Searches for Natural Supersymmetry with the ATLAS Detector

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On Behalf of the ATLAS Collaboration

International Workshop on Discovery Physics at the LHC, Kruger National Park, December 2012

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- Discussion of Searches and Results
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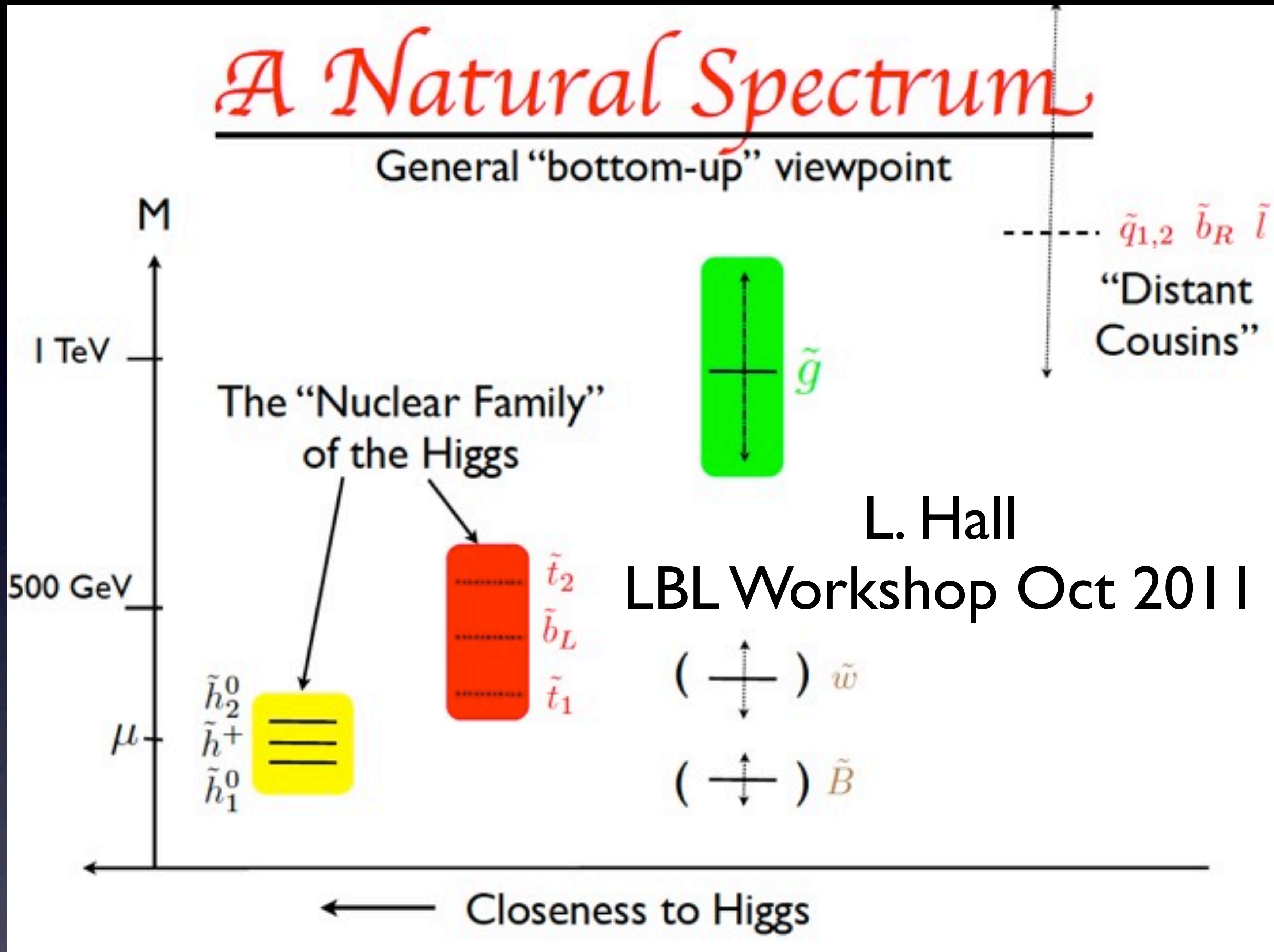
Naturalness



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- Typical natural spectrum contains light third generation squarks
- Typical natural spectrum contains light charginos and neutralinos

Third Generation Squarks

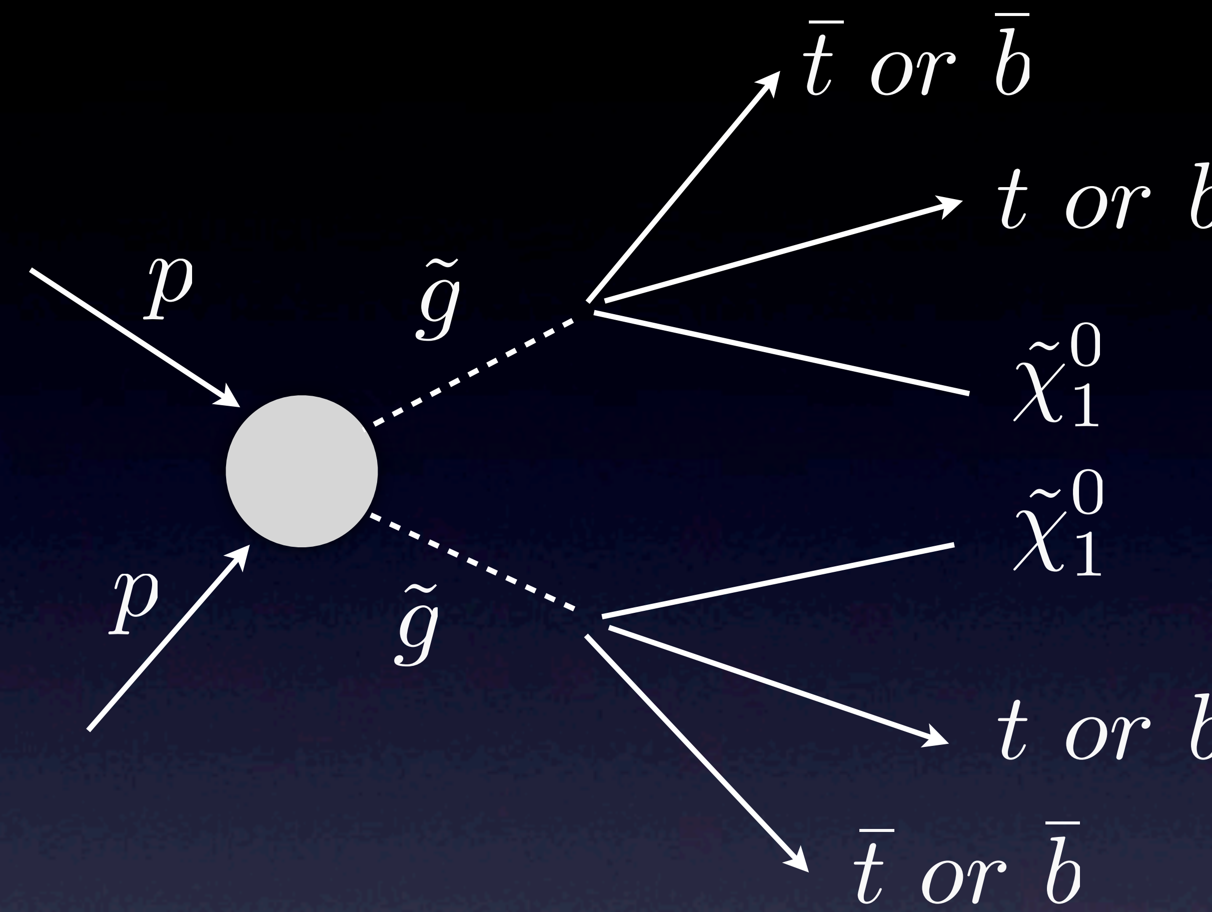
- Dominant radiative corrections to Higgs mass arise from top quark in SM - relatively light stop can balance these corrections
- Can search for gluino mediated stop (Gtt) and sbottom production (Gbb), and direct production of sbottom or stop quarks
- Search for Gtt and Gbb - 3 B-Jets + MET
- Search for Gtt and direct sbottom, with decay to top and charginos - 3-Leptons + Jets + MET
- Search for direct sbottom production - 2 B-Jets + MET
- Search for direct stop production - 0-lepton, 1-lepton and 2-lepton analyses

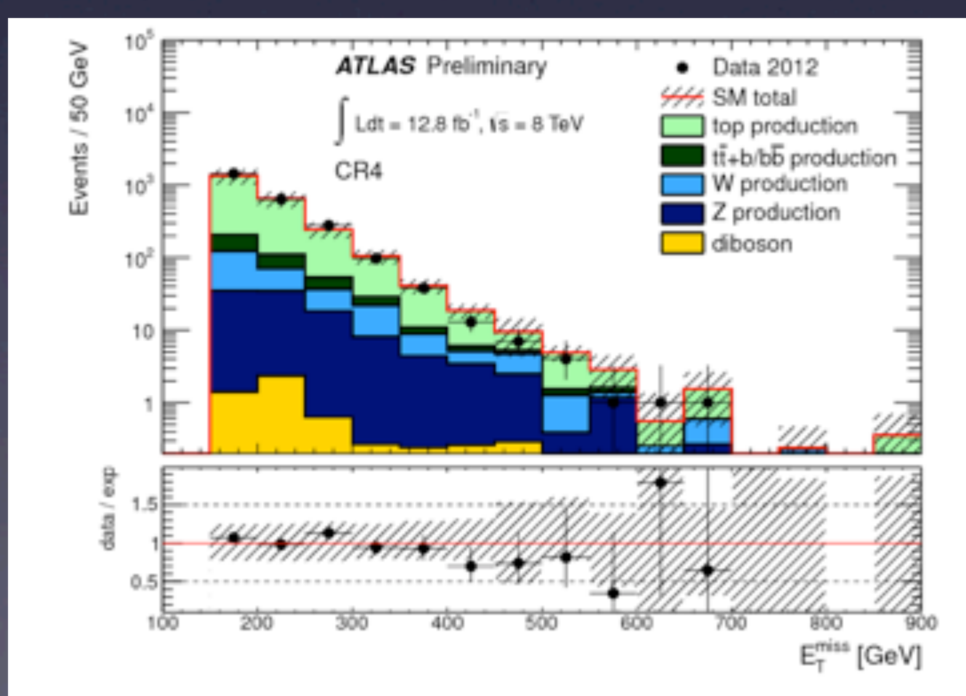
Search for Gauginos

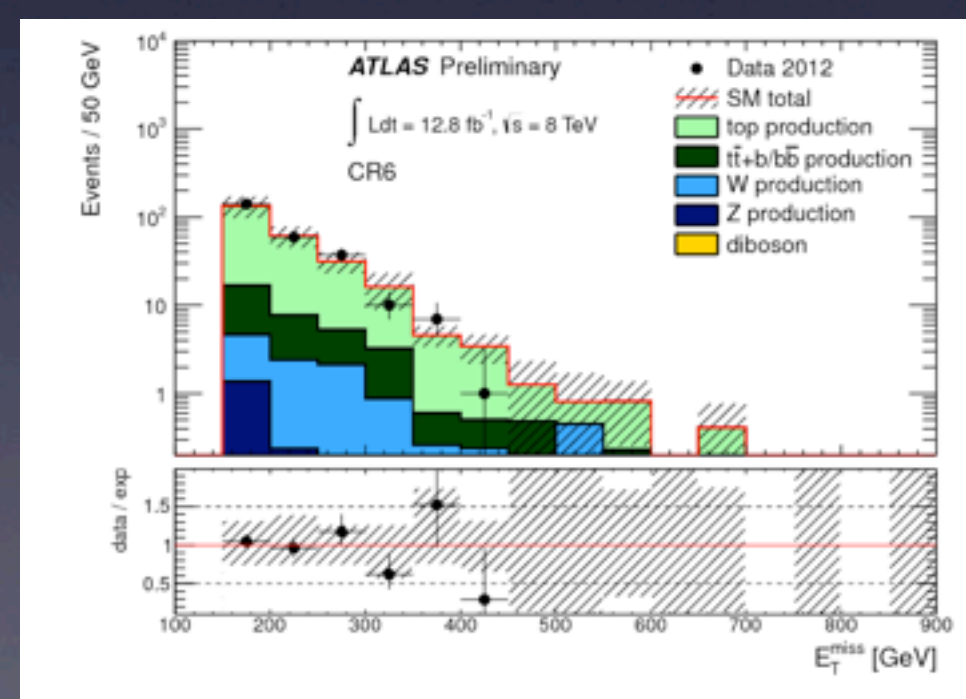
- Z Boson mass and gaugino masses related to μ in SUSY - expect gaugino masses around electroweak scale
- Search for production of chargino and neutralino - 3-lepton searches
- Search for pair production of charginos - 2-lepton final states

Search for Gluino Mediated Stop or Sbottom Production with 3 B-Jets and MET in 8 TeV Data

- Two main SR used - 4 Jet SR and 6 Jet SR
- DeltaPhi(Jet,MET) > 0.4 and MET/MEff > 0.2
- Further subdivided each into loose, medium and tight in MEff cuts
- SR4Jet - MET > 200, 3 B-Jets with P_T > 50 GeV
- SR6Jet - MET > 200, 3 B-Jets with P_T > 30 GeV
- Top pair CR - exactly 2 B-Jets with relaxed MET and MEff cuts







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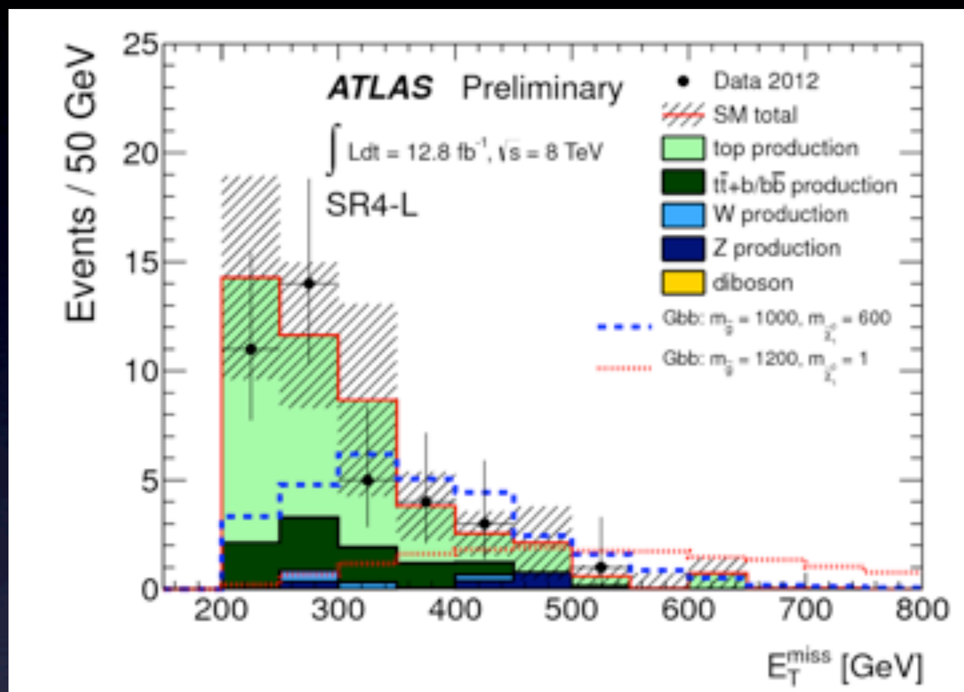
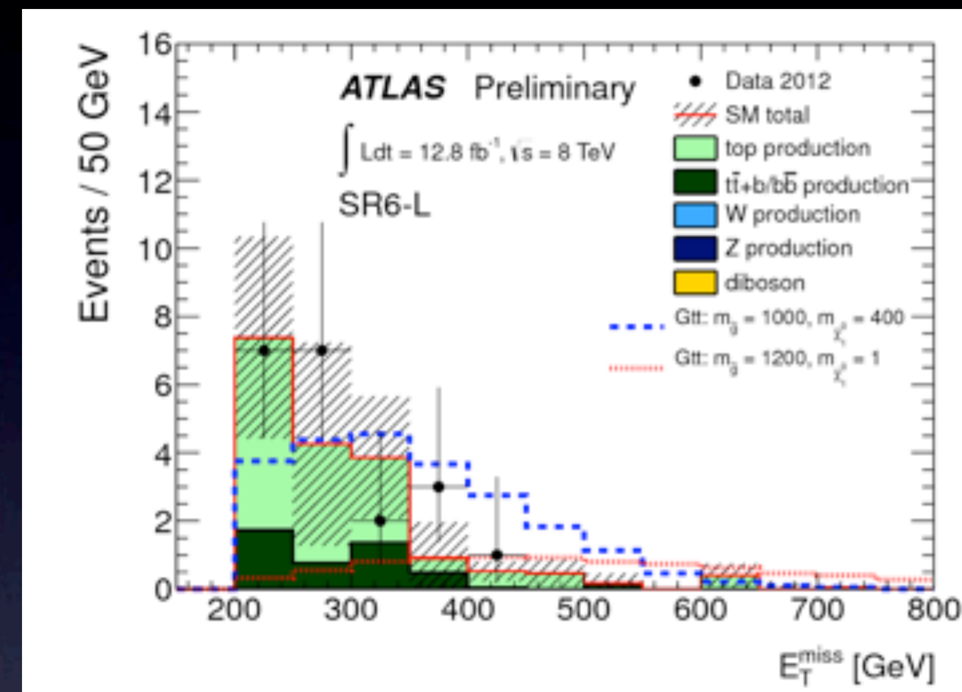
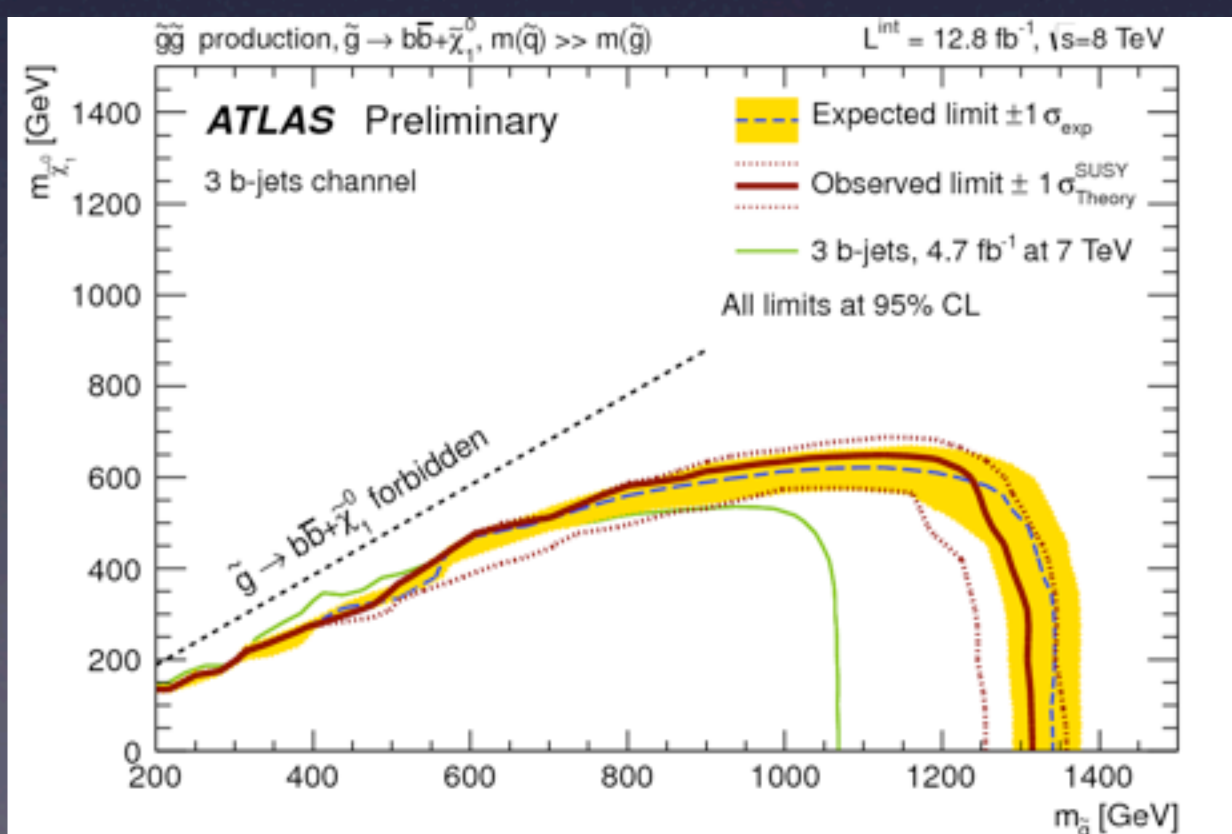
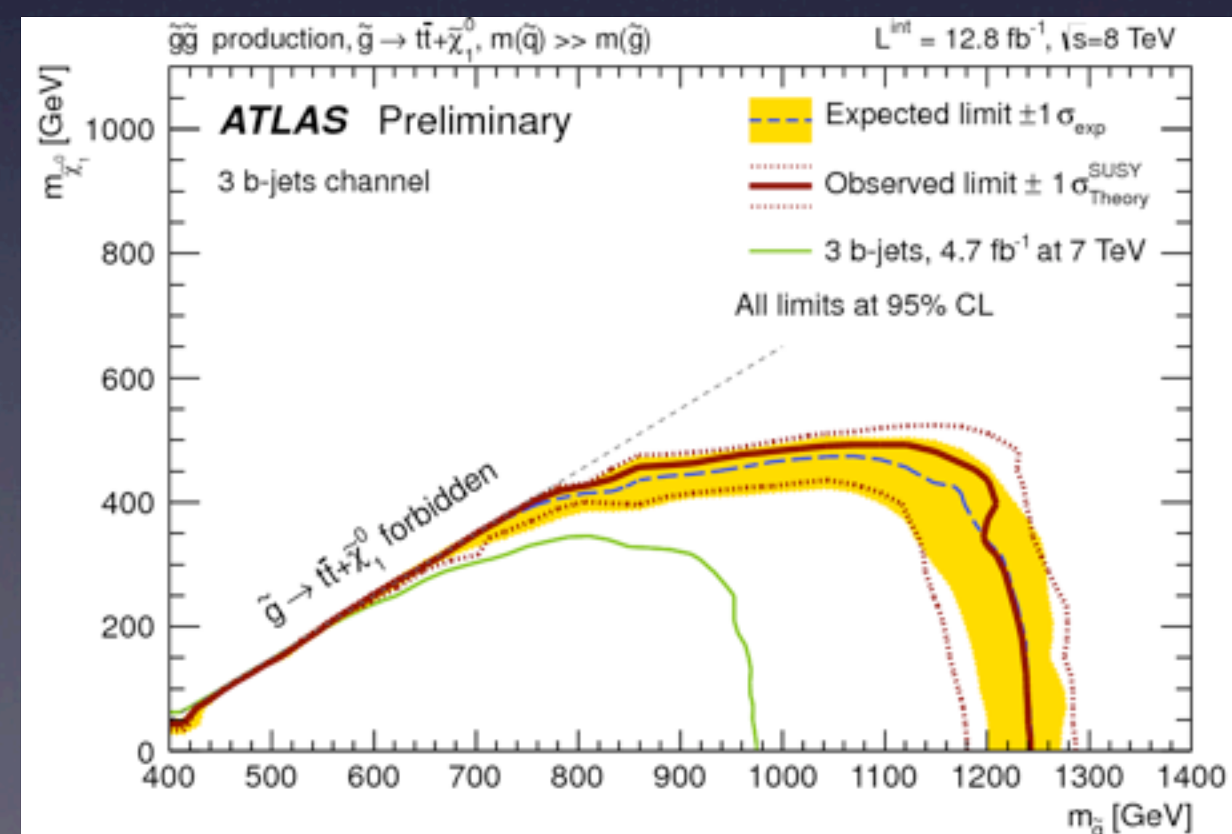
Search for Gluino Mediated Stop or Sbottom Production with 3 B-Jets and MET in 8 TeV Data

