W polarization and anomalous *Wtb* couplings studies at LIP/UGR

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in collaboration with:
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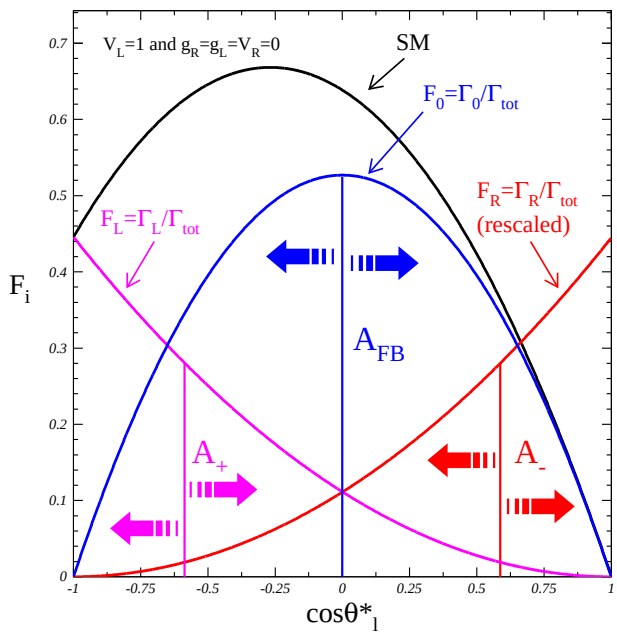
measuring the W helicity states

1. Fitting $\cos\theta^*_\ell$ (or $m_{\ell b}$) to obtain the W helicity fractions
   - ☞ correction function
   - ☞ templates
2. Fitting $\cos\theta^*_\ell$ to obtain the W helicity ratios:
   - ☞ $\rho_L = F_L/F_0 = 0.438$ (SM, NLO)
   - ☞ $\rho_R = F_R/F_0 = 1.4 \times 10^{-3}$ (SM, NLO)
3. Computing angular asymmetries: $A_t = \frac{N(\cos\theta^*_\ell > t) - N(\cos\theta^*_\ell < t)}{N(\cos\theta^*_\ell > t) + N(\cos\theta^*_\ell < t)}$

A_{FB}=-0.2269 (SM, NLO)

A_+=0.5429 (SM, NLO)

A_-=-0.8402 (SM, NLO)



MC samples @ $\sqrt{s} = 10$ TeV

- D3PDs produced with `TopPhysDPDMaker` rel14050006:
  - Protos samples (private production, 105362-9):
    - SM semileptonic $t\bar{t}$
    - semileptonic $t\bar{t}$ W polarization templates: F_0, F_R and F_L

    samples available at CASTOR:
`/castor/cern.ch/user/n/nfcastro/mc08_private_production_Protos_1.1`
  - Official production of Protos $t\bar{t}$ should start once the needed tag (production release 15.1.0.8) becomes available
  - MC@NLO and AcerMC $t\bar{t}$ samples:
    `mc08.105200.T1_McAtNlo_Jimmy.e357_s462_r635_t53`
    `mc08.105205.AcerMCttbar.recon.AOD.e352_s462_r541`
  - MC08 background samples (`s462_r635_t53`):
    - W+jets (`Alpgen` 106280-3, 107682-5, 107692-5, 107702-5)
    - Z+jets (`Alpgen` 107652-5, 107662-5, 107672-5)
    - dibosons (`Herwig` 105985-7)
    - single top (`AcerMC` 105500, 105502)
- Plans: move to the new samples (re-reconstructed MC08 with rel. 15.3.1.6) and to rel. 15 for analysis

object reconstruction

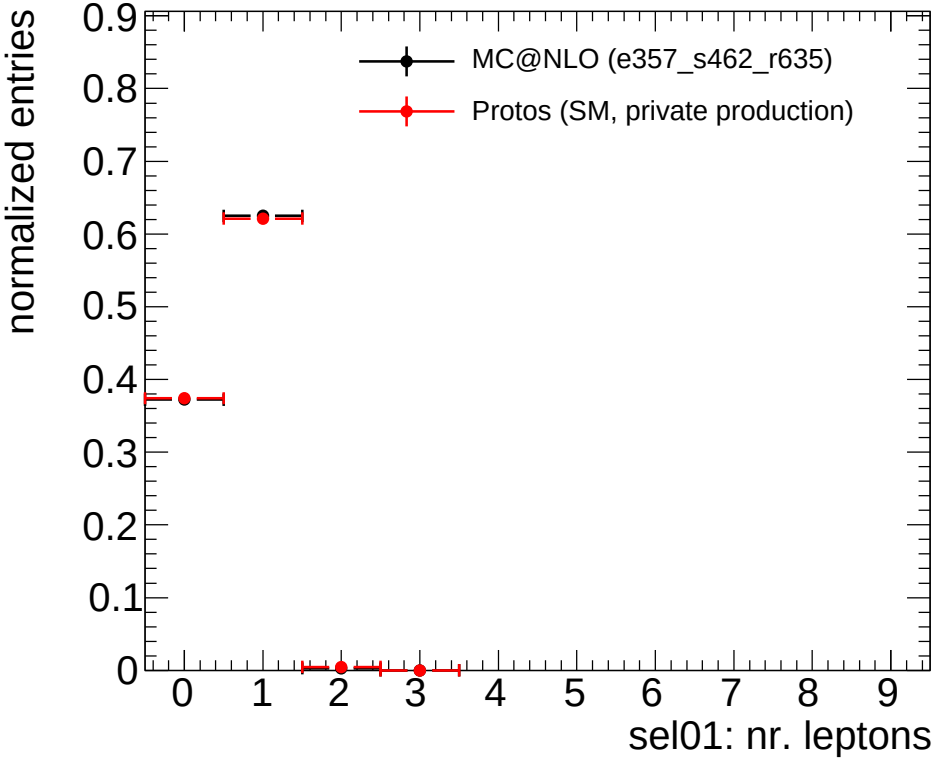
- Criteria from $\sigma(t\bar{t})$ note (semileptonic topology) used:

  `https://twiki.cern.ch/twiki/bin/view/AtlasProtected/TopSingleleptonPubNote`

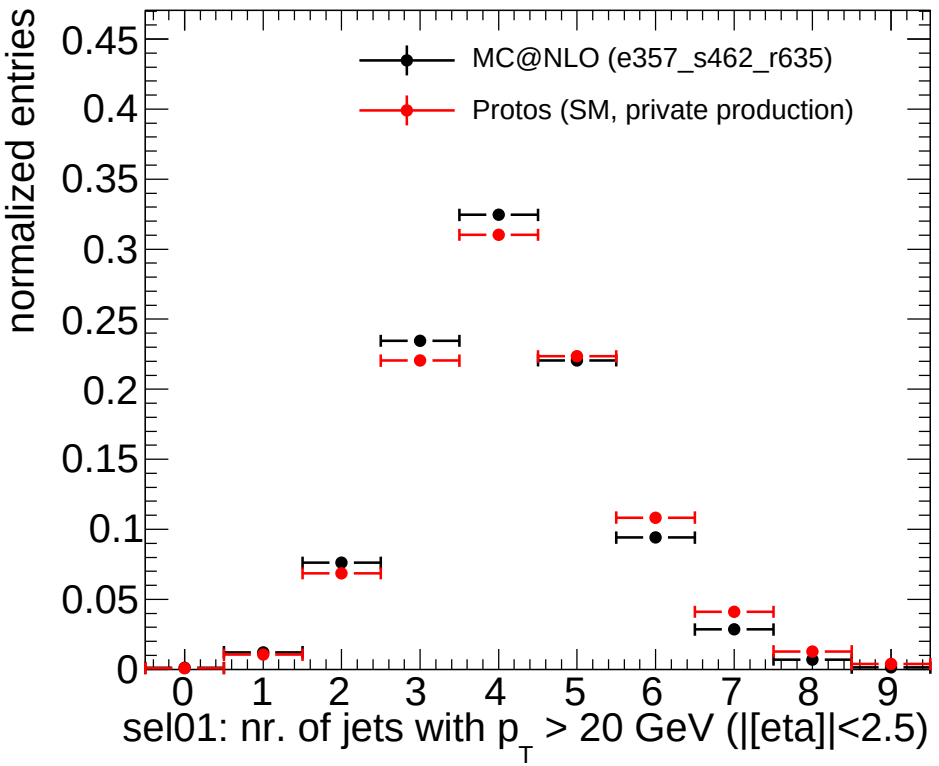
  1. electrons
     - `author==1 || author == 3`
     - `egamma isEM medium`
     - $p_T > 20$ GeV
     - `etcone20` < 6 GeV
     - $|\eta| < 2.47$ (removing electrons in crack, $1.37 < |\eta| < 1.52$)
  2. jets
     - `Cone4H1Tower`
     - $p_T > 20$ GeV, $|\eta| < 2.5$
     - jets overlaping with reco. electrons ($\Delta R < 0.2$) removed
  3. muons
     - `StacoMuonCollection`
     - `isCombinedMuon == 1`
     - `etcone30` < 6 GeV
     - $p_T > 20$ GeV, $|\eta| < 2.5$
     - muons overlaping with reco. jets ($\Delta R < 0.3$) removed

