Top squark search in the 1-lepton channel with CMS

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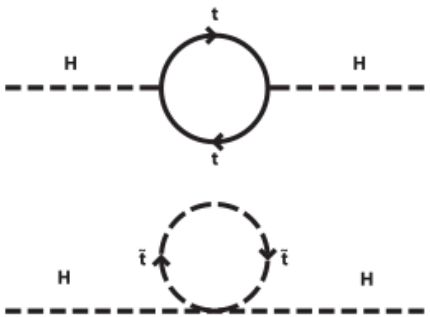
Context

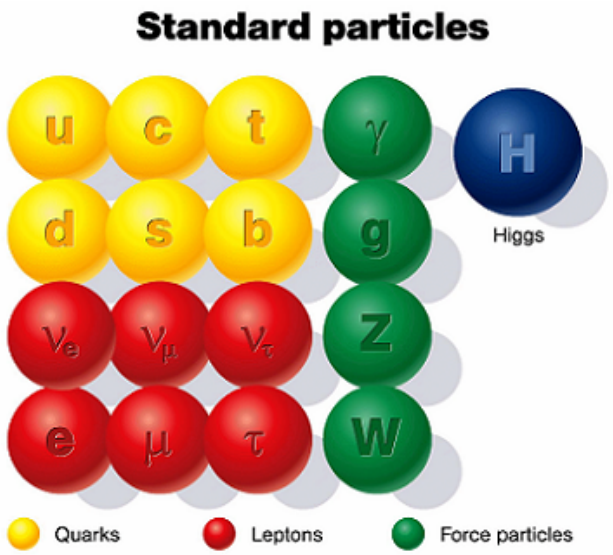
Super-symmetry

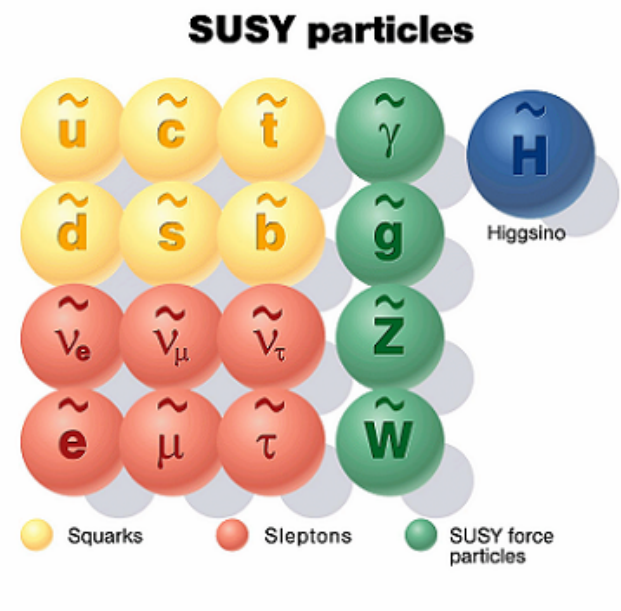
- Standard model extension
- Boson $\leftrightarrow$ fermion symmetry
- Provides dark matter candidate
  (R-parity conserved)
- Solves the hierarchy problem

Why top squarks?

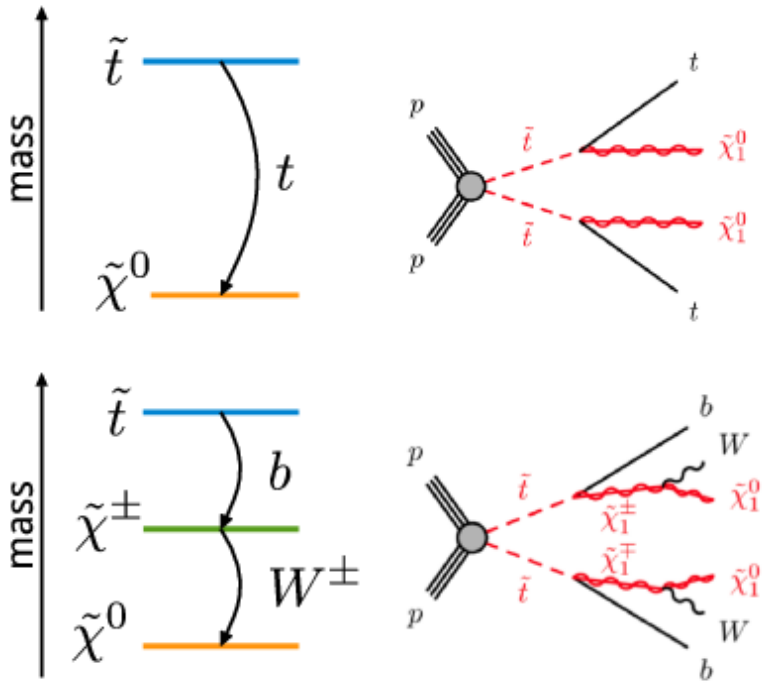
- "Natural" SUSY ($m_{\tilde{t}} \sim 1$ TeV)





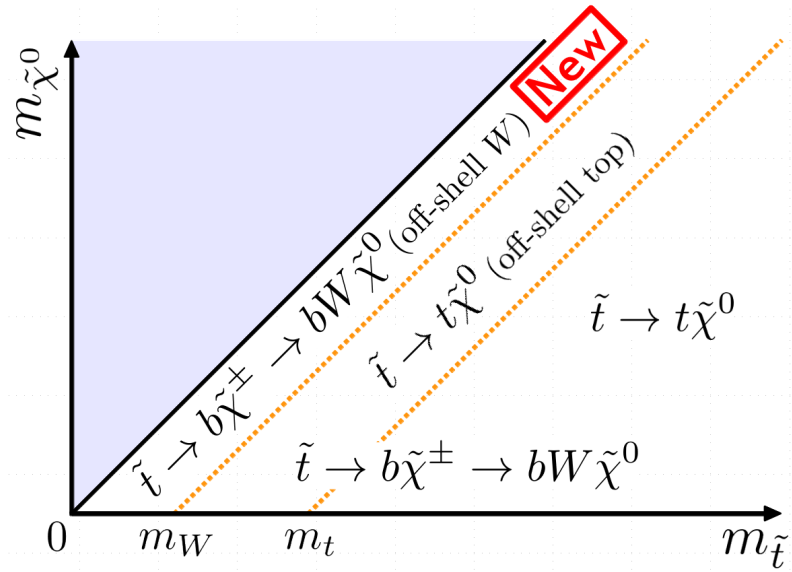


Context



Direct stop pair production
two decay modes considered, same final state

$$pp \to \tilde{t}\tilde{t}^* \to bbWW + \tilde{\chi}^0\tilde{\chi}^0$$



Assumptions

- Simplified SUSY models reduces complexity to 2-3 parameters
- BR = 100%
- $\tilde{\chi}^0$ and $\tilde{\chi}^{\pm}$ are linear combination of gauginos and higgsinos

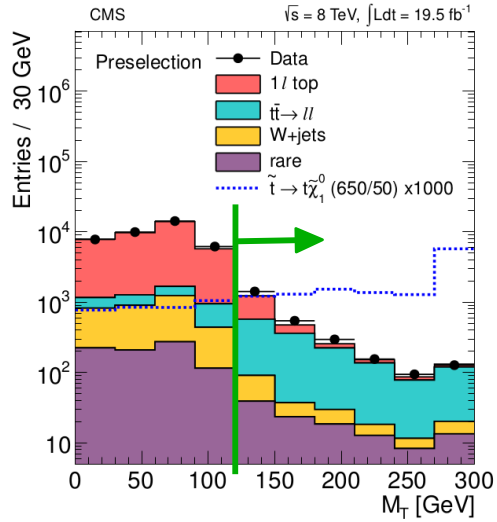
focus here on 1-lepton channel (CMS-SUS-13-011, arXiv :1308.1586)

Selection

$$pp \to \tilde{t}\tilde{t}^* \quad \to bbWW + \tilde{\chi}^0\tilde{\chi}^0$$
$$\to \ell + qqbb + \nu_\ell\tilde{\chi}^0\tilde{\chi}^0$$

Pre-selection

- 1 lepton (e/μ)
- $\geq$ 4 jets, $\geq$ 1 b-tag
- MET $\geq$ 100 GeV
- second-lepton vetos
  (isolated track, hadronic τ)



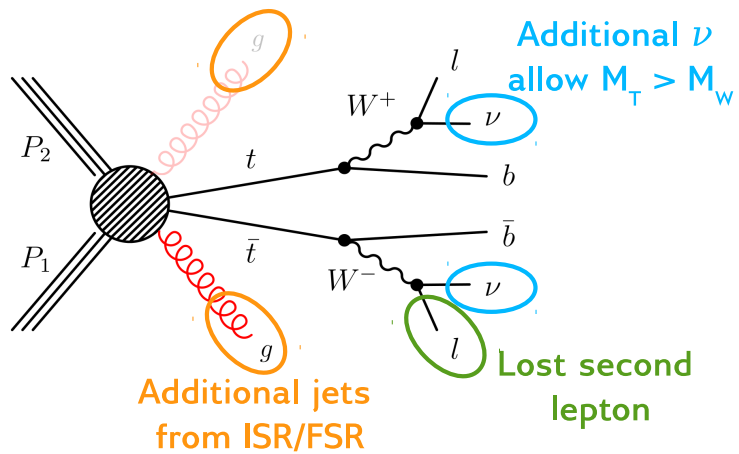
Signal region

Cut & count and BDT analysis after

$M_T = m_T(\ell, MET) > 120$ GeV

Backgrounds

- $t\bar{t} \to \ell\ell$
- $t\bar{t} \to \ell$ + jets, single t
- W ($\to \ell\nu_\ell$) + jets
- rare (diboson, triboson, $t\bar{t} + V$, Drell-Yan)

