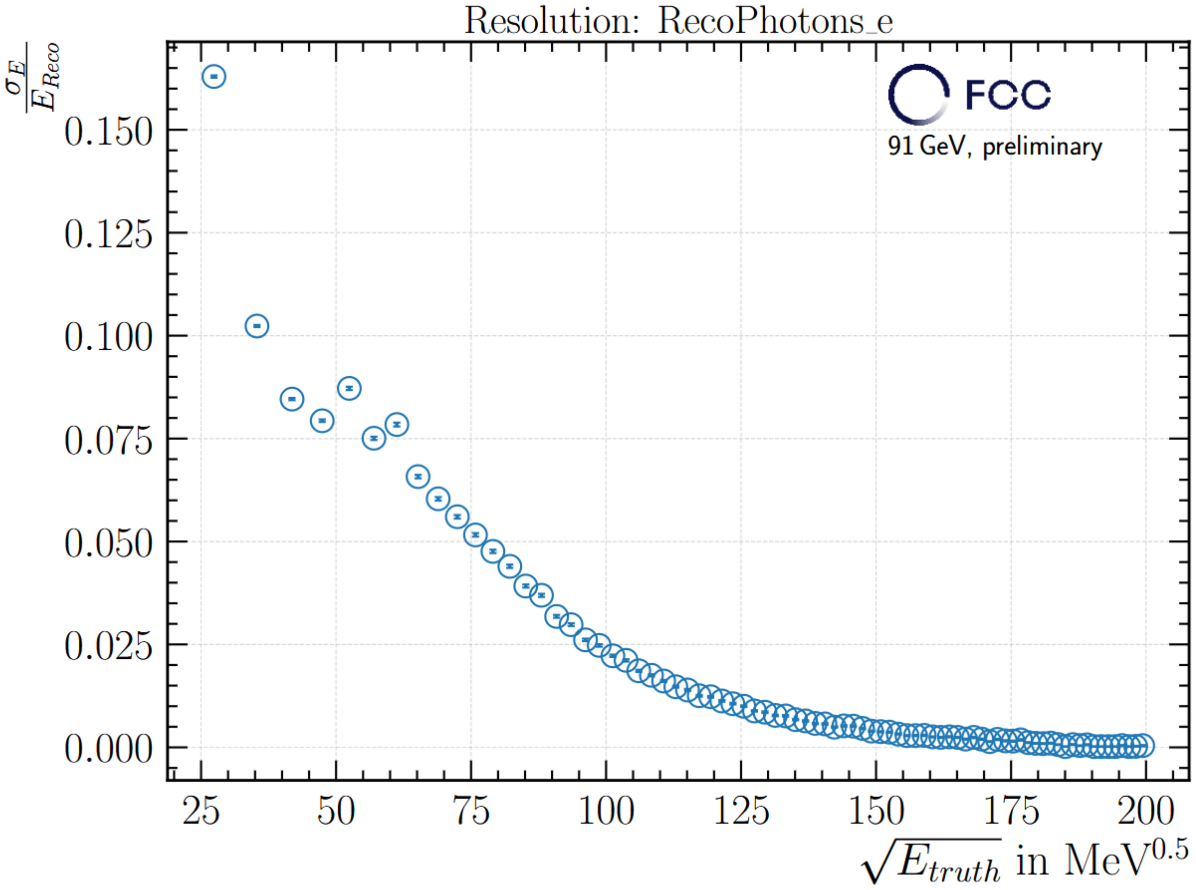
Photon-E-cut	Photonpair-cos(Θ)-cut	Photon-pair-E-cut	Pion-E-Cut	Pion-σ-Cut	Pionpair-cos(Θ)-cut	Effeciency
0 MeV	-1	0 MeV	0 MeV	64 MeV	0.8	59.78 %

In future compare to this value?!

