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Searches for high mass Higgs bosons with the ATLAS detector*

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Abstract

Recent results from searches for heavy Higgs bosons, using the ATLAS detector at the CERN LHC are presented. The searches use proton–proton collision data collected during the second running period of the LHC (LHC Run-II), at a centre-of-mass energy of 13 TeV, corresponding to an integrated luminosity of 3.2 fb^{-1}. The results are interpreted in a range of scenarios, including theories beyond the Standard Model of particle physics, and extend the upper limits set during LHC Run-I toward higher mass regions.

Keywords: Higgs, ATLAS, LHC

1. Introduction

The discovery of a new particle with a mass of about 125 GeV by the ATLAS [1] and CMS [2] experiments at the Large Hadron Collider (LHC) [3], which was announced in July 2012 [4, 5], provided, by all experimental evidence so far, an excellent candidate for the Higgs boson predicted by the Standard Model (SM) of particle physics [6, 7, 8]. One important remaining question is whether or not the newly discovered particle is part of an extended scalar sector as postulated by various extensions to the SM such as the two-Higgs-doublet model (2HDM) [9] and the Minimal Supersymmetric Standard Model (MSSM) [10]. These models predict additional Higgs bosons, motivating searches at masses other than 125 GeV. The sections that follow report separate searches with the ATLAS detector for additional, heavy Higgs-like bosons. Unless specified otherwise, the results presented have been produced using the data collected with ATLAS during 2015, at $\sqrt{s}$ = 13 TeV, which correspond to an integrated luminosity of 3.2 fb^{-1}.

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2. $H \to ZZ$

The various final states of the $H \to ZZ$ decay mode are studied in search of a neutral, CP-even, spin-0 Higgs boson H with SM-like couplings. Both narrow (i.e. narrower than the experimental resolution) and large-width hypotheses are examined for the Higgs boson.

2.1. $ZZ \to \ell^+\ell^- q\bar{q}$

In the final state with two leptons and two quarks, a pair of oppositely charged leptons (electrons or muons) and a pair of high-p_T jets are searched for [11, 12]. The analysis is divided into two main channels; the *resolved* analysis attempts to reconstruct and identify two separate hadronic jets from the $Z \to qq$ decay whereas the *merged* analysis implements boosted techniques, evaluating the jet-substructure, in order to identify a $Z \to qq$ decay that has been reconstructed as a single large-radius (large-R) jet. The latter is expected when the resonance mass is significantly higher than the Z boson mass. For the resolved analysis, candidate events are further categorised based on the number of b-tagged jets in order to take advantage of the different signal-to-background ratios in these categories. No significant excess of data is found over the SM prediction in the spectrum of the invariant mass of the two leptons and the one/two jet system. Upper limits on the product

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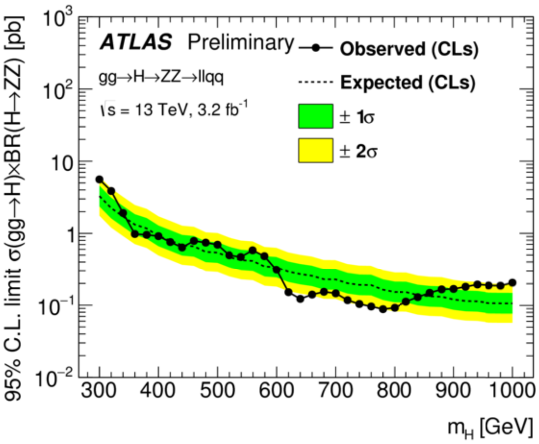

Figure 1: Observed (solid line) and median expected (dashed line) 95% CL limits on the product of the production cross section times the branching ratio to a pair of Z bosons, derived with the $\ell\ell qq$ channel, for a narrow-width Higgs boson, as a function of the hypothesized Higgs boson mass m_H [11]. The green and yellow bands correspond to $\pm 1\sigma$ and $\pm 2\sigma$ intervals for the expected exclusion limit, respectively.

of the Higgs boson production cross section times the branching ratio to a pair of Z bosons are estimated at 95% confidence level (CL) as shown in Figure 1 for the intermediate Higgs boson mass range 300 GeV – 1 TeV.

