



# Tau Reconstruction Performance and Decay Mode Finding Studies

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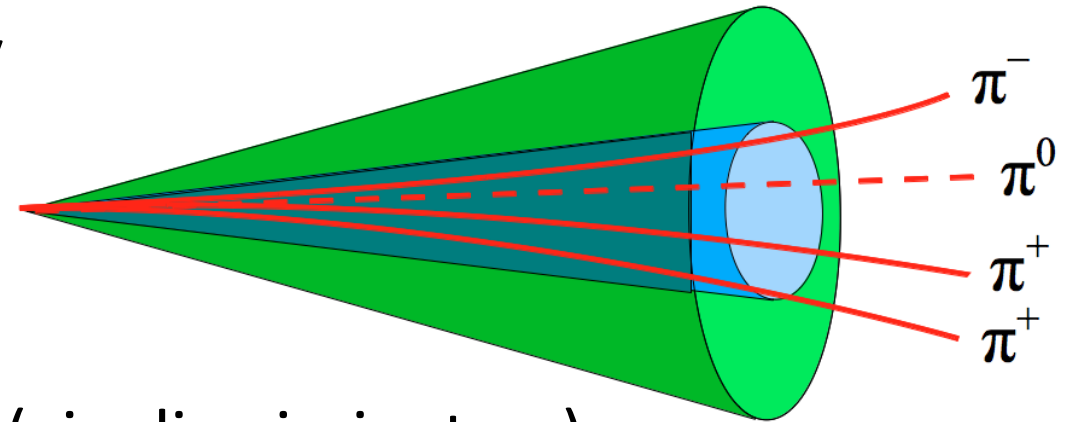
# Overview

- Summary of tau lepton reconstruction
- MVA antielectron discriminator performance
- Tau efficiencies under “new” decay mode finding
- Failed 3-prong tau reconstruction studies



# Tau Reconstruction Challenges

- About 2/3 of taus decay hadronically.
  - Typically to 1 or 3 charged mesons + up to 2 neutral pions
- Some event objects can be incorrectly identified as taus.
  - Quark-gluon jets
  - Electrons, muons
- Taus must meet certain requirements (via discriminators) to prevent these improper reconstructions.

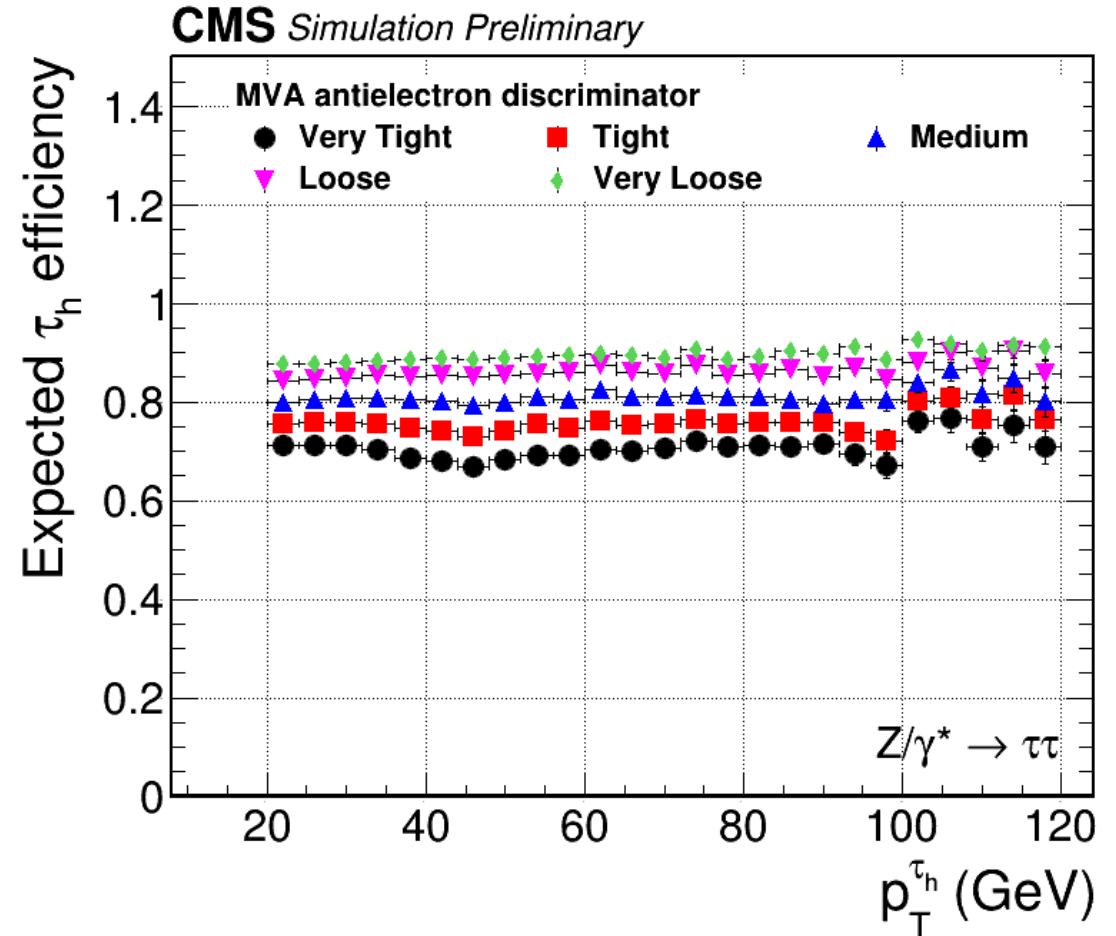
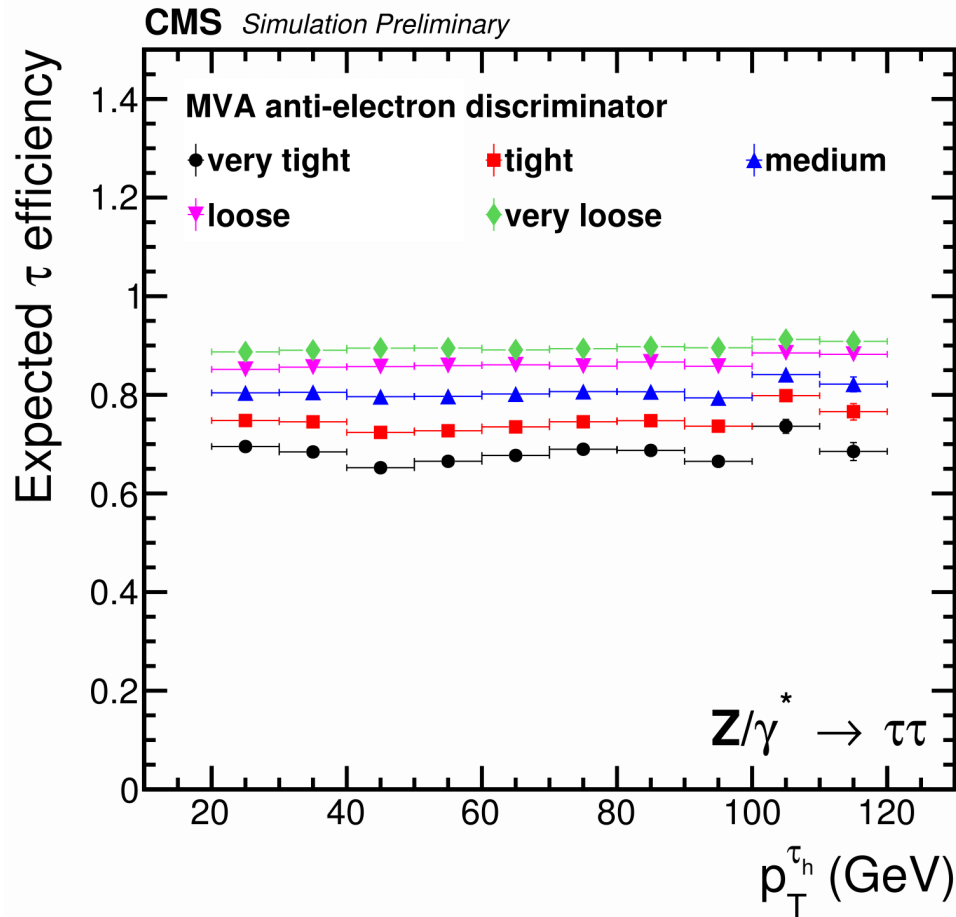




