LPC-SUSY-NEF 2013

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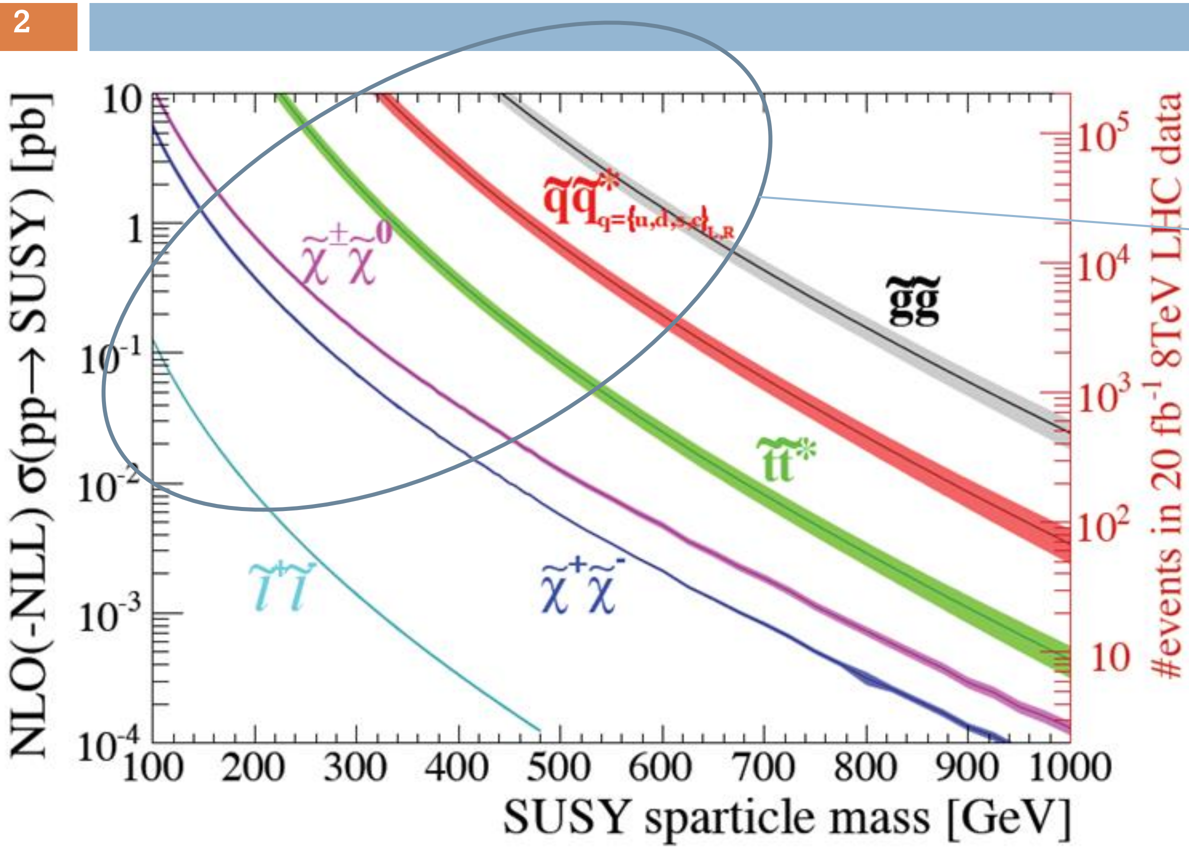
Weizmann Institute of Science

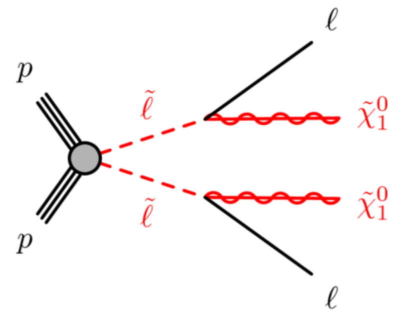
Production cross sections



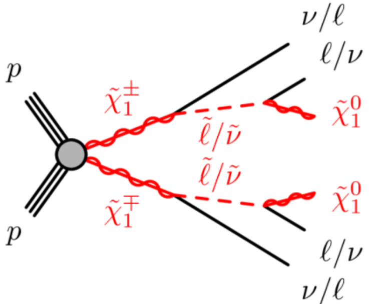
- Charginos and neutralinos are expected to be light in natural SUSY scenarios
- sleptons could be lighter than squarks
- Electroweak production of SUSY could dominate the SUSY cross section if the mass of squarks ($1^{st}/2^{nd}$ generation) and gluinos is larger than that of the electroweakinos by a factor 2 to 5

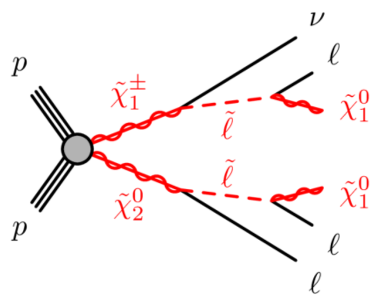
Electroweakino and Slepton production – Search strategy

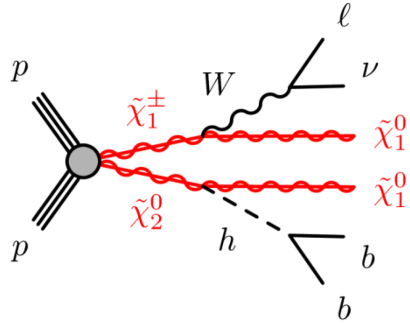
- direct slepton (or stau)production

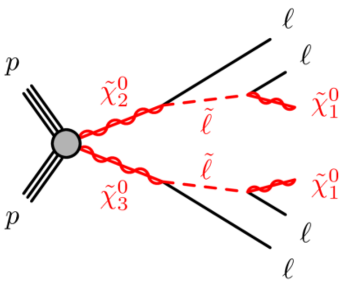


- By electroweakino production (decay via sleptons,staus,gauge bosons and higgs)









Final states include leptons, bottom quarks initiated jet and hadronic taus.
Optimization done using simpified models and pMSSM models

Electroweakino and Slepton production – SM backgrounds

The backgrounds can be divided to two types:

Reducible - Processes containing non-prompt leptons or conversions/light quarks/gluons misidentified as leptons).

- Irreducible - (events containing real and isolated leptons)

Electroweakino and Slepton production – background estimation

Irreducible:

- NLO MC
- Generally normalize to data in control regions

Reducible background Estimated using data driven method:

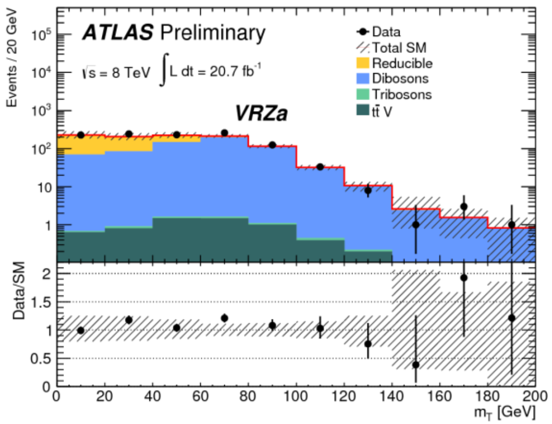
- In the "matrix method" one expresses the number of events with real and fake leptons in the signal region in terms of the efficiency and fake rate kinematics, type, process
- 'weighting method' (rescaling the yield of a fake-dominated sample of loosely identified leptons by the probability the loose lepton be identified as a tight lepton; probabilities depend on fake object kinematics, type, process)
- In the "ABCD method" the signal region yield is obtained by extrapolating the yields from control regions using two variables that are approximately independent.

