Searches for a heavy Higgs boson at ATLAS

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1 Introduction

The Higgs mechanism is the source of electroweak symmetry breaking in the Standard Model of particle physics (SM), providing mass to the W and Z vector bosons. The Higgs boson is a physical manifestation of the scalar Higgs field. Global fits to electroweak measurements provide indirect constraints on the unknown mass of the Higgs boson (m_H), predicting $m_H = 94^{+30}_{-23}$ GeV [1]. A high mass Higgs boson, $m_H \geq 200$ GeV, is therefore highly disfavoured by indirect constraints however such measurements should be complemented by direct searches. Direct Higgs boson searches made at LEP excluded $m_H \leq 114.4$ GeV [2], while the combined Tevatron searches exclude the ranges 100 GeV $\leq m_H \leq$ 106 GeV and 147 GeV $\leq m_H \leq$ 179 GeV [3]. The high mass range therefore remains the domain of the LHC experiments. The search for high mass Higgs boson with the ATLAS detector with data up to 4.8 fb^{-1} of data taken at $\sqrt{s} = 7$ TeV at the LHC is discussed.

2 The ATLAS Detector

The ATLAS Detector [4] is a large multi-purpose detector at the LHC. ATLAS has a forward-backwards cylindrical geometry, providing comprehensive coverage around the interaction point. The high granularity inner tracking detector (ID) immediately surrounds the interaction point, covering $|\eta| < 2.5$. The ID is contained within a thin superconducting solenoid providing a 2 T axial magnetic field. A lead/liquid-argon (LAr) sampling electromagnetic calorimeter encloses the solenoid. The hadronic calorimeters follow, comprised of LAr calorimeters in the end-cap and forward regions and iron/scintillating tile calorimeters in the barrel. The muon spectrometer encompasses the whole detector contained inside the magnetic field of three large toroidal magnets. A three level trigger system selects events to be recorded for offline analysis.

3 Individual Search Channels

Higgs boson searches at ATLAS make use of varied production and decay channels. In the high mass regime, the dominant decay processes are to two on-shell vector bosons. The following search channels were analysed with the data corresponding to 4.7-4.8 fb^{-1} of 7 TeV ATLAS data.

3.1 $H \to ZZ \to llll$

The decay channel to four leptons provides a striking and low background environment in which to search for the Higgs boson. The search has been performed by looking for a resonant peak in the m_{4l} distribution. This channel has sensitivity to the full Higgs mass range of 110 GeV to 600 GeV. In the high mass range, the limits from this channel, shown in Figure 1, show two deviations from the background: a 2.2σ deviation at 244 GeV and a 2.1σ deviation at 500 GeV. Neither excess remains significant after the look-elsewhere effect is taken into account. In high Higgs mass regions this channel excludes at 95 % C.L. a SM Higgs mass in three ranges: 182 GeV $< m_H <$ 233 GeV, 256 GeV $< m_H <$ 265 GeV and 268 GeV $< m_H <$ 415 GeV [5].

3.2 $H \to ZZ \to ll\nu\nu$

The presence of two neutrinos in the final state leads to the distinctive signature of large missing transverse energy, $E_{\mathrm{T}}^{\mathrm{miss}}$, combined with two high p_T leptons. As the final state cannot be fully reconstructed, the search is performed by searching for an excess in the transverse mass distribution. Separate selections are made in the low and high mass regions. In the high mass region where the Z bosons become partially boosted, an additional cut is made on the maximum opening angle between the two leptons. The results for this channel, ranging from 200 GeV to 600 GeV, show no significant excesses and exclude at 95 % C.L. a SM Higgs in the range 319 GeV $< m_H <$ 558 GeV [6].

3.3 $H \to ZZ \to llq\overline{q}$

The complete final state can be reconstructed in this channel, an excess of events in the m_{lljj} distribution is searched for. A cut on the opening angle between the leptons once again takes advantage of the moderately boosted Z bosons present in the high mass region. The analysis is split into samples containing ≥ 2 b-tagged jets and < 2 b-tagged jets. In the former a large reduction in the Z+jets background is observed. No significant excesses are seen and this channel excludes at 95 % C.L. a Standard Model Higgs in two small ranges: 300 GeV $< m_H <$ 310 GeV and 360 GeV $< m_H <$ 400 GeV [7].

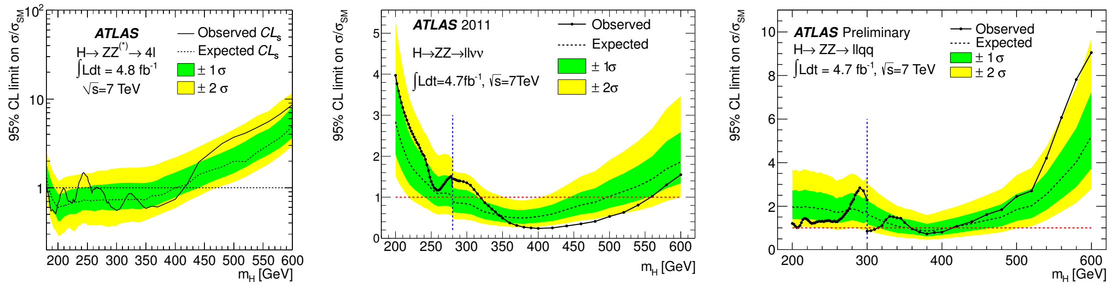

Figure 1: The 95 % C.L. limits on σ/σ_{SM} for the $H \to ZZ \to llll$ (left), $H \to ZZ \to ll\nu\nu$ (middle) and $H \to ZZ \to llqq$ (right) channels.

3.4 $H \to WW \to l\nu l\nu$

The full mass range is covered by this channel, however the presence of the neutrinos in the final state causes it to have a poor mass resolution. The analysis uses the transverse mass of the $l\nu l\nu$ system to search for an excess of events and is split into 0, 1 and ≥ 2 associated jet categories. This channel excludes at 95 % C.L. a SM Higgs boson with 133 GeV $< m_H <$ 261 GeV [8]. A multivariate boosted decision tree (BDT) analysis has been performed which extends the exclusion in the high mass regime to 130 GeV $< m_H <$ 281 GeV [9].

3.5 $H \to WW \to l\nu q\bar{q}$

This analysis searches for an excess in the $m_{l\nu q\bar{q}}$ invariant mass distribution. It covers a mass range above 300 GeV using three separate jet channels: 0, 1 or ≥ 2 associated jets. The expected sensitivity of this channel is around two times the SM Higgs production cross section; no excesses of events are observed in the data [10].

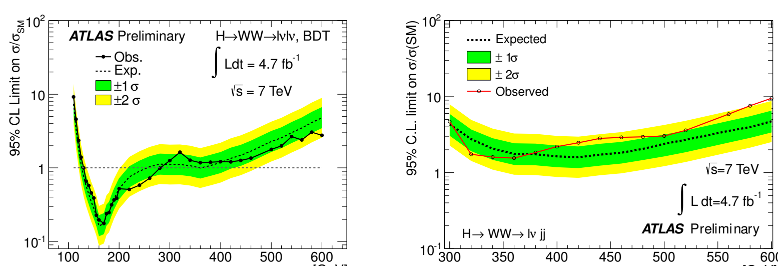

Figure 2: The 95 % C.L. limits on σ/σ_{SM} for the $H \to WW \to l\nu l\nu$ BDT (left), $H \to WW \to l\nu q\bar{q}$ (right) channels.

4 Combination

The search channels presented here have been combined to provide an overall ATLAS Higgs search result. The combined limits exclude the SM Higgs boson at 95 % C.L. in the mass range 129 GeV $< m_H <$ 539 GeV[11].

5 Summary

Searches for a high mass SM Higgs boson in various diboson decay channels based on 4.7-4.8 fb^{-1} of data recorded by the ATLAS detector at $\sqrt{s}$ = 7 TeV during the 2011 run have been presented. Individually, the $H \to ZZ$ channels and the $H \to WW \to l\nu l\nu$ channel exclude parts of the SM Higgs mass range above 200 GeV. When combined, the SM Higgs boson is excluded at the 95 % C.L. in the mass range 129 GeV $< m_H <$ 539 GeV. This represents a significant exclusion of the presence of a high mass SM Higgs boson. The largest upward deviations from the background-only hypothesis are observed in the $H \to ZZ \to llll$ channel, for m_H = 244 GeV and 500 GeV with local significances of 2.2 and 2.1 standard deviations, respectively. Once the look-elsewhere effect is considered, neither of these excesses are significant.

References

[1] The GFitter Group, Eur. Phys. J. **C72**,2003 (2012).

[2] ALEPH, DELPHI, OPAL and OPAL Collaborations, Phys. Lett. B**565**, 61-75 (2003).

[3] CDF and D0 Collaborations, FERMILAB-CONF-12-065-E

[4] ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003

[5] ATLAS Collaboration, Phys. Lett. B**710**, 383-402 (2012).

[6] ATLAS Collaboration, arXiv:1205.6744, submitted to Phys. Lett. B.

[7] ATLAS Collaboration, ATLAS-CONF-2012-017

[8] ATLAS Collaboration, arXiv:1206.0756, submitted to Phys. Lett. B.

[9] ATLAS Collaboration, ATLAS-CONF-2012-060

[10] ATLAS Collaboration, ATLAS-CONF-2012-018

[11] ATLAS Collaboration, ATLAS-CONF-2012-019