

# SUSY SEARCHES WITH LEPTONS IN ATLAS

CHICAGO 2012 Workshop on LHC Physics in the Higgs Era

**Zoltan Gecse**

(University of British Columbia, ATLAS)

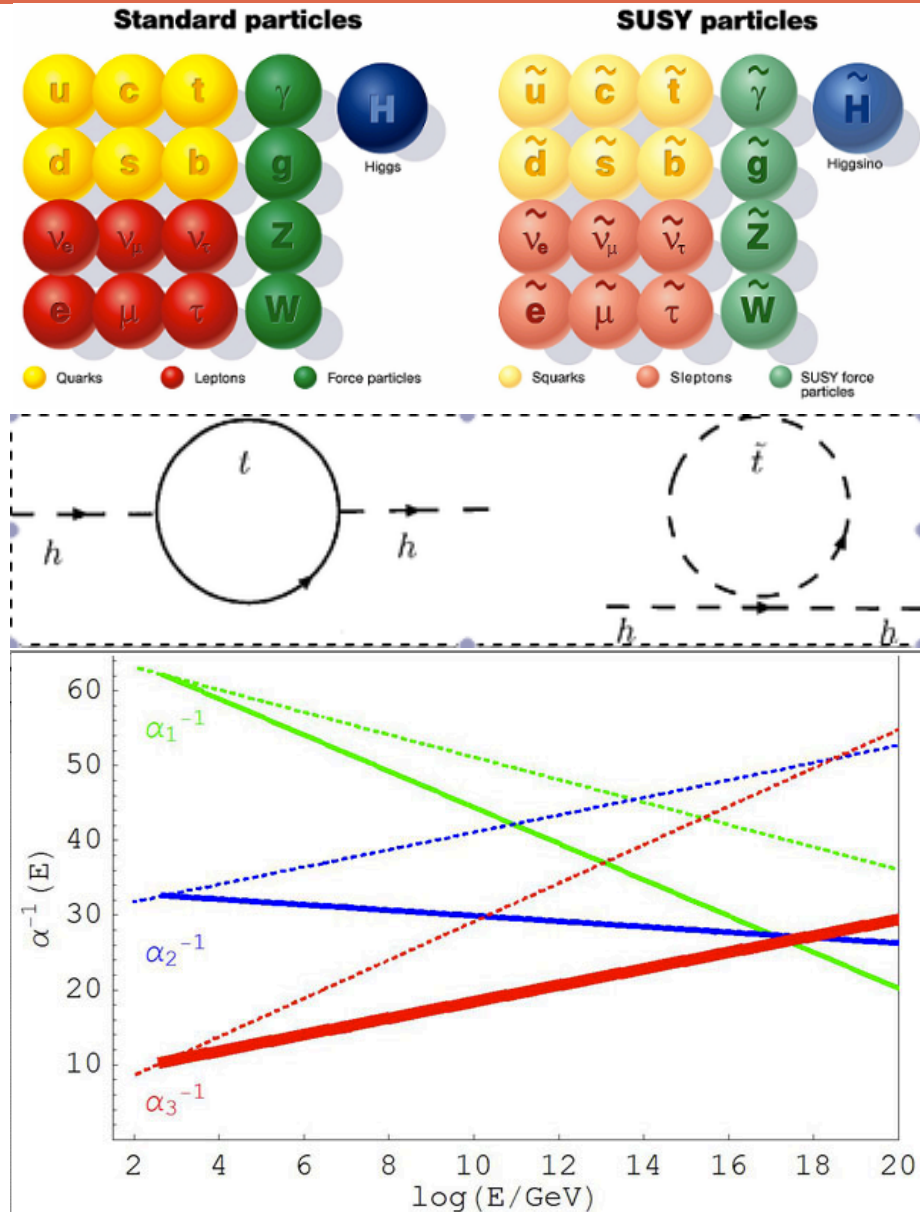


The University of Chicago  
November 12-14, 2012

- **Motivations**
  - Natural SUSY
- **3<sup>rd</sup> Generation**
  - Direct stop production limits, 7 TeV, 4.7/fb
  - Gluino mediated stop production, 2 same-sign leptons, 8 TeV, 5.8/fb
  - Gluino mediated stop, direct sbottom production, 3 leptons, 8 TeV, 13.0/fb
- **Electroweak production**
  - Slepton and chargino pair-production, 2 leptons, 7 TeV, 4.7/fb
  - Chargino-neutralino production, 3 leptons, 8 TeV, 13.0/fb
- **R-parity Violation**
  - NLSP pair-production, 4 leptons, 8 TeV, 13.0/fb
- **Summary**

# SuperSYmmetry

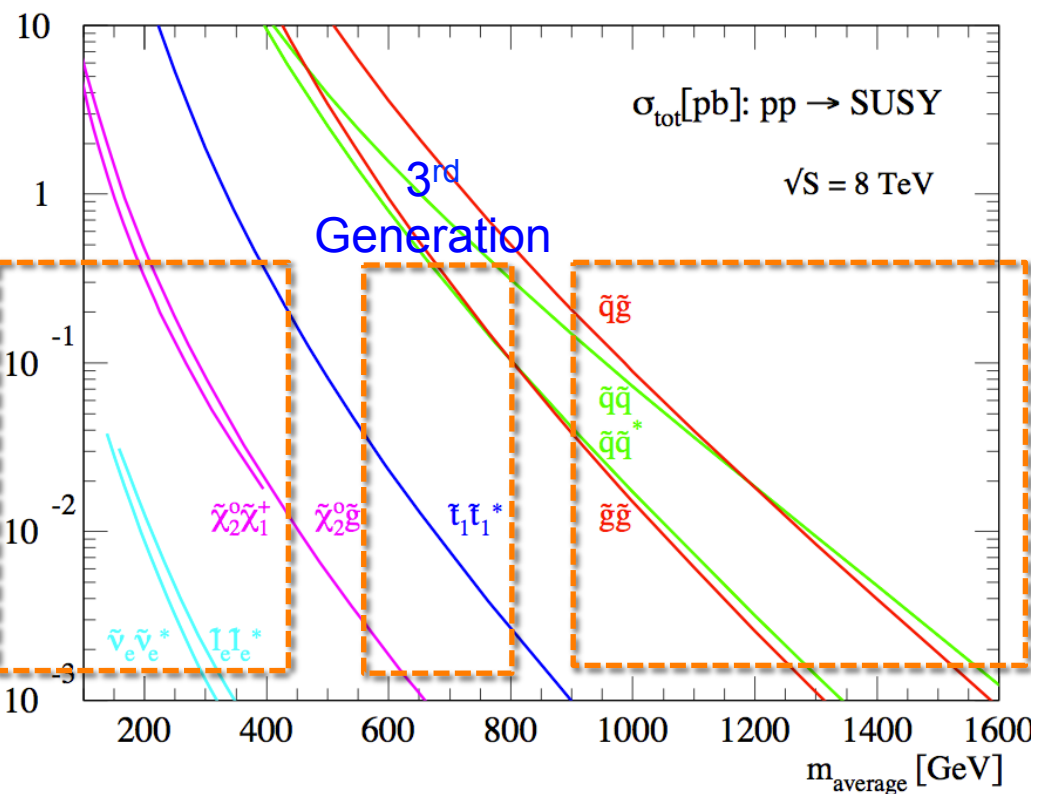
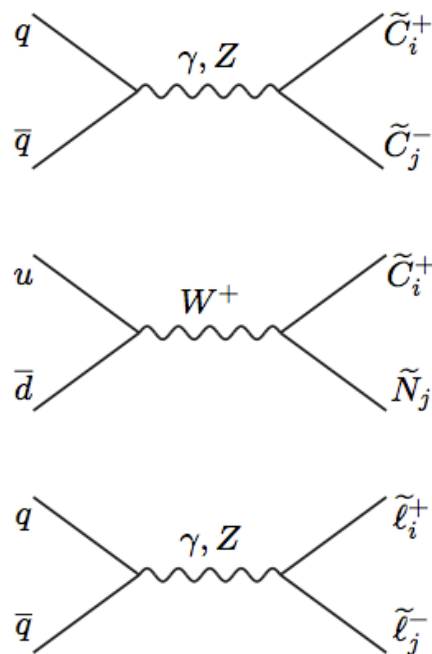
- Most popular theory beyond the Standard Model
- Introduces SUSY partners to each SM particle with spin different by 1/2
- Regularizes electroweak scale
  - Stop must be similar to top in mass
- Gauginos coupling to the Higgs sector should be light
- Unification of gauge couplings at GUT scale
  - Mass unification at GUT in parallel  
Implies  $M_1:M_2:M_3 \sim 1:2:7$  at EW
- Higher GUT scale ( $\sim 10^{17}$  GeV) prevents GUT-mediated proton decays
- R-parity conserving models can provide dark matter candidate
  - large missing momentum collider signature



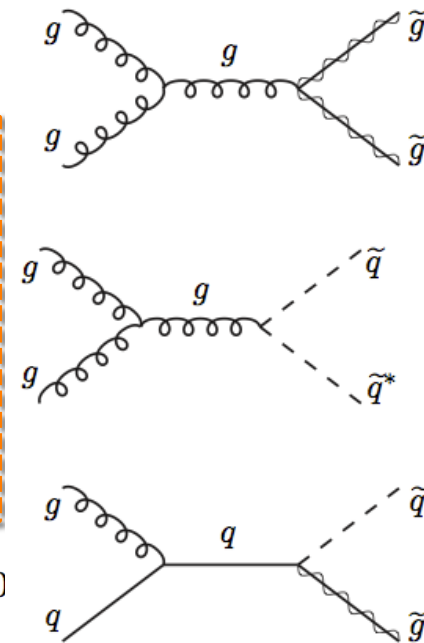
# Production of SUSY Particles

- Strong production is dominant unless squark and gluino masses are large
- Stop has to be light to solve hierarchy problem
- Gaugino masses expected to be light as they couple to the Higgs sector
- Stop and weak production could be the dominant production at this stage
- Large MET signature could be lost due to RPV