object reconstruction

leptons



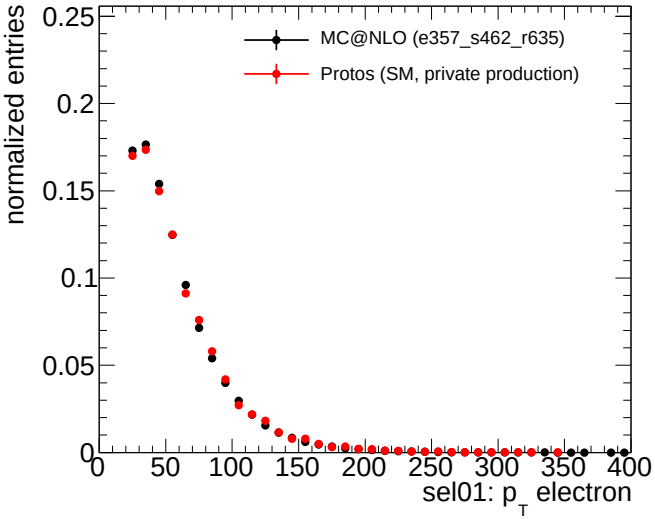
jets $p_T > 20$ GeV



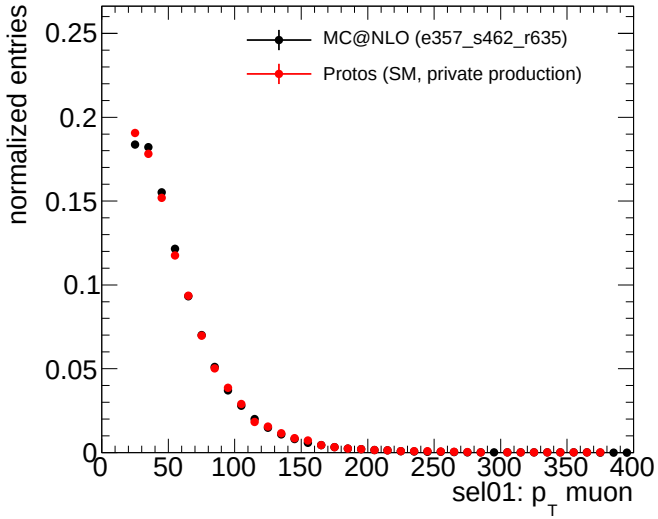
MC@NLO Protos

object reconstruction

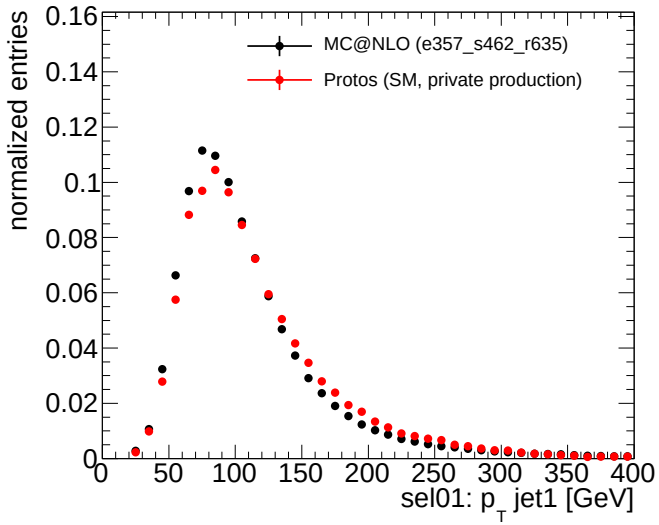
p_T (e)



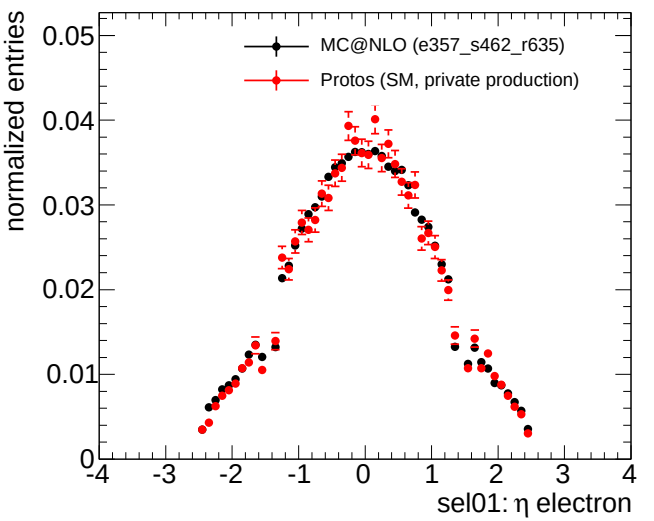
p_T (μ)



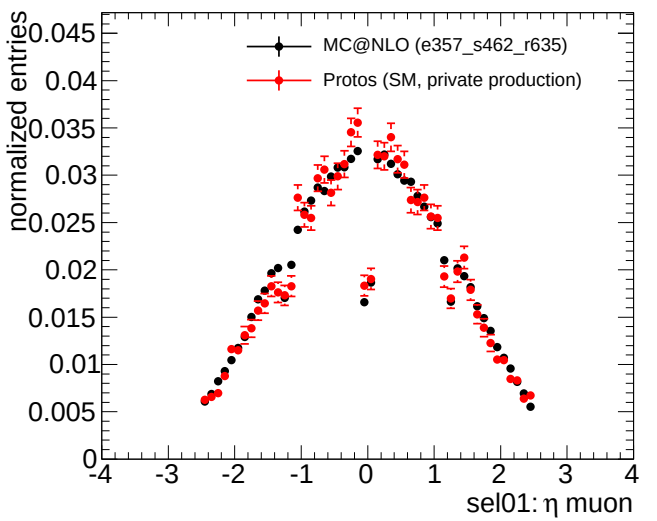
p_T (jet 1)



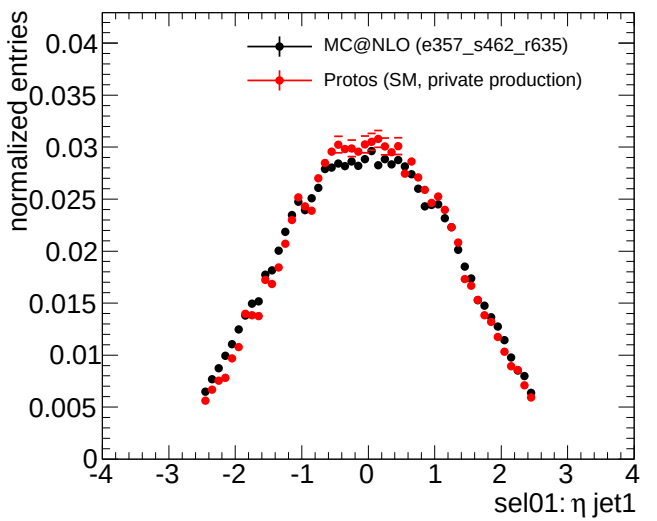
η (e)



η (μ)



η (jet 1)

