Search for the Standard Model Higgs boson in the $H \to WW^{(*)}$ decay mode with 4.7 fb^{-1} of ATLAS data at $\sqrt{s} = 7$ TeV

Magda A. Chelstowska
on behalf of the ATLAS Collaboration

Radboud University Nijmegen and Nikhef, The Netherlands

Abstract. A Higgs boson search in the $H \to WW^{(*)}$ decay mode has been performed using 4.7 fb^{-1} of proton-proton collisions at a centre-of-mass energy of 7 TeV collected in 2011 with the ATLAS detector [1]. The search in the final state with two leptons and two neutrinos covers a broad Higgs boson mass range from 110 to 600 GeV. In addition, the high mass region from 300 to 600 GeV is explored by the semi-leptonic final state with a lepton, neutrino and two or more jets. Upper limits are derived on the cross section of a Standard Model Higgs boson.

Keywords: Standard Model, Higgs Boson, $H \to WW^{(*)}$, ATLAS, CERN
PACS: 14.80.Bn

INTRODUCTION

The Higgs Boson is the last predicted, but not yet discovered particle in the Standard Model (SM). The dominant Higgs production processes at the LHC are the gluon-gluon fusion (ggF, $gg \to H$) and vector-boson fusion (VBF, $qq' \to qq'H$). At the ATLAS experiment, the search strategy depends on the Higgs decay channel considered. The $H \to WW^{(*)}$ channel plays an important role in the searches as it is the most sensitive at the low and intermediate masses (125-190 GeV) with the di-leptonic decay ($WW^{(*)} \to \ell\nu\ell\nu$, $\ell = e/\mu$). With the current dataset, the semi-leptonic channel ($WW \to \ell\nu jj$), is not sensitive to the SM prediction but contributes to the Higgs boson sensitvity for a high mass Higgs boson with SM-like properties.

$H \to WW^{(*)} \to \ell\nu\ell\nu$ DECAY CHANNEL

$H \to WW^{(*)} \to \ell\nu\ell\nu$ decay channel is a very important channel as it has a high production cross section via ggF. It also is the most sensitive channel for Higgs boson masses between the LEP exclusion (114 GeV, [2]) and the electroweak fits (158 GeV, [3]). The final state of this decay channel consists of two high p_T isolated leptons and large $E_{\mathrm{T}}^{\mathrm{miss}}$. The $E_{\mathrm{T}}^{\mathrm{miss}}$ is the magnitude of $\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}$, the opposite of the vector sum of the transverse momenta of the reconstructed objects, including muons, electrons, photons, jets, and clusters of calorimeter cells not associated with these objects. The mass of the Higgs boson cannot be fully reconstructed because of the two neutrinos in the final state. This

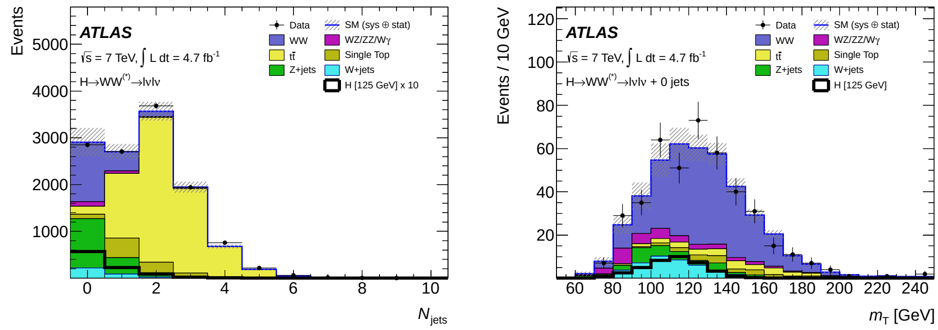

FIGURE 1. Jet multiplicity after the $E_{\mathrm{T}}^{\mathrm{miss}}$ cut (left) and m_{T} after the final event selection in H+0j channel (right) [4].

channel will therefore have poor mass resolution and larger backgrounds as compared with other multi-lepton channels.

Event selection

Higgs candidate events are pre-selected by requiring two oppositely charged leptons with p_{T} greater than 15 GeV (25 GeV for the leading lepton). After the selection on the leptons' invariant mass, $m_{\ell\ell}$, and $E_{\mathrm{T,rel}}^{\mathrm{miss}}$, as defined in [4], the analysis is separated into jet bin categories. As can be seen from Figure 1 (left), the background composition is quite different as a function of the jet multiplicity. Further cuts, tailored to reject the backgrounds and enhance the signal, are applied. In the case of the $e\mu + 0$ jets channel, which is the most sensitives, the p_{T} of the dilepton system ($p_{\mathrm{T}}^{\ell\ell}$) is required to be greater than 30 GeV. At the last stage, where the signal region is mostly dominated by the irreducible WW continuum, the topological cuts are applied. They exploit the spin correlations in the $WW^{(*)}$ system arising from the Higgs boson's spin-0 nature ($m_{\ell\ell} <$50 GeV and the opening angle between the leptons $\Delta\phi_{\ell\ell} <$1.8 radians).

