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Search for a Standard Model Higgs in the mass range 200–600 GeV in the channel $H \to ZZ \to \ell^+\ell^- q\bar{q}$ with the ATLAS detector

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Summary. — We describe the searches for a Standard Model (SM) Higgs boson in the channel $H \to ZZ \to \ell^+\ell^- q\bar{q}$ ($\ell = e, \mu$), in the range 200–600 GeV, using 4.71 fb^{-1} of pp collision data collected by the ATLAS experiment at $\sqrt{s} = 7$ TeV taken in 2011. Events with two b-tagged jets, which have a better signal-to-background ratio, are treated as a separate channel. No significant excess of events above the estimated background is found and upper limits at 95% confidence level (CL) on the production cross section (relative to that expected from the Standard Model) of the Higgs boson with a mass in the range between 200 and 600 GeV are derived.

PACS 14.80.Bn – Standard-model Higgs bosons.

The search for the Standard Model (SM) Higgs boson is one of the most important aspects of the CERN Large Hadron Collider (LHC) physics program. If m_H is larger than twice the Z boson mass, m_Z, the Higgs boson is expected to decay to two on-shell Z bosons with a high branching fraction. We consider the Higgs boson mass range 200–600 GeV and search for a SM Higgs boson decaying to a pair of Z bosons, where one Z decays leptonically and the other hadronically: $H \to ZZ \to \ell^+\ell^- q\bar{q}$ with $\ell = e, \mu$ [1]. The largest background to this signal is due to Z + jets production. This analysis uses the full data set of 4.71 fb^{-1} recorded by the ATLAS experiment in 2011.

The offline selection starts with the reconstruction of either a $Z \to ee$ or a $Z \to \mu\mu$ pair. Both electron and muon candidates must satisfy $p_T > 20$ GeV and $|\eta| < 2.5$, and must also be isolated from surrounding tracks. The lepton pairs invariant mass must lie within the range $83 < m_{\ell\ell} < 99$ GeV. Events with more than two selected electrons or muons are rejected to reduce background from WZ decay. Candidates also contain a pair of jets from $Z \to q\bar{q}$ decay and no high-p_T neutrinos. At least two jets with $E_T > 25$ GeV and $|\eta| < 2.5$ are required. The missing transverse momentum, E_T^{miss}, is computed from

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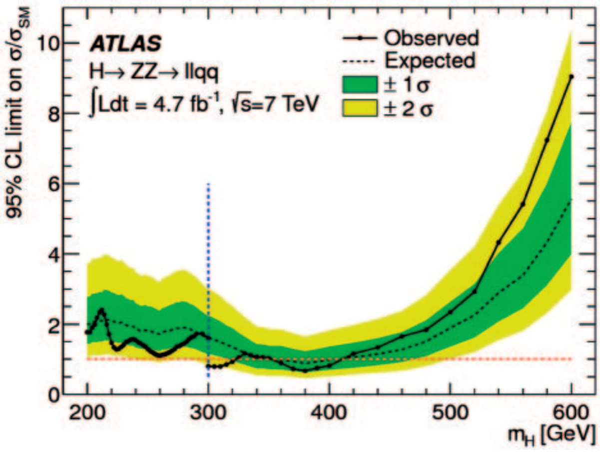

Fig. 1. – The expected (dashed line) and observed (solid line) upper limits on the total cross section divided by the expected SM Higgs boson cross section, calculated using CLs at 95%. The inner and outer bands, indicate the one- and two-sigma ranges. The horizontal dotted line shows the SM value of unity. The discontinuity in the limit at $m_H = 300\,\text{GeV}$ is due to the transition between the low- and high-m_H selections.

quantities measured within $|\eta| < 4.5$, and must satisy $E_T^{miss} < 50\,\text{GeV}$, reducing mostly the background from $t\bar{t}$ production.

Jets which originate from b-quarks can be discriminated (tagged) from other jets based on the relatively long decay length ($c\tau \approx 450\,\mu\text{m}$) of hadrons containing b-quarks. This is important since about 21% of signal events contain b-jets from $Z \to b\bar{b}$ decay, while a b-jet decay is produced less often ($\sim 2\%$) in the $Z+$jets background. To optimise the expected sensitivity, the analysis is divided into a tagged subchannel, using events with two b-tags, and an untagged subchannel, using events with less than two b-tags. Events are then required to have at least one candidate $Z \to q\bar{q}$ decay with dijet invariant mass satisfying $70 < m_{jj} < 105\,\text{GeV}$. Following this selection, an $H \to ZZ \to \ell^+\ell^- q\bar{q}$ signal is expected to appear as a peak in the invariant mass distribution of the $\ell\ell jj$ system, with $m_{\ell\ell jj}$ around m_H, defining the "low-m_H" selection. For $m_H \geq 300\,\text{GeV}$, the Z bosons from $H \to ZZ$ decay have large momenta in the laboratory reference frame and therefore the opening angles between their decay products are smaller. A "high-m_H" selection is defined by the following additional requirements, aimed at improving signal sensitivity: (1) the two jets must have $p_T > 45\,\text{GeV}$, and (2) $\Delta\phi_{\ell\ell} < \pi/2$ and $\Delta\phi_{jj} < \pi/2$.

No significant excess over the expected background is found. A Standard Model Higgs boson is excluded at a 95% CL within the range $300 \leq m_H \leq 322\,\text{GeV}$ or $353 \leq m_H \leq 410\,\text{GeV}$. The corresponding expected exclusion range is $351 \leq m_H \leq 404\,\text{GeV}$ at 95% CL. Figure 1 shows the resulting upper limit on the cross section for Higgs boson production and decay in the channel $H \to ZZ \to \ell^+\ell^- q\bar{q}$ relative to the prediction of the Standard Model as a function of the hypothetical Higgs boson mass.

REFERENCES

[1] Aad G. *et al.*, "Search for a Standard Model Higgs boson in the mass range 200–600 GeV in the $H \to ZZ \to \ell^+\ell^- q\bar{q}$ decay channel", arXiv:1206.2443 [hep-ex].