

## LHC HIGGS WORKING GROUP\*

## PUBLIC NOTE

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# Predictions for Production Cross Sections of the Higgs Boson at the LHC and HL-LHC

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**Instructions for authors:**

- Add your name on the author list in the appropriate group. Anyone who was/is a convener since we started this work should be listed as such. External people should be listed in the “In collaboration with”. All groups should be alphabetical.
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**Abstract** This note documents state-of-the-art predictions for the production cross sections of the Higgs Boson at the LHC. Specifically, Standard Model predictions for the LHC with centre-of-mass. energy of 7, 8, 13, 13.6 and 14 TeV are presented.

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## 1 Introduction

Production cross sections for the Higgs boson based on the Standard Model of particle physics were collected in the CERN Yellow Report "Deciphering the Nature of the Higgs Sector" (YR4) (CERN-2017-002) [1]. Since this document became public many advancements in our abilities to predict production cross sections were achieved. Furthermore, the LHC performed measurements at a higher centre-of-mass energy of 13.6 TeV for which YR4 does not contain any predictions. Looking ahead to Run-3 and the High Luminosity phase of the LHC (HL-LHC) and the associated wealth of data that will be collected an update of the HWG recommendation of all production cross sections to reflect the current state of the art is called for. The aim of this note is to document recent advancements and review the ingredients for the prediction of Standard Model predictions for the production cross sections of the Higgs boson at the LHC (similar in spirit as in YR4). Updated numerical predictions for central values of the production cross sections and associated theoretical and parametric uncertainties are the main result of this article. This note supersedes the interpolation of Ref. [2].

For now, instructions and input parameters for the generation of numerical values can be found here: <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHWG136TeVxsec>

**2** Common setup

**3**  $ggF$

**4**  $VBF$

**5**  $VH$

**6**  $t\bar{t}H$  and  $tH$

**7**  $b\bar{b}H$

**8** Conclusions

## Acknowledgments

This work was done on behalf of the LHCHWG.

## A Reference tables

### A.1 ggF

### A.2 VBF

Table 1: Total VBF cross sections in the SM for a LHC CM energy of  $\sqrt{s} = 8$  TeV, including QCD and EW corrections and their uncertainties for different Higgs-boson masses  $M_H$ . For more details see section 4.

$M_H[\text{GeV}]$	$\sigma^{\text{VBF}}[\text{fb}]$	$\Delta_{\text{scale}}[\%]$	$\Delta_{\text{PDF}/\alpha_s/\text{PDF}\oplus\alpha_s}[\%]$	$\Delta_{\text{TU}}[\%]$	$\sigma_{\text{N3LO}}^{\text{DIS}}[\text{fb}]$	$\delta_{\text{EW}}[\%]$	$\sigma_\gamma[\text{fb}]$	$\sigma_{\text{nf}}[\text{fb}]$	$\sigma_{\text{s/t/u}}[\text{fb}]$
120.00	1687	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1754	-4.6	13.2	—	-6.2
122.00	1657	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1722	-4.6	13	—	-5.9
124.00	1627	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1691	-4.5	12.9	—	-5.5
124.60	1618	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1681	-4.5	12.8	—	-5.5
124.80	1615	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1678	-4.5	12.8	—	-5.5
125.00	1612	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1675	-4.5	12.8	—	-5.4
125.09	1611	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1674	-4.5	12.8	—	-5.4
125.20	1609	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1672	-4.5	12.8	—	-5.4
125.30	1608	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1671	-4.5	12.8	—	-5.4
125.38	1607	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1669	-4.5	12.8	—	-5.4
125.60	1604	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1666	-4.5	12.8	—	-5.3
126.00	1598	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1660	-4.5	12.7	—	-5.2
128.00	1569	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1630	-4.5	12.6	—	-4.9
130.00	1542	$^{+0.1}_{-0.1}$	$\pm 2.3/\pm 0.3/\pm 2.3$	$\pm 1.0$	1601	-4.5	12.4	—	-4.6

Table 2: Total VBF cross sections in the SM for a LHC CM energy of  $\sqrt{s} = 13$  TeV, including QCD and EW corrections and their uncertainties for different Higgs-boson masses  $M_H$ . For more details see section 4.

$M_H[\text{GeV}]$	$\sigma^{\text{VBF}}[\text{fb}]$	$\Delta_{\text{scale}}[\%]$	$\Delta_{\text{PDF}/\alpha_s/\text{PDF}\oplus\alpha_s}[\%]$	$\Delta_{\text{TU}}[\%]$	$\sigma_{\text{N3LO}}^{\text{DIS}}[\text{fb}]$	$\delta_{\text{EW}}[\%]$	$\sigma_\gamma[\text{fb}]$	$\sigma_{\text{nf}}[\text{fb}]$	$\sigma_{\text{s/t/u}}[\text{fb}]$
120.00	3967	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4148	-5.2	36.1	-8.9	-11.5
122.00	3905	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4082	-5.2	35.8	-8.5	-10.6
124.00	3844	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4017	-5.2	35.4	-8.2	-10.2
124.60	3825	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	3998	-5.2	35.3	-8.1	-10
124.80	3819	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	3992	-5.2	35.25	-8.1	-10
125.00	3813	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	3985	-5.2	35.2	-8.0	-10
125.09	3811	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	3982	-5.2	35.2	-8.0	-10
125.20	3807	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	3979	-5.2	35.2	-8.0	-10
125.30	3804	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	3976	-5.2	35.2	-8.0	-9.9
125.38	3802	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	3973	-5.2	35.2	-8.0	-9.8
125.60	3795	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	3966	-5.2	35.1	-8.0	-9.7
126.00	3784	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	3954	-5.2	35.1	-7.9	-9.6
128.00	3725	$^{+0.1}_{-0.1}$	$\pm 2.2/\pm 0.4/\pm 2.2$	$\pm 1.0$	3892	-5.2	34.7	-7.7	-9.2
130.00	3667	$^{+0.1}_{-0.1}$	$\pm 2.2/\pm 0.3/\pm 2.2$	$\pm 0.9$	3831	-5.2	34.3	-7.5	-8.6

