Karlsruhe Institute of Technology

Same Sign Top Signals within the Flavour Violating MSSM

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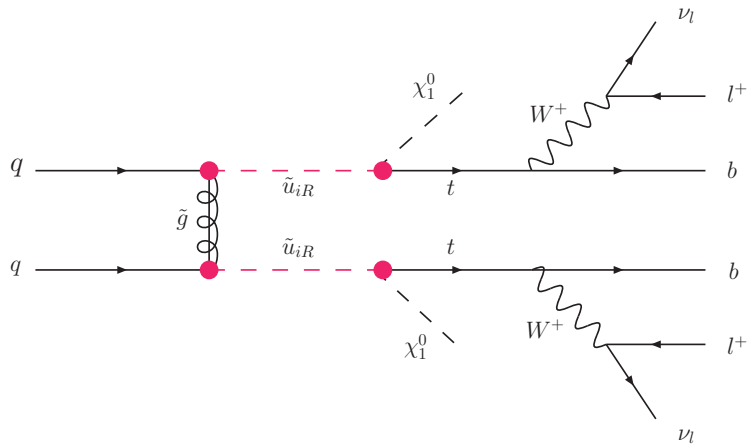
Yasmin Anstruther | January 19, 2012

INSTITUTE FOR THEORETICAL PHYSICS

Outline

Motivation

Signal



- NMFV connected to susy breaking $\rightsquigarrow$ pin down breaking mechanism
- Study changes within analysis of discovery processes
- Process may have good significance $\rightsquigarrow$ measure parameters precisely

Implementation

Mainly used:

- Herwig++ 2.5.2 : flavourviolation at matrixelement-level roughly by extending the 2×2 to 6×6 mixing matrices within the Feynman rules
- Madgraph & Madevent 5 : generate LesHouches event files for the backgrounds to feed Herwig++
- SPheno 3.0.beta56 : passes mixing parameters to Herwig++, generates squark masses and checks constraints
- ROOT 5.28.00b : performs analysis and draws plots

Experimental Constraints

How would the choice of our parameters influence other observables?

- $B-$Physics $\rightarrow$ generation mixing
- Vacuum Stability Conditions $\rightarrow$ LR mixing
- Susy corrections to electroweak $\rho-$parameter: $\Delta\rho$
- Recent LHC exclusion limits

Make sure that our parameter points haven't been excluded yet.

$B-$Physics

No FCNCs at tree-level $\rightarrow$ very sensitive to new physics.

	rad. decays	semilept. decays	mass differences
2 & 3	$B \rightarrow X_s\gamma$	$B \rightarrow X_s l^+ l^-$	$\lvert\Delta M_{B_s}\rvert$
1 & 3	$B \rightarrow X_d\gamma$	$B \rightarrow X_d l^+ l^-$	$\lvert\Delta M_{B_d}\rvert$

Effective low energy theory: decompose Hamiltonian

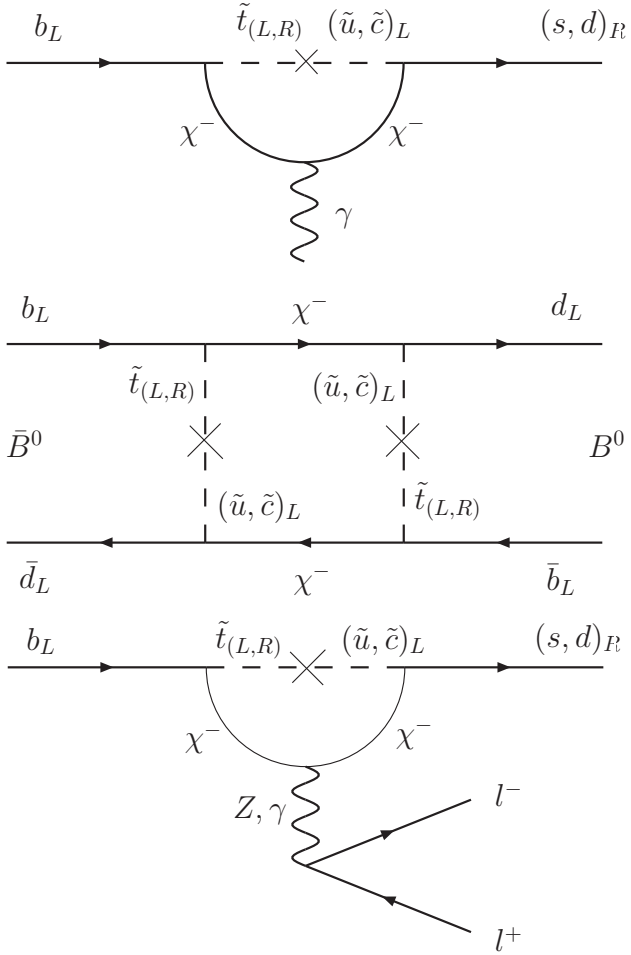
$$H_{eff} \propto \sum_i [C_i(\mu) O_i(\mu)] \tag{1}$$

- model-independent, non-pert. Operators O_i
- model-dependent, pert. Wilson Coefficients C_i
- RGE running: $\mu = M_Z \rightarrow \mu = m_b$

[M. Spannowsky, PhD thesis]

$B-$Physics

- radiative decays:
- $B^0 \bar{B}^0-$oscillations:
- semileptonic decays: negligible



Vacuum Stability Conditions

avoid charge and colour breaking (CCB) minima of the superpotential, as long as:

$$|T_{u\alpha\alpha}|^2 < 3f^{u_\alpha}(M^2_{Q\alpha\alpha} + M^2_{u\alpha\alpha} + (m^2_{H^\pm} + m^2_Z \sin\theta_W)\sin^2\beta - \frac{1}{2}m^2_Z) \quad (2)$$

