Searches for electroweak production of supersymmetry, supersymmetry in resonance production, R-parity violating signatures, and events with long-lived particles with the ATLAS detector

Preema Pais
University of Massachusetts, Amherst

On behalf of the ATLAS Collaboration

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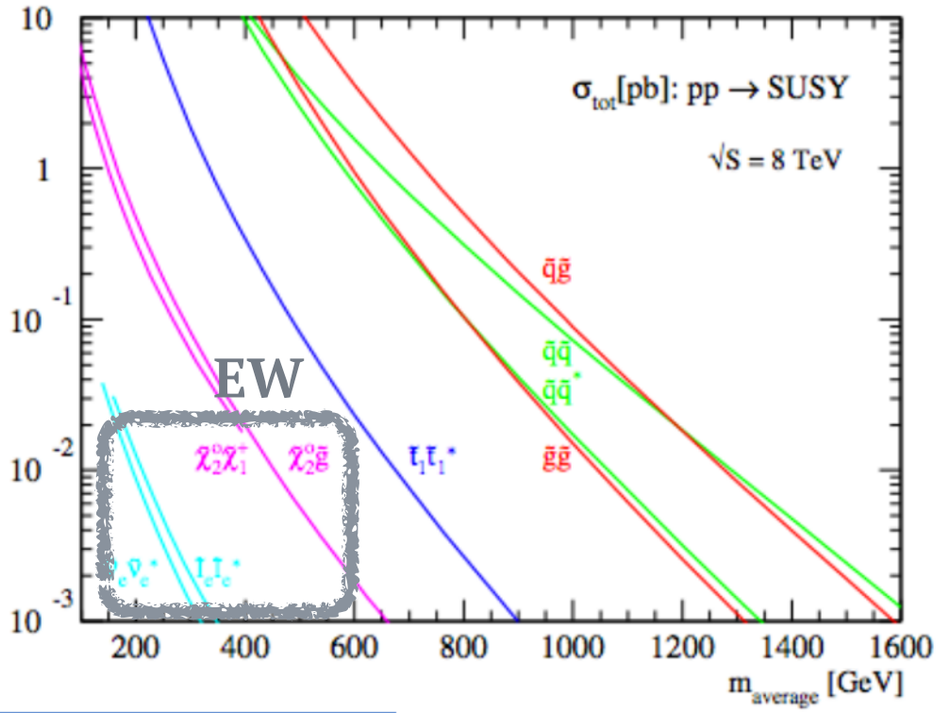
Electroweak Production of SUSY

Electroweak SUSY

- Pair production of gauginos and sleptons, not much hadronic activity
- Chargino-neutralino pairs - decay to W, Z, h bosons, or sleptons
- Many different final states: missing transverse momentum (E_T^{miss}), leptons and/or jets

Strong production covered by Yousuke Kataoka's presentation



Detector Signature	Interpretation	Reference	
$2e/\mu + E_T^{miss}$	pMSSM, simplified models	1403.5294	chargino-neutralino chargino-chargino
$\geq 2\tau + E_T^{miss}$	pMSSM, simplified models	1407.0350	
$3L + E_T^{miss}$	RPC pMSSM, simplified models	1402.7029	
$\geq 4L + E_T^{miss}$	RPC, GGM simplified models (also RPV)	1405.5086	
$1l + bb/\gamma\gamma + E_T^{miss}$ $2l + jets + E_T^{miss}$	Simplified models	1501.07110	chargino-neutralino w/ Higgs
$\geq 1\gamma + 2j + E_T^{miss}$	GMSB, nMSSM	ATLAS-CONF-2015-001	VBF production

Many new/updated results since Pheno2014 (including **combinations, re-interpretations**)!
Will only cover a few in this talk

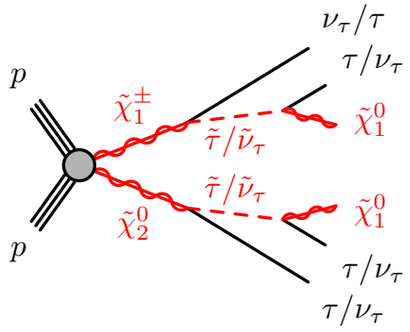
Multi-Lepton Final States

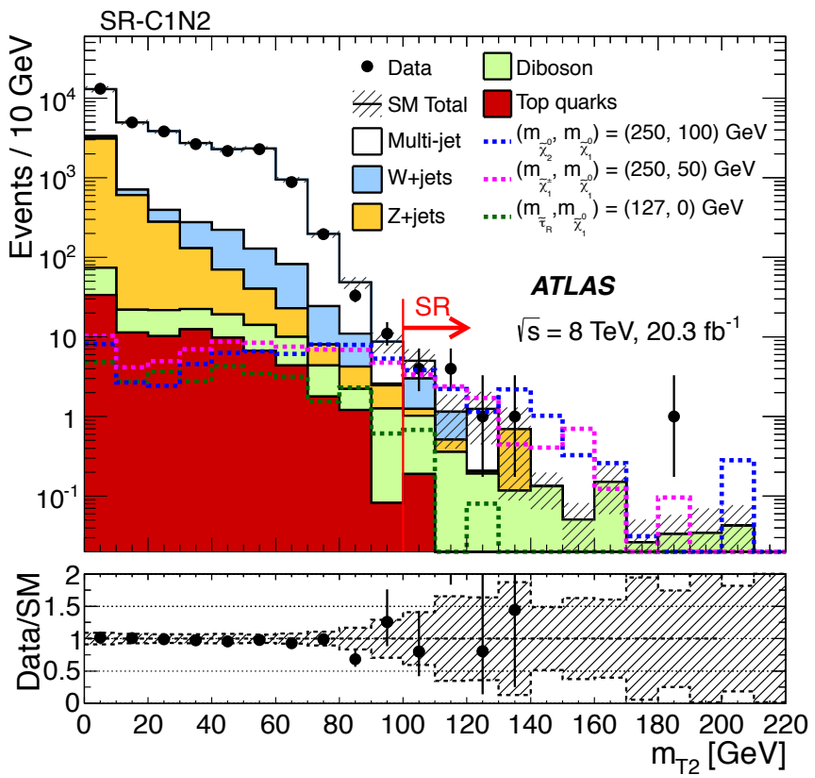
Direct chargino-neutralino, chargino-chargino pair production:

- Detector signatures with 2,3,4 leptons + E_T^{miss}
- Relatively clean signal
- Background predominantly from di-boson or ttbar events

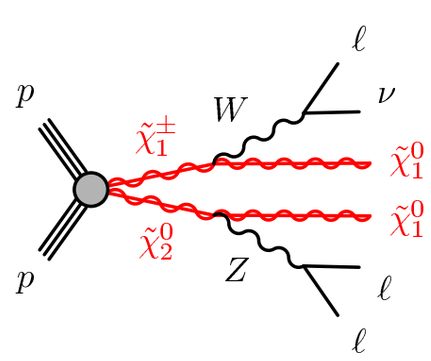
arXiv:1405.5086
1402.7029
1407.0352
1403.5294

