

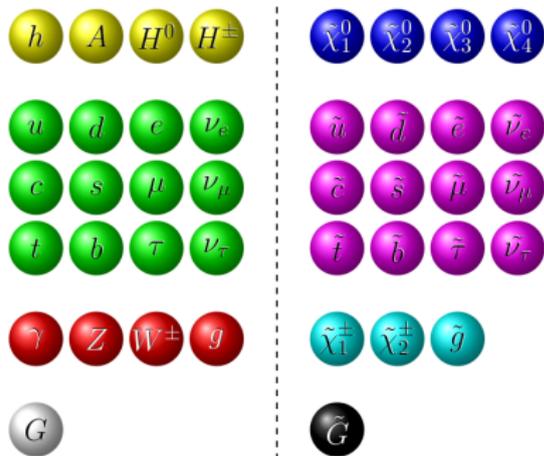
ATLAS Electroweak Supersymmetry Search Results

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Supersymmetry

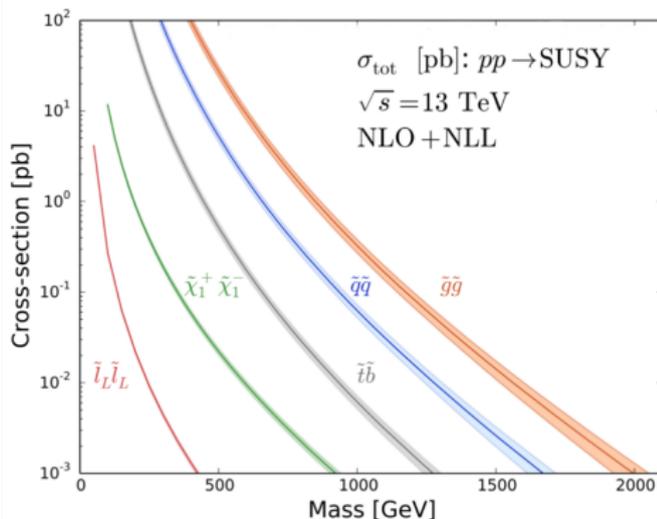


- Electroweak production has lower cross-sections
- Limits less stringent, and motivated by naturalness
- Multileptonic final states

Well motivated theory - solves hierarchy problem, potential dark matter candidate and unifies forces

$$Q|\text{boson}\rangle = |\text{fermion}\rangle$$

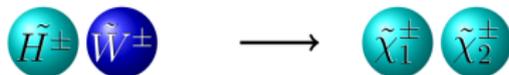
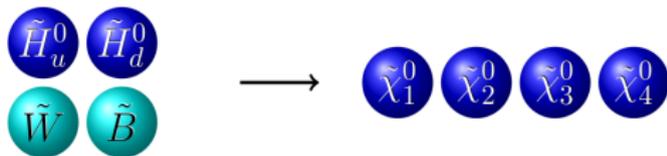
$$Q|\text{fermion}\rangle = |\text{boson}\rangle$$



Cross-sections taken from
<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections>

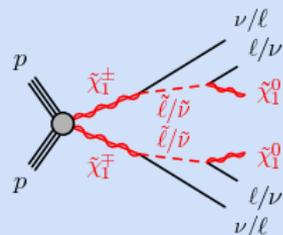
Electroweak Sparticles

- **Neutralinos** and **charginos** are mixtures of the SUSY partners of the **W**, **B** and **h** fields
- Neutral components give the neutralinos
- Charged components give the charginos



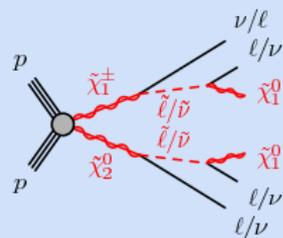
- **Electroweak production** - pairs of $\tilde{\chi}_i^0$, $\tilde{\chi}_i^\pm$, and sleptons (\tilde{e} , $\tilde{\mu}$, $\tilde{\tau}$)
- These can then undergo EW decays - branching ratios depend on the *mixing*

