Inclusive cross section for Higgs in gluon fusion

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Ingredients of prediction   The inclusive Higgs cross section prediction we present here has been computed according to [3] We summarise below the different contributions to the inclusive cross section:

- Exact LO and NLO QCD cross-sections including the full quark mass dependence from top, bottom and charm quarks, in the $\overline{\text{MS}}$ scheme.

- N3LO QCD corrections in the effective field theory (EFT) approach, rescaled by $R_{LO} = \frac{\sigma_{\text{LO,top}}}{\sigma_{\text{LO,eff}}}$.

- Two-loop electroweak corrections and mixed QCD-electroweak corrections.

- Top quark effects at NNLO as a series expansion over m_h^2/m_t^2.

The central value for the cross-section is obtained with the contributions above at the scale $\mu_f = \mu_r = m_H/2$.

Table 1: Setup

$\sqrt{S}$	13 TeV
PDF	`PDF4LHC15_nnlo_100`
$a_s(m_Z)$	0.118
$m_t(m_t)$	162.7 GeV ($\overline{\text{MS}}$)
$m_b(m_b)$	4.18 GeV ($\overline{\text{MS}}$)
$m_c(3GeV)$	0.986 GeV ($\overline{\text{MS}}$)
$\mu = \mu_R = \mu_F$	$= m_H/2$

Description of predictions The total cross section along with its theory, PDF and α_s uncertainties is presented in tables 2,4,6,8 for 7,8,13 and 14TeV. In each case $m_h \in \{124.5, 125.0, 125.09, 125.5\}$. The recommendation of the PDF4LHC working group were followed when computing uncertainties due to PDF and α_s. The parameters used are described in table 1. The theory uncertainty is computed as a linear combination of uncertainties of various sources, as

$$\delta(TH) = \delta(\text{scale}) + \delta(\text{trunc}) + \delta(\text{PDF-TH}) + \delta(\text{EW}) + \delta(\text{t,b,c}) + \delta(1/m_t) \qquad (1)$$

The estimates for the individual uncertainties are explained in detail in [3]. The theory uncertainty should be interpreted as definining an upper and lower bound of the cross-section which has been derived by requiring perturbativity.

Furthermore, the contributions due to different quark combinations, as well as the total EW corrections, are presented in tables 3, 5, 7, 9. We denote by σ_{X+Y} the contributions to the cross section with the Yukawa couplings of X and Y set to their SM values and those of the other quarks set to zero. Then

$$\sigma_{XY} \equiv \sigma_{X+Y} - \sigma_X - \sigma_Y \qquad (2)$$

Moreover $\sigma_{XX} \equiv \sigma_X$.

A note on theory uncertainties The theory uncertainty assigned to individual light quark contributions follows eqs.5.5-5.7 of ref. [4] which we reproduce here for convenience:

$$\frac{\delta\sigma^{\text{NLO}}[n_1, n_2]}{\sigma^{\text{NLO}}[n_1, n_2]} = \pm\delta_{>\text{NLO}} \left(1 + \delta_{\text{schemeXY}}\right), \quad n_i \in \{0, 1\}, \qquad (3)$$

where

$$\delta_{>\text{NLO}} = \left(\frac{\sigma^{\text{N}^3\text{LO}} - \sigma^{\text{NLO}}}{\sigma^{\text{NLO}}}\right)_{\text{EFT}} \qquad (4)$$

is the relative change of the gluon-fusion cross-section in the effective theory from NLO to N³LO. Note that in this way make the assumption that the cross-section components that are not known beyond NLO will not have a worse perturbative convergence than in the effective theory. Finally, we enlarge this uncertainty further by

$$\delta_{\text{schemeXY}} = \frac{\left|\sigma^{\text{NLO},\overline{\text{MS}}}_{\text{exact XY}} - \sigma^{\text{NLO,OS}}_{\text{exact XY}}\right|}{\sigma^{\text{NLO},\overline{\text{MS}}}_{\text{exact XY}}}, \qquad (5)$$

which measures the renormalisarion scheme dependence of the quark masses at NLO.

Note that the scheme dependence measure, $\delta_{schemeXY}$ is larger than one in the contributions that do not contain the top quark, and reaches 10 for the σ_{cc}.

