Search for SUSY in final states with same charge or three leptons and jets using 13 TeV ATLAS data

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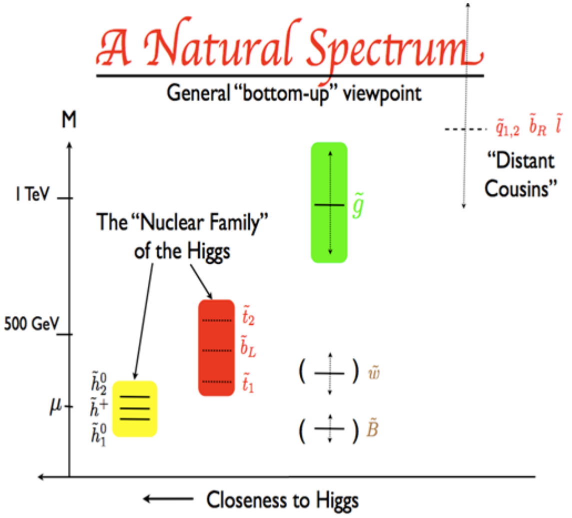
A natural SUSY spectrum



expanded mass spectra

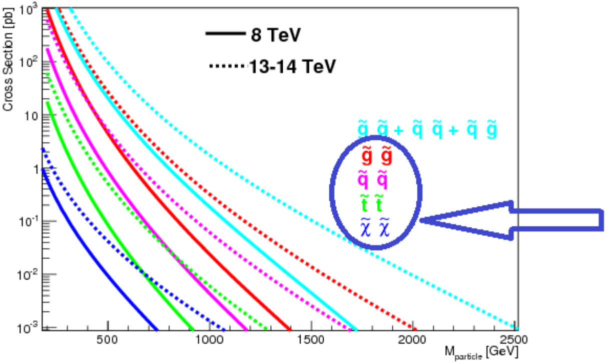
(hard kinematics in the final state)

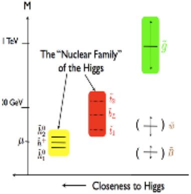
(Soft kinematics in the final state)

compressed mass spectra

Eur.Phys.J. C74 (2014) 2801

SUSY: PRODUCTION CROSS-SECTION





If natural SUSY,
first discoverable at LHC
(high production σ)

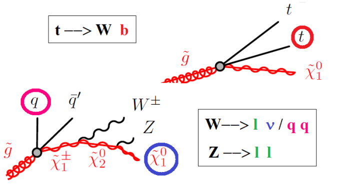
[Ann.Rev.Nucl.Part.Sci. 64 (2014) 319-342]

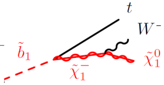
- Search for "Natural" SUSY in final states with two leptons of same electric charge (SS) or three leptons (3Lep) using 36 fb^{-1} of $\sqrt{s}$=13 TeV ATLAS data ([Paper], [arxiv])

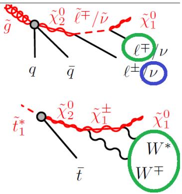
Signal regions (SRs)

- Several SRs defined targeting compressed (S) and open spectra (H):

Signal region	$N_{\text{leptons}}^{\text{signal}}$	$N_{b\text{-jets}}$	N_{jets}	$p_{\text{T}}^{\text{jet}}$ [GeV]	$E_{\text{T}}^{\text{miss}}$ [GeV]	m_{eff} [GeV]	$E_{\text{T}}^{\text{miss}}/m_{\text{eff}}$	
Rpc2L2bS	≥ 2SS	≥ 2	≥ 6	> 25	> 200	> 600	> 0.25	
Rpc2L2bH	≥ 2SS	≥ 2	≥ 6	> 25	–	> 1800	> 0.15	
Rpc2L0bS	≥ 2SS	$= 0$	≥ 6	> 25	> 150	–	> 0.25	
Rpc2L0bH	≥ 2SS	$= 0$	≥ 6	> 40	> 250	> 900	–	
Rpc3L0bS	≥ 3	$= 0$	≥ 4	> 40	> 200	> 600		
Rpc3L0bH	≥ 3	$= 0$	≥ 4	> 40	> 200	> 1600		
Rpc2L1bS	≥ 2SS	≥ 1	≥ 6	> 25	> 150	> 600	> 0.25	
Rpc2L1bH	≥ 2SS	≥ 1	≥ 6	> 25	> 250	–	> 0.2	
Rpc3LSS1b	$\geq \ell^{\pm}\ell^{\pm}\ell^{\pm}$	≥ 1	–	–	–	–	–	veto $81 < m_{e^{\pm}e^{\pm}} < 101$ GeV