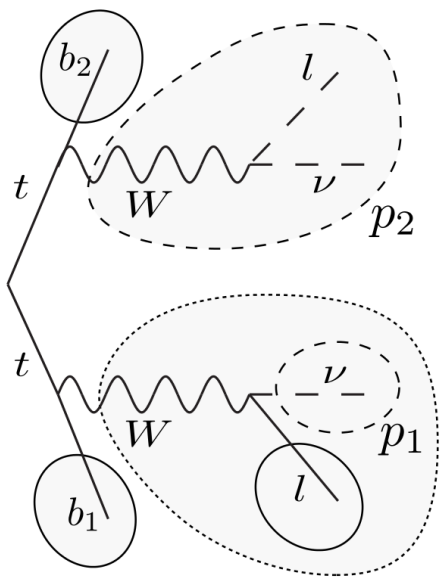


Selected $t\bar{t} \to \ell\ell$ events

Discriminating variables

$$M_{T2}^{W}$$

$$M_{T2}^{W} = min\left\{ m_y \text{ consistent with : } \left[\begin{array}{r} \vec{p}_1^{\,T} + \vec{p}_2^{\,T} = \vec{E}_T^{mis}, p_1^2 = 0, (p_1 + p_l)^2 = p_2^2 = M_W^2, \\ (p_1 + p_l + p_{b_1})^2 = (p_2 + p_{b2})^2 = m_y^2 \end{array} \right] \right\}$$



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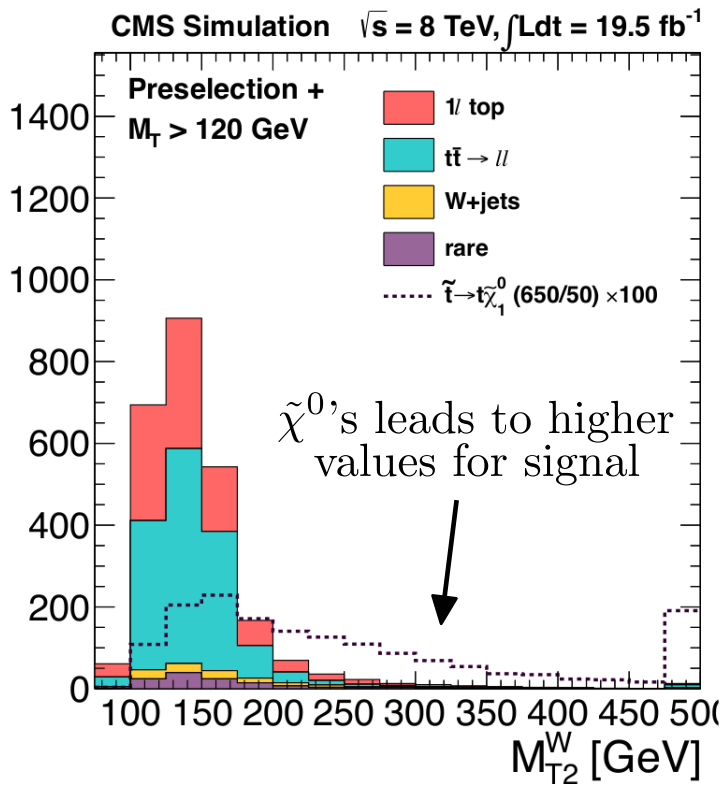
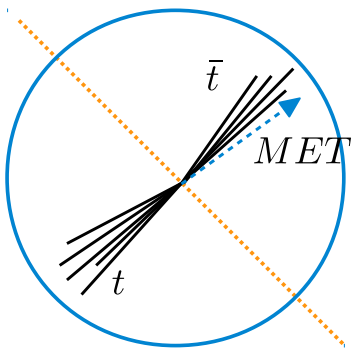


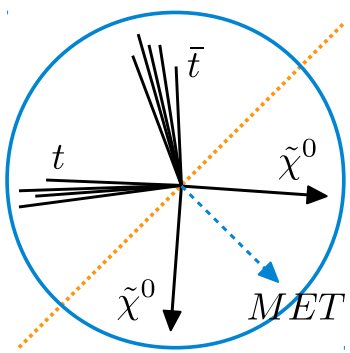
Discriminating variables

$$H_T^{\text{ratio}}$$

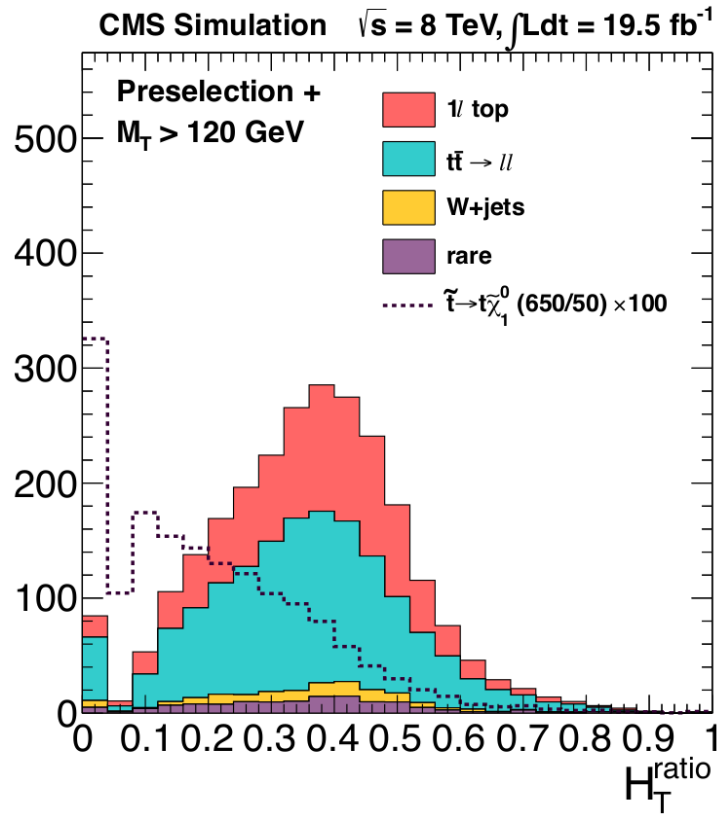
$$H_T^{\text{ratio}} = \frac{H_T^{\text{same side as MET}}}{H_T^{\text{total}}} = \frac{\sum_{\text{MET side}} p_T(jet)}{\sum p_T(jet)}$$



$t\bar{t}$ topology



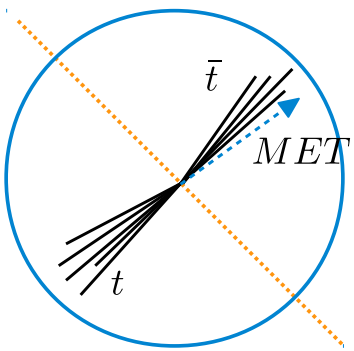
signal topology



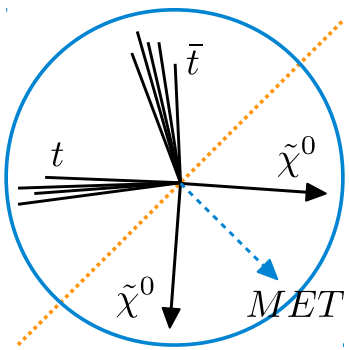
Discriminating variables

minΔΦ

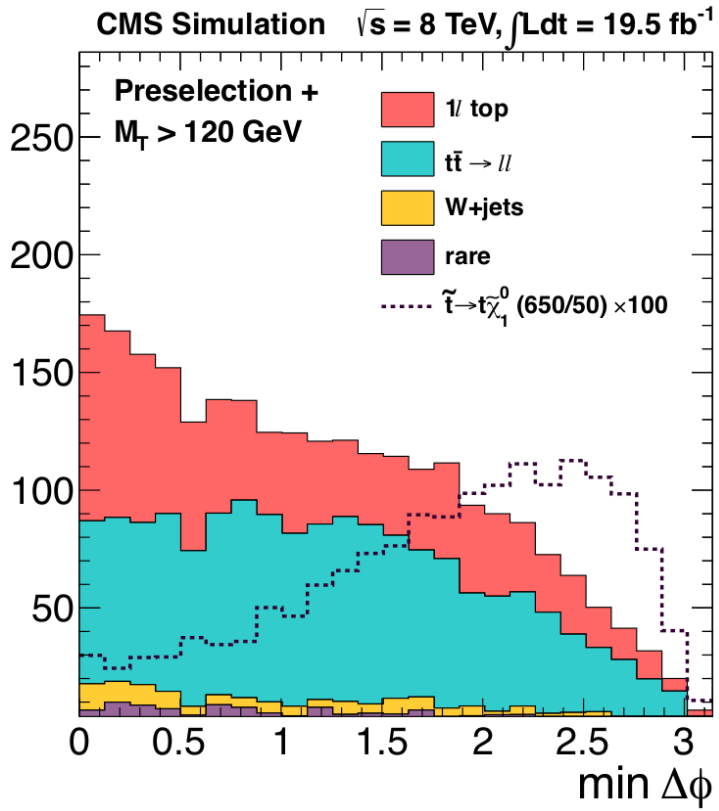
$$\text{min}\Delta\Phi = \text{min}\left\{\Delta\phi(MET, j_1), \Delta\phi(MET, j_2)\right\}$$



