Searches for sleptons with the ATLAS detector

Margherita Primavera
INFN-Lecce
On behalf of the ATLAS Collaboration

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SuperSYmmetry (SUSY) is one of the most popular extensions of the Standard Model (SM), predicting new particles which differ from their SM partners by $\frac{1}{2}$ in spin. R-parity ($=(-1)^{3(B-L)+2S}$) conserving (RPC) or violating (RPV) models can be considered.

**SUSY Electroweak (EWK) production** can dominate over the strong production at LHC if gluinos and squarks are significantly heavy. Colored sparticles already excluded up to $\sim1-2$ TeV.

- **Large mass range** for **sleptons and EWK-inos** still unexplored

- **In Run II** EWK-ino production cross sections expected to be $\sim5$ times larger than in Run I

- Decays happen to multi-lepton final states, producing experimentally “clean” signatures, with little hadronic activity and large $E_T^{miss}$
General search strategy

- **Data sample** → analyses presented here: 36.1 fb⁻¹ of pp collisions at √s = 13 TeV collected in 2015 and 2016
- **SUSY Models** → simplified models assumed, with cross sections very small compared to the SM processes and Branching Ratios (BR) of 100% in the searched decay
- **Event selection** → through sensitive kinematic observables, selecting regions where to maximize the signal from background discrimination (Signal Regions, SRs)
- **Background estimate** → with fully data driven or semi data driven techniques, in last case normalizing Monte Carlo (MC) to data in Control Regions (CRs) properly chosen for a specific background. Normalization is validated in Validation Regions (VRs).
- **Results** → expected to “unblind” results and compare data to expected background in SRs only after that a reliable background estimate strategy has been developed
- **Interpretation** → if a large excess over the expected background observed in data, claim for evidence (discovery), otherwise set upper limits on the signal cross sections and on the parameters of the tested model (e.g. SUSY particle masses)
Slepton direct production or via chargino decays

[arXiv:1803.02762]

2 leptons (e or $\mu$, in events passing dilepton triggers) Opposite Sign (OS), Same Flavour (SF) or Different Flavour (DF), high $p_T^{l1}$ ($p_T^{l2}$) >25 (20) GeV
No jet, Large $E_T^{\text{miss}}$
17 Exclusive SRs, requiring large dilepton $m_{T2} \rightarrow$ to reject $t\bar{t}$, WW and invariant mass ($m_{ll}$) $\rightarrow$ high $m_{ll}$ in SF strongly rejects the Z

$\tilde{\chi}_1^0$ Lightest SUSY Particle (LSP)
Slepton direct production or via chargino decays

[arXiv:1803.02762]

- Assuming s-electron\textsubscript{L/R}, s-muon\textsubscript{L/R} and s-tau\textsubscript{L/R} to be mass-degenerate

2\ell+0 jets: direct \tilde{\ell}\tilde{\ell} production

2\ell+0 jets: direct \tilde{\chi}_1^+\tilde{\chi}_1^- with \tilde{\ell} mediated decays

- 95\% C.L. exclusion limits in the m(\tilde{\ell})-m(\tilde{\chi}_1^0) plane $\rightarrow$ \tilde{\ell} excluded up to $\sim$500 GeV

- \tilde{\chi}_1^+\tilde{\chi}_1^- with \tilde{\ell} mediated decays $\rightarrow$ excluded up to $\sim$750 GeV
Sleptons via gaugino decays

- **3 leptons** (e or µ) in the final state
- Large $E_{T}^{\text{miss}} (> 130$ GeV)
- 1 SF-Opposite Sign (SFOS) lepton pair with $m_{ll}$ far away from the Z mass peak to suppress WZ dominant background
- 5 SRs, with definition based on $m_{\text{SFOS}}$ and $p_{T}^{\ell 3}$
- Main systematic uncertainties -> detector-related (e.g. $E_{T}^{\text{miss}}$ modelling), theory (e.g. MC modelling, cross sections)

$\tilde{\chi}_{1}^{0}$ + $\tilde{\chi}_{2}^{0}$ (assumed to be mass degenerate) with $\tilde{\ell}$ mediated decays $\rightarrow$ excluded $\sim$1100 GeV
Sleptons in RPV scenarios

