New ATLAS results in inclusive searches for supersymmetric squarks and gluinos

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SUSY in strong production

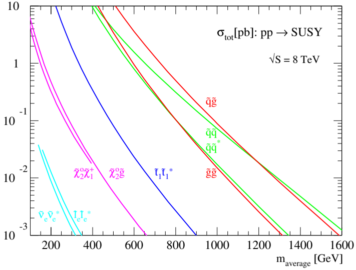
If present at TeV scale, squarks and gluinos may be copiously produced at the LHC.

Gluinos and squarks decay either directly or via a cascade into:

- **jets**, coming from gluinos and squarks decays
- **the LSP** (the lightest supersymmetric particle), escaping the detector and resulting in E_T^{miss} (assuming R-parity conservation in this talk)

and:

- possibly **lepton(s)**, coming from chargino, neutralino or slepton decays



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

$\int \mathcal{L}\,dt = (4.6 - 22.9)\ \text{fb}^{-1}$ $\sqrt{s}$ = 7, 8 TeV

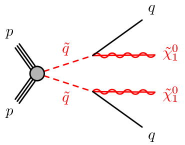
Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\,dt[fb^{-1}]$	Mass limit		Reference
MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	1308.1841
$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2013-062
$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-089
⋮							
$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061

Analyses

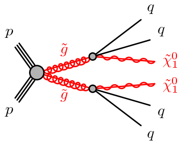
0-lepton + 2-6 jets

ATLAS-CONF-2013-047

Very powerful analysis requiring 2-6 high p_T jets, E_T^{miss} and no electrons or muons



(Examples)



Requirement	Channel: A (2-jets) L	A (2-jets) M	B (3-jets) M	B (3-jets) T	C (4-jets) M	C (4-jets) T	D (5-jets) –	E (6-jets) L	E (6-jets) M	E (6-jets) T
E_T^{miss}[GeV] >	160									
$p_T(j_1)$ [GeV] >	130									
$p_T(j_2)$ [GeV] >	60									
$p_T(j_3)$ [GeV] >	–		60		60		60	60		
$p_T(j_4)$ [GeV] >	–		–		60		60	60		
$p_T(j_5)$ [GeV] >	–		–		–		60	60		
$p_T(j_6)$ [GeV] >	–		–		–		–	60		
$\Delta\phi(\text{jet}_i, \mathbf{E}_T^{miss})_{min}$ >	0.4 ($i = \{1, 2, (3$ if $p_T(j_3) > 40$ GeV$)\}$)				0.4 ($i = \{1, 2, 3\}$), 0.2 ($p_T > 40$ GeV jets)					
$E_T^{miss}/m_{eff}(Nj)$ >	0.2	–[a]	0.3	0.4	0.25	0.25	0.2	0.15	0.2	0.25
m_{eff}(incl.) [GeV] >	1000	1600	1800	2200	1200	2200	1600	1000	1200	1500

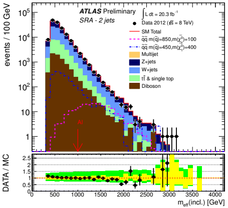
(a) For SR A-medium the cut on $E_T^{miss}/m_{eff}(Nj)$ is replaced by a requirement $E_T^{miss}/\sqrt{H_T} > 15$ GeV$^{1/2}$.

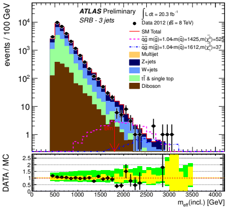
trigger

QCD rejection

SR

squark pair production | squark-gluino production | gluino pair production long decay chains





Main discriminating variables:

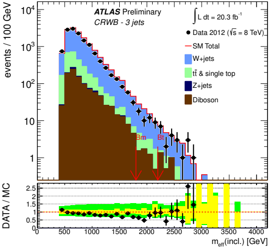
E_T^{miss} and

$m_{eff} = \sum p_T^{jet} + E_T^{miss}$

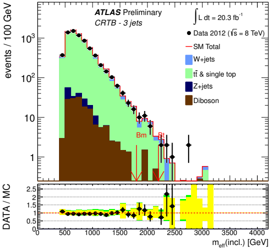
0-lepton + 2-6 jets

Four control regions are assigned to each signal region to constrain backgrounds:

- **QCD multi-jet background** (inverted $\Delta\phi(\text{jet}_i, E_{\text{T}}^{\text{miss}})$ and $E_{\text{T}}^{\text{miss}}/m_{\text{eff}}$ cut)
- **Z/γ+jets** (control region requires isolated photon)
- $t\bar{t}$/**single** t and **W+jets** backgrounds (control regions require one lepton and either a b-tagged jet or a b-jet veto)



extrapolation to signal regions
by using transfer factors
from MC
(from data for QCD mutli-jet BG)
(background estimates in SRs
technically obtained by minimisation
of a profile log likelihood)



model inde- pendent upper limits

Signal Region	A-loose	A-medium	B-medium	B-tight	C-medium	C-tight	D	E-loose	E-medium	E-tight
Total bkg	4700 ± 500	122 ± 18	33 ± 7	2.4 ± 1.4	210 ± 40	1.6 ± 1.4	15 ± 5	113 ± 21	30 ± 8	2.9 ± 1.8
Observed	5333	135	29	4	228	0	18	166	41	5
$\langle\epsilon\sigma\rangle_{\text{obs}}^{95}$[fb]	66.07	2.52	0.73	0.33	4.00	0.12	0.77	4.55	1.41	0.41
S_{obs}^{95}	1341.2	51.3	14.9	6.7	81.2	2.4	15.5	92.4	28.6	8.3
S_{exp}^{95}	$1135.0^{+332.7}_{-291.5}$	$42.7^{+15.5}_{-11.4}$	$17.0^{+6.6}_{-4.6}$	$5.8^{+2.9}_{-1.8}$	$72.9^{+23.6}_{-18.0}$	$3.3^{+2.1}_{-1.2}$	$13.6^{+5.1}_{-3.5}$	$57.3^{+20.0}_{-14.4}$	$21.4^{+7.6}_{-5.8}$	$6.5^{+3.0}_{-1.9}$
p_0 (Z_n)	0.45 (0.1)	0.27 (0.6)	0.50 (0.0)	0.34 (0.4)	0.34 (0.4)	0.50 (0.0)	0.32 (0.5)	0.03 (1.9)	0.14 (1.1)	0.22 (0.8)

Detailed tables in backup

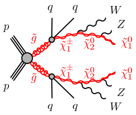
consistent with SM expectation

0-lepton + multi-jets: signal regions

arXiv:1308.1841, submitted to JHEP

Dedicated analysis to look for longer SUSY decay chains - up to 10 jets in the final state

The usage multi-jet triggers without E_T^{miss} requirements allows to have low cuts on E_T^{miss}



Three sets of signal regions:

Veto events with isolated electrons or muons in order to suppress W+jets or $t\bar{t}$ background

- 8, 9 or at least 10 jets with $p_T > 50$ GeV and zero, one or at least two b-tagged jets
- 7 or at least 8 jets with $p_T > 80$ GeV and zero, one or at least two b-tagged jets

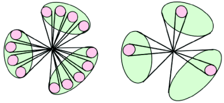
Signal regions with "mega-jets":

- At least 8, 9 or 10 jets with $p_T > 50$ GeV and $M_J^{\Sigma} > 340$ or 420 GeV

All signal regions also impose $E_T^{miss}/\sqrt{H_T} > 4\sqrt{\text{GeV}}$ ($H_T = \sum p_T^{jet}$ using jets with $p_T > 40$ GeV and $|\eta| < 2.8$)

Mega-jets:

- Re-clustering anti-k_T jets with cone radius of 0.4 into 'mega'-jets: anti-k_T jets with cone radius of 1.0
- Discriminating variable $M_J^{\Sigma} = \sum m_{jet}^{R=1.0}$ constructed by using mega-jets with $p_T > 100$ GeV and $|\eta| < 1.5$

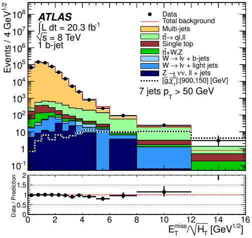


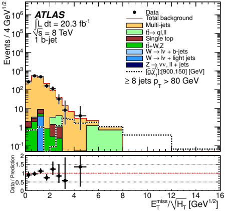
(SUSY) (BG)

0-lepton + multi-jets

Backgrounds:

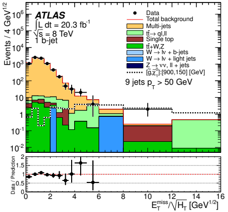
- Multi-jet production: strong production, fully hadronic decays of $t\bar{t}$, W and Z bosons
  - Observation: E_T^{miss} resolution of the detector approximately proportional to $\sqrt{H_T}$ and $\sim$ independent of jet multiplicity in events dominated by jet activity
  - $\rightarrow$ Shape of $E_T^{miss}/\sqrt{H_T}$ $\sim$ invariant under changes in jet multiplicity
  - $\rightarrow$ Can use lower jet multiplicity to retrieve $E_T^{miss}/\sqrt{H_T}$ shape and lower $E_T^{miss}/\sqrt{H_T}$ to normalise distribution to data
- Leptonic backgrounds, as semi- or di-leptonic decaying $t\bar{t}$, leptonic decaying W or Z bosons
  - Estimated by normalising MC to data in background dominating control regions, which require at least one lepton





Standard Model predictions consistent with data in all signal regions (see also detailed tables in back-up)

Most stringent upper limit on $\sigma_{BSM}^{95\%} \cdot A \cdot \epsilon(\text{obs}) = 0.17$ fb obtained in the signal region requiring 8 jets with $p_T > 80$ GeV and one b-jet



At least one isolated lepton + 2-6 jets

ATLAS-CONF-2013-062

- Reduction of the large QCD multi-jet background by requiring at least one lepton (electron or muon)
- Powerful discriminant between background and signal:

$$m_{\mathrm{T}} = \sqrt{2 \cdot p_{\mathrm{T}}^{l} \cdot E_{\mathrm{T}}^{\mathrm{miss}} (1 - \cos(\Delta\phi(\vec{p}_{\mathrm{T}}^{\,l}, \vec{E}_{\mathrm{T}}^{\mathrm{miss}})))}$$

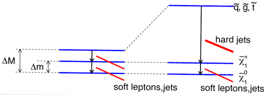
Decays of gluinos or squarks via one, two or more steps into the LSP

at least one soft lepton

(6 (μ)/10 (e) $< p_{\mathrm{T}} <$ 25 GeV)

+ 2 - 5 jets (+1 or 2 b-jets)

targeting compressed scenarios



one hard lepton

($p_{\mathrm{T}} >$ 25 GeV)

+ 3 - 6 jets

lepton+$E_{\mathrm{T}}^{\mathrm{miss}}$ triggers used

"workhorse"

↳ provides the sensitivity in most models

Background estimates:

- **QCD multi-jet background** (significant in the soft lepton case, negligible in the hard lepton case): via a matrix method by relaxing the isolation criteria on the lepton
- $t\bar{t}$, W **+jets (**Z**+jets, in the soft lepton case)**:
  by a semi-data-driven method; normalising MC to data in a background dominated control region (lower $E_{\mathrm{T}}^{\mathrm{miss}}$ and m_{T}) and extrapolate to the signal regions by a transfer factor taken from MC
- Smaller backgrounds as **single top, dibosons,** $t\bar{t}$**+V** and Z+jets (in the hard lepton case) directly taken from MC

Hard 1-lepton: signal regions

Signal regions requiring high E_T^{miss}, high m_T and high $m_{eff} = \sum p_T^{jet} + p_T^{l} + E_T^{miss}$

squark pair production → gluino pair production, long decay chains

	inclusive (binned) hard single-lepton		
	3-jet	5-jet	6-jet
N_ℓ	1 (electron or muon)		
p_T^ℓ (GeV)	> 25		
$p_T^{add.\ \ell}$ (GeV)	< 10		
N_{jet}	≥ 3	≥ 5	≥ 6
p_T^{jet} (GeV)	$> 80, 80, 30$	$> 80, 50, 40, 40, 40$	$> 80, 50, 40, 40, 40, 40$
$p_T^{add.\ jets}$ (GeV)	– (< 40)	– (< 40)	–
E_T^{miss} (GeV)	>500 (300)	>300	>350 (250)
m_T (GeV)	> 150	> 200 (150)	> 150
$E_T^{miss}/m_{eff}^{excl}$	> 0.3	–	–
m_{eff}^{incl} (GeV)	> 1400 (800)		> 600
binning	– (in m_{eff}^{incl}, four bins in [800,1600] GeV)		– (in E_T^{miss}, three bins in [250,550] GeV)

Main discriminating variables:

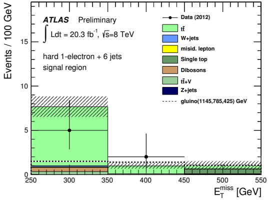
jets, E_T^{miss}, m_T and m_{eff}

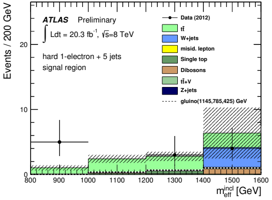
Tighter signal regions:
used to derive model independent upper limits on the visible cross section

Looser signal regions:
binned in m_{eff} or in E_T^{miss}
→ shape of E_T^{miss} or m_{eff} distribution used as further discriminant between signal and background
→ used to derive model dependent limits

The number of observed events is consistent with SM expectations in every signal region

Tightest model independent upper limit on the visible cross section obtained in the tighter 6-jet signal region in the muon channel: 0.15 fb





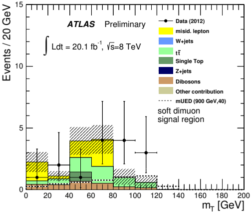
Soft 1-lepton: signal regions

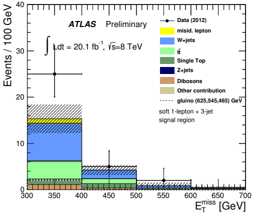
Various signal regions, targeting different decay types:

- **one soft lepton + 3 or 4 jets**: $E_{\mathrm{T}}^{\mathrm{miss}} > 400$ GeV, $m_{\mathrm{T}} > 100$ GeV, $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}} > 0.3$, $\Delta R_{\mathrm{min}}(\mathrm{jet}, l) > 1.0$ — short decay chains, very compressed scenarios
- **one soft lepton + at least 5 jets**: $E_{\mathrm{T}}^{\mathrm{miss}} > 300$ GeV, $m_{\mathrm{T}} > 100$ GeV, $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}} > 0.3$ — longer decay chains
- **two soft muons + at least 2 jets**: $E_{\mathrm{T}}^{\mathrm{miss}} > 170$ GeV, $m_{\mathrm{T}} > 80$ GeV, $\Delta R_{\mathrm{min}}(\mathrm{jet}, l) > 1.0$ — minimal Univeral Extra Dimensions

Observed data in signal regions mostly in agreement with SM expectation

	soft single-lepton 3-jet	soft single-lepton 5-jet	soft dimuon 2-jet
Observed events	7	9	7
Fitted background events	5.6 ± 1.6	14.8 ± 3.7	1.6 ± 1.0
Fitted $t\bar{t}$ events	1.3 ± 1.0	7.8 ± 3.3	1.2 ± 1.0
Fitted W+jets events	2.6 ± 0.7	2.1 ± 0.9	-
Fitted diboson events	0.6 ± 0.4	0.7 ± 0.4	0.4 ± 0.3
Fitted misidentified lepton events	$0.00^{+0.05}_{-0.00}$	3.3 ± 1.4	$0.0^{+0.3}_{-0.0}$
Fitted other background events	1.1 ± 0.5	0.9 ± 0.5	$0.01^{+0.06}_{-0.01}$
$\langle\epsilon\sigma\rangle^{95}_{\mathrm{obs}}$[fb]	0.40	0.35	0.57





2-leptons + jets + E_T^{miss}

New! ATLAS-CONF-2013-089

Also exploit the longitudinal information of an event.

