

$$h(125) \rightarrow aa \rightarrow \gamma\gamma\gamma\gamma$$

NEU Meeting
25th July 2018

Tanvi Wamorkar¹, Toyoko Orimoto¹, Andrea Massironi²

[1] Northeastern University

[2] INFN Milano-Bicocca and CERN



Overview of the updates

- Presented at the Hgg working group meeting
 - [Link](#)
 - Strategy to divide the analysis into 3 broad categories depending on $m(a)$
- This presentation:
 - Present trigger studies
 - Aim of these studies is to establish that the low mass $h \rightarrow \gamma\gamma$ online triggers can be utilized by us

Triggers and Pre-Selection

- For 2016
 - OR of the two Di-photon triggers is applied
 - HLT_Diphoton30EB_18EB_R9Id_OR_IsoCalId_AND_HE_R9Id_DoublePixelVeto_Mass55
 - HLT_Diphoton30PV_18PV_R9Id_AND_IsoCalId_AND_HE_R9Id_DoublePixelVeto_Mass55
 - Schematic diagrams illustrating the two HLT paths are in the backup
- To achieve good data/simulation comparison, a pre-selection that is tighter than the online selection is applied on data and Monte Carlo

		R9 (5x5)	HoE	$\sigma_{in\eta}$ (5x5)	pfPhoIso	TrackerIso
Both photons in barrel	Barrel	> 0.5	< 0.07	< 0.0105	< 4 GeV	< 6 GeV
At least one in endcap	Barrel	> 0.85	< 0.07	< 0.0105	< 4 GeV	< 6 GeV
At least one in endcap	Endcap	> 0.9	< 0.035	< 0.0275	< 4 GeV	< 6 GeV

- Electron Veto: no Pixel seed
- p_T leading γ > 30 GeV, p_T subleading γ > 18 GeV
- For both γ 's $|\eta| < 2.5$, but not in the ECAL EB-EE gap
- $M_{\gamma\gamma} > 55$ GeV
- Have not applied the loose photon ID MVA > -0.9 yet (to remain unbiased)
- Scaled p_T 's: p_T leading γ / $M_{\gamma\gamma} > 0.47$ and p_T subleading γ / $M_{\gamma\gamma} > 0.28$