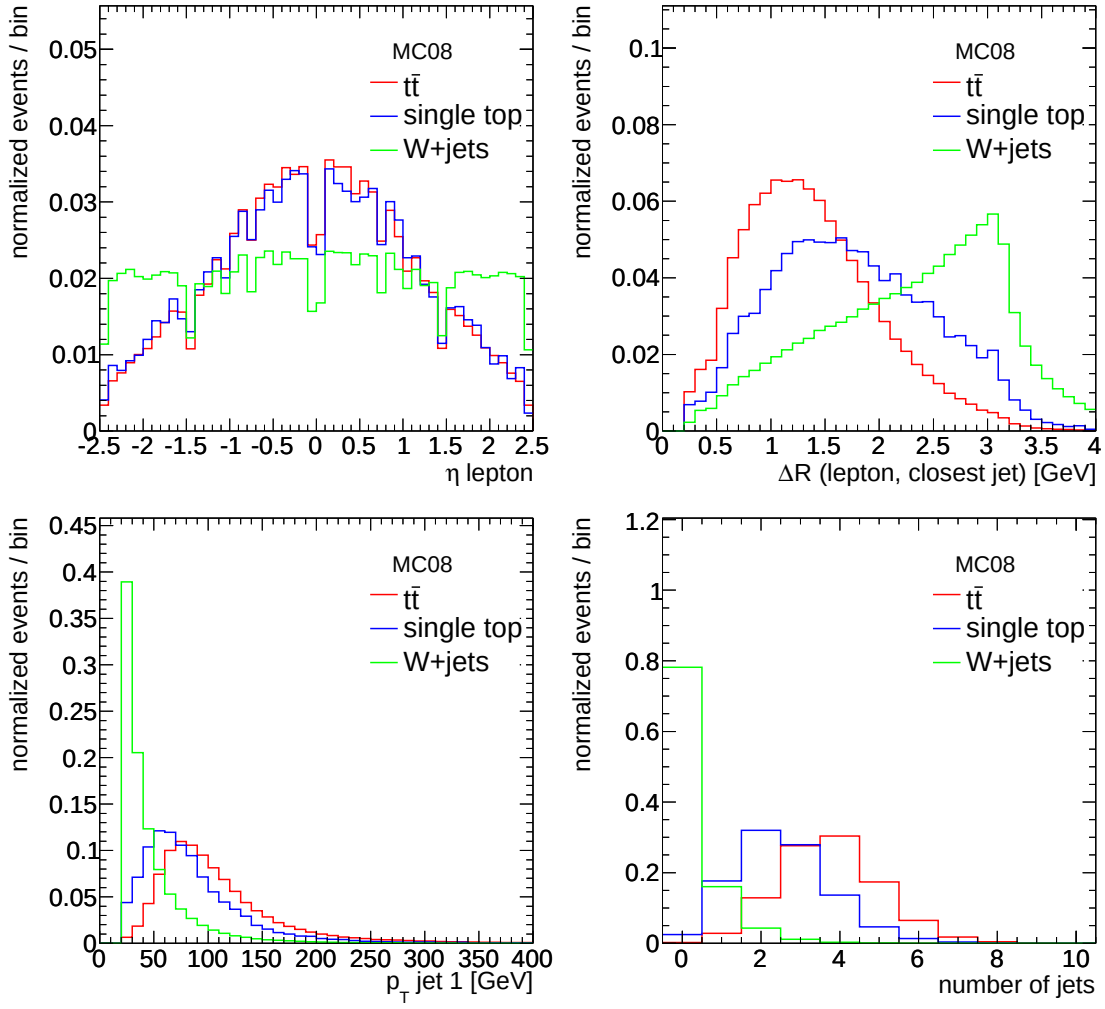


MC@NLO Protos

background normalization

- Obtain MC normalization from data
- Shapes for different processes obtained from MC
- Obtain normalizations for $t\bar{t}$ and $W + \text{jets}$

Plots made requiring trigger, 1 lepton and MET$>$ 20 GeV



preselection — consistency check

cuts at preselection:

1. trigger: `e15_medium` (e), `mu15` (μ)
2. lepton (e or μ)
3. $\not{E}_T >$ 20 GeV
4. at least 3 jets with $p_T > 40$ GeV
5. at least 4 jets with $p_T > 20$ GeV

checks with Andrea Knue (Göttingen) under way

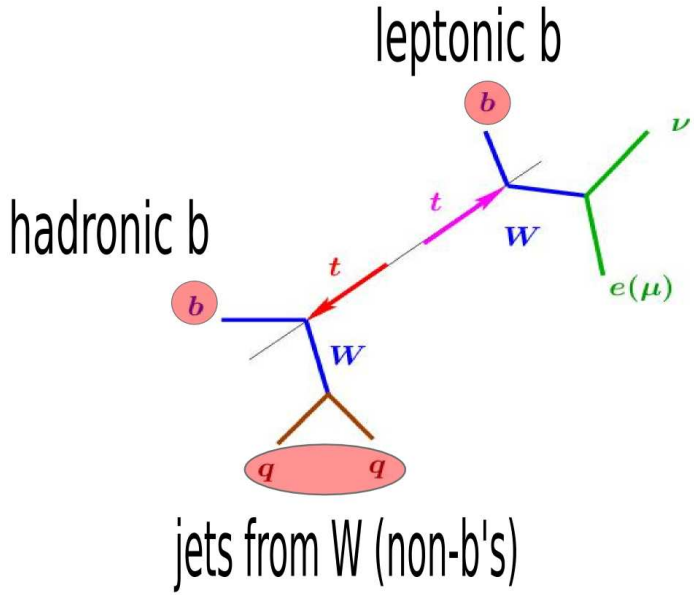
MC@NLO $t\bar{t}$ with leptons (105200)

	electrons	muons
cut 1	28.6 %	30.3 %
cut 2	69.7 %	67.4 %
cut 3	90.1 %	90.9 %
cut 4	47.6 %	47.3 %
cut 5	80.2 %	80.6 %

(no truth level separation was done)

event reconstruction using a χ^2 (no b-tag used)

after preselection
(trigger, 1 charged lepton
MET $>$ 20 GeV and
$\geq$ 4 jets, being 3 of them
with $p_T > 40$ GeV)

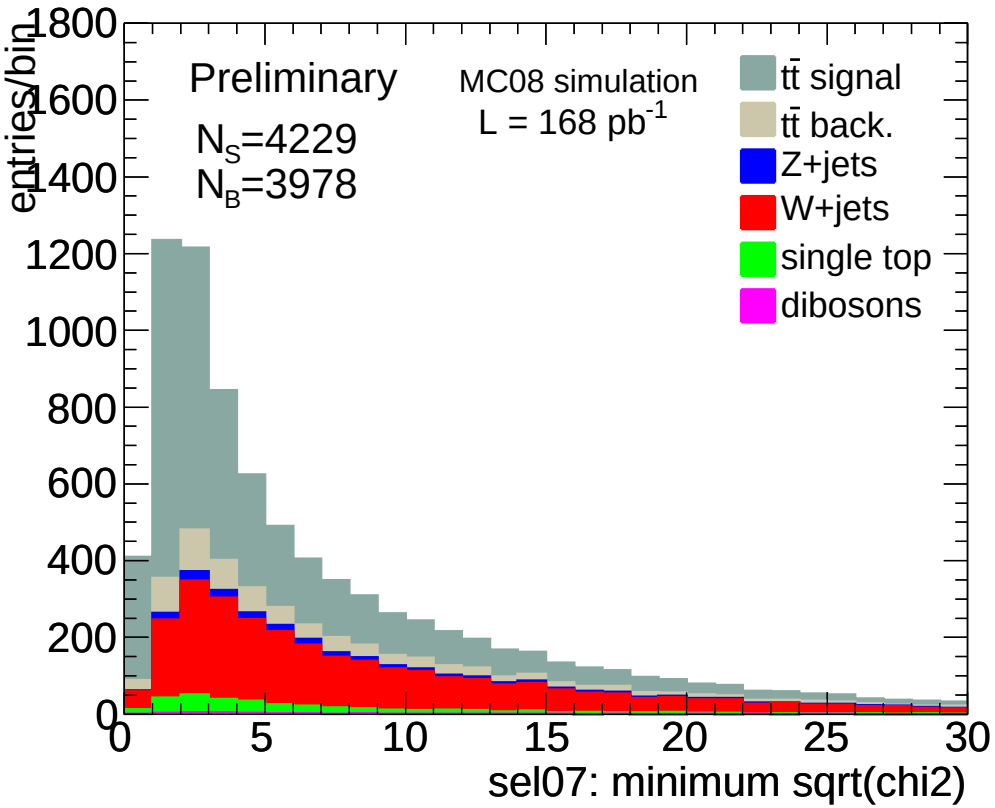


$$\chi^2 = \frac{(m_{\ell\nu j_a} - 172.5)^2}{\sigma_t^2} + \frac{(m_{j_b j_c j_d} - 172.5)^2}{\sigma_t^2} + \frac{(m_{\ell\nu} - 80.4)^2}{\sigma_W^2} + \frac{(m_{j_c j_d} - 80.4)^2}{\sigma_W^2}$$

- $\sigma_t = 14$ GeV, $\sigma_W = 10$ GeV
- $[j_a, j_b, j_c, j_d] \rightarrow$ combinations of the four highest p_T jets (12 hypotheses)

