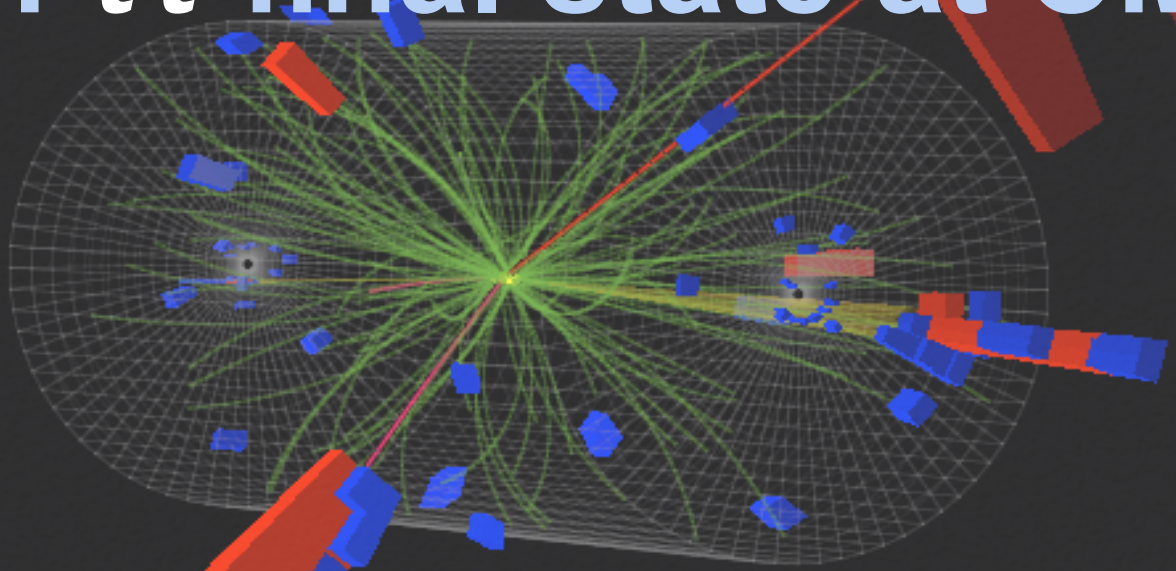
CMS Experiment at LHC, CERN
Data recorded: Sun Nov 25 00:15:46 2012 CEST
Run/Event: 207898 / 97057018

ULB

Search for SM Higgs boson in $\tau\tau$ final state at CMS



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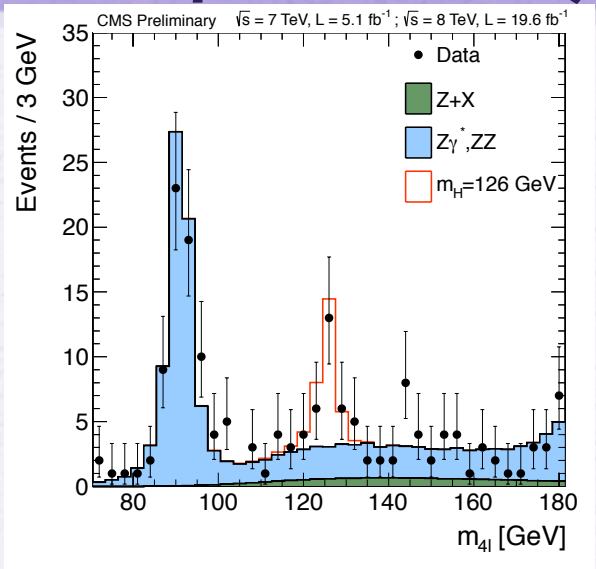
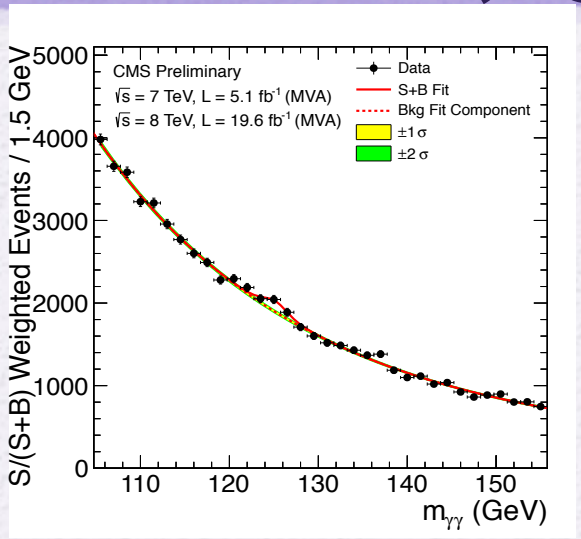
16th Lomonosov Conference, Moscow

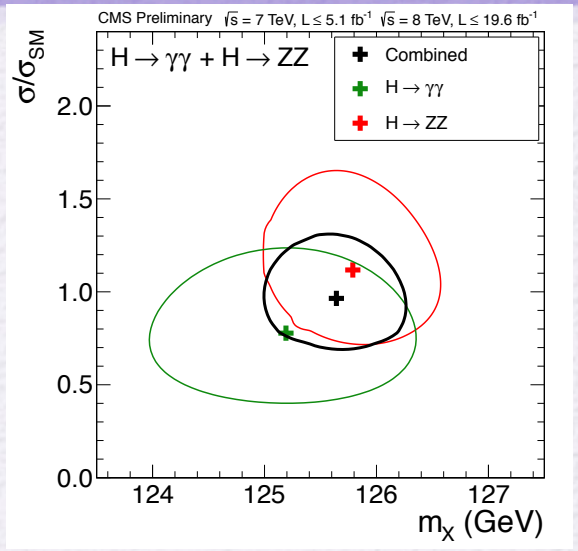
27 Aug. 2013

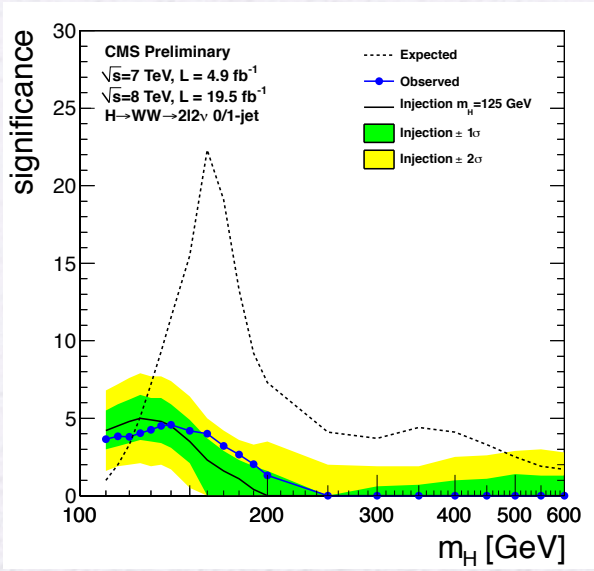
CMS

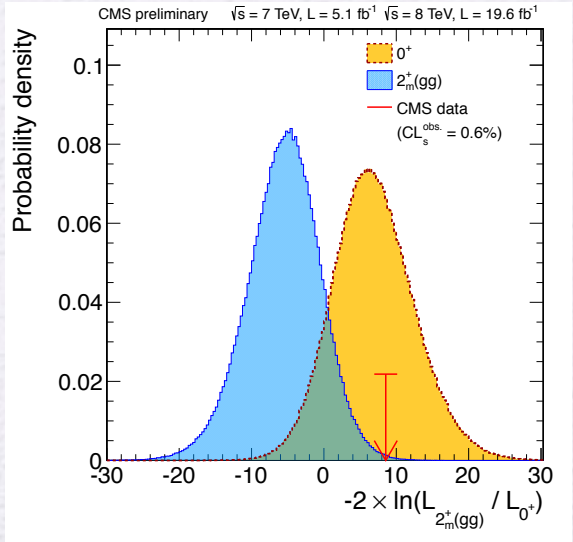
Enough indications for a **new** particle (scalar boson) @ ~125 GeV







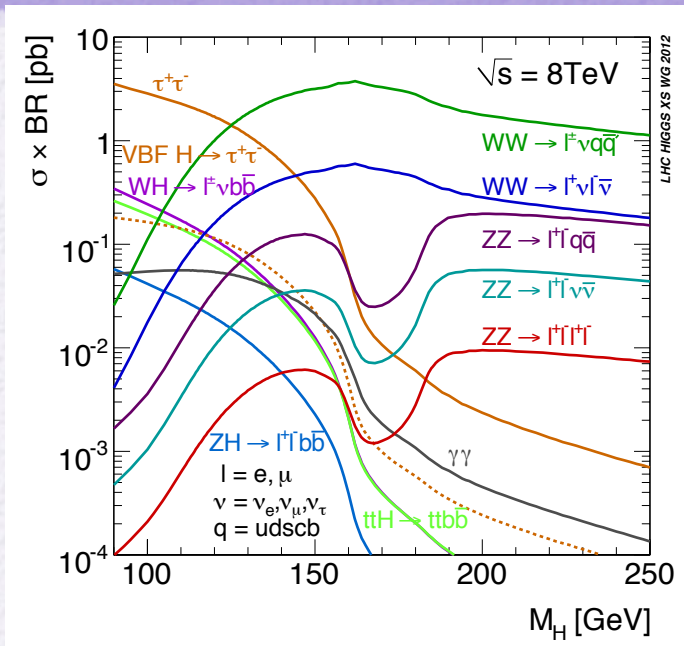


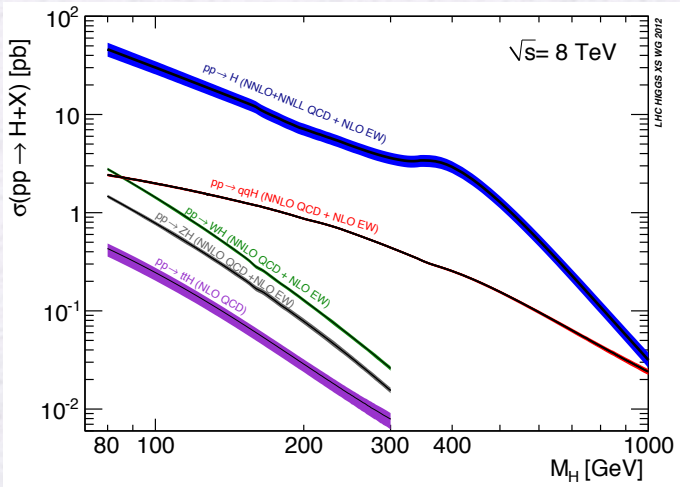


Our friend couples to bosons, what about coupling to fermions??