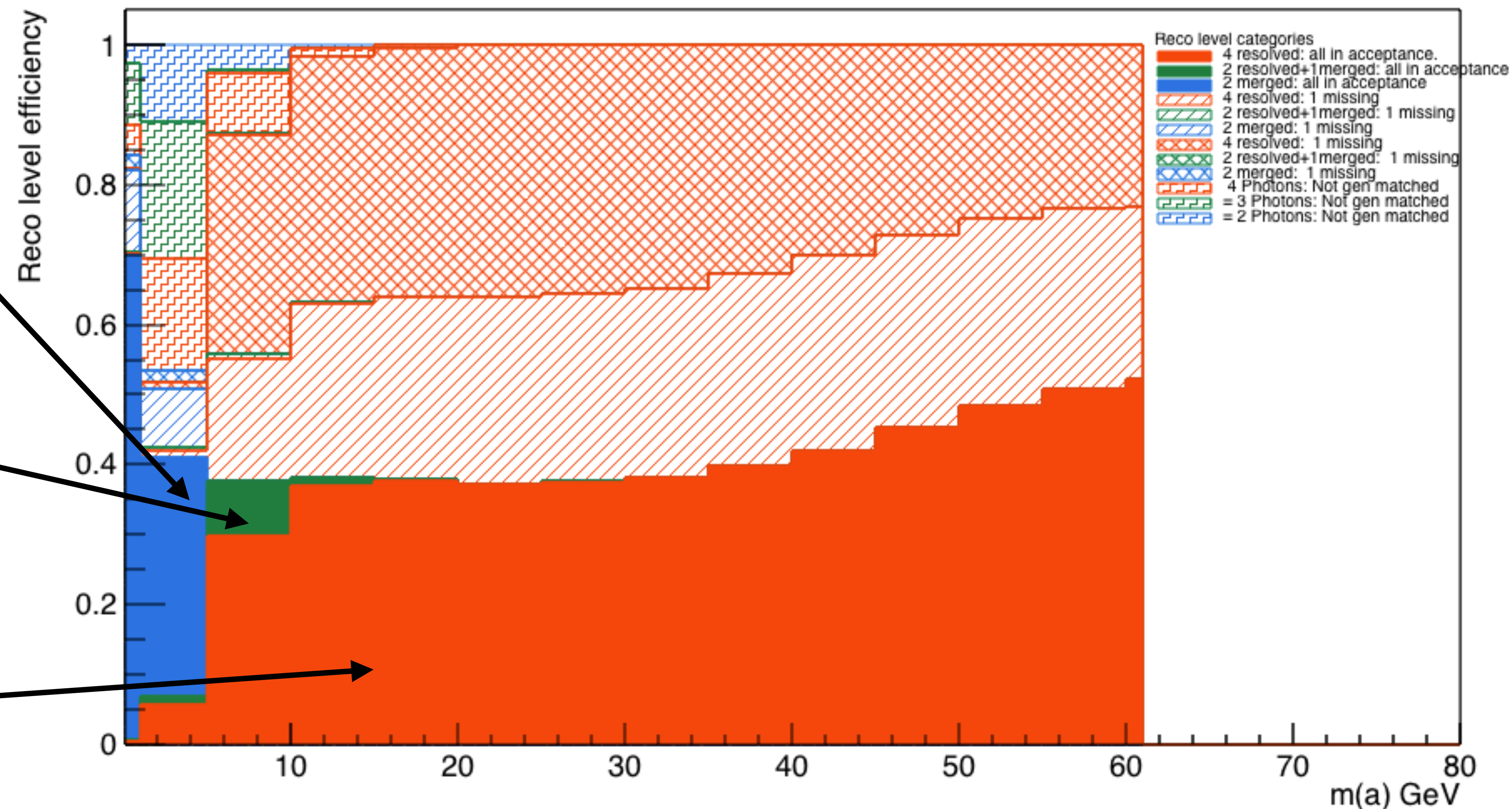
Recap: Reco level categorization

Possible to reconstruct the 4γ invariant mass in these categories

2 pairs of merged
reconstructed γ 's

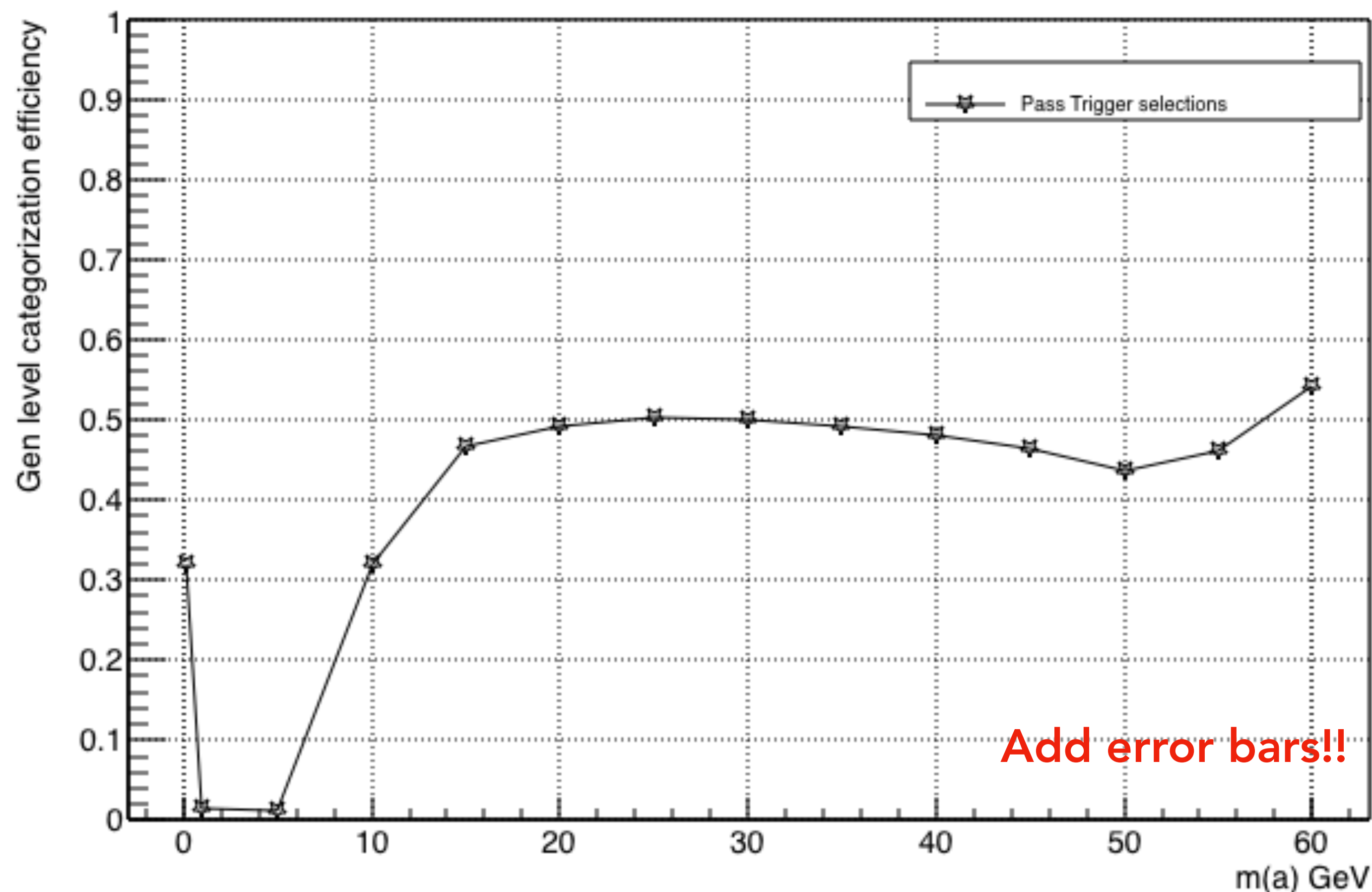
2 resolved + 1merged
reconstructed γ 's

4 reconstructed
resolved γ 's



4 Resolved Photons case

$$\epsilon_{4\gamma} = \frac{\begin{array}{l} \text{\# of events w/ 4 resolved photons} \\ \text{(all photons within detector acceptance)} \\ \text{+ pass (pre-selection \& \& trigger)} \end{array}}{\begin{array}{l} \text{\# of events w/ 4 resolved photons} \\ \text{(all photons within detector acceptance)} \end{array}}$$

