Search for Production of SUSY Particles Produced via Electroweak Interactions with the ATLAS Experiment

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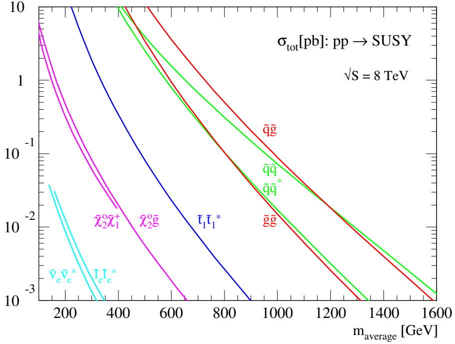
Outline

- Introduction to Electroweak Supersymmetry Searches
- Motivations for Searches with Compressed Spectra
- ATLAS Electroweak SUSY 8 TeV Run-1 Summary Paper Results
- Summary & Outlook

Supersymmetry in the Electroweak Sector

arXiv:1412.2784

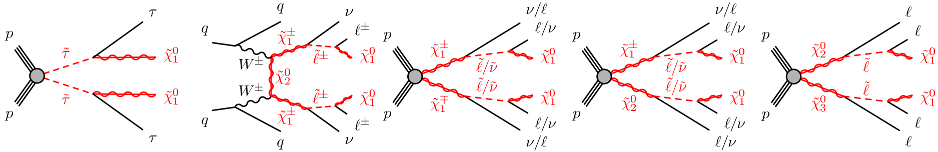


- **Natural** SUSY requires **light** stops and charginos/neutralinos to cancel divergences in Higgs mass.
- LHC limits place $m_{\tilde{g},\tilde{q}} > 1$ TeV
- If the masses of the gluinos and squarks are **large**, direct production of charginos/neutralinos/sleptons **may dominate** the SUSY production at the LHC.

- Charginos ($\chi_i^{\pm}$)/neutralinos (χ_j^0) can decay via sleptons ($\tilde{\ell}_{\rm L}$, $\tilde{\ell}_{\rm R}$)/sneutrinos ($\tilde{\nu}$), gauge bosons (W/Z) or Higgs bosons
- Can lead to final states with **high lepton multiplicity**

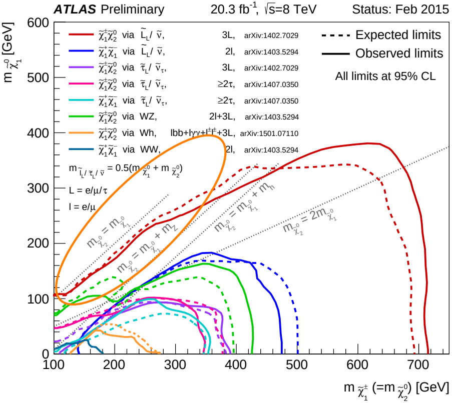
Simplified Models for Electroweak SUSY

- **Simplified Models**: Used for SUSY searches, taking **essential** features from viable SUSY models
  - Target production of charginos, neutralinos and sleptons.
  - Assumed 100% BR, parameterised in terms of **sparticle masses**
  - Fixed decay chain considered for signal optimisation in searches



- Results also interpreted in **phenomenological models** for broad range of applicability of the searches

Motivations for Compressed Spectra Searches



ATL-COM-PHYS-2015-1351

- Light $\tilde{\chi}_1^0 \approx$ mass degenerate with $\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ (compressed scenarios) is well motivated theoretically
- **Naturalness-inspired** models motivate light higgsino-like $\tilde{\chi}_1^0$ and small mass splitting with $\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$
  - Also connected to cosmologically favoured relic **dark matter** density
- Result in **low-momentum decay products**; experimentally challenging as they are difficult to trigger on and reconstruct

Scope of Paper

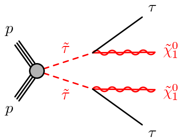
- Summarises and extends the search for electroweak supersymmetry on ATLAS experiment **at 8 TeV**
- Focuses on improvements for **compressed scenarios** and models with **low cross sections**

New Run-1 Analyses in the Paper

- 2 Opposite Sign (OS) τ (MVA)
- 2 OS ℓ Initial State Radiation (ISR)
- 3ℓ incl. 1 Same Flavour Opposite Sign (SFOS) ℓ pair (ISR)
- 2 SS ℓ Multivariate Analysis (MVA)
- 2 Same Sign (SS) ℓ Vector Boson Fusion (VBF)

