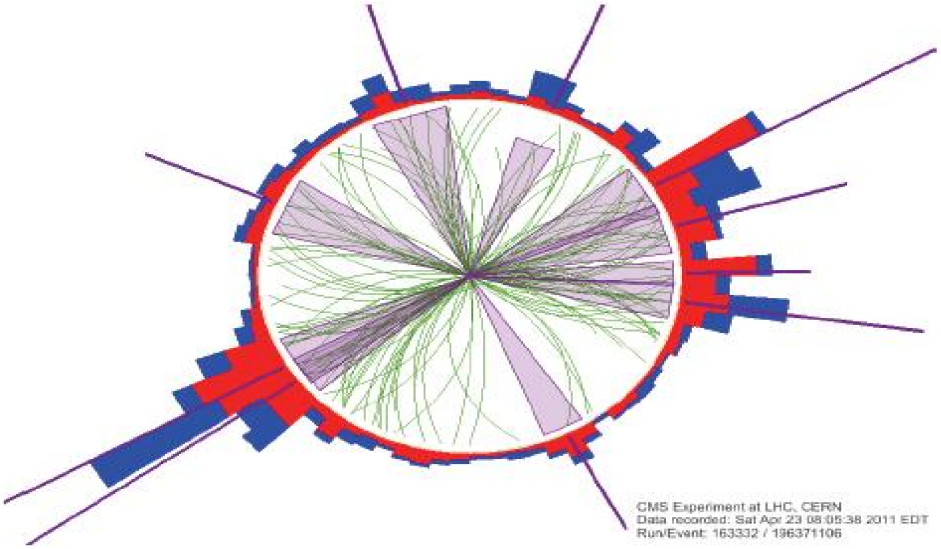
Measurement of Higgs boson production & properties in di-lepton channel (CMS)

38th International conference on High Energy Physics



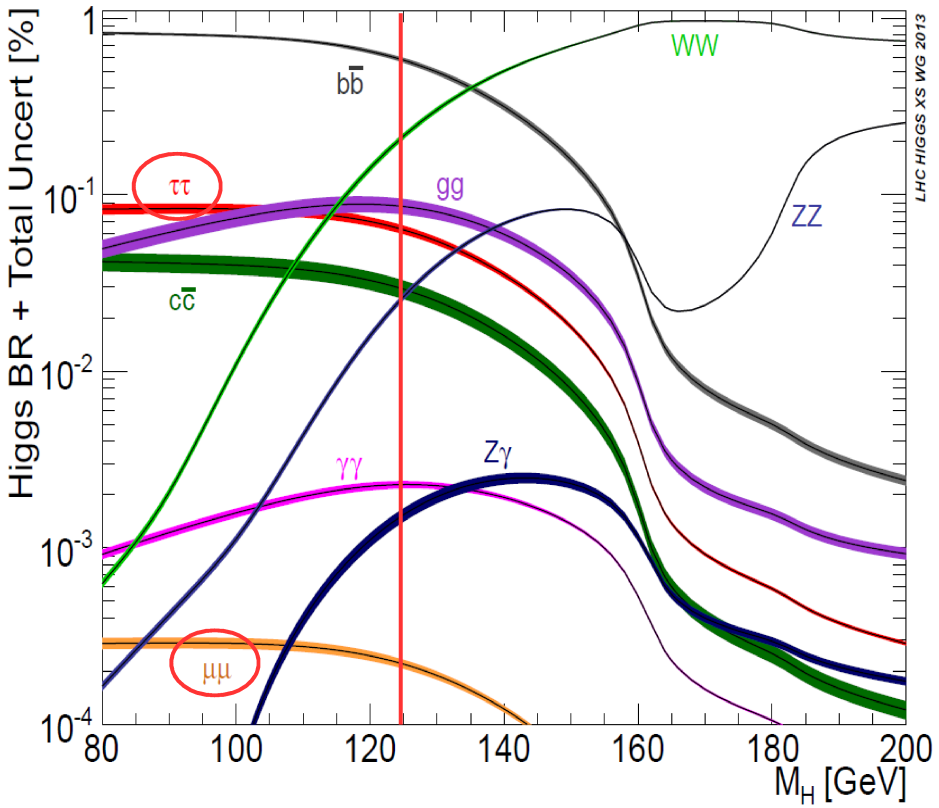
Pooja Saxena
(On behalf of the CMS collaboration)
August 3-10, 2016

HELMHOLTZ ASSOCIATION

DESY

Content

- SM Higgs(125):
  - Does it decay to leptons?
  - Measurement of lepton coupling.
  - Coupling to lepton flavour universal?
  - Higgs in Run-II New!



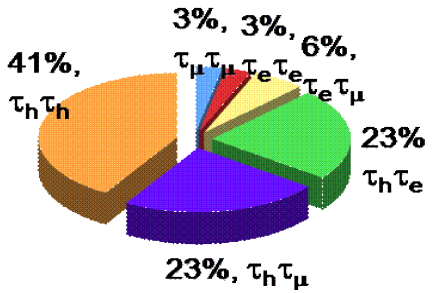
New! for 13 TeV results

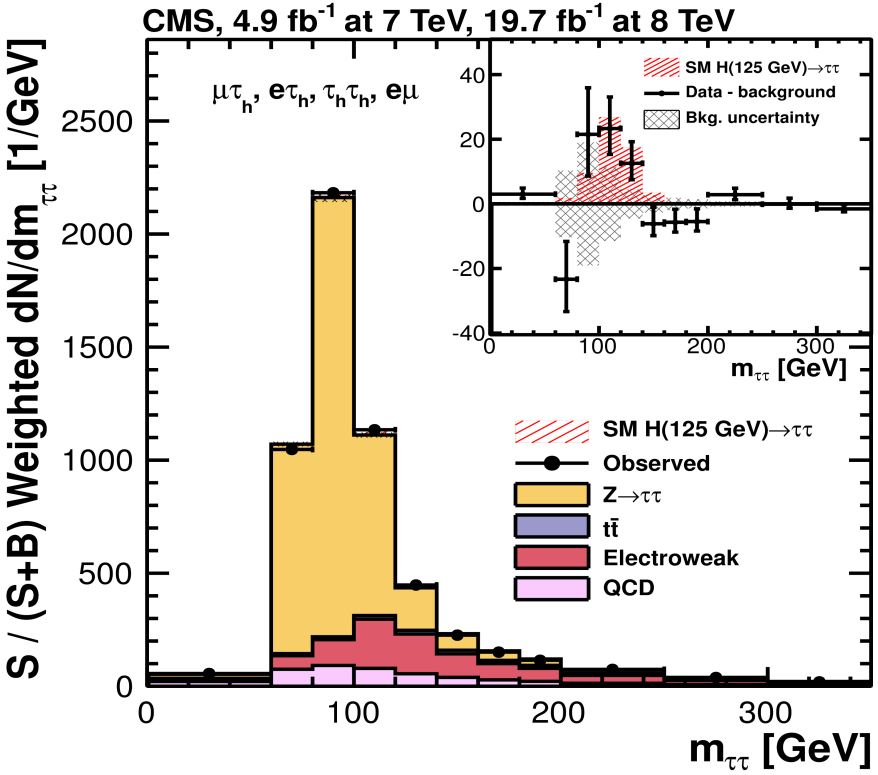
Does H(125) decay to leptons?

