Reinterpretation of ATLAS Searches for Supersymmetry in the Context of R-Parity Violating Models

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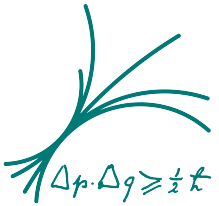

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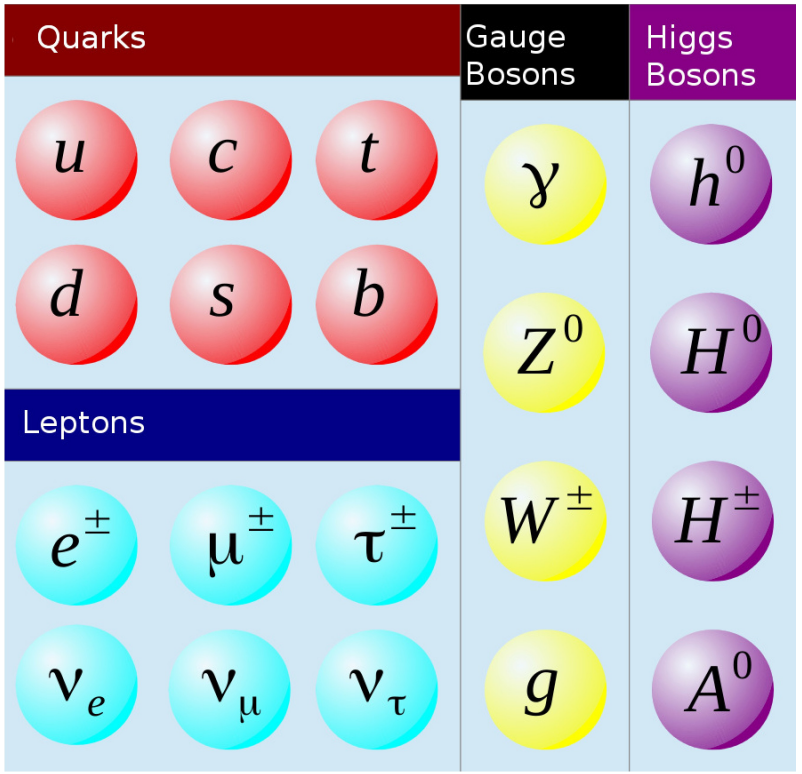
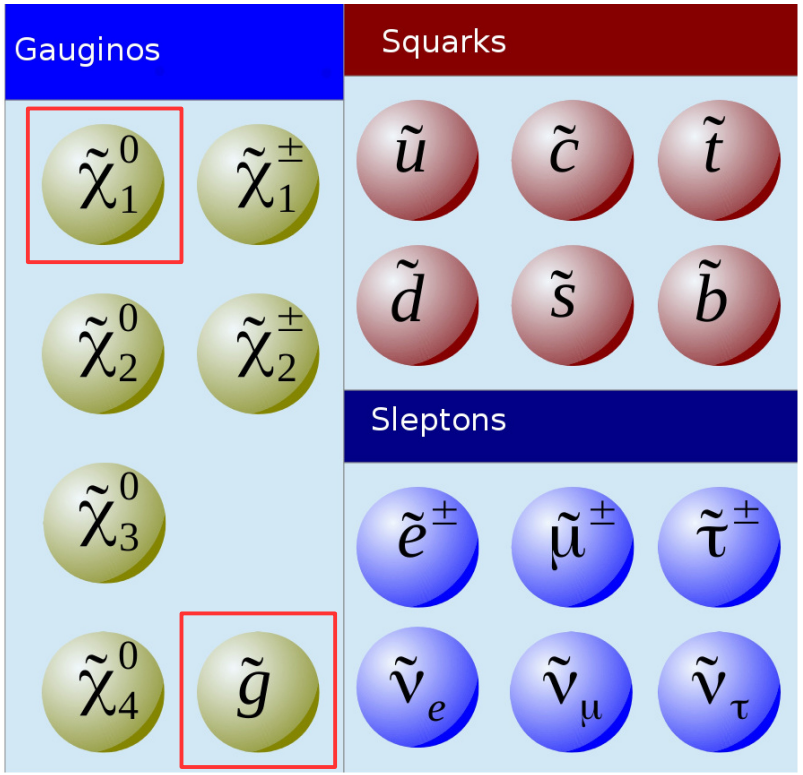
Introduction to SUSY

- Symmetry between fermions and bosons
- Each standard model particle gets a superpartner
- Spin of the superpartner = spin of the SM particle +- ½
- All other properties like charges are the same except mass
  => SUSY is a broken symmetry





Introduction to R-Parity Violation

- R-parity:
  - +1 for standard model particles
  - -1 for SUSY particles
  - Conserved in the MSSM to prevent proton decay
- R-parity violated (RPV) => lightest supersymmetric particle (LSP) unstable
- Superpotential with the RPV terms => describe LSP decay:

$$W_{RPV} = \frac{1}{2}\lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \frac{1}{2}\lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k + \mu_i H_u L_i$$

