Search for $T' \longrightarrow t + H^0$ in the trilepton channel

Status report #4 (weeks 7, 8, 9, 10)

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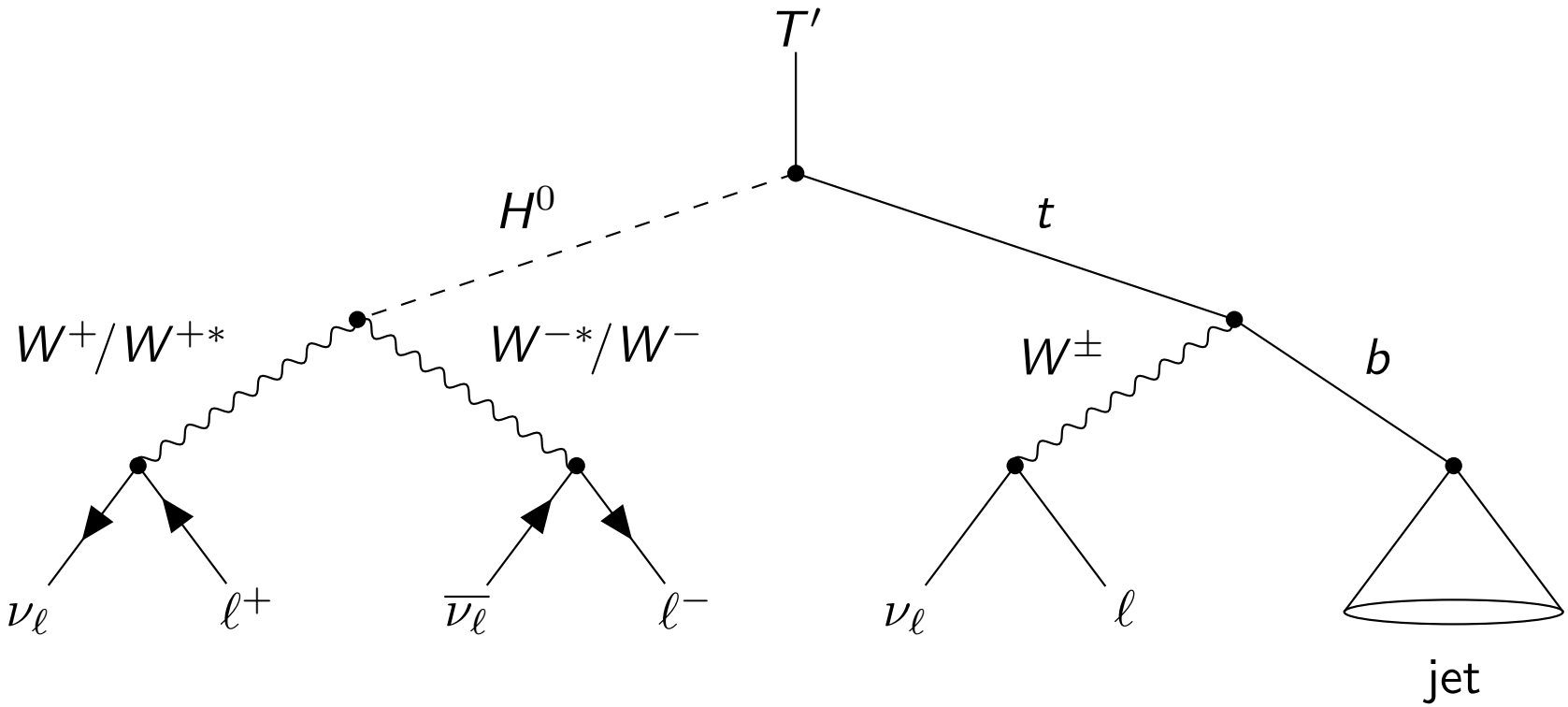
July 8, 2022

Signal

$\sigma\left(T' \longrightarrow t + H^0\right) = 89\,\text{fb}$

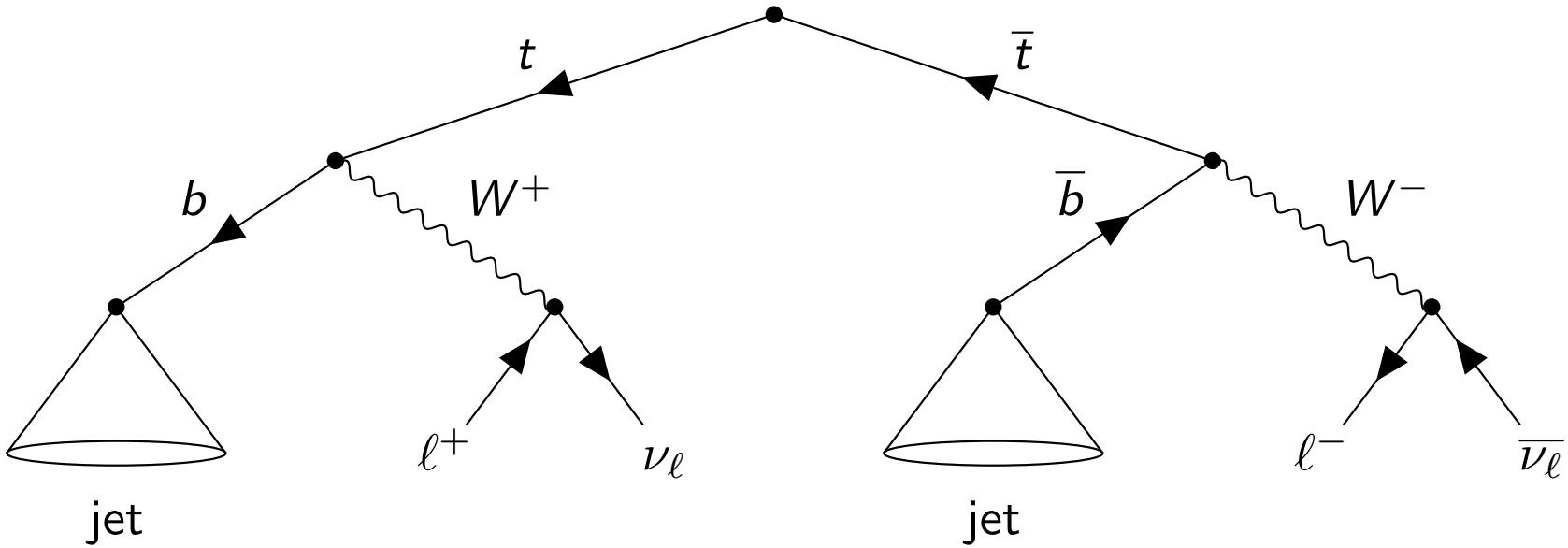


Final state: $\ell^+\ell^-\ell^\pm\nu\nu\nu + b$-tagged jet

Unless the Higgs boson is sufficiently boosted, one the two intermediate W bosons is off-shell ($m_{H^0} = 125\,\text{GeV}$, $m_{W^\pm} = 80.4\,\text{GeV}$)