- No excess in data observed

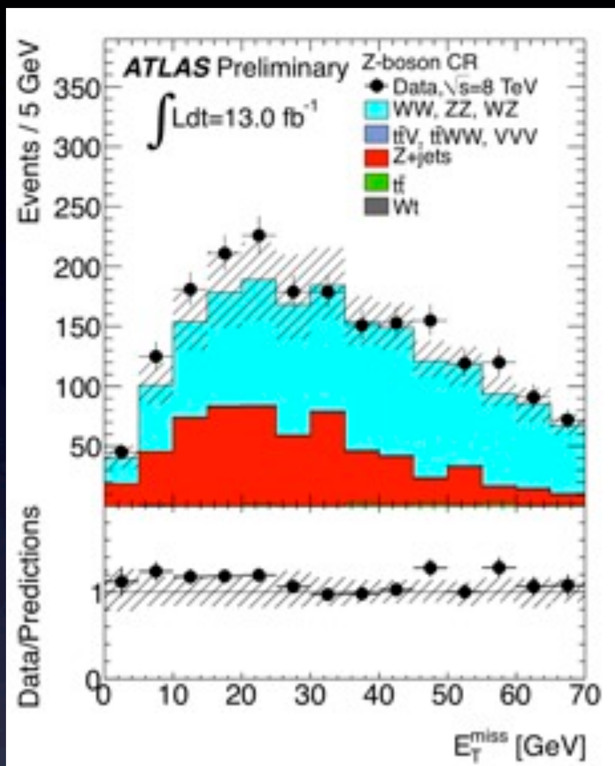


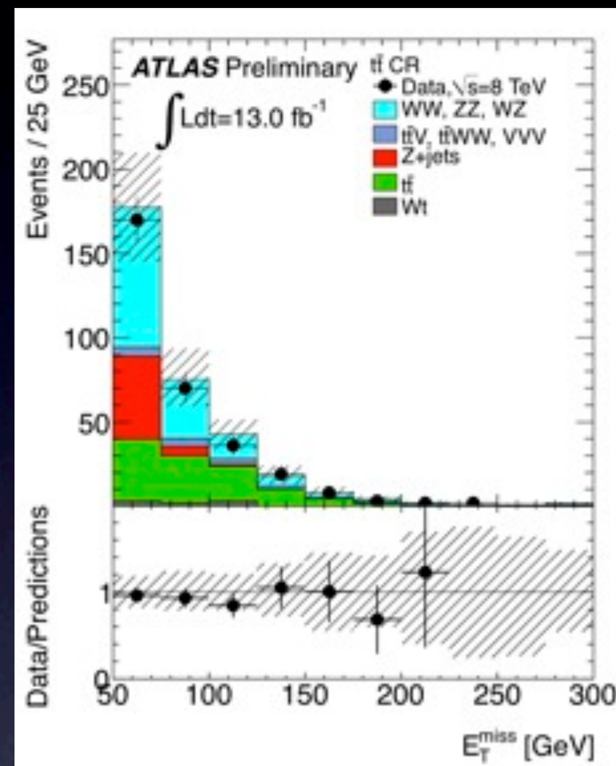


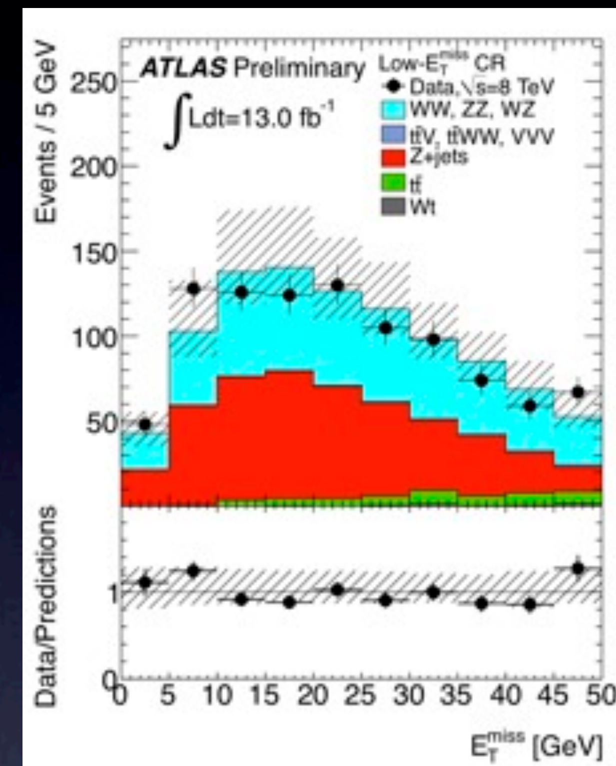




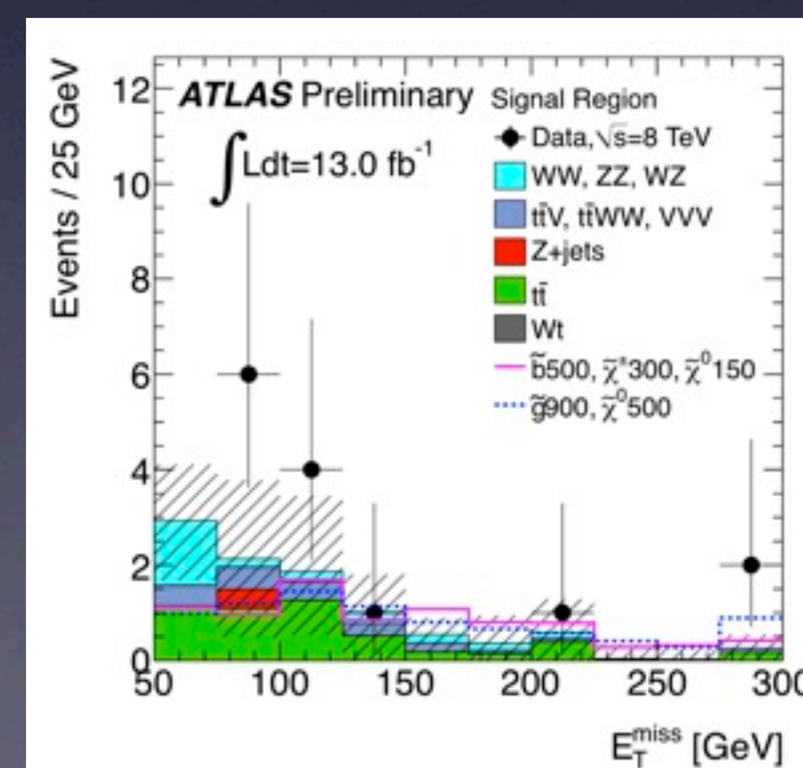
Search for Gluino Mediated Stop Production, and Direct Sbottom Production with 3 Leptons + Jets + MET in 8 TeV Data





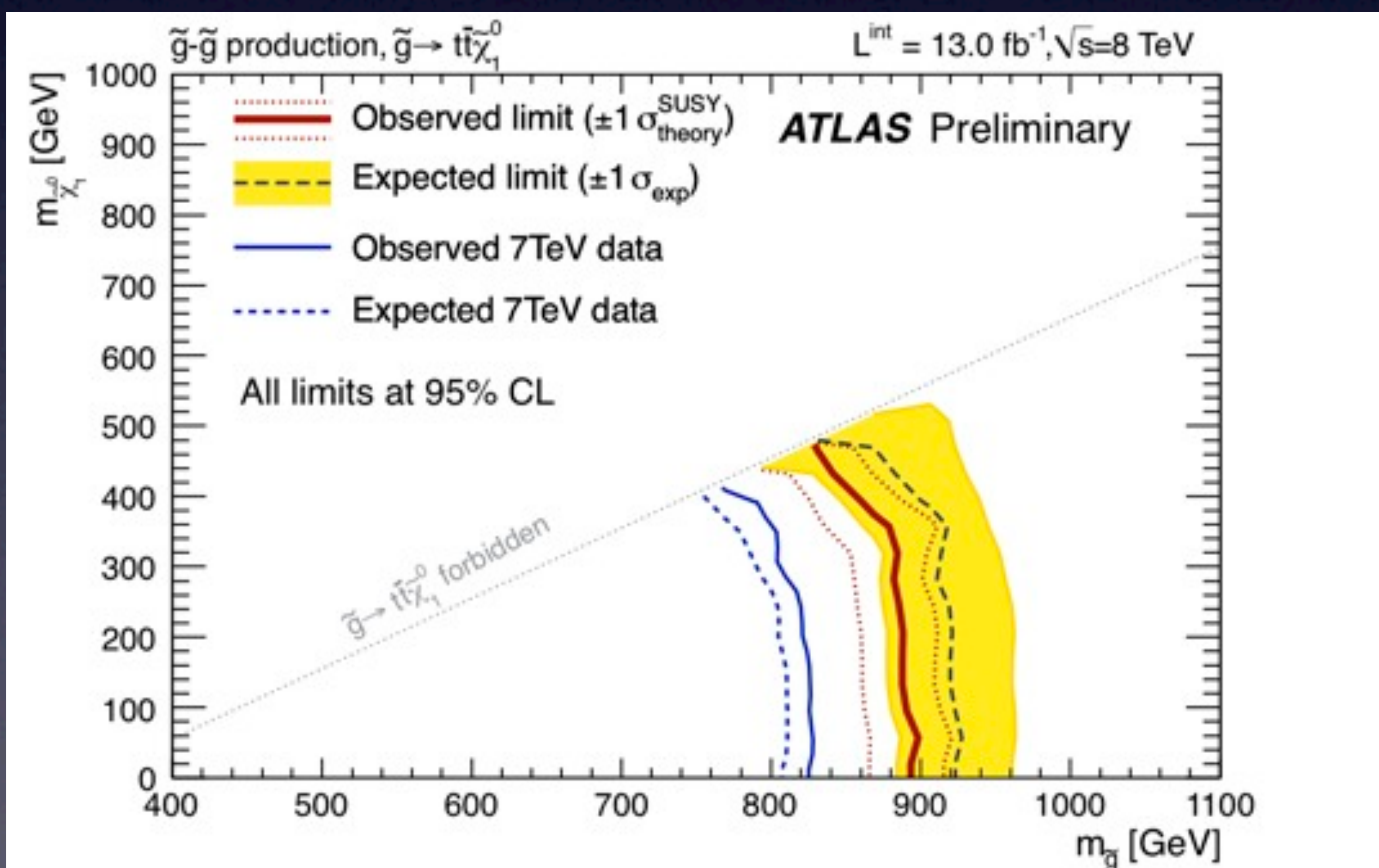


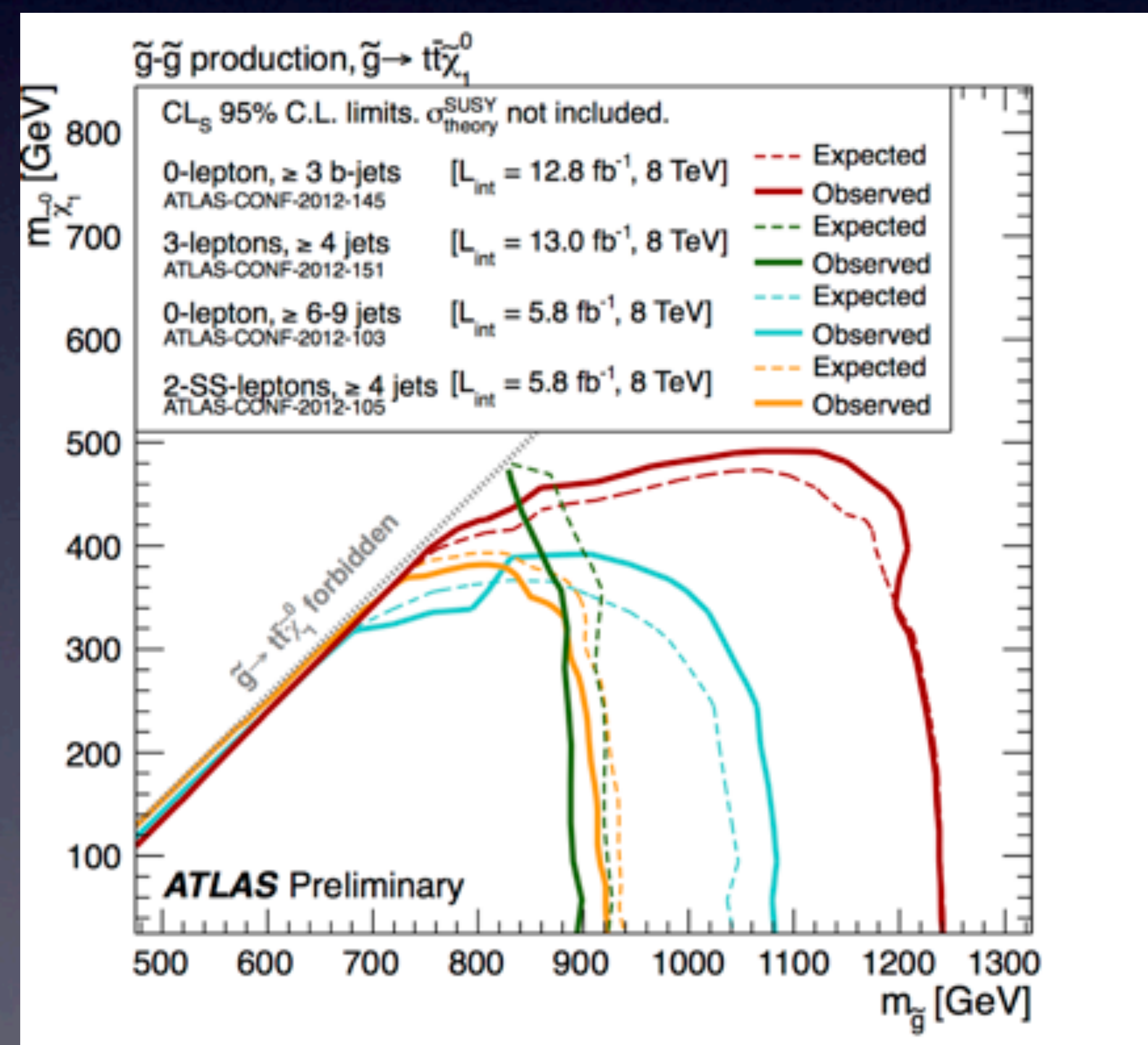
- 6 SR, sensitive to top and W production, based on possible electron/muon combinations - at least 4 jets, MET > 50 GeV and SFOS m_ll not inside 81 -> 101 GeV
- 3 CR used to adjust the four MC fake rates for light or heavy jets to fake electrons or muons in SM backgrounds
- Z CR - SFOS m_ll in range 81 to 101 GeV
- Top CR - less than 4-jets
- MET CR - MET < 50 GeV



Search for Gluino Mediated Stop Production, and Direct Sbottom Production with 3 Leptons + Jets + MET in 8 TeV Data

- No excess in data observed





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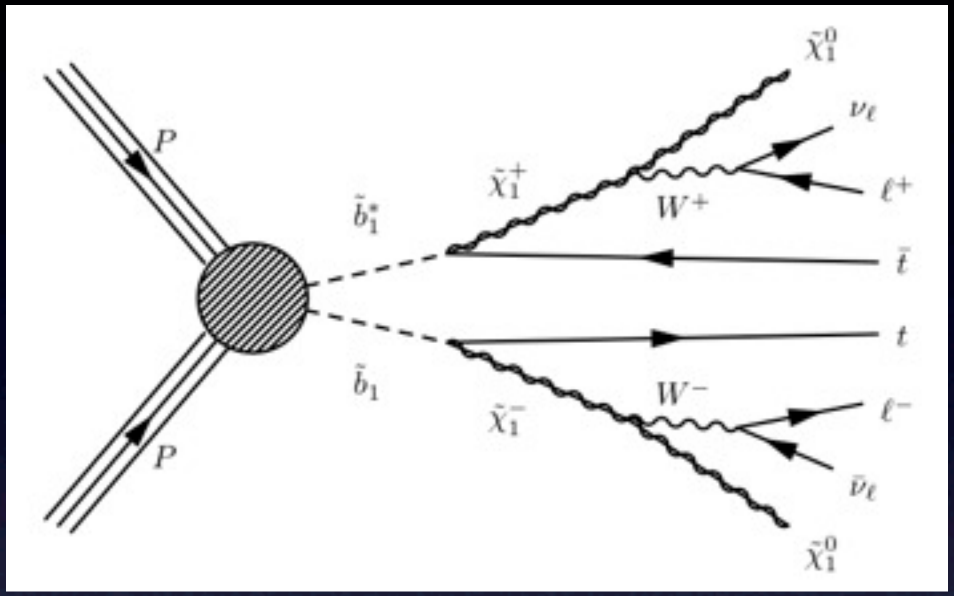
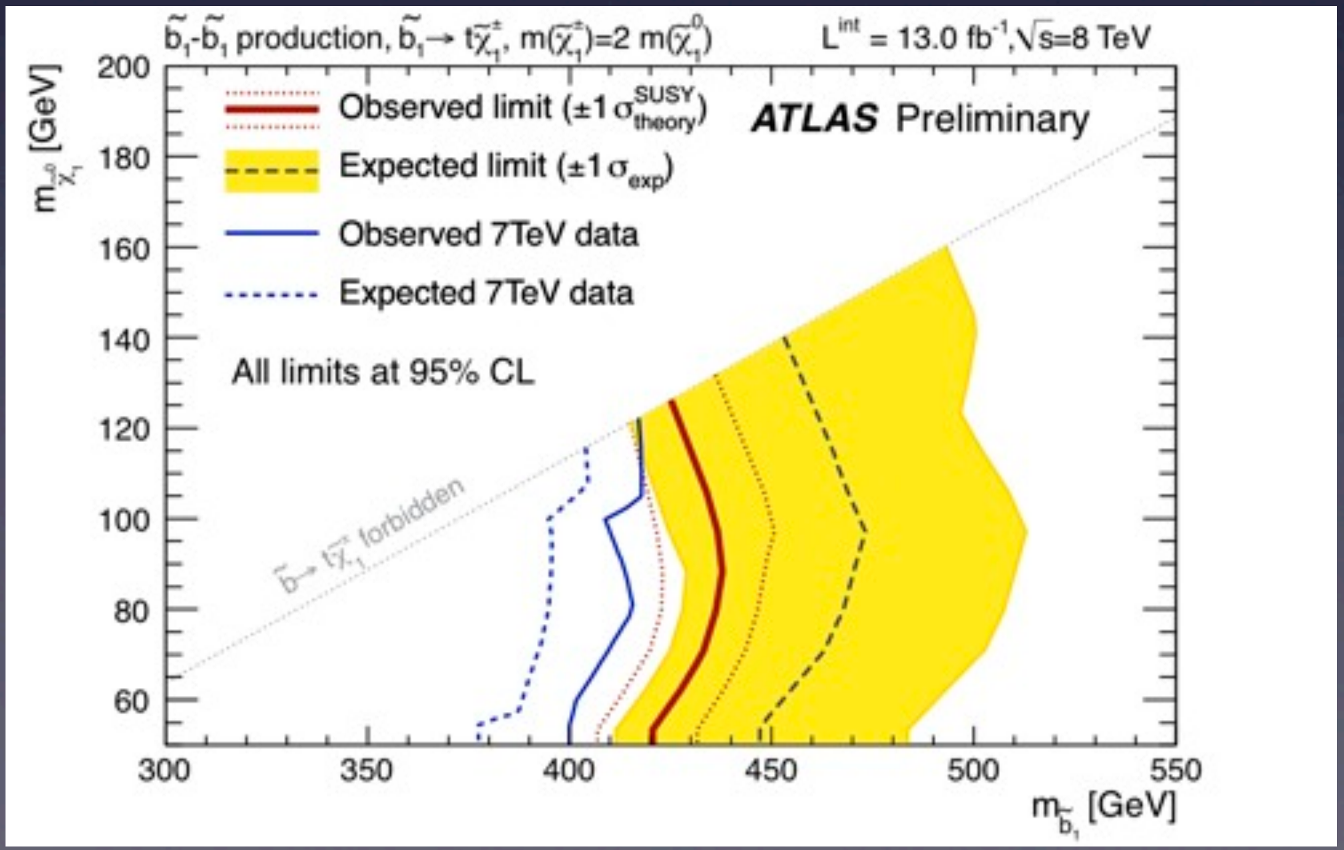
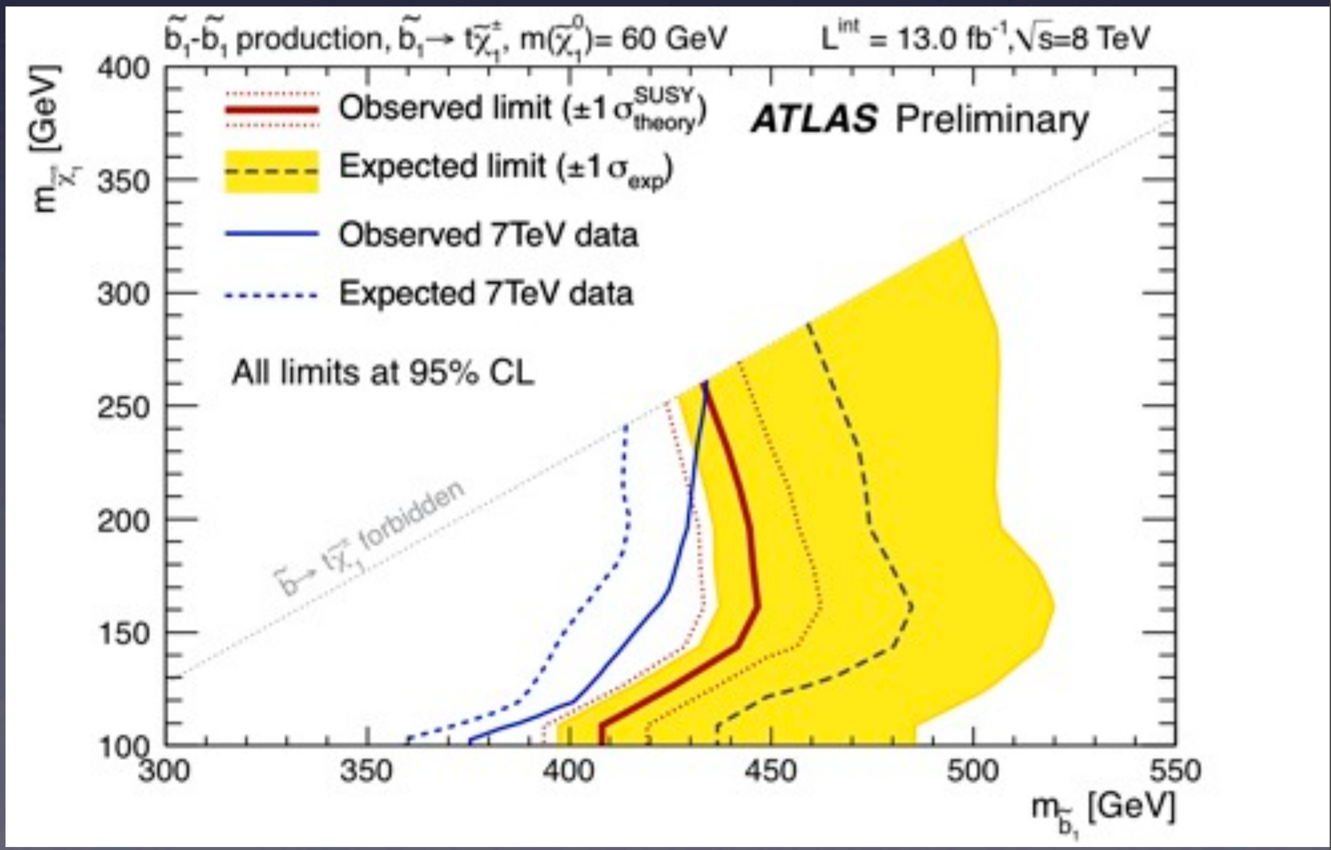
Search for Gluino Mediated Stop Production, and Direct Sbottom Production with 3 Leptons + Jets + MET in 8 TeV Data



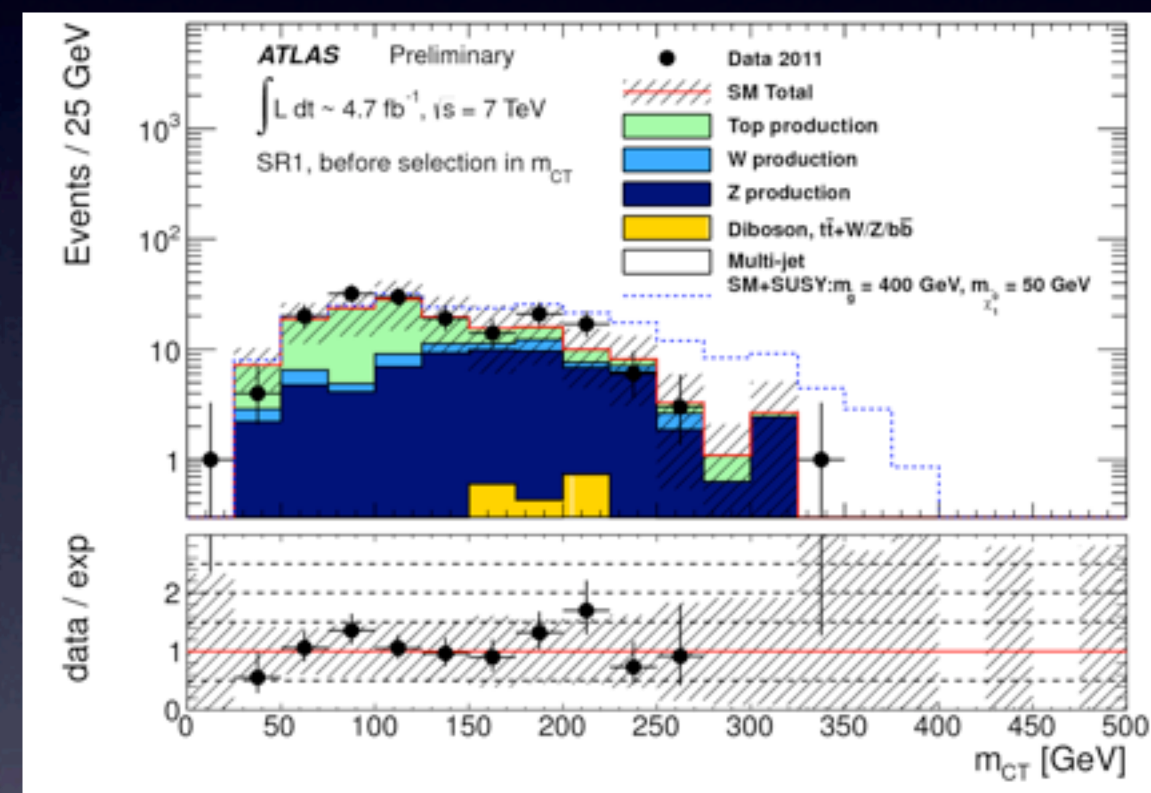




Search for Direct Sbottom Production with 2 B-Jets + MET in 7 TeV Data

$$\tilde{b} \rightarrow b\tilde{\chi}_1^0$$

- 3 SR for large, medium, small mass difference - $\Delta m = m_{\tilde{b}_1} - m_{\chi_1^0}$
- Large mass difference - two hard b-jets, use contransverse mass variable
- Small mass difference - use ISR recoiling against the two b-jets
- 1-lepton CR for top pair production and W +HF jets
- 2-lepton CR for Z decaying to two neutrinos + HF jets and top pair production



$$m_{CT}^2(\nu_1, \nu_2) = [E_T(\nu_1) + E_T(\nu_2)]^2 - [P_T(\nu_1) - P_T(\nu_2)]^2$$

