

Chapter 6

Measurements of Property of Higgs with Mass Near 125 GeV, CMS Collaboration



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Abstract During run 2016 at LHC, the total recorded luminosity is 35.9 fb^{-1} by CMS detector [1]. Measurements of properties of Higgs boson can be determined where Higgs decaying to oppositely charged W bosons and W again decaying leptonically. Events are selected on basis of oppositely charged leptons pair, large missing transverse energy and with different number of jets in final state. Higgs producing from vector boson fusion and associated production with W and Z boson are also included on the basis of two jets and three or four leptons in final state. After Combining all these events corresponding to total integrated luminosity 35.9 fb^{-1} , total calculated cross-sectional times branching ratio is 1.28 ± 0.17 times the standard model prediction for the Higgs boson with a mass of 125.09 GeV [2].

6.1 Introduction

Electroweak symmetry breaking is achieved through the prediction of a neutral scalar particle known as Higgs boson after the introduction of complex doublet scalar field which also leads masses of W and Z bosons [3]. Higgs was observed by CMS and ATLAS combined at 7 and 8 TeV using Run 1 dataset and the observed mass of Higgs is $m_H = 125.09 \pm 0.21(\text{stat}) \pm 0.11(\text{syst})\text{GeV}$.

This paper reports decay of Higgs boson to oppositely charged W boson using 2015 and 2016 dataset at center of mass energy of 13 TeV at total integrated luminosity of 35.9 fb^{-1} . The large branching fraction of Higgs to WW, makes this channel to study cross section of Higgs production through gluon–gluon fusion (ggH), vector-boson fusion (VBF) and associated production of Higgs (VH) [4]. In fully leptonic decay of W boson is the cleanest channel despite having presence of neutrino in final state which prevents clear mass peak of Higgs signal.

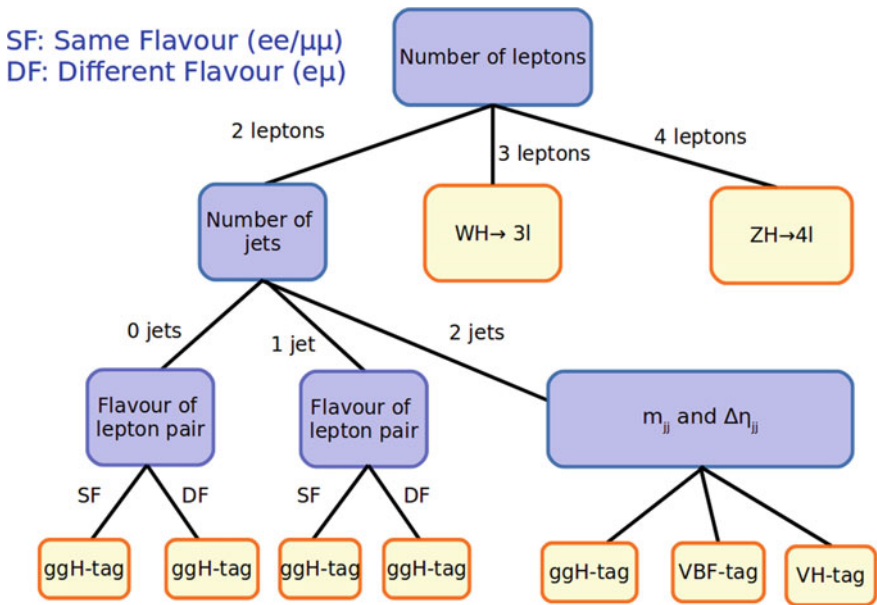
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6.2 CMS Detector

CMS is situated at one collision point of 27 Km large hadron collider (LHC) which accelerated the proton at nearly the speed of light in clockwise and anti-clockwise direction and then collide them. CMS is designed in a compact shape to measure energy and for the tracking of particles. It uses magnetic field of 3.8T for bending of charge particle and to measure momentum accordingly. Charge particle trajectories are measured with silicon pixel and tracker detector, which covers center pseudo-rapidity of $\eta \leq 2.5$. It consists of ECAL, HCAL, and muon system, where electron and photon deposits their energy in ECAL, whereas hadrons in HCAL system. Muon system consists of RPC, drift tube and CSC and Iron yoke.

