HIGGS SEARCHES AT ATLAS

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Abstract. We review the current searches at ATLAS for Higgs bosons in the Standard Model performed at the LHC with a center of mass energy of 7 TeV. Results from pp-collision data with an integrated luminosity of up to 2.3 fb^{-1} are discussed.

1 Introduction

The discovery of the mechanism for electroweak symmetry breaking is one of the goals of the physics programme at the Large Hadron Collider (LHC). In the Standard Model (SM), this is achieved by invoking what is known as the Higgs mechanism, leading to the production of the Higgs boson [1, 2]. The Higgs boson mass, m_H , is an unknown parameter in the SM, although it is weakly coupled to other observables. The ATLAS [3] collaboration has carried out Higgs boson searches in different channels with pp collision data at a centre-of-mass energy of 7 TeV with an integrated luminosity of up to 2.3 fb^{-1} . The systematic uncertainty of the luminosity measurement is estimated to be 3.4%. Exclusion limit results are presented using CLs technique [4, 5].

2 SM Higgs boson search channels in ATLAS

The different SM Higgs boson searches carried out in ATLAS are briefly described in the following paragraphs. Some of them already provide exclusion results for the integrated luminosity analysed, as shown in Figure 1.

The $H \rightarrow \gamma\gamma$ [6] analysis is carried out for Higgs boson mass hypotheses between 110 and $150 \text{ GeV}/c^2$. Selected events are separated into five independent channels based on the direction in which each photon was emitted and its photon to electron-pair conversion status. The background is estimated from an unbinned fit of the diphoton invariant mass spectrum. Total integrated luminosity analysed in this channel is 1.08 fb^{-1} .

The $H \rightarrow \tau\tau \rightarrow \ell\tau_{had} + 3\nu$ [7] (semi-leptonic) and $H \rightarrow \tau\tau \rightarrow \ell^+\ell^- + 4\nu$ [8] (fully leptonic) searches are performed as a counting analysis for Higgs boson mass hypotheses between 110 and $150 \text{ GeV}/c^2$. These events are required to have one or two high p_T leptons in the final state and a jet with transverse momentum that exceeds 40 GeV. The resulting boost of the Higgs boson implies a large missing transverse energy in the event, which, allows for a good discrimination against $Z/\gamma^* \rightarrow \ell\ell$, $Z \rightarrow \tau\tau$ and QCD multi-jet backgrounds. The top-quark pair production and all other backgrounds are taken from the simulation, except for the QCD background with jets faking leptons which is

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Figure 1: Observed and expected 95% C.L. upper limits on the signal strength modifier $\mu = \sigma/\sigma_{SM}$, obtained with the CLs method, for the different SM Higgs searches in ATLAS, as a function of the SM Higgs boson mass in the range 110-600 GeV/ c^2 .

estimated within an independent control sample. Analysis is carried out with a dataset corresponding to an integrated luminosity of 1.06 fb $^{-1}$.

The $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$ [9] search is performed as a counting analysis for Higgs boson mass hypotheses between 110 and 300 GeV/ c^2 , for an integrated luminosity of 1.7 fb $^{-1}$. The main background contributions are estimated from the data using control regions. The analysis is separated into 0-jet and 1-jet channels. The systematic uncertainty on the WW background estimate comes mainly from the low number of counts, and to the uncertainty on the extrapolation from theoretical scale variations and jet energy scale uncertainties. There are significant uncertainties considered on the top-quark background in both the 0-jet channel and 1-jet channels. The other backgrounds are also measured in control samples of data, except for the small contributions of WZ and ZZ that are taken from simulation. The discriminant is the transverse mass distribution, and the event selection is optimised in three mass regions (< 170 GeV/ c^2 , 170-220 GeV/ c^2 , and > 200 GeV/ c^2) with different signal and background control regions.

The $H \rightarrow ZZ^* \rightarrow \ell\ell\ell\ell$ [10] search is performed for Higgs boson mass hypotheses in the range from 110 to 600 GeV/ c^2 , selecting three distinct final states: 4μ , $2e2\mu$ and $4e$. The integrated luminosity for each final state is 2.3 fb $^{-1}$, 2.0 fb $^{-1}$ and 2.0 fb $^{-1}$ respectively. The main background of this search is the ZZ^* production, and is estimated from simulation. The reducible Z +jets background is estimated from control regions in data. The final discriminating variable is the invariant mass distribution of the selected events.

59 The $H \rightarrow ZZ \rightarrow \ell\ell\nu\nu$ [11] analysis is carried out for the 200 to 600 GeV/ c^2
60 range of Higgs boson mass hypotheses, and divided in a high (≥ 280 GeV/ c^2)
61 and a low mass region. A total integrated luminosity of 1.04 fb $^{-1}$ is considered.
62 This search is orthogonal with respect to the $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$ search by
63 design. Diboson production, ZZ , WW and WZ , is the main background to
64 this search for high transverse mass values. Its normalisation uncertainty is
65 taken from theory. Normalisation uncertainties for Z+jets, W+jets, top and
66 QCD-multijet production are estimated from data. The final discriminating
67 variable is the transverse mass of the dilepton plus missing momentum system,
68 where the missing momentum is assumed to originate from a Z-boson decay.

69 The $H \rightarrow ZZ \rightarrow \ell\ell qq$ [12] analysis is performed for Higgs boson mass hy-
70 potheses in the 200 to 600 GeV/ c^2 range, divided into two regions: below and
71 above 300 GeV/ c^2 . A total integrated luminosity of 1.04 fb $^{-1}$ is used. The
72 final state is separated into two categories: the tagged analysis where the two
73 jets are b-tagged and the untagged analysis where at most one of the jets is b-
74 tagged. The dominant background in this analysis is Z+jets production, which
75 is normalised from a control region defined by the sidebands of the dijet mass
76 distribution. The other backgrounds are estimated with the simulation verified
77 with data control samples for the top-quark background. The dilepton-dijet in-
78 variant mass is used as the final discriminant and its shape is estimated using
79 simulation for both the signal and the backgrounds.

80 The $H \rightarrow \bar{b}b$ [13] analysis combines WH ($\ell\nu\bar{b}b$) and ZH ($\ell^+\ell^-\bar{b}b$) searches
81 for the Higgs boson in the mass range between 110 and 130 GeV/ c^2 for an
82 integrated luminosity of 1.04 fb $^{-1}$. In the $\ell\nu\bar{b}b$ channel, the dominant back-
83 grounds arise from top-quark production and W+jets. The contribution from
84 the multi-jet, top and W+jets backgrounds is determined by a simultaneous
85 template fit to control regions of data. In the $\ell^+\ell^-\bar{b}b$ channel, the dominant
86 background comes from Z+jets production and is estimated using a control re-
87 gion of data for normalisation and MC simulations for a shape template. Other
88 sources of background are estimated by MC simulation. The discriminant is
89 the invariant mass distribution of the $\bar{b}b$ pairs.

90 3 Combined SM Higgs boson search in ATLAS

91 The result of the combined SM Higgs boson search performed by the ATLAS
92 experiment is presented in Figure 2, where the CLs value for the SM Higgs
93 boson hypothesis is shown as a function of the Higgs boson mass in the range
94 110-600 GeV/ c^2 . The SM Higgs boson is excluded at 95% C.L. in the mass
95 range 145-231 GeV/ c^2 , 254-281 GeV/ c^2 , and 294-466 GeV/ c^2 .

Figure 2: ATLAS combined 95% C.L. upper limits on the signal strength modifier $\mu = \sigma/\sigma_{SM}$, obtained with the CLs method, as a function of the SM Higgs boson mass in the range 110-600 GeV/ c^2 .

4 Conclusions

SM Higgs searches in ATLAS are described. Individual and combined results with up to 2.3fb^{-1} of integrated luminosity are presented. A large exclusion band is placed over the production of a SM Higgs boson with the amount of data analysed.

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