Idea:

- Both sparticles are pair-produced, the initial heavy sparticles are assumed here to have the same masses or to be at the same mass scale

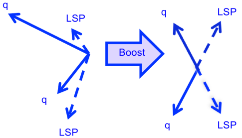
→ Both decay chains are symmetric if going into the frame where the initial heavy sparticle is at rest

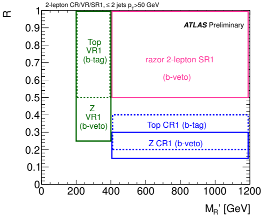
→ Can group all visible particles of one decay chain into a mega-jet; both mega-jets should have the same energy

Variables to benefit from this configuration:

- **Characteristic mass of the event:** $M'_R = \sqrt{(j_{1,E} + j_{2,E})^2 - (j_{1,L} + j_{2,L})^2}$ (E: energy, L: longitudinal component, j_1 and j_2: four-vectors of the two mega-jets)
- **Transverse information of the event:** $M_T^R = \sqrt{\frac{|\vec{E}_T^{miss}|(|\vec{j}_{1,T}|+|\vec{j}_{2,T}|)+\vec{E}_T^{miss}\cdot(\vec{j}_{1,T}+\vec{j}_{2,T})}{2}}$
- **Razor:** $R = \frac{M_T^R}{M'_R}$

Background events tend to have lower R, SUSY like signal events tend to be uniformly distributed between 0 and 1 in R





Signal regions:

2 leptons (opposite- and same-lepton flavour channels) +

SR1: < 3 jets with $p_T > 50$ GeV, $R > 0.5$, $M'_R > 400$ GeV

SR2: ≥ 2 jets with $p_T > 50$ GeV, $R > 0.35$, $M'_R > 800$ GeV

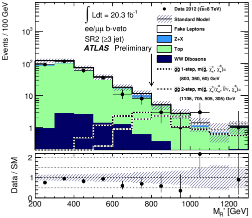
+ veto on b-jets and Z-veto (only for the same-lepton flavour channels)

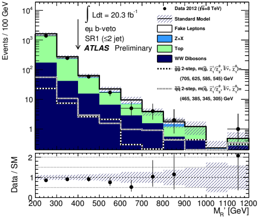
2-leptons + jets + E_T^{miss}

Background estimates:

- **Backgrounds with two real leptons:**
  fully leptonic decaying $t\bar{t}$ events, single top and $t\bar{t}$+V, Z/γ+jets, WZ and ZZ; MC normalised to data in control regions at lower R + b-jet requirement for top dominated control regions; extrapolation to signal regions via transfer factors
- **Backgrounds with mis-identified leptons:**
  W+jets, semi-leptonic decaying $t\bar{t}$; estimated via a matrix method similar to the one lepton analyses
- **WW production:**
  prediction directly taken from MC

channel	$ee/\mu\mu$ SR1	$e\mu$ SR1	$ee/\mu\mu$ SR2	$e\mu$ SR2
Observed events	102	87	8	8
Fitted bkg events	116.6 ± 16	102.5 ± 15	11.0 ± 2.8	10.1 ± 2.7
Fitted DibosonWW events	31.5 ± 8.3	28.1 ± 7.3	0.9 ± 0.3	0.44 ± 0.15
Fitted ZX events	6.8 ± 1.5	3.6 ± 0.3	0.57 ± 0.14	0.22 ± 0.06
Fitted Top events	65.6 ± 11.4	55.0 ± 9.8	8.9 ± 2.4	8.6 ± 2.4
Fitted reducible bkg. events	12.8 ± 6.6	15.8 ± 7.5	$0.7^{+1.0}_{-0.7}$	$0.8^{+1.1}_{-0.8}$
95% C.L. upper limit on σ_{BSM} [fb]	$1.4\ (1.7^{\uparrow 2.3}_{\downarrow 1.2})$	$1.2\ (1.5^{\uparrow 2.1}_{\downarrow 1.1})$	$0.33\ (0.42^{\uparrow 0.61}_{\downarrow 0.29})$	$0.35\ (0.41^{\uparrow 0.60}_{\downarrow 0.29})$





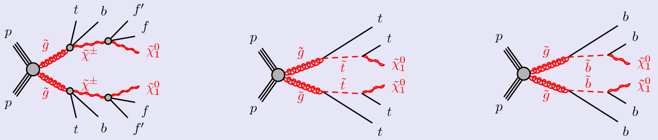
see also poster by E. Torro

0- or 1-lepton + 3 b-jets

ATLAS-CONF-2013-061

Analysis specialised to search for stop and sbottom quarks produced in gluino decays, for example $\tilde{g} \rightarrow \tilde{b}b$ or $\tilde{g} \rightarrow \tilde{t}t$

Example diagrams



complementary signal regions optimised for many b-jets in the final state

Baseline selection: p_{T}(leading jet) > 90 GeV, $E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV, at least 3 b-jets

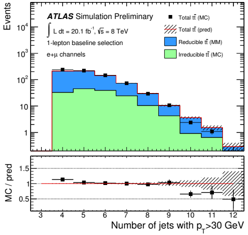
- **0-lepton + $\geq$ 4 jets:** $E_{\mathrm{T}}^{\mathrm{miss}} > 200$, 350 or 250 GeV, $m_{\mathrm{eff}}^{4\mathrm{j}} > 1000$, 1100 or 1300 GeV, $\Delta\phi_{\mathrm{min}}^{4\mathrm{j}} > 0.5$, $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}^{4\mathrm{j}} > 0.2$ (in total 3 signal regions)
- **0-lepton +$\geq$ 7 jets:** $E_{\mathrm{T}}^{\mathrm{miss}} > 200$, 350 or 250 GeV, $m_{\mathrm{eff}}^{4\mathrm{j}} > 1000$, 1000 or 1500 GeV, $\Delta\phi_{\mathrm{min}}^{4\mathrm{j}} > 0.5$, $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}^{4\mathrm{j}} > 0.2$ (in total 3 signal regions)
- **$\geq$ 1-lepton +$\geq$ 6 jets:** $E_{\mathrm{T}}^{\mathrm{miss}} > 175$, 225 or 275 GeV, $m_{\mathrm{T}} > 140$, 140 or 160 GeV, $m_{\mathrm{eff}}^{4\mathrm{j}} > 700$, 800 or 900 GeV, $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_T^{\mathrm{incl}}} > 5\sqrt{\mathrm{GeV}}$ (in total 3 signal regions)

0- or 1-lepton + 3 b-jets

Backgrounds

- **Irreducible:** $t\bar{t}$+b, $t\bar{t}$+ $b\bar{b}$, $t\bar{t}$+ Z/h with $Z/h \rightarrow b\bar{b}$; taken from MC
- **Reducible:** background events without 3 real b-jets, e.g. $t\bar{t}$ production in association with light jets, single t, W+jets, Z+jets, dibosons

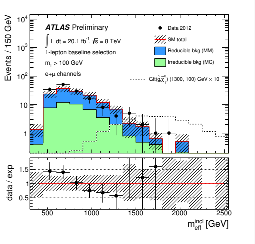
  $\rightarrow$ estimated by a *matrix method based on the number of b-jets* in the event



(matrix method closure test)

Background estimates in the signal regions

region	reducible bkg	irreducible bkg	total bkg (MC)	data
SR-0l-4j-A	2.2 ± 1.1	0.8 ± 0.7	3.0 ± 1.3 (5.1)	2
SR-0l-4j-B	0.8 ± 0.9	0.5 ± 0.5	1.3 ± 1.0 (3.9)	3
SR-0l-4j-C	1.2 ± 0.8	0.6 ± 0.6	1.8 ± 1.0 (2.5)	2
SR-0l-7j-A	15.5 ± 3.4	7.0 ± 6.0	22.5 ± 6.9 (28.8)	22
SR-0l-7j-B	2.3 ± 2.3	1.3 ± 1.1	3.6 ± 2.5 (6.2)	3
SR-0l-7j-C	$0 \pm 0.5^{+0.5}_{-0}$	0.8 ± 0.7	$0.8 \pm ^{+0.9}_{-0.8}$ (3.1)	1
SR-1l-6j-A	$10.7\ ^{+7.5}_{-6.8}$	4.8 ± 3.7	15.5 ± 8.4 (13.8)	7
SR-1l-6j-B	5.7 ± 5.5	1.7 ± 1.4	7.4 ± 5.7 (6.3)	0
SR-1l-6j-C	$2.4\ ^{+2.7}_{-2.4}$	$0.6\ ^{+0.6}_{-0.5}$	3.0 ± 2.8 (2.6)	0

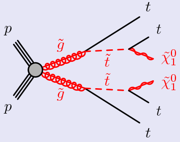


Good agreement between background estimation and observed data. Tightest limit on the visible cross section in the 1-lepton + 6 jets SRs: 0.15 fb

2-leptons same-sign

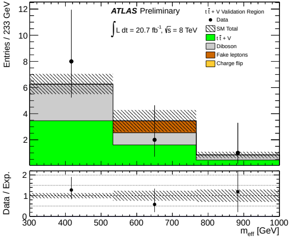
ATLAS-CONF-2013-007

- Production of same-sign lepton pairs (focus here on *ee*, $e\mu$ and $\mu\mu$) rare in the SM
- Several production possibilities in SUSY decay chains, e.g. in $\tilde{g} \rightarrow t\tilde{t} \rightarrow tt\tilde{\chi}_1^0$



Due to rareness of same-sign events in SM processes low background expectation:

- **prompt same-sign lepton pairs** with two real same-sign leptons:
  $t\bar{t}$+ vector boson, dibosons; estimated by using the MC prediction and validated in validation regions
- **fake lepton background - at least one of the selected leptons is misidentified:**
  mostly semi-leptonic $t\bar{t}$ events; estimated by a matrix method
- **charge mis-identification:**
  emission of hard bremsstrahlung followed by an asymmetric conversion ($e^{\pm} \rightarrow e^{\pm}\gamma \rightarrow e^{\pm}e^{\pm}e^{\mp}$)
  only for events with electrons; mostly di-leptonic $t\bar{t}$ events; estimated by determining the ratio between same-sign and opposite-sign electron pairs in Drell-Yan events and applying this ratio to regions similar to the SRs, but containing opposite-sign events



(m_{eff} distribution in the $t\bar{t}$+V validation region)

See poster by O. Ducu

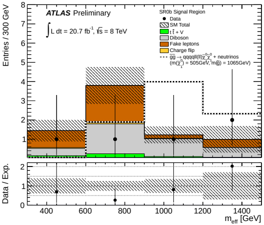
2-leptons same-sign signal regions

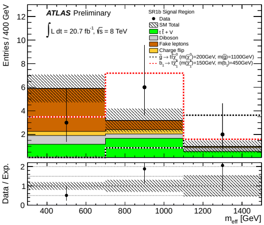
Signal region	N_{b-jets}	Signal cuts (discovery case)	Signal cuts (exclusion case)
SR0b	0	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV $m_T > 100$ GeV, $m_{eff} > 400$ GeV	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV, $m_T > 100$ GeV, binned shape fit in m_{eff} for $m_{eff} > 300$ GeV
SR1b	≥ 1	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV $m_T > 100$ GeV, $m_{eff} > 700$ GeV	$N_{jets} \geq 3$, $E_T^{miss} > 150$ GeV, $m_T > 100$ GeV, binned shape fit in m_{eff} for $m_{eff} > 300$ GeV
SR3b	≥ 3	$N_{jets} \geq 4$ -	$N_{jets} \geq 5$, $E_T^{miss} < 150$ GeV or $m_T < 100$ GeV

→ gluino or squark pair production and no b-jets in the final state

→ final states with b-jets

→ compressed scenarios with large b-jet multiplicity and small E_T^{miss}





Background estimate in good agreement with data in all regions; strongest model independent upper limit on the visible cross section in SR0b (discovery case): 0.33 fb

Results in exclusion signal regions

B) Exclusion case	SR0b	SR1b	SR3b
Observed events	5	11	1
Expected background events	7.5 ± 3.2	10.1 ± 3.9	1.8 ± 1.3
Expected $t\bar{t}+V$ events	0.5 ± 0.4	3.4 ± 1.5	0.6 ± 0.4
Expected diboson events	3.4 ± 1.1	1.4 ± 0.7	< 0.1
Expected fake lepton events	3.4 ± 2.9	4.4 ± 3.1	1.0 ± 1.1
Expected charge mis-measurement events	0.2 ± 0.1	0.8 ± 0.3	0.1 ± 0.1

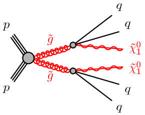
Interpretation

Interpretation summary

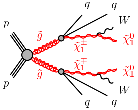
The various analyses are interpreted in multiple models:

Simplified models

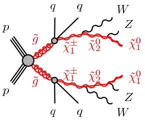
direct:
$\tilde{g} \rightarrow qq\tilde{\chi}_1^0$ or $\tilde{q} \rightarrow q\tilde{\chi}_1^0$
▶ **Analysis:** 0-lepton+2-6 jets



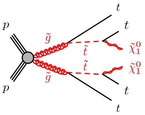
via one step:
$\tilde{g} \rightarrow qqW\tilde{\chi}_1^0$ or $\tilde{q} \rightarrow qW\tilde{\chi}_1^0$
▶ **Analyses:**
0-lepton+2-6 jets,
0-lepton multi-jet, one hard and soft lepton, 2-lepton Razor



via two steps:
$\tilde{g} \rightarrow qqWZ\tilde{\chi}_1^0$
$\tilde{g} \rightarrow qq(ll/l\nu/\nu\nu)\tilde{\chi}_1^0$ or
$\tilde{q} \rightarrow q(ll/l\nu/\nu\nu)\tilde{\chi}_1^0$
▶ **Analyses:**
0-lepton+2-6 jets,
0-lepton multi-jet, one hard lepton, 2-lepton Razor,
2-lepton same-sign



gluino mediated stop or sbottom production:
$\tilde{g} \rightarrow tt\tilde{\chi}_1^0$
▶ **Analysis:** 0-lepton multi-jet,
0- or 1-lepton + 3 b-jets,
2-lepton same-sign



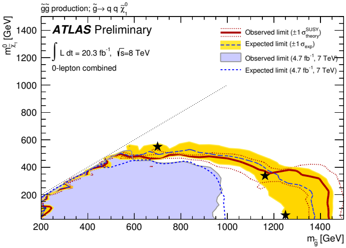
MSUGRA

$\tan\beta = 30$, $A_0 = -2m_0$ and $\mu > 0$
▶ **Analyses:** 0-lepton+2-6 jets, 0-lepton multi-jet, one hard lepton, 0- or 1-lepton + 3 b-jets, 2-lepton same-sign

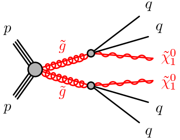
+ further models (pMSSM, mUED,...)

