ATLAS Supersymmetry Searches

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Weak-scale supersymmetry is an highly appealing BSM candidate:

- all Standard Model (SM) fields are associated to a partner with $\Delta s = \frac{1}{2}$
- can solve the electroweak hierarchy problem
- R-Parity Conservation (RPC) implies stability for the Lightest Supersymmetric Particule (LSP): natural dark matter candidate
- points to SM-gauges unification

Searching for SUSY is complex:

- SUSY-breaking mechanism needs to be parametrized;
- Hundreds of free parameters;
- Rich phenomenology and large number of possible experimental signatures.
The ATLAS Experiment

- Multipurpose collider detector for high-precision SM measurements and searches beyond the SM
- Two magnet systems: solenoidal for inner detector and toroidal for the muon system

- Tracking system for $|\eta| < 2.5$: silicon pixels, strips and transition radiation tracker
- EM and hadronic calorimeters for $|\eta| < 4.9$: resp. liquid Argon and scintillating tile
- Muon spectrometer for $|\eta| < 2.7$

![ATLAS Detector Diagram]
SUSY searches (1/2)

Three main SUSY searches axis:

- **Strong production**: direct gluino/squark production
- **Third generation**: direct stop/sbottom production
- **Electroweak**: direct sleptons/gauginos production

for both RPC and RPV scenarios.

- **Strong production**: highest cross-sections, high mass objects, high jet multiplicities
- **3rd generation**: lower masses, b-jets in the final states
- **Electroweak**: lowest of cross-sections, low-mass objects, clean signatures

arXiv:1407.5066v2
Selection of analysis in this talk

<table>
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<th>Final State</th>
<th>Reference</th>
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<td>Long Lived Particles (Pixel+Tile)</td>
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All public results are listed here:

[ATLAS Supersymmetry Public Results](#)
Typical SUSY search strategy

- Data selected in the trigger plateau, good data-taking conditions required
- Rely on understanding of the SM backgrounds
- Rely on good understanding of the detector and reconstruction performance

Combined fit of all regions and backgrounds including systematic, experimental and theoretical uncertainties as nuisance parameters
Strong production: $0L+(\geq2-\geq6)\text{jets}+\vec{E}_T\text{miss}$

- Event selection: no lepton, presence of jets, significant $\vec{E}_T\text{miss}$.
- Main signal discriminants: $m_{\text{eff}}$, Recursive Jigsaw Reconstruction (RJG) variables: $H_{1,1}^{PP}$, $H_{2,1}^{PP}$ and $H_{4,1}^{PP}$.
- 13 $m_{\text{eff}}$ signal regions, 17 RJR signal regions.
Strong production: $0L + (\geq 2 - \geq 6) \text{jets} + E_T^{\text{miss}}$

- Event selection: no lepton, presence of jets, significant $E_T^{\text{miss}}$;
- Main signal discriminants: $m_{\text{eff}}$, Recursive Jigsaw Reconstruction (RJR) variables: $H^{PP}_1$, $H^{PP}_2$, and $H^{PP}_4$;
- 13 $m_{\text{eff}}$ signal regions, 17 RJR signal regions.

For a massless $\tilde{\chi}^0_1$: $m_{\tilde{q}} > 1.35$ TeV and $m_{\tilde{g}} > 1.9$ TeV

**Ughetto M.**

**ATLAS Supersymmetry Searches**
Strong production: multi b-jets (1/2) \[14.8/fb\]

Gbb event selection:
- \( \geq 4 \) jets, \( \geq 3 \) b-jets, no leptons
- \( m_{4j}^{\text{eff}}, E_T^{\text{miss}} \)

Gtt event selection:
- \( \geq 8 \) jets, \( \geq (3-4) \) b-jets, possible leptons
- \( m_{\text{incl}}^{\text{eff}}, m_{b\text{-jets}}^{T,\text{min}}, N \) b-tag, N top, \( E_T^{\text{miss}} \)

7 signal regions:
- 2 all-hadronic Gbb for large and small mass splitting
- 2 all-hadronic Gtt for large and small mass splitting
- 3 semileptonic Gtt for large, moderate and small mass splitting
No excess observed:

- For $m_{\tilde{\chi}_1^0} = 0$ to $m_{\tilde{\chi}_1^0} \simeq 700$ GeV:
  - $m_{\tilde{g}} > 1.89$ TeV for Gbb
  - $m_{\tilde{g}} > 1.89$ TeV for Gtt
Third generation: stop 1L (1/2)

- Event selection: 1 lepton, at least 2 jets, large $E_T^{miss}$
- Main signal discriminants: $E_T^{miss}$, $H_T^{miss}$, mT, aMT2, topness, large-R jet mass