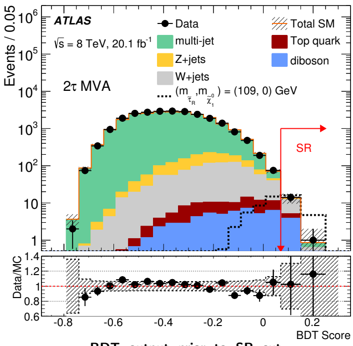
These analyses are **combined** with results from existing electroweak SUSY searches at 8 TeV

Direct Stau Pair Production - 2 OS τ (MVA) - Overview



- Searches for two hadronically decaying taus, low jet activity and large E_T^{miss} in the final state
- Low mass taus in final state difficult to **trigger** on and separate from background
- Uses **multivariate analysis** technique with Boosted Decision Tree SR designed to improve sensitivity to low mass stau region

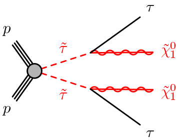
arXiv:1509.07152



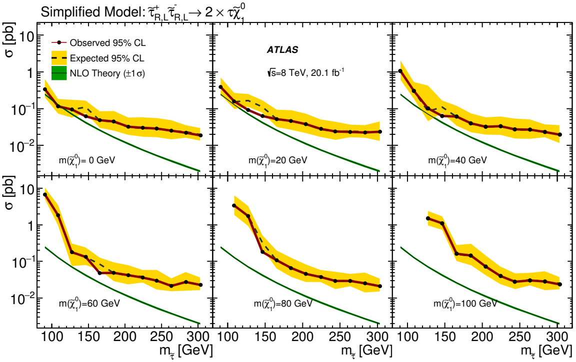
BDT output prior to SR cut

- BDT cut chosen based on the best expected sensitivity for **discovery**

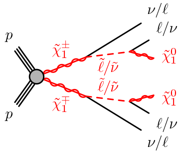
Direct Stau Pair Production - 2 OS τ (MVA) - Results



No significant excess observed above SM expectations

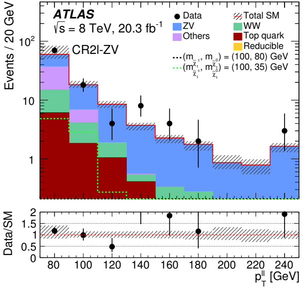


- **95% CL exclusion limits** on cross-section for combined production of $\tilde{\tau_L}\tilde{\tau_L}$ and $\tilde{\tau_R}\tilde{\tau_R}$, with $m(\tilde{\chi}_1^0)$ ranging from 0-100 GeV
- Best observed upper limit for $m(\tilde{\tau}) =$ **109 GeV** for massless $\tilde{\chi}_1^0$
- For this scenario, cross sections **above 0.115 pb** are excluded, where the theoretical cross section at NLO is **0.128 pb**

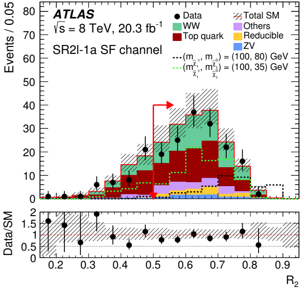


arXiv:1509.07152

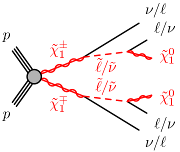
- Previous searches extended to increase sensitivity to compressed scenarios - $\tilde{\chi}_1^{\pm} - \tilde{\chi}_1^0$ **mass splittings below 100 GeV**
- Two signal region request ISR jet(s) - provides **boost to final state objects**
- **"Super-Razor variables"** are used in signal and control regions - variables with kinematic endpoints directly related to **mass splitting** of $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^0$.



