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Search for chargino and neutralino production with a Higgs boson in the decay chain in 1 or 3 leptons final state events with ATLAS

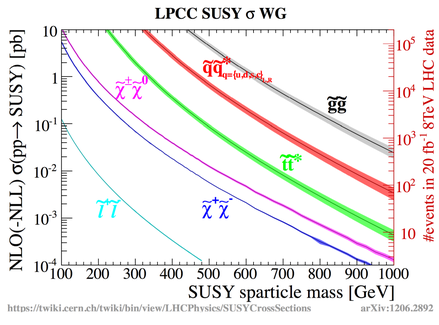
Abstract
Searches for direct production of chargino and neutralino leading to final states characterized by the presence of a Higgs boson are reported. Events containing missing transverse momentum and one or three leptons are selected, and two channels sensitive to different Higgs decays are considered. The analyses use 20.3 fb^{-1} of proton-proton collision data at $\sqrt{s}$ = 8 TeV recorded in 2012 with the ATLAS detector at the Large Hadron Collider. Observations are consistent with the Standard Model expectations and limits are set in R-parity conserving phenomenological Minimal Supersymmetric Standard Models and in simplified supersymmetric models.

Motivations

Based on **"Naturalness"**: lightest electro-weakinos expected to have mass of $\sim \mathcal{O}(100$ GeV$) \Rightarrow$ can be detected at the LHC!

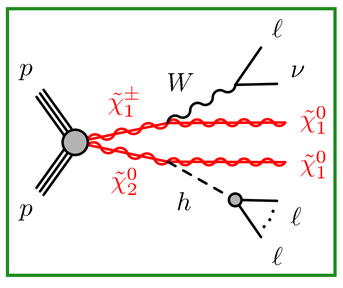
Target
- direct production of $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ pair

Signature
- *Wh*-mediated with
  3 leptons or 1 lepton + 2 *b*-jets
- R-parity conserved $\Rightarrow$ significant missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$)



Signal Model: Simplified Models

- Cross sections are determined by the masses and composition of $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$, assumed to be wino-like and mass degenerate: $m_{\tilde{\chi}_1^{\pm}} = m_{\tilde{\chi}_2^0}$



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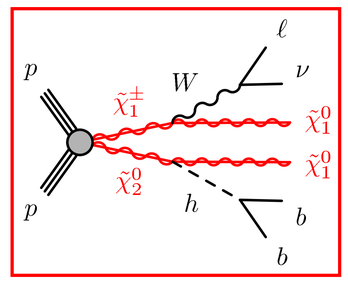
- Lightest Supersymmetric Particle (LSP) $\Rightarrow \tilde{\chi}_1^0$ (bino-like)
- Sleptons and sneutrinos assumed to be heavy
- BR($\tilde{\chi}_1^{\pm} \to W^{\pm}\tilde{\chi}_1^0$) = 1
- BR($\tilde{\chi}_2^0 \to h\tilde{\chi}_1^0$) = 1
- BR($h \to bb$) = SM-like $\quad m_h = 125$ GeV

← 3 leptons (including **tau** new!)

1 lepton (e/μ) and 2 *b*-tagged jets from a Higgs boson →



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Signal selections in 3 leptons scenario *Wh*-mediated

- Hadronically decaying τ identification using jet anti-k_t optimised with a boosted decision tree algorithm
- **exactly 3 tagged signal leptons** separated by $\Delta R > 0.3$ (with $\geq$ **1 electron or muon**, triggered)
- *b*-jets vetoed.

	SR0τa (20 bins)	SR0τb	SR1τ	SR2τb
Flavour/sign	$\ell^+\ell^-\ell$, $\ell^+\ell^-\ell'$	$\ell^{\pm}\ell^{\pm}\ell'^{\mp}$	$\tau^{\pm}\ell^{\mp}\ell^{\mp}$, $\tau^{\pm}\ell^{\mp}\ell'^{\mp}$	$\tau^+\tau^-\ell$
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 50 GeV	> 50 GeV	> 50 GeV	> 60 GeV
Kinematics	20 bins using $E_{\mathrm{T}}^{\mathrm{miss}}$, $m_{\ell^+\ell^-}$ and $m_{\mathrm{T}} = \sqrt{2p_{\mathrm{T}}^{\ell}E_{\mathrm{T}}^{\mathrm{miss}} - 2\mathbf{p}_{\mathrm{T}}^{\ell}\cdot\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}}$	$p_{\mathrm{T}}^{3^{\mathrm{rd}}\ell} > 20$ GeV $\Delta\phi_{\ell\ell'}^{\mathrm{min}} \leq 1.0$	$p_{\mathrm{T}}^{3^{\mathrm{rd}}\ell} > 30$ GeV $\Sigma\, p_{\mathrm{T}}^{\ell} > 70$ GeV $m_{\ell\tau} < 120$ GeV Z veto: $m_{ee} \notin [81.2, 101.2]$	$\Sigma\, p_{\mathrm{T}}^{\tau} > 110$ GeV $70 < m_{\tau\tau} < 120$ GeV