$t\bar{t}$ background

$\sigma(t\bar{t} \longrightarrow \text{dilepton}) = 87.315\,\text{pb}$

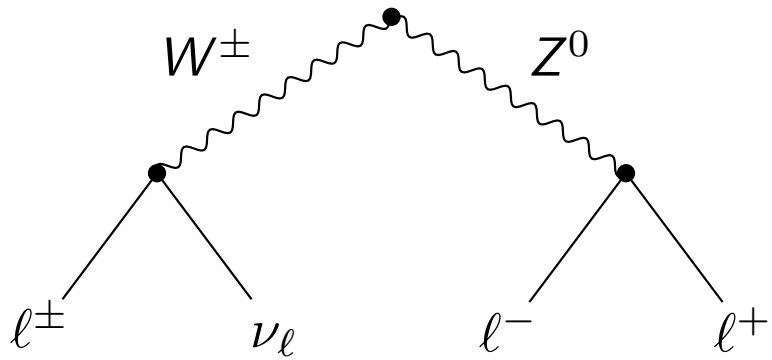


Final state: $\ell^+\ell^-\nu\nu + 2\,b$-tagged jets

The top quarks are heavy enough compared to the bottom quarks for the intermediate W bosons to be on-shell ($m_t = 173\,\text{GeV}$, $m_b = 4.2\,\text{GeV}$)

WZ background

$\sigma(WZ) = 4.4297\,\text{pb}$



Final state: $\ell^+\ell^-\ell^{\pm}\nu$ (no b-tagged jet for $\ell \in \{\mu, e\}$)

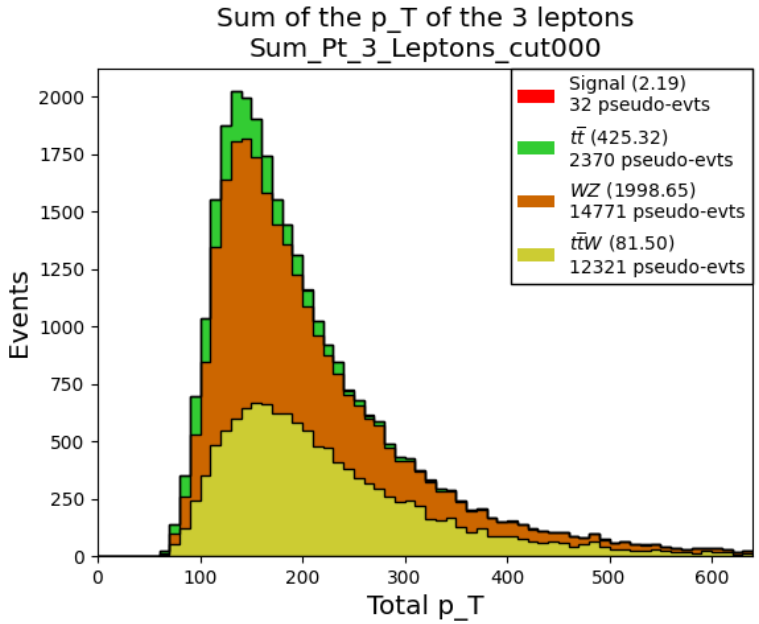
New variables: invariant masses of the two lepton pairs

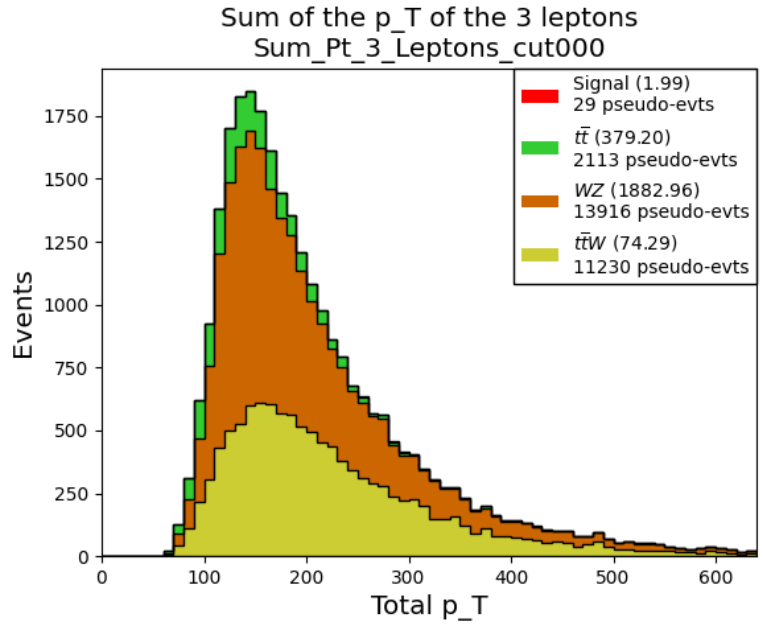
- Order by ΔR (pair_0 contains the closest leptons, pair_1 the most distant ones)
- Order by p_T

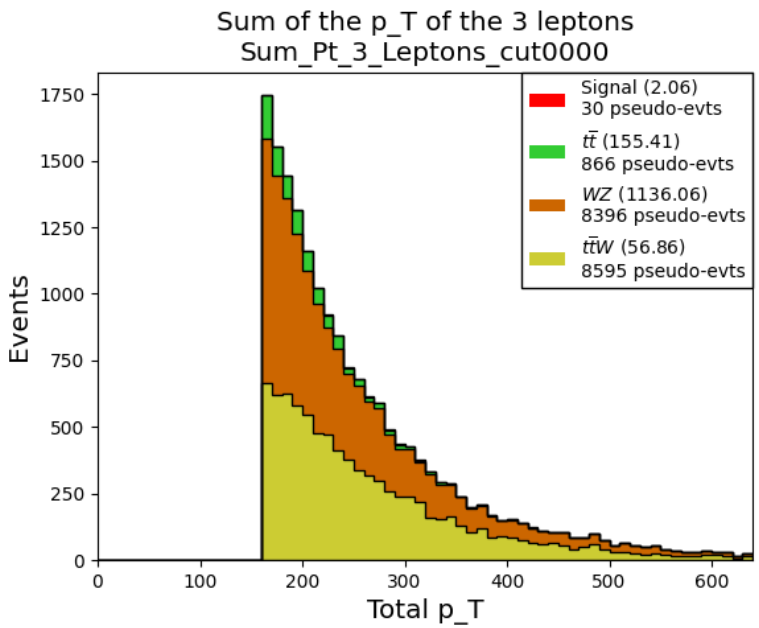
$$\overset{0}{\downarrow}\ \overset{1}{\downarrow}\ \overset{2}{\downarrow}$$

