The apparent excess in the Higgs to di-photon rate at the LHC: New Physics or QCD uncertainties?

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ABSTRACT

The Higgs boson with a mass $M_H \approx 126$ GeV has been observed by the ATLAS and CMS experiments at the LHC and a total significance of about five standard deviations has been reported by both collaborations when the channels $H \to \gamma\gamma$ and $H \to ZZ \to 4\ell$ are combined. Nevertheless, while the rates in the later search channel appear to be in accord with those predicted in the Standard Model, there seems to be an excess of data in the case of the $H \to \gamma\gamma$ discovery channel. Before invoking new physics contributions to explain this excess in the di-photon Higgs rate, one should verify that standard QCD effects cannot account for it. We describe how the theoretical uncertainties in the Higgs boson cross section for the main production process at the LHC, $gg \to H$, which are known to be large, should be incorporated in practice. We further show that the discrepancy between the theoretical prediction and the measured value of the $gg \to H \to \gamma\gamma$ rate, reduces to about one standard deviation when the QCD uncertainties are taken into account.

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The Higgs particle [1] has been, at last, observed by the ATLAS and CMS experiments at the LHC as a signal with about five standard deviations has been reported by each collaboration when the main search channels are combined [2]. This discovery represents a triumph for the Standard Model (SM) of particle physics and crowns more than four decades of theoretical and experimental endeavour. Now that the Higgs discovery chapter is closing, a new and even more challenging chapter is opening: the verification of the fundamental properties of the particle and the precise determination of its couplings. This program can be started at the LHC since, for the reported mass $M_H \approx 126$ GeV [2], one can have access to the Higgs boson in many production and decay channels [3].

At the LHC, the main Higgs production channel is the top and bottom quark loop mediated gluon–gluon fusion mechanism $gg \to H$: at center of mass energies of $\sqrt{s} = 7$ and 8 TeV and for a Higgs boson mass of $M_H \approx 126$ GeV, the inclusive cross sections are about $\sigma(gg \to H) \approx 15$ pb and 20 pb, respectively [4,5]. The vector boson fusion $qq \to Hqq$ and the Higgs-strahlung $q\bar{q} \to HW + HZ$ mechanisms add only little to these rates, respec-

tively $\approx 8\%$ and $\approx 5.5\%$, before kinematical cuts are applied [4,5]. The $gg \to H$ cross section is known up to next-to-next-to-leading order (NNLO) in perturbative QCD: the K-factor defined as the ratio of the higher order to the leading order (LO) [6] cross sections is ≈ 1.8 at NLO [7,8] and ≈ 2.5 at NNLO [9]. The cross section receives also small contributions from the resummation of soft gluons [10] and electroweak corrections [11,12]. Some small corrections that go beyond NNLO accuracy are also available [13] but have not been included in the predictions used by the LHC experimental collaborations. It is clear that it is this exceptionally large K-factor that allows for a sensitivity to the Higgs boson at the LHC with the presently collected data. The main Higgs search channels take advantage of the clean $H \to \gamma\gamma$, $H \to ZZ \to 4\ell^{\pm}$ and $H \to WW \to \ell\nu\ell\nu$ final states (with $\ell = e, \mu$), while the significance of other modes such as $H \to \tau^+\tau^-$ and $VH \to Vb\bar{b}$ is presently low. The Higgs decay branching ratios are rather precisely known [14].

