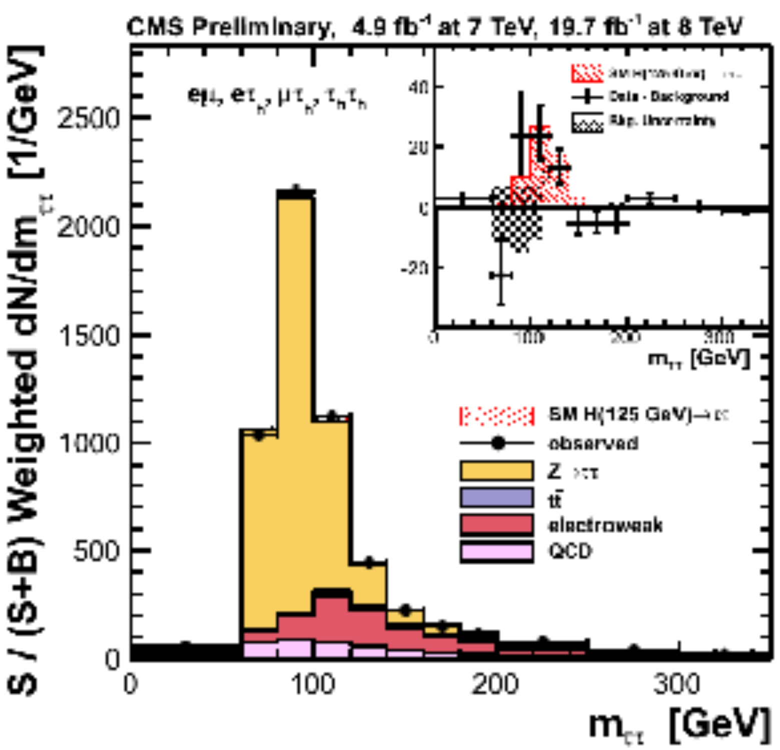
Observation of the Higgs Decaying to a Pair of Tau Leptons



Dr. Isobel Ojalvo Nov. 13 2017 **Higgs to ττ @ CMS**

Overview

Very brief review

Tau Physics

Detector Setup

Online Data Selection at CMS

Level 1 Trigger

Particle Reconstruction (Offline)

Particle Flow

Tau ID using Hadron Plus Strips Method

SM Higgs to Tau Tau

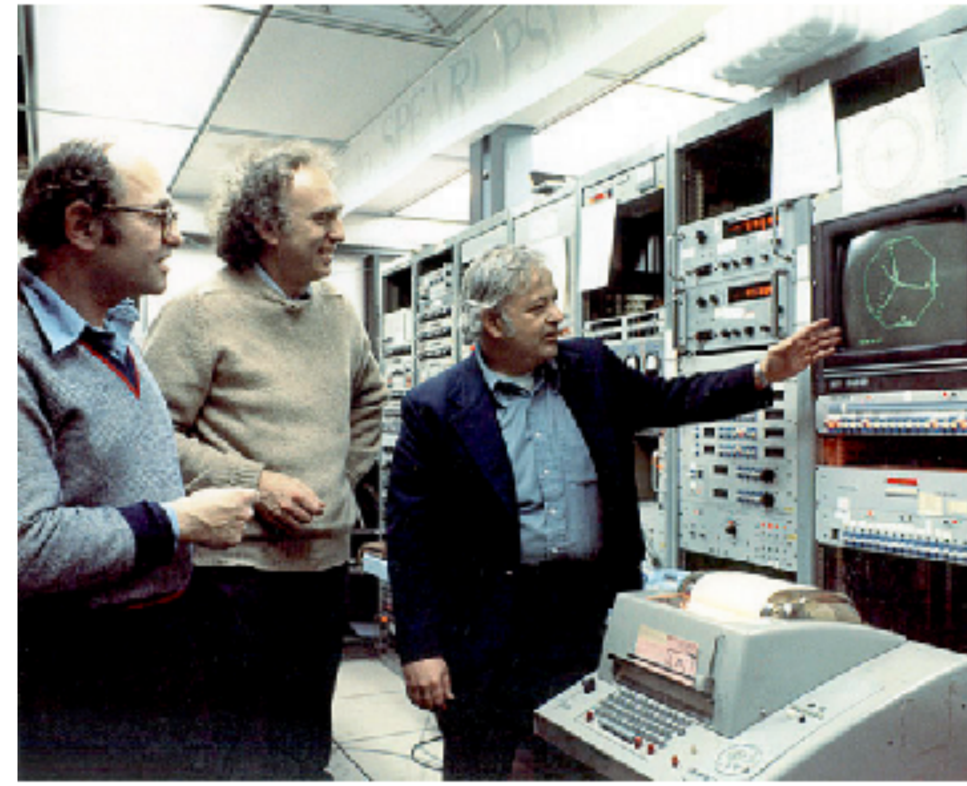
BSM Searches Using Taus

History of the Tau Lepton

Discovered by Martin L. Perl et al. (1974/1975)

- Stanford Positron Electron Accelerating Ring (SPEAR) — at SLAC
    - e+e- collider (CoM 7.4 GeV)
- Discovered via $e^+e^- \to \tau\,\tau \to \mu^\pm e^\mp \nu\nu$
- Search for a heavier lepton already underway at ADONE (Italy, 1.5 GeV CoM)

- M.L. Perl recognized the potential for discovery of a heavier lepton using SPEAR



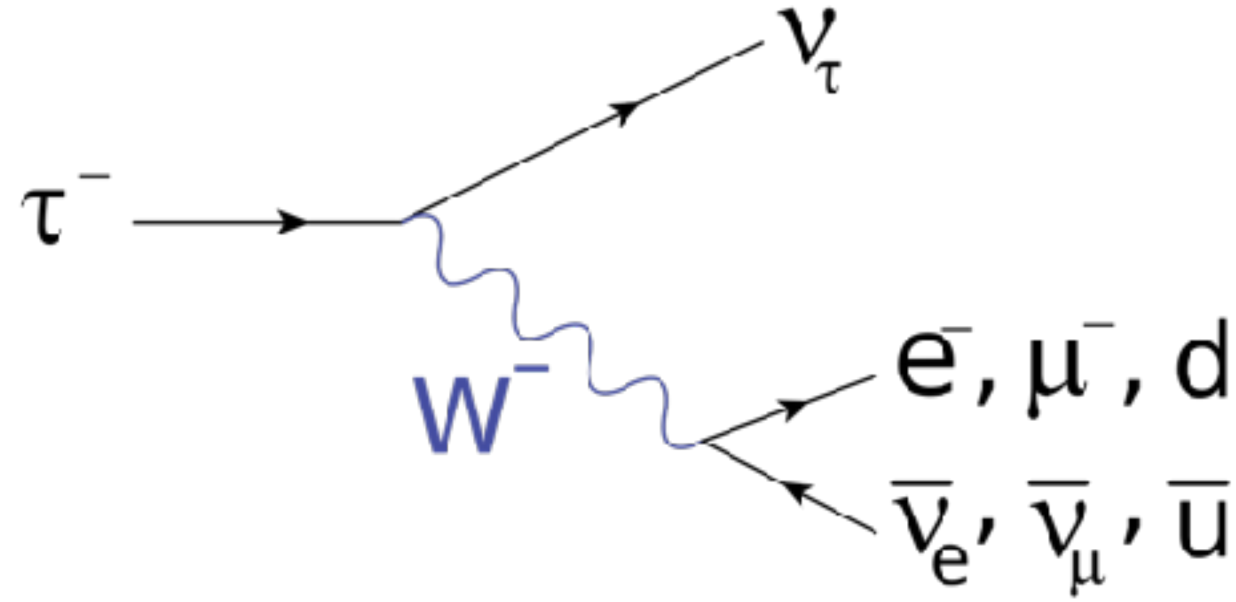
Martin in the SPEAR Control Room in November 1974, following discovery of the J/Psi. Left to right, Gerson Goldhaber (LBL), Martin Perl, and Burton Richter.)

Tau Lepton was first of the **third generation** fermions discovered

- Followed by the discovery of the **bottom quark** (1977), the **top quark** (1995) and the **tau neutrino** (2000)

http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/perl-martin.pdf

Basic Characteristics



Third generation lepton

* **charge**: +/-1
* **mass**: 1776.86 ± 0.12 MeV
* **spin**: 1/2 (fermion)
* **mean lifetime**: 2.9×10^{-13} s

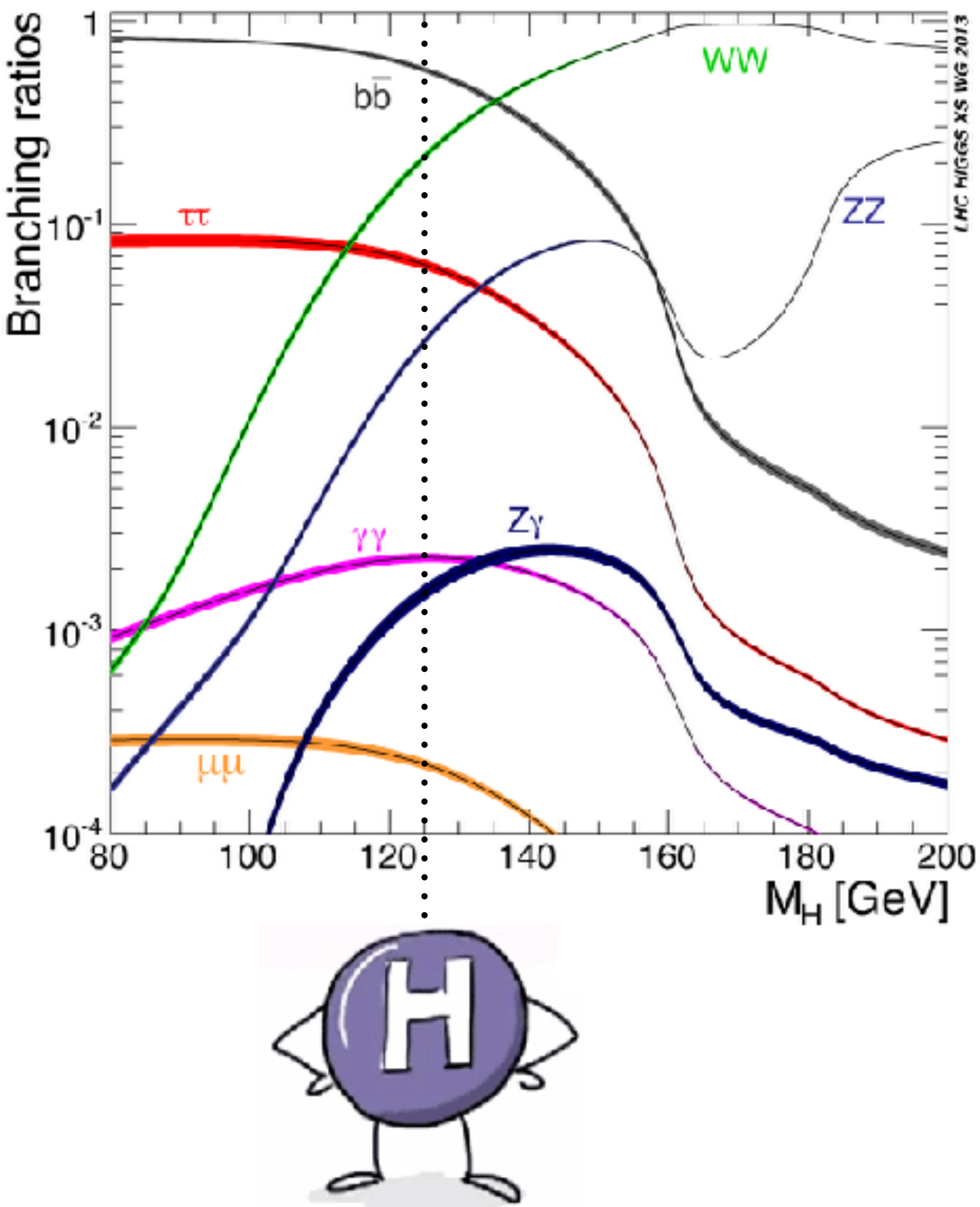
Taus Decay Weakly

- Leptonic e/muon + 2ν
- Hadronic + ν

Decay Mode	Resonance	$\mathcal{B}$ [%]
$\tau^- \rightarrow e^- \bar{\nu}_e \nu_\tau$		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
$\tau^- \rightarrow h^- \pi^0 \pi^0 \nu_\tau$	$a_1(1260)$	10.8
$\tau^- \rightarrow h^- h^+ h^- \nu_\tau$	$a_1(1260)$	9.8
$\tau^- \rightarrow h^- h^+ h^- \pi^0 \nu_\tau$		4.8
Other hadronic modes		1.8
All hadronic modes		64.8

At CMS Taus are never Fully Reconstructed due to the presence of Neutrinos, instead studies of Tau Leptons make use of the **'visible decay products'**

the SM @ LHC (with Taus)



Why use τ's to study the Standard Model?

- Hadronic τ (τ_h) Decay **cleanly reconstructed**
- 3rd Generation Lepton, and largest lepton Yukawa coupling
- Sizable Branching Ratio of Higgs

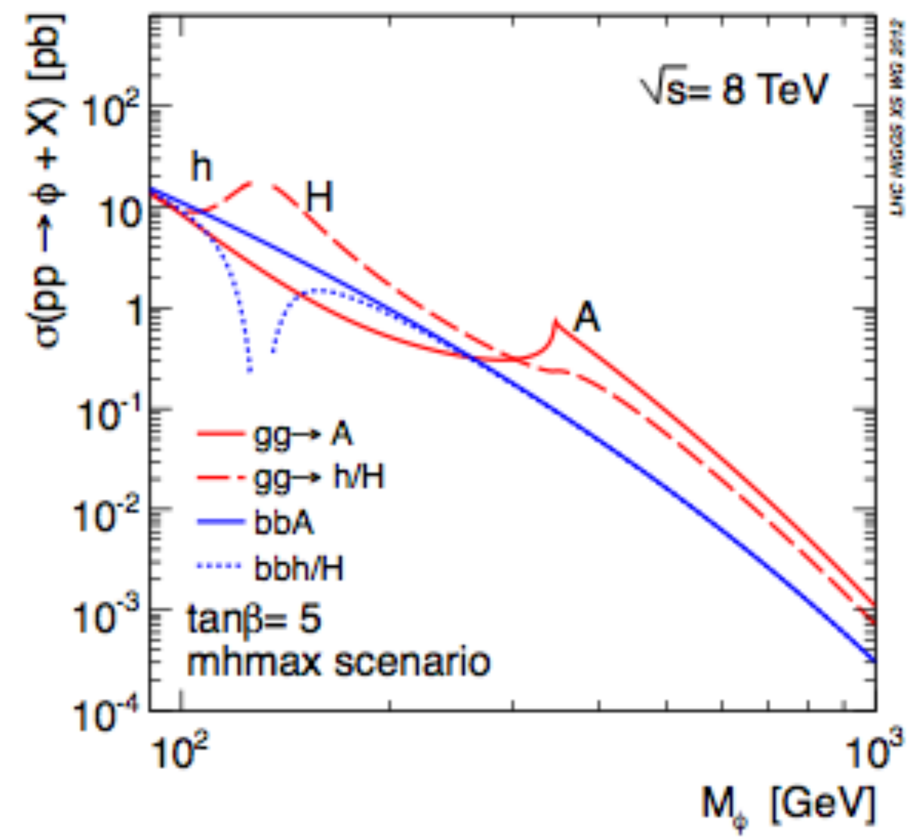
- Also a useful object to test Lepton Universality

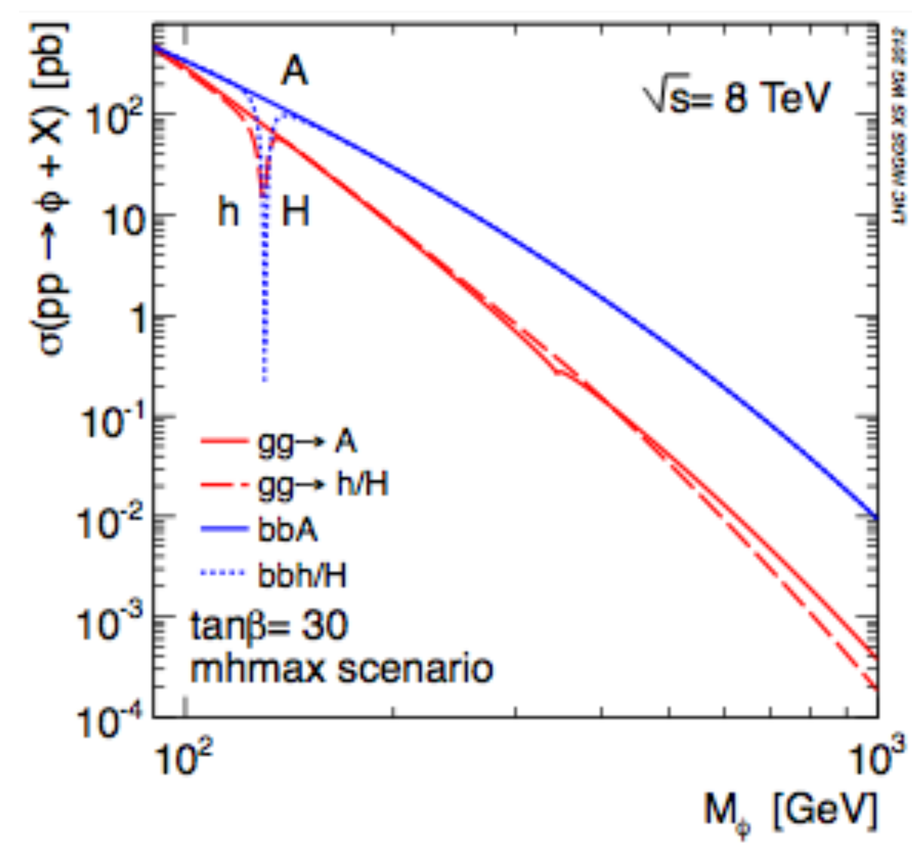
$$\Gamma(W^+ \rightarrow e^+\nu_e) = \Gamma(W^+ \rightarrow \mu^+\nu_\mu)$$

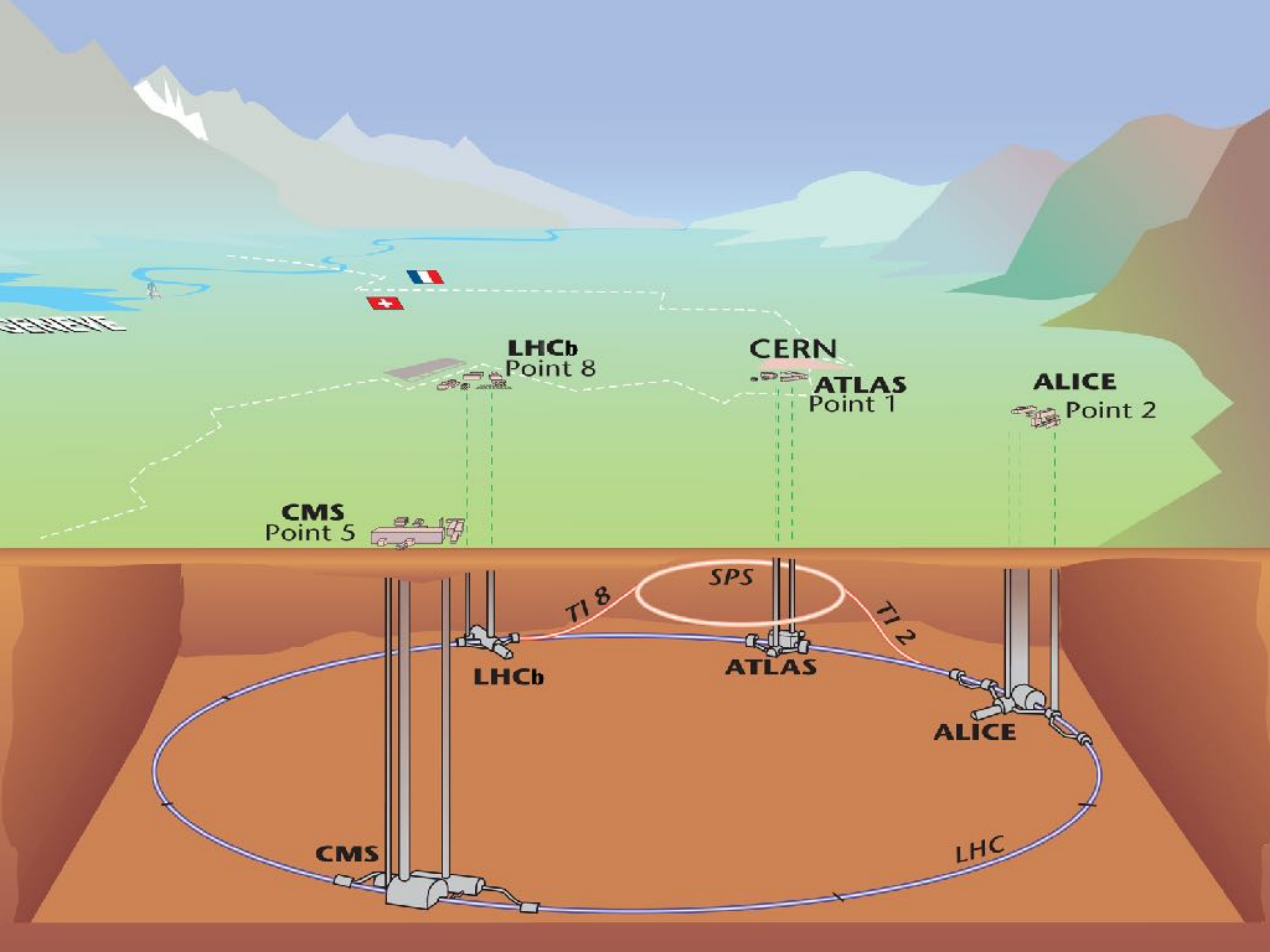
Beyond the Standard Model

Why use τ's to study physics Beyond the Standard Model?

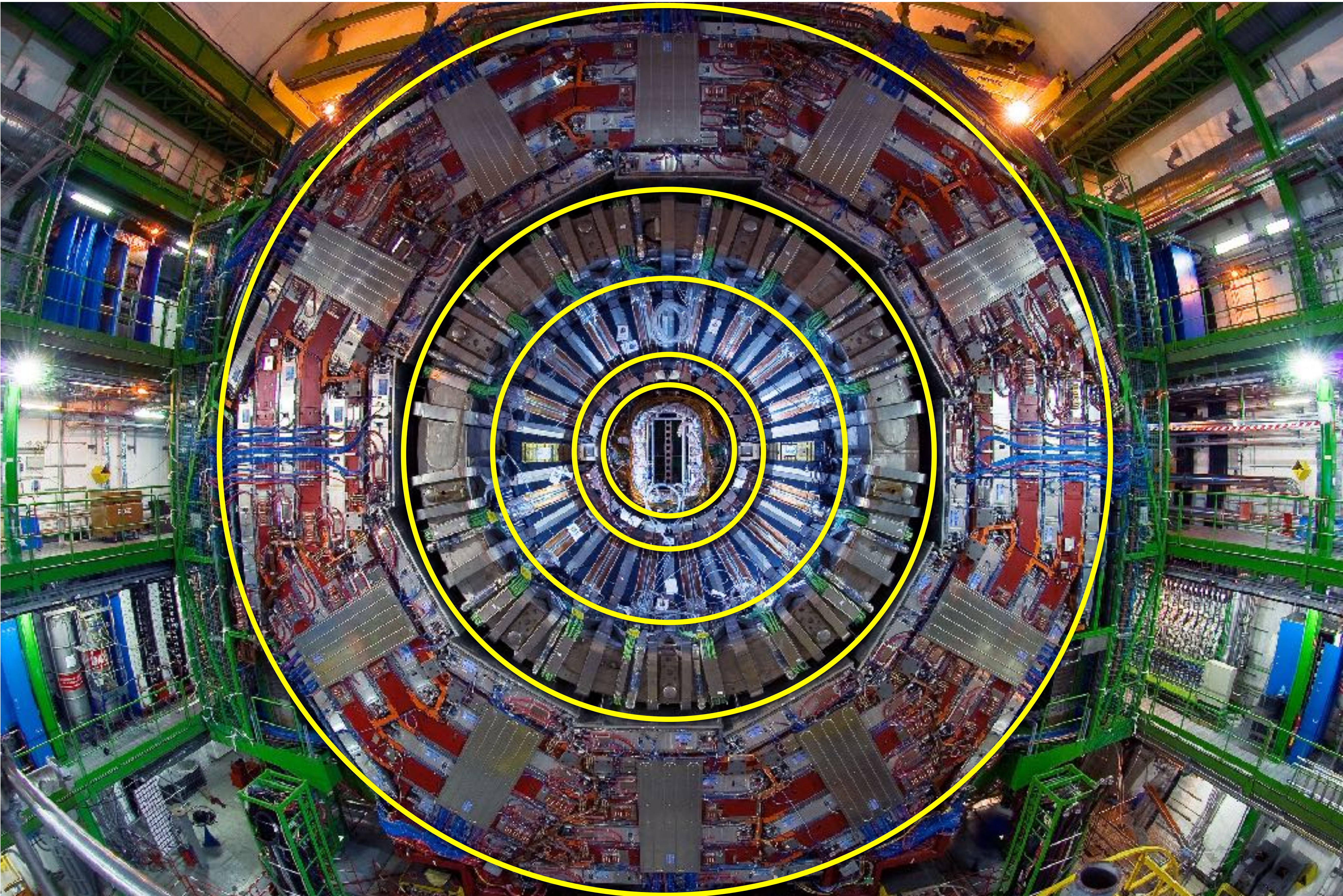
- In **2HDM** τ's can have enhanced couplings to down type quarks and leptons
- **$H^{\pm} \rightarrow \tau^{\pm} \nu$**
- Insight into the Flavor puzzle: Large branching fraction for the study of **Lepton Flavor Violation**
- **W'**, **Z'** - Universality is not guaranteed in these models
- Enhanced couplings for **Long Lived Particles**






GENEVE
LHCb
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHCb
ATLAS
ALICE
CMS
LHC

Particle Detection at CMS



Online Data Selection at CMS

The First Analytical Step

Data Selection at CMS

Data is selected for offline analysis with the 2-tiered **trigger system**

Level 1 Trigger

Coarse Calorimeter Readout

No Tracking Input! **Very Fast!**

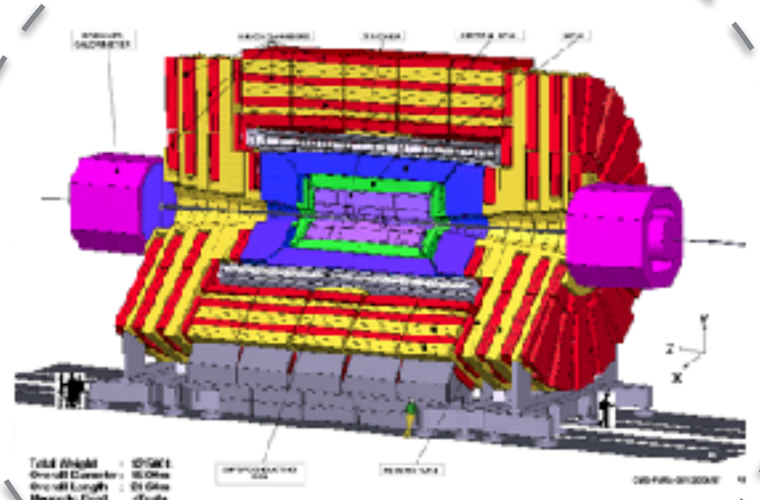
L1A 100kHz

High Level Trigger

Full Detector Information Available -> trade off: Fast Algos

Final Decision ~1 kHz

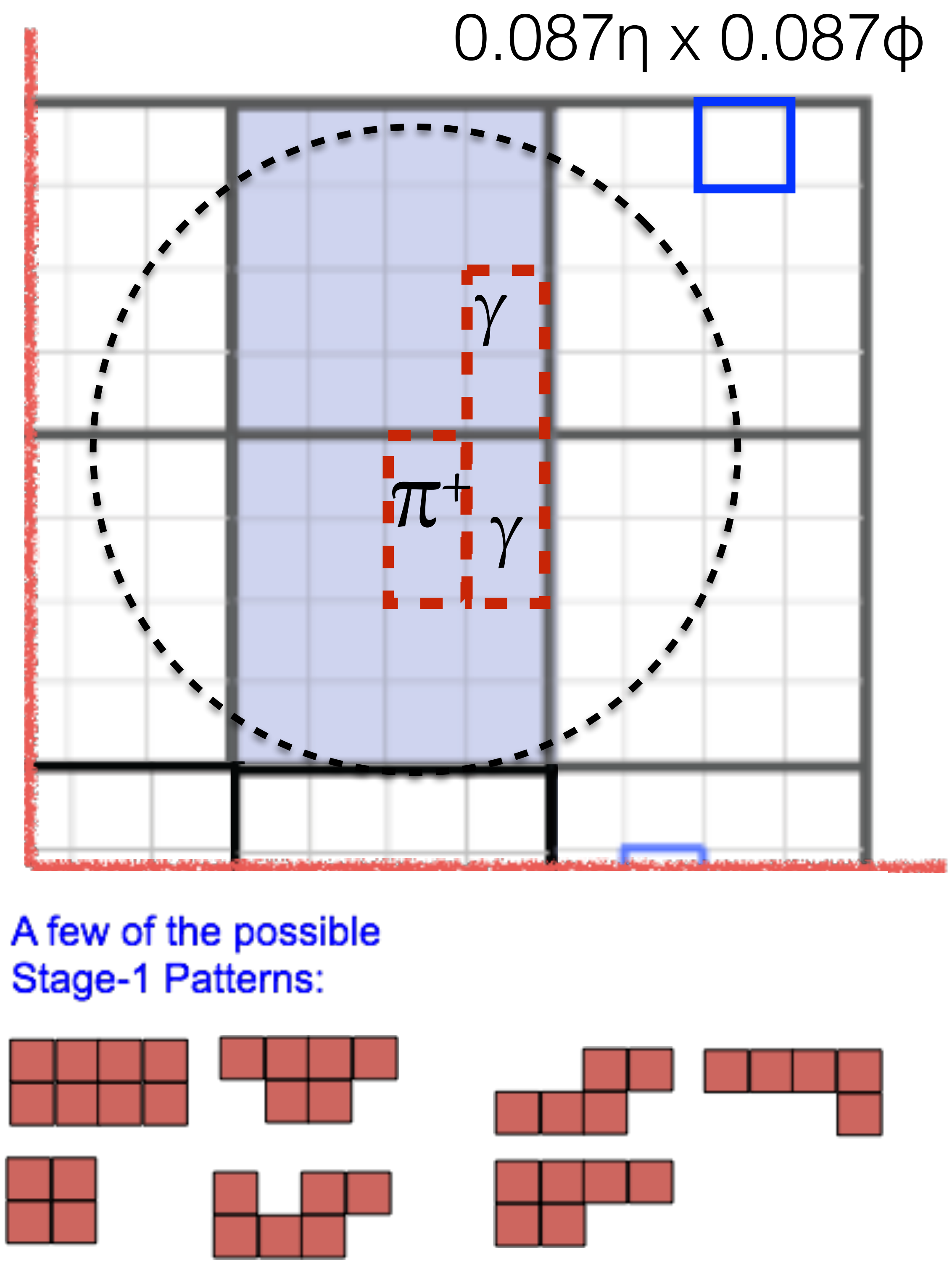
Full Detector Readout for RECO and Offline Analysis



40MHz Collision Rate

~1 MB/event

Stage-1 Tau Trigger 2015



-> Energy deposited in at most 8 towers

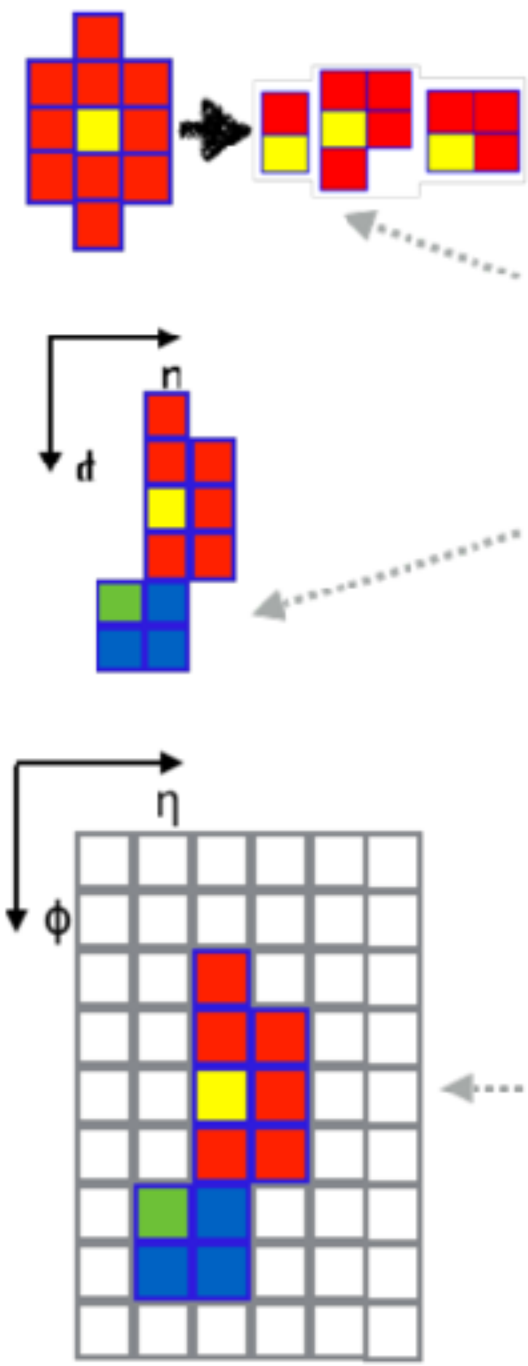
Cluster Finding:
Taus are composed of two neighboring 4x4 towers

Shape Finding:
Require energy above 3 GeV to be found in specified patterns

Isolation:
Candidate P_T/Surrounding P_T< Threshold

Tau candidates are processed in parallel from the full calorimeter total latency: ~500 ns

Stage-2 Tau Trigger 2016



Clustering

- Create tau clusters from TT
- **Mostly common to EG**

Merging

- Search for neighbors in a defined path (tau decay products can be spread out)
- ~**15%** merged, **85%** non merged

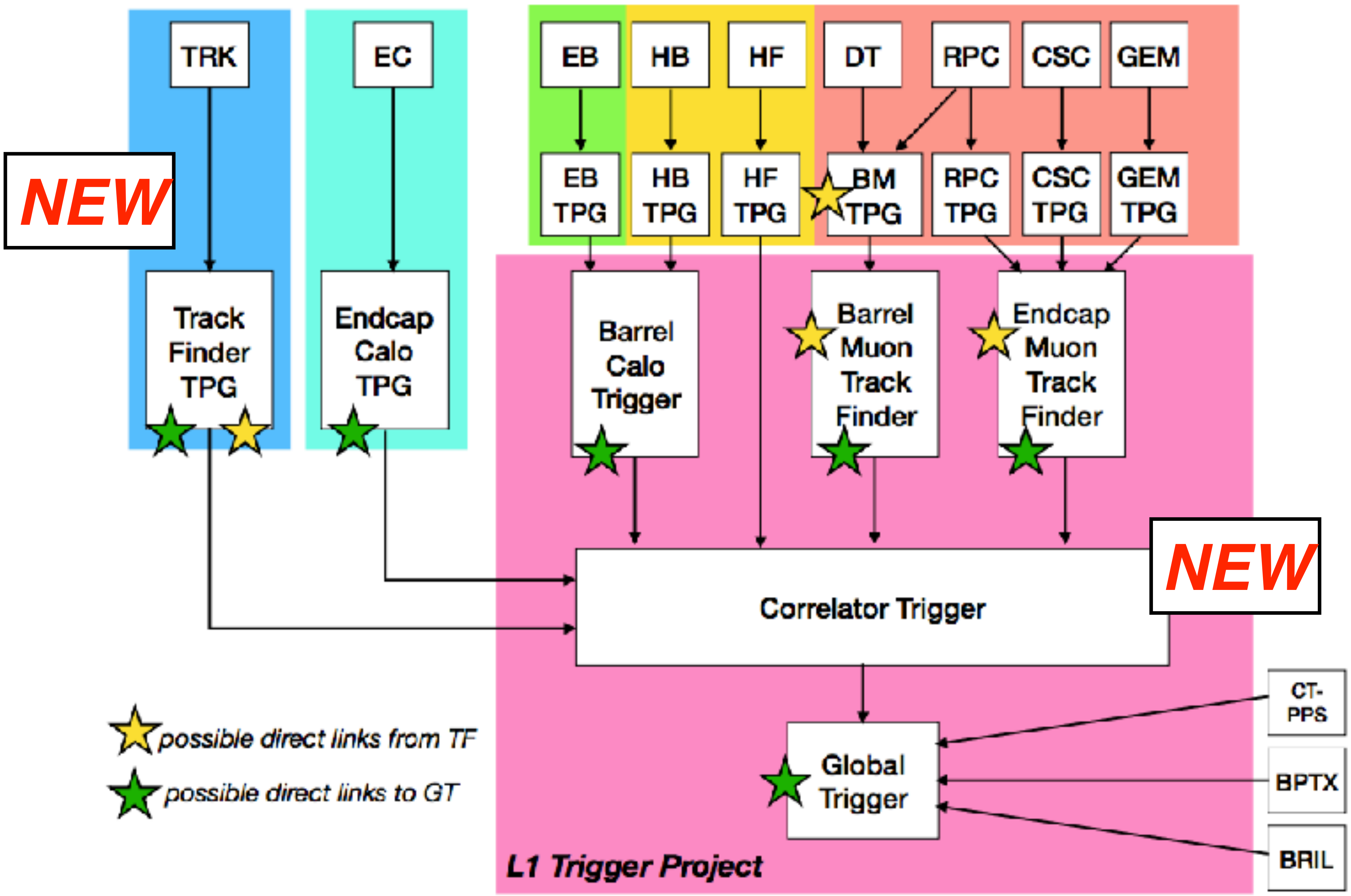
Calibration

- Function of eta position, ET, merging and presence of energy deposit in ECAL

Isolation

- Compute isolation as E(6x9) - E (tau)
- **PU estimator common to EG**

Data Selection at CMS *Phase II*



TIFR

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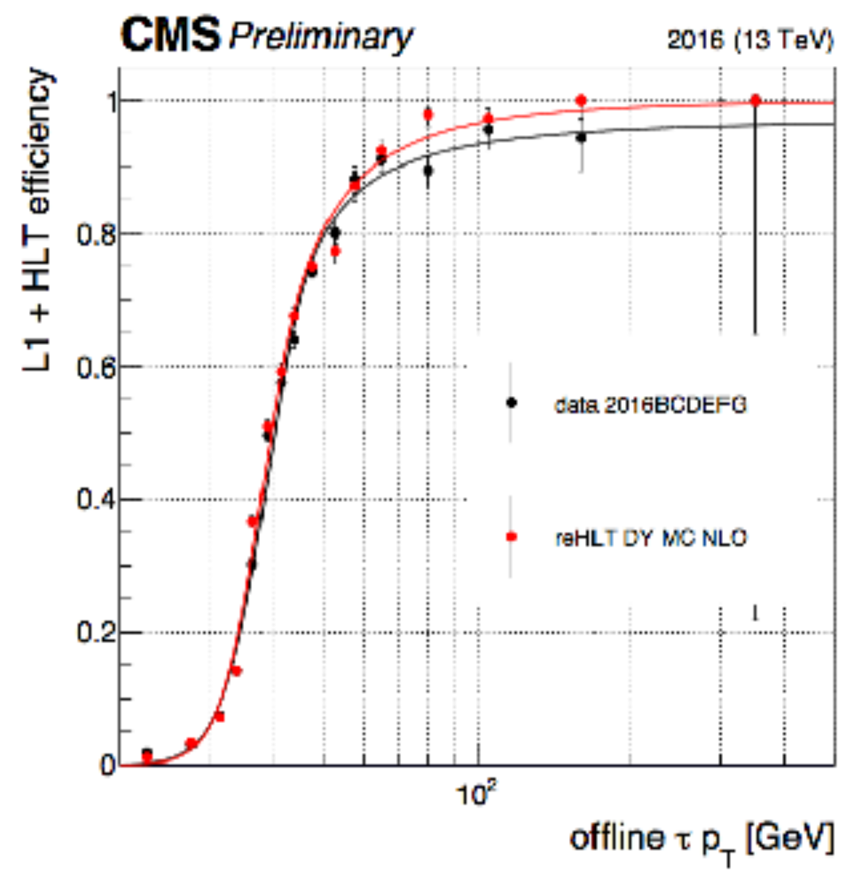
HLT Tau Trigger

