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# SM Higgs production cross sections at $\sqrt{s} = 14$ 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\_nnlo\_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\_nnlo\_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	5.871E+01	+4.7	-6.9	±4.0	±3.2	±1.9	±2.6	5.327E+01	+7.8	-8.2	
120.50	5.829E+01	+4.7	-6.9	±4.0	±3.2	±1.9	±2.6	5.289E+01	+7.8	-8.2	
121.00	5.787E+01	+4.7	-6.8	±3.9	±3.2	±1.9	±2.6	5.252E+01	+7.8	-8.2	
121.50	5.745E+01	+4.7	-6.8	±3.9	±3.2	±1.9	±2.6	5.215E+01	+7.7	-8.2	

122.00	5.704E+01	+4.7	-6.8	±3.9	±3.2	±1.9	±2.6	5.179E+01	+7.7	-8.2
122.50	5.664E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	5.143E+01	+7.7	-8.2
123.00	5.624E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	5.107E+01	+7.7	-8.2
123.50	5.584E+01	+4.6	-6.8	±3.9	±3.2	±1.9	±2.6	5.072E+01	+7.7	-8.2
124.00	5.545E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	5.037E+01	+7.7	-8.2
124.10	5.537E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	5.030E+01	+7.7	-8.2
124.20	5.529E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	5.023E+01	+7.7	-8.1
124.30	5.521E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	5.016E+01	+7.7	-8.1
124.40	5.514E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	5.009E+01	+7.7	-8.1
124.50	5.506E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	5.003E+01	+7.7	-8.1
124.60	5.498E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.996E+01	+7.7	-8.1
124.70	5.490E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.989E+01	+7.7	-8.1
124.80	5.483E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.982E+01	+7.7	-8.1
124.90	5.475E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.975E+01	+7.6	-8.1
125.00	5.467E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.968E+01	+7.6	-8.1
125.09	5.461E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.962E+01	+7.6	-8.1
125.10	5.460E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.962E+01	+7.6	-8.1
125.20	5.452E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.955E+01	+7.6	-8.1
125.30	5.445E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.948E+01	+7.6	-8.1
125.40	5.437E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.941E+01	+7.6	-8.1
125.50	5.429E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.935E+01	+7.6	-8.1
125.60	5.422E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.928E+01	+7.6	-8.1
125.70	5.414E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.921E+01	+7.6	-8.1
125.80	5.407E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.915E+01	+7.6	-8.1
125.90	5.399E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.908E+01	+7.6	-8.1
126.00	5.392E+01	+4.6	-6.7	±3.9	±3.2	±1.9	±2.6	4.901E+01	+7.6	-8.1
126.50	5.355E+01	+4.6	-6.7	±3.8	±3.2	±1.9	±2.6	4.868E+01	+7.6	-8.1
127.00	5.318E+01	+4.6	-6.6	±3.8	±3.2	±1.9	±2.6	4.836E+01	+7.6	-8.1
127.50	5.282E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.803E+01	+7.6	-8.1
128.00	5.246E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.771E+01	+7.6	-8.1
128.50	5.210E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.740E+01	+7.6	-8.1
129.00	5.175E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.708E+01	+7.5	-8.0
129.50	5.140E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.677E+01	+7.5	-8.0
130.00	5.105E+01	+4.5	-6.6	±3.8	±3.2	±1.9	±2.6	4.647E+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	4.448E+00	+0.5	-0.3	±2.1	±2.1	±0.5
120.50	4.431E+00	+0.5	-0.3	±2.1	±2.1	±0.5
121.00	4.414E+00	+0.5	-0.3	±2.1	±2.1	±0.5
121.50	4.396E+00	+0.5	-0.3	±2.1	±2.1	±0.5
122.00	4.379E+00	+0.5	-0.3	±2.1	±2.1	±0.5

