



Constraints on Supersymmetry after Run 1 ATLAS Searches

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On behalf of the ATLAS Collaboration

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SUperSYmmetry (SUSY) in a Nutshell

One of the most popular extensions of the Standard Model (SM)

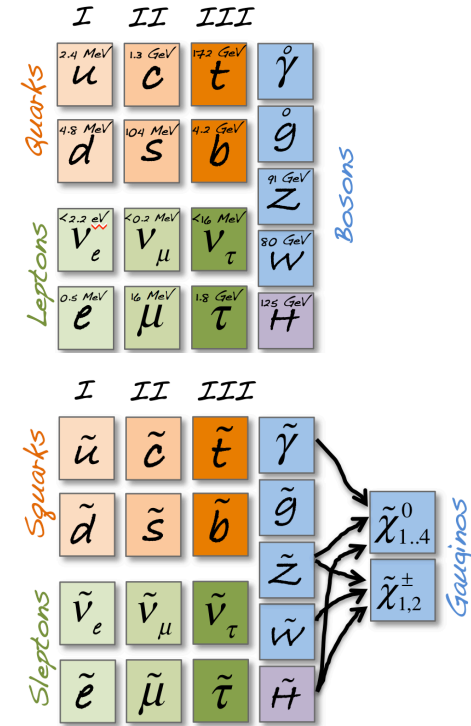
- ✓ SUSY postulates “superpartners” to each SM particles
- ✓ Higgs sector extended to 5 Higgs
- ✓ **Charginos**: mixture of Wino/charged Higgsinos
- ✓ **Neutralinos**: mixture of Bino/Wino/neutral Higgsinos

Why is SUSY popular ? It answers many open questions at once:

- ✓ Provides a solution to the hierarchy problem
 - The fermion/boson contributions to the Higgs mass cancel
- ✓ Allows unification of gauge couplings
- ✓ Offers a dark matter (DM) candidate (if R-parity is conserved)

The SUSY experimental challenge:

- ✓ SUSY is very predictive in terms of spins and couplings, but tells us nothing about the masses after symmetry breaking
- ✓ Results: >100 free parameters !
 - All possible mass hierarchies between SUSY particles: 9! models
- ✓ Unknown mass hierarchy determines decay chain and (possibly long) lifetimes



Complete SUSY Models

- mSUGRA, AMSB, GMSB

Phenomenological Models:

- pMSSM (19 parameters), GGM (gravitino)

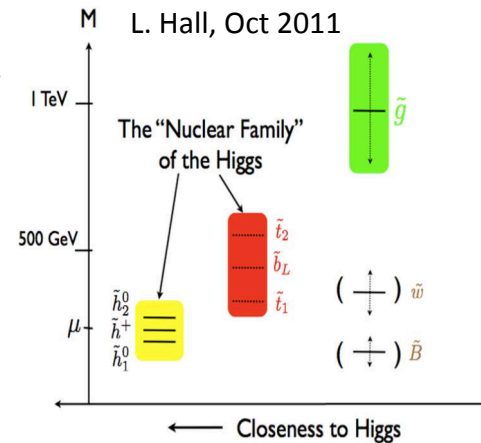
Simplified Models

- Physical masses of SUSY particles
- Fixed decay chain & branching fractions

Guidance from naturalness

✓ Because of sparticles contribution to the Higgs mass, can approximate their upper limits from the requirement of “small” (<10%) fine-tuning of the Higgs mass :

- Gluino \sim few TeV
- Stop \sim 1TeV (lowest mass squark)
- Higgsino \sim 200-300 GeV



In this talk, will focus on:

R-Parity violation: See Minghui Liu's talk

✓ **R-Parity is conserved** ($P_R = -1$ SUSY particles / $+1$ SM particles) $P_R = (-1)^{2s+3B+L}$

- SUSY particles are pair produced at the LHC and the lightest one is stable.

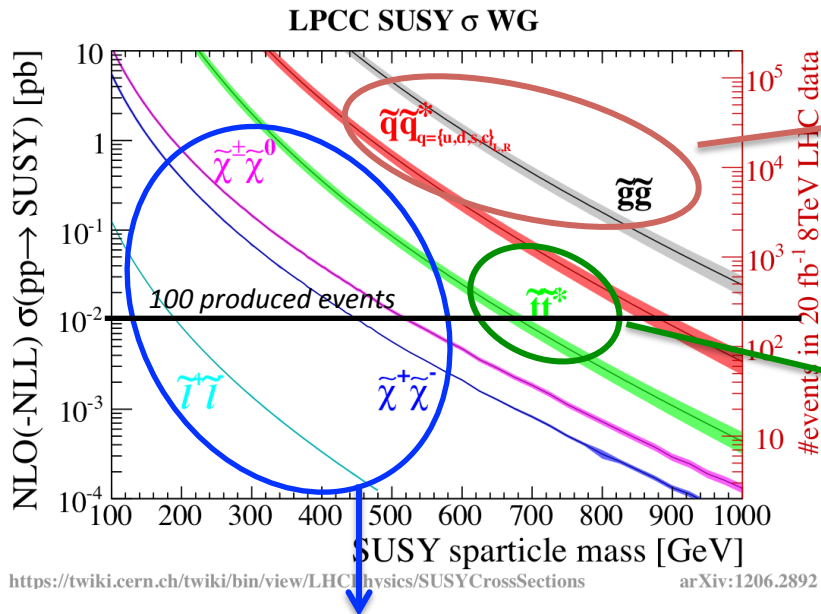
✓ Nature of the stable Lightest SUSY particle (LSP) in MSSM:

- $\tilde{\chi}_1^0$ with $M_{LSP} > \text{GeV}$ or \tilde{G} with $M_{LSP} \ll \text{GeV}$

✓ The value of the $\Delta M = M_{\text{SUSY}}$ (highest particle produced at LHC) $- M_{LSP}$

- If $\Delta M > O(100)$ GeV \rightarrow open spectra \rightarrow high energetic objects
- If $\Delta M < O(100)$ GeV \rightarrow compressed spectra \rightarrow very difficult experimentally

Production of SUSY Particles at the LHC



Strong production of gluinos, 1st and 2nd generation squarks
 expected sensitivity up to ~1.2 TeV

Strong production of 3rd generation squarks
 expected sensitivity ~0.7 TeV

Electro-weak production of electroweakinos and sleptons
 expected sensitivity ~0.2-0.5 TeV

Stringent constraint on strong production

- ✓ squarks (~850 GeV) gluinos (~1.33 TeV)
- May favor electroweak production at the LHC
- ✓ Final states with multi-leptons and $E_{T,miss}$

ATLAS SUSY searches focus largely in addressing direct production of gluinos, stops, EW-gauginos with simplified models

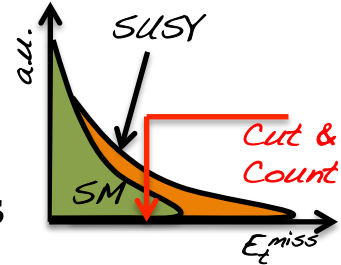
Common Analysis Strategies

Some SUSY processes can be SM-like.

SUSY searches rely on accurate modeling of SM backgrounds.

The presented analyses follow a common strategy:

- ✓ Define **Signal Regions** (SRs) based on signal kinematic features
- ✓ Estimate the SM processes in the SRs using:
 - **Semi-data driven** method for irreducible backgrounds:
 - Define a **Control Region** (CR) for each background
 - Normalized Monte Carlo yield to data in Control Regions (CR)
 - Apply transfer factor to extrapolate background yield from CRs to SRs
 - **Data-driven** method for instrumental background (QCD multijet backgrounds)
 - **Monte Carlo simulation** only for minor backgrounds.
- ✓ All predictions are **validated against data in Validation Regions** (VRs)
- ✓ Finally, look at the observed data in the SRs



Strong Production Searches

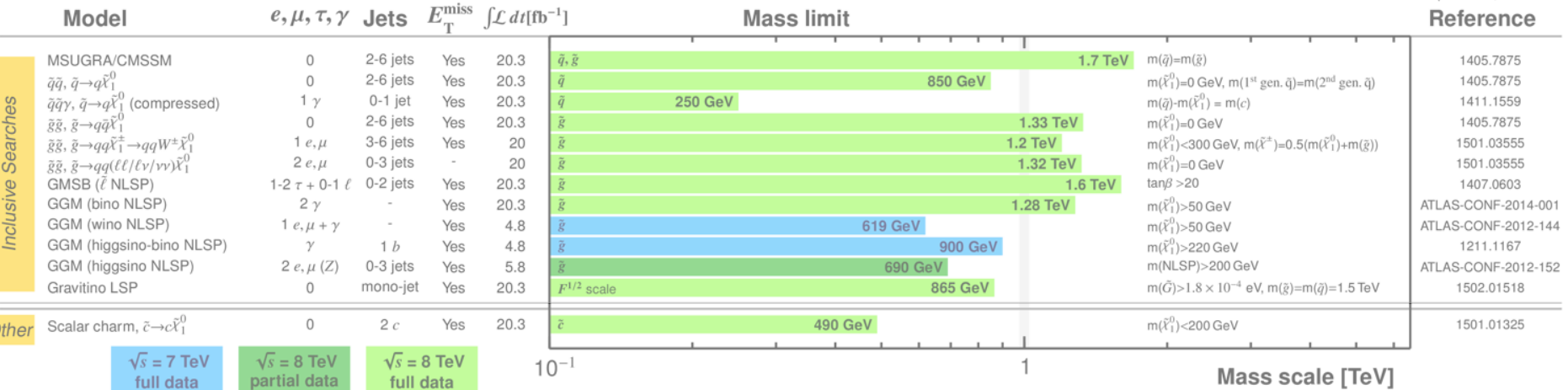
ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Feb 2015