LLE: Neutralino → 2 leptons + 1 neutrino
LQD: Neutralino → 1 lepton / neutrino + 2 quarks

- Decay of the proton: UDD (1st generation) + LLE or LQD
  => We assume λ'' = 0 (might plausibly be forbidden by a new symmetry)
  => No proton decay

RPV Parameters

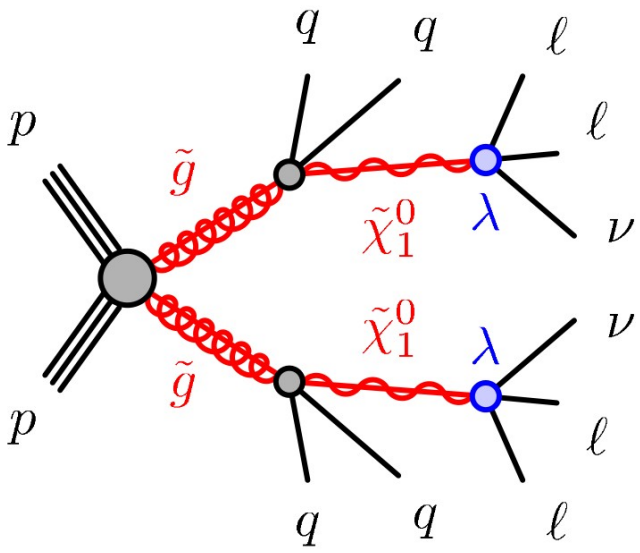
- Superpotential for leptonic RPV: $W_{RPV} = \frac{1}{2}\lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k$
- 9 LLE parameters (λ) and 27 LQD parameters (λ')
  - Big parameter space to be investigated
  - All parameters compete with each other and could be ≠ 0
    => Complicated LSP decays with many channels possible
  - There is little reason to think a single coupling dominates in nature
- Most RPV analyses present results just for specific LSP decay assumptions
  - Standard approach: Investigate only one coupling at a time
  - Reasons:
    - High effort to treat all parameters
    - e, μ, τ and jets have very different experimental signatures
  - Low coverage of the RPV parameter space

Aims and strategy

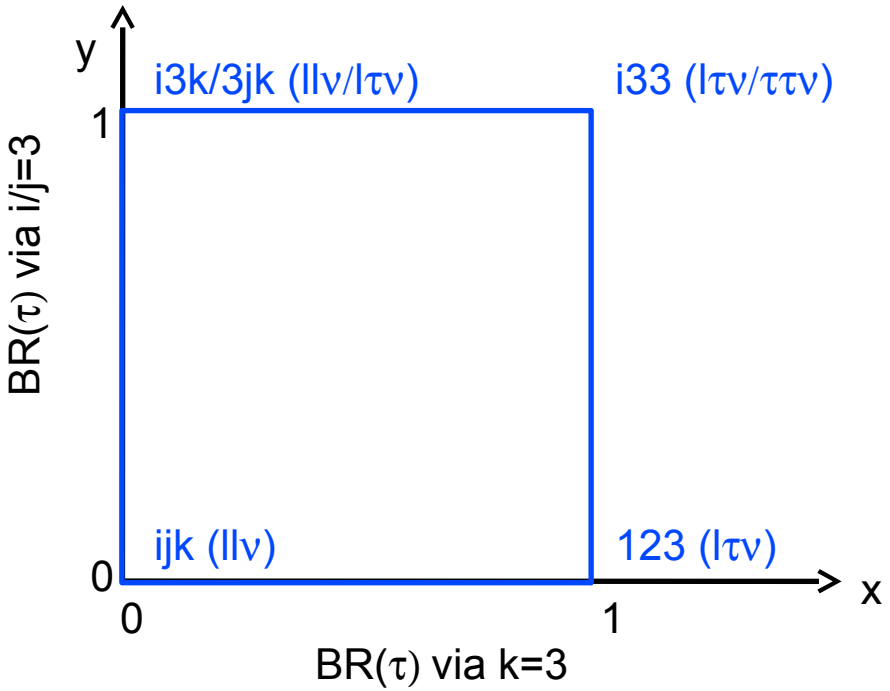
- Break the assumption of single coupling dominance for LLE and LQD couplings
- Reinterpret ATLAS searches for SUSY in RPV models
- Perform the first interpretation of prompt LQD-mediated decays by ATLAS
- Scan parameter space of different LSP decays
  => Use the event weighting technique to save computational resources
- Test the acceptance of multiple analyses to find where ATLAS searches are sensitive

LLE Model

- Gluino pair production
- Gluino decays to 2 quarks (1st and 2nd generation) and a neutralino (LSP)
- Neutralino decays promptly via all 9 LLE couplings
- 3 types of LSP decay channels: llν, lτν and ττν (l: electron or muon)
- All of the decay channels are simulated simultaneously
- e and μ symmetrized to reduce the dimensionality of the parameter space
  => Empirically justified by similar performance



Coupling plane and grid for LLE Model



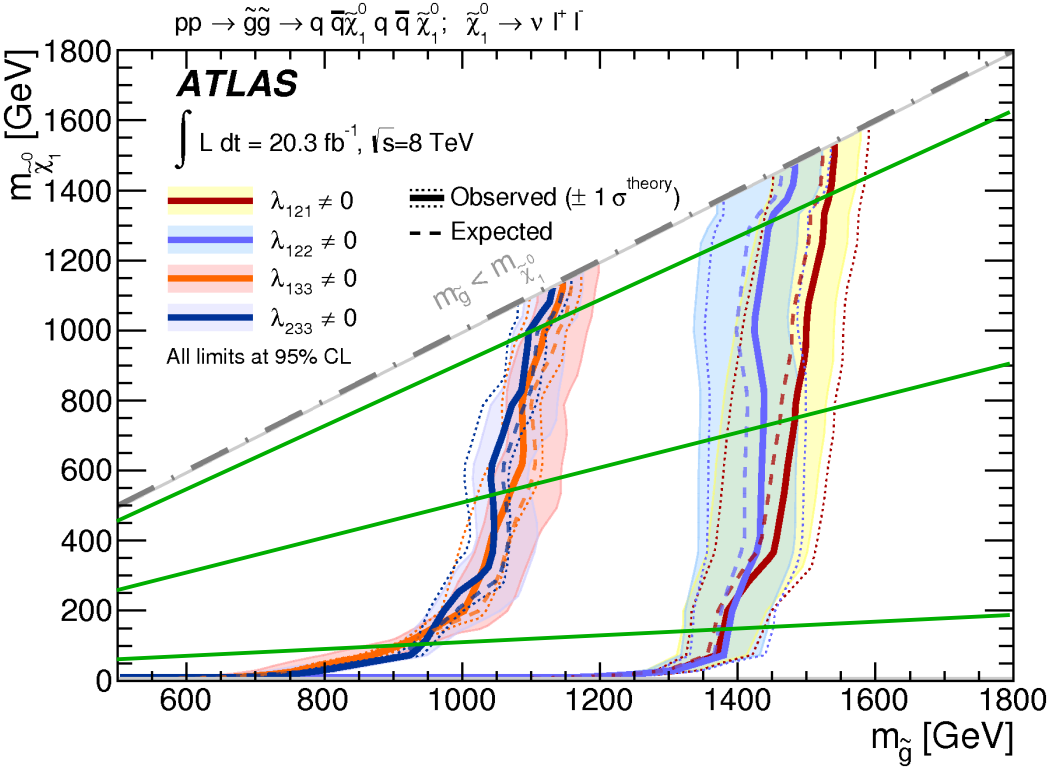
- Corners correspond to specific couplings
- Decay channels are weighted to interpolate between corners

- 3 different mass ratios were simulated:

$$R = \frac{m_{Neutralino}}{m_{Gluino}}$$

R = 0.1, 0.5 or 0.9

- With 13 mass points in total



ATLAS 4L Analysis

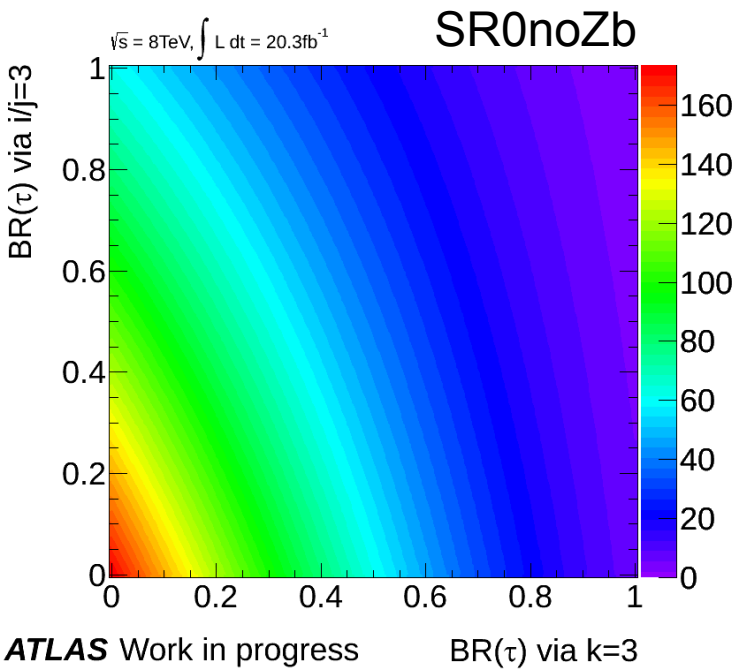
- ArXiv: 1405.5086
- Cuts:

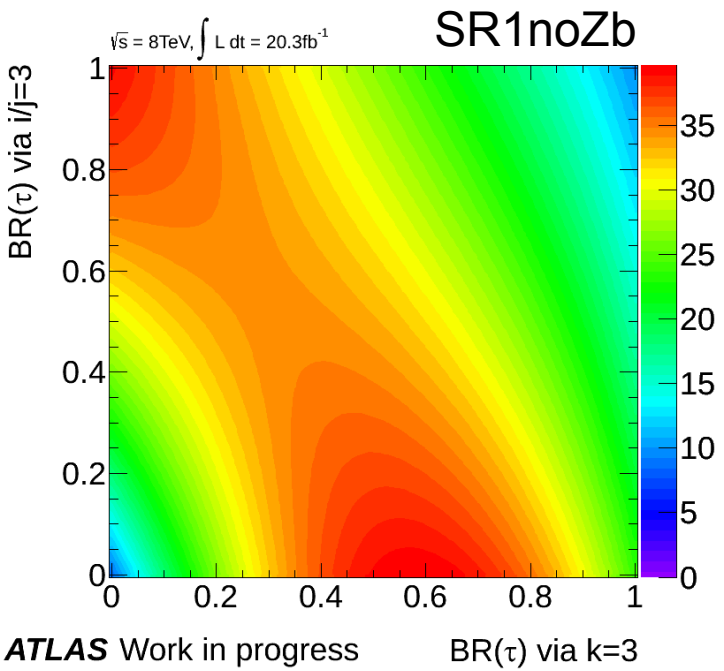
	e	μ	τ	Jet
pT [GeV]	>10	>10	>20	>20
|η|	<2.47	<2.5	<2.47	<2.5

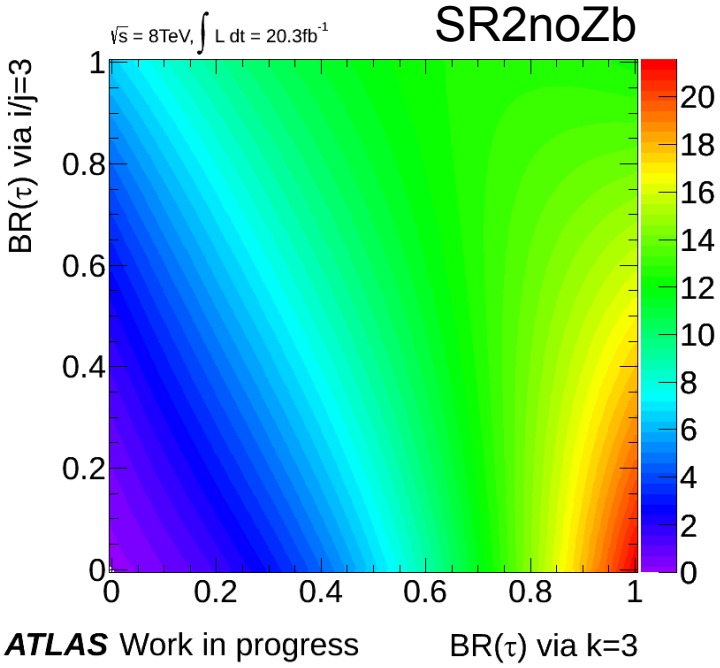
- Meff = MET + ∑pT(e) + ∑pT(μ) + ∑pT(τ) + ∑pT(jets with pT > 40 GeV)
- 9 signal regions:

	$N(\ell)$	$N(\tau)$	Z-veto	$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]		m_{eff} [GeV]
SR0noZa	≥ 4	≥ 0	SFOS, SFOS+ℓ, SFOS+SFOS	>50		–
SR1noZa	$=3$	≥ 1	SFOS, SFOS+ℓ	>50		–
SR2noZa	$=2$	≥ 2	SFOS	>75		–
SR0noZb	≥ 4	≥ 0	SFOS, SFOS+ℓ, SFOS+SFOS	>75	or	>600
SR1noZb	$=3$	≥ 1	SFOS, SFOS+ℓ	>100	or	>400
SR2noZb	$=2$	≥ 2	SFOS	>100	or	>600
	$N(\ell)$	$N(\tau)$	Z-requirement	$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]		
SR0Z	≥ 4	≥ 0	SFOS	>75		–
SR1Z	$=3$	≥ 1	SFOS	>100		–
SR2Z	$=2$	≥ 2	SFOS	>75		–

Signal Yields: Shape of the SRs





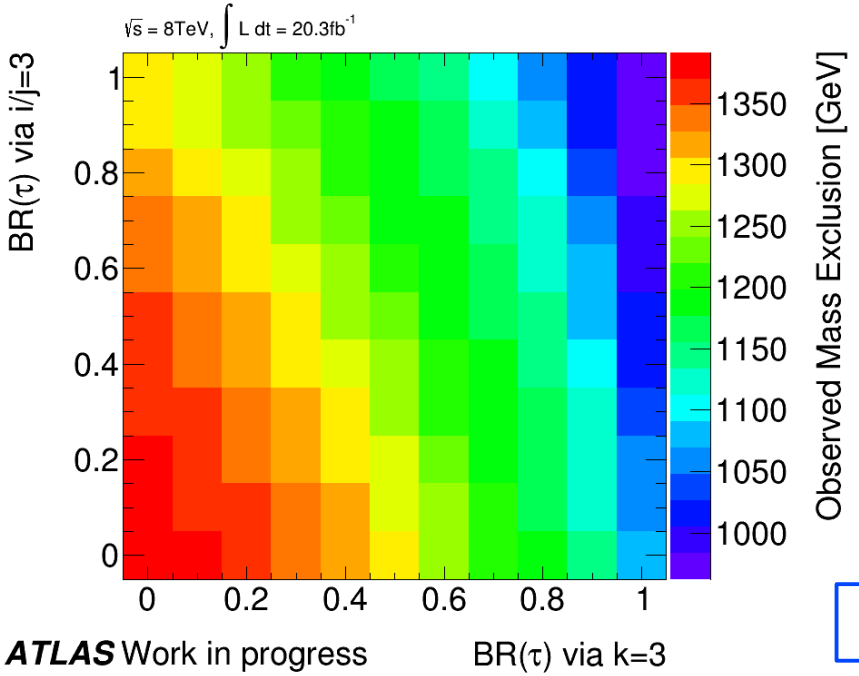


Gluino mass: 1000 GeV
Neutralino mass: 900 GeV

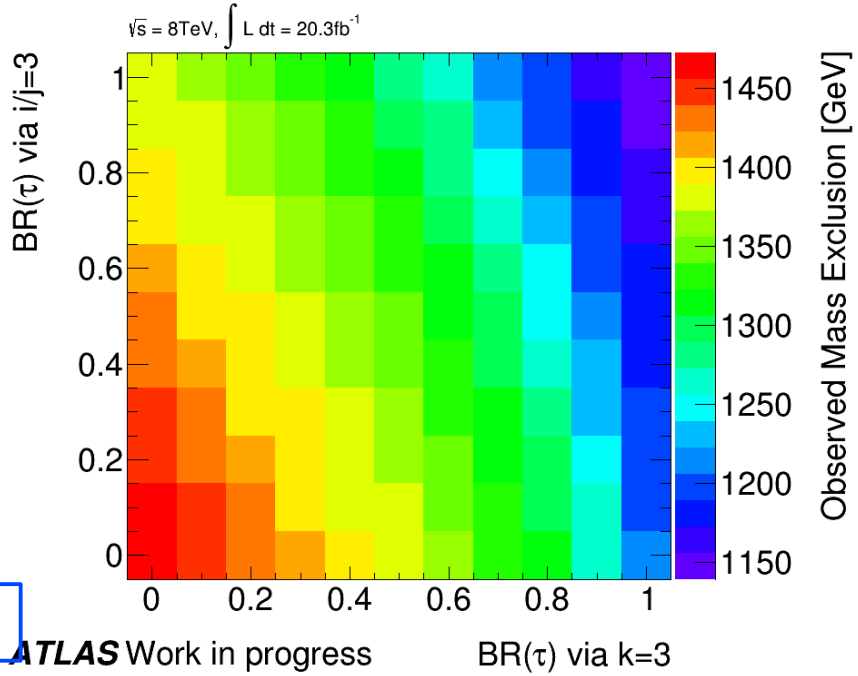
95% exclusion:

- SR0noZb: > 3.7 events
- SR1noZb: > 3.5 events
- SR2noZb: > 8.7 events

Observed Mass Exclusion (Preliminary)

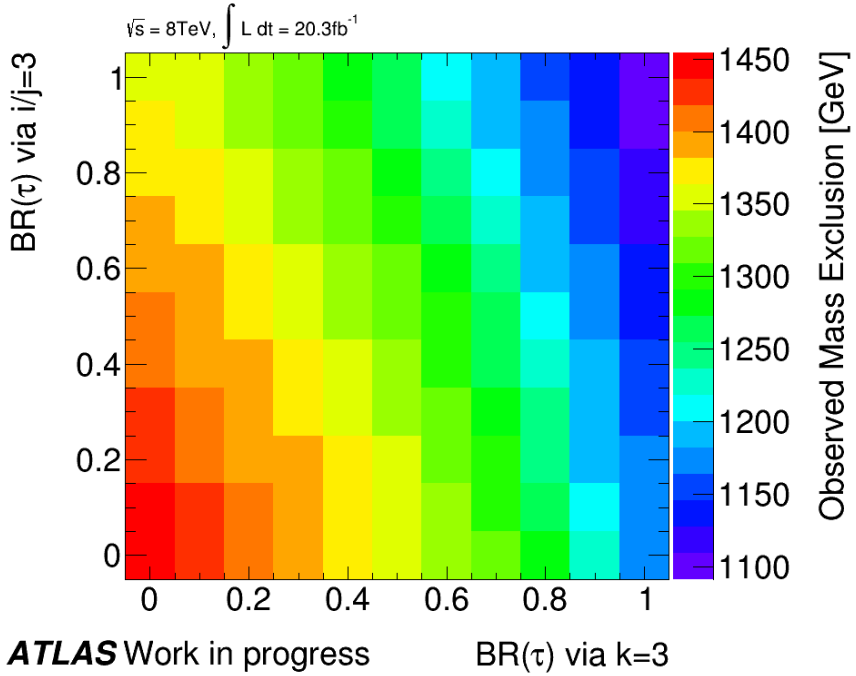


Mass ratio = 0.5

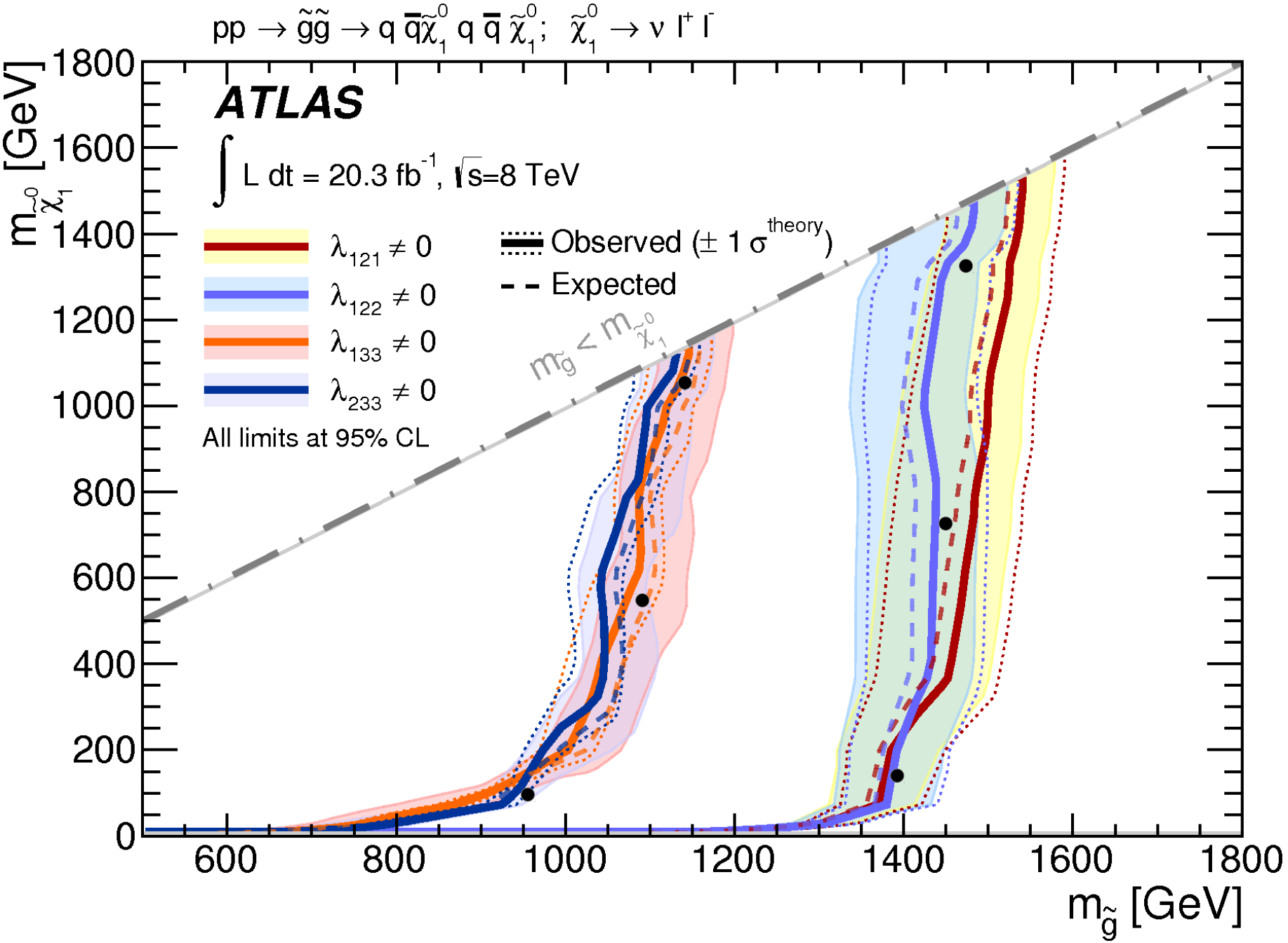


Mass ratio = 0.1

Mass ratio = 0.9



Comparison With Existing Results

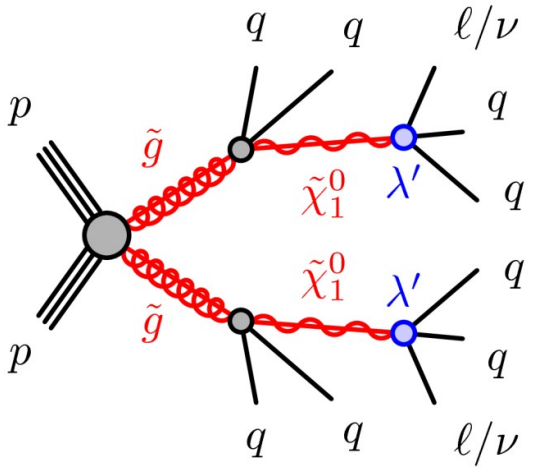


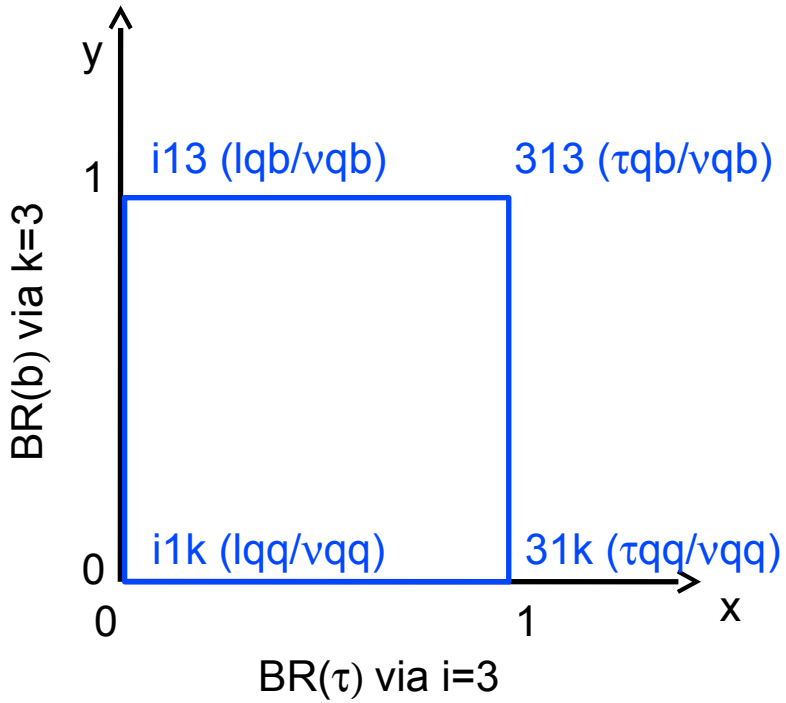
LQD Model

- Gluino pair production and neutralino as LSP
- LSP decays promptly via LQD couplings
  - “Only” 18 of 27 couplings included
  - BRs of decay channels with top quarks depend on stop mass