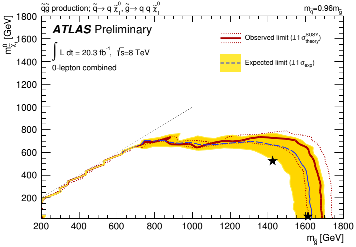
Direct decay of gluinos/squarks

Limits by the 0-lepton+2-6 jets analysis

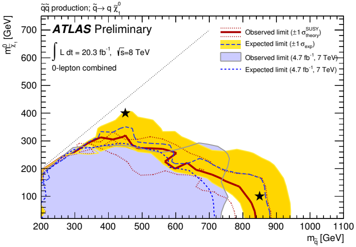


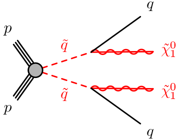
gluino pair-production





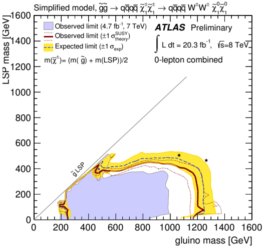
gluino-squark production



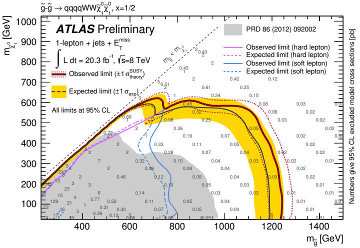


squark pair-production

Decay of gluinos via an intermediate chargino

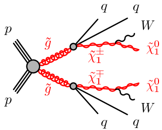


0-lepton+2-6 jets

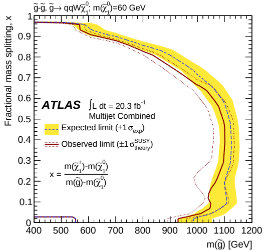


one soft and hard lepton analyses combined

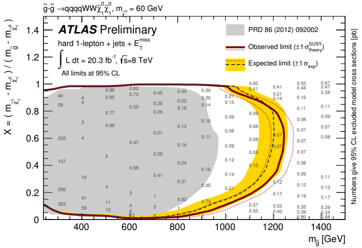
gluino masses up to 700 GeV excluded for nearly all allowed neutralino masses (if neutralino-gluino mass difference larger than 25 GeV)



gluino masses up to 1.18 TeV excluded for small neutralino masses

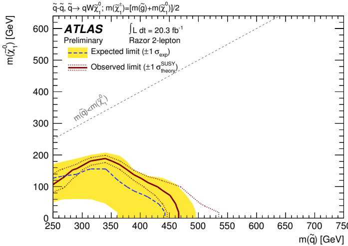


0-lepton multi-jet

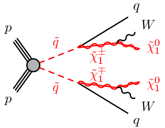


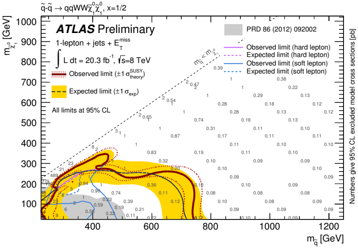
one hard lepton analysis

Decay of squarks via an intermediate chargino

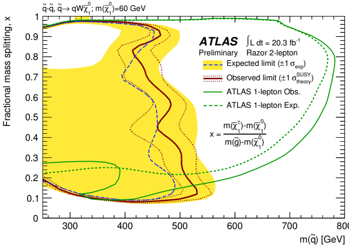


2-lepton Razor

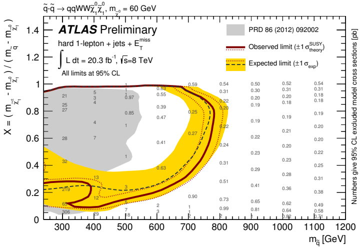




one soft and hard lepton analyses combined

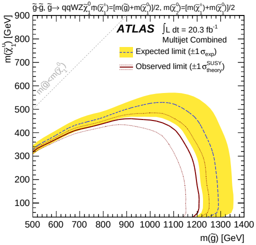


strongest limit
$\sim$ 700 GeV on the
squark mass

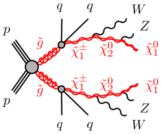


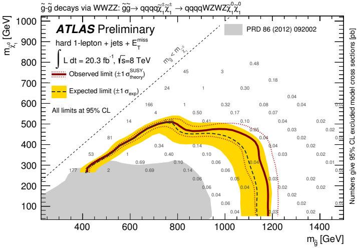
one hard lepton analysis

Decay of gluinos/squarks via two steps

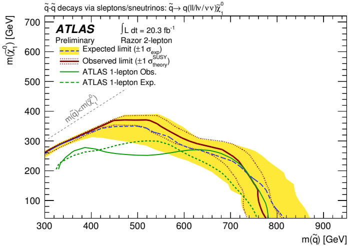


0-lepton + multi-jets

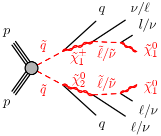


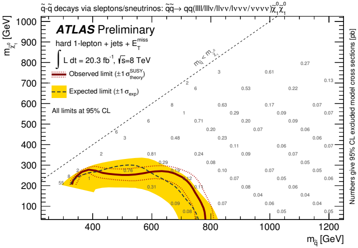


one hard lepton analysis



2-lepton Razor

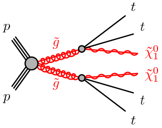




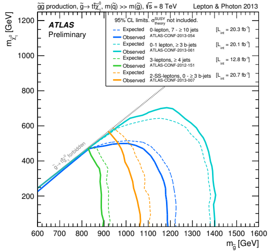
Gluino mediated stop quark production

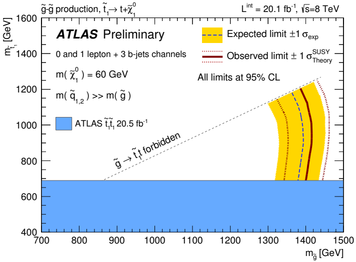
Gluino masses up to ∼ 1350 GeV excluded

Limits on stop masses can reach as high as ∼ 1150 GeV

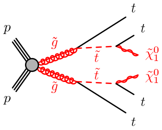


(stop off-shell)

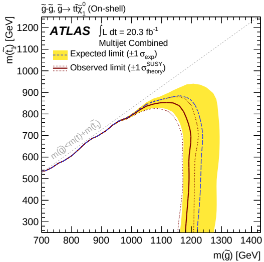




0- or 1-lepton + 3 b-jets

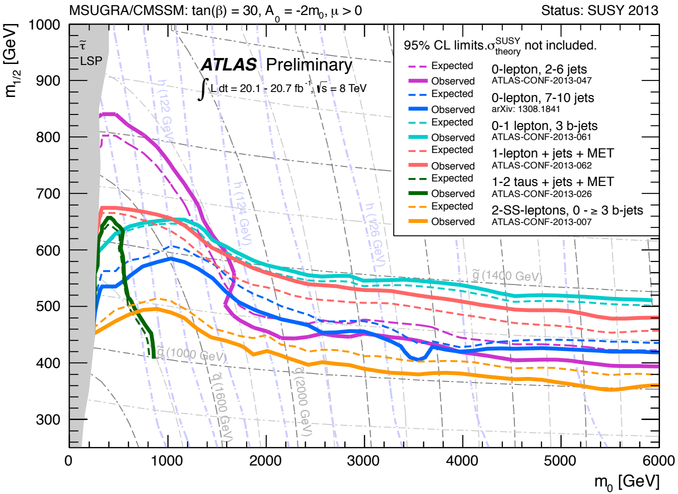


(stop on-shell)



0-lepton multi-jets

“Higgs aware” MSUGRA



gluino masses up to ∼ 1.3 TeV excluded for any m_0

Summary

Presented some very powerful analyses to look for SUSY produced in strong production

No significant excess above SM expectations has been seen.

Limits are placed on the gluino mass (up to $\sim$ 1.3 TeV, depending on model) and on the squark masses (up to $\sim$ 700 GeV, depending on model).

Model independent upper limits on the visible cross section have been derived and can be as low as 0.15 fb (depending on the analysis).

All results can be found on this webpage, summarising all public ATLAS SUSY results.

Additional material

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

$\int \mathcal{L}\, dt = (4.6 - 22.9)\ \text{fb}^{-1}$ $\sqrt{s}$ = 7, 8 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [\text{fb}^{-1}]$	Mass limit			Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	$\tan\beta$<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	$\tan\beta$ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$	1.07 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$	619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	$m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	275-430 GeV	$m(\tilde{\chi}_1^\pm)=2\ m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV	$m(\tilde{\chi}_1^0)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	130-220 GeV	$m(\tilde{\chi}_1^0) = m(\tilde{t}_1)-m(W)$-50 GeV, $m(\tilde{t}_1)<<m(\tilde{\chi}_1^\pm)$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e, μ	2 jets	Yes	20.3	$\tilde{t}_1$	225-525 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-200 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$	500 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$	271-520 GeV	$m(\tilde{t}_1)=m(\tilde{\chi}_1^0)$+180 GeV	ATLAS-CONF-2013-025
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	$\tilde{\ell}$	85-315 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	125-450 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell}, \tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	180-330 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau}, \tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	600 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell}, \tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	315 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e, μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	285 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-093
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, $\tau(\tilde{\chi}_1^\pm)$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$	832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e}, \tilde{\mu})+\tau(e, \mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<$\tan\beta$<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}, \tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}_1^0)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e + \mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e(\mu) + \tau$	1 $e, \mu + \tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e, μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$	1.2 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	760 GeV	$m(\tilde{\chi}_1^0)$>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.7	$\tilde{\chi}_1^\pm$	350 GeV	$m(\tilde{\chi}_1^0)$>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e, μ (SS)	1 b	Yes	14.3	sgluon	800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

10^{-1} 1 **Mass scale [TeV]**

$\sqrt{s}$ = 7 TeV full data | $\sqrt{s}$ = 8 TeV partial data | $\sqrt{s}$ = 8 TeV full data

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Detailed results of the 0-lepton + 2-6 jets analysis (I)

Signal Region	**A-loose**	**A-medium**	**B-medium**	**B-tight**	**C-medium**	**C-tight**
			MC expected events			
Diboson	428.6	15.0	4.3	0.0	25.5	0.0
Z/γ^*+jets	2044.4	83.1	20.6	2.3	119.4	2.6
W+jets	2109.0	58.8	16.4	2.1	88.7	1.0
$t\bar{t}$(+EW) + single top	785.9	8.2	2.0	0.3	45.9	0.3
			Fitted background events			
Diboson	430 ± 190	15 ± 7	4.3 ± 2.0	–	26 ± 11	–
Z/γ^*+jets	1870 ± 320	57 ± 11	16 ± 5	0.2 ± 0.5	80 ± 29	$0.0^{+0.6}_{-0.0}$
W+jets	1540 ± 260	42 ± 11	10 ± 4	1.6 ± 1.2	55 ± 18	0.7 ± 0.9
$t\bar{t}$(+EW) + single top	870 ± 180	7.8 ± 2.8	2.2 ± 2.0	0.6 ± 0.7	50 ± 11	0.9 ± 0.9
Multi-jets	33 ± 33	–	0.1 ± 0.1	–	–	–
Total bkg	4700 ± 500	122 ± 18	33 ± 7	2.4 ± 1.4	210 ± 40	1.6 ± 1.4
Observed	5333	135	29	4	228	0
$\langle\epsilon\sigma\rangle^{95}_{\mathrm{obs}}$[fb]	66.07	2.52	0.73	0.33	4.00	0.12
S^{95}_{obs}	1341.2	51.3	14.9	6.7	81.2	2.4
S^{95}_{exp}	$1135.0^{+332.7}_{-291.5}$	$42.7^{+15.5}_{-11.4}$	$17.0^{+6.6}_{-4.6}$	$5.8^{+2.9}_{-1.8}$	$72.9^{+23.6}_{-18.0}$	$3.3^{+2.1}_{-1.2}$
p_0 (Z_n)	0.45 (0.1)	0.27 (0.6)	0.50 (0.0)	0.34 (0.4)	0.34 (0.4)	0.50 (0.0)

Detailed results of the 0-lepton + 2-6 jets analysis (II)

Signal Region	**D**	**E-loose**	**E-medium**	**E-tight**
MC expected events				
Diboson	2.0	5.5	1.7	0.0
Z/γ^*+jets	8.5	19.6	6.3	1.9
W+jets	4.8	23.1	5.2	0.8
$t\bar{t}$(+EW) + single top	5.0	67.3	16.8	1.5
Fitted background events				
Diboson	2.0 ± 2.0	5.5 ± 2.1	1.7 ± 0.8	–
Z/γ^*+jets	3.8 ± 2.5	12 ± 7	2.9 ± 2.6	0.4 ± 0.6
W+jets	3.3 ± 2.5	18 ± 7	4.9 ± 2.7	0.7 ± 0.5
$t\bar{t}$(+EW) + single top	5.8 ± 2.1	76 ± 19	20 ± 6	1.7 ± 1.4
Multi-jets	–	1.0 ± 1.0	–	–
Total bkg	15 ± 5	113 ± 21	30 ± 8	2.9 ± 1.8
Observed	18	166	41	5
$\langle\epsilon\sigma\rangle^{95}_{\mathrm{obs}}$[fb]	0.77	4.55	1.41	0.41
S^{95}_{obs}	15.5	92.4	28.6	8.3
S^{95}_{exp}	$13.6^{+5.1}_{-3.5}$	$57.3^{+20.0}_{-14.4}$	$21.4^{+7.6}_{-5.8}$	$6.5^{+3.0}_{-1.9}$
p_0 (Z_n)	0.32 (0.5)	0.03 (1.9)	0.14 (1.1)	0.22 (0.8)

