

July 13'18

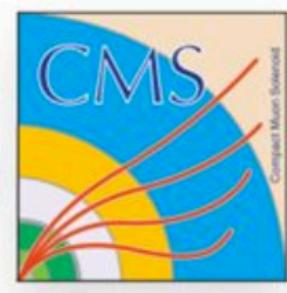
- Applying the exact pre-selections as the Low mass H- $\gamma\gamma$ analysis now (can directly use their trigger SF's)

```
1022      // 2016 pre-selection requirements (based on the OR of two low mass H->gg analysis)
1023      if ( ( diph->leadingPhoton()->full5x5_r9() > 0.8
1024          || diph->leadingPhoton()->egChargedHadronIso() < 20
1025          || diph->leadingPhoton()->egChargedHadronIso()/diph->leadingPhoton()->pt() < 0.3 )
1026          &&
1027          ( diph->subLeadingPhoton()->full5x5_r9() > 0.8
1028              || diph->subLeadingPhoton()->egChargedHadronIso() < 20
1029              || diph->subLeadingPhoton()->egChargedHadronIso()/diph->subLeadingPhoton()->pt() < 0.3 )
1030          &&
1031          (((fabs(diph->leadingPhoton()->superCluster()->eta()) < 1.4442 && diph->leadingPhoton()->hadronicOverEm()
1032              || (fabs(diph->leadingPhoton()->superCluster()->eta()) > 1.566 && diph->leadingPhoton()->hadronicOverEm() <
1033                  && ((fabs(diph->subLeadingPhoton()->superCluster()->eta()) < 1.4442 && diph->subLeadingPhoton()->hadronic
1034                      || (fabs(diph->subLeadingPhoton()->superCluster()->eta()) > 1.566 && diph->subLeadingPhoton()->hadronicOver
1035                      &&
1036                          (diph->leadingPhoton()->pt() >30.0 && diph->subLeadingPhoton()->pt() > 18.0)
1037                      &&
1038                          (fabs(diph->leadingPhoton()->superCluster()->eta()) < 2.5 && fabs(diph->subLeadingPhoton()->superCluster()-
1039                              &&
1040                                  (fabs(diph->leadingPhoton()->superCluster()->eta()) < 1.4442 || fabs(diph->leadingPhoton()->superCluster()-
1041                                      &&
1042                                          (fabs(diph->subLeadingPhoton()->superCluster()->eta()) < 1.4442 || fabs(diph->subLeadingPhoton()->superClus
1043                                          &&
1044                                              ( (fabs(diph->leadingPhoton()->superCluster()->eta()) < 1.4442 && fabs(diph->subLeadingPhoton()->superClust
1045                                              || (fabs(diph->leadingPhoton()->superCluster()->eta()) < 1.4442 && diph->leadingPhoton()->full5x5_r9()>0.85
1046                                              || (fabs(diph->leadingPhoton()->superCluster()->eta()) > 1.566 && diph->leadingPhoton()->full5x5_r9()>0.90
1047                                              || (fabs(diph->leadingPhoton()->superCluster()->eta()) > 1.566 && diph->leadingPhoton()->full5x5_r9()>0.90
1048                                              && diph->mass() > 55
1049                                              && (diph->leadingPhoton()->pt() > 0.47*diph->mass() && diph->subLeadingPhoton()->pt() > 0.28*diph->mass())
1050                                              && (!diph->leadingPhoton()->hasPixelSeed()) && (!diph->subLeadingPhoton()->hasPixelSeed())
1051      ){
1052          presel = 1;
1053          if ( (diph->leadPhotonId() > -0.9 && diph->subLeadPhotonId() > -0.9)
1054          ){
1055              passMVA = 1; // this is evaluated for diphotons that have passed pre-selection
1056          }
1057      }
```

- For trigger studies, there are 2 things that can be checked:
 - Effect of applying the trigger bit
 - Effect of pre-selection (tighter than online selections)

$$\epsilon = \frac{\# \text{ generated events passing HLT}}{\# \text{ generated events}}$$

trigger bit	m(a) GeV	# of generated events	# of generated events passing HLT	Efficiency	Uncertainty in efficiency
	60	198014	102514	0.518	0.002
	55	199200	99582	0.500	0.002
	50	200000	91078	0.455	0.002
	45	198033	94683	0.478	0.002
	40	200000	98215	0.491	0.002
	35	200000	99519	0.498	0.002
	30	200000	98218	0.491	0.002
	25	200000	98595	0.493	0.002
	20	200000	97189	0.486	0.002
	15	200000	95781	0.479	0.002
	10	195505	87388	0.447	0.002
	5	200000	65917	0.330	0.001
		1	69837	0.349	0.002
	0.1	200000	91119	0.456	0.002

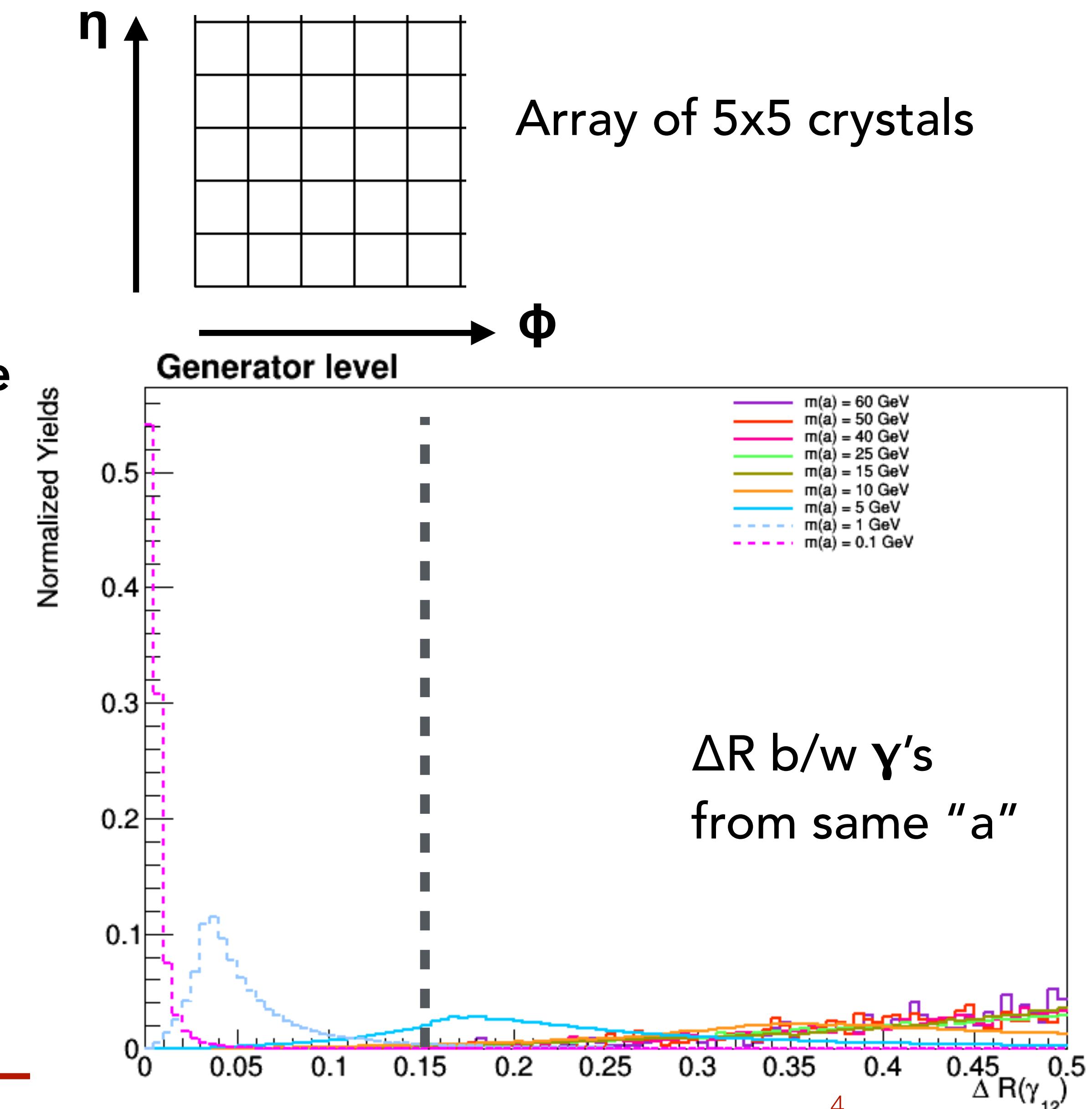


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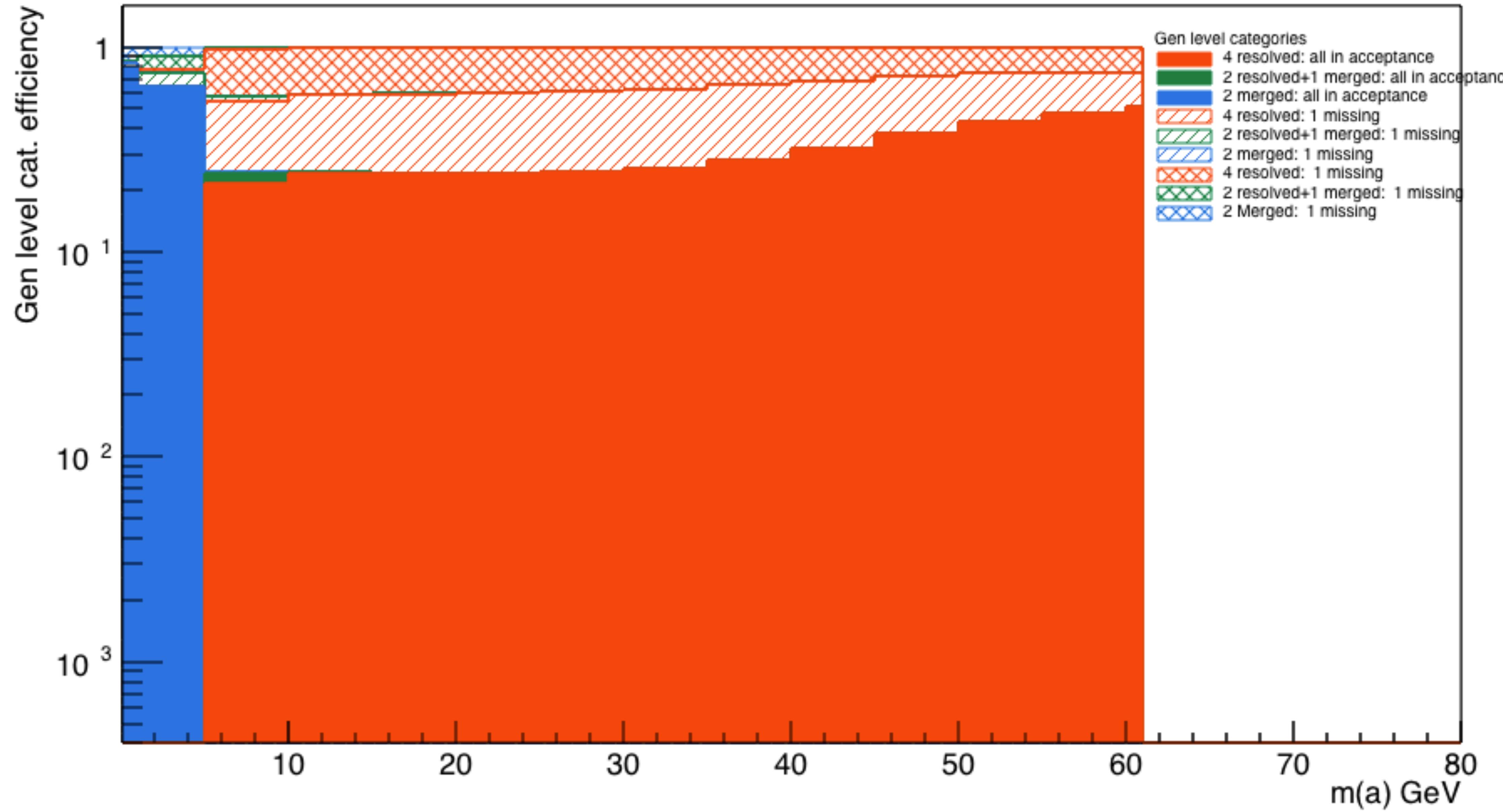
Pre-selection requirements

m(a) GeV	# of generated events	# of generated events passing preselection	Preselection efficiency	Uncertainty in efficiency
60	198014	83713	0.423	0.002
55	199200	70663	0.355	0.002
50	200000	64571	0.323	0.001
45	198033	67101	0.339	0.002
40	200000	68680	0.343	0.002
35	200000	68911	0.345	0.002
30	200000	67268	0.336	0.001
25	200000	66559	0.333	0.001
20	200000	64649	0.323	0.001
15	200000	63799	0.319	0.001
10	195505	60739	0.311	0.001
5	200000	58878	0.294	0.001
1	200000	45663	0.228	0.001
0.1	200000	49355	0.247	0.001

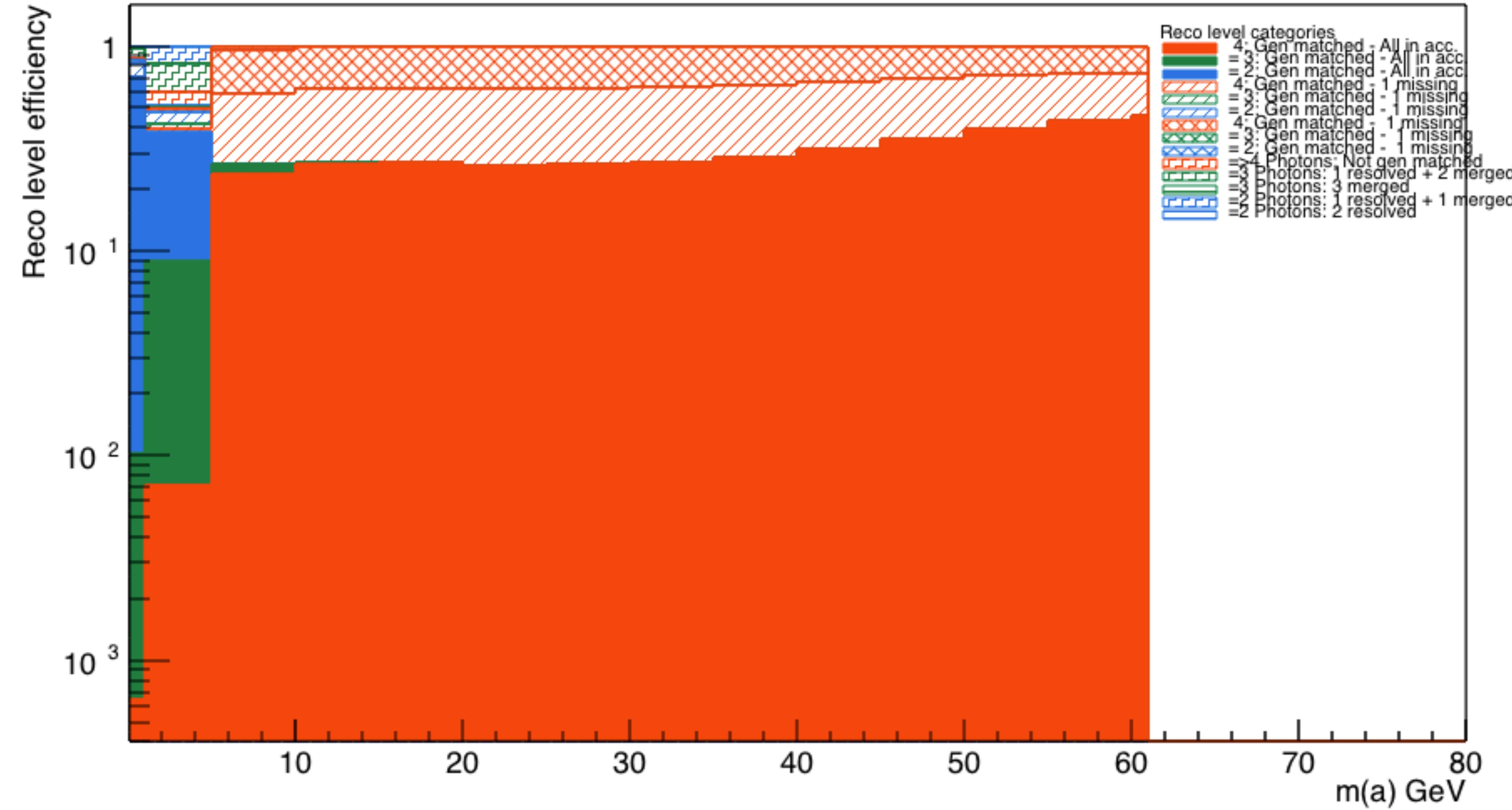
- Selections at the online level are based on 5x5 and Supercluster based variables
- For $m(a) < 5 \text{ GeV}$, photons are mostly merged
- There is a Diphoton mass cut at 55 GeV at the online trigger level
- Since for $m(a) < 5 \text{ GeV}$, the event would almost look like $H \rightarrow \gamma\gamma$, the diphoton object is then the Higgs (and not "a") and the probability of the event passing the diphoton trigger increases
- Are there any checks I can perform to test this hypothesis?



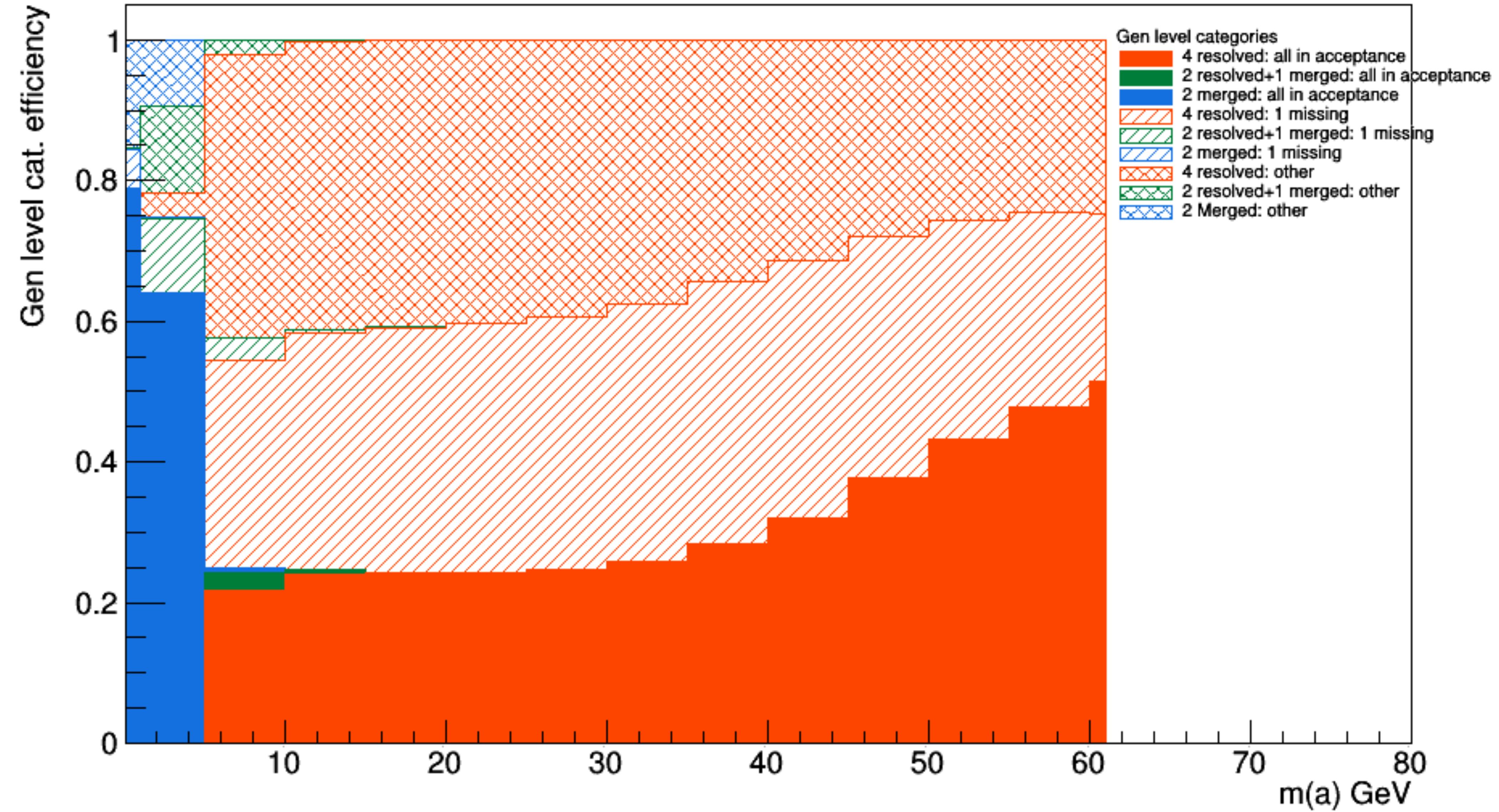
Gen level categorization



Reco level categorization

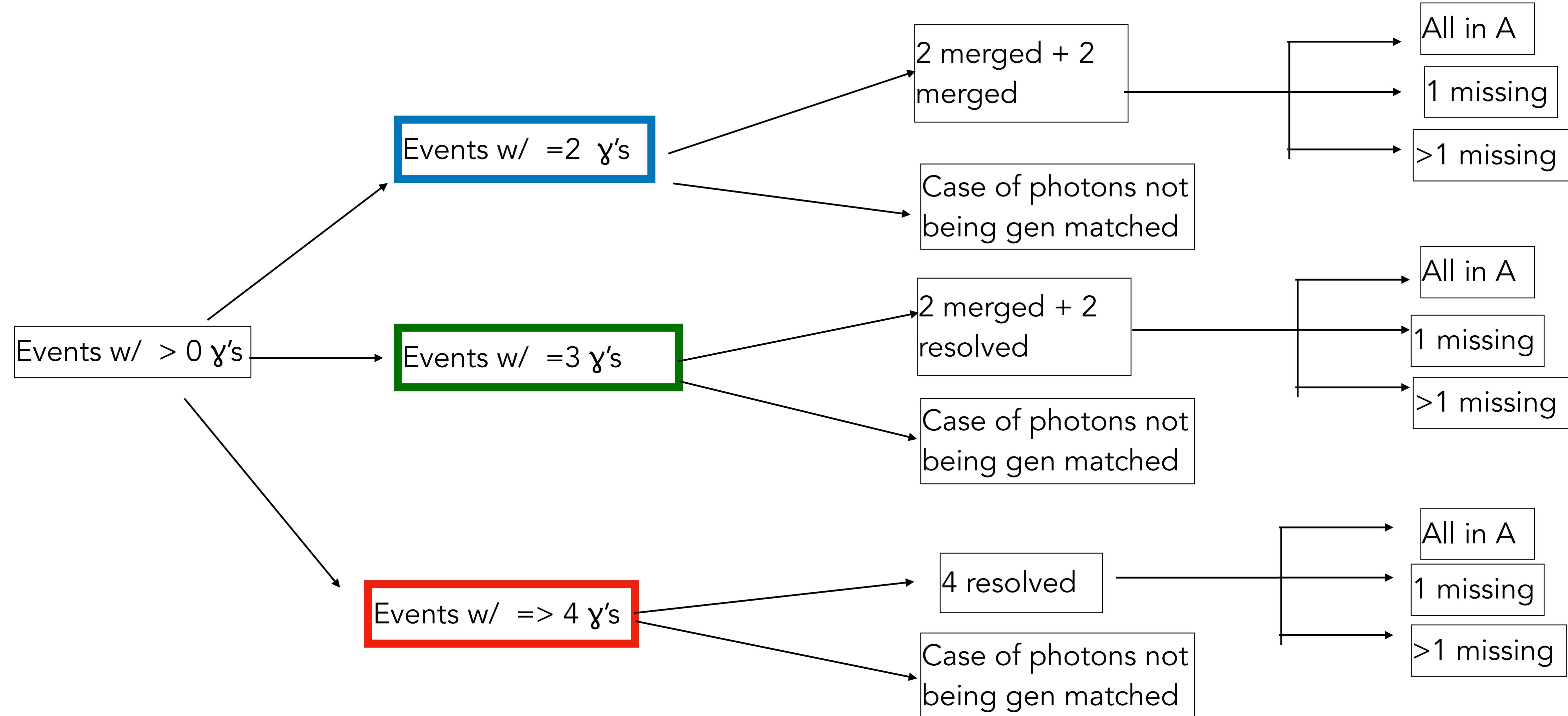


Gen level categorization



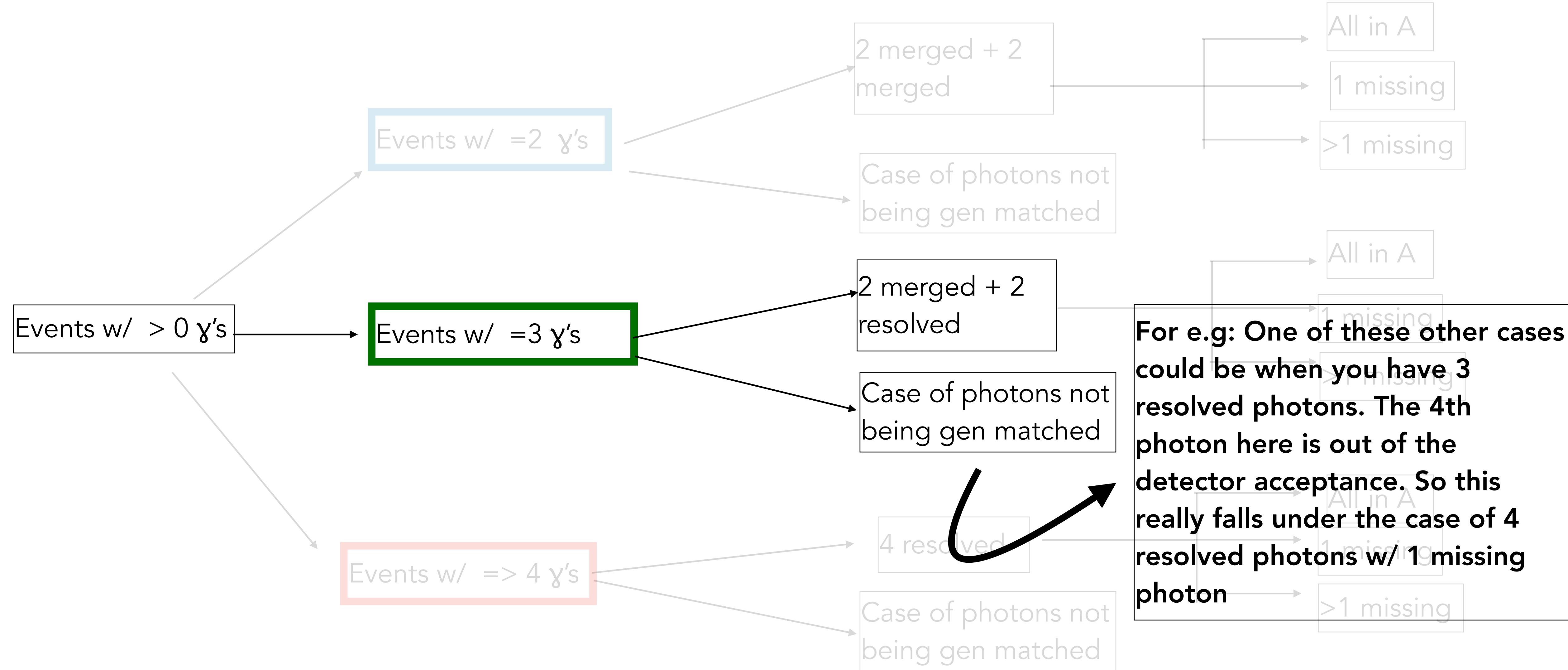


Replicating the categorization @Reco level 14th June '18

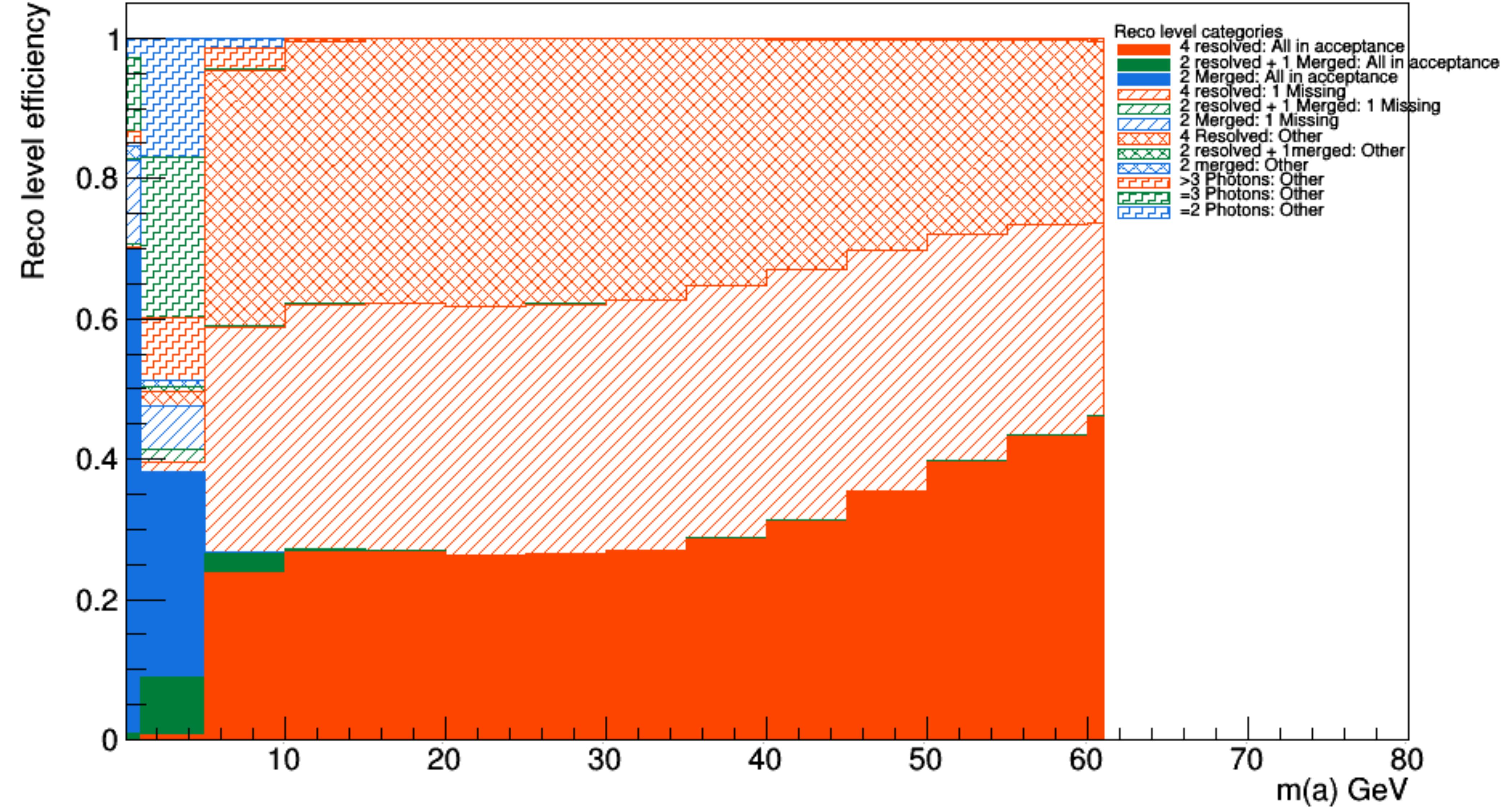




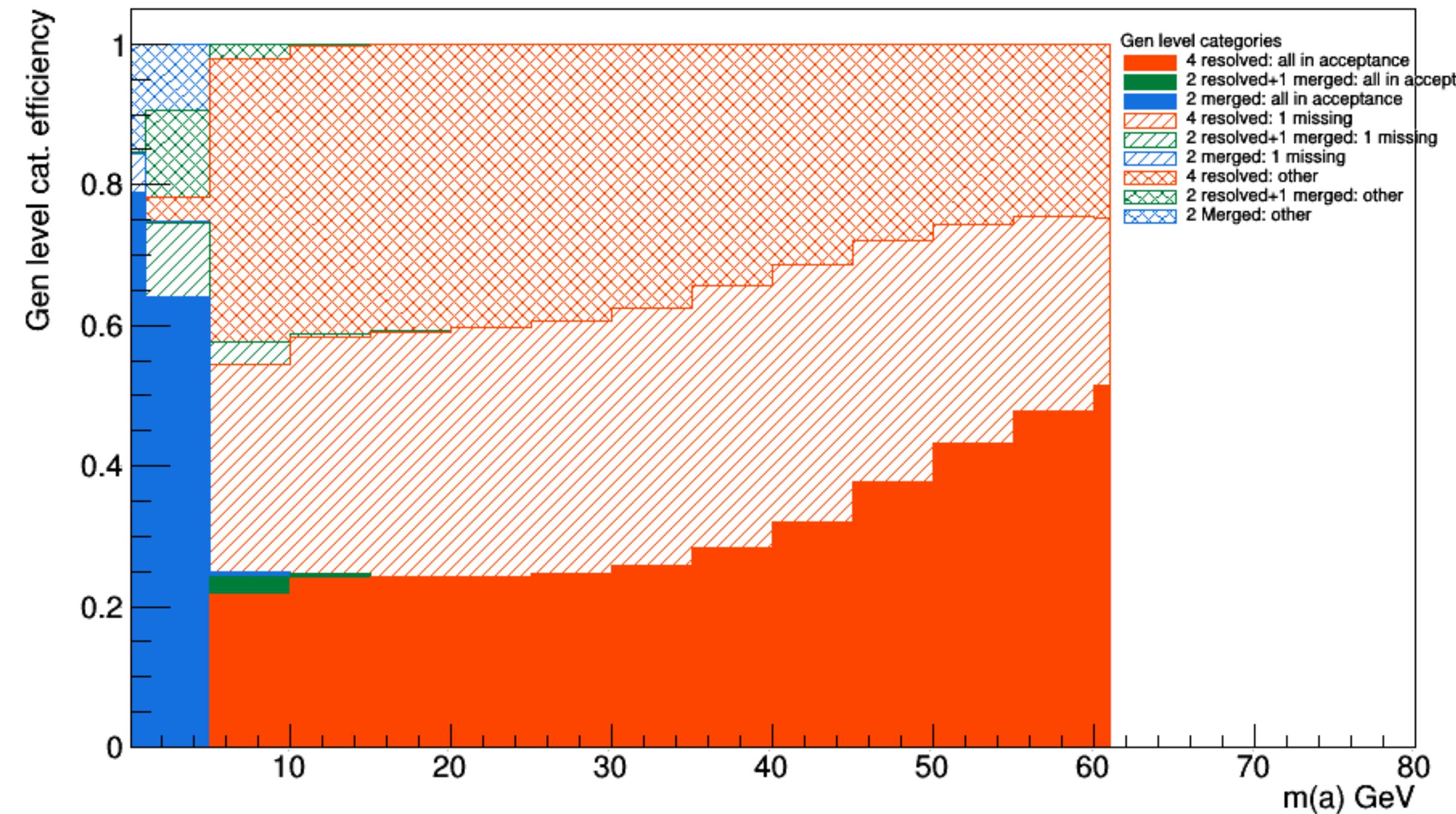
Replicating the categorization @Reco level 14th June '18