122.50	4.362E+00	+0.5	-0.3	±2.1	±2.1	±0.5
123.00	4.345E+00	+0.5	-0.3	±2.1	±2.1	±0.5
123.50	4.328E+00	+0.5	-0.3	±2.1	±2.1	±0.5
124.00	4.311E+00	+0.5	-0.3	±2.1	±2.1	±0.5
124.10	4.308E+00	+0.5	-0.3	±2.1	±2.1	±0.5
124.20	4.305E+00	+0.5	-0.3	±2.1	±2.1	±0.5
124.30	4.301E+00	+0.5	-0.3	±2.1	±2.1	±0.5
124.40	4.298E+00	+0.5	-0.3	±2.1	±2.1	±0.5
124.50	4.295E+00	+0.5	-0.3	±2.1	±2.1	±0.5
124.60	4.291E+00	+0.5	-0.3	±2.1	±2.1	±0.5
124.70	4.288E+00	+0.5	-0.3	±2.1	±2.1	±0.5
124.80	4.285E+00	+0.5	-0.3	±2.1	±2.1	±0.5
124.90	4.281E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.00	4.278E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.09	4.275E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.10	4.275E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.20	4.272E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.30	4.268E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.40	4.265E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.50	4.262E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.60	4.258E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.70	4.255E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.80	4.252E+00	+0.5	-0.3	±2.1	±2.1	±0.5
125.90	4.249E+00	+0.5	-0.3	±2.1	±2.1	±0.5
126.00	4.245E+00	+0.5	-0.3	±2.1	±2.1	±0.5
126.50	4.229E+00	+0.5	-0.3	±2.1	±2.1	±0.5
127.00	4.213E+00	+0.5	-0.3	±2.1	±2.1	±0.5
127.50	4.196E+00	+0.5	-0.3	±2.1	±2.1	±0.5
128.00	4.180E+00	+0.4	-0.3	±2.1	±2.1	±0.5
128.50	4.164E+00	+0.4	-0.3	±2.1	±2.1	±0.5
129.00	4.148E+00	+0.4	-0.3	±2.1	±2.1	±0.5
129.50	4.133E+00	+0.4	-0.3	±2.1	±2.1	±0.5
130.00	4.117E+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 <sup>+</sup> H (pb)	W <sup>-</sup> H (pb)
120.00	1.724E+00	+0.5	-0.6	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	1.048E+00	6.761E-01
120.50	1.702E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	1.035E+00	6.669E-01
121.00	1.680E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	1.022E+00	6.579E-01
121.50	1.657E+00	+0.4	-0.6	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	1.007E+00	6.497E-01
122.00	1.636E+00	+0.4	-0.6	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.951E-01	6.410E-01
122.50	1.615E+00	+0.4	-0.8	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.823E-01	6.326E-01
123.00	1.595E+00	+0.5	-0.8	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.704E-01	6.242E-01
123.50	1.572E+00	+0.5	-0.6	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.566E-01	6.158E-01
124.00	1.553E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.457E-01	6.077E-01
124.10	1.549E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.429E-01	6.061E-01
124.20	1.545E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.411E-01	6.042E-01
124.30	1.542E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.392E-01	6.028E-01
124.40	1.537E+00	+0.4	-0.6	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.356E-01	6.014E-01
124.50	1.534E+00	+0.4	-0.8	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.338E-01	5.997E-01
124.60	1.530E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.310E-01	5.987E-01
124.70	1.526E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.292E-01	5.965E-01
124.80	1.521E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.264E-01	5.945E-01
124.90	1.517E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.246E-01	5.929E-01
125.00	1.513E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.218E-01	5.912E-01
125.09	1.510E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.201E-01	5.898E-01
125.10	1.510E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.201E-01	5.896E-01
125.20	1.506E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.173E-01	5.888E-01
125.30	1.502E+00	+0.4	-0.8	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.155E-01	5.869E-01
125.40	1.498E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.127E-01	5.854E-01
125.50	1.494E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.099E-01	5.841E-01
125.60	1.490E+00	+0.5	-0.6	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.073E-01	5.826E-01
125.70	1.487E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.054E-01	5.815E-01
125.80	1.483E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.036E-01	5.796E-01
125.90	1.479E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	9.008E-01	5.782E-01
126.00	1.476E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	8.990E-01	5.770E-01
126.50	1.456E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	8.873E-01	5.692E-01
127.00	1.437E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	8.762E-01	5.612E-01
127.50	1.420E+00	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	8.655E-01	5.547E-01
128.00	1.401E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	8.543E-01	5.472E-01
128.50	1.384E+00	+0.4	-0.8	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	8.442E-01	5.395E-01
129.00	1.367E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	8.341E-01	5.328E-01
129.50	1.350E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	8.234E-01	5.262E-01
130.00	1.333E+00	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.6	$\pm$ 0.9	8.131E-01	5.199E-01

**WH I H (l=e,μ or τ) Process**

$m_H$ (GeV)	W <sup>+</sup> H I <sup>+</sup> H						W <sup>-</sup> H I <sup>-</sup> H				
	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	1.174E-01	+0.5	-0.6	$\pm$ 1.8	$\pm$ 1.5	$\pm$ 0.9	3.63E-03	7.577E-02	+0.4	-0.6	$\pm$ 1.9
120.50	1.160E-01	+0.4	-0.7	$\pm$ 1.8	$\pm$ 1.5	$\pm$ 0.9	3.62E-03	7.476E-02	+0.4	-0.6	$\pm$ 1.9
121.00	1.145E-01	+0.5	-0.7	$\pm$ 1.8	$\pm$ 1.5	$\pm$ 0.9	3.61E-03	7.378E-02	+0.4	-0.6	$\pm$ 1.9

