

Searches for multi-lepton Production in ATLAS

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- Motivation and SUSY scenarios
- Analysis object and event selection
- Results and interpretation
- [ATLAS-CONF-2011-039](#)

Motivation

- LHC pp-collisions
 - ▷ Strong processes dominate
 - ▷ Dominant SM processes: QCD
 - ▷ Signal: \tilde{g} and \tilde{q}
 - ▷ \tilde{g} , \tilde{q} decays can include charginos and neutralinos

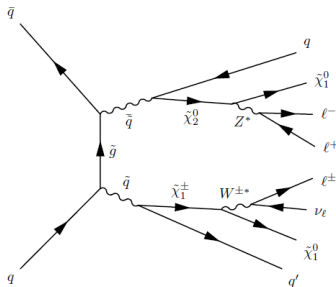
$$\tilde{\chi}_i^0 (\rightarrow \ell^\pm \tilde{\ell}^\mp / Z \tilde{\chi}_j^0) \rightarrow \ell^+ \ell^- \tilde{\chi}_j^0$$

$$\tilde{\chi}_i^\pm (\rightarrow \ell^\pm \tilde{\nu}_\ell / \nu \tilde{\ell}^\pm / W^\pm \tilde{\chi}_j^0) \rightarrow \nu \ell^\pm \tilde{\chi}_j^0$$

$$\tilde{\chi}_i^0 (\rightarrow \nu \tilde{\nu}_\ell / W^\mp \tilde{\chi}_j^\pm) \rightarrow \nu \ell^\mp \tilde{\chi}_j^\pm$$

$$\tilde{\chi}_i^\pm (\rightarrow \ell^\pm \tilde{\nu}_\ell / Z \tilde{\chi}_j^\pm) \rightarrow \ell^+ \ell^- \tilde{\chi}_j^\pm$$

- High lepton multiplicity
 - ▷ Suppression of QCD background
- Final states may have high- p_T jets and sizable \cancel{E}_T



Ex. R-parity conserving SUSY scenario

- Two R-parity conserving scenarios considered here
- **mSUGRA**
- $m_0, m_{1/2}, A_0, \tan\beta$ and $\text{sign}(\mu)$
 - ▷ Common scalar mass (m_0)
 - sets squark and slepton mass
 - ▷ Common gaugino mass ($m_{1/2}$)
 - sets neutralino, chargino and gluino mass
- $m_{\tilde{g}} : (m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^\pm}) : m_{\tilde{\chi}_1^0} \approx 7 : 2 : 1$ at Electro-Weak scale
- mSUGRA grid $\tan\beta = 3, A_0 = 0, \mu > 0$
 - ▷ $m_0 \in (40, 1160)$ GeV \times
 $m_{1/2} \in (100, 340)$ GeV

- **MSSM PhenoGrids**

- Bino-like LSP and wino-like $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm$
- No mass relations are enforced on $m_{\tilde{g}}, m_{\tilde{q}}, m_{\tilde{\chi}_2^0}(=m_{\tilde{\chi}_1^\pm}), m_{\tilde{\ell}}$ and $m_{\tilde{\chi}_1^0}$
- $m_{3^{\text{rd gen}}} = 2$ TeV
- $m_{\tilde{\chi}_1^0} < m_{\tilde{\ell}} < m_{\tilde{\chi}_2^0} \rightarrow$ lepton final states
- Grid spanned by $m_{\tilde{g}}$ and $m_{\tilde{q}}$

Mode	minMD	maxMD
$m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^\pm)$	h-50	h-100
$m(\tilde{\ell})$	h-100	h/2
$m(\tilde{\chi}_1^0)$	h-150	100

$$h \equiv \min(m_{\tilde{g}}, m_{\tilde{q}})$$

- PhenoGrid2: $m_{\tilde{l}_R} = m_{\tilde{l}_L}, m_{\tilde{q}_R} = m_{\tilde{q}_L}$
- PhenoGrid3: $m_{\tilde{l}_R} = m_{\tilde{q}_R} = 2$ TeV

Analysis object definitions

● Electrons

- ▷ $p_T > 20 \text{ GeV}$ $|\eta| < 2.47$
- ▷ Shower shape and track requirements
- ▷ Reject if passing defect detector regions
- ▷ Isolation and separation from a jet

● Muons

- ▷ $p_T > 10 \text{ GeV}$ $|\eta| < 2.4$
- ▷ Combined muons, good match between track in Muons Spectrometer (MS) and Inner Detector (ID)
- ▷ Track quality requirements
- ▷ Isolation and separation from a jet

● Jets

- ▷ $p_T > 20 \text{ GeV}$ $|\eta| < 2.5$
- ▷ Anti- k_t algorithms $\Delta R = 0.4$

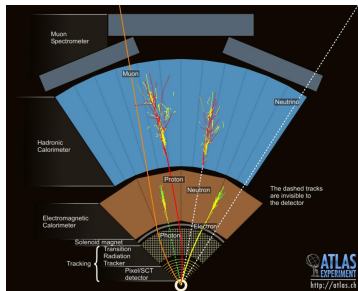
$$\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$$

● Trigger

- ▷ Single electron or muon trigger

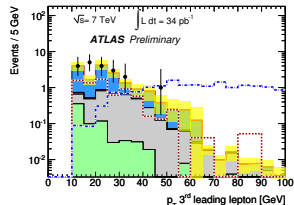
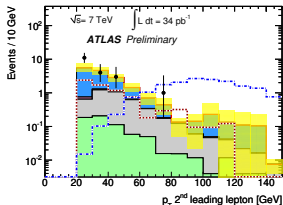
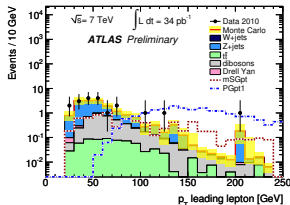
● Event selection

- ▷ High quality collision candidates
- ▷ $M_{SFOS} > 20 \text{ GeV}$ reject Drell-Yan and low-mass particles

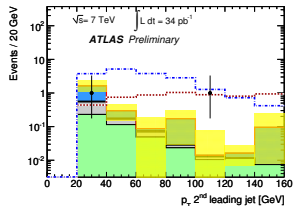
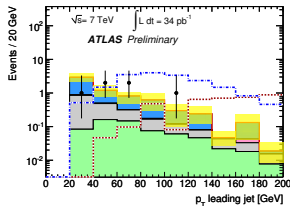
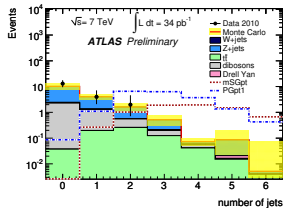


Event selection

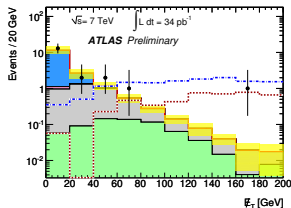
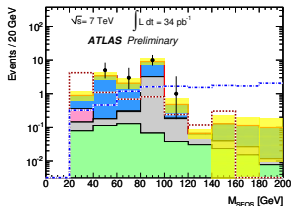
- Data: 7 TeV pp-collisions collected during 2010
- After basic beam, detector and data quality requirements: 34 pb^{-1}
- Dominant backgrounds
 - ▷ $Z + \text{jets}, t\bar{t} \rightarrow 2$ isolated leptons, one non-signal lepton
 - ▷ Di-boson: $WZ, ZZ \rightarrow 3-4$ isolated leptons
- Reference SUSY scenarios:
 - ▷ mSUGRA “mSGpt” and PhenoGrid “PGpt1” with light neutralino
- $N_l \geq 3$
- $p_T > 20, 20, 20(10) \text{ GeV}$ for the three leading electrons (muons)



Event selection



- 2 jets with $p_T > 50 \text{ GeV}$



- $|M_{SFOS} - M_Z| > 5 \text{ GeV}$

- $E_T > 50 \text{ GeV}$

Results

- Integrated luminosity: 34 pb^{-1} , 2010 data
- Blind analysis
- Number of SM trilepton events
 - ▷ p_T above threshold 20,20,20,(10), $e(\mu)$

Multilep. events	All	eee	$ee\mu$	$e\mu\mu$	$\mu\mu\mu$
$t\bar{t}$	0.68 ± 0.16	0.032 ± 0.016	0.24 ± 0.07	0.31 ± 0.08	0.096 ± 0.030
Z backgrounds	15.6 ± 1.3	3.8 ± 0.8	1.60 ± 0.34	7.9 ± 1.0	2.4 ± 0.4
Other backgrounds	0.28 ± 0.13	0.02 ± 0.14	0.03 ± 0.06	0.21 ± 0.09	0.01 ± 0.11
Total SM	16.6 ± 1.3	3.8 ± 0.8	1.9 ± 0.4	8.4 ± 1.0	2.5 ± 0.4
Data	19	2	1	10	6

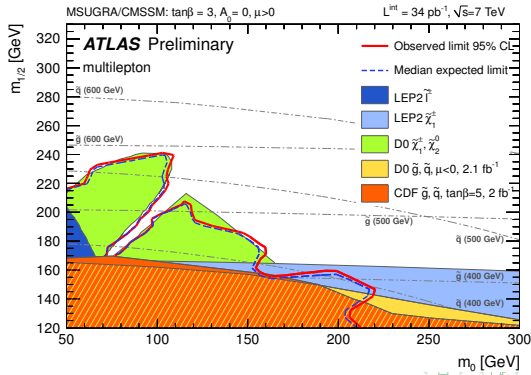
- No 4-lepton events observed
- Dominant systematic uncertainties
 - ▷ Jet energy scale ($\sim 12\%$)
 - ▷ Electron energy scale ($\sim 20\%$) and resolution ($\sim 10\%$)
 - ▷ Pile-up ($\sim 11\%$)
 - ▷ Luminosity ($\sim 11\%$)
 - ▷ MC-cross section ($\sim 10\%$)