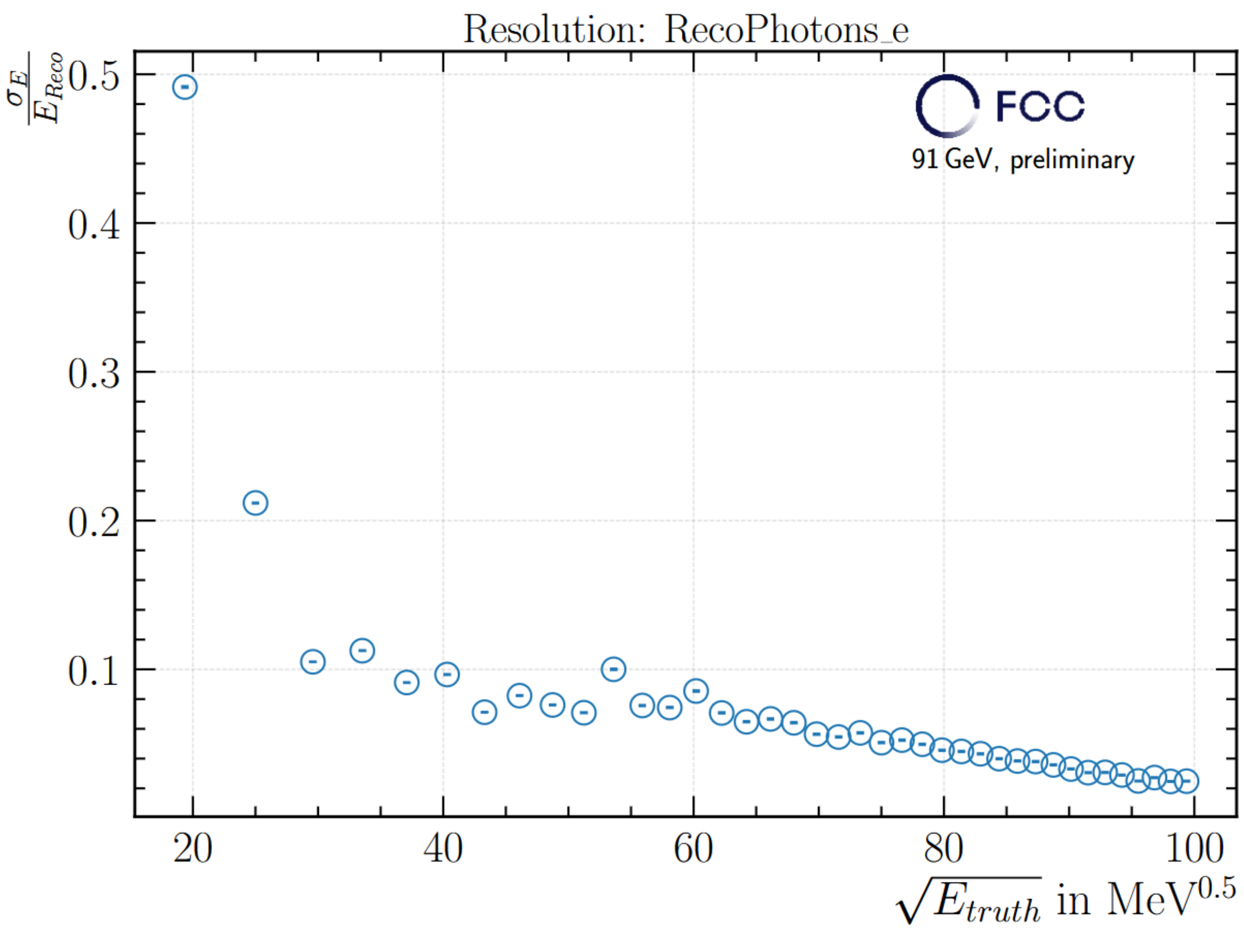
Energy-Resolution

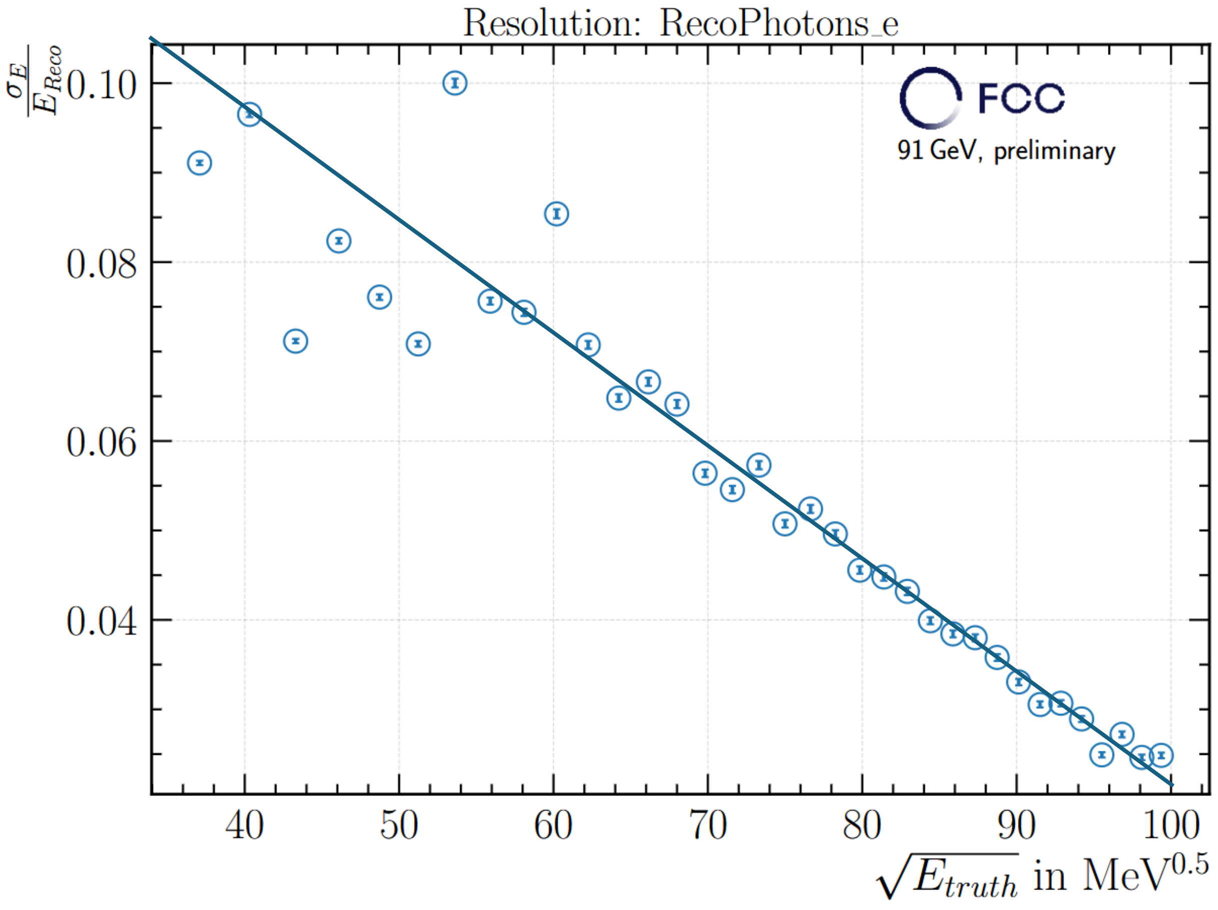




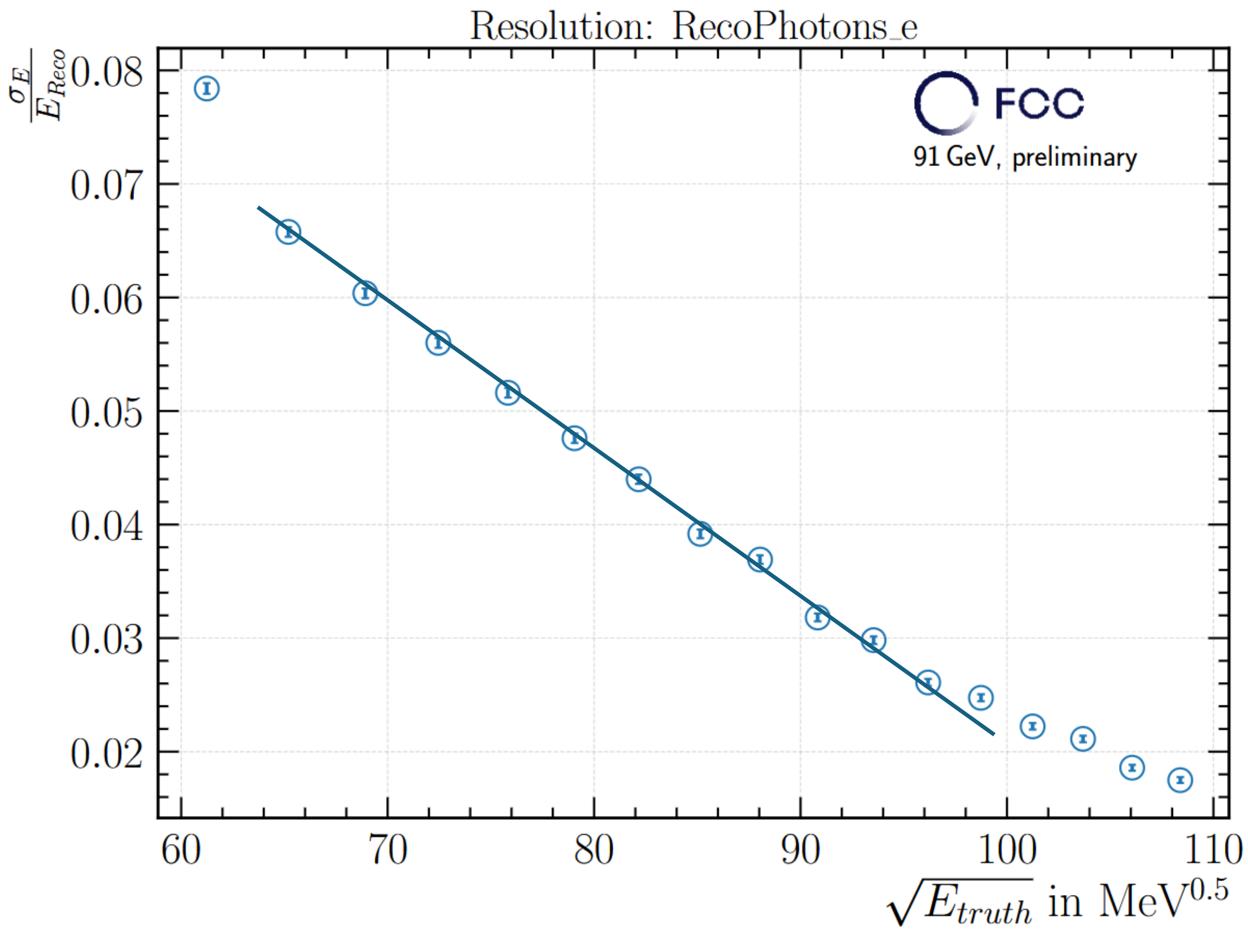


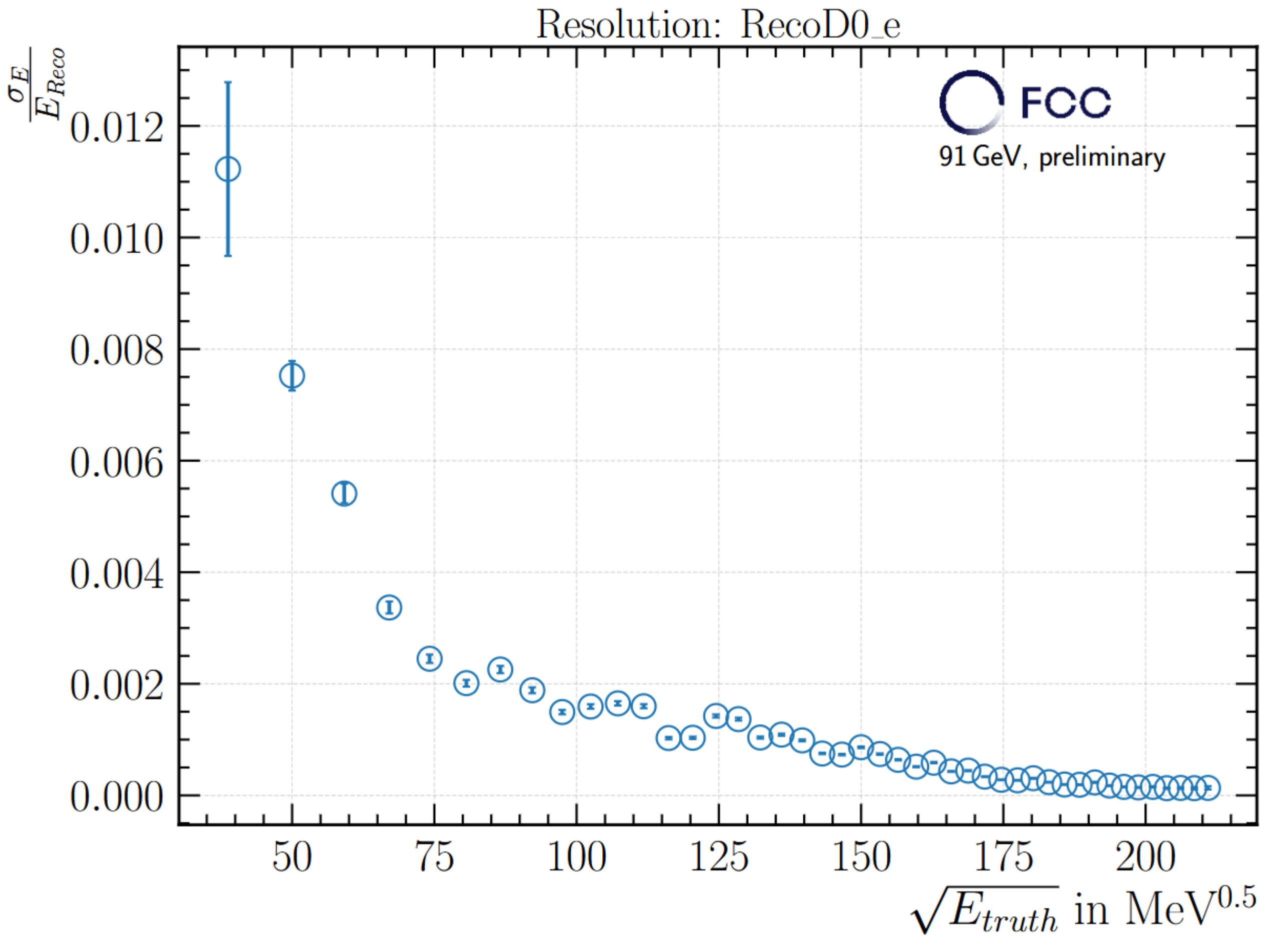
Not linear…


Resolution: RecoPhotons_e
$\frac{\sigma_E}{E_{Reco}}$
0.5
0.4
0.3
0.2
0.1
FCC
91 GeV, preliminary
20
40
60
80
100
$\sqrt{E_{truth}}$ in MeV$^{0.5}$


Resolution: RecoPhotons_e
$\frac{\sigma_E}{E_{Reco}}$
0.10
0.08
0.06
0.04
FCC
91 GeV, preliminary
40
50
60
70
80
90
100
$\sqrt{E_{truth}}$ in MeV$^{0.5}$

Linear area: 4-10 GeV





Decay channels in the pipeline

- **Already produced:** $B \rightarrow Kee$ **Master 2**

Bd_Kstee=btosllball05.dec (~543 B) — **10k**

Bu_Kee=btosllball05.dec (~337 B) — **10k**

- **Will be produced in the future:** $B \rightarrow \mu\mu$

Bd_mumu=DecProdCut.dec (~212 B) — **10k**

Bd_pi+pi-=CPV,DecProdCut.dec (~323 B) — **1000k**

Bs_mumu=DecProdCut.dec (~215 B) — **10k**

Thanks for listening ☺

```
#############
# Calorimeter
#############
module DualReadoutCalorimeter Calorimeter {
  set ParticleInputArray ParticlePropagator/stableParticles
  set TrackInputArray TrackMerger/tracks

  set TowerOutputArray towers
  set PhotonOutputArray photons

  set EFlowTrackOutputArray eflowTracks
  set EFlowPhotonOutputArray eflowPhotons
  set EFlowNeutralHadronOutputArray eflowNeutralHadrons

  set ECalMinSignificance 2.0
  set HCalMinSignificance 2.5

  set SmearLogNormal false

  set SmearTowerCenter true
  #set SmearTowerCenter false
    set pi [expr {acos(-1)}]

    # Lists of the edges of each tower in eta and phi;
    # each list starts with the lower edge of the first tower;
    # the list ends with the higher edged of the last tower.
    # Barrel:  deta=0.02 towers up to |eta| <= 0.88 ( up to 45°)
    # Endcaps: deta=0.02 towers up to |eta| <= 3.0 (8.6° = 100 mrad
