Inclusive searches for supersymmetric signatures with the ATLAS detector

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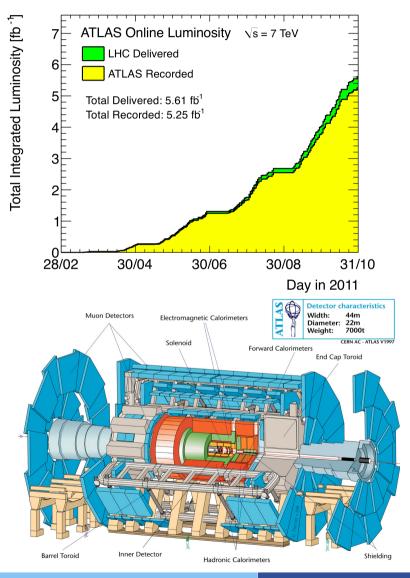
ATLAS and the LHC

LHC

-Very successful run on 2011 -pp collisions at √s=7TeV, -Delivered 5.6fb⁻¹ -Atlas recorded 5.25fb⁻¹

ATLAS

-General propose experiment -2T Solenoid magnet surrounds ID -Toroid magnet supporting the MS -Tracking $|\eta| < 2.5$ -Muon Reconstruction $|\eta| < 2.7$ -Calorimetry $|\eta| < 4.9$ -Three Level Trigger system

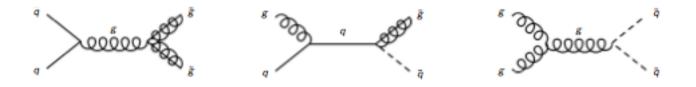


Supersymmetry (SUSY)

- Well motivated extension to the Standard Model
 - Solves the hierarchy problem by postulating a symmetry between fermions and bosons:
 - Every Fermion (Boson) has a Bosonic (Fermionic) twin
 - Quadratic divergences cancel
 - If exists must be broken m_{susy} > m_{SM}
 - Hierarchy problem solvable and GUT for m_{BSM}~O(1TeV)
 - R-Parity: LSP is stable and WIMP
 - \mathbb{E}_{T} in event, no mass peaks \rightarrow search for SUSY in tails of distributions
 - SUSY particles created in pairs
 - Most General Broken SUSY ~ O(100) parameters
 - SUSY models reduce the number of free parameters

Outlook

- Searches with integrated luminosity up to 4.7fb⁻¹
- **I** jets + E_T + X based searches



- Strong production of SUSY decaying through long chains \rightarrow Jets
- SM Decay Products of SUSY particles (GMSB)
 - In some models the LSP is the gravitino
 - Phenomenology is dominated by the NLSP
 - NLSP decays to its SM partner
- Search for the SUSY particle itself (AMSB)
 - In some models (mass degeneracy or small coupling) SUSY particles live long and decay outside the interaction region.

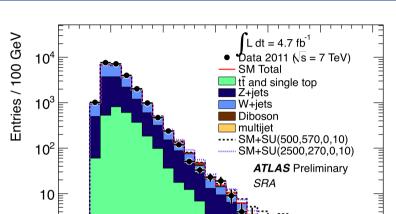
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Search with $\geq 2-6$ jets + \mathbb{E}_{T}

performed with 4.7fb⁻¹

- Production of g̃g,q̃q, q̃g
 - $\tilde{g} \rightarrow qq \tilde{X}_0$ and $\tilde{q} \rightarrow q \tilde{X}_0$
- Selection
 - Lepton veto (avoid overlap with 1L analysis)
 - 2-6 jets
 - ∉_T > 160 GeV
 - $\Delta \Phi (E_T, jet)_{min}$ reject multi jet bkg.
- **5** Signal Regions , 11- Channels
 - SRs based on N_{iet}
 - Channels based on SR + m_{eff} (incl.)
- Background