121.50	1.129E-01	+0.5	-0.6	±1.8	±1.5	±0.9	3.60E-03	7.289E-02	+0.3	-0.7	±1.9
122.00	1.116E-01	+0.4	-0.6	±1.8	±1.5	±0.9	3.60E-03	7.193E-02	+0.4	-0.7	±1.9
122.50	1.102E-01	+0.4	-0.8	±1.8	±1.5	±0.9	3.59E-03	7.101E-02	+0.5	-0.7	±1.9
123.00	1.089E-01	+0.5	-0.8	±1.8	±1.5	±0.9	3.58E-03	7.010E-02	+0.4	-0.7	±1.9
123.50	1.074E-01	+0.6	-0.6	±1.8	±1.5	±0.9	3.57E-03	6.918E-02	+0.4	-0.7	±1.9
124.00	1.062E-01	+0.5	-0.7	±1.8	±1.5	±0.9	3.56E-03	6.829E-02	+0.4	-0.6	±1.9
124.10	1.059E-01	+0.5	-0.7	±1.8	±1.5	±0.9	3.56E-03	6.811E-02	+0.4	-0.6	±1.9
124.20	1.057E-01	+0.3	-0.7	±1.8	±1.5	±0.9	3.56E-03	6.791E-02	+0.5	-0.6	±1.9
124.30	1.055E-01	+0.3	-0.8	±1.8	±1.5	±0.9	3.56E-03	6.776E-02	+0.5	-0.6	±1.9
124.40	1.051E-01	+0.4	-0.6	±1.8	±1.5	±0.9	3.56E-03	6.760E-02	+0.5	-0.6	±1.9
124.50	1.049E-01	+0.4	-0.8	±1.8	±1.5	±0.9	3.55E-03	6.742E-02	+0.4	-0.7	±1.9
124.60	1.046E-01	+0.5	-0.7	±1.8	±1.5	±0.9	3.55E-03	6.731E-02	+0.3	-0.8	±1.9
124.70	1.044E-01	+0.4	-0.8	±1.8	±1.5	±0.9	3.55E-03	6.707E-02	+0.4	-0.6	±1.9
124.80	1.041E-01	+0.4	-0.7	±1.8	±1.5	±0.9	3.55E-03	6.684E-02	+0.5	-0.6	±1.9
124.90	1.039E-01	+0.3	-0.8	±1.8	±1.5	±0.9	3.55E-03	6.667E-02	+0.5	-0.5	±1.9
125.00	1.036E-01	+0.3	-0.8	±1.8	±1.5	±0.9	3.55E-03	6.649E-02	+0.5	-0.6	±1.9
125.09	1.034E-01	+0.4	-0.8	±1.8	±1.5	±0.9	3.54E-03	6.633E-02	+0.5	-0.5	±1.9
125.10	1.034E-01	+0.4	-0.8	±1.8	±1.5	±0.9	3.54E-03	6.631E-02	+0.5	-0.5	±1.9
125.20	1.031E-01	+0.5	-0.7	±1.8	±1.5	±0.9	3.54E-03	6.623E-02	+0.4	-0.7	±1.9
125.30	1.029E-01	+0.3	-0.9	±1.8	±1.5	±0.9	3.54E-03	6.602E-02	+0.5	-0.6	±1.9
125.40	1.026E-01	+0.4	-0.7	±1.8	±1.5	±0.9	3.54E-03	6.586E-02	+0.4	-0.6	±1.9
125.50	1.023E-01	+0.4	-0.7	±1.8	±1.5	±0.9	3.54E-03	6.572E-02	+0.4	-0.6	±1.9
125.60	1.020E-01	+0.6	-0.6	±1.8	±1.5	±0.9	3.53E-03	6.555E-02	+0.3	-0.6	±1.9
125.70	1.018E-01	+0.6	-0.7	±1.8	±1.5	±0.9	3.53E-03	6.542E-02	+0.3	-0.7	±1.9
125.80	1.016E-01	+0.4	-0.7	±1.8	±1.5	±0.9	3.53E-03	6.522E-02	+0.4	-0.7	±1.9
125.90	1.013E-01	+0.4	-0.7	±1.8	±1.5	±0.9	3.53E-03	6.507E-02	+0.3	-0.7	±1.9
126.00	1.011E-01	+0.5	-0.7	±1.8	±1.5	±0.9	3.53E-03	6.493E-02	+0.3	-0.7	±1.9
126.50	9.982E-02	+0.5	-0.7	±1.8	±1.5	±0.9	3.52E-03	6.409E-02	+0.3	-0.7	±1.9
127.00	9.861E-02	+0.5	-0.7	±1.8	±1.5	±0.9	3.51E-03	6.321E-02	+0.4	-0.6	±1.9
127.50	9.744E-02	+0.4	-0.7	±1.8	±1.5	±0.9	3.50E-03	6.250E-02	+0.3	-0.7	±1.9
128.00	9.621E-02	+0.5	-0.7	±1.8	±1.5	±0.9	3.49E-03	6.168E-02	+0.5	-0.7	±1.9
128.50	9.511E-02	+0.4	-0.8	±1.8	±1.5	±0.9	3.48E-03	6.085E-02	+0.5	-0.7	±1.9
129.00	9.400E-02	+0.5	-0.8	±1.8	±1.5	±0.9	3.47E-03	6.011E-02	+0.5	-0.6	±1.9
129.50	9.283E-02	+0.5	-0.7	±1.8	±1.5	±0.9	3.46E-03	5.939E-02	+0.5	-0.7	±1.9
130.00	9.171E-02	+0.5	-0.7	±1.8	±1.5	±0.9	3.46E-03	5.870E-02	+0.4	-0.7	±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  $\sqrt{s}=14$  TeV,

