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

Status report #1 (weeks 1, 2, 3)

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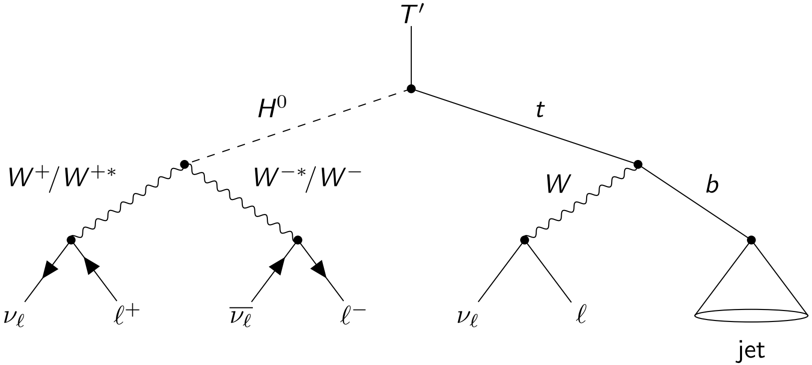
Signal

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

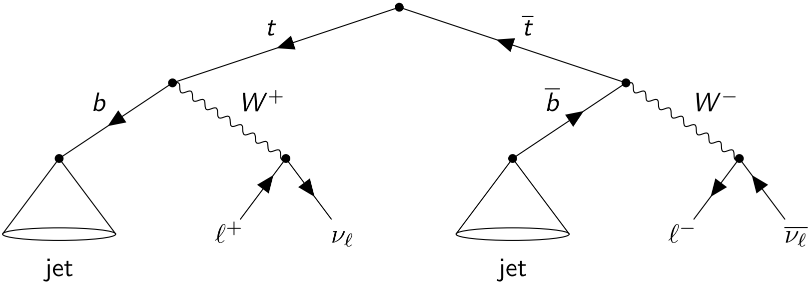


Final state: $\ell^+\ell^-\ell^\pm\nu\nu\nu$ + b-tagged jet

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

$\sigma(t\bar{t}) = 862\,\text{pb}$



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 $(m_t = 173\,\text{GeV},\ m_b = 4.2\,\text{GeV})$

Basic cuts and matching to generator particles

Signal and $t\bar{t}$ background

Cut 1: `Selected_muon_number == 3 && abs(Selected_muon_charge_sum) == 1`
Cut 2: `Selected_bjet_number >= 1`

Gen. matching: many muons come from Z^0 bosons or τ leptons

		Events	Reduction
Signal	Before any cut	1184	
	Cut 1 (3 muons of total charge ± 1)	7.5	−99.4 %
	Cut 2 (at least one b-tagged jet)	6.9	−7.34 %
	3 muons from W bosons	2.1	−69 %
$t\bar{t}$	Before any cut	?	
	Cut 1 (3 muons of total charge ± 1)	1000	?
	Cut 2 (at least one b-tagged jet)	929	−7.15 %

Basic cuts and matching to generator particles

Signal and $t\bar{t}$ background

Cut 1: `Selected_muon_number == 3 && abs(Selected_muon_charge_sum) == 1`
Cut 2: `Selected_bjet_number >= 1`

Gen. matching: many muons come from Z^0 bosons or τ leptons

	Events (signal)	Events ($t\bar{t}$)	S/B
Before	1184	?	
After Cut 1	7.5	1000	0.747 %
After Cut 2	6.9	929	0.7456 %

Signal vs. $t\bar{t}$ comparison

Automation (./compare_trilepton_ttbar.py)

Two input directories: `rootfiles` (e.g. signal) and `rootfilesstorage` (e.g. $t\bar{t}$ background)
One output directory: `analysed`
Two debug/log files: `stderrout.log` and `make.log`

