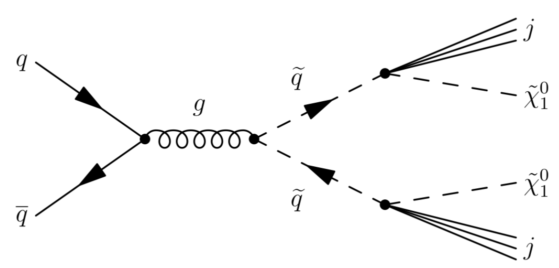
LHCC Poster Session - CERN, 23 March 2011

Search for squarks and gluinos with jets and missing transverse momentum

2010 ATLAS search [1]

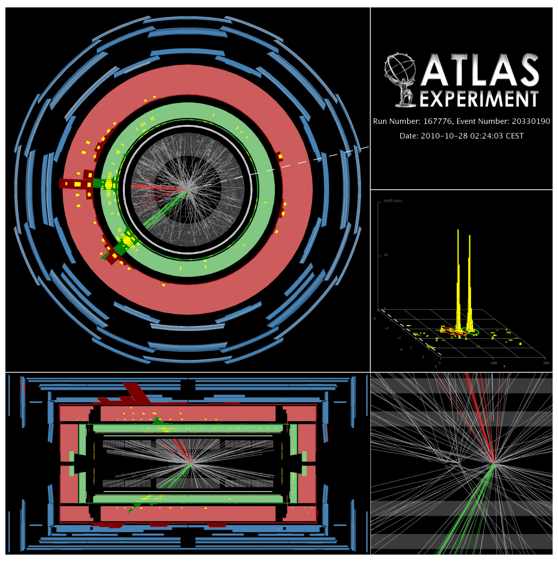
- LHC produces coloured supersymmetric particles, i.e. squarks and gluinos [2].
- Sparticles decay to Standard Model quarks ⇒ at least two energetic jets.
- Lightest supersymmetric particle (LSP) is stable and non-interacting ⇒ large missing transverse momentum (MPT).



- 35 pb^{-1} of 7 TeV proton-proton collision data used for analysis, after selections on data quality and trigger decision.
- Channel without leptons benefits from more statistics, though backgrounds are larger.
- The tightest constraints to date were set on the SUSY parameter space.

Target topologies

- Squarks decay directly to a jet and LSP.
- Gluinos undergo three-body direct decays to two jets and LSP.
- Dijet signatures give better squark sensitivity, requiring a third jet improves gluino sensitivity.
- Longer cascade decays via charginos and neutralinos can produce even more jets.



Prototypical event observed in 2010, passing the 2-jet event selection criteria.
- Jets highlighted in red and green.
- Dashed line indicates direction of the missing momentum vector.

Signal selection and distributions

Two signal variables were used, both of which are sensitive to the mass scale m_{SUSY} of supersymmetric particle production.

Effective mass (m_{eff}) – the scalar sum of the MPT and the transverse momenta of the first N jets, where here N = 2, 3.

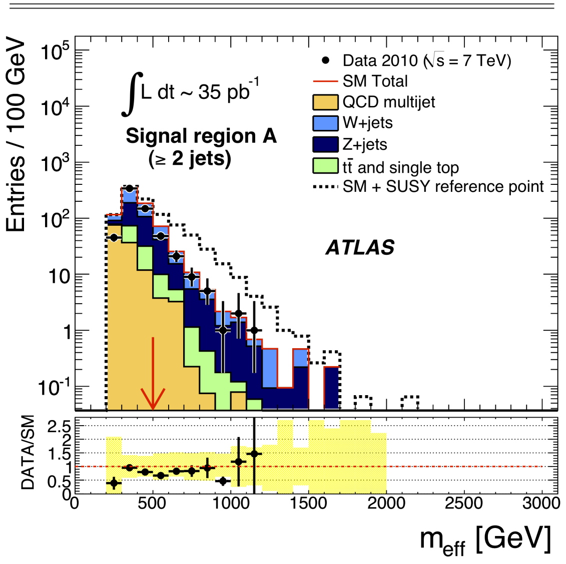
Stransverse mass (m_{T2}) [3] – generalisation of the familiar transverse mass to the pair-production of heavy particles, each decaying to some visible objects and one invisible object. It gives an optimal lower bound on the mass of the pair-produced particles, assuming the stated decay topology.