    # Cell size: about 6 cm x 6 cm

    set EtaPhiRes 0.02
    set EtaMax 3.0

    set pi [expr {acos(-1)}]

    set nbins_phi [expr {$pi/$EtaPhiRes} ]
    set nbins_phi [expr {int($nbins_phi)} ]

    set PhiBins {}
    for {set i -$nbins_phi} {$i <= $nbins_phi} {incr i} {
      add PhiBins [expr {$i * $pi/$nbins_phi}]
    }

    set nbins_eta [expr {$EtaMax/$EtaPhiRes} ]
    set nbins_eta [expr {int($nbins_eta)} ]

    for {set i -$nbins_eta} {$i <= $nbins_eta} {incr i} {
      set eta [expr {$i * $EtaPhiRes}]
      add EtaPhiBins $eta $PhiBins
    }

    # default energy fractions {abs(PDG code)} {Fecal Fhcal}
    add EnergyFraction {0} {0.0 1.0}
    # energy fractions for e, gamma and pi0
    add EnergyFraction {11} {1.0 0.0}
    add EnergyFraction {22} {1.0 0.0}
    add EnergyFraction {111} {1.0 0.0}
    # energy fractions for muon, neutrinos and neutralinos
    add EnergyFraction {12} {0.0 0.0}
    add EnergyFraction {13} {0.0 0.0}
    add EnergyFraction {14} {0.0 0.0}
    add EnergyFraction {16} {0.0 0.0}
    add EnergyFraction {1000022} {0.0 0.0}
    add EnergyFraction {1000023} {0.0 0.0}
    add EnergyFraction {1000025} {0.0 0.0}
    add EnergyFraction {1000035} {0.0 0.0}
    add EnergyFraction {1000045} {0.0 0.0}
    # energy fractions for K0short and Lambda
    add EnergyFraction {310} {0.3 0.7}
    add EnergyFraction {130} {0.3 0.7}
    add EnergyFraction {3122} {0.3 0.7}


    ## ECAL crystals for the EM part from 2008.00338
    # set ECalResolutionFormula {resolution formula as a function of eta and energy}
    set ECalResolutionFormula {
    (abs(eta) <= 0.88 )                        * sqrt(energy^2*0.005^2 + energy*0.03^2 + 0.002^2)+
    (abs(eta) > 0.88 && abs(eta) <= 3.0)    * sqrt(energy^2*0.005^2 + energy*0.03^2 + 0.002^2)
    }
```

