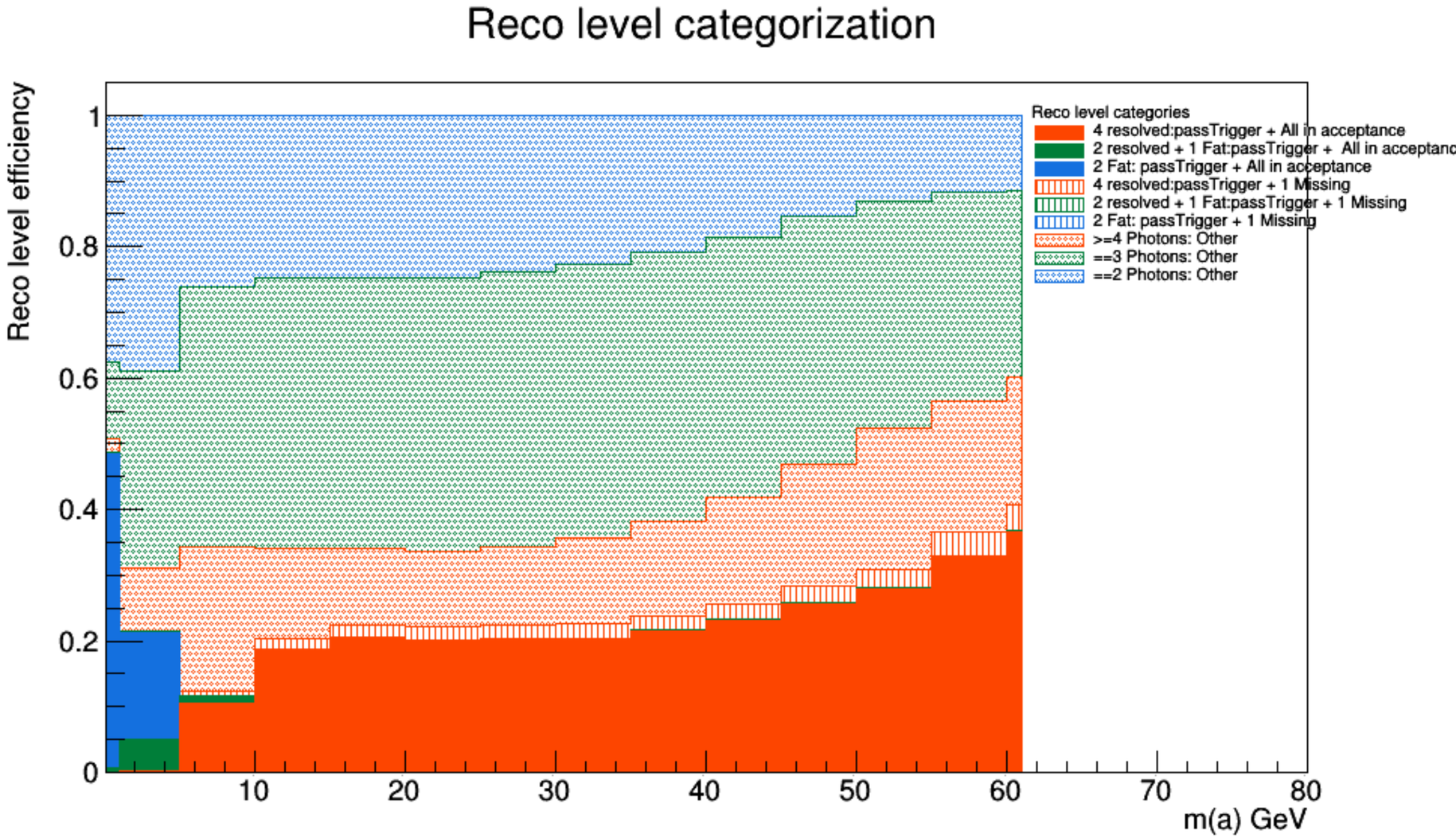
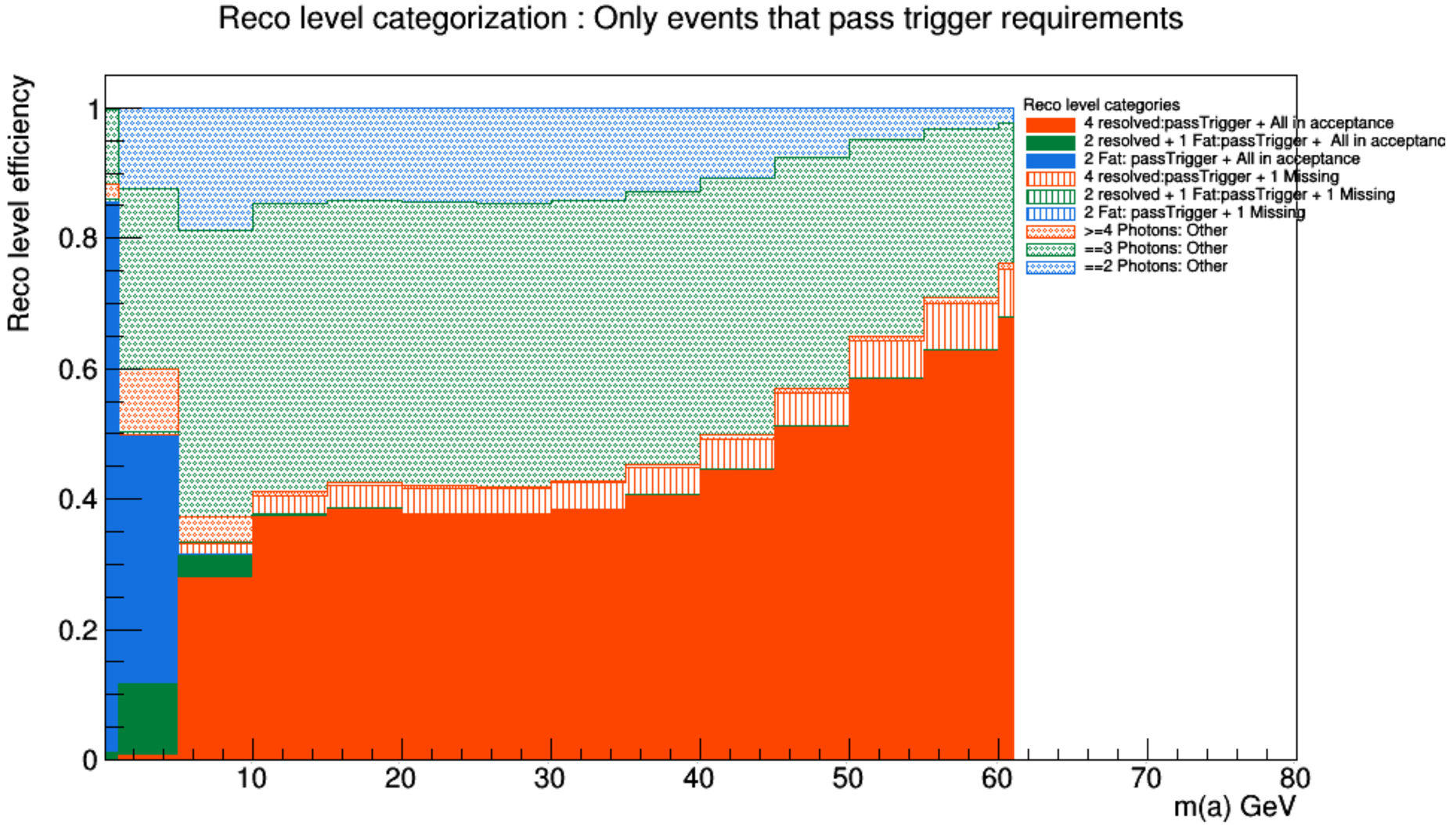
“Other” (dotted region)

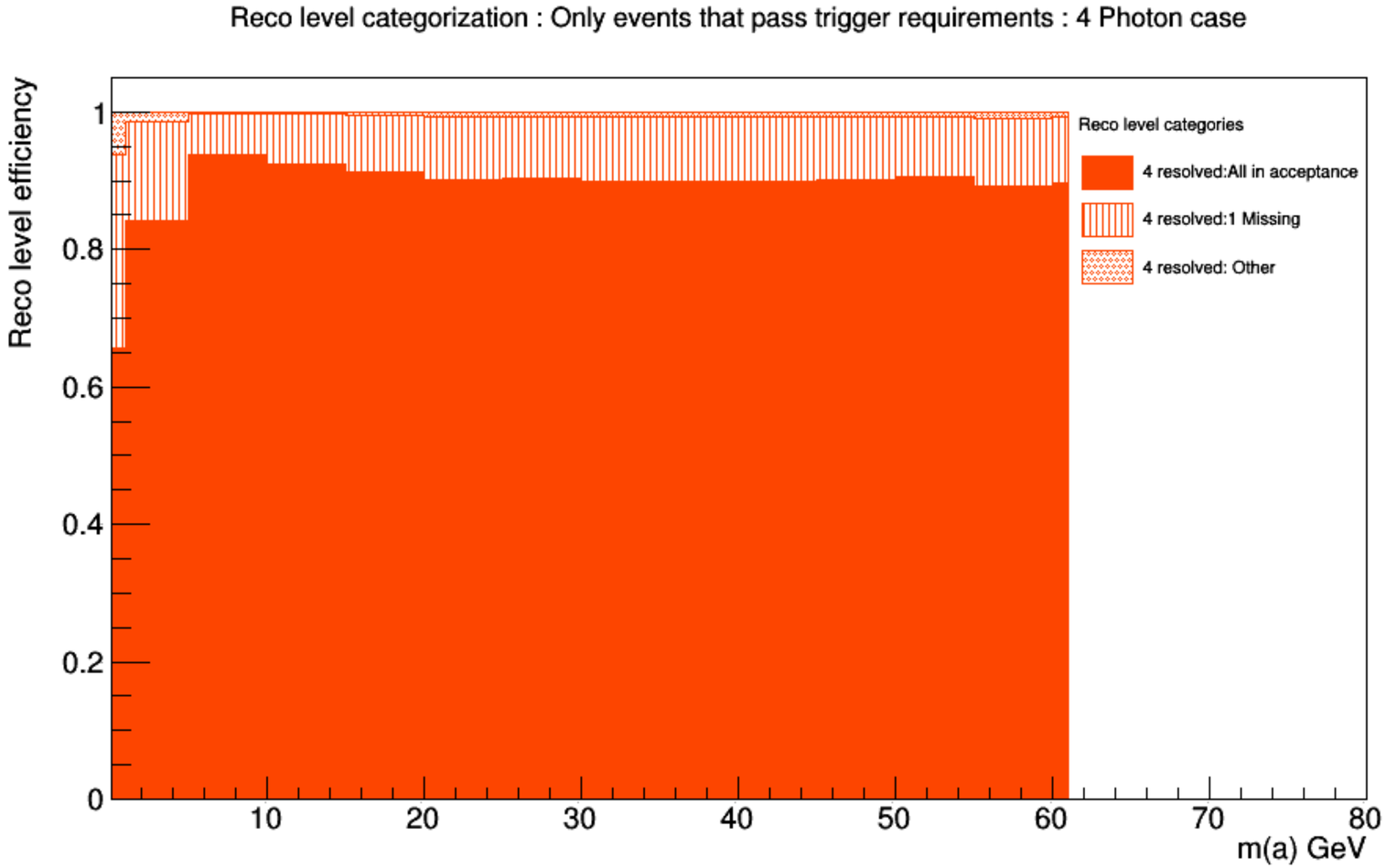
Eg : Red Dotted Region - **Does not** contain events with just 4 resolved photons (it really is everything left after categorization for events with at least 4 photons)



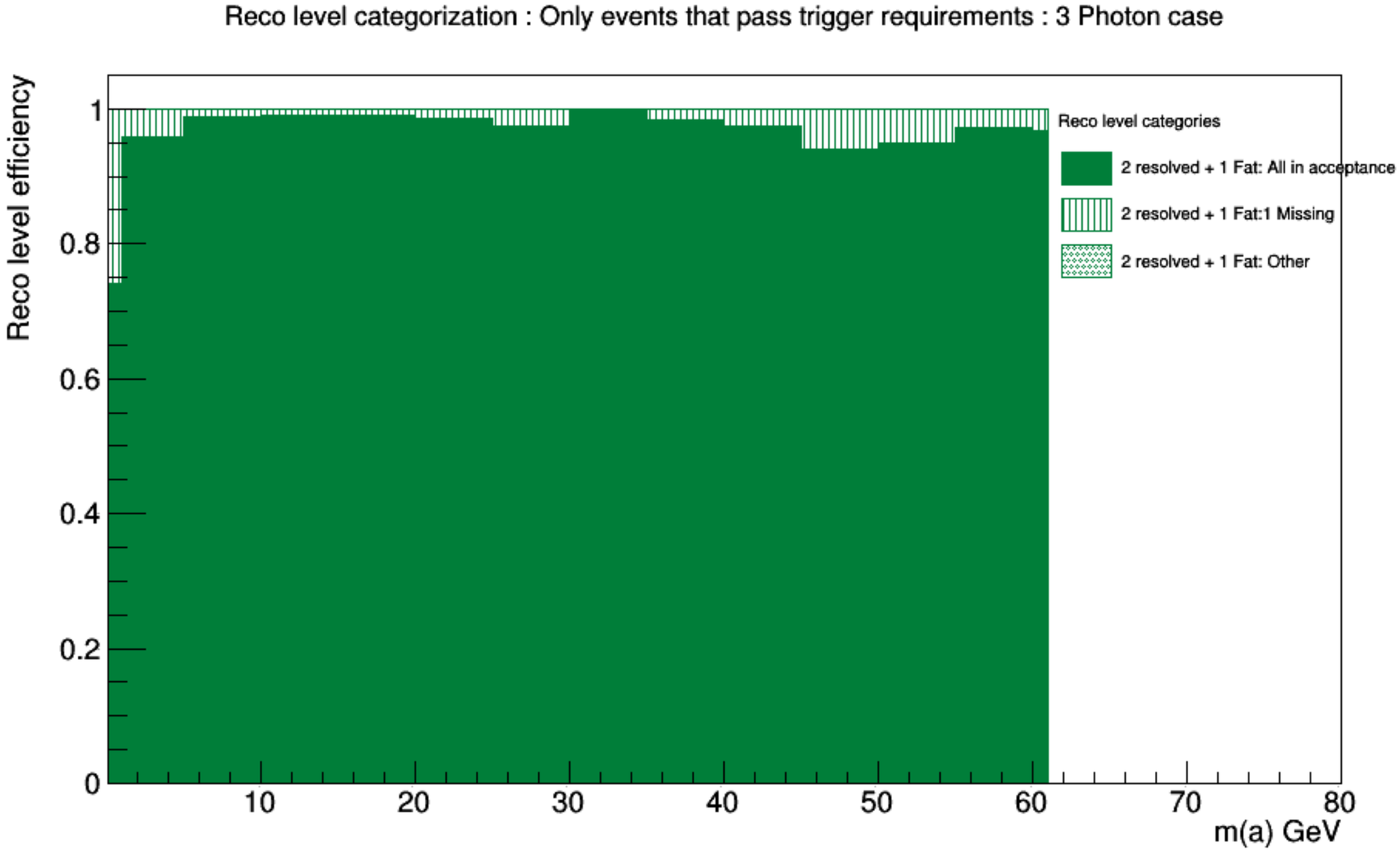
Same plot but only with for events that pass Trigger



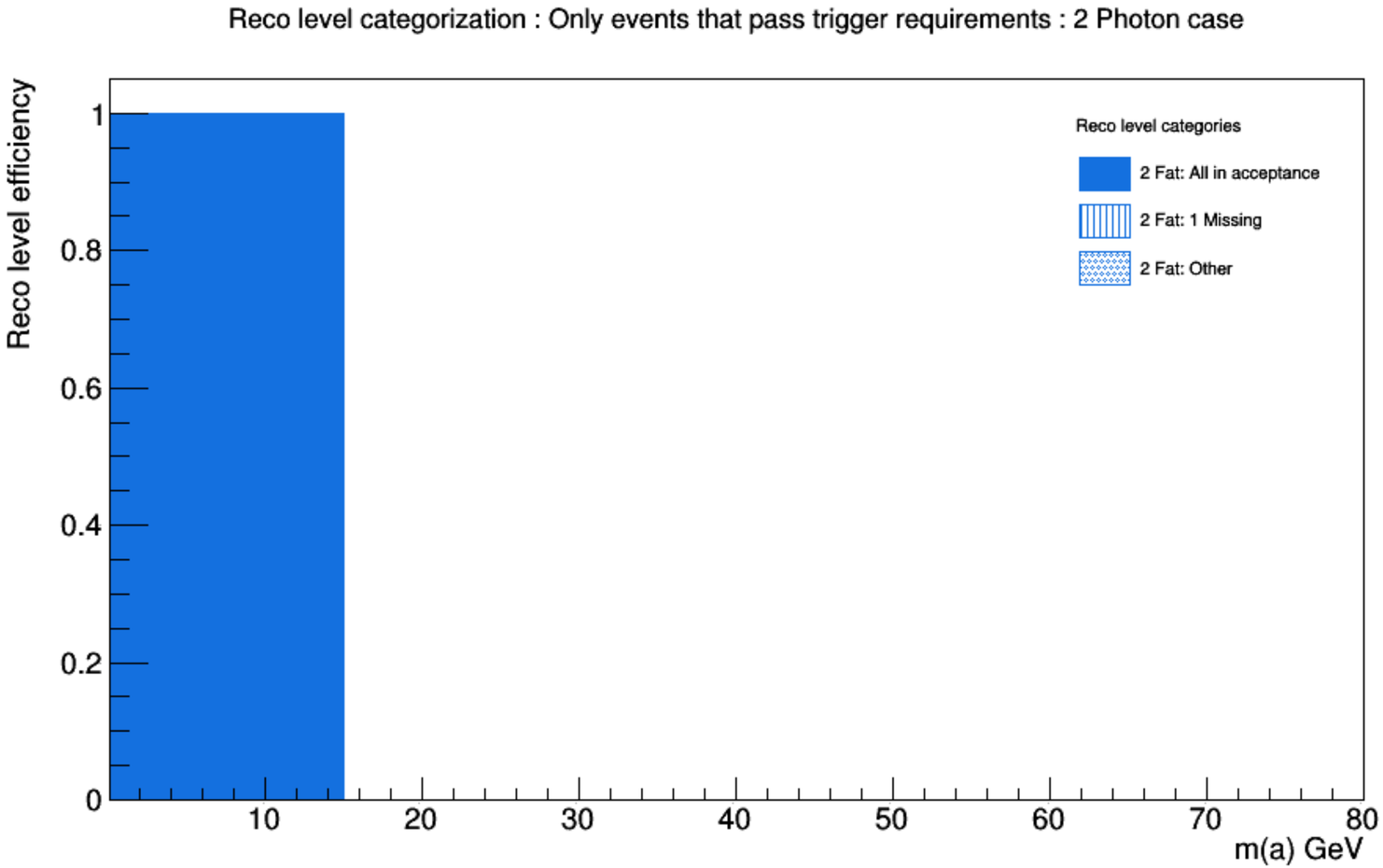
Start with events with at least 4 photons
+ pass trigger requirements
+ Photons are gen matched to resolved



Start with events with exactly 3 photons
+ pass trigger requirements
+ Photons are gen matched such that in an event there are 2 resolved + 1 merged photon

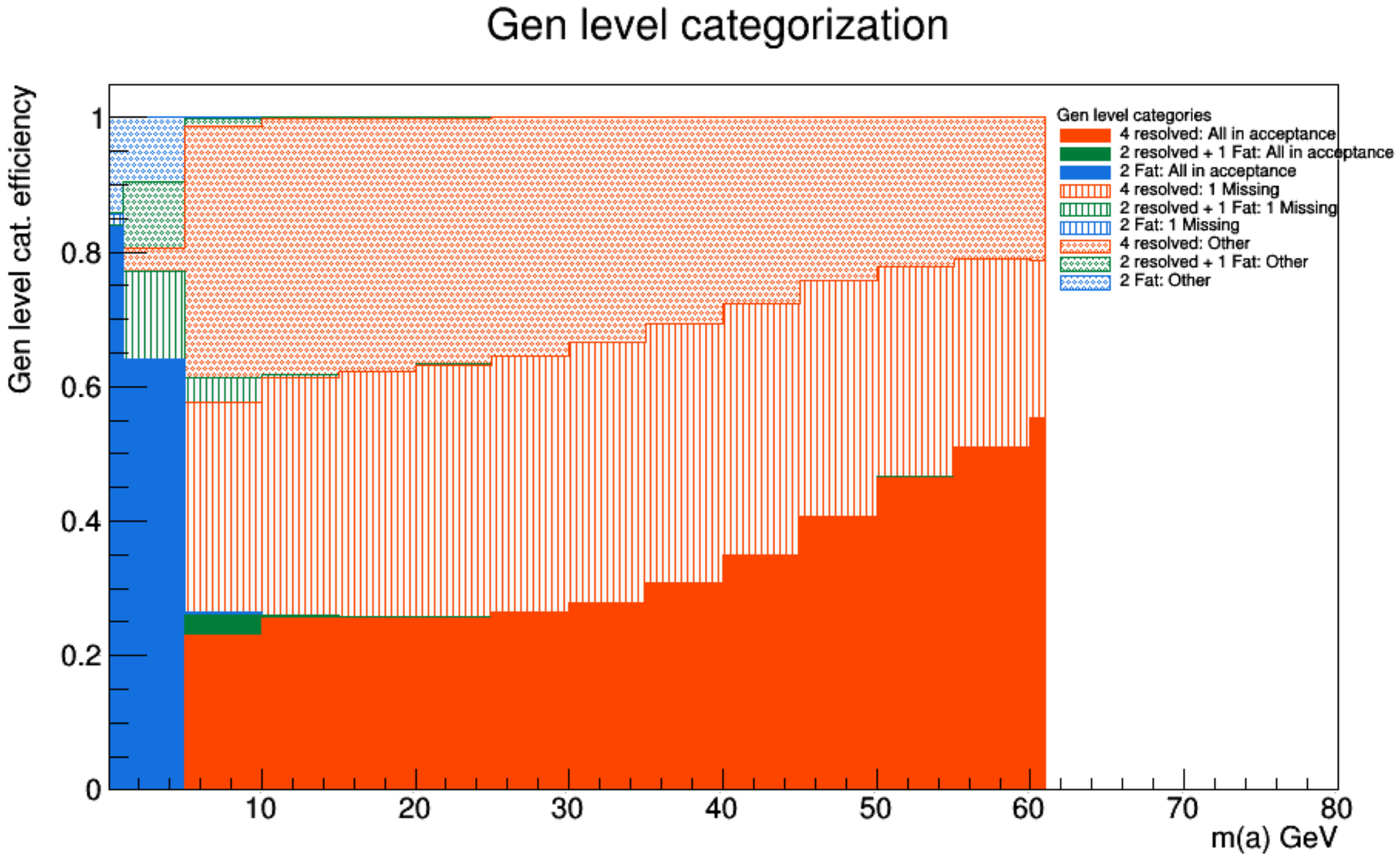


Start with events with exactly 2 photons
+ pass trigger requirements
+ Photons are gen matched such that in an event there are 2 merged photons