- `source /cvmfs/cms.cern.ch/slc7_amd64_gcc900/lcg/root/6.24.07-db9b7135424812ed5b8723a7a77f4016/bin/thisroot.sh`
- `./compare_trilepton_ttbar.py`
  - `make clean`
  - `make -j24 > make.log 2>&1`
  - `./submitanalysisjob.py jobconfiganalysis.py`
  - `mv analysed/analysed.root analysed/analysed_DATASET.root`
  - `root -l analysed/analysed_DATASET.root`
  - Swap data sets
  - `./submitanalysisjob.py jobconfiganalysis.py`
  - `mv analysed/analysed.root analysed/analysed_DATASET.root`
  - `root -l analysed/analysed_DATASET.root`
  - Swap data sets again to restore initial state

https://github.com/bastienvoirin/fly → https://gitlab.cern.ch/fly/fly

Signal vs. $t\bar{t}$ comparison ($L_{\mathrm{int}} = 300\,\mathrm{fb}^{-1}$)

Punzi formula

$$\mathrm{Punzi} \equiv \frac{S}{0.2B + \sqrt{B} + 0.2/2}$$

- p_T of the leading muon
- p_T of the subleading muon
- p_T of the subsubleading muon
- Total p_T of the three muons
- $\Delta\phi\,(\mathrm{leading, subleading})$
- $\Delta\phi\,(\mathrm{leading, subsubleading})$
- $\Delta\phi\,(\mathrm{subleading, subsubleading})$
- $\Delta\phi_{\min}$
- $\Delta R\,(\mathrm{leading, subleading})$
- $\Delta R\,(\mathrm{leading, subsubleading})$
- $\Delta R\,(\mathrm{subleading, subsubleading})$
- $\Delta R_{\min}$

Signal vs. $t\bar{t}$ comparison ($L_{\text{int}} = 300\,\text{fb}^{-1}$)

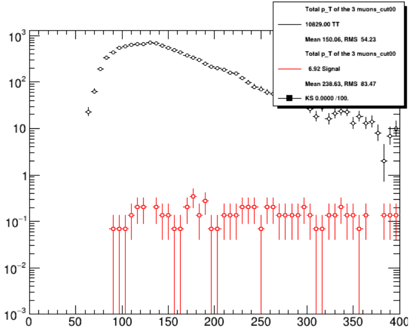
Punzi formula

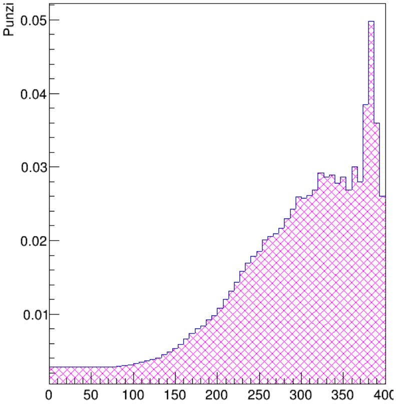
$$\text{Punzi} \equiv \frac{S}{0.2B + \sqrt{B} + 0.2/2}$$

- p_T of the leading muon $> 60\,\text{GeV}$?
- p_T of the subleading muon $> 35\,\text{GeV}$?
- p_T of the subsubleading muon $< 125\,\text{GeV}$?
- Total p_T of the three muons $> 130\,\text{GeV}$ **(cut 3)**
- $\cancel{\Delta\phi\,(\text{leading}, \text{subleading})}$
- $\cancel{\Delta\phi\,(\text{leading}, \text{subsubleading})}$
- $\cancel{\Delta\phi\,(\text{subleading}, \text{subsubleading})}$
- $\cancel{\Delta\phi_{\text{min}}}$
- $\Delta R\,(\text{leading}, \text{subleading}) < 4$ **(cut 4)**
- $\Delta R\,(\text{leading}, \text{subsubleading}) < 4$ **(cut 4)**
- $\Delta R\,(\text{subleading}, \text{subsubleading}) < 4$ **(cut 4)**
- ΔR_{min} **(cut? todo: define)**

Signal vs. $t\bar{t}$ comparison ($L_{\text{int}} = 300\,\text{fb}^{-1}$)