$t\bar{t}$ topology



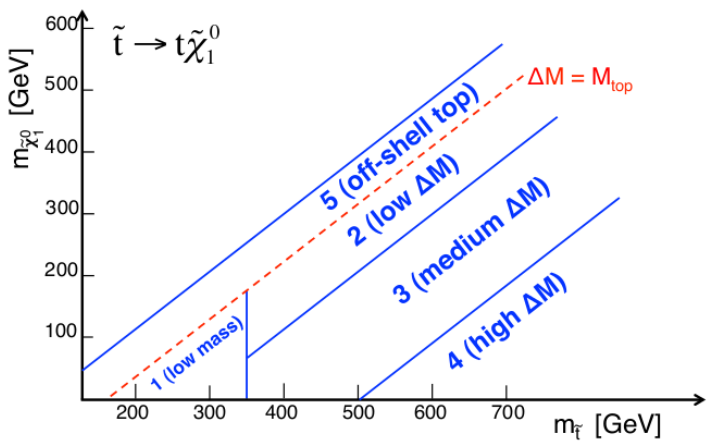
signal topology

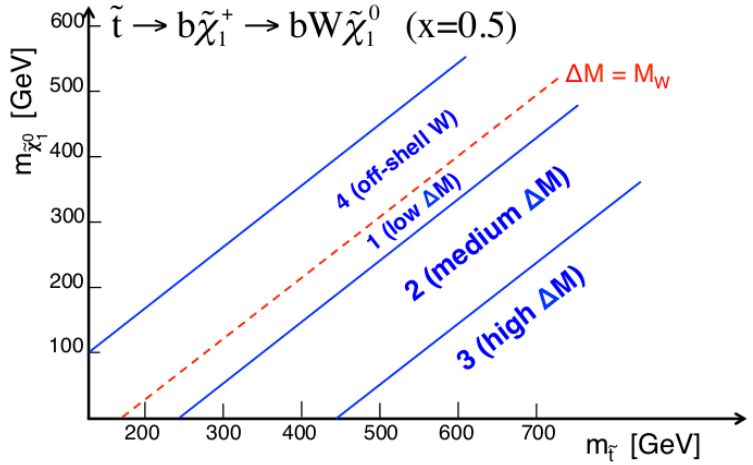


Discriminating variables

Variable	$\tilde{t} \to t\tilde{\chi}^0$	$\tilde{t} \to b\tilde{\chi}^{\pm}$
MET	X	X
M_{T2}^{W}	X	X
min$\Delta\Phi$	X	X
HT_{T}^{ratio}	X	X
hadronic top χ^2	on-shell t	
leading b-tagged jet p_T	off-shell t	X
$\Delta R(\ell$, leading b-tagged jet)		X
lepton p_T		off-shell W

- **Cut & count** (cross-check)
- **Boosted decision trees** (primary)
- **Different regions $\leftrightarrow$ specific kinematics**





Background estimation

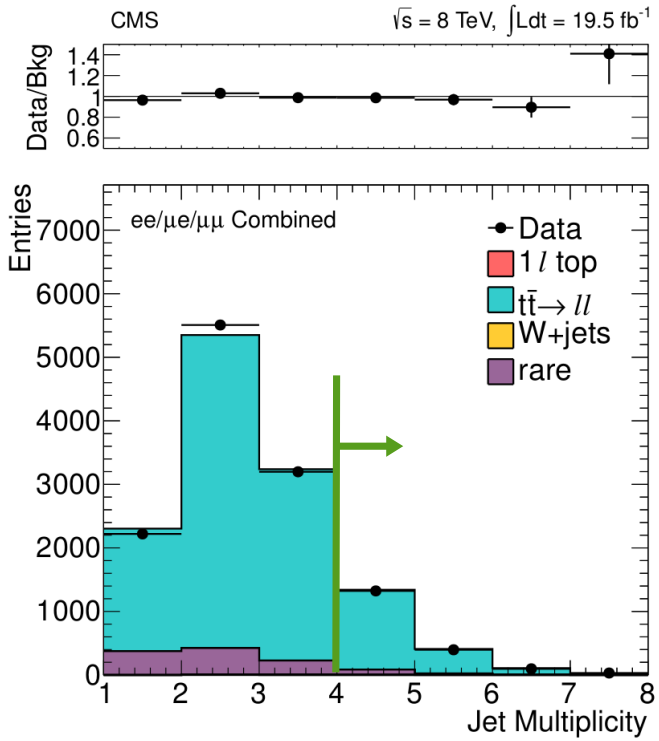
Key points

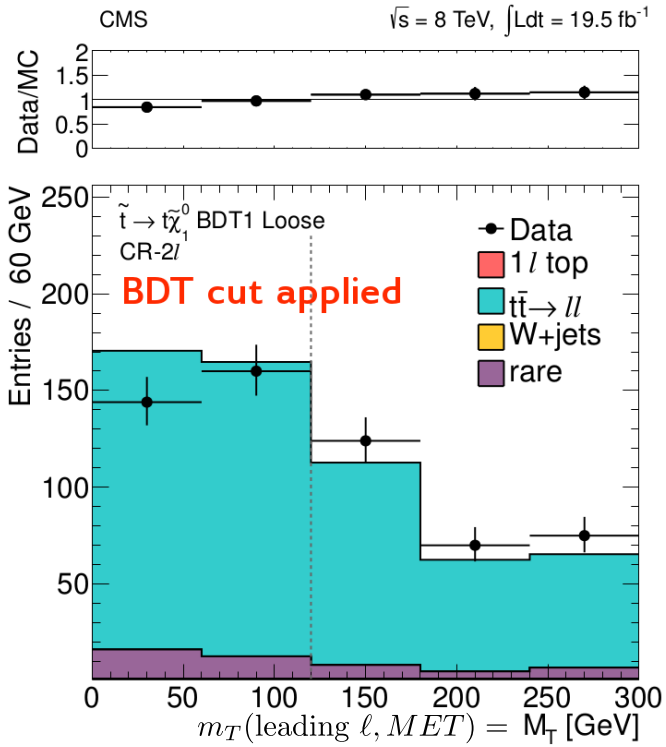
- $t\bar{t} \to \ell\ell$ modelization
- M_T tail control

Selection criteria	1ℓ	2ℓ	1ℓ + iso. track / τ
0 b-tag	**W+jets** dominated → validate W+jets M_T tail	-	-
≥1 b-tag	**Signal region**	**tt** → $\ell\ell$ dominated → validate dilepton modelization	**tt**→ ℓ**+iso.trk/**τ dominated → validate detector effects

