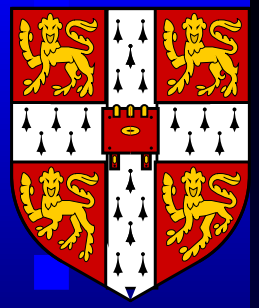


Implications for Constrained SUSY Models

by

Ben Allanach (University of Cambridge)

Talk outline

- Interpretations of SUSY searches for constrained models
- An example in depth: mAMSB
- A phenomenologist's shopping list

SPS Points Savaged at 165 pb^{-1}

Benchmark point	Model scenario	σ/pb				status
		A	B	C	D	ATLAS 35, 165/pb
ATLAS Limits		1.3	0.35	1.1	0.11	
SPS 1a [52]	CMSSM	2.031	0.933	1.731	0.418	A,B,C,D
SPS 1b [52]	CMSSM	0.120	0.089	0.098	0.067	165/pb
SPS 2 [52]	CMSSM	0.674	0.388	0.584	0.243	B,D
SPS 3 [52]	CMSSM	0.123	0.093	0.097	0.067	165/pb
SPS 4 [52]	CMSSM	0.334	0.199	0.309	0.144	D
SPS 5 [52]	CMSSM	0.606	0.328	0.541	0.190	D
SPS 6 [52]	CMSSM (non-universal $m_{1/2}$)	0.721	0.416	0.584	0.226	B,D
SPS 7 [52]	mGMSB ($\tilde{\tau}_1$ NLSP)	0.022	0.016	0.023	0.015	allowed
SPS 8 [52]	mGMSB ($\tilde{\chi}_1^0$ NLSP)	0.021	0.011	0.022	0.009	allowed
SPS 9 [52]	mAMSB	0.019*	0.004*	0.006*	0.002*	allowed