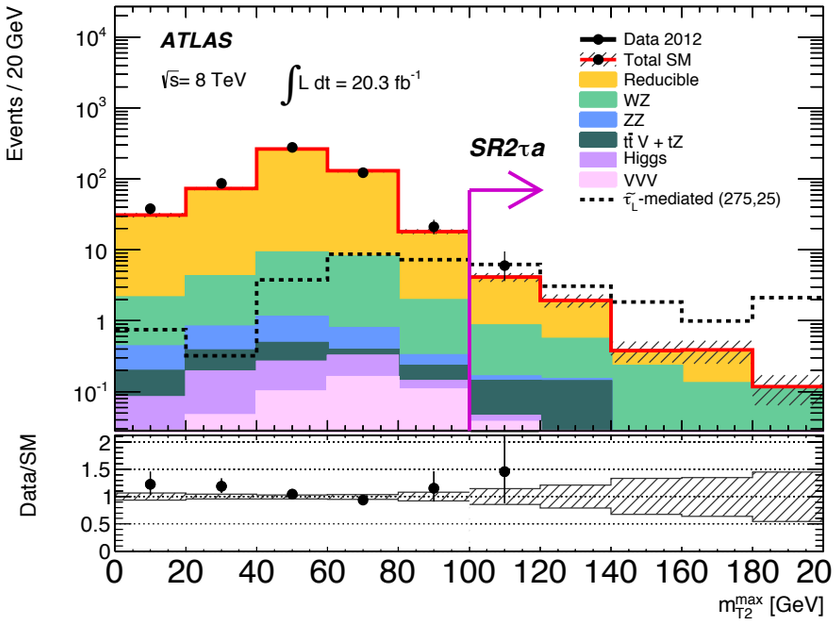
2τ+E_T^{miss}



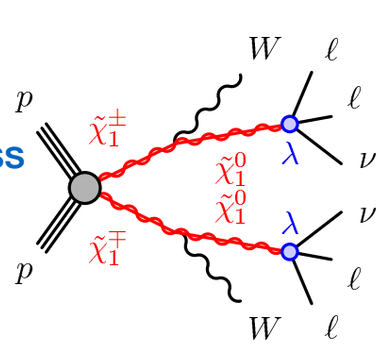


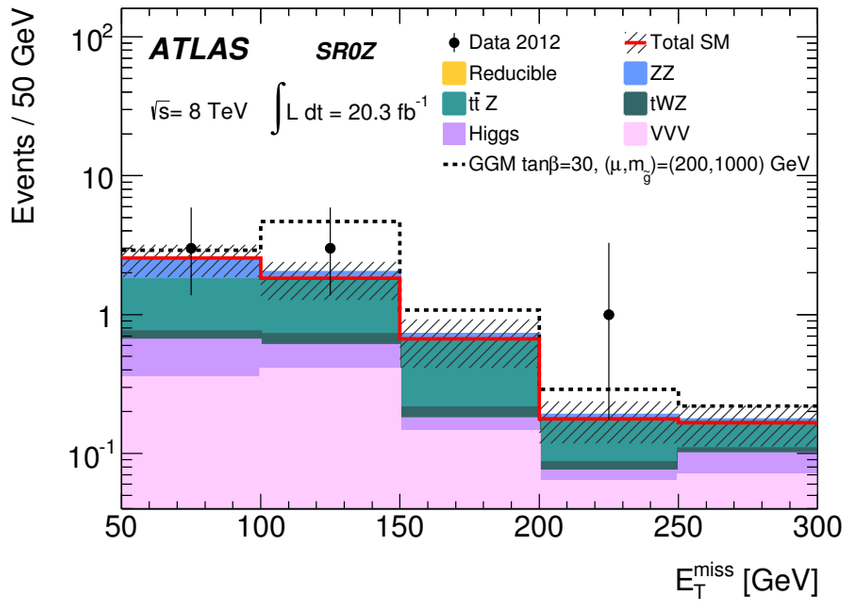
3L+E_T^{miss}





4L+E_T^{miss}





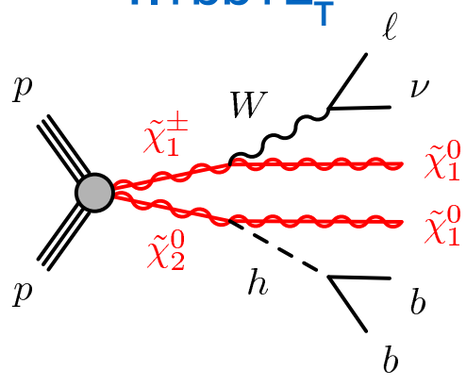
Chargino/Neutralino Decay to Wh

arXiv:1501.07110

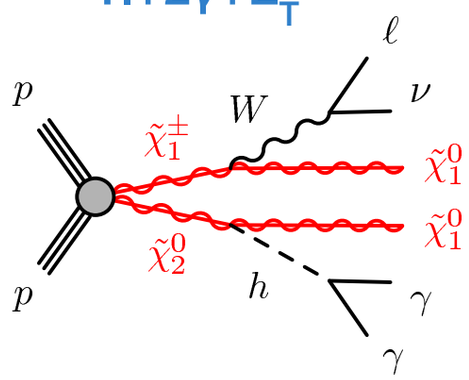
Direct pair production of chargino, neutralino; subsequent decay via **Wh**

Three final states considered:

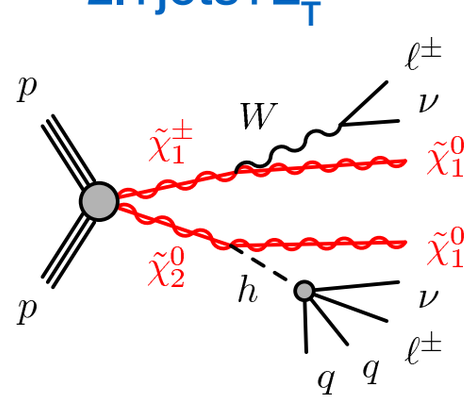
1l+bb+E_T^{miss}



1l+2γ+E_T^{miss}



2l+jets+E_T^{miss}

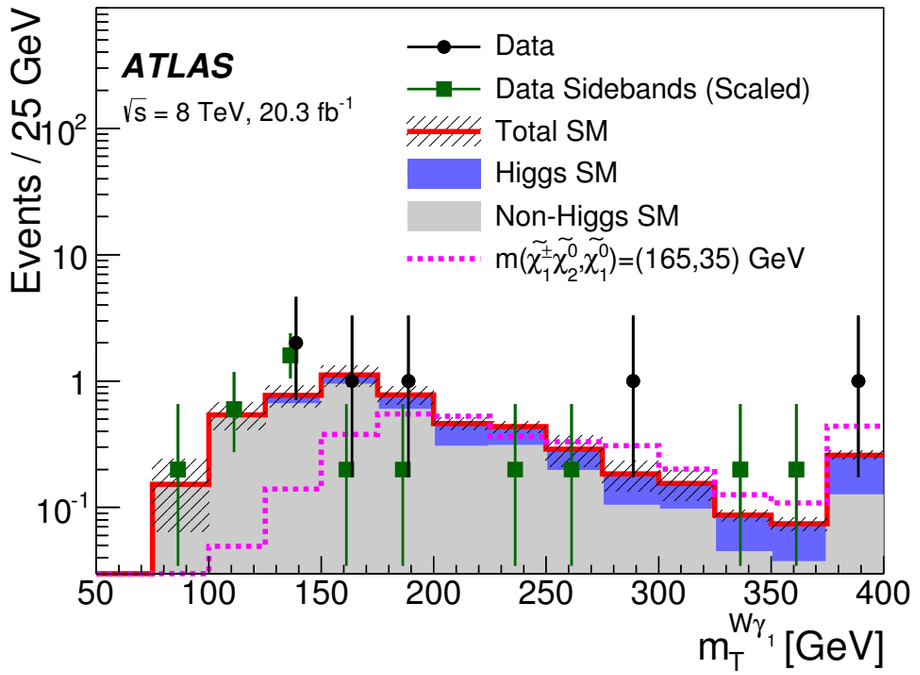


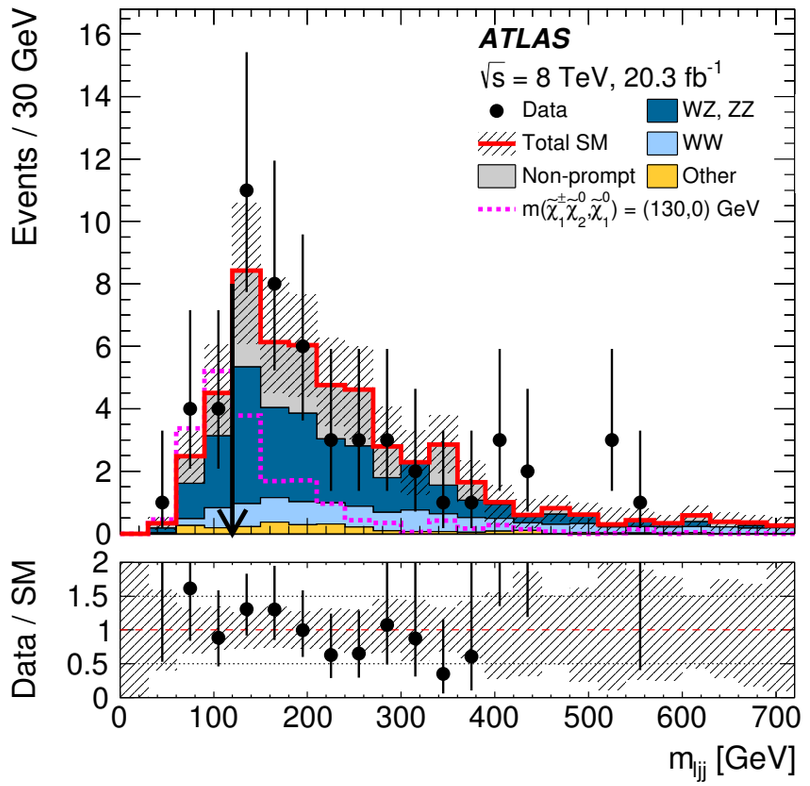
bb/2γ channels →Higgs candidate reconstruction

2l (same-sign) channel → small SM bkg.

Dominant background:

- 1l+bb channel **W+jets, ttbar**
- 1l+2γ channel **multi-jet, Zγ**
- 2l+jets channel **di-bosons**