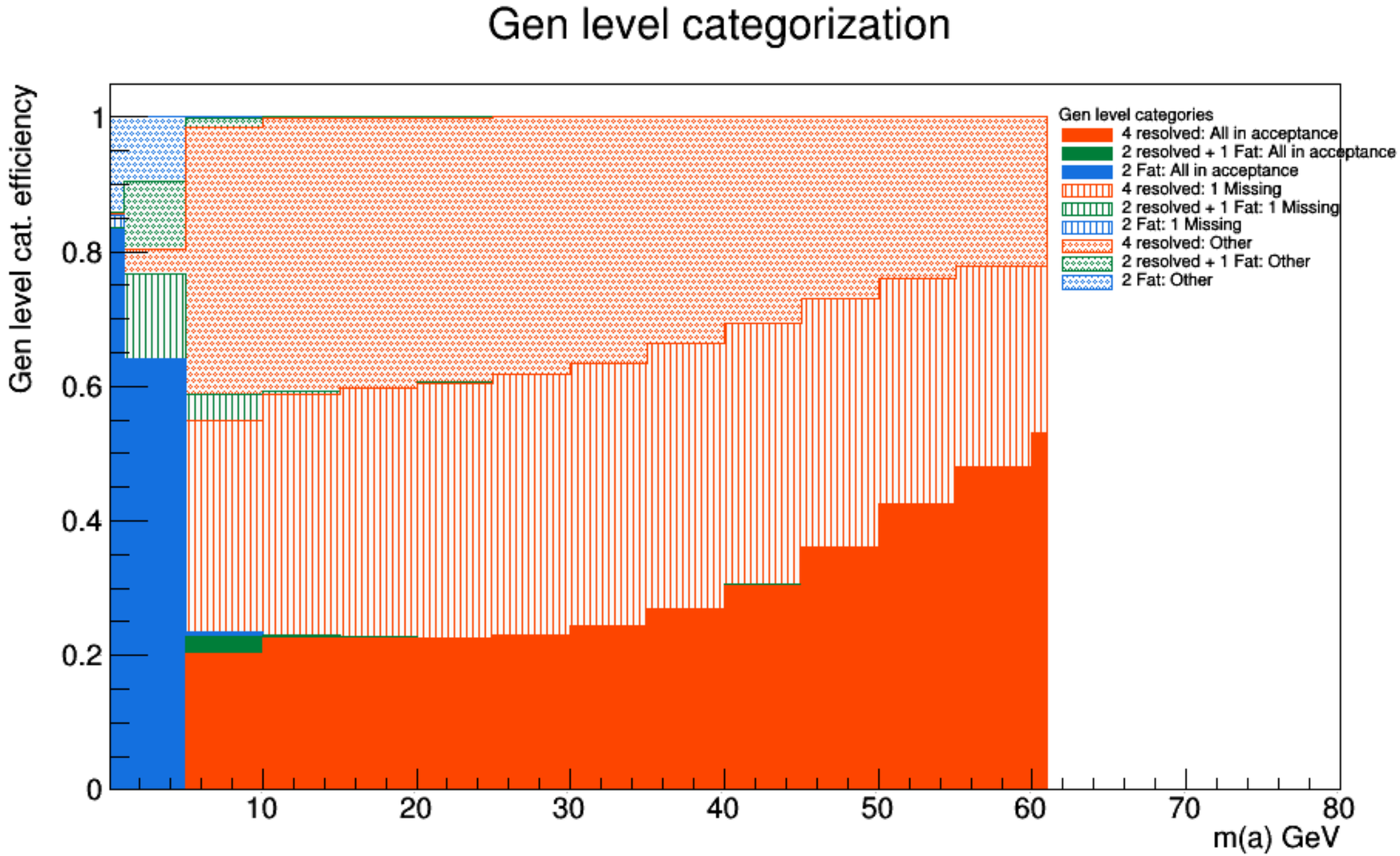


Changes since last chat on 24 Apr ’18 (older slides in backup)

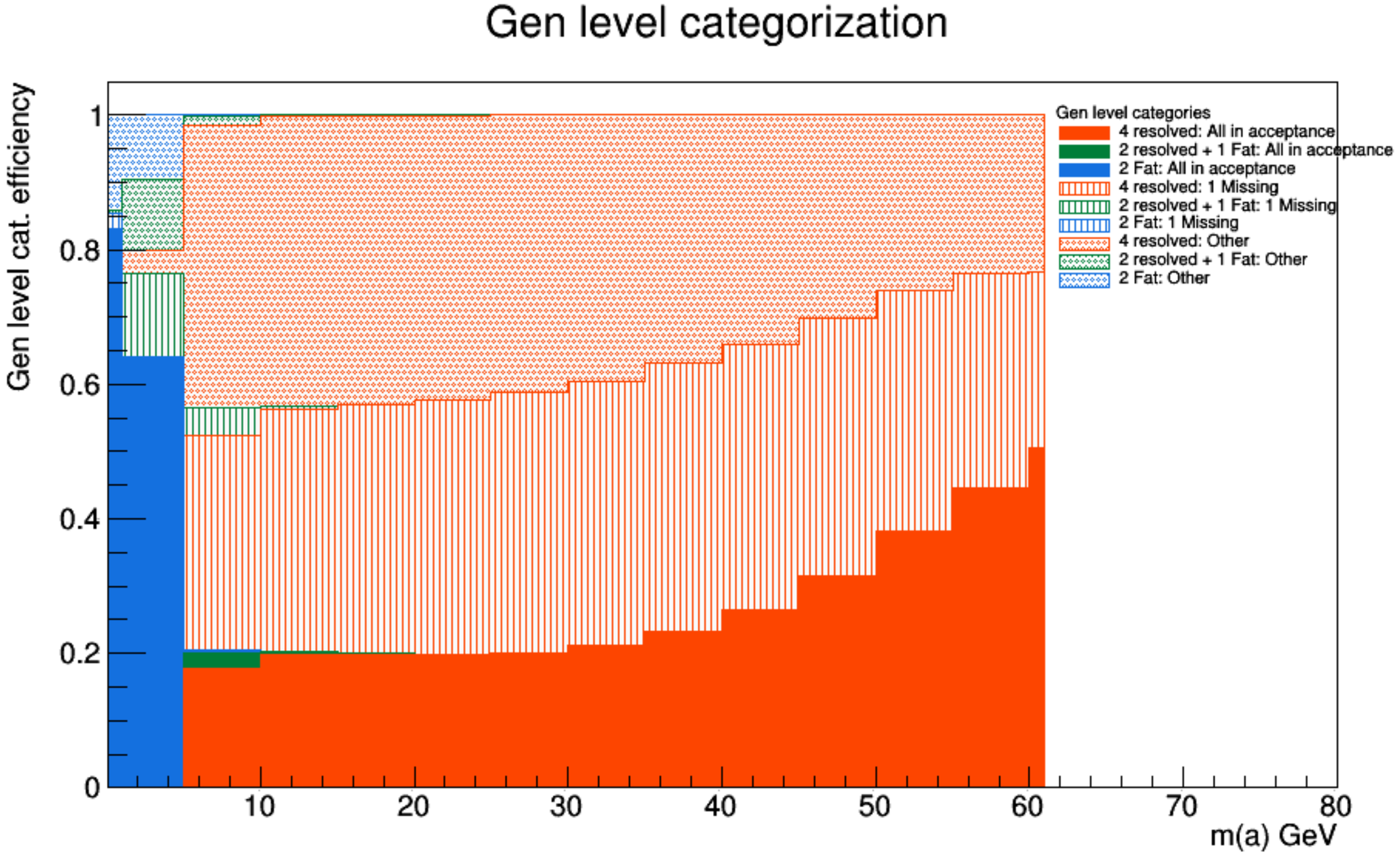
- Gen level categorization
  - abs(eta) < 2.5
  - Photon1 Pt > 10
  - Photon2 Pt > 10
  - Photon3 Pt > 10
  - Photon4 Pt > 10



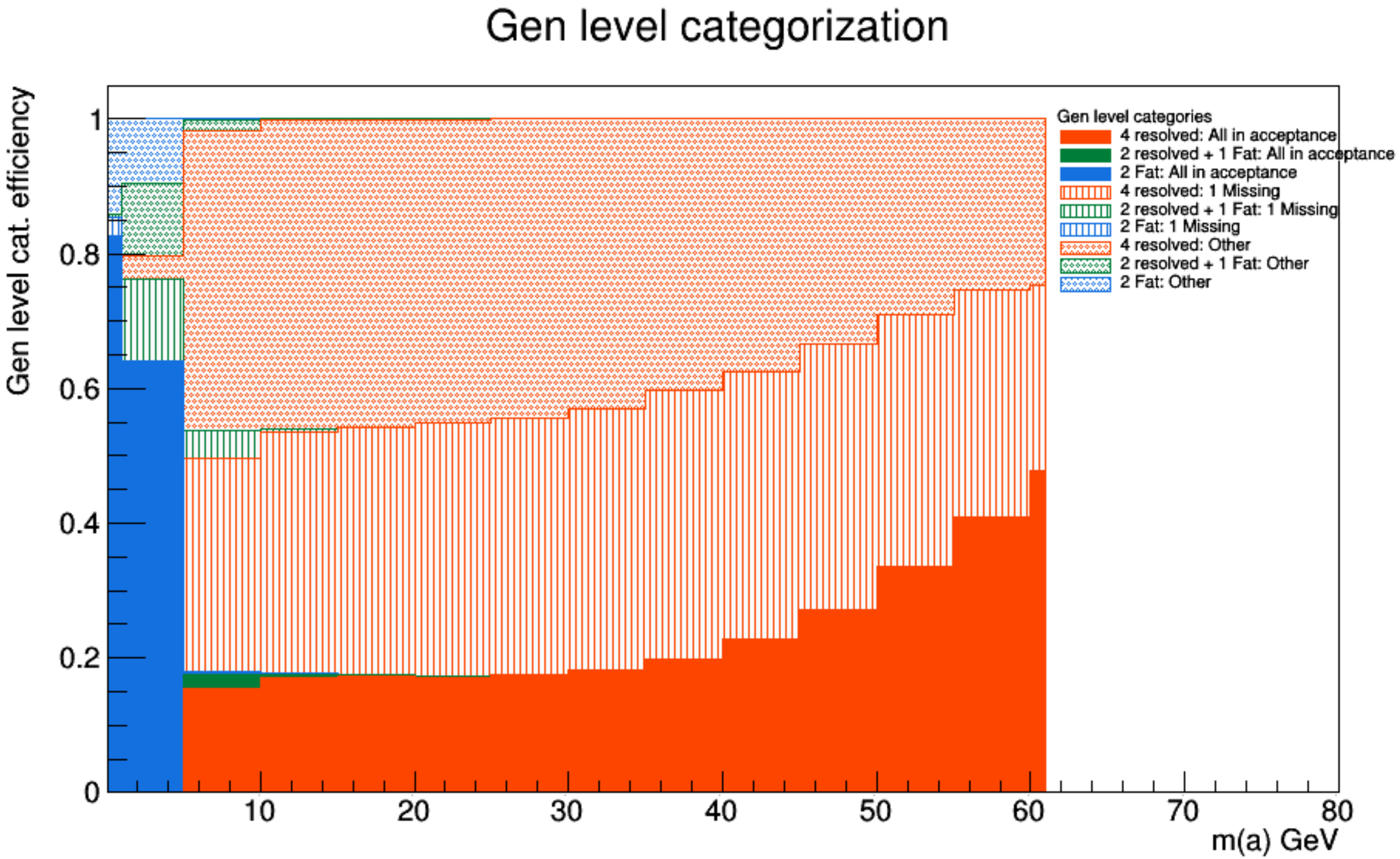
- Gen level categorization
  - abs(eta) < 2.5
  - Photon1 Pt > 11
  - Photon2 Pt > 11
  - Photon3 Pt > 11
  - Photon4 Pt > 11



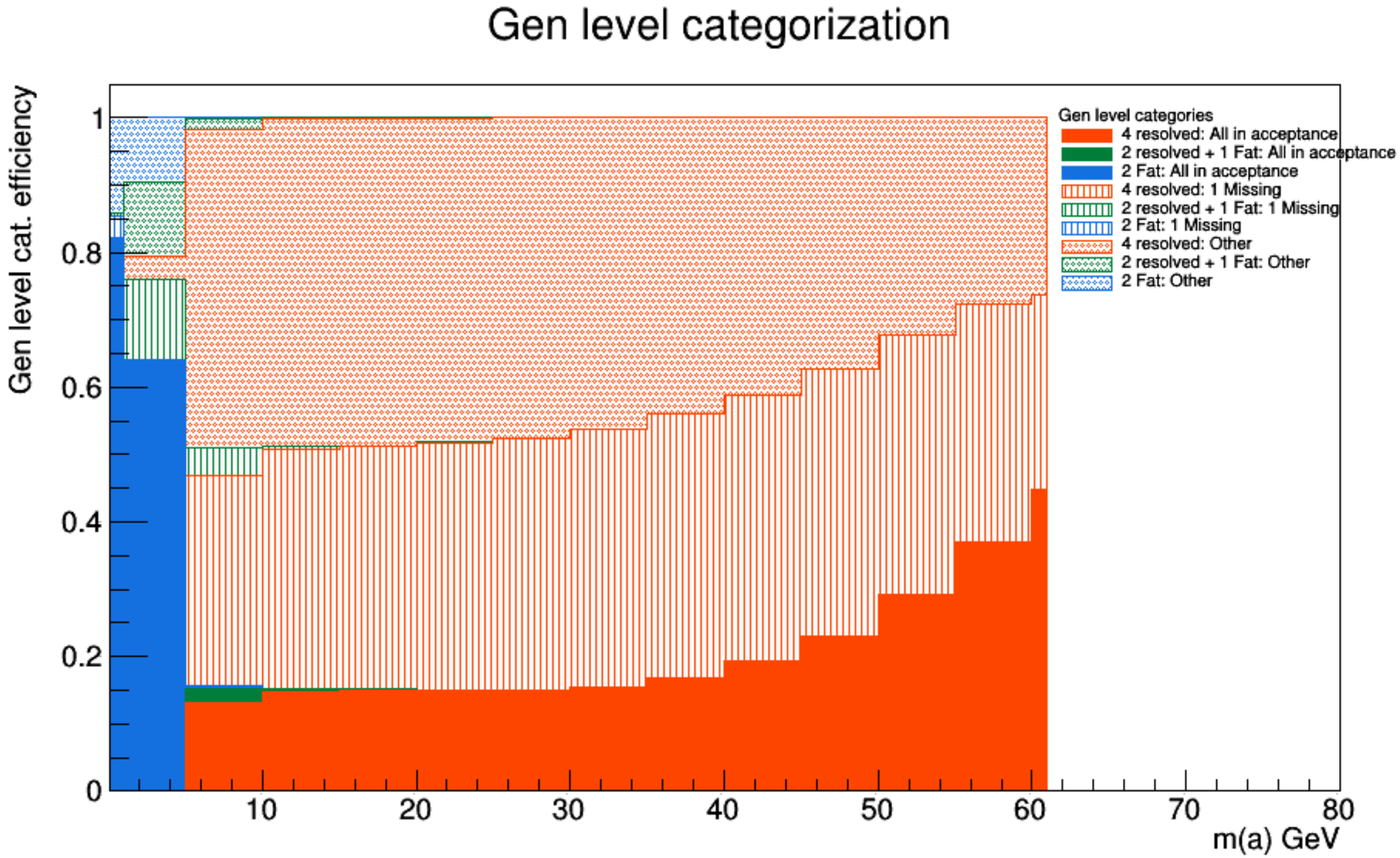
- Gen level categorization
  - abs(eta) < 2.5
  - Photon1 Pt > 12
  - Photon2 Pt > 12
  - Photon3 Pt > 12
  - Photon4 Pt > 12



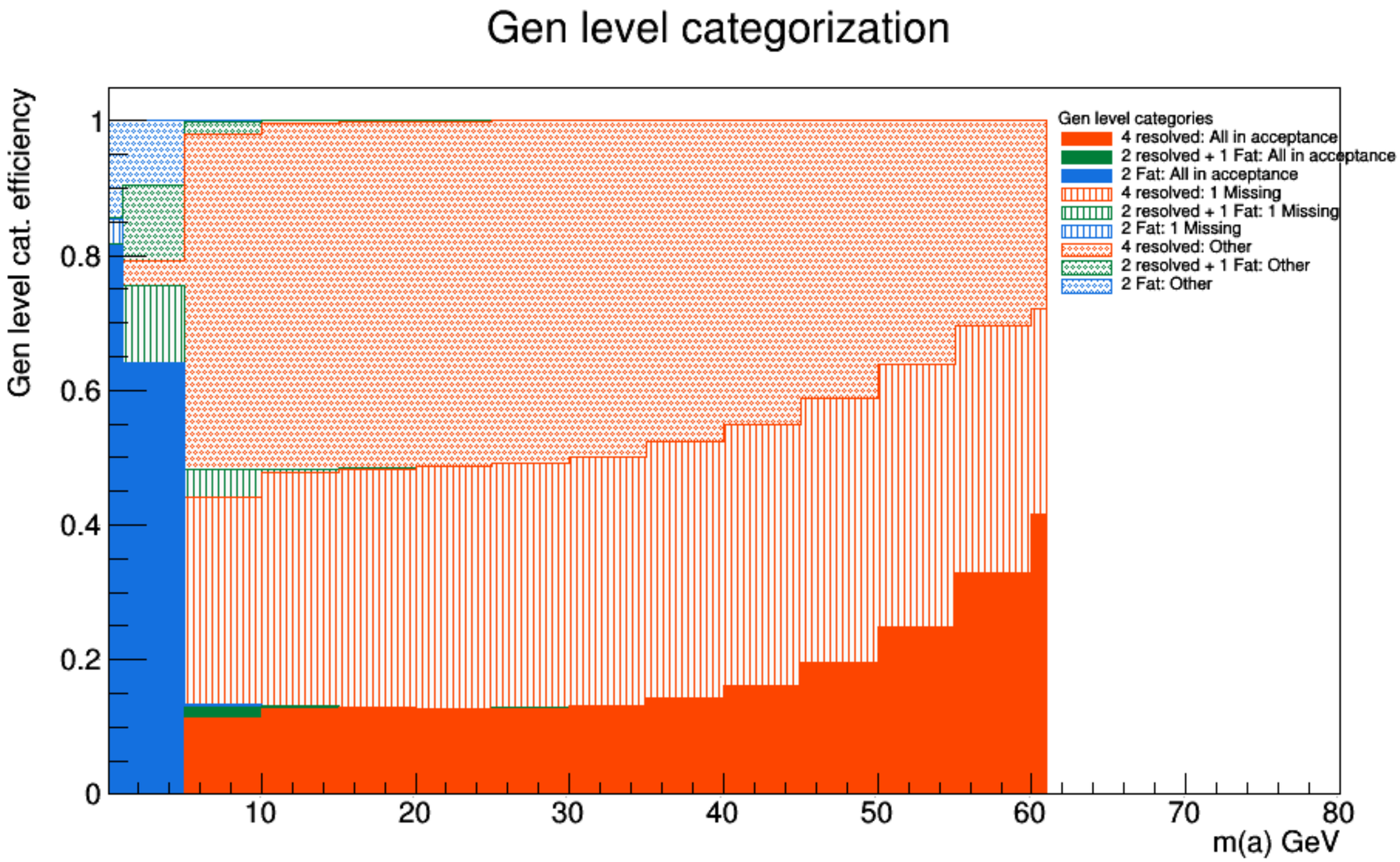
- Gen level categorization
  - abs(eta) < 2.5
  - Photon1 Pt > 13
  - Photon2 Pt > 13
  - Photon3 Pt > 13
  - Photon4 Pt > 13



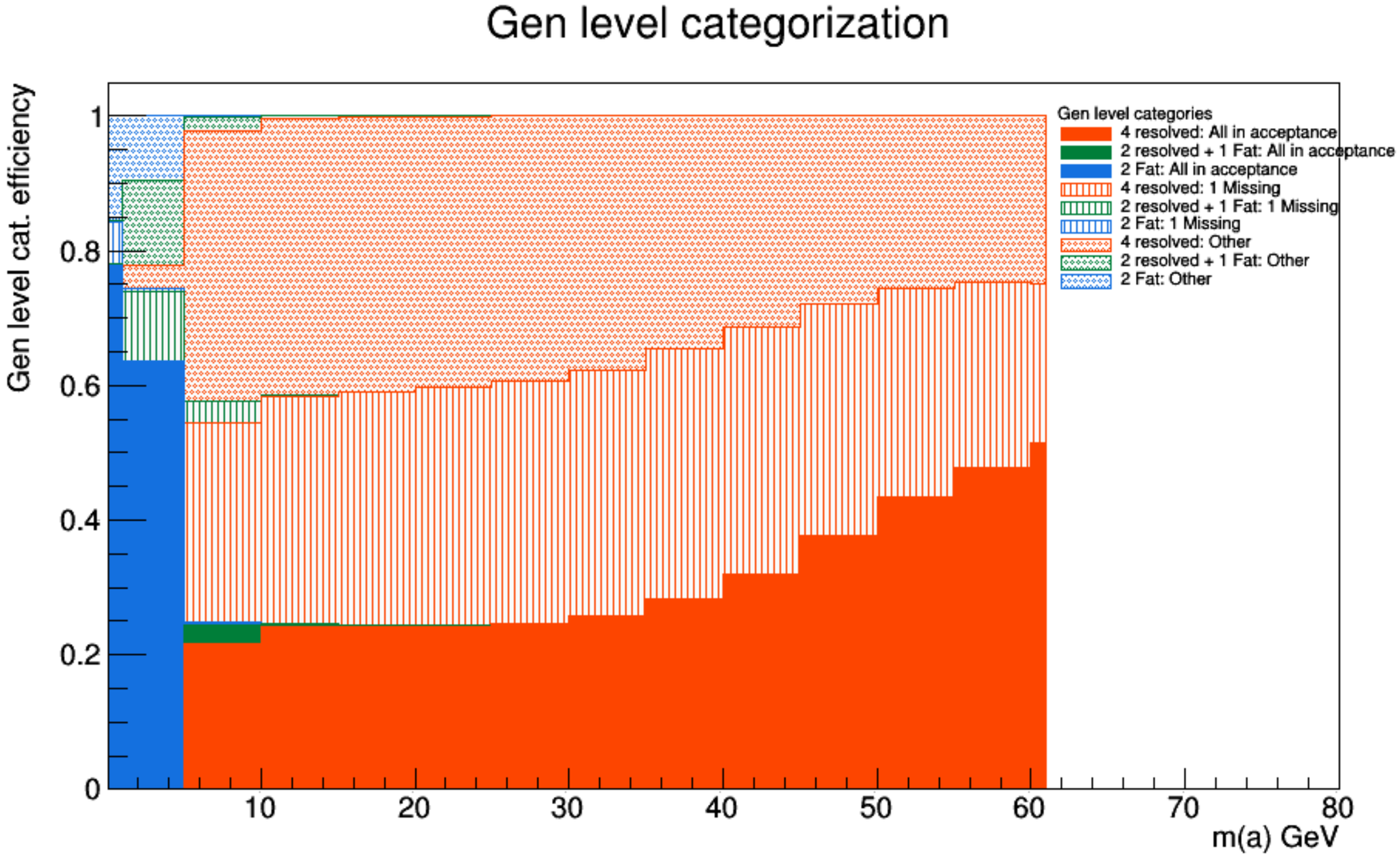
- Gen level categorization
  - abs(eta) < 2.5
  - Photon1 Pt > 14
  - Photon2 Pt > 14
  - Photon3 Pt > 14
  - Photon4 Pt > 14