Figure 1: Dolan, Grellscheid, Jaeckel, Khoze, Richardson, arXiv:1104.0585

CMSSM at $1fb^{-1}$ is Getting Heavier

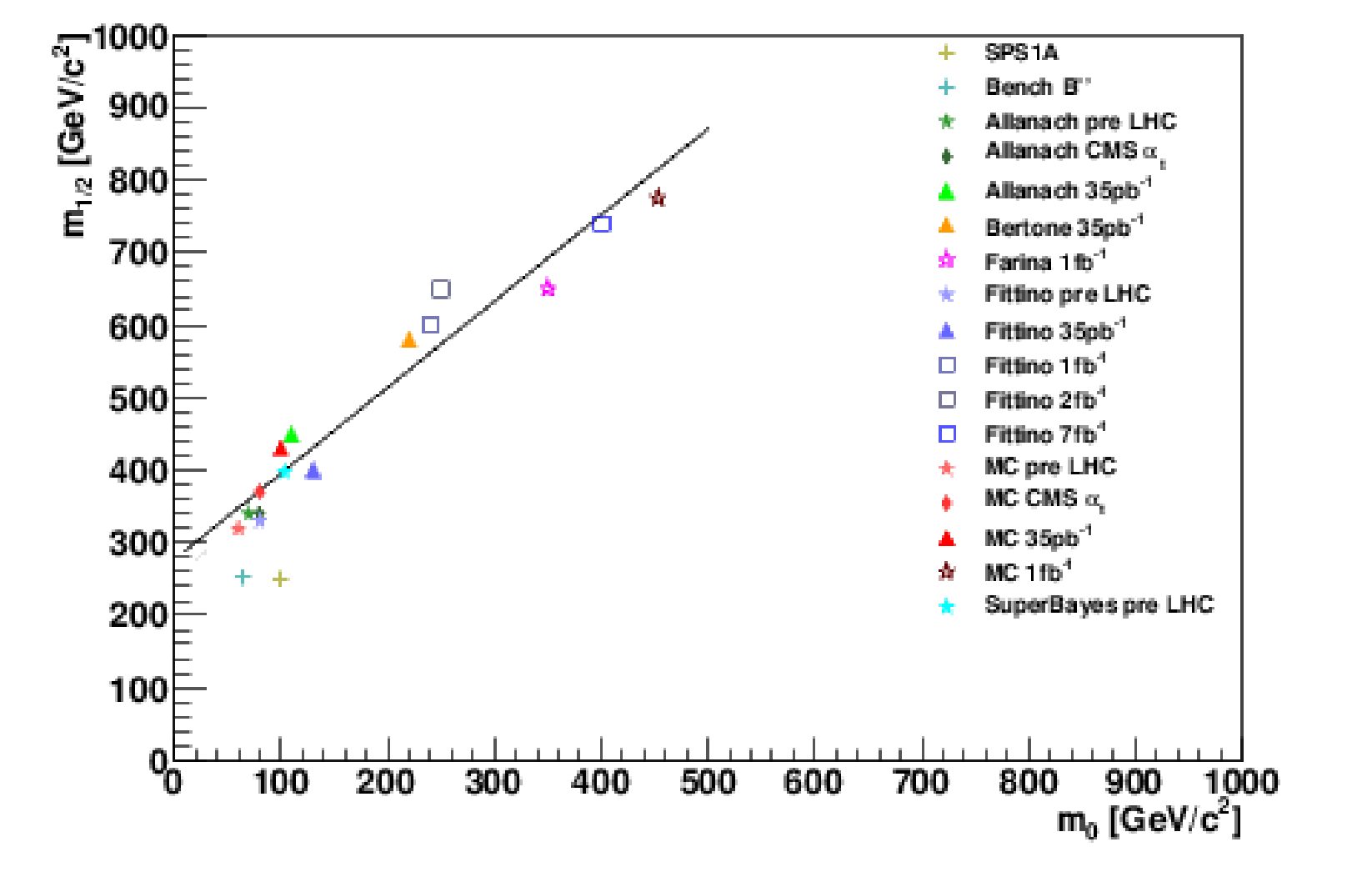


Figure 2: CMSSM good/best fit-points arXiv:1109.3859

Searches and the CMSSM

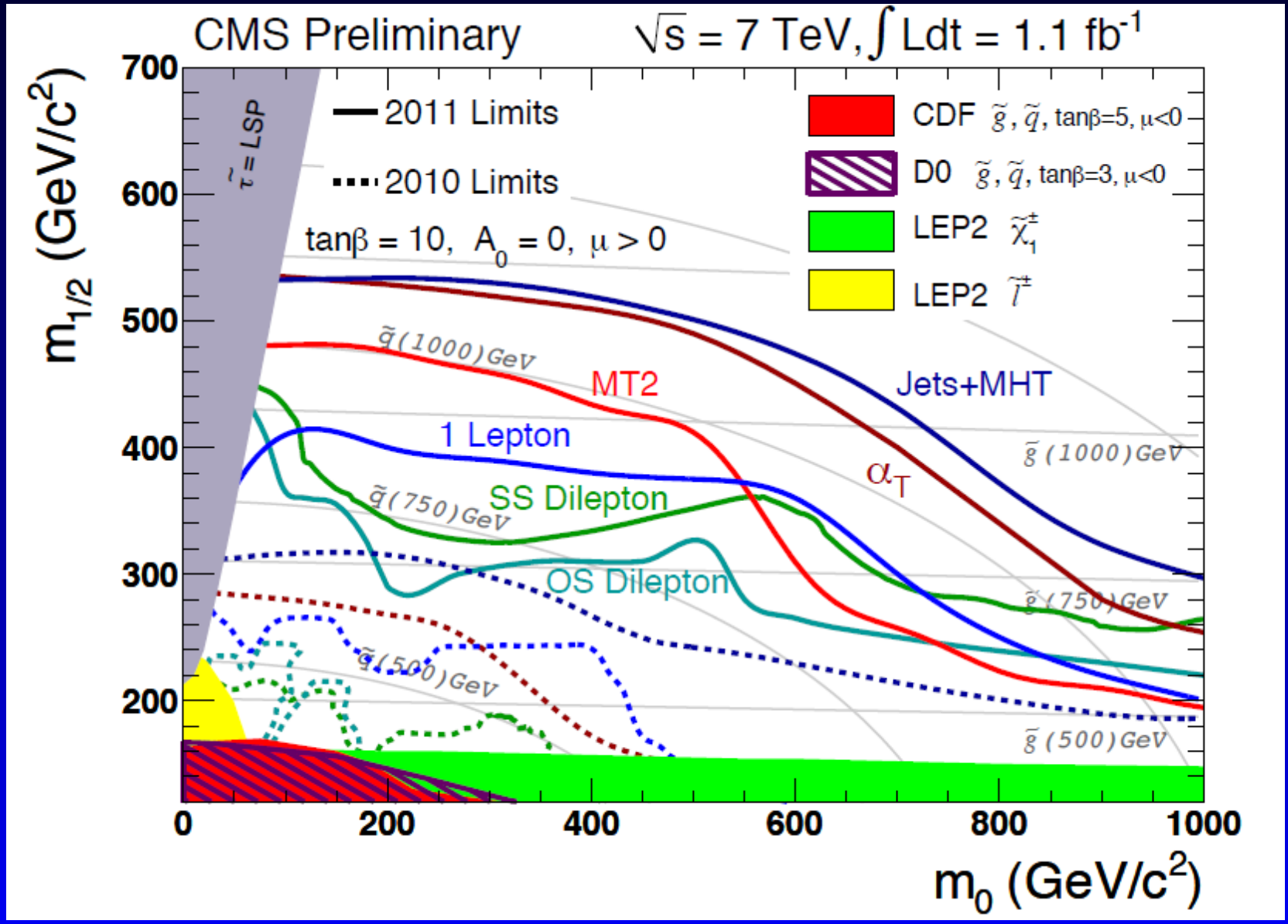
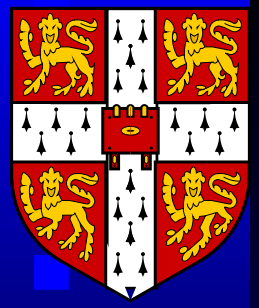


Figure 3: CMSSM CMS exclusions



Searches and the CMSSM

Interesting new search[a] for many jet final states (eg from gluinos). Shape of $\not{E}_T/\sqrt{H_T}$ does not depend on N_j: determine shape from lower N_j, normalise background to $\not{E}_T/\sqrt{H_T} < 1.5\sqrt{GeV}$ region and then you have a measured background extrapolation for $\not{E}_T/\sqrt{H_T} > 3.5\sqrt{GeV}$.

Signal region	7j55	8j55	6j80	7j80
Jet p_T	> 55 GeV		> 80 GeV	
Jet $\|\eta\|$	< 2.8			
ΔR_{ij}	> 0.6 for any pair of jets			
Number of jets	≥ 7	≥ 8	≥ 6	≥ 7
$E_{\mathrm{T}}^{\mathrm{miss}} / \sqrt{H_T}$	> 3.5 GeV$^{1/2}$			

Table 1: Definitions of the four signal regions.

