3rd Generation SUSY Searches at the LHC

Riccardo Bellan

Università di Torino and INFN

On behalf of the ATLAS and CMS Collaborations

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Session: BSM/DM

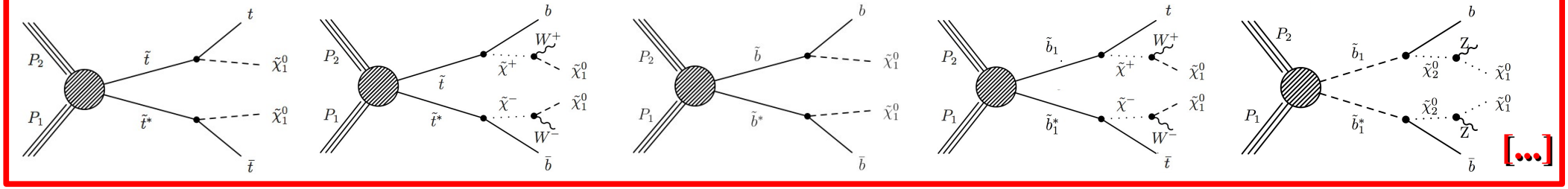
Formerly at UCSB

Motivation

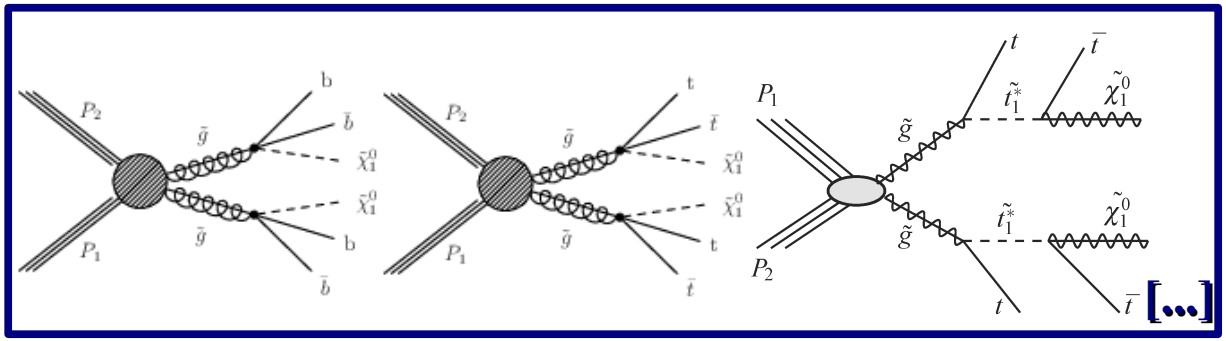
- In the search for the Higgs boson we found a **new particle** that up to now has properties compatible with the **SM Higgs boson hypothesis**
- The next question to address was therefore: "***is the weak-scale natural?***"
  - We know that without a modification of the theory the quantum correction to the Higgs mass can only be explained by an **enormous fine tuning of parameters**
  - **Answer yes or no to this question is equally important** (perhaps, one case might be more exciting than the other)
  - Many **SUSY models provide a *natural* extension** of the Standard Model
  - Lightest SuperSymmetric partner of SM quarks (top in particular) must have ***m ~ few hundred GeV*** to maintain the **fine tuning below 10%**
- Search in R-Parity **conserved** and **violated** scenarios
  - Quite a difference in the final states being investigated

A Rich Program

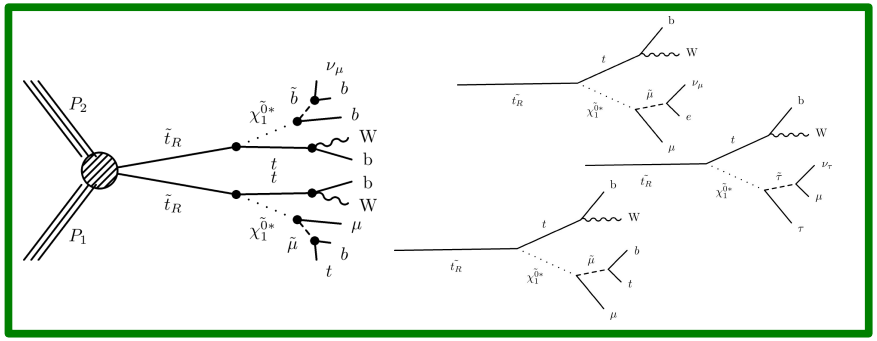
Direct production



Gluino mediated production



RPV scenarios



- **Wide program** from both experiments
- In addition to "basic" topology scanning, each topology is investigated in **several channels** (here in the diagrams, top, W/Z still need to decay)
  - 0,1,2, ≥3 leptons, from 0 to n jets, from 0 to m b-tagged jets

→ Clearly *impossible* to give **full justice** to all analysis in < 20 min

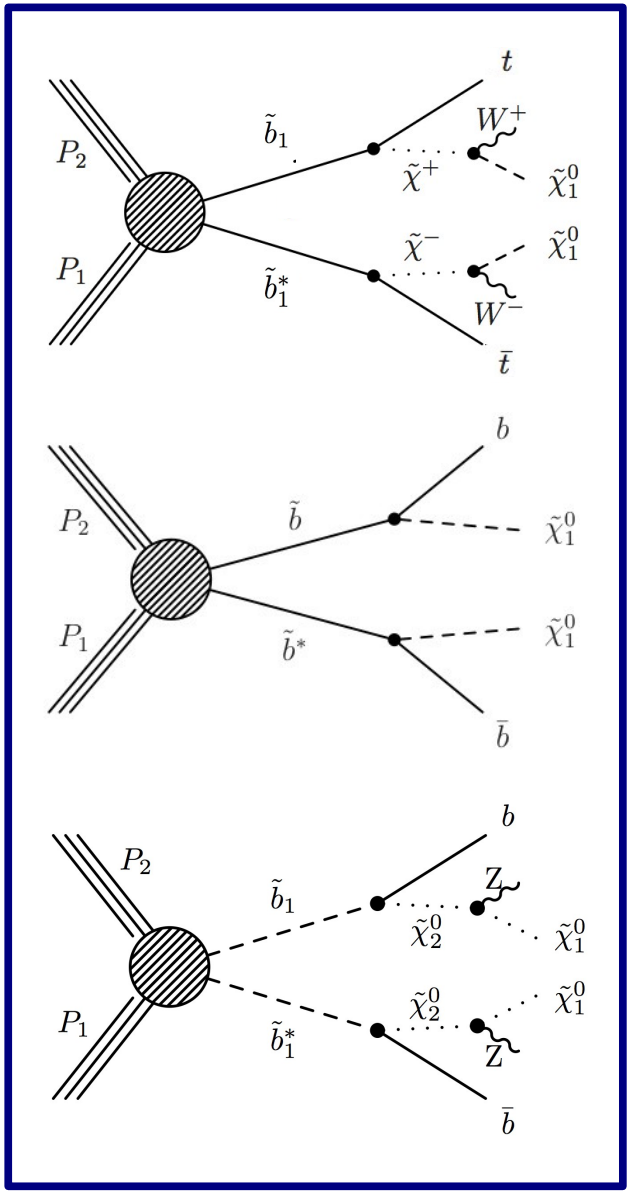
Sbottom Direct Production

Presented here

- 0 leptons + 2 b-jets + MET
  - *ATLAS-CONF-2013-053*
- 2 same-sign leptons + 0-3 b-jets + MET
  - *ATLAS-CONF-2013-007*
- 3 leptons + ≥1 b-jet + MET
  - *CMS-SUS-13-008*

Other reference analyses on this topic

- *CMS-SUS-12-028*
- *CMS-SUS-12-017*
- *ATLAS-CONF-2012-151*



Direct Sbottom Production

0 leptons + 2 b-jets + MET

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

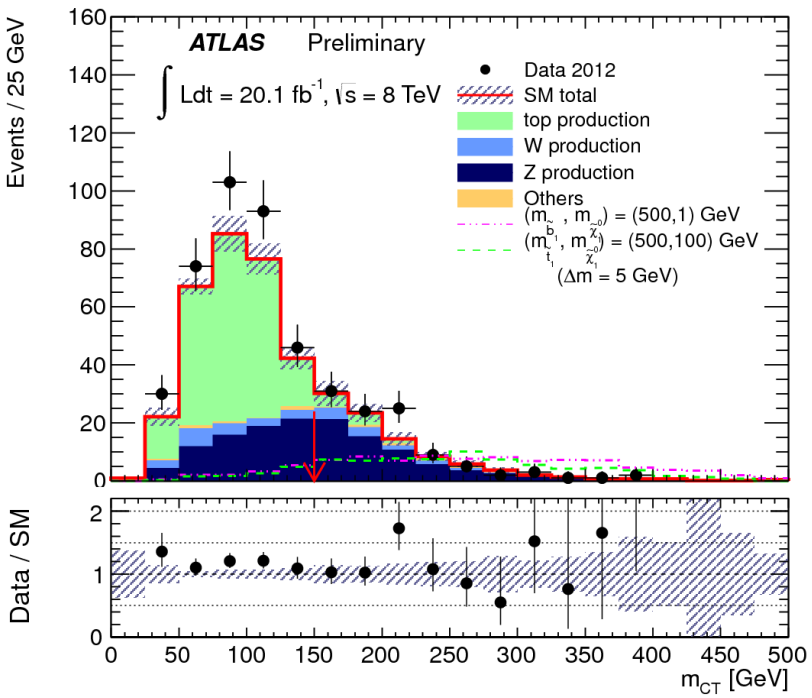
$$m_{CT}^2(v_1, v_2) = [E_T(v_1) + E_T(v_2)]^2 - [\mathbf{p}_T(v_1) - \mathbf{p}_T(v_2)]^2$$

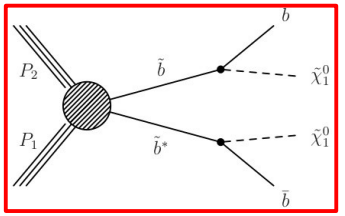
- Require **2 b-tagged jets**, veto almost any other activity in the event (leptons and jets).
- Two search regions. "A" for large $\mathbf{m_{squark}}$-$\mathbf{m_{\chi}}$. "B" for low splitting (exploiting hard ISR emission).
- Cut on m_{CT}, $H_{T,3}$ (upper cut), m_{bb}, MET, MET/$m_{eff}(j_{1,2(,3)})$

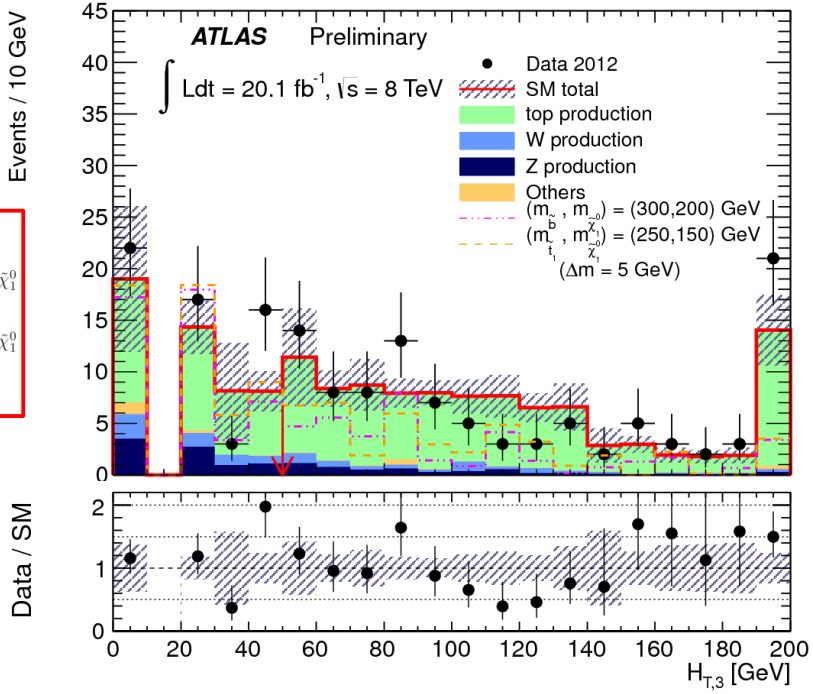
ATLAS-CONF-2013-053

M_{CT} cuts

Channel	SRA, m_{CT} selection					SRB
	150 GeV	200 GeV	250 GeV	300 GeV	350 GeV	
Observed	103	48	14	7	3	58
Total SM	92 ± 12	38 ± 6	15.3 ± 2.7	5.8 ± 1.2	2.6 ± 0.6	50 ± 9
Top production	11.3 ± 1.8	2.5 ± 1.4	0.45 ± 0.25	< 0.01	< 0.01	34 ± 7
Z production	64 ± 10	28 ± 5	11.1 ± 2.1	4.7 ± 0.9	2.0 ± 0.4	8 ± 3
W production	12 ± 6	4.6 ± 2.5	2.0 ± 1.1	1.0 ± 0.5	0.48 ± 0.27	5 ± 4
Others	4.3 ± 1.5	3.3 ± 1.3	1.8 ± 0.6	0.12 ± 0.11	$0.10^{+0.12}_{-0.10}$	1.5 ± 0.7
Multijet production	0.21 ± 0.21	0.06 ± 0.06	0.02 ± 0.02	< 0.01	< 0.01	0.2 ± 0.2







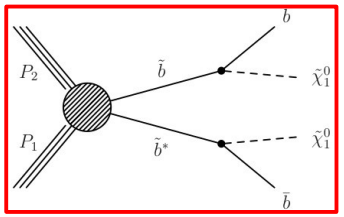
Direct Sbottom Production

0 leptons + 2 b-jets + MET

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

$m^2_{CT}(v_1, v_2) = [E_T(v_1) + E_T(v_2)]^2 - [\mathbf{p}_T(v_1) - \mathbf{p}_T(v_2)]^2$

- Set upper limits using Simplified Models: **on cross section**, considering BR(100%) in hadronic final state, and **on BR**



M_{CT} cuts

ATLAS-CONF-2013-053

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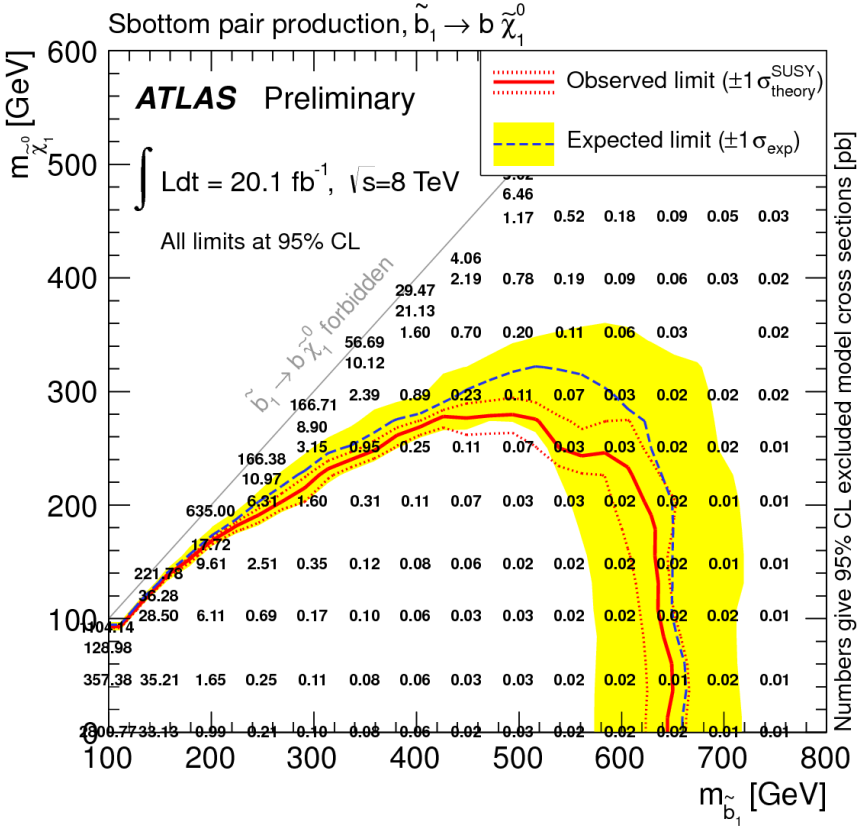
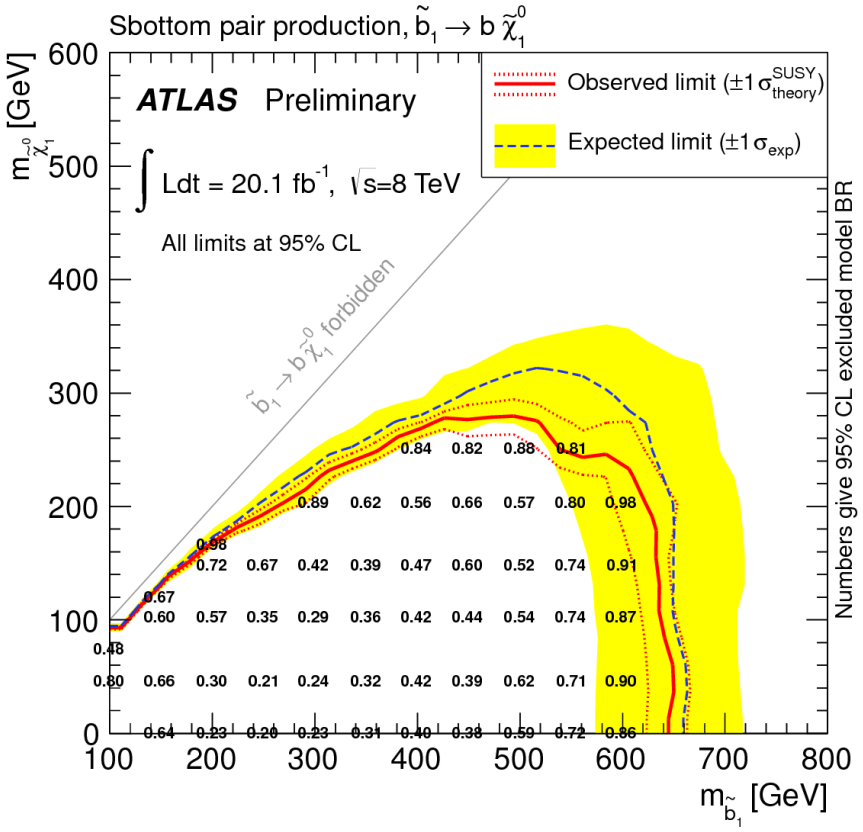




Direct Sbottom Production

2 same-sign leptons + 0-3 b-jets + MET

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

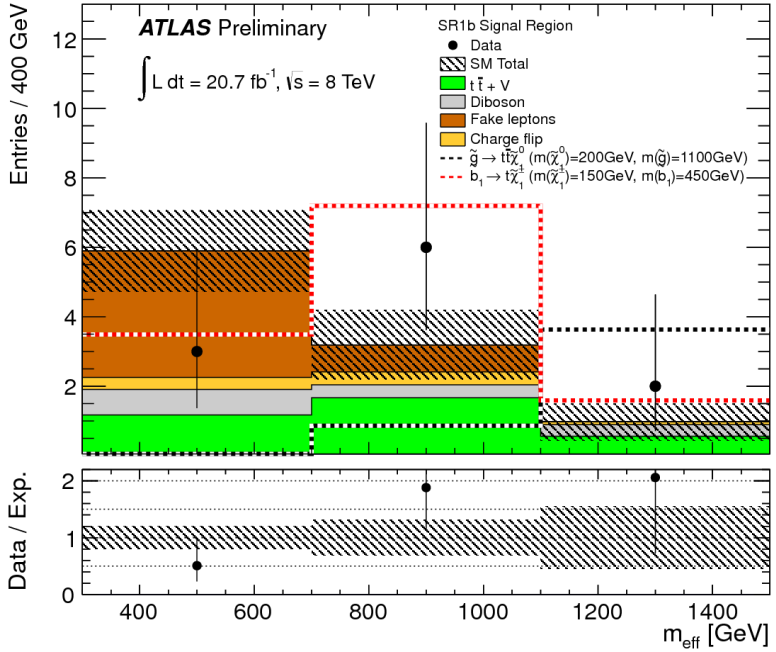
- Require **2 same-sign leptons**
- Signature interesting for many SUSY models (as gluino is a Majorana fermion)

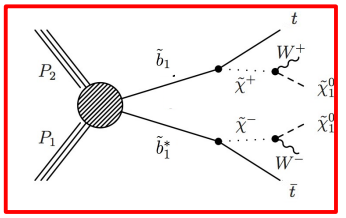
Signal region	N_{b-jets}	Signal cuts (discovery case)	Signal cuts (exclusion case)
SR0b	0	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV, $m_T > 100$ GeV,
		$m_T > 100$ GeV, $m_{eff} > 400$ GeV	binned shape fit in m_{eff} for $m_{eff} > 300$ GeV
SR1b	≥1	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV, $m_T > 100$ GeV,
		$m_T > 100$ GeV, $m_{eff} > 700$ GeV	binned shape fit in m_{eff} for $m_{eff} > 300$ GeV
SR3b	≥3	$N_{jets} \geq 4$	$N_{jets} \geq 5$,
			$E_T^{miss} < 150$ GeV or $m_T < 100$ GeV

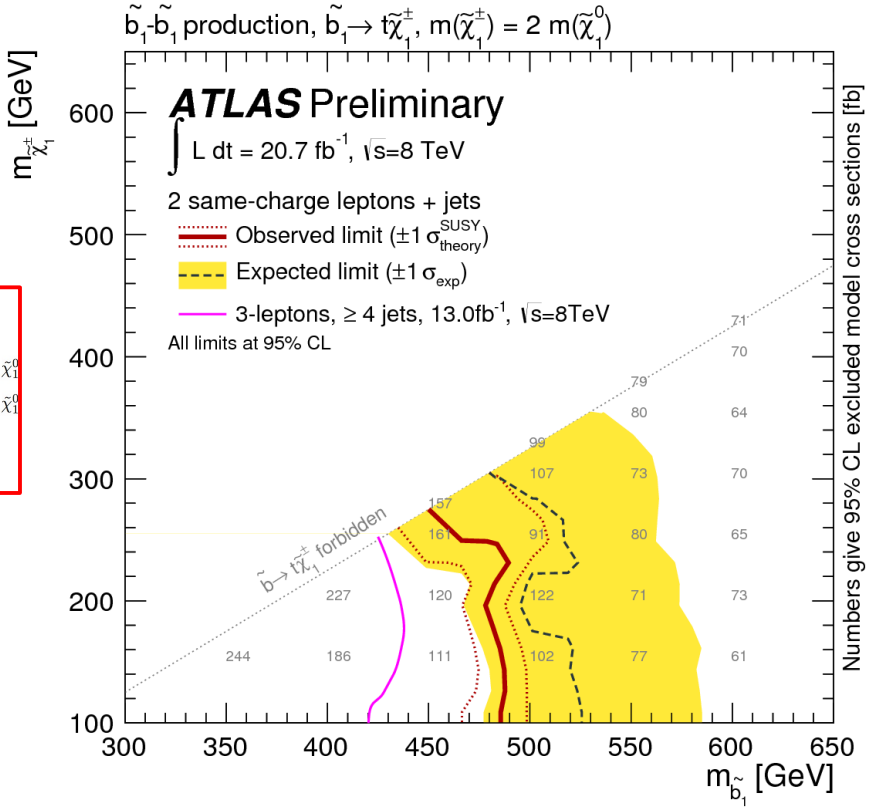
For compress spectra-

SR1B is the search region important for this analysis. The most important background arises from single lepton **ttbar** and **W+jets** decays where one lepton comes from hadrons. The **UL 95% on Aεσ is 0.53 fb**.

ATLAS-CONF-2013-007







Direct Sbottom Production

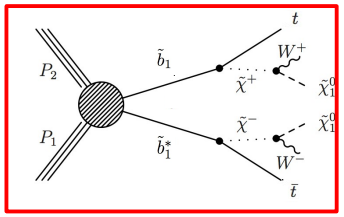
3 leptons + ≥1 b-jet + MET

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

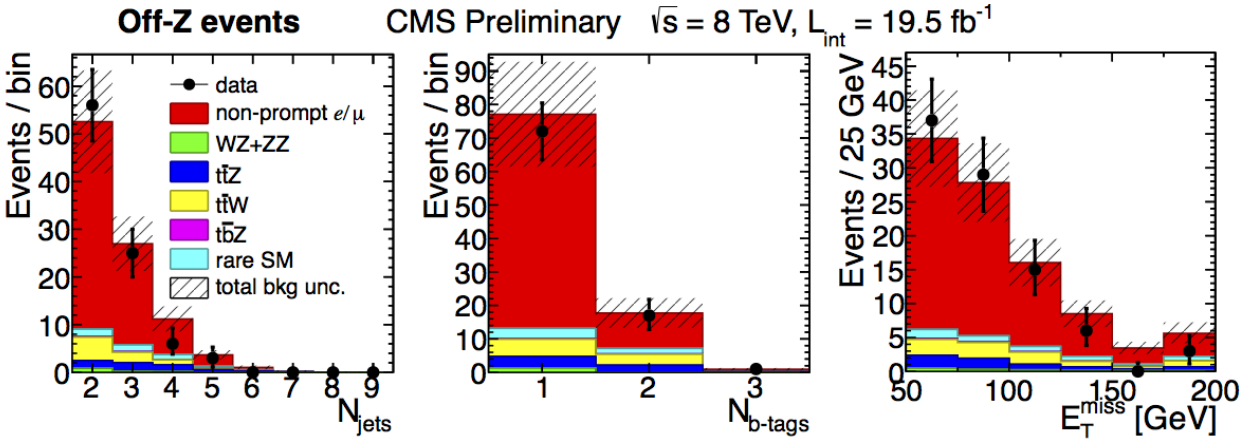
CMS-SUS-13-008

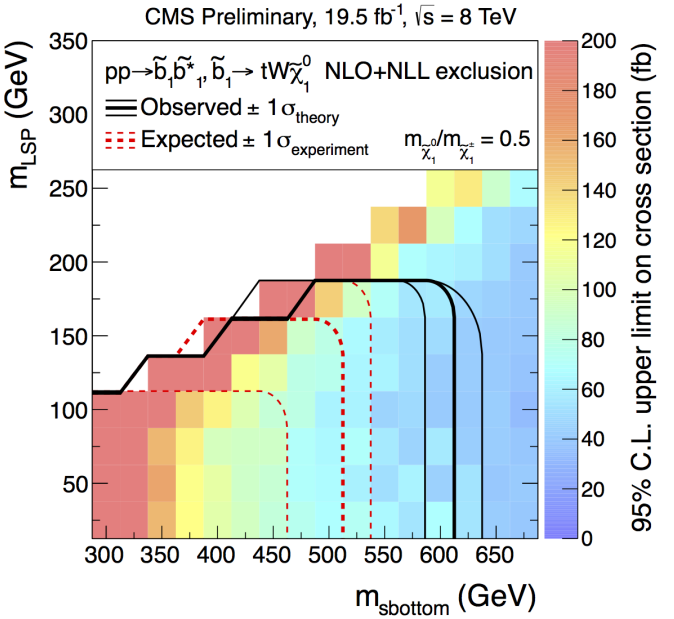
Divide the 3 leptons sample in 2 *categories*, depending on if a pair of same flavour leptons has $\mathbf{m_{ll} \sim m_Z}$. Then build exclusive regions in **# jets**, **# b-jets** and **MET**.