Variables for background rejection

Each search is carried out in a number of signal regions. Each signal region is defined by an event selection based on various observables.

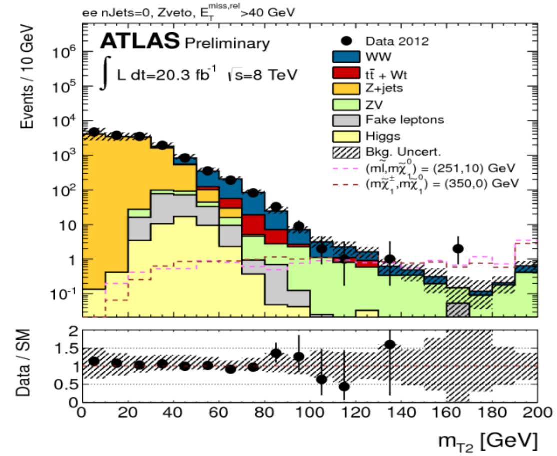
The transverse mass m_T is defined as the following:

- $m_T(p_T, q_T) = \sqrt{2(p_T q_T - \overrightarrow{p_T} \cdot \overrightarrow{q_T})}$
- It is useful in $3l + E_T^{miss}$ rejecting WZ background as the E_T^{miss} and lepton not associated to the Z both come from the W



The “stransverse” mass variable

- $m_{T2} = min_{q_T}(\max(m_T(p_T^{l1}, q_T), m_T(p_T^{l2}, p_T^{miss} - q_T)))$
- Has an endpoint in the mass of the pair produced particle decaying to leptons is very effective in rejecting WW and $t\bar{t}$ background due to the lower mass of W.
- This plot from $2l + E_T^{miss}$ shows how WW and $t\bar{t}$ are suppressed for $m_{T2} > M_w$ while the ZV background is much less affected

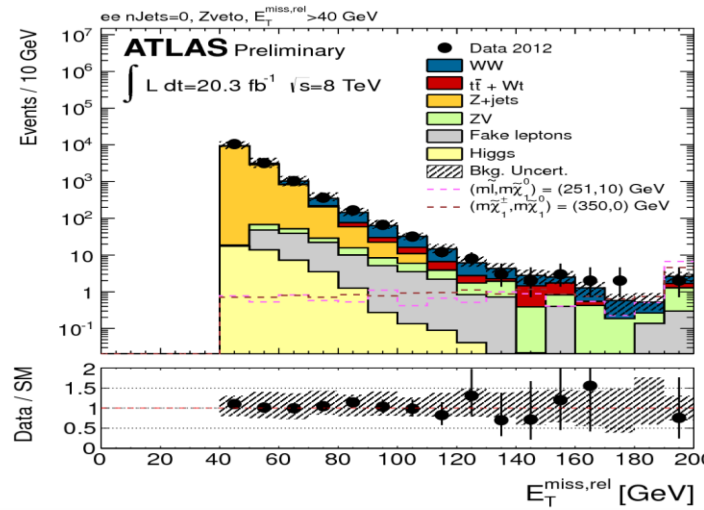


Variables used for background rejection

- The idea behind $E_T^{miss,rel}$ is to project the $\vec{E}_T^{miss}$ vector on the momenta of the closest object (lepton, jet) .
- Is it defined as the following:

$$E_T^{miss,rel} = \begin{cases} E_T^{miss} & if\ \Delta\varphi_{l,j} \geq \frac{\pi}{2} \\ E_T^{miss} \times \sin(\Delta\varphi_{l,j}) & if\, \Delta\varphi_{l,j} \leq \frac{\pi}{2} \end{cases}$$

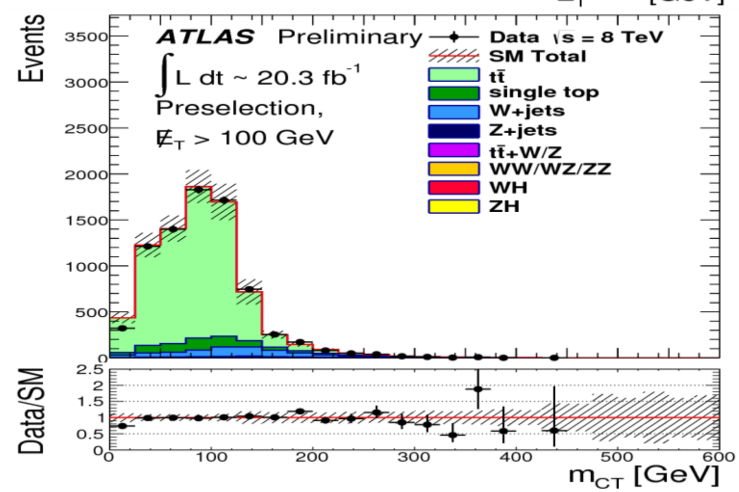
- $E_T^{miss,rel}$ is very effective in rejecting background with instrumental E_T^{miss}.
- As can be seen from the plot it is effective in rejecting Z+Jets background, which has no genuine E_T^{miss}



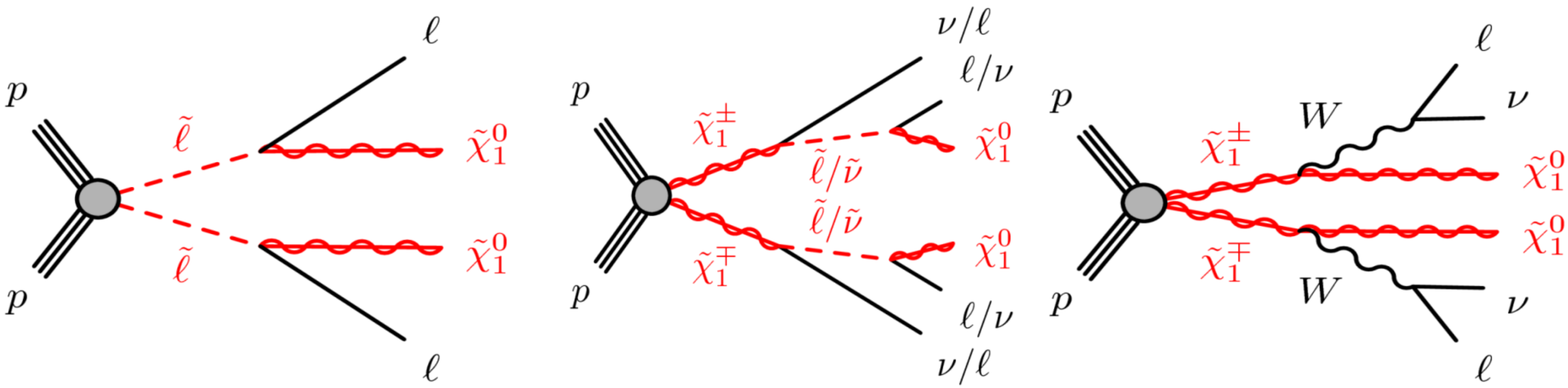
The contransverse mass is defined as the following:

$m_{CT}^2 = (E_T^{b1}+E_T^{b2})^2$-$(\vec{p}_T^{b1}-\vec{p}_T^{b2})^2$

It is useful in rejecting $t\bar{t}$ as can be seen from this plot from $l + bb(h) + E_T^{miss}$



search for charginos and sleptons - overview



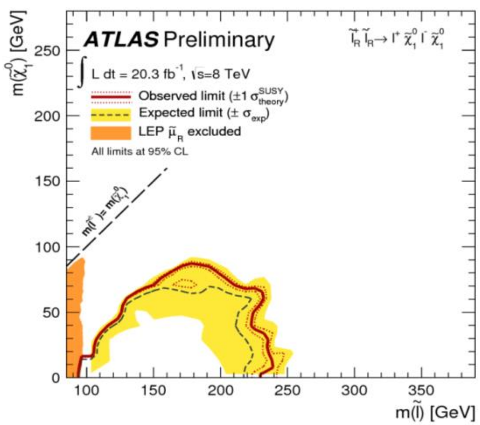
- 5 different signal regions using OS electons/muons leptons tageting decay through sleptons and gauge bosons
- WW, $t\bar{t}$ and WZ from normalization to CR and reducible background from matrix method

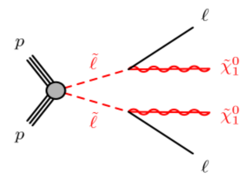
	SR-$m_{T2,90}$	SR-$m_{T2,110}$	SR-WWa	SR-WWb	SR-WWc
lepton flavour	$e^+e^-, \mu^+\mu^-, e^\pm\mu^\mp$		$e^\pm\mu^\mp$		
$p_T^{\ell 1}$	—		> 35 GeV		
$p_T^{\ell 2}$	—		> 20 GeV		
$m_{\ell\ell}$	Z veto		< 80 GeV	< 130 GeV	—
$p_{T,\ell\ell}$	—		> 70 GeV	< 170 GeV	< 190 GeV
$\Delta\phi_{\ell\ell}$	—		< 1.8 rad		
$E_T^{\text{miss,rel}}$	> 40 GeV		> 70 GeV	—	
m_{T2}	> 90 GeV	> 110 GeV	—	> 90 GeV	> 100 GeV

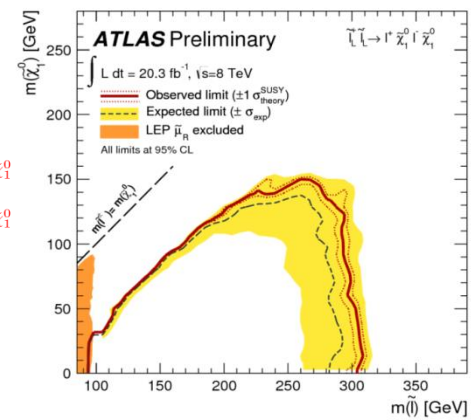
SR-$m_{T2,90}$	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all
Observed	15	19	19	53
Background total	16.6 ± 2.3	20.7 ± 3.2	22.4 ± 3.3	59.7 ± 7.3
SR-$m_{T2,110}$	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all
Observed	4	5	4	13
Background total	6.1 ± 2.2	4.4 ± 2.0	6.3 ± 2.4	16.9 ± 6.0

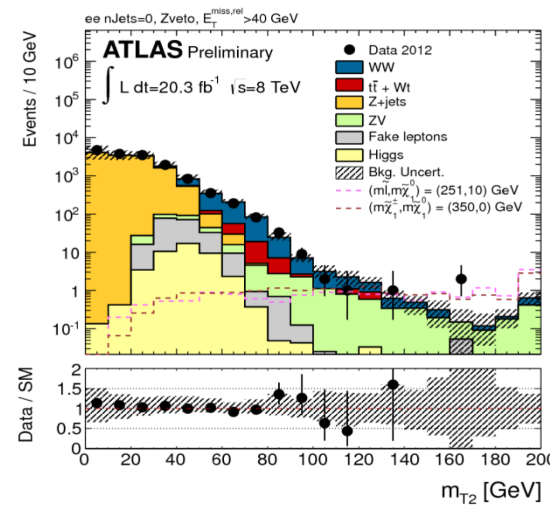
	SR-WWa	SR-WWb	SR-WWc
Observed	123	16	9
Background total	117.9 ± 14.6	13.6 ± 2.3	7.4 ± 1.5

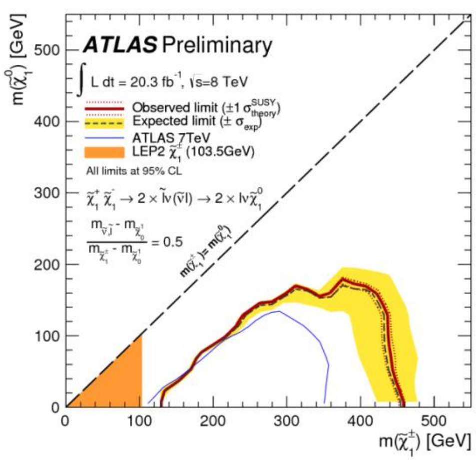
search for charginos and sleptons - results