[a] ATLAS, arXiv:1110.2299

Multijets Method

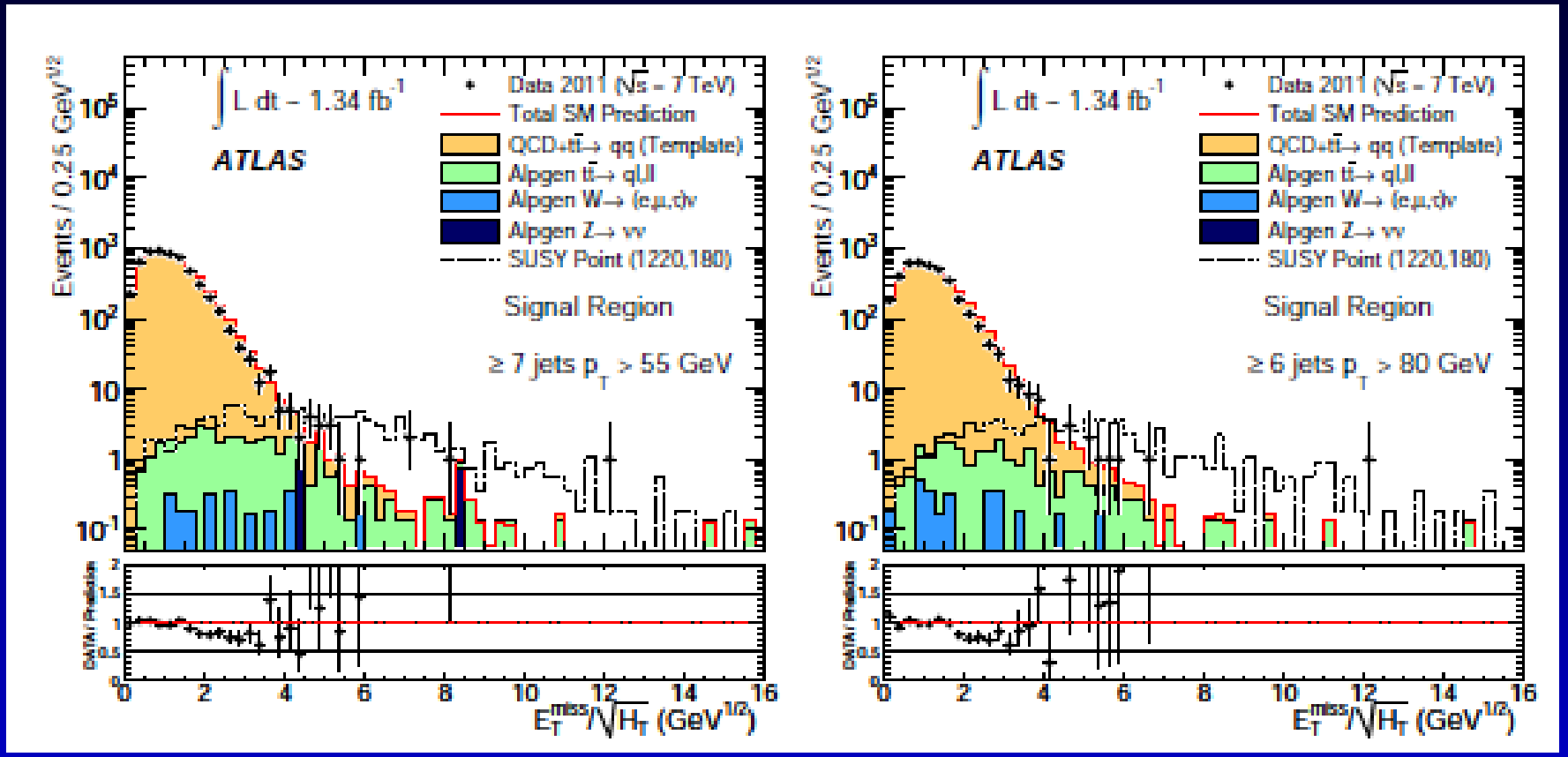
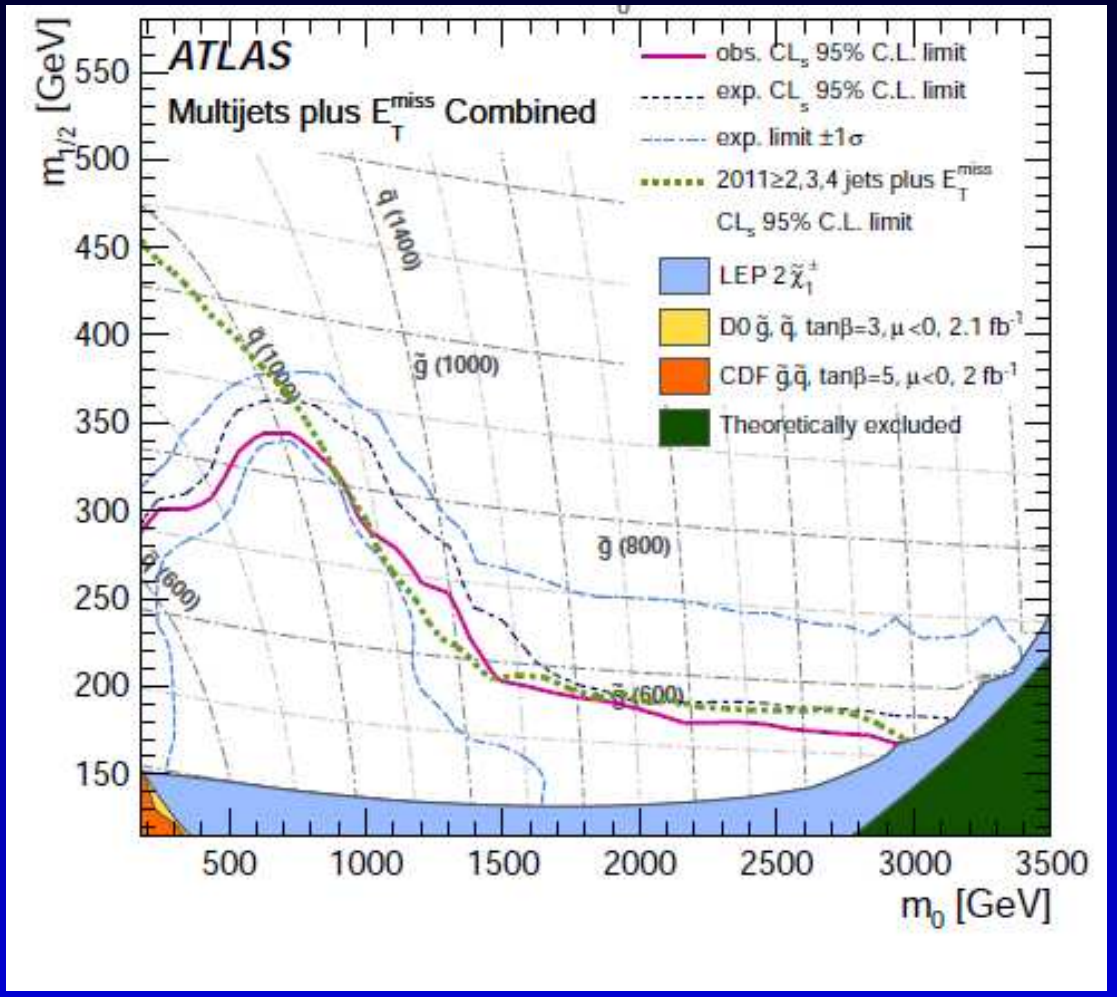


Figure 4: QCD template normalised to < 1.5 region. Smaller N_j used for shape in each case.

