Presentation of ATLAS SUSY results

LPCC workshop:
Searches for new physics: recommendations for the presentation of LHC results

Disclaimer:
Current ATLAS SUSY guidelines on presenting results do not necessarily apply to previously published results, or non-SUSY results.

CERN, February 13th 2012

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ATLAS

Results provided in paper/conf note

example **upper limits table**

4 signal-regions | σ_{vis} | N_{vis} | N_{vis}

Electron channel	$\langle\epsilon\sigma\rangle^{95}_{obs}$ [fb]	S^{95}_{obs}	S^{95}_{exp}
3JL	50	52	63^{+23}_{-11}
3JT	14	14.3	$16.5^{+6.7}_{-3.0}$
4JL	33	34	38^{+15}_{-7}
4JT	10	10.6	$9.5^{+4.3}_{-1.6}$

Example from SUSY 1-lepton paper (arxiv 1109.6606)

For each signal-region (SR) provide

- upper limit on the number of visible signal events in SR:
  $N_{vis} = N_{vis}(N^{obs}, N^{bkg}, \Delta^{bkg})$

- upper limit on the visible signal cross-section in SR:
  $\sigma_{vis} = A x \epsilon x \sigma = N_{vis} / L$
  $\sigma_{vis}(N^{obs}, N^{bkg}, \Delta^{bkg}, L, \Delta L)$

Blue: uncertainties (some complexity e.g. correlated unc. not shown here)

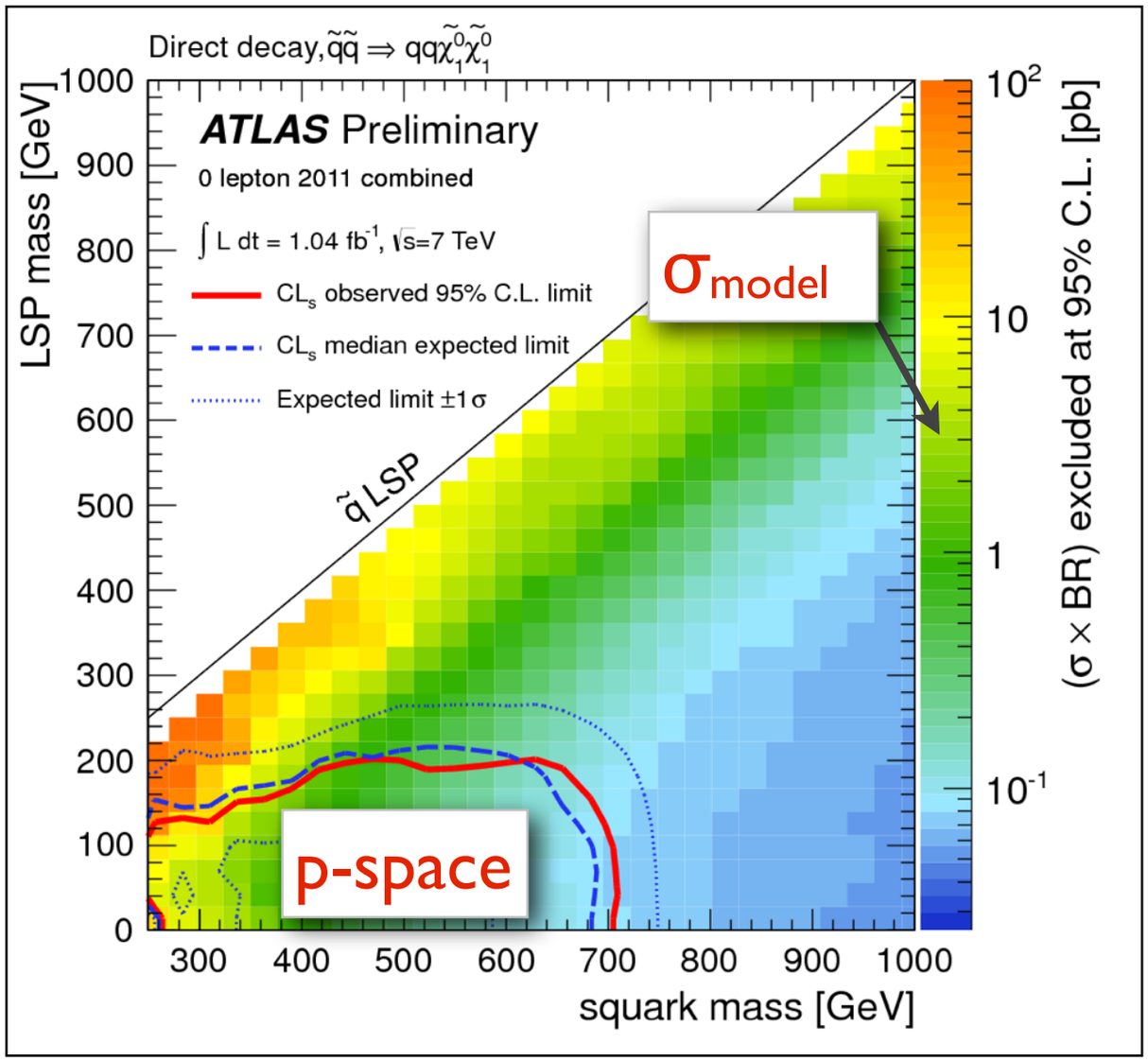
- Provide expected and observed limits.

