PROCEEDINGS OF SCIENCE

Searches for Higgs boson like high mass resonances in the bosonic decay channels with ATLAS and CMS

Francesco Lo Sterzo*, **on behalf of the ATLAS and CMS Collaborations**
Academia Sinica, Institute of Physics
E-mail: francesco.lo.sterzo@cern.ch

Searches for an additional heavy Higgs-like boson have been performed by both ATLAS and CMS with data collected in Run 1 of the LHC. This document reports searches in the diboson decay channels ($\gamma\gamma$, WW, ZZ). Exclusion limits have been set for different hypotheses: model independent narrow-resonance, Standard Model-like Higgs boson, Electroweak Singlet and 2HDM. No excess of events is found over the Standard Model background-only expectation.

The European Physical Society Conference on High Energy Physics
22-29 July 2015
Vienna, Austria

*Speaker.

PoS(EPS-HEP2015)170

1. Introduction

The discovery of a Higgs-like particle announced by the ATLAS and CMS Collaborations in 2012 [1, 2] has been the main experimental result of the Run 1 of the LHC. One of the most important open questions is whether this particle is the only one responsible for the electroweak symmetry breaking or if it is part of an extended scalar sector as postulated by several extensions of the Standard Model (SM): the electroweak singlet (EWS) and two-Higgs-doublet-model (2HDM) are taken into account in this document, as well as model independent searches. For the sake of brevity, only the free parameters taken into account in the searches described here are highlighted in the following.

For the EWS the important parameters are κ, κ', $\mathrm{BR}_{H,\mathrm{new}}$ and m_H. The κ and κ' constants are used to parametrize the shift of the properties (cross section and width) of two bosons h and H with respect to the SM prediction, $\mathrm{BR}_{H,\mathrm{new}}$ is used to take into account possible non-SM decays of H and m_H is its mass.

In the 2HDM the important parameters are the mass of the heavy Higgs boson m_H, $\tan\beta$ which represents the ratio of the vacuum expectation values of the two doublets taken into account in the model, and α which is the mixing angle between the two doublets. Several types of 2HDM exist depending on the symmetry chosen for the Yukawa coupling to fermions in the Lagrangian. In the searches presented here only type I and type II are taken into account.

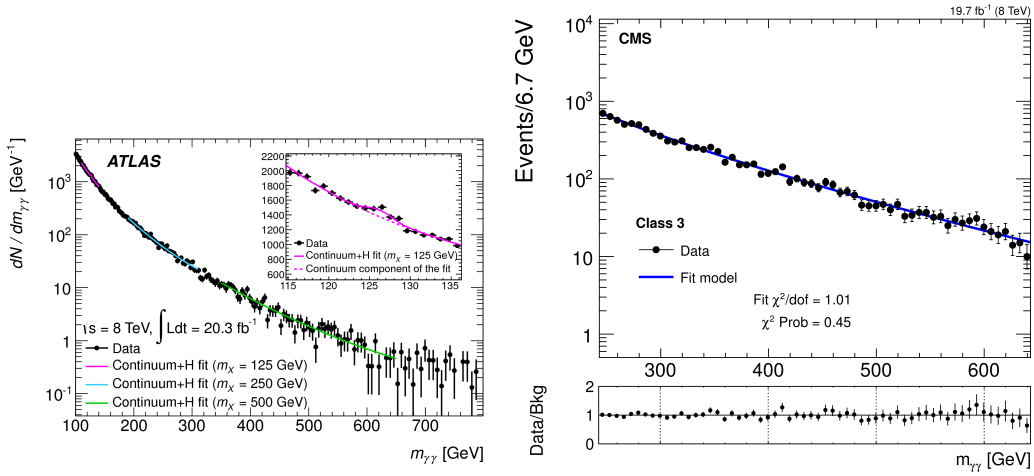
The searches summarized in this document are performed with the ATLAS and CMS detectors [3, 4] using the data collected in the Run 1 of the LHC.

