



R-Parity violating SUSY searches in ATLAS

Johannes Junggeburth
on behalf of the ATLAS collaboration

Max Planck Institute for Physics
(Werner-Heisenberg-Institut)

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MAX-PLANCK-GESELLSCHAFT

- Discrete quantum number in Supersymmetric theories

$$P_R = (-1)^{B-L+2s} = \begin{cases} 1 & \text{for SM particles} \\ -1 & \text{for their Superpartners} \end{cases}$$

- Conserved in many cases to avoid rapid proton decay & to obtain $\tilde{\chi}_1^0$ Dark Matter candidate

It can also be violated (RPV):

- The most general superpotential of the MSSM contains terms explicitly violating R-parity

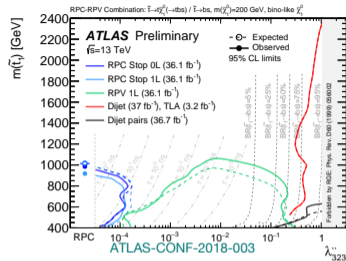
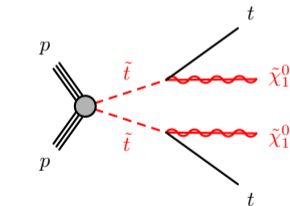
$$W_{\text{RPV}} = \underbrace{\kappa_i H_u \tilde{L}_i + \lambda_{ijk} \tilde{L}_i \tilde{L}_j \tilde{e}_k^*}_{\Delta L = 1} + \underbrace{\lambda'_{ijk} \tilde{L}_i \tilde{Q}_j \tilde{d}_k^*}_{\Delta B = 1}$$

But: Proton can be protected by less stringent symmetries allowing for **L** or **B** violating terms

- Spontaneously violated if MSSM is extended by ν_R and gauged $U(1)_{B-L}$ where the $\tilde{\nu}$ acquire VEV ([arxiv:1810.11035](https://arxiv.org/abs/1810.11035))

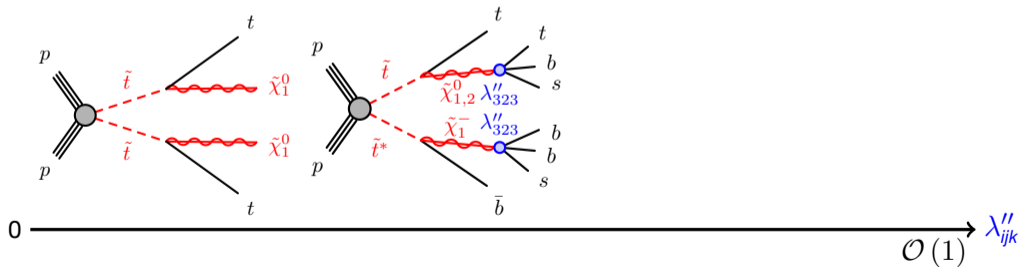
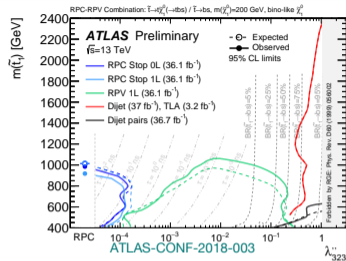
$$W \propto \langle \tilde{\nu}_R \rangle e_i H_u^+ - \langle \tilde{\nu}_L \rangle H_d^- e_i^c$$

- E_T^{miss} generated by escaping $\tilde{\chi}_1^0$ essential part of signature
- In RPV models all SUSY particles decay into SM particles
 - (Displaced) decays of produced $\tilde{\chi}_1^0$
 - Direct decay of the primary produced particle
 - Single SUSY particle production