- These limits are signal model independent, [but analysis and detector dependent]
  can be used to compare against prediction of any signal model (in the analysis' SR).

Default stats. method: CL_S

Results provided in paper/conf note

example **interpretation**



Example from ATLAS-CONF-2011-155

- For multi-SR analyses:
  Check in the paper whether SR bins (channels) are combined, or only one is chosen. In the latter case, it's always the best expected SR per signal model point.

- Limits in the model parameter space
  $CLs(N^{obs}, N^{bkg}, \Delta^{bkg}, L, \Delta L, (Ax\varepsilon)^{model}, \Delta(Ax\varepsilon)^{model}, \sigma^{sig\ prod}, \Delta\sigma^{sig\ prod})$

  - Provide observed & expected p-space limits, and 1σ band around expectation.

- [optional] upper limit on the production cross-section:
  $\sigma_{model} = N_{vis} / [(Ax\varepsilon)^{model} \times L]$
  $\sigma_{model}\ (N^{obs}, N^{bkg}, \Delta^{bkg}, L, \Delta L, (Ax\varepsilon)^{model}, \Delta(Ax\varepsilon)^{model})$

  - No dependence on $\sigma^{sig\ prod}$, $\Delta\sigma^{sig\ prod}$

  - So far provided for simplified models only.

Default stats. method: CL_S

Blue: uncertainties (some complexity e.g. correlated unc. not shown here)

Numerical results in HEPdata

Published + auxiliary plots and interpretations are numerically available from HEPdata.

ATLAS SUSY results from https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

2011 Data

Short Title of the Search	Date	√s (TeV)	L (fb^{-1})	Document	Plots+Aux. Material	Journal
Direct sbottom (2bjets + Etmiss)	12/2011	7	2.05	1112.3832	Link	Accepted by PRL
2photons + Etmiss	11/2011	7	1.07	1111.4116	Link	Submitted to PLB
2leptons + jets + Etmiss	10/2011	7	1.04	1110.6189	Link	Accepted by PLB
0lepton + >=6jets + Etmiss	10/2011	7	1.34	1110.2299	Link (inc. HEPData)	JHEP 11 (2011) 99
1lepton + jets + Etmiss	09/2011	7	1.04	1109.6606	Link	Accepted by PRD
0lepton + jets + Etmiss	09/2011	7	1.04	1109.6572	Link (inc. HEPData)	Submitted to PLB
Electron-muon resonance (RPV)	09/2011	7	1.07	1109.3089	Link (inc. HEPData)	EPJC 71 (2011) 1809

2010 Data

Short Title of the Search	Date	√s (TeV)	L (pb^{-1})	Document	Plots+Aux. Material	Journal
Long-lived stopped gluinos NEW	01/2012	7	31	1201.5595	Link	Submitted to EP
Massive colored scalars (4jets)	10/2011	7	34	1110.2693	Link (inc. HEPData)	EPJC 71 (2011)
Displaced vertices	09/2011	7	33	1109.2242	Link	PLB 707 (2012)
2photons + Etmiss	07/2011	7	36	1107.0561	Link (inc. HEPData)	EPJC 71 (2011
Heavy long-lived charged particles	06/2011	7	37	1106.4495	Link (inc. HEPData)	PLB 703 (2011)
2leptons + Etmiss	03/2011	7	35	1103.6214	Link	EPJC 71 (2011)
Same Flavor 2leptons+Etmiss	03/2011	7	35	1103.6208	Link	EPJC 71 (2011)
Electron-muon resonance (RPV)	03/2011	7	35	1103.5559	Link (inc. HEPData)	PRL 106 (2011)
bjets + jets + Etmiss	03/2011	7	35	1103.4344	Link (inc. HEPData)	PLB 701 (2011)
Stable hadronising squarks and gluinos	03/2011	7	34	1103.1984	Link (inc. HEPData)	PLB 701 (2011)
0lepton + jets + Etmiss	02/2011	7	35	1102.5290	Link (inc. HEPData)	PLB 701 (2011)
1lepton + jets + Etmiss	02/2011	7	35	1102.2357	Link (inc. HEPData)	PRL 106 (2011)