Transverse momentum of two-lepton system in Diboson control region



R_2 **in same flavour channel of signal region**



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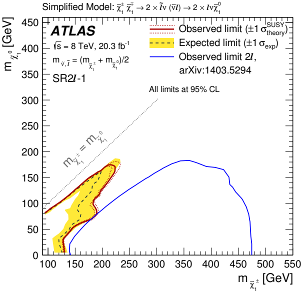
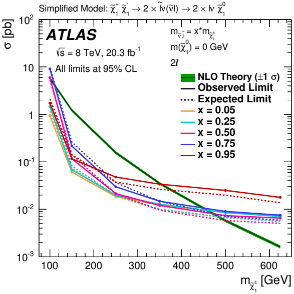
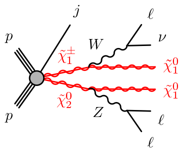


- Limits set on $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$ pair production and decay through **sleptons**
- m($\tilde{\ell}_L$) is **halfway** between the m($\tilde{\chi}_1^\pm$) and m($\tilde{\chi}_1^0$)
- New sensitivity to compressed scenarios for m($\tilde{\chi}_1^\pm$) < **220 GeV**

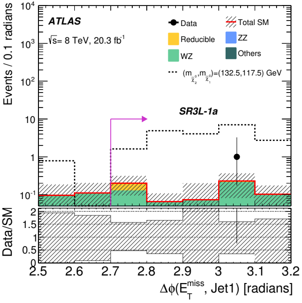
- Production cross-section limits set for **varied slepton masses** in appropriate intervals with massless $\tilde{\chi}_1^0$
- Slepton mass has no significant effect on sensitivity, m($\tilde{\chi}_1^\pm$) **up to 500 GeV excluded**



Direct Chargino-Neutralino Production - 3ℓ (ISR) - Overview

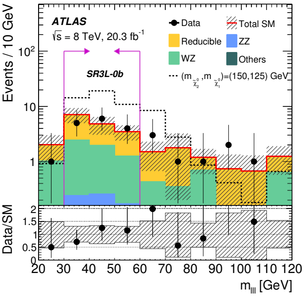


arXiv:1509.07152

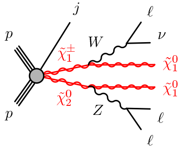


$\Delta\phi(\mathbf{E_T^{miss}}$, jet1) in ISR signal region

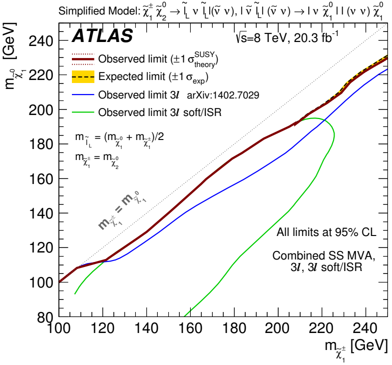
- Previous searches for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production with 3ℓ are extended to increase sensitivity to $\tilde{\chi}_1^{\pm}$-$\tilde{\chi}_1^0$ mass splittings **below 50 GeV**, low-p$_T$ leptons in final state
- Use high p$_T$ jet (ISR): boost to E_T^{miss} and leptons, **unique topology**, provides discriminatory power
- One signal region utilises soft leptons
- One signal region utilises soft leptons and ISR jet



Invariant mass of 3ℓ system in soft lepton signal region



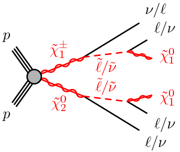
No significant excess observed above SM expectations



- Significance of the two orthogonal regions are **statistically combined**
- Final result provides sensitivity to compressed scenarios with up to m($\tilde{\chi}_1^\pm$) up to **220 GeV excluded** where $m(\tilde{\ell}_L)$ set **halfway** between m($\tilde{\chi}_1^\pm$) and m($\tilde{\chi}_1^0$).

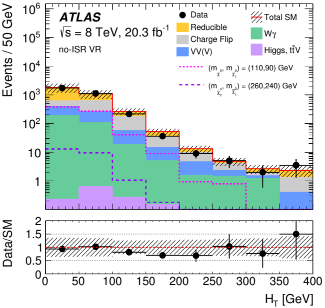
- Results **combined** with previous 3ℓ results and 2ℓ SS MVA results for **final exclusion plot**

