The Compact Muon Solenoid Experiment
Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

25 February 2017 (v3, 07 March 2017)

Re-discovery of the SM Higgs boson in diphoton channel at $\sqrt{s} = 13$ TeV at CMS in LHC

Arnab Purohit for the CMS Collaboration

Abstract

Techniques and results of the re-discovery analysis of standard model Higgs boson decaying to two photons are presented. The analysis is performed on 2016 data at 13TeV centre of mass energy corresponding to an integrated luminosity of 12.9 1/fb taken by the CMS detector in LHC experiment. The central value of mass distribution of the standard model Higgs boson at the Run 1 ATLAS+CMS combined result was $m(\text{Higgs}) = 125.09$ GeV. At this mass point, with the data taken by CMS in 2016, 6.2σ significance is expected where the observed significance is 5.6σ . At 126.0 GeV the maximum significance of 6.1σ is observed.

Presented at *DAE-HEP Symposium XXII DAE-BRNS High Energy Physics Symposium*

Re-discovery of the SM Higgs boson in diphoton channel at $\sqrt{s} = 13$ TeV at CMS in LHC

Arnab Purohit

On behalf of the CMS Collaboration

Saha Institute of Nuclear Physics, HBNI, Kolkata, West Bengal, INDIA,
arnabpurohit@cern.ch

Abstract. Techniques and results of the re-discovery analysis of standard model Higgs boson decaying to two photons are presented. The analysis is performed on 2016 data at 13 TeV centre of mass energy corresponding to an integrated luminosity of 12.9 fb^{-1} taken by the CMS detector in LHC experiment. The central value of mass distribution of the standard model Higgs boson at the Run 1 ATLAS+CMS combined result was $m(\text{Higgs}) = 125.09 \text{ GeV}$. At this mass point, with the data taken by CMS in 2016, 6.2σ significance is expected where the observed significance is 5.6σ . At 126.0 GeV the maximum significance of 6.1σ is observed.

Keywords: Standard Model, Higgs boson, CMS, ATLAS, significance

1 Introduction

After almost half a century from Higgs boson's theoretical developments [1], in July 2012, in the two large particle detectors, ATLAS and CMS, of LHC a new particle whose properties are most consistent with Standard Model (SM) Higgs boson, with mass around 125 GeV, was announced to be discovered. The particle, the Higgs boson, was predicted to exist as a consequence of the spontaneous symmetry breaking mechanism in the electro-weak sector of the SM [1,2]. In this report mass measurement of the Higgs boson in its diphoton decay channel, at the CMS detector, is presented. It summarises the work presented in Ref. [3]. The analysis is based on 12.9 fb^{-1} of p-p collision data collected at center-of-mass energy of 13 TeV. The SM Higgs bosons are produced in the LHC environment primarily through gluon-gluon fusion (ggH), about 88%, with smaller contributions from vector boson fusion (VBF), characterised by two forward-backward jets, about 8%, and associated production with a W or Z (VH) or $t\bar{t}$ pairs (ttH), about 3% and 1% respectively. The clean final state topology of the diphoton decay channel allows the mass of the Higgs boson to be reconstructed with high precision. However there is large background originating from irreducible background processes producing two prompt γ (about 70% of the events selected) and reducible background processes producing one prompt photon and a neutral meson, where the meson is misidentified as a γ (about 30% of the events selected) and two misidentified neutral mesons, which

are reconstructed as γ (less than 1% of the selected events). As a consequence we search for a small peak on a large falling background. The Higgs boson decays into two photons primarily via either a top quark loop or a W boson loop. But the amplitudes of those modes interfere destructively resulting in a branching fraction of around 0.2% for a SM Higgs boson at 125 GeV. Despite the small branching fraction and the presence of a large diphoton continuum background, the diphoton decay mode provides an expected signal significance for the 125 GeV SM Higgs boson that is one of the highest among all the decay modes.

2 Analysis Strategy

Energy of the photon candidates are reconstructed by building clusters of energy deposits in the electromagnetic calorimeter (ECAL). A multivariate likelihood regression technique is used to correct individual photons energies and provide an estimate of the per-photon energy resolution.

There can be several proton-proton collisions in each bunch crossing resulting in multiple primary vertices in each event. In order to select the primary vertex from those of other interactions in the same bunch crossing a boosted decision tree (BDT) is deployed. This uses information from transverse momentum (p_T) of tracks associated to the vertex, the $p_T^{\gamma\gamma}$ and conversions informations. An additional BDT is trained to know the probability that the vertex choice was correct.

A Boosted Decision Tree (BDT) is trained to distinguish prompt photons from non-prompt photons, using shower topology variables and isolation variables. Figure 1 shows the BDT output of the photon ID.

Fig. 1. Photon Id BDT output [3]

Fig. 2. Diphoton MVA output [3]

To achieve the best performance, after the selection of the diphoton system, the events are categorized in eight mutually exclusive classes depending on the

production modes and the different signal over background ratio. Figure 2 shows the distribution of the diphoton MVA output for simulated events (stacked histograms) and data (black dots). The variable is built to have a flat distribution on signal events (red shades histograms). The vertical dashed lines show the boundaries for the definition of the four Untagged categories. Several systematic uncertainties have been evaluated: the scale and resolution for the photon's energy, photon identification (preselection and BDT), vertex finding efficiency, trigger efficiency, theoretical production crosssections and uncertainty due to the additional objects in the exclusive categories (jet, leptons and missing energy).

Parametric models are built both for signal and background components in order to perform the signal extraction in the different categories. Extraction of the signal model is done from simulation, using a sum of gaussian functions to describe the different components contributing to the diphoton invariant mass. The model is fit to several Higgs mass hypotheses in a mass range between 120 and 130 GeV.

The extraction of the background model is completely data driven. The choice of the functional form for the description of the background diphoton mass distribution in each category is treated as a discrete nuisance parameter floating over an initial set of possible functional forms. This technique is described in detail in [3].

Fig. 3. diphoton invariant mass distribution in data [3]

Fig. 4. p value [3]

3 Results

Figure 3 shows the invariant mass weighted for their signal to signal-plus-background ratio of the diphoton system for all the events selected by the different categories. The lower plot shows the excess of events due to the presence of the Higgs boson, after the subtraction of the background. The solid red line

shows the signal-plus-background fit, while the dashed red line indicates the background component of the fit. Figure 4 shows the local p-value observed in data (solid black line), expected local p-value for a Higgs boson with a mass of 125.09 GeV (blue dashed line) and minimum expected local p-value as function of the mass hypothesis of the Higgs boson (red dashed line). The maximum observed significance, with 12.9 fb^{-1} taken by the CMS detector in 2016, is 6.1σ with a best fit at mass 126.0 GeV, 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).

References

1. Higgs, P. :Broken Symmetries and the Masses of Gauge Bosons. Physical Review Letters. 13 (16): 508–509.(1964). doi:10.1103/PhysRevLett.13.508
2. Englert, F.; Brout, R. :Broken Symmetry and the Mass of Gauge Vector Mesons. Physical Review Letters. 13 (9): 321–323 (1964). doi:10.1103/PhysRevLett.13.321
3. Updated measurements of Higgs boson production in the diphoton decay channel at $\sqrt{s} = 13\text{ TeV}$ in pp collisions at CMS. Technical Report. CMS-PAS-HIG-16-020, CERN, Geneva, 2016.
4. S. Chatrchyan et al. The CMS experiment at the CERN LHC. JINST, 3:S08004, 2008.