Higgs Boson decay to Tau Pairs at the CMS experiment

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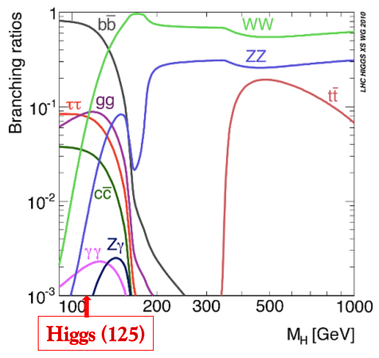
Motivation

Great achievement to a four decade long quest
A Higgs-like state pinned down at 125 GeV mass

- Access to coupling of Higgs field with fermions
- Proportionality between mass and coupling in the fermion sector

Different production mechanisms exploited (gg fusion, VBF and VH) for Standard Model Higgs Boson search



Minimal Super- Symmetric Standard Model (MSSM)

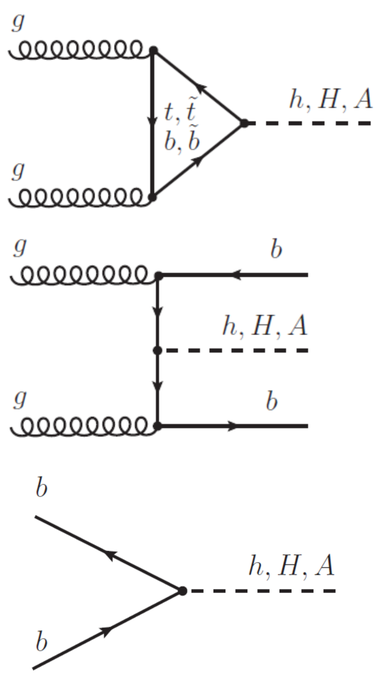
Two isospin Higgs doublets $H_1 = \begin{pmatrix} H_1^0 \\ H_1^- \end{pmatrix}$ and $H_2 = \begin{pmatrix} H_2^+ \\ H_2^0 \end{pmatrix}$

2 Higgs doublets each with 4 degrees of freedom
EW symmetry breaking: 5 physical Higgs bosons

Φ { h, H (scalar, CP-even); A (pseudoscalar, CP-odd); $H^{\pm}$ (charged) }

- Coupling bbA ~ tanβ (ratio of the vev of the two doublets) at LO
- Production rate enhanced – high tanβ

Φ (h/H/A) decays to b-quark (~ 90%) and τ (~ 10%) pairs enhanced at all masses
MSSM Higgs production and decays significantly affected by radiative corrections to Higgs mass
2 free parameters (M_A , tan β) in MSSM space
MSSM predicts low mass Higgs $M_h \lesssim 135$ GeV in the m_h^{max} scenario



The Higgs mass value 125 GeV measured is rather large for the MSSM light h boson
Maximizing M_h is maximizing the radiative corrections to Higgs mass at 1-loop level
A new MSSM m_h benchmark scenario introduced – m_h^{mod+} consistent with H(125)
M. Carena et. al. , arXiv:1302.7033 [hep-ph]

SM Higgs Analysis

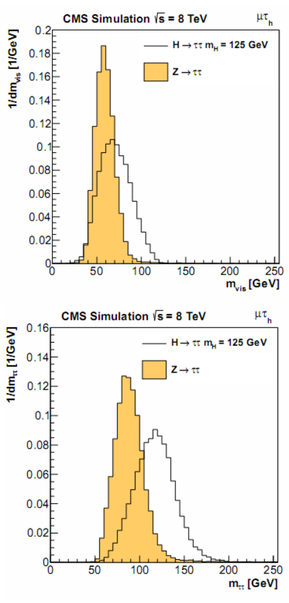
Mass of τ lepton pair reconstructed via a Likelihood technique:

- τ decay kinematics
- Compatibility of reconstructed E_T^{miss} with neutrino hypotheses

$m_{\tau\tau}$ obvious observable to discriminate Z boson from Higgs signal
Majority di-tau decay channels use $m_{\tau\tau}$ for signal extraction
$m_{\tau\tau}$ mass resolution ~ 10 - 20% depending on channel / category
.