$\Longrightarrow$ minimization of χ^2:
scan over jet combinations and possible values for neutrino p_Z

control region



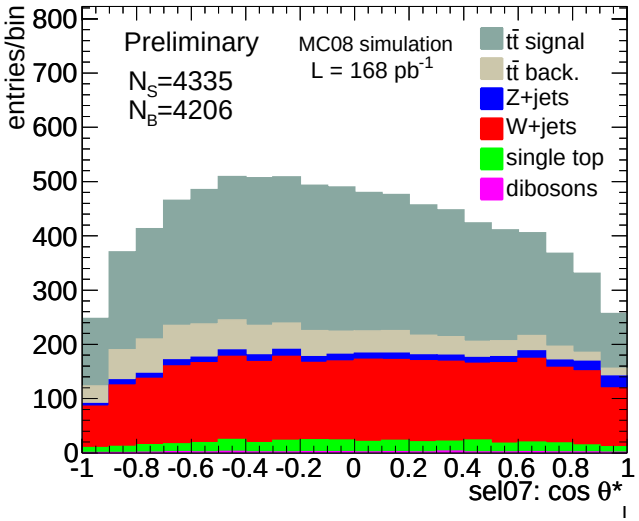
- use $\sqrt{\chi^2}$ cut to define 2 regions:
  1. signal region: $\sqrt{\chi^2} < 10$
  2. background region: $\sqrt{\chi^2} \geq 10$ (can be used for control)

control region: behaviour of $\cos\theta^*_\ell$

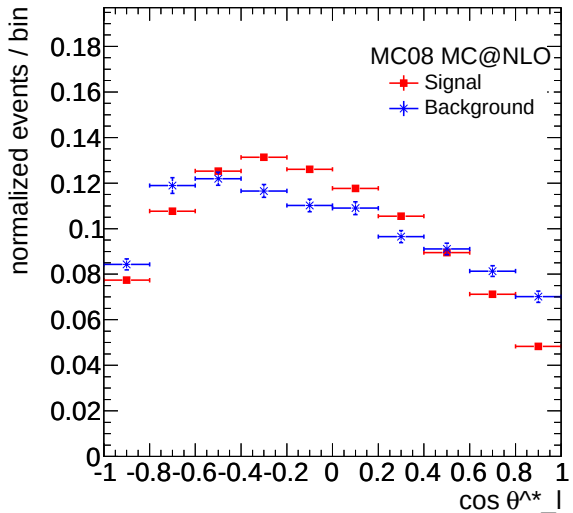
expected events for $L = 168$ pb^{-1}:

	no $\sqrt{\chi^2}$ cut	$\sqrt{\chi^2} < 10$	$\sqrt{\chi^2} \geq 10$
signal	4334.9±10.2	3439.8±9.1	895.1±4.5
background	4205.5±27.6	2703.0±22.3	1502.5±17.4

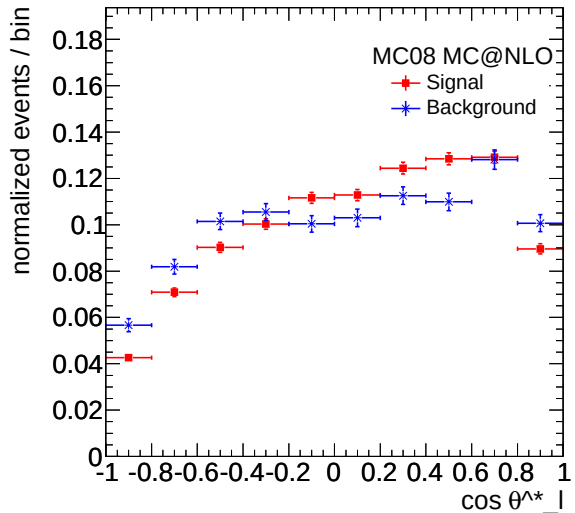
no $\sqrt{\chi^2}$ cut



$\sqrt{\chi^2} < 10$

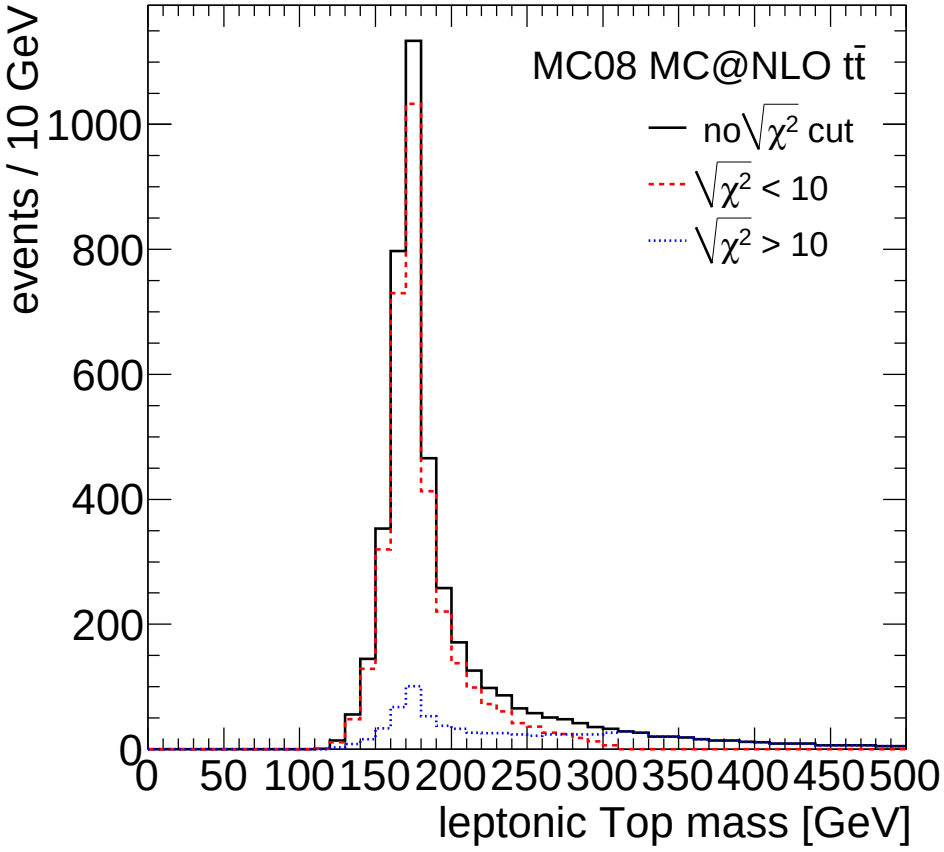


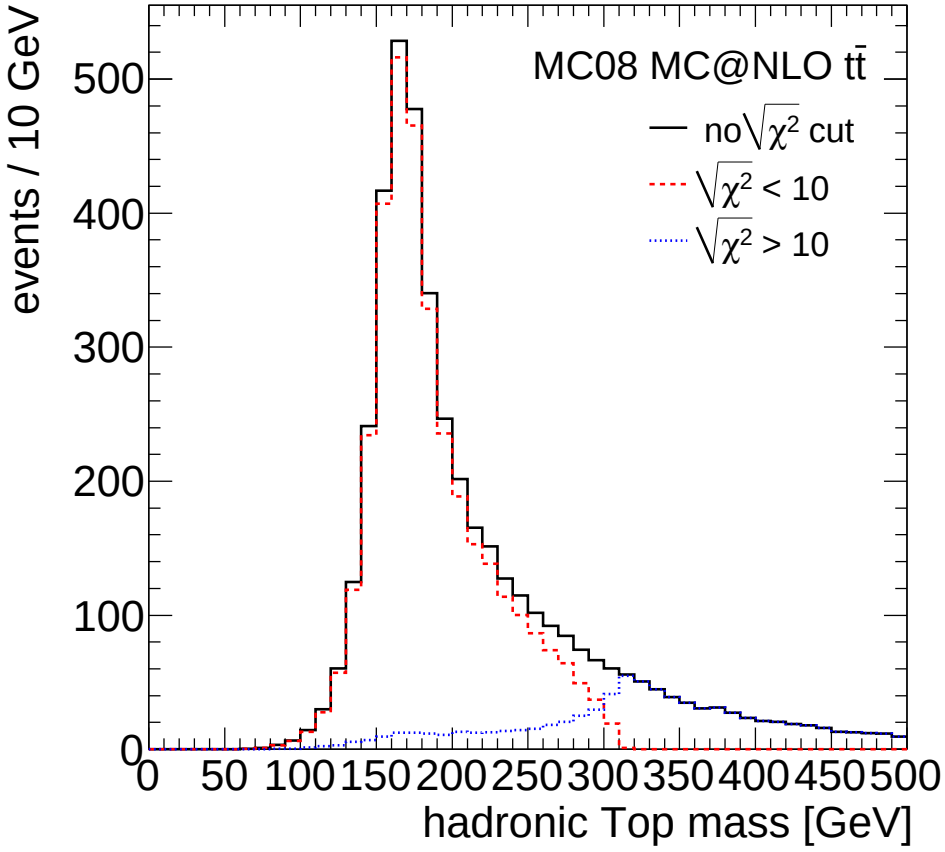
$\sqrt{\chi^2} \geq 10$



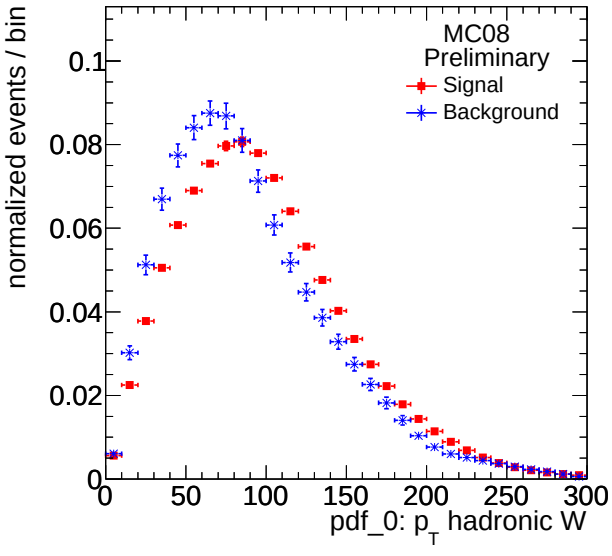
- Bias on $\cos\theta^*_\ell$ introduced by badly reconstructed events (combinatorial background?)

