

In the following we propose preliminary guidelines (including some open issues) for the calculation of official inclusive cross section for ttH and tH production. They should be adopted for the calculations only once discussed and approved by the ttH and WG1 conveners (mid November at the latest).

## ttV cross sections at NLO QCD+EW

### Final state bosons

- $V=W^+,W^-,Z$  without decays

### Collider energy

- 13 and 14 TeV

### Other input parameters and PDFs

- $M_t=172.5$  GeV according to <https://cds.cern.ch/record/2047636>
- the  $G_{\mu}$  input scheme should be used for EW couplings (and EW corrections) with  $G_{\mu}$ , MW and MZ as defined in <https://cds.cern.ch/record/2047636>
- PDFs and  $\alpha_S=0.118+0.0015$  according to PDF4LHC15 recommendation 2015 <http://arxiv.org/abs/1510.03865> (see below for QED PDF effects)
- two central-scale choices should be compared: (a)  $\mu=m_t+m_V/2$  and (b)  $\mu=HT/2$ , where  $HT=\text{sum of } t,T,V \text{ transverse energies (ignoring extra jet emissions)}$

### (N)LO EW ingredients

(a) Similarly as for the ttH calculation the following LO and NLO EW ingredients should be included:

- LO EW contributions of  $O(\alpha^3)$
- LO mixed EW-QCD contributions of  $O(\alpha^2*\alpha_S)$
- Complete  $O(\alpha^2*\alpha_S^2)$  corrections

(b) All relevant photon induced channels at the abovementioned orders should be included

(c) QED-PDF effects should be included as follows (approach adopted for ttH)

- all quark/gluon induced channels with PDF4LHC15
- reconstruct effects due to QED-evolution of PDFs evaluating the LO QCD ttV cross section with NNPDF.2.3 QED (at NLO QCD) and subtracting the corresponding results with NNPDF2.3 NLO QCD without QED effects
- all gamma-induced channels using NNPDF2.3 QED PDFs

### Presentation of the results

- absolute NLO QCD prediction at the central scale in femtobarn (not the midpoint of the uncertainty band)
- positive and negative scale variation in percent. Here the usual 6-point variation should be applied, including independent factor 0.5 and 2 variations of  $\mu_R$  and  $\mu_F$  apart from uncorrelated ones.
- positive and negative PDF+ $\alpha_S$  variations in percent (see PDF4LHC recommendation 2015)
- also the NLO QCD K factor ( $K=NLO/LO$  both with the same NLO PDFs and input parameters) should be provided
- absolute NLO QCD+EW prediction at the central scale. No scale variation should be applied to the NLO EW correction
- EW K factor defined as  $(NLO\ QCD+EW)/(NLO\ QCD)$



**QCD and EW corrections**

- Both NLO QCD and NLO QCD+EW predictions should be prepared.
- (N)LO EW effects should be computed using nominal input parameters and PDFs, without any variation. For EW contributions the latest NNPDF QED set (NLO QCD+LO QED) should be used.
- the G\_mu input scheme should be used for EW corrections with G\_mu, MW and MZ as defined in <https://cds.cern.ch/record/2047636>
- separate K-factors  $K_{QCD}=(NLO\ QCD)/(LO\ QCD)$  and  $K_{EW}=(NLO\ QCD+EW)/(NLO\ QCD)$  should be provided; Optionally, also additional numerical results for an alternative EW K-factor defined as  $(NLO\ QCD+EW)/(LO\ QCD)=K_{EW}*K_{QCD}$  can be presented
- At 13 TeV with Mh=125 GeV NLO EW and LO EW contributions, as well as photon- and q/g-induced contributions are of similar size (see numbers below by M.Zaro) and add up to 0.0%.

	QCD induced	gamma-induced	Sum
NLO EW	-1.4%	+0.2%	-1.2%
LO EW-QCD	-0.4%	+1.6%	+1.2%
Sum	- 1.8%	+1.8%	0.0%

in addition there is a residual ~0.5% pure LO EW ttH contribution: it should be included together with the various abovementioned EW contributions.

- we plan to discuss and decide with the WG1 conveners whether EW corrections will be included in the official predictions or presented in the dedicated YR4 section in the form of a relative correction (K\_EW). The same applies to other suppressed effects of order 1% (e.g. off-shell effects, resummation effects)

**tH specific aspects**

Recommended singl-top+Higgs cross sections will presented only for the t-channel and s-channel processes. Results for WtH production (to date still unpublished) will be presented in a dedicated section of YR4.

**Production of cross sections**

- Federico Demartin has volunteered to ake care of the calculations
- other groups might want to cross check the results (?)

**t-channel**

- scale=(Mt+MH)/4
- nominal prediction in the 5F scheme
- scale uncertainty from full envelope of 6-point scale variations in the 5F and 4F scheme
- standard PDF and alphaS variations (PDF4LHC15)
- no Mb-variations (can be discussed in tH YR4 subsection)

**s-channel**

- scale=(Mt+MH)/2
- nominal prediction in the 5F scheme
- standard 6-point scale variation in the 5F scheme

\* standard PDF and alphaS variations (PDF4LHC15)

**Mass scan strategy: priorities for precision SM range**

MH	13 TeV	14 TeV	7 TeV	8 TeV
120	x			

120.5				
121	x			
121.5				
122	x			
122.5				
123	x			
123.5				
124.0	x			
124.1				
124.2				
124.3				
124.4				
124.5				
124.6				
124.7				
124.8				
124.9				
125.0	x			
125.1				
125.2				
125.3				
125.4				
125.5				
125.6				
125.7				
125.8				
125.9				
126.0	x			
126.5				
127	x			
127.5				
128	x			
128.5				
129	x			
129.5				
130	x			

### Top-antitop splitting of results

- results and uncertainties should be presented for the combined (anti)top+H cross section
- in addition also central-value predictions for the individual top+H and antitop+H contributions should be presented (similarly as for WH production)  
[https://twiki.cern.ch/twiki/bin/view/LHCPHysics/CERNYellowReportPageAt7TeV2014#WH\\_Production](https://twiki.cern.ch/twiki/bin/view/LHCPHysics/CERNYellowReportPageAt7TeV2014#WH_Production)

-- StefanoPozzorini - 2015-10-30

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