# Tau Efficiencies Under Anti-e Discriminators

CMSSW 7\_6\_x

CMSSW 8\_0\_10

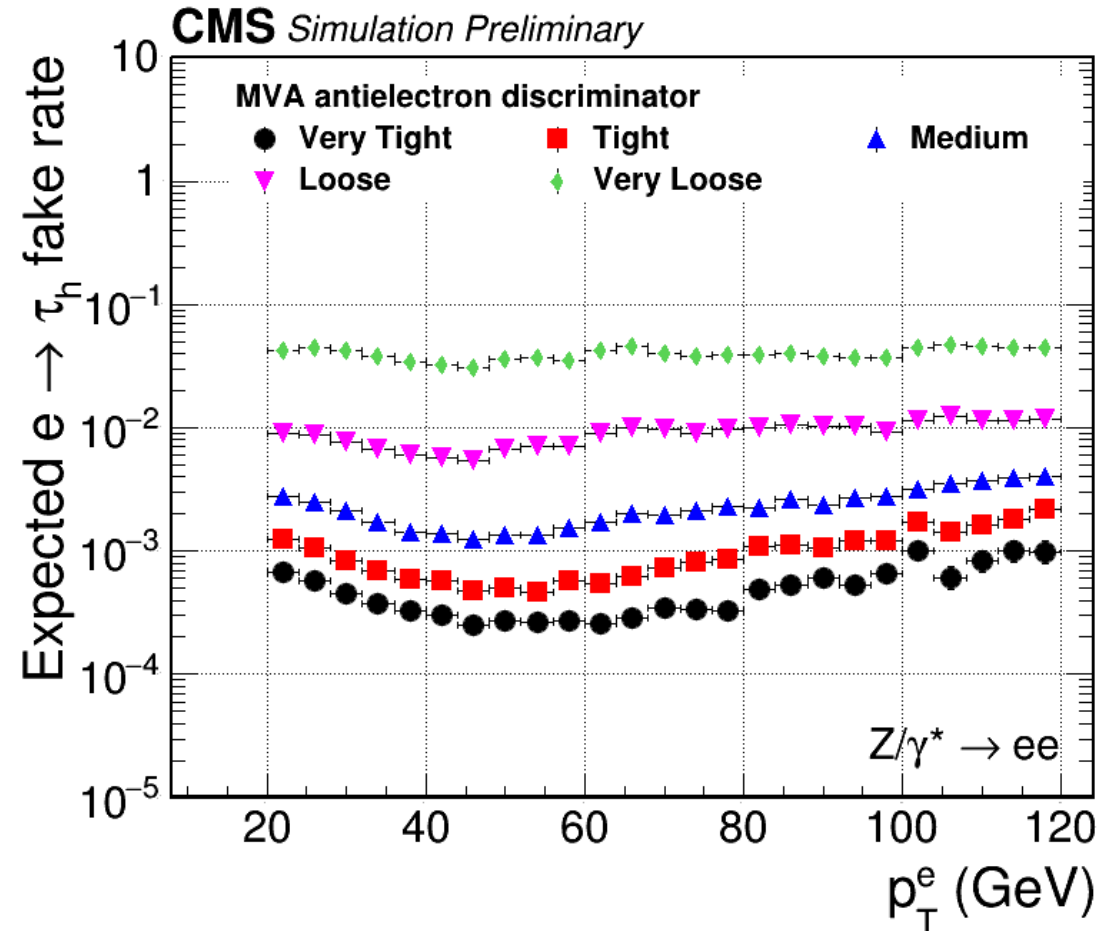
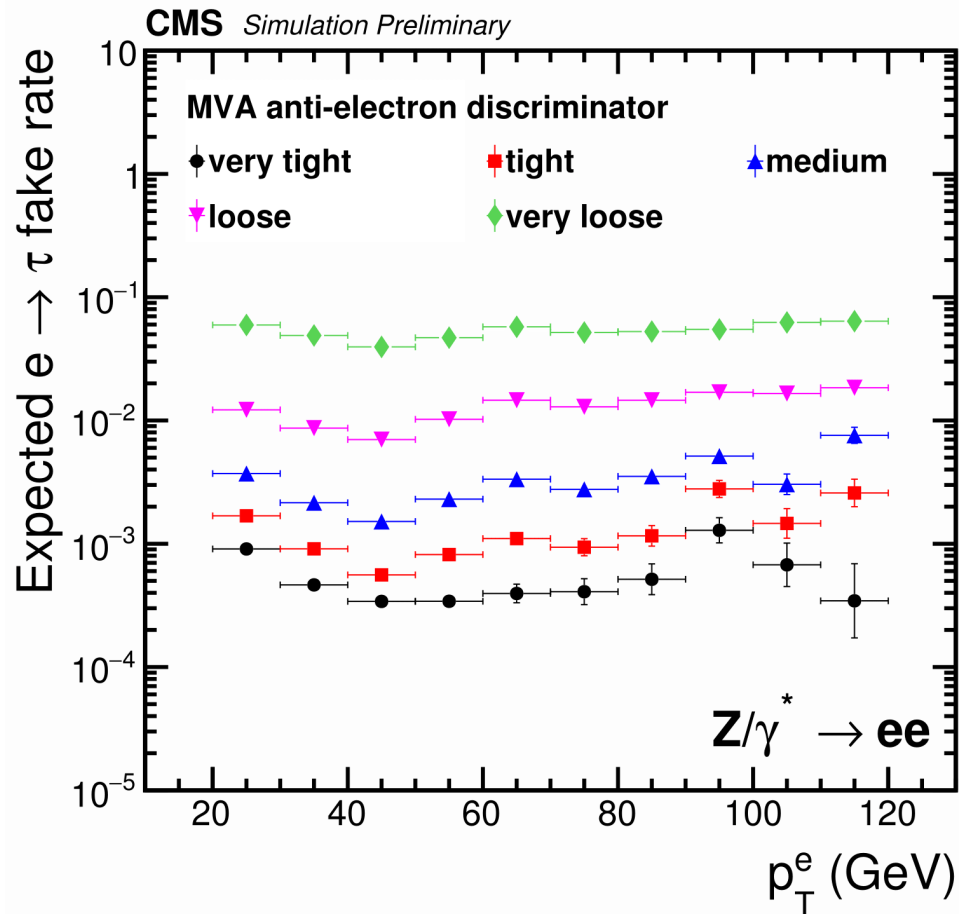




# Electron to Tau Fake Rates

## CMSSW 7\_6\_x

## CMSSW 8\_0\_10





Run 1:

- 1 prong
- 1 prong +  $\pi_0$ s
- 3 prong

New decay modes in Run-2:

- 3 prong +  $\pi_0$ s
- 2 prong
- 2 prong +  $\pi_0$ s

$\pi_0$ s do not contribute to the tau isolation anymore → higher efficiency

To account for tracking inefficiencies

- “Old” and “new” decay modes supported in Run-2

Decay mode	Resonance	BR[%]
$\tau^- \rightarrow e^- \bar{\nu}_e \nu_\tau$		17.8
$\tau^- \rightarrow \mu^- \bar{\nu}_\mu \nu_\tau$		17.4
$\tau^- \rightarrow h^- \nu_\tau$		11.5
$\tau^- \rightarrow h^- \pi^0 \nu_\tau$	$\rho(770)$	26.0
$\tau^- \rightarrow h^- \pi^0 \pi^0 \nu_\tau$	$a_1(260)$	10.8
$\tau^- \rightarrow h^- h^+ h^- \nu_\tau$	$a_1(260)$	9.8
$\tau^- \rightarrow h^- h^+ h^- \pi^0 \nu_\tau$		4.8
Other hadronic modes		1.8



# Reconstruction Ratio Definition

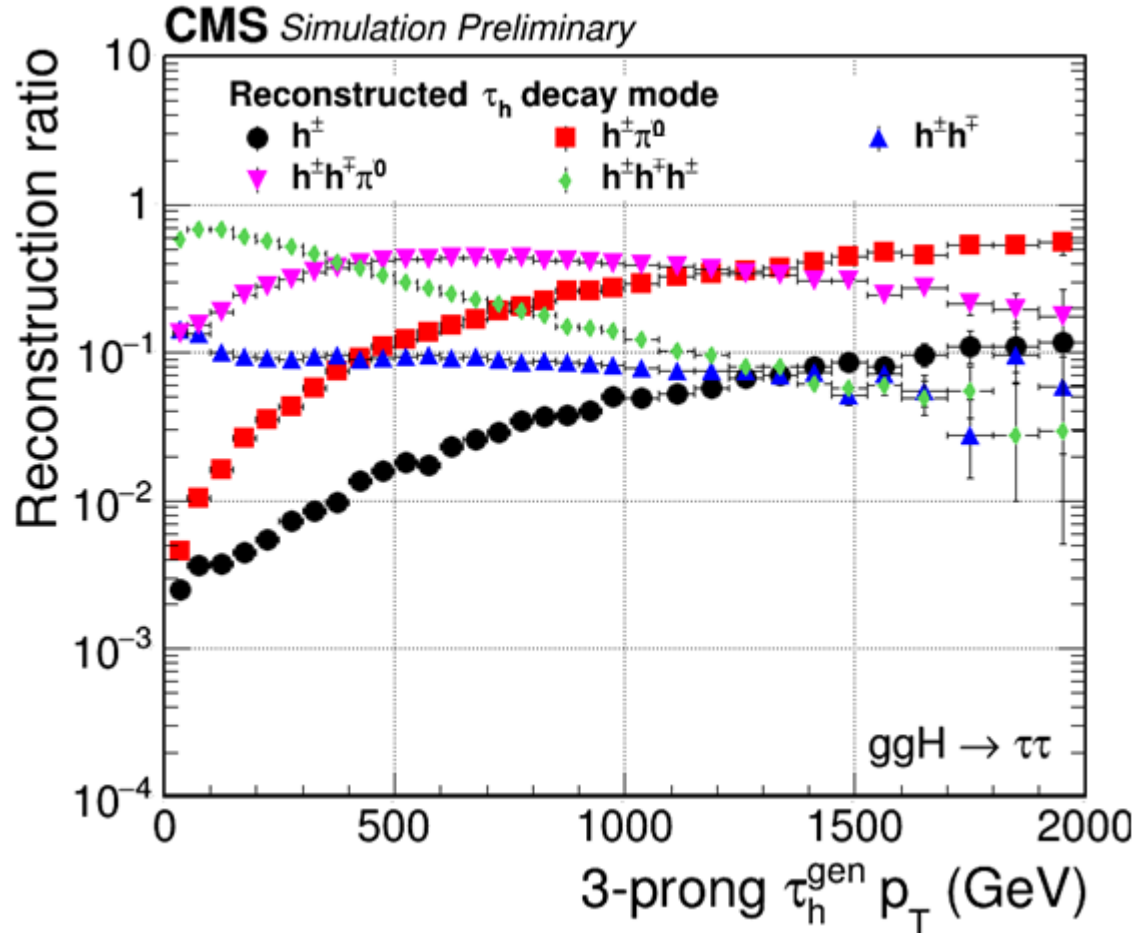
- Generator-level taus are classified by decay mode according to:
  - number of charged hadrons
  - number of neutral pions
- Reconstructed taus in each decay mode are matched with generator-level 3-prong taus ( $dR < 0.3$ )
- A ratio is found for each of the “new” decay modes:

$$\frac{\text{gen-matched } \tau_h^{\text{reco}} \text{ with chosen decay mode}}{\text{all 3-prong } \tau_h^{\text{gen}}}$$

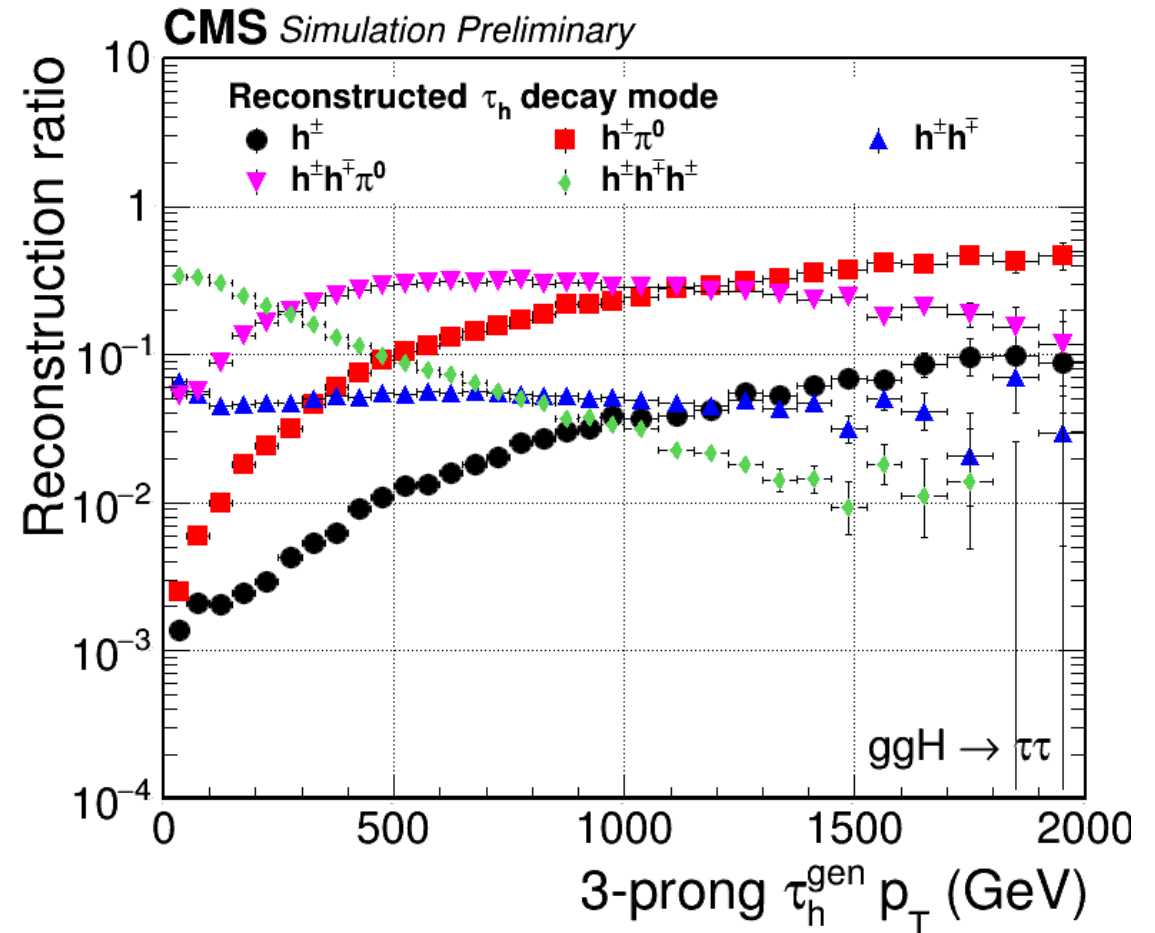


# Reconstruction Ratio Plots

## No discriminator



## Loose Isolation





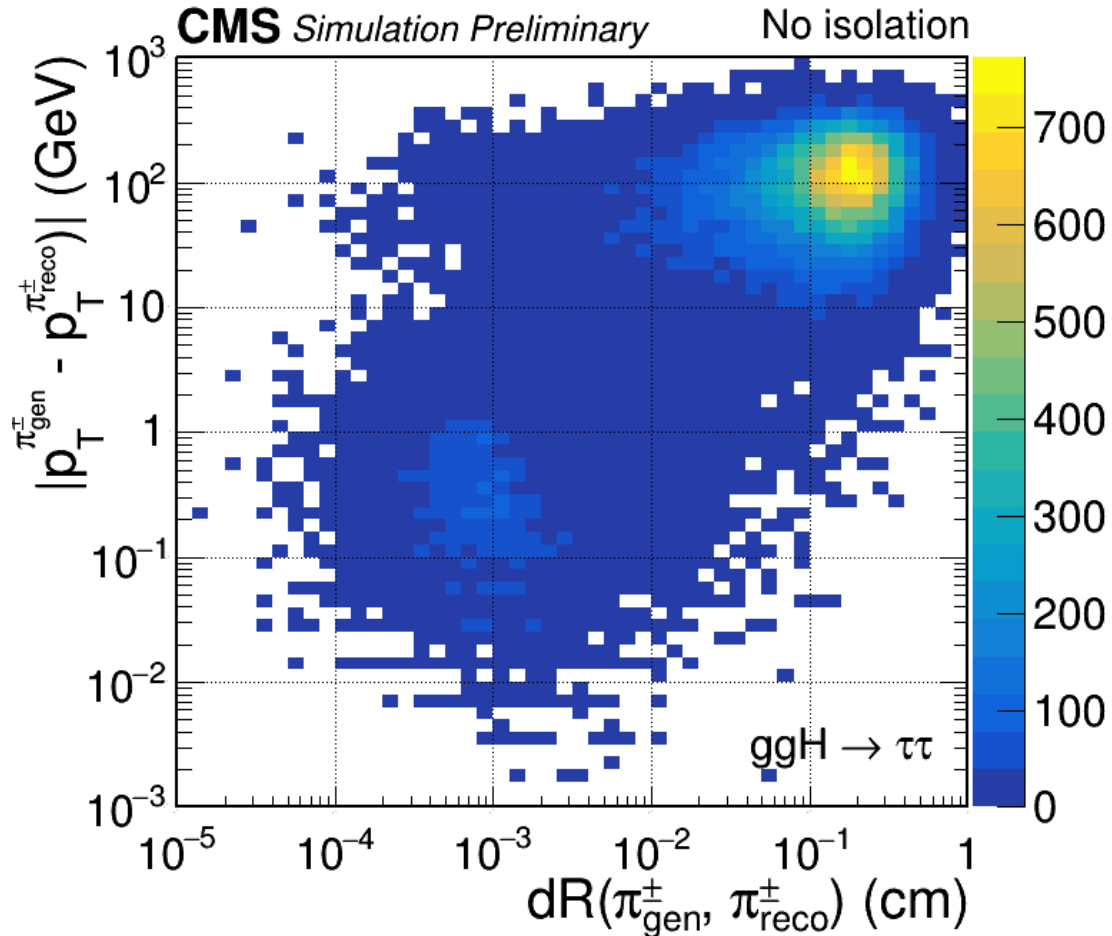


# Failed Track Definition

- “2-prong” reconstructed taus ( $\pi^\pm\pi^\pm$ ,  $\pi^\pm\pi^\pm\pi^0$ ) are matched to generated 3-prong taus ( $\pi^\pm\pi^\mp\pi^\pm + \pi^0$ s)
- From the Particle Flow candidate collection, an attempt is made to find the “failed” track: a charged pion reconstructed from the generator-level third track, but not used in the tau reconstruction.
- Not all generated pions are properly reconstructed, so dR minimization and a  $|\Delta p_T|$  cut are used to distinguish between failed tracks and improper reconstructions.