- Gen level categorization
  - abs(eta) < 2.5
  - Photon1 Pt > 15
  - Photon2 Pt > 15
  - Photon3 Pt > 15
  - Photon4 Pt > 15

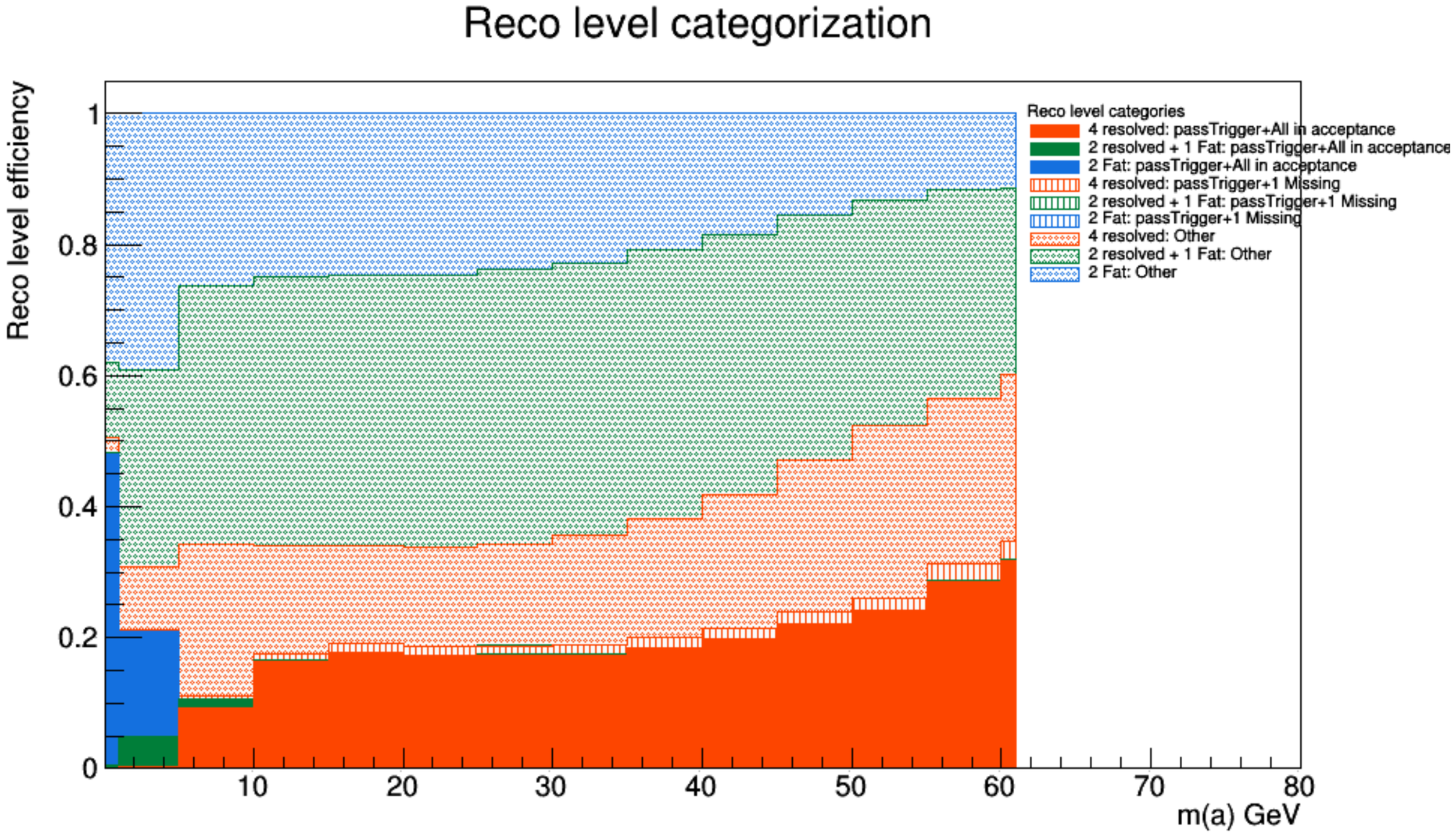


- Gen level categorization
  - abs(eta) < 2.5
  - Photon1 Pt > 30
  - Photon2 Pt >18
  - Photon3 Pt > 10
  - Photon4 Pt >10

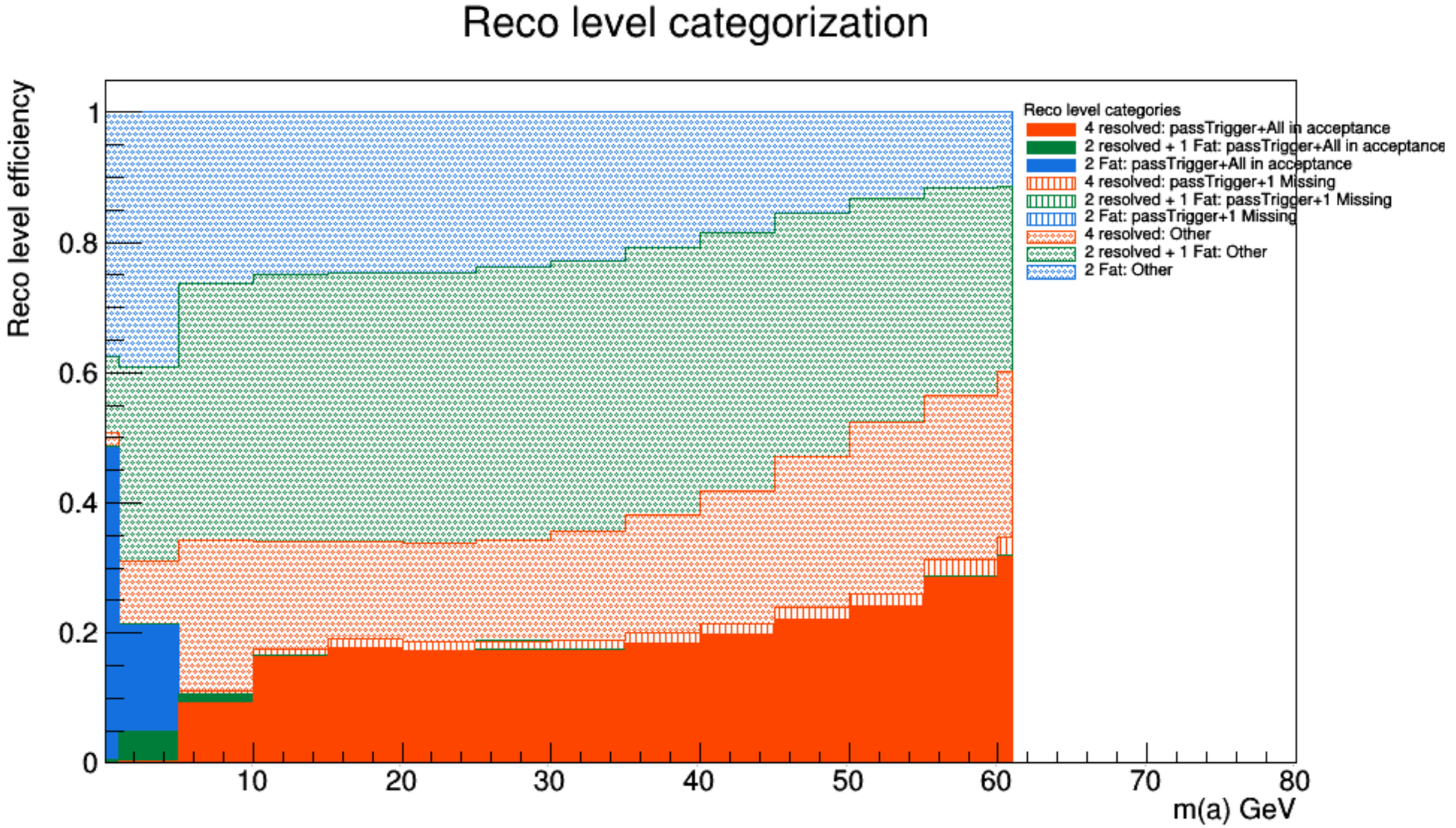


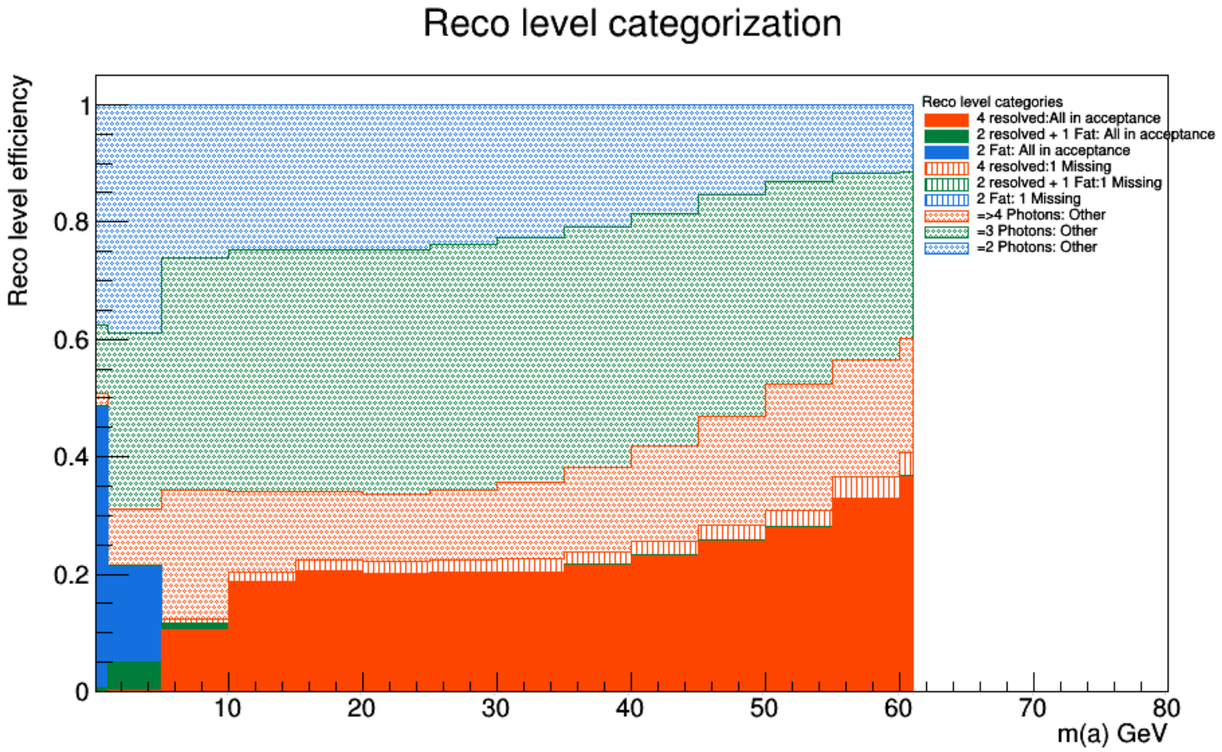
deltaR (Reco, Gen) <0.10

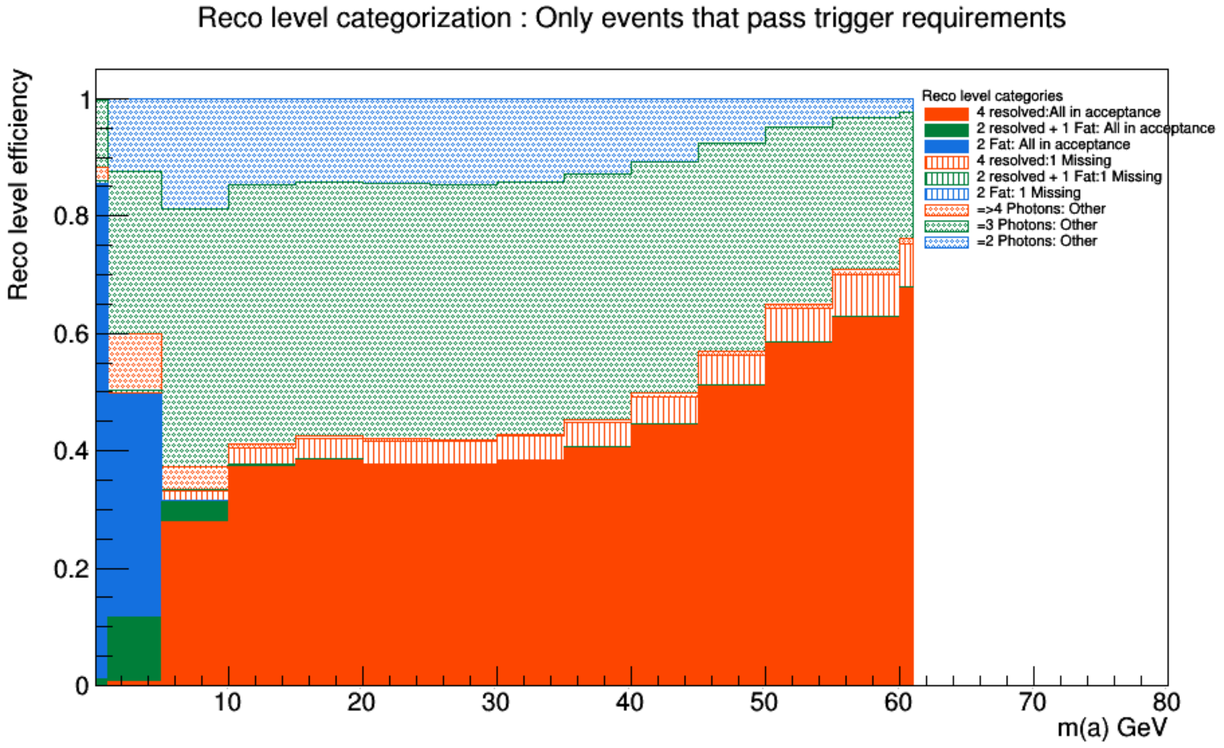
Others (dotted region) also contains events that have not passed trigger



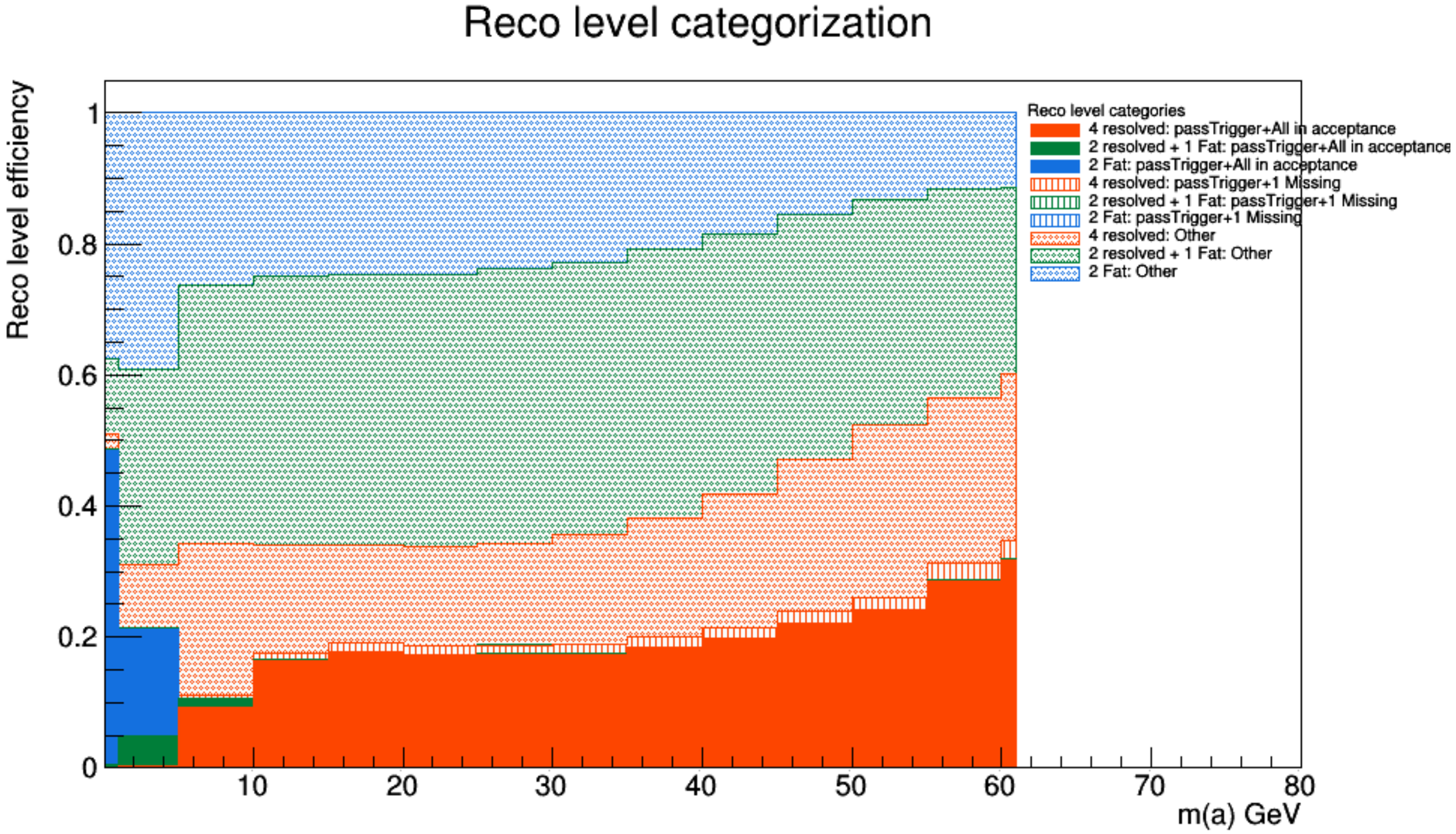
deltaR (Reco, Gen) <0.15



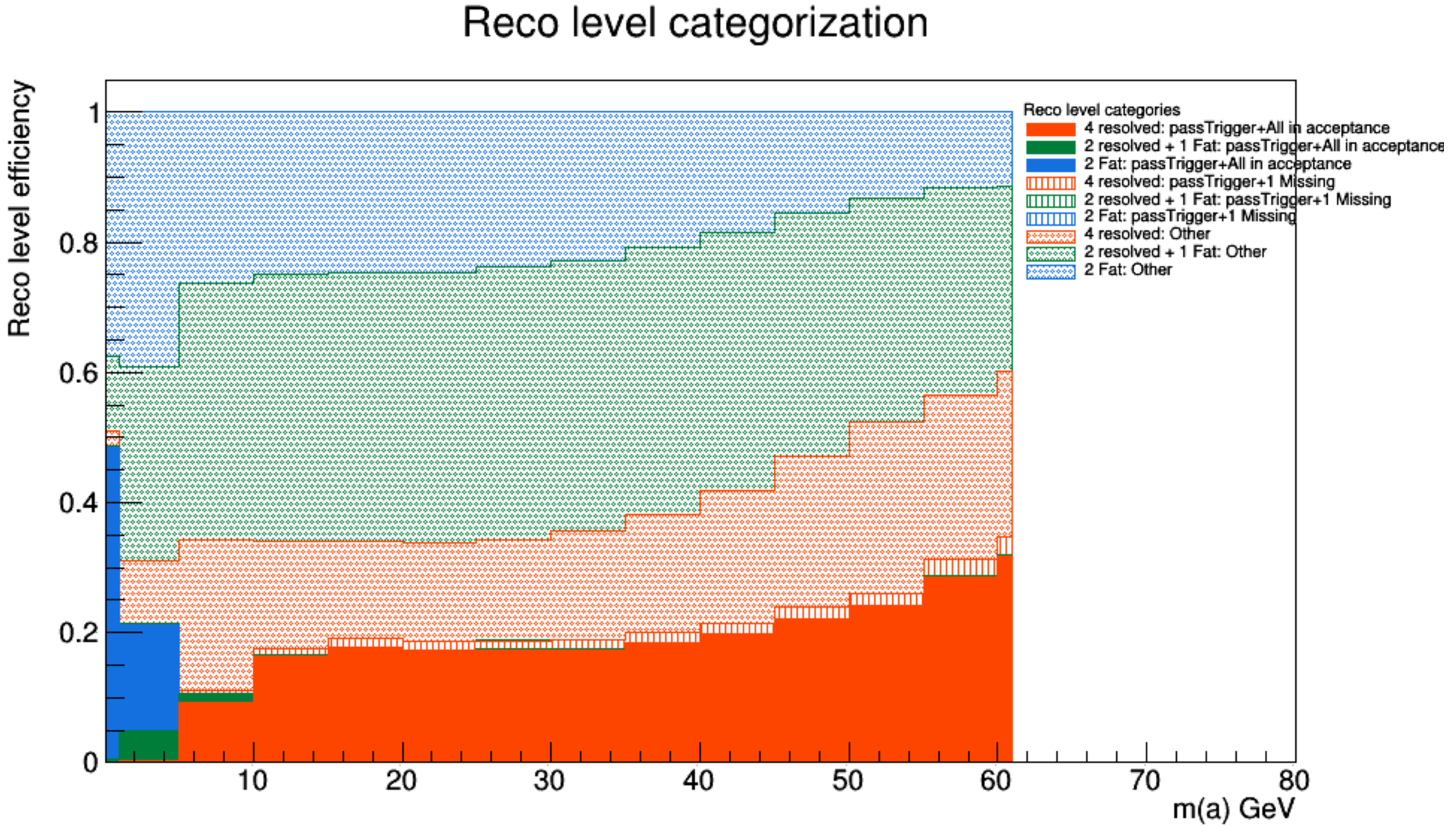

Reco level categorization
Reco level efficiency
1
0.8
0.6
0.4
0.2
0
10
20
30
40
50
60
70
80
m(a) GeV
Reco level categories
4 resolved:All in acceptance
2 resolved + 1 Fat: All in acceptance
2 Fat: All in acceptance
4 resolved:1 Missing
2 resolved + 1 Fat:1 Missing
2 Fat: 1 Missing
=>4 Photons: Other
=3 Photons: Other
=2 Photons: Other


Reco level categorization : Only events that pass trigger requirements
Reco level efficiency
m(a) GeV
Reco level categories
4 resolved:All in acceptance
2 resolved + 1 Fat: All in acceptance
2 Fat: All in acceptance
4 resolved:1 Missing
2 resolved + 1 Fat:1 Missing
2 Fat: 1 Missing
=>4 Photons: Other
=3 Photons: Other
=2 Photons: Other