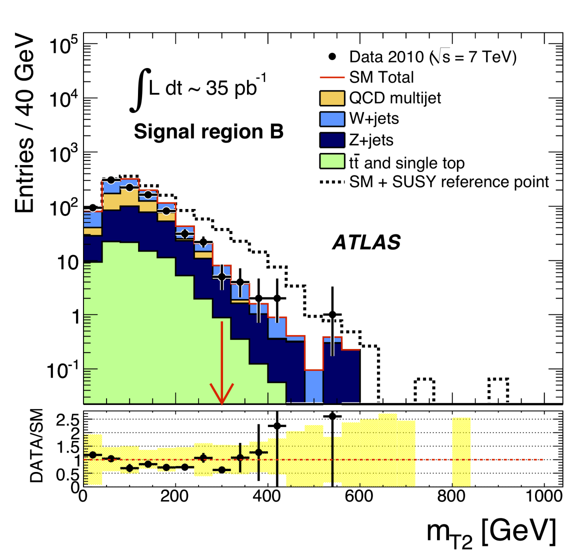
Basic event selection:
- primary vertex and "cleaning" cuts to reduce non-collision backgrounds and cosmics.
- veto on isolated leptons and electrons in calorimeter transition region.
- cuts on leading jet p_T and E_T^{miss} to ensure fully efficient triggers.

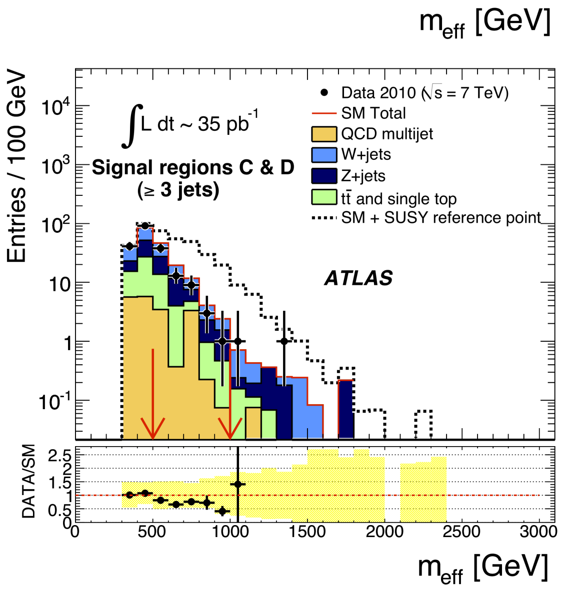
Additional background reduction cuts:
- azimuthal distance ($\Delta\phi$) between the p_T vectors of the first two or three jets and the MPT vector.
- ratio of E_T^{miss} to m_{eff}.
- QCD background is strongly suppressed, leaving vector boson production as the dominant SM contribution.

Four signal regions defined to cover a variety of SUSY signatures:
- A – low-mass disquark production
- B – high-mass disquark production
- C – digluino production
- D – associated squark-gluino production

		A	B	C	D
Pre-selection	Number of required jets	≥ 2	≥ 2	≥ 3	≥ 3
	Leading jet p_T [GeV]	> 120	> 120	> 120	> 120
	Other jet(s) p_T [GeV]	> 40	> 40	> 40	> 40
	E_T^{miss} [GeV]	> 100	> 100	> 100	> 100
Final selection	$\Delta\phi(\text{jet}, \vec{P}_T^{miss})_{min}$	> 0.4	> 0.4	> 0.4	> 0.4
	E_T^{miss}/m_{eff}	> 0.3	–	> 0.25	> 0.25
	m_{eff} [GeV]	> 500	–	> 500	> 1000
	m_{T2} [GeV]	–	> 300	–	–