2. $H \to \gamma\gamma$

The searches for Higgs-like bosons in the di-photon final state performed by the ATLAS and CMS collaborations are described in detail in [5] and [6]. Events with two prompt photons are selected and the di-photon mass spectrum ($m_{\gamma\gamma}$) is studied looking for a peak on top of a smooth background. Since, as can be see in figures 1(a) and 1(b), no significant excess of data over the background expectations is found, exclusion limits are set with these searches. Figures 2(a) and 2(b) show the exclusion limits set by ATLAS and CMS respectively for a narrow resonance. In particular the signal hypothesis used in ATLAS has a width which weakly depends on the mass of the resonance ($\Gamma_H = 0.09 + 0.01 \times m_H$), while a fixed width is used in CMS ($\Gamma_H = 0.1$ GeV). In both searches the data are consistent with the background-only hypothesis and the largest observed discrepancies are not statistically significant (the local significance is less than 2.5σ for all of them). In addition to the narrow signal hypothesis, wider signals were also probed by the CMS collaboration. Results are shown in figure 3 for two different configurations: a scan in m_H for a wide resonance (i.e. $\Gamma_H = 0.1 \times m_H$) and a scan in width for a fixed mass $m_H = 840$ GeV. Also for the wider hypotheses no discrepancies with respect to the background only expectation are found.

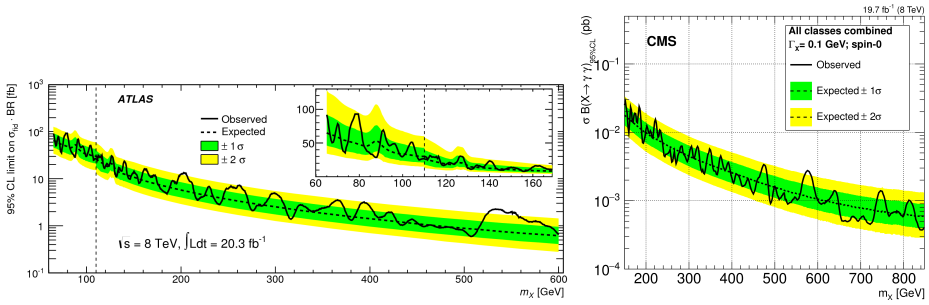
3. $H \to ZZ/WW$

$H \to WW$ and $H \to ZZ$ decays are among the most powerful channels to search for heavy resonances. These searches have been carried out by both the ATLAS and CMS collaborations



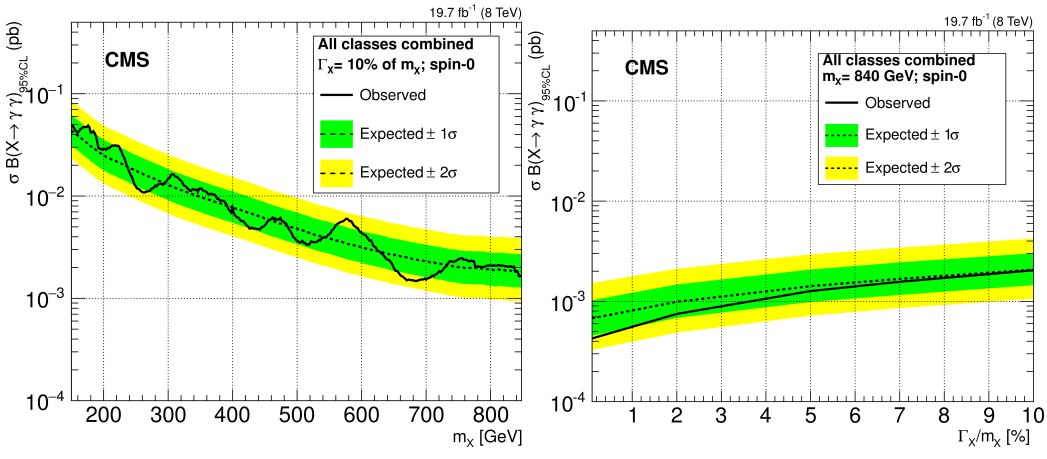
(a) (b)

Figure 1: Final diphoton mass spectrum obtained in ATLAS 1(a), [5] and in CMS 1(b), [6].