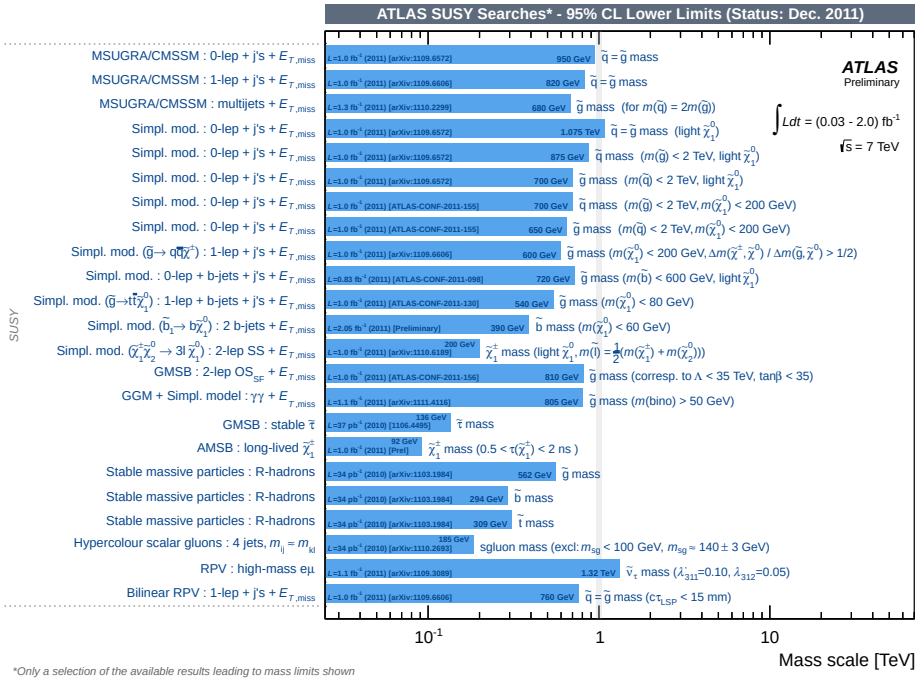
$$|T_{u\alpha\beta}|^2 < 3f^{u_\gamma}(M^2_{Q\alpha\alpha} + M^2_{u\beta\beta} + (m^2_{H^\pm} + m^2_Z \sin\theta_W)\cos^2\beta - \frac{1}{2}m^2_Z) \quad (3)$$

with $\gamma = \max_{\alpha\neq\beta}(\alpha, \beta)$.

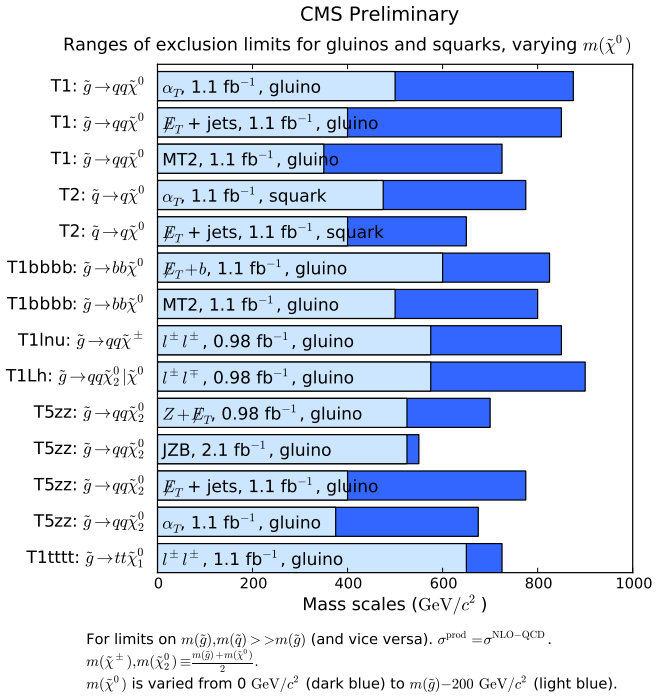
Regarding LR mixing, these constraints are stronger than the ones from FCNCs.

[J. A. Casas, S. Dimopoulos, Phys.Lett. B387 (1996) 107-112]

LHC exclusion limits



*Only a selection of the available results leading to mass limits shown



For limits on $m(\tilde{g}),m(\tilde{q})>>m(\tilde{g})$ (and vice versa). $\sigma^{\text{prod}}=\sigma^{\text{NLO-QCD}}$.
$m(\tilde{\chi}^\pm),m(\tilde{\chi}^0_2)\equiv\frac{m(\tilde{g})+m(\tilde{\chi}^0)}{2}$.
$m(\tilde{\chi}^0)$ is varied from 0 GeV/c^2 (dark blue) to $m(\tilde{g})-200$ GeV/c^2 (light blue).

$\rightsquigarrow$ squark masses bigger than 1 TeV

$\rho-$parameter

Def. at LO: $\rho := \frac{M_W^2}{M_Z^2 \cos^2\theta_W}$

quantum (incl. Susy) corrections: $\Delta\rho = \frac{\Sigma_Z(0)}{M_Z^2} - \frac{\Sigma_W(0)}{M_W^2} < 0.0012$

$\Sigma(0)$: transverse part of unren. self-energies

Heavy Flavor Averaging Group[1]:

$B \to s\gamma$	$B \to s l^+ l^-$	$\lvert\Delta M_{B_s}\rvert$
$(3.55 \pm 0.33) \cdot 10^{-4}$ GeV	$(3.66 \pm 0.77) \cdot 10^{-6}$ GeV	17.77 ± 0.17 ps^{-1}

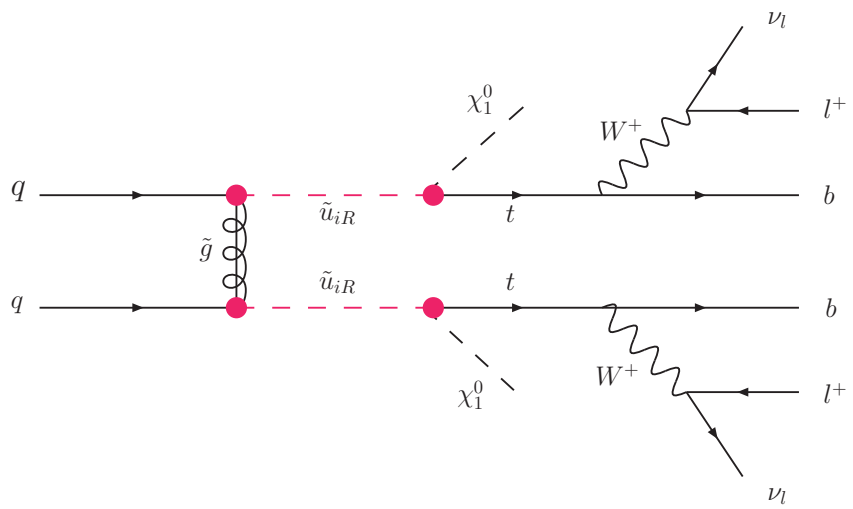
$B \to \rho\gamma$	$B \to \pi l^+ l^-$	$\lvert\Delta M_{B_d}\rvert$
$(1.39 \pm 0.22) \cdot 10^{-6}$ GeV	$< 0.062 \cdot 10^{-6}$ GeV	0.507 ± 0.004 ps^{-1}

$\bar{m}_{\tilde{q}}$	$\Delta\rho$
1 TeV	0.0012

[1] without theory uncertainties

Signal process

Same-sign top quark production via flavour-violating t-channel gluino exchange:

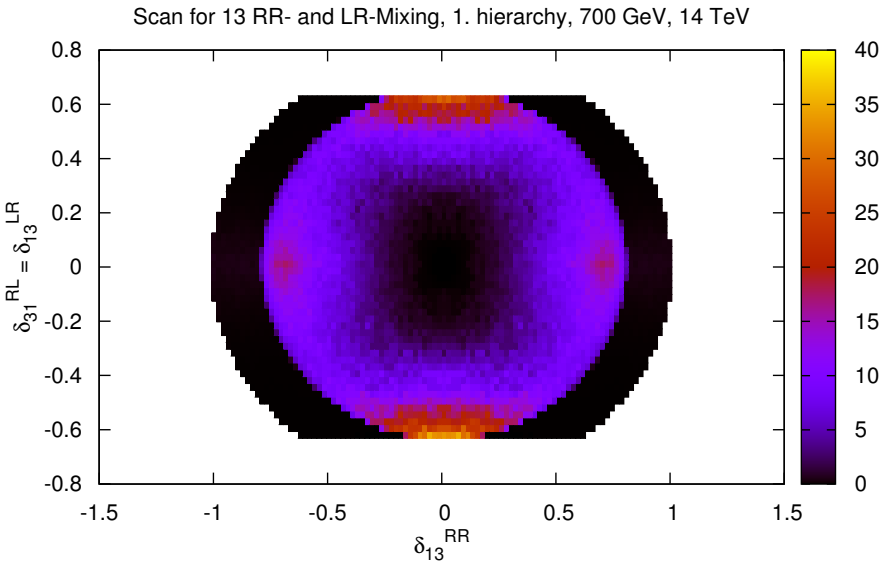


- diagonal entries $\rightsquigarrow m_{\tilde{q}} \approx 1\text{TeV}$
- hierarchy: ascending or descending
- offdiagonal entries $\rightsquigarrow$ mass splitting

$\Rightarrow$ 2 variable parameters and hierarchies

Scenario I - Porod et al.[2]

$\sigma(pp \to tt\chi_0^1\chi_0^1)$ in fb:



squark masses:

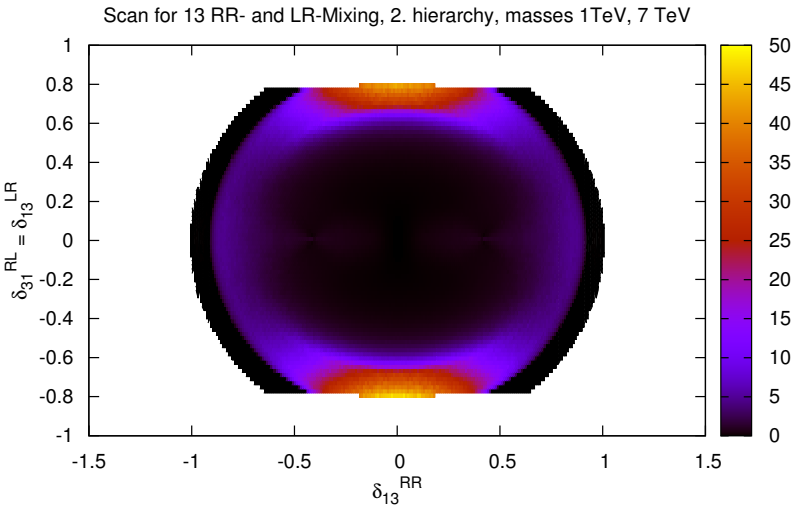
$\tilde{u}_1$	496
$\tilde{u}_6$	1062
$\bar{m}_{\tilde{u}}$	768

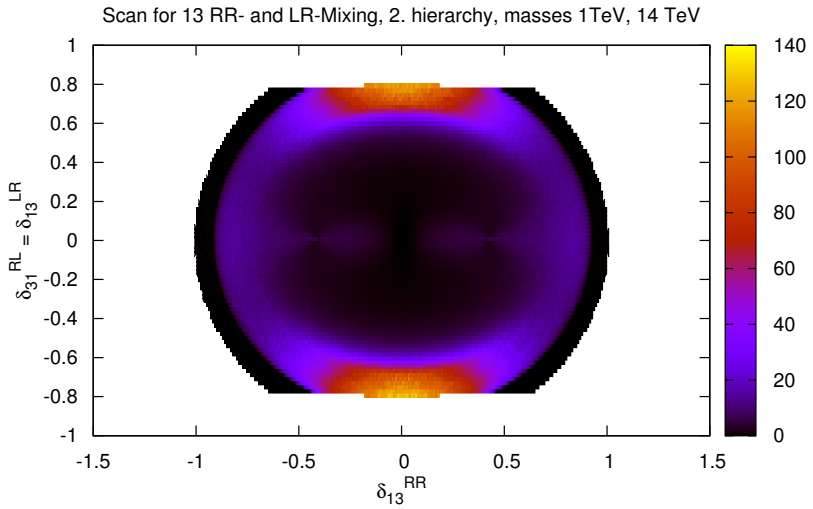
I	11	12	13	21	22	23	31	32	33
$M^2_{Q\alpha\beta}/\text{GeV}^2$	$85 \cdot 10^4$	-	-	-	$77 \cdot 10^4$	-	-	-	$70 \cdot 10^4$
$M^2_{u\alpha\beta}/\text{GeV}^2$	$67 \cdot 10^4$	-	x	-	$36 \cdot 10^4$	-	x	-	$34 \cdot 10^4$
$M^2_{d\alpha\beta}/\text{GeV}^2$	$69 \cdot 10^4$	-	-	-	$67 \cdot 10^4$	-	-	-	$66 \cdot 10^4$
$T_{u\alpha\beta}/\text{GeV}$	0.007	-	-	-	2.68	-	y	-	488

[2] Phys.Lett.B698: 380-388, 2011

Scenario II - $m_{\tilde{q}} \approx 1$TeV

$\sigma(pp \to tt\chi_0^1\chi_0^1)$ in fb:





Hierarchy 2: inverted

I	11	12	13	21	22	23	31	32	33
$M^2_{Q\alpha\beta}/\text{GeV}^2$	$60 \cdot 10^4$	-	-	-	$62 \cdot 10^4$	-	-	-	$93 \cdot 10^4$
$M^2_{u\alpha\beta}/\text{GeV}^2$	$96 \cdot 10^4$	-	x	-	$103 \cdot 10^4$	-	x	-	$111 \cdot 10^4$
$M^2_{d\alpha\beta}/\text{GeV}^2$	$96 \cdot 10^4$	-	-	-	$103 \cdot 10^4$	-	-	-	$111 \cdot 10^4$
$T_{u\alpha\beta}/\text{GeV}$	0.067	-	-	-	0.36	-	y	-	34

Scenario III - Effective Susy

Idea of effective Susy

- squark masses of 1st and 2nd generation of $\mathcal{O}(10)$TeV
- 3rd generation squarks $\approx$ 1TeV

Choice: $m^{1,2} \approx 15$ TeV and $m^3 \approx 1$TeV

+ contributions to constraints strongly suppressed
- $\tilde{q}^{1,2}$ can't be produced
- only small mixing possible

$$\rightsquigarrow \sigma(pp \to tt\chi_0^1\chi_0^1) \approx 10^{-7}\text{fb}$$

Backgrounds - Supersymmetry

Other processes with the same visible final state particles?