Direct Chargino-Neutralino Production - 2 SS ℓ (MVA) - Overview



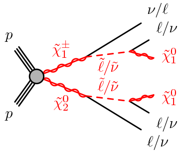
arXiv:1509.07152

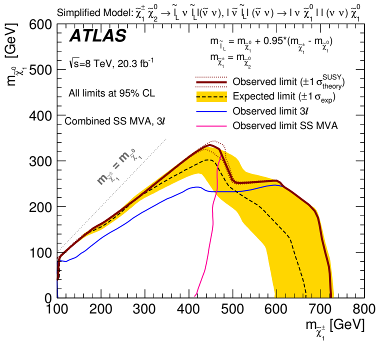
- **One** of the three leptons from $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production **too soft** for reconstruction
- Use two same-sign leptons to extend 3ℓ search for small mass splittings
- **Multivariate analysis** (MVA) technique used to discriminate between signal and background
- 8 BDTs trained **8 signal regions** optimised for 4 mass splitting regions, each request/veto ISR jet



- $\mathbf{H_T}$: Scalar sum of the p_T of the leptons and jets in the non-ISR VR.
  - One of the variables used in the MVA

Direct Chargino-Neutralino Production - Combined Results

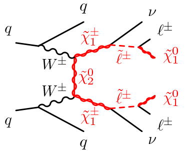




No significant excess observed above SM expectations

- 2ℓ-SS combined with previous 3ℓ and 3ℓ+ISR searches
- For large mass splittings m($\tilde{\chi}_1^\pm$) are **excluded up to 720 GeV** for massless $\tilde{\chi}_1^0$
- In the compressed scenario with $\tilde{\ell}_L$-mediated decays, with m($\tilde{\ell}_\text{L}$) set to:
  - 50% between $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^0$ masses, the 3ℓ analysis has the strongest sensitivity
  - 95% between $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^0$ masses, the 2ℓ-SS analysis has the strongest sensitivity

Chargino Pair Production - 2 SS ℓ (VBF) - Overview



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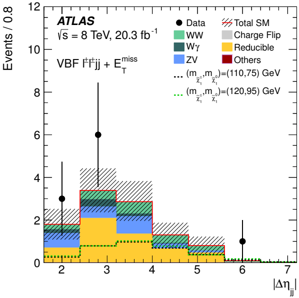
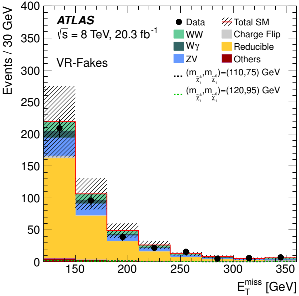


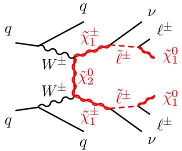
$|\Delta\eta_{jj}|$ in SS VBF signal region



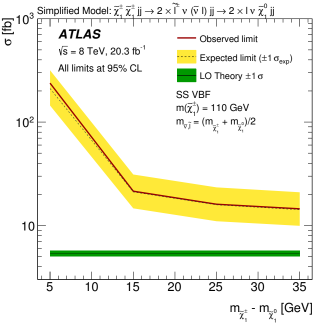
E_T^{miss} in SS VBF validation region

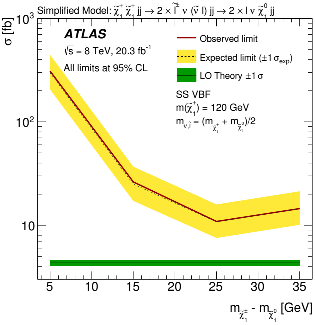
- Well motivated by **dark matter** searches and probing $\tilde{\chi}_1^0$ mass and composition
- Use discriminatory power of **2 additional jets** - well separated in η and large invariant mass to probe compressed scenarios and **complement** direct production searches
- Search for two SS light leptons, $>=$ 2 jets, and large E_T^{miss} in final state