ATLAS Preliminary

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

Reference

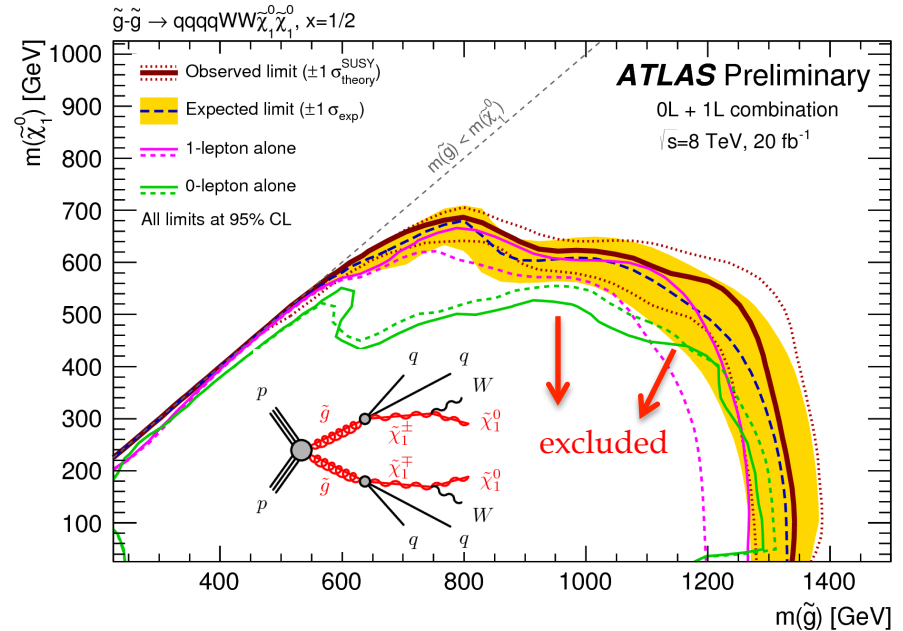
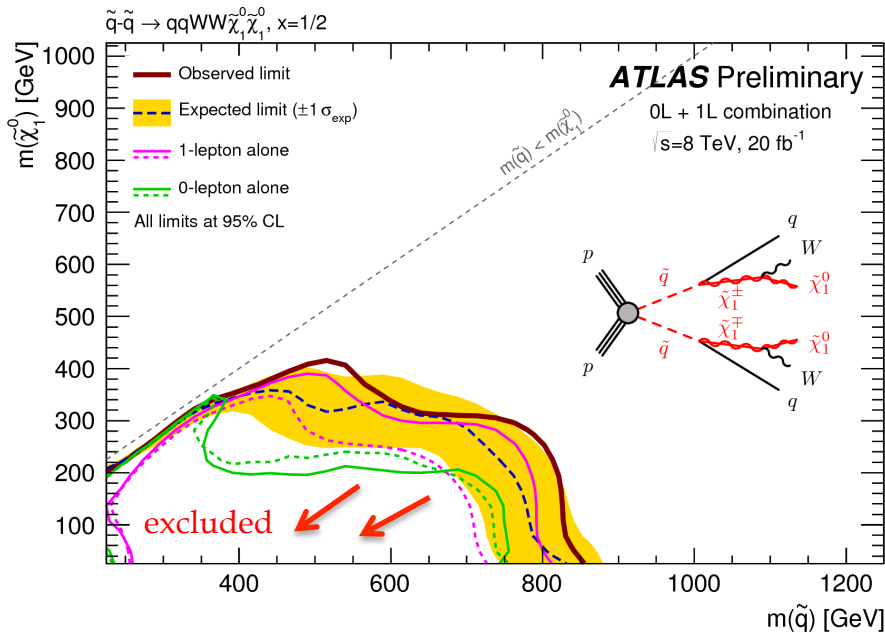


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- Inclusive Search
- $\tilde{g} \rightarrow t\bar{t} \tilde{\chi}_1^0$
- Scalar charm
- Z+Met

Inclusive Searches

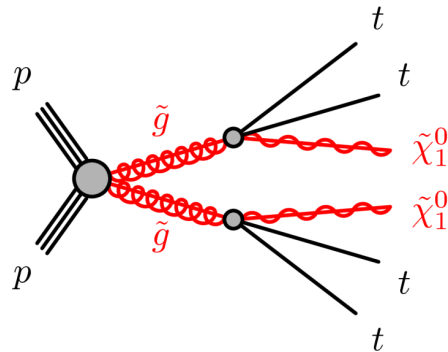
- ✓ Final states with **jets**, missing transverse momentum (E_T^{miss}) and **zero or one isolated lepton** (e/ μ)
- ✓ Broad search strategy with **several SRs** to obtain best sensitivity:
 - Lepton veto SRs [arXiv: [1405.7875](#)]
 - Soft lepton SRs
 - Hard leptons SRs
 } [arXiv: [1501.03555](#)]
- ✓ Many Simplified Model interpretations, with single production and decay process.
- ✓ **Combinations to strengthen limits (~ 50 GeV) and test holes in sensitivity.**



Glauino Searches with top quarks

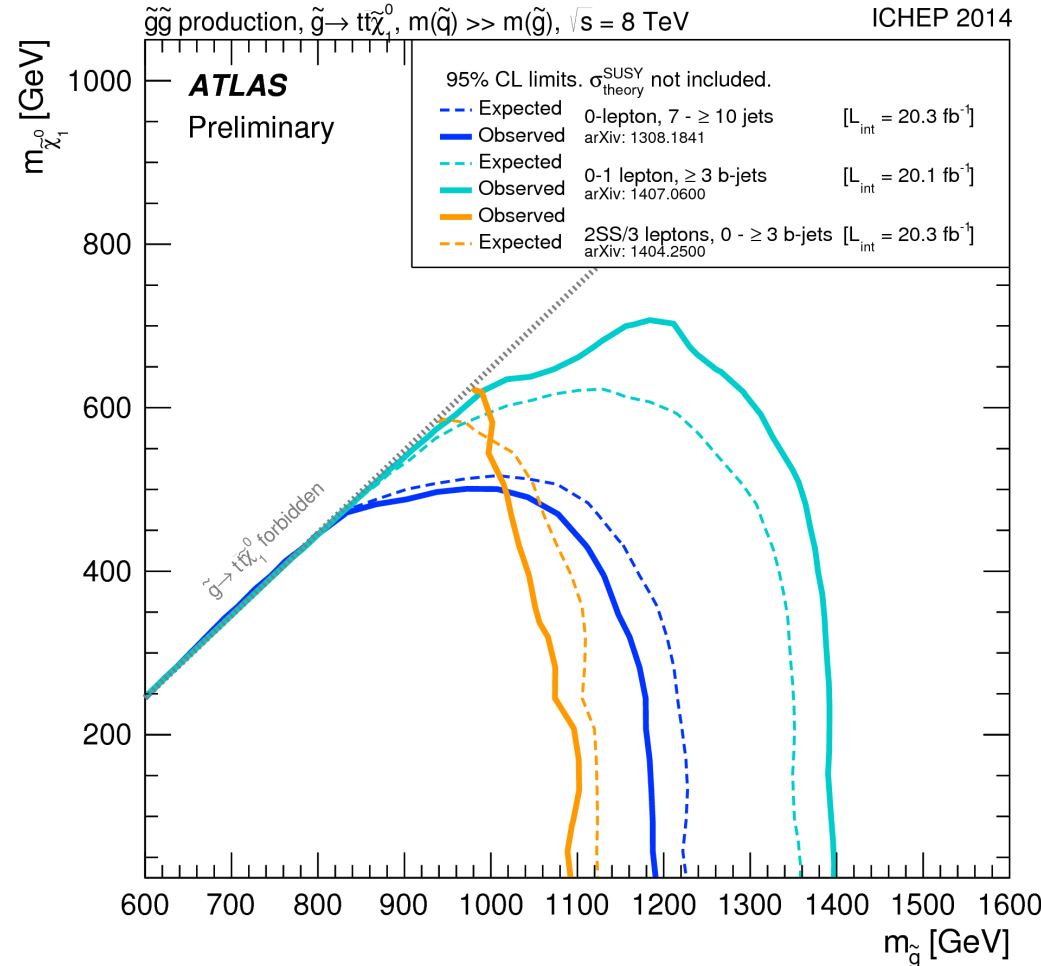
✓ Interpretation for a pair of gluinos decaying promptly via off-shell stop

