Searches for exotic H(125) Boson decays

with CMS in Run II

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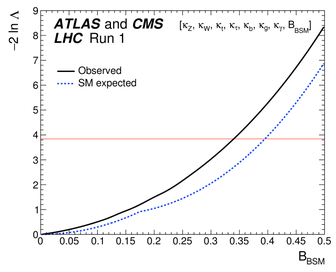
Exotic Higgs Decays

New physics hiding around the corner?

- Exotic decays of the Higgs are a fertile ground to look for physics Beyond the Standard Model (BSM)
- From CMS+ATLAS combined analysis of Higgs couplings there is still plenty of room available for searches targeting exotic decays
- Such decays are a portal that could provide direct evidence into BSM Higgs sector

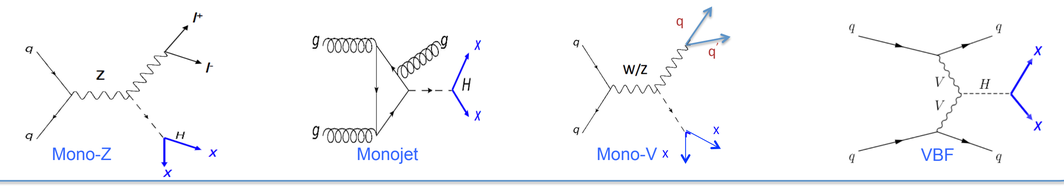


CMS has been working actively on broadening coverage of these searches in RUN II

H(125)→Invisible Decays

Signature: Large MET recoiling against visible particles

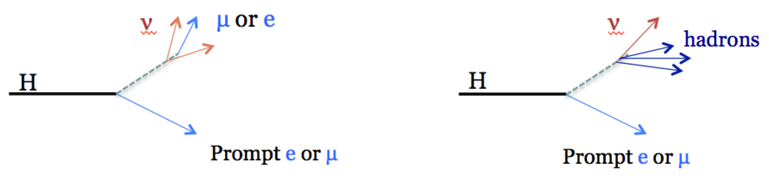
- Several BSM models allow such exotic decays of the Higgs including SUSY models with Higgs decaying to a pair of LSP and large extra dimensional models with mixing of graviscalars with the Higgs boson.
- Several searches target different Higgs production modes: mono-Z, mono-V, monojet and VBF channels



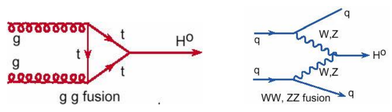
LFV H(125) Decays

Higgs decays to charged leptons of different flavor

- Allowed in several BSM theories such as Higgs Doublet and Randal-Sundrum models
- Search in four channels:



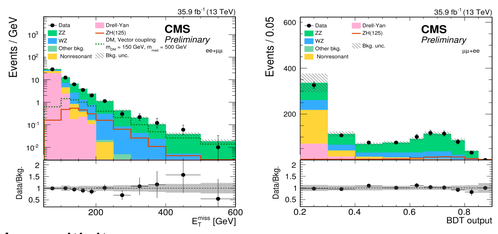
- Four categories per channel for signal extraction targeting different production modes:
  - 0-jet: targets ggH events
  - 1-jet: targets ggH events produced in association with a jet
  - 2-jet, m_{jj}<550(500) GeV: targets ggH events with additional jets
  - 2-jet, m_{jj}>550(500) GeV: targets VBF events



Z→*ee/μμ* + MET

2 opposite sign same flavor leptons recoil against MET

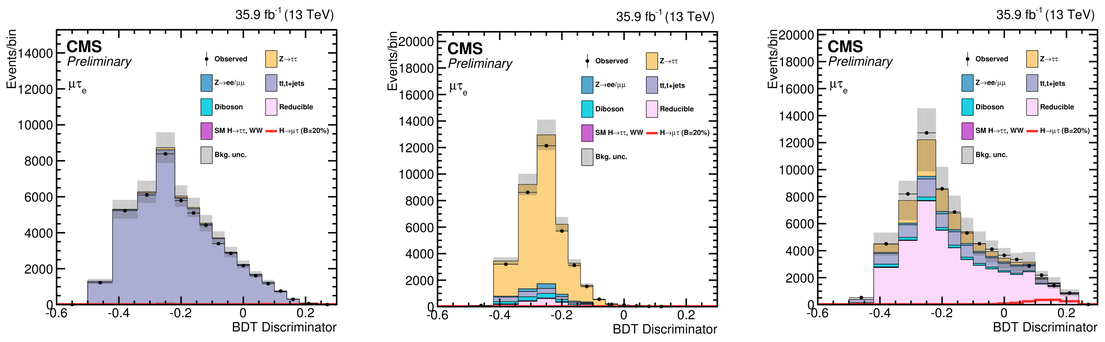
- Main backgrounds are ZZ (2ℓ2ν) and WZ (3ℓν) with 60% and 25 % events respectively. Data driven estimation using lepton control regions. Smaller backgrounds include WW , Drell-Yan, triboson.
- Select di-lepton mass within tight Z mass window.
- Cuts to reject backgrounds using variables such as: MET; dilepton p; Δϕ, ΔR between various objects
- Binned Maxlikelihood Fit to MET shape to extract result