Supersymmetry:

- jbl^+l^+ and E_t^{miss}
- jjl^+l^+ and E_t^{miss}

only due to b-mis-tagging, either once or twice.

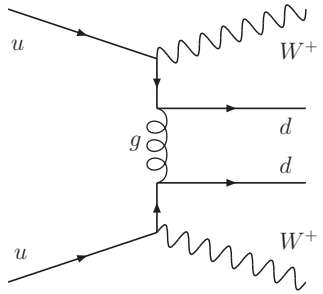
$\rightsquigarrow$ reduction of signal-events by 10% or 1%, respectively

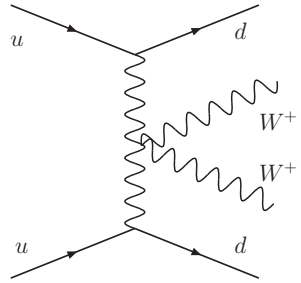
$\rightsquigarrow$ negligible background?

More Backgrounds

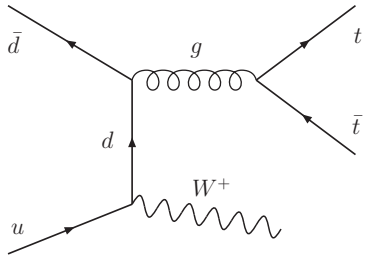
Standardmodel:

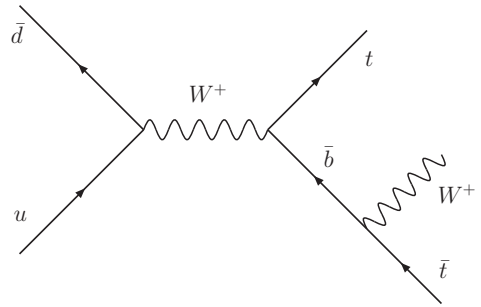
- W^+W^+jj
- $t\bar{t}W^+$
- $ZZjj$, W^+Zjj (negligible)





leptonic decays
of $W^+, Z \overset{\nu}{\rightsquigarrow} E_t^{miss}$





but consider the benefit of b-tagging!

$B-$Tagging[3]

per final-state jet in the detector:

- jets identified as b-jet by:

efficiencies	$30\text{GeV} < p_{Tb} < 50\text{GeV}$	$p_{Tb} > 50\text{GeV}$
$\lvert\eta\rvert < 1.4$	0.65	0.75
$1.4 < \lvert\eta\rvert < 2.4$	0.6	0.7

- mis-tagging: 10%
- no assumptions about the possibility of distinguishing between b and $\bar{b}$ have been made yet
- Poisson Statistic:

$$S_{cL} = \sqrt{2[(s+b)\ln(1+s/b) - s]}$$

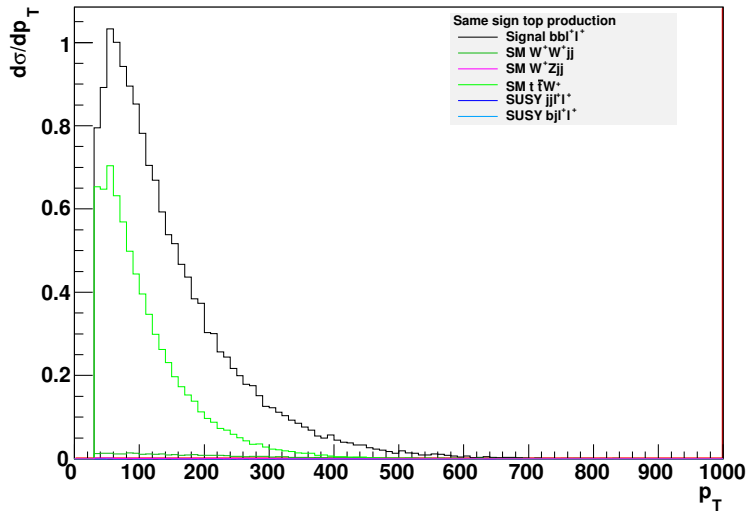
[3] C. Weiser, CERN-CMS-NOTE-2006-014

Cuts, $\sqrt{s} = 7$ TeV and $\int \mathcal{L} dt = 30$ fb^{-1}

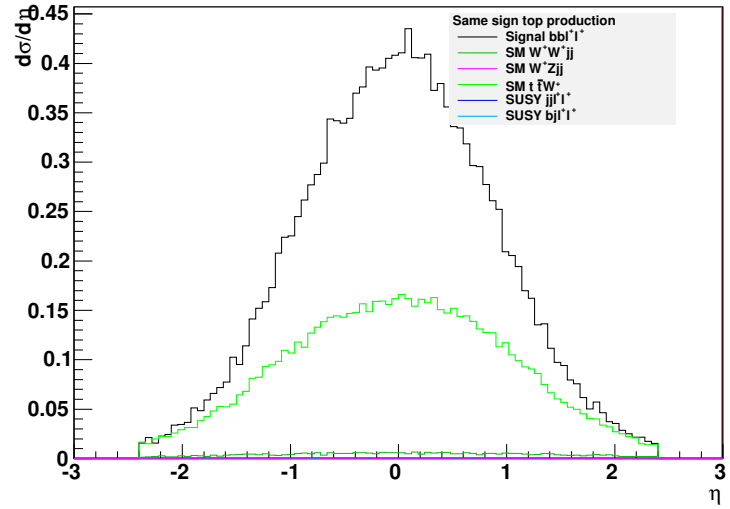
- $p_T > 30$ GeV
- $|\eta| < 2.4$
- $\Delta R_{ll}, \Delta R_{lb} > 0.4$
- $p_T^{miss} > 100$ GeV