Chargino Pair Production - 2 SS ℓ (VBF) - Results



No significant excess observed above SM expectations

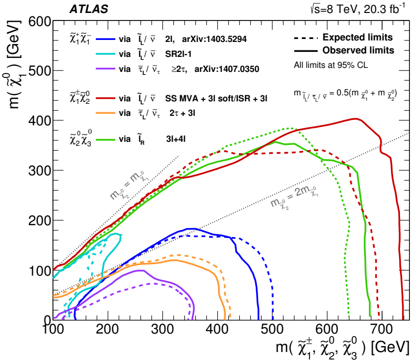


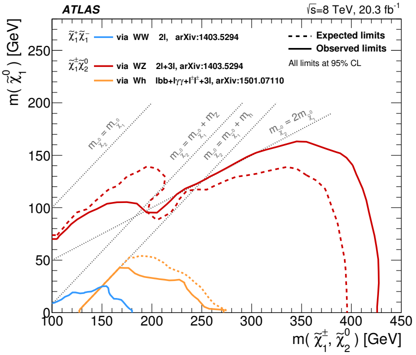


- 95% CL upper limits on cross-section for VBF $\tilde{\chi}_1^\pm \tilde{\chi}_1^\pm$ production as a function of mass splitting for $m(\tilde{\chi}_1^\pm) =$ 110 and 120 GeV
- Best observed upper limit for $m(\tilde{\chi}_1^\pm) =$ **120 GeV** and $m(\tilde{\chi}_1^\pm)$ - $m(\tilde{\chi}_1^0) =$ **25 GeV**: **excluded cross-section 10.9fb**, **approaching** theoretical LO cross section 4.33 fb
- Small cross-section makes VBF production **very difficult** to probe!

Summary of ATLAS Results for Electroweak SUSY Searches at 8 TeV

arXiv:1509.07152





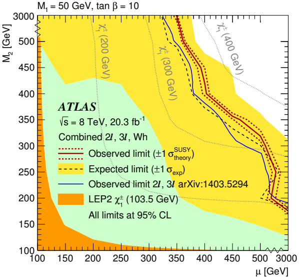
- Greatest impact of new analyses seen in $\tilde{\ell}$-mediated channels
- Combinations of 2 SS ℓ, existing 3ℓ and new 3ℓ+ISR (red contour) delivers improvement to compressed region and excludes m($\tilde{\chi}_1^{\pm}$) **up to 740 GeV** for massless $\tilde{\chi}_1^0$
- Combination of 2ℓ and 3ℓ searches excluding m($\tilde{\chi}_1^{\pm}$) **up to 420 GeV** for massless $\tilde{\chi}_1^0$ in $W/Z/h$-mediated channels

Summary

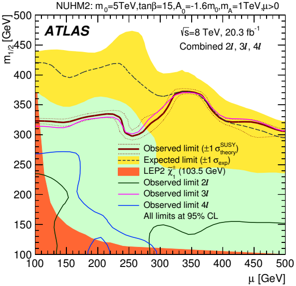
- If coloured sparticles are too heavy, electroweak SUSY may be the **dominant SUSY production** mechanism at the LHC
- Presented final Electroweak SUSY results at **8 TeV** on ATLAS with emphasis on **compressed spectra**
- Electroweak SUSY Searches will profit from **higher luminosity** in Run-2, making 2016 a very **important and interesting year**!

Back-up

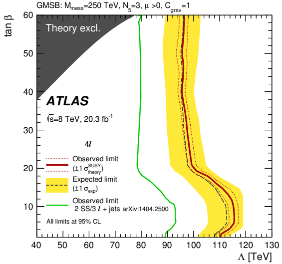
arXiv:1509.07152



pMSSM

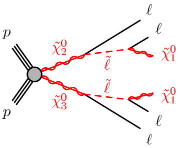


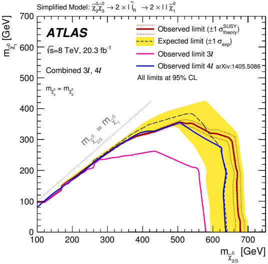
NUHM2



GMSB

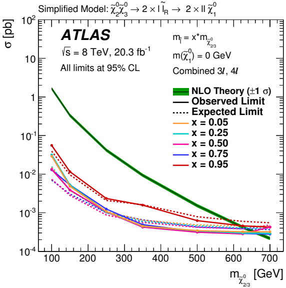
- pMSSM ($\mu - M_2$ plane): combination of 2ℓ, 3ℓ, and Wh included
- NUHM2 ($\mu - m_{1/2}$ plane): interpretation of 2ℓ, 3ℓ (drives exclusion limit) and 4ℓ
- GMSB ($\Lambda - \tan\beta$ plane): reinterpretation of 4ℓ analysis, yields improvement by 15-20 TeV w.r.t earlier combination of 2ℓSS/3ℓ analyses