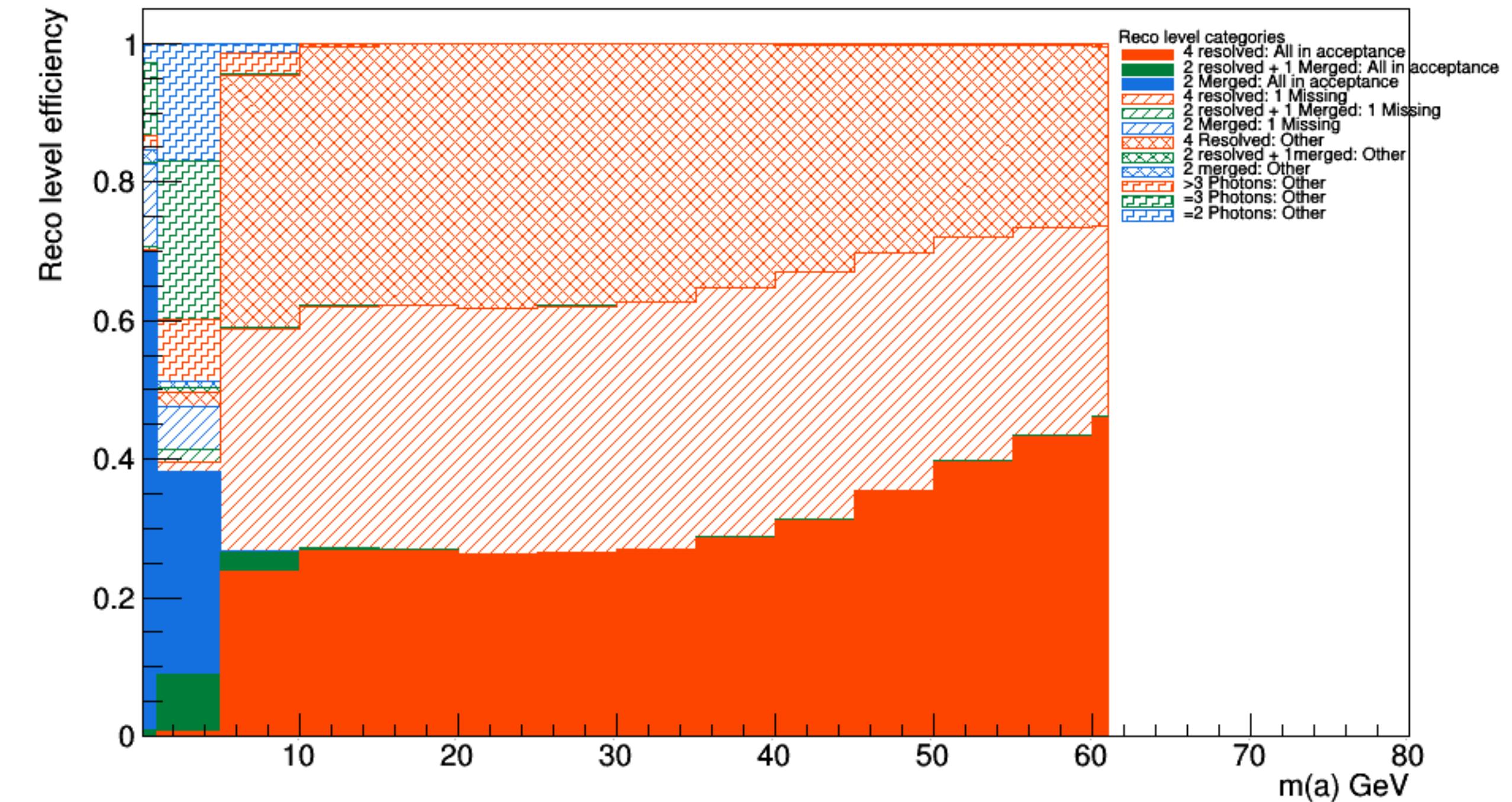
Reco level categorization : Resolved and Merged



Gen level categorization



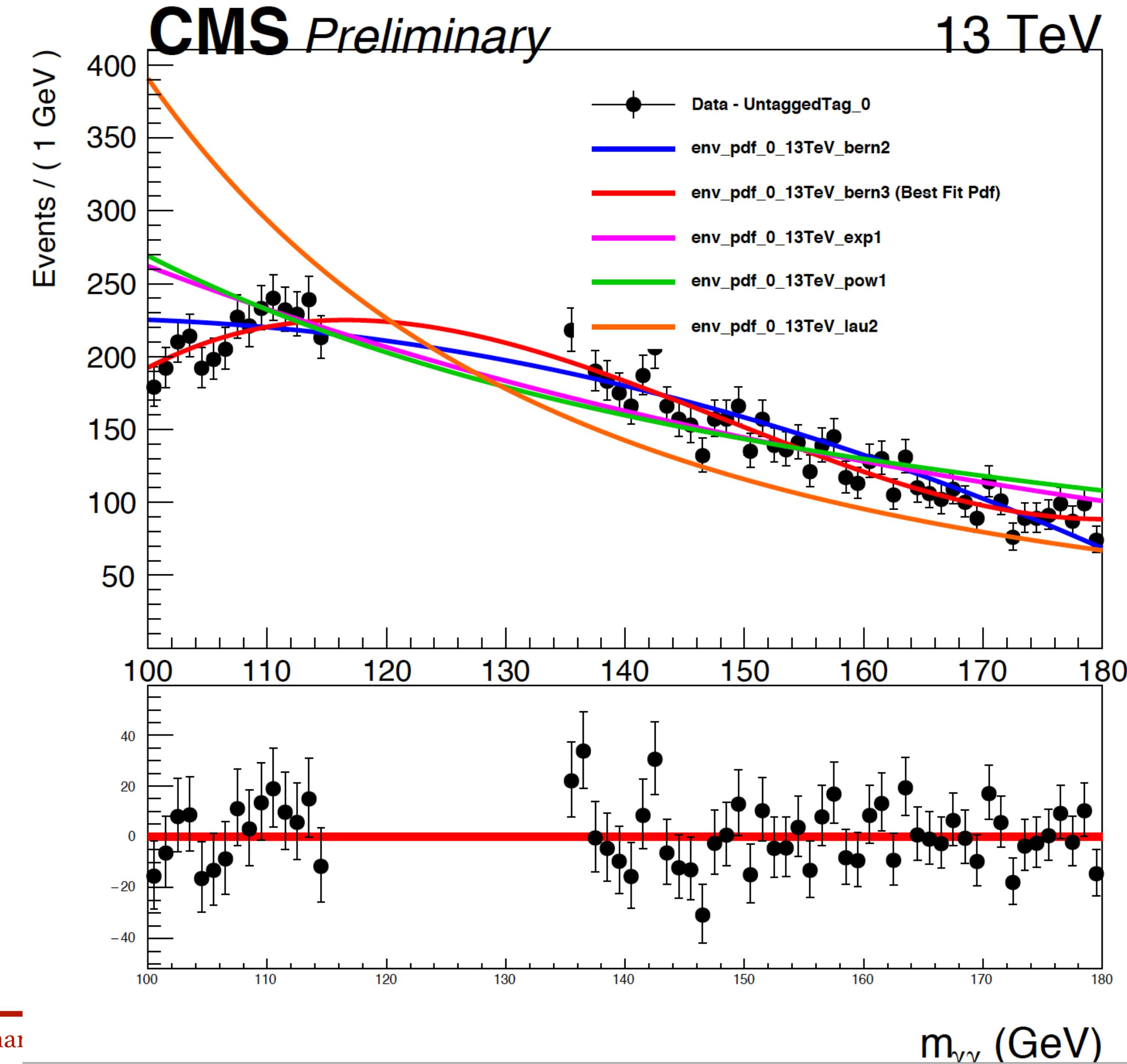
Reco level categorization : Resolved and Merged



Progress on Background modeling

14th June '18

- Managed to adapt the flashggfinal fit framework (used by standard & low mass $H \rightarrow \gamma\gamma$) to be used for our background modeling
- Now we have more background pdf's to perform the fit with
- Can also determine which PDF is the best fit to data





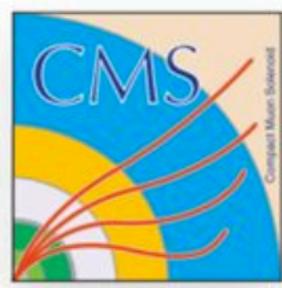
Next tasks

14th June '18

- For $m(a) < 10 \text{ GeV}$, we need an MVA to discriminate merged photons from resolved ones 
- How to implement this in flashgg such that the new MVA can be added as a variable in our ntuples? Contacted Seth for this
- Trigger SF's are missing Meeting w/ Linda (h-> $\gamma\gamma$ trigger contact) next week
- 2017 Signal MC samples
- Start looking at 2017 data
- For very low mass $m(a) < 1 \text{ GeV}$..is it time to get back in touch with Michael and Manfred?

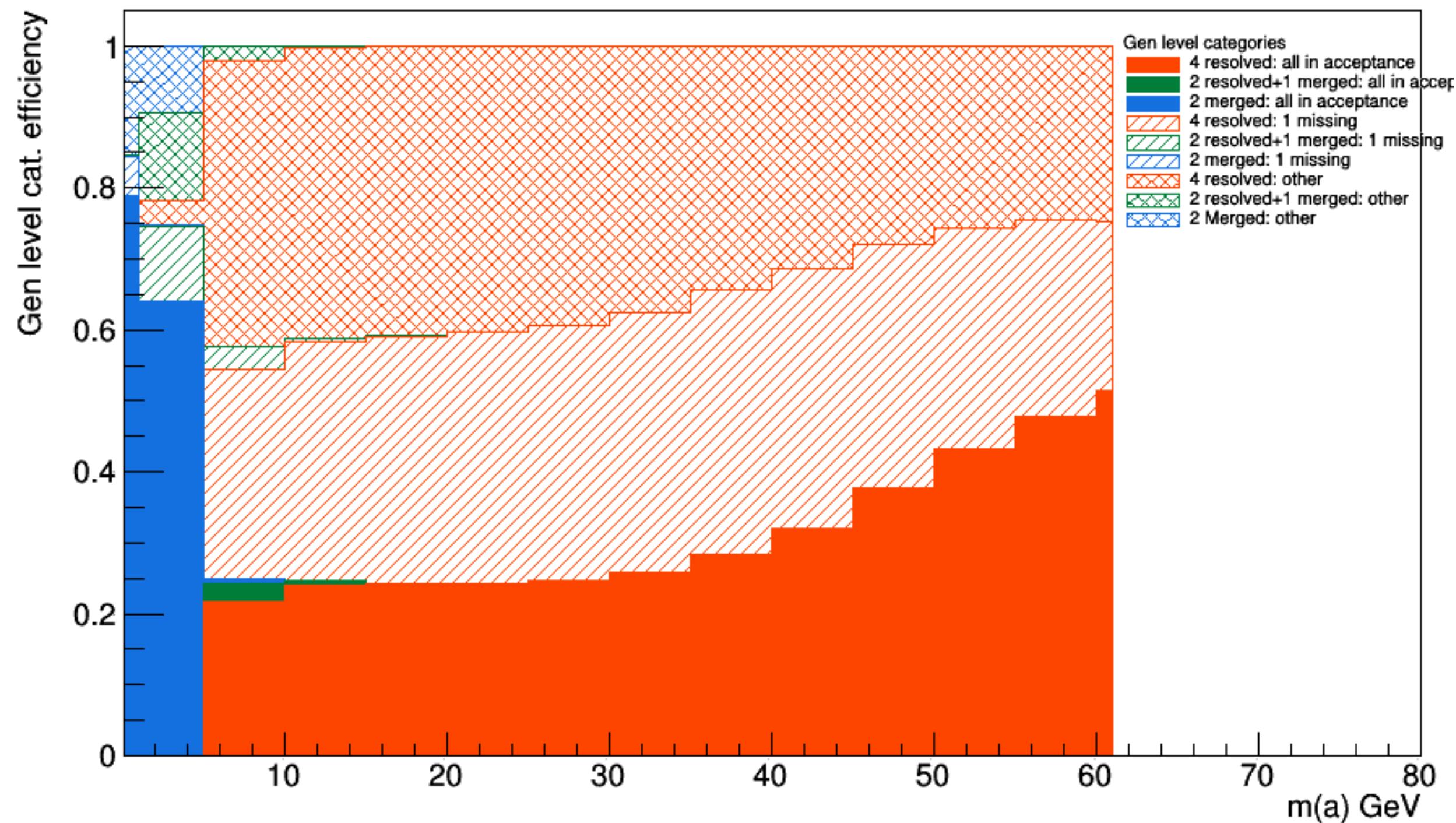


- If 2 photons are very close to each other, they can be reconstructed as one merged photon
- To better understand this, a generator level study is done
- @ Gen level, there are always 4 photons
 - Calculate ΔR b/w each of the 6 possible photon pairs
 - If $\Delta R < 0.1 \Rightarrow$ Merged photon
 - No pairs found with $\Delta R < 0.1$: **4 Photon category** (all photons are resolved)
 - 1 pair found with $\Delta R < 0.1$: **3 Photon category** (1 merged + 2 resolved photons)
 - 2 pairs found with $\Delta R < 0.1$: **2 Photon category** (2 pairs of merged photons)

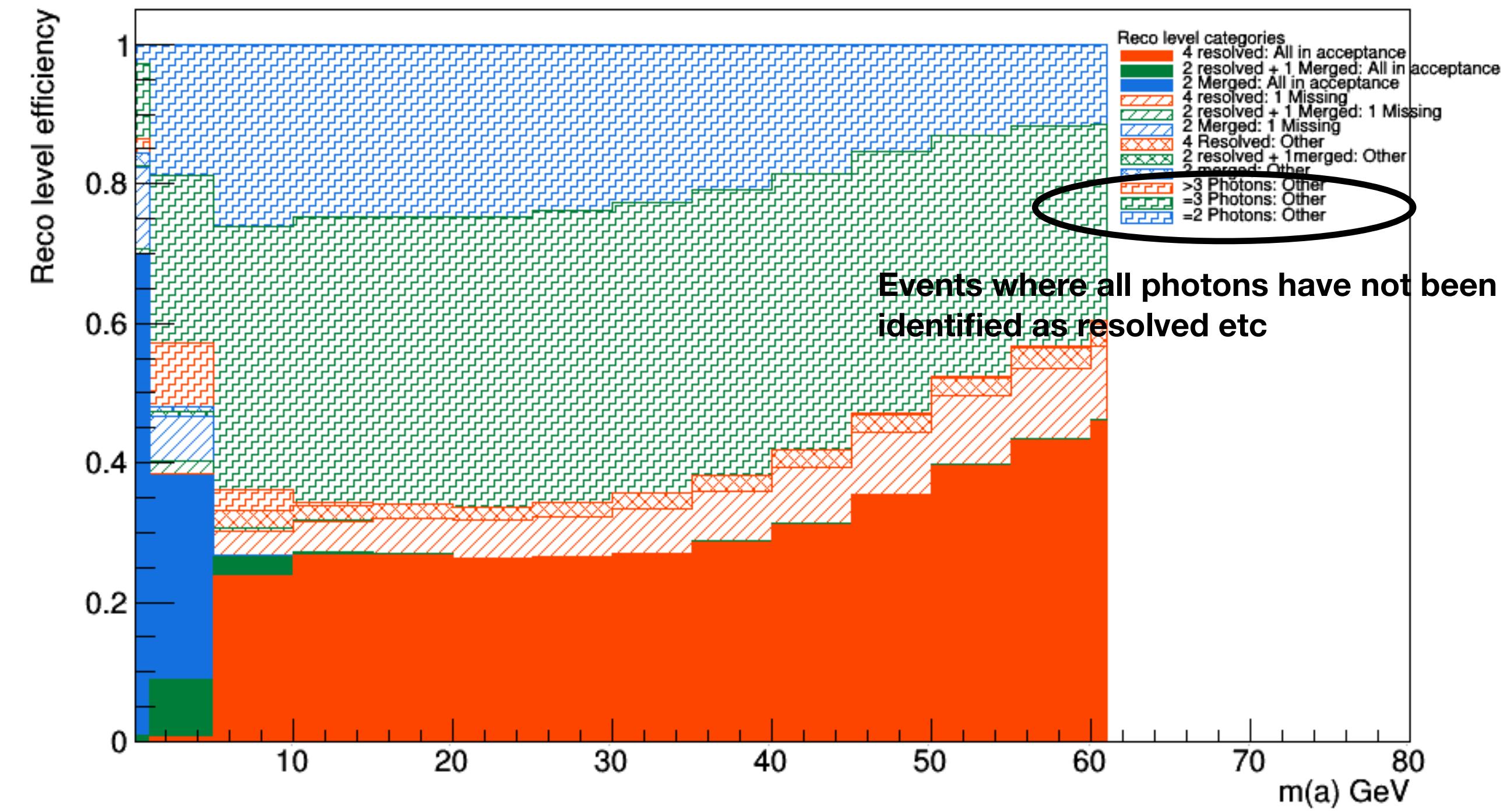


12th June '18

Gen level categorization



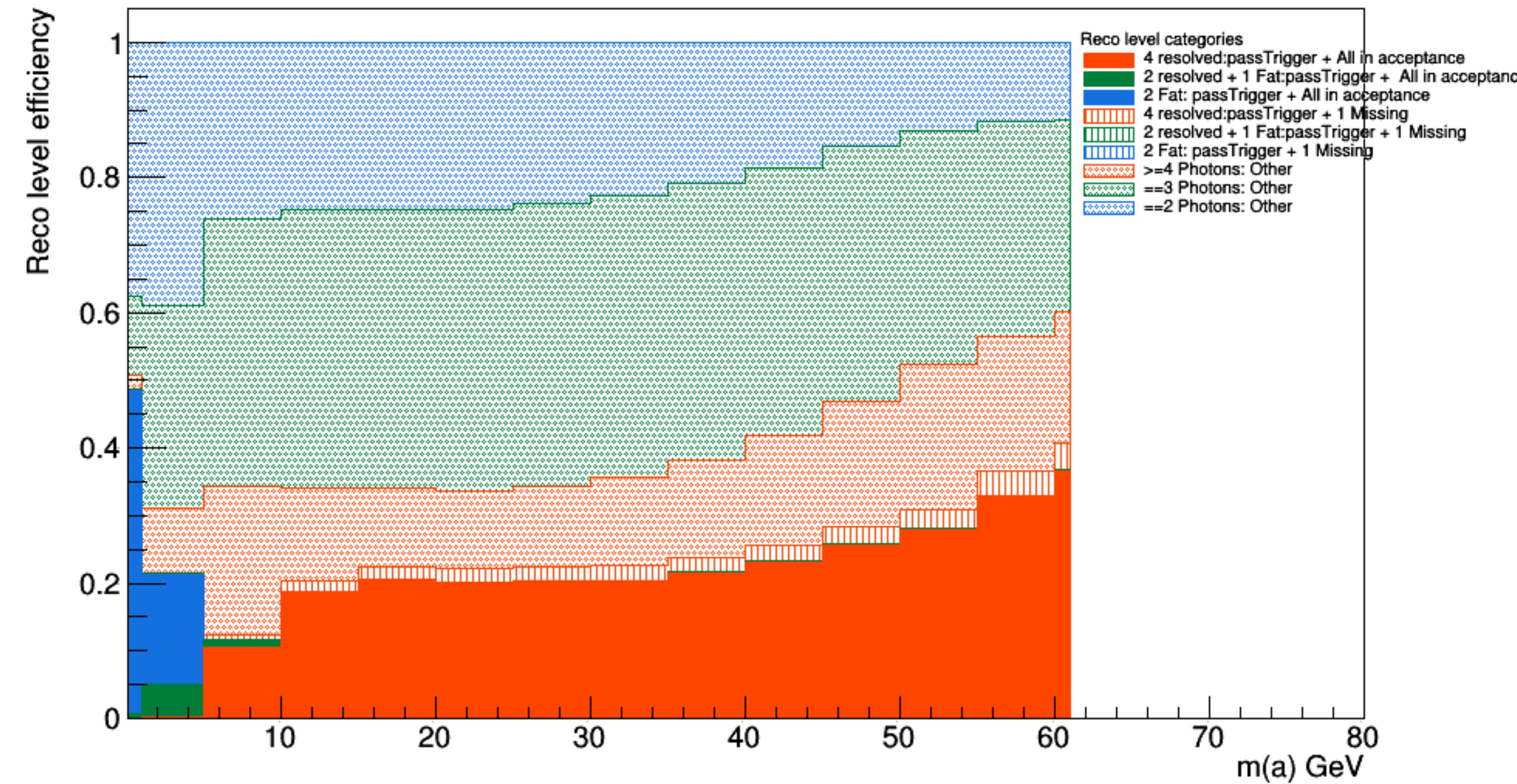
Reco level categorization : Resolved and Merged

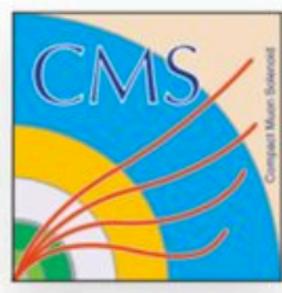


Reco level categorization

“Other” (dotted region)

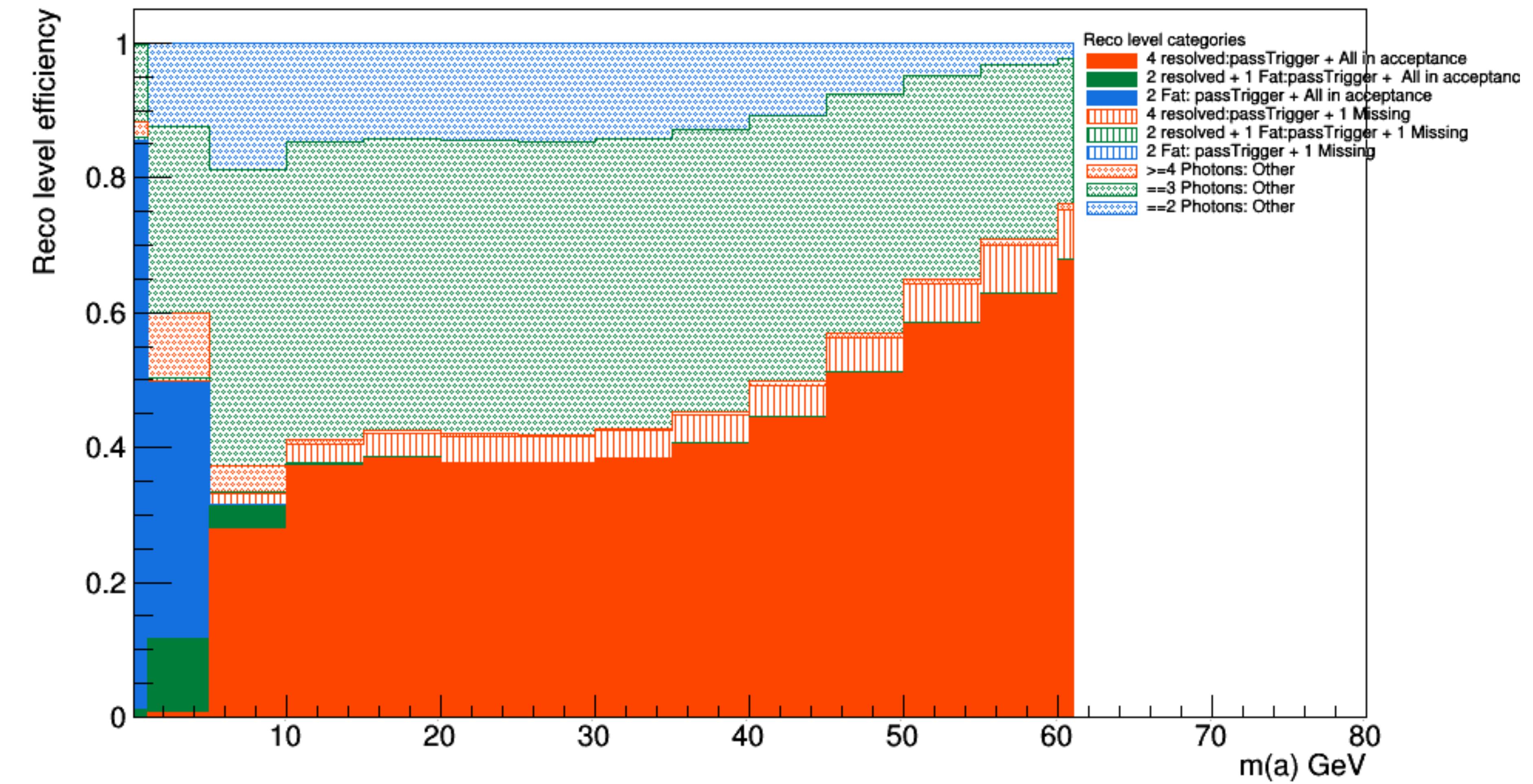
Eg : Red Dotted Region - **Does not** contain events with just 4 resolved photons (it really is everything left after categorization for events with at least 4 photons)





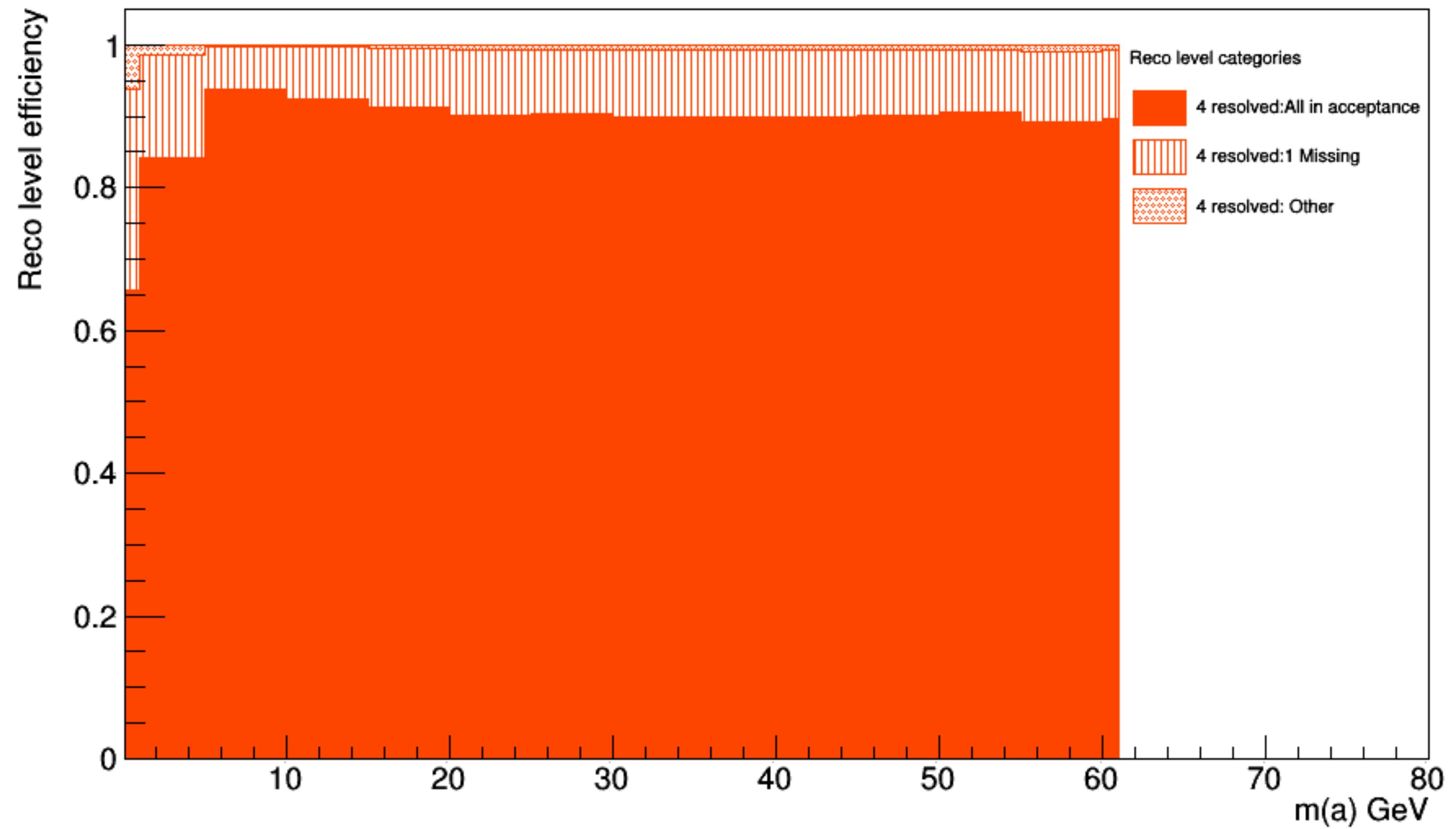
Reco level categorization : Only events that pass trigger requirements

Same plot but only with for events that pass Trigger



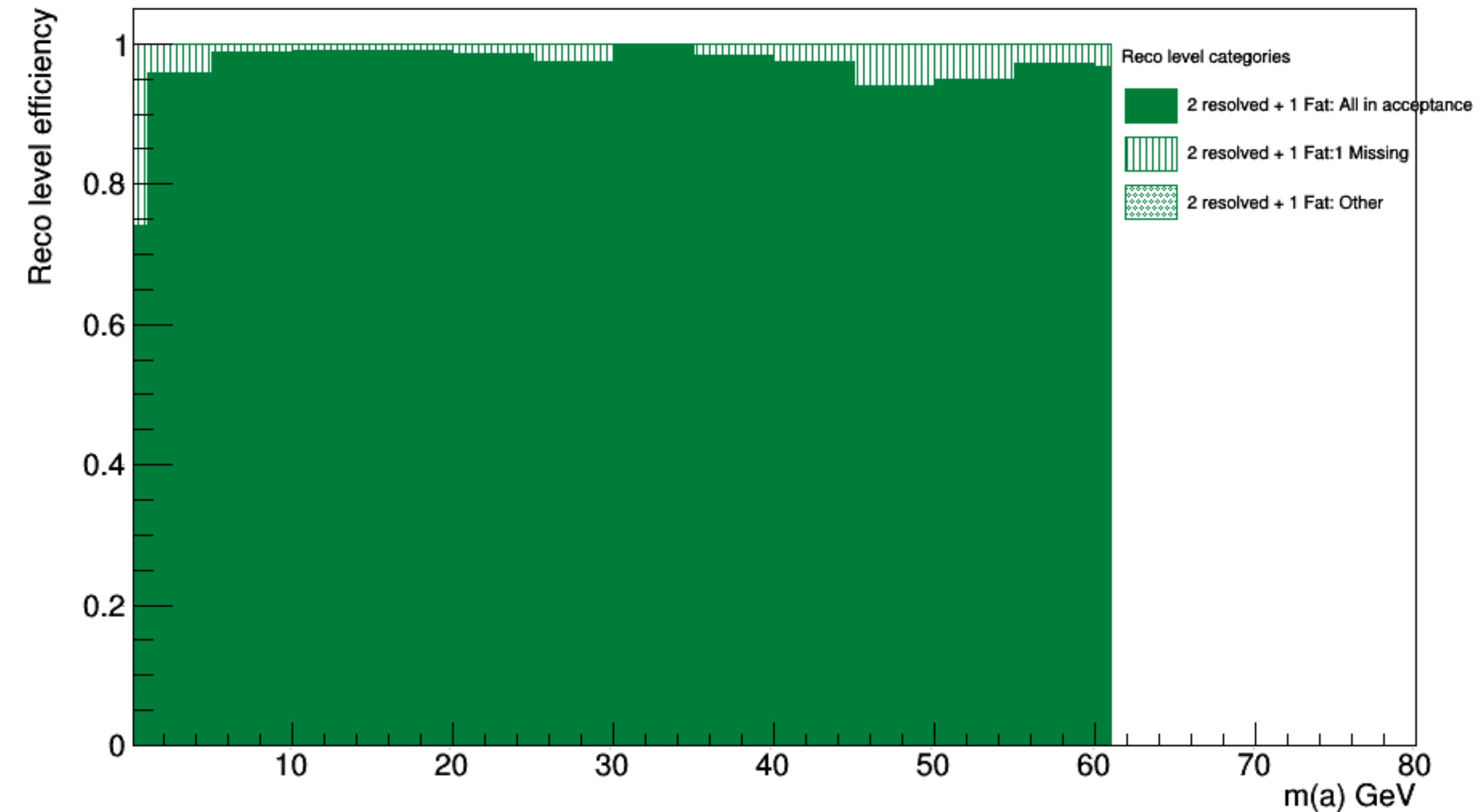
Start with events with at least 4 photons
+ pass trigger requirements
+ Photons are gen matched to resolved

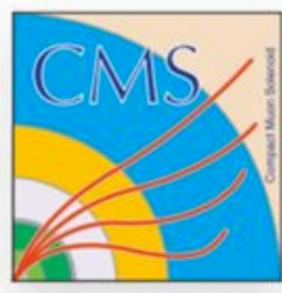
Reco level categorization : Only events that pass trigger requirements : 4 Photon case



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

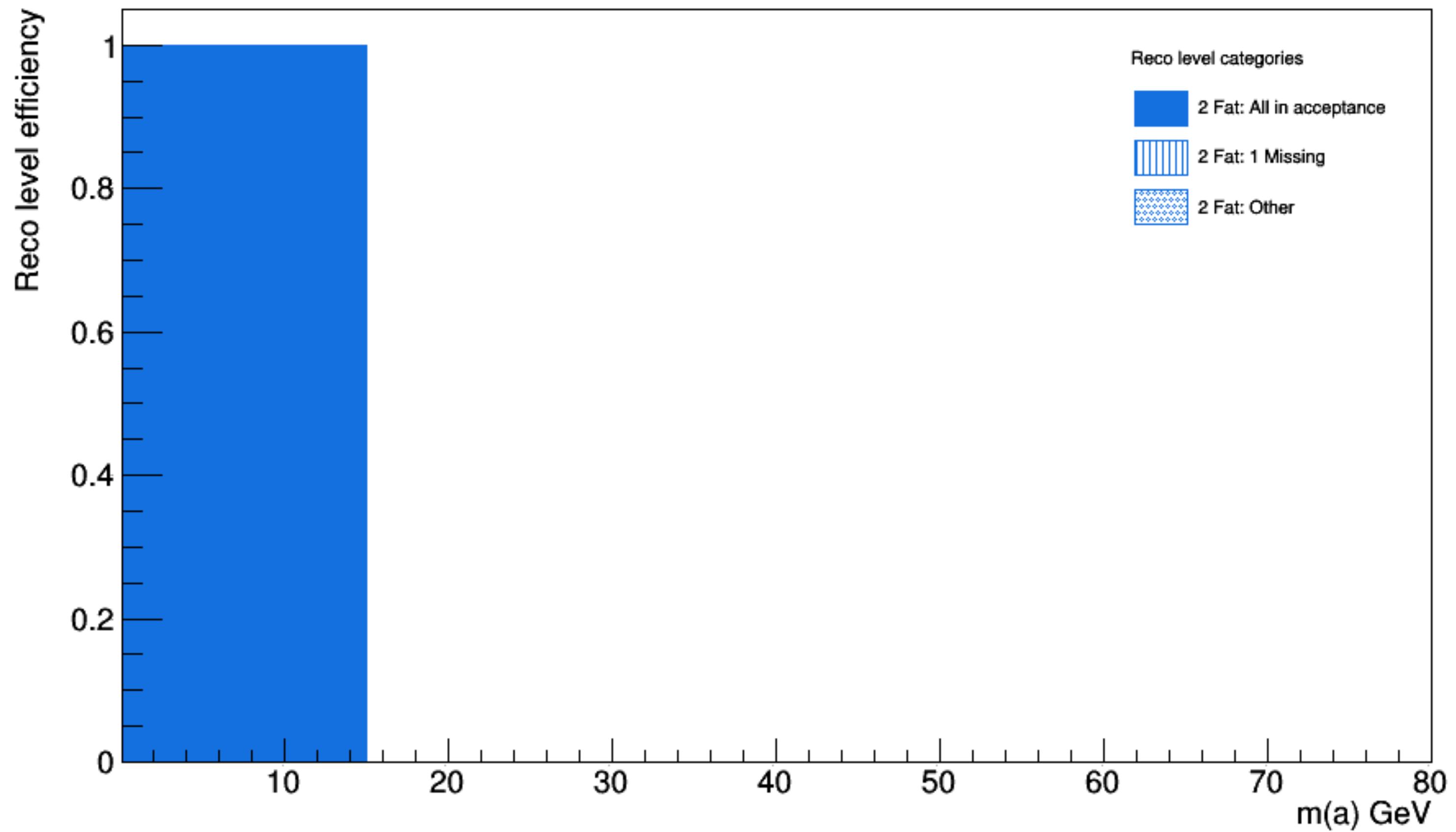
Reco level categorization : Only events that pass trigger requirements : 3 Photon case