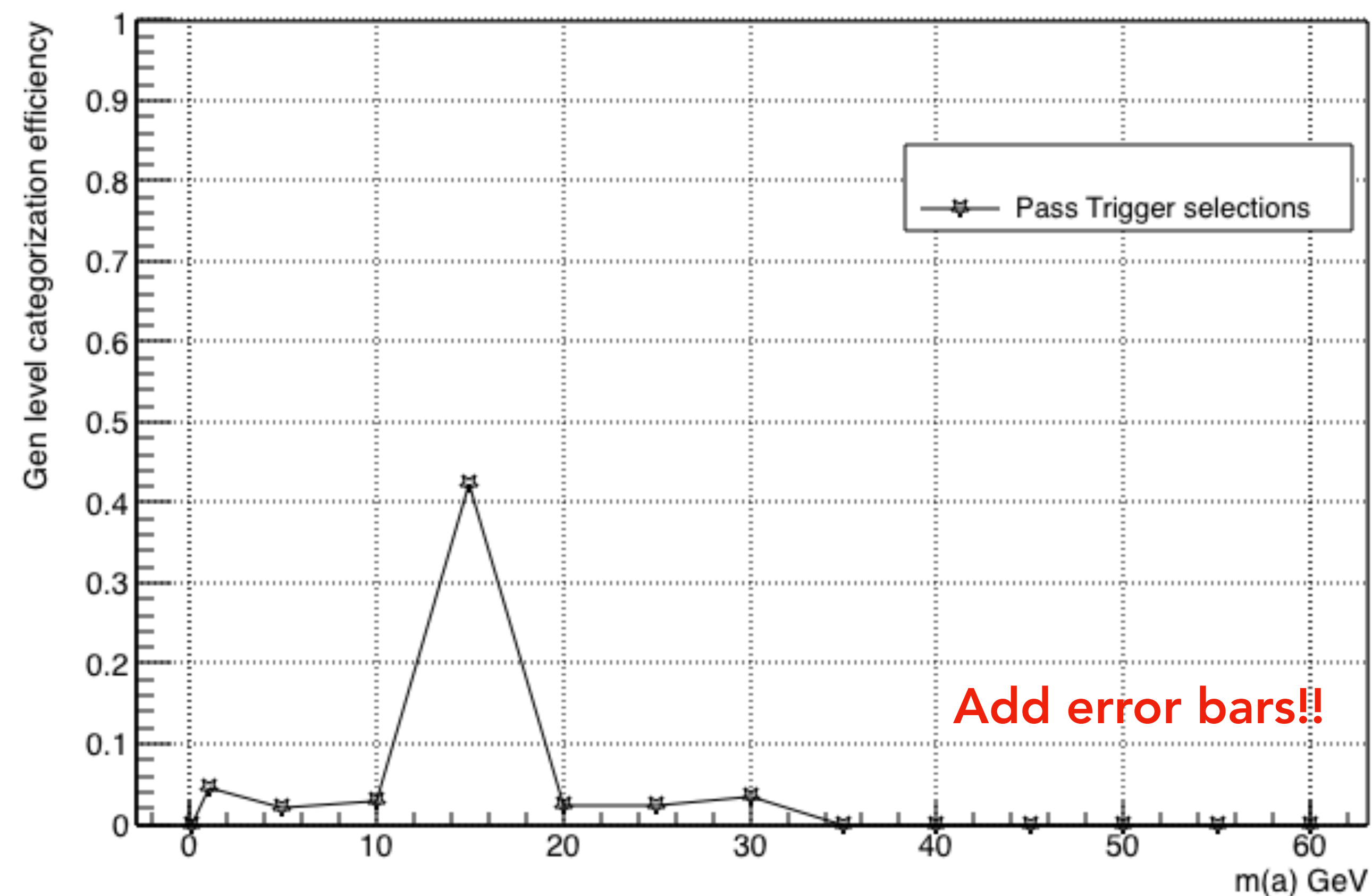


Add error bars!!

- For $m(a) > 10$ GeV the fully resolved topology is the dominant one (26% for $m(a) = 10$ GeV to 46% for $m(a) = 60$ GeV)
- From this simple study, we can see that the existing low mass diphoton triggers have an efficiency ranging from 30% for $m(a) = 10$ GeV to 55% for $m(a) = 60$ GeV