- $\Leftarrow$ In this plot, combination of the $3\ell + 4\ell$ analyses used to set limits on $\tilde{\chi}_2^0\tilde{\chi}_3^0$ production with $\tilde{\ell}_R$-mediated decays
- $\tilde{\ell}_R$ is halfway between the $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^0$ masses
- Masses up to 670 GeV are excluded improving previous limits by 30 GeV for $\tilde{\chi}_1^0$ masses below 200 GeV

- Slepton mass is 5%, 25%, 50%, 75% and 95% of the $\tilde{\chi}_2^0$ mass studied for massless $\tilde{\chi}_1^0$
- This plot shows slepton mass has no significant effect on sensitivity, $\tilde{\chi}_2^0$ masses up to 600 GeV excluded $\Rightarrow$



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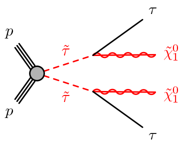
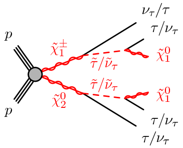
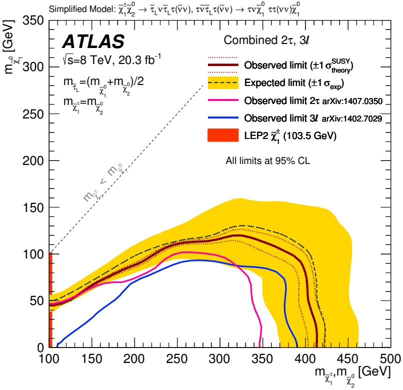




- Combination of the 2 tau + 3ℓ analyses used to set limits on $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production with $\tilde{\tau}$-mediated decays
- Sensitivity to large $\tilde{\chi}_1^\pm$ masses improved by 20 GeV with combination, with respect to 3ℓ limit (blue line)
- $\tilde{\chi}_1^\pm$ masses excluded up to 400 GeV for massless $\tilde{\chi}_1^0$



