PROCEEDINGS OF SCIENCE

Search for a new spin-zero resonance in diboson channels at 13 TeV with the CMS experiment

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Searches for an additional heavy scalar resonance have been performed by CMS with data collected during 2015 (2.3 fb^{-1}) and 2016 (12.9 fb^{-1}) of the LHC at 13 TeV. This document reports searches in the diboson decay channels WW and ZZ. Exclusion limits have been set for different hypotheses: model in-dependent scalar boson, narrow-resonance, Electroweak Singlet model and 2HDM. No excess of events is found over the Standard Model background-only expectation.

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1. Introduction

The discovery of a Higgs-like particle announced by the CMS and ATLAS Collaborations in 2012 [1, 3] has been the main experimental result of the Run 1 of the LHC and marks a point of no return in High Energy Physics, indeed with this measurement the Standard Model of Particle Physics (SM) is complete since all its predictions were both confirmed and measured. It is well established, inside the high energy physics community, the fact that the SM is not the ultimate representation of the sub-atomic world and a lots of both experimental and theoretical hints support this position. A huge effort was needed during the last decades by the theoretician to propose the right extension of the Standard Model. Currently a lot models are available and not yet neither confirmed nor completely excluded by the experiments. The results that will be presented are related to the diboson channel (WW and ZZ) availing the data collected by CMS detector [2] during 2015 and 2016. The analyses are targeting different models: narrow and wide resonances, 2HDM Type-I and Type-II, and EWS model.

2. ZZ Channel

2.1 ZZ $\rightarrow$ 2l 2ν

The search for a generic heavy scalar boson in the ZZ $\rightarrow$ 2l 2ν final state performed by the CMS collaboration using 2.3 fb^{-1} at 13 TeV is described in detail in [4]. Events with two leptons (e,μ) coming from a boosted Z boson (p_T(Z) > 55 GeV) are selected and categorized in three jet bins (0 jet, 1 jets and VBF), the transverse mass is studied looking for a peak on top of a smooth background. Since, as can be seen in the Figure 1, no excess of data over the background expectations is found, exclusion limits are set with these searches.

The limits are set both in gluon fusion (GGF) and vector boson fusion (VBF) production mode for a generic heavy scalar resonance with a $M_H \in [200, 1500]$ GeV and a $\Gamma_H \in [1\%, 100\%]$ the width of the equivalent heavy Higgs boson SM like. The results, reported in the Fig. 2, are then re-interpreted as constraints on the production of a heavy scalar in the electroweak singlet model (EWS) and 2HDM model (Type-I and Type-II). For 2HDM the limits are set only in gluon fusion as function of $\tan\beta - M_H$.

2.2 ZZ $\rightarrow$ 4l

The CMS collaboration has performed a search for a generic heavy resonance in the ZZ $\rightarrow$ 4l $(l = e, \mu)$ channel optimizing the analysis performed in the same channel but targeting the Higgs boson properties [5]. These study is achieved using a data sample corresponding to an integrated luminosity of 12.9 fb^{-1} of protons collisions at a center-of-mass energy of 13 TeV collected by the CMS experiment at the LHC during 2016. The events are selected and categorized exploiting the multiplicity of jets, b-tagged jets and additional leptons, and requirements on the kinematic discriminants based on matrix-element technique. For the signal modeling the interference with both the continuum background and the SM Higgs boson is taken into account both in GGF and in VBF production mode. The limits (Fig. 3) are finally set on the final invariant mass scanning a region between 130 GeV and 2.5 TeV in mass and various width.

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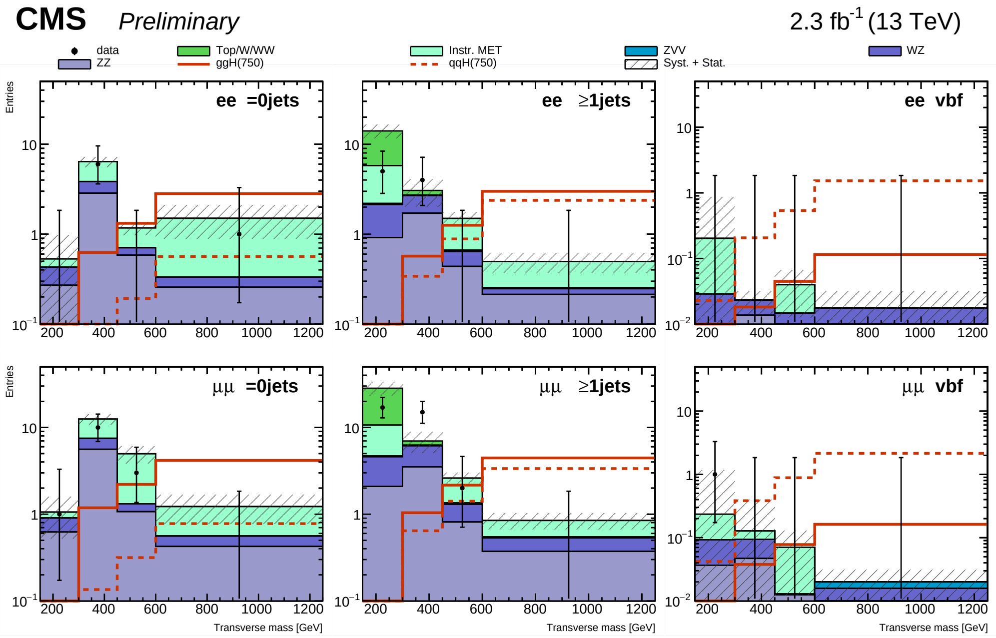