2 Resolved + 1 Merged Photons case

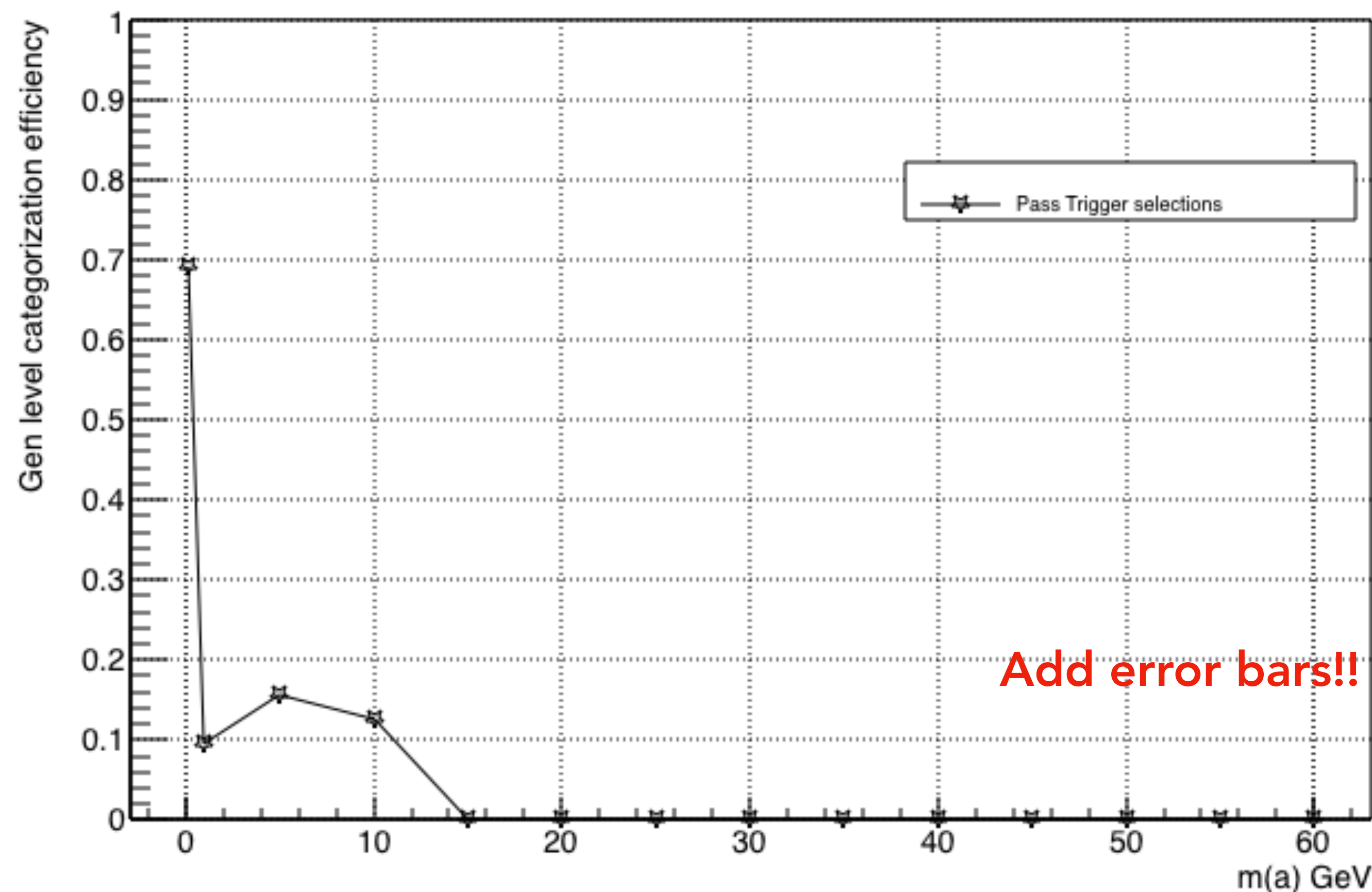
$$\epsilon_{3\gamma} = \frac{\begin{array}{l} \text{\# of events w/ 2 resolved + 1 merged photons} \\ \text{(all photons within detector acceptance)} \\ \text{+ pass (pre-selection \&\& trigger)} \end{array}}{\begin{array}{l} \text{\# of events w/ 2 resolved + 1 merged photons} \\ \text{(all photons within detector acceptance)} \end{array}}$$

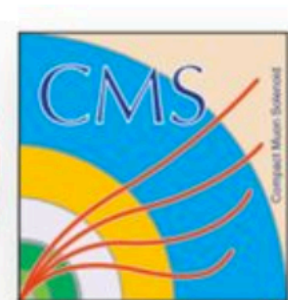


- For $m(a) = 5$ GeV, around $\sim 10\%$ of the events lie under this category

2 pairs of Merged Photons case (1)

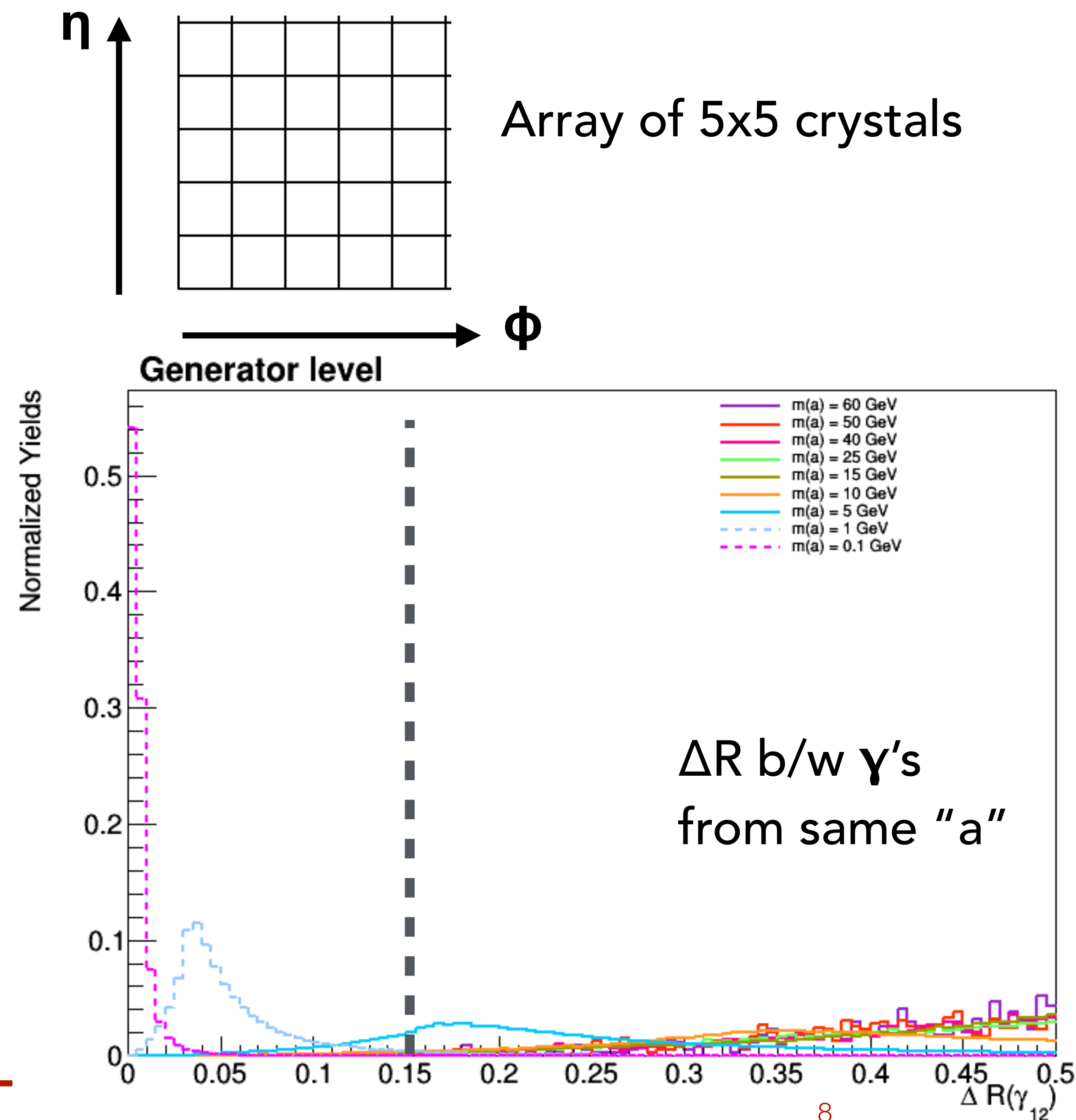
$$\epsilon_{2\gamma} = \frac{\begin{array}{l} \text{\# of events w/ 2 merged photons} \\ \text{(all photons within detector acceptance)} \\ \text{+ pass (pre-selection \& \& trigger)} \end{array}}{\begin{array}{l} \text{\# of events w/ 2 merged photons} \\ \text{(all photons within detector acceptance)} \end{array}}$$