(a) (b)

Figure 2: Exclusion limits obtained by ATLAS 2(a), [5] and CMS 2(b), [6] for a narrow scalar resonance decaying to two photons. The CMS collaboration also probed a spin-2 signal with very similar results.



(a) (b)

Figure 3: Exclusion limits obtained by CMS for a wide resonance: 3(a) shows the mass scan, 3(b) shows the width scan for m_H fixed at 840 GeV [6].

and the details of the analyses are given in [7], [8] and [9]. The background composition and contamination for these searches strongly depend on the final state that is taken into account. Some examples can be seen in figure 4. In these channels the events are split into sub-categories according

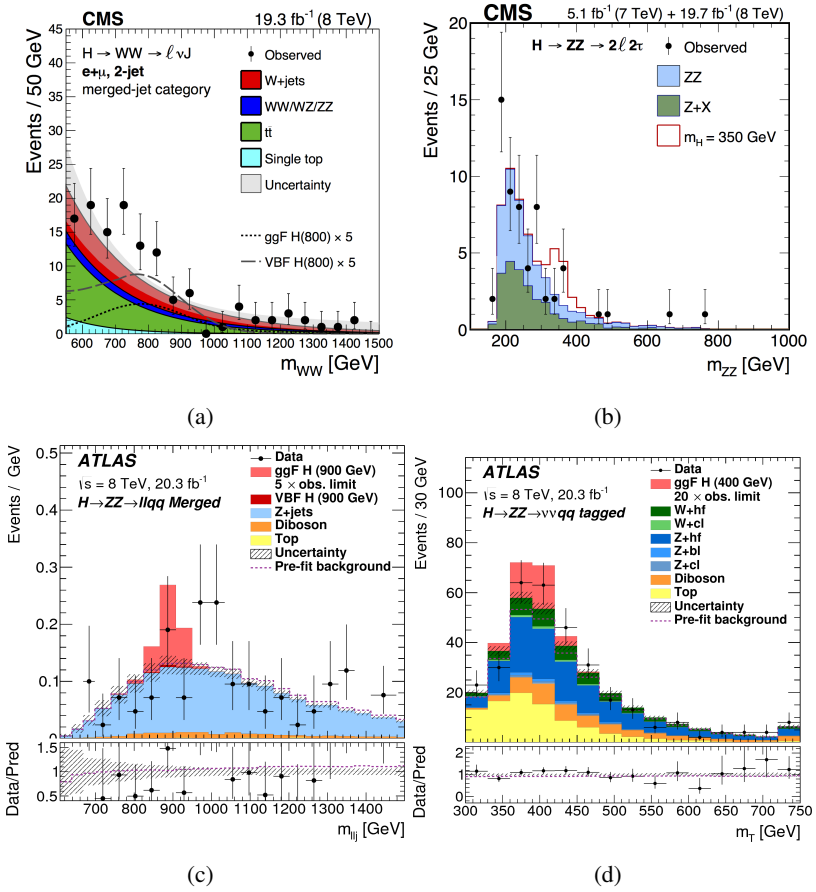


Figure 4: Final discriminants for some of the final states of the $H \to WW$ and $H \to ZZ$ searches from ATLAS and CMS [7, 8, 9].

to the number of additional jets and number of b-tagged jets in order to reduce the background contamination. The VBF category (targeting the Higgs boson production via vector boson fusion) is usually defined requiring at least two jets with large invariant mass m_{jj} and high pseudorapidity separation $|\Delta\eta|$. The results for these searches are shown in figures 5–7. In figure 5 the limits obtained by the ATLAS collaboration for a narrow signal decaying to Z or W boson pairs are shown. Over the whole mass spectrum data are consistent with the background-only interpretation. The same happens for the corresponding search performed by CMS probing the SM-like hypothesis, the results of which are shown [9].