Final event selection:

- SM expected background:
 - ▷ $0.109 \pm 0.023^{+0.036}_{-0.025}$
 - ▷ $t\bar{t}$ dominates
- No events in data pass all event selection criteria

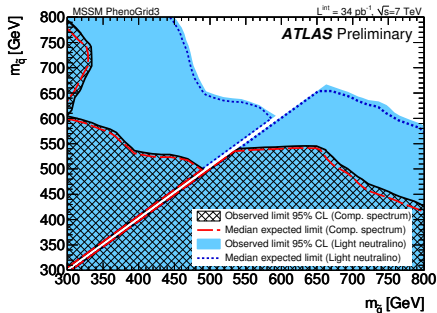
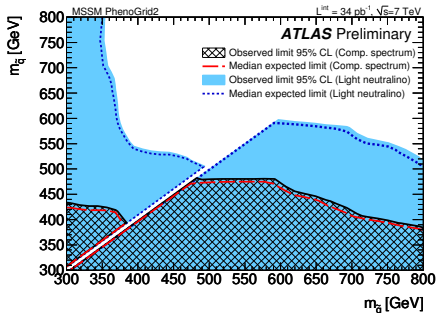
Limits

- Profile-likelihood ratio method
- Upper limit on the cross section \times branching ratio \times acceptance at 95% C.L. 62 fb
- mSUGRA/CMSSM framework: $m_0 - m_{1/2}$ plane
 - ▷ $\tan\beta = 3$, $A_0 = 0$, $\mu > 0$
- Excluded region similar to Tevatron trilepton results



Limits

- PhenoGrid2 $m_{\tilde{l}_R} = m_{\tilde{l}_L}, m_{\tilde{q}_R} = m_{\tilde{q}_L}$
- PhenoGrid3 $m_{\tilde{l}_R} = m_{\tilde{q}_R} = 2 \text{ TeV}$, favorable for leptons in final state
 - ▷ Compressed spectrum: softer final state kinematics
 - ▷ Light neutralino (LSP): harder spectrum of leptons, jets and \cancel{E}_T



Exclusion

- Assumption: $m_{\tilde{g}} = m_{\tilde{q}} + 10 \text{ GeV}$, limits on compressed spectrum (light neutralino):
 - ▷ PhenoGrid2 $m_{\tilde{q}} < 480(600) \text{ GeV}$
 - ▷ PhenoGrid3 $m_{\tilde{q}} < 540(670) \text{ GeV}$

Conclusion and outlook

- First ATLAS search for SUSY in multilepton final state
 - ▷ Integrated luminosity 34 pb^{-1} , 2010 data
- No significant excess of events
- Observation in agreement with SM expectations within uncertainties
- No events pass all event selection requirements
- Exclusion limits:
 - ▷ mSUGRA: compatible results from Tevatron trilepton SUSY searches
 - ▷ Limits in a less constrained MSSM scenario

- Outlook
 - ▷ Analysis of 2011 data
 - ▷ Higher statistics – data-driven background estimations



Back-up slides

● MSSM PhenoGrids – 24 parameters

- ▷ Bino-like LSP and wino-like $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm$
- ▷ No mass relations are enforced on $m_{\tilde{g}}$, $m_{\tilde{q}}$, $m_{\tilde{\chi}_2^0}(=m_{\tilde{\chi}_1^\pm})$, $m_{\tilde{\ell}}$ and $m_{\tilde{\chi}_1^0}$
- ▷ $m_{3^{\text{rd gen}}} = 2 \text{ TeV}$
- ▷ $m_{\tilde{\chi}_1^0} < m_{\tilde{\ell}} < m_{\tilde{\chi}_2^0} \rightarrow$ lepton final states
- ▷ Fixed parameters: $m_{3^{\text{rd gen}}} = 2 \text{ TeV}$, $m_A = 1000 \text{ GeV}$, $\mu = 1.5 \min(m_{\tilde{g}}, m_{\tilde{q}})$, $\tan \beta = 4$, $A_t = \mu / \tan \beta$, $A_b = \mu \tan \beta$, and $A_l = \mu \tan \beta$

● mSUGRA grid

- ▷ $\tan \beta = 3$, $A_0 = 0$, $\mu > 0$
- ▷ $m_0 \in (40, 1160) \text{ GeV} \times m_{1/2} \in (100, 340) \text{ GeV}$

● Reference SUSY scenarios:

- ▷ mSUGRA “mSGpt” $(m_0, m_{1/2}, A_0) = (80, 180, 0) \text{ GeV}$, $\tan \beta = 3$ and $\mu > 0$
- ▷ PhenoGrid3 “PGpt1”, $m_{\tilde{g}} = 510 \text{ GeV}$, $m_{\tilde{q}} = 500 \text{ GeV}$, $m_{\tilde{\chi}_2^0} = 400 \text{ GeV}$, $m_{\tilde{L}} = 250 \text{ GeV}$, and $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$