PROCEEDINGS OF SCIENCE

Search for the 125 GeV Higgs Boson at 13 TeV in the diboson decay channels, by the ATLAS collaboration

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The ATLAS collaboration has searched for the Standard Model Higgs Boson in the first run-2 data using 3.2 fb^{-1} at 13 TeV delivered by LHC. Results are presented in terms of central value and limits on the fiducial and total cross-sections. Run-1 results are also presented for the $H \to WW^*$ channel. In addition, the search for Higgs events with missing transverse energy and the search for a Higgs pair production in the $b\bar{b}\gamma\gamma$ final state are also shown.

XXIV International Workshop on Deep-Inelastic Scattering and Related Subjects
11-15 April, 2016
DESY Hamburg, Germany

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PoS(DIS2016)088

1. Introduction

In 2012, both the ATLAS[1] and CMS[2] experiments at the Large Hadron Collider (LHC) discovered a particle with couplings to elementary fermions and bosons consistent with those of the Standard Model. One essential confirmation of the SM predictions shown in this article, is the direct observation of the Higgs boson in the $H \to WW$ channel. Further studies have shown its compatibility with this model through different measurements. In particular, here we present the cross sections in the $H \to \gamma\gamma$, $H \to Z^*Z$ and the combination of them. These results have opened up new possibilities in searches for new physics. In this paper two analyses regarding Beyond the Standard Model physics are shown: the search for Higgs events with missing transverse energy, and the search for a Higgs pair production in the $b\bar{b}\gamma\gamma$ final state.

2. Higgs cross section measurements at $\sqrt{s} =$ 7, 8 and 13 TeV

2.1 $H \to \gamma\gamma$

The diphoton decay mode is well suited for the cross-section measurement of the Higgs boson due to the simple signature, the large experimental selection efficiency and the excellent invariant-mass resolution.

The event selection used in this analysis requires the two highest-p_T photons with invariant mass 105 $GeV \leq m_{\gamma\gamma} \leq 160$ GeV, in $|\eta| < 2.37$ and outside of the region of transition between the endcaps and barrel of the detector. Both photons must satisfy relative p_T cuts: $E_T^{\gamma 1}/m_{\gamma\gamma} \geq 0.35$ and $E_T^{\gamma 2}/m_{\gamma\gamma} \geq 0.25$, where $E_T^{\gamma i}$ is the transverse energy of the leading (i=1) and subleading (i=2) photons, and $m_{\gamma\gamma}$ is the invariant mass of the diphoton system. The isolation requirement on the energy is $E_{T\ iso}^{calo} < 0.0065 \times E_T^{\gamma}$ and $E_{T\ iso}^{track} < 0.05 \times E_T^{\gamma}$. It is worth mentioning that the isolation definition changed with respect to the Run-1 one. Now it has a dependence on the p_T of the Higgs whilst before it used a fixed value.

Fig. 1 shows the mass if the diphoton system with the fit from where yields are obtained.

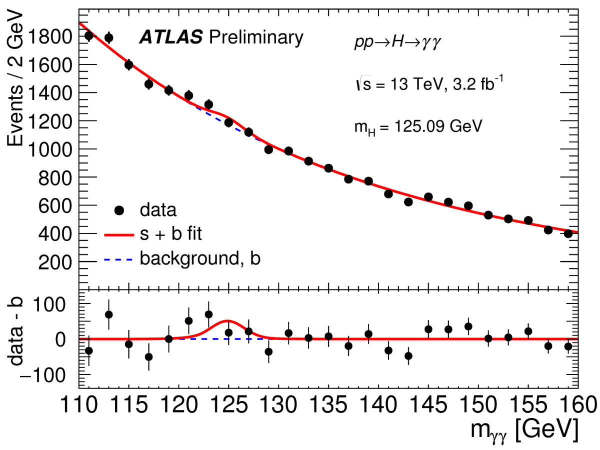

Figure 1: Distribution of the mass of the diphoton system. Black dots are data while red line is the fit to it.[3]

2.2 $H \to ZZ^* \to \ell^+\ell\ell'^+\ell'$

The Higgs boson decay to four leptons provides good sensitivity for the measurement of its properties due to its high signal-to-background ratio.

In this analysis, we require 4 leptons (e^- or μ) in the final state having a $p_T(E_T)$> 7 (6) GeV with an $|\eta|$<2.47 (2.7). The three leading leptons must satisfy: p_T > 20, 15, 10 GeV. Two dileptons systems are constructed under the requirement that: 50 < m_{Z1} < 106 GeV and 12-50 < m_{Z2} < 115 GeV. Where m_{Zi} is the invariant mass of the leading (i=1) or subleading (i=2) dilepton system. The invariant mass of the 4 leptons system can be seen in Fig. 2.