Process	Cross Section (pb)	+QCD Scale %	-QCD Scale %	$\pm$ (PDF+ $\alpha_s$ ) %	$\pm$ PDF% $\pm$ $\alpha_s$ %	$\pm$ %
pp ZH	0.9861	+3.8%	-3.3%	$\pm 1.6\%$	$\pm 1.3\%$	$\pm 1.0\%$
qq/qg ZH, gg HZ+qqbar (all but gg ZH)	0.8418	+0.4%	-0.7%	$\pm 1.8\%$	$\pm 1.6\%$	$\pm 0.8\%$
gg ZH	0.1443	+25.1%	-18.8%	$\pm 2.4\%$	$\pm 1.7\%$	$\pm 1.7\%$

## pp ZH Total Cross Section (with approximation)

$m_H$ (GeV)	Cross Section (pb)	+QCD Scale %	-QCD Scale %	$\pm$ (PDF+ $\alpha_s$ ) %	$\pm$ PDF% $\pm$ $\alpha_s$ %	$\pm$ %	(gg ZH) (pb)
120.00	1.106E+00	+3.6	-3.0	$\pm 1.7$	$\pm 1.3$	$\pm 1.0$	1.523E-01
120.50	1.094E+00	+3.7	-3.1	$\pm 1.7$	$\pm 1.3$	$\pm 1.0$	1.517E-01
121.00	1.081E+00	+3.6	-3.1	$\pm 1.7$	$\pm 1.3$	$\pm 1.0$	1.505E-01
121.50	1.069E+00	+3.5	-3.1	$\pm 1.7$	$\pm 1.3$	$\pm 1.0$	1.502E-01
122.00	1.057E+00	+3.6	-3.1	$\pm 1.7$	$\pm 1.3$	$\pm 1.0$	1.491E-01
122.50	1.045E+00	+3.6	-3.2	$\pm 1.7$	$\pm 1.3$	$\pm 1.0$	1.481E-01
123.00	1.032E+00	+3.8	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.473E-01
123.50	1.020E+00	+3.7	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.464E-01
124.00	1.009E+00	+3.8	-3.2	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.461E-01
124.10	1.006E+00	+3.7	-3.2	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.457E-01
124.20	1.004E+00	+3.7	-3.1	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.455E-01
124.30	1.002E+00	+3.7	-3.2	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.458E-01
124.40	9.989E-01	+3.8	-3.2	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.452E-01
124.50	9.974E-01	+3.7	-3.3	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.452E-01
124.60	9.945E-01	+3.8	-3.2	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.449E-01
124.70	9.928E-01	+3.8	-3.3	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.449E-01
124.80	9.900E-01	+3.8	-3.2	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.444E-01
124.90	9.876E-01	+3.8	-3.2	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.444E-01
125.00	9.861E-01	+3.8	-3.3	$\pm 1.6$	$\pm 1.3$	$\pm 1.0$	1.443E-01