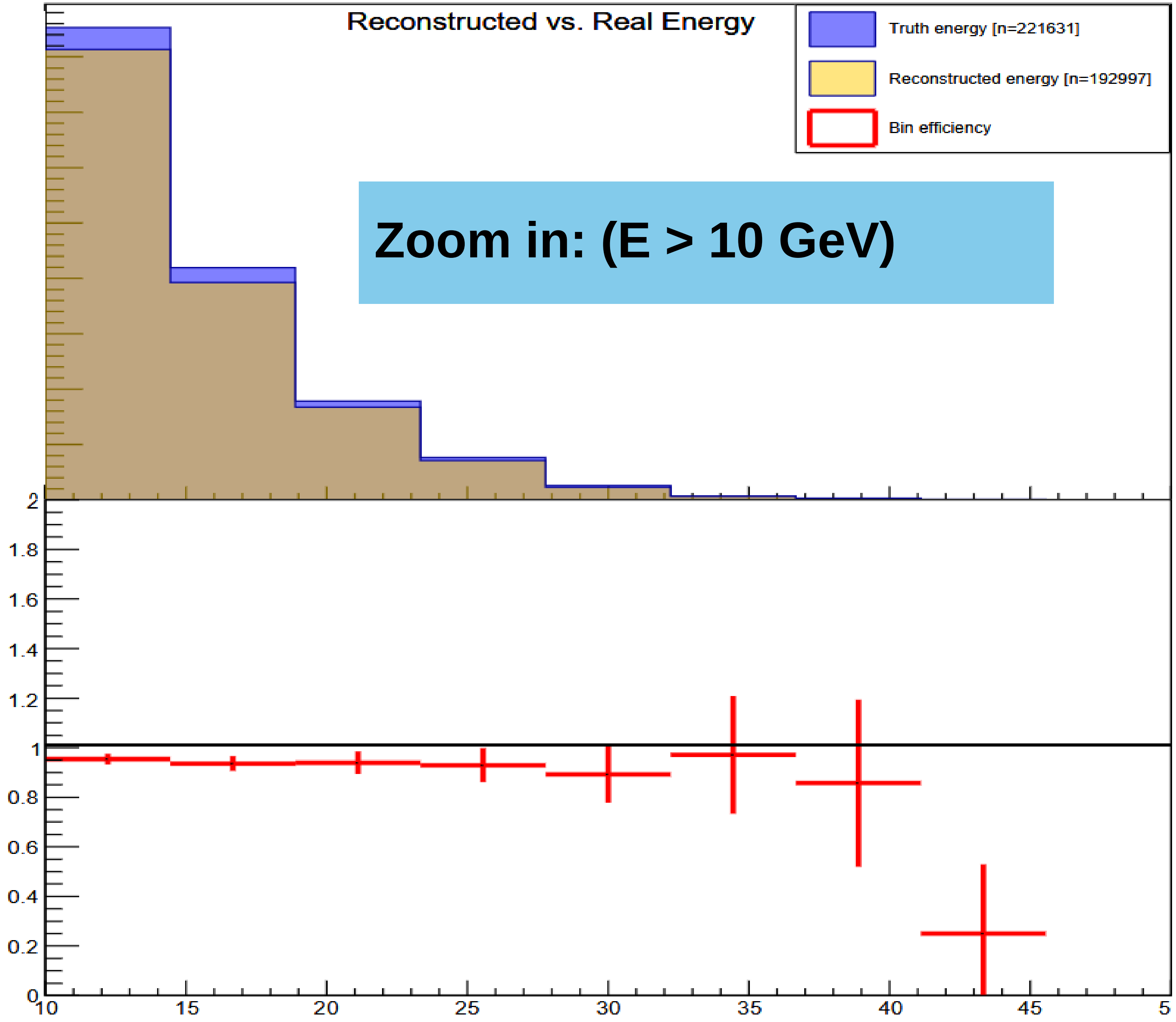
Annexe

Photon reconstruction effeciency

$$D^0 \rightarrow \pi^0\pi^0 \rightarrow 4\gamma$$

- **Broader bins** because of the smaller samplesize
- **Low** efficiency in last bin **(E > 40 GeV, 27%)**

Why?