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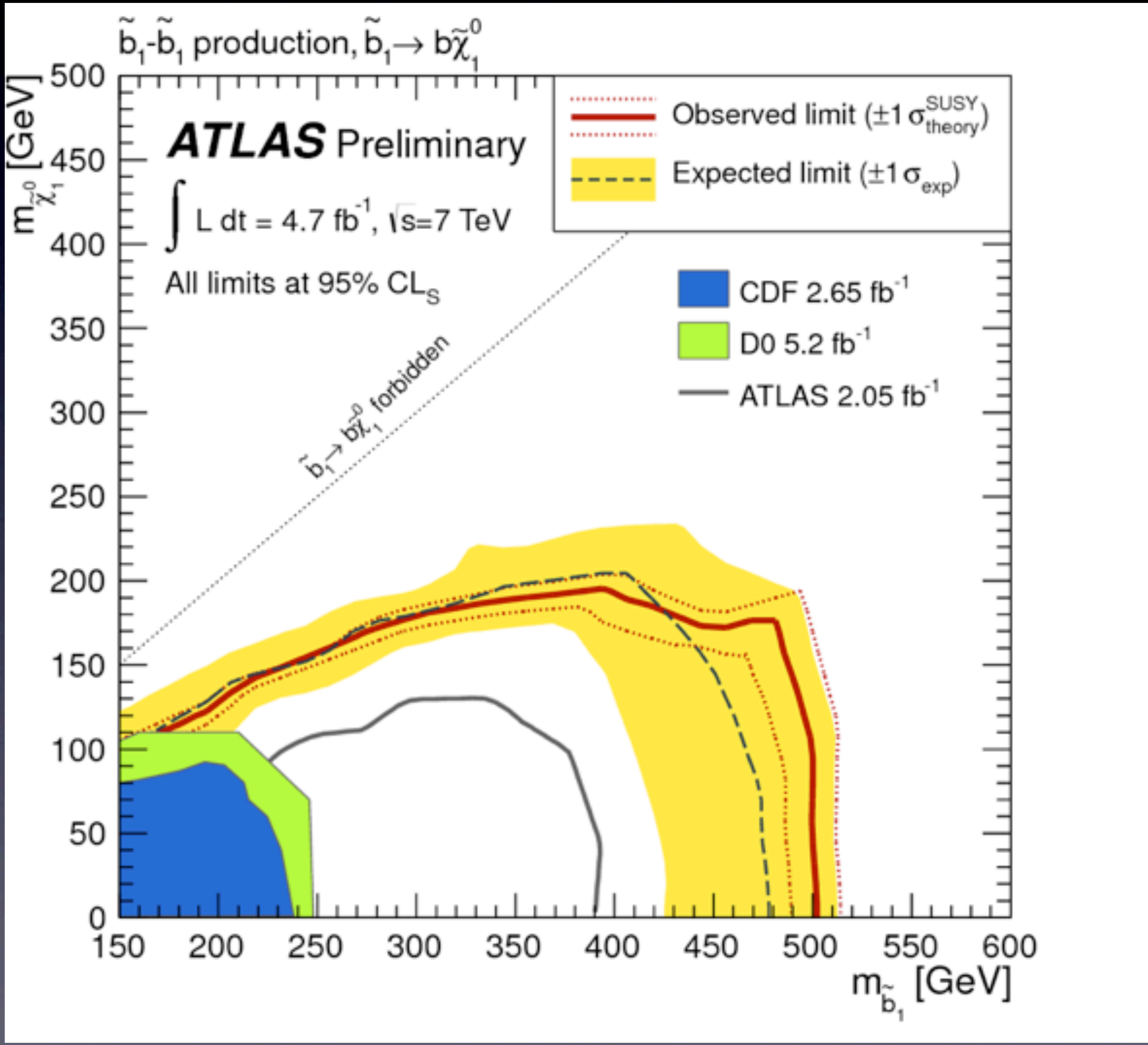
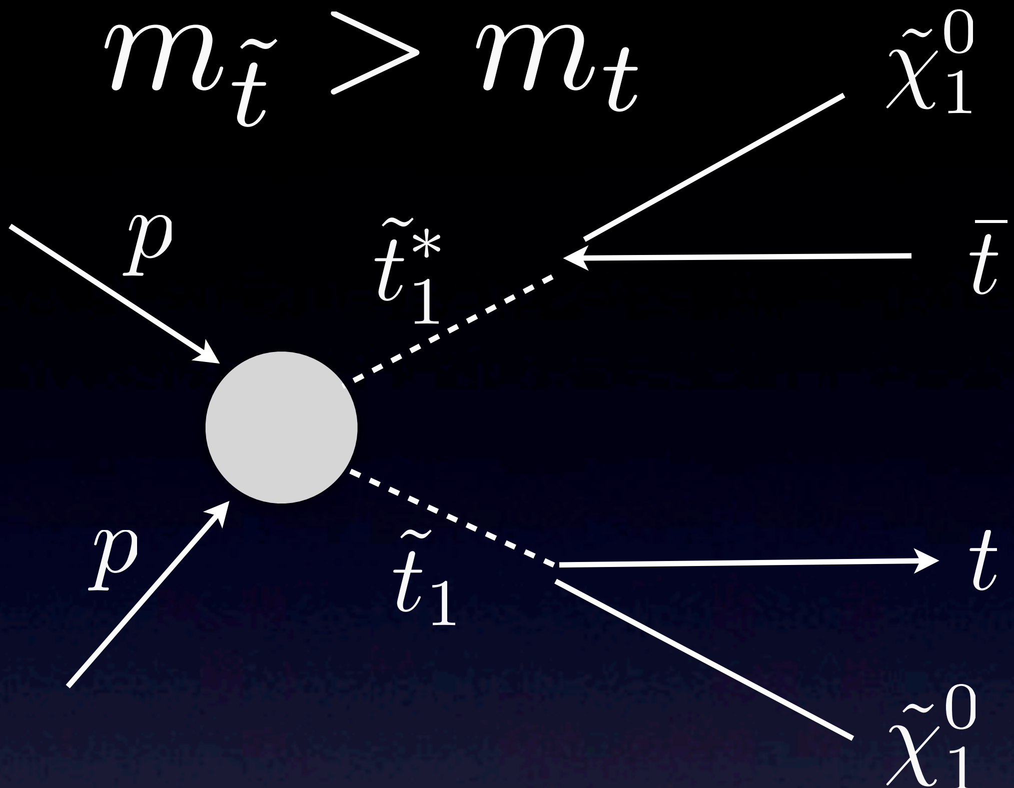
Search for Direct Sbottom Production with 2 B-Jets + MET in 7 TeV Data

- No excess in data observed



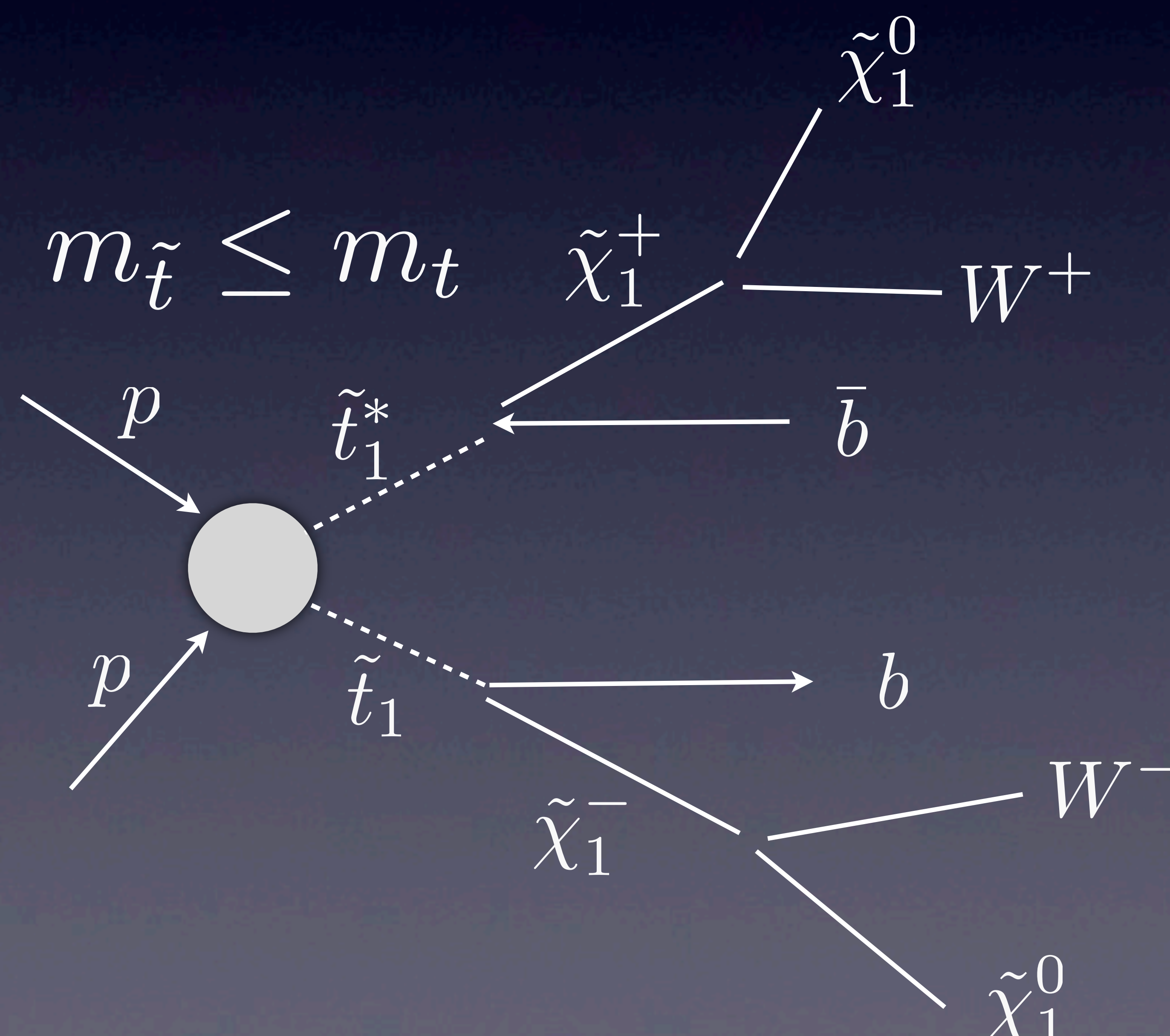
Search for Direct Stop Production in 7 TeV Data

$m_{\tilde{t}} > m_t$



Heavier Stop - Search for 0-2 leptons, multiple jets and MET

$m_{\tilde{t}} \leq m_t$

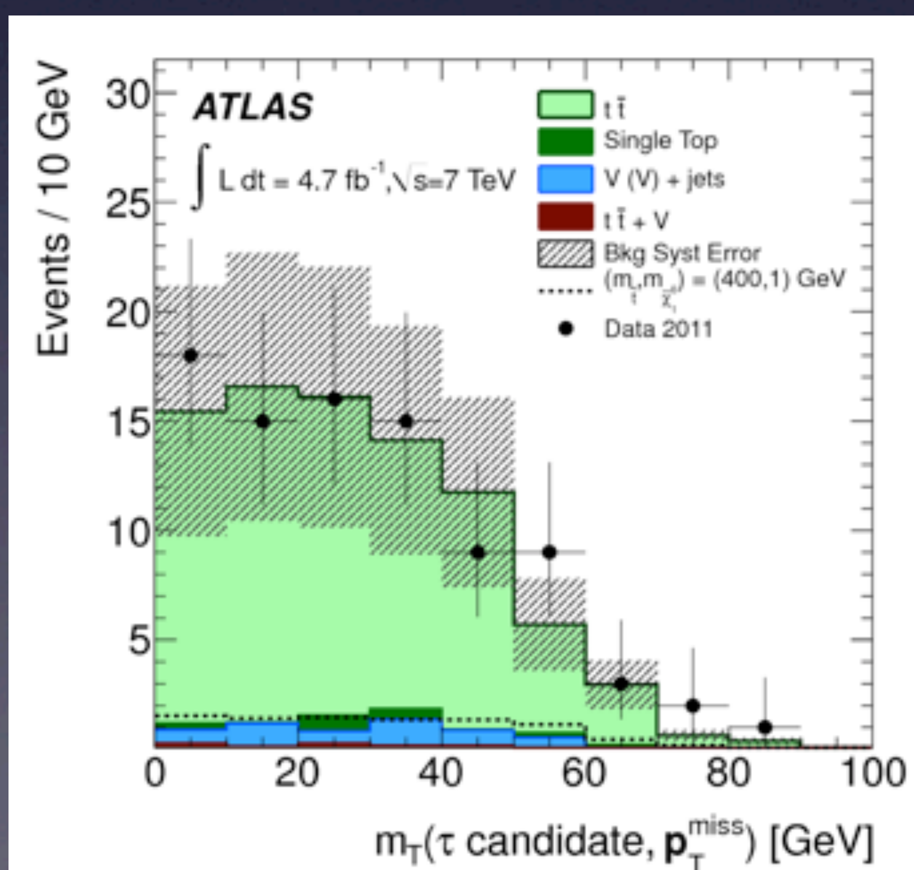


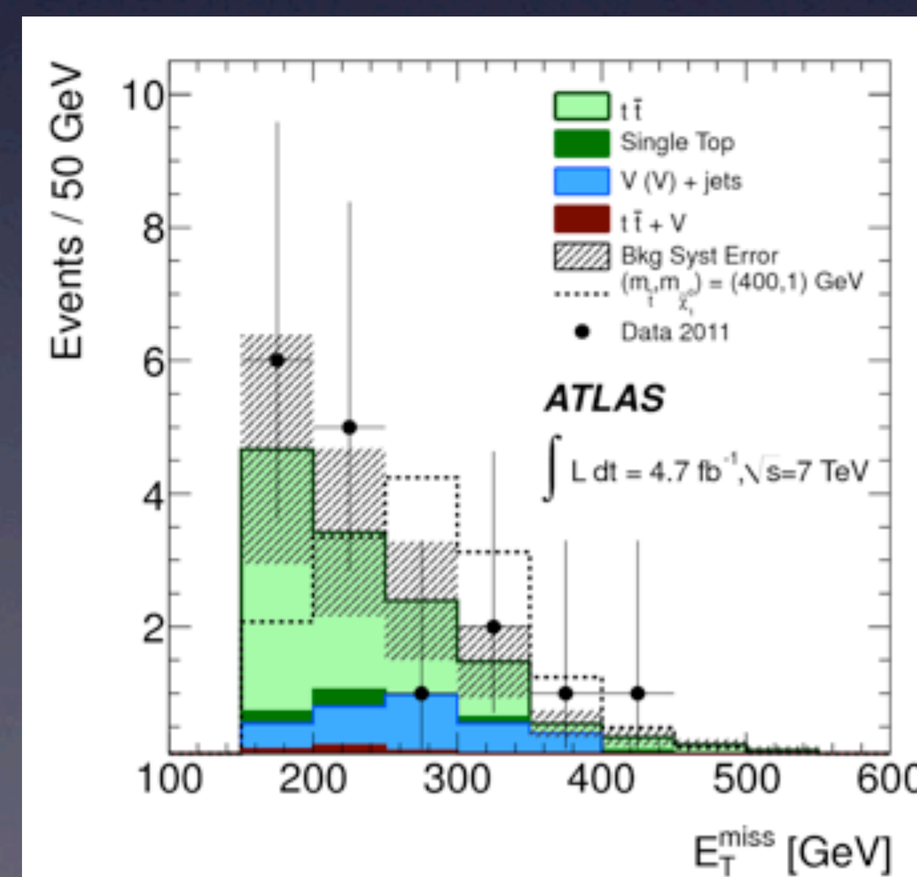
Lighter Stop

- Search for 1-2 leptons, B-Jets and MET - $m_{\tilde{t}} \sim m_t$
- Search for 2 soft leptons, Jets and MET - very light stop

Search for Direct Stop Production in 7 TeV Data, with Stop Decaying to Top + LSP

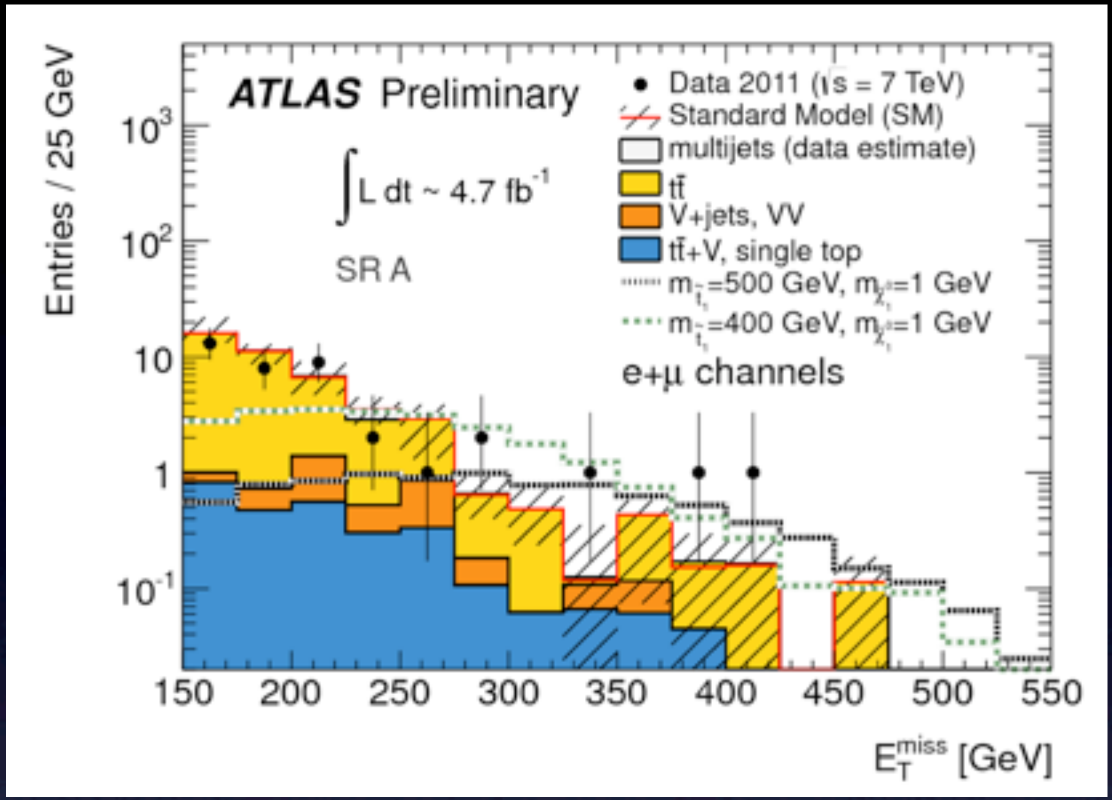
- Require at least 5 jets and no leptons or tau-like jets
- Invariant mass of hadronic top between 80 and 270 GeV and M_T(b,MET) > 175 GeV
- Two SR with MET > 150, 260 GeV
- CR for top pair production where a tau fakes a jet - isolated non-tau lepton with M_T(l,MET) between 40 and 120 GeV





Search for Direct Stop Production in 7 TeV Data, with Stop Decaying to Top + LSP

- 1-Lepton + Jets + MET
- 5 SR based on MET , MET/ sqrt(H_T) and M_T
- 3 CR for top and W backgrounds

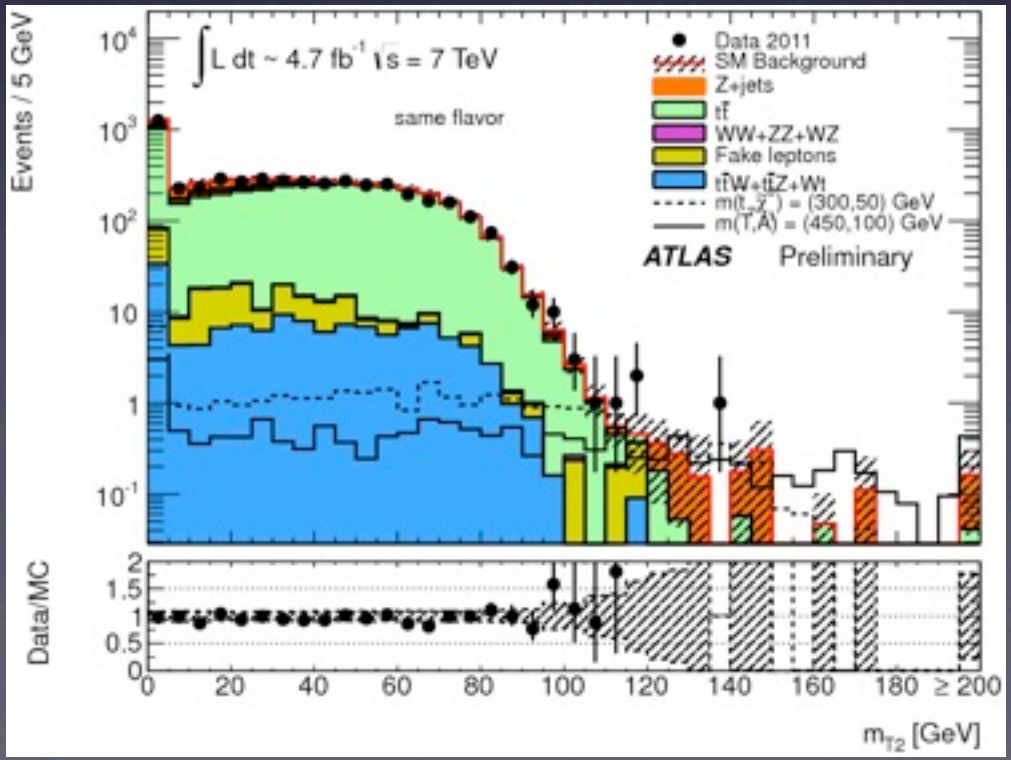


$$m_{T2}(P_T^{l1}, P_T^{l2}, P_T^{miss}) = min[max[m_T(P_T^{l1}, q_T), m_T(P_T^{l2}, r_T)]]$$

$$q_T + r_T = P_T^{miss}$$

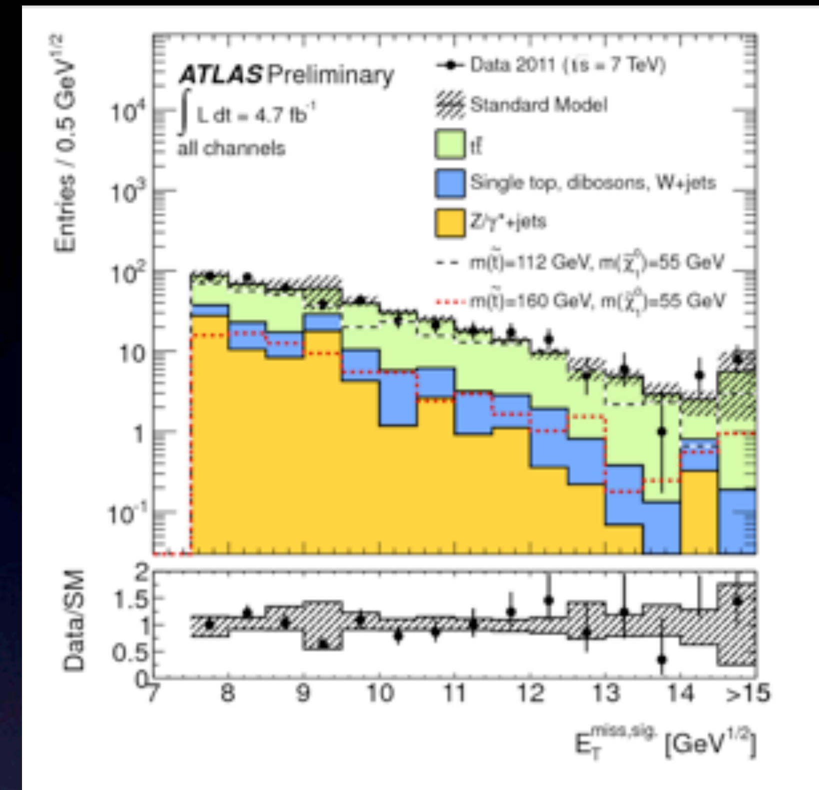
- 2-Lepton + Jets + MET
- Use MT2 to separate signal and background
- Same-Flavour and Different-Flavour SR

+ top/Z CR



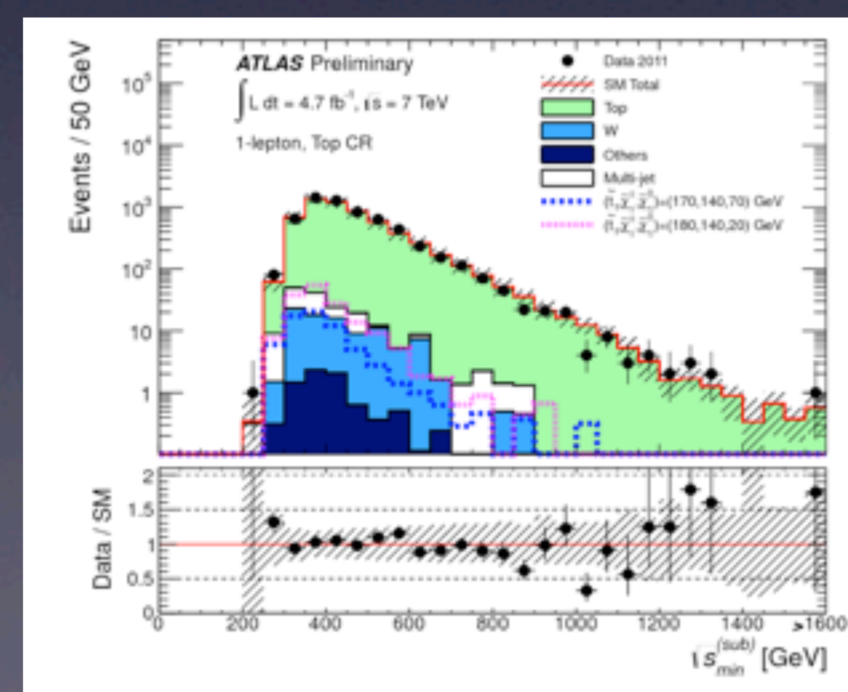
Search for Direct Stop Production in 7 TeV Data, with Stop Decaying to Bottom + Chargino

- 2 soft leptons + Jets + MET
- Define SR using MET significance and upper cut on lepton P_T of 30 GeV
- Top pair and Z from CR



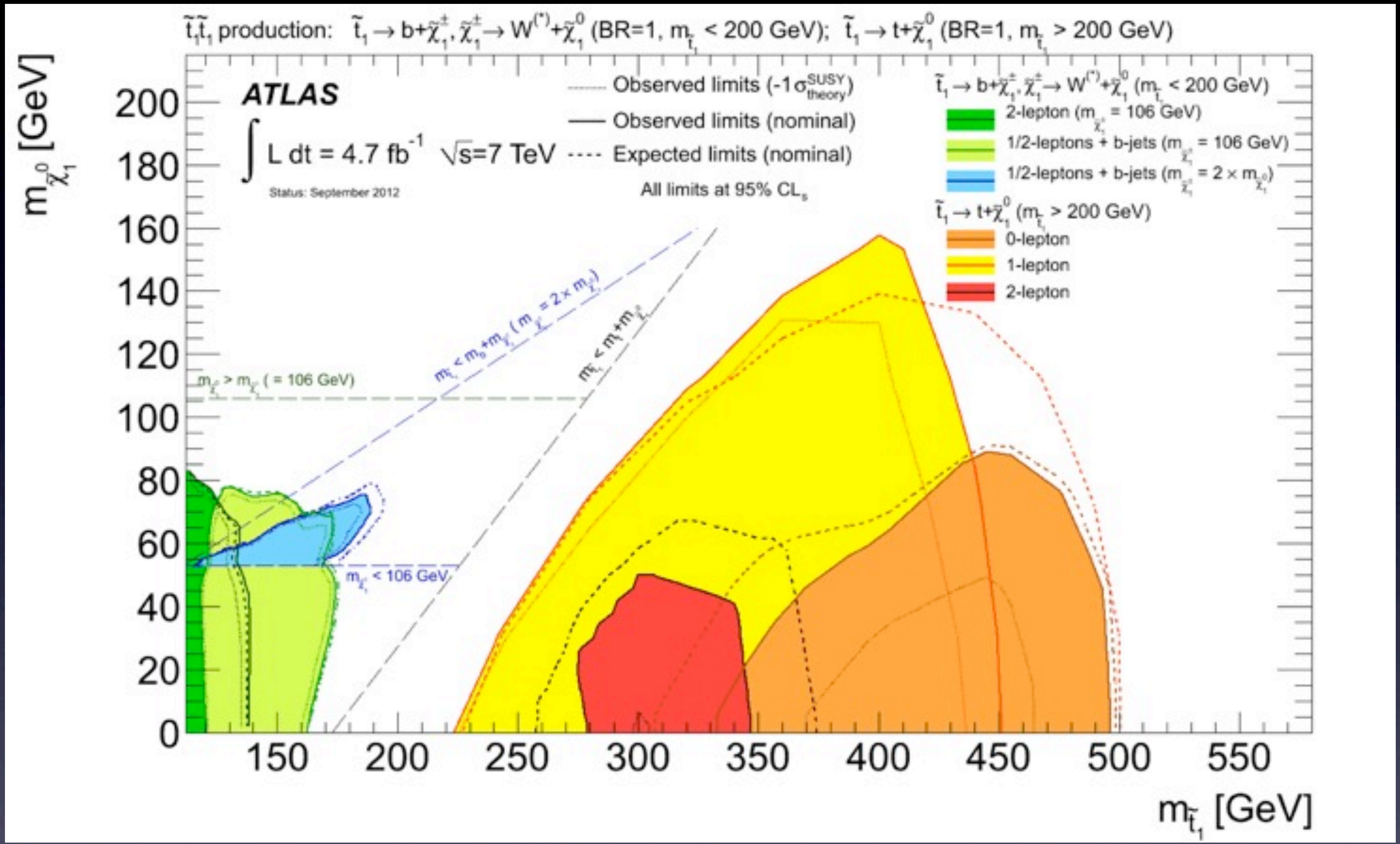
$$\sqrt{S_{min}^{sub}} = \sqrt{(\sqrt{m_{sub}^2 + P_{T,sub}^2} + \sqrt{m_{miss}^2 + MET^2})^2 - (\bar{P}_{T,sub} + \bar{P}_T^{Miss})^2}$$

