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Search for the Higgs boson in $H \to WW \to 2l2\nu$ mode with the CMS detector

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Abstract. A search is reported for the Higgs boson decaying to W^+W^- in pp collisions at $\sqrt{s} = 7$ TeV. The analysis is performed using LHC data recorded by the CMS detector, corresponding to an integrated luminosity of 1.55 fb^{-1}. No significant excess above the Standard Model background expectation is observed, and upper limits on Higgs boson production are derived, excluding the presence of a Higgs boson with a mass in the range of 147–194 GeV/c^2 at the 95% confidence level (CL) using the CLs approach.

Keywords. CMS; Higgs.

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1. Introduction

This document reports a search for the Higgs boson in the channel $H \to W^+W^- \to 2l2\nu$ in the mass range of 115–600 GeV/c^2. Results with a cut-based approach for an integrated luminosity of 1.55 ± 0.07 fb^{-1} are presented here. $H \to W^+W^- \to 2l2\nu$ events are separated into three categories according to the event jet multiplicity: $H + 0$ jets, $H + 1$ jet, and $H + 2$ jets. All Higgs production mechanisms are considered as part of the signal: the gluon fusion process, a Higgs boson in the final state accompanied by a W or Z boson or by a pair of top quarks, and the vector–boson fusion (VBF) process.

2. Event selection

Several Standard Model (SM) processes can lead to a final state similar to that of the $H \to W^+W^-$ signal, in addition to the irreducible non-resonant W^+W^- process. These backgrounds include W + jets and QCD multijet events, where at least one of the jets is misidentified as a lepton, top production ($t\bar{t}$ and tW), the Drell–Yan $Z/\gamma^* \to l^+l^-$ process, and diboson production ($W\gamma$, WZ and ZZ). The event selection is based on the analysis described in ref. [1]. Events are selected with two high transverse momentum (p_{T}), oppositely-charged, isolated leptons, in three final states: e^+e^-, $\mu^+\mu^-$ and $e^\pm\mu^\pm$.

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These final states include $W \rightarrow \tau\nu$ events with leptonic τ decays. Muons are measured with all-silicon tracker and muon system in the CMS detector [2]. Electron candidates are reconstructed from clusters of energy deposits in the ECAL, which are then matched to hits in the tracker. Both muons and electrons are required to have at least $p_{\mathrm{T}} > 10$ GeV/c (varies with the Higgs mass). They are measured within a pseudorapidity range of $|\eta| < 2.4$ for muons and $|\eta| < 2.5$ for electrons. Neutrinos from W boson decays escape detection resulting in an imbalance in the measured energy deposits in the transverse plane ($E_{\mathrm{T}}^{\mathrm{miss}}$). Here, we have used the projected $E_{\mathrm{T}}^{\mathrm{miss}}$ calculated as the component of $E_{\mathrm{T}}^{\mathrm{miss}}$ transverse to the closest lepton if it is closer than $\pi/2$ in azimuthal angle, and the full $E_{\mathrm{T}}^{\mathrm{miss}}$ otherwise. Minimum condition on projected $E_{\mathrm{T}}^{\mathrm{miss}}$ has been applied depending on the final state. To further reduce the Drell–Yan background in the ee and $\mu\mu$ final states, events with a dilepton invariant mass within ± 15 GeV/c^2 of the Z mass are rejected. Jets are reconstructed from calorimeter and tracker information using a particle flow algorithm [3]. Jets are required to have $p_{\mathrm{T}} > 30$ GeV/c within $|\eta| < 5.0$. Any event with a third lepton passing the identification and isolation requirements is rejected.

After preselection requirements, to enhance the sensitivity to the Higgs signal, a simple cut-based approach is performed. Further requirements on a few observables separately optimized for different m_{H} hypotheses are applied. In the 0- and 1-jet categories, extra requirements are placed on the transverse momenta of the harder and the softer leptons, the dilepton mass, the transverse Higgs mass and the azimuthal angle difference between the two selected leptons. Figure 1 shows the m_{ll} distributions, after applying the WW selections, for a simulated SM Higgs signal with $m_{\mathrm{H}} = 160$ GeV/c^2, and for backgrounds in the 0- and 1-jet categories.