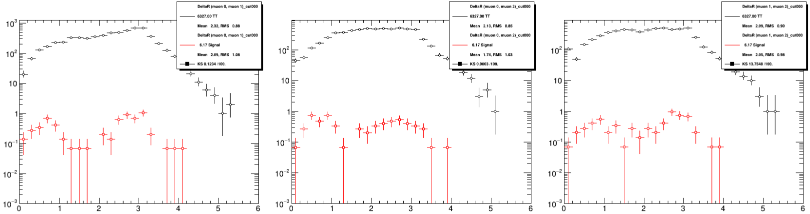
Cut 3: total $p_T > 130$ GeV





Signal vs. $t\bar{t}$ comparison ($L_{\text{int}} = 300\,\text{fb}^{-1}$)

Cut 4: $\Delta R(i,j) \leqslant 4, \forall(i,j)$



Signal vs. $t\bar{t}$ comparison ($L_{\text{int}} = 300\,\text{fb}^{-1}$)

Results

Cut 1: `Selected_muon_number == 3 && abs(Selected_muon_charge_sum) == 1`
Cut 2: `Selected_bjet_number >= 1`
Cut 3: `Selected_muon_sum_all_muons_pt >= 130.0`
Cut 4: `Selected_muon_deltaR_01 <= 4.0 && Selected_muon_deltaR_02 <= 4.0 && Selected_muon_deltaR_12 <= 4.0`

	Events (sig.)	Events ($t\bar{t}$)	Cut (sig.)	Cut ($t\bar{t}$)	S/B
Before	1184	2 728 521*			0.0044 %*
After Cut 1	7.47	2093*	−99.4 %	−99.92 %*	0.357 %*
After Cut 2	6.92	1943*	−7.36 %	−7.17 %*	0.356 %*
After Cut 3	6.17	1135*	−10.8 %	−41.6 %*	0.544 %*
After Cut 4	6.10	1097*	−1.13 %	−3.35 %*	0.556 %*

What's next

- Define ΔR_{min} as $\min(\Delta R_{01}, \Delta R_{02}, \Delta R_{12})$
- Try $\Delta R(i, j)$ or $\Delta R_{\mathrm{min}} \leqslant 3.6$ or even 3.4
- Estimate the p_T of the muons for the signal and the $t\bar{t}$ background; define/refine cuts based on p_T
- Try to find other relevant variables and cuts
- Tame the export process of comparison histograms and Punzi plots 💀🤠 (export cropped and scaled SVG and bitmap files along with the PDF file)

Appendix

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

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

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

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

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

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

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

$$N_{\text{expected}}(t\bar{t}) = \underbrace{L_{\text{int}} \times \sigma(t\bar{t})}_{258\,600\,000} \times \underbrace{\text{BR}\left(t \longrightarrow Wb\right)}_{\approx 100\,\%} \times \text{BR}\left(W \longrightarrow \ell\nu\right)^2 \tag{8}$$

$$= \ 3\,129\,060 \ (\ell = \mu) \tag{9}$$

$$= \ 4\,370\,340 \ (\ell = \mu) \ (\text{intermediate } \tau \text{ leptons allowed}) \tag{10}$$

$$= 12\,516\,240 \ (\ell = e, \mu) \tag{11}$$

$$= 17\,481\,360 \ (\ell = e, \mu) \ (\text{intermediate } \tau \text{ leptons allowed}) \tag{12}$$

$$N_{\text{scaled}}(\text{sig.}) = N_{\text{unscaled}} \times \frac{\sigma(\text{sig.}) \times L_{\text{int}}}{N_{\text{data set}}} = N_{\text{unscaled}} \times \frac{26\,700}{389\,500} = N_{\text{unscaled}} \times 0.068\,55 \tag{13}$$

$$N_{\text{scaled}}(t\bar{t}) = N_{\text{unscaled}} \times \frac{\sigma(t\bar{t}) \times L_{\text{int}}}{N_{\text{data set}}} = N_{\text{unscaled}} \times \frac{258\,600\,000}{145\,962\,000} = N_{\text{unscaled}} \times 1.7717 \tag{14}$$