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

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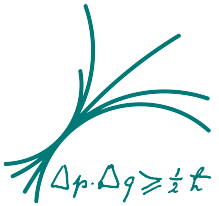

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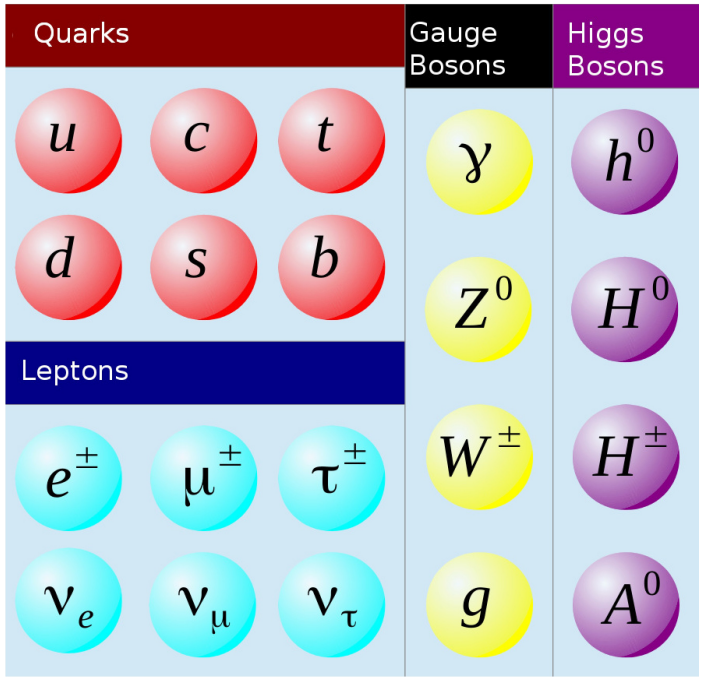
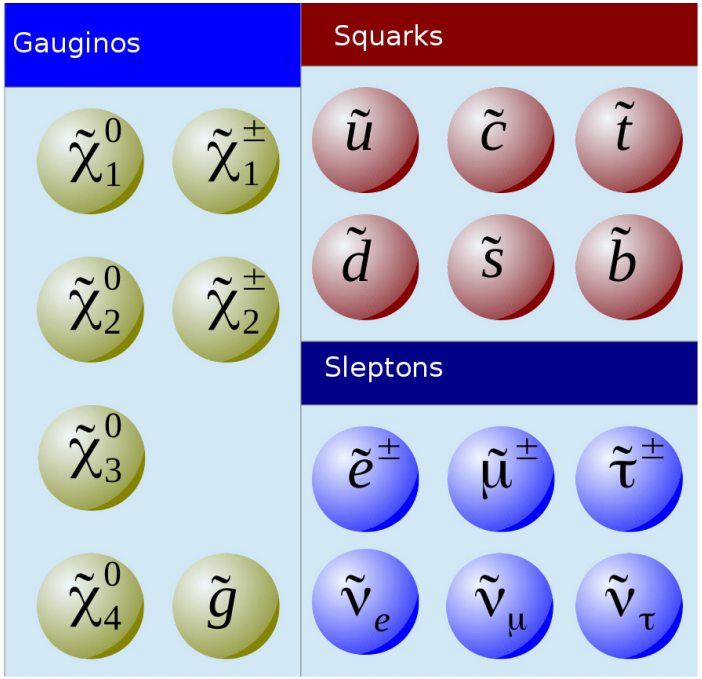
Introduction to Supersymmetry (SUSY)

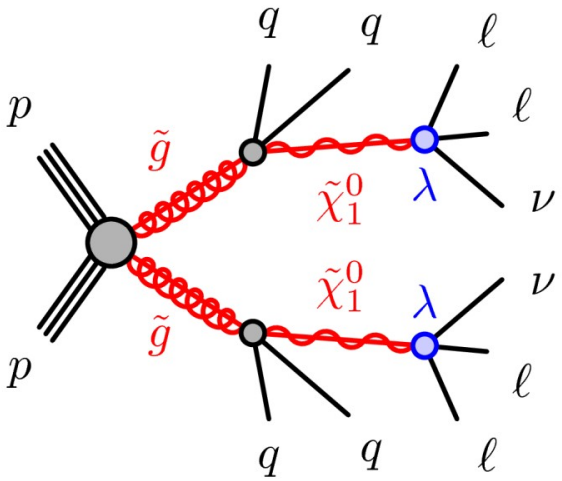
- Symmetry between fermions and bosons
- Every Standard Model (SM) particle gets a superpartner
- Spin differs by ½
- Minimal supersymmetric Standard Model (MSSM):





R-Parity Violation (RPV)