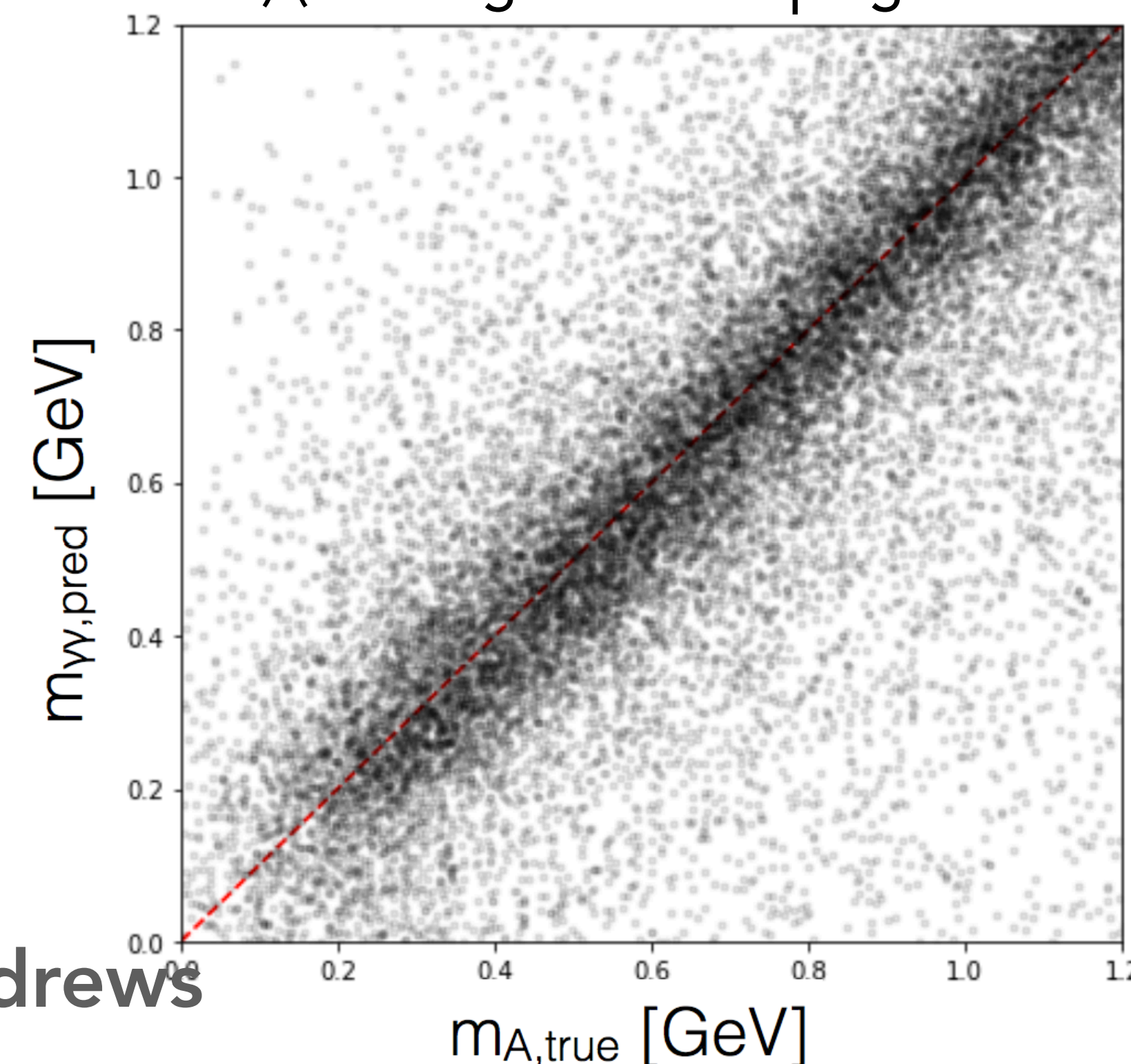
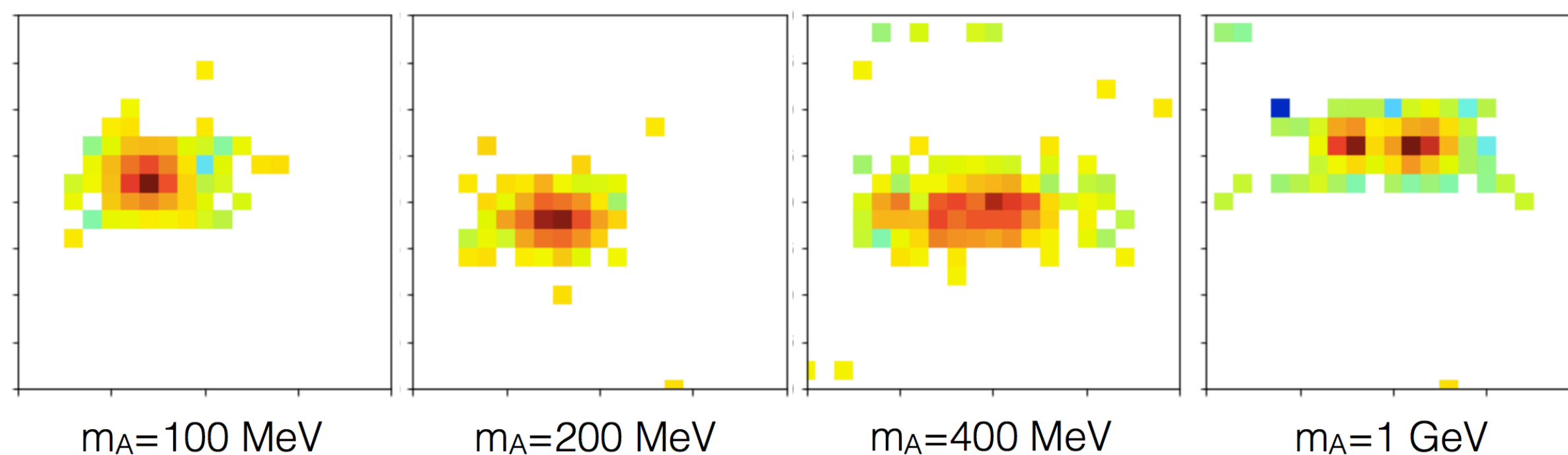
2 pairs of Merged Photons case (2)