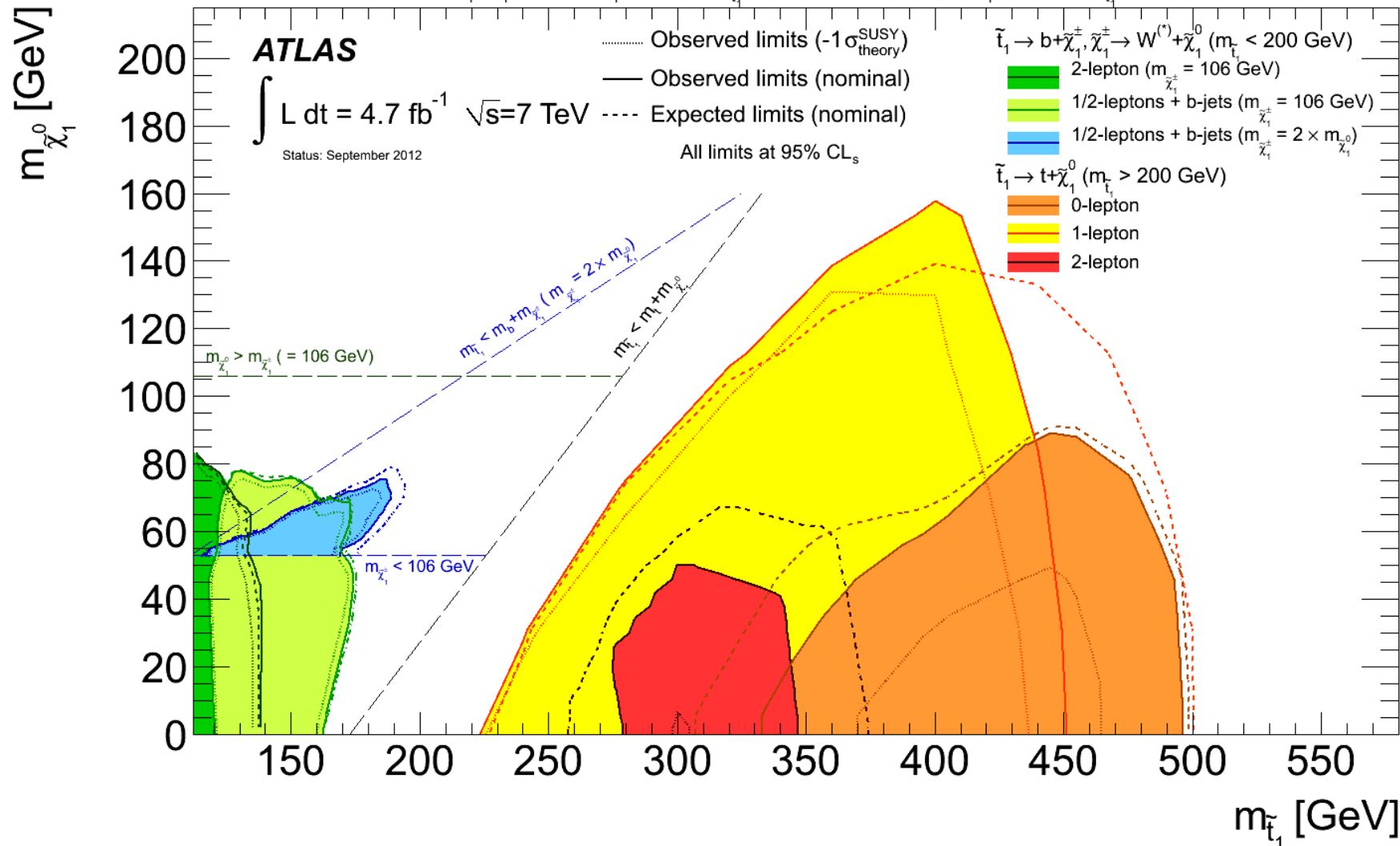
## Electroweak Production



## Strong Production

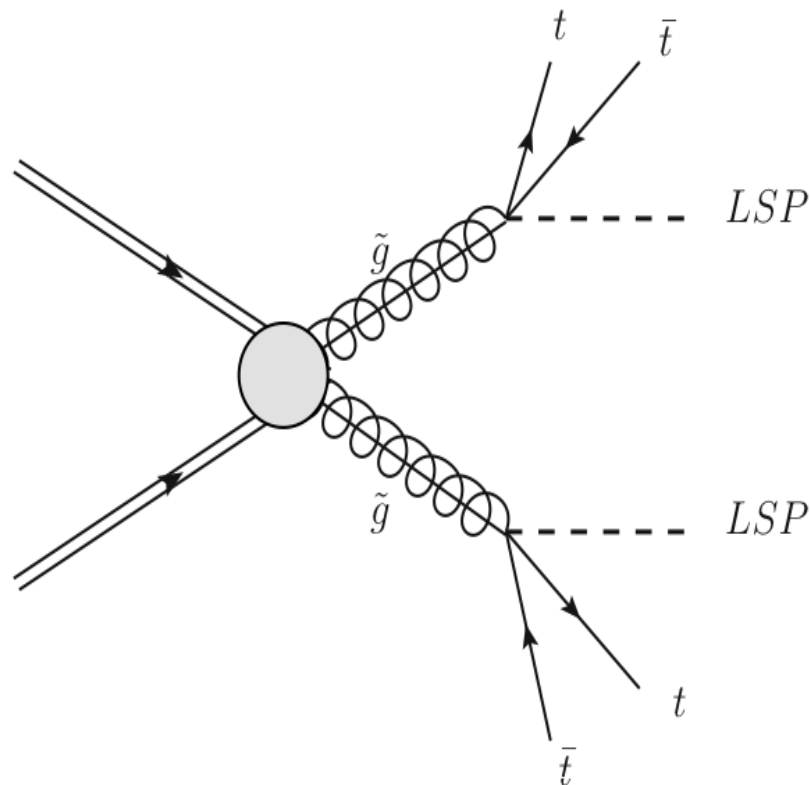
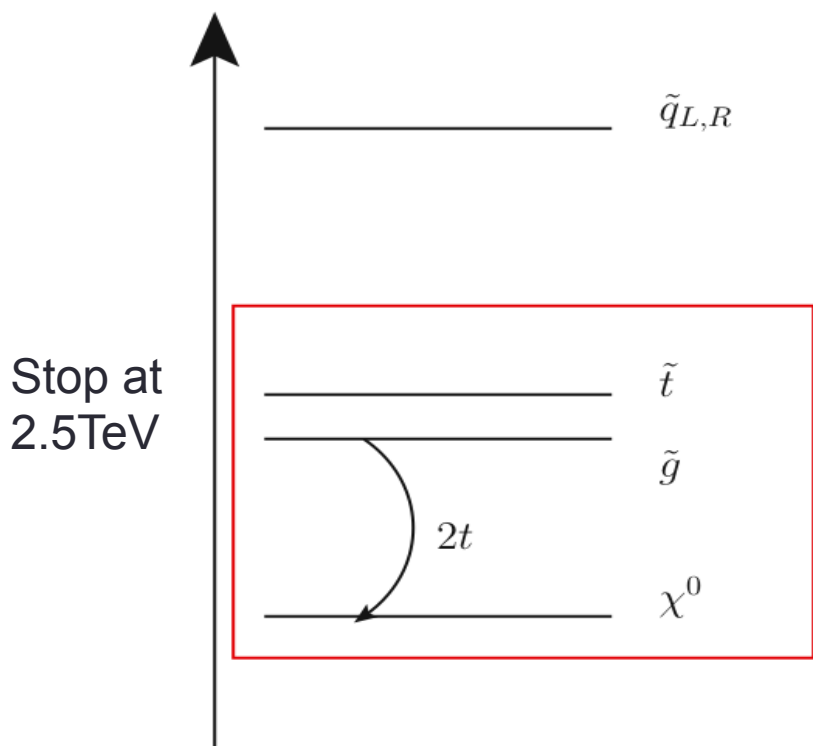


# Direct Stop Limits, 7 TeV



# Gluino Mediated Stop Searches

- Targeting RPC models where gluino and N1 are the lightest SUSY particles
- Pair-produced gluinos decay to  $t\bar{t}$  + N1 final states via off-shell stops
- Two topologies are used for the search:
  - 2 same-sign (SS) leptons + jets + MET (8 TeV, 5.8/fb)
  - **3 leptons + jets + MET (8TeV, 13/fb)**





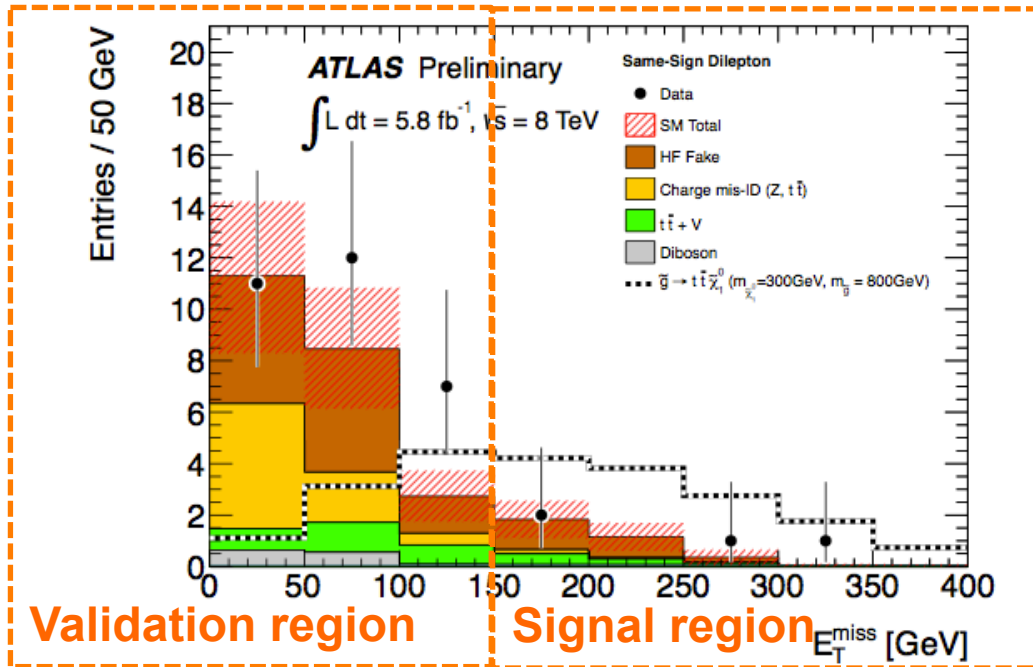
# 2 SS Leptons + Jets Search

Signal region
2 leptons, $p_T > 20$ GeV, same sign
$\geq 4$ jets, $E_T > 50$ GeV
$MET > 150$ GeV

- **Background classified into 3 classes:**
- Real SS lepton pair from VV and ttV
  - Estimated from MC
- Fake leptons from semi-leptonic tt
  - Matrix method using fake rates measured in SS control samples
- Charge mis-identification from electrons undergoing bremsstrahlung with subsequent photon conversion
  - Charge mis-ID probability measured in data using OS and SS events forming a Z candidate and applied to MC

# 2 LS Leptons + Jets Results

ATLAS-CONF-2012-105



$$\sigma_{\text{vis}} = \sigma \times \text{acceptance} \times \text{efficiency} < 1.08 \text{ fb}$$

Category	$ee$	$e\mu$	$\mu\mu$	$\ell\ell$
HF fake	$0.74 \pm 0.53$	$1.16 \pm 0.70$	$0.25^{+0.30}_{-0.25}$	$2.14 \pm 1.08$
$t\bar{t} + V$	$0.17 \pm 0.08$	$0.44 \pm 0.18$	$0.23 \pm 0.10$	$0.84 \pm 0.34$
Charge mis-ID (Z, $t\bar{t}$ )	$0.13 \pm 0.06$	$0.14 \pm 0.06$	—	$0.27 \pm 0.10$
Diboson	$0.04 \pm 0.04$	$0.10 \pm 0.05$	$0.03 \pm 0.03$	$0.18 \pm 0.07$
Total background	$1.1 \pm 0.5$	$1.8 \pm 0.7$	$0.5 \pm 0.3$	$3.4 \pm 1.1$
Observed in data	1	2	1	4

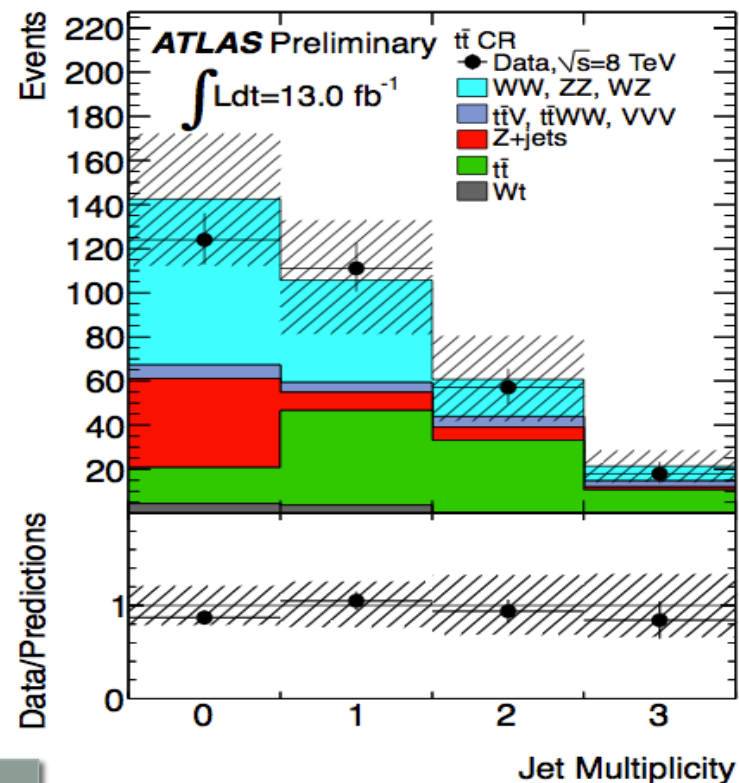


# 3 Leptons + Jets Search



Counting Experiment	
$\geq 3$ leptons, $p_T > 15$ GeV	$ \Sigma q  = \pm 1$
$\geq 4$ jets, $E_T > 30$ GeV	Third electron with $q = \Sigma q$
$MET > 50$ GeV	Z-veto

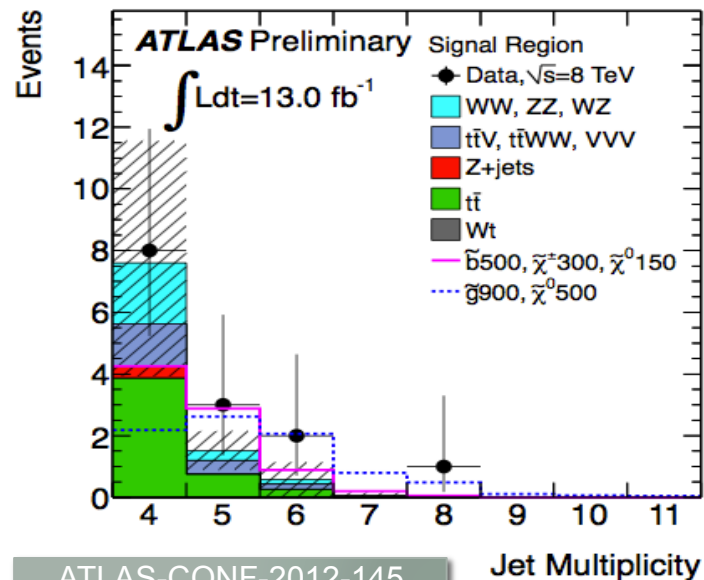
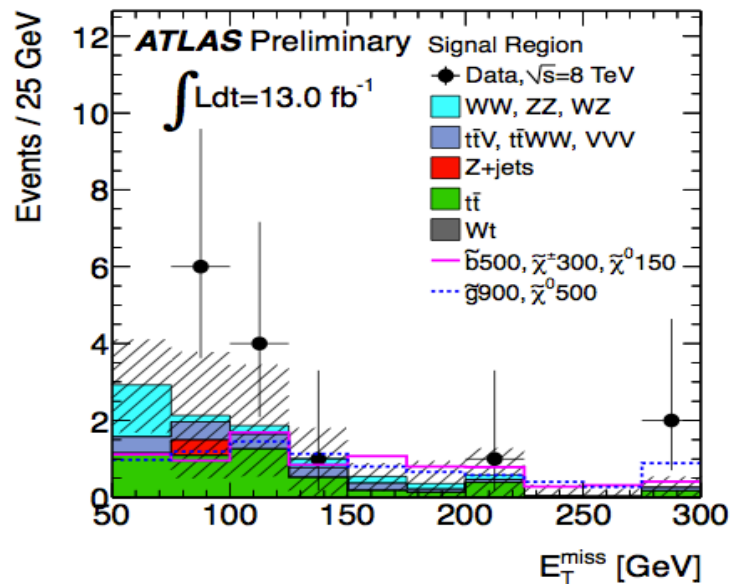
- Irreducible background ( $t\bar{t}V$ ,  $VVV$ ) is estimated from MC
- Reducible background is estimated from MC with correction factors from data
  - Scale factors for electrons/muons and heavy/light flavor
  - Scale factors obtained with likelihood function:
    - four fake-rate scale factors
    - 16 binned distributions in 3 dedicate control regions each with different flavor/charge combinations



