The Higgs condensate as a quantum liquid: Comparison with the full Run 2 CMS data

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Abstract

We compare our proposal for an additional heavy Standard Model Higgs boson to the available full data set collected by the CMS detector during Run 2 at the Large Hadron Collider (LHC) corresponding to an integrated luminosity of 138 fb$^{-1}$. The CMS Collaboration performed a search for a high mass Higgs boson decaying into a pair of W bosons in the dileptonic channel. Our analysis of the CMS data indicated the presence of a broad excess in the mass range 600 GeV - 800 GeV with respect to the expected Standard Model background with a rather significative statistical significance. We found that our theoretical proposal is in reasonable agreement with the experimental observations.

Keywords: Large Hadron Collider; Higgs Boson; Higgs production mechanisms; Higgs decays

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1 Introduction

In 2012 a new particle was discovered by the ATLAS and CMS experiments at the LHC [1, 2]. This new particle, with a mass of about 125 GeV, is consistent with the Standard Model Higgs boson. With this discovery the Higgs mechanism [3, 4, 5, 6] has been validated. The Standard Model of Particle Physics introduces the Higgs mechanism in order to explain particle masses by means of the so-called spontaneous symmetry breaking mechanism. Spontaneous symmetry breaking can be obtained by introducing a scalar field, the Higgs field, with a specific potential. Actually, the Higgs mechanism had emerged as the only mechanism capable of reconciling gauge field theories with the observed mass spectrum. Indeed, the striking conceptual and empirical success of the Standard Model established increasing trust in the viability of the Higgs mechanism.

Usually the spontaneous symmetry breaking in the Standard Model is implemented within the perturbation theory which leads to predict that the Higgs boson mass squared is proportional to $\lambda v^2$, where $\lambda$ is the renormalised scalar self-coupling and $v \approx 246$ GeV is the known weak scale. On the other hand, it is known that, within the non-perturbative description of spontaneous symmetry breaking, self-interacting scalar fields are subject to the triviality problem [7], namely the renormalised self-coupling $\lambda \rightarrow 0$ when the ultraviolet cutoff is sent to infinity. Strictly speaking, there are no rigorous proof of triviality [8].

On the other hand, there exist several numerical studies which leave little doubt on the triviality conjecture. As a consequence, within the perturbative approach, the scalar sector of the Standard Model must be considered just an effective description valid only up to some (unknown) cut-off scale. Notwithstanding, extensive numerical simulations showed that even without self-interactions the scalar bosons could trigger spontaneous symmetry breaking. Moreover, precise non-perturbative numerical simulations [9, 10] indicated that the excitation of the Bose-Einstein scalar condensate should be a rather heavy scalar particle with mass of about 750(30) GeV [10].