Background estimation

CR-2ℓ

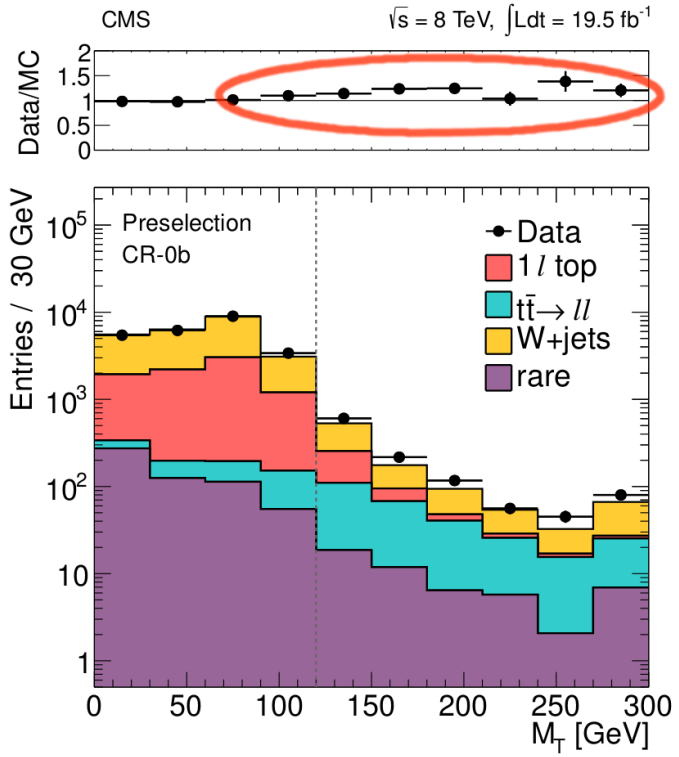




- Strong dependence to ISR/FSR description
- Agreement with the data is okay

Background estimation

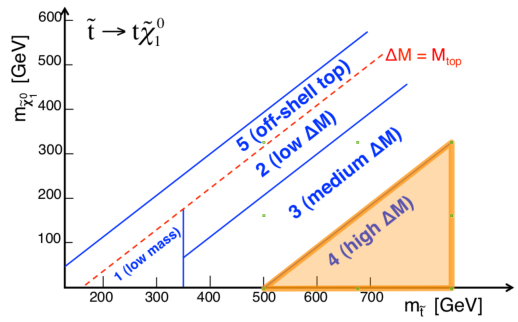
CR-0b

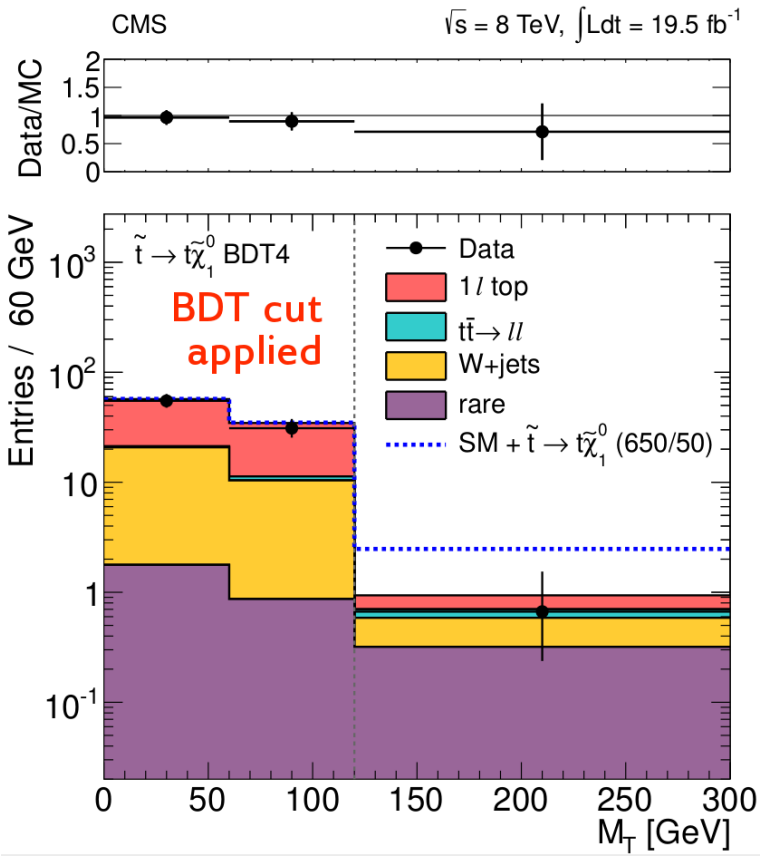


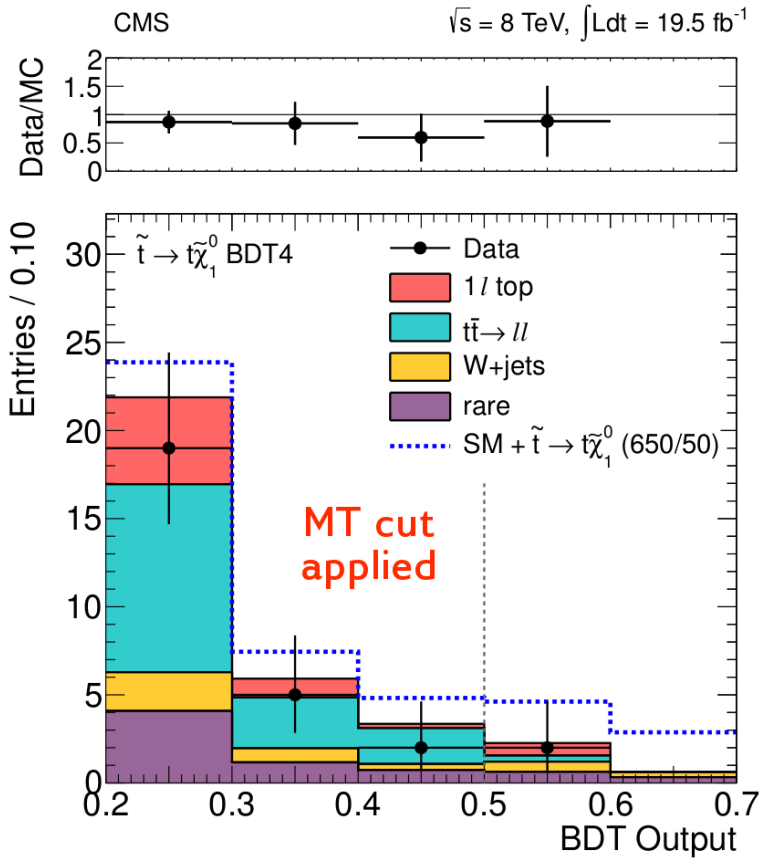
- M_T tail underestimated by MC for W+jets
- Correction with a scale-factor = 1.2 $\pm$ 0.3