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

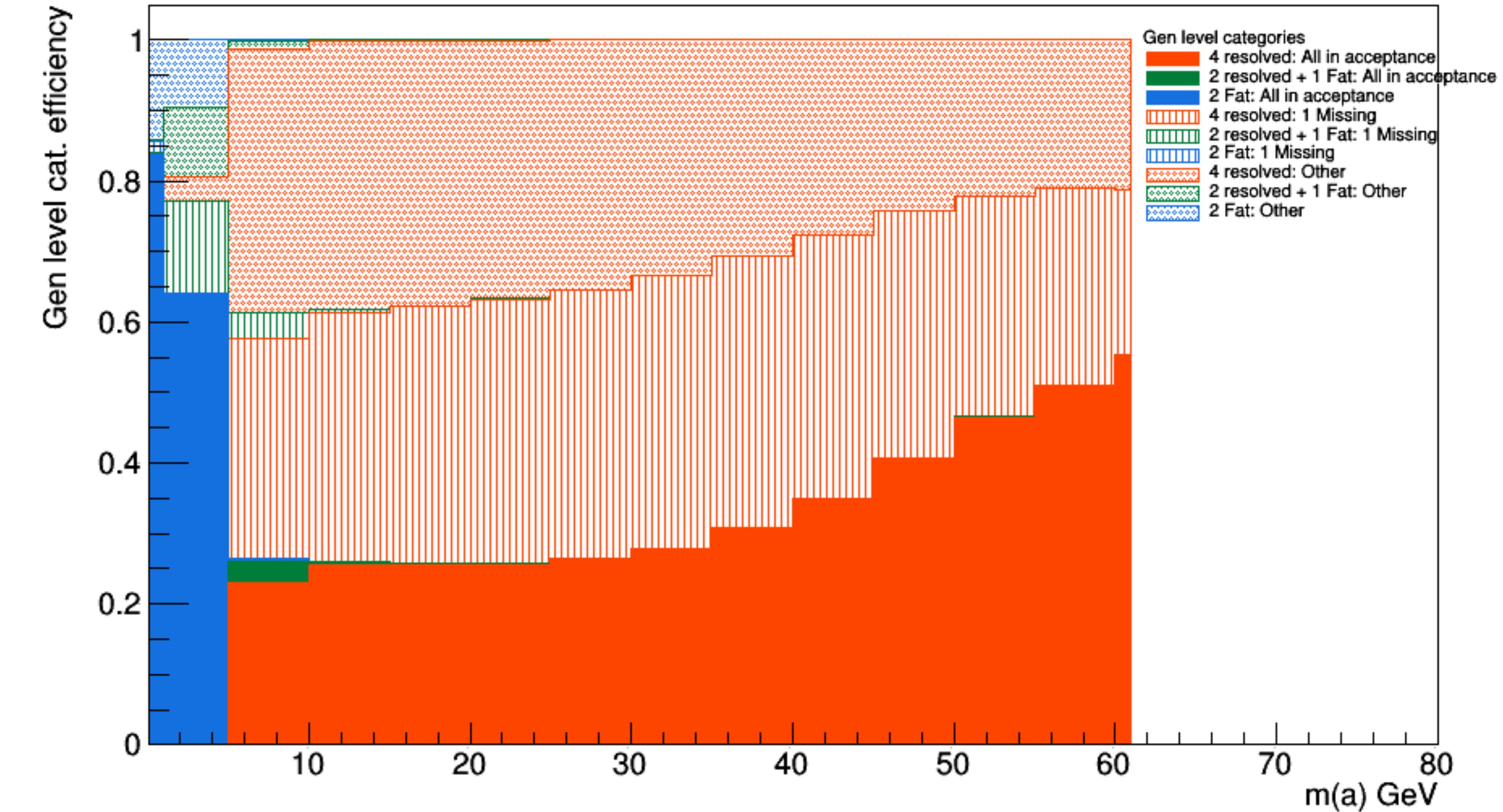
Reco level categorization : Only events that pass trigger requirements : 2 Photon case



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

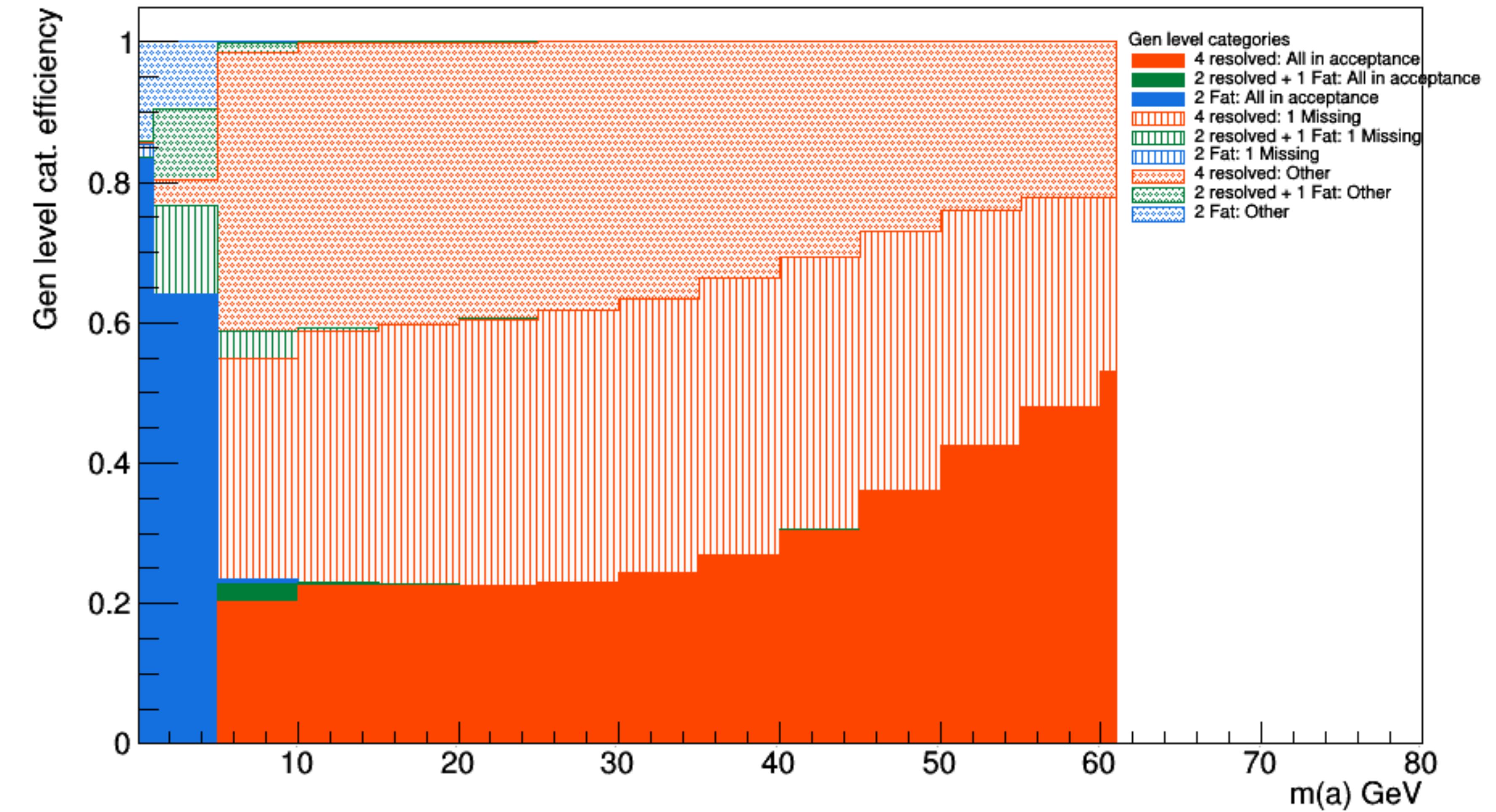
- Gen level categorization
 - $\text{abs}(\eta) < 2.5$
 - Photon1 $\text{Pt} > 10$
 - Photon2 $\text{Pt} > 10$
 - Photon3 $\text{Pt} > 10$
 - Photon4 $\text{Pt} > 10$

Gen level categorization



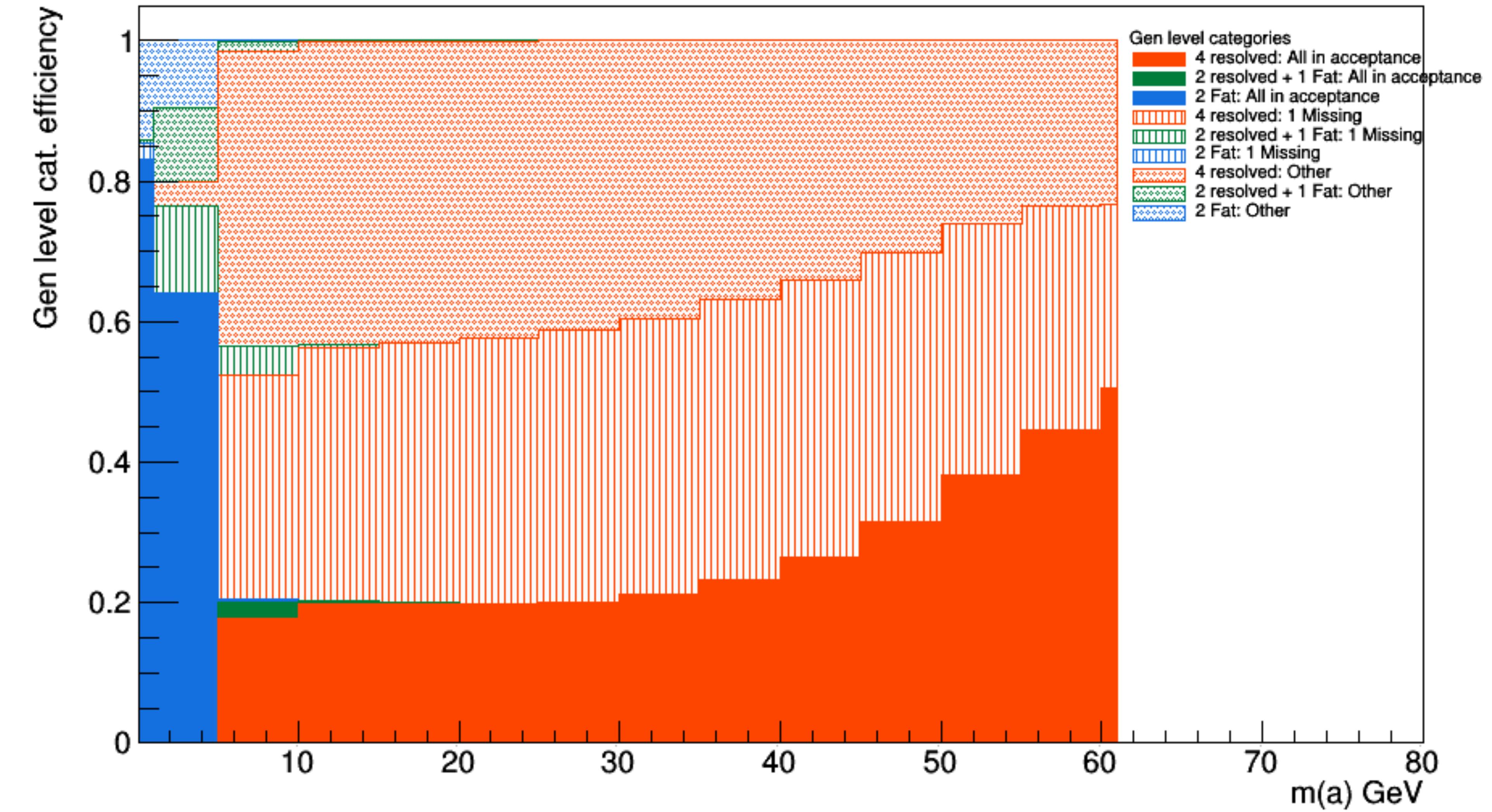
- Gen level categorization
 - $\text{abs}(\text{eta}) < 2.5$
 - Photon1 Pt > 11
 - Photon2 Pt > 11
 - Photon3 Pt > 11
 - Photon4 Pt > 11

Gen level categorization



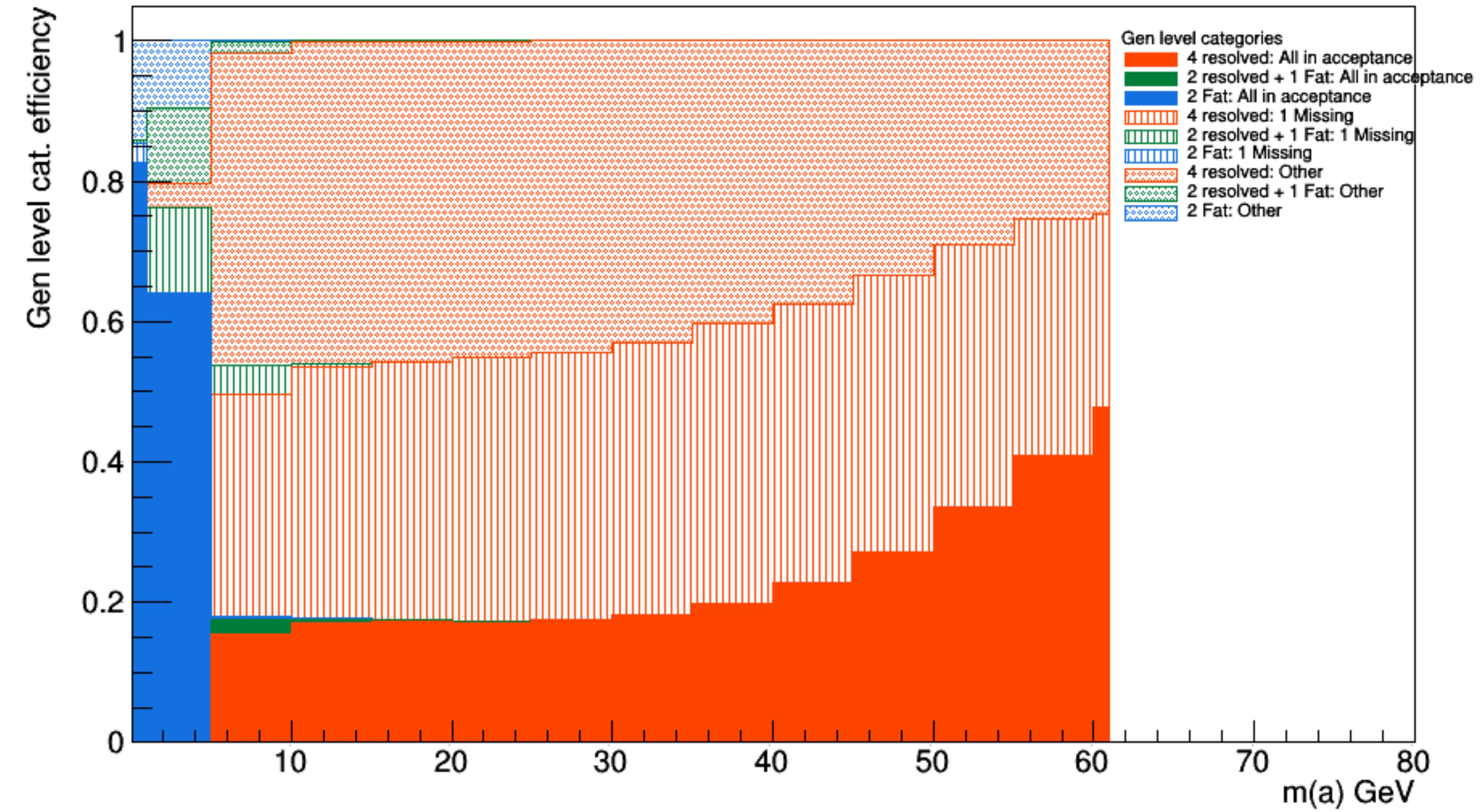
Gen level categorization

- Gen level categorization
 - $\text{abs}(\text{eta}) < 2.5$
 - Photon1 Pt > 12
 - Photon2 Pt > 12
 - Photon3 Pt > 12
 - Photon4 Pt > 12



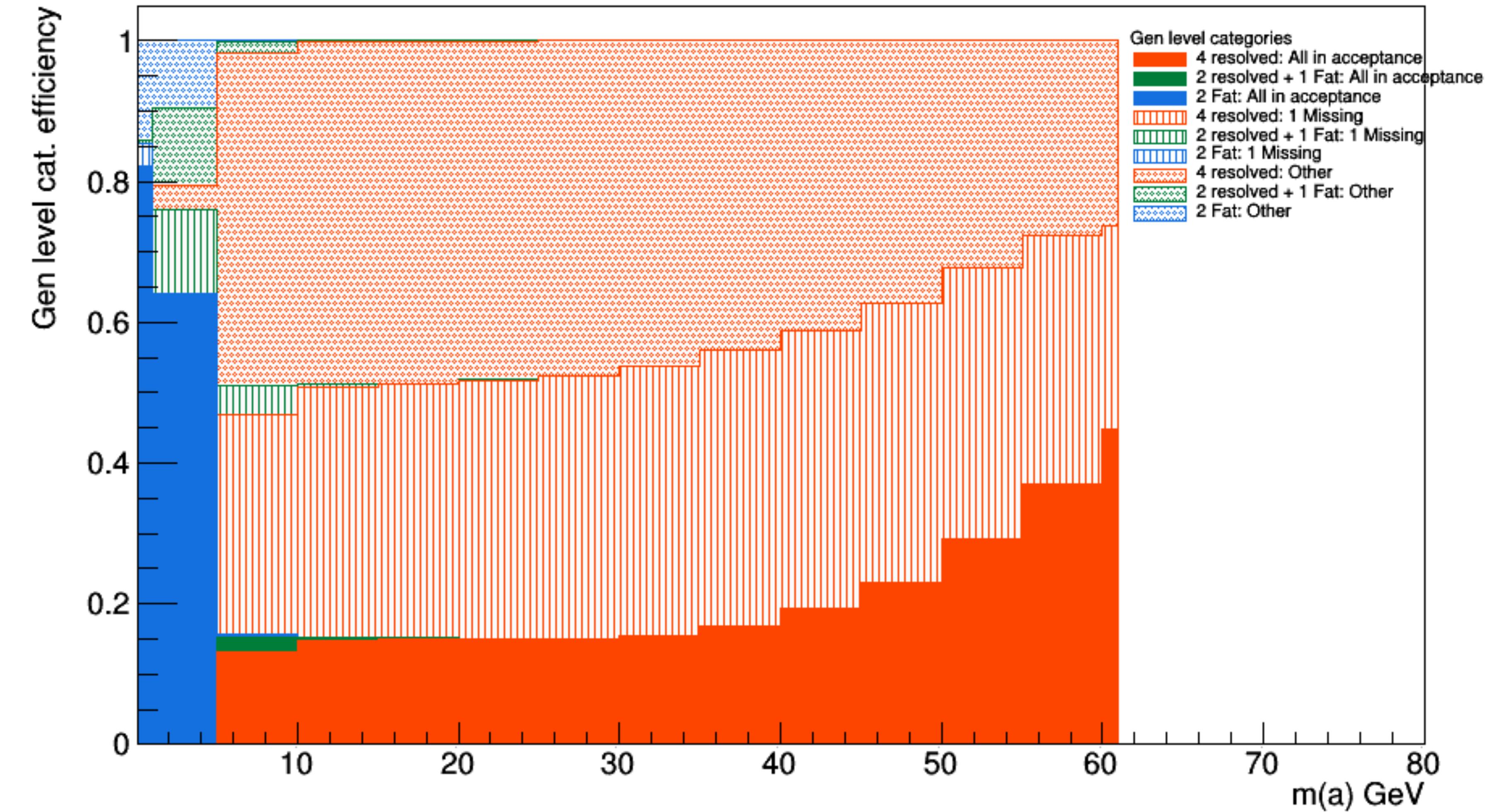
Gen level categorization

- Gen level categorization
 - $\text{abs}(\text{eta}) < 2.5$
 - Photon1 $\text{Pt} > 13$
 - Photon2 $\text{Pt} > 13$
 - Photon3 $\text{Pt} > 13$
 - Photon4 $\text{Pt} > 13$



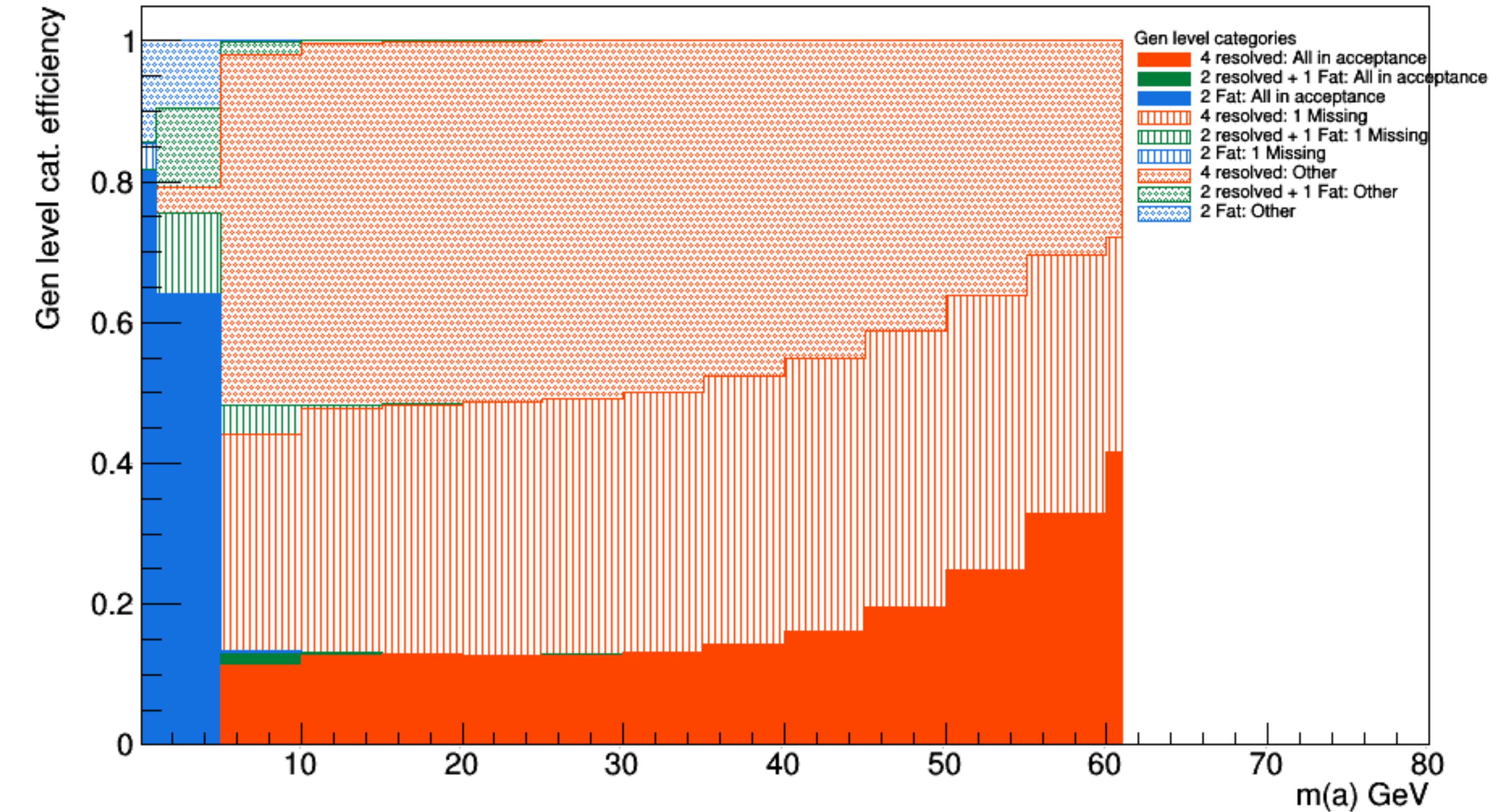
- Gen level categorization
 - $\text{abs}(\text{eta}) < 2.5$
 - Photon1 Pt > 14
 - Photon2 Pt > 14
 - Photon3 Pt > 14
 - Photon4 Pt > 14

Gen level categorization



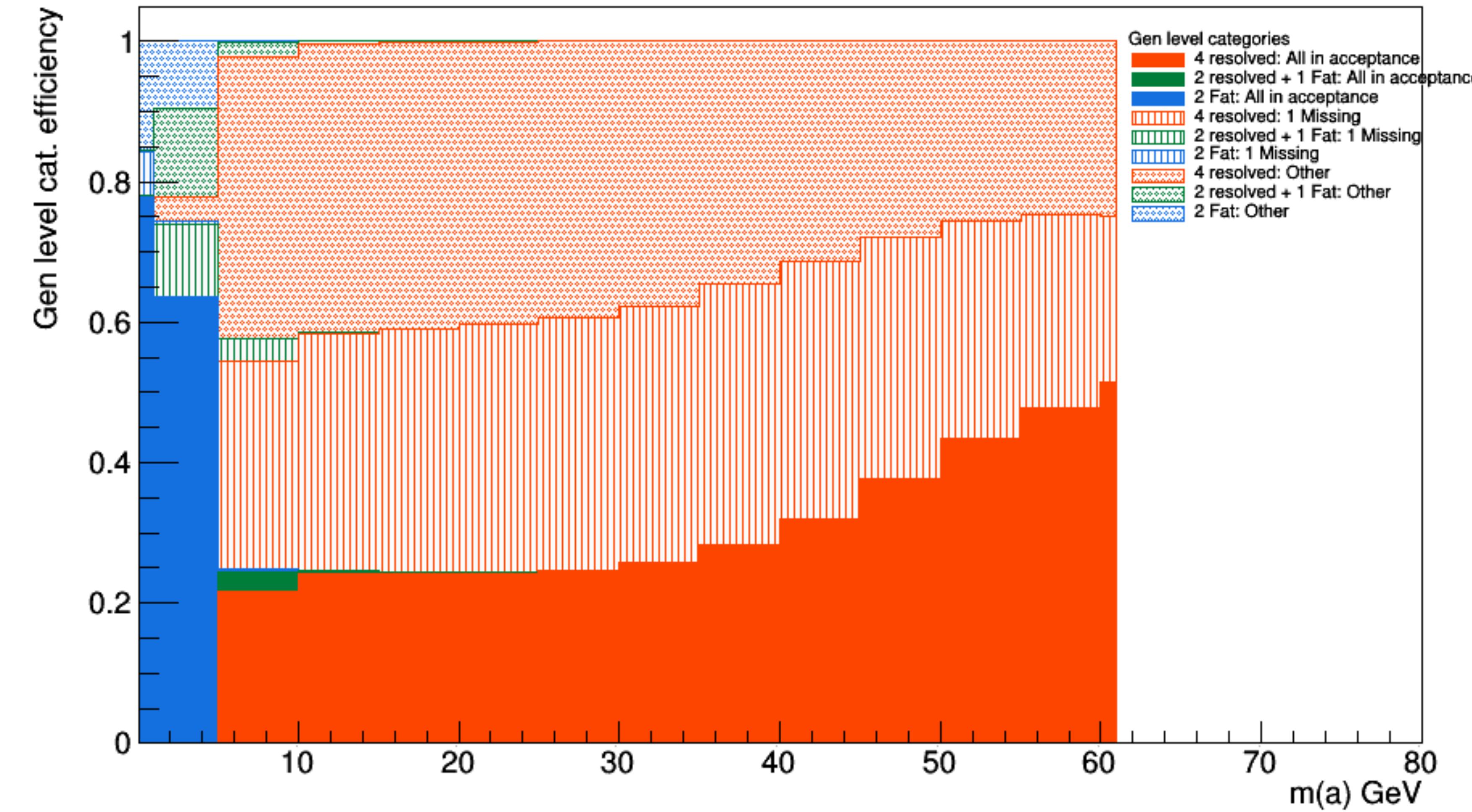
- Gen level categorization
 - $\text{abs}(\text{eta}) < 2.5$
 - Photon1 Pt > 15
 - Photon2 Pt > 15
 - Photon3 Pt > 15
 - Photon4 Pt > 15

Gen level categorization



- Gen level categorization
 - $\text{abs}(\text{eta}) < 2.5$
 - Photon1 Pt > 30
 - Photon2 Pt > 18
 - Photon3 Pt > 10
 - Photon4 Pt > 10

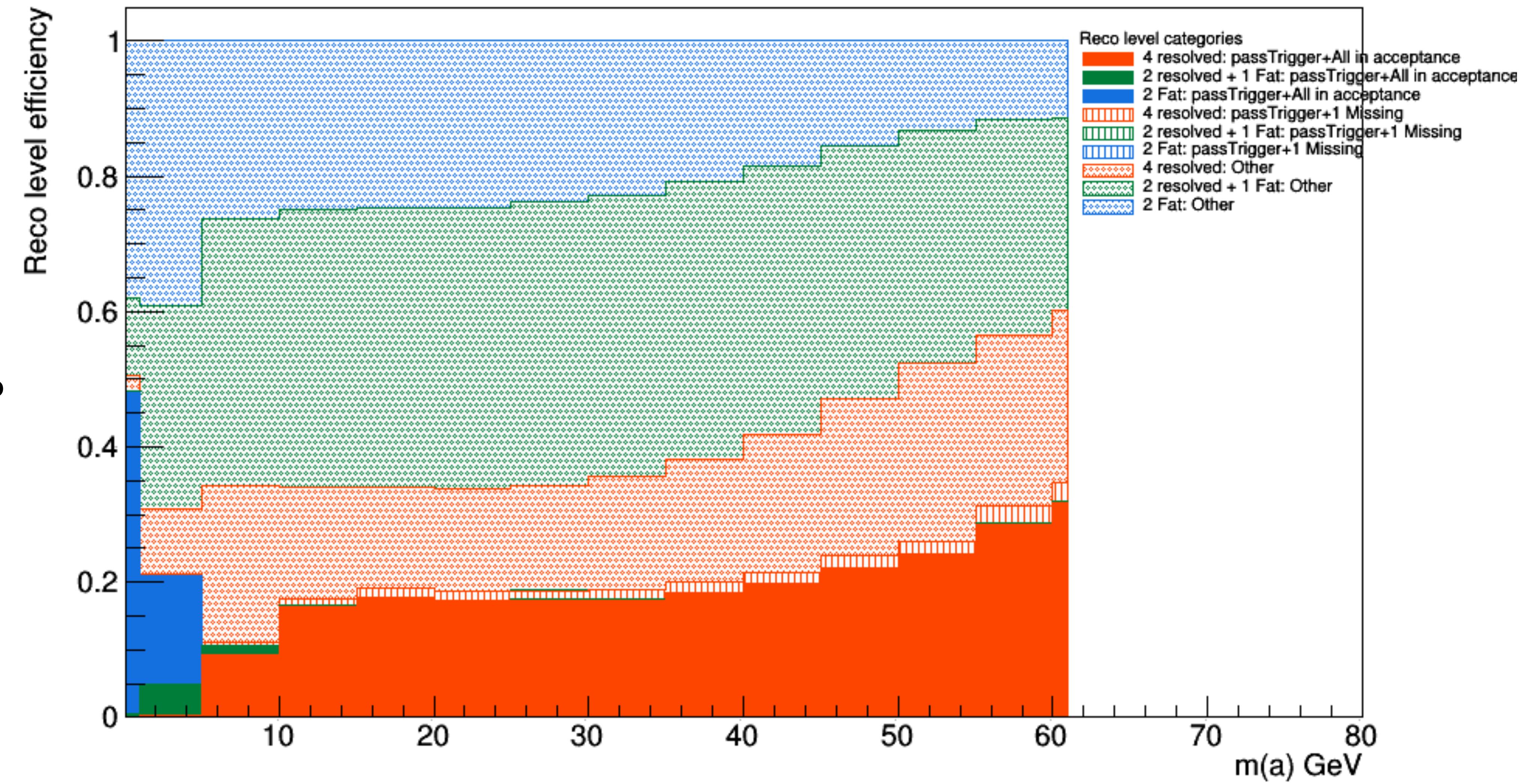
Gen level categorization



deltaR (Reco, Gen) <0.10

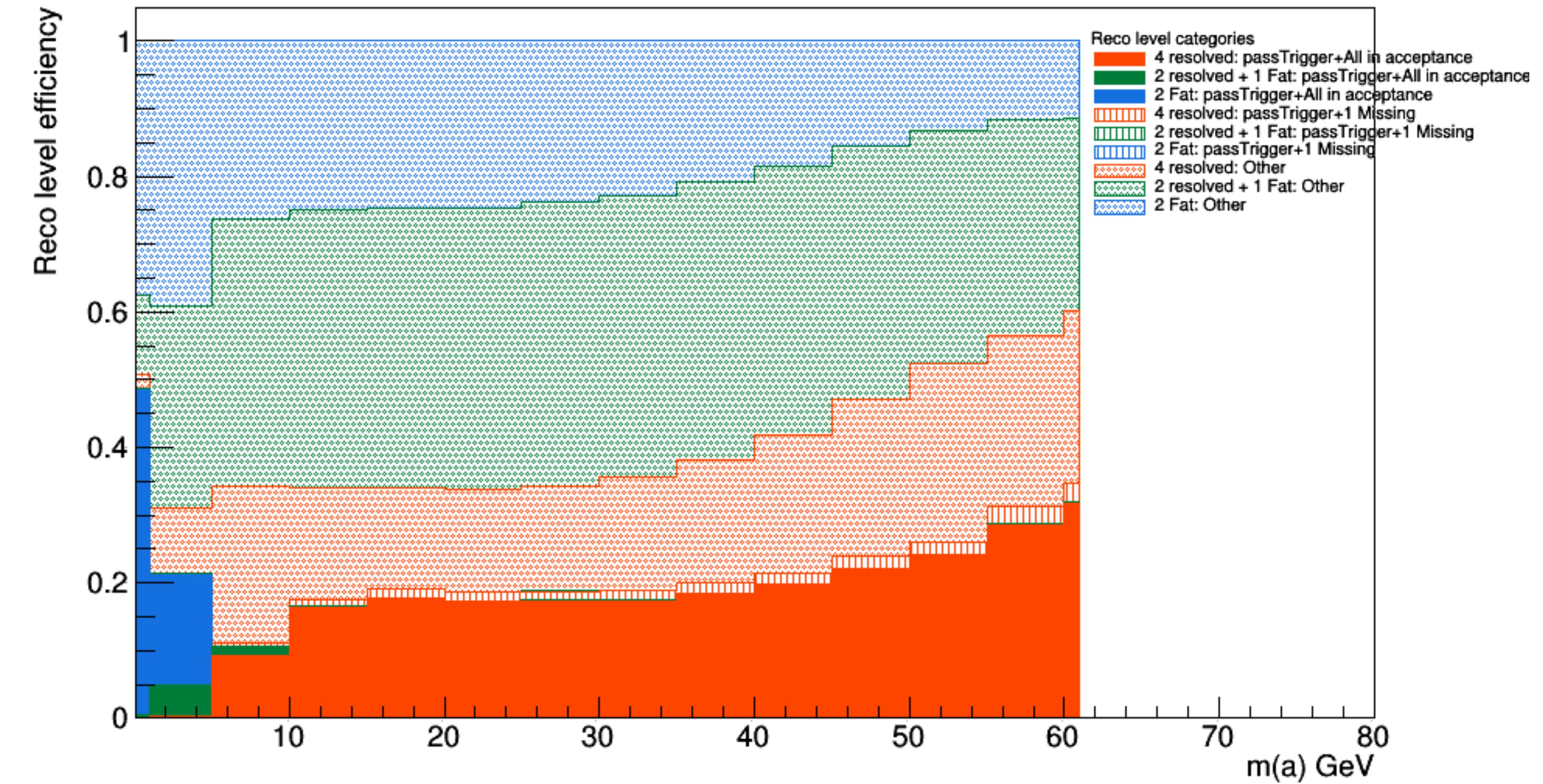
Reco level categorization

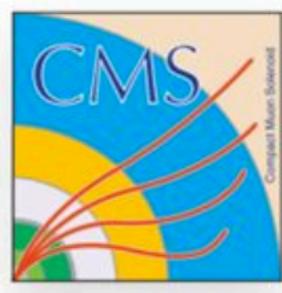
Others (dotted region) also contains events that have not passed trigger