The Durham HepData Project

REACTION DATABASE | DATA REVIEWS | PARTON DISTRIBUTION FUNCTION SERVER | OTHER HEP RESOURCES

Extra resource relating to the paper arxiv:1109.6572 - CERN-PH-2011-145

Experimental acceptance/efficiency and excluded cross section*branching ratios:
- Signal expectations and experimental acceptance/efficiency for M_gluino vs M_squark grid (massless LSP)
- Signal expectations and experimental acceptance/efficiency for CMSSM/MSUGRA grid

SLHA files:
- susy sqgl slha files
- susy CMSSM/MSUGRA slha files

Extra resource relating ot the ATLAS NOTE ATLAS-CONF-2011-155

Experimental acceptance/efficiency and excluded cross section*branching ratio for M_gluino vs M_LSP grid:
- (direct decays) - SHLA files
- (one-step cascade decays, x=1/4) - SHLA files

Example of extra resources from 0-lepton search (http://hepdata.cedar.ac.uk/view/p8106)

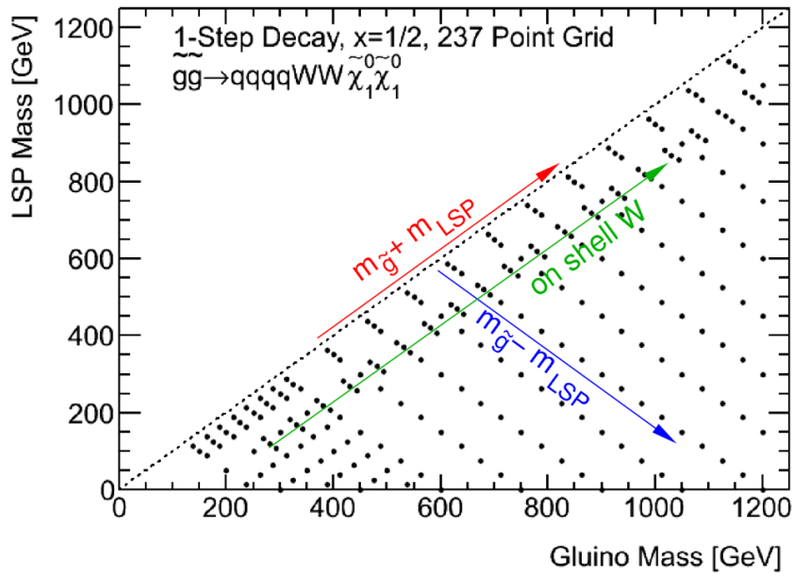
- Extra resources: $(A\times\varepsilon)^{\text{signal model}}$, SLHA files
- available for several publications

Input to HEPdata (starting with winter 2012 results)

Refined and extended list of input to HEPdata, starting with winter 2012 results.

- Plots, interpretation (CLs limits) from paper and auxiliary material
- For each signal region, and for all relevant models
  - acceptance (A), defined next page [$A=N_{fiducial}/N_{total}$]
  - efficiency (ε), defined next page [$\varepsilon=N_{fiducial\text{-}reco}/N_{fiducial}$]
  - Δ^{tot} total systematic and theoretical signal uncertainty, not including MC stat. unc.
  - CLs value
- For all relevant models
  - Number of generated MC events (can be used to derive all signal MC stat. unc.)
  - σ^{tot} total signal production cross section
  - SUSY Les Houches Accord (SLHA) files
- Relevant models:
  - E.g. small number of simplified models (easy kinematics)
  - no smoothing/interpolation between points

example "plane"



Definition of "fiducial" (or what's A and ε)

Guiding idea for fiducial cuts:

- defined using truth and hadron level quantities
- can be implemented by externals (w/o detector simulation)

Use a **common definition** for all ATLAS SUSY public results !

Axε is the full event selection efficiency at detector level.

