SUSY Searches with the ATLAS Experiment

Epiphany 2016

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on behalf of the ATLAS Collaboration

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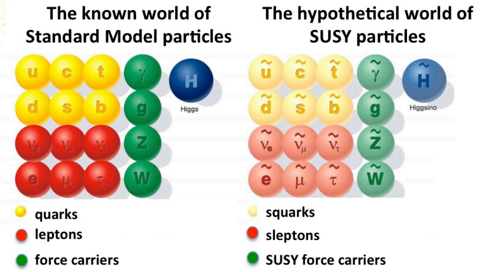
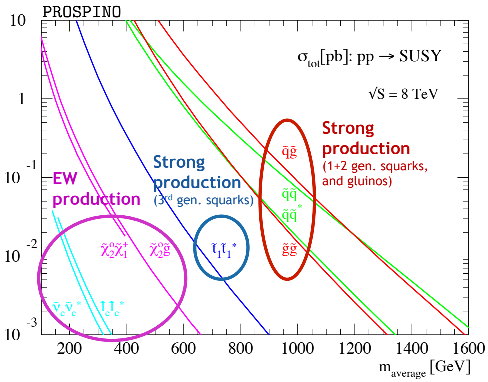
Supersymmetry

- Extends the Standard Model
- Each SM particle has at least one superpartner
- Superpartners have the same properties as their SM counterparts except for the spin that differs by 1/2
- SUSY is broken since superpartners have higher masses
- New quantum number: R-parity
- If R-parity conserved, LSP is stable



- Provides solution for hierarchy problem
- If R-parity is conserved, provides a dark matter candidate

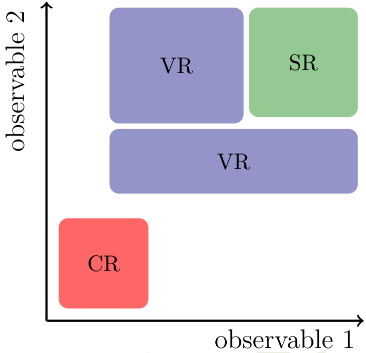
Introduction



- SUSY has a very diverse phenomenology
- ATLAS search strategy is to cover a broad range of SUSY models to enhance discovery potential
- Increasing luminosity gives sensitivity to low cross section processes
- This talk will show a selection of few recent Run 1 results and new Run 2 results
- For other Run 2 results see Da Xu's talk

SUSY Search Strategy

- Signal region (SR) targets a specific SUSY production/decay mode
- Background estimation
  - Irreducible background estimated using data in control region (CR) and extrapolated from CR to SR with Monte Carlo
  - Reducible background (fake/non isolated leptons, charge flip) estimated using data
  - Minor backgrounds estimated with pure Monte Carlo
- The predictions are validated in validation regions (VR)



Strong Production

- May be the dominant SUSY production process at the LHC due to high cross sections if squarks/gluinos are not too heavy
- Large yield even in small datasets
- Strong SUSY particle production: gluino, gluino-squark and squark pairs
- Typical signature: high-momentum jets, 0-1-2 leptons, large $E_{\mathrm{T}}^{\mathrm{miss}}$ from LSP

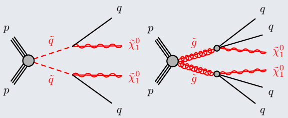
New Run 2 SUSY strong production searches in ATLAS

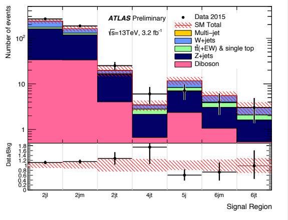
0 leptons + 2-6 jets + $E_{\mathrm{T}}^{\mathrm{miss}}$	ATLAS-CONF-2015-062	
0 leptons + 7-10 jets + $E_{\mathrm{T}}^{\mathrm{miss}}$	ATLAS-CONF-2015-077	
0 leptons + b-jets + boosted t	ATLAS-CONF-2015-067	
1 lepton + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$	ATLAS-CONF-2015-076	see Da Xu's talk
2 leptons + Z boson + $E_{\mathrm{T}}^{\mathrm{miss}}$	ATLAS-CONF-2015-082	see Da Xu's talk
2 SS or 3 leptons + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$	ATLAS-CONF-2015-078	see Da Xu's talk