The results presented by the ATLAS and CMS Collaborations on their Higgs search [2] turn out to be a little surprising. Indeed, while the rates for the $H \to ZZ$ search channel seem to reasonably agree with the SM expectations, a discrepancy mostly driven by the ATLAS results is observed in the channel $H \to \gamma\gamma$ which has the largest signal significance. Defining the ratios $R_{XX} = \sigma^{obs}_{H \to XX}/\sigma^{SM}_{H \to XX}$ of the measured cross section in a given search

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channel compared to the theoretical expectation, one finds for the two experiments[1]

ATLAS: $\quad R_{\gamma\gamma} = 1.90 \pm 0.50, \quad R_{ZZ} = 1.3 \pm 0.6,$

CMS: $\qquad R_{\gamma\gamma} = 1.56 \pm 0.43, \quad R_{ZZ} = 0.7 \pm 0.5,$

ATLAS $\oplus$ CMS: $\quad R_{\gamma\gamma} = 1.71 \pm 0.33, \quad R_{ZZ} = 0.95 \pm 0.40. \quad$ (1)

It then seems that the rate in the $H \to \gamma\gamma$ channel is more than two standard deviations larger compared to the SM prediction, when the ATLAS and CMS measurements are combined. This is a rather exciting situation as, not only the Higgs boson has been finally discovered, but in addition it appears to come with hints of some new physics. This could be the first (long awaited) signal for beyond the SM physics at the LHC. It is expected that a large number of studies (including some by the present authors and in addition to the many which were done after the first hint for this excess was reported in the 2011 data) will be devoted to the explanation of this feature in terms of new phenomena.[2]

However, before doing so, it would be probably wiser to consider more conventional explanations for this intriguing excess. The first one would be simply that this is the result of a statistical fluctuation (in both signal and backgrounds); after all, many $\gtrsim 2\sigma$ excesses appeared in the recent years and faded away when more data was collected.[3] Another possibility would be that the systematical uncertainties in the extremely difficult $H \to \gamma\gamma$ channel have been underestimated[4]; potential experimental problems (if any) could also be fixed when more data is accumulated and the detector response better understood.

A third conventional possibility to explain the $H \to \gamma\gamma$ excess would be that the QCD uncertainties may have been underestimated[5] by the experimental collaborations. This is the option that we will investigate in the present paper. We will show that if the theoretical uncertainties in the prediction of the cross section for the by far dominant $gg \to H$ production process at the LHC are properly included, the significance of the di-photon excess becomes substantially lower and agreement between theory and experiment can be reached at the $\approx 1\sigma$ level. This is achieved at the expense of slightly increasing the discrepancy of the $H \to ZZ$ and $H \to WW$ signals which, however, are affected by much larger experimental (mainly statistical) uncertainties.

Let us start by discussing the two main theoretical uncertainties that enter into play in $\sigma(gg \to H)$ and which have been discussed in detail by the LHC Higgs cross section working group

(LHCHWG) [4] and in Refs. [5,17–20]: the scale and PDF $+ \alpha_s$ uncertainties.[6]

The perturbative QCD corrections to the $gg \to H$ cross section are so large, leading to a K-factor of about 2.5, that it raises worries about the rate of convergence of the perturbative series. The possibility of still large higher order contributions beyond NNLO hence cannot be totally excluded. The effects of the unknown contributions are usually estimated from the variation of the cross section with the renormalisation μ_R and factorisation μ_F scales at which the process is evaluated. In the $gg \to H$ process, the median scale is taken to be $\mu_R = \mu_F = \mu_0 = \frac{1}{2}M_H$ [5,19] in order to absorb some of the soft-gluon resummation corrections. Indeed, $\sigma(gg \to H)$ calculated at NNLO with $\mu_0 = \frac{1}{2}M_H$ is then approximately the same (up to a few percent) as the resummed cross section at next-to-next-to-leading-logarithm (NNLL) with $\mu_0 = M_H$ [20]. However, the scale variation of the two cross sections is different.