- Selections at the online level are based on 5x5 and Supercluster based variables
- For $m(a) < 5$ GeV, photons are mostly merged
- Since for $m(a) < 5$ GeV, the event would almost look like $H \rightarrow \gamma\gamma$, the diphoton object is then the Higgs (and not "a")
- Maybe its a good idea to check the effect of application of the standard $h \rightarrow \gamma\gamma$ trigger on $m(a) < 10$ GeV? \rightarrow **Doing currently!**
- Major difference b/w the standard and low-mass diphoton trigger is in the diphoton mass cut
 - For standard $h \rightarrow \gamma\gamma$: $M_{\gamma\gamma} > 90$ GeV
 - For low mass $h \rightarrow \gamma\gamma$: $M_{\gamma\gamma} > 55$ GeV

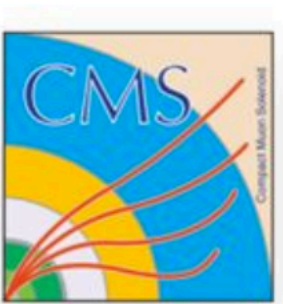


Low mass/Merged photons scenario

- For $m(a) > 10$ GeV the fully resolved topology is the dominant one (26% for $m(a) = 10$ GeV to 46% for $m(a) = 60$ GeV)
- For $m(a) = 100$ MeV and 1 GeV, the dominant category is 2 pairs of merged γ 's (all γ 's in acceptance)
 - However, for this mass regime a separate analysis has to be developed since the standard photon identification MVA will cease to work
 - New classification would be needed in this case; In contact with Michael Andrews (from CMU) (working on developing mass regression on merged photon clusters) [Link to Michael's presentation](#)
- **Mass regression on merged photon clusters:**
For exotic light scalar decays, $A \rightarrow \gamma\gamma$, try to perform mass regression on the merged photon cluster