- Makes use of the shrinking cone algorithm at HLT
- Slightly tighter working point in data than in MC due to (excellent) LHC performance



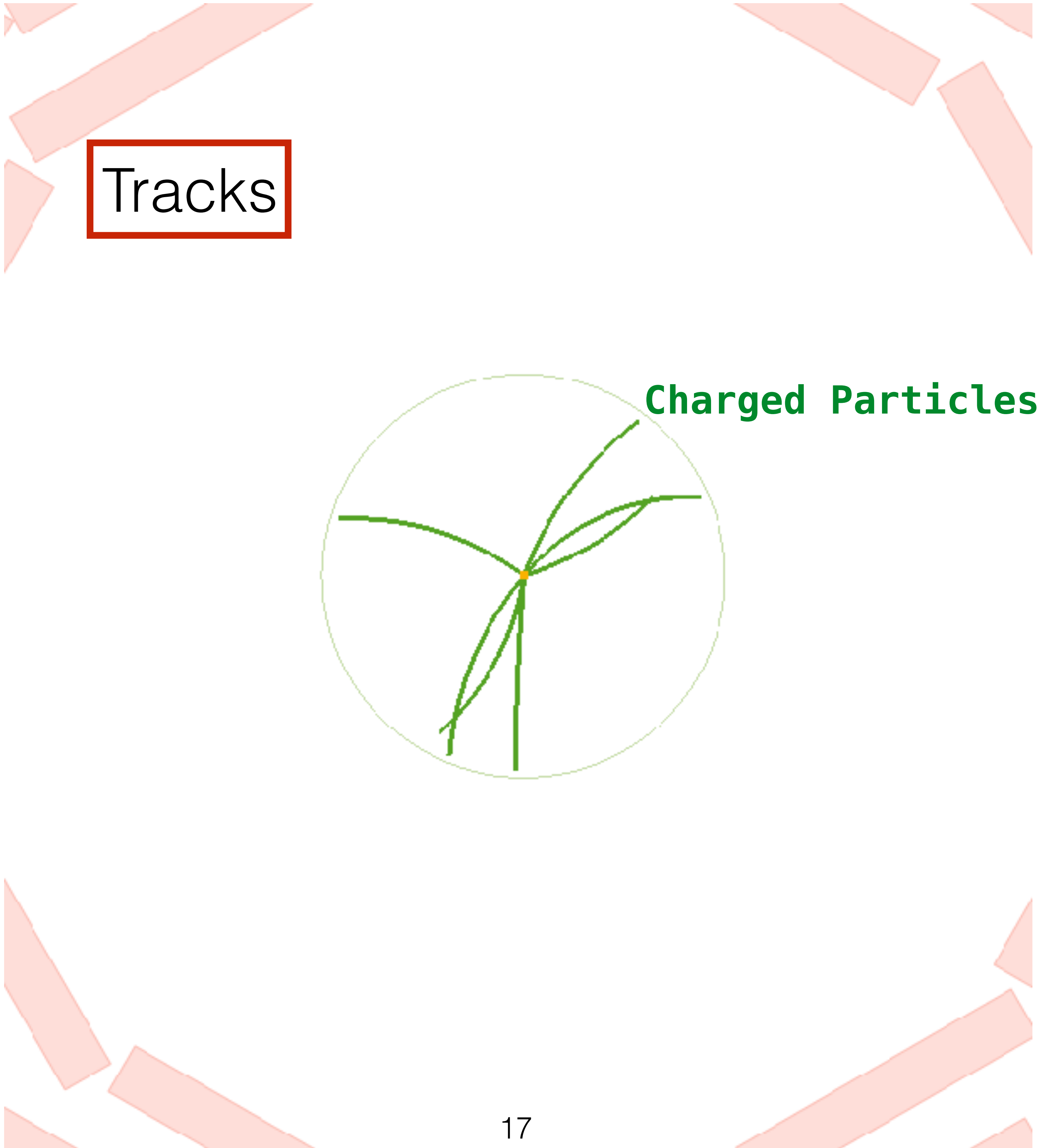
HLT Path	L1 Seeds
HLT_IsoMu{19,21}_eta2p1_LooseIsoPFTau20_SingleL1 HLT_IsoMu19_eta2p1_LooseIsoPFTau20	L1_SingleMu20er
HLT_Ele24_eta2p1_WPLoose_Gsf_LooseIsoPFTau30	L1_SingleIsoEG22er
HLT_DoubleMedium{Combined}IsoPFTau35_Trk1_eta2p1_Reg	L1_DoubleIsoTau30er
HLT_VLooseIsoPFTau140_eta2p1	L1_SingleTau120er
HLT_LooseIsoPFTau50_Trk30_eta2p1_MET90	L1_ETM{80,100}

Tau Reconstruction @ CMS:

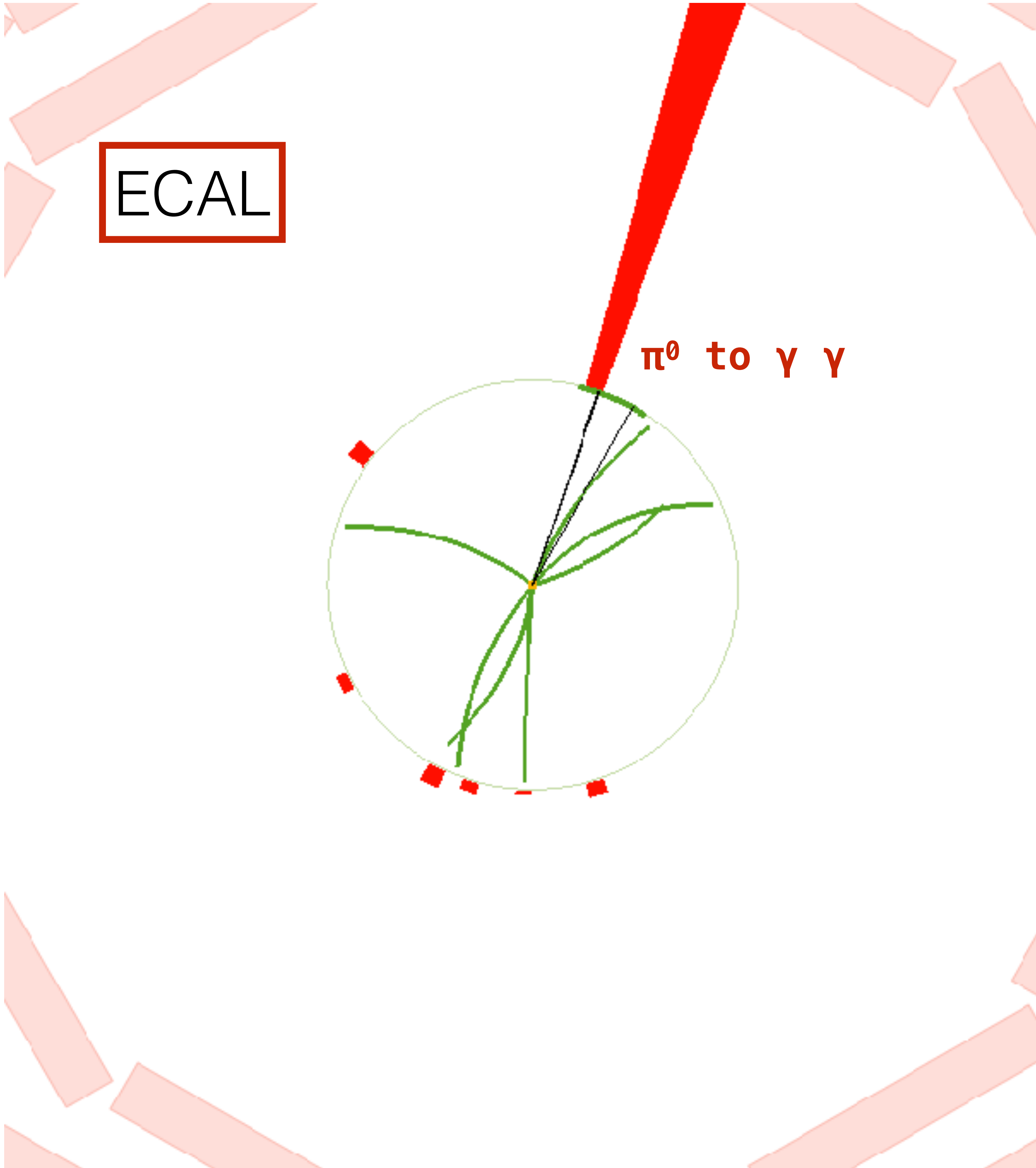
Tau Reconstruction @ CMS: Cut-Based Approach for a Complex decay

First, an interactive overview

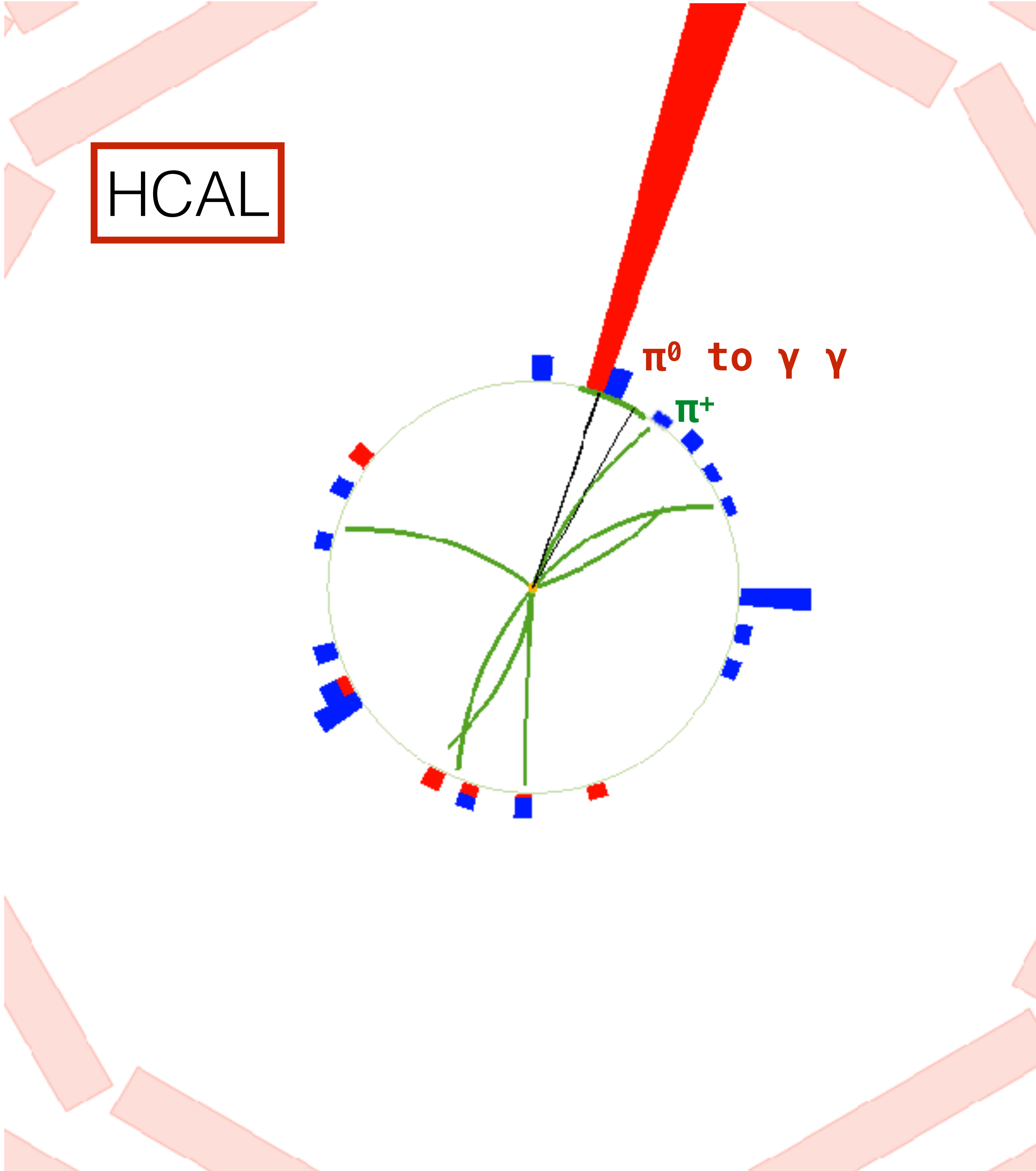
Particle Detection at CMS



Particle Detection at CMS

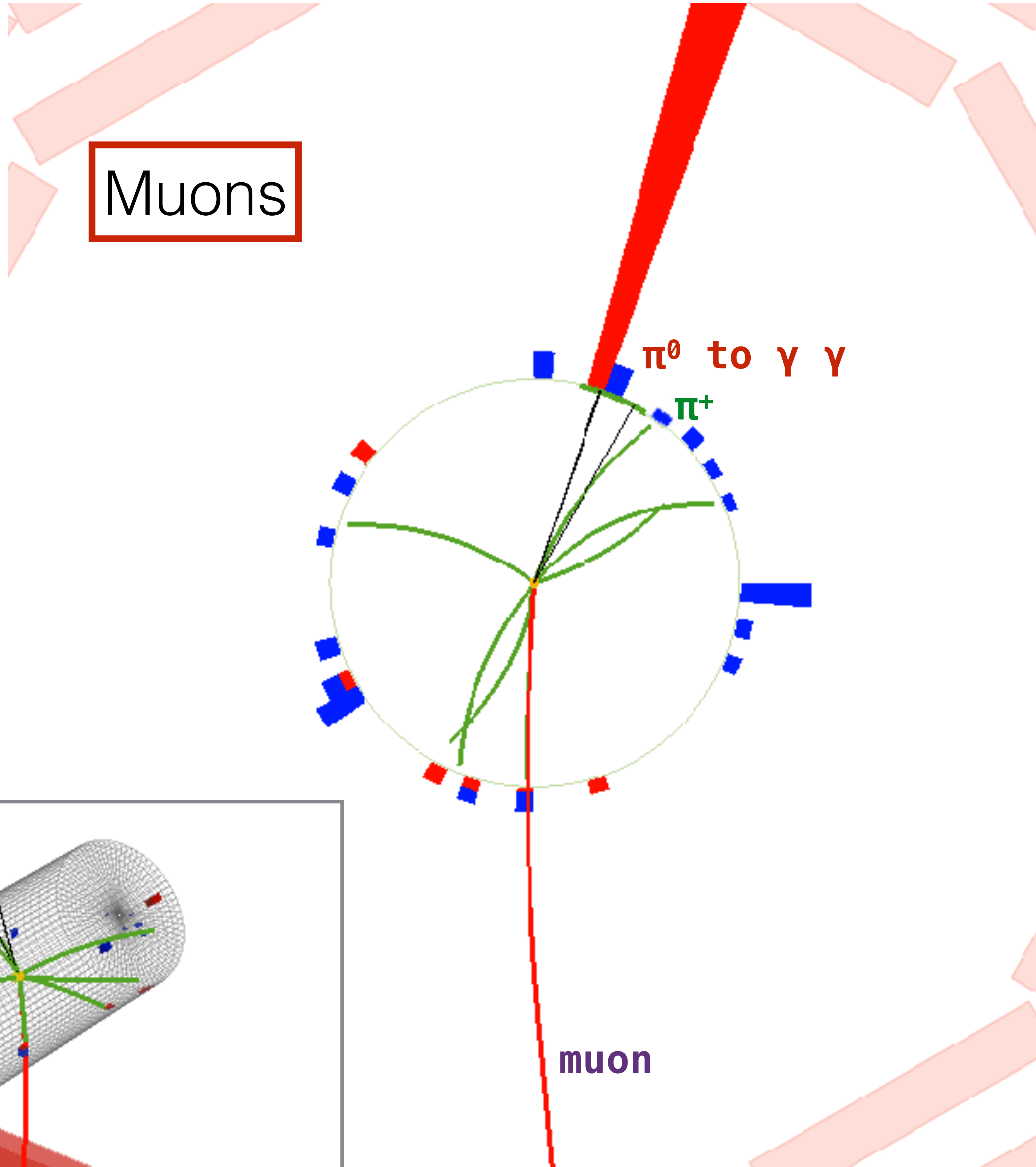


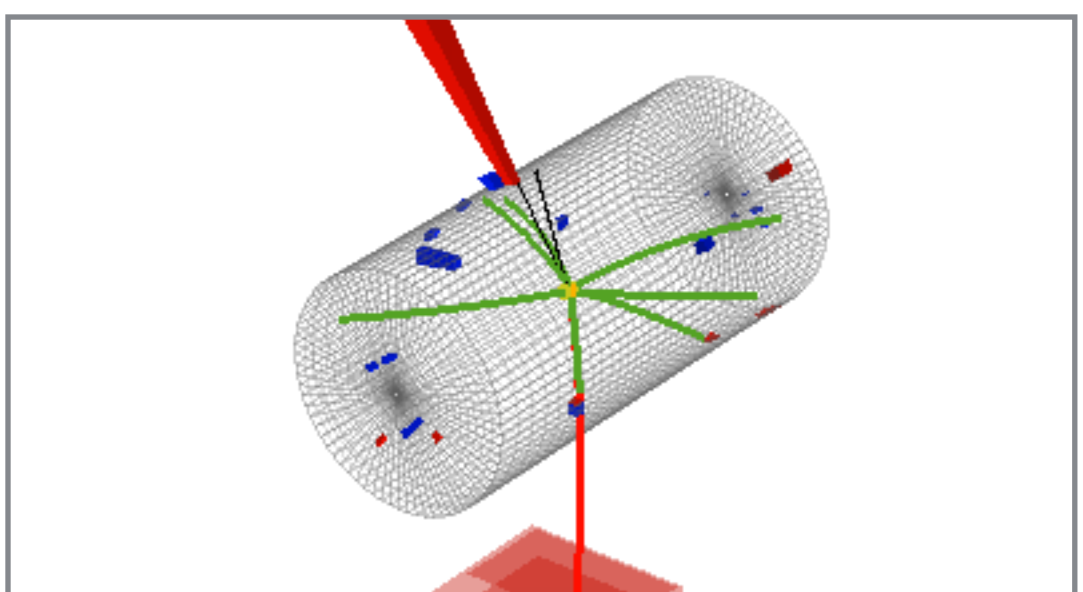
Particle Detection at CMS



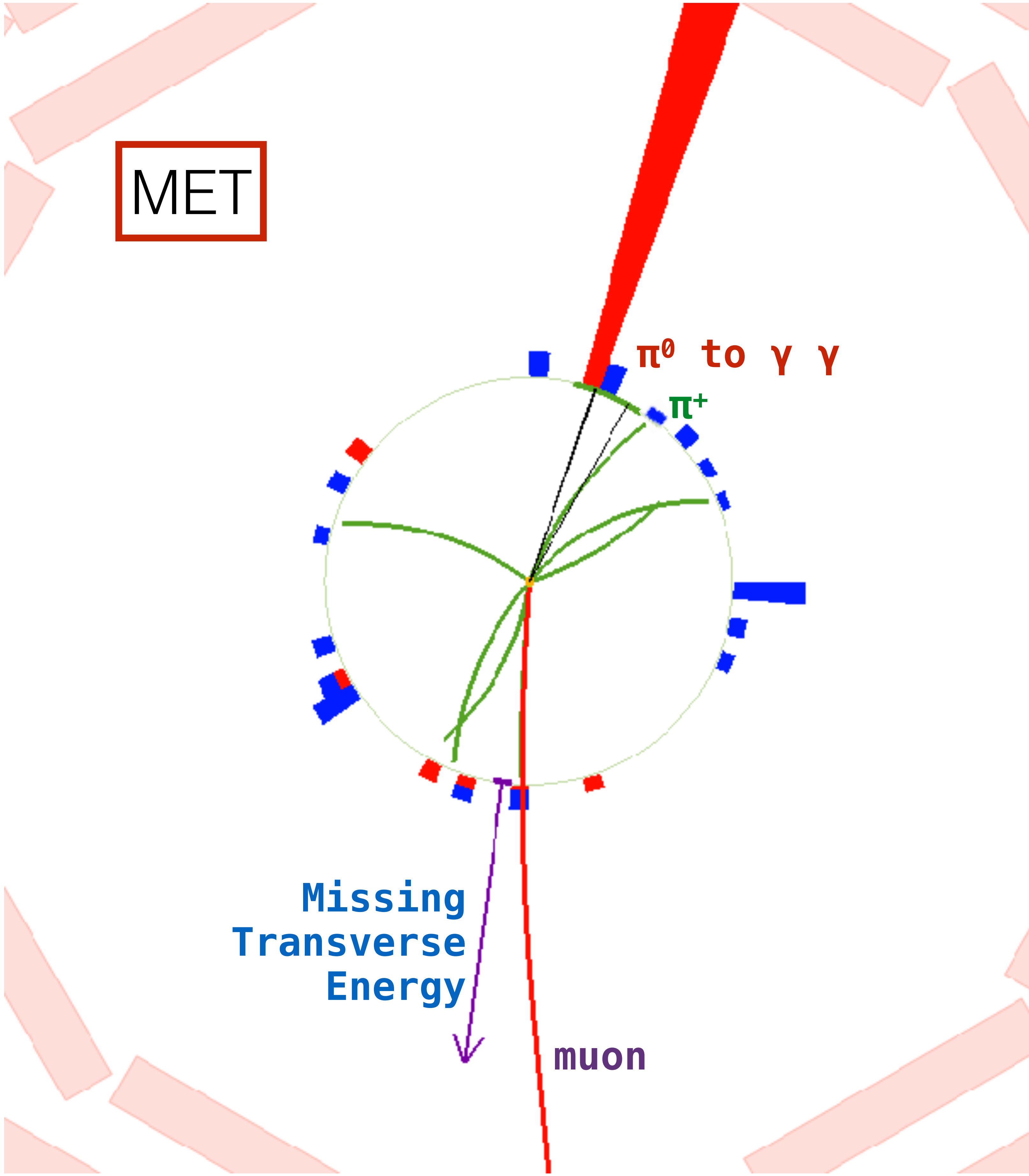
Particle Detection at CMS

Muons

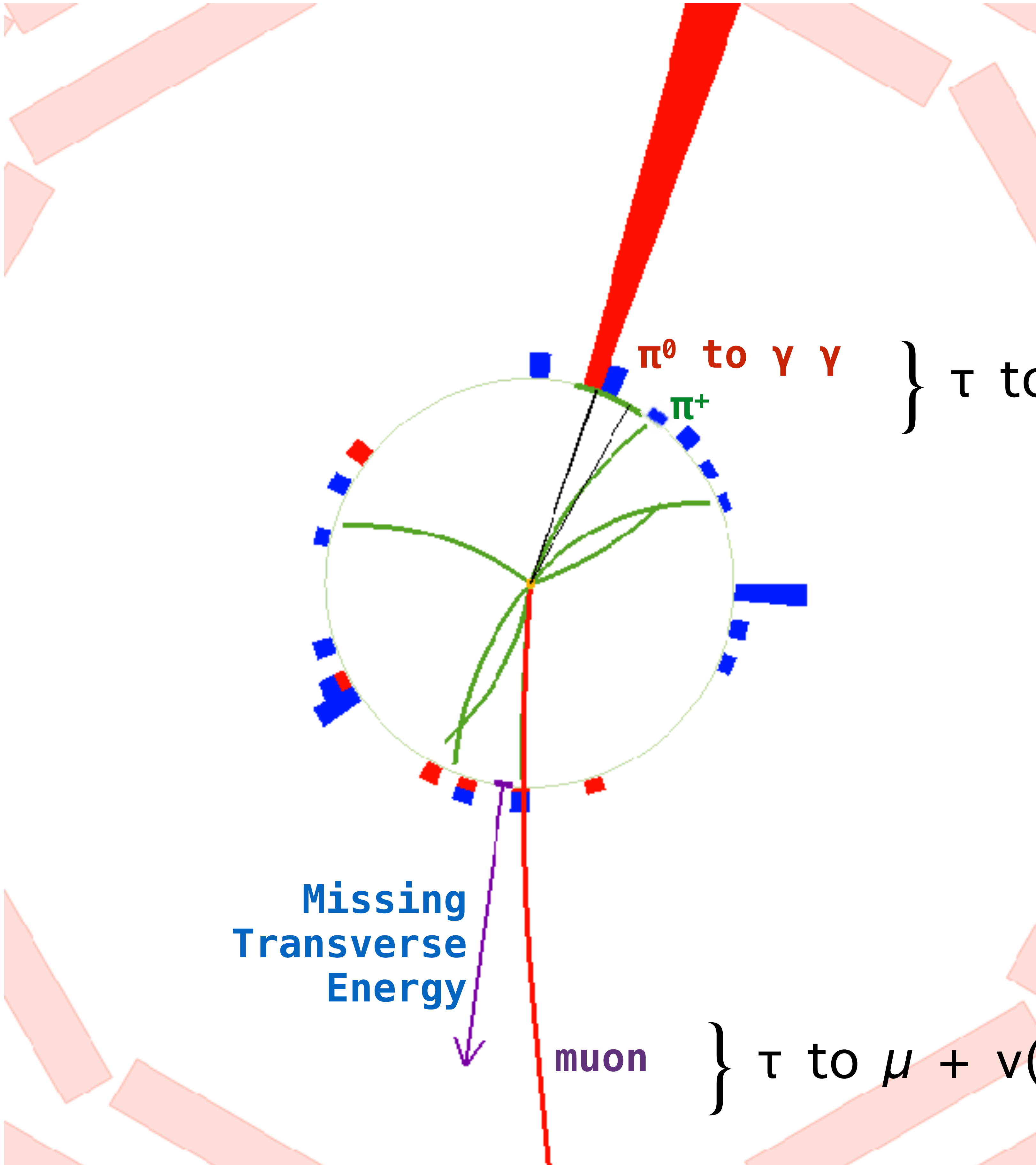




Particle Detection at CMS



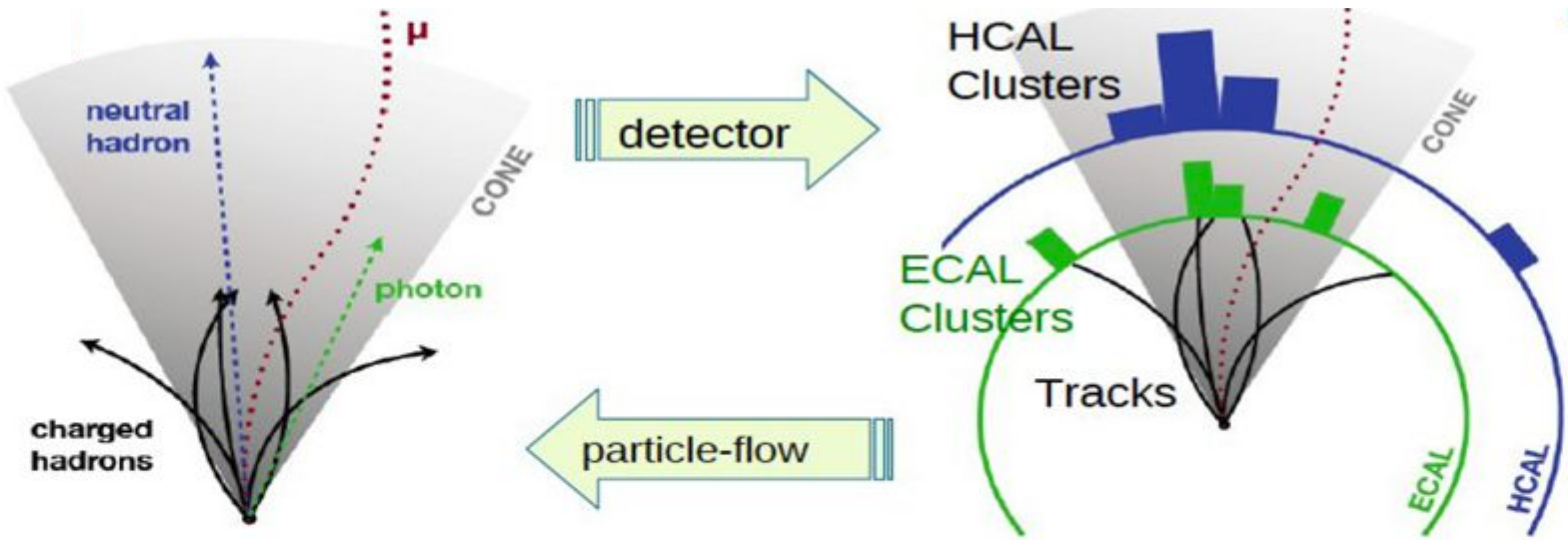
Particle Detection at CMS



} τ to $\pi^0\pi^+$

} τ to μ + ν('s)

Particle Flow Reconstruction



A well known graphic and idea for, a few details important for Taus:

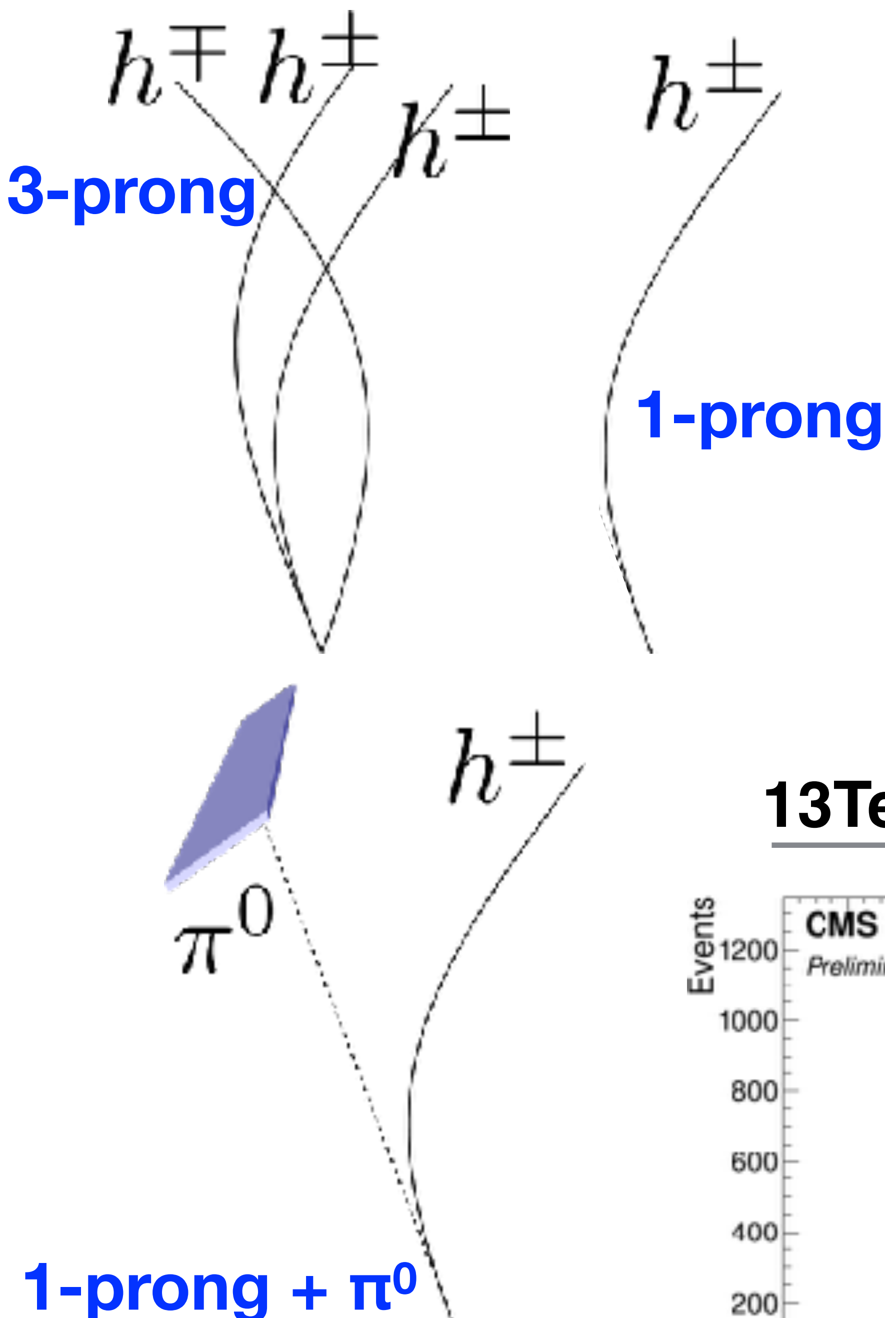
With the use of Particle Flow, PF Candidates can reconstruct the mass of the Tau

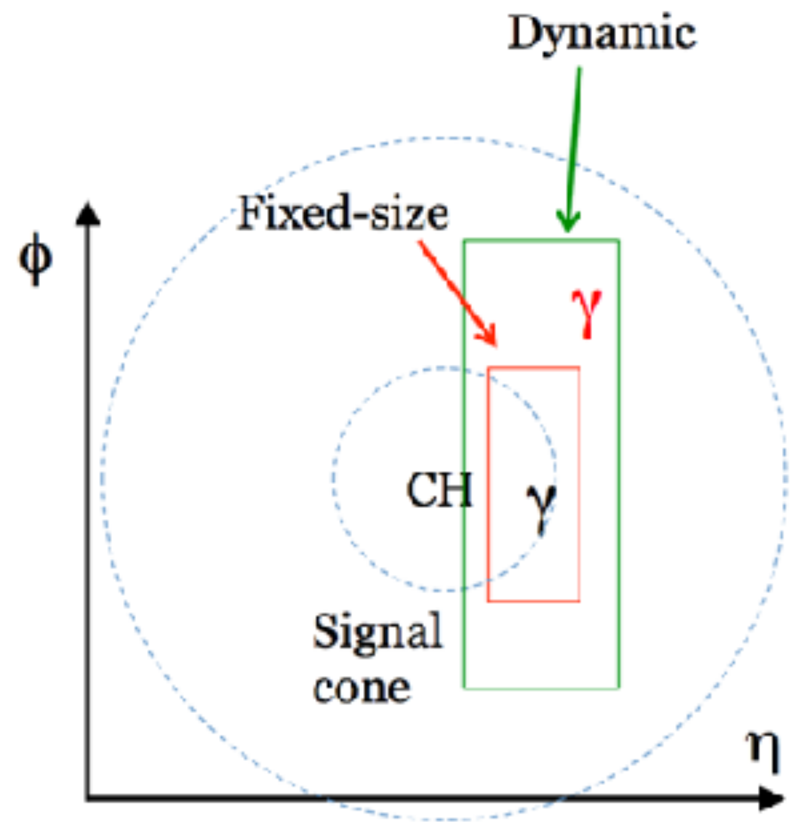
No double counting of Hadronic deposits as PF algorithm cleans them
- Able to reconstruct even highly boosted Taus

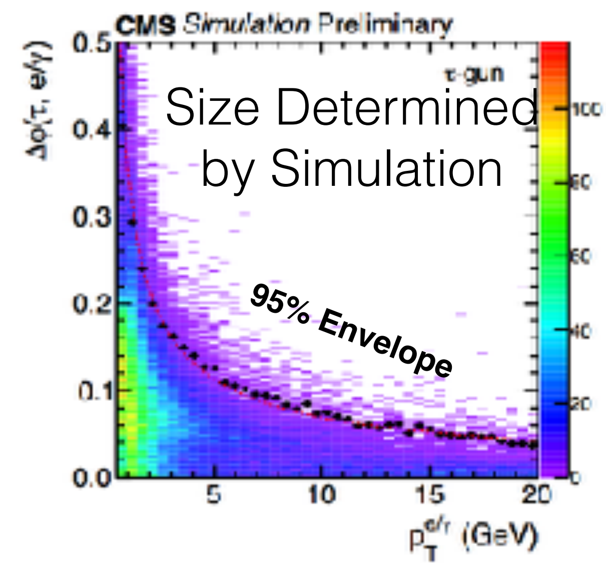
Allows for Nuclear Interactions in the tracker of charged hadrons

Run II Tau Reconstruction at CMS

Tau Reconstruction uses a Cut-Based **Hadron Plus Strips (HPS)** Algorithm to Reconstruct **1-prong**, **1-prong + π^0** and **3-prong** Taus from "Particle Flow" Charged Hadron and e/gamma Candidates