Results

$$\tilde{t} \rightarrow t\tilde{\chi}^0$$

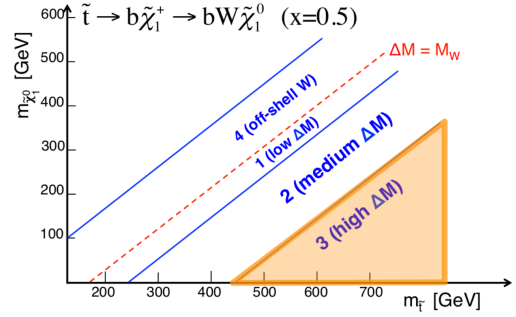




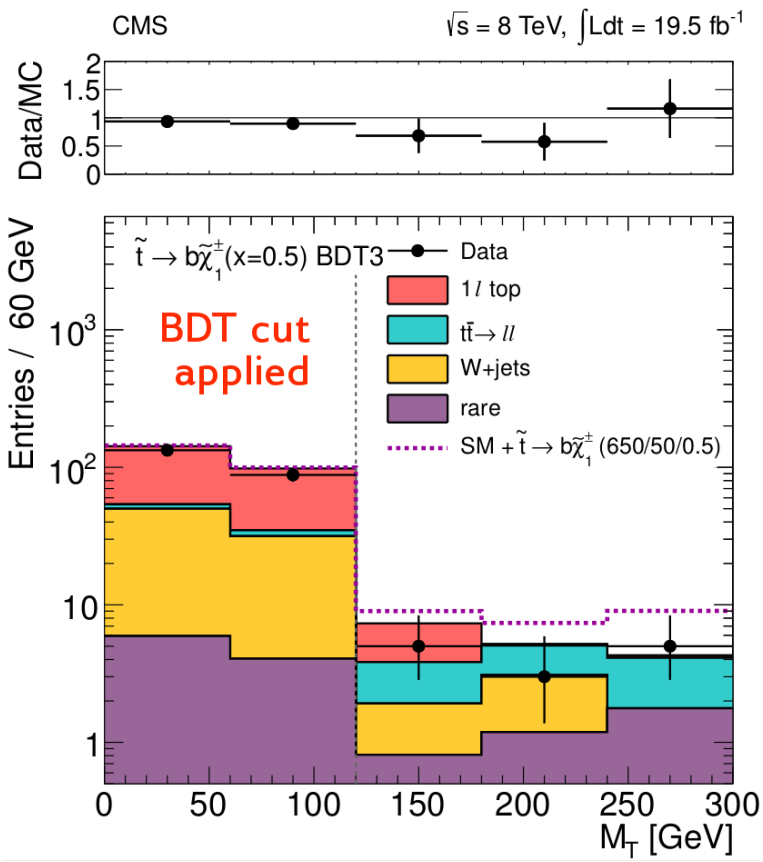


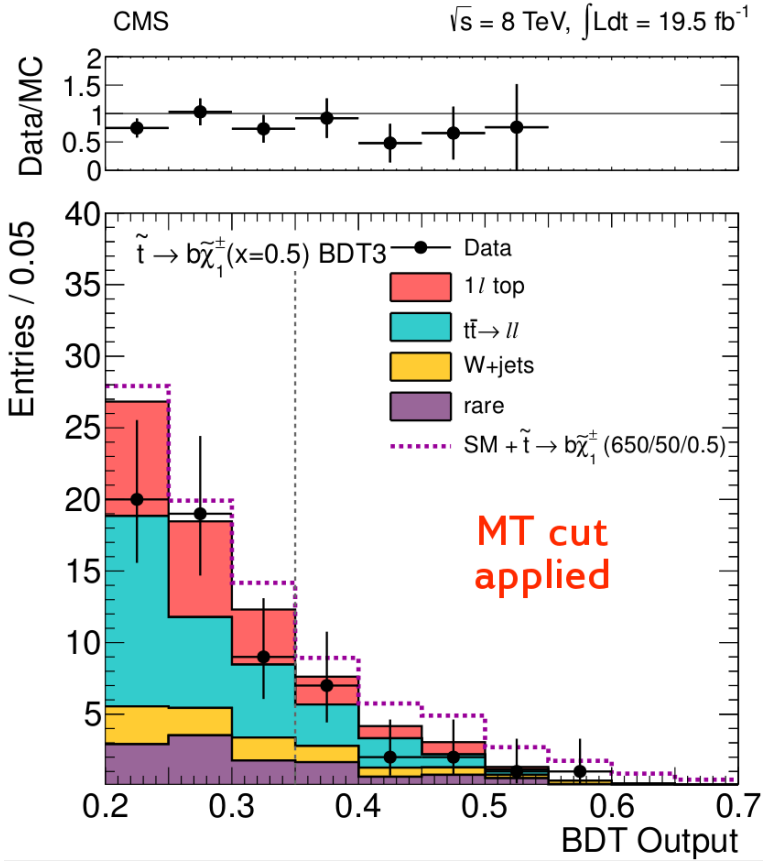
$\Rightarrow$ no excess is observed

Results



$$\tilde{t} \to b\tilde{\chi}^{\pm}$$

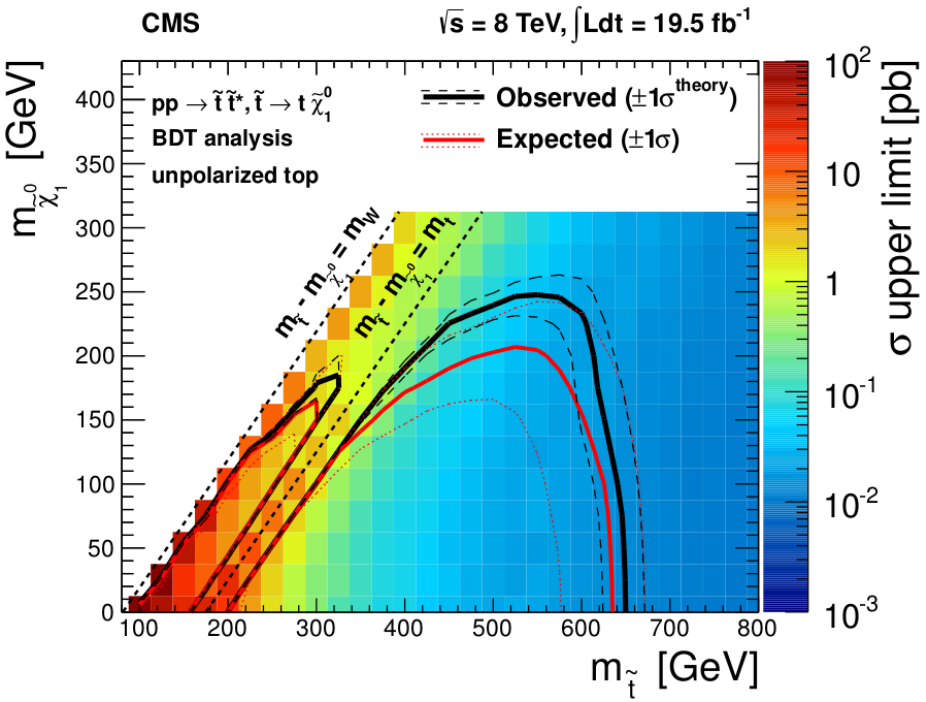




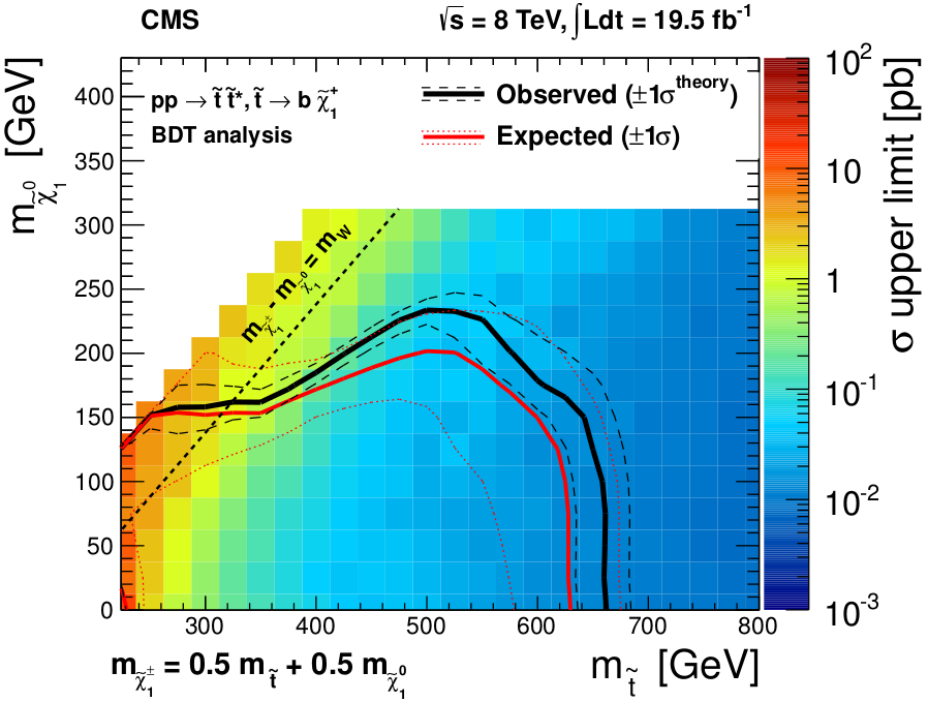
$\Rightarrow$ no excess is observed

Interpretation

$$\tilde{t} \rightarrow t\tilde{\chi}^0$$



$$\tilde{t} \rightarrow b\tilde{\chi}^{\pm}$$



Hypothesis reminder

- Signal is $\tilde{t}$ pair production only
- Unpolarized tops (see next slide)
- BR is 100% (see back-up)

Results also available for

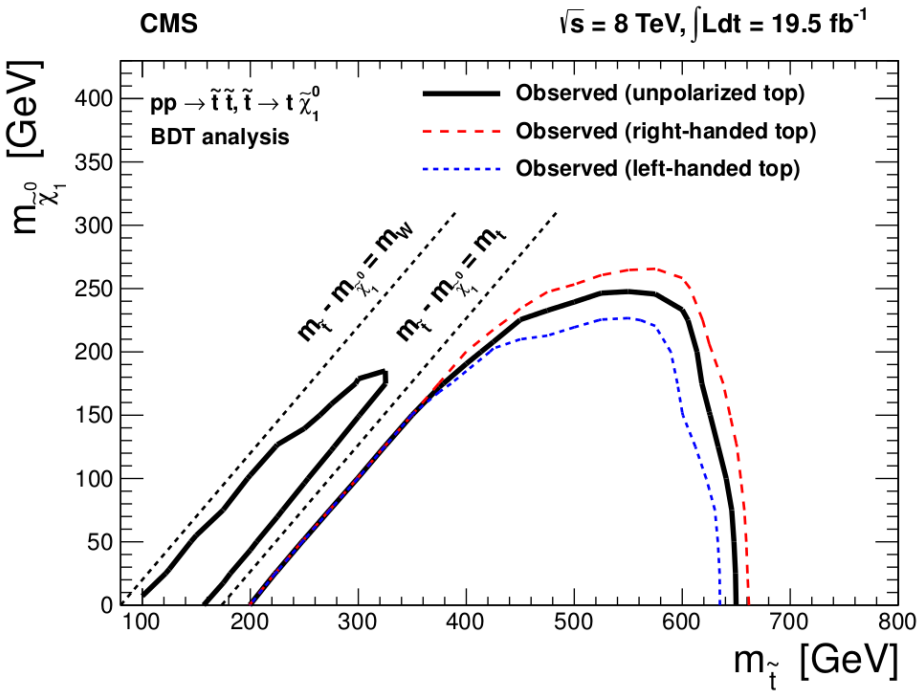
$$m_{\tilde{\chi}^{\pm}} = 0.25 m_{\tilde{t}} + 0.75 m_{\tilde{\chi}^0}$$

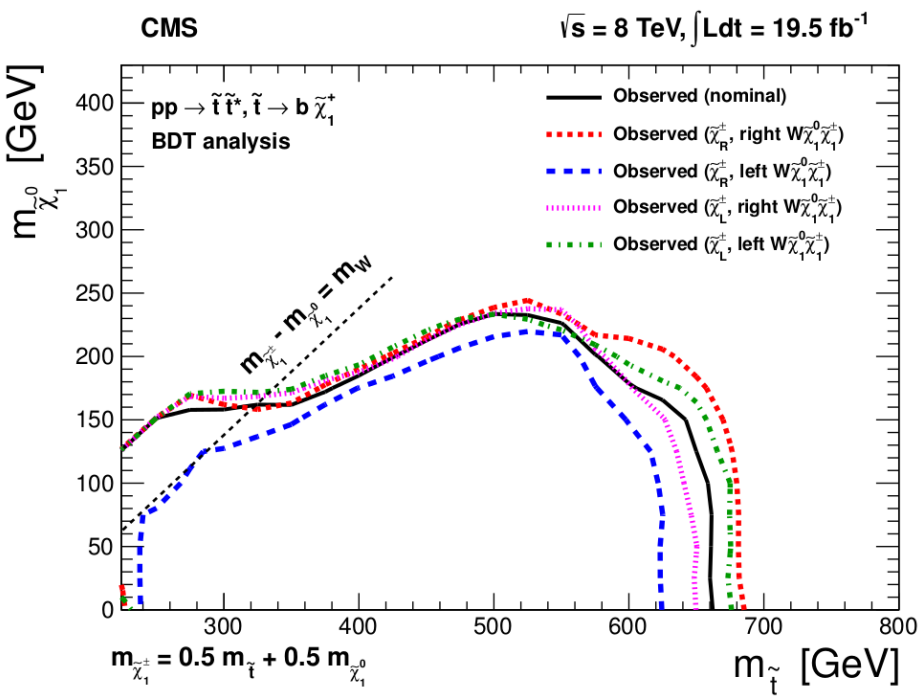
$$m_{\tilde{\chi}^{\pm}} = 0.75 m_{\tilde{t}} + 0.25 m_{\tilde{\chi}^0}$$