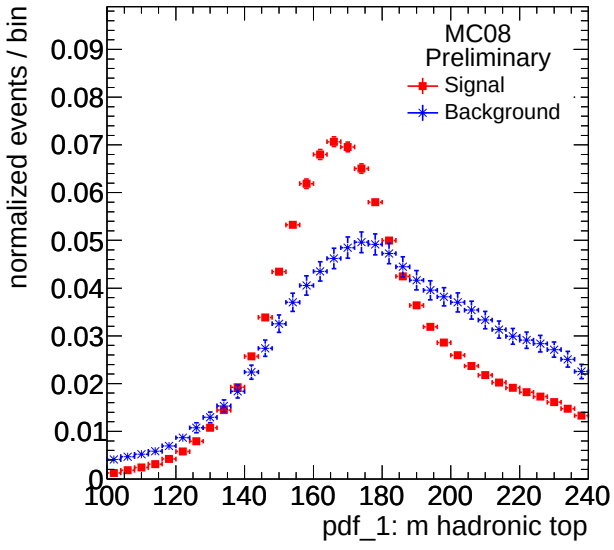
control region: behaviour of the reconstructed m_t

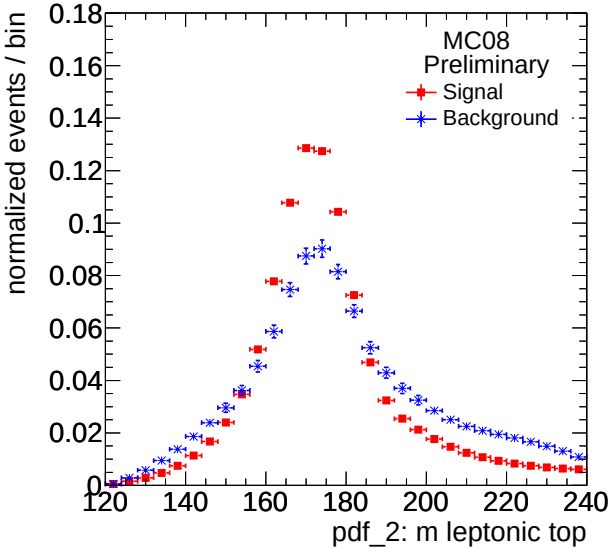


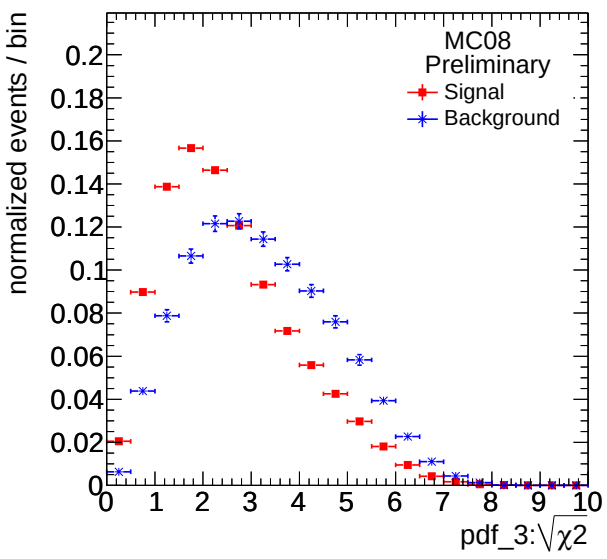


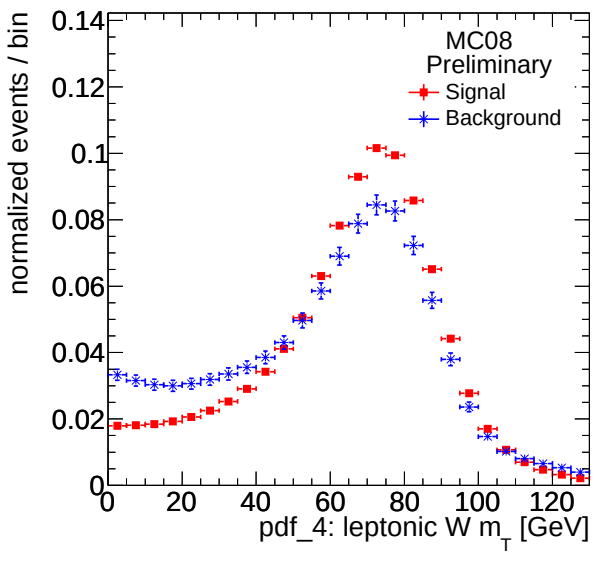
probabilistic analysis: probability density functions