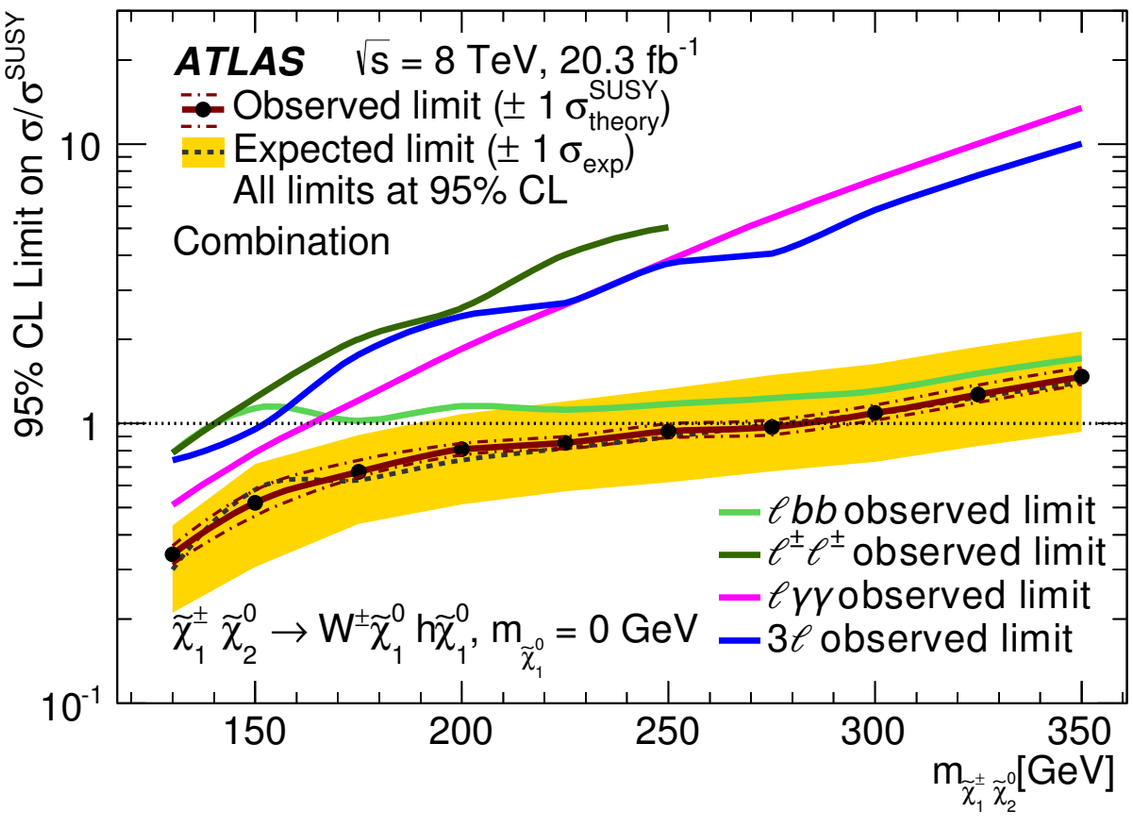
Chargino/Neutralino Decay to Wh

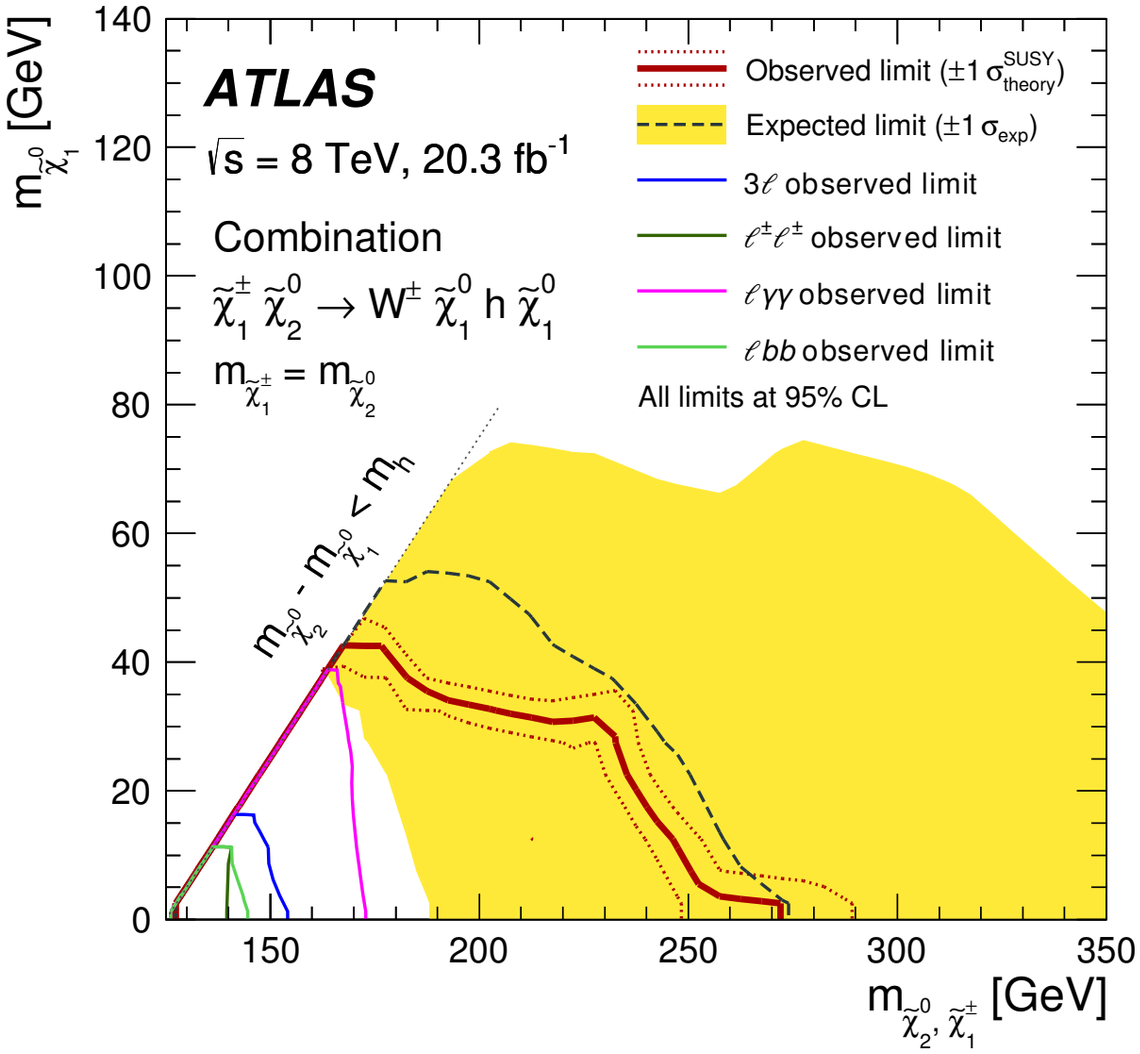
Combine results with 3l + E_T^{miss} search

No significant deviation from SM

Combination of all search channels results in increased excluded region

arXiv:1501.07110



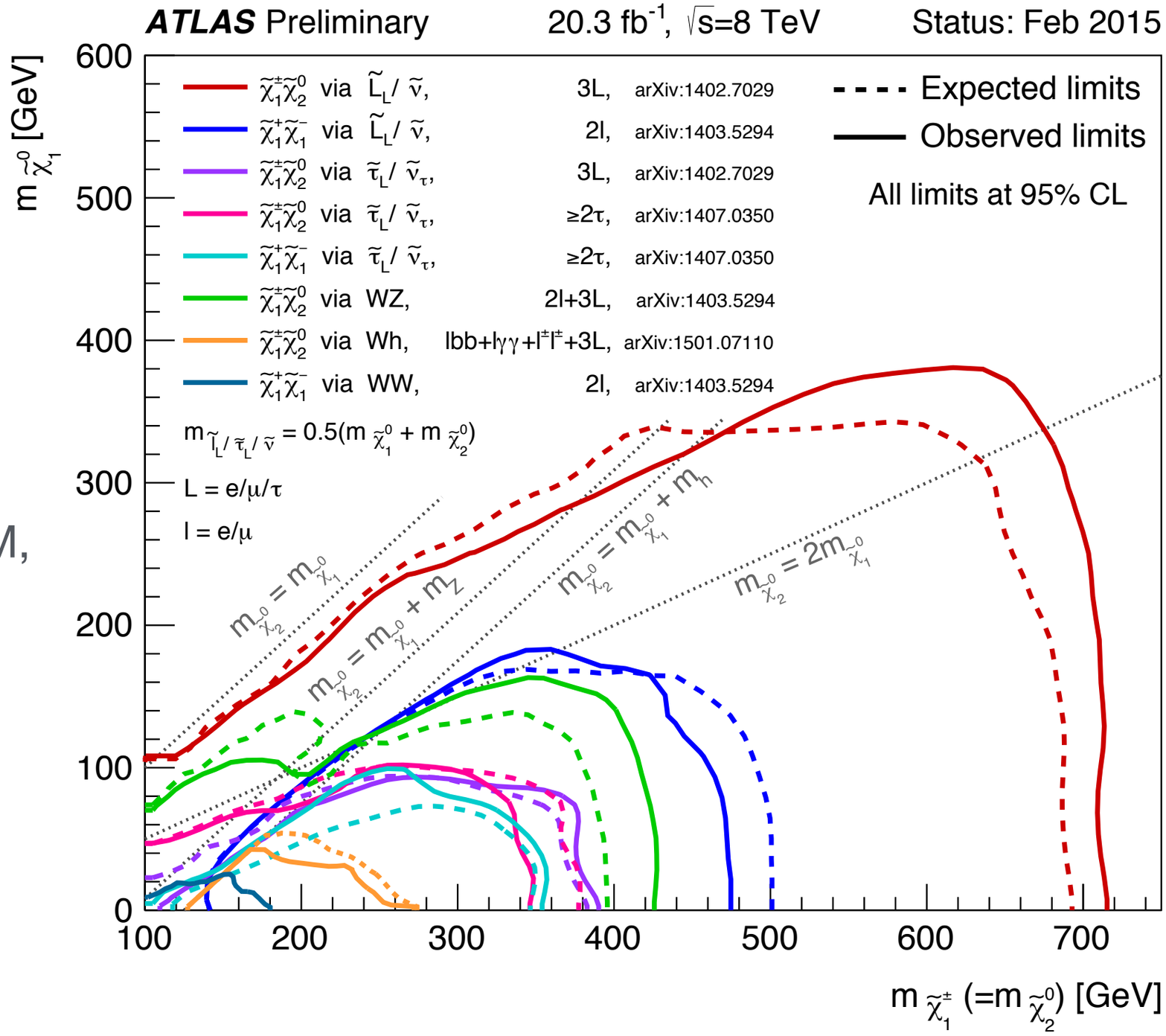


Electroweak Production - Summary

Run I searches cover many different detector signatures

No excess found in any channel

Exclusion limits set on pMSSM, simplified models



R-Parity Violation, Long-Lived Particles

R-parity conservation in SUSY:

- LSP is stable - potential dark matter candidate (if electrically neutral)

An R-parity violating term can be introduced into the superpotential:

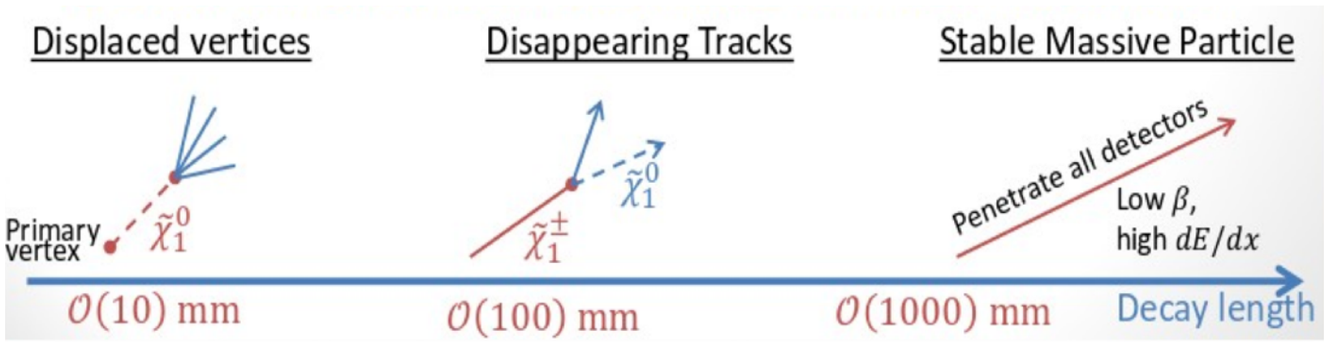
- LSP decays either through couplings to/mixing with SM particles
- Significantly lower E_T^{miss} than parity conserving scenarios

Certain SUSY models can also give rise to **long-lived particles**

Distinctive detector signatures - can be challenging to reconstruct!