Searches and the CMSSM



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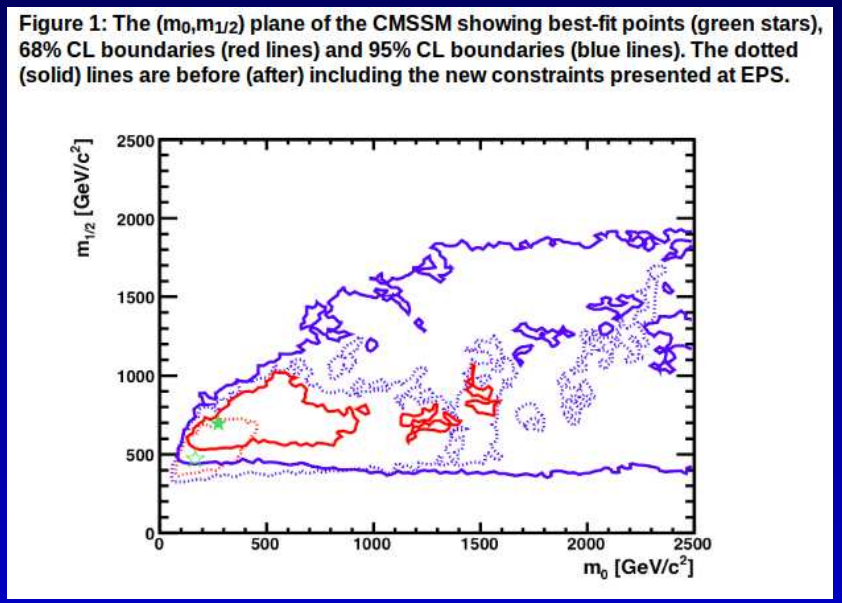
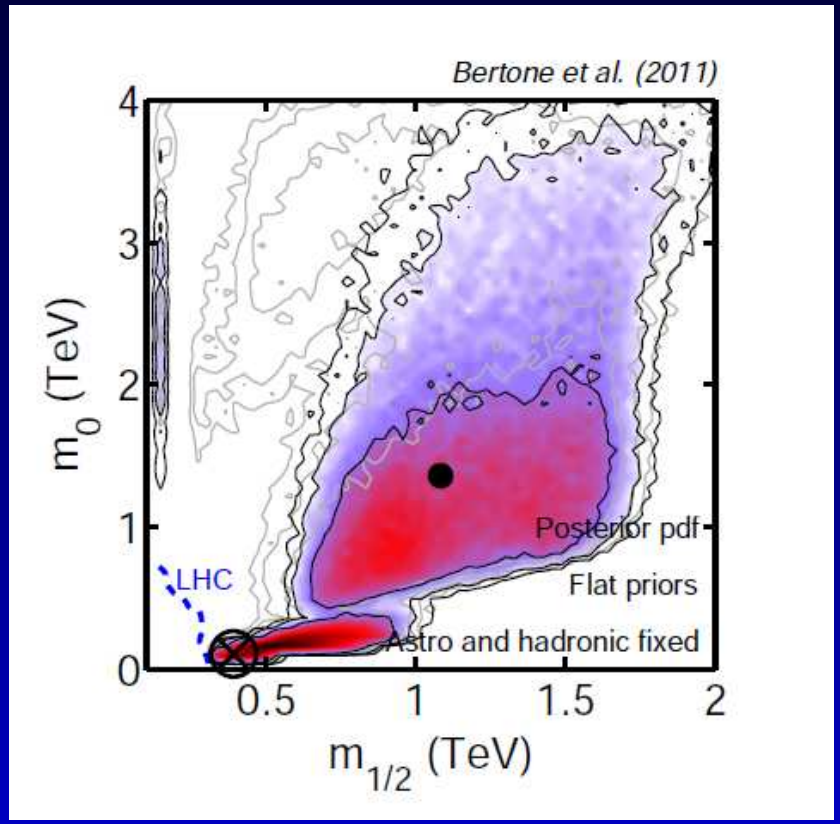
Updated Constraints on CMSSM Data

Including Xenon100 and 1fb^{-1} of LHC data:





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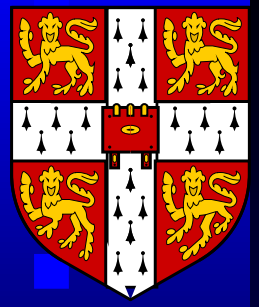

Benchmarks

Currently we[a] have devised SUSY benchmark models. 1109.3859

- CMSSM, NUHM, mAMSB, mGMSB, RPV and some simplified models (via pMSSM) are defined.
- Defining interesting *parameter planes*: identifying important parameters which control the masses of sparticles in each case.
- Discrete set of points along monotonic lines: next point for the experiments to study is defined as the lightest one that is not ruled out to 95% CL.

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[a] S.S. AbdusSalam, BCA H. Dreiner, J. Ellis, S. Heinemeyer, M. Krämer, M. Mangano, K.A. Olive, S. Rogerson, L. Roszkowski, M. Schlaffer, G. Weiglein

Benchmarks Example: mAMSB

Plane: $(m_{\rm aux}, m_0)$ with $\tan\beta = 10, \mu > 0$.
Line: $m_0 = 0.0075 m_{\rm aux}$, $\tan\beta = 10, \mu > 0$.
Points:

Point	$m_{\rm aux}$	m_0	$m_{\tilde{g}}$	$\langle m_{\tilde{q}} \rangle$	$m_{\tilde{t}_1}$	$m_{\tilde{b}_1}$	BR($\tilde{g} \to \tilde{t}t$)	BR($\tilde{g} \to \tilde{b}b$)
mAMSB1.1	4×10^4	300	890	880	630	765	69	29
mAMSB1.2	5×10^4	375	1085	1080	780	940	74	25
mAMSB1.3	6×10^4	450	1280	1280	925	1110	76	24
mAMSB1.N	...	...	...	...	...	...	...	...