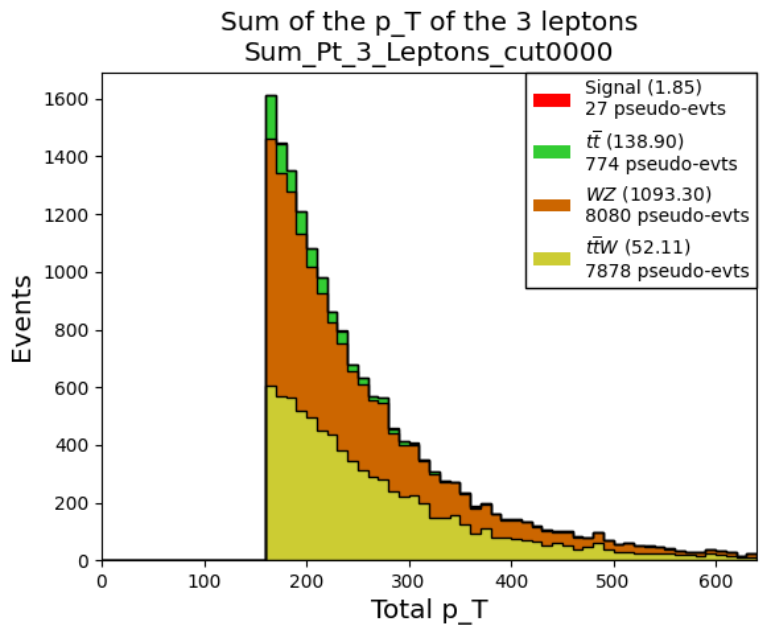
  - $(\pm, \pm, \mp) \implies \text{pair}_0 = (0,2),\ \text{pair}_1 = (1,2)$
  - $(\pm, \mp, \pm) \implies \text{pair}_0 = (0,1),\ \text{pair}_1 = (1,2)$
  - $(\mp, \pm, \pm) \implies \text{pair}_0 = (0,1),\ \text{pair}_1 = (0,2)$

$\sum p_T$(leptons)