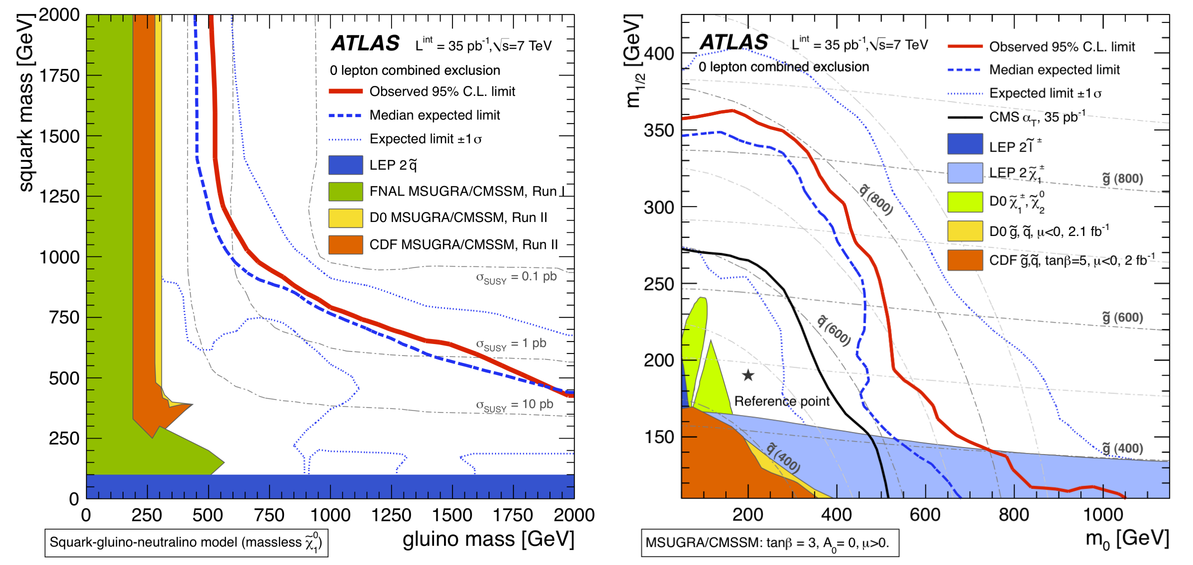


Plots of the signal variables m_{eff} and m_{T2} after pre-selection and $\Delta\phi$ and E_T^{miss}/m_{eff} cuts.
- Red arrows: cuts defining the relevant signal regions.
- Yellow shading in ratio plots: range of statistical, jet energy scale and jet energy resolution uncertainties summed in quadrature.
- Dotted histogram: reference signal point (★) in the CMSSM/MSUGRA [4] exclusion plot.
- All signal distributions agree within uncertainties with the Standard Model predictions.