2 SR for $\tilde{t} \to t\tilde{\chi}_1^0$

3 SR for $\tilde{t} \to b\tilde{\chi}_1^\pm$

2 SR for $tt+$dark-matter
Third generation: stop 1L (2/2)

- 3.3σ excess in DM_low
- For a massless $\tilde{\chi}_1^0$, $m_{\tilde{t}_1} > 830$ GeV
- Assuming a 1 GeV DM mass, scalar mediator mass is excluded up to 320 GeV
Third generation: 2 b-jets + met

- Pair-production of sbottom, both decaying to $b + \tilde{\chi}_1^0$
- Event selection: no lepton, 2-4 jets, 2 b-jets, large $E_T^{miss}$
- Main signal discriminants: $m_{CT}$, $m_{bb}$, $E_T^{miss}/m_{eff}$
- 4 signal regions with no observed excess
- For a massless $\tilde{\chi}_1^0$, $m_{\tilde{b}_1} > 840$ GeV
Monojet analysis

- compressed squarks-LSP scenario: squark decay products too soft to be separated from multijet background
- ISR jet can boost the squark-squark system: high-pT jet and additional jets
- Signal regions defined with increasing $E_T^{miss}$ thresholds: 7 inclusive SR and 6 exclusive SR

**ATLAS**

- $\sqrt{s} = 13$ TeV, 3.2 fb$^{-1}$
- Signal Region
  - $p_T > 250$ GeV, $E_T^{miss} > 250$ GeV
- $\tilde{t}\tilde{t}$ production, $\tilde{t} \rightarrow c \chi^0_1$

**ATLAS**

- $\sqrt{s} = 13$ TeV, 3.2 fb$^{-1}$
- All limits at 95% CL
- $m_{\tilde{t}} < m_{\tilde{t}} + m_c$
- $m_{\tilde{t}} > m_{\tilde{\chi}_1^0} + m_W$
EWK production: $2/3 \, e/\mu + E_T^{\text{miss}} \, (1/2)$ [

$13.3/fb$

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EWK production: $2/3 \, e/\mu + E_T^{\text{miss}}$ (2/2) 

No excess observed

- For $m_{\tilde{\chi}_1^0} = 100$ GeV:
  - $m_{\tilde{\chi}_1^{\pm}} > 650$ GeV for $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$ production
  - $m_{\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0} > 1000$ GeV for $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production
EWK production: $2 \tau + E_T^{\text{miss}}$ (1/2) [14.8/fb]

- Event selection: hadronically decaying $\tau$, b-jets veto, Z-veto
- Main signal discriminants: $E_T^{\text{miss}}$ and $m_{T2}$
- Two signal regions

![Graph showing EWK production and signal regions](attachment:image.png)
EWK production: $2 \tau + E_T^{\text{miss}}$ (2/2)

No excess observed

- For a massless $\tilde{\chi}_1^0$:
  - $m_{\tilde{\chi}_1^\pm} > 580$ GeV for $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$ production
  - $m_{\tilde{\chi}_1^\pm, \tilde{\chi}_2^0} > 700$ GeV for $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production

\[\tilde{\chi}_1^\pm \rightarrow \tau \nu \tilde{\nu}, \tau \tilde{\nu} \nu \tilde{\nu} \rightarrow \tau \nu \tilde{\nu} \nu \tilde{\nu}, \tilde{\chi}_2^0 \rightarrow 2 \tau \nu \tilde{\nu} \rightarrow 2 \tau \nu \tilde{\nu}\]
RPV 1L multijet (1/2)

- Event selection: at least 1 lepton and at least 5 jets
- Events categorized in two dimensions:
  - 6 jet multiplicity bins;
  - 5 b-jet multiplicity bins.
- 30 bins, simultaneously fitted for BSM model-dependent limits.
RPV 1L multijet (2/2)

- For $m_{\tilde{\chi}_1^0} = 500$ GeV:
  - Assuming $\lambda''_{112}$ is the only non-zero RPV coupling:
    $m_{\tilde{g}} > 1.75$ TeV
  - Assuming $\lambda''_{323}$ is the only non-zero RPV coupling:
    $m_{\tilde{g}} > 1.4$ TeV
Long Lived Particles (R-hadrons)

- R-hadrons: long-lived, charged colorless bound state of gluino/squarks with SM quarks or gluons
- Expected to have low velocity $\beta = v/c$, and higher $dE/dX$
- Exploited by using the pixel detector and the tile calorimeter timing
- Events selected with large $E_T^{\text{miss}}$ and isolated tracks
- Excludes gluino R-hadrons masses lower than 1580 GeV
Conclusion

- Presented a selection of SUSY analyses performed on the 2015 ATLAS dataset (3.2 fb$^{-1}$), or the first-half of the 2016 dataset (13-14 fb$^{-1}$);
- Many other results already available: [ATLAS Supersymmetry Public Results](#);
- No significant excess observed;
- Much more results to come with the full 2016 dataset ($\simeq$36 fb$^{-1}$ recorded).