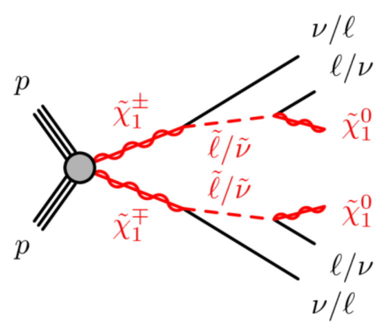


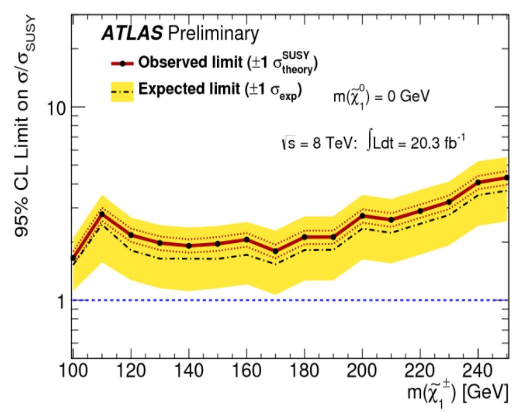


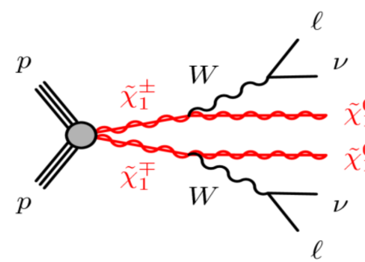










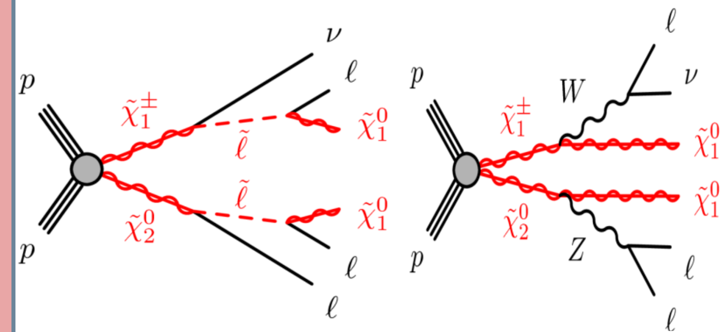


ATLAS-CONF-2013-035

Search for charginos and neutralinos- overview

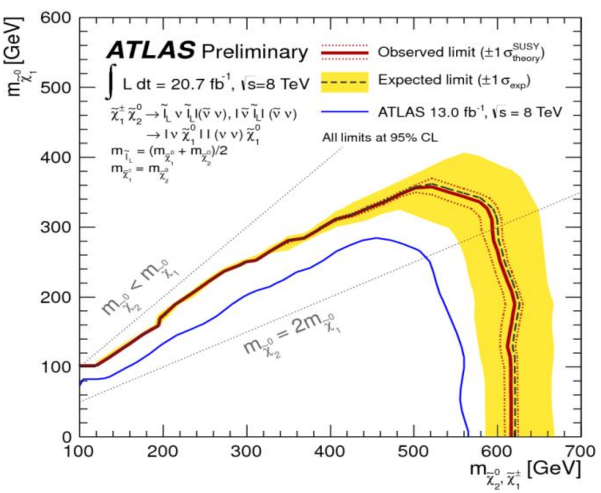
- 6 different signal regions using 3 leptons targeting decay through sleptons and gauge bosons
- Irreducible background from MC and reducible background from matrix method

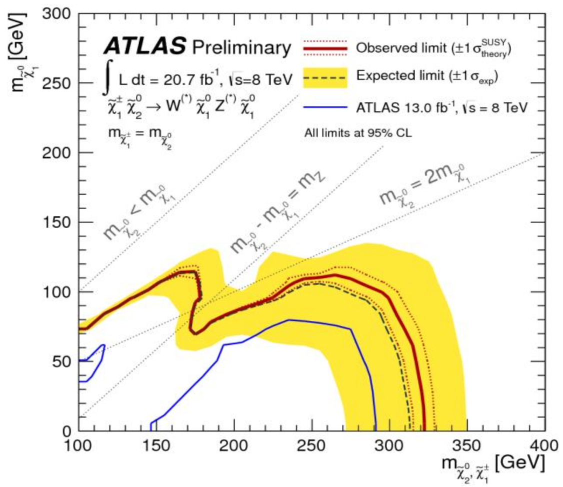
Selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
m_{SFOS} [GeV]	<60	60–81.2	<81.2 or >101.2	81.2–101.2	81.2–101.2	81.2–101.2
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	>50	>75	>75	75–120	75–120	>120
m_{T} [GeV]	–	–	>110	<110	>110	>110
p_{T} 3$^{\mathrm{rd}}$ ℓ [GeV]	>10	>10	>30	>10	>10	>10
SR veto	SRnoZc	SRnoZc	–	–	–	–

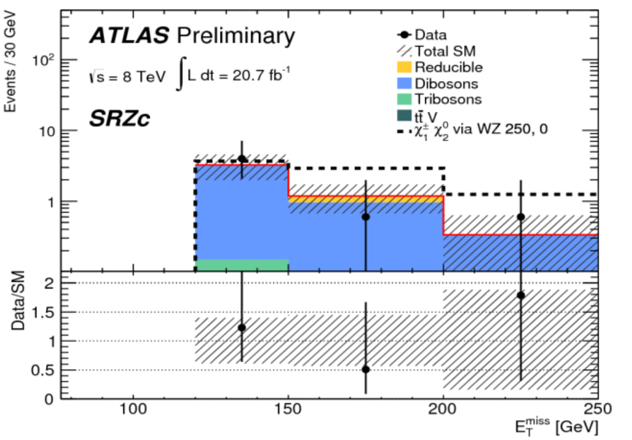


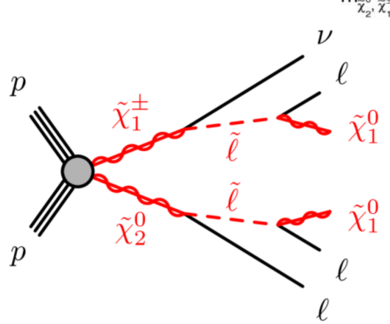
Selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
Tri-boson	1.7 ± 1.7	0.6 ± 0.6	0.8 ± 0.8	0.5 ± 0.5	0.4 ± 0.4	0.29 ± 0.29
ZZ	14 ± 8	1.8 ± 1.0	0.25 ± 0.17	8.9 ± 1.8	1.0 ± 0.4	0.39 ± 0.28
$t\bar{t}V$	0.23 ± 0.23	0.21 ± 0.19	$0.21^{+0.30}_{-0.21}$	0.4 ± 0.4	0.22 ± 0.21	0.10 ± 0.10
WZ	50 ± 9	20 ± 4	2.1 ± 1.6	235 ± 35	19 ± 5	5.0 ± 1.4
Σ SM irreducible	65 ± 12	22 ± 4	3.4 ± 1.8	245 ± 35	20 ± 5	5.8 ± 1.4
SM reducible	31 ± 14	7 ± 5	1.0 ± 0.4	4^{+5}_{-4}	1.7 ± 0.7	0.5 ± 0.4
Σ SM	**96 ± 19**	**29 ± 6**	**4.4 ± 1.8**	**249 ± 35**	**22 ± 5**	**6.3 ± 1.5**
Data	**101**	**32**	**5**	**273**	**23**	**6**

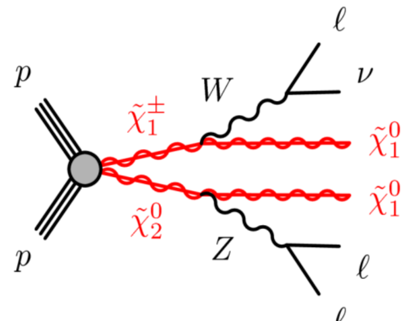
Search for charginos and neutralinos- results

