Summary of Searches for Electroweak production of SUSY particles in √s=8 TeV pp collisions in ATLAS

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IoP HEPP and APP 2016

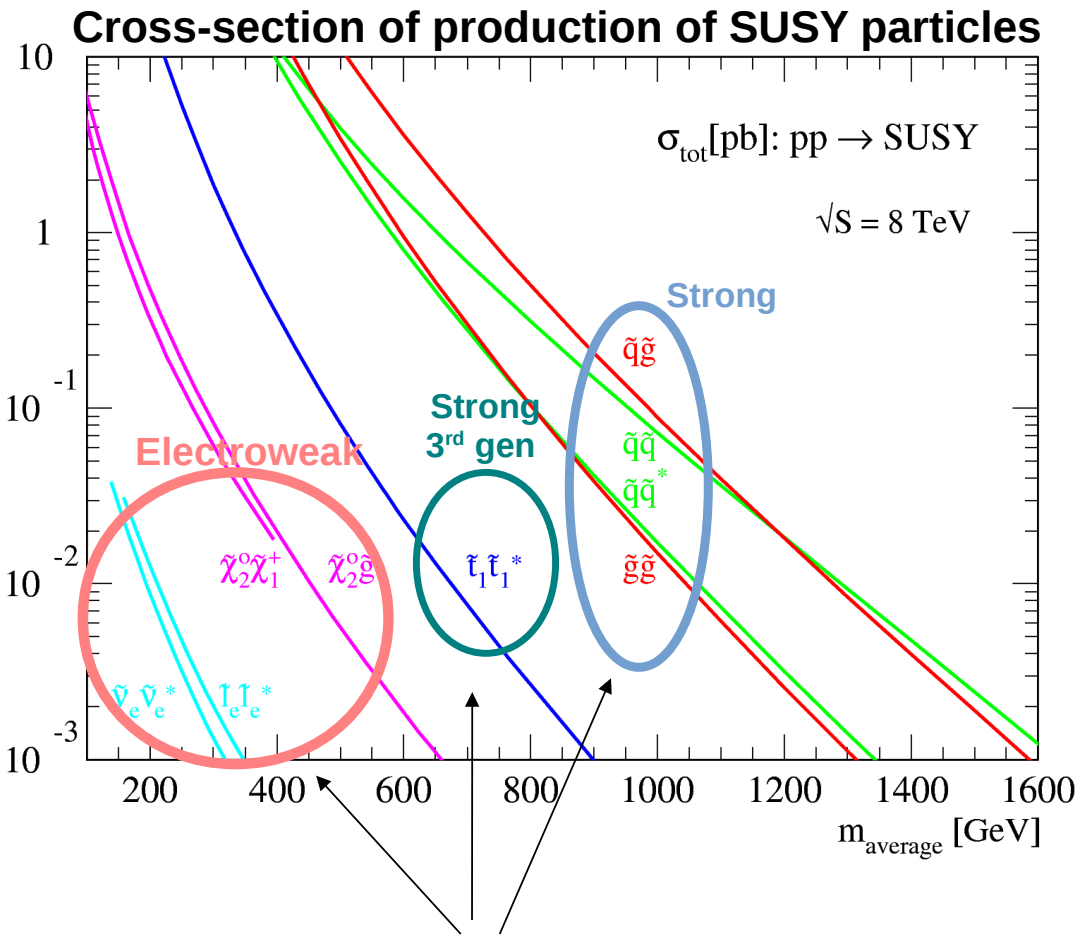
Outline

Overview of Run1 EWK SUSY results

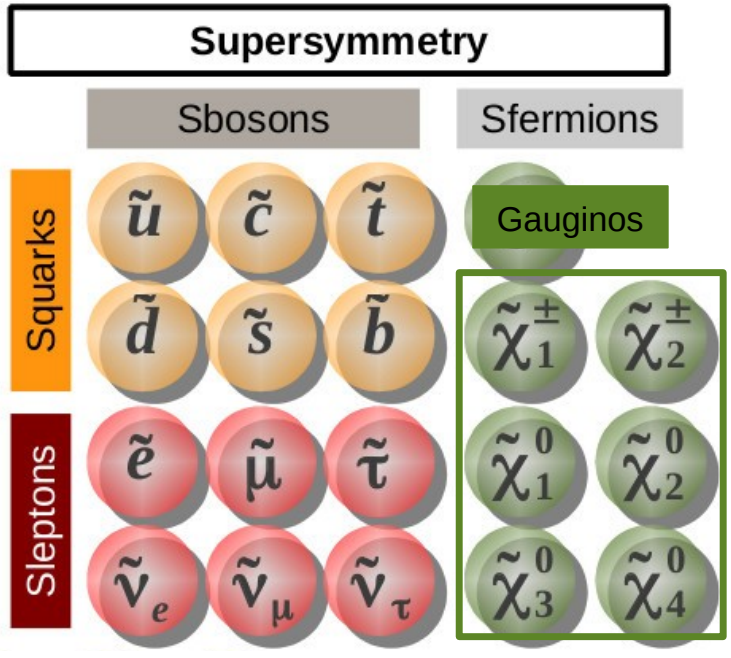
- **Impressive range of new techniques**
- **Reinterpretation of results in new models**
- **Statistical combination of results to provide the best limits**

Prospects for the new run (Run2) of the LHC

Motivation for EWK Supersymmetry



Search strategies developed by ATLAS target all these SUSY production modes



Electroweak (EWK) production can be dominant at the LHC.