- 1-2 leptons + b-jets + MET
- Use $\sqrt{S_{min}^{sub}}$ as discriminating variable
- 1LSR and 2LSR + 3 CR (top, W, Z)



Search for Direct Stop Production in 7 TeV Data

- No excess in data observed



http://arxiv.org/abs/1208.4305

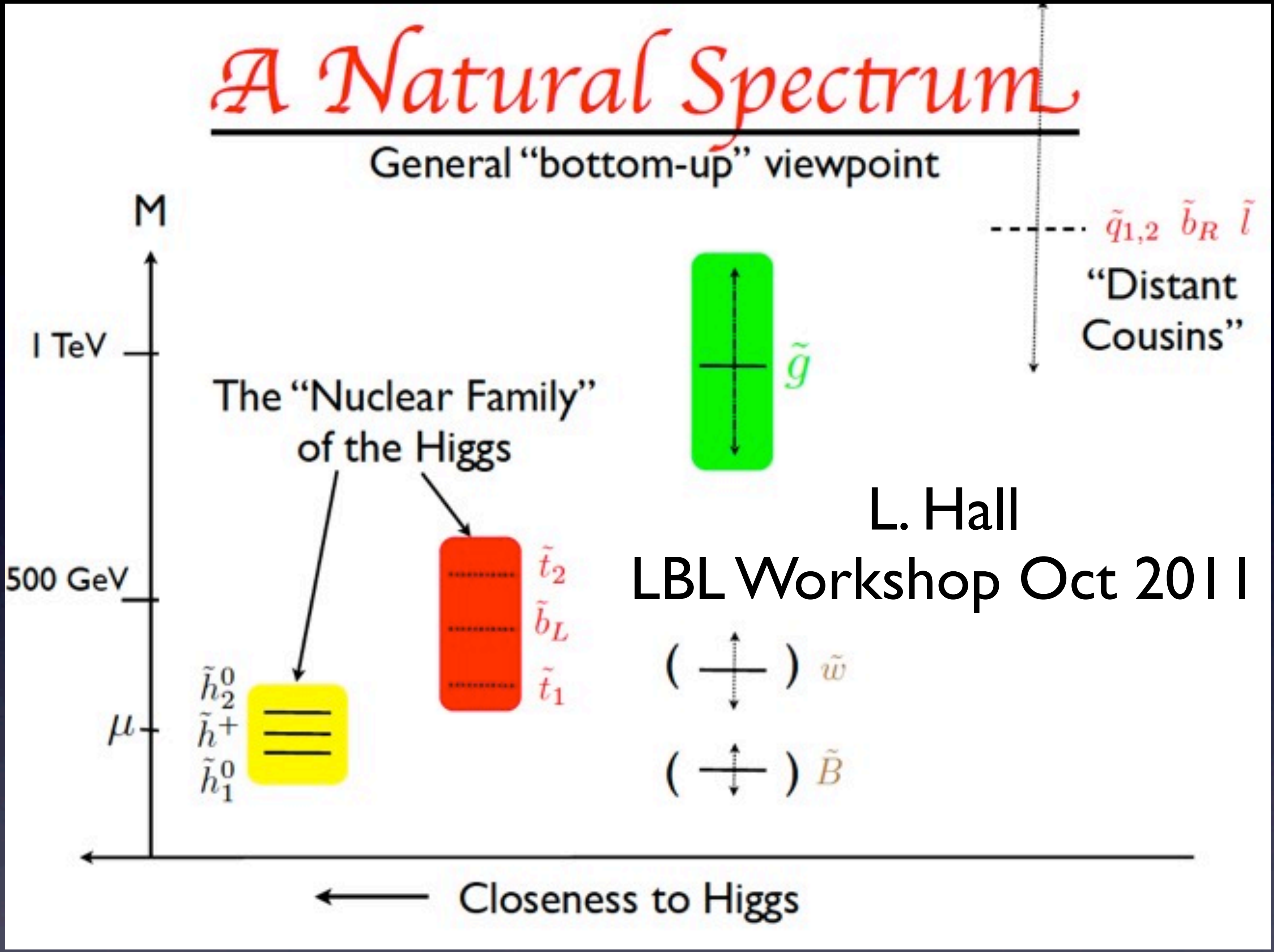
http://arxiv.org/abs/1209.2102

http://arxiv.org/abs/1208.1447

http://arxiv.org/abs/1208.2590

http://arxiv.org/abs/1209.4186

Naturalness



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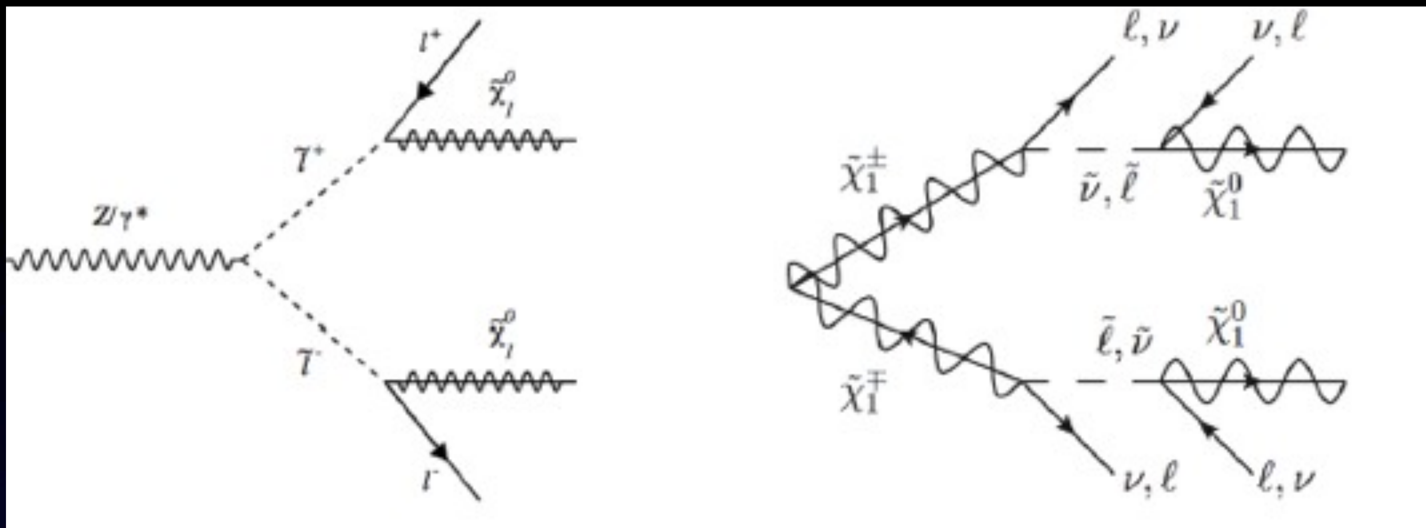
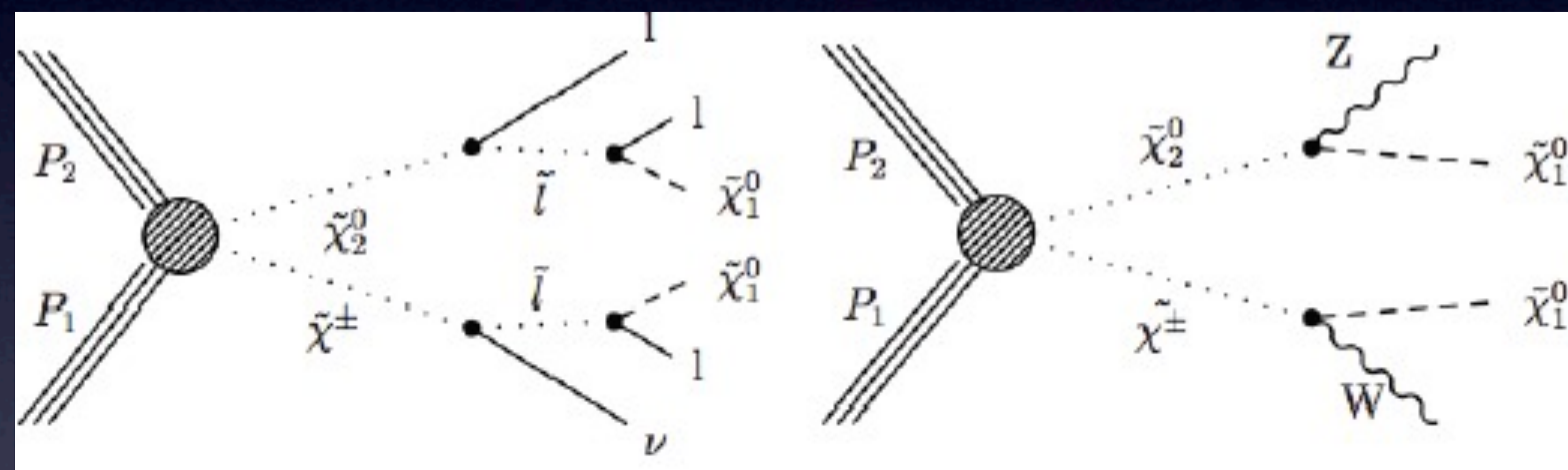
- Typical natural spectrum contains light third generation squarks
- Typical natural spectrum contains light charginos and neutralinos

Search for Direct Slepton and Gaugino Pair Production in 7 and 8 TeV Data





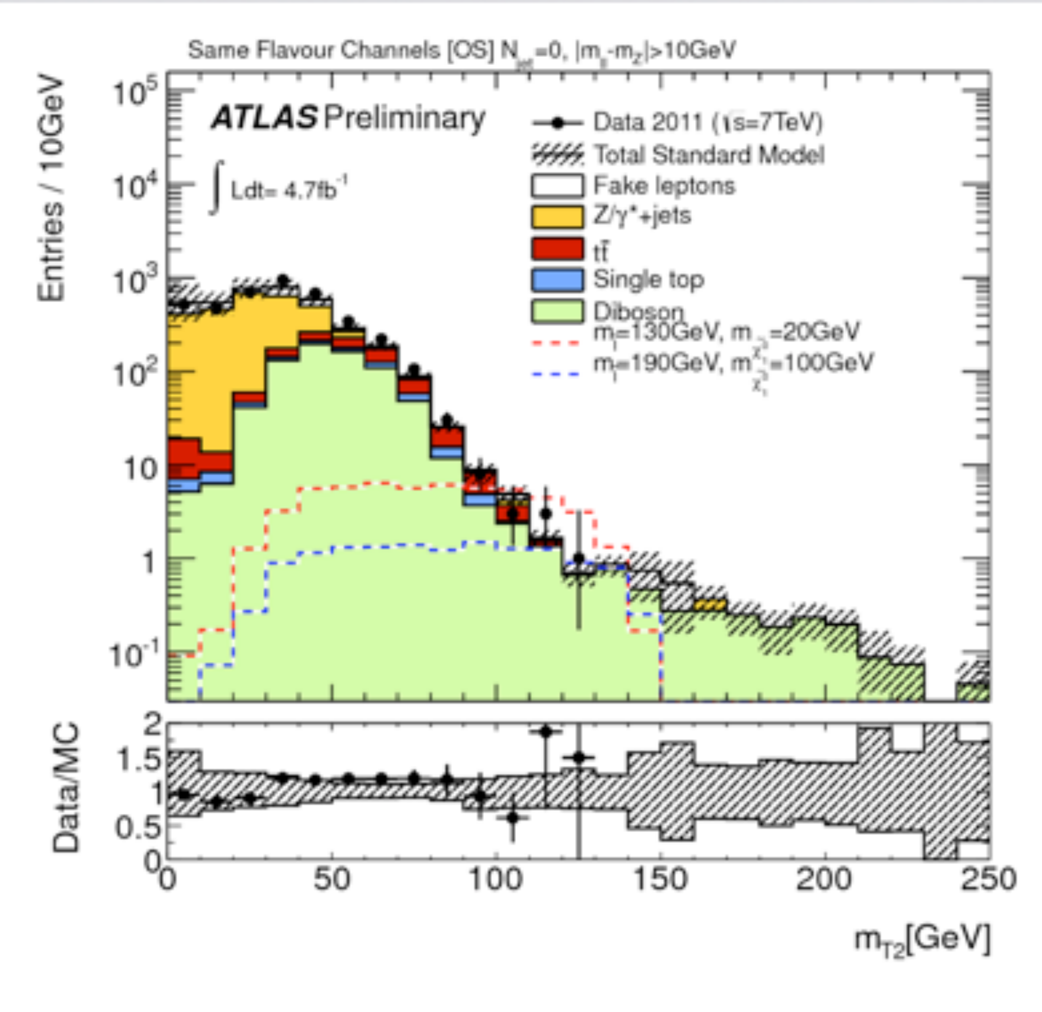
Light sleptons:
Decays via sleptons
Slepton Pair Production

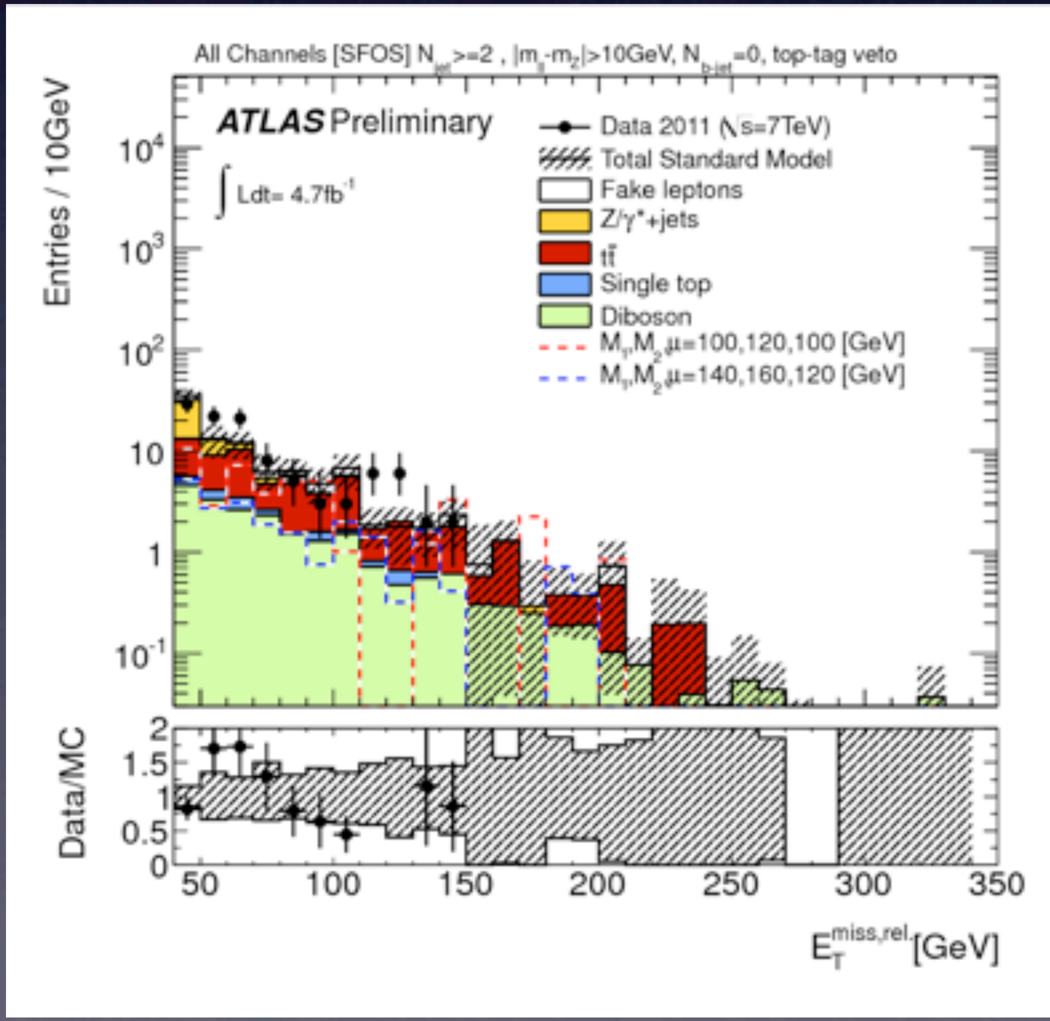
Heavy sleptons:
Decays via W and Z

Search for Direct Slepton and Gaugino Pair Production in 7 TeV Data with 2 Leptons + MET

- Pair of leptons, Z mass veto and MET cut
- CR for top (SR1-3), WW (SR2) and Z + jets (SR3)

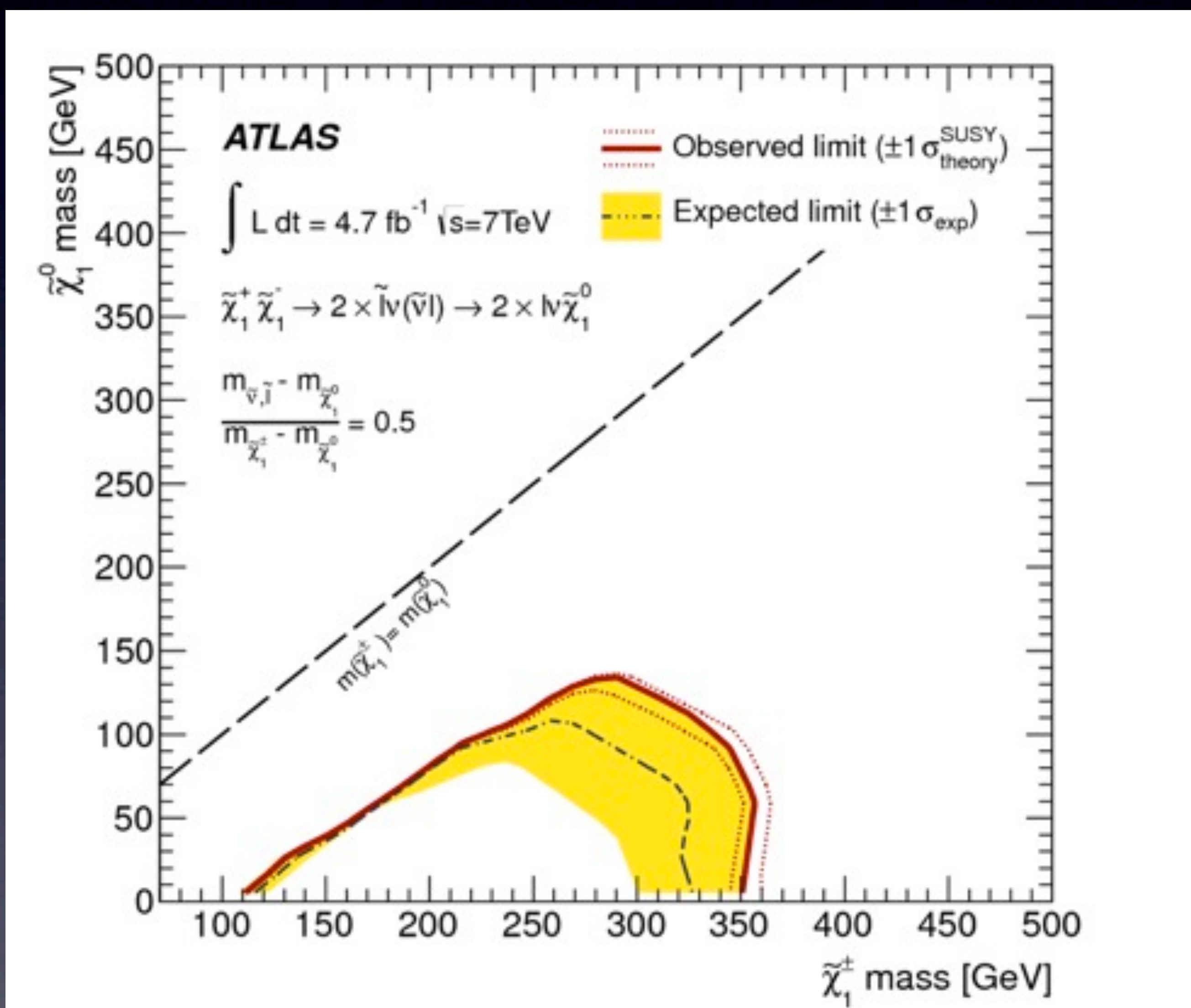
SR-	m_{T2}	OSjveto	SSjveto	2jets
charge	OS	OS	SS	OS
flavour	any	any		SF
m_{ll}	Z-veto	Z-veto	-	Z-veto
signal jets	$= 0$	$= 0$		≥ 2
signal b-jets	-	-		$= 0$
$E_T^{\mathrm{miss,rel.}}$	> 40	> 100		> 50
other	$m_{T2} > 90$	-		m_{CT}-veto

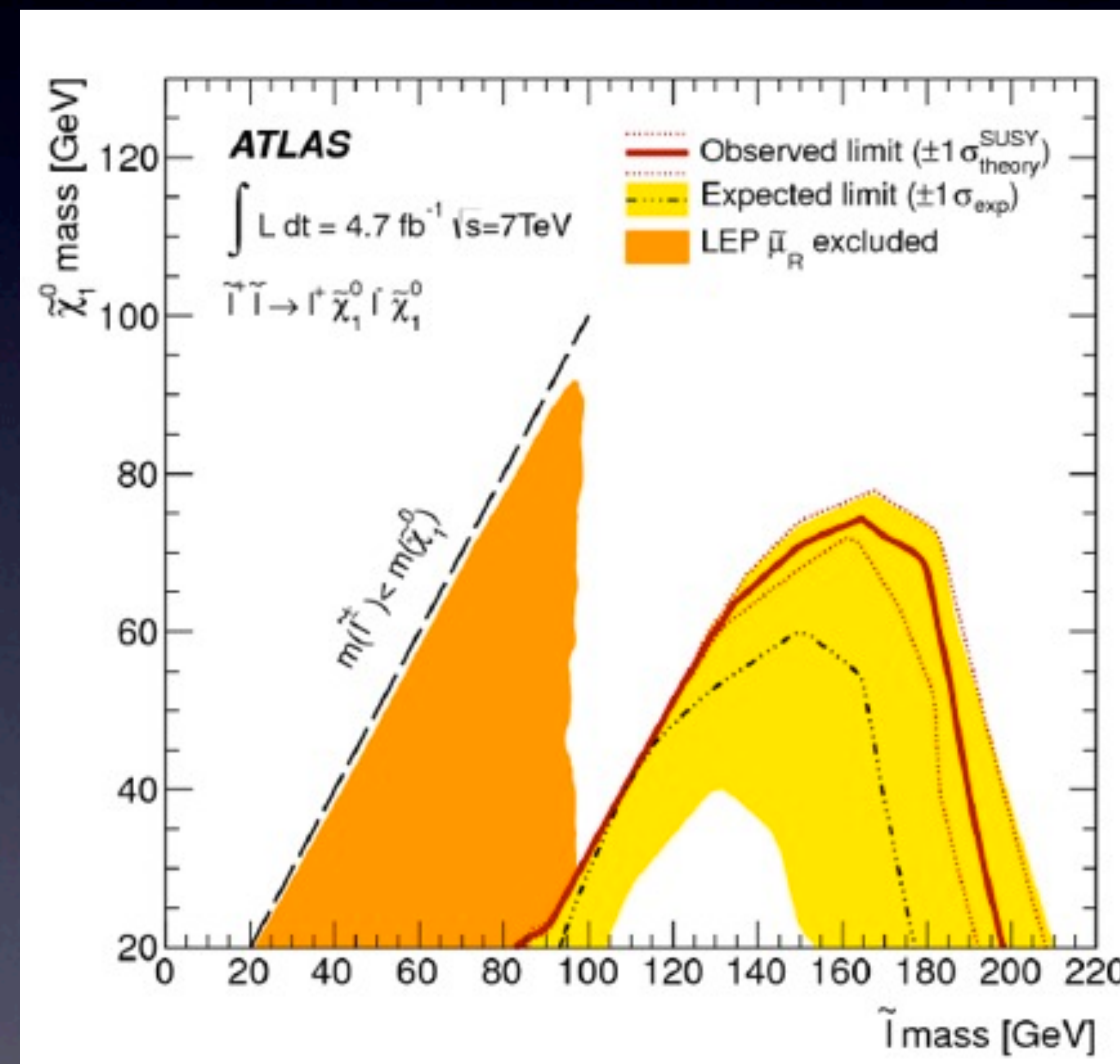




Search for Direct Slepton and Gaugino Pair Production in 7 TeV Data with 2 Leptons + MET

- No excess in data observed

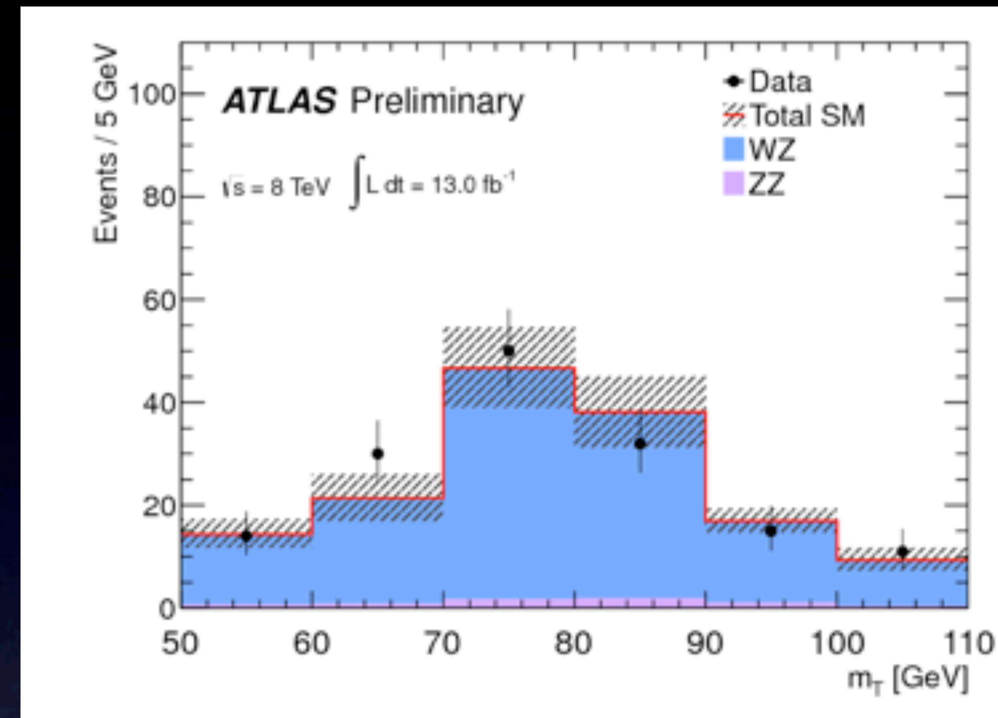




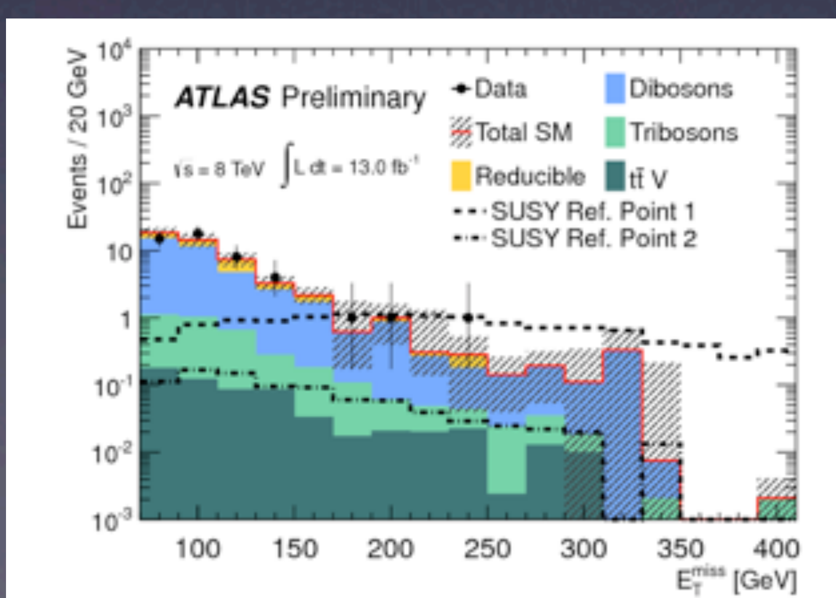
http://arxiv.org/abs/1208.2884

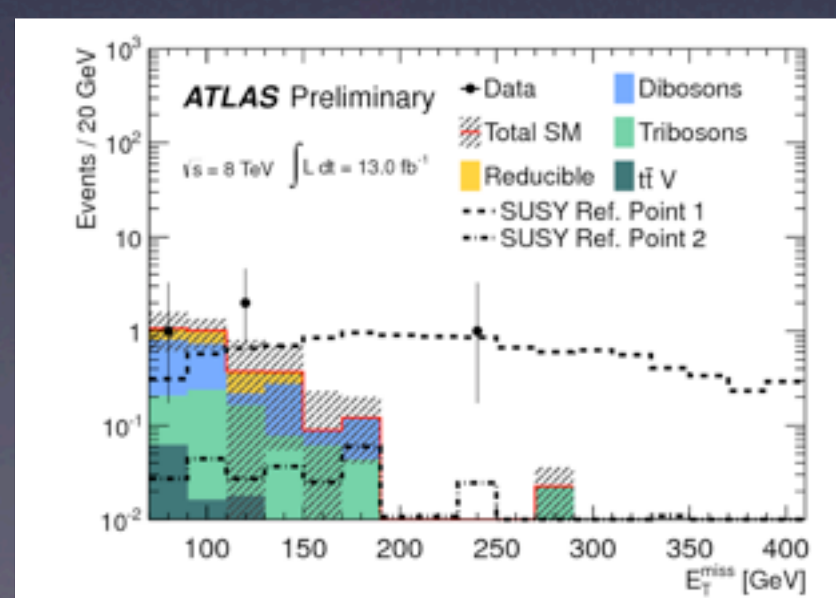
Search for Gaugino Pair Production in 8 TeV Data with 3 Leptons + MET

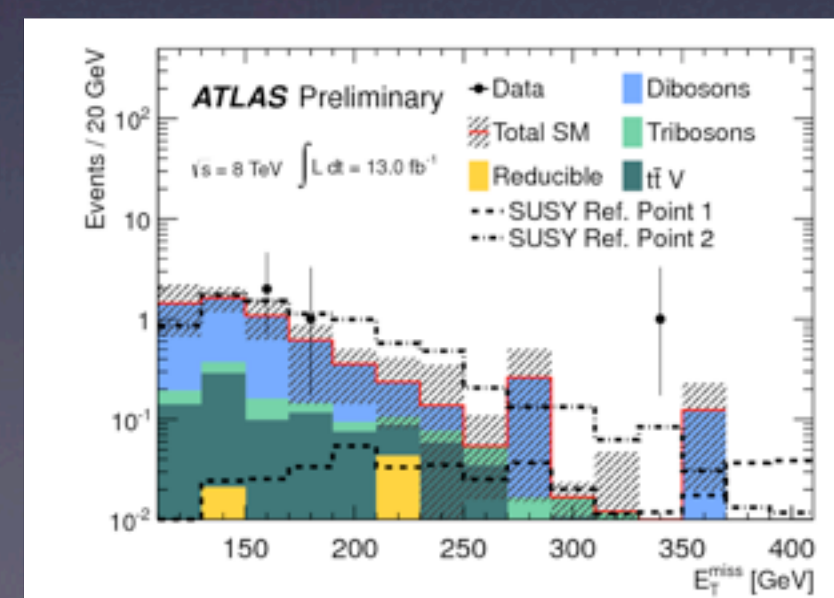
Selection	SR1a	SR1b	SR2
Targeted $\tilde{\chi}_2^0$ decay	$\tilde{\ell}^{(*)}$ or Z^*		on-shell Z
$\lvert m_{\mathrm{SFOS}} - m_Z \rvert$	$> 10\,\mathrm{GeV}$		$< 10\,\mathrm{GeV}$
Number of b-jets	0		any
$E_{\mathrm{T}}^{\mathrm{miss}}$	$> 75\,\mathrm{GeV}$		$> 120\,\mathrm{GeV}$
m_{T}	any	$> 110\,\mathrm{GeV}$	$> 110\,\mathrm{GeV}$
p_{T} of leptons	$> 10\,\mathrm{GeV}$	$> 30\,\mathrm{GeV}$	$> 10\,\mathrm{GeV}$



- SR have 3 isolated leptons
- WZ CR - MET between 50 and 75 GeV, M_T between 50 and 110 GeV
- No Excess observed

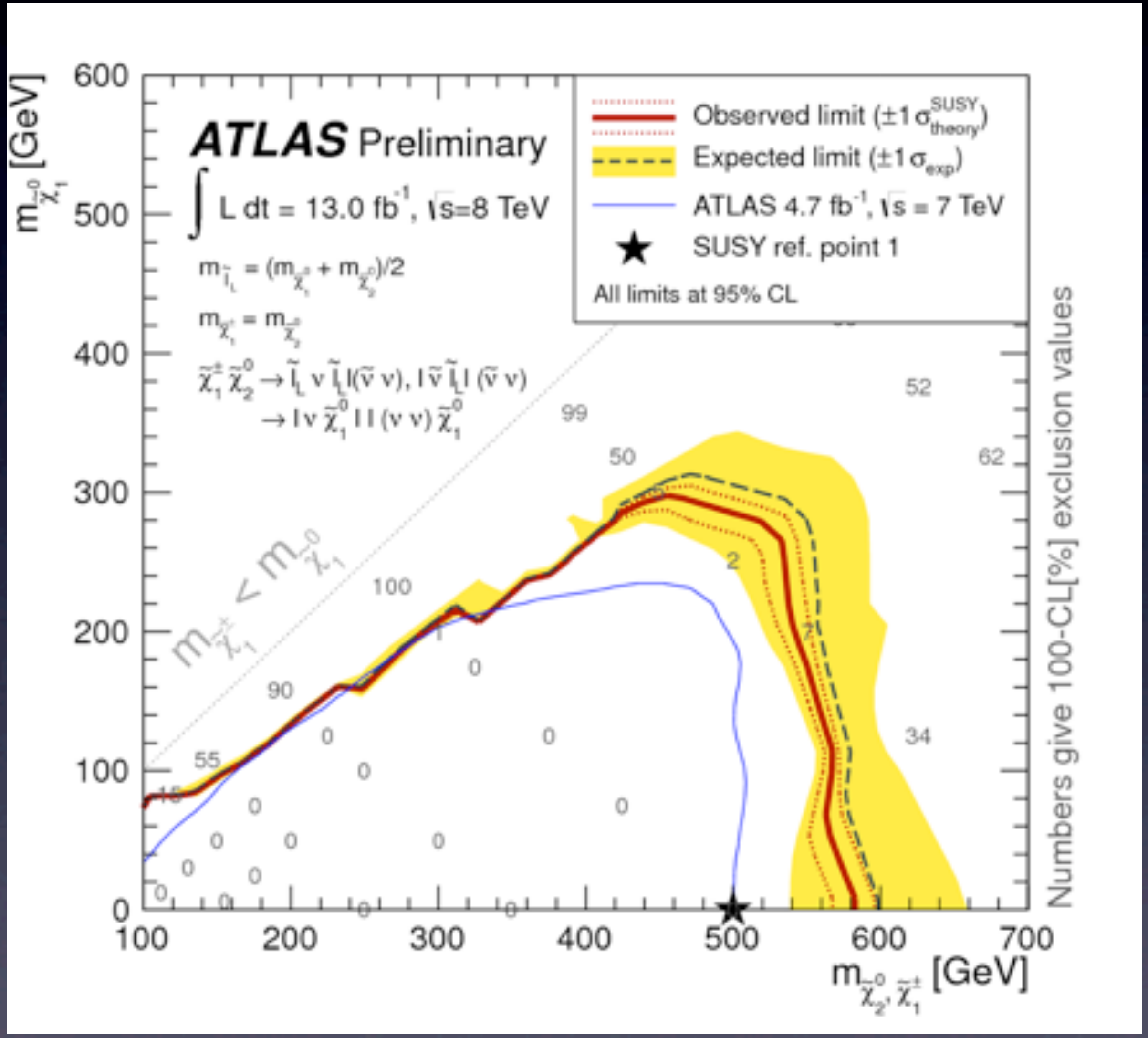


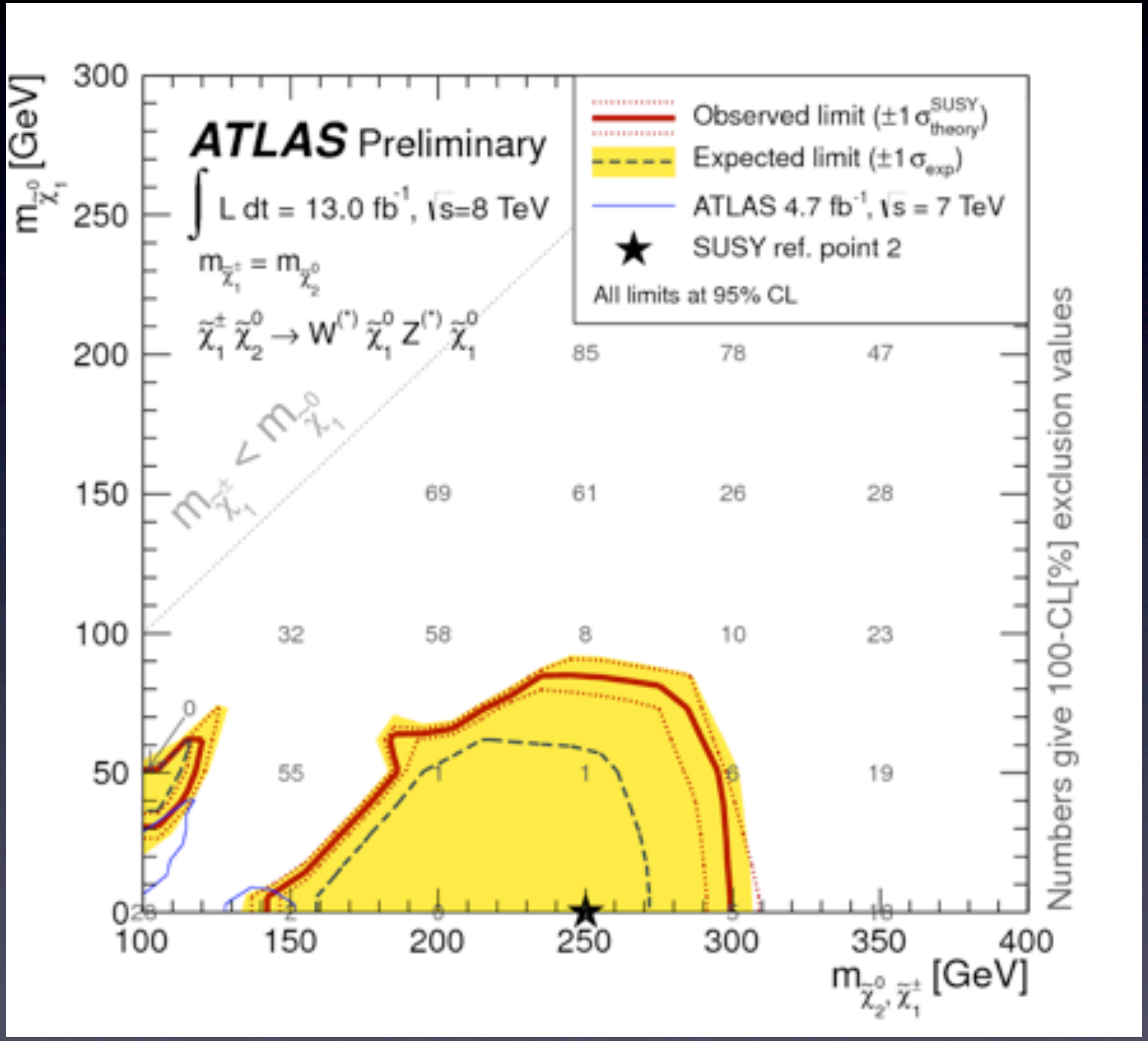




Search for Gaugino Pair Production in 8 TeV Data with 3 Leptons + MET

- No excess in data observed





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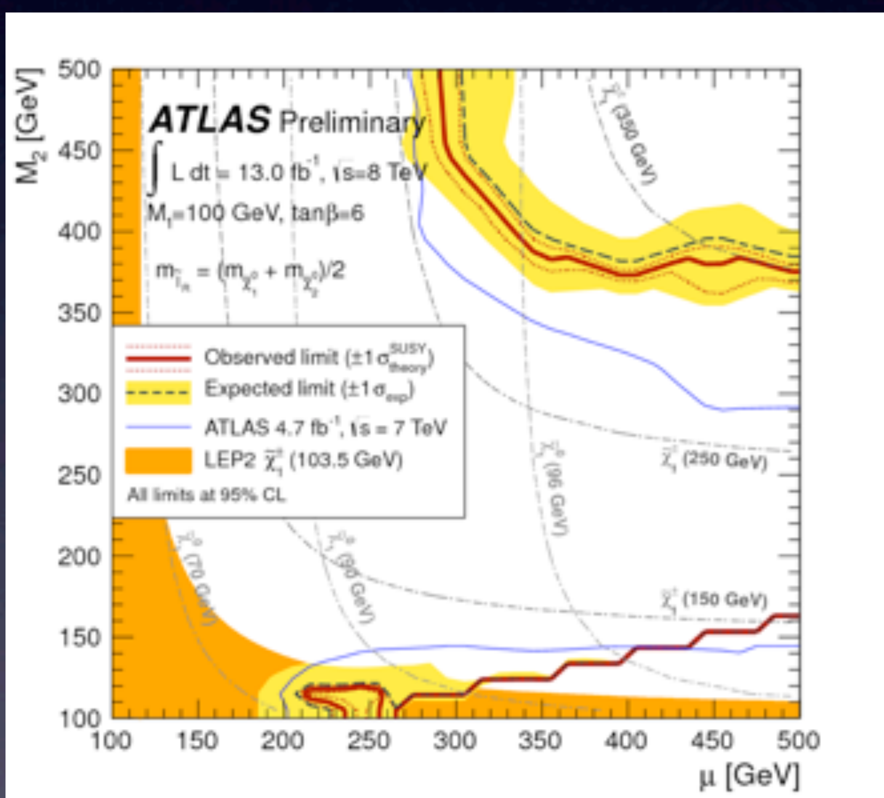
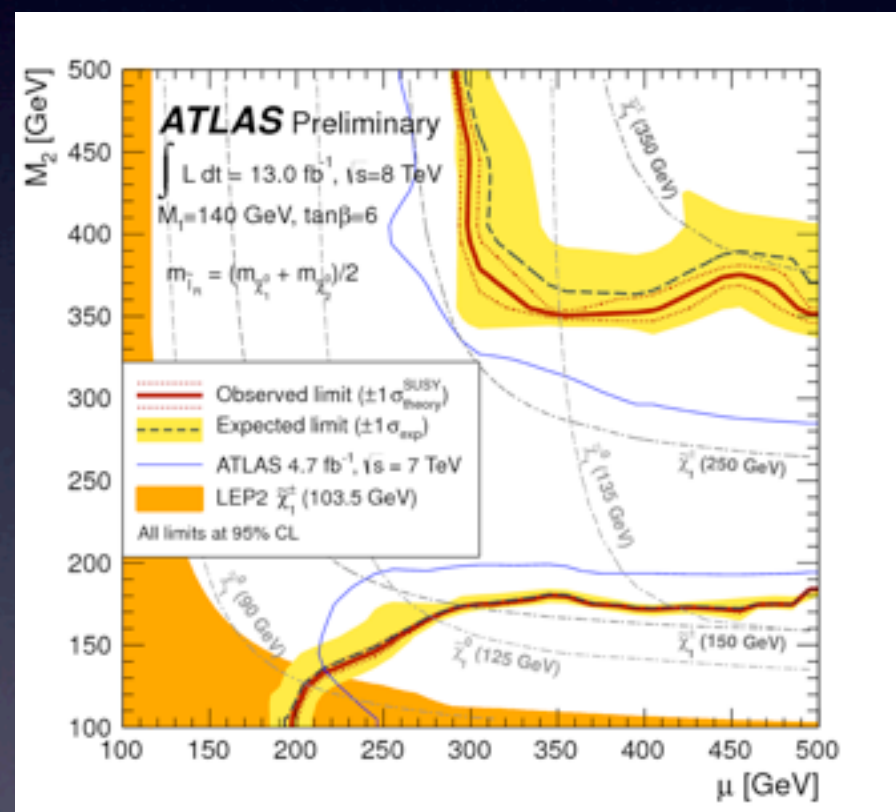
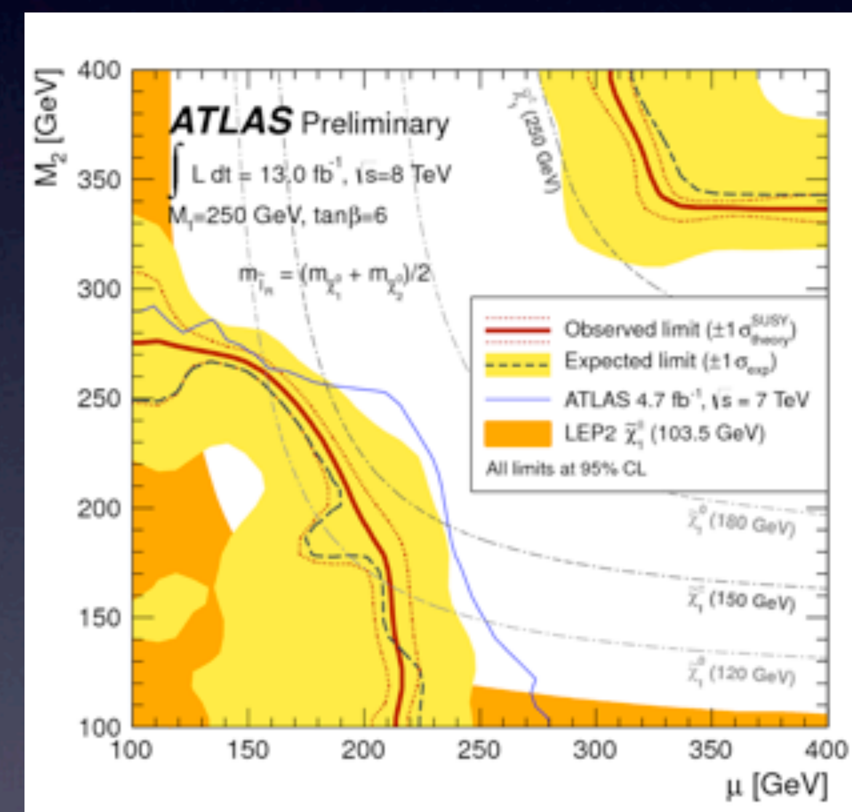
Search for Gaugino Pair Production in 8 TeV Data with 3 Leptons + MET

- Interpret in terms of PMSSM parameters - μ and M_2



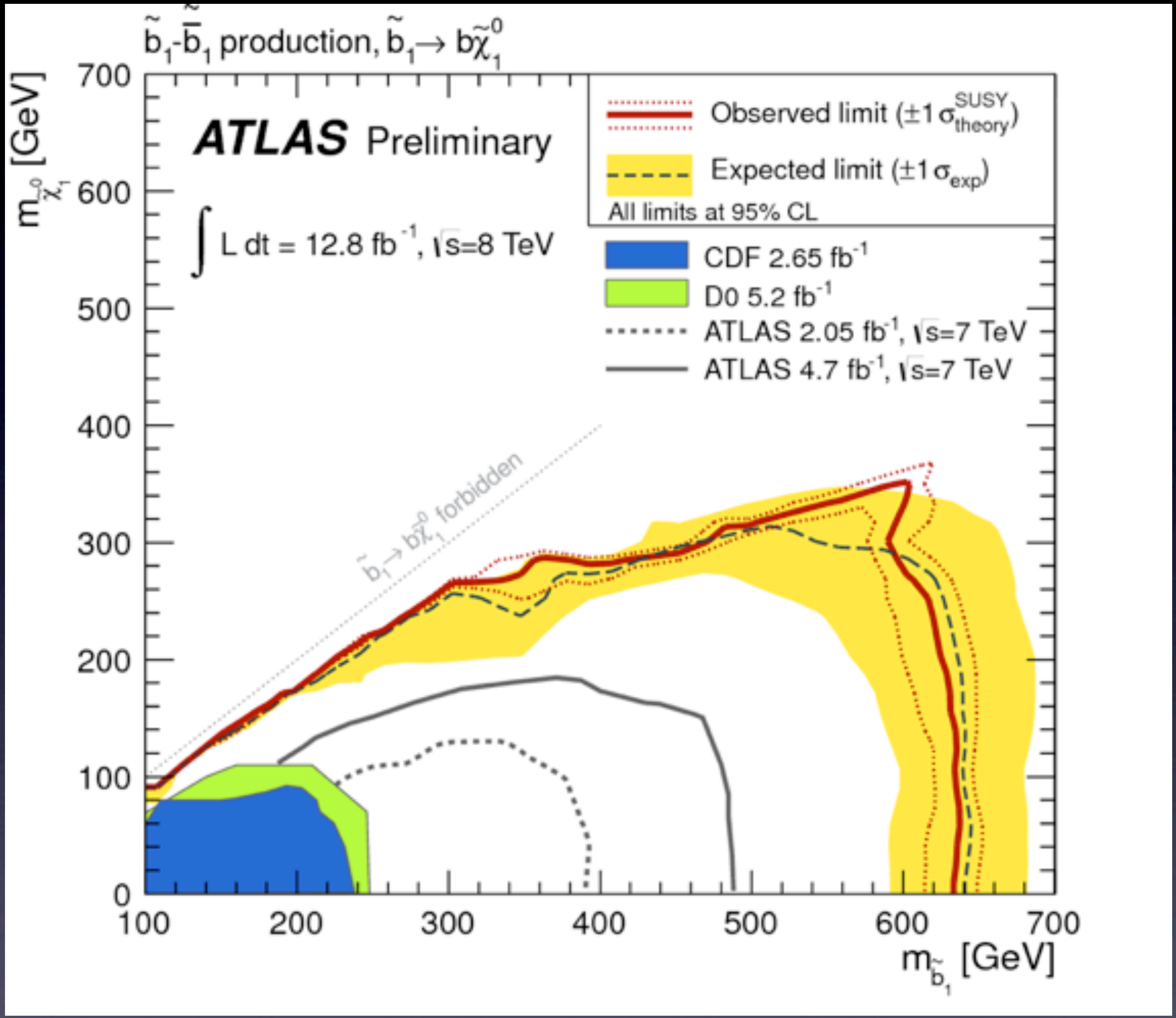




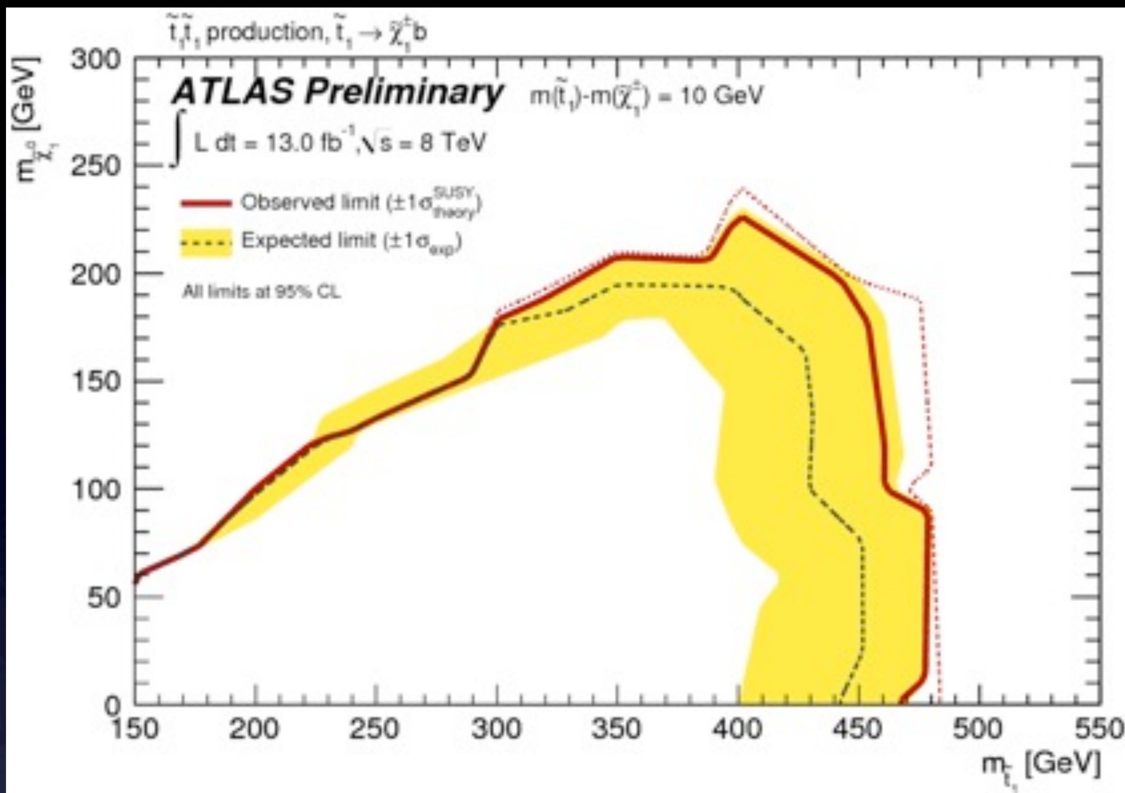
Stop the Press!

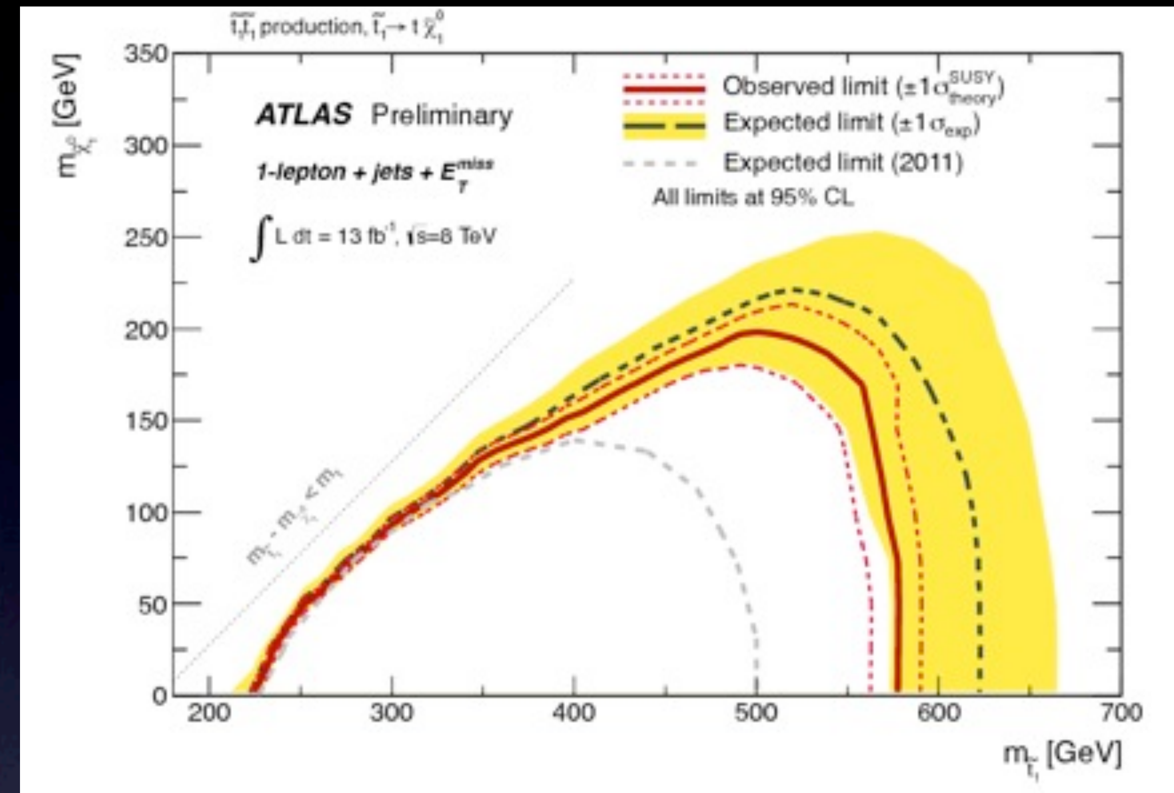
- Direct Stop 8 TeV AND Sbottom 2 B-JETS + MET results should be public by the end of today…
- See ATLAS public results page or…
- ATLAS-CONF-2012-165
- ATLAS-CONF-2012-166
- ATLAS-CONF-2012-167

Direct Sbottom



Direct Stop



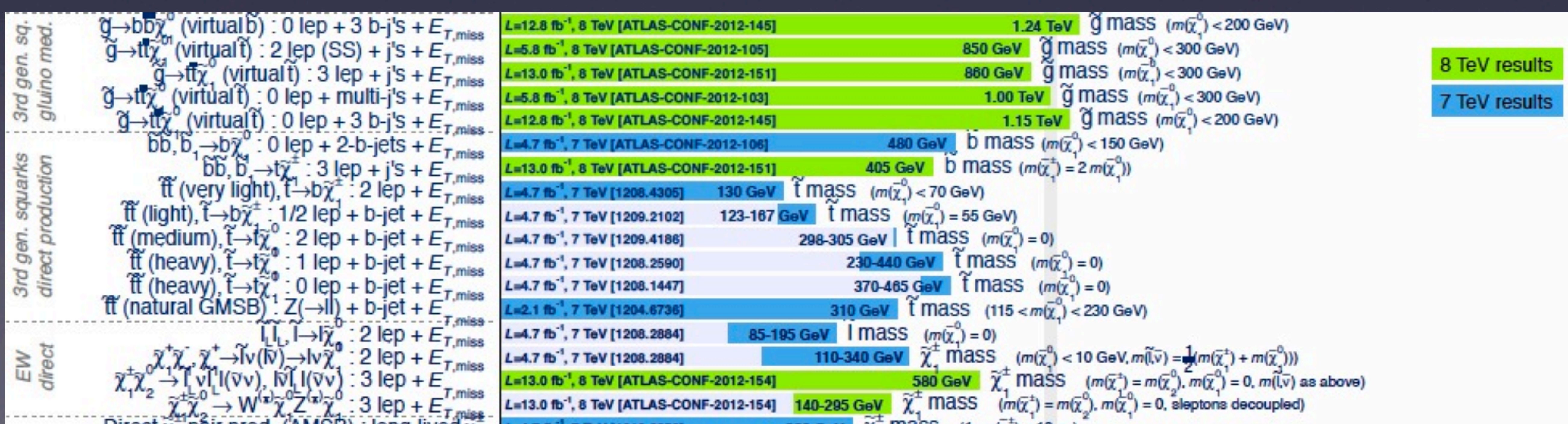


New 2-lepton analysis designed for near degenerate stop-chargino scenario (left) + other scenarios in CONF notes

New summary plot of all Direct Stop should also be out soon!

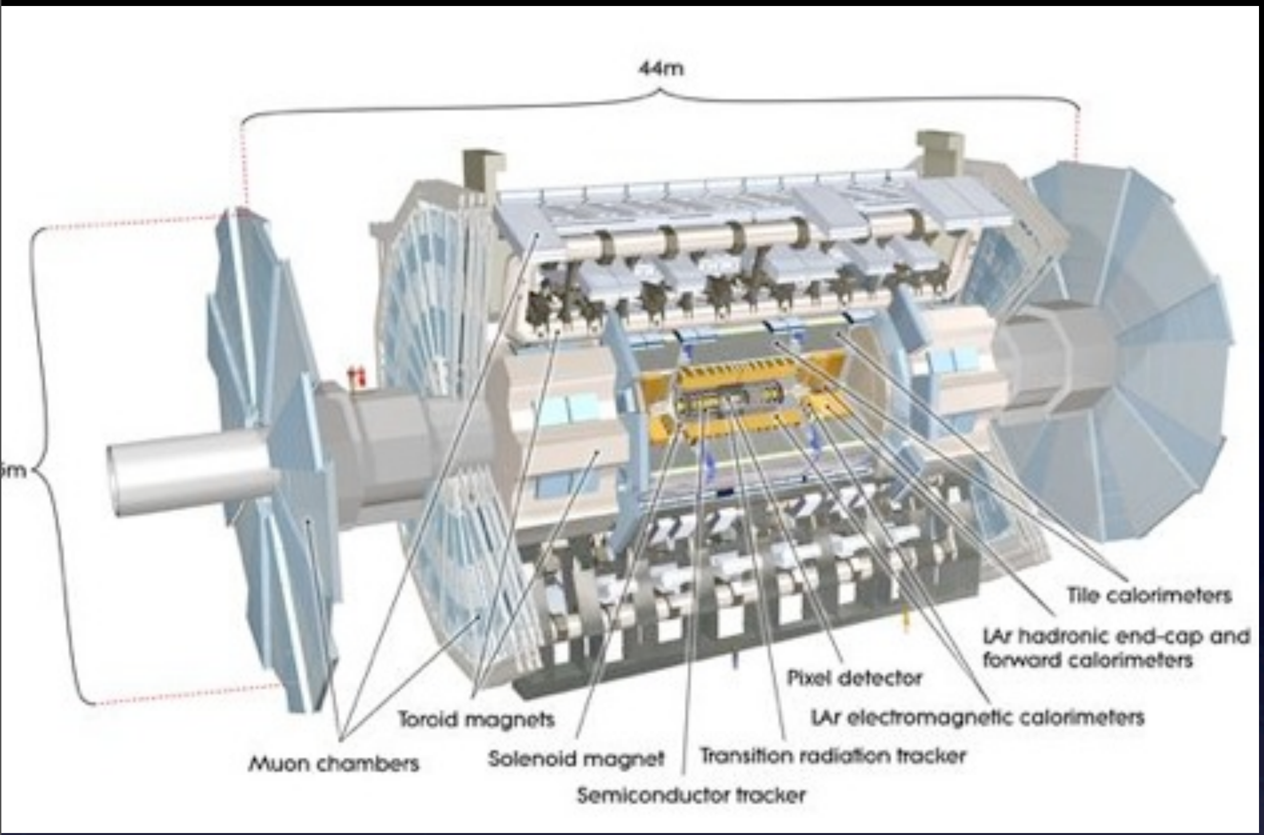
Conclusions

- ATLAS has performed careful searches for production of third generation squarks and gauginos
- Extensive range of scenarios covered using leptons, jets and MET - no excess seen
- 8 TeV searches already have extended 7 TeV limits on SUSY models, other searches are in process of being updated to 8 TeV



Extras

Detectors for Analyses



- Topological clusters formed from energy deposits in calorimeters
- AntiKt jet algorithm, size = 0.4, runs on topological clusters

Hermetic calorimeter coverage important for reconstructing Missing ET :

- Coverage out to $|\eta| < 4.9$

- Calorimeters and Inner Detector systems used for electron reconstruction
- Muon systems and Inner Detector systems used for muon reconstruction

Electron Reconstruction

- Selected based on calorimeter shower shape variables and track information.
- P_T cut is analysis dependent, $|\eta| < 2.47$

Muon Reconstruction

- Search for matched track in muon and inner detectors.
- P_T cut is analysis dependent, $|\eta| < 2.4$

Jet Reconstruction

- Jet reconstruction uses topological clusters at hadronic scale as input to Anti-Kt 0.4 algorithm
- Jet energy scale corrections derived from MC and validated on data are applied
- Pileup corrections derived from data are applied
- Additional jet cleaning cuts are applied to remove jets due to bursts of coherent noise in the calorimeter, cosmic rays and dead (hot) cells
- P_T and $|\eta|$ cuts are analysis dependent

Missing ET (MET) Reconstruction

- Calculated from all Jets, electrons, muons and calorimeter topological clusters not associated to these objects

Third Generation Squarks

- Direct production of sbottom pairs

$$\tilde{b}_1\tilde{b}_1^* \rightarrow b\tilde{\chi}_1^0\bar{b}\tilde{\chi}_1^0$$

2 B-Jets + MET

$$\tilde{b}_1\tilde{b}_1^* \rightarrow t\tilde{\chi}_1^-\bar{t}\tilde{\chi}_1^+ \rightarrow \tilde{\chi}_1^0\nu l^+\bar{t}\tilde{\chi}_1^0\bar{\nu}l^-t$$

3-leptons + 4 jets + MET

- Direct production of stop pairs

$$\tilde{t}_1\tilde{t}_1^* \rightarrow t\tilde{\chi}_1^0\bar{t}\tilde{\chi}_1^0$$

0, 1 or 2 leptons + jets + MET

$$\tilde{t}_1\tilde{t}_1^* \rightarrow b\tilde{\chi}_1^+\bar{b}\tilde{\chi}_1^- \rightarrow bW^+\tilde{\chi}_1^0\bar{b}W^-\tilde{\chi}_1^0$$

1-2 leptons + B-Jets + MET

- Direct production of gluino pairs

$$\tilde{g}\tilde{g} \rightarrow \bar{t}t\bar{t}t\chi_1^0\chi_1^0$$

$$\tilde{g}\tilde{g} \rightarrow \bar{b}b\bar{b}b\chi_1^0\chi_1^0$$

3-leptons + 4-jets + MET
2 Same-Sign Leptons
0-Leptons + 6-9 Jets + MET
3 B-Jets + MET

Gauginos

Chargino Pair Production

$\tilde{\chi}_1^+ \tilde{\chi}_1^- \rightarrow l^+ \bar{\nu} \tilde{\chi}_1^0 l^- \nu \tilde{\chi}_1^0$ 2 Leptons + MET

Chargino-Neutralino Production

$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow l^\pm \nu \tilde{\chi}_1^0 l^- l^+ \tilde{\chi}_1^0$

3 Leptons + MET

2 Leptons + MET

2 B-Jets + MET
ATLAS-CONF-2012-106

$$m_{CT}^2(\nu_1, \nu_2) = [E_T(\nu_1) + E_T(\nu_2]^2 - [P_T(\nu_1) - P_T(\nu_2)]^2$$

M_{CT} has endpoint: $\tilde{b} \rightarrow b\tilde{\chi}_1^0$

$$m_{CT}^{max} = \frac{m^2(\tilde{b}) - m^2(\tilde{\chi}_1^0)}{m(\tilde{b})}$$

The analysis uses a boost corrected version of M_{CT}, which accounts for any boost in the transverse plane due to ISR

Cut	Description	Signal region			
		SR1	SR2	SR3a	SR3b
1	Trigger	E_T^{miss} trigger > 99% efficient for $E_T^{miss} > 150$ GeV			
2	Event cleaning	Common to all SR			
3	Lepton veto	No e/μ after overlap removal with $p_T > 20/10$ GeV.			
4	E_T^{miss}	> 150 GeV	> 200 GeV	> 150 GeV	> 250 GeV
5	Leading jet $p_T(j_1)$	> 130 GeV, $\lvert\eta\rvert < 2.8$	> 60 GeV, $\lvert\eta\rvert < 2.8$	> 130 GeV, $\lvert\eta\rvert < 2.8$	> 150 GeV, $\lvert\eta\rvert < 2.8$
6	Second jet $p_T(j_2)$	> 50 GeV, $\lvert\eta\rvert < 2.8$	> 60 GeV, $\lvert\eta\rvert < 2.8$	> 30 GeV, $\lvert\eta\rvert < 2.8$	
7	Third jet $p_T(j_3)$	veto if > 50 GeV, $\lvert\eta\rvert < 2.8$		> 30 GeV, $\lvert\eta\rvert < 2.8$	
8	$\Delta\phi(E_T^{miss}, j_1)$	-		> 2.5	
9	b-jet multiplicity	leading 2 jets ($p_T > 50$ GeV, $\lvert\eta\rvert < 2.5$) $n_{b\text{-jets}} = 2$		2nd- and 3rd-leading jets ($p_T > 30$ GeV, $\lvert\eta\rvert < 2.5$) $n_{b\text{-jets}} = 2$	
10	Leading b-jet p_T	-		< 110 GeV	
11	$\Delta\phi_{min}(n)$	> 0.4 ($n = 2$)		> 0.4 ($n = 3$)	
12	$E_T^{miss}/m_{eff}(j_1, j_2, j_3)$	> 0.25			
13	m_{CT}	> 150, 200, 250 GeV	> 100 GeV	-	
14	$H_{T,x}$	-	< 50 GeV, $x = 2$	< 50 GeV, $x = 3$	

Table 1: Summary of the event selection in each signal region.

SR1,2 use 2 B-Jets to tag the sbottom decays
SR3 tags the ISR as a high pt jet, and the sbottom decays via 2 lower pt b-jets

$\Delta\phi_{min}$

Minimum azimuthal angle between jet and MET
Suppresses multijets

Backgrounds

CR1L_SR1	CR2L_SR1
1 tight electron or muon	ee or $\mu\mu$
two reconstructed jets (veto on 3rd jet with $p_T > 50$ GeV):	
$p_T(j_1) > 130$ GeV and $p_T(j_2) > 50$ GeV	$p_T(j_1) > 50$ GeV and $p_T(j_2) > 50$ GeV
$E_T^{miss} > 90$ GeV	E_T^{miss} (lepton-corrected) > 90 GeV
two reconstructed b-jets (leading jets)	
40 GeV < m_T < 100 GeV	40 GeV < m_{ll} < 140 GeV

Table 2: Definition of the control regions adopted for SR1.

CR1L_SR2	CR2L_SR2
1 tight electron or muon	ee or $\mu\mu$
two reconstructed jets (veto on 3rd jet with $p_T > 50$ GeV):	
$p_T(j_1) > 60$ GeV and $p_T(j_2) > 60$ GeV	$p_T(j_1) > 50$ GeV and $p_T(j_2) > 50$ GeV
$E_T^{miss} > 120$ GeV	E_T^{miss} (lepton-corrected)> 90 GeV
two reconstructed b-jets (leading jets)	
40 GeV < m_T < 100 GeV	40 GeV < m_{ll} < 140 GeV

Table 3: Definition of the control regions adopted for SR2.

CR2L: Use Z->ll to mimic Z->νν

channel	CR1L_SR1	CR2L_SR1	0-lepton validation
Observed events	202	211	57
Fitted bkg events	205 ± 15	209 ± 16	48 ± 7
Fitted Top events	167 ± 16	143 ± 16	34 ± 6
Fitted Z events	1.2 ± 0.4	63 ± 14	11 ± 3
Fitted W events	31 ± 17	0	3 ± 1
Fitted Others events	5.9 ± 1.4	2.6 ± 0.5	0.21 ± 0.06
Fitted multijet events	0	0	0.7 ± 0.7
MC exp. SM events	210	178	45
MC exp. Top events	173	138	35
MC exp. Z events	0.7	37	7
MC exp. W events	30	0	2.5
MC exp. Others events	6.8	2.9	0.2
exp. multijet events	0	0	0.7

Table 5: Results of the fit for the control regions and 0-lepton validation region (defined as $m_{CT} < 100$ GeV) adopted for SR1.

Similar agreement found in cases of SR2,3

Multijets Background

- Used jet smearing technique
- Constrained jet response shape from data control analyses
- Use this response to smear jets in “seed events” with well measured jets
- Produces multi-jet pseudo-data

channel	SR1			SR2	SR3	
	$m_{CT} > 150$ GeV	$m_{CT} > 200$ GeV	$m_{CT} > 250$ GeV		SR3a	SR3 b
Observed	62	27	4	20	86	7
Fitted bkg	56 ± 11	24.9 ± 5.8	6.9 ± 2.3	27 ± 7	81 ± 14	8.0 ± 2.7
Fitted Top	13 ± 3	5 ± 1	1.5 ± 0.5	4.8 ± 1.2	47.8 ± 9.5	4.1 ± 1.2
Fitted Z	35 ± 10	16 ± 5	4.1 ± 1.7	17 ± 6	11.1 ± 4.5	1.3 ± 0.9
Fitted W	6.2 ± 3.8	2.3 ± 1.1	0.8 ± 0.6	3.1 ± 1.5	13 ± 8	2.4 ± 2.0
Fitted Others	2.2 ± 0.6	1.2 ± 0.4	0.5 ± 0.2	2.5 ± 0.8	1.6 ± 0.3	0.2 ± 0.1
Fitted multijet	0.5 ± 0.5	0.4 ± 0.4	0.07 ± 0.07	0	7.9 ± 4.5	0
MC exp. SM	44 ± 17	20 ± 8	6.7 ± 3.0	22 ± 9	79 ± 21	7.5 ± 2.5
MC exp. Top	13 ± 5	6.1 ± 2.9	1.5 ± 0.8	4.7 ± 2.2	51 ± 14	4.3 ± 1.6
MC exp. Z	22 ± 15	10 ± 7	3 ± 2	11 ± 7	7.3 ± 4.9	0.8 ± 0.8
MC exp. W	6.1 ± 4.0	2.2 ± 1.5	1 ± 1	3.5 ± 2.1	11 ± 7	2.2 ± 2.0
MC exp. Others	2.5 ± 1.0	1.4 ± 0.8	0.6 ± 0.4	2.9 ± 0.7	1.5 ± 0.4	0.2 ± 0.1
exp. multijet	0.5 ± 0.5	0.4 ± 0.4	0.07 ± 0.07	0	7.9 ± 4.5	0

Table 6: For each signal region, the observed event yield is compared with the prediction obtained from the fit. The contribution of each SM process to each signal region yield is also shown before and after the fit. The errors on the expected MC includes statistical and systematic uncertainties.

Signal region	Background estimate	Observed data	UL on BSM event yield		UL on σ_{vis} (fb^{-1})	
			expected	observed	expected	observed
SR1 ($m_{CT} > 150$ GeV)	56 ± 11	62	25.6	28.9	5.43	6.14
SR1 ($m_{CT} > 200$ GeV)	24.9 ± 5.8	27	15.6	16.9	3.31	3.59
SR1 ($m_{CT} > 250$ GeV)	6.9 ± 2.3	4	6.94	5.22	1.47	1.11
SR2	27 ± 7	20	14.4	10.8	3.06	2.29
SR3a	81 ± 14	86	34.3	36.9	7.28	7.83
SR3b	8.0 ± 2.7	7	8.04	7.45	1.71	1.58

Table 7: Expected and observed Upper Limits (UL) on a generic BSM yield, and on $\sigma_{vis} = \sigma \cdot A \cdot \varepsilon$ for all the signal regions defined.

Systematic Uncertainties

- Dominant detector uncertainty from b-jet tag efficiency and mistag rates for light jets - 10-20% per jet
- Jet Energy Scale (JES) uncertainty of 10-20% per SR
- Jet Energy Resolution (JER) uncertainty is smaller per SR
- Lepton ID efficiency and energy scale negligible
- Object uncertainties propagated to MET - typically less than 5% per SR
- Theoretical uncertainty of 10-15% per SR (e.g. choice of top pair generator, cross-section etc)

Systematic Uncertainties

- Multijet background has an uncertainty of 50-100% per SR - comes from shape of jet response
- Luminosity uncertainty of 3.9%

3 Leptons + 4 Jets + MET
ATLAS-CONF-2012-151

Fakes

Process	3μ	$1e2OS\mu$	$1e2SS\mu$	$2OSe1\mu$	$2SSe1\mu$	$3e$
Z+ LF jets, $Z\to ee$				$S(\text{LF}\to\mu)$	$S(\text{LF}\to\mu)$	$S(\text{LF}\to e)$
Z+ LF jets, $Z\to\mu\mu$	$S(\text{LF}\to\mu)$	$S(\text{LF}\to e)$	$S(\text{LF}\to e)$			
Z+ HF jets, $Z\to ee$				$S(\text{HF}\to\mu)$	$S(\text{HF}\to\mu)$	$S(\text{HF}\to e)$
Z+ HF jets, $Z\to\mu\mu$	$S(\text{HF}\to\mu)$	$S(\text{HF}\to e)$	$S(\text{HF}\to e)$			
$t\bar{t}$	$S(\text{HF}\to\mu)$	$S_c(\text{HF})$	$S(\text{HF}\to\mu)$	$S_c(\text{HF})$	$S(\text{HF}\to e)$	$S(\text{HF}\to e)$
Wt	$S(\text{HF}\to\mu)$	$S_c(\text{HF})$	$S(\text{HF}\to\mu)$	$S_c(\text{HF})$	$S(\text{HF}\to e)$	$S(\text{HF}\to e)$
WW+jets	$S(\text{LF}\to\mu)$	$S_c(\text{LF})$	$S(\text{LF}\to\mu)$	$S_c(\text{LF})$	$S(\text{LF}\to e)$	$S(\text{LF}\to e)$

Table 1: The multiplicative fake-rate scale factors are applied to the simulated processes depending on the flavors and charges of the final-state leptons. Since some processes contribute through both fake electrons and muons, the linear combinations $S_c(\text{HF}) = \{\epsilon_e \cdot S(\text{HF}\to\mu) + \epsilon_\mu \cdot S(\text{HF}\to e)\}/(\epsilon_e+\epsilon_\mu)$ and $S_c(\text{LF}) = \{\epsilon_e \cdot S(\text{LF}\to\mu) + \epsilon_\mu \cdot S(\text{LF}\to e)\}/(\epsilon_e+\epsilon_\mu)$ are defined, where ϵ_e and ϵ_μ are the reconstruction efficiencies for electrons and muons obtained from simulation of $t\bar{t}$ events. The scale factors are not applied to WZ, ZZ, $t\bar{t}$+W, and $t\bar{t}$+Z samples.

- light-flavor jet faking an electron, $S(\text{LF}\to e)$, (applied to Z+ LF jets and WW+jets),
- light-flavor jet faking a muon, $S(\text{LF}\to\mu)$, (applied to Z+ LF jets and WW+jets),
- heavy-flavor jet faking an electron, $S(\text{HF}\to e)$, (applied to Z + HF jets, Wt, and $t\bar{t}$),
- heavy-flavor jet faking a muon, $S(\text{HF}\to\mu)$, (applied to Z+ HF jets, Wt, and $t\bar{t}$).

Fakes

- Likelihood in terms of the four Scale Factors and Poisson probabilities on the observed and expected numbers of events
- 16 distributions chosen (not also used for validation of MC)

- four distributions of E_T^{miss} for the flavor and charge categories in the Z-boson control region[3],
- four distributions of E_T^{miss} for the flavor and charge categories excluding those with leptons of the same charge and flavor in the low-E_T^{miss} control region,
- two distributions of jet multiplicity for the low-E_T^{miss} control region for charge-flavor final states with two leptons of the same charge and flavor,
- six distributions of jet multiplicity for the flavor and charge categories in the $t\bar{t}$ control region.

Fakes

- Scale factors calculated using 14 of the 16 distributions - 1e2OSμ and 3e in Z CR not included
- Systematic uncertainty by comparing usage of all 16 distributions and 14 - not including 1e2OSμ and 3e in low MET CR
- Many fake electrons are photon conversions - above procedure evaluates uncertainty of QED radiation.

Systematic Uncertainties

- Scale factors have uncertainties between 7 S(LF/HF to fake μ) and 60% S(HF to fake e) - large due to QED radiation
- Gives up to 15% uncertainty on background predictions
- Uncertainty on MC by using different generators, MC statistics, cross-sections etc - 10%
- JES,JER and MET result in 20% uncertainty on background in SR

Systematic Uncertainties

- Luminosity uncertainty of 3.6%
- Lepton energy scale < 4%
- Lepton efficiencies - 2%
- Pileup - vary by 10% in simulations - gives 1% uncertainty on background predictions

	3μ	$1e2SS\mu$	$1e2OS\mu$	$2SSe1\mu$	$2OSe1\mu$	$3e$	3ℓ
Z+jets and $Z+b\bar{b}$+jets	-	-	-	-	-	$0.4^{+0.4}_{-0.4}$	$0.4^{+0.4}_{-0.4}$
$t\bar{t}$ and Wt	0.7±0.8	0.5±0.5	$1.5^{+0.9}_{-0.8}$	$0.9^{+1.0}_{-0.9}$	$1.0^{+0.9}_{-0.8}$	$0.2^{+0.4}_{-0.2}$	$4.9^{+2.6}_{-2.0}$
WW, WZ, and ZZ	$0.7^{+0.4}_{-0.3}$	-	$0.8^{+0.3}_{-0.5}$	-	$0.3^{+0.3}_{-0.2}$	0.6±0.6	$2.4^{+1.3}_{-1.2}$
$t\bar{t}+W$ and $t\bar{t}+Z$, and VVV	0.3±0.2	0.2 ±0.2	0.6±0.5	0.3±0.2	0.4±0.3	0.2±0.1	2.0±1.0
Total SM	1.8±1.0	0.8±0.5	2.9±1.2	$1.2^{+1.2}_{-1.0}$	$1.7^{+1.1}_{-1.0}$	$1.4^{+0.9}_{-0.8}$	$9.7^{+3.8}_{-3.4}$
Signal1	$1.3^{+0.4}_{-0.5}$	$1.2^{+0.3}_{-0.4}$	$2.2^{+0.6}_{-0.7}$	$1.2^{+0.3}_{-0.4}$	$2.2^{+0.6}_{-0.8}$	$0.7^{+0.2}_{-0.3}$	$8.9^{+2.2}_{-3.0}$
Signal2	0.9±0.3	$1.2^{+0.3}_{-0.4}$	$2.0^{+0.5}_{-0.6}$	$1.4^{+0.4}_{-0.5}$	2.0±0.6	$0.8^{+0.3}_{-0.3}$	$8.3^{+1.9}_{-2.3}$
Data	1	2	3	1	4	3	14

Table 3: Expected number of events from SM backgrounds and number of events observed in data in tri-lepton signal region. Expectations for two SUSY benchmark models for gluino mediated stop production with $m_{\tilde{g}}$=900 GeV and $m_{\tilde{\chi}_1^0}$=500 GeV (Signal1) and direct sbottom production with $m_{\tilde{b}}$=500 GeV, $m_{\tilde{\chi}_1^\pm}$=300 GeV and $m_{\tilde{\chi}_1^0}$=150 GeV (Signal2) are also shown. Numbers are shown for each of the six categories. Uncertainties on the backgrounds and SUSY signals include statistical and systematic uncertainties. Correlations between uncertainties are taken into account.

3 B-Jets + MET
ATLAS-CONF-2012-105

Common criteria: lepton veto, $p_T^{j_1} > 90$ GeV, $E_T^{miss} > 200$ GeV, ≥ 3 b-jets, $E_T^{miss}/m_{eff}^{4j} > 0.2$, $\Delta\phi_{min}^{4j} > 0.4$			
SR	N_J ($p_T > 50$ GeV)	p_T b-jets	m_{eff}
SR4-L/M/T	≥ 4 jets	> 50 GeV	$m_{eff}^{4j} > 900/1100/1300$ GeV
SR6-L/M/T	≥ 6 jets	> 30 GeV	$m_{eff}^{incl} > 1100/1300/1500$ GeV

Table 1: Definition of the six signal regions based on the number of jets (N_J), the b-jets p_T and the effective mass.

$$m_{eff}^{incl} = MET + \sum_{i=1}^{n} P_{T,Jet\ i, P_T > 30GeV}$$

Correlated with mass scale, suppresses SM

$$m_{eff}^{4j} = MET + \sum_{i=1}^{4} P_{T,Jet\ i}$$

Suppresses multijet, targets

$$\tilde{g}\tilde{g} \to \bar{b}b\bar{b}b\chi_1^0\chi_1^0$$

Backgrounds

Common criteria: lepton veto, $p_T^{j_1} > 90$ GeV, $E_T^{miss} > 150$ GeV, $= 2$ b-jets, $E_T^{miss}/m_{eff}^{4j} > 0.2$, $\Delta\phi_{min}^{4j} > 0.4$				
CR	N_J ($p_T > 50$ GeV)	p_T b-jets	m_{eff}	corresponding SR
CR4	≥ 4 jets	> 50 GeV	$m_{eff}^{4j} > 500$ GeV	SR4-L, SR4-M, SR4-T
CR6	≥ 6 jets	> 30 GeV	$m_{eff}^{incl} > 600$ GeV	SR6-L, SR6-M, SR6-T

Table 2: Definition of the two control regions used to estimate the $t\bar{t}$ background.

Targets top pairs + jets, with leptonic W
(not seen, tau or fakes a jet)

- Multijets estimated from jet smearing method (negligible)
- Other SM estimated using MC

Systematic uncertainties

- Detector uncertainties dominated by JES, JER and b-tagging efficiency + mistag rates
- Propagate into MET calculation
- Theoretical uncertainties from generator choice, cross-section and MC statistics - between 50 and 100%

Common criteria: lepton veto, $p_T^{j_1} > 90$ GeV, $\geqslant 3$ b-jets, $E_T^{miss}/m_{eff}^{4j} > 0.2$, $\Delta\phi_{min}^{4j} > 0.4$				
VR	N_J ($p_T > 50$ GeV)	p_T b-jets	E_T^{miss} [GeV]	m_{eff} [GeV]
VR4-1	≥ 4 jets	> 50 GeV	$150 < E_T^{miss} < 200$	$m_{eff}^{4j} > 500$
VR4-2	≥ 4 jets	> 50 GeV	$E_T^{miss} > 200$	$500 < m_{eff}^{4j} < 900$
VR6-1	≥ 6 jets	> 30 GeV	$150 < E_T^{miss} < 200$	$m_{eff}^{incl} > 600$
VR6-2	≥ 6 jets	> 30 GeV	$E_T^{miss} > 200$	$600 < m_{eff}^{incl} < 1100$

Table 3: Definition of the four validation regions.

channel	CR4	VR4-1	VR4-2
Observed events	2518	249	158
Total background events	2518 ± 80	291 ± 50	176 ± 30
(MC prediction)	(2400 ± 700)	(280 ± 100)	(170 ± 60)
$t\bar{t}$ + jets events	1936 ± 200	217 ± 40	126 ± 24
(MC prediction)	(1800 ± 600)	(210 ± 70)	(120 ± 40)
$t\bar{t} + b/b\bar{b}$ events	155 ± 150	46 ± 46	25 ± 25
single top events	125 ± 45	12 ± 5	8 ± 3
$t\bar{t} + W/Z$ events	28 ± 15	3 ± 2	4 ± 2
W/Z events	269 ± 120	12 ± 7	13 ± 8
diboson events	5 ± 3	–	–
Gbb : $m_{\tilde{g}} = 1000$ GeV, $m_{\tilde{\chi}_1^0} = 600$ GeV	39 ± 16	12 ± 2	29 ± 5
Gbb : $m_{\tilde{g}} = 1200$ GeV, $m_{\tilde{\chi}_1^0} = 1$ GeV	8.9 ± 5.5	0.1 ± 0.1	0.1 ± 0.1

Table 4: Results of the background fit to the control region CR4 extrapolated to the validation regions VR4-1 and VR4-2. Nominal MC expectations (normalised to MC cross-sections) for the $t\bar{t}$+jets and the total backgrounds are given for comparison. The yield for two signal points (with small and large mass splitting between the gluino and the LSP) for the *Gbb* ($\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$) model are also shown. Statistical plus systematic uncertainties are shown. The systematic uncertainties include all detector related and theoretical uncertainties for the background, and only the detector related uncertainties for the signal.

channel	CR6	VR6-1	VR6-2
Observed events	255	52	34
Total background events	255 ± 20	55 ± 15	32 ± 9
(MC prediction)	(255 ± 100)	(55 ± 26)	(32 ± 17)
$t\bar{t}$ + jets events	205 ± 30	35 ± 8	20 ± 5
(MC prediction)	(205 ± 80)	(35 ± 16)	(20 ± 11)
$t\bar{t} + b/b\bar{b}$ events	24 ± 24	16 ± 16	9 ± 9
single top events	10 ± 4	2 ± 1	1 ± 1
$t\bar{t} + W/Z$ events	5 ± 3	1 ± 1	1 ± 1
W/Z events	11 ± 6	1 ± 1	2 ± 1
diboson events	–	–	–
Gtt : $m_{\tilde{g}} = 1000$ GeV, $m_{\tilde{\chi}_1^0} = 400$ GeV	15 ± 5	5.9 ± 0.6	8.6 ± 0.8
Gtt : $m_{\tilde{g}} = 1200$ GeV, $m_{\tilde{\chi}_1^0} = 1$ GeV	3.6 ± 1.6	0.2 ± 0.1	0.1 ± 0.1

Table 5: Results of the background fit to the control region CR6 extrapolated to the validation regions VR6-1 and VR6-2. Nominal MC expectations (normalised to MC cross-sections) for the $t\bar{t}$+jets and the total backgrounds are given for comparison. The yield for two signal points (with small and large mass splitting between the gluino and the LSP) for the *Gtt* ($\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$) model are also shown. Statistical plus systematic uncertainties are shown. The systematic uncertainties include all detector related and theoretical uncertainties for the background, and only the detector related uncertainties for the signal.

channel	SR4-L	SR4-M	SR4-T
Observed events	38	8	4
Total background events	46 ± 10	10.7 ± 2.9	2.9 ± 1.0
(MC prediction)	(44 ± 17)	(10.3 ± 4.6)	(2.7 ± 1.3)
$t\bar{t}$ + jets events	30 ± 6	7.0 ± 1.8	2.4 ± 0.9
(MC prediction)	(29 ± 11)	(6.6 ± 2.5)	(2.3 ± 1.1)
$t\bar{t} + b/b\bar{b}$ events	8.1 ± 8.3	2.5 ± 2.5	0.1 ± 0.2
single top events	3.5 ± 1.3	0.4 ± 0.5	0.2 ± 0.1
$t\bar{t} + W/Z$ events	1.4 ± 0.8	0.5 ± 0.3	0.2 ± 0.1
W/Z events	2.6 ± 1.9	0.4 ± 0.6	–
diboson events	–	–	–
Gbb : $m_{\tilde{g}}$ = 1000 GeV, $m_{\tilde{\chi}_1^0}$ = 600 GeV	30 ± 7	11 ± 3	3.8 ± 1.3
Gbb : $m_{\tilde{g}}$ = 1200 GeV, $m_{\tilde{\chi}_1^0}$ = 1 GeV	17 ± 2	17 ± 2	15 ± 2

Table 6: Results of the background fit to the control region CR4 extrapolated to the signal regions SR4-L, SR4-M and SR4-T. Nominal MC expectations (normalised to MC cross-sections) for the $t\bar{t}$+jets and the total backgrounds are given for comparison. The yield for two signal points (with small and large mass splitting between the gluino and the LSP) for the *Gbb* ($\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$) model are also shown. Statistical plus systematic uncertainties are shown. The systematic uncertainties include all detector related and theoretical uncertainties for the background, and only the detector related uncertainties for the signal.

channel	SR6-L	SR6-M	SR6-T
Observed events	20	4	2
Total background events	18 ± 6	6.3 ± 2.4	2.2 ± 1.3
(MC prediction)	(18 ± 9)	(6.3 ± 3.4)	(2.2 ± 1.8)
$t\bar{t}$ + jets events	12 ± 4	4.3 ± 1.9	1.7 ± 1.0
(MC prediction)	(12 ± 6)	(4.3 ± 2.4)	(1.7 ± 1.5)
$t\bar{t} + b/b\bar{b}$ events	4.6 ± 5.0	1.3 ± 1.4	0.2 ± 0.3
single top events	0.6 ± 0.3	0.4 ± 0.2	0.2 ± 0.1
$t\bar{t} + W/Z$ events	0.8 ± 0.4	0.3 ± 0.2	0.1 ± 0.1
W/Z events	0.1 ± 0.1	–	–
diboson events	–	–	–
Gtt : $m_{\tilde{g}} = 1000$ GeV, $m_{\tilde{\chi}_1^0} = 400$ GeV	18 ± 3	8.8 ± 2.2	3.6 ± 1.2
Gtt : $m_{\tilde{g}} = 1200$ GeV, $m_{\tilde{\chi}_1^0} = 1$ GeV	8.2 ± 0.4	7.8 ± 0.5	6.8 ± 0.6

Table 7: Results of the background fit to the control region CR6 extrapolated to the signal regions SR6-L, SR6-M and SR6-T. Nominal MC expectations (normalised to MC cross-sections) for the $t\bar{t}$+jets and the total backgrounds are given for comparison. The yield for two signal points (with small and large mass splitting between the gluino and the LSP) for the *Gtt* ($\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$) model are also shown. Statistical plus systematic uncertainties are shown. The systematic uncertainties include all detector related and theoretical uncertainties for the background, and only the detector related uncertainties for the signal.

SR	95% CL UL on N_{BSM}		95% CL UL on $\sigma \times \mathscr{A} \times \varepsilon$ [fb]	
	Observed	Expected	Observed	Expected
SR4-L	17.9	$20.5^{+8.0}_{-5.2}$	1.4	1.6
SR4-M	7.6	$8.8^{+3.5}_{-2.1}$	0.59	0.69
SR4-T	6.5	$5.0^{+2.2}_{-1.1}$	0.51	0.39
SR6-L	17.0	$15.5^{+6.2}_{-3.8}$	1.3	1.2
SR6-M	5.9	$6.6^{+2.8}_{-1.5}$	0.46	0.52
SR6-T	5.1	$4.6^{+1.9}_{-0.6}$	0.40	0.36

Table 8: Observed and expected new physics-model independent upper limits at 95% CL for the six signal regions. Limits are given on the number of signal events N_{BSM} and in terms of visible cross-section, defined as the cross-section times kinematic acceptance times experimental efficiency. The systematic uncertainties on the SM background estimation discussed in Section 7 are included.

Direct Stop
0 Lepton + Jets + MET
http://arxiv.org/abs/1208.1447

Tau Veto

- Build transverse mass from jet with 1-4 tracks if jet is closer than pi/5 to MET
- Veto event if $M_T < 100$ GeV - gets rid off top pair production with a tau decay

TABLE I. The numbers of expected events for the SM backgrounds and an example SUSY signal point, and the observed number of events in data. The 95% CL_s upper limit on the observed (expected) visible cross section is appended below.

	SRA	SRB
E_T^{miss}	> 150 GeV	> 260 GeV
$t\bar{t}$	9.2 ± 2.7	2.3 ± 0.6
$t\bar{t} + W/Z$	0.8 ± 0.2	0.4 ± 0.1
Single top	0.7 ± 0.4	$0.2^{+0.3}_{-0.2}$
Z+jets	$1.3^{+1.1}_{-1.0}$	$0.9^{+0.8}_{-0.7}$
W+jets	$1.2^{+1.4}_{-1.0}$	0.5 ± 0.4
Diboson	$0.1^{+0.2}_{-0.1}$	$0.1^{+0.2}_{-0.1}$
Multi-jets	0.2 ± 0.2	0.02 ± 0.02
Total SM	$13.5^{+3.7}_{-3.6}$	$4.4^{+1.7}_{-1.3}$
SUSY $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = (400, 1)$ GeV	14.8 ± 4.0	8.9 ± 3.1
Data (observed)	16	4
Visible cross section [fb]	2.9 (2.5)	1.3 (1.3)

Direct Stop

1 Lepton + Jets + MET

http://arxiv.org/abs/1208.2590

- Exactly one isolated lepton
- At least 4 Jets with P_T > 80,60,40,25
- At least one b-tagged jet
- DeltaPhiMin < 0.8 - defined as azimuth angle between two highest P_T jets and MET
- Top Mass: Build W from jet-jet pair with smallest separation in eta,phi and with mass > 60 GeV, then add closest jet to W that makes a top mass between 130 and 205 GeV

Table 1: Selection requirements defining the SR A - E.

Requirement	SR A	SR B	SR C	SR D	SR E
E_T^{miss} [GeV] >	150	150	150	225	275
$E_T^{miss} / \sqrt{H_T}$ [GeV$^{1/2}$] >	7	9	11	11	11
m_T [GeV] >	120	120	120	130	140

- Choice of cuts reflects increasing stop mass and increasing mass difference between stop and LSP (neutralino1)

Backgrounds

- 1-Lep T-CR - transverse mass in range 60 to 90 GeV - single-leptonic top events
- 1-Lep W-CR - transverse mass in range 60 to 90 GeV + B-Veto - W events
- 2-Lep T-CR - exactly 2 leptons, no cut on transverse mass or MET/sqrt(H_T) and MET > 125 GeV - di-leptonic top
- Multijets estimated with matrix method
- Other backgrounds from SM MC

Table 2: Numbers of observed events in the five signal regions and three background control regions, as well as their estimated values and all (statistic and systematic) uncertainties from a fit to the control regions only, for the combined electron and muon channels. The expected numbers of signal events for $m_{\tilde{t}_1} = 400$ GeV (500 GeV) and $m_{\tilde{\chi}_1^0} = 1$ GeV for benchmark points 1 (2) are listed for comparison. The central values of the fitted sum of backgrounds in the control regions agree with the observations by construction. Furthermore, p_0-values and 95% CL$_s$ observed (expected) upper limits on beyond-SM events, obtained from fits to each signal regions and the control regions, are given.

Regions	SR A	SR B	SR C	SR D	SR E	*2-lep TR*	*1-lep TR*	*1-lep WR*
$t\bar{t}$	36 ± 5	27 ± 4	11 ± 2	4.9 ± 1.3	1.3 ± 0.6	109 ± 10	364 ± 23	59 ± 19
$t\bar{t} + V$, single top	2.9 ± 0.7	2.5 ± 0.6	1.6 ± 0.3	0.9 ± 0.3	0.4 ± 0.1	7.2 ± 1.3	18 ± 3	6.1 ± 1.6
V+jets, VV	2.5 ± 1.3	1.7 ± 0.8	0.4 ± 0.1	0.3 ± 0.1	0.1 ± 0.1	1.6 ± 0.8	38 ± 11	162 ± 23
Multijet	$0.4^{+0.4}_{-0.4}$	$0.3^{+0.3}_{-0.3}$	$0.3^{+0.3}_{-0.3}$	$0.3^{+0.3}_{-0.3}$	$0.0^{+0.3}_{-0.0}$	$0.0^{+0.6}_{-0.0}$	1.7 ± 1.7	0.8 ± 0.8
Total background	42 ± 6	31 ± 4	13 ± 2	6.4 ± 1.4	1.8 ± 0.7	118 ± 10	421 ± 20	228 ± 15
Signal benchmark 1 (2)	25.6 (8.8)	23.0 (8.1)	17.5 (6.9)	13.5 (6.2)	7.1 (4.5)	1.7 (0.6)	2.3 (0.6)	0.4 (0.1)
Observed events	38	25	15	8	5	118	421	228
p_0-values	0.5	0.5	0.32	0.24	0.015	-	-	-
Obs. (exp.) $N_{\text{beyond-SM}} <$	15.1 (17.2)	10.1 (13.8)	10.8 (9.2)	8.4 (7.0)	8.2 (4.6)	-	-	-

Systematic Uncertainties

- Detector uncertainties dominated by JES, JER and b-tagging efficiency and mistag rate
- Lepton reconstruction and ID gives small uncertainty
- Pileup, luminosity, statistics give small uncertainties
- Top pair theoretical uncertainty give 10-30% uncertainty on background estimation
- Diboson and multijets have 100% theory uncertainty

Direct Stop
2 Lepton + Jets + MET
http://arxiv.org/abs/1209.4186

MT2

$$m_{T2}(P_T^{l1}, P_T^{l2}, P_T^{miss}) = min[max[m_T(P_T^{l1}, q_T), m_T(P_T^{l2}, r_T)]]$$

Sharp endpoint at W mass for top pairs,
SUSY decreases slowly towards higher MT2

- Two OS leptons with invariant mass > 20 GeV
- Third lepton veto
- At least two jets with P_T > 50,25 GeV - suppresses di-boson and Z+Jets
- SF SR: m_{ll} outside range 71 to 101 GeV + at least one B-Jet - Z +Jets , WZ and ZZ can have high MT2
- MT2 > 120 GeV

Table 3: Expected background composition and comparison of the predicted total SM event yield to the observed number of events in the top quark control regions described in the text. The expected $Z/\gamma^{\star}$+jets rate in the DF channel is negligible. The quoted uncertainties include the systematic uncertainties described in Section 7.

Process	$t\bar{t}$ CR DF	$t\bar{t}$ CR SF
$t\bar{t}$	68 ± 11	39 ± 11
$t\bar{t}W + t\bar{t}Z$	0.37 ± 0.07	0.20 ± 0.05
Wt	2.7 ± 1.0	1.8 ± 0.6
$Z/\gamma^{\star}$+jets	-	3.5 ± 1.4
Fake leptons	0.4 ± 0.3	0.5 ± 1.6
Diboson	0.49 ± 0.14	0.10 ± 0.05
Total non-$t\bar{t}$	4.0 ± 1.5	6.1 ± 3.7
Total expected	72 ± 11	45 ± 12
Data	79	53

- Top pair CR - MT2 in range 85 to 100 GeV

Fake Leptons

$$
\begin{aligned}
N^{\text{loose}} &= N^{\text{loose}}_{\text{real}} + N^{\text{loose}}_{\text{fake}}, \\
N^{\text{std}} &= rN^{\text{loose}}_{\text{real}} + fN^{\text{loose}}_{\text{fake}},
\end{aligned}
$$

r and f known from control samples of Z->ll and multijets

Allows to calculate fake lepton rate in SR

Backgrounds

- Z CR - reverse di-lepton mass cut
- Other backgrounds that give 2 isolated leptons + MET estimated directly with MC

Systematic Uncertainties

Table 4: Total expected background yield and systematic uncertainties in the SF and DF signal regions. When the uncertainty is not symmetric, the upwards and downwards values are given.

Channel	SF	DF
Total event yield	1.58	0.94
JES + JER	16%	22%
b-tagging	1%	–
$E_{\mathrm{T}}^{\mathrm{miss}}$ and pile-up modeling	6%	25%
Luminosity	1%	2%
Theory	14%	48%
Statistics	+29/-26%	20%
Fake-lepton uncertainties	+8/-0%	+9/-0%
Total uncertainty	+40/-37%	64%

- Fake lepton from comparison of CR's - 63 (55) %
- Theory includes cross-section and generator uncertainties
- Theory uncertainty much smaller for Z+jets and hence SF

Table 5: Number of expected SM background events and number of observed events in data in both SRs. The quoted errors are the total uncertainty on the expected rates. For $Z/\gamma^{\star}$+jets and $t\bar{t}$ the scale factors (SF) from measurements in the CR which have been applied to the MC predictions are also reported. A dash symbol indicates negligible background predictions. The expected yield for two signal models is also reported. Observed and expected upper limits at 95% confidence level on $\sigma_{\text{vis}} = \sigma \times \epsilon \times \mathcal{A}$ are also shown.

	SF	DF
$Z/\gamma^{\star}$+jets	1.2 ± 0.5	-
($Z/\gamma^{\star}$+jets scale factor)	(1.27)	-
$t\bar{t}$	0.23 ± 0.23	0.4 ± 0.3
($t\bar{t}$ scale factor)	(1.21)	(1.10)
$t\bar{t}W + t\bar{t}Z$	0.11 ± 0.07	0.19 ± 0.12
WW	$0.01^{+0.02}_{-0.01}$	0.19 ± 0.18
$WZ + ZZ$	0.05 ± 0.05	0.03 ± 0.03
Wt	$0.00^{+0.17}_{-0.00}$	$0.10^{+0.18}_{-0.10}$
Fake leptons	$0.00^{+0.14}_{-0.00}$	$0.00^{+0.09}_{-0.00}$
Total SM	1.6 ± 0.6	0.9 ± 0.6
Signal, m($\tilde{t}_1$) = 300 GeV, m($\tilde{\chi}^0_1$)= 50 GeV	2.15	3.73
Signal, m(T) = 450 GeV, m(A_0)= 100 GeV	3.10	5.78
Observed	1	2
95% CL limit on $\sigma^{\text{obs}}_{\text{vis}}$[fb]	0.86	1.08
95% CL limit on $\sigma^{\text{exp}}_{\text{vis}}$[fb]	0.89	0.79

Direct Stop
2 Soft Lepton +1 Jet + MET

http://arxiv.org/abs/1208.4305

Requirement	ee channel	$e\mu$ channel	$\mu\mu$ channel
Signal Region			
lepton p_T	> 17 GeV	$> 17(12)$ GeV for $e(\mu)$	> 12 GeV
highest lepton p_T	< 30 GeV	< 30 GeV	< 30 GeV
m_{ll}	> 20 GeV and Z veto	> 20 GeV	> 20 GeV and Z veto
jet p_T	≥ 1 jet, $p_T > 25$ GeV	≥ 1 jet, $p_T > 25$ GeV	≥ 1 jet, $p_T > 25$ GeV
E_T^{miss}	> 20 GeV	> 20 GeV	> 20 GeV
$E_T^{miss,sig}$	> 7.5 GeV$^{1/2}$	> 7.5 GeV$^{1/2}$	> 7.5 GeV$^{1/2}$
Top Control Region			
lepton p_T	> 17 GeV	$> 17(12)$ GeV for $e(\mu)$	> 12 GeV
highest lepton p_T	> 30 GeV	> 30 GeV	> 30 GeV
m_{ll}	> 20 GeV and Z veto	> 20 GeV	> 20 GeV and Z veto
jet p_T	≥ 2 (b)jets, $p_T > 25$ GeV	≥ 2 (b)jets, $p_T > 25$ GeV	≥ 2 (b)jets, $p_T > 25$ GeV
b jet p_T	≥ 1 b jet, $p_T > 25$ GeV	≥ 1 b jet, $p_T > 25$ GeV	≥ 1 b jet, $p_T > 25$ GeV
E_T^{miss}	> 20 GeV	> 20 GeV	> 20 GeV
$E_T^{miss,sig}$	> 7.5 GeV$^{1/2}$	> 7.5 GeV$^{1/2}$	> 7.5 GeV$^{1/2}$
Z Control Region			
lepton p_T	> 17 GeV	n/a	> 12 GeV
highest lepton p_T	< 30 GeV	n/a	< 30 GeV
m_{ll}	> 81 GeV and < 101 GeV	n/a	> 81 GeV and < 101 GeV
jet p_T	≥ 1 jet, $p_T > 25$ GeV	n/a	≥ 1 jet, $p_T > 25$ GeV
E_T^{miss}	> 20 GeV	n/a	> 20 GeV
$E_T^{miss,sig}$	> 4.0 GeV$^{1/2}$	n/a	> 4.0 GeV$^{1/2}$

Table 1: Signal region, top control region and Z control region requirements in each flavour channel. The Z veto rejects events with $m_{ll} > 81$ GeV and $m_{ll} < 101$ GeV.