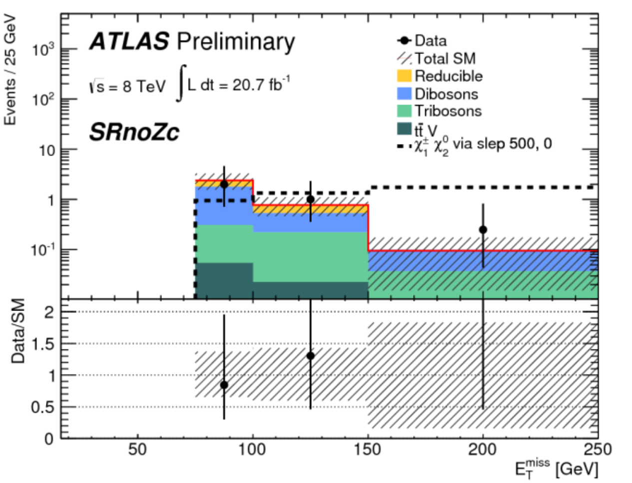












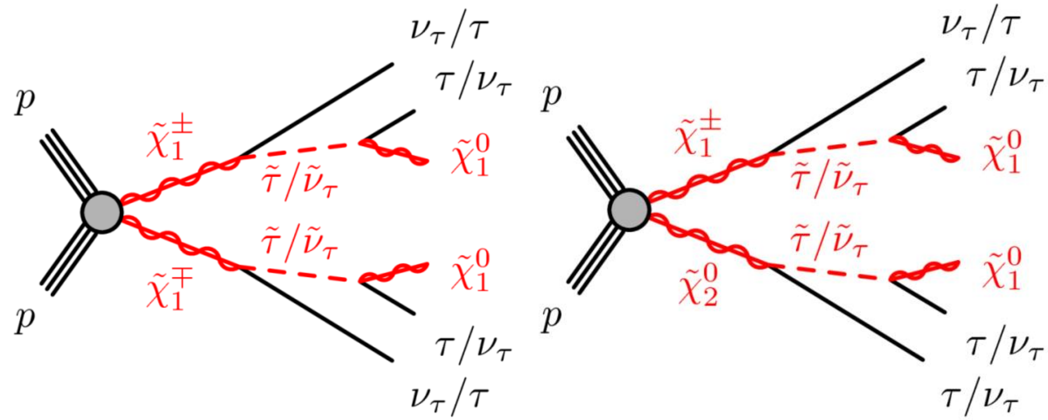
the sensitivity is improved for difficult WZ-like scenarios

ATLAS-CONF-2013-028

Search for charginos and neutralinos - overview

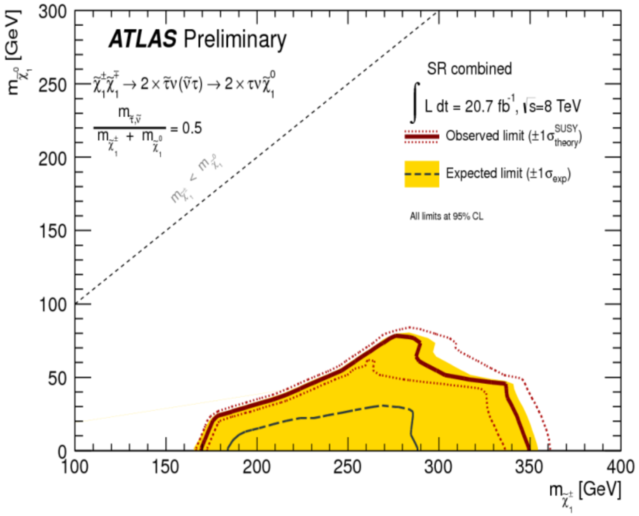
- Two signal region requiring OS hadronic taus
- Reducible background estimated with "ABCD method" using tau id and m_{T2} as independent variables

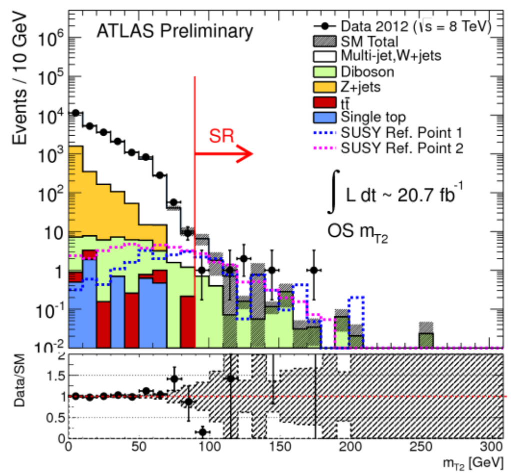
Signal region	requirements
OS m_{T2}	at least 1 OS tau pair
	jet veto
	Z-veto
	E_T^{miss}> 40 GeV
	m_{T2}> 90 GeV
OS m_{T2}-nobjet	at least 1 OS tau pair
	b-jet veto
	Z-veto
	E_T^{miss}> 40 GeV
	m_{T2}> 100 GeV

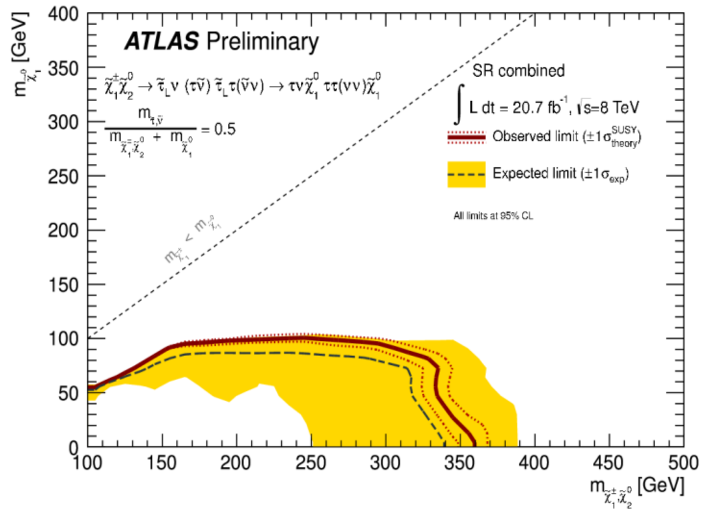


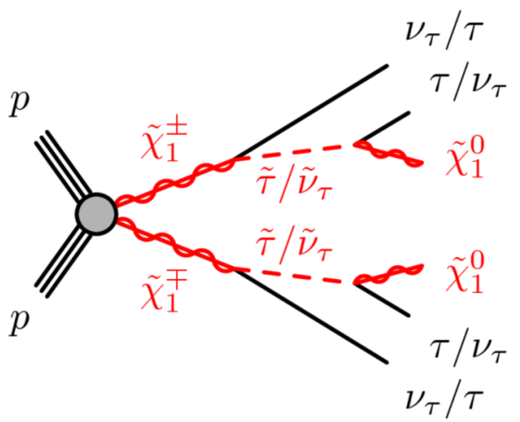
SM process	SR OS m_{T2}	SR OS m_{T2} -nobjet
top	0.2 ± 0.5 ± 0.1	1.6 ± 0.8 ± 1.2
Z+jets	0.28 ± 0.26 ± 0.23	0.4 ± 0.3 ± 0.3
diboson	2.2 ± 0.5 ± 0.5	2.5 ± 0.5 ± 0.9
multi-jet & W+jets	8.4 ± 2.6 ± 1.4	12 ± 3 ± 3
SM total	11.0 ± 2.7 ± 1.5	17 ± 4 ± 3
data	6	14

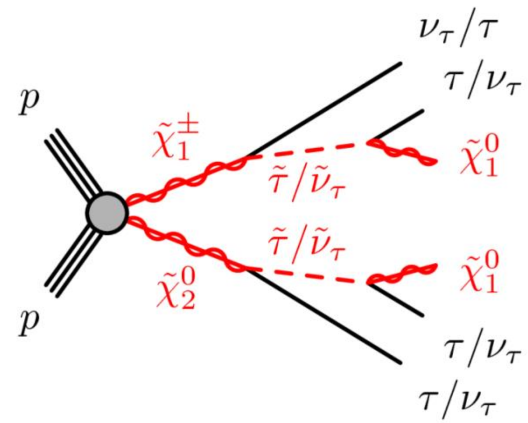
Search for charginos and neutralinos-results





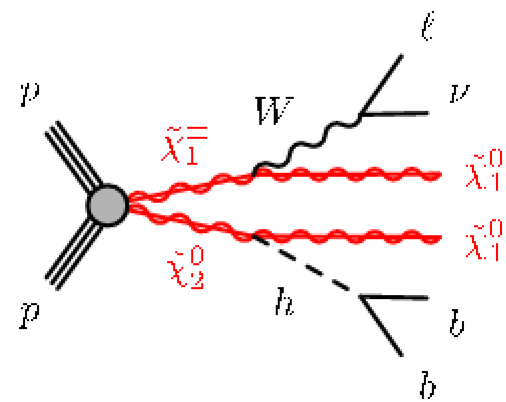






Search for charginos and neutralinos- overview

- Two signal regions requiring one lepton and two b-tagged jets



Two signal regions SRA and SRB have in common the following requirements:

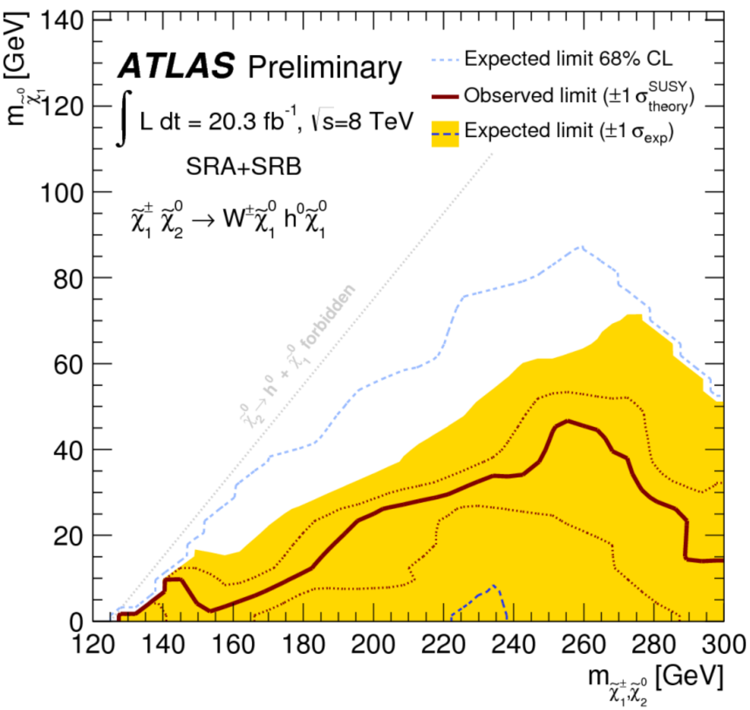
- E_T^{miss}>100GeV
- $m_{CT} > 160GeV$
- $m_{bb} > 160GeV$

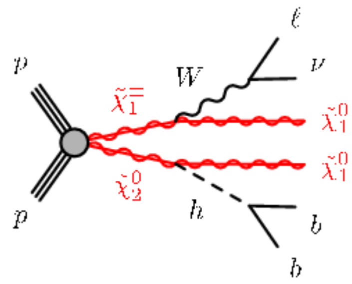
	SRA	SRB
Number of b-tagged jets	2	2
m_{T} (GeV)	100–130	> 130

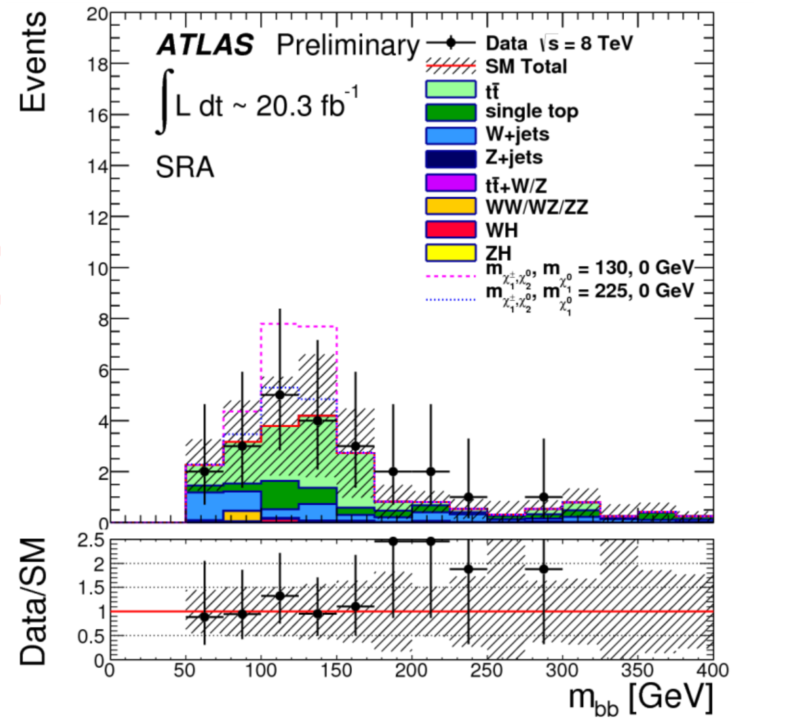
Background estimated with a maximum likelihood fit using the yields in the control and signal region and the MC transfer factors as input, keeping the overall normalization of the W+jets and $t\bar{t}$ backgrounds as free parameters. This is done across 8 bins in m_{bb}

	SRAh	SRBh
Observed events	4	2
Background estimate		
$t\bar{t}$	2.9 ± 2.8	1.0 ± 0.6
W + jets	0.7 ± 0.4	0.3 ± 0.2
Single top	1.6 ± 1.3	0.6 ± 0.4
Z+jets	$0.01^{+0.02}_{-0.01}$	$0.00^{+0.01}_{-0.00}$
Diboson (VV)	$0.01^{+0.05}_{-0.01}$	$0.05^{+0.07}_{-0.05}$
WH	0.18 ± 0.10	0.12 ± 0.07
$t\bar{t}$+V	0.01 ± 0.01	0.11 ± 0.06
Total	5.4 ± 3.1	2.1 ± 0.7

Search for charginos and neutralinos- results



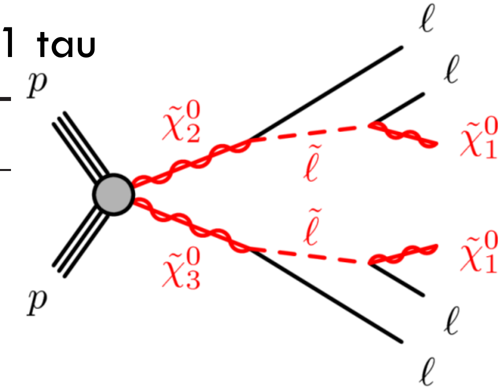




Search for Supersymmetry with 4 leptons or more-overview

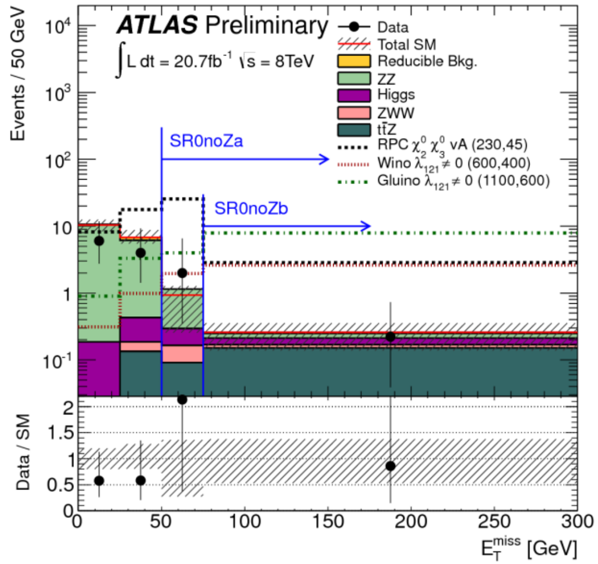
- 3 different signal regions using 4 leptons and 2 using 3 leptons and 1 tau

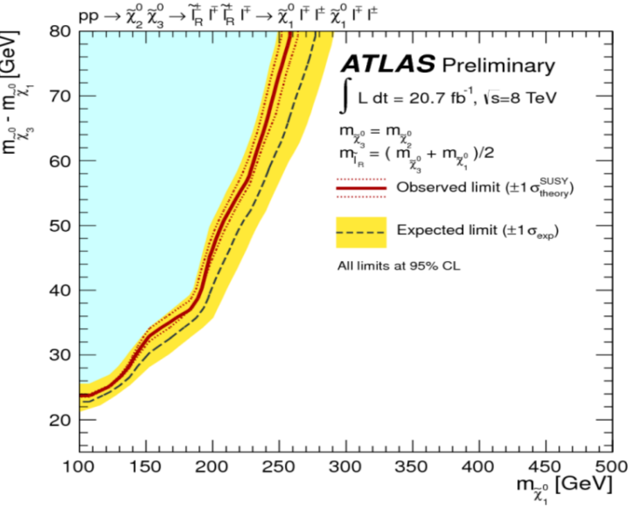
SR	N($\ell = e, \mu$)	N(τ)	Z Candidate	$E_{\mathrm{T}}^{\mathrm{miss}}$[GeV]		m_{eff}[GeV]	Scenario
SR0noZa	≥4	≥0	extended veto	>50			RPC
SR0noZb	≥4	≥0	extended veto	>75	or	>600	RPV
SR1noZ	=3	≥1	extended veto	>100	or	>400	RPV
SR0Z	≥4	≥0	request	>75			GGM
SR1Z	=3	≥1	request	>100			GGM

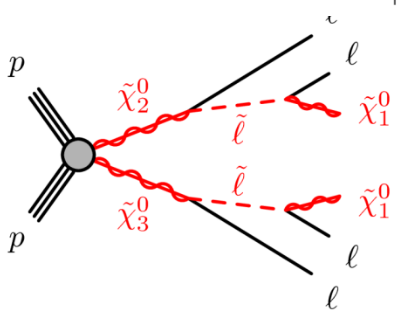


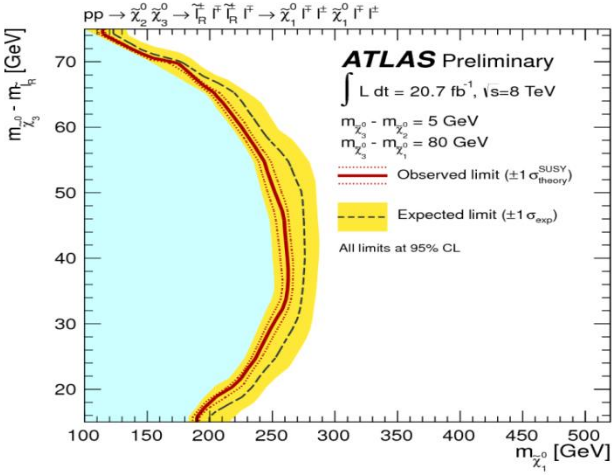
Sample	SR0noZa	SR0noZb	SR1noZ	SR0Z	SR1Z
ZZ	0.6 ± 0.5	0.50 ± 0.26	0.19 ± 0.05	1.2 ± 0.4	0.49 ± 0.10
ZWW	0.12 ± 0.12	0.08 ± 0.08	0.05 ± 0.05	0.6 ± 0.6	0.13 ± 0.13
$t\bar{t}Z$	0.73 ± 0.34	0.75 ± 0.35	0.16 ± 0.12	2.3 ± 0.9	0.29 ± 0.24
Higgs	0.26 ± 0.07	0.22 ± 0.07	0.23 ± 0.06	0.58 ± 0.15	0.14 ± 0.05
Irreducible Bkg.	1.7 ± 0.8	1.6 ± 0.6	0.62 ± 0.21	4.8 ± 1.8	1.1 ± 0.4
Reducible Bkg.	$0^{+0.16}_{-0}$	$0.05^{+0.14}_{-0.05}$	1.4 ± 1.3	$0^{+0.14}_{-0}$	$0.3^{+1.0}_{-0.3}$
Total Bkg.	1.7 ± 0.8	1.6 ± 0.6	2.0 ± 1.3	4.8 ± 1.8	$1.3^{+1.0}_{-0.5}$
Data	2	1	4	8	3