Signal processes



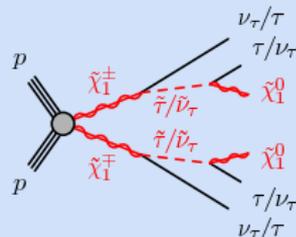
$2l$

ATLAS-CONF-2016-096



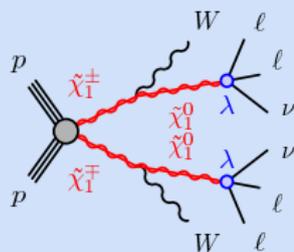
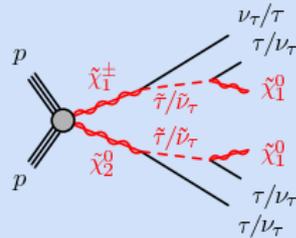
$3l$

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2τ

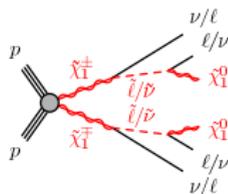
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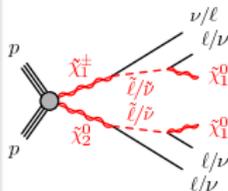
$4l$

ATLAS-CONF-2016-075

Variable	SR2 ℓ	
lepton	$\ell^+ \ell^-$	
lepton flavour	SF	DF
central light jets	0 ₂₀	0 ₃₀
central b -jets	0 ₂₀	0 ₂₀
forward jets	0 ₃₀	0 ₃₀
$ m_{\ell\ell} - m_Z $ [GeV]	> 10	-
m_{T2} [GeV]	> 90,	120, 150

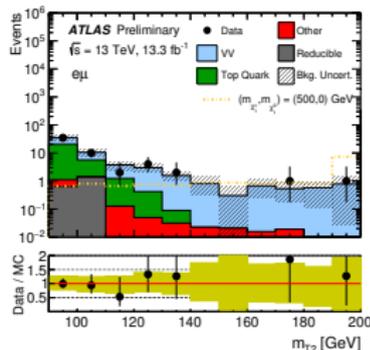


- Target different electroweakino masses with multiple SRs
- Reduce background process contributions with jet and b -jet vetoes, mass constraint on SFOS pairs and E_T^{miss} requirements



m_{T2} - stransverse mass

- m_{T2} sensitive to (s)particle mass splittings
- Find decomposition of E_T^{miss} which gives minimum value



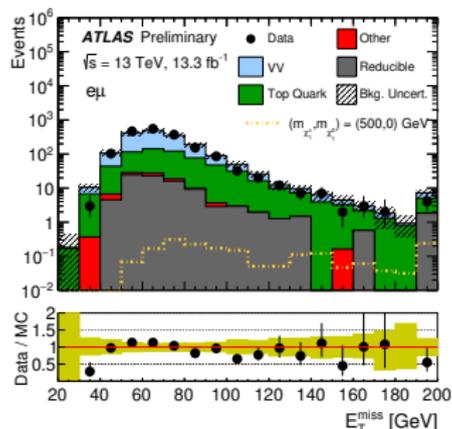
$$m_{T2} = \min_{\mathbf{q}_T} \left[\max \left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{\text{miss}} - \mathbf{q}_T) \right) \right]$$

$$m_T(\mathbf{p}_T, \mathbf{q}_T) = \sqrt{2(p_T q_T - \mathbf{p}_T \cdot \mathbf{q}_T)}$$

Variable	SR3 ℓ -I	SR3 ℓ -H
lepton	$\ell^+ \ell^- \ell$	
b -tagged jet	veto	
$m_T >$	110	
m_{SFOS}	$\notin [81.2, 101.2]$	> 101.2
$p_T^{3^{\text{rd}} \ell} >$	30	80
$E_T^{\text{miss}} >$	120	60