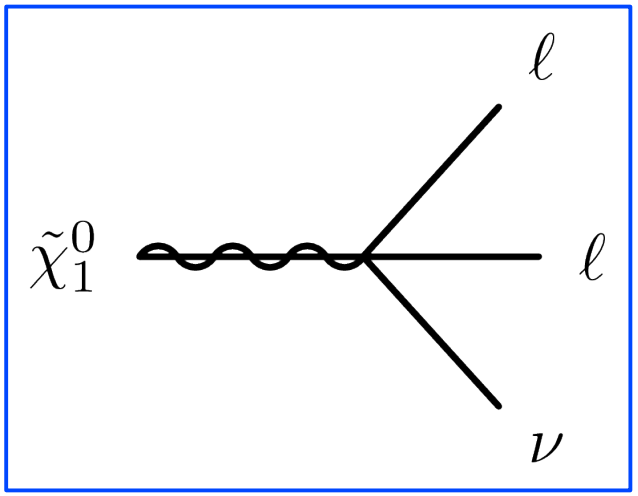
- R-parity: +1 (SM) and -1 (SUSY)
- Conserved in the MSSM to prevent proton decay
- R-parity violated:
  - Lightest supersymmetric particle (LSP) unstable
  - SUSY and SM particles can mix
  - Lepton and baryon number violation
    - Proton decay becomes possible
    - Solution: Introduce new symmetry
    - This symmetry allows only one type of violation



What does Reinterpretation mean?

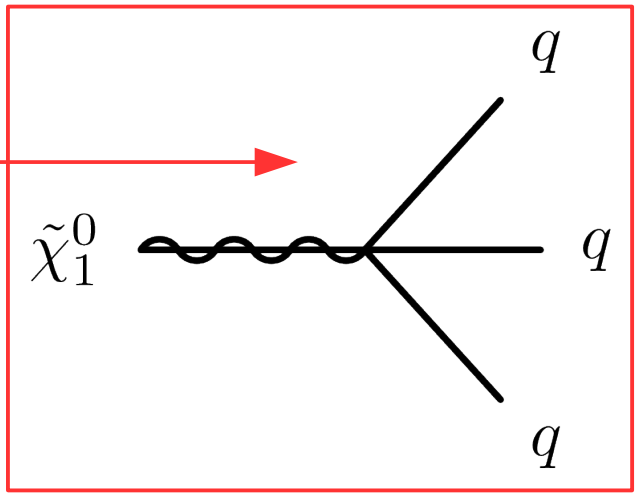
- Goal: Testing existing searches in new SUSY models
  => Find holes in the parameter coverage of the searches
- Model development
- Preliminary studies to find sensitive searches
- Large-scale Monte Carlo simulations
- Study of model dependent systematic uncertainties
- Reinterpretation of searches for SUSY
  - Published results are used for:
    - Event selection and signal regions
    - SM background predictions
    - Observed events in data
  - Run statistical analysis for new models

