PROCEEDINGS OF SCIENCE

Search for the Higgs Boson Decaying to W^+W^- in the Fully Leptonic Final State

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This paper reports a search for the Higgs boson decaying to W^+W^- in pp collisions at $\sqrt{s} = 7$ TeV. The analysis is performed using LHC data recorded with the CMS detector, corresponding to an integrated luminosity of 1.1 fb^{-1}. W^+W^- candidates are selected in events with two leptons, electrons or muons. No significant excess above the standard model background expectation is observed, and upper limits on Higgs boson production are derived, excluding the presence of Higgs boson with a mass in [150 - 193] GeV/c^2 range at 95% C.L.

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1. Introduction

The first search for the Higgs boson published by CMS was based on a data sample recorded in 2010 corresponding to an integrated luminosity of 35 pb^{-1} [1]. The analysis strategy have been improved to cope with a larger number of collisions within a single bunch crossing, referred to as *pile-up*. Furthermore, to improve the signal sensitivity, lower transverse momentum(p_{T}) leptons and events with one and two reconstructed jets are now considered. The analysis is performed using an integrated luminosity of 1.1 ± 0.1 fb^{-1} collected by the CMS detector [3] in pp collisions at $\sqrt{s} = 7$ TeV. We present a brief summary of the results shown at the conference. Additional details can be found in [2].

2. Event Selection

Events are selected with two energetic oppositely-charged, isolated leptons, in three final states: $\mathrm{e^+e^-}$, $\mu^+\mu^-$ and $\mathrm{e}^\pm\mu^\mp$. We require $p_{\mathrm{T}} > 20$ (10) GeV/c for the leading (trailing) lepton.

Neutrinos from W boson decays escape detection. This results in an imbalance in the measured energy depositions in the transverse plane, denoted by $E_{\mathrm{T}}^{\mathrm{miss}}$. We use 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. To control the Drell-Yan background in large pile-up conditions we use the minimum of two different estimators: the first includes all particle candidates in the event, while the second uses only the charged particle candidates associated to the primary vertex. Events are required to have $E_{\mathrm{T}}^{\mathrm{miss}}$ above 40 GeV in the $\mathrm{e^+e^-}$ and $\mu^+\mu^-$ final states, and above 20 GeV for the $\mathrm{e}^\pm\mu^\mp$ final state. We also require the angle in the transverse plane between the dilepton system and the most energetic jet to be smaller than 165 degrees in the $ee/\mu\mu$ final states. This selection is only applied if the leading jet $E_T > 15$ GeV/c.

To further reduce the Drell-Yan background in the ee and $\mu\mu$ final states, events with a dilepton invariant mass within $\pm$ 15 $\mathrm{GeV/c^2}$ of the Z mass are rejected. Events with dilepton masses below 12 $\mathrm{GeV/c^2}$ are also rejected to suppress contributions from low mass resonances.

Jets are reconstructed from calorimeter and tracker information using a particle flow algorithm [4]. The anti-$\mathrm{k_T}$ clustering algorithm with distance parameter $\mathrm{R} = 0.5$ is used. Jets are counted if they have $p_{\mathrm{T}} >$ 30 GeV/c within $|\eta| < 5.0$.

To suppress the top quark background, we apply a *top veto* based on soft-muon and b-jet tagging. The first method vetoes events containing muons from the b-quark decays. The second method uses standard b-jet tagging looking for tracks with large impact parameter within jets. The algorithm is applied also in the case of zero counted jets bin, which can still contain low p_{T} tagged jets.

To reduce the background from diboson processes, such as WZ and ZZ production, any event that has an additional third lepton passing the identification and isolation requirements is rejected. Wγ production, where the photon is misidentified as an electron, is suppressed by stringent γ conversion rejection requirements.

To enhance the sensitivity to the Higgs signal, two different analyses are performed. The first analysis is a cut-based approach where further requirements on a few observables are applied, while the second analysis makes use of multivariate techniques to produce a single discriminating variable that is used in a shape analysis.Both approaches are optimized for different m_{H} hypotheses.

In the cut-based approach, extra requirements are placed on the transverse momenta of the harder ($p_{\mathrm{T}}^{\ell,\max}$) and the softer ($p_{\mathrm{T}}^{\ell,\min}$) leptons, the dilepton mass ($m_{\ell\ell}$), the transverse Higgs mass ($m_T^{\ell\ell E_{\mathrm{T}}^{\mathrm{miss}}}$), and the azimuthal angle difference ($\Delta\phi_{\ell\ell}$) between the two selected leptons.

In the multivariate approach a boosted decision tree (BDT) technique is used. The multivariate technique uses the following additional variables compared to the cut-based analysis: $\Delta R_{\ell\ell} \equiv \sqrt{\Delta\eta_{\ell\ell}^2 + \Delta\phi_{\ell\ell}^2}$ between the leptons, with $\Delta\eta_{\ell\ell}$ the η difference between the leptons, which has similar properties as $\Delta\phi_{\ell\ell}$; the transverse mass of both lepton-$E_{\mathrm{T}}^{\mathrm{miss}}$ pairs and the lepton flavors. The training is performed using $H \to \mathrm{W^+W^-}$ as signal and $\mathrm{W^+W^-}$ continuum as background.