Interpretation

$$\tilde{t} \rightarrow t\tilde{\chi}^0$$

$$\tilde{t} \rightarrow b\tilde{\chi}^{\pm}$$

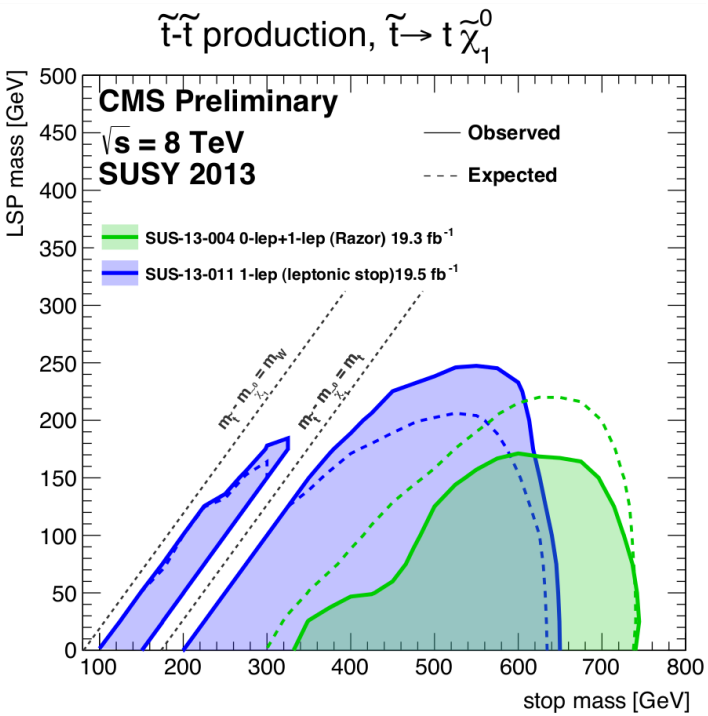


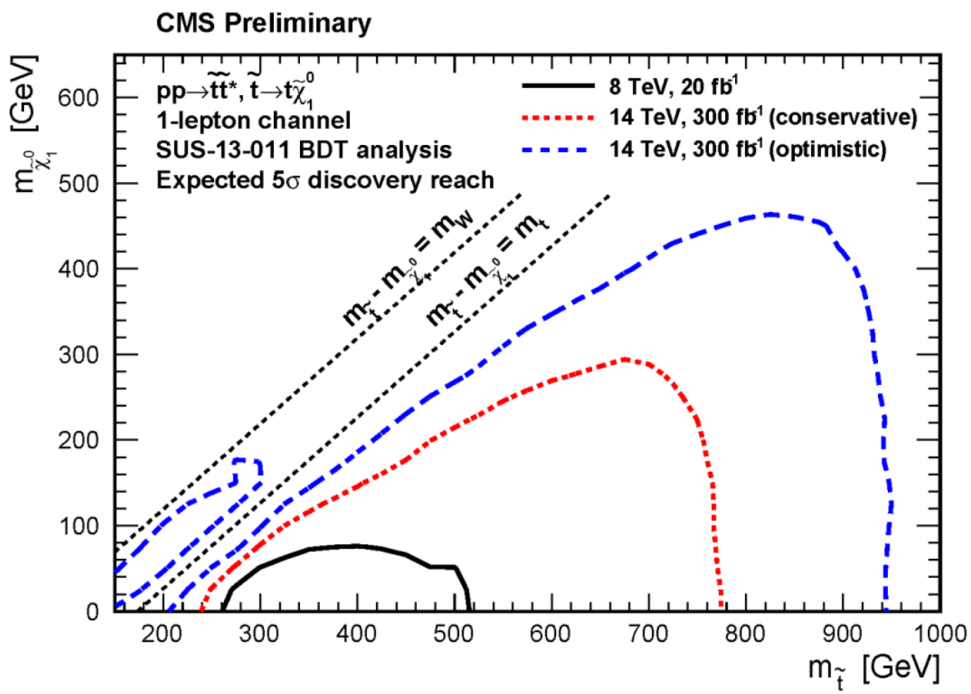


- Polarization effects affects signal acceptance

Perspectives

- Other analysis providing complementary results
- Ongoing combination with 0ℓ and 2ℓ channels
- 14 TeV projections predicts 5σ discovery potential up $m_{\tilde{t}} \sim$ 750-950 GeV





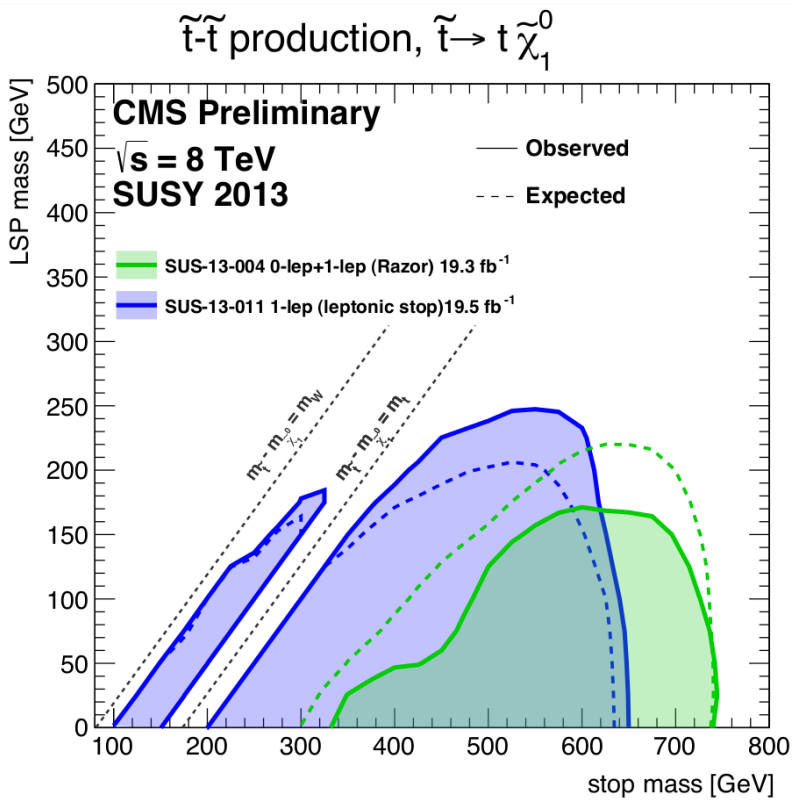
Conclusion

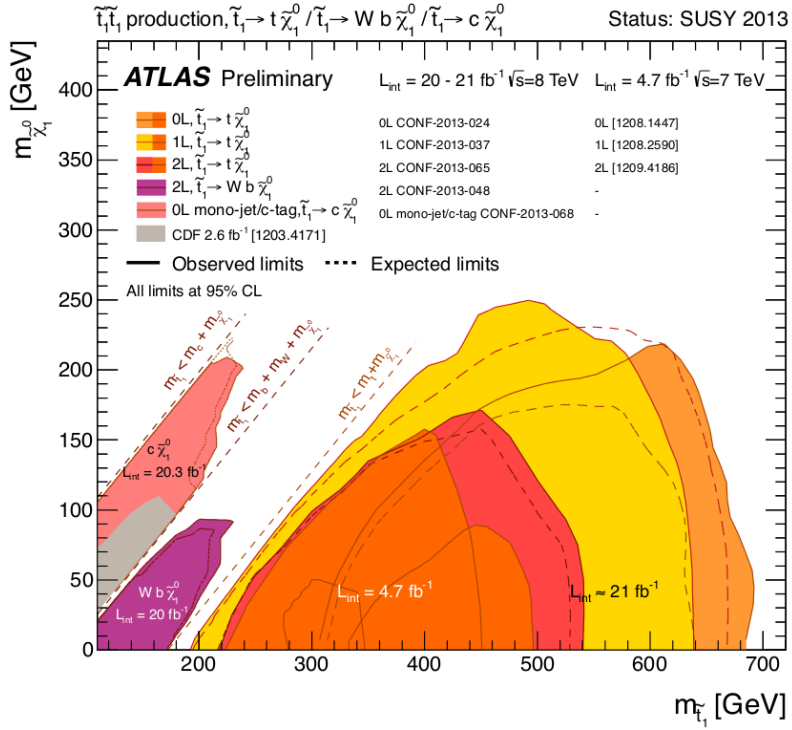
- Hot topic for SUSY searches and naturalness constrains
- Analyzed the full 8 TeV data recorded by CMS. BDT probes top squarks masses up to 650 GeV.
- Natural SUSY far to be ruled out
- Ongoing combination with 0-lep and 2-lep channels, and looking forward to the 13-14 TeV.

