Searches for the SM Higgs boson with ATLAS

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1 Introduction

The search for the Standard Model (SM) Higgs boson is one of the major goals of the LHC. At 95% Confidence Level (CL), direct searches at the LEP collider exclude the SM Higgs boson mass (m_H) hypothesis below 114.4 GeV [1]. Combined analysis of the Fermilab Tevatron data from CDF and D0 yields a 95% CL exclusion of a Higgs boson in the mass region $158 < m_H < 175$ GeV [2]. Searches at ATLAS for the SM Higgs boson have been performed with 35 to 40 pb^{-1} of data recorded in 2010 or 209 pb^{-1} of data recorded in 2011 at 7 TeV proton-proton center-of-mass energy.

2 Search for the SM Higgs boson

$H \to \gamma\gamma$ [3]: This decay mode provides a very good sensitivity to observe Higgs boson production in the mass range $110 < m_H < 140$ GeV. The analysis based on 38 pb^{-1} of data recorded in 2010 is used for the combination of all decay channels in the search for the SM Higgs boson. The analysis based on 209 pb^{-1} of 2011 data is also presented. Irreducible backgrounds originate from the continuum $q\bar{q}, gg \to \gamma\gamma$, and reducible background are mostly due to γ-jet and jet-jet events with one or more jets misidentified as photons. The number of observed events is compatible with the background expectation, see Figure 1. At 95% CL, the resulting observed (expected) limit for a Higgs boson mass of 115 GeV is $4.2 \times \sigma_{SM}$ [1] ($6.5 \times \sigma_{SM}$).

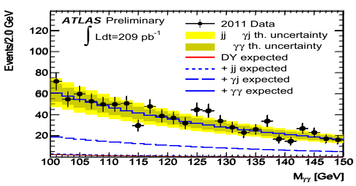

Figure 1: Diphoton invariant mass distributions for data and the background predictions in the $H \to \gamma\gamma$ search. The two yellow bands depict the total uncertainty on the prediction and the uncertainty on the reducible background only.

$H \to WW^* \to l\nu l\nu$ [4]: This decay mode is expolited to look for the SM Higgs boson in the range $120 < m_H < 200$ GeV using 35 pb^{-1} of 2010 data. The zero jet and the one jet analysis are dominated by the gluon fusion process, and the two

[1] σ_{SM} represents the Standard Model cross section.

jets analysis is dominated by vector boson fusion process. The distribution of the transverse mass after all cuts for the zero, one and two jets analysis are shown in Figure 2. The major background contributions come from the irreducible SM WW and reducible W/Z+jets and top quark production. All background processes are measured using control regions or validated with the data. No evidence for a SM-like Higgs boson is found. For a Higgs boson mass of 160 GeV, the observed (expected) exclusion limit is 1.2 $\times$ σ_{SM} (2.4 $\times$ σ_{SM}) at 95% CL.

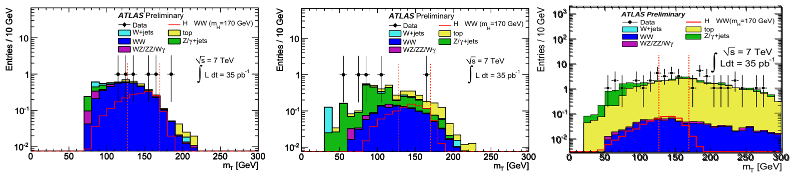

Figure 2: Observed transverse mass distributions compared to the background predictions with the zero (left), one (middle) and two jets (right) analysis in the $H \to WW^* \to l\nu l\nu$ search.

$H \to WW \to l\nu qq$ [5]: The analysis is performed using 35 pb^{-1} of 2010 data. Figure 3 shows the distributions of the invariant mass $m_{l\nu qq}$ for the zero jet and one jet analysis. The dominant background comes from W+jets and top quark production, with minor background from WW, WZ, Z+jets and QCD dijets. Since no significant excess is observed over the expected background, limits on the Higgs production cross section are derived in the mass range $200 < m_H < 600$ GeV. For a Higgs boson mass of 400 GeV, the observed (expected) exclusion limit is 11.2 $\times$ σ_{SM} (10.8 $\times$ σ_{SM}).

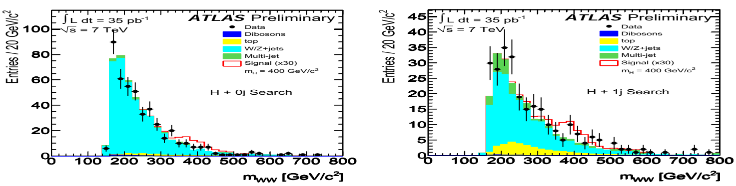

Figure 3: Distributions of the invariant mass $M_{l\nu qq}$ with zero jet (left) and with one jet (right) analysis in the $H \to WW \to l\nu qq$ search.