To estimate the scale uncertainty, the current convention is to vary the renormalisation and factorisation scales within the range $\mu_0/\kappa \leqslant \mu_R, \mu_F \leqslant \kappa\mu_0$, with the ratio of scales restricted to the range $1/\kappa \leqslant \mu_F/\mu_R \leqslant \kappa$. The choice $\kappa = 2$ is usually adopted. For a Higgs mass $M_H = 126$ GeV, this leads to a scale uncertainty of $\Delta\sigma_\mu \approx {}^{+9\%}_{-10\%}$ at $\sqrt{s} = 7$ TeV and $\Delta\sigma_\mu \approx {}^{+12\%}_{-9.5\%}$ at $\sqrt{s} = 8$ TeV when the constraint $\frac{1}{2} \leqslant \mu_F/\mu_R \leqslant 2$ is imposed.[7] Slightly larger uncertainties occur if the scale is varied in a wider domain. If for instance one chooses $\kappa = 3$, the scale variation would lead to a few percent more uncertainty.

A second issue is related to the not yet entirely satisfactory determination of the parton distribution functions (PDFs) and in particular, the gluon densities. In addition to this, since $\sigma^{\mathrm{LO}}(gg \to H) \propto \alpha_s^2$ and receives large contributions at $\mathcal{O}(\geqslant \alpha_s^3)$, a modest change of α_s (which is possible as the average α_s value [22] can be rather different from the ones obtained from deep-inelastic scattering data that are used in some of the PDFs) can lead to sizable change in the cross section value. There is a statistical method to estimate the PDF uncertainties by allowing a 1σ (or more) excursion of the experimental data that is used to perform the global fits. In addition, the MSTW Collaboration [23] provides a scheme that allows for a combined evaluation of the PDF and α_s uncertainties.

To take into account this additional uncertainty and the spread in the predictions using the various NNLO PDF sets [23,24], the PDF4LHC working group recommends [25] to take as a global PDF uncertainty the MSTW PDF $+ \Delta^{\mathrm{exp}}\alpha_s$ uncertainty at the 68% confidence level (CL) and multiply it by a factor of two. This procedure gives nearly the same answer as the one proposed in Refs. [17,18] in which one evaluates the combined 90% CL MSTW PDF $+ \Delta^{\mathrm{exp}}\alpha_s + \Delta^{\mathrm{th}}\alpha_s$ uncertainty, where $\Delta^{\mathrm{th}}\alpha_s$ is for the error generated by the theoretical uncertainty on α_s estimated to be ≈ 0.002 at NNLO [23]. For $\sigma(gg \to H)$ at NNLO, one then finds a total PDF uncertainty of $\Delta\sigma^{\mathrm{PDF}} \approx 9\%$ at both $\sqrt{s} = 7$ and 8 TeV for a 126 GeV Higgs boson.

This discussion is illustrated in Fig. 1 where the $gg \to H$ inclusive cross section for a $M_H = 126$ GeV Higgs boson, evaluated at NNLO-QCD and including the electroweak corrections, is displayed as a function of the reduced scale μ/μ_0 with $\mu = \mu_R = \mu_F$ and

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[1] The numbers given by the collaborations correspond to the optimal (i.e. which maximises the likelihood of the test statistics) value $\hat{\mu}$ of the signal strength modifier that multiplies the expected cross section such that $\hat{\mu} = \sigma/\sigma^{\mathrm{SM}}$. As such, strictly speaking, they are not the true cross section ratios R_{XX}. We will nevertheless assume that they are the same for simplicity and for purposes of illustrating our point.

[2] However, because R_{ZZ} seems to be in agreement with the SM and there is no sign of a new particle in direct searches at the LHC, the $H \to \gamma\gamma$ excess will be particularly difficult to accommodate in relatively simple and/or well motivated SM extensions. One would probably have to resort to slightly "baroque" new constructions or scenarios to explain the excess.

[3] It might be noted that history could repeat itself: in the first $Z \to \ell^+\ell^-$ events observed by both the UA1 and UA2 Collaborations and which led to the discovery of the Z boson in 1983, a significant fraction were accompanied by additional photons [15]. This triggered a plethora of papers proposing composite models of quarks, leptons and weak bosons, before the excess of photons died away with more statistics.