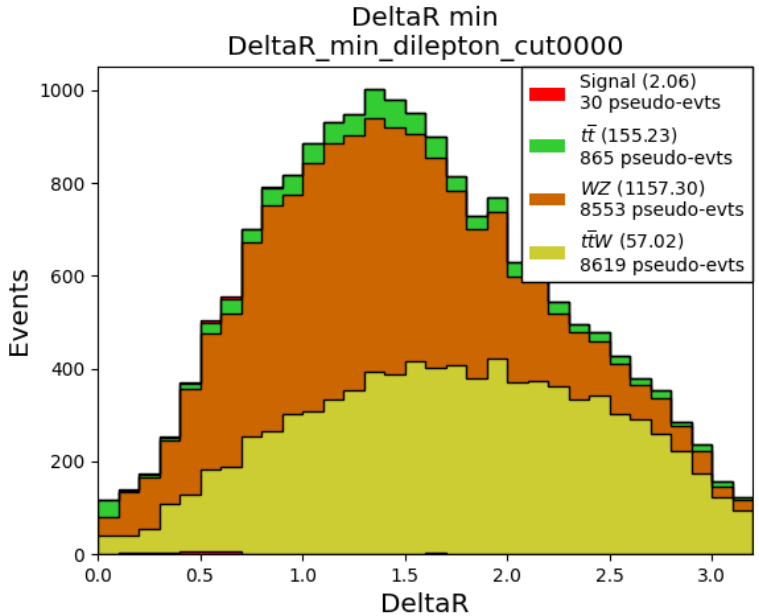


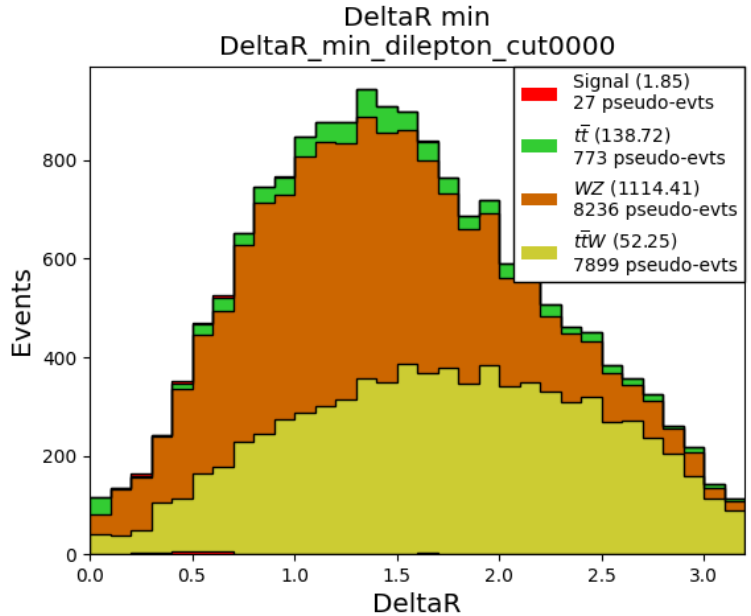


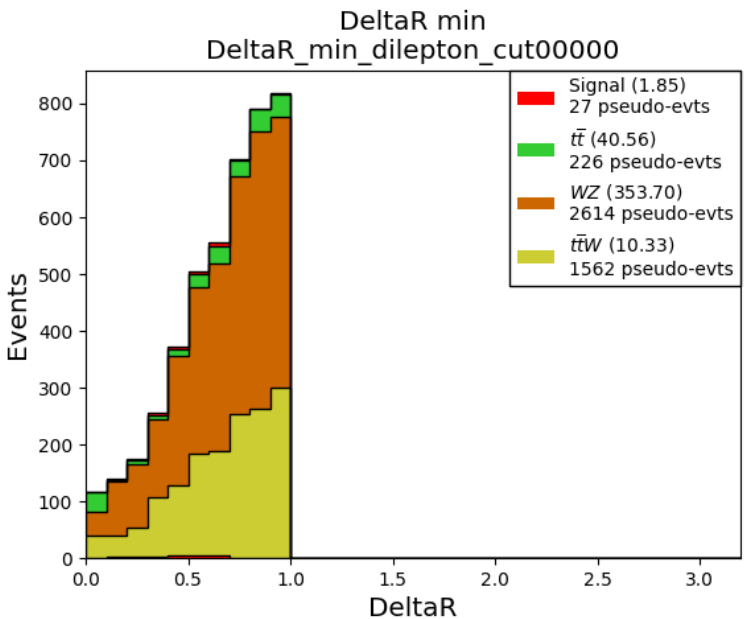


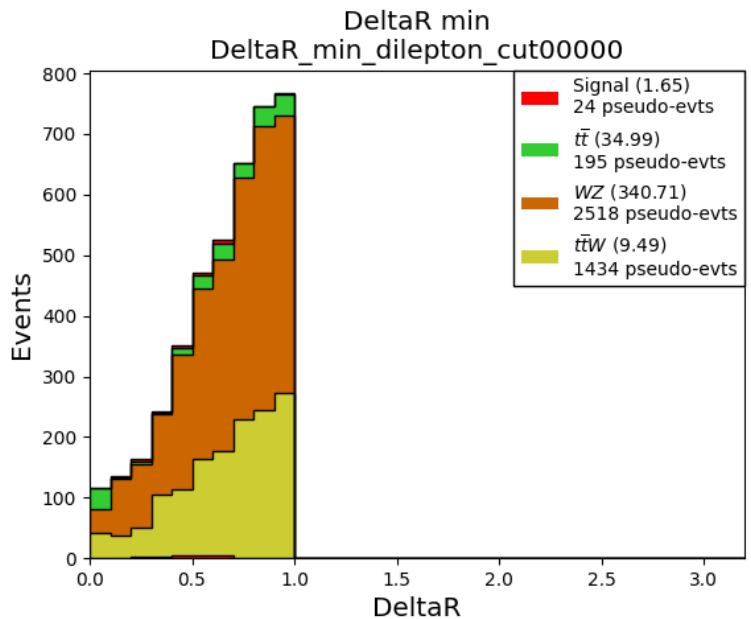


ΔR_{min}