125.09	9.836E-01	+3.8	-3.2	±1.6	±1.3	±1.0	1.443E-01
125.10	9.835E-01	+3.9	-3.3	±1.6	±1.3	±1.0	1.441E-01
125.20	9.815E-01	+3.8	-3.2	±1.6	±1.3	±1.0	1.443E-01
125.30	9.794E-01	+3.8	-3.3	±1.6	±1.3	±1.0	1.440E-01
125.40	9.770E-01	+3.9	-3.2	±1.6	±1.3	±1.0	1.437E-01
125.50	9.745E-01	+3.9	-3.2	±1.6	±1.3	±1.0	1.435E-01
125.60	9.727E-01	+3.8	-3.3	±1.6	±1.3	±1.0	1.434E-01
125.70	9.701E-01	+3.9	-3.3	±1.6	±1.3	±1.0	1.434E-01
125.80	9.676E-01	+3.9	-3.2	±1.6	±1.3	±1.0	1.431E-01
125.90	9.656E-01	+3.9	-3.2	±1.6	±1.3	±1.0	1.429E-01
126.00	9.626E-01	+4.0	-3.2	±1.6	±1.3	±1.0	1.428E-01
126.50	9.526E-01	+4.0	-3.3	±1.6	±1.3	±1.0	1.419E-01
127.00	9.422E-01	+4.1	-3.3	±1.6	±1.3	±1.0	1.413E-01
127.50	9.317E-01	+4.0	-3.3	±1.6	±1.3	±1.0	1.404E-01
128.00	9.207E-01	+4.1	-3.2	±1.6	±1.3	±1.0	1.395E-01
128.50	9.114E-01	+4.0	-3.4	±1.6	±1.3	±1.0	1.390E-01
129.00	9.019E-01	+3.9	-3.4	±1.6	±1.3	±1.0	1.381E-01
129.50	8.913E-01	+3.9	-3.4	±1.6	±1.3	±1.0	1.375E-01
130.00	8.805E-01	+4.1	-3.4	±1.6	±1.3	±1.0	1.363E-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 %	± s %	gg ZH (pb)	
	Cross Section (pb)	+QCD Scale %	-QCD Scale %	±(PDF+ s) %	±PDF s %	± s %										
120.00	3.731E-02	+3.6	-3.0	±1.7	±1.3	±1.0	5.14E-03	1.30E-04	2.223E-01	+3.6	-3.0					
120.50	3.690E-02	+3.7	-3.1	±1.7	±1.3	±1.0	5.12E-03	1.30E-04	2.198E-01	+3.7	-3.1					
121.00	3.646E-02	+3.6	-3.1	±1.7	±1.3	±1.0	5.08E-03	1.30E-04	2.172E-01	+3.6	-3.1					
121.50	3.606E-02	+3.5	-3.1	±1.7	±1.3	±1.0	5.07E-03	1.30E-04	2.148E-01	+3.5	-3.1					
122.00	3.564E-02	+3.6	-3.1	±1.7	±1.3	±1.0	5.03E-03	1.30E-04	2.123E-01	+3.6	-3.1					
122.50	3.525E-02	+3.6	-3.2	±1.7	±1.3	±1.0	5.00E-03	1.30E-04	2.099E-01	+3.6	-3.2					
123.00	3.482E-02	+3.8	-3.1	±1.6	±1.3	±1.0	4.97E-03	1.30E-04	2.074E-01	+3.8	-3.1					
123.50	3.441E-02	+3.7	-3.1	±1.6	±1.3	±1.0	4.94E-03	1.30E-04	2.049E-01	+3.7	-3.1					
124.00	3.403E-02	+3.8	-3.2	±1.6	±1.3	±1.0	4.93E-03	1.20E-04	2.027E-01	+3.8	-3.2					
124.10	3.395E-02	+3.7	-3.2	±1.6	±1.3	±1.0	4.92E-03	1.20E-04	2.022E-01	+3.7	-3.2					
124.20	3.386E-02	+3.7	-3.1	±1.6	±1.3	±1.0	4.91E-03	1.20E-04	2.017E-01	+3.7	-3.1					
124.30	3.380E-02	+3.7	-3.2	±1.6	±1.3	±1.0	4.92E-03	1.20E-04	2.013E-01	+3.7	-3.2					
124.40	3.370E-02	+3.8	-3.2	±1.6	±1.3	±1.0	4.90E-03	1.20E-04	2.007E-01	+3.8	-3.2					
124.50	3.365E-02	+3.7	-3.3	±1.6	±1.3	±1.0	4.90E-03	1.20E-04	2.004E-01	+3.7	-3.3					
124.60	3.355E-02	+3.8	-3.2	±1.6	±1.3	±1.0	4.89E-03	1.20E-04	1.998E-01	+3.8	-3.2					
124.70	3.349E-02	+3.8	-3.3	±1.6	±1.3	±1.0	4.89E-03	1.20E-04	1.995E-01	+3.8	-3.3					
124.80	3.340E-02	+3.8	-3.2	±1.6	±1.3	±1.0	4.87E-03	1.20E-04	1.989E-01	+3.8	-3.2					
124.90	3.332E-02	+3.8	-3.2	±1.6	±1.3	±1.0	4.87E-03	1.20E-04	1.984E-01	+3.8	-3.2					
125.00	3.327E-02	+3.8	-3.3	±1.6	±1.3	±1.0	4.87E-03	1.20E-04	1.981E-01	+3.8	-3.3					
125.09	3.319E-02	+3.8	-3.2	±1.6	±1.3	±1.0	4.87E-03	1.20E-04	1.976E-01	+3.8	-3.2					
125.10	3.318E-02	+3.9	-3.3	±1.6	±1.3	±1.0	4.86E-03	1.20E-04	1.976E-01	+3.9	-3.3					
125.20	3.311E-02	+3.8	-3.2	±1.6	±1.3	±1.0	4.87E-03	1.20E-04	1.972E-01	+3.8	-3.2					
125.30	3.304E-02	+3.8	-3.3	±1.6	±1.3	±1.0	4.86E-03	1.20E-04	1.968E-01	+3.8	-3.3					
125.40	3.296E-02	+3.9	-3.2	±1.6	±1.3	±1.0	4.85E-03	1.20E-04	1.963E-01	+3.9	-3.2					
125.50	3.288E-02	+3.9	-3.2	±1.6	±1.3	±1.0	4.84E-03	1.20E-04	1.958E-01	+3.9	-3.2					