Introduction

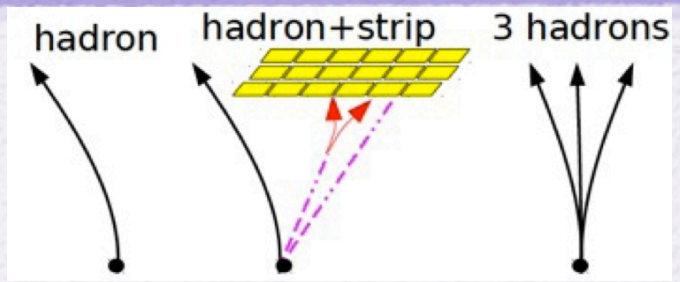
- $H \rightarrow \tau\tau$ is important channel to check the Yukawa couplings between fermions and Higgs bosons
- The current results are based on full 2011 and 2012 CMS data and includes 4 main Higgs production modes.
- The analysis covers most of the decay modes: $e\tau_h$, $\mu\tau_h$, $e\mu$, $\mu\mu$, $\tau_h\tau_h$



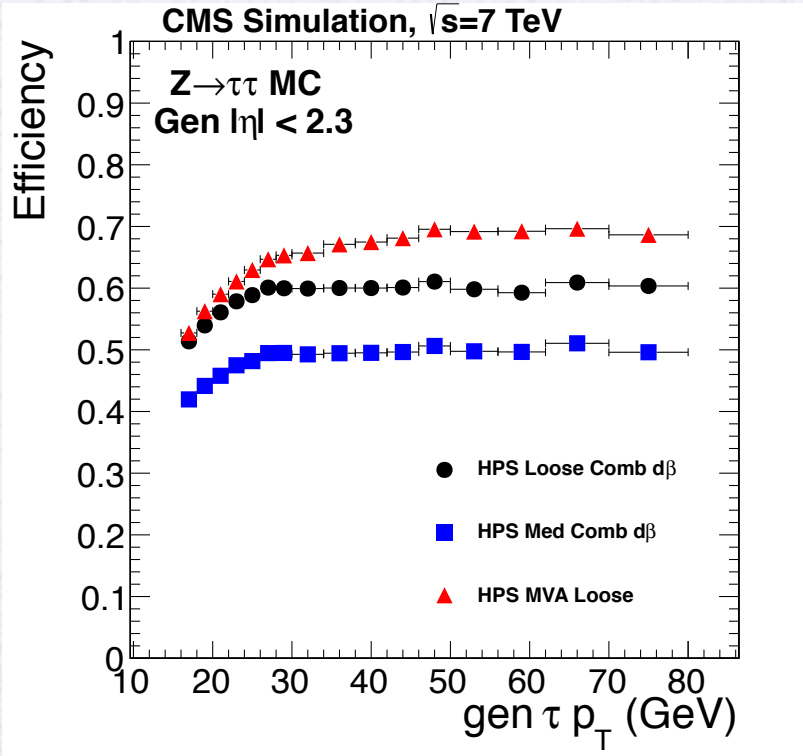


Tau Reco & Id

Decay mode	Resonance	Mass (MeV/c^2)	Branching fraction (%)
$\tau^- \to h^- \nu_\tau$			11.6%
$\tau^- \to h^- \pi^0 \nu_\tau$	ρ^-	770	26.0%
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	a_1^-	1200	9.5%
$\tau^- \to h^- h^+ h^- \nu_\tau$	a_1^-	1200	9.8%
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$			4.8%

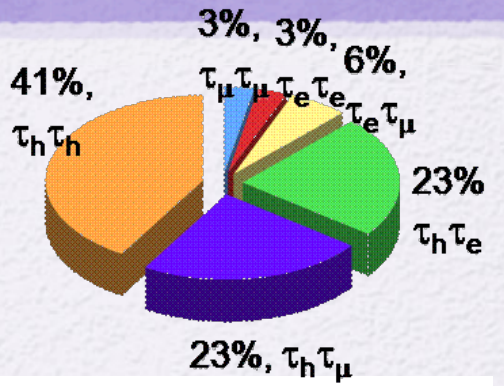


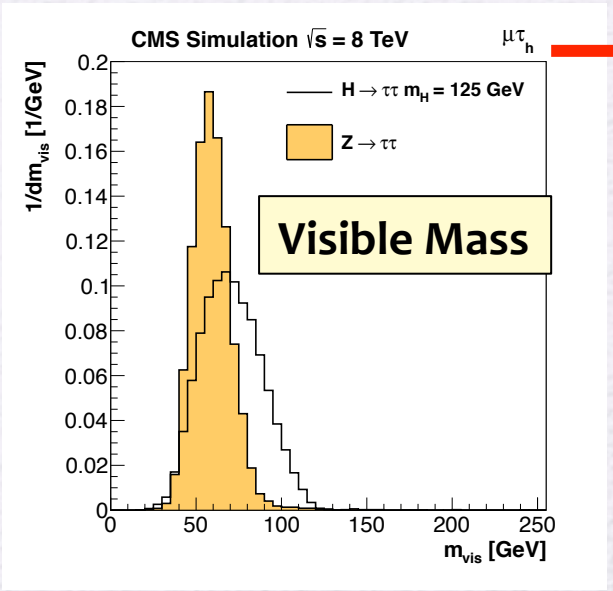
- Reconstruct the hadronic decays of tau based on the Pflow algorithm in 1-prong, 1-prong+π_0's and 3-prongs.
- For isolation, use multivariate discriminant based on Σp_T of particles in rings around τ_h
- ε_{rec}>60% (flat for $p_T(\tau)$>30GeV),Fakerate 1–3%.
- Efficiency and momentum resolution (nearly) independent from pileup(backup)



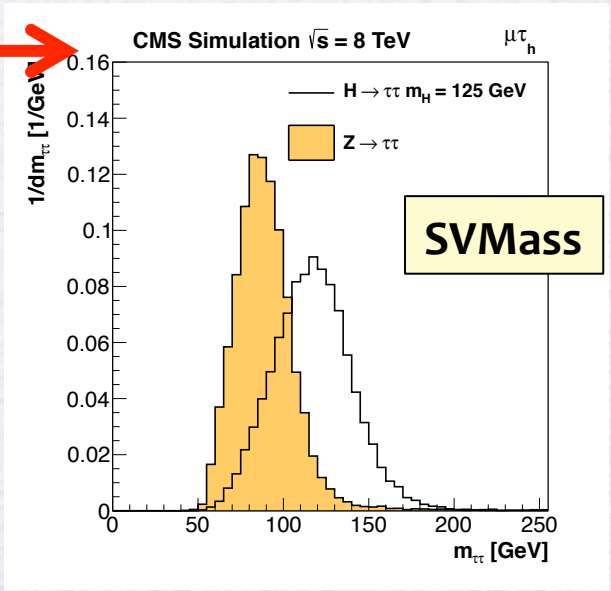
di-τ Mass Reconstruction

- Determine invariant mass of di-τ system with maximum likelihood method.
- marginalize the unobserved neutrinos d.o.f.
- Inputs: four-vector information of visible leptons, x- and y- component of MET and MET resolution





- Improve the Mass resolution (15-20%)
- Increase Z/H separation
- Impact on Limit/Sign. ~ 30%



Event Categories

$e\tau_h$, $\mu\tau_h$, $e\mu$, $\mu\mu$

Number of Jets

Pt (τ/μ)