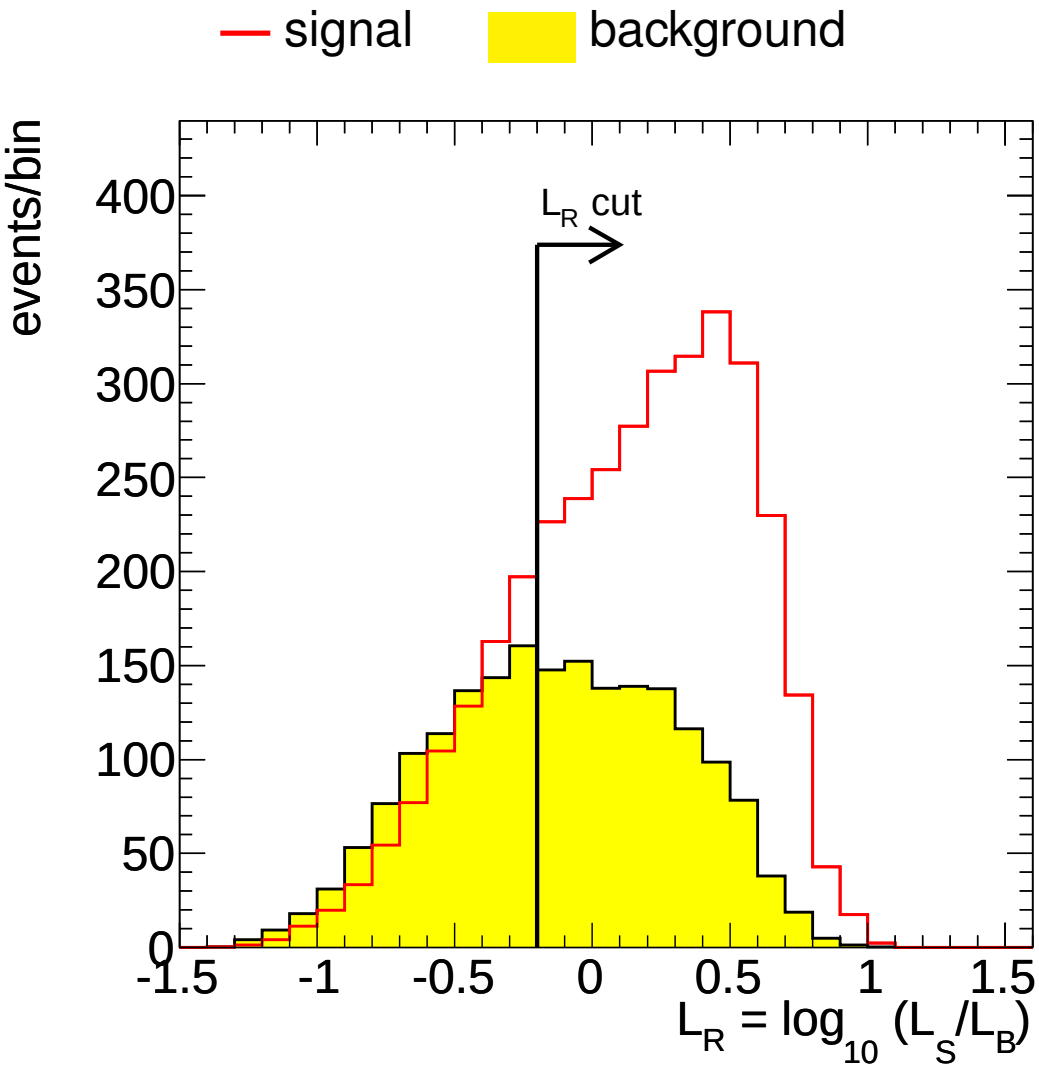






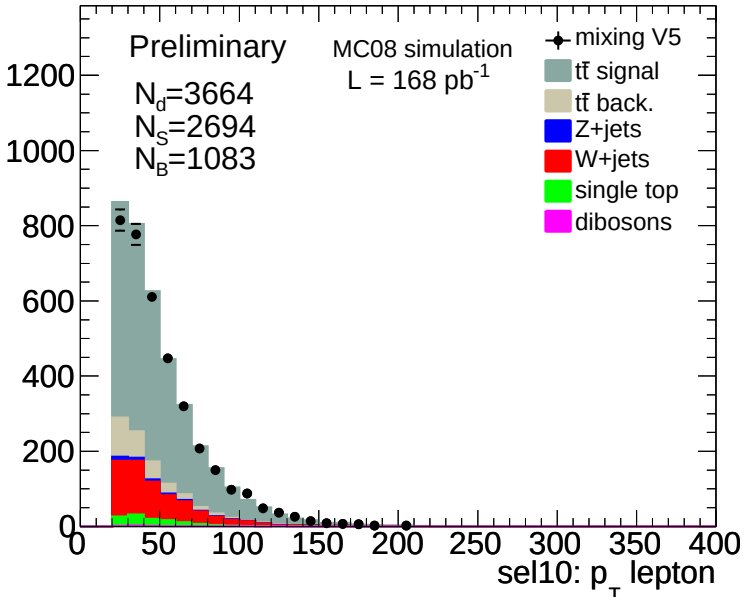


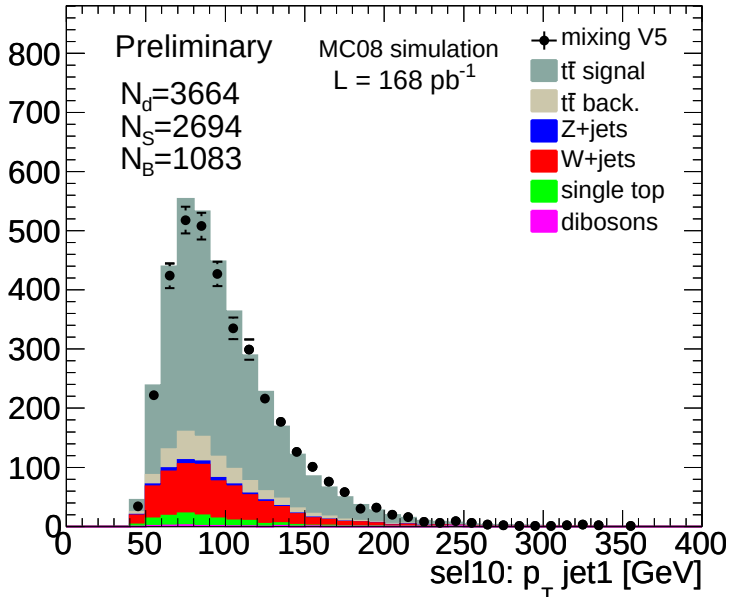
probabilistic analysis: likelihood ratio

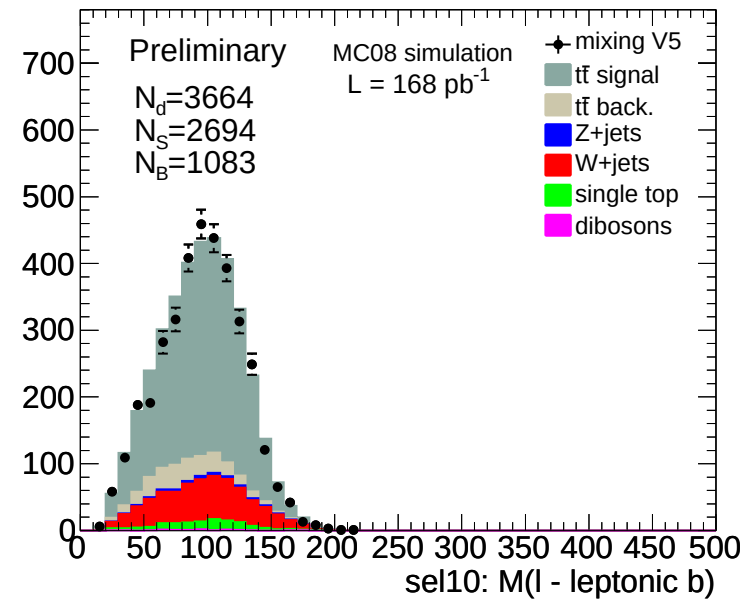


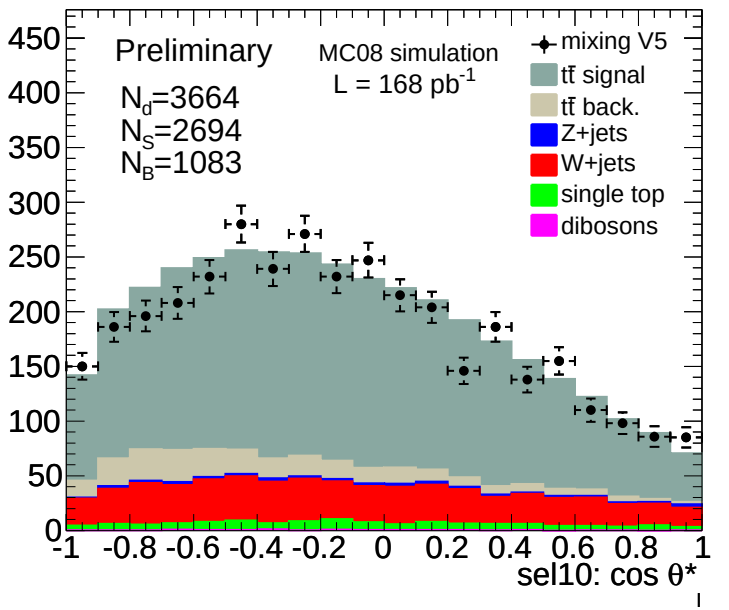
☞ final selection cut: $L_R = \log_{10}(L_S/L_B) > -0.2$

plots after the final selection









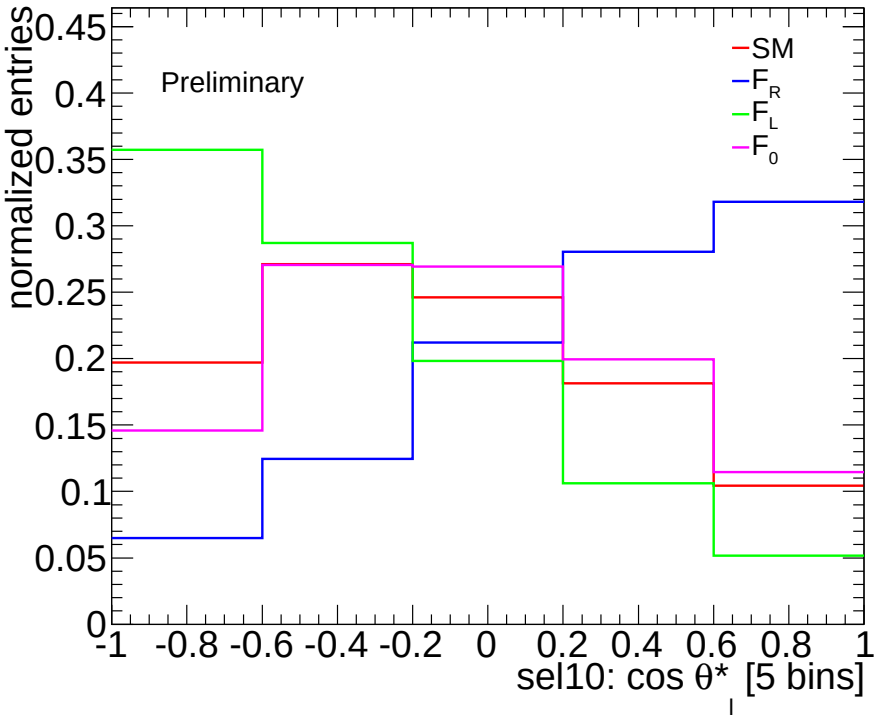
selected events after the final selection

	expected events for $L = 168$ pb^{-1}
signal (MC@NLO, SM)	2694 ± 9
dileptonic $t\bar{t}$	54 ± 1
semileptonic $t\bar{t}$ ($W \to \tau\nu$)	231 ± 3
hadronic $t\bar{t}$	11 ± 1
single top (t-channel)	61 ± 4
single top (Wt channel)	56 ± 4
W+jets	618 ± 11
dibosons (WW, ZZ, WZ)	9 ± 1
Z+jets	43 ± 2
total background	1083 ± 16