ATLAS-CONF-2012-145

# 3 Leptons + Jets Results

	$3\mu$	$1e2SS\mu$	$1e2OS\mu$	$2SSe1\mu$	$2OSE1\mu$	$3e$	$3\ell$
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	$0.7 \pm 0.8$	$0.5 \pm 0.5$	$1.5^{+0.9}_{-0.8}$	$0.9^{+1.0}_{-0.9}$	$1.0^{+0.9}_{-0.8}$	$0.2^{+0.4}_{-0.2}$	$4.9^{+2.6}_{-2.0}$
WW, WZ, and ZZ	$0.7^{+0.4}_{-0.3}$	-	$0.8^{+0.3}_{-0.5}$	-	$0.3^{+0.3}_{-0.2}$	$0.6 \pm 0.6$	$2.4^{+1.3}_{-1.2}$
$t\bar{t}+W$ and $t\bar{t}+Z$ , and VVV	$0.3 \pm 0.2$	$0.2 \pm 0.2$	$0.6 \pm 0.5$	$0.3 \pm 0.2$	$0.4 \pm 0.3$	$0.2 \pm 0.1$	$2.0 \pm 1.0$
Total SM	$1.8 \pm 1.0$	$0.8 \pm 0.5$	$2.9 \pm 1.2$	$1.2^{+1.2}_{-1.0}$	$1.7^{+1.1}_{-1.0}$	$1.4^{+0.9}_{-0.8}$	$9.7^{+3.8}_{-3.4}$
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	$0.9 \pm 0.3$	$1.2^{+0.3}_{-0.4}$	$2.0^{+0.5}_{-0.6}$	$1.4^{+0.4}_{-0.5}$	$2.0 \pm 0.6$	$0.8^{+0.3}_{-0.3}$	$8.3^{+1.9}_{-2.3}$
Data	1	2	3	1	4	3	14

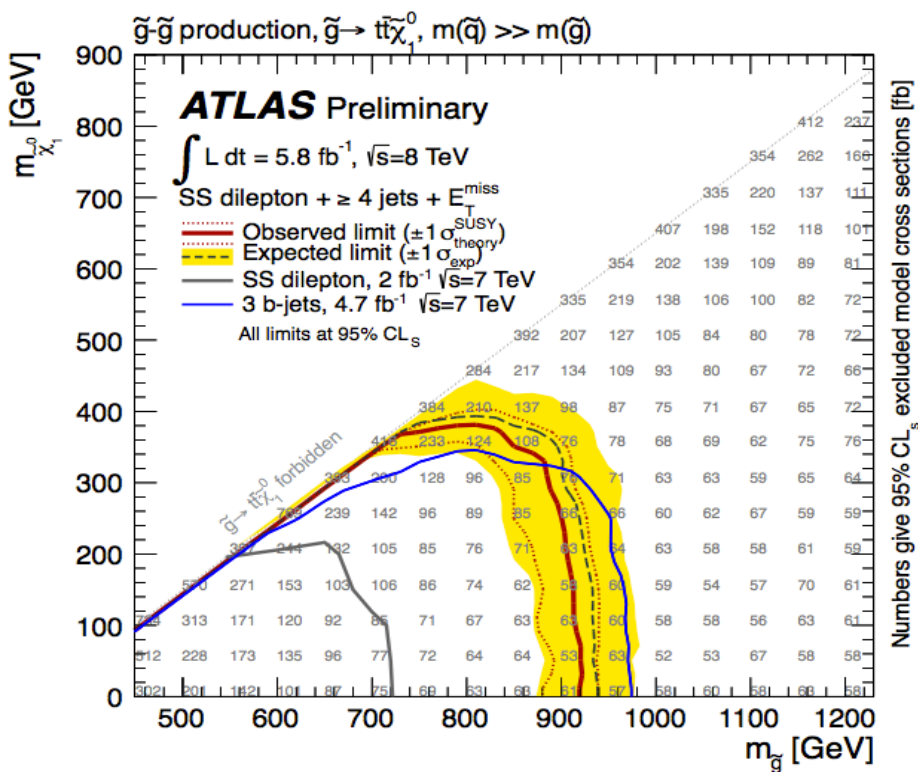


ATLAS-CONF-2012-145

Jet Multiplicity

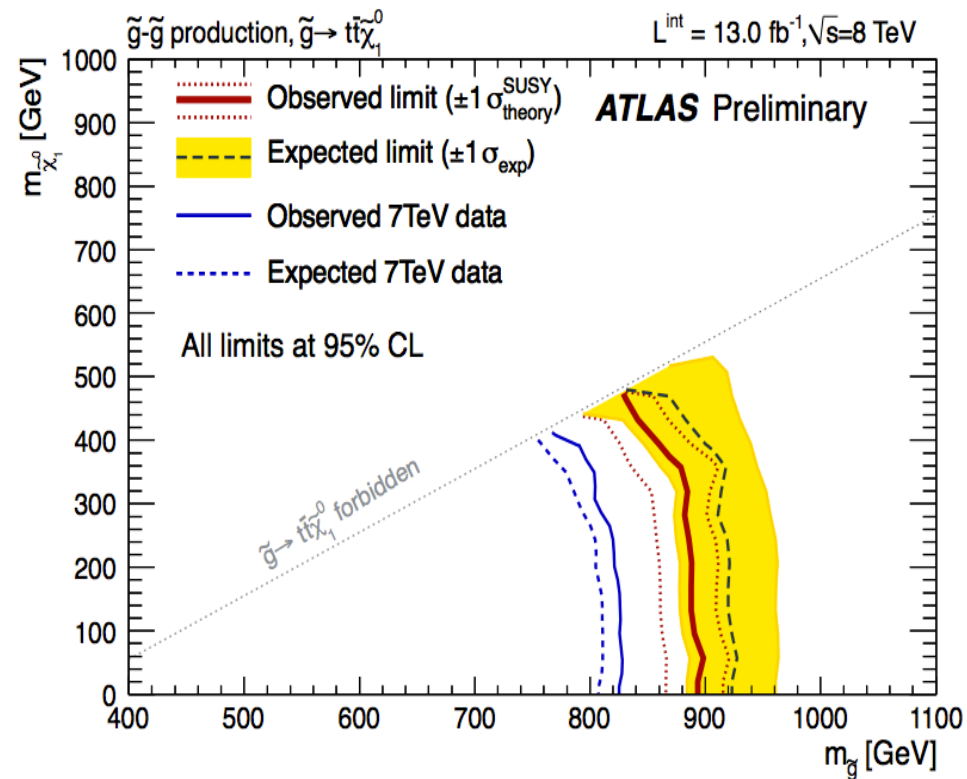
# Gluino Mediated Stop Limits

## 2 SS L + jets + MET



ATLAS-CONF-2012-105

## 3L + jets + MET

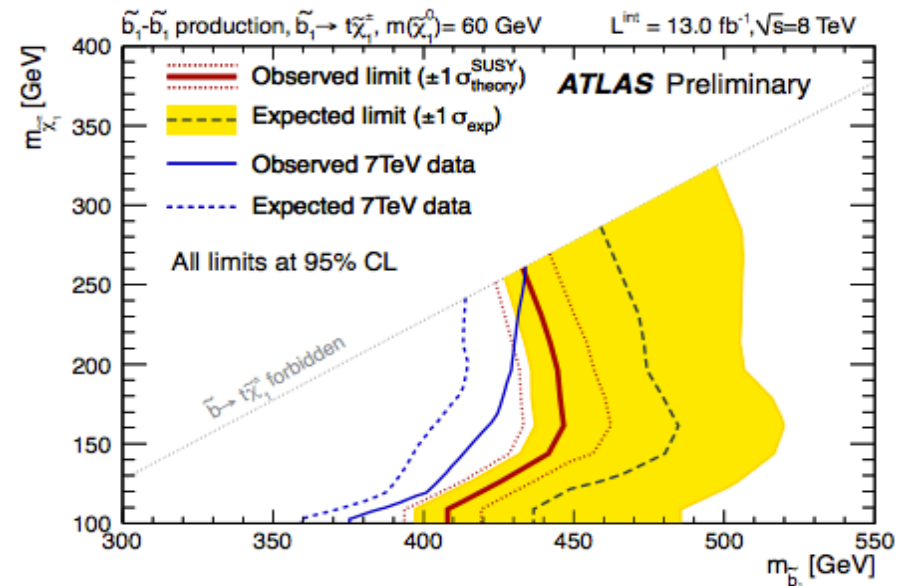
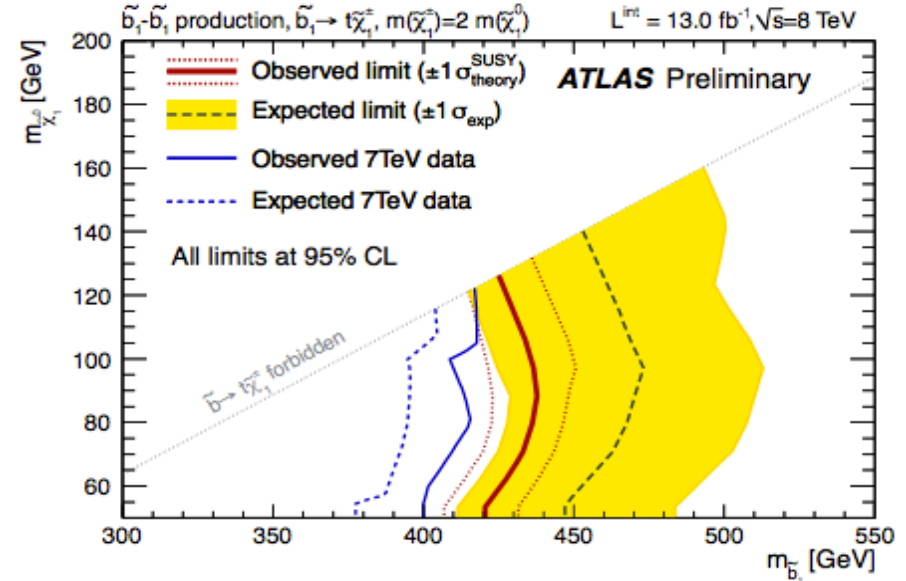
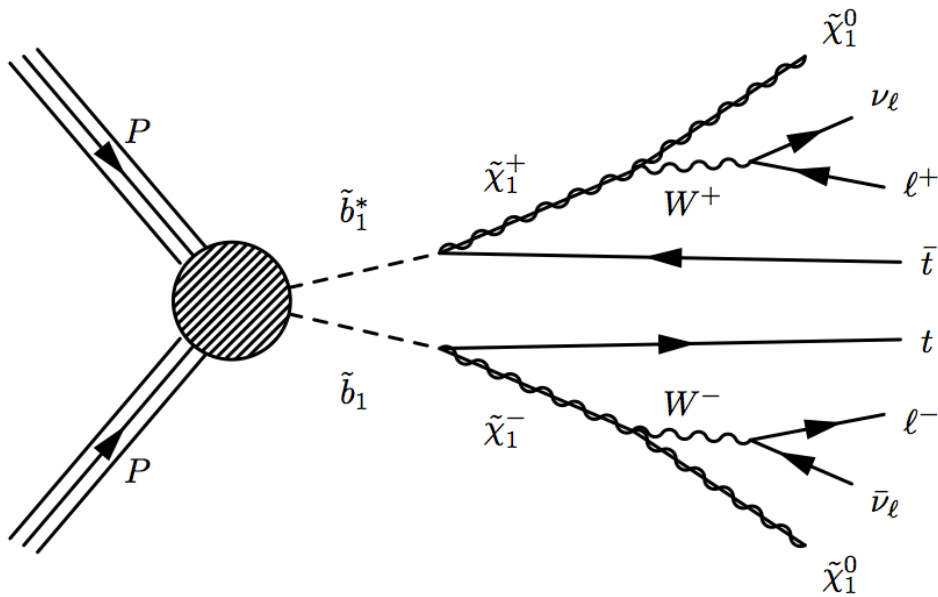


ATLAS-CONF-2012-145

# Direct Sbottom Search

## In the 3L + jets final state

- Sbottom  $\rightarrow$  top + C1
  - C1 into W + N1
  - With  $m_{C1} = 2 \times m_{N1}$
  - With  $m_{N1} = 60$  GeV

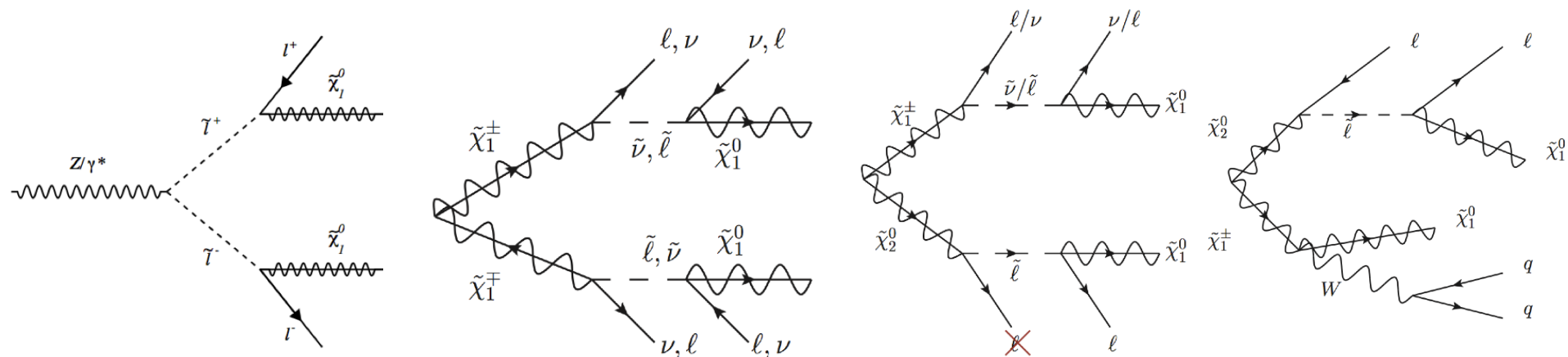


# EW 2 Leptons Search

- Four SR optimized for direct slepton production and different Chargino/Neutralino decay modes.
- 7 TeV, 4.7/fb