125.60	3.282E-02	+3.8	-3.3	±1.6	±1.3	±1.0	4.84E-03	1.20E-04	1.954E-01	+3.8	-3.3
125.70	3.273E-02	+3.9	-3.3	±1.6	±1.3	±1.0	4.84E-03	1.20E-04	1.949E-01	+3.9	-3.3
125.80	3.265E-02	+3.9	-3.2	±1.6	±1.3	±1.0	4.83E-03	1.20E-04	1.944E-01	+3.9	-3.2
125.90	3.258E-02	+3.9	-3.2	±1.6	±1.3	±1.0	4.82E-03	1.20E-04	1.940E-01	+3.9	-3.2
126.00	3.248E-02	+4.0	-3.2	±1.6	±1.3	±1.0	4.82E-03	1.20E-04	1.934E-01	+4.0	-3.2
126.50	3.214E-02	+4.0	-3.3	±1.6	±1.3	±1.0	4.79E-03	1.20E-04	1.914E-01	+4.0	-3.3
127.00	3.179E-02	+4.1	-3.3	±1.6	±1.3	±1.0	4.77E-03	1.20E-04	1.893E-01	+4.1	-3.3
127.50	3.144E-02	+4.0	-3.3	±1.6	±1.3	±1.0	4.74E-03	1.20E-04	1.872E-01	+4.0	-3.3
128.00	3.107E-02	+4.1	-3.2	±1.6	±1.3	±1.0	4.71E-03	1.20E-04	1.850E-01	+4.1	-3.2
128.50	3.076E-02	+4.0	-3.4	±1.6	±1.3	±1.0	4.69E-03	1.20E-04	1.831E-01	+4.0	-3.4
129.00	3.044E-02	+3.9	-3.4	±1.6	±1.3	±1.0	4.66E-03	1.20E-04	1.812E-01	+3.9	-3.4
129.50	3.008E-02	+3.9	-3.4	±1.6	±1.3	±1.0	4.64E-03	1.20E-04	1.791E-01	+3.9	-3.4
130.00	2.972E-02	+4.1	-3.4	±1.6	±1.3	±1.0	4.60E-03	1.20E-04	1.769E-01	+4.1	-3.4

## 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	6.888E-01	+6.1	-9.2	±3.5	±2.9	±1.9
120.50	6.812E-01	+6.1	-9.2	±3.5	±2.9	±1.9
121.00	6.722E-01	+6.1	-9.2	±3.5	±2.9	±1.9
121.50	6.656E-01	+6.1	-9.2	±3.5	±2.9	±1.9
122.00	6.584E-01	+6.1	-9.3	±3.5	±2.9	±1.9
122.50	6.508E-01	+6.1	-9.3	±3.5	±3.0	±1.9
123.00	6.426E-01	+6.1	-9.2	±3.5	±2.9	±1.9
123.50	6.353E-01	+6.1	-9.2	±3.5	±2.9	±1.9
124.00	6.279E-01	+6.1	-9.2	±3.5	±2.9	±1.9
124.10	6.268E-01	+6.1	-9.2	±3.5	±2.9	±1.9
124.20	6.258E-01	+6.2	-9.3	±3.5	±2.9	±1.9
124.30	6.250E-01	+6.1	-9.2	±3.5	±2.9	±1.9
124.40	6.230E-01	+6.1	-9.3	±3.5	±2.9	±1.9
124.50	6.217E-01	+6.1	-9.3	±3.5	±2.9	±1.9
124.60	6.193E-01	+6.1	-9.2	±3.5	±2.9	±1.9
124.70	6.186E-01	+6.1	-9.2	±3.5	±2.9	±1.9
124.80	6.169E-01	+6.1	-9.2	±3.5	±2.9	±1.9
124.90	6.152E-01	+6.1	-9.2	±3.5	±2.9	±1.9
125.00	6.137E-01	+6.0	-9.2	±3.5	±2.9	±1.9
125.09	6.128E-01	+6.0	-9.2	±3.5	±2.9	±1.9
125.10	6.127E-01	+6.1	-9.3	±3.5	±2.9	±1.9
125.20	6.121E-01	+6.1	-9.3	±3.5	±2.9	±1.9
125.30	6.100E-01	+6.1	-9.2	±3.5	±2.9	±1.9
125.40	6.089E-01	+6.1	-9.2	±3.5	±2.9	±1.9
125.50	6.075E-01	+6.1	-9.2	±3.5	±2.9	±1.9
125.60	6.056E-01	+6.1	-9.2	±3.5	±2.9	±1.9