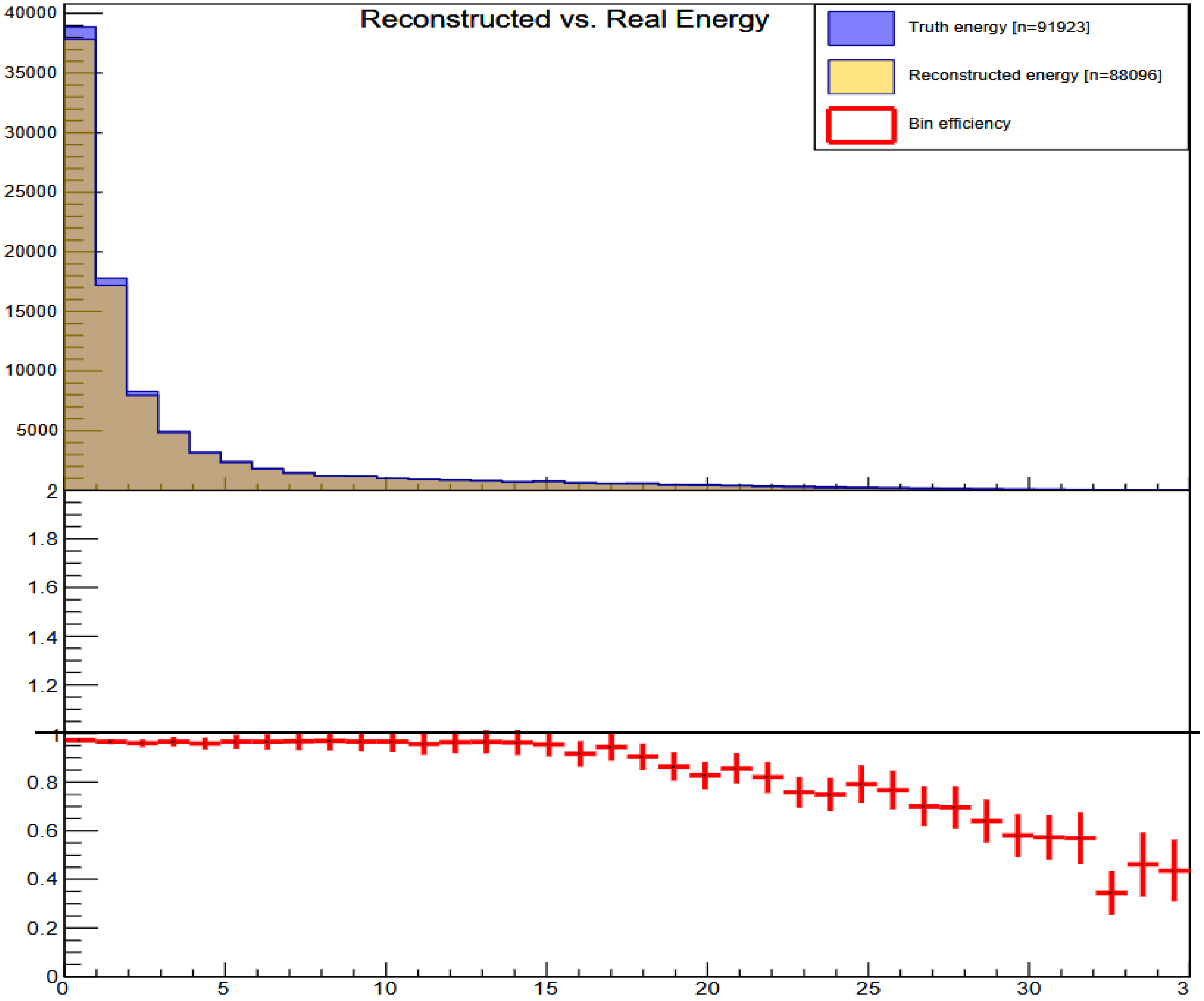


Pion reconstruction effeciency

$$\pi^0 \rightarrow \gamma\,\gamma$$

$$D^0 \rightarrow \pi^0\pi^0 \rightarrow 4\gamma$$

- **Efficiency decreases** steadily for **E > 15 GeV**



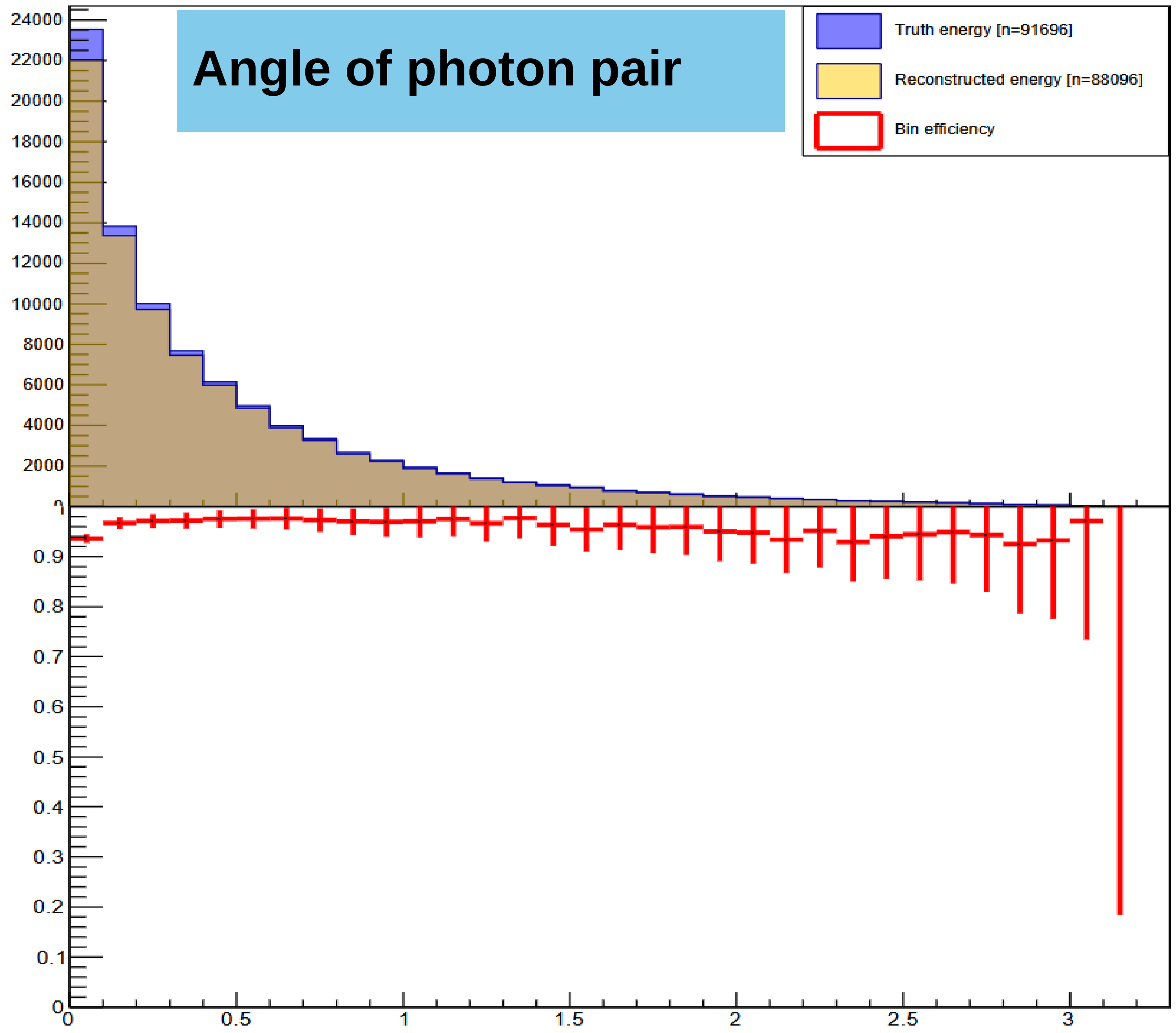
Pion reconstruction effeciency

$$\pi^0 \rightarrow \gamma\,\gamma$$