 - CR extrapolated to SR using MC



ATLAS-CONF-2012-033

Backgrounds and Control Regions

1000

1500

500

1⊧

2.5 2 1.5

0.5 00

DATA / SM

SR Background	CR process	CR selection
$Z(\rightarrow vv)$ +jets	γ+jets	Isolated photon
$Z(\rightarrow \nu\nu)$ +jets	$Z(\rightarrow \ell\ell)$ +jets	$ m(\ell,\ell) - m(Z) < 25 \text{ GeV}$
Multi-jets	Multi-jets	Reversed $\Delta \phi(j_i, E_{\rm T}^{\rm miss})$ cut
$W(\rightarrow \ell \nu)$ +jets	$W(\rightarrow \ell \nu)$ +jets	$30 \text{ GeV} < m_T(\ell, E_T^{\text{miss}}) < 100 \text{ GeV}, b\text{-veto}$
$t\bar{t}$ and single- t	$t\bar{t} \rightarrow bbqq'\ell\nu$	$30 \text{ GeV} < m_T(\ell, E_{\text{T}}^{\text{miss}}) < 100 \text{ GeV}, b\text{-tag}$

2500

m_{eff}(incl.) [GeV]

3000

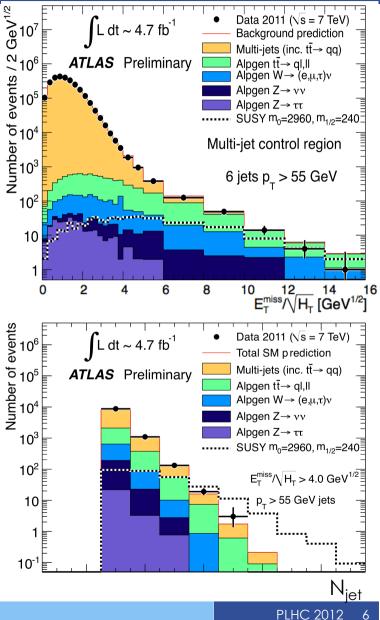
2000

Search with \geq 6-9 jets + $\not\!\!E_T$

performed with 4.7fb⁻¹

ATLAS-CONF-2012-037

- ĝ decay can produce many jets e.g. ĝ→ttX_{0,} long decay chains (mSUGRA)
- **Trigger:** Multi-jet based instead of E_{T}
 - small overlap with 2-6j analysis
- Selection
 - 6-9 jets , Lepton Veto
 - \mathcal{E}_{T} significance: $\mathcal{E}_{T} / \sqrt{H_{T}} > 4 \text{ GeV}^{1/2}$
- Multi Jet Background
 - Shape of $\not{E}_T / \sqrt{H_T}$ independent on N_{iet}
 - Extract shape from N_{Jet}(CR) < N_{jet}(SR)
 - Normalisation $N_{iet}(SR) E_T / \sqrt{H_T} < 1.5 \text{ GeV}^{1/2}$
- Leptonic Background (W+jets, Z+jets, tt)
 - Sub-dominant, from MC, normalised according to CR and then validated in VR



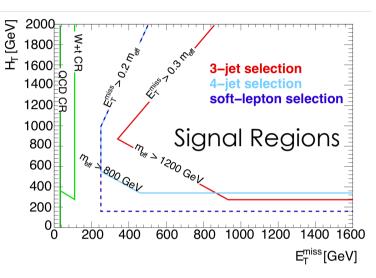
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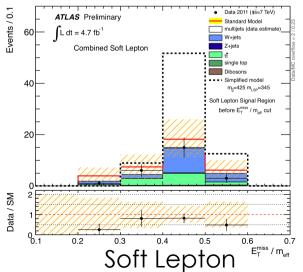
Search with $1L + jets + \not \! E_T$

performed with 4.7fb⁻¹

ATLAS-CONF-2012-041

- Isolated Lepton from SUSY chain-decay
 - Clean Signature
 - Soft Lepton analysis more sensitive where neutralino and gluino are close in mass (20-30 times)
- Selection
 - Isolated Lepton (e,μ)
 - Signal Regions
 - N_{jet} , E_T , m_{eff} , E_T / m_{eff}
- Backgrounds
 - tt, W+jets, Z+jets, single t, di-boson
 - Simultaneous Profile Likelihood with nuisance parameters
 - Determines parts of theoretical uncertainties from data in the TFs