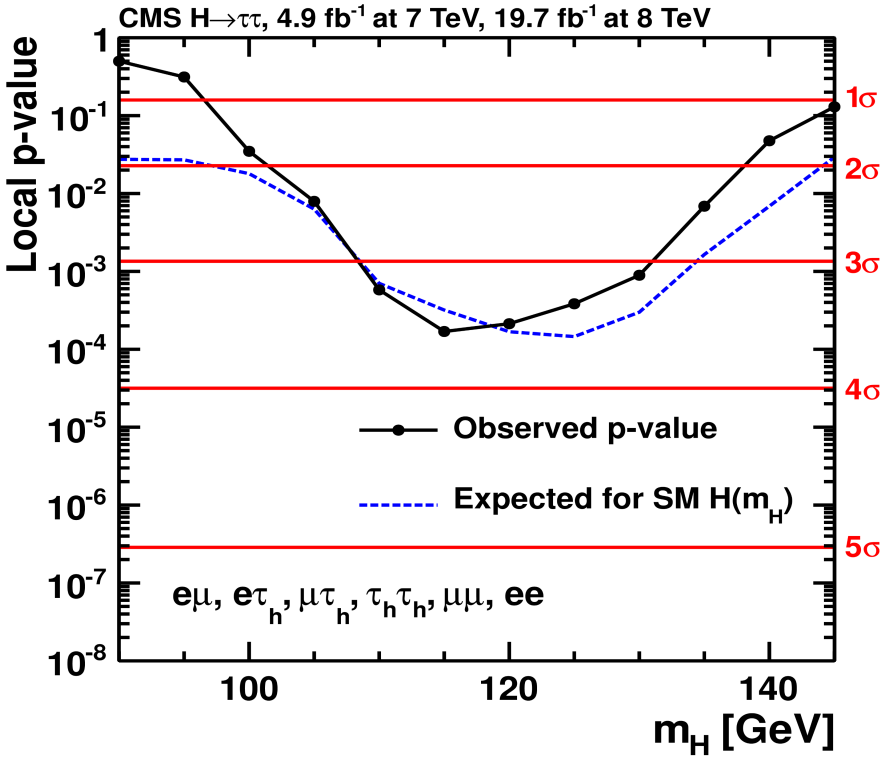
H→ττ (7+8 TeV)

JHEP 05(2014) 1-72

- Include all 6 di-tau decay channels
- Challenges:
  - Final state, poor mass resolution, missing transverse energy
- Event categorization:
  - 0-jet, 1-jet and VBF-tag (GGF & VBF)







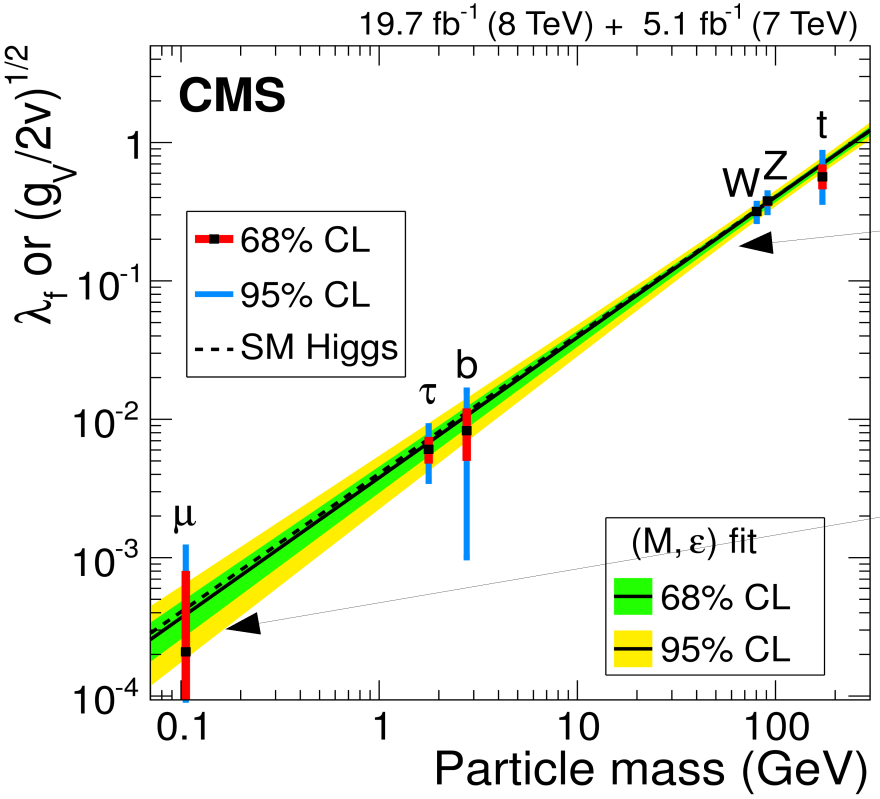
- 3.2σ evidence (3.7 expected) at H(125)

Measurement of lepton coupling

H→ττ (7+8 TeV)

JHEP 75(2015) 5, 1-50

- Constrains on lepton couplings
  - Fitted Yukawa coupling (proportional to lepton mass)



Linear dependence on mass parameter

- Large uncertainty
- Consistent with the fitted line

- The observed lepton coupling is consistent with SM expectation.

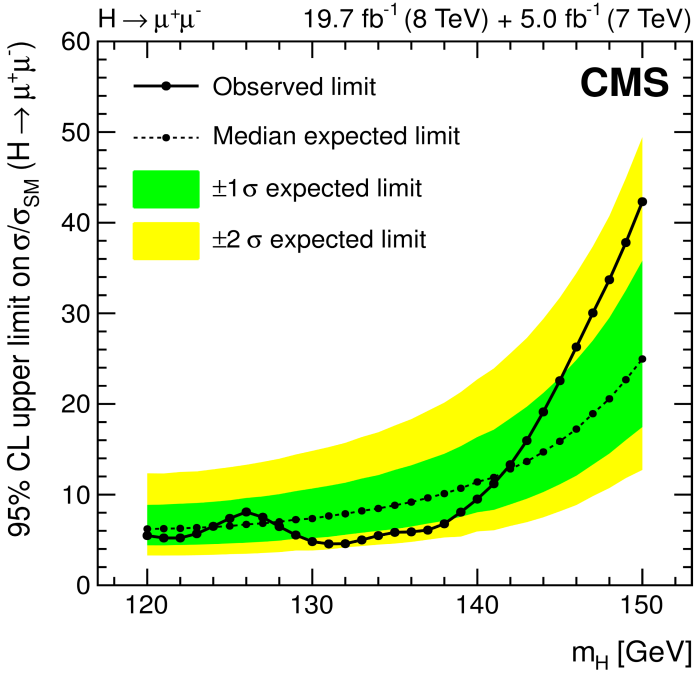
In this plot the H → μμ channel is also included and, even though it currently has a large uncertainty, it is consistent with the fitted

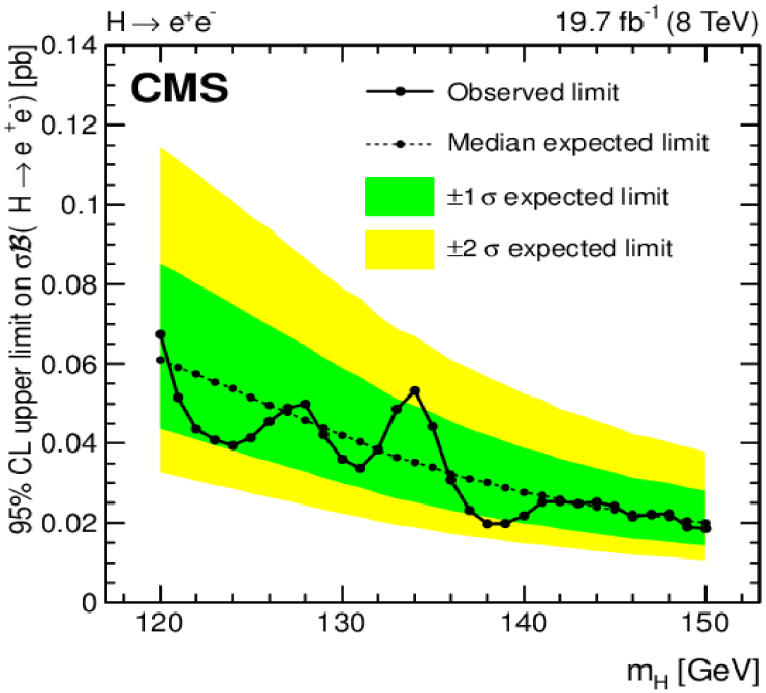
Coupling to leptons is flavour universal?

H→μμ (7 + 8 TeV) & H → ee (8 TeV)

Physics Letter B 744(2015), 184-207

- BR(H → μμ) = 2.2 x 10^{-4}
  - Observed (expected) 95% CL upper limit on the signal strength is 7.4 (6.5) for H(125)
- BR(H → ee) ~ 5 x 10^{-9}
  - SM Higgs boson decays at LHC are too rare to detect
  - For H(125), upper limit of 0.041 pb is set on B(H → ee) at 8 TeV.