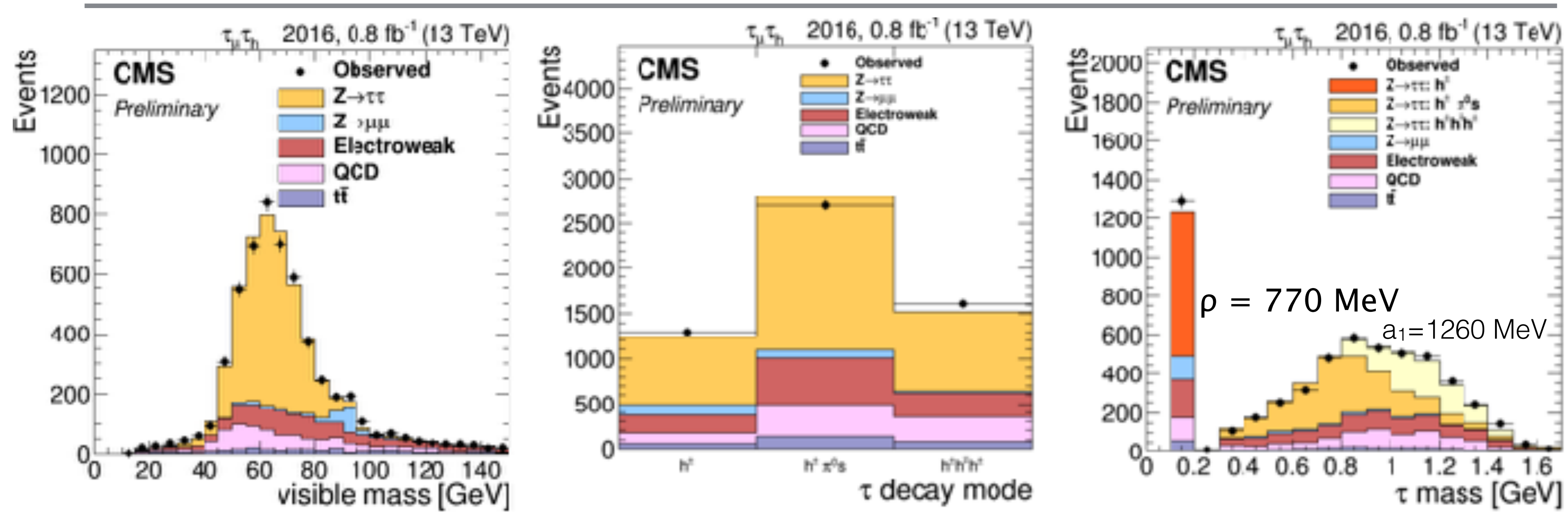






New for Run II 1-prong + π^0: Take into account the expected size of the strip based on the e/gamma p_T

13TeV Performance



LPC Forum: Tau Leptons @ CMS

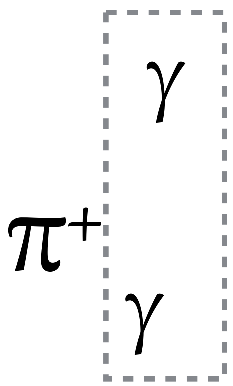
1/19/17

Isobel Ojalvo

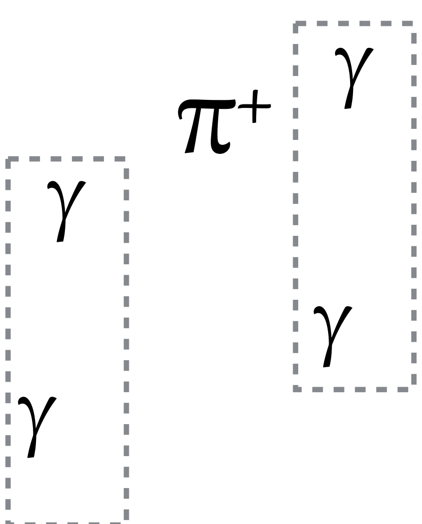
Tau ID: Hadron+Strips

Tau Algorithm Starts from a Particle Flow Jet

1 prong + 1pi0



1 prong + 2pi0



Special attention paid to photon conversions in the tracker material which decay into "Dynamic Strips"

- $\gamma \to e^+e^-$ undergoes bending of e^+,e^- tracks in B-field of CMS, broadens the signature of neutral pions
- Strips are then built out of EM Particles (PF photons and electrons)
- Strip reconstruction starts by centering on the most energetic EM particles within the PF Jet
- The algorithm searches for other particles within a dynamic window of eta 0.05 phi 0.20
- If other EM particles are found within that window, the most energetic one is associated with the strip and the strip four-momentum is recalculated
- p_T(strip) > 1 GeV

Tau ID: Hadron+Strips

1 prong

π^+

Single Hadron is assumed to have the mass of the pion

3 prong

π^+

π^-

π^+

Three charged hadrons are required to come from the same secondary vertex created using a kalman vertex fitter

The τ_h mass distribution is used to control the tau energy-scale

Decay Mode	Resonance	$\mathcal{B}$ [%]
$\tau^- \to e^- \bar{\nu}_e \nu_\tau$		17.8
$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$		17.4
$\tau^- \to h^- \nu_\tau$		11.5
$\tau^- \to h^- \pi^0 \nu_\tau$	$\rho(770)$	26.0
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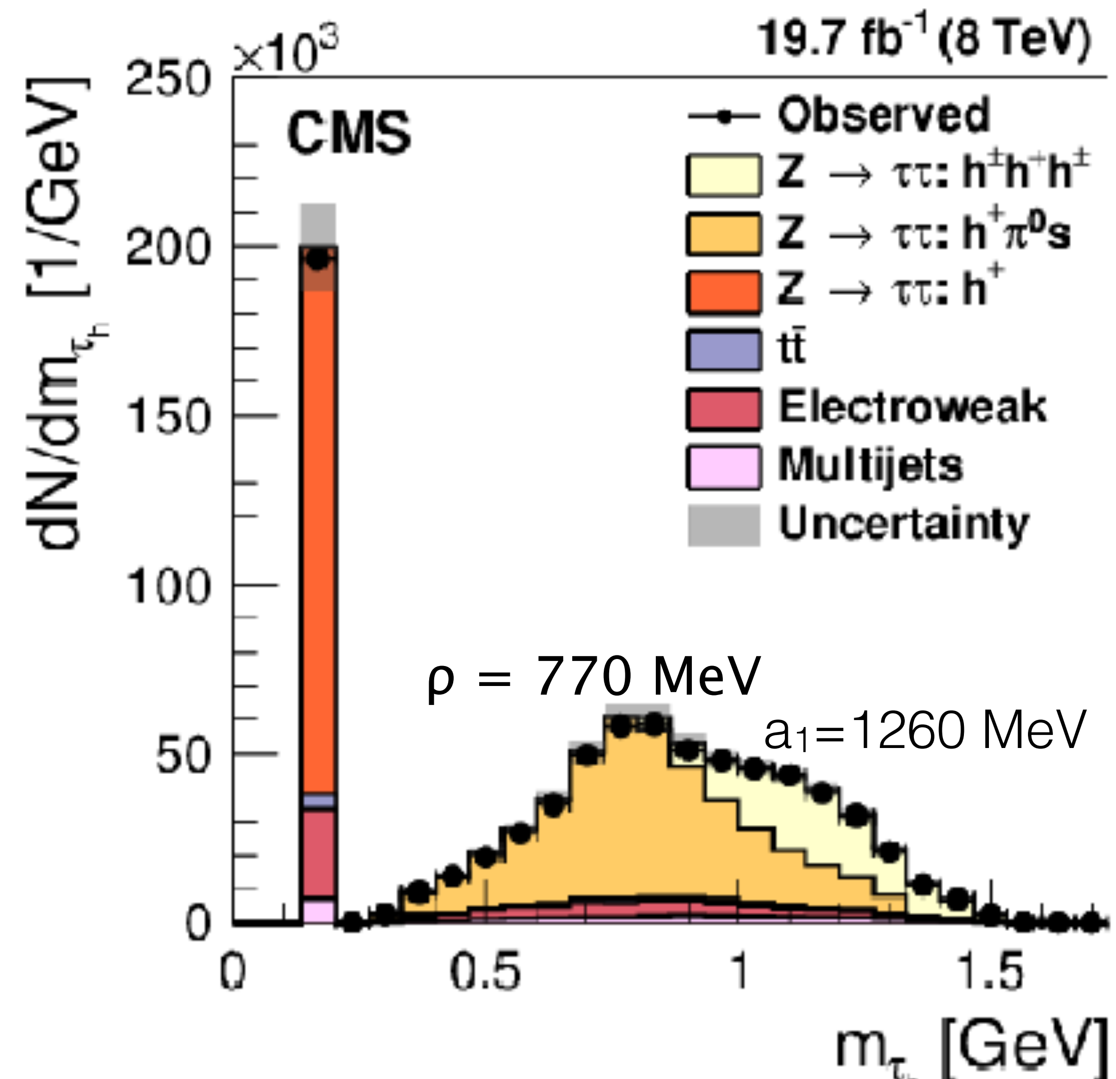
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$		4.8
Other hadronic modes		1.8
All hadronic modes		64.8

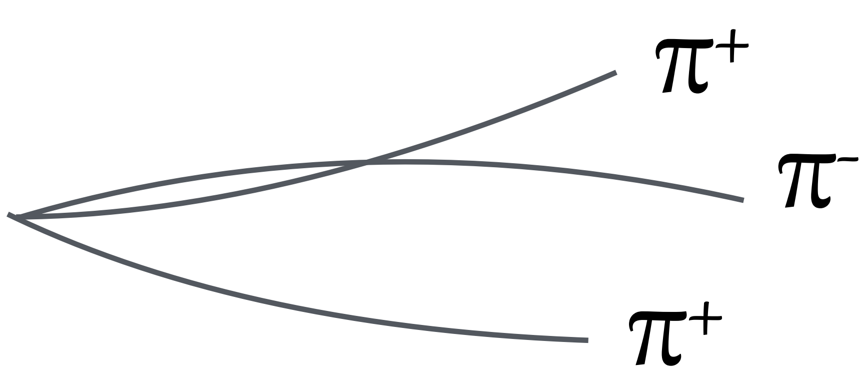


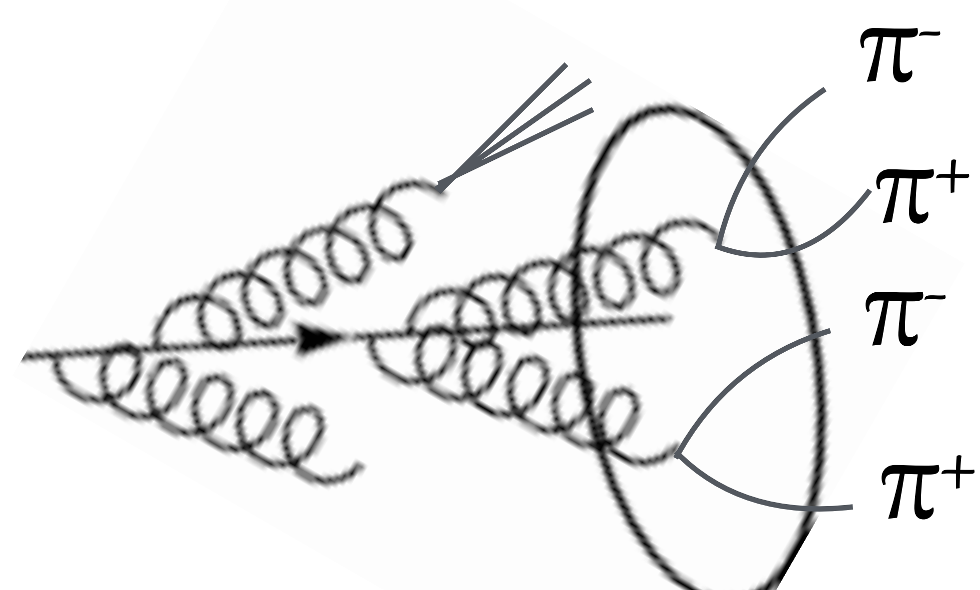
Fake τ_h: Jets

Jets are produced in large amounts at Hadron Colliders

- QCD, Pileup, other EWK interactions, ect.
- Jets consist of a wide range of charged and neutral particles with **various multiplicities**
- Able to produce **exactly the same decay products** as can be found in Hadronically decaying Taus
- However, almost always produce **more constituents** than are produce in Hadronic Taus

➡ **Key to reduce Jets faking Taus? Isolation**
New for Run II: Also using Tau Lifetime Information

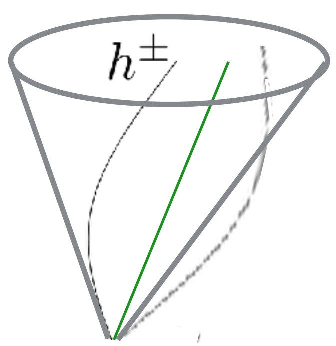




Jet→τ_h Discriminator

For Jet, τ_h Discrimination we have developed a cut-based and an MVA based approach

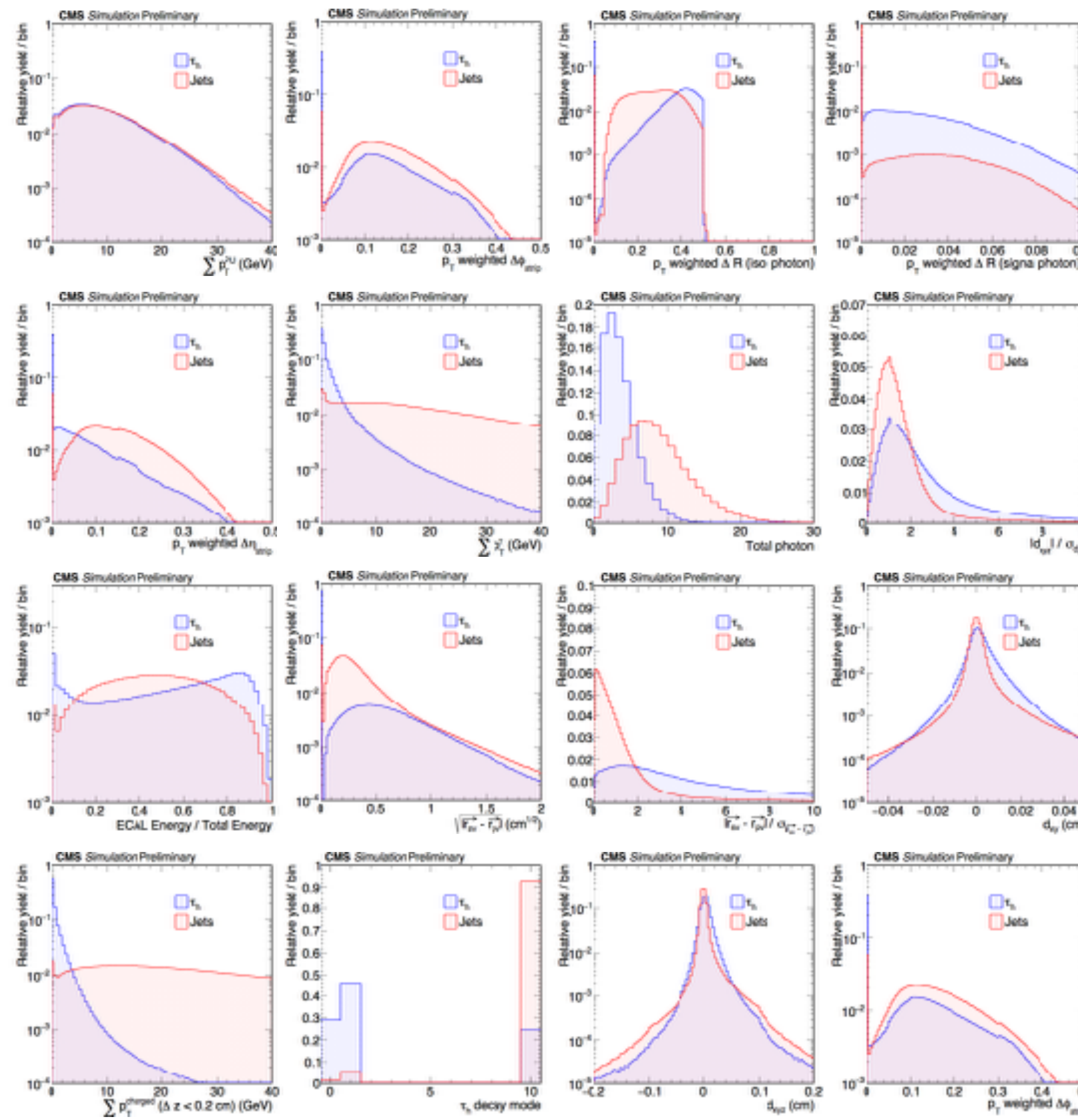
cut-based
calculated using the particles found within the τ_h Isolation cone



$$I_{\tau_{had}} = \sum P_T^{charged}(\Delta z < 2\text{ mm}) + \max\left(P_T^{\gamma} - \Delta\beta, 0\right)$$

MVA-based (a few highly discriminant**)**:

- Signed impact parameter + significance of leading track (i.e. Life Time Variables)
- Number of photons
- Photon Energy Sum
- Decay Mode
- Shape Variables



Inputs to the MVA-based jet discriminators

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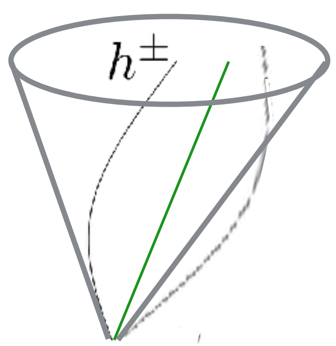

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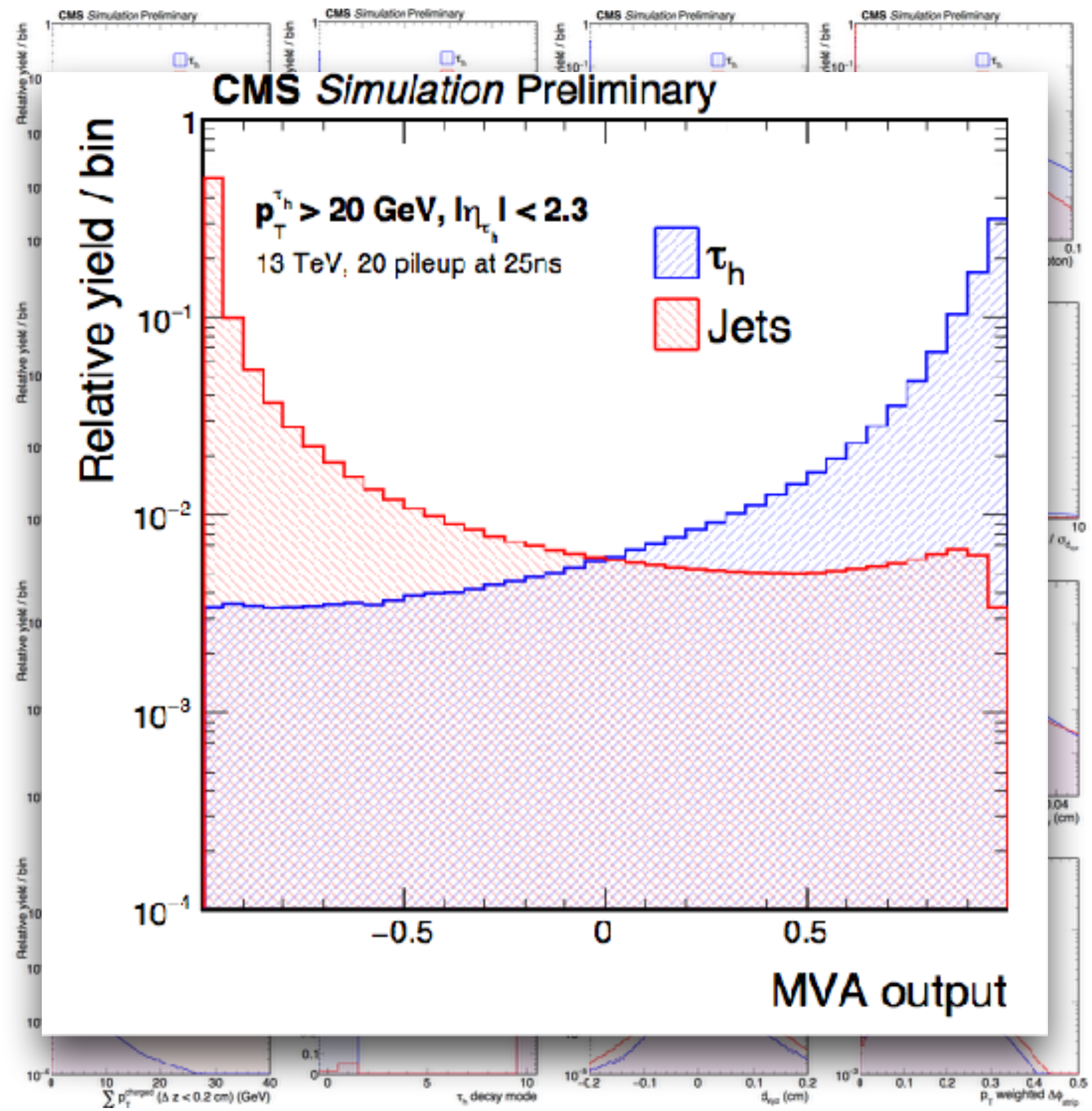
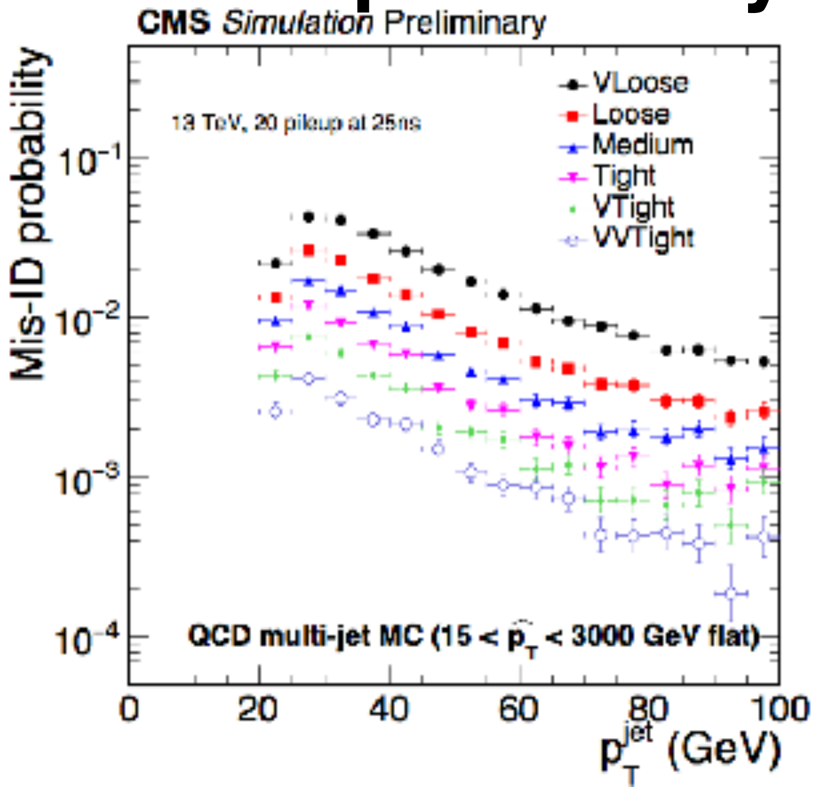


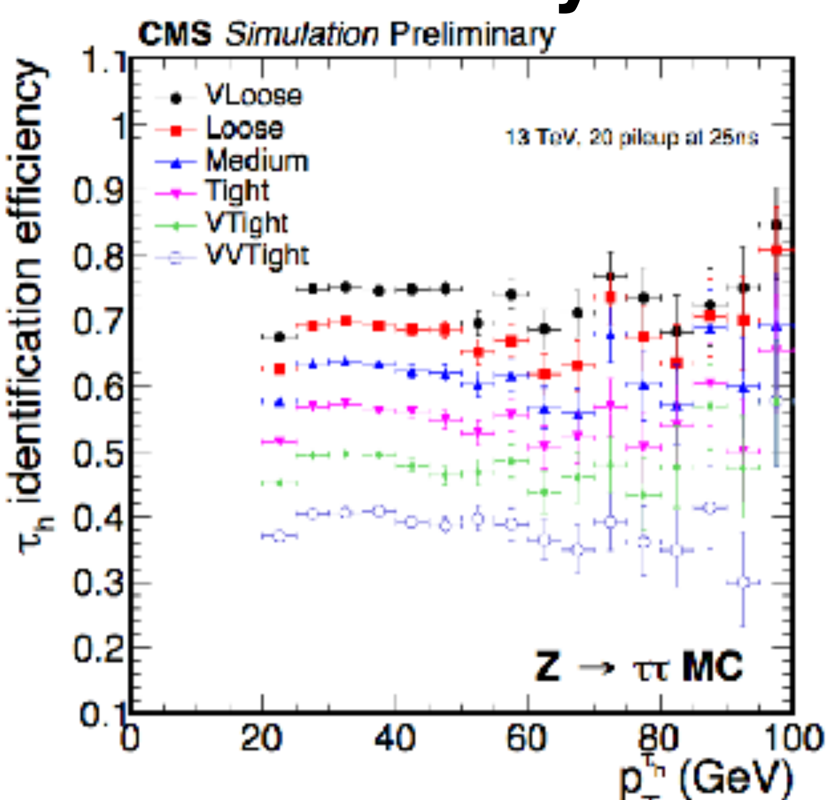
Inputs to the MVA-based jet discriminators

Jet→τ_h Discriminator

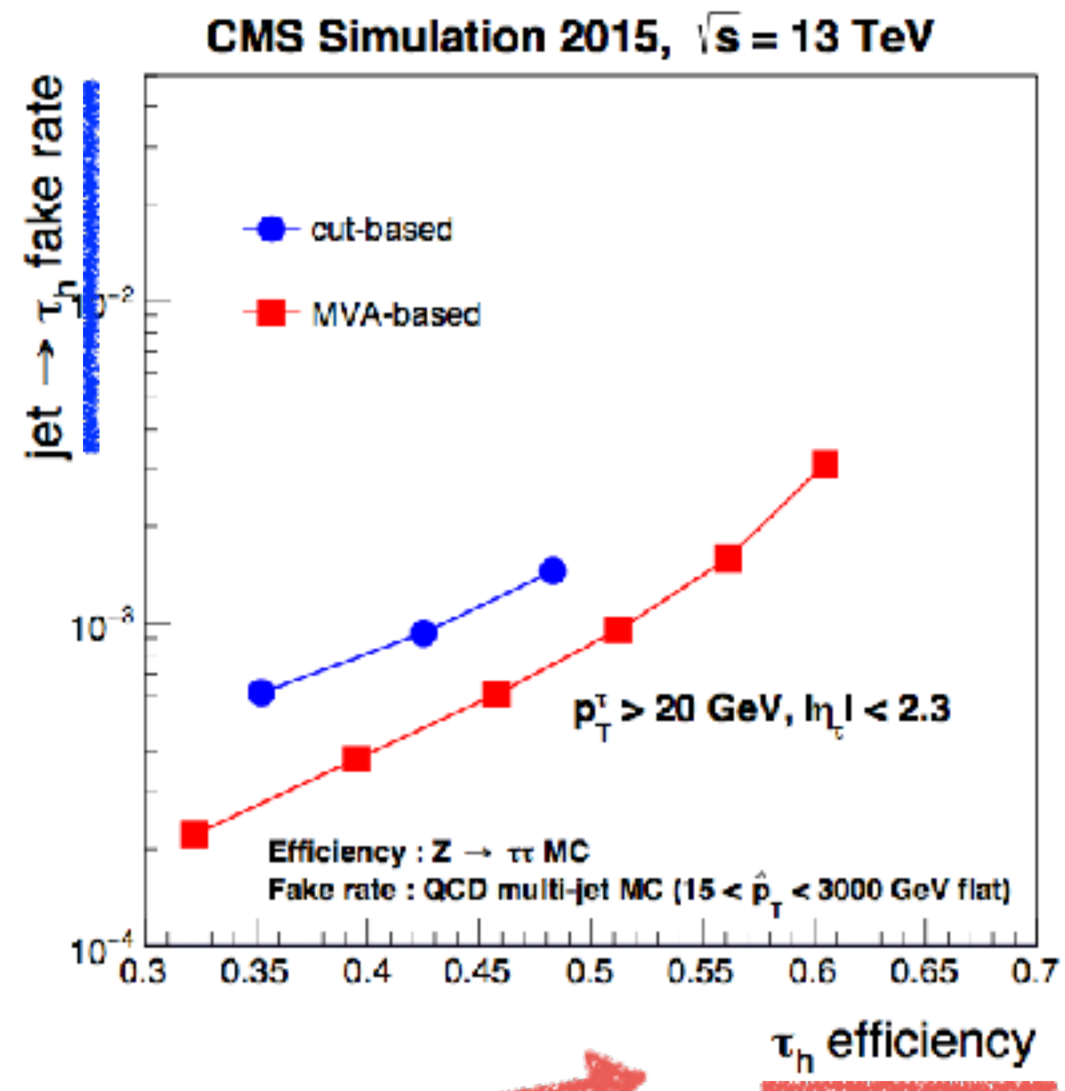
Tau Mis-ID probability



Tau ID Efficiency



Isolation Discriminator Performance



Higgs to ττ @ CMS

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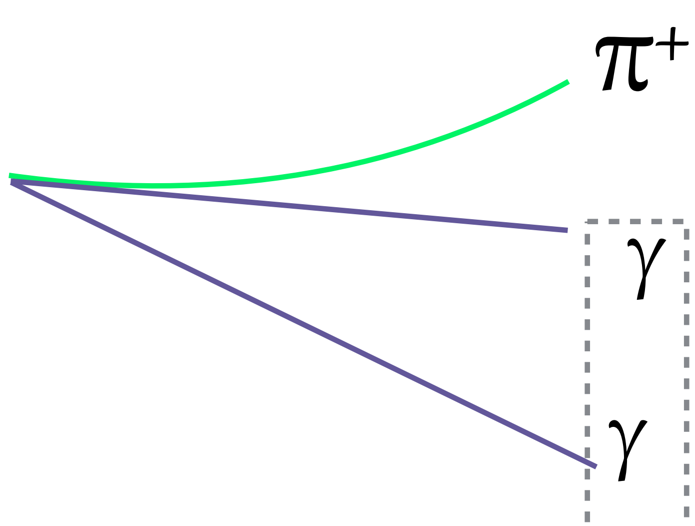
Fake τ_h: Electrons

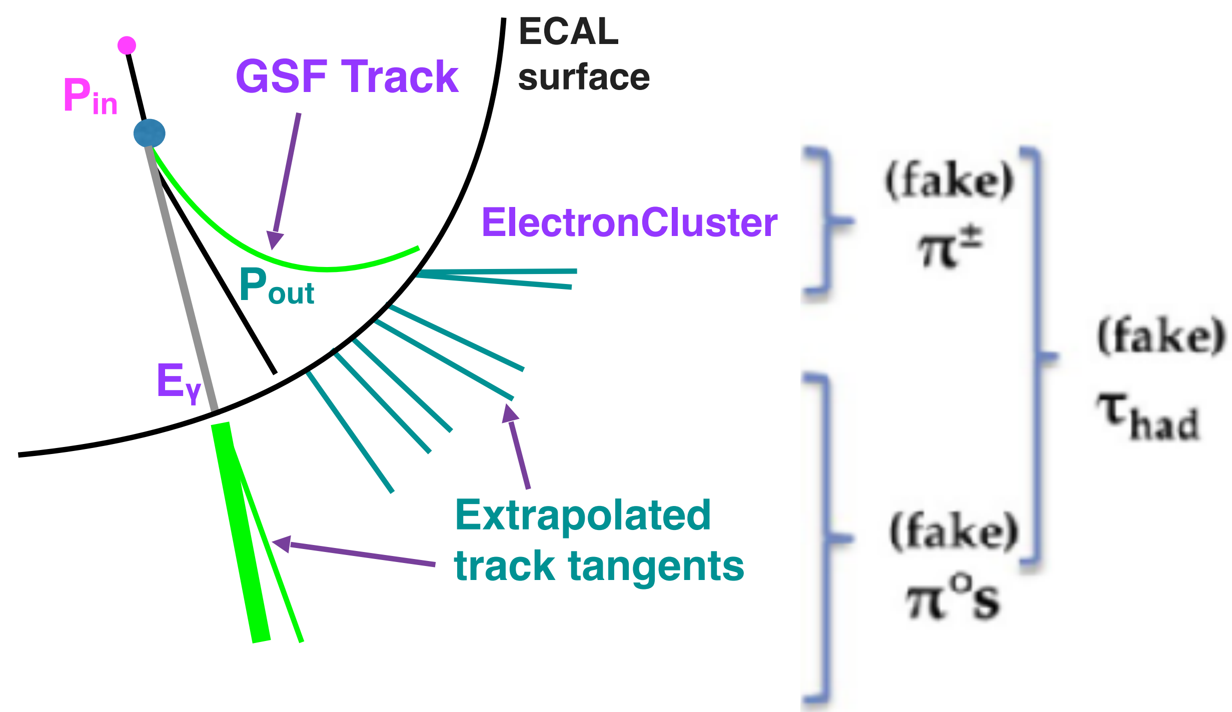
Electrons Faking Taus

- a “perfect” electron (1 GSF track + ECAL deposit) can pass the tau-ID reconstruction algorithm
- Will pass isolation requirements

* However, charged hadrons have a higher HCAL to ECAL ratio
* Electron ID also uses the shape of energy deposits in the ECAL

➡Key to reduce Electrons faking Taus?
Invert Electron ID using an MVA

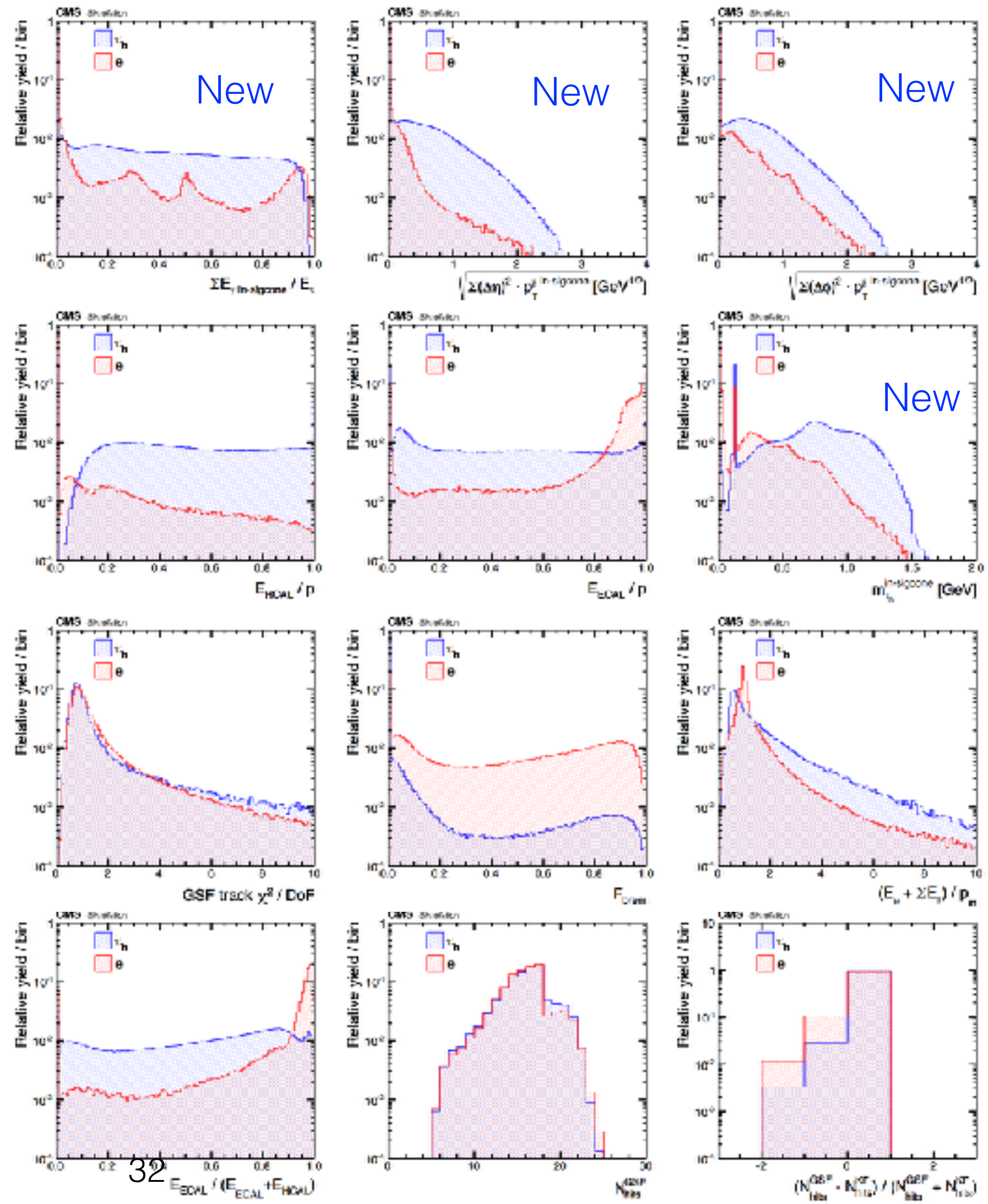




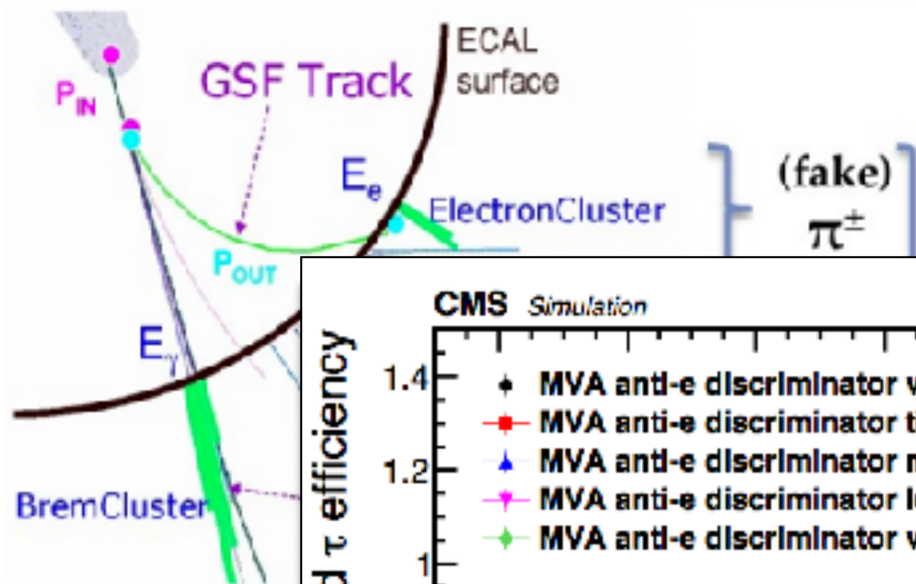
$e^{\pm} \rightarrow \tau_h$ Discriminator