$H \to ZZ^* \to llll$ [6]: This decay mode is one of the cleanest decay modes to search for a SM Higgs boson at the LHC, with only SM irreducible ZZ^* process as a significant background. Background measurements, based on the data-driven techniques, are found to be in agreement with the Monte Carlo predictions. The mass distribution of $4l$ events selected before applying the lepton impact parameter and isolation requirements is shown in the left-hand plot of Figure 4. No candidate events is retained after all selection criteria in 40 pb^{-1} of 2010 data. The highest sensitivity in the mass range $130 < m_H < 600$ GeV is obtained for Higgs boson mass of about 220 GeV where the observed (expected) upper limit is $24 \times \sigma_{SM}$ ($25 \times \sigma_{SM}$).

$H \to ZZ \to llqq$, $ll\nu\nu$ [7]: Using 35 pb^{-1} of data recorded in 2010, the searches are performed in $H \to ZZ \to llqq$, $ll\nu\nu$ decay modes which have substantially larger branching ratios but also larger backgrounds compared to the $4l$ decay. For the analysis with $llqq$ final states, the mass distribution is shown in the middle plot of Figure 4, and the dominant background is Z+jets production which is estimated in M_{jj} sidebands. The $ll\nu\nu$ analysis has contributions from W/Z+jets, $t\bar{t}$ and di-boson production, and the dilepton transverse mass distribution is shown in the right plot of Figure 4. Except for di-boson production which is estimated from simulation, all background contributions are measured by means of control samples. Since no significant excess beyond the estimated background is observed, the combined limits are extracted in the mass range $200 < m_H < 600$ GeV. At 95% CL, the combined observed (expected) limit for a Higgs boson mass of 200 GeV is $3.5 \times \sigma_{SM}$ ($15.5 \times$ $\times\ \sigma_{SM}$).

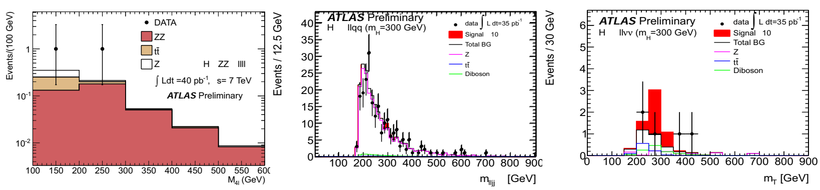

Figure 4: Left: Distribution of M_{4l} in the $H \to ZZ^* \to llll$ search. Middle: Distribution of M_{lljj} in the $H \to ZZ \to llqq$ search. Right: Distribution of dilepton transverse mass, m_T, in the $H \to ZZ \to ll\nu\nu$ search.

Based on 35 to 40 pb^{-1} of 2010 data, several Higgs boson decay channels: $H \to \gamma\gamma$, $H \to WW^* \to l\nu l\nu$, $H \to WW \to l\nu qq$, $H \to ZZ^* \to llll$, $H \to ZZ \to llqq, ll\nu\nu$, where $l = e, \mu$, are combined in the Higgs mass range of $110 \sim 600$ GeV [8]. The test statistic is based on the profile likelihood ratio described in [9]. The exclusion limits are set using a Power Constrained Limit (PCL) technique [10]. Limits using the CL_s technique [11] are also calculated for comparison with the Tevatron and LEP results. The higheset sensitivity is achieved for a Higgs boson mass of 160 GeV where the observed (expected) exclusion limit is $1.6 \times \sigma_{SM}$ ($2.3 \times \sigma_{SM}$).

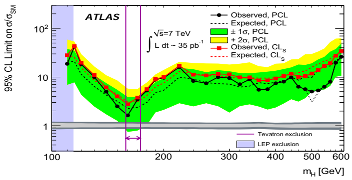

Figure 5: Combined limit on the production cross section of a SM-like Higgs bosons divided by expectation in the Standard Model.

3 Conclusion

Searches for the SM Higgs boson in various channels were performed using 35 to 40 pb^{-1} of 2010 data or 209 pb^{-1} of 2011 data, covering a mass range $110 < m_H < 600$ GeV. No evidence for a SM Higgs boson is found as compared to predicted background rates. So far mostly simple cut based selections have been performed and the major background contributions have been determined with data-driven methods. In the search of $H \to \gamma\gamma$ an exclusion limit down to $4.2 \times \sigma_{SM}$ has been achieved. The $H \to WW$ search allows to exclude a production rate of $1.2 \times \sigma_{SM}$ at $m_H = 160$ GeV. The search for $H \to ZZ$ decay yields an exclusion limit down to $3.5 \times \sigma_{SM}$ at $m_H = 200$ GeV. The combined exclusion limits are computed based on 2010 data, and the best exclusion limit is $1.6 \times \sigma_{SM}$ at $m_H = 160$ GeV.

References

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