Results and interpretation

	Signal region A	Signal region B	Signal region C	Signal region D
QCD	$7\,^{+8}_{-7}$[u+j]	$0.6\,^{+0.7}_{-0.6}$[u+j]	$9\,^{+10}_{-9}$[u+j]	$0.2\,^{+0.4}_{-0.2}$[u+j]
W+jets	50 ± 11[u] $^{+14}_{-10}$[j] $\pm$ 5[$\mathcal{L}$]	4.4 ± 3.2[u] $^{+1.5}_{-0.8}$[j] ± 0.5[$\mathcal{L}$]	35 ± 9[u] $^{+10}_{-8}$[j] ± 4[$\mathcal{L}$]	1.1 ± 0.7[u] $^{+0.2}_{-0.3}$[j] ± 0.1[$\mathcal{L}$]
Z+jets	52 ± 21[u] $^{+15}_{-11}$[j] $\pm$ 6[$\mathcal{L}$]	4.1 ± 2.9[u] $^{+2.1}_{-0.8}$[j] ± 0.5[$\mathcal{L}$]	27 ± 12[u] $^{+10}_{-6}$[j] ± 3[$\mathcal{L}$]	0.8 ± 0.7[u] $^{+0.6}_{-0.0}$[j] ± 0.1[$\mathcal{L}$]
$t\bar{t}$ and t	10 ± 0[u] $^{+3}_{-2}$[j] $\pm$ 1[$\mathcal{L}$]	0.9 ± 0.1[u] $^{+0.4}_{-0.3}$[j] ± 0.1[$\mathcal{L}$]	17 ± 1[u] $^{+6}_{-4}$[j] ± 2[$\mathcal{L}$]	0.3 ± 0.1[u] $^{+0.2}_{-0.1}$[j] ± 0.0[$\mathcal{L}$]
Total SM	118 ± 25[u] $^{+32}_{-23}$[j] ± 12[$\mathcal{L}$]	10.0 ± 4.3[u] $^{+4.0}_{-1.9}$[j] ± 1.0[$\mathcal{L}$]	88 ± 18[u] $^{+26}_{-18}$[j] ± 9[$\mathcal{L}$]	2.5 ± 1.0[u] $^{+1.0}_{-0.4}$[j] ± 0.2[$\mathcal{L}$]
Data	87	11	66	2

Expected and observed numbers of events in the four signal regions.
- Backgrounds predicted from Monte Carlo simulations, verified against data-driven methods.
- QCD expectation further normalised to the data in a control region.
- Sources of uncorrelated uncertainties [u] include MC statistics, statistics in and extrapolation from control regions, the jet energy resolution and lepton efficiencies.
- Correlated systematics include the jet energy scale [j], and the luminosity [$\mathcal{L}$].
- The 2010 data are consistent at the 1-sigma level with the Standard Model predictions.



Interpretation of the ATLAS results as 95% C.L. exclusion limits on the SUSY parameter space.
Left: Simplified MSSM model containing only the gluino, first- and second-generation squarks and a massless neutralino LSP, enforcing direct squark and gluino decays.
Right: Slice of the CMSSM/MSUGRA parameter space with tan(β)=3, A0=0, μ>0.

- Limits are robust against changes in model parameters, e.g. the LSP mass (up to ~100 GeV) in the MSSM phenological grid, and tan(β) in the CMSSM/MSUGRA grid.
- Results from CMS [5], LEP [6] and the Tevatron [7] are shown for comparison, but may have different model assumptions, as noted in the legends.