Signal selections in 1 lepton 2 *b*-jets scenario

- 2 signal regions sensitive to low (SRA) and high (SRB) $\Delta m = m_{\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$

Contransverse mass $m_{\mathrm{CT}}(v_1, v_2) = \sqrt{[E_{\mathrm{T}}(v_1) + E_{\mathrm{T}}(v_2)]^2 - [\mathbf{p}_{\mathrm{T}}(v_1) - \mathbf{p}_{\mathrm{T}}(v_2)]^2}$ → removes $t\bar{t}$

Transverse mass $m_{\mathrm{T}} = \sqrt{2p_{\mathrm{T}}^{\ell}E_{\mathrm{T}}^{\mathrm{miss}} - 2\mathbf{p}_{\mathrm{T}}^{\ell}\cdot\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}}$ → removes W+jets

	SRA	SRB
Number of *b*-jets	Exactly two *b*-tagged leading jets (MV1 @ 70%) no 4$^{\mathrm{th}}$ jet with $p_{\mathrm{T}} > 25$ GeV	
Lepton	Exactly one baseline = signal lepton (trigger matched)	
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 100 GeV	
m_{CT}	> 160 GeV	
m_{bb}	$105 < m_{bb} < 135$ GeV	
m_{T}	$100 < m_{\mathrm{T}} < 130$ GeV	> 130 GeV

Background Estimates

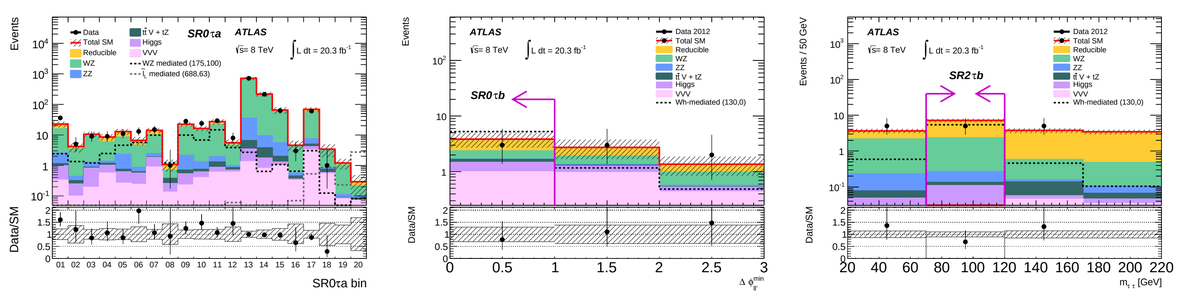
	SR0τ a/b	SR1τ	SR2τb
Irreducible background	≥ 3 real, prompt and isolated leptons $\Rightarrow$ estimated from MC Dominant: WZ(*) Others: VVV, $t\bar{t}V$, tZ, Higgs boson production		
Reducible background	Estimated using "matrix method" $t\bar{t}$ (dominant), Z+jets		W+jets
Uncertainty	MC generator and cross-section ~30%	MC cross-section ~10% τ fake rate ~10%	τ fake rate ~10%

	SRA	SRB
Irreducible background	Estimated from MC $t\bar{t}$ ~47%, W+jets ~27%	$t\bar{t}$ ~31%, W+jets ~20%
	5% [diboson + Z+jets + $t\bar{t}$V + SM Higgs production] 12%	
Reducible background	QCD $b\bar{b}$: lepton from *b*-decay fakes signal lepton estimated using "matrix method" $\Rightarrow$ negligible in CRs	
Uncertainty	Jet Energy Scale (JES) ~9%, *b*-tagging ~4% Single-top ~27%	JES ~11%, *b*-tagging ~4% Single-top ~16%

← A simultaneous fit of the control and signal regions is performed.

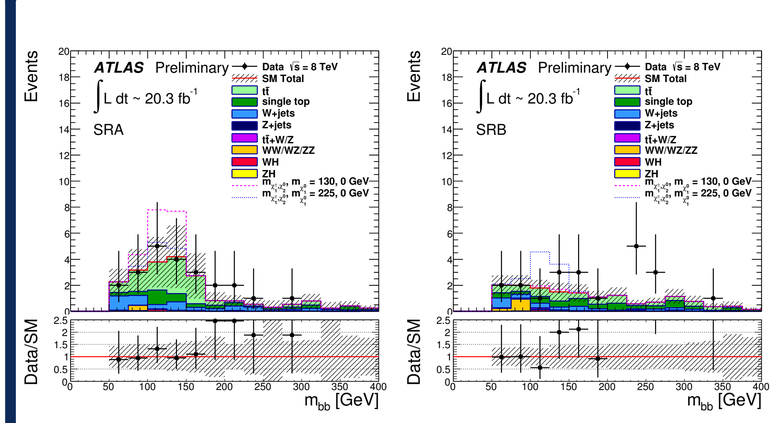
← Overall normalizations of main backgrounds are allowed to float, along with the signal strength to account for potential signal contamination in the control regions.