Irreducible processes

- real and prompt leptons



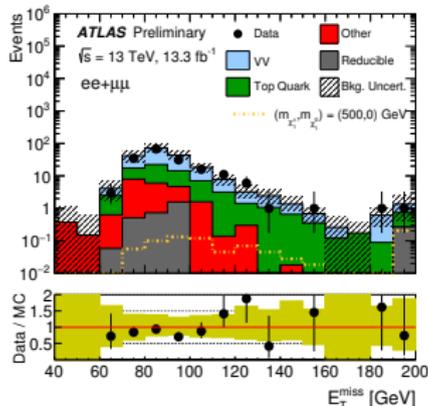
- **WZ, ZZ and WW** dominate
- Normalised in two control regions
- Small contributions from $t\bar{t}$, **Z+jets** and **Higgs** estimated with MC

Reducible processes

- ≥ 1 lepton not real or prompt

Multijet, W+jets and top background processes estimated using the data-driven “matrix method (loose-to-tight)”

Validation Regions



All estimation methods tested against data in four validation regions

Irreducible processes

- real and prompt leptons

- Dominated by **WZ**
- Small contributions include **VVV**, **t \bar{t} V** and **Higgs**
- All estimated using MC

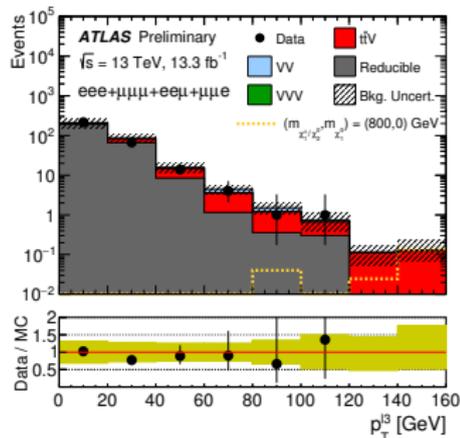
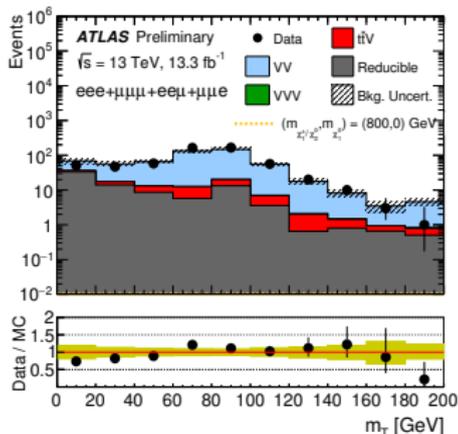
Reducible processes

- ≥ 1 lepton not real or prompt

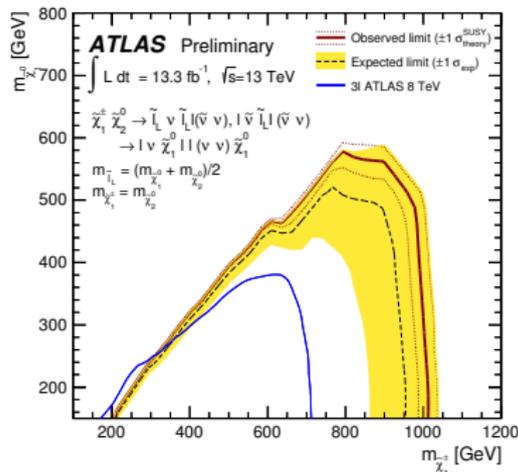
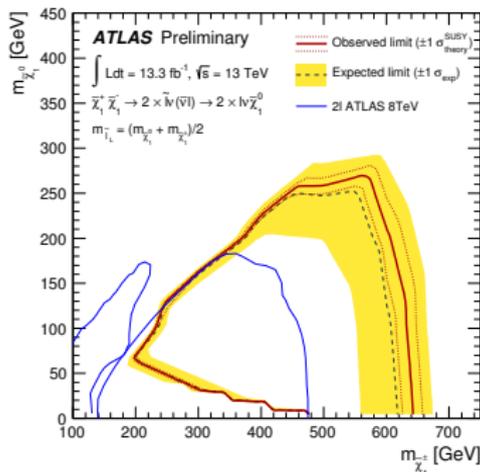
- Main processes are **Z+jets**, **t \bar{t}** and **WW**
- Matrix method is used to estimate these
- Assume leading lepton is always real - processes with three fakes negligible