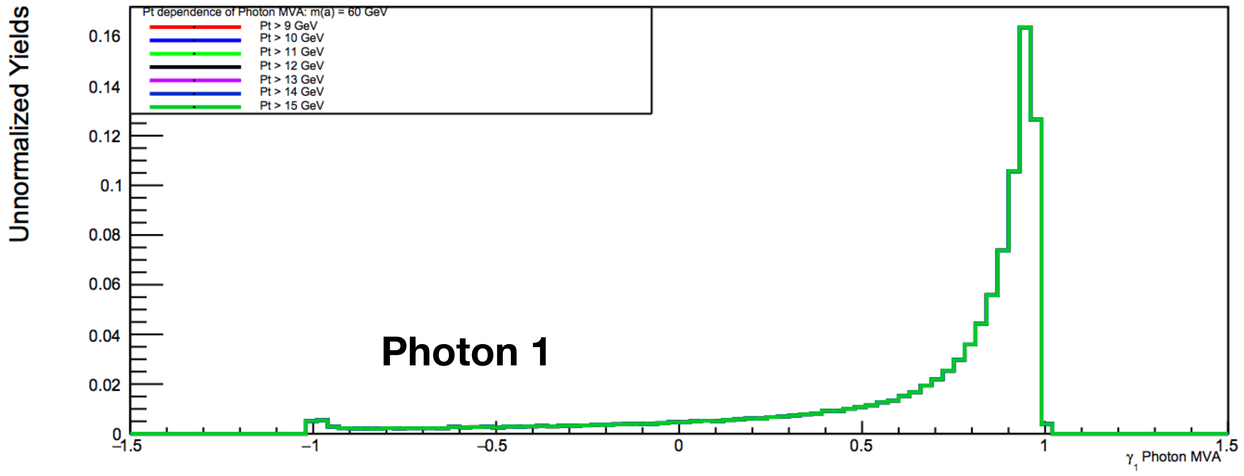
deltaR (Reco, Gen) <0.2

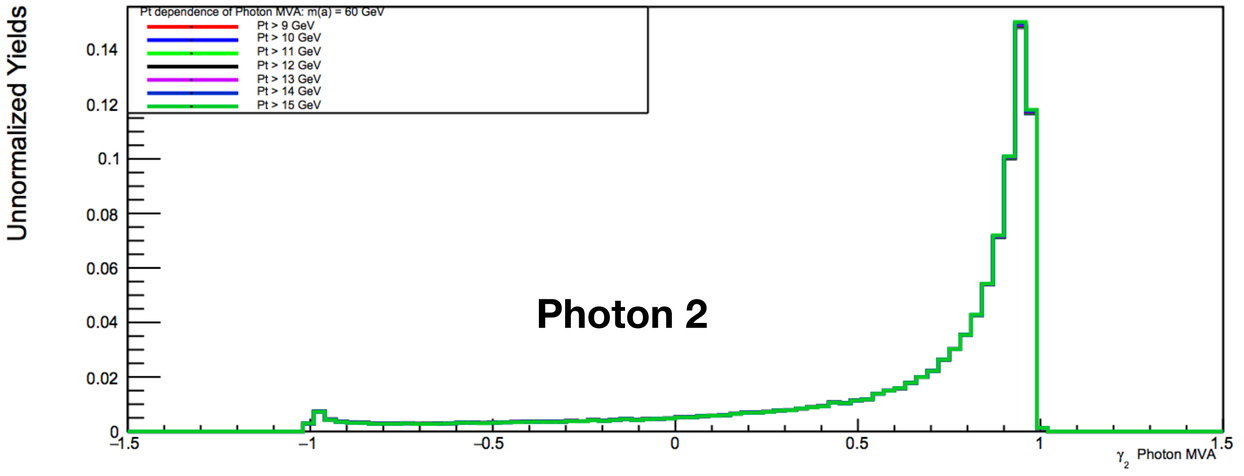


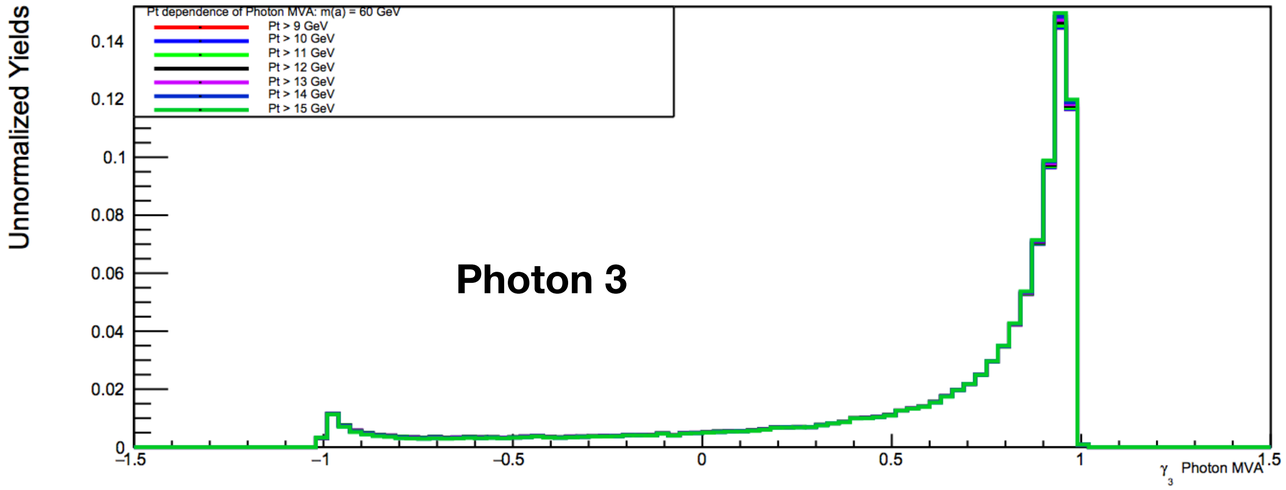
deltaR (Reco, Gen) <0.3

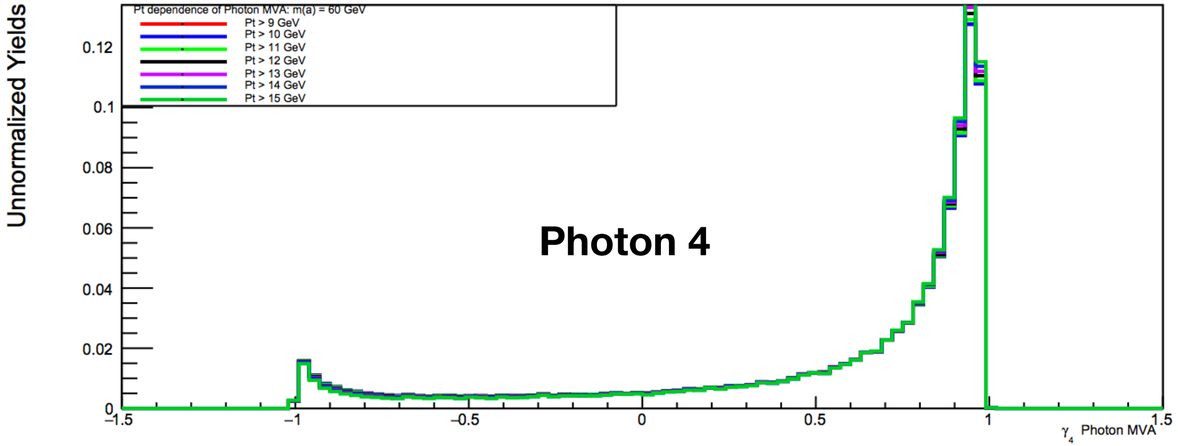


m(a) = 60 GeV

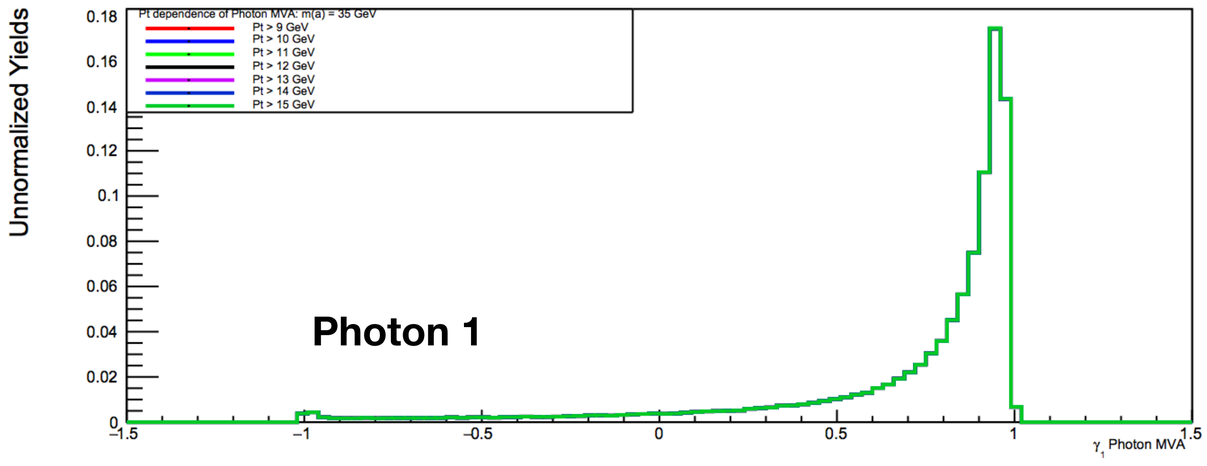

Pt dependence of Photon MVA: m(a) = 60 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 1
γ1 Photon MVA

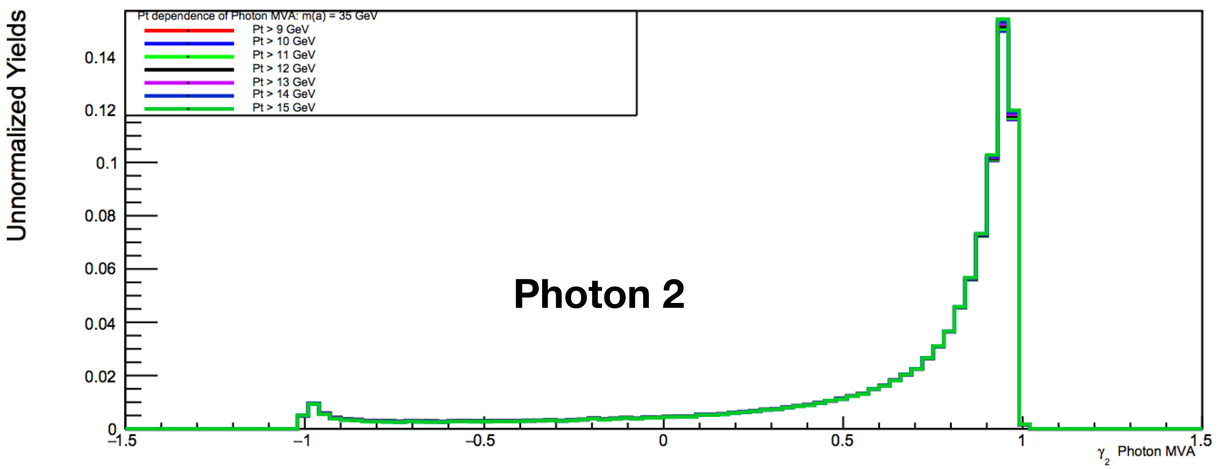

Pt dependence of Photon MVA: m(a) = 60 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 2
γ2 Photon MVA

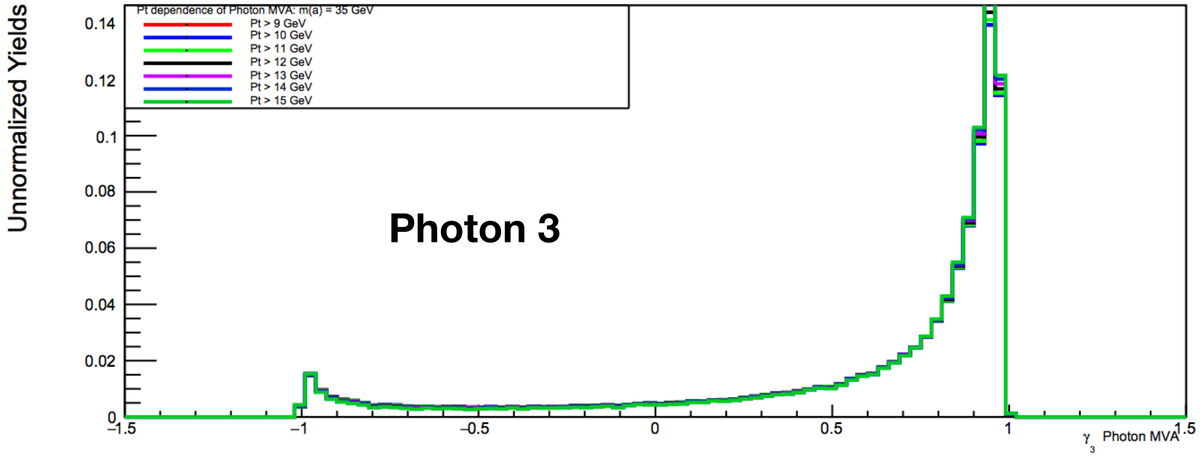

Pt dependence of Photon MVA: m(a) = 60 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 3
γ3 Photon MVA

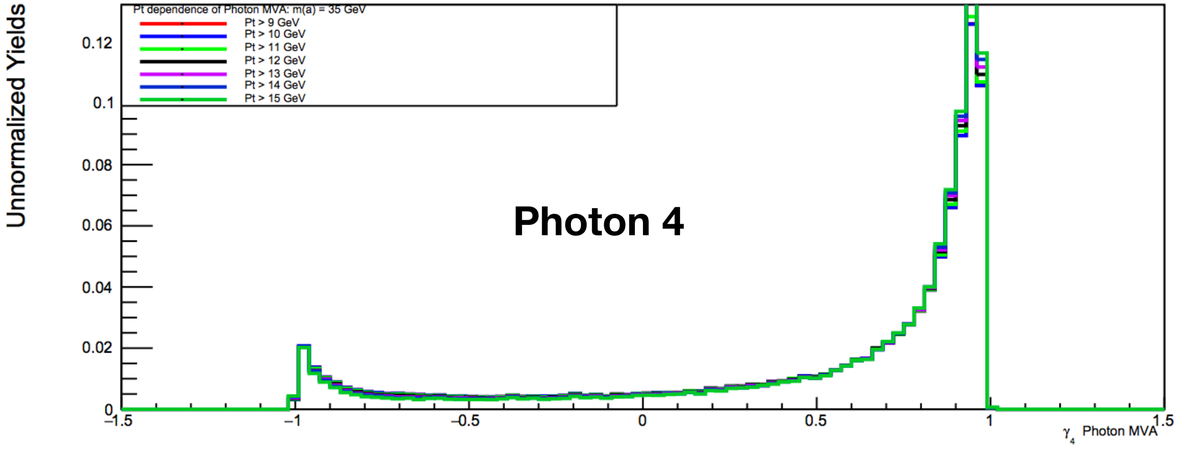

Pt dependence of Photon MVA: m(a) = 60 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 4
γ4 Photon MVA

m(a) = 35 GeV

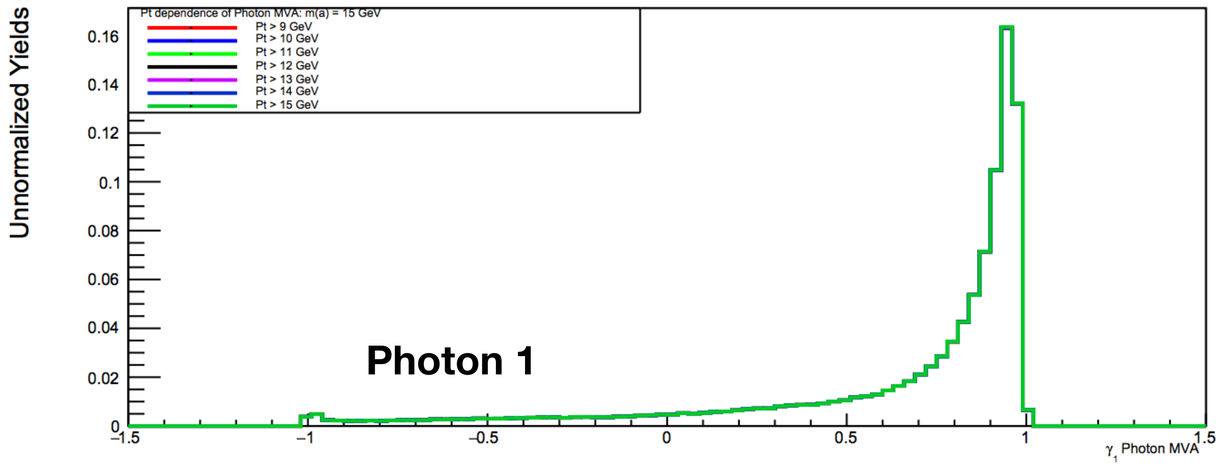

Pt dependence of Photon MVA: m(a) = 35 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 1
γ1 Photon MVA

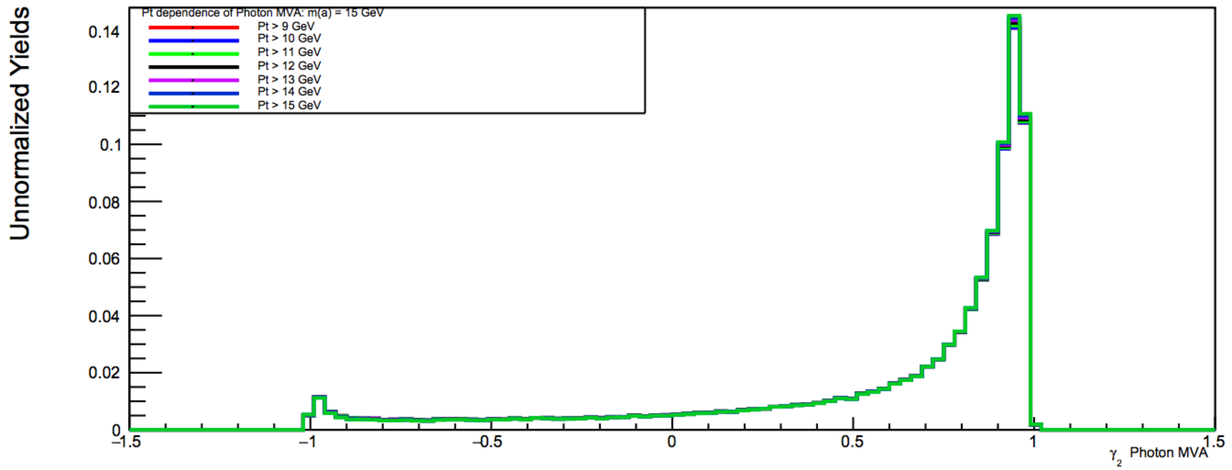

Pt dependence of Photon MVA: m(a) = 35 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 2
γ2 Photon MVA

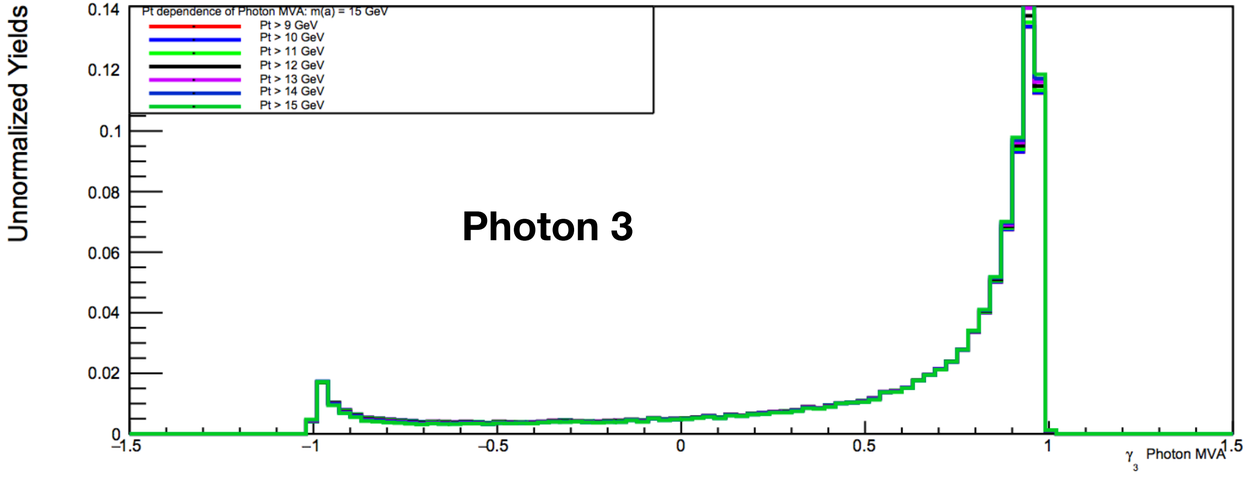

Pt dependence of Photon MVA: m(a) = 35 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 3
γ3 Photon MVA

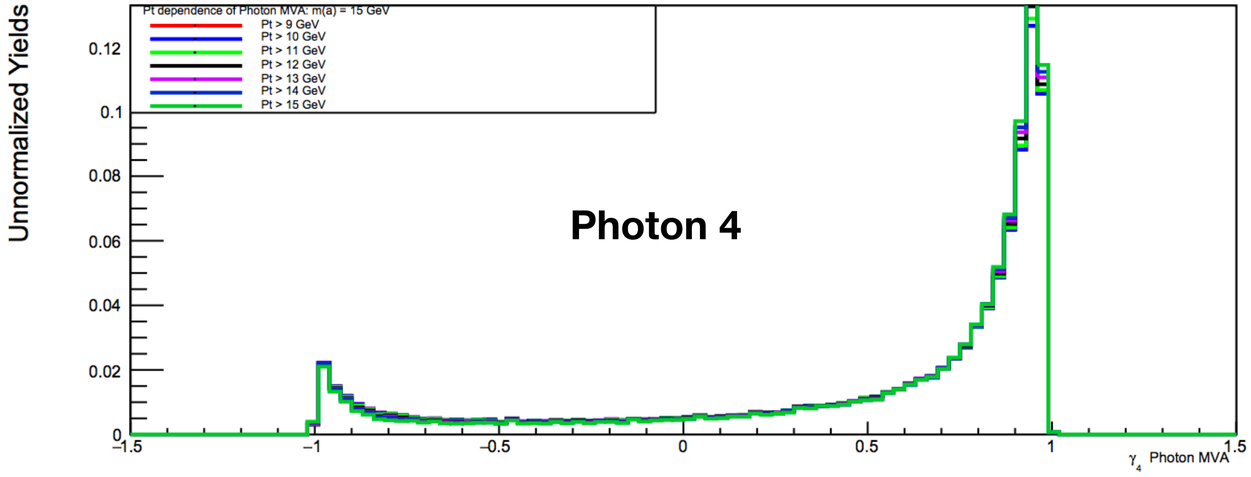

Pt dependence of Photon MVA: m(a) = 35 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 4
γ4 Photon MVA

m(a) = 15 GeV

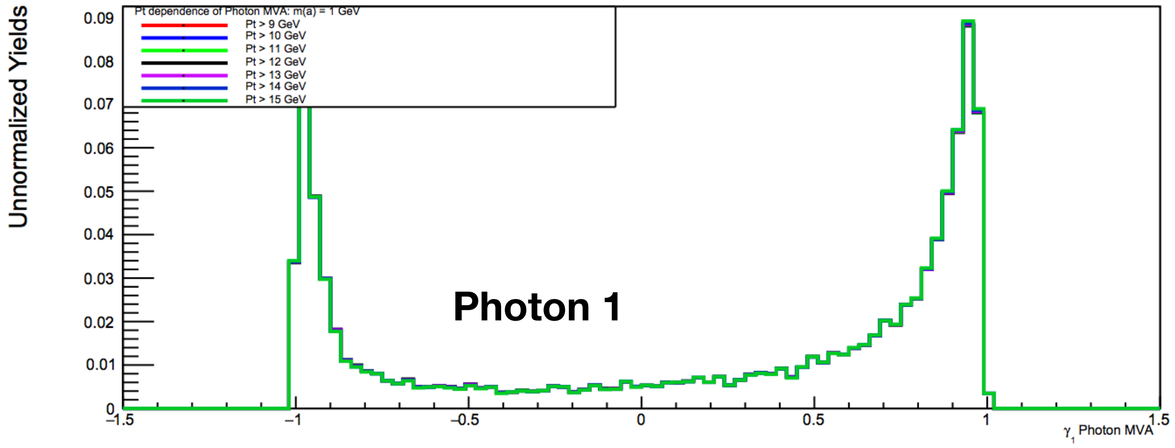

Pt dependence of Photon MVA: m(a) = 15 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 1
γ1 Photon MVA