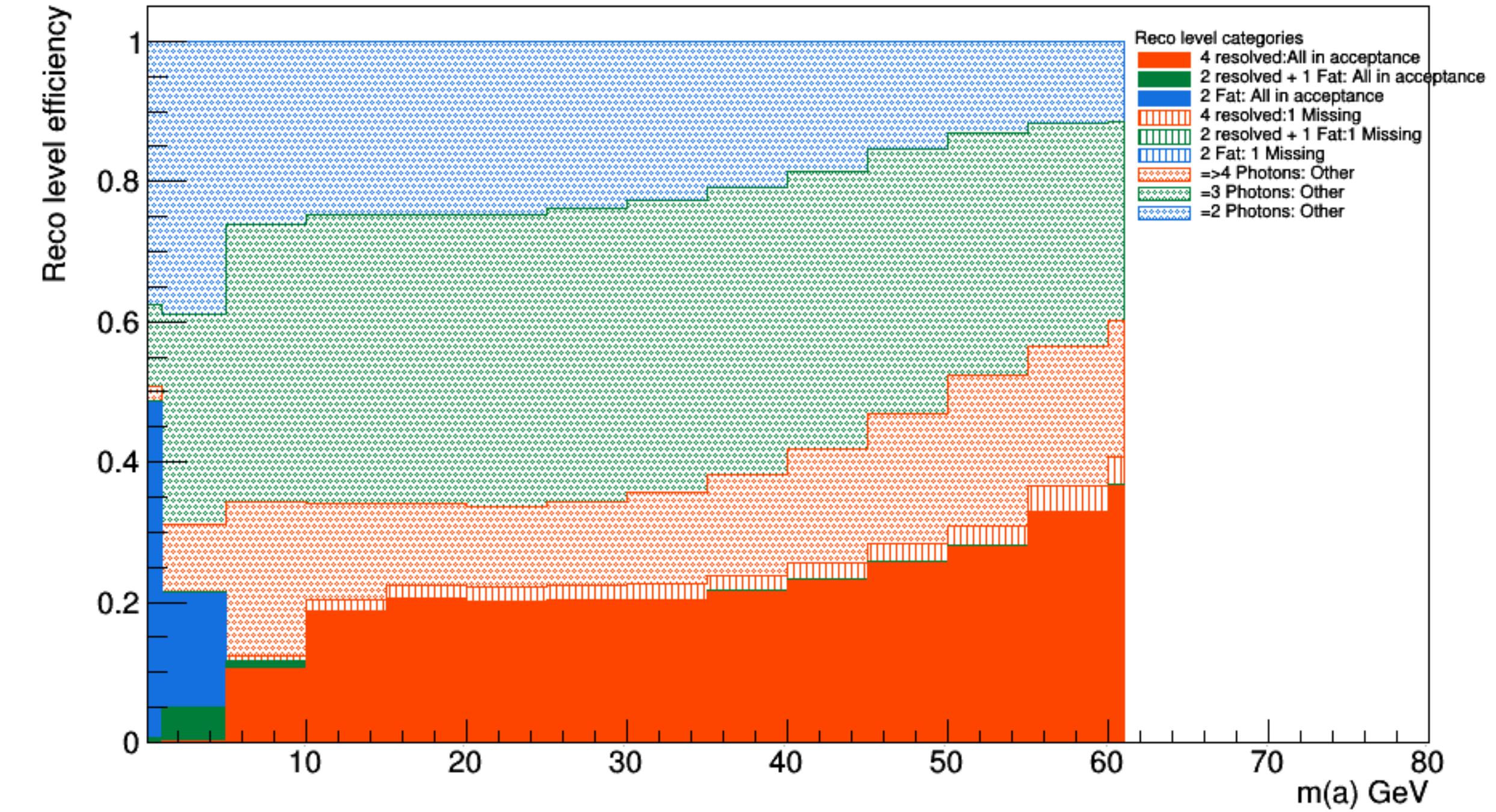
deltaR (Reco, Gen) <0.15

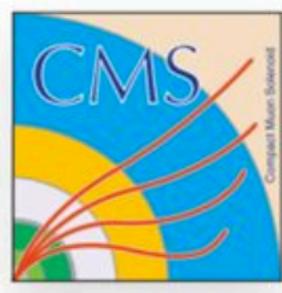
Reco level categorization



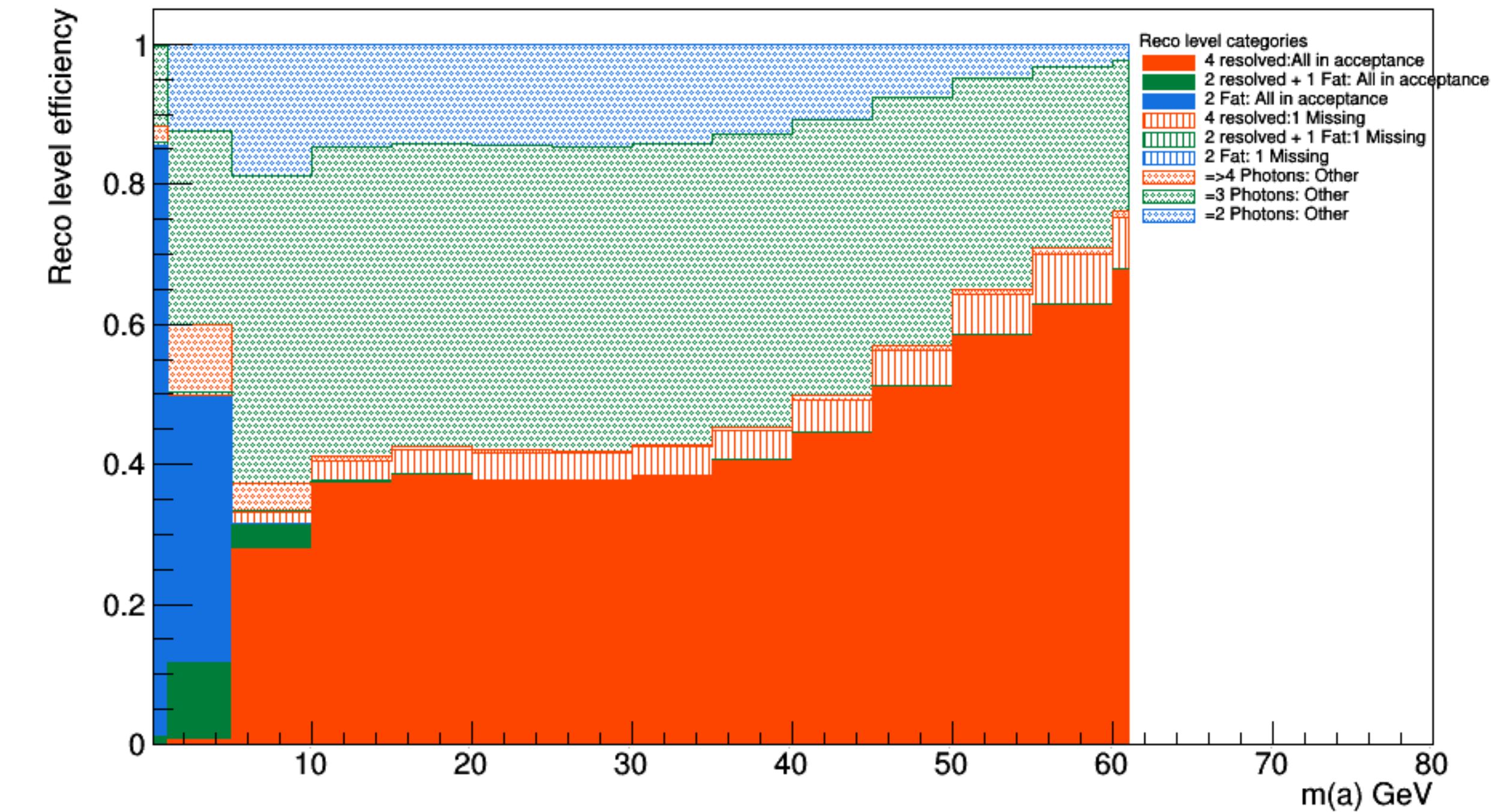


Reco level categorization



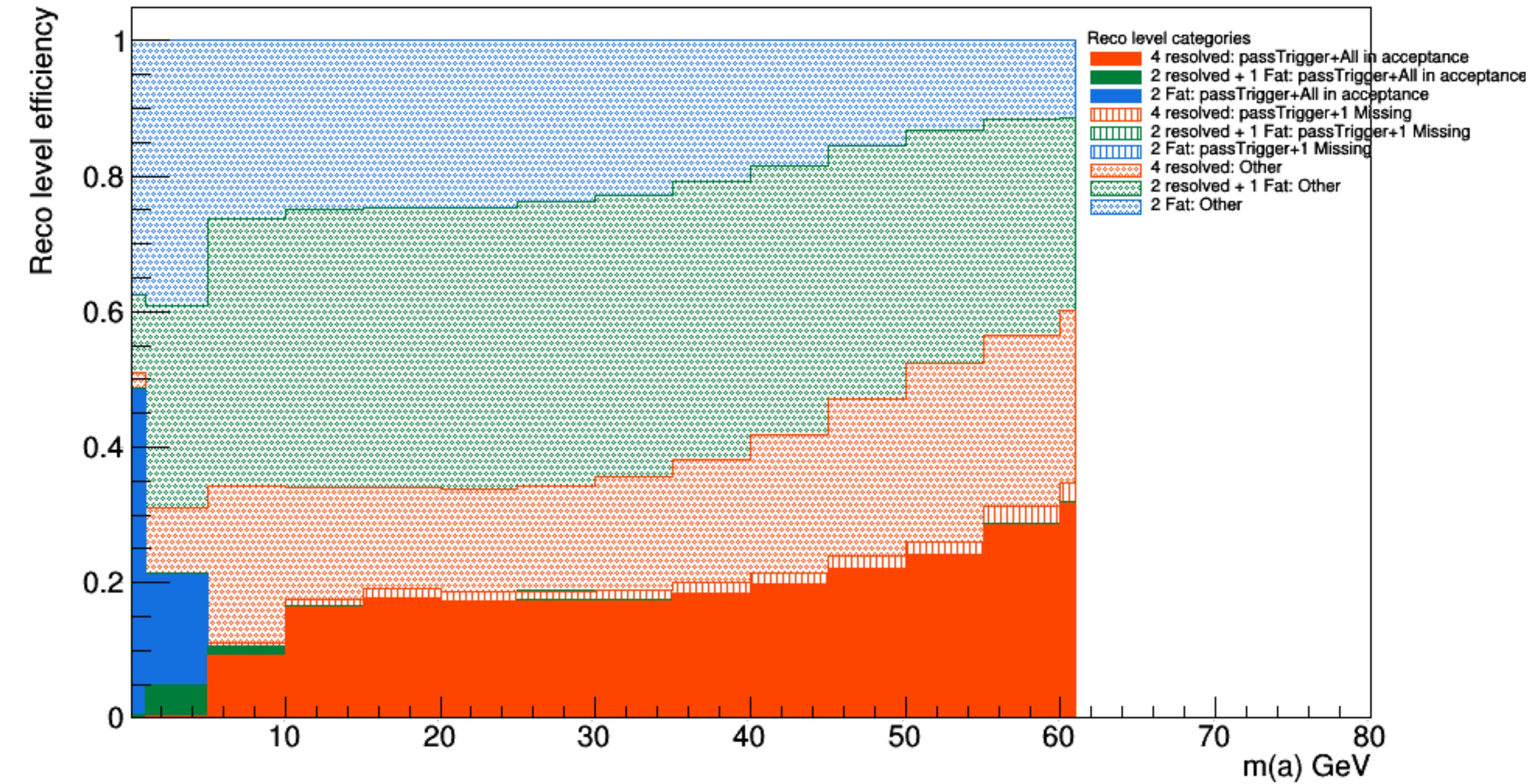


Reco level categorization : Only events that pass trigger requirements



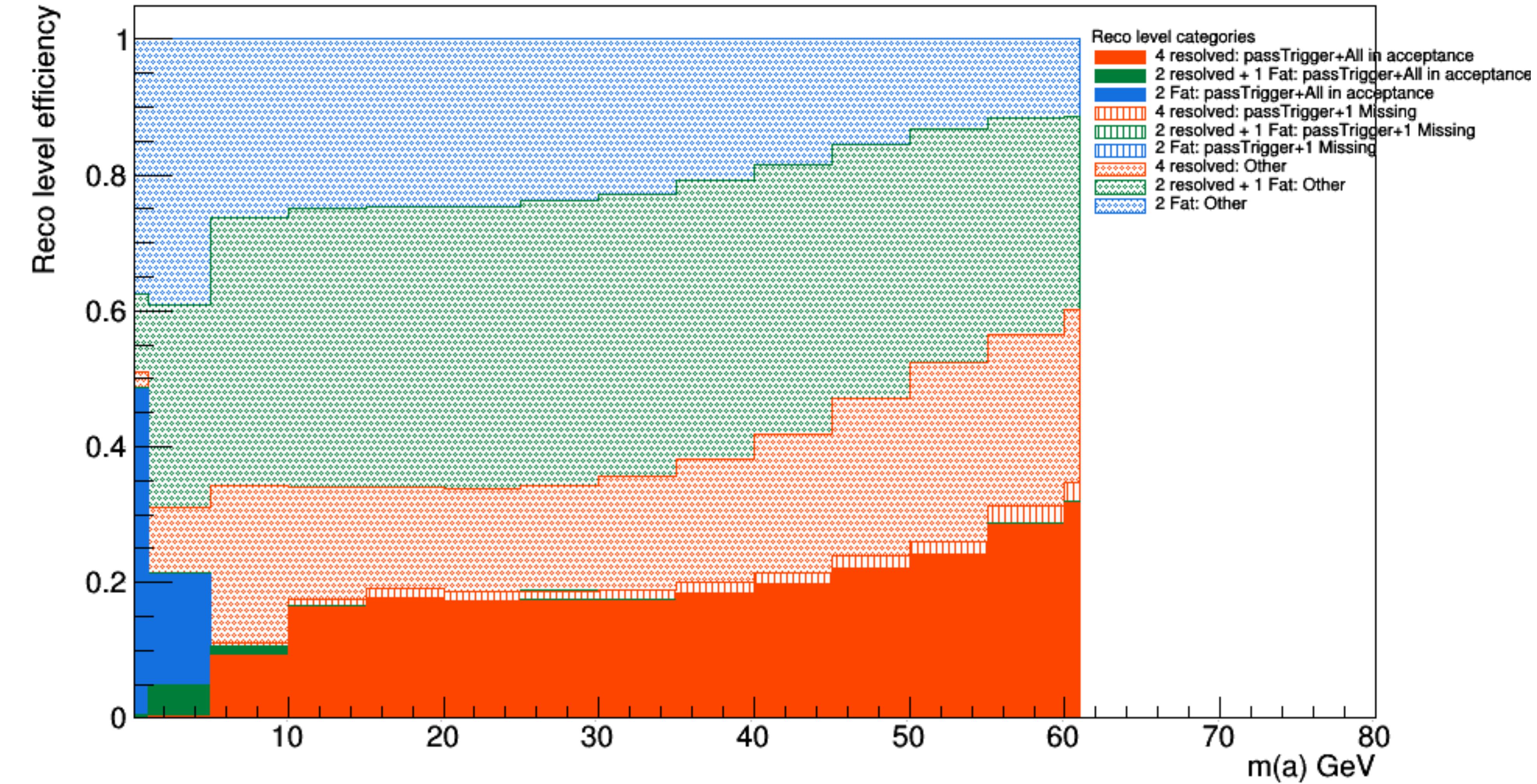
deltaR (Reco, Gen) <0.2

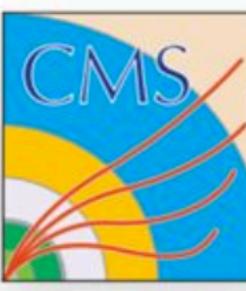
Reco level categorization



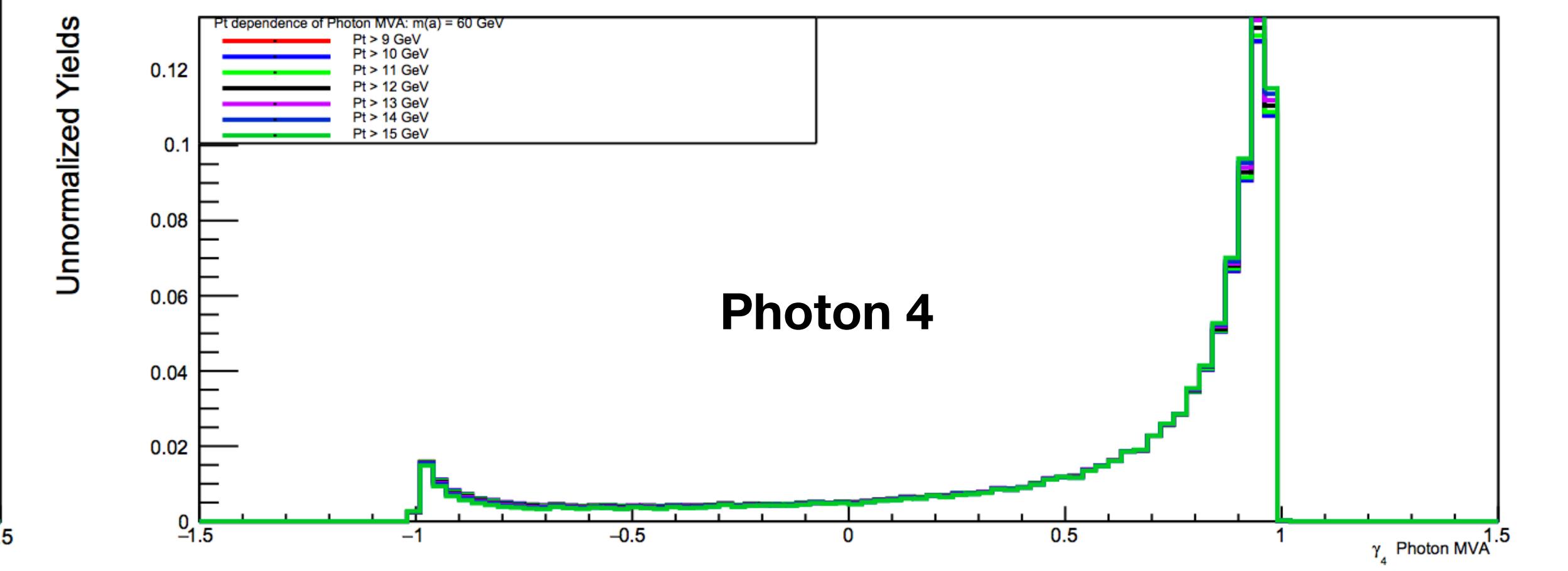
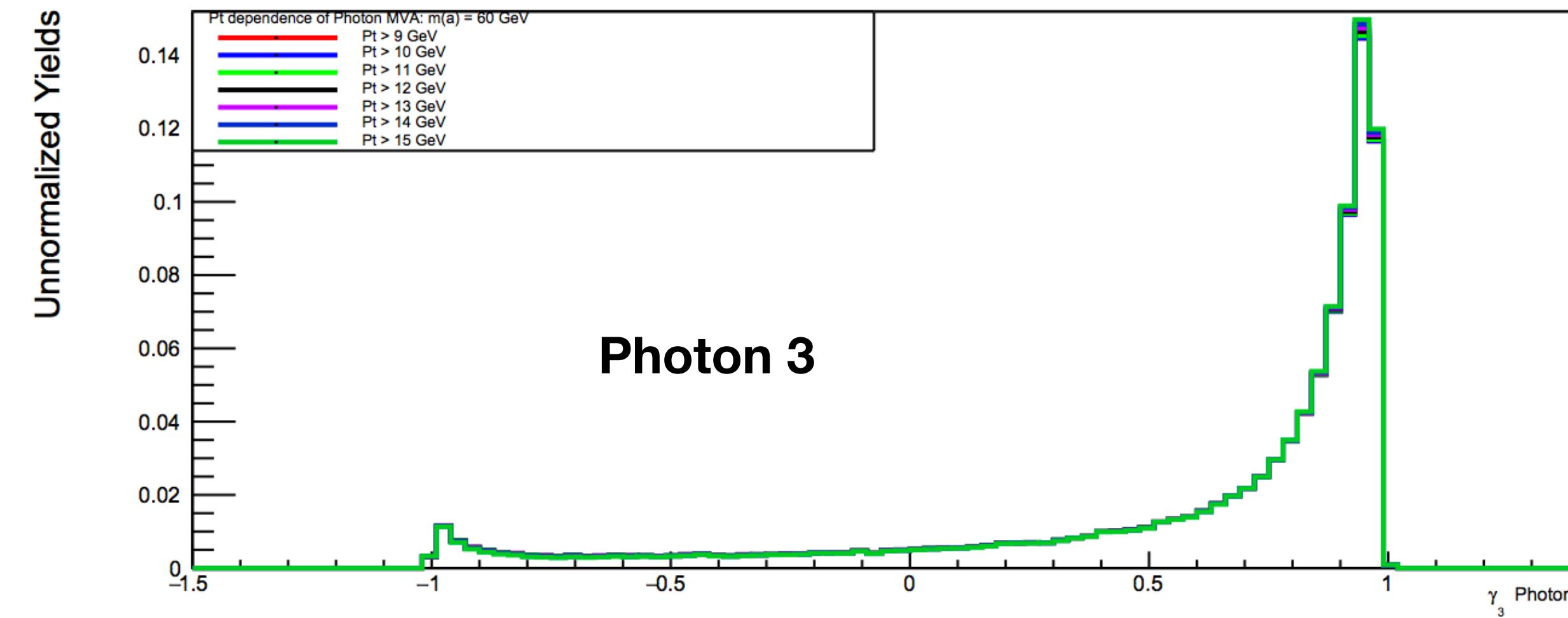
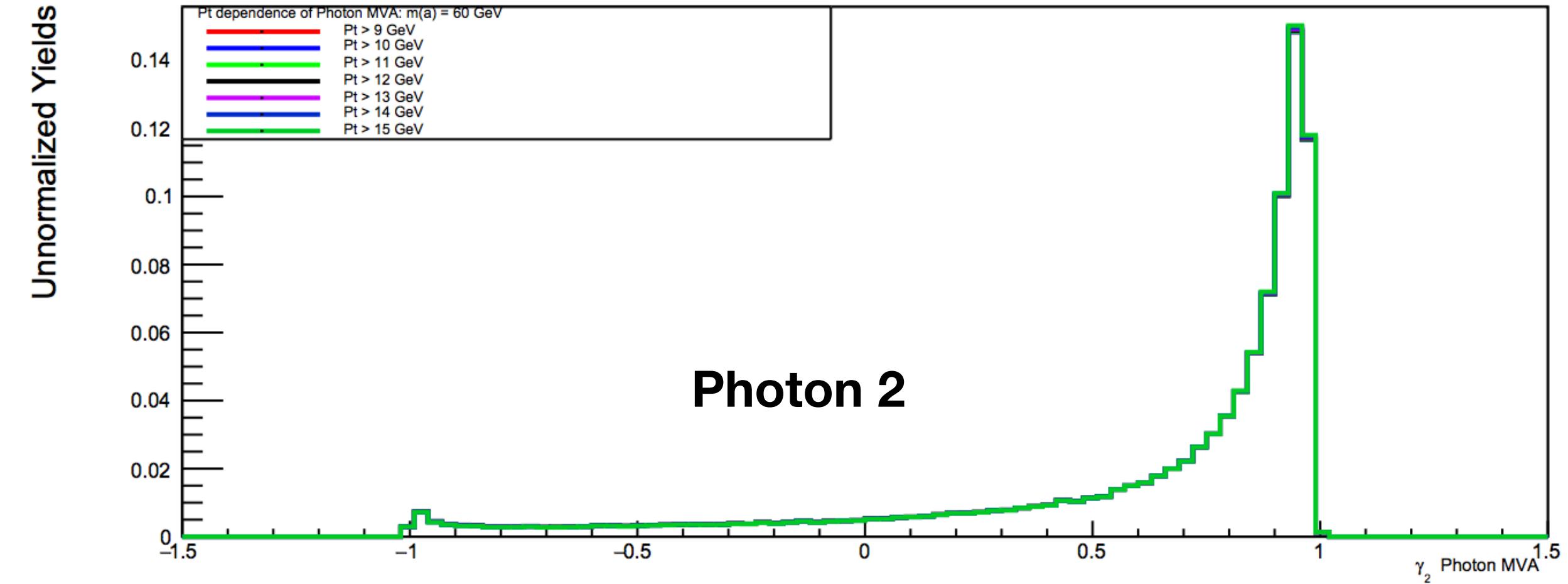
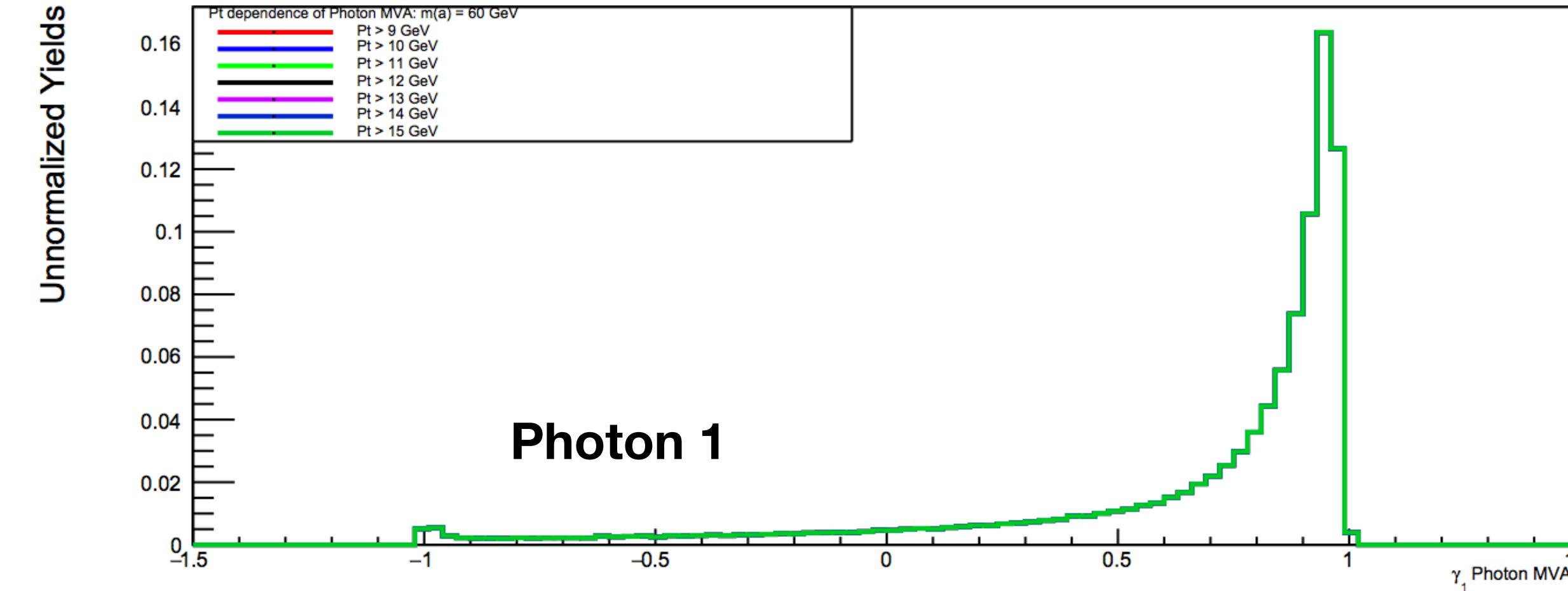
deltaR (Reco, Gen) <0.3

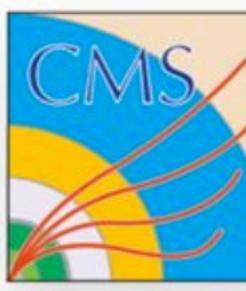
Reco level categorization



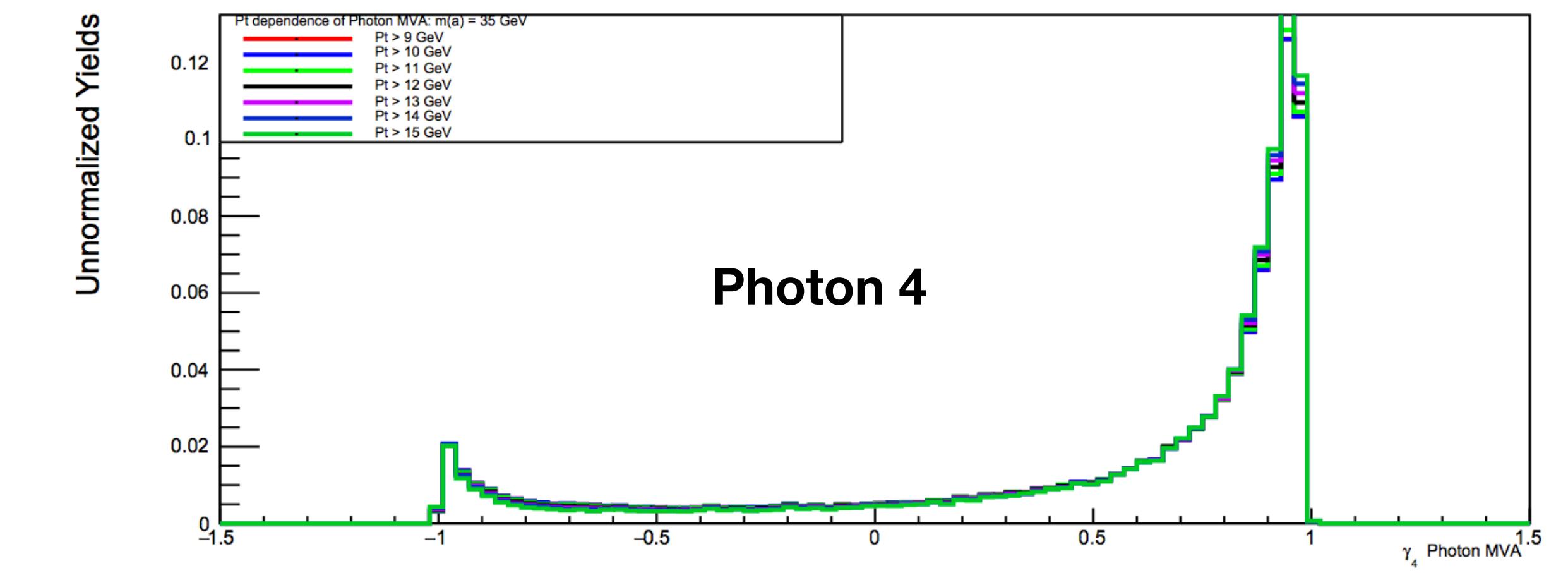
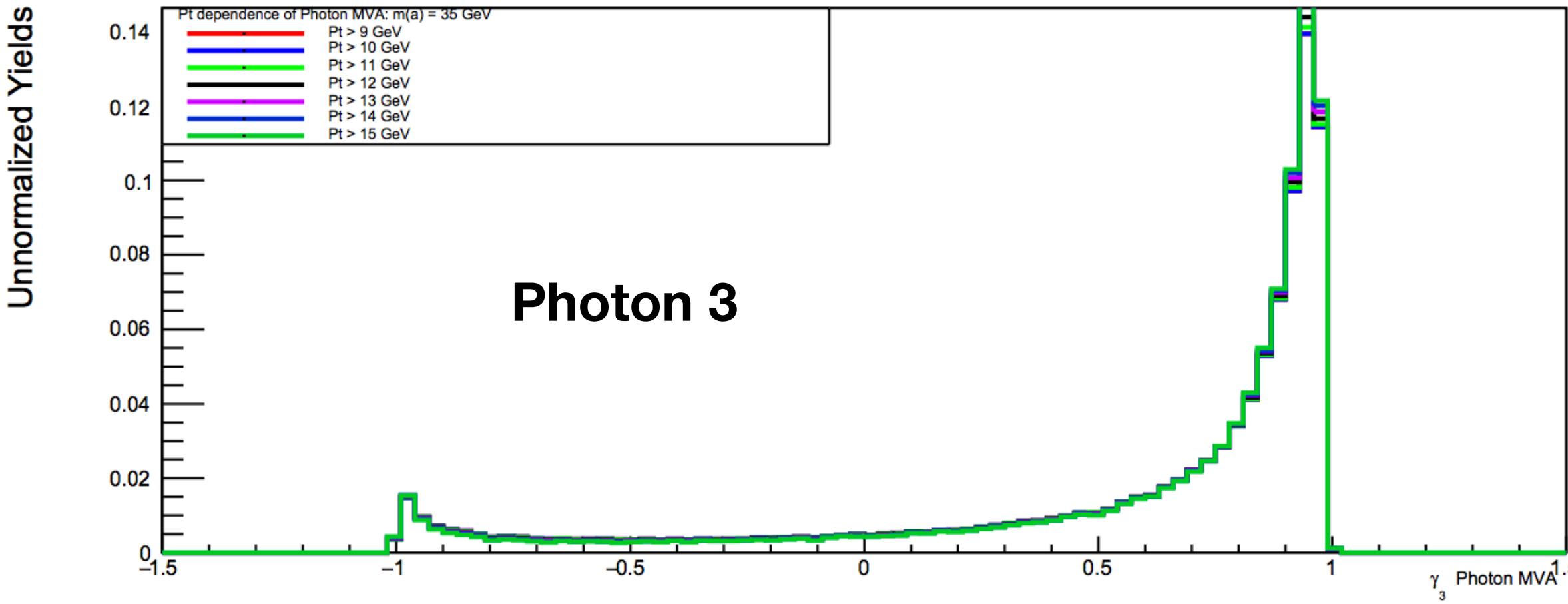
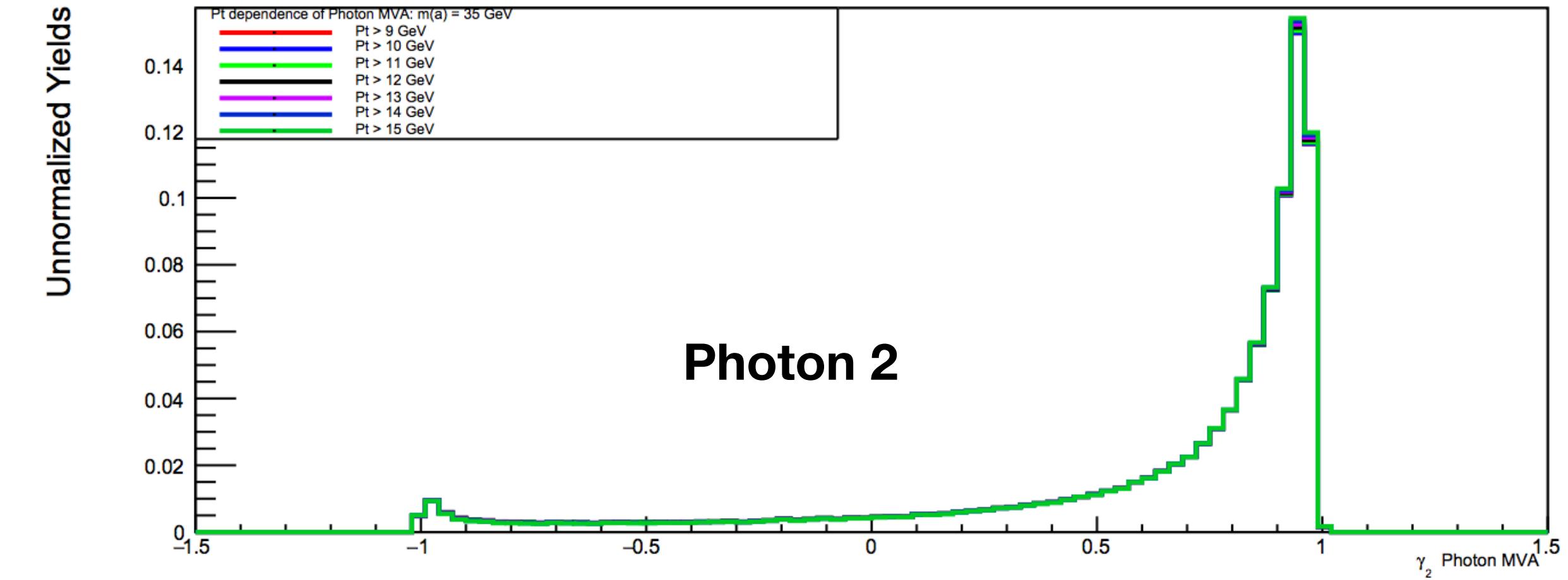
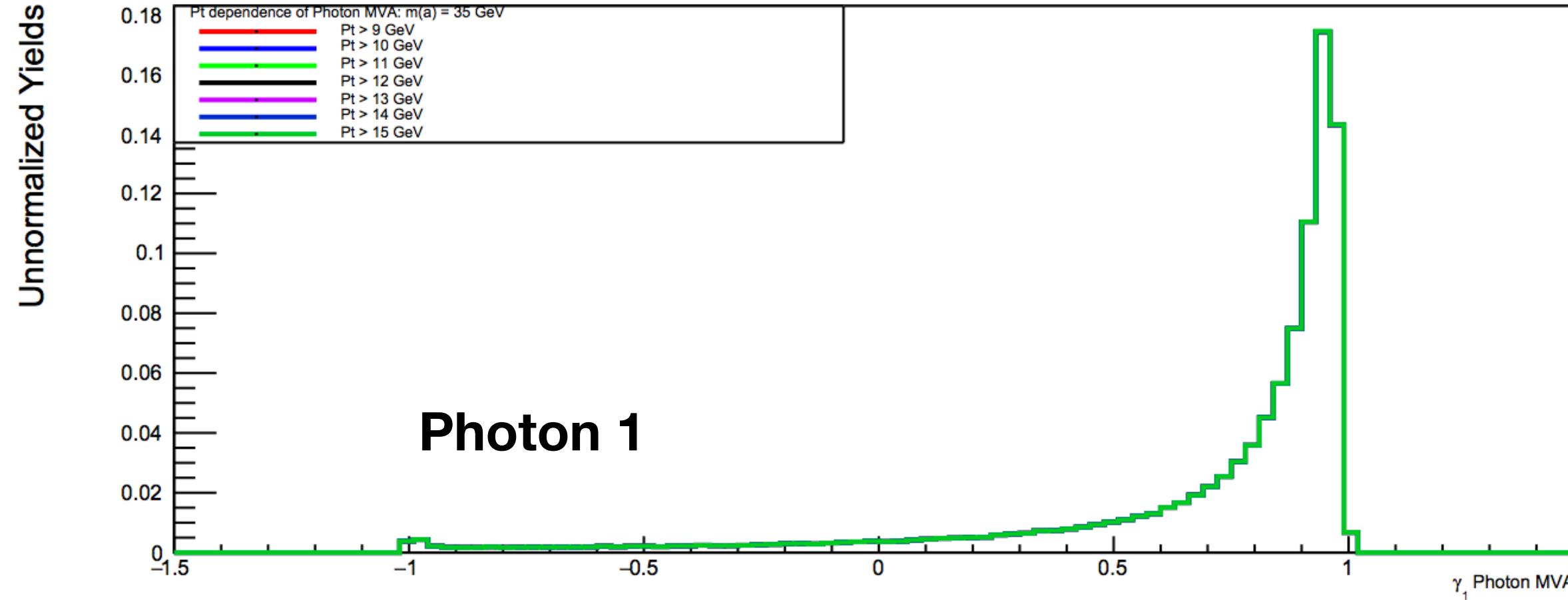