In addition to the model-independent (i.e. narrow signal) and the SM-like hypotheses, the EWS and the 2HDM hypotheses have been tested by the ATLAS and CMS collaborations. The results of the 2HDM interpretation performed by ATLAS in the $H \to ZZ$ search are shown in figure 6 for both type I and type II. Results on the EWS interpretation from the CMS collaboration are shown in figure 7.

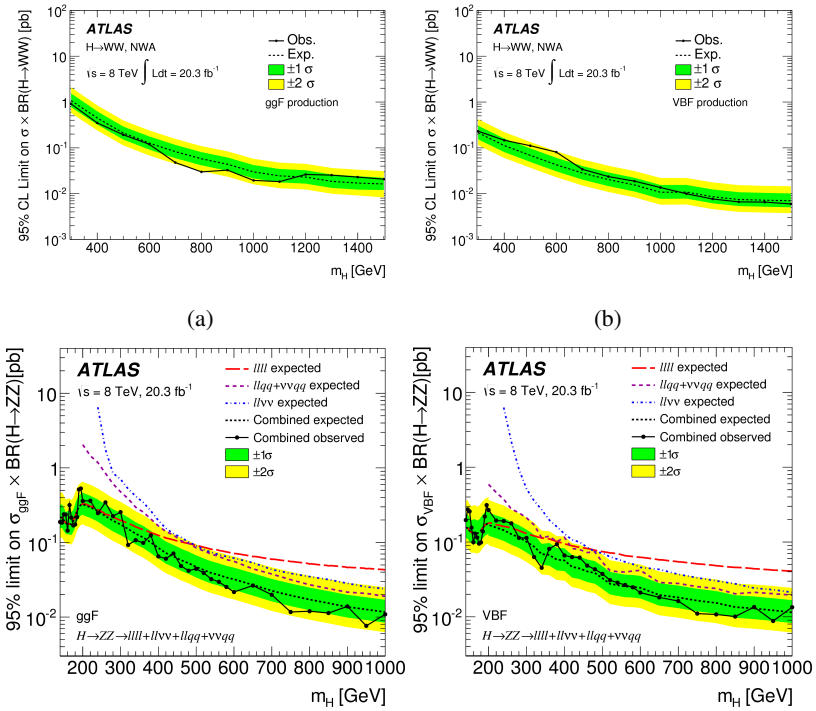


Figure 5: Limits obtained by ATLAS in the $H \to ZZ$ and $H \to WW$ searches combining all the final states. The limits are obtained for a narrow resonance scenario [7, 8].

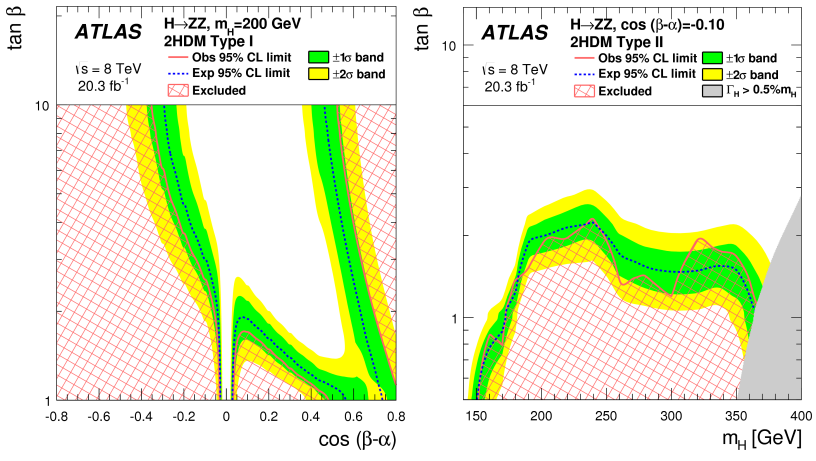


Figure 6: Limits from ATLAS on the 2HDM type I 6(a) and type II 6(b) hypotheses in the $\tan\beta$ vs m_H and $\tan\beta$ vs $\cos(\beta - \alpha)$ planes respectively [7, 8].