125.70	6.044E-01	+6.1	-9.3	±3.5	±2.9	±1.9
125.80	6.035E-01	+6.1	-9.3	±3.5	±2.9	±1.9
125.90	6.022E-01	+6.1	-9.2	±3.5	±2.9	±1.9
126.00	6.009E-01	+6.1	-9.2	±3.5	±2.9	±1.9
126.50	5.938E-01	+6.1	-9.2	±3.5	±2.9	±1.9
127.00	5.874E-01	+6.1	-9.2	±3.5	±2.9	±1.9
127.50	5.807E-01	+6.0	-9.2	±3.5	±2.9	±1.9
128.00	5.748E-01	+6.1	-9.2	±3.5	±2.9	±1.9
128.50	5.673E-01	+6.1	-9.2	±3.5	±2.9	±1.9
129.00	5.613E-01	+6.1	-9.2	±3.5	±2.9	±1.9
129.50	5.551E-01	+6.1	-9.2	±3.5	±2.9	±1.9
130.00	5.486E-01	+6.1	-9.2	±3.5	±2.9	±1.9

## 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	6.288E-01	+20.4	-24.7
120.50	6.204E-01	+20.3	-24.6
121.00	6.105E-01	+20.2	-24.5
121.50	6.032E-01	+20.2	-24.4
122.00	5.961E-01	+20.2	-24.4
122.50	5.884E-01	+20.2	-24.3
123.00	5.801E-01	+20.0	-24.2
123.50	5.745E-01	+20.1	-24.2
124.00	5.672E-01	+23.4	-24.2
124.10	5.656E-01	+20.1	-24.2
124.20	5.642E-01	+20.1	-24.2
124.30	5.621E-01	+20.1	-24.2
124.40	5.608E-01	+20.1	-24.3
124.50	5.596E-01	+20.1	-24.1
124.60	5.577E-01	+20.0	-24.1
124.70	5.563E-01	+20.1	-24.2
124.80	5.551E-01	+20.2	-24.2
124.90	5.545E-01	+20.3	-24.2

125.00	5.529E-01	+20.0	-24.0
125.09	5.522E-01	+20.1	-24.1
125.10	5.521E-01	+20.2	-24.1
125.20	5.501E-01	+23.0	-24.0
125.30	5.481E-01	+20.1	-24.2
125.40	5.474E-01	+20.6	-24.1
125.50	5.453E-01	+19.9	-24.0
125.60	5.448E-01	+20.6	-24.0
125.70	5.422E-01	+20.0	-24.0
125.80	5.415E-01	+20.8	-24.1
125.90	5.398E-01	+20.0	-24.1
126.00	5.384E-01	+19.9	-23.9
126.50	5.342E-01	+20.0	-23.9
127.00	5.260E-01	+19.9	-23.8
127.50	5.200E-01	+19.8	-23.7
128.00	5.124E-01	+19.8	-23.7
128.50	5.062E-01	+19.8	-23.7
129.00	5.002E-01	+19.7	-23.6
129.50	4.943E-01	+19.7	-23.6
130.00	4.878E-01	+21.4	-23.5

## 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 %	$\pm$ ; s %	tH (pb)	tbarH (pb)
120.00	9.364E-02	+6.6	-14.4	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	6.129E-02	3.231E-02
120.50	9.330E-02	+6.6	-14.4	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	6.110E-02	3.217E-02
121.00	9.298E-02	+6.5	-14.4	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	6.080E-02	3.207E-02
121.50	9.239E-02	+6.5	-14.3	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	6.056E-02	3.192E-02
122.00	9.226E-02	+6.5	-14.4	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	6.028E-02	3.183E-02
122.50	9.178E-02	+6.5	-14.4	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	6.004E-02	3.169E-02
123.00	9.148E-02	+6.5	-14.3	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	5.986E-02	3.160E-02
123.50	9.094E-02	+6.5	-14.4	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	5.972E-02	3.149E-02
124.00	9.083E-02	+6.5	-14.6	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	5.943E-02	3.134E-02
124.10	9.081E-02	+6.5	-14.6	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	5.934E-02	3.135E-02
124.20	9.062E-02	+6.5	-14.6	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	5.935E-02	3.133E-02
124.30	9.054E-02	+6.4	-14.6	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	5.927E-02	3.130E-02
124.40	9.055E-02	+6.5	-14.8	$\pm 3.6$	$\pm 3.4$	$\pm 1.2$	5.923E-02	3.124E-02