- RPC pair production of NLSP followed by RPV decays of LSP (100% BR in $\ell \nu$)
- $>= 4$ leptons ($e, \mu$ or hadronically decaying $\tau$) in the final state
- SR definition based on $\tau$ multiplicity, $Z$ veto and $m_{\text{eff}} = E_{T}^{\text{miss}} + \Sigma_i p_{T}^{\ell_i} + \Sigma_i p_{T}^{j_i}$ ($p_{T}^{j_i} > 40$ GeV)

$\tilde{\ell} / \tilde{\nu}$ Next Lightest SUSY Particle (NLSP): mass-degenerate left-handed sleptons and sneutrinos

- 95% C.L. exclusion limits for RPV NLSP $\tilde{\ell} / \tilde{\nu}$ models $\rightarrow \tilde{\ell} / \tilde{\nu}$ excluded up to $\sim 1.06$ TeV for $LL\tilde{\ell} 12k$ (allowed only decays to $e$ or $\mu$) and up to 780 GeV for $LL\tilde{\ell} i33$ models (allowed decays to $e$, $\mu$, $\tau$)
Sleptons with soft leptons

- Compressed scenario → sleptons have masses near the weak scale and just above the mass of a pure bino LSP.
- **SF OS soft leptons** (e or μ, >4-5 GeV, m_{ll} [1,60] excluding J/ψ) and E_T^{miss} (> 200 GeV)
- Initial state radiation jet to boost the system (>100 GeV, no b-jet), large E_T^{miss}/(p_T^{l1} + p_T^{l2}) requested
- 6 exclusive SRs, definition based on large dilepton m_T^{2} (>100 GeV), largely affected by “fake”/non-prompt leptons reducible background (the largest source of experimental systematics)

**ATLAS**

\[ \sqrt{s} = 13 \text{ TeV}, 36.1 \text{ fb}^{-1} \]

**Expected limit** (±1σ_{exp})
Expected limit (±1σ_{theory})
ATLAS 8 TeV \( \tilde{\ell}_{L,R} \) excluded
LEP \( \tilde{\tau} \) excluded

L/R handed \( \tilde{e}/\tilde{\mu} \) mass degenerate excluded up to \( \sim 190 \text{ GeV} \) for low mass splittings (\( \sim 5 \text{ GeV} \))
Staus via gaugino decays

- $\tilde{\tau}_1$ assumed to be purely $\tilde{\tau}_1$
- On-shell stau and tau sneutrino, assumed to be mass-degenerate
- $\tilde{\chi}^+_1$ and $\tilde{\chi}^0_2$ are assumed to be pure wino and mass-degenerate
- $\geq 2$ OS hadronically decaying $\tau$
  (dedicated triggers + id. based on Boosted Decision Tree) and $E_T^{\text{miss}}$ in the final state, b-jet veto, Z veto
- 2 SRs with large $m_{T2}$ (>70/90 GeV for low/high mass)

Only these sparticles are assumed to be enough light in the model to be produced at LHC
- Searches for direct, or from gaugino decay, production of sleptons in ATLAS presented in several final states
- No significant excess above the Standard Model predictions observed in data corresponding to 36.1 fb$^{-1}$
- 95% CL exclusion limits on the SUSY particle masses set, largely improving the Run I results
- The search continues, aiming to new results from the full data set at the end of Run II (~140 fb$^{-1}$ expected)
- All results in https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

Thank you for your attention!
Backup slides
ATLAS detector

LHC Peak instantaneous luminosity of \(2.14 \times 10^{34} \text{ cm}^{-2} \text{s}^{-1}\)
# ATLAS SUSY Searches - 95% CL Lower Limits