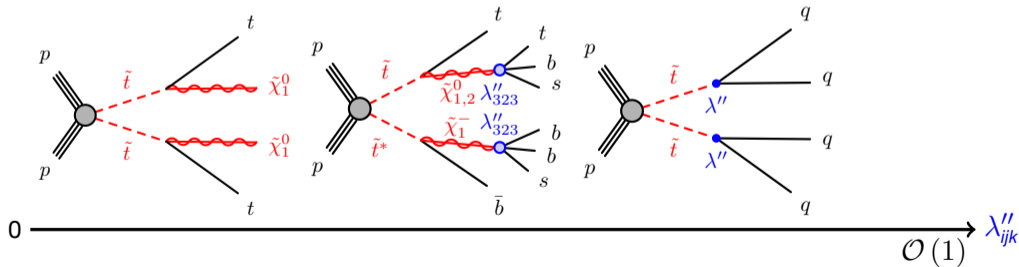
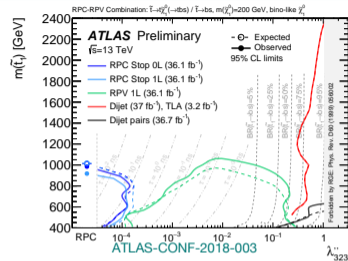


0 $\xrightarrow{\mathcal{O}(1)} \lambda''_{ijk}$

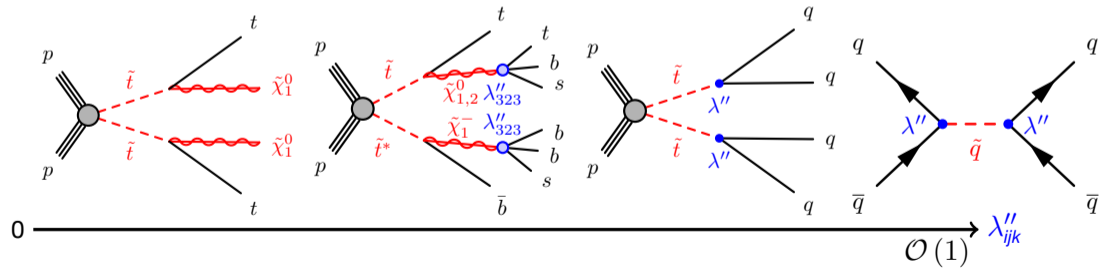
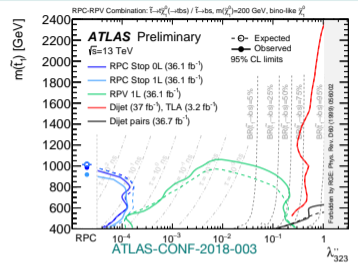
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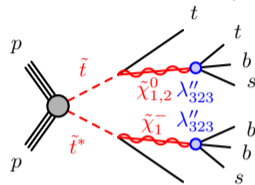
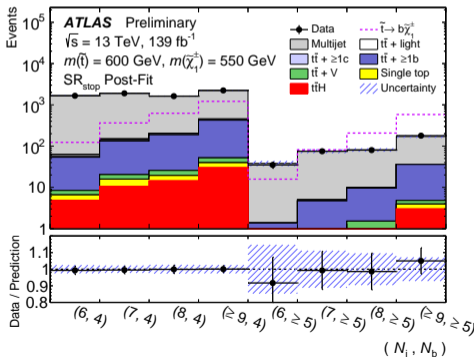
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This talk covers prompt RPV decays – For displaced scenarios please c.f. Tova Holmes's talk