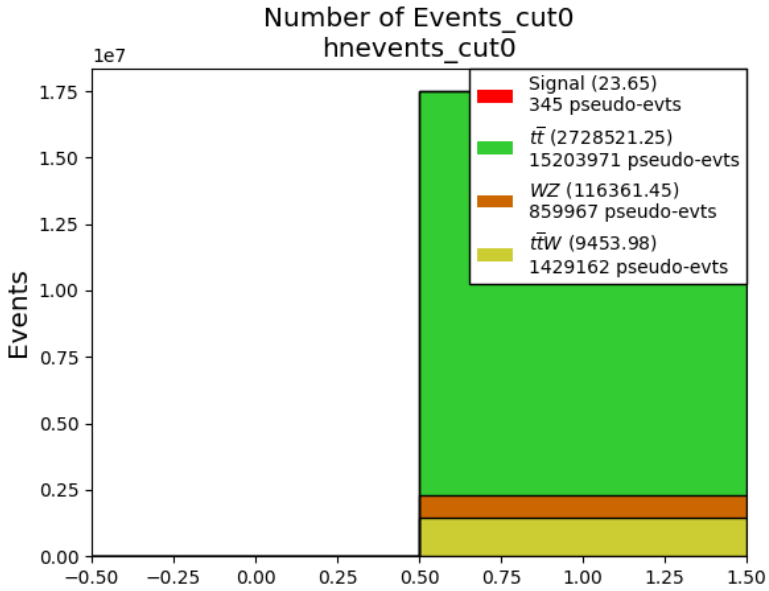


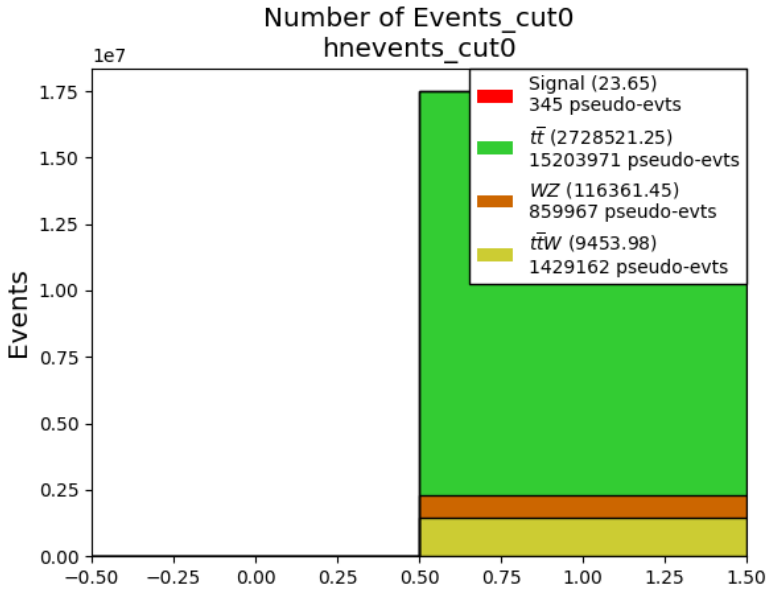


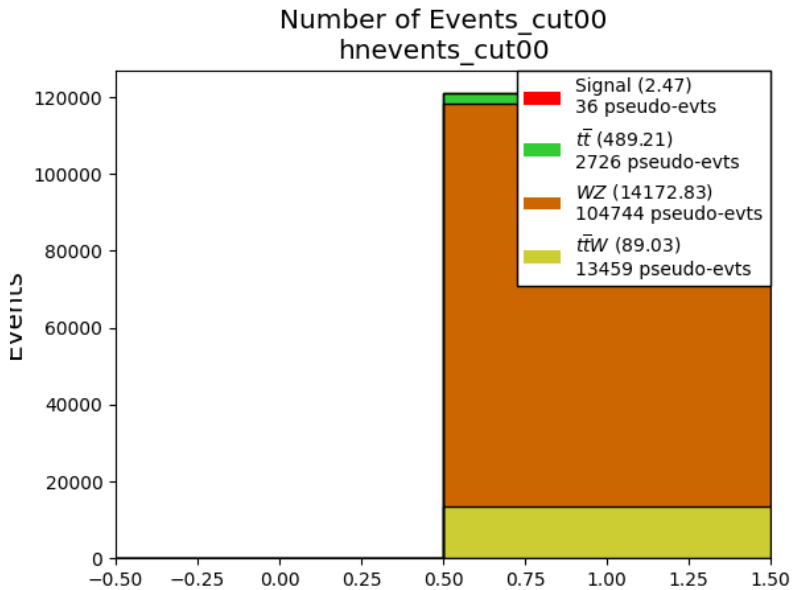


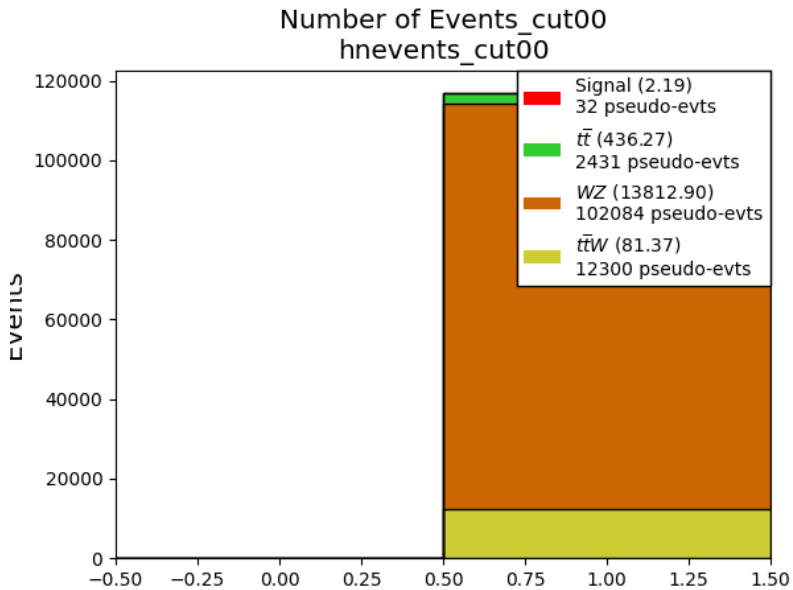


of events (part 1)