To reconcile the overwhelming evidence of a rather light Higgs boson with mass of 125 GeV (indicated with $h$) with the indications from non-perturbative studies of a heavy Higgs boson with mass around 750 GeV (indicated with $H$), in a recent article [11] we advanced the proposal that the Higgs condensate of the Standard Model should be considered like a relativistic quantum fluid analogous to superfluid helium. As discussed at length in Ref. [11], we found that there are two different kind of Higgs condensate excitations that are similar to phonon and rotons in He II. Moreover, in the dilute gas approximation these two Higgs condensate excitations behave like the perturbative Standard Model Higgs boson and a heavy Standard Model Higgs boson. Indeed, in Ref. [12] we presented some phenomenological consequences of the Standard Model heavy Higgs boson proposal. In particular, we discussed the couplings of the $H$ Higgs boson to the massive vector bosons and to fermions, the expected production mechanisms, and the main decay modes. We also attempted a quantitative comparison in the so-called golden channel $H \rightarrow \ell^+\ell^-\ell'^+\ell'^-$ where $\ell, \ell' = e$ or $\mu$. More precisely, by means of an unofficial combination of the preliminary Run 2 data collected by the ATLAS and CMS experiments, we found some evidence of a broad scalar resonance that looked consistent with our Standard Model heavy Higgs boson [12, 11]. Unfortunately, this preliminary evidence has not been corroborated by the numerical results.
full data sets collected by the ATLAS Collaboration during the LHC Run 2. In Ref. [13] we critically compared our proposal to the full Run 2 data sets released by the ATLAS Collaboration. A search for a new high-mass resonance has been performed by the ATLAS experiment using data collected at \( \sqrt{s} = 13 \) TeV corresponding to an integrated luminosity of 139 fb\(^{-1}\) both in the golden channel \( H \rightarrow \ell^+\ell^-\ell'^+\ell'^- \), \( \ell, \ell' = e \) or \( \mu \), and in the decays into WW or ZZ with production mechanisms and branching ratios that mimic the ones of a heavy Standard Model Higgs boson. We do not found a clear statistical evidence for our heavy Higgs boson. At least we found a hint of a signal in the gluon-gluon fusion Higgs production mechanism. As a matter of fact, we reached the conclusion that there was not enough sensitivity to detect the signal in vector-boson fusion mechanism mainly due to tight event-selection cuts. In any case, we concluded that our theoretical proposal was still not ruled out by the ATLAS observations. However, we must admit that it is problematic the absence of experimental evidence in the decays of the heavy Higgs boson into two W vector bosons. It is known that the main decay mode of a heavy Higgs boson is the decay into WW. Therefore, the most stringent constraints should arise from the experimental searches for a heavy Higgs boson decaying into two W gauge bosons. Fortunately, the CMS Collaboration recently reported a search for high-mass resonances decaying into a pair of W bosons into the fully leptonic final state using the full Run 2 data set corresponding to an integrated luminosity of 138 fb\(^{-1}\) [14]. The aim of the present note is to contrast our theoretical expectations to the LHC Run 2 data from the CMS Collaboration in the above specified decay channel. We will show that the CMS data display a broad excess that seems to compare favourably with our proposal. This paper is organised as follows. In Sect. 2 for the reader’s convenience, we briefly discuss our theoretical proposal for two Standard Model Higgs bosons together with the main production mechanisms and decay modes. Sect. 3 is devoted to the comparison with the latest available CMS data. Finally, in Sect. 4 we summarise the main result of the present paper and draw our conclusions.

## 2 Heavy and light Higgs bosons

In the present Section we would like to illustrate very briefly the proposal advanced in Ref. [11] to look at the Higgs condensate as a quantum liquid analogous to the Bose-Einstein condensate in superfluid He II. We found that the low-lying excitations of the Higgs condensate resembled two Higgs bosons that were the relativistic version of the phonons and rotons in superfluid He II. Actually, in the dilute gas approximation that is the relevant regime for the LHC physics, these low-lying excitations of the Higgs condensate resembled two Standard Model Higgs bosons with masses around 100 GeV and 750 GeV, respectively. The lighter Higgs boson \( h \) was identified with the new LHC particle with mass \( M_h \simeq 125 \) GeV that seemed to behave consistently with the Standard Model perturbative Higgs boson. On the other hand, the heavy Standard Model Higgs boson \( H \), in accordance with the phenomenological analyses presented in Ref. [12], was assumed to have mass \( M_H \simeq 730 \) GeV. Note that this mass value is in accordance with previous extensive numerical studies [9, 10]. We emphasise that we are not saying that there are two different elementary quantum Higgs fields. On the contrary, we have a unique quantum Higgs field. However, since the scalar condensate behaves like the He II quantum liquid, when the Higgs field acts on the condensate it can give rise to two elementary excitations,
namely the phonon-like and roton-like excitations corresponding to long-range collective and localised disturbances of the condensate, respectively. These elementary condensate excitations behave as weakly interacting scalar fields with vastly different mass. Moreover, one remarkable aspect of our approach is that the Higgs boson masses are not free parameters, but these can be estimated from first principles.

Once established that the perturbations of the scalar condensate due to the quantum Higgs field behave as two independent weakly interacting massive scalar fields, we need to investigate the experimental signatures and the interactions of these Higgs condensate elementary excitations. Obviously, the most striking consequence of our approach is the prevision of an additional heavy Higgs boson. As we already said, the light Higgs boson is the natural candidate for the new LHC scalar resonance at 125 GeV. On the other hand, our previous phenomenological analysis of the preliminary LHC Run 2 data in the golden channel [12] corroborated the presence of a broad scalar resonance with central mass at 730 GeV. These two Higgs bosons will interact with the gauge vector bosons. We already pointed out [11, 12] that the couplings of the Higgs condensate elementary excitations to the gauge vector bosons are fixed by the gauge symmetries. As a consequence, both the Higgs bosons h and H will be coupled to gauge bosons as in the usual perturbative approximation of the Standard Model. Moreover, these scalar bosons have an effective finite self-coupling $\lambda_{\text{eff}}$ that, in general, is smaller than the perturbative renormalised scalar self-coupling $\lambda$. As concern the coupling to fermion fields, if we admit the presence of the Yukawa terms in the Lagrangian, then we are led to an effective Yukawa lagrangian:

$$L_{Y}^{\text{eff}}(x) = \sqrt{Z_{w_{f}}^{h}} \frac{\lambda_{f}}{\sqrt{2}} \hat{\psi}_{f}(x) \hat{\psi}_{f}(x) \hat{h}(x) + \sqrt{Z_{w_{f}}^{H}} \frac{\lambda_{f}}{\sqrt{2}} \hat{\psi}_{f}(x) \hat{\psi}_{f}(x) \hat{H}(x),$$

where $\hat{\psi}_{f}(x)$ indicates a generic fermion quantum field and the Yukawa coupling satisfies the usual relation:

$$\lambda_{f} = \frac{\sqrt{2} m_{f}}{v}.$$  \hspace{1cm} (2.2)

In Eq. (2.1) $Z_{w_{f}}^{h}$ and $Z_{w_{f}}^{H}$ are wavefunction renormalisation constant that, roughly, take care of the eventual mismatch in the overlap between the fermion and quasiparticle wavefunctions. A direct calculation of the wavefunction renormalisation constants is not easy. Nevertheless, in Ref. [11] we fixed these constants from a comparison with the experimental observations. As a result we argued that

$$Z_{w_{f}}^{h} \simeq 1 , \quad Z_{w_{f}}^{H} \simeq \frac{m_{h}}{m_{H}}.$$ \hspace{1cm} (2.3)

Note that Eq. (2.3) has the remarkable consequence that our light Higgs boson h is practically indistinguishable from the perturbative Higgs boson. As a consequence, in the following we shall concentrate on the hypothetical heavy Higgs boson.

In our previous papers [11, 12] we argued that for large Higgs masses the main production processes are by vector-boson fusion and gluon-gluon fusion processes. To evaluate the Higgs event production at LHC we need the inclusive Higgs production cross section. As in perturbation theory, for large Higgs masses the main production processes are by vector-boson fusion (VBF) and gluon-gluon fusion (GGF). In fact, since the couplings of

\footnote{The wavefunction renormalisation constant $Z_{w_{f}}^{H}$ coincides with the phenomenological parameter $\kappa$ introduced in Ref. [12].}
the H boson to vector bosons are the same as those of a Standard Model Higgs boson, the H boson production cross section by vector-boson fusion is the same as in the perturbative Standard Model calculations. As concern the gluon fusion production mechanism, it is known that the gluon coupling to the Higgs boson in the Standard Model is mediated mainly by triangular loops of top and bottom quarks. Indeed, in perturbation theory the Yukawa couplings of the Higgs particle to heavy quarks grows with quark mass, thus balancing the decrease of the triangle amplitude so that the effective gluon coupling approaches a non-zero value for large loop-quark masses. This means that for heavy Higgs the gluon fusion inclusive cross section is almost completely determined by the top quark. Therefore, the total inclusive cross section for the production of the H Higgs boson can be written as:

$$\sigma(pp \rightarrow H) \simeq \sigma_{VBF}(pp \rightarrow H) + \sigma_{GGF}(pp \rightarrow H), \quad (2.4)$$

where $\sigma_{VBF}$ and $\sigma_{GGF}$ are the vector-boson fusion and gluon-gluon fusion inclusive cross sections, respectively. In the Standard Model the calculations of the cross sections computed at next-to-next-to-leading and next-to-leading order for a high mass Higgs boson with Standard Model-like couplings at $\sqrt{s} = 13$ TeV are provided by the LHC Higgs Cross Section Working Group [15]. As concern the Standard Model gluon-gluon fusion cross section we found [12] that this cross section can be usefully interpolated by:

$$\sigma_{SM}^{GGF}(pp \rightarrow H) \simeq \begin{cases} \left( \frac{a_1}{M_H} + a_2 M_H^3 \right) \exp(-a_3 M_H) & M_H \leq 300 \text{ GeV} \\ a_4 \exp \left[ -a_5(M_H - 400 \text{ GeV}) \right] & 300 \text{ GeV} \leq M_H \leq 400 \text{ GeV} \\ a_4 \exp \left[ -a_5(M_H - 400 \text{ GeV}) \right] & 400 \text{ GeV} \leq M_H \end{cases} \quad (2.5)$$