Low cross sections

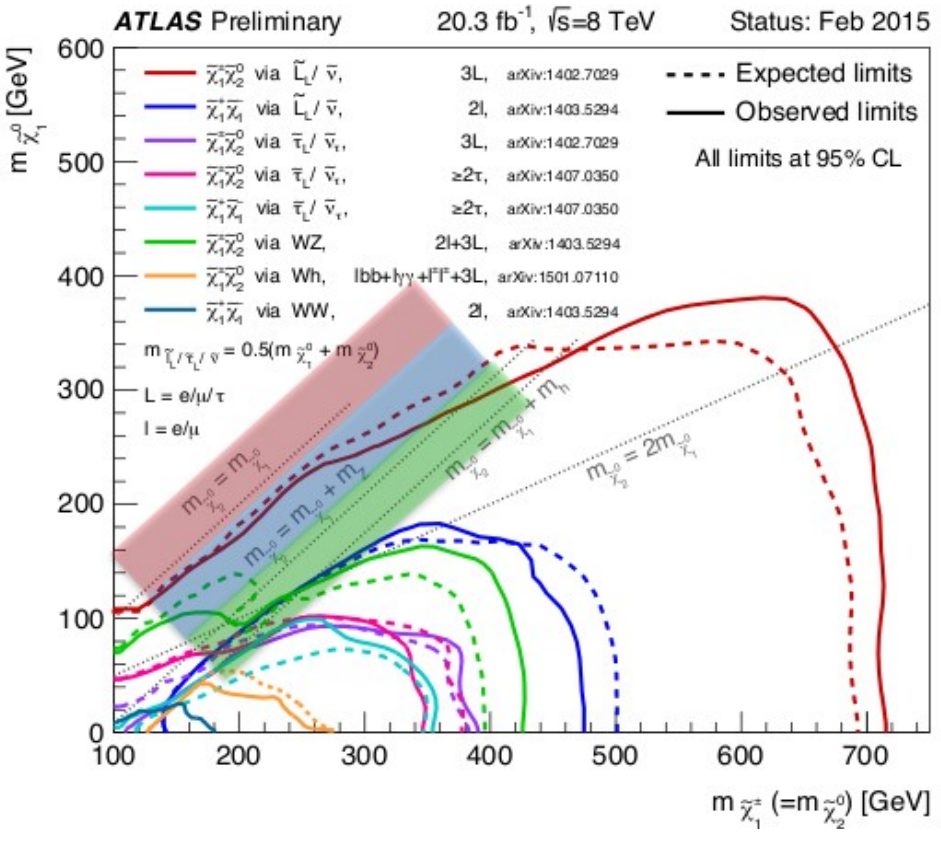
Suppressed SM backgrounds

Multileptonic signatures with large missing transverse energy

Run1 Overview

([1] Phys. Rev. D 93, 052002 (2016))

Focus of this talk is on the results from electroweak Supersymmetry searches with the full 8TeV data collected by ATLAS during the first run of the LHC [1]



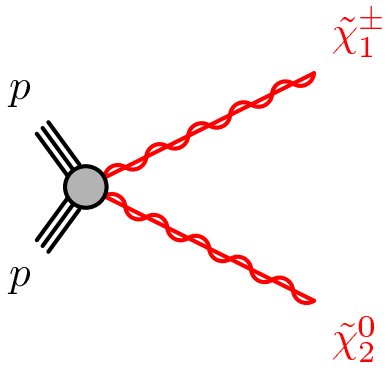
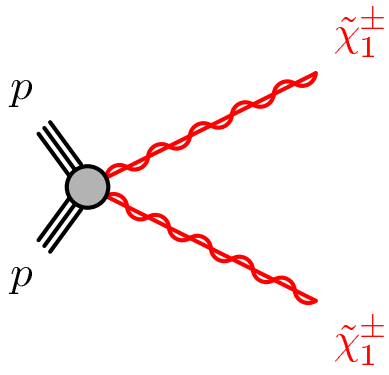
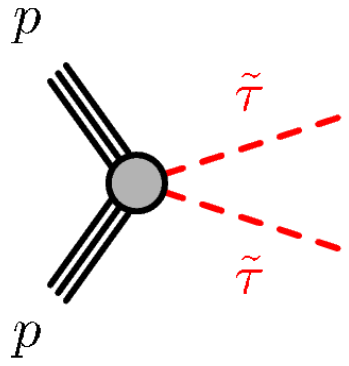
The Strategy

- Employ new and improved strategies to target compressed spectra and low cross section regions using MVA techniques, low-pT leptons and ISR jets
- Cover as many physics scenarios as possible with the available information

Outstanding UK involvement!

New Optimisation Strategies

Signature-based analyses characterised by lepton multiplicity (L) and missing transverse energy

Channel			
2L (e, μ)	**via** $\tilde{\ell}$ (SS) ISR + MVA approach	**via** $\tilde{\ell}$ Super-razor + ISR approach (OS), VBF + soft-leptons approach (SS)	
2L (τ)			**with** $\tilde{\ell} = \tilde{\tau}$ (OS) MVA approach
3L (e, μ, τ)	**via** $\tilde{\ell}$ ISR and soft-lepton approach		

Supersymmetric Models

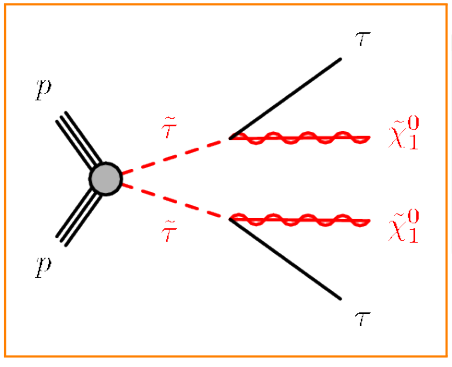
- R-parity conserved models (LSP is neutral and stable)
- Optimisation performed using simplified models
  - One simulated process with 100% BR

SS(OS): Same(Opposite)-Sign

2τ MVA Analysis

Phys. Rev. D 93, 052002 (2016)