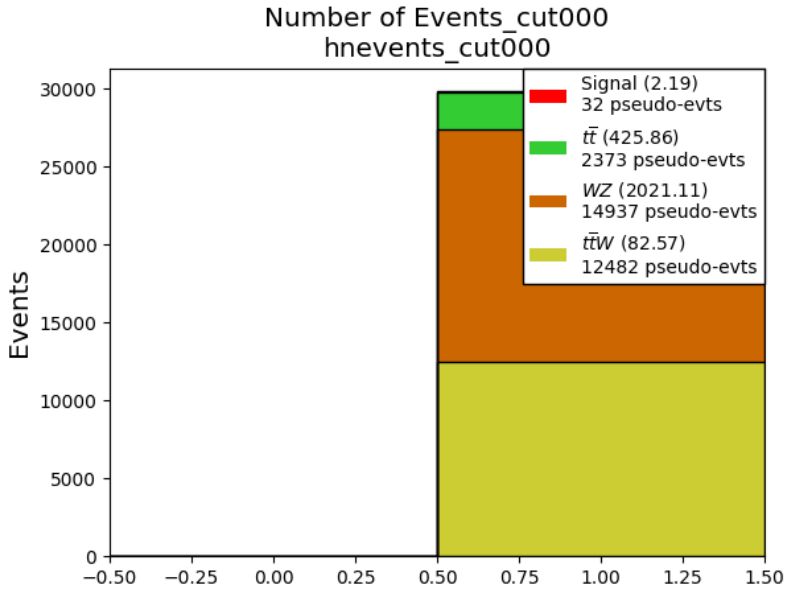


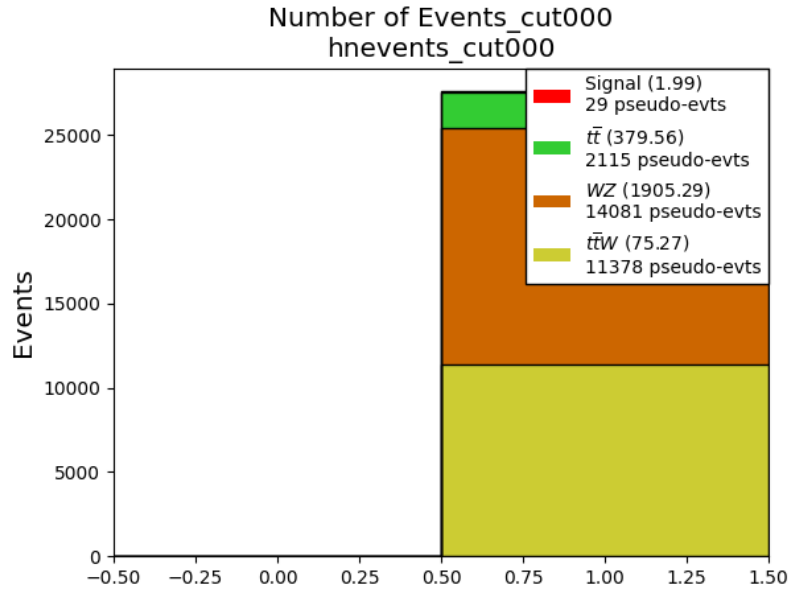


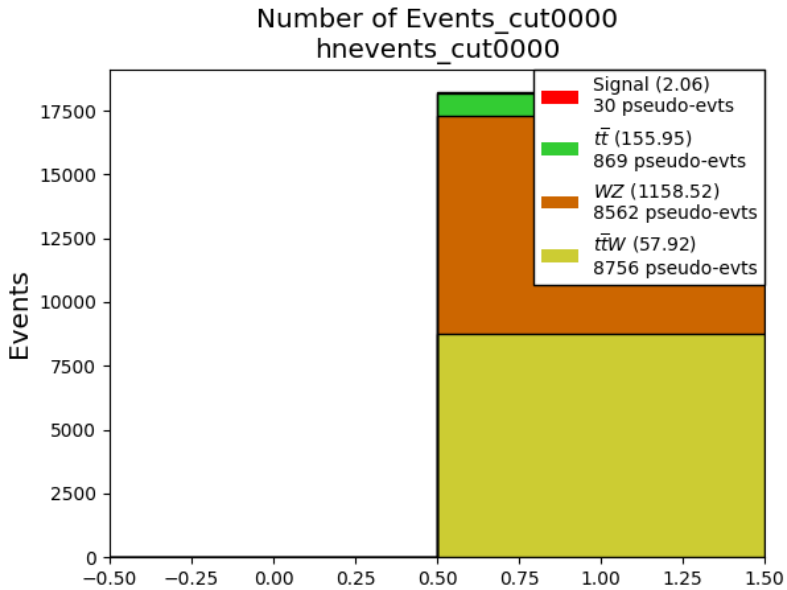


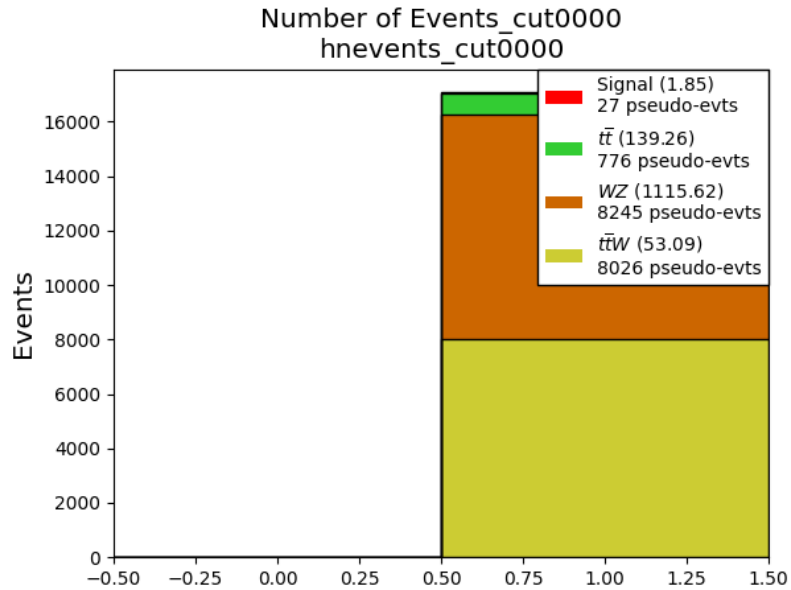


of events (part 2)