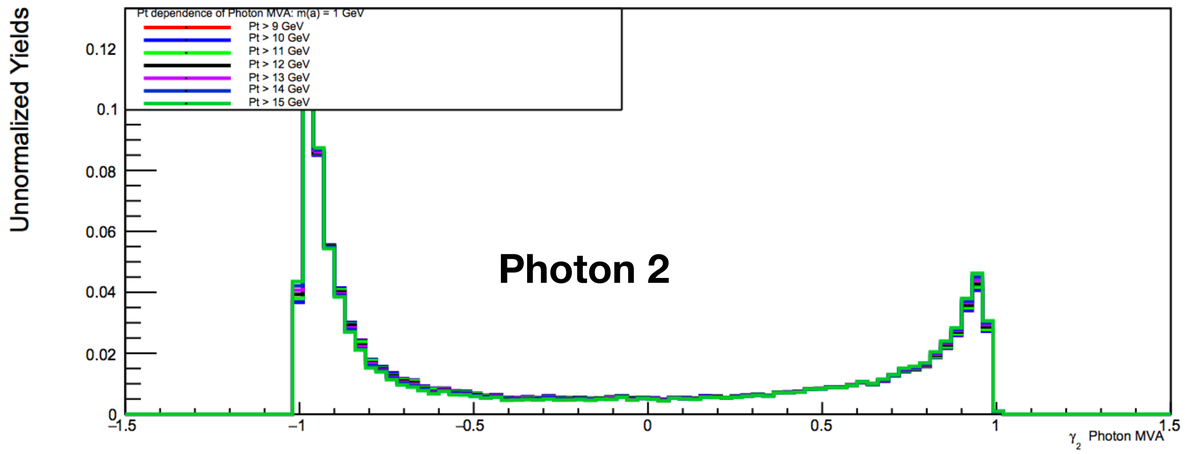

Pt dependence of Photon MVA: m(a) = 15 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
γ2 Photon MVA

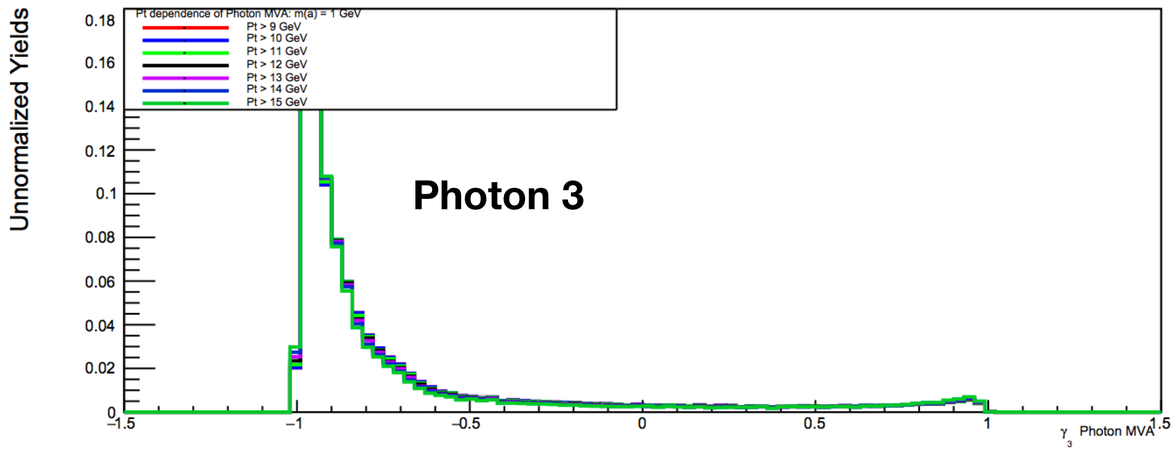

Pt dependence of Photon MVA: m(a) = 15 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 3
γ3 Photon MVA

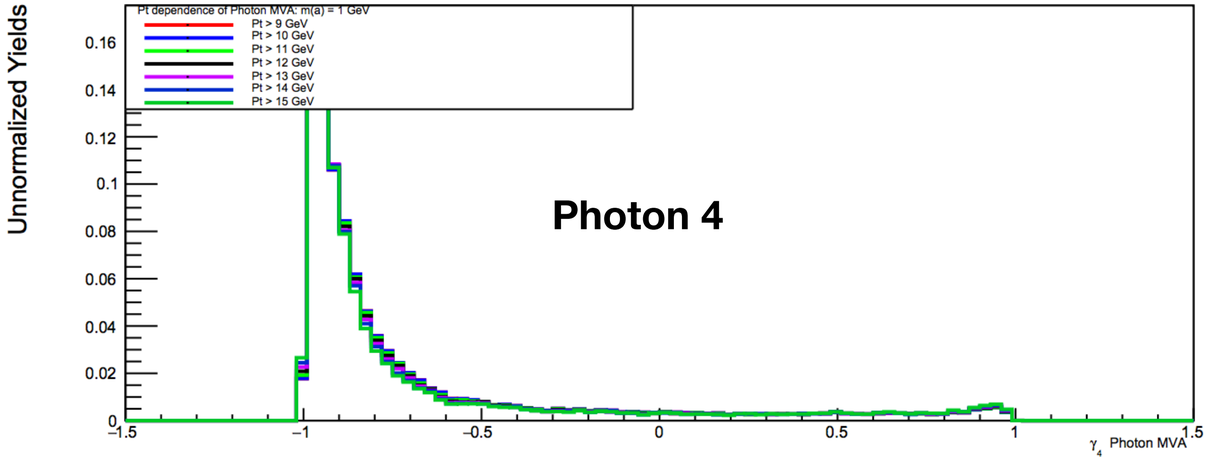

Pt dependence of Photon MVA: m(a) = 15 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 4
γ4 Photon MVA

m(a) = 1 GeV

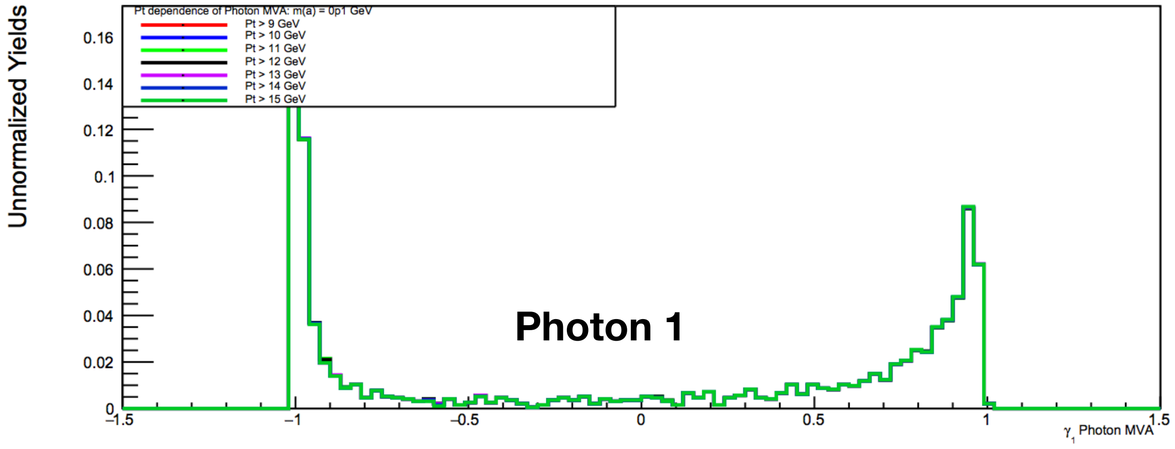

Pt dependence of Photon MVA: m(a) = 1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 1
γ1 Photon MVA

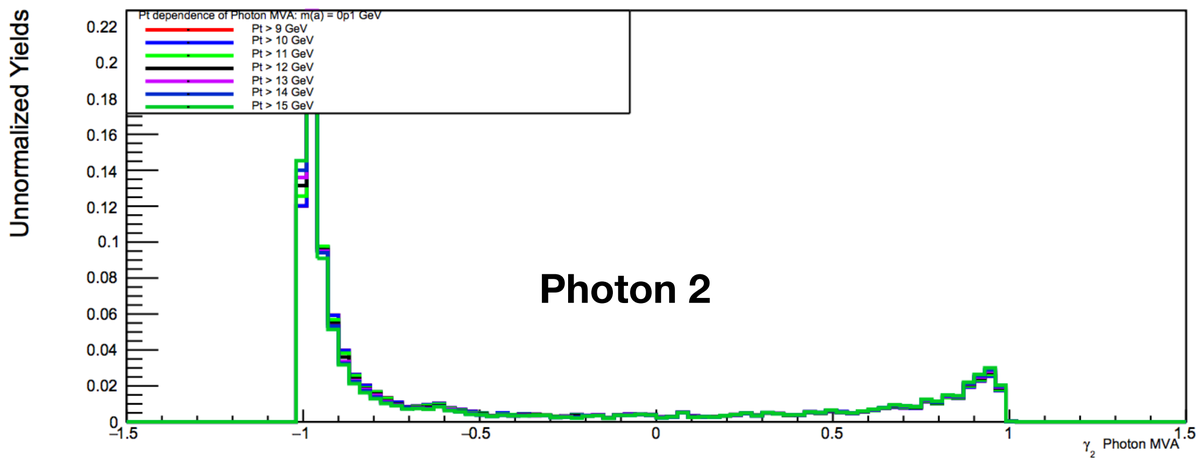

Pt dependence of Photon MVA: m(a) = 1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 2
γ2 Photon MVA

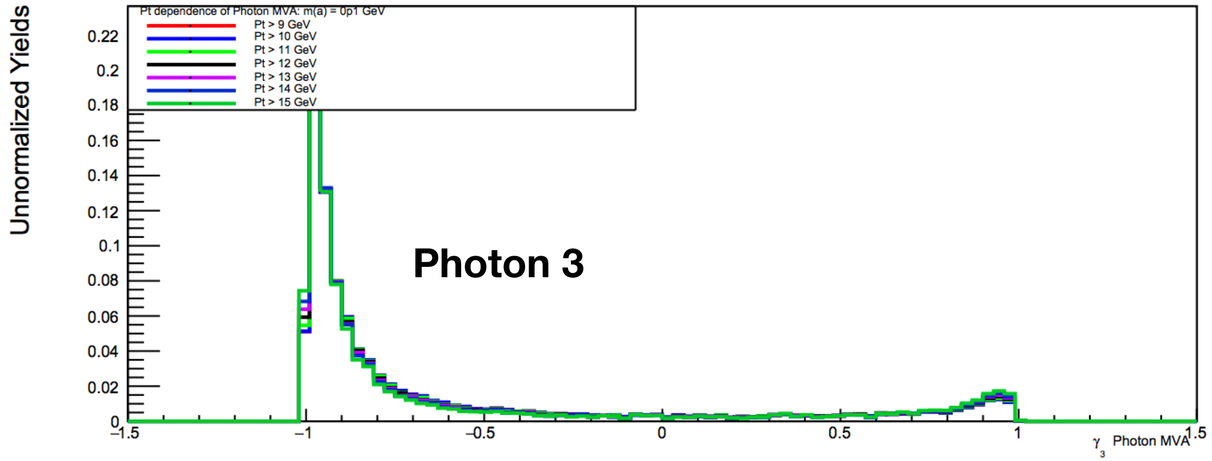

Pt dependence of Photon MVA: m(a) = 1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 3
γ3 Photon MVA

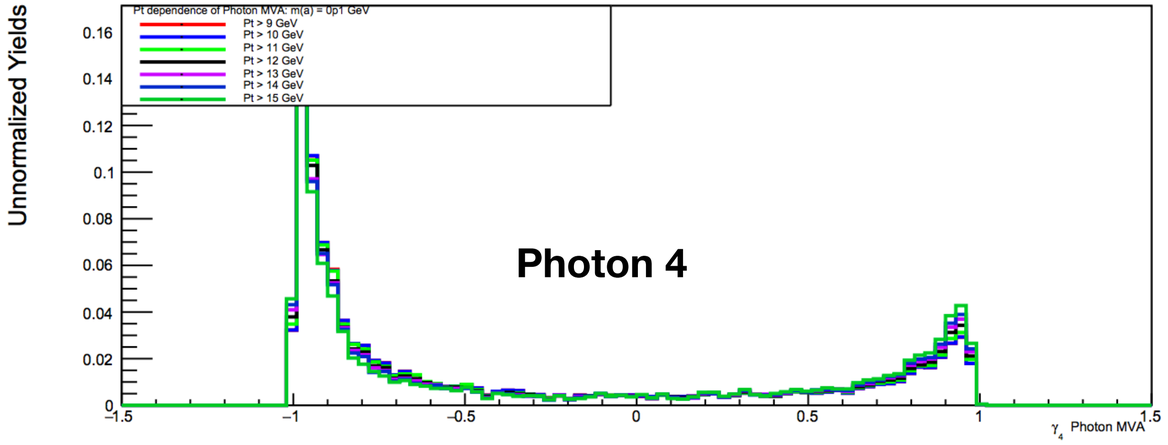

Pt dependence of Photon MVA: m(a) = 1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 4
γ4 Photon MVA

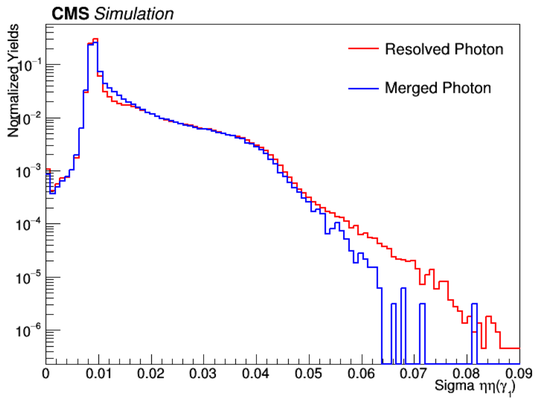
m(a) = 0.1 GeV

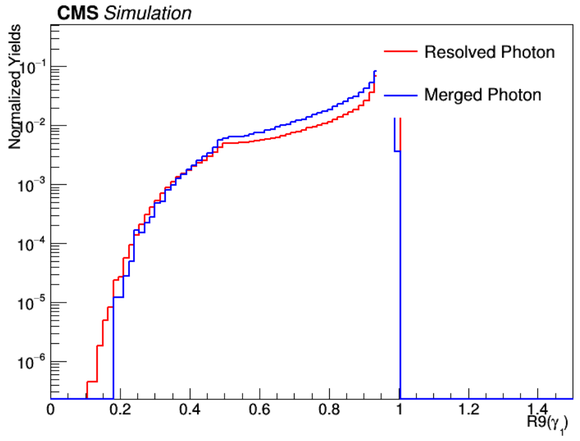

Pt dependence of Photon MVA: m(a) = 0p1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 1
γ1 Photon MVA

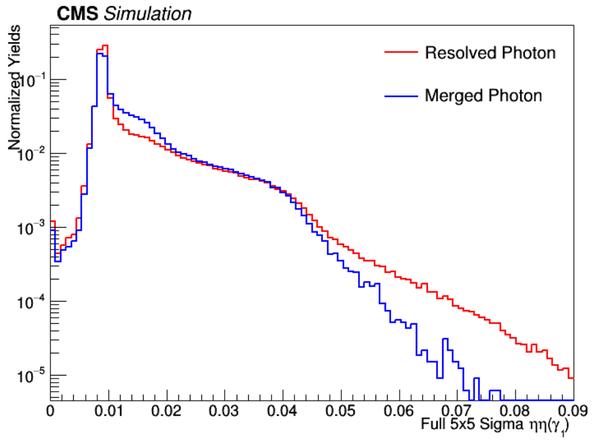

Pt dependence of Photon MVA: m(a) = 0p1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 2
γ2 Photon MVA

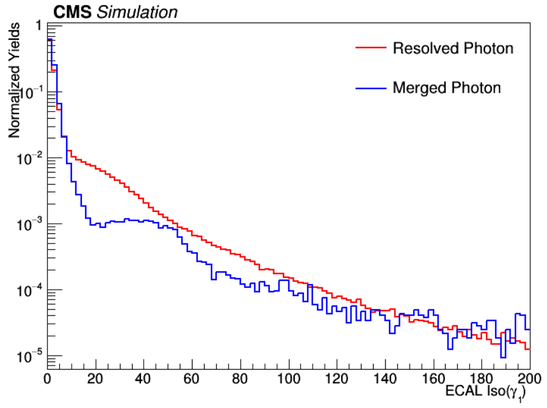

Pt dependence of Photon MVA: m(a) = 0p1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 3
γ3 Photon MVA

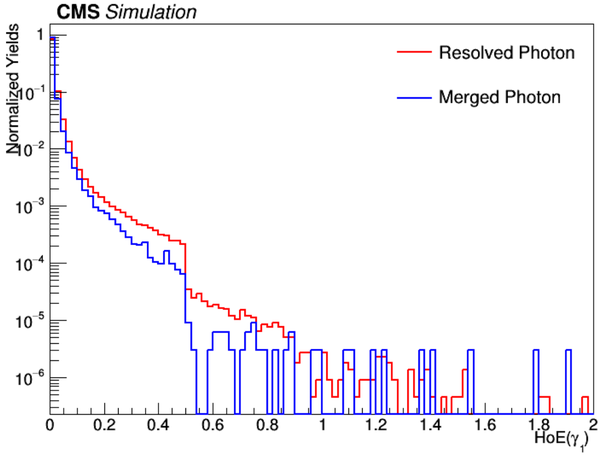

Pt dependence of Photon MVA: m(a) = 0p1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 4
γ4 Photon MVA

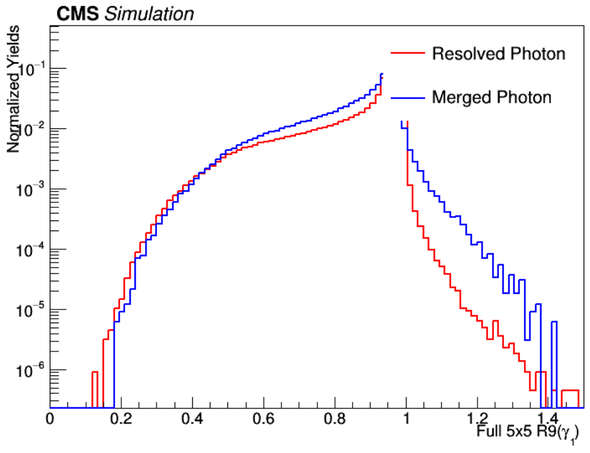

CMS Simulation
Resolved Photon
Merged Photon
Normalized Yields
Sigma ηη(γ1)

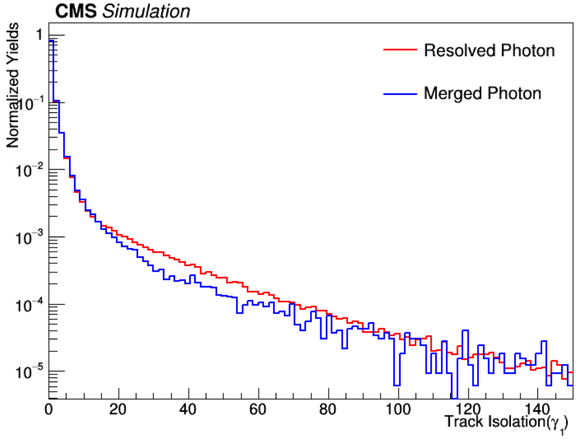

CMS Simulation
Resolved Photon
Merged Photon
Normalized Yields
R9(γ1)

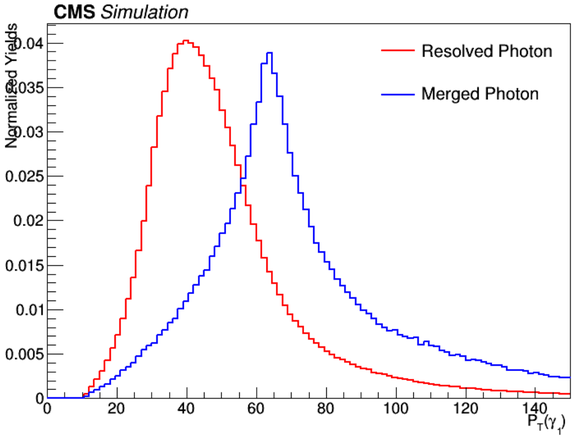

CMS Simulation
Resolved Photon
Merged Photon
Normalized Yields
Full 5x5 Sigma ηη(γ1)