$$\tilde{g} \rightarrow t\bar{t} \tilde{\chi}_1^0$$



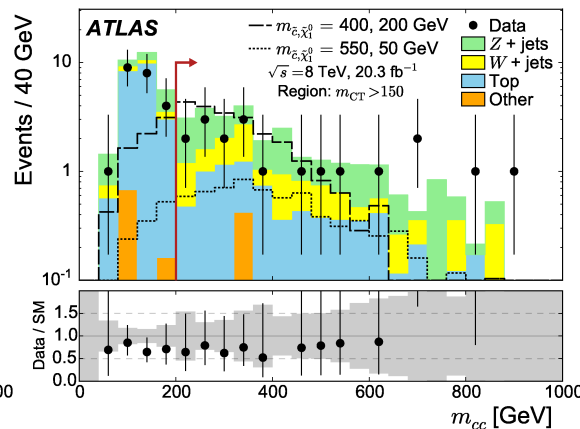
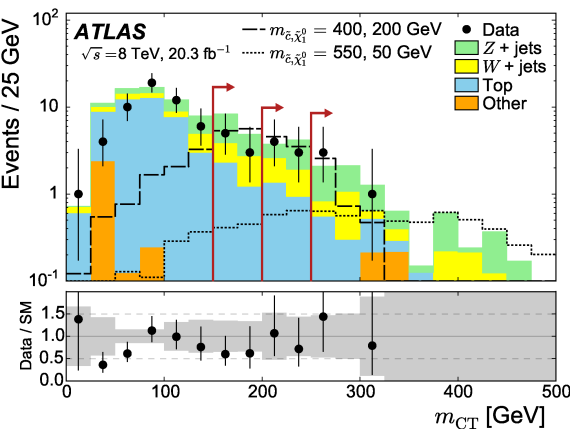
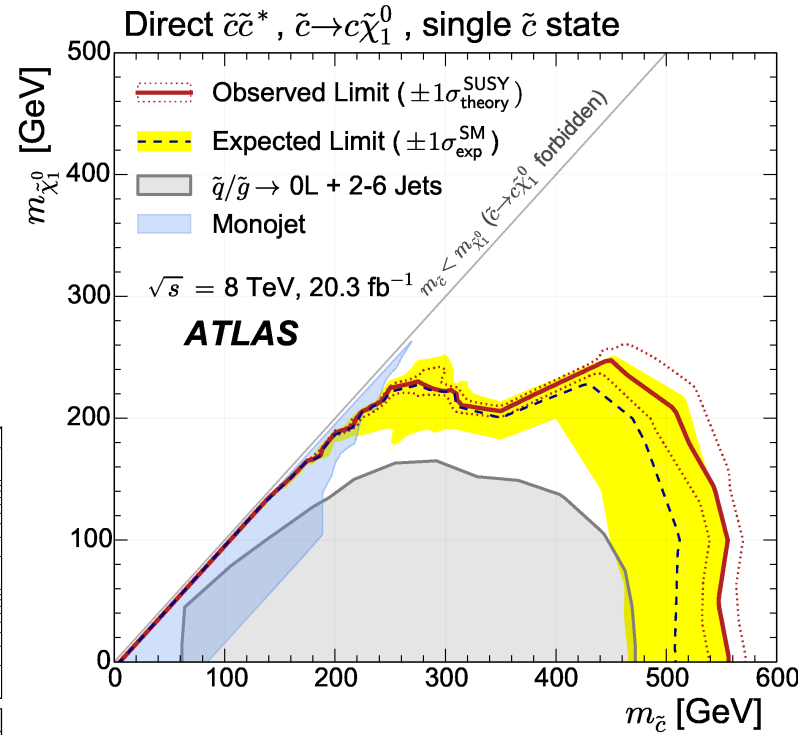
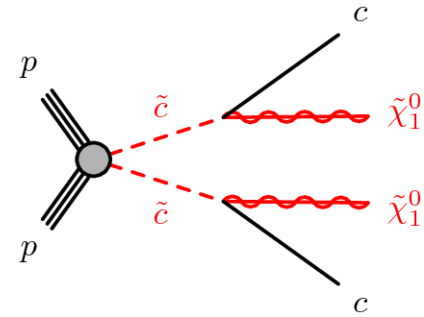
✓ Broad search strategy:

- 0L + 7-10 jets [arXiv: [1308.1841](https://arxiv.org/abs/1308.1841)]
- 0-1L + ≥ 3 b-jets [arXiv: [1407.0600](https://arxiv.org/abs/1407.0600)]
- 2L same sign/3L [arXiv: [1404.2500](https://arxiv.org/abs/1404.2500)]
 - Benefit from low SM backgrounds
 - Can also target low E_T^{miss} scenarios such as RPV or compress spectra



Direct Scalar Charm

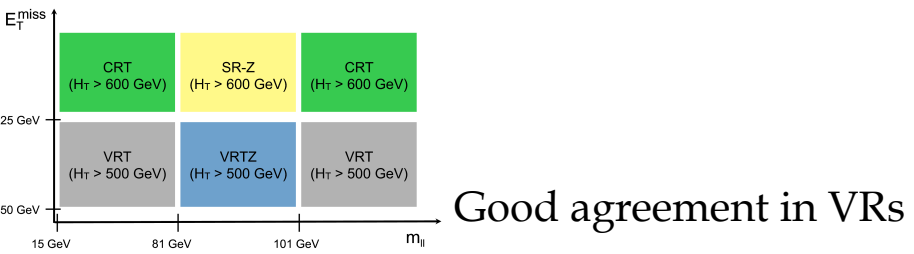
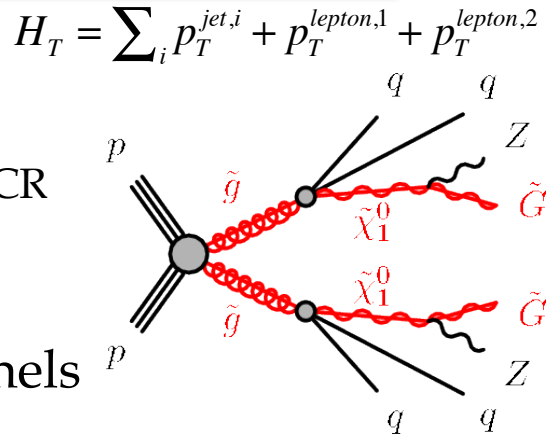
- ✓ Final state with large E_T^{miss} and at least two jets, with the **two leading tagged as originating from c-quarks**.
- ✓ c-jet tagging efficiency as a function of jet p_T , is calibrated from data in inclusive jets events containing D^* mesons.
 - Tagging efficiency of 19% (13%, 0.5%) is achieved for c-jets (b-jets, light-flavor/gluon jets)
- ✓ Final SR selection based on:
 - **Contranverse mass m_{CT}** $m_{CT} = \sqrt{(E_T^{v_1} + E_T^{v_2}) - |\mathbf{p}_T^{v_1} - \mathbf{p}_T^{v_2}|^2}$
 - Reduces ttbar with mis-tagged b's as c-jet
 - **Invariant mass of the two c-tagged jets: m_{cc}**
 - Reduces Z+jets, with c from gluon splitting



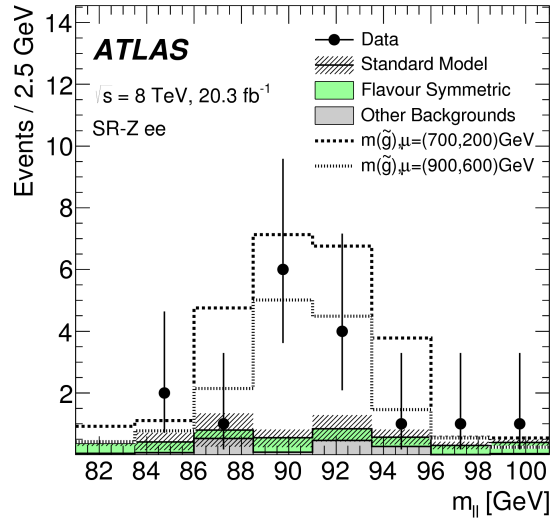
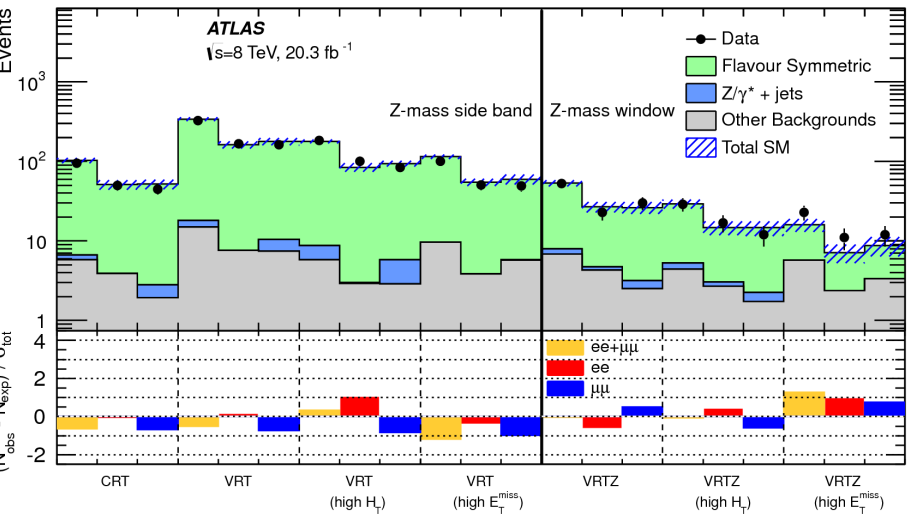
100 GeV gain compared to 0L

Squarks/gluinos Search with Z final state

- ✓ Final state with $Z, \geq 2$ jets and large E_T^{miss} and H_T
- ✓ Data driven estimates for all major backgrounds
 - Flavor symmetric background (eg tt, WW) estimated from $e\mu$ CR
 - Several regions and alternative background estimate methods used for cross-checks
- ✓ Observed 3.0σ (1.7σ) over fluctuation in ee ($\mu\mu$) channels



Over fluctuation in SR



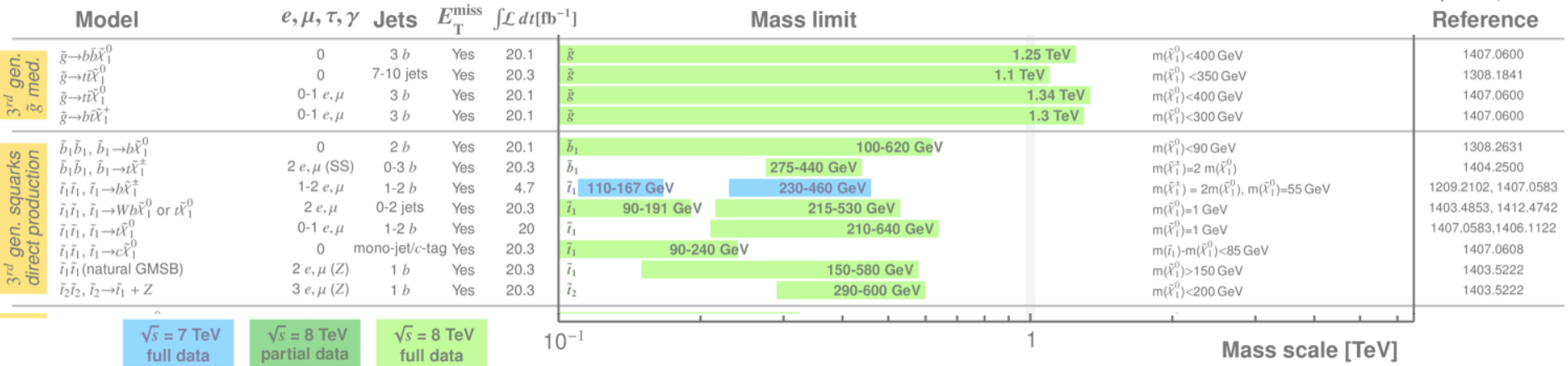
Third Generation Squark Searches

ATLAS SUSY Searches* - 95% CL Lower Limits

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ATLAS Preliminary

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



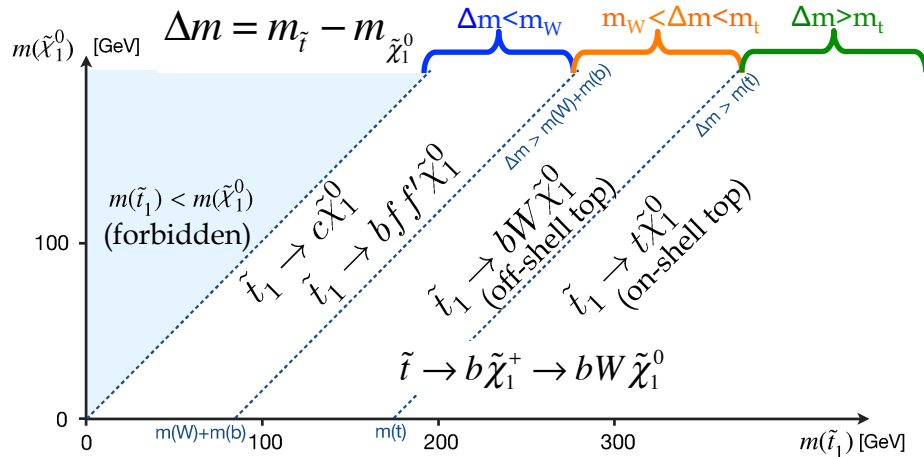
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- Overview
- Stop search combination
- Stealth stops