Thank you for your attention, stay tuned!

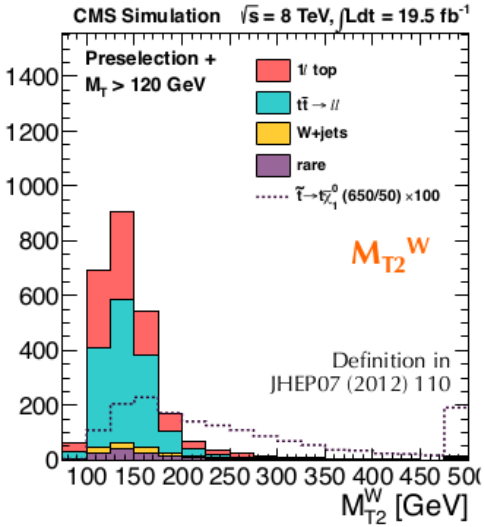
Back-up

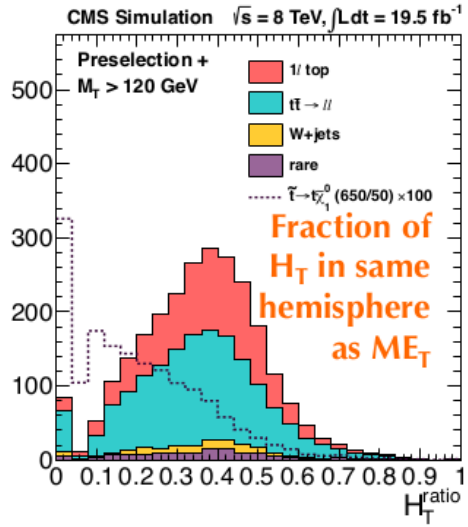
ATLAS results

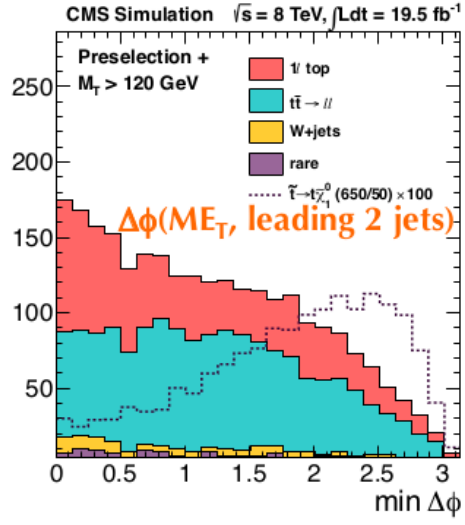


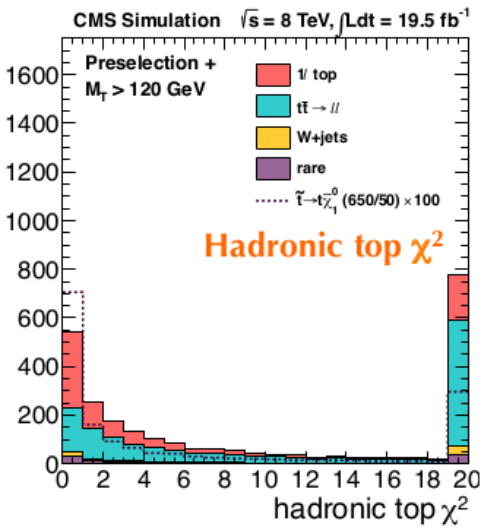


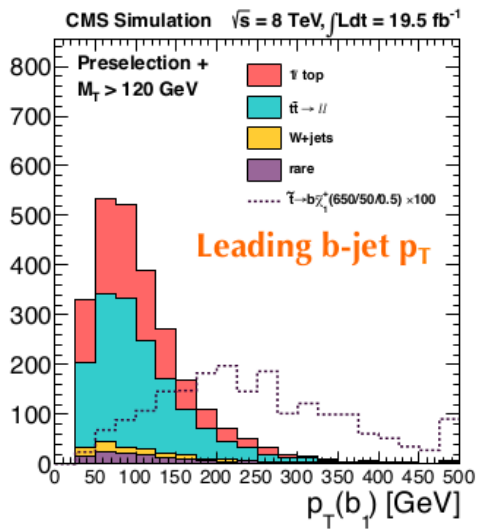
Kinematic variables

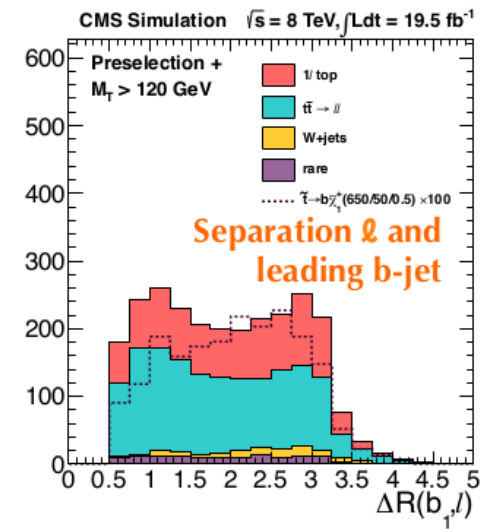




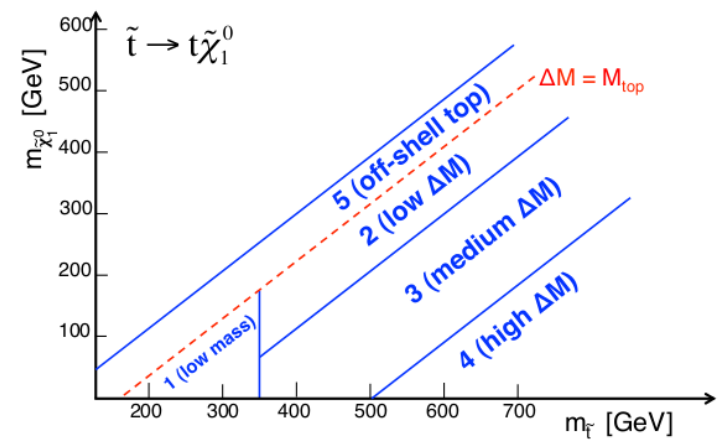


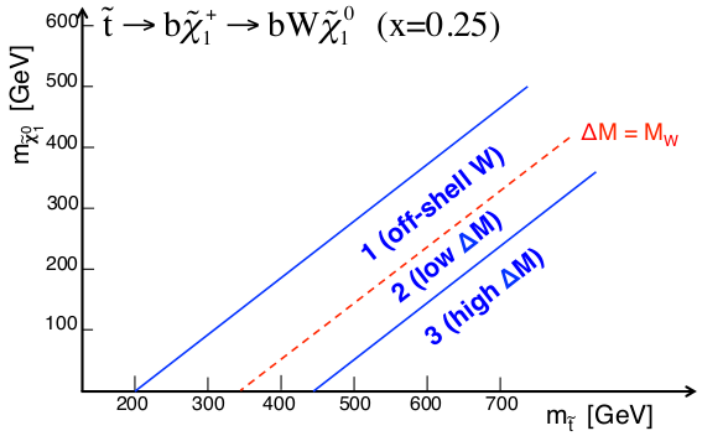


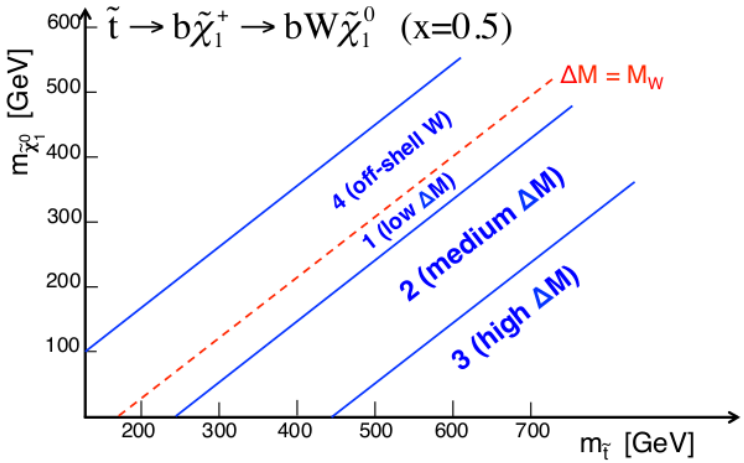


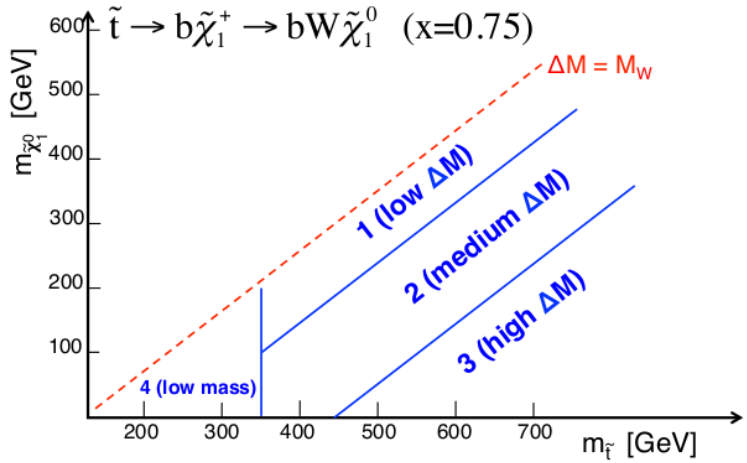


Signal regions









BDT and cut & count

	$t\chi^0$			$b\chi^{\pm}$		
Selection	$\tilde{t} \to t\tilde{\chi}_1^0$ cut-based Low ΔM	$\tilde{t} \to t\tilde{\chi}_1^0$ cut-based High ΔM	$\tilde{t} \to t\tilde{\chi}_1^0$ BDT	$\tilde{t} \to b\tilde{\chi}_1^+$ cut-based Low ΔM	$\tilde{t} \to b\tilde{\chi}_1^+$ cut-based High ΔM	$\tilde{t} \to b\tilde{\chi}_1^+$ BDT
E_T^{miss}(GeV)	> 150,200, 250,300	> 150,200, 250,300	yes	> 100,150, 200,250	> 100,150, 200,250	yes
M_{T2}^W (GeV)		> 200	yes		>200	yes
min $\Delta\phi$	> 0.8	> 0.8	yes	> 0.8	> 0.8	yes
H_T^{ratio}			yes			yes
χ^2	<5	<5	(on-shell top)			
leading b-jet p_T (GeV)			(off-shell top)		> 100	yes
$\Delta R(\ell$,leading b-jet)						yes

Results (event yields)

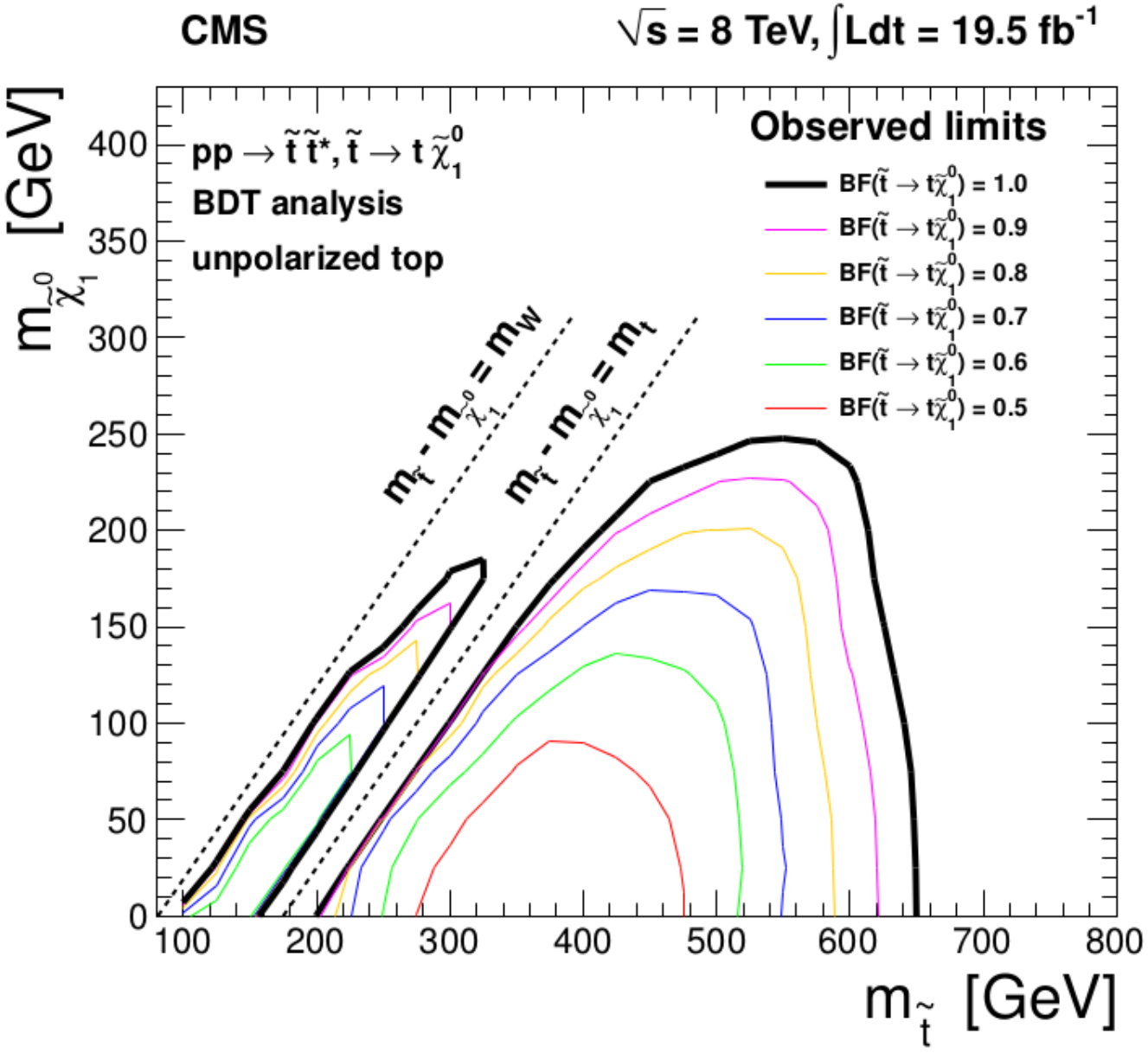
$$\tilde{t} \rightarrow t\tilde{\chi}^0$$

Sample	BDT1 Loose	BDT1 Tight	BDT2	BDT3	BDT4	BDT5
$t\bar{t} \rightarrow \ell\ell$	438 ± 37	68 ± 11	46 ± 10	5 ± 2	0.3 ± 0.3	48 ± 13
