Search for lepton flavour violation decays of the Higgs boson with CMS

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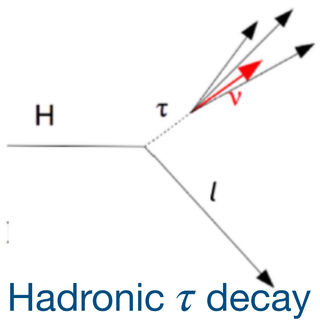
Search for Standard Model Higgs LFV decays

Lepton Flavour Violation (LFV)

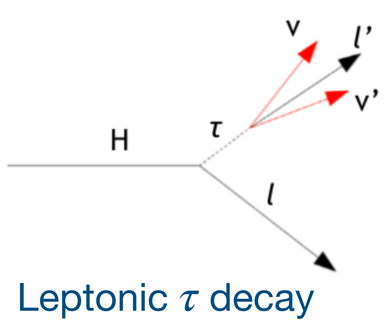
- Standard Model does not allow LFV interactions
- However, many beyond the standard model theories like, two Higgs Doublet model (2HDM) and Randal-Sundrum model allow for LFV Higgs decays

Analysis Overview

- The analysis is divided into four channels depending on the final states, $H \to e\tau_h$, $H \to e\tau_\mu$, $H \to \mu\tau_h$, and, $H \to \mu\tau_e$ in 4 categories based on the jet kinematics

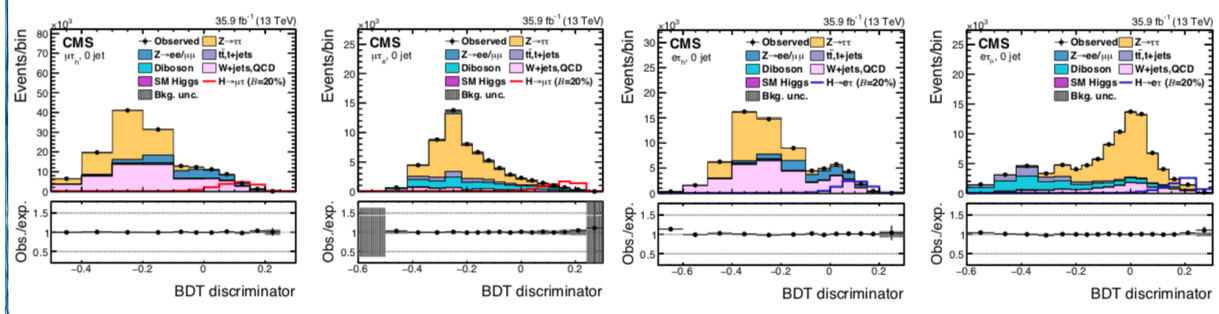


Hadronic τ decay



Leptonic τ decay

- In $e\tau_h$ and $\mu\tau_h$, the Boosted Decision Tree (BDT) is trained with a mixture of $gg \to H$ and $qq \to H$ signal events, against events with misidentified leptons
- In $e\tau_\mu$ and $\mu\tau_e$, the BDT is trained with a mixture of $gg \to H$ and $qq \to H$ signal events, against ttbar events ($e\tau_\mu$), or a mixture of ttbar and $Z \to \tau\tau$ events ($\mu\tau_e$)



- Fit of BDT output distributions is performed in order to calculate the limits from the analysis
- Cross-checked with a fit to the Collinear Mass distribution

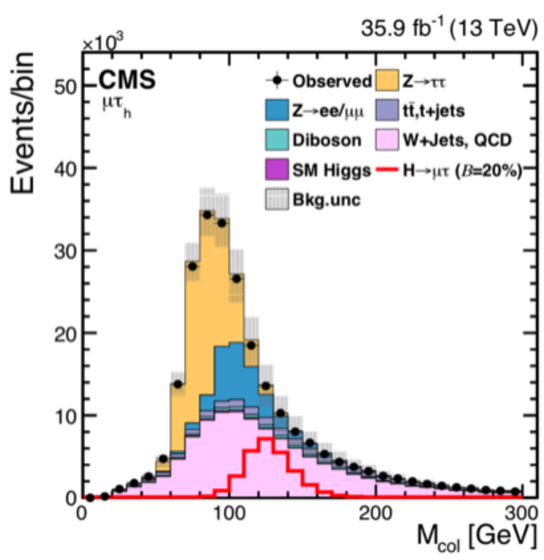
Background Processes

- $H \to \mu\tau$ and $H \to e\tau$ share similar background processes, the demonstration below is in $\mu\tau_h$ channel as an example
- In leptonic channels, an extra $W\gamma$ process is considered