$$D^0 \rightarrow \pi^0\pi^0 \rightarrow 4\gamma$$

- **Efficiency** stable **high**
- ~~**Weird peak** at **Pi/2**~~

SOLVED ☺

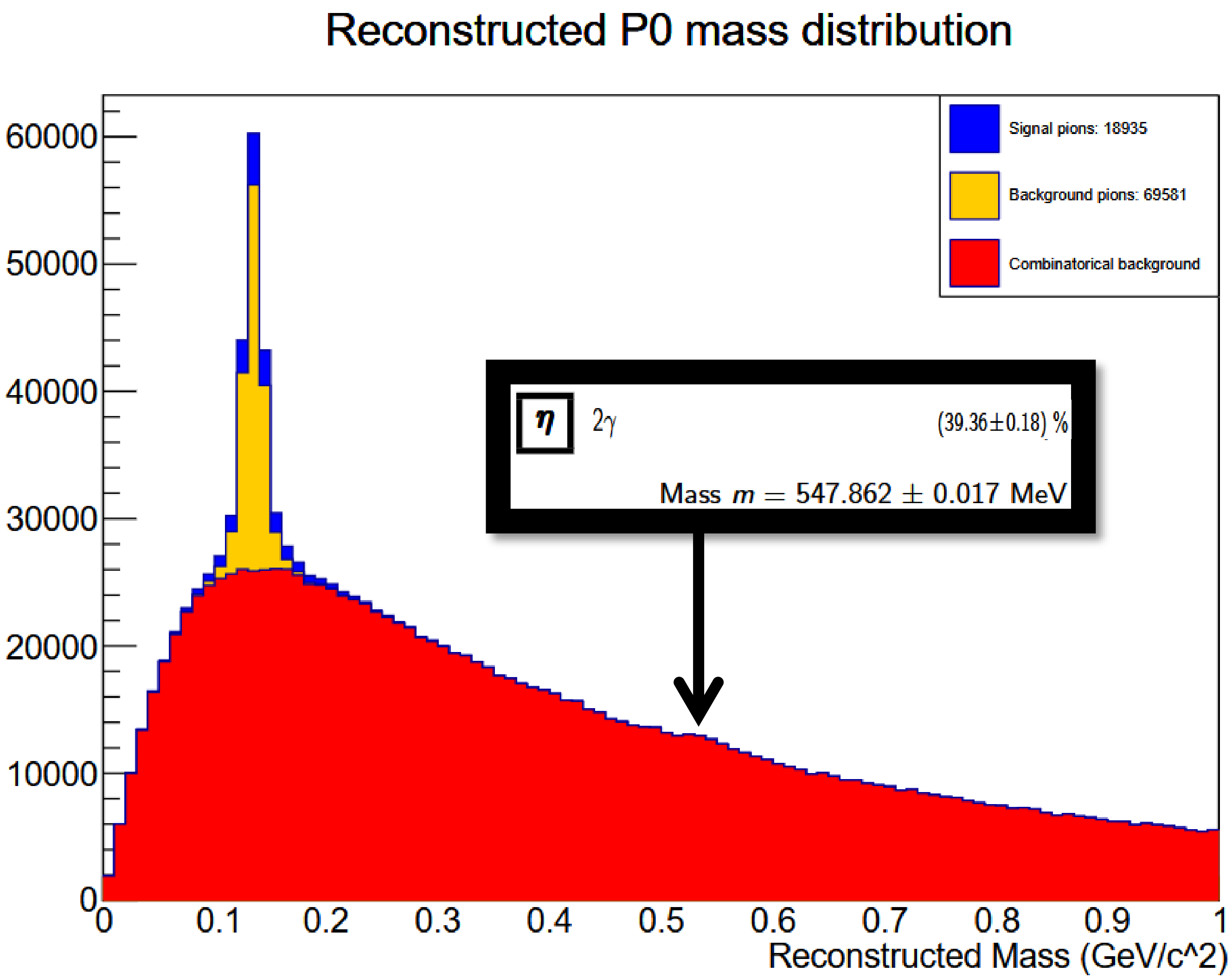


Pion decay: Background consideration

$$\pi^0 \rightarrow \gamma\,\gamma$$

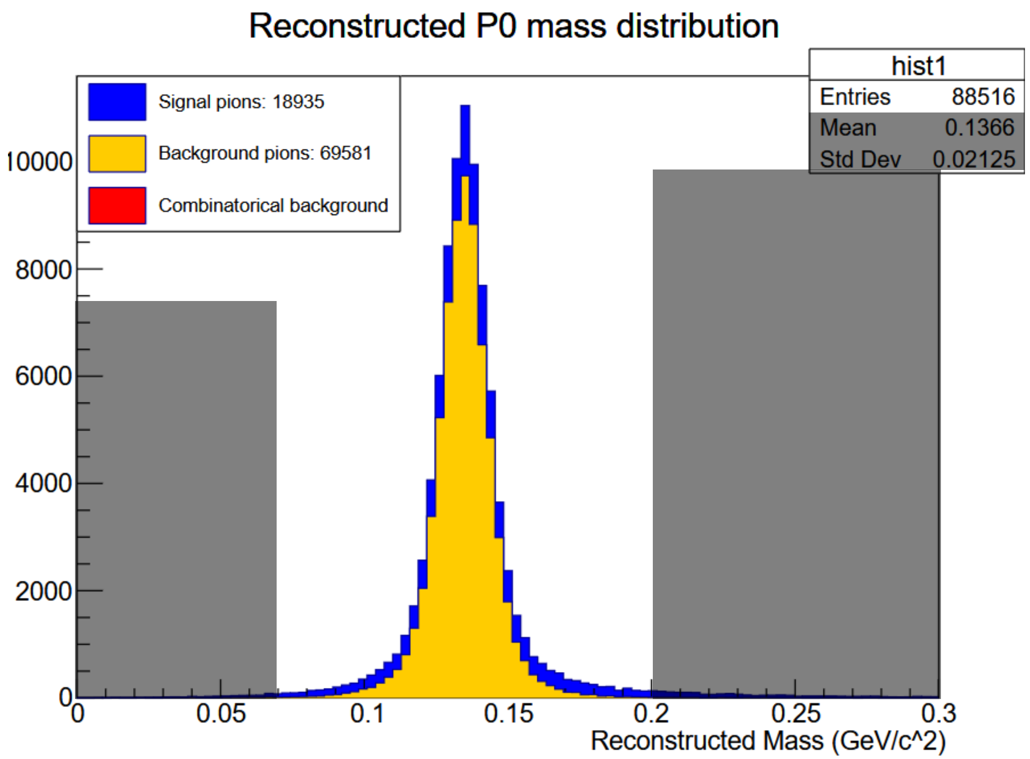
$$D^0 \rightarrow \pi^0\pi^0 \rightarrow 4\gamma$$