Figure 1: Transverse mass shape used to set limits in ZZ $\rightarrow$ 2l 2ν channel considering both *ee* and $\mu\mu$ flavor channels and the different jet bins category. No excess of data is found in all the categories and flavor bins. The different colors correspond to different backgrounds: the azure and green distributions report the backgrounds estimated using a data-driven approach (Top/W/WWW and Z+jets labeled as Inst.MET), whereas the violet distributions described the contribution of the irreducible background (ZZ, WZ, and ZVV) to the missing transverse energy. Only the 750 GeV signal mass point both in gluon fusion (solid line) and vector boson fusion (dotted line) production mode is reported. Finally, the diagonal lines show the impact of the combination of both the statistical and systematic uncertainties.

2.3 ZZ $\rightarrow$ 2l 2q

The ZZ $\rightarrow$ 2l 2q search is characterized by a boosted phase space identified by a pair of Z bosons where one boson decays hadronically and the other decays into two charged leptons with a transverse momentum greater than 100 and 170 GeV rispectively. As in four lepton case, the results are based on proton-proton collision data corresponding to an integrated luminosity of 12.9 fb^{-1}. To increase the efficiency to reconstruct the hadronic Z on the entire signal region, the substructure of the jets is studied. To achieve the maximum separation between signal and background the events are categorized according their jet substructure, their jet flavor composition and their jets kinematic information. The search is performed in the narrow width approximation hypothesis in the range between 550 GeV and 2000 GeV without taking into account any interference between the signal and the continuum background. The final limits are set using the invariant mass shape of the ZZ couple and they are reported in the figure 4. The entire description of the analysis can be found in the following paper [6].

3. WW Channel

The WW $\rightarrow$ lν lν analysis is characterized by a search for a scalar resonance with mass

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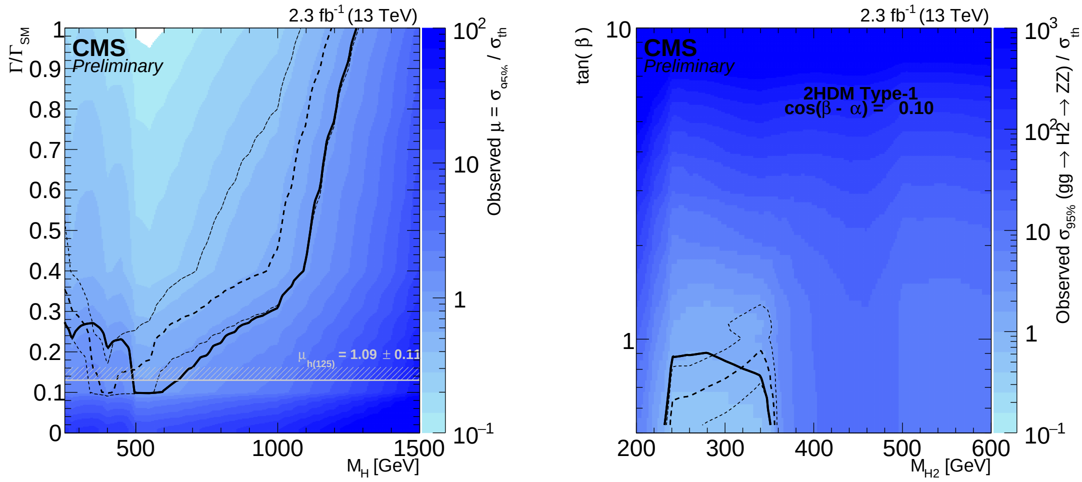

Figure 2: Limits set in ZZ $\to$ 2l 2ν in EWS (*right*) and 2HDM (Type-I) (*left*).