ATLAS-CONF-2012-076

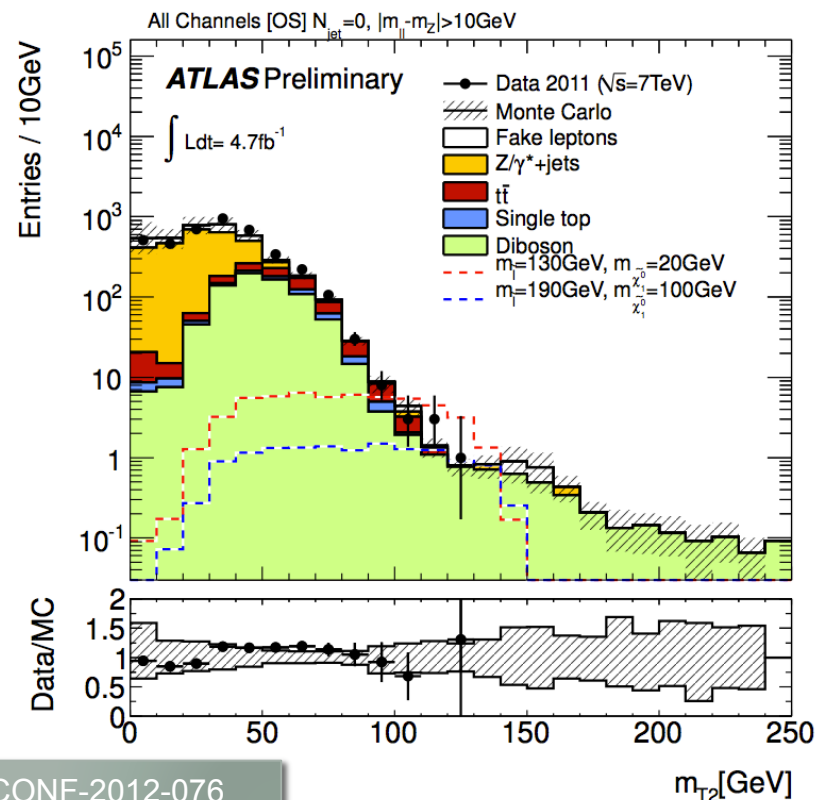
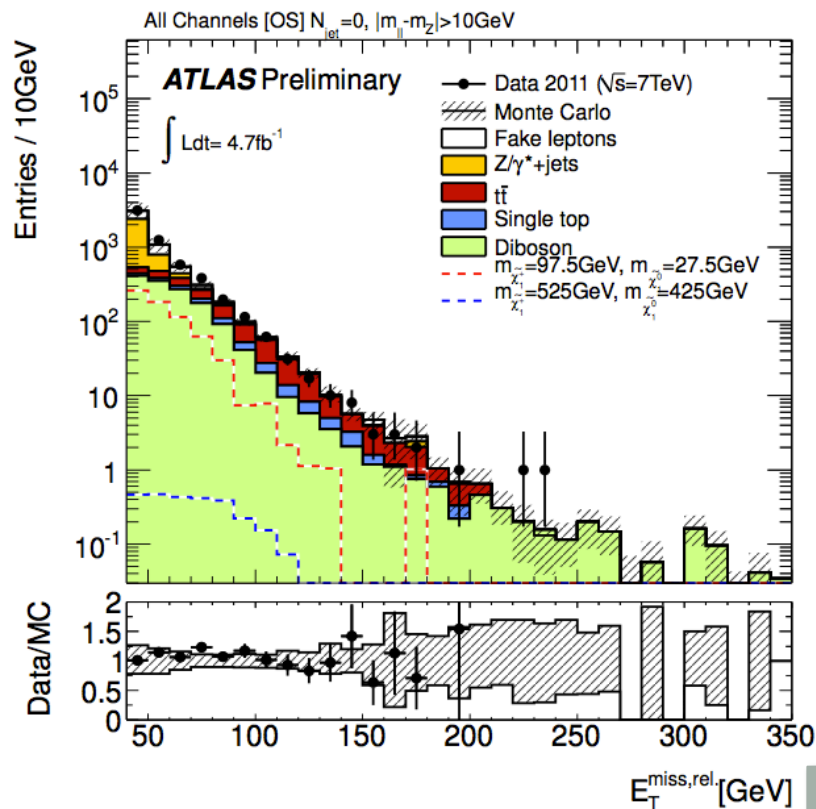
SR-	$m_{T2}$	OSjveto	SSjveto	2jets
charge	OS	OS	SS	OS
flavour	any		any	SF
$m_{ll}$	Z-veto	Z-veto	-	Z-veto
signal jets	= 0	= 0		$\geq 2$
signal $b$ -jets	-	-		= 0
$E_T^{\text{miss,rel.}}$	> 40	> 100		> 50
other	$m_{T2} > 90$	-		$m_{CT}$ -veto



# Background Estimation

## • mT2 signal region

- tt, Z+j normalized to data in control regions
- WW from MC simulation
- reducible background (W+j, and QCD) from loose lepton sample using the loose to tight efficiency

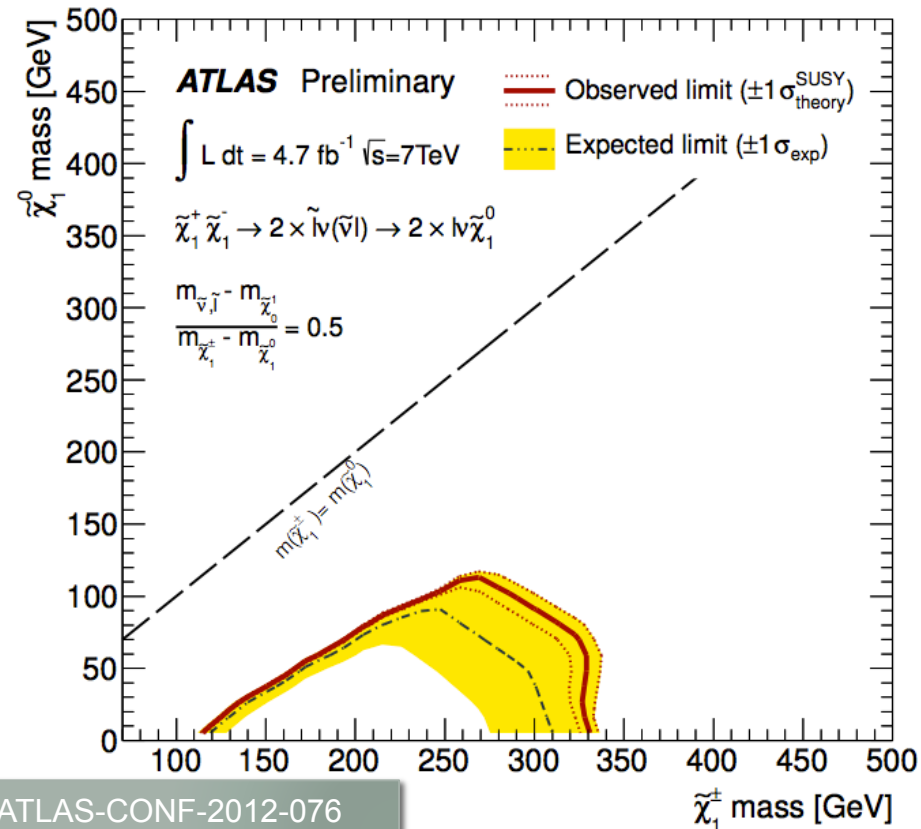
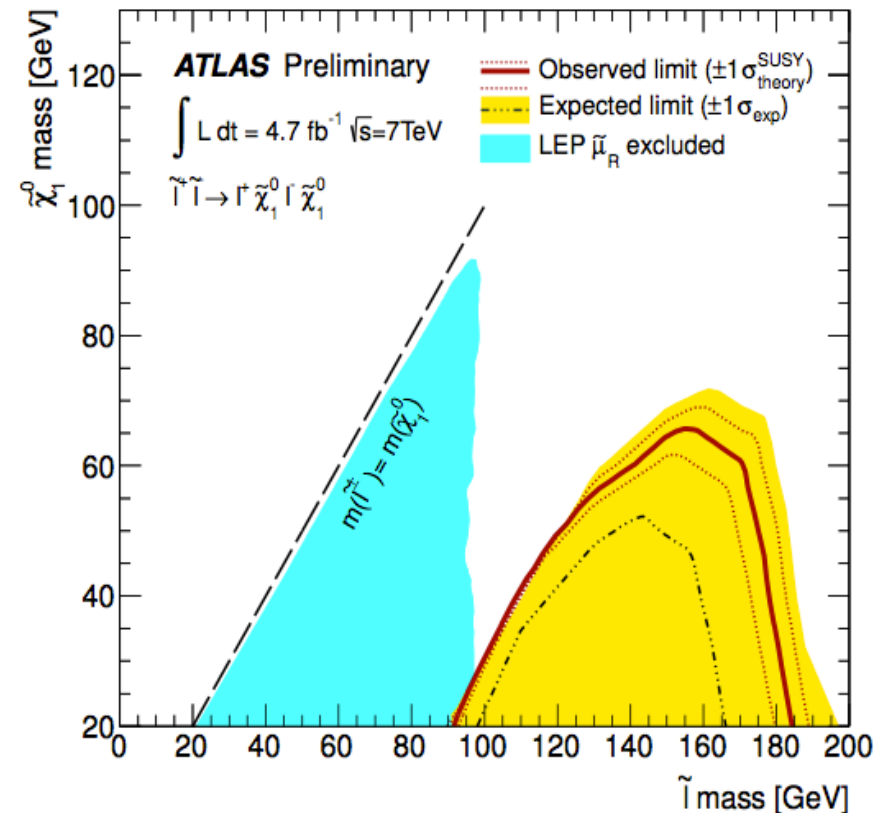
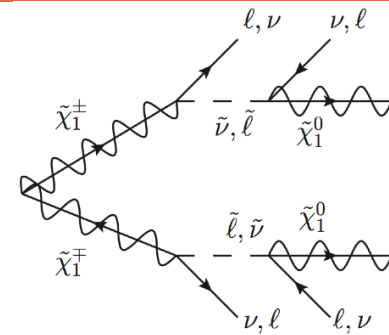
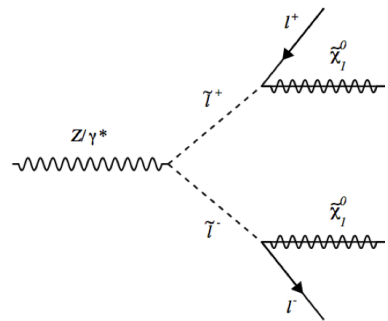


ATLAS-CONF-2012-076



# Direct Slepton and Chargino Limits

- mT2 SF signal region
- Direct sleptons within the pMSSM model
- Direct Charginos with Simplified Models, Chargino1 and Neutralino1 masses, light sleptons

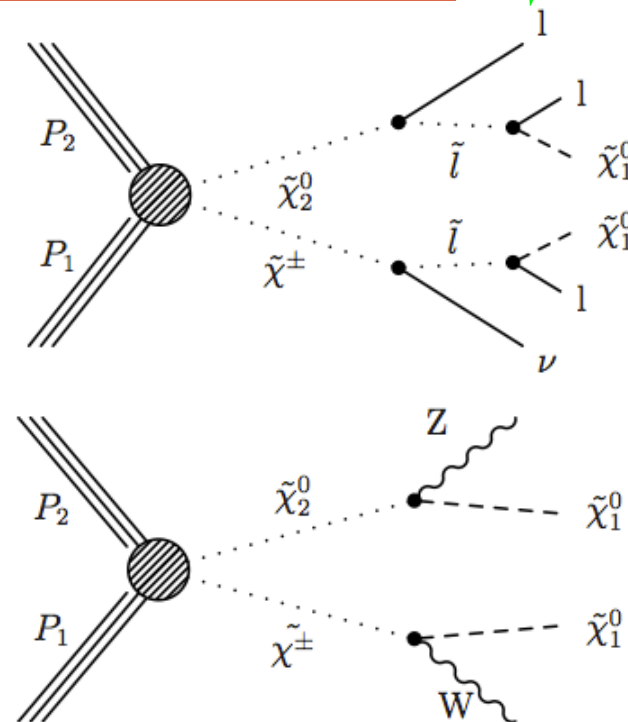


ATLAS-CONF-2012-076

# EW 3 Leptons Search



- Targeting C1-N2 direct production
- Both decays via intermediate sleptons or gauge bosons
  - Z-enriched and Z-depleted
- Targeting models with either small or large mass splitting
  - moderate or large MET & mT cuts
- Lepton  $p_T > 10\text{GeV}$
- 8 TeV, 13.0/fb, dilepton triggers



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

# Background Estimation

## • Dominant Irreducible WZ

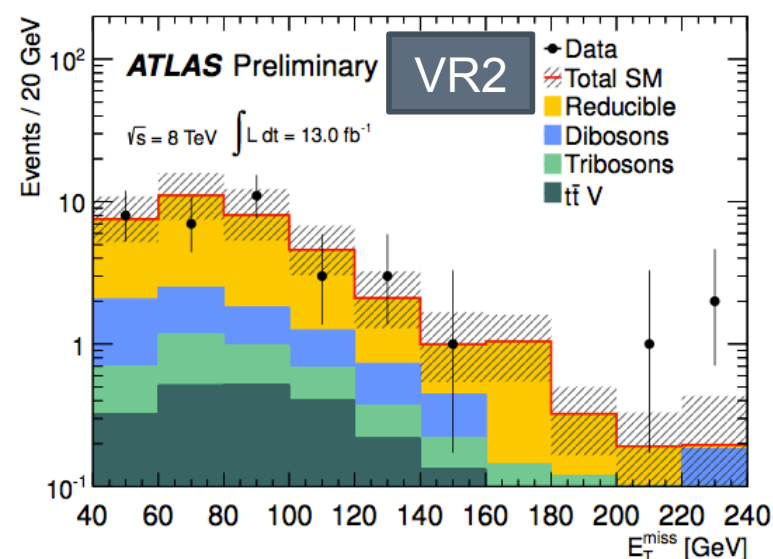
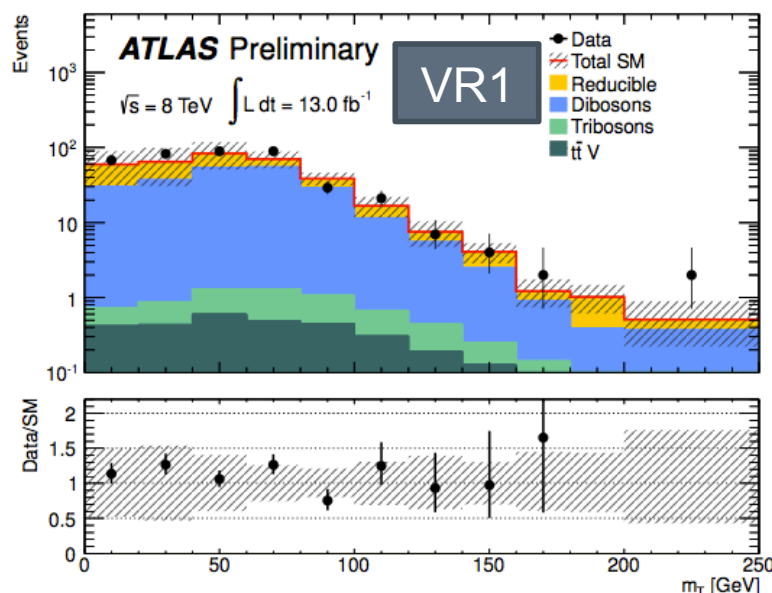
- Normalized in dedicated region to data via simultaneous fit accounting for potential signal contamination in control region