Decay final states : $\mu + \tau_h$, $e + \tau_h$, $\mu + e$, $\mu\mu$, ee , $\tau_h + \tau_h$

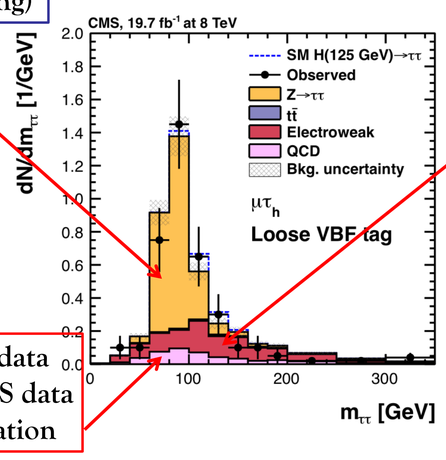
Improve sensitivity:
Different categories based on jet multiplicity and τ p_t
Optimized τ_{had}-isolation and e,μ→τ_{had} fake rejection



0 – jet category : constrains background, id efficiencies, energy scales
1 – jet category : improves the resolution of Higgs mass
2 – jet category : VBF process - high Signal/Background ratio

Z→ττ : observed Z→μμ sample and replace μ by simulated τ (embedding)

W + jets : Shape from simulation, normalization from m_T/P_ζ sideband
Z + jets : OS/SS ratio and lepton/jet→τ fakes with shape from simulation

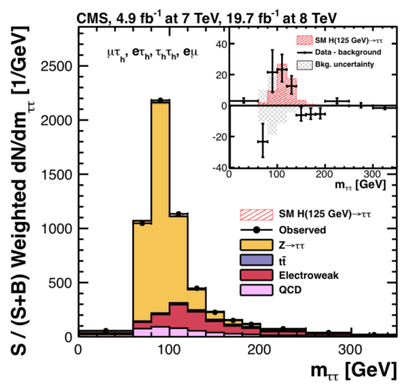


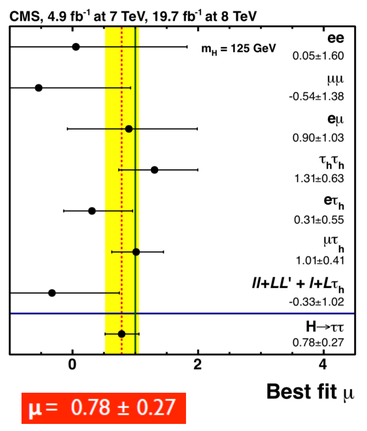
QCD : From OS/SS data and mass shape from SS data in relaxed lepton isolation

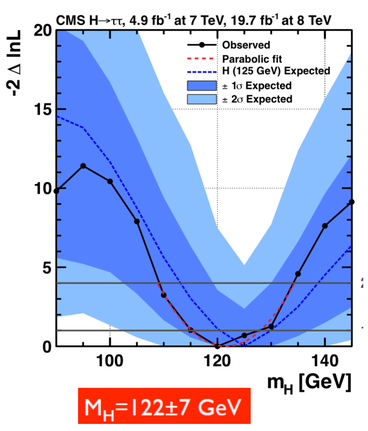
Top pair and Di-boson from simulation

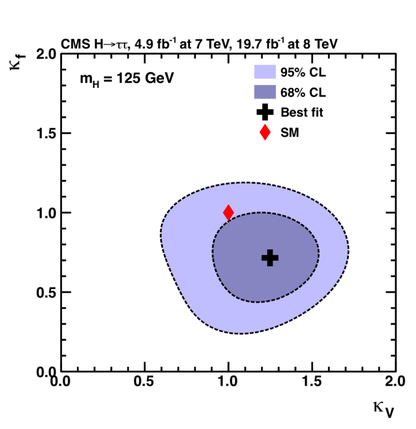
Higgs – Lepton Coupling

- Excess >3σ observed over m_H 110–130 GeV
- Observed (expected) Significance 3.2σ (3.7σ) for m_H = 125 GeV
- H→ττ best fit signal strength 0.78 ± 0.27 for m_H = 125 GeV
- Direct Evidence of Higgs–Lepton coupling