Search with 2L (s.s.) + jets + $\not\!\!E_T$

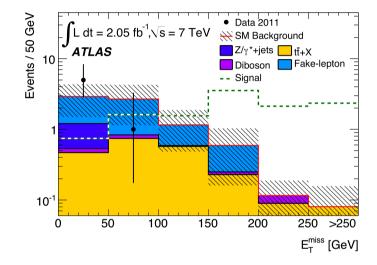
performed with 2.05fb⁻¹

arXiv: hep-ex-1203.5764

- gluino is majorana fermion
 - Equal probability to produce SS and OS leptons
 - SS clean signature
 - Enhances sensitivity in the region

 $m_{\tilde{g}} \sim m_t + m_t + m_{\chi_0}$

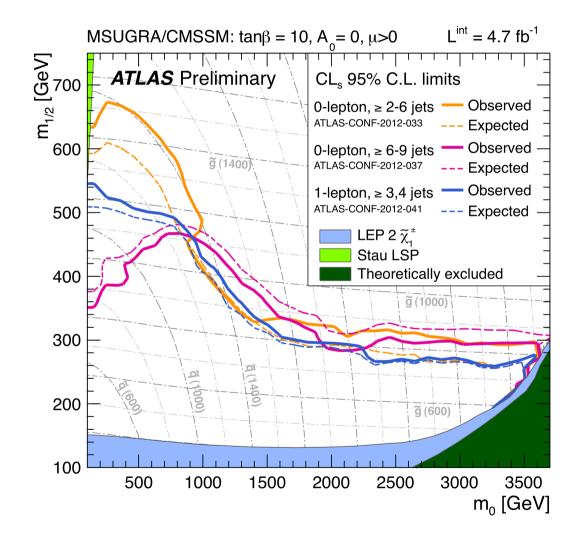
- Selection
 - Two highest p_T leptons with SS
 - N_{iet}≥ 4
 - ∉_T> 150 GeV
 - and m_T (SR2)
- tt+X, diboson Backgrounds
- "Fake Lepton" Backgrounds
 - misidentified jet
 - lepton from b or c
- Charge Misidentification Backgrounds
 - electrons



	SR1	SR2
		0.21 ± 0.16
Diboson	0.05 ± 0.02	0.02 ± 0.01
Fake-lepton	0.34 ± 0.20	< 0.17
Charge mis-ID Total SM	0.08 ± 0.01	0.039 ± 0.007
Total SM	0.84 ± 0.33	0.27 ± 0.24
Observed	0	0