Figure 5: mAMSB benchmark points arXiv:1109.3859.

Next point for consideration is *the next one that hasn't been yet ruled out to 95%*

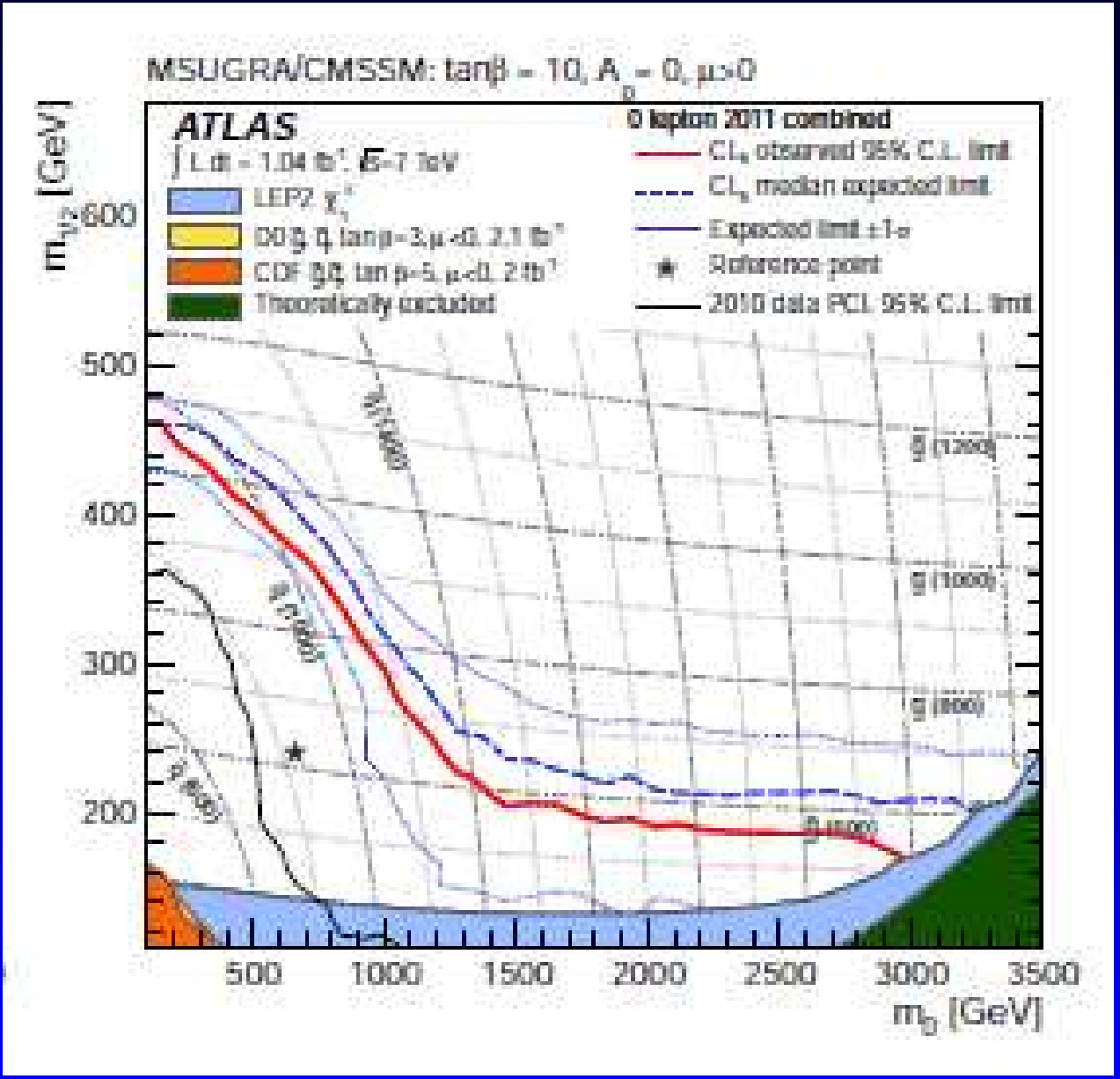
ATLAS 1 fb^{-1} 0-lepton Search

	≥ 2 jets	≥ 3 jets	≥ 4 jets	≥ 4 jets'	High mass
$p_T(j_1)$	> 130 GeV	> 130 GeV	> 130 GeV	> 130 GeV	> 130 GeV
$p_T(j_2)$	> 40 GeV	> 40 GeV	> 40 GeV	> 40 GeV	> 80 GeV
$p_T(j_3)$	–	> 40 GeV	> 40 GeV	> 40 GeV	> 80 GeV
$p_T(j_4)$	–	–	> 40 GeV	> 40 GeV	> 80 GeV
$\lvert\not{p}_T^{\rm miss}\rvert$	> 130 GeV	> 130 GeV	> 130 GeV	> 130 GeV	> 130 GeV
$\Delta\phi$	> 0.4	> 0.4	> 0.4	> 0.4	> 0.4
$\not{p}_T^{\rm miss}/m_{\rm eff}$	> 0.3	> 0.25	> 0.25	> 0.25	> 0.2
$m_{\rm eff}$	> 1000 GeV	> 1000 GeV	> 500 GeV	> 1000 GeV	> 1100 GeV
Observed	58	59	1118	40	18
Background	$62.4 \pm 4.4 \pm 9.3$	$54.9 \pm 3.9 \pm 7.1$	$1015 \pm 41 \pm 144$	$33.9 \pm 2.9 \pm 6.2$	$13.1 \pm 1.9 \pm 2.5$
$\sigma \times A \times \epsilon$/fb	22	25	429	27	17

At any point in parameter space, one chooses the set of cuts with the greatest expected sensitivity[a].

[a] ATLAS, arxiv:1109.6572

Results



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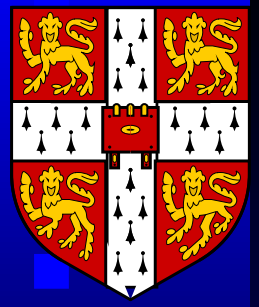

Intepretation

The results give a lower limit of 1020 GeV for $m_{\tilde{g}} = m_{\tilde{q}}$ in the CMSSM. We wish to *reinterpret* the search in mAMSB, to find the exclusion there (and study if mAMSB evades the search). We simulate *signal* only, with `HERWIG++-2.5.1`, and use ATLAS' upper limits on $\sigma \times A \times \epsilon$. However *we have to fit the signal systematics*.