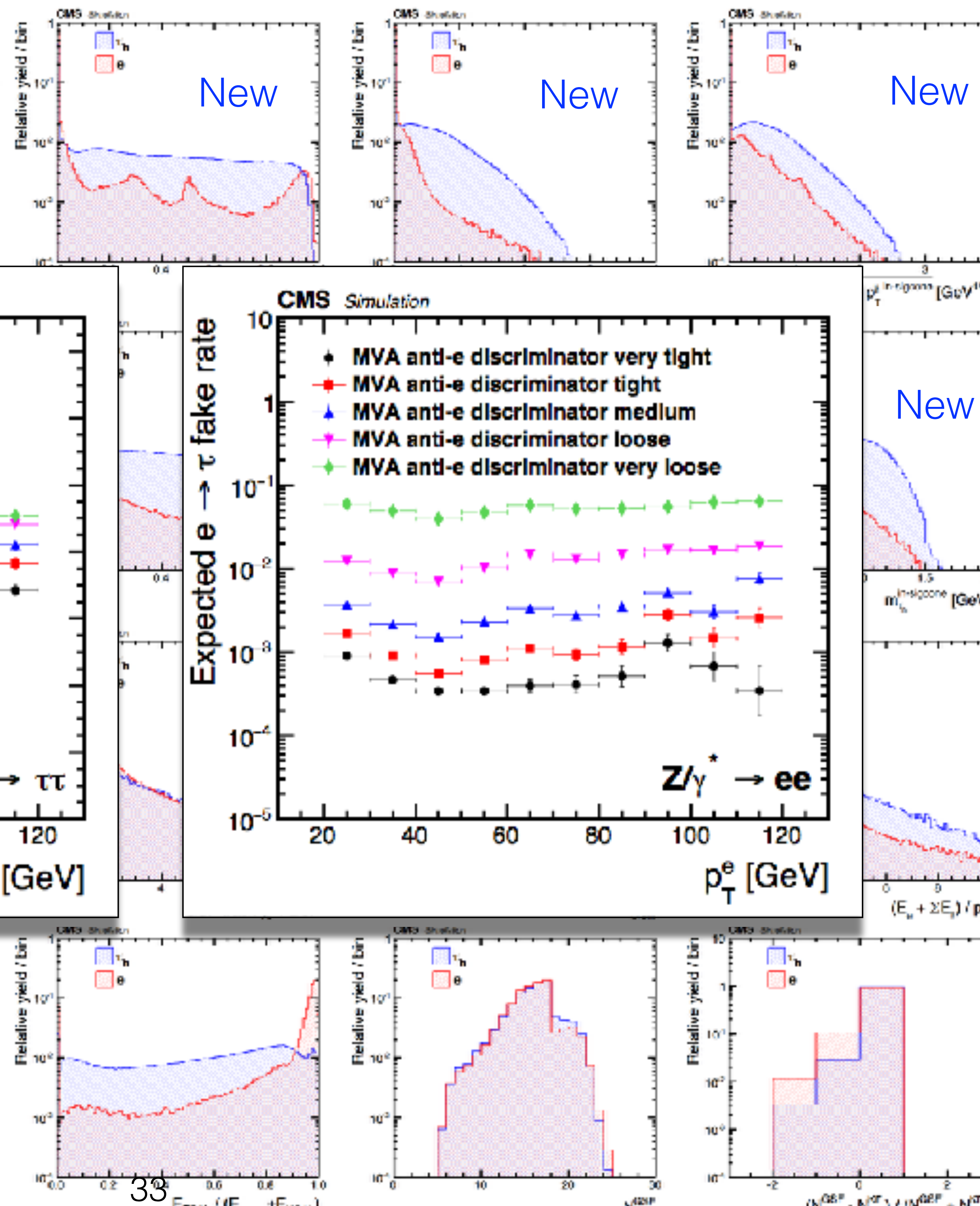
Additional Variables for anti-electron discriminator + retraining for Run II conditions

-> Tight WP significantly improved with respect to Run I



$e^{\pm} \rightarrow \tau_h$ Discriminator





Additiona
electron c
retraining

-> Tight WP significantly improved with respect to Run I

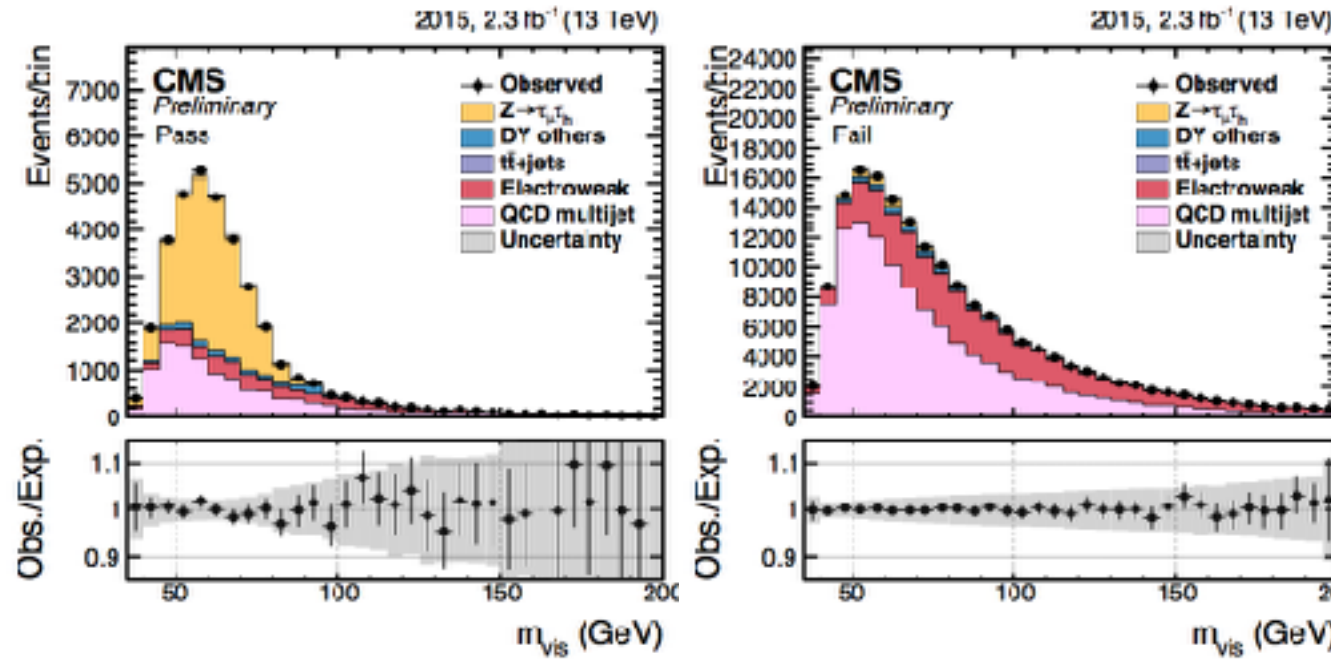
τ_h ID Efficiency: Tag and Probe

Tau Identification Efficiency measured using $Z/\gamma^* \rightarrow \tau_\mu\tau_h$

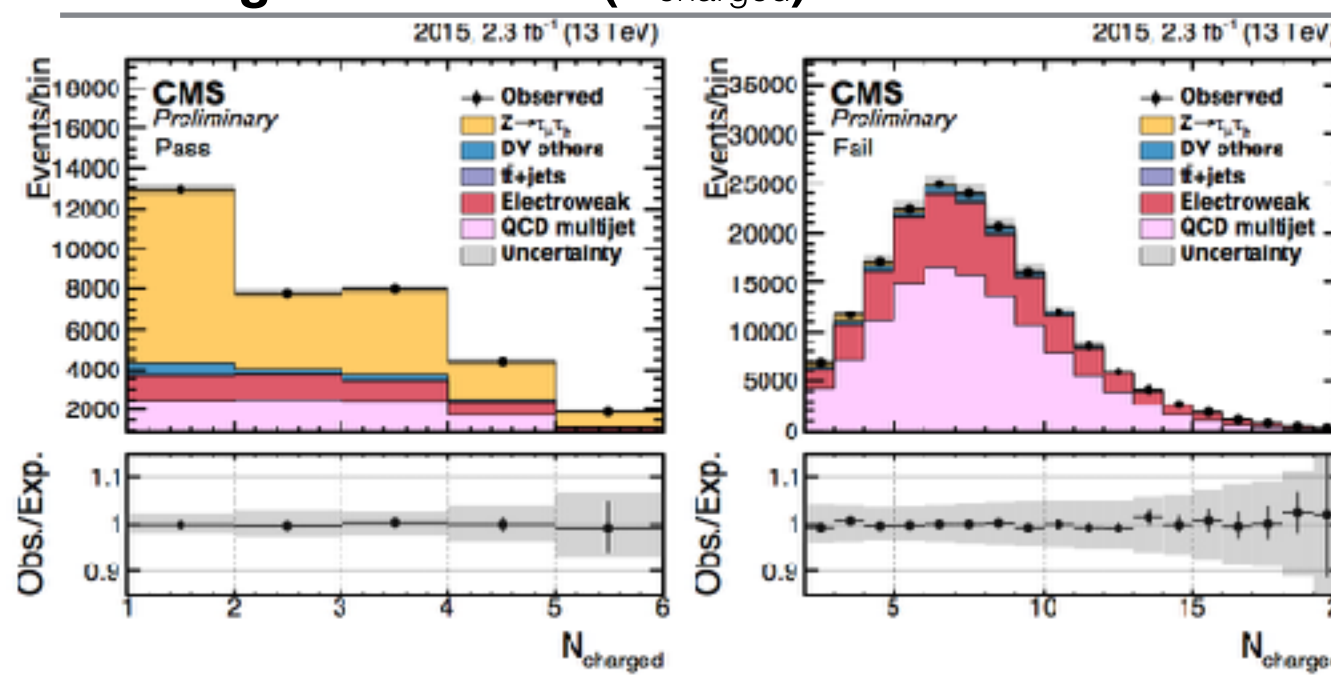
- **Tag:** Identified, Isolated Muon
- **Probe:** τ_h candidate which either **Passes** or **Fails** discriminant ID working points
- Maximum Likelihood Fit performed using the **Visible Mass of the $\tau_\mu\tau_h$ System** similar performance seen using the number of charged particles distribution

		Data/MC (m_{vis})
Cut-based	Loose	0.93 ± 0.02
	Medium	0.91 ± 0.02
	Tight	0.89 ± 0.02
MVA-based	Loose	0.99 ± 0.01
	Medium	0.97 ± 0.01
	Tight	0.95 ± 0.01
	Very Tight	0.93 ± 0.01

Visible Mass of the $\tau_\mu\tau_h$ System (m_{vis})



N-Charged Particles ($N_{charged}$)



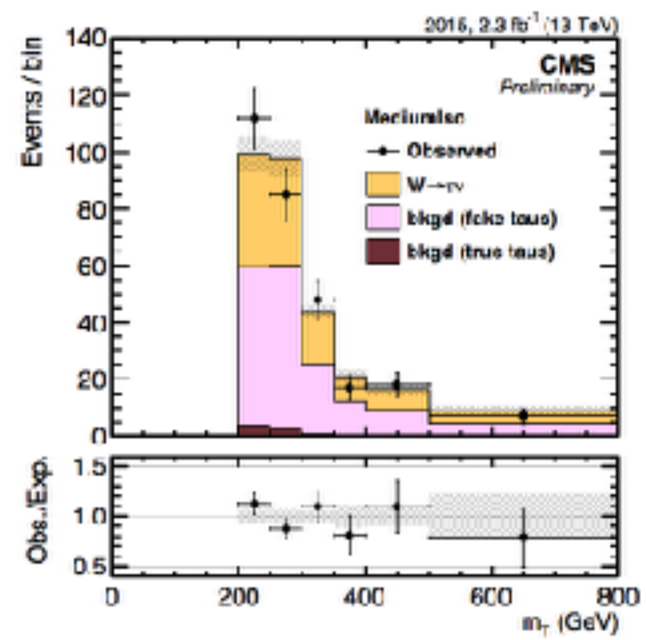
τ_h ID Efficiency: $W^* \to \tau_h \nu$

Targets High p_T τ_h

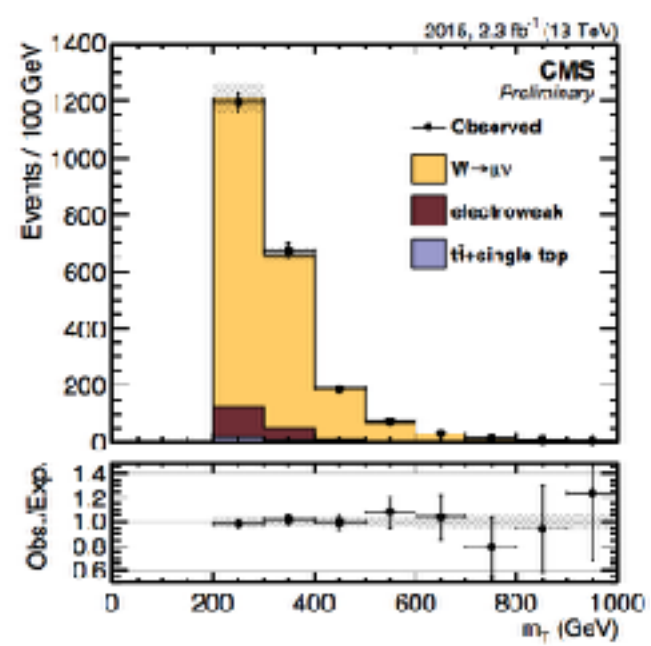
- Important uncertainty in searches for high mass resonances which decays to τ's
- Efficiency measured using $W^* \to \tau_h \nu$ events **with a highly virtual W Selected:** $p_T(\tau_h)$ >100 GeV, ME_T>100 GeV and a back-to-back topology
- **Fake Tau Background** estimated using a control region where the τ_h is not isolated
- **Systematic uncertainties** due to the cross-section of the virtual W are constrained through a simultaneous fit with a $W^* \to \mu\nu$ control region

		Data/MC (m_T)
Cut-based	Loose	0.94 ± 0.21
	Medium	0.91 ± 0.19
	Tight	0.83 ± 0.20
MVA-based	Loose	0.96 ± 0.17
	Medium	0.95 ± 0.15
	Tight	0.94 ± 0.15
	Very Tight	0.94 ± 0.14

Transverse Mass of the τ_h+MET System (m_T)



Transverse Mass of the μ+MET System (m_T)



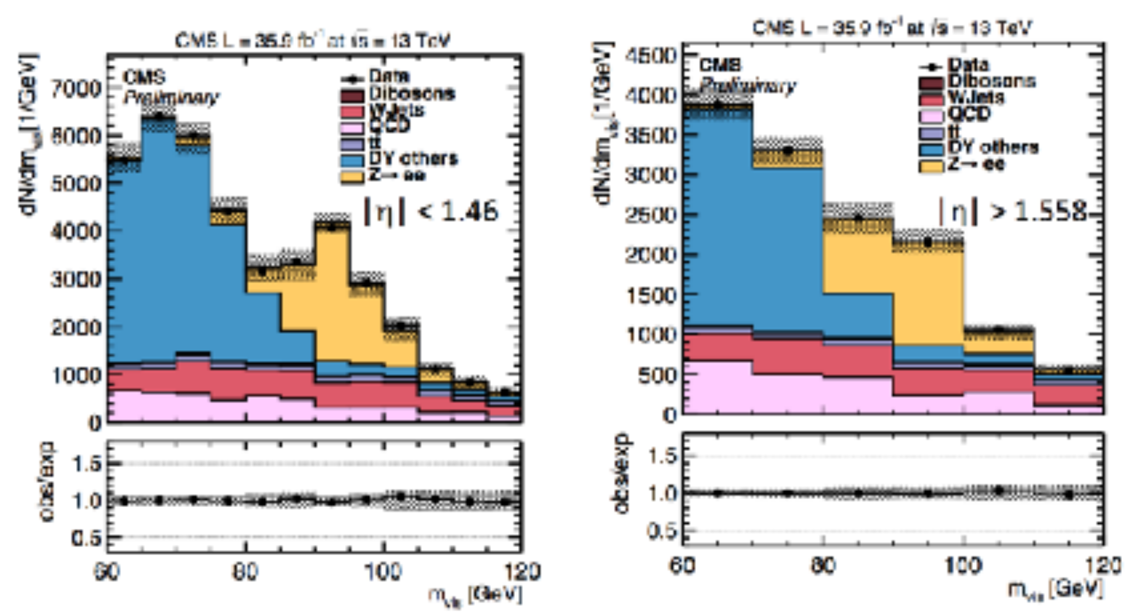
Tau ID is described well in the high p_T regime

τ_h ID Performance: e/μ/jet→τ_h

Fake Probability for electrons (muons) measured using $Z/\gamma^* \rightarrow \tau_e \tau_h$ ($Z/\gamma^* \rightarrow \tau_\mu \tau_h$) and enriched Jet events

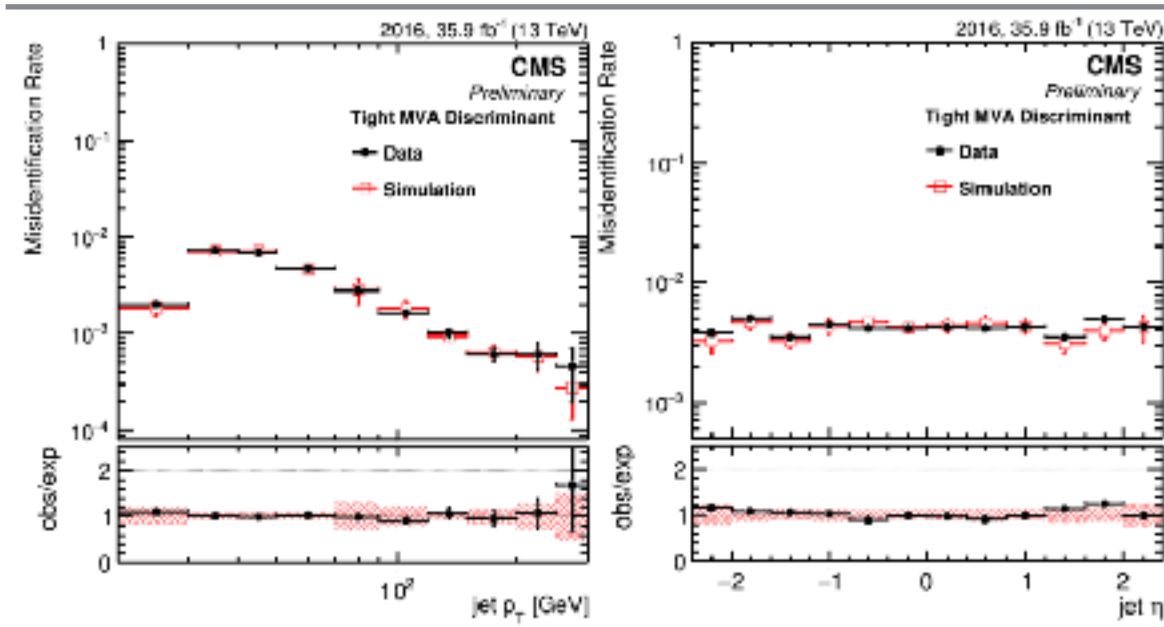
- Ratio of Data to Simulation is measured
  - General agreement for loose electron and muon rejection working points
  - Some disagreement seen where strict requirements are made and for jet to fake distributions

Data / MC e→τ_h Fake Probability (m_{vis})



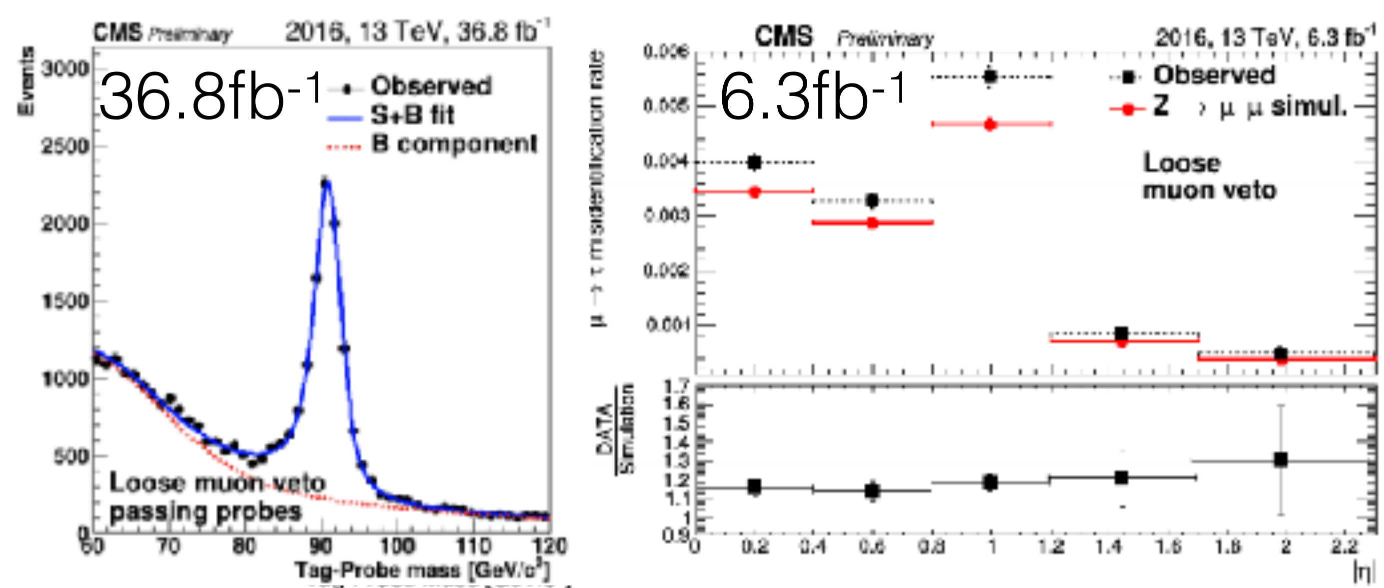
- Similar Tag and Probe method
- Higher Observed/Expected factor for Tight Working Points

Data / MC Jet→τ_h Fake Probability



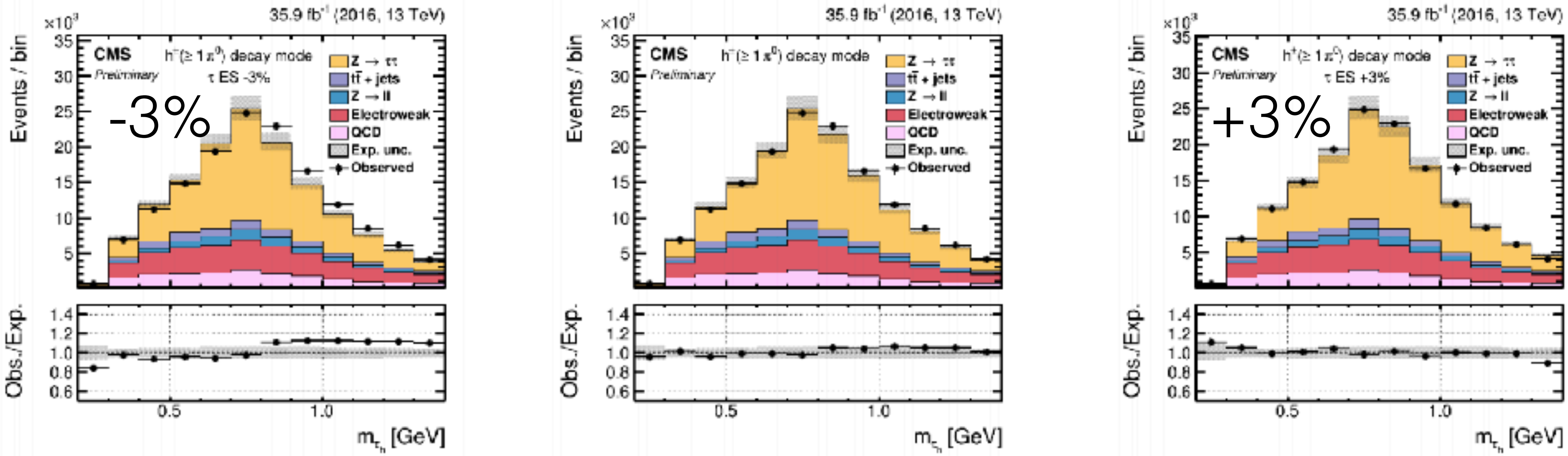
- Fake probability dependent on the selected final state
- Good Data MC Agreement

Data / MC μ→τ_h Fake Probability (m_{vis})



- Increased misidentification probability in Barrel-Endcap transitional region (expected)
- Higher Observed/Expected factor for Tight Working Points

τ_h Energy Scale Measurement



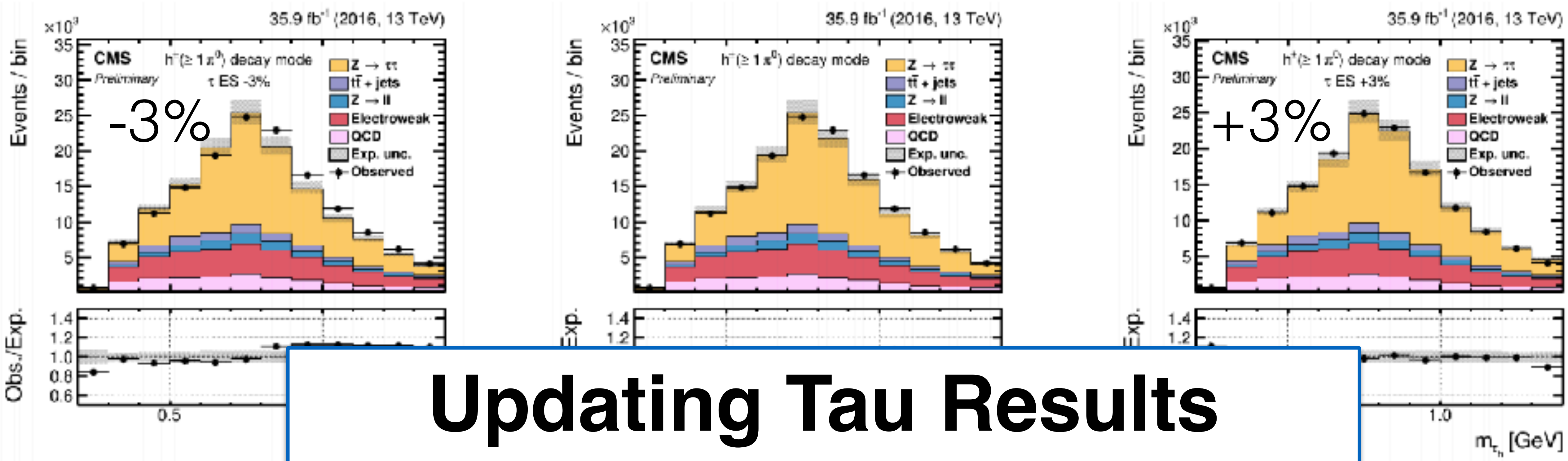
Decay mode	Tau energy scale [%]
1-prong	+0.0 ± 1.1
1-prongπ^0	+1.0 ± 0.4
3-prong	-0.1 ± 0.2

A **leading systematic uncertainty** arising from Tau Reconstruction is the uncertainty due to the estimated Tau Energy Scale

- Measurement for the **1-prong + π^0** and **3-prong** reconstruction decay modes performs a shape fit using the invariant mass of the hadronic tau
- **1-prong** decay mode fit is performed using the visible mass of the $\tau_\mu\tau_h$ system

NOTE:
Recommend 3% uncertainty for high pT

τ_h Energy Scale Measurement



Updating Tau Results this winter in a Paper using the Full 2016 Dataset

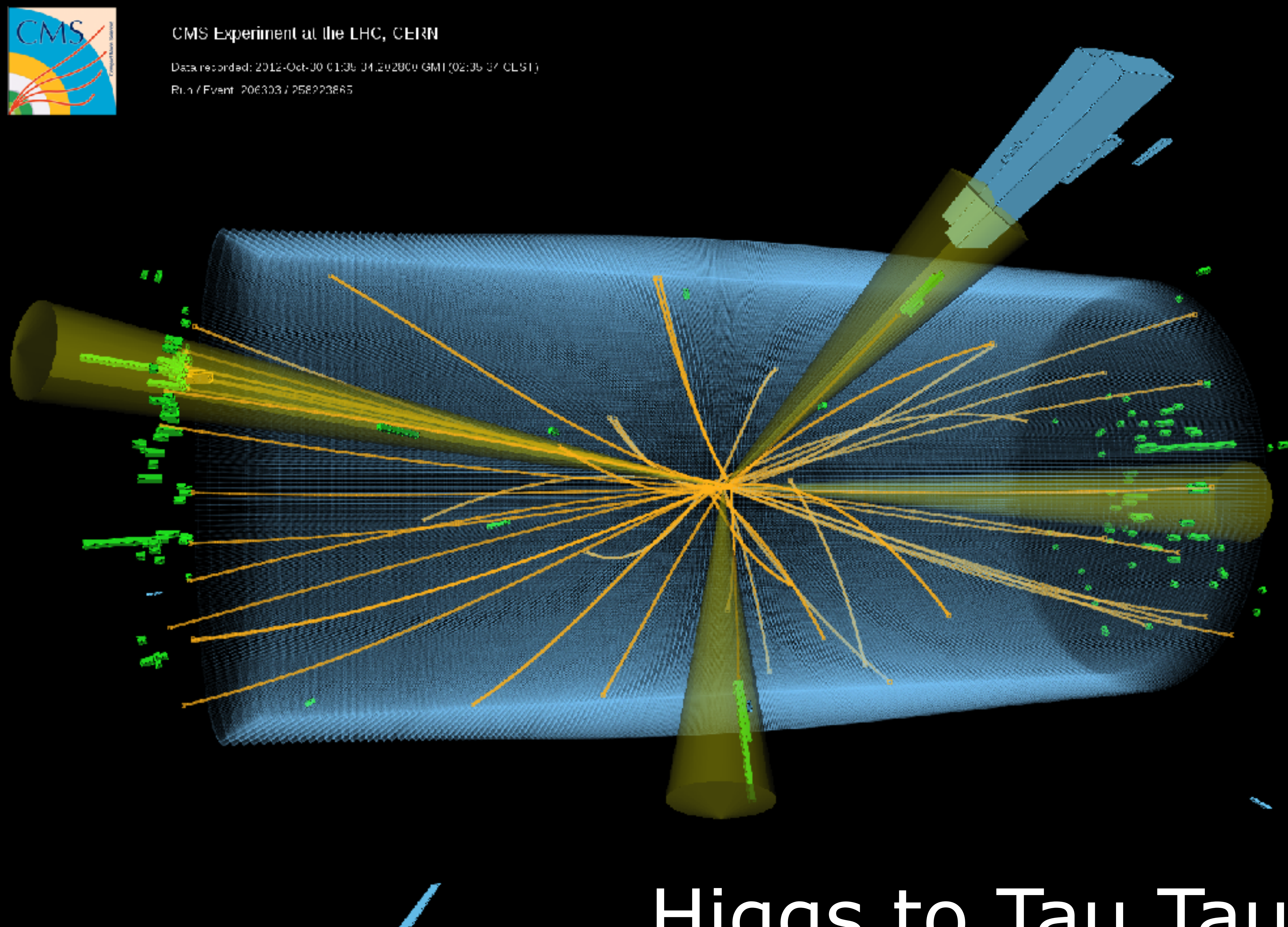
y arising
certainty
Scale

Decay mode	T
1-prong	+0.0 ± 1.1
1-prongπ^0	+1.0 ± 0.4
3-prong	-0.1 ± 0.2

- Measurement for the **1-prong + π^0** and **3-prong** reconstruction decay modes performs a shape fit using the invariant mass of the hadronic tau
- **1-prong** decay mode fit is performed using the visible mass of the $\tau_\mu\tau_h$ system

NOTE:

Recommend 3% uncertainty for high pT



Higgs to Tau Tau

Analysis in the Higgs Sector

Reconstruct Data + Monte Carlo

↓

Select for Signal

↓

Define Systematic Uncertainties

↓

Extract Signal

The Good

Enhanced Branching Fractions

Excellent Online Data Selection

Detector Designed to Reconstruct Taus

The Bad

High Number of Fakes (Jets Look Like Taus)

Energy ‘lost’ from decays to Neutrinos

Large Number of Systematic Uncertainties

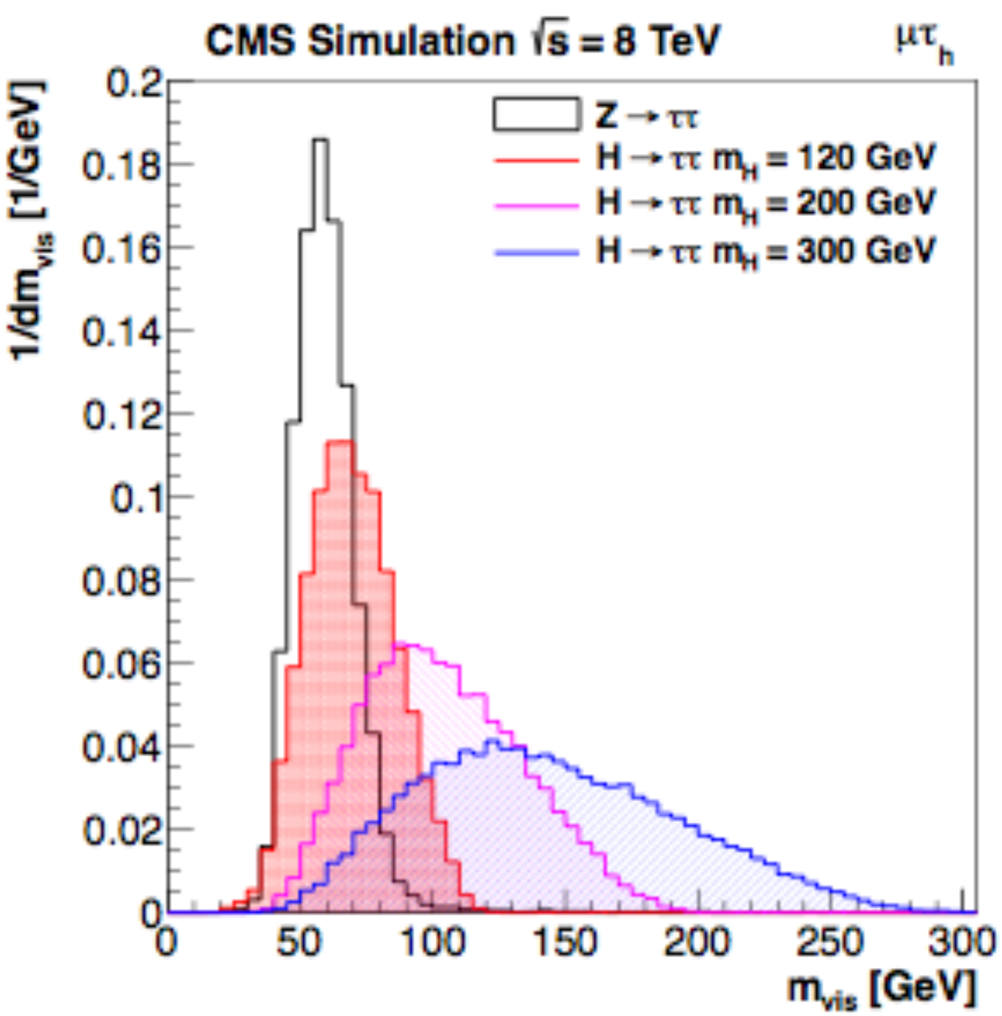
Difficult to Extract Signal from Background

ττ Mass Estimation

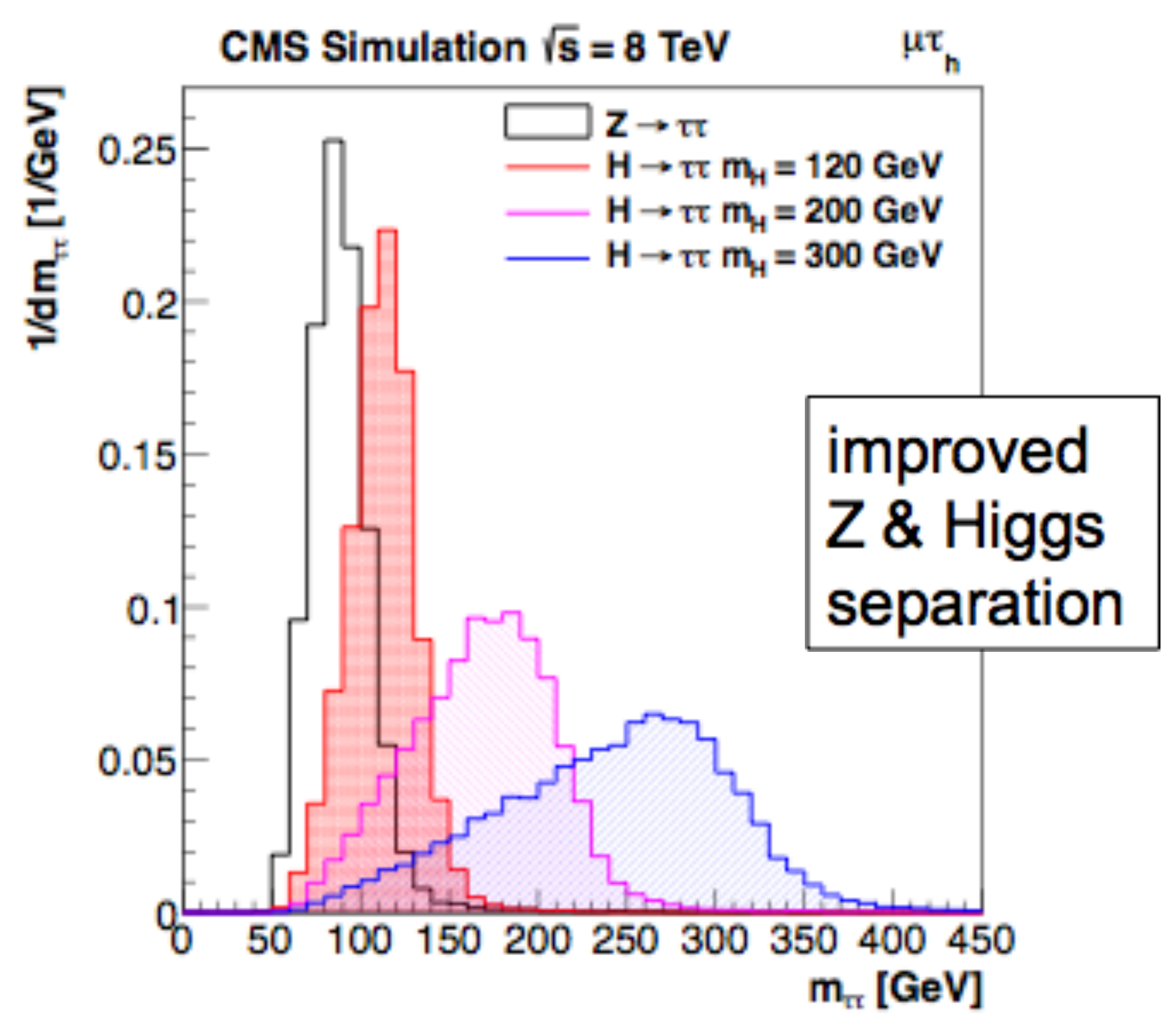
ττ Mass estimation uses visible decay products & missing E_T in a maximum likelihood fit to estimate neutrino momentum

