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Measurement of the Higgs boson properties in the $WW^{(*)} \to \ell\nu\ell\nu$ decay mode with the ATLAS detector at the LHC

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This article describes the measurements of the Higgs boson properties in the $H \to WW^{(*)} \to \ell\nu\ell\nu$ ($\ell = e, \mu$) decay mode using the ATLAS detector at the CERN Large Hadron Collider. The results are obtained using the proton-proton collisions dataset which corresponds to an integrated luminosity of 20.7 fb^{-1} at a centre of mass energy of 8 TeV and 4.6 fb^{-1} at 7 TeV. An excess over the expected number of background events is observed in the data. The significance of the excess for the Higgs boson with a mass of 125 GeV is estimated to be 3.8 standard deviations, while the expected value is 3.7. The signal strength μ, defined as a ratio of the cross-section for the observed signal to the cross section predicted for a Standard Model Higgs boson with a mass of 125 GeV, is measured to be $\mu = 1.01 \pm 0.31$. The results obtained by including the $H \to WW^{(*)} \to \ell\nu\ell\nu$ channel where the Higgs boson is produced in association with a W or a Z boson which decay leptonically are also reported. Finally, results of the searches for resonances up to 1 TeV are briefly summarised. An additional signal with the Standard Model like production cross-section and couplings is excluded in the range $260 < m_H < 642$ GeV.

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1. Introduction

The $H \to WW^{(*)} \to \ell\nu\ell\nu$ ($\ell = e,\mu$) analysis provides an important measurement of the overall production rate of the new boson discovered in July 2012 [1, 2] and of its couplings to the gauge bosons. The results shown in this article are based on a dataset which corresponds to an integrated luminosity of 20.7 fb^{-1} at a centre of mass energy of 8 TeV and 4.6 fb^{-1} at 7 TeV recorded by the ATLAS detector. The analysis focuses on measuring the Standard Model (SM) Higgs boson produced through the gluon-gluon fusion (ggF) or vector boson fusion (VBF) production mechanism. A combined result with the $H \to WW^{(*)} \to \ell\nu\ell\nu$ channel where the Higgs boson is produced in association with W or Z bosons which decay leptonically (VH analysis) is also presented. Extensions of the SM which predict the existence of an additional resonance at higher mass have also been probed and the results are included in section 3.

2. Analysis description

The experimental signature of the $H \to WW^{(*)} \to \ell\nu\ell\nu$ decay is characterised by two oppositely charged leptons [1] and a large missing transverse energy (E_T^{miss}) from two undetected neutrinos in the direction opposite to the transverse momentum of the di-lepton system. The analysis is performed separately for four different lepton flavour pair combinations ($e\mu, \mu e, ee$ and $\mu\mu$) and three different jet multiplicities (0, 1, and ≥ 2 jets). Categories with 0 and 1 jet are expected to be dominated by events where the Higgs boson is produced through ggF, while events with ≥ 2 jets are mainly produced through VBF. In order to reduce the backgrounds coming from events with misidentified objects and conversions ($W+$ jets, $W\gamma$), we select events with two oppositely charged, well isolated and well identified leptons with high transverse momentum ($p_T > 25, 15$ GeV). Contamination from on-shell Z decays in channels with same flavour leptons (ee and $\mu\mu$) is suppressed by requiring that the di-lepton invariant mass is not consistent with the Z boson mass. Background form the Drell-Yan (DY) process is suppressed by requiring E_T^{miss} or its projection on the direction of the closest reconstructed object to be larger then 45 GeV. In different flavour channels ($e\mu$ and μe) the requirement of $E_T^{miss} > 20$ (25) GeV is sufficient to suppress the QCD background for categories with 2 (0 or 1) jets. After this selection, dominant backgrounds in $e\mu$ and μe channels are WW and top quark production. In the ee and $\mu\mu$ channels the DY process is dominant background in the 0 and 1 jet category, while the top quark production is the main background in the 2 jet category. The DY background is further reduced by requirements on the amount of soft hadronic recoil opposite to the di-lepton system in the transverse plane, as well as on the E_T^{miss} calculated using Inner Detector tracks. Background from top quarks is reduced by vetoing events with b-jets. Finally, topological criteria on the di-lepton invariant mass and opening angle, which exploit the angular correlation between two leptons of the WW system to discriminate between the $H \to WW$ and $qq \to WW$ processes, are applied in all categories. The remaining backgrounds are estimated using control samples from data. The final discriminating variable is the transverse mass defined as $m_T^2 = (\sqrt{m_{\ell\ell}^2 + \vec{p}_{T_{\ell\ell}}^2} + E_T^{miss})^2 - (\vec{p}_{T_{\ell\ell}} + \vec{E}_T^{miss})^2$. An excess of events over the expected background has been observed in data for a broad m_T range in all final states. Figure 1 (left) shows the m_T distribution for the different flavour channels with 0 jets.