Signal region definitions of the 0-lepton+multi-jet analysis

<table>
<tr><th></th><th colspan="13">Multi-jet + flavour stream</th><th colspan="3">Multi-jet + M_J^Σ stream</th></tr>
<tr><td>Identifier</td><td colspan="3">8j50</td><td colspan="3">9j50</td><td>$\geq$ 10j50</td><td colspan="3">7j80</td><td colspan="3">$\geq$ 8j80</td><td>$\geq$ 8j50</td><td>$\geq$ 9j50</td><td>$\geq$ 10j50</td></tr>
<tr><td>Jet $|\eta|$</td><td colspan="7">< 2.0</td><td colspan="6">< 2.0</td><td colspan="3">< 2.8</td></tr>
<tr><td>Jet p_T</td><td colspan="7">> 50 GeV</td><td colspan="6">> 80 GeV</td><td colspan="3">> 50 GeV</td></tr>
<tr><td>Jet count</td><td colspan="3">$= 8$</td><td colspan="3">$= 9$</td><td>≥ 10</td><td colspan="3">$= 7$</td><td colspan="3">≥ 8</td><td>≥ 8</td><td>≥ 9</td><td>≥ 10</td></tr>
<tr><td>b-jets
($p_T > 40$ GeV, $|\eta| < 2.5$)</td><td>0</td><td>1</td><td>≥ 2</td><td>0</td><td>1</td><td>≥ 2</td><td>—</td><td>0</td><td>1</td><td>≥ 2</td><td>0</td><td>1</td><td>≥ 2</td><td colspan="3">—</td></tr>
<tr><td>M_J^Σ [GeV]</td><td colspan="7">—</td><td colspan="6">—</td><td colspan="3">> 340 and > 420 for each case</td></tr>
<tr><td>$E_T^{miss}/\sqrt{H_T}$</td><td colspan="7">> 4 GeV$^{1/2}$</td><td colspan="6">> 4 GeV$^{1/2}$</td><td colspan="3">> 4 GeV$^{1/2}$</td></tr>
</table>

Table 1: Definition of the nineteen signal regions. The jet $|\eta|$, p_T and multiplicity all refer to the $R = 0.4$ jets. Composite jets with the larger radius parameter $R = 1.0$ are used in the multi-jet + M_J^Σ stream when constructing M_J^Σ. A long dash '—' indicates that no requirement is made.

Detailed results of the 0-lepton+multi-jet analysis

Signal region	8j50			9j50			10j50
b-jets	0	1	≥ 2	0	1	≥ 2	—
Observed events	40	44	44	5	8	7	3
Total events after fit	35 ± 4	40 ± 10	50 ± 10	3.3 ± 0.7	6.1 ± 1.7	8.0 ± 2.7	1.37 ± 0.35
Fitted $t\bar{t}$	2.7 ± 0.9	11.8 ± 3.0	23.0 ± 5.0	0.36 ± 0.18	1.5 ± 0.5	3.2 ± 1.1	$0.06^{+0.09}_{-0.06}$
Fitted W+jets	$2.0^{+2.6}_{-2.0}$	$0.62^{+0.81}_{-0.62}$	$0.20^{+0.28}_{-0.20}$	–	$0.24^{+0.65}_{-0.24}$	–	–
Fitted others	$2.9^{+1.8}_{-1.8}$	$1.7^{+1.5}_{-1.2}$	$2.8^{+2.3}_{-2.0}$	0.03 ± 0.03	0.38 ± 0.25	$0.40^{+0.60}_{-0.24}$	0.08 ± 0.08
Total events before fit	36	48	59	3.4	6.6	8.9	1.39
$t\bar{t}$ before fit	3.5	15	30	0.41	1.8	4	0.08
W+jets before fit	2.9	1.0	0.29	–	0.40	–	–
Others before fit	2.4	1.8	2.8	0.03	0.34	0.4	0.08
Multi-jets	27 ± 3	30 ± 10	26 ± 10	3.0 ± 0.6	4.0 ± 1.4	4.4 ± 2.2	1.23 ± 0.32
$N^{95\%}_{\mathrm{BSM}}$ (exp)	16	23	26	5	7	8	4
$N^{95\%}_{\mathrm{BSM}}$ (obs)	20	23	22	7	9	7	6
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (exp) [fb]	0.8	1.2	1.3	0.26	0.36	0.40	0.19
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (obs) [fb]	0.97	1.1	1.1	0.34	0.43	0.37	0.29
p_0	0.24	0.5	0.7	0.21	0.28	0.6	0.13
Significance (σ)	0.7	-0.02	-0.6	0.8	0.6	-0.28	1.14

Table 4: Number of observed and expected (fitted) events for the seven $p_{\mathrm{T}}^{\mathrm{min}} = 50$ GeV signal regions of the multi-jet + flavour stream. The category indicated by 'others' includes the contributions from $Z+$jets, $t\bar{t}+W$, $t\bar{t}+Z$, and single top. The table also contains for each signal region the probability, p_0, that a background-only pseudo-experiment is more signal-like than the observed data; the significance, σ, of the agreement between data and the Standard Model prediction; the 95% CL upper limit on the number of events, $N^{95\%}_{\mathrm{BSM}}$, originating from sources other than the Standard Model; and the corresponding cross section times acceptance times efficiency, $\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$.

Detailed results of the 0-lepton+multi-jet analysis

Signal region	7j80			8j80		
b-jets	0	1	≥ 2	0	1	≥ 2
Observed events	12	17	13	2	1	3
Total fitted events	11.0 ± 2.2	17 ± 6	25 ± 10	0.9 ± 0.6	1.5 ± 0.9	3.3 ± 2.2
Fitted $t\bar{t}$	$0.00^{+0.26}_{-0.00}$	5.0 ± 4.0	12 ± 9	$0.10^{+0.14}_{-0.10}$	$0.32^{+0.67}_{-0.32}$	$1.5^{+1.9}_{-1.5}$
Fitted W+jets	$0.07^{+0.38}_{-0.07}$	$0.29^{+0.37}_{-0.29}$	–	–	–	–
Fitted others	$1.9^{+1.1}_{-0.9}$	$0.71^{+0.31}_{-0.25}$	$2.6^{+1.7}_{-1.1}$	0.02 ± 0.02	0.02 ± 0.02	$0.32^{+0.36}_{-0.21}$
Total events before fit	11.7	16	23	0.8	1.8	3.3
$t\bar{t}$ before fit	0.34	4	10	0.08	0.6	1.5
W+jets before fit	0.46	0.29	–	–	–	–
Others before fit	1.8	0.89	3.0	0.02	0.02	0.35
Multi-jets	9.1 ± 1.6	11 ± 4	10 ± 4	0.75 ± 0.56	1.2 ± 0.5	1.4 ± 1.0
N^{95}_{BSM} (exp)	10	17	14	4	4	6
N^{95}_{BSM} (obs)	10	16	12	5	3.5	6
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (exp) [fb]	0.5	0.8	0.7	0.18	0.18	0.31
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (obs) [fb]	0.5	0.8	0.6	0.24	0.17	0.31
p_0	0.5	0.6	0.8	0.19	0.6	0.5
Significance (σ)	0.05	-0.14	-1.0	0.9	-0.28	-0.06

Table 5: As for table 4 but for the six signal regions for which $p_{\mathrm{T}}^{\mathrm{min}} = 80$ GeV.

Detailed results of the 0-lepton+multi-jet analysis

Signal region	8j50	
M_J^{Σ} [GeV]	340	420
Observed events	69	37
Total events after fit	75 ± 19	45 ± 14
Fitted $t\bar{t}$	17 ± 11	16 ± 13
Fitted W+jets	$0.8^{+1.3}_{-0.8}$	$0.4^{+0.7}_{-0.4}$
Fitted others	$5.2^{+4.0}_{-2.5}$	$2.8^{+2.9}_{-1.6}$
Total events before fit	85	44
$t\bar{t}$ before fit	27	14
W+jets before fit	0.8	0.4
Others before fit	5	2.8
Multi-jets	52 ± 15	27 ± 7
$N^{95\%}_{\mathrm{BSM}}$ (exp)	40	23
$N^{95\%}_{\mathrm{BSM}}$ (obs)	35	20
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (exp) [fb]	1.9	1.1
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (obs) [fb]	1.7	1.0
p_0	0.60	0.7
Significance (σ)	-0.27	-0.6

Table 6: As for table 4 but for the signal regions in the multi-jet + M_J^{Σ} stream for which the number of events in the control regions allowed background determination using a fit.

Detailed results in the hard single lepton signal regions (binned)

	binned hard single-lepton					
	3-jet		5-jet		6-jet	
	electron	muon	electron	muon	electron	muon
Observed events	45	28	12	7	7	7
Fitted background events	46.4 ± 8.0	38.1 ± 5.8	12.2 ± 5.2	7.1 ± 1.6	9.7 ± 2.0	7.4 ± 1.7
Fitted $t\bar{t}$ events	23.8 ± 6.4	20.0 ± 5.0	7.4 ± 3.3	5.6 ± 1.5	8.0 ± 1.9	5.6 ± 1.5
Fitted W+jets events	15.4 ± 5.5	10.7 ± 4.0	3.1 ± 2.2	0.4 ± 0.4	$0.1^{+0.2}_{-0.1}$	0.3 ± 0.3
Fitted diboson events	4.4 ± 2.3	3.3 ± 1.7	0.9 ± 0.6	0.4 ± 0.2	0.5 ± 0.3	0.06 ± 0.03
Fitted misidentified lepton events	$0.4^{+0.5}_{-0.4}$	$0.8^{+0.9}_{-0.8}$	$0.01^{+0.08}_{-0.01}$	$0.0^{+0.03}_{-0.0}$	$0.07^{+0.09}_{-0.07}$	$0.8^{+0.9}_{-0.8}$
Fitted other background events	2.3 ± 0.8	3.3 ± 1.1	0.7 ± 0.3	0.6 ± 0.2	1.0 ± 0.3	0.6 ± 0.1
MC expected SM events	54.8 ± 10.3	43.0 ± 7.1	14.1 ± 6.3	7.0 ± 1.6	10.1 ± 1.9	7.9 ± 1.7
MC expected $t\bar{t}$ events	23.3 ± 3.7	19.7 ± 2.6	7.1 ± 3.0	5.3 ± 1.2	8.4 ± 1.7	6.0 ± 1.3
MC expected W+jets events	24.4 ± 7.3	16.1 ± 5.1	5.3 ± 3.4	0.6 ± 0.5	0.2 ± 0.2	0.5 ± 0.5
MC expected diboson events	4.5 ± 2.3	3.4 ± 1.7	0.9 ± 0.6	0.4 ± 0.2	0.6 ± 0.3	0.07 ± 0.03
data-driven misidentified lepton events	$0.4^{+0.5}_{-0.4}$	$0.8^{+0.9}_{-0.8}$	$0.01^{+0.08}_{-0.01}$	$0.0^{+0.03}_{-0.0}$	$0.07^{+0.09}_{-0.07}$	$0.8^{+0.9}_{-0.8}$
MC expected other background events	2.1 ± 0.8	3.1 ± 1.2	0.8 ± 0.3	0.7 ± 0.2	1.0 ± 0.3	0.6 ± 0.2

Detailed results in the hard single lepton signal regions (tighter version)

	inclusive hard single-lepton					
	3-jet		5-jet		6-jet	
	electron	muon	electron	muon	electron	muon
Observed events	4	5	4	2	2	0
Fitted background events	3.9 ± 1.0	2.7 ± 0.9	3.6 ± 1.0	2.5 ± 0.8	2.0 ± 0.7	1.7 ± 0.6
Fitted $t\bar{t}$ events	1.4 ± 0.5	1.6 ± 0.5	2.7 ± 0.8	2.0 ± 0.7	1.3 ± 0.5	1.3 ± 0.5
Fitted W+jets events	0.9 ± 0.4	0.6 ± 0.5	0.11 ± 0.08	0.08 ± 0.08	0.00 ± 0.00	$0.07^{+0.15}_{-0.07}$
Fitted diboson events	0.8 ± 0.5	0.4 ± 0.2	0.7 ± 0.4	0.10 ± 0.05	0.06 ± 0.04	0.00 ± 0.00
Fitted misidentified lepton events	$0.15^{+0.17}_{-0.15}$	0.00 ± 0.02	0.00 ± 0.01	0.00 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
Fitted other background events	0.6 ± 0.3	0.09 ± 0.05	0.12 ± 0.07	0.3 ± 0.1	0.7 ± 0.3	0.3 ± 0.1
MC expected SM events	4.2 ± 1.1	2.9 ± 1.0	3.6 ± 0.9	2.4 ± 0.7	2.1 ± 0.8	1.9 ± 0.7
MC expected $t\bar{t}$ events	1.3 ± 0.4	1.5 ± 0.4	2.6 ± 0.7	1.9 ± 0.6	1.4 ± 0.5	1.4 ± 0.5
MC expected W+jets events	1.3 ± 0.5	0.9 ± 0.7	0.2 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	$0.1^{+0.2}_{-0.1}$
MC expected diboson events	0.8 ± 0.5	0.4 ± 0.2	0.7 ± 0.4	0.10 ± 0.05	0.07 ± 0.04	0.00 ± 0.00
data-driven misidentified lepton events	$0.15^{+0.17}_{-0.15}$	0.00 ± 0.02	0.00 ± 0.01	0.00 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
MC expected other background events	0.6 ± 0.3	0.09 ± 0.05	0.13 ± 0.07	0.3 ± 0.1	0.6 ± 0.3	0.3 ± 0.1

