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# SM Higgs production cross sections at $\sqrt{s} = 13$ TeV (update in CERN Report4 2016)

- Cross sections reported in CERN Report 4. See here and here here for previous numbers in CERN Report 3.
- Higgs cross sections and BRs in Spread sheet are available in xlsx format [NEW](#)
- You can find figures at our gallery here.

## Mass range and step for SM-like Higgs boson:

Higgs Mass range	step size	# of points	addendum
[120,124] GeV	0.5 GeV	9 points	
[124,126] GeV	0.1 GeV	20 points	+ $M_H=125.09$ GeV
[126,130] GeV	0.5 GeV	8 points	

- Total 38 points for  $M_H=[120,130]$  GeV.

## gluon-gluon Fusion Process

### *N3LO QCD cross sections supercede those of NNLO+NNLL QCD*

- Cross sections are calculated by Zürich group at N3LO QCD and NLO EW accuracies [Anastasiou:2016cez].
- QCD scales:  $\mu=\mu_F=\mu_R=M_H/2$  varied in the range of  $[M_H/4, M_H]$ .
- Theory uncertainty:
  - ◆ "±Theory" uncertainty is interpreted as a flat 100% confidence level.
  - ◆ "TH Gaussian" uncertainty is interpreted as a one-sigma range. It is estimated by  $\max\{+TH, -TH\}/\sqrt{3}$  as discussed in CERN Report 4 ggF section.
  - ◆ "TH Gaussian" uncertainty should be used for the construction of the workspace in the current LHC-HCG prescription [↗](#).
- PDF set: PDF4LHC15\_nlo\_100
- Cross sections are calculated with dFG program at NNLO+NNLL QCD and NLO EW accuracies.
- Calculations are the same as CERN Report 3 (i.e. top, bottom and charm quark effects are taken into account), except it is in NWA (CPS in CERN Report 3).
- Program: dFG
- QCD scales:  $\mu=\mu_F=\mu_R=M_H$ , uncertainty estimated in the range  $1/2 < \mu/M_H < 2$  with  $1/2 < \mu_F/\mu_R < 2$  constraint.
  - ◆ No additional THU nor PU uncertainties assigned.
- PDF set: PDF4LHC15\_nlo\_30

$m_H$ (GeV)	N3LO							NNLO+NNLL			
	Cross Section (pb)	+Theory %	-Theory %	TH Gaussian %	±(PDF+ %)	±PDF %	± %	Cross Section (pb)	+QCD Scale %	-QCD Scale %	± %
120.00	5.222E+01	+4.7	-6.9	±4.0	±3.2	±1.9	±2.6	4.738E+01	+7.7	-8.2	
120.50	5.184E+01	+4.7	-6.9	±4.0	±3.2	±1.9	±2.6	4.704E+01	+7.7	-8.2	
121.00	5.146E+01	+4.6	-6.9	±4.0	±3.2	±1.9	±2.6	4.670E+01	+7.7	-8.2	
121.50	5.108E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	4.637E+01	+7.7	-8.2	

122.00	5.071E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	4.604E+01	+7.7	-8.2
122.50	5.035E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	4.571E+01	+7.7	-8.2
123.00	4.998E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	4.539E+01	+7.7	-8.2
123.50	4.963E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	4.507E+01	+7.7	-8.1
124.00	4.927E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	4.476E+01	+7.6	-8.1
124.10	4.920E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	4.470E+01	+7.6	-8.1
124.20	4.913E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	4.463E+01	+7.6	-8.1
124.30	4.906E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.457E+01	+7.6	-8.1
124.40	4.899E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.451E+01	+7.6	-8.1
124.50	4.892E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.445E+01	+7.6	-8.1
124.60	4.885E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.438E+01	+7.6	-8.1
124.70	4.878E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.432E+01	+7.6	-8.1
124.80	4.871E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.426E+01	+7.6	-8.1
124.90	4.864E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.420E+01	+7.6	-8.1
125.00	4.858E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.414E+01	+7.6	-8.1
125.09	4.852E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.408E+01	+7.6	-8.1
125.10	4.851E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.408E+01	+7.6	-8.1
125.20	4.844E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.402E+01	+7.6	-8.1
125.30	4.837E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.396E+01	+7.6	-8.1
125.40	4.830E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.390E+01	+7.6	-8.1
125.50	4.823E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.383E+01	+7.6	-8.1
125.60	4.816E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.377E+01	+7.6	-8.1
125.70	4.810E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.371E+01	+7.6	-8.1
125.80	4.803E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.365E+01	+7.6	-8.1
125.90	4.796E+01	+4.5	-6.7	±3.9	±3.2	±1.9	±2.6	4.359E+01	+7.6	-8.1
126.00	4.789E+01	+4.5	-6.7	±3.9	±3.2	±1.9	±2.6	4.353E+01	+7.6	-8.1
126.50	4.756E+01	+4.5	-6.7	±3.9	±3.2	±1.9	±2.6	4.324E+01	+7.6	-8.1
127.00	4.723E+01	+4.5	-6.7	±3.8	±3.2	±1.9	±2.6	4.294E+01	+7.6	-8.1
127.50	4.690E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.265E+01	+7.5	-8.1
128.00	4.658E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.236E+01	+7.5	-8.1
128.50	4.625E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.207E+01	+7.5	-8.0
129.00	4.594E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.179E+01	+7.5	-8.0
129.50	4.562E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.151E+01	+7.5	-8.0
130.00	4.531E+01	+4.5	-6.6	±3.8	±3.2	±1.8	±2.6	4.123E+01	+7.5	-8.0

## VBf Process

- Cross sections are calculated at (approx.) NNLO QCD and NLO EW accuracies.
- Calculations are the same as CERN Report 3, except it is in NWA (CPS in CERN Report 3).
- Program: NNLO QCD (VBf@NNLO) and NLO EW (HAWK).
- QCD scales:  $\mu = \mu_F = \mu_R = M_W$ , uncertainty estimated in the range  $1/2 < \mu/M_W < 2$  (keeping  $\mu_F = \mu_R$ ).
  - ◆ No additional THU nor PU uncertainties assigned.
- PDF set: PDF4LHC15\_nnlo\_100 (QCD corrections) and NNPDF2.3QED (EW corrections + photon PDF)