The mass resolution is ~ 10-20% depending on channel/category

Visible mass



SV fit Reconstructed mass



SM Hττ Categories

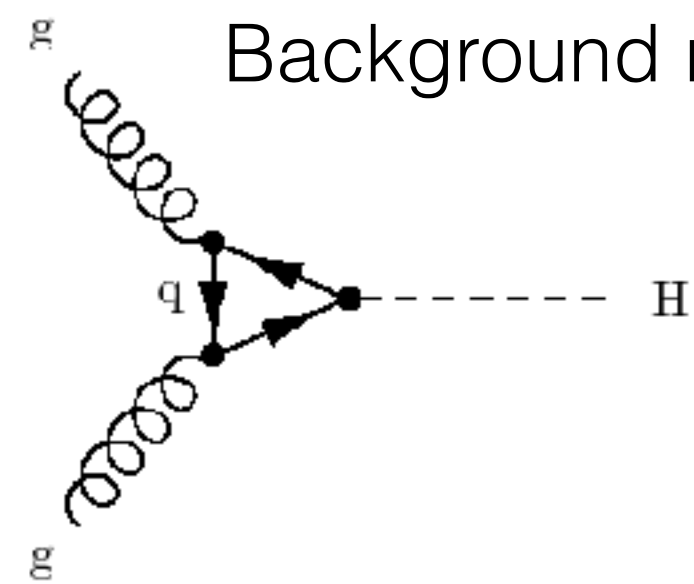
Four di-Tau Final States:

eτ, μτ, ττ, eμ

Three categories for signal extraction:

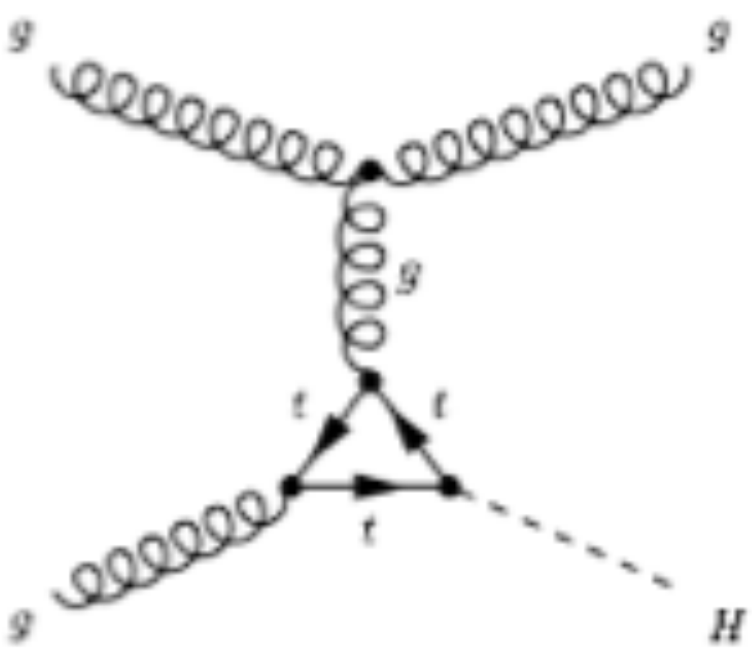
0-Jet

Background normalization



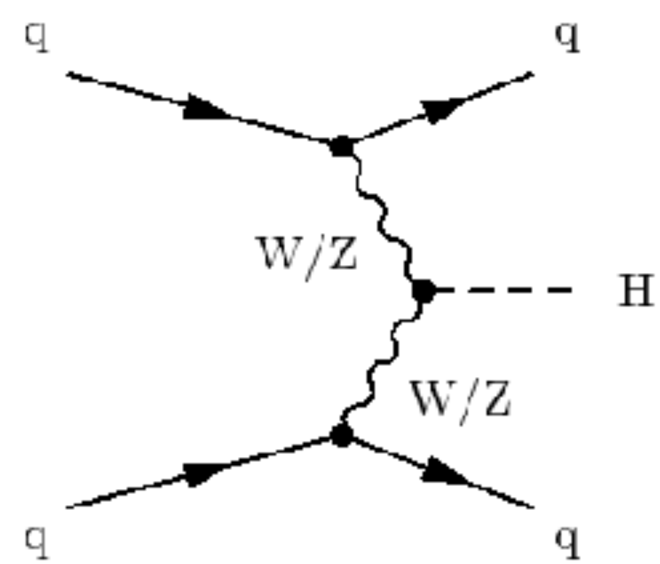
1-Jet

Boosted higgs



2-Jet

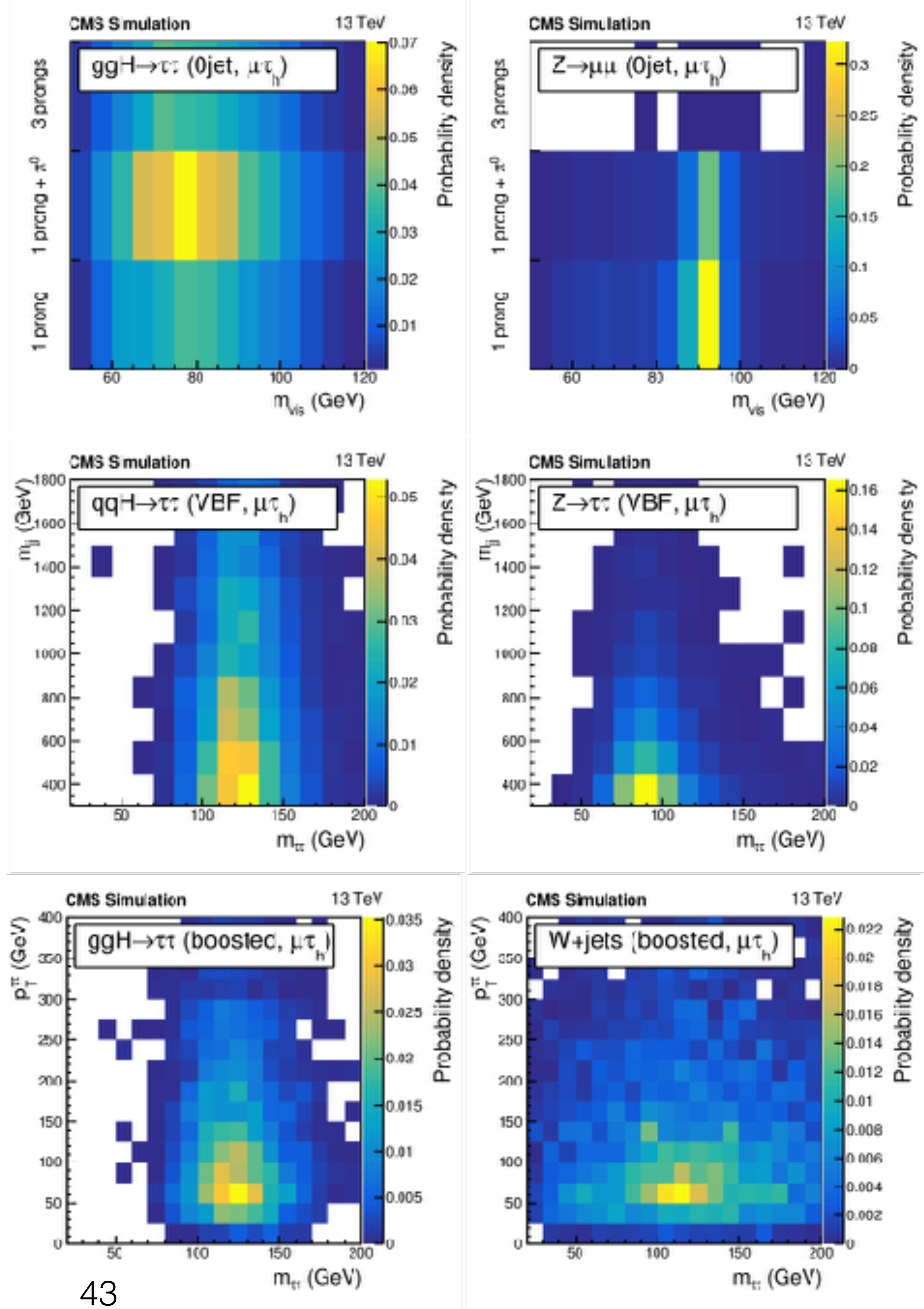
Select VBF, Suppress ggH



SM Hττ Categories

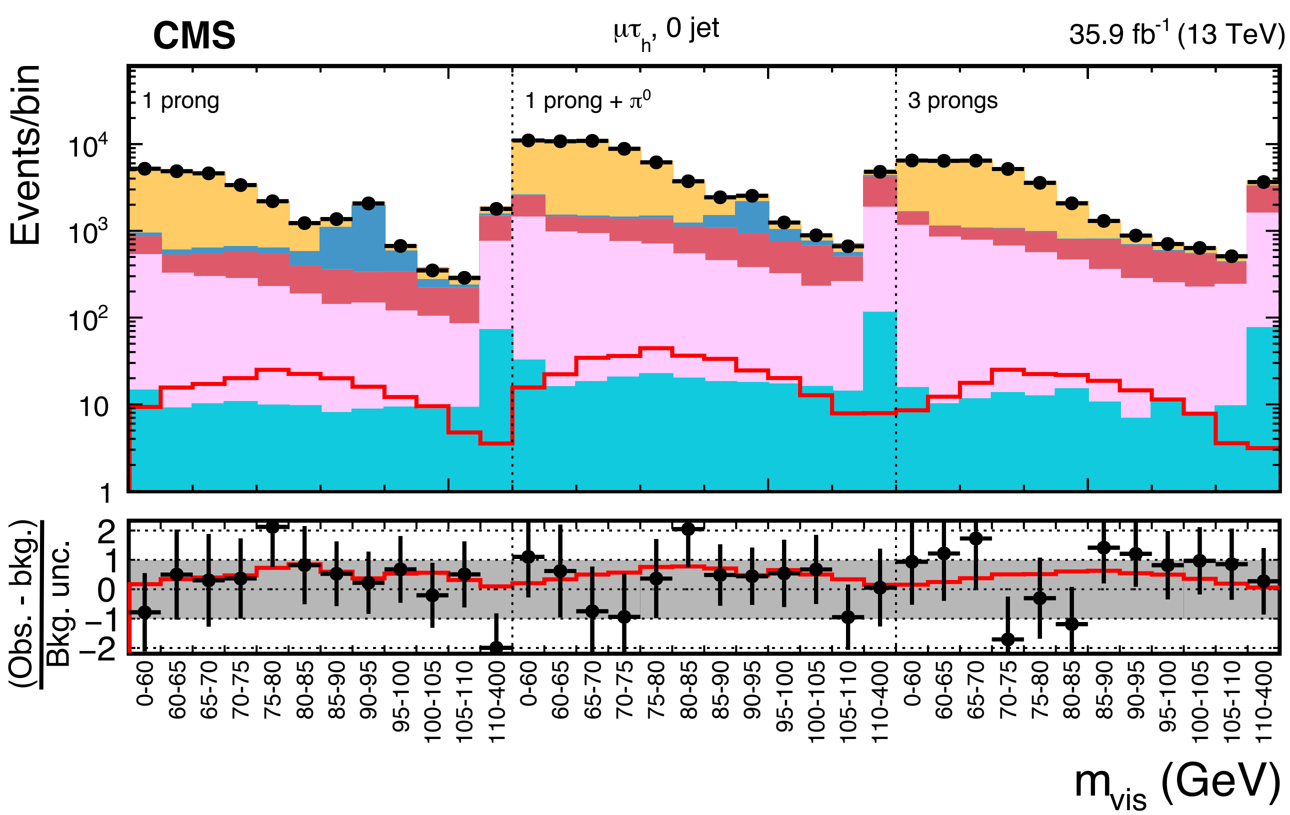
Using Two dimensional Fits:

0 jet*: M_{vis} vs. **τ/μ** p_T
or M_{vis} vs. **τ** DM
VBF: SVMass vs. M_{jj}
Boosted: SVMass vs. Higgs p_T

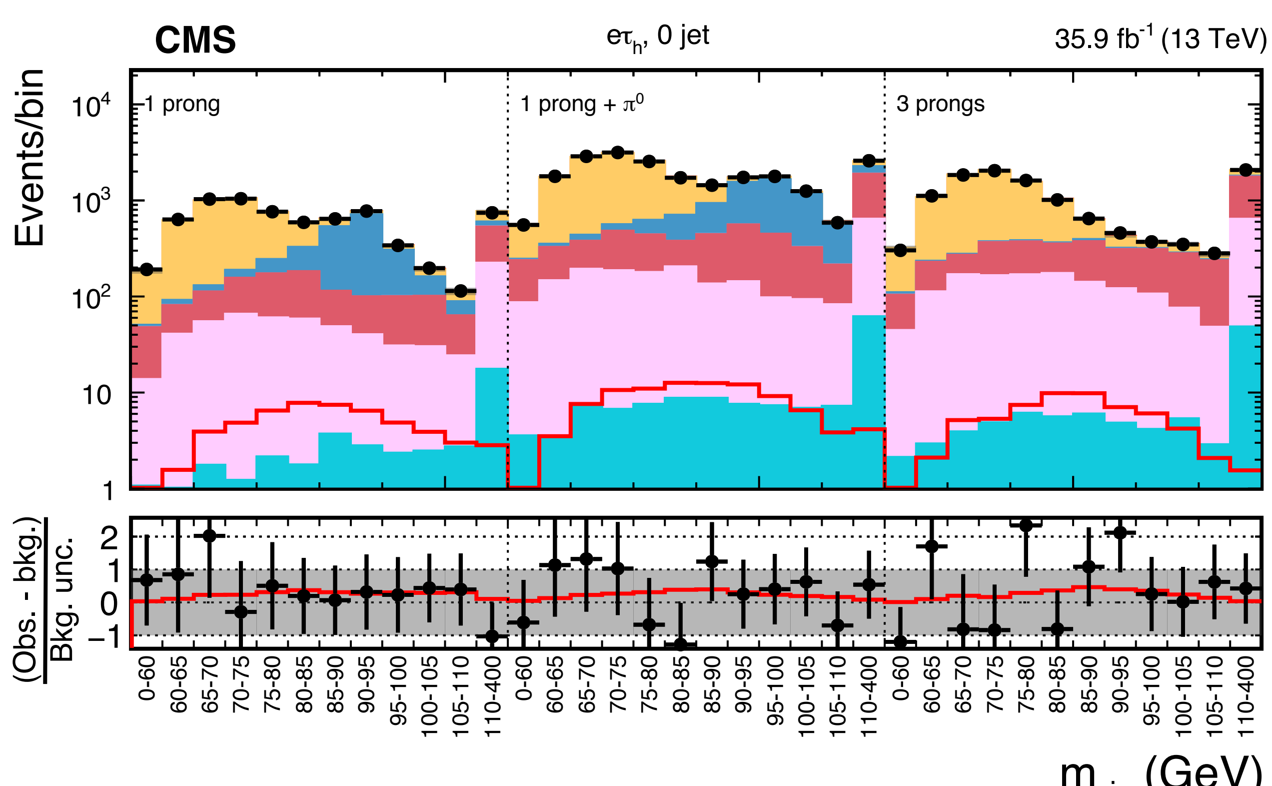


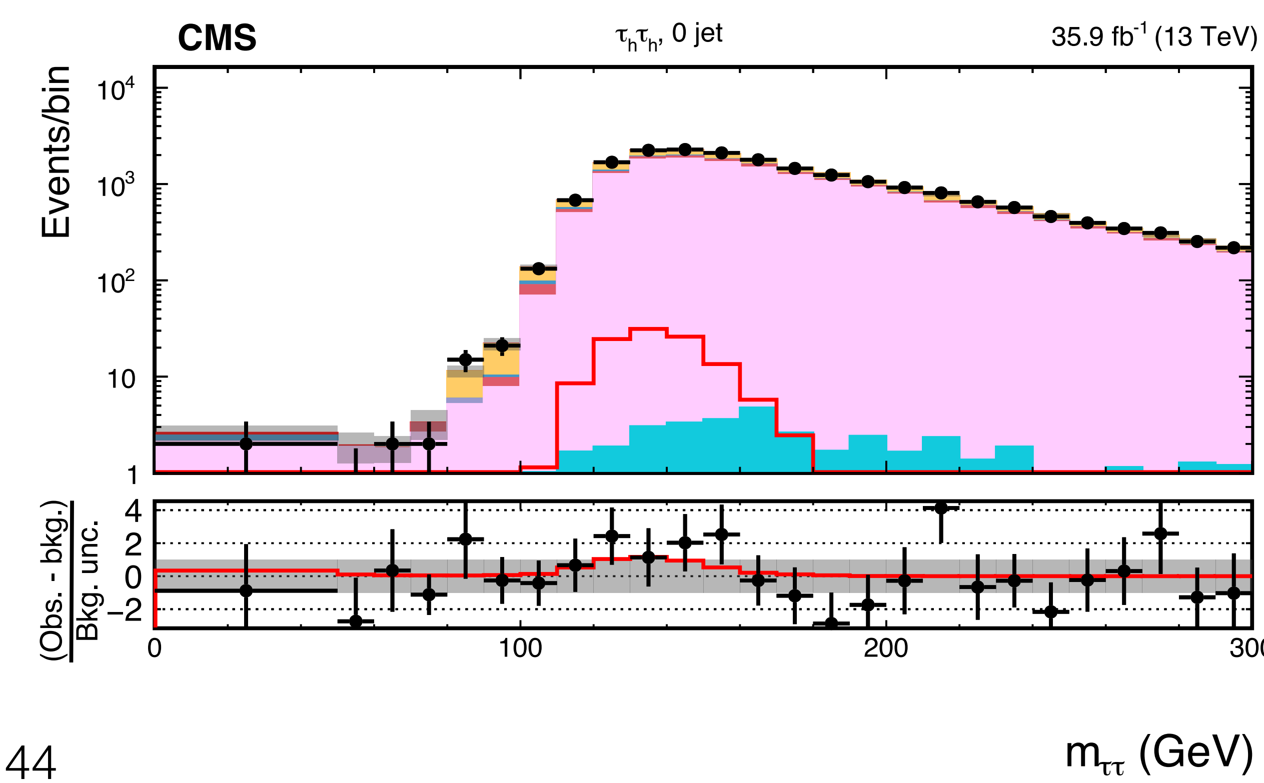
Standard Model H→ττ

Two Dimensional Distributions:



0-Jet Category Used to Model backgrounds including
- Z->TauTau
- Z->ee/Z->mumu
- and QCD





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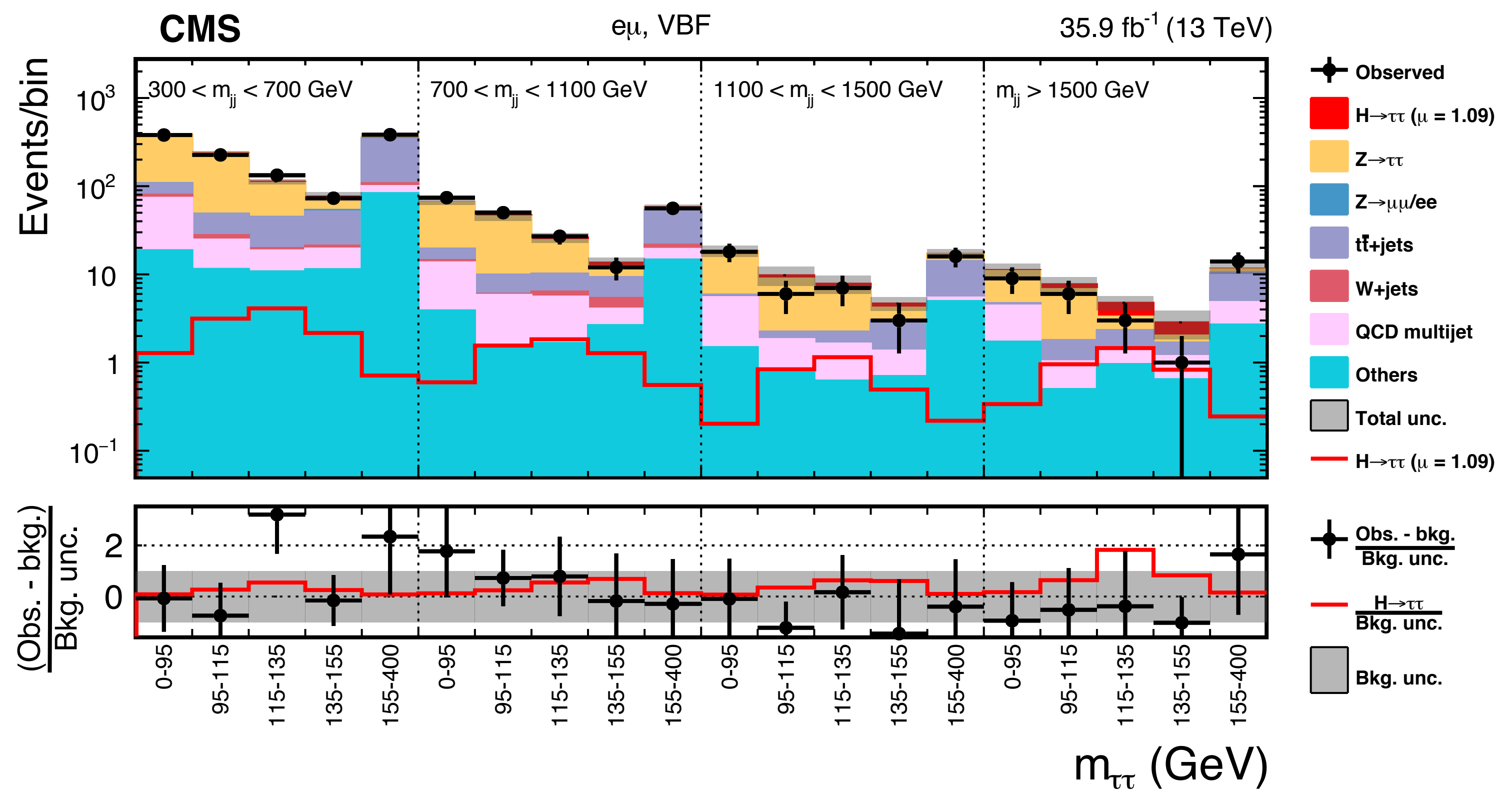
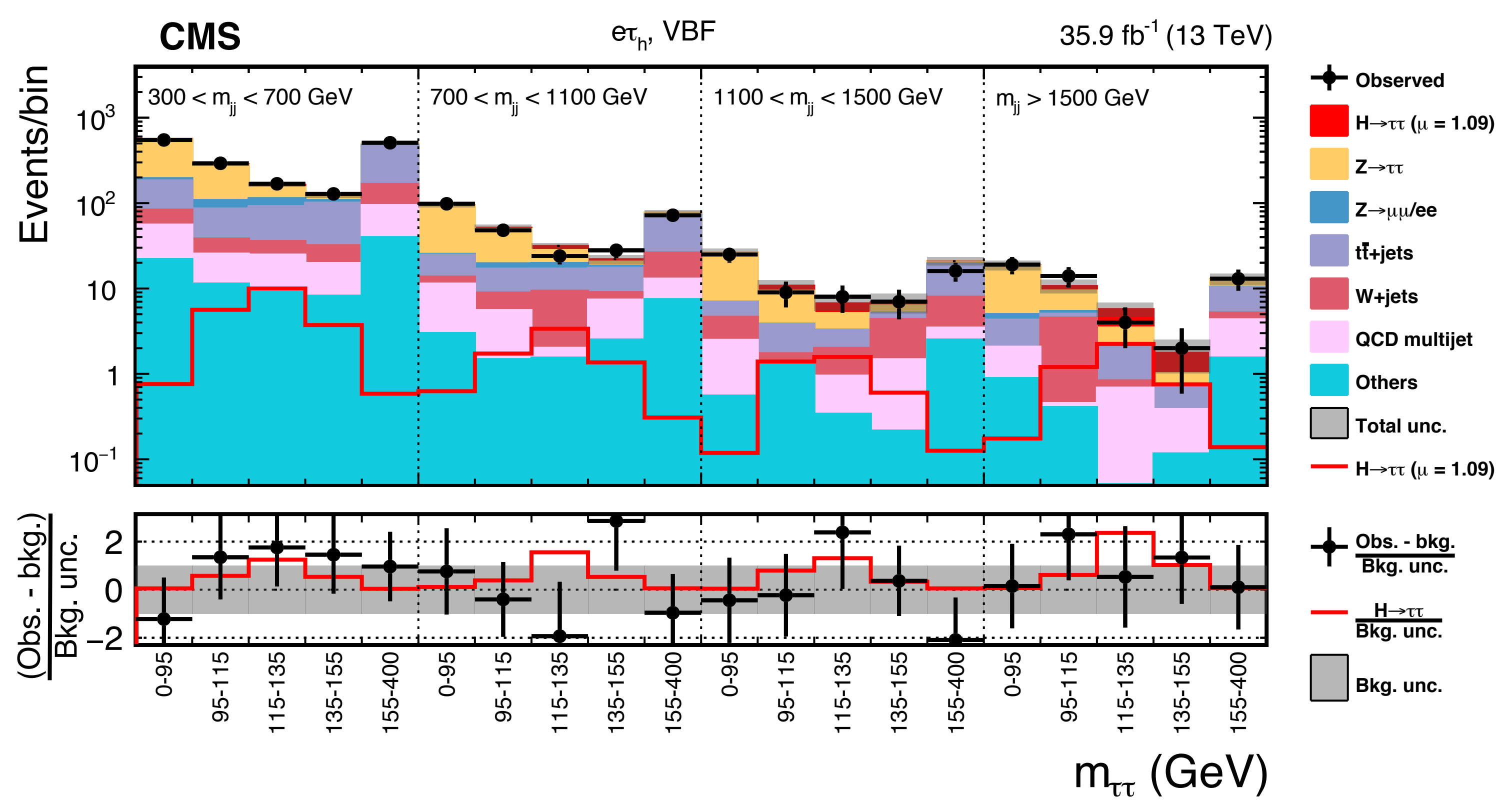
Standard Model H→ττ

VBF High Signal Region:

eμ, VBF



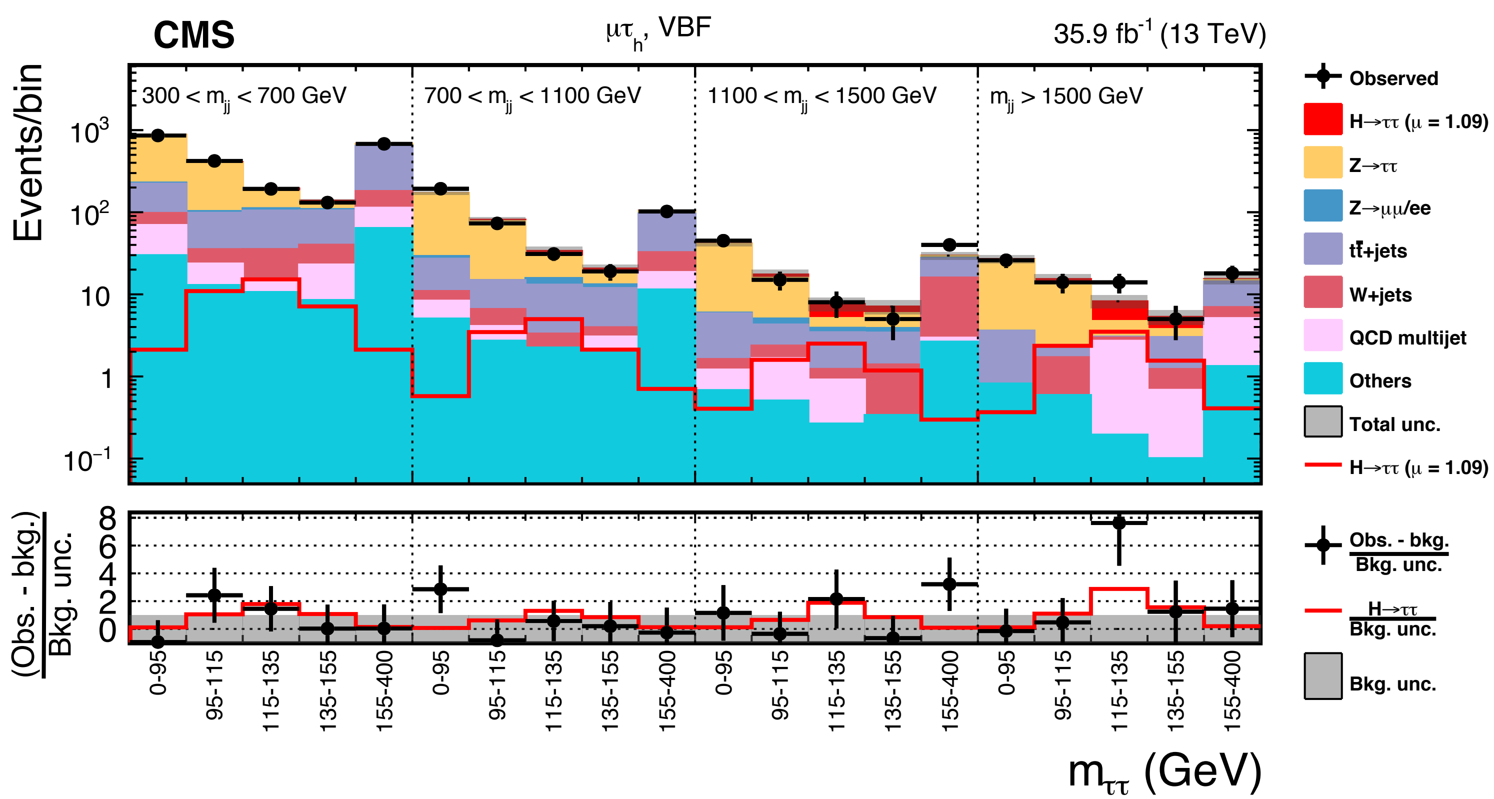
eτh, VBF



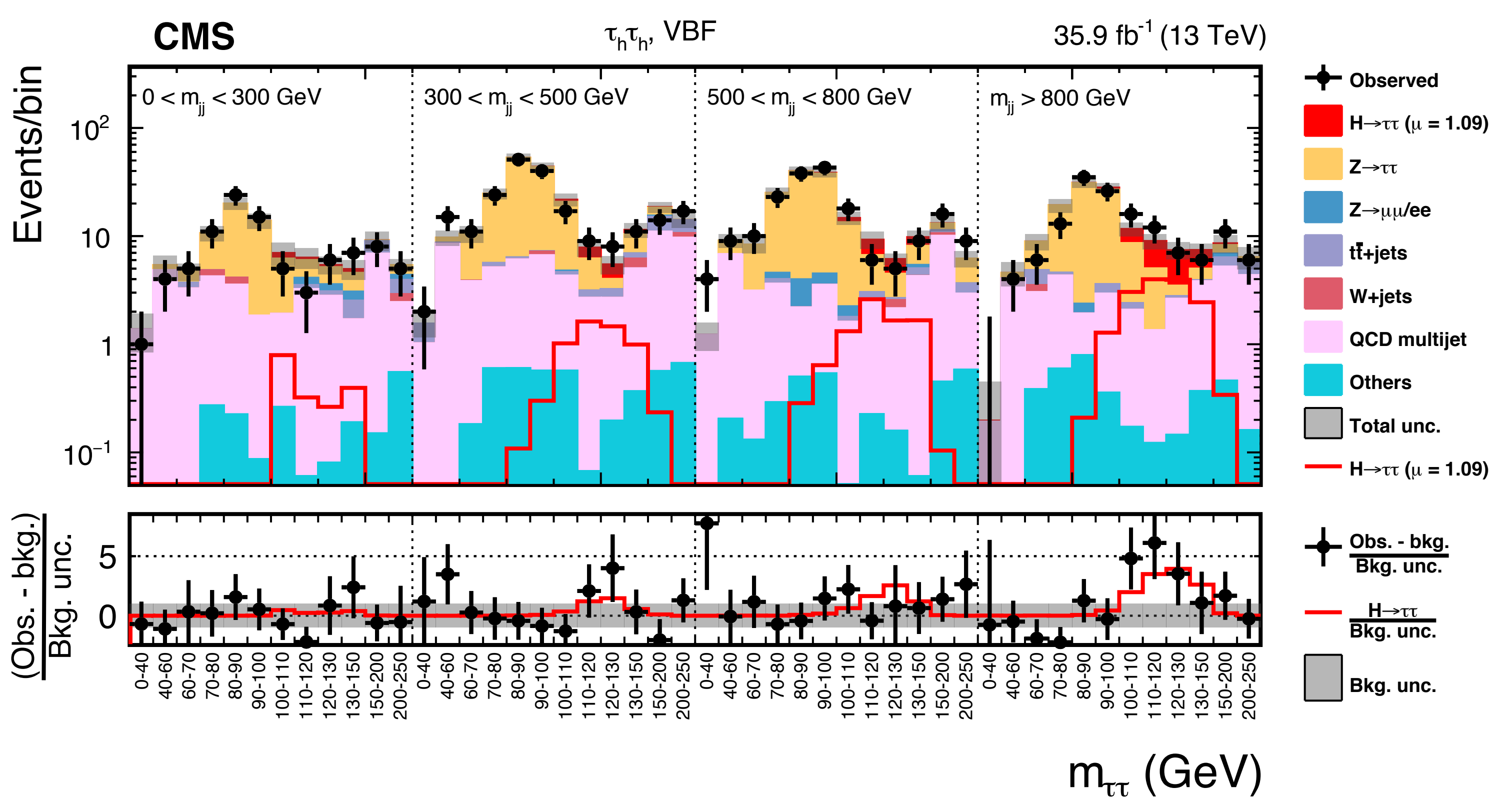
Standard Model H→ττ

VBF High Signal Region:

$\mu\tau_h$, VBF



$\tau_h\tau_h$, VBF



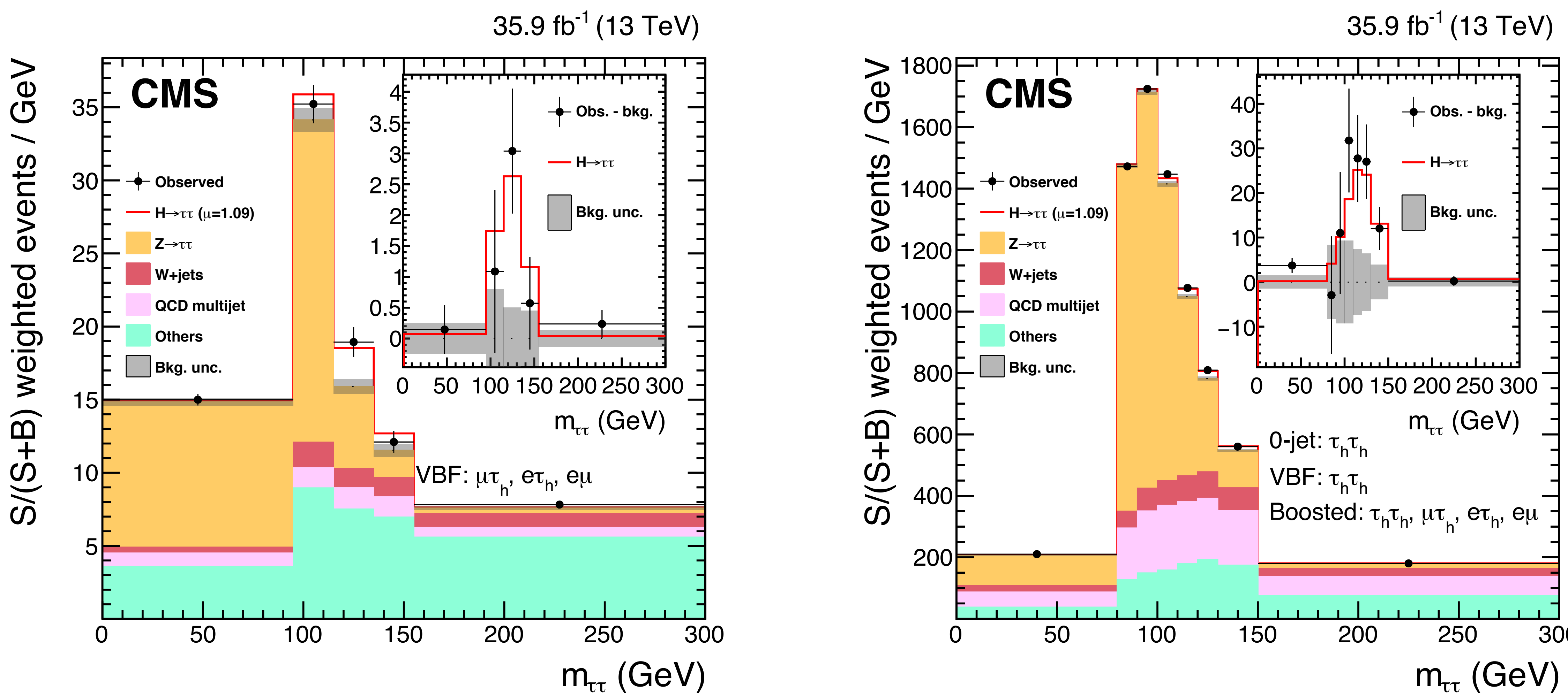
Systematic Uncertainties

Source of uncertainty	Prefit	Postfit (%)
τ_h energy scale	1.2% in energy scale	0.2–0.3
e energy scale	1–2.5% in energy scale	0.2–0.5
e misidentified as τ_h energy scale	3% in energy scale	0.6–0.8
μ misidentified as τ_h energy scale	1.5% in energy scale	0.3–1.0
Jet energy scale	Dependent upon p_T and η	—
$\vec{p}_T^{miss}$ energy scale	Dependent upon p_T and η	—
τ_h ID & isolation	5% per τ_h	3.5
τ_h trigger	5% per τ_h	3
τ_h reconstruction per decay mode	3% migration between decay modes	2
e ID & isolation & trigger	2%	—
μ ID & isolation & trigger	2%	—
e misidentified as τ_h rate	12%	5
μ misidentified as τ_h rate	25%	3–8
Jet misidentified as τ_h rate	20% per 100 GeV τ_h p_T	15
$Z \to \tau\tau/\ell\ell$ estimation	Normalization: 7–15%	3–15
	Uncertainty in $m_{\ell\ell/\tau\tau}$, $p_T(\ell\ell/\tau\tau)$, and m_{jj} corrections	—
W + jets estimation	Normalization ($e\mu$, $\tau_h\tau_h$): 4–20%	—
	Unc. from CR ($e\tau_h$, $\mu\tau_h$): $\simeq$5–15	—
	Extrap. from high-m_T CR ($e\tau_h$, $\mu\tau_h$): 5–10%	—
QCD multijet estimation	Normalization ($e\mu$): 10–20%	5–20%
	Unc. from CR ($e\tau_h$, $\tau_h\tau_h$, $\mu\tau_h$): $\simeq$5–15%	—
	Extrap. from anti-iso. CR ($e\tau_h$, $\mu\tau_h$): 20%	7–10
	Extrap. from anti-iso. CR ($\tau_h\tau_h$): 3–15%	3–10
Diboson normalization	5%	—
Single top quark normalization	5%	—
$t\bar{t}$ estimation	Normalization from CR: $\simeq$5%	—
	Uncertainty on top quark p_T reweighting	—
Integrated luminosity	2.5%	—
b-tagged jet rejection ($e\mu$)	3.5–5.0%	—
Limited number of events	Statistical uncertainty in individual bins	—
Signal theoretical uncertainty	Up to 20%	—

Major Systematic Uncertainties: Theory, MET, JET and Tau Energy Scale

Using Dedicated Control Regions to estimate ttbar, z->TauTau, W+Jets, ect.