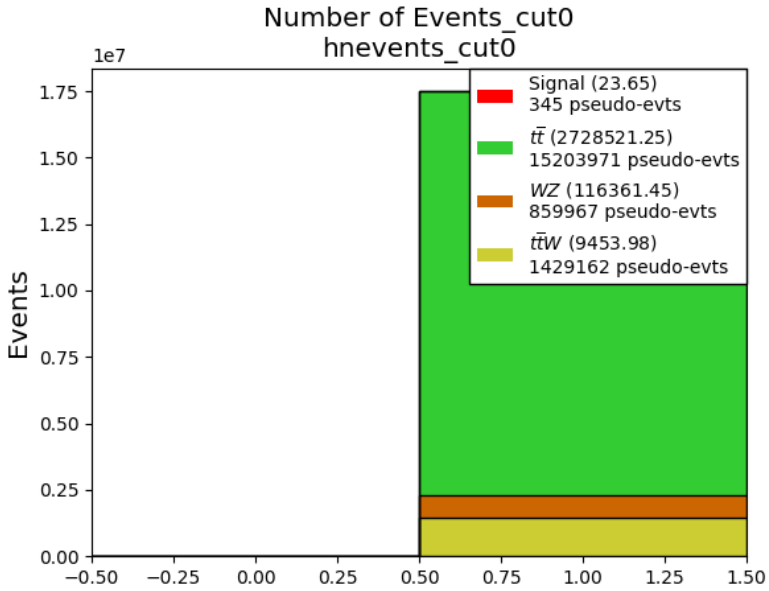


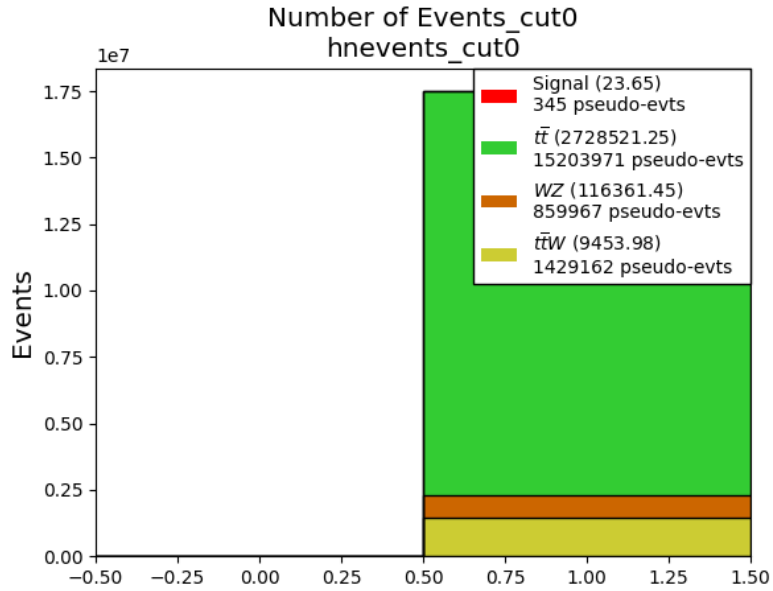


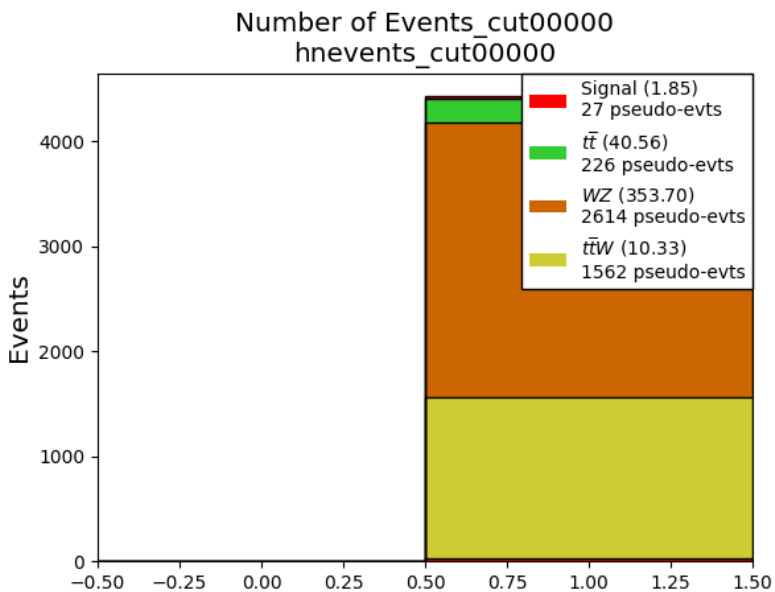


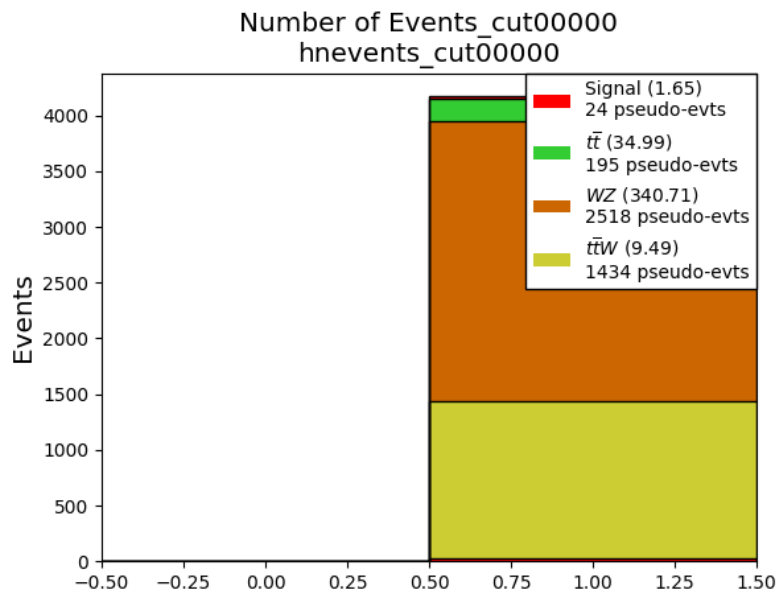


of events (part 3)