(some of the optimized SRs and the targeted SUSY signal model)

SS/3Lep final states: powerful tool to search for new physics

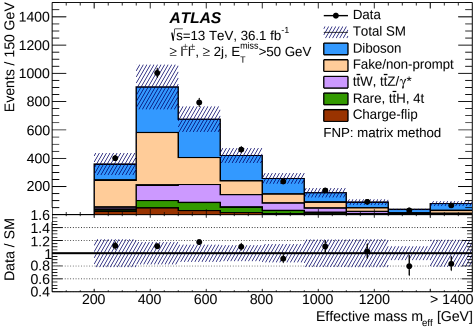
- Low Standard Model Background
- Independent decays of the two SUSY particles that can proceed through charged particles

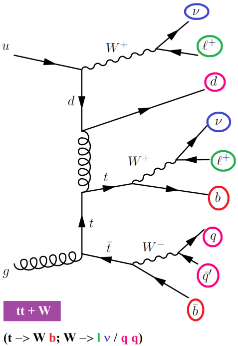
Background classification

Two background categories: irreducible/Standard Model (SM) and reducible/detector

Irreducible/SM backgrounds with similar final states as the considered SUSY models

- Processes: $t\bar{t}+W/Z$, WZ, ZZ, $W^{\pm}W^{\pm}$, etc.
- Estimated using MC simulations
- Detailed validation using dedicated regions enriched in a given type of SM processes





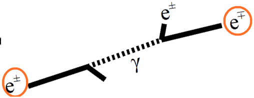
- Generally good agreement between SM processes and data

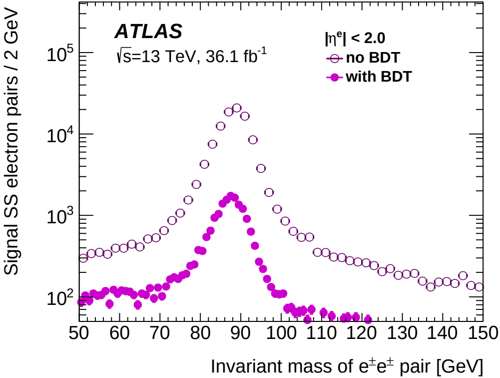
Background classification (cont'd)

Reducible background: charge flip electrons

→ Reconstructed electron charge flipped with respect to original electron (negligible for μ)

- Estimation done with opposite-sign data events weighted by charge flip probability
- Large fraction of such electrons are rejected by applying requirements on η and BDT algorithm using as input e.g the electron cluster and track properties

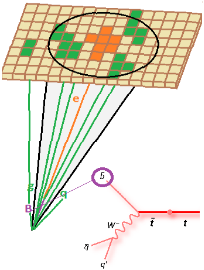




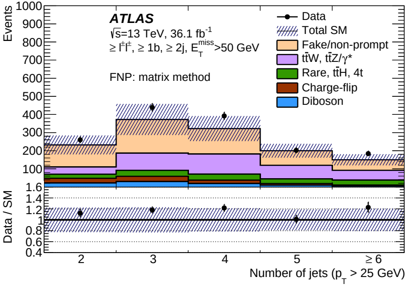
Background classification (cont'd)

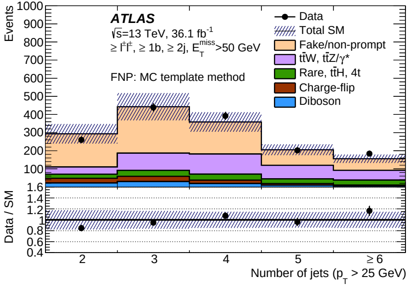
Reducible background: fake/non-prompt leptons (electrons or muons)

→ Hadrons misidentified as leptons, leptons from heavy flavor decays, electrons from photon conversions, etc.