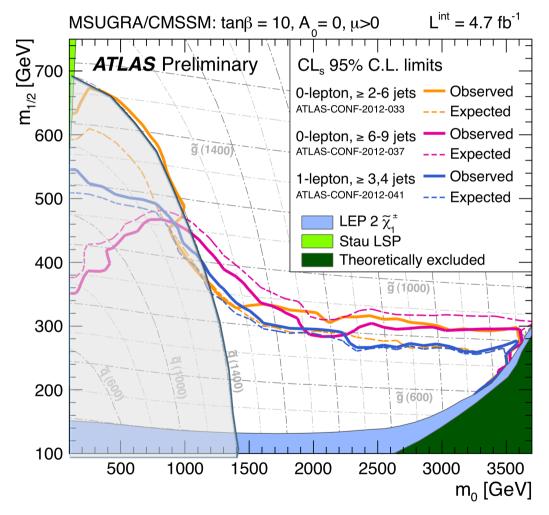
mSUGRA limits with jets + E_T

performed with 4.7fb⁻¹



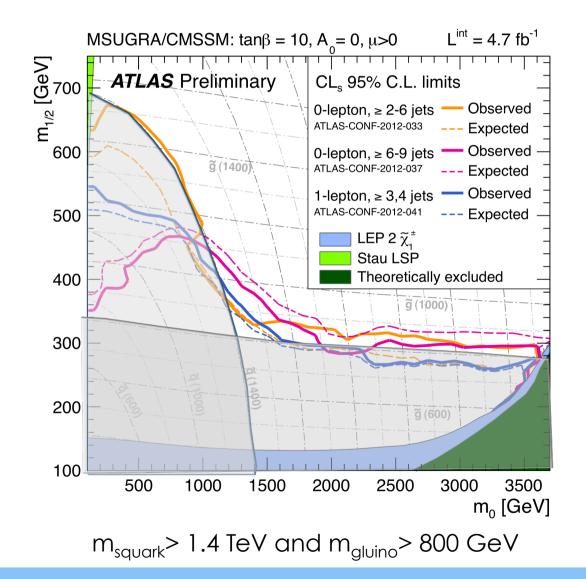
mSUGRA limits with jets + $\not\!\!E_T$

performed with 4.7fb⁻¹



mSUGRA limits with jets + $\not\!\!E_T$

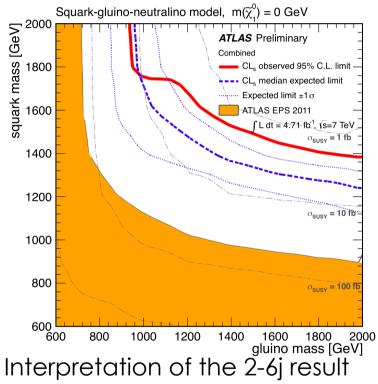
performed with 4.7fb⁻¹



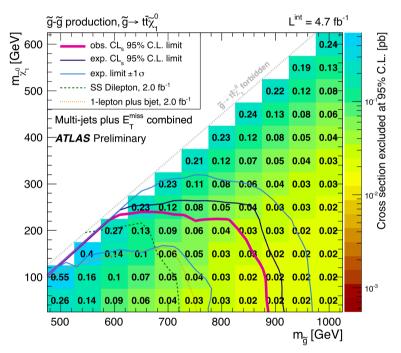
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Simplified models - limits $OL + jets + \not E_T$

Models with ad-hoc particle content - new interpretation of results



 $m(\tilde{X}_0) = 0$ 2^{nd} generation squarks as $m_{\tilde{q}}$ 3^{rd} generation squarks at 5TeV Direct decays to jets+neutralinos

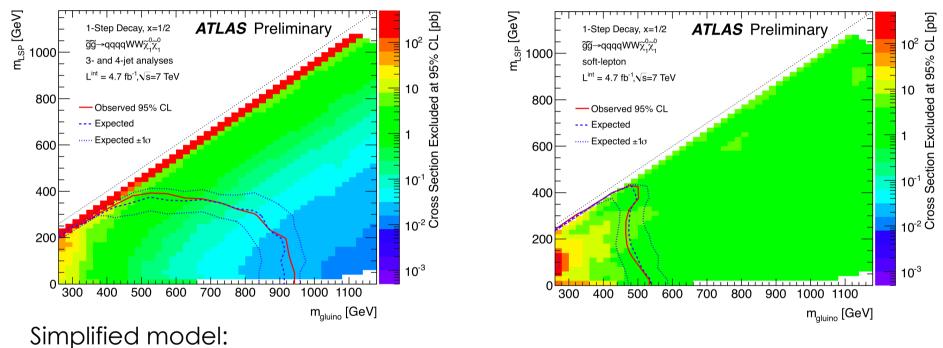


Interpretation of the 6-9j result

 $\tilde{g}\tilde{g}$ pair production $\tilde{g} \rightarrow tt \tilde{X}_0$ with probability 1

Simplified models limits – 1L + jets + $\not\!\!E_T$

performed with 4.7fb⁻¹



Simplified model: $\tilde{g}\tilde{g}$ production $\tilde{g} \rightarrow qq\tilde{X}^+ \rightarrow qqW^+\tilde{X}_0$