From Michael Andrews



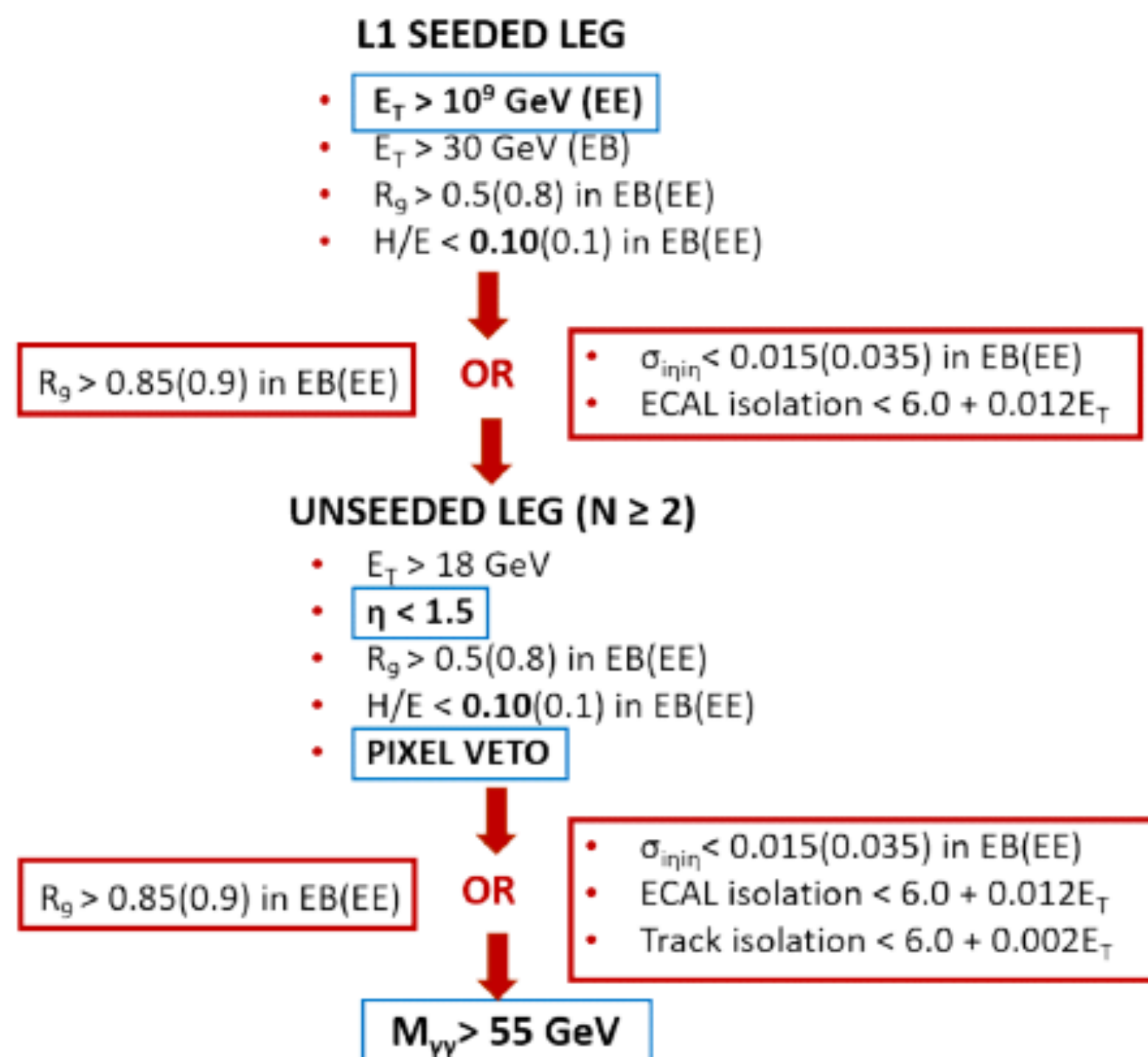
Comments & Future steps

- For 2017 data taking
 - One HLT path was active during data taking
 - HLT_Diphoton30EB_18EB_R9Id_OR_IsoCalId_AND_HE_R9Id_DoublePixelVeto_Mass55
 - Currently producing MicroAOD's with the 2017 recipe of flashgg (framework for $h \rightarrow \gamma\gamma$ analyses)
- For 2018 data taking
 - The diphoton mass requirement has been removed from the online HLT path for the low mass diphoton triggers **Good News :)**
- With additional plots (& corrections to the existing plots), present the detailed trigger study at the Hgg working group meeting tomorrow

