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The new Higgs particle in the H$\rightarrow$ZZ$^{(*)}$ $\rightarrow$4l searches with the ATLAS detector

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This document presents results and measurements of the properties of the newly observed Higgs particle in the decay channel $H \rightarrow ZZ^{(*)} \rightarrow l^+l^-l'^+l'^-$, where $l, l' = e$ or μ. The analysis is based on 4.6 fb^{-1} and 20.7 fb^{-1} of proton-proton collisions at 7 TeV and 8 TeV, respectively, recorded with the ATLAS detector [1] at the LHC. An excess of events over background is observed at $m_H = 124.3$ GeV with a significance of 6.6 standard deviations. The mass is measured to be $m_H = 124.3^{+0.6}_{-0.5}$ (stat) $^{+0.5}_{-0.3}$ (syst) GeV and the signal strength at this mass is found to be $\mu = 1.7^{+0.5}_{-0.4}$. A spin-parity analysis is also performed: the Higgs-like boson is found to be compatible with the Standard Model (SM) expectation of $J^P = 0^+$, when compared pair-wise with 0^-, 1^+, 1^-, 2^+ and 2^- [2].

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1. Introduction

This document is a very short summary of the latest results on search for the SM Higgs boson through the decay $H \to ZZ^{(*)} \to l^+l^-l'^+l'^-$, where $l, l' = e$ or μ. Four distinct final states are selected: 4μ, 4e, 2μ2e and 2e2μ. The analysis is done with a total of 25 fb^{-1} of data collected in 2011 and 2012, at 7 TeV and 8 TeV respectively, with the ATLAS detector. The resulting mass and signal strength are presented. The spin and parity of the $H \to ZZ^{(*)} \to 4l$ decay are also discussed.

2. Event selection and backgrounds

This analysis searches for Higgs boson candidates by selecting two same-flavour, opposite-sign lepton pairs in an event. Each electron (muon) must satisfy $E_T > 7$ GeV ($p_T > 6$ GeV) and be measured in $|\eta| < 2.47$ ($|\eta| < 2.7$). The first three leptons of the quadruplet must satisfy the p_T requirement of 20, 15 and 10 GeV, respectively. The lepton pair closest to the Z boson, called m_{12}, is required to be between 50 and 106 GeV, while the other, called m_{34}, must be in the range $m_{min} < m_{34} < 115$ GeV, where m_{min} varies from 12 to 50 GeV, depending on the four-lepton invariant mass, m_{4l}. The resolution is improved applaying FSR correction and on-shell Z mass constraint. Details concerning the selection can be found in Ref. [2].

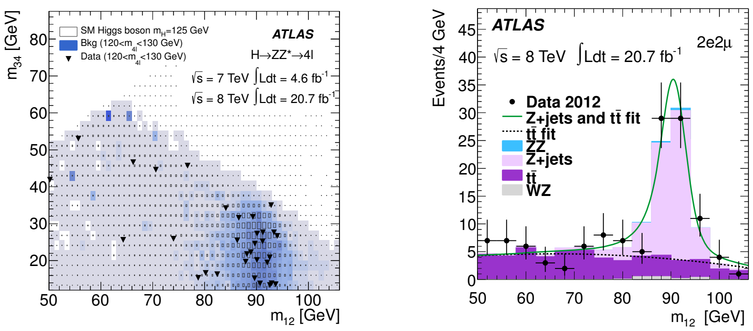

Figure 1: $ZZ^{(*)}$ background rejection (left) and reducible background estimation from control region (right).

The largest background ($\sim 70\%$) in this search comes from continuum $(Z^{(*)}/\gamma^*)(Z^{(*)}/\gamma^*)$ production and is estimated using MC simulation normalised to the theoretical cross section. The rejection is done through kinematic cuts, e.g. on m_{34}, comparing data and MC in different regions of m_{4l}. Other important background contributions come from Zbb, $Z+$jets and $t\bar{t}$ production: these processes compose the so called *reducible background* estimated from 'background-enriched' control regions in data, in which no isolation requirements on the subleading lepton pair are applied. Control regions are defined in order to enhance the Zbb and $t\bar{t}$ contribution ($ll + \mu\mu$), when leptons fail the impact parameter significance requirement, and the $Z+$jets contribution ($ll + ee$), when electron identification requirements are relaxed [2].

3. Mass and signal strength measurement

In Fig. 2, on the left, the expected m_{4l} distributions for the total background and one signal hypothesis (125 GeV) are compared to the data, in the low mass range 80-250 GeV. The mass is measured to be $m_H = 124.3^{+0.6}_{-0.5}$ (stat) $^{+0.5}_{-0.3}$ (syst) GeV and the signal strength of the Higgs-like particle at this mass is $\mu = 1.7^{+0.5}_{-0.4}$. The maximum deviation from the background-only expectation, p_0, observed for this mass value is 2.7×10^{-11}, corresponding to 6.6 σ [2].

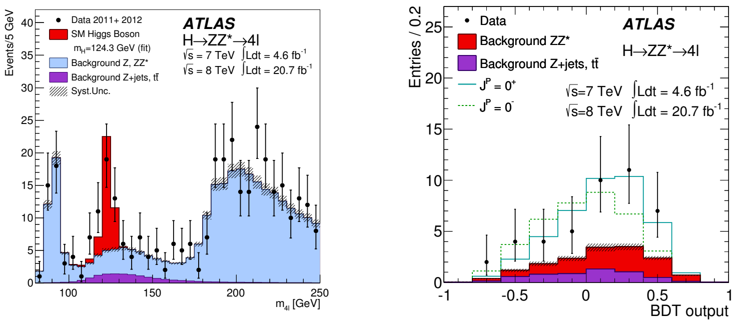

Figure 2: The m_{4l} distribution (left) and the BDT discriminants for the 0^+ versus 0^- hypothesis (right).

4. Spin-Parity measurement

For $X \rightarrow ZZ^{(*)} \rightarrow 4l$ decays, the observables sensitive to the underlying spin and parity of X are the masses of the two Z bosons, a production angle, θ^*, and four decay angles, Φ_1, Φ, θ_1 and θ_2 [2]. Two multivariate approaches are used to distinguish the spin/parity states: BDT and J^P-MELA [4]. In Fig. 2, on the right, are shown the distributions of the BDT discriminants for data and MC comparing the 0^+ and 0^- hypotheses. The observed CL_s exclusion confidence levels for 0^-, 1^+, 1^- and 2^+_m hypotheses are 97.8% (99.6%), 99.8% (99.4%), 94.4% (96.4%), and 83.2% (81.8%), respectively, in favour of 0^+ for the BDT (JP-MELA) analysis [2] [4].

5. Conclusion

The latest results for the newly observed Higgs boson have been presented, using 25 fb^{-1} of data recorded by the ATLAS detector. The observation is fully confirmed [3], with a mass of $124.3^{+0.6}_{-0.5}$ (stat) $^{+0.5}_{-0.3}$ (syst) GeV and a signal strength of $\mu = 1.7^{+0.5}_{-0.4}$. The spin and parity analysis shows a preference for the Standard Model, 0^+, hypothesis [4].

References

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