Soft Lepton –20-30 times more sensitive in the $m_{LSP} \sim m_{gluino}$ region

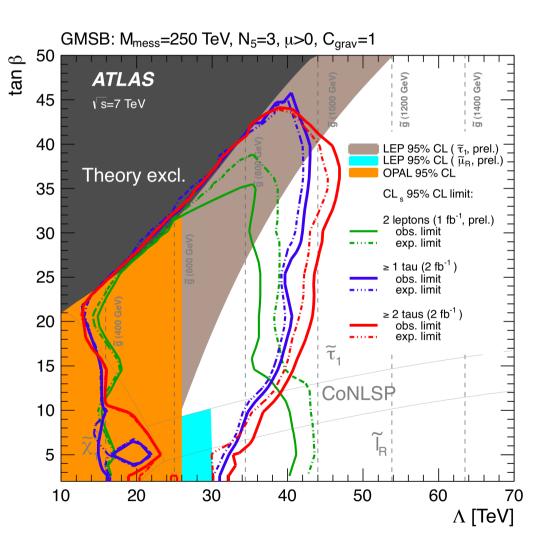
 m_{gluino} > 900 GeV for m_{LSP} < 200 GeV and $m_{chargino}$ = ½ (m_{gluino} - m_{LSP})

Search with $\geq 1,2 \tau + jets + \not{E}_{T}$ (GMSB)

performed with 2.05fb⁻¹

GMSB

- LSP is the gravitino (G̃)
- NLSP can be $\widetilde{X}_0, \widetilde{g}, \widetilde{l}, \widetilde{\tau}$
- $\tilde{\tau} \rightarrow G \tau$
- Selection
 - Hadronic τ based on BDT
 - SR Ε_T, m_{eff}, m_t(Ε_T, τ)
- Backgrounds
 - W+jet, Z+jets and tt
- □ $1 \ge \tau$: arXiv:1204.3852
- □ $2 \ge \tau$: arXiv:1203.6580

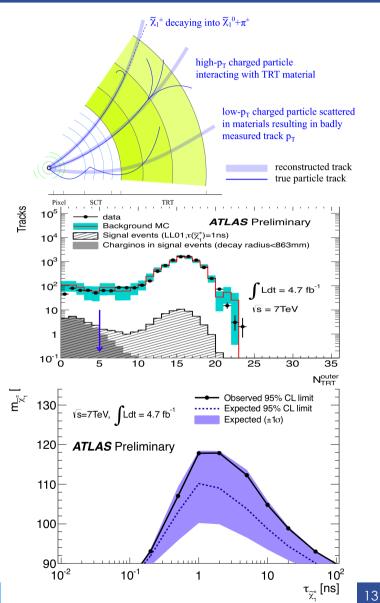


Long Lived Chargino (AMSB)

performed with 4.7fb⁻¹

ATLAS-CONF-2012-034

- In AMSB models
 - Chargino can live long enough to be detected directly
- Direct search for a chargino that decays in the inner detector
- Selection
 - Event Selection: E_T , N_{iet}, Lepton Veto
 - Candidate Selection:
 - Good quality track in the before the TRT
 - N_{hits} < 5 for outer TRT module
- Backgrounds
 - High p₁ interacting track
 - Bad Track