arXiv:1509.07152

Summary of Exclusion Ranges from ATLAS SUSY Searches in Run-1

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: March 2016

ATLAS Preliminary

$\sqrt{s}$ = 7, 8, 13 TeV

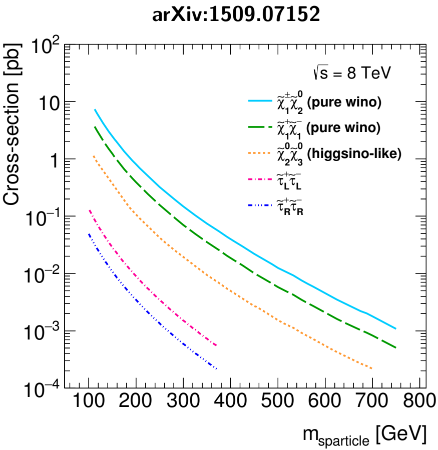
$\sqrt{s}$ = 7, 8 TeV | $\sqrt{s}$ = 13 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [fb^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e, μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.85 TeV	m($\tilde{q}$)=m($\tilde{g}$)	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	3.2	$\tilde{q}$ 980 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	ATLAS-CONF-2015-062
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde{q}$ 610 GeV	m($\tilde{q}$)-m($\tilde{\chi}_1^0$)<5 GeV	To appear
	$\tilde{q}\tilde{q}, \tilde{q}\to q(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ (off-Z)	2 jets	Yes	20.3	$\tilde{q}$ 820 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1503.03290
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	3.2	$\tilde{g}$ 1.52 TeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2015-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	1 e, μ	2-6 jets	Yes	3.3	$\tilde{g}$ 1.6 TeV	m($\tilde{\chi}_1^0$)<350 GeV, m($\tilde{\chi}^{\pm}$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	ATLAS-CONF-2015-076
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20	$\tilde{g}$ 1.38 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1501.03555
	$\tilde{g}\tilde{g}, \tilde{g}\to qqWZ\tilde{\chi}_1^0$	0	7-10 jets	Yes	3.2	$\tilde{g}$ 1.4 TeV	m($\tilde{\chi}_1^0$) =100 GeV	1602.06194
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$ 1.63 TeV	tanβ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.34 TeV	$c\tau$(NLSP)<0.1 mm	1507.05493
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde{g}$ 1.37 TeV	m($\tilde{\chi}_1^0$)<950 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	m($\tilde{\chi}_1^0$)<850 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	1507.05493
	GGM (higgsino NLSP)	2 e, μ (Z)	2 jets	Yes	20.3	$\tilde{g}$ 900 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	m($\tilde{G}$)>1.8 × 10^{-4} eV, m($\tilde{g}$)=m($\tilde{q}$)=1.5 TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	3.3	$\tilde{g}$ 1.78 TeV	m($\tilde{\chi}_1^0$)<800 GeV	ATLAS-CONF-2015-067
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	3.3	$\tilde{g}$ 1.76 TeV	m($\tilde{\chi}_1^0$)=0 GeV	To appear
	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.37 TeV	m($\tilde{\chi}_1^0$)<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	3.2	$\tilde{b}_1$ 840 GeV	m($\tilde{\chi}_1^0$)<100 GeV	ATLAS-CONF-2015-066
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^{\pm}$	2 e, μ (SS)	0-3 b	Yes	3.2	$\tilde{b}_1$ 325-540 GeV	m($\tilde{\chi}_1^0$)=50 GeV, m($\tilde{\chi}_1^{\pm}$)= m($\tilde{\chi}_1^0$)+100 GeV	1602.09058
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	1-2 e, μ	1-2 b	Yes	4.7/20.3	$\tilde{t}_1$ 117-170 GeV, 200-500 GeV	m($\tilde{\chi}_1^{\pm}$) = 2m($\tilde{\chi}_1^0$), m($\tilde{\chi}_1^0$)=55 GeV	1209.2102, 1407.0583
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e, μ	0-2 jets/1-2 b	Yes	20.3	$\tilde{t}_1$ 90-198 GeV, 205-715 GeV, 745-785 GeV	m($\tilde{\chi}_1^0$)=1 GeV	1506.08616, ATLAS-CONF-2016-007
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-245 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-600 GeV	m($\tilde{\chi}_1^0$)>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to \tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$ 290-610 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to \tilde{t}_1 + h$	1 e, μ	6 jets + 2 b	Yes	20.3	$\tilde{t}_2$ 320-620 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1506.08616
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to \ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$ 90-335 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to \tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 140-475 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to \tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 355 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\tau}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1407.0350
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to \tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 715 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e, μ	0-2 jets	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 425 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e, μ, γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 270 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0 \to \tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$ 635 GeV	m($\tilde{\chi}_2^0$)=m($\tilde{\chi}_3^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_2^0$)+m($\tilde{\chi}_1^0$))	1405.5086
	GGM (wino NLSP) weak prod.	1 $e, \mu + \gamma$	-	Yes	20.3	$\tilde{W}$ 115-370 GeV	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 270 GeV	m($\tilde{\chi}_1^{\pm}$)-m($\tilde{\chi}_1^0$)~160 MeV, τ($\tilde{\chi}_1^{\pm}$)=0.2 ns	1310.3675
	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	dE/dx trk	-	Yes	18.4	$\tilde{\chi}_1^{\pm}$ 495 GeV	m($\tilde{\chi}_1^{\pm}$)-m($\tilde{\chi}_1^0$)~160 MeV, τ($\tilde{\chi}_1^{\pm}$)<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$ 850 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<τ($\tilde{g}$)<1000 s	1310.6584
	Metastable $\tilde{g}$ R-hadron	dE/dx trk	-	-	3.2	$\tilde{g}$ 1.54 TeV	m($\tilde{\chi}_1^0$)=100 GeV, τ>10 ns	To appear
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0\to \tilde{\tau}(\tilde{e}, \tilde{\mu})+\tau(e, \mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}_1^0$ 537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde{\chi}_1^0\to \gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$ 440 GeV	1<τ($\tilde{\chi}_1^0$)<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	7 <$c\tau$($\tilde{\chi}_1^0$)< 740 mm, m($\tilde{g}$)=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	6 <$c\tau$($\tilde{\chi}_1^0$)< 480 mm, m($\tilde{g}$)=1.1 TeV	1504.05162
RPV	LFV $pp\to \tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu, e\tau, \mu\tau$	-	-	20.3	$\tilde{\nu}_\tau$ 1.7 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1503.04430
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.45 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 760 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^{\pm}$), $\lambda_{121}\neq$0	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to \tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 450 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^{\pm}$), $\lambda_{133}\neq$0	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 917 GeV	BR(t)=BR(b)=BR(c)=0%	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 980 GeV	m($\tilde{\chi}_1^0$)=600 GeV	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\to \tilde{t}_1 t, \tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$ 880 GeV		1404.2500
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$	0	2 jets + 2 b	-	20.3	$\tilde{t}_1$ 320 GeV		1601.07453
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$	2 e, μ	2 b	-	20.3	$\tilde{t}_1$ 0.4-1.0 TeV	BR($\tilde{t}_1\to be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	$\tilde{c}$ 510 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1501.01325