Detailed results in the soft lepton signal regions

	soft single-lepton 3-jet	5-jet	soft dimuon 2-jet
Observed events	7	9	7
Fitted background events	5.6 ± 1.6	14.8 ± 3.7	1.6 ± 1.0
Fitted $t\bar{t}$ events	1.3 ± 1.0	7.8 ± 3.3	1.2 ± 1.0
Fitted W+jets events	2.6 ± 0.7	2.1 ± 0.9	-
Fitted diboson events	0.6 ± 0.4	0.7 ± 0.4	0.4 ± 0.3
Fitted misidentified lepton events	$0.00^{+0.05}_{-0.00}$	3.3 ± 1.4	$0.0^{+0.3}_{-0.0}$
Fitted other background events	1.1 ± 0.5	0.9 ± 0.5	$0.01^{+0.06}_{-0.01}$
MC expected SM events	6.3 ± 1.9	15.9 ± 3.8	1.9 ± 1.2
MC expected $t\bar{t}$ events	1.4 ± 1.1	7.8 ± 3.0	1.5 ± 1.2
MC expected W+jets events	3.1 ± 0.9	3.2 ± 0.9	-
MC expected diboson events	0.6 ± 0.4	0.7 ± 0.4	0.4 ± 0.3
data-driven misidentified lepton events	$0.00^{+0.05}_{-0.00}$	3.3 ± 1.4	$0.0^{+0.3}_{-0.0}$
MC expected other background events	1.1 ± 0.6	0.9 ± 0.4	$0.01^{+0.06}_{-0.01}$

Upper limits for the one lepton analyses

Signal channel	$\langle \epsilon \sigma \rangle^{95}_{obs}$ [fb]	S^{95}_{obs}	S^{95}_{exp}	CL_B	$p(s=0)$
soft single-lepton one *b*-jet channels					
low-mass	0.43 (0.42)	8.8 (8.6)	$6.9^{+3.0}_{-2.0}$ $(6.9^{+3.4}_{-2.1})$	0.76 (0.71)	0.26 (0.27)
high-mass	0.39 (0.38)	7.9 (7.7)	$6.3^{+1.9}_{-1.1}$ $(5.9^{+3.0}_{-1.9})$	0.79 (0.75)	0.21 (0.22)
soft single-lepton two *b*-jet channels					
low-mass	0.66 (0.62)	13.4 (12.7)	$13.2^{+5.9}_{-4.1}$ $(13.1^{+5.6}_{-3.8})$	0.52 (0.46)	0.50 (0.50)
high-mass	0.26 (0.24)	5.3 (4.9)	$5.3^{+2.4}_{-1.4}$ $(5.5^{+2.8}_{-1.8})$	0.50 (0.40)	0.50 (0.50)
soft single-lepton channels					
3-jet	0.40 (0.39)	8.1 (8.1)	$7.3^{+2.7}_{-1.8}$ $(6.8^{+3.3}_{-2.1})$	0.67 (0.66)	0.36 (0.31)
5-jet	0.35 (0.33)	7.1 (6.8)	$10.0^{+3.6}_{-3.0}$ $(9.8^{+4.2}_{-2.9})$	0.15 (0.15)	0.50 (0.50)
soft dimuon channel	0.57 (0.54)	11.5 (11.1)	$5.9^{+2.1}_{-1.0}$ $(6.5^{+3.1}_{-1.9})$	0.98 (0.92)	0.01 (0.02)
binned hard single-lepton channels					
3-jet (electron)	0.97 (0.98)	19.8 (19.9)	$20.2^{+8.3}_{-4.8}$ $(20.7^{+7.9}_{-5.6})$	0.47 (0.45)	0.50 (0.50)
3-jet (muon)	0.57 (0.52)	11.6 (10.6)	$15.6^{+5.8}_{-3.8}$ $(15.8^{+6.5}_{-4.4})$	0.13 (0.12)	0.50 (0.50)
5-jet (electron)	0.63 (0.60)	12.7 (12.1)	$12.6^{+3.2}_{-2.7}$ $(12.2^{+4.5}_{-3.2})$	0.50 (0.49)	0.50 (0.50)
5-jet (muon)	0.38 (0.36)	7.7 (7.2)	$7.6^{+2.8}_{-2.4}$ $(7.3^{+3.4}_{-2.2})$	0.53 (0.49)	0.50 (0.50)
6-jet (electron)	0.33 (0.34)	6.6 (6.8)	$7.8^{+3.1}_{-2.4}$ $(7.7^{+3.6}_{-2.4})$	0.32 (0.37)	0.50 (0.50)
6-jet (muon)	0.35 (0.35)	7.1 (7.1)	$7.1^{+3.4}_{-1.4}$ $(7.4^{+3.5}_{-2.3})$	0.50 (0.46)	0.50 (0.50)
inclusive hard single-lepton channels					
3-jet (electron)	0.30 (0.28)	6.0 (5.7)	$5.7^{+2.2}_{-1.5}$ $(5.6^{+2.9}_{-1.8})$	0.56 (0.51)	0.48 (0.48)
3-jet (muon)	0.38 (0.37)	7.7 (7.5)	$5.1^{+2.0}_{-1.5}$ $(5.1^{+2.7}_{-1.7})$	0.89 (0.82)	0.13 (0.13)
5-jet (electron)	0.30 (0.29)	6.0 (5.9)	$5.4^{+2.3}_{-1.5}$ $(5.5^{+2.9}_{-1.7})$	0.60 (0.56)	0.43 (0.43)
5-jet (muon)	0.22 (0.21)	4.6 (4.2)	$4.7^{+1.9}_{-1.2}$ $(4.7^{+2.5}_{-1.6})$	0.44 (0.41)	0.50 (0.50)
6-jet (electron)	0.23 (0.22)	4.6 (4.4)	$4.4^{+1.9}_{-0.8}$ $(4.4^{+2.5}_{-1.5})$	0.56 (0.49)	0.50 (0.50)
6-jet (muon)	0.15 (0.12)	3.0 (2.5)	$4.1^{+1.3}_{-1.1}$ $(3.8^{+2.3}_{-1.3})$	0.13 (0.16)	0.50 (0.50)

Detailed results of the 2-lepton Razor analysis

channel	$ee/\mu\mu$ SR1	$e\mu$ SR1	$ee/\mu\mu$ SR2	$e\mu$ SR2
Observed events	102	87	8	8
Fitted bkg events	116.6 ± 16	102.5 ± 15	11.0 ± 2.8	10.1 ± 2.7
Fitted DibosonWW events	31.5 ± 8.3	28.1 ± 7.3	0.9 ± 0.3	0.44 ± 0.15
Fitted ZX events	6.8 ± 1.5	3.6 ± 0.3	0.57 ± 0.14	0.22 ± 0.06
Fitted Top events	65.6 ± 11.4	55.0 ± 9.8	8.9 ± 2.4	8.6 ± 2.4
Fitted reducible bkg. events	12.8 ± 6.6	15.8 ± 7.5	$0.7^{+1.0}_{-0.7}$	$0.8^{+1.1}_{-0.8}$
MC exp. SM events	115	101	12.8	10.4
MC exp. DibosonWW events	29.1	25.9	0.8	0.5
MC exp. ZX events	8.2	3.5	0.7	0.19
MC exp. Top events	65	56	10.6	8.9
Exp. reducible bkg events	12.8	15.8	0.7	0.8
95% C.L. upper limit on N_{BSM}	$28\ (35^{\uparrow 48}_{\downarrow 25})$	$24\ (31^{\uparrow 43}_{\downarrow 23})$	$6.7\ (8.5^{\uparrow 12.4}_{\downarrow 6.0})$	$7.1\ (8.4^{\uparrow 12.2}_{\downarrow 5.9})$
95% C.L. upper limit on σ_{BSM} [fb]	$1.4\ (1.7^{\uparrow 2.3}_{\downarrow 1.2})$	$1.2\ (1.5^{\uparrow 2.1}_{\downarrow 1.1})$	$0.33\ (0.42^{\uparrow 0.61}_{\downarrow 0.29})$	$0.35\ (0.41^{\uparrow 0.60}_{\downarrow 0.29})$
p_0-value (Gauss. σ)	0.76 (−0.70)	0.80 (−0.86)	0.77 (−0.75)	0.69 (−0.49)

Detailed results of the 2-lepton Razor analysis - opposite-lepton flavour signal regions

channel	OS $ee/\mu\mu$ SR1	OS $e\mu$ SR1	OS $ee/\mu\mu$ SR2	OS $e\mu$ SR2
Observed events	91	81	7	8
Fitted bkg events	112 ± 16	92 ± 13	10.3 ± 2.6	9.8 ± 2.7
Fitted DibosonWW events	31.4 ± 8.4	28.0 ± 7.2	0.89 ± 0.25	0.45 ± 0.14
Fitted ZX events	5.1 ± 1.1	1.90 ± 0.15	0.44 ± 0.10	0.10 ± 0.03
Fitted Top events	64 ± 11	53.2 ± 9.5	8.6 ± 2.4	8.4 ± 2.3
Fitted reducible bkg. events	11.4 ± 6.1	8.9 ± 5.1	$0.4^{+0.7}_{-0.4}$	$0.8^{+1.1}_{-0.8}$
MC exp. SM events	109	90	11.9	10.1
MC exp. DibosonWW events	29.0	25.8	0.84	0.45
MC exp. ZX events	6.3	1.84	0.54	0.10
MC exp. Top events	62	54	10.2	8.7
Exp. reducible bkg. events	11.4	8.9	0.4	0.8
95% C.L. upper limit on N_{BSM}	$24\ (33^{\uparrow 45}_{\downarrow 24})$	$25\ (30^{\uparrow 41}_{\downarrow 22})$	$6.1\ (8.2^{\uparrow 11.9}_{\downarrow 5.7})$	$7.3\ (8.3^{\uparrow 12.1}_{\downarrow 5.8})$
95% C.L. upper limit on σ_{BSM} [fb]	$1.2\ (1.6^{\uparrow 2.2}_{\downarrow 1.2})$	$1.2\ (1.5^{\uparrow 2.0}_{\downarrow 1.0})$	$0.30\ (0.40^{\uparrow 0.59}_{\downarrow 0.28})$	$0.36\ (0.41^{\uparrow 0.59}_{\downarrow 0.29})$
p_0-value (Gauss. σ)	$0.86\ (-1.1)$	$0.73\ (-0.60)$	$0.81\ (-0.88)$	$0.66\ (-0.42)$

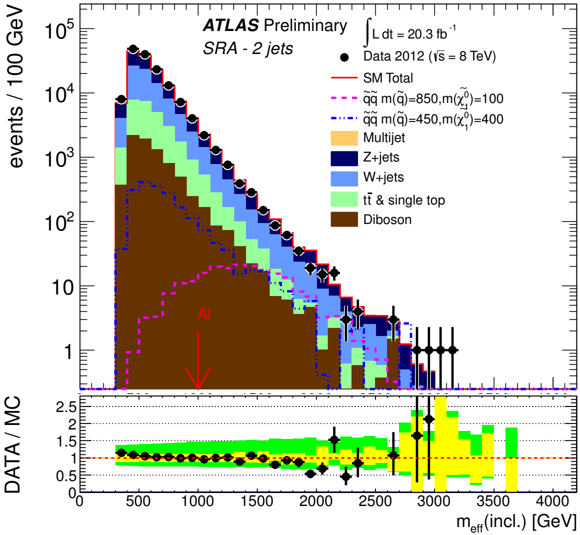
Detailed results of the 2-lepton Razor analysis -tighter signal regions

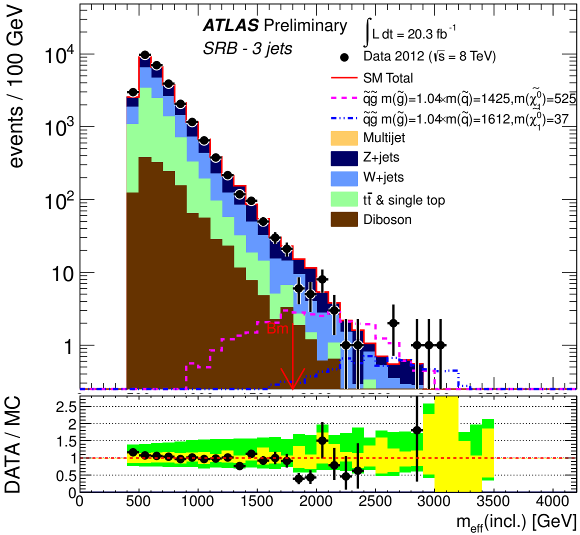
channel	$ee/\mu\mu$ DR	$e\mu$ DR
Observed events	17	12
Fitted bkg events	17.3 ± 2.6	17.8 ± 3.2
Fitted DibosonWW events	5.9 ± 1.3	5.8 ± 1.5
Fitted ZX events	1.52 ± 0.30	0.76 ± 0.11
Fitted Top events	7.7 ± 1.5	7.6 ± 1.7
Fitted reducible bkg. events	1.2 ± 1.2	2.6 ± 1.7
MC exp. SM events	17.6	17.3
MC exp. DibosonWW events	5.6	5.4
MC exp. ZX events	1.83	0.78
MC exp. Top events	7.96	7.6
Exp. reducible bkg events	1.2	2.6
95% C.L. upper limit on N_{BSM}	$11.0\ (10.4^{\uparrow 15.1}_{\downarrow 7.3})$	$7.6\ (10.4^{\uparrow 15.0}_{\downarrow 7.3})$
95% C.L. upper limit on σ_{BSM} [fb]	$0.54\ (0.51^{\uparrow 0.74}_{\downarrow 0.36})$	$0.37\ (0.51^{\uparrow 0.74}_{\downarrow 0.36})$
p_0-value (Gauss. σ)	0.44 (0.16)	0.84 (−0.98)

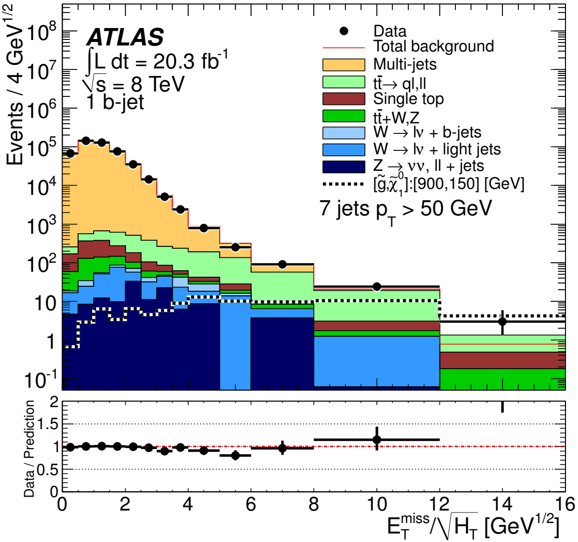
Observed numbers of events and predictions from the fit to the SM backgrounds in the control regions extrapolated to the signal regions, for an integrated luminosity of 20.3 fb^{-1}. Nominal MC expectations (normalised to MC cross-sections) are given for comparison. The errors shown are the statistical plus systematic uncertainties. The observed p-values and Gaussian significances for the single-bin discovery regions are given, along with the 95% C.L. upper limit on the cross-section, σ, and number of events, N_{BSM}, for non-Standard Model production in each region. These regions are identical to $ee/\mu\mu$ SR1 and $e\mu$ SR1 but with a higher $M_R' > 600$ GeV requirement. The nominal expected limits are shown in parentheses along with the limits in the case of a one-σ upward (↑) or downward (↓) fluctuation in observation.