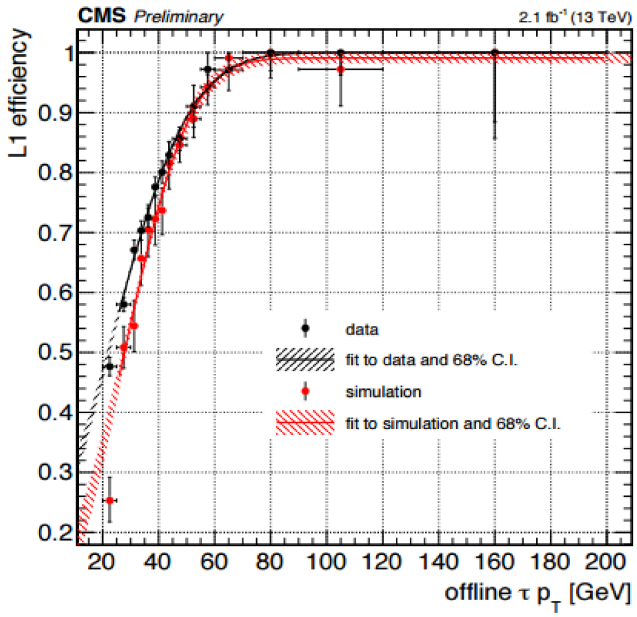


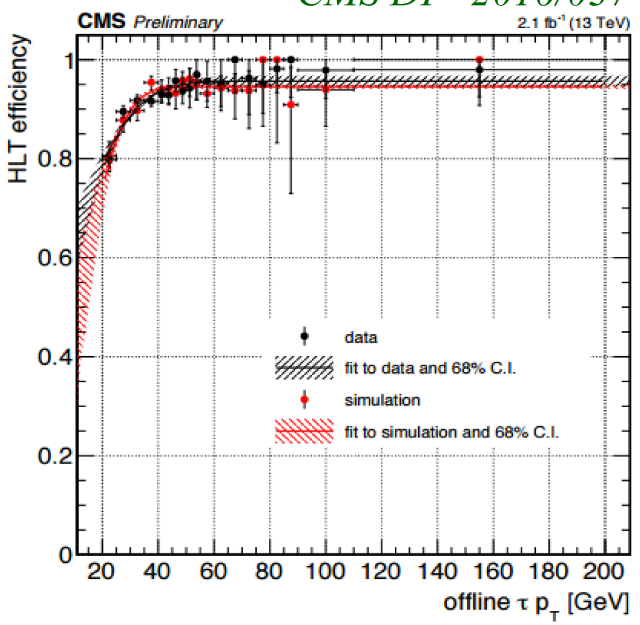
- As expected in SM, Higgs boson decay to leptons are not universal.

Towards Higgs to ττ measurements in Run-II

- Challenging trigger

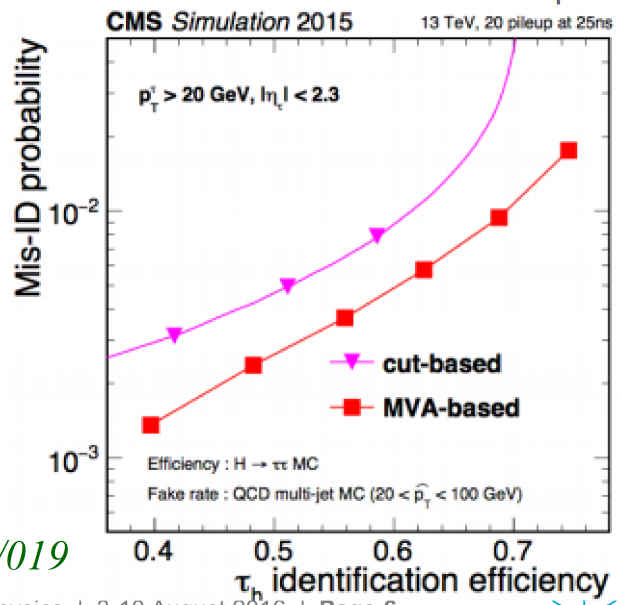
CMS DP -2016/037





- Improved MVA based discriminates
  - Combine isolation & lifetime information

- Improved tau reconstruction and identification new strip reconstruction algorithm
  - account for ECAL energy leakage of τ_h decay