Validation Regions

Four VRs defined, three to target the **WZ** estimation, and one to target reducible processes

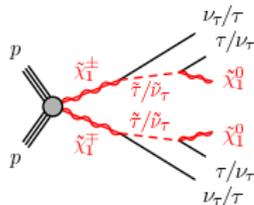


Region	SR2lA (SF)	SR2lA (DF)	SR2lB (SF)	SR2lB (DF)	SR2lC (SF)	SR2lC (DF)	SR3lI	SR3lH
Observed events	56	55	19	8	9	2	2	0
Fitted bkg events	70 ± 12	57.6 ± 8.5	20.7 ± 5.0	8.5 ± 3.6	10.2 ± 3.3	3.1 ± 2.3	4.41 ± 1.14	0.98 ± 0.50

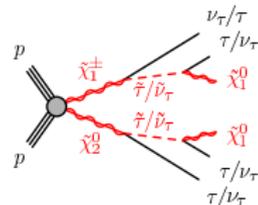


Signal Region	$\langle \epsilon \sigma \rangle_{\text{obs}}^{95}$ [fb]	S_{obs}^{95}	S_{exp}^{95}	CL_B
SR2l-A	1.89	25.1	35^{+13}_{-10}	0.17
SR2l-B	1.24	16.5	$17.0^{+7.1}_{-2.8}$	0.41
SR2l-C	0.87	11.6	$12.7^{+3.0}_{-4.1}$	0.36
SR3l-I	0.28	3.7	$5.5^{+3.0}_{-1.8}$	0.16
SR3l-H	0.18	3.0	$3.4^{+2.2}_{-0.4}$	0.22

- Extended exclusion limit reach to higher masses in both channels
- Also set model-independent limits which can be re-interpreted



SR-C1C1	SR-C1N2
light lepton veto	-
at least two medium taus	
at least one opposite sign tau pair	
b-jet veto	
Z-veto	
$E_T^{\text{miss}} > 150 \text{ GeV}$	
$m_{T2} > 70 \text{ GeV}$	

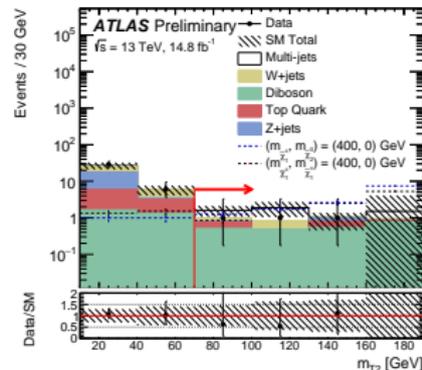
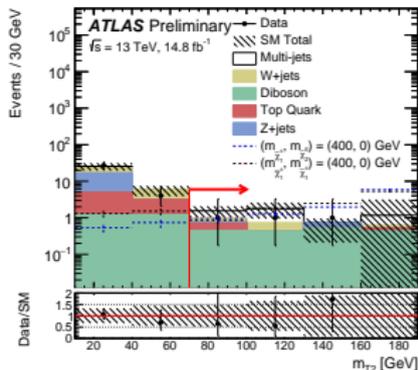