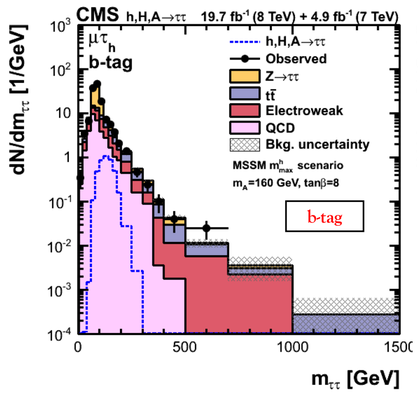


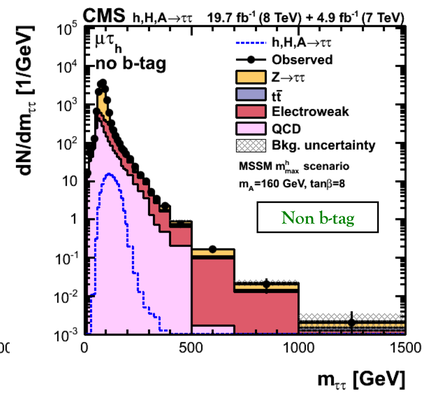




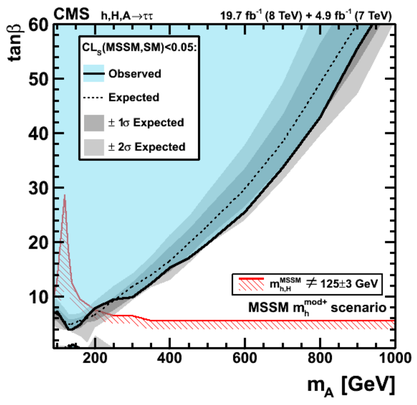
MSSM Higgs Search

Decay final states : $\mu + \tau_h$, $e + \tau_h$, $\mu + e$, $\mu\mu$, $\tau_h + \tau_h$
Selected Events analyzed in 2 Categories: b-Tag and non b-Tag (to enhance sensitivity of bbΦ coupling) B-tagging : based on secondary vertex + track-based life-time information





95% CL upper bound on Cross-section x $\mathcal{B}r(\Phi\rightarrow\tau\tau)$ based on the mass shape of $m_{\tau\tau}$ distribution- mapping m_A–tanβ plane (4FS+5FS)



Uncertainties entering the limit calculation–

- Theoretical (PDF, factorization)
- Normalization (Lumi, Efficiencies)
- Shape (Energy / momentum scale)

This excludes previously unexplored region now reaching as low as tan β ~ 3.9 at m_A = 140 GeV

Summary

- Higgs Boson @ 125 GeV - avenue of great interest in fermion decay modes
- Excess > 3σ observed over m_H 110–130 GeV in di-tau decay consistent with H(125)
- First Indication of Higgs coupling to Leptons from tau pair decay
- Properties measurement of Higgs in tau pair decay in Run 2 LHC
- Robust program of MSSM Higgs Boson searches with the CMS detector
- MSSM Higgs parameters significantly constrained with H→ττ (with different MSSM benchmark scenarios)

References

1. The CMS Collaboration, JHEP 05 (2014) 104 and all references therein
2. The CMS Collaboration, arXiv:1408.3316 [hep-ex] and all references therein