Search for physics beyond the Standard Model at ATLAS

Les Rencontres de Physique de la Vallée d’Aoste

Helenka Przysiezniak – LAPP-Université de Savoie-IN2P3-CNRS – On behalf of the ATLAS collaboration
What’s up in searches – SUSY and Exotics – at the LHC

LHC-ATLAS

2010-11  $\sqrt{s} = 7 \text{ TeV}$  4.7 fb-1
2012  $\sqrt{s} = 8 \text{ TeV}$  21 fb-1

Although a new boson has been discovered at the LHC “it” can’t explain “everything” e.g.
- Hierarchy issues $M_{\text{weak}} \rightarrow M_{\text{planck}}$?
- Dark matter/energy
- Gauge Coupling Unification
- etc.

Exotics and SUSY searches excluding more and more phase space.

Signature and model based searches
Sometimes cross-over with SM/Exotics/SUSY/Top/Higgs searches
SU Sy

@ $\sqrt{s}=8\text{TeV}$

unless otherwise mentioned

all exclusions @ 95% C.L.
We know SUSY must be broken (or absent)
The analyses shown here consider MSSM
→ gravity mediated MSUGRA or gauge mediated GMSB breaking
→ R-parity conserving
→ Prompt particles

Production of
(in order of decreasing cross sections):
- squarks/gluinos
- 3rd gen. stop/sbottom
- gauginos/sleptons

If $m \sim 125$ GeV boson is MSSM Higgs then in a “Natural spectrum”
Light stop-sbottom and charginos should be fairly light ($< \sim 500$ GeV)
$m(\text{gluinos}) \sim 1500$ GeV [arxiv 1302.2146v1, 1110.6670]
→ Hence emphasize search for
→ gluino mediated and direct production of stops or sbottoms
→ direct production of charginos and neutralinos (see Stewart Martin-Haugh’s talk)
Searching for SUSY and Exotics (non SUSY) – Experimental issues

Signal and background separation ; exploit :
- High-mass/high-MET/Signal-Background mass gap
- More than one signal region
- Jet, lepton multiplicities; high ET photons
- Variables : MET, $M_{\text{eff}}$, $m_{\text{CT}}$, etc.

Background estimation
- Using control regions (CRs) in data or MC and apply to signal region (SR) using transfer factors
- Reducible backgrounds directly from data : fake leptons/b-jets, charge flip, etc.
- Irreducible backgrounds using MC
- Fitting functional form to data (resonances)

Mains systematics
- Theoretical uncertainties : scale, PDFs, parton showering
- JES/JER, Lepton/Photon id, b-tagging, luminosity, MC statistics, etc.
- Background extrapolations

Limit setting : 95% Confidence Level (C.L.)

N.B. The following are a selection of recent SUSY and Exotics (non SUSY) analyses performed and clearly NOT A SUMMARY OF ALL ANALYSES !!!
Many upcoming updates.
Inclusive searches: (lepton+) jets + MET

Signal: jets + MET
15 signal regions (SRs)
4 control regions (CRs)/SR for background estimation

Backgrounds
W/Z+jets backgrounds, top \(\rightarrow\) from CR; Diboson \(\rightarrow\) MC

Variables e.g. \(M_{\text{eff}} = \sum p_T^{\text{jets}} + E_T^{\text{miss}} (+p_T^{\text{lepton}})\)

ATLAS PRELIMINARY

\[
\int L \ dt = 5.8 \text{ fb}^{-1} \quad \text{s} = 8 \text{ TeV}
\]

DATA 2012 (s = 8 TeV)
- SM Total
- SM+SU(1600,400,0,10)
- Multijet
- t\bar{t} & single top
- W+jets
- Z+jets
- Diboson

ATLAS
Preliminary

ATLAS-CONF-2012-109 (103; 104)