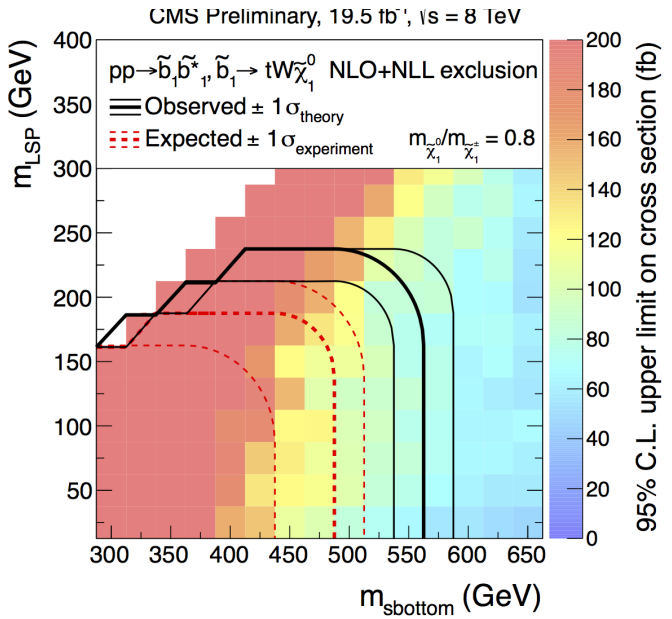
***Off-shell Z* case**



$N_{b\text{-tags}}$	N_{jets}	E_T^{miss} (GeV)	H_T < 200 GeV		H_T > 200 GeV	
			Expected	Observed	Expected	Observed
1	2–3	50–100	33.3 ± 7.0	36	10.9 ± 2.4	9
		100–200	11.8 ± 2.6	13	9.0 ± 2.0	6
		≥200	0.33 ± 0.21	0	1.2 ± 0.4	0
	≥4	50–100	0.92 ± 0.36	2	5.3 ± 1.3	3
		100–200	0.10 ± 0.12	0	3.5 ± 1.0	3
		≥200	< 0.09	0	0.74 ± 0.31	0
2	2–3	50–100	4.7 ± 1.9	7	3.8 ± 1.1	7
		100–200	2.2 ± 0.7	1	1.9 ± 0.7	0
		≥200	0.22 ± 0.19	1	0.14 ± 0.13	0
	≥4	50–100	< 0.13	0	2.7 ± 0.8	1
		100–200	< 0.16	0	1.7 ± 0.6	0
		≥200	< 0.09	0	0.33 ± 0.18	0
≥3		50–100	< 0.09	0	0.56 ± 0.27	1
		100–200	< 0.12	0	0.17 ± 0.13	0
		≥200	< 0.09	0	0.20 ± 0.19	0







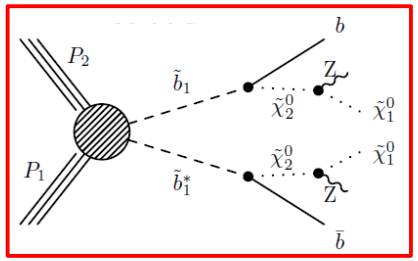
Direct Sbottom Production

3 leptons + ≥1 b-jet + MET $\tilde{b} \to b\chi_2^0 \to bZ\chi_1^0$

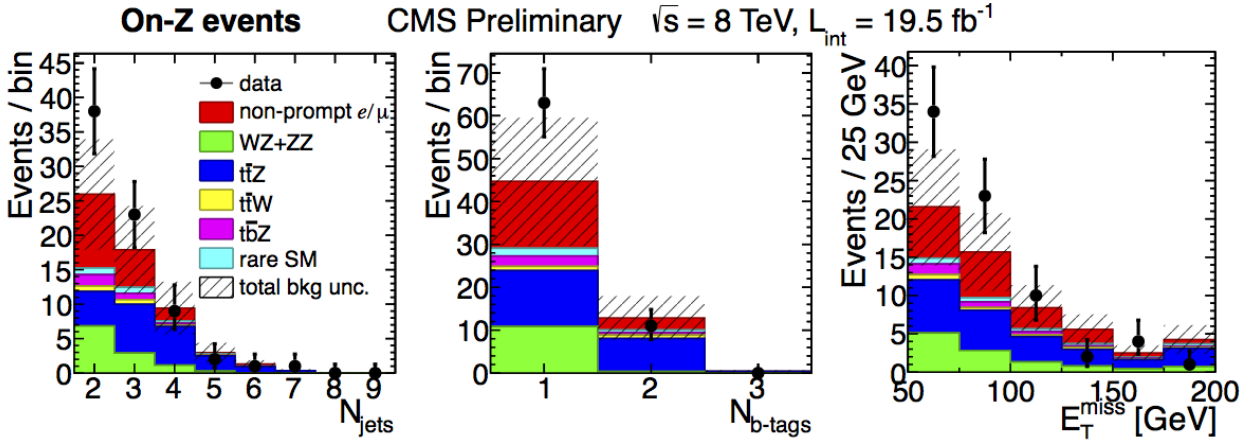
Divide the 3 leptons sample in 2 *categories*, depending on if a pair of same flavour leptons has $\mathbf{m_{ll} \sim m_Z}$. Then build exclusive regions in **# jets**, **# b-jets** and **MET**.

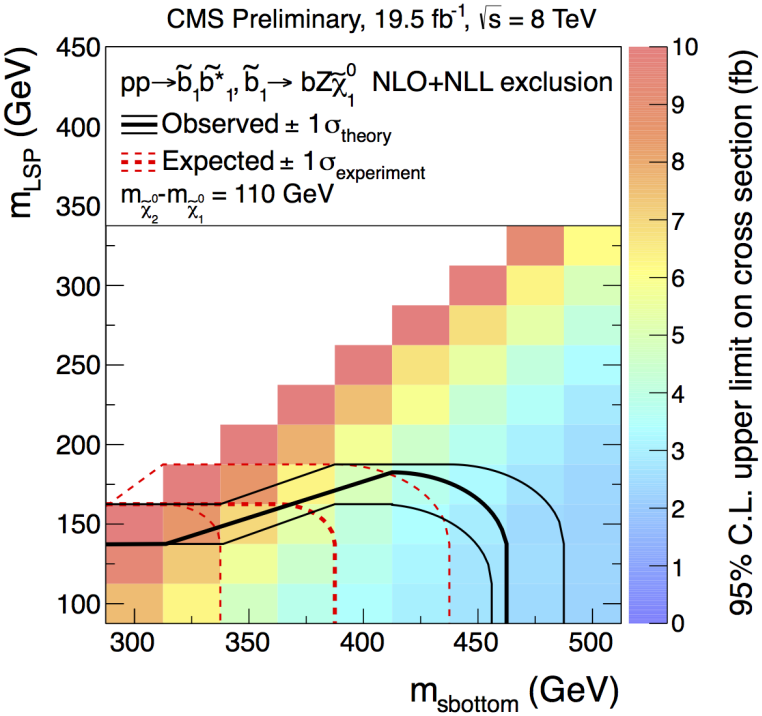
CMS-SUS-13-008

On-shell Z case



$N_{b\text{-tags}}$	N_{jets}	E_T^{miss} (GeV)	$H_T < 200$ GeV		$H_T > 200$ GeV	
			Expected	Observed	Expected	Observed
1	2–3	50–100	15.0 ± 4.5	30	9.3 ± 3.2	13
		100–200	5.0 ± 1.7	6	5.5 ± 2.0	3
		≥200	0.36 ± 0.22	0	0.9 ± 0.4	0
	≥4	50–100	0.11 ± 0.12	1	4.9 ± 2.0	4
		100–200	< 0.19	0	3.0 ± 1.3	5
		≥200	< 0.11	0	0.56 ± 0.31	1
2	2–3	50–100	2.3 ± 0.8	5	2.6 ± 1.0	2
		100–200	1.3 ± 0.5	1	1.3 ± 0.6	1
		≥200	0.12 ± 0.12	0	0.46 ± 0.24	0
	≥4	50–100	0.20 ± 0.16	1	2.9 ± 1.3	1
		100–200	< 0.22	0	1.6 ± 0.8	0
		≥200	< 0.09	0	0.29 ± 0.19	0
≥3		50–100	< 0.09	0	0.17 ± 0.14	0
		100–200	< 0.09	0	0.25 ± 0.16	0
		≥200	< 0.09	0	0.02 ± 0.09	0





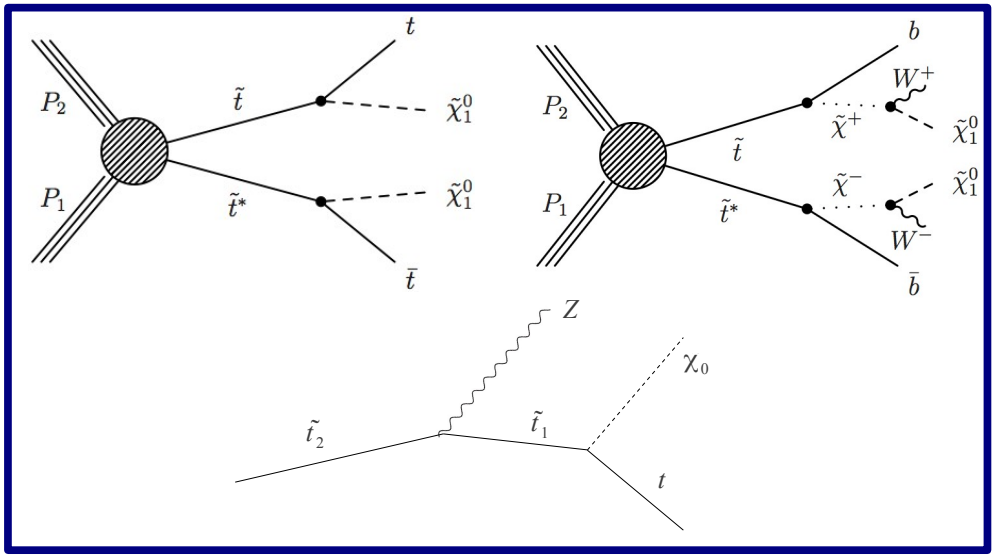
Direct Stop Production

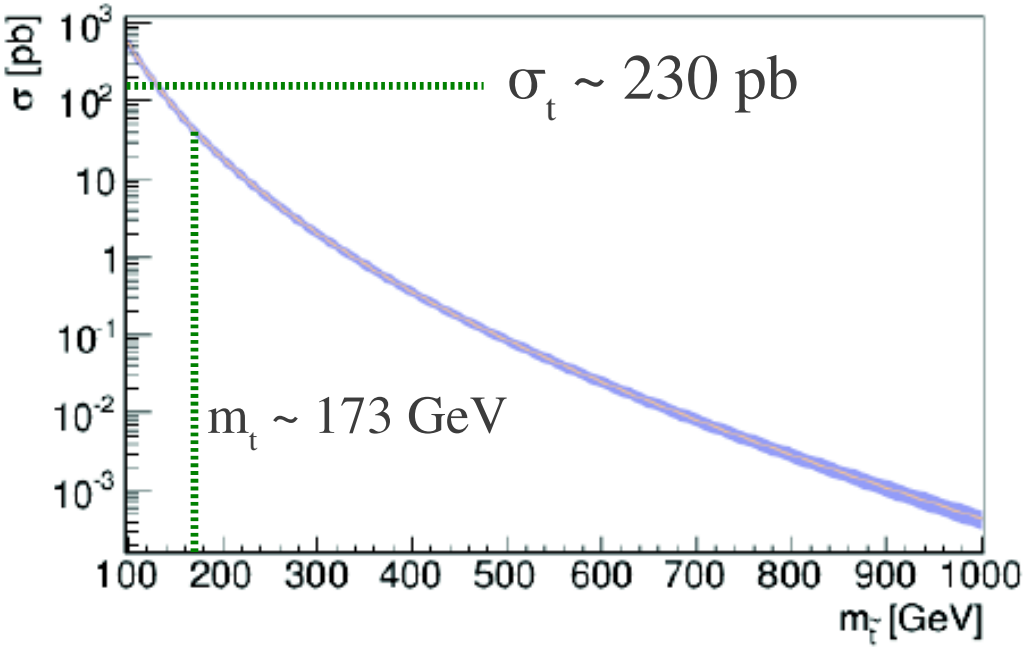
Presented here

- 0 leptons + 2 b-jets + MET
  - *ATLAS-CONF-2013-053*
  - *ATLAS-CONF-2013-024* (≥6 jets)
- 1 lepton + ≥1 b-jet + ≥ 4 jets +MET
  - *CMS-SUS-13-011*
    - *ATLAS-CONF 2013-037*
- 2 leptons + jets + MET
  - *ATLAS-CONF-2013-48*
- 3 Leptons + jets + MET
  - *ATLAS-CONF-2013-025*

Other reference analyses on this subject

- *CMS-SUS-11-030*
- *CMS-SUS-12-005*
- *CMS-SUS-11-024*



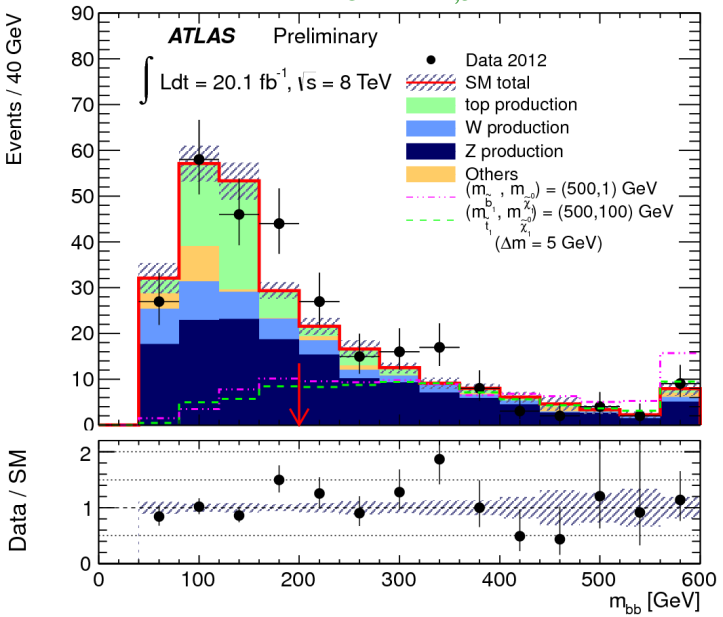


Direct Stop Production
0 leptons + 2 b-jets + MET

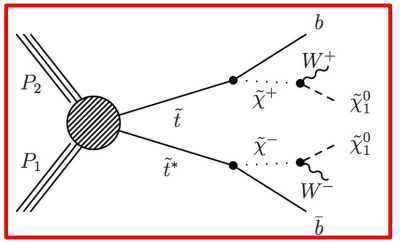
$\tilde{t} \rightarrow b \chi^{\pm}$

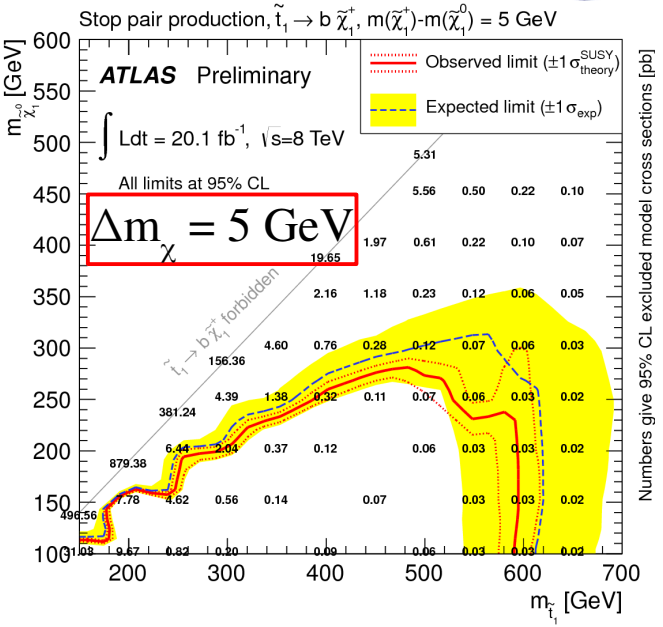
ATLAS-CONF-2013-053

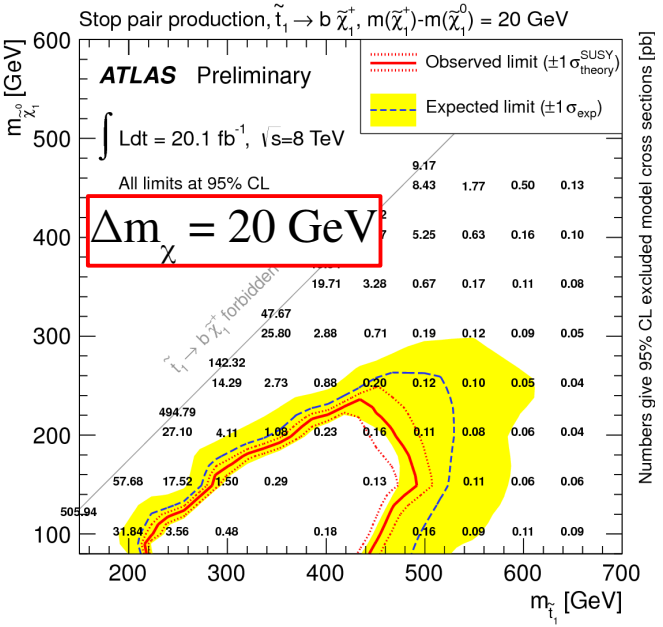
- This analysis is also interpreted in direct stop production model, where stop decays to a *b* and a *chargino*, with target to **small $\Delta m_{\chi} = m_{\chi^{\pm}} - m_{\chi^0}$**.
- *Reminder*:
  - Require **2 b-tagged jets**, veto other activity in the event (leptons and jets). Additional jet in SRB allowed.
  - Cut on m_{CT}, $H_{T,3}$ (upper cut), m_{bb}, MET, MET/$m_{eff}(j_{1,2(,3)})$



The most important regions for the exclusion of this interpretation are for **m_{CT} > 150, 200 GeV**







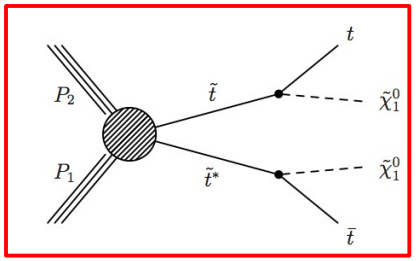
Direct Stop Production

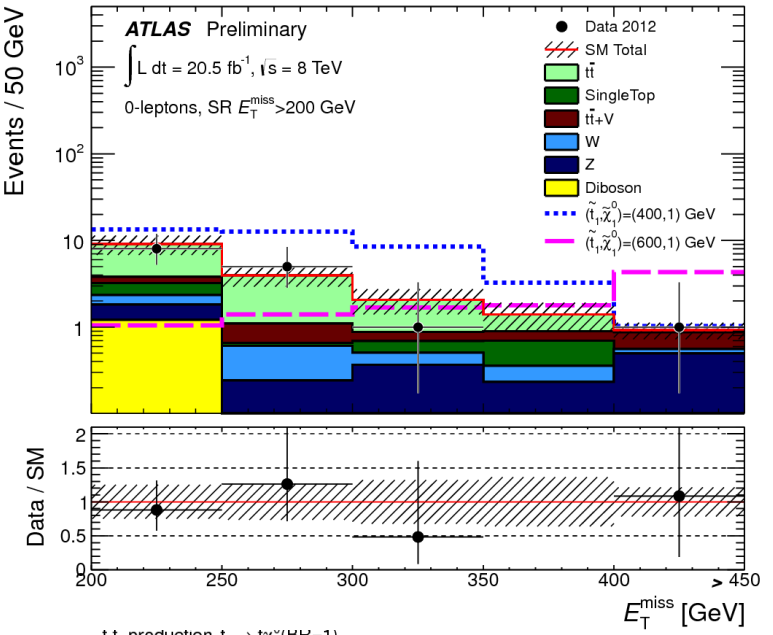
0 leptons + ≥ 6 (2 b-jets) jets + MET

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

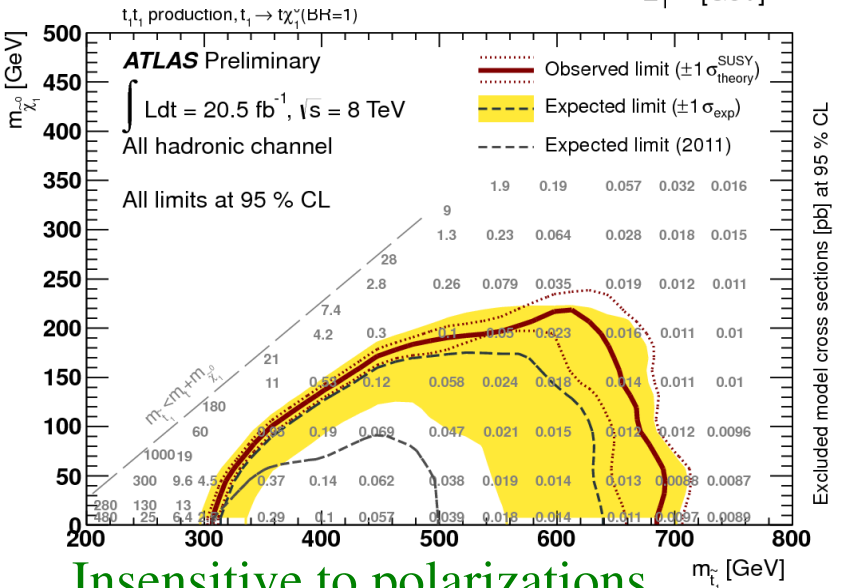
ATLAS-CONF-2013-024

- Cut on MET, Δϕ between several objects in the event (MET, jets), m_T(b-jet,MET)
- Reconstruct **2 x *top* → *had*** based on **$m_{jjj} - m_{top}$ compatibility**
- Use **MET** cut to define 3 non-exclusive regions
- Main background (ttbar) from **MC normalized in control regions**, QCD multijet from **data**, rare processes from **MC**





Number of events	SR1	SR2	SR3
Observed	15	2	1
Expected background	17.5 ± 3.2	4.7 ± 1.5	2.7 ± 1.2
Expected $t\bar{t}$	9.8 ± 2.6	1.9 ± 1.3	0.9 ± 0.7
Expected $t\bar{t} + W/Z$	1.7 ± 1.0	0.7 ± 0.4	0.51 ± 0.30
Expected Z+jets	2.1 ± 1.0	1.2 ± 0.5	0.8 ± 0.4
Expected W+jets	1.2 ± 0.8	0.32 ± 0.29	$0.19^{+0.23}_{-0.19}$
Expected single-top	1.5 ± 0.9	0.5 ± 0.4	$0.3^{+0.5}_{-0.3}$
Expected multijet	0.12 ± 0.12	0.01 ± 0.01	< 0.01
Expected diboson	1.2 ± 1.2	< 0.22	< 0.22
Fit input expectation $t\bar{t}$	9.9	1.7	0.6



Insensitive to polarizations

Direct Stop Production

0 leptons + ≥ 6 (2 b-jets) jets + MET

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

ATLAS-CONF-2013-024

- Cut on MET, Δϕ between several objects in the event (MET, jets), m_T(b-jet,MET)
- Reconstruct **2 x *top* → *had*** based on $\mathbf{m_{jjj} - m_{top}}$ **compatibility**
- Use **MET** cut to define 3 non-exclusive regions
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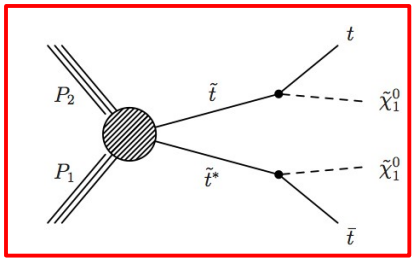

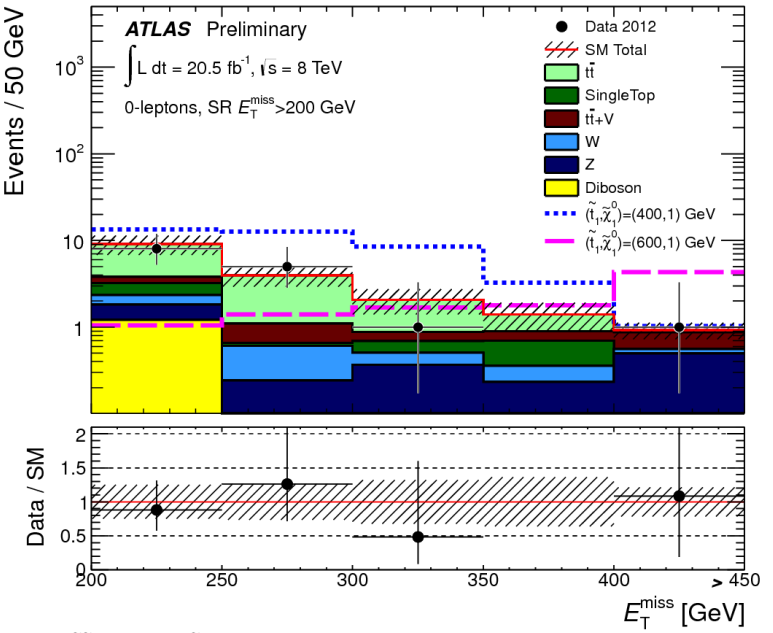

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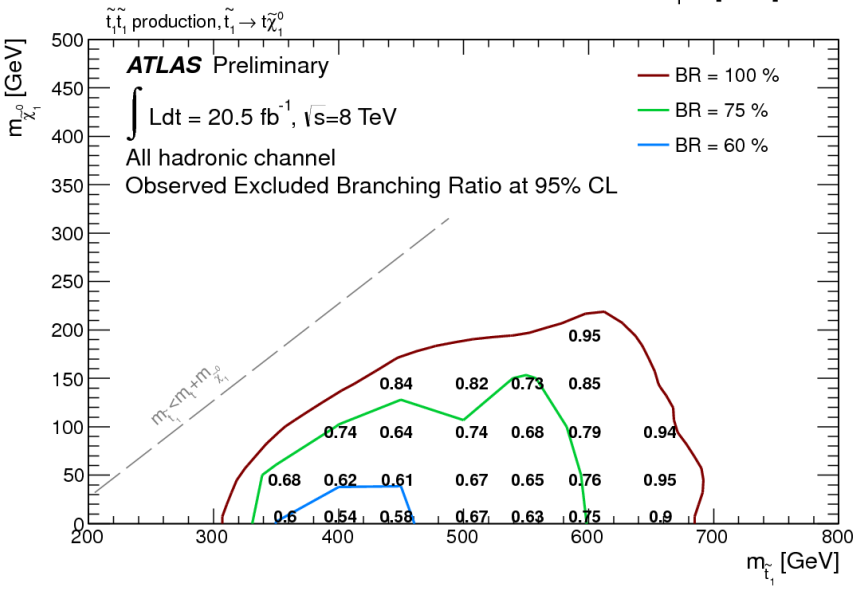
Observed	15	2	1
Expected background	17.5 ± 3.2	4.7 ± 1.5	2.7 ± 1.2
Expected $t\bar{t}$	9.8 ± 2.6	1.9 ± 1.3	0.9 ± 0.7
Expected $t\bar{t} + W/Z$	1.7 ± 1.0	0.7 ± 0.4	0.51 ± 0.30
Expected Z+jets	2.1 ± 1.0	1.2 ± 0.5	0.8 ± 0.4
Expected W+jets	1.2 ± 0.8	0.32 ± 0.29	$0.19^{+0.23}_{-0.19}$
Expected single-top	1.5 ± 0.9	0.5 ± 0.4	$0.3^{+0.5}_{-0.3}$
Expected multijet	0.12 ± 0.12	0.01 ± 0.01	< 0.01
Expected diboson	1.2 ± 1.2	< 0.22	< 0.22
Fit input expectation $t\bar{t}$	9.9	1.7	0.6



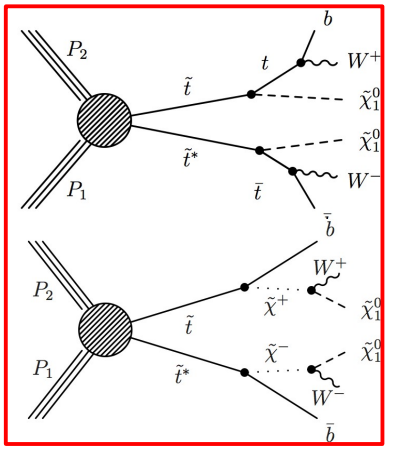
Direct Stop Production

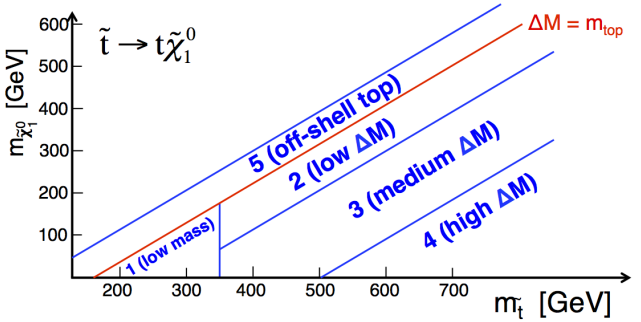
1 lepton + ≥1 b-jet + ≥ 4 jets +MET

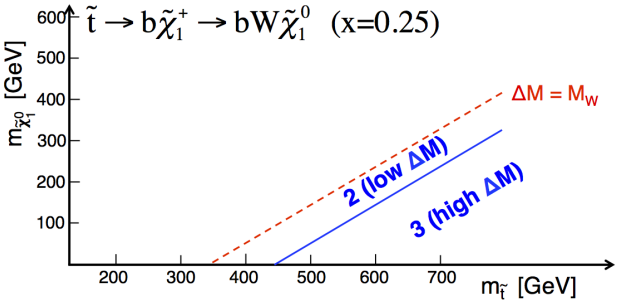
$\tilde{t} \to t \chi^0$

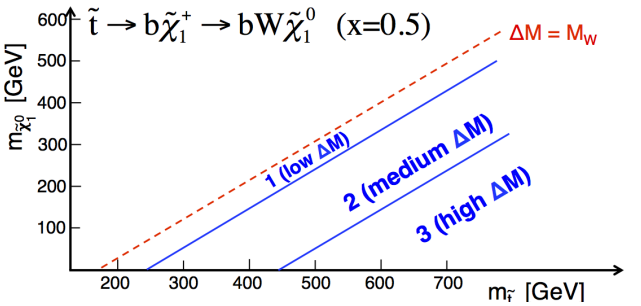
$\tilde{t} \to b \chi^{\pm}$

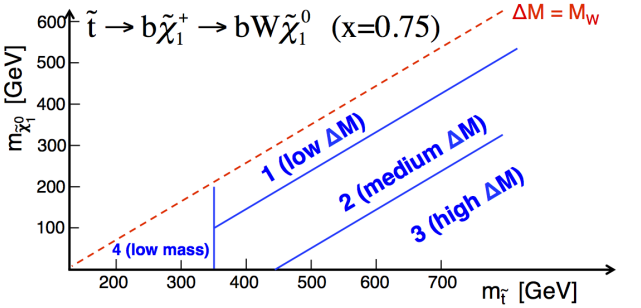
- Pre-selection: 1 lepton, MET > 100 GeV, at least 4 jets, 1 b-tagged jet, large M_T
- **Train BDT** with hadronic top χ^2, M_{T2}, topological cuts, b-quark kinematics
  - Extract scale factors from Control Regions