Trilinear LSP Decays

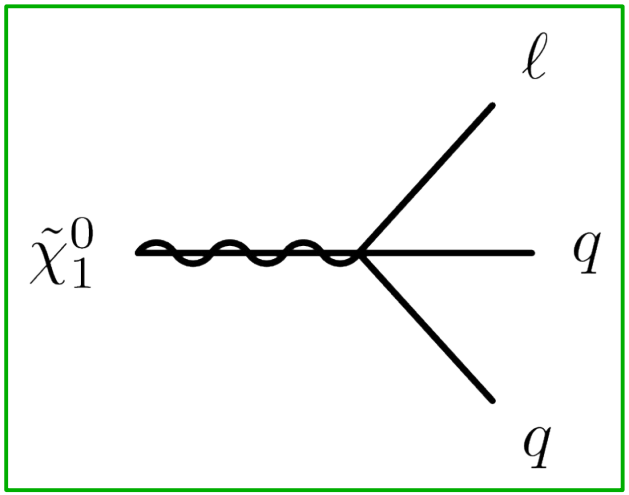


Purely leptonic

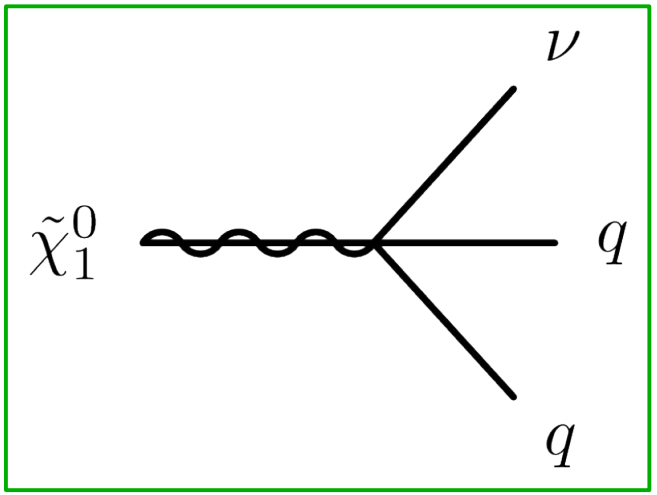
Not covered by my work



Purely hadronic



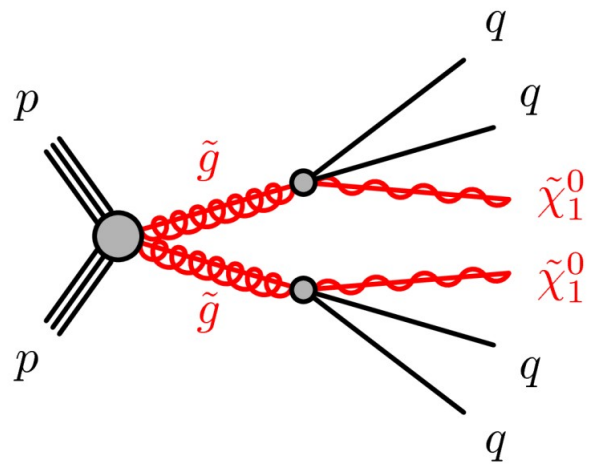
Semileptonic

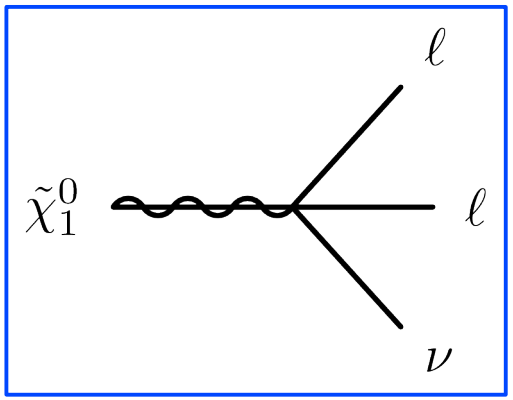


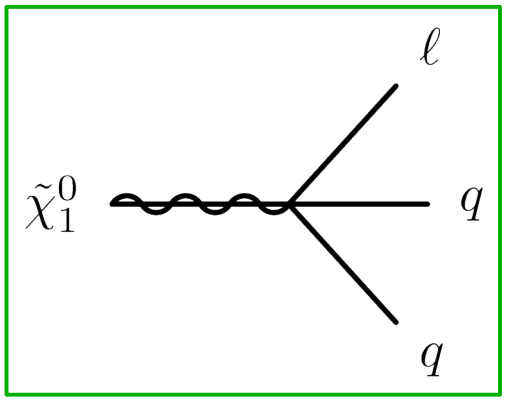
Not covered by any ATLAS search until now!

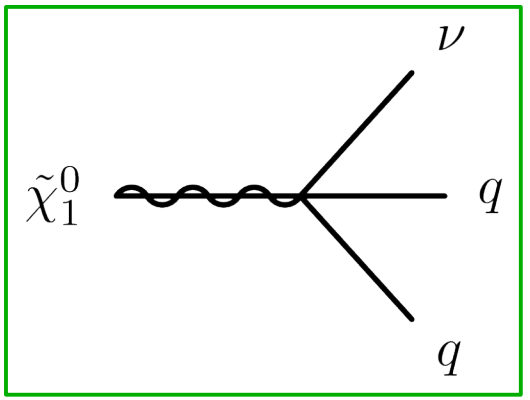
RPV SUSY Models

- Gluino pair production
- Neutralino as LSP
- Other SUSY particles decoupled
- Gluino mass range: 600 GeV up to 1600 GeV
- $R = m_{\text{Neutralino}}/m_{\text{Gluino}} = 0.1, 0.5 \text{ or } 0.9$
- LSP decay:









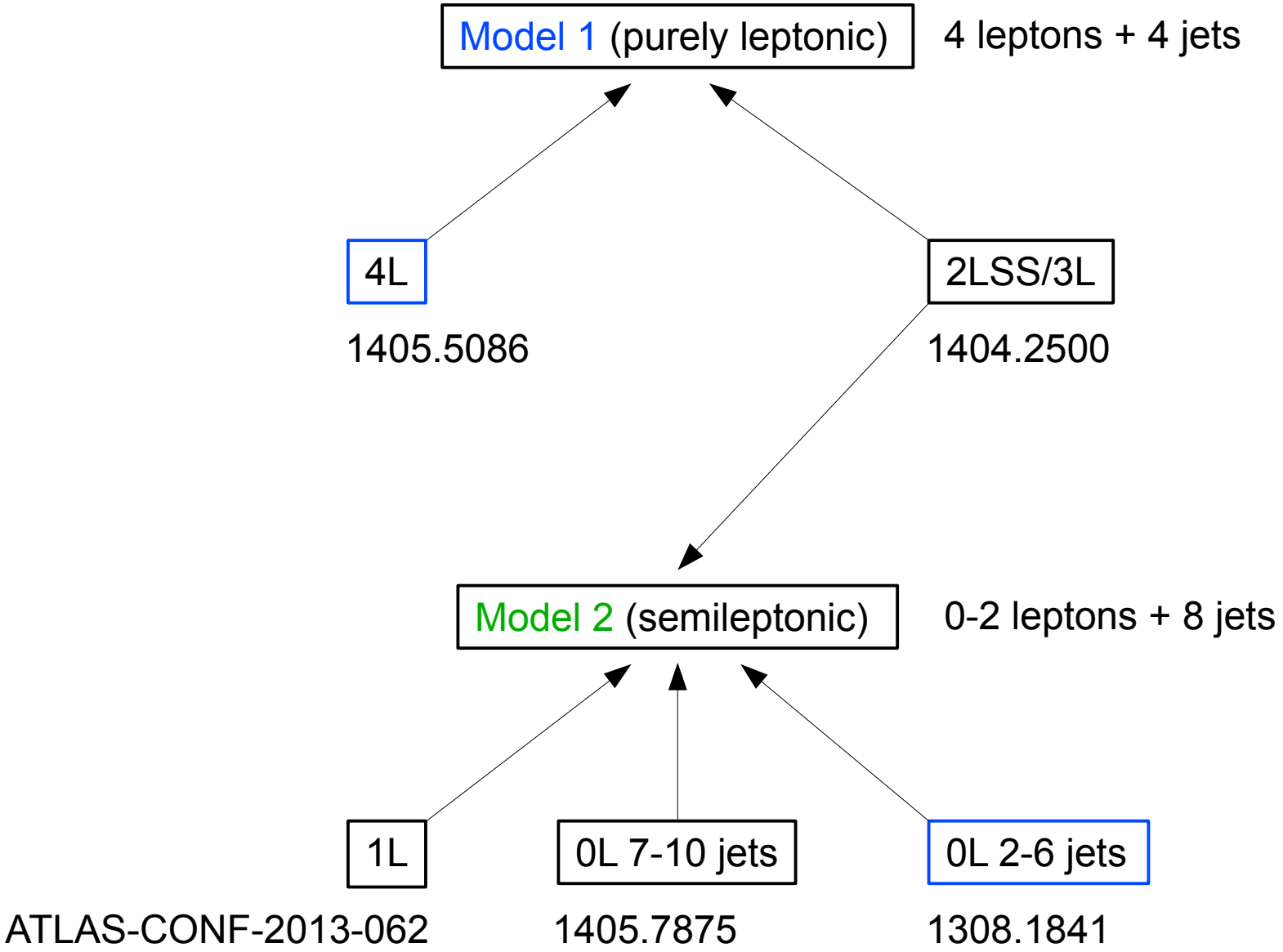
Model 1

4 leptons + 4 jets + E_T^{miss}

Model 2

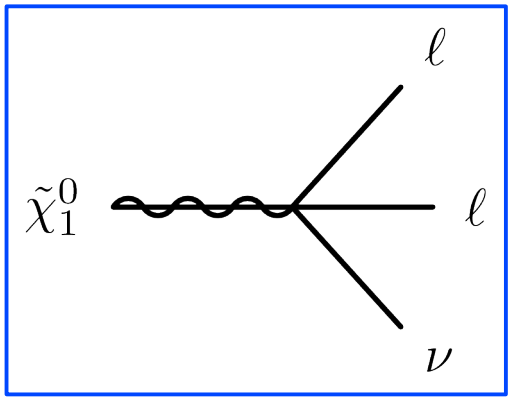
0-2 leptons + 8 jets (+ E_T^{miss})