Signature-driven reconstruction techniques based on particle decay position:

- Displaced vertices (silicon tracker, muon spectrometer)
- Displaced photons
- Displaced leptons
- Disappearing tracks
- Stopped particles
- Highly ionizing signatures



R-Parity Violation, Long-Lived Particles

	Detector Signature	Interpretation	Reference
RPV	Opposite-sign, diff. flavor dilepton	LFV-RPV	1403.5294
	Opposite-sign dilepton + 2b	minimal B-L SUSY extension	ATLAS-CONF-2015-015
	Multi-jets	RPV SUSY (gluino pair prodn.)	1502.05686
	≥4L	RPV Simplified models (also RPC)	1405.5086
	2-3l + b-jets	bRPV, gluino-mediated top squark	1404.2500
Long-Lived Paticles	Displaced vertex + l/j/E	RPV, Split-SUSY, GGM	1504.05162
	Displaced dileptons	RPV, Split-SUSY, GGM	1504.05162
	Displaced diphotons	GMSB	1409.5542
	2 displaced vertices	Stealth SUSY	1504.03634
	Disappearing tracks	AMSB	1310.3675
	Stable massive particles	GMSB, LeptoSUSY, R-hadrons	1411.1559
	Stopped particles	generic/Regge R-hadron models	1310.6584

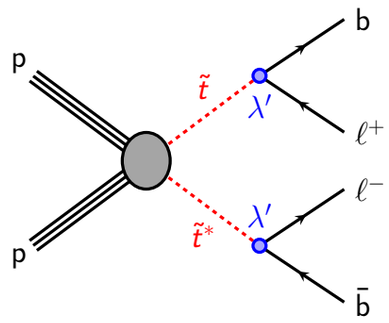
Prompt SUSY (jets + E_T^{miss}) search re-interpreted for metastable gluinos (ATLAS-CONF-2014-037)

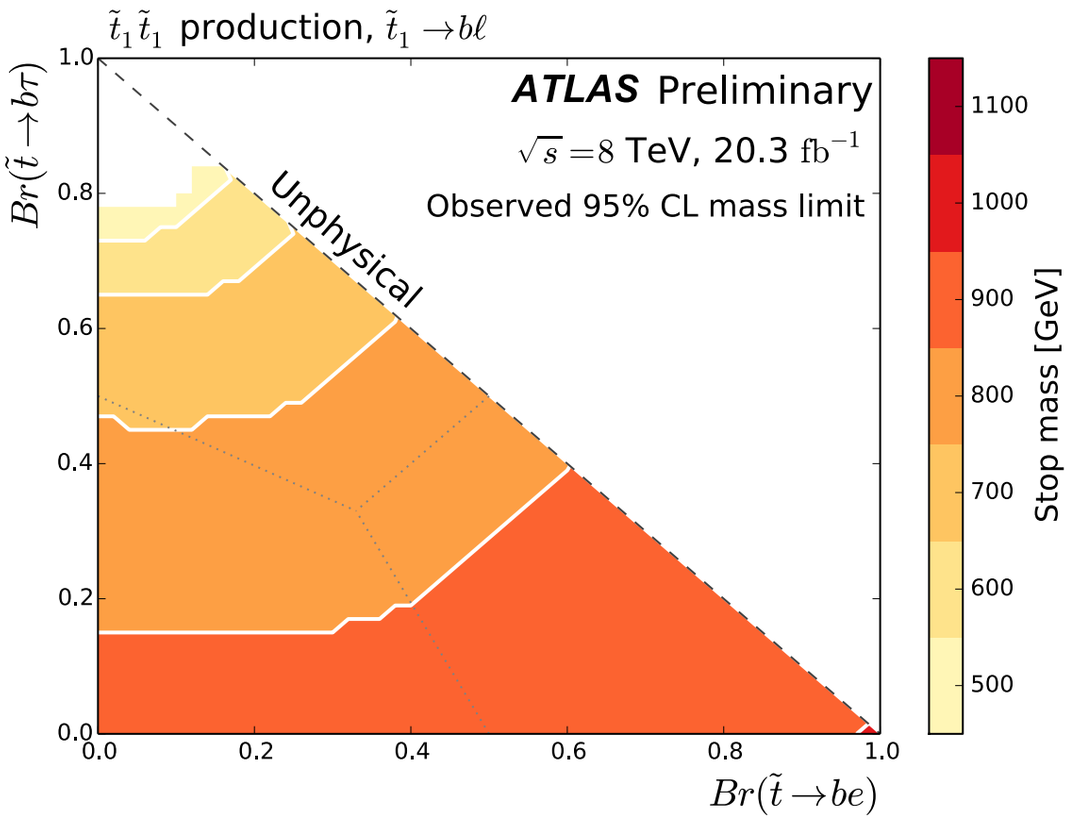
B – L RPV Scalar Top Decays

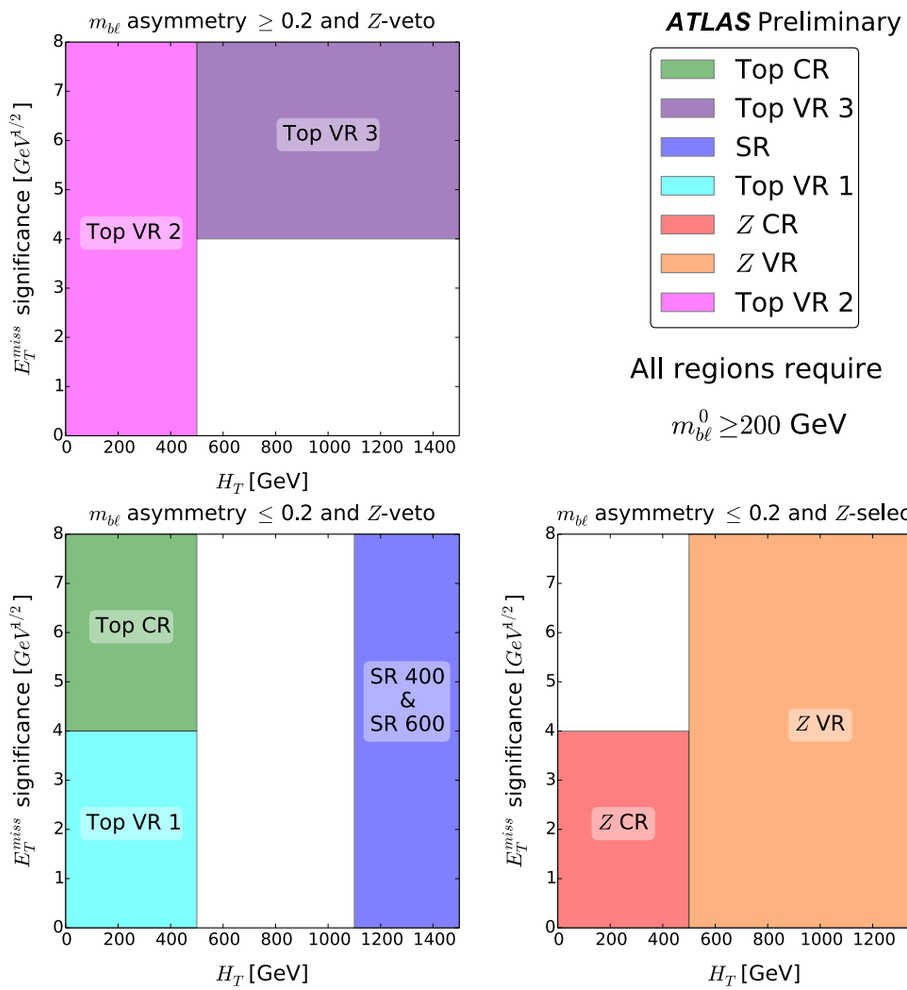
ATLAS-CONF-2015-015

Minimal B-L SUSY extension:

- Search for 2 b-tagged jets + 2 opposite sign leptons
- Use scalar sum of p_T (H_T) and missing E_T to define signal regions
  - Main backgrounds - ttbar, Z/γ + jets
  - Use MC simulation normalized in data control regions to estimate background



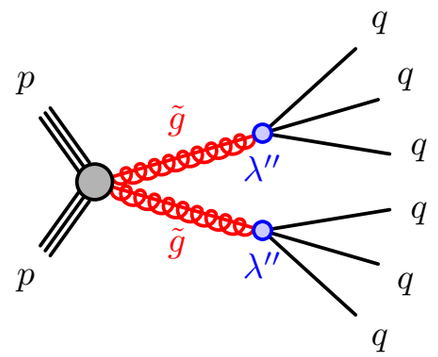


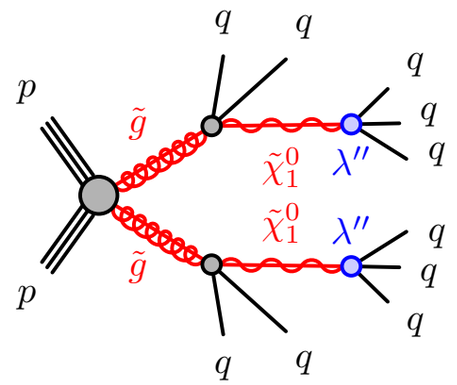


RPV Gluino decay to Quarks

RPV gluino decay (directly or via neutralino) to quarks

arXiv:1502.05686



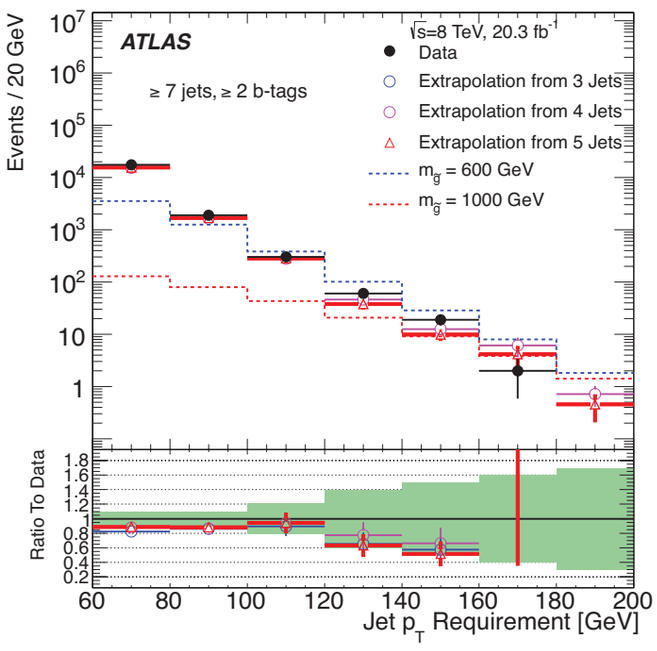


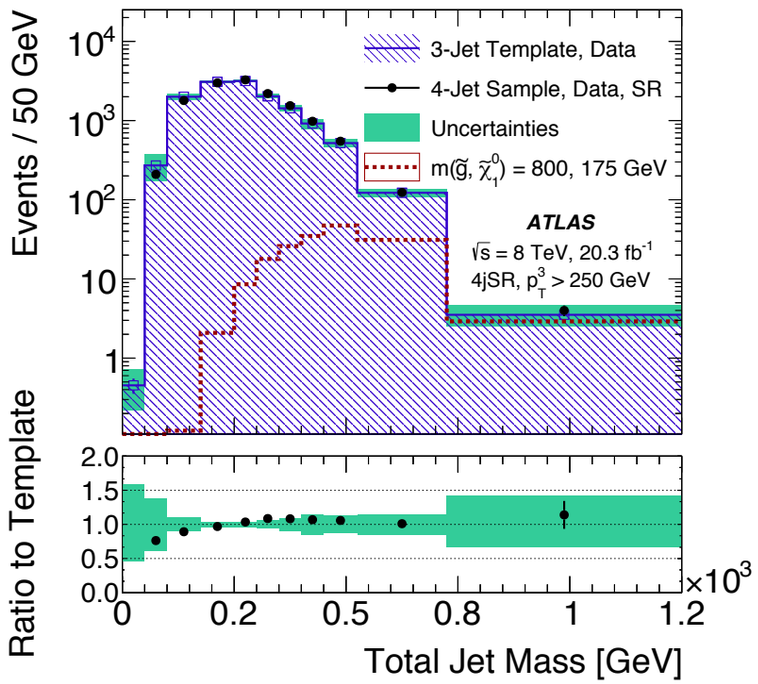
Two search strategies:

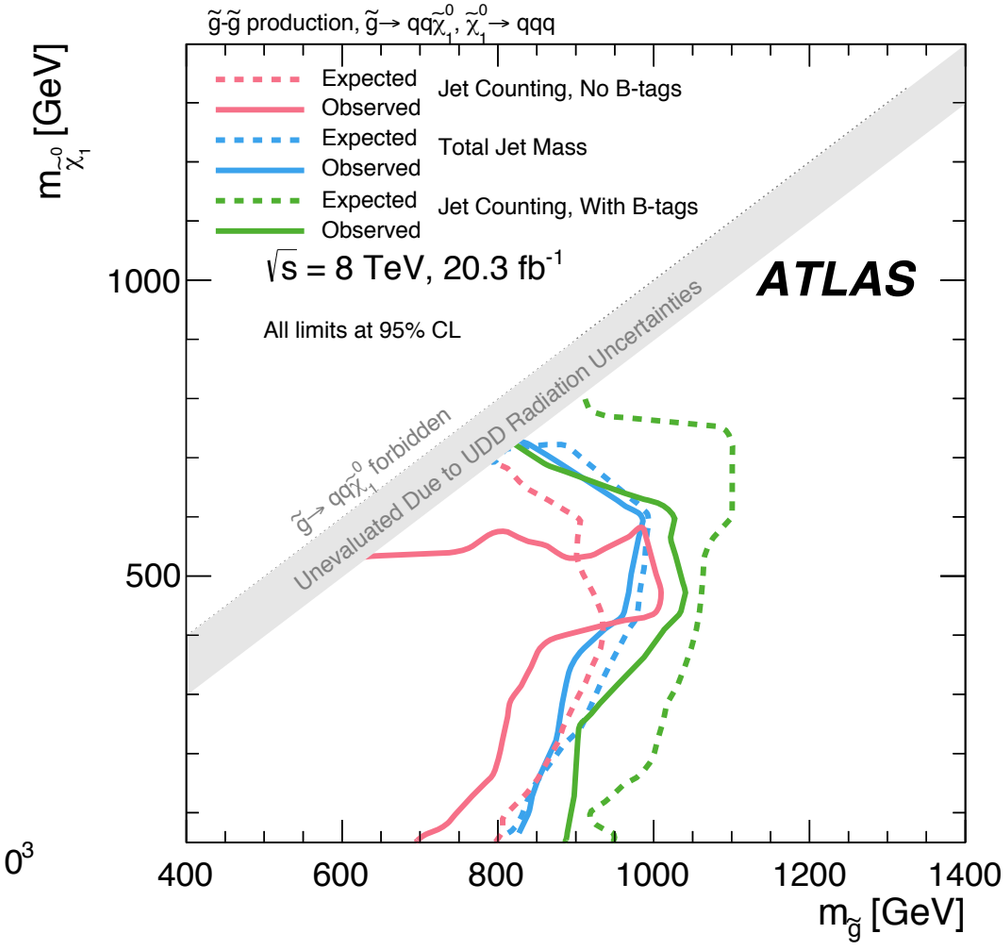
- **Jet-counting**
  - ≥ 6 or 7 high p_T jets
  - Estimate background in signal-depleted control region (lower jet multiplicity), then extrapolate to signal region
- **Observable calculated from large-radius (R=1.0) jets**

$$M_J^{\Sigma} = \sum_{\substack{p_T > 100\ \mathrm{GeV} \\ |\eta| \leq 2.5}}^{4} m^{\mathrm{jet}}$$

  - Data-driven background estimate using jet mass templates







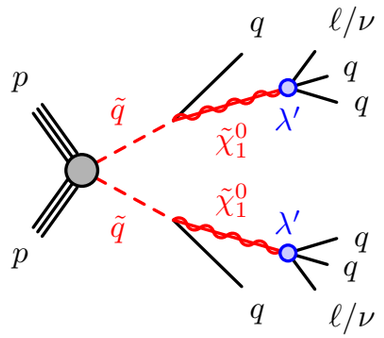
DISPLACED VERTICES - I

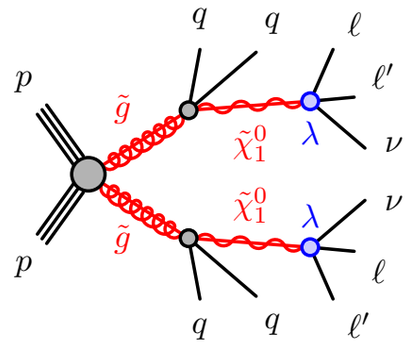
Search for displaced vertices (DV) in the Inner Detector

arXiv:1504.05162

Many final states

- Multi-track DV + electron/muon/jet/E_T^{miss}
- Displaced dilepton pairs





Special displaced track/vertex reconstruction in the Inner Detector (r < 30cm, |z| < 30 cm)

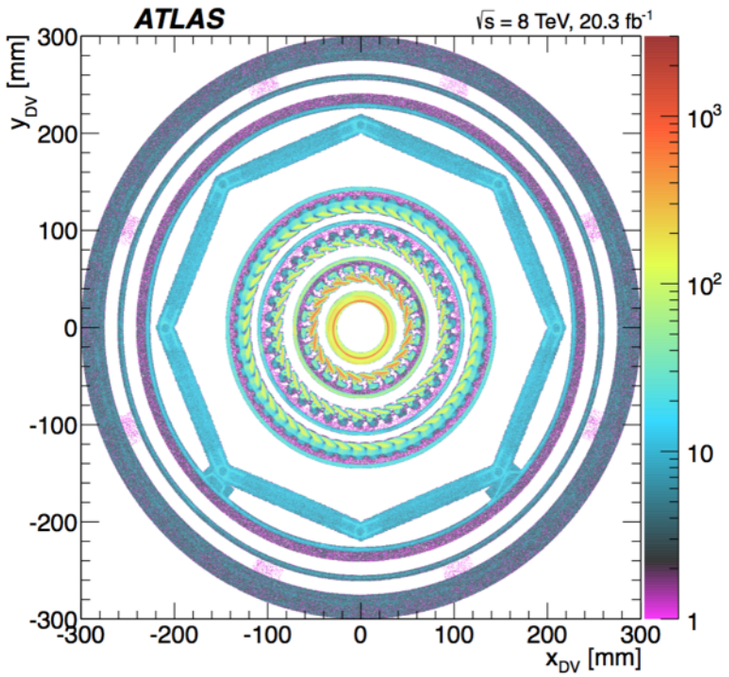
Sources of background:

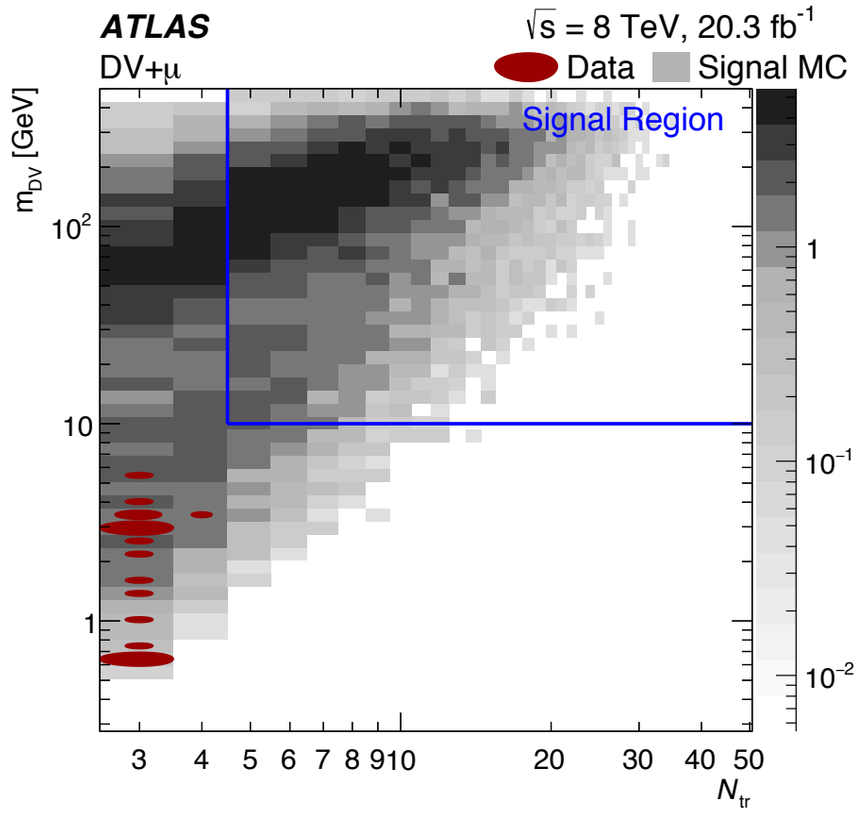
Multi-track vertex

- Hadronic interactions with detector material
- Random track crossing a vertex
- Low track multiplicity vertices

Dilepton pairs

- Random crossing of unrelated lepton tracks





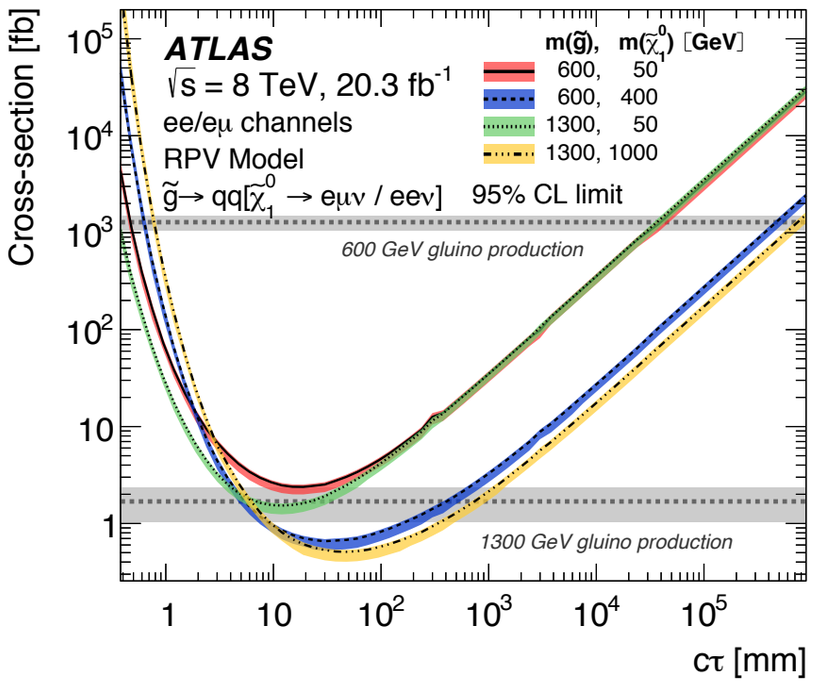
Data-based background estimate - **0 bkg. events** expected in all channels

DISPLACED VERTICES - I

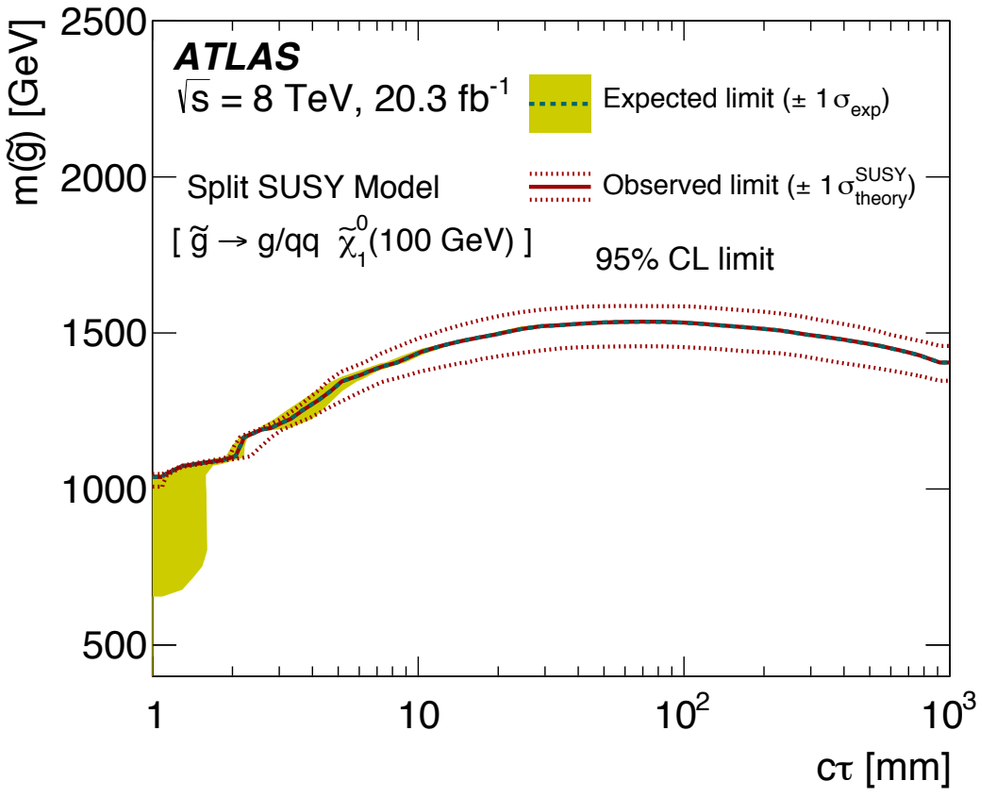
No observed events found in any channel

Results interpreted for **RPV, split SUSY, gauge-mediated** scenarios

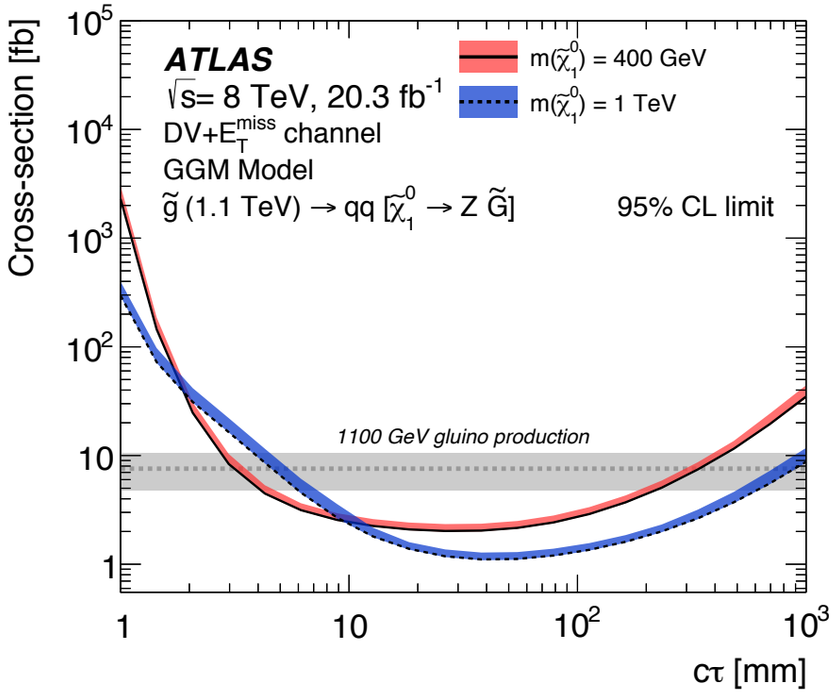
RPV - displaced dilepton



Split SUSY - DV + jets



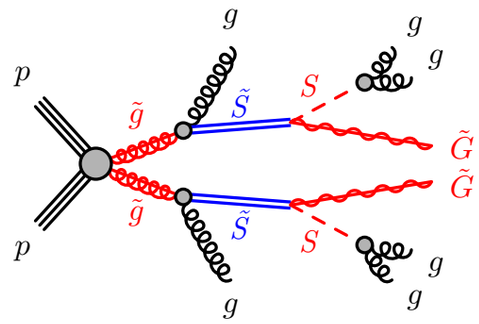
GGM - DV+E_T^{miss}



DISPLACED VERTICES - II

Stealth SUSY - low missing E_T, long-lived singlino

arXiv:1504.03634



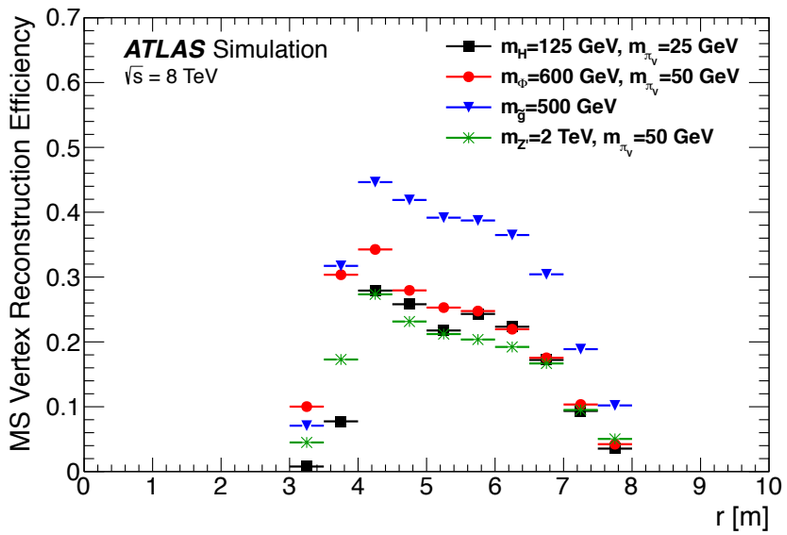
Search strategy:

- Trigger on Muon Spectrometer (MS) region of interest
- Require ***two*** displaced vertices:

Muon Spectrometer

- *multi-tracklet*
- *isolated from IP jets, tracks*

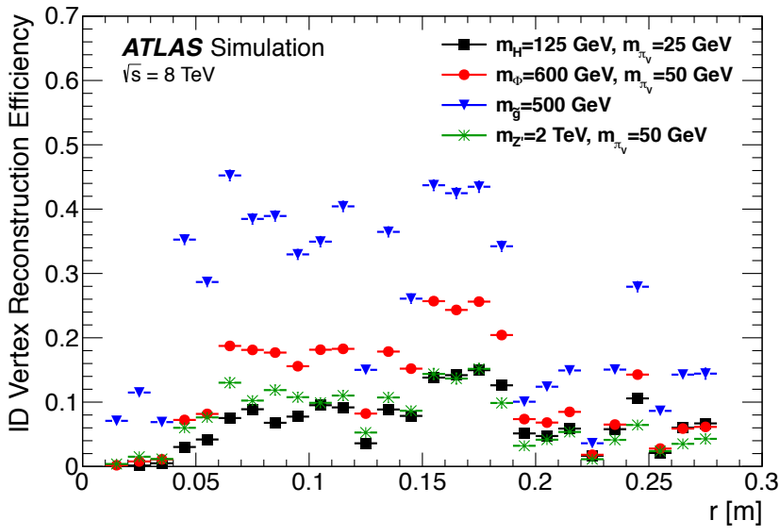
Background: Punch-through jets

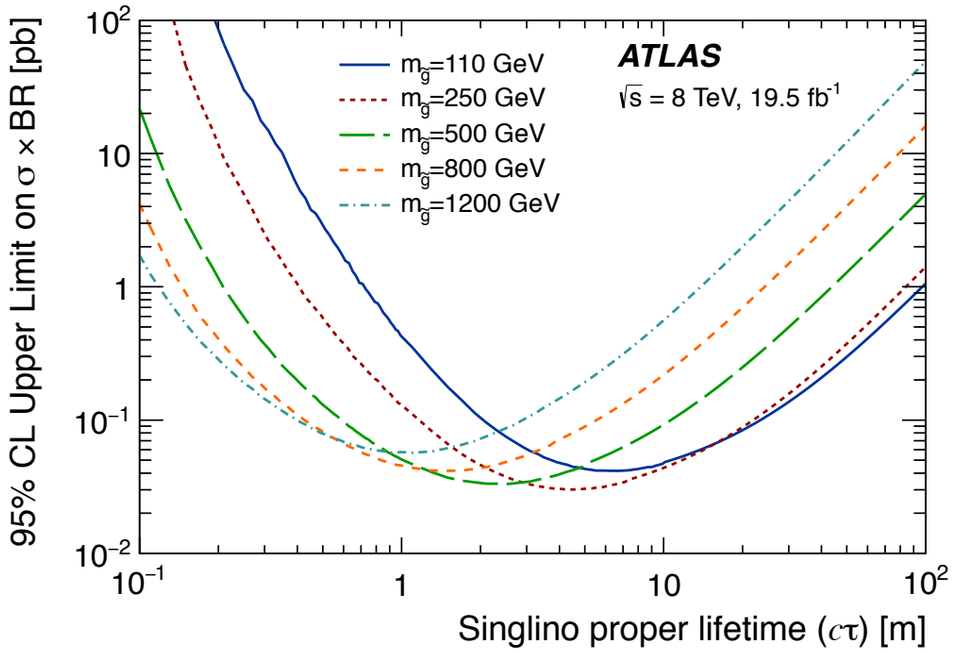


Silicon Tracker

- *multi-track*
- *near a jet*

Background: Combinatorics, random tracks crossing a vertex





Use of ID+MS vertex reco. allows for a broad range of excluded lifetimes

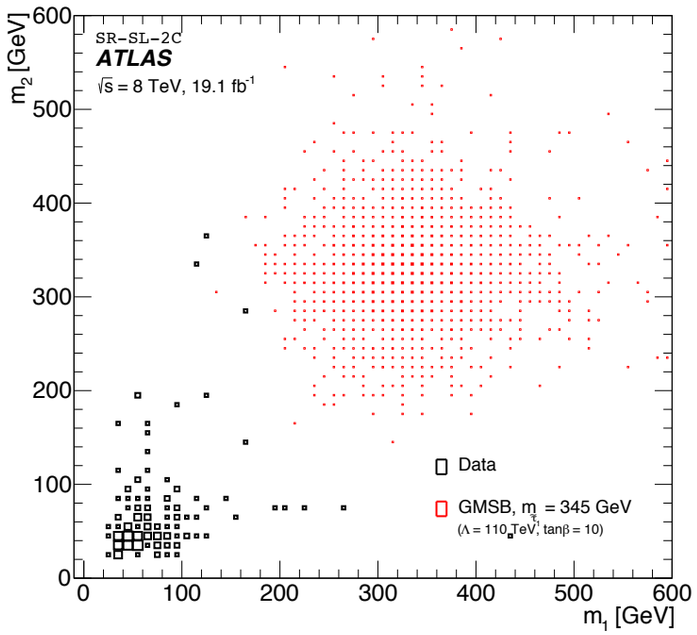
Stable Massive Particles

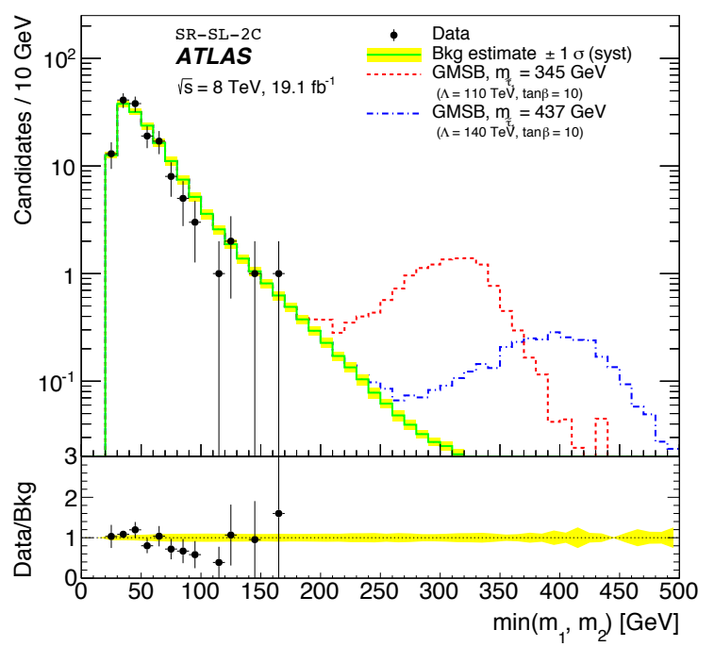
arXiv:1411.6795

Search for heavy, charged, stable, slow-moving (β < 1) particles using:

- **Ionization energy loss (dE/dx) → βγ**
  - Measured in pixel detector
- **Time-of-flight measurement → β**
  - Muon system, calorimeters

- Background - high-p_T muons with large ionization, mis-measured β
  - Contribution estimated from data

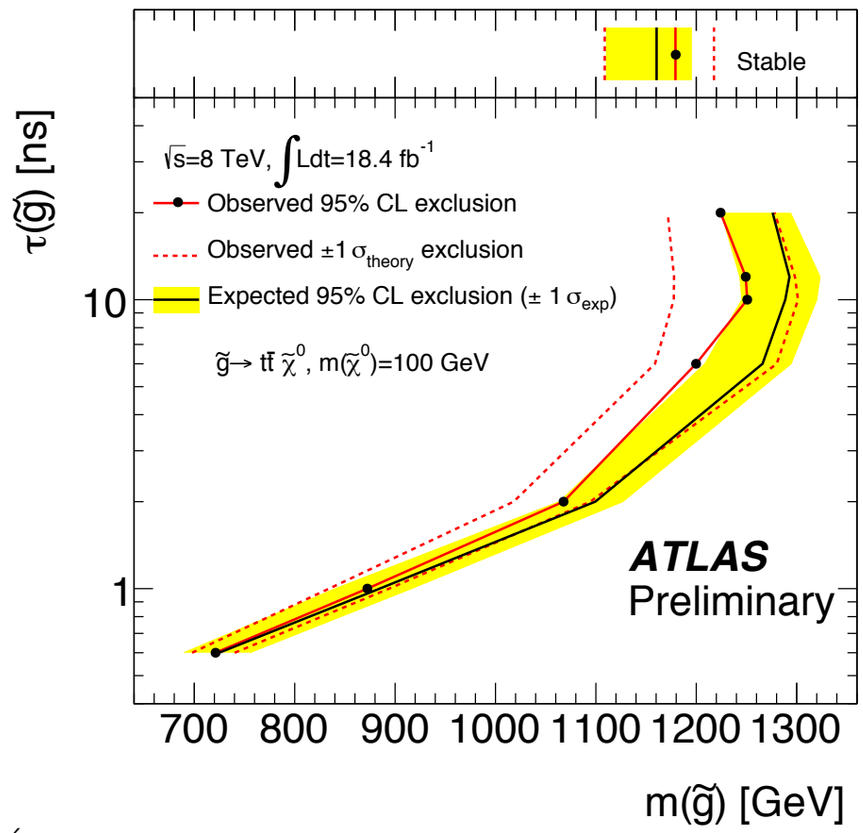




Interpretations - stable sleptons, leptoSUSY, charginos, R-hadrons

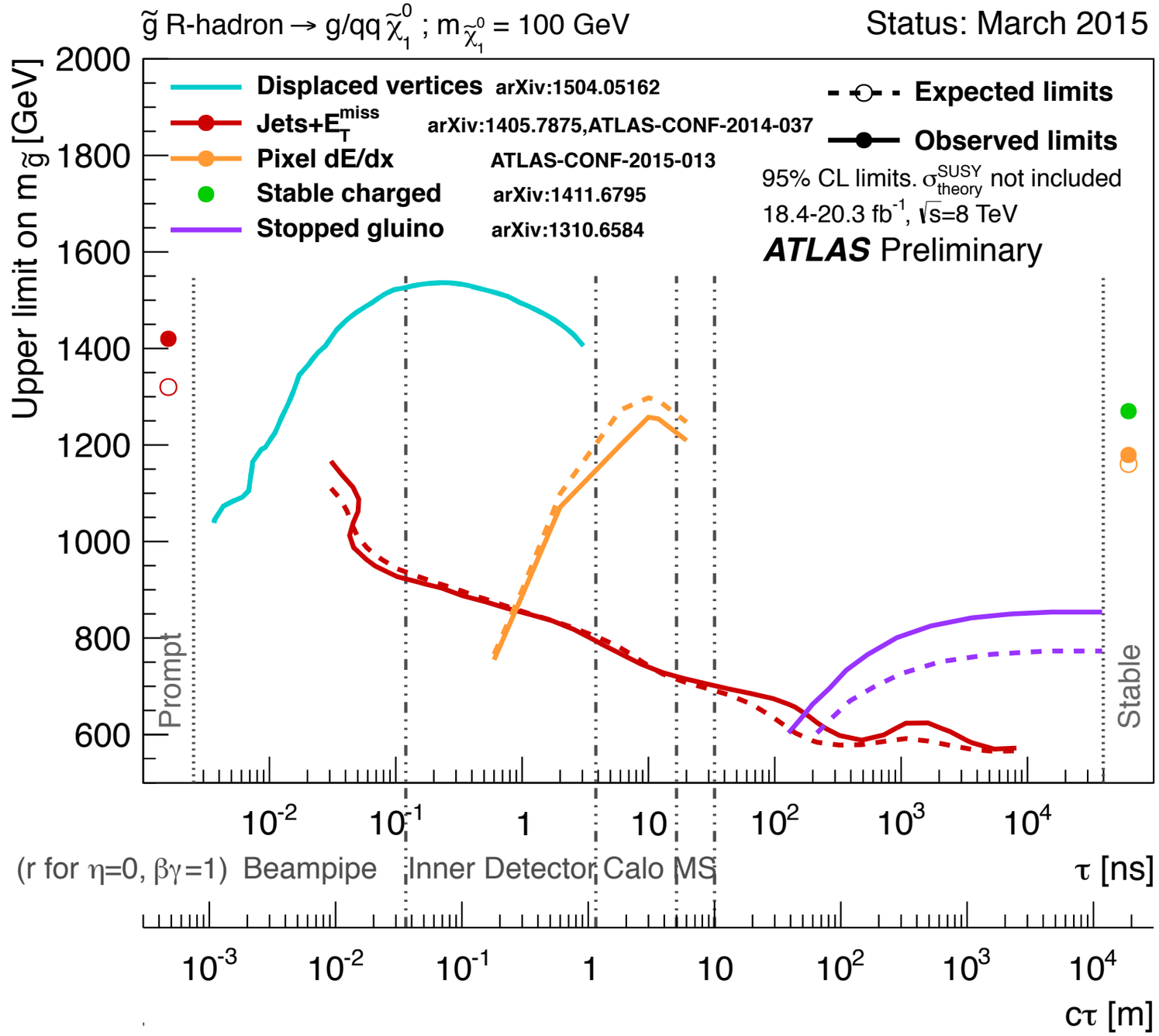
NEW! (ATLAS-CONF-2015-013)

- Update search → pixel dE/dx only
- Extends sensitivity to lower lifetimes



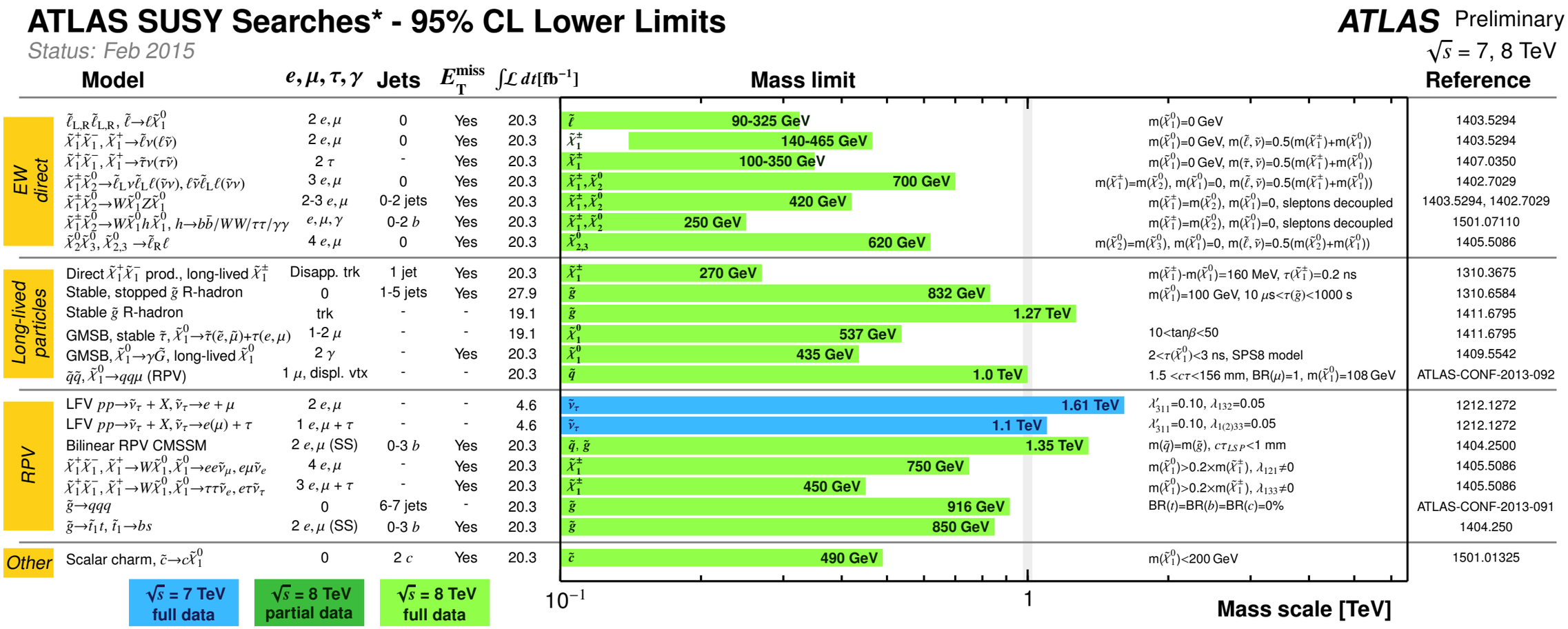
Long-Lived Particles - Summary

- Long-lived particles can have interesting detector signatures
- Require novel reconstruction techniques
- Combination of different Run I searches excludes a wide range of lifetimes
- Still have a lot of phase space to search for new physics in Run II!



SUMMARY

- Extensive set of searches for SUSY signatures in Run I, encompassing a wide variety of theoretical models and final states
  - No SUSY observed (yet)!
- Higher center of mass energy for Run II → increased sensitivity



*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.

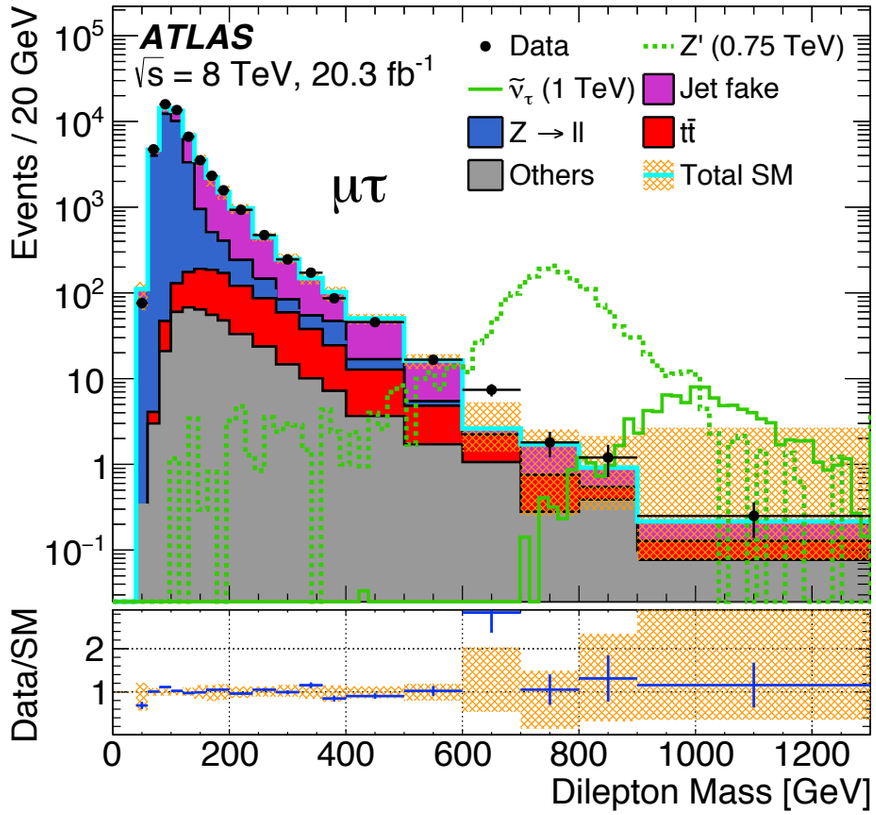
BACKUP

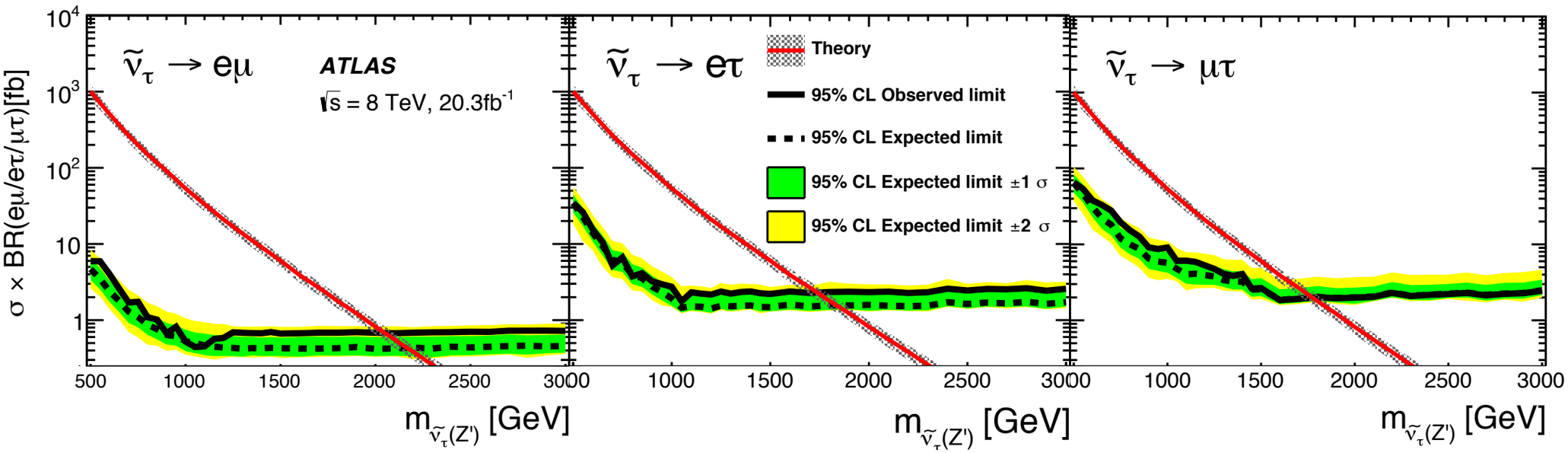
Heavy Neutral Particles → $e^{\pm}\mu^{\mp}/e^{\pm}\tau^{\mp}/\mu^{\pm}\tau^{\mp}$

arXiv:1503.04430

Lepton-flavor violation in RPV-SUSY

- Opposite-sign different flavor lepton pairs from tau sneutrino decays
- Background from mis-ID of jets as leptons
  - W+jets, multijet events
  - Difficult to model the mis-ID - use data-based background estimation
- Expected background, observed events in good agreements in all channels

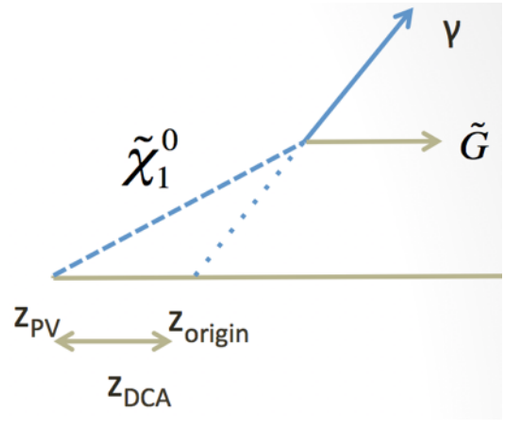




Non-Pointing, Delayed Photons

Some GMSB models have NLSP decaying to photon + (stable) gravitino LSP:

arXiv:1409.5542



Finite NLSP lifetime → Final state with large E_T^{miss} and two photons that:

- Do not point towards the primary vertex
  - Require large separation (along BL) between PV and photon origin ($|\Delta z_{DCA}|$)
- Arrive later than expected in the EM calorimeter (large t_γ)

- *Z* →*ee* data events used for performance studies
- Background contribution estimated from low E_T^{miss} data control region