Direct-stau Production

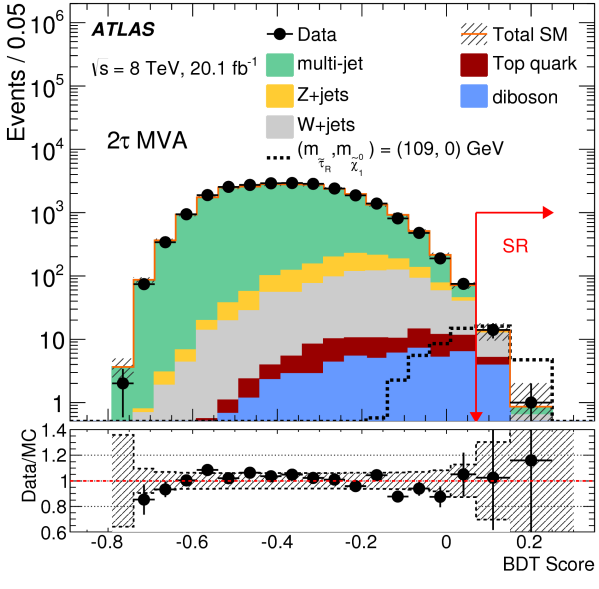


- Small production cross-section
- Update of previous result JHEP 1410 (2014) 96

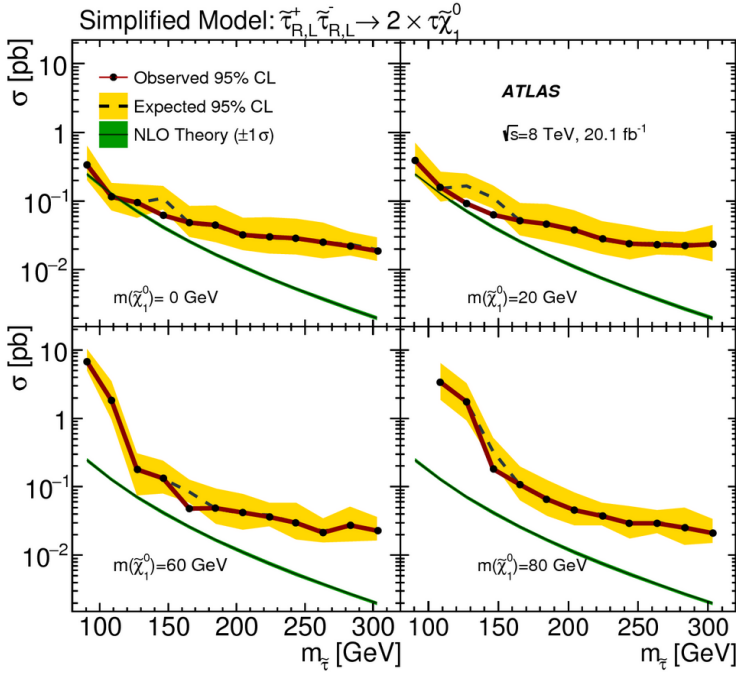
Analysis Design

- Events selected with two opposite-sign hadronic taus
- Multi Variate Analysis (MVA) optimised to yield best exp. discovery sensitivity (using Boosted Decision Trees, BDTs)
- Dominant backgrounds: processes with one or more "fake" taus (multijets), V+jets and dobosons

No excess observed



Combined result with previous cut-and-count analysis shows improvent on the 95% CL exclusion limits on the cross-section



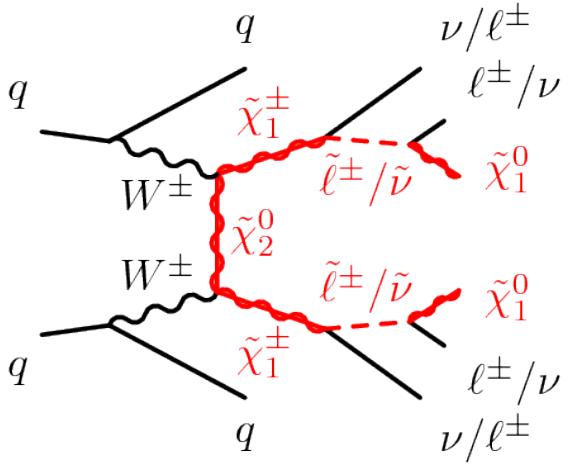
One point can now be excluded for $m_{\tilde{\tau}} = 109$ GeV and massless LSP

VBF Analysis

Phys. Rev. D 93, 052002 (2016)

Vector-boson-fusion (VBF) decaying into charginos

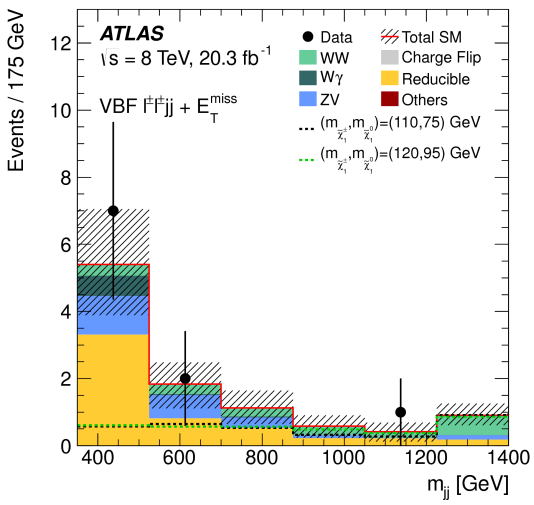
- First ATLAS SUSY VBF search
- Low cross-section

