Associated WH-Production in the Leptonic Decay Channel at ATLAS

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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, a Higgs boson can be produced in several ways (e.g. in gluon-gluon fusion 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, see fig. 1. The final state studied consists of three leptons (e, μ) and missing transverse energy from the $W \to l\nu$ decays [1].

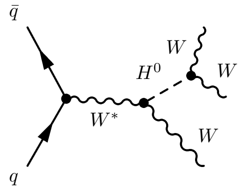

Fig. 1: Associated production of a Higgs boson and a W boson.

The production cross section of this process is small compared to the dominating channels, gg fusion and VBF. This analysis uses a Higgs mass of $M_H = 170$ GeV, because for this value the branching ratio $H \to WW$ is near to 1 and, on the other hand, the branching ratio of the decay $H \to ZZ$ has a minimum. This leads to a $\sigma \cdot BR = 554.7$ fb $\cdot\, 0.965 = 535.6$ fb in Next to Leading Order calculation. This Monte Carlo based analysis uses fully simulated and reconstructed events, which are limited by the available statistics. Therefore we require at least two same sign leptons instead of strictly three leptons in order to increase the remaining statistics after the subsequent cuts.

In the next paragraph we will describe the relevant backgrounds for this study. 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. Fake rate and charge flip probabilities are critical for this same sign analysis, especially because of the huge production cross section of the W+jets processes. An obvious background, WW QCD production, is not of interest because of the same sign requirement. The next paragraph describes the steps of the cut based analysis. Initially, trigger decisions are checked to separate uninteresting events. Then several preselection cuts are applied in order to reduce badly reconstructed events. Starting from this reduced sample a cut on the transverse momenta (p_T) of the leptons is applied, as well as a same sign requirement in case of two reconstructed leptons. The p_T cuts are as follows: in case of two reconstructed same sign leptons, $p_T^1 \geq 30$ GeV and $p_T^2 \geq 25$ GeV and if more than two leptons have been reconstructed an additional cut on the third lepton is applied, $p_T \geq 22.5$ GeV. All leptons are required to be within a pseudorapidity range of $|\eta| < 2.7$. The p_T cuts efficiently reduce the $t\bar{t}$ and $Wb\bar{b}$ backgrounds, because the leptons have a softer p_T distribution. After this cut, a veto on the Z boson mass of $m_Z \pm 15$ GeV is applied. This mainly reduces the backgrounds including a Z boson, namely the ZZ and WZ processes. In order to reduce the large $t\bar{t}$ background a cut on the sum of the transverse energies of the reconstructed jets is applied, $H_T = \sum E_T^{\text{jet}} \leq 100$ GeV. As we expect the W bosons from the signal to decay leptonically, mostly soft jets should occur. On the other hand, a top quark mainly decays hadronically, hence leading to harder jets.

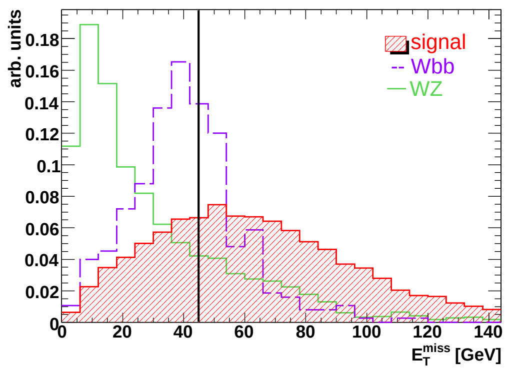

Fig. 2: Distribution of missing transverse energy for the signal and selected backgrounds.

Finally, a cut on the missing transverse energy of $E_T^{\text{miss}} \geq 45$ GeV is applied, see fig. 2. For the signal we expect a high part of missing transverse energy because of three neutrinos from the W boson decays. Especially the W+jets backgrounds possess a lower missing transverse energy spectrum, which makes this a useful cut to reduce another big fraction of this large cross section background.

	WH	WZ	ZZ	$Wb\bar{b}$	$t\bar{t}$
presel.	538.7	10644.9	8128.4	1109.1	393782
after cuts	141.1 ± 1.9	239.2 ± 33.5	10.4 ± 3.7	5.5 ± 2.1	162 ± 61

Table 1: Event selection for the signal and selected backgrounds. Event numbers are normalised to 30fb^{-1} and include statistical errors.

Table 1 lists the efficiencies of the cuts described above, not including systematical errors, which are currently studied. Combining the results for the signal and the background processes yields a significance of $\sigma = \frac{S}{\sqrt{B}} = 6.9$. Next steps before the data taking period include further study of the background with increased statistics, of triggers and systematical errors.

References

[1] CSC Note, Search for a SM Higgs Boson in the ttH and WH Channel with $H \to WW$ in the Final State, to be published