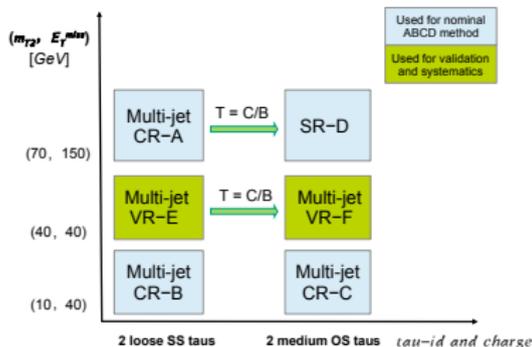
$$m_{T2} = \min_{\mathbf{q}_T} \left[\max \left(m_{T,\tau 1}(\mathbf{p}_{T,\tau 1}, \mathbf{q}_T), m_{T,\tau 2}(\mathbf{p}_{T,\tau 2}, \mathbf{p}_T^{\text{miss}} - \mathbf{q}_T) \right) \right]$$

SRC1C1

SRC1N2

- Z-veto requires mass of OS tau pair to be $\pm 10 \text{ GeV}$ from 79 GeV
- Transverse mass is a key variable here too, using tau leptons
- Define one SR for each signal process





Reducible processes

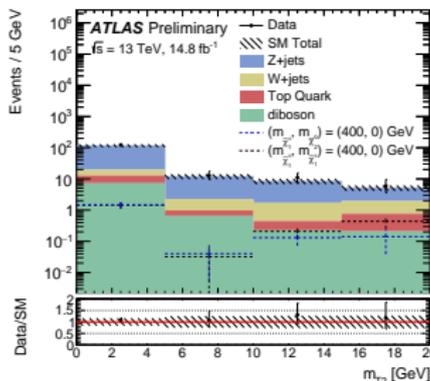
- ≥ 1 tau not real or prompt

- Large **multijet** contribution estimated using data-driven ABCD method
- Contribution from **W+jets** estimated from MC normalised in control regions
- Normalisation factors extracted with a simultaneous fit for each SR

Irreducible processes

- taus real or prompt

- Includes **WW**, **WZ**, **ZZ**, **$t\bar{t}$** , **$t\bar{t}V$** and **top**
- Can also have reducible contributions from these backgrounds
- All estimated with MC

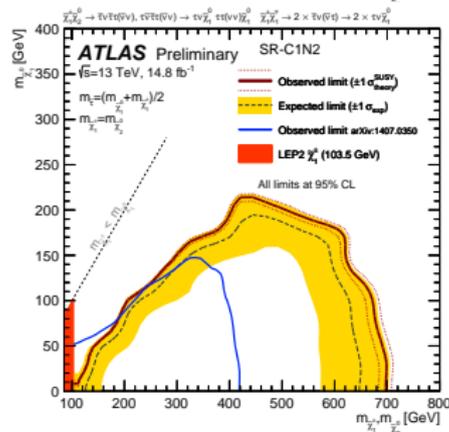
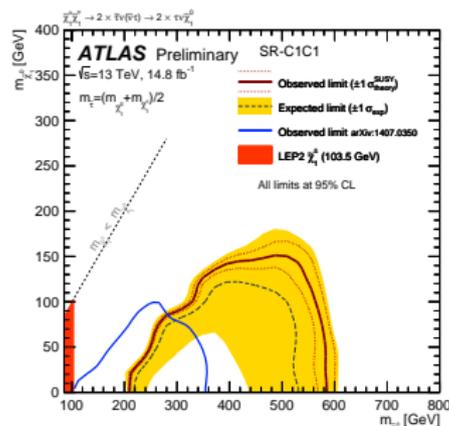


Validation Regions

All estimation methods tested against data in validation regions targeting multijet, Z (left), top and W processes