$\Rightarrow S_{cL} = 3.16\sigma$

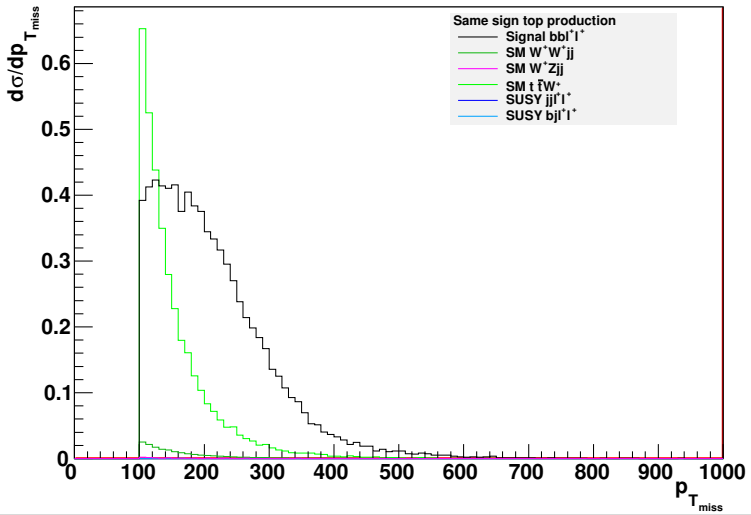
pT of b-quarks



pseudo-rapidity of b-quarks

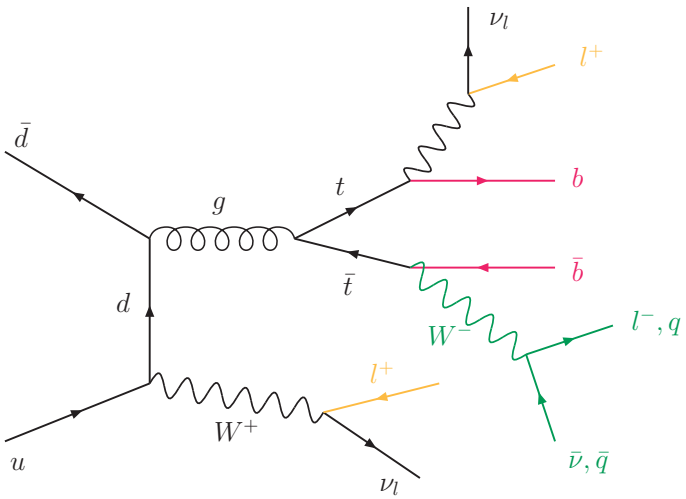


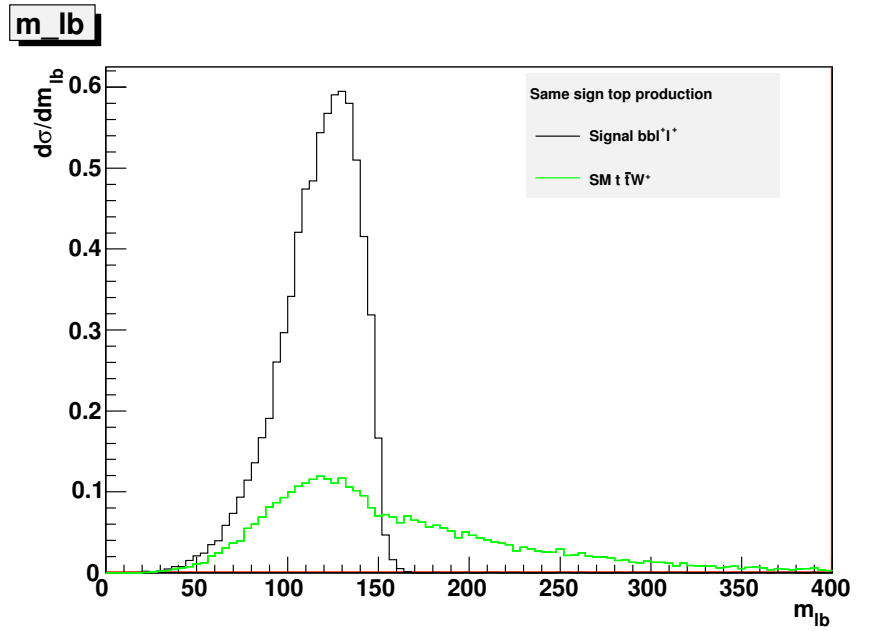
pT_miss



More Cuts

substantial amount of background from $t\bar{t}W^+$, but suitable for additional cuts:



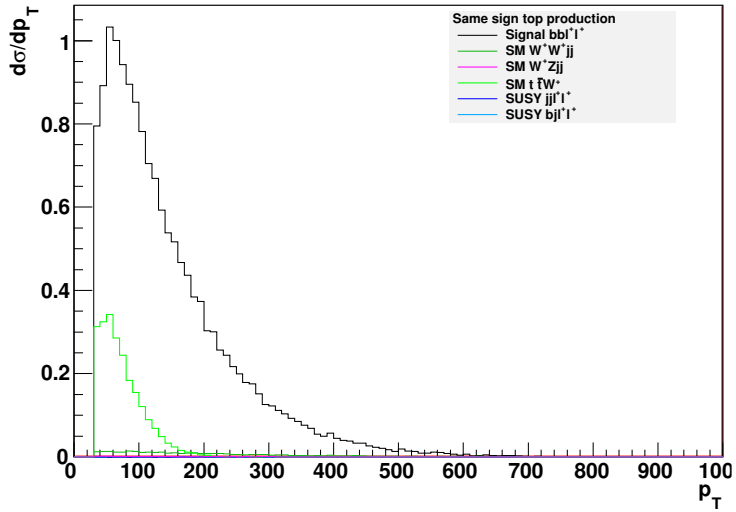


- jet-veto: 50 GeV, but this is dangerous!
- invariant mass m_{bl^+} can be larger than m_t:

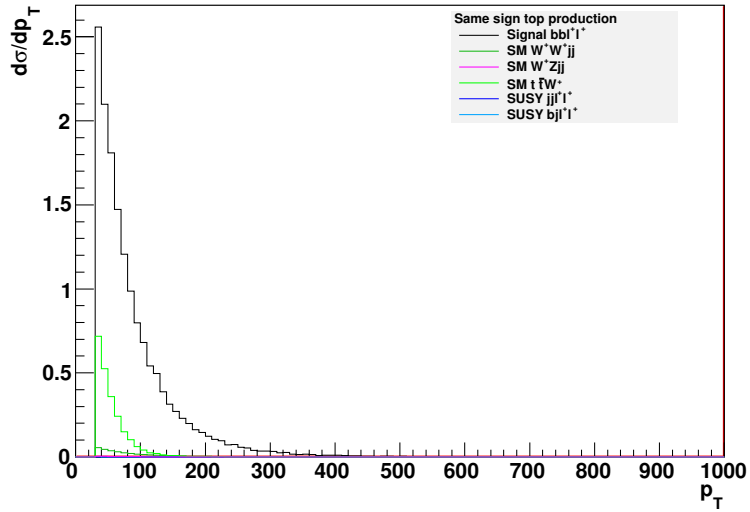
$$\min\{\max\{m_{l_1^+ b_1}, m_{l_2^+ b_2}\}, \max\{m_{l_1^+ b_2}, m_{l_2^+ b_1}\}\} = m_{bl^+} \overset{!}{<} m_t$$