ATLAS SUSY searches

~1TeV No hint of new physics :-(

	ATLAS SUSY Searches* - 95% CL Lower Limits (Status: March 2012)
$\longrightarrow MSUGRA/CMSSM : 0 - lep + j's + E_{T, miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-033] 1.40 TeV $\tilde{q} = \tilde{g}$ mass
$\longrightarrow MSUGRA/CMSSM : 1-lep + j's + E_{T,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-041] 1.20 TeV $\vec{q} = \vec{g}$ mass $\int Ldt = (0.03 - 4.7)$ fb ⁻¹
$_{g}$ MSUGRA/CMSSM : multijets + $E_{T,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-037] 850 GeV \tilde{g} mass (large m_0) Is = 7 TeV
ξ Pheno model : 0-lep + j's + $E_{\tau,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-033] 1.38 TeV \tilde{q} mass $(m(\tilde{g}) < 2$ TeV, light $\tilde{\chi}_1^0$) ATLAS
$g \longrightarrow$ Pheno model : 0-lep + j's + $E_{T,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-033] 940 GeV \tilde{g} mass $(m(\tilde{q}) < 2 \text{ TeV}, \text{light} \tilde{\chi}_1^0)$ Preliminary
Pheno model : 0-lep + j's + $E_{T,miss}$ Pheno model : 0-lep + j's + $E_{T,miss}$ Pheno model : 0-lep + j's + $E_{T,miss}$ Clono med. $\tilde{\chi}^{\pm}$ ($\tilde{g} \rightarrow q \bar{q} \tilde{\chi}^{\pm}$) : 1-lep + j's + $E_{T,miss}$ GMSB : 2-lep OS _{SF} + $E_{T,miss}$ CMSD : 1 - lep + j's + $E_{T,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-041] 900 GeV \tilde{g} mass $(m(\tilde{\chi}_1^0) < 200 \text{ GeV}, m(\tilde{\chi}^*) = \frac{1}{2}(m(\tilde{\chi}^0) + m(\tilde{g}))$
$GMSB : 2-lep OS_{SF} + E_{T,miss}$	L=1.0 fb ⁻¹ (2011) [ATLAS-CONF-2011-156] 810 GeV g̃ mass (tanβ < 35)
\sim GIVISB: $1-\tau + JS + E_{\perp}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-005] 920 GeV \tilde{g} mass (tan β > 20)
$GMSB : 2-\tau + j's + E_{\tau_{min}}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-002] 990 GeV g̃ mass (tanβ > 20)
$GGM: \gamma\gamma + E_{T,miss}^T$	L=1.1 fb ⁻¹ (2011) [1111.4116] 805 GeV \tilde{g} mass ($m(\tilde{\chi}_{4}^{0}) > 50$ GeV)
Gluino med. \tilde{b} ($\tilde{g} \rightarrow b \bar{b} \tilde{\chi}^0$) : 0-lep + b-j's + $E_{\tau miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-003] 900 GeV g mass ($m(\chi_1^0) < 300$ GeV)
Gluino med. \tilde{t} ($\tilde{g} \rightarrow t\bar{t}\chi_1^0$) : 1-lep + b-j's + $E_{T,miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-003] 710 GeV \tilde{g} mass ($m(\chi_1^0) < 150$ GeV)
$\widetilde{\mathbb{Q}}$ — Cluip med. \widetilde{t} ($\widetilde{g} \rightarrow tt \widetilde{\chi}_1^0$) : 2-lep (SS) + j's + $E_{\tau, \text{miss}}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-004] 650 GeV \tilde{g} mass ($m(\tilde{\chi}_1^0) < 210$ GeV)
Gluino med. \tilde{t} ($\tilde{g} \rightarrow t\bar{t}_{\chi_{1}}^{-1}$) : 1-lep + b-j's + $E_{T,miss}$ Gluino med. \tilde{t} ($\tilde{g} \rightarrow t\bar{t}_{\chi_{1}}^{-0}$) : 2-lep (SS) + j's + $E_{T,miss}$ Gluino med. \tilde{t} ($\tilde{g} \rightarrow t\bar{t}_{\chi_{1}}^{-0}$) : multi-j's + $E_{T,miss}$ Direct $\tilde{b}\tilde{b}$ ($\tilde{b}_{1} \rightarrow b\chi_{1}^{-0}$) : 2 b-jets + $E_{T,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-037] 830 GeV g̃ mass ($m(\tilde{\chi}_1^0) < 200 \text{ GeV}$)