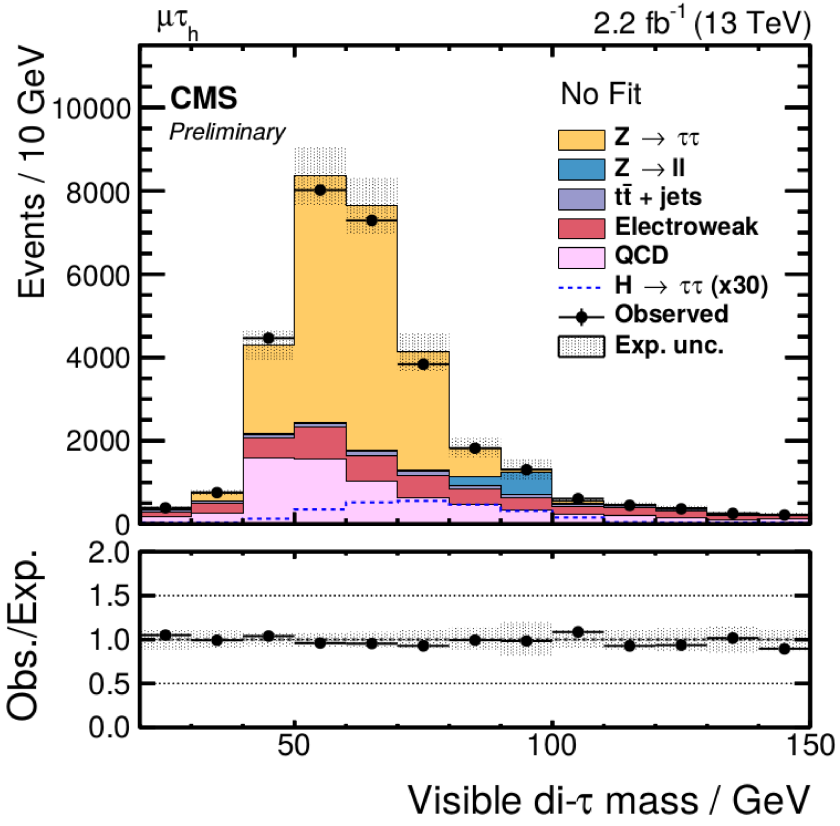


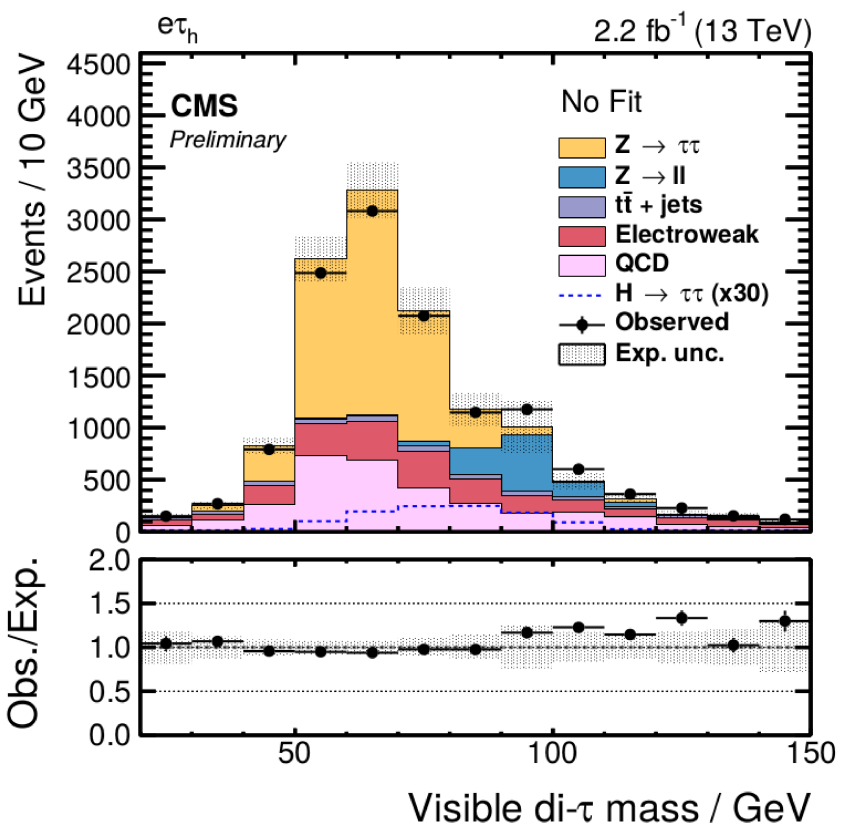
CMS DP -2016/019

Towards Higgs to ττ measurements in Run-II

CMS DP -2016/015

- Mass distribution with 13 TeV data





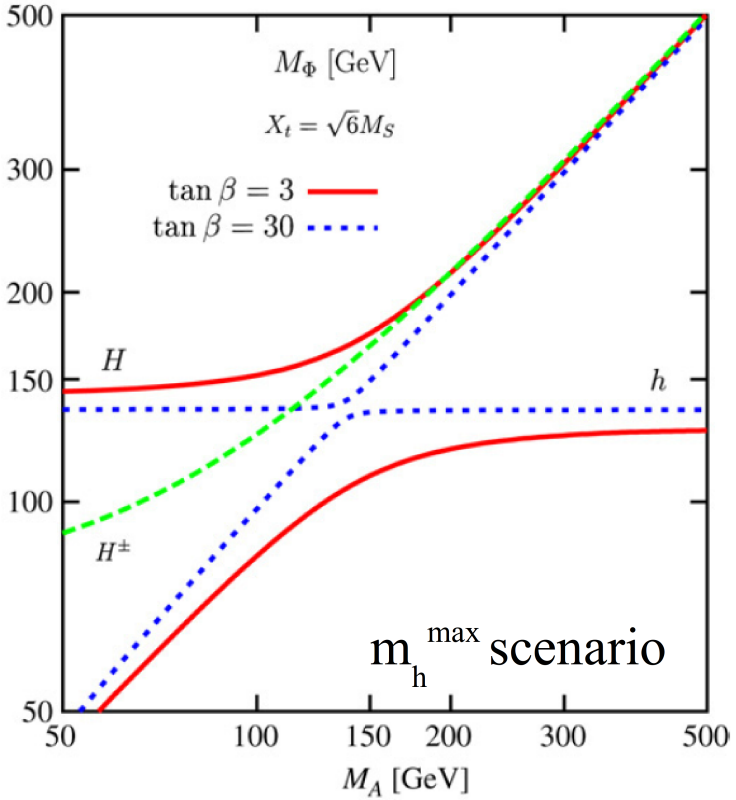
Higgs at 13 TeV

New!

MSSM H→ττ (13 TeV)

CMS HIG-16-006-PAS

- Use analysis as stepping stone to 2016 data
- Two Higgs doublet (5 Higgs boson)
  - 2 scalars : h, H
  - 1 pseudoscaler : A
  - 2 charged Higgs bosons : H^+ H^-
- Tree-level, Higgs masses defined by:
  - m_A - mass of psudoscalar A
  - tanβ - ratio of vacuum expectation values of Higgs doublet
- Radiative correction lead to Higgs mass > m_Z
  - large stop mass and large stop mixing required to reach m_h=125 GeV
- For large tanβ, coupling of MSSM heavy Higgs boson to down-type fermions is enhanced w.r.t SM
  - Increased branching fraction to τ lepton and b-quark



A. Djouadi, Physics Reports 459 (2008) 1

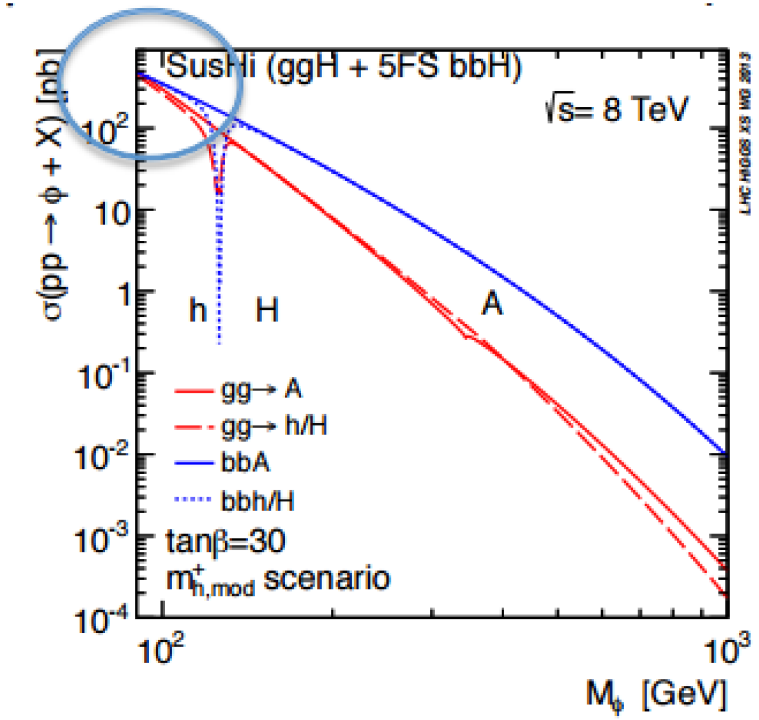
Higgs at 13 TeV

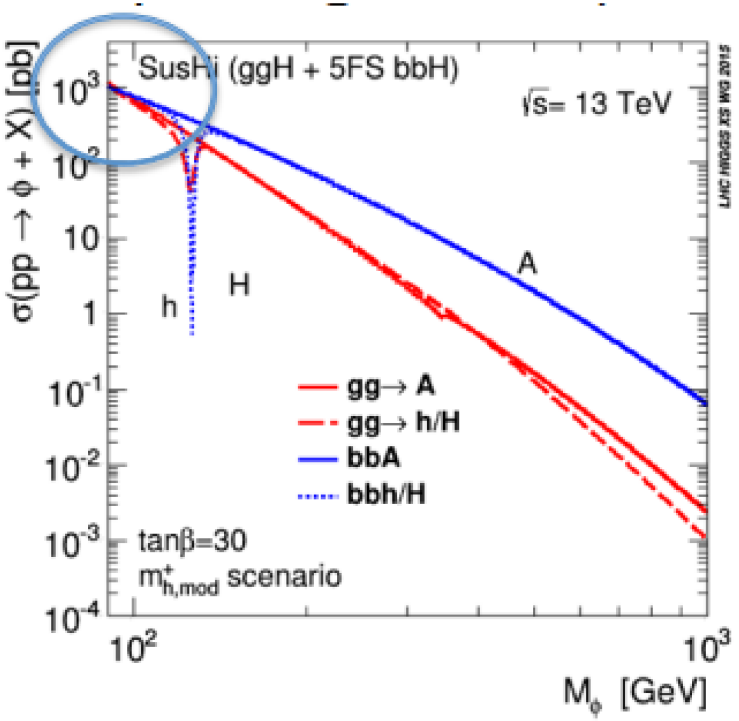
New!

MSSM H→ττ (13 TeV)

XSWG

- Increase in center of mass energy gives enhancement in heavy φ production cross section (factor 2-6, depending on the mass)
  - Factor of 2-3 increase in production cross section of backgrounds





Higgs at 13 TeV

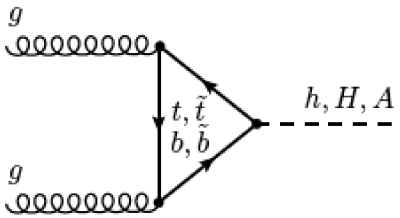
New!

CMS HIG-16-006-PAS

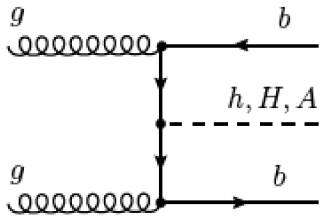
- Analysis strategy:
  - Use final state channels: $\mu\tau_h$, $e\tau_h$, $\tau_h\tau_h$ and $e\mu$
  - Stay close to 8 TeV MSSM analysis
  - Re-optimize physics objects, selections & analysis tools
  - Event categorization (split events into 2 b-jets):
    - b-tagged: >=1 b-tagged-jet, <=1 jet with p_T > 30 GeV
    - No b-tag: 0 b-tagged-jet

- Dominant h/H/A (φ) production:

$gg \rightarrow \varphi$ (gluon fusion)



$gg \rightarrow bb\varphi$ (b-associated)



Higgs at 13 TeV

New!