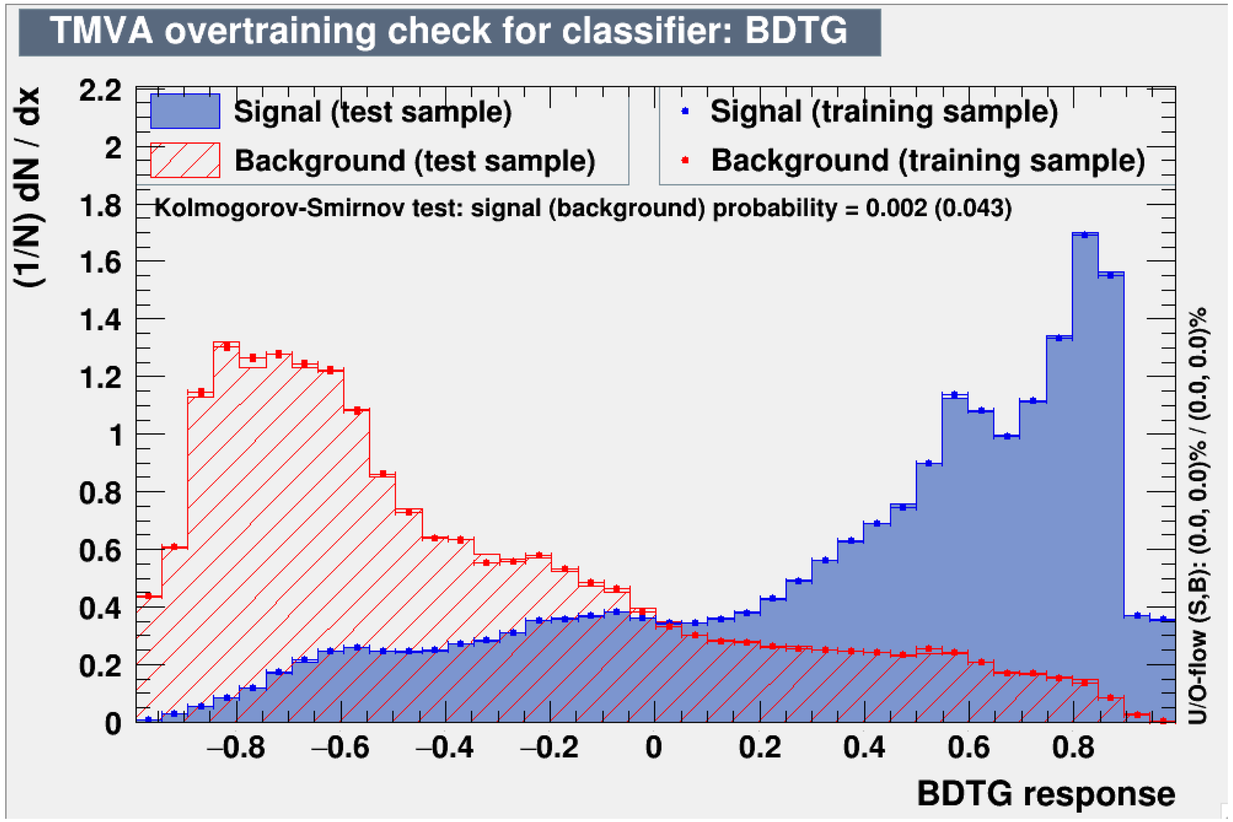

CMS Simulation
Resolved Photon
Merged Photon
Normalized Yields
ECAL Iso(γ1)

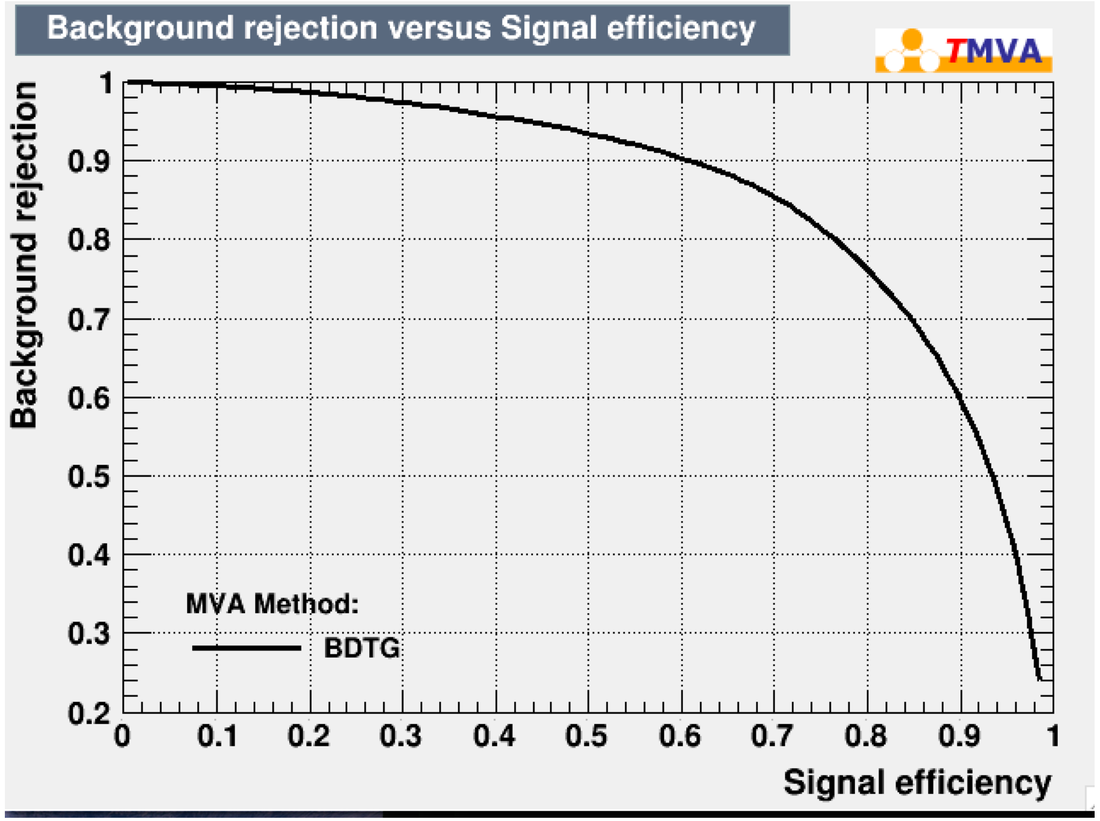

CMS Simulation
Resolved Photon
Merged Photon
Normalized Yields
HoE(γ1)


CMS Simulation
Resolved Photon
Merged Photon
Normalized Yields
Full 5x5 R9(γ1)


CMS Simulation
Resolved Photon
Merged Photon
Normalized Yields
Track Isolation(γ1)


CMS Simulation
Resolved Photon
Merged Photon
Normalized Yields
PT(γ1)

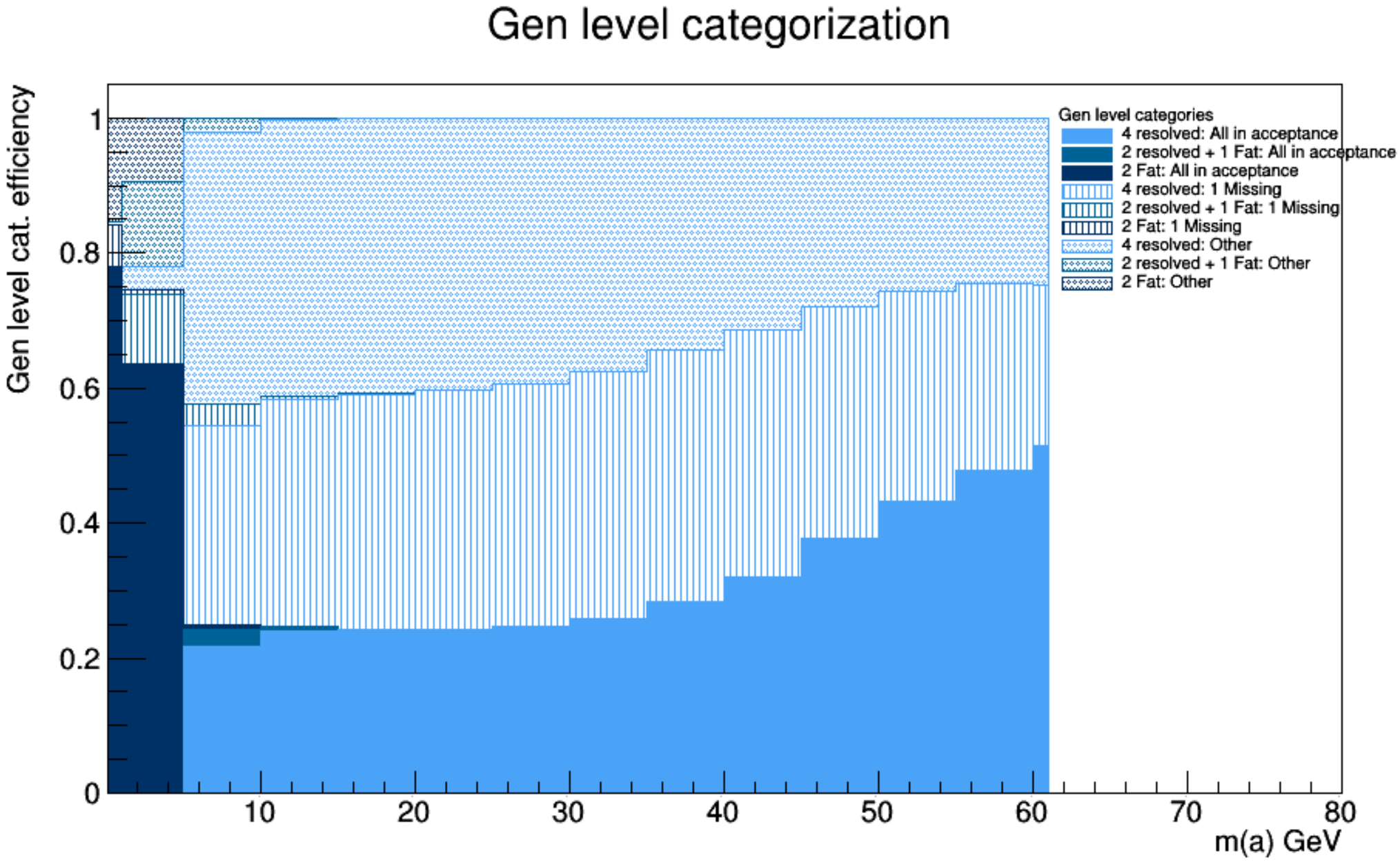

TMVA overtraining check for classifier: BDTG
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.002 (0.043)
(1/N) dN / dx
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDTG response


Background rejection versus Signal efficiency
TMVA
Background rejection
MVA Method:
BDTG
Signal efficiency

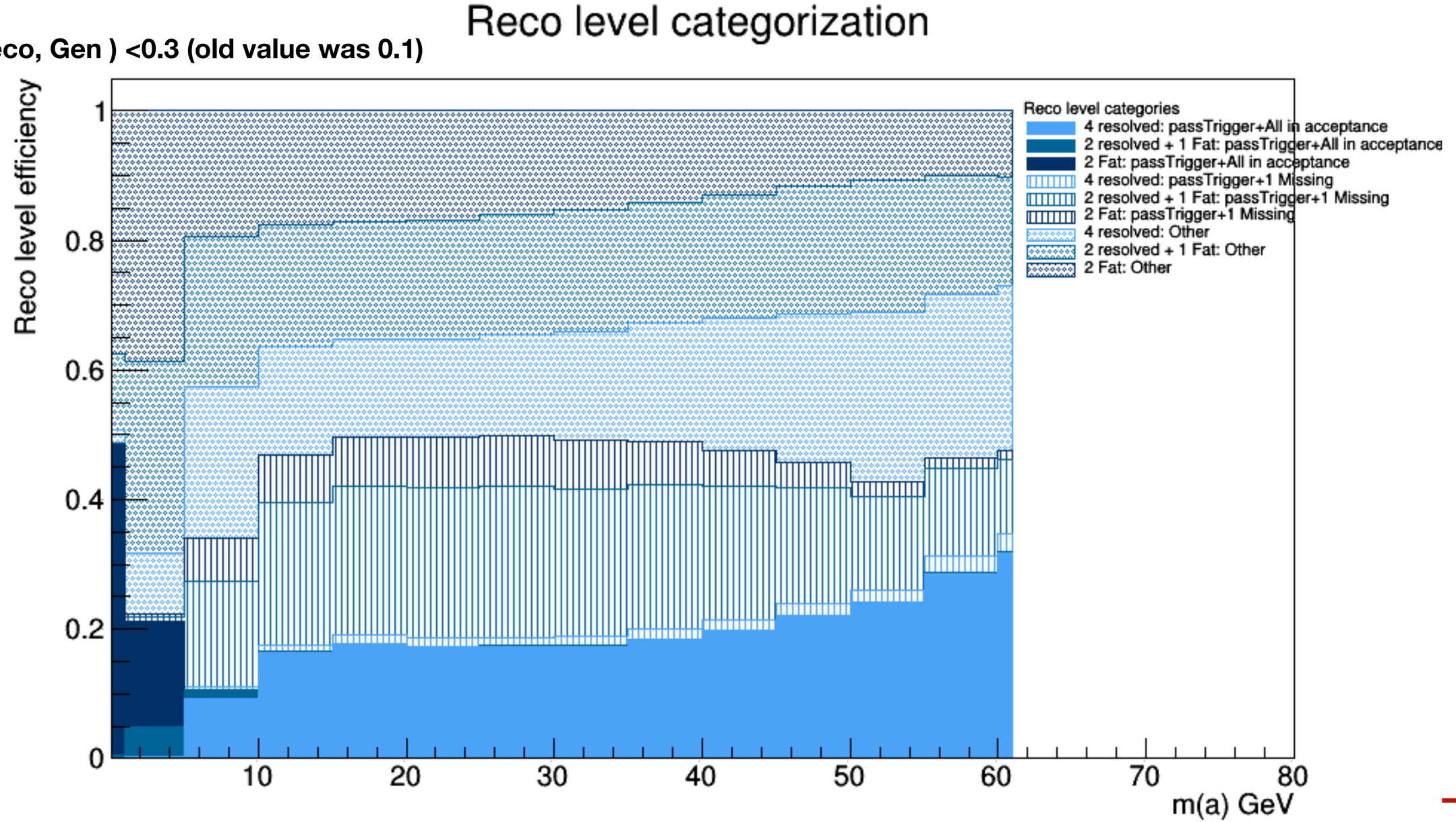
Backup - older slides

Merged photon definition: dR < 0.1 (old value was 0.3)

- abs(eta) < 2.5
- Photon1 Pt > 30
- Photon2 Pt >18
- Photon3 Pt > 10
- Photon4 Pt >10

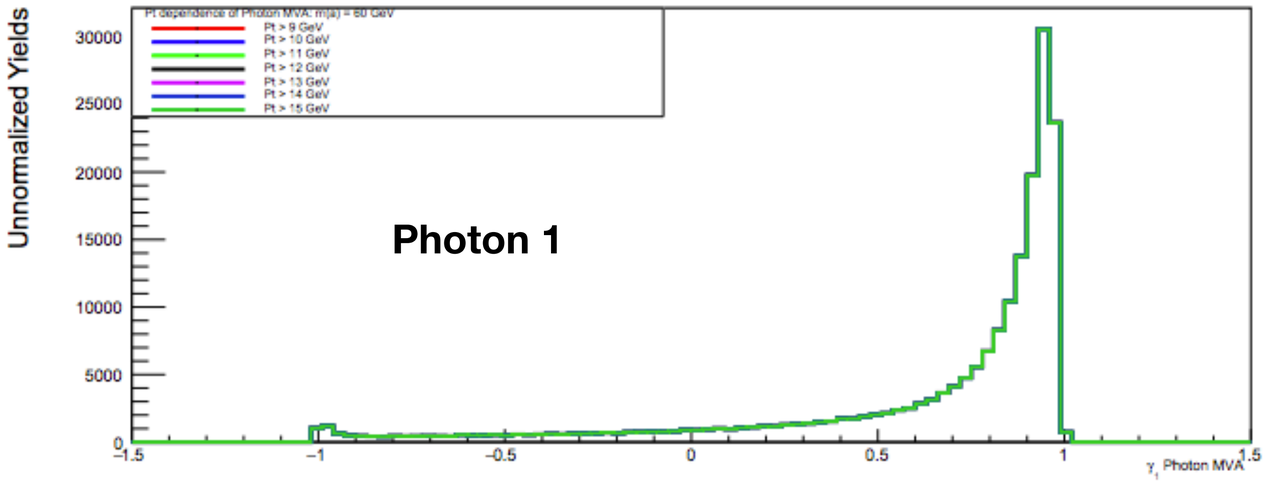


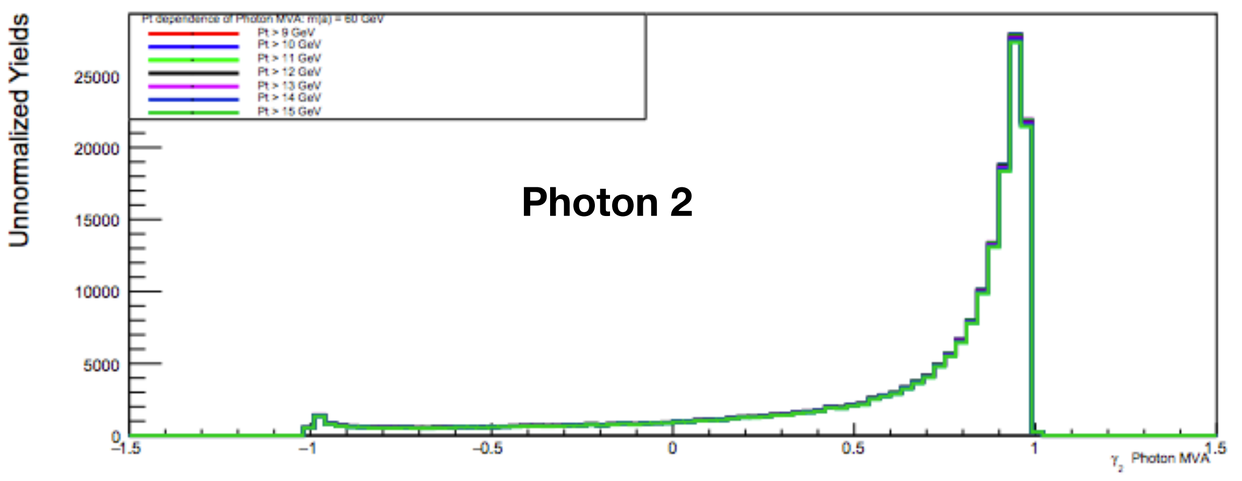
For matching:
Require deltaR (Reco, Gen) <0.3 (old value was 0.1)

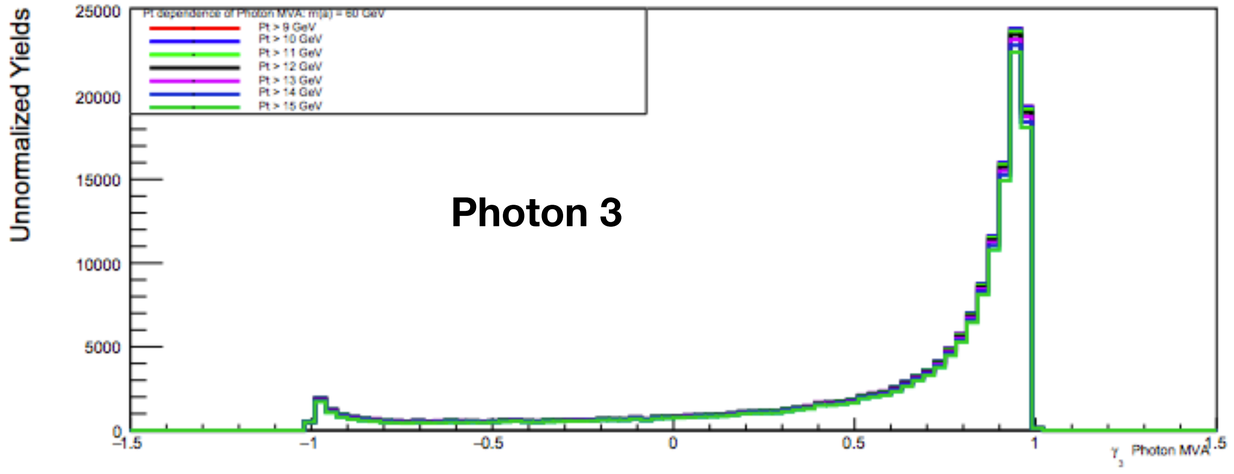


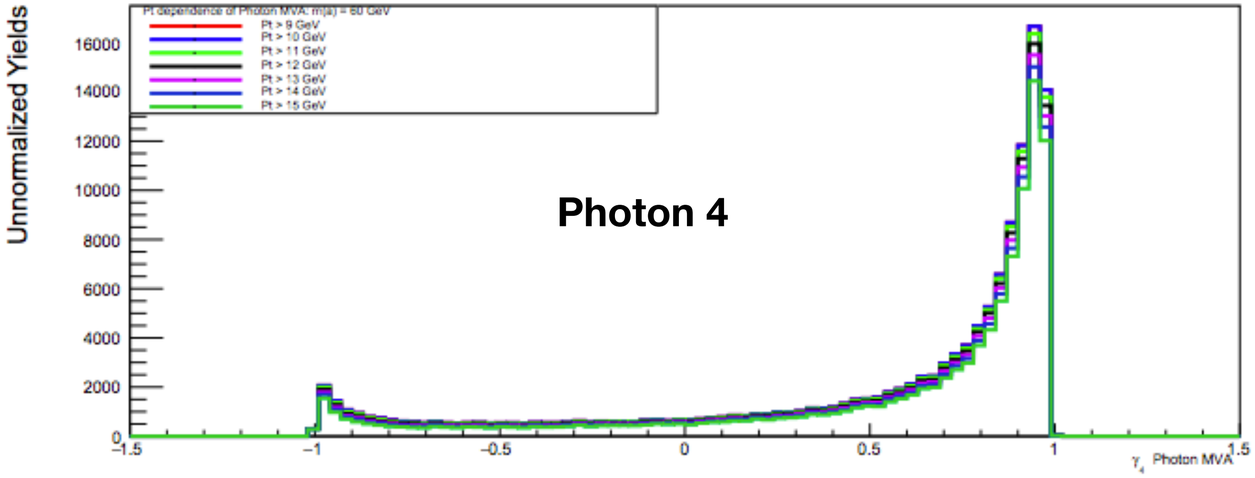
Pt dependence of Photon MVA ID

Plotted here are the Photon MVA ID values for photons for different Pt values (so selection applied on the photon)
Reminder : Basic Pt cut on photons >10 GeV