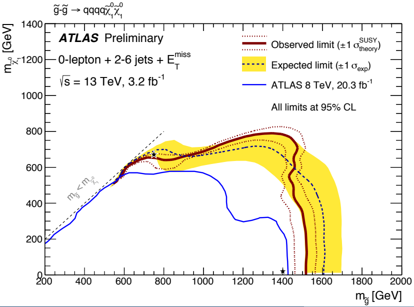
Inclusive Strong Production

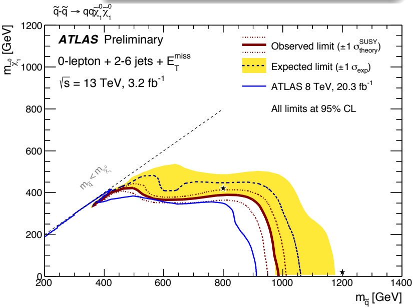
New Run 2 results - simplified model interpretation

- 0 leptons
- 2-6 jets
- $E_{\mathrm{T}}^{\mathrm{miss}}$
- New limits exceed Run 1 results
- Gluino mass up to 1520 GeV and squark mass up to 980 GeV excluded for massless neutralino



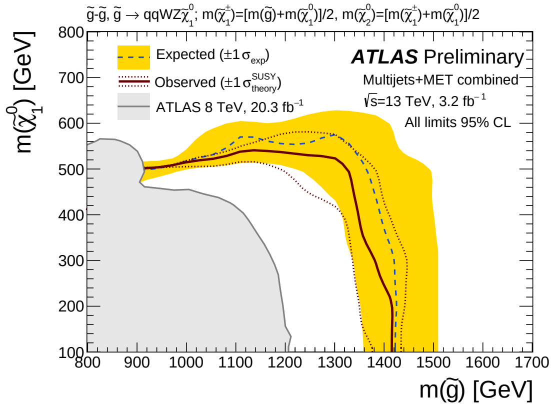


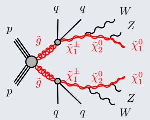


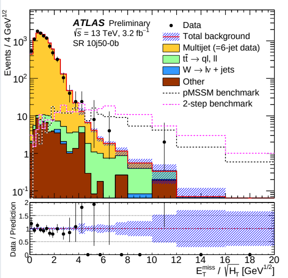


Inclusive Strong Production

New Run 2 results - simplified model interpretation







$$H_T = \sum_i p_{\mathrm{T}}^{jet_i}$$

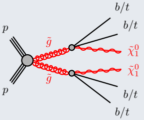
- 0 leptons
- 7-10 jets
- $E_{\mathrm{T}}^{\mathrm{miss}}$

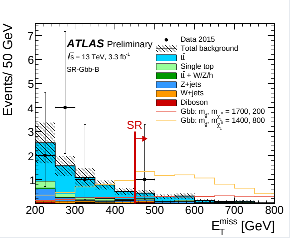
- The increase of the centre of mass energy provided increased sensitivity to higher mass sparticles
- Gluino mass up to 1400 GeV excluded for neutralino mass below 240 GeV

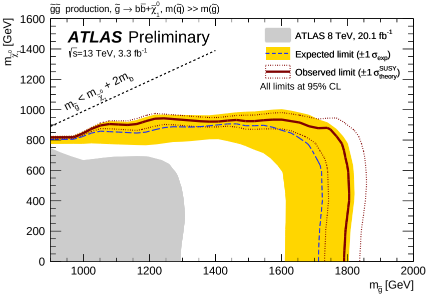
Inclusive Strong Production

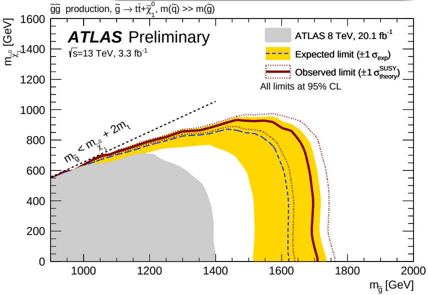
New Run 2 results - Gbb and Gtt models interpretation

- 0, 1 lepton (e, μ)
- $E_{\mathrm{T}}^{\mathrm{miss}}$
- ≥ 3 b-jets
- Boosted top for the selection targeting Gtt models with light neutralino
- New limits exceed Run 1 results









3$^{\text{rd}}$ generation squark direct production

- Natural (i.e. not fine-tuned) SUSY requires light stop and sbottom, gluino relatively light. 1$^{\text{st}}$ and 2$^{\text{nd}}$ generation squarks are allowed to be very heavy.
- 3$^{\text{rd}}$ generation squark production: stop, sbottom
- Typical signature: jets (usually including heavy-flavor, b- or c-jets), 0-1-2 leptons, large $E_{\mathrm{T}}^{\mathrm{miss}}$ from LSP
- Effort concentrated on simplified models with 100% branching ratios to chosen final state