$Z \to \tau\tau$
From MC Simulation

$Z \to \mu\mu/ee$
From MC Simulation

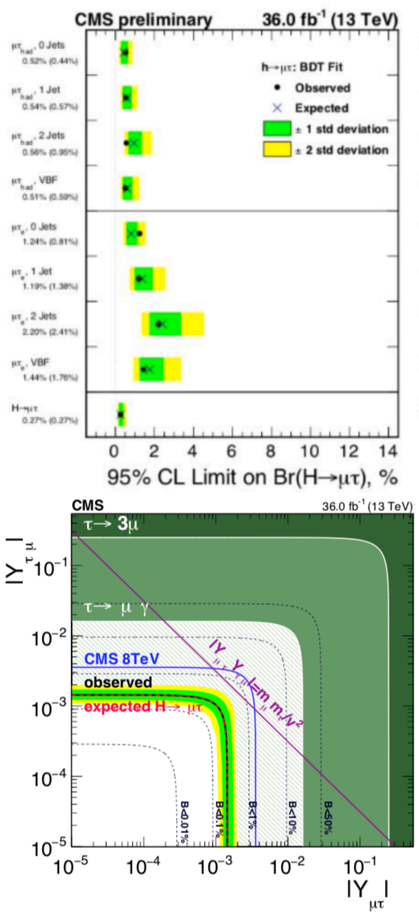
Misidentified lepton background
(Fully or Semi-data driven method)

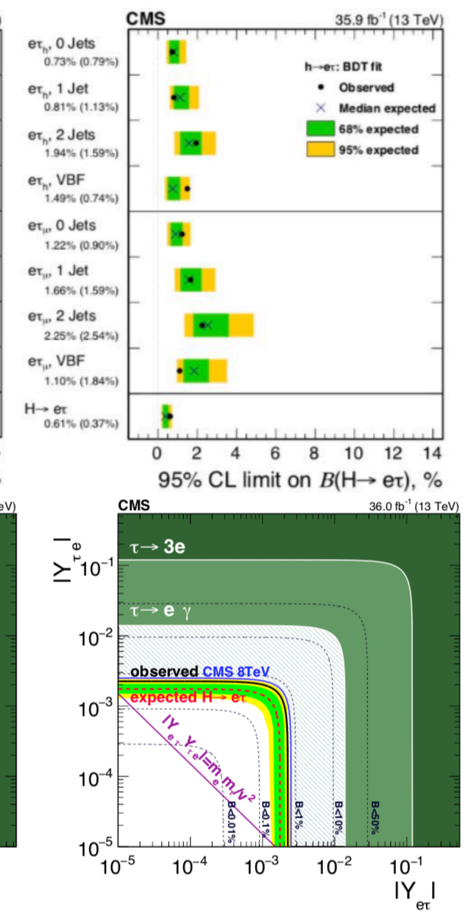


SM Higgs
From MC Simulation

TTbar/Single Top
From MC Simulation

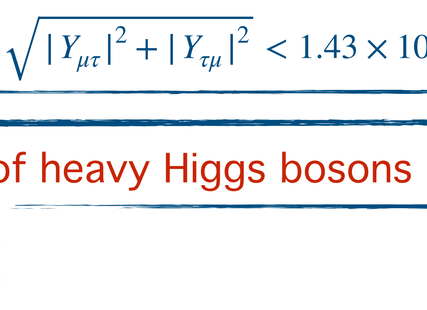
Diboson
From MC Simulation

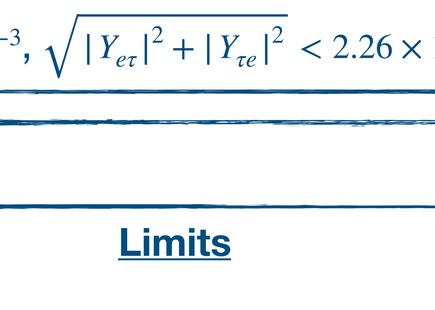




Limits

Observed limits
$B(H \to \mu\tau) < 0.25\,\%$
$B(H \to e\tau) < 0.61\,\%$
Expected limits
$B(H \to \mu\tau) < 0.25\,\%$
$B(H \to e\tau) < 0.37\,\%$