Results: $S_{cL} = 4.36\sigma$

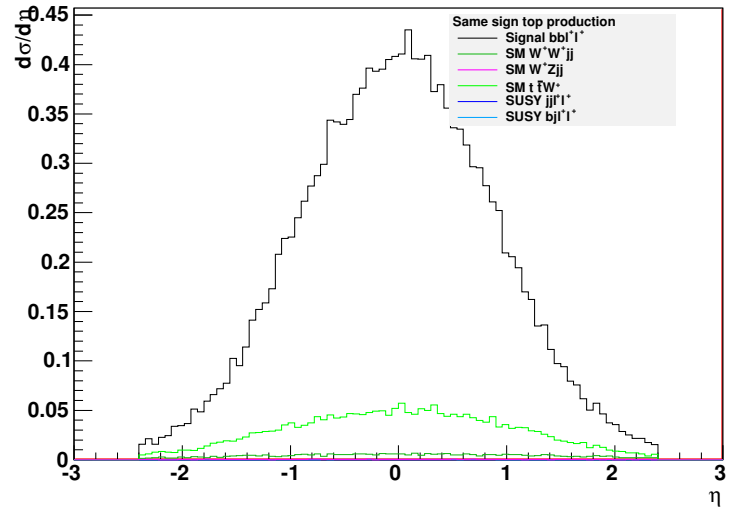
pT of b-quarks



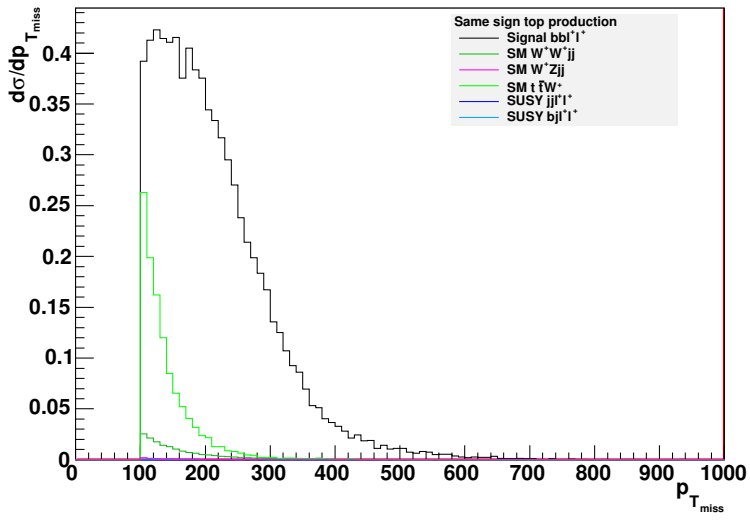
pT of leptons



pseudo-rapidity of b-quarks

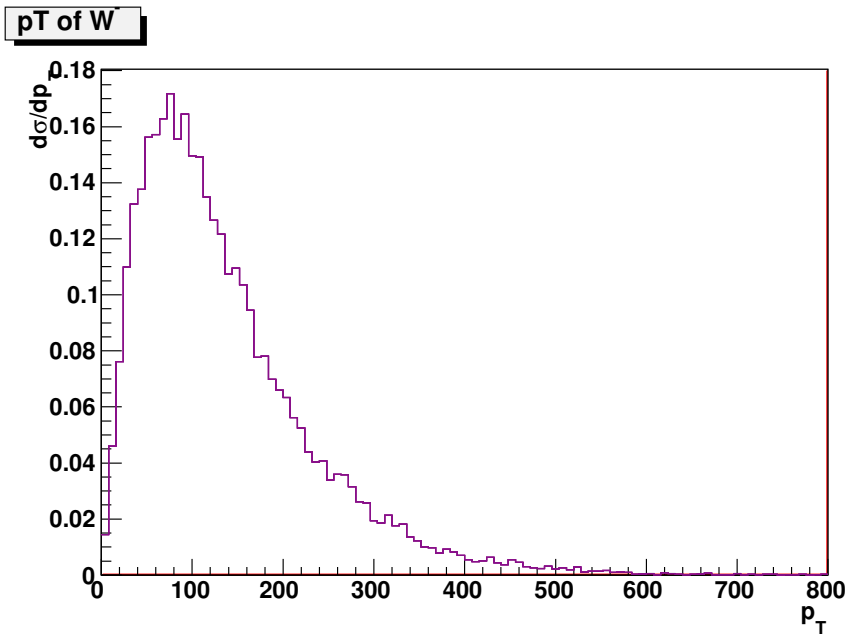


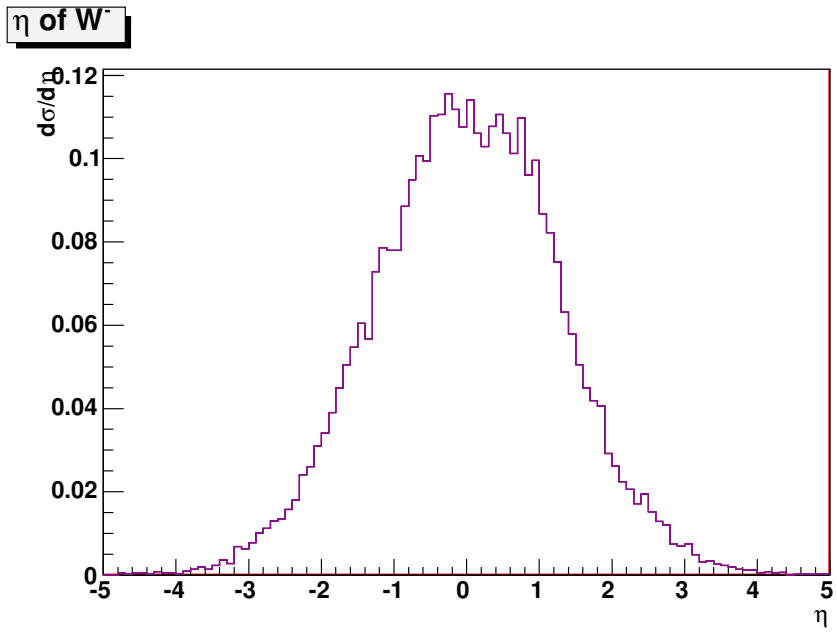
pT_miss



More Cuts?

Distributions of W^- from $t\bar{t}W^+$:





Problem: W^- will decay

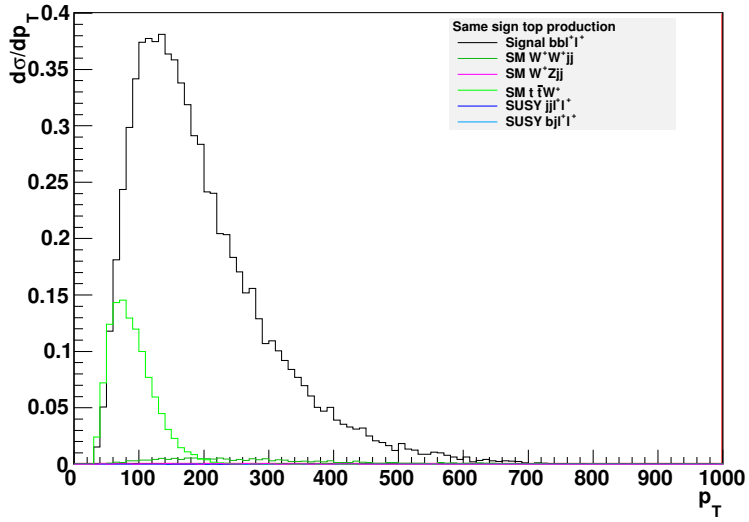
Conclusion & Outlook

- This seems to be a useful process to explore flavour violation
- Background could be further reduced by distinguishing b and $\bar{b}$
- Analysis power parameter-dependent, only one parameter set
- Effect on recent studies?