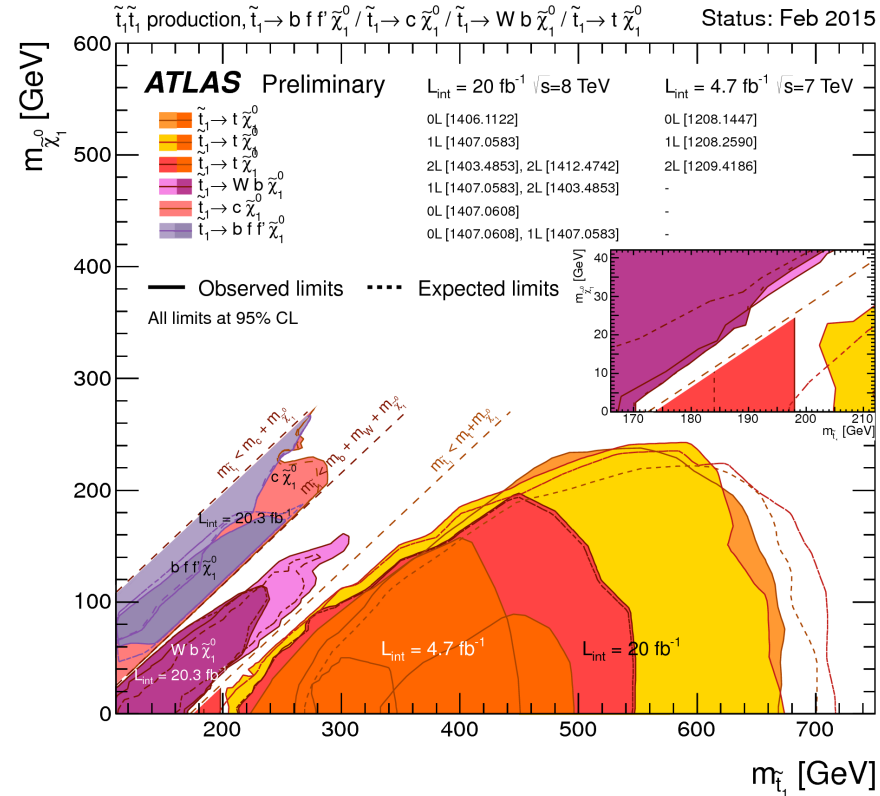
See Alexandre Aubin's talk

Stop Searches Overview

- ✓ Complicated search due to heavy quark masses
- ✓ Decays depends strongly on mass hierarchy of sparticles
 - Required dedicated SRs



- If $\Delta m > m_{\text{top}}$
 - Decay to on-shell top quarks ($t \rightarrow Wb$).
- If $\Delta m < m_W$ (compress region)
 - No phase space left to produce massive bottom/top quarks or high p_T objects. Decay can include “soft” charm quark.
- If $m_W < \Delta m < m_{\text{top}}$:
 - Can have W 's, charginos etc... (depending on mass of sparticles).

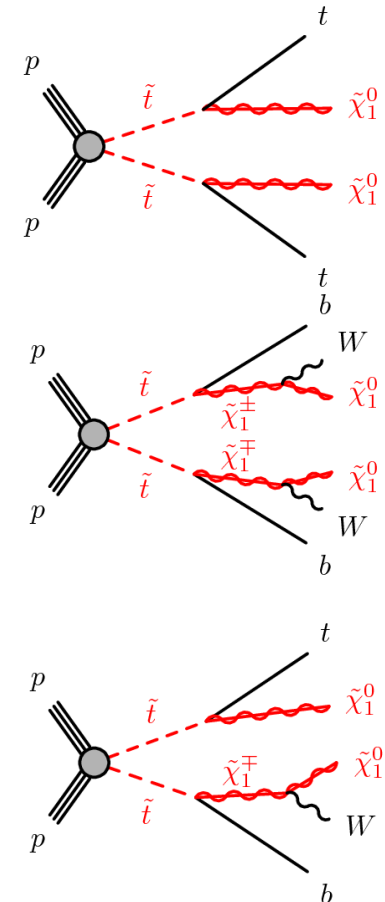
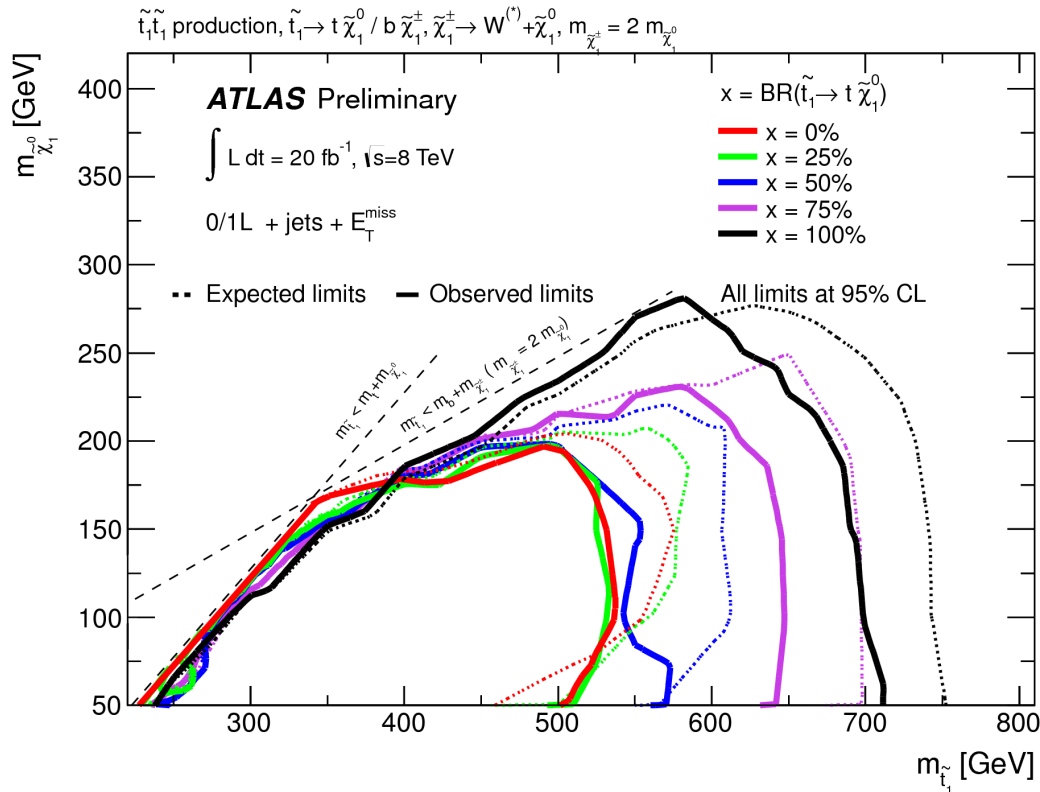


Broad search strategy:

- 0L, 1L, 2L, mono-jets searches
- Challenging low-mass models still not excluded