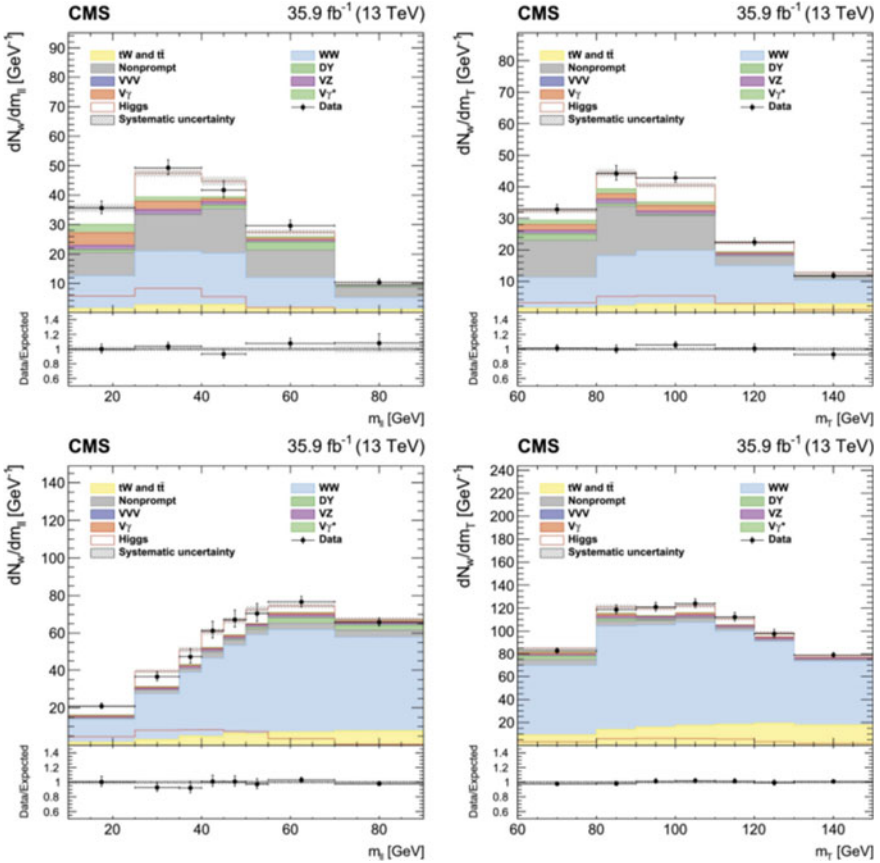
6.3 Data and Simulated Samples

Events are selected on the basis of one or two electrons and muons. Combination of single or dilepton triggers give total trigger efficiency of more than 98 VBF process which are generated by POWHEG v2 [5].



Out of category, one category can be discussed in detail, since ggH is the main production mode of Higgs. In ggH production mechanism different flavors final state, the main background process are WW, top, DY and W+jets. WW process can be distinguished from signal by different kinematic properties of leptons. To suppress process of three leptons, lepton ≥ 10 GeV is not allowed in final state. Final state transverse mass is defined as $m_T = \sqrt{2p_T^{\text{ll}} * E_T^{\text{miss}} [1 - \cos \Delta\phi]}$, which should be greater than 30 GeV; where $\Delta\phi$: angle between di lepton momentum and E_T^{miss} .