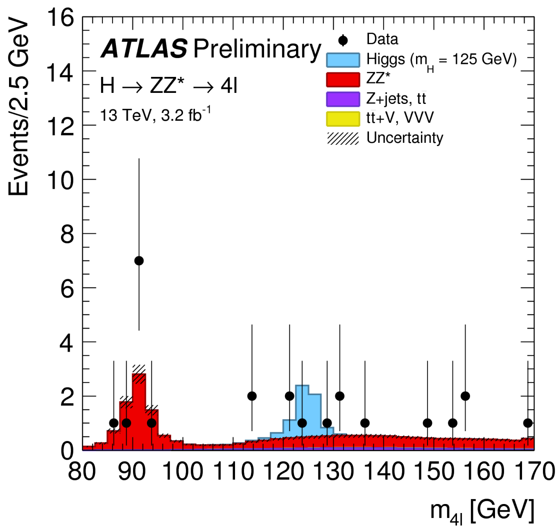

Figure 2: Distribution of the invariant mass of the 4 leptons systems. Black dots are data, red is the main irreducible background, and light blue is the Higgs signal. [4]

2.3 Cross section results

The cross section is measured in a certain fiducial region to be as model independent as possible and allow a comparison to any theoretical prediction. However, the measurement result is also extrapolated to the total phase space under the assumption that the signal corresponds to the SM Higgs boson. The signal yield is extracted using a fit to the corresponding diphoton invariant-mass spectrum. The cross section is determined by correcting these yields for detector inefficiency and resolution, and by accounting for the integrated luminosity of the dataset.

Fig. 3 shows the results obtained for each of the channels as well as the combined measurement.

3. Observation and measurement of $H \to WW^*$

In this subsection, results for this channel using $\sqrt{s} = 8\ TeV$ are presented.

For this analysis, one electron and one μ should be in every event. They must have opposite charges and $m_{\ell\ell} > 10$ GeV. They must both satisfy $p_T^{lead.\ \ell} > 22$ GeV and $p_T^{sublead.\ \ell} > 15$ GeV.

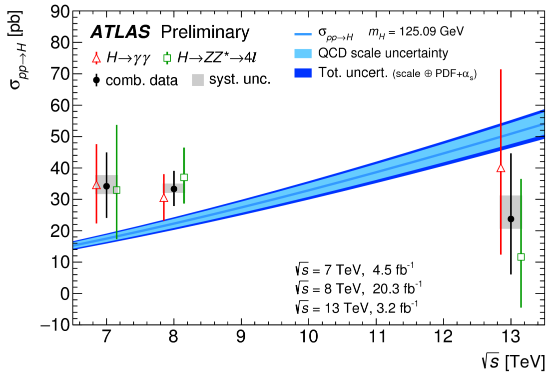

Figure 3: Cross sections measurements for $\sqrt{s} = 7,\ 8$ *and* 13 *TeV* for $H \rightarrow \gamma\gamma$ (red), $H \rightarrow ZZ^* \rightarrow 4\ell$ (green) and the combination of both of them (black).[5]

Three signal regions are constructed based on lepton flavour and jet multiplicity and are motivated by the relevant backgrounds.

The tranvsverse mass for the Higgs is built using $m_T = \sqrt{(E_T^{\ell\ell} + p_T^{miss})^2 - |p_T^{\ell\ell} + p_T^{miss}|^2}$, where $E_T^{\ell\ell} = \sqrt{|p_T^{\ell\ell}|^2 + m_{\ell\ell}^2}$ and $p_T^{miss} = E_T^{miss}$, and it is shown in Fig. 4.

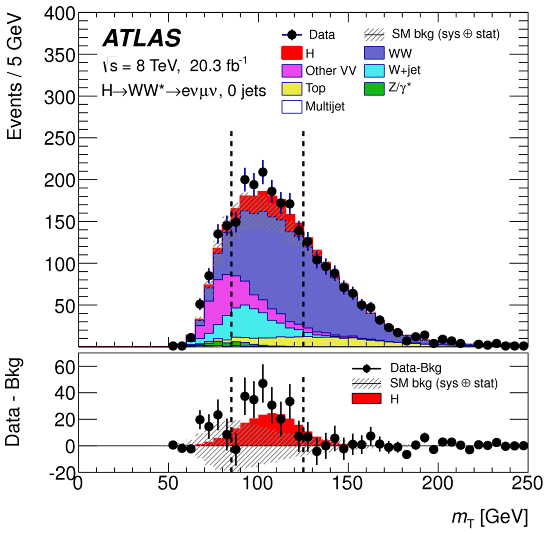

Figure 4: Distribution of the transverse mass m_T for data (black dots), signal (red) and non resonant WW production as major background in violet. [6]

Differential cross section distributions are shown for N_{jet} and p_T^H in Fig. 5. The total cross section results: $\sigma_{ggF}^{fid} = 36.0 \pm 9.7$ fb which agrees with LHC-XS calculation $\sigma_{ggF}^{fid} = 25.1 \pm 2.6$ fb[7].