where $M_H$ is expressed in GeV and

$$a_1 \simeq 1.24 \times 10^4 \text{ pb GeV}^{-1}, \quad a_2 \simeq 1.49 \times 10^{-6} \text{ pb GeV}^{-3},$$

$$a_3 \simeq 7.06 \times 10^{-3} \text{ GeV}^{-1}, \quad a_4 \simeq 9.80 \text{ pb},$$

$$a_5 \simeq 7.63 \times 10^{-3} \text{ GeV}^{-1}. \quad (2.6)$$

Likewise the Standard Model vector-boson fusion cross section can be parametrised as:

$$\sigma_{SM}^{VBF}(pp \rightarrow H) \simeq \left( b_1 + \frac{b_2}{M_H} + \frac{b_3}{M_H^2} \right) \exp(-b_4 M_H), \quad (2.7)$$

with:

$$b_1 \simeq -2.69 \times 10^{-6} \text{ pb}, \quad b_2 \simeq 8.08 \times 10^2 \text{ pb GeV},$$

$$b_3 \simeq -1.98 \times 10^4 \text{ pb GeV}^2, \quad b_4 \simeq 2.26 \times 10^{-3} \text{ GeV}^{-1}. \quad (2.8)$$

Our previous discussion lead us to assume that to a good approximation we can write:

$$\sigma_{VBF}(pp \rightarrow H) \simeq \sigma_{SM}^{VBF}(pp \rightarrow H), \quad \sigma_{GGF}(pp \rightarrow H) \simeq Z_{w_M}^H \sigma_{SM}^{GGF}(pp \rightarrow H). \quad (2.9)$$

In Fig. 1 we compare the VBF and GGF production cross sections given by Eq. (2.9) after taking into account the value of $Z_{w_M}^H$ in Eq. (2.3). From Fig. 1 we see that the main production mechanism of the heavy H Higgs boson is by the VBF processes since:

$$\sigma_{VBF}(pp \rightarrow H) \simeq 2 \sigma_{GGF}(pp \rightarrow H), \quad M_H \simeq 730 \text{ GeV}. \quad (2.10)$$
Figure 1: Inclusive $H$ Higgs boson production cross sections for the VBF processes (blue continuous line) and GGF processes (red continuous line) as a function of $M_H$ at $\sqrt{s} = 13$ TeV.

In order to determine the phenomenological signatures of the massive $H$ Higgs boson we need to examine the decay modes. Given the rather large mass of the heavy Higgs boson, the main decay modes are the decays into two massive vector bosons (see, e.g., Refs. [16, 17]):

$$\Gamma(H \rightarrow W^+ W^-) \simeq \frac{G_F M_H^3}{8\pi \sqrt{2}} \sqrt{1 - \frac{4m_W^2}{M_H^2}} \left(1 - 4 \frac{m_W^2}{M_H^2} + 12 \frac{m_W^4}{M_H^4}\right)$$ \hspace{1cm} (2.11)

and

$$\Gamma(H \rightarrow Z^0 Z^0) \simeq \frac{G_F M_H^3}{16\pi \sqrt{2}} \sqrt{1 - \frac{4m_Z^2}{M_H^2}} \left(1 - 4 \frac{m_Z^2}{M_H^2} + 12 \frac{m_Z^4}{M_H^4}\right).$$ \hspace{1cm} (2.12)

The couplings of the $H$ Higgs boson to the fermions are given by the Yukawa couplings. For heavy Higgs the only relevant fermion coupling is the top Yukawa coupling. The width for the decays of the $H$ boson into a $t\bar{t}$ pairs is easily found [16, 17]:

$$\Gamma(H \rightarrow t\bar{t}) \simeq Z_{wf}^H \frac{3G_F M_H m_t^2}{4\pi \sqrt{2}} \left(1 - 4 \frac{m_t^2}{M_H^2}\right)$$ \hspace{1cm} \left(2.13\right)

where we have taken into account Eq. (2.1). So that, to a good approximation, the heavy Higgs boson total width is given by:

$$\Gamma_H \simeq \Gamma(H \rightarrow W^+ W^-) + \Gamma(H \rightarrow Z^0 Z^0) + \Gamma(H \rightarrow t\bar{t}).$$ \hspace{1cm} (2.14)