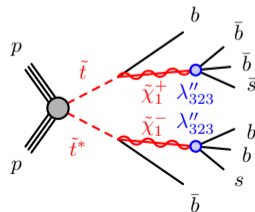


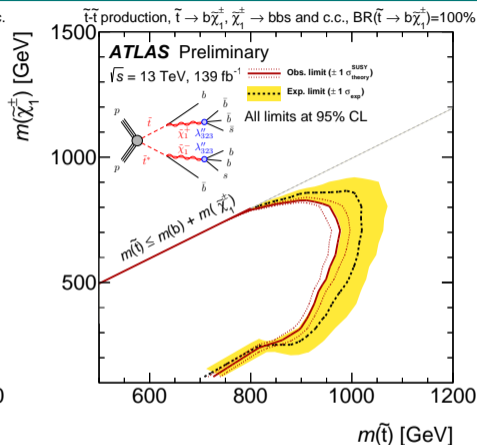
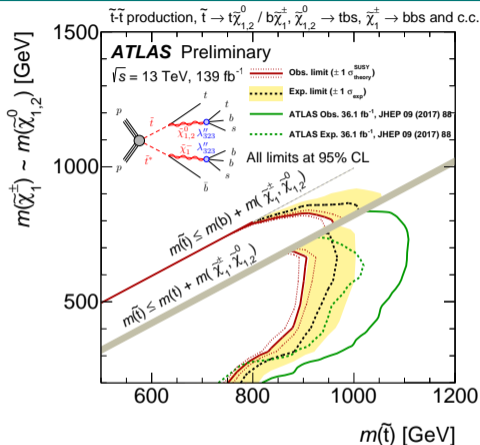
- Light \tilde{t} and \tilde{H} motivated by hierarchy problem
- **B-violating $\tilde{u}_3^* \tilde{d}_2^* \tilde{d}_3^*$** term gives final state with large (b)-jet multiplicities, no leptons and low E_T^{miss}
- Multi-jet and top-quark production as backgrounds
- Signal extracted from simultaneous fit in 8 SRs binned in jet (N_j) and (N_b) b -jet multiplicities



$$m_{\tilde{t}} - m_{\tilde{\chi}} > m_t$$

$$BR(\tilde{t} \rightarrow \tilde{\chi}_1^0 t) = 50\%$$



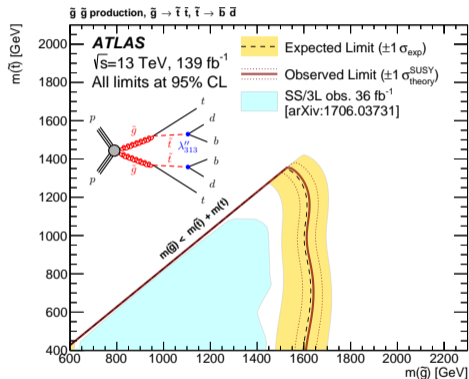


- Final state considered for the first time at the LHC
- No excess above SM expectation observed

\tilde{t} with masses up to 950 GeV excluded



- Assuming light \tilde{g} and \tilde{t} and relatively large $\lambda'' \Rightarrow$ Direct RPV decays of \tilde{t}



- Search for such models in di-lepton events covered by the SS/3L analysis

Signal selection

- 2 e/μ with same-sign
- At least 6 jets
- $m_{\text{eff}} = E_{\text{T}}^{\text{miss}} + \sum_{\text{jets}, e, \mu} p_{\text{T}} \geq 2.6$ TeV

\tilde{g} with $m_{\tilde{g}} \sim 1.6$ TeV excluded



- Same model also targeted by analysis using final states with large N_{jet} and some $E_{\text{T}}^{\text{miss}}$

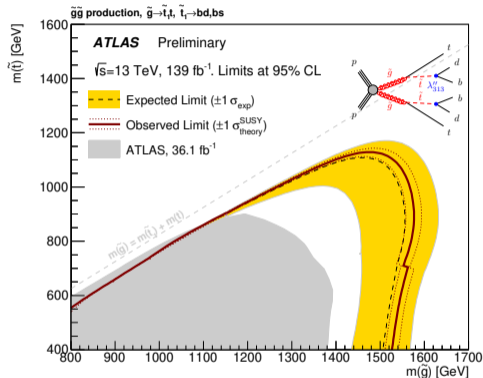
- Real $E_{\text{T}}^{\text{miss}}$ generated from $t \rightarrow \tau$ or non-identified $t \rightarrow e/\mu$ decays