Combined Observed and Predicted m(ττ) Distributions

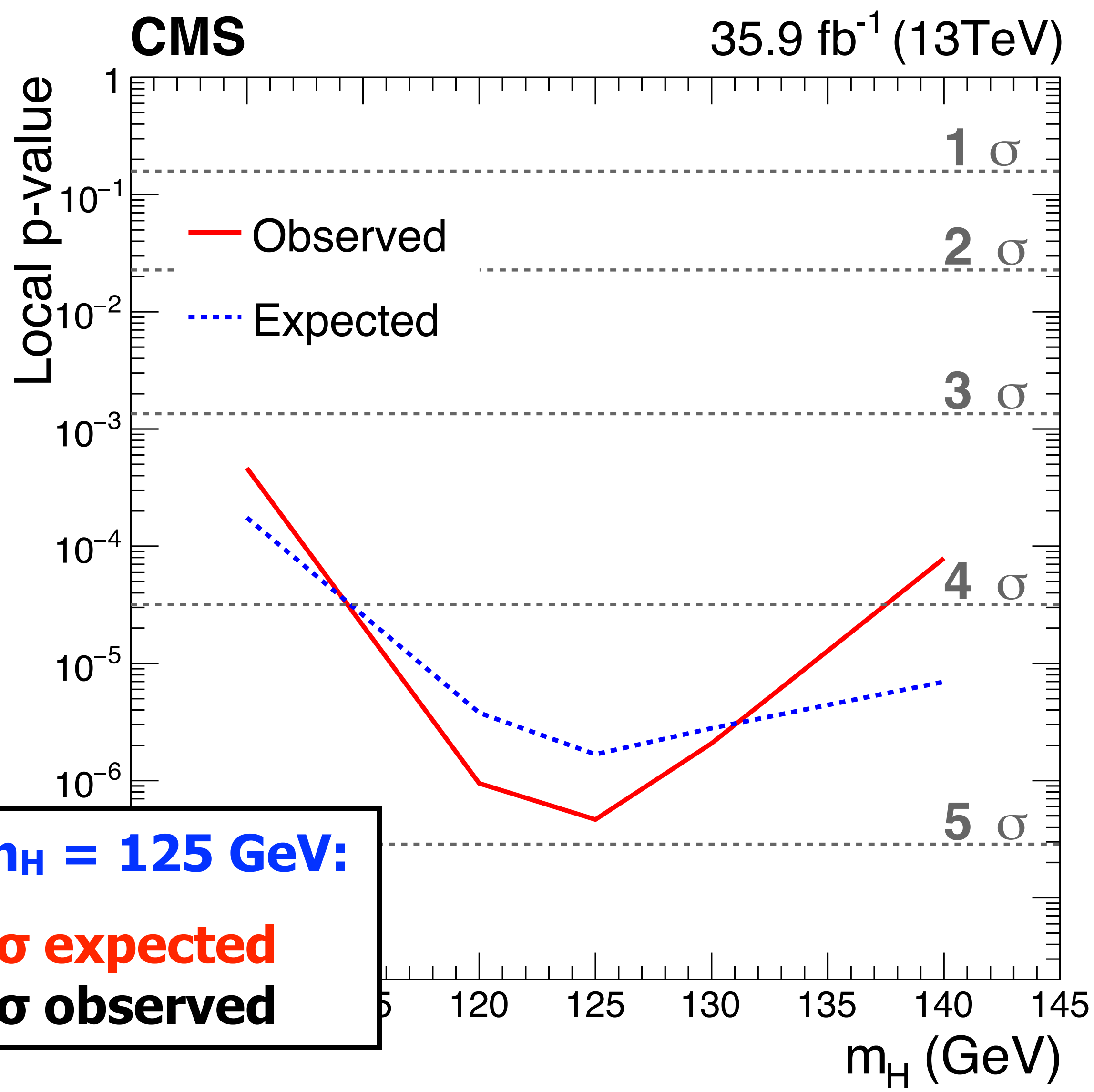


The binning reflects the one used in the 2D distributions, and does not allow merging of the two figures

- The normalization of the predicted background distributions corresponds to the result of the global fit, while the signal is normalized to its best fit signal strength

- The inset shows the corresponding difference between the observed data and expected background distributions, together with the signal expectation

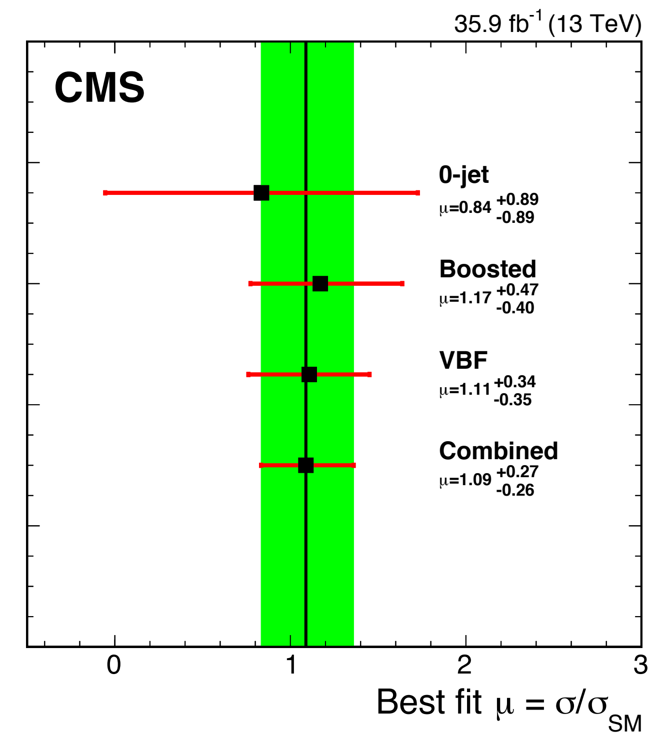
SM Hττ Results

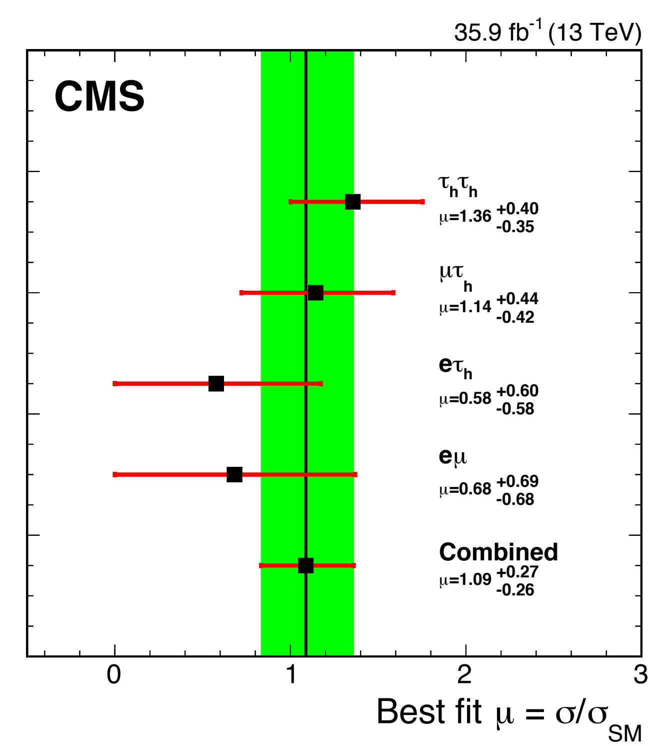


At m_H = 125 GeV:

4.7 σ expected

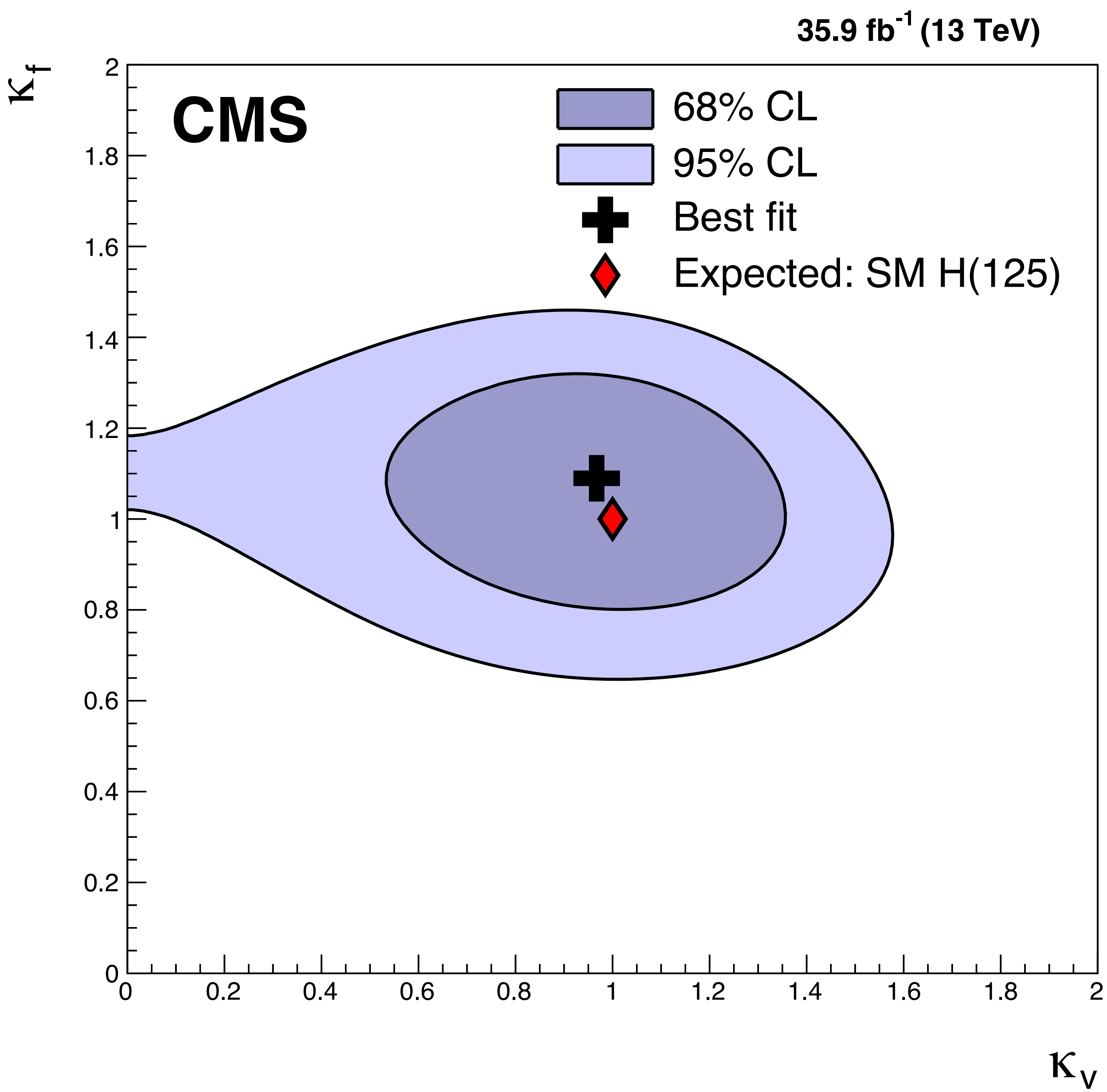
4.9 σ observed





5.9 σ observed significance when combined with Run I (7 and 8 TeV)

Combination with Run I

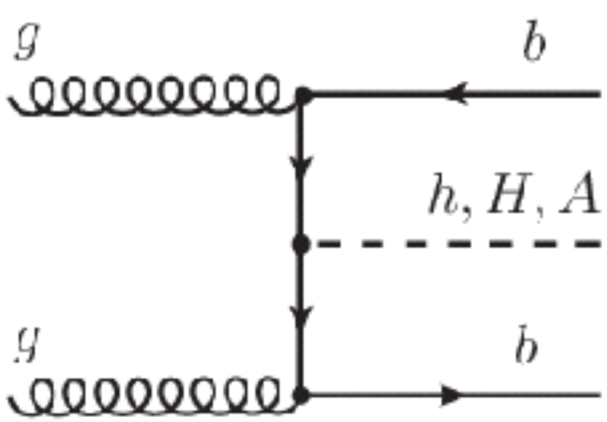


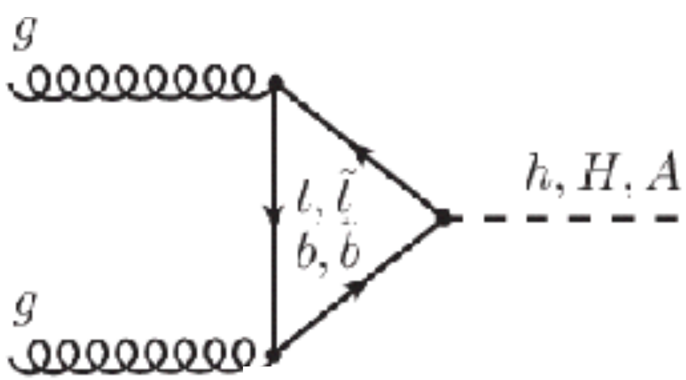
Coupling strength to Fermions vs. Bosons

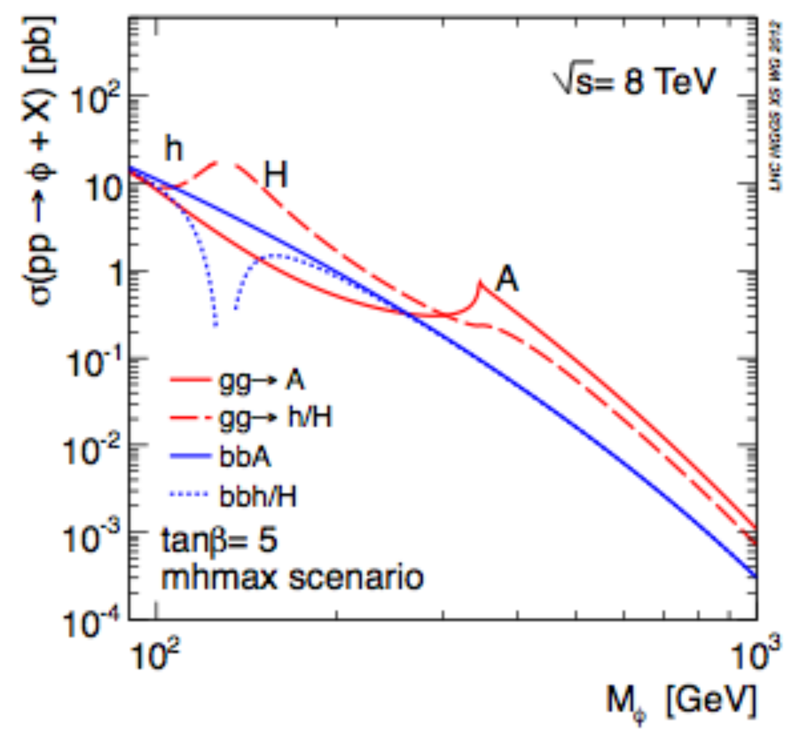
Consistent with SM, where $\kappa_V=\kappa_F=1$

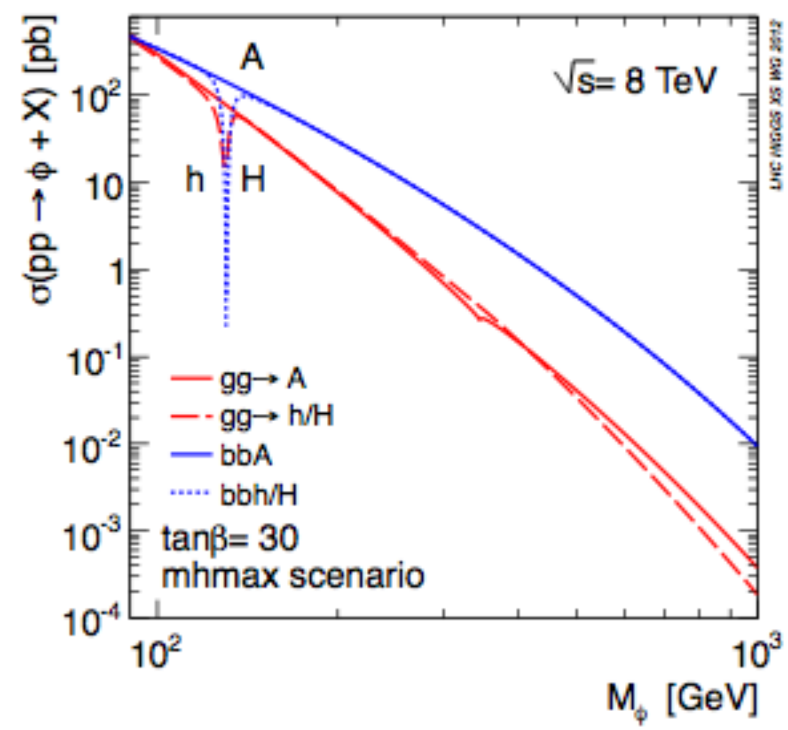
BSM Searches using τ's

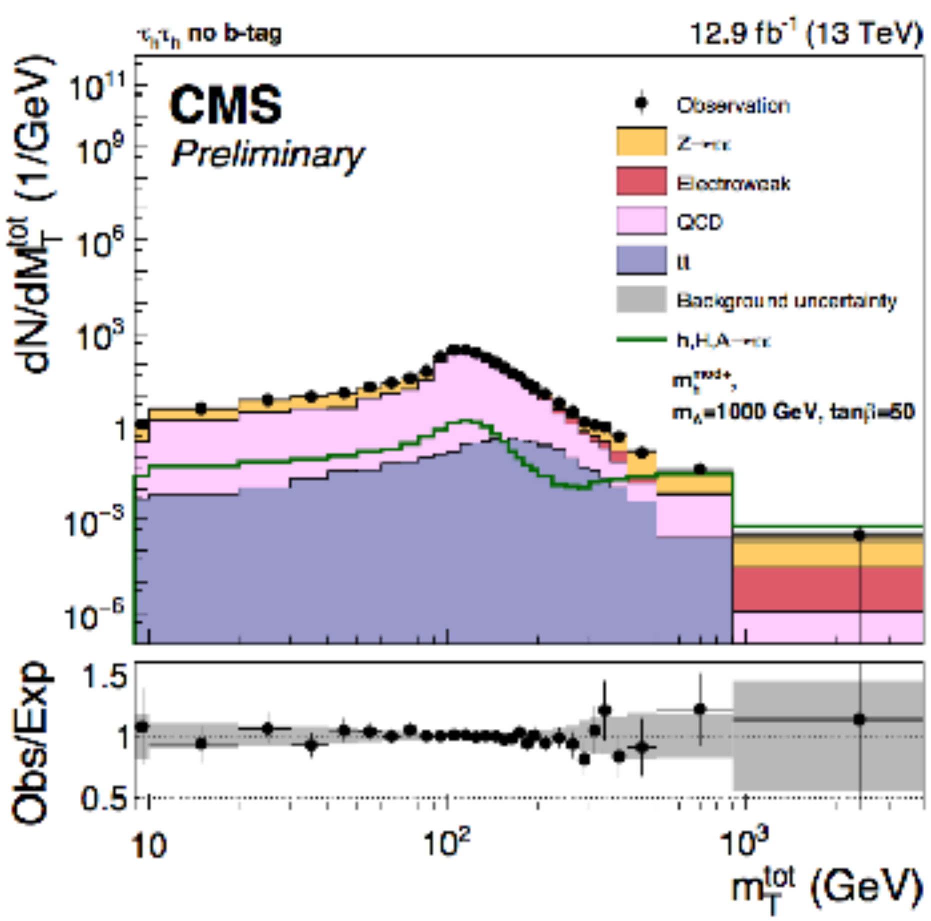
MSSM **h/A/H->**ττ

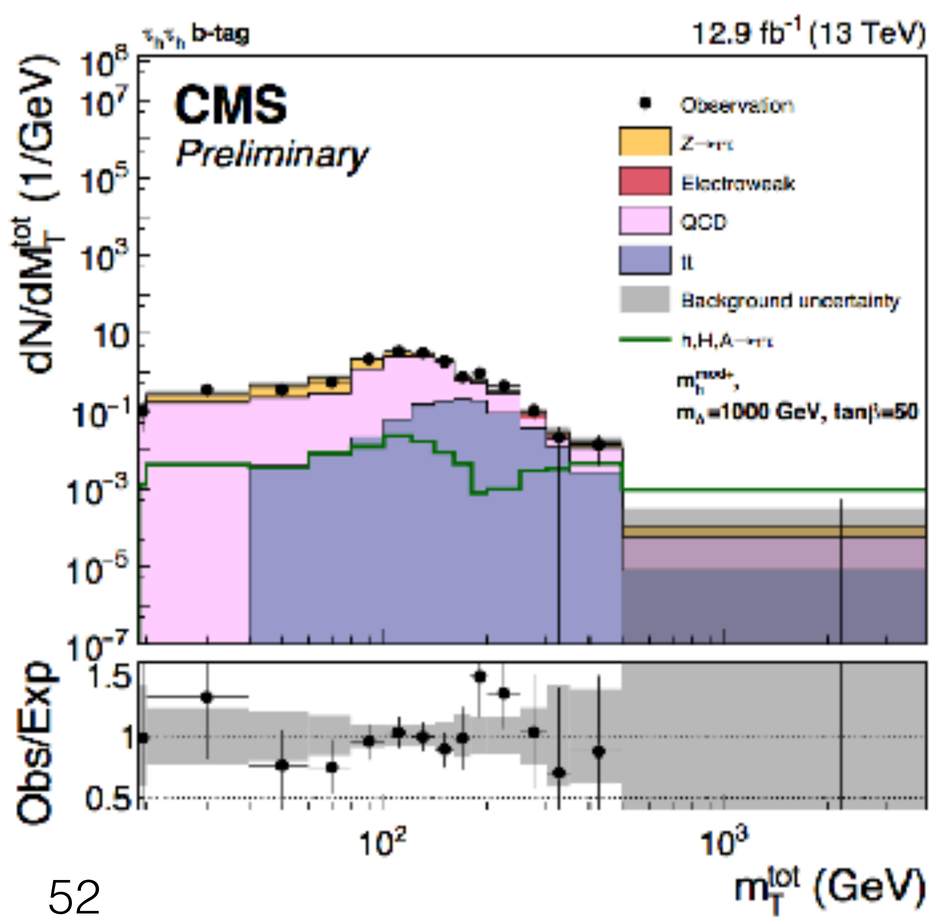












Full 2016
Coming
Soon!

Higgs to ττ @ CMS

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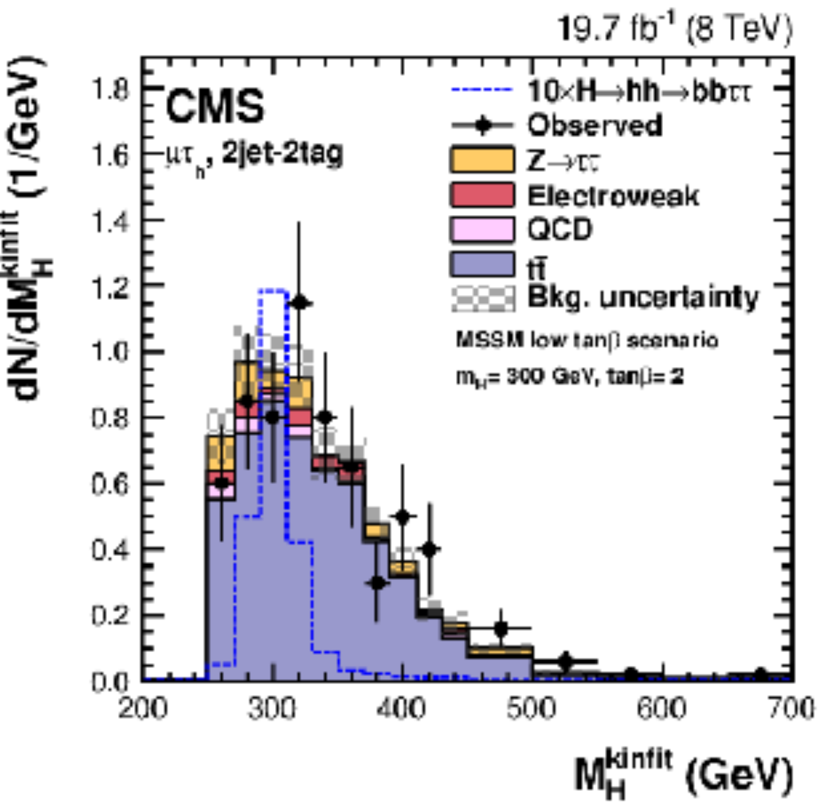
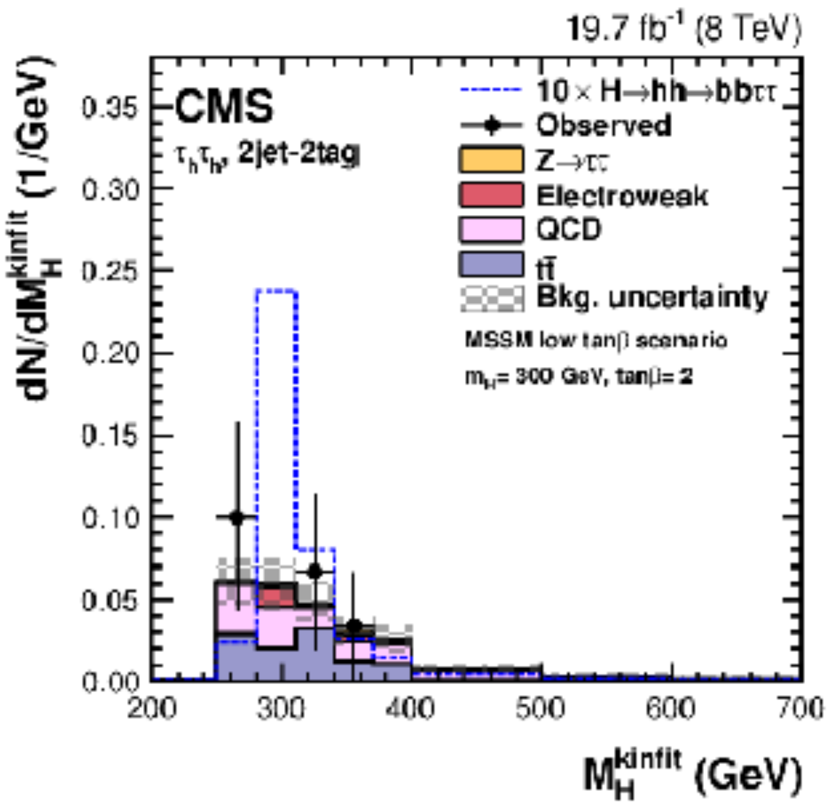
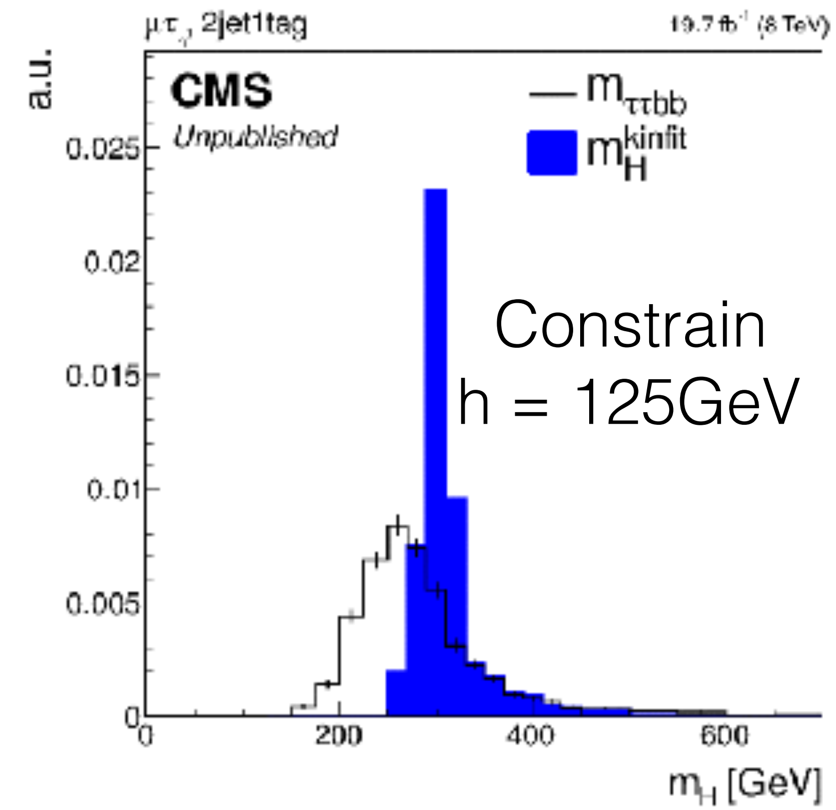
MSSM **H->hh**/A->Zh

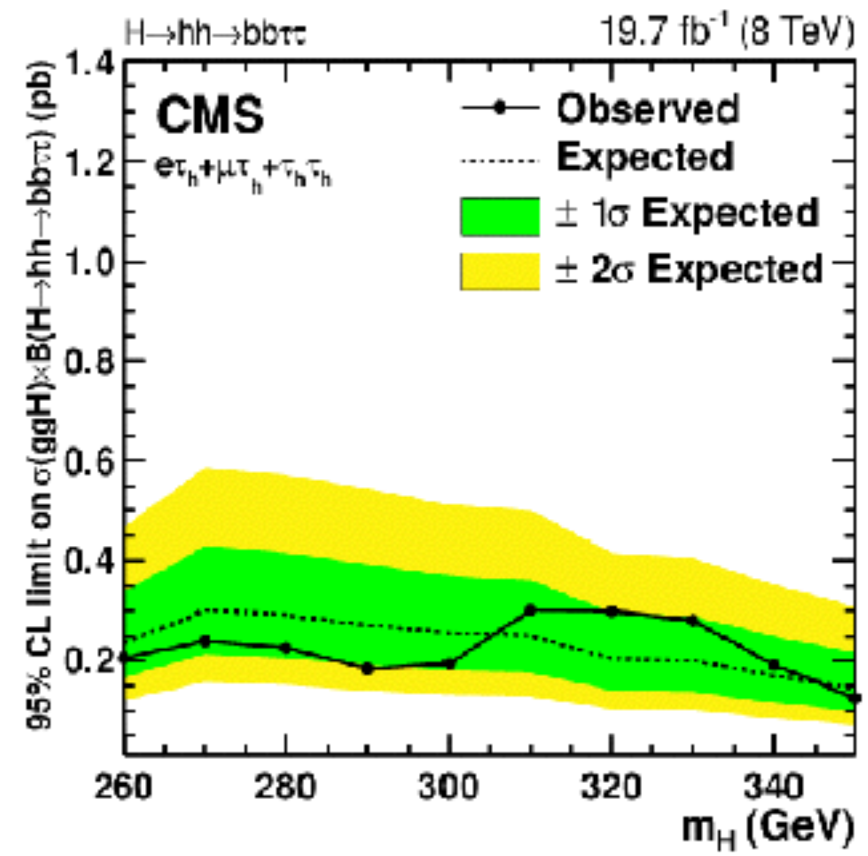




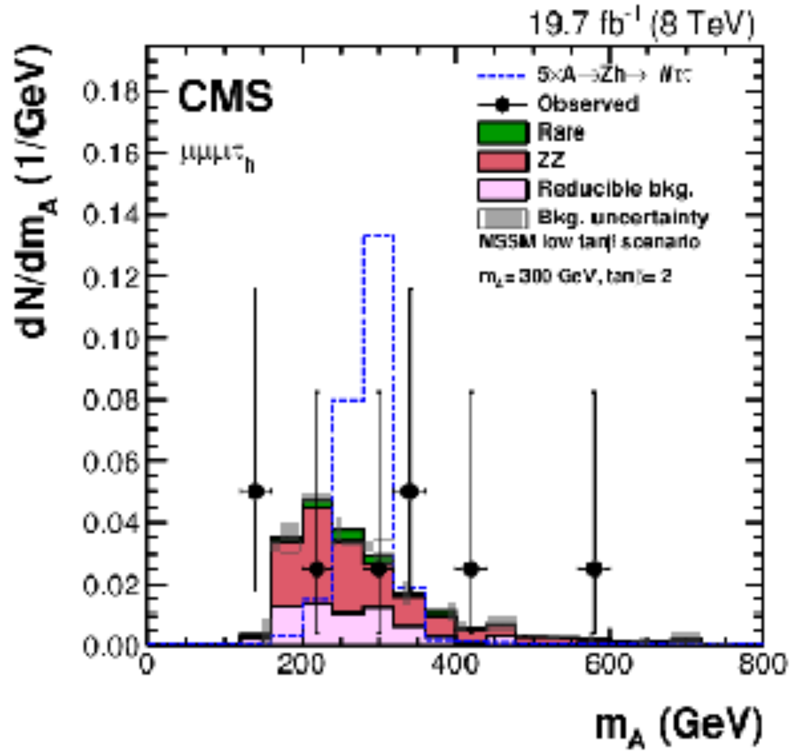


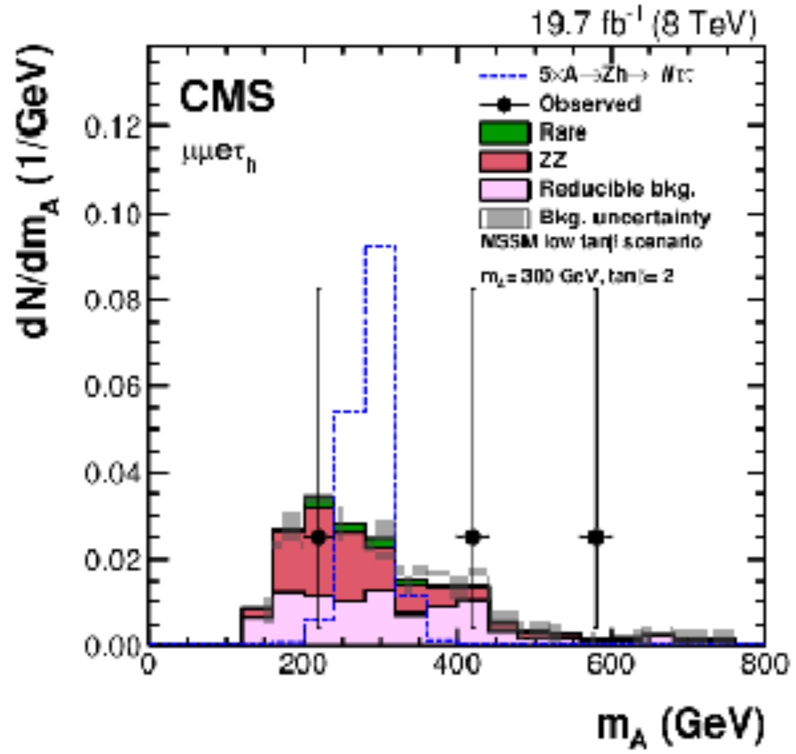
Constrain
h = 125GeV

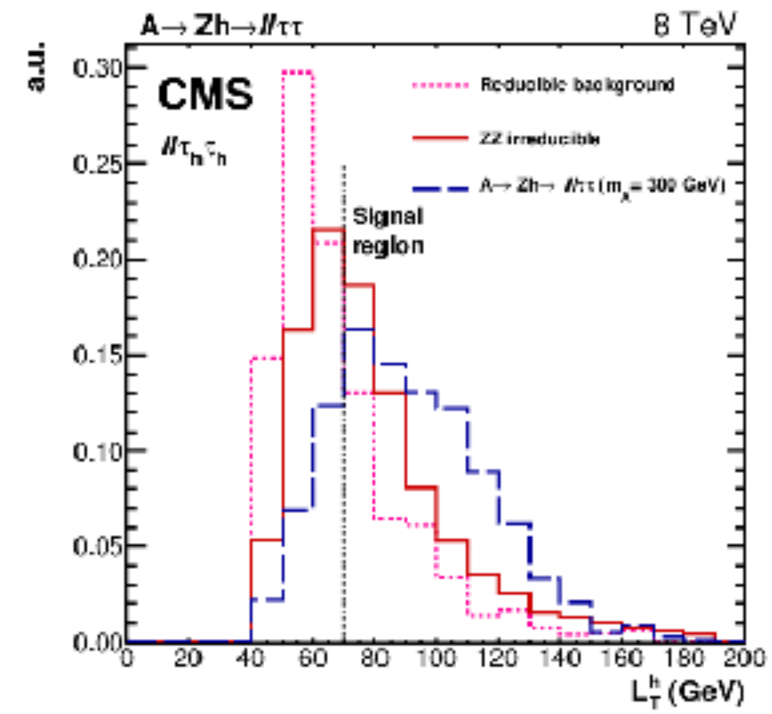
Search for H->hh coupling
muTau and tautau shown
2 Jets, 0, 1, 2 b-tags are required