[4] In particular, a significant fraction of the $\gamma\gamma$ events seem to come with two additional jets, while the predicted rate in the SM from vector boson fusion $qq \to qqH$ and $gg \to Hgg$ is expected to be small.

[5] An example out of many for such a possibility is the $p\bar{p} \to b\bar{b}$ production cross section at the Tevatron that had been first determined to be a factor of two to three larger than the QCD prediction, before higher order effects and various uncertainties were included; see Ref. [16] for a discussion.

[6] An addendum with the complete analysis for Higgs production at $\sqrt{s} = 8$ TeV has been added to the version of Ref. [5] submitted to the archives (arXiv:1012.0530v5).

[7] The uncertainty is a few % smaller if the two scales are equated, $\mu_R = \mu_F$, and one would obtain at NNLO $\Delta\sigma_\mu \approx {}^{+8.7\%}_{-9.5\%}$ at $\sqrt{s} = 8$ TeV in accord with Refs. [5,19]. The small difference for the central value of the cross section, obtained in our case by using the latest version of the program HIGLU [21], is due to some refinements in the treatment of the electroweak corrections performed in Ref. [19].
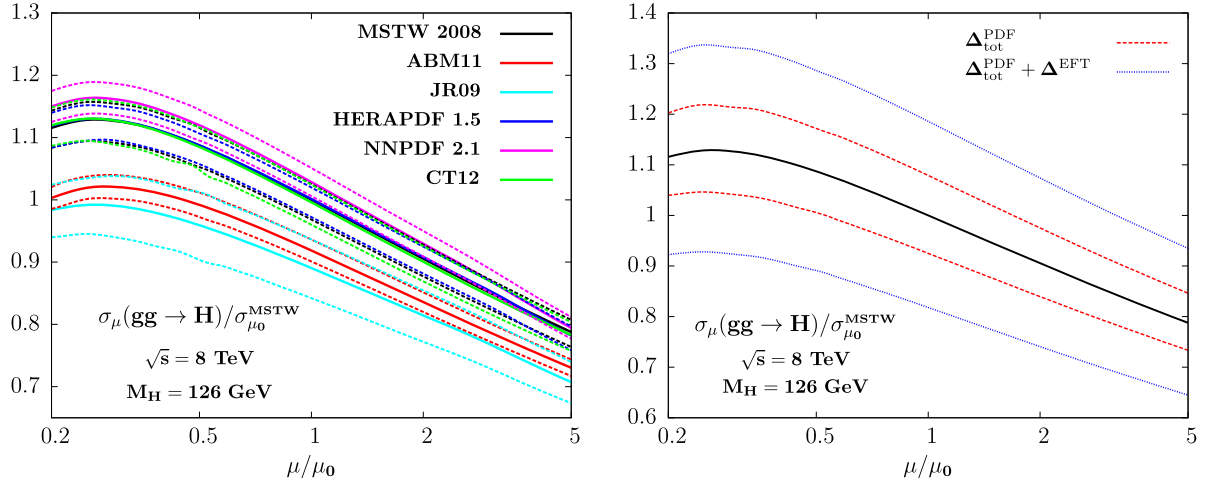
Fig. 1. $\sigma(gg \to H)$ at NNLO as a function of μ/μ_0 for $M_H = 126$ GeV and $\sqrt{s} = 8$ TeV. Left: the spread in the cross sections when the six NNLO PDF sets are used, normalised to the central MSTW cross section with $\mu_0 = \frac{1}{2}M_H$. Right: the relative PDF + α_s uncertainties in the MSTW case, when compared to the central value, as advocated by the LHCHWG group as well as the total uncertainty when the EFT uncertainty is linearly added.