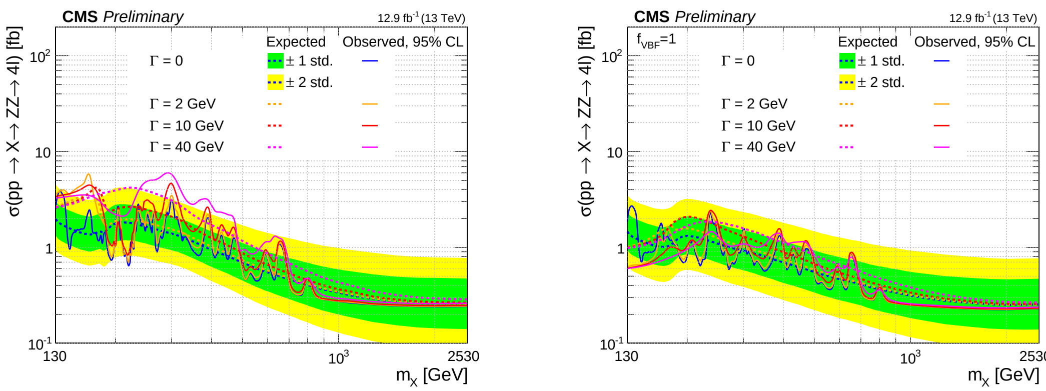

Figure 3: Limits in ZZ $\to$ 4l channel for a generic heavy scalar resonance in the case where the ratio between GGF and VBF is left floating (*right*) and in the VBF case only (*left*).

between 200 GeV and 1000 GeV and width between 9% and 100% the width predicted for an heavy Higgs boson SM-like. The analysis is performed both in gluon fusion and in vector boson fusion targeting the EWS model. For a more detailed description of the analysis refer to the following article [7]. The interesting events are selected in one single flavor combination ($e\mu$) and categorized according to the number of reconstructed jets in the final state (0 jet, 1 jets and VBF). The signal is modeled considering the interference with the background only in the gluon fusion channel. The final limits, reported in the Figure 5, are set on the total cross section assuming a SM ratio between the production mechanism consider in the analysis availing the transverse mass shape.

4. Conclusion

CMS has searched for heavy scalar boson particles in diboson (ZZ, WW) channels. These decays give rise to a multitude of different final states, each of them with their own peculiarities and experimental challenges. No excess of events over the SM background-only expectations have

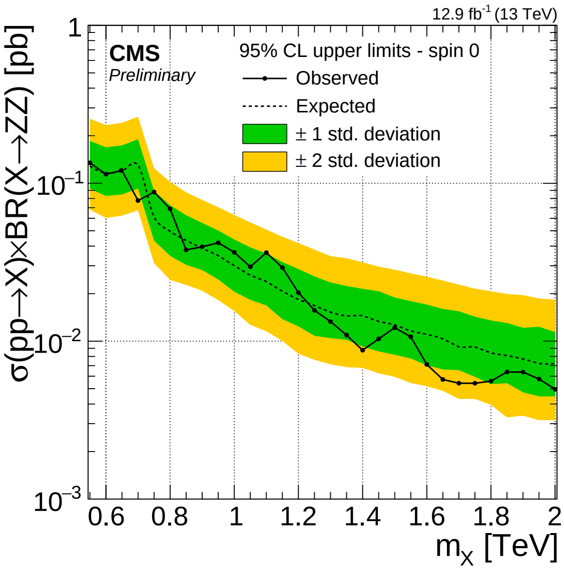

Figure 4: Limits in ZZ → 2l 2q channel. The ratio between GGF and VBF is floated.

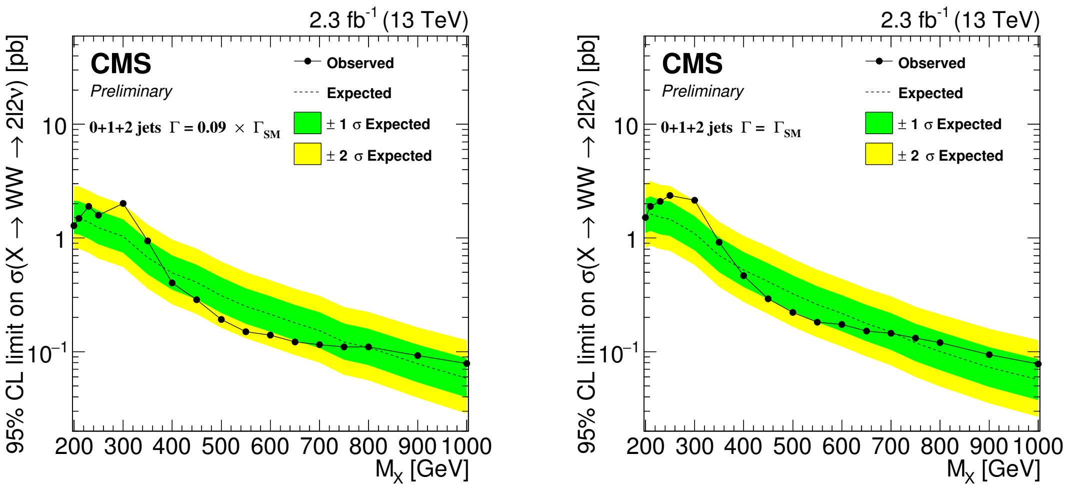

Figure 5: Limits for the WW → lν lν for two different values of width.

been found in any of the final states considered. Exclusion limits have been set for different signal hypotheses: narrow and wide resonances, 2HDM Type-I and Type-II, and EWS model.

References

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