### 3 Comparison with the CMS Run 2 dataset

The discussion in the previous Section showed that our heavy Higgs boson is a rather broad resonance and that almost all the decay modes are given by the decays into $W^+ W^-$. 
and \( Z^0Z^0 \) with:

\[
Br(H \rightarrow W^+W^-) \simeq 2 \ Br(H \rightarrow Z^0Z^0) .
\]  

(3.1)

In our previous papers we found some evidence of a broad scalar resonance that looks consistent with our Standard Model heavy Higgs boson in the golden channel. Actually, the decay channels \( H \rightarrow ZZ \rightarrow 4\ell \) have very low branching ratios, but the presence of leptons allows to efficiently reduce the huge background due mainly to diboson production. In fact, the four-lepton channel, albeit rare, has the clearest and cleanest signature of all the possible Higgs boson decay modes due to the small background contamination. Nevertheless, from one hand we did not find convincingly evidence of a heavy Standard Model Higgs boson in the comparison with the full LHC Run 2 data sets released by the ATLAS Collaboration. On the other hand, according to Eq. (3.1), the main decay mode of a heavy Higgs boson is the decays into two W vector bosons. As a consequence, the most stringent constraints should arise from the experimental searches for a heavy Higgs boson decaying into two W gauge bosons. The lack, at least up to now, of experimental evidences in this decay channel looks problematic. In fact, if this situation should persist our theoretical proposal should not be in agreement with observations and, therefore, should be rejected. The aim of the present Section is to contrast our proposal with the recent document Ref. [14] where the CMS Collaboration presented a search for a high mass resonance decaying into a pair of W bosons, using the full data set recorded by CMS during the LHC Run 2 corresponding to an integrated luminosity of 138 fb\(^{-1}\). The search strategy for \( H \rightarrow W^+W^- \) was based on the final state in which both W bosons decay leptonically, resulting in a signature with two isolated, oppositely charged, high \( p_T \) leptons (electrons or muons) and large missing transverse momentum, due to the undetected neutrinos. So that, the bulk of the signal comes from direct W decays to electrons or muons of opposite charge. However, even if not explicitly mentioned in Ref. [14], the small contributions proceeding through an intermediate \( \tau \) lepton are implicitly included. Therefore, in Ref. [14] it is always included the W boson decays into all three lepton types, so that the \( \ell \) symbol in \( W \rightarrow \ell + \nu \) comprises all three leptons \( e, \mu, \tau \). To increase the signal sensitivity event categorisation optimised for the gluon-gluon fusion and vector-boson fusion production mechanisms were used. To this end, it was introduced a parameter \( f_{VBF} \) corresponding to the fraction of the VBF production cross section with respect to the total cross section. In this way, \( f_{VBF} = 0 \) corresponds to GGF production signal, while \( f_{VBF} = 1 \) considers only the VBF production signal. For a heavy scalar resonance with Standard Model-like couplings \( f_{VBF} \) was set to the expectation using the cross sections provided by the LHC Higgs Cross Section Working Group [15]. The results are presented as upper limits on the product of the cross section with the relevant branching ratio on the production of a high mass scalar resonance. The 68 \% and 95 \% confidence level upper limits on \( \sigma(pp \rightarrow H \rightarrow WW \rightarrow 2\ell2\nu) \) are displayed in Fig. 4 of Ref. [14] for four different scenarios, \( f_{VBF} = 0, f_{VBF} = 1, \) floating \( f_{VBF} \) and Standard Model \( f_{VBF} \). Interestingly enough, the CMS Collaboration reported a small excess of data over the Standard Model background expectations for heavy Higgs boson masses ranging in the interval 500 GeV - 1000 GeV. Moreover, the signal hypothesis with the highest local significance was found in the VBF production mechanism ( \( f_{VBF} = 1 \) ) around the Higgs mass \( M_H \simeq 650 \) GeV.