Multijets BG estimated with matrix method

- Reverse lepton isolation
- Remove MET Significance cut
- Compare MET Significance shape with and without lepton isolation - verifies shape unaffected
- Normalise MET Significance without lepton isolation to post-lepton isolation
- This template then shows multijet background will be 2% in SR

Systematic Uncertainties

- JES, JER, theory, b-tagging and statistics also contribute
- JER gives largest uncertainty in Z+Jets
- JES gives largest uncertainty in top pair
- Lepton ID and reconstruction give very small uncertainties
- Luminosity uncertainty of 3.9%
- Multijet uncertainty from varying template fit range

	ee	$e\mu$	$\mu\mu$	all
$t\bar{t}$	$44 \pm 4 \pm 5$	$139 \pm 7 \pm 22$	$111 \pm 8 \pm 10$	$293 \pm 12 \pm 34$
Z/γ^{*}+jets	$5 \pm 1 \pm 2$	$23 \pm 2 \pm 8$	$48 \pm 16 \pm 27$	$76 \pm 16 \pm 27$
Single top	$3 \pm 0.5 \pm 1$	$12 \pm 1 \pm 2$	$12 \pm 1 \pm 2$	$28 \pm 2 \pm 5$
W+jets	$3 \pm 3 \pm 3$	$5 \pm 2 \pm 1$	$6 \pm 2 \pm 1$	$13 \pm 3 \pm 3$
Diboson	$4 \pm 0.4 \pm 0.5$	$9 \pm 0.7 \pm 2$	$10 \pm 0.7 \pm 1$	$22 \pm 1 \pm 3$
multijet	$2.9\,^{+3.2}_{-2.9} \pm 2.2$	$2.0 \pm 1.4 \pm 0.3$	$3.0 \pm 2.8 \pm 0.3$	$8.0 \pm 3.7 \pm 2.3$
Total	$61 \pm 6 \pm 6$	$189 \pm 8 \pm 21$	$190 \pm 19 \pm 31$	$440 \pm 21 \pm 43$
Data	48	188	195	431
σ_{vis} (exp. limit) [fb]	4.9	11.1	16.2	22.0
σ_{vis} (obs. limit) [fb]	3.3	10.9	16.9	21.0
$m(\tilde{t},\tilde{\chi}_1^0) = (112, 55)$ GeV	44.1 ± 4.8	137 ± 8	140 ± 8	322 ± 13
$m(\tilde{t},\tilde{\chi}_1^0) = (160, 55)$ GeV	8.8 ± 1.5	31.4 ± 2.7	36.5 ± 2.9	76.6 ± 4.3

Table 2: The expected and observed numbers of events in the signal region for each flavour channel. In the combined flavour column ("all"), the statistical uncertainty (first uncertainty quoted, includes limited MC statistics, and limited data statistics in the CR where appropriate) on the various background estimates have each been added in quadrature whilst the systematic uncertainties (second uncertainty quoted) have been combined taking into account the correlations between background sources. Observed and expected upper limits at 95% confidence level on the visible cross section $\sigma_{\mathrm{vis}} = \sigma \times A \times \epsilon$ are also shown. The expected signal yields and statistical uncertainties on the yields are quoted for the two mass points illustrated in the figures.

Direct Stop
1-2 Leptons +B Jets+ MET
http://arxiv.org/abs/1209.2102

Single Lepton Channel

- Try to reconstruct semi-leptonic top-pair system
- One electron (muon) with $P_T > 25$ (20) GeV
- Veto second lepton with $P_T > 20$ (10) GeV
- At least 4 jets, including at least 2 b-tagged jets and 2 b-vetoed jets
- MET > 140 GeV
- MT > 30 GeV - rejects multijets with fake lepton
- Reconstruct hadronic top with algorithm on next slide

Single Lepton Channel

- Construct hadronic and leptonic W, hadronic and leptonic tops
- Find combination which maximises P_{tot}

$$P_{tot} = P(m_W^{had})P(m_W^{lep})P(m_t^{had})P(m_t^{lep})$$

- P is Gaussian probability to reconstruct particle of mass m, assuming experimentally measured mean and width
- Once chosen require

$$m_t^{had} < \hat{\mu} - 0.5\hat{\sigma}$$

Mean and width from fit to 40 GeV window around hadronic top mass

Two Lepton Channel

- Try to reconstruct di-leptonic top pair system
- 2 OS leptons
- If SF require P_T > 25 (20) for electrons (muons)
- If DF require either electron P_T > 25 GeV or muon P_T > 20 GeV
- Require at least 2 jets, and at least one of the two hardest jets is b-tagged
- MET > 40 and dilepton mass in range 30 to 81 GeV

Mass Scale Subsytem Variable

$$\sqrt{S^{sub}_{min}} = \sqrt{(\sqrt{m^2_{sub} + P^2_{T,sub}} + \sqrt{m^2_{miss} + MET^2})^2 - (\bar{P}_{T,sub} + \bar{P}^{Miss}_T)^2}$$

- Derived from Mandelstam S variable - only consider “visible subsystem” of event
- Peaks at twice top mass for top pair production
- If mass difference between stop and neutralino is less than top mass then peak is shifted to lower values
- 1-Lepton SR - require is less than 250 GeV
- 2-Lepton SR - require is less than 225 (235) GeV for 2SR1 (2SR2)
- Furthermore require in 2SR2 $m_{lljj} < 140$ GeV

Backgrounds

- 1 Lepton Top CR requires

$$\hat{\mu} - 0.5\hat{\sigma} < m_t^{had} < \hat{\mu} + 0.5\hat{\sigma}$$

$$\sqrt{s_{min}^{sub}} < 320GeV$$

- 1 Lepton W + b-jets CR requires hadronic top mass > 250 GeV and m_{bb} < 50 GeV
- W CR has 60% top pair contamination
- Both CR used simultaneously to constrain these BG

Backgrounds

- 2 Lepton Top CR requires m_{ll} > 101 GeV and $\sqrt{s_{min}^{sub}} < 325 GeV$
- 2 Lepton Z CR requires m_{llSF} between 81 and 101 GeV and $\sqrt{s_{min}^{sub}} < 225 GeV$

Both 1 and 2-Leptons use matrix method for multijets (1L) and top pair, W (2L) with 1 or 2 fake lepton - 2 fake leptons negligible BG

All remaining small BG directly from MC

Systematic Uncertainties

- JES - 6-10% per SR
- JER - 1-10% per SR
- Lepton ID - 1%
- MET (pileup, out of cluster) - 9%
- B-tagging - 1%
- Theory top pair - 10-15%
- Theory W (1L) - 15%
- Theory Z + Jets - 9 (2) % for 2LSR1 (2LSR2)
- Uncertainty of 45-84% on fake contributions

	Number of events		
Process	1LSR	2LSR1	2LSR2
Top	$24 \pm 3 \pm 5$	$89 \pm 6 \pm 10$	$36 \pm 2 \pm 5$
W+jets	$6 \pm 1 \pm 2$	n/a	n/a
Z+jets	$0.5 \pm 0.3 \pm 0.3$	$11 \pm 4 \pm 3$	$3 \pm 1 \pm 1$
Fake leptons	$7 \pm 1 \pm 2$	$12 \pm 5 \pm 11$	$6 \pm 4 \pm 4$
Others	$0.3 \pm 0.1 \pm 0.1$	$2.7 \pm 0.9 \pm 0.7$	$0.9 \pm 0.2 \pm 0.5$
Total SM	$38 \pm 3 \pm 7$	$115 \pm 8 \pm 15$	$46 \pm 4 \pm 7$
Data	50	123	47
$m_{\tilde{t}_1} = 170$ GeV, $m_{\tilde{\chi}_1^0} = 70$ GeV	$26 \pm 2 \pm 6$	$57 \pm 3 \pm 6$	$36 \pm 2 \pm 4$
$m_{\tilde{t}_1} = 180$ GeV, $m_{\tilde{\chi}_1^0} = 20$ GeV	$20 \pm 2 \pm 4$	$41 \pm 3 \pm 5$	$27 \pm 2 \pm 3$
	95% CL upper limits		
σ_{vis} (expected) [fb]	4.2	9.3	4.6
σ_{vis} (observed) [fb]	6.1	11	5.2

Table 1: Predicted and observed number of events in all signal regions together with their statistical and systematic uncertainties. No values are shown for the W+jets contribution in the 2-lepton channel as these are included in the fake contribution. The expected number of events for two signal scenarios, both with a chargino mass of 140 GeV, are also shown. The observed and expected upper limits at 95% confidence level on $\sigma_{\text{vis}} = \sigma \cdot A \cdot \varepsilon$ are also given.

3-Leptons + MET
ATLAS-CONF-2012-154

Table 1: The selection requirements for the three signal regions. All regions require exactly three signal leptons and a same-flavour opposite-sign (SFOS) lepton pair with mass $m_{\text{SFOS}} > 12\,\text{GeV}$. Events with $m_{\text{SFOS}} < 12\,\text{GeV}$ are rejected. The m_{T} is calculated from the $E_{\text{T}}^{\text{miss}}$ and the lepton not forming the SFOS lepton pair closest to the Z mass.

Selection	SR1a	SR1b	SR2
Targeted $\tilde{\chi}_2^0$ decay	$\tilde{l}^{(*)}$ or Z^*		on-shell Z
$\lvert m_{\text{SFOS}} - m_Z \rvert$	$> 10\,\text{GeV}$		$< 10\,\text{GeV}$
Number of b-jets	0		any
$E_{\text{T}}^{\text{miss}}$	$> 75\,\text{GeV}$		$> 120\,\text{GeV}$
m_{T}	any	$> 110\,\text{GeV}$	$> 110\,\text{GeV}$
p_{T} of leptons	$> 10\,\text{GeV}$	$> 30\,\text{GeV}$	$> 10\,\text{GeV}$

Fake lepton background for leptons 2 and 3 uses matrix method described on previous slides

Table 2: The selection requirements for the three validation regions. All regions require exactly three signal leptons and veto events with a same-flavour opposite-sign (SFOS) lepton pair with mass $m_{\mathrm{SFOS}} <$ 12 GeV.

Selection	VR1	VR2	VR3
$\lvert m_{\mathrm{SFOS}} - m_Z \rvert$	> 10 GeV	SFOS veto	< 10 GeV
$E_{\mathrm{T}}^{\mathrm{miss}}$ min	30 GeV	50 GeV	30 GeV
$E_{\mathrm{T}}^{\mathrm{miss}}$ max	75 GeV	–	50 GeV

Table 3: Expected numbers of events from SM backgrounds and observed numbers of events in data, for 13.0 fb^{-1}, in validation regions VR1, VR2 and VR3. The yields for two of the simplified model scenarios, "SUSY Ref. Point 1" with intermediate sleptons, ($m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_L}, m_{\tilde{\chi}_1^0}$ = 500, 500, 250, 0 GeV) and "SUSY Ref. Point 2" with no intermediate sleptons, ($m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0}$ = 250, 250, 0 GeV) are also presented. Both statistical and systematic uncertainties are included.

Selection	VR1	VR2	VR3
$t\bar{t}$+V	3.1 ± 1.2	2.5 ± 0.8	3.9 ± 1.9
triboson	4 ± 4	2.1 ± 2.1	0.7 ± 0.7
ZZ	64 ± 17	0.41 ± 0.23	49 ± 4
WZ (normalised)	161 ± 19	4.5 ± 0.7	385 ± 50
Reducible Bkg.	121 ± 50	27 ± 13	185 ± 70
Total Bkg.	353 ± 60	36 ± 14	624 ± 90
Data	391	36	692
SUSY Ref. Point 1	1.2 ± 0.1	0.2 ± 0.0	0.0 ± 0.0
SUSY Ref. Point 2	0.3 ± 0.1	0.1 ± 0.0	1.5 ± 0.2

Table 4: Expected numbers of events from SM backgrounds and observed numbers of events in data, for 13.0 fb^{-1}, in signal regions SR1a, SR1b and SR2. The yields for two of the simplified model scenarios, "SUSY Ref. Point 1" with intermediate sleptons, ($m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_L}, m_{\tilde{\chi}_1^0}$ = 500, 500, 250, 0 GeV) and "SUSY Ref. Point 2" with no intermediate sleptons, ($m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0}$ = 250, 250, 0 GeV) are also presented. Both statistical and systematic uncertainties are included. Upper limits on the observed and expected visible production cross-section at 95% CL are also shown.

Selection	SR1a	SR1b	SR2
$t\bar{t}$+V	0.62 ± 0.28	0.13 ± 0.07	0.9 ± 0.4
triboson	3.0 ± 3.0	0.7 ± 0.7	0.34 ± 0.34
ZZ	2.0 ± 0.7	0.30 ± 0.23	0.10 ± 0.10
WZ (normalised)	34 ± 4	1.2 ± 0.6	4.7 ± 0.8
Reducible Bkg.	10 ± 6	0.8 ± 0.4	$0.012^{+1.6}_{-0.012}$
Total Bkg.	50 ± 8	3.1 ± 1.0	$6.1^{+2.0}_{-1.2}$
Data	48	4	4
SUSY Ref. Point 1	13.9 ± 1.0	11.4 ± 0.9	0.5 ± 0.1
SUSY Ref. Point 2	0.9 ± 0.1	0.3 ± 0.1	8.0 ± 0.6
Visible σ (exp)	< 1.5 fb	< 0.4 fb	< 0.5 fb
Visible σ (obs)	< 1.3 fb	< 0.5 fb	< 0.4 fb

Systematic Uncertainty Irreducible backgrounds

- SR1a - 12% - dominated by JES and cross-sections (6%), followed by electron efficiency and b-tagging (5%)
- SR1b - 40% - dominated by 100% uncertainty on triboson cross-section and generator choice
- SR2 - 18% - WZ generator uncertainty and MC statistics

Systematic Uncertainty Reducible backgrounds

- SR1a - 60% - dominated by dependence of mis-id on MET
- SR1b - 40% - dominated by statistics of number of data events with three tagged leptons
- SR2 - 0.01 (+1.6, -0.012) due to bias of method on closure tests - limited MC statistics for this test in SR2

Systematic Uncertainty

- Luminosity - 3.6%
- Trigger efficiency data/MC difference - 5%

2-Leptons + MET

http://arxiv.org/abs/1208.2884

Targeted Process	Signal Region
Two Lepton Final States	
$\tilde{l}^{\pm}\tilde{l}^{\mp} \to (l^{\pm}\tilde{\chi}_1^0) + (l^{\mp}\tilde{\chi}_1^0)$	SR-m_{T2}
$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp} \to (l^{\pm}\nu\tilde{\chi}_1^0) + (l^{\mp}\nu\tilde{\chi}_1^0)$	SR-m_{T2}, SR-OSjveto
$\tilde{\chi}_2^0\tilde{\chi}_i \to (l^{\pm}l^{\mp}\tilde{\chi}_1^0) + (q\bar{q}'\tilde{\chi}_1^0)$	SR-2jets
Three Lepton Final States	
$\tilde{\chi}_2^0\tilde{\chi}_1^{\pm} \to (l^{\pm}l^{\mp}\tilde{\chi}_1^0) + (l^{\pm}\nu\tilde{\chi}_1^0)$	SR-OSjveto, SR-SSjveto

Table 1: Decay modes targeted by each SR, $\tilde{\chi}_i$ denotes either a chargino or a neutralino. In decays producing three real leptons, one must be mis-reconstructed or fall outside the acceptance of the detector.

SR-	m_{T2}	OSjveto	SSjveto	2jets
charge	OS	OS	SS	OS
flavour	any	any		SF
m_{ll}	Z-veto	Z-veto	-	Z-veto
signal jets	= 0	= 0		≥ 2
signal b-jets	-	-		= 0
$E_T^{\text{miss,rel.}}$	> 40	> 100		> 50
other	$m_{T2} > 90$	-		m_{CT}-veto

Table 2: Signal regions. OS (SS) denotes two opposite-sign (same-sign) signal leptons, of same (SF) or different (DF) flavour. The Z-veto rejects events with m_{ll} within 10 GeV of the Z-mass (91.2 GeV). The m_{CT}-veto rejects events kinematically consistent with $t\bar{t}$. The values quoted for $E_T^{\text{miss,rel}}$ and m_{T2} are in units of GeV.

	top	WW	$Z+X$
m_{ll}	Z-veto	Z-veto	Z-window
signal jets	≥ 2	=0	$= 0, \geq 2, \geq 0$
signal b-jets	≥ 1	=0	$\geq 0, = 0, \geq 0$
$E_{\mathrm{T}}^{\mathrm{miss,rel.}}$	$> 100, 50, 40$	70-100	$> 100, 50, 40$
other	-	-	-, m_{CT}-veto, -

Table 3: Requirements for entering each CR for top, WW and $Z+X$ background estimation in the OS SR. These are used to estimate the top background in all OS SR, WW in SR-OSjveto and $Z+X$ in all SF channels of the OS SR. When each OS SR requires differing CR definitions, the conditions are given as a comma separated list (SR-OSjveto, SR-2jets, SR-m_{T2}). The Z-veto is a rejection of events with m_{ll} within 10 GeV of the Z-mass (91.2 GeV), whereas the Z-window defines the reverse. In the WW control region the b-jets considered are those with $p_{\mathrm{T}} > 20$ GeV. The values quoted for $E_{\mathrm{T}}^{\mathrm{miss,rel}}$ are in units of GeV.

$$E_{\mathrm{T}}^{\mathrm{miss,rel.}} = \begin{cases} E_{\mathrm{T}}^{\mathrm{miss}} & \text{if } \Delta\phi_{\ell,j} \geq \pi/2 \\ E_{\mathrm{T}}^{\mathrm{miss}} \times \sin \Delta\phi_{\ell,j} & \text{if } \Delta\phi_{\ell,j} < \pi/2 \end{cases}$$

If MET aligned with a jet or lepton only consider MET orthogonal to that jet/lepton - reduces fake MET

Background

- Fake leptons from matrix method previously described
- Top, WW (only OSJVeto) and Z+X CR used
- Other backgrounds from MC directly
- SR-SSJVeto has "charge-flip" background - electron with hard bremsstrahlung and photon conversion - shown to be very

Systematic Uncertainties

SR-	m_{T2}	OSjveto	2jets	SSjveto
Total statistical	9	4	6	13
Total systematic	19	19	49	35
Jet systematics	9	8	5	3
Lepton systematics	14	1	5	1
b-tagging efficiency	1	1	14	0
MC modelling	7	17	45	4
Fake leptons	5	5	4	35

Table 4: Systematic uncertainties (%) on the background estimates in each SR for all flavours combined. The total statistical uncertainty includes limited MC statistics in the CR and SR. Jet systematics include: JES, JER and E_T^{miss} cluster and pile-up uncertainties. Lepton systematics include: all lepton scales and resolutions, reconstruction and trigger efficiencies. MC modelling uncertainties include choice of generator, ISR/FSR and modelling of the Z/γ^*+jets line-shape.

SR-m_{T2}					
	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all	SF
Z+X	$3.2 \pm 1.1 \pm 1.7$	$0.3 \pm 0.1 \pm 0.2$	$3.6 \pm 1.3 \pm 1.7$	$7.1 \pm 1.7 \pm 2.1$	$6.8 \pm 1.7 \pm 2.1$
WW	$2.3 \pm 0.3 \pm 0.4$	$4.8 \pm 0.4 \pm 0.7$	$3.5 \pm 0.3 \pm 0.5$	$10.6 \pm 0.6 \pm 1.5$	$5.8 \pm 0.4 \pm 0.9$
$t\bar{t}$, single top	$2.6 \pm 1.2 \pm 1.3$	$6.2 \pm 1.6 \pm 2.9$	$4.1 \pm 1.3 \pm 1.6$	$12.9 \pm 2.4 \pm 4.6$	$6.8 \pm 1.8 \pm 2.3$
Fake leptons	$1.0 \pm 0.6 \pm 0.6$	$1.1 \pm 0.6 \pm 0.8$	$-0.02 \pm 0.01 \pm 0.05$	$2.2 \pm 0.9 \pm 1.4$	$1.0 \pm 0.6 \pm 0.6$
Total	$9.2 \pm 1.8 \pm 2.5$	$12.4 \pm 1.7 \pm 3.1$	$11.2 \pm 1.9 \pm 3.0$	$32.8 \pm 3.2 \pm 6.3$	$20.4 \pm 2.6 \pm 3.9$
Data	7	9	8	24	15
$\sigma_{\rm vis}^{\rm obs(exp)}$ (fb)	1.6 (1.9)	1.7 (2.2)	1.7 (2.1)	2.6 (3.8)	2.0 (2.7)

SR-OSjveto				
	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all
Z+X	$4.5 \pm 1.2 \pm 1.2$	$3.0 \pm 0.9 \pm 0.5$	$4.7 \pm 1.1 \pm 1.2$	$12.2 \pm 1.8 \pm 1.8$
WW	$8.8 \pm 1.8 \pm 4.4$	$20.9 \pm 2.6 \pm 6.2$	$13.3 \pm 1.9 \pm 3.5$	$43.0 \pm 3.7 \pm 12.2$
$t\bar{t}$, single top	$21.1 \pm 2.3 \pm 4.2$	$47.7 \pm 3.4 \pm 20.5$	$27.5 \pm 2.5 \pm 9.0$	$96.2 \pm 4.8 \pm 29.5$
Fake leptons	$2.9 \pm 1.2 \pm 1.2$	$6.9 \pm 1.8 \pm 2.6$	$0.4 \pm 0.6 \pm 0.3$	$10.3 \pm 2.2 \pm 4.1$
Total	$37.2 \pm 3.3 \pm 6.4$	$78.5 \pm 4.7 \pm 20.9$	$45.9 \pm 3.4 \pm 9.4$	$161.7 \pm 6.7 \pm 30.8$
Data	33	66	40	139
$\sigma_{\rm vis}^{\rm obs(exp)}$ (fb)	3.5 (4.0)	8.1 (9.6)	4.3 (5.1)	11.4 (14.1)

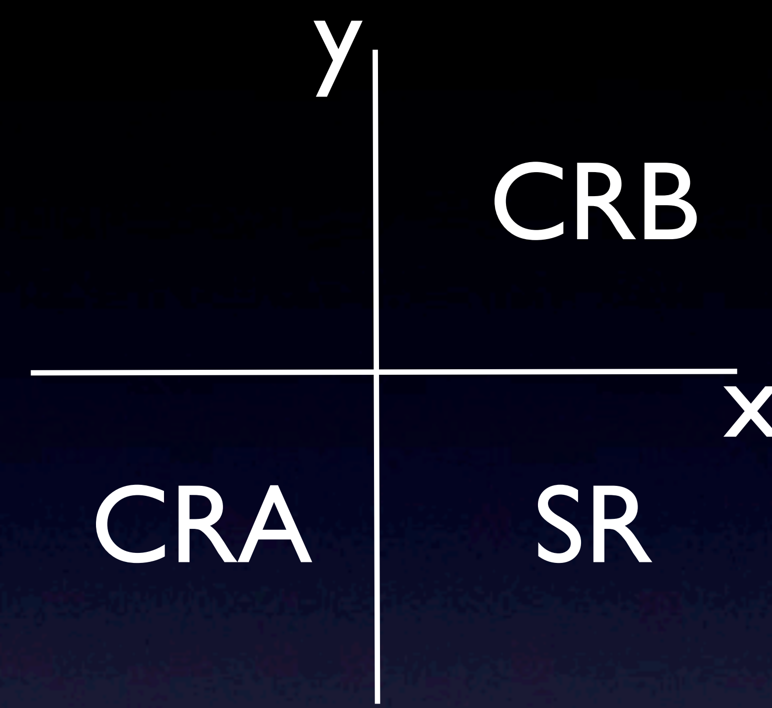
SR-2jets				
	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	SF
Z+X	$3.8 \pm 1.3 \pm 2.7$	—	$5.8 \pm 1.6 \pm 3.9$	$9.6 \pm 2.0 \pm 5.1$
WW	$6.4 \pm 0.5 \pm 4.3$	—	$8.4 \pm 0.6 \pm 5.7$	$14.8 \pm 0.7 \pm 9.9$
$t\bar{t}$, single top	$14.8 \pm 1.9 \pm 9.2$	—	$22.1 \pm 2.1 \pm 20.7$	$36.9 \pm 2.9 \pm 29.6$
Fake leptons	$2.5 \pm 1.2 \pm 1.5$	—	$1.7 \pm 1.3 \pm 0.8$	$4.2 \pm 1.8 \pm 2.3$
Total	$27.5 \pm 2.6 \pm 10.6$	—	$37.9 \pm 3.0 \pm 21.0$	$65.5 \pm 4.0 \pm 31.8$
Data	39	—	39	78
$\sigma_{\rm vis}^{\rm obs(exp)}$ (fb)	7.1 (5.1)	—	9.7 (9.6)	15.6 (13.9)

SR-SSjveto				
	e^+e^-	$e^\pm\mu^\pm$	$\mu^+\mu^-$	all
Charge flip	$0.49 \pm 0.03 \pm 0.17$	$0.34 \pm 0.02 \pm 0.11$	—	$0.83 \pm 0.04 \pm 0.18$
Dibosons	$0.62 \pm 0.13 \pm 0.18$	$1.93 \pm 0.23 \pm 0.36$	$0.94 \pm 0.16 \pm 0.26$	$3.50 \pm 0.31 \pm 0.54$
Fake leptons	$3.2 \pm 0.9 \pm 1.7$	$2.9 \pm 0.9 \pm 1.9$	$0.6 \pm 0.6 \pm 0.3$	$6.6 \pm 1.4 \pm 3.8$
Total	$4.3 \pm 0.9 \pm 1.7$	$5.1 \pm 1.0 \pm 1.9$	$1.5 \pm 0.6 \pm 0.4$	$11.0 \pm 1.5 \pm 3.9$
Data	1	5	3	9
$\sigma_{\rm vis}^{\rm obs(exp)}$ (fb)	0.8 (1.2)	1.5 (1.5)	1.3 (0.8)	2.0 (2.3)

Table 5: Evaluated SM backgrounds in each SR separated by flavour (ee, $e\mu$, $\mu\mu$) and combined in an "all" channel. In SR-m_{T2} the evaluated background components in the SF channel are quoted separately as the $e\mu$ channel is not appropriate for a direct slepton search. The second quoted error is the total systematic uncertainty whereas the first is the statistical uncertainty arising from limited numbers of MC events. The effect of limited data events in the CR is included in the systematic uncertainty. In all OS SR and channels the component Z+X includes the contributions from Z/γ^*+jets, WZ and ZZ events. All statistical uncertainties are added in quadrature whereas the systematic uncertainties are obtained after taking full account of all correlations between sources, backgrounds and channels. Quoted also are the observed (expected) 95% confidence limits on the visible cross-section for non-SM events in each SR, $\sigma_{\rm vis}^{\rm obs(exp)}$.

Anatomy of a Search

- Pick a signal region (SR)
- Define N Control Regions (CR) for large or poorly modelled backgrounds
- CR can be used to constrain and/or validate MC estimate
- Transfer factor (TF) can be used to take N_CR to N_SR
- Background in SR can also be measured directly in Monte Carlo



$$N^{BGA}_{SR,data} = TF \times N^{BGA}_{CRA,data}$$