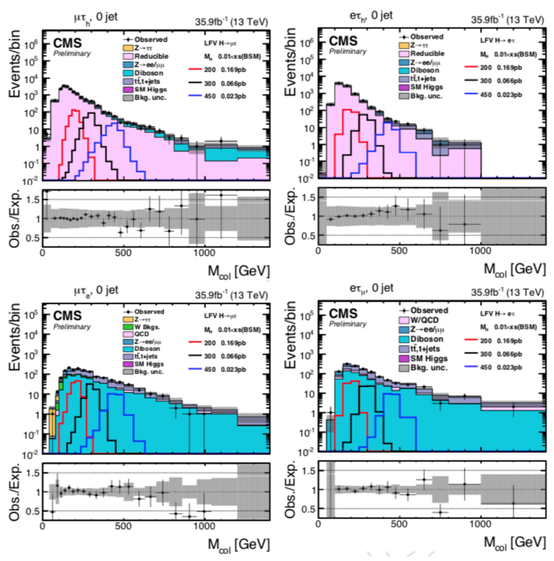
$\sqrt{|Y_{\mu\tau}|^2 + |Y_{\tau\mu}|^2} < 1.43 \times 10^{-3}$, $\sqrt{|Y_{e\tau}|^2 + |Y_{\tau e}|^2} < 2.26 \times 10^{-3}$

Search for LFV decays of heavy Higgs bosons

Introduction

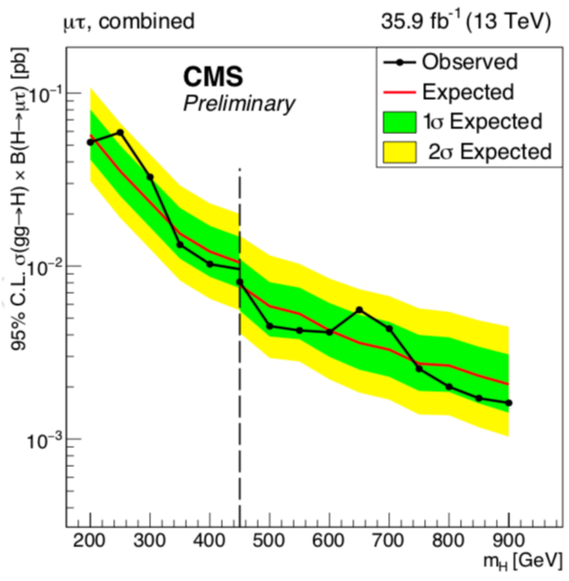
- 2HDM foresees additional bosons and Type-III 2HDM allows for LFV decays
- Only GGF production mode is targeted with 0 and 1 Jet categories in each channel
- The masses that are probed are 200, 300, 450, 600, 750, and, 900 GeV
- τ coming from Higgs decay is Lorentz boosted $P_T^\nu = E_T^{miss} . \hat{P}_T^{\tau_{vis}}$,

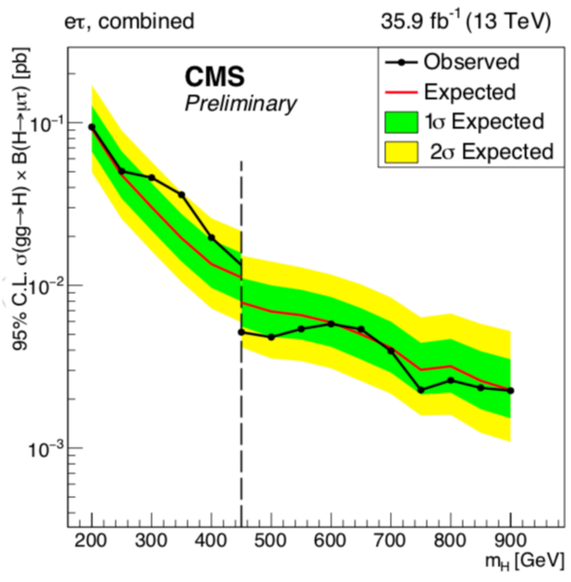
$$X_{\tau_{vis}} = \frac{P_T^{\tau_{vis}}}{P_T^{\tau_{vis}} + P_T^\nu},\ M_H = \frac{M_{vis}}{\sqrt{X_{\tau_{vis}}}}$$



- Fit of the Collinear Mass distributions is performed to calculate the limits

Limits





Observed(Expected) limits on the cross section times the branching fraction of a BSM Higgs boson

$\sigma(gg \to H) \times B(H \to \mu\tau)$: 0.0516 (0.0570) *to* 0.0017 (0.0021) *pb*

$\sigma(gg \to H) \times B(H \to e\tau)$: 0.0970 (0.0880) *to* 0.0023 (0.0016) *pb*

References

- CMS Collaboration, "Search for lepton flavour violating decays of the Higgs boson to μτ and eτ in proton-proton collisions at $\sqrt{s} = 13TeV$ doi:10.1007/JHEP06(2018)001, arXiv:1712.07173
- Search for lepton flavour violating decays of neutral heavy Higgs boson to μτ and eτ in proton-proton collisions at $\sqrt{s} = 13TeV$, CMS-PAS-HIG-18-017