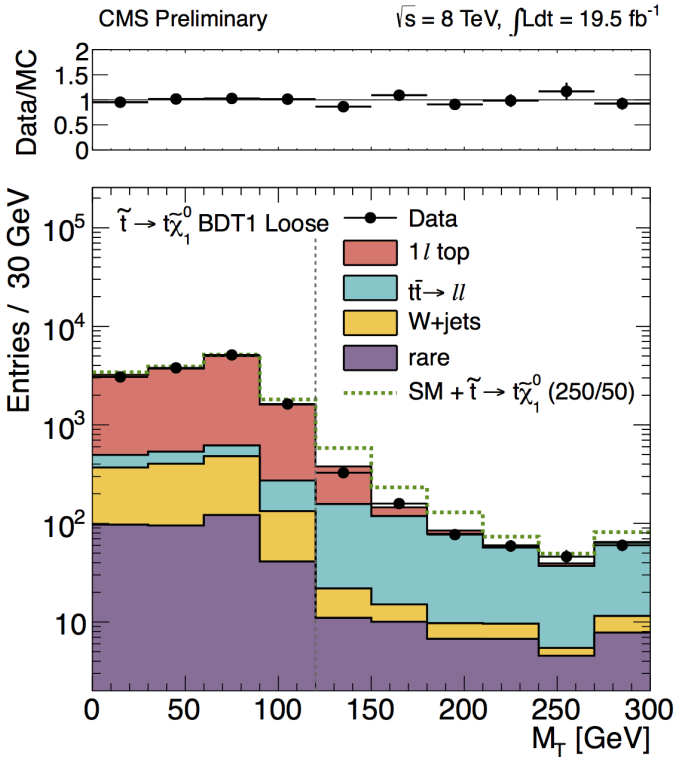


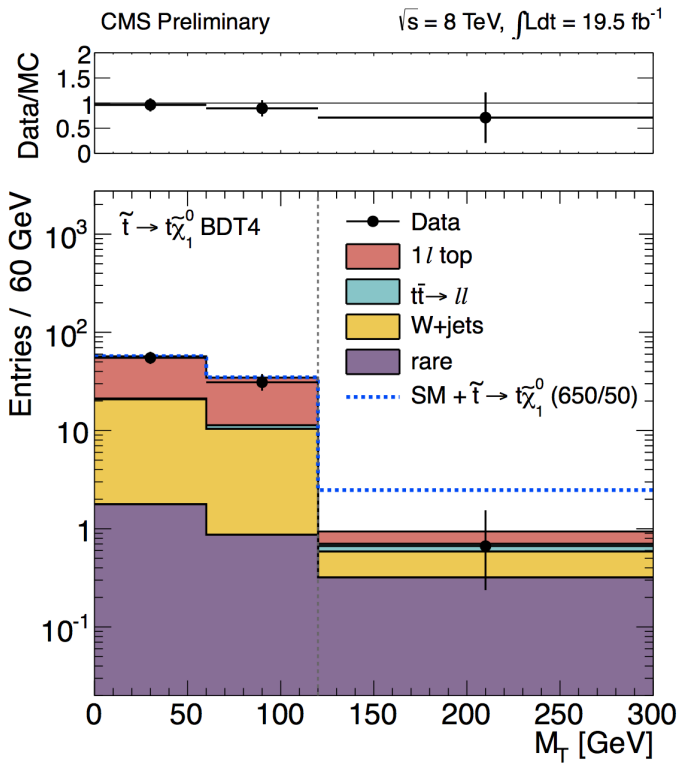






CMS-SUS-13-011





Direct Stop Production

1 lepton + ≥1 b-jet + ≥ 4 jets +MET

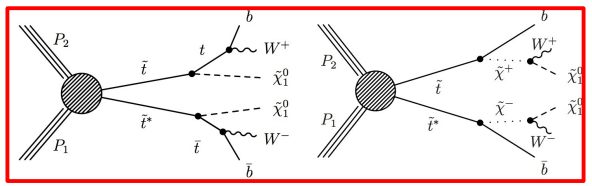
$\tilde{t} \to t \chi^0$

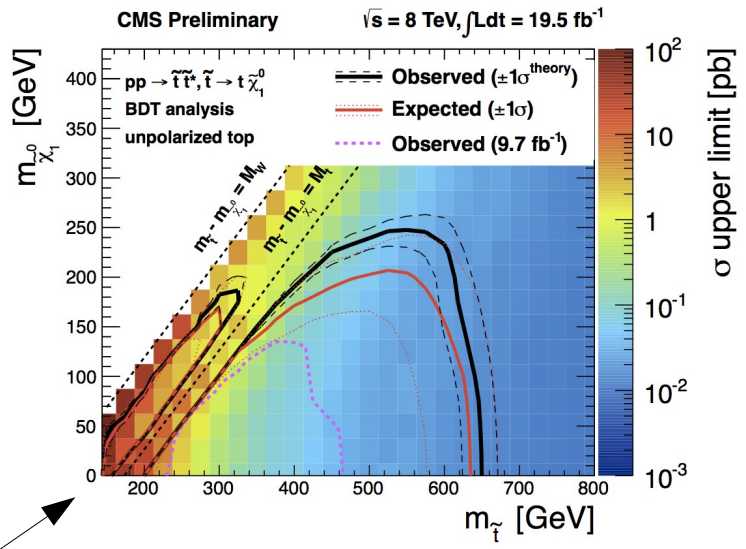
$\tilde{t} \to b \chi^{\pm}$

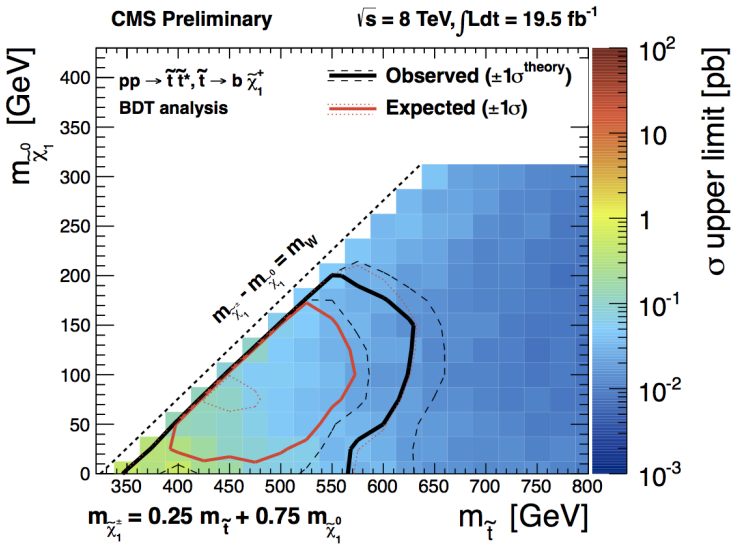
Set limits using cut-and-count results from all BDT signal regions and for each model point **use results from the expected most sensitive signal region**

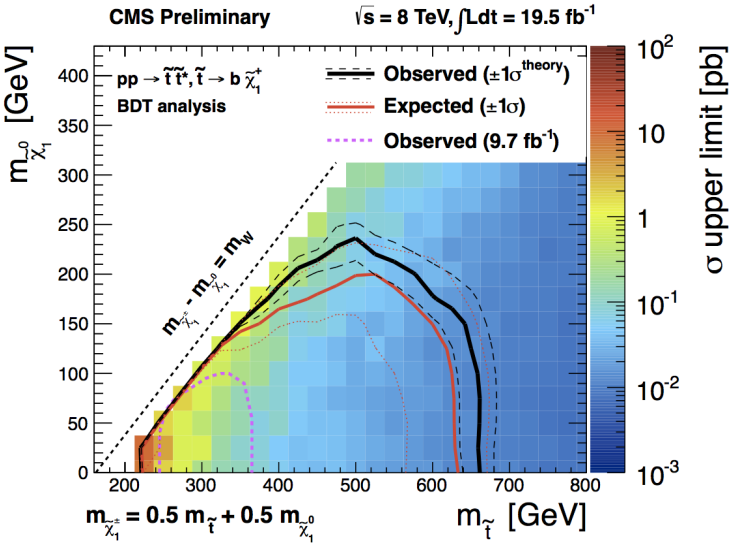
The analysis is sensitive to **off-shell stop production**

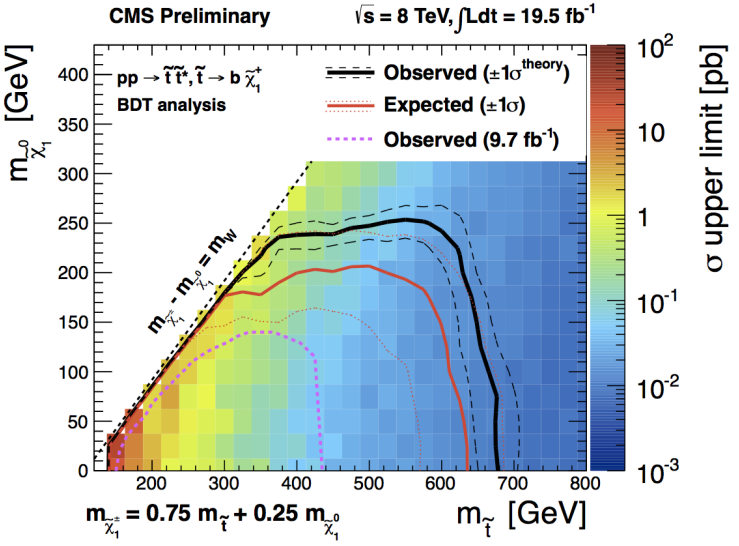
CMS-SUS-13-011











Direct Stop Production
1 lepton + ≥1 b-jet + ≥ 4 jets +MET

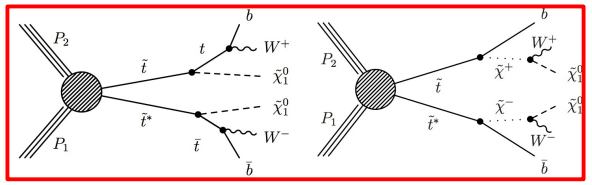
$\tilde{t} \to t \chi^0$

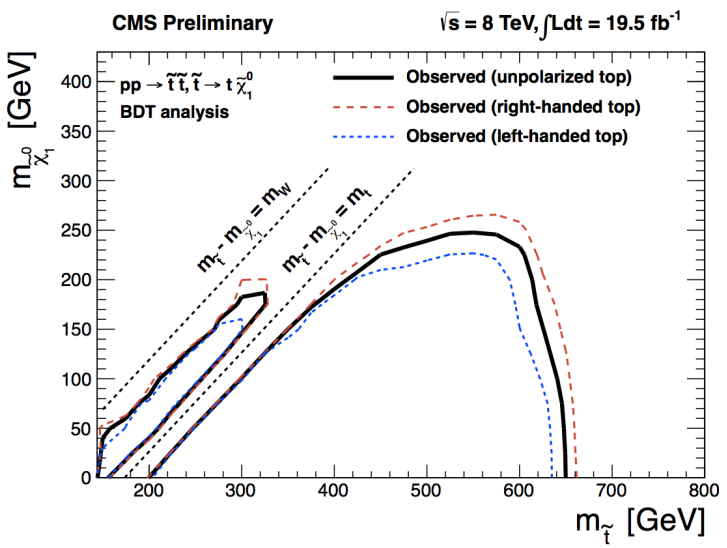
$\tilde{t} \to b \chi^{\pm}$

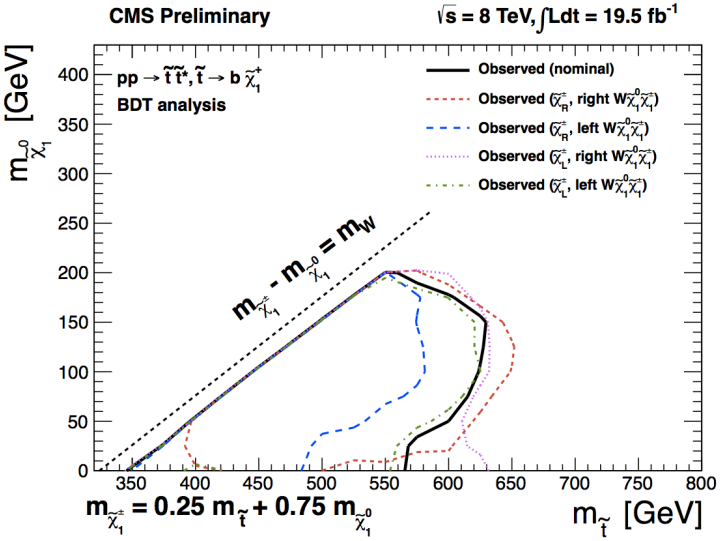
Signal acceptance depends on the **polarization** of the intermediate decay particles:

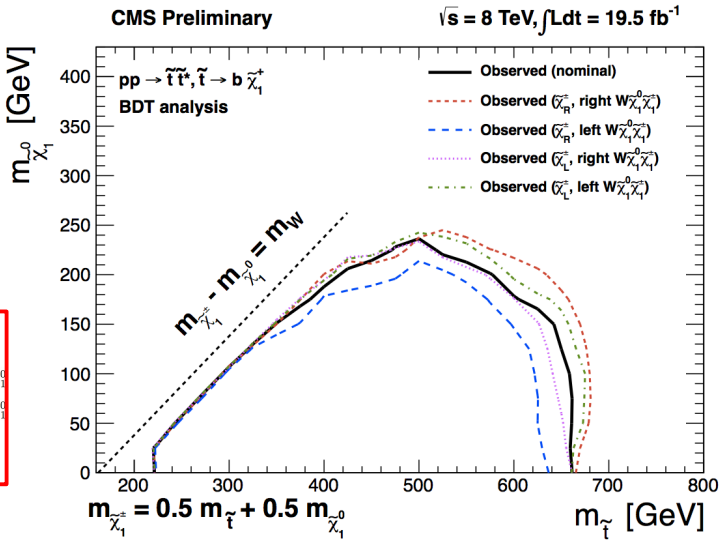
- the **top quark** for the decay in $t\chi^0$
- The **charginos** and the **W** for the decay into $b\chi^{\pm}$

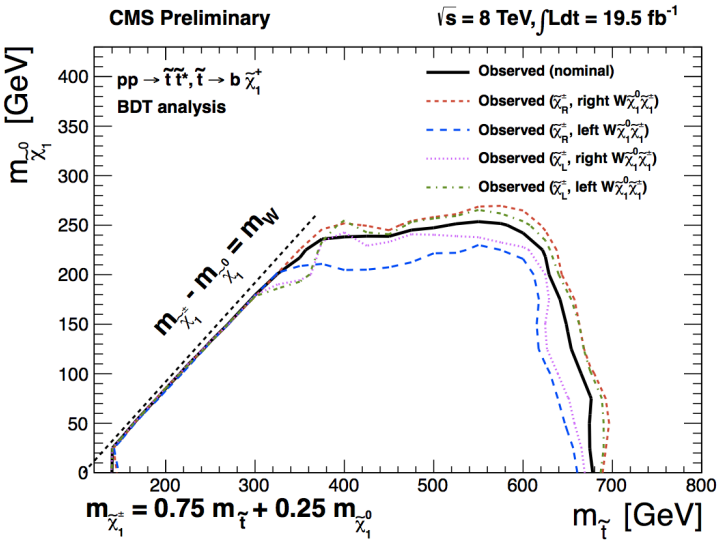
CMS-SUS-13-011











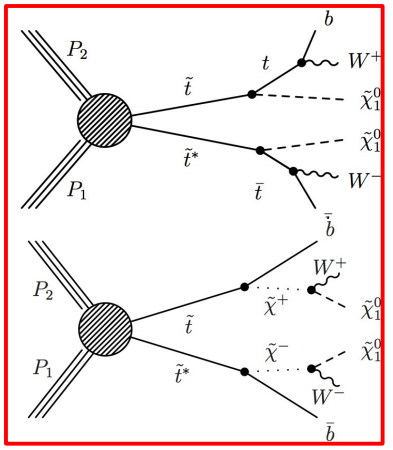
Similar studies done in ***ATLAS-2013-037*** on $t\chi^0$ model (the analysis is a bit more sensitive to polarization).

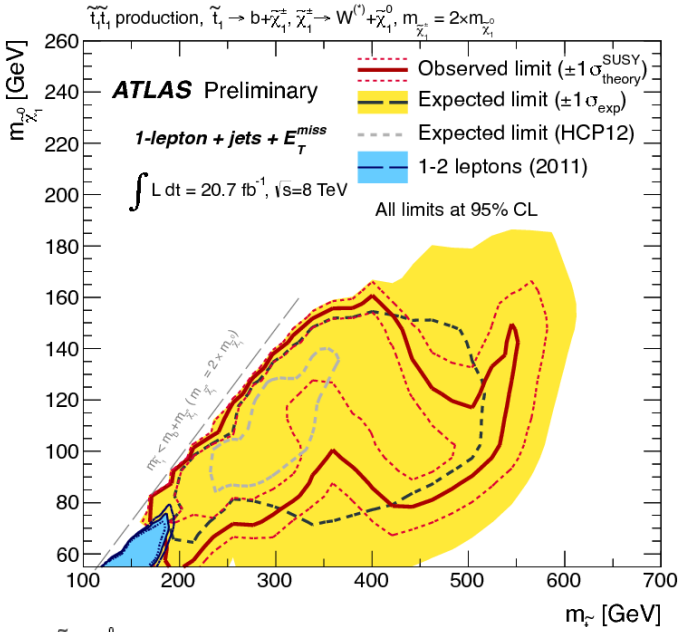
Direct Stop Production
1 lepton + ≥1 b-jet + ≥ 4 jets +MET

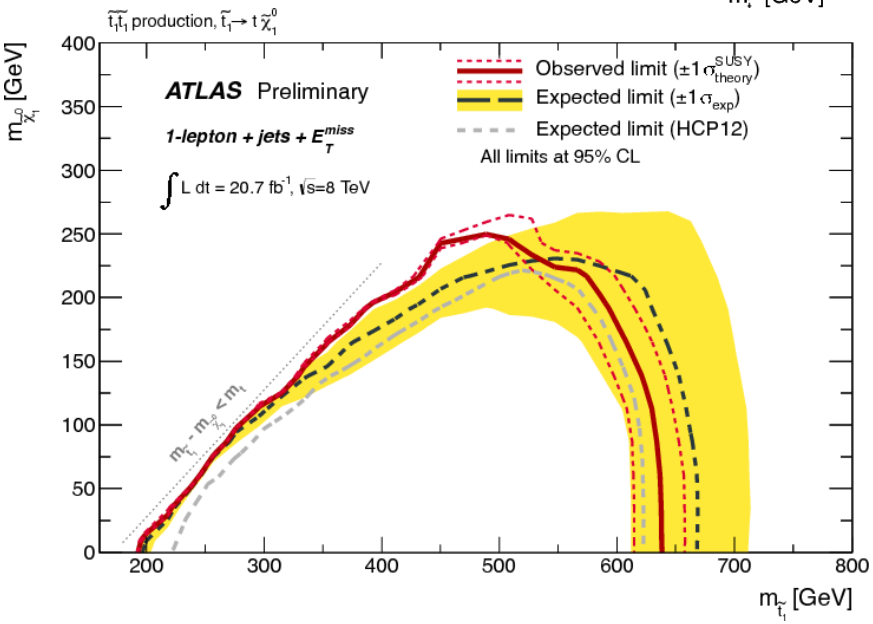
$\tilde{t} \rightarrow t\chi^0$

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

- Ask for **1 well ID lepton**, at least 4 jets, 1 of which b-tagged.
- Discriminate signal/background using $\Delta\varphi$(MET,jets), MET, MET/$\sqrt{H_T}$, m_T
  - am_T, m^{τ}_{T2} (**two variant of classic m_{T2}**, with different assumptions on the input masses) and m_{jjj} on for the $t\chi^0$ case. ***ATLAS-CONF-2013-037***
  - m_{eff}, only the $b\chi^{\pm}$ case.
- **Define several SR** to cover the **different scenarios**: $m_{stop} \sim m_{top} + m_{\chi 0}$, large $m_{\chi 0}$, medium/large $m_{\chi^{\pm}}$, medium/large m_{stop}, medium/large m_{stop}-$m_{\chi^{\pm}}$.



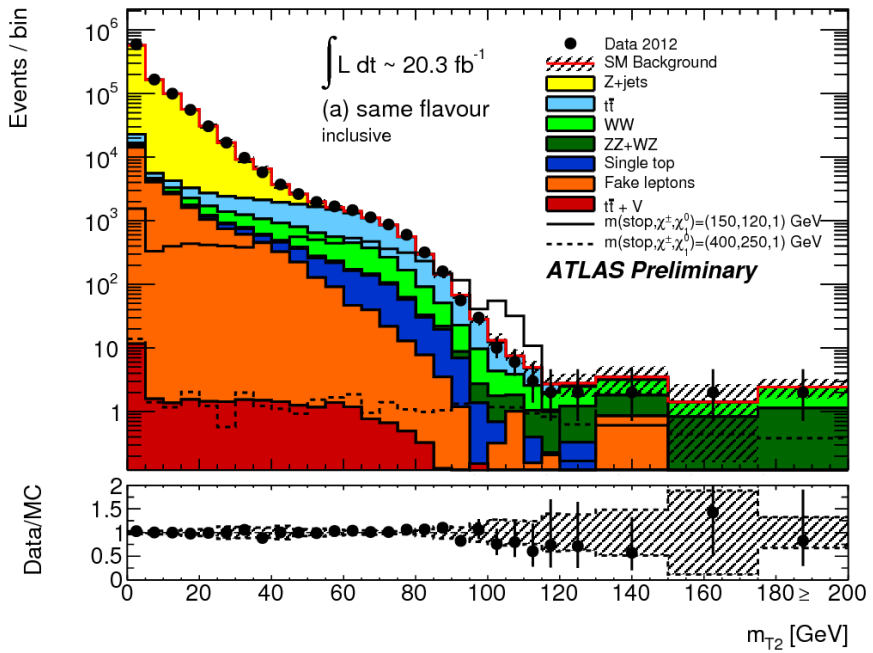




Direct Stop Production
2 OS leptons + jets + MET

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

ATLAS-CONF-2013-048

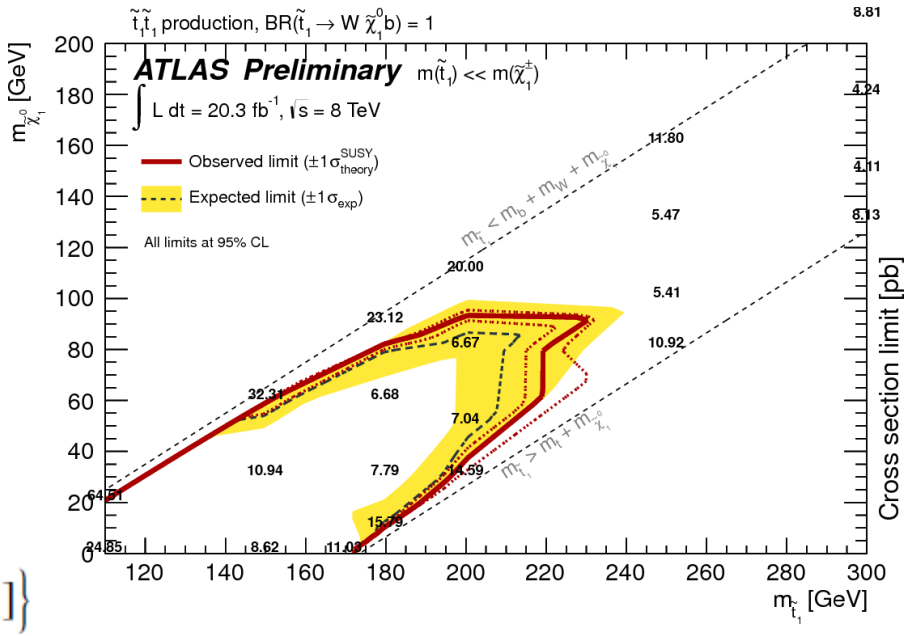


m_{ll} Outside Z window mass

Process	M90	M100	M110	M120
Observed events	260	3	7	3
Total expected bkg events	300 ± 40	4.8 ± 2.2	11 ± 4	4.3 ± 1.3
Fitted $t\bar{t}$ events	181 ± 25	3.2 ± 2.0	5.1 ± 3.4	0.8 ± 0.7
Fitted WW events	71 ± 17	0.9 ± 0.4	3.1 ± 0.9	2.0 ± 0.7
Fitted $WZ - ZZ$ events	12 ± 2	0.18 ± 0.13	0.9 ± 0.4	0.7 ± 0.3
Expected Z+jets	2.9 ± 1.4	0.2 ± 0.2	0.08 ± 0.13	0.05 ± 0.06
Expected $t\bar{t}V$ events	1.7 ± 0.5	0.3 ± 0.1	0.5 ± 0.2	0.35 ± 0.11
Expected Wt events	20 ± 7	-	-	-
Events with fake leptons	14 ± 8	-	0.8 ± 0.5	0.5 ± 0.4
Signal, m($\tilde{t}_1$,$\tilde{\chi}^{\pm}_1$,$\tilde{\chi}^0_1$) = (150,120,1) GeV	610 ± 110	2.6 ± 1.9	10 ± 6	5 ± 3
Signal, m($\tilde{t}_1$,$\tilde{\chi}^{\pm}_1$,$\tilde{\chi}^0_1$) = (400,250,1) GeV	21 ± 4	8.1 ± 1.5	11.1 ± 2.2	7.6 ± 1.5
Fit inputs, expected $t\bar{t}$ events	180 ± 30	3.0 ± 2.0	4.5 ± 3.5	0.7 ± 0.8
Fit inputs, expected WW events	55 ± 9	0.7 ± 0.3	2.5 ± 0.8	1.6 ± 0.7
Fit inputs, expected $WZ - ZZ$ events	13 ± 4	0.2 ± 0.4	1.0 ± 0.7	0.8 ± 0.4
95% CL limit on σ^{obs}_{vis}[fb]	2.5	0.27	0.40	0.23
95% CL limit on σ^{exp}_{vis}[fb]	3.5	0.30	0.42	0.27

SR	M90	M100	M110	M120
p_T leading lepton	> 25 GeV			
$\Delta\phi(E_T^{miss}$, closest jet)	> 1.0			
$\Delta\phi(E_T^{miss}, p_{Tb}^{\ell\ell})$	< 1.5			
m_{T2}	> 90 GeV	> 100 GeV	> 110 GeV	> 120 GeV
p_T leading jet	no selection	> 100 GeV	> 20 GeV	> 20 GeV
p_T second jet	no selection	> 50 GeV	> 20 GeV	> 20 GeV

$$m_{T2}(\mathbf{p}_T^{\ell_1}, \mathbf{p}_T^{\ell_2}, \mathbf{p}_T^{miss}) = \min_{\mathbf{q}_T+\mathbf{r}_T=\mathbf{p}_T^{miss}} \left\{ \max[\, m_T(\mathbf{p}_T^{\ell_1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell_2}, \mathbf{r}_T)\,] \right\}$$

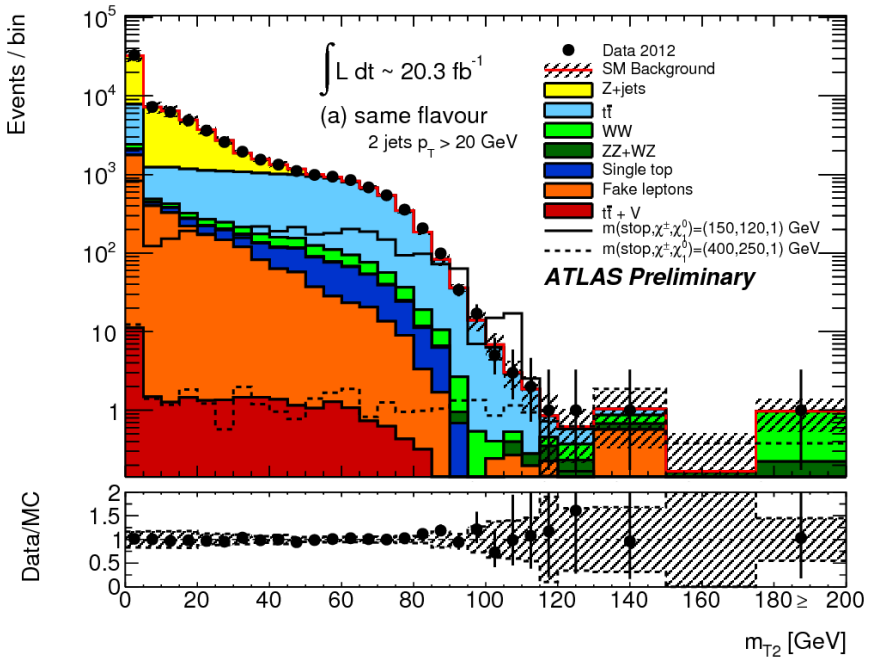


Direct Stop Production
2 OS leptons + jets + MET

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

m_{ll} outside Z window mass

ATLAS-CONF-2013-048



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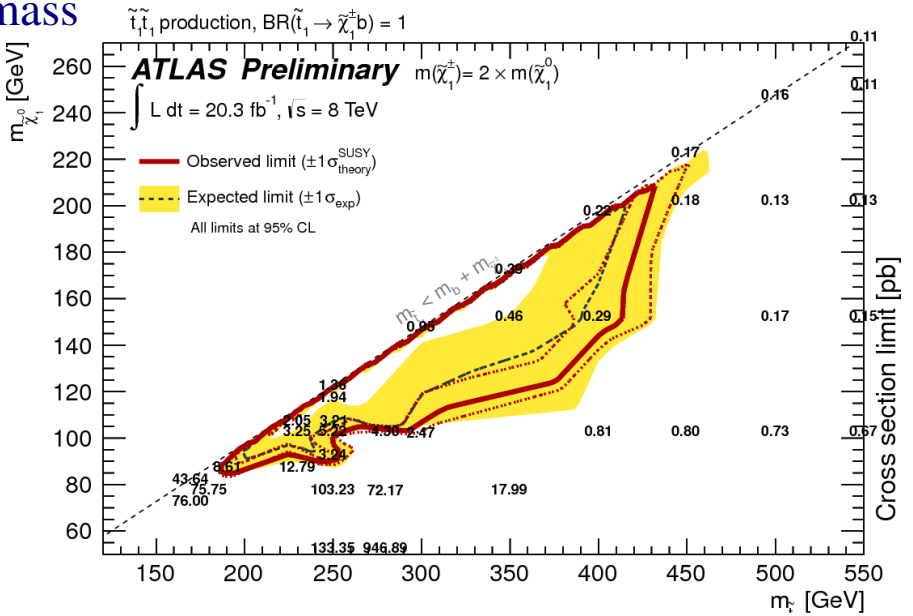
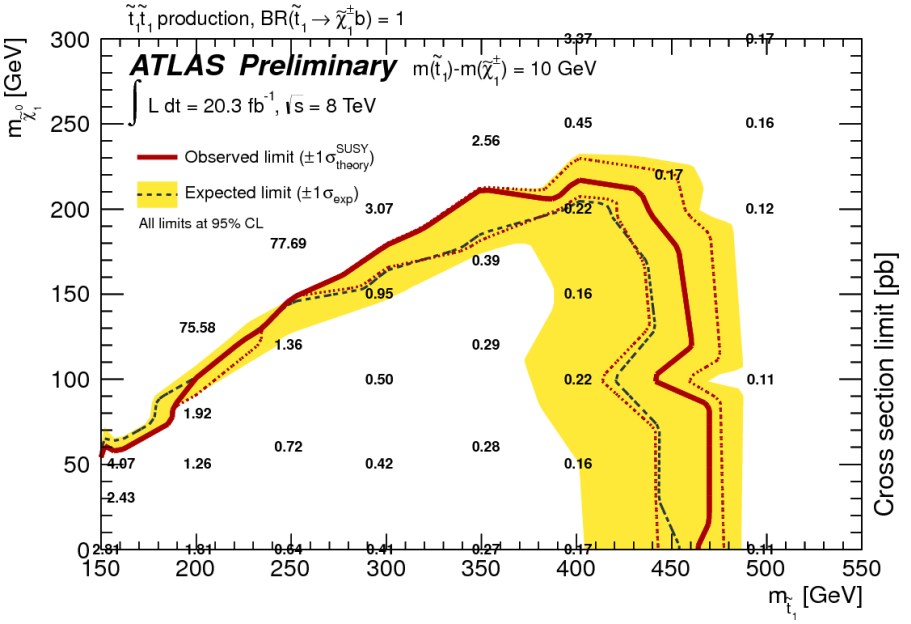




Stop$_2$ to Stop$_1$

3 leptons + ≥1 b-jet + MET

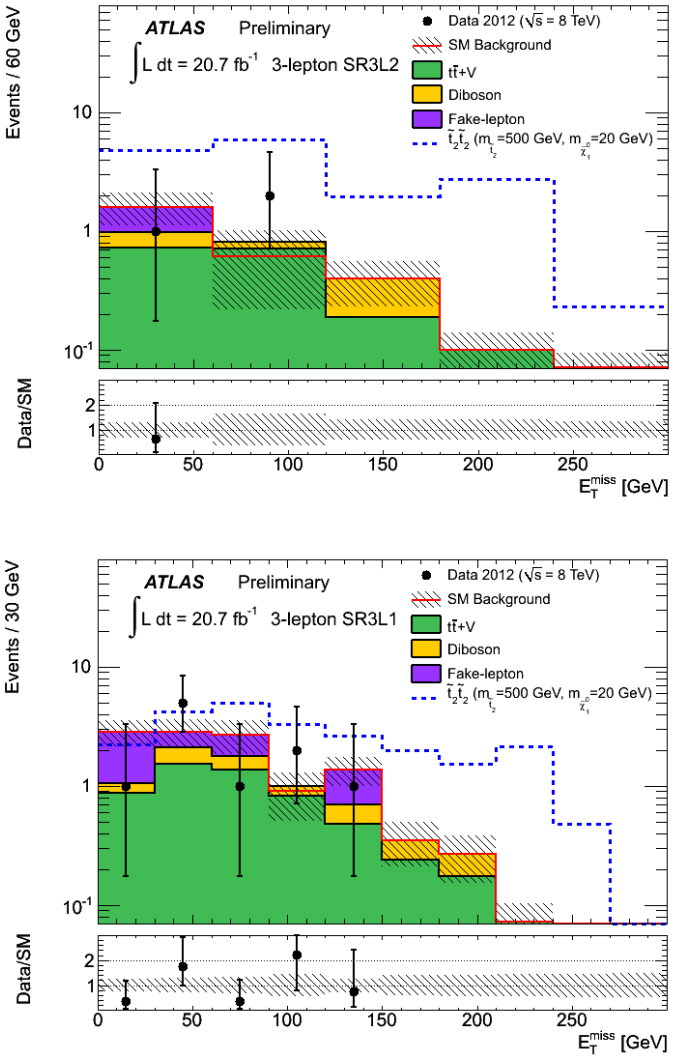
$\tilde{t}_2 \to Z\,\tilde{t}_1 \to Z\,t\,\chi^0$

2 Search region for this Topology.

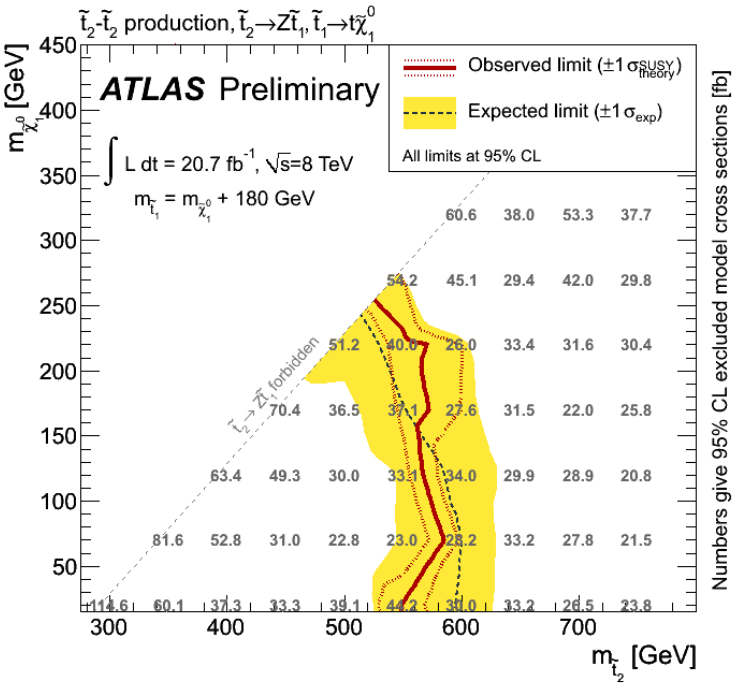
N^{lepton}	≥ 3	
$\lvert m_{\ell\ell} - m_Z \rvert$	< 10 GeV	
$N^{b\text{-jets}}$	≥ 1	
N^{jets}	≥ 5	
$p_T(\text{jet}_1)$	> 50 GeV	> 40 GeV
$p_T(\text{jet}_N)$	> 30 GeV	> 40 GeV
E_T^{miss}	> 60 GeV	
$p_T(\ell\ell)$	-	> 75 GeV
$\Delta\phi^{\ell\ell}$	-	
$p_T(\ell_1)$	> 40 GeV	> 60 GeV

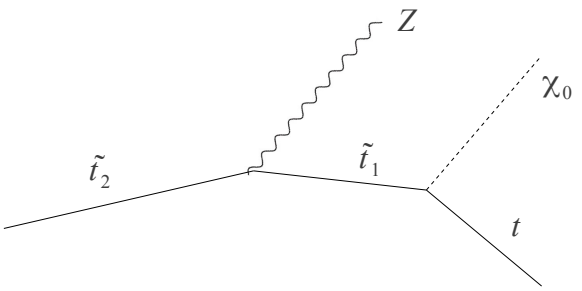
$\tilde{t}_2 - \chi^0 \Rightarrow$ **low** **large**

Data	4	2
Total SM	5.8 ± 2.0	1.2 ± 0.6
Diboson	1.0 ± 0.6	0.3 ± 0.2
$t\bar{t} + V$	3.3 ± 1.4	1.1 ± 0.5
Fake-lepton	1.5 ± 1.0	-0.2 ± 0.3



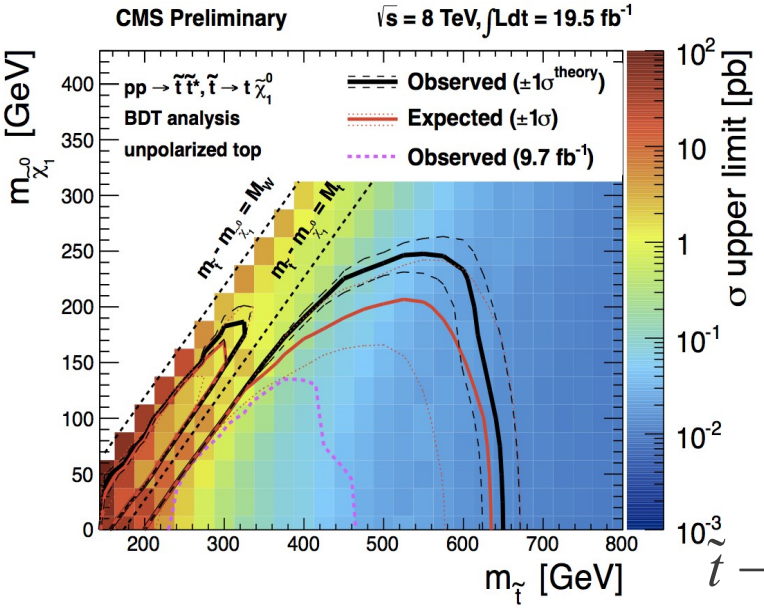
ATLAS-CONF-2013-025

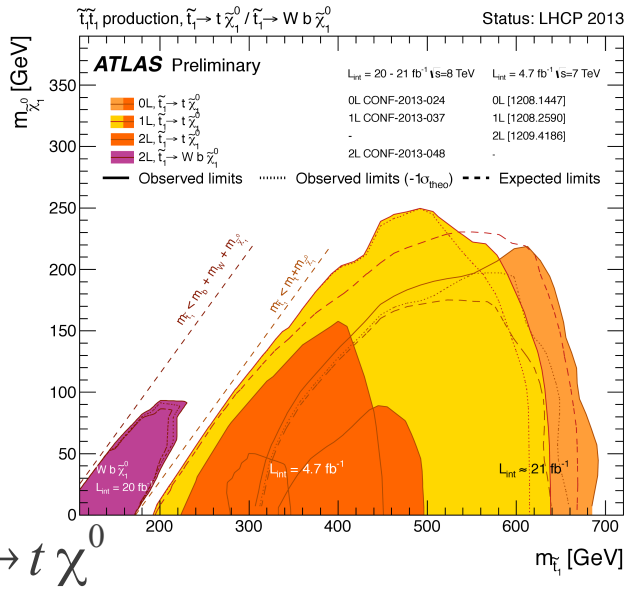


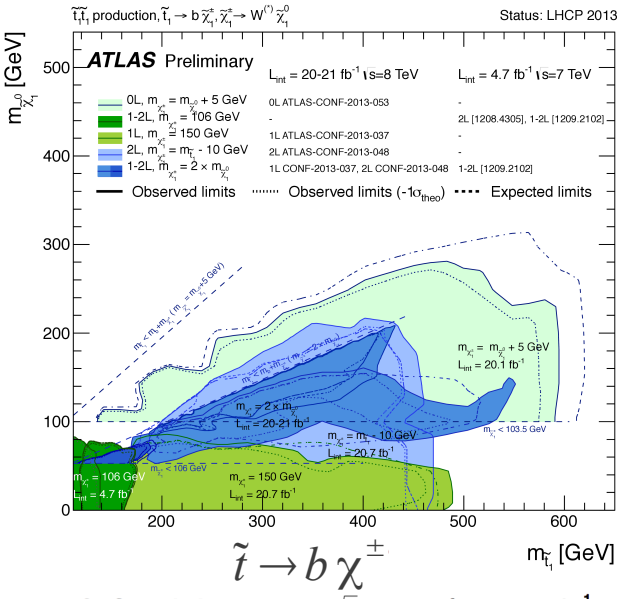


This analysis interpret the results also for nGMSB scenario

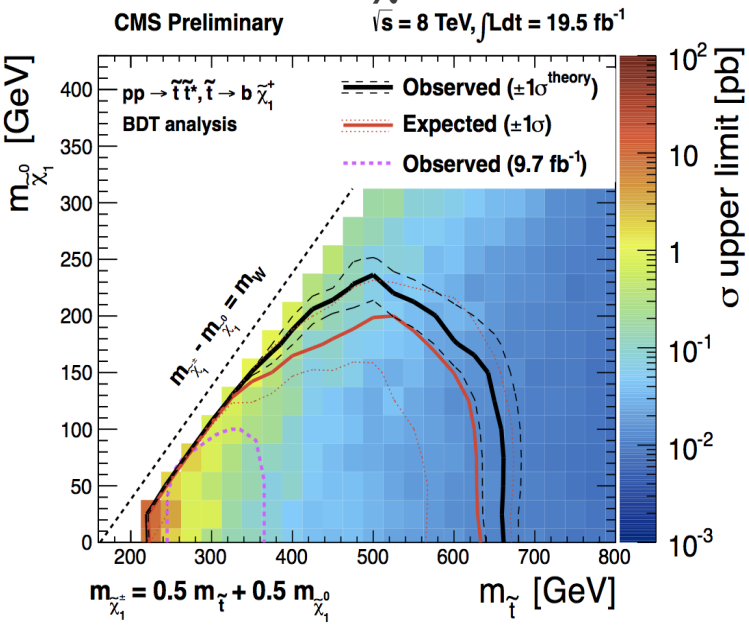
Summary Stop







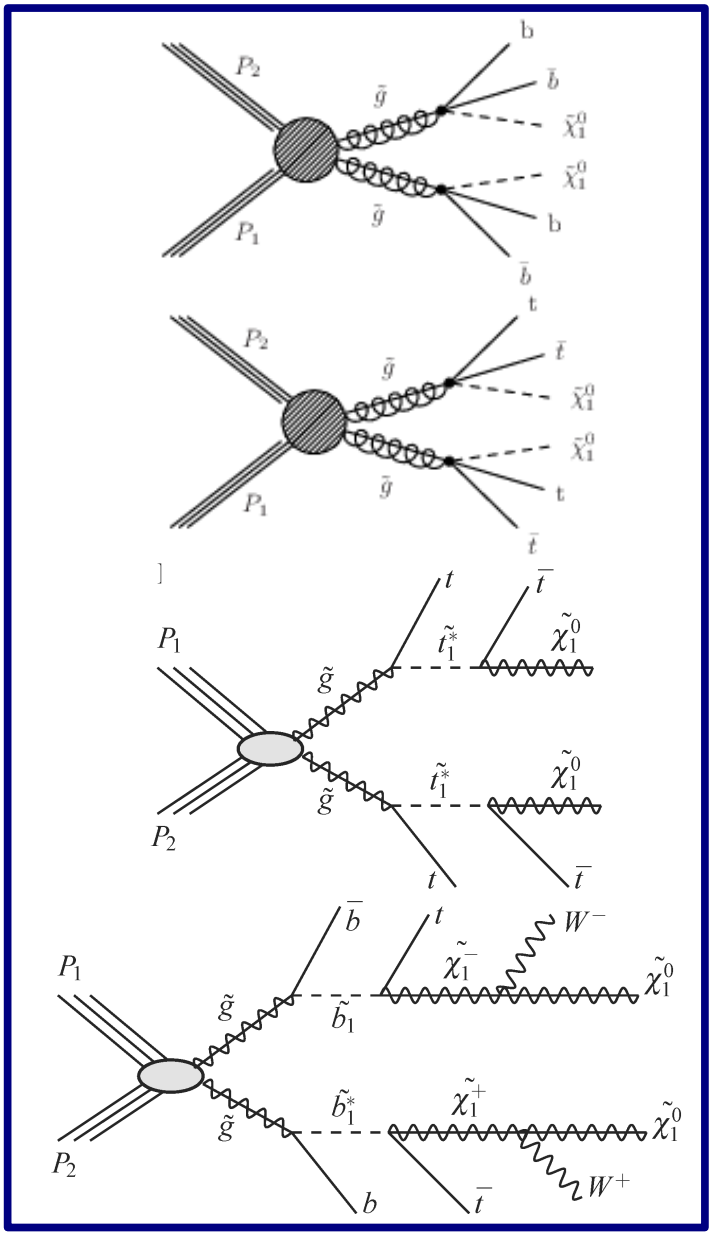
- Stop masses **probed up to ~650 GeV** by LHC in many channels and different models
  - (Natural) stop existence severely **constrained**
- Comparison between ATLAS and CMS in st → bχ± *not immediate*, be careful.



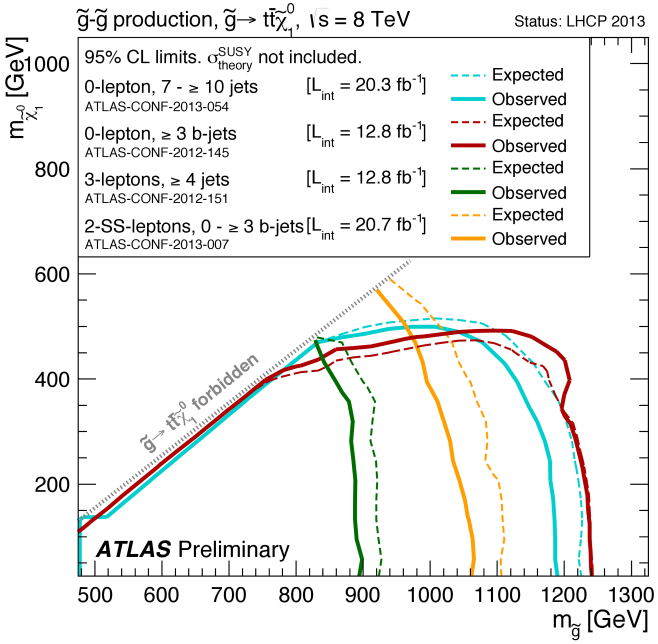
Gluino Mediated Sbottom/Stop Production

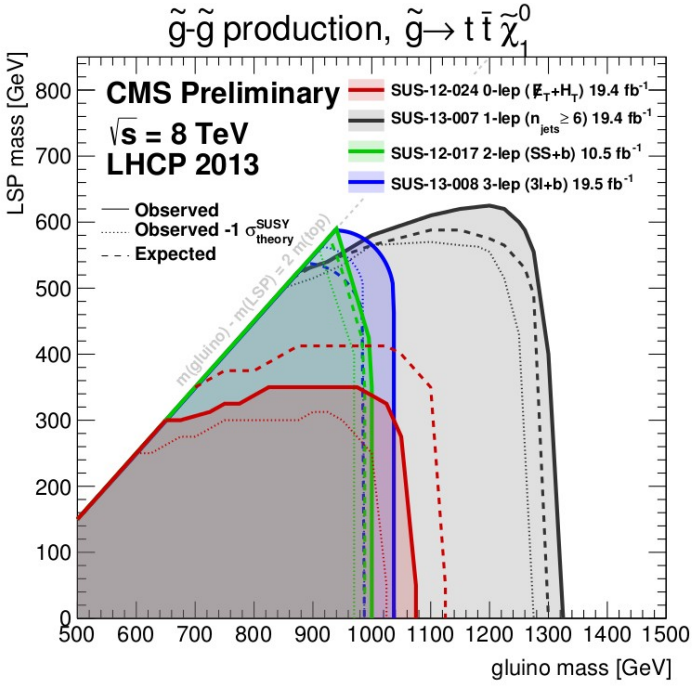
Analyses targeted this models

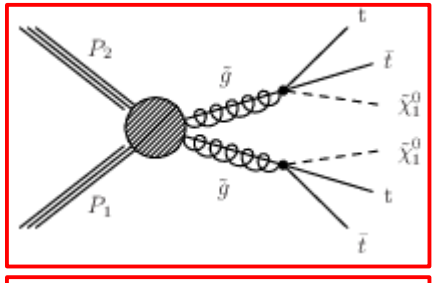
- 0 leptons + jets + (possibly) b-jets + MET
  - *ATLAS-CONF-2013-54 (7 – ≥10 jets)*
  - *ATLAS-CONF-2012-145 (≥3 b-jets)*
  - *CMS-SUS-12-024 (≥1 b-jets)*
- 1 lepton + b-jet + jets + MET
  - *CMS-SUS-13-007* **See also Marti's talk**
- 2 Same-sign leptons + jets + b-jets + MET
  - *ATLAS-CONF-2013-007*
  - *CMS-SUS-12-017*
- 3 leptons + jets + b-jets + MET
  - *ATLAS-CONF-2012-151*
  - *CMS-SUS-13-008*

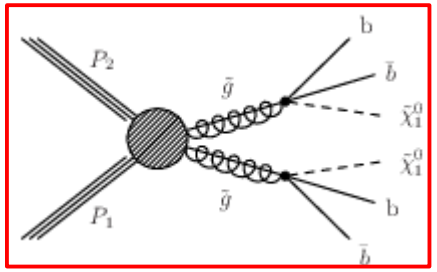


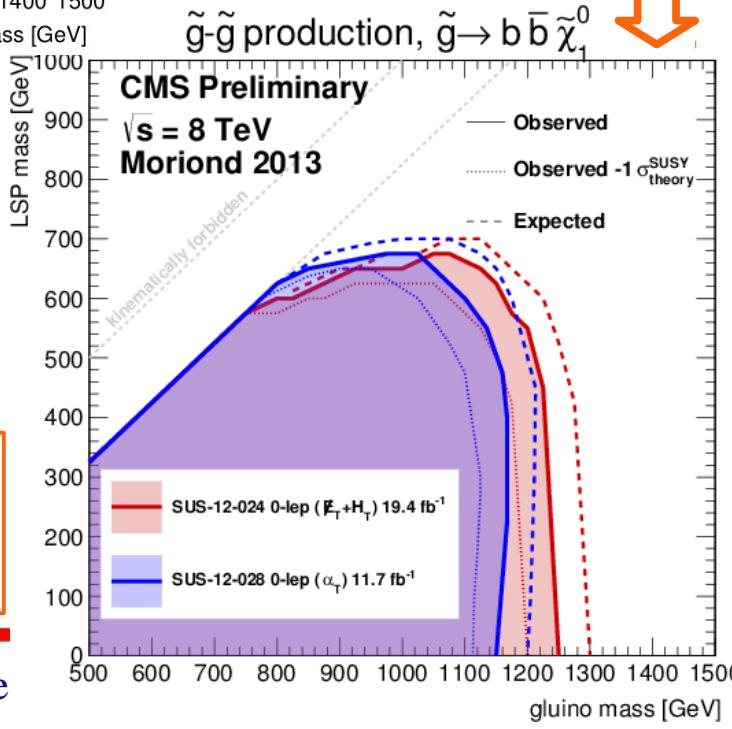
Gluino Mediated Sbottom/Stop Production
Off-shell











- Search for **4 bottoms/tops in final state**
- Sensitive to models in which the *squarks* (except 3rd generation) are much **heavier than the gluinos**.
- Depending on the decay of the stop/sbottom quarks, **several signatures are possible**

Multijets (> 5) + b-tagging + MET

- All hadronic or 1 lepton

Multiple W bosons decaying in leptons + jets and b-tagging

Gluino Mediated Sbottom/Stop Production
On-shell

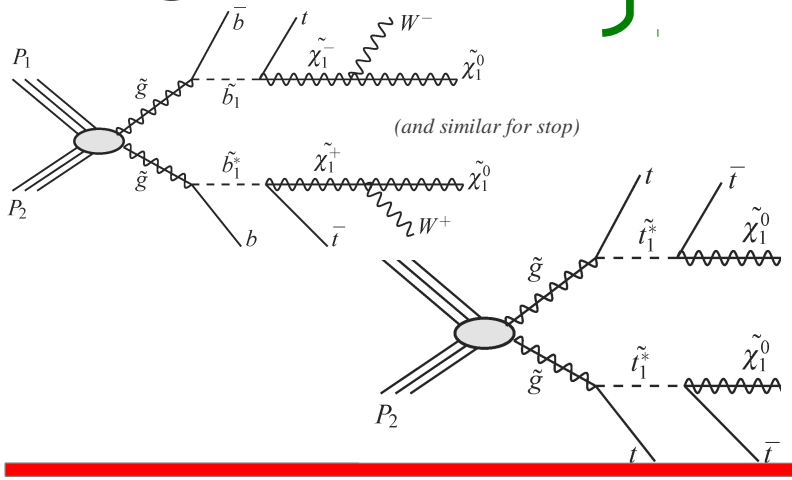
Results of ***CMS-SUS-13-008*** and ***ATLAS-CONF-2013-007/ 2013-047***, interpreted also in models where the $\tilde{b}$ or $\tilde{t}$ are produced **on-shell**.

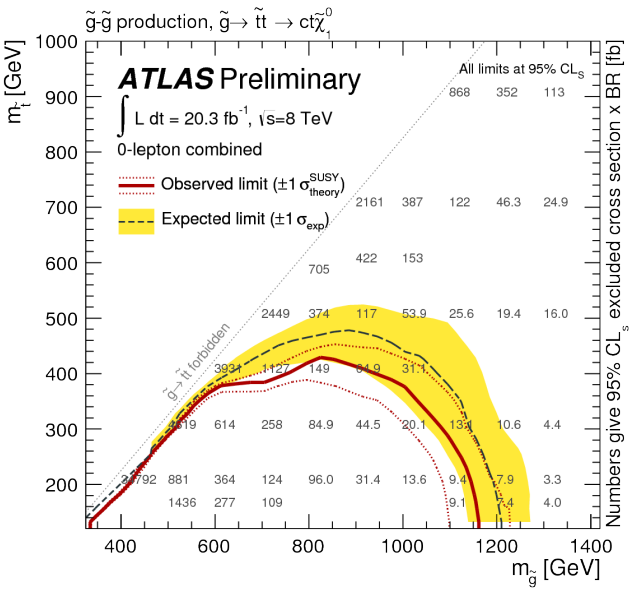
ATLAS

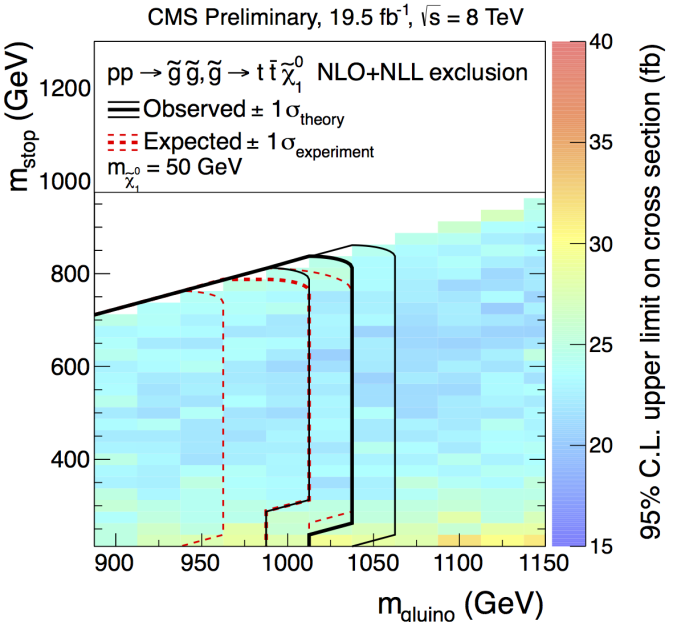
$$\tilde{g} \to t\,\tilde{t} \to tb\,\chi^{\pm}$$
$$\tilde{g} \to t\,\tilde{t} \to ct\,\chi^{0}$$

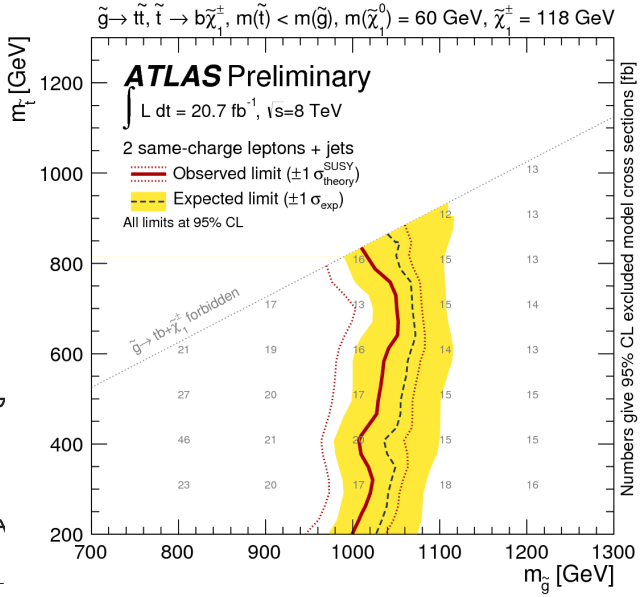
CMS

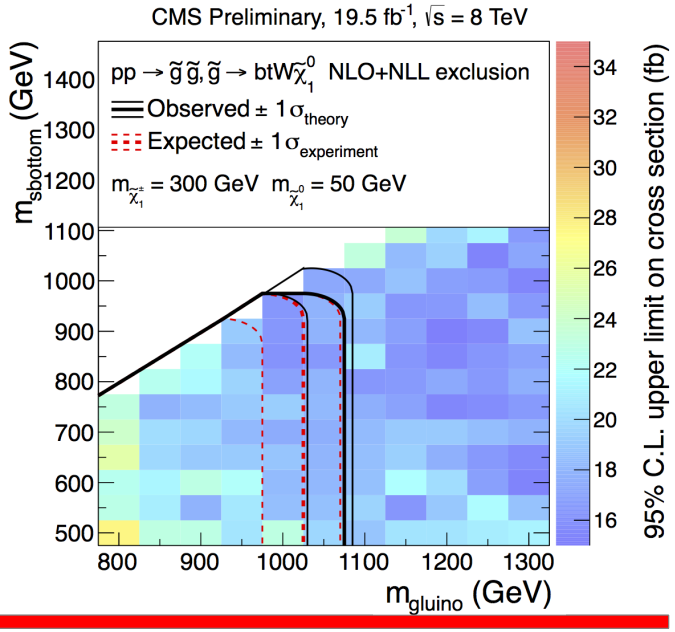
$$\tilde{g} \to t\,\tilde{t} \to tt\,\chi^{0}$$
$$\tilde{g} \to b\,\tilde{b} \to tb\,\chi^{\pm}$$



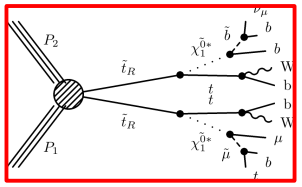


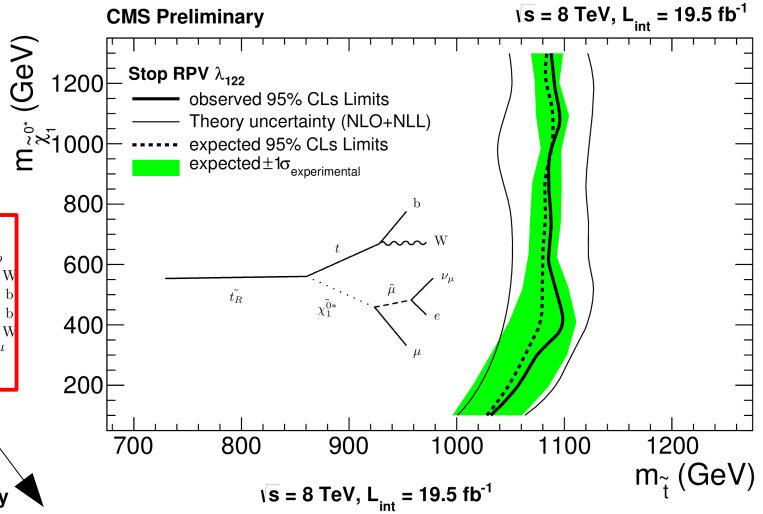


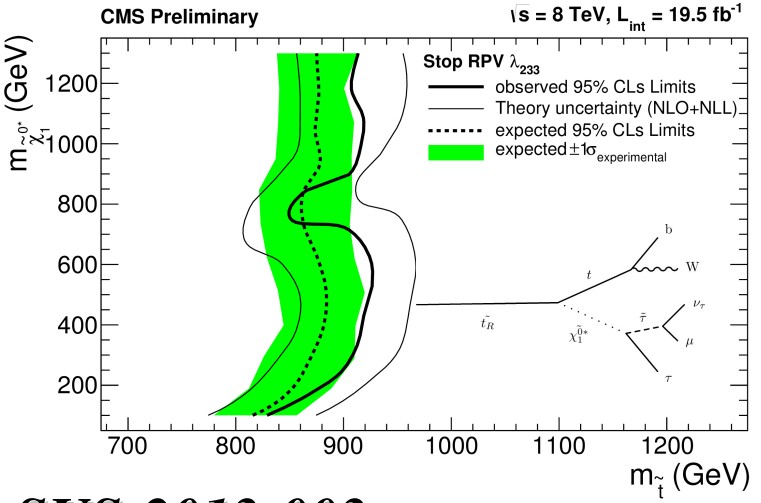


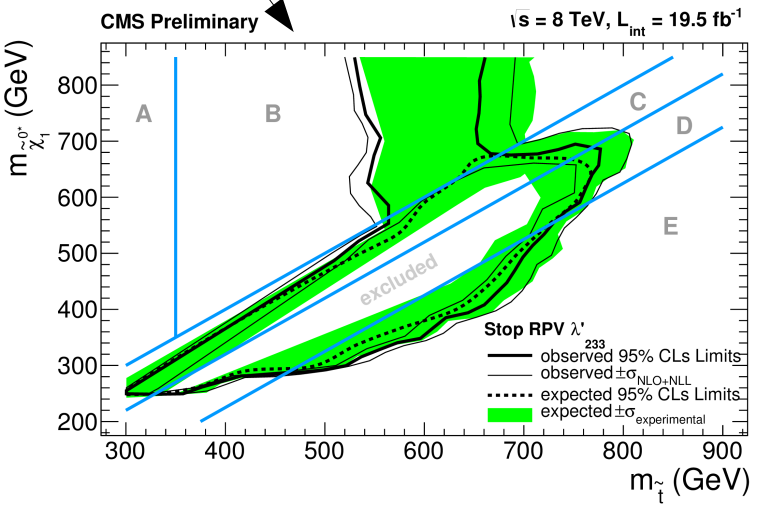


RPV Scenarios







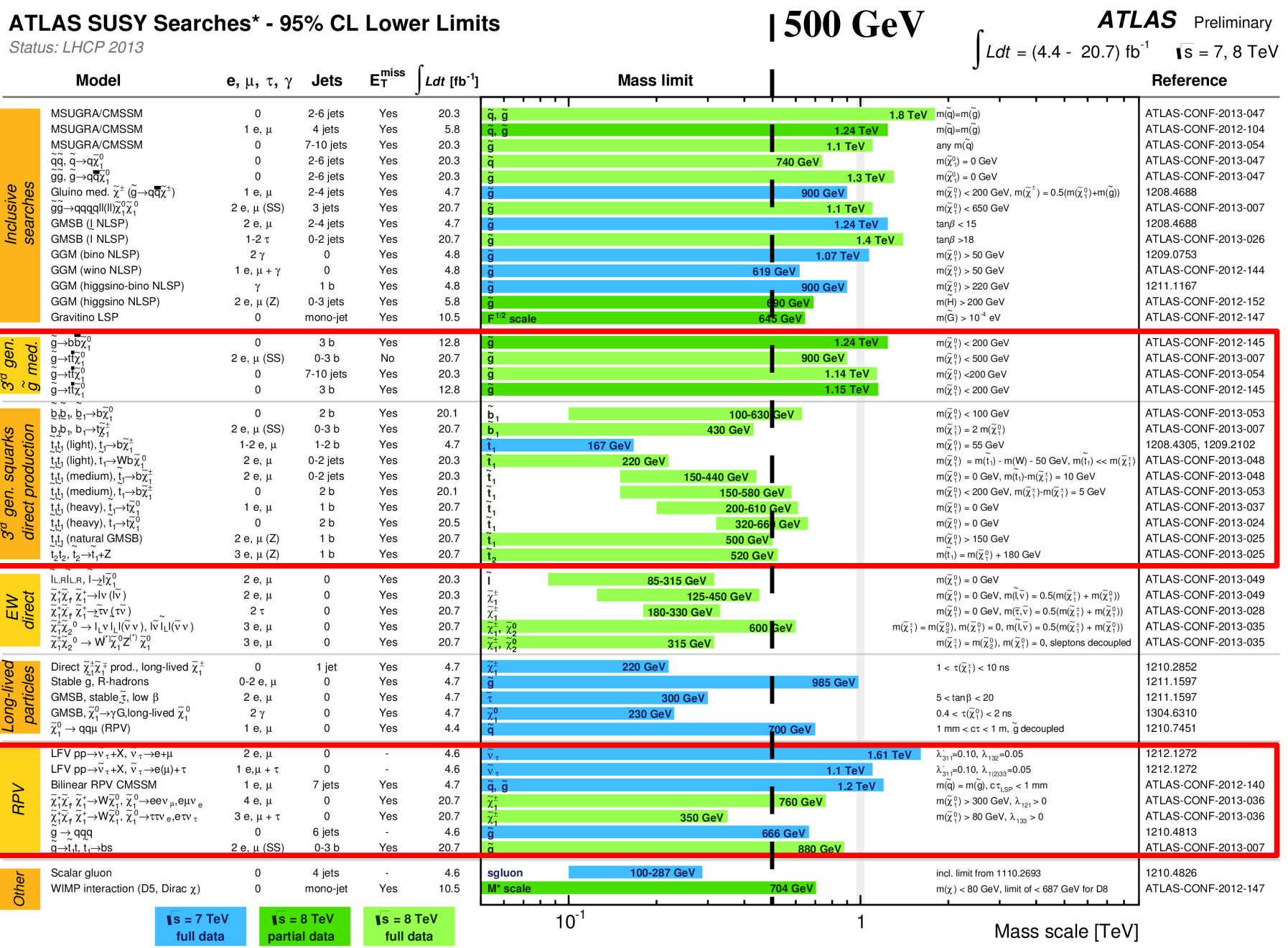


region label	kinematic region	stop decay mode(s)
A	$m_t < m_{\tilde{t}} < 2m_t, m_{\tilde{\chi}_1^0}$	$\tilde{t} \to t\nu b\bar{b}$
B	$2m_t < m_{\tilde{t}} < m_{\tilde{\chi}_1^0}$	$\tilde{t} \to t\mu t\bar{b} + t\nu b\bar{b}$
C	$m_{\tilde{\chi}_1^0} < m_{\tilde{t}} < m_W + m_{\tilde{\chi}_1^0}$	$\tilde{t} \to \ell\nu b\tilde{\chi}_1^0 + jjb\tilde{\chi}_1^0$
D	$m_W + m_{\tilde{\chi}_1^0} < m_{\tilde{t}} < m_t + m_{\tilde{\chi}_1^0}$	$\tilde{t} \to Wb\tilde{\chi}_1^0$
E	$m_t + m_{\tilde{\chi}_1^0} < m_{\tilde{t}}$	$\tilde{t} \to t\tilde{\chi}_1^0$

CMS-SUS-2013-003

- Several models investigated by both ATLAS (see ***ATLAS-CONF-2013-007***) and CMS.
- Final states requires **multi-leptons** (3 or more in case of the CMS analysis presented here, 2 SS for ATLAS analysis), **b-tagged jets** and missing energy. CMS uses S_T variable, also.
- Main background from diboson and V+jet where a fake lepton is reconstructed in the event

Summary (I)



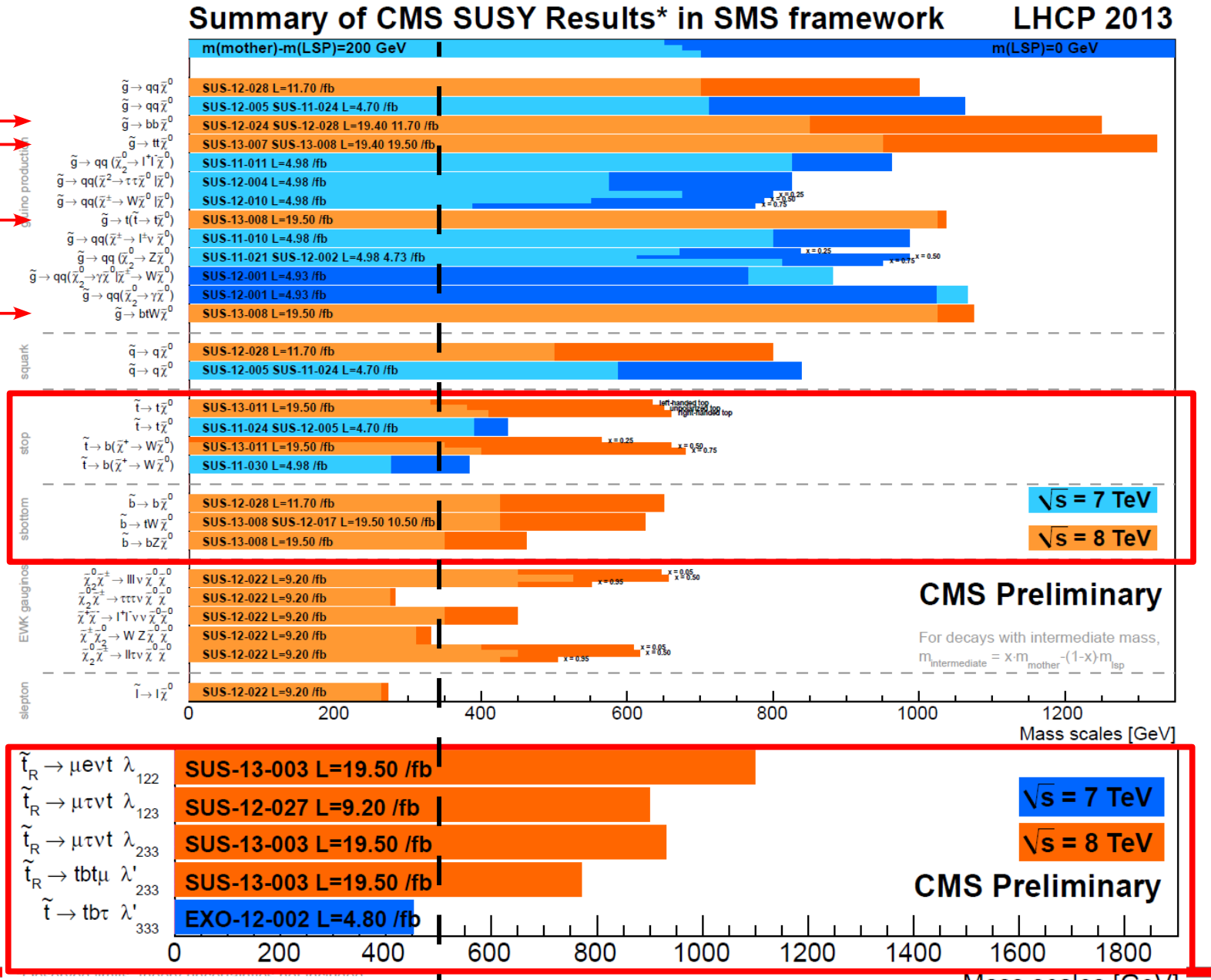
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Summary (II)

Gluino mediated summary

RPC summary

RPV summary



Conclusions

- ***Rich* LHC program** to discover the bottom and top super-partners
- 3rd Generation SUSY squark **constrained**
  - Sbottom and stop have been **probed up to 650 GeV** (depending on the decay)
- **Naturalness** under severe pressure
- More analyses on 8 TeV are in the pipe-line, should wait for those to say that the 8 TeV game is closed
- **Explore** missing corners with present data
- Looking forward to ***13-14 TeV***
  - Bigger samples and higher sqrt(s)

Details and many other results can be found in the public SUSY pages of the two experiments:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

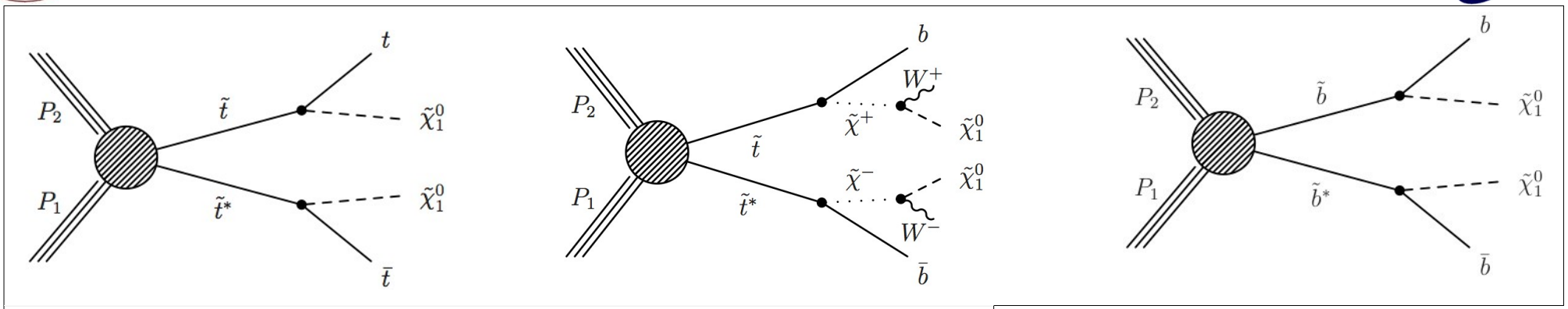
More Material

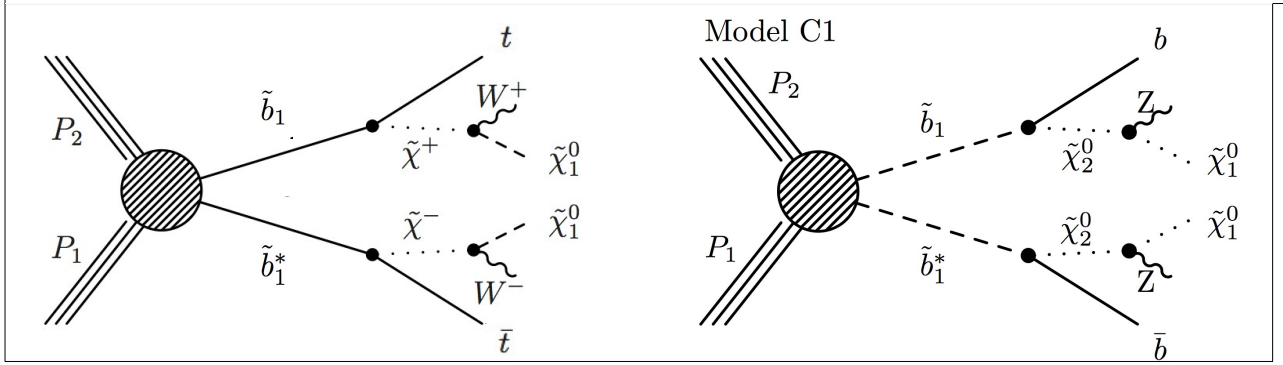
Sbottom/Top: 0 lep, 2b jets

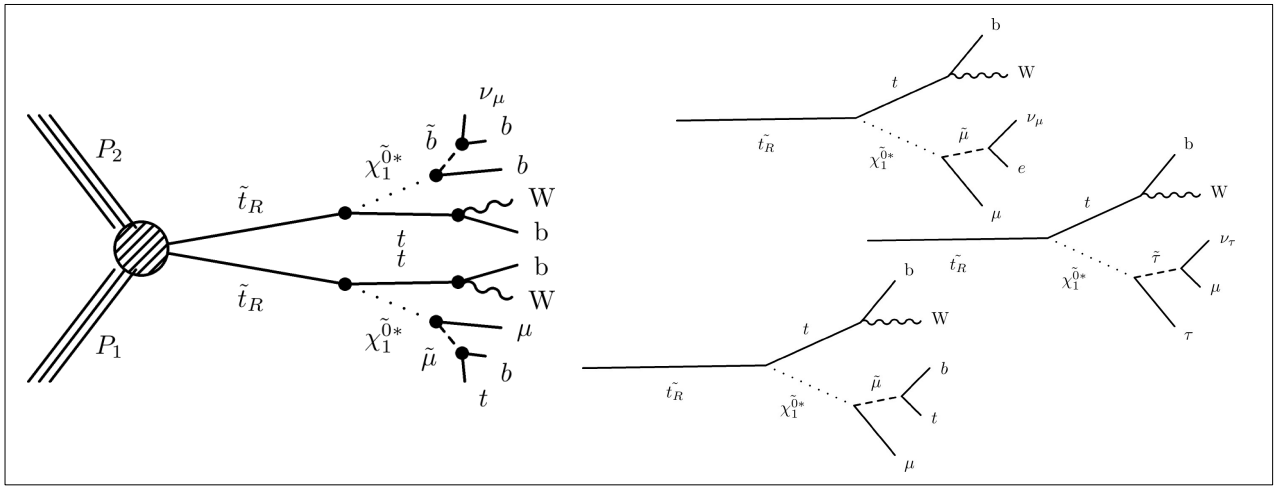
ATLAS-CONF-2013-053

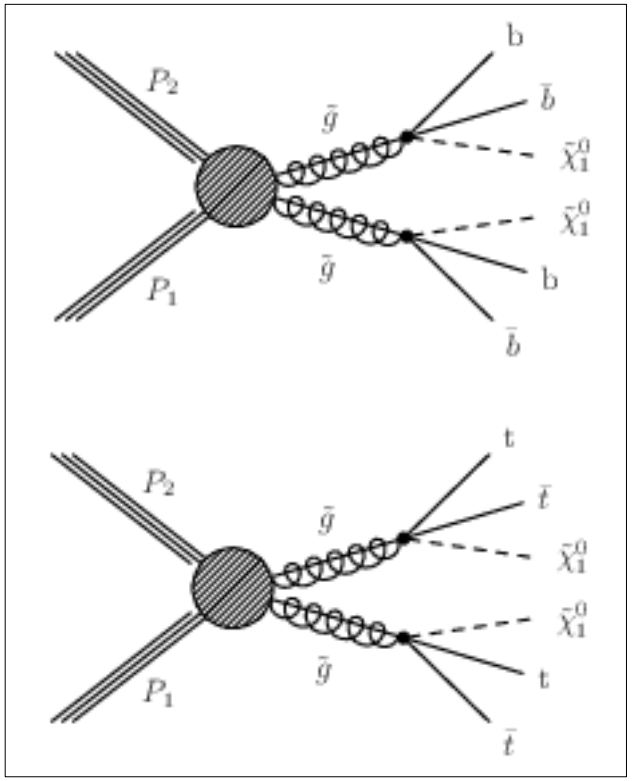
Signal Regions	Bkg. estimate	Obs. data	95% CL upper limit			
			on BSM event yield		on σ_{vis} (fb)	
			expected	observed	expected	observed
SRA (m_{CT} > 150 GeV)	92 ± 12	103	31^{+12}_{-8}	39.2	$1.5^{+0.6}_{-0.4}$	1.95
SRA (m_{CT} > 200 GeV)	38 ± 6	48	18^{+7}_{-5}	25.9	$0.89^{+0.35}_{-0.25}$	1.29
SRA (m_{CT} > 250 GeV)	15.3 ± 2.7	14	$10.0^{+4.6}_{-2.9}$	9.2	$0.50^{+0.23}_{-0.14}$	0.46
SRA (m_{CT} > 300 GeV)	5.8 ± 1.2	7	$6.5^{+3.3}_{-2.1}$	7.6	$0.32^{+0.16}_{-0.1}$	0.38
SRA (m_{CT} > 350 GeV)	2.6 ± 0.6	3	$4.7^{+2.6}_{-1.6}$	5.2	$0.23^{+0.13}_{-0.08}$	0.26
SRB	50 ± 9	58	24^{+9}_{-7}	30.0	$1.21^{+0.45}_{-0.35}$	1.49

A Rich Program

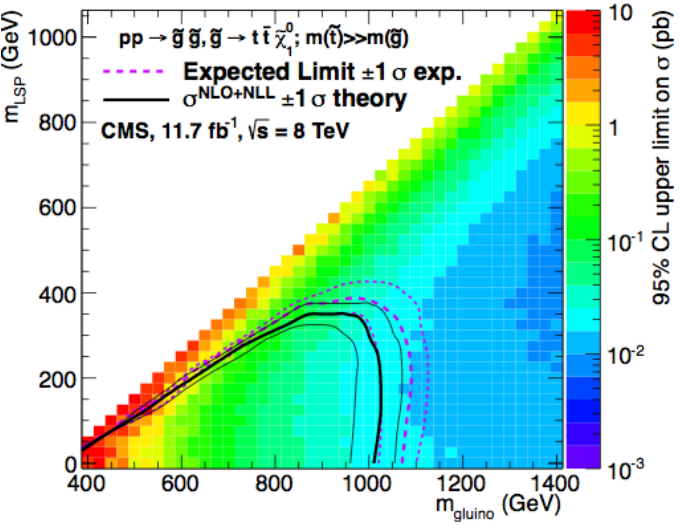


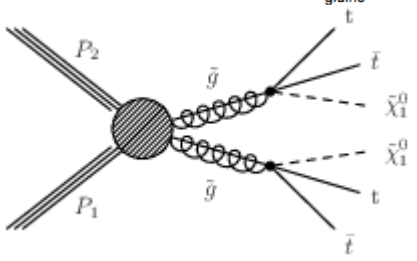


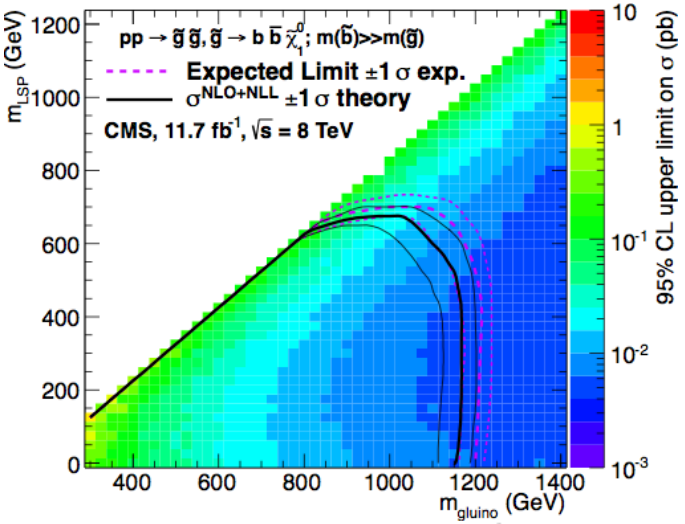


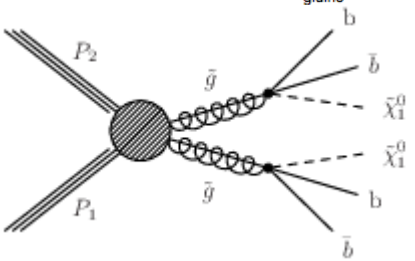


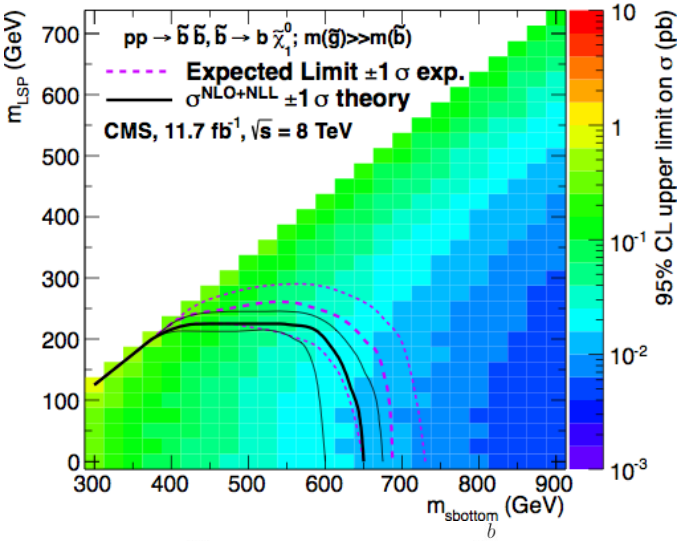
Direct Sbottom Production (α_T)

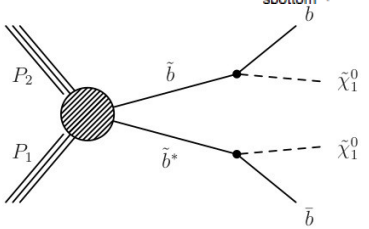


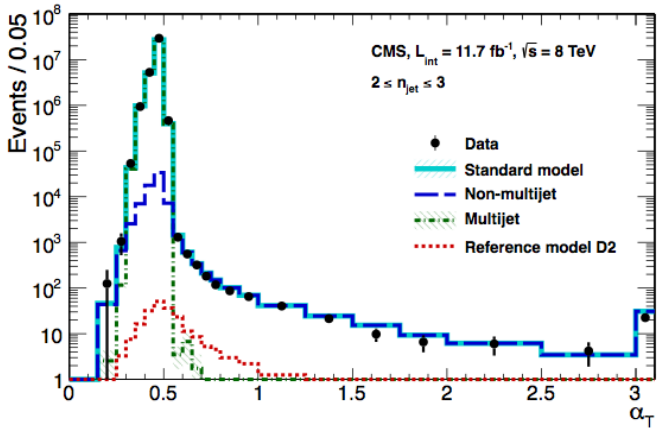










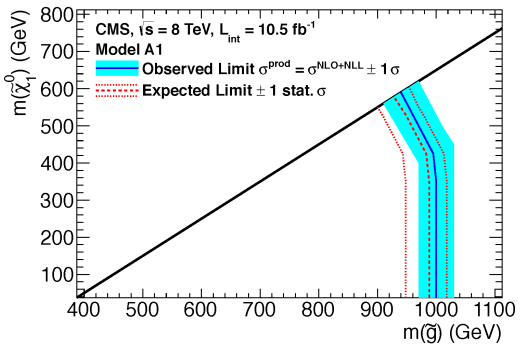


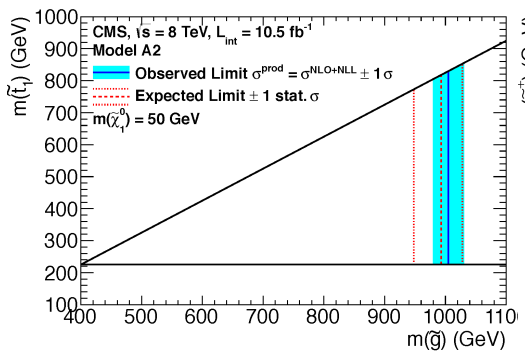
CMS-SUS-12-028

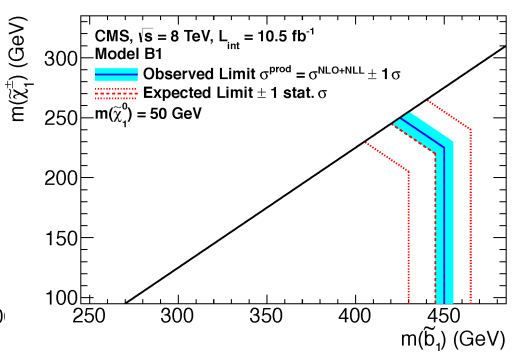
Direct and Indirect Sbottom Production

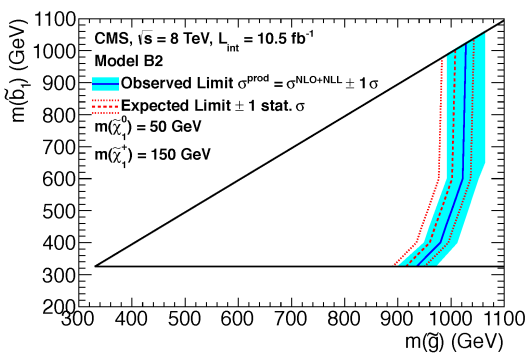
2 Same-sign leptons + jets + b-jets + MET

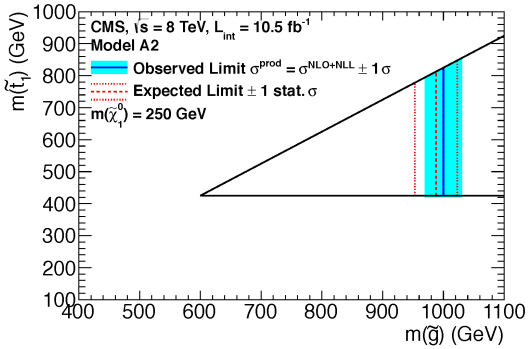
CMS-SUS-12-017

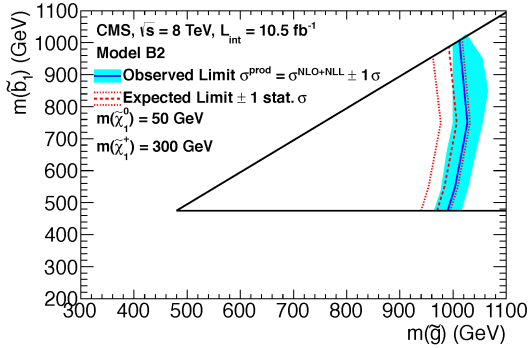


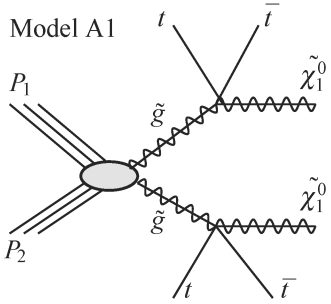


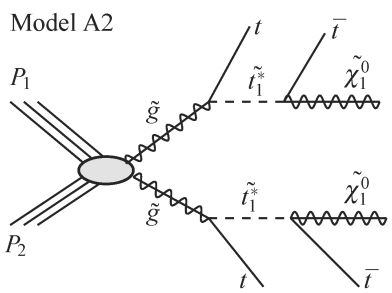


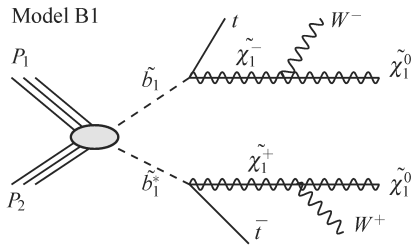


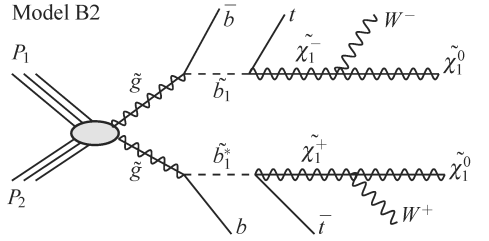












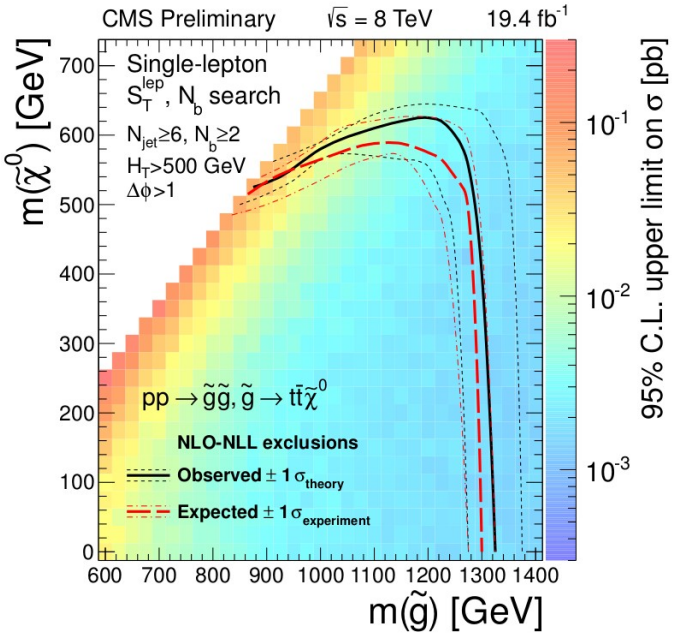
Gluino Mediated Sbottom/Stop Production

1 lepton + b-jet + jets + MET

2 complementary methods used:

1) Lepton Spectrum Method:

- Selection using MET , HT, Njets > 5
- Main background is semi-leptonic ttbar
- Charged lepton pT spectrum used to model MET



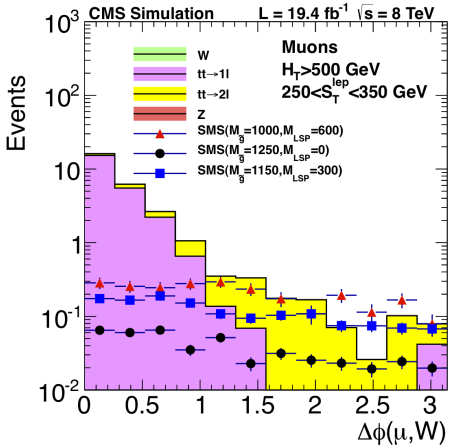
2) Δφ Method: CMS-SUS-13-007

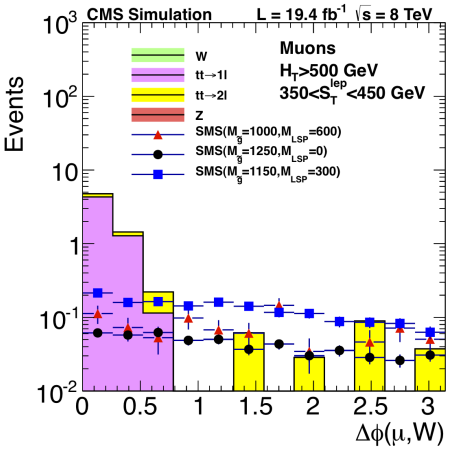
- Use the angle between W and lepton to together with ST

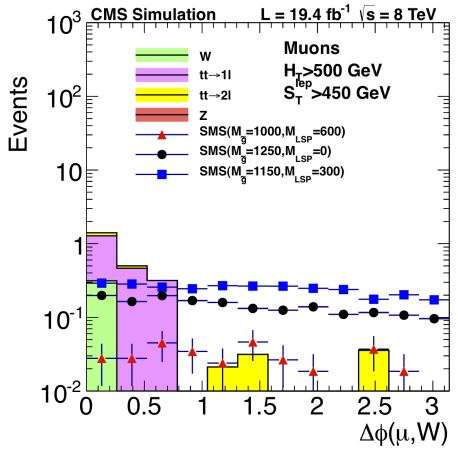
$$S_T^{lep} \equiv \sqrt{p_T(W)^2 + M_T(W)^2},$$

to suppress the background

- Δφ(W,l) gets small values for SM processes
- In SUSY Δφ(W,l) expected to remain flat
- Background is predicted using CR an a transfer factor from the small Δφ(W, l) to the signal region



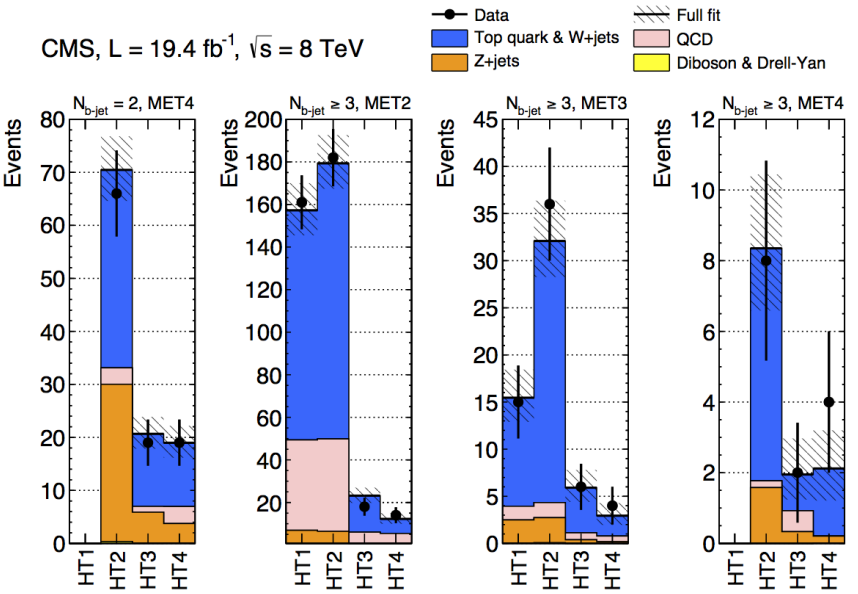




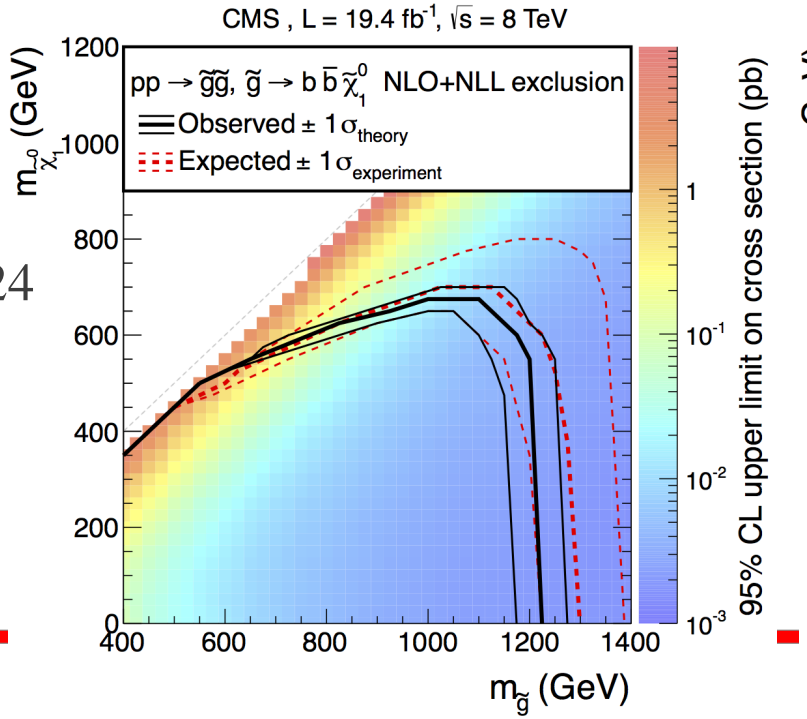
Gluino Mediated Sbottom/Stop Production

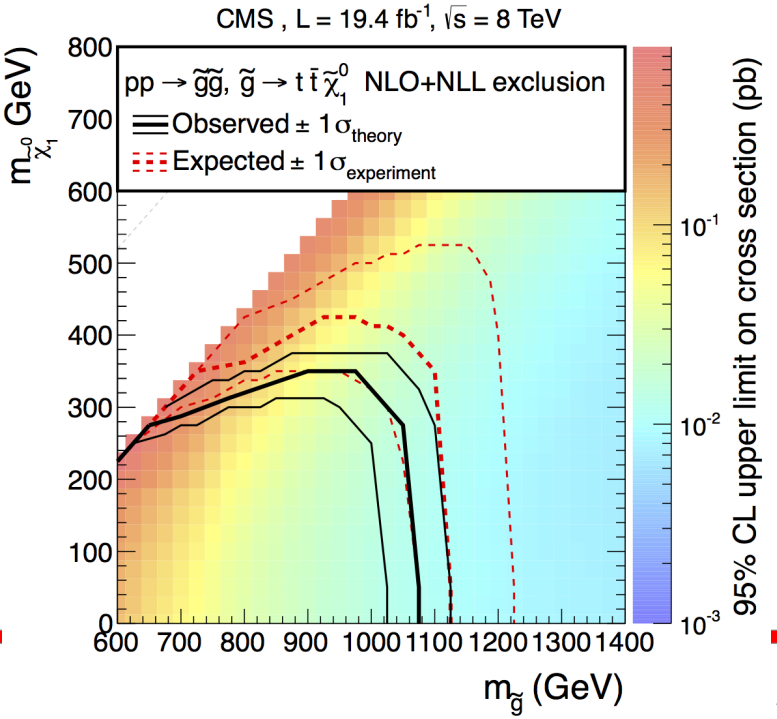
0 leptons + jets + (possibly) b-jets + MET

- **Veto leptons**, require at least **3 central jets** (p_T > 70,70,50,...,50 GeV), one of which **b-tagged**
- Largest background **ttbar and W+jets**, followed by **Z → inv** and QCD multijets
- Analysis performed in bins of **MET, HT and # b-jets** (4x4x3)
  - HT > 400 GeV, MET > 125 GeV



CMS-SUS-12-024





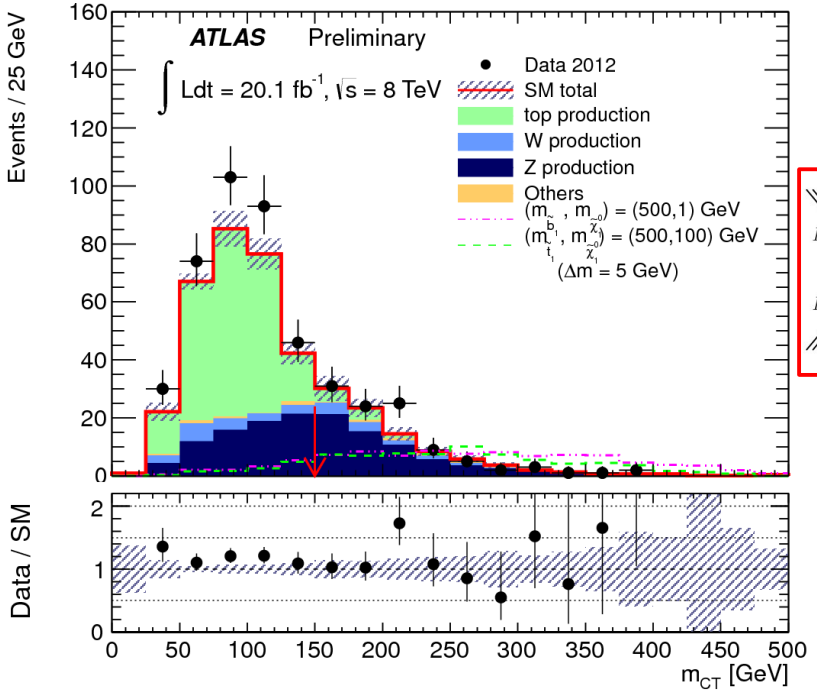
Sbottom: sb → bχ; 0 lept + 2 bjets

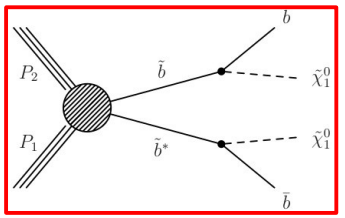
$$m_{CT}^2(v_1, v_2) = [E_T(v_1) + E_T(v_2)]^2 - [\mathbf{p}_T(v_1) - \mathbf{p}_T(v_2)]^2$$

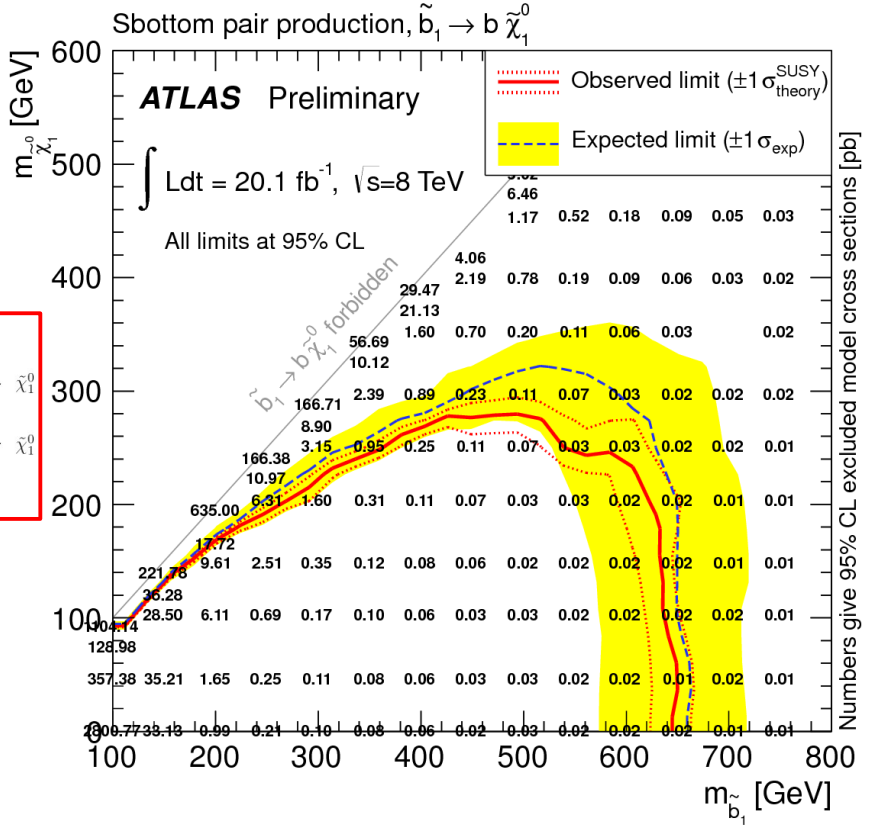
- Two search regions. A for large Δχ. B for low.
- Require 2 b-tagged jets, veto other activity in the event (leptons and jets). More stringent for SRB.
- Cut on m_{CT}, $H_{T,3}$ (upper cut), m_{bb}, MET, MET/$m_{eff}(j_{1,2(,3)})$

ATLAS-CONF-2013-053

Channel	SRA, m_{CT} selection					SRB
	150 GeV	200 GeV	250 GeV	300 GeV	350 GeV	
Observed	103	48	14	7	3	58
Total SM	92 ± 12	38 ± 6	15.3 ± 2.7	5.8 ± 1.2	2.6 ± 0.6	50 ± 9
Top production	11.3 ± 1.8	2.5 ± 1.4	0.45 ± 0.25	< 0.01	< 0.01	34 ± 7
Z production	64 ± 10	28 ± 5	11.1 ± 2.1	4.7 ± 0.9	2.0 ± 0.4	8 ± 3
W production	12 ± 6	4.6 ± 2.5	2.0 ± 1.1	1.0 ± 0.5	0.48 ± 0.27	5 ± 4
Others	4.3 ± 1.5	3.3 ± 1.3	1.8 ± 0.6	0.12 ± 0.11	$0.10^{+0.12}_{-0.10}$	1.5 ± 0.7
Multijet production	0.21 ± 0.21	0.06 ± 0.06	0.02 ± 0.02	< 0.01	< 0.01	0.2 ± 0.2

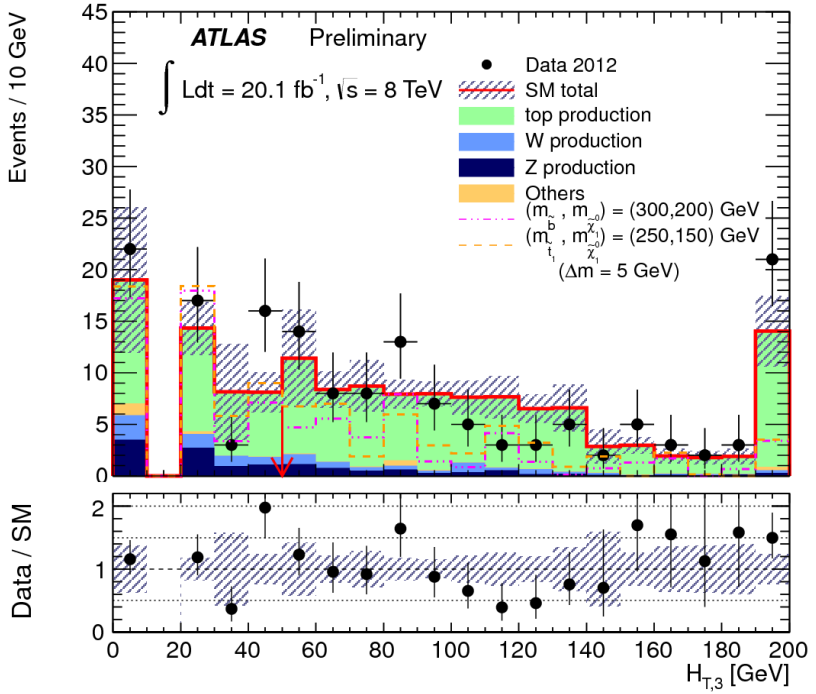






Sbottom: sb → bχ; 0 lept + 2 bjets

Description	Signal Regions	
	SRA	SRB
Trigger	E_T^{miss} > 150 GeV	
Event cleaning	Common to all SR	
Lepton veto	No e/μ after overlap removal with p_T > 7(6) GeV for $e(\mu)$.	
E_T^{miss}	> 150 GeV	> 250 GeV
Leading jet $p_T(j_1)$	> 130 GeV, $\|\eta\|$ < 2.8	> 150 GeV, $\|\eta\|$ < 2.8
Second jet $p_T(j_2)$	> 50 GeV, $\|\eta\|$ < 2.8	> 40 GeV, $\|\eta\|$ < 2.8
Third jet $p_T(j_3)$	veto if > 50 GeV, $\|\eta\|$ < 2.8	> 40 GeV, $\|\eta\|$ < 2.8
$\Delta\phi(\mathbf{p}_T^{miss}, j_1)$	-	> 2.5
b-jet multiplicity	leading 2 jets (p_T > 50 GeV, $\|\eta\|$ < 2.5)	2nd- and 3rd-leading jets (p_T > 40GeV, $\|\eta\|$ < 2.5)
	$n_{b\text{-jets}} = 2$	
$\Delta\phi_{min}$	> 0.4	> 0.4
$E_T^{miss}/m_{\text{eff}}(j_1, j_2, (j_3))$	> 0.25 (2 jets)	> 0.25 (3 jets)
m_{CT}	> 150, 200, 250, 300, 350 GeV	-
$H_{T,3}$	-	< 50 GeV
m_{bb}	> 200 GeV	-



ATLAS-CONF-2013-053

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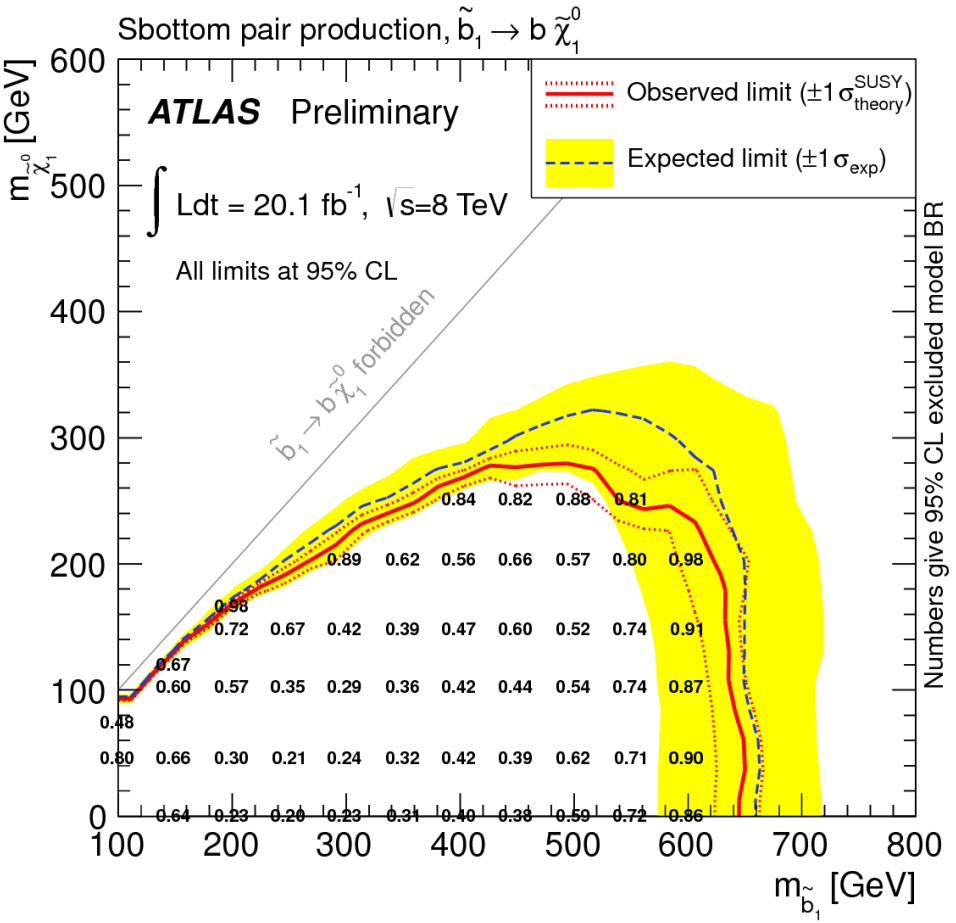
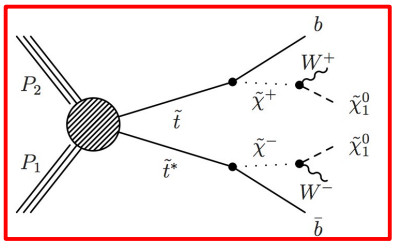
Top production	11.3 ± 1.8	2.5 ± 1.4	0.45 ± 0.25	< 0.01	< 0.01	34 ± 7
Z production	64 ± 10	28 ± 5	11.1 ± 2.1	4.7 ± 0.9	2.0 ± 0.4	8 ± 3
W production	12 ± 6	4.6 ± 2.5	2.0 ± 1.1	1.0 ± 0.5	0.48 ± 0.27	5 ± 4
Others	4.3 ± 1.5	3.3 ± 1.3	1.8 ± 0.6	0.12 ± 0.11	$0.10^{+0.12}_{-0.10}$	1.5 ± 0.7
Multijet production	0.21 ± 0.21	0.06 ± 0.06	0.02 ± 0.02	< 0.01	< 0.01	0.2 ± 0.2

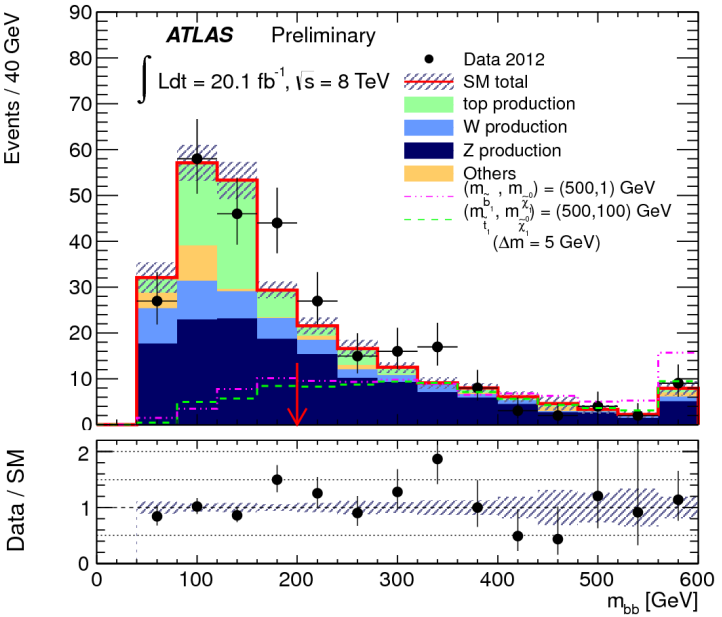


Direct Stop Production
0 leptons + 2 b-jets + MET

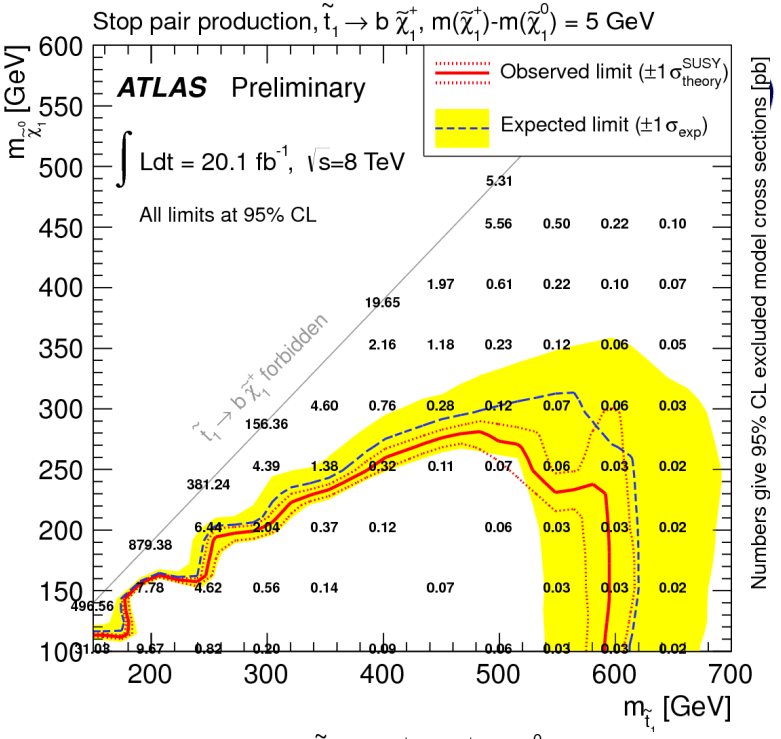
ATLAS-CONF-2013-053

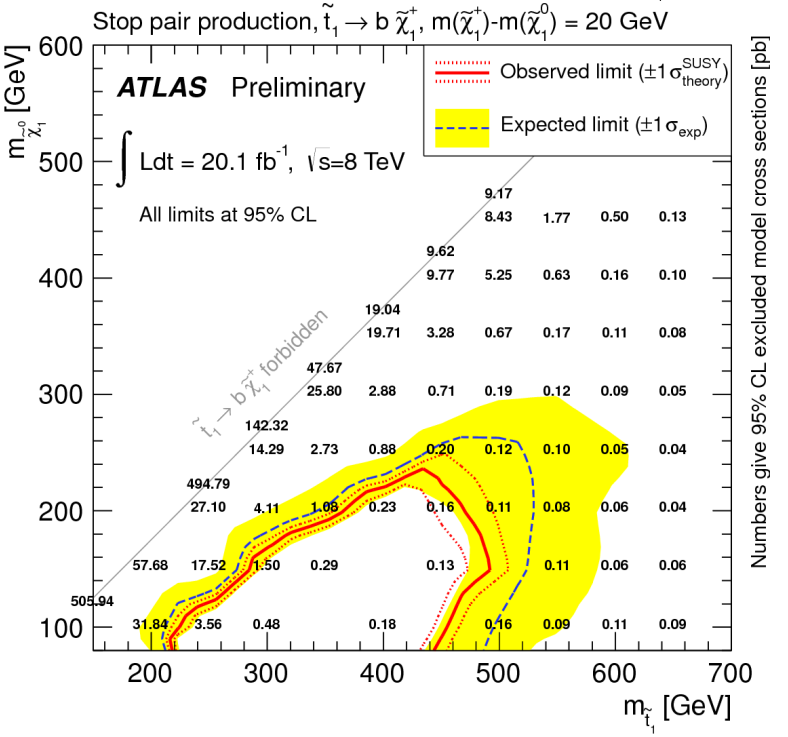


- This analysis is also interpreted in direct stop production model, where stop decays to a b and a chargino



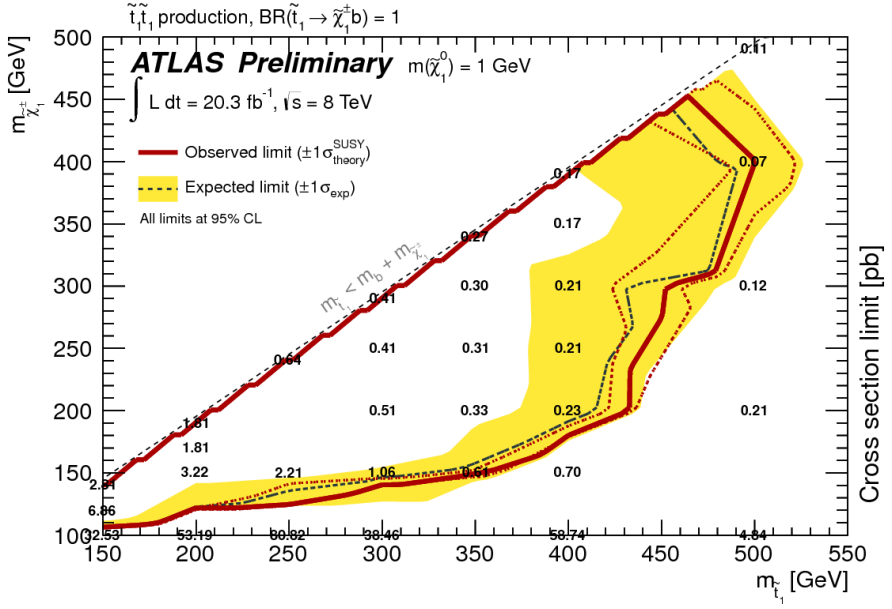
Channel	SRA, m_{CT} selection					SRB
	150 GeV	200 GeV	250 GeV	300 GeV	350 GeV	
Observed	103	48	14	7	3	58
Total SM	92 ± 12	38 ± 6	15.3 ± 2.7	5.8 ± 1.2	2.6 ± 0.6	50 ± 9
Top production	11.3 ± 1.8	2.5 ± 1.4	0.45 ± 0.25	< 0.01	< 0.01	34 ± 7
Z production	64 ± 10	28 ± 5	11.1 ± 2.1	4.7 ± 0.9	2.0 ± 0.4	8 ± 3
W production	12 ± 6	4.6 ± 2.5	2.0 ± 1.1	1.0 ± 0.5	0.48 ± 0.27	5 ± 4
Others	4.3 ± 1.5	3.3 ± 1.3	1.8 ± 0.6	0.12 ± 0.11	$0.10^{+0.12}_{-0.10}$	1.5 ± 0.7
Multijet production	0.21 ± 0.21	0.06 ± 0.06	0.02 ± 0.02	< 0.01	< 0.01	0.2 ± 0.2

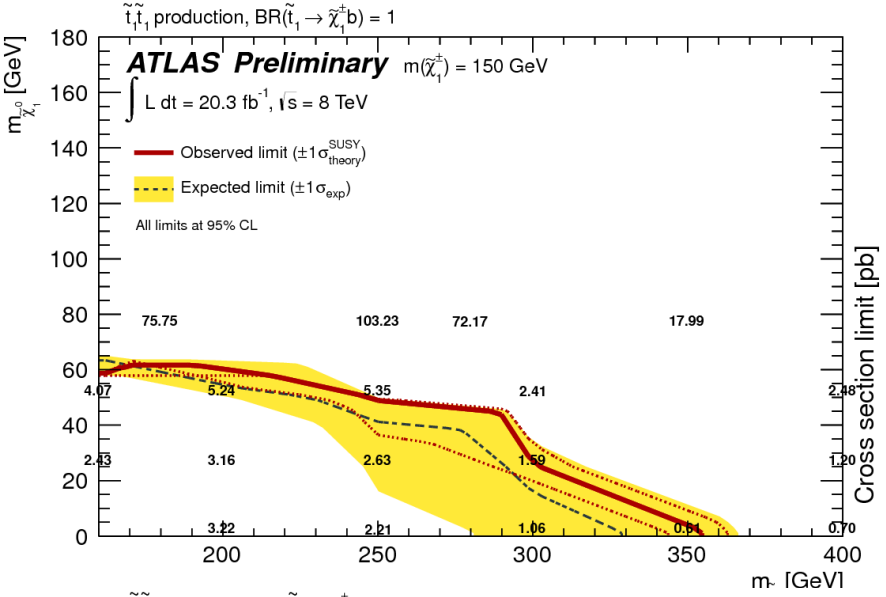


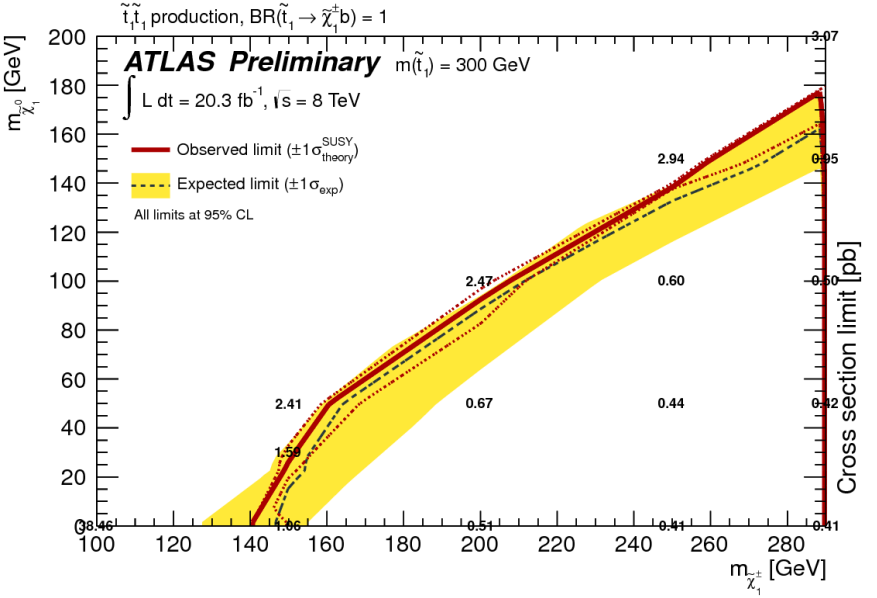


Direct Stop Production
2 OS leptons + jets + MET

ATLAS-CONF-2013-048







	M90	M100	M110	M120
jet energy scale and resolution	6%	22%	7%	5%
cluster energy scale and resolution	5%	24%	5%	5%
pile-up	6%	6%	3%	7%
diboson generator	3%	4%	8%	14%
top generator	3%	6%	11%	5%
top ISR/FSR	2%	6%	1%	5%
top parton shower	4%	19%	27%	7%
samples size	3%	17%	11%	19%
$t\bar{t}$ normalization	3%	4%	1%	0%
WW normalization	4%	2%	2%	2%
WZ/ZZ normalization	1%	0%	1%	2%
Fake-lepton uncertainties	2%	0%	1%	2%
Total uncertainty	12%	46%	35%	28%

Direct Sbottom Production

2 same-sign leptons + 0-3 b-jets + MET

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

Signal region	N_{b-jets}	Signal cuts (discovery case)	Signal cuts (exclusion case)
SR0b	0	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV, $m_T > 100$ GeV, $m_{eff} > 400$ GeV	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV, $m_T > 100$ GeV, binned shape fit in m_{eff} for $m_{eff} > 300$ GeV
SR1b	≥1	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV, $m_T > 100$ GeV, $m_{eff} > 700$ GeV	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV, $m_T > 100$ GeV, binned shape fit in m_{eff} for $m_{eff} > 300$ GeV
SR3b	≥3	$N_{jets} \geq 4$	$N_{jets} \geq 5$, $E_T^{miss} < 150$ GeV or $m_T < 100$ GeV

For compress spectra

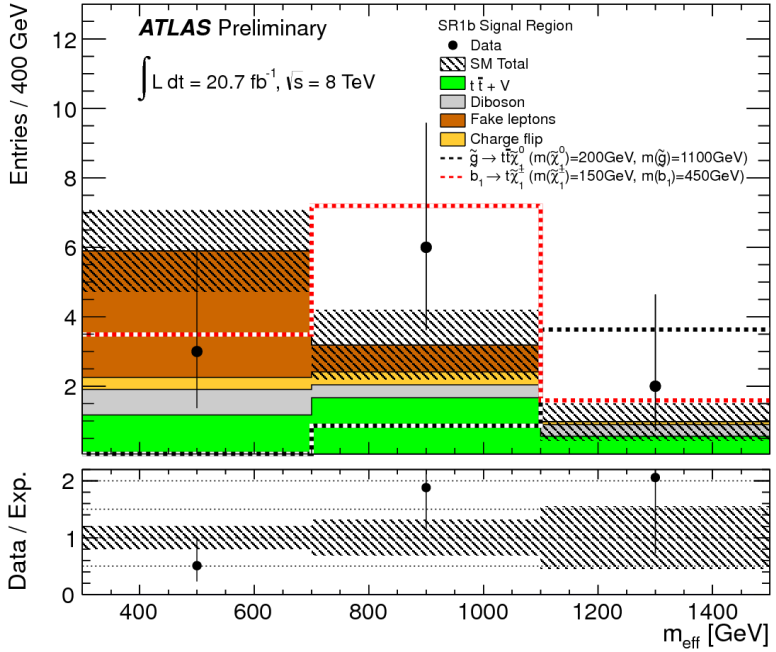
Require **2 same-sign leptons**

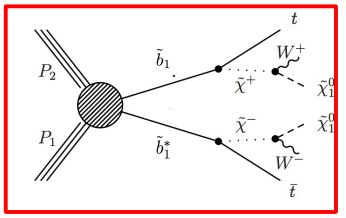
ATLAS-CONF-2013-007

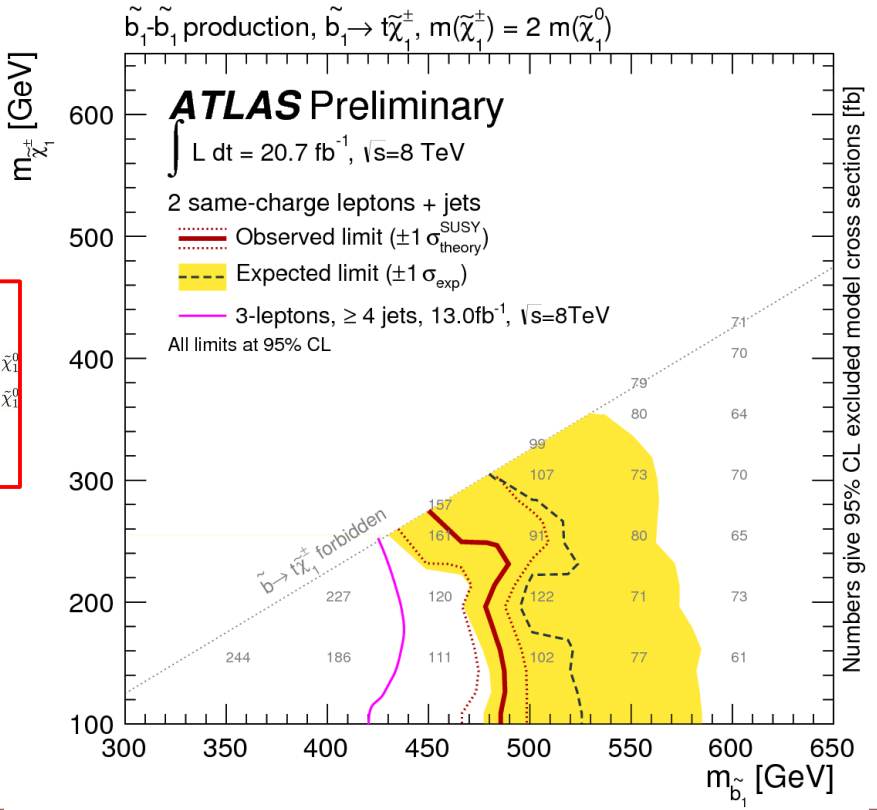
B) Exclusion case	SR0b	SR1b	SR3b
Observed events	5	11	1
Expected background events	7.5 ± 3.2	10.1 ± 3.9	1.8 ± 1.3
Expected $t\bar{t} + V$ events	0.5 ± 0.4	3.4 ± 1.5	0.6 ± 0.4
Expected diboson events	3.4 ± 1.1	1.4 ± 0.7	< 0.1
Expected fake lepton events	3.4 ± 2.9	4.4 ± 3.1	1.0 ± 1.1
Expected charge mis-measurement events	0.2 ± 0.1	0.8 ± 0.3	0.1 ± 0.1

UL 95% on $\epsilon\sigma$(fb) = 0.33, 0.53, 0.34

- Signature interesting for many SUSY models (as gluino is a Majorana fermion)







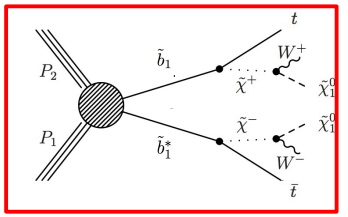
Direct Sbottom Production

3 leptons + ≥1 b-jet + MET

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

Variable	Baseline	Search Regions		
Sign/Flavor	3 e/μ	On-Z	Off-Z	
$N_{b\text{-jets}}$	≥ 1	1	2	≥ 3
N_{jets}	≥ 2	2–3	≥ 4	
H_T (GeV)	≥ 60	60–200	≥ 200	
E_T^{miss} (GeV)	≥ 50	50–100	100–200	≥ 200

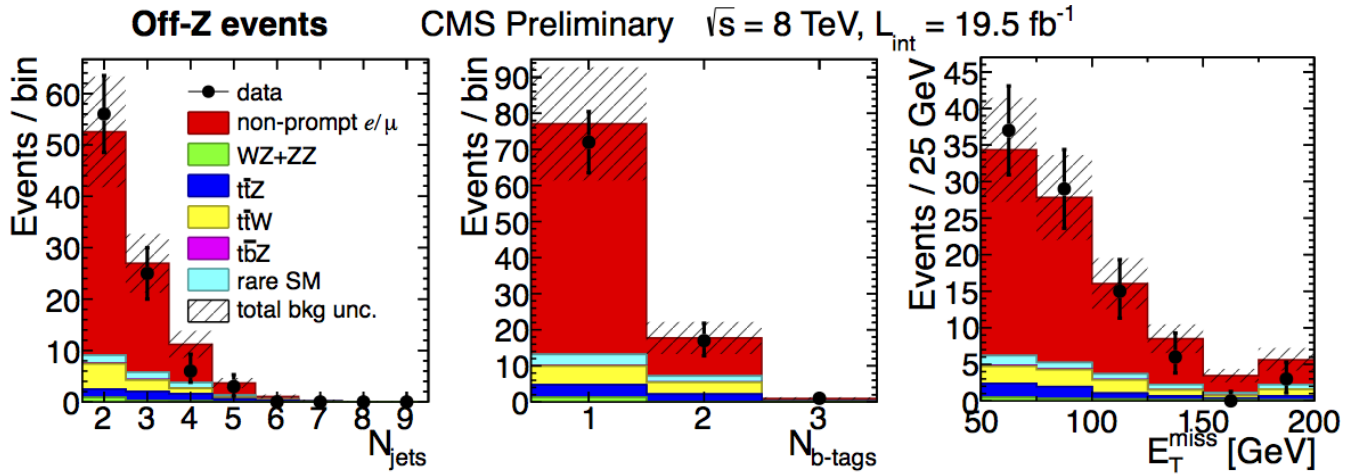
CMS-SUS-13-008

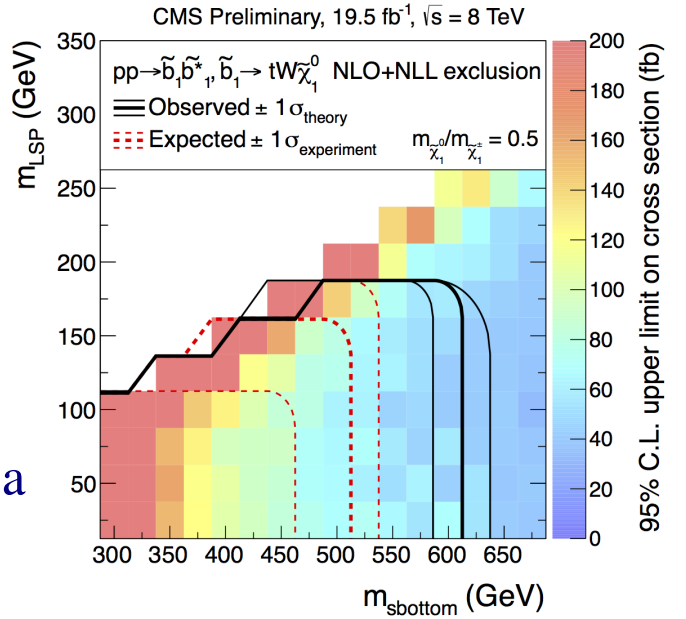


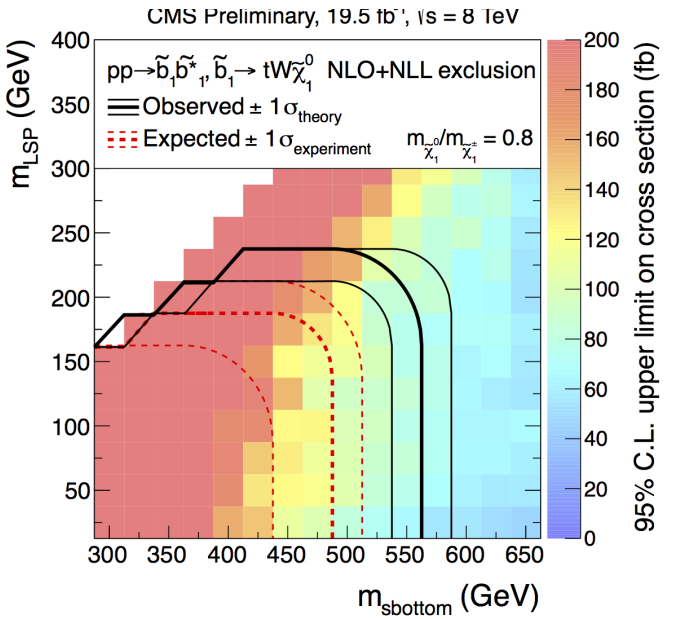
$N_{b\text{-tags}}$	N_{jets}	E_T^{miss} (GeV)	H_T < 200 GeV		H_T > 200 GeV	
			Expected	Observed	Expected	Observed
1	2–3	50–100	33.3 ± 7.0	36	10.9 ± 2.4	9
		100–200	11.8 ± 2.6	13	9.0 ± 2.0	6
		≥200	0.33 ± 0.21	0	1.2 ± 0.4	0
	≥4	50–100	0.92 ± 0.36	2	5.3 ± 1.3	3
		100–200	0.10 ± 0.12	0	3.5 ± 1.0	3
		≥200	< 0.09	0	0.74 ± 0.31	0
2	2–3	50–100	4.7 ± 1.9	7	3.8 ± 1.1	7
		100–200	2.2 ± 0.7	1	1.9 ± 0.7	0
		≥200	0.22 ± 0.19	1	0.14 ± 0.13	0
	≥4	50–100	< 0.13	0	2.7 ± 0.8	1
		100–200	< 0.16	0	1.7 ± 0.6	0
		≥200	< 0.09	0	0.33 ± 0.18	0
≥3		50–100	< 0.09	0	0.56 ± 0.27	1
		100–200	< 0.12	0	0.17 ± 0.13	0
		≥200	< 0.09	0	0.20 ± 0.19	0

Divide the 3 lepton samples in two categories, depending if a pair of same flavour leptons has $\mathbf{m_{ll} \sim m_Z}$

Off-shell Z case







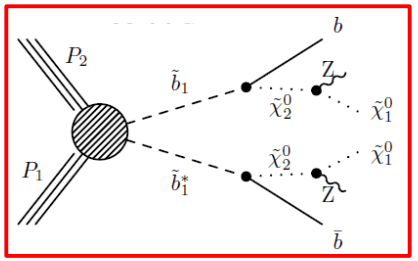
Direct Sbottom Production

3 leptons + ≥1 b-jet + MET $\tilde{b} \to b\chi_2^0 \to bZ\chi_1^0$

Variable	Baseline	Search Regions		
Sign/Flavor	3 e/μ	On-Z	Off-Z	
$N_{b\text{-jets}}$	≥ 1	1	2	≥ 3
N_{jets}	≥ 2	2–3	≥ 4	
H_T (GeV)	≥ 60	60–200	≥ 200	
E_T^{miss} (GeV)	≥ 50	50–100	100–200	≥ 200

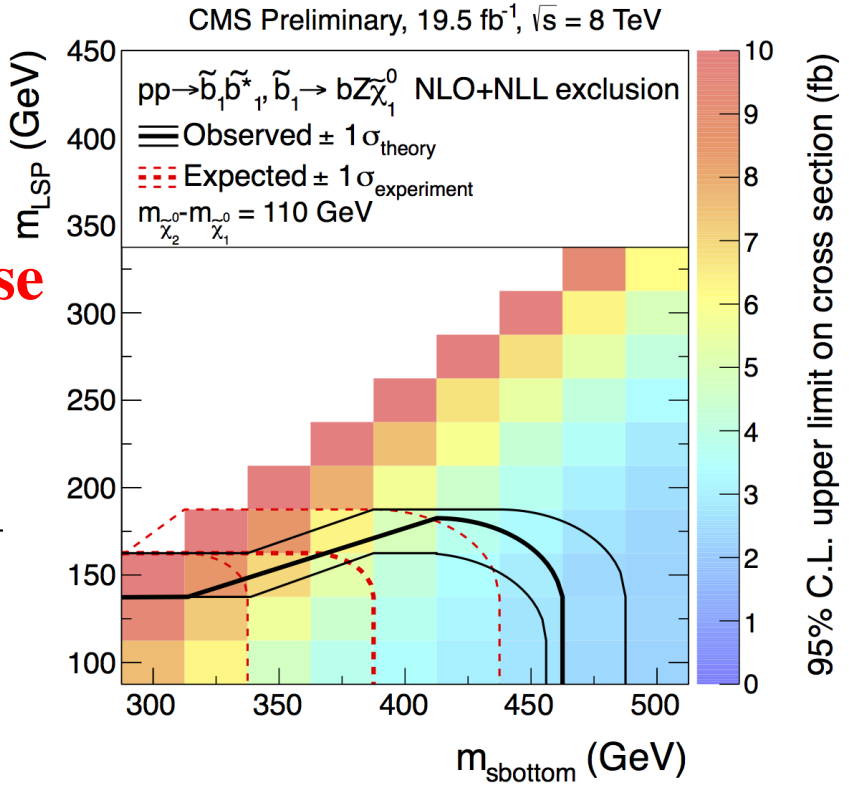
Interpret a different model

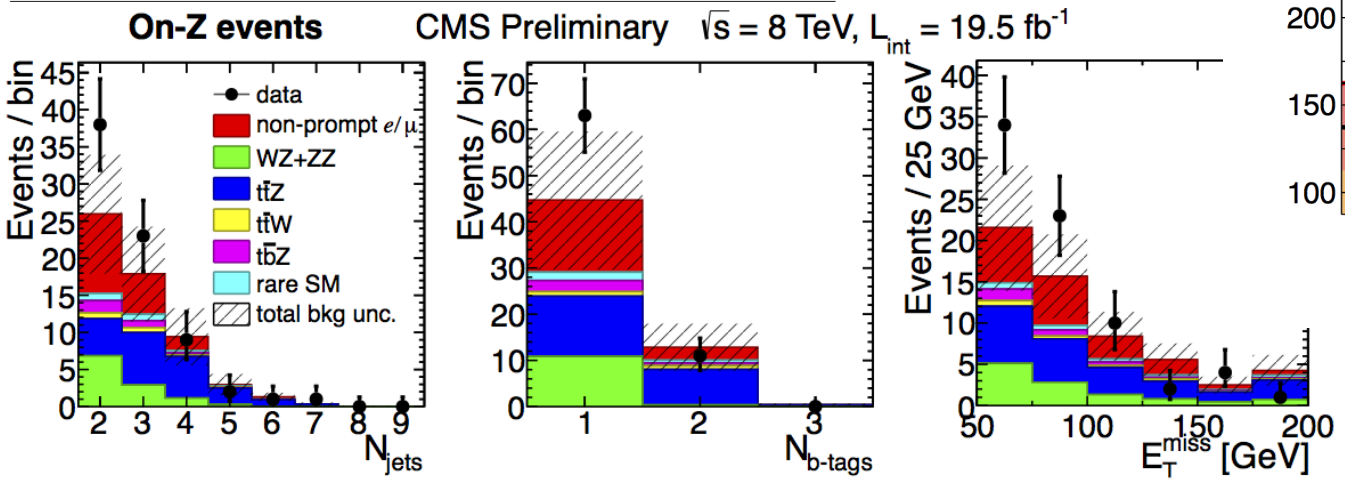
CMS-SUS-13-008



$N_{b\text{-tags}}$	N_{jets}	E_T^{miss} (GeV)	$H_T < 200$ GeV		$H_T > 200$ GeV	
			Expected	Observed	Expected	Observed
1	2–3	50–100	15.0 ± 4.5	30	9.3 ± 3.2	13
		100–200	5.0 ± 1.7	6	5.5 ± 2.0	3
		≥200	0.36 ± 0.22	0	0.9 ± 0.4	0
	≥4	50–100	0.11 ± 0.12	1	4.9 ± 2.0	4
		100–200	< 0.19	0	3.0 ± 1.3	5
		≥200	< 0.11	0	0.56 ± 0.31	1
2	2–3	50–100	2.3 ± 0.8	5	2.6 ± 1.0	2
		100–200	1.3 ± 0.5	1	1.3 ± 0.6	1
		≥200	0.12 ± 0.12	0	0.46 ± 0.24	0
	≥4	50–100	0.20 ± 0.16	1	2.9 ± 1.3	1
		100–200	< 0.22	0	1.6 ± 0.8	0
		≥200	< 0.09	0	0.29 ± 0.19	0
≥3		50–100	< 0.09	0	0.17 ± 0.14	0
		100–200	< 0.09	0	0.25 ± 0.16	0
		≥200	< 0.09	0	0.02 ± 0.09	0

On-shell Z case



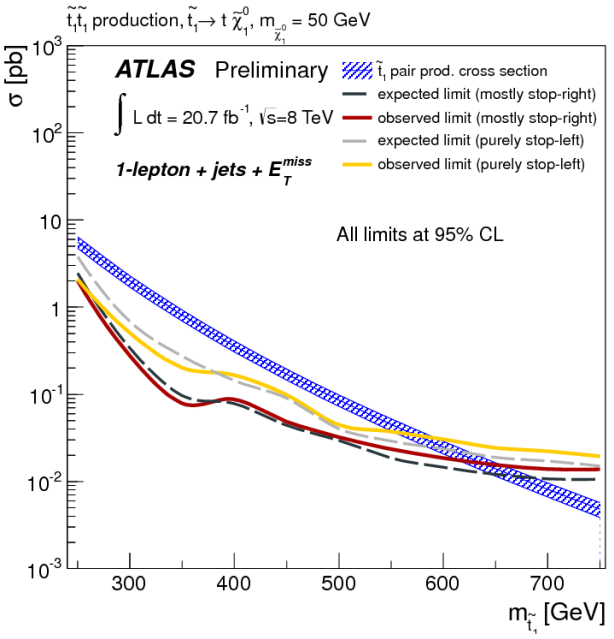


Direct Stop Production
1 lepton + ≥1 b-jet + ≥ 4 jets +MET

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

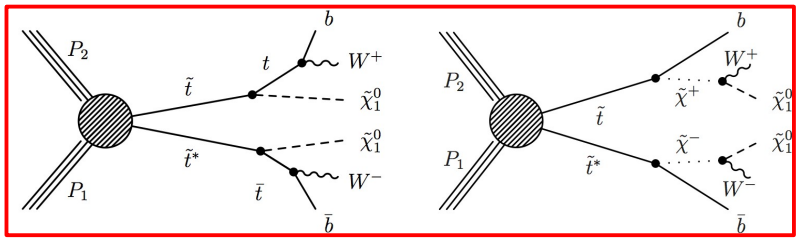
$\tilde{t} \to b \chi^{\pm}$

Requirement	SRtN1_shape	SRtN2	SRtN3	SRbC1	SRbC2	SRbC3
$\Delta\varphi(\text{jet}_1, \vec{p}_T^{\text{miss}}) >$	0.8	-	0.8	0.8	0.8	0.8
$\Delta\varphi(\text{jet}_2, \vec{p}_T^{\text{miss}}) >$	0.8	0.8	0.8	0.8	0.8	0.8
E_T^{miss} [GeV] >	$100^{(\star)}$	200	275	150	160	160
$E_T^{\text{miss}} / \sqrt{H_T}$ [GeV$^{1/2}$] >	5	13	11	7	8	8
m_T [GeV] >	$60^{(\star)}$	140	200	120	120	120
m_{eff} [GeV] >	-	-	-	-	550	700
am_{T2} [GeV] >	-	170	175	-	175	200
m_{T2}^{τ} [GeV] >	-	-	80	-	-	-
m_{jjj}	Yes	Yes	Yes	-	-	-
$N^{\text{iso-trk}} = 0$	-	-	-	Yes	Yes	Yes
Number of b-jets ≥	1	1	1	1	2	2
p_T (leading b-jet) [GeV] >	25	25	25	25	100	120
p_T (second b-jet) [GeV] >	-	-	-	-	50	90



ATLAS-CONF-2013-037

- **SRtN1_shape**: $m_{stop} \sim m_{top} + m_{\chi 0}$.
- **SRtN2**: large $m_{\chi 0}$.
- **SRtN3**: large m_{stop}.



- **SRbC1**: medium m_{stop} (200-400 GeV) and medium/large $m_{\chi^{\pm}}$ (100-300 GeV).
- **SRbC2/3**: high m_{stop} (350-400 GeV) and medium/high m_{stop}-$m_{\chi^{\pm}}$ (>150 GeV).

Direct Stop Production
0 leptons + ≥ 6 (2 b-jets) jets + MET

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

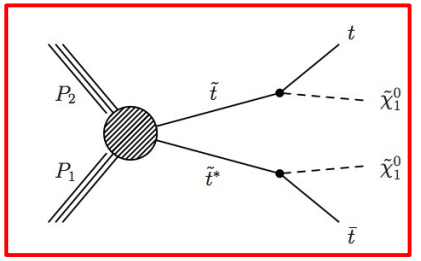
ATLAS-CONF-2013-024

	Signal	$t\bar{t}$ CR	Z+jets CR	Multijet CR
Trigger	$E_{\mathrm{T}}^{\mathrm{miss}}$	single electron (muon)	two electron (muon)	$E_{\mathrm{T}}^{\mathrm{miss}}$
N_{lep}	0	1	2	0
p_{T}^{ℓ}	< 10 (10)	> 35 (35)	> 20 (20)	< 10 (10)
$p_{\mathrm{T}}^{\ell_2}$	—	< 10 (10)	> 20 (10)	—
$m_{\ell\ell}$	—	—	81 to 101	—
N_{jet}	≥ 6	≥ 6	≥ 6	≥ 6
p_{T}^{jet}	$> 80,80,35,...35$	$> 80,80,35,...35$	$> 80,80,35,...35$	$> 80,80,35,...35$
$N_{b\text{-jet}}$	≥ 2	≥ 2	≥ 2	≥ 2
m_{jjj}	80 to 270	0 to 600	80 to 270	—
$E_{\mathrm{T}}^{\mathrm{miss}}$	$> 200, 300, 350$	$> 200, 300, 350$	> 70	> 160
$E_{\mathrm{T}}^{\mathrm{miss,track}}$	> 30	> 30	> 30	> 30
$\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, E_{\mathrm{T}}^{\mathrm{miss,track}})$	$< \pi/3$	$< \pi/3$	$< \pi/3$	$> \pi/3$
$m_{\mathrm{T}}(\ell, E_{\mathrm{T}}^{\mathrm{miss}})$	—	40 to 120	—	—
$\Delta\phi(\mathrm{jet}, E_{\mathrm{T}}^{\mathrm{miss}})$	$> \pi/5$	$> \pi/10$	$> \pi/5$	$< \pi/5$
$m_{\mathrm{T}}(b\text{-jet}, E_{\mathrm{T}}^{\mathrm{miss}})$	> 175	—	> 175	> 175
Tau veto	yes	no	yes	no

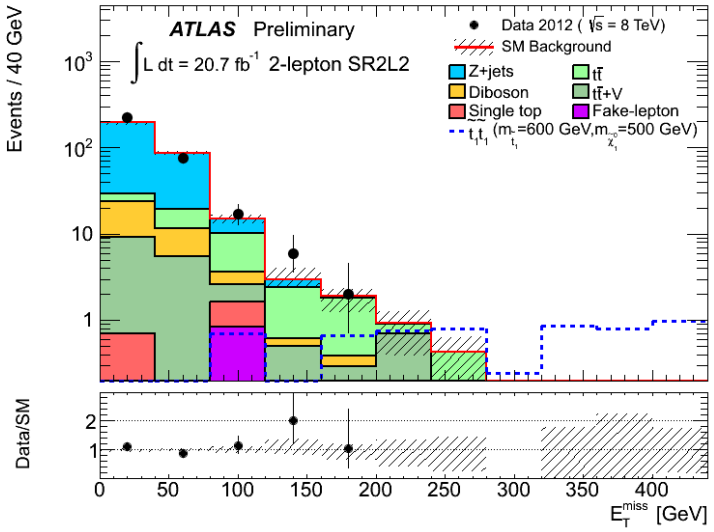
Uncertainty	SR1	SR2	SR3
Total	18%	33%	45%
Background sample sizes (data and simulation)	10%	17%	21%
Jet energy scale and resolution	10%	10%	25%
$t\bar{t}$ theory	10%	19%	22%
Z+jets theory	4%	8%	8%
$t\bar{t} + W/Z$ theory	5%	8%	10%

Number of events	SR1	SR2	SR3
Observed	15	2	1
Expected background	17.5 ± 3.2	4.7 ± 1.5	2.7 ± 1.2
Expected $t\bar{t}$	9.8 ± 2.6	1.9 ± 1.3	0.9 ± 0.7
Expected $t\bar{t} + W/Z$	1.7 ± 1.0	0.7 ± 0.4	0.51 ± 0.30
Expected Z+jets	2.1 ± 1.0	1.2 ± 0.5	0.8 ± 0.4
Expected W+jets	1.2 ± 0.8	0.32 ± 0.29	$0.19^{+0.23}_{-0.19}$
Expected single-top	1.5 ± 0.9	0.5 ± 0.4	$0.3^{+0.3}_{-0.3}$
Expected multijet	0.12 ± 0.12	0.01 ± 0.01	< 0.01
Expected diboson	1.2 ± 1.2	< 0.22	< 0.22
Fit input expectation $t\bar{t}$	9.9	1.7	0.6

UL 95% on $\epsilon\sigma$(fb) = 0.49, 0.17, 0.19

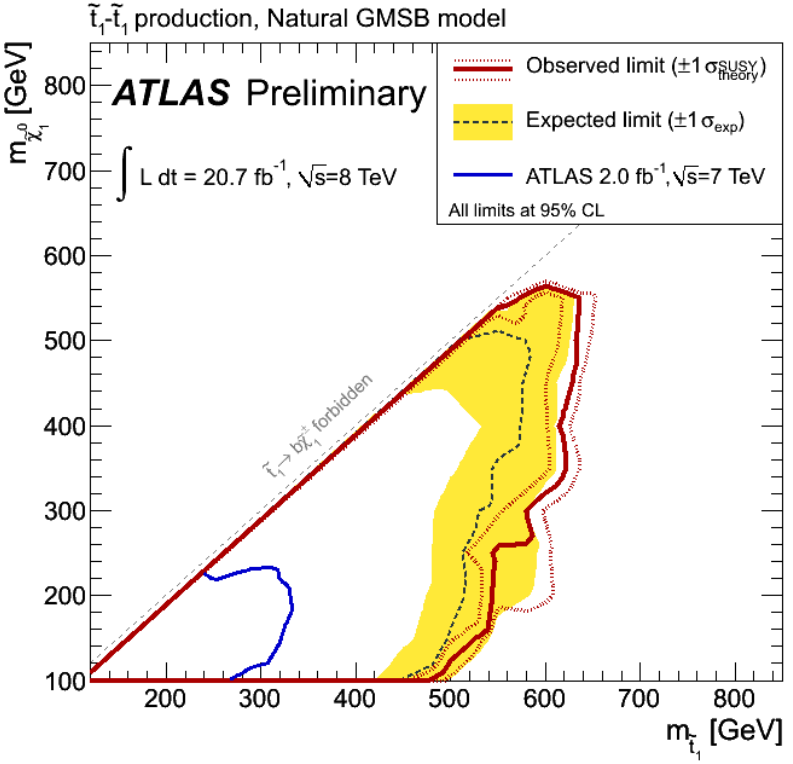


Direct Stop Production
GMSB



ATLAS-CONF-2013-025

	SR2L1A	SR2L1B	SR2L2
N^{lepton}	2		
$\lvert m_{\ell\ell} - m_Z \rvert$	< 5 GeV	< 10 GeV	< 5 GeV
$N^{b\text{-jets}}$	≥ 1		
N^{jets}	3, 4		≥ 5
$p_{\text{T}}(\text{jet}_1)$	> 30 GeV		
$p_{\text{T}}(\text{jet}_N)$	> 30 GeV		
$E_{\text{T}}^{\text{miss}}$	> 160 GeV	> 200 GeV	> 160 GeV
$p_{\text{T}}(\ell\ell)$	> 80 GeV	> 160 GeV	> 80 GeV
$\Delta\phi^{\ell\ell}$	< 1.5 rad		
$p_{\text{T}}(\ell_1)$	> 25 GeV		



	SR2L1A	SR2L1B	SR2L2	SR3L1	SR3L2
Data	10	1	2	4	2
Total SM	12.4 ± 2.3	2.7 ± 1.2	3.8 ± 1.4	5.8 ± 2.0	1.2 ± 0.6
Diboson	1.4 ± 1.2	0.8 ± 0.7	0.3 ± 0.3	1.0 ± 0.6	0.3 ± 0.2
$t\bar{t} + V$	0.9 ± 0.7	0.36 ± 0.09	1.4 ± 0.4	3.3 ± 1.4	1.1 ± 0.5
Fake-lepton	0.3 ± 0.5	0.0 ± 0.02	0.0 ± 0.03	1.5 ± 1.0	-0.2 ± 0.3
$t\bar{t}$	8.6 ± 2.2	1.1 ± 0.7	1.9 ± 1.3		
Z+jets	0.9 ± 0.3	0.13 ± 0.07	0.2 ± 0.1		
Single top	0.09 ± 0.06	0.4 ± 0.6	< 0.2		
$t\bar{t}$ (before fit)	8.2 ± 3.3	1.0 ± 0.7	2.7 ± 2.7		

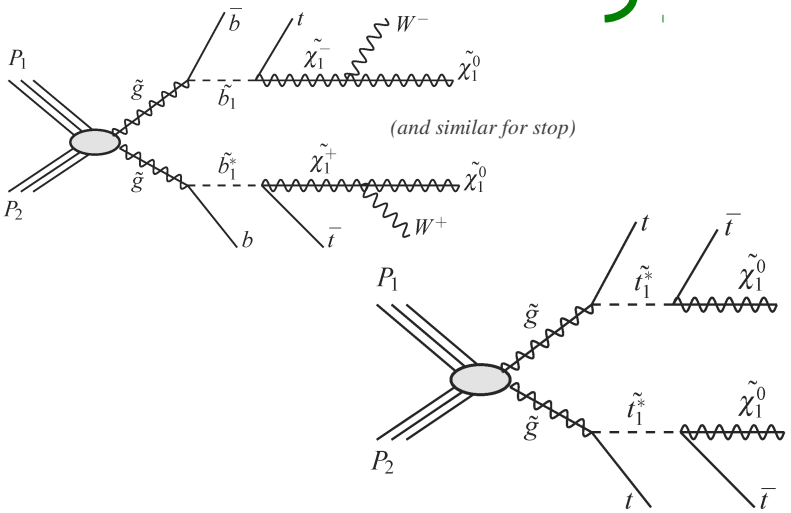
Gluino Mediated Sbottom/Stop Production
On-shell

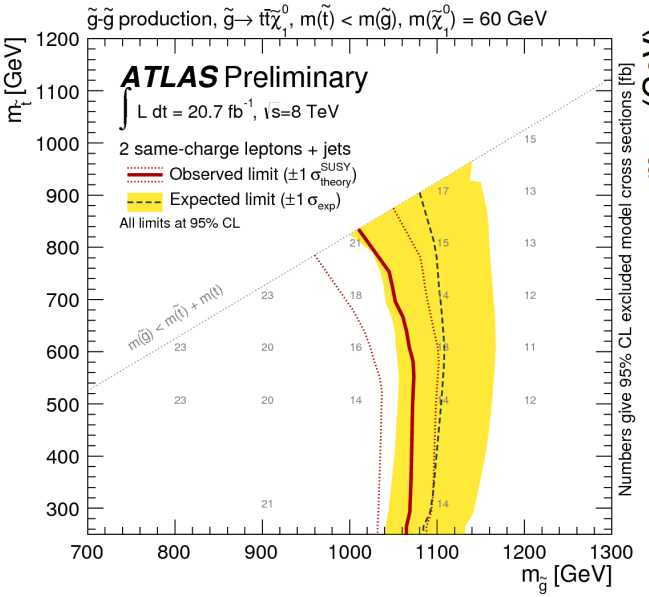
Results of ***CMS-SUS-13-008*** and ***ATLAS-CONF-2013-007*** interpreted also in models where the sbottoms or the stops are produced **on-shell**.

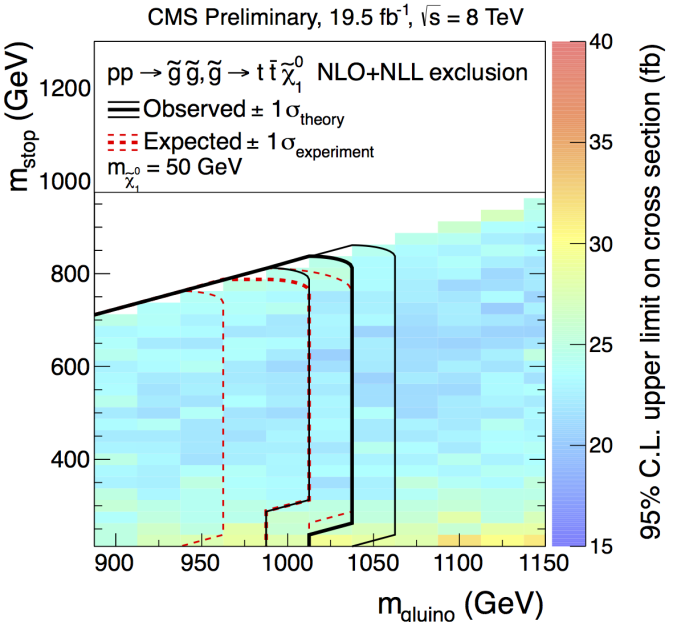
ATLAS

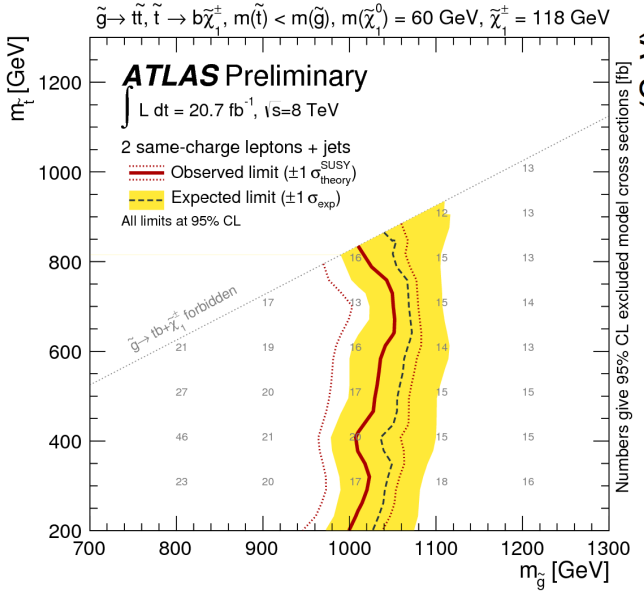
$$\tilde{g} \to t\,\tilde{t} \to tb\,\chi$$
$$\tilde{g} \to t\,\tilde{t} \to tt\,\chi^{0}$$
$$\tilde{g} \to b\,\tilde{b} \to tb\,\chi^{\pm}$$

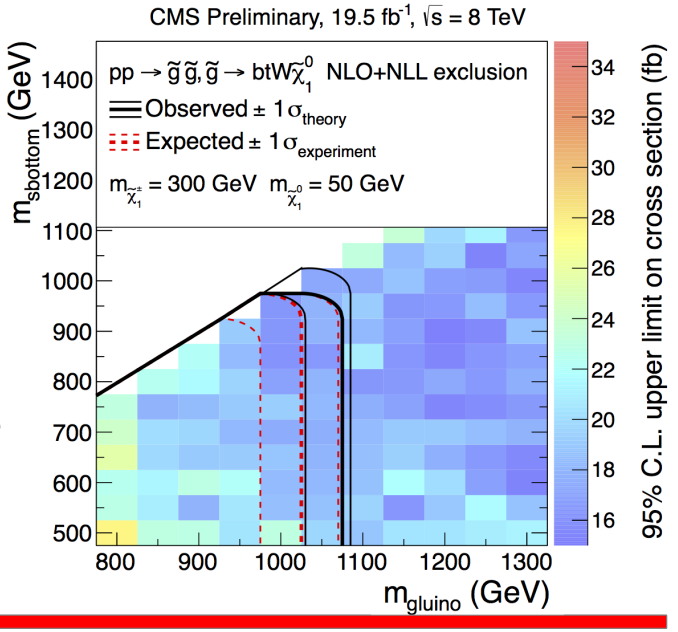
CMS











Strategy Tools

A number of variables (sometimes quite complex) used to discriminate from signal to background

Scalar sum of the pT of jets (+ lepton)

$$H_T = \sum p_T^l + \sum p_T^{jet}$$

Effective mass: H_T + E_T^{miss}

$$m_{eff} = \left(\sum_{i=1}^{Nlep} p_{T,i}^l \right) + \sum_{i=1}^{Njet} p_{T,i} + E_T^{miss}$$

Transverse mass:

$$m_T = \sqrt{2 p_T E_T^{miss} (1 - cos(\Delta\phi(p_T, E_T^{miss})))}$$

Stransverse mass: minimization performed on all possible decomposition of the p_T^{miss}

$$m_{T2}(\mathbf{p}_T^{\ell_1}, \mathbf{p}_T^{\ell_2}, \mathbf{p}_T^{\rm miss}) = \min_{\mathbf{q}_T + \mathbf{r}_T = \mathbf{p}_T^{\rm miss}} \left\{ \max[\, m_T(\mathbf{p}_T^{\ell_1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell_2}, \mathbf{r}_T)\,] \right\}$$

ATLAS

Cotransverse mass: E_T and p_T of the visible particle in the event

$$m_{CT}^2(v1, v2) = (E_T(v1) + E_T(v2))^2 - (\mathbf{p}_T(v1) - \mathbf{p}_T(v2))^2$$

CMS

- alpha_t
  - = 0.5 perfect balanced dijet event;
  - < 0.5 jet mismeasurement
  - > 0.5 recoil against genuine E_T^{miss}

$$\alpha_T = \frac{E_T^{jet_2}}{M_T} = \frac{E_T^{jet_2}}{\sqrt{\left(\sum_{i=1}^2 E_T^{jet_i}\right)^2 - \left(\sum_{i=1}^2 p_x^{jet_i}\right)^2 - \left(\sum_{i=1}^2 p_y^{jet_i}\right)^2}},$$

- razor: decomposition of the particle boost,

$$R = \frac{M_R^T}{M_R}$$

M_R is defined using momentum after trasformation, assuming jet have the same momentum

$$M_R \equiv \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}\,.$$

M_T^R is defined using transverse quantities and it is MET-related

$$M_R^T = \sqrt{\frac{\not{E}_T(p_T^{j_1} + p_T^{j_2}) - \vec{\not{E}}_T \cdot (\vec{p}_T^{\,j_1} + \vec{p}_T^{\,j_2})}{2}}$$

Gluino Mediated

Sensitive to model in which squarks (except 3rd gen) are much heavier than gluinos

Depending on the decay of the stop/sbottom quarks, several signatures are possible

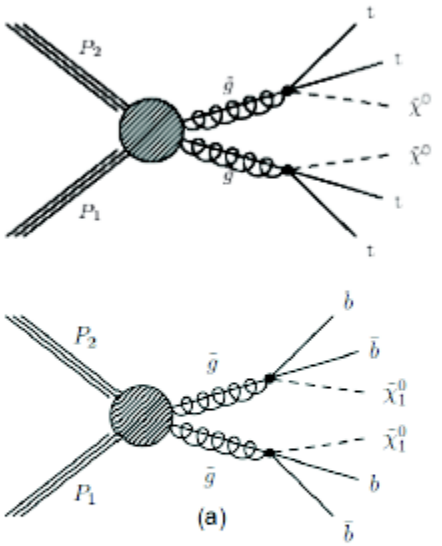
$\tilde{g} \to b\,\tilde{b}_1$, $\tilde{b}_1 \to t\,\tilde{\chi}_1^{\pm}$ — Gluino-stop ($b\tilde{\chi}_1^{\pm}$) degenerate ($m_{\tilde{\chi}_1^{\pm}}, m_{\tilde{\chi}_1^0}$)

$\tilde{g} \to t\,\tilde{t}_1$, $\tilde{t}_1 \to b\,\tilde{\chi}_1^{\pm}$ — Gluino-stop ($b\tilde{\chi}_1^{\pm}$) on-shell

$\tilde{\chi}_1^{\pm} \to W^{\pm(*)}\,\tilde{\chi}_1^0$

$\tilde{t}_1 \to t\,\tilde{\chi}_1^0$ — Gluino-stop ($t\tilde{\chi}_1^0$) off-shell ($m_{\tilde{g}} < m_{\tilde{t}} + m_t$)

Gluino-stop ($t\tilde{\chi}_1^0$) on-shell ($m_{\tilde{g}} > m_{\tilde{t}} + m_t$)



- multijet (> 6, some of which b-tagged) + E_T^{miss}
  - all hadronic or 1lepton signature
- Final states with multiple W bosons decaying leptonically (+bjets)
  - 2 leptons SS signatures (gluino is a strongly interacting Majorana particle) ⇒ small SM background
  - events with ≥ 3 lep + multiple jets → suppression of charge flip and fakes

Missing Corners

- Compressed Spectra
  - If degenerate, see SUSY only through ISR
  - With some splitting, can do a bit more (as ATLAS-CONF-2013-053)
- RPV SUSY
  - Multijets, no MET. If stop is light, trigger could be a problem
- If not Natural
  - Gluinos could have long decay lifetime
  - Charginos/neutralinos too → long living particle