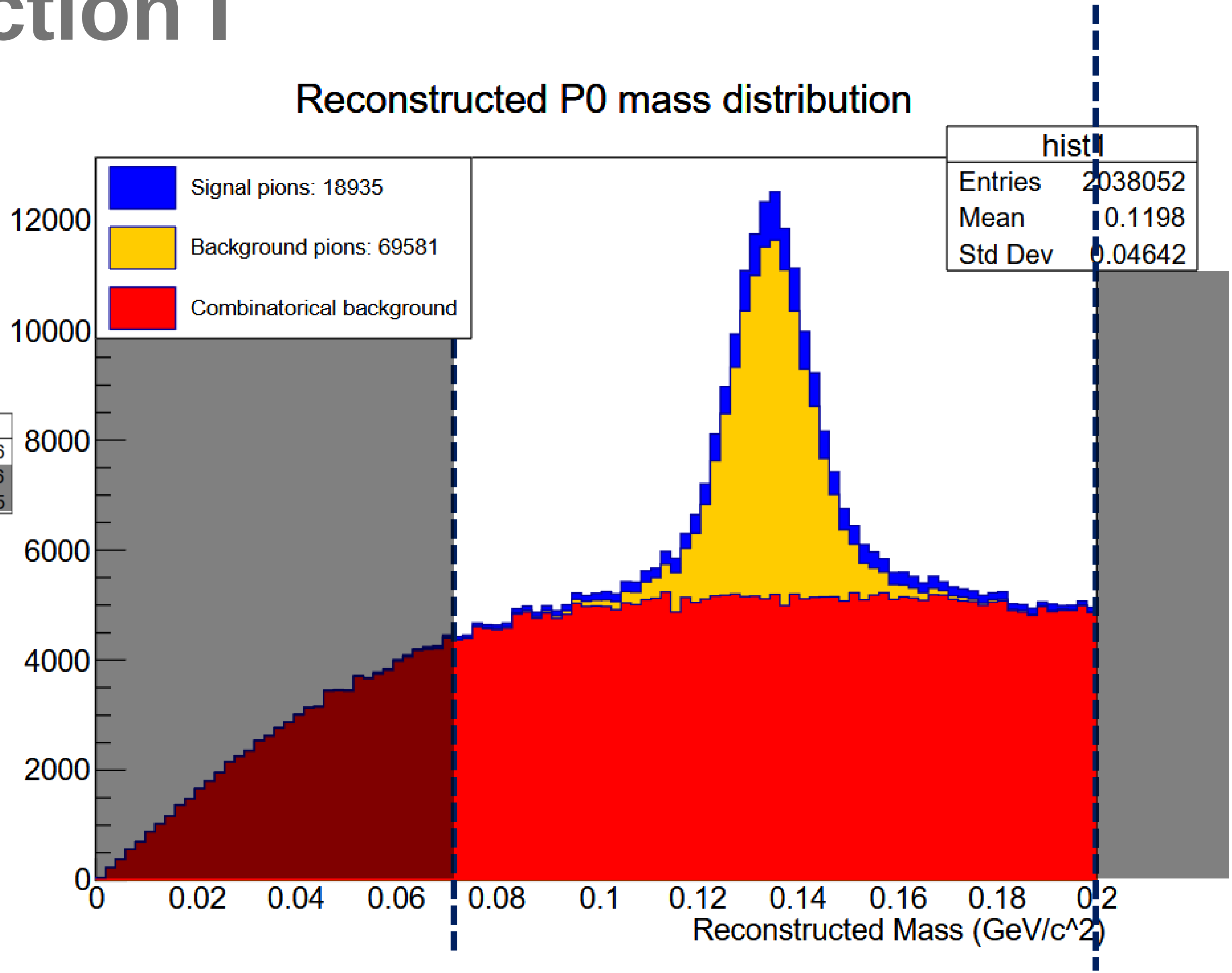
- D0-signal pions
- Pion background
- Combinatorical background



Background reduction I

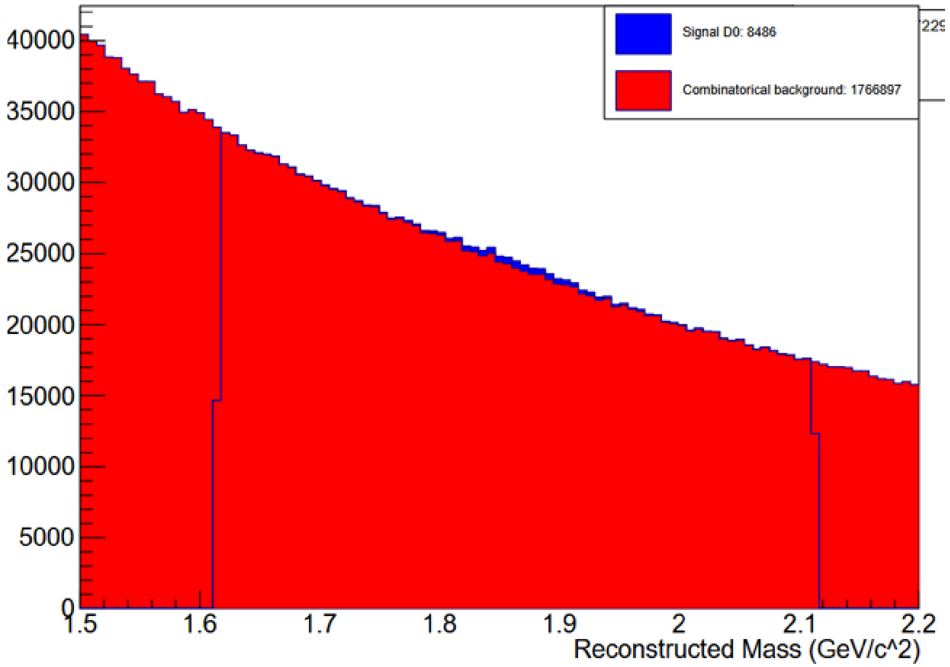
- Cutting off combinatorical background outside the peak region (3 sigma)





Background reduction II

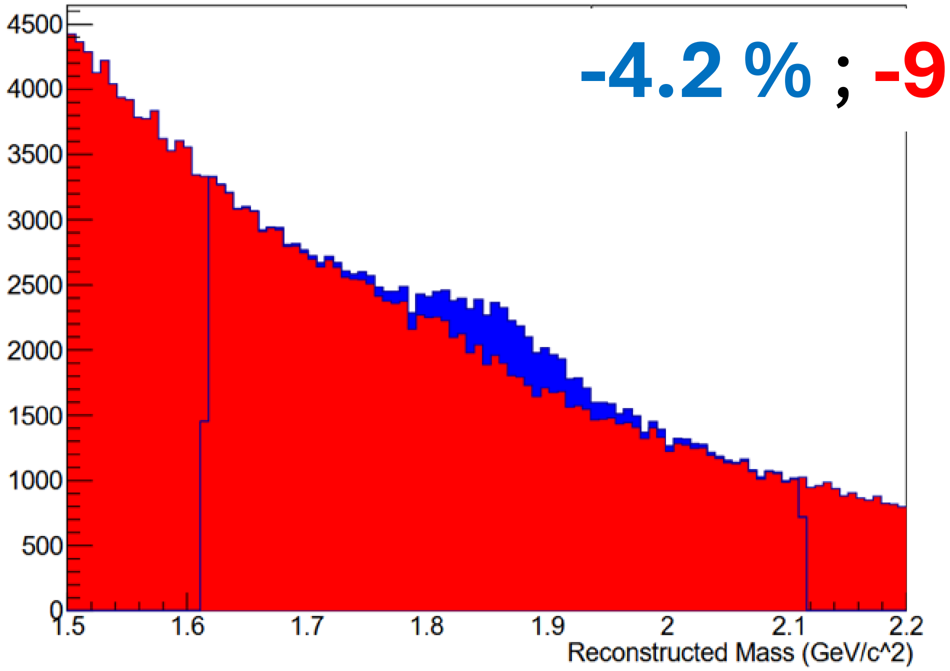
Before:



Signal D0: 8486

Combinatorical background: 1766897

Cos(theta) > 0.6:

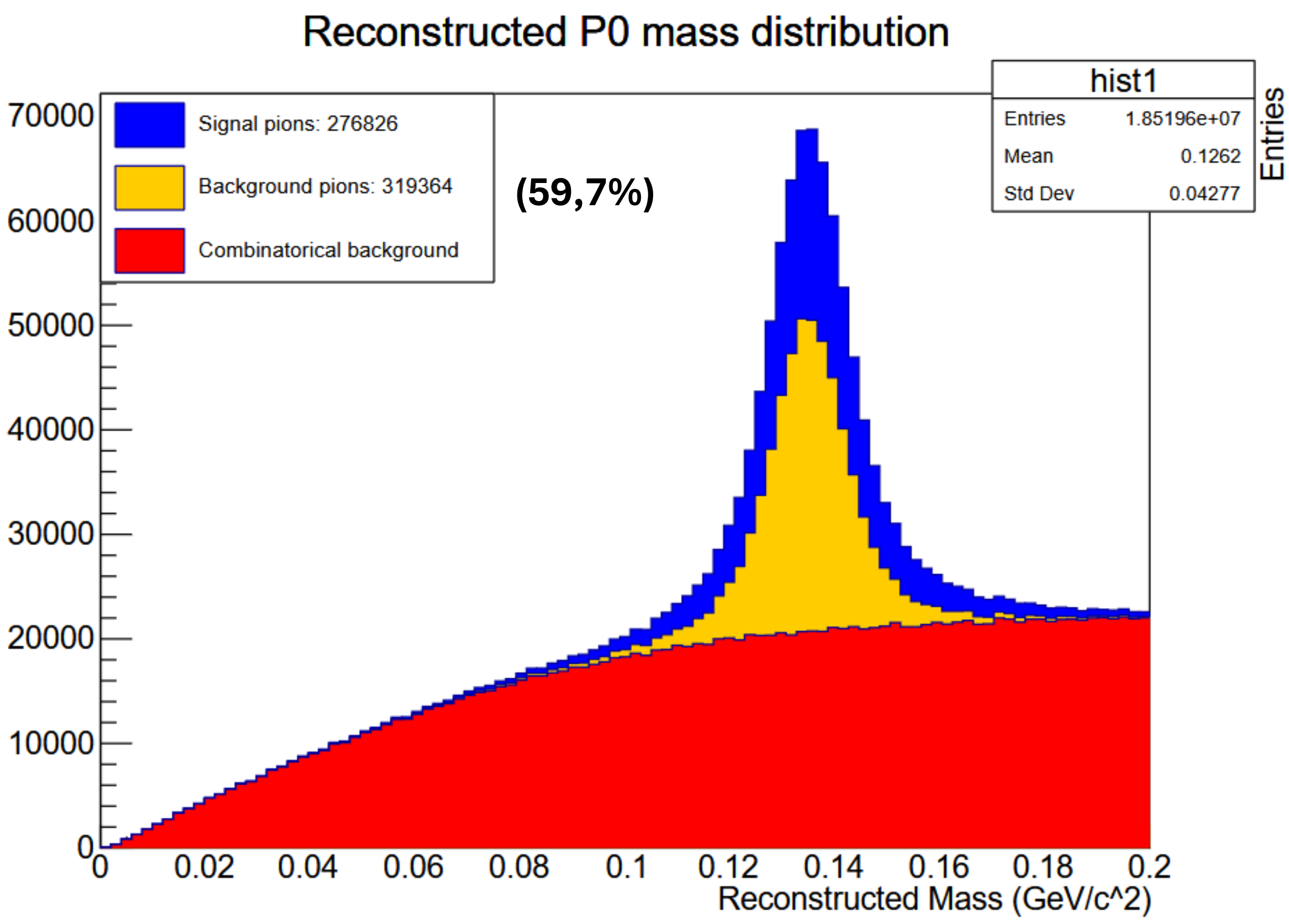


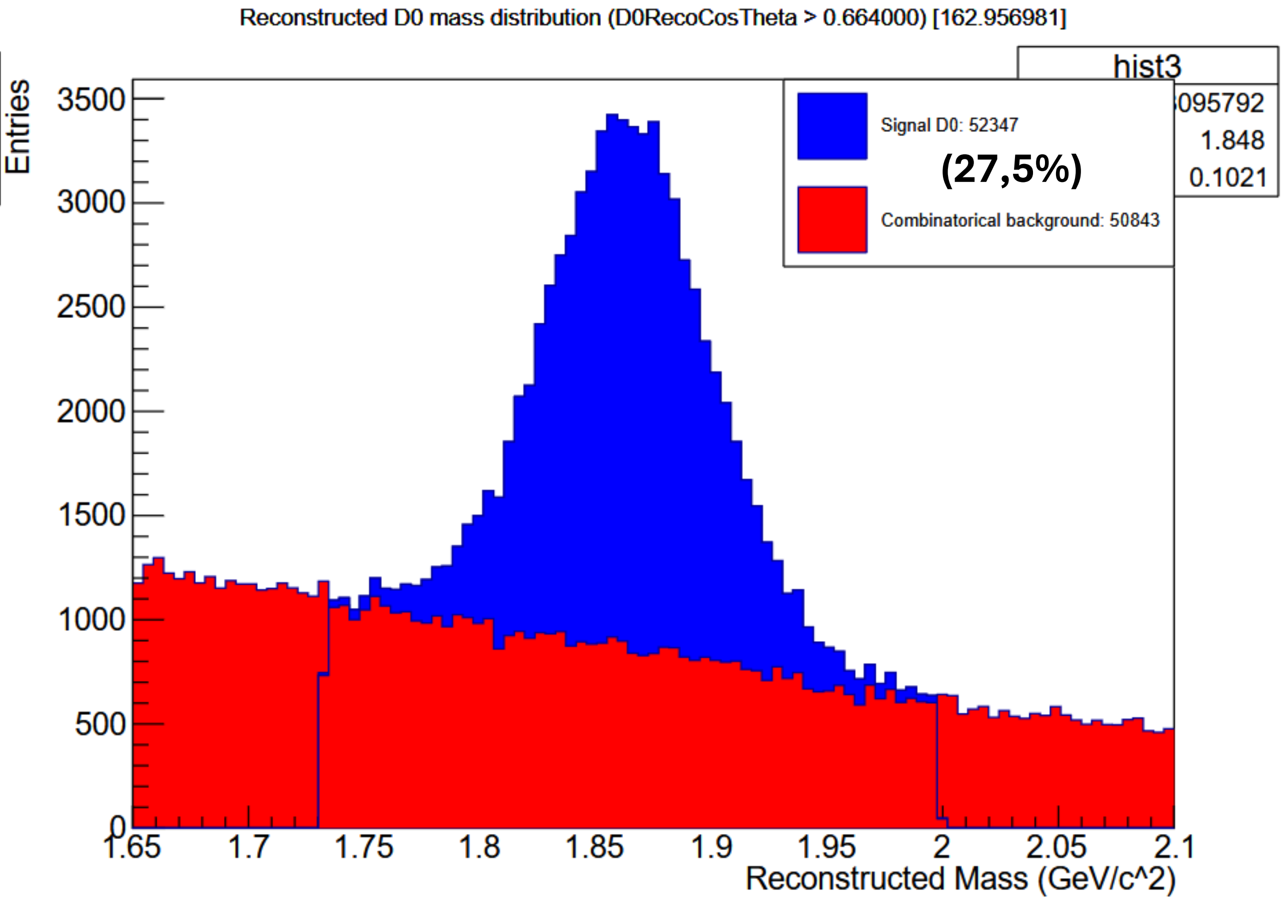
-4.2 % ; -92.0 %

Signal D0: 8129

Combinatorical background: 141496

Best result old sampls (purity: 18.75 (51% Signal))





(59,7%)^2 = 35,6 %

79220 Events, 998.817 P0, 189.933 D0