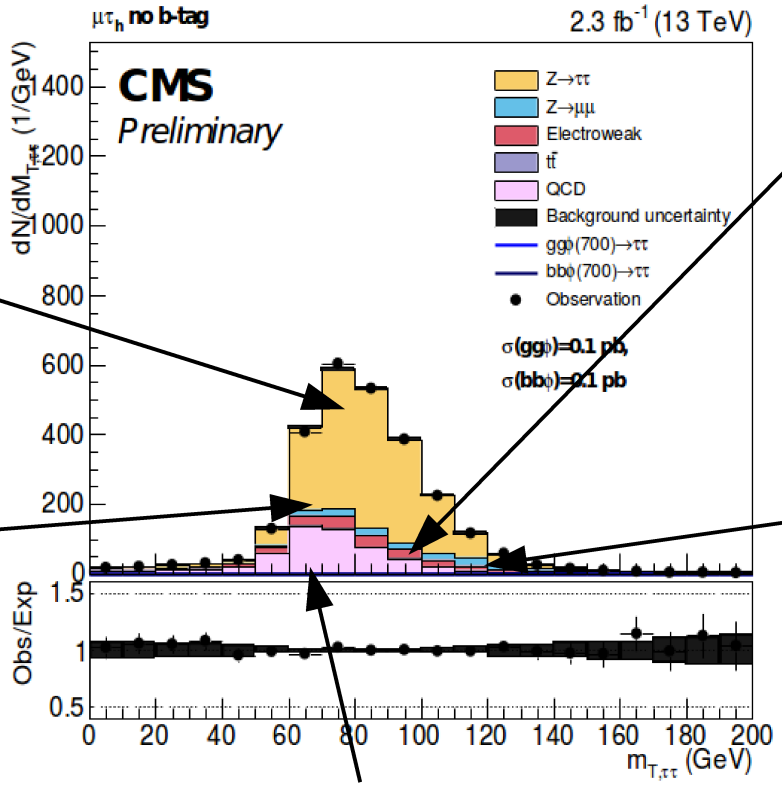
Analysis Background Methods

CMS HIG-16-006-PAS

- Utilize both MC based background and data driven backgrounds

$Z \rightarrow \tau\tau$:
- MC based, data driven corrections applied

$Z \rightarrow ll$:
- MC based



W+jets:
- $\mu\tau_h$ & $e\tau_h$ uses data driven scale factor
- $\tau_h\tau_h$ & $e\mu$: MC based

ttbar:
- MC based, validated in data control region

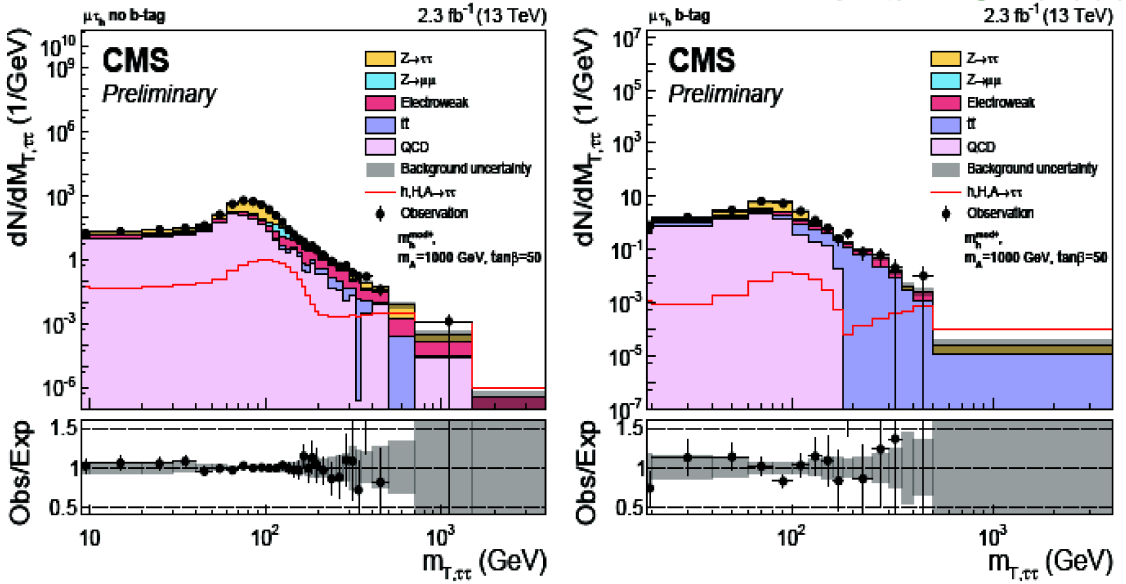
QCD: fully data driven estimation
- τ_h, $e\mu$ & $e\tau_h$ - shape from SS with OS/SS scale factor
- $\tau_h\tau_h$ - shape from relaxed loose isolation OS

Higgs at 13 TeV

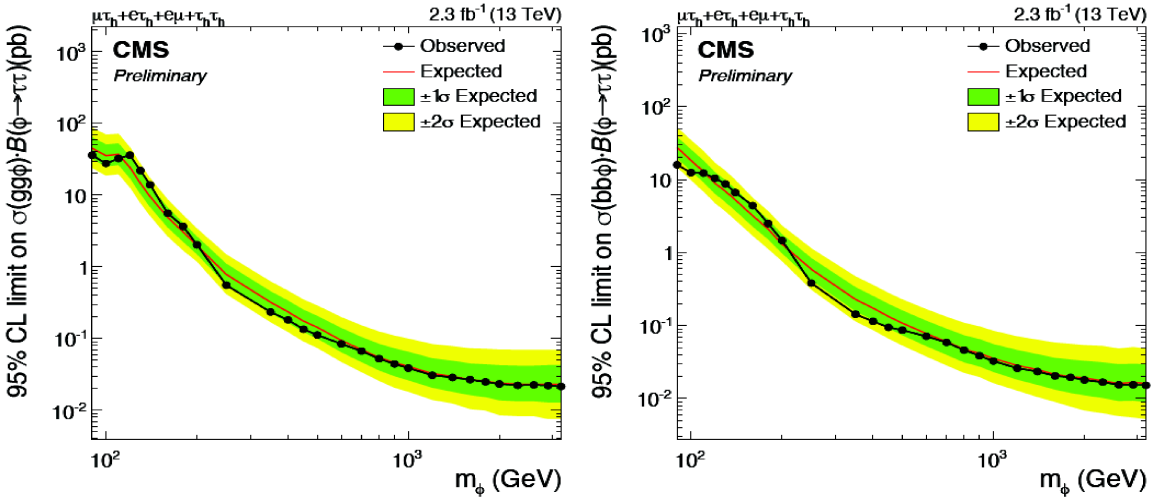
New!