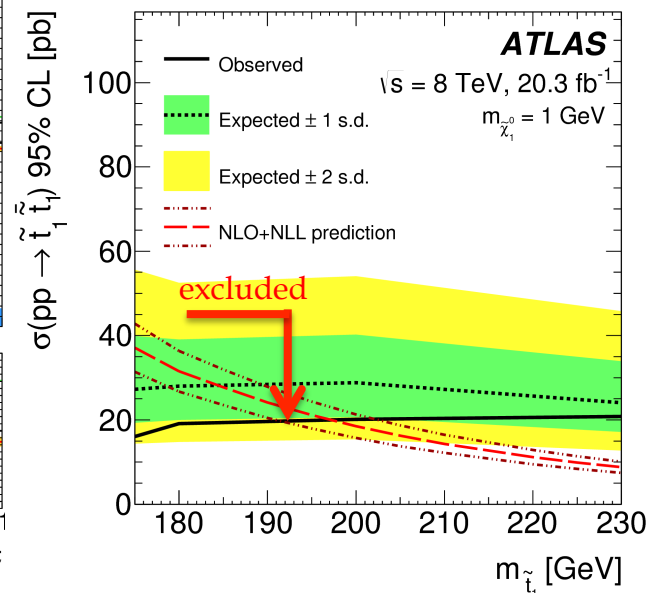
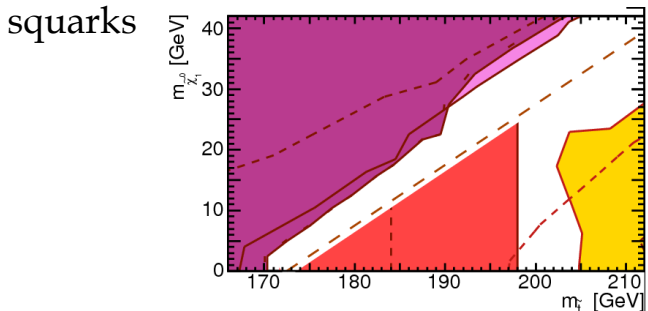
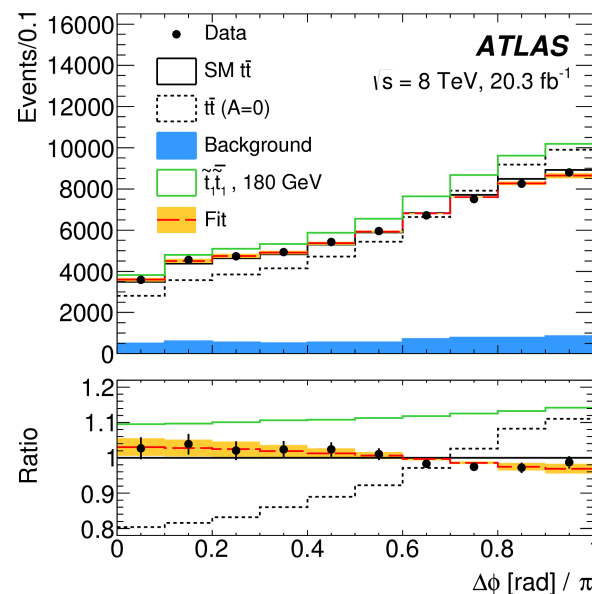
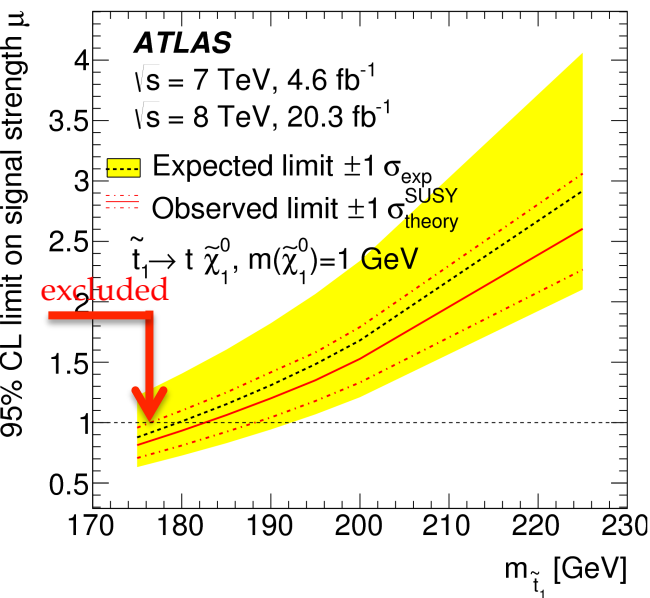
Stop Searches Combination

- ✓ Search for light scalar top motivated by naturalness argument.
- ✓ **Statistical combination of 0L and 1L search channels** for $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ or $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$
 - Improve expected limit by ~ 50 GeV in stop mass at low LSP mass.
- ✓ Exclusion limits set for different branching ratios x for $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ and $(1-x)$ for $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$



Stealth stops

- ✓ Stop quarks with mass just slightly above the top mass, are very difficult to find
 - Theory uncertainty on $t\bar{t}$ theory cross section is comparable to stop cross section at this mass
 - Stop-antistop could mimic top pair production $\tilde{t}\tilde{t} \rightarrow t\bar{t} \tilde{\chi}_1^0 \tilde{\chi}_1^0$
- ✓ Use $t\bar{t}$ dilepton candidates (90% pure) to constraint “stealthy stop”
 - Re-interpret $t\bar{t}$ cross section measurement to place limit on top squarks
 - Measure angle between leptons (related to $t\bar{t}$ spin correlation) and test consistency between SM and SM + very light top squark
 Can exclude $m_{top} < m_{stop} < 191 \text{ GeV}$



Electroweak Searches

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Feb 2015

ATLAS Preliminary

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

Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L} dt [\text{fb}^{-1}]$	Mass limit	Reference
$\tilde{\ell}_{L,R} \tilde{\ell}_{L,R}^*, \tilde{\ell} \rightarrow \ell \tilde{\chi}_1^0$	$2 e, \mu$	0	Yes	20.3	$\tilde{\ell}$ 90-325 GeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}$ 1403.5294
$\tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow \tilde{\ell} \nu(\ell \bar{\nu})$	$2 e, \mu$	0	Yes	20.3	$\tilde{\chi}_1^\pm$ 140-465 GeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}, m(\tilde{\ell}, \bar{\nu})=0.5(m(\tilde{\chi}_1^+)+m(\tilde{\chi}_1^0))$ 1403.5294
$\tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow \tilde{\tau} \nu(\tau \bar{\nu})$	2τ	-	Yes	20.3	$\tilde{\chi}_1^\pm$ 100-350 GeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}, m(\tilde{\tau}, \bar{\nu})=0.5(m(\tilde{\chi}_1^+)+m(\tilde{\chi}_1^0))$ 1407.0350
$\tilde{\chi}_1^+ \tilde{\chi}_2^0 \rightarrow \tilde{\ell}_L \nu \tilde{\ell}_L^* \ell(\bar{\nu} \nu), \ell \bar{\nu} \tilde{\ell}_L \ell(\bar{\nu} \nu)$	$3 e, \mu$	0	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 700 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^0)=0, m(\tilde{\ell}, \bar{\nu})=0.5(m(\tilde{\chi}_1^+)+m(\tilde{\chi}_1^0))$ 1402.7029
$\tilde{\chi}_1^+ \tilde{\chi}_2^0 \rightarrow W \tilde{\chi}_1^0 Z \tilde{\chi}_1^0$	$2-3 e, \mu$	0-2 jets	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 420 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^0)=0, \text{ sleptons decoupled}$ 1403.5294, 1402.7029
$\tilde{\chi}_1^+ \tilde{\chi}_2^0 \rightarrow W \tilde{\chi}_1^0 h \tilde{\chi}_1^0, h \rightarrow b\bar{b}/WW/\tau\tau/\gamma\gamma$	e, μ, γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 250 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^0)=0, \text{ sleptons decoupled}$ 1501.07110
$\tilde{\chi}_2^0 \tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0 \rightarrow \tilde{\ell}_R \ell$	$4 e, \mu$	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$ 620 GeV	$m(\tilde{\chi}_2^0)=m(\tilde{\chi}_3^0), m(\tilde{\chi}_1^0)=0, m(\tilde{\ell}, \bar{\nu})=0.5(m(\tilde{\chi}_2^0)+m(\tilde{\chi}_1^0))$ 1405.5086

$\sqrt{s} = 7 \text{ TeV}$
full data

$\sqrt{s} = 8 \text{ TeV}$
partial data

$\sqrt{s} = 8 \text{ TeV}$
full data

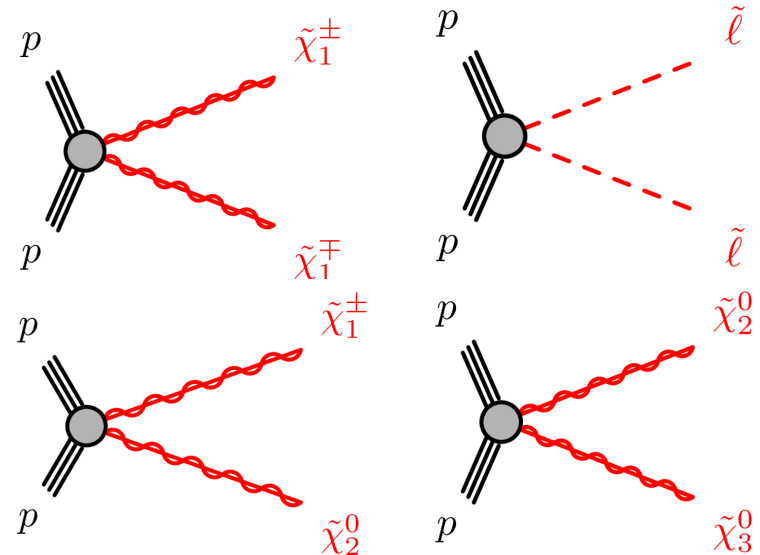
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Mass scale [TeV]

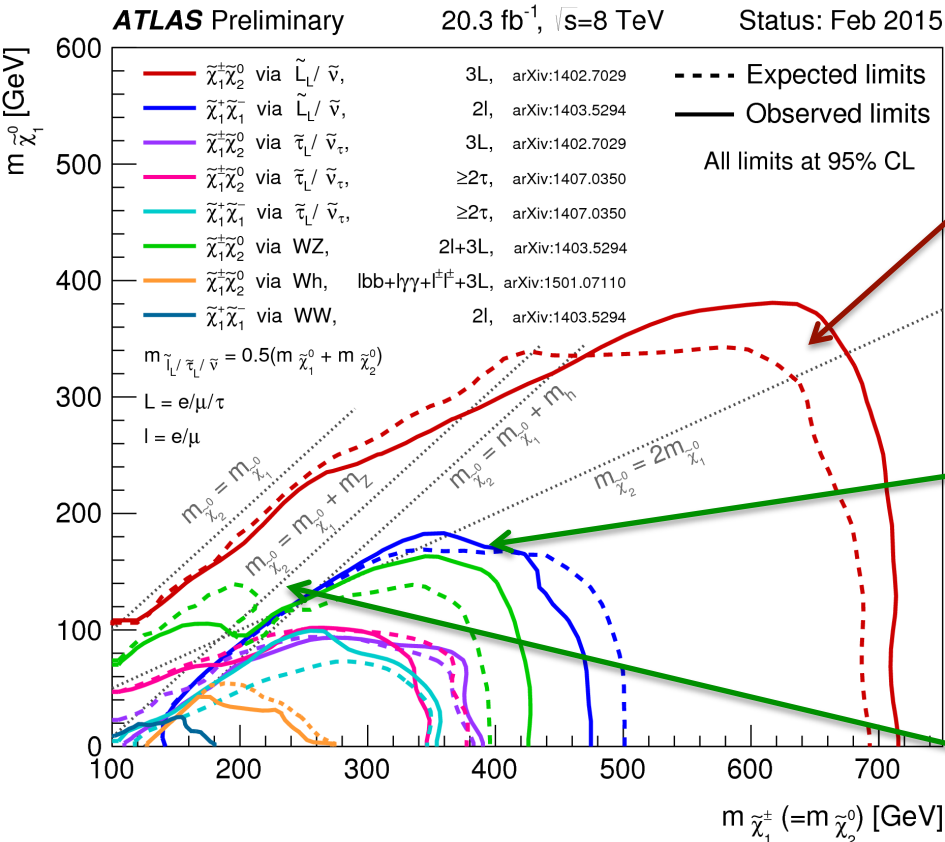
- Electroweak Summary
- Searches with Higgs

See Alexandre Aubin's talk



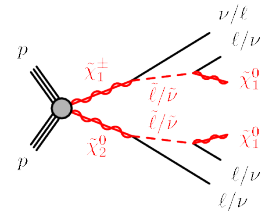
Electroweak SUSY Summary

- ✓ Very **clean multi-lepton (e, μ , τ) signatures** with low jet activity
 - Low cross-section balanced by smaller and relatively well understood SM backgrounds
- ✓ Many different final states to consider. Broad search strategy.