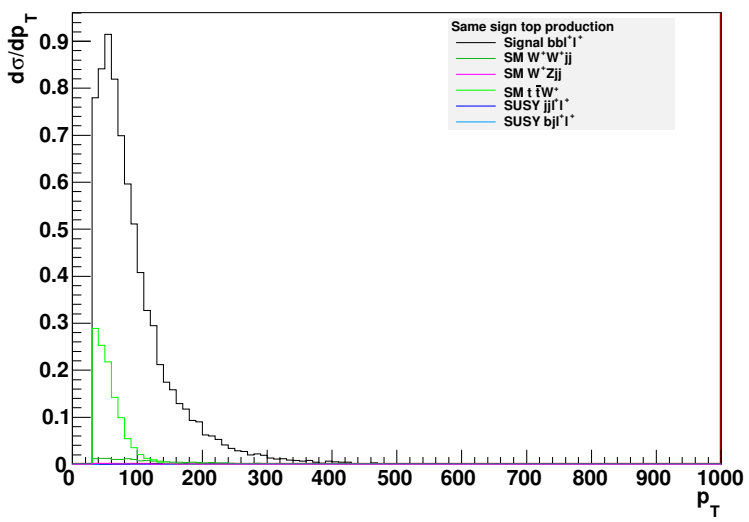
Thank you!