$\mu_0 = \frac{1}{2}M_H$ at $\sqrt{s} = 8$ TeV. The situation at $\sqrt{s} = 7$ TeV is very similar. One can see that indeed, for the usual choice $\mu/\mu_0 = \frac{1}{2}$ (2) of scale variation, the cross section increases (decreases) by $\approx 10\%$. If one is conservative and enlarges the domain of scale variation, one notices that $\sigma(gg \to H)$ decreases monotonically with increasing μ/μ_0 but it has a plateau for about $\mu/\mu_0 \approx \frac{1}{3}$ where the cross section is maximal.

In the left-hand side of Fig. 1, the spread in the prediction for $\sigma(gg \to H)$ is shown for the six PDF sets that are available at NNLO [23,24], including the pure 90% CL PDF uncertainty bands. One sees that the spread of the cross sections is rather significant, but most sets predict a rate that is smaller than the MSTW prediction except for NNPDF and HERAPDF. The right-hand side of the figure shows the PDFs uncertainty that the PDF4LHC group [25] recommends to retain, i.e. the MSTW 68% CL PDF + $\Delta^{exp}\alpha_s$ combined uncertainty multiplied by a factor of 2, which is about $\pm 9\%$ in the entire μ/μ_0 range.

A critical issue is the way the scale and PDF uncertainties should be combined. As advocated by the LHCHWG [4], one should be conservative and add the two uncertainties linearly; this is equivalent of assuming that the PDF uncertainty is a pure theoretical uncertainty with a flat prior.[8] For $M_H \approx 126$ GeV, this procedure leads to a total uncertainty of about $\Delta^{scale+PDF}\sigma \approx \pm 20\%$. This is shown in the right-hand side of Fig. 1.

There is, however, a third source of uncertainty which has not been accounted for by the LHCHWG [4] but has been discussed in Refs. [5,17,18]. As the gluon–gluon fusion process, already at LO, occurs at the one-loop level with the additional complication of having to account for the finite mass of the loop particle, the NLO calculation is extremely complicated and the NNLO calculation a formidable task. Luckily, one can work in an effective field theory (EFT) approach in which the heavy quark in the loop is integrated out, making the calculation of the contributions beyond NLO possible. While this approach is justified for the dominant top quark contribution for $M_H \lesssim 2m_t$ [26], it is not valid for the b-quark loop (and for the interference between the b- and the t-loops) and for those involving the electroweak gauge bosons [11]. The uncertainties induced by the use of the EFT approach at NNLO are estimated,

from the NLO case in which both the exact and EFT calculations are available, to be of $\mathcal{O}(9\%)$ for $M_H \approx 126$ GeV [5].

This uncertainty is of pure theoretical origin as it is due to an approximation in the calculation and has nothing to do with the scale uncertainty. Hence it should be added linearly to the scale + PDF uncertainty. For $M_H \approx 126$ GeV, this leads to a total uncertainty of $\Delta^{tot}\sigma \approx \pm 30\%$ on the NNLO $gg \to H$ cross section when the scale is varied in the commonly adopted range $\frac{1}{2} \leqslant \mu/\mu_0 \leqslant 2$ as also shown in the right-hand side of Fig. 1.

In the case of interest, i.e. for the normalised cross section times branching ratios R_{XX} given by the ATLAS and CMS Collaborations, the story is not yet over and there are in fact two additional sources which lead to uncertainties or normalisation problems, albeit smaller than the ones discussed above:

(i) There are first uncertainties in the Higgs branching ratios. Indeed, while Higgs decays into leptons and gauge bosons are well under control, as mainly small electroweak effects are involved, the partial widths into quark pairs and gluons are subject to uncertainties. These are mainly due to the errors on input values of the bottom and charm quark masses and α_s, which then migrate to the other decays branching fractions [5,27]. For $M_H \approx 126$ GeV, one would obtain $\Delta BR(\gamma\gamma, WW, ZZ) \approx \pm 4\%$ when slightly smaller errors on the input masses m_b and m_c [27] compared to the PDG input values [22] are adopted.