## • Remaining Irreducible from MC simulation

## • Fake leptons with data-driven matrix method

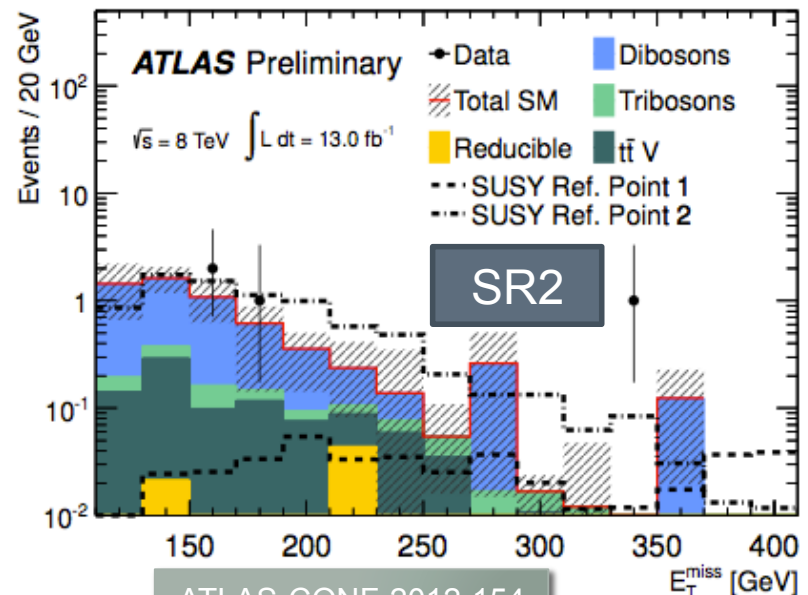
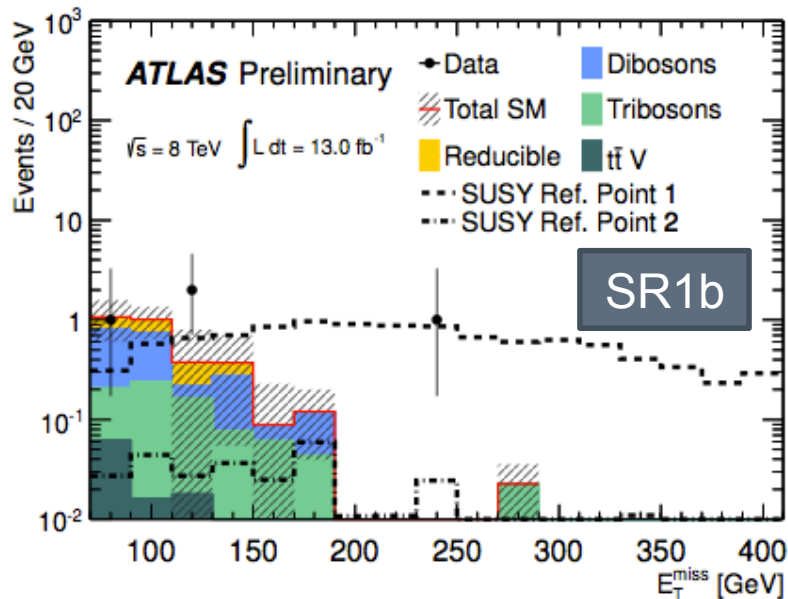
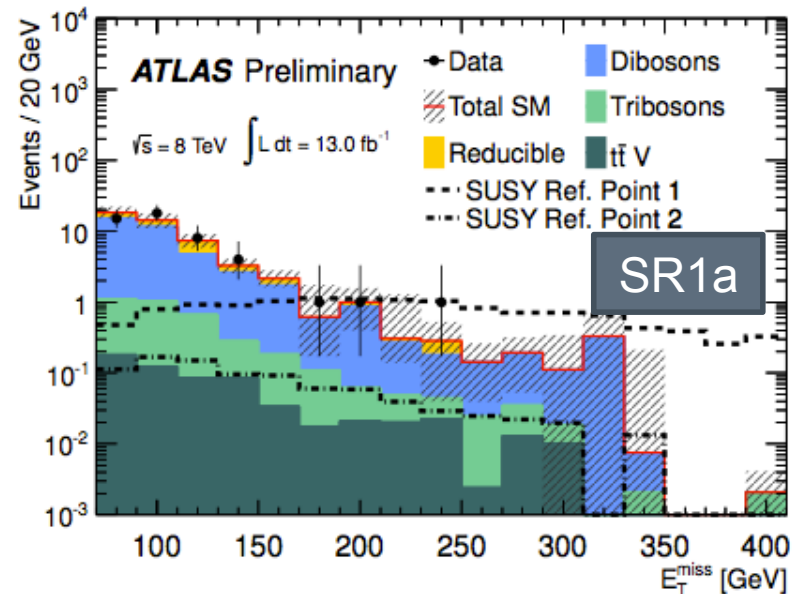
- Using loose lepton data sample plus fake rates and efficiencies to solve system of equations

Selection	VR1	VR2	VR3
$ m_{\text{SFOS}} - m_Z $	$> 10 \text{ GeV}$	SFOS veto	$< 10 \text{ GeV}$
$E_T^{\text{miss}} \text{ min}$	30 GeV	50 GeV	30 GeV
$E_T^{\text{miss}} \text{ max}$	75 GeV	–	50 GeV
$t\bar{t}+V$	$3.1 \pm 1.2$	$2.5 \pm 0.8$	$3.9 \pm 1.9$
triboson	$4 \pm 4$	$2.1 \pm 2.1$	$0.7 \pm 0.7$
ZZ	$64 \pm 17$	$0.41 \pm 0.23$	$49 \pm 4$
WZ (normalised)	$161 \pm 19$	$4.5 \pm 0.7$	$385 \pm 50$
Reducible Bkg.	$121 \pm 50$	$27 \pm 13$	$185 \pm 70$
Total Bkg.	$353 \pm 60$	$36 \pm 14$	$624 \pm 90$
Data	391	36	692



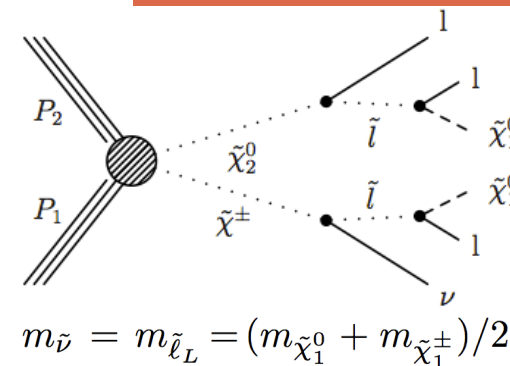
# 3 Leptons Results

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



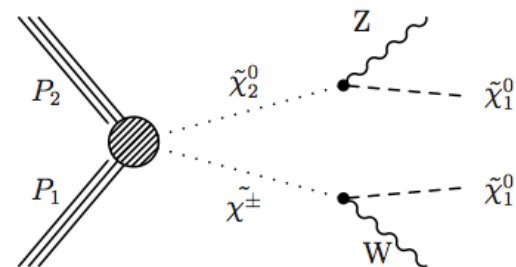
ATLAS-CONF-2012-154

# C1-N2 Simplified Models Limits

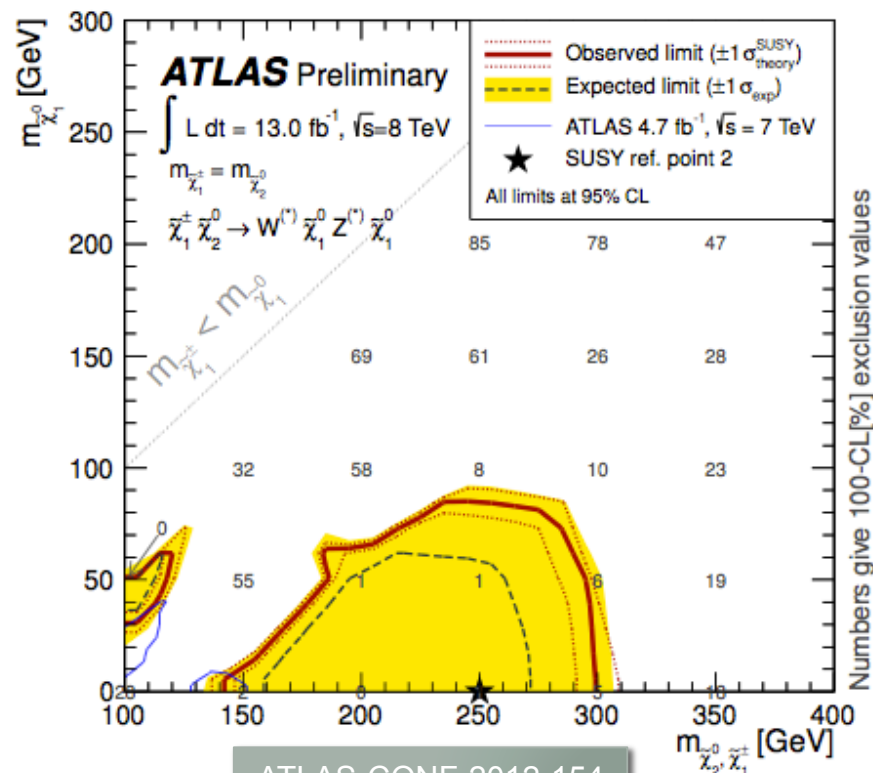
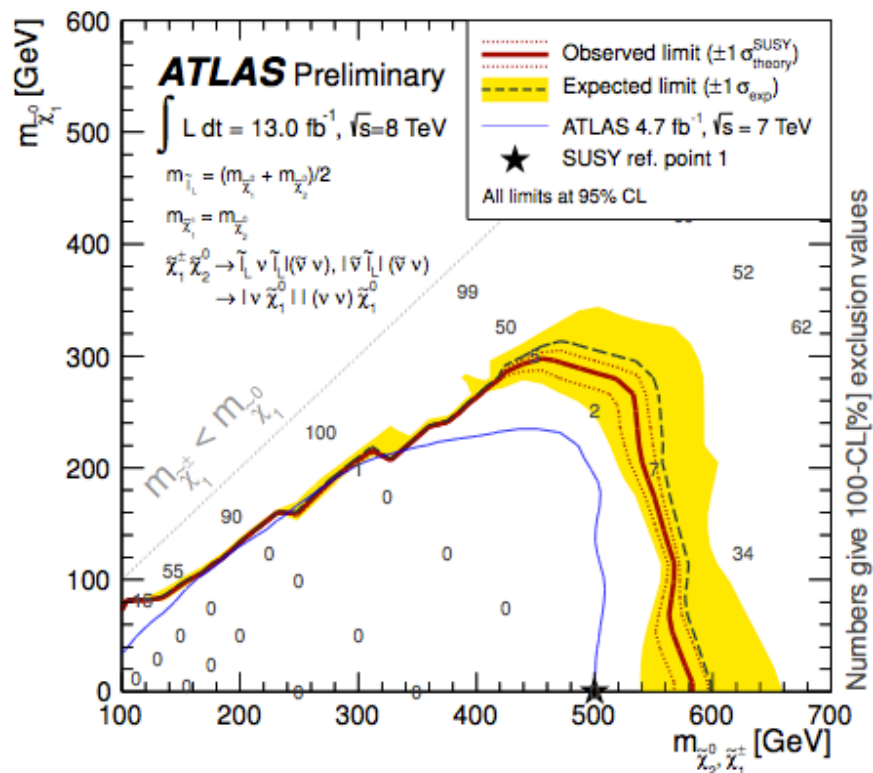


- **Simplified models**
- Mass degenerate, wino like Chargino1 and Neutralino2
- Neutralino1, bino like
- **Free parameters: Chargino and neutralino masses**