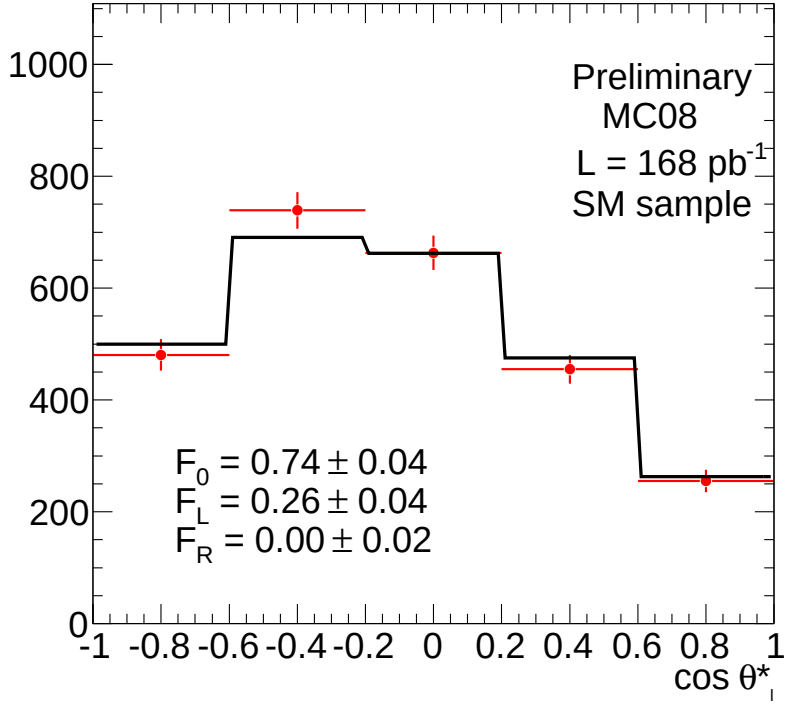
W polarization: templates method

1. Perform a background subtraction (back. shapes from MC)
2. Fit the “subtracted data” with the MC templates

templates
(`Protos` MC)



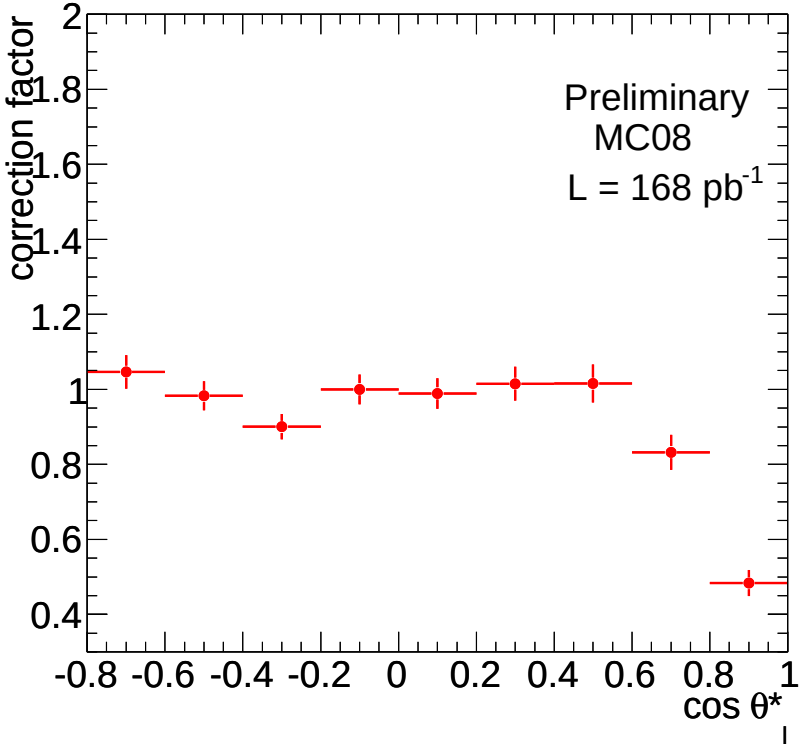
fitted function
(mixing V5 subtracted)



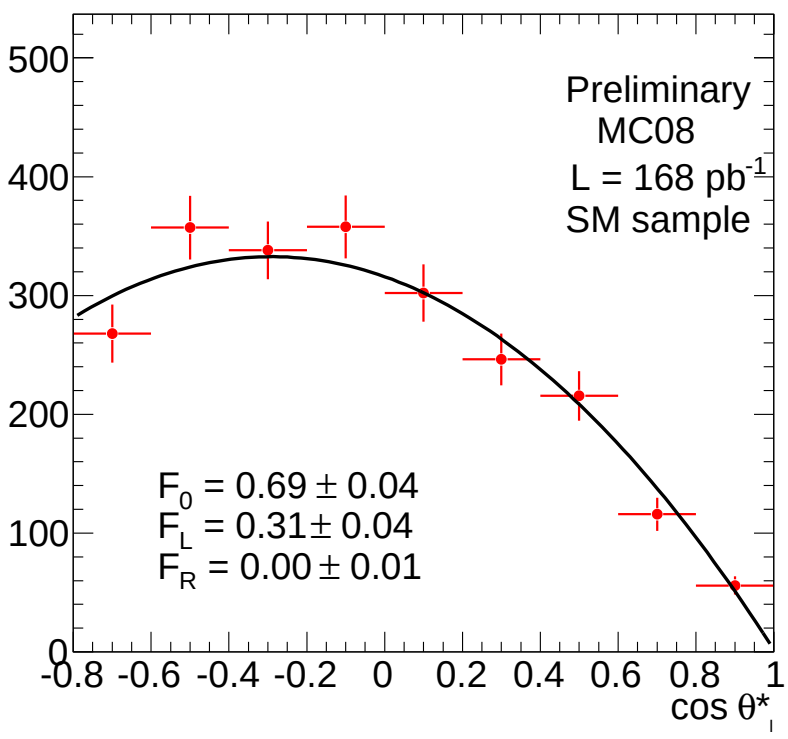
W polarization: correction function method

1. Perform a background subtraction (back. shapes from MC)
2. evaluate a correction function: $f_c = \frac{\text{truth distribution}}{\text{rec. MC signal distribution}}$
3. Fit the "subtracted and corrected data" with the theoretical $\cos\theta^*_\ell(F_0, F_L, F_R)$ distribution

correction function
(MC@NLO)



fitted function
(mx V5 subtr. and corrected)

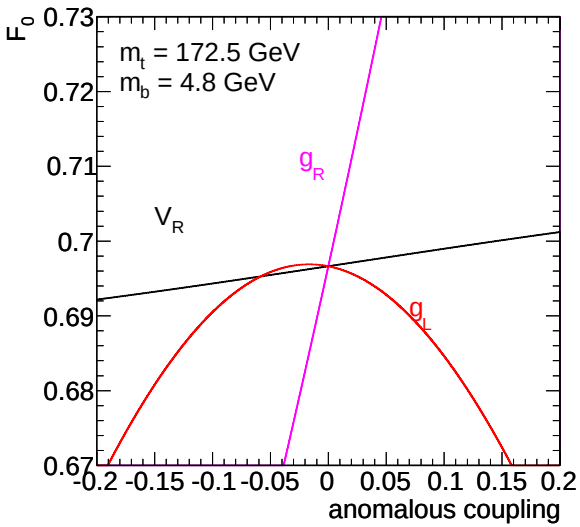


anomalous *Wtb* couplings

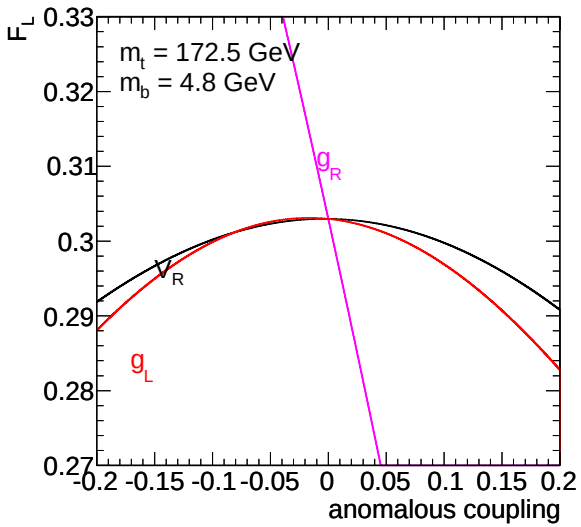
most general *Wtb* vertex:

$$\mathcal{L} = -\frac{g}{\sqrt{2}}\bar{b}\,\gamma^{\mu}\left(V_L P_L + V_R P_R\right) t\; W_{\mu}^{-}$$
$$-\frac{g}{\sqrt{2}}\bar{b}\,\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(g_L P_L + g_R P_R\right) t\; W_{\mu}^{-} + \text{h.c.}$$

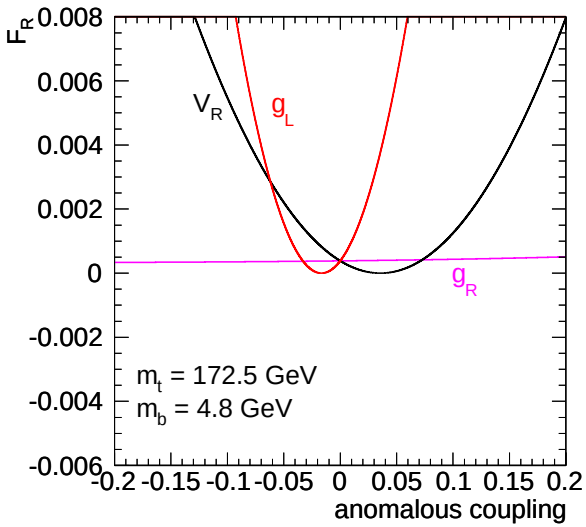
anomalous couplings $\Rightarrow$ deviations in W helicity fractions:



F_0



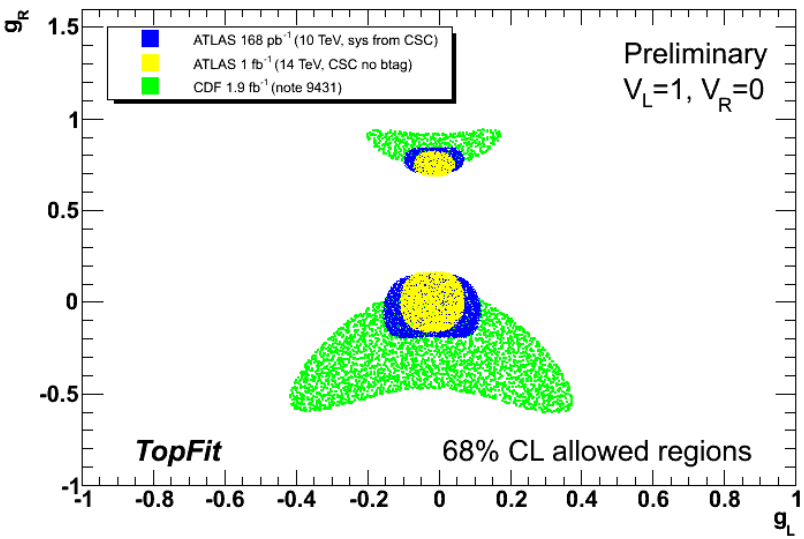
F_L

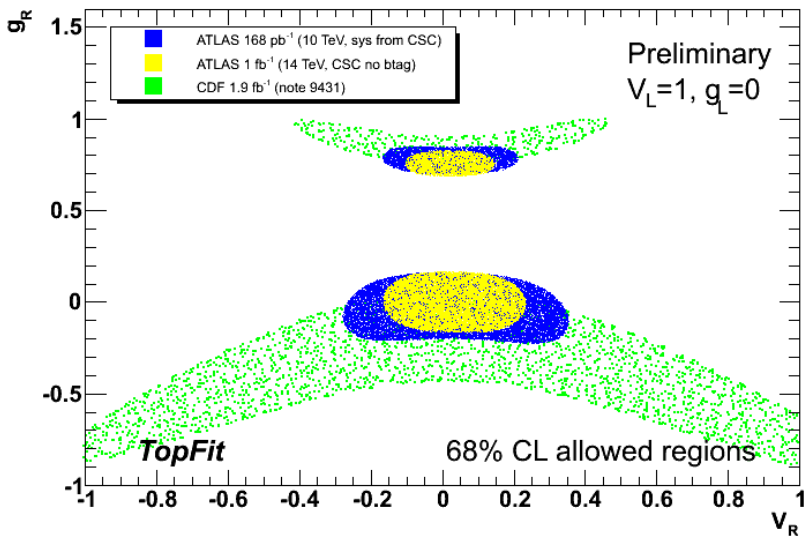


F_R

anomalous Wtb couplings: expected sensitivity

$$\left.\begin{matrix}\rho_L \\ \rho_R \\ A_+ \\ A_-\end{matrix}\right\} \rightarrow \text{TopFit} \rightarrow \left\{\begin{matrix}V_R \\ g_L \\ g_R\end{matrix}\right.$$





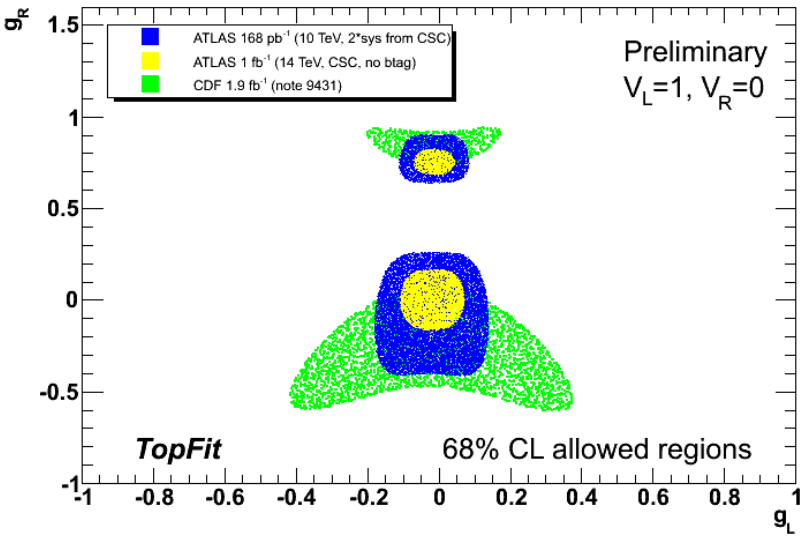
green area: limits obtained with the CDF results (Conf. Note 9215)

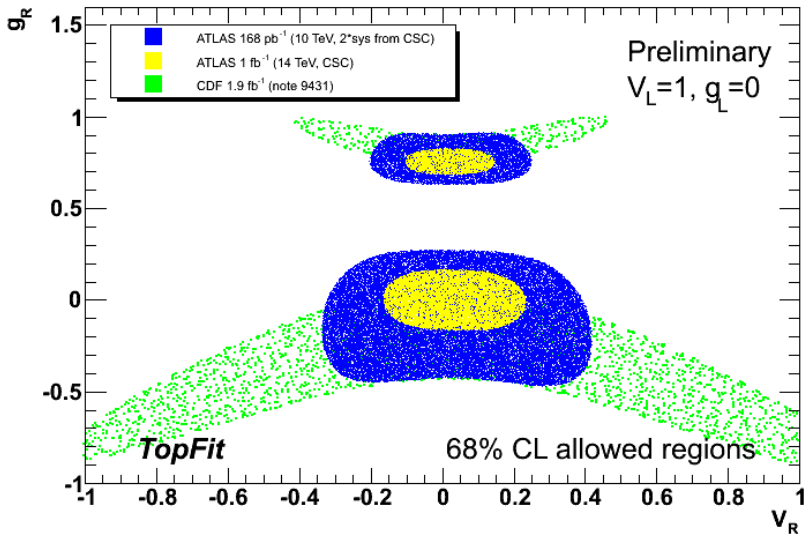
yellow area: ATLAS expectation for $\sqrt{s} = 14$ TeV, $L = 1$ fb^{-1} (CSC, no btag)

blue area: ATLAS expectation for $\sqrt{s} = 10$ TeV, $L = 0.168$ fb^{-1} (assuming the CSC systematical error)

anomalous Wtb couplings: expected sensitivity

$$\left.\begin{matrix}\rho_L \\ \rho_R \\ A_+ \\ A_-\end{matrix}\right\} \rightarrow \text{TopFit} \rightarrow \left\{\begin{matrix}V_R \\ g_L \\ g_R\end{matrix}\right.$$





green area: limits obtained with the CDF results (Conf. Note 9215)

yellow area: ATLAS expectation for $\sqrt{s} = 14$ TeV, $L = 1$ fb^{-1} (CSC, no btag)

blue area: ATLAS expectation for $\sqrt{s} = 10$ TeV, $L = 0.168$ fb^{-1} (assuming $2\times$ the CSC systematical error)

plans for the next steps

- use rel. 15.3.1.6 AODs (and rel. 15.5.1 for analysis)
- consider two scenarios for the signal:
  1) semileptonic $t\bar{t}$ with the lep. $W \rightarrow \tau\nu$ events is background (as done for the CSC)
  2) all the semileptonic $t\bar{t}$ events are signal
- compare results for $\sigma_{t\bar{t}}$ with other generators (POWHEG, MC@NLO)
- for the analysis using templates, use the template samples produced with PROTOS
- use $\sigma_{t\bar{t}}$ $(\ell + \text{jets})$ analysis as benchmark and drive any changes on the selection criteria as a function of the improvement of the physics result
- the figure of merit for the analysis comparison will be the two dimensional W polarization fit
- observables under study are: $\cos\theta^*_\ell$, m_{bl} and lepton p_T
- finalize the data-driven method to evaluate the background level for $t\bar{t}$, W+jets, etc
- b-tag information (use shape of the tagger for the b candidates as p.d.f.s)
  - early taggers (JetProb, SV0, etc)
- systematics ($t\bar{t}$ generator, background level, jet energy scale, luminosity, PDFs, top mass, ISR/FSR, pile-up, etc)
- INT note by January next year