- BDT based analysis brings 10% additional sensitivity

LFV Background Estimation

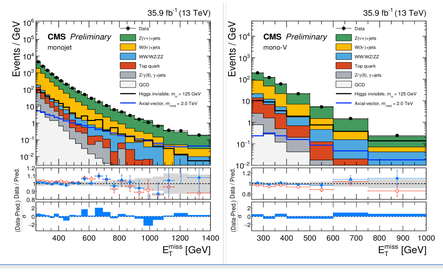
- Z→ττ+jets, Jet→e/μ/τ_h (fake background composed mostly of W+jets) and tt +jets are main backgrounds.
- Jet→e/μ/τ_h background in hadronic channels and QCD multijet background in fully leptonic channels are estimated using data-driven techniques. All other backgrounds are estimated from MC simulation.
- Descriptions checked in several control regions enriched in these backgrounds.



Monojet & V(jj)

ggH with ISR and VH with hadronic decays

- Main backgrounds are Z(2ν)+jets and W(ℓν)+jets. Smaller backgrounds include Diboson, Drell-Yan, QCD.

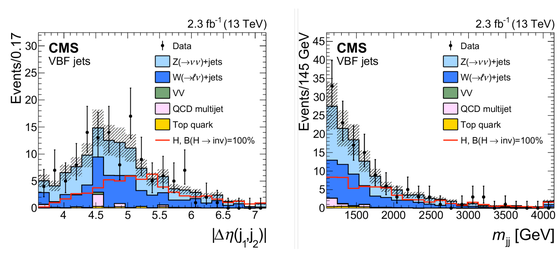


- One or more jets in event with large (MET>250 GeV). Events with high p_T fat jets go to Mono V category, others go to monojet.
- Simultaneous fit of MET distributions in signal and control regions

VBF H(125)→ invisible

Two jets with VBF topology and Large MET

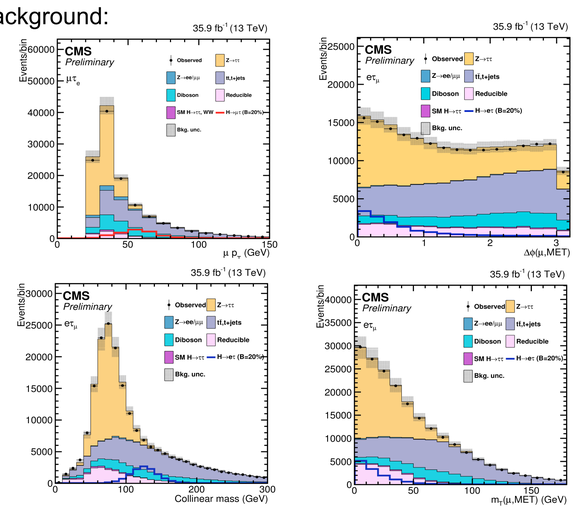
- Dedicated trigger used to select such events. Offline selection driven by requirement to remain efficient wrt trigger .
- Data-driven estimation of major backgrounds using control regions with one or more leptons.
- Jets required to recoil against MET to reduce QCD background. Other cuts based on jet p_T, dijet mass and MET.



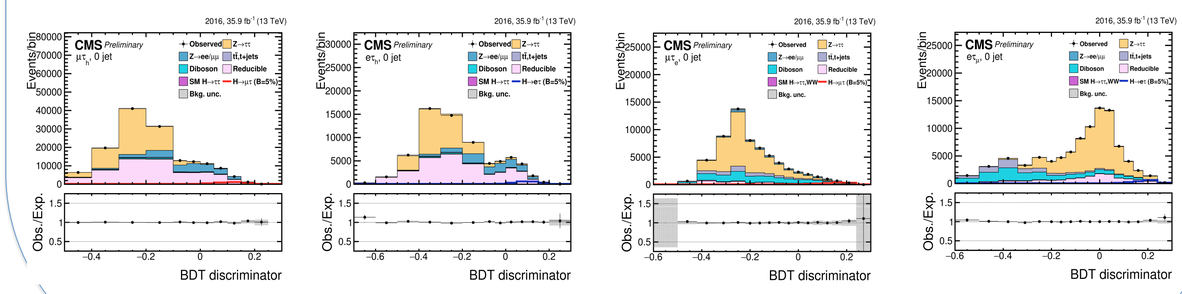
Selection & Signal extraction

Signature: opposite sign isolated leptons of different flavor

- Events selected using a combination of lepton triggers
- Following variables help in separation signal from background:
  - **Δϕ** : For signal, MET is closely aligned with visible τ decay products ; μ/e and τ are separated
  - **Transverse Mass**: Invariant mass formed using transverse components of one lepton and missing energy.
  - **μ, e, τ_{had} p_T** : Leptons from signal process are expected to be generally higher $\mathbf{p_T}$ than many backgrounds
  - Collinear Mass of the Higgs: calculated under the approximation that neutrino is collinear to the direction of the visible decay products of the highly boosted tau