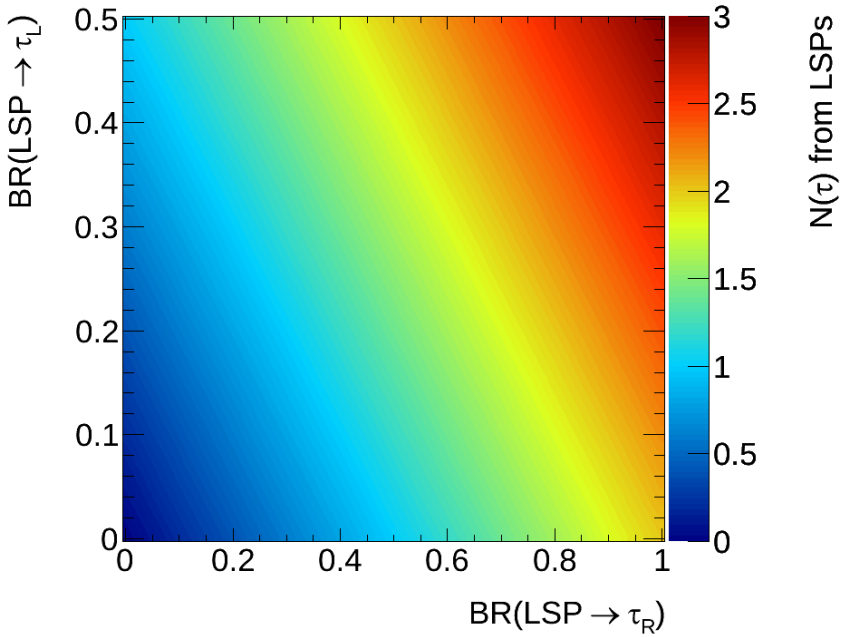
ATLAS Searches Used for the Studies

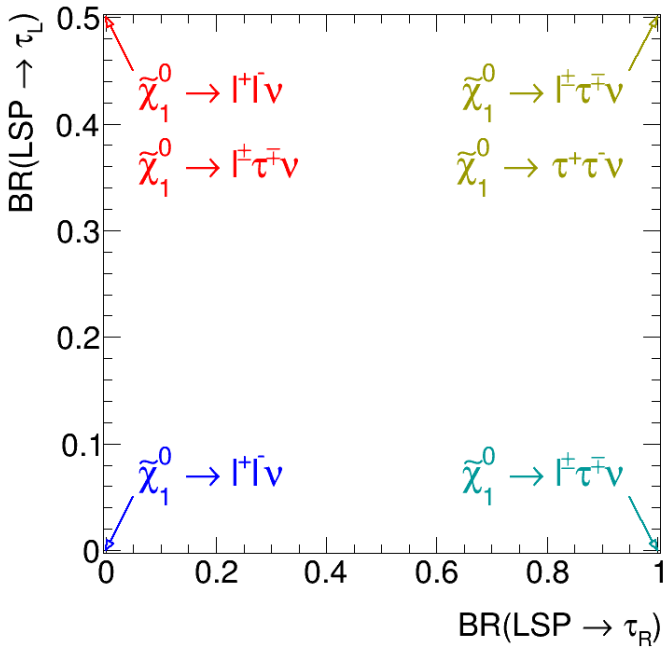


Parameterisation of the LSP Decay

- Considering model 1 (pure leptonic decay)
- Detector response is different for e, μ and τ.
  => Sensitivity depends mainly on BR(LSP → τ)
- Goal: Present limits for as many LSP decays as possible
- Approach: Scan BR(LSP → τ) over allowed range
- Two leptons per decay => 2D scan





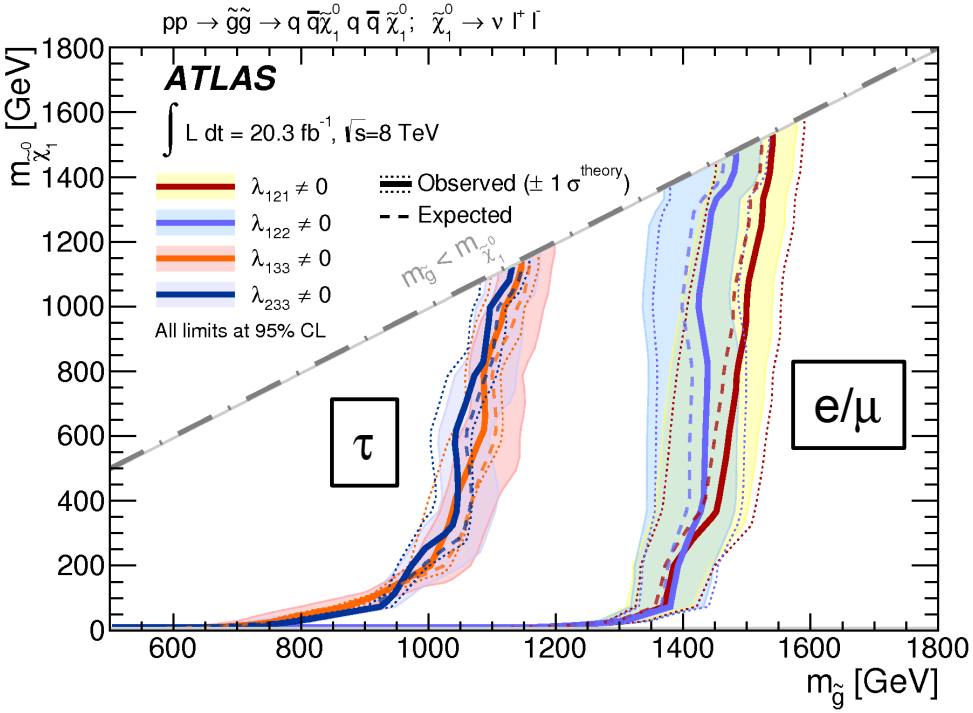


Search for 4L Final States [1405.5086]