2.2. $ZZ \to \nu\bar{\nu}q\bar{q}$

The final state with two neutrinos and two quarks is studied in the context of both $H \to ZZ$ and $H \to WZ$ decay modes [13]. Both cases consider a Z boson decaying to neutrinos, giving rise to large missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$), while the other boson (W or Z) decays hadronically. The search is performed in the mass interval from 1 TeV to 3 TeV. As in the previous case, for high mass states, the decay products of the hadronically decaying vector boson are expected to appear as a single jet in the detector, therefore, the candidate is reconstructed using boosted techniques. The discriminating variable used is an estimator of the ZZ invariant mass known as the transverse mass (m_{T}) of the di-jet and $E_{\mathrm{T}}^{\mathrm{miss}}$ system. No significant deviation from the expected background is observed in the data. The estimated exclusion limits are presented in Figure 2.

2.3. $ZZ \to \ell^+\ell^-\ell'^+\ell'^-$

The Higgs boson decay to four leptons provides good sensitivity due to its high signal-to-background ratio (S/B). A search for a heavy, scalar resonance S is performed in the final states: 4μ, $2\mu 2e$, $2e2\mu$, $4e$, where the first lepton pair is the one with invariant mass closest to the Z boson mass [14]. Although the relatively

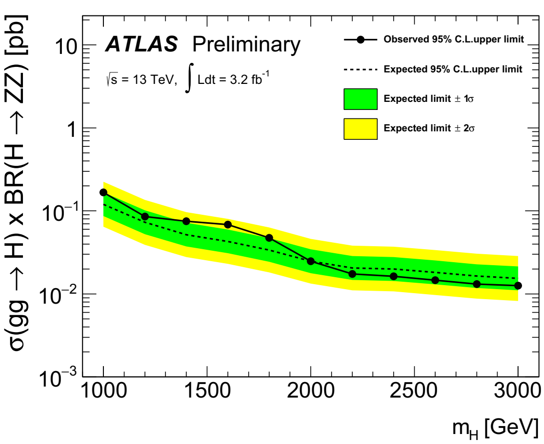

Figure 2: 95% CL upper limits on the product of the production cross section times the branching ratio to a pair of Z bosons, derived with the $\nu\nu qq$ channel, for a narrow-width Higgs boson, as a function of the hypothesized Higgs boson mass [13].

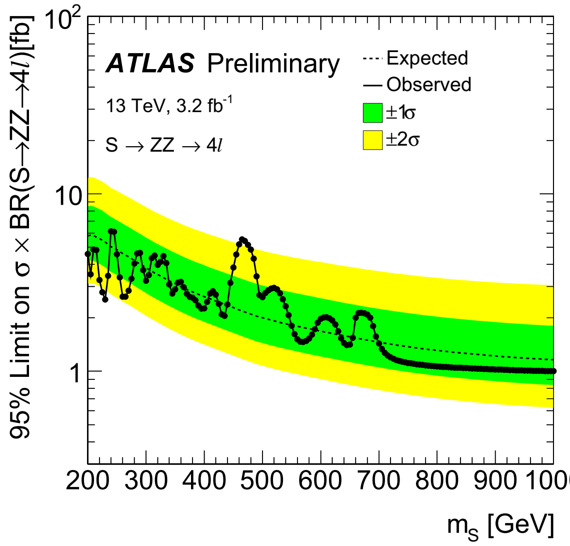

Figure 3: 95% CL upper limits on $\sigma \times BR(S \to ZZ^* \to 4\ell)$, derived with the 4ℓ channel, for a narrow-width resonance, as a function of the hypothesized resonance mass [14].

small branching ratio of $ZZ \to \ell^+\ell^-\ell'^+\ell'^-$ compared to $ZZ \to \ell^+\ell^-q\bar{q}$ and $ZZ \to \ell^+\ell^-\nu_\ell\bar{\nu}_\ell$ renders the latter channels more sensitive for large scalar boson masses ($m_S \gtrsim 500$ GeV), the 4ℓ channel still improves the overall sensitivity. The search is performed in the mass interval $200 \leq m_S \leq 1000$ GeV. No significant excess of the data is observed in the m_S spectrum. The estimated 95% CL upper limits on $\sigma \cdot BR(S \to ZZ^* \to 4\ell)$ are presented in Figure 3.