$m_H$ (GeV)	Cross Section (pb)	+QCD Scale %	-QCD Scale %	±(PDF+ <sub>s</sub> ) %	±PDF %	± <sub>s</sub> %
120.00	3.935E+00	+0.4	-0.3	±2.1	±2.1	±0.5
120.50	3.919E+00	+0.4	-0.3	±2.1	±2.1	±0.5
121.00	3.904E+00	+0.4	-0.3	±2.1	±2.1	±0.5
121.50	3.888E+00	+0.4	-0.3	±2.1	±2.1	±0.5
122.00	3.873E+00	+0.4	-0.3	±2.1	±2.1	±0.5

122.50	3.858E+00	+0.4	-0.3	±2.1	±2.1	±0.5
123.00	3.842E+00	+0.4	-0.3	±2.1	±2.1	±0.5
123.50	3.827E+00	+0.4	-0.3	±2.1	±2.1	±0.5
124.00	3.812E+00	+0.4	-0.3	±2.1	±2.1	±0.5
124.10	3.809E+00	+0.4	-0.3	±2.1	±2.1	±0.5
124.20	3.806E+00	+0.4	-0.3	±2.1	±2.1	±0.5
124.30	3.803E+00	+0.4	-0.3	±2.1	±2.1	±0.5
124.40	3.800E+00	+0.4	-0.3	±2.1	±2.1	±0.5
124.50	3.797E+00	+0.4	-0.3	±2.1	±2.1	±0.5
124.60	3.794E+00	+0.4	-0.3	±2.1	±2.1	±0.5
124.70	3.791E+00	+0.4	-0.3	±2.1	±2.1	±0.5
124.80	3.788E+00	+0.4	-0.3	±2.1	±2.1	±0.5
124.90	3.785E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.00	3.782E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.09	3.779E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.10	3.779E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.20	3.776E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.30	3.773E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.40	3.770E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.50	3.767E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.60	3.764E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.70	3.761E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.80	3.758E+00	+0.4	-0.3	±2.1	±2.1	±0.5
125.90	3.755E+00	+0.4	-0.3	±2.1	±2.1	±0.5
126.00	3.752E+00	+0.4	-0.3	±2.1	±2.1	±0.5
126.50	3.738E+00	+0.4	-0.3	±2.1	±2.1	±0.5
127.00	3.723E+00	+0.4	-0.3	±2.1	±2.1	±0.5
127.50	3.708E+00	+0.4	-0.3	±2.1	±2.1	±0.5
128.00	3.694E+00	+0.4	-0.3	±2.1	±2.1	±0.5
128.50	3.680E+00	+0.4	-0.3	±2.1	±2.1	±0.5
129.00	3.665E+00	+0.4	-0.3	±2.1	±2.1	±0.5
129.50	3.651E+00	+0.4	-0.3	±2.1	±2.1	±0.5
130.00	3.637E+00	+0.4	-0.3	±2.1	±2.1	±0.5

## WH Process

- Cross sections are calculated at NNLO QCD and NLO EW accuracies.
  - ◆ Calculations are the same as CERN Report 3, except photon-induced contribution (see below).
  - ◆ Total cross section is calculated from WH 1 H cross section by subtracting photon-induced cross section, and then scaled via  $BR(W 1 H)=0.108535$  in NLO EW accuracy.
- Program: NNLO QCD (VH@NNLO) and NLO EW (HAWK).
- QCD scales:  $\mu=\mu_F=\mu_R=M_{VH}=(p_V+p_H)^2$  for QCD part and  $\mu=\mu_F=\mu_R=M_{VH}+M_H$  for EW part. Uncertainty is estimated in the range  $1/3 < \mu/M_{VH} < 3$  ( $\mu_F$  and  $\mu_R$  are varied independently).
  - ◆ No additional THU nor PU uncertainties assigned.
- PDF set: PDF4LHC15\_nnlo\_mc (QCD part) and NNPDF2.3QED (EW part).
- Photon-induced contribution of O(5%)
  - ◆ NOT included for total cross section (agrees with CERN Report 3 numbers within 1%).
  - ◆ Included in cross sections for dedicated WH 1 H ( $l=e,\mu$  or  $\tau$ ) process (we strongly recommend to use these numbers for dedicated analyses).

**pp WH Total Cross Section (with approximation)**

$m_H$ (GeV)	Cross Section (pb)	+QCD Scale %	-QCD Scale %	$\pm$ (PDF+ $s$ ) %	$\pm$ PDF %	$\pm$ $s$ %	W+H (pb)	W-H (pb)
120.00	1.565E+00	+0.5	-0.6	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.558E-01	6.092E-01
120.50	1.545E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.439E-01	6.007E-01
121.00	1.524E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.7	$\pm$ 0.9	9.320E-01	5.925E-01
121.50	1.505E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.7	$\pm$ 0.9	9.201E-01	5.845E-01
122.00	1.486E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.7	$\pm$ 0.9	9.091E-01	5.765E-01
122.50	1.466E+00	+0.5	-0.8	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.971E-01	5.693E-01
123.00	1.446E+00	+0.6	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.843E-01	5.618E-01
123.50	1.427E+00	+0.6	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.725E-01	5.544E-01
124.00	1.408E+00	+0.6	-0.6	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.611E-01	5.466E-01
124.10	1.405E+00	+0.5	-0.6	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.591E-01	5.455E-01
124.20	1.401E+00	+0.5	-0.6	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.569E-01	5.439E-01
124.30	1.398E+00	+0.6	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.548E-01	5.429E-01
124.40	1.394E+00	+0.5	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.527E-01	5.415E-01
124.50	1.390E+00	+0.6	-0.6	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.500E-01	5.395E-01
124.60	1.387E+00	+0.5	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.487E-01	5.386E-01
124.70	1.383E+00	+0.5	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.462E-01	5.372E-01
124.80	1.380E+00	+0.5	-0.8	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.442E-01	5.360E-01
124.90	1.376E+00	+0.5	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.419E-01	5.345E-01
125.00	1.373E+00	+0.5	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.400E-01	5.328E-01
125.09	1.369E+00	+0.5	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.380E-01	5.313E-01
125.10	1.369E+00	+0.5	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.377E-01	5.313E-01
125.20	1.365E+00	+0.6	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.355E-01	5.298E-01
125.30	1.362E+00	+0.6	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.334E-01	5.282E-01
125.40	1.358E+00	+0.6	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.313E-01	5.272E-01
125.50	1.355E+00	+0.5	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.291E-01	5.259E-01
125.60	1.351E+00	+0.5	-0.6	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.270E-01	5.243E-01
125.70	1.347E+00	+0.5	-0.6	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.243E-01	5.230E-01
125.80	1.344E+00	+0.6	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.224E-01	5.217E-01
125.90	1.341E+00	+0.5	-0.8	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.211E-01	5.202E-01
126.00	1.337E+00	+0.6	-0.8	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.184E-01	5.187E-01
126.50	1.320E+00	+0.6	-0.7	$\pm$ 1.9	$\pm$ 1.7	$\pm$ 0.9	8.080E-01	5.123E-01
127.00	1.304E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.7	$\pm$ 0.9	7.987E-01	5.051E-01
127.50	1.287E+00	+0.6	-0.7	$\pm$ 1.8	$\pm$ 1.7	$\pm$ 0.9	7.879E-01	4.988E-01
128.00	1.271E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.7	$\pm$ 0.9	7.785E-01	4.924E-01
128.50	1.255E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.7	$\pm$ 0.9	7.687E-01	4.862E-01
129.00	1.239E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.7	$\pm$ 0.9	7.593E-01	4.801E-01
129.50	1.224E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.7	$\pm$ 0.9	7.501E-01	4.738E-01
130.00	1.209E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.7	$\pm$ 0.9	7.414E-01	4.676E-01

**WH I H (l=e,μ or τ) Process**

$m_H$ (GeV)	W+H 1+ H							W-H 1-			
	Cross Section (pb)	+QCD Scale %	-QCD Scale %	$\pm$ (PDF+ $s$ ) %	$\pm$ PDF %	$\pm$ $s$ %		Cross Section (pb)	+QCD Scale %	-QCD Scale %	$\pm$ (PDF+ $s$ ) %
120.00	1.069E-01	+0.6	-0.6	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	3.16E-03	6.817E-02	+0.4	-0.6	$\pm$ 1.9
120.50	1.056E-01	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	3.15E-03	6.725E-02	+0.5	-0.6	$\pm$ 1.9
121.00	1.043E-01	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	3.15E-03	6.635E-02	+0.5	-0.6	$\pm$ 1.9

121.50	1.030E-01	+0.4	-0.8	±1.8	±1.6	±0.9	3.14E-03	6.548E-02	+0.5	-0.6	±1.9
122.00	1.018E-01	+0.3	-0.8	±1.8	±1.6	±0.9	3.13E-03	6.460E-02	+0.6	-0.6	±1.9
122.50	1.005E-01	+0.5	-0.8	±1.8	±1.6	±0.9	3.13E-03	6.382E-02	+0.4	-0.7	±2.0
123.00	9.910E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.12E-03	6.299E-02	+0.5	-0.6	±2.0
123.50	9.781E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.11E-03	6.219E-02	+0.5	-0.7	±2.0
124.00	9.657E-02	+0.6	-0.6	±1.8	±1.6	±0.9	3.11E-03	6.133E-02	+0.6	-0.6	±2.0
124.10	9.634E-02	+0.5	-0.6	±1.8	±1.6	±0.9	3.10E-03	6.122E-02	+0.5	-0.7	±2.0
124.20	9.610E-02	+0.5	-0.6	±1.8	±1.6	±0.9	3.10E-03	6.104E-02	+0.5	-0.6	±2.0
124.30	9.588E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.10E-03	6.093E-02	+0.5	-0.6	±2.0
124.40	9.565E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.10E-03	6.078E-02	+0.4	-0.7	±2.0
124.50	9.536E-02	+0.6	-0.6	±1.8	±1.6	±0.9	3.10E-03	6.057E-02	+0.6	-0.6	±2.0
124.60	9.521E-02	+0.5	-0.7	±1.8	±1.6	±0.9	3.10E-03	6.047E-02	+0.4	-0.7	±2.0
124.70	9.494E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.10E-03	6.031E-02	+0.4	-0.7	±2.0
124.80	9.471E-02	+0.6	-0.8	±1.8	±1.6	±0.9	3.09E-03	6.018E-02	+0.4	-0.7	±2.0
124.90	9.447E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.09E-03	6.002E-02	+0.3	-0.7	±2.0
125.00	9.426E-02	+0.5	-0.7	±1.8	±1.6	±0.9	3.09E-03	5.983E-02	+0.4	-0.7	±2.0
125.09	9.404E-02	+0.5	-0.7	±1.8	±1.6	±0.9	3.09E-03	5.967E-02	+0.4	-0.6	±2.0
125.10	9.401E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.09E-03	5.966E-02	+0.4	-0.6	±2.0
125.20	9.377E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.09E-03	5.950E-02	+0.5	-0.6	±2.0
125.30	9.354E-02	+0.6	-0.8	±1.8	±1.6	±0.9	3.09E-03	5.933E-02	+0.5	-0.6	±2.0
125.40	9.331E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.09E-03	5.922E-02	+0.5	-0.8	±2.0
125.50	9.308E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.09E-03	5.908E-02	+0.4	-0.7	±2.0
125.60	9.284E-02	+0.5	-0.6	±1.8	±1.6	±0.9	3.08E-03	5.891E-02	+0.4	-0.7	±2.0
125.70	9.254E-02	+0.6	-0.6	±1.8	±1.6	±0.9	3.08E-03	5.876E-02	+0.3	-0.7	±2.0
125.80	9.234E-02	+0.7	-0.7	±1.8	±1.6	±0.9	3.08E-03	5.862E-02	+0.4	-0.8	±2.0
125.90	9.220E-02	+0.6	-0.8	±1.8	±1.6	±0.9	3.08E-03	5.845E-02	+0.4	-0.7	±2.0
126.00	9.191E-02	+0.6	-0.8	±1.8	±1.6	±0.9	3.08E-03	5.829E-02	+0.5	-0.7	±2.0
126.50	9.077E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.07E-03	5.759E-02	+0.5	-0.7	±2.0
127.00	8.975E-02	+0.5	-0.7	±1.8	±1.6	±0.9	3.06E-03	5.680E-02	+0.5	-0.6	±1.9
127.50	8.858E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.06E-03	5.612E-02	+0.5	-0.6	±1.9
128.00	8.754E-02	+0.5	-0.7	±1.8	±1.6	±0.9	3.05E-03	5.541E-02	+0.4	-0.6	±1.9
128.50	8.647E-02	+0.6	-0.7	±1.8	±1.6	±0.9	3.04E-03	5.474E-02	+0.4	-0.7	±1.9
129.00	8.545E-02	+0.5	-0.7	±1.8	±1.6	±0.9	3.04E-03	5.407E-02	+0.4	-0.7	±1.9
129.50	8.444E-02	+0.5	-0.7	±1.8	±1.6	±0.9	3.03E-03	5.338E-02	+0.5	-0.7	±1.9
130.00	8.349E-02	+0.4	-0.8	±1.8	±1.6	±0.9	3.02E-03	5.270E-02	+0.5	-0.6	±1.9

## ZH Process

- Cross sections are calculated at NNLO QCD and NLO EW accuracies.
  - ◆ Calculations are the same as CERN Report 3, except photon-induced contribution (see below).
  - ◆ Total cross section is calculated from ZH llH,  $\gamma\gamma$  H cross sections by subtracting photon-induced cross section, and then scaled via  $BR(Z \rightarrow ll)=0.0335962$  and  $BR(Z \rightarrow \gamma\gamma)=0.201030$  in NLO EW accuracy.
  - ◆  $gg \rightarrow ZH$  (box-diagram) occurs as a part of NNLO QCD correction and included in the total cross section.
  - ◆ ZH cross section went up by +1~2%, due to +22~16% for  $\sqrt{s} = 7-14$  TeV, due to increase in  $gg \rightarrow ZH$  for NLO+NLL QCD corrections (NLO in CERN Report 3).
- Program: NNLO QCD (VH@NNLO) and NLO EW (HAWK).
- QCD scales:  $\mu = \mu_F = \mu_R = M_{VH} = (p_V + p_H)^2$  for QCD part and  $\mu = \mu_F = \mu_R = M_{VH} + M_H$  for EW part. Uncertainty is estimated in the range  $1/3 < \mu/M_{VH} < 3$  ( $\mu_F$  and  $\mu_R$  are varied independently).

- ◆ No additional THU nor PU uncertainties assigned.
- PDF set: PDF4LHC15\_nnlo\_mc (QCD part) and NNPDF2.3QED (EW part).
- Photon-induced contribution of O(1%) or below
  - ◆ NOT included for total cross section (agrees with CERN Report 3 numbers).
  - ◆ Included in cross sections for dedicated ZH  $\rightarrow$  H,  $\rightarrow$  H ( $l=e,\mu$  or  $\tau$ ) processes (we strongly recommend to use these numbers for dedicated analyses).

## gg ZH Cross Section

- ZH production has two distinct sources of gg ZH:
  1. a genuine NNLO contribution to what called Drell-Yan-like, where ZH is accompanied by two-parton radiation, gg HZ+qqbar.
  2. top- and bottom-loop induced contribution without any additional partons in the final state.
- What is usually meant by gg HZ below is 2) above.
- The statement that all but gg HZ is the same as qq- and qg-initiated is correct only through NLO QCD.
- For separate cross sections and associated QCD scale uncertainties in qq/qg ZH(+gg HZ+qqbar) and gg ZH for NLO/LO MC normalization, use
  - ◆ (all but gg ZH) = (pp ZH)@(NNLO QCD + NLO EW, NLO+NLL QCD gg ZH) - (gg ZH)@(NLO+NLL QCD),
  - ◆ Separate QCD scale uncertainties are (all but gg ZH) or on (gg ZH) are calculated with VH@NNLO program.
- For  $M_H=125.0$  GeV and at  $\sqrt{s}=13$  TeV,

Process	Cross Section (pb)	+QCD Scale %	-QCD Scale %	$\pm$ (PDF+ $\alpha_s$ ) %	$\pm$ PDF %	$\pm$ $\alpha_s$ %
pp ZH	0.8839	+3.8%	-3.1%	$\pm 1.6\%$	$\pm 1.3\%$	$\pm 0.9\%$
qq/qg ZH, gg HZ+qqbar (all but gg ZH)	0.7612	+0.5%	-0.6%	$\pm 1.9\%$	$\pm 1.7\%$	$\pm 0.9\%$
gg ZH	0.1227	+25.1%	-18.9%	$\pm 2.4\%$	$\pm 1.8\%$	$\pm 1.6\%$

## pp ZH Total Cross Section (with approximation)

$m_H$ (GeV)	Cross Section (pb)	+QCD Scale %	-QCD Scale %	$\pm$ (PDF+ $\alpha_s$ ) %	$\pm$ PDF %	$\pm$ $\alpha_s$ %	(gg ZH) (pb)
120.00	9.939E-01	+3.4	-3.0	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.299E-01
120.50	9.829E-01	+3.4	-3.0	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.292E-01
121.00	9.705E-01	+3.5	-3.0	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.281E-01
121.50	9.591E-01	+3.6	-3.0	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.269E-01
122.00	9.485E-01	+3.6	-3.0	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.271E-01
122.50	9.371E-01	+3.6	-3.0	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.265E-01
123.00	9.266E-01	+3.6	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.254E-01
123.50	9.157E-01	+3.5	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.250E-01
124.00	9.051E-01	+3.6	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.242E-01
124.10	9.037E-01	+3.7	-3.2	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.242E-01
124.20	9.008E-01	+3.8	-3.0	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.241E-01
124.30	8.988E-01	+3.7	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.239E-01
124.40	8.964E-01	+3.7	-3.0	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.236E-01
124.50	8.943E-01	+3.8	-3.0	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.235E-01
124.60	8.923E-01	+3.8	-3.0	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.233E-01
124.70	8.902E-01	+3.8	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.235E-01
124.80	8.884E-01	+3.7	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.230E-01
124.90	8.858E-01	+3.9	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.227E-01
125.00	8.839E-01	+3.8	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 0.9$	1.227E-01

125.09	8.824E-01	+3.8	-3.0	±1.6	±1.3	±0.9	1.227E-01
125.10	8.819E-01	+3.9	-3.0	±1.6	±1.3	±0.9	1.226E-01
125.20	8.800E-01	+3.8	-3.1	±1.6	±1.3	±0.9	1.223E-01
125.30	8.783E-01	+3.8	-3.1	±1.6	±1.3	±0.9	1.224E-01
125.40	8.767E-01	+3.8	-3.1	±1.6	±1.3	±0.9	1.223E-01
125.50	8.744E-01	+3.7	-3.1	±1.6	±1.3	±0.9	1.221E-01
125.60	8.728E-01	+3.8	-3.1	±1.6	±1.3	±0.9	1.224E-01
125.70	8.703E-01	+3.8	-3.0	±1.6	±1.3	±0.9	1.218E-01
125.80	8.690E-01	+3.7	-3.2	±1.6	±1.3	±0.9	1.219E-01
125.90	8.668E-01	+3.8	-3.1	±1.6	±1.3	±0.9	1.218E-01
126.00	8.649E-01	+3.8	-3.1	±1.6	±1.3	±0.9	1.218E-01
126.50	8.549E-01	+3.7	-3.2	±1.6	±1.3	±0.9	1.211E-01
127.00	8.446E-01	+3.7	-3.2	±1.6	±1.3	±0.9	1.203E-01
127.50	8.350E-01	+3.8	-3.2	±1.6	±1.3	±0.9	1.197E-01
128.00	8.255E-01	+3.9	-3.1	±1.6	±1.3	±0.9	1.190E-01
128.50	8.161E-01	+3.9	-3.2	±1.6	±1.3	±0.9	1.180E-01
129.00	8.073E-01	+3.8	-3.2	±1.6	±1.3	±0.9	1.177E-01
129.50	7.980E-01	+3.9	-3.2	±1.6	±1.3	±0.9	1.171E-01
130.00	7.899E-01	+3.9	-3.2	±1.6	±1.3	±0.9	1.164E-01

### ZH IH, H (l=e,μ or τ) Process

m <sub>H</sub> (GeV)	ZH l+lH								Cross Section (pb)	+QCD Scale %	-QCD Scale %	±(PDF+ s) %	±PDF s %	gg ZH (pb)	
	Cross Section (pb)	+QCD Scale %	-QCD Scale %	±(PDF+ s) %	±PDF s %	±(PDF+ s) %	±PDF s %								
120.00	3.352E-02	+3.4	-3.0	±1.6	±1.3	±1.0	4.38E-03	1.10E-04	1.997E-01	+3.4	-3.0				
120.50	3.315E-02	+3.4	-3.0	±1.6	±1.3	±1.0	4.36E-03	1.10E-04	1.975E-01	+3.4	-3.0				
121.00	3.273E-02	+3.5	-3.0	±1.6	±1.3	±1.0	4.32E-03	1.10E-04	1.950E-01	+3.5	-3.0				
121.50	3.235E-02	+3.6	-3.0	±1.6	±1.3	±1.0	4.28E-03	1.10E-04	1.927E-01	+3.6	-3.0				
122.00	3.199E-02	+3.6	-3.0	±1.6	±1.3	±1.0	4.29E-03	1.10E-04	1.906E-01	+3.6	-3.0				
122.50	3.161E-02	+3.6	-3.0	±1.6	±1.3	±0.9	4.27E-03	1.10E-04	1.883E-01	+3.6	-3.0				
123.00	3.125E-02	+3.6	-3.1	±1.6	±1.3	±0.9	4.23E-03	1.10E-04	1.862E-01	+3.6	-3.1				
123.50	3.089E-02	+3.5	-3.1	±1.6	±1.3	±0.9	4.22E-03	1.10E-04	1.840E-01	+3.5	-3.1				
124.00	3.053E-02	+3.6	-3.1	±1.6	±1.3	±0.9	4.19E-03	1.10E-04	1.819E-01	+3.6	-3.1				
124.10	3.048E-02	+3.7	-3.2	±1.6	±1.3	±0.9	4.19E-03	1.10E-04	1.816E-01	+3.7	-3.2				
124.20	3.039E-02	+3.8	-3.0	±1.6	±1.3	±0.9	4.19E-03	1.10E-04	1.810E-01	+3.8	-3.0				
124.30	3.032E-02	+3.7	-3.1	±1.6	±1.3	±0.9	4.18E-03	1.10E-04	1.806E-01	+3.7	-3.1				
124.40	3.024E-02	+3.7	-3.0	±1.6	±1.3	±0.9	4.17E-03	1.10E-04	1.801E-01	+3.7	-3.0				
124.50	3.017E-02	+3.8	-3.0	±1.6	±1.3	±0.9	4.17E-03	1.10E-04	1.797E-01	+3.8	-3.0				
124.60	3.010E-02	+3.8	-3.0	±1.6	±1.3	±0.9	4.16E-03	1.10E-04	1.793E-01	+3.8	-3.0				
124.70	3.003E-02	+3.8	-3.1	±1.6	±1.3	±0.9	4.17E-03	1.10E-04	1.789E-01	+3.8	-3.1				
124.80	2.997E-02	+3.7	-3.1	±1.6	±1.3	±0.9	4.15E-03	1.10E-04	1.785E-01	+3.7	-3.1				
124.90	2.988E-02	+3.9	-3.1	±1.6	±1.3	±0.9	4.14E-03	1.10E-04	1.780E-01	+3.9	-3.1				
125.00	2.982E-02	+3.8	-3.1	±1.6	±1.3	±0.9	4.14E-03	1.10E-04	1.776E-01	+3.8	-3.1				
125.09	2.977E-02	+3.8	-3.0	±1.6	±1.3	±0.9	4.14E-03	1.10E-04	1.773E-01	+3.8	-3.0				
125.10	2.975E-02	+3.9	-3.0	±1.6	±1.3	±0.9	4.14E-03	1.10E-04	1.772E-01	+3.9	-3.0				
125.20	2.969E-02	+3.8	-3.1	±1.6	±1.3	±0.9	4.13E-03	1.10E-04	1.768E-01	+3.8	-3.1				
125.30	2.963E-02	+3.8	-3.1	±1.6	±1.3	±0.9	4.13E-03	1.10E-04	1.765E-01	+3.8	-3.1				
125.40	2.957E-02	+3.8	-3.1	±1.6	±1.3	±0.9	4.13E-03	1.10E-04	1.762E-01	+3.8	-3.1				
125.50	2.950E-02	+3.7	-3.1	±1.6	±1.3	±0.9	4.12E-03	1.10E-04	1.757E-01	+3.7	-3.1				



125.60	2.944E-02	+3.8	-3.1	±1.6	±1.3	±0.9	4.13E-03	1.10E-04	1.754E-01	+3.8	-3.1
125.70	2.936E-02	+3.8	-3.0	±1.6	±1.3	±0.9	4.11E-03	1.10E-04	1.749E-01	+3.8	-3.0
125.80	2.932E-02	+3.7	-3.2	±1.6	±1.3	±0.9	4.11E-03	1.10E-04	1.746E-01	+3.7	-3.2
125.90	2.924E-02	+3.8	-3.1	±1.6	±1.3	±0.9	4.11E-03	1.10E-04	1.742E-01	+3.8	-3.1
126.00	2.918E-02	+3.8	-3.1	±1.6	±1.3	±0.9	4.11E-03	1.10E-04	1.738E-01	+3.8	-3.1
126.50	2.884E-02	+3.7	-3.2	±1.6	±1.3	±0.9	4.09E-03	1.10E-04	1.718E-01	+3.7	-3.2
127.00	2.850E-02	+3.7	-3.2	±1.6	±1.3	±0.9	4.06E-03	1.10E-04	1.697E-01	+3.7	-3.2
127.50	2.817E-02	+3.8	-3.2	±1.6	±1.3	±0.9	4.04E-03	1.10E-04	1.678E-01	+3.8	-3.2
128.00	2.785E-02	+3.9	-3.1	±1.6	±1.3	±0.9	4.02E-03	1.10E-04	1.659E-01	+3.9	-3.1
128.50	2.754E-02	+3.9	-3.2	±1.6	±1.3	±0.9	3.98E-03	1.10E-04	1.640E-01	+3.9	-3.2
129.00	2.724E-02	+3.8	-3.2	±1.6	±1.3	±0.9	3.97E-03	1.00E-04	1.622E-01	+3.8	-3.2
129.50	2.693E-02	+3.9	-3.2	±1.6	±1.3	±0.9	3.95E-03	1.00E-04	1.603E-01	+3.9	-3.2
130.00	2.665E-02	+3.9	-3.2	±1.6	±1.3	±0.9	3.93E-03	1.00E-04	1.587E-01	+3.9	-3.2

## ttH Process

- Cross sections are calculated at NLO QCD and NLO EW accuracies.
  - ◆ Calculations are the same as CERN Report 3, except NLO EW corrections are adopted now.
- Program: MadGraph5\_aMC@NLO (Sherpa+OpenLoops as cross ceck)
- QCD scales:  $\mu=\mu_F=\mu_R=M_{top}+M_H/2$ , uncertainty estimated in the range  $1/2 < \mu/(M_{top}+M_H/2) < 2$  (with  $1/2 < \mu_F/\mu_R < 2$  constraint).
  - ◆ No additional THU nor PU uncertainties assigned.
- PDF set: PDF4LHC15\_nlo\_30\_pdfas

$m_H$ (GeV)	Cross Section (pb)	+QCD Scale %	-QCD Scale %	±(PDF+ ) %	±PDF %	± <sub>s</sub> %
120.00	5.697E-01	+5.9	-9.3	±3.6	±3.0	±2.0
120.50	5.625E-01	+5.8	-9.2	±3.6	±3.0	±2.0
121.00	5.568E-01	+5.9	-9.3	±3.6	±3.0	±2.0
121.50	5.502E-01	+5.9	-9.3	±3.6	±3.0	±2.0
122.00	5.438E-01	+5.9	-9.3	±3.6	±3.0	±2.0
122.50	5.375E-01	+5.8	-9.2	±3.6	±3.0	±2.0
123.00	5.315E-01	+5.8	-9.2	±3.6	±3.0	±2.0
123.50	5.259E-01	+5.9	-9.2	±3.6	±3.0	±2.0
124.00	5.193E-01	+5.9	-9.2	±3.6	±3.0	±2.0
124.10	5.179E-01	+5.8	-9.2	±3.6	±3.0	±2.0
124.20	5.167E-01	+5.8	-9.2	±3.6	±3.0	±2.0
124.30	5.161E-01	+5.9	-9.3	±3.6	±3.0	±2.0
124.40	5.143E-01	+5.8	-9.2	±3.6	±3.0	±2.0
124.50	5.132E-01	+5.8	-9.2	±3.6	±3.0	±2.0
124.60	5.122E-01	+5.8	-9.2	±3.6	±3.0	±2.0
124.70	5.115E-01	+5.9	-9.3	±3.6	±3.0	±2.0
124.80	5.100E-01	+5.9	-9.3	±3.6	±3.0	±2.0
124.90	5.086E-01	+5.8	-9.2	±3.6	±3.0	±2.0
125.00	5.071E-01	+5.8	-9.2	±3.6	±3.0	±2.0
125.09	5.065E-01	+5.8	-9.2	±3.6	±3.0	±2.0
125.10	5.060E-01	+5.9	-9.3	±3.6	±3.0	±2.0
125.20	5.052E-01	+5.8	-9.2	±3.6	±3.0	±2.0
125.30	5.043E-01	+5.8	-9.2	±3.6	±3.0	±2.0
125.40	5.033E-01	+5.9	-9.3	±3.6	±3.0	±2.0
125.50	5.023E-01	+5.9	-9.3	±3.6	±3.0	±2.0
125.60	5.007E-01	+5.8	-9.2	±3.6	±3.0	±2.0

125.70	4.993E-01	+5.8	-9.2	±3.6	±3.0	±2.0
125.80	4.982E-01	+5.8	-9.2	±3.6	±3.0	±2.0
125.90	4.971E-01	+5.9	-9.3	±3.6	±3.0	±2.0
126.00	4.964E-01	+5.8	-9.2	±3.6	±3.0	±2.0
126.50	4.909E-01	+5.8	-9.2	±3.6	±3.0	±2.0
127.00	4.851E-01	+5.8	-9.2	±3.6	±3.0	±2.0
127.50	4.799E-01	+5.8	-9.2	±3.6	±3.0	±2.0
128.00	4.742E-01	+5.8	-9.2	±3.6	±3.0	±2.0
128.50	4.689E-01	+5.8	-9.2	±3.6	±3.0	±2.0
129.00	4.639E-01	+5.8	-9.3	±3.6	±3.0	±2.0
129.50	4.586E-01	+5.8	-9.2	±3.6	±3.0	±2.0
130.00	4.539E-01	+5.8	-9.3	±3.6	±3.0	±2.0

## bbH Process

- The cross sections are the Santander matched numbers with 5FS (NNLO) and 4FS (NLO). No EW corrections.
- Program: SusHi for 5FS and dedicated version of MadGraph5\_aMC@NLO for 4FS.
- QCD scales:
  - ◆ 5FS:  $\mu_F=M_H/4$ ,  $\mu_R=M_H$ ,
  - ◆ 4FS:  $\mu_F=\mu_R=(M_H+2M_b)/4$ ,
  - ◆ scale with 7-point variation by a factor of 2 in both cases.
- Uncertainties
  - ◆ 5FS: Linearly added scale + (PDF  $\sigma_s$ ) +  $M_b$  +  $\mu_b$  (PDF and  $\sigma_s$  uncertainties are added in quadrature).
  - ◆ 4FS: Only scale uncertainties (as they are the dominant ones) and no PDF uncertainties are included.
- PDF set
  - ◆ 5FS: Dedicated sets produced with APFEL are used which are generated from the PDF4LHC15\_nlo\_100 sets taken below the  $M_b$ -threshold and evolved upwards, while generating a b-PDF set at high scale.
  - ◆ 4FS: PDF4LHC15\_nlo\_nf4\_100

$m_H$ (GeV)	Cross Section (pb)	+(QCD Scale+PDF+ $\sigma_s$ ) %	-(QCD Scale+PDF+ $\sigma_s$ ) %
120.00	5.534E-01	+20.3	-24.4
120.50	5.471E-01	+20.3	-24.4
121.00	5.414E-01	+20.4	-24.3
121.50	5.343E-01	+20.5	-24.3
122.00	5.268E-01	+20.4	-24.3
122.50	5.200E-01	+20.2	-24.2
123.00	5.124E-01	+21.2	-24.1
123.50	5.066E-01	+20.1	-24.0
124.00	4.999E-01	+20.1	-24.0
124.10	4.985E-01	+20.1	-24.0
124.20	4.976E-01	+20.3	-24.1
124.30	4.955E-01	+20.2	-24.1
124.40	4.950E-01	+20.3	-24.1
124.50	4.930E-01	+20.0	-23.9
124.60	4.918E-01	+20.1	-24.0
124.70	4.919E-01	+20.6	-24.1
124.80	4.899E-01	+20.2	-24.0
124.90	4.891E-01	+20.3	-24.1

125.00	4.880E-01	+20.2	-23.9
125.09	4.863E-01	+20.1	-23.9
125.10	4.860E-01	+20.5	-23.9
125.20	4.850E-01	+20.1	-24.0
125.30	4.833E-01	+20.1	-24.0
125.40	4.822E-01	+20.2	-24.0
125.50	4.809E-01	+20.1	-23.8
125.60	4.792E-01	+20.1	-23.9
125.70	4.789E-01	+20.1	-23.9
125.80	4.768E-01	+20.1	-23.9
125.90	4.757E-01	+20.2	-24.0
126.00	4.760E-01	+20.2	-23.8
126.50	4.695E-01	+20.0	-23.7
127.00	4.635E-01	+20.0	-23.7
127.50	4.580E-01	+20.0	-23.6
128.00	4.513E-01	+19.9	-23.6
128.50	4.463E-01	+19.9	-23.5
129.00	4.416E-01	+20.0	-23.4
129.50	4.358E-01	+19.9	-23.4
130.00	4.304E-01	+19.9	-23.3

## tH Process

### t-ch (qb tHq)

- Cross sections are calculated at NLO QCD accuracy (no NLO EW correction) in 5FS.
- Program: MadGraph5\_aMC@NLO
- QCD scales:  $\mu = \mu_F = \mu_R = (M_{top} + M_H)/4$ , uncertainty estimated in the range  $1/2 < \mu / \{(M_{top} + M_H)/4\} < 2$  (with  $1/2 < \mu_F / \mu_R < 2$  constraint).
  - ◆ Flavour scheme (FS) dependence (4FS - 5FS envelope) included in the scale uncertainty. No PU uncertainty assigned.
- PDF set:
  - ◆ PDF4LHC15\_nlo\_30\_pdfas (5FS)
  - ◆ PDF4LHC15\_nlo\_nf4\_100 (4FS central set), used to compute the combined scale+FS uncertainty in tH t-channel.

$m_H$ (GeV)	Cross Section (pb)	+(QCD Scale + FS) %	-(QCD Scale + FS) %	$\pm$ ;(PDF+ %)	$\pm$ ;PDF %	$\pm$ ; %	tH (pb)	tbarH (pb)
120.00	7.731E-02	+6.7	-14.6	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	5.086E-02	2.643E-02
120.50	7.711E-02	+6.7	-14.8	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	5.071E-02	2.633E-02
121.00	7.684E-02	+6.7	-14.7	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	5.047E-02	2.623E-02
121.50	7.648E-02	+6.6	-14.7	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	5.024E-02	2.613E-02
122.00	7.614E-02	+6.7	-14.7	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	5.011E-02	2.602E-02
122.50	7.581E-02	+6.6	-14.6	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	4.985E-02	2.590E-02
123.00	7.552E-02	+6.6	-14.8	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	4.972E-02	2.584E-02
123.50	7.523E-02	+6.6	-14.9	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	4.947E-02	2.575E-02
124.00	7.499E-02	+6.6	-15.1	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	4.930E-02	2.560E-02
124.10	7.471E-02	+6.6	-14.6	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	4.935E-02	2.559E-02
124.20	7.477E-02	+6.6	-14.7	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	4.925E-02	2.558E-02
124.30	7.481E-02	+6.5	-14.9	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	4.915E-02	2.556E-02
124.40	7.477E-02	+6.6	-14.9	$\pm 3.7$	$\pm 3.5$	$\pm 1.2$	4.918E-02	2.557E-02

124.50	7.459E-02	+6.6	-14.9	±3.7	±3.5	±1.2	4.914E-02	2.553E-02
124.60	7.452E-02	+6.6	-14.7	±3.7	±3.5	±1.2	4.904E-02	2.549E-02
124.70	7.448E-02	+6.6	-14.8	±3.7	±3.5	±1.2	4.901E-02	2.549E-02
124.80	7.448E-02	+6.6	-14.9	±3.7	±3.5	±1.2	4.898E-02	2.546E-02
124.90	7.447E-02	+6.6	-15.1	±3.7	±3.6	±1.2	4.894E-02	2.542E-02
125.00	7.425E-02	+6.5	-14.9	±3.7	±3.5	±1.2	4.889E-02	2.542E-02
125.09	7.426E-02	+6.5	-14.7	±3.7	±3.5	±1.2	4.889E-02	2.540E-02
125.10	7.426E-02	+6.5	-14.7	±3.7	±3.5	±1.2	4.889E-02	2.540E-02
125.20	7.432E-02	+6.5	-15.0	±3.7	±3.5	±1.2	4.887E-02	2.540E-02
125.30	7.430E-02	+6.6	-14.9	±3.8	±3.6	±1.2	4.881E-02	2.538E-02
125.40	7.414E-02	+6.6	-14.9	±3.7	±3.6	±1.2	4.879E-02	2.534E-02
125.50	7.407E-02	+6.6	-15.0	±3.7	±3.5	±1.2	4.877E-02	2.534E-02
125.60	7.409E-02	+6.5	-15.2	±3.7	±3.6	±1.2	4.875E-02	2.532E-02
125.70	7.401E-02	+6.5	-15.0	±3.7	±3.6	±1.2	4.870E-02	2.531E-02
125.80	7.390E-02	+6.5	-15.0	±3.7	±3.6	±1.2	4.865E-02	2.530E-02
125.90	7.370E-02	+6.6	-14.8	±3.7	±3.5	±1.2	4.857E-02	2.530E-02
126.00	7.375E-02	+6.5	-15.0	±3.7	±3.6	±1.2	4.858E-02	2.527E-02
126.50	7.353E-02	+6.5	-14.9	±3.8	±3.6	±1.2	4.837E-02	2.516E-02
127.00	7.329E-02	+6.5	-15.1	±3.8	±3.6	±1.2	4.820E-02	2.511E-02
127.50	7.304E-02	+6.5	-15.1	±3.8	±3.6	±1.2	4.807E-02	2.499E-02
128.00	7.277E-02	+6.5	-15.1	±3.8	±3.6	±1.2	4.793E-02	2.491E-02
128.50	7.244E-02	+6.4	-15.0	±3.8	±3.6	±1.2	4.765E-02	2.481E-02
129.00	7.223E-02	+6.4	-15.1	±3.8	±3.6	±1.2	4.755E-02	2.474E-02
129.50	7.203E-02	+6.4	-15.2	±3.8	±3.6	±1.2	4.734E-02	2.466E-02
130.00	7.184E-02	+6.4	-15.3	±3.8	±3.6	±1.2	4.723E-02	2.459E-02

### s-ch (qq tHb)

- Cross sections are calculated at NLO QCD accuracy (no NLO EW correction) in 5FS.
- Program: MadGraph5\_aMC@NLO
- QCD scales:  $\mu = \mu_F = \mu_R = (M_{\text{top}} + M_H)/2$ , uncertainty estimated in the range  $1/2 < \mu / \{(M_{\text{top}} + M_H)/2\} < 2$  (with  $1/2 < \mu_F/\mu_R < 2$  constraint).
  - ◆ No additional THU nor PU uncertainties assigned.
- PDF set:
  - ◆ PDF4LHC15\_nlo\_30\_pdfas (5FS)

$m_H$ (GeV)	Cross Section (pb)	+QCD Scale %	-QCD Scale %	±(PDF+ <sub>s</sub> ) %	±PDF %	± <sub>s</sub> %	tH (pb)	tbarH (pb)
120.00	3.158E-03	+2.4	-1.8	±2.2	±2.2	±0.3	2.060E-03	1.095E-03
120.50	3.124E-03	+2.4	-1.8	±2.2	±2.2	±0.3	2.042E-03	1.083E-03
121.00	3.101E-03	+2.4	-1.8	±2.2	±2.2	±0.3	2.022E-03	1.073E-03
121.50	3.068E-03	+2.4	-1.8	±2.2	±2.2	±0.3	2.006E-03	1.063E-03
122.00	3.045E-03	+2.4	-1.8	±2.2	±2.2	±0.3	1.989E-03	1.052E-03
122.50	3.007E-03	+2.4	-1.8	±2.2	±2.2	±0.3	1.971E-03	1.043E-03
123.00	2.988E-03	+2.4	-1.8	±2.2	±2.2	±0.3	1.953E-03	1.033E-03
123.50	2.960E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.935E-03	1.023E-03
124.00	2.932E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.915E-03	1.014E-03
124.10	2.928E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.916E-03	1.012E-03
124.20	2.920E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.912E-03	1.010E-03
124.30	2.918E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.906E-03	1.008E-03
124.40	2.908E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.904E-03	1.006E-03
124.50	2.907E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.902E-03	1.004E-03

124.60	2.901E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.897E-03	1.003E-03
124.70	2.900E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.892E-03	1.000E-03
124.80	2.895E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.891E-03	9.980E-04
124.90	2.886E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.888E-03	9.960E-04
125.00	2.879E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.882E-03	9.960E-04
125.09	2.875E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.881E-03	9.930E-04
125.10	2.875E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.881E-03	9.930E-04
125.20	2.871E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.876E-03	9.910E-04
125.30	2.861E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.874E-03	9.890E-04
125.40	2.860E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.871E-03	9.880E-04
125.50	2.857E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.868E-03	9.870E-04
125.60	2.851E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.863E-03	9.830E-04
125.70	2.845E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.859E-03	9.820E-04
125.80	2.842E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.858E-03	9.800E-04
125.90	2.835E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.855E-03	9.790E-04
126.00	2.826E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.849E-03	9.770E-04
126.50	2.802E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.837E-03	9.670E-04
127.00	2.780E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.820E-03	9.590E-04
127.50	2.752E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.804E-03	9.500E-04
128.00	2.726E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.788E-03	9.410E-04
128.50	2.705E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.771E-03	9.330E-04
129.00	2.683E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.755E-03	9.240E-04
129.50	2.657E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.742E-03	9.160E-04
130.00	2.633E-03	+2.4	-1.8	±2.2	±2.2	±0.2	1.728E-03	9.080E-04

## W-associated (gb tHW)

- Cross sections are calculated at NLO QCD accuracy (no NLO EW correction) in 5FS
  - ◆ With DR2 (Diagram Removal plus interference) described in [Demartin:2016axk]
  - ◆  $(tHW^-) = (tbarHW^+) = ((tHW^-) + (tbarHW^+))/2$
- Program: MadGraph5\_aMC@NLO
- QCD scales:  $\mu = \mu_F = \mu_R = (M_{top} + M_H + M_W)/2$ , uncertainty estimated in the range  $1/2 < \mu / \{(M_{top} + M_H + M_W)/2\} < 2$  (with  $1/2 < \mu_F/\mu_R < 2$  constraint).
- PDF set:
  - ◆ PDF4LHC15\_nlo\_30\_pdfas (5FS)

$m_H$ (GeV)	Cross Section (pb)	+QCD Scale %	-QCD Scale %	±(PDF+ ) %	±PDF %	± %
125.00	1.517E-02	+4.9	-6.7	±6.3	±6.1	±1.5

-- ReiTanaka - 2016-03-01

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