(ii) There is a slight problem with the overall normalisation of $\sigma(gg \to H)$. The normalisation adopted by the experiments (and which comes from the LHCHWG) is the one obtained at NNLL [20] and not at NNLO [5,19]. Besides the fact that it is theoretically not entirely consistent to use the resummed result (as the PDFs are defined at NNLO and not NNLL), the resummation is available only for the inclusive rate and not for the cross sections when experimental cuts are incorporated and that are actually used by the experiments. It turns out that for $M_H \approx 126$ GeV, σ^{NNLL} is $\approx 3\%$ smaller than σ^{NNLO} and has a smaller scale dependence [20]. Hence, the $gg \to H$ cross section might have been underestimated from the very beginning, albeit by only a small amount.

These might affect the total rate and the uncertainties, increasing them by a few percent. If one also takes a non-dogmatic approach and increase the scale variation beyond the commonly chosen range $\frac{1}{2} \leqslant \mu/m_0 \leqslant 2$, one might end up with a total theoretical uncertainty that is closer to $\Delta^{th}\sigma \approx 40\%$ than 30% for $M_H \approx 126$ GeV.

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[8] Despite the fact that the Hessian method provides an error that is of probabilistic nature, it does not account for the theoretical assumptions that enter into the PDF parametrisation. This theoretical uncertainty is reflected in the larger spread in the central values of the PDF predictions.
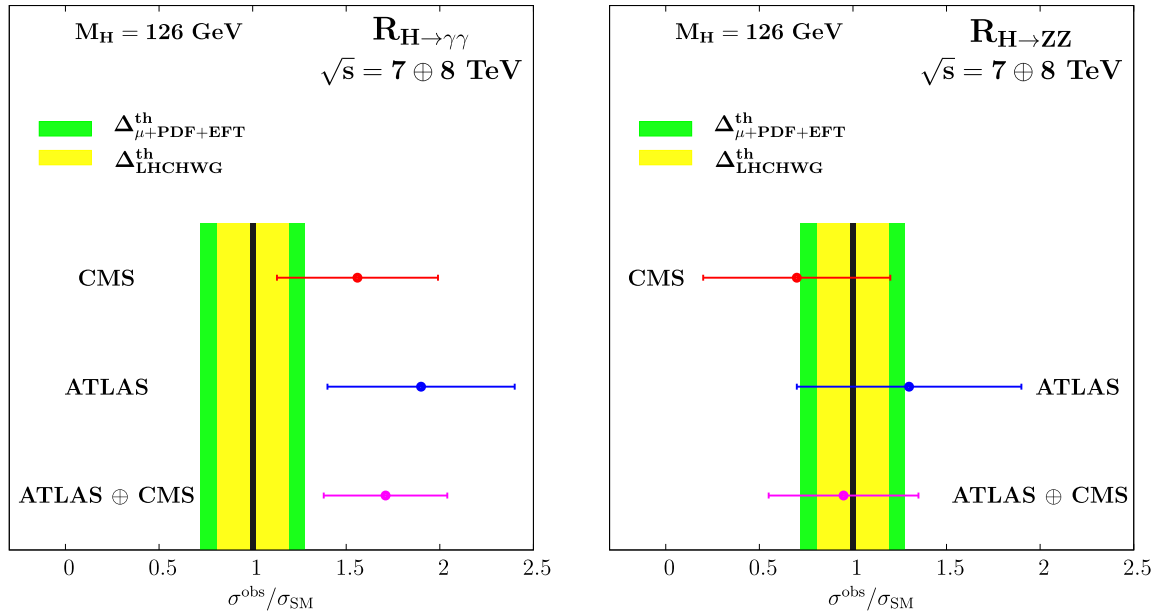
Fig. 2. The value of R_{XX} for the $H \to \gamma\gamma$ and ZZ final states given by the ATLAS and CMS Collaborations, as well as their combination, compared to the theoretical uncertainty bands.