## July 2018

### Model | \(e, \mu, \tau, \gamma\) | Jets | \(E_T^{miss}\) | \(L (\text{fb}^{-1})\) | Mass limit | \(\sqrt{s} = 7, 8\ TeV\) | \(\sqrt{s} = 13\ TeV\) | Reference
---|---|---|---|---|---|---|---|---
| \(|q, q' \rightarrow q'q|\) | 0 | 2-6 jets | Yes | 36.1 | | | | 1712.03321
| \(|R, R' \rightarrow q'q|\) | 0 | 2-6 jets | Yes | 36.1 | | | | 1712.03232
| \(|R, R' \rightarrow quq'q'|\) | 3, \(e, \mu\) | 4 jets, 2 \(R\) jets | Yes | 36.1 | | | | 1712.03232
| \(|R, R' \rightarrow WqX|\) | 0 | 7-11 jets | Yes | 36.1 | | | | 1708.03731
| \(|R, R' \rightarrow \tau\ell\ell|\) | 0 | 3, \(e, \mu\) | 4 jets | Yes | 36.1 | | | 1709.02794
| \(|R, R' \rightarrow \tau\ell\ell|\) | 0 | 3, \(e, \mu\) | 4 jets | Yes | 36.1 | | | 1709.02731
| \(|R, R' \rightarrow \ell\ell|\) | 0-1, \(e, \mu\) | 3 jets | Yes | 36.1 | | | | 1711.01921

### Inclusive Searches

| \(b\bar{b}, b\bar{b} \rightarrow \ell\ell|\) | Multiple | | 36.1 | | 0.9 \(b\bar{b}\) | | | 1708.09826
| \(b\bar{b}, b\bar{b} \rightarrow \ell\ell|\) | Multiple | | 36.1 | | 0.0 \(b\bar{b}\) | | | 1708.09826
| \(b\bar{b}, b\bar{b} \rightarrow \ell\ell|\) | Multiple | | 36.1 | | 0 \(b\bar{b}\) | | | 1708.09826

### 3rd gen. quark direct production

| \(b\bar{b}, b\bar{b} \rightarrow \ell\ell|\) | Multiple | | 36.1 | | 0.9 \(b\bar{b}\) | | | 1708.09826
| \(b\bar{b}, b\bar{b} \rightarrow \ell\ell|\) | Multiple | | 36.1 | | 0 \(b\bar{b}\) | | | 1708.09826
| \(b\bar{b}, b\bar{b} \rightarrow \ell\ell|\) | Multiple | | 36.1 | | 0 \(b\bar{b}\) | | | 1708.09826

### EW direct

| \(\ell\ell|\) | 2, \(e, \mu\) | 4 jets | Yes | 36.1 | 0.0 \(\ell\ell|\) | | | 1403.5255
| \(\ell\ell|\) | 2, \(e, \mu\) | 4 jets | Yes | 36.1 | 0.0 \(\ell\ell|\) | | | 1403.5255

### Direct \(\ell\ell\) prod., long-lived \(\ell\ell\)

| \(\ell\ell|\) | Disapp. trk | 1 jet | Yes | 36.1 | 0.0 \(\ell\ell|\) | | | 1712.02118

### Stable \(p\)-hadron

| \(\ell\ell|\) | SMP | - | - | 36.1 | 0.0 \(\ell\ell|\) | | | 1712.02118

### Metastable \(p\)-hadron

| \(\ell\ell|\) | Multiple | | 36.1 | | 0.0 \(\ell\ell|\) | | | 1712.02118

### DM/DM, \(\ell\ell\), long-lived \(\ell\ell\)

| \(\ell\ell|\) | Multiple | | 20.3 | | 0.0 \(\ell\ell|\) | | | 1409.5512

### RPV

| \(\ell\ell|\) | Multiple | | 36.1 | | 0.0 \(\ell\ell|\) | | | 1409.5512

### Long-lived particles

| \(\ell\ell|\) | Multiple | | 36.1 | | 0.0 \(\ell\ell|\) | | | 1409.5512

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*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.*
**ABCD method to estimate multi-jet background** [arXiv:1708.07875]

Table 2: Definition of the regions used in the ABCD method for the multi-jet estimation in SR-lowMass (left) and SR-highMass (right). Only those requirements that are different in the CRs/VRs with respect to the SRs are listed.

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<td><strong>Di-tau trigger</strong></td>
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<td>$m(\tau_1, \tau_2) &lt; 250$ GeV</td>
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<td>$2$ loose tau leptons (SS)</td>
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<td>$\geq 1$ tight tau lepton</td>
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