Table 3: Total VBF cross sections in the SM for a LHC CM energy of  $\sqrt{s} = 13.6$  TeV, including QCD and EW corrections and their uncertainties for different Higgs-boson masses  $M_H$ . For more details see section 4.

$M_H[\text{GeV}]$	$\sigma^{\text{VBF}}[\text{fb}]$	$\Delta_{\text{scale}}[\%]$	$\Delta_{\text{PDF}/\alpha_s/\text{PDF}\oplus\alpha_s}[\%]$	$\Delta_{\text{TU}}[\%]$	$\sigma_{\text{N3LO}}^{\text{DIS}}[\text{fb}]$	$\delta_{\text{EW}}[\%]$	$\sigma_\gamma[\text{fb}]$	$\sigma_{\text{nf}}[\text{fb}]$	$\sigma_{\text{s/t/u}}[\text{fb}]$
120.00	4276	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4473	-5.3	39.4	-9.2	-11.9
122.00	4210	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4403	-5.3	39	-8.8	-11.4
124.00	4144	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4334	-5.3	38.6	-8.5	-10.9
124.60	4125	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4313	-5.3	38.5	-8.4	-10.8
124.80	4118	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4307	-5.3	38.5	-8.4	-10.7
125.00	4112	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4300	-5.3	38.5	-8.3	-10.7
125.09	4109	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4297	-5.3	38.4	-8.3	-10.7
125.20	4106	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4293	-5.3	38.4	-8.3	-10.6
125.30	4102	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4290	-5.3	38.4	-8.3	-10.5
125.38	4100	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4287	-5.3	38.4	-8.3	-10.4
125.60	4093	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4280	-5.3	38.3	-8.3	-10.4
126.00	4080	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4266	-5.3	38.3	-8.2	-10.3
128.00	4018	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 0.9$	4200	-5.2	37.9	-8.0	-9.8
130.00	3956	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 0.9$	4135	-5.2	37.5	-7.8	-9.1

### A.3 VH

### A.4 ttH

### A.5 bbH

## References

- [1] LHC HIGGS CROSS SECTION WORKING GROUP collaboration, D. de Florian et al., *Handbook of LHC Higgs Cross Sections: 4. Deciphering the Nature of the Higgs Sector*, 1610.07922.
- [2] A. Karlberg et al., *Ad interim recommendations for the Higgs boson production cross sections at  $\sqrt{s} = 13.6$  TeV*, 2402.09955.

Table 4: Total VBF cross sections in the SM for a LHC CM energy of  $\sqrt{s} = 14$  TeV, including QCD and EW corrections and their uncertainties for different Higgs-boson masses  $M_H$ . For more details see section 4.

$M_H[\text{GeV}]$	$\sigma^{\text{VBF}}[\text{fb}]$	$\Delta_{\text{scale}}[\%]$	$\Delta_{\text{PDF}/\alpha_s/\text{PDF}\oplus\alpha_s}[\%]$	$\Delta_{\text{TU}}[\%]$	$\sigma_{\text{N}^3\text{LO}}^{\text{DIS}}[\text{fb}]$	$\delta_{\text{EW}}[\%]$	$\sigma_\gamma[\text{fb}]$	$\sigma_{\text{nf}}[\text{fb}]$	$\sigma_{\text{s/t/u}}[\text{fb}]$
120.00	4486	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4694	-5.3	41.7	-9.9	-12.4
122.00	4416	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4620	-5.3	41.3	-9.5	-11.9
124.00	4348	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4549	-5.3	40.8	-9.1	-11.2
124.60	4328	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4527	-5.3	40.7	-9.0	-11
124.80	4322	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4520	-5.3	40.7	-9.0	-11
125.00	4315	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4513	-5.3	40.7	-8.9	-10.9
125.09	4312	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4510	-5.3	40.6	-8.9	-10.9
125.20	4308	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4506	-5.3	40.6	-8.9	-10.9
125.30	4305	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4503	-5.3	40.6	-8.9	-10.8
125.38	4302	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4500	-5.3	40.6	-8.9	-10.8
125.60	4295	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4492	-5.3	40.5	-8.9	-10.6
126.00	4282	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4478	-5.3	40.5	-8.8	-10.5
128.00	4216	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4409	-5.3	40	-8.6	-10
130.00	4152	$^{+0.1}_{-0.1}$	$\pm 2.1/\pm 0.4/\pm 2.2$	$\pm 1.0$	4342	-5.3	39.7	-8.4	-9.5