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Search for the Higgs boson in the $H \to WW \to \ell\nu jj$ decay channel in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

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Abstract. A search for a Higgs boson has been performed in the $H \to WW \to \ell\nu jj$ channel using 1.04 fb^{-1} of pp collision data at $\sqrt{s} = 7$ TeV recorded with the ATLAS detector at the Large Hadron Collider. No significant excess of events is observed over the expected Standard Model (SM) background and limits on the Higgs boson production cross-section are derived for a Higgs boson mass in the range 240 GeV $< m_{\text{H}} <$ 600 GeV. The best sensitivity is obtained for $m_{\text{H}} = 400$ GeV, where the 95% confidence level upper bound on the cross-section for $H \to WW$ production is 3.1 pb, or 2.7 times the Standard Model prediction.

Keywords. ATLAS; HIGGS.

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1. Introduction

In the Standard Model [1], a scalar field vacuum expectation value breaks the electroweak symmetry, gives masses to the W and Z bosons and manifests itself directly as the so-called Higgs boson. One of the primary goals of the Large Hadron Collider (LHC) is to search for Higgs boson production in high-energy proton–proton collisions. The Higgs boson is predominantly produced via gluon fusion ($gg \to H$) and to a lesser extent via vector boson fusion ($qq \to qqH$) at LHC energies. The direct searches at ATLAS and CMS exclude Higgs boson masses within the limits 141 GeV $< m_{\text{H}} <$ 476 GeV at 95% CL [2,3].

This note describes a search for a SM Higgs boson in the $H \to WW \to \ell\nu jj$ decay channel using the ATLAS detector at the LHC, using 1.04 fb^{-1} of pp collision data at a centre-of-mass energy $\sqrt{s} = 7$ TeV collected during 2011. A detailed description of the analysis can be found in [4]. The present search, based on the measured shape of the $m(\ell\nu jj)$ distribution, is restricted to 240 GeV $< m_{\text{H}} <$ 600 GeV, in order to ensure a smoothly varying non-resonant background. For $m_{\text{H}} \gtrsim 600$ GeV, the jets from $W \to jj$ decay begin to overlap due to the large W boost, and the natural width of the Higgs boson becomes large. A detailed treatment of these issues is beyond the scope of the present analysis. The best sensitivity in this analysis is expected for $m_{\mathrm{H}} \sim 400$ GeV. In this analysis, the distribution of the $\ell\nu jj$ invariant mass $m(\ell\nu jj)$, reconstructed using the charged-lepton neutrino invariant mass constraint $m(\ell\nu) = m(W)$ and the requirement that two of the jets in the event are consistent with a $W \to jj$ decay, is used to search for a Higgs boson signal.

2. Physics analysis and results

The ATLAS detector [5] is a multipurpose particle physics apparatus with forward–backward symmetric cylindrical geometry covering the pseudorapidity range $|\eta| < 2.5$ for track and $|\eta| < 4.9$ for jet measurements. Detailed Monte Carlo (MC) studies of the signal and backgrounds have been performed. The interaction of particles with the ATLAS detector is modelled using GEANT4. The effect of multiple pp interactions in the same bunch crossing (pile-up) at high luminosities is modelled by superimposing several simulated minimum-bias events on the simulated signal and background events at the generation stage. MC samples were generated with different pile-up levels and subsequently reweighted to match the pile-up conditions observed in the data.

For the events to be triggered, the presence of an electron candidate with transverse energy $E_{\mathrm{T}} > 20$ GeV or a muon candidate with transverse momentum $p_{\mathrm{T}} > 18$ GeV is required. Electron candidates are selected from clustered energy deposits in the EM calorimeter with an associated track and are required to satisfy a set of identification cuts [6] with an efficiency of $71 \pm 1.6\%$. Muons are reconstructed by combining tracks in the inner detector and muon spectrometer, with an efficiency of $92 \pm 0.6\%$ [6]. Jets are reconstructed from topological clusters using the anti-k_{t} algorithm with radius parameter $R = 0.4$. They are required to have $E_{\mathrm{T}} > 25$ GeV and $|\eta| < 4.5$. Jets are considered b-tagged if reconstructed displaced secondary vertex $SV0 > 5.85$ with 50% operating point. The event missing transverse momentum E_{T} is reconstructed starting from topological energy clusters in the calorimeters calibrated according to the type of the object to which they are associated.