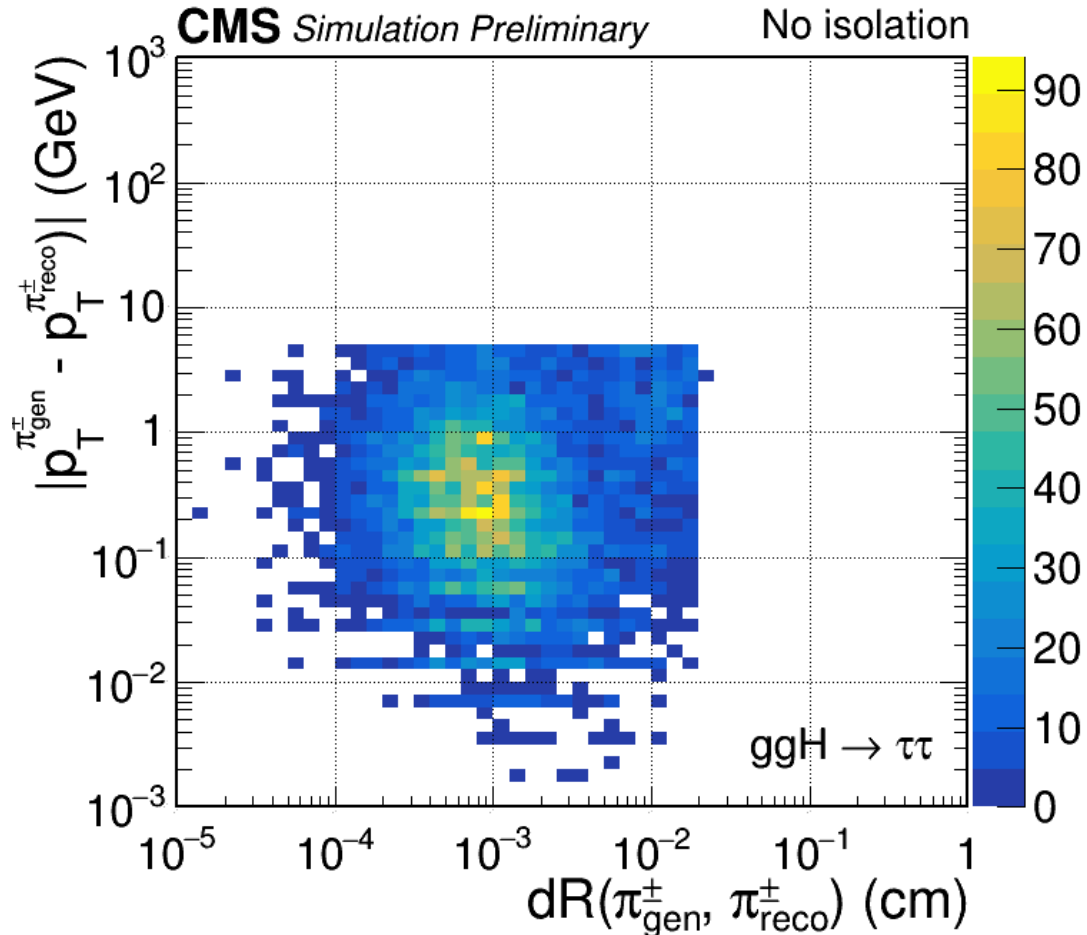
# Finding Failed Tracks



- For each generated third track, the closest (by dR) PF candidate with the same pdg ID is found.
- Plotting the difference in  $p_T$  against dR shows two groups of tracks.



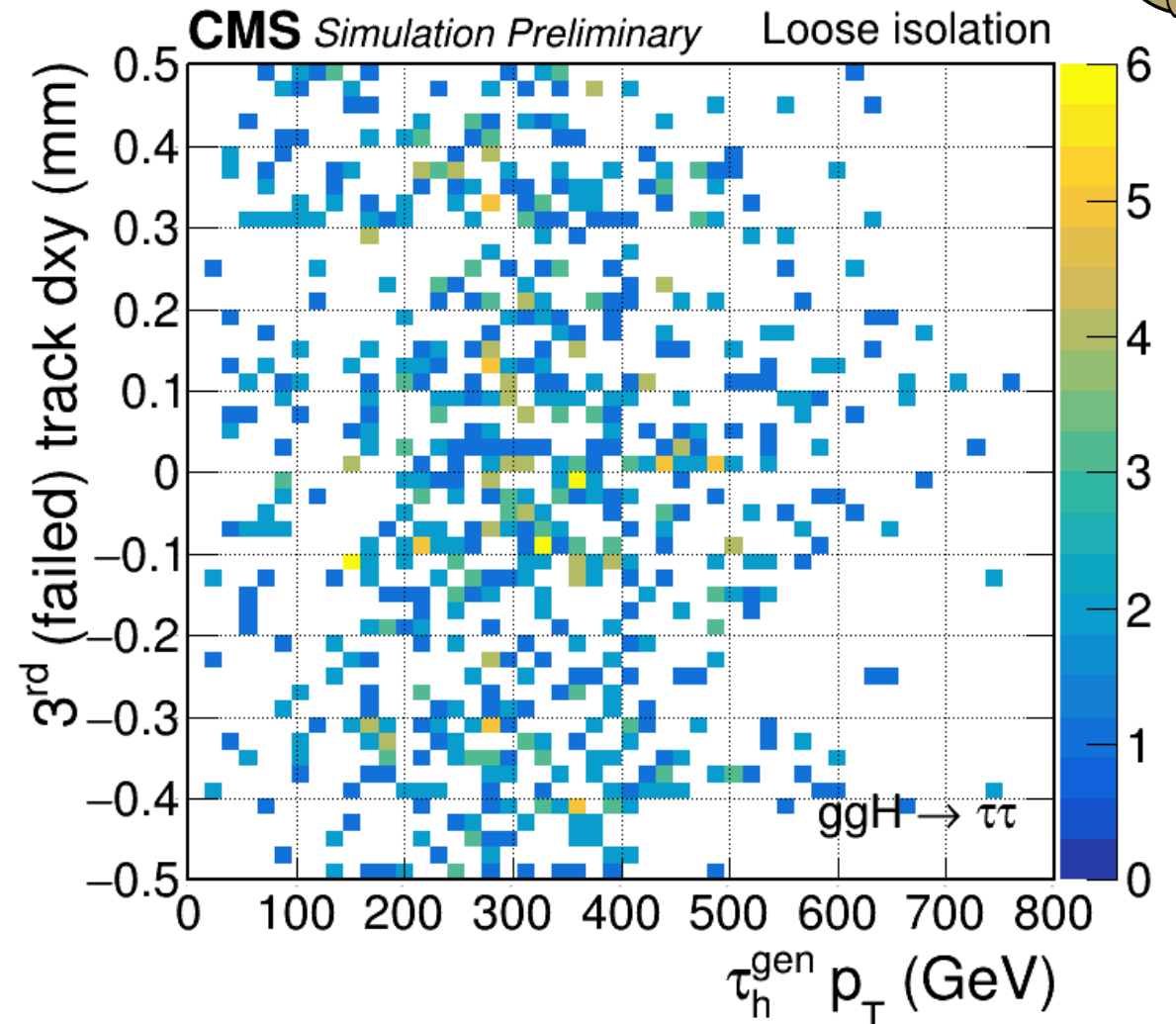
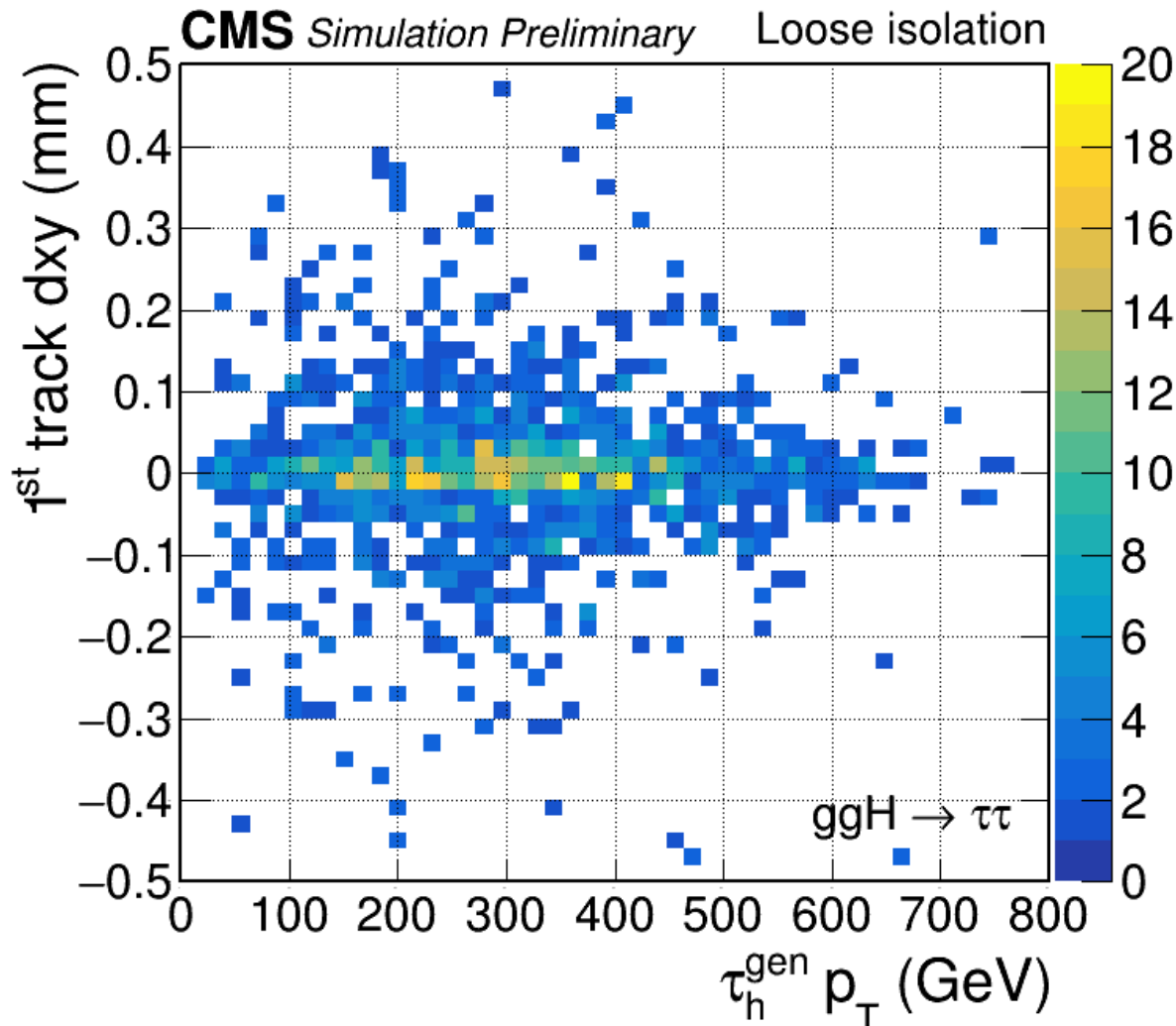
# Finding Failed Tracks (cont.)