Other particle masses are set to high values



On-shell Z, off-shell Z  
No Higgs decays



ATLAS-CONF-2012-154

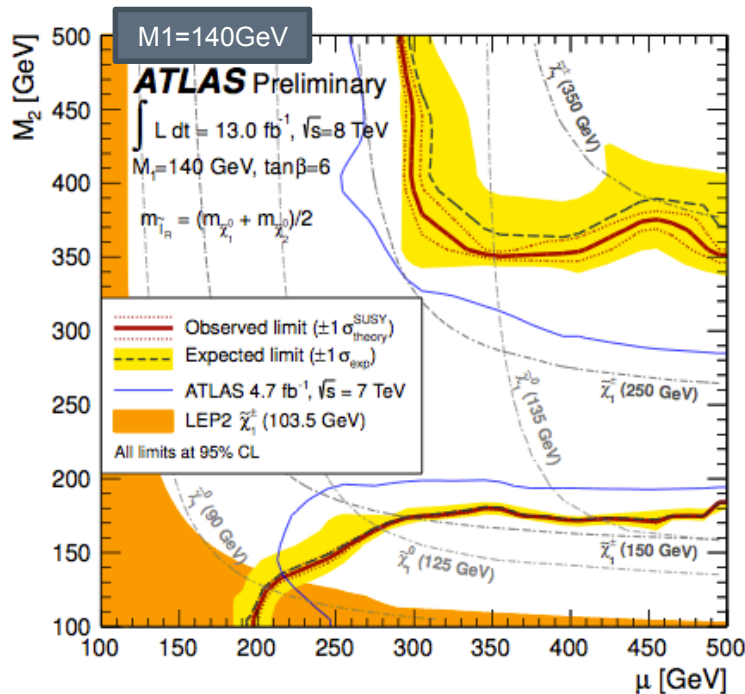
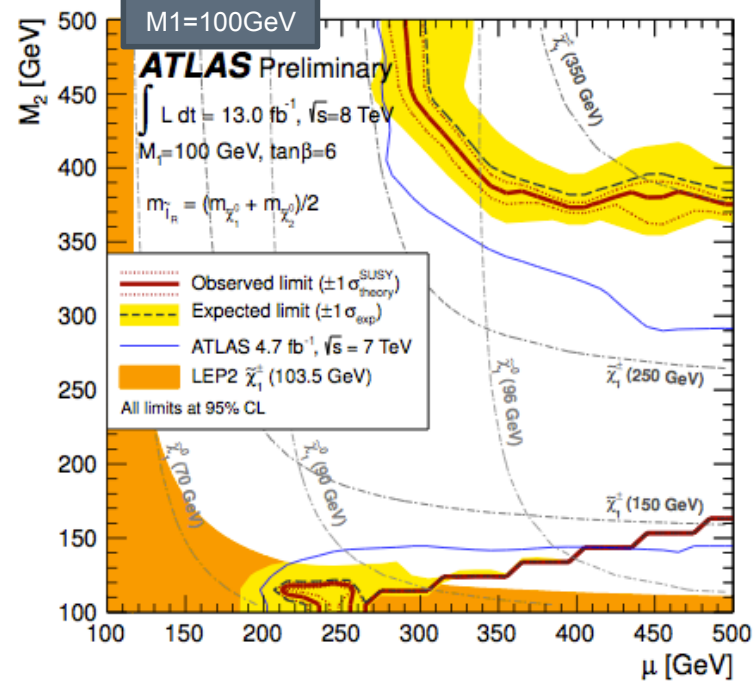




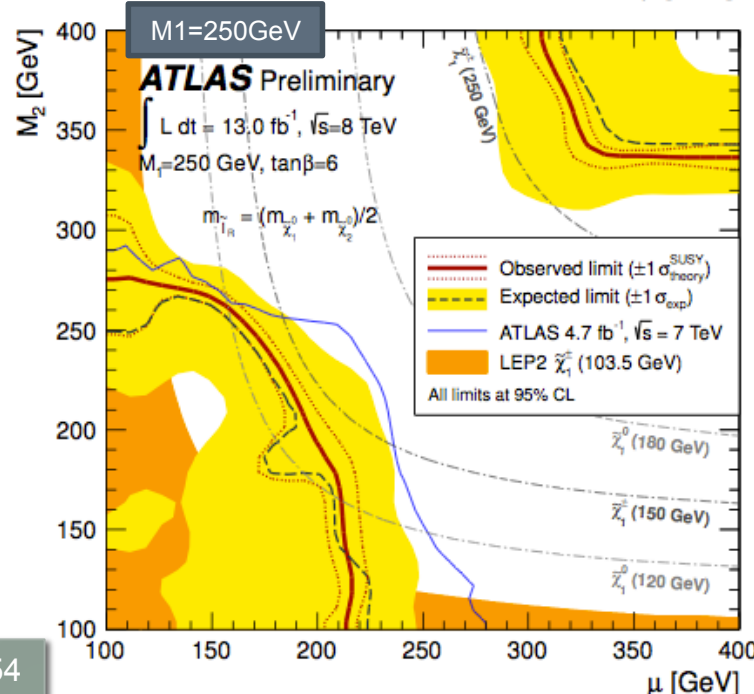
# 3L pMSSM Limits

- pMSSM**: number of free parameters reduced to 19 (from 105) by the following assumptions
  - CP conservation, minimal flavour violation, negligible trilinear couplings for 1st and 2nd generation, degenerate 1st and 2nd generation sfermion masses
- Heavy squarks, gluinos and left-handed sleptons,  $\tan\beta=6$ ,  $m_A=500\text{GeV}$ 

$$m_{\tilde{\ell}_R} = (m_{\tilde{\chi}_2^0} + m_{\tilde{\chi}_1^0})/2$$
- Right-handed slepton masses
- Free parameters remain: M1, M2,  $\mu$**



- Blue lines 2L+3L  
ATLAS 7TeV



ATLAS-CONF-2012-154



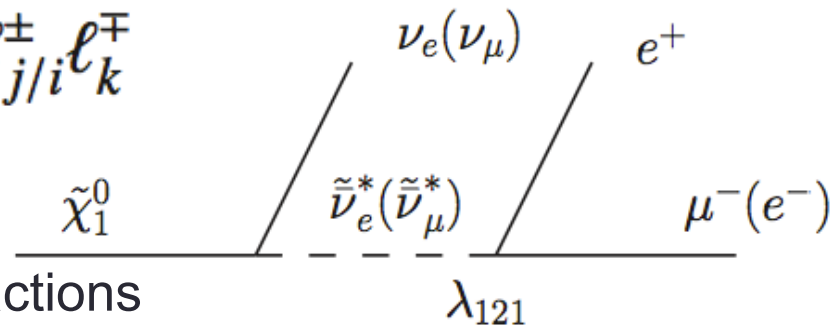
# RPV 4 Leptons Search



$$W_{\text{RPV}} = \lambda_{ijk} L_i L_j \bar{E}_k$$

$$\tilde{\chi}_1^0 \rightarrow \nu_{i/j} \ell_{j/i}^{\pm} \ell_k^{\mp}$$

$\lambda_{121}$  or  $\lambda_{122}$



- Sparticles **pair-produced** via gauge interactions
- Decay to LSPs via gauge interactions
- LSPs decay **promptly** to 2 leptons and neutrino via RPV

- 4 Lepton (electron, muon) final state

- **Moderate MET and high Meff signature**

$$m_{\text{eff}} = E_{\text{T}}^{\text{miss}} + \sum_{\mu} p_{\text{T}}^{\mu} + \sum_e E_{\text{T}}^e + \sum_j E_{\text{T}}^j$$

- 8 TeV, 13.0/fb

- Lepton  $p_{\text{T}} > 10\text{GeV}$

- Dilepton triggers

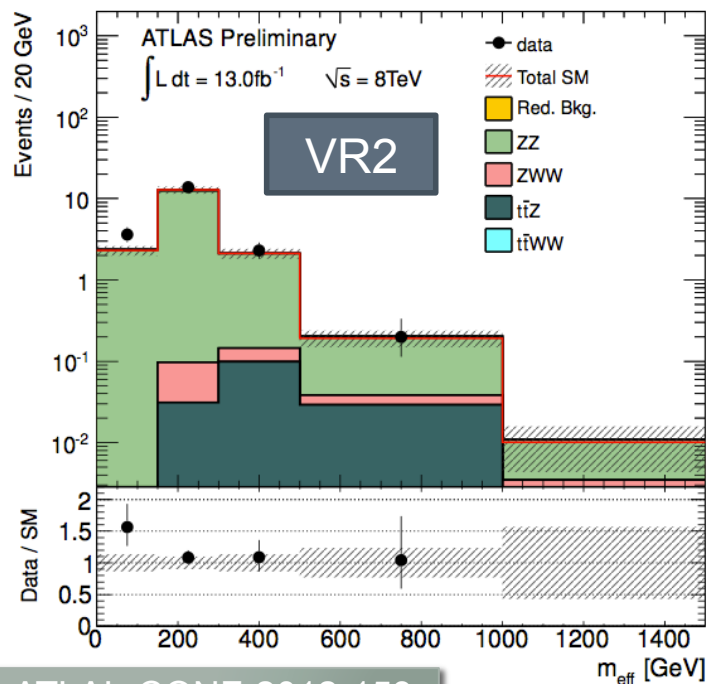
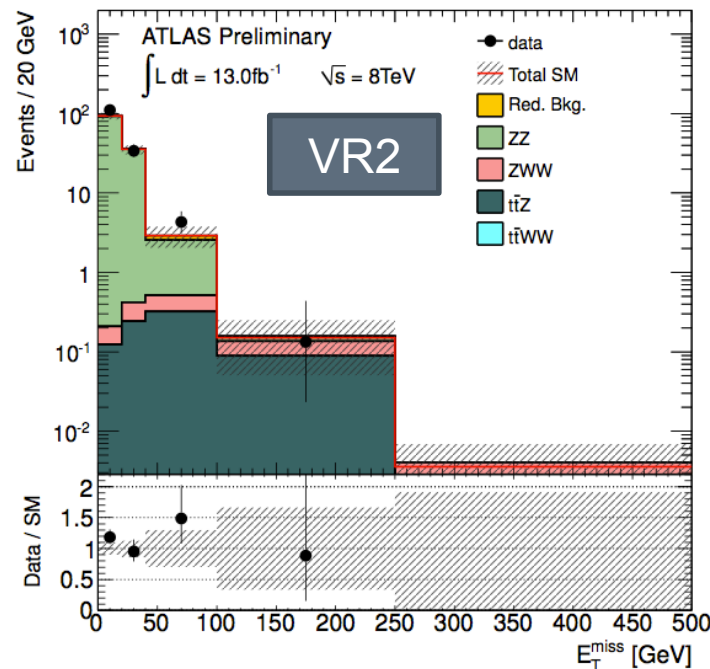
Selection	SR1	SR2
Number of leptons	$\geq 4$	$\geq 4$
SFOS pair	–	–
Z-candidate	Z-veto	Z-veto
$E_{\text{T}}^{\text{miss}}/\text{GeV}$	$> 50$	–
$m_{\text{eff}}/\text{GeV}$	–	$> 300$



# Background Estimation

- MC simulation for irreducible 4 real leptons
- Data-driven for processes with 1-2 fake leptons
  - Weight non-isolated events with Fake Ratio

Selection	VR1	VR2	VR3
Number of leptons	3	$\geq 4$	$\geq 4$
SFOS pair	SFOS-veto	SFOS requirement	–
Z-candidate	Z-veto	Z requirement	Z-veto
$E_T^{\text{miss}}/\text{GeV}$	$> 50$	–	$< 50$
$m_{\text{eff}}/\text{GeV}$	–	–	$< 300$
<i>ZZ</i>	$0.43^{+0.32}_{-0.32}$	$135^{+13}_{-13}$	$3.9^{+1.7}_{-1.7}$
<i>ZWW</i>	$0.29^{+0.29}_{-0.29}$	$1.2^{+1.2}_{-1.2}$	$0.018^{+0.018}_{-0.018}$
<i>t<math>\bar{t}</math>Z</i>	$0.44^{+0.23}_{-0.23}$	$2.0^{+1.0}_{-1.0}$	$0.011^{+0.011}_{-0.011}$
<i>t<math>\bar{t}</math>WW</i>	$0.057^{+0.031}_{-0.031}$	$(2.5^{+2.3}_{-2.3}) \times 10^{-3}$	$(4^{+1}_{-4}) \times 10^{-3}$
<i>WZ</i> (†)	$4.4^{+0.9}_{-0.8}$	–	–
<i>t<math>\bar{t}</math>W</i> (†)	$2.1^{+0.7}_{-0.7}$	–	–
<i>WWW</i> (†)	$1.9^{+1.9}_{-1.9}$	–	–
Irreducible Bkg.	$10^{+4}_{-4}$	$138^{+15}_{-15}$	$3.9^{+1.7}_{-1.7}$
Reducible Bkg.	$19^{+46}_{-6}$	$1.2^{+1.5}_{-1.2}$	$0.0^{+0.40}_{-0.0}$
Total Bkg.	$29^{+46}_{-7}$	$139^{+14}_{-14}$	$3.9^{+1.5}_{-1.5}$
Data	35	159	0



ATLAS-CONF-2012-153

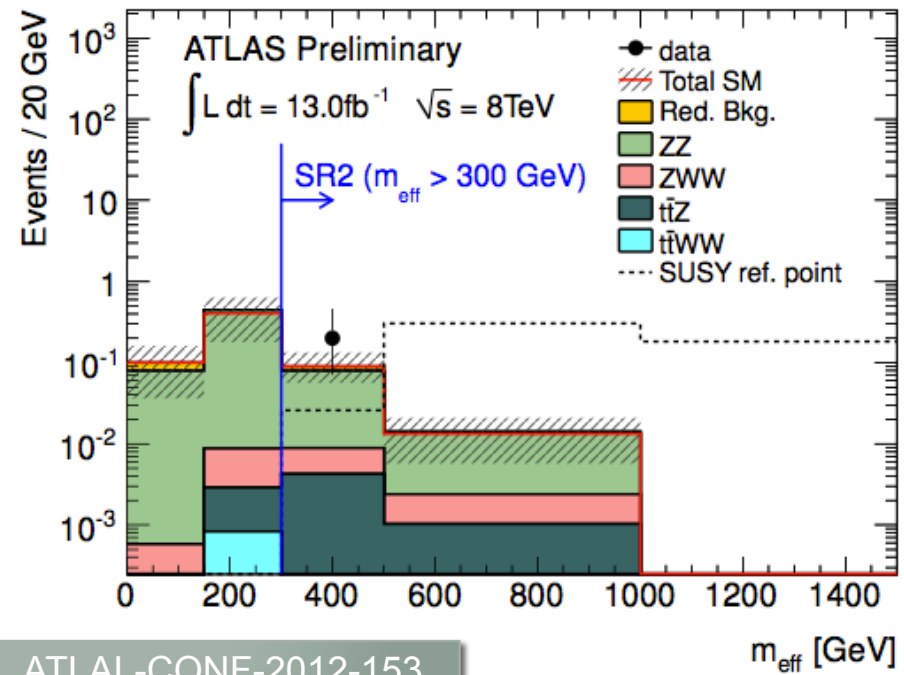
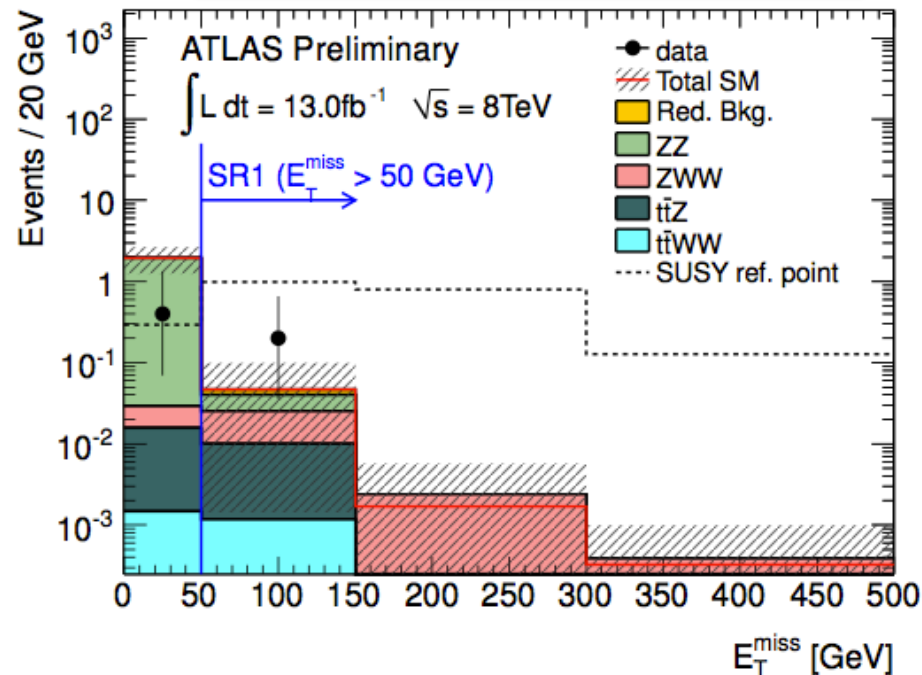
# 4 Leptons Results

Selection	SR1	SR2
$ZZ$	$0.07^{+0.22}_{-0.07}$	$1.0^{+0.4}_{-0.4}$
$ZWW$	$0.10^{+0.10}_{-0.10}$	$0.09^{+0.09}_{-0.09}$
$t\bar{t}Z$	$0.045^{+0.028}_{-0.028}$	$0.06^{+0.04}_{-0.04}$
$t\bar{t}WW$	$(6^{+6}_{-5}) \times 10^{-3}$	$(3.3^{+4.8}_{-3.3}) \times 10^{-3}$
Irreducible Bkg.	$0.22^{+0.27}_{-0.21}$	$1.1^{+0.5}_{-0.4}$
Reducible Bkg.	$0.028^{+0.107}_{-0.028}$	$0.10^{+0.14}_{-0.10}$
Total Bkg.	$0.25^{+0.29}_{-0.25}$	$1.2^{+0.5}_{-0.4}$
Data	1	2

Selection	SR1	SR2
$p_0$ -value ( $\sigma$ )	0.037 (1.8)	0.16 (1.0)
$\sigma_{vis}$ (exp)	$< 0.28$ fb	$< 0.28$ fb
$\sigma_{vis}$ (obs)	$< 0.34$ fb	$< 0.38$ fb

- No significant excess found, set limits

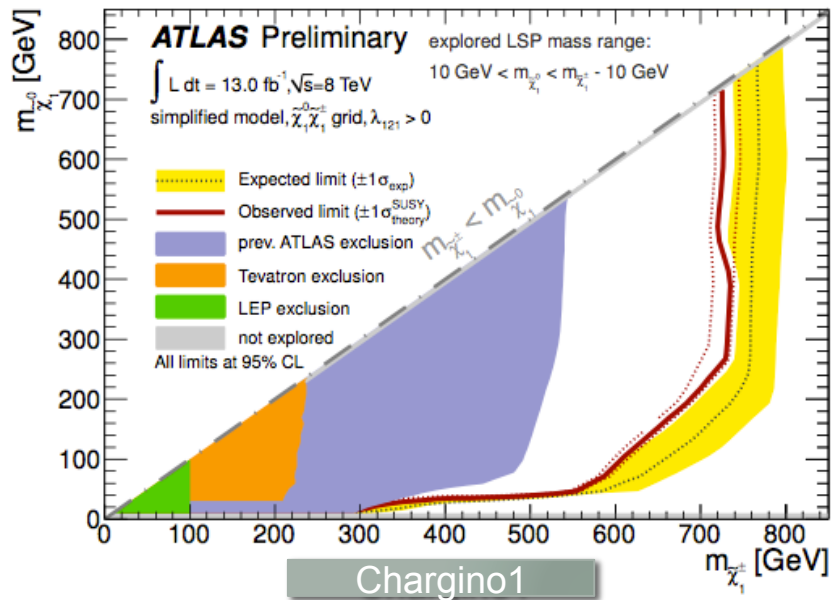
$$\sigma_{vis} = \sigma \times \text{acceptance} \times \text{efficiency}$$



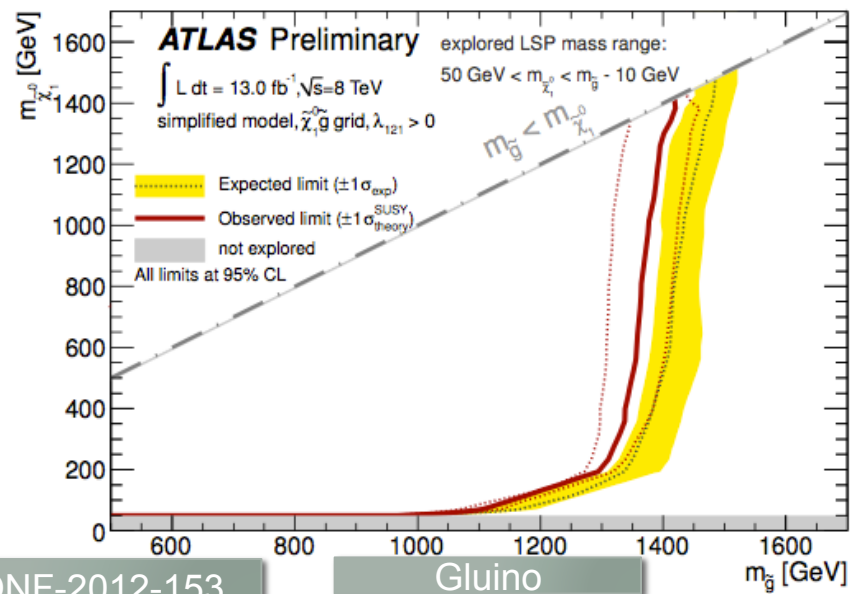
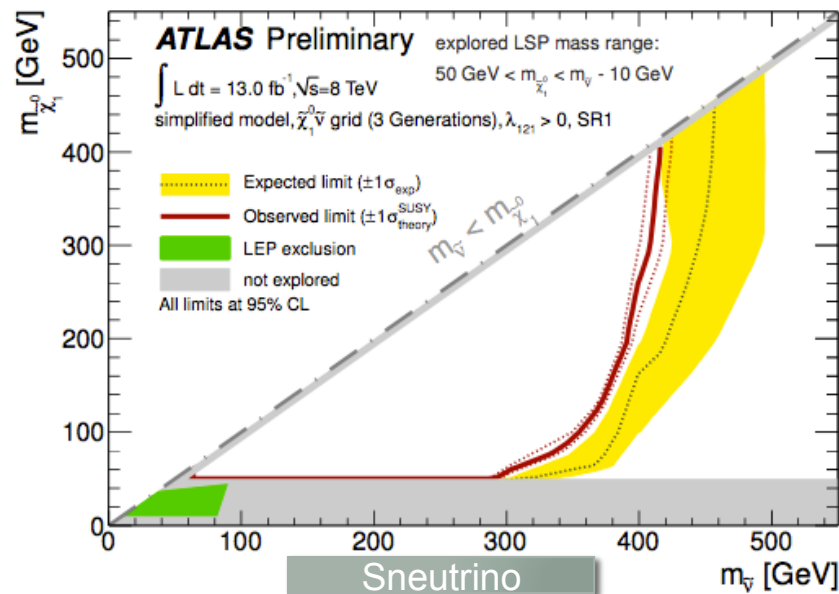
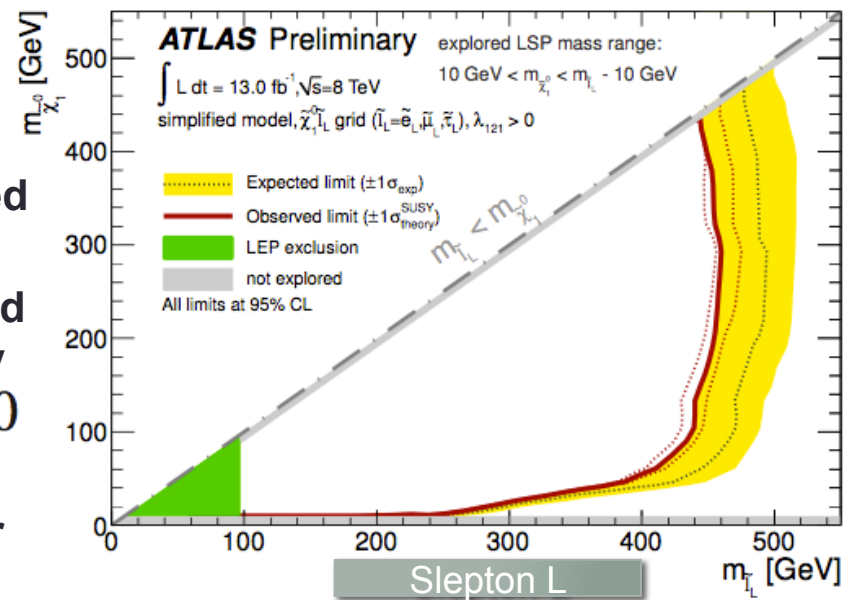
ATLAS-CONF-2012-153



# RPV NLSP-N1 Simplified Models



- Simplified Models
- NLSP and LSP only
- Similar limits for  $\lambda_{122} > 0$ .