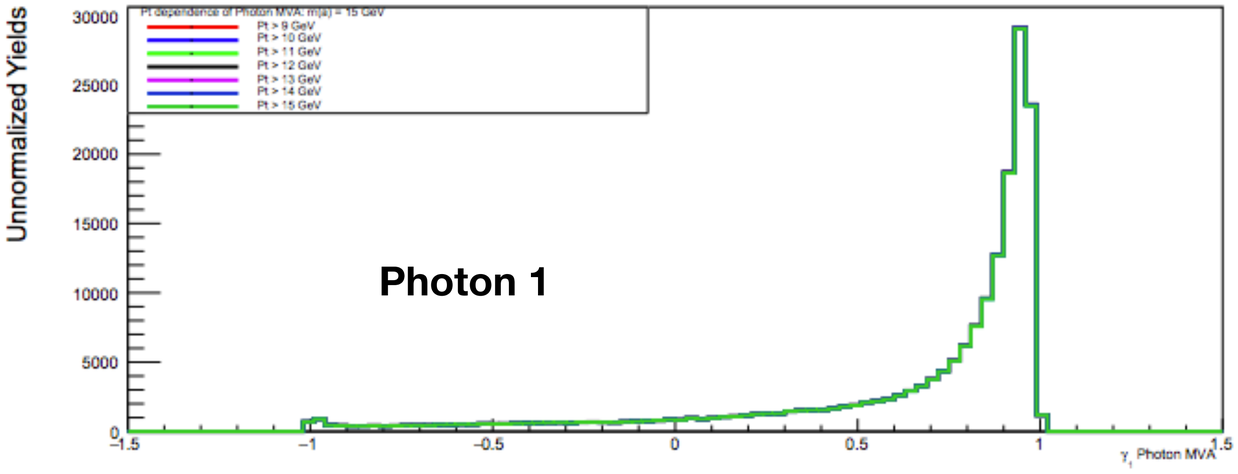


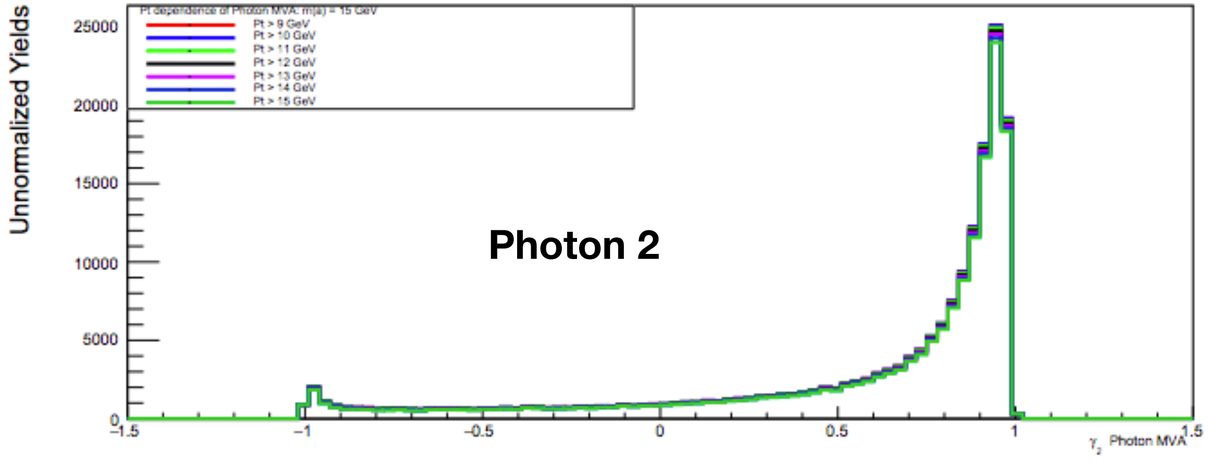


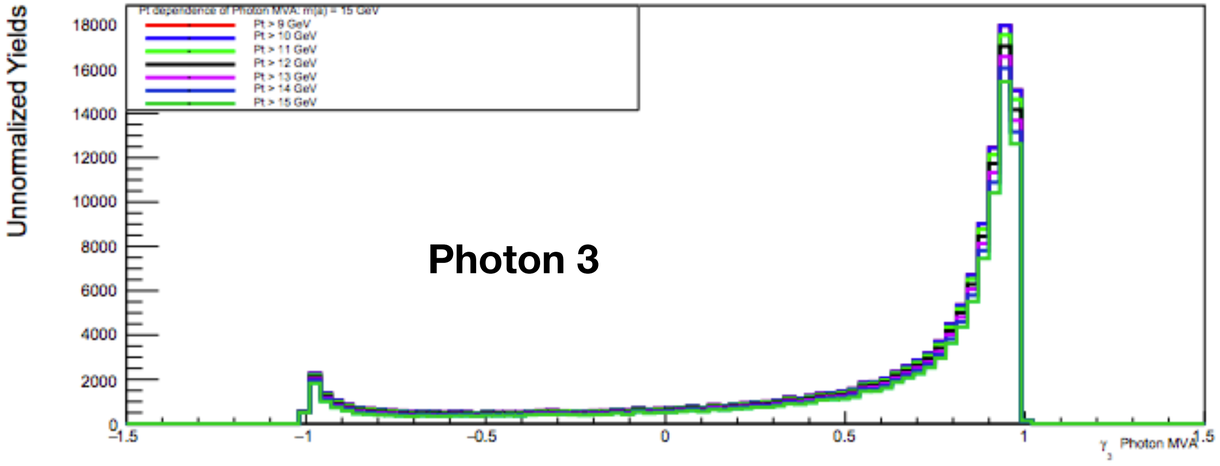


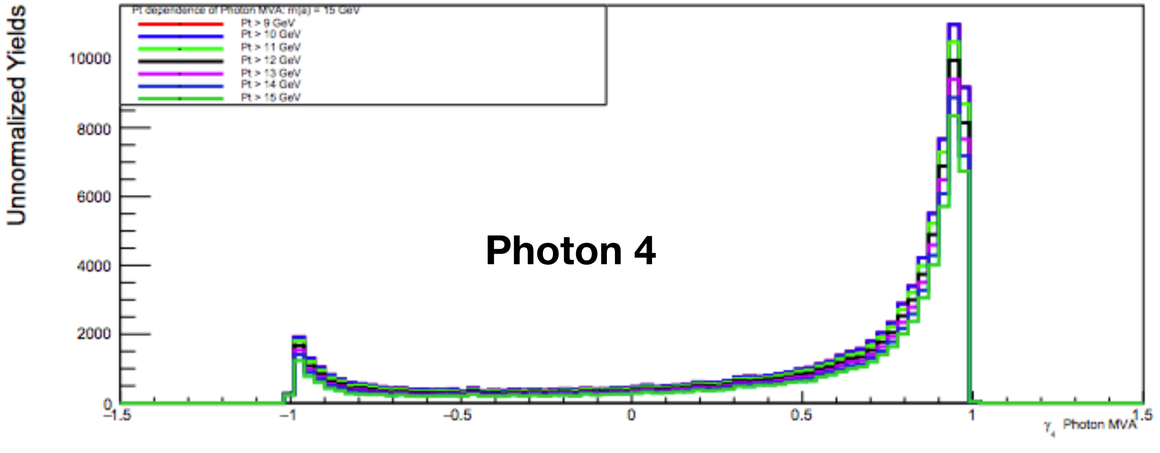


m(a) = 15 GeV

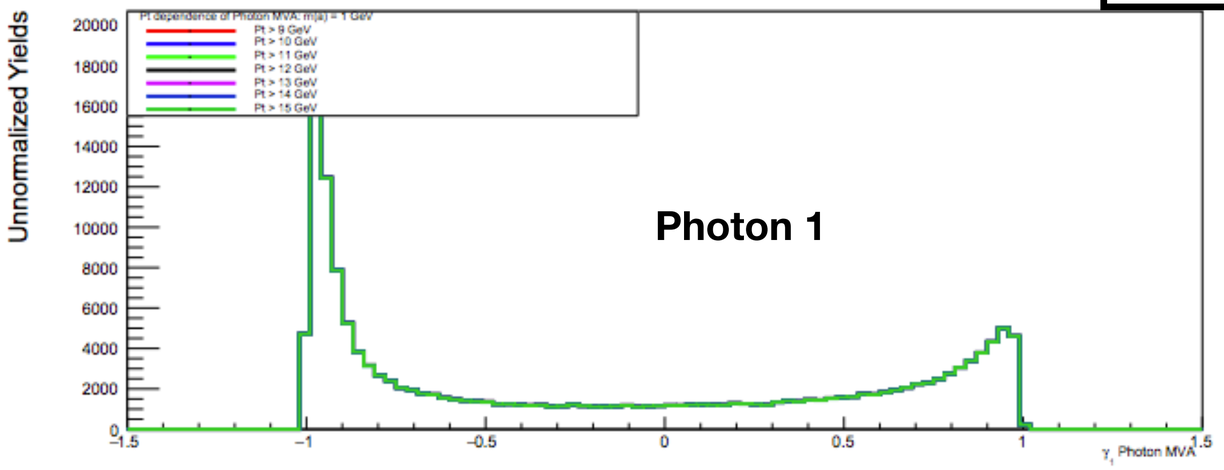

Pt dependence of Photon MVA: m(a) = 15 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 1
γ1 Photon MVA

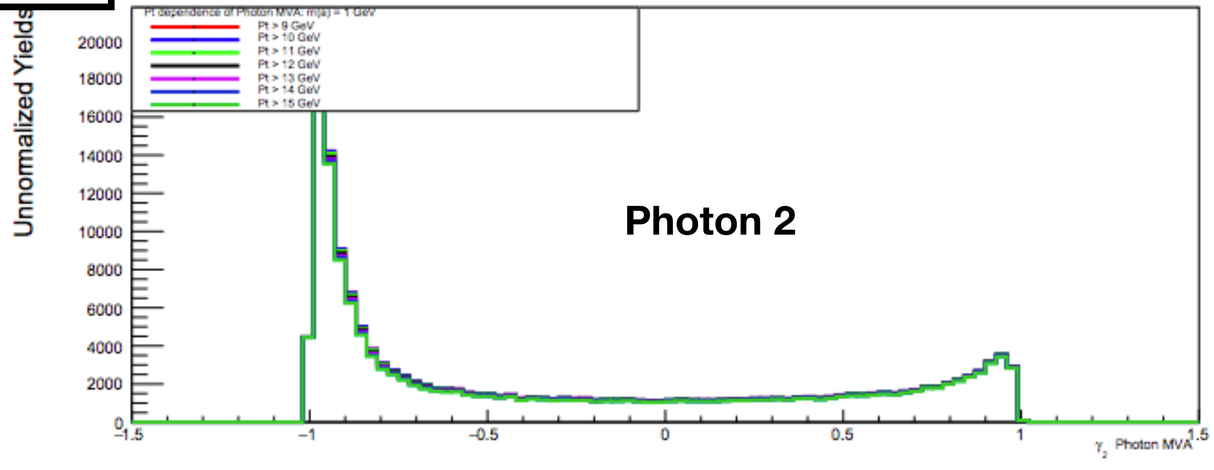

Pt dependence of Photon MVA: m(a) = 15 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 2
γ2 Photon MVA

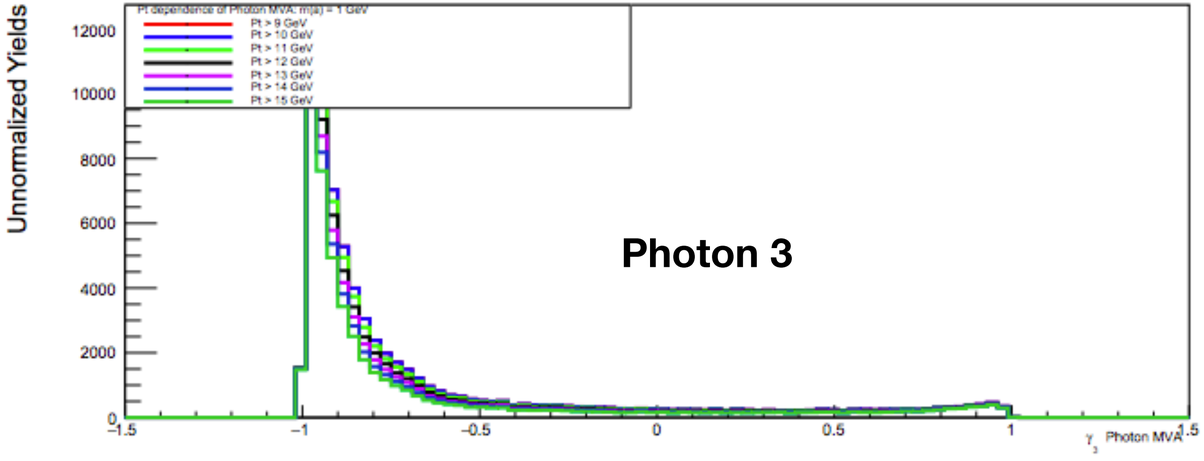

Pt dependence of Photon MVA: m(a) = 15 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 3
γ3 Photon MVA

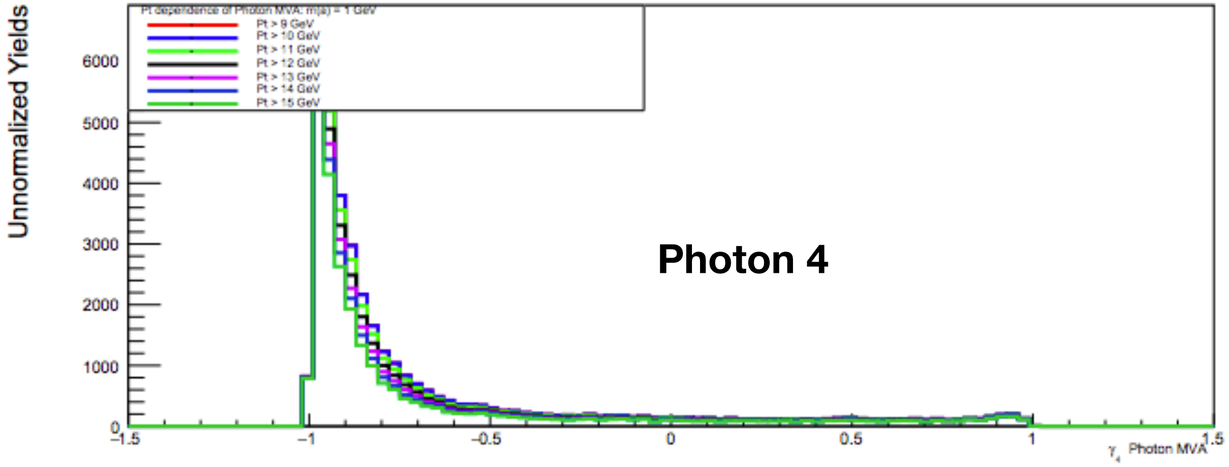

Pt dependence of Photon MVA: m(a) = 15 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 4
γ4 Photon MVA

m(a) = 1 GeV

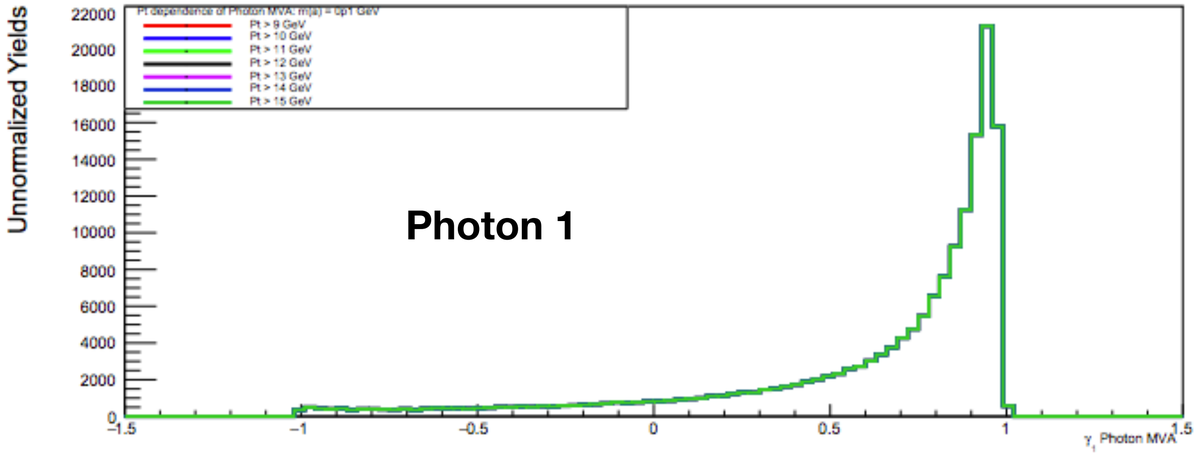

Pt dependence of Photon MVA: m(a) = 1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
γ1 Photon MVA
Photon 1

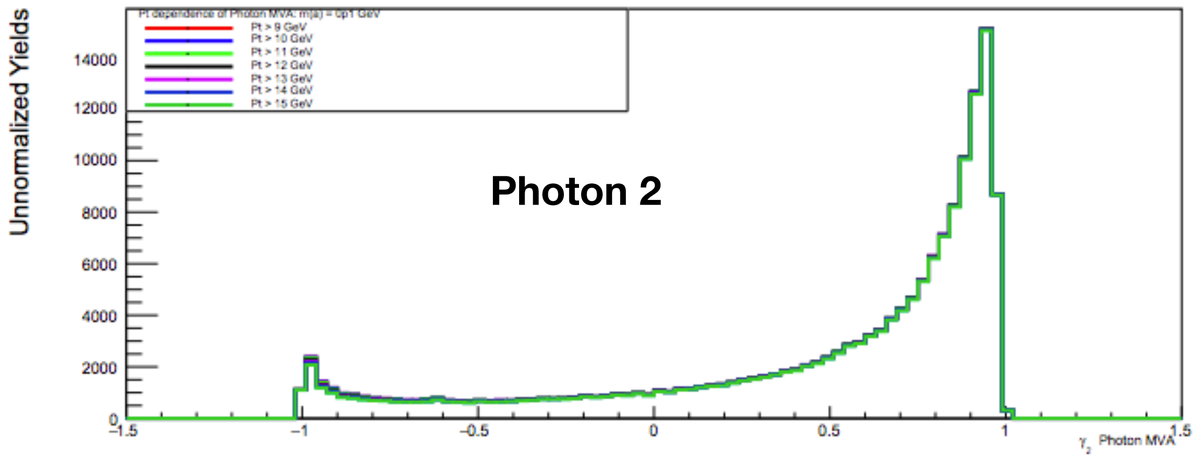

Pt dependence of Photon MVA: m(a) = 1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
γ2 Photon MVA
Photon 2

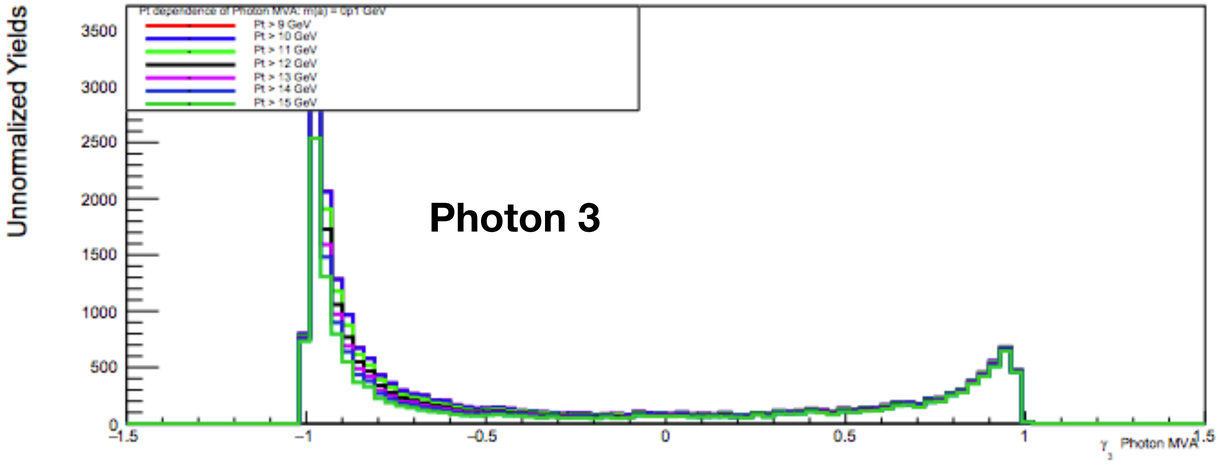

Pt dependence of Photon MVA: m(a) = 1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
γ3 Photon MVA
Photon 3

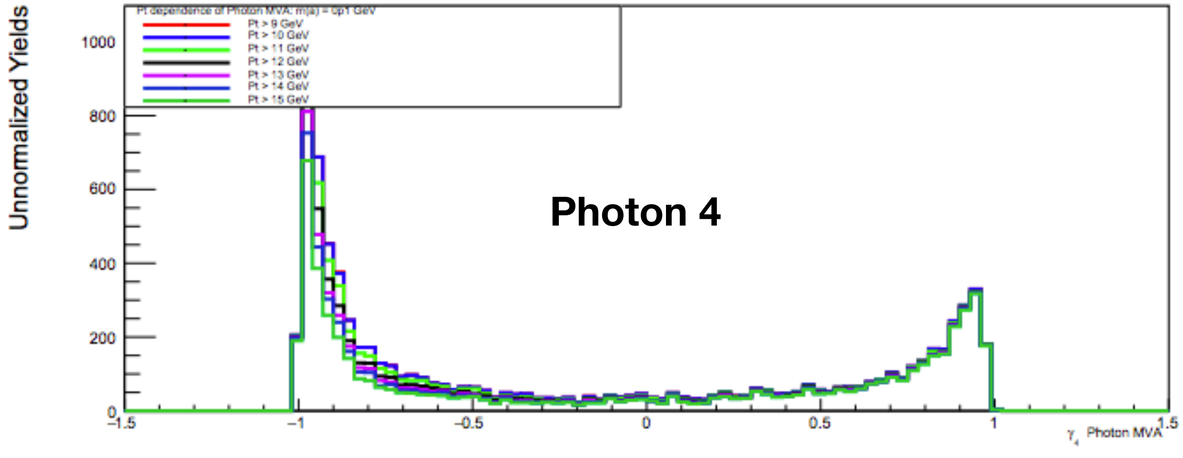

Pt dependence of Photon MVA: m(a) = 1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
γ4 Photon MVA
Photon 4

m(a) = 0p1 GeV


Pt dependence of Photon MVA: m(a) = 0p1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 1
γ1 Photon MVA


Pt dependence of Photon MVA: m(a) = 0p1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 2
γ2 Photon MVA

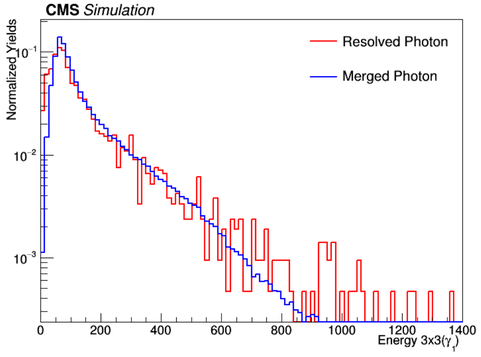

Pt dependence of Photon MVA: m(a) = 0p1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 3
γ3 Photon MVA


Pt dependence of Photon MVA: m(a) = 0p1 GeV
Pt > 9 GeV
Pt > 10 GeV
Pt > 11 GeV
Pt > 12 GeV
Pt > 13 GeV
Pt > 14 GeV
Pt > 15 GeV
Unnormalized Yields
Photon 4
γ4 Photon MVA

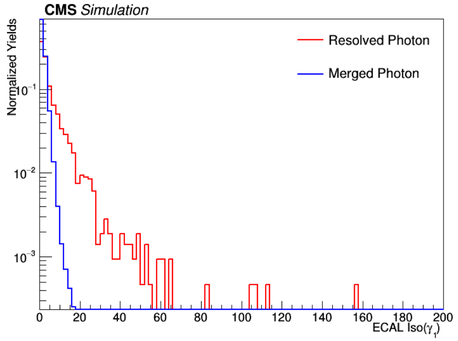
Distinction b/w Merged and Resolved Photons

Test Case : m(a) = 100 MeV

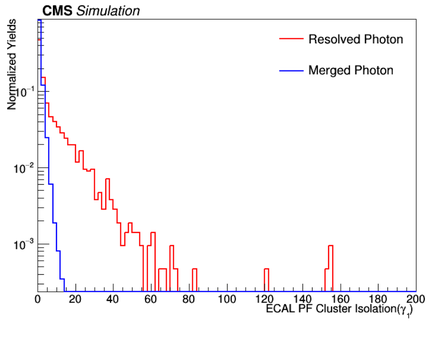
(I only put plots with good(distinction b/w merged and Isolated Photons here)
Full set of plots for every mass point are here : http://twamorka.web.cern.ch/twamorka/H4G_forPrelim/MergedIso/