Acceptance $A=N_{fiducial} / N_{total}$

where fiducial cuts are based on the following objects:

- truth electrons/muons/E_T^{miss} (non-interacting)
- hadron level jets
- heavy-flavor: b-quark matched to jet, at parton level

all above with analysis cuts on pT, eta.

Apply

- object overlap-removal (in eta-phi space)
- avoid leptons from b-jets: require mother's mass above 10 GeV or mother being a tau.

Efficiency $\varepsilon=N_{fiducial\text{-}reco}/N_{fiducial}$

where fiducial-reco cuts are our nominal analysis cuts, applied to detector level variables.
Differences to Acceptance include:

- Reconstruction inefficiencies
- Full particle identification cuts
- Resolution effects
- trigger inefficiencies

Note that ε can be bigger or smaller than one.

ATLAS SM group uses b-hadrons to define fiducial cross-sections.

Re-interpreting Results

A user can probe his/her favorite model(s) by:

1. take our background estimate (per SR): $N^{tot} \pm \Delta^{tot}$ (numbers in publication)
2. implement event selection (per SR), validate against our acceptance numbers (in HEPdata)
3. implement a detector response, validate against our efficiency numbers (in HEPdata)
4. run on favorite model, and calculate sensitivity/limits using our visible upper limits (from publication)

The limit setting code (CLs, p-values, combination of channels/bins) used within the ATLAS SUSY group is based on the public ROOT / RooStats package. From this public package it is a small step to a standalone statistics tool to be used with our data input from HepData and some signal model (passed through Axε). The ATLAS SUSY group considers to provide such a standalone statistics tool.

Overlap with Recommendations Document

Analysis Description

Recommendation 1a: *Provide a clear, explicit description of the analysis in publications. In particular, the most crucial information such as basic object definitions and event selection should be clearly displayed in the publications, preferably in tabular form, and kinematic variables utilised should be unambiguously defined. Further information necessary to reproduce the analysis should be provided on a suitable common platform.*

→ Provide accurate description in publications; concrete feedback is very much appreciated.

Missing pieces of information identified and remedied thanks to user feedback.

Example event selection from arxiv 1109.6572

Signal Region	≥ 2-jet	≥ 3-jet	≥ 4-jet	High mass
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 130	> 130	> 130	> 130
Leading jet p_{T}	> 130	> 130	> 130	> 130
Second jet p_{T}	> 40	> 40	> 40	> 80
Third jet p_{T}	–	> 40	> 40	> 80
Fourth jet p_{T}	–	–	> 40	> 80
$\Delta\phi(\mathrm{jet}, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$	> 0.4	> 0.4	> 0.4	> 0.4
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$	> 0.3	> 0.25	> 0.25	> 0.2
m_{eff}	> 1000	> 1000	> 500/1000	> 1100

Recommendation 1b: *Provide a common analysis database where all the experimental results are stored together with all necessary information about the analyses, including well-encapsulated functions, such as multivariate analysis (MVA) functions if they are needed.*

→ Publications + HepData records provide all relevant information. If and when future analyses employ encapsulated functions (e.g. MVA), then we intend to make the relevant functions (in form of code, or weight files) public too.

Disclaimer: the given comments/answers apply only to the ATLAS SUSY group

Detector Modeling

Recommendation 2a: *Provide histograms or functional forms of efficiency maps wherever possible in the auxiliary information, along with precise definitions of the efficiencies, and preferably provide them in standard electronic forms that can easily be interfaced with simulation or analysis software.*

→ Provide A and ε numbers (event-wise) for signal grid(s) in HEPdata, where a common definition for A, ε is used across the analyses.

Recommendation 2b: *Provide and maintain a public simulator developed by the collaboration, or provide official support of an existing one. The public simulator would provide the mapping from the pre-detector data to the post-reconstruction data.*

→ ATLAS is not planning to provide, maintain, and update a public simulation which is both simple/easy to use and sophisticated enough to be useful.

Note that by providing A and ε numbers separately, we facilitate the usage of external detector response numbers.

Analysis Dissemination (I)

Recommendation 3a: *Provide all crucial numbers regarding the results of the analysis, preferably in tabulated form in the publication itself. Further relevant information, like fit functions or distributions, should be provided as auxiliary material.*

→ Provide all crucial numbers in signal-region, and control-region(s), either in publication or in auxiliary material.