New Run 2 SUSY 3$^{\text{rd}}$ generation squark direct production searches in ATLAS

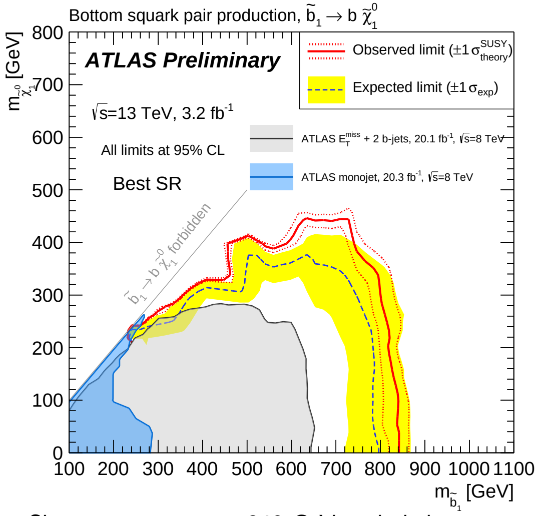
0 leptons + 2 b-jets + $E_{\mathrm{T}}^{\mathrm{miss}}$	ATLAS-CONF-2015-066	
2 SS or 3 leptons + jets + $E_{\mathrm{T}}^{\mathrm{miss}}$	ATLAS-CONF-2015-078	} see Da Xu's talk

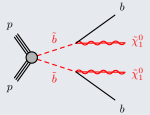
Run 1 SUSY 3$^{\text{rd}}$ generation squark direct production searches in ATLAS

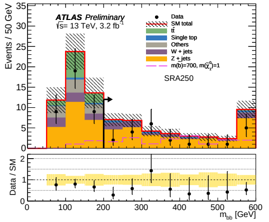
3$^{\text{rd}}$ generation squark summary paper *Eur. Phys. J.* C (2015) 75:510

3rd generation squark direct production

New Run 2 results - simplified model interpretation





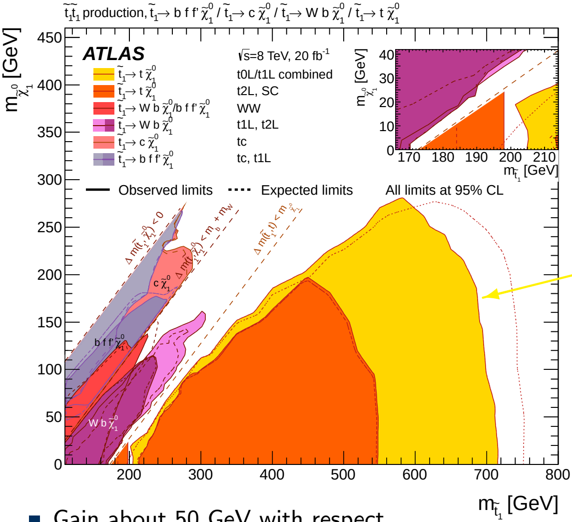


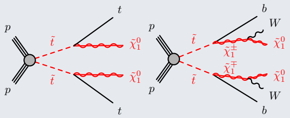
- 0 leptons
- 2 b-jets
- E_T^{miss}

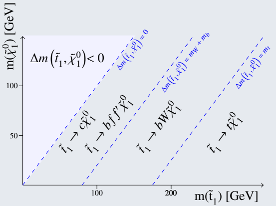
- Sbottom mass up to 840 GeV excluded for neutralino mass below 100 GeV

3$^{\rm rd}$ generation squark direct production

Run 1 results - simplified model interpretation







- Statistical combination of 0L and 1L analyses
- $E_{\rm T}^{\rm miss}$
- 2 b-jets

- Gain about 50 GeV with respect to the individual 0L and 1L analyses for $\tilde{t} \to t\tilde{\chi}_1^0$