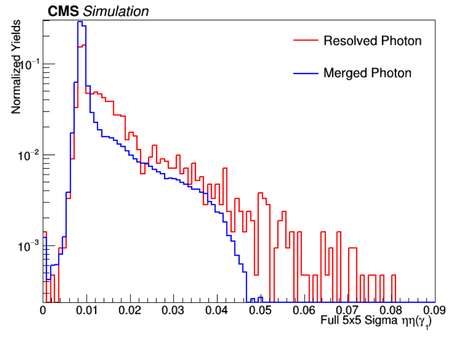
3x3 Energy



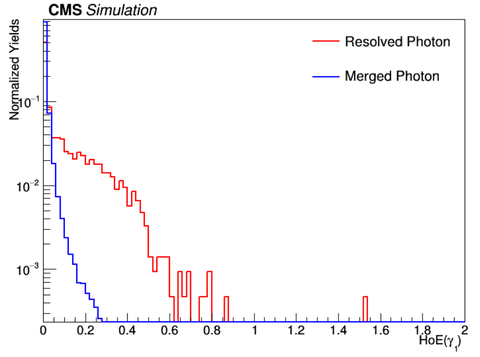
ECAL Iso



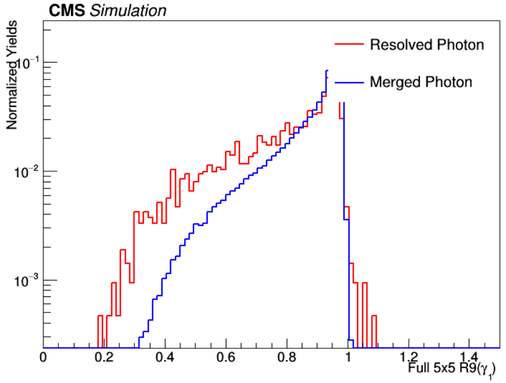
ECAL PF Cluster Iso



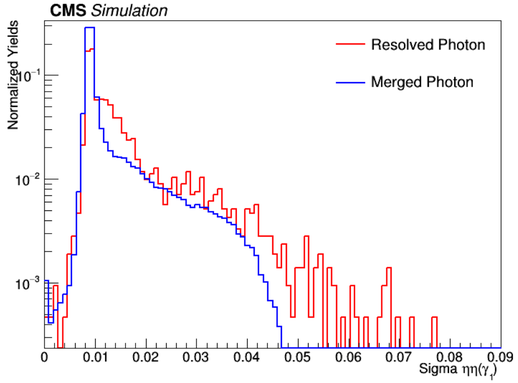
Full 5x5 SigmaEtaEta



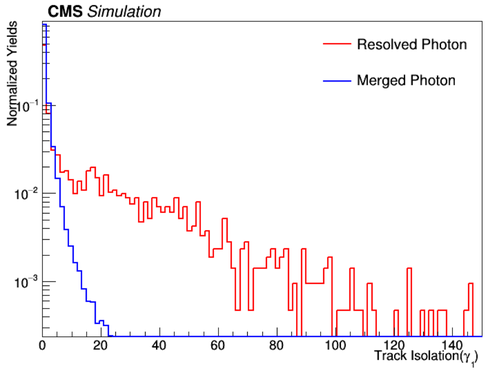
HoE



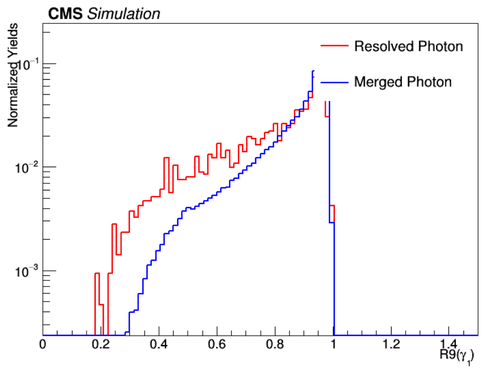
Full 5x5 R9



Sigma EtaEta

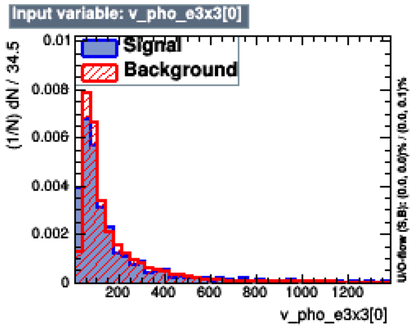


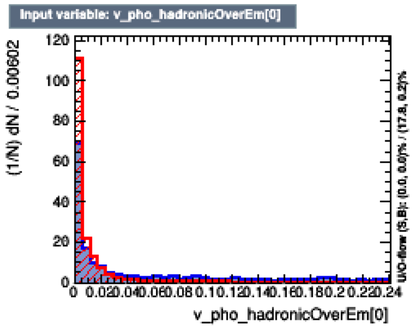
Track Isolation

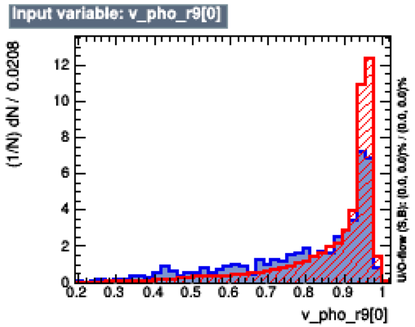


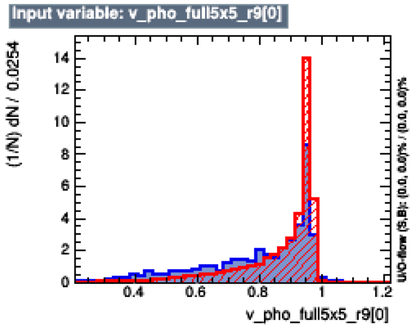
R9

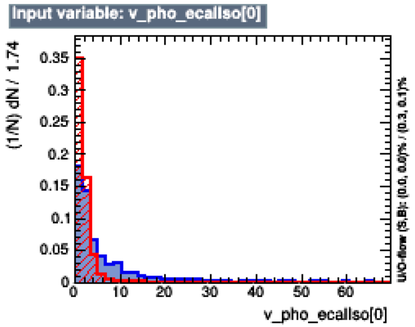
TMVA Study to differentiate Merged and Resolved Photons

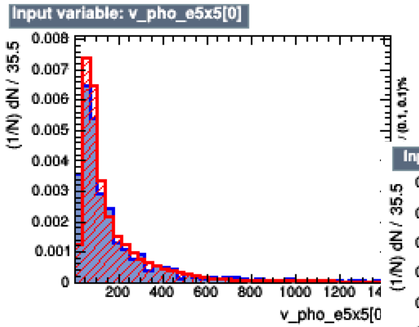


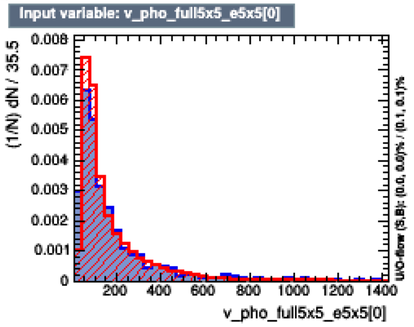


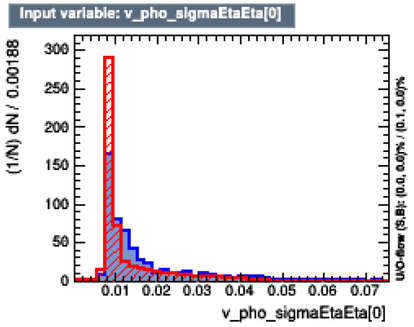


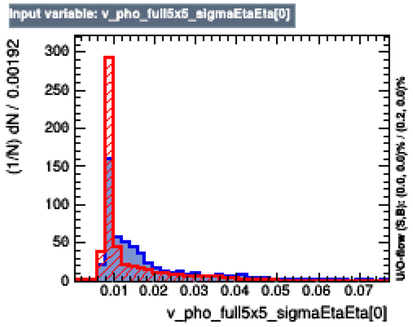


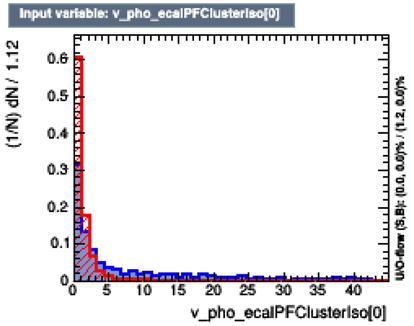


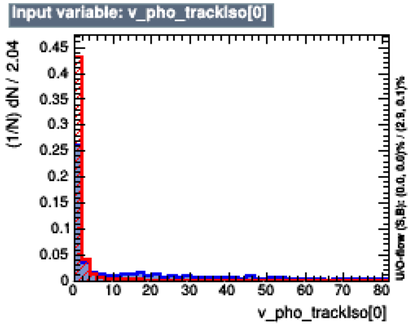






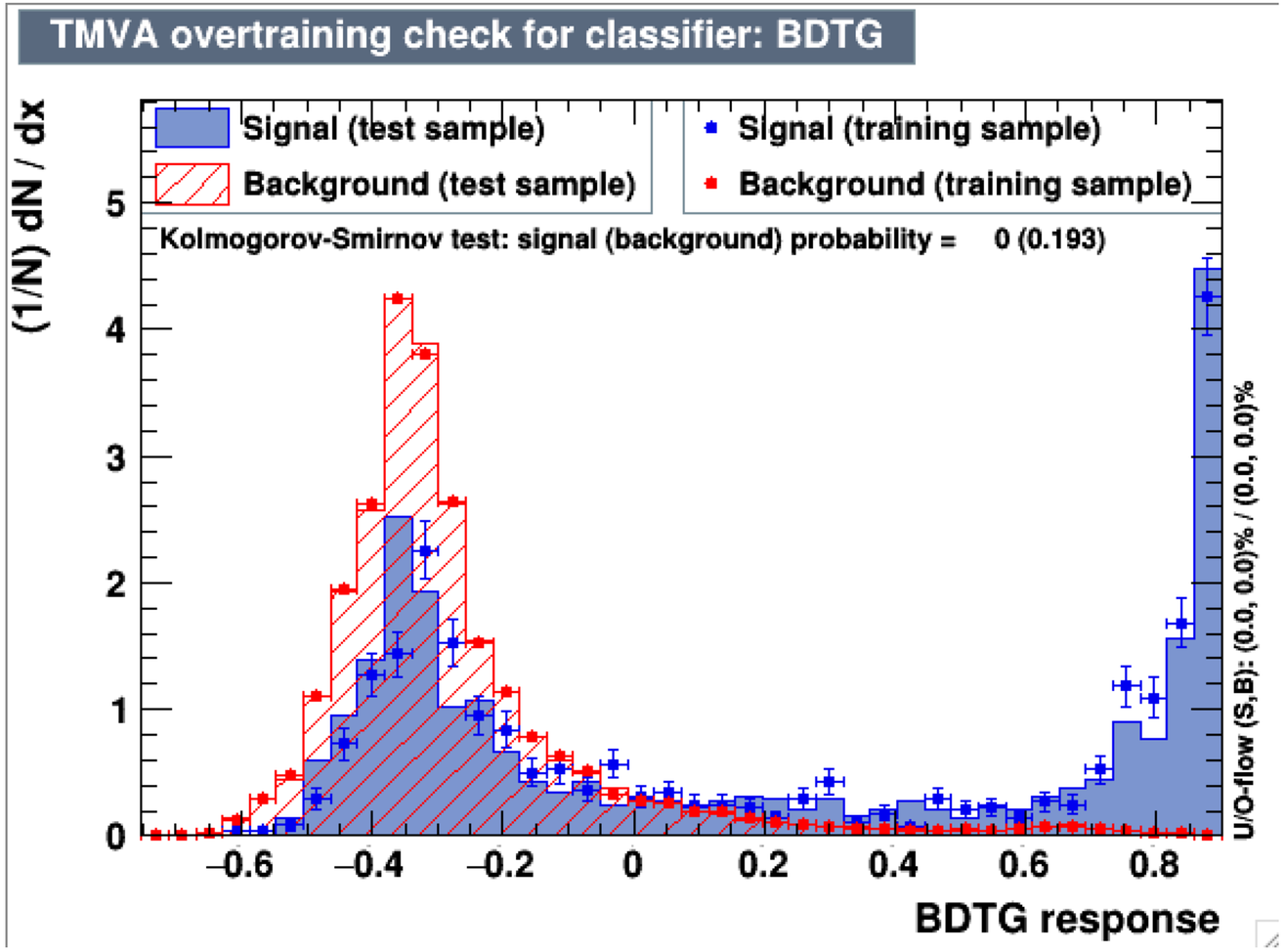


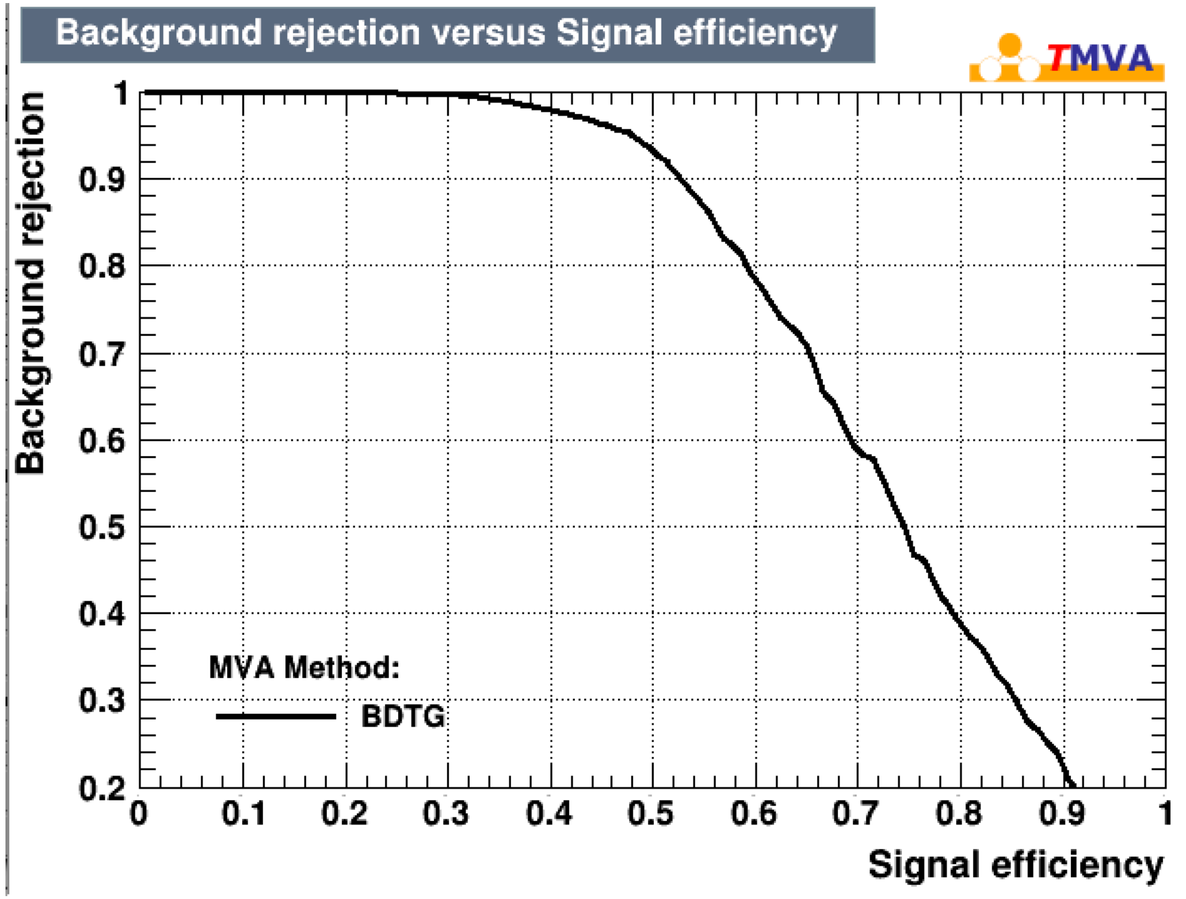


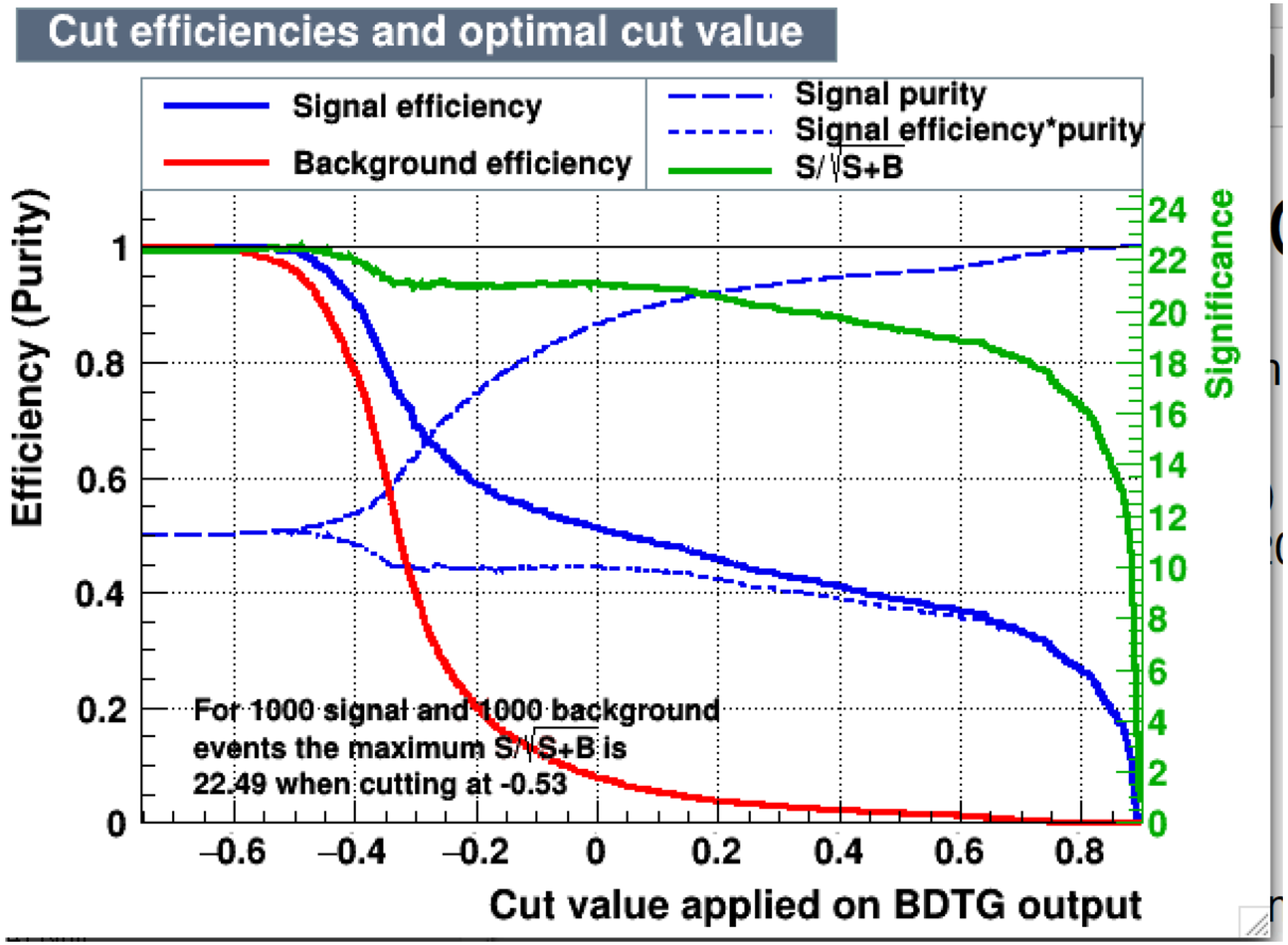


Signal : Resolved Photon

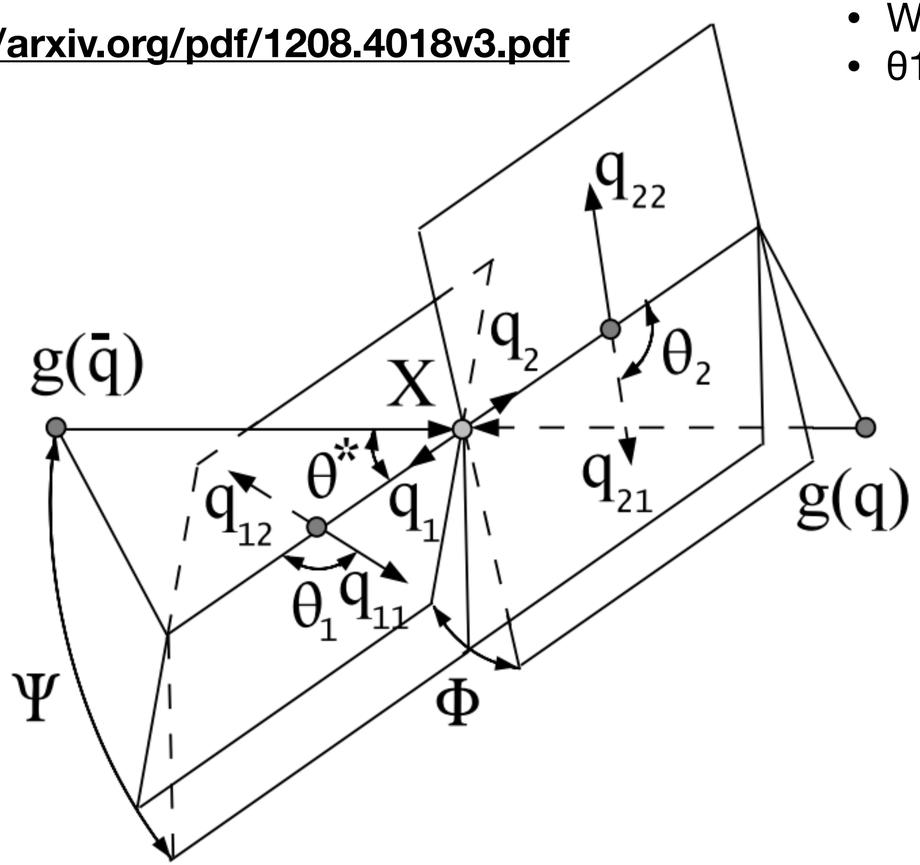
Background : Merged Photon


TMVA overtraining check for classifier: BDTG
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0 (0.193)
(1/N) dN / dx
BDTG response
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Background rejection versus Signal efficiency
TMVA
Background rejection
Signal efficiency
MVA Method:
BDTG


Cut efficiencies and optimal cut value
Signal efficiency
Background efficiency
Signal purity
Signal efficiency*purity
S/√S+B
Efficiency (Purity)
Significance
For 1000 signal and 1000 background events the maximum S/√S+B is 22.49 when cutting at -0.53
Cut value applied on BDTG output

https://arxiv.org/pdf/1208.4018v3.pdf



- Would be interesting to see what these angles look like for H4gamma
- θ1, θ2 should be different for merged and isolated photons (Looking into this!)