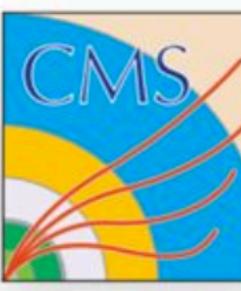
m(a) = 60 GeV



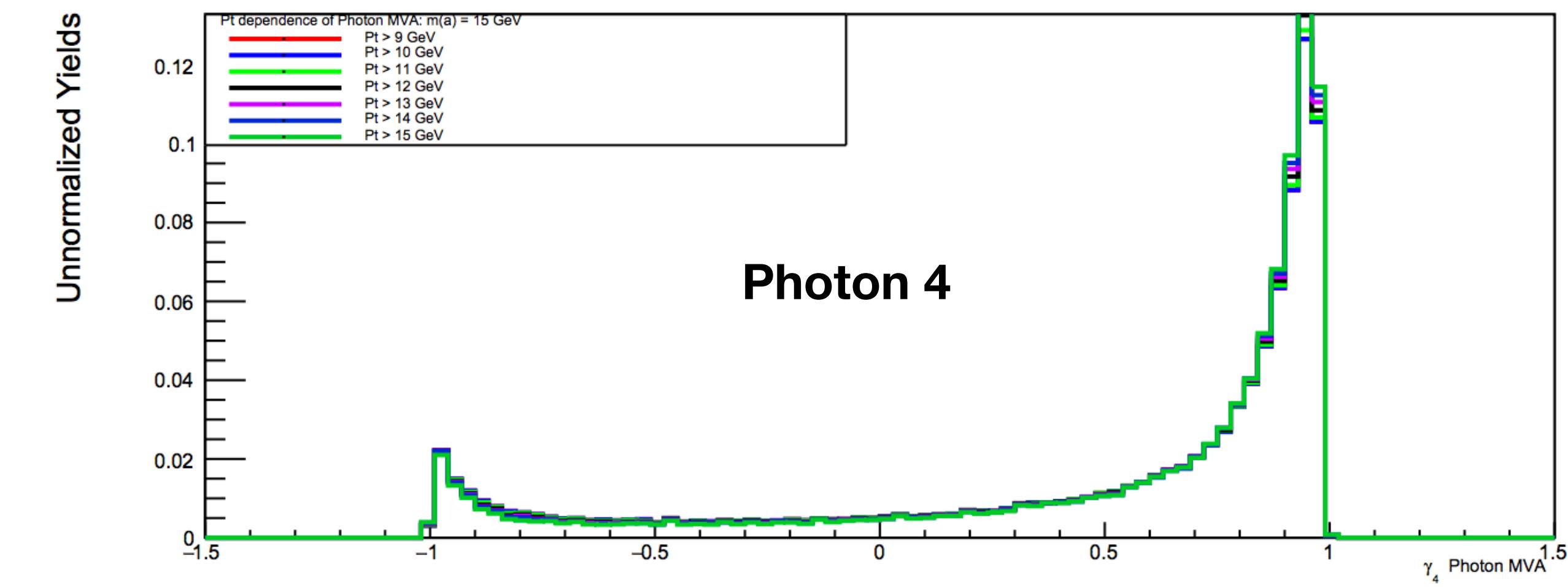
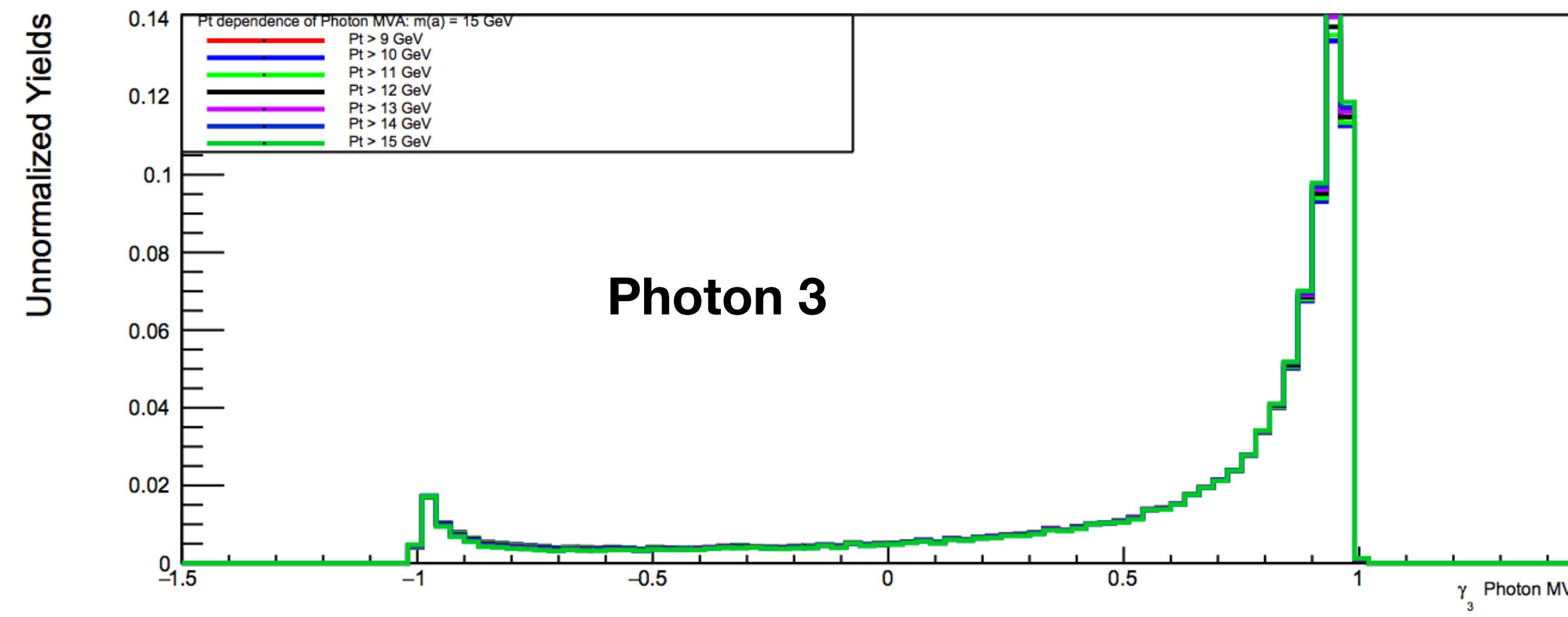
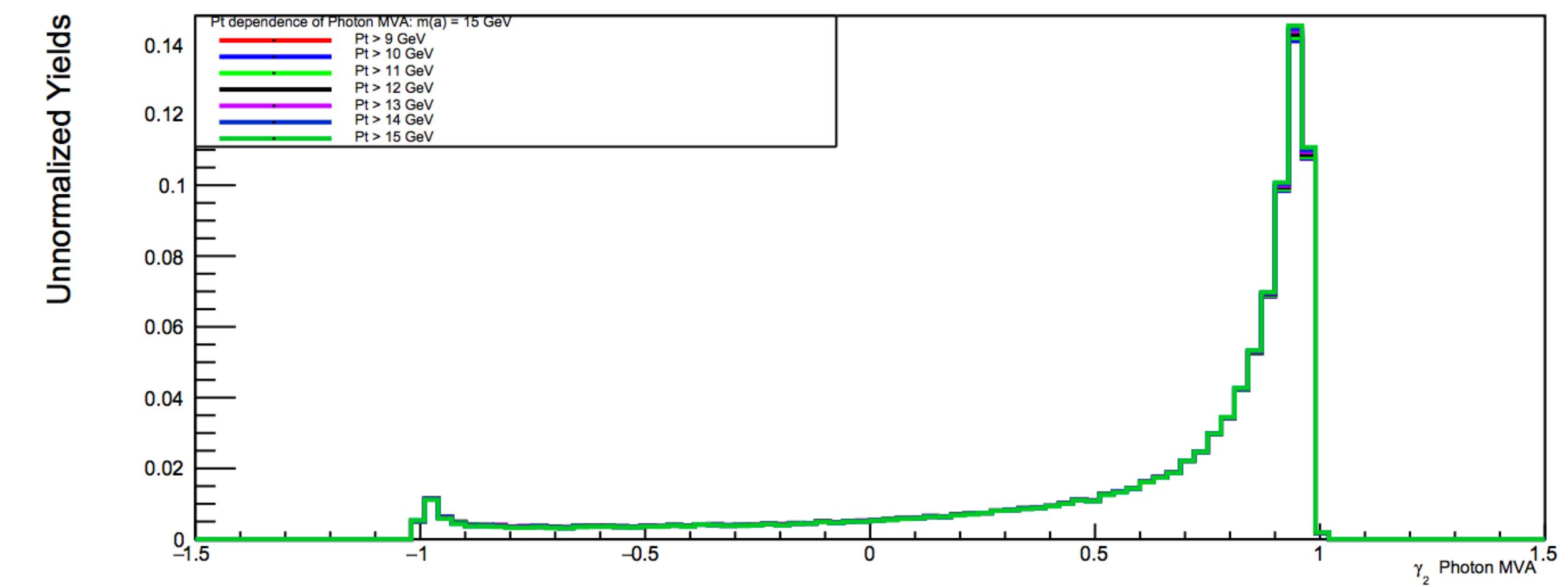
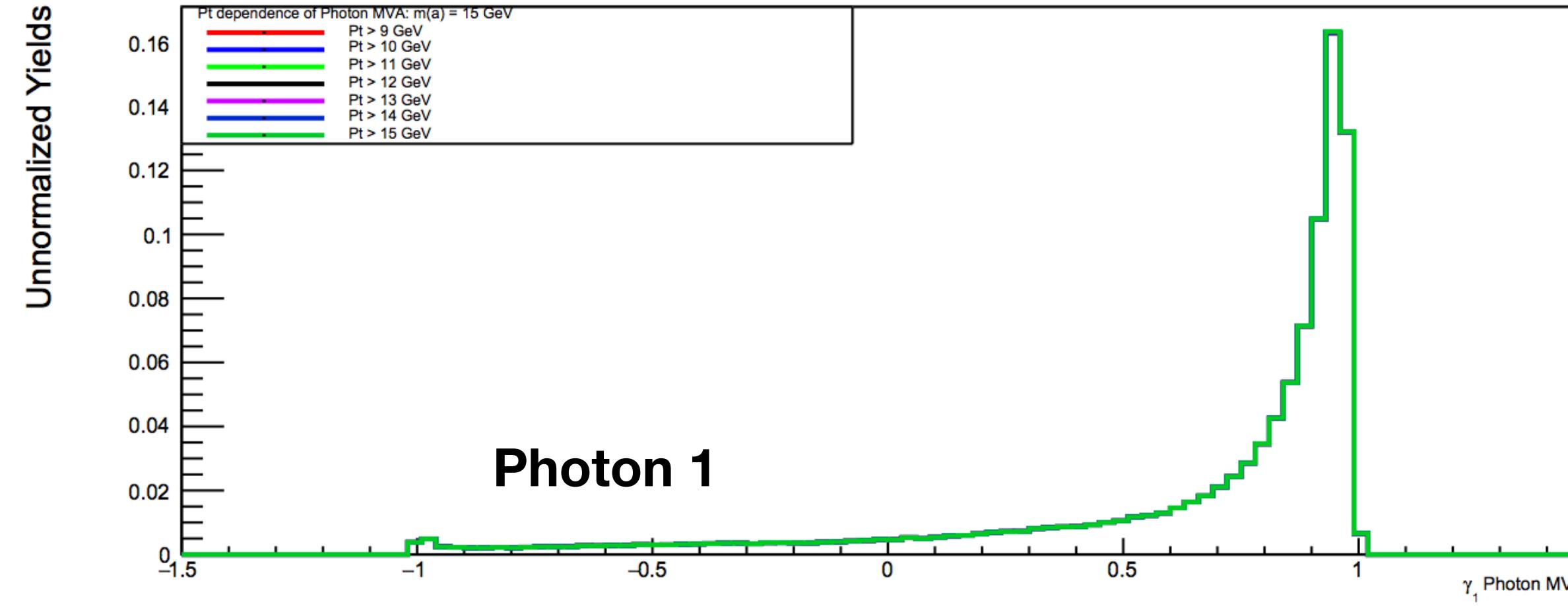


m(a) = 35 GeV



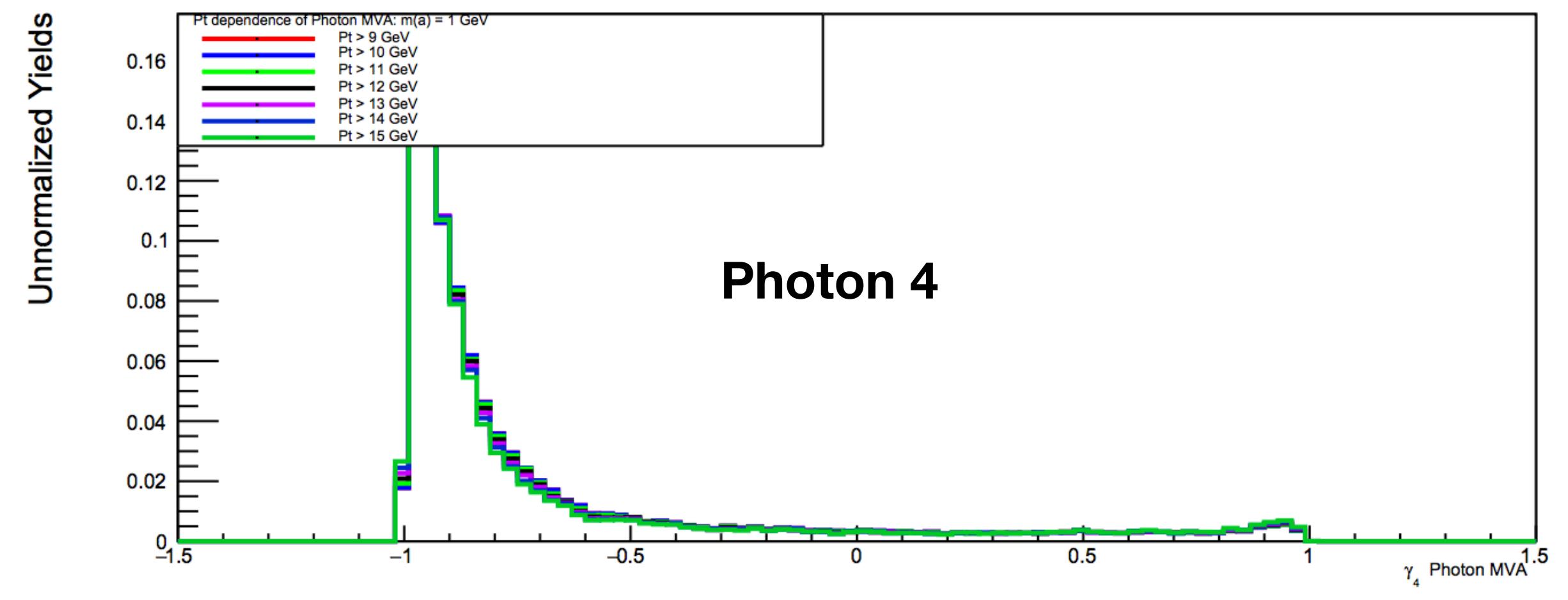
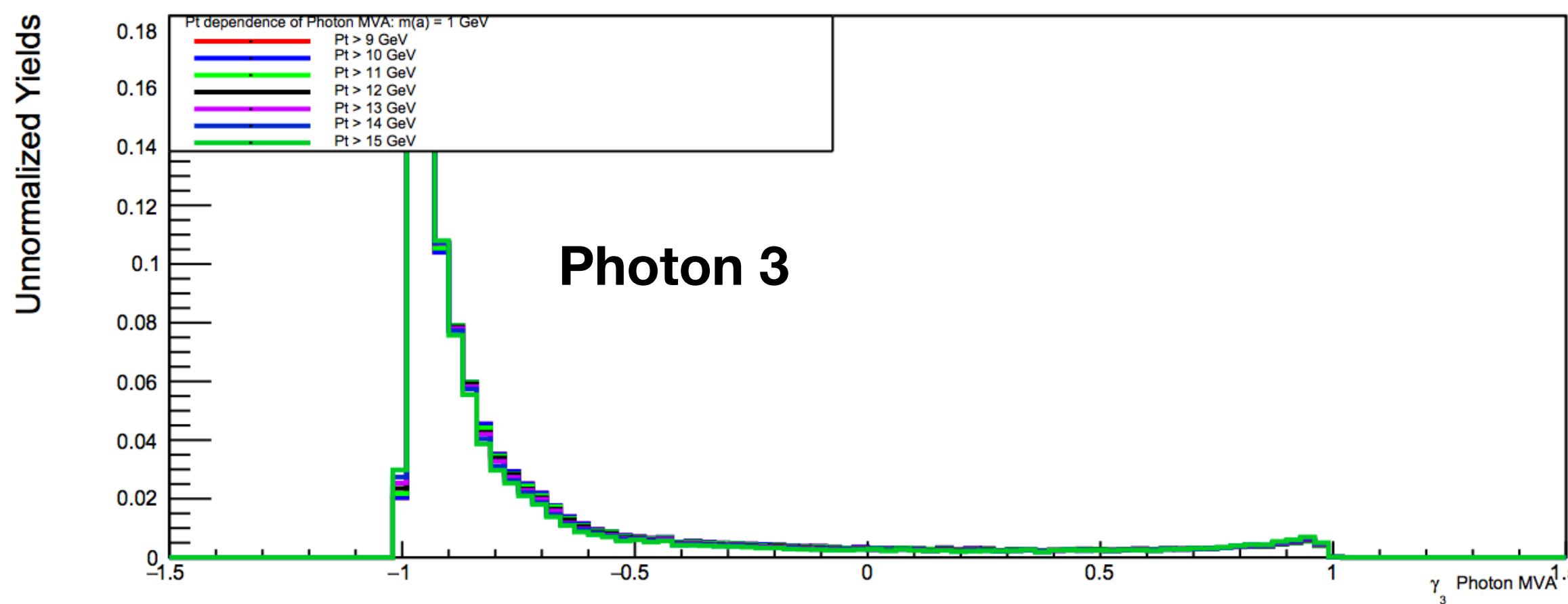
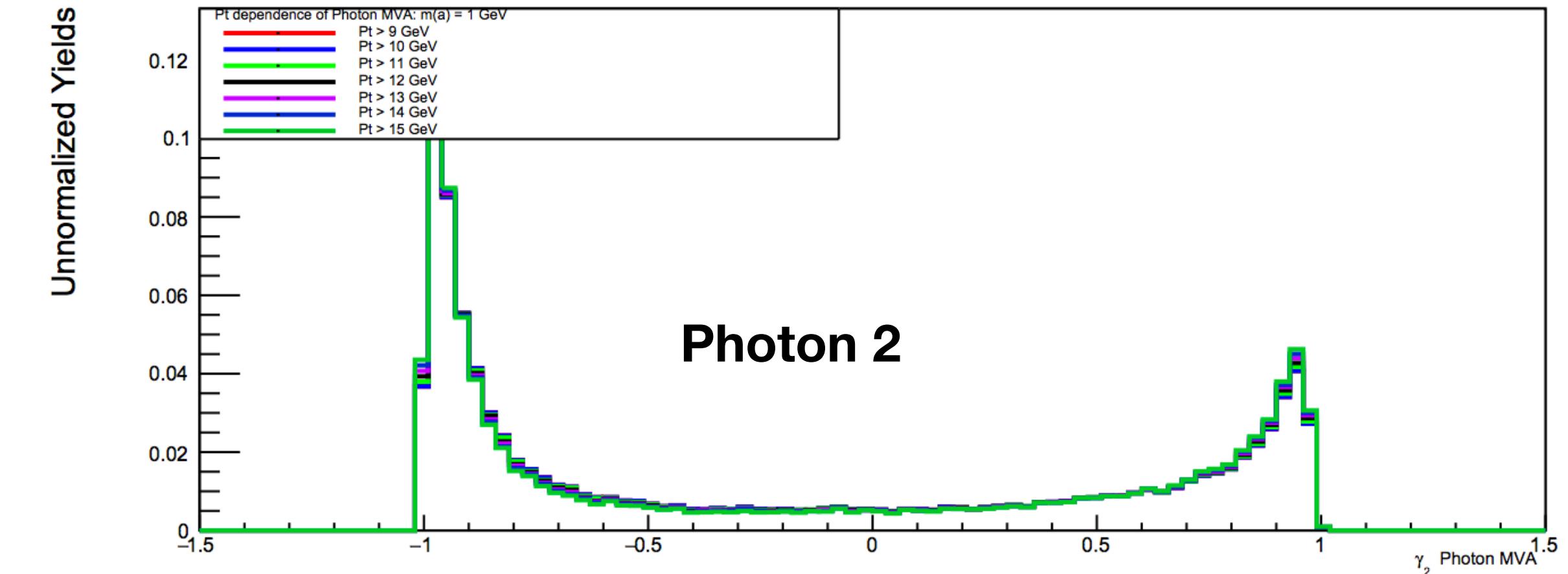
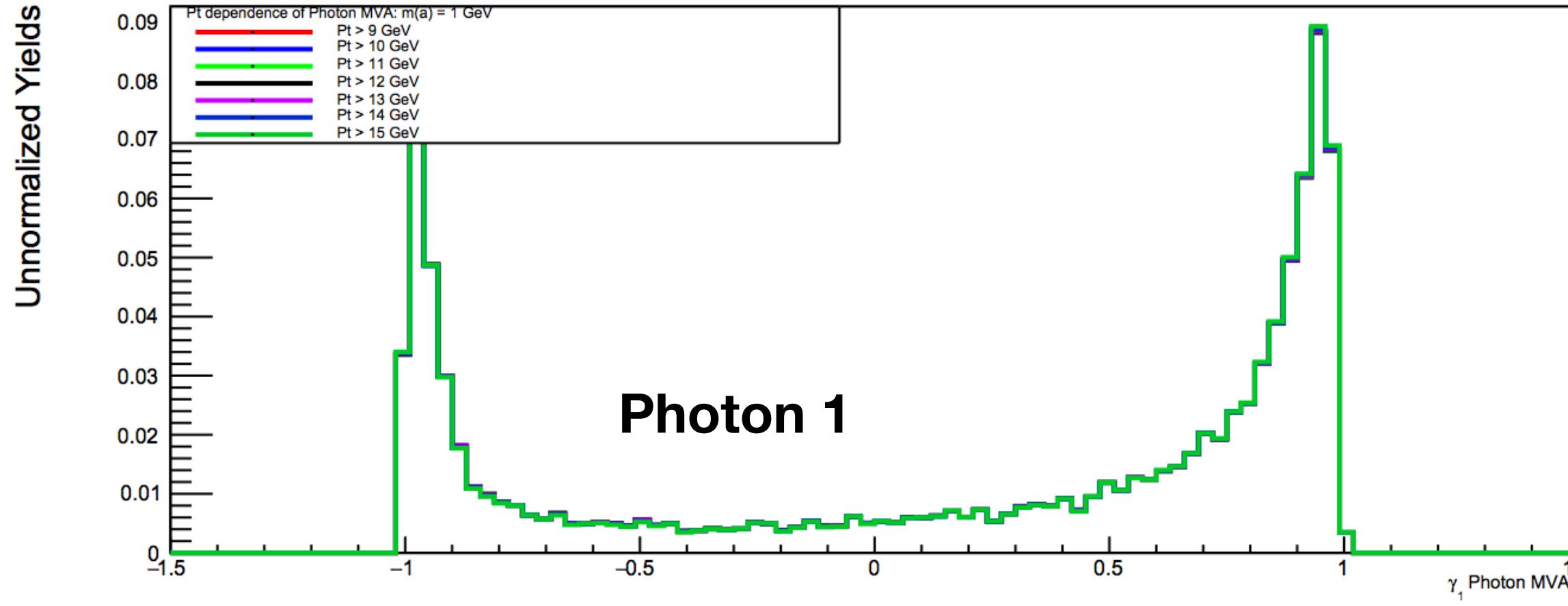


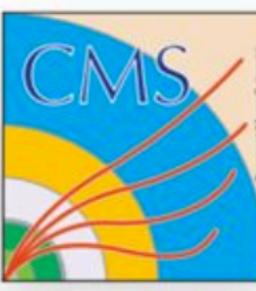
m(a) = 15 GeV



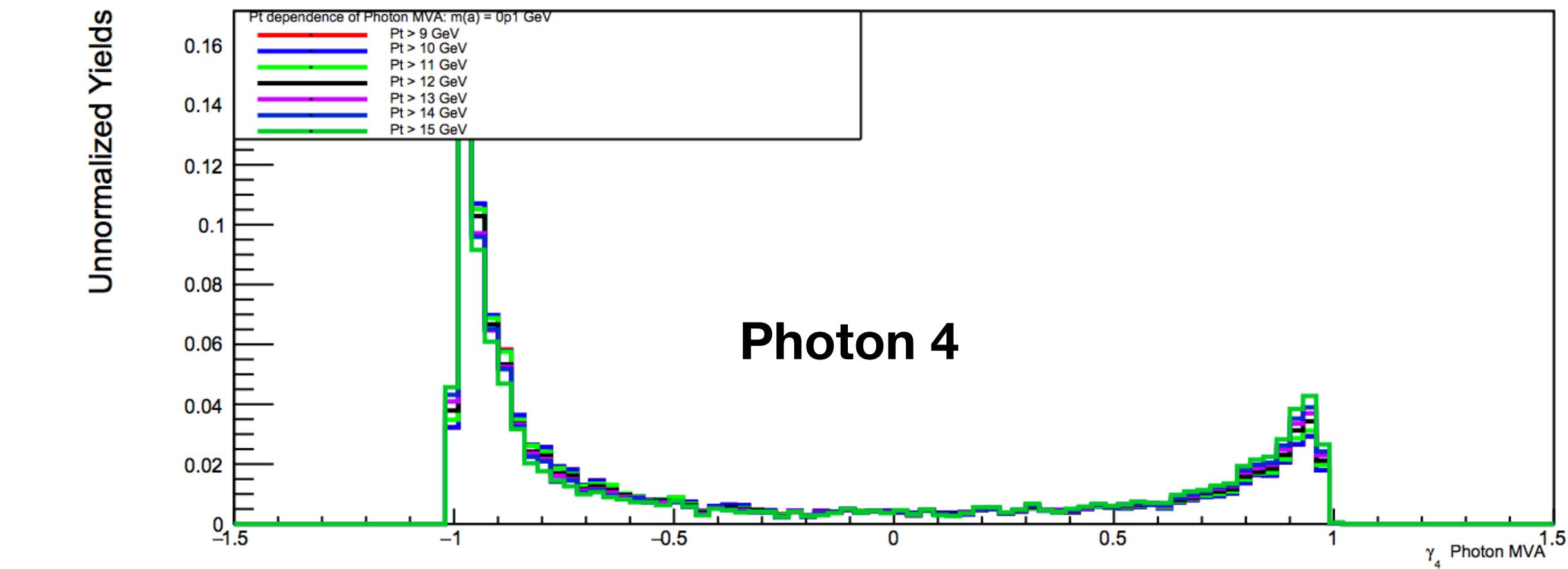
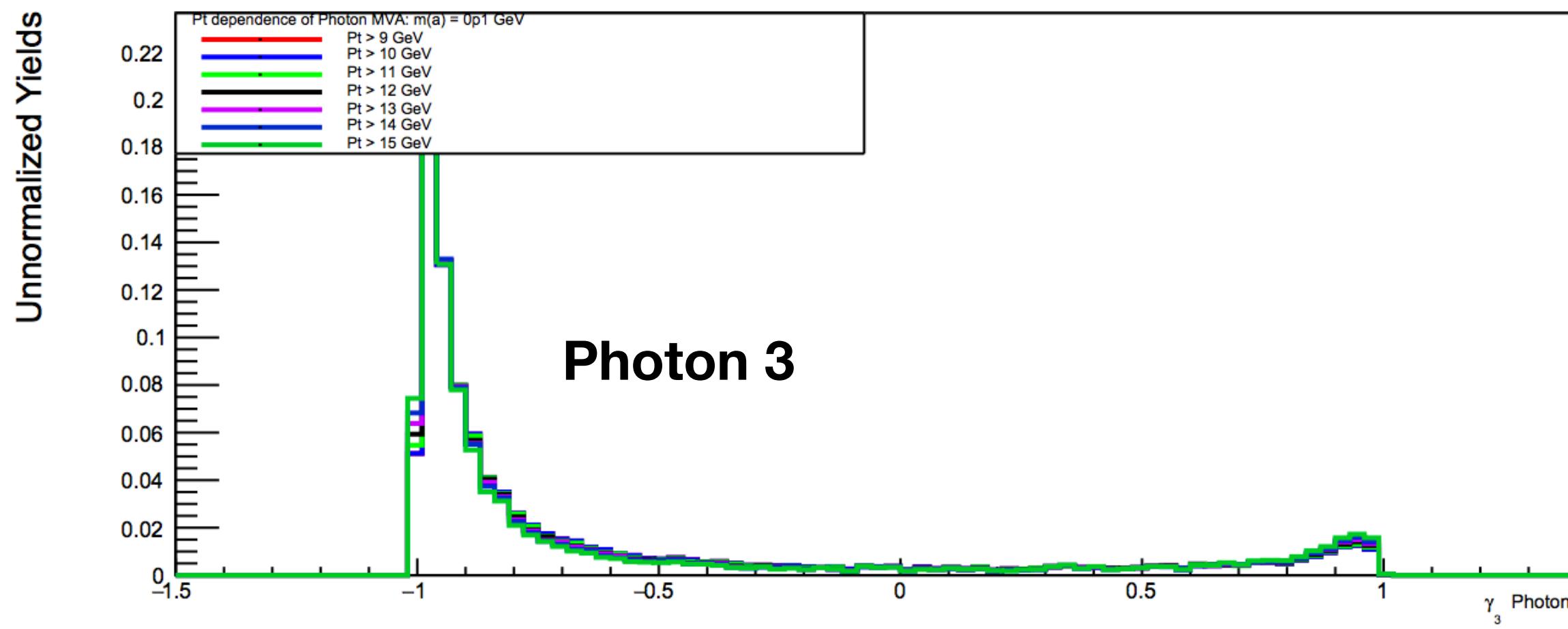
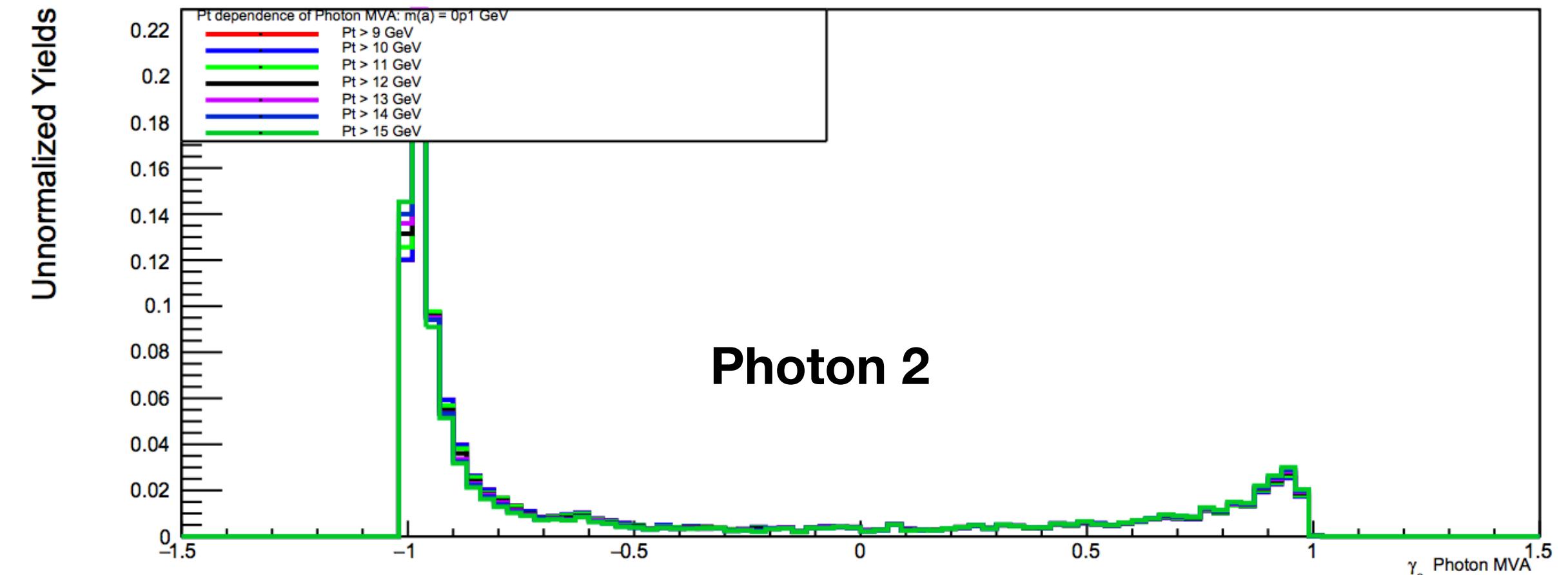
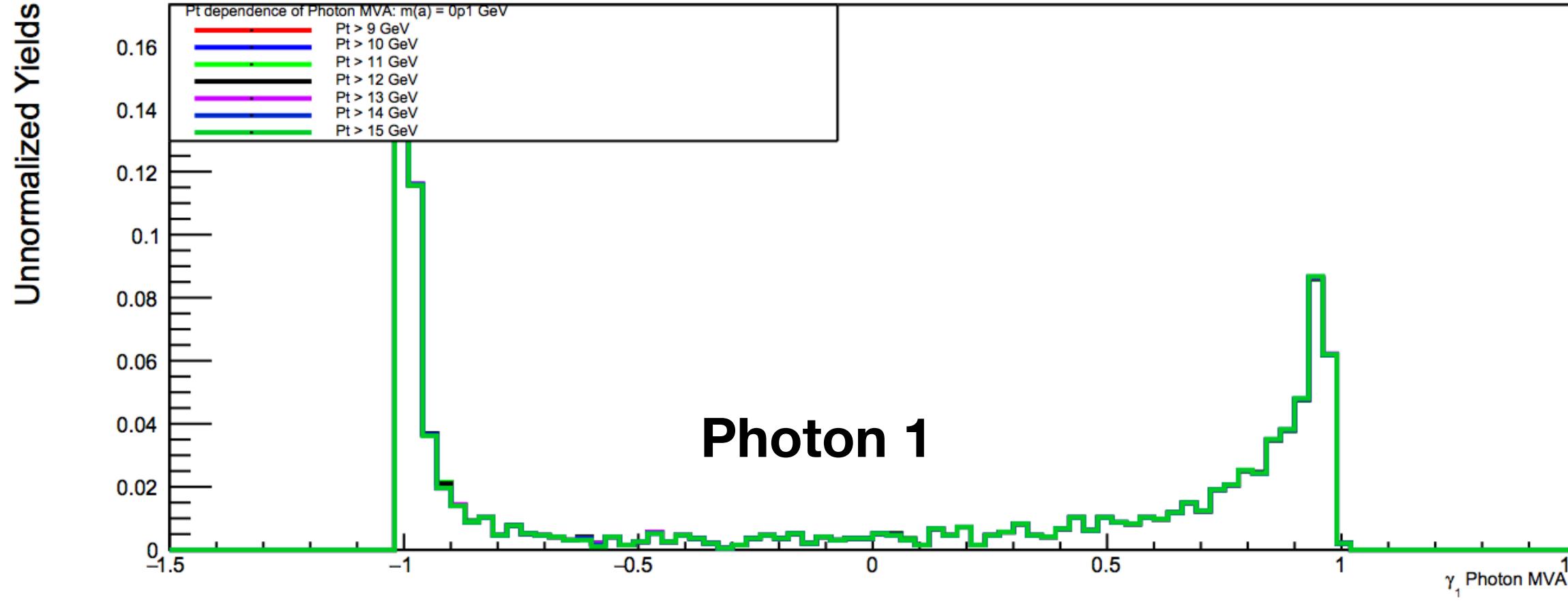


