Prospects for inclusive searches for supersymmetry in ATLAS

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Introduction

Supersymmetry is one of the most promising extension of SM

- dark matter candidate
- solves Higgs hierarchy problem

Assume R-Parity Conservation

- SUSY particles produced in pairs
  - if light, abundant production of squarks & gluinos
- cascade decay into LSP
- LSP escapes detection

Signature: high $p_T$ jets plus missing transverse energy

maybe additional leptons or photons
Strategies for Discovery

detailed studies on specific benchmark points for various signatures
- understanding of events
- develop analysis strategies
- inclusive in respect to jet multiplicities
- leptonic signatures exclusive for better combination in future

scans over subsets of SUSY parameter space
- large number of signal points $\rightarrow$ use of fast simulation (ATLFAST1)
- try cuts developed in detailed studies on broad range of models

develop techniques to estimate background from data
Studies on Benchmark Points

Overview of all detailed studies

**Zero-lepton mode**
- Four or more jets
- Two or more jets
- Three or more jets

**One-lepton mode**
- Four or more jets
- Two or more jets
- Three or more jets

**Two-lepton mode**
- Opposite sign diphotons
  - Four or more jets
- Same sign diphotons
  - Four or more jets

**Three-lepton mode**
- Three-lepton+jet
- Three-lepton+$E_T^{\text{miss}}$

**Tau mode**

**b-jet mode**

examples for 14TeV and 1fb$^{-1}$ on the following slides
4-Jet-Zero-Lepton-Mode

Event Selection:

- **J70_X70** combined trigger ($\text{jet} + \text{E}_{T}^{\text{miss}}$)
- At least 4 jets with $p_T > 100, 50, 50, 50 \text{ GeV}$ & $E_{T}^{\text{miss}} > 100 \text{ GeV}$
- $E_{T}^{\text{miss}} > 0.2 \cdot M_{\text{eff}}$; $M_{\text{eff}} = E_{T}^{\text{miss}} + \Sigma p_T(\text{jet}_i)$
- Transverse sphericity $S_T > 0.2$
- $\Delta\Phi(\text{jet}_j - \text{E}_{T}^{\text{miss}}) > 0.2; 1 \leq j \leq 3$
- Veto events with isolated $e$ or $\mu$
- Effective Mass $M_{\text{eff}} > 800 \text{ GeV}$

![Graph showing distribution of effective mass](image)

- **$M_{\text{eff}}$** distribution before last $M_{\text{eff}}$ cut

**S/B** ratio large in region of high $M_{\text{eff}}$
4-Jet-Zero-Lepton-Mode

$M_{\text{eff}}$ distribution before last $M_{\text{eff}}$ cut for various benchmark points

All benchmark points accessible with significance $Z_n > 5$ besides SU2 (dominated by direct gaugino production)

$Z_n$: convolution of poison with gaussian (syst. errors)
One-Lepton-Mode

Event Selection:

- J70_X70 combined trigger
- Exactly one isolated lepton with $p_T > 20$ GeV
- No additional lepton with $p_T > 10$ GeV
- At least 4 jets with $p_T > 100, 50, 50, 50$ GeV & $E_T^{\text{miss}} > 100$ GeV
- $E_T^{\text{miss}} > 100$ GeV and $E_T^{\text{miss}} > 0.2 \cdot M_{\text{eff}}$
- Transverse sphericity $S_T > 0.2$
- Transverse mass $M_T > 100$ GeV
- Effective Mass $M_{\text{eff}} > 800$ GeV

QCD background drastically reduced
main contribution from $tt$ and $W/Z$
One-Lepton-Mode

$M_{\text{eff}}$ distribution before last $M_{\text{eff}}$ cut for various benchmark points

With harder $M_{\text{eff}}$ cut even SU2 within reach
(given relative background uncertainties do not increase)
Examples for other Modes

- **two jet zero lepton**
- **one lepton two jets**
- **same sign dilepton**
- **tau**

Detailed studies cover a wide range of different possible signal topologies
Scans in SUSY Parameter Space

Scan a subset of the parameter space for different SUSY models
- generate events for various points in the parameter space
- apply cuts from detailed studies to each signal point
- scan $M_{\text{eff}}$ distribution for greatest deviation from SM

finding the optimal $M_{\text{eff}}$ cut
- calculate probability $p$ to find $D$ data events if $B$ SM events are expected
- choose region with lowest $p$
- correct $p$ for multiple testing via a Monte Carlo method
- calculate significance