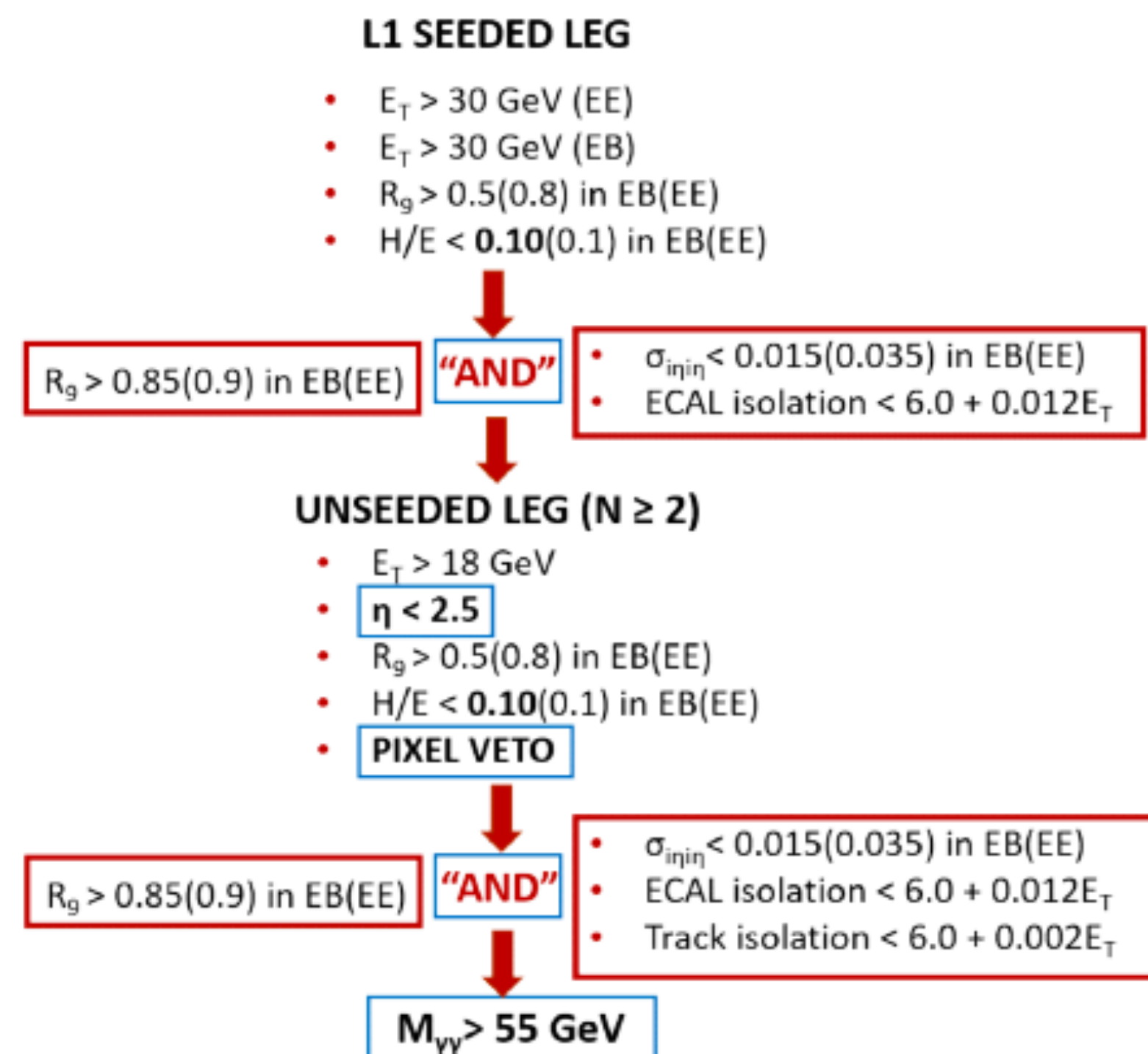


Backup

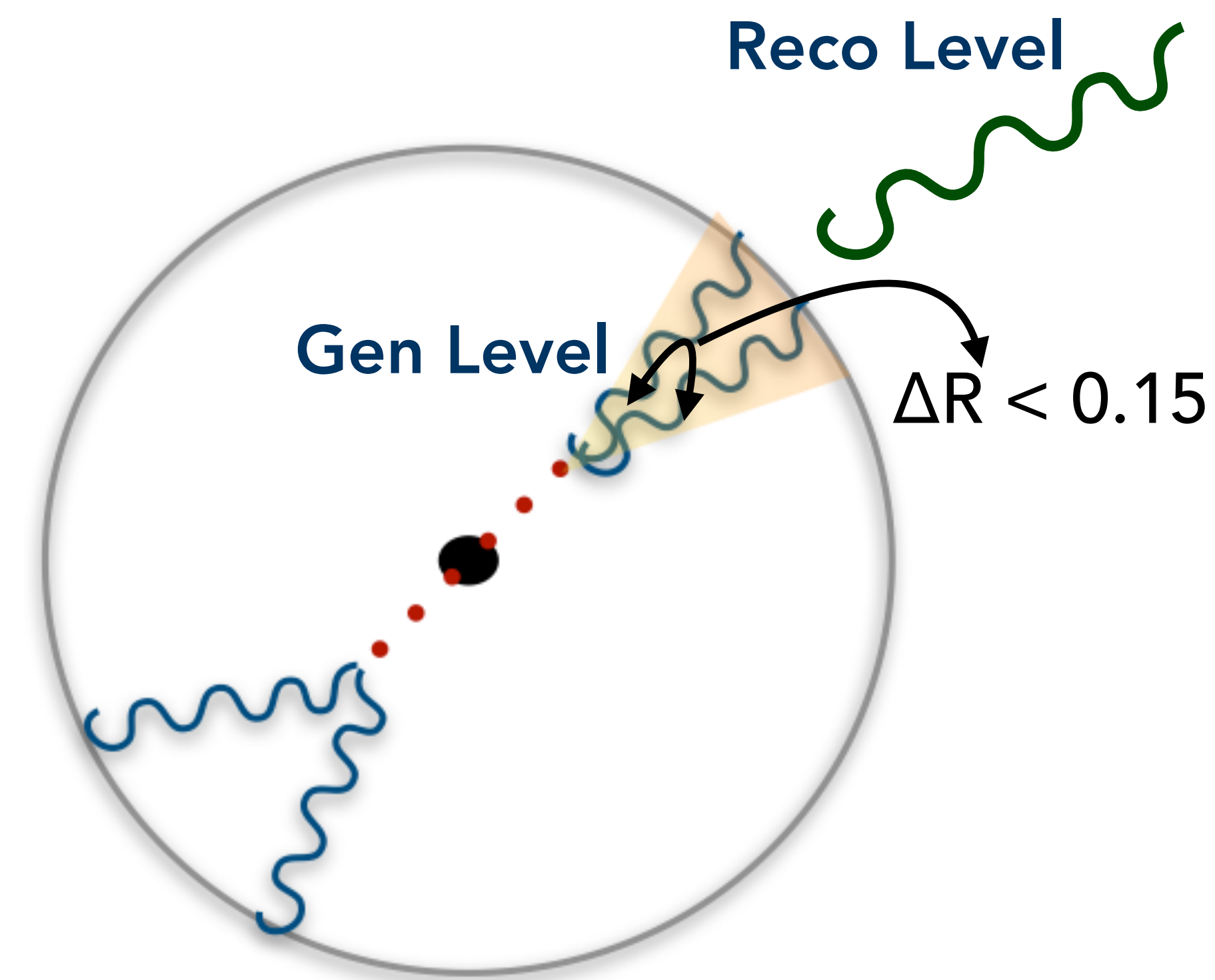
“OR” PATH



“AND” PATH



Logic of Gen-Reco Matching



- Start by identifying a merged photon at Gen level (if $\Delta R < 0.15$)
- Loop over the collection of Reco photons and look for one which is close to the Gen-level merged photon within a cone of $\Delta R = 0.15$
- If more than one such Reco photons are found, then the one with the least ΔR is flagged as a merged photon at the Reco-level
- By doing this, we can flag each photon at the Reco level as "resolved" or "merged"
- Next step is to mimic the categories @ Reco level