	SR-C1C1	SR-C1N2
SM total	5.1 ± 2.0	5.9 ± 2.1
Observed	3	3
Reference point 1	10.1 ± 2.0	13.0 ± 2.6
Reference point 2	10.4 ± 2.0	10.4 ± 2.0
Expected σ_{vis}^{95} [fb]	$0.41^{+0.20}_{-0.12}$	$0.43^{+0.21}_{-0.12}$
Observed σ_{vis}^{95} [fb]	0.33	0.32
S_{obs}^{95}	4.9	4.7
CL_b	0.28	0.22

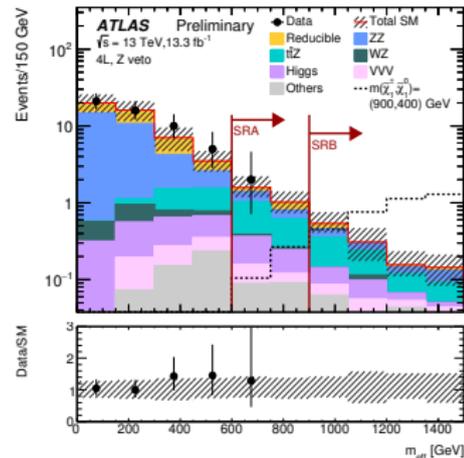
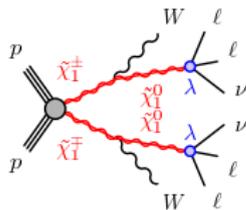
- No significant deviations from SM expectation observed
- Exclusion limits for chargino pair production and chargino neutralino production extended significantly in sparticle mass
- Limits also set on cross-section for re-interpretation



R-parity

$$W_{\text{RPV}} = \frac{1}{2} \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \frac{1}{2} \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k + \kappa_i L_i H_2$$

- Usually assumed to be conserved - violation allows sparticle \rightarrow SM particle decays
- Only first term (LLE) violated - resulting in final-state leptons



Two SRs with different cuts on

$$m_{\text{eff}} = E_{\text{T}}^{\text{miss}} + p_{\text{T}}^l + p_{\text{T}}^{\text{jet}, p_{\text{T}} > 40 \text{ GeV}}$$

Sample	$N(e, \mu)$	Z boson	m_{eff} [GeV]
SRA	≥ 4	veto	> 600
SRB	≥ 4	veto	> 900

Irreducible processes

- leptons real or prompt

- Dominated by $t\bar{t}Z$, VVZ and ZZ
- Other contributions from $t\bar{t}WW$, tWZ , $t\bar{t}t\bar{t}$, Higgs and $t\bar{t}tW$
- All estimated from MC with validation

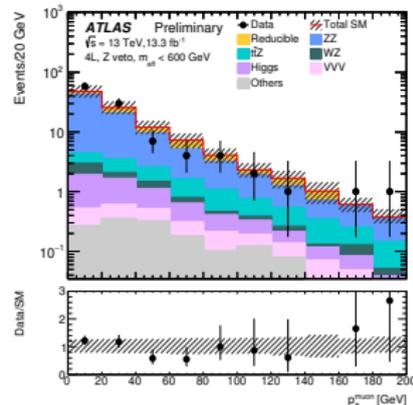
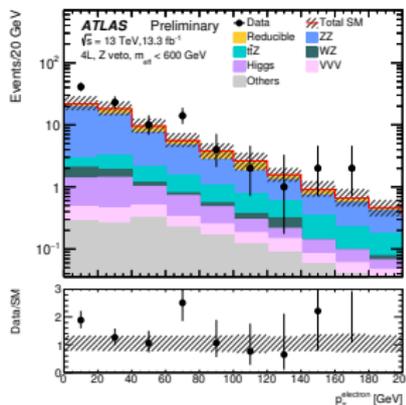
Reducible processes