We are now in a position to discuss the impact of this total uncertainty on the rates for Higgs production times decay branching ratios in the channels $H \to \gamma\gamma$ and $H \to ZZ$ that have been measured by the ATLAS and CMS Collaborations. A very important fact to note from the very beginning is that, in the experimental combination of different uncertainties, the theoretical uncertainty is not treated as a bias, as should be the case[9] but, instead, as a nuisance parameter. Therefore, the scale and PDF uncertainties are not added linearly to the experimental uncertainties in contradiction with the LHCHWG recommendation, but are combined quadratically with the experimental statistical and systematical errors. As the latter are much larger than the scale and PDF uncertainties, at least 30% for the experimental errors and only 10% for the scale and 10% for the PDF uncertainties, the magic of statistics and the combination in quadrature makes that

$$\Delta^{\text{tot}}\sigma = \sqrt{\left(\Delta^{\text{exp}}\sigma\right)^2 + \left(\Delta^{\mu}\sigma\right)^2 + \left(\Delta^{\text{PDF}}\sigma\right)^2} \approx \Delta^{\text{exp}}\sigma$$

for $\Delta^{\text{exp}}\sigma \gg \Delta^{\mu}\sigma, \Delta^{\text{PDF}}\sigma$.

This means that for $\Delta^{\text{exp}}\sigma \approx 30\%$, which is the minimal experimental error, one would obtain only $\Delta^{\text{tot}}\sigma \approx 33\%$. Hence, one can consider that, in practice, the above mentioned theoretical uncertainties are simply not reflected in the errors of Eq. (1) for the ATLAS and CMS measurements of the rates in the different channels.

For the comparison of theoretical predictions and the experimental measurements, it is more convenient to adopt the procedure advocated, for instance, in Ref. [18], that is to ignore the

theoretical uncertainties in the likelihood fit performed in the experimental analyses and simply confront the pure experimental error with the theoretical prediction that includes the theory uncertainty band. For the cross section in a given channel[10] and because the experimental values obtained from the multivariate analyses have been cross-checked by a cut based analysis, it should be possible to use such a procedure.

This is what is done in Fig. 2 for a Higgs mass of 126 GeV. First we combine the theory predictions for the $gg \to H$ cross section and their uncertainties at $\sqrt{s} = 7$ and 8 TeV and, because the integrated luminosity in both the 2011 and 2012 data samples is approximately the same, we simply perform an average. We then add all the theoretical uncertainties in two possible scenarios: (i) only the scale and PDF uncertainties as advocated by the LHCHWG and which leads to $\Delta^{\text{th}}_{\text{LHCHWG}}\sigma \approx \pm 19\%$, (ii) add linearly to the previous result the EFT uncertainty leading to a total of $\Delta^{\text{th}}_{\mu+\text{PDF}+\text{EFT}}\sigma \approx 28\%$.

In Fig. 2, the green and yellow bands represent these two possibilities for the total uncertainty. These bands are compared with the experimental measurements (which again we identify as a first approximation with the optimal value of the strength modifier $\hat{\mu}$) for the normalised production rates in the two channels,[11] $R_{\gamma\gamma}$ and R_{ZZ} of the ATLAS and CMS Collaborations, as well as the ATLAS and CMS combination, given in Eq. (1).

It is clear that including the theoretical uncertainty helps to reduce the discrepancy between the experimental and theoretical values in the $H \to \gamma\gamma$ channel, while keeping the accord between the data and the SM prediction in the $H \to ZZ$ channel. In the

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[9] Let us illustrate this important point by calculating $\sigma(gg \to H)$ in a consistent way but different from the one which gives the central value of Ref. [4] and which has been adopted as a normalisation by the ATLAS and CMS Collaborations. We choose to use the NNPDF2.1 set and evaluate the cross section at a scale $\mu_R = \mu_F = \mu_0 = \frac{1}{4}M_H$, which is within the range adopted for the scale uncertainty. We then obtain a NNLO cross section of $\sigma(gg \to H) = 22.9$ pb for $M_H = 126$ GeV and $\sqrt{s} = 8$ TeV. This value is $\approx 20\%$ larger than the reference value of $\sigma(gg \to H) = 19.2$ pb used by ATLAS and CMS. It is therefore clear that treating this theoretical uncertainty, which leads to the 20% change in the normalisation, as a mere nuisance can affect the conclusions in a very significant way.