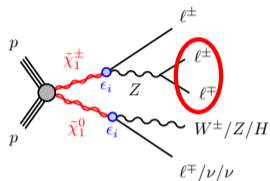
Signal selection:

- Lepton veto with $p_{\text{T}} > 10$ GeV
- $E_{\text{T}}^{\text{miss}} > 45\text{--}70$ GeV & $S_{E_{\text{T}}^{\text{miss}}} > 5$ (CONF-2018-038)
- Categorization according to $N_{\text{jet}} \geq 9\text{--}12$ & $N_{b\text{-jets}}$
- Multi-bin fit in the summed masses of reclustered large radius jets $M_J^{\Sigma} = \sum_j m_j^{R=1.0}$

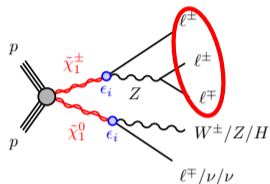
- $t\bar{t}$, W +jets estimated from MC & normalized to data
- Multi-jet events estimated from data using ABCD method ($S_{E_{\text{T}}^{\text{miss}}}$ vs. N_{jet})

Gluinos with masses up to 1.5 TeV excluded comparable to the limit of the SS/3L search





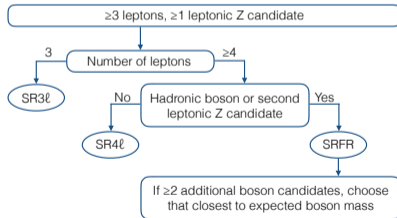
- Motivated by extensions of the MSSM, e.g. $SU(2)_L \otimes SU(2)_R$
- Wino-like $\tilde{\chi}_1^\pm \tilde{\chi}_1^0 / \tilde{\chi}_1^+ \tilde{\chi}_1^-$ produced in collisions
- Decay into leptonic Z boson
- Classification according to 2nd reconstructed boson

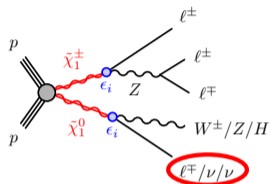


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- Decay into leptonic Z boson \rightarrow peak in $m_{Z\ell}$
- Classification according to 2nd reconstructed boson

3ℓ : Selection on E_T^{miss} , $m_T^{\text{min}}(\ell, E_T^{\text{miss}})$

4ℓ :
 – Veto 2nd Z \rightarrow ℓℓ candidate
 – Impose cut on E_T^{miss} or on mass asymmetry between $m_{Z\ell}$ and $m_{\tilde{\chi}_1^0}$

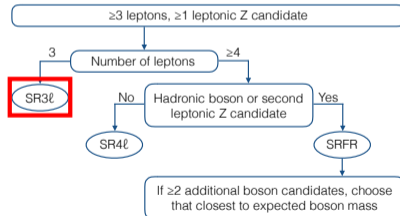


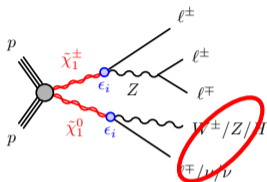


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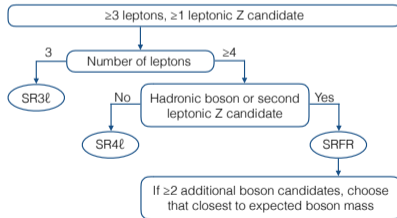