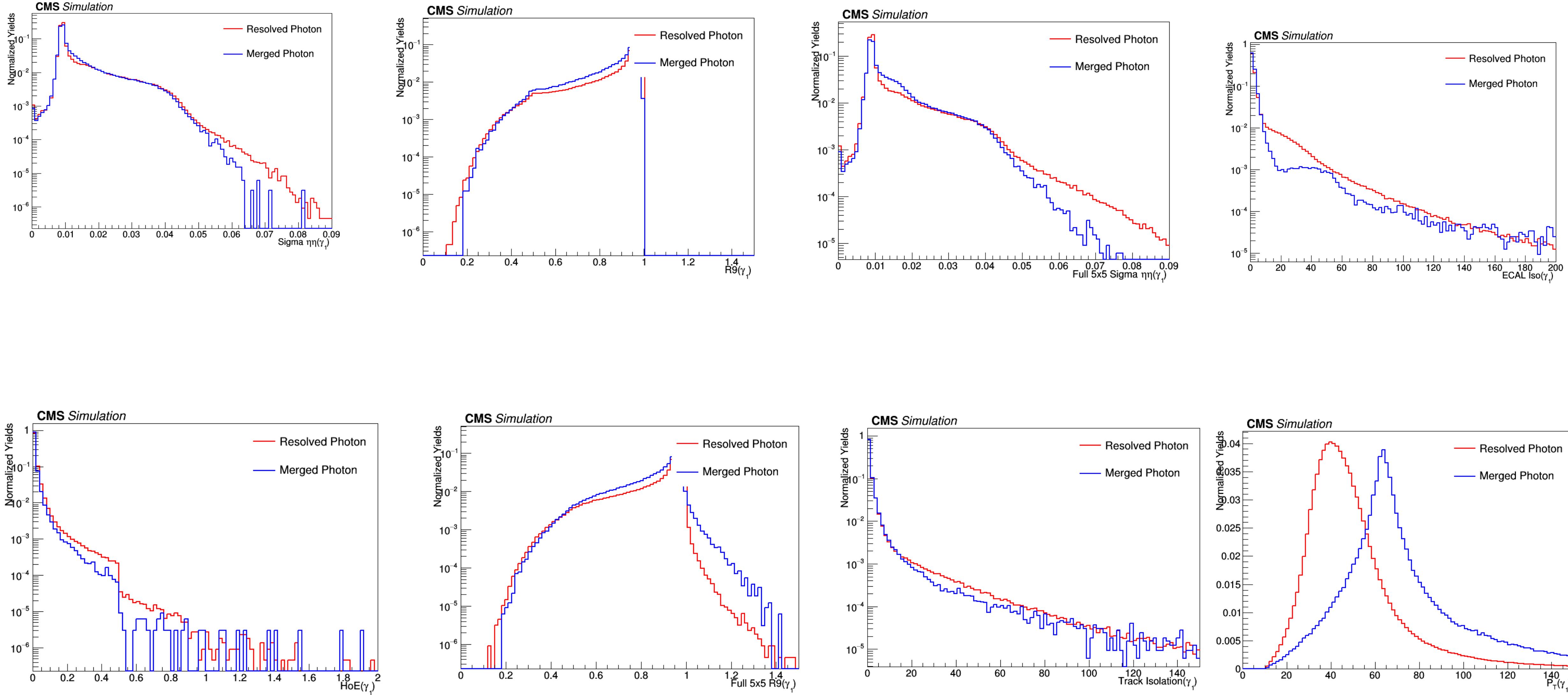
m(a) = 1 GeV

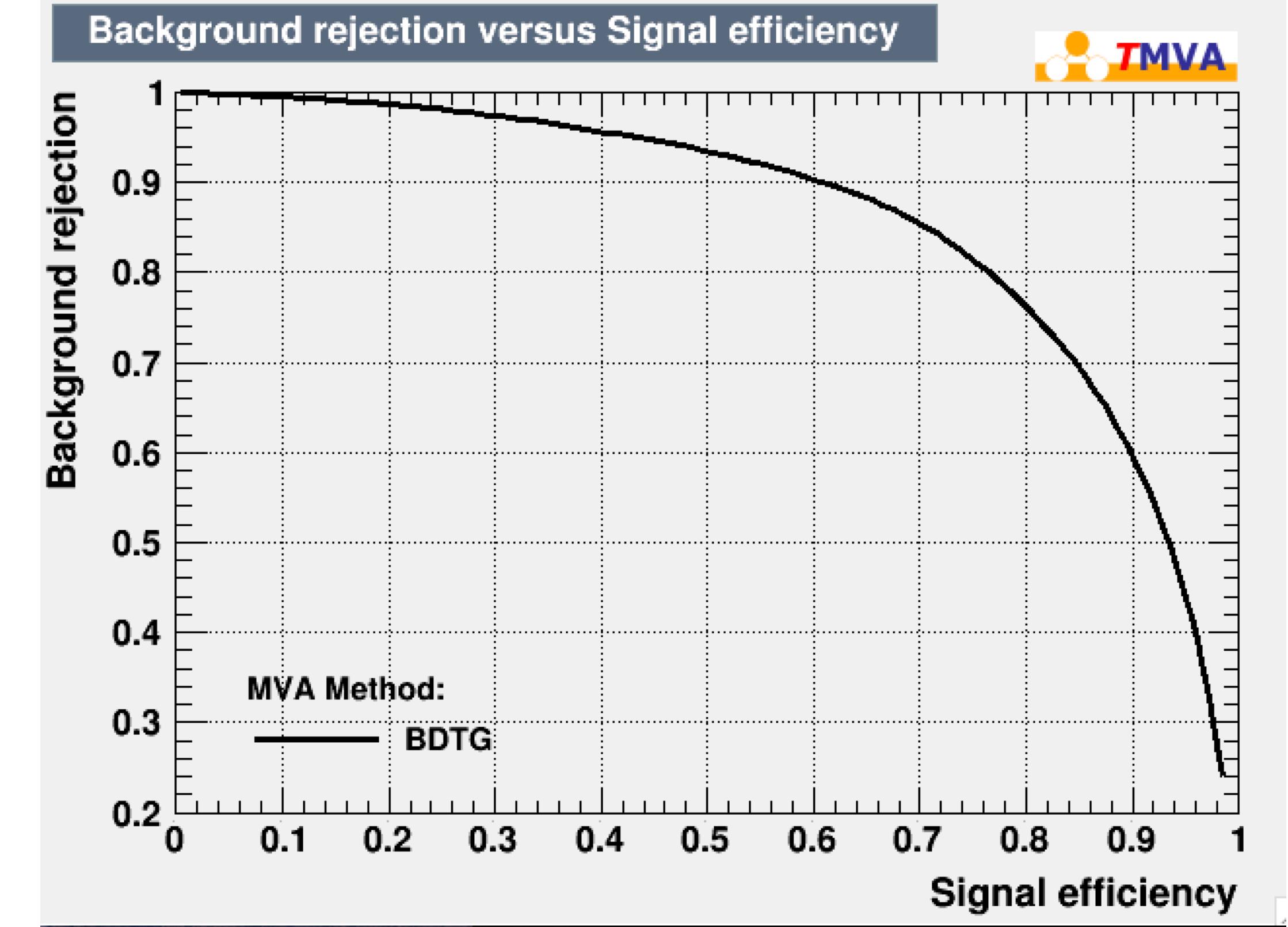
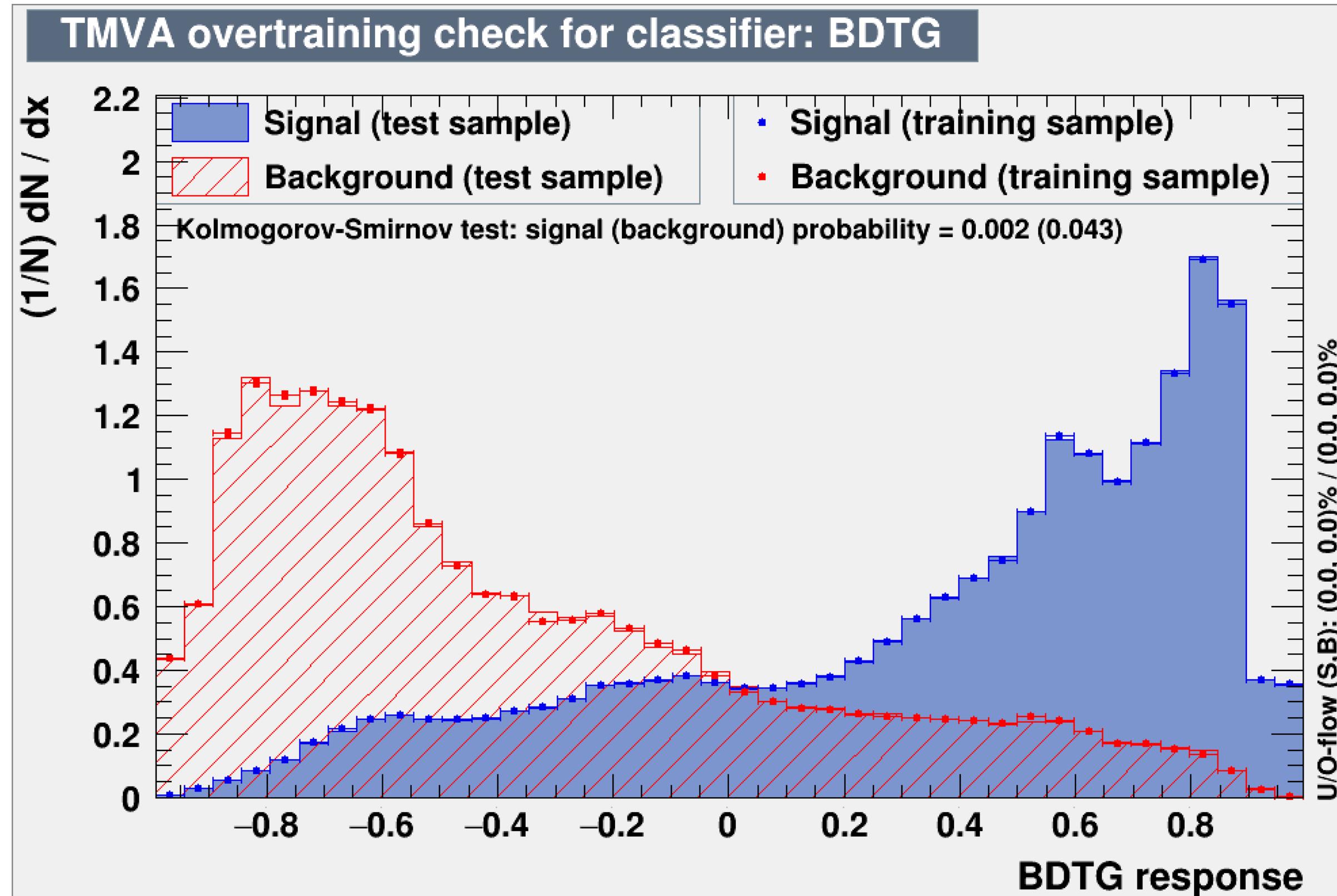
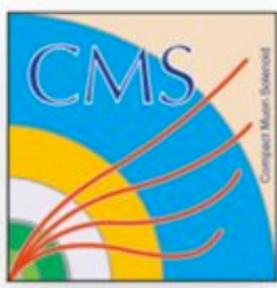


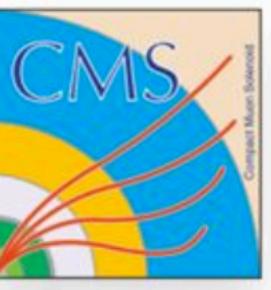


m(a) = 0.1 GeV

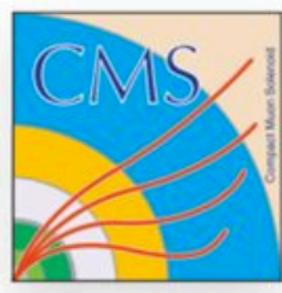








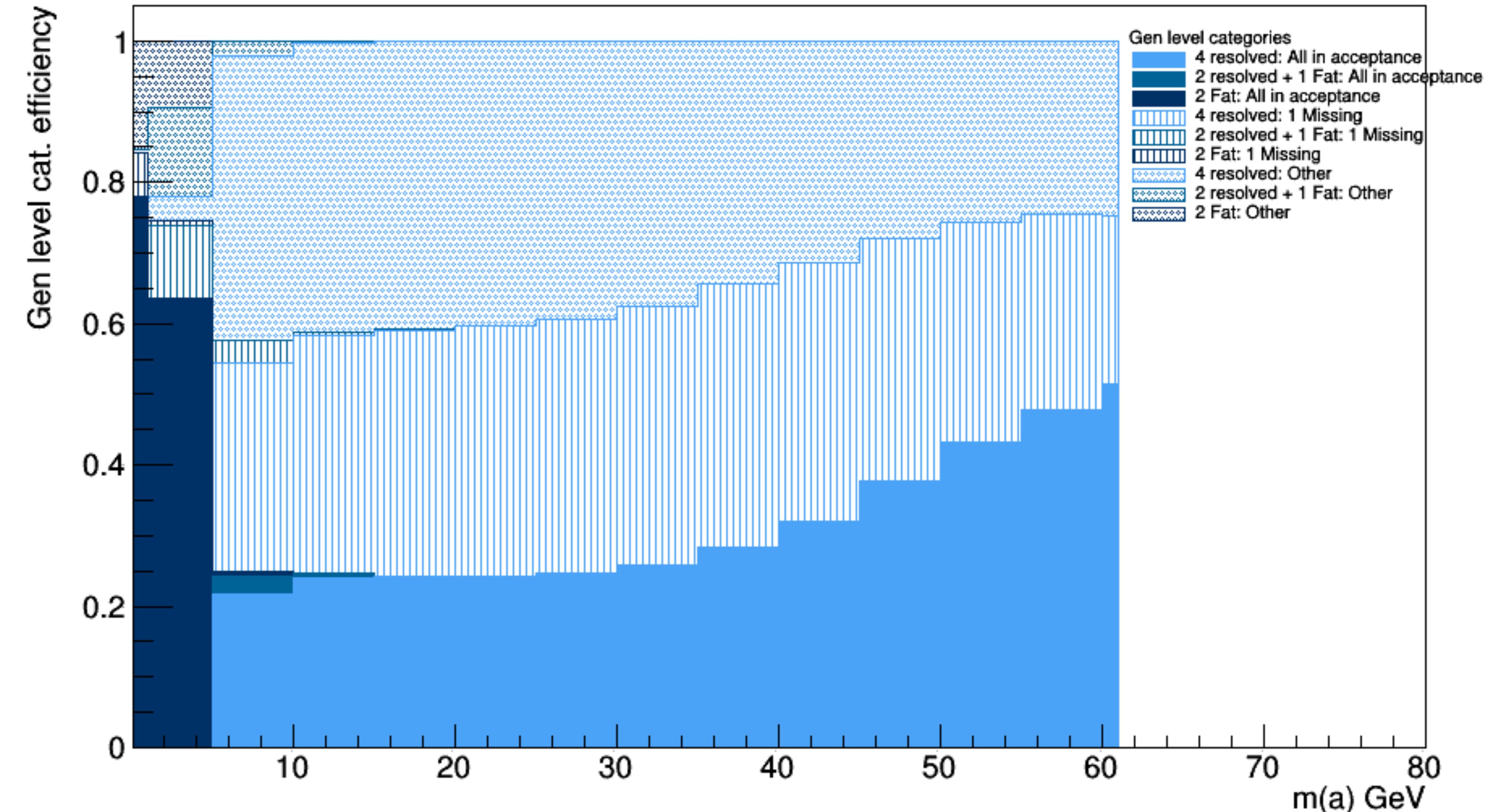
Backup - older slides

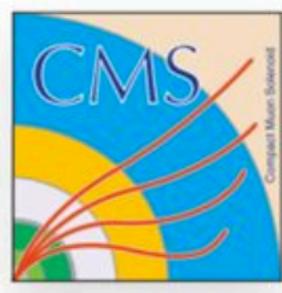


Merged photon definition: $dR < 0.1$ (old value was 0.3)

- $\text{abs}(\eta) < 2.5$
- Photon1 $\text{Pt} > 30$
- Photon2 $\text{Pt} > 18$
- Photon3 $\text{Pt} > 10$
- Photon4 $\text{Pt} > 10$

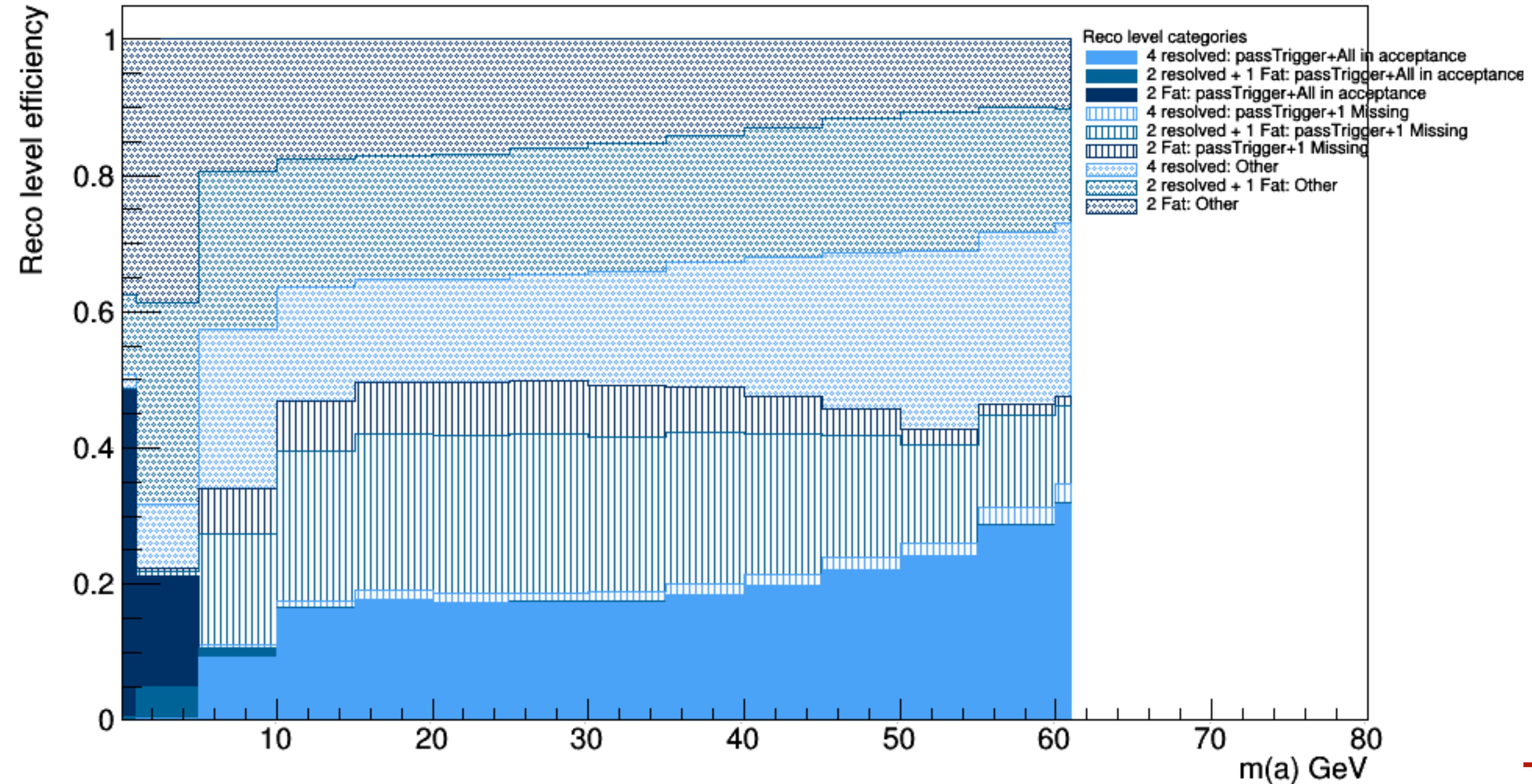
Gen level categorization





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

Reco level categorization

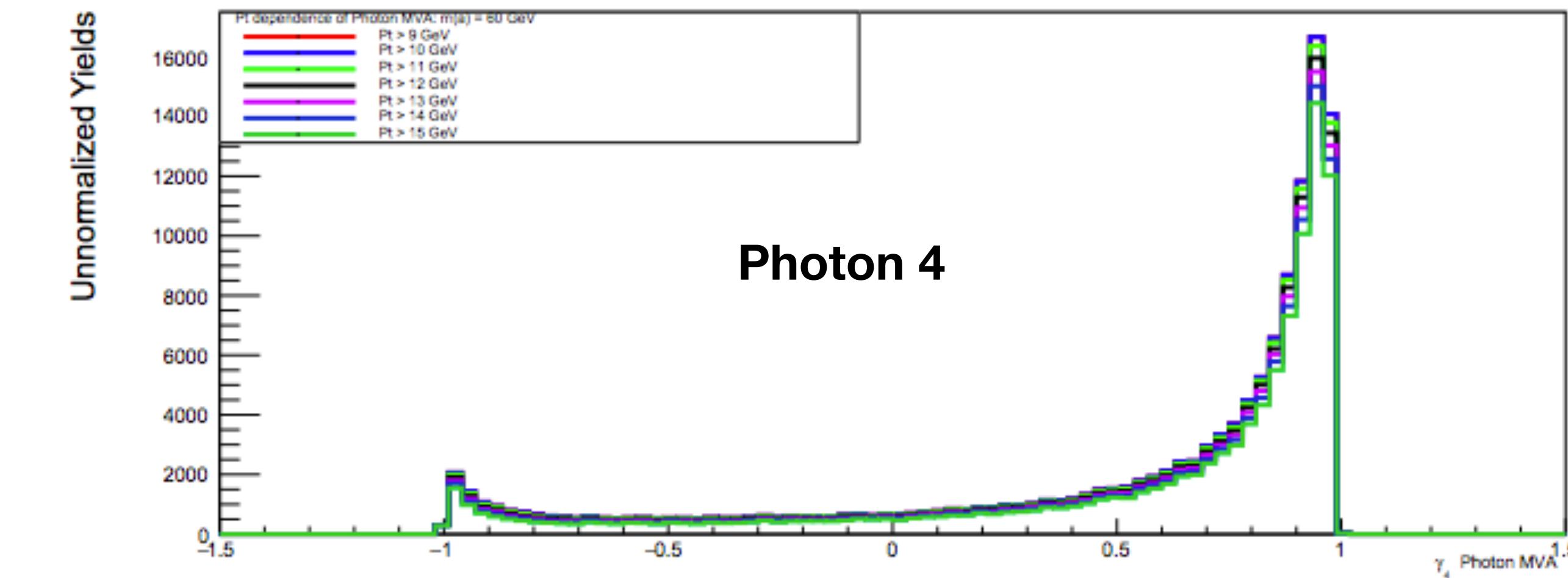
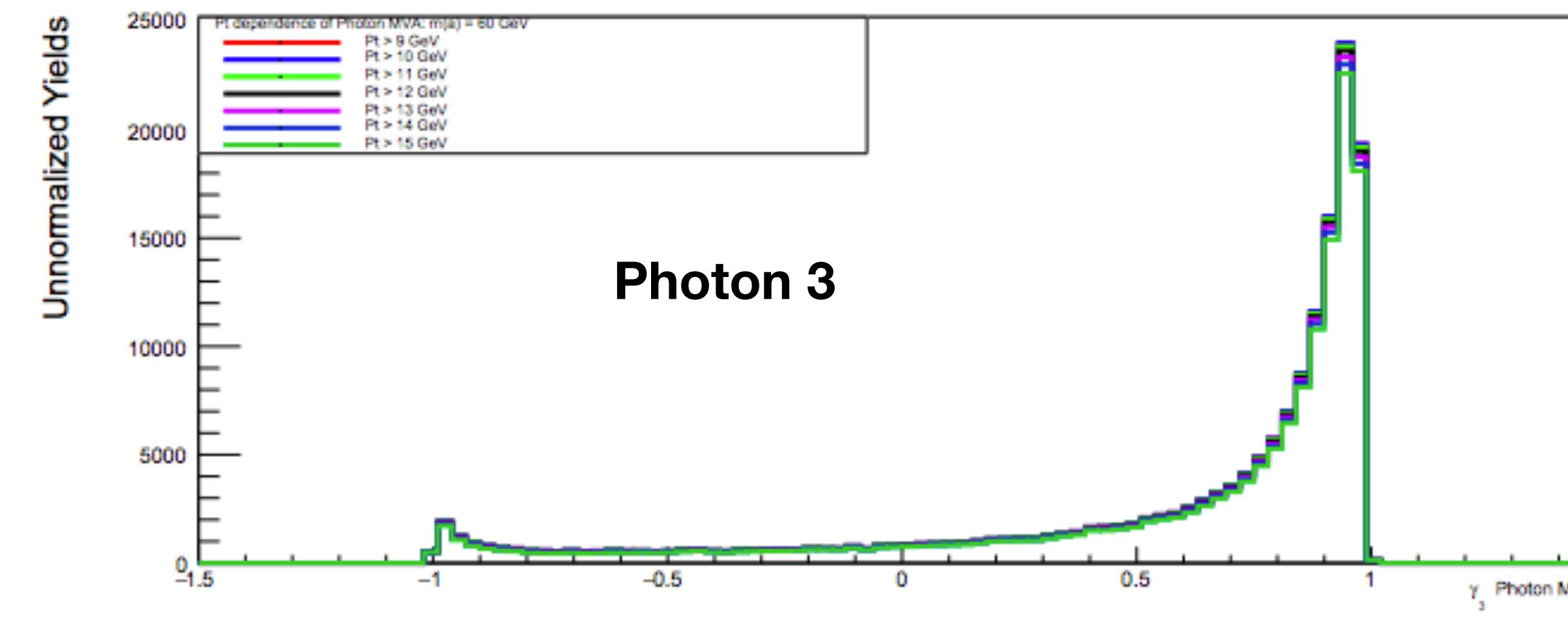
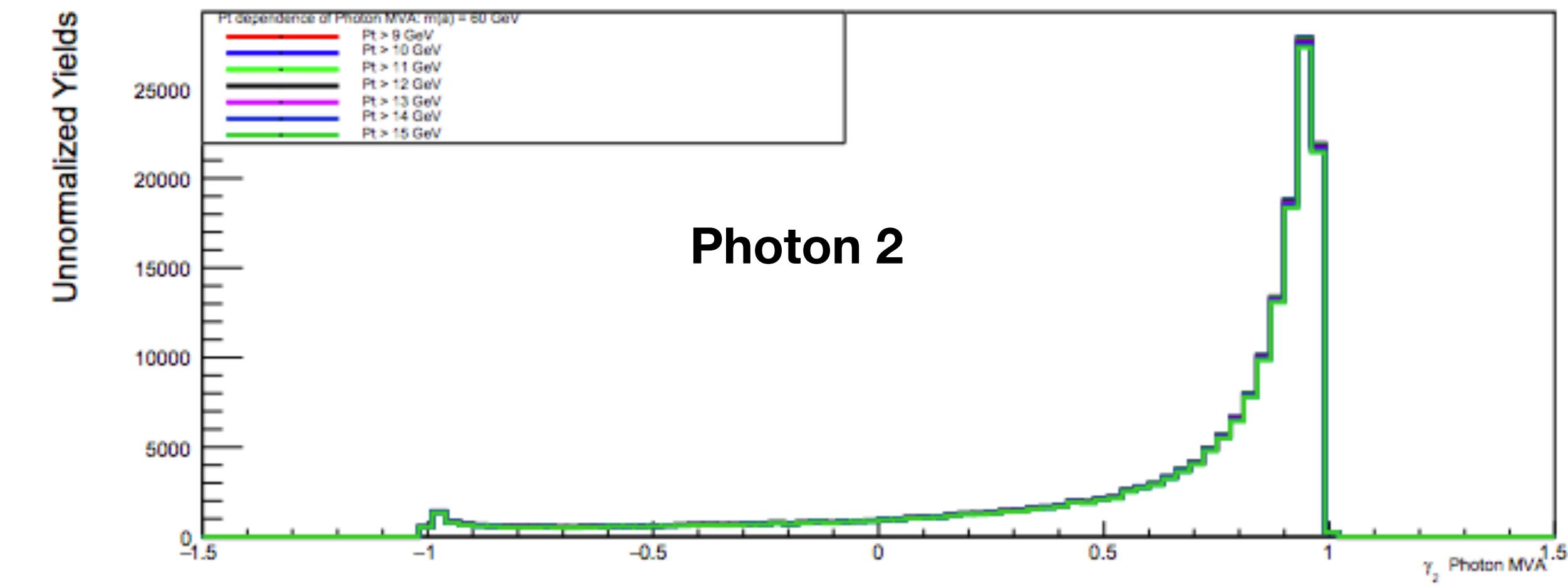
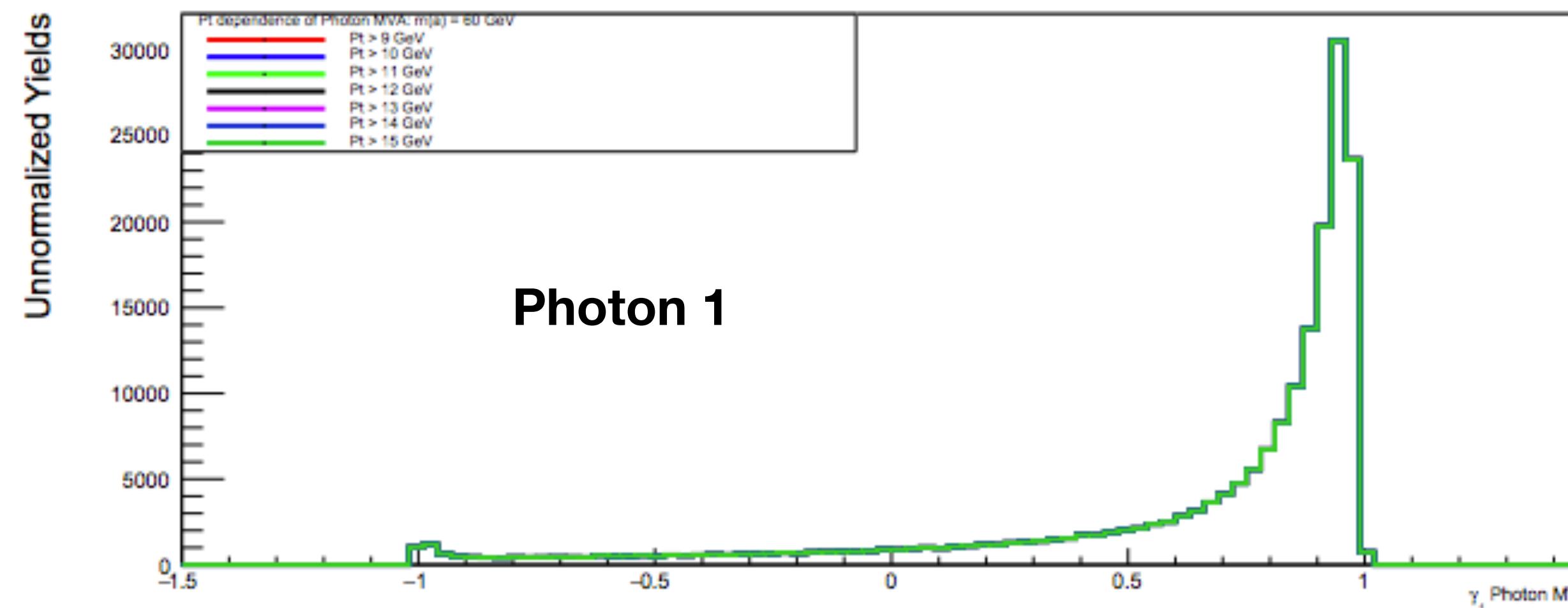