CMS HIG-16-006-PAS

- Mass distribution



- 2 types of Limits
  - Cross section x BX
  - Limit in MSSM parameter space



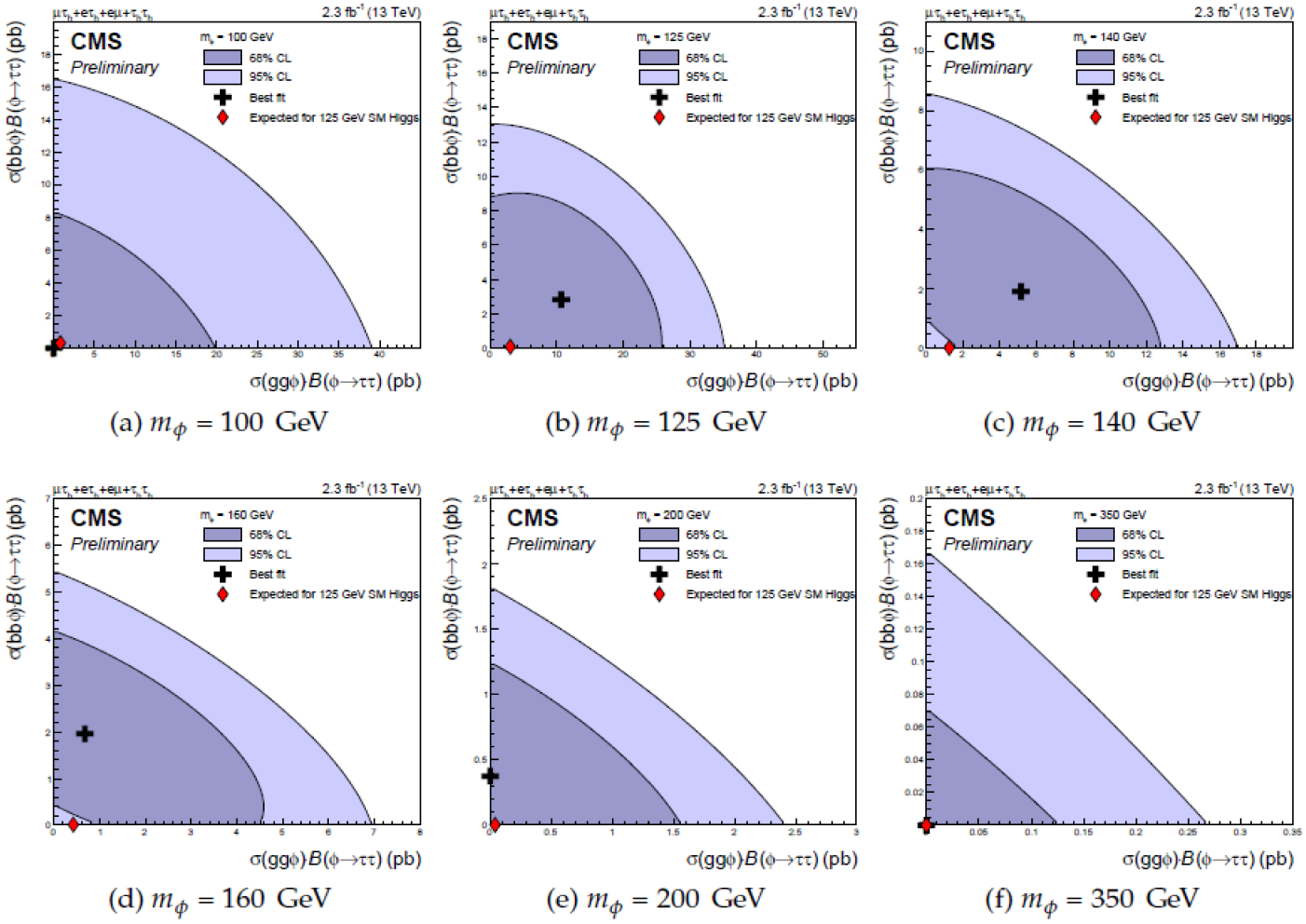
Limit on Cross Section x BX

Higgs at 13 TeV

New!

CMS HIG-16-006-PAS

- 2D Limit on cross-section x BX (ggφ and bbφ)
  - Fits are performed without taking SM(125) Higgs in background.
  - ★ indicate the expected resulting fit with inclusion of a SM(125) Higgs



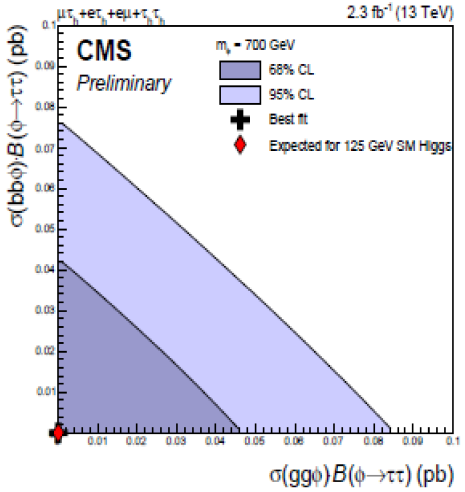
(a) $m_\phi = 100$ GeV (b) $m_\phi = 125$ GeV (c) $m_\phi = 140$ GeV

(d) $m_\phi = 160$ GeV (e) $m_\phi = 200$ GeV (f) $m_\phi = 350$ GeV

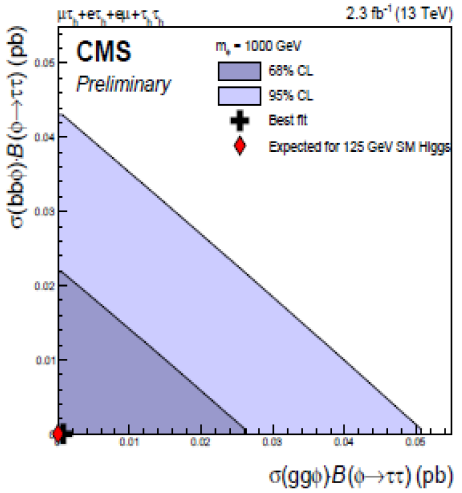
Higgs at 13 TeV

New!

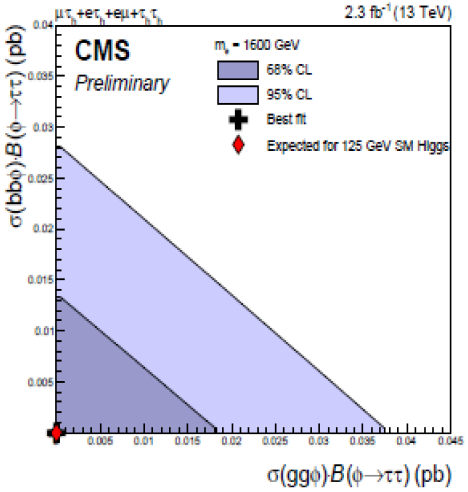
CMS HIG-16-006-PAS



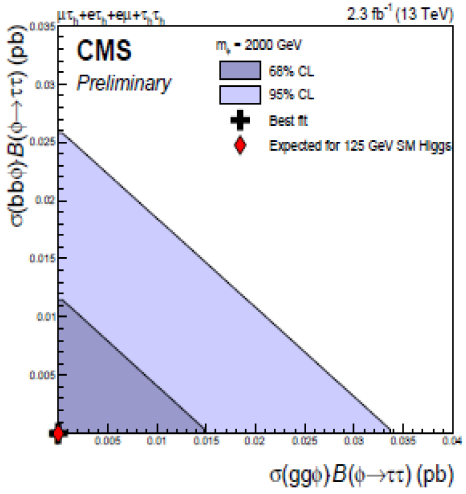
(g) $m_\phi = 700$ GeV



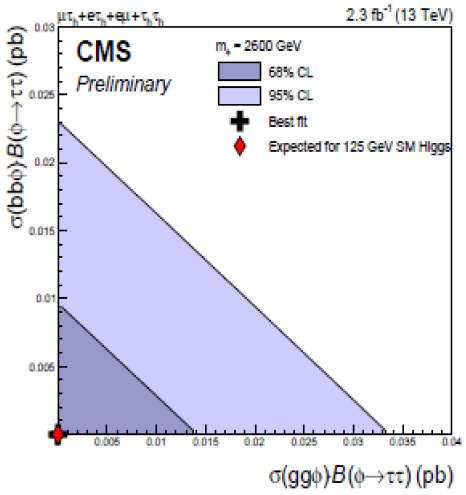
(h) $m_\phi = 1000$ GeV



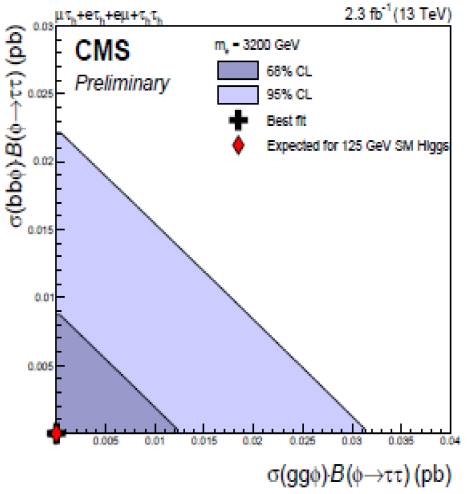
(i) $m_\phi = 1600$ GeV



(j) $m_\phi = 2000$ GeV



(k) $m_\phi = 2600$ GeV



(l) $m_\phi = 3200$ GeV

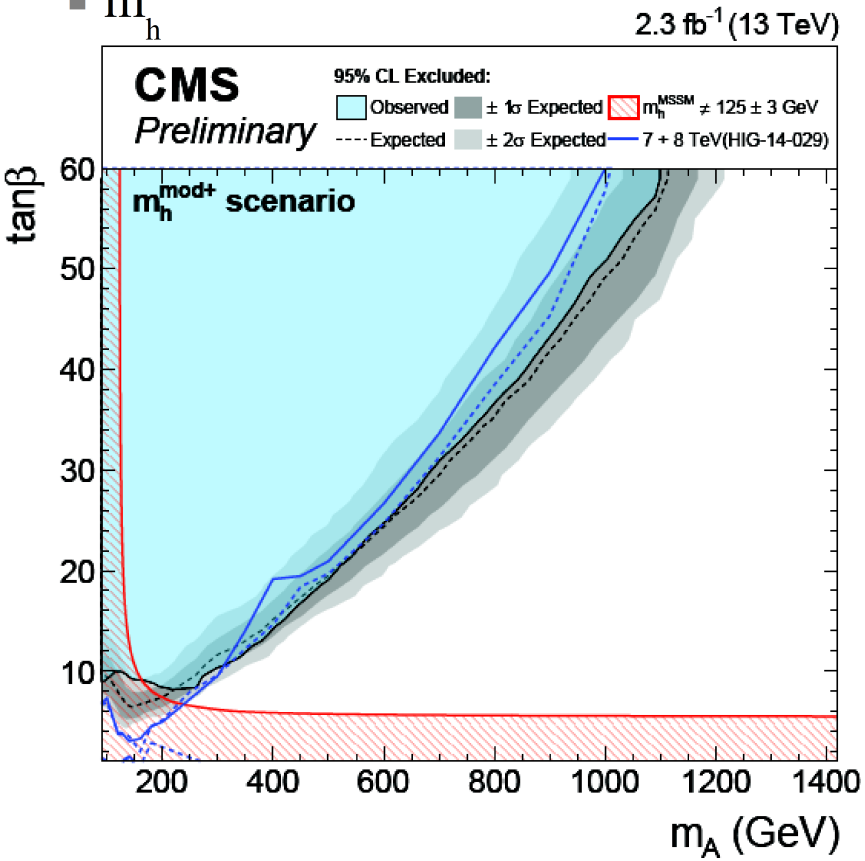
Higgs at 13 TeV

New!

