Standard Model Higgs Boson Searches at ATLAS

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Abstract. An overview of the Standard Model Higgs Boson discovery potential of the ATLAS experiment at the Large Hadron Collider (LHC) is given. The main observable channels and their discovery potential will be reviewed, together with the experimental aspects which are most relevant for their observation. A final review of the signal significances expected for the ATLAS experiment will be given.

1. The ATLAS Experiment
The ATLAS experiment is a multi-purpose experiment designed for the observation of a wide span of physics signatures, in the p-p collisions at 14 TeV center of mass energy of the Large Hadron Collider (LHC). A full description of the ATLAS and of its physics performance can be found in [1]. The experiment is due to start data taking during 2008, and one of its primary goals will be the search for the Standard Model (SM) Higgs boson.

2. Standard Model Higgs boson production and decay channels
The main SM Higgs boson production mechanism at the LHC will be the gluon-gluon fusion, while the $q\bar{q}\rightarrow q\bar{q}H$ process, or Vector Boson Fusion (VBF), will account for about 20% of the total cross section. Next-to-leading order (NLO) corrections are of major relevance in particular for the gluon-gluon fusion production, with K-factors ranging from 1.7 to 2.0. A review of Higgs production cross sections can be found in [2],[3].

3. Main search channels and experimental aspects
In this section a few search channels for the Standard Model Higgs boson will be reviewed, together with the most relevant experimental aspects related to their observation.

3.1. $H\rightarrow \gamma\gamma$
This channel is relevant for Higgs masses below 150 GeV. The main background is the irreducible $\gamma\gamma$ continuum, and other backgrounds are $\gamma$/jet or jet/jet events, the latter being rejected mainly through isolation cuts and $\pi_0$ rejection. The normalization of the background can be done through the fit of the sidebands with respect to the signal peak. Key points for this channel are the electromagnetic calorimeter resolution and the determination of the primary interaction vertex, which defines the photons direction. At low luminosity ($2\times10^{33}$ cm$^{-2}$s$^{-1}$), the primary vertex is fitted using the tracks from the underlying event, with a resolution, along the direction of the beam, of 40 $\mu$m. At high luminosity ($10^{34}$ cm$^{-2}$s$^{-1}$), with in average 23 interaction vertexes for each bunch crossing, the possibility of reconstructing the photon direction using the
calorimeter information alone becomes more relevant. The vertex position resolution that can be obtained at ATLAS from the reconstruction of the photon direction done using only the EM calorimeter is 1.6 cm. The expected signal significance that can be obtained in this channel, computed for NLO cross sections, and for an Higgs mass of 120 GeV, is 6.3.

3.2. $H \rightarrow ZZ^* \rightarrow 4$-leptons

Key points for this channel are optimal efficiency and resolution in the reconstruction of electrons and muons. Main background is the irreducible $ZZ^*/\gamma^* \rightarrow 4$-leptons, while other reducible backgrounds are $Zb\bar{b}$ and $t\bar{t}$. The reducible backgrounds can be rejected through cuts on the lepton isolation and impact parameter significance. Also for this channel the Higgs mass peak can be reconstructed, and background shape and normalization can be inferred from the data, through the fit of the sidebands of the mass peak. This channel provides a rather clean signature over the full possible range of Higgs masses, with a statistics smaller than for other channels. For Higgs masses above 200 GeV, this channel becomes the “golden” channel for SM Higgs searches.

3.3. VBF, $H \rightarrow \tau\tau$

The events with a $Z$ boson and two jets are the main background for this channel. This background can be rejected, in case of QCD production, by vetoing central jets, and in case of Electro-Weak production, by reconstructing the $\tau\tau$ mass. The Higgs mass is reconstructed with the collinear approximation for the $\tau$ decays. With this approximation, the mass resolution that can be obtained is about 10%, and it is dominated by the resolution on the $E_T^{miss}$. For an Higgs mass of 130 GeV, and after an integrated luminosity of 30 fb$^{-1}$, the signal significance that ATLAS can reach is 4.4 in the $\tau\tau \rightarrow lH$ channel only. The expected significance becomes 5.7 when adding the $\tau\tau \rightarrow ll$ channel.

3.4. VBF, $H \rightarrow WW$

This channel is one of the most relevant for Higgs masses between 125 and 190 GeV. The two decay channels that can be taken into account are $WW \rightarrow l\nu jj$ and $WW \rightarrow l\nu l\nu$. The main

![Figure 1.](image1.png)  
**Figure 1.** Transverse mass distribution in the VBF $H \rightarrow WW \rightarrow l\nu l\nu$, for an Higgs mass of 120 GeV, for Higgs signal and background processes.

![Figure 2.](image2.png)  
**Figure 2.** Transverse mass distribution in the VBF $H \rightarrow WW \rightarrow l\nu l\nu$, for an Higgs mass of 160 GeV, for Higgs signal and background processes.
background processes are $tt+\text{jets}$, $W(Z)+\text{jets}$ and $\text{WW(ZZ)+jets}$. The Higgs mass peak cannot be reconstructed for this channel, and the distribution of the transverse mass, calculated as $m_T = \sqrt{2P_T^f E_{T}^{\text{miss}} (1 - \cos\Delta\phi)}$, is used instead. In figures 1 and 2 the transverse mass distribution is shown, for the $H\rightarrow\text{WW} \rightarrow l\nu l\nu$ and for Higgs masses of 120 and 160 GeV, respectively. The signal significance for the $H\rightarrow\text{WW} \rightarrow l\nu l\nu$ is greater than 5 over the full mass range from 125 to 190 GeV, for $30 \text{ fb}^{-1}$.

3.5. $ttH$, $H\rightarrow b\bar{b}$
The associated production of a Higgs and a $t\bar{t}$ pair, with the Higgs decaying to $b\bar{b}$ is a potential discovery channel for light Higgs. The main reducible backgrounds are $t\bar{t}(+\text{jets})$, whose rejection strongly relies on b-tagging, and $\text{WW}b\bar{b}jj$, whose signature is $W+6\text{ Jets}$. The irreducible background $ttb\bar{b}$ can be rejected exploiting the kinematic differences with respect to the signal, through the use of multivariate methods. The expected signal significance for this channel, calculated with LO cross sections, is 2.8, for $M_H=120\text{ GeV}$ and an integrated luminosity of $30 \text{ fb}^{-1}$.

4. Expected significances
The expected significances for the main search channels are shown in Figure 3, as a function of the Higgs mass. The significances shown are computed with LO cross sections, and for $30 \text{ fb}^{-1}$. The discovery potential is already good with $10 \text{ fb}^{-1}$ of integrated luminosity, provided that detector performance and background systematics will be under control.

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