4. Search for new phenomena in events with missing transverse momentum and a $H \rightarrow \gamma\gamma$

New physics possibilities were opened once the Higgs boson was discovered in 2012. In

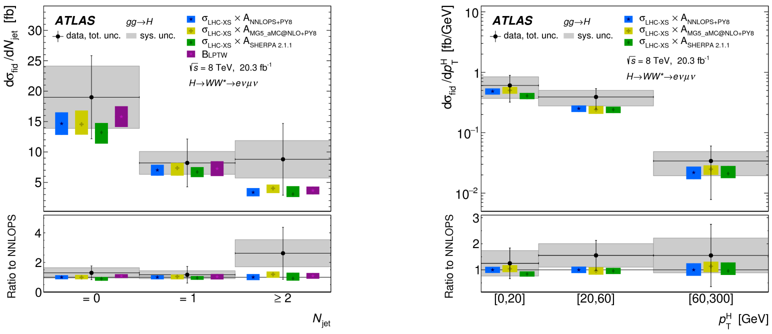

Figure 5: Measured fiducial differential cross section as a function of N_{jets} (left) and p_T^H (right), overlaid with the signal predictions.[6]

particular, events with a Higgs boson and missing transverse momentum (E_T^{miss}) in the final state can be sensitive probes of scenarios predicting dark matter (DM) candidates.

This analysis is very similar as the nominal SM analysis presented before. Both the selection and the way in which the signal and background are modeled are the same.

The results are interpreted in two theoretical models: decays of a heavy scalar into a Higgs boson and a pair of dark matter candidates, and a vector mediator emitting a Higgs boson and decaying into two dark matter candidates. To increase the sensitivity to these two models, the data is divided into different categories using E_T^{miss}, and $p_T^{\gamma\gamma}$.

As no excess over the background expectation is observed, upper limits are set on the rates of the processes involving a Higgs (decaying to two photons) with two dark matter candidates χ. For the Heavy scalar production model: 29.6 fb (for a mass of $m_H = 270\ GeV$) 95% CL upper limit on $\sigma(pp \to h\chi\chi) \times BR(h \to \gamma\gamma)$[8], while for the Massive mediator model: 5.3 fb ($m_{med} = 10\ GeV$ and $m_{DM} = 1\ GeV$) 95% CL upper limit on $\sigma(pp \to h\chi\chi) \times BR(h \to \gamma\gamma)$[8].

5. Search for Higgs boson pair production in the $b\bar{b}\gamma\gamma$

A search for the production of pairs of Higgs bosons with mass m_X is performed. This pair, which could be produced either through a resonant state X decaying via $X \to hh$ or through production processes that do not involve a resonance, is then required to decay through the $h \to b\bar{b}\gamma\gamma$ channel. The selection for the two photons, is very similar to the one in the nominal SM analysis, while the two b jets should have an invariant mass larger than 95 GeV but smaller than 135 GeV.

An upper limit of 3.9 pb on the cross-section for non-resonant production is extracted at the 95% confidence level, while the expected limit is 5.4 pb. In the search for a narrow $X \to hh$ resonance, the observed limit ranges between 7.0 pb and 4.0 pb for masses of the resonance between 275 and 400 GeV. The corresponding expected limit varies between 7.5 pb and 4.4 pb for the same mass range. These results can be seen in Fig. 6.

6. Conclusions

This summary of analyses perfomed by the ATLAS experiment involving photons, show the high performance achieved in the last years. It has not only accomplished a major discovery, but

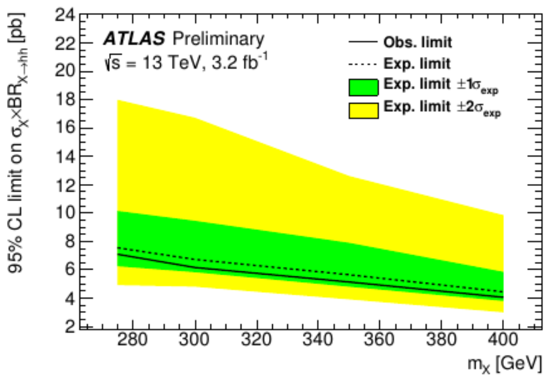

Figure 6: Using the CLS method, 95% CL expected (dashed line) and observed (solid line) limits on the production cross-section times $X \to hh$ branching fraction in the search for a narrow resonance with a mass m_X. [9]

is accurately measuring properties of the Higgs Boson and setting limits on models regarding new physics which will be updated through this year when more data is collected.

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