MSUGRA/CMSSM \(\tan\beta = 10, A_0 = 0\) and \(\mu > 0\)
Exclude \(\@ 95\% \text{ C.L.}\)
\(m(\text{squark}) = m(\text{gluino}) < 1500 \text{ GeV}\)
\(m(\text{gluino}) < \sim 900 \text{ GeV}\) at high \(m_0\)
from lepton+jets+MET
Also interpretations in various
“process-driven” \(<<\text{simplified models}>>\)

DATA/MC

\(m_{\text{eff}}(\text{incl.}) \text{ [GeV]}\)

\(0 \quad 500 \quad 1000 \quad 1500 \quad 2000 \quad 2500 \quad 3000 \quad 3500 \quad 4000\)
Gluino pair production: 3 b-jets + MET

Gluino pair production

\( \text{gluino} \rightarrow \text{sbottom}_1 + \text{b} \text{ (Gbb)} \) or \( \text{stop}_1 + \text{t} \text{ (Gtt)} \)

18 signal regions

Main backgrounds

Top \( \rightarrow \) from MC; ttbar + jets \: from data CR

Variables e.g. MET, Meff

Exclude – for BR(gluino\( \rightarrow \)bbar \( \chi^0_1 \))=100%

[fors BR(gluino\( \rightarrow \)ttbar \( \chi^0_1 \))=100%]

\( m(\chi^0_1) < 200 \text{ GeV} \)

\( m(\text{gluino}) < 1240 \text{ [1150] GeV} \)

for \( m(\text{gluino})=1100 \text{ GeV} \)

\( m\chi^0_1 < 570 \text{ [440] GeV} \)

ATLAS-CONF-2012-145
General gauge mediation: photon + b-jets + MET
\( \sqrt{s} = 7 \) TeV

LSP = light gravitino
NSLP=neutralino
bino/wino/higgsino-like neutralino \( \rightarrow \) \( \gamma/Z/h \) + gravitino

Signal
higgsino-like neutralino \( \rightarrow \gamma/h/Z \)

Backgrounds
QCD multijet, W+jets, top \( \rightarrow \) from data

Variables e.g.
MET

\( \text{Exclude} \) for \( m_{\text{neutralino}} > 220 \) GeV
\( m(\text{gluino}) < 900 \) GeV and \( m(\text{squark}) < 1020 \) GeV

arXiv:1211.1167
Direct sbottom production: two b-jets + MET

4 signal regions
Background
Top, W/Z+heavy flavour hadrons → data CR
Other backgrounds (except multijet) → MC

Variables e.g.
Contransverse mass
\[ m_{CT}^2 = \left[ E_T(\nu_1) + E_T(\nu_2) \right]^2 - [p_T(\nu_1) - p_T(\nu_2)]^2 \]
where \( \nu_i \) = visible particle \( i \)

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Exclude − if BR(sbottom\(_1\)→b \( \chi^0_1 \))=100%
\[ m(\text{sbottom}_1) < 620 \text{ GeV} \]  for \( m_{\chi^0_1} < 150 \text{ GeV} \)
\[ m_{\chi^0_1} < 320 \text{ GeV} \]  for \( m(\text{sbottom}_1) \sim 550 \text{ GeV} \)
\[ (m_{\text{sbottom}_1} - m_{\chi^0_1}) > 40 \text{ GeV} \]  for \( m(\text{sbottom}_1) < 300 \text{ GeV} \)

ATLAS-CONF-2012-165
Direct medium/heavy stop production: two b-jets + MET

Reinterpretation of previous analysis

\[
\text{stop1} \rightarrow b \chi_1^+ \text{ with } \chi_1^+ \rightarrow W(\ast) \chi_1^0
\]

Exclude

- assuming \((m_{\text{chargino}} - m_{\chi^0})=5 \text{ GeV}\)
  \(m(\text{stop1}) < 580 \text{ GeV}\)
  for \(m_{\chi^0} \approx 100 \text{ GeV}\)

\(m_{\chi^0} < 300 \text{ GeV}\)
  for \(m(\text{stop1}) \approx 500 \text{ GeV}\)

If \((m_{\text{chargino}} - m_{\chi^0})=20 \text{ GeV}\)
limits weaken by up to 100 GeV
Direct stop exclusion limits summary

\[ \text{BR}(\text{stop}1 \rightarrow b + \chi_{\pm 1}^1); \]
\[ \chi_{\pm 1}^1 \rightarrow W(\ast plus) + \chi_0^1) = 100\% \]
(green and blue):

0L : \( m(\chi_{\pm 1}^1) = 106 \text{ GeV} \) (dark green) @7TeV
1L : \( m(\chi_{\pm 1}^1) = 150 \text{ GeV} \) (light green)

1-2L : \( m(\chi_{\pm 1}^1) = 2m(\chi_0^1) \) (dark blue)
2L : \( m(\text{stop}_1) - m(\chi_{\pm 1}^1) = 10 \text{ GeV} \) (light blue)
0L : \( m(\chi_{\pm 1}^1) - m(\chi_0^1) = 5 \text{ GeV} \) (light turquoise)

\[ \text{BR}(\text{stop}1 \rightarrow t + \chi_0^1) = 100\% \]
(orange):

0-1-2L : 4.7 fb-1 @ 7TeV (dark orange)
1L : 13 fb-1 @ 8 TeV (light orange)

arxiv1208.1447 ; 1208.2590 ; 1209.4186 ;
ATLAS-CONF-2012-166 ; 1208.4305 ; 1209.2102 ;
ATLAS-CONF-2012-167 ; ATLAS-CONF-2013-001
Other SUSY options if nothing is seen

Compressed spectrum
ATLAS studies → squark/gluino limits collapse for small mass gaps

Long lived particles
See 1211.1597

R-parity violation
See recent arXiv:1212.1272

Beyond the MSSM
Stealth SUSY, scalar gluons, NMSSM ?
Exotics

@ $\sqrt{s}=8\text{TeV}$

unless otherwise mentioned

all exclusions @ 95% C.L.
Theoretical issues

Same theoretical issues as for SUSY...
...However different possible origins

- Extra dimensions
- Compositeness
- 4th generation particles
- Strong symmetry breaking
- New gauge bosons
- etc.

Final states

→

- Leptons+jets
- Leptonic
- Jet(s)
Leptons + jets final state – Resonant ZZ with ZZ → llqq

The model
Small extra dimensions Randall-Sundrum-2 (RS2)
- $M_{\text{planck}} \rightarrow M_{\text{weak}}$
- Exponentially warped fifth dimension
  
  $ds^2 = e^{-2krc|y|} \eta_{\mu\nu} \, dx_\mu \, dx_\nu - r_c^2 \, dy^2$
  
  where $k=$ curvature, of order of Planck scale
  $r_c$ compactification radius
- $k/M_{\text{Pl}} \approx 0.01$-1.0
  
  → Heavy excited graviton $J=2$ in the bulk

2 signal regions – 2 channels (ee, $\mu\mu$)
N.B. Resolved (low mass) and merged jets (high mass) from Z

Background: Fitting functional form to data
Variables: $m(jjll)$, low and high $p_T$ dilepton

Exclude – for $k/M_{\text{planck-reduced}} = 1.0$

$M_{\text{Graviton}} < 850$ GeV

ATLAS-CONF-2012-150
Leptonic final states – Excited electrons and muons $\ell^* \rightarrow \ell\gamma$

The model
Contact Interaction
Compositeness

$\Lambda = \text{compositeness scale}$
where $m(\ell^*) \leq \Lambda$

$q\bar{q} \rightarrow \ell^*\ell\bar{\ell} ; \sigma(\ell^+\ell^-) \text{ too low}$

Signal $\ell^+\ell^-\gamma - e\bar{e}\gamma, \mu\bar{\mu}\gamma$
Isolated leptons ($e, \mu$) with pT cut; isolated photon
$m(\ell\ell) > 110$ GeV

Background $\rightarrow$ from MC scaled to data
DY + ISR/FSR $\gamma$/jets
ttbar and diboson $\rightarrow$ small

Excluded $- \text{ for } \Lambda = m(\ell^*)$

$m(\ell^*) < 2.2$ TeV

ATLAS-CONF-2012-146
Leptonic final states – High mass dilepton searches

The models
- Sequential Standard Model Z’
  Same couplings to fermions as SM Z
- Grand Unification model
  with broken E6 gauge group

Signal – ee, µµ

Background
DY Z/γ*, Diboson, ttbar
→ from MC normalized w.r.t each other in Z peak region
Dijets (mostly ee) → from data in low mass region

 Exclude – for combined (ee, µµ) channels
mZ’ (SSM) < 2.49 (2.39, 2.19) TeV
mZ’ (E6 models) < 2.09 – 2.24 TeV

ATLAS-CONF-2012-129
Leptonic final states – W\gamma and Z\gamma Production

\( m(W\gamma) \) and \( m(Z\gamma) \) → limits on TC

The models

- Anomalous Triple Gauge Couplings
  → Already covered in Konstantinos Bachas’ talk

- Low Scale Techni-Colour (LSTC) resonances

Signal – (\ell\ell, \ell\nu, \nu\nu) + \gamma

Background

\( Z/W/\gamma + \text{jets} \), multijets → from data

Others → from MC

Variables: \( m(\ell\ell) \), \( m_T \), MET

LSTC: Fit to invariant mass distribution of \( W\gamma \) and \( Z\gamma \)

Exclude

\( m(\omega T) < 494 \text{ GeV} \) in \( Z\gamma \) mode
\( m(aT) < 703 \text{ GeV} \) in \( W\gamma \) mode

No deviations from SM \( WW\gamma, ZZ\gamma \) and \( Z\gamma\gamma \) triple-gauge-boson couplings \( (\lambda_\gamma, \Delta K_\gamma, h_3^V, h_4^V) \)

arXiv:1302.1283
Jet final state – Monojet + MET $\rightarrow$ Both SUSY and Exotics search (1)

The models

- **Large Extra Dimensions** e.g. ADD $M_{Pl}^2 \sim M_D^{2+n} R^n$
  MD=fundamental Planck scale in 4+n dimensions
  $R$=compactification radius
  $n$ = number of XtraDs
- **WIMPs** : Dirac fermions
  Non-renormalizable effective theory with vertex operators e.g. D5, D9, D11
  Effective cutoff mass scale (suppression scale) $M^*$
- **GMSB**
  $m_{Gravitino} \propto (\text{SUSY breaking scale } F) / M_{Pl}$

4 signal regions
Background
$Z(\rightarrow \nu \nu)/W (\rightarrow l\nu) + \text{jets}$:
  from MC normalized to data CRs
Other (except multijet) : from MC

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ATLAS Preliminary

\[
\int L dt = 10.5 fb^{-1}
\]
$\sqrt{s} = 8$ TeV

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ATLAS-CONF-2012-147
Jet final state – Monojet + MET → Both SUSY and Exotics search (2)

Exclude:
- ADD fundamental Planck scale in 4+n dimensions
  \[ M_D < 4.37 \ (2.53) \text{ TeV for } n = 2 \ (6) \ \text{(NLO)} \]
- WIMP suppression scale (effective cut-off mass scale) @ 90% CL
  \[ M^* < 704, 608, 336 \text{ GeV} \]
  for \( m_{\text{WIMP}} \leq 80, =400, =1000 \text{ GeV with the D5 contact operator} \)
- GMSB \( m(\text{Gravitino}) < 3 \cdot 10^{-4} \text{ eV} - 3 \cdot 10^{-5} \text{ eV} \) depending on \( m(\text{squark}) \) and \( m(\text{gluino}) \)
Conclusion and outlook

- Individual searches are sensitive to different complementary regions of the SUSY/Exotics parameter space.

- 2011 – gradually coming in 2012 – data results are truly amazing and together disconcerting for the “Searches clan”

- What if there isn’t anything more than the 125 Gev boson – SM Higgs? – to discover at the LHC? Would this really be The Nightmare Scenario?

- On the other hand, other particles e.g. light stop/sbottom/gauginos could be just around the corner!!

- 13-14 TeV high luminosity upgrade very promising
Backup slides
Recent searches results – more to come in upcoming conferences

@ 8TeV
New Phenomena in the Dijet Mass Distribution @8TeV ATLAS-CONF-2012-148

0 lepton + 2 b-jets + Etmiss [Medium / heavy stop] ATLAS-CONF-2013-001
2 leptons + Etmiss [Medium stop] ATLAS-CONF-2012-167
1 lepton + >=4 jets (>=1 b-jet) + Etmiss [Medium / heavy stop] ATLAS-CONF-2012-166

@ 7 TeV
WH production with a light Higgs boson decaying to prompt electron-jets 1302.4393
   Single b*-quark production 1301.1583
   Long-lived, multi-charged particles 1301.5272

0-2 leptons + 0-1 b-jets multichannel (razor) 1212.6149
   Heavy resonance to eμ, eτ, μτ [RPV-LFV] 1212.1272
   Long-lived particles [R-hadrons, slepton] 1211.1597
ATLAS
A Toroidal LHC Apparatus

Calorimetry $|\eta| < 4.9$
- EMBC, EMEC accordion LAr + Pb $|\eta| < 3.2$
- Tile Hadronic Fe + scintillator $|\eta| < 1.7$
- HEC Hadr end cap Cu+Lar $1.5 < |\eta| < 3.2$
- FCAL Forward calo Cu+W+Lar $3.1 < |\eta| < 4.9$

Muon spectrometer $|\eta| < 2.7$
- High precision tracking
  - MDT Monitored Drift Tubes
  - CSC Cathode Strip Chambers
- Trigger chambers
  - RPC Resistive Plate Chambers
  - TGC Thin Gap Chambers

Air core toroid system
→ strong bending power in large volume

Inner Detector
~6m long 1.1m radius inside 2T Solenoid
- Pixels
- SCT Silicon Strips
- TRT Transition Radiation Tracker $e/\pi$ separation

3 trigger levels: L1, L2, Event Filter (L2+EF=HLT)
- 40 MHz → 200 Hz
Summary

ATLAS SUSY Searches* - 95% CL Lower Limits (Status: Dec 2012)

*Only a selection of the available mass limits on new states or phenomena shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.
Expected limits in TeV

$Z'(SSM)\rightarrow ee$ and $Z'(SSM)\rightarrow \mu\mu$ for pp collisions at 14 TeV

<table>
<thead>
<tr>
<th>model</th>
<th>300 fb$^{-1}$</th>
<th>1000 fb$^{-1}$</th>
<th>3000 fb$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z_{SSM}' \rightarrow ee$</td>
<td>6.5</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>$Z_{SSM}' \rightarrow \mu\mu$</td>
<td>6.4</td>
<td>7.1</td>
<td>7.6</td>
</tr>
</tbody>
</table>
Backup slides
SUSY searches
Jets + missing momentum - MSUGRA/CMSSM interpretation

8TeV data – 5 signal regions Njets=2 - ≥6 with loose-medium-tight selection – each signal has 4 CRs for background estimation

\[ \text{Meff} = \sum p_T^{\text{jets}} + E_T^{\text{miss}} (+p_T^{\text{lepton}}) \]

Observed \( m_{\text{eff}} \) (incl.) distributions for medium (left) and loose (right) cuts.

The histogram denotes the MC background expectations, normalised to cross section times integrated luminosity. In the lower panels the yellow error bands denote the experimental and MC statistical uncertainties, while the green bands show the total uncertainty.

The red arrows indicate the values at which the cuts on \( m_{\text{eff}} \) (incl.) are applied.

The expected distributions for a MSUGRA/CMSSM benchmark model point with \( m_0=1600 \text{ GeV}, m_{1/2}=400 \text{ GeV}, A_0=0, \tan(\beta)=10 \text{ and } \mu>0 \) are also shown for comparison.
SUSY Jets + MET

95% CL exclusion limits for MSUGRA/CMSSM models with tan(\beta)=10, A_0=0 and \mu>0 presented in the $m_{\text{gluino}}$--$m_{\text{squark}}$ plane. Exclusion limits are obtained by using the signal region with the best expected sensitivity at each point. The blue dashed lines show the expected limits at 95% CL, with the light (yellow) bands indicating the $1\sigma$ excursions due to experimental uncertainties. Observed limits are indicated by medium (maroon) curves, where the solid contour represents the nominal limit, and the dotted lines are obtained by varying the cross section by the theoretical scale and PDF uncertainties. The theoretically excluded regions (green and blue) are described in Ref. [63].
Inclusive searches: (one isolated lepton +) jets + MET (2)

MSUGRA/CMSSM

\[ \tan\beta = 10, \ A_0 = 0 \text{ and } \mu > 0 \]

Exclude @95% C.L.

\[ m_{1/2} < 350 \text{ GeV for all } m_0 \]

\[ m_{1/2} < 740 \text{ GeV for low } m_0 \text{ from jets+MET} \]

\[ m(\text{squark}) = m(\text{gluino}) < 1500 \ (1240) \text{ GeV from jets+MET (lepton+jets+MET)} \]

\[ m(\text{gluino}) < \sim 900 \text{ GeV at high } m_0 \text{ from lepton+jets+MET} \]

Also interpretations in various “process-driven” simplified models

ATLAS-CONF-2012-109

ATLAS-CONF-2012-104 (103)
Multichannel search for squarks/gluinos: 0-1-2 lepton(s)+jets + MET

Razor variable

N.B. $E_{cm} = 7$ TeV

\[ R = \frac{M_R^R}{M_R} \]

\[ M_R = \sqrt{(E_{j1} + E_{j2})^2 - (p_{z1} + p_{z2})^2} \]

\[ M_R^R = \sqrt{E_T^{miss} (p_T^{j1} + p_T^{j2}) - \overline{E_T} \cdot (\overline{p_T}^{j1} + \overline{p_T}^{j2})} \]

Exclusion:

- Between $m_{gluino}$ and $m_{LSP}$
- For 0-1-2 lepton + jets + MET

arXiv:1211.6149
Gluino pair production : 3 b-jets + MET (1)

Gluino pair production \( \text{gluino} \rightarrow \text{sbottom}_1 + b \text{ or stop}_1 + t \)
6 signal regions

**Main backgrounds**
- \( \text{ttbar} + \text{jets} \) : from data CR
- QCD multijet : from data \( \rightarrow \) negligible

**Other backgrounds** \( \rightarrow \) from MC

**Discriminating variables**
- \( E_T^{\text{miss}}, \text{Meff} + \text{variants} \),
- \( \Delta \phi_{\min}^{4j} \) : minimum azimuthal separation between any of the 4 leading jets and the MET
Gluino pair production: 3 b-jets + MET (2)

Gbb model: $\text{BR}(\tilde{g} \rightarrow b\bar{b} \chi_1^0) = 100\%$

Gtt model: $\text{BR}(\tilde{g} \rightarrow t\bar{t} \chi_1^0) = 100\%$

The shaded (yellow) bands around the expected limits show the impact of the experimental uncertainties while the dotted red lines show the impact on the observed limit of the variation of the nominal signal cross-section by 1 sigma theoretical uncertainty. Also shown for reference are the results of the previous analysis.

- $m_{\chi_1^0} < 200$ GeV: exclude $\tilde{g}$ mass up to 1240 (1100) GeV in Gbb (Gtt) model.

- $m_{\tilde{g}} = 1100$ GeV: exclude $\chi_1^0$ mass below 570 (440) GeV in Gbb (Gtt) model.
Feeling a bit cramped?
Relaxing the constraints using “Simplified models”

Which atl conf or note???
Gauge mediation put 7TeV photon + b-jets + MET 1211.1167

N.B. \( E_{cm} = 7 \) TeV

Light gravitino LSP \( \rightarrow \) several candidates for NLSP
Stau/slepton/neutralino \( \rightarrow \) tau/lepton/\( X \) + gravitino

If neutralino NSLP \( \rightarrow \) decay depends on bino/wino/higgsino mixture
bino/wino/higgsino-like : neutralino \( \rightarrow \) photon/Z/h + gravitino

Search for combinations of photons/Z/h + missing transverse momentum
Prompt or non-prompt decay

Gluino (left) and squark (right) limits in GGM model with a prompt decay

Conclusion???
Previous results impose severe constraints on SUSY

If \( m(\text{Higgs}) \sim 125 \text{ GeV} \)

**then in a “Natural spectrum”**

\( m(\text{light-stop-bottom, charginos}) \leq 500 \text{ GeV} \)

\( m(\text{gluino}) \leq 1100-1500 \text{ GeV} \) [arxiv 1302.2146v1, 1110.6670]

Hence emphasize search for

\[ \rightarrow \text{gluino mediated and direct production of stops or sbottoms} \]

\[ \rightarrow \text{direct production of charginos and neutralinos (see Stewart Martin-Haugh’s talk)} \]
Direct medium stop production: two leptons + MET

3 signal regions

Background
Top production, diboson: from data CR
Fake leptons, QCD multijet: from data;
Other backgrounds: MC

Discriminating variable MT2

\[ m_{T2}(\mathbf{p}_T^\ell_1, \mathbf{p}_T^\ell_2, \mathbf{p}_T^{\text{miss}}) = \min_{q_T + r_T = \mathbf{p}_T^{\text{miss}}} \left\{ \max[ m_T(\mathbf{p}_T^\ell_1, q_T), m_T(\mathbf{p}_T^\ell_2, r_T) ] \right\} \]

Exclude

150 GeV < m_{\text{stop}} < 450 GeV

for m_{\text{chargino}} and m_{\text{stop}} approximately degenerate and m_{\chi_1^0} = 0

ATLAS-CONF-2012-167
Direct stop production: one lepton + jets + MET

Both stop1 → b \(\chi_1^+\) with \(\chi_1^+ \rightarrow W(\ast) \chi_1^0\)
or both stop1 → t \(\chi_1^0\)

Exclude
If both stop → top + LSP
225 GeV < \(m_{\text{stop}}\) < 560 GeV for \(m_{\text{LSP}}=0\)
and \(m_{\text{stop}}\) < 500 GeV for \(m_{\text{LSP}}<175\) GeV
If both stop → b + chargino
\(m_{\text{stop}}\) < 350 GeV for \(m_{\text{LSP}}=0\) and \(m_{\text{chargino}}=150\) GeV

6 signal regions
Background
Dileptonic ttbar, W+jets, top: from data CR
QCD multijet: from data
Other: from MC

Discriminating variables
MET, MET/√HT, mT, mT2
Gluino mediated stop production

\[ \tilde{g}\tilde{g} \text{ production, } \tilde{g} \rightarrow t\tilde{t}\chi_1^0 \]

CL$_S$ 95% C.L. limits. $\sigma_{\text{susy}}$\text{theory not included.}

- 0-lepton, $\geq$ 3 b-jets
  $[L_{\text{int}} = 12.8 \text{ fb}^{-1}, 8 \text{ TeV}]$
  ATLAS-CONF-2012-145

- 3-leptons, $\geq$ 4 jets
  $[L_{\text{int}} = 13.0 \text{ fb}^{-1}, 8 \text{ TeV}]$
  ATLAS-CONF-2012-151