Mass scale [TeV] (10^{-1} – 1)

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

Electroweak Production Cross Sections



Production cross sections for the simplified models of the direct production of $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$, $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$, $\tilde{\chi}_2^0\tilde{\chi}_3^0$, and $\tilde{\tau}^+\tilde{\tau}^-$

List of Triggers

Table 2: The triggers used in the analyses and the offline p_T threshold used, ensuring that the lepton(s) or E_T^{miss} triggering the event are in the plateau region of the trigger efficiency. Where multiple triggers are listed for an analysis, events are used if any of the triggers is passed. Muons are triggered within a restricted range of $|\eta| < 2.4$.

Trigger	p_T threshold [GeV]	Analysis
Single τ Double τ	150 40,25	Direct stau production
Single Isolated e Single Isolated μ	25 25	Compressed spectra $\ell^+\ell^-$, 3ℓ
Double e	14,14 25,10	Compressed spectra $\ell^+\ell^-$, $\ell^\pm\ell^\pm$, 3ℓ
Double μ	14,14 18,10	Compressed spectra $\ell^+\ell^-$, $\ell^\pm\ell^\pm$, 3ℓ
Triple e	20,9,9	Compressed spectra 3ℓ
Triple μ	7,7,7 19,5,5	Compressed spectra 3ℓ
Combined $e\mu$	14(e),10(μ) 18(μ),10(e) 9(e),9(e),7(μ) 9(e),7(μ),7(μ)	Compressed spectra 3ℓ
E_T^{miss}	120	Chargino production via VBF

Dominating Backgrounds

- 2τ OS (MVA):
  - Irreducible (2 prompt taus): Diboson ($t\bar{t}$, Z+jets)
  - Reducible ($\geq$ 1 fake taus): W+jets (multi-jet)
- 2ℓ OS (ISR):
  - Irreducible (2 prompt leptons): WW, top, (ZV, Higgs, Z+jets)
  - Reducible ($\geq$ 1 fake leptons, e.g. electron conversions)
- 2ℓ SS (MVA):
  - Irreducible (2 prompt SS leptons): Diboson (triboson, $t\bar{t}$-V, tZ, Higgs)
  - Reducible ($\geq$ 1 fake lepton): Wγ
  - Charge flip ($\geq$ 1 lepton with mismeasured charge)
- 3ℓ incl. 1 SFOS ℓ pair (ISR):
  - Irreducible (3 prompt leptons): WZ/ZZ (triboson, $t\bar{t}$-V, tZ, Higgs)
  - Reducible ($\geq$ 1 fake leptons): $t\bar{t}$, Z+jets, (W+jets, WW, top)
- 2ℓ SS (VBF)
  - Irreducible (2 prompt leptons): WZ, WW
  - Reducible ($\geq$ 1 fake leptons): W+jets ($t\bar{t}$, Wγ)
  - Charge flip ($\geq$ 1 lepton with mismeasured charge)

Dominating Systematic Uncertainties

- 2τ OS (MVA): Stat. unc. on MC samples (20%), E_T^{miss} soft-term resolution (20%); total: 35%
- 2ℓ OS (ISR): Theory & modelling (generator modelling, parton shower etc) (22-24)%; total 23-28%
- 2ℓ SS (MVA): Stat. unc. on MC samples (7-74%), real lepton subtraction (8-33%), jet-energy resolution (1-35%); total: 18-81%
- 3ℓ incl. 1 SFOS ℓ pair (ISR): Stat. unc. on reducible bg. estimate (11-34%), muon misidentification probability (red. bg. est., $<$ 1-27%); total: 25-59%
- 2ℓ SS (VBF): Fake-factor closure test (13%), stat. unc. on the red. bg. (11%); total: 21%