In order to compare with our theoretical expectations, for definiteness, in Fig. 2 we report \( \sigma(pp \rightarrow H \rightarrow WW \rightarrow 2\ell2\nu) \) as a function of the Higgs mass \( M_H \) in the case of a heavy scalar resonance with Standard Model-like couplings (Standard Model \( f_{VBF} \)). The data
Figure 2: Product of the cross section $\sigma(pp \rightarrow H)$ with the branching ratio $Br(H \rightarrow WW \rightarrow 2\ell 2\nu)$ for a heavy Higgs boson with Standard Model $f_{VBF}$ versus the Higgs mass $M_H$ obtained by combining the Run 2 data sets. The data have been adapted from Fig. 4, bottom right panel, in Ref. [14]. Full black circles correspond to the observed signal, the red dashed line is the expected Standard Model background together with the 68 % CL limits (red dotted lines). The full green line corresponds to the product of the cross section and branching ratio for our heavy Higgs boson with central mass $M_H \simeq 730$ GeV.

have been extracted from Fig. 4, bottom right panel, of Ref. [14]. Looking at Fig. 2 we see that the observed signals display a sizeable broad excess with respect to expected Standard Model signal in the mass range 600 GeV - 800 GeV. Clearly, these excesses cannot be accounted for by a heavy scalar resonance with a narrow width. In addition, for a heavy Standard Model Higgs boson the main production mechanism would be by gluon-fusion processes for $M_H \lesssim 1000$ GeV, so that the resulting production cross section would lead to a signal greater by at least a factor of two with respect to the observed signal (see red line in Fig. 4, bottom right panel, of Ref. [14]). On the other hand, in our theoretical proposal the heavy Standard Model Higgs boson has a rather large width. So that, the expected main signal extends on the mass range 600 GeV - 800 GeV with a broad peak around $M_H \simeq 700$ GeV. Moreover, as we said in Sect. 2 the main production mechanism is by vector-boson fusion since the gluon-gluon fusion processes are strongly suppressed (see Fig. 1). To be quantitative, using Eqs. (2.4) and (2.10) we may easily evaluate the inclusive production cross section for our heavy Higgs boson. The result, displayed in Fig. 2 seems to compare reasonable well to the observed signal in the relevant Higgs mass range 600 GeV $\lesssim M_H \lesssim 800$ GeV. It should be emphasised that the rejection of the background-only hypothesis in a statistical sense will depend in general on the plausibility of the new signal hypothesis and the degree to which it can describe the data. In this respect, the presence of a rather broad excess around $M_H \simeq 700$ GeV is perfectly consistent with the fact that our Standard Model heavy Higgs boson has a central mass at $M_H \simeq 730$ GeV and a huge width. Moreover, we have estimate that the cumulative effects of the excesses in the mass range 600 GeV - 800 GeV reach a statistical significance of about
eight standard deviations. However, when searching for a new resonance somewhere in a possible mass range, the significance of observing a local excess of events must take into account the probability of observing such an excess anywhere in the range. This is the so called “look elsewhere effect” [18]. Even taking into account the look elsewhere effect, the cumulative statistical significance is at level of five standard deviations. To obtain more precise statements it should be necessary to implement our heavy Higgs boson in the Monte Carlo numerical simulations. However, we are aware that the implementation of a heavy resonance with a large width is still problematic.

4 Conclusions

In our previous papers we pictured the Higgs condensate of the Standard Model as a quantum liquid analogous to the superfluid He II. We found that the low-lying Higgs condensate excitations behave as two Standard Model Higgs bosons. The light Higgs boson, identified with the LHC narrow resonance at 125 GeV, turned out to practically indistinguishable from the perturbative Standard Model Higgs boson. As concern the heavy Higgs boson, we found some evidence in our previous phenomenological analysis in the golden channel of the preliminary LHC Run 2 data from ATLAS and CMS Collaborations. However, that evidence was not corroborated by the full Run 2 data sets recently released by the ATLAS Collaboration. Moreover, considering that the main decay mode of a heavy Higgs boson is the decay into two W vector bosons, the absence of experimental evidences of a heavy Higgs boson in this decay channel constituted a serious problem for our proposal. In the present note we compared our theoretical proposal to the CMS full Run 2 data set dealing with the search for a high mass Higgs boson decaying into a pair of W bosons in the dileptonic channel. The main results of the present paper, showed in Fig. 2 indicated that our prevision of an additional heavy Standard Model Higgs boson compared in a satisfying way to the experimental findings. The agreement between our estimate of the inclusive production cross section and the observed signal in the Higgs mass range \(600 \text{ GeV} \lesssim M_H \lesssim 800 \text{ GeV}\) seems to us particularly significative. Indeed, once one fixes the Higgs masses, \(M_h \simeq 125 \text{ GeV}\) and \(M_H \simeq 730 \text{ GeV}\), in our theory there are no more free parameters. Obviously, to further validate our theoretical proposal we must wait for further LHC Run 2 data, in particular the release by the CMS Collaboration of the full Run 2 dataset in the so-called golden channel.

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