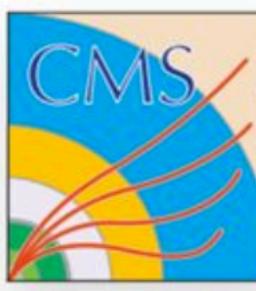


Pt dependence of Photon MVA ID

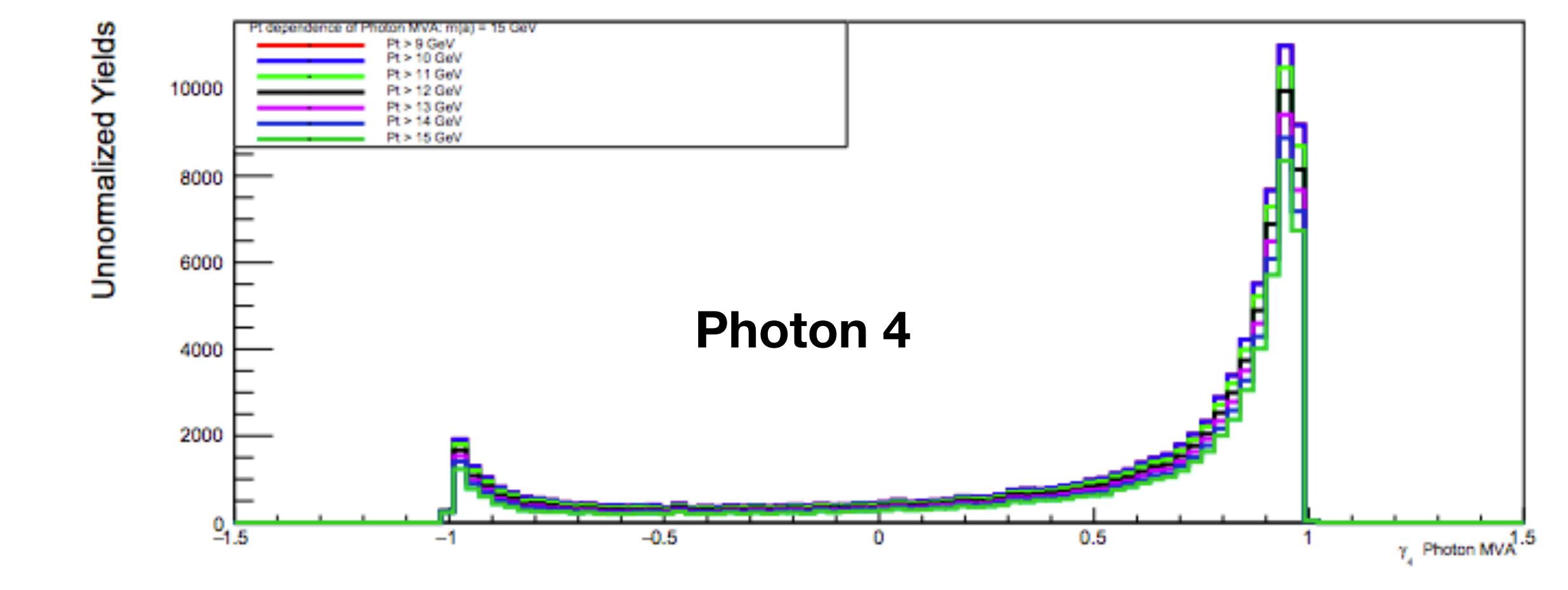
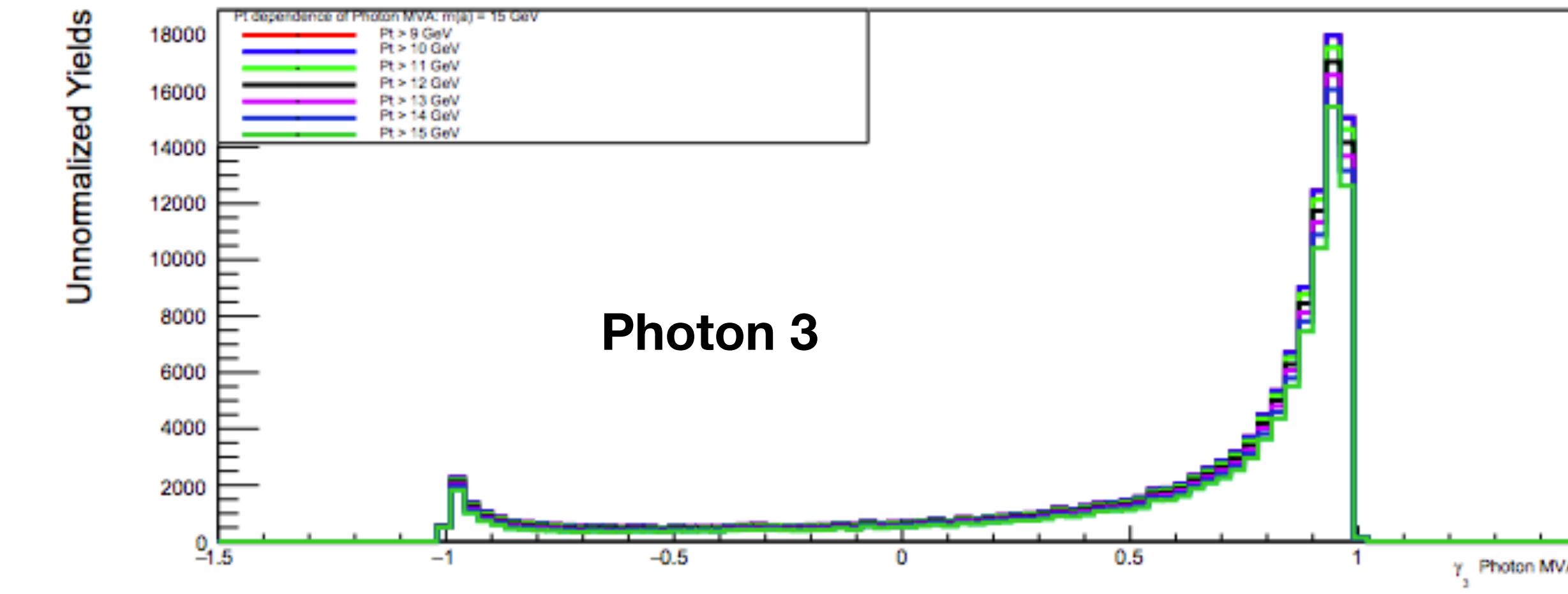
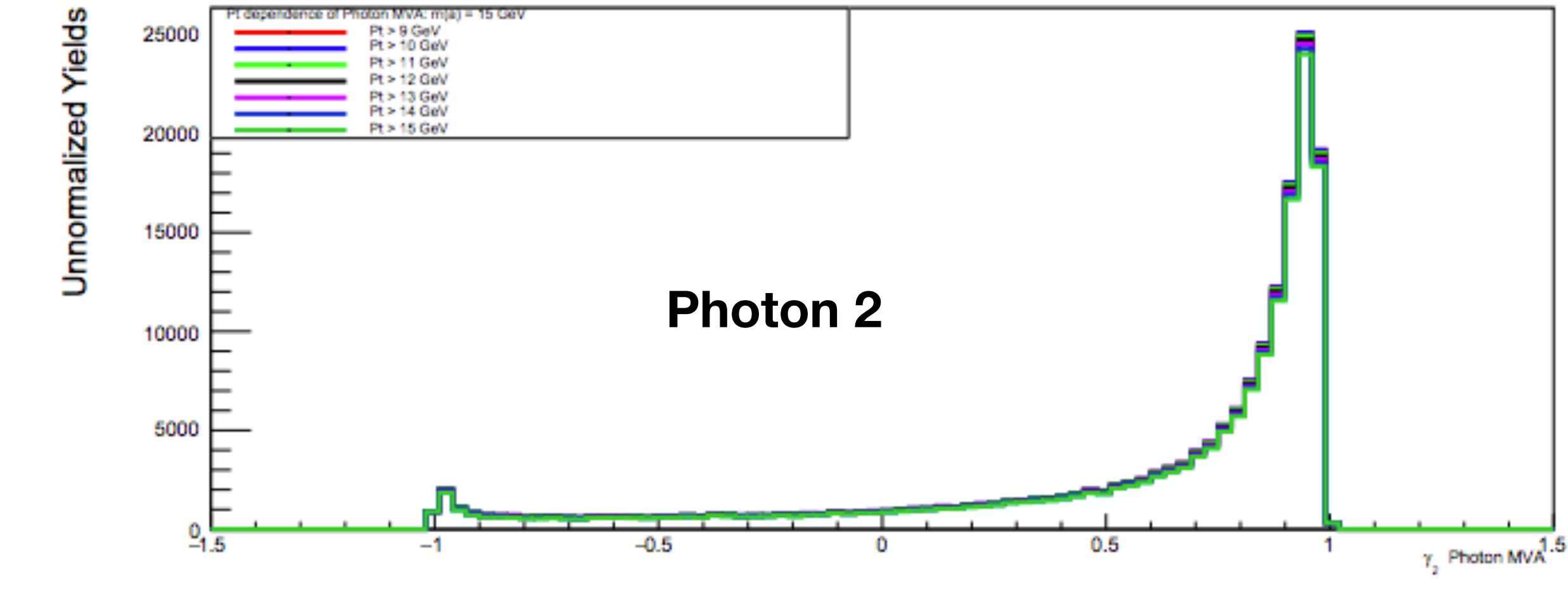
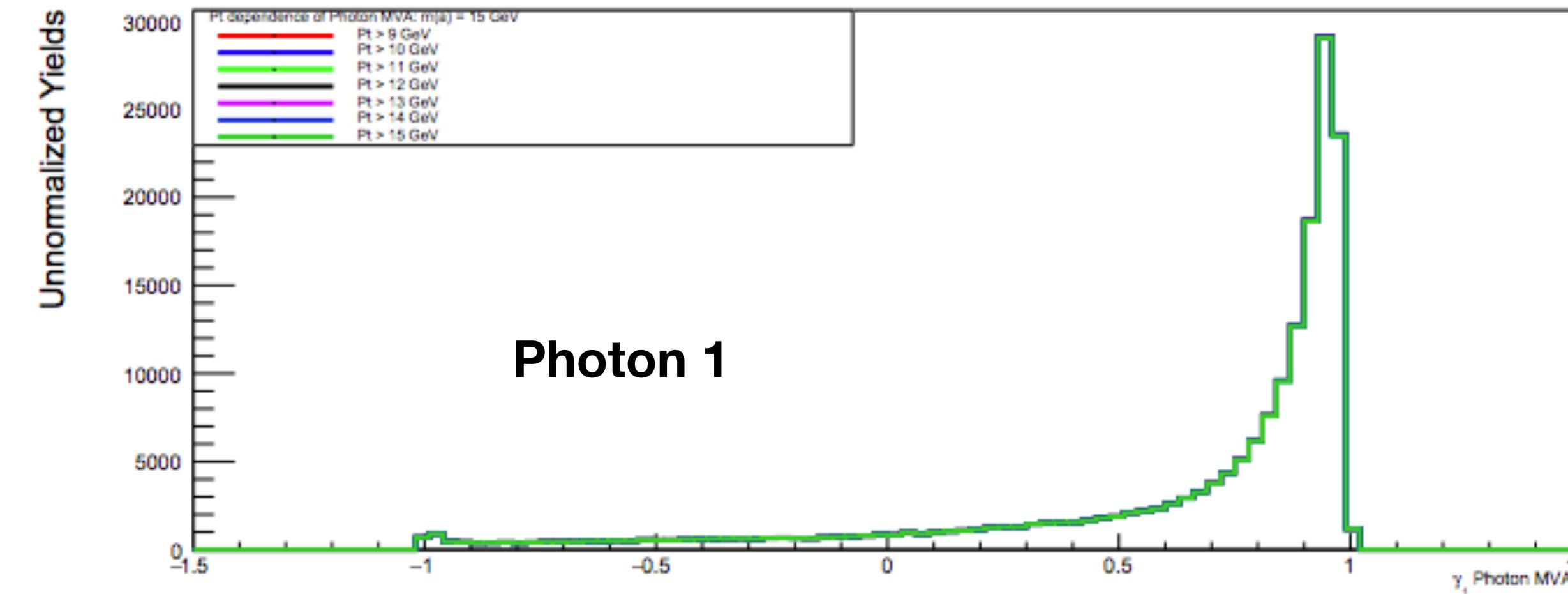
Plotted here are the Photon MVA ID values for photons for different Pt values (so selection applied on the photon)

Reminder : Basic Pt cut on photons >10 GeV



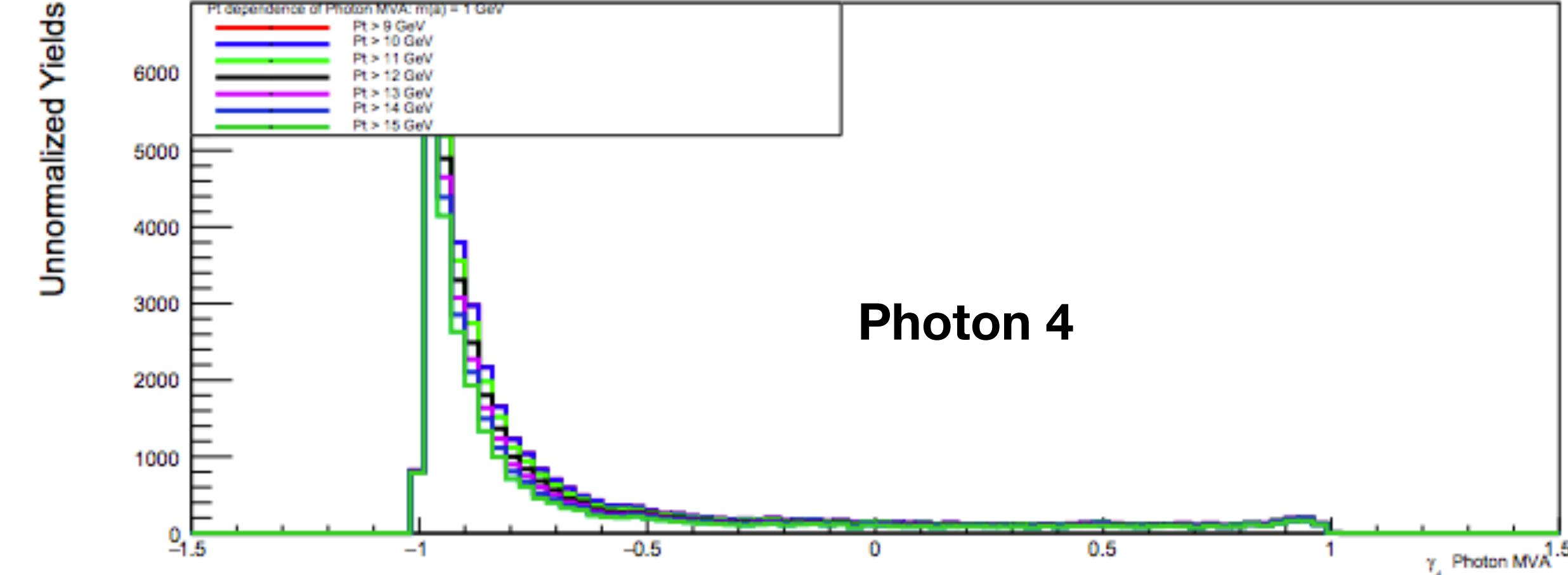
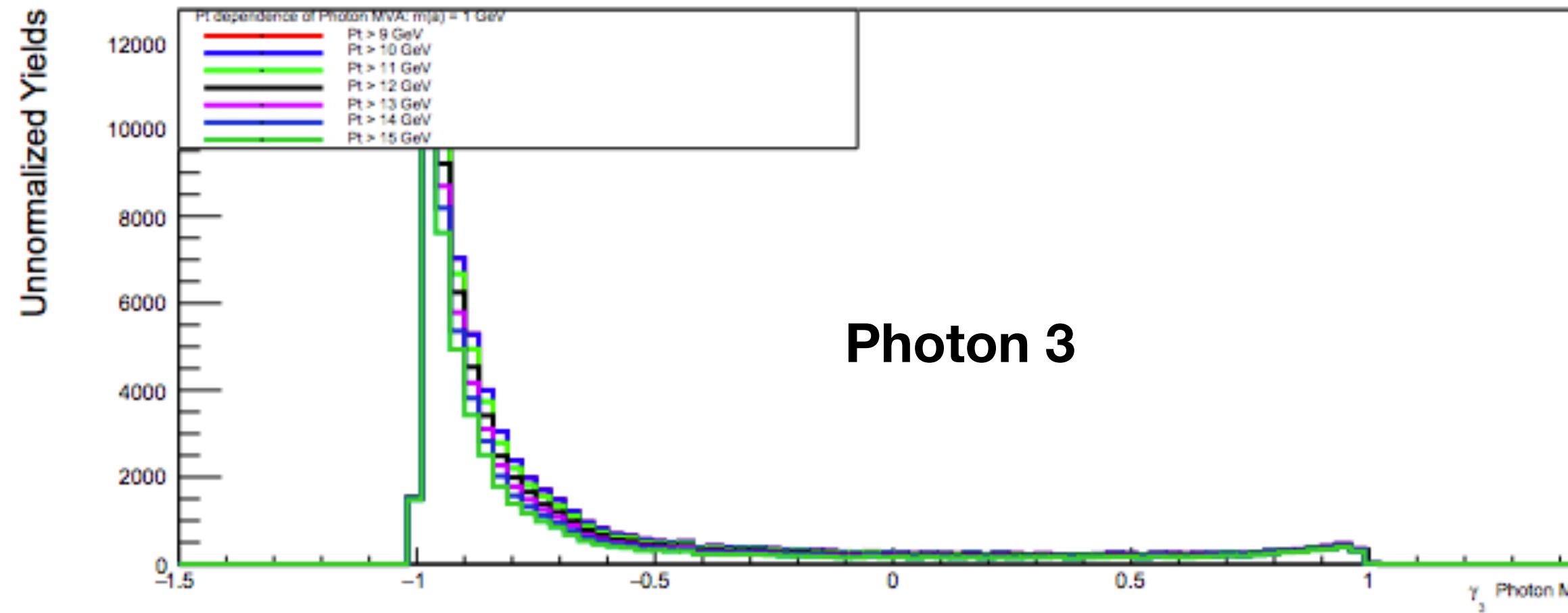
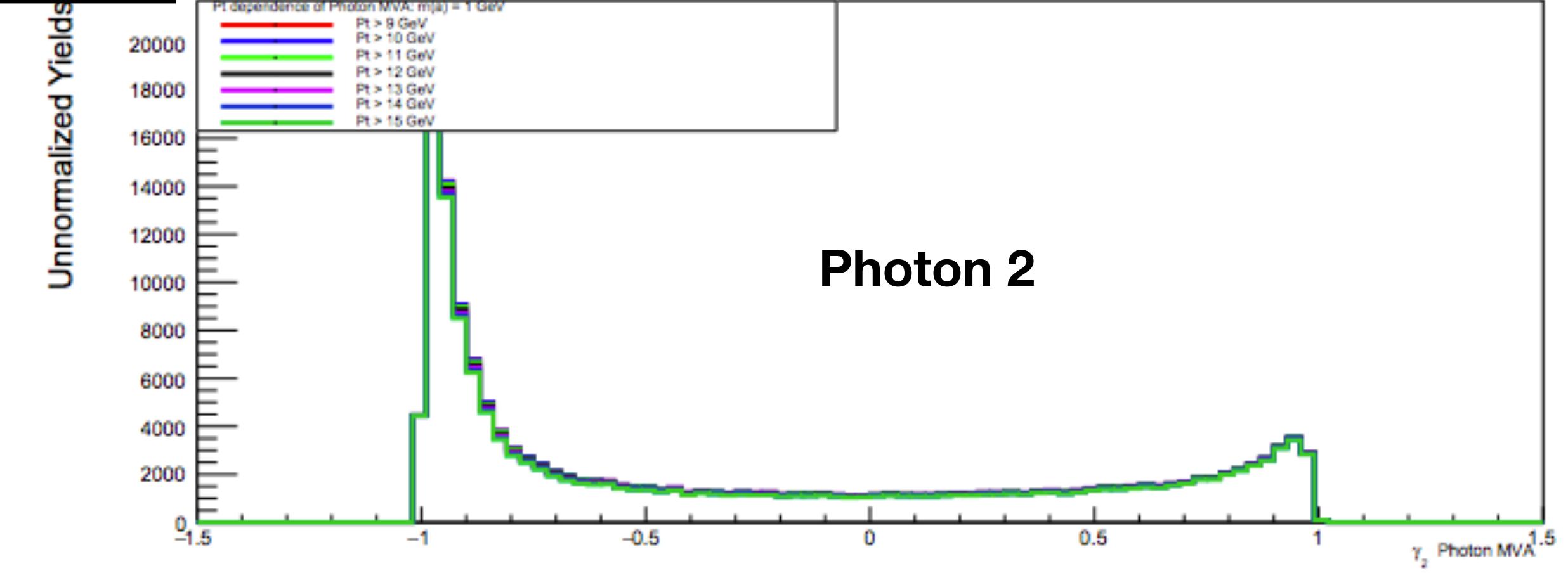
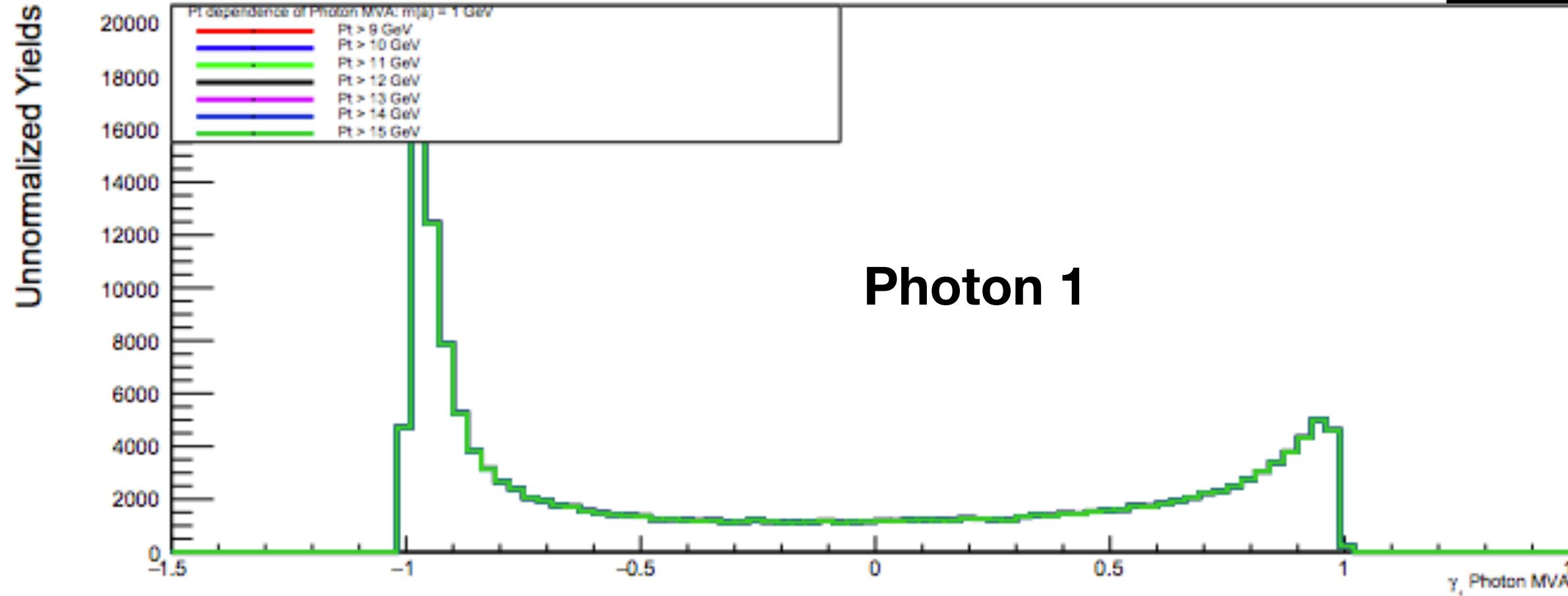


m(a) = 15 GeV

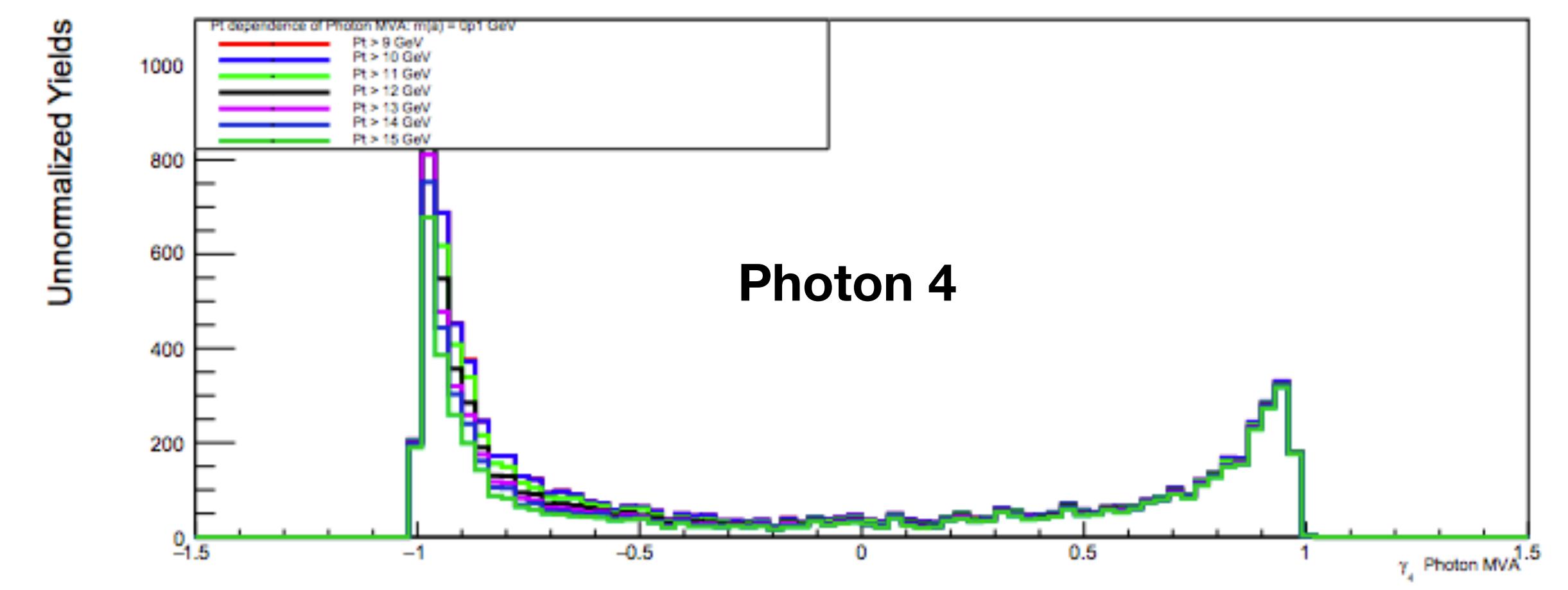
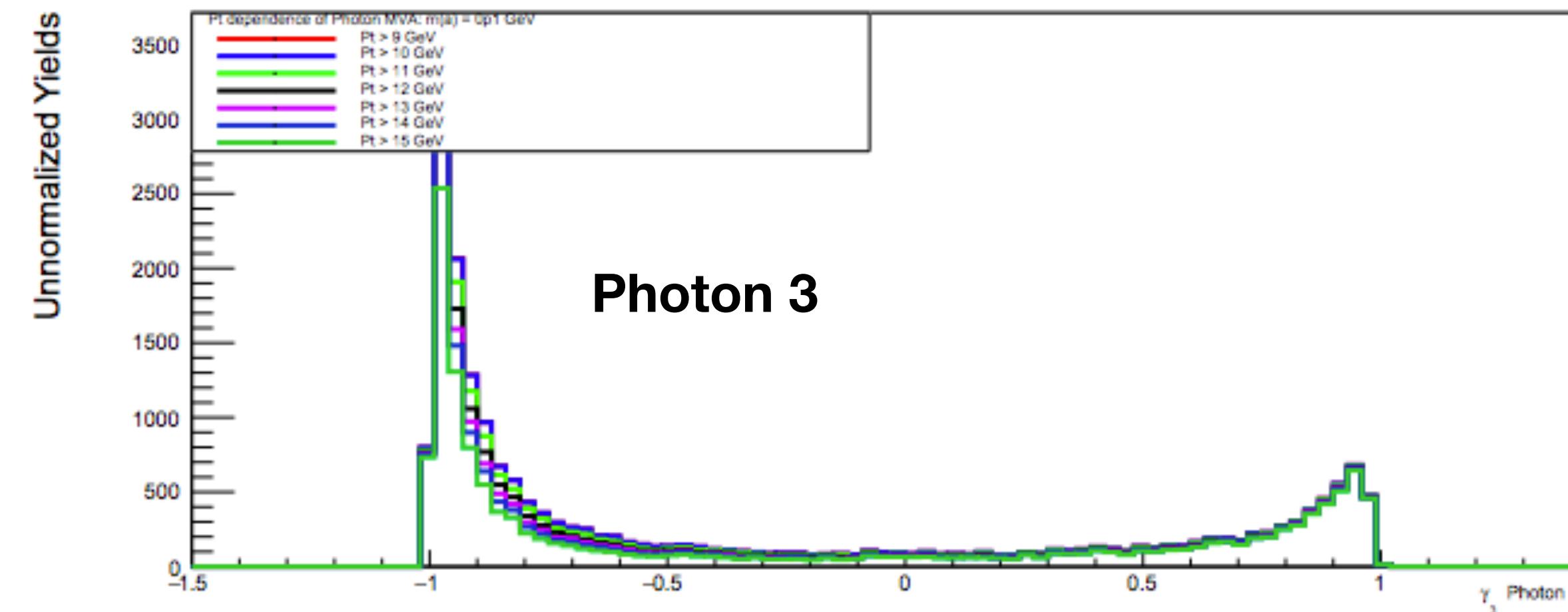
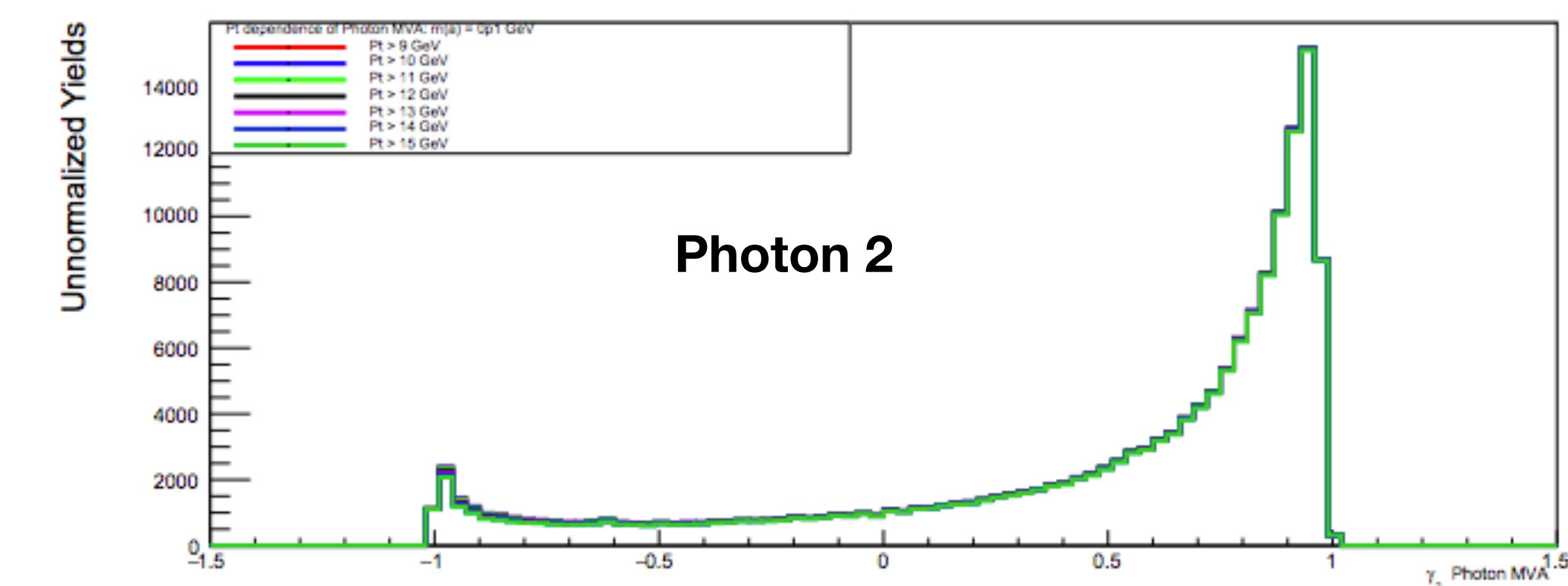
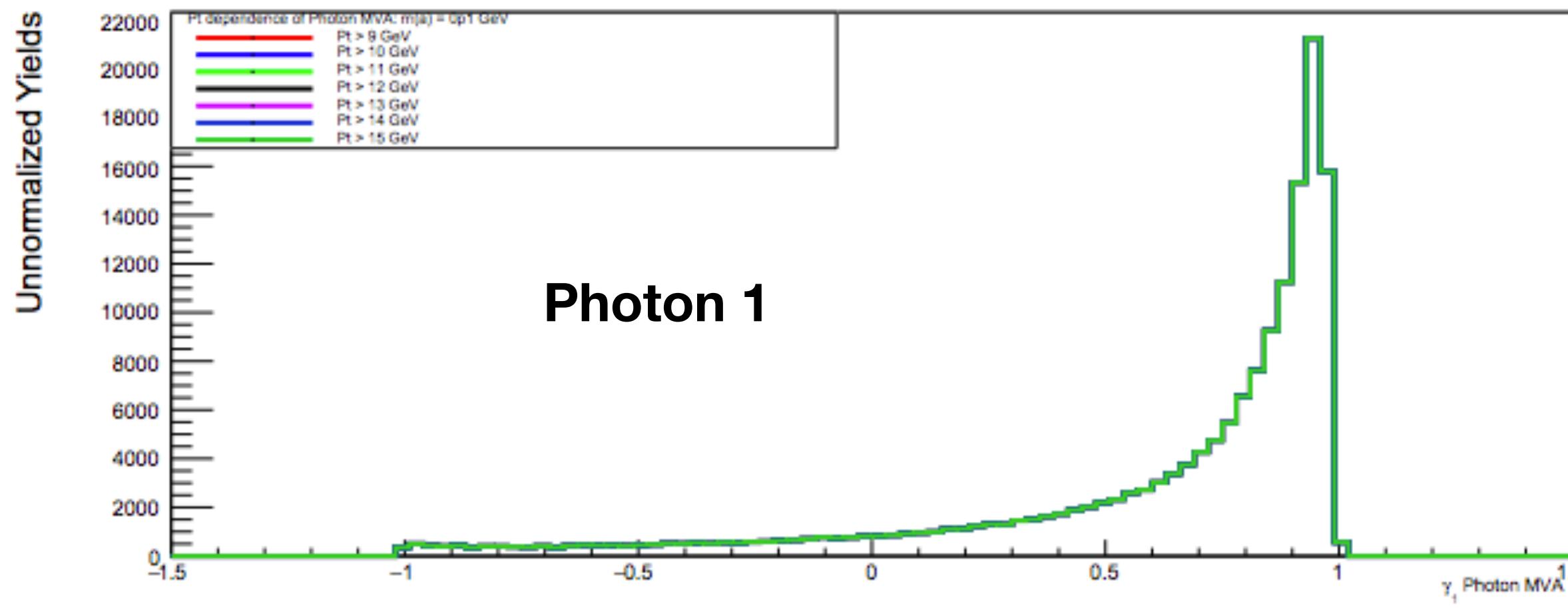




m(a) = 1 GeV



m(a) = 0p1 GeV



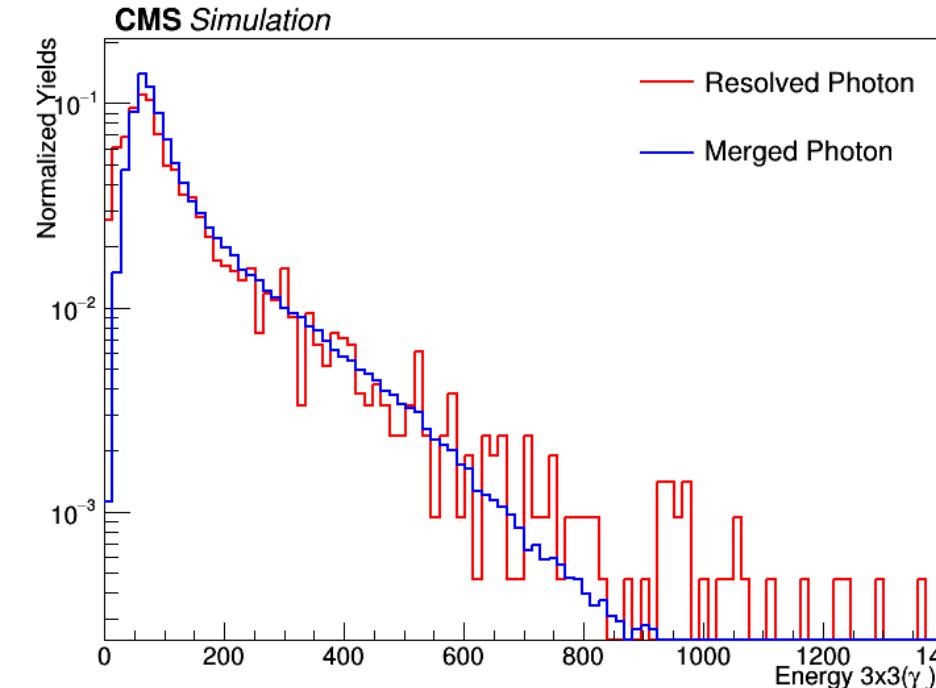


Distinction b/w Merged and Resolved Photons

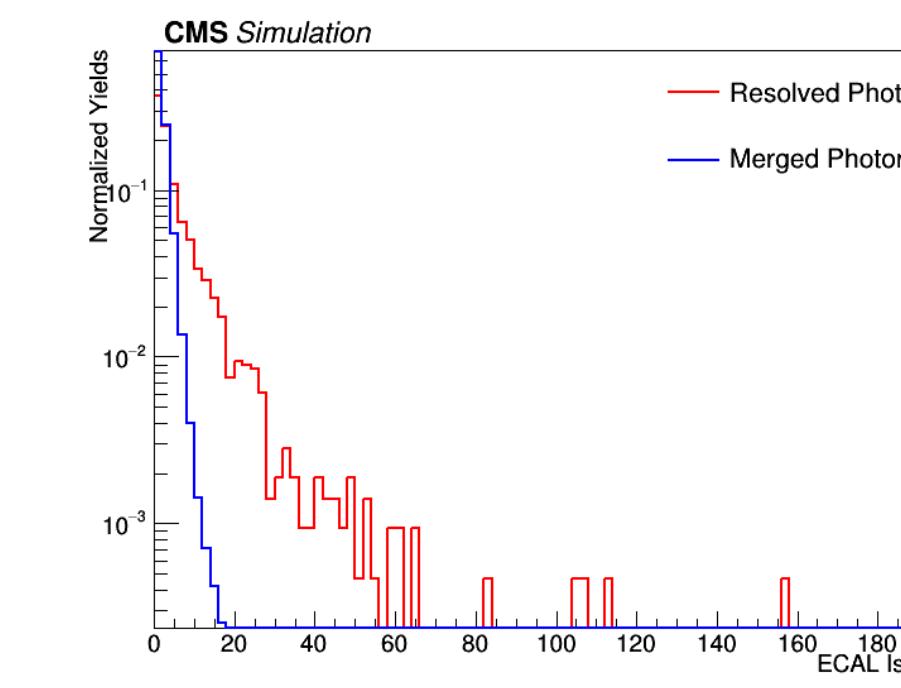
Test Case : $m(a) = 100 \text{ MeV}$

(I only put plots with good(distinction b/w merged and Isolated Photons here)