124.50	9.038E-02	+6.4	-14.4	±3.6	±3.4	±1.2	5.918E-02	3.122E-02
124.60	9.035E-02	+6.4	-14.6	±3.6	±3.4	±1.2	5.915E-02	3.121E-02
124.70	9.038E-02	+6.5	-14.6	±3.6	±3.4	±1.2	5.917E-02	3.120E-02
124.80	9.029E-02	+6.4	-14.7	±3.6	±3.4	±1.2	5.907E-02	3.117E-02
124.90	9.021E-02	+6.5	-14.7	±3.6	±3.4	±1.2	5.911E-02	3.111E-02
125.00	9.010E-02	+6.4	-14.7	±3.6	±3.4	±1.2	5.907E-02	3.112E-02
125.09	9.012E-02	+6.4	-14.7	±3.6	±3.4	±1.2	5.896E-02	3.111E-02
125.10	9.012E-02	+6.4	-14.7	±3.6	±3.4	±1.2	5.896E-02	3.111E-02
125.20	8.998E-02	+6.4	-14.6	±3.6	±3.4	±1.2	5.892E-02	3.109E-02
125.30	8.994E-02	+6.4	-14.6	±3.6	±3.4	±1.2	5.883E-02	3.107E-02
125.40	8.988E-02	+6.4	-14.7	±3.6	±3.4	±1.2	5.898E-02	3.102E-02
125.50	8.976E-02	+6.4	-14.6	±3.6	±3.4	±1.2	5.881E-02	3.104E-02
125.60	8.972E-02	+6.4	-14.8	±3.6	±3.4	±1.2	5.870E-02	3.100E-02
125.70	8.973E-02	+6.4	-14.7	±3.6	±3.4	±1.2	5.878E-02	3.099E-02
125.80	8.962E-02	+6.4	-14.7	±3.6	±3.4	±1.2	5.872E-02	3.093E-02
125.90	8.958E-02	+6.4	-14.7	±3.6	±3.4	±1.2	5.866E-02	3.096E-02
126.00	8.950E-02	+6.4	-14.7	±3.6	±3.4	±1.2	5.859E-02	3.095E-02
126.50	8.911E-02	+6.4	-14.8	±3.6	±3.4	±1.2	5.838E-02	3.083E-02
127.00	8.886E-02	+6.4	-14.8	±3.7	±3.5	±1.2	5.819E-02	3.072E-02
127.50	8.844E-02	+6.4	-14.5	±3.6	±3.4	±1.2	5.794E-02	3.062E-02
128.00	8.828E-02	+6.4	-14.9	±3.6	±3.4	±1.2	5.776E-02	3.051E-02
128.50	8.791E-02	+6.3	-14.8	±3.6	±3.5	±1.2	5.752E-02	3.042E-02
129.00	8.762E-02	+6.3	-14.8	±3.6	±3.5	±1.2	5.735E-02	3.028E-02
129.50	8.744E-02	+6.3	-15.1	±3.7	±3.5	±1.2	5.717E-02	3.017E-02
130.00	8.710E-02	+6.3	-14.9	±3.7	±3.5	±1.2	5.692E-02	3.006E-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	3.558E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.310E-03	1.248E-03
120.50	3.523E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.289E-03	1.235E-03
121.00	3.490E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.267E-03	1.225E-03
121.50	3.457E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.246E-03	1.213E-03
122.00	3.429E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.226E-03	1.201E-03
122.50	3.395E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.206E-03	1.190E-03
123.00	3.363E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.188E-03	1.179E-03
123.50	3.335E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.168E-03	1.168E-03
124.00	3.307E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.148E-03	1.159E-03
124.10	3.298E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.146E-03	1.154E-03
124.20	3.294E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.138E-03	1.153E-03
124.30	3.286E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.136E-03	1.149E-03
124.40	3.280E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.136E-03	1.148E-03
124.50	3.274E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.131E-03	1.147E-03

124.60	3.273E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.128E-03	1.145E-03
124.70	3.261E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.122E-03	1.143E-03
124.80	3.261E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.119E-03	1.141E-03
124.90	3.251E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.117E-03	1.138E-03
125.00	3.249E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.110E-03	1.137E-03
125.09	3.240E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.104E-03	1.134E-03
125.10	3.240E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.104E-03	1.134E-03
125.20	3.234E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.102E-03	1.130E-03
125.30	3.227E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.102E-03	1.129E-03
125.40	3.222E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.098E-03	1.128E-03
125.50	3.219E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.094E-03	1.126E-03
125.60	3.215E-03	+2.4	-1.7	±2.1	±2.1	±0.3	2.091E-03	1.124E-03
125.70	3.205E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.086E-03	1.122E-03
125.80	3.202E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.083E-03	1.119E-03
125.90	3.195E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.080E-03	1.118E-03
126.00	3.191E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.074E-03	1.115E-03
126.50	3.160E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.058E-03	1.106E-03
127.00	3.133E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.040E-03	1.095E-03
127.50	3.104E-03	+2.4	-1.7	±2.1	±2.1	±0.3	2.023E-03	1.085E-03
128.00	3.079E-03	+2.3	-1.7	±2.1	±2.1	±0.3	2.001E-03	1.073E-03
128.50	3.053E-03	+2.4	-1.7	±2.1	±2.1	±0.3	1.987E-03	1.065E-03
129.00	3.025E-03	+2.3	-1.7	±2.2	±2.1	±0.3	1.969E-03	1.054E-03
129.50	2.998E-03	+2.3	-1.7	±2.2	±2.1	±0.3	1.953E-03	1.047E-03
130.00	2.971E-03	+2.3	-1.7	±2.2	±2.1	±0.3	1.937E-03	1.037E-03

## 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	1.856E-02	+5.0	-6.9	±6.2	±6.0	±1.5

-- ReiTanaka - 2016-03-01

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