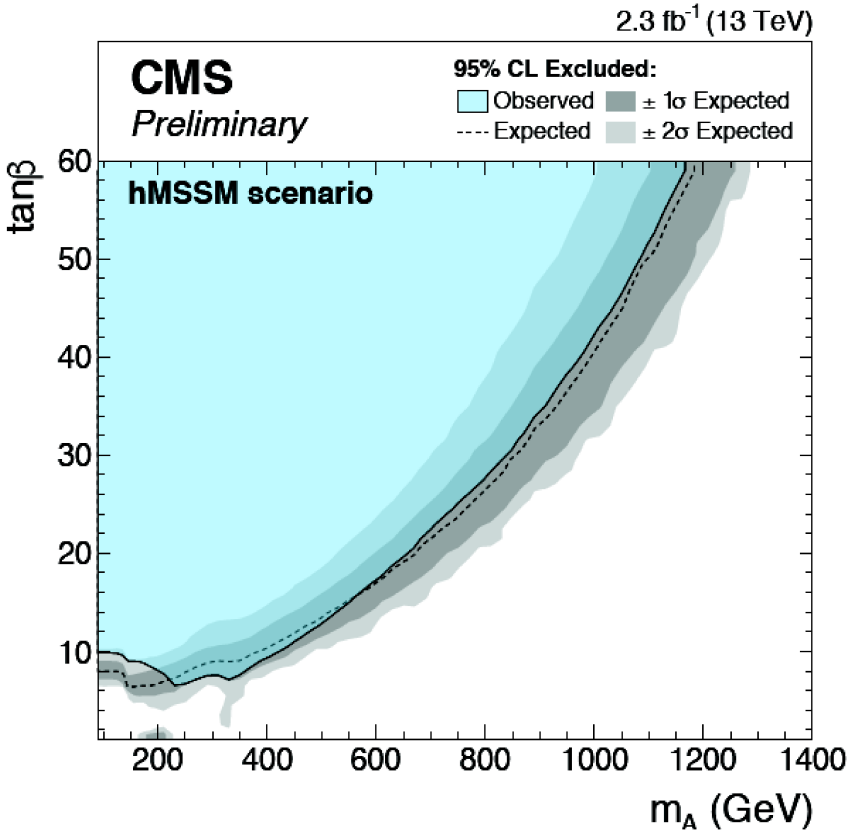
Limit in MSSSM Parameter space

CMS HIG-16-006-PAS

- m_h^{mod+}



- hMSSM

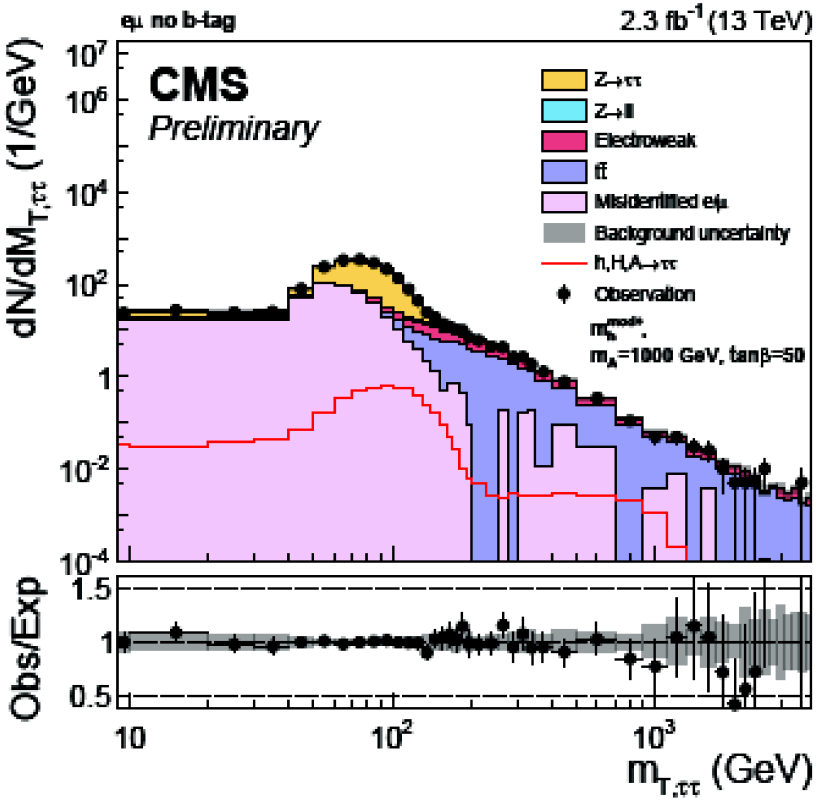


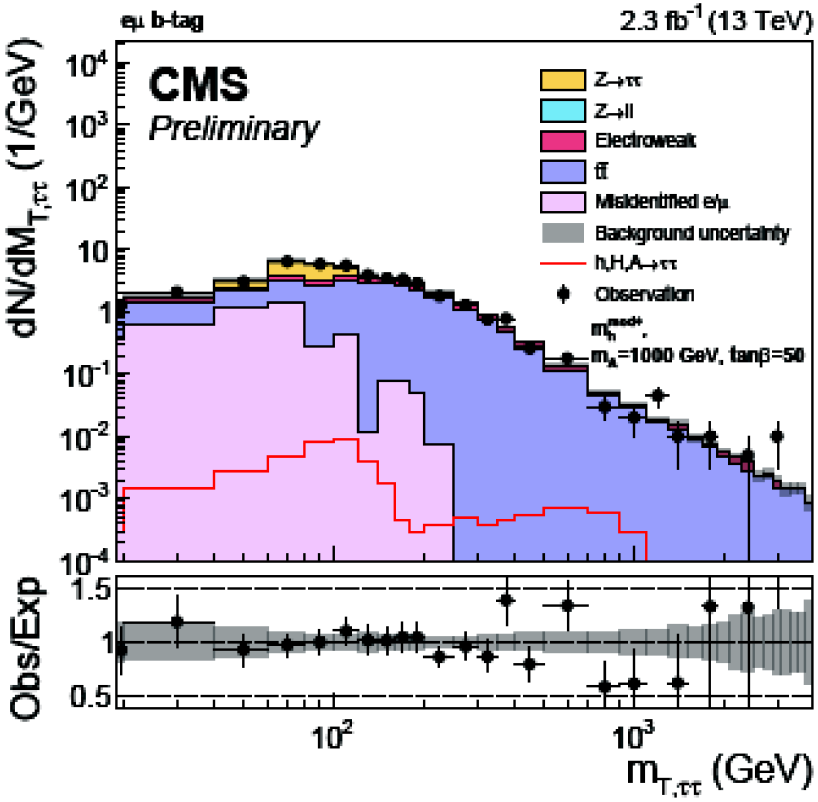
- Red exclusion at low tanβ, low mass attributed to existence of SM-125 Higgs
- Run-I results at 7 & 8 TeV are plotted as Blue lines
- Starting from m_A=300, the 13 TeV limits are stronger than 8 TeV limits

Summary..

- CMS Higgs physics program for Run-2 is progressing well.
- Analysis methods has been improved compared to Run-I.
- CMS physicist analyzing new data..