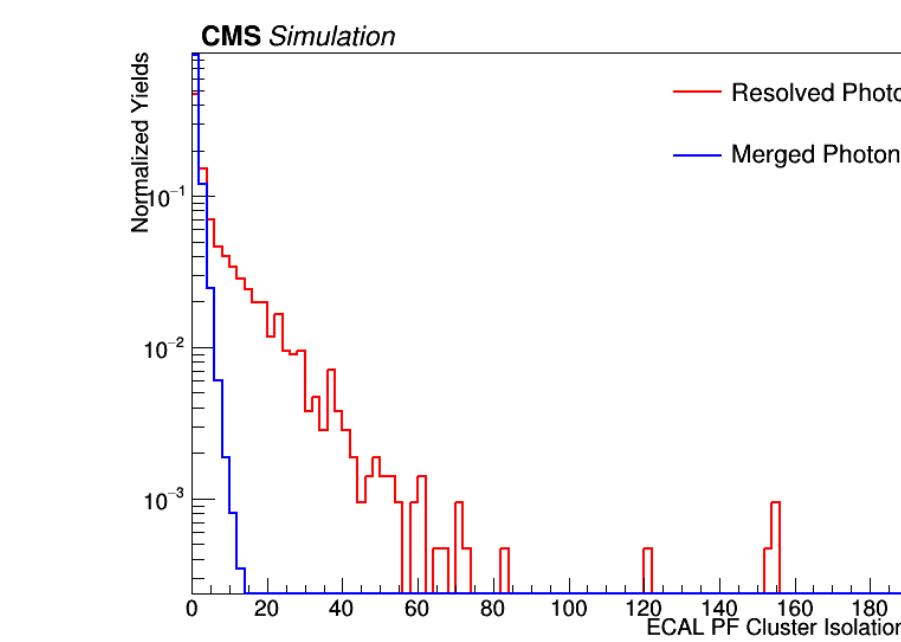
Full set of plots for every mass point are here : http://twamorka.web.cern.ch/twamorka/H4G_forPrelim/MergedIso/



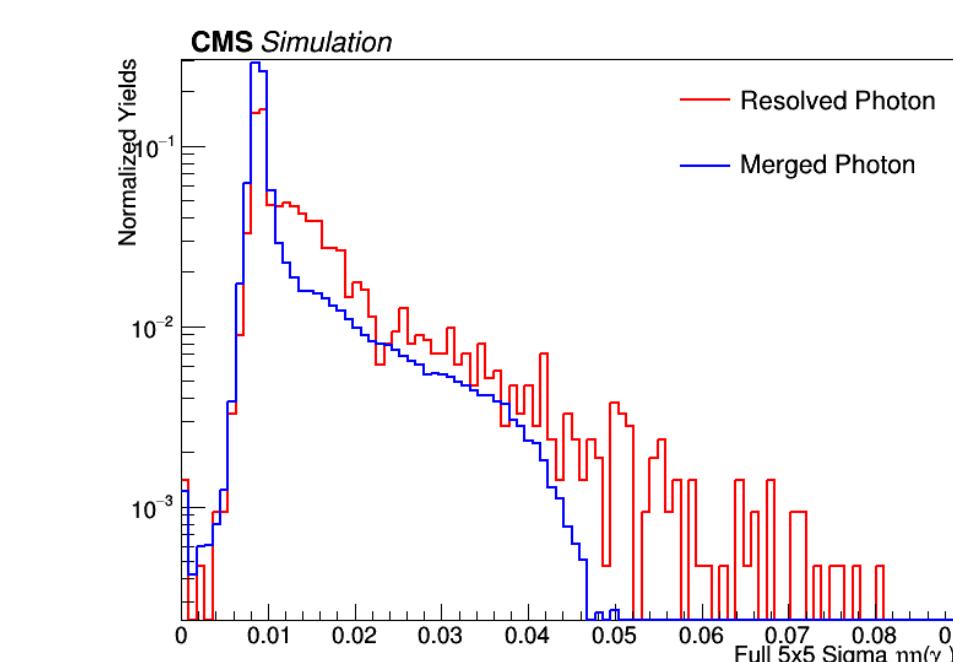
3x3 Energy



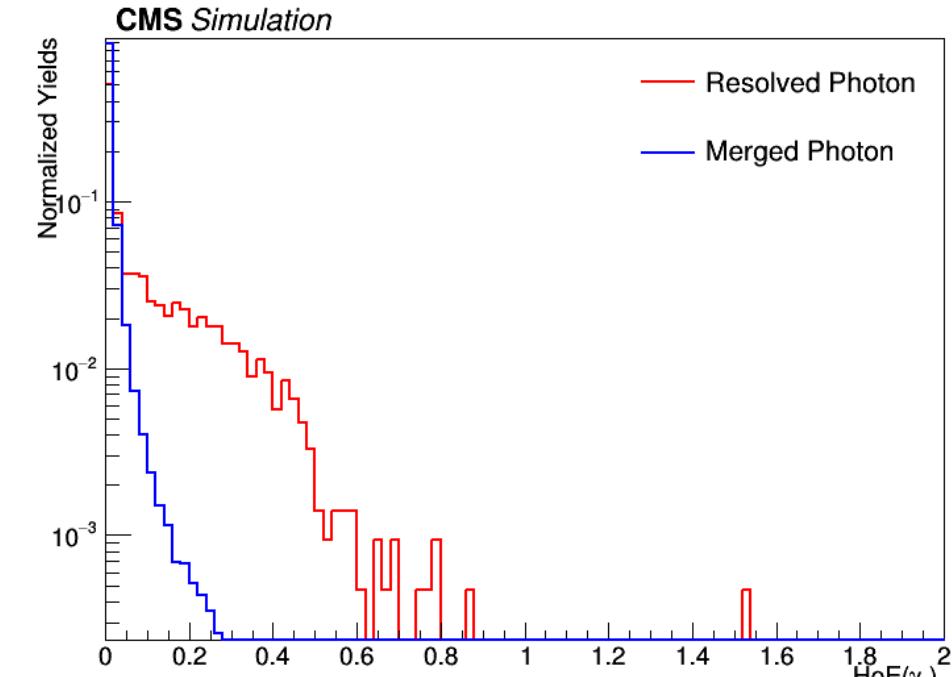
ECAL Iso



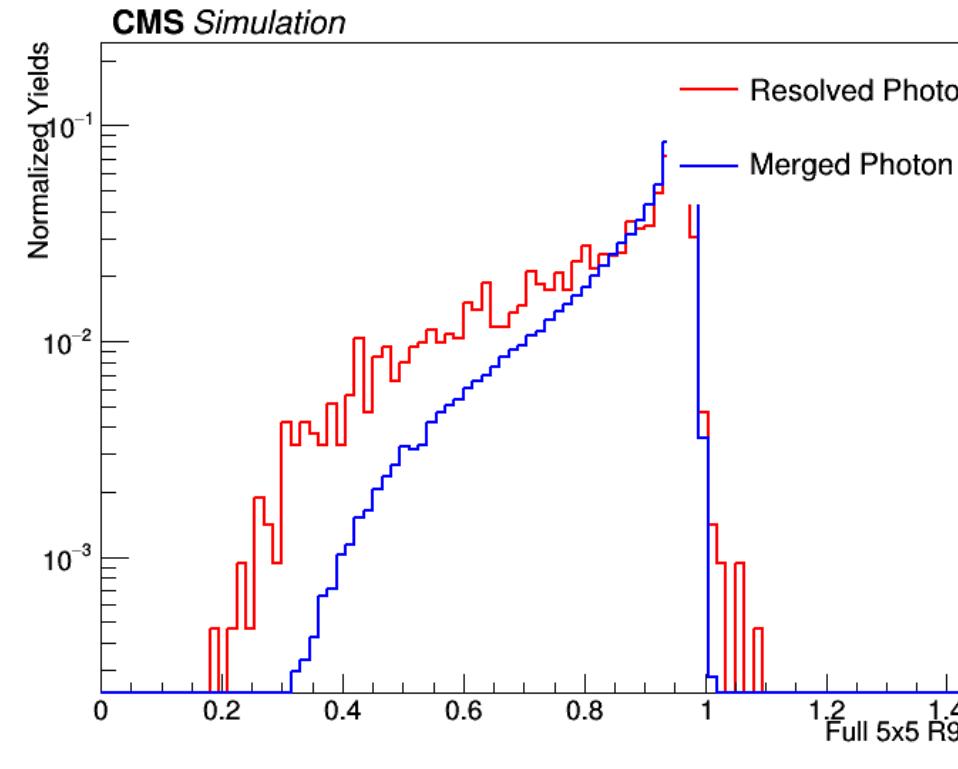
ECAL PF Cluster Iso



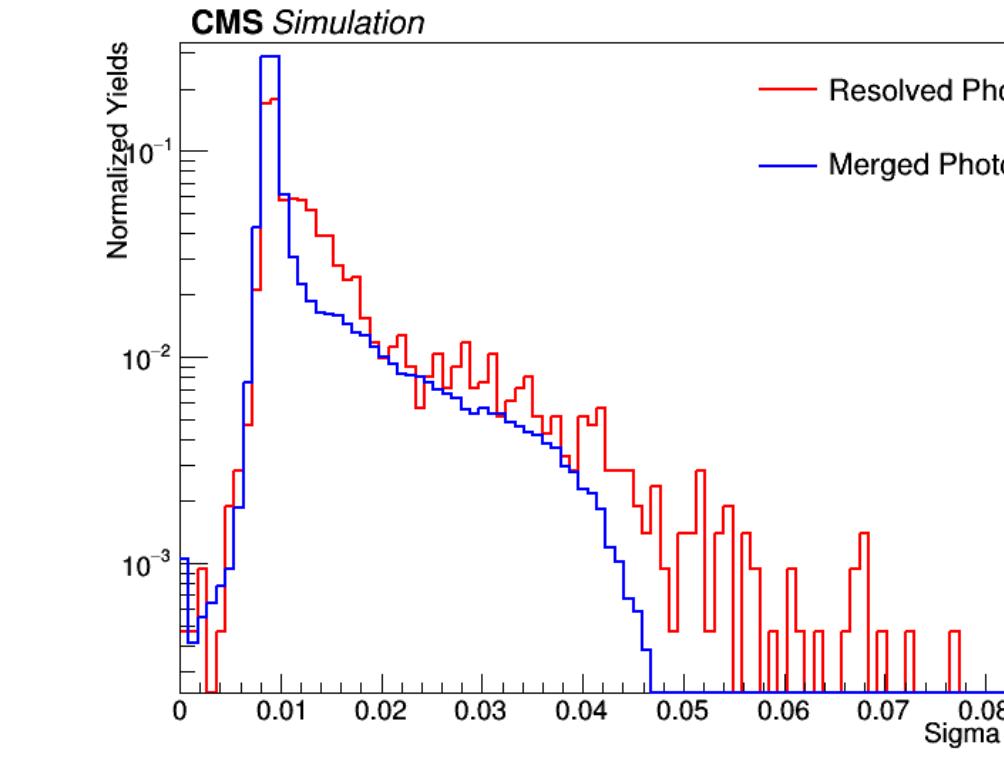
Full 5x5 SigmaEtaEta



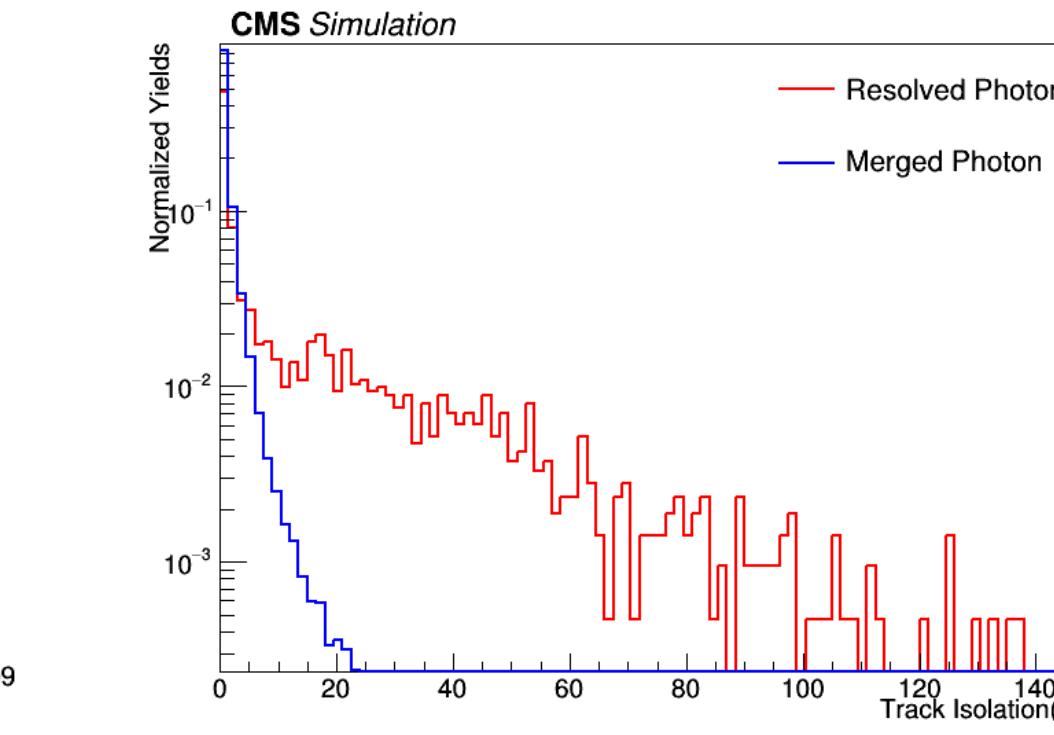
HoE



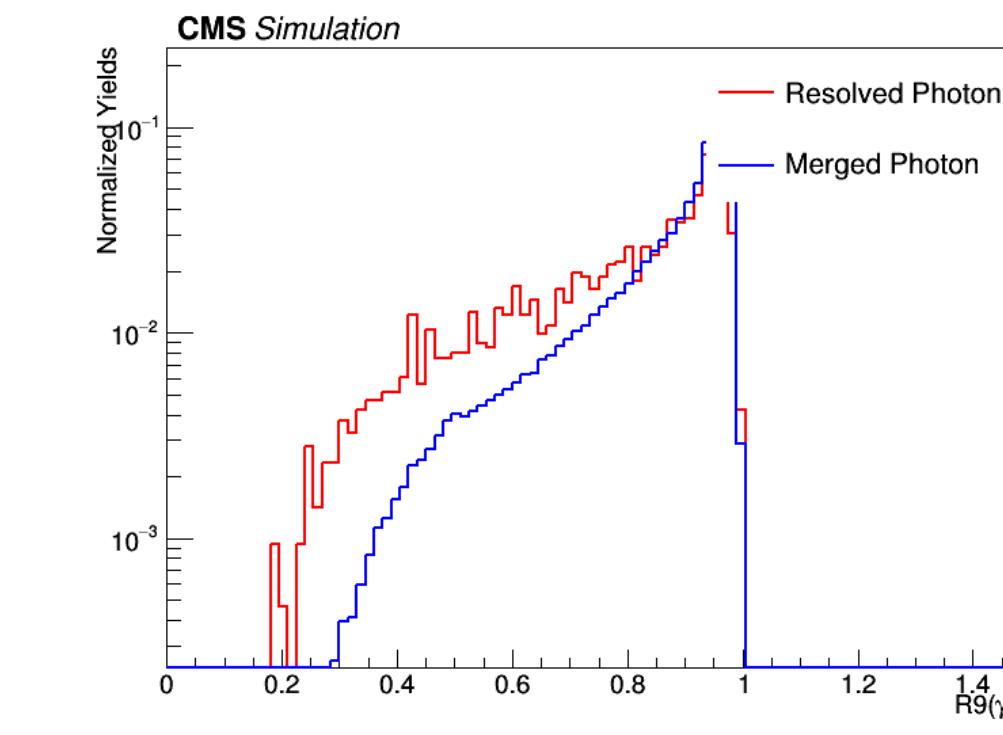
Full 5x5 R9



Sigma EtaEta



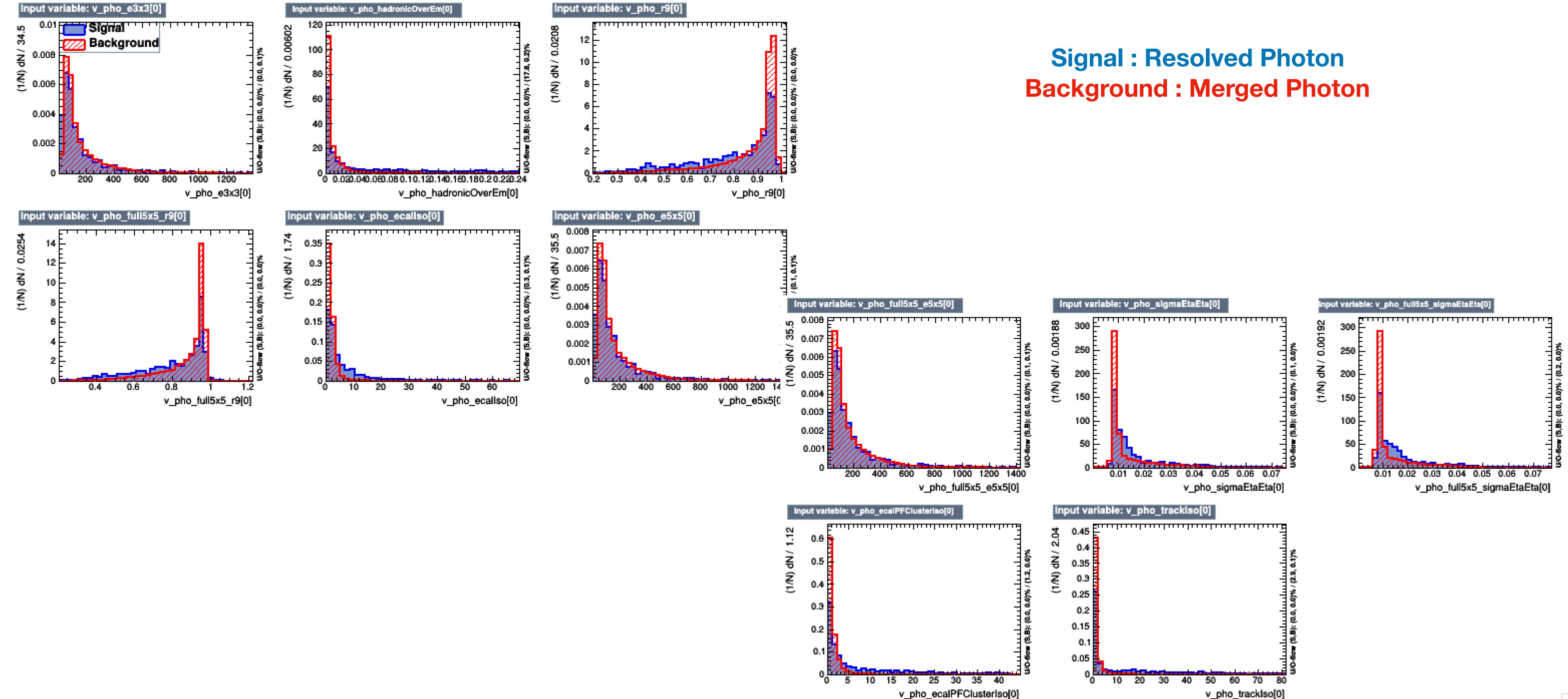
Track Isolation



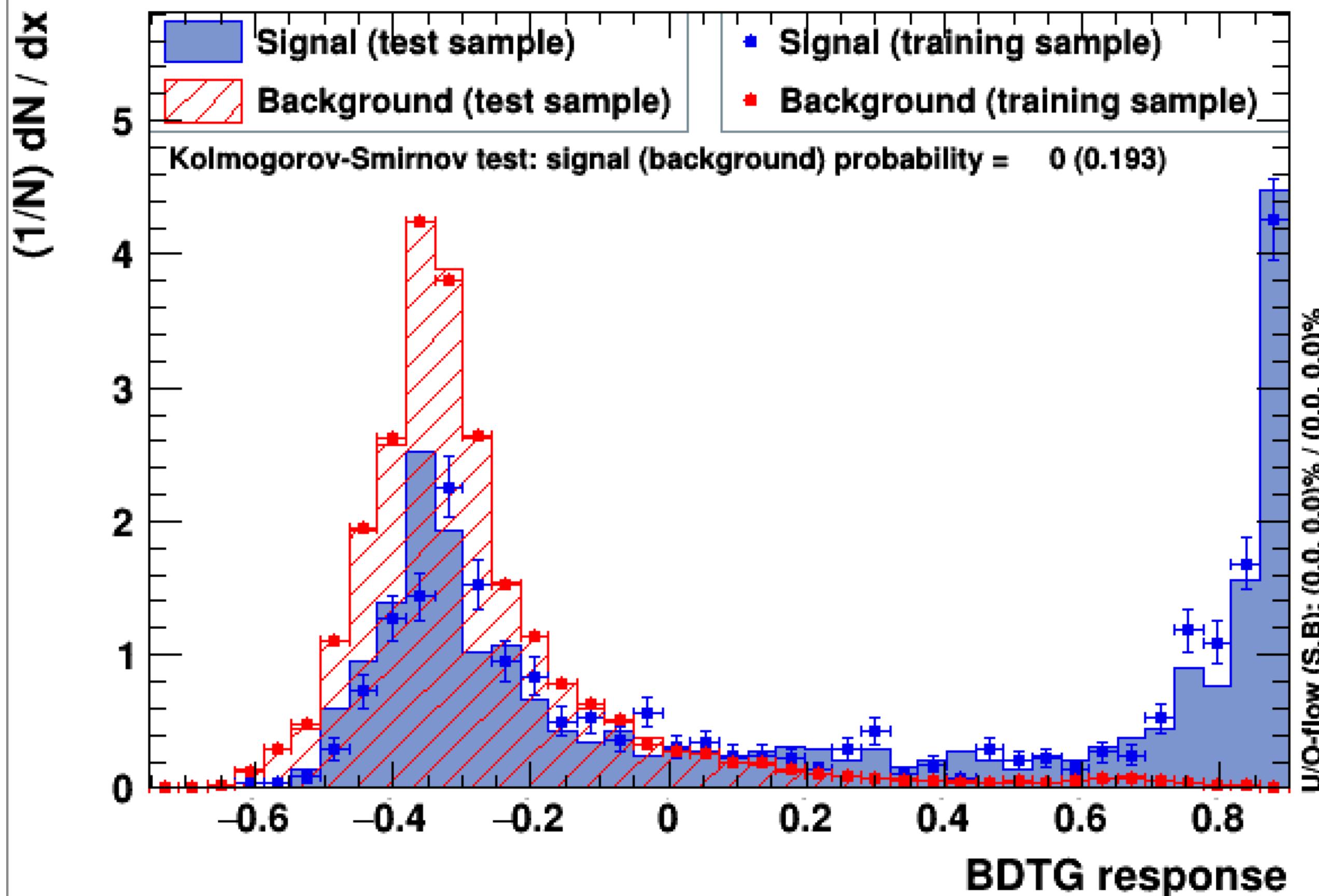
R9



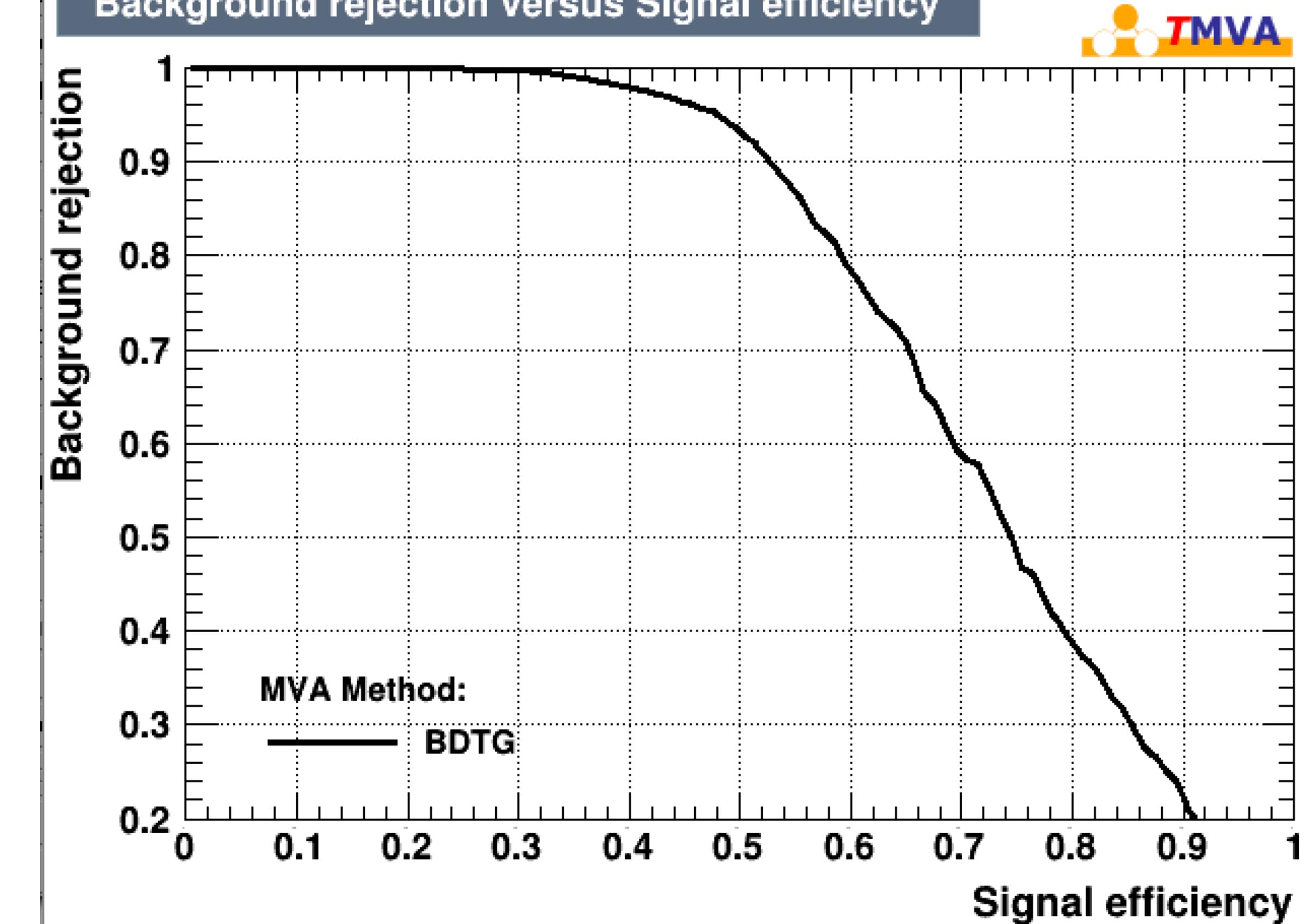
TMVA Study to differentiate Merged and Resolved Photons



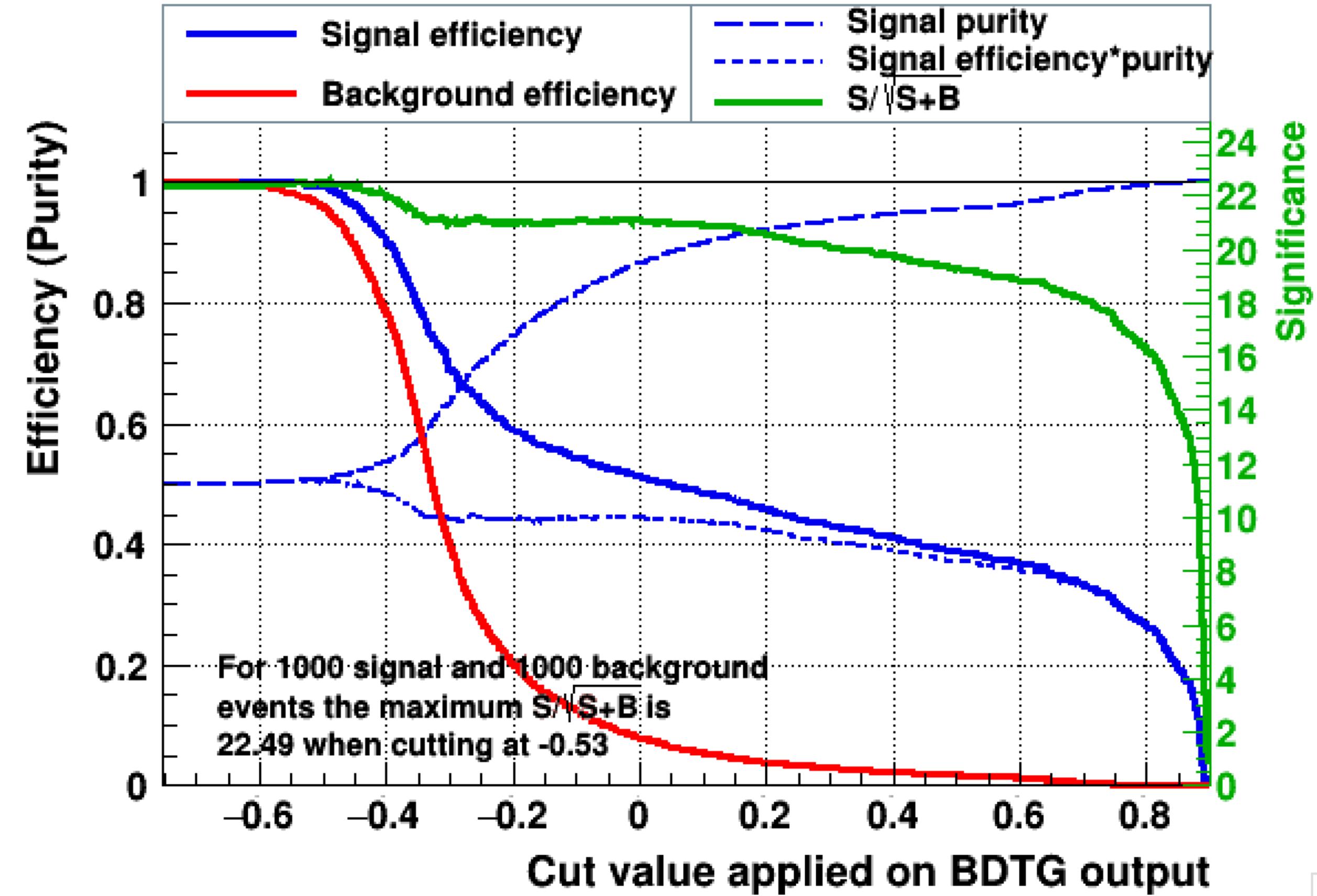
TMVA overtraining check for classifier: BDTG



Background rejection versus Signal efficiency



Cut efficiencies and optimal cut value



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

- Would be interesting to see what these angles look like for H4gamma
- θ_1, θ_2 should be different for merged and isolated photons (Looking into this!)