Search for Supersymmetry with 4 leptons or more- results







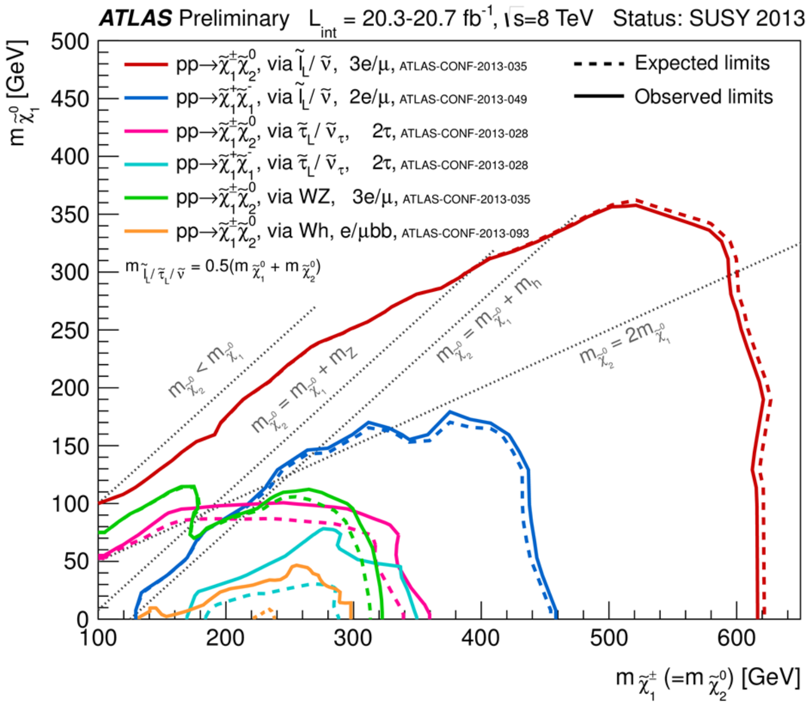


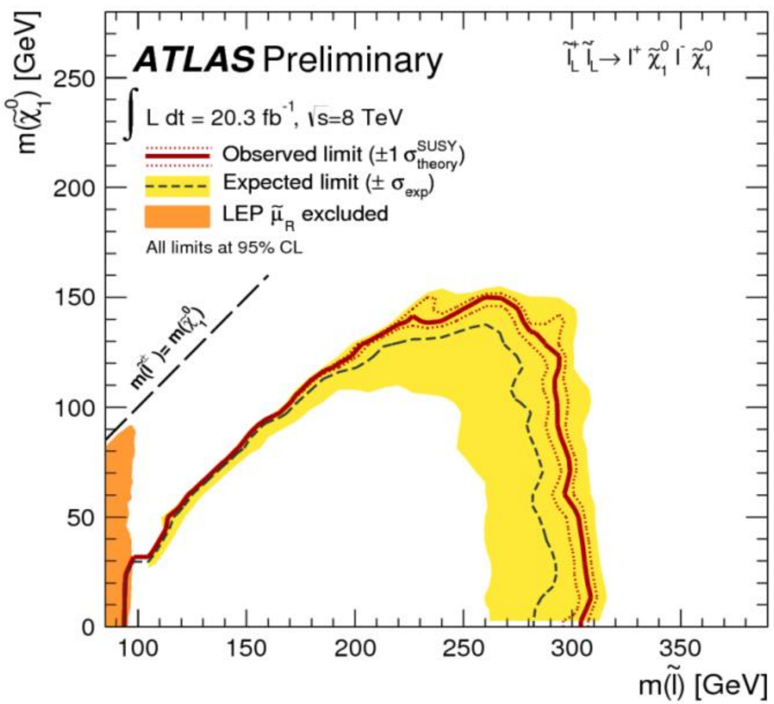
Other searches

Searches for electroweak production of long lived particles are covered in Andy Haas talk :

- Disappearing tracks: long-lived chargino CERN-PH-EP-2013-155 (Submitted to PRD)
- Long-lived slepton (stau) search- ATLAS-CONF-2013-058

Currents Limits on electroweakino and slepton production

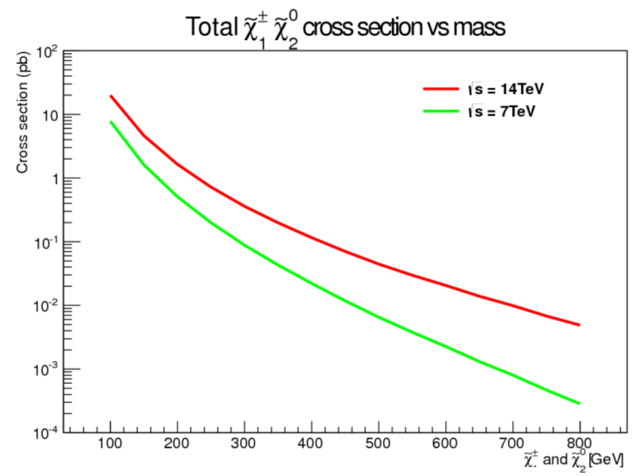




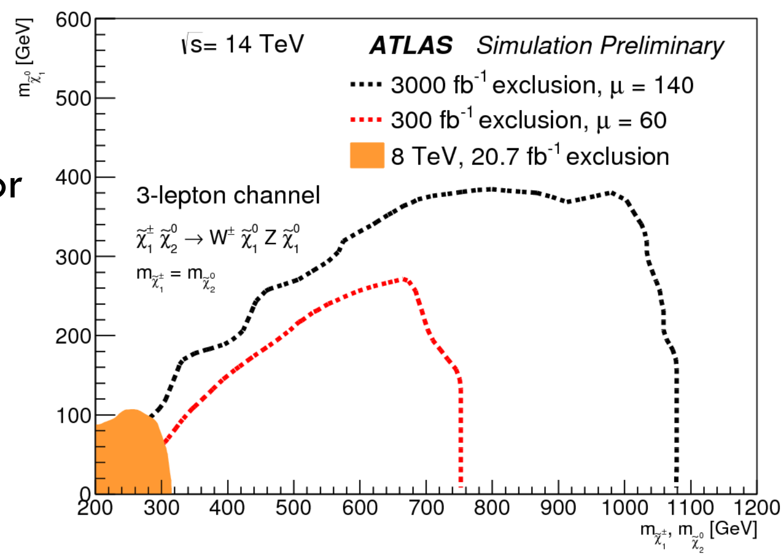
Limits on $\tilde{\chi}_2^0\ \tilde{\chi}_1^\pm$ from all analyses described above. For comparison, the limits on direct left handed slepton production is shown. As one can see, The limits on $\tilde{\chi}_2^0\ \tilde{\chi}_1^\pm$ are stronger due to the higher cross section

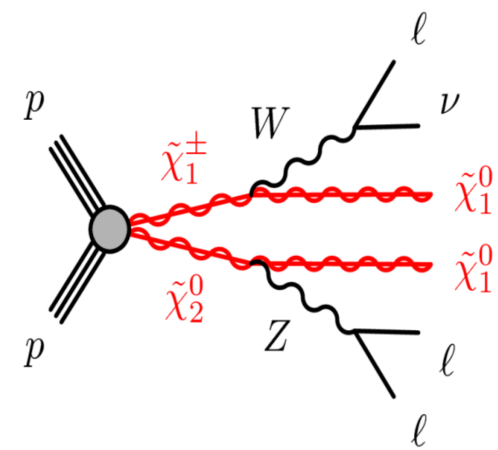
Future sensitivity

Moving to 14 TeV after the shutdown with eventually higher integrated Luminosity will increase sensitivity drastically, as can be seen in the following projection.



Future sensitivity for $\tilde{\chi}_2^0\ \tilde{\chi}_1^{\pm}$ production decaying through gauge bosons.





Conclusions

- A review of recent ATLAS results on searches for direct EW production of electroweakinos and sleptons is presented – no significant excess above SM predictions is found.
- Limits on electroweakino masses when decay through sleptons are typically between 400-600GeV
- Limits on electroweakino masses when decay through staus or gauge bosons are typically between 350-400GeV
- Limits on electroweakino masses when decay through higgs and gauge bosons are typically 280GeV