Backup


eμ no b-tag
2.3 fb-1 (13 TeV)
CMS
Preliminary
Zττ
Zll
Electroweak
tt
Misidentified e/μ
Background uncertainty
h,H,Aττ
Observation
mh^mod+,
mA=1000 GeV, tanβ=50
dN/dmT,ττ (1/GeV)
Obs/Exp
mT,ττ (GeV)


eμ b-tag
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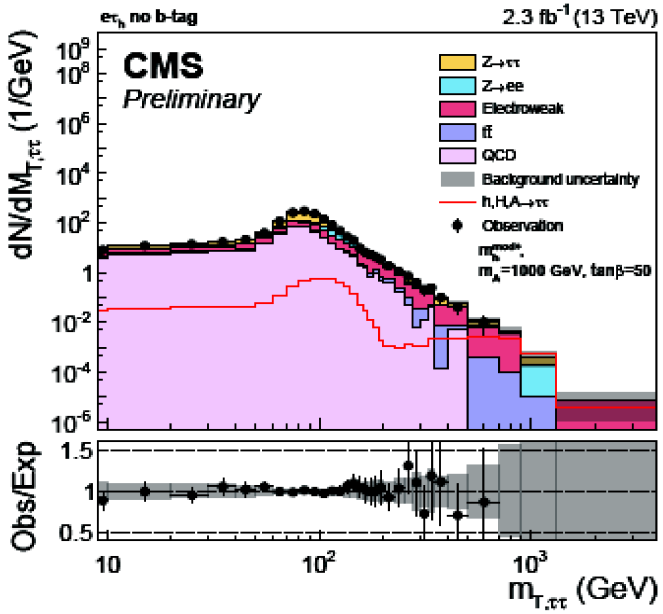
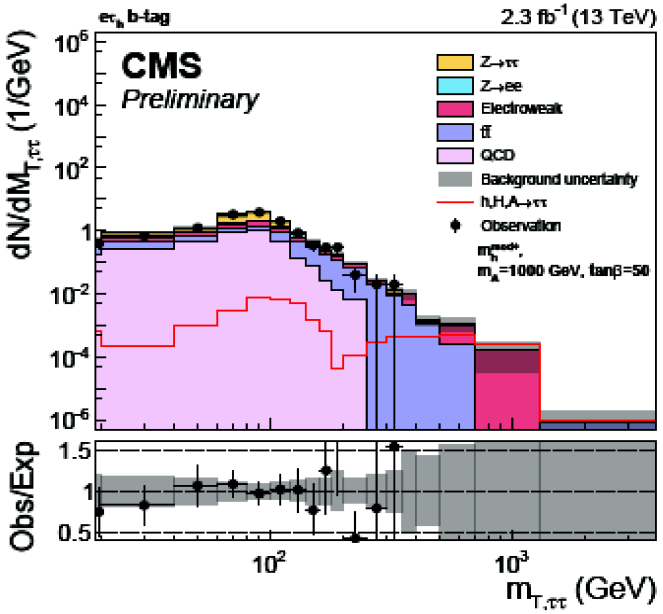

eτh no b-tag
2.3 fb-1 (13 TeV)
CMS
Preliminary
Z→ττ
Z→ee
Electroweak
tt
QCD
Background uncertainty
h,H,A→ττ
Observation
mmod+h
mA=1000 GeV, tanβ=50
dN/dMT,ττ (1/GeV)
Obs/Exp
mT,ττ (GeV)


eτh b-tag
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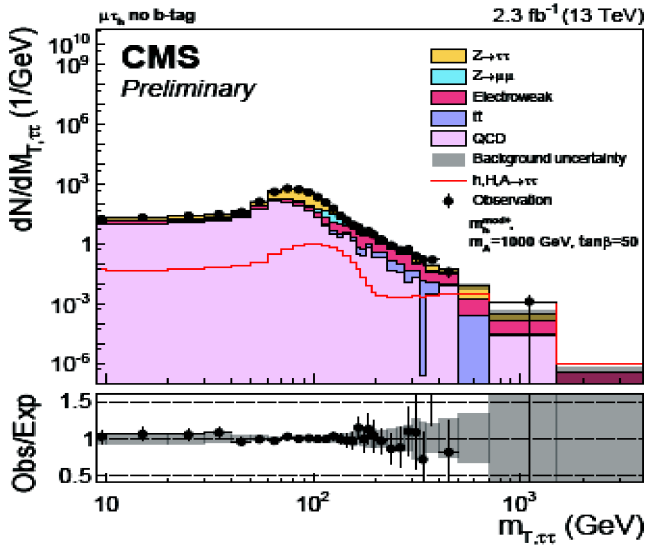
μτh no b-tag
2.3 fb-1 (13 TeV)
CMS
Preliminary
Z→ττ
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dN/dMT,ττ (1/GeV)
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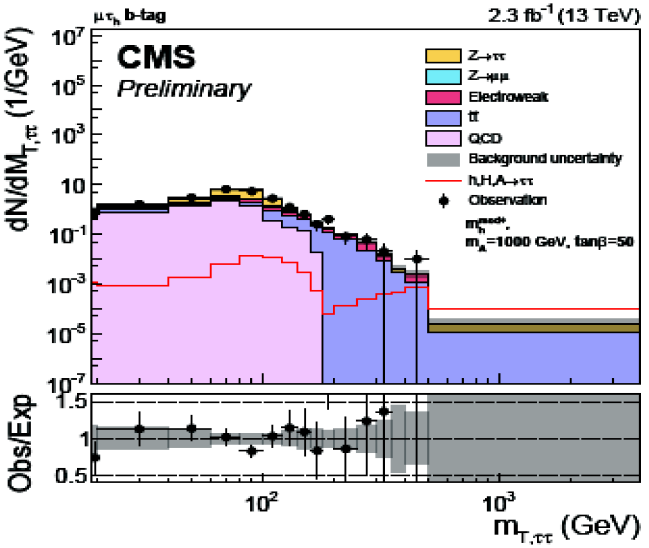
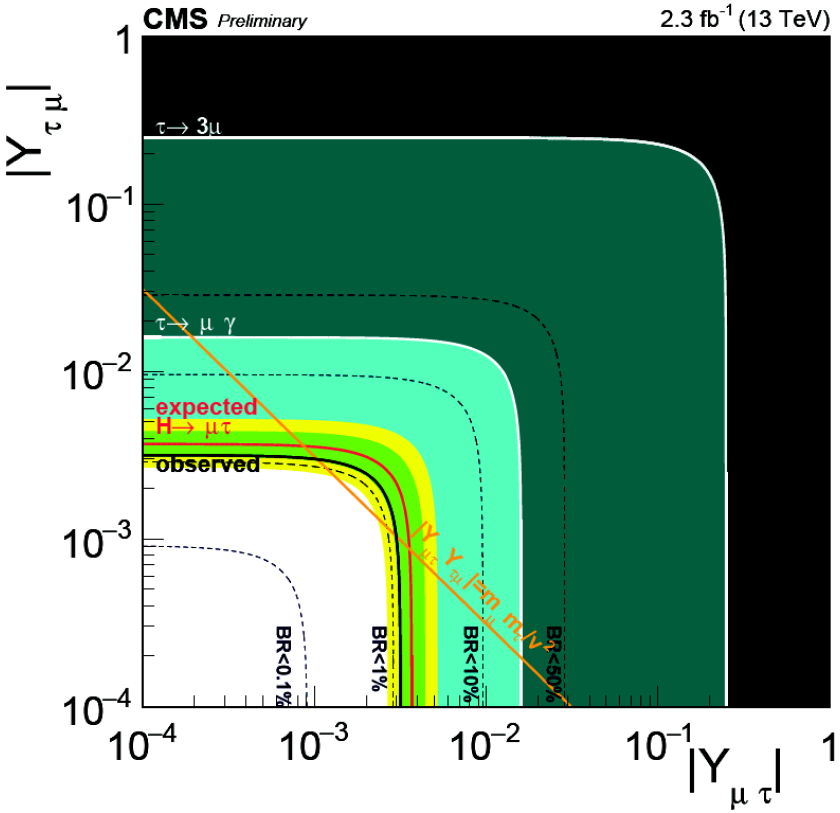

μτh b-tag
2.3 fb-1 (13 TeV)
CMS
Preliminary
Z→ττ
Z→μμ
Electroweak
tt
QCD
Background uncertainty
h,H,A→ττ
Observation
mmod+h
mA=1000 GeV, tanβ=50
dN/dMT,ττ (1/GeV)
Obs/Exp
mT,ττ (GeV)

Lepton Flavour Violation

New!

- Limits on Yukawa couplings
  - Translate branching ratio limits to limits on Yukawa couplings
  - Best limit from $\tau \rightarrow \mu\gamma$: $\sqrt{|Y_{\mu\tau}|^2 + |Y_{\tau\mu}|^2} < 3.16 \times 10^{-3}$



CMS PAS HIG-16-005