This becomes more involved when you want to do a fit and reconstruct the likelihood. To validate then, you need also details on the statistics.

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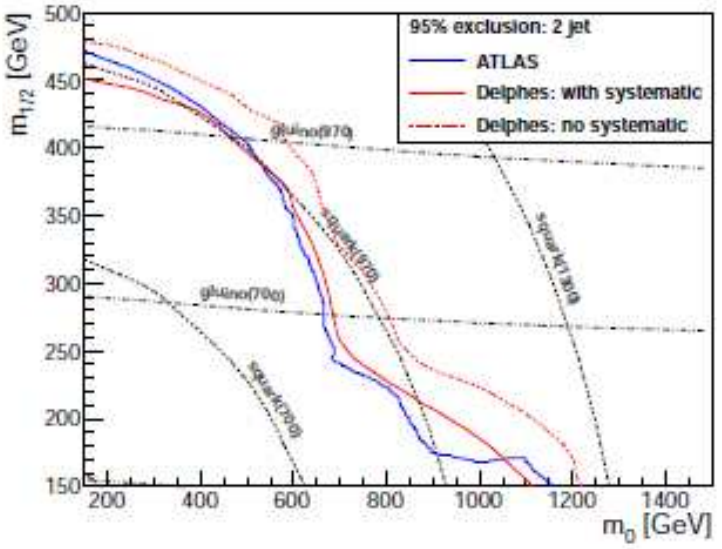
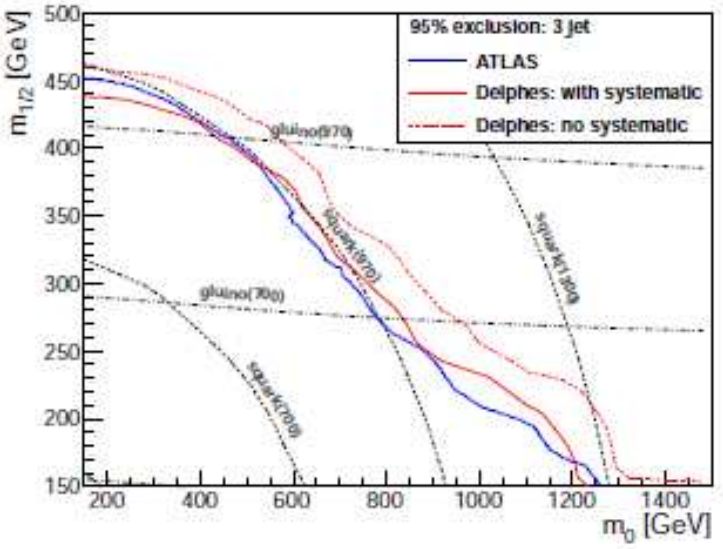
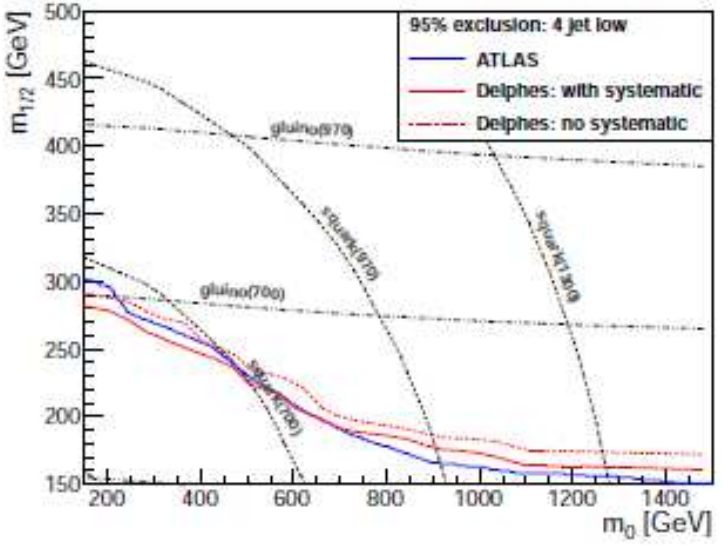
ATLAS Validation