The 2-jet category is mainly sensitive to the VBF production mode. $H \to W^+W^-$ events from VBF production are characterized by a pair of energetic forward-backward jets and very little hadronic activity in the rest of the event. To reject background from top decays we apply two additional requirements on the jets j_1 and j_2: $|\Delta\eta(j_1 - j_2)| > 3.5$ and $m_{j_1 j_2} > 450$ GeV/c^2.

3. Background Estimation

$\mathrm{W}+$jets and QCD multi-jet events form a background to $\mathrm{W^+W^-}$ production when jets are misidentified as leptons. A set of loosely selected lepton-like objects is defined in a sample of events dominated by di-jet production. The probability is calculated for those objects to be misidentified as a lepton passing all lepton selection criteria. This probability is then applied to a sample of events selected using the final selection criteria, except for one of the leptons for which the selection has been relaxed to the looser criteria and that has failed the nominal selection. The systematic uncertainty on this estimate is obtained by applying the same method to another control sample with different selection criteria. This procedure is validated in simulated events and applied on same-sign events in data.

The remaining top background is estimated from data as well by using top-tagged events and applying the corresponding tagging efficiency, which is measured in a data control sample with one counted jet.

An estimate of the residual Z boson contribution to the $\mathrm{e^+e^-}$ and $\mu^+\mu^-$ final states is obtained by normalising the simulation to the observed number of events inside the Z mass window in data.

Other backgrounds are estimated from simulation. The $\mathrm{W}\gamma$ background estimate was cross-checked in data using the events passing all selection requirements, except that the two leptons must have the same charge.

The non-resonant $\mathrm{W^+W^-}$ contribution in the $H \to W^+W^-$ low mass signal region, $m_{\mathrm{H}} < 200\,\mathrm{GeV/c^2}$, can be estimated from data. This is done using events with a dilepton mass larger than 100 GeV/c^2, where there is a negligible contamination from the Higgs boson signal. For larger Higgs boson masses we estimate the background from simulation.

The background estimates for all processes after the $\mathrm{W^+W^-}$ preselection are summarised in Table 1.

The overall signal efficiency uncertainty is estimated to be $\sim 20\%$ and is dominated by the theoretical uncertainty in the jet veto efficiency determination. The uncertainty on the background

	data	all bkg.	W^+W^-	$t\bar{t}+tW$	$W+\gamma$	$WZ/ZZ/Z/\gamma^*$	W + jets
0-jet	626	568.6 ± 52.2	366.9 ± 30.3	63.8 ± 15.9	8.7 ± 1.7	22.3 ± 5.4	106.9 ± 38.9
1-jet	334	316.0 ± 24.7	107.3 ± 9.3	141.1 ± 14.1	2.4 ± 0.8	28.3 ± 11.5	36.9 ± 13.8
2-jet	175	164.6 ± 18.0	23.2 ± 2.0	99.3 ± 9.9	1.1 ± 0.5	24.6 ± 13.5	16.4 ± 6.4

Table 1: Expected number of signal and background events from the data-driven methods for an integrated luminosity of 1.1 fb^{-1}after applying the W^+W^- selection requirements. Statistical and systematic uncertainties on the processes are reported. The W^+W^- contribution corresponds to the estimated value from the simulation.

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 data.

4. Results

Upper limits are derived on the product of the Higgs boson production cross section and the H$\to$ W^+W^- branching fraction, $\sigma_H\times$BR(H $\to W^+W^-\to 2\ell2\nu$), with respect to the SM expectation, $(\sigma^{95\%}/\sigma^{SM})$. The observed and expected median upper limits are shown in Figure 1. The bands represent the 1σ and 2σ probability intervals around the expected limit. Upper limits on Higgs boson production are derived, excluding the precence of Higgs boson with a mass in [150-193] GeV/c^2 range at 95% C.L.

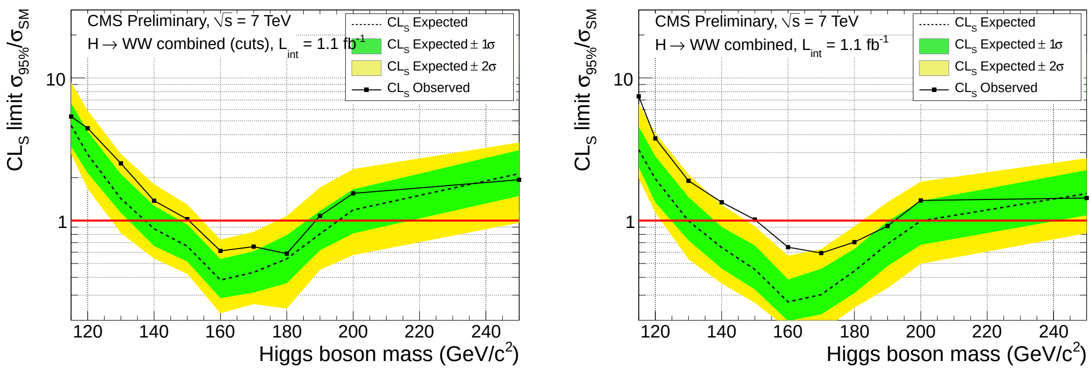

Figure 1: 95% expected and observed C.L. upper limits on the cross section times branching ratio $\sigma_H\times$BR(H $\to W^+W^-\to 2\ell2\nu$), relative to the SM value using (a) cut-based and (b) multivariate BDT event selections. Results are obtained using the CL_s approach.

References

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