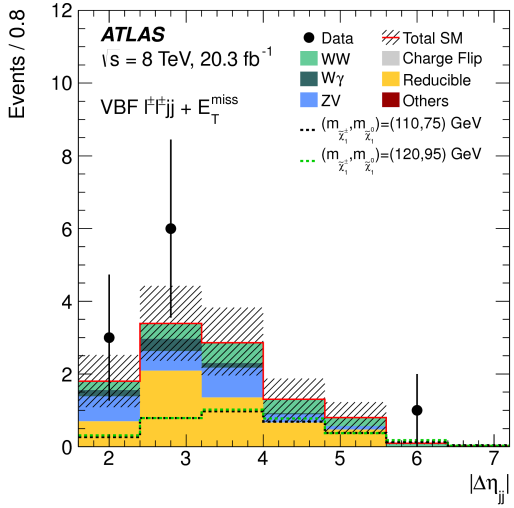


Analysis Design

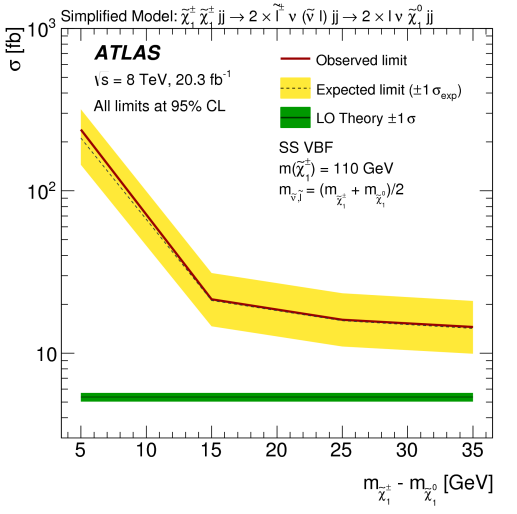
- Event Selection: two same-sign light-leptons, at least two jets and $E_{\mathrm{T}}^{\mathrm{miss}}$
- event selection optimized to exploit VBF di-jet topology m_{jj}, $\Delta\eta(jj)$
- main backgrounds: dibosons and non-prompt lepton (fake) processes

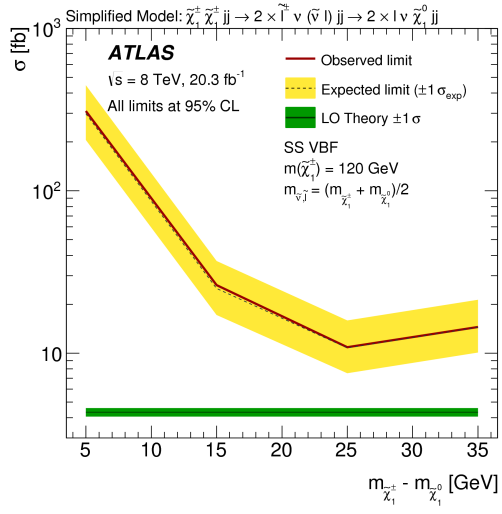
No significant deviation from SM.





95% CL upper limits on the cross-section for VBF production of $\tilde{\chi}_1^{\pm}$ pairs



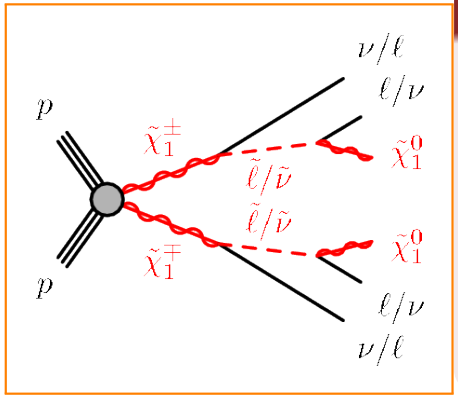


Close to excluding point used for the optimisation where the difference between the NLSP and LSP is 25 GeV

Super-Razor Analysis (2ℓ)

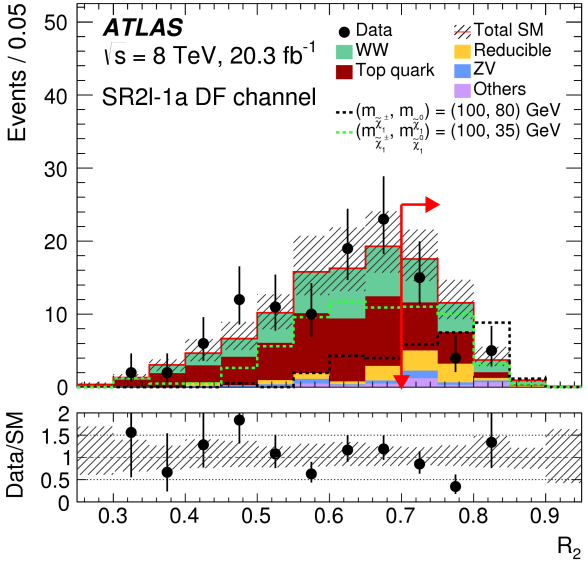
Phys. Rev. D 93, 052002 (2016)

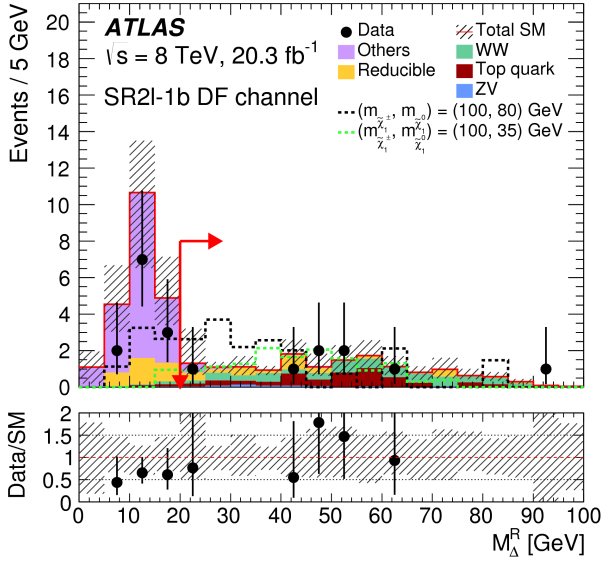
- Exploiting new super-razor variables sensitive to $\tilde{\chi}_1^{\pm} - \tilde{\chi}_1^0$
- Super Razor aims to describe kinematic degrees of freedom in an event

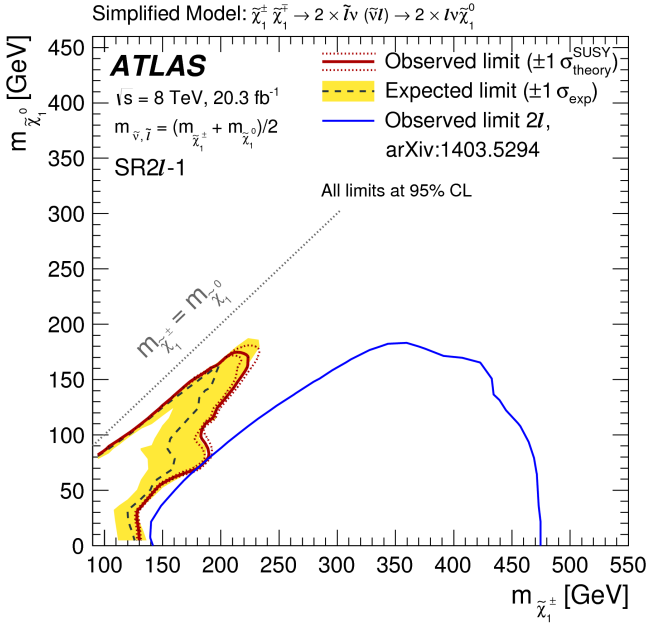


Analysis Design

- Signature: 2 opposite-sign light leptons, high-p_{T} jet, Z-veto (if same-flavour)
- Dominating background processes: *WW*, top and *ZV*
- Optimisation done exploiting super-razor variables: M_{Δ}^{R}, provides background rejection for large mass difference scenarios, and R_2, which combines the p_{T} of both leptons and $E_{\mathrm{T}}^{\mathrm{miss}}$







Limits are set on compressed region, excluding up 20 GeV in mass differences for $\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_1^0$

2ℓ and 3ℓ Analyses

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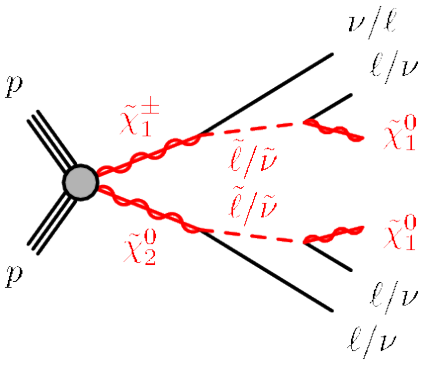


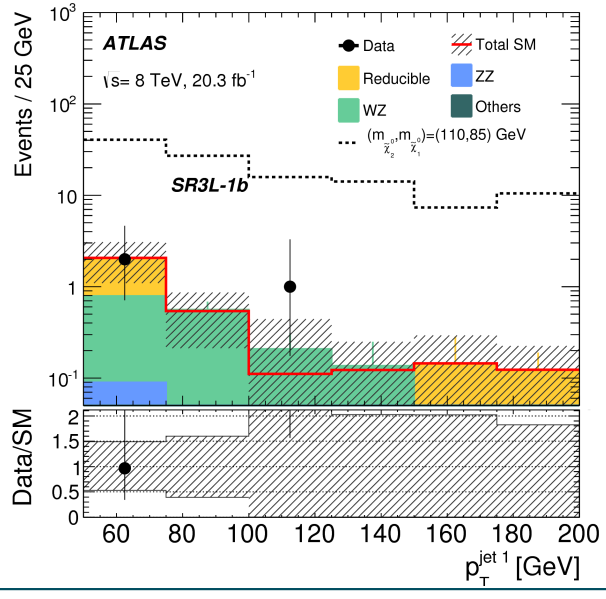
MVA Analysis with 2ℓ SS

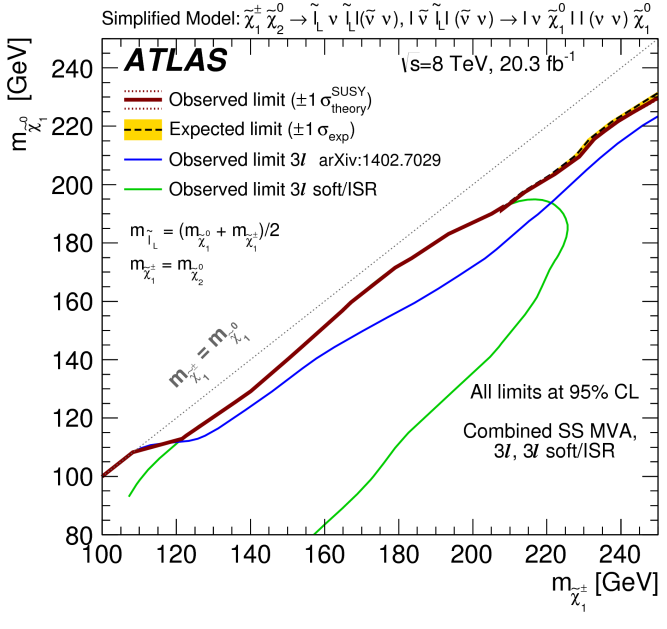
- 2 signal regions: 2 same-sign light leptons, *b*-jet veto, presence/veto of ISR jet
- Trained BDTs for various mass differences between $\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_1^0$, and tighter lepton isolation
- *W*+jets (fakes), charge flip (one or more leptons with mis-measured charge) and diboson SM background processes dominate

3ℓ Analysis

- Four signal regions: three light leptons, *b*-jet veto, one same-flavour OS pair, presence/veto of ISR jet
- Exploiting low leptons pT (<30 GeV), two $min(m_{SFOS})$ mass windows, and/or ISR topologies
- Low mass regions dominated by fakes and diboson SM background processes dominate

Overall very good agreement between data and expectation





Reinterpretations and Combinations

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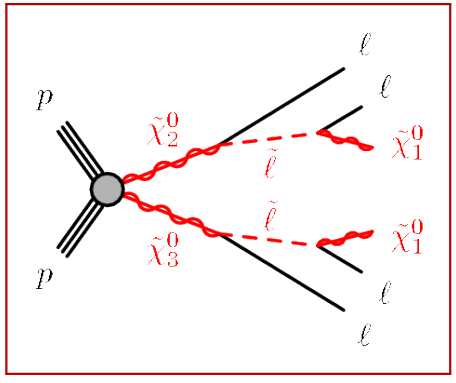
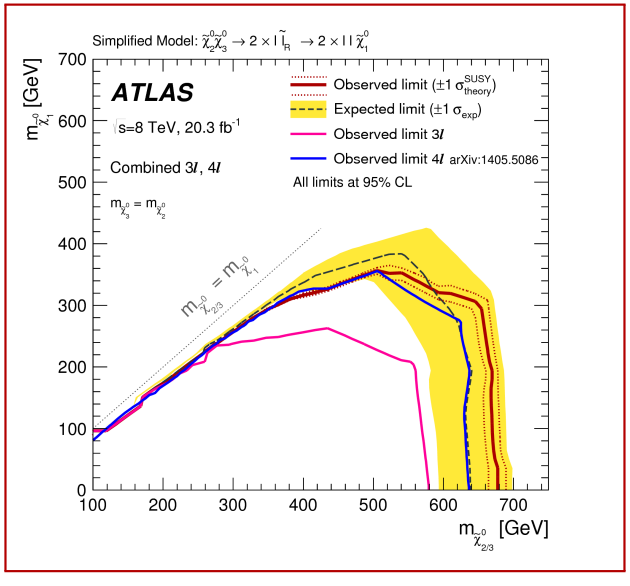
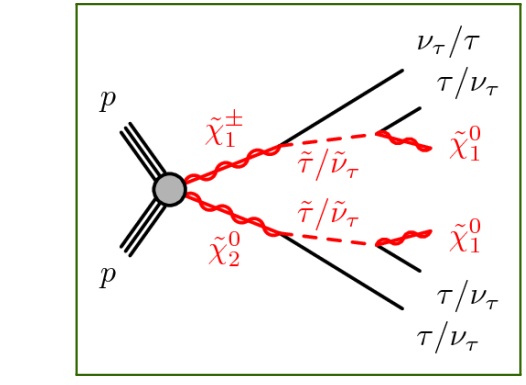
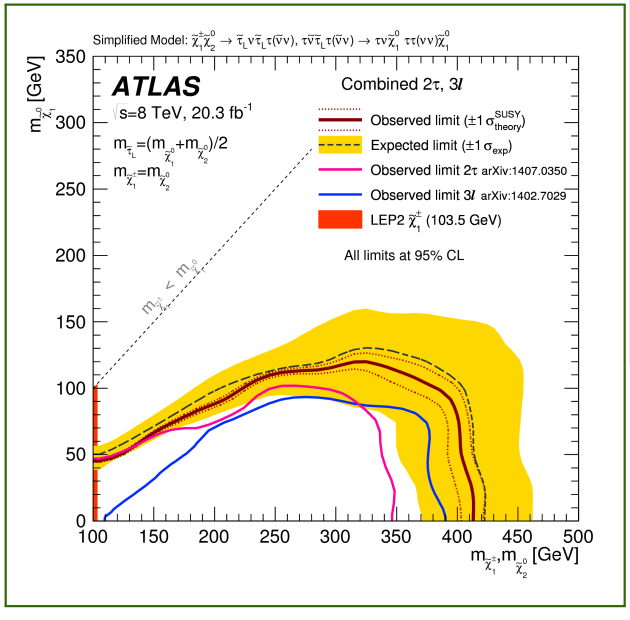


$3\ell+4\ell$





$2\tau+3\ell$

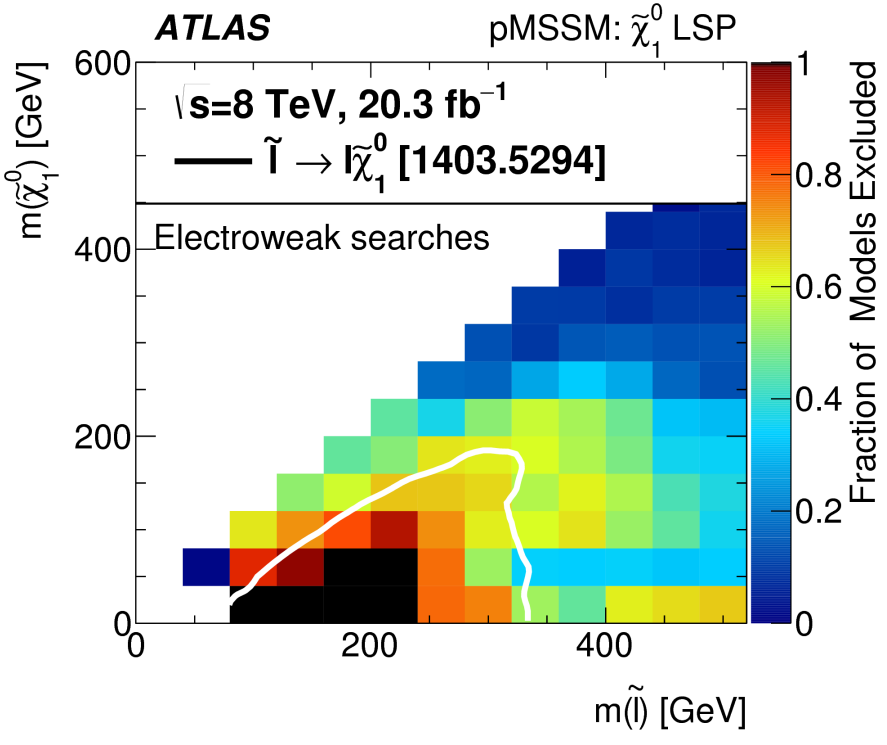


- Design of all the optimisation strategies ensures orthogonality between analyses making the combination of them possible
- **Combination of different channels shows the best exclusion yet**
- Many more models are included in the paper not only for simplified SUSY models but also for full models like pMSSM, NUHM and GMSB

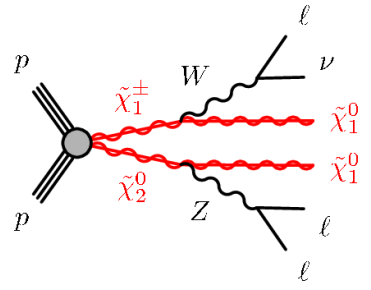
What next for EWK searches?

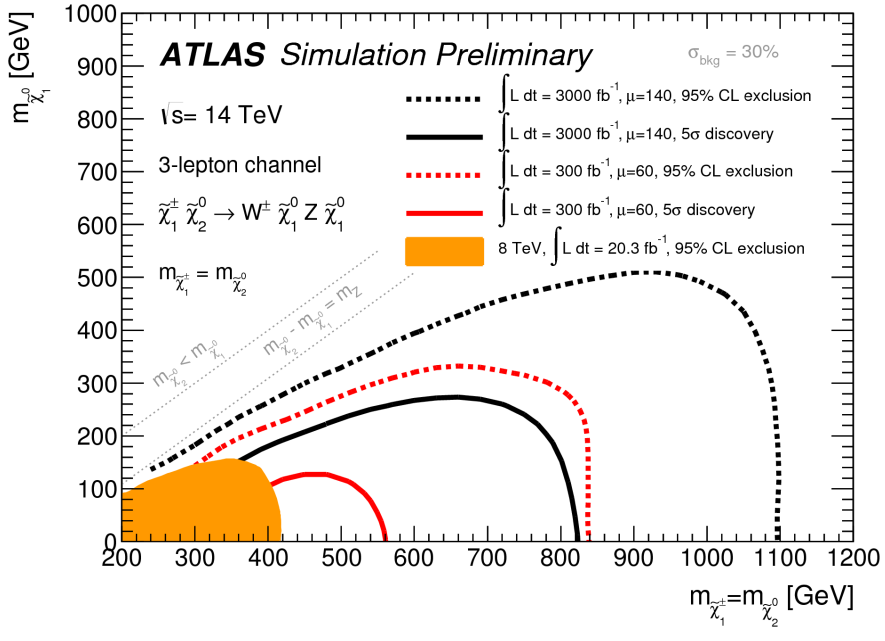
Summary of the ATLAS experiment's sensitivity to supersymmetry after LHC Run1 - interpreted in the phenomenological MSSM
JHEP 10 (2015) 134

- Translating these limits into a "fuller" supersymmetric model like the pMSSM
- Models with even very light sleptons remain viable!



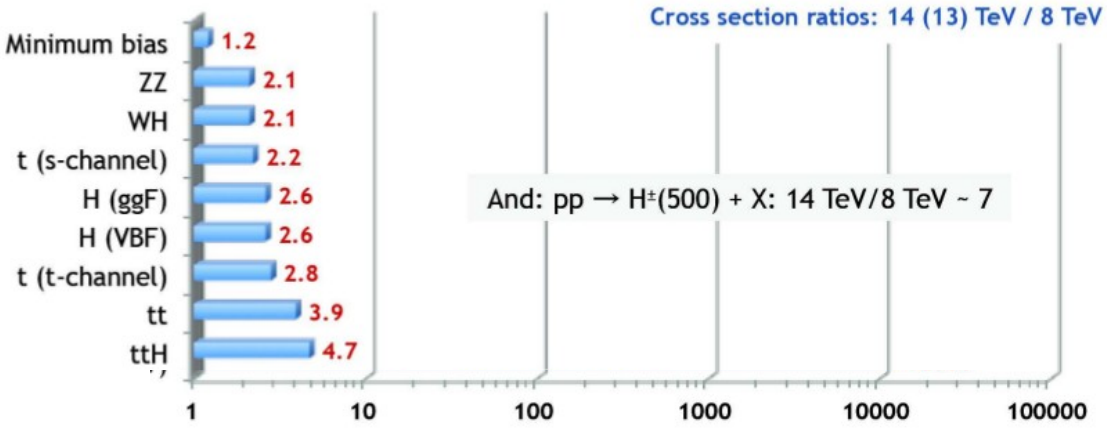
Upgrade Studies
ATL-PHYS-PUB-2014-010



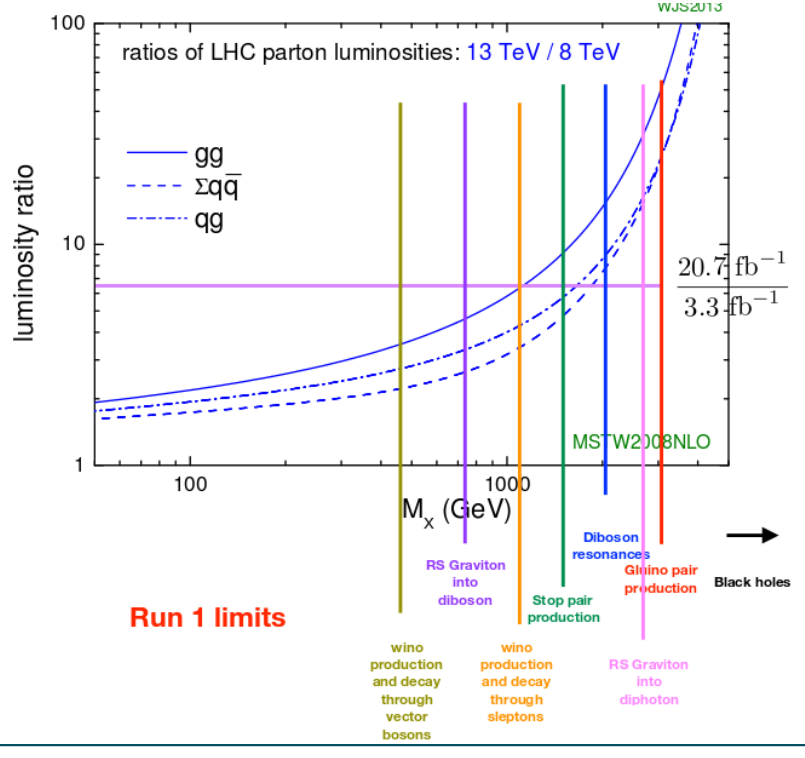


Discovery and exclusion shown for an integrated luminosity of 300 and 3000 fb^1 at a centre-of-mass energy of 14 TeV

Prospects for Run2



Signal production cross section gain significantly higher than SM background at 13 TeV centre-of-mass energy!



Summary

- The ATLAS SUSY search for electroweak production using the full 8 TeV data delivered by the LHC during RunI was presented
- New and improved sensitivity for a wide variety of SUSY scenarios, covering much of the SUSY parameter space
- No significant deviation from SM observed
- Stringent exclusion limits are set on masses of SUSY particles
- Very fruitful first run ($\sim$ 10 CONF notes and $\sim$ 10 papers just on EWK SUSY searches!) and two more reinterpretations are in the pipeline with leading UK efforts: Higgsino-wino GGM and dark matter pMSSM models
- Higher energy offers possibility of fast discovery in Run-2 for strongly produced SUSY but for EWK production the cross-section gain is smaller, hence, more luminosity will be required.

Stay tuned for the latest SUSY Run II results

Backup

Standard Model Background Modelling

Some SUSY processes can be SM-like.
SUSY searches rely on accurate modelling of SM background.

Standard Model Background

Irreducible (prompt leptons)

Reducible (non-prompt leptons)

Dominant sources: normalised to data in dedicated **Control Regions**

Sub-dominant sources: estimated with MC-simulated data

Data-driven estimation analyses dependent

All predictions are thoroughly validated using dedicated **Validation Regions**

Signal Regions

The ATLAS detector

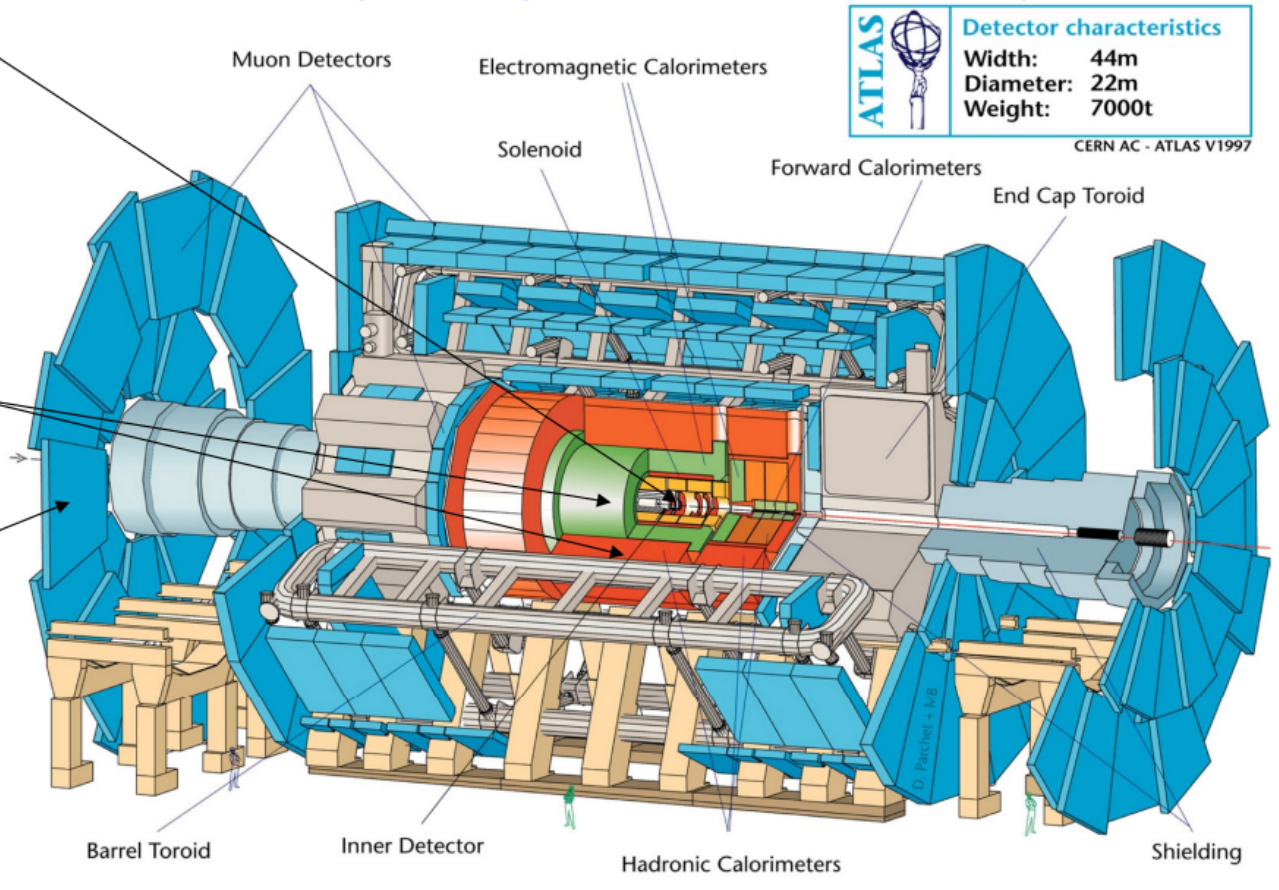
Inner Detector
Pixel detector
Semi-conductor(silicon) tracker
The Transition Radiation Tracker
Precise Tracking

Electromagnetic and Hadronic Calorimeters

Muon Detectors
Monitored Drift Tube
Thin Gap Chamber
Inside 1T toroidal magnetic system

3 Level Trigger
Event rate
40MHz ⟶ 400Hz

http://www.youtube.com/watch?v=XCq1LalDDZ0



Components were constructed in over 35 countries around the world