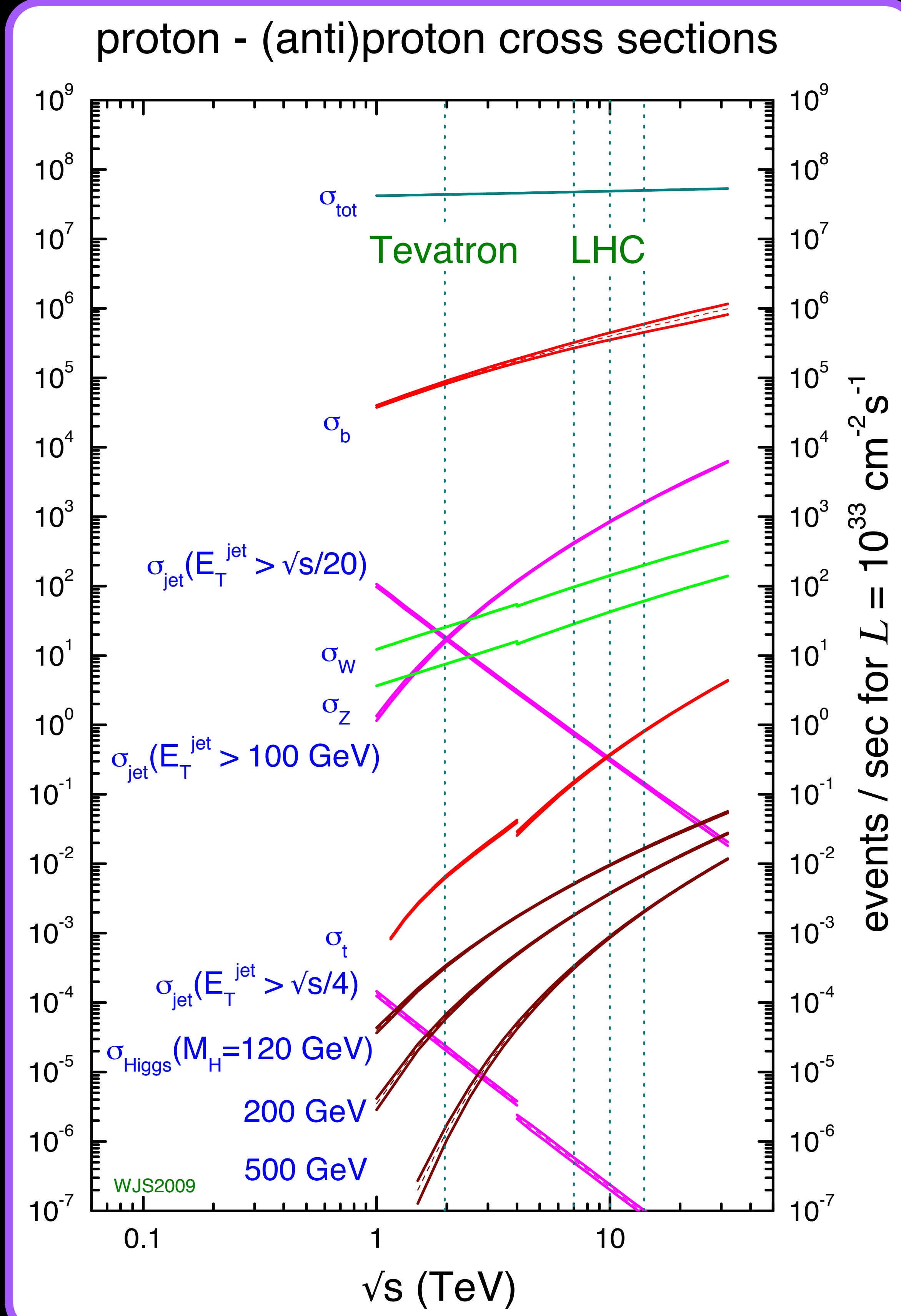
# Tau Reconstruction and Identification in CMS

Evan Friis
on behalf of the CMS Collaboration

UC DAVIS
UNIVERSITY OF CALIFORNIA

# Tau ID at hadron colliders

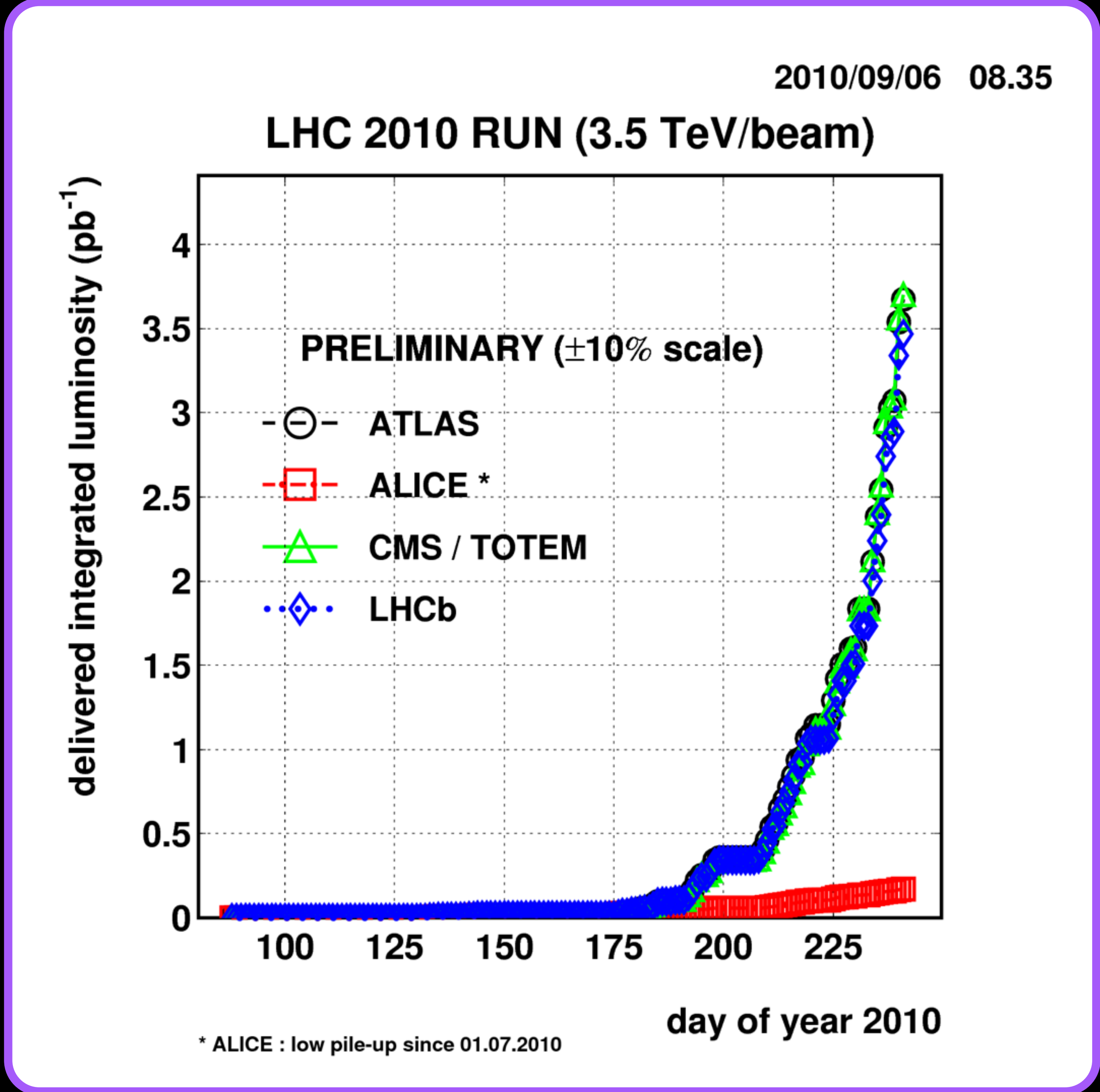
- Many exciting new physics signals could appear in tau channels
- QCD background is very large!
- Dominant background in many analyses is fake taus