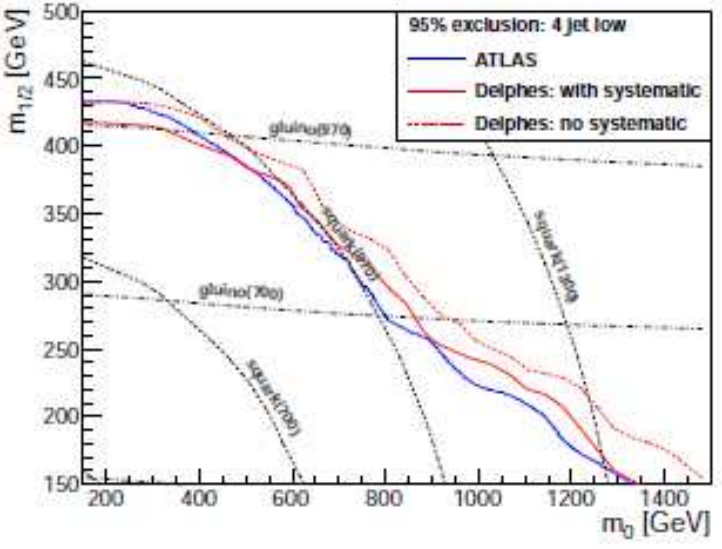
(a) 2 jets



(b) 3 jets



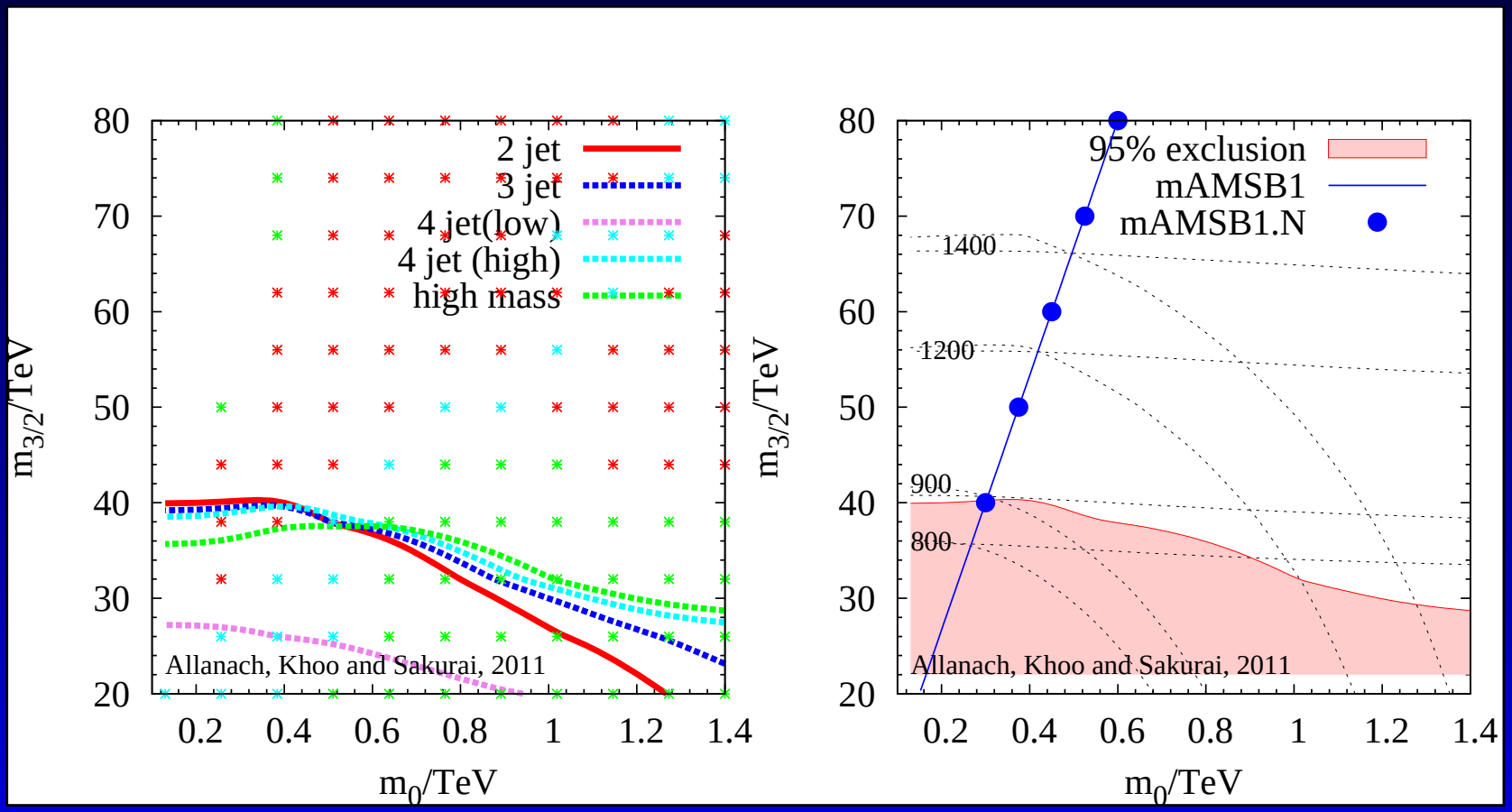
(c) 4 jets

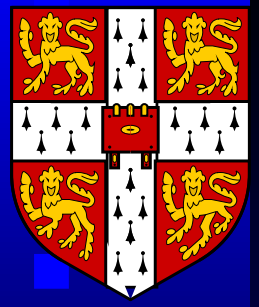


(d) 4 jets'

mAMSB Exclusion

Interpret ATLAS exclusion in a different model: mAMSB.





Shopping List

Things that the CMS/ATLAS always provide that we need:

- Cuts and numbers of events observed past them
- Expected background numbers with systematic errors

We could really do with:

- Keeping in mind: we can't combine analyses that use the same events: much better to keep the events disjoint. Doesn't preclude fully inclusive analysis, but make the others as disjoint as possible.
- Likelihood versus predicted number of events past cuts (before efficiency correction). Ideally, sanitized `RooStats`

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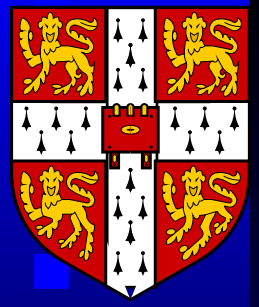

Shopping List II

Failing that, then we must calculate the likelihood:

- Systematic errors on signals: perhaps at least a range over parameter space in one model. Ideally, it would be parameterised in terms of important quantities.
- Other contours (eg 1/5 sigma exclusion contours) so we can check our likelihood away from 95% excluded region.
- Numbers in histogram plots attached to `arXiv` publication