ATLAL-CONF-2012-153





# ATLAS SUSY Grand Summary

## ATLAS SUSY Searches\* - 95% CL Lower Limits (Status: HCP 2012)

ATLAS  
Preliminary

$$\int L dt = (2.1 - 13.0) \text{ fb}^{-1}$$
$$\sqrt{s} = 7, 8 \text{ TeV}$$

8 TeV results

7 TeV results

Inclusive searches	MSUGRA/CMSSM : 0 lep + j's + $E_{T,miss}$	$L=5.8 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-109]	1.50 TeV	$\tilde{g} = \tilde{g} \text{ mass}$
	MSUGRA/CMSSM : 1 lep + j's + $E_{T,miss}$	$L=5.8 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-104]	1.24 TeV	$\tilde{g} = \tilde{g} \text{ mass}$
	Pheno model : 0 lep + j's + $E_{T,miss}$	$L=5.8 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-109]	1.18 TeV	$\tilde{g} \text{ mass } (m(\tilde{g}) < 2 \text{ TeV, light } \tilde{\chi}_1^0)$
	Pheno model : 0 lep + j's + $E_{T,miss}$	$L=5.8 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-109]	1.38 TeV	$\tilde{q} \text{ mass } (m(\tilde{q}) < 2 \text{ TeV, light } \tilde{\chi}_1^0)$
3rd gen. sq. gluino med.	Gluino med. $\tilde{\chi}^\pm (\tilde{g} \rightarrow q\tilde{q}^*)$ : 1 lep + j's + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1208.4688]	900 GeV	$\tilde{g} \text{ mass } (m(\tilde{g}) < 200 \text{ GeV, } m(\tilde{\chi}_1^\pm) = \frac{1}{2}(m(\tilde{\chi}_1^0) + m(\tilde{g})))$
	GMSB ( $\tilde{l}$ NLSP) : 2 lep (OS) + j's + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1208.4688]	1.24 TeV	$\tilde{g} \text{ mass } (\tan\beta < 15)$
	GMSB ( $\tilde{\tau}$ NLSP) : 1-2 $\tau$ + 0-1 lep + j's + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1210.1314]	1.20 TeV	$\tilde{g} \text{ mass } (\tan\beta > 20)$
	GGM (bino NLSP) : $\gamma\gamma$ + $E_{T,miss}$	$L=4.8 \text{ fb}^{-1}$ , 8 TeV [1209.0753]	1.07 TeV	$\tilde{g} \text{ mass } (m(\tilde{g}) > 50 \text{ GeV})$
3rd gen. squarks direct production	GGM (wino NLSP) : $\gamma$ + lep + $E_{T,miss}$	$L=4.8 \text{ fb}^{-1}$ , 7 TeV [ATLAS-CONF-2012-144]	619 GeV	$\tilde{g} \text{ mass}$
	GGM (higgsino-bino NLSP) : $\gamma$ + b + $E_{T,miss}$	$L=4.8 \text{ fb}^{-1}$ , 7 TeV [1211.1167]	900 GeV	$\tilde{g} \text{ mass } (m(\tilde{g}) > 220 \text{ GeV})$
	GGM (higgsino NLSP) : Z + jets + $E_{T,miss}$	$L=5.8 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-152]	690 GeV	$\tilde{g} \text{ mass } (m(\tilde{H}) > 200 \text{ GeV})$
	Gravitino LSP : 'monojet' + $E_{T,miss}$	$L=10.5 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-147]	645 GeV	$F^{1/2} \text{ scale } (m(\tilde{G}) > 10^{-4} \text{ eV})$
EW direct	$\tilde{g} \rightarrow b\tilde{b}^*$ (virtual b) : 0 lep + 3 b-j's + $E_{T,miss}$	$L=12.6 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-145]	1.24 TeV	$\tilde{g} \text{ mass } (m(\tilde{g}) < 200 \text{ GeV})$
	$\tilde{g} \rightarrow t\tilde{t}^*$ (virtual t) : 2 lep (SS) + j's + $E_{T,miss}$	$L=5.8 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-105]	850 GeV	$\tilde{g} \text{ mass } (m(\tilde{g}) < 300 \text{ GeV})$
	$\tilde{g} \rightarrow t\tilde{t}^*$ (virtual t) : 3 lep + j's + $E_{T,miss}$	$L=13.0 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-151]	860 GeV	$\tilde{g} \text{ mass } (m(\tilde{g}) < 300 \text{ GeV})$
	$\tilde{g} \rightarrow t\tilde{t}^*$ (virtual t) : 0 lep + multi-j's + $E_{T,miss}$	$L=5.8 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-103]	1.00 TeV	$\tilde{g} \text{ mass } (m(\tilde{g}) < 300 \text{ GeV})$
Long-lived particles	$\tilde{g} \rightarrow t\tilde{t}^*$ (virtual t) : 0 lep + 3 b-j's + $E_{T,miss}$	$L=12.6 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-145]	1.15 TeV	$\tilde{g} \text{ mass } (m(\tilde{g}) < 200 \text{ GeV})$
	$\tilde{b}\tilde{b}, \tilde{b} \rightarrow b\tilde{b}^*$ : 0 lep + 2-b-jets + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [ATLAS-CONF-2012-106]	480 GeV	$\tilde{b} \text{ mass } (m(\tilde{g}) < 150 \text{ GeV})$
	$\tilde{b}\tilde{b}, \tilde{b} \rightarrow t\tilde{t}^*$ : 3 lep + j's + $E_{T,miss}$	$L=13.0 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-151]	405 GeV	$\tilde{b} \text{ mass } (m(\tilde{g}) = 2 m(\tilde{\chi}_1^0))$
	$\tilde{t}\tilde{t}$ (very light), $\tilde{t} \rightarrow b\tilde{b}^*$ : 2 lep + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1208.4305]	130 GeV	$\tilde{t} \text{ mass } (m(\tilde{g}) < 70 \text{ GeV})$
RPV	$\tilde{t}\tilde{t}$ (light), $\tilde{t} \rightarrow b\tilde{b}^*$ : 1/2 lep + b-jet + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1209.2102]	123-167 GeV	$\tilde{t} \text{ mass } (m(\tilde{g}) = 55 \text{ GeV})$
	$\tilde{t}\tilde{t}$ (medium), $\tilde{t} \rightarrow t\tilde{b}^*$ : 2 lep + b-jet + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1209.4186]	298-305 GeV	$\tilde{t} \text{ mass } (m(\tilde{g}) = 0)$
	$\tilde{t}\tilde{t}$ (heavy), $\tilde{t} \rightarrow t\tilde{b}^*$ : 1 lep + b-jet + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1208.2590]	230-440 GeV	$\tilde{t} \text{ mass } (m(\tilde{g}) = 0)$
	$\tilde{t}\tilde{t}$ (heavy), $\tilde{t} \rightarrow t\tilde{b}^*$ : 0 lep + b-jet + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1208.1447]	370-465 GeV	$\tilde{t} \text{ mass } (m(\tilde{g}) = 0)$
WIMP interaction (D5, Dirac $\chi$ ) : 'monojet' + $E_{T,miss}$	$\tilde{t}\tilde{t}$ (natural GMSB) : Z( $\rightarrow ll$ ) + b-jet + $E_{T,miss}$	$L=2.1 \text{ fb}^{-1}$ , 7 TeV [1204.6736]	310 GeV	$\tilde{t} \text{ mass } (115 < m(\tilde{g}) < 230 \text{ GeV})$
	$\tilde{t}\tilde{t}, \tilde{t} \rightarrow b\tilde{b}^*$ : 2 lep + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1208.2884]	85-195 GeV	$\tilde{t} \text{ mass } (m(\tilde{g}) = 0)$
	$\tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow \tilde{t}\tilde{t}^* (\tilde{t} \rightarrow b\tilde{b}^*)$ : 2 lep + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1208.2884]	110-340 GeV	$\tilde{\chi}_1^0 \text{ mass } (m(\tilde{g}) < 10 \text{ GeV, } m(\tilde{l}, \tilde{\nu}) = \frac{1}{2}(m(\tilde{\chi}_1^0) + m(\tilde{g})))$
	$\tilde{\chi}_1^0 \tilde{\chi}_2^0 \rightarrow \tilde{t}\tilde{t}^* (\tilde{t} \rightarrow b\tilde{b}^*)$ : 3 lep + $E_{T,miss}$	$L=13.0 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-154]	580 GeV	$\tilde{\chi}_1^0 \text{ mass } (m(\tilde{g}) = m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^0) = 0, m(\tilde{l}, \tilde{\nu}) \text{ as above})$
RPV	$\tilde{\chi}_1^0 \tilde{\chi}_2^0 \rightarrow W^+ \tilde{\chi}_1^\pm Z \tilde{\chi}_1^\mp$ : 3 lep + $E_{T,miss}$	$L=13.0 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-154]	140-295 GeV	$\tilde{\chi}_1^\pm \text{ mass } (m(\tilde{g}) = m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^\pm) = 0, \text{ sleptons decoupled})$
	Direct $\tilde{\chi}_1^\pm$ pair prod. (AMSB) : long-lived $\tilde{\chi}_1^\pm$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1210.2852]	220 GeV	$\tilde{\chi}_1^\pm \text{ mass } (1 < \tau(\tilde{\chi}_1^\pm) < 10 \text{ ns})$
	Stable $\tilde{g}$ R-hadrons : low $\beta, \beta_\gamma$ (full detector)	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1211.1597]	985 GeV	$\tilde{g} \text{ mass}$
	Stable $\tilde{t}$ R-hadrons : low $\beta, \beta_\gamma$ (full detector)	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1211.1597]	683 GeV	$\tilde{t} \text{ mass}$
RPV	GMSB : stable $\tilde{\tau}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1211.1597]	300 GeV	$\tilde{\tau} \text{ mass } (5 < \tan\beta < 20)$
	$\tilde{\chi}_1^0 \rightarrow q\bar{q}\mu$ (RPV) : $\mu$ + heavy displaced vertex	$L=4.4 \text{ fb}^{-1}$ , 7 TeV [1210.7451]	700 GeV	$\tilde{q} \text{ mass } (0.3 \times 10^{-5} < \lambda_{211} < 1.5 \times 10^{-5}, 1 \text{ mm} < c\tau < 1 \text{ m, } \tilde{g} \text{ decoupled})$
	LFV : $pp \rightarrow \tilde{\nu} + X, \tilde{\nu} \rightarrow e + \mu$ resonance	$L=4.6 \text{ fb}^{-1}$ , 7 TeV [Preliminary]	1.61 TeV	$\tilde{\nu} \text{ mass } (\lambda_{311}=0.10, \lambda_{123}=0.05)$
	LFV : $pp \rightarrow \tilde{\nu} + X, \tilde{\nu} \rightarrow e(\mu) + \tau$ resonance	$L=4.6 \text{ fb}^{-1}$ , 7 TeV [Preliminary]	1.10 TeV	$\tilde{\nu} \text{ mass } (\lambda_{311}=0.10, \lambda_{123}=0.05)$
RPV	Bilinear RPV CMSSM : 1 lep + 7 j's + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [ATLAS-CONF-2012-140]	1.2 TeV	$\tilde{q} = \tilde{g} \text{ mass } (c\tau_{\tilde{q}} < 1 \text{ mm})$
	$\tilde{\chi}_1^0 \tilde{\chi}_2^0 \rightarrow W^+ \tilde{\chi}_1^\pm \tilde{\chi}_2^\mp$ : 4 lep + $E_{T,miss}$	$L=13.0 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-153]	700 GeV	$\tilde{\chi}_2^\pm \text{ mass } (m(\tilde{g}) > 300 \text{ GeV, } \lambda_{121} \text{ or } \lambda_{122} > 0)$
	$\tilde{\chi}_1^0 \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^\mp$ : 4 lep + $E_{T,miss}$	$L=13.0 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-153]	430 GeV	$\tilde{l} \text{ mass } (m(\tilde{g}) > 100 \text{ GeV, } m(\tilde{u})=m(\tilde{d}), \lambda_{121} \text{ or } \lambda_{122} > 0)$
	$\tilde{g} \rightarrow q\bar{q}q$ : 3-jet resonance pair	$L=4.6 \text{ fb}^{-1}$ , 7 TeV [1210.4813]	666 GeV	$\tilde{g} \text{ mass}$
WIMP interaction (D5, Dirac $\chi$ ) : 'monojet' + $E_{T,miss}$	Scalar gluon : 2-jet resonance pair	$L=4.6 \text{ fb}^{-1}$ , 7 TeV [1210.4826]	100-287 GeV	$\text{sgluon mass (incl. limit from 1110.2693)}$
	Scalar gluon : 2-jet resonance pair	$L=10.5 \text{ fb}^{-1}$ , 8 TeV [ATLAS-CONF-2012-147]	704 GeV	$M^* \text{ scale } (m_\chi < 80 \text{ GeV, limit of } < 687 \text{ GeV for p8})$

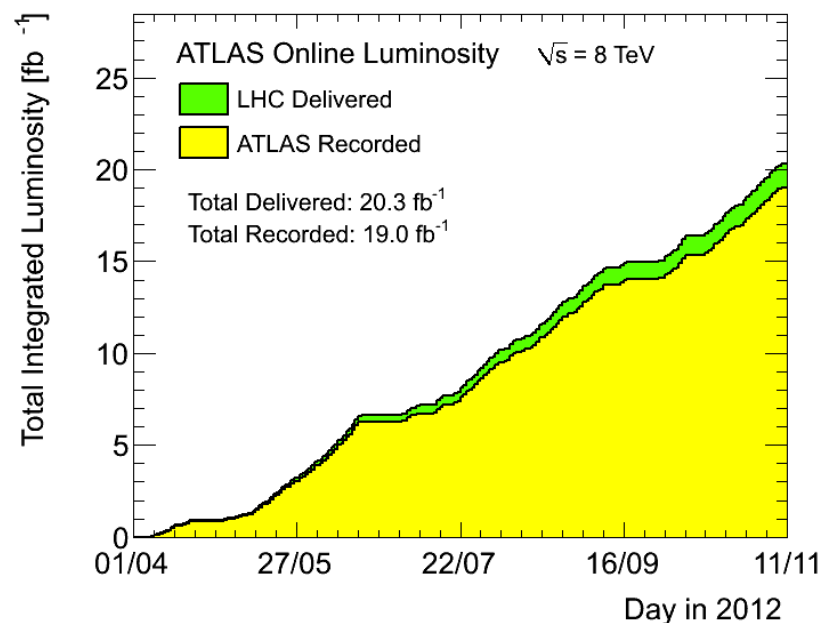
\*Only a selection of the available mass limits on new states or phenomena shown.

All limits quoted are observed minus  $1\sigma$  theoretical signal cross section uncertainty.

<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults>

# Summary and Outlook

- **Excellent performance of LHC and ATLAS in 2012**
- **Broad spectrum of SUSY leptonic searches, focusing on Natural SUSY**
- **Setting stringent limits in the SUSY parameter space**
  - C1N2: w sleptons  $\sim 580\text{GeV}$ , wo sleptons  $150\text{-}300\text{GeV}$
  - RPV: Winos  $\sim 710\text{GeV}$ , sleptons  $L \sim 450\text{GeV}$ , sneutrinos  $\sim 410\text{GeV}$ , gluinos  $\sim 1300\text{GeV}$
- More data already available from the 8 TeV run, expected  $\sim 25/\text{fb}$  by end of the year
- Optimize search strategy
  - Extend to higher masses
  - Focus on processes preferred by naturalness
  - Explore further final states





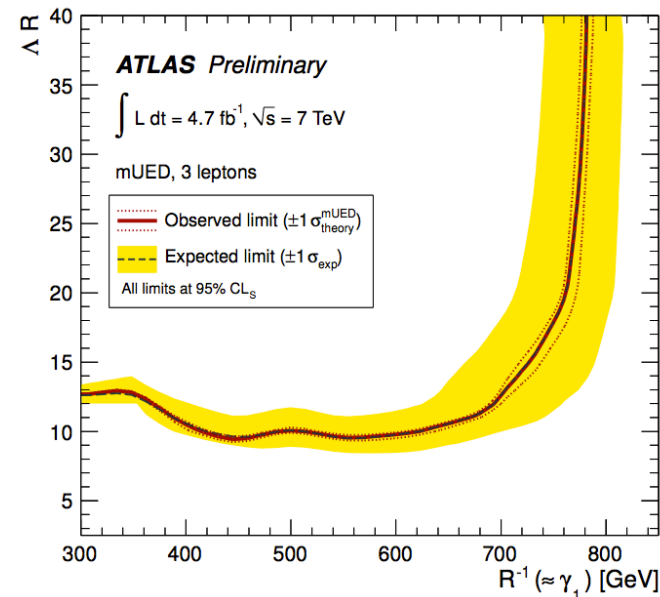
# Additional Interpretations, 3L 7 TeV

## • mUED

- 1 extra dimension,  $S^1/Z_2$  orbifold of size  $R$
- $\Lambda$  cut-off scale of the effective theory
- KK-photon is the lightest stable KK-particle

## • GGM

- Strong production through gluinos
- LSP  $\sim$  massless Gravitino
- NLPS Higgsino (left),
- Wino-like Chargino1, Neutralino1 (right)



$$\tilde{H} \rightarrow \gamma \tilde{G}$$

$$\tilde{H} \rightarrow Z \tilde{G}$$

$$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$$

$$\tilde{\chi}_1^0 \rightarrow Z \tilde{G}$$

$$\tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{G}$$

