Associated WH-Production in the Leptonic Decay Channel at ATLAS

B. Ruckert, J. Ebke, J. Elmsheuser, T. Langer, M.P. Sanders, and D. Schaile

The standard model of particle physics describes the electroweak and the strong interactions of elementary particles exceedingly well. However the theory itself does not include mass terms for the particles. This problem can be solved by introducing a symmetry breaking of a scalar field which leads to a physical particle, the Higgs boson.

According to the standard model (SM), at LHC a Higgs boson can be produced in several ways (e.g. in gluon-gluon fusion (fig. 1) or vector boson fusion, VBF). This analysis studies the production of a Higgs boson in association with a W boson, where the Higgs boson subsequently decays into a pair of W bosons.

Two independent analyses are performed, the final states studied consist either of exactly two leptons (e, μ) with the same charge plus jets or of three leptons (e, μ) and neutrinos [1]. The production cross section of this process is small compared to the dominating channels, gg fusion and VBF. We investigate the following mass points for a Higgs boson for a centre of mass energy $\sqrt{s} = 14$ TeV: $m_H = 130$ GeV, 150 GeV, 170 GeV and 190 GeV. The NLO production cross sections are 1094.9 fb, 683.9 fb, 554.7 fb and 377.2 fb, respectively.

This analysis relies on counting signal and background events, because no mass peak can be reconstructed. Understanding the following backgrounds is crucial for this analysis. A very important background is WZ production, as both vector bosons can decay leptonically and hence fake a signal consisting of two or three leptons. ZZ production is another interesting vector boson process: if both Z bosons decay leptonically a signal will be faked – especially if one lepton is not reconstructed, as this adds to the missing transverse energy. $t\bar{t}$ production is a background process with a large production cross section, similarly the W+jets processes. The latter are of interest because a jet could be misidentified as lepton and hence fake a signal. These processes are studied with full and fast detector simulation.

Firstly, we describe the same sign analysis ($WH, H \rightarrow WW \rightarrow l\nu\, l\nu$+jets). Initially, a preselection is done, which separates interesting from badly reconstructed events through a set of quality criteria. Thereafter we require exactly two leptons with the same charge. This means one lepton from the associatively produced W boson decay and the other lepton originates from one of the W bosons of the Higgs decay. Through this requirement SM backgrounds with a huge cross section, e.g. $Z \rightarrow \mu\mu$ are discriminated. A cut on the transverse momenta p_T of the two leptons is applied at $p_T^{1;2} \geq 35$ GeV. The third W boson is required to decay into jets, from which we calculate the invariant mass. For diboson backgrounds this mass is likely to be different from the true W boson mass and we reject events outside the mass window 60 GeV $< m_W <$ 95 GeV. The Higgs boson is a spin 0 particle, which implies an angular correlation between its decay products. As we can expect one high energetic jet from the Higgs decay, we calculate its distance in the ϕ plane to all leptons and neglect events with a distance $\Delta\phi > 1.1$. The $t\bar{t}$ background has a lot of jet activity, hence we apply a cut on the transverse sum H_T of the jet energies rejecting $H_T > 140$ GeV. Finally, a cut on the missing transverse energy is applied. From the signal we expect missing transverse energy from the neutrinos of the W boson decays and reject events with a missing transverse energy of less than 40 GeV. Studies showed only little influence of the different Higgs boson masses on the selection, hence we chose the same cuts for all masses. Table 1 summarises the results of the cutflow for signal and background events.

	WH	WZ	ZZ	$Wb\bar{b}$	$t\bar{t}$
Preselection (2l)	479.5	10740	7044	101	11530
after cuts	12.8 ± 0.4	0.9 ± 0.9	0.8 ± 0.5	1.7 ± 1.2	3.5 ± 2.5

Table 1: Event selection for the signal and selected backgrounds for the 2 lepton analysis for $\mathcal{L} = 30$ fb^{-1} and $m_H = 170$ GeV.

Now we describe the fully leptonic analysis ($WH, H \rightarrow WW \rightarrow 3l3\nu$). The same preselection as for the two leptonic analysis applies, but we require at least three leptons. The third lepton must have a $p_T \geq 22.5$ GeV. Using the spin correlation we cut on $\Delta\phi < 1.1$ of the two OSSF leptons. From the signal we do not expect hard jets, therefore we reject events with $p_T^{jet1} \geq 60$ GeV and $p_T^{jet2} \geq 30$ GeV. One of the largest irreducible backgrounds is the WZ diboson process. The most important cut for the discrimination of this background is a cut on the dilepton mass of two opposite sign, same flavour leptons. We cut in a window around the true Z boson mass: $m_Z \pm 20$ GeV. Finally a cut on the missing transverse energy is applied. It must be larger than 45 GeV, as shown in fig. 1. Table 2 shows the results of the cutflow for signal and background events of the 3 lepton analysis.

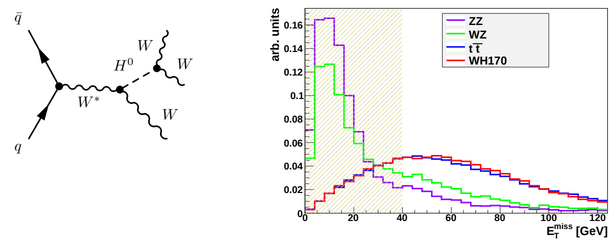

Fig. 1: Left: Feynman diagram for the WH mechanism. Right: missing transverse energy, 3 leptonic analysis.

Both channels are suitable for a discovery of the the Higgs boson with $\mathcal{L} = 30$ fb^{-1} and for a thorough understanding of the Higgs process [2].

	WH	WZ	ZZ	$Wb\bar{b}$	$t\bar{t}$
Preselection (3l)	101.6	1585	659	5.2	378
after cuts	23.8 ± 0.7	1.9 ± 1.4	0 ± 0.3	0 ± 2.1	7.0 ± 3.5

Table 2: Event selection for the signal and selected backgrounds for the 3 lepton analysis for $\mathcal{L} = 30$ fb^{-1} and $m_H = 170$ GeV.

References

[1] G. Aad *et al.*, Expected Performance of the ATLAS Experiment Detector, Trigger, Physics, CERN, Geneva, 2008, CERN-OPEN-2008-020

[2] B. Ruckert, Search for a Standard Model Higgs Boson Produced in Association with a W Boson in the $H \rightarrow WW$ Final State, to be published