Meff scan step size 400 GeV
Discovery Reach for mSUGRA

leading order cross sections

events reconstructed with fast detector simulation (ATLFAST1)

uncertainties on background: 50% (QCD), 20% (other)

4 jet 0 lepton is most promising mode
1 lepton mode less sensitive to QCD background

tau mode may help for large $\tan \beta$

Florian Ahles - Berkeley Workshop on Physics Opportunities with Early LHC Data 2009
Discovery Reach for mSUGRA

Comparison of different jet multiplicities in

zero lepton mode

4 jet mode performs best

one lepton mode

different jet multiplicities compatible
Discovery Reach for Other Models

mSUGRA with DM constraints

Non Universal Higgs Mass Model

Discovery reach similar to the one for mSUGRA
Example: estimation of Z background

$Z \rightarrow \nu\nu + \text{jets}$ irreducible background for SUSY searches in 0 lepton channel

idea:
estimation from $Z \rightarrow l^+l^- + \text{jets}$

estimation works well within $\sim 20\%$ uncertainty for $1\text{fb}^{-1}$
Disclaimer

- studies done for LHC Chamonix meeting 2009
- intended to serve as rapid turn-around information for LHC operating strategy
- using simpler techniques and approximations than usual for ATLAS results

- mSUGRA model with equal mass squarks and gluinos
- events generated for 6 different center of mass energies
- events reconstructed with fast detector simulation (ATLFAST1)
- 100% systematic error on background
- lepton+jets+$E_T^{\text{miss}}$ channel (better understood in early data)
Reach at Different Center of Mass Energies

5σ discovery reach for three masses beyond Tevatron limit

ATLAS Preliminary
5σ discovery
mSUGRA tanβ = 10, A₀ = 0, μ = +

new ATLAS benchmark:
200 pb⁻¹ @ 10 TeV

Tevatron limit in this model: ~400 GeV
three investigated masses above Tevatron limit accessibly with ~50 pb⁻¹
Summary & Conclusion

Detailed studies were developed on different signal benchmark points

Scans over parameter space for different SUSY models show promising discovery reach

First studies for 10 TeV show discovery potential well beyond the Tevatron limit even for early data

Monte Carlo studies are currently redone for 10 TeV
  - wider range of signal models
  - better background (error) estimation from data

We are looking forward to an exciting period of first data taking
SUSY Benchmark Points

SU1 \( m_0 = 70 \text{ GeV}, \; m_{1/2} = 350 \text{ GeV}, \; A_0 = 0, \; \tan \beta = 10, \; \mu > 0. \) Coannihilation region where \( \tilde{\chi}_1^0 \) annihilate with near-degenerate \( \tilde{\ell} \).

SU2 \( m_0 = 3550 \text{ GeV}, \; m_{1/2} = 300 \text{ GeV}, \; A_0 = 0, \; \tan \beta = 10, \; \mu > 0. \) Focus point region near the boundary where \( \mu^2 < 0. \) This is the only region in mSUGRA where the \( \tilde{\chi}_1^0 \) has a high higgsino component, thereby enhancing the annihilation cross-section for processes such as \( \tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow WW \).

SU3 \( m_0 = 100 \text{ GeV}, \; m_{1/2} = 300 \text{ GeV}, \; A_0 = -300 \text{ GeV}, \; \tan \beta = 6, \; \mu > 0. \) Bulk region: LSP annihilation happens through the exchange of light sleptons.

SU4 \( m_0 = 200 \text{ GeV}, \; m_{1/2} = 160 \text{ GeV}, \; A_0 = -400 \text{ GeV}, \; \tan \beta = 10, \; \mu > 0. \) Low mass point close to Tevatron bound.

SU6 \( m_0 = 320 \text{ GeV}, \; m_{1/2} = 375 \text{ GeV}, \; A_0 = 0, \; \tan \beta = 50, \; \mu > 0. \) The funnel region where \( 2m_{\tilde{\chi}_1^0} \approx m_A. \) Since \( \tan \beta \gg 1, \) the width of the pseudoscalar Higgs boson \( A \) is large and \( \tau \) decays dominate.

SU8.1 \( m_0 = 210 \text{ GeV}, \; m_{1/2} = 360 \text{ GeV}, \; A_0 = 0, \; \tan \beta = 40, \; \mu > 0. \) Variant of coannihilation region with \( \tan \beta \gg 1, \) so that only \( m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0} \) is small.

SU9 \( m_0 = 300 \text{ GeV}, \; m_{1/2} = 425 \text{ GeV}, \; A_0 = 20, \; \tan \beta = 20, \; \mu > 0. \) Point in the bulk region with enhanced Higgs production.