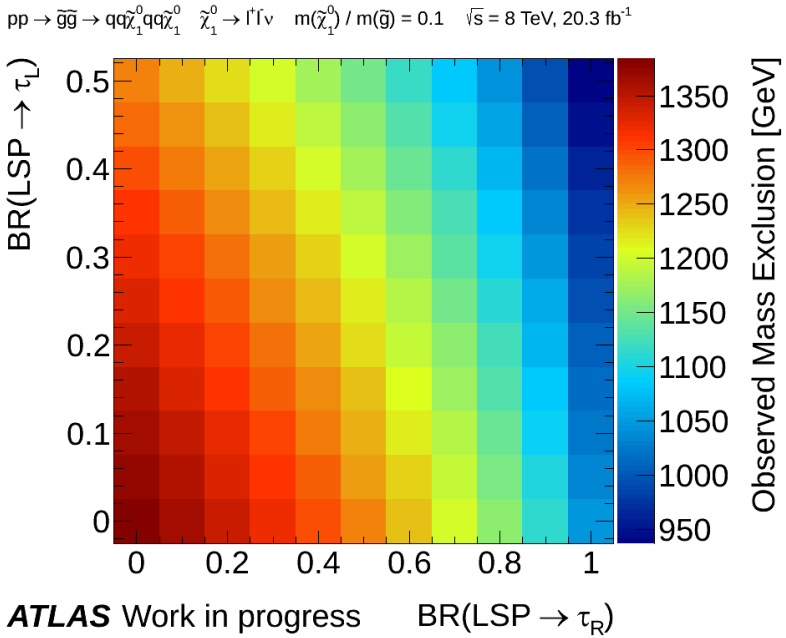
- Requires at least four leptons in the final state
- Three signal regions are sensitive to model 1:

N(e/μ)	N(τ)	E_T^{miss} [GeV] **or** m_{eff} [GeV]	
≥ 4	≥ 0	> 75	> 600
= 3	≥ 1	> 100	> 400
= 2	≥ 2	> 100	> 600

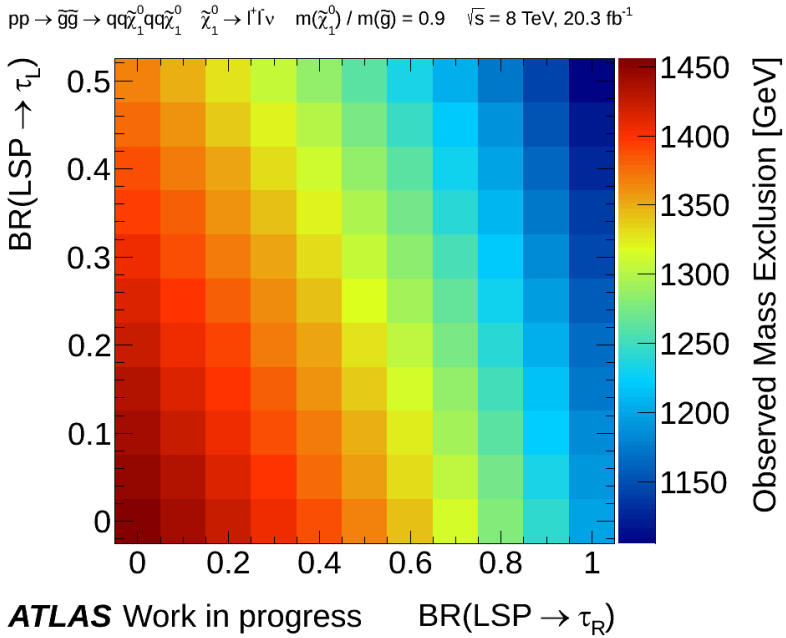
  - $m_{\text{eff}} = E_T^{\text{miss}} + \sum^{\text{leptons}} p_T + \sum_{p_T>40\,\text{GeV}}^{\text{jets}} p_T$
  - Events with Z candidates are vetoed
- Limits on model 1 only for pure couplings:



Model 1 - Gluino Mass Limits (4L)

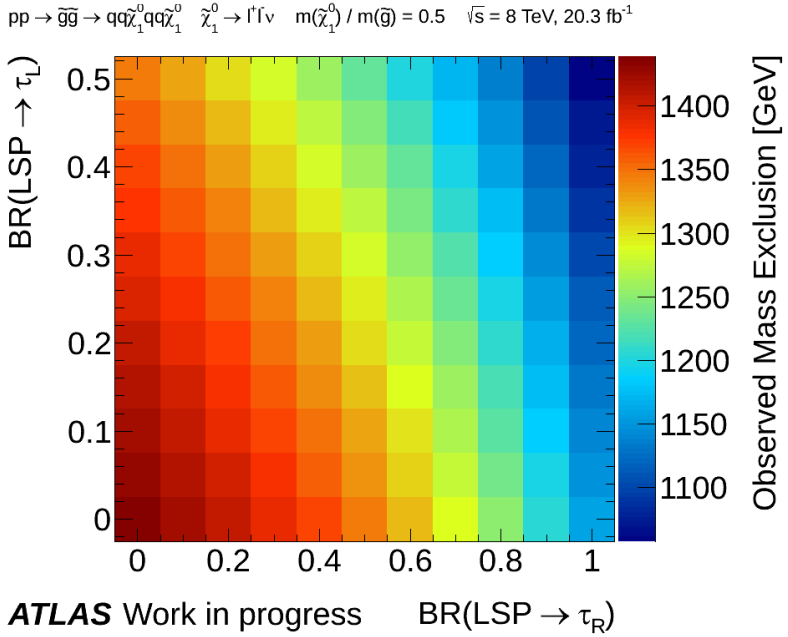


R = 0.5



R = 0.1

$$R = m_{\text{Neutralino}} / m_{\text{Gluino}}$$



R = 0.9

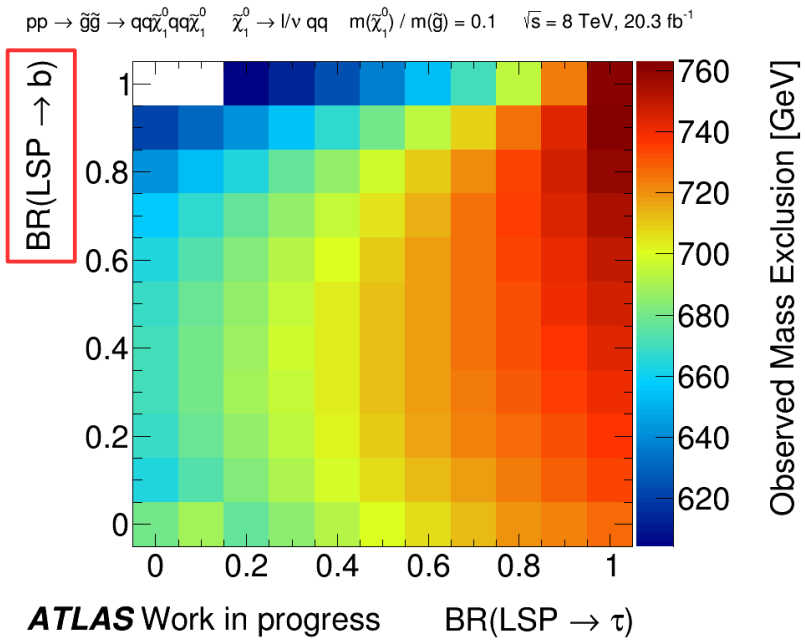
Search for 0L Final States [1405.7875]

Requirement	Signal Regions	
$N_{\text{jet}} \geq$	6	
$E_{\text{T}}^{\text{miss}}$ [GeV] $>$	160	
$p_{\text{T}}(\text{jet}_1)$ [GeV] $>$	130	
$p_{\text{T}}(\text{jet}_2)$ [GeV] $>$	60	
$p_{\text{T}}(\text{jet}_3)$ [GeV] $>$	60	
$p_{\text{T}}(\text{jet}_4)$ [GeV] $>$	60	
$p_{\text{T}}(\text{jet}_5)$ [GeV] $>$	60	
$p_{\text{T}}(\text{jet}_6)$ [GeV] $>$	60	
$\Delta\Phi(\text{jet}_{1,2,(3)}, E_{\text{T}}^{\text{miss}})_{\text{min}} >$	0.4	
$\Delta\Phi(\text{jet}_{i>3}, E_{\text{T}}^{\text{miss}})_{\text{min}} >$	0.2	
$E_{\text{T}}^{\text{miss}}/m_{\text{eff}}(N_{\text{jet}} = 6) >$	0.2	0.15
$m_{\text{eff}}(\text{incl})$ [GeV] $>$	900	1700