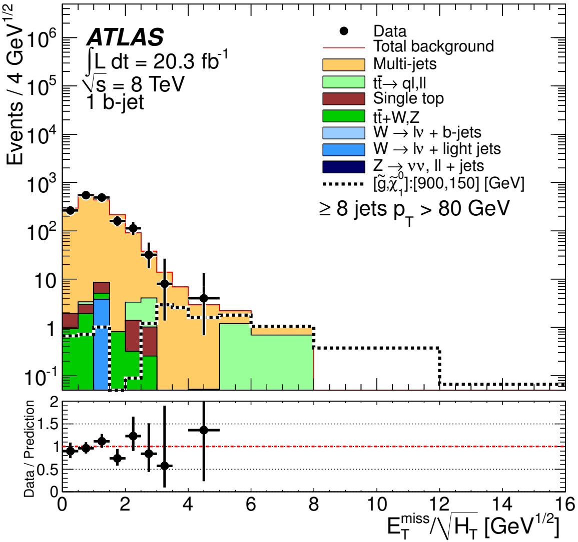
Further results in the 2-leptons SS signal regions

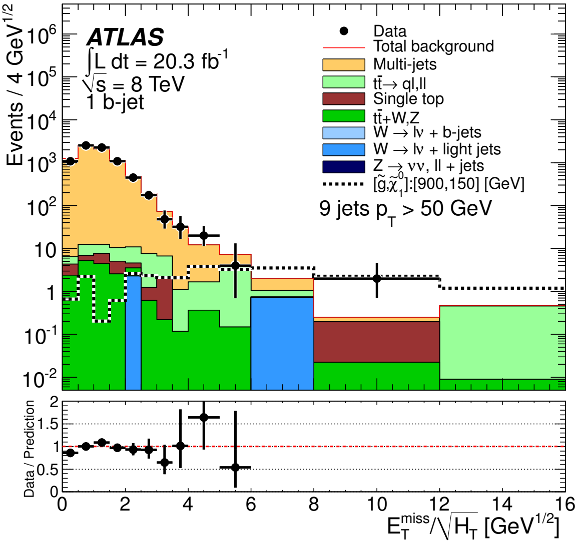
A) Discovery case	**SR0b**	**SR1b**	**SR3b**
Observed events	5	8	4
Expected background events	7.5 ± 3.3	3.7 ± 1.6	3.1 ± 1.6
Expected $t\bar{t}+V$ events	0.5 ± 0.4	2.2 ± 1.0	1.7 ± 0.8
Expected diboson events	3.4 ± 1.0	0.7 ± 0.4	0.1 ± 0.1
Expected fake lepton events	3.4 ± 3.1	$0.3^{+1.1}_{-0.3}$	$0.9^{+1.4}_{-0.9}$
Expected charge mis-measurement events	0.1 ± 0.1	0.5 ± 0.2	0.4 ± 0.1
p_0	0.50	0.11	0.36

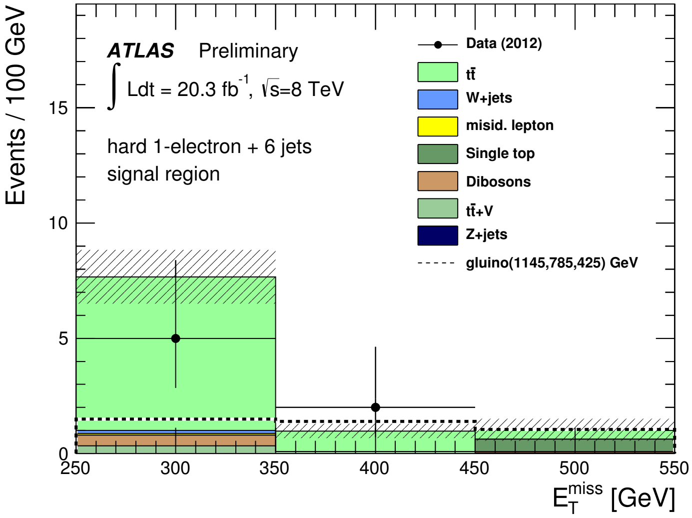

ATLAS Preliminary
SRA - 2 jets
∫L dt = 20.3 fb⁻¹
Data 2012 (√s = 8 TeV)
SM Total
q̃q̃ m(q̃)=850,m(χ̃⁰₁)=100
q̃q̃ m(q̃)=450,m(χ̃⁰₁)=400
Multijet
Z+jets
W+jets
tt̄ & single top
Diboson
events / 100 GeV
DATA / MC
m_eff(incl.) [GeV]
AI

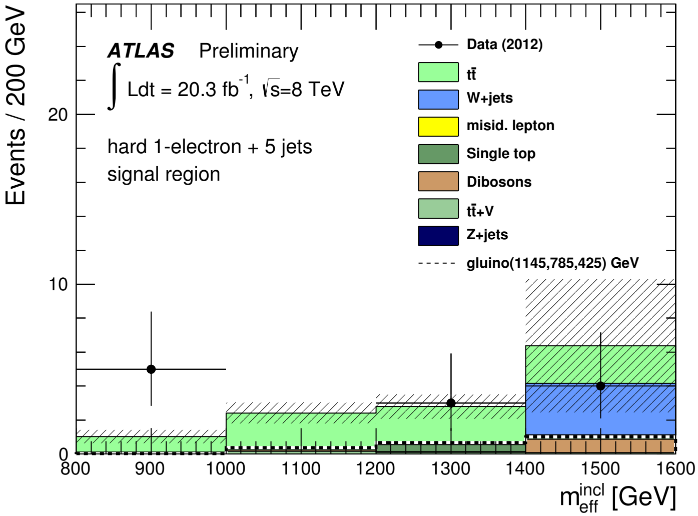

ATLAS Preliminary
SRB - 3 jets
∫L dt = 20.3 fb⁻¹
Data 2012 (√s = 8 TeV)
SM Total
q̃g̃ m(g̃)=1.04×m(q̃)=1425,m(χ̃⁰₁)=525
q̃g̃ m(g̃)=1.04×m(q̃)=1612,m(χ̃⁰₁)=37
Multijet
Z+jets
W+jets
tt̄ & single top
Diboson
Bm
events / 100 GeV
DATA / MC
m_eff(incl.) [GeV]


ATLAS
∫L dt = 20.3 fb^-1
√s = 8 TeV
1 b-jet
Data
Total background
Multi-jets
tt̄→ ql,ll
Single top
tt̄+W,Z
W → lν + b-jets
W → lν + light jets
Z → νν, ll + jets
[g̃,χ̃⁰₁]:[900,150] [GeV]
7 jets p_T > 50 GeV
Events / 4 GeV^1/2
Data / Prediction
E_T^miss/√H_T [GeV^1/2]

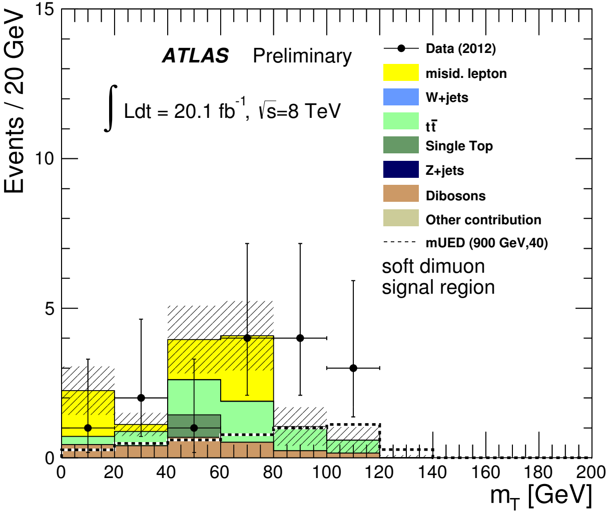

ATLAS
∫L dt = 20.3 fb⁻¹
√s = 8 TeV
1 b-jet
Data
Total background
Multi-jets
tt̄→ ql,ll
Single top
tt̄+W,Z
W → lν + b-jets
W → lν + light jets
Z → νν, ll + jets
[g̃,χ̃⁰₁]:[900,150] [GeV]
≥ 8 jets pT > 80 GeV
Events / 4 GeV^1/2
Data / Prediction
E_T^miss/√H_T [GeV^1/2]

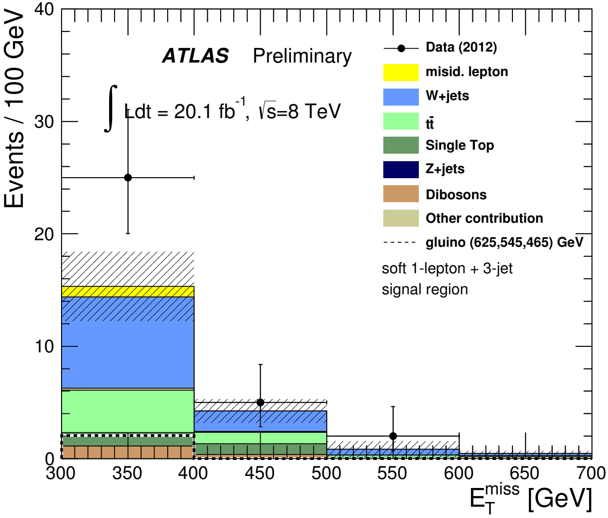

ATLAS
∫L dt = 20.3 fb-1
√s = 8 TeV
1 b-jet
Data
Total background
Multi-jets
tt̄→ ql,ll
Single top
tt̄+W,Z
W → lν + b-jets
W → lν + light jets
Z → νν, ll + jets
[g̃,χ̃10]:[900,150] [GeV]
9 jets pT > 50 GeV
Events / 4 GeV1/2
Data / Prediction
ETmiss/√HT [GeV1/2]

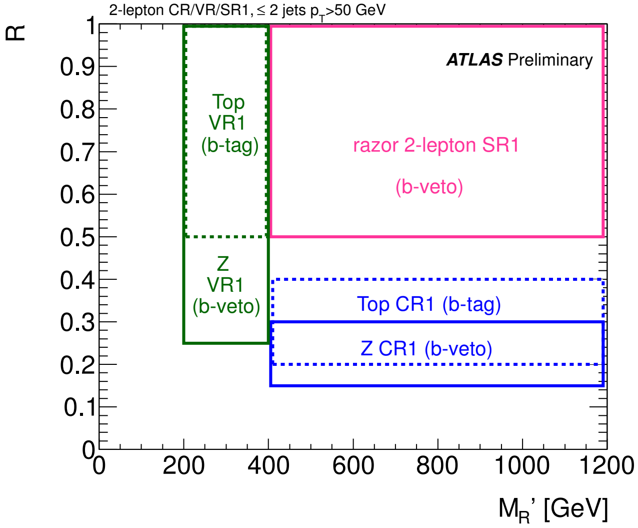

ATLAS Preliminary
∫ Ldt = 20.3 fb^{-1}, √s=8 TeV
hard 1-electron + 6 jets
signal region
Data (2012)
$t\bar{t}$
W+jets
misid. lepton
Single top
Dibosons
$t\bar{t}$+V
Z+jets
gluino(1145,785,425) GeV
Events / 100 GeV
E_T^{miss} [GeV]
0
5
10
15
250
300
350
400
450
500
550

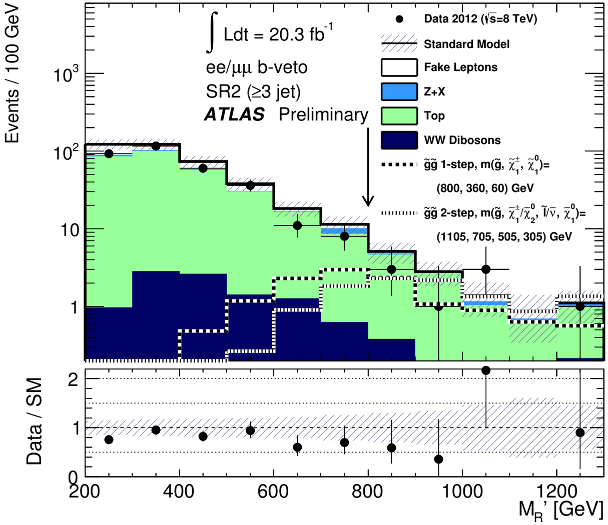


ATLAS Preliminary
∫ Ldt = 20.3 fb^{-1}, √s=8 TeV
hard 1-electron + 5 jets
signal region
Data (2012)
$t\bar{t}$
W+jets
misid. lepton
Single top
Dibosons
$t\bar{t}$+V
Z+jets
gluino(1145,785,425) GeV
Events / 200 GeV
0
10
20
800
900
1000
1100
1200
1300
1400
1500
1600
m_{eff}^{incl} [GeV]

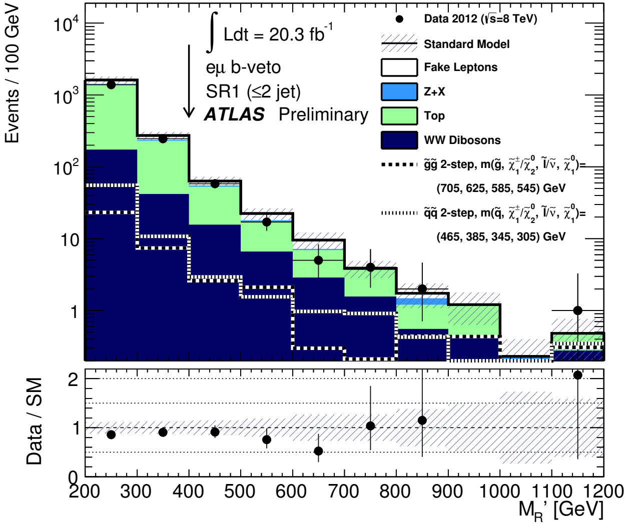

ATLAS Preliminary
∫ Ldt = 20.1 fb-1, √s=8 TeV
Data (2012)
misid. lepton
W+jets
tt̄
Single Top
Z+jets
Dibosons
Other contribution
mUED (900 GeV,40)
soft dimuon
signal region
Events / 20 GeV
0
5
10
15
0
20
40
60
80
100
120
140
160
180
200
mT [GeV]