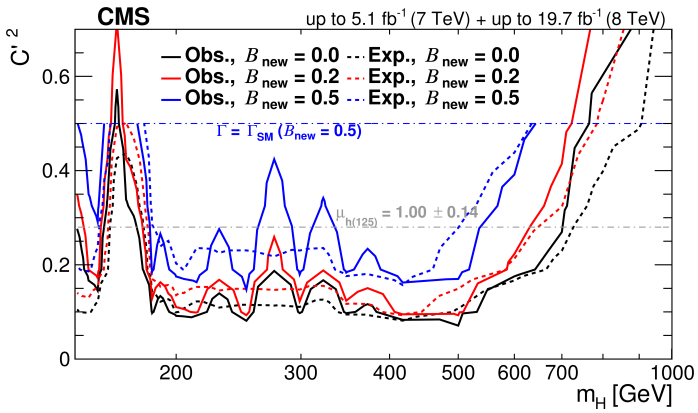


Figure 7: EWS intrpretation by the CMS collaboration in the $H \to ZZ/WW$ decays. The different colours show different assumptions on $\mathrm{BR}_{H,\mathrm{new}}$ [9].

4. Conclusions

Both ATLAS and CMS have searched for heavy Higgs-like particles in its diboson ($\gamma\gamma$, ZZ, WW) decays. These decays give rise to a multitude of different final states, each of them with its own peculiarities and experimental challenges. No excess of events over the SM background-only expectations have been found in any of the final states taken into account. Exclusion limits have been set for the hypotheses of a generic resonance (both narrow and wide signals are considered), the 2HDM type I and type II as well as for the EWS model.

References

[1] ATLAS Collaboration, *Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC*, Phys. Lett. B **716** (2012) 1, arXiv:1207.7214

[2] CMS Collaboration, *Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC*, Phys. Lett. B **716** (2012) 30, arXiv:1207.7235

[3] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, 2008 JINST 3 S08003

[4] CMS Collaboration, *The CMS experiment at the CERN LHC*, 2008 JINST 3 S08004

[5] ATLAS Collaboration, *Search for Scalar Diphoton Resonances in the Mass Range 65 - 600 GeV with the ATLAS Detector in pp Collision Data at* $\sqrt{s} = 8$ *TeV*, Phys. Rev. Lett. 113, 171801 (2014), arXiv:1407.6583

[6] CMS Collaboration, *Search for diphoton resonances in the mass range from 150 to 850 GeV in pp collisions at* $\sqrt{s} = 8$ *TeV*, Phys. Lett. B 10.1016/j.physletb.2015.09.062, arXiv:1506.02301

[7] ATLAS Collaboration, *Search for an additional, heavy Higgs boson in the* $H \to ZZ$ *decay channel at* $\sqrt{s} = 8$ *TeV in pp collision data with the ATLAS detector*, Submitted to EPJC, arXiv:1507.05930

[8] ATLAS Collaboration, *Search for a high-mass Higgs boson decaying to a W boson pair in pp collisions at* $\sqrt{s} = 8$ *TeV with the ATLAS detector*, Submitted to JHEP, arXiv:1509.00389

[9] CMS Collaboration, *Search for a Higgs boson in the mass range from 145 to 1000 GeV decaying to a pair of W or Z bosons*, Accepted for publication in JHEP, arXiv:1504.00936