- Boosted decision trees using the above variable as input are trained for each channel with signal against a combination of backgrounds. A maximum likelihood fit to BDT output shape is used to extract limits.

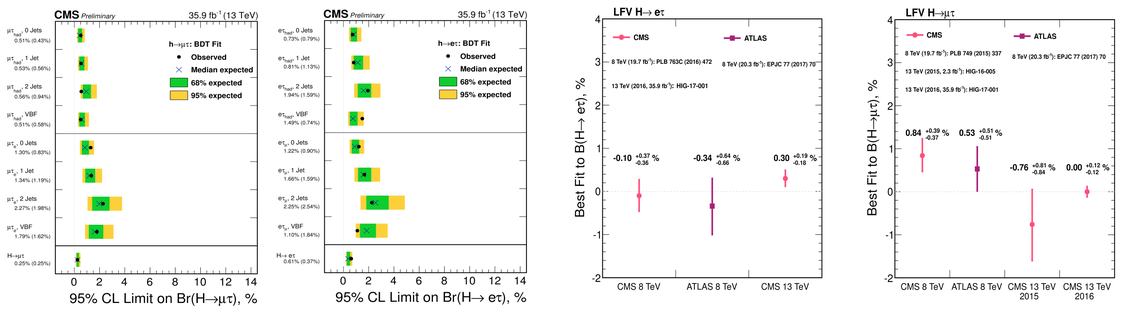


- A cut based analysis using collinear mass as fit variable is also retained as a cross-check

Search Results

No excess observed and limits on BR set

LFV H(125) Decays



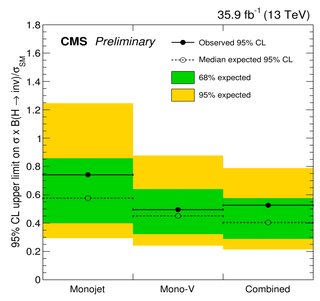
Best fit branching fraction:

BR(***H→μτ***)= **0.00±0.12** BR(***H→eτ***)= **0.30±0.18**

Compilation of LFV results

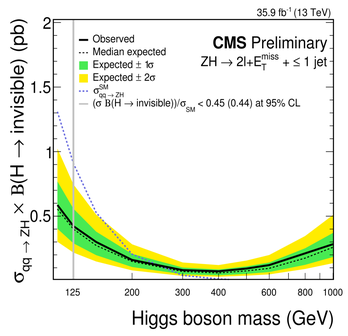
H(125)→Invisible Decays

Monojet and Mono-V analyses updated with full 2016 dataset:



BR(H->inv)<0.53/0.40

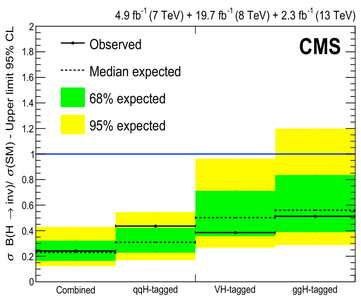
Z(ll) + MET analyses updated with full 2016 dataset:



BR(H->inv)<0.45/0.43

(obs/exp) @ 95% CL

Combination of 2011 (7 TeV), 2012 (8TeV) and 2015 (13 TeV):



BR(H->inv)<0.24/0.23

CMS is working actively on updating these and other exotic searches with larger amounts of data and using more sophisticated techniques. Stay tuned for more exciting results!

References:

- Search for lepton flavour violating decays of the Higgs boson to μτ and eτ in proton-proton collisions at √s = 13 TeV, CMS-PAS-HIG-17-001
- Search for dark matter, invisible Higgs boson decays, and large extra dimensions in the e+ E_T^{miss} final state using 2016 data, CMS-PAS-EXO-16-052
- Search for new physics in final states with an energetic jet or a hadronically decaying W or Z boson using 35.9 fb^{-1} of data at √s = 13 TeV, CMS-PAS-EXO-16-048
- Searches for invisible decays of the Higgs boson in pp collisions at √s =7, 8, and 13 TeV JHEP 02 (2017) 135

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