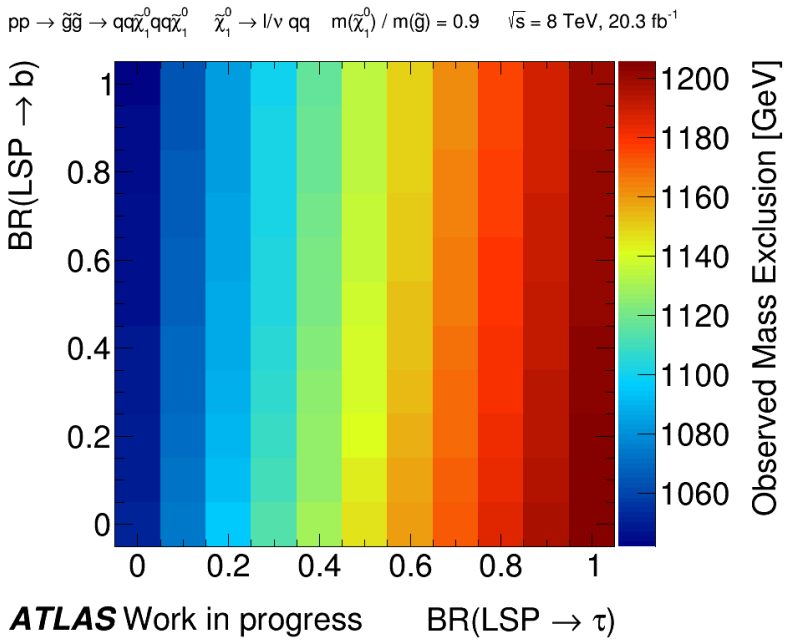
- Final states: 0 leptons + 2-6 jets + E_T^{miss}
- Events with isolated electrons and muons are rejected
- Taus are treated as jets
- $m_{\text{eff}} = E_T^{\text{miss}} + \sum^{\text{jets}} p_T$
  - $m_{\text{eff}}(\text{incl})$:
    Sum over all jets with $p_T > 40\,\text{GeV}$
  - $m_{\text{eff}}(N_{\text{jet}} = 6)$:
    Sum over the 6 leading jets

These two signal regions are relevant for the limits

Model 2 - Gluino Mass Limits (0L)

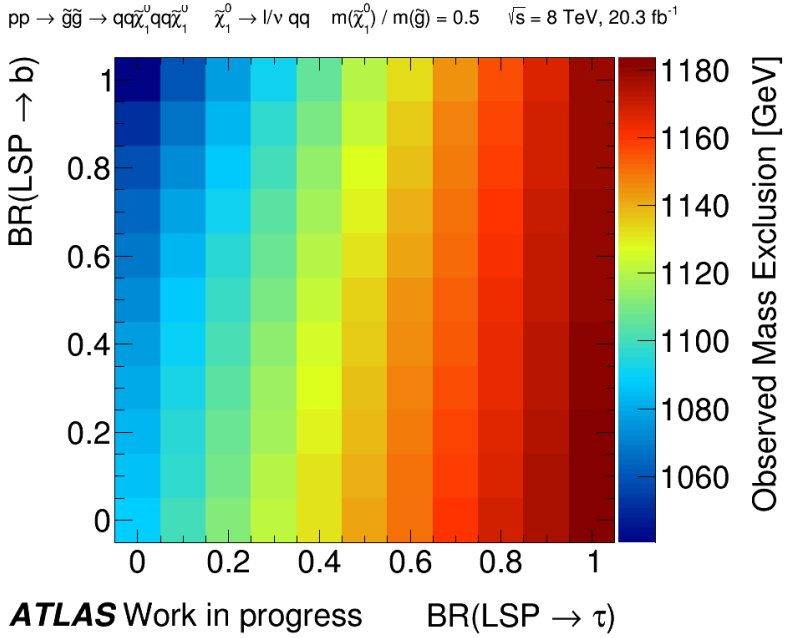


R = 0.5



R = 0.1

$$R = m_{\text{Neutralino}} / m_{\text{Gluino}}$$



R = 0.9

Conclusion

- RPC searches can provide a good sensitivity to RPV signals
- Limits for two models with leptonic RPV signatures have been presented
- Prompt semileptonic RPV decays investigated for the first time by an ATLAS analysis
- Third model with squark pair production and semileptonic RPV decays under investigation
- Combination with other sensitive searches in progress

Thank you for your attention!

Backup

RPV Terms of the Superpotential

- RPV terms of the superpotential => describe LSP decay:

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

L: left-handed (S)leptons; E: right-handed (S)leptons
Q: left-handed (S)quarks; U,D: right-handed (S)quarks
H: higgs doublet
} supermultipletts

λ, λ', λ'', μ: coupling constants
i, j, k: number of the corresponding (S)fermion generation (1, 2, 3)

- 9 λ, 27 λ', 9 λ'' and 3 μ terms
- λ, λ' and μ: Lepton number violation
- λ'': Baryon number violation

Model 3

- Left-handed squark pair production
- Right-handed squarks and gluino decoupled
- Same mass for all 6 left-handed squarks
- No 3rd generation mixing
- Neutralino as LSP
- LSP decays promptly via semileptonic decays: