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 $\mu$. 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].
1. Introduction

This document is a very short summary of the latest results on search for the SM Higgs boson through the decay $H \rightarrow ZZ^{(*)} \rightarrow l^+l^-l'^+l'^-$, where $l, l' = e$ or $\mu$. Four distinct final states are selected: $4\mu$, $4e$, $2\mu 2e$ and $2e 2\mu$. 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 $H \rightarrow ZZ^{(*)} \rightarrow 4l$ 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 $|\eta| < 2.47$. 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 $m_{\text{min}} < m_{34} < 115$ GeV, where $m_{\text{min}}$ varies from 12 to 50 GeV, depending on the four-lepton invariant mass, $m_{4l}$. The resolution is improved applying FSR correction and on-shell Z mass constraint. Details concerning the selection can be found in Ref. [2].

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 when leptons fail the impact parameter significance requirement, and the $Z +$ jets contribution 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 $\mu = 1.7^{+0.5}_{-0.3}$. The maximum deviation from the background-only expectation, $p_0$, observed for this mass value is $2.7 \times 10^{-11}$, corresponding to 6.6 $\sigma$ [2].

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

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, $\theta^+$, and four decay angles, $\Phi_1, \Phi, \theta_1$ and $\theta_2$ [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 25fb$^{-1}$ 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 $\mu = 1.7^{+0.5}_{-0.3}$. The spin and parity analysis shows a preference for the Standard Model, $0^+$, hypothesis [4].

References