- In the analysis—for each generated third track—the closest (by dR) PF candidate with the same pdg ID is found while requiring that  $|\Delta p_T| < 5$  GeV.
- The collection with  $dR < 0.2$  mm is considered to be the failed third tracks.

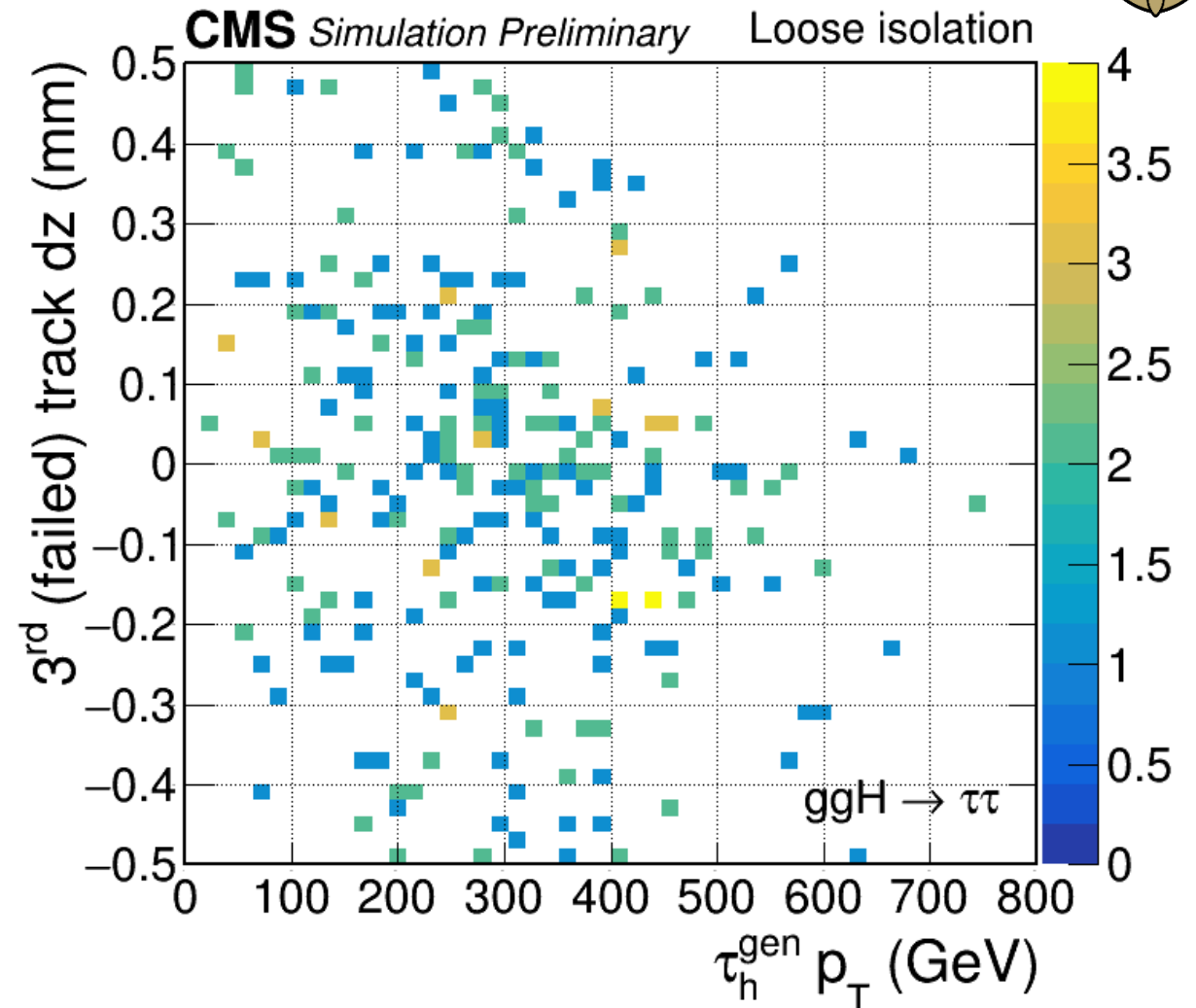
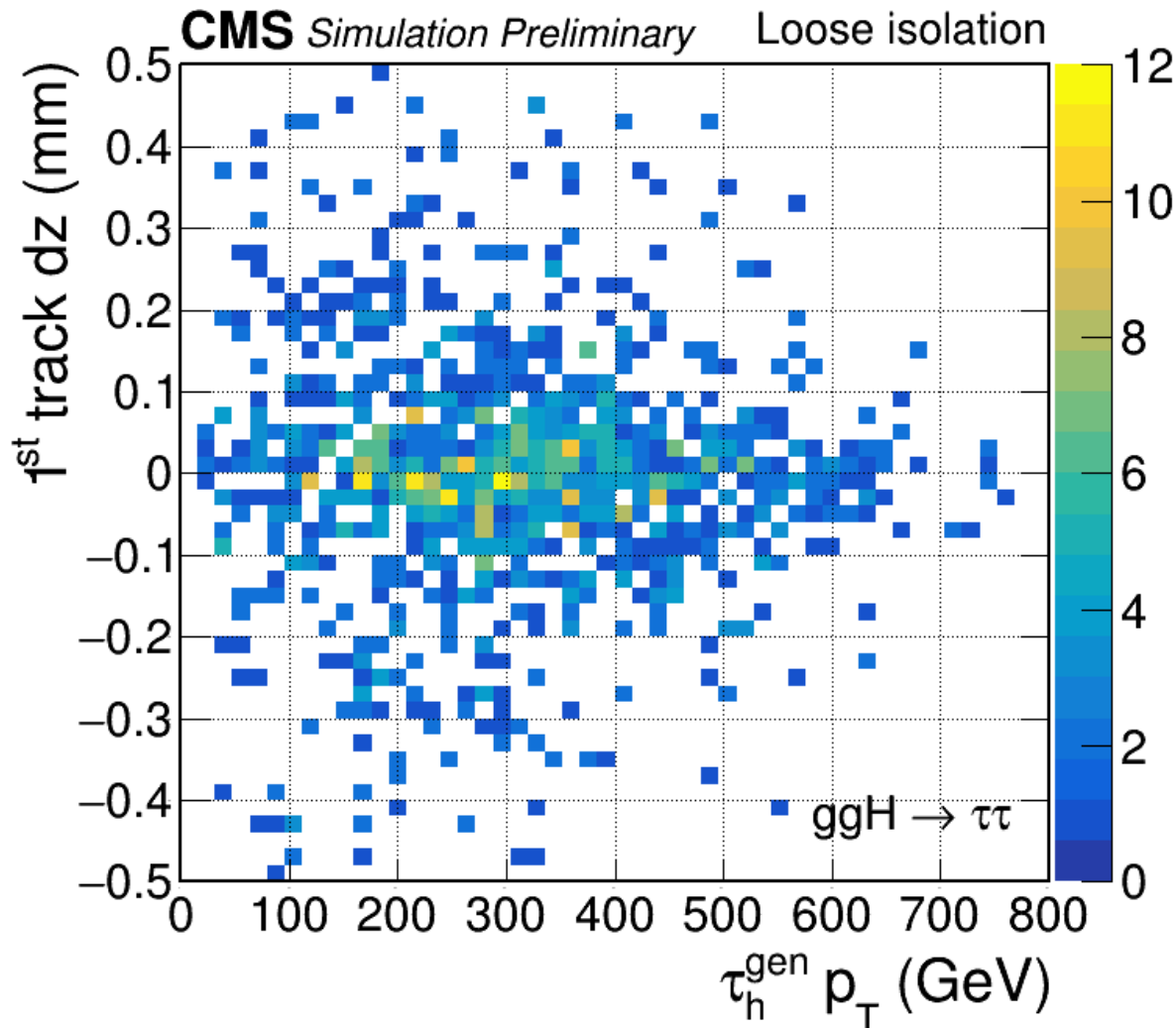