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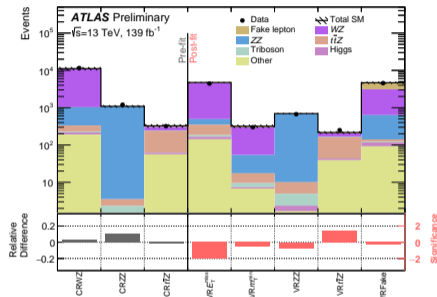
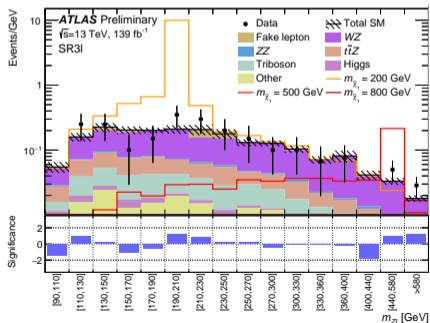
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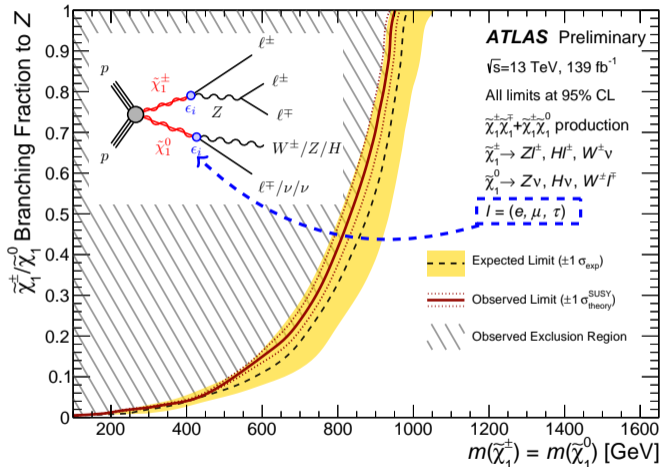


- Dominant irreducible background sources: $t\bar{t}Z$, ZZ & WZ
- Simulation based estimate normalized to data
- Fake lepton bkg. estimated from sample enriched in ℓ from hadronic decays



- Signal extracted from multi-bin fit in 16 bins of $m_{Z\ell}$ for each SR

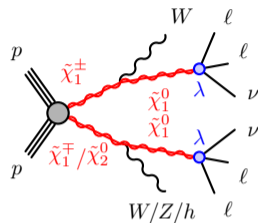
Limits set on $m_{\tilde{\chi}_1^\pm/\tilde{\chi}_1^0}$ and $\mathcal{BR}(\tilde{\chi} \rightarrow Z)$ assuming lepton universal RPV-couplings



Winos with masses up to 950 GeV excluded (see also Sara Alderweireldt's contribution)

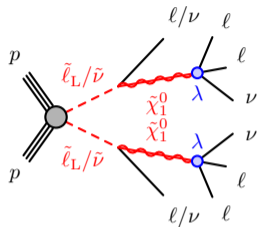


- $\tilde{\chi}_1^0 \rightarrow \nu_{i/j} \ell_{j/i} \ell_k$ decays caused by $\lambda_{ijk} \neq 0$ RPV-coupling
- Prompt $\tilde{\chi}_1^0 \rightarrow ee/\mu e/\mu\mu$ ($\lambda_{12k} \neq 0$) and $\tilde{\chi}_1^0 \rightarrow e\tau/\mu\tau/\tau\tau$ ($\lambda_{i33} \neq 0$) investigated
- Models with $\chi_{1/2}^{\pm/0}$, $\tilde{\ell}_L \tilde{\nu}$ and \tilde{g} as NLSP considered



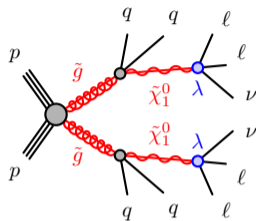


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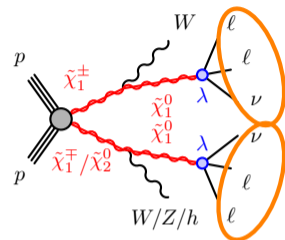