Furthermore, when the perturbative behaviour from LO to NLO is, in fact, worse than that of the EFT, as is the case for σ_{bb} (marginally) and σ_{bc}, σ_{cc}, we enhance the theory uncertainty by an extra factor

$$\delta_{convergence} = 1 + \left| 1 - \frac{K^{NLO}_{exactXY}}{K^{NLO}_{eft}} \right| \quad , \quad K^{NLO}_S \equiv \frac{\sigma^{NLO}_S}{\sigma^{LO}_S} \tag{6}$$

which reaches the level of 1.2 for σ_{bc}, σ_{cc}.

We finally note that, to a good approximation, the PDF and a_s uncertainty for individual quark contributions are the same, in percentage, as those of the total cross section, and therefore we do not include them in the tables.

The information contained in this document is based on the analytic and numerical results presented in refs [4, 3, 2, 1] and references therein. We would be happy if you cite this work when using the theoretical prediction of this note for the inclusive Higgs cross section.

m_h	σ_{tot}	$\delta(TH)$	$\delta(PDF)$	$\delta(a_s)$
124.5	16.99	$^{+0.75\text{pb}}_{-1.19\text{pb}}\left(^{+4.42\%}_{-6.98\%}\right)$	± 0.32 pb ($\pm 1.89\%$)	$^{+0.45\text{pb}}_{-0.45\text{pb}}\left(^{+2.67\%}_{-2.66\%}\right)$
125.0	16.85	$^{+0.74\text{pb}}_{-1.17\text{pb}}\left(^{+4.41\%}_{-6.96\%}\right)$	± 0.32 pb ($\pm 1.89\%$)	$^{+0.45\text{pb}}_{-0.45\text{pb}}\left(^{+2.67\%}_{-2.66\%}\right)$
125.09	16.83	$^{+0.74\text{pb}}_{-1.17\text{pb}}\left(^{+4.41\%}_{-6.96\%}\right)$	± 0.32 pb ($\pm 1.89\%$)	$^{+0.45\text{pb}}_{-0.45\text{pb}}\left(^{+2.67\%}_{-2.66\%}\right)$
125.5	16.71	$^{+0.74\text{pb}}_{-1.16\text{pb}}\left(^{+4.40\%}_{-6.95\%}\right)$	± 0.32 pb ($\pm 1.89\%$)	$^{+0.45\text{pb}}_{-0.44\text{pb}}\left(^{+2.67\%}_{-2.66\%}\right)$

Table 2: $\sqrt{S} = 7$TeV: Total cross section (including light quark and EW corrections) and uncertainties.

m_h	124.5	125.0	125.09	125.5
σ_{EW}	$0.84 \pm 1\%$	$0.83 \pm 1\%$	$0.83 \pm 1\%$	$0.83 \pm 1\%$
σ_{tt}	$16.86^{+2.4\%}_{-5.0\%}$	$16.71^{+2.4\%}_{-5.0\%}$	$16.69^{+2.4\%}_{-5.0\%}$	$16.57^{+2.4\%}_{-5.0\%}$
σ_{tb}	$-0.67 \pm 28.1\%$	$-0.66 \pm 28\%$	$-0.66 \pm 28\%$	$-0.65 \pm 28\%$
σ_{bb}	$0.04 \pm 83.5\%$	$0.04 \pm 83.5\%$	$0.04 \pm 83.5\%$	$0.04 \pm 83.6\%$
σ_{tc}	$-0.08 \pm 69.3\%$	$-0.08 \pm 69.3\%$	$-0.08 \pm 69.2\%$	$-0.08 \pm 69.2\%$
σ_{bc}	$0.01 \pm 165\%$	$0.01 \pm 165\%$	$0.01 \pm 165\%$	$0.01 \pm 165\%$
σ_{cc}	$3.43 \times 10^{-4} \pm 336\%$	$3.35 \times 10^{-4} \pm 336\%$	$3.34 \times 10^{-4} \pm 336\%$	$3.28 \times 10^{-4} \pm 336\%$

Table 3: $\sqrt{S} = 7$TeV: total Electroweak corrections, as well as heavy and light quark contributions (QCD corrections only) and theory uncertainties.