0-jet, low-p_T

Large background & **No fit for signal,** constrain uncertainties

1-jet, low-p_T

Enhancement due to jet requirement & Better mass resolution

2-jet, VBF

≥ 2 jets

M_{jj} > 500 GeV & $\Delta\eta$ > 3.5

Central jet veto

VBF H signal enhanced

0-jet, high-p_T

Large background & **No fit for signal,** constrain uncertainties

1-jet, high-pT

$Z\rightarrow\tau\tau$ suppressed by high-$p_T(\tau)$

$\tau_h\tau_h$

1-jet

$p_T(\tau\tau)$ > 140 GeV

Better mass resolution

2-jet, VBF

$p_T(\tau\tau)$ > 110 & M_{jj} > 250 GeV

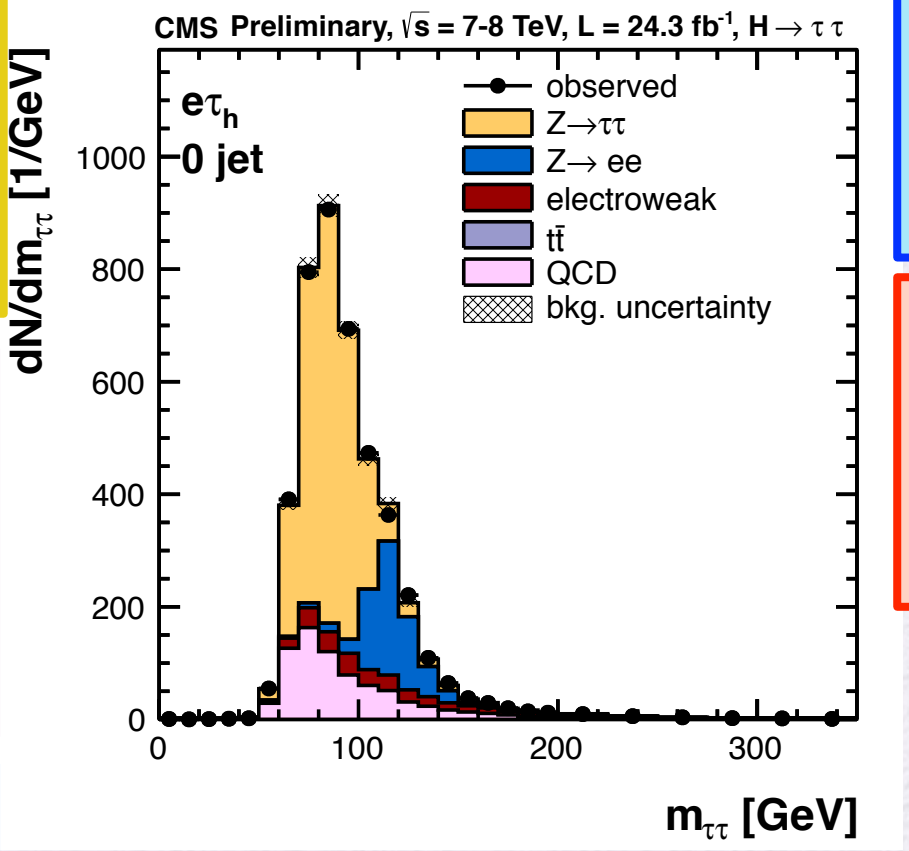
$\Delta\eta$> 2.5 & Central jet veto

Background Anatomy

Z→ττ:
- Irreducible BG
- Shape and norm from Embedded samples: Take the Z→μμ, replace μ by sim. τ decay.
- Norm is rescaled to observed Z→μμ

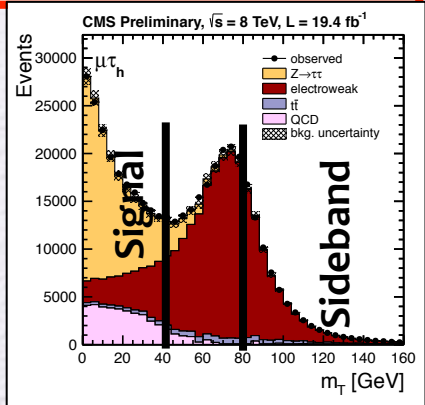
QCD:
- Suppressed by isolation
- Normalization & shape taken from LS/OS or fakerate from Data

TTbar:
- Normalization & shape from MC from Sideband



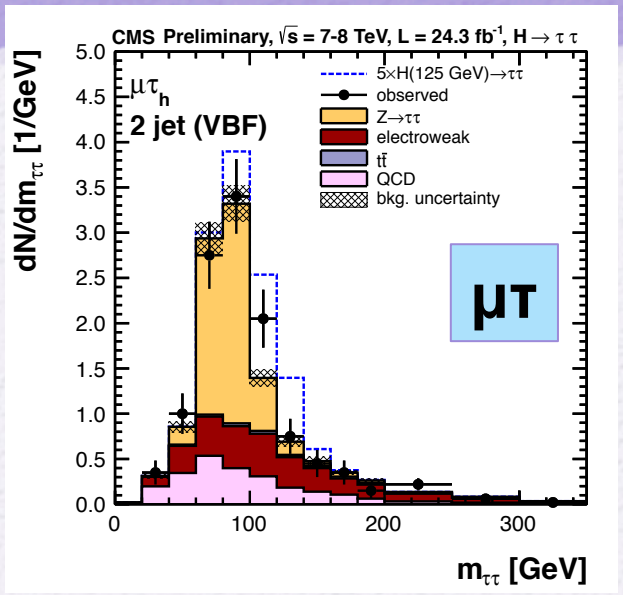
Z→ee(/μμ):
- Suppressed by extra lep. veto and tau dis. against leptons
- Normalization and shape from MC
- Corrected for Z→μμ data over MC

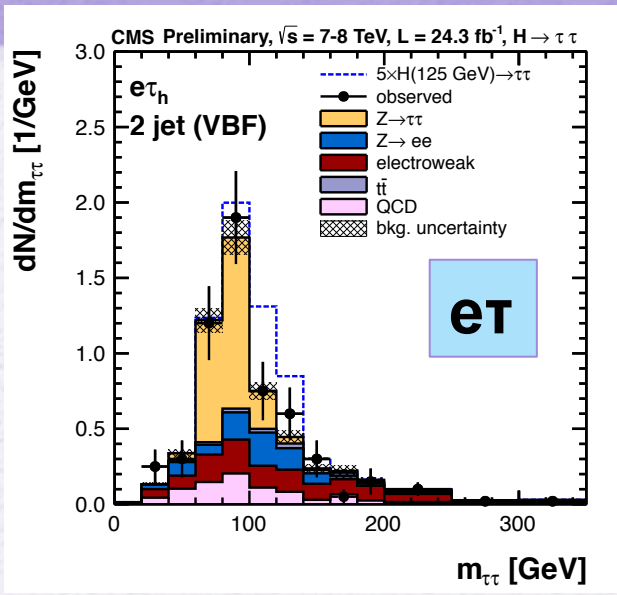
Diboson/W+jets:
- Suppressed by topological cuts
- Normalization from sideband. (data/mc scale)
- Shape from MC

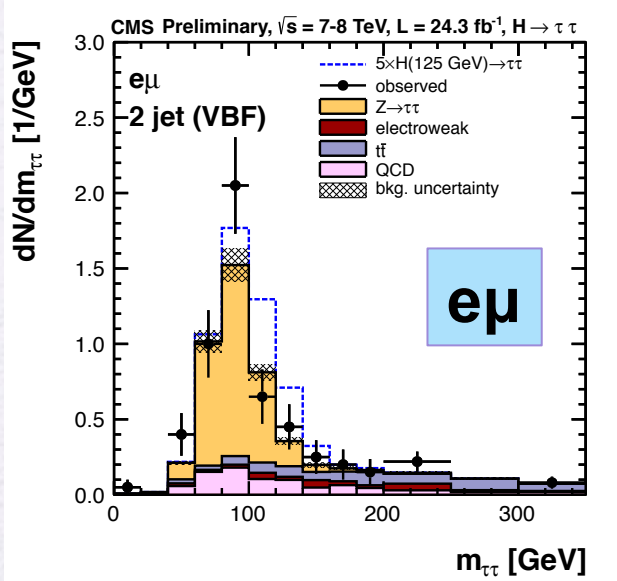


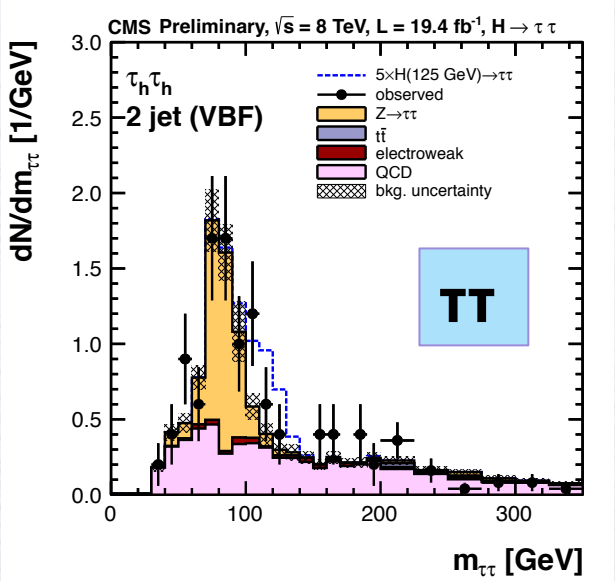
2-Jet VBF Category

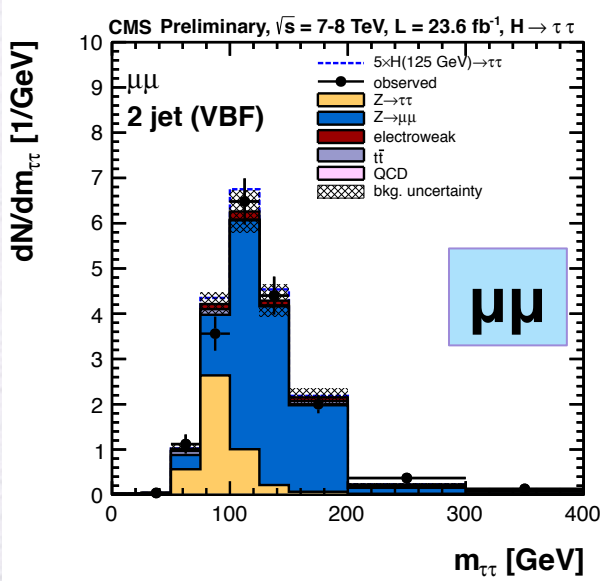
- After template fit has been applied (S+B hypothesis)
- Shaded bands correspond to uncertainties after fit.









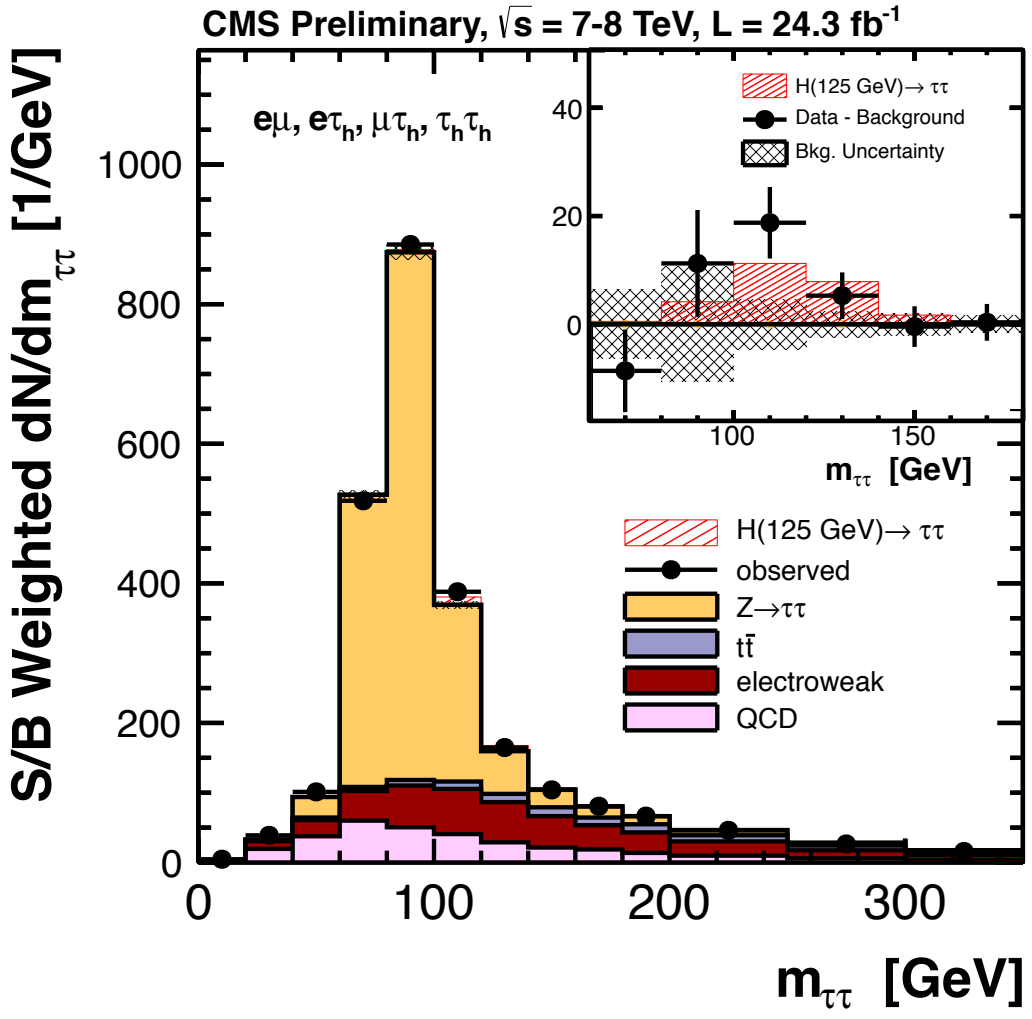


Combined Weighted Mass

Combine channels and categories weighting each by **S/B** :

*(**S** is expected signal and **B** is fitted background in $m_{\tau\tau}$ interval containing 68% of signal around 125 GeV)*

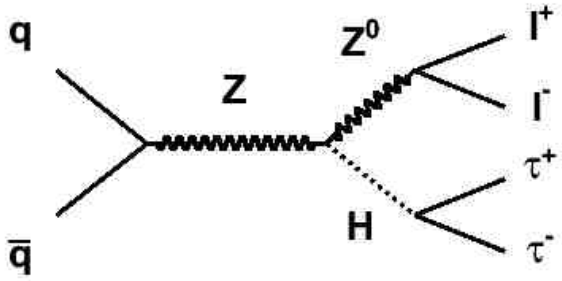
Excess of events between 100-140 GeV compatible with H→$\tau\tau$ *from SM*

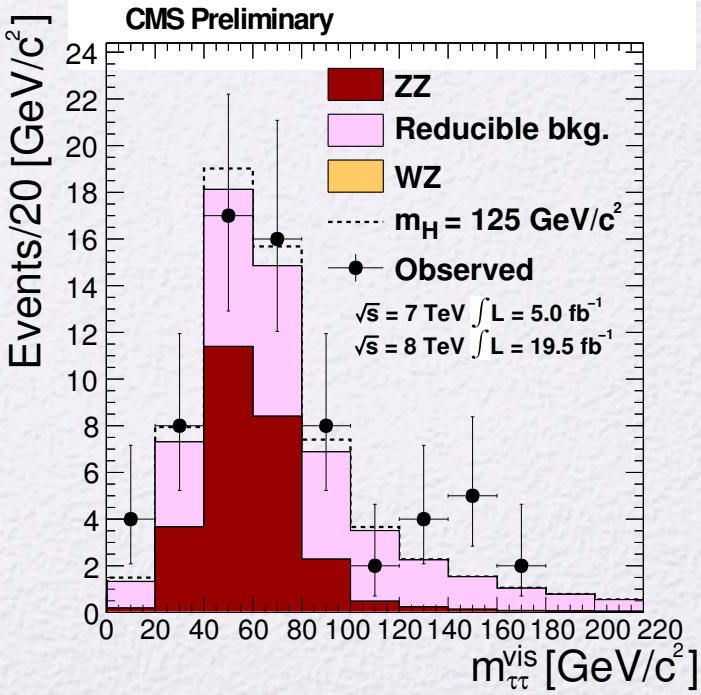


$ZH \rightarrow \ell\ell\tau\tau$

$$Z \rightarrow (\mu\mu, ee) \;\&\; H \rightarrow (\tau_h\tau_h, \tau_h\mu, \tau_h e, e\mu)$$

- A pair of identified/isolated **e/μ** compatible with Z boson + 2 more id/iso **e/μ/τ_h**
- Backgrounds:
  - Reducible BG: Z+jets, WZ+jets, ttbar, … (from data using fake rate method)
  - Irreducible BG: ZZ (from MC)
- Veto extra lepton to be inclusive from H→ZZ→4l
- Visible Mass as the observable
- ZH_HWW is also considered as signal

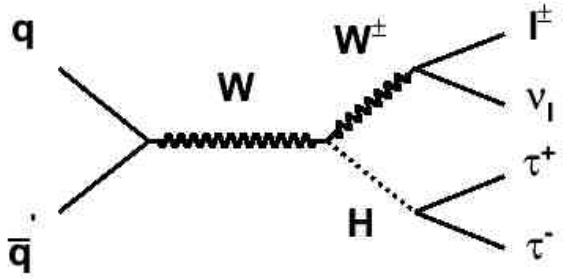


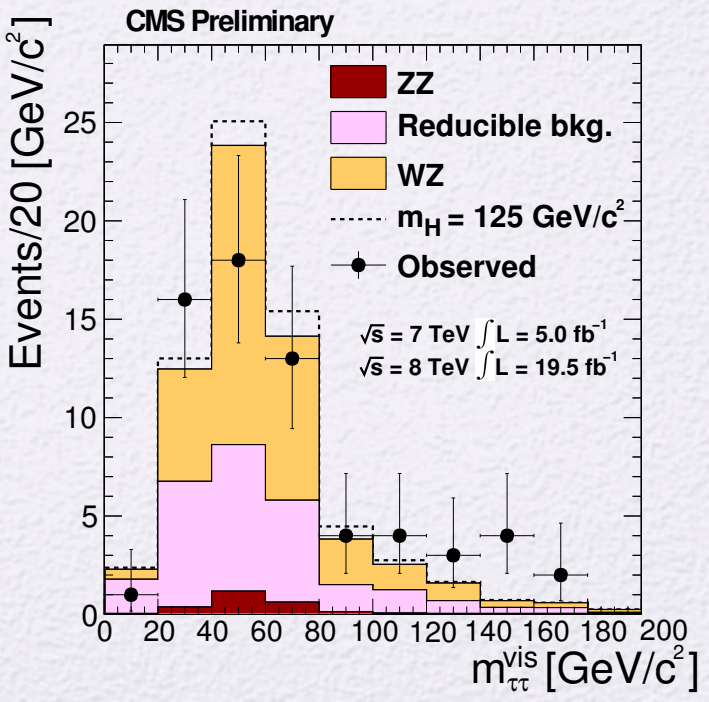


$WH \rightarrow \ell\ell\tau_h$

$$W \rightarrow (\mu\nu) \,\&\, H \rightarrow (\tau_h\mu, \tau_h e)$$

- 2 identified/isolated ***e/μ***+ 1 isolated τ_h
- Require both lepton to be Same Sign to suppress huge DY→ll background
- Backgrounds:
  - Reducible BG: W/Z+jets, ttbar, … (from data using fake rate method)
  - Irreducible BG: WZ and ZZ (from MC)
- Visible Mass as the observable

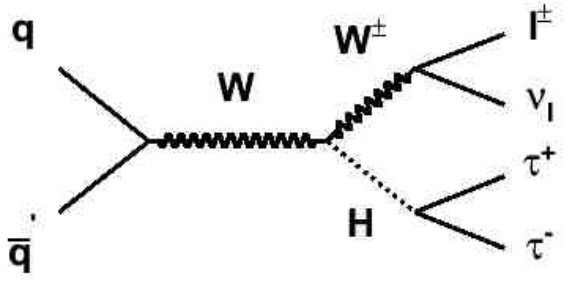


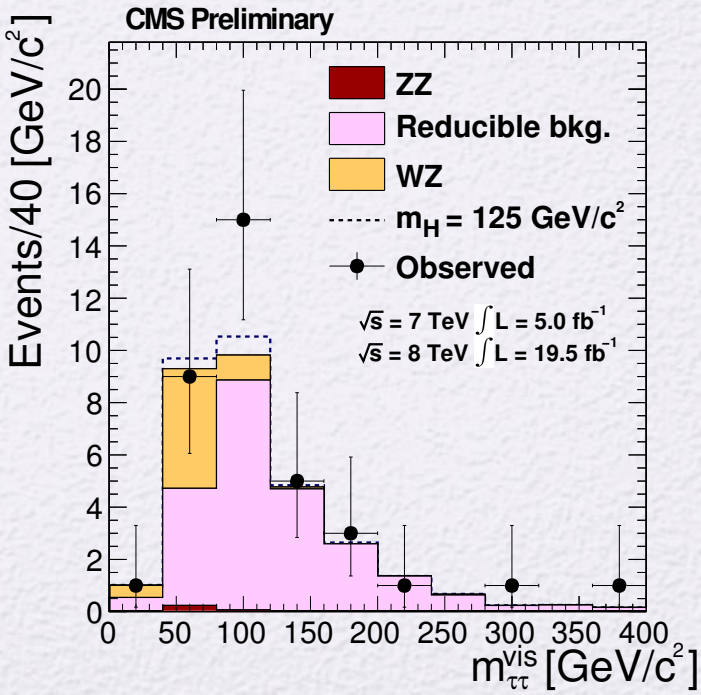


$WH \rightarrow \ell\tau_h\tau_h$

$$W \rightarrow (\mu\nu, e\nu) \,\&\, H \rightarrow (\tau_h\tau_h)$$

- One id/isolated ***e/μ***+ 2 isolated τ_h
- Backgrounds:
  - Reducible BG: QCD,W/Z+jets, ttbar, … (from data using fake rate method)
  - Irreducible BG: WZ (from MC)
- Further topological cuts to suppress large backgrounds
- Visible Mass as the observable

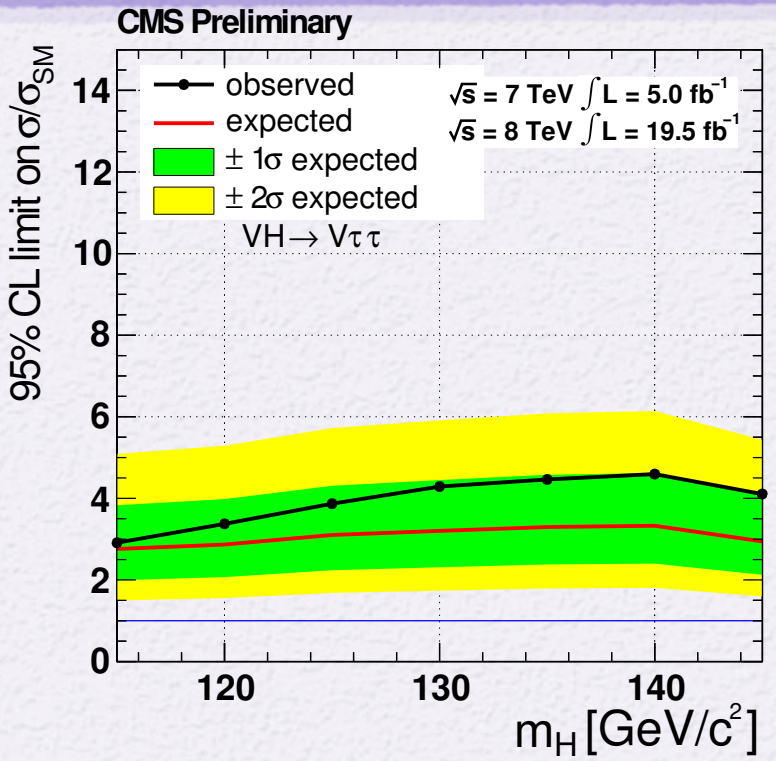


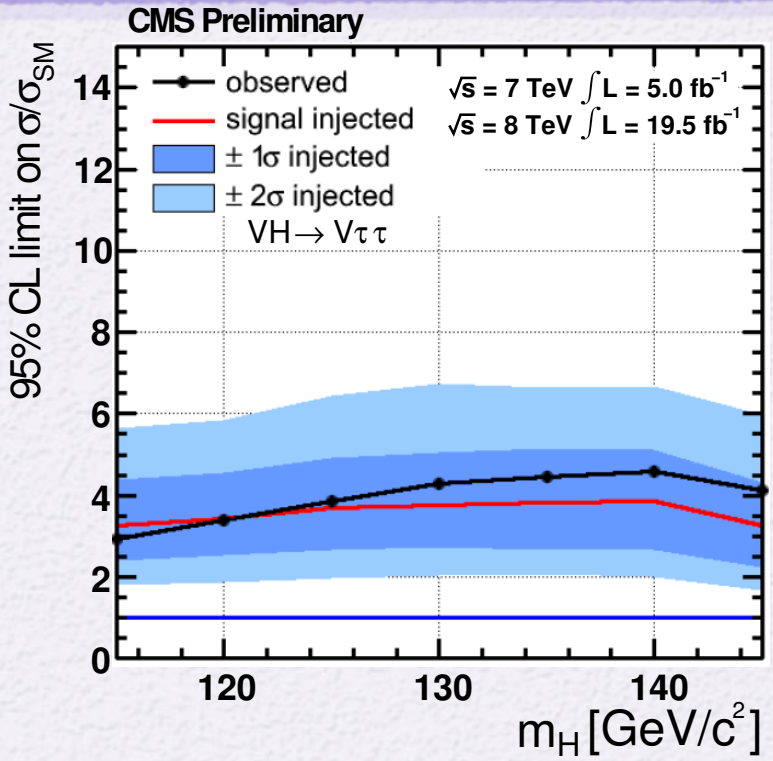


Systematics

Uncertainty	Uncert.	Applied on …
Electron Id & Trigger	2%	Normalization
Muon Id & Trigger	2%	Normalization
Tau Id & Trigger	8%	Normalization
Tau Energy Scale	3%	Shape
Electron Energy Scale	1%	Shape (emu channel)
JES	2.5-5%	Normalization
MET	5%	Normalization
b-tag efficiency	10%	Normalization
Luminosity 7 TeV (8TeV)	2.2% (4.2%)	Normalization
ttbar and Diboson	10-30%	Normalization
QCD multijet	6-32%	Normalization
Z→ll (e,mu,jet fake)	(20%,30%,20%)	Normalization
PDF	2-8 %	Normalization

Combined VH Results

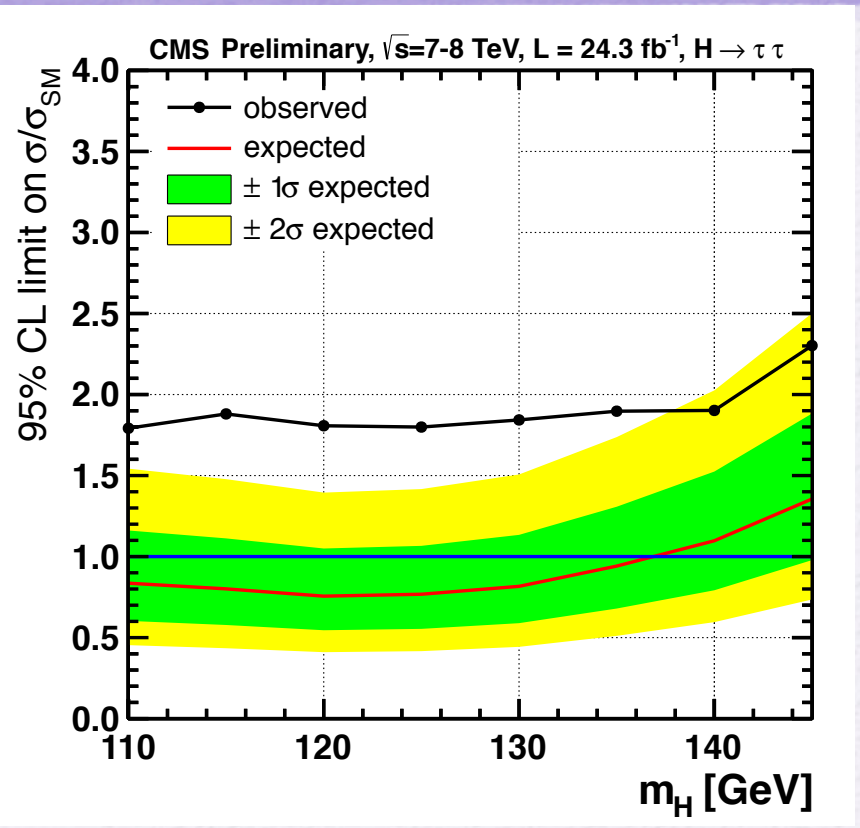


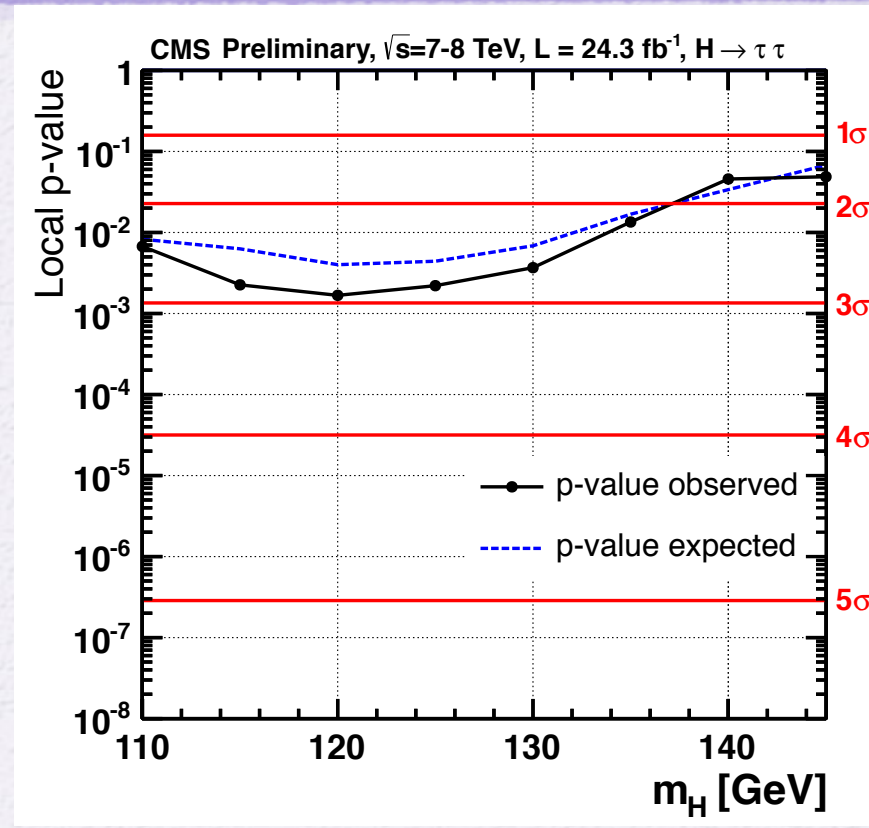


- Sensitivity of ~3xSM
- Small excess

- consistent with both SM Higgs at 125 GeV and background

Limit, p-value and Significance



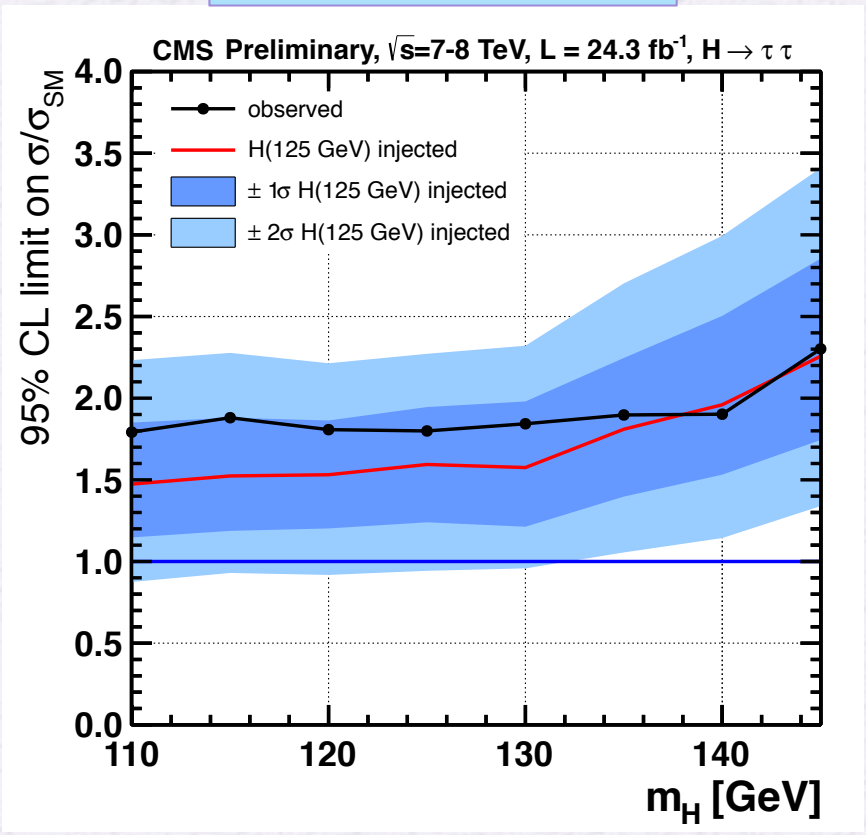


- Broad excess compatible with a presence of a SM Higgs boson at 125 GeV

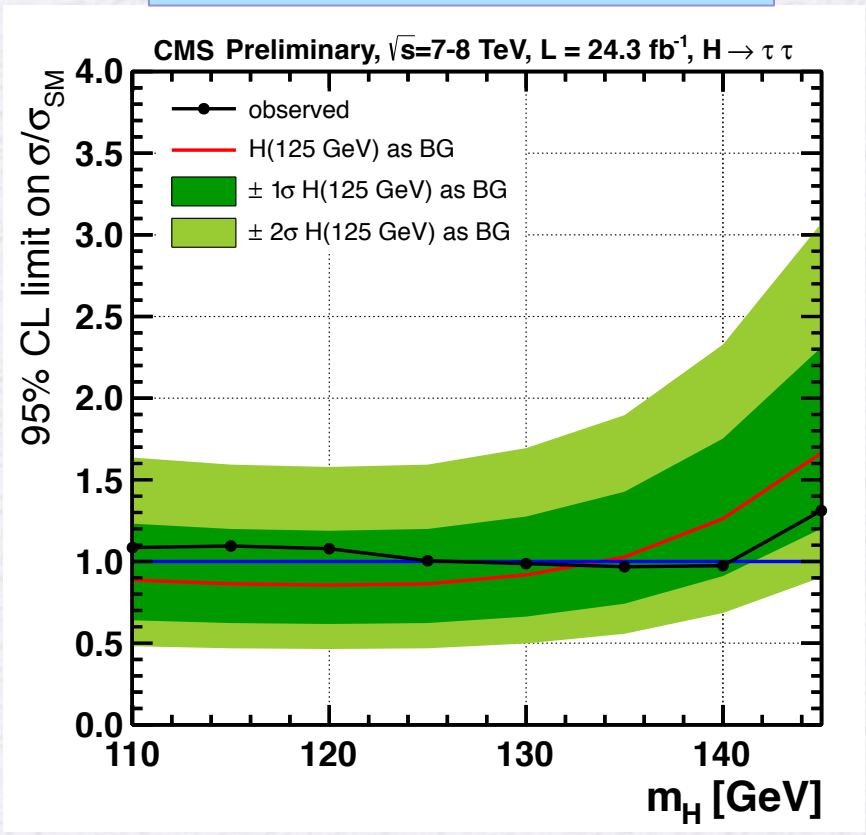
- Minimum p-value at 120 GeV corresponds to 2.93σ → **Indicate that our friend couples to τ lepton**

Compatibility of Excess with SM Higgs boson

Signal Injection

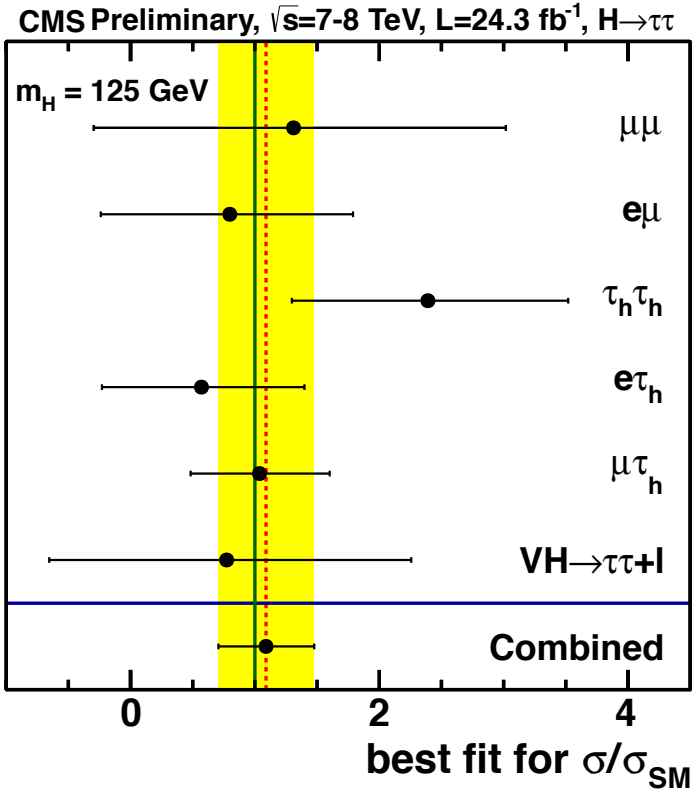


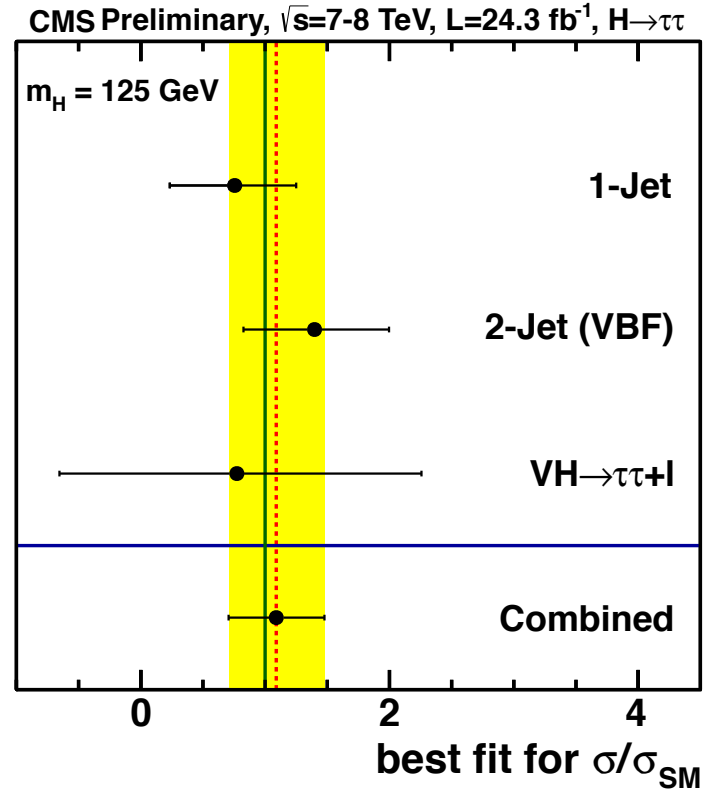
H125 as background



Both limit plots shows consistency of the excess with one and only one SM Higgs boson at 125 GeV.

Signal Cross-Section

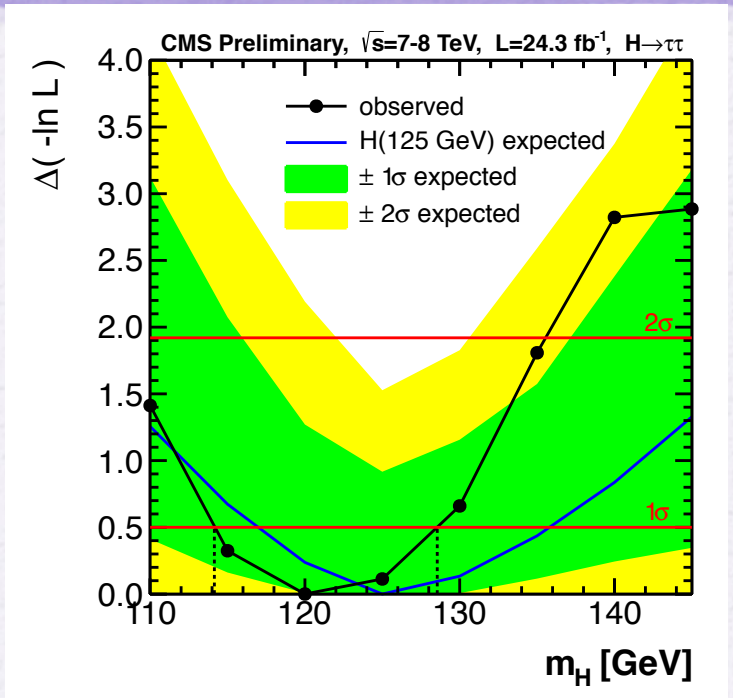


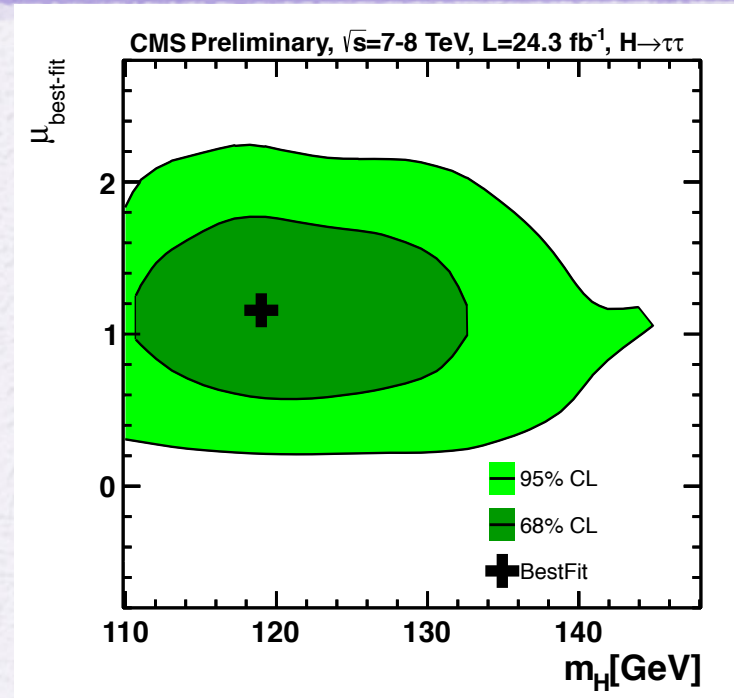


Best-fit signal strength values, σ/σ_{SM} for independent Channel(categories) on left(right)

signal strength $\mu=1.1\pm0.4$

Mass and Best Fit v.s. Mass





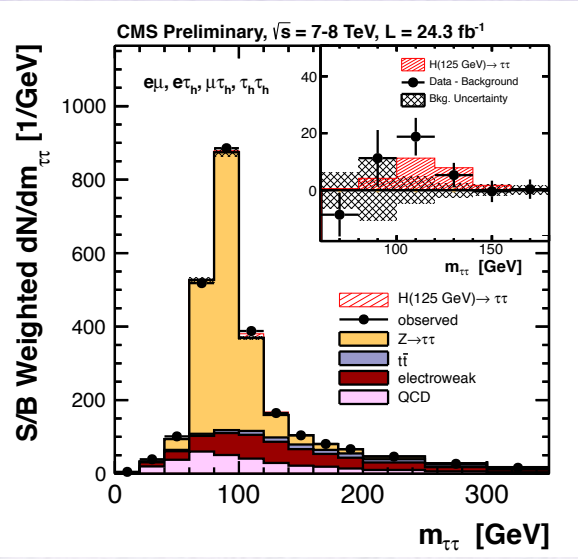
Log likelihood versus SM Higgs boson fit mass

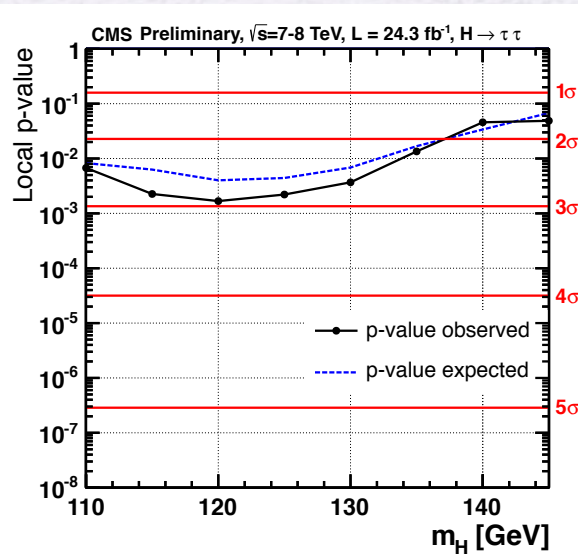
$m_H = 120^{+9}_{-7}(\text{stat+syst})$ GeV

Best fit of signal strength compared to the SM expectation (mu) as a function of the Higgs mass

Conclusions

- Search for **H→ττ** with the full 2011+2012 dataset collected by CMS was shown
- A wide excess compatible with SM Higgs is observed
  - Obs. limit of 1.81xSM at 125 GeV, while 0.76xSM exp.
  - Signal strength of 1.1 ± 0.4
  - Significance of 2.85σ obs. (2.62 exp.) at 125 GeV
- Strong indication that this new particle couples to **τ** lepton.
- New updated and improved results will appear soon, stay tuned …