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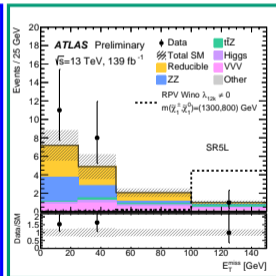
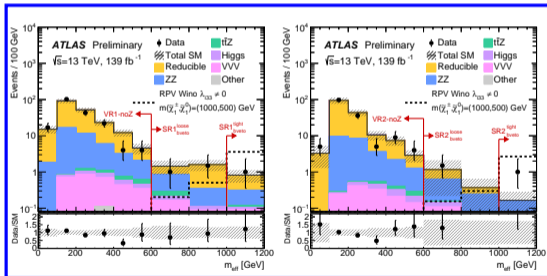
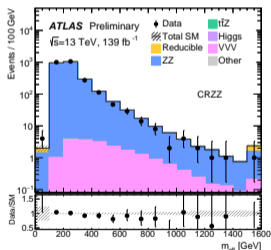
- Common characteristic for all NLSP 4ℓ from $\tilde{\chi}_1^0$

Signal selection

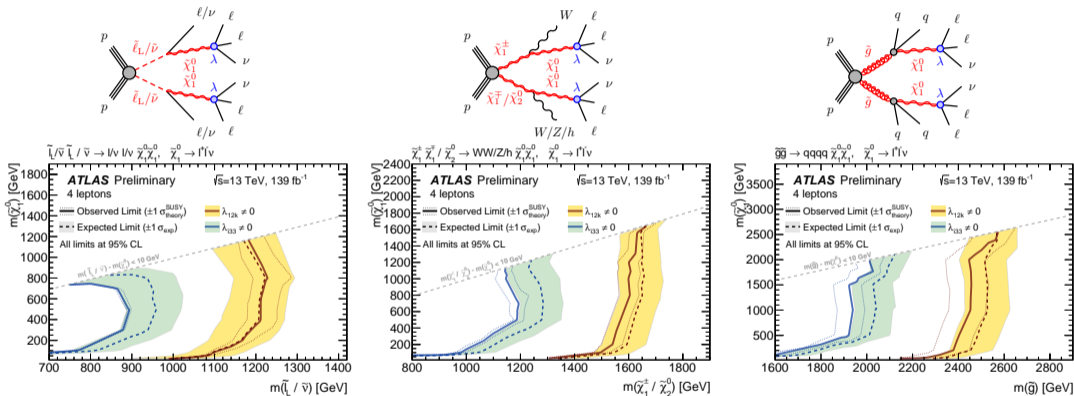
- $N_\ell \geq 4$ with up to 2τ s
 - Veto leptonic Z boson candidate
 - Discriminating variable $m_{\text{eff}} = E_T^{\text{miss}} + \sum_{e,\mu,\tau} p_T + \sum_{\text{jets}}_{p_T > 40 \text{ GeV}} p_T$
 - Thresholds optimized ≥ 1 –1.3 TeV separately for each N_τ bin and for events with(out) b -jets
- 1st time: Dedicated signal selection with $N_{e/\mu} \geq 5$



- Dominant background sources: ZZ , $t\bar{t}Z$
- Estimated from MC & normalized to data
- Fake-lepton background extrapolated from data enriched in ℓ from secondary decays (Dominant in SR with τ)



Data follows well the SM prediction



Exclusion of $\tilde{l}/\tilde{\nu}$, $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ or \tilde{g} with masses up to 1.2 TeV, 1.6 TeV & 2.6 TeV

- Supersymmetry popular framework to extend the SM
- Conservation/violation of R-parity crucial aspect for collider searches
- Presented SUSY searches in ATLAS for models with R-parity violation based on the Run 2 dataset
- Each data agrees well with the SM prediction

B-violating RPV:

- \tilde{t} mass exclusion of up to 1 TeV (Comparable to RPC models $m_{\tilde{t}} \sim 1.2$ TeV)

L-violating RPV:

- \tilde{W} mass exclusion of 1–1.6 TeV
 - \tilde{g} mass exclusion of up to 2.6 TeV
- Most stringent limits available
- Further reinterpretation efforts of existing R-parity conservation analyses in pipeline



Thanks for your attention!