# Good Track vs Failed Track, dxy



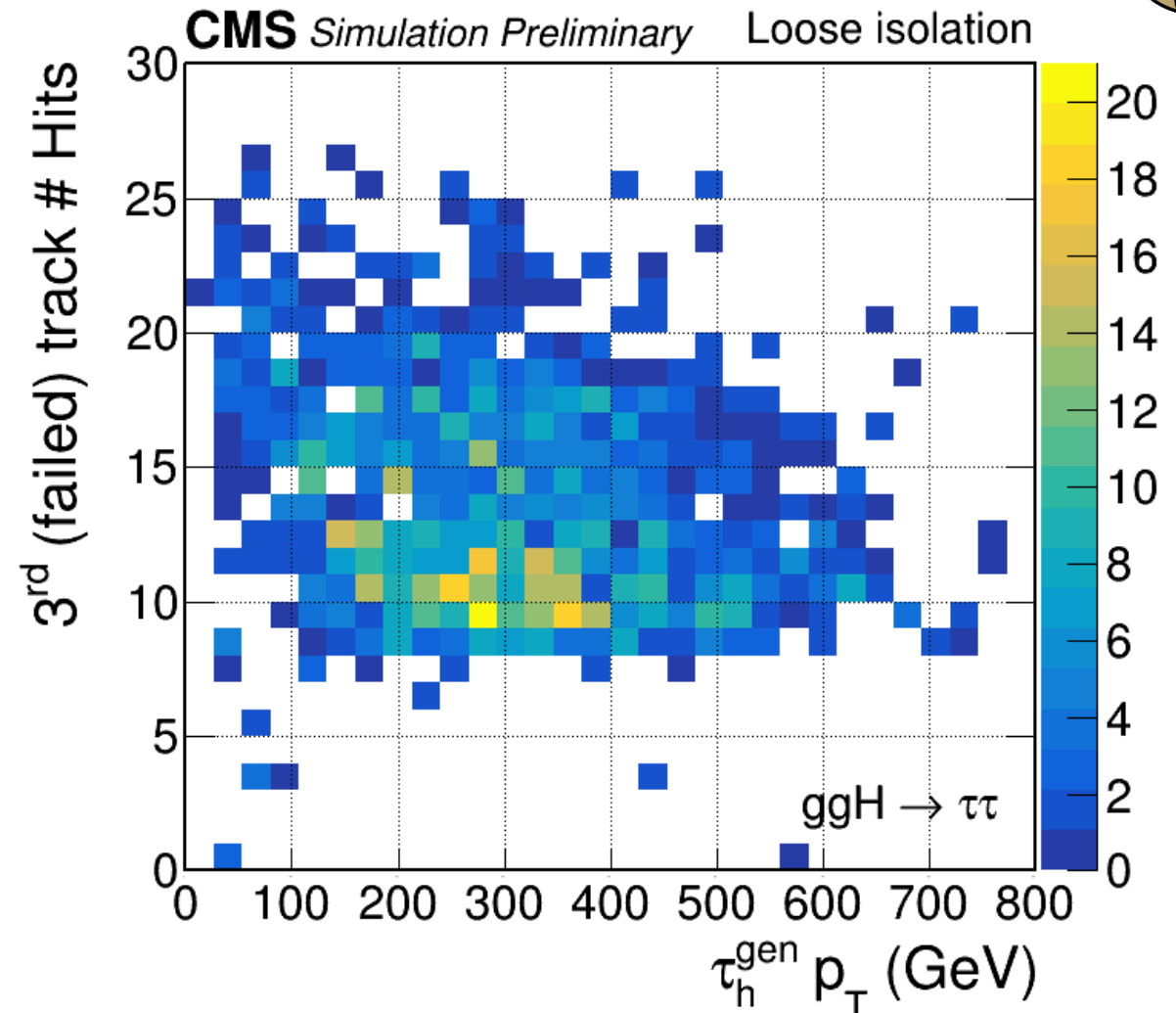
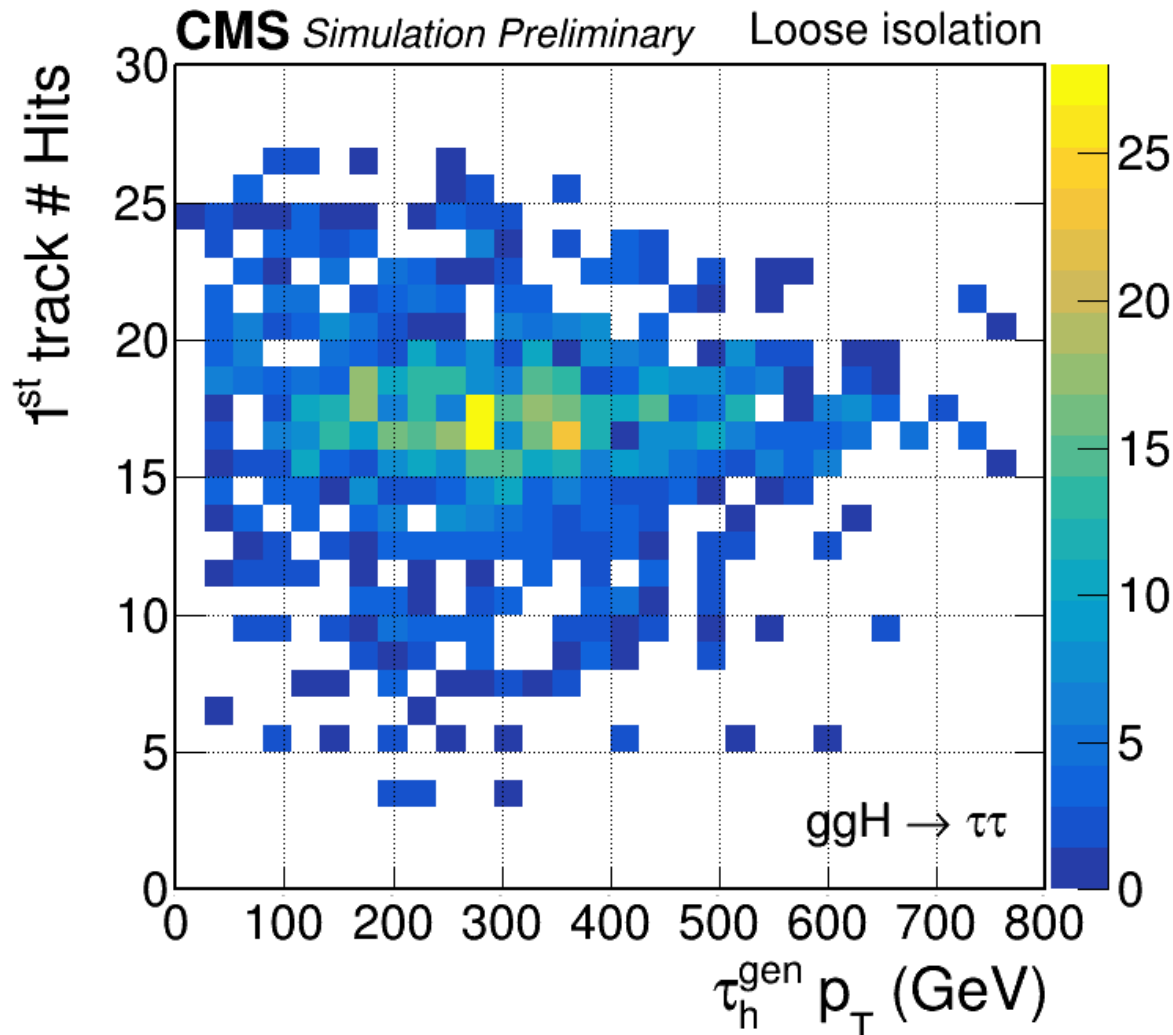


# Good Track vs Failed Track, dz





# Good Track vs Failed Track, # hits



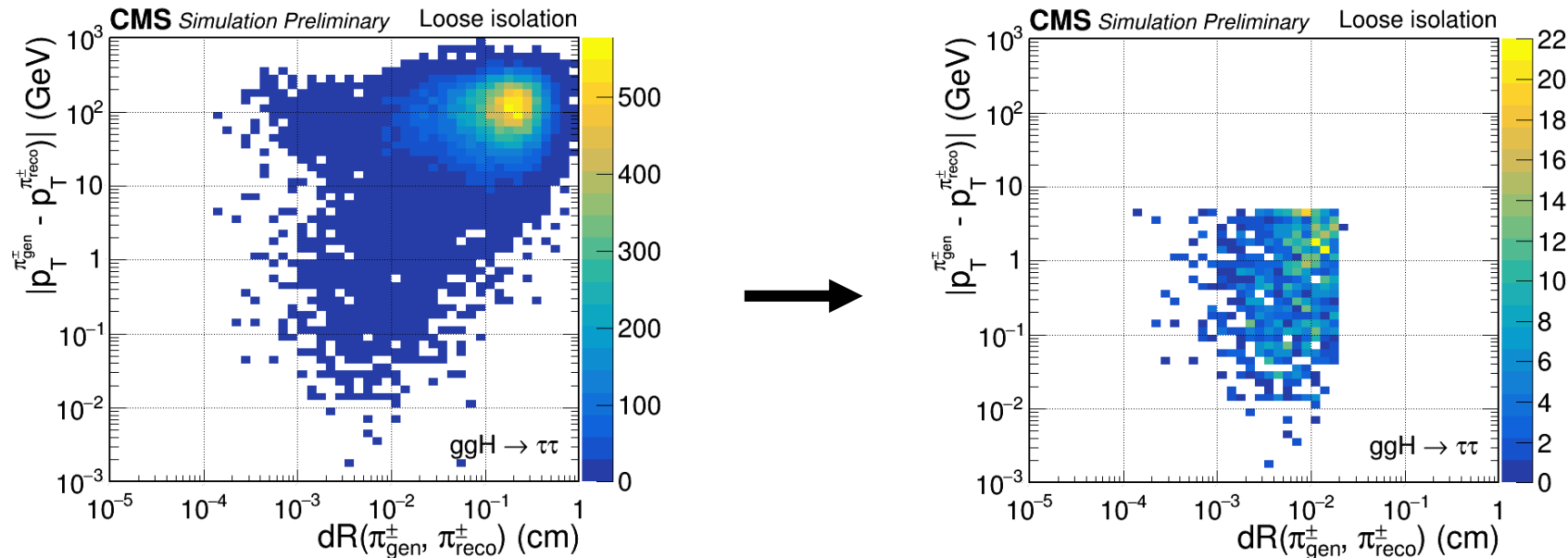


# Discussion

- Although reconstruction mode is strongly dependent on tau  $p_T$ , these plots do not show any correlation between failed track information and  $p_T$ .
- There are clear differences between failed and passing tracks.
  - Greater spread in distance from the primary vertex for failed tracks
  - Lower number of detector hits for failed tracks
- However, these failed tracks closely match their respective generated pions in terms of  $p_T$  and detector position, so we would like to salvage some of them.
- Loosening the tau track quality cuts (e.g. minimum # hits) may allow some to be included in the tau reconstruction.



# Future work: missing tracks



- Of all 3-prong taus being reconstructed as “2-prong” taus, only  $\sim 4\%$  meet the failed track criteria.
- This other  $\sim 96\%$  may be poorly reconstructed or merged with another object into a signal PF candidate.
- Further investigation into these missing tracks could benefit tau efficiencies.







# Many thanks to the National Science Foundation

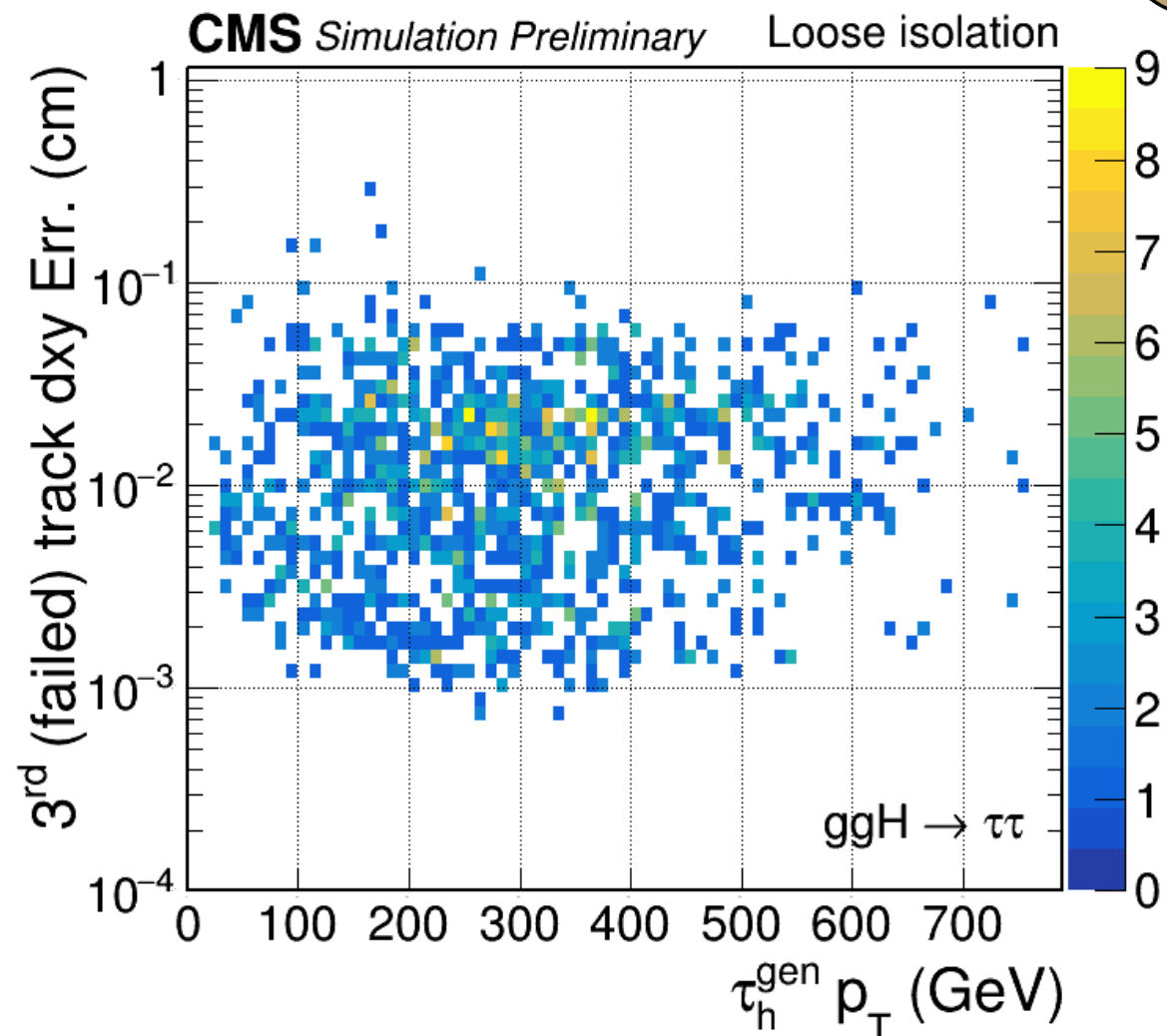
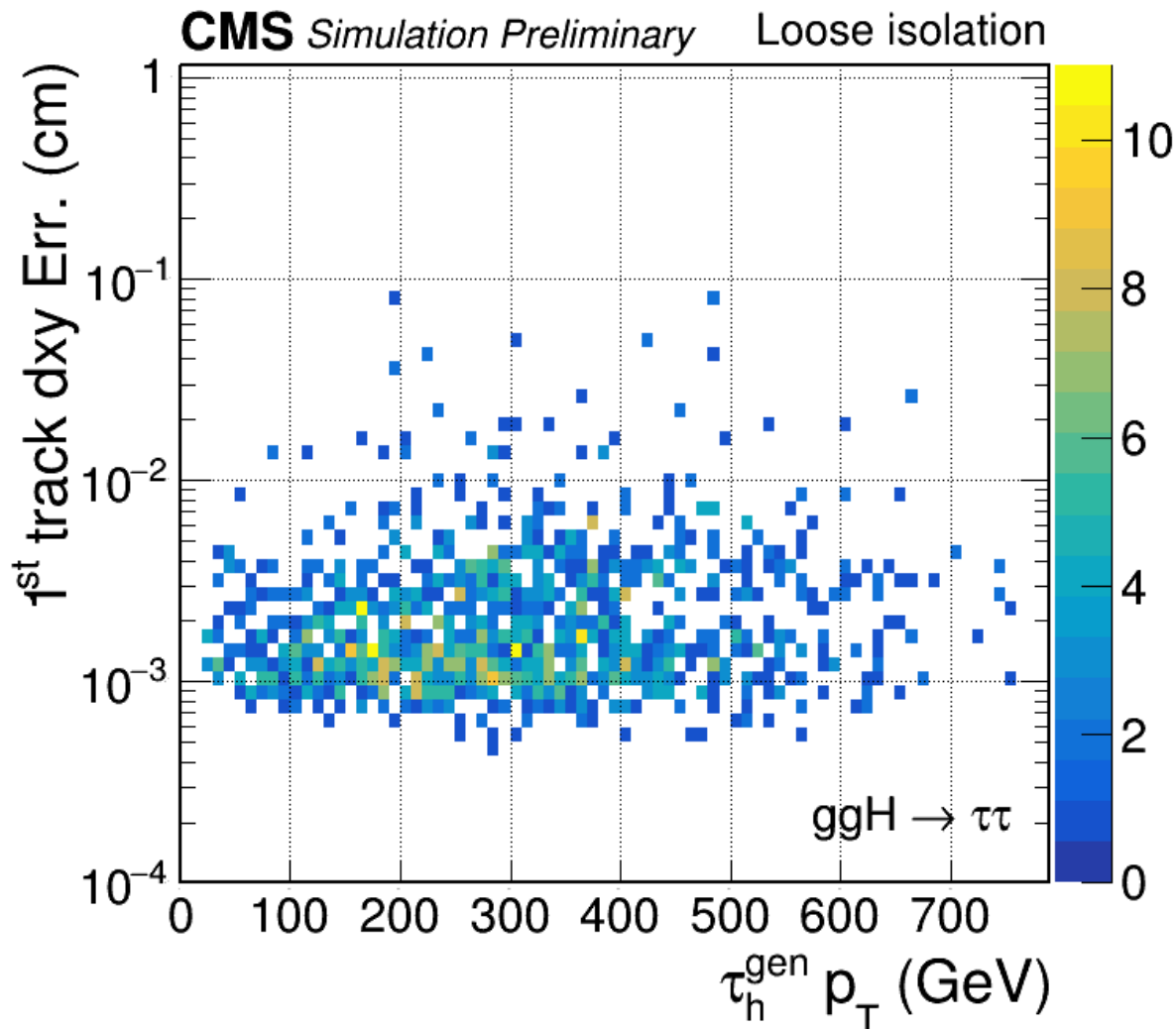
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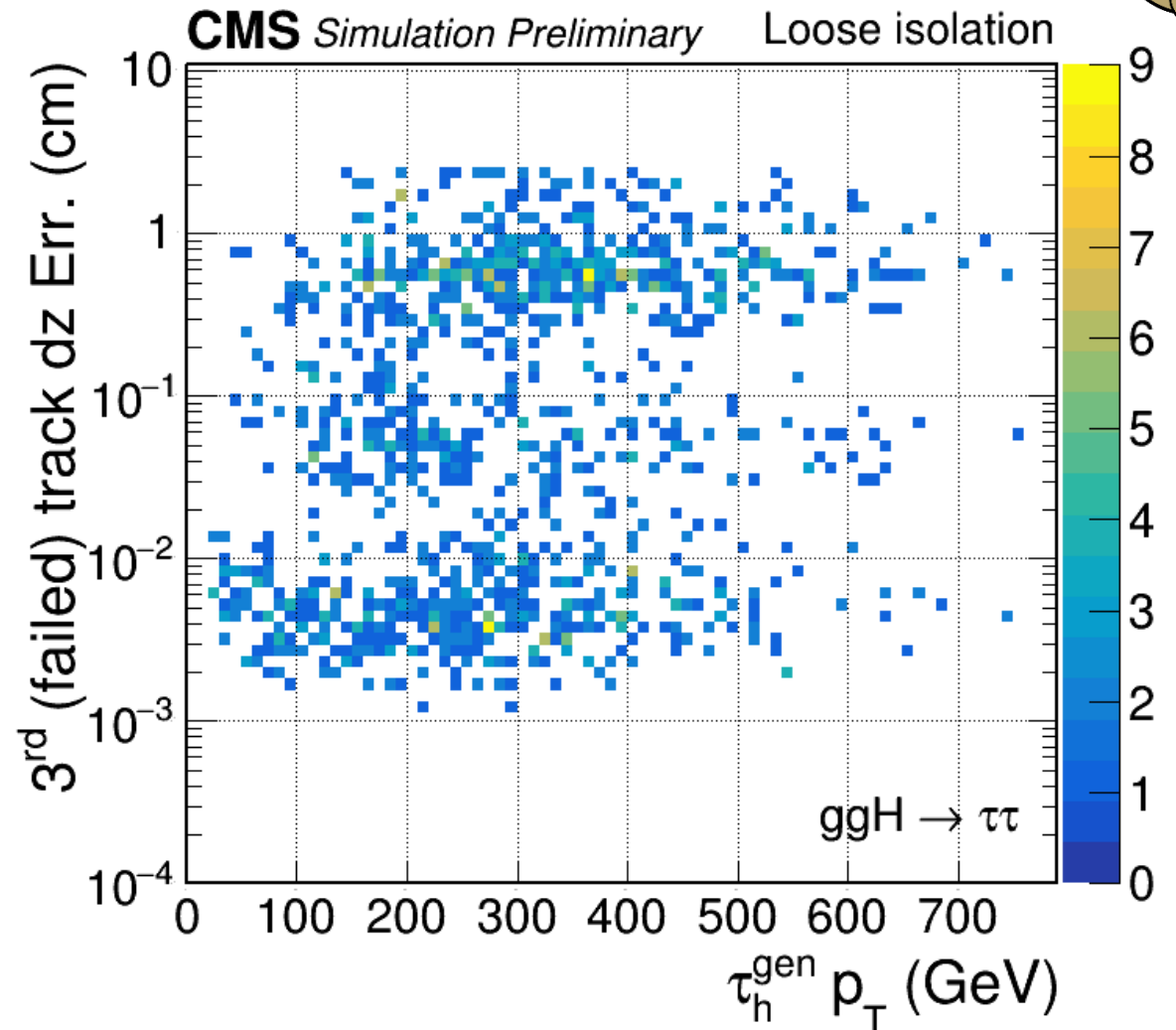
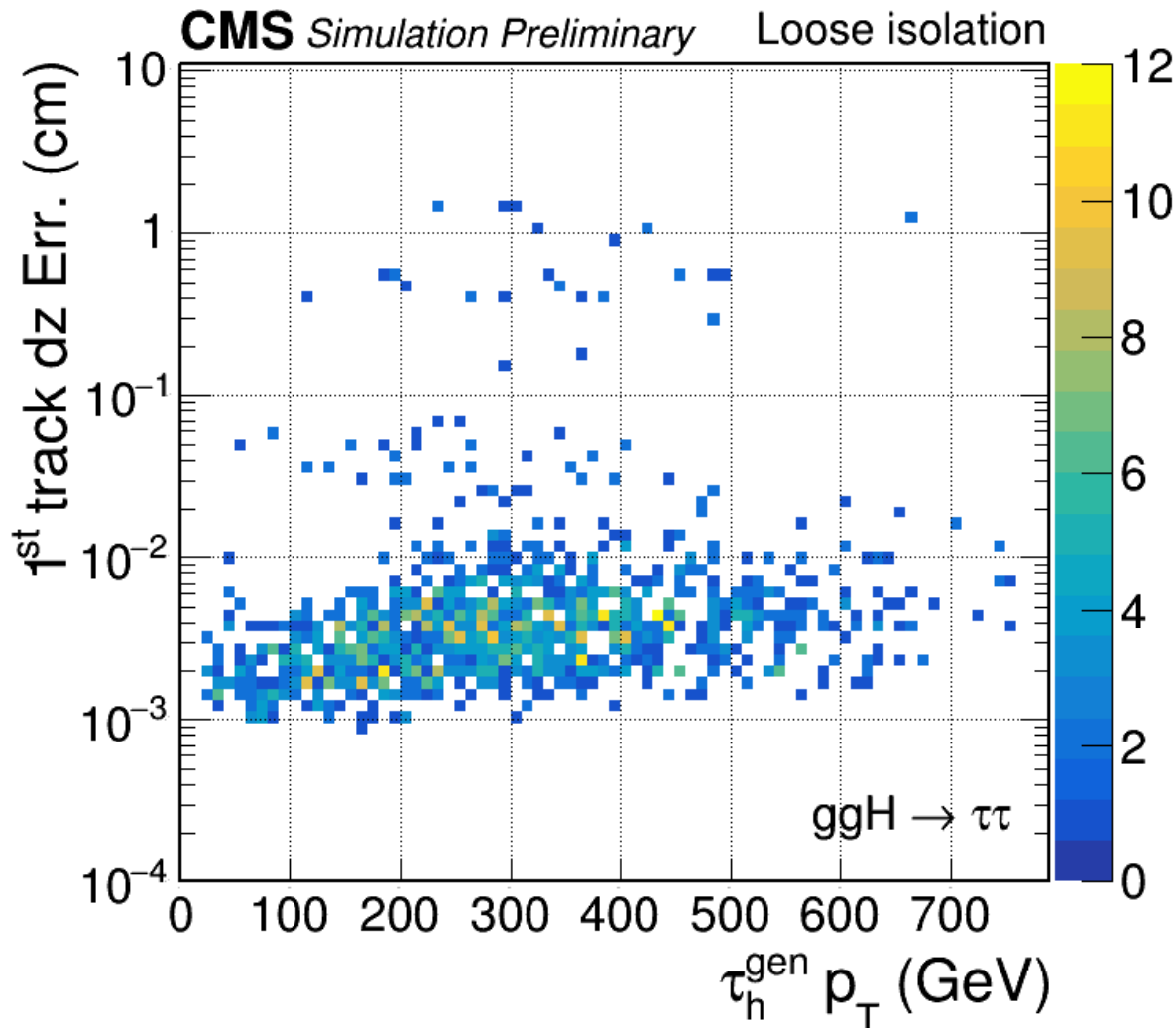


# Good track vs failed track, dxy error





# Good track vs failed track, dz error





# Good track vs failed track, detector hits