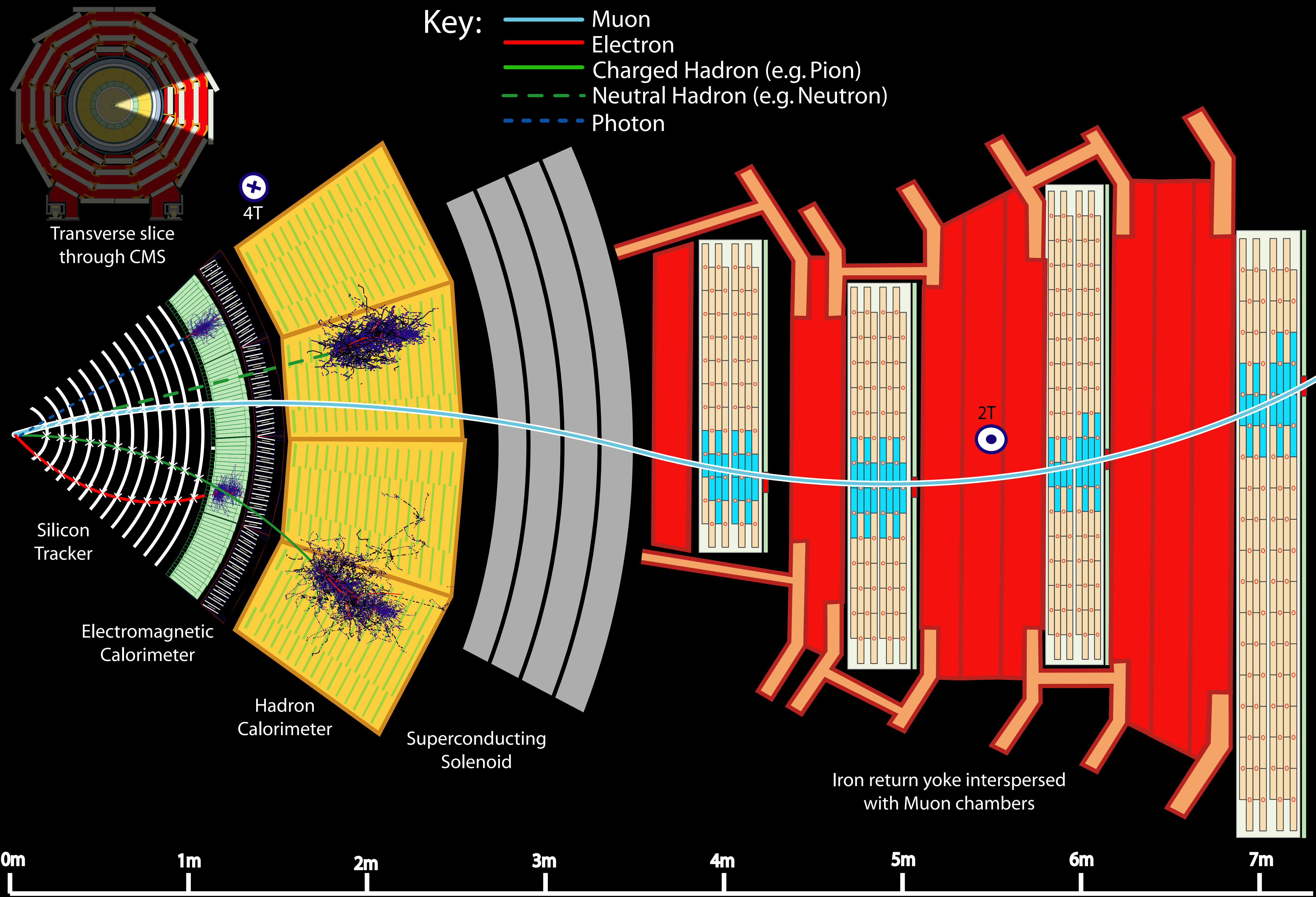

http://projects.hepforge.org/mstwpdf/plots/plots.html

# The Large Hadron Collider

- ~3.7 $pb^{-1}$ delivered
- $\sqrt{s}$ = 7 TeV for 2011
  - expect 1 $fb^{-1}$
  - O(10k) of real taus!
- Shutdown at end of 2011
  - Upgrade to $\sqrt{s}$ = 14 TeV



# Compact Muon Solenoid



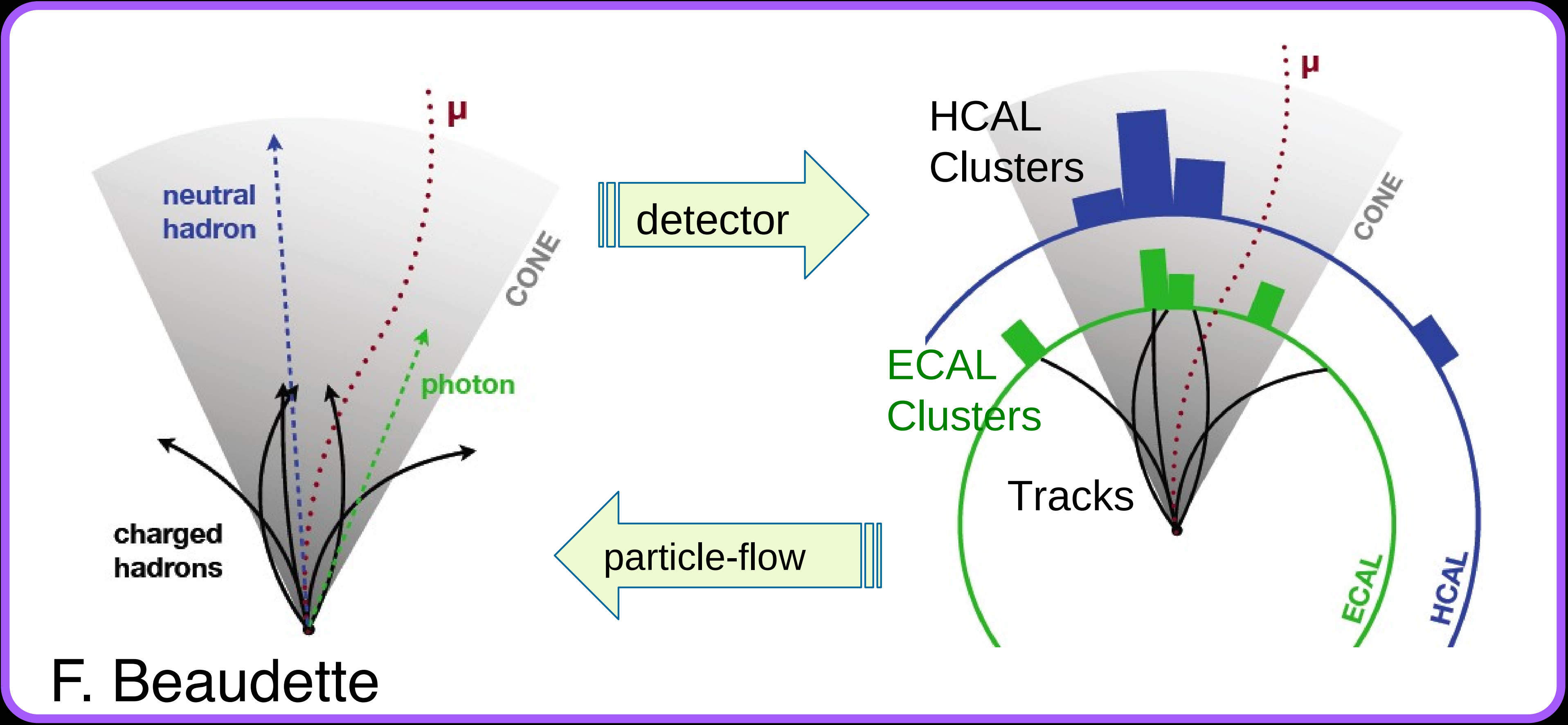
# Particle Flow Algorithm

taus in CMS are built using Particle Flow objects

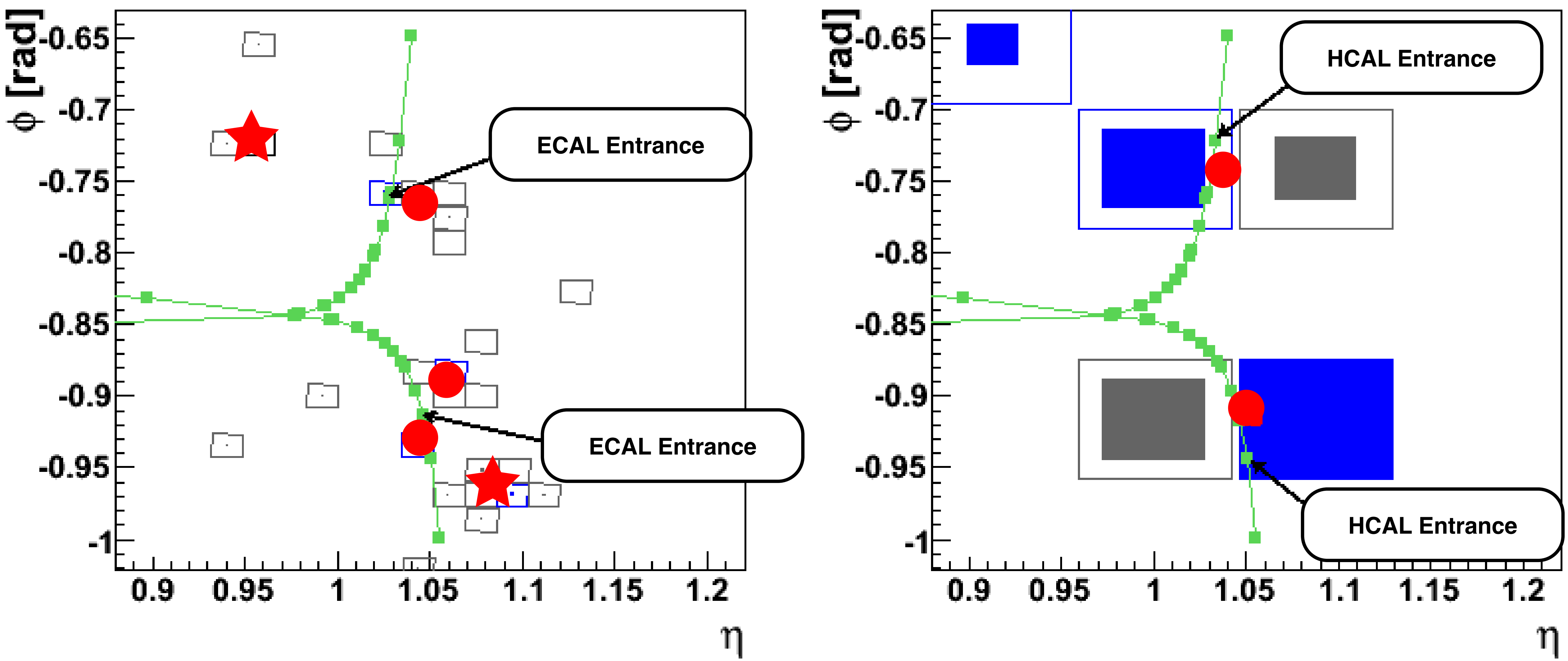
- Clusters and links signals from all subdetectors
- Produces a list of particle candidates

