The Compact Muon Solenoid Experiment
Conference Report

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Measurements of Higgs boson production and properties in di-photon decay channel using data collected by CMS detector at center-of-mass energy of 13 TeV

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Abstract

A summary of the analyses towards search for Higgs boson and measurements of its properties in di-photon decay channel using the data collected by CMS detector at center-of-mass energy of 13 TeV will be presented in this talk.

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Measurements of Higgs boson production and properties in di-photon decay channel using data collected by CMS detector at center of mass energy of 13TeV

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Abstract. The Higgs boson has been rediscovered in diphoton decay channel with 12.9fb^{-1} data collected by the CMS in the year 2016 (subset of total data collected during the whole year) from proton-proton collisions at LHC at center of mass energy 13TeV, with a maximum significance of 6.1σ at mass of 126.0GeV, with a best-fit signal strength relative to standard model prediction of $0.95 \pm 0.20 = 0.95 \pm 0.17$ (stat) $^{+0.10}_{-0.07}$ (syst) $^{+0.08}_{-0.05}$ (theo).

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Keywords: Higgs boson, Diphoton, CMS

1 Introduction

In the year 2012, during RunI at LHC a Standard Model Higgs boson like particle was discovered by the CMS detector. Further studies are being made with the goal to measure the properties of the newly measured particle. Among the different decay channels $H \rightarrow \gamma\gamma$ has a very small branching ratio (0.2%). Still the clear final state topology makes it the most sensitive channel for study of Higgs boson and its different production mechanisms. In the report we discuss the first measurements with data collected by CMS in the year 2016 during LHC RunII at center of mass energy of 13TeV corresponding to integrated luminosity of 12.9fb^{-1} . Signal strength relative to Standard Model prediction for different production mechanisms like gluon-gluon fusion (ggH), vector boson fusion (VBF) and associated production with a $t\bar{t}$ pair (ttH) have also been measured.

2 Analysis outline

The search for Higgs signal is based on looking for a fully reconstructed peak over a large continuously falling background. The detector resolution dominates the experimental width of the observed signal, considering the narrow width (4MeV)

of the Higgs boson. In order to maximise the signal sensitivity, the photon energy resolution needs to be optimised. The CMS electromagnetic calorimeter [1] response has been uniformised at single channel level, to correct for response variation with time and position. A multivariate approach has been used to correct per event per photon energy and estimate the energy resolution taking into account global and local electromagnetic shower containment. A final energy scale and resolution correction is done by comparing data and simulation for $Z \rightarrow ee$ events.

2.1 Vertex identification

The invariant mass for the two photons depend on the angle between them. So it is very much important to reconstruct correct vertex for the photon pair. Photons do not have any tracks in the CMS tracker and any information on their direction of flight from electromagnetic calorimeter unless they are converted to e^+e^- inside tracker material. So the correct vertex identification is done by a mutivariate technique (MVA) using kinematic correlations between the two photons, track momentum imbalance due to the photon pair, direction of tracks for e^+e^- in case of converted photons. For the analysis a vertex assignment is taken to be correct if its longitudinal displacement with respect to true primary vertex of the same event, has much less effect on mass resolution compared to the impact of photon energy resolution. The average vertex assignment efficiency is measured to be 80%. The vertex identification method has been validated for $Z \rightarrow \mu\mu$ events from data and simulation.

2.2 Photon identification

First events are required to pass a diphoton trigger based on transverse energy of the photons, invariant mass of the photon pair, and combined cut on isolation variables and electromagnetic energy shower shape variables. Background for this process can be classified into two parts, irreducible dipoton production and reducible photon+jet production (where the jet has been mis-identified as a photon). Also there is a small contribution to the background from QCD processes with jet+jet production (where two jets have been reconstructed as photons). Again to identify prompt and isolated photons from faking jets a multivariate technique (MVA) is used using kinematic properties, energy shower shape variables and isolation variables of photons. After selecting prompt photons, a diphoton MVA is used to select diphoton objects with signal-like kinematics and good mass resolution over the diphotons pairs coming from background events. The diphoton MVA uses per event mass resolution estimate, kinematic variables of photon pair, photon identification MVA output value and probability of assigning the correct vertex.

Fig. 1. Left: Diphoton mass distribution combined for all categories weighted to their respective signal over signal-plus-background ratio. Right: Local p-value observed (black line), expected local p-value for Higgs mass 125.09 GeV (blue dashed line), minimum expected local p-value as function of mass (red dashed line). [2]

2.3 Event categories

The selected events are further categorized in eight different production categories in the following order based on the additional particles present in the event along with the diphoton pair

- $t\bar{t}H$ mechanism: Defined in two categories. When both W bosons coming from t, decay hadronically (labeled as *$t\bar{t}H$ Hadronic Tag*) and when at least one W boson decays leptonically (labeled as *$t\bar{t}H$ Leptonic Tag*).
- VBF mechanism: Multivariate technique has been used to select events with two jets along with diphoton pair having characteristic kinematic properties of a VBF process. Two subcategories labeled as *VBF 0* and *1* has been defined in descending order of VBF MVA output value.
- ggH mechanism: All remaining events correspond to ggH production mode and are further categorised as *Untagged 0, 1, 2, 3* in descending order of diphoton MVA output value.

2.4 Signal and background models

To extract signal events parametric models for signal and background have been built separately for each category. The signal model is extracted from simulation as a combination of several gaussian function taking into account different correction and scale factors and is fit for several mass point in the mass range of 120 to 130 GeV. The background models are completely data driven where a nuisance parameter is set to vary over a set of possible functional forms. This technique is discussed in details in [3]

3 Results

Figure 1 shows the sum of events combining all categories weighted to their expected signal to signal-plus-background ratio. The maximum observed significance is 6.1σ with a best fit at mass 126.0GeV, with a signal strength relative to standard model of $0.95 \pm 0.20 = 0.95 \pm 0.17$ (stat) $^{+0.10}_{-0.07}$ (syst) $^{+0.08}_{-0.05}$ (theo) [2].

4 Summary

This report summarizes the observation of the Higgs boson in diphoton decay channel with 12.9fb^{-1} data collected by CMS detector in $p-p$ collision at LHC at center of mass energy of 13 TeV in the year 2016. The signal has a maximum significance of 6.1σ at a mass of 126.0GeV. The signal strength has also been measured individually for ttH, VBF, ggH production mode which are compatible with SM predictions.

References

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