A shape analysis based on two-dimensional fit of m_{ll} and m_T in different flavors of ggH is done to extract Higgs signal.



| Category | Sub-category | Requirements |
|------------------|--|---|
| Preselection | - | $m_{ll} > 12$ GeV, $p_{T1} > 25$ GeV, $p_{T2} > 13(10)$ GeV for $e(\mu)$, $p_T^{miss} > 20$ GeV, $p_T^l > 30$ GeV, no additional lepton with $p_T > 10$ GeV, electron and muon with opposite charge |
| 0 jet ggH-tagged | $e^+\mu^-, e^-\mu^+, \mu^+e^-, \mu^-e^+$ ($p_{T2} > 20$ GeV) $e^+\mu^-, e^-\mu^+, \mu^+e^-, \mu^-e^+$ ($p_{T2} < 20$ GeV) | $m_T > 60$ GeV, $p_T^{l2, p_T^{miss}} > 30$ GeV, sub-leading lepton with $p_T > 20$ GeV, no jets with $p_T > 30$ GeV, no b tagged jets with p_T between 20 and 30 GeV $m_T > 60$ GeV, $p_T^{l2, p_T^{miss}} > 30$ GeV, sub-leading lepton with $p_T < 20$ GeV, no jets with $p_T > 30$ GeV, no b tagged jets with p_T between 20 and 30 GeV |
| 1 jet ggH-tagged | $e^+\mu^-, e^-\mu^+, \mu^+e^-, \mu^-e^+$ ($p_{T2} > 20$ GeV) $e^+\mu^-, e^-\mu^+, \mu^+e^-, \mu^-e^+$ ($p_{T2} < 20$ GeV) | $m_T > 60$ GeV, $p_T^{l2, p_T^{miss}} > 30$ GeV, sub-leading lepton with $p_T > 20$ GeV, exactly 1 jets with $p_T > 30$ GeV, no b tagged jets with p_T between 20 and 30 GeV $m_T > 60$ GeV, $p_T^{l2, p_T^{miss}} > 30$ GeV, sub-leading lepton with $p_T < 20$ GeV, no jets with $p_T > 30$ GeV, no b tagged jets with p_T between 20 and 30 GeV |
| 2 jet ggH-tagged | $e\mu$ | at least two jets with $m_T > 30$ GeV, $m_T > 60$ GeV, $p_T^{l2, p_T^{miss}} > 30$ GeV, no b tagged jets with $p_T > 20$ GeV, $m_{jj} > 65$ or 110 GeV $< m_{jj} < 400$ GeV |

6.4 Source of Systematical and Statistical Uncertainties

1. Source of systematical and statistical uncertainties

- a. Experimental Uncertainties: sources are—
luminosity (2.3%), muon momentum (0.2%) and electron energy scale (0.6–1%), jet energy scale uncertainty (<10%), trigger efficiency (<1%).
- b. Theoretical Uncertainties: sources are—
ggH theory uncertainties, Parton Shower, QCD scale uncertainty.

6.5 Results

Signal strength modifier is defined as the ratio of measured and expected signal of Higgs mass of 125.09 GeV including systematical and statistical uncertainty. A summary of signal strength can be seen in Fig. 6.1.

The combined signal strength modifier is $\mu = 1.28_{-0.17}^{+0.18} = 1.28 \pm 0.10(\text{stat}) \pm 0.11(\text{sys})_{-0.07}^{+0.10}(\text{theo})$ which means observed significance of Higgs boson is $\sigma = 9.1$ and expected value of significance is $\sigma = 7.1$ (Fig. 6.2).

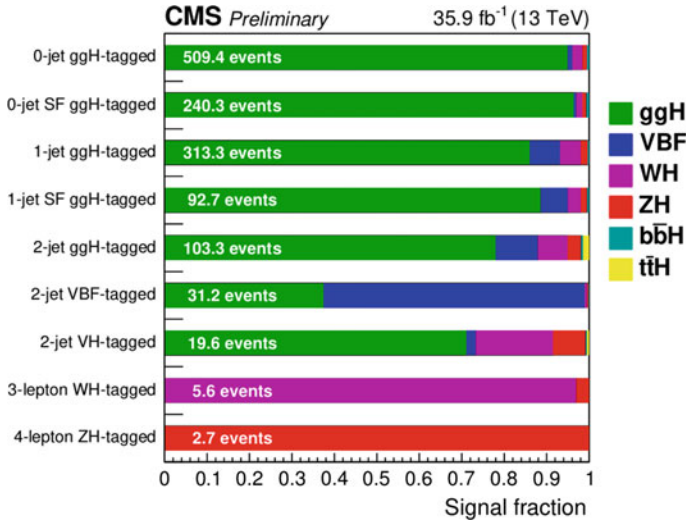


Fig. 6.1 Relative fraction of Higgs signal in measured and expected from SM

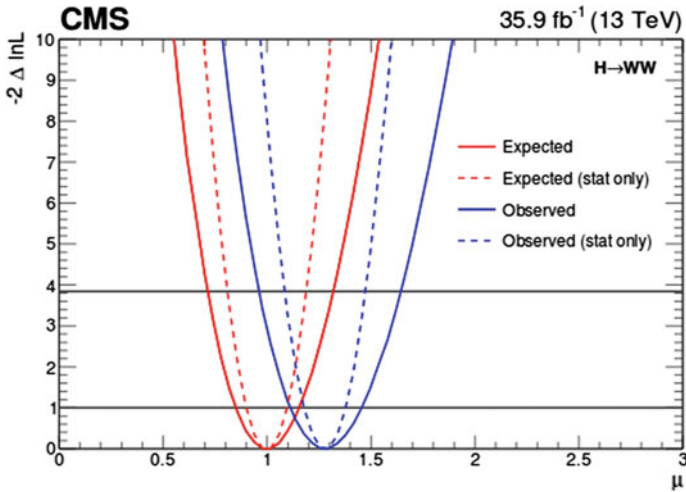


Fig. 6.2 Observed and expected profile likelihood for signal strength modifier

6.6 Summary

Using Run 2 data at total integrated luminosity of 35.9fb⁻¹, W⁺, and W⁻ events are selected on basis of two, three, or four leptons in final state and large missing transverse energy and same flavor(SF) or different flavors(DF) final state. After combining all category, the observed value of significance is 9.1 σ and expected (Fig. 6.3).

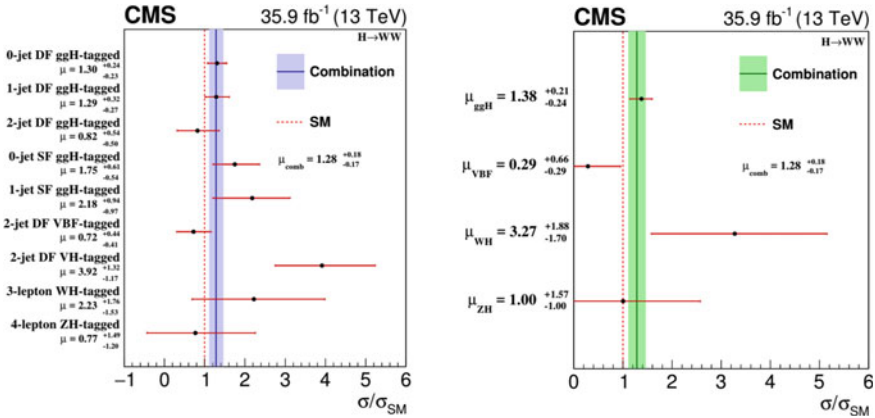


Fig. 6.3 Left plot is the observed signal strength modifier for different category and right plot corresponds to Higgs main production mode. Vertical dashed line is SM prediction and vertical line represents combined signal strength best fit value and filled shows 68% confidence interval

Value is 7.1σ . Hence, measured signal strength modifier is $\mu = 1.28^{+0.18}_{-0.17} = 1.28 \pm 0.10(\text{stat}) \pm 0.11(\text{sys})^{+0.10}_{-0.07}(\text{theo})$.

References

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