ATLAS Preliminary
$\int$ Ldt = 20.1 fb^{-1}, $\sqrt{s}$=8 TeV
Data (2012)
misid. lepton
W+jets
$t\bar{t}$
Single Top
Z+jets
Dibosons
Other contribution
gluino (625,545,465) GeV
soft 1-lepton + 3-jet
signal region
Events / 100 GeV
E_T^{miss} [GeV]

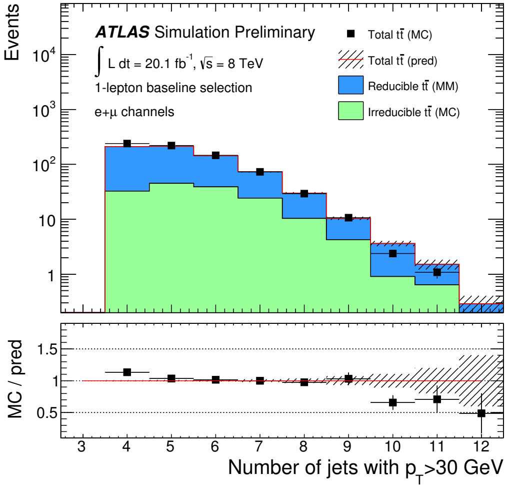

2-lepton CR/VR/SR1, ≤ 2 jets p_T>50 GeV
ATLAS Preliminary
Top
VR1
(b-tag)
razor 2-lepton SR1
(b-veto)
Z
VR1
(b-veto)
Top CR1 (b-tag)
Z CR1 (b-veto)
R
M_R' [GeV]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
200
400
600
800
1000
1200

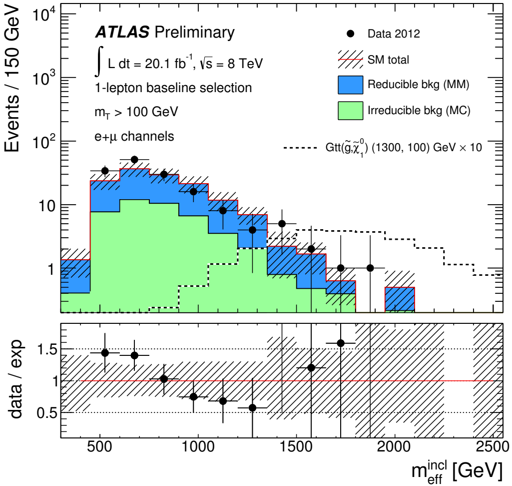


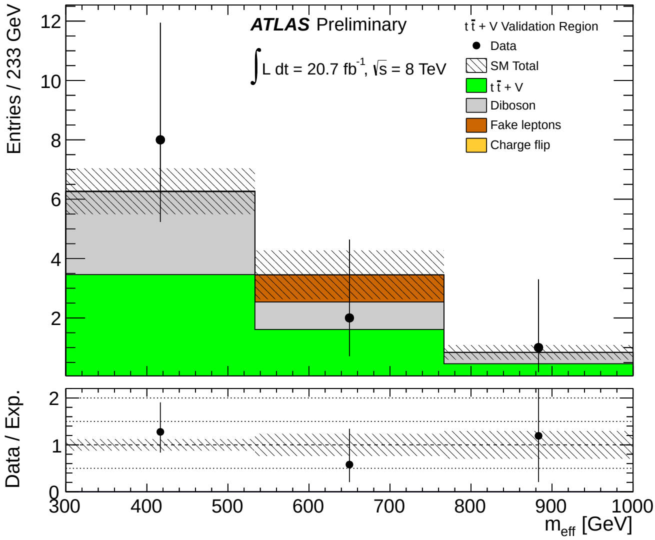
$\int$ Ldt = 20.3 fb^{-1}
ee/μμ b-veto
SR2 (≥3 jet)
ATLAS Preliminary
Data 2012 ($\sqrt{s}$=8 TeV)
Standard Model
Fake Leptons
Z+X
Top
WW Dibosons
$\tilde{g}\tilde{g}$ 1-step, m($\tilde{g}$, $\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^0$)=
(800, 360, 60) GeV
$\tilde{g}\tilde{g}$ 2-step, m($\tilde{g}$, $\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$, $\tilde{l}/\tilde{\nu}$, $\tilde{\chi}_1^0$)=
(1105, 705, 505, 305) GeV
Events / 100 GeV
Data / SM
M_R' [GeV]

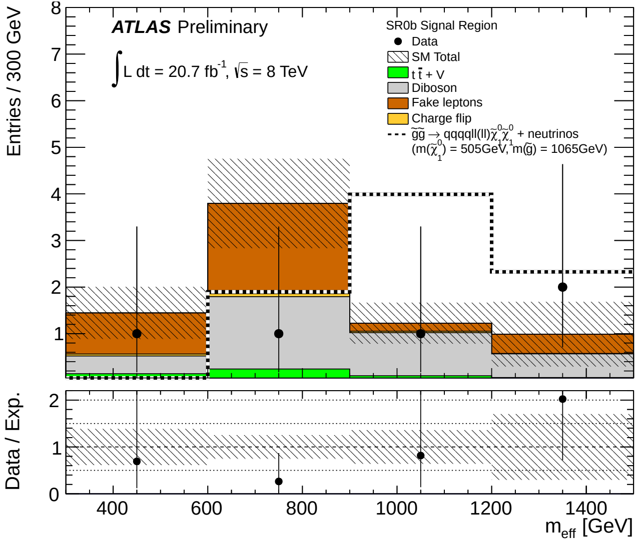


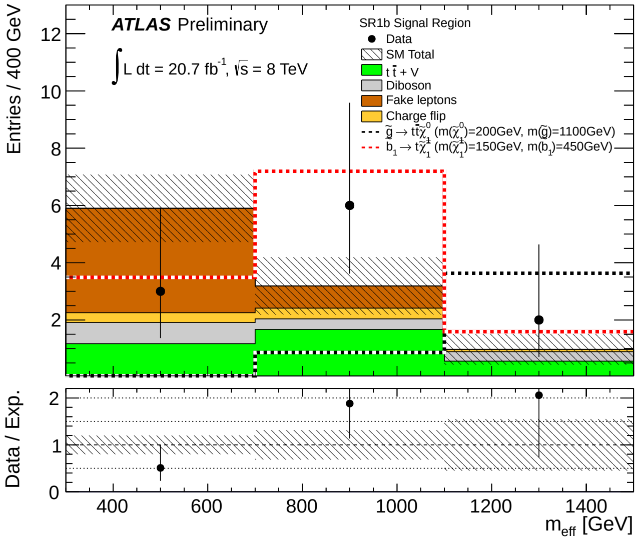
Events / 100 GeV
$\int$ Ldt = 20.3 fb^{-1}
eμ b-veto
SR1 (≤2 jet)
ATLAS Preliminary
Data 2012 ($\sqrt{s}$=8 TeV)
Standard Model
Fake Leptons
Z+X
Top
WW Dibosons
$\tilde{g}\tilde{g}$ 2-step, m($\tilde{g}$, $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$, $\tilde{l}/\tilde{\nu}$, $\tilde{\chi}_1^0$)=
(705, 625, 585, 545) GeV
$\tilde{q}\tilde{q}$ 2-step, m($\tilde{q}$, $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$, $\tilde{l}/\tilde{\nu}$, $\tilde{\chi}_1^0$)=
(465, 385, 345, 305) GeV
Data / SM
M_R' [GeV]


ATLAS Simulation Preliminary
∫ L dt = 20.1 fb⁻¹, √s = 8 TeV
1-lepton baseline selection
e+μ channels
Total tt̄ (MC)
Total tt̄ (pred)
Reducible tt̄ (MM)
Irreducible tt̄ (MC)
Events
MC / pred
Number of jets with p_T>30 GeV

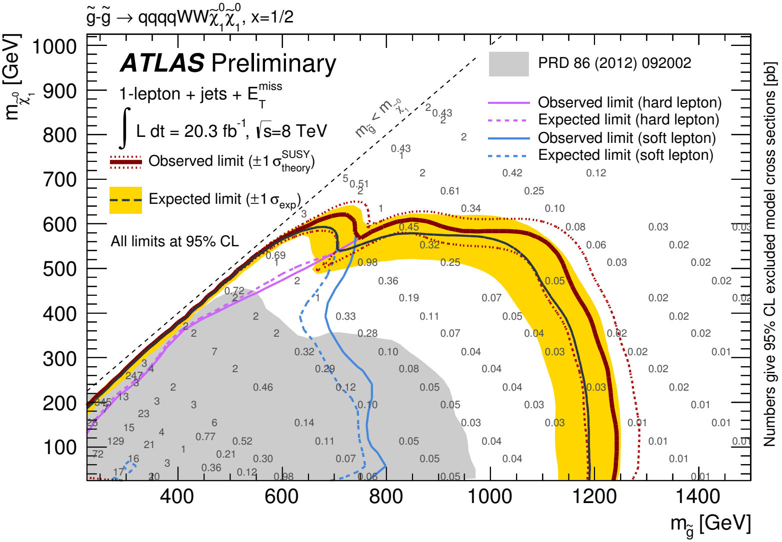

ATLAS Preliminary
∫ L dt = 20.1 fb-1, √s = 8 TeV
1-lepton baseline selection
mT > 100 GeV
e+μ channels
Data 2012
SM total
Reducible bkg (MM)
Irreducible bkg (MC)
Gtt(g̃,χ̃01) (1300, 100) GeV × 10
Events / 150 GeV
data / exp
m_eff^incl [GeV]

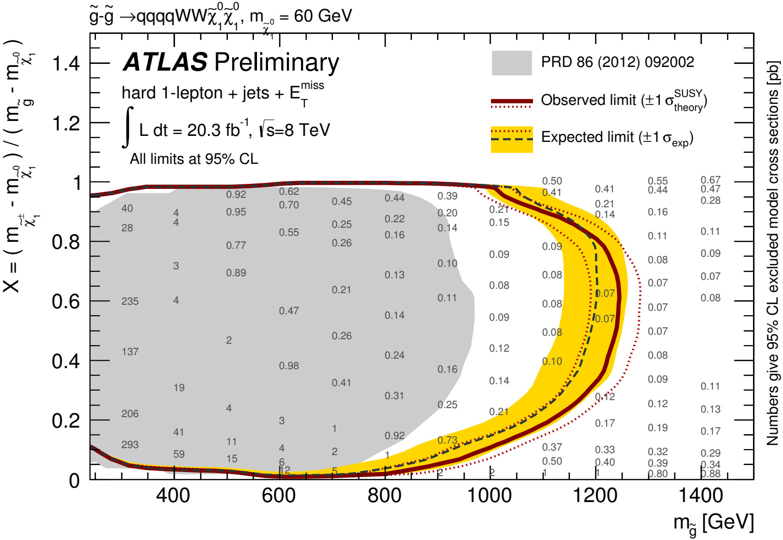

ATLAS Preliminary
$\int L\,dt$ = 20.7 fb^{-1}, $\sqrt{s}$ = 8 TeV
$t\bar{t}$ + V Validation Region
Data
SM Total
$t\bar{t}$ + V
Diboson
Fake leptons
Charge flip
Entries / 233 GeV
Data / Exp.
m_{eff} [GeV]

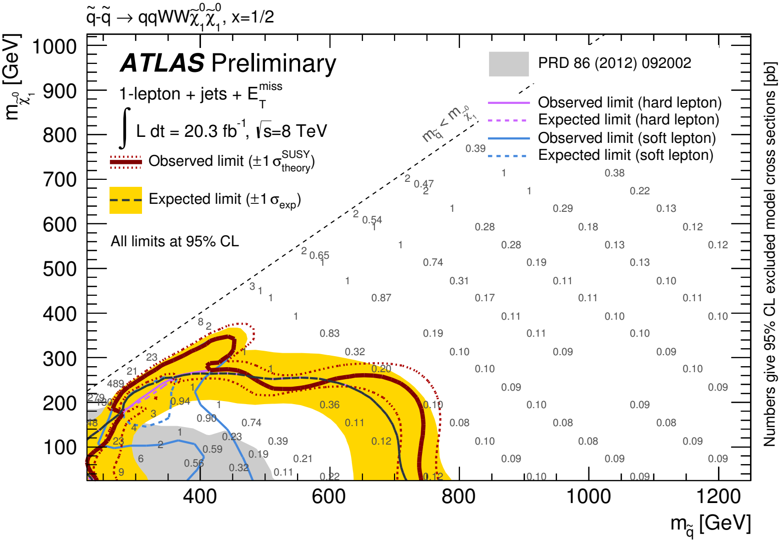

ATLAS Preliminary
∫ L dt = 20.7 fb^{-1}, √s = 8 TeV
SR0b Signal Region
Data
SM Total
t t̄ + V
Diboson
Fake leptons
Charge flip
g̃g̃ → qqqqll(ll)χ̃$^0_1$χ̃$^0_1$ + neutrinos
(m(χ̃$^0_1$) = 505GeV, m(g̃) = 1065GeV)
Entries / 300 GeV
Data / Exp.
m_{eff} [GeV]



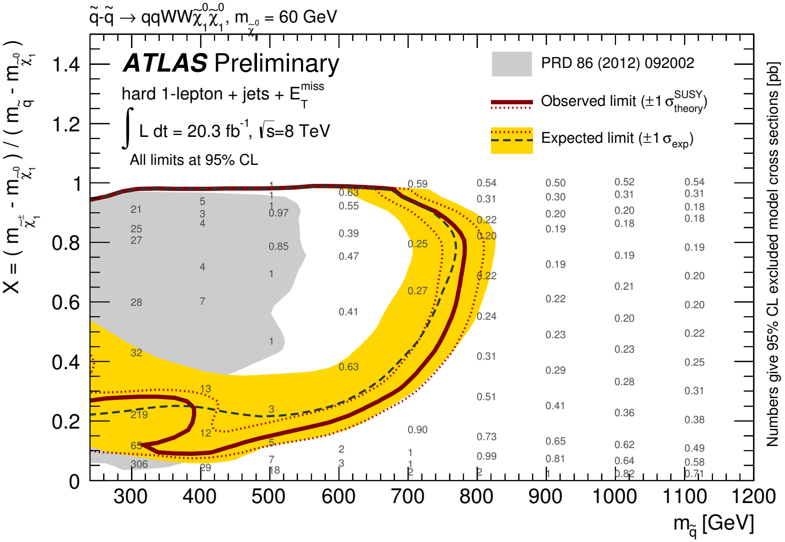
ATLAS Preliminary
$\int L\,dt$ = 20.7 fb^{-1}, $\sqrt{s}$ = 8 TeV
SR1b Signal Region
Data
SM Total
$t\bar{t}$ + V
Diboson
Fake leptons
Charge flip
$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}^0_1$ (m($\tilde{\chi}^0_1$)=200GeV, m($\tilde{g}$)=1100GeV)
$\tilde{b}_1 \rightarrow t\tilde{\chi}^{\pm}_1$ (m($\tilde{\chi}^{\pm}_1$)=150GeV, m($\tilde{b}_1$)=450GeV)
Entries / 400 GeV
Data / Exp.
m_{eff} [GeV]