Example from arxiv 1109.6572 (similar table for CRs)

Process	Signal Region				
	≥ 2-jet	≥ 3-jet	≥ 4-jet, $m_{\text{eff}} > 500$ GeV	≥ 4-jet, $m_{\text{eff}} > 1000$ GeV	High mass
Z/γ+jets	32.3 ± 2.6 ± 6.9	25.5 ± 2.6 ± 4.9	209 ± 9 ± 38	16.2 ± 2.2 ± 3.7	3.3 ± 1.0 ± 1.3
W+jets	26.4 ± 4.0 ± 6.7	22.6 ± 3.5 ± 5.6	349 ± 30 ± 122	13.0 ± 2.2 ± 4.7	2.1 ± 0.8 ± 1.1
$t\bar{t}$+ single top	3.4 ± 1.6 ± 1.6	5.9 ± 2.0 ± 2.2	425 ± 39 ± 84	4.0 ± 1.3 ± 2.0	5.7 ± 1.8 ± 1.9
QCD multi-jet	0.22 ± 0.06 ± 0.24	0.92 ± 0.12 ± 0.46	34 ± 2 ± 29	0.73 ± 0.14 ± 0.50	2.10 ± 0.37 ± 0.82
Total	62.4 ± 4.4 ± 9.3	54.9 ± 3.9 ± 7.1	1015 ± 41 ± 144	33.9 ± 2.9 ± 6.2	13.1 ± 1.9 ± 2.5
Data	58	59	1118	40	18

Addendum to 3a: *For multi-bin results, provide an ensemble of sets of the numbers B, δB, $\mathcal{L}$, $\delta\mathcal{L}$, Q, k, etc in the auxiliary information. These would be created by sampling from the various experiment-specific systematic effects, such as the jet energy scale, jet energy resolution, etc. Systematic uncertainties external to the experiment, such as PDF uncertainties, need not be included because they induce correlations across measurements.*

→ For search results using binned shape fits and or combined signal-regions we intend to provide the crucial numbers tabulated for all bins/signal-regions in HepData.

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Analysis Dissemination (II)

Recommendation 3b: *Provide a mathematical description of the final likelihood function in which experimental data and parameters are clearly distinguished, either in the publication or the auxiliary information.*

→ A simplified description of the final likelihood function is given in the publications. The full likelihood can be complicated -- in particular for complex searches with several signal and control regions -- and would thus be hard to describe.

Recommendation 3c: *Additionally provide an digitized implementation of the likelihood that is consistent with the mathematical description.*

→ ATLAS has doubts about providing the full likelihood (in parameterised or digitised form). Making sure the likelihood is correct, and fully validated in all the corners of phase space / parameters is a lot of work which can only be done by experts in the analysis within the collaboration. Before publication, a huge amount of time is spent on every analysis to validate and debug all subtleties of correlated systematics etc for the publication's phase/p-space.

Interpretation of exp. results

Recommendation 4: *In the interpretation of experimental results, preferably provide the final likelihood function (following 3b or 3c), or provide a grid of confidence levels over the parameter space. The expected constraints should be given in addition to the observed ones, and whatever sensitivity measure is applied must be be precisely defined. Modeling of the acceptance needs to be precisely described.*

→ Starting with winter 2012 results, the ATLAS SUSY group will provide obs. CLs values, A, ε, Δ^{tot}(signal) for signal grid(s) on HepData. For some fall 2011 publications, part of this is already available on HepData.

The observed and expected visible upper limits (Axεxσ) are stated in every publication.

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Exclusive Analysis Design

Recommendation 5: *For Higgs searches, provide all relevant information on a channel-by-channel basis.*

→ Not covered in this talk.

Recommendation 6: *When relevant, design analyses and signal regions that are based on disjoint sets of events.*

→ This is the general approach taken in the ATLAS SUSY group. However, experimental and or analysis constraints (e.g. from background determination) render this difficult in some cases.

Note that searches can always be combined using the best expected signal-region.

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Summary

ATLAS SUSY group guidelines for presenting results

- ☑ Many of the draft Recommendations Document are in line with our current practices.
  - But also careful to not provide too much raw, undigested information that would allow unreliable conclusions to be too easily drawn.
- ☑ Our current result presentation strategy:
  - publish visible cross-section and chosen signal model(s) limits,
  - provide detailed analysis description, and crucial numbers for SRs and CRs,
  - provide acceptance and efficiency grids for benchmark or simplified models,
  - numerical results available from HEPData
- ☑ We want people to **use** our data and then tell us what information is missing.
  - will continue to refine our presentation strategy.