[10] Although the situation here might be slightly complicated as, in practice, one has to add to the cross section of the $gg \to H$ process those of the vector boson fusion and Higgs-strahlung processes. However, because the $gg \to H$ cross section is an order of magnitude larger than the summed cross section of the vector boson and Higgs-strahlung processes, the latter can be omitted in a first approximation.

[11] We do not include the $gg \to H \to WW$ channel as first, it has not been yet analysed fully by the ATLAS Collaboration and second, the cross section in this case is broken into 0, 1 and 2 jet bins and this introduces an additional uncertainty due to the jet veto which can be significant [28].

approach where the scale, PDF and EFT uncertainty are added linearly, one would obtain in the $H \to \gamma\gamma$ channel deviations with a significance of 0.7σ, 1.24σ and 1.3σ for the CMS, ATLAS and ATLAS⊕CMS results, respectively.

One should finally comment on the optimal value of the strength modifier when all channels are combined, $\hat{\mu}_{\text{tot}}$, given by the ATLAS and CMS Collaborations when the 2011 and 2012 data are added: $\hat{\mu}_{\text{tot}} = 1.2 \pm 0.3$ and $\hat{\mu}_{\text{tot}} = 0.8 \pm 0.22$, respectively.[12] If this parameter is to be viewed as a cross section measurement, it would mean that the $gg \to H$ is already "measured" to better than $\approx 25\%$ (since all channels analysed by the two collaborations are initiated by $gg \to H$, except for the $H \to b\bar{b}$ channel for which the sensitivity is still rather low). This total error, which should be in principle largely due to the presently limited statistics, is of the same order of the theory uncertainty in the best case. We believe that this "paradox" will be resolved if the approach that we advocate, that is comparing the data for the cross sections including only the experimental uncertainties to the theoretical prediction with the uncertainty bands, is adopted.

In conclusion, we have first recalled that there are substantial theoretical uncertainties in the cross section for the dominant Higgs production channel at the LHC, gluon–gluon fusion, stemming from the scale dependence, the parton distribution functions and the use of an effective field theory approach to evaluate some higher order corrections. They are about 10% each and if they are combined according to the LHCHWG, they reach the level of 30% when the EFT uncertainty is also included. However, in the experimental analyses, these theoretical uncertainties in $\sigma(gg \to H)$ are treated as nuisance parameters rather than a bias. As they are still individually smaller than the experimental (statistical) errors, the net result is as if they had not been included in the total errors given by the ATLAS and CMS Collaborations. If the experimental results for the production cross sections times decay branching ratios in the various analysed channels are confronted with the theoretical prediction, including the theoretical uncertainty band added linearly on top of the experimental error, the discrepancy between the measurements and the prediction becomes smaller. This is particularly the case for $\sigma(gg \to H) \times \text{BR}(H \to \gamma\gamma)$, where the $\approx 2\sigma$ discrepancy with the SM prediction reduces to the level of $\approx 1\sigma$ if the 30% theory uncertainty is properly considered.

Acknowledgements

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[12] As can be seen, there is an apparent deficit in the CMS Higgs cross sections despite the apparent excess in $H \to \gamma\gamma$ rate. If the latter should turn out to be due to an upward statistical fluctuation and the global deficit should remain, the situation can be very easily accommodated by the 20–30% theoretical uncertainty in the normalisation of $\sigma(gg \to H)$, that we have been discussing here.