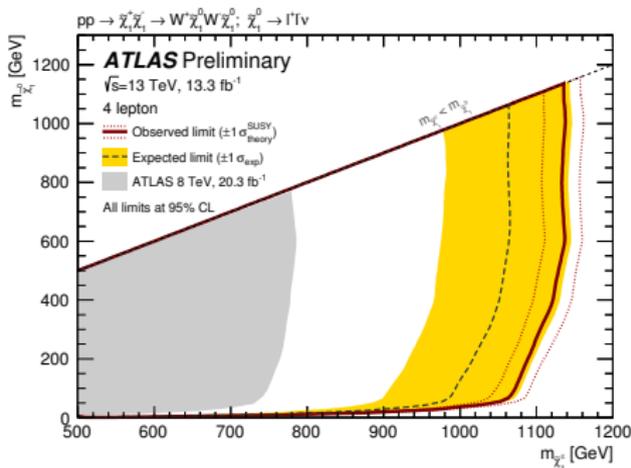
- ≥ 1 lepton not real or prompt

- Small contributions from WZ , WWW and $t\bar{t}tW$ produce one fake lepton - "1-fake" processes which are estimated from MC
- Reducible dominated by $t\bar{t}$, which along with Z +jets forms "2-fake" background
- 2-fake processes estimated with the data-driven "fake factor method"
- $N_{\text{red}}^{\text{SR}} = [N_{\text{data}}^{\text{CR}} - N_{\text{irr,1-fake}}^{\text{CR}}] \times F_{w,1} \times F_{w,2}$

Validation Region

Reverse lowest m_{eff} cut to test all background estimation methods for electrons(left) and muons(right)





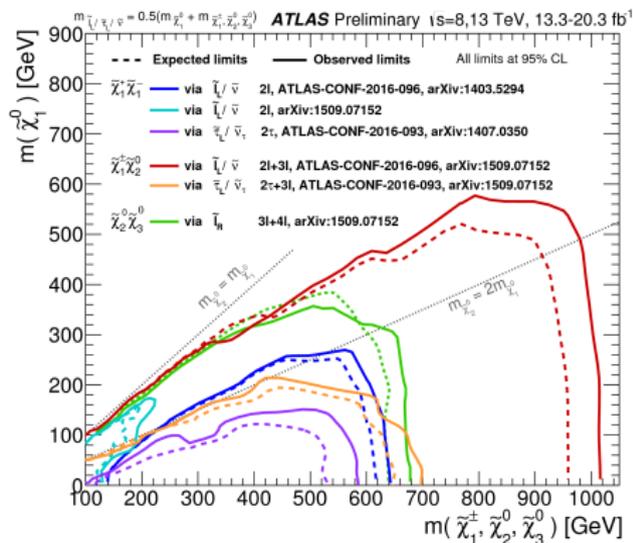
	SRA	SRB
Σ SM	3.6 ± 0.6	1.26 ± 0.26
Data	2	0
p_0	0.64	0.80
S_{obs}^{95}	4.3	3.0
S_{exp}^{95}	$5.4^{+1.6}_{-1.3}$	$3.8^{+1.3}_{-0.8}$
$\langle \epsilon \sigma \rangle_{\text{obs}}^{95}$ [fb]	0.32	0.22
CL_b	0.21	0.15

- No significant deviations from SM expectation
- Extend exclusion limit to much higher chargino mass values
- Can also exclude lower neutralino masses than 8 TeV analysis
- Model-independent cross-section limits can be re-interpreted

Conclusions

- Electroweak analyses presented using 13.3fb^{-1} of 13 TeV dataset, covering chargino pair production and chargino-neutralino production
- Made use of signal regions using 2ℓ , 3ℓ , 2τ and 4ℓ to cover wide range of decay modes, including R-parity violating
- All exclusion limits extended to much higher sparticle masses
- Small mass splitting regions more challenging for R-parity conserving models
- Effort is ongoing with full 2015+2016 Run 2 dataset and extension of analysis methods and scenarios considered - stay tuned for new results!

ATLAS-SUSY-summary-twiki



Thanks for listening!