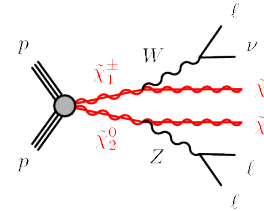


Limit strength vary widely depending on the model assumptions

- Decay through intermediary sleptons



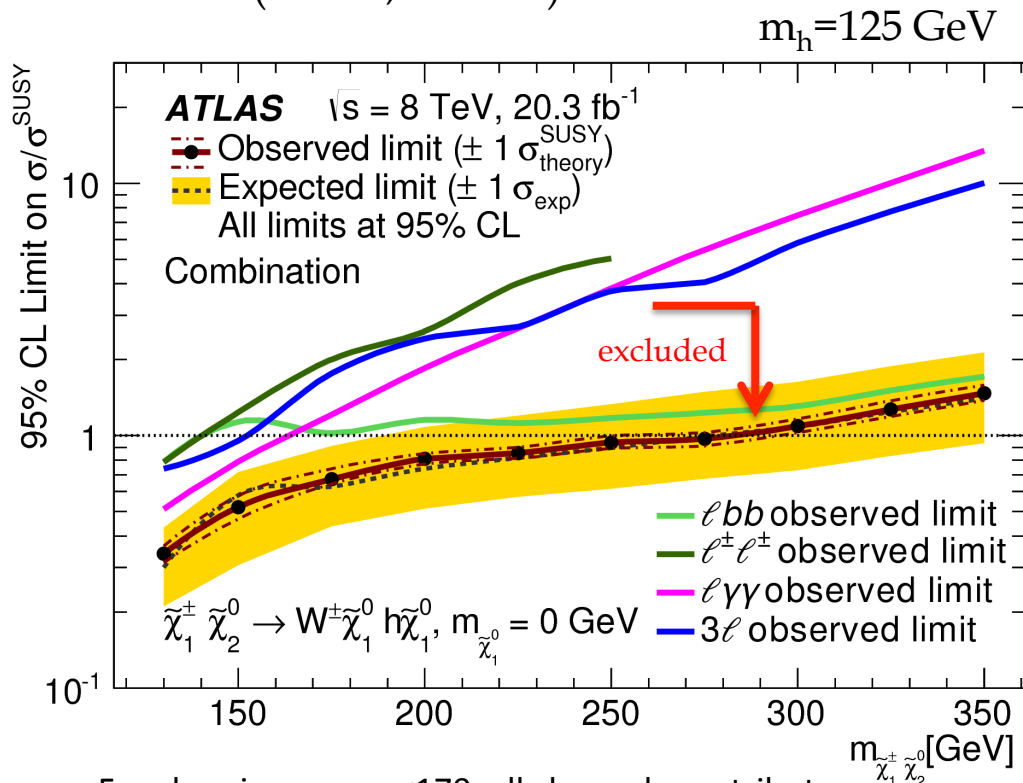
- Decay through SM vector bosons



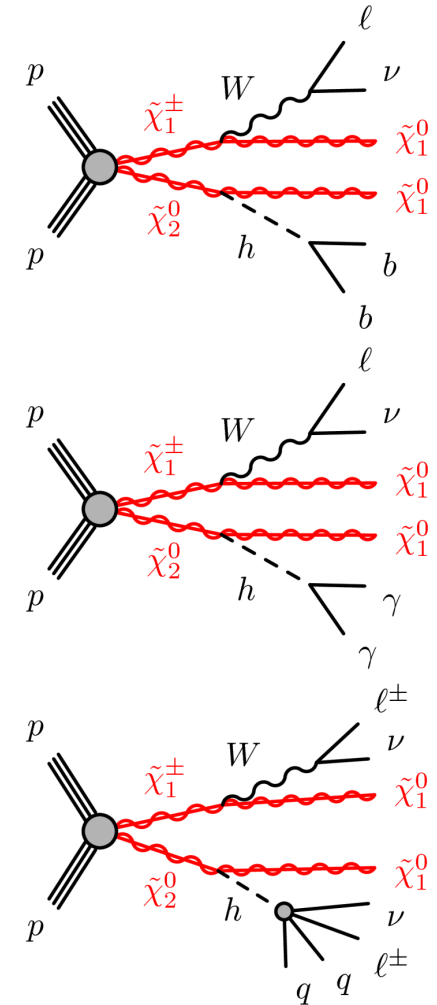
Compress spectra region can be challenging

Chargino, neutralino decaying to Higgs

- ✓ If the electroweakinos (C_1, N_2) are Wino-like, mostly Higgs in decay
- ✓ Three channels analyzed and statistically combined with 3L
 - 1L bb ($W \rightarrow \ell\nu, h \rightarrow bb$)
 - 1L $\gamma\gamma$ ($W \rightarrow \ell\nu, h \rightarrow \gamma\gamma$)
 - 2L SS ($W \rightarrow \ell\nu, h \rightarrow WW$)



For charginos mass < 170 , all channels contribute
 For charginos mass > 170 , 1L+bb channel dominates



Run 2 Prospects

4-jets event.
Highest p_T jet >200 GeV



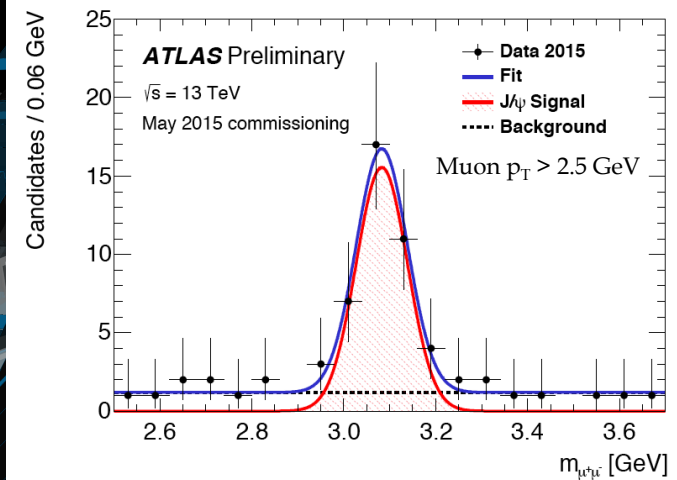
13 TeV collisions

Run: 265545

Event: 2501742

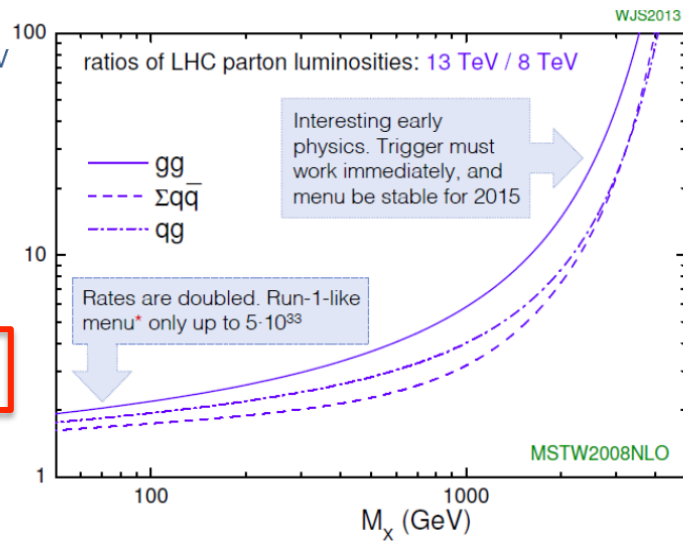
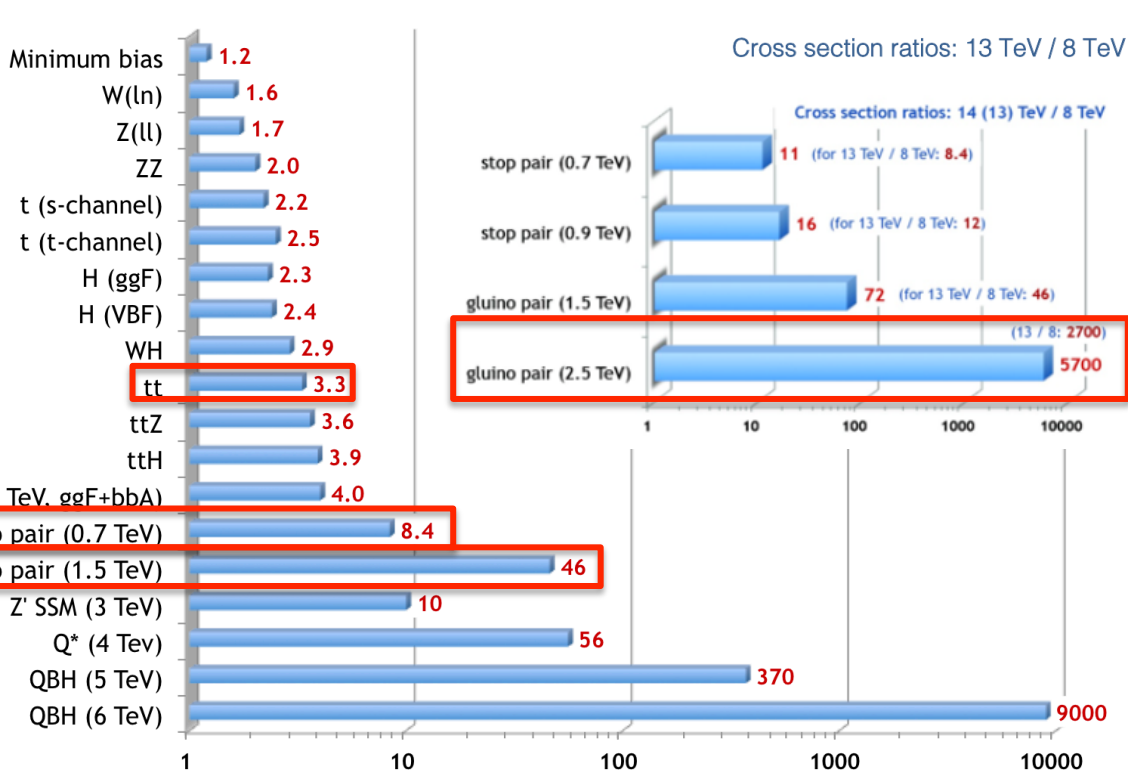
2015-05-21 09:58:30 CEST