Electroweak production

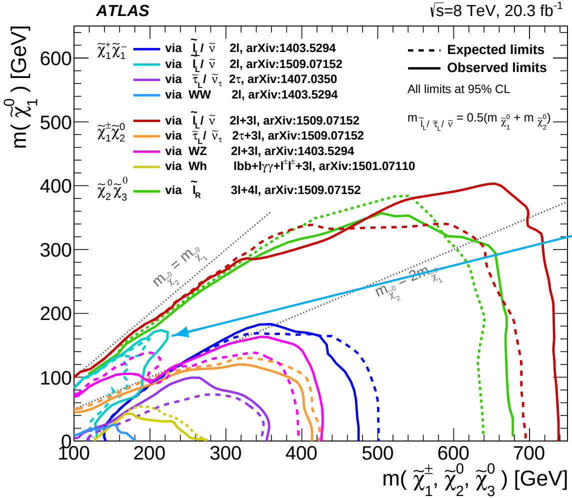
- May be the dominant SUSY production process at the LHC if squarks/gluinos are heavy and neutralinos/charginos are light
- Electroweak SUSY particle production: neutralinos, charginos, sleptons
- Typical signature: one or more leptons in the final state arising from the decay of sleptons or neutralinos/charginos decaying through intermediate sleptons, sneutrinos or gauge/Higgs bosons. Large $E_{\mathrm{T}}^{\mathrm{miss}}$ from LSP, often low hadronic activity.

Run 1 SUSY electroweak production searches in ATLAS

Electroweak production summary paper arXiv:1509.07152

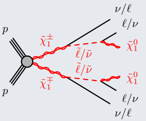
Electroweak production

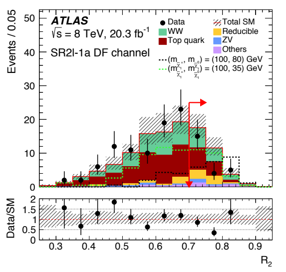
Run 1 results - simplified model interpretation



- New sensitivity for compressed scenarios for chargino masses below 220 GeV

Direct chargino production



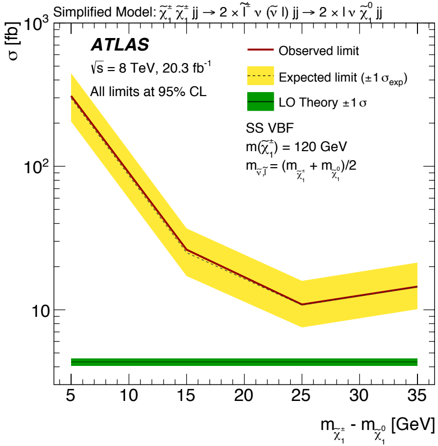


$$R_2 = \frac{E_T^{\mathrm{miss}}}{E_T^{\mathrm{miss}} + p_T^{\ell 1} + p_T^{\ell 2}}$$

- 2 leptons $(e,\ \mu)$
- jets
- super-razor variables

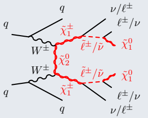
Electroweak production

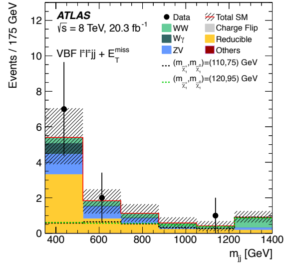
Run 1 results - simplified model interpretation



- VBF production of SUSY particles investigated for the first time in ATLAS
- If observed it would prove that the exchanged neutralino is a Majorana particle

$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\pm}$ production via VBF





- 2 SS leptons (e, μ)
- $E_{\mathrm{T}}^{\mathrm{miss}}$
- 2 jets

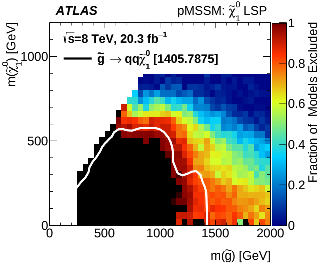
pMSSM Interpretation

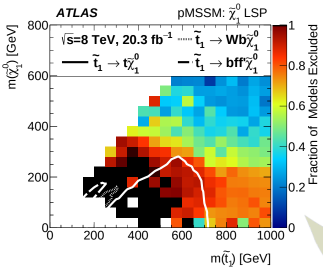
- Phenomenological MSSM (pMSSM)
  - no additional source of CP violation
  - quark and lepton flavour conservation in the SUSY sector
  - no additional source of flavour changing neutral currents
  - degenerate 1st and 2nd generation sfermions
- Interpretation of all ATLAS SUSY searches
- 22 Run 1 SUSY searches reinterpreted in pMSSM - 200 SR
- 500 milion pMSSM models randomly sampled
- 300 thousand models survive theory and non-LHC constraints (precision EW measurements, LEP, Tevatron Higgs, DM)
- Most comprehensive SUSY results from ATLAS