$$h \; h^0 \; e \; \mu \; \gamma$$

- To the user looks just like Monte Carlo



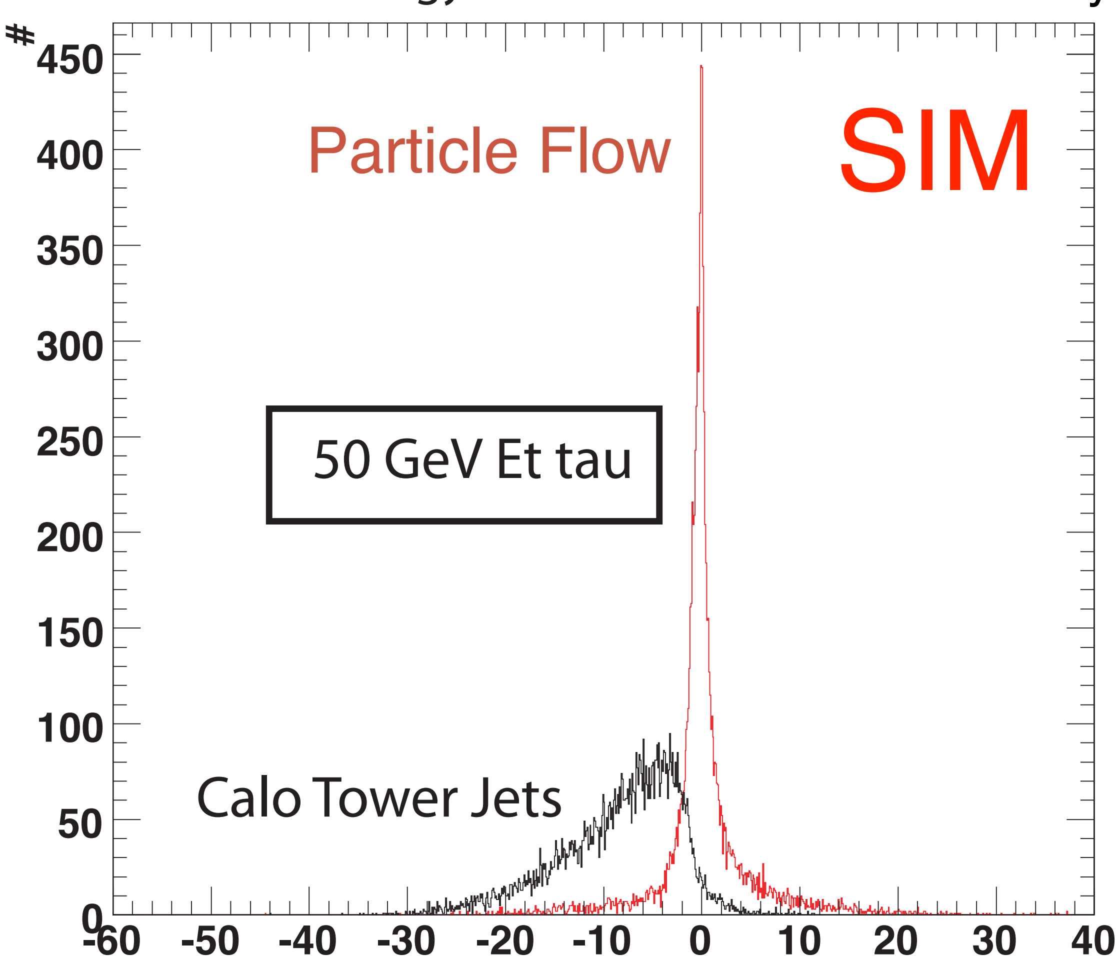
# Particle Flow Algorithm




- cluster linked to track
- unlinked cluster
- tracker hit

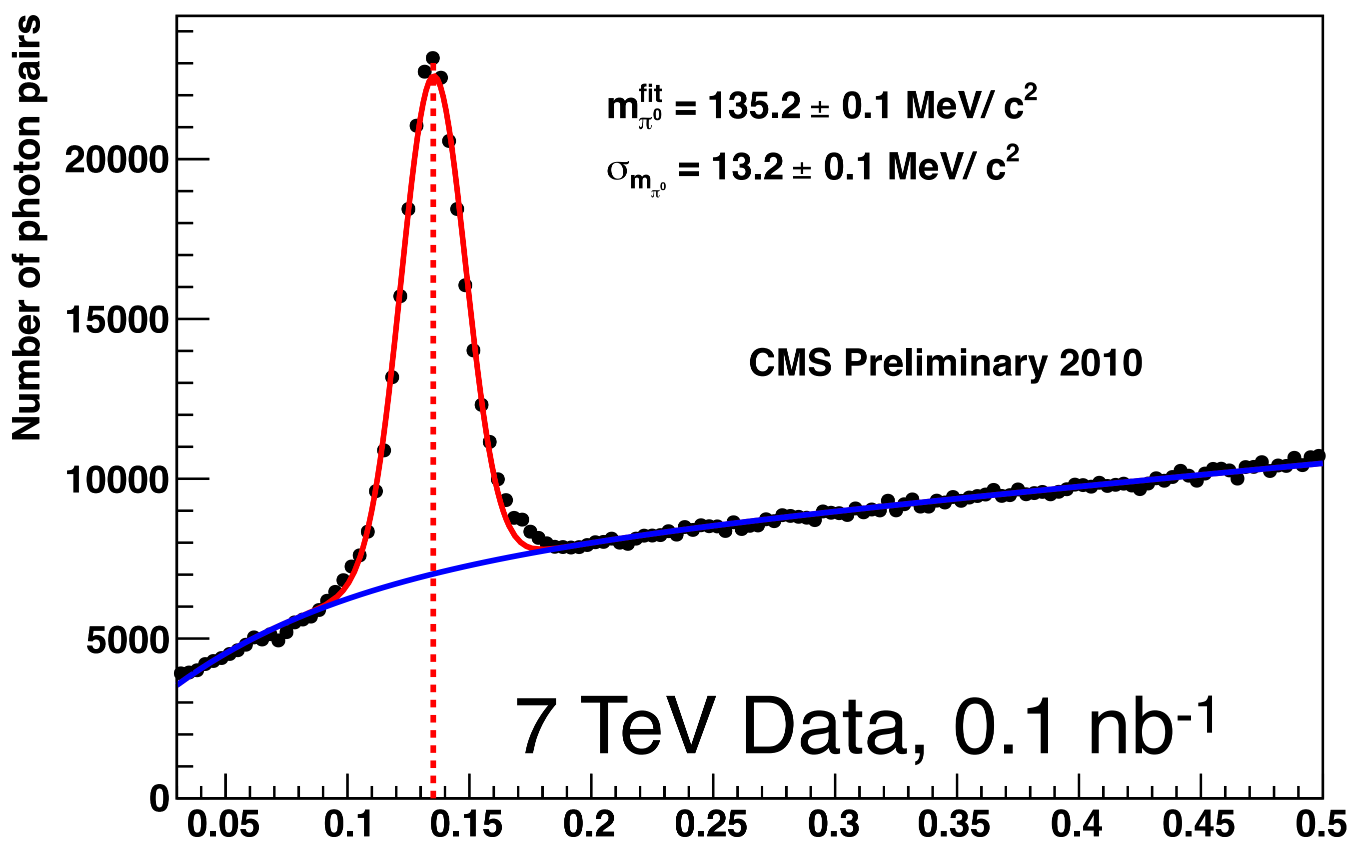
see CMS PAS PFT-10-002

# Particle Flow Performance




Tau $E_T$ resolution

invariant mass of PF photon pairs




Mass of photon pair [GeV/$c^2$]