$\tilde{g}$-$\tilde{g}$ → qqqqWW$\tilde{\chi}^0_1\tilde{\chi}^0_1$, x=1/2
ATLAS Preliminary
1-lepton + jets + E_T^{miss}
$\int L\,dt$ = 20.3 fb^{-1}, $\sqrt{s}$=8 TeV
Observed limit (±1 σ^{SUSY}_{theory})
Expected limit (±1 σ_{exp})
All limits at 95% CL
PRD 86 (2012) 092002
Observed limit (hard lepton)
Expected limit (hard lepton)
Observed limit (soft lepton)
Expected limit (soft lepton)
$m_{\tilde{g}} < m_{\tilde{\chi}^0_1}$
$m_{\tilde{\chi}^0_1}$ [GeV]
$m_{\tilde{g}}$ [GeV]
Numbers give 95% CL excluded model cross sections [pb]

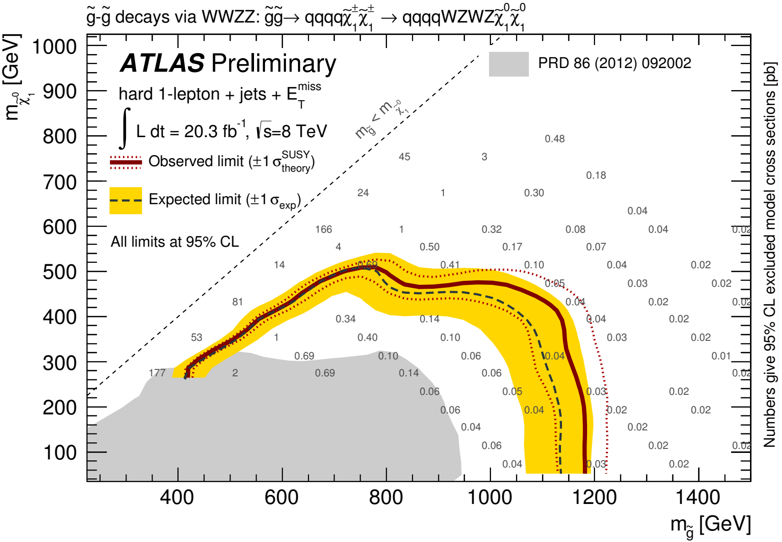

g̃-g̃ →qqqqWWχ̃₁⁰χ̃₁⁰, m_χ̃₁⁰ = 60 GeV
ATLAS Preliminary
hard 1-lepton + jets + E_T^miss
∫ L dt = 20.3 fb⁻¹, √s=8 TeV
All limits at 95% CL
PRD 86 (2012) 092002
Observed limit (±1 σ^SUSY_theory)
Expected limit (±1 σ_exp)
X = (m_χ̃₁± - m_χ̃₁⁰) / (m_g̃ - m_χ̃₁⁰)
m_g̃ [GeV]
Numbers give 95% CL excluded model cross sections [pb]



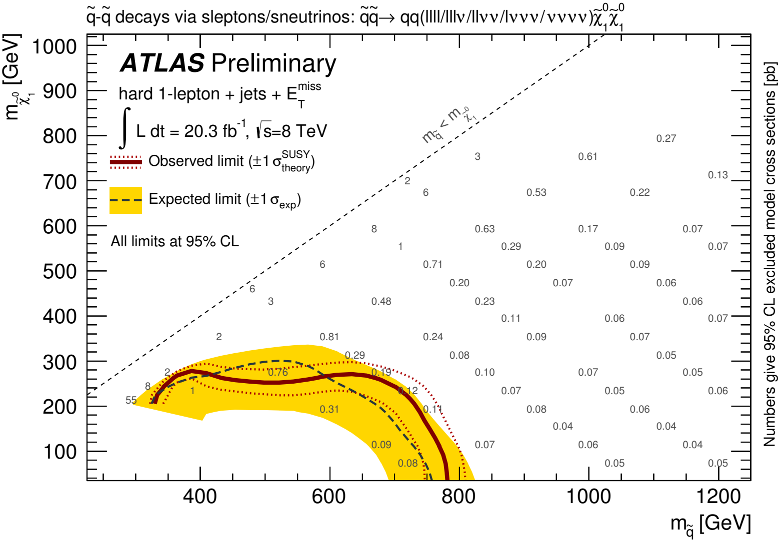
$\tilde{q}$-$\tilde{q}$ → qqWW$\tilde{\chi}^0_1\tilde{\chi}^0_1$, x=1/2
ATLAS Preliminary
1-lepton + jets + E_T^{miss}
$\int$ L dt = 20.3 fb^{-1}, $\sqrt{s}$=8 TeV
Observed limit (±1 σ^{SUSY}_{theory})
Expected limit (±1 σ_{exp})
All limits at 95% CL
PRD 86 (2012) 092002
Observed limit (hard lepton)
Expected limit (hard lepton)
Observed limit (soft lepton)
Expected limit (soft lepton)
$m_{\tilde{q}} < m_{\tilde{\chi}^0_1}$
$m_{\tilde{\chi}^0_1}$ [GeV]
$m_{\tilde{q}}$ [GeV]
Numbers give 95% CL excluded model cross sections [pb]

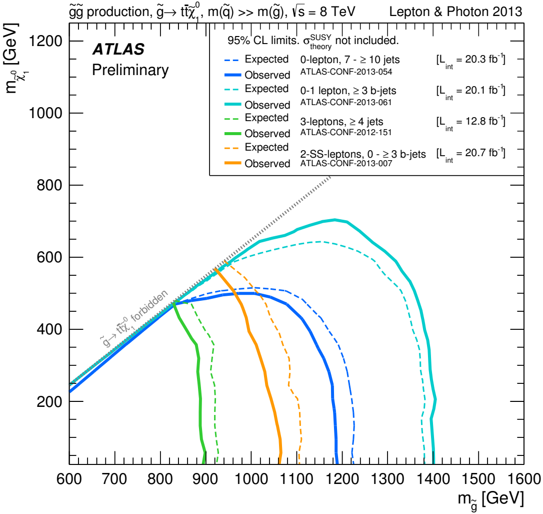


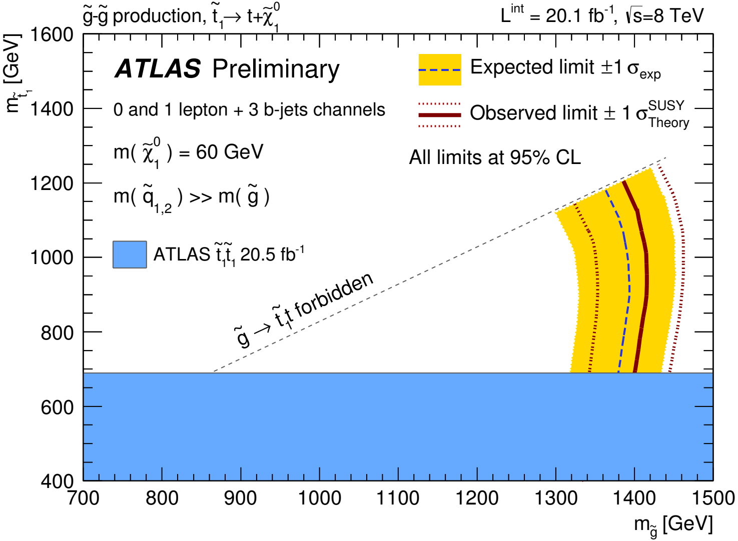
$\tilde{q}$-$\tilde{q}$ → qqWW$\tilde{\chi}^0_1\tilde{\chi}^0_1$, $m_{\tilde{\chi}^0_1}$ = 60 GeV
ATLAS Preliminary
hard 1-lepton + jets + E_T^{miss}
$\int$ L dt = 20.3 fb^{-1}, $\sqrt{s}$=8 TeV
All limits at 95% CL
PRD 86 (2012) 092002
Observed limit ($\pm 1\ \sigma^{SUSY}_{theory}$)
Expected limit ($\pm 1\ \sigma_{exp}$)
X = ($m_{\tilde{\chi}^\pm_1}$ - $m_{\tilde{\chi}^0_1}$) / ($m_{\tilde{q}}$ - $m_{\tilde{\chi}^0_1}$)
$m_{\tilde{q}}$ [GeV]
Numbers give 95% CL excluded model cross sections [pb]



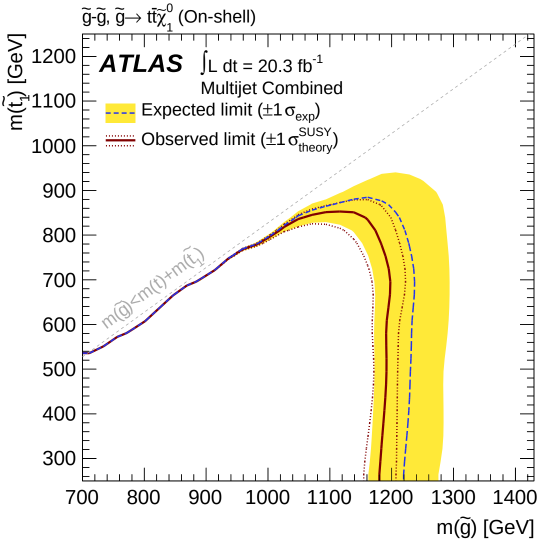
g̃-g̃ decays via WWZZ: g̃g̃→ qqqq$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\pm}$ → qqqqWZWZ$\tilde{\chi}_1^0\tilde{\chi}_1^0$
ATLAS Preliminary
hard 1-lepton + jets + E_T^{miss}
$\int L\,dt$ = 20.3 fb^{-1}, $\sqrt{s}$=8 TeV
Observed limit (±1 σ_{theory}^{SUSY})
Expected limit (±1 σ_{exp})
All limits at 95% CL
PRD 86 (2012) 092002
$m_{\tilde{g}} < m_{\tilde{\chi}_1^0}$
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{g}}$ [GeV]
Numbers give 95% CL excluded model cross sections [pb]


q̃-q̃ decays via sleptons/sneutrinos: q̃q̃→ qq(llll/lllν/llνν/lννν/νννν)$\tilde{\chi}_1^0\tilde{\chi}_1^0$
ATLAS Preliminary
hard 1-lepton + jets + E_T^{miss}
$\int L\,dt$ = 20.3 fb^{-1}, $\sqrt{s}$=8 TeV
Observed limit (±1 σ_{theory}^{SUSY})
Expected limit (±1 σ_{exp})
All limits at 95% CL
$m_{\tilde{q}} < m_{\tilde{\chi}_1^0}$
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{q}}$ [GeV]
Numbers give 95% CL excluded model cross sections [pb]
1000
900
800
700
600
500
400
300
200
100
400
600
800
1000
1200
0.27
3
0.61
0.13
2
6
0.53
0.22
8
0.63
0.17
0.07
1
0.29
0.09
0.07
6
0.71
0.20
0.09
0.20
0.07
0.06
6
3
0.48
0.23
0.06
0.11
0.06
0.07
2
0.81
0.24
0.09
0.07
0.29
0.08
0.05
2
0.76
0.19
0.10
0.07
0.05
8
1
0.12
0.07
0.05
0.06
55
0.31
0.11
0.08
0.06
0.04
0.04
0.09
0.07
0.06
0.04
0.08
0.05
0.05


g̃g̃ production, g̃→ tt̄χ̃⁰₁, m(q̃) >> m(g̃), √s = 8 TeV
Lepton & Photon 2013
ATLAS
Preliminary
95% CL limits. σ^SUSY_theory not included.
Expected
Observed
0-lepton, 7 - ≥ 10 jets
ATLAS-CONF-2013-054
[L_int = 20.3 fb⁻¹]
Expected
Observed
0-1 lepton, ≥ 3 b-jets
ATLAS-CONF-2013-061
[L_int = 20.1 fb⁻¹]
Expected
Observed
3-leptons, ≥ 4 jets
ATLAS-CONF-2012-151
[L_int = 12.8 fb⁻¹]
Expected
Observed
2-SS-leptons, 0 - ≥ 3 b-jets
ATLAS-CONF-2013-007
[L_int = 20.7 fb⁻¹]
g̃→ tt̄χ̃⁰₁ forbidden
m_χ̃⁰₁ [GeV]
m_g̃ [GeV]
200
400
600
800
1000
1200
600
700
800
900
1000
1100
1200
1300
1400
1500
1600



$\tilde{g}$-$\tilde{g}$ production, $\tilde{t}_1 \rightarrow t+\tilde{\chi}_1^0$
L^{int} = 20.1 fb^{-1}, $\sqrt{s}$=8 TeV
ATLAS Preliminary
0 and 1 lepton + 3 b-jets channels
$m(\tilde{\chi}_1^0)$ = 60 GeV
$m(\tilde{q}_{1,2}) >> m(\tilde{g})$
ATLAS $\tilde{t}_1\tilde{t}_1$ 20.5 fb^{-1}
Expected limit $\pm 1\ \sigma_{exp}$
Observed limit $\pm$ 1 σ^{SUSY}_{Theory}
All limits at 95% CL
$\tilde{g} \rightarrow \tilde{t}_1 t$ forbidden
$m_{\tilde{t}_1}$ [GeV]
$m_{\tilde{g}}$ [GeV]
1600
1400
1200
1000
800
600
400
700
800
900
1000
1100
1200
1300
1400
1500


g̃-g̃, g̃→ tt̄χ̃$_1^0$ (On-shell)
ATLAS
∫L dt = 20.3 fb^{-1}
Multijet Combined
Expected limit (±1 σ$_{exp}$)
Observed limit (±1 σ$^{SUSY}_{theory}$)
m(g̃)<m(t)+m(t̃$_1$)
m(t̃$_1$) [GeV]
m(g̃) [GeV]
1200
1100
1000
900
800
700
600
500
400
300
700
800
900
1000
1100
1200
1300
1400