[1] In the following text lepton refers to an electron or a muons

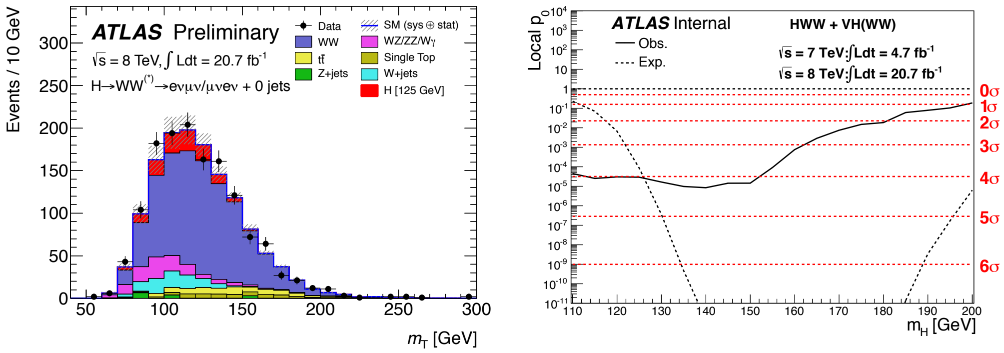

Figure 1: The left plot shows the m_T distribution for different flavour channels with 0 jets. The right plot shows the local p_0 value as a function of m_H when the VH result is included.

3. Results

The significance of the excess is determined by a binned likelihood fit to the m_T spectra in events satisfying all selections. An excess is observed over a wide range of m_H values with a local p_0 minimum at $m_H = 140$ GeV, corresponding to a 4.1σ significance. The observed signal significance at $m_H = 125$ GeV is 3.8σ (expected 3.7σ). The best fit of the signal strength, defined as a ratio of the cross-section for the observed signal to the cross section predicted for a Standard Model Higgs boson with a mass of 125 GeV, is measured to be $\mu = 1.01 \pm 0.31$. The dominant contribution to the total uncertainty is from statistical uncertainty, the theoretical uncertainty on the WW background estimation and the uncertainty on the identification of b jets. All results are consistent with the SM expectations and given in [3]. The p_0 curve obtained by including the results of the VH analysis [4] is shown in Figure 1 (right). The observed signal significance at $m_H = 125$ GeV is 4.0σ (expected 3.8σ). No evidence of an additional signal with Standard Model-like production cross-section and couplings is found in the range $260 < m_H < 642$ GeV [5].

References

[1] ATLAS Collaboration, Phys. Lett. B **716**, 1 (2012) [arXiv:1207.7214 [hep-ex], `http://arxiv.org/abs/1207.7214`]

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[3] ATLAS Collaboration, ATLAS-CONF-2013-030, `https://cds.cern.ch/record/1527126`

[4] ATLAS Collaboration, ATLAS-CONF-2013-075, `http://cds.cern.ch/record/1562933`

[5] ATLAS Collaboration, ATLAS-CONF-2013-067, `http://cds.cern.ch/record/1562879`