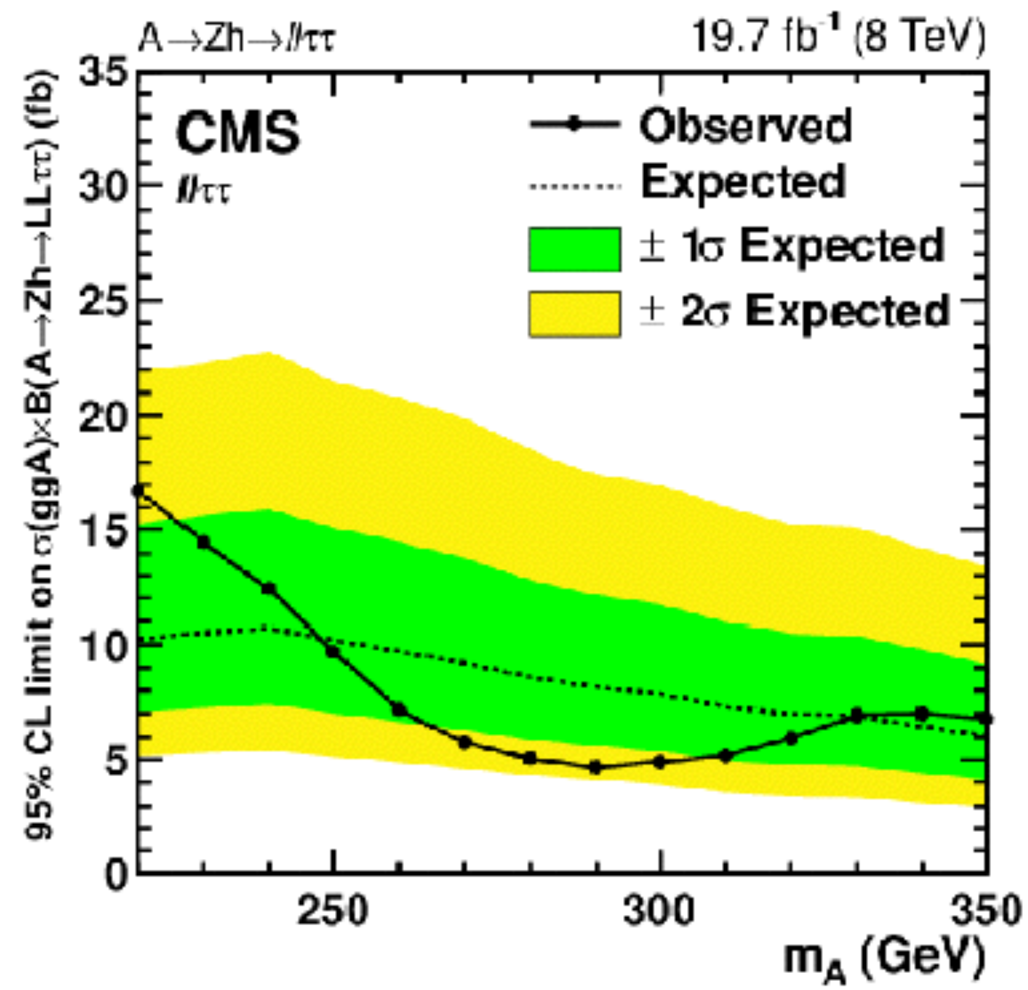
MSSM H->hh/**A->Zh**



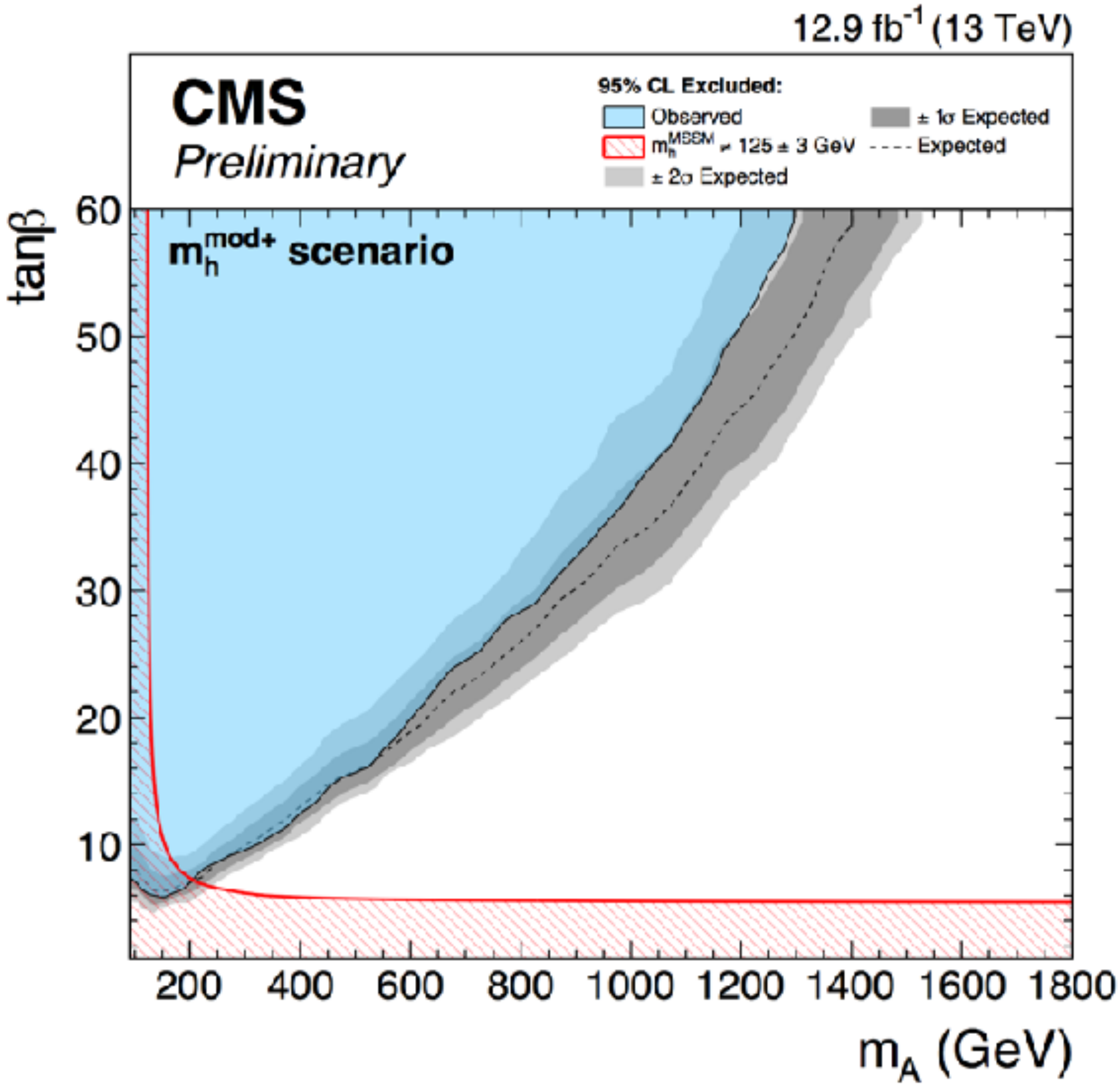


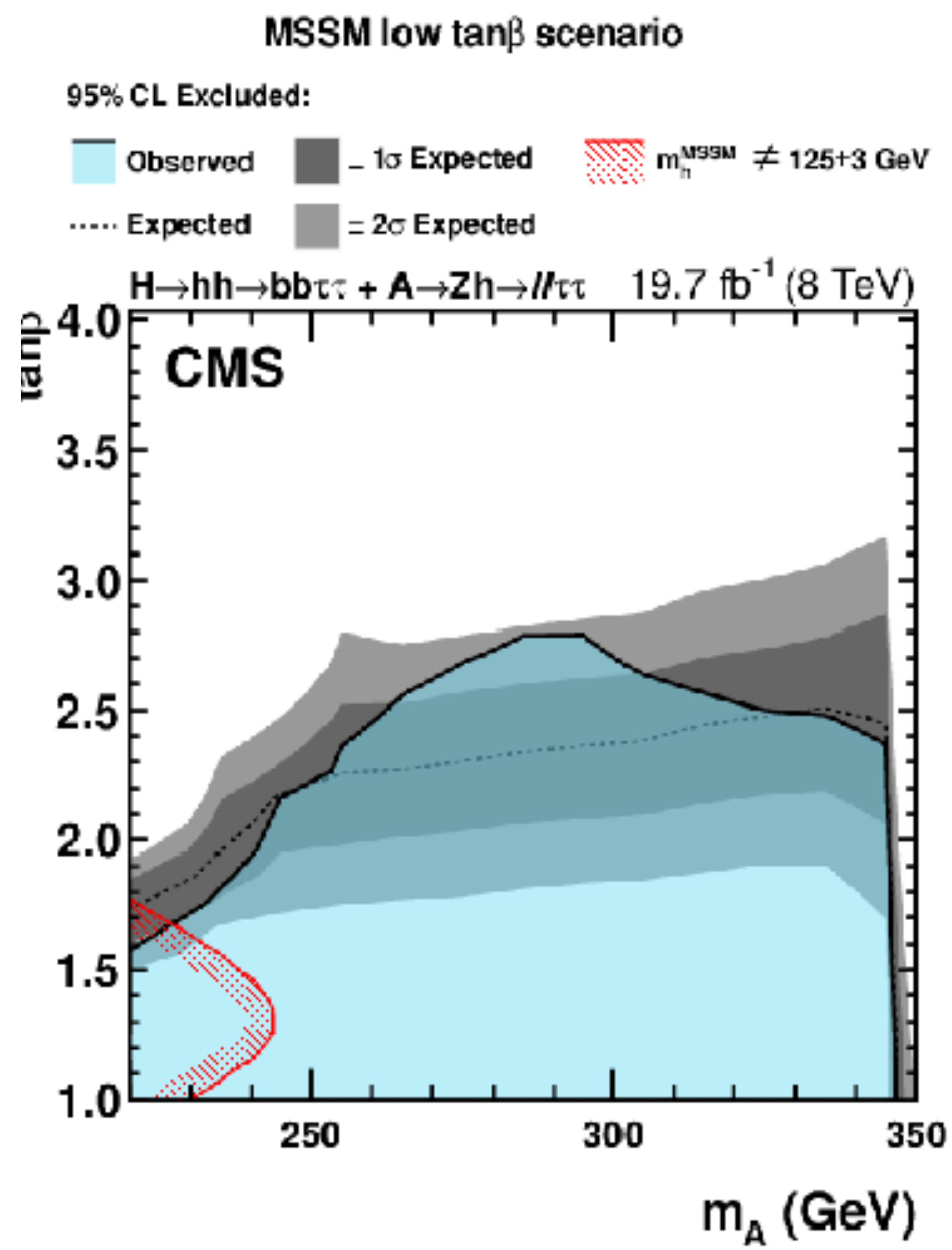


A->Zh with Z->ll and
h->tautau



MSSM **H->hh/A->Zh**





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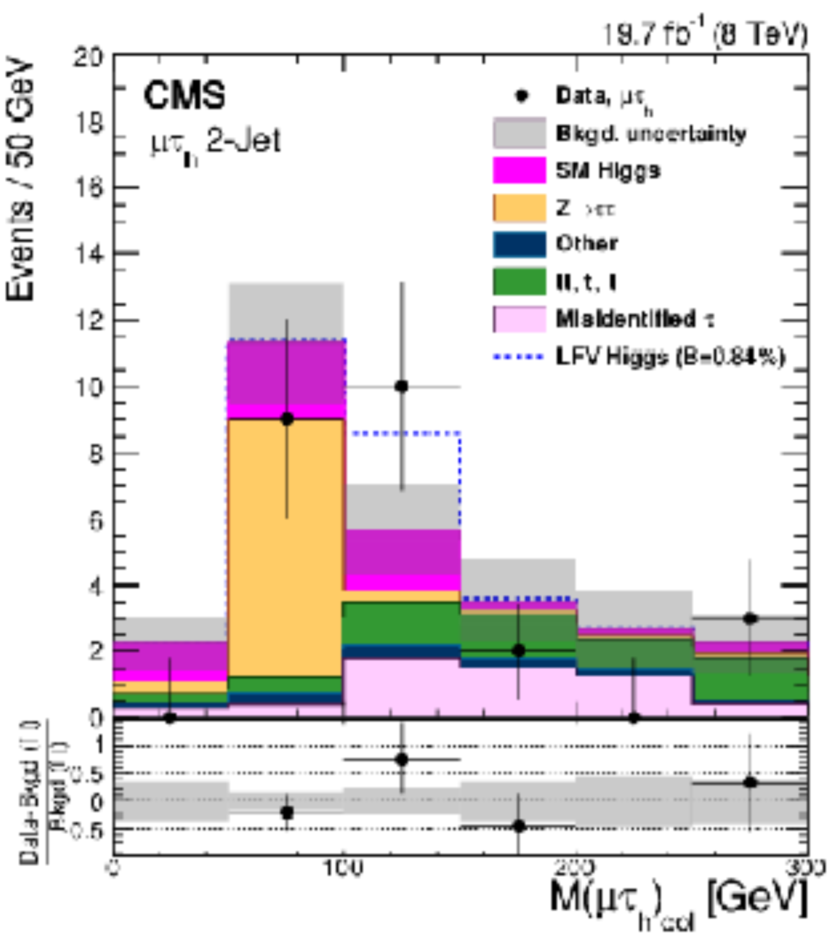
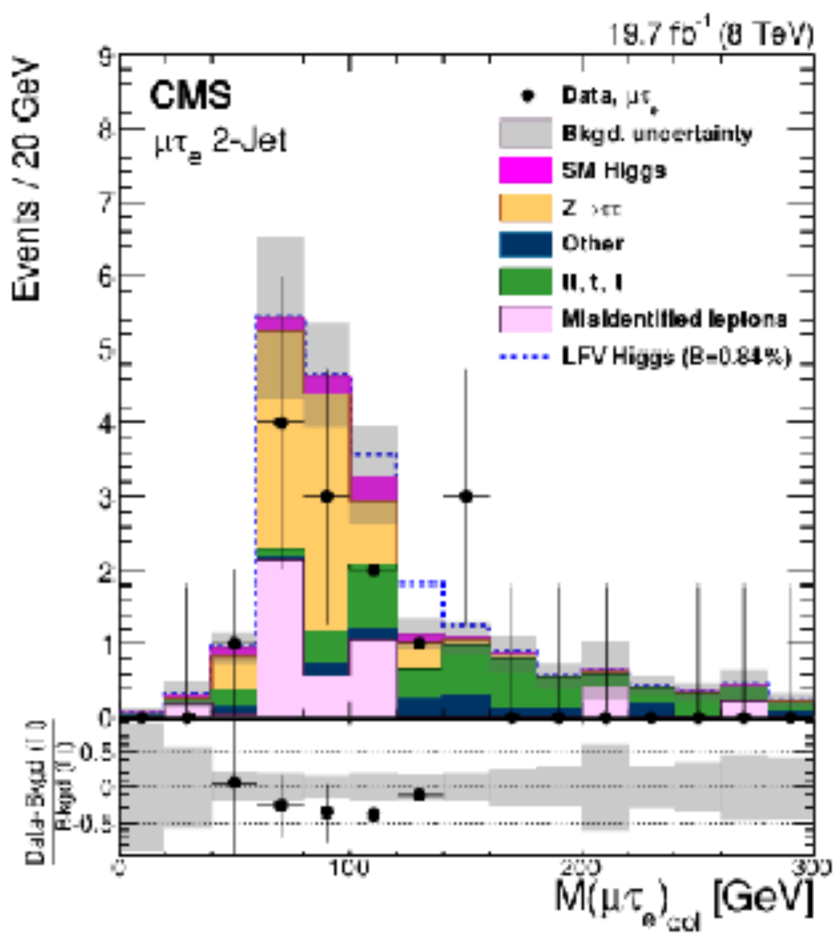
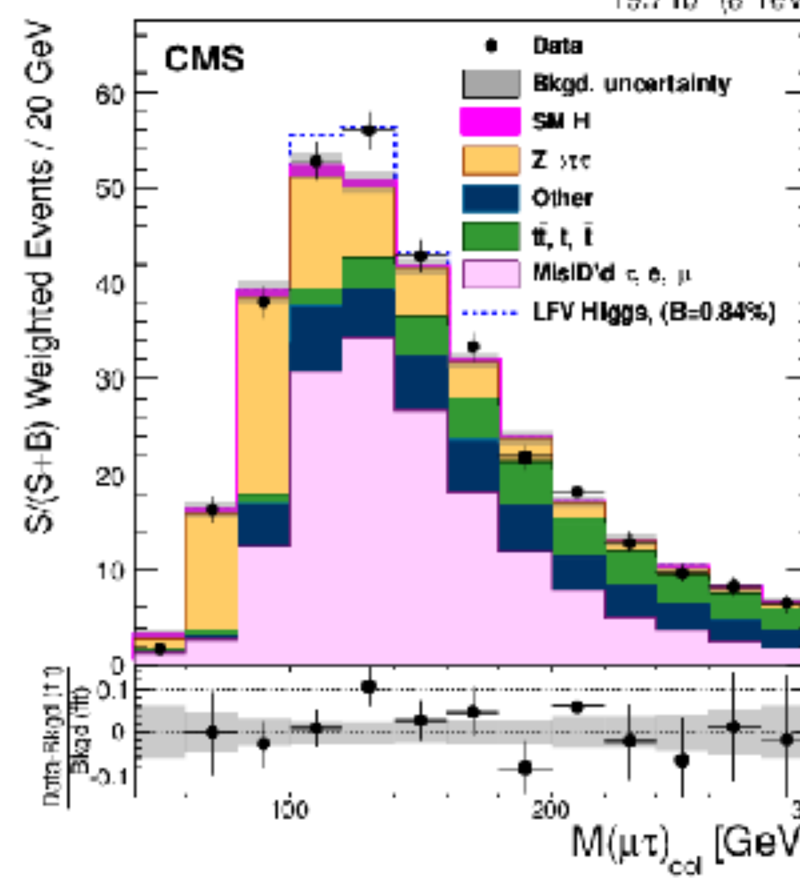
Lepton Flavor Violation

- Searches for the 125 GeV Higgs decay to Flavor Violating Couplings: $\mu\tau_e$ and $\mu\tau_h$
- In the SM the Higgs couplings are diagonal: $Y_{ij} = (m_i/v)\delta_{ij}$
- Discovery of LFV would suggest a Flavor Structure

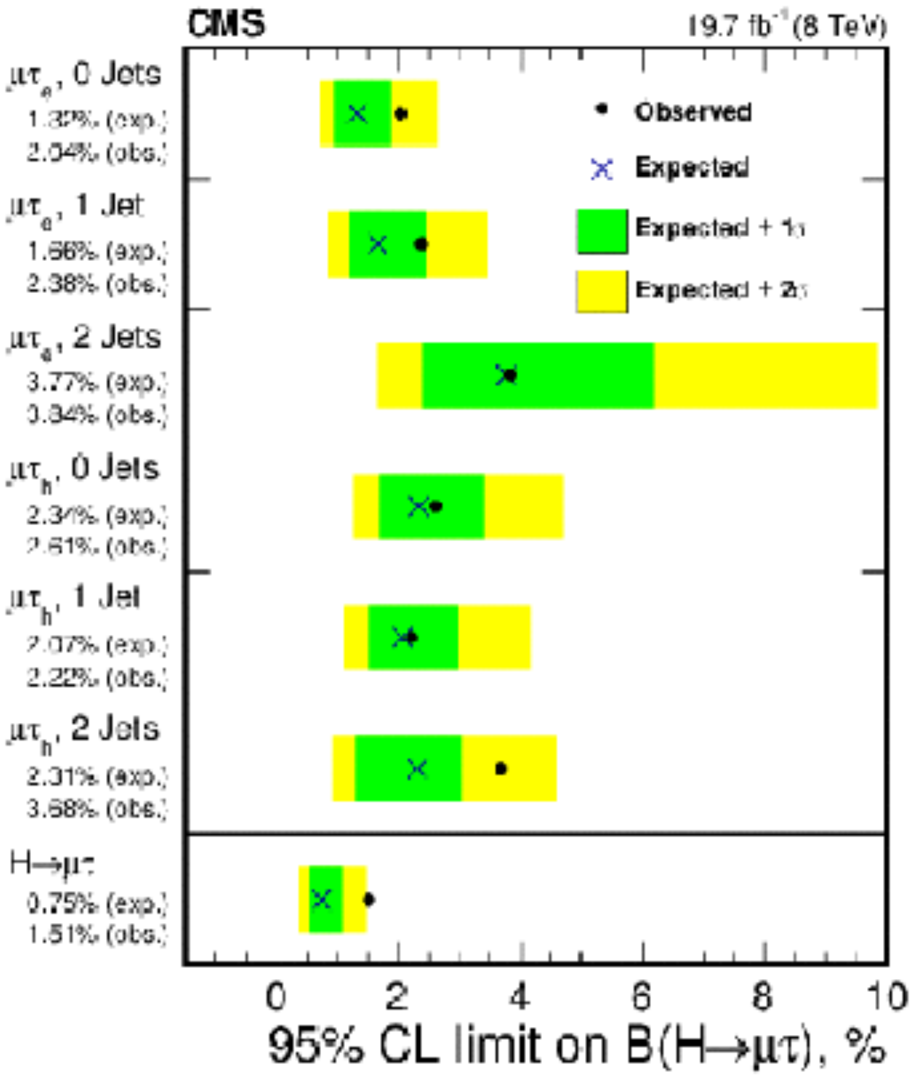


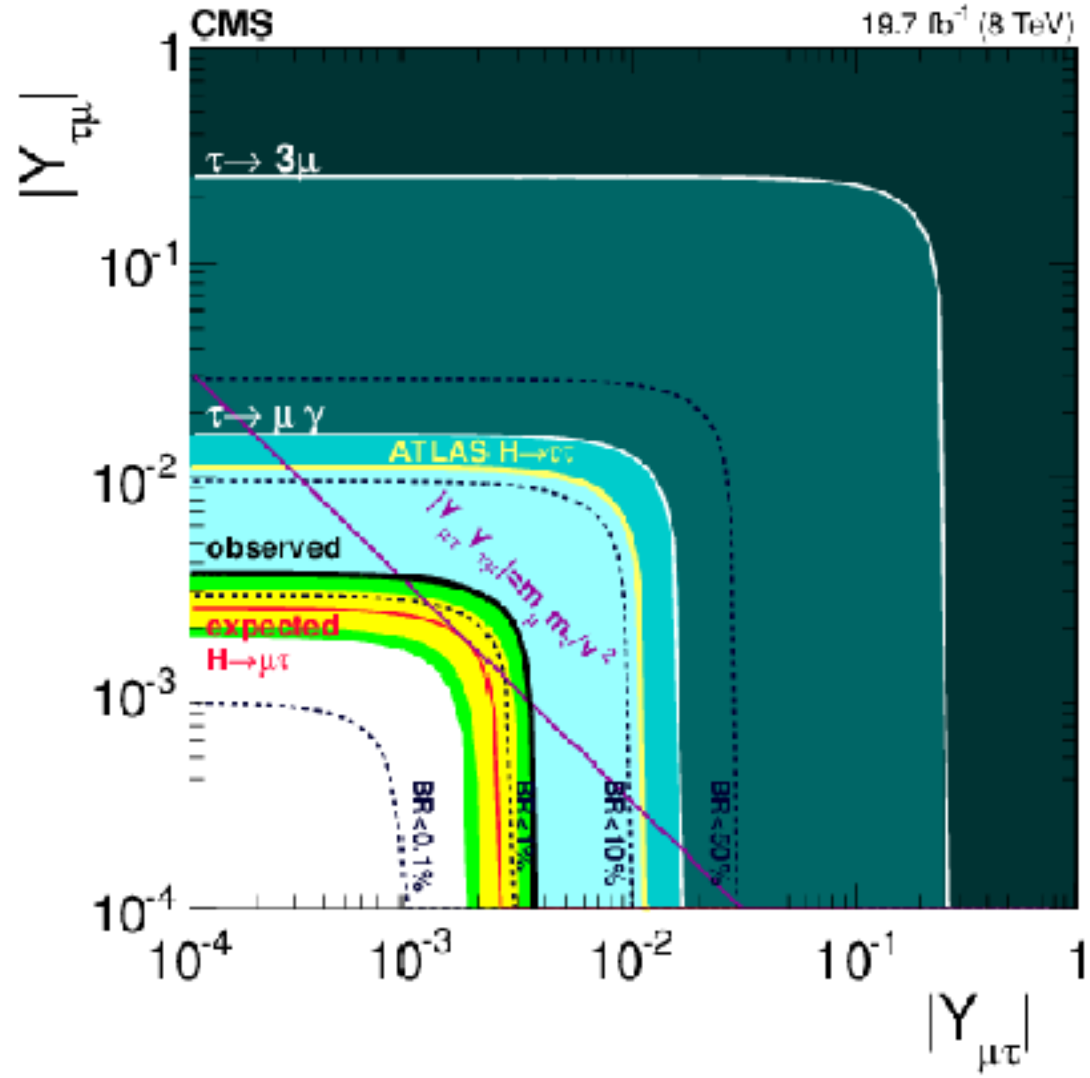


Combined



Lepton Flavor Violation





'Slight Excess' of signal events observed with a significance of 2.4 σ in Run-1 data

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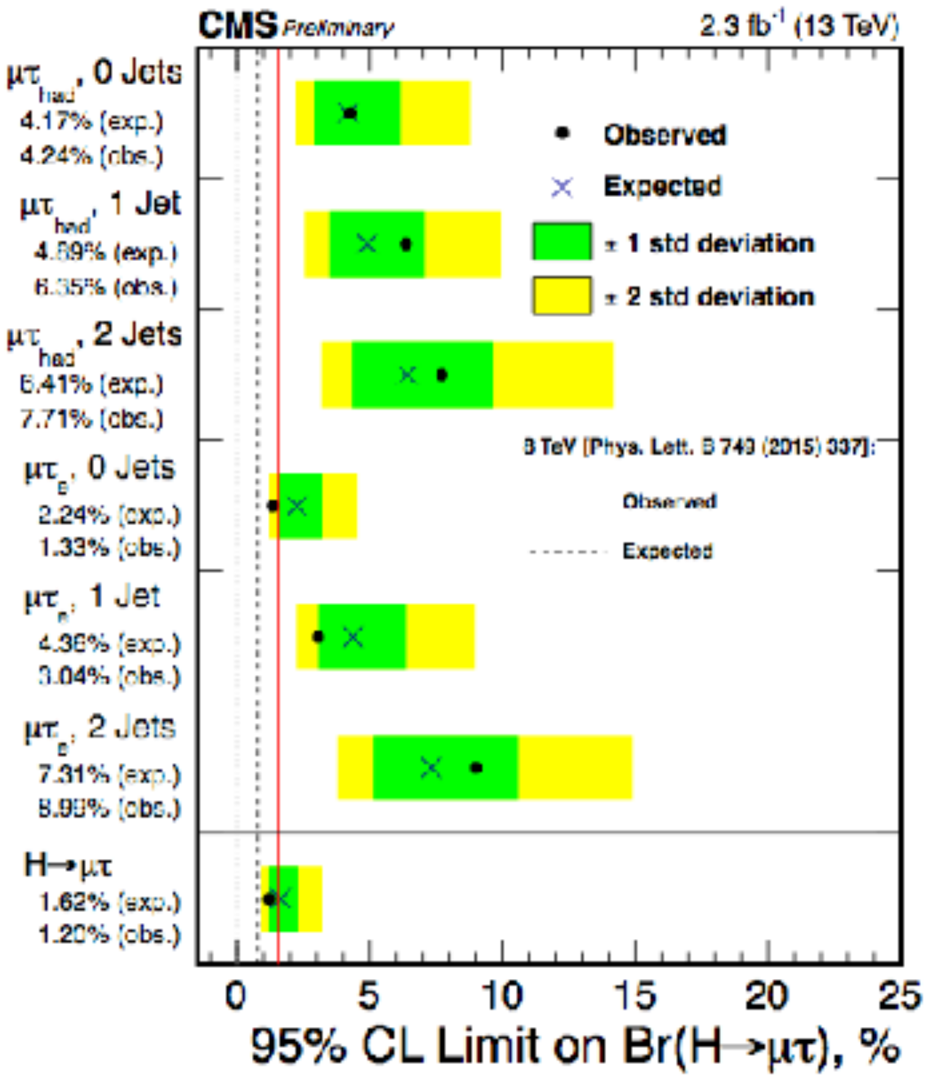
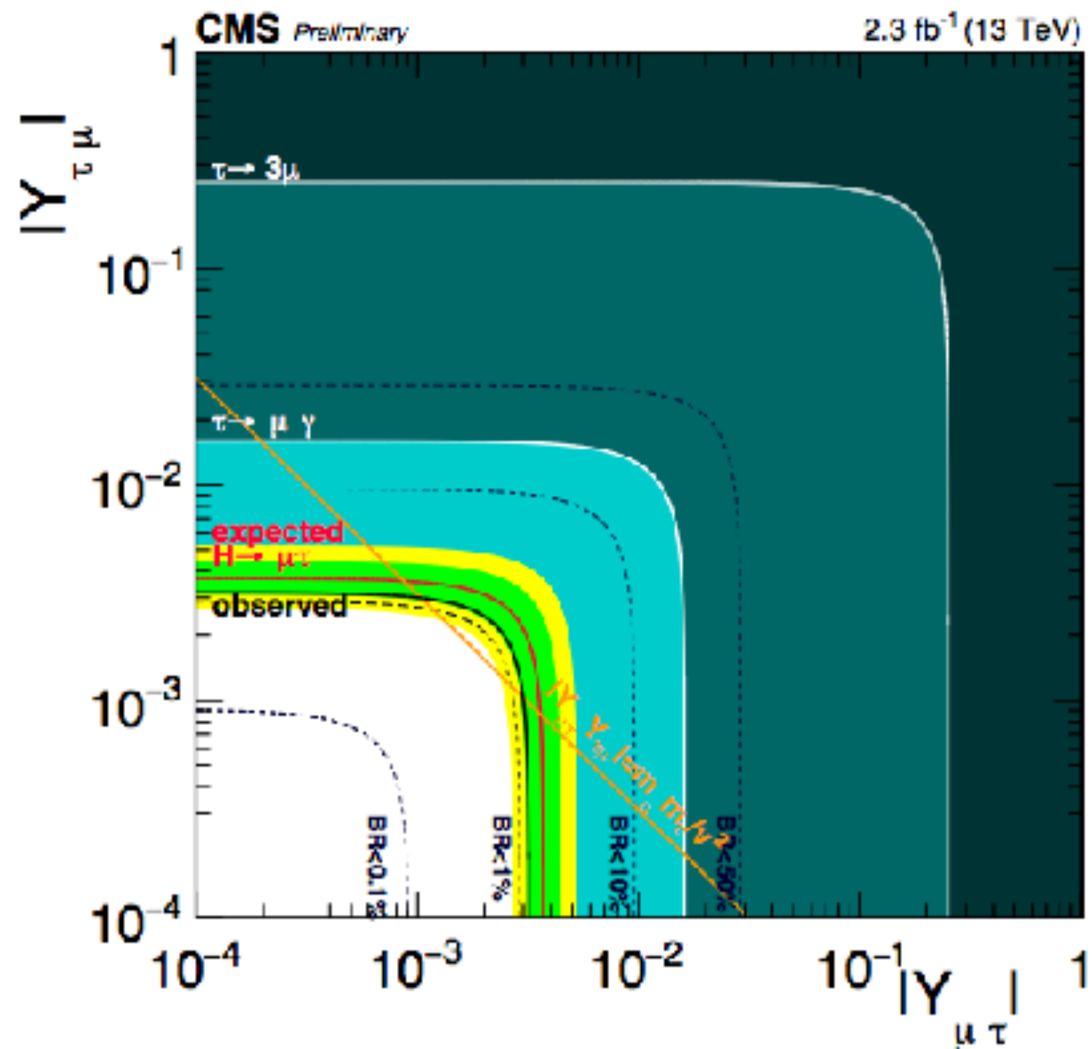
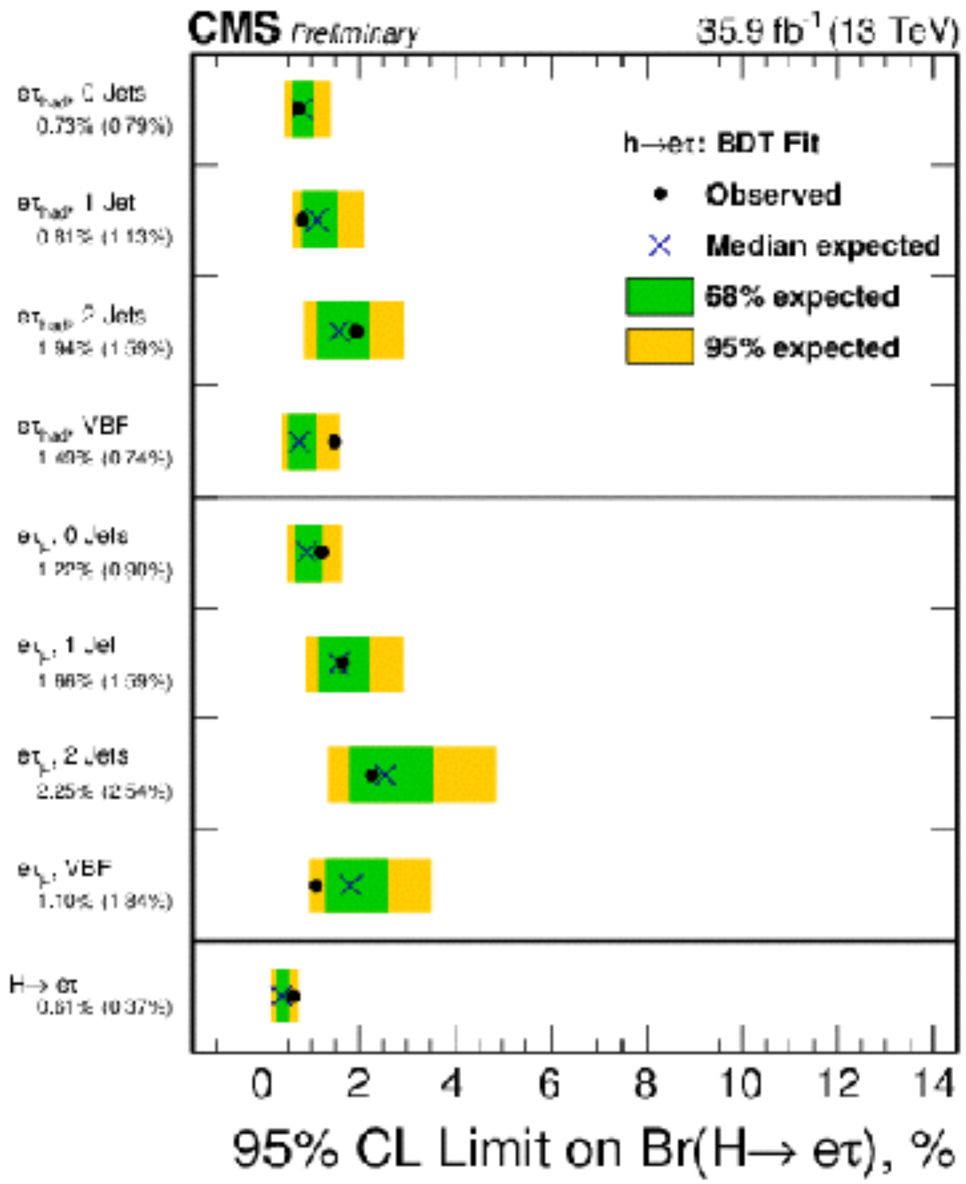
Lepton Flavor Violation