Invariant mass of di-muon candidates



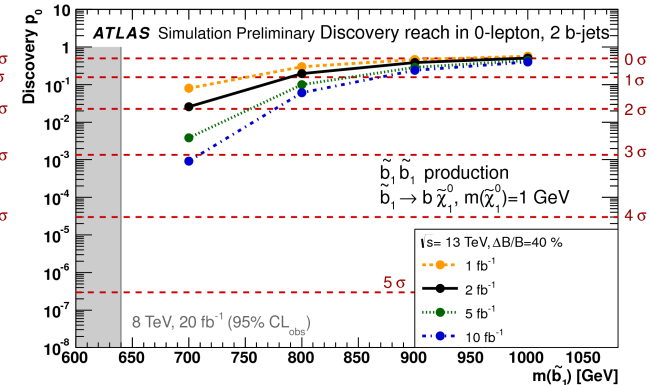
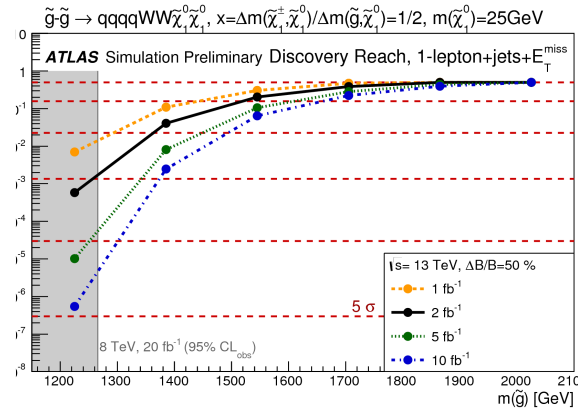
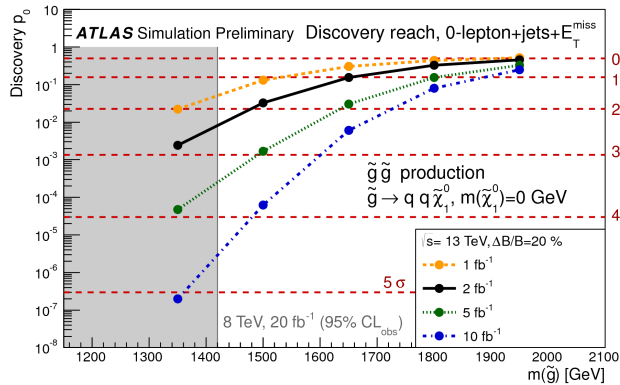
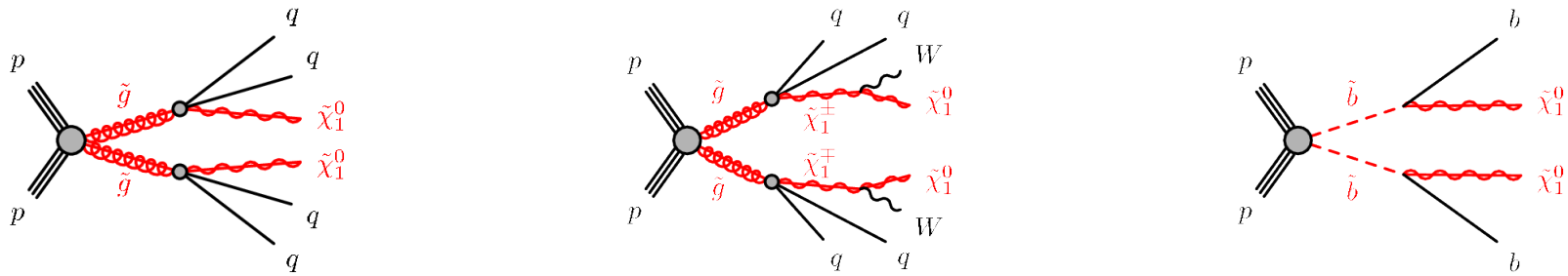
Near future

- ✓ Significant preparation for Run 2 in progress
- ✓ 13TeV Collisions starting THIS WEEK !!!
- ✓ Excited to finally lay hands on 13 TeV data
 - Reach for strongly produced SUSY is expected to increase significantly in Run-2
 - New heavy state could be discovered relatively quickly !
 - The HL-LHC will allow to ultimately probe the TeV scale and Natural SUSY



Early Run-2 Prospects

- ✓ How much data is needed at 13TeV for the discovery potential to surpass the 8TeV limit ?
 - Potential of 3σ evidence with $2\text{-}10\text{fb}^{-1}$, even with poor systematics
- ✓ The early months of the 2015 run should be exciting !



Summary And Outlook

- ✓ Comprehensive set of SUSY searches performed with ATLAS Run-1 data yielded many results.
- ✓ No significant excess above SM expectations is observed in any searches
 - Strong exclusion for $m_{\text{LSP}} \sim 0$ GeV for color and electroweak sectors
- ✓ 95% CL exclusion limits are set for various phenomenological models
- ✓ Parameter space favored by naturalness argument narrowing
 - Compress spectra region remains challenging

Run-2 is starting !

- ✓ Increase in SUSY cross section due to higher center of mass energy, once again opens the door to discovery.
 - Largest increase in energy for many years to come
- ✓ Looking forward to run-2 dataset
 - *and hopefully not having to make exclusion plots anymore !*
- ✓ If have to be guided by “natural SUSY”, have a long way to go... and it will take time.