1ℓ Top	251 ± 93	37 ± 17	22 ± 12	4 ± 3	0.8 ± 0.9	30 ± 12
W+jets	27 ± 7	7 ± 2	6 ± 2	2 ± 1	0.8 ± 0.3	5 ± 2
rare	47 ± 23	11 ± 6	10 ± 5	3 ± 1	1.0 ± 0.5	4 ± 2
Total	**763 ± 102**	**124 ± 21**	**85 ± 16**	**13 ± 4**	**2.9 ± 1.1**	**87 ± 18**
Data	**728**	**104**	**56**	**8**	**2**	**76**

$$\tilde{t} \rightarrow b\tilde{\chi}^{\pm}$$

$\tilde{t} \rightarrow b\tilde{\chi}_1^+$ x=0.5				
Sample	BDT1	BDT2 Loose	BDT2 Tight	BDT3
$t\bar{t} \rightarrow \ell\ell$	40 ± 5	21 ± 4	4 ± 2	6 ± 2
1ℓ Top	24 ± 10	15 ± 7	4 ± 3	4 ± 2
W+jets	5 ± 1	5 ± 1	2 ± 1	3 ± 1
Rare	8 ± 4	8 ± 4	3 ± 1	4 ± 2
Total	77 ± 12	50 ± 9	13 ± 4	17 ± 4
Data	67	35	12	13

Results (BR variation)



Systematics

Relative uncertainty on the total background prediction [%]

	Sample	$\tilde{t} \to t\tilde{\chi}_1^0$ BDT1 Loose	BDT1 Tight	BDT2	BDT3	BDT4	BDT5
M_T SF	M_T peak data and MC (stat)	1.0	2.1	2.7	5.3	8.7	3.0
tt→ℓℓ	$t\bar{t} \to \ell^+\ell^-$ N_{jets} modeling	1.7	1.6	1.6	1.1	0.4	1.7
	$t\bar{t} \to \ell^+\ell^-$ (CR-ℓt and CR-2ℓ tests)	4.0	8.2	11.0	12.5	7.2	13.8
	2nd lepton veto	1.5	1.4	1.4	0.9	0.3	1.4
	$t\bar{t} \to \ell^+\ell^-$ (stat)	1.1	2.8	3.4	7.0	7.4	3.3
1ℓ bkg	W+jets cross section	1.6	2.2	2.8	1.7	2.7	2.2
	W+jets (stat)	1.1	1.9	2.0	4.6	10.8	5.2
	W+jets SF uncertainty	8.3	7.7	6.8	8.1	9.7	8.6
	1-ℓ Top (stat)	0.4	0.8	0.8	1.4	4.4	1.2
	1-ℓ Top tail-to-peak ratio	9.0	11.4	12.4	19.6	28.5	9.1
Rare bkg	rare cross sections	1.8	3.0	4.0	8.1	15.7	0.7
13-38%	Total	13.4	17.1	19.3	27.8	38.4	20.2