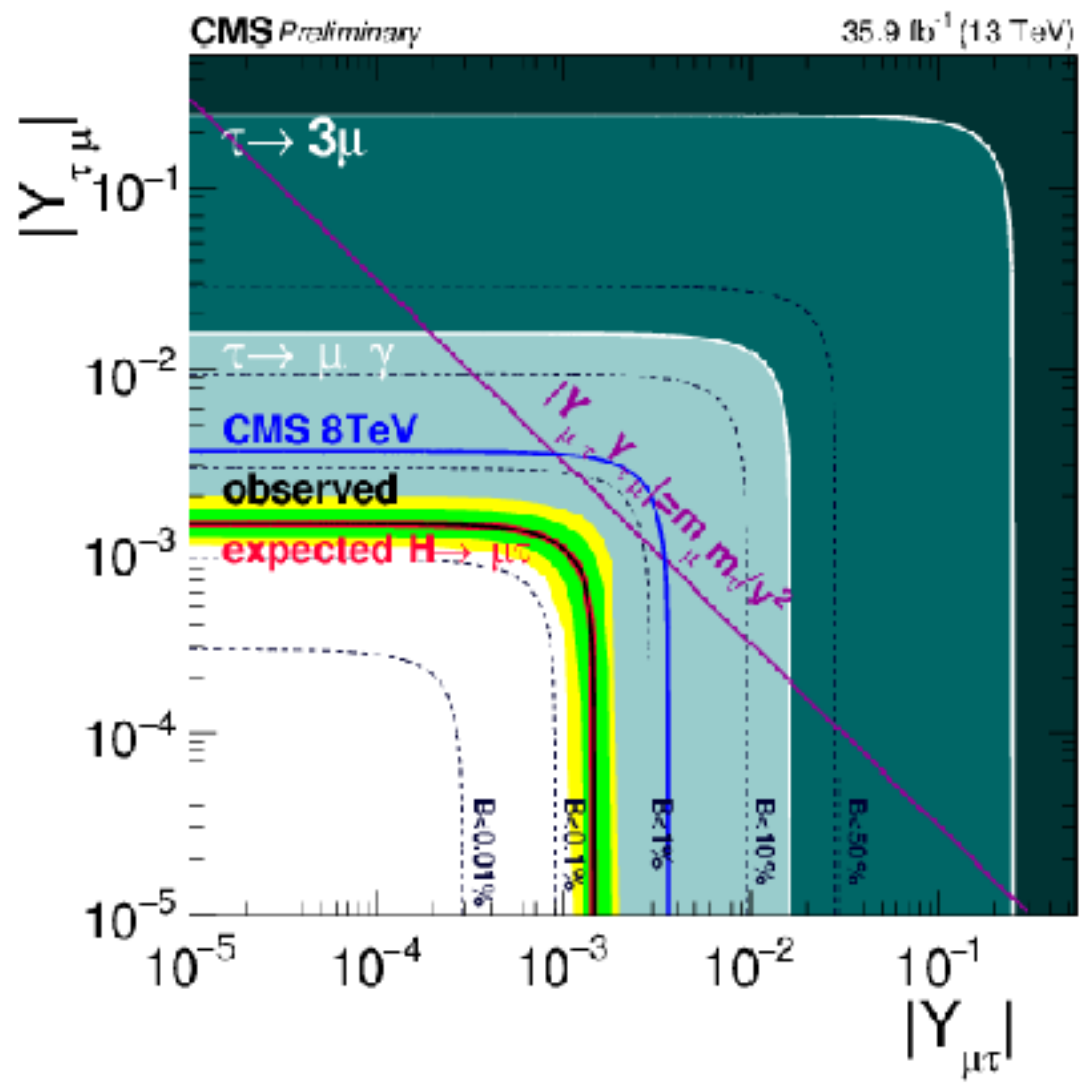




Agreement with Standard Model with first 2016 data

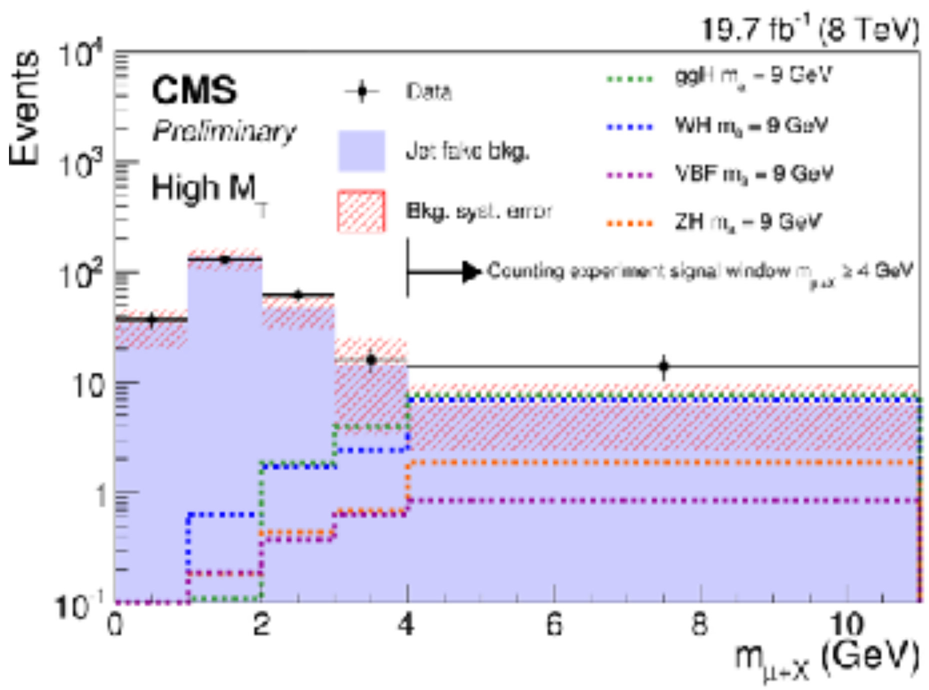
Lepton Flavor Violation

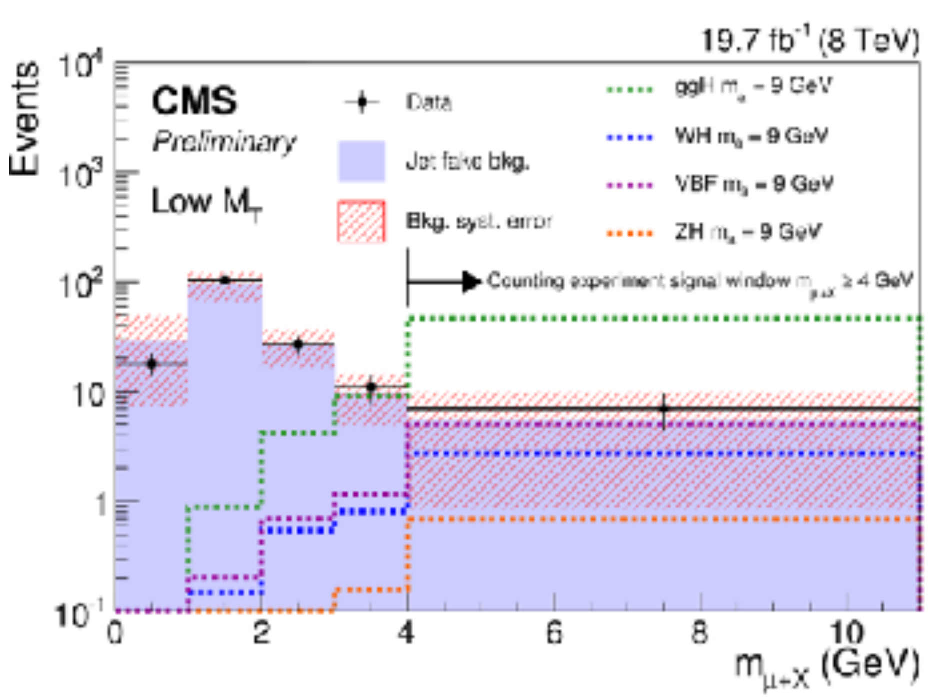


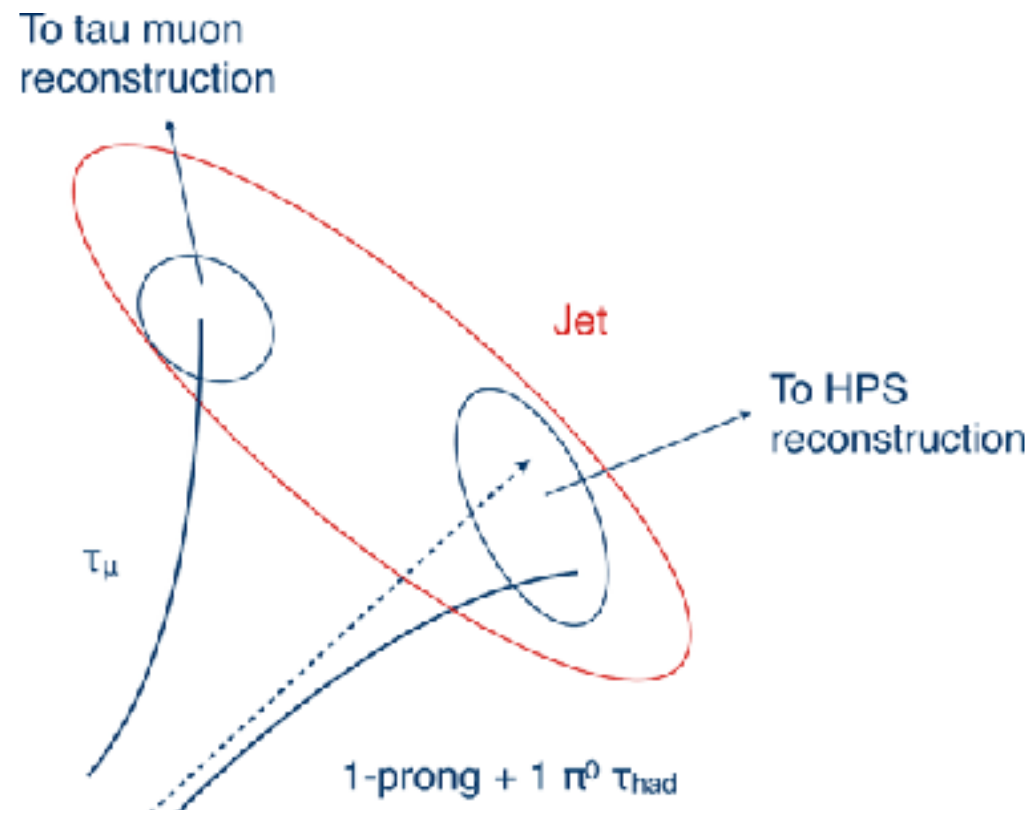


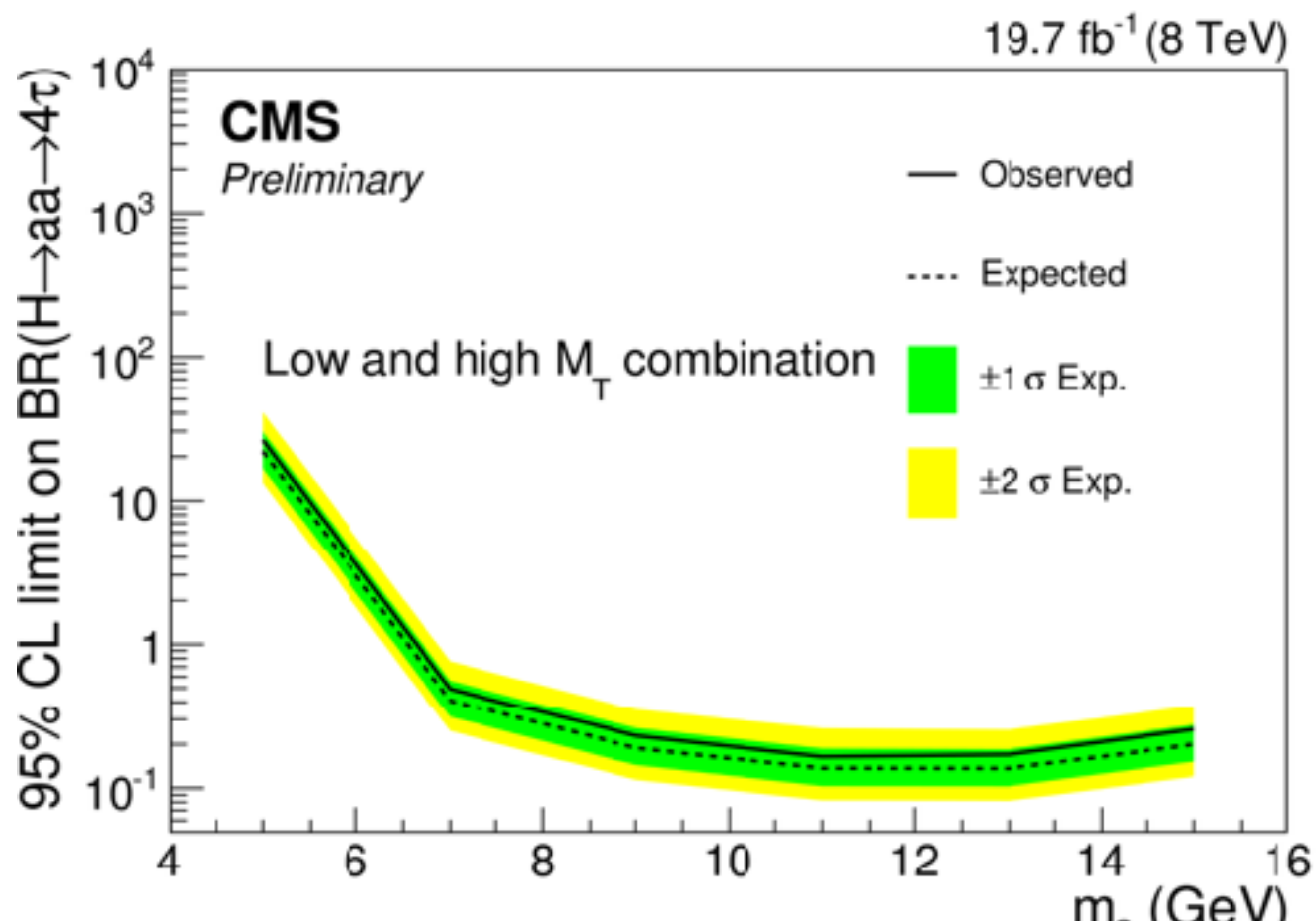
Looking at the Full 2016 36 fb-1 Dataset

Boosted Low Mass Searches



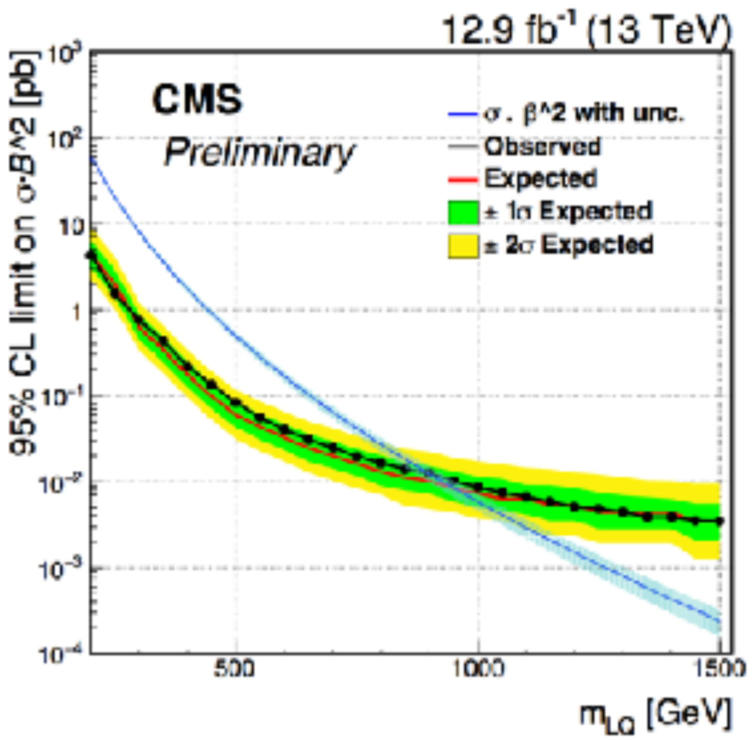




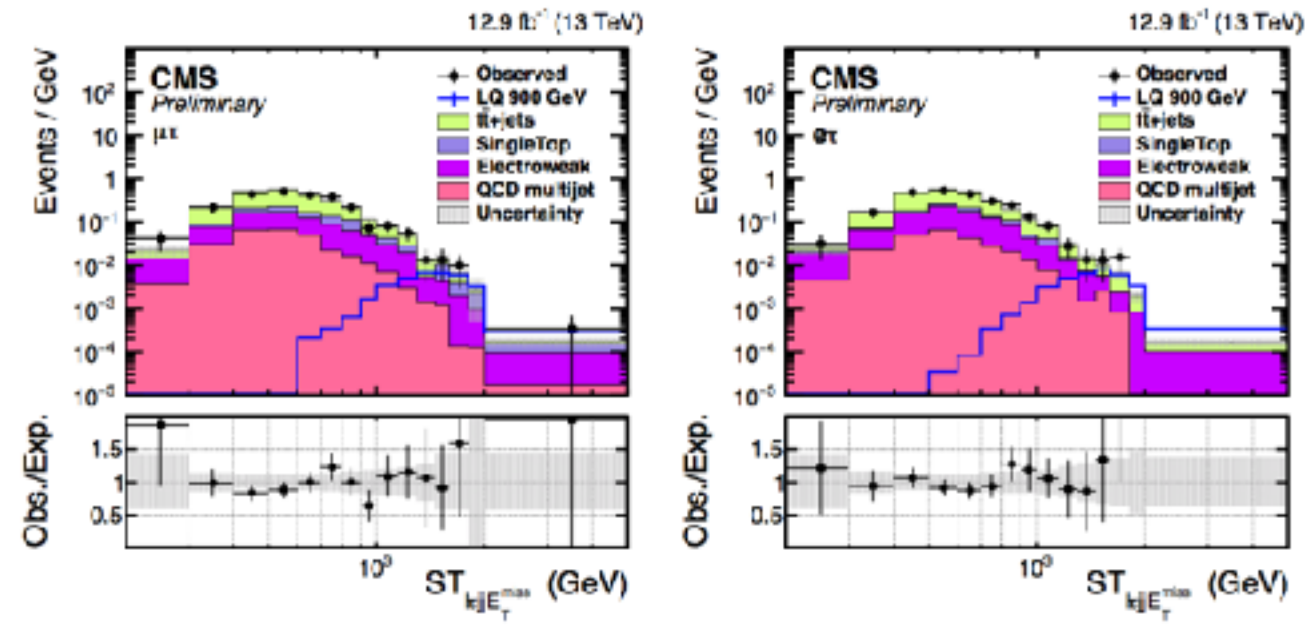


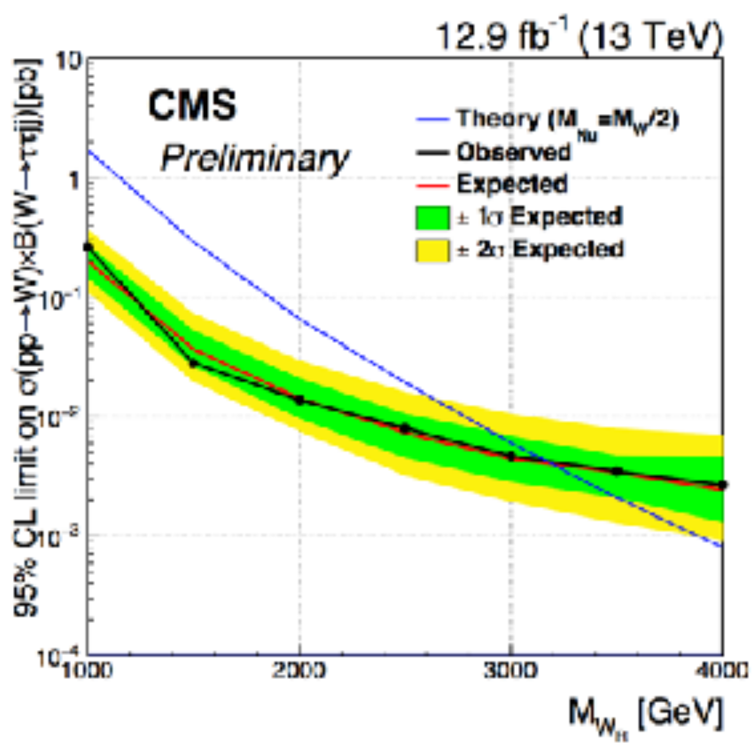
- Offering collection of 'boosted' Taus

3rd Generation Leptoquarks Search for heavy RH neutrinos

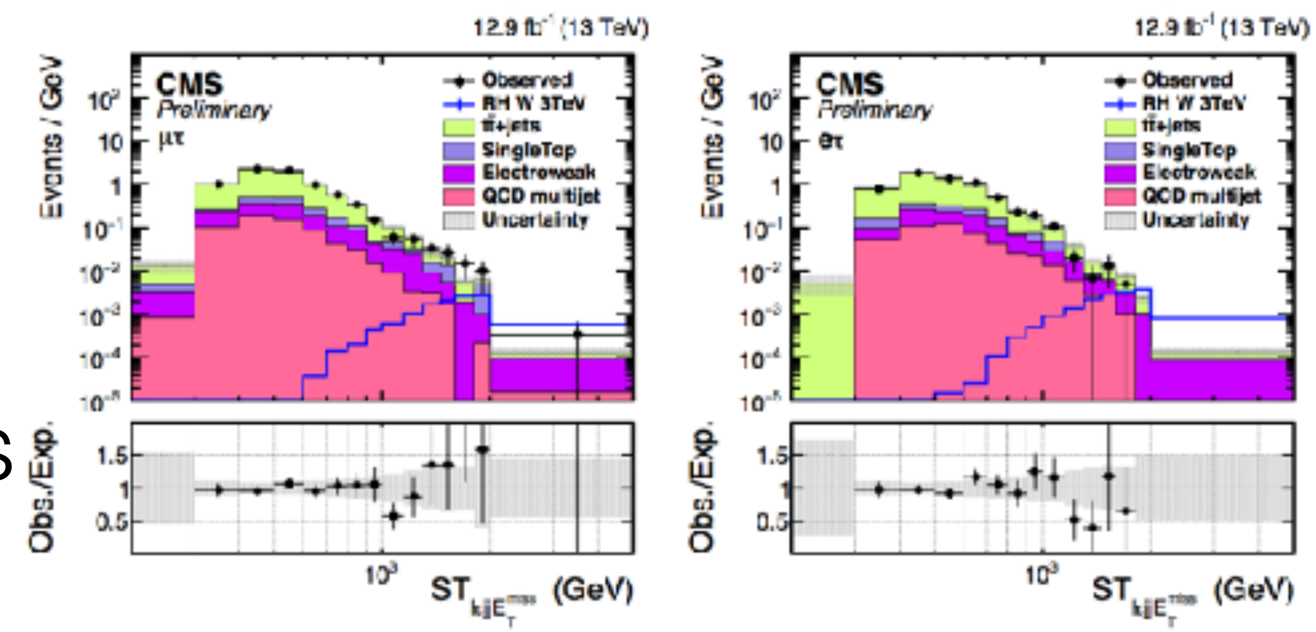


Lepto-quark



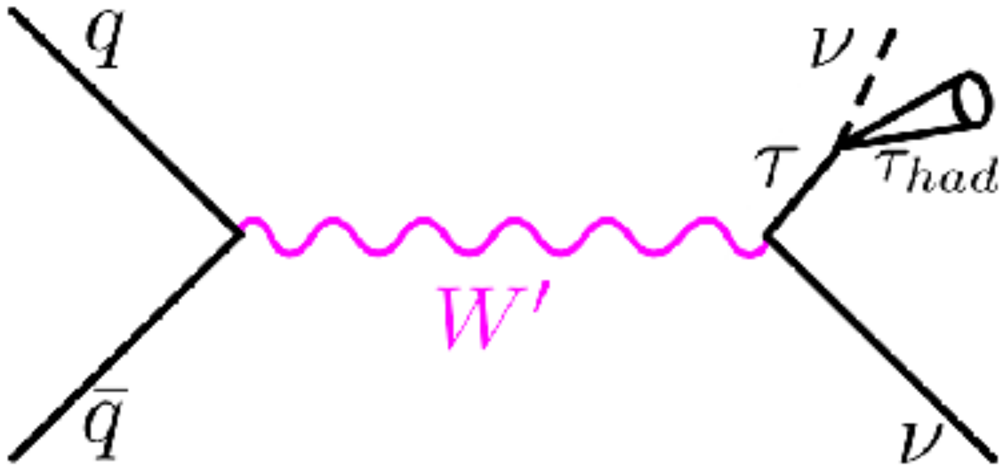


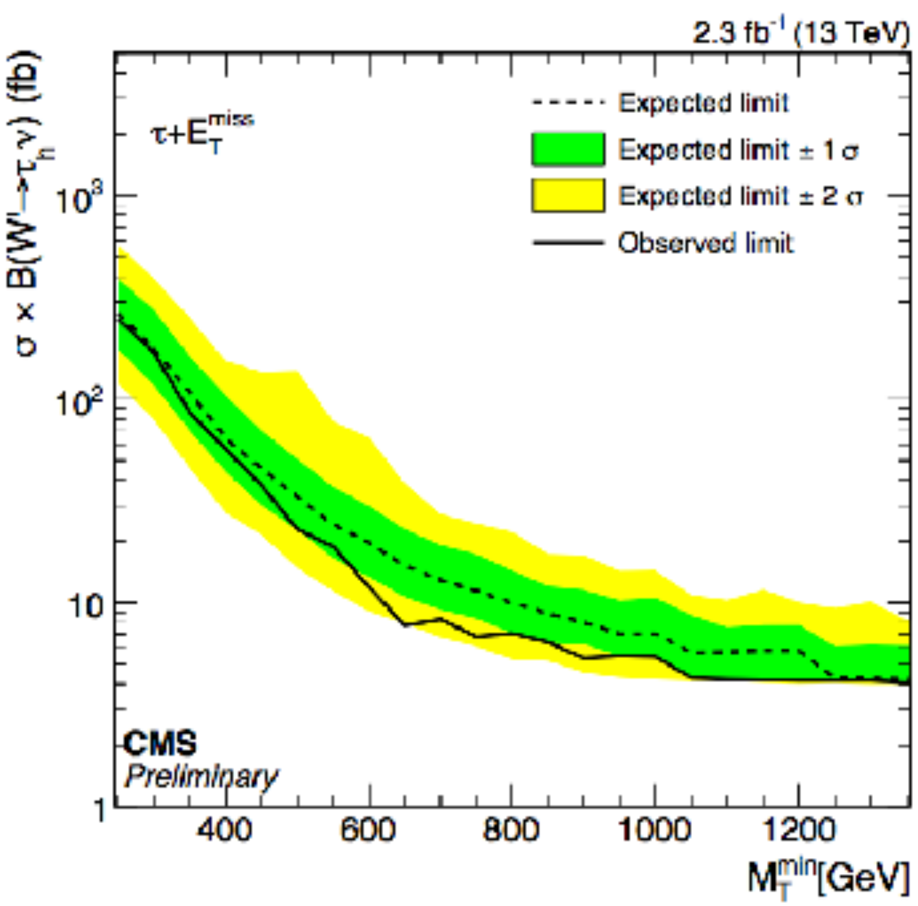
RH Neutrinos

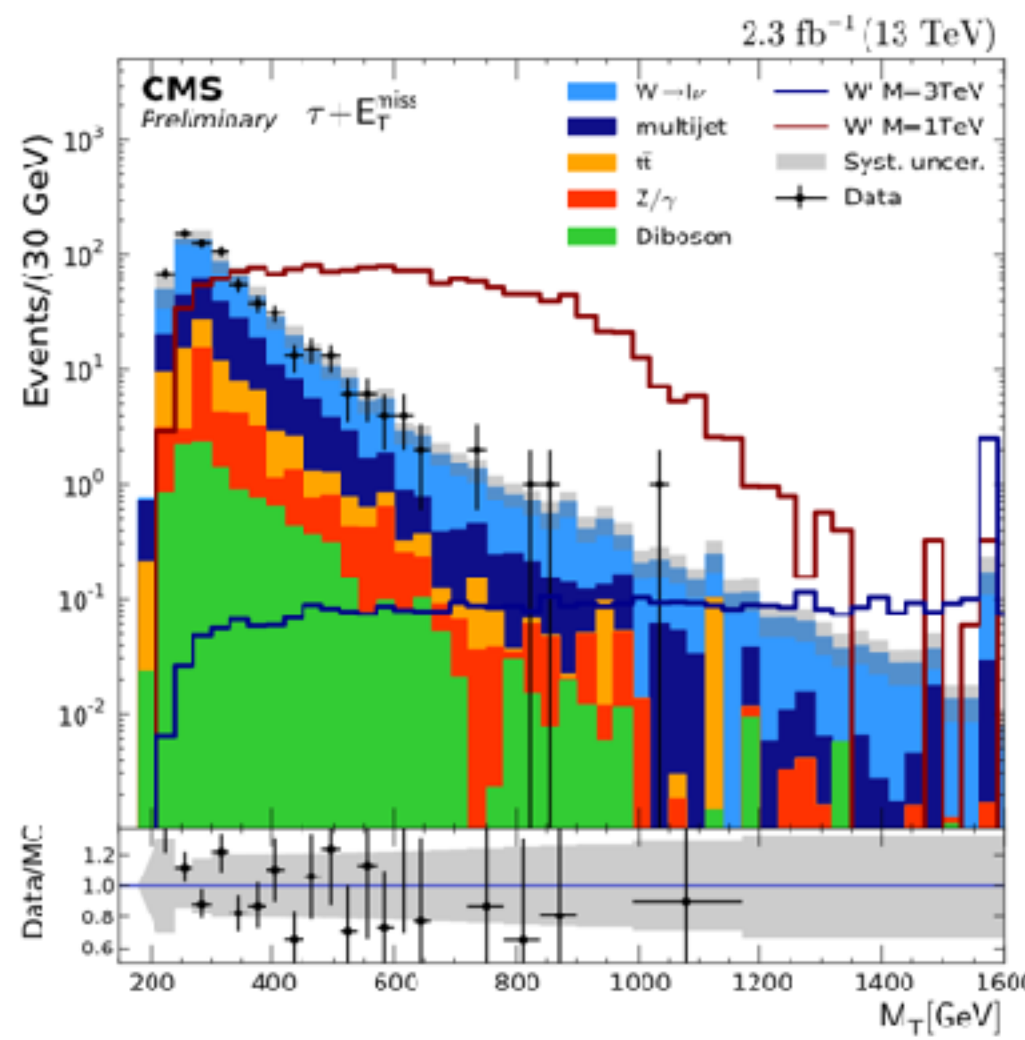


- Search for third-generation scalar leptoquarks and heavy right handed neutrinos in events containing one e or μ, one τ_h and >1 jet

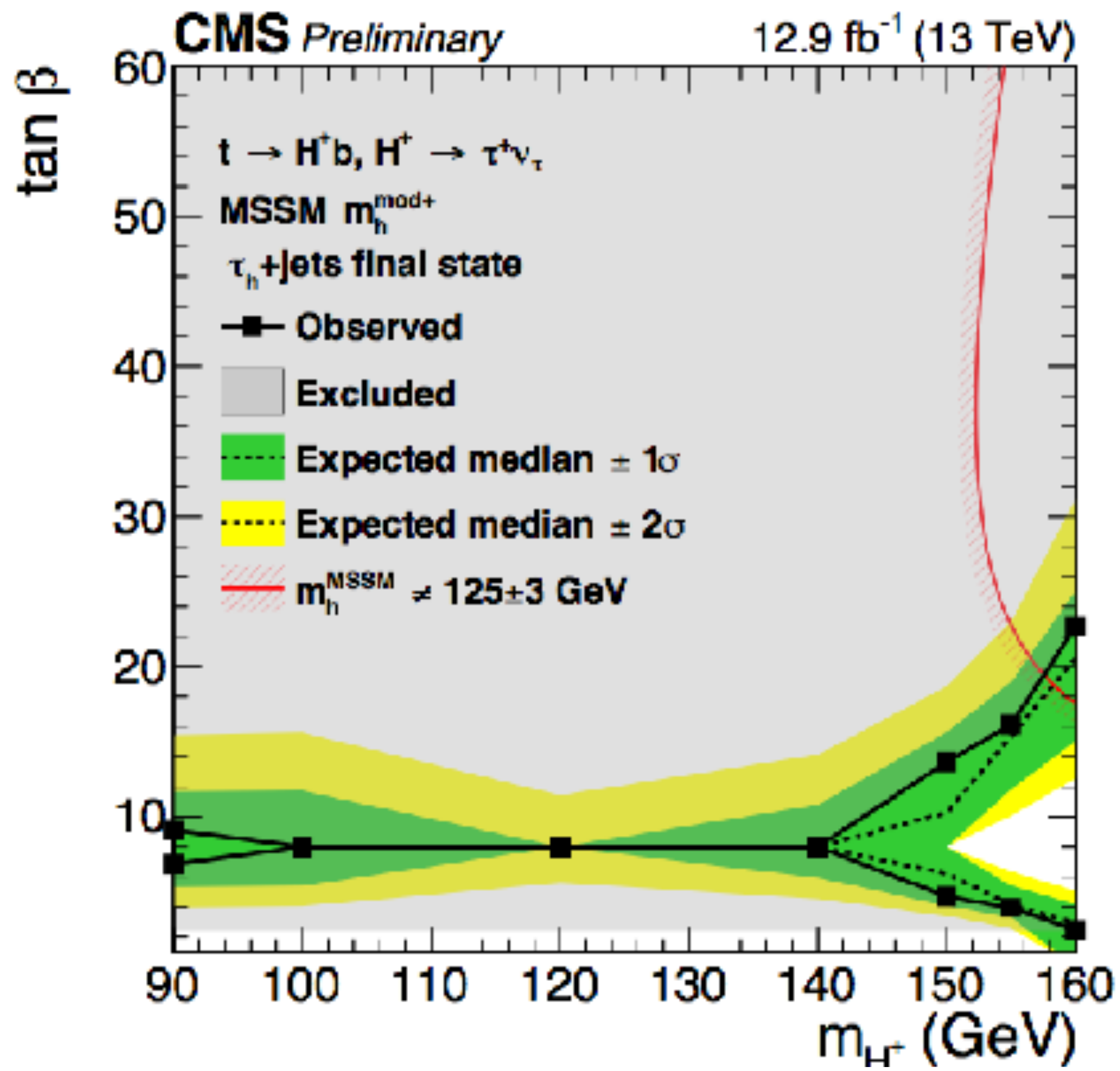
W’ Search

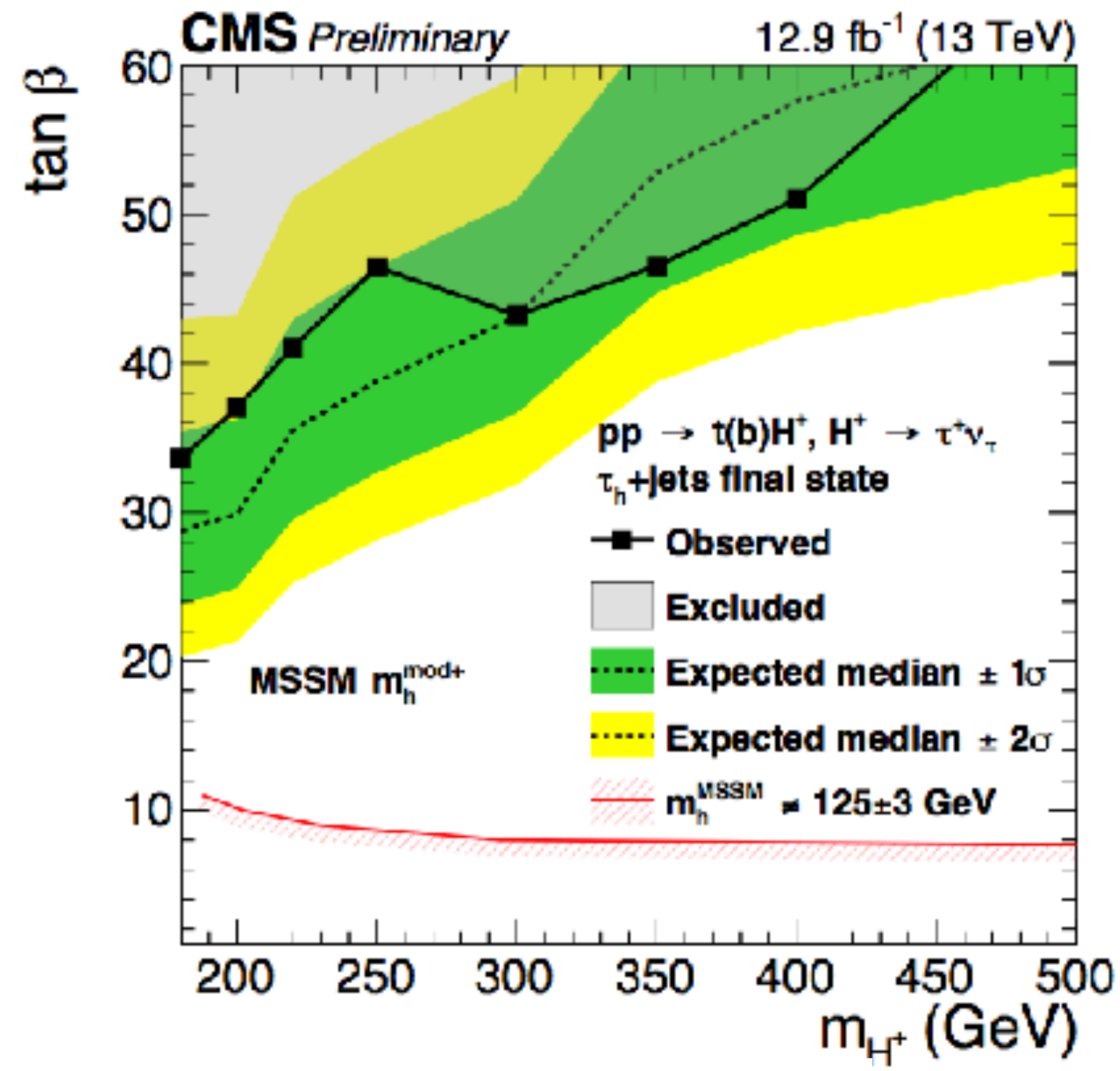

q
$\bar{q}$
W′
τ
ν
τ_{had}
ν

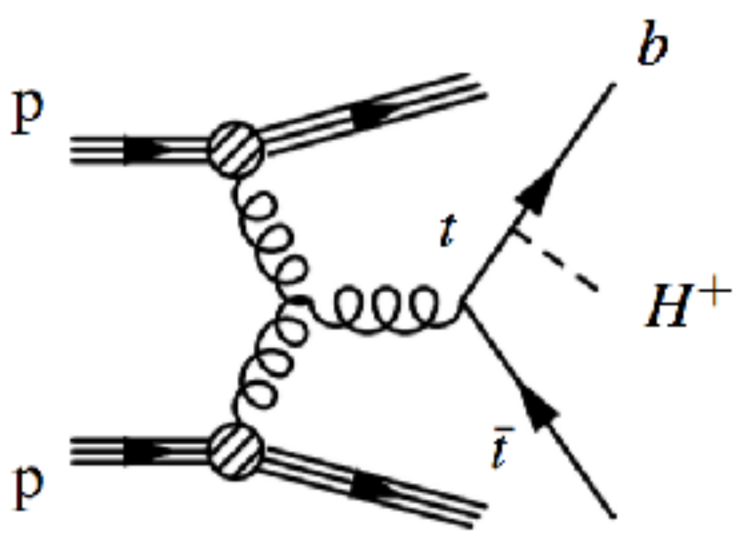

2.3 fb⁻¹ (13 TeV)
τ+E_T^miss
Expected limit
Expected limit ± 1 σ
Expected limit ± 2 σ
Observed limit
CMS
Preliminary
σ × B(W′→τ_h ν) (fb)
M_T^min [GeV]

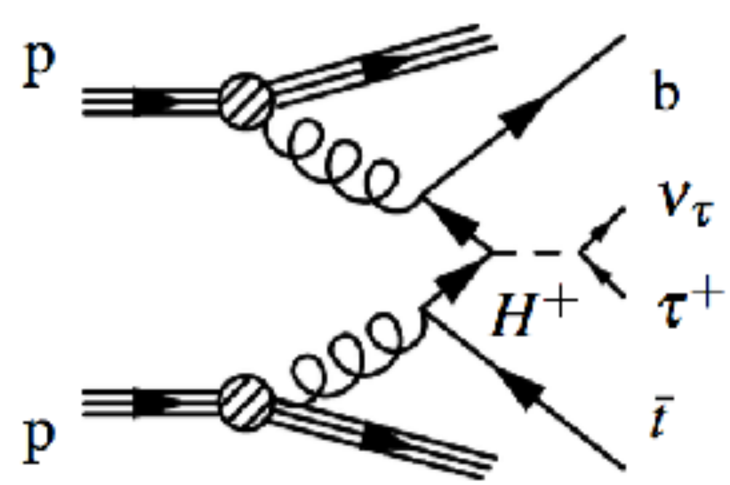

2.3 fb⁻¹ (13 TeV)
CMS
Preliminary
τ+E_T^miss
W→lν
multijet
tt̄
Z/γ
Diboson
W′ M=3TeV
W′ M=1TeV
Syst. uncer.
Data
Events/(30 GeV)
Data/MC
M_T [GeV]

Charged Higgs









Dr. Isobel Ojalvo Nov. 13 2017 Higgs to ττ @ CMS

Prospects for 2018 and Beyond

- No sign of new physics… yet!
- Data collected in the next 10 years will be used to measure the properties of the SM Higgs and continue the search of SUSY particles
- Taus will play an important roll in these searches
- Conditions at the LHC will become more challenging and it is important to be able to maintain manageable rates and have efficient data collection for important physics analyses
- Analyses on the full 2016 dataset are still being made public
- Many opportunities for innovation!

In 1975 the discovery of the Tau was new land in the sea of two generations. Perhaps the Tau will lead us out of the sea of the standard model.

- Martin L. Perl

Back Up