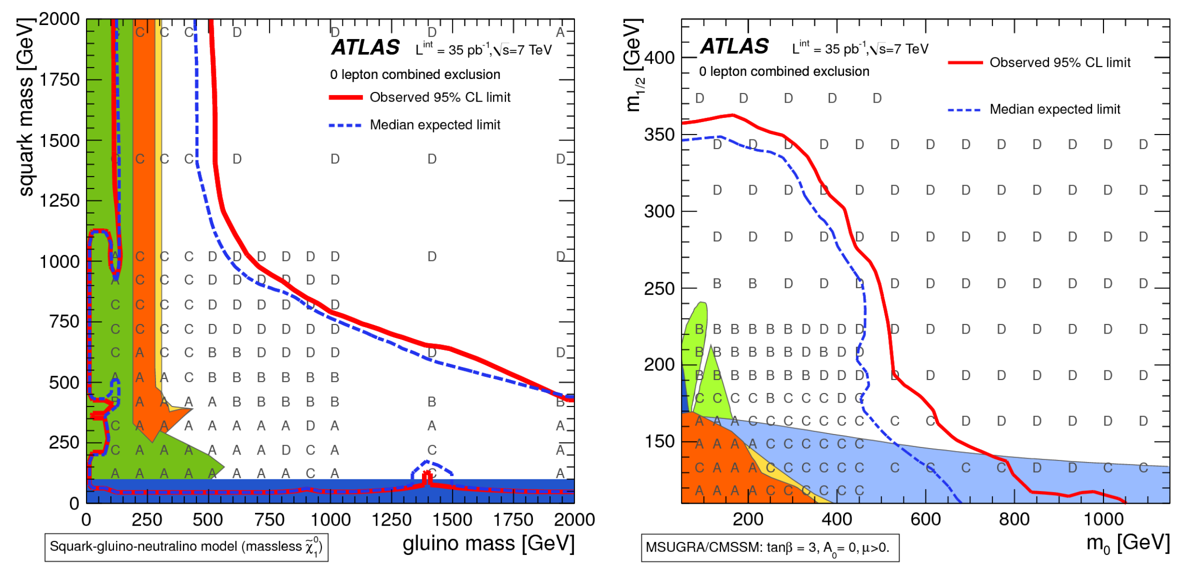


Illustration of signal region optimisation for decay topologies
- Limits from the four signal regions were combined to produce the final exclusion plot.
- At each grid point, determined exclusion significance using optimal signal region, i.e. that giving the best expected sensitivity.
- Each signal region is optimal in a different (contiguous) region of parameter space.
- No data was used in optimisation, hence no bias or "Look Elsewhere Effect" was introduced.

Summary

In 35 pb^{-1} of 7 TeV proton-proton collision data, ATLAS observed no substantial excesses over the Standard Model expectations.

Each signal region set an upper limit on the effective cross-section ($\sigma_{eff} = \sigma \cdot A \cdot BR$) due to BSM physics:

- A – $\sigma_{eff} < 1.3$ pb
- B – $\sigma_{eff} < 0.35$ pb
- C – $\sigma_{eff} < 1.1$ pb
- D – $\sigma_{eff} < 0.11$ pb

The upper limits on SUSY production set by ATLAS imply that in various classes of SUSY models, squarks and gluinos must have masses in excess of 400-800 GeV.

Bibliography

[1] The ATLAS Collaboration. arXiv:1102.5290 [hep-ex].

[2] Yu.A. Golfand and E.P. Likhtman, JETP Lett. 13 (1971) 323-326.
A. Neveu and J.H. Schwartz, Nucl. Phys. B31 (1971) 86-112.
A. Neveu and J.H. Schwartz, Phys. Rev. D4 (1971) 1109-1111.
P. Ramond, Phys. Rev. D3 (1971) 2415-2418.
D.V. Volkov and V.P. Akulov, Phys. Lett. B46 (1973) 109-130.
J. Wess and B. Zumino, Phys. Lett. B49 (1974) 52-60.
J. Wess and B. Zumino, Nucl. Phys. B70 (1974) 39-50.

[3] C. G. Lester et al., Phys. Lett. B463 (1999) 99–103.
A. Barr et al., J. Phys. G29 (2003) 2343–2363.
H.-C. Cheng and Z. Han, JHEP 12 (2008) 063.

[4] A. H. Chamseddine et al., Phys. Rev. Lett. 49 (1982) 970.
R. Barbieri et al., Phys. Lett. B119 (1982) 343.
L. E. Ibanez, Phys. Lett. B118 (1982) 73.
L. J. Hall et al., Phys. Rev. D27 (1983) 2359–2378.
N. Ohta, Prog. Theor. Phys. 70 (1983) 542.
G. L. Kane et al., Phys. Rev. D49 (1994) 6173–6210.

[5] CMS Collaboration, arXiv:1101.1628 [hep-ex].

[6] L3 Collaboration, Phys. Lett. B580 (2004) 37.

[7] D0 Collaboration, Phys. Rev. Lett. 75 (1995) 618–623.
D0 Collaboration, Phys. Lett. B660 (2008) 449–457.
D0 Collaboration, Phys. Lett. B680 (2009) 34–43.
CDF Collaboration, Phys. Rev. Lett. 88 (2002) 041801.
CDF Collaboration, Phys. Rev. Lett. 102 (2009) 121801.

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