For this analysis, events are required to have at least one vertex with at least three associated tracks having $p_{\mathrm{T}} > 400$ MeV. There must be exactly one reconstructed lepton candidate (electron or muon) with $p_{\mathrm{T}} > 30$ GeV. Events are required to have $E_{\mathrm{T}} > 30$ GeV to account for an unobserved neutrino from $W \to \ell\nu$ decay. There must be exactly two jets ($H + 0$ jet sample) or exactly three jets ($H + 1$ jet sample) with $E_{\mathrm{T}} > 25$ GeV and $|\eta| < 4.5$. Events are rejected if any of the jets is b-tagged. Two jets with invariant mass (m_{jj}) closest to the mass of the W boson are required to satisfy 71 GeV $< m_{jj} <$ 91 GeV. These two jets are taken as the W decay jets and are required to lie in the range $|\eta| < 2.8$, where the jet energy scale (JES) is best known to be better than $\pm$(4–8)%.

In order to reconstruct the invariant mass $m(\ell\nu jj)$ of the WW system, the mass constraint $m(\ell\nu) = m(W)$ is used, where the neutrino transverse momentum p_{T}^{ν} is taken from the event E_{T}. This equation can have real or complex solutions. In the case of complex solutions, the event is rejected. This requirement rejects 45% of background events in both data and MC, but only 36% of MC signal events with $m_{\mathrm{H}} = 400$ GeV. In the case of two real solutions, the solution with smaller neutrino longitudinal momentum $|p_z^{\nu}|$ is

Table 1. Expected and observed number of event at 1 fb^{-1}.

	$H(e\nu jj) + 0\text{j}$	$H(\mu\nu jj) + 0\text{j}$	$H(e\nu jj) + 1\text{j}$	$H(\mu\nu jj) + 1\text{j}$
W/Z+jets	10780 ± 290	13380 ± 470	6510 ± 250	7410 ± 670
QCD multijet	890 ± 24	256 ± 17	669 ± 25	212 ± 19
Top	170 ± 34	164 ± 33	489 ± 98	500 ± 100
Dibosons	397 ± 79	414 ± 83	161 ± 32	204 ± 41
Expected background	12240 ± 300	14210 ± 870	7830 ± 270	8330 ± 680
Data	11988	13906	7543	8250
Expected signal	14 ± 3.6	12 ± 3.1	18 ± 4.7	14 ± 3.6

taken, based on simulation studies. After this event selection, the background is expected to be dominated by W+jets production. Other important backgrounds are Z+jets, QCD multijets (MJ), top quark and diboson (WW, WZ and ZZ) production. Table 1 shows the observed and expected number of events for signal and background after this full selection.

No significant excess of events is observed over the expected Standard Model (SM) background, and limits on the SM Higgs boson cross-section has been set. MC is used to motivate but not to determine the background shape. A combination of MC and data-driven methods is used to understand the background yields better.

Figure 1 shows the 95% CL upper bound on the cross-section times branching ratio for Higgs production with respect to the Standard Model prediction as a function of m_H. The observed cross-section limit for $m_\text{H} = 400$ GeV is 3.1 pb, or 2.7 times the SM prediction, while the corresponding expected limits are 5.2 pb or 4.5 times the SM expectation. In the SM with an additional heavy fourth generation, the gluon fusion mechanism for the production of a Higgs boson is expected to be substantially enhanced. Within the four-generation context, a Higgs boson is excluded at 95% CL by the present data over the range $m_\text{H} = 310$–430 GeV.

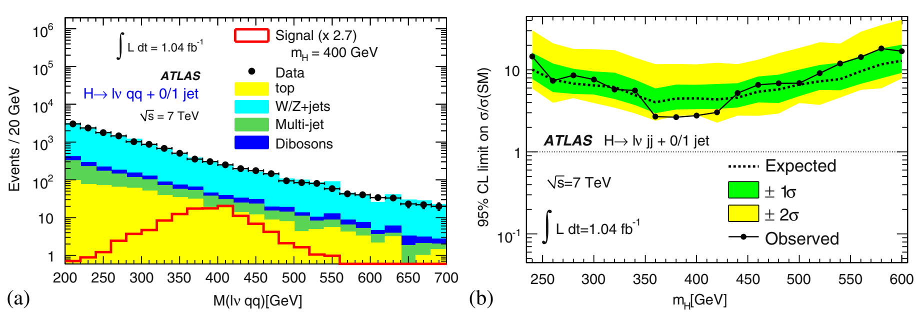

Figure 1. (**a**) The reconstructed invariant mass $m(\ell\nu jj)$. The expected contribution from Higgs boson decays for $m_\text{H} = 400$ GeV in the SM is also shown, multiplied by a factor of 2.7. (**b**) The expected and observed 95% confidence level upper limits on the Higgs boson production cross-section divided by the SM prediction for an integrated luminosity of 1.04 fb^{-1}.

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