Backup

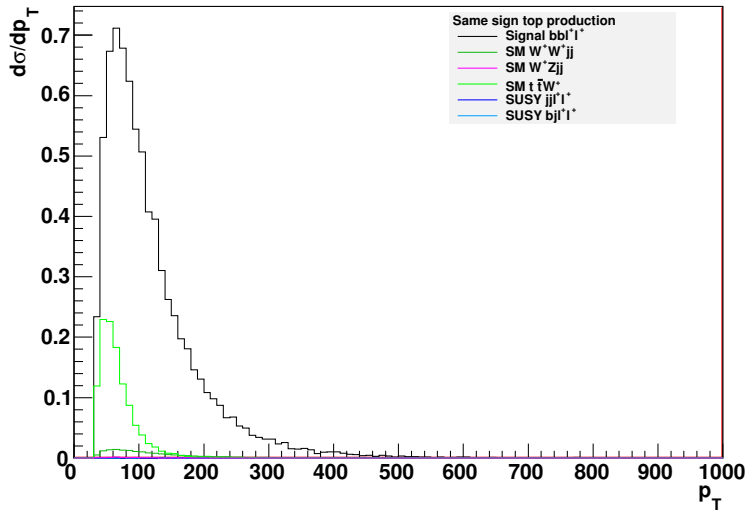
high pT of b-quarks



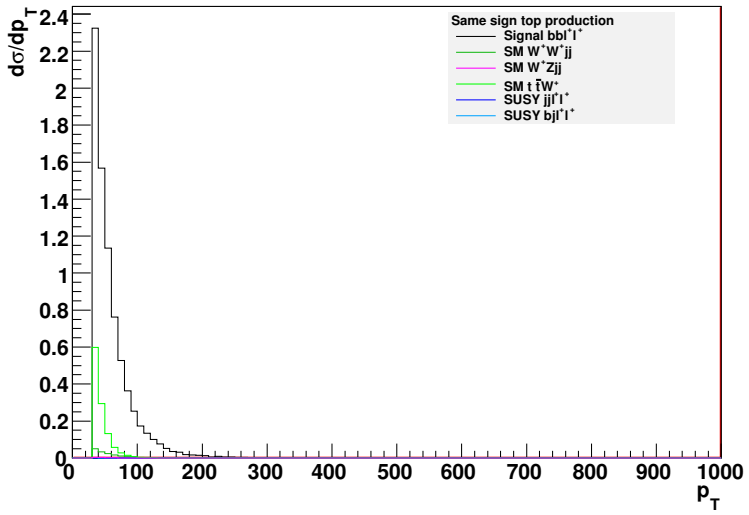
low pT of b-quarks



high pT of leptons

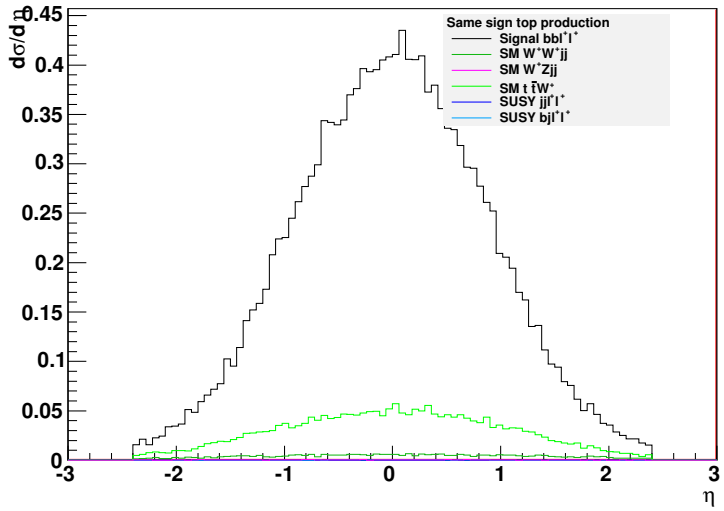


low pT of leptons

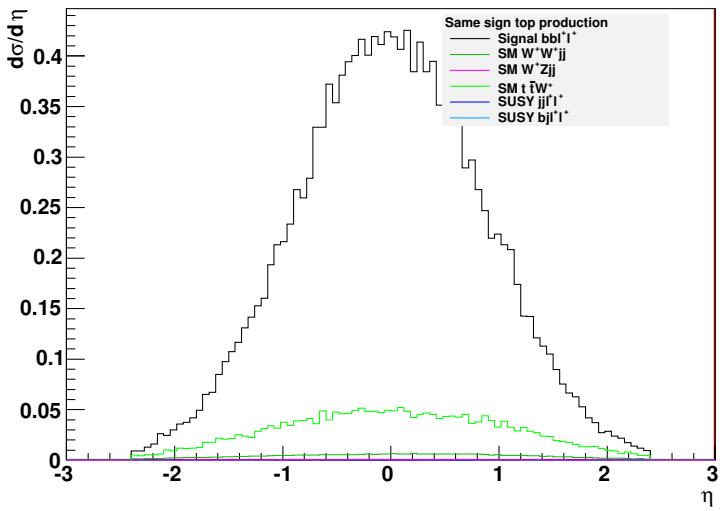


Backup

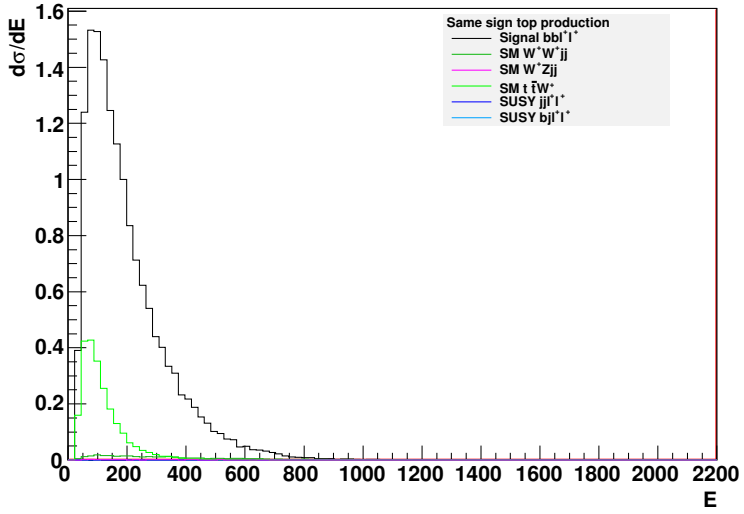
pseudo-rapidity of b-quarks



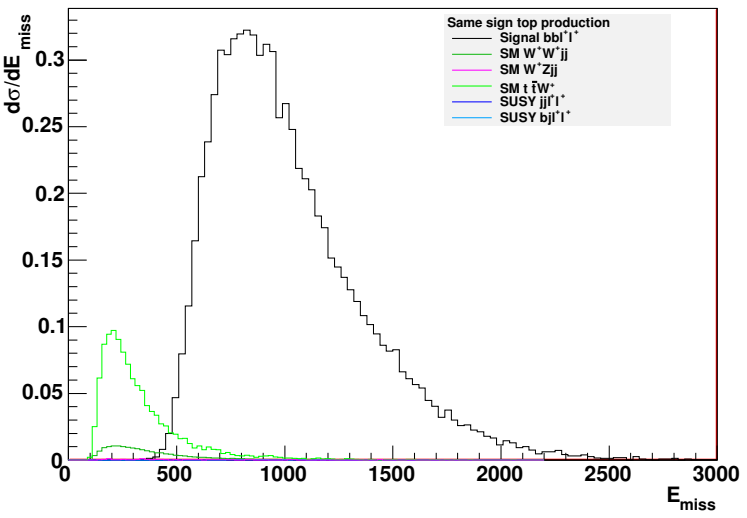
pseudo-rapidity of leptons



E of b-quarks

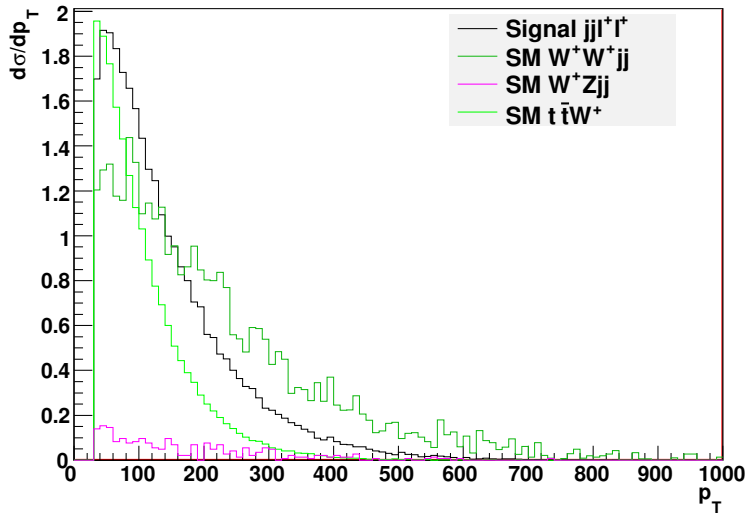


E_{miss}

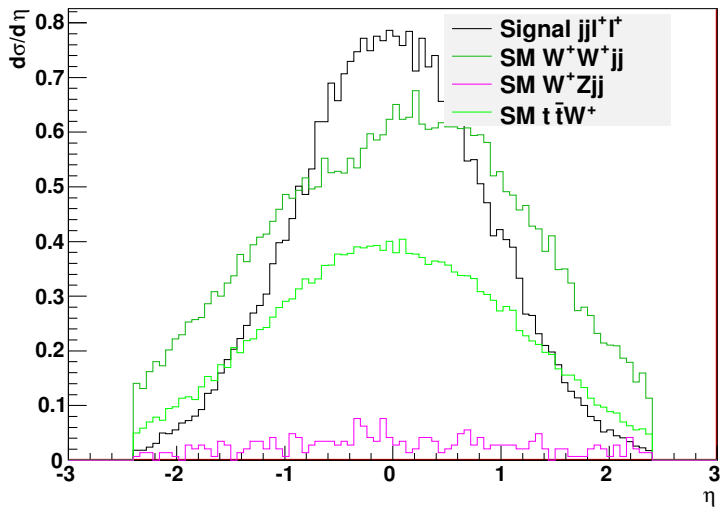


Backup

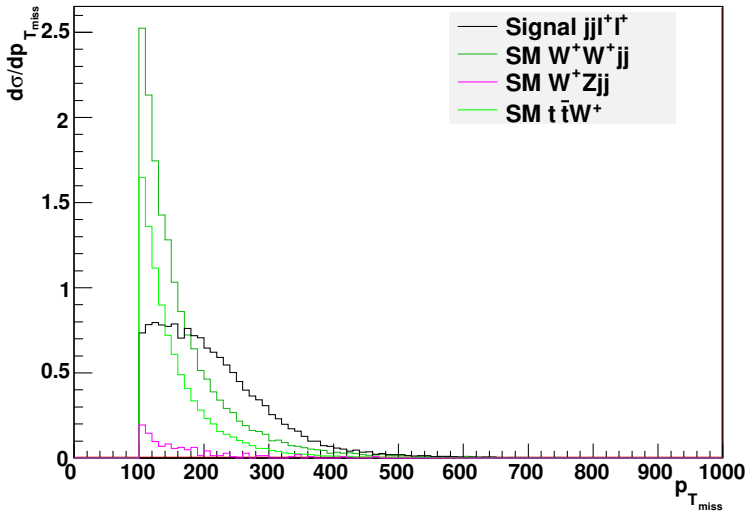
pT of quarks



pseudo-rapidity of leptons



pT_miss



E_{miss}