m_h	σ_{QCD}^{N3LO}	$\delta(TH)$	$\delta(PDF)$	$\delta(a_s)$
124.5	21.59	$^{+0.96\text{pb}}_{-1.49\text{pb}}\left(^{+4.44\%}_{-6.91\%}\right)$	$\pm$ 0.40 pb ($\pm$ 1.87%)	$^{+0.57\text{pb}}_{-0.57\text{pb}}\left(^{+2.65\%}_{-2.63\%}\right)$
125.0	21.42	$^{+0.95\text{pb}}_{-1.48\text{pb}}\left(^{+4.43\%}_{-6.9\%}\right)$	$\pm$ 0.40 pb ($\pm$ 1.87%)	$^{+0.57\text{pb}}_{-0.56\text{pb}}\left(^{+2.65\%}_{-2.62\%}\right)$
125.09	21.39	$^{+0.95\text{pb}}_{-1.47\text{pb}}\left(^{+4.43\%}_{-6.89\%}\right)$	$\pm$ 0.40 pb ($\pm$ 1.87%)	$^{+0.57\text{pb}}_{-0.56\text{pb}}\left(^{+2.65\%}_{-2.63\%}\right)$
125.5	21.26	$^{+0.94\text{pb}}_{-1.46\text{pb}}\left(^{+4.42\%}_{-6.88\%}\right)$	$\pm$ 0.40 pb ($\pm$ 1.87%)	$^{+0.56\text{pb}}_{-0.56\text{pb}}\left(^{+2.65\%}_{-2.62\%}\right)$

Table 4: $\sqrt{S} = 8$TeV: Total cross section (including light quark and EW corrections) and uncertainties.

m_h	124.5	125.0	125.09	125.5
σ_{EW}	1.06 $\pm$1%	1.06$\pm$1%	1.06 $\pm$1%	1.05 $\pm$1%
σ_{tt}	21.41 $^{+2.5\%}_{-5.0\%}$	21.23 $^{+2.5\%}_{-4.9\%}$	21.20 $^{+2.5\%}_{-4.9\%}$	21.06 $^{+2.5\%}_{-4.9\%}$
σ_{tb}	-0.83 $\pm$28.5%	-0.82 $\pm$28.4%	-0.82 $\pm$28.4%	-0.81 $\pm$28.4%
σ_{bb}	0.05 $\pm$83.%	0.05$\pm$83.1%	0.05$\pm$83.1%	0.05 $\pm$83.2%
σ_{tc}	-0.10 $\pm$68.5%	-0.10$\pm$68.5%	-0.10$\pm$68.5%	-0.10 $\pm$68.6%
σ_{bc}	0.01 $\pm$164%	0.01 $\pm$164%	0.01 $\pm$164%	0.01 $\pm$164%
σ_{cc}	4.29×10^{-4} $\pm$332%	4.2×10^{-4} $\pm$332%	4.18×10^{-4} $\pm$332%	4.11×10^{-4} $\pm$332%

Table 5: $\sqrt{S} = 8$TeV: total Electroweak corrections, as well as heavy and light quark contributions (QCD corrections only) and theory uncertainties.

m_h	σ_{QCD}^{N3LO}	$\delta(TH)$	$\delta(PDF)$	$\delta(a_s)$
124.5	48.91	$^{+2.24\text{pb}}_{-3.30\text{pb}}\left(^{+4.57\%}_{-6.74\%}\right)$	$\pm$ 0.91 pb ($\pm$ 1.86%)	$^{+1.28\text{pb}}_{-1.26\text{pb}}\left(^{+2.61\%}_{-2.59\%}\right)$
125.0	48.57	$^{+2.22\text{pb}}_{-3.27\text{pb}}\left(^{+4.56\%}_{-6.72\%}\right)$	$\pm$ 0.90 pb ($\pm$ 1.86%)	$^{+1.27\text{pb}}_{-1.25\text{pb}}\left(^{+2.61\%}_{-2.58\%}\right)$
125.09	48.51	$^{+2.21\text{pb}}_{-3.26\text{pb}}\left(^{+4.56\%}_{-6.72\%}\right)$	$\pm$ 0.90 pb ($\pm$ 1.86%)	$^{+1.27\text{pb}}_{-1.25\text{pb}}\left(^{+2.61\%}_{-2.58\%}\right)$
125.5	48.23	$^{+2.20\text{pb}}_{-3.23\text{pb}}\left(^{+4.55\%}_{-6.71\%}\right)$	$\pm$ 0.89 pb ($\pm$ 1.85%)	$^{+1.26\text{pb}}_{-1.24\text{pb}}\left(^{+2.61\%}_{-2.58\%}\right)$

Table 6: $\sqrt{S} = 13$TeV: Total cross section (including light quark and EW corrections) and uncertainties.