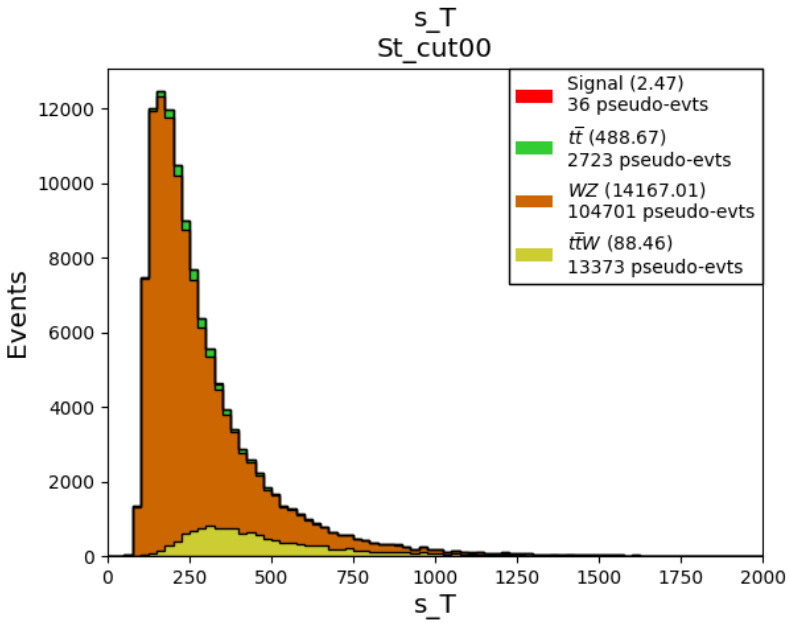


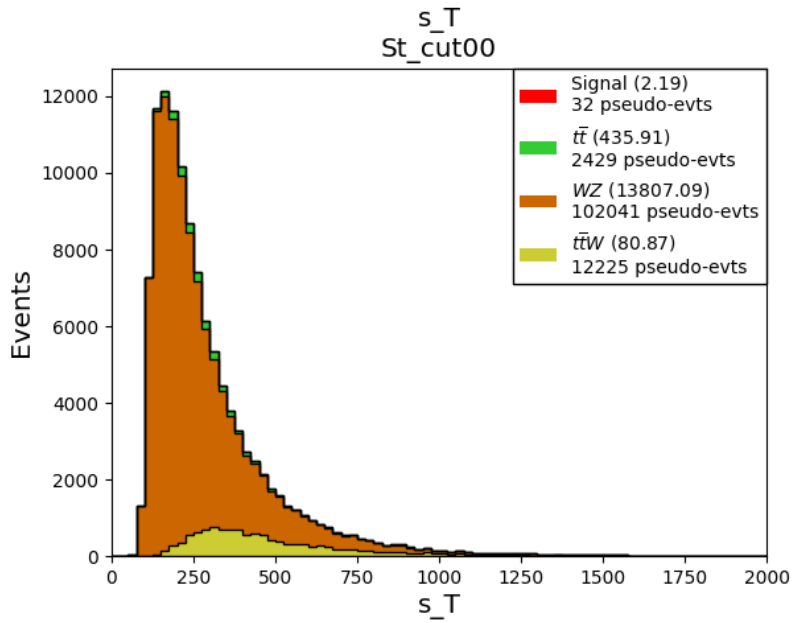


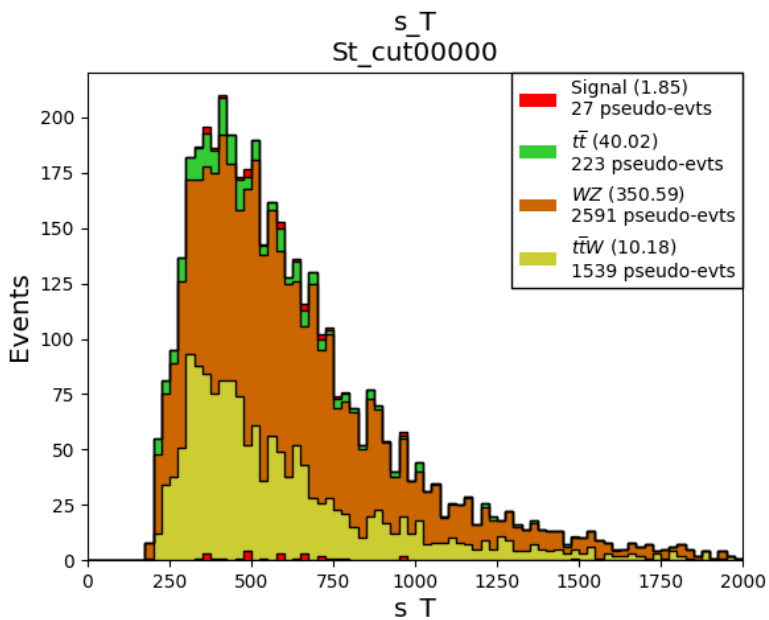


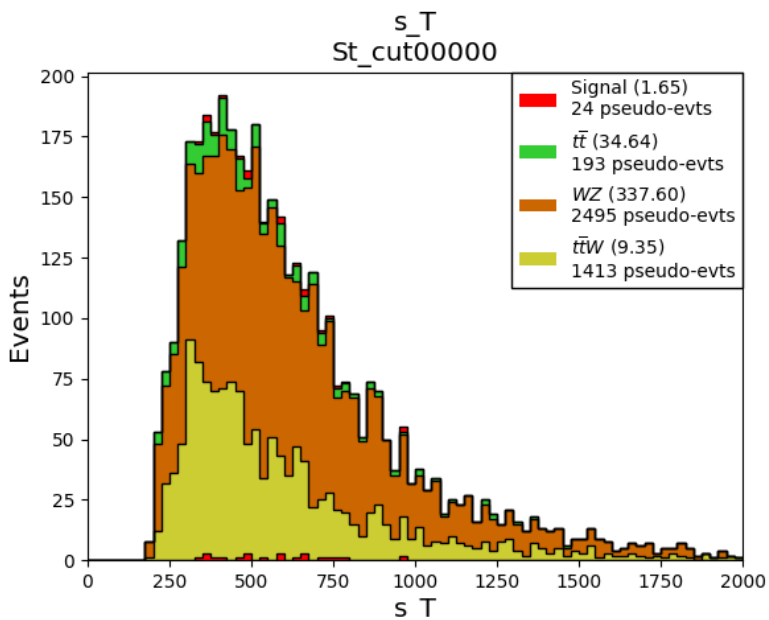


New variable: $s_T \equiv \sum_{\text{leptons}} p_T + \sum_{\text{jets}} p_T$









What's next

- Debug `StackPlots.cc` 😅
- Try to improve the $S/\sum B$ to get closer to a few percents
- If time allows, look for a variable that exhibit a signature of the signal (eg. a peak where the backgrounds are flat)

Appendix (signal and $t\bar{t}$ background)

$$N_{\text{data set}}(\text{sig.}) = 389\,500 \tag{1}$$

$$N_{\text{data set}}(t\bar{t}) = 145\,962\,000 \tag{2}$$

$$N_{\text{expected}}(\text{sig.}) = \underbrace{L_{\text{int}} \times \sigma(\text{sig.})}_{26\,700} \times \underbrace{\text{BR}\left(H^0 \longrightarrow WW\right)}_{21\ \%} \times \underbrace{\text{BR}\left(t \longrightarrow Wb\right)}_{\approx 100\ \%} \times \text{BR}\left(W \longrightarrow \ell\nu\right)^3 \tag{3}$$

$$= 7.46\ (\ell = \mu) \tag{4}$$

$$= 12.32\ (\ell = \mu)\ \text{(intermediate } \tau \text{ leptons allowed)} \tag{5}$$

$$= 59.70\ (\ell = e, \mu) \tag{6}$$

$$= 98.55\ (\ell = e, \mu)\ \text{(intermediate } \tau \text{ leptons allowed)} \tag{7}$$

$$N_{\text{expected}}(t\bar{t}) = \underbrace{L_{\text{int}} \times \sigma(t\bar{t})}_{26\,194\,500} \times \underbrace{\text{BR}\left(t \longrightarrow Wb\right)^2}_{\approx 100\ \%} \times \text{BR}\left(W \longrightarrow \ell\nu\right)^2 \tag{8}$$

$$= 316\,953\ (\ell = \mu) \tag{9}$$

$$= 442\,687\ (\ell = \mu)\ \text{(intermediate } \tau \text{ leptons allowed)} \tag{10}$$

$$= 1\,267\,814\ (\ell = e, \mu) \tag{11}$$

$$= 1\,770\,748\ (\ell = e, \mu)\ \text{(intermediate } \tau \text{ leptons allowed)} \tag{12}$$

(13)

$$N_{\text{scaled}}(\text{sig.}) = N_{\text{unscaled}} \times \frac{\sigma(\text{sig.}) \times L_{\text{int}}}{N_{\text{data set}}} = N_{\text{unscaled}} \times \frac{26\,700}{389\,500} = N_{\text{unscaled}} \times 0.068\,55 \tag{14}$$

$$N_{\text{scaled}}(t\bar{t}) = N_{\text{unscaled}} \times \frac{\sigma(t\bar{t}) \times L_{\text{int}}}{N_{\text{data set}}} = N_{\text{unscaled}} \times \frac{26\,194\,500}{145\,962\,000} = N_{\text{unscaled}} \times 0.179\,46 \tag{15}$$

Appendix (WZ and ttW backgrounds)

$$N_{\text{data set}}(WZ) = 9\,821\,283 \tag{16}$$

$$N_{\text{data set}}(ttW) = 27\,686\,862 \tag{17}$$

$$N_{\text{expected}}(WZ) = \underbrace{L_{\text{int}} \times \sigma(WZ)}_{1\,328\,910} \times \underbrace{\text{BR}\Big(Z \longrightarrow \ell^+\ell^-\Big)}_{\approx 3.365\,\%} \times \text{BR}\Big(W \longrightarrow \ell\nu\Big) \tag{18}$$

$$= 4919\ (\ell = \mu) \tag{19}$$

$$= 5813?\ (\ell = \mu)\ \text{(intermediate } \tau \text{ leptons allowed)} \tag{20}$$

$$= 19\,676\ (\ell = e, \mu) \tag{21}$$

$$= 23\,253?\ (\ell = e, \mu)\ \text{(intermediate } \tau \text{ leptons allowed)} \tag{22}$$

$$N_{\text{expected}}(ttW) = \underbrace{L_{\text{int}} \times \sigma(ttW)}_{183\,150} \times \underbrace{\text{BR}\Big(t \longrightarrow Wb\Big)^2}_{\approx 100\,\%} \times \text{BR}\Big(W \longrightarrow \ell\nu\Big)^3 \tag{23}$$

$$= 244\ (\ell = \mu) \tag{24}$$

$$= 402\ (\ell = \mu)\ \text{(intermediate } \tau \text{ leptons allowed)} \tag{25}$$

$$= 1950\ (\ell = e, \mu) \tag{26}$$

$$= 3219\ (\ell = e, \mu)\ \text{(intermediate } \tau \text{ leptons allowed)} \tag{27}$$

$$N_{\text{scaled}}(WZ) = N_{\text{unscaled}} \times \frac{\sigma(WZ) \times L_{\text{int}}}{N_{\text{data set}}} = N_{\text{unscaled}} \times \frac{1\,328\,910}{9\,821\,283} = N_{\text{unscaled}} \times 0.1353 \tag{28}$$

$$N_{\text{scaled}}(ttW) = N_{\text{unscaled}} \times \frac{\sigma(ttW) \times L_{\text{int}}}{N_{\text{data set}}} = N_{\text{unscaled}} \times \frac{183\,150}{27\,686\,862} = N_{\text{unscaled}} \times 0.006\,615 \tag{29}$$