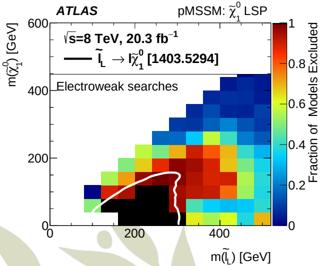
Inclusive	0-lepton + 2–6 jets + E_T^{miss}
	0-lepton + 7–10 jets + E_T^{miss}
	1-lepton + jets + E_T^{miss}
	$\tau(\tau/\ell)$ + jets + E_T^{miss}
	SS/3-leptons + jets + E_T^{miss}
	0/1-lepton + 3b-jets + E_T^{miss}
	Monojet
3rd generation	0-lepton stop
	1-lepton stop
	2-leptons stop
	Monojet stop
	Stop with Z boson
	2b-jets + E_T^{miss}
	$tb+E_T^{miss}$, stop
Electroweak	ℓh
	2-leptons
	2-τ
	3-leptons
	4-leptons
	Disappearing Track
Other	Long-lived particles
	$H/A \rightarrow \tau^+\tau^-$

pMSSM Interpretation

Strong production	3^{rd} generation	Electroweak production







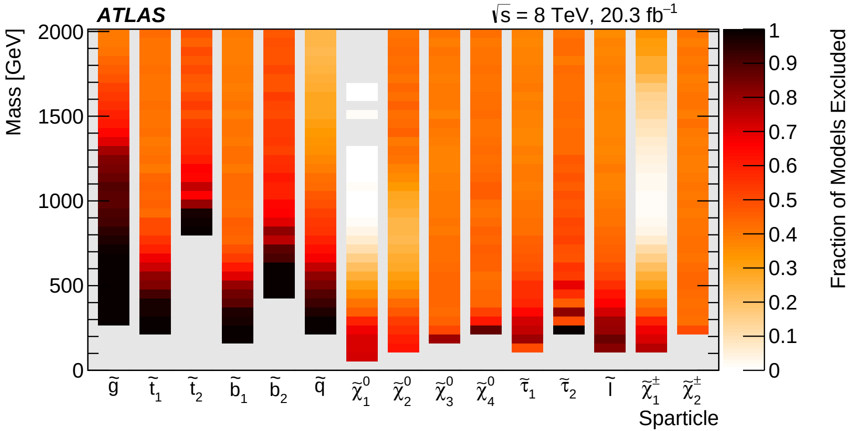
- Good agreement with simplified models
- Diagonal excluded by mono-jet analysis
- Intermediate sparticles reduce exclusion for heavy gluino

- Simplified model overestimates reach (100% BR)
- Higgs mass constraint excludes light $\tilde{t}$ models

- Good agreement with simplified models

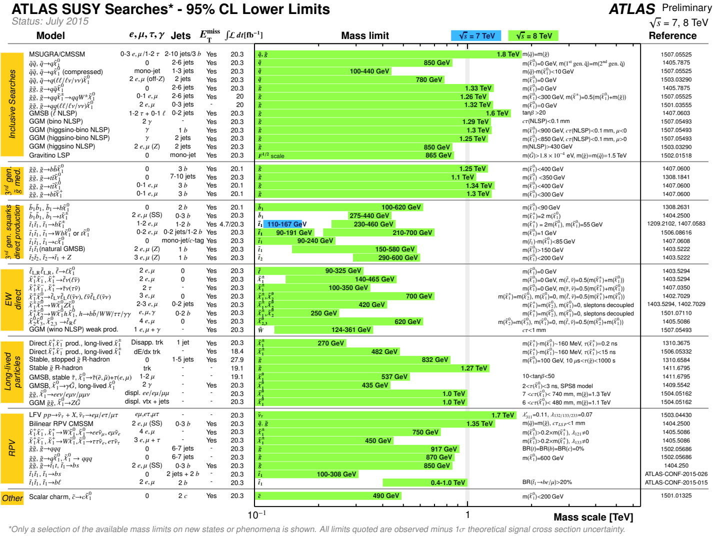
pMSSM Interpretation

- Highest sensitivity to strong processes
- Some differences observed between simplified models and pMSSM interpreation
- Good complementarity between different searches and with direct detection experiments



SUSY Searches Summary

Not including yet Run 2 results



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

Conclusions & summary

- ATLAS SUSY searches cover broad range of signatures.
  Effort to cover maximum area of the SUSY parameter space.
- The 8 TeV LHC data have been investigated extensively.
- First results have been obtained using the entire dataset collected in 2015 at 13 TeV.
- No sign of SUSY in the LHC data yet. Therefore, exclusion limits are set.
- High energy running and higher luminosity will significantly increase the sensitivity to many SUSY scenarios in Run 2.