Summary of ATLAS Run-1 SUSY Searches

<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults>

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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{g}, \tilde{g} 1.7 TeV	$m(\tilde{g})=m(\tilde{g})$	1405.7875	
	$\tilde{q}\tilde{q}, \tilde{q}-\tilde{q}K_1^0$	0	2-6 jets	Yes	20.3	\tilde{q} 850 GeV	$m(\tilde{q})=0 \text{ GeV}, m(1^{\text{st}} \text{ gen. } \tilde{q})=m(2^{\text{nd}} \text{ gen. } \tilde{q})$	1405.7875	
	$\tilde{q}\tilde{q}\tilde{\nu}, \tilde{q}-\tilde{q}K_1^0$ (compressed)	1 γ	0-1 jet	Yes	20.3	\tilde{q} 250 GeV	$m(\tilde{q})-m(\tilde{K}_1^0) = m(c)$	1411.1559	
	$\tilde{g}\tilde{g}, \tilde{g}-\tilde{g}K_1^0$	0	2-6 jets	Yes	20.3	\tilde{g} 1.33 TeV	$m(\tilde{g})=0 \text{ GeV}$	1405.7875	
	$\tilde{g}\tilde{g}, \tilde{g}-\tilde{g}K_1^0 \rightarrow \tilde{q}\tilde{q}W^\pm K_1^0$	1 e, μ	3-6 jets	Yes	20	\tilde{g} 1.2 TeV	$m(\tilde{K}_1^0) < 300 \text{ GeV}, m(\tilde{K}^\pm) = 0.5(m(\tilde{K}_1^0) + m(\tilde{g}))$	1501.03555	
	$\tilde{g}\tilde{g}, \tilde{g}-\tilde{g}K_1^0(\ell f \nu/\nu) K_1^0$	2 e, μ	0-3 jets	-	20	\tilde{g} 1.32 TeV	$m(\tilde{K}_1^0) = 0 \text{ GeV}$	1501.03555	
	GMSB ($\tilde{\ell}$ NLSP)	1-2 $\tau + 0-1 \ell$	0-2 jets	Yes	20.3	\tilde{g} 1.6 TeV	$\tan\beta > 20$	1407.0603	
	GGM (bino NLSP)	2 γ	-	Yes	20.3	\tilde{g} 1.28 TeV	$m(\tilde{K}_1^0) > 50 \text{ GeV}$	ATLAS-CONF-2014-001	
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	\tilde{g} 619 GeV	$m(\tilde{K}_1^0) > 50 \text{ GeV}$	ATLAS-CONF-2012-144	
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	\tilde{g} 900 GeV	$m(\tilde{K}_1^0) > 220 \text{ GeV}$	1211.1167	
3 rd Gen. \tilde{g} med.	$\tilde{g}-b\tilde{K}_1^0$	0	3 b	Yes	20.1	\tilde{g} 1.25 TeV	$m(\tilde{K}_1^0) < 400 \text{ GeV}$	1407.0600	
	$\tilde{g}-b\tilde{K}_1^0$	0	7-10 jets	Yes	20.3	\tilde{g} 1.1 TeV	$m(\tilde{K}_1^0) < 350 \text{ GeV}$	1308.1841	
	$\tilde{g}-b\tilde{K}_1^0$	0-1 e, μ	3 b	Yes	20.1	\tilde{g} 1.34 TeV	$m(\tilde{K}_1^0) < 400 \text{ GeV}$	1407.0600	
	$\tilde{g}-b\tilde{K}_1^0$	0-1 e, μ	3 b	Yes	20.1	\tilde{g} 1.3 TeV	$m(\tilde{K}_1^0) < 300 \text{ GeV}$	1407.0600	
	3 rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1-b\tilde{K}_1^0$	0	2 b	Yes	20.1	\tilde{b}_1 100-620 GeV	$m(\tilde{K}_1^0) < 90 \text{ GeV}$	1308.2631
		$\tilde{b}_1\tilde{b}_1, \tilde{b}_1-b\tilde{K}_1^0$	2 e, μ (SS)	0-3 b	Yes	20.3	\tilde{b}_1 275-440 GeV	$m(\tilde{K}_1^0) = 2 m(\tilde{K}_1^0)$	1404.2500
		$\tilde{t}_1\tilde{t}_1, \tilde{t}_1-b\tilde{K}_1^0$	1-2 e, μ	1-2 b	Yes	4.7	\tilde{t}_1 110-167 GeV	$m(\tilde{K}_1^0) = 2m(\tilde{K}_1^0), m(\tilde{K}_1^0) = 55 \text{ GeV}$	1209.2102, 1407.0583
		$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow W b \tilde{K}_1^0$ or \tilde{d}_1^0	2 e, μ	0-2 jets	Yes	20.3	\tilde{t}_1 90-191 GeV	$m(\tilde{K}_1^0) = 1 \text{ GeV}$	1403.4853, 1412.4742
		$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow \tilde{d}_1^0$	0-1 e, μ	1-2 b	Yes	20	\tilde{t}_1 210-640 GeV	$m(\tilde{K}_1^0) = 1 \text{ GeV}$	1407.0608
		$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow c\tilde{K}_1^0$	0 mono-jet/ c -tag	Yes	20.3	\tilde{t}_1 90-240 GeV	$m(\tilde{K}_1^0) = 1 \text{ GeV}$	1407.0608	
$\tilde{t}_1\tilde{t}_1$ (natural GMSB)		2 e, μ (Z)	1 b	Yes	20.3	\tilde{t}_1 150-580 GeV	$m(\tilde{K}_1^0) > 150 \text{ GeV}$	1403.5222	
$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$		3 e, μ (Z)	1 b	Yes	20.3	\tilde{t}_2 290-600 GeV	$m(\tilde{K}_1^0) < 200 \text{ GeV}$	1403.5222	
EW direct		$\tilde{L}_{L,R}\tilde{L}_{L,R}, \tilde{L} \rightarrow \tilde{L}K_1^0$	2 e, μ	0	Yes	20.3	\tilde{L} 90-325 GeV	$m(\tilde{K}_1^0) = 0 \text{ GeV}$	1403.5294
		$\tilde{X}_1^0\tilde{X}_1^0, \tilde{X}_1^0 \rightarrow \tilde{\nu}(\nu)$	2 e, μ	0	Yes	20.3	\tilde{X}_1^0 140-465 GeV	$m(\tilde{K}_1^0) = 0 \text{ GeV}, m(\tilde{L}, \tilde{\nu}) = 0.5(m(\tilde{X}_1^0) + m(\tilde{K}_1^0))$	1403.5294
	$\tilde{X}_1^\pm\tilde{X}_1^\pm, \tilde{X}_1^\pm \rightarrow \tilde{\nu}(\nu)$	2 τ	-	Yes	20.3	\tilde{X}_1^\pm 100-350 GeV	$m(\tilde{K}_1^0) = 0 \text{ GeV}, m(\tilde{L}, \tilde{\nu}) = 0.5(m(\tilde{X}_1^\pm) + m(\tilde{K}_1^0))$	1407.0350	
	$\tilde{X}_1^0\tilde{X}_2^0 \rightarrow \tilde{L}_i\nu\tilde{L}_i(\tilde{\nu}\nu), \tilde{\nu}\tilde{L}_i(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.3	$\tilde{X}_1^0, \tilde{X}_2^0$ 700 GeV	$m(\tilde{K}_1^0) = m(\tilde{K}_2^0), m(\tilde{K}_1^0) = 0, m(\tilde{L}, \tilde{\nu}) = 0.5(m(\tilde{X}_1^0) + m(\tilde{K}_1^0))$	1402.7029	
	$\tilde{X}_1^0\tilde{X}_2^0 \rightarrow W\tilde{X}_1^0\tilde{Z}_1^0$	2-3 e, μ	0-2 jets	Yes	20.3	$\tilde{X}_1^0, \tilde{X}_2^0$ 420 GeV	$m(\tilde{K}_1^0) = m(\tilde{K}_2^0), m(\tilde{K}_1^0) = 0, \text{ sleptons decoupled}$	1403.5294, 1402.7029	
	$\tilde{X}_1^0\tilde{X}_2^0 \rightarrow W\tilde{X}_1^0h\tilde{K}_1^0, h \rightarrow bb WW/\tau\tau/\gamma\gamma$	e, μ, γ	0-2 b	Yes	20.3	$\tilde{X}_1^0, \tilde{X}_2^0$ 250 GeV	$m(\tilde{K}_1^0) = m(\tilde{K}_2^0), m(\tilde{K}_1^0) = 0, \text{ sleptons decoupled}$	1501.07110	
	$\tilde{X}_2^0\tilde{X}_3^0, \tilde{X}_2^0 \rightarrow \tilde{L}_R\ell$	4 e, μ	0	Yes	20.3	$\tilde{X}_2^0, \tilde{X}_3^0$ 620 GeV	$m(\tilde{K}_2^0) = m(\tilde{K}_3^0), m(\tilde{K}_1^0) = 0, m(\tilde{L}, \tilde{\nu}) = 0.5(m(\tilde{X}_2^0) + m(\tilde{K}_1^0))$	1405.5086	
	Long-lived particles	Direct $\tilde{X}_1^0\tilde{X}_1^0$ prod., long-lived \tilde{X}_1^0	Disapp. trk	1 jet	Yes	20.3	\tilde{X}_1^0 270 GeV	$m(\tilde{K}_1^0) = m(\tilde{K}_2^0) = 160 \text{ MeV}, \tau(\tilde{X}_1^0) = 0.2 \text{ ns}$	1310.3675
		Stable, stopped \tilde{g} R-hadron	0	1-5 jets	Yes	27.9	\tilde{g} 832 GeV	$m(\tilde{K}_1^0) = 100 \text{ GeV}, 10 \mu\text{s} < \tau(\tilde{g}) < 1000 \text{ s}$	1310.6584
		Stable \tilde{g} R-hadron	trk	-	-	19.1	\tilde{g} 1.27 TeV	$10 < \tan\beta < 50$	1411.6795
GMSB, stable $\tilde{\tau}, \tilde{X}_1^0 \rightarrow \tilde{\tau}(\tilde{\nu}, \tilde{\mu}) + \tau(e, \mu)$		1-2 μ	-	-	19.1	\tilde{X}_1^0 537 GeV	$2 < \tau(\tilde{X}_1^0) < 3 \text{ ns}, \text{SPS8 model}$	1411.6795	
GMSB, $\tilde{X}_1^0 \rightarrow \gamma G, \text{long-lived } \tilde{X}_1^0$		2 γ	-	Yes	20.3	\tilde{X}_1^0 435 GeV	$1.5 < \tau < 156 \text{ mm}, \text{BR}(\mu) = 1, m(\tilde{K}_1^0) = 108 \text{ GeV}$	1409.5542	
$\tilde{q}\tilde{q}, \tilde{X}_1^0 \rightarrow qq\mu$ (RPV)		1 $\mu, \text{ displ. vtx}$	-	-	20.3	\tilde{q} 1.0 TeV	ATLAS-CONF-2013-092		
RPV	LFV $pp \rightarrow \tilde{\nu}_\tau + X, \tilde{\nu}_\tau \rightarrow e + \mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	$\lambda'_{311} = 0.10, \lambda_{132} = 0.05$	1212.1272	
	LFV $pp \rightarrow \tilde{\nu}_\tau + X, \tilde{\nu}_\tau \rightarrow e(\mu) + \tau$	1 $e, \mu + \tau$	-	-	4.6	$\tilde{\nu}_\tau$ 1.1 TeV	$\lambda'_{311} = 0.10, \lambda_{1233} = 0.05$	1212.1272	
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	\tilde{g}, \tilde{g} 1.35 TeV	$m(\tilde{g}) = m(\tilde{g}), c\tau_{333} < 1 \text{ mm}$	1404.2500	
	$\tilde{X}_1^0\tilde{X}_1^0, \tilde{X}_1^0 \rightarrow W\tilde{X}_1^0, \tilde{X}_1^0 \rightarrow ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.3	\tilde{X}_1^0 750 GeV	$m(\tilde{K}_1^0) > 0.2 m(\tilde{X}_1^0), \lambda_{121} \neq 0$	1405.5086	
	$\tilde{X}_1^0\tilde{X}_1^0, \tilde{X}_1^0 \rightarrow W\tilde{X}_1^0, \tilde{X}_1^0 \rightarrow \tau\tilde{\nu}_\tau, e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.3	\tilde{X}_1^0 450 GeV	$m(\tilde{K}_1^0) > 0.2 m(\tilde{X}_1^0), \lambda_{133} \neq 0$	1405.5086	
	$\tilde{g} \rightarrow qq\tilde{q}$	0	6-7 jets	0	20.3	\tilde{g} 916 GeV	$\text{BR}(\tilde{g}) - \text{BR}(\tilde{b}) = \text{BR}(c) = 0\%$	ATLAS-CONF-2013-091	
Other	$\tilde{g} \rightarrow \tilde{t}_1 t, \tilde{t}_1 \rightarrow bs$	2 e, μ (SS)	0-3 b	Yes	20.3	\tilde{g} 850 GeV		1404.250	
	Scalar charm, $\tilde{c} \rightarrow c\tilde{K}_1^0$	0	2 c	Yes	20.3	\tilde{c} 490 GeV	$m(\tilde{K}_1^0) < 200 \text{ GeV}$	1501.01325	

*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.

In canonical scenarios, sensitivity achieved up to ~1.3 TeV gluinos, ~700 GeV stop, and ~400 GeV EWK-inos

BACKUPS

Charm Tagger Performance