After all the criteria have been applied, a fit of the m_{T} distribution is performed (see Figure 1 (right)). The transverse mass is a key variable in the $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ analysis and it is defined as $m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T}}^{\ell\ell} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - |\mathbf{p}_{\mathrm{T}}^{\ell\ell} + \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}|^{\mathbf{2}}}$, where $E_{\mathrm{T}}^{\ell\ell} = \sqrt{|\mathbf{p}_{\mathrm{T}}^{\ell\ell}|^2 + m_{\ell\ell}^2}$.

Background estimation

The backgrounds in the $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ channel include the irreducible SM WW continuum, top and Z/γ^*+jets which are all estimated using partially data-driven techniques based on normalising the Monte Carlo (MC) predictions to the data in control regions. The W+jets is fully estimated from data. The same sign diboson background (W$\gamma^{(*)}$/WZ/ZZ) is estimated using MC simulation only.

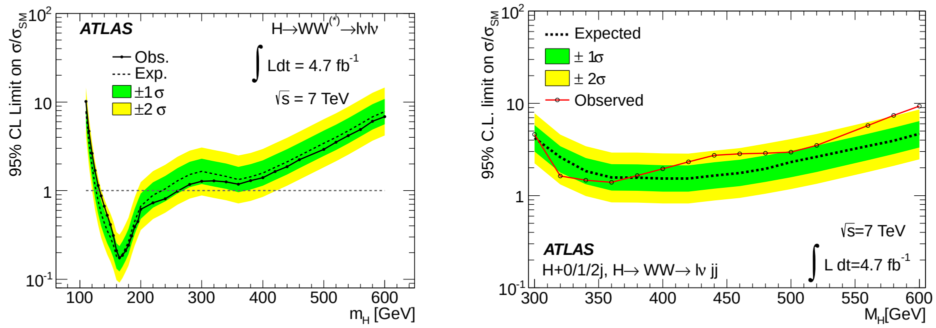

FIGURE 2. Observed (solid) and expected (dashed) 95% CL upper limits on the Higgs boson production cross section as a function of m_{H} and normalised to the SM cross section in the $H \to WW^{(*)} \to \ell\nu\ell\nu$ (left) [4] and $H \to WW^{(*)} \to \ell\nu jj$ (right) [5] channels.

Results

No significant excess of events beyond the background expectation is observed. Figure 2 (left) shows, the observed and expected cross section upper limits at 95% confidence level (CL), as a function of m_{H} and normalised to the SM cross section. The limits exclude a SM Higgs boson with a mass in the range from 133 GeV to 261 GeV at 95% CL, while the expected exclusion range in the absence of a signal is 127 GeV $\leq m_{\mathrm{H}} \leq$ 233 GeV.

$H \to WW \to \ell\nu jj$ DECAY CHANNEL

For $m_{\mathrm{H}} > 160$ GeV, where two W bosons are on-shell, the search for $H \to WW \to \ell\nu jj$ produced in association with zero, one or two jets, becomes interesting. This decay mode has a larger branching ratio but it also suffers from a higher W+jets background. The final state consists of one lepton, two jets coming from W decay and the $E_{\mathrm{T}}^{\mathrm{miss}}$. The distribution of $\ell\nu jj$ invariant mass, reconstructed using the $\ell\nu$ mass constraint $m(\ell\nu) = m(W)$ and requirement that two of the jets are consistent with the $W \to jj$ decay, is used to test for the Higgs signal presence. As can be seen from the Figure 2 (right), this channel is not sensitive to SM Higgs production but contributes to the Higgs boson sensitivity for a high mass Higgs boson with SM-like properties and is the first search for VBF production in this decay channel [5].

REFERENCES

1. The ATLAS Collaboration, *JINST* **3**, S08003 (2008).
2. LEP Working Group for Higgs boson searches **565**, 61 (2003), `hep-ex/0306033`.
3. The ALEPH, DELPHI, L3, OPAL, SLD, CDF, and DØ Collaborations, and the LEP Tevatron SLD Electroweak Working Group, CERN-PH-EP-2010-095 (2010), `arXiv:1012.2367`.
4. The ATLAS Collaboration, *arXiv:1206.0756, to appear in Phys. Lett. B* (2012).
5. The ATLAS Collaboration, *arXiv:1206.6074, submitted to Phys. Lett. B* (2012).