m_h	124.5	125.0	125.09	125.5
σ_{EW}	2.40 $\pm$1%	2.39$\pm$1%	2.39 $\pm$1%	2.39$\pm$1%
σ_{tt}	48.35 $^{+2.7\%}_{-4.9\%}$	48.00 $^{+2.7\%}_{-4.9\%}$	47.94 $^{+2.7\%}_{-4.9\%}$	47.65 $^{+2.7\%}_{-4.9\%}$
σ_{tb}	-1.76 $\pm$30.6%	-1.74 $\pm$30.5%	-1.73 $\pm$30.5%	-1.72 $\pm$30.4%
σ_{bb}	0.10 $\pm$81.8%	0.10$\pm$81.8%	0.10$\pm$81.8%	0.10 $\pm$81.9%
σ_{tc}	-0.22 $\pm$69.2%	-0.22$\pm$69.1%	-0.22$\pm$69.1%	-0.22 $\pm$69.1%
σ_{bc}	0.02 $\pm$160%	0.02 $\pm$160%	0.02 $\pm$160%	0.02 $\pm$160%
σ_{cc}	9.15×10^{-4} $\pm$320%	$8.96 \times 10^{-4}$$\pm$320%	8.92×10^{-4} $\pm$320%	8.77×10^{-4} $\pm$320%

Table 7: $\sqrt{S} = 13$TeV: total Electroweak corrections, as well as heavy and light quark contributions (QCD corrections only) and theory uncertainties.

m_h	σ_{QCD}^{N3LO}	$\delta(TH)$	$\delta(PDF)$	$\delta(a_s)$
124.5	55.05	$^{+2.53\text{pb}}_{-3.70\text{pb}}\left(^{+4.60\%}_{-6.72\%}\right)$	$\pm$ 1.02 pb ($\pm$ 1.86%)	$^{+1.44\text{pb}}_{-1.42\text{pb}}\left(^{+2.61\%}_{-2.59\%}\right)$
125.0	54.67	$^{+2.51\text{pb}}_{-3.67\text{pb}}\left(^{+4.58\%}_{-6.71\%}\right)$	$\pm$ 1.02 pb ($\pm$ 1.86%)	$^{+1.43\text{pb}}_{-1.41\text{pb}}\left(^{+2.61\%}_{-2.59\%}\right)$
125.09	54.60	$^{+2.50\text{pb}}_{-3.66\text{pb}}\left(^{+4.58\%}_{-6.70\%}\right)$	$\pm$ 1.02 pb ($\pm$ 1.86%)	$^{+1.42\text{pb}}_{-1.41\text{pb}}\left(^{+2.61\%}_{-2.58\%}\right)$
125.5	54.29	$^{+2.48\text{pb}}_{-3.63\text{pb}}\left(^{+4.58\%}_{-6.69\%}\right)$	$\pm$ 1.01 pb ($\pm$ 1.86%)	$^{+1.42\text{pb}}_{-1.4\text{pb}}\left(^{+2.61\%}_{-2.58\%}\right)$

Table 8: $\sqrt{S} = 14$TeV: Total cross section (including light quark and EW corrections) and uncertainties.

m_h	124.5	125.0	125.09	125.5
σ_{EW}	2.70$\pm$1%	2.69 $\pm$1%	2.69$\pm$1%	2.69 $\pm$1%
σ_{tt}	54.39$^{+2.8\%}_{-4.9\%}$	54.00 $^{+2.8\%}_{-4.9\%}$	53.93 $^{+2.8\%}_{-4.9\%}$	53.61 $^{+2.8\%}_{-4.9\%}$
σ_{tb}	-1.95 $\pm$30.9%	-1.93 $\pm$30.8%	-1.92 $\pm$30.8%	-1.91 $\pm$30.7%
σ_{bb}	0.12 $\pm$81.7%	0.11 $\pm$81.7%	0.11 $\pm$81.7%	0.11 $\pm$81.7%
σ_{tc}	-0.25 $\pm$69.4%	-0.24 $\pm$69.7%	-0.24 $\pm$69.7%	-0.24 $\pm$69.6%
σ_{bc}	0.02 $\pm$160%	0.02 $\pm$160%	0.02 $\pm$160%	0.02 $\pm$160%
σ_{cc}	$1.02 \times 10^{-3}$$\pm$318%	9.98×10^{-4} $\pm$318%	9.95×10^{-4} $\pm$318%	9.78×10^{-4} $\pm$318%

Table 9: $\sqrt{S} = 14$TeV: total Electroweak corrections, as well as heavy and light quark contributions (QCD corrections only) and theory uncertainties.

References

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