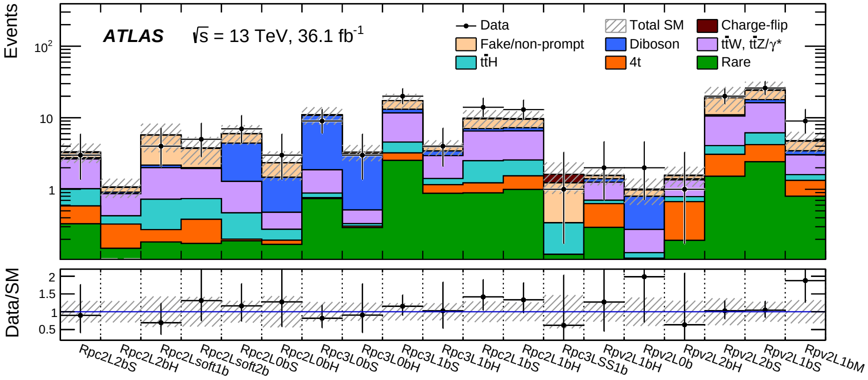


- Data driven estimation using a *Tight* to *Loose* matrix method combined with a MC-template method
- Good agreement between the two methods when looking in a region dominated by fake/non-prompt (FNP) leptons
- The estimates from these methods are combined to give the final estimate in the signal regions



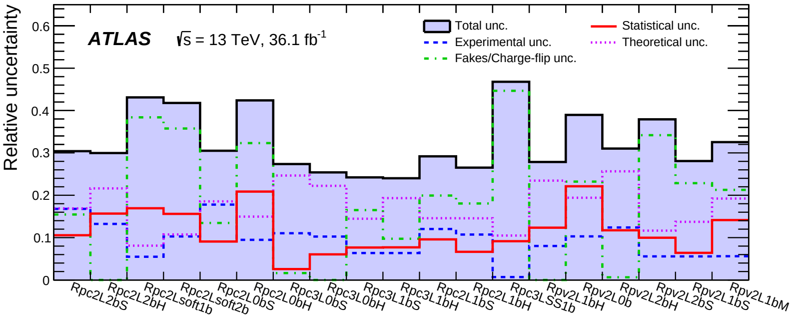


Results in the signal regions



No significant excess: background estimation agrees, withing the uncertainties, with the observed data in all defined signal regions

Sources of uncertainties

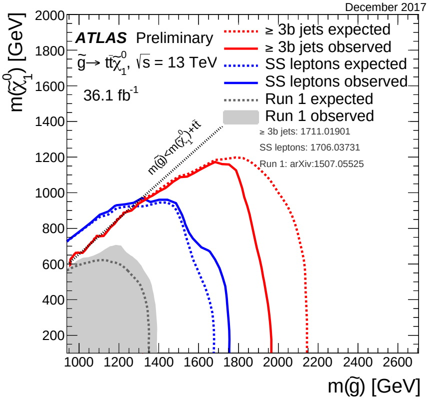


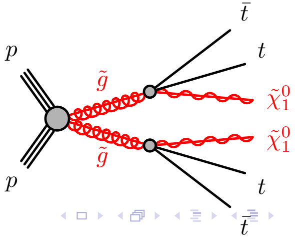
Depending on the signal region the statistical, fake/non-prompt and charge flip or theoretical uncertainties are dominant

Exclusion limits: glino pair production via virtual stop model

No significant excess → place limits on sparticles masses using simplified SUSY models

- Limits obtained also with other final states → complementary to other ATLAS searches
- SS/3Lep analysis performs better in the compressed spectra (or when it's a low mass difference between $\tilde{g}$ and $\tilde{\chi}_1^0$ SUSY particles)

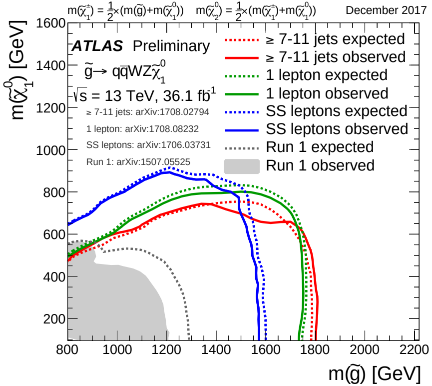


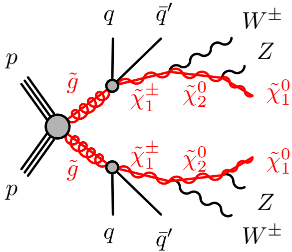


Exclusion limits: gluino pair production via $\tilde{\chi}_1^\pm$ $\tilde{\chi}_2^0$ and W/Z bosons model