# Traditional CMS Tau ID

geometrically defined isolation

define geometric region around tau
candidate and require low detector activity

relies on the fact that taus
are more collimated than QCD

CMS Physics TDR results use these algorithms

presented today: “shrinking cone” algorithm

see CMS PAS PFT-08-001

# Shrinking Cone Algorithm

## reduce QCD by applying isolation requirement

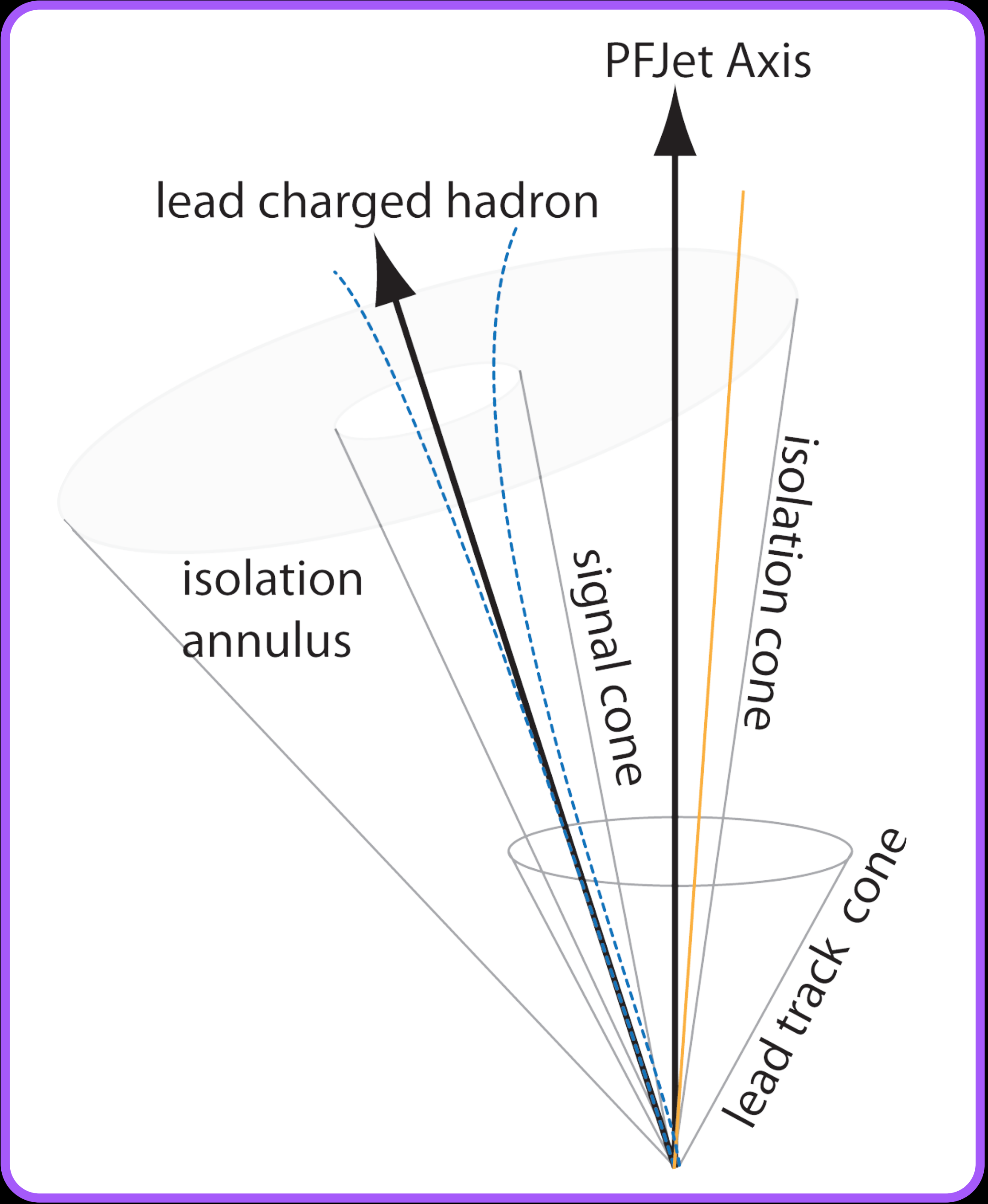
require a *leading candidate* with $p_T > 5$ within $\Delta R < 0.1$ of jet axis

signal objects are those with $\Delta R < \Delta R_{sig}$ of the lead candidate

$$\Delta R_{sig} = 5.0/E_T^{jet}$$

isolation objects are those in the region $\Delta R_{sig} < \Delta R < 0.5$ about the lead candidate

$$\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$$



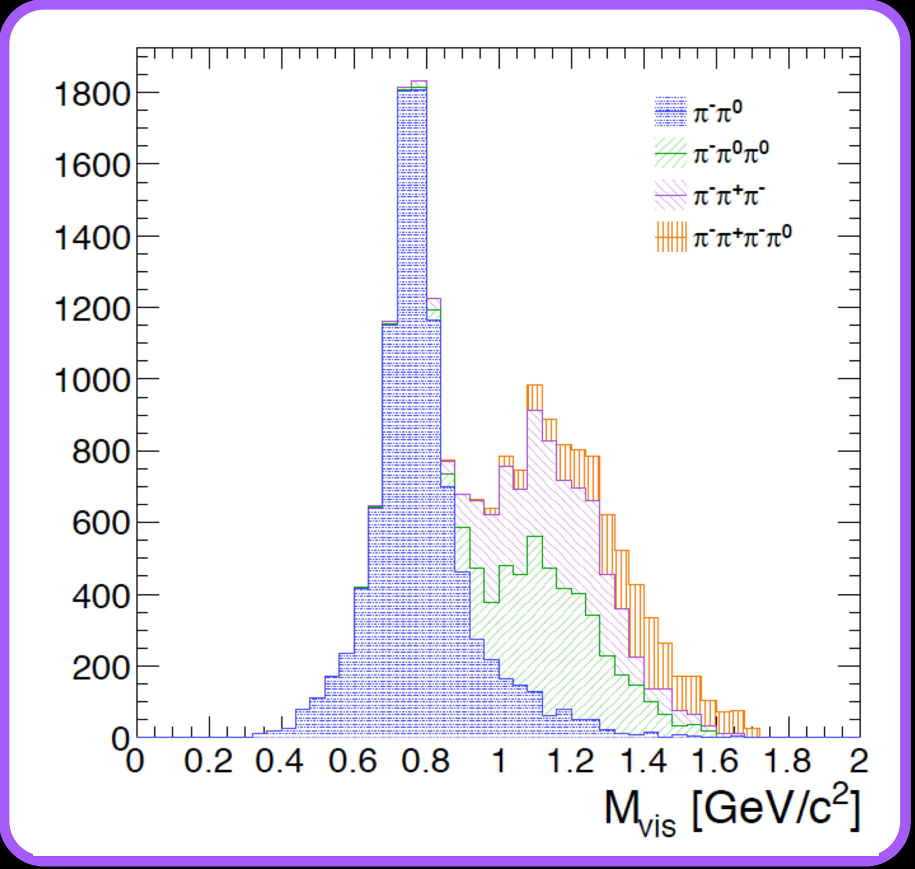
# Decay Mode CMS Tau ID

Particle Flow algorithm allows examination of meson content

two new algorithms:

Hadrons Plus Strips (HPS) algorithm

Tau Neural Classifier (TaNC) algorithm

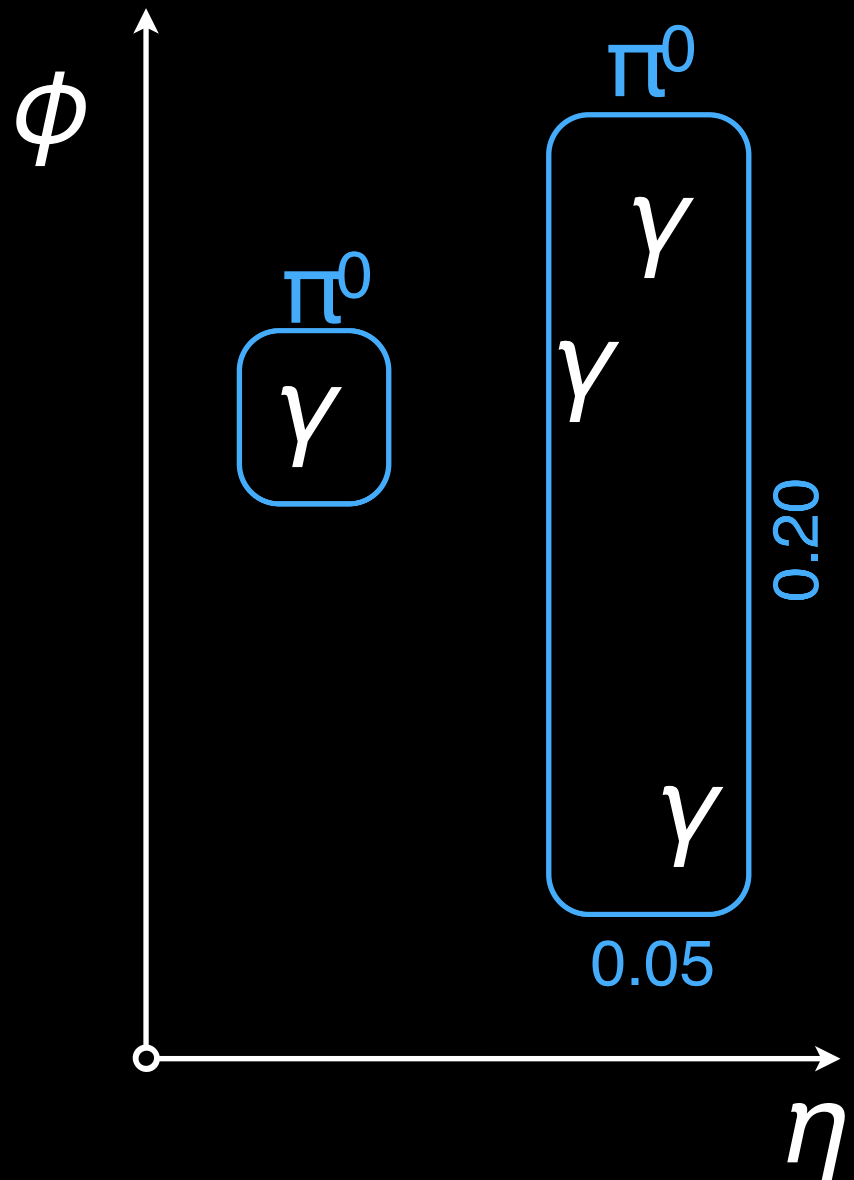



GOAL:
optimize tau identification for individual tau decay modes

# Hadrons Plus Strips Algorithm

build signal components combinatorially

cluster gammas into $\pi^0$ candidates using η-ϕ strips




build all possible taus that have a ‘tau-like’ multiplicity from the seed jet

$\pi^+$

$\pi^+ \pi^0$

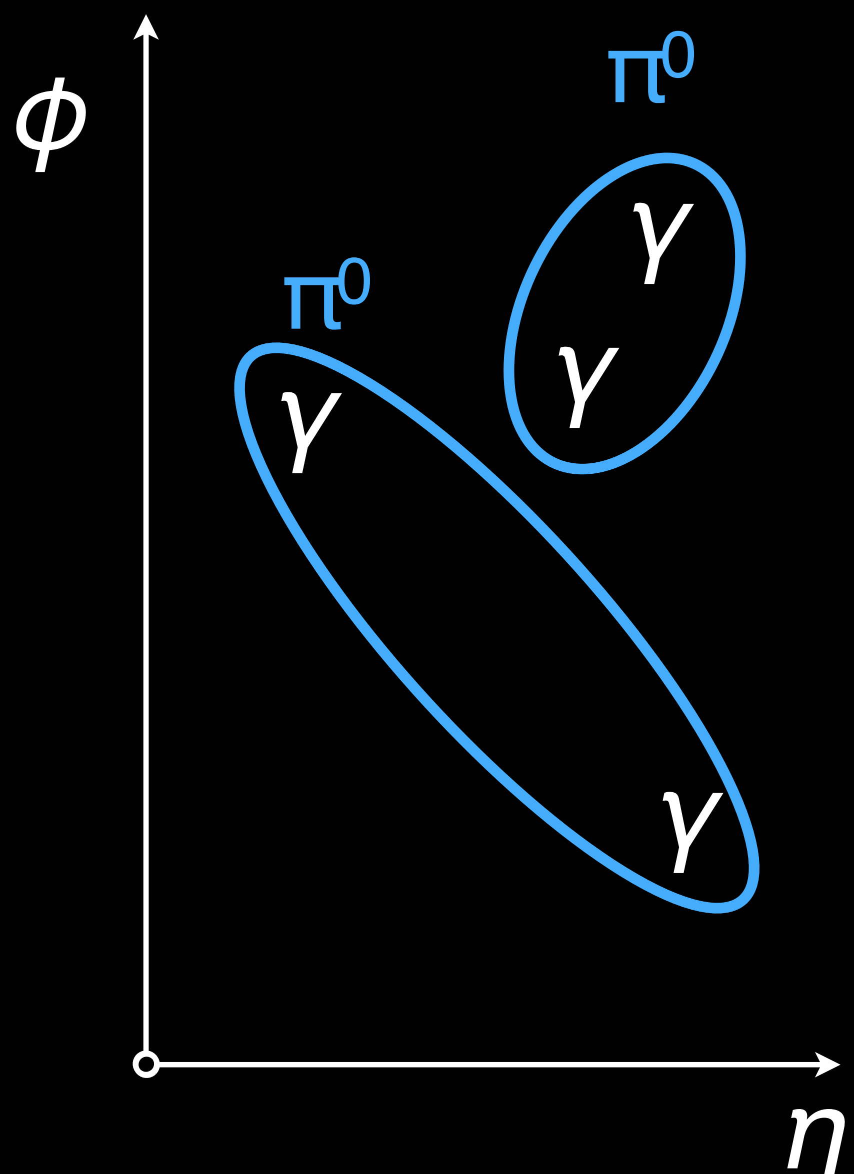
$\pi^+ \pi^+ \pi^-$

tau that is ‘most isolated’ with compatible $m_{vis}$ is the final tau candidate associated to the seed jet

# Tau Neural Classifier

## a neural network for each decay mode

cluster gammas into $\pi^0$ candidates by combinatoric pairs compatible with $m_{\pi 0}$




signal objects are defined using shrinking cone

depending on decay mode

$\pi^+$

$\pi^+ \pi^0$

$\pi^+ \pi^0 \pi^0$

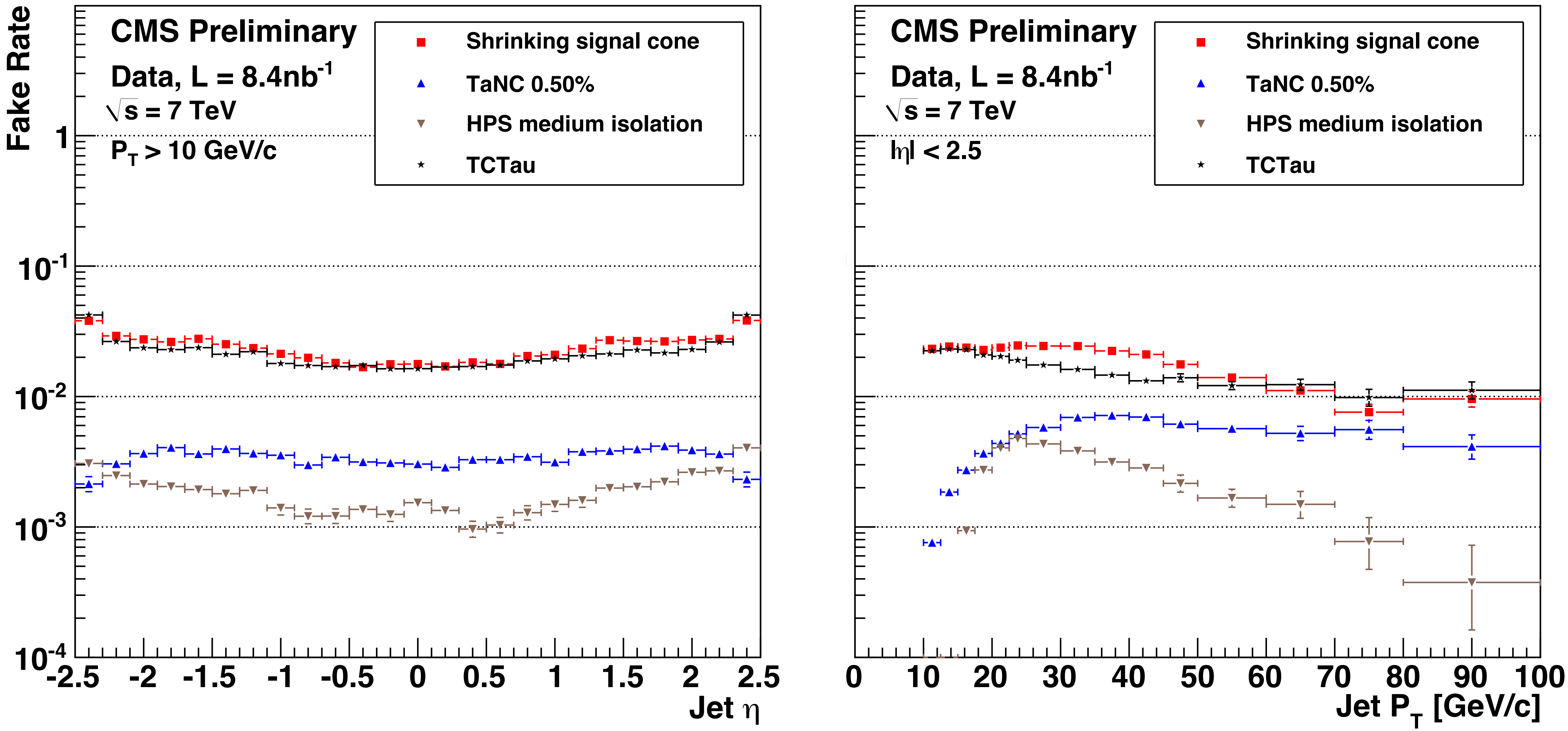
$\pi^+ \pi^+ \pi^-$

$\pi^+ \pi^+ \pi^- \pi^0$

a different neural network is applied!

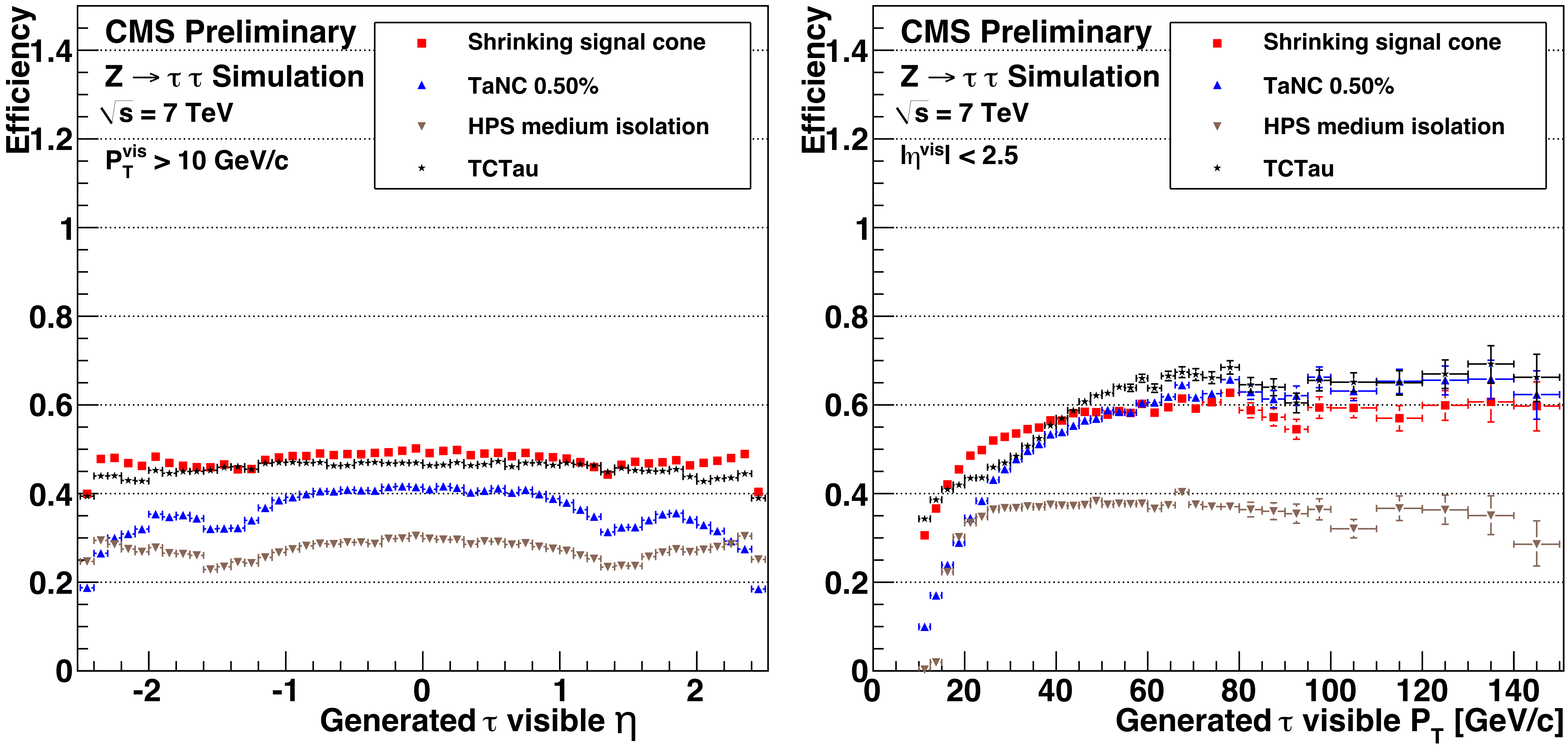
# Fake Rates

7 TeV, 8.4 $nb^{-1}$

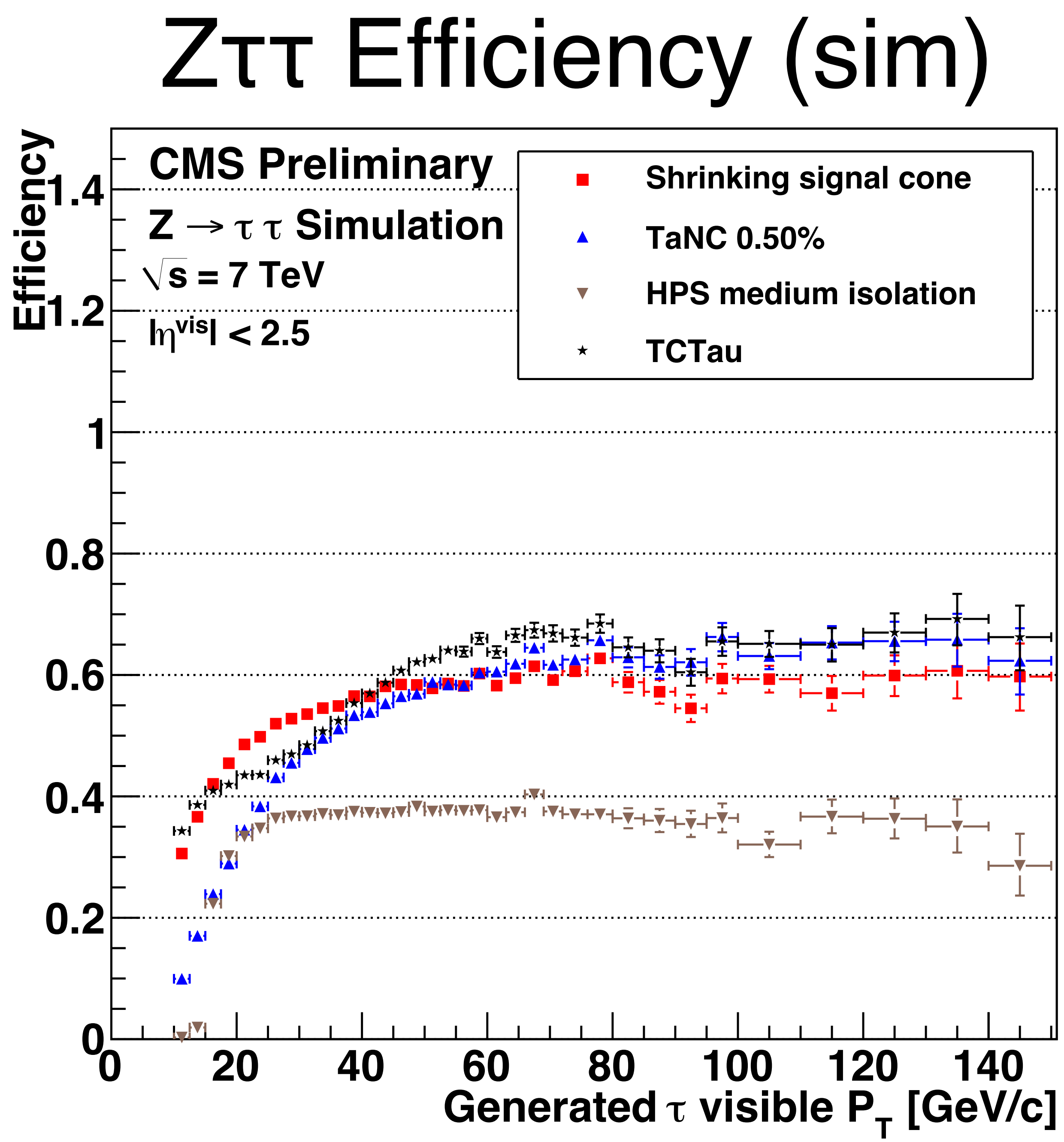


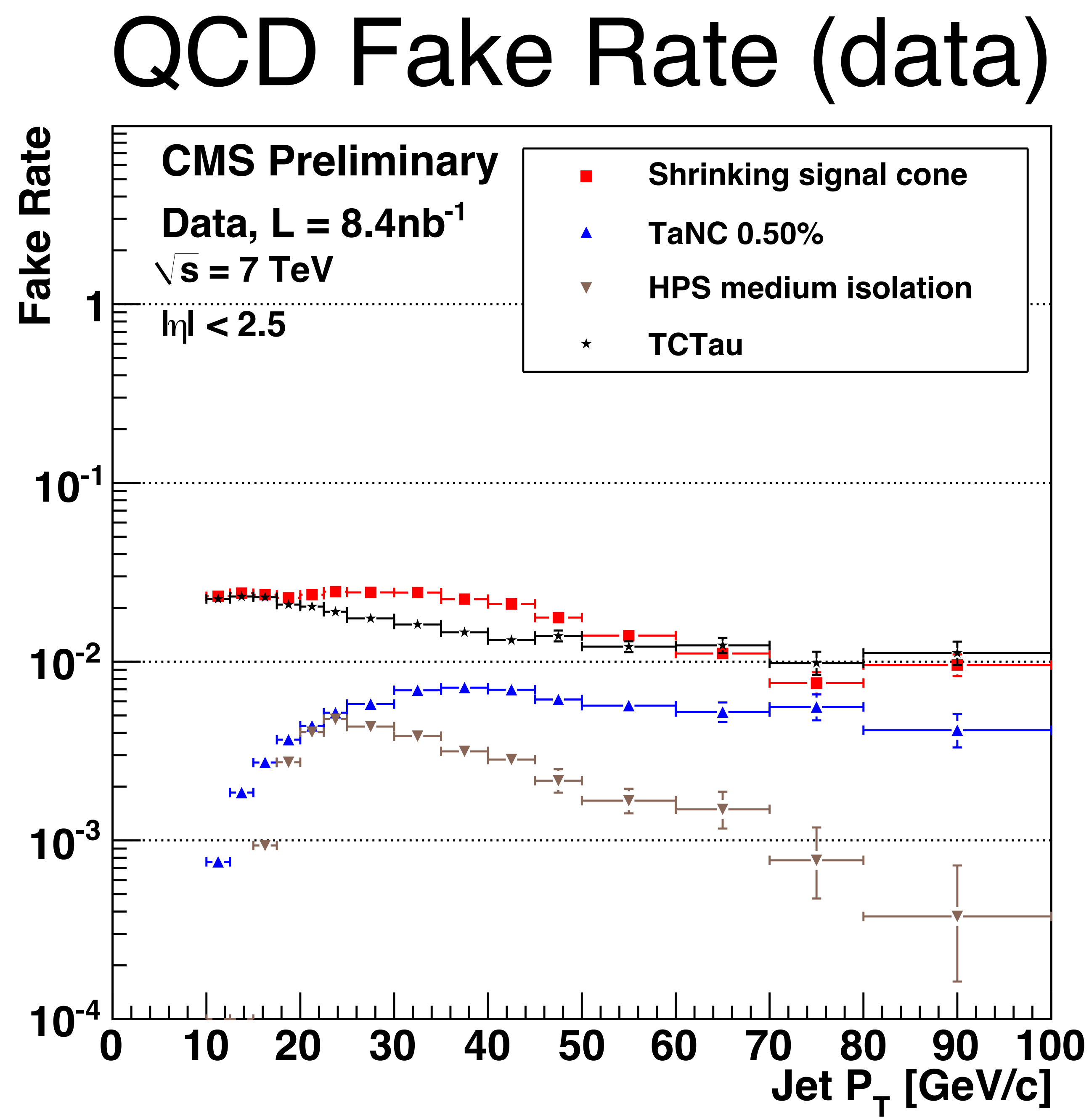
# Zττ efficiencies

simulation



# Efficiency vs. Fake Rate



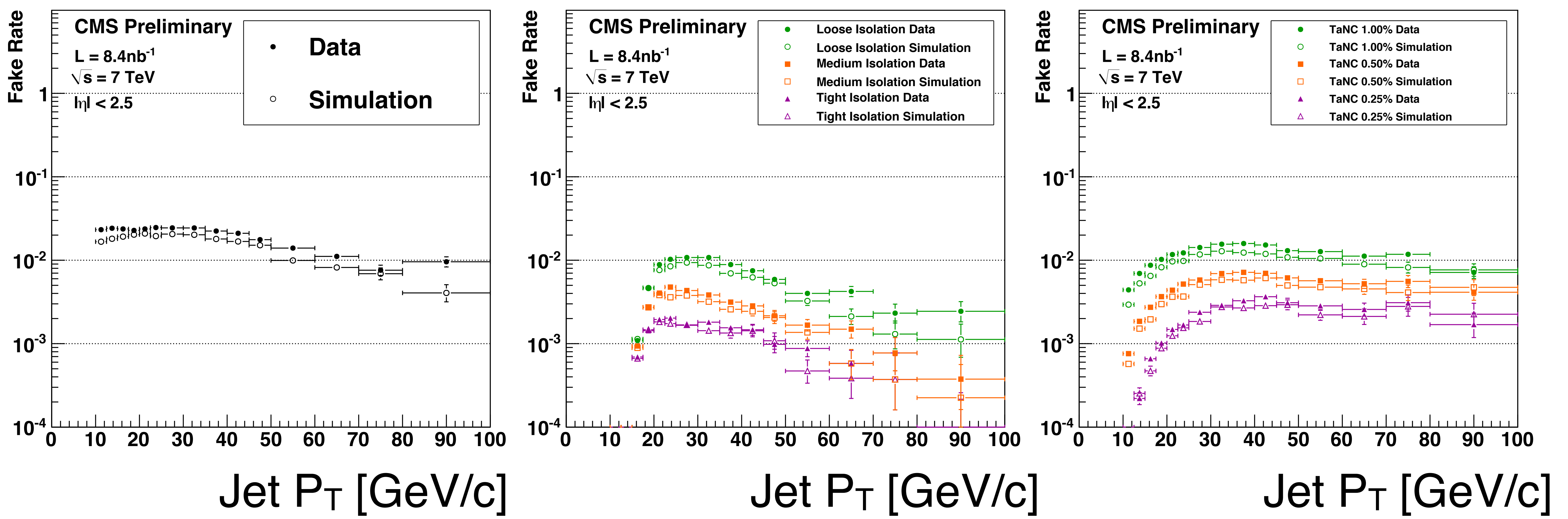




decay mode algorithms preserve high τ efficiency while lowering fake rate by 5 to 10 times

# Comparison to Monte Carlo

measured fake rates versus Pythia 8 dijet simulation

shrinking cone HPS TaNC

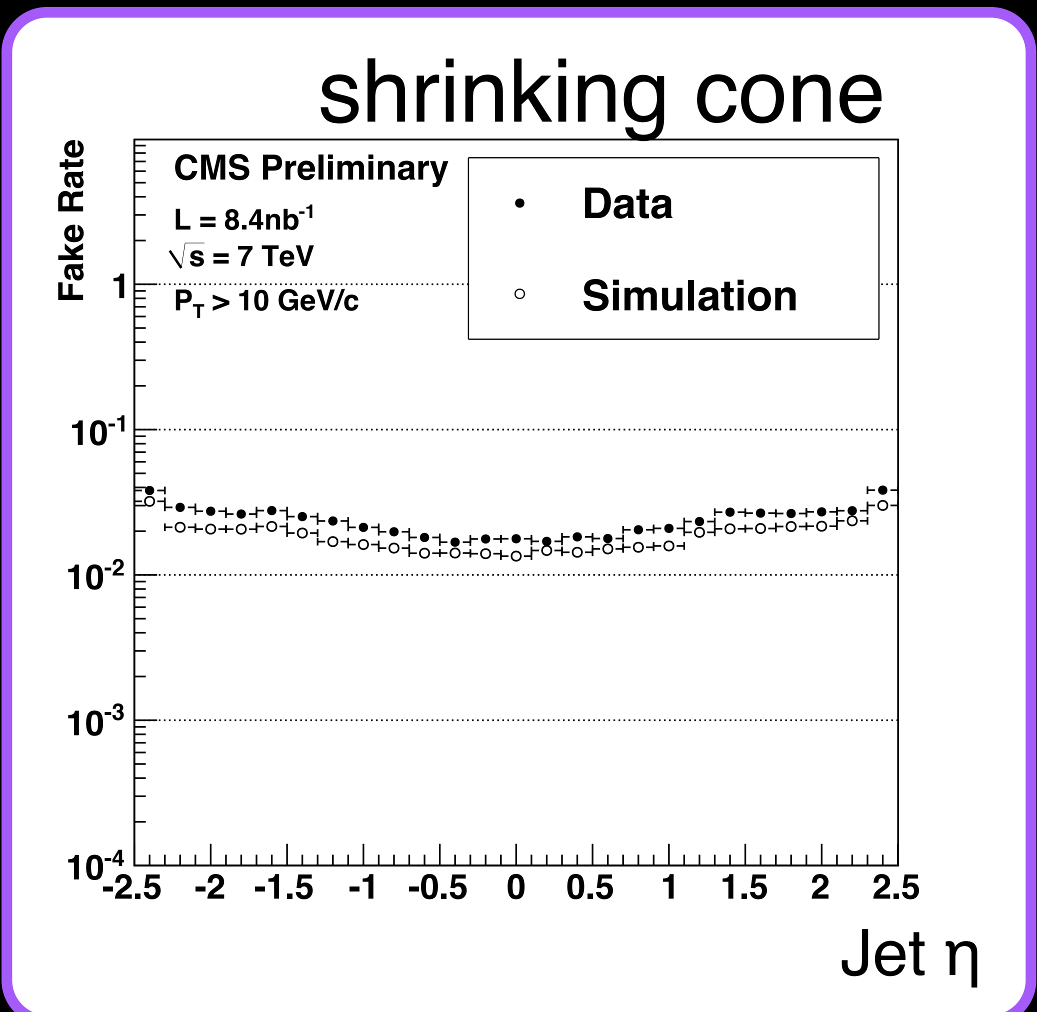


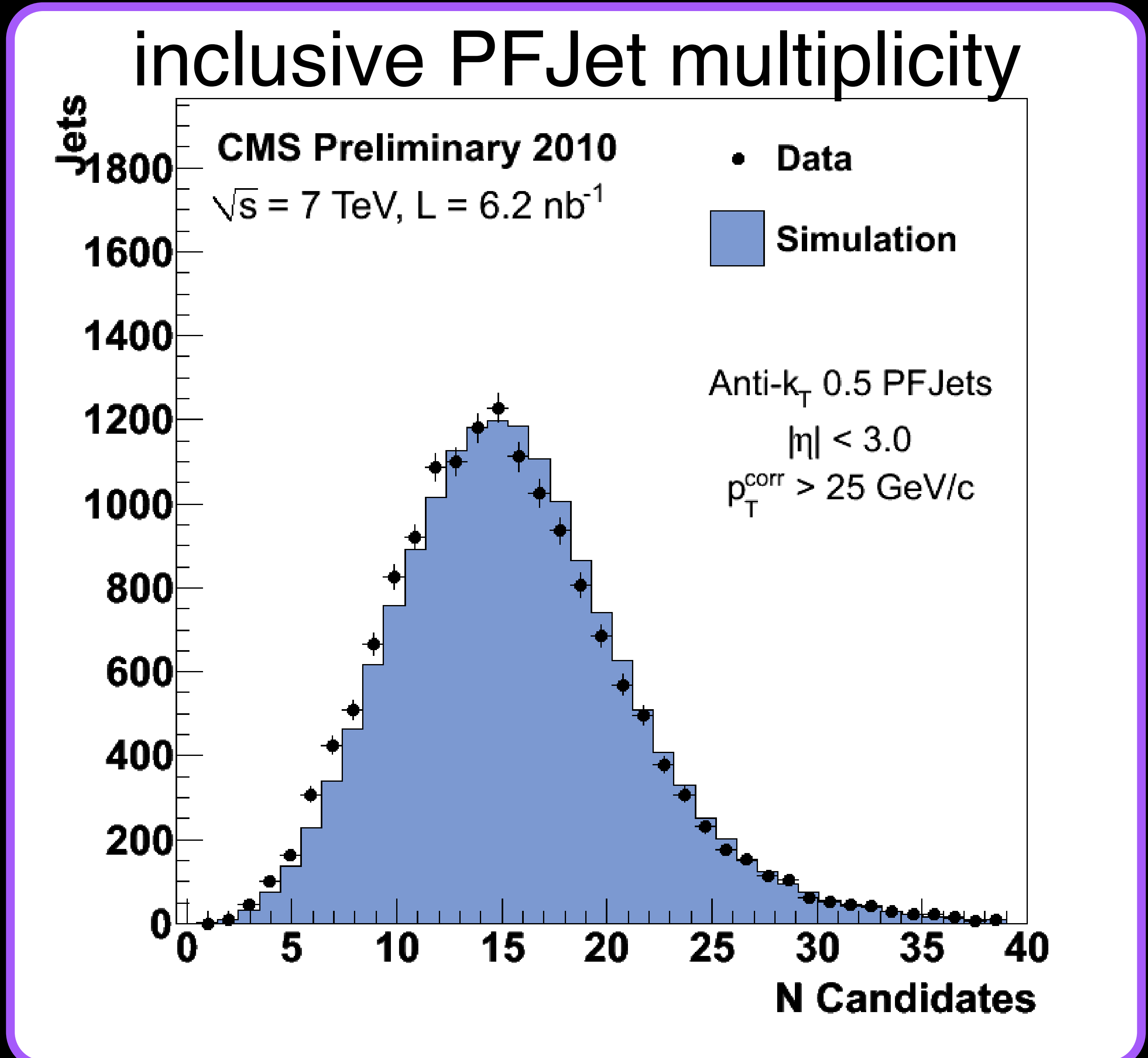

MC simulation underestimates fake rate by 20-30%

all algorithms affected

# Comparison to Monte Carlo

effect does not depend on η



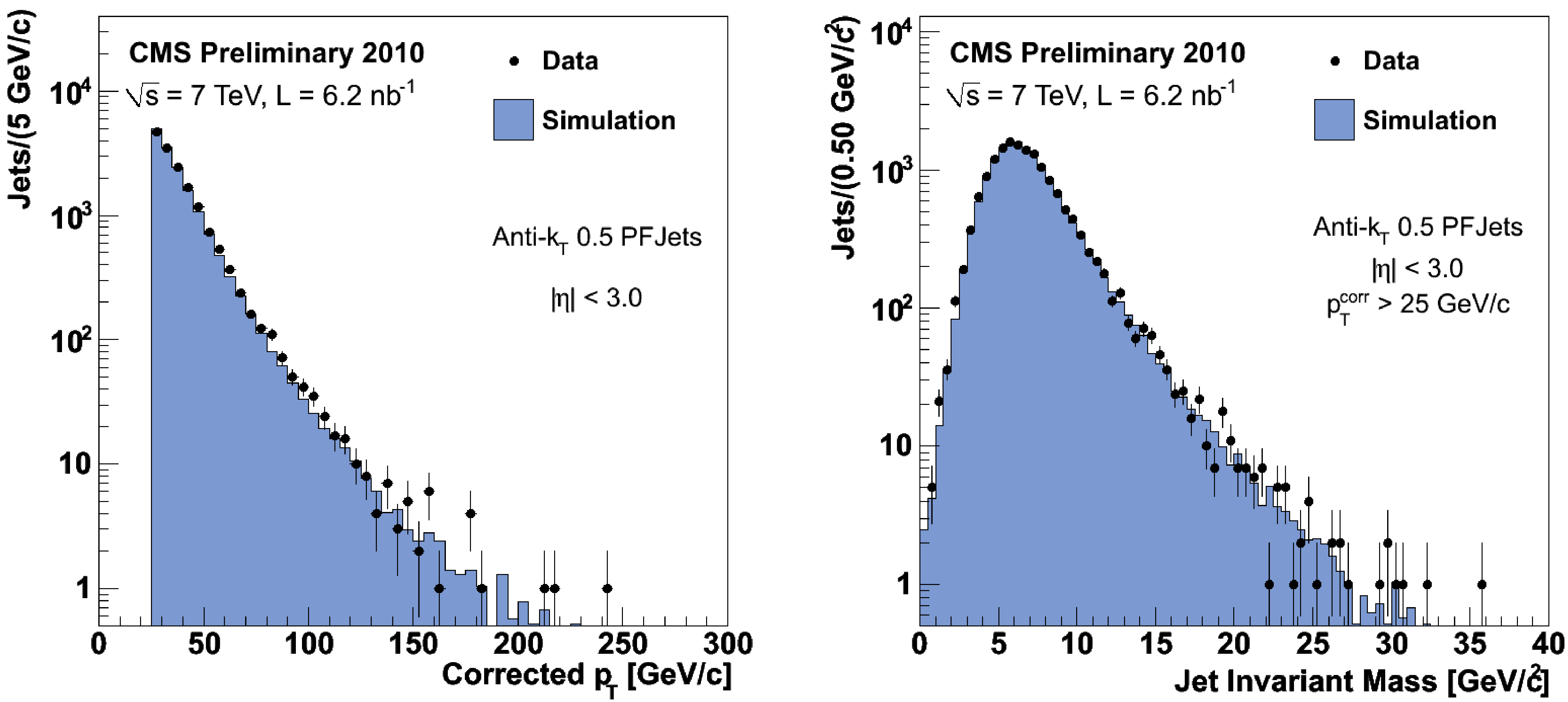

preliminary studies indicate disagreement due to Monte Carlo hadronization modeling

# Summary

- CMS Particle Flow algorithm has been commissioned with data