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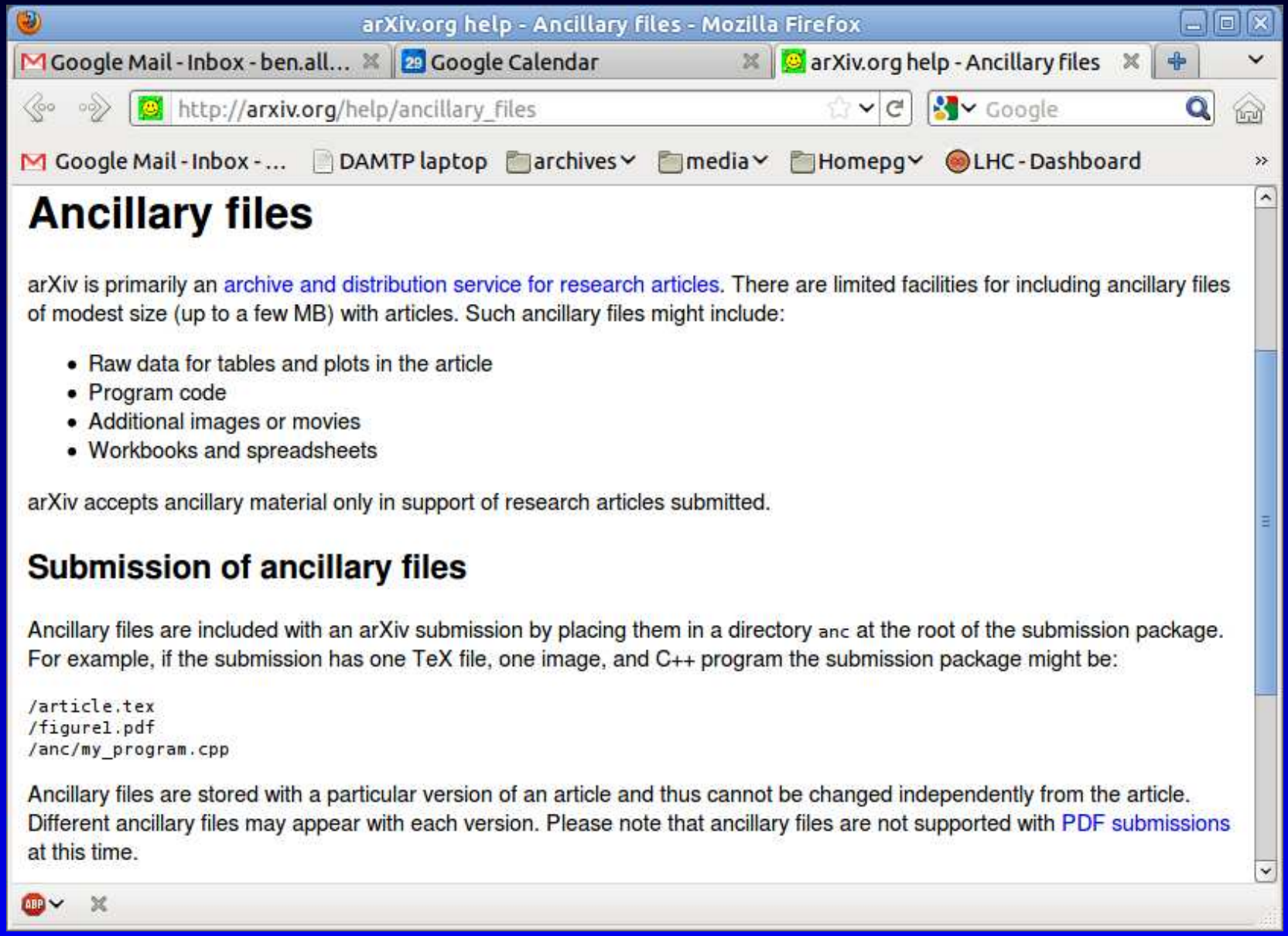
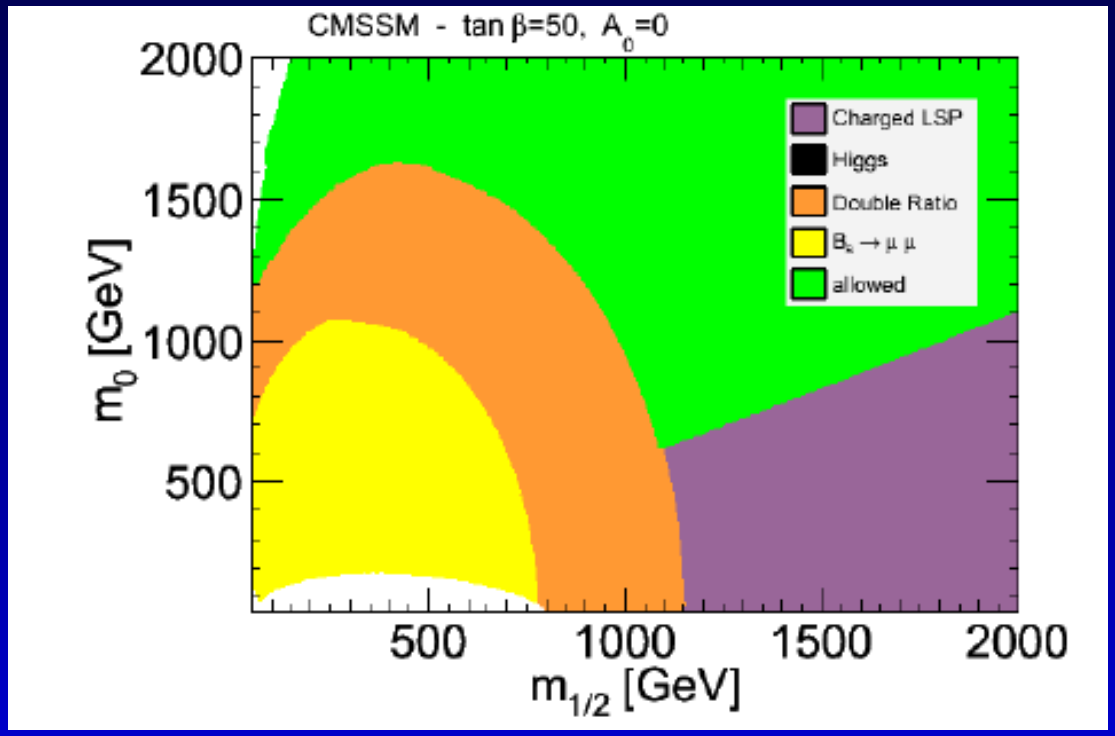
Ancillary Files in arXiv Submission



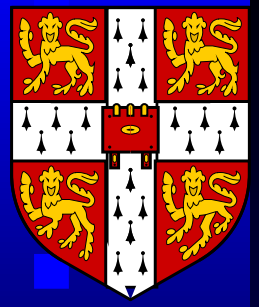
B decays

$$BR(B_s \to \mu\mu) < 1.1 \times 10^{-8}$$

from LHCb/CMS[a].



[a] Akeroyd, Mahmoudi, Santos arXiv:1108.3018.



Summary

- LHC analyses providing a nice amount of information for interpretation of data. There's always room for improvement...
- Validation step very important for us when we're interpreting experiments' results.
- Current searches reach squark and gluino masses of 1020 GeV (CMSSM), 900 GeV (mAMSB). Too early to give up on SUSY though.

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