No significant excess → place limits on sparticles masses using simplified SUSY models

- SS/3Lep analysis performs better in the compressed spectra

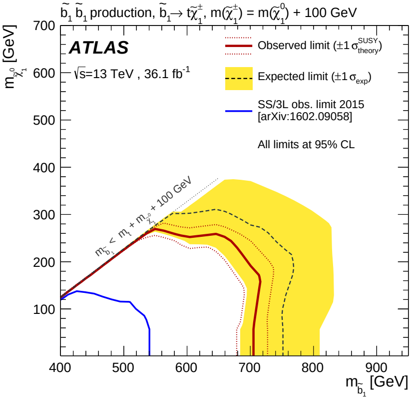


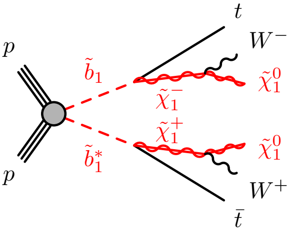


Exclusion limits: direct sbottom pair production via $\tilde{\chi}_1^{\pm}$ model

No significant excess → place limits on sparticles masses using simplified SUSY models

- Only SS/3Lep analysis provides limits for this scenario in ATLAS



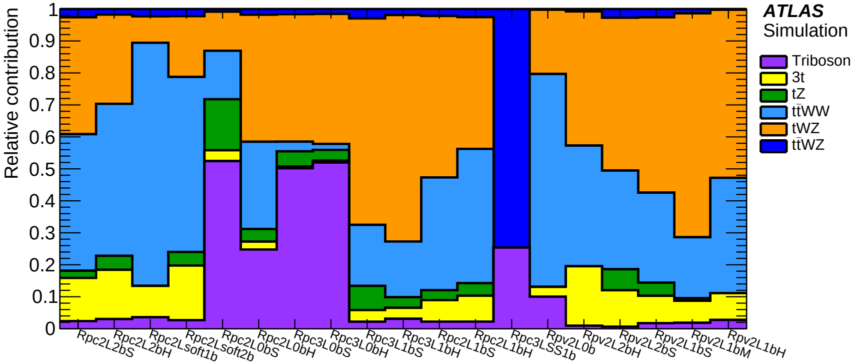


Conclusions/Discussion

- Excellent LHC performance!
- ATLAS has a wide BSM physics program, scrutinizing each corner of the phase space
- As for today, (unfortunately) no evidence of SUSY or other BSM particles...
- New limits significantly extend the 8 TeV results $\rightarrow$ check out also the ATLAS public page
- Exciting future in front of us: at the end of the LHC 13 TeV (Run-2) expect 120-150 fb^{-1} and by 2035 $\sim$3000 fb^{-1} of data!
  - With this particular analysis we can gain even more by reducing the systematic uncertainties (which dominate some of the SRs)

BACKUP

Rare backgrounds in the SRs



Relative contribution in each SR from the processes in the category labelled as *rare*