The 2-jet category is mainly sensitive to the VBF production mode and can be extracted using simple selection, as the backgrounds are expected to be relatively low. These events are characterized by a pair of energetic forward–backward jets and very little hadronic

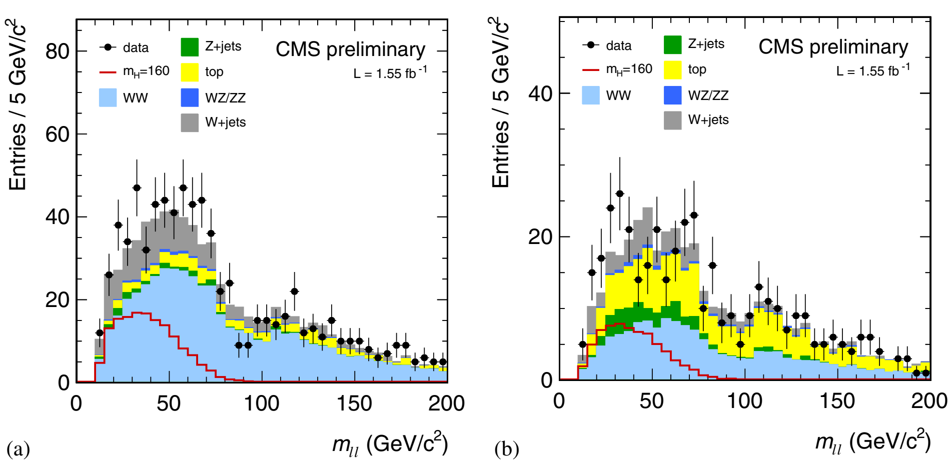

Figure 1. Dilepton invariant mass after the WW selection in (**a**) 0-jet and (**b**) 1-jet category for $m_{\mathrm{H}} = 160$ GeV/c^2 simulated SM Higgs signal and backgrounds.

activity in the rest of the event. We select events that pass the W^+W^- selection requiring two reconstructed jets with $p_T > 30$ GeV/c and no other jets.

3. Background estimation and systematics

We use a combination of techniques to evaluate the background contributions. The accurate simulation of the W + jets and QCD suffers from large systematic uncertainties. So the normalization and the relevant kinematic distributions are estimated directly from the data. The background due to top quarks is estimated from the data as well by counting top-tagged events and applying the corresponding tagging efficiency, which is measured in a data control sample with one observed jet, dominated by $t\bar{t}$ and tW events. The non-resonant W^+W^- contribution is also estimated from the data. An estimate of the residual Z boson contribution is obtained by extrapolating the observed number of events with dilepton invariant mass within ± 15 GeV/c^2 of the nominal Z mass observed in the data. Other backgrounds (WZ, ZZ, $W\gamma$) are estimated by simulation. The uncertainty on the signal efficiency is estimated to be $\sim 20\%$ and is dominated by the theoretical uncertainty in the jet veto efficiency determination. The uncertainty on the background estimations in the $H \to W^+W^-$ signal region is $\sim 15\%$, which is dominated by the statistical uncertainties of the background control regions in the data.

4. Results

After applying the Higgs mass-dependent selections, no significant excess is found with respect to the expected SM backgrounds. A reasonably good agreement between the data and the predicted background is seen at all steps of the analysis. Upper limits are derived on the product of the Higgs boson production cross-section and the $H \to W^+W^-$ branching fractions with respect to the SM expectation using CLs, which is based on the

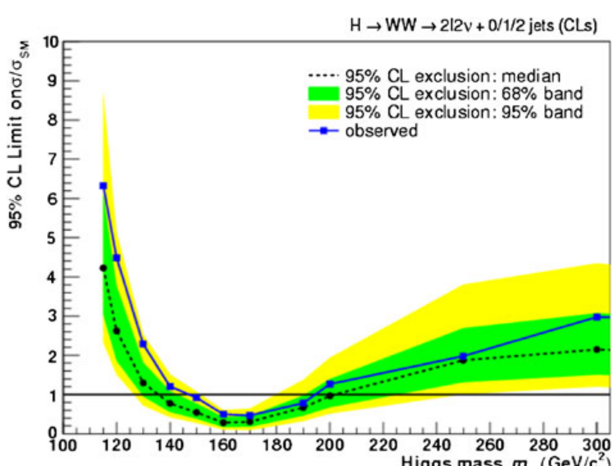

Figure 2. The 95% CL expected and the observed upper limits on the cross-section times branching ratio, relative to the SM value using a cut-based event selection.

hybrid frequentist–bayesian approach [4]. The 95% CL observed and the expected median upper limits are shown in figure 2. We exclude the presence of a Higgs boson with a mass in the range of 147–194 GeV/c^2 at 95% CL, with an expected exclusion sensitivity in the range of 136–200 GeV/c^2.

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