Searches for top and bottom squarks with the ATLAS experiment

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Introduction

- Supersymmetry (SUSY) is a theoretical extension of the Standard Model
  - Would explain the hierarchy problem
  - Lightest supersymmetric particle is a Dark Matter candidate (neutralino)
  - Unifies Gravity with the Standard Model
- Third generation squarks (stop and sbottom) expected to be light
  - Could be produced in pairs in the LHC
  - Different final states and decay modes studied depending on SUSY parameters

**SUPERSYMMETRY**

Standard particles | SUSY particles
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Sbottom

- Latest ATLAS results published with 36.1 fb$^{-1}$ arXiv:1708.09266v1
- Direct production of sbottom pairs
- Decay through bottom or top quark and neutralino → final states with two b-jets and $E_T^{miss}$
- Optimized separately depending on $\Delta m = m_{\tilde{t}} - m_{\tilde{\chi}}$
- Two sets of Signal Regions
  - No leptons: Targeting decay through bottom quarks
  - One lepton: Targeting scenario with one or two tops
- Common signal region selection: 2 b-jets, $N_{jets} \leq 4$

### All-hadronic

- **b0L-SRA**: Large $\Delta m$. Bins on main discriminant variable $m_{CT}$, with $m_{bb} > 200$, and $E_T^{miss} > 250$ GeV
- **b0L-SRB**: Intermediate $\Delta m$. Main discrimination through $m_{min}^{T}(jet_{1-4}, E_T^{miss}) > 250$ GeV
- **SRC**: Low $\Delta m$, sbottom pair produced in association with ISR jet. One jet with $p_T > 500$ GeV and $E_T^{miss} > 500$ GeV required

### One-lepton

- **b1L-SRA**: Large $\Delta m$. Large $E_T^{miss}$ and $E_T^{miss} / \sqrt{H_T}$ are required, and $m_T, am_{T2}$ and $m_{bb}$ are used for further discrimination
- **b1L-SRB**: Compressed mass scenario. $m_{min}^{T}(b, E_T^{miss})$
- **b1L-SRA300-2j**: Compressed mass. Similar to b1L-SRA but only the two b-jets are required, and $m_{eff} > 300$ GeV.
Background estimation

- Dedicated Control Regions are designed to constrain the main backgrounds in the Signal Region
- Independent CRs are designed for the one and zero-lepton SRs, except for Single Top
- A simultaneous profile likelihood fit is then performed on all the regions to estimate the background in the SRs

Control Regions

- $Z \rightarrow \nu\nu$ from a $Z \rightarrow \ell\ell$ Control Region
- $W+\text{jets}$ from a one-lepton CR
- $T\bar{T}$ from a 1-lepton region
- **Single Top** from a 1-lepton region

Good agreement found in all regions
Results

- No excess found over standard model expectation
- Limits set on the masses of the supersymmetric particles
Stop+0lepton

- Search for stop squark in fully hadronic final states
- Latest results published with 36.1 fb$^{-1}$ arXiv:1709.04183
- Main process targeted: direct production of stop pair decaying into top quark and neutralino
- Different SRs for the different areas of the Stop-neutralino mass plane
- Final state containing two b-jets, large jet multiplicity and large $E_T^{miss}$

Other processes with similar final states also considered
- Stop decaying to b quark and chargino
- Stop decaying to b quark and W boson
- Gluino mediated stop production where the stop decays into light quarks and neutralino
Signal Region overview

- Common selection for signal regions: \( \geq 2 \) b-jets, \( \geq 4 \) jets, and large \( E_T^{\text{miss}} \)
- Divide events into three categories depending on the top reconstruction \( \rightarrow \) mass of the reclustered \( R=1.2 \) jets

### Top categories

- **TT**: Two reconstructed tops, \( m^{1,2}_{\text{antikt12}} > 120 \) GeV
- **TW**: One reconstructed top, one \( W \), \( m^1_{\text{antikt12}} > 120 \) GeV, \( 60 < m^2_{\text{antikt12}} < 120 \) GeV
- **T0**: One reconstructed top, \( m^1_{\text{antikt12}} > 120 \) GeV, \( m^2_{\text{antikt12}} < 60 \) GeV

### Different SRs depending on \( \Delta m = m_{\tilde{t}} - m_{\tilde{\chi}^0} \):

- **SRA**: Direct stop to top neutralino \( \rightarrow \) large stop-neutralino mass splitting
  - Boosted scenario: Large \( E_T^{\text{miss}} \)
- **SRB**: Direct stop to top neutralino \( \rightarrow \) small stop-neutralino mass splitting
  - Lower \( E_T^{\text{miss}} \)
- **SRC**: Direct stop to top neutralino \( \rightarrow \) stop-neutralino mass splitting \( \sim m_t \)
  - No categories, use of ISR variables to discriminate from \( \text{ttbar} \)

- **SRD**: Direct stop to \( b \) chargino
  - Higher jet \( p_T \), high reconstructed top mass

- **SRE**: Gluino mediated stop
  - Very boosted tops
Background estimation

- Dedicated control regions were designed to constrain the main backgrounds in the SR

Control Regions

- $Z \rightarrow \nu\nu+jets$ from a $Z \rightarrow \ell\ell+jets$ CR
- $W+jets$ from $1\ell$ CR
- $t\bar{t}$ from $1\ell$ CR (with dedicated ISR top CR for SRD)
- Single top from $1\ell$ CR
- $t\bar{t}+Z$ from $t\bar{t}+\gamma$

- Showing $Z+jets$ CR (left), $W+jets$ CR (center), and $T\bar{T}$ CR (right)

- Good agreement found in all regions
Results

- No excess was found over the Standard Model expectation
- Constraints set on SUSY masses extending Run 1 limits
Monojet analysis

- Search for new phenomena in events with one energetic jet and large missing transverse momentum
- Last public results with 36.1 fb$^{-1}$

**ATLAS-CONF-2017-060**, paper in process of submission to JHEP
- Squark search among other interpretations
- Background estimation through dedicated CRs for main backgrounds
  - W+jets
  - Z+jets
  - Top

**Selection**

- One energetic jet ($p_T > 250$ GeV)
- Large $E_T^{miss}$ (> 250 GeV)
- Maximum of four jets
- Shape fit in $E_T^{miss}$ (10 bins)
Stop 1-lepton

- Last public results ATLAS-CONF-2017-037 with 36.1 fb$^{-1}$

- Five sets of Signal Regions optimized for the different areas of the $m_{\tilde{t}} - m_{\tilde{\chi}_1^0}$ plane, with several analysis techniques
  - Cut-and-count fit
  - Boosted Decision Tree (BDT) optimization
  - Shape fit ($E_T^{\text{miss}}$, $a m_{T2}$, $p_T^\ell / E_T^{\text{miss}}$)

- Man backgrounds estimated through Control Regions ($t\bar{t}$, Single Top, $t\bar{t} + Z$, $W$+jets)

- No excess found with respect to the Standard Model prediction
Stop 2-Lepton

- Last public results arXiv:1708.03247 with 36.1 fb$^{-1}$
- Three sets of Signal Regions designed for the two, three and four body decay modes of the stop pair
- Dedicated discriminating variables for each set
- Main background contributions normalized in dedicated Control Regions (Diboson, $t\bar{t}$, $t\bar{t} + Z$)
- No excess over SM found
Summary and Conclusions

- A big variety of analyses looking for third generation SUSY particles
- Exclusion limits widely improved the ones published in Run 1
- Improvements to the analysis techniques and new ideas ongoing for the full Run2 publications in 2019
- Still lots of possibilities to explore!