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# Mass measurement of the Higgs-like boson in $ZZ^{(*)} \rightarrow 4\ell$ channel with the ATLAS detector

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**Summary.** — The measurement of the mass of the observed Higgs-like boson in the decay channel $H \rightarrow ZZ^{(*)} \rightarrow \ell^+\ell^-\ell'^+\ell'^-$ is presented. Proton-proton collision data recorded by the ATLAS detector at the LHC, corresponding to an integrated luminosity of $\sim 25\,\text{fb}^{-1}$, have been used. A clear excess of events over the background is observed at $m_H = 124.3\,\text{GeV}$ with a significance of 6.6 $\sigma$ in $ZZ^{(*)} \rightarrow 4\ell$ analysis, corresponding to a background fluctuation probability of $2.7 \times 10^{-11}$. The mass of the Higgs-like boson is measured to be $m_H = 124.3^{+0.6}_{-0.5}(\text{stat})^{+0.5}_{-0.3}(\text{syst})$ GeV, and the signal strength (the ratio of the observed cross section to the expected SM cross section) at this mass is found to be $\mu = 1.7^{+0.5}_{-0.4}$.

PACS 14.80.Bn – Standard-model Higgs bosons.

## 1. – Introduction

The search for the SM Higgs boson through the decay $H \rightarrow ZZ^{(*)} \rightarrow \ell^+\ell^-\ell'^+\ell'^-$, where $\ell, \ell' = e$ or $\mu$, provides good sensitivity over a wide mass range and due to its experimentally clean signature and an excellent signal-background ratio it is a "golden" channel for the Higgs boson discovery. Its main background comes from continuum $(Z^{(*)}/\gamma^*)(Z^{(*)}/\gamma^*)$ production. For $m_H < 180\,\text{GeV}$, there are also non-negligible background contributions from $Z$ + jets and $t\bar{t}$ production, where the additional charged lepton candidates arise either from decays of hadrons with $b$ or $c$-quark content or from misidentification of jets.

The measurement of the mass of the observed Higgs-like boson using data recorded by the ATLAS detector [1] at the LHC corresponding to integrated luminosities of $4.6\,\text{fb}^{-1}$ and $20.7\,\text{fb}^{-1}$ at $\sqrt{s} = 7\,\text{TeV}$ and $\sqrt{s} = 8\,\text{TeV}$, respectively, is presented.

## 2. – Mass measurement

The events are selected by single-lepton and di-lepton triggers, searching for two same-flavour, opposite-sign lepton pairs (a lepton quadruplet). The lepton pair with the mass closest to the $Z$ boson mass is referred to as the leading di-lepton (its invariant

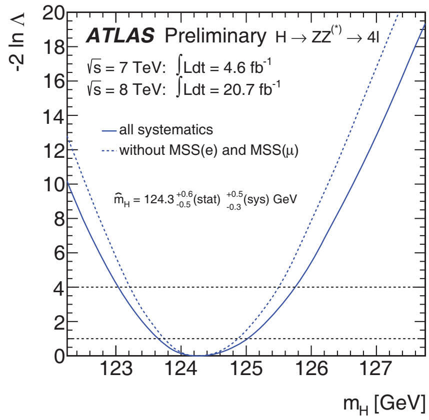


Fig. 1. – The profile likelihoods are shown with and without the mass scale systematics [2].

mass, $m_{12}$, is required to be between 50 and 106 GeV). The remaining same-flavour, opposite-sign lepton pair is the sub-leading di-lepton: $m_{34}$, is required to be in the range $m_{min} < m_{34} < 115$ GeV, where $m_{min}$ is 12 GeV for $m_{4\ell} < 140$ GeV and rises linearly to 50 GeV at $m_{4\ell} = 190$ GeV. The $Z+$jets and $t\bar{t}$ background contributions are reduced by applying impact parameter requirements as well as track and calorimeter-based isolation requirements on the leptons.

The mass distributions are described using smooth, non-parametric, unbinned estimates of the relevant probability density functions obtained from simulation. The signal $m_{4\ell}$ shape, normalisation and corresponding uncertainties are parametrised as a function of $m_H$. Main background shapes are varied from the nominal expectation to allow for shape systematics. The statistical test used is the profile likelihood ratio and it is valued using a Maximum Likelihood [3] fit of signal and background. In fig. 1 the profile likelihood is shown as a function of $m_H$ for the combined 2011 and 2012 data samples. It is

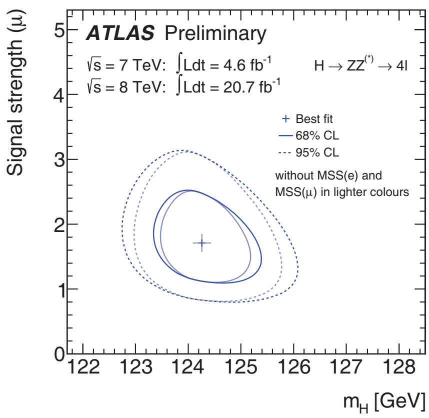


Fig. 2. – Likelihood ratio contours in the $(\mu,\, m_H)$ plane [2].

shown with the mass scale systematic uncertainties from electrons (MSS($e$)) and muons (MSS($\mu$)) applied (solid curve) and without applying them. The value for the fitted mass from the profile likelihood is $m_H = 124.3^{+0.6}_{-0.5}(\mathrm{stat})^{+0.5}_{-0.3}(\mathrm{syst})$ GeV, where the systematic uncertainty is dominated by the energy and momentum scale uncertainties [2].

The global signal strength factor $\mu$ acts as a scale factor on the total number of events predicted by the Standard Model for each of the Higgs boson signal processes. Figure 2 presents the best $\mu$ and $m_H$ fit values and the profile likelihood ratio contours that, in the asymptotic limit, would correspond to 68% and 95% confidence levels both with mass scale systematics applied (dark colour curves) and without applying them (lighter colour curves). The value of the signal strength $\mu$ at the best fit value for $m_H = 124.3\,\mathrm{GeV}$ is $\mu = 1.7^{+0.5}_{-0.4}$. For a value of $m_H = 125.5\,\mathrm{GeV}$ [4], the signal strength is found to be $\mu = 1.43 \pm 0.16(\mathrm{stat}) \pm 0.14(\mathrm{syst})$.

## REFERENCES

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