Direct $\widetilde{b}\widetilde{b}$ $(\widetilde{b}_1 \rightarrow b\widetilde{\chi}_1^0)$: 2 b-jets + $E_{T,miss}$	L=2.1 fb ⁻¹ (2011) [1112.3832] 390 GeV \tilde{b} mass ($m(\tilde{\chi}_{t}^{0}) < 60$ GeV)
Direct $\widetilde{t}\widetilde{t}$ (GMSB) : Z(\rightarrow II) + b-jet + E	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-036] 310 GeV \tilde{t} mass (115 < $m(\chi_1^{-0})$ < 230 GeV)
Unit Direct gaugino $(\tilde{\chi}_1^* \tilde{\chi}_2^0 \rightarrow 3I \tilde{\chi}_1^0)$: 2-lep SS + $E_{T,miss}$	$ L_{\pm 1.0 \text{ fb}^{-1} (2011) [1110.6189] } 170 \text{ GeV} \tilde{\chi}_{1}^{\pm} \text{ mass} \left((m(\tilde{\chi}_{1}^{0}) < 40 \text{ GeV}, \tilde{\chi}_{1}^{0}, m(\tilde{\chi}_{1}^{\pm}) = m(\tilde{\chi}_{2}^{0}), m(\tilde{l}, \tilde{v}) = \frac{1}{2} (m(\tilde{\chi}_{1}^{0}) + m(\tilde{\chi}_{2}^{0})) \right) $
Direct gaugino $(\tilde{\chi}_{\chi}^* \tilde{\chi}_{\chi}^0 \rightarrow 3I \tilde{\chi}_{\chi}^0)$: 3-lep + $E_{T,\text{miss}}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-023]250 GeV $\tilde{\chi}_1^{\pm}$ mass ($m(\tilde{\chi}_1^0) < 170$ GeV, and as above)
	L=4.7 fb ⁻¹ (2011) [CF-2012-034] ^{118 GeV} $\tilde{\chi}_1^{\pm}$ mass (1 < $\tau(\tilde{\chi}_1^{\pm})$ < 2 ns, 90 GeV limit in [0.2,90] ns)
Stable massive particles (SMP) : R-hadrons	L=34 pb ⁻¹ (2010) [1103.1984] 562 GeV g mass
AMSB : long-lived χ_1 Stable massive particles (SMP) : R-hadrons SMP : R-hadrons SMP : R-hadrons SMP : R-hadrons (Pixel det. only)	L=34 pb ⁻¹ (2010) [1103.1984] 294 GeV b mass
SMP : R-hadrons	L=34 pb ⁻¹ (2010) [1103.1984] 309 GeV T mass
ති SMP : R-hadrons (Pixel det. only)	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-022] 810 GeV g mass
GMSB : stable $\widetilde{\tau}$	L=37 pb ⁻¹ (2010) [1106.4495] 136 GeV τ̃ mass
RPV : high-mass eµ	L=1.1 fb ⁻¹ (2011) [1109.3089] 1.32 TeV \tilde{v}_{τ} mass (λ'_{311} =0.10, λ_{312} =0.05)
Bilinear RPV : 1-lep + j's + $E_{T,miss}$	L=1.0 fb ⁻¹ (2011) [1109.6606] 760 GeV q = g mass (cr _{LSP} < 15 mm)
MSUGRA/CMSSM - BC1 RPV : 4-lepton + $E_{T,miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-035] 1.77 TeV g̃ mass
Hypercolour scalar gluons : 4 jets, $m_{\rm ij} \approx m_{\rm kl}$	L=34 pb ⁻¹ (2010) [1110.2693] 185 GeV sgluon mass (excl: m _{sg} < 100 GeV, m _{sg} ≈ 140 ± 3 GeV)
	10 ⁻¹ 1 10
	Mass scale [TeV]

ATLAS SUSY Searches* - 95% CL Lower Limits (Status: March 2012)

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

Mass scale [TeV]

Summary

-No evidence of SUSY has been found :-(

-m_{susy} > 1TeV for strongly interacting paticles +

-Thriving SUSY community in ATLAS

-Many new results soon

Total Integrated Luminosity [fb ⁻¹] ATLAS Online Luminosity $\sqrt{s} = 8 \text{ TeV}$ 4^E LHC Delivered 3.5 ATLAS Recorded З Total Delivered: 3.21 fb1 Total Recorded: 3.03 fb¹ 0.5 30/04 04/03 18/03 02/04 16/04 14/05 28/05 Date in 2012

-Exciting times!

-Already recorded more than half the integrated luminosity in 2011 but with $\sqrt{s}=8$ TeV

-Excited for the possibility to find some BSM physics