- 0-lepton, $\geq$ 6-9 jets
  $[L_{\text{int}} = 5.8 \text{ fb}^{-1}, 8 \text{ TeV}]$
  ATLAS-CONF-2012-103

- 2-SS-leptons, $\geq$ 4 jets
  $[L_{\text{int}} = 5.8 \text{ fb}^{-1}, 8 \text{ TeV}]$
  ATLAS-CONF-2012-105

\[ m_{\tilde{g}} \text{ [GeV]} \]

\[ m_{\tilde{t}} \text{ [GeV]} \]

ATLAS Preliminary
Searches for gaugino pair production: 3 leptons + MET

Simplified models i.e. $m_{\chi_1^0} = 0$
exclude

$m_{\text{chargino}} < 580 \text{ GeV}$ when light sleptons
$150 \text{ GeV} < m_{\text{chargino}} < 300 \text{ GeV}$ when heavy sleptons

ATLAS-CONF-2012-154
RPV tau sneutrino:
search for heavy narrow resonance → $e\mu$, $e\tau$, $\mu\tau$

RPV lagrangian = $\frac{1}{2} \lambda_{ijk} L_i L_j e_k + \lambda'_{ijk} L_i Q_j d_k = \text{Multileptons} + \text{Leptoquarks}$

Upper limit on $\sigma_{\text{prod}} \times \text{B.R.}$ versus $m_{\text{sneutrino}}$ for the $e\mu$ mode

arXiv:1212.1272
Long lived sleptons and R-hadrons

**Signal**
Sleptons (two muons)
and R-hadrons (3 different detector analyses)
i.e. bound colourless states
of Long-Lived-Particle (squarks/gluinos)
with quarks/gluons

**Background**
High pT muons with mis-measured
$\beta=v/c$ or large ionisation: from data

Long-lived staus in GMSB models excluded for $M_{\text{stau}} < 300$ GeV for $\tan \beta = 5-20$.
Directly produced long-lived sleptons are excluded for $M_{\text{slepton}} < 278$ GeV.

R-hadrons,
composites of gluino (stop, sbottom) and light quarks, excluded for $m_{\text{R-hadron}} < 985$ GeV (683 GeV, 612 GeV)
when using a generic interaction model.
Additionally 2 sets of limits on R-hadrons
obtained less sensitive to interaction model.

arXiv:1212.1597
SUSY - Upgrade
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[Graph showing mass spectra for SUSY particles, with ATLAS preliminary simulation results at √s = 14 TeV.]

- Red dashed line: 3000 fb⁻¹, 95% exclusion limit
- Red solid line: 3000 fb⁻¹, 5σ discovery reach
- Blue dotted line: 300 fb⁻¹, 95% exclusion limit
- Blue solid line: 300 fb⁻¹, 5σ discovery reach

The mass scale is shown on the x-axis for \( \tilde{\chi}_1^\pm \) and \( \tilde{\chi}_2^0 \) with mass values ranging from 100 to 800 GeV. The y-axis shows the mass of \( \tilde{\chi}_1^0 \) ranging from 0 to 700 GeV.

The graph includes the cross section (pb) for pp → \( \tilde{\chi}_1^+ \tilde{\chi}_2^0 \), with \( \tilde{\chi}_2^0 \) decaying to WZ, which is 100%.

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Exotics searches
Searches in the dijet mass distribution

The models
• **Excited quarks (Pythia6/8)**
• Also looked at Axigluon, Quantum Black Hole, RS Graviton in arXiv:1210.1718

**Background**
Fitting smooth functional form to data

**Variable**
Dijet invariant mass

\[ \text{ATLAS Preliminary} \]
\[ \sigma \times A \text{ [pb]} \]

\[ \text{ATLAS Preliminary} \]
\[ \int L dt = 13.0 \text{ fb}^{-1} \]
\[ \sqrt{s} = 8 \text{ TeV} \]

**Exclude**
excited quark mass \( m(q^*) < 3.84 \text{ TeV} \)

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