Comparison between analyses for semi- and dileptonic channel HH production at HL-LHC

Izaak Neutelings

October 26, 2015

1 Cross section

For our analysis, we have been using the following cross sections for all final states at $\sqrt{s} = 14$ TeV:

Table 1: Cross sections and branching ratios used in our analysis.

process	σ [fb]	branching ratio without taus
HH	40	1
HH→ bbWW → bbqqlν	2.8	0.07
HH→ bbWW → bblνlν	0.4	0.01
$\mathbf{t\bar{t}}$	984 500	1
$t\bar{t}$→ bbWW → bbqqlν	295 350	0.30
$t\bar{t}$→ bbWW → bblνlν	59 070	0.06

$\sigma(\mathrm{HH}) = 40$ fb and $\sigma(t\bar{t}) = 984500$ fb. The analysis note for the dileptonic final state by Delaere et al. only list next leading order σ_{LO} with k-factor k_{NNLO} (Table 2). We calculate back to the full cross section of HH or $t\bar{t}$ production using

$$\sigma_{\mathrm{full}} = \frac{k_{\mathrm{NNLO}}\sigma_{\mathrm{LO}}}{\mathrm{BR}} \tag{1}$$

with the appropriate branching ratios BR.

Table 2: Cross sections used in the analysis note by C. Deleare et al. [1]

process	σ_{LO} [fb]	k_{NNLO}	σ_{full} [fb]
HH → bbWW → bblνlν	0.163	2.3	37.49
$t\bar{t}$ full leptonic	9030	1.85	278 425

2 Sample, event selections & clean-up

To reproduce the results by C. Delaere et al. [1], the event selections & clean-up as described in their analysis note are applied to our samples. These cuts and the ones we use for the semileptonic final state are compared in Table 3.

3 Significance & yield

Using the yield

$$N = \sigma L \tag{2}$$

with integrated luminosity $L = 3000\ \mathrm{fb}^{-1}$, the Punzi significance is calculated as:

$$P = \frac{N(\mathrm{HH})}{\sqrt{1 + N(t\bar{t})}} \tag{3}$$

Table 3: Event selectiona and clean-up comparison between the dileptonic and semileptonic final state.

	dileptonic final state	semileptonic final state
Gen level cuts on background		
	b-quarks: $p_T > 15$ GeV	b-quark: $p_T > 15$ GeV
	leptons: $p_T > 15$ GeV, $\lvert\eta\rvert < 2.5$	lepton: $p_T > 15$ GeV, $\lvert\eta\rvert < 2.5$
	$\Delta R_{\mathrm{ll}} < 2.5$	
Selection		
	two b-jets: $p_T > 30$ GeV, $\lvert\eta\rvert < 2.5$	two b-jets: $p_T > 30$ GeV, $\lvert\eta\rvert < 2.5$
		two non b-jets: $p_T > 30$ GeV, $\lvert\eta\rvert < 2.5$
	two opposite charged leptons with:	one lepton with:
	muons: $p_T > 20$ GeV, $\lvert\eta\rvert < 2.5$	muon: $p_T > 20$ GeV, $\lvert\eta\rvert < 2.5$
	electrons: $p_T > 25$ GeV, $\lvert\eta\rvert < 2.5$	electron: $p_T > 25$ GeV, $\lvert\eta\rvert < 2.5$
	MET > 20 GeV	MET > 20 GeV
Clean-up		
	60 GeV $< m_{\mathrm{bb}} <$ 160 GeV	60 GeV $< m_{\mathrm{bb}} <$ 160 GeV
	$\Delta R_{\mathrm{bb}} < 3.1$ GeV	$\Delta R_{\mathrm{bb}} < 3.1$ GeV
	$m_{ll} < 85$ GeV	
	$\Delta R_{\mathrm{ll}} < 2$	

4 Results

Results are summarized in Table 4. To compare the dileptonic to the semileptonic case, the significance is scaled by $\sqrt{5}/7$, since the latter has a 7 (5) times higher branching ratio for signal (background).

Table 4: Comparison of the significance and yields between the semileptonic and dileptonic final state.

	dileptonic final state			semileptonic final state			
	P	N(HH)	N($\mathrm{t\bar{t}}$)	P	$\sqrt{5}/7$P	N(HH)	N($\mathrm{t\bar{t}}$)
Gen level							
Our results	0.090	1200	177 210 000	0.282	0.090	8400	886 050 000
Gen level cuts on background							
Our results	0.149	1200	65 940 000	0.314	0.100	8400	713 565 555
C. Delaere, et al.	0.159	1125	50 117 000				
Selection							
Our results	0.028	69	6 574 000	0.067	0.022	669	98 591 205
C. Delaere, et al.	0.043	113	6 759 579				
Clean-Up							
Our results	0.054	55	1 096 000	0.080	0.025	519	42 335 190
C. Delaere, et al.	0.075	90	1 437 144				
Neural network							
C. Delaere, et al.	0.60	37	3875				

References

[1] C. Delaere et al. *Study of HH production with $H \to bb$, $H \to WW \to l\nu l\nu$for an upgraded CMS detector at the HL-LHC*. CMS draft analysis note 2014/141.

[2] D. de Florian & J. Mazzitelli. *Higgs Boson Pair Production at Next-to-Next-to-Leading Order in QCD*. Phys. Rev. Lett. 111 (Nov, 2013) 201801, doi:10.1103/PhysRevLett.111.201801.

[3] *NNLO+NNLL top-quark-pair cross sections - ATLAS-CMS recommended predictions for top-quark-pair cross sections using the Top++v2.0 program (M. Czakon, A. Mitov, 2013).* https://twiki.cern.ch/twiki/bin/view/LHCPhysics/TtbarNNLO#Top_quark_pair_cross_sections_at