SR DEFINITIONS

Signal region	$N_{\text{leptons}}^{\text{signal}}$	$N_{b\text{-jets}}$	N_{jets}	$p_{\text{T}}^{\text{jet}}$ [GeV]	$E_{\text{T}}^{\text{miss}}$ [GeV]	m_{eff} [GeV]	$E_{\text{T}}^{\text{miss}}/m_{\text{eff}}$	Other	Targeted Signal
Rpc2L2bS	$\geq$ 2SS	≥ 2	≥ 6	> 25	> 200	> 600	> 0.25	–	Fig. 1(a)
Rpc2L2bH	$\geq$ 2SS	≥ 2	≥ 6	> 25	–	> 1800	> 0.15	–	Fig. 1(a), NUHM2
Rpc2Lsoft1b	$\geq$ 2SS	≥ 1	≥ 6	> 25	> 100	–	> 0.3	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100$ GeV	Fig. 1(b)
Rpc2Lsoft2b	$\geq$ 2SS	≥ 2	≥ 6	> 25	> 200	> 600	> 0.25	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100$ GeV	Fig. 1(b)
Rpc2L0bS	$\geq$ 2SS	$= 0$	≥ 6	> 25	> 150	–	> 0.25	–	Fig. 1(c)
Rpc2L0bH	$\geq$ 2SS	$= 0$	≥ 6	> 40	> 250	> 900	–	–	Fig. 1(c)
Rpc3L0bS	≥ 3	$= 0$	≥ 4	> 40	> 200	> 600	–	–	Fig. 1(d)
Rpc3L0bH	≥ 3	$= 0$	≥ 4	> 40	> 200	> 1600	–	–	Fig. 1(d)
Rpc3L1bS	≥ 3	≥ 1	≥ 4	> 40	> 200	> 600	–	–	Other
Rpc3L1bH	≥ 3	≥ 1	≥ 4	> 40	> 200	> 1600	–	–	Other
Rpc2L1bS	$\geq$ 2SS	≥ 1	≥ 6	> 25	> 150	> 600	> 0.25	–	Fig. 1(e)
Rpc2L1bH	$\geq$ 2SS	≥ 1	≥ 6	> 25	> 250	–	> 0.2	–	Fig. 1(e)
Rpc3LSS1b	$\geq \ell^{\pm}\ell^{\pm}\ell^{\pm}$	≥ 1	–	–	–	–	–	veto $81 < m_{e^{\pm}e^{\pm}} < 101$ GeV	Fig. 1(f)
Rpv2L1bH	$\geq$ 2SS	≥ 1	≥ 6	> 50	–	> 2200	–	–	Figs. 1(g), 1(h)
Rpv2L0b	$=$ 2SS	$= 0$	≥ 6	> 40	–	> 1800	–	veto $81 < m_{e^{\pm}e^{\pm}} < 101$ GeV	Fig. 1(i)
Rpv2L2bH	$\geq$ 2SS	≥ 2	≥ 6	> 40	–	> 2000	–	veto $81 < m_{e^{\pm}e^{\pm}} < 101$ GeV	Fig. 1(j)
Rpv2L2bS	$\geq \ell^{-}\ell^{-}$	≥ 2	≥ 3	> 50	–	> 1200	–	–	Fig. 1(k)
Rpv2L1bS	$\geq \ell^{-}\ell^{-}$	≥ 1	≥ 4	> 50	–	> 1200	–	–	Fig. 1(l)
Rpv2L1bM	$\geq \ell^{-}\ell^{-}$	≥ 1	≥ 4	> 50	–	> 1800	–	–	Fig. 1(l)

SUSY MODELS CONSIDERED

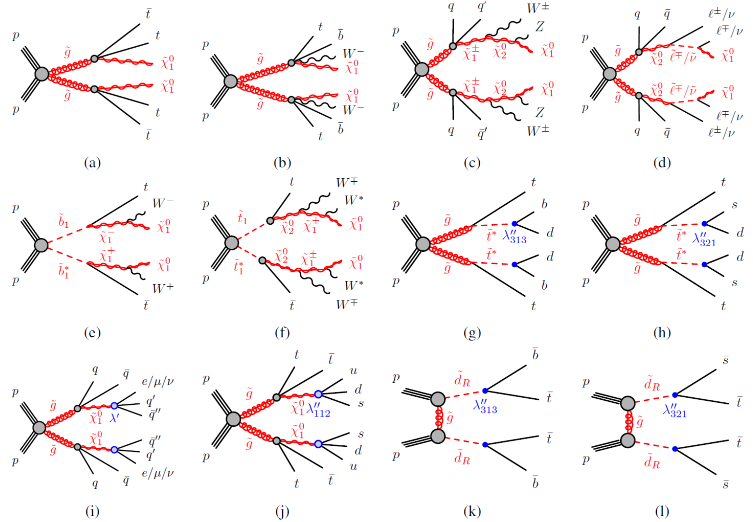


Figure 1: RPC SUSY processes featuring gluino ((a), (b), (c), (d)) or third-generation squark ((e), (f)) pair production studied in this analysis. RPV SUSY models considered are gluino pair production ((g), (h), (i), (j)) and t-channel production of down squark-rights ((k), (l)) which decay via baryon- or lepton-number violating couplings λ'' and λ' respectively. In the diagrams, $q \equiv u, d, c, s$ and $\ell \equiv e, \mu, \tau$. In Figure 1(d), $\tilde{\ell} \equiv \tilde{e}, \tilde{\mu}, \tilde{\tau}$ and $\tilde{\nu} \equiv \tilde{\nu}_e, \tilde{\nu}_\mu, \tilde{\nu}_\tau$. In Figure 1(f), the W^* labels indicate largely off-shell W bosons – the mass difference between $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^0$ is around 1 GeV.