    => Not included to avoid additional parameter
- 6 different decay channels:

lqq lqb	τqq τqb	νqq νqb

- Different coupling plane compared to LLE:





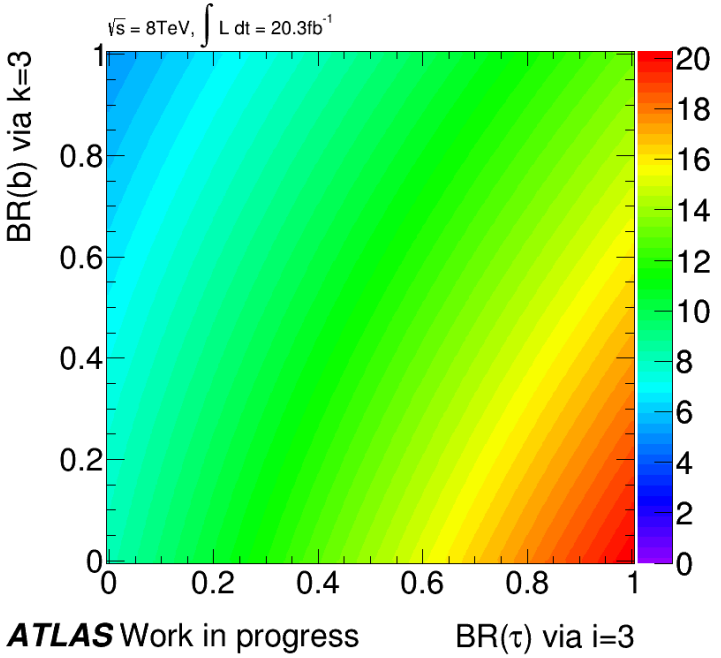
ATLAS 0L Analysis

- Classic search for squark and gluino production with RPC decays
- Final states: 0 leptons + 2-6 jets + MET
- Events with isolated electrons and muons are rejected
- Taus are reconstructed as jets
- meff(N) = scalar sum of the pT of the leading N jets and MET
- Part of the signal regions:

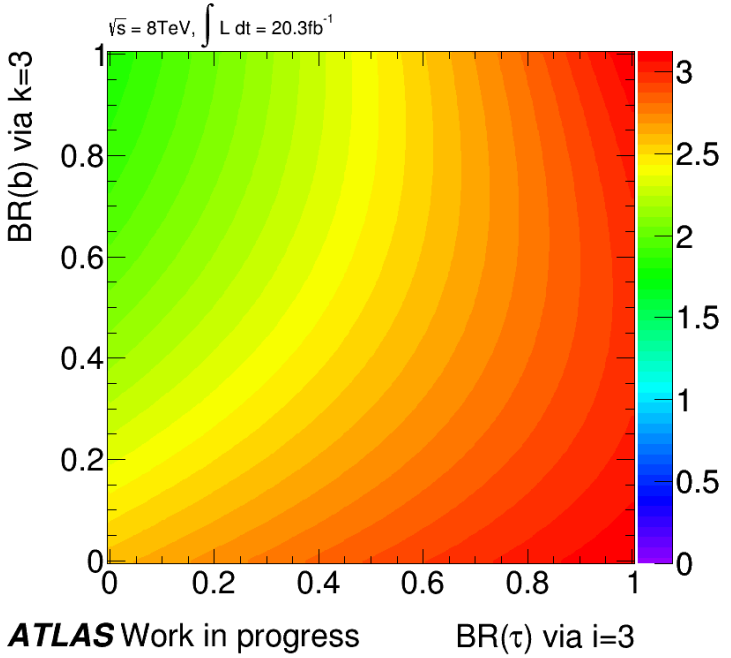
Requirement	Signal Region								
	4jl-	**4jl**	**4jm**	**4jt**	**5j**	**6jl**	**6jm**	**6jt**	**6jt+**
$E_{\mathrm{T}}^{\mathrm{miss}}$[GeV] >	160								
$p_{\mathrm{T}}(j_1)$ [GeV] >	130								
$p_{\mathrm{T}}(j_2)$ [GeV] >	60								
$p_{\mathrm{T}}(j_3)$ [GeV] >	60								
$p_{\mathrm{T}}(j_4)$ [GeV] >	60								
$p_{\mathrm{T}}(j_5)$ [GeV] >	–				60				
$p_{\mathrm{T}}(j_6)$ [GeV] >	–					60			
$\Delta\phi(\mathrm{jet}_{1,2,(3)}, \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ >	0.4								
$\Delta\phi(\mathrm{jet}_{i>3}, \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ >	0.2								
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$ [GeV$^{1/2}$] >	10		–						
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(N_{\mathrm{j}})$ >	–		0.4	0.25	0.2			0.25	0.15
m_{eff}(incl.) [GeV] >	700	1000	1300	2200	1200	900	1200	1500	1700

Table from:
ArXiv 1405.7875

Truth yields for SR6jvt

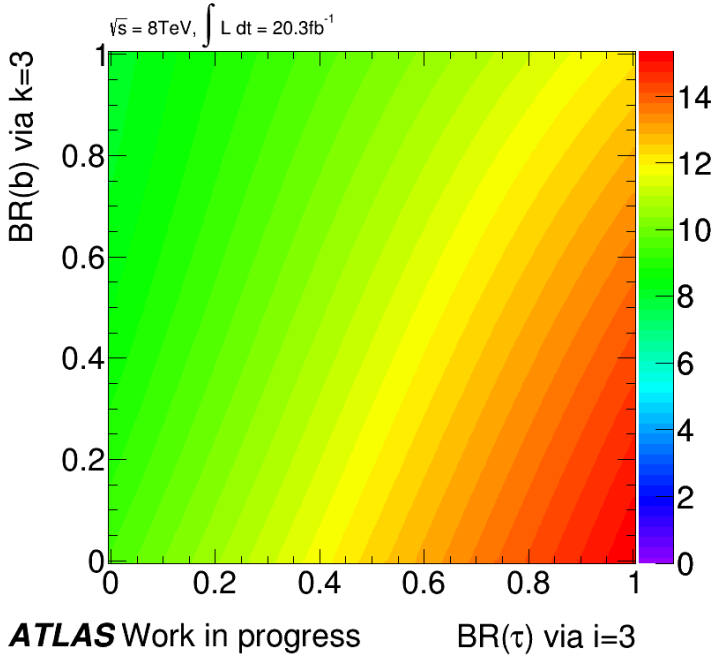


Mass point: [1000, 500]



Mass point: [1000, 900]

Mass point: [1000, 100]



No detector simulation

95% exclusion:
SR6jvt: > 7.9 events

Summary

- Searches for RPV SUSY typically assume a single dominant coupling
- Sensitivity to mixed couplings is being investigated
- LLE model:
  - Variation on existing model for 4L analysis
  - First mass limits as a function of branching ratios obtained
  - Further cross-checks in progress
- LQD model:
  - First test of prompt LQD decays by ATLAS
  - RPC analyses have good sensitivity
  - Further analysis with simulated + reconstructed events to come