Results for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \Rightarrow$ 3 leptons in final-states



	SR0τb	SR1τ	SR2τb
Total SM / **Data**	3.8 ± 1.2 / **3**	10.3 ± 1.2 / **13**	$7.2^{+0.7}_{-0.8}$ / **5**
p_0	0.50	0.19 (0.86 σ)	0.50

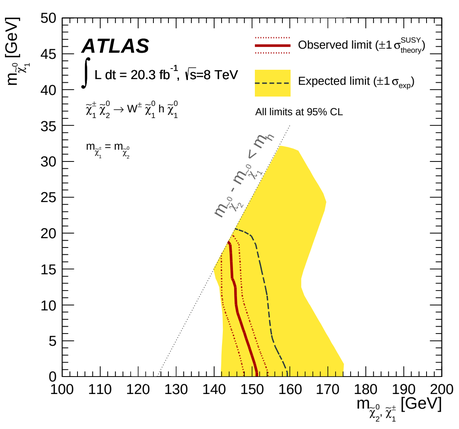
Results for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \Rightarrow$ 1 lepton 2 *b*-jets in final-states



	SRA	SRB
$t\bar{t}$	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	$0.01^{+0.05}_{-0.01}$	$0.05^{+0.07}_{-0.05}$
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**
Observed	4	2
Signal (130,0)	6.5	0.2
Signal (225,0)	1.9	4.1

No significant excess above SM expectation found in data $\Rightarrow$ 95% CLs limits calculated using pseudo-experiments for each SUSY model point

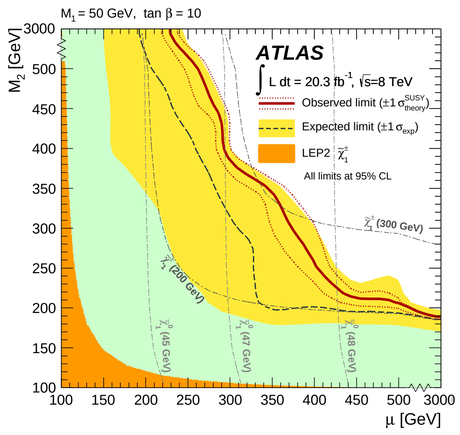
Interpretation for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \Rightarrow$ 3 leptons in final-states



$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ excluded up to $m_{\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0} = 148$ GeV

← **Simplified Model**

pMSSM→ heavy Higgses, $\tilde{q}$ and $\tilde{g}$ all decoupled. Sleptons assumed to be heavy



⇒ decay $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to W/Z/h$ dominant

Interpretation $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \Rightarrow$ 1 lepton 2 *b*-jets in final states

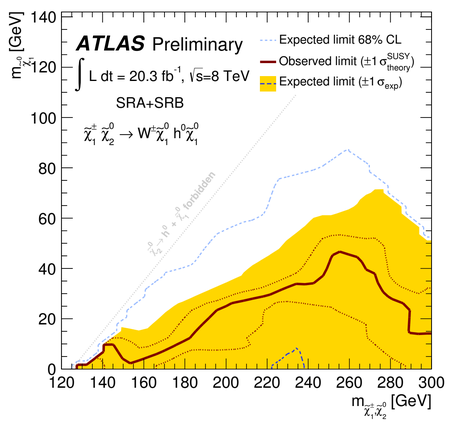
- Model-independent limits in signal regions for the m_{bb} signal bin [105,135] GeV. Observed 95% CLs upper limits on expected number of signal event (S_{obs}^{95}) and visible cross-section ($\sigma_{\mathrm{vis}}^{95}$) for non-SM events.

		SRA	SRB
Asymptotic	Observed S_{obs}^{95} ($\sigma_{\mathrm{vis}}^{95}$)	6.5 (0.32 fb)	4.4 (0.21 fb)
	Expected S_{exp}^{95}	$7.0^{+3.1}_{-1.9}$	$4.4^{+2.5}_{-1.5}$
Pseudo-experiments	Observed S_{obs}^{95} ($\sigma_{\mathrm{vis}}^{95}$)	6.9 (0.34 fb)	4.4 (0.21 fb)
	Expected S_{exp}^{95}	$7.0^{+2.8}_{-1.6}$	$4.4^{+1.8}_{-0.8}$

- Limits set on $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ mass at -1σ signal theoretical uncertainty (for $m_{\tilde{\chi}_1^0} = 0$), 95% CL exclusion:

  $125 < m_{\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0} < 141$ and $166 < m_{\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0} < 287$ GeV

- Expected exclusion range: $225 < m_{\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0} < 235$ GeV



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