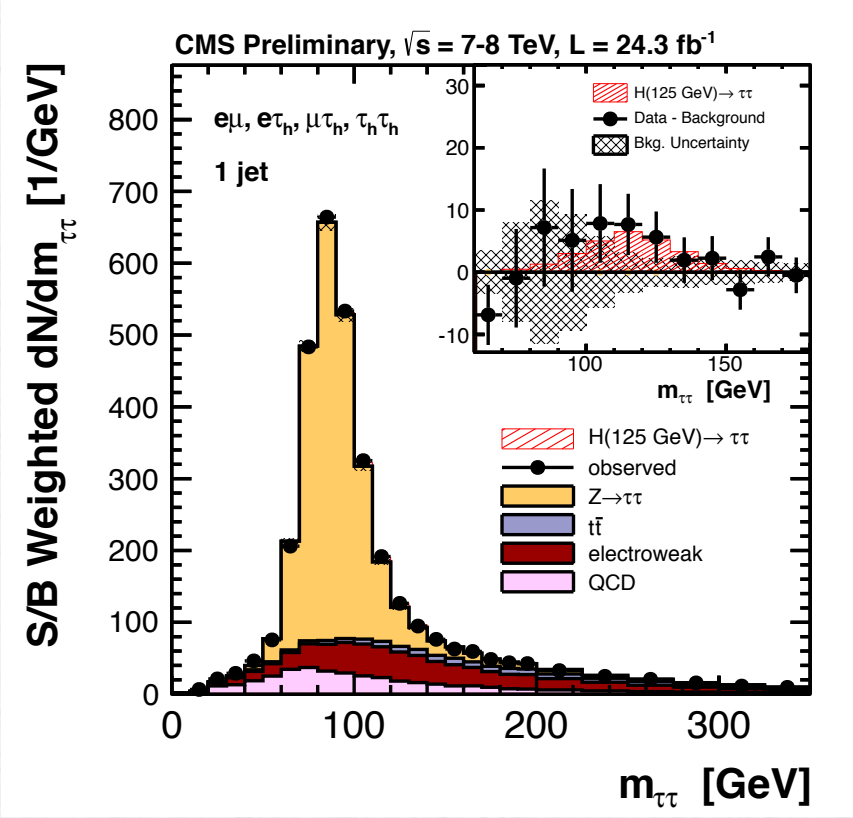




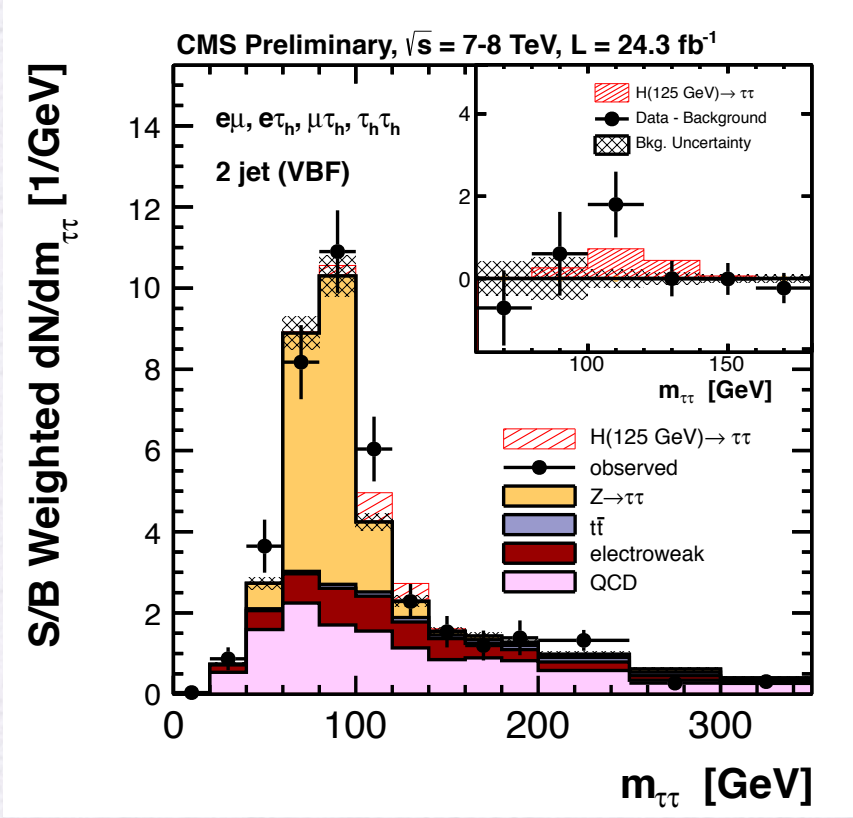
Back Up

Weighted Mass

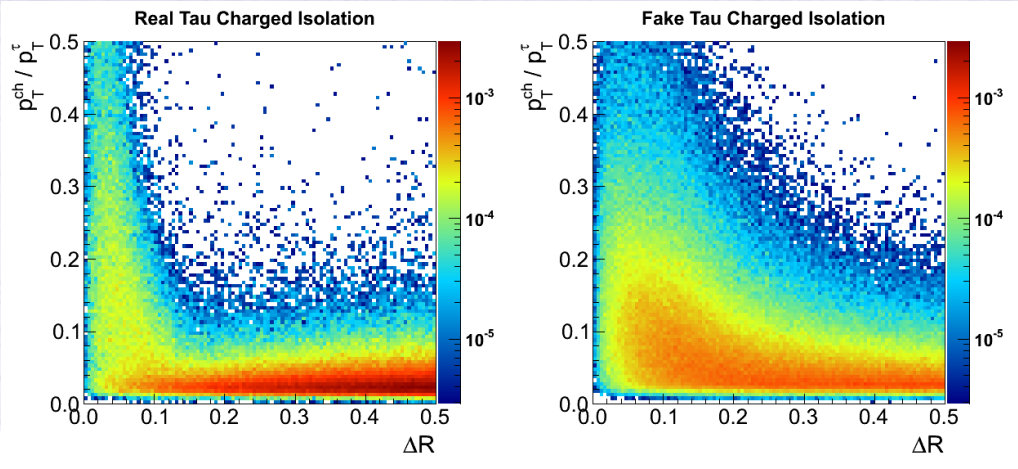
1 Jet Category

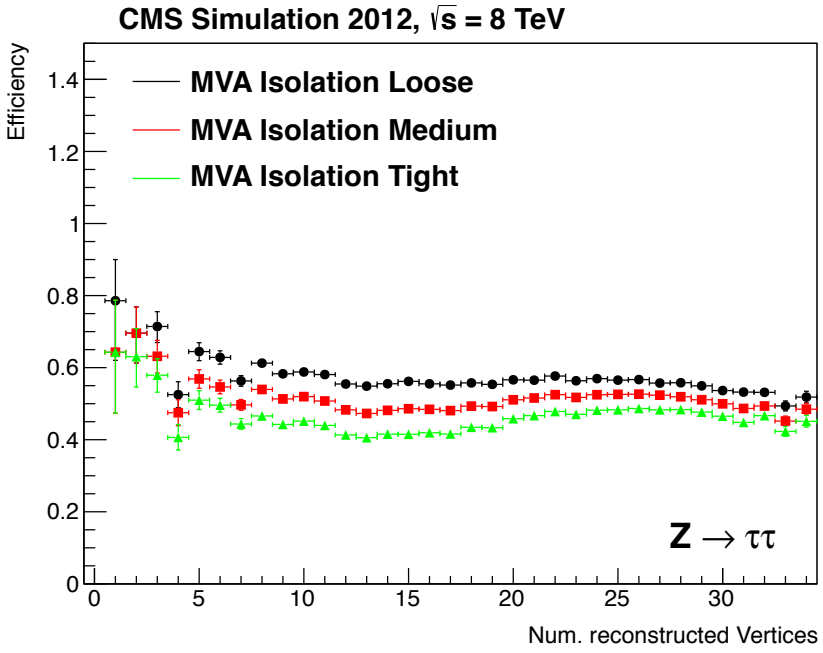


VBF Category



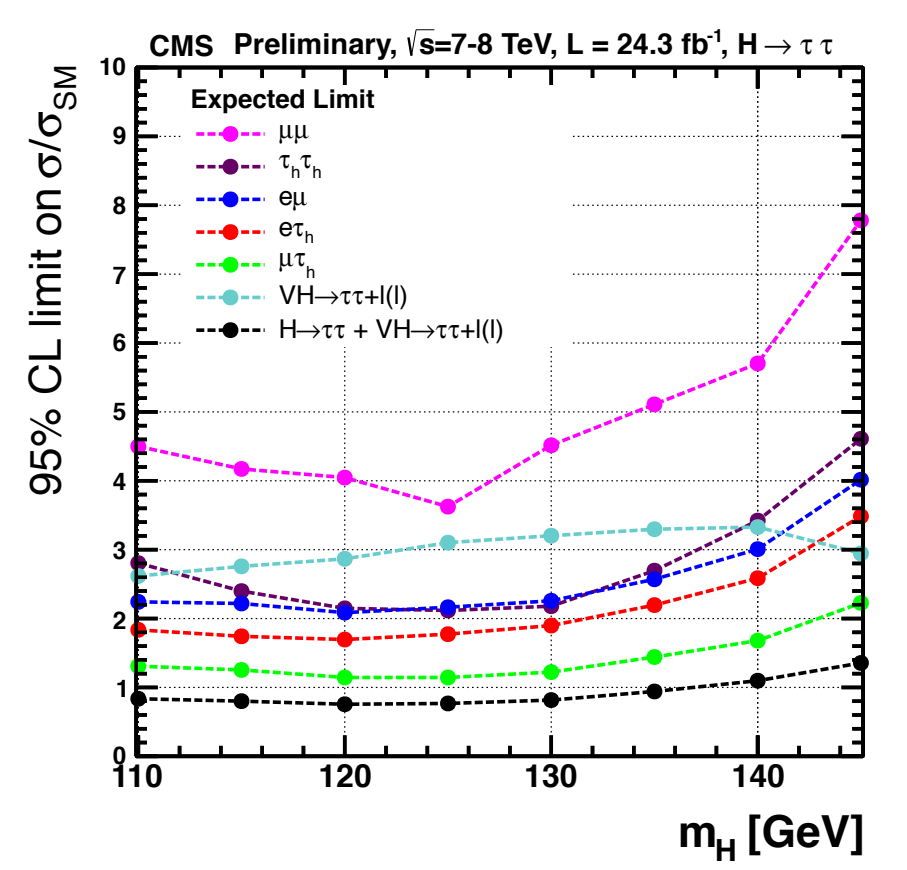
More about Tau ID



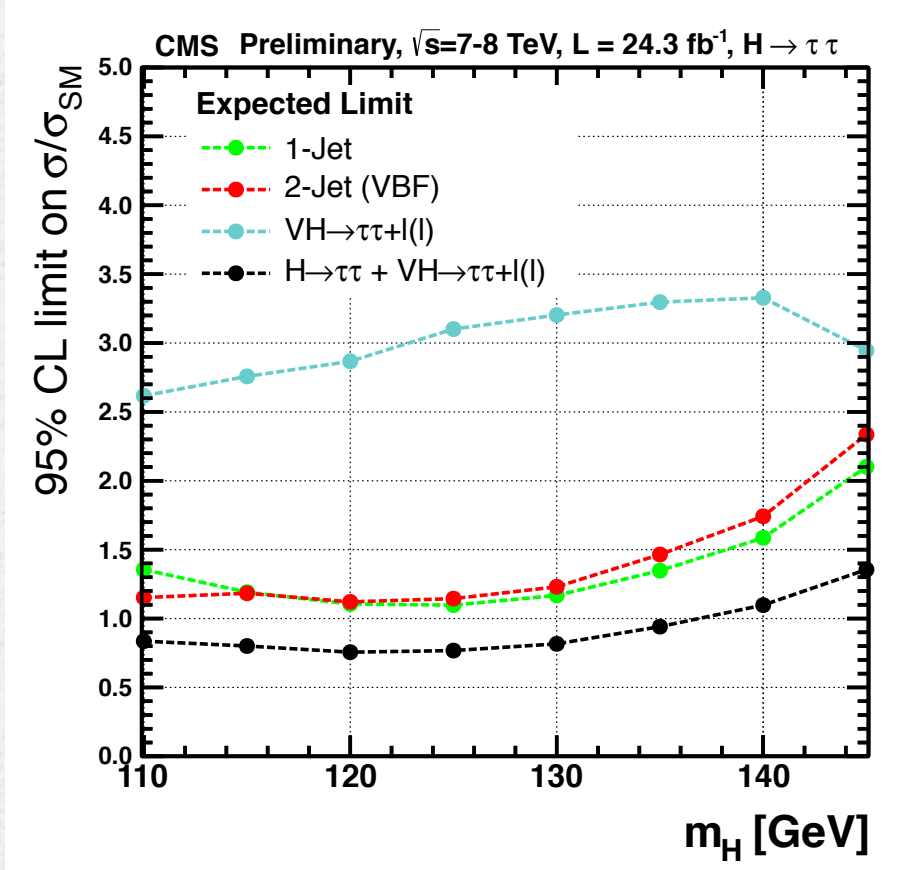


Expected Limit

Per Channel



Per Category



Extended Limit (down to 90 GeV)