- Advanced tau identification algorithms have reduced QCD fake rate by ~5X for similar signal efficiency
- Tau ID fake rate measurements within 20-30% of MC prediction
- Investigations into effect of MC QCD hadronization model ongoing

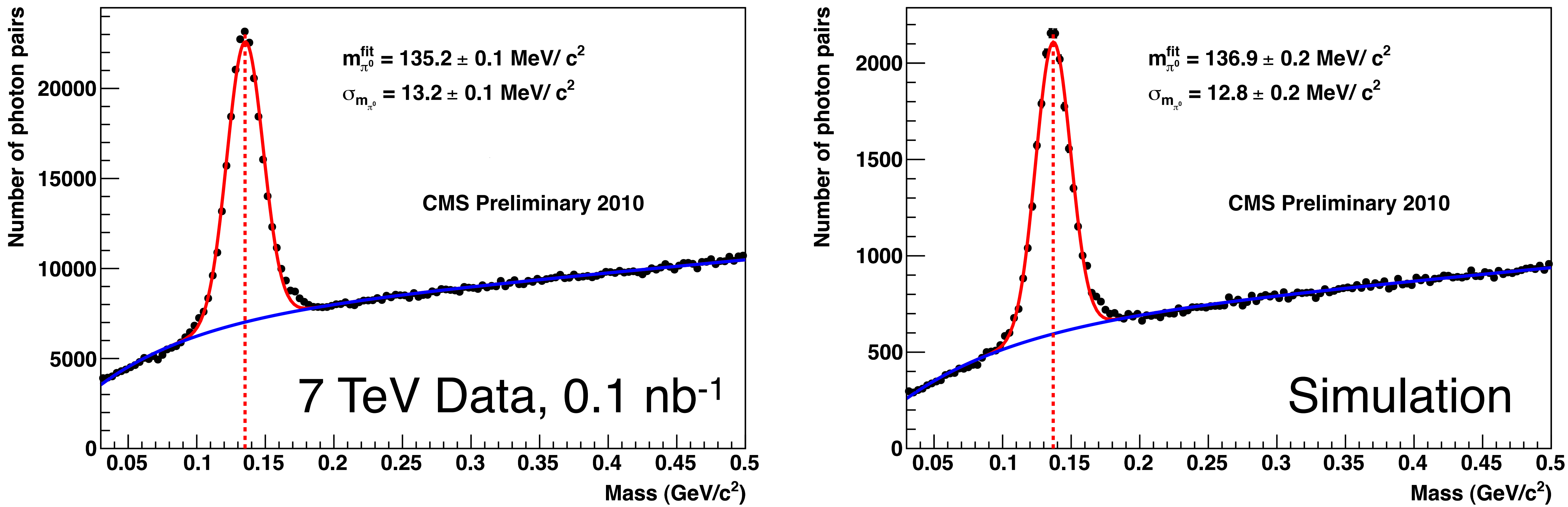
# Particle Flow Commissioning

## observables from particle flow jets



# Particle Flow Commissioning

## invariant mass of PF photon pairs




$\pi^0$ mass agrees with world average within 1%