

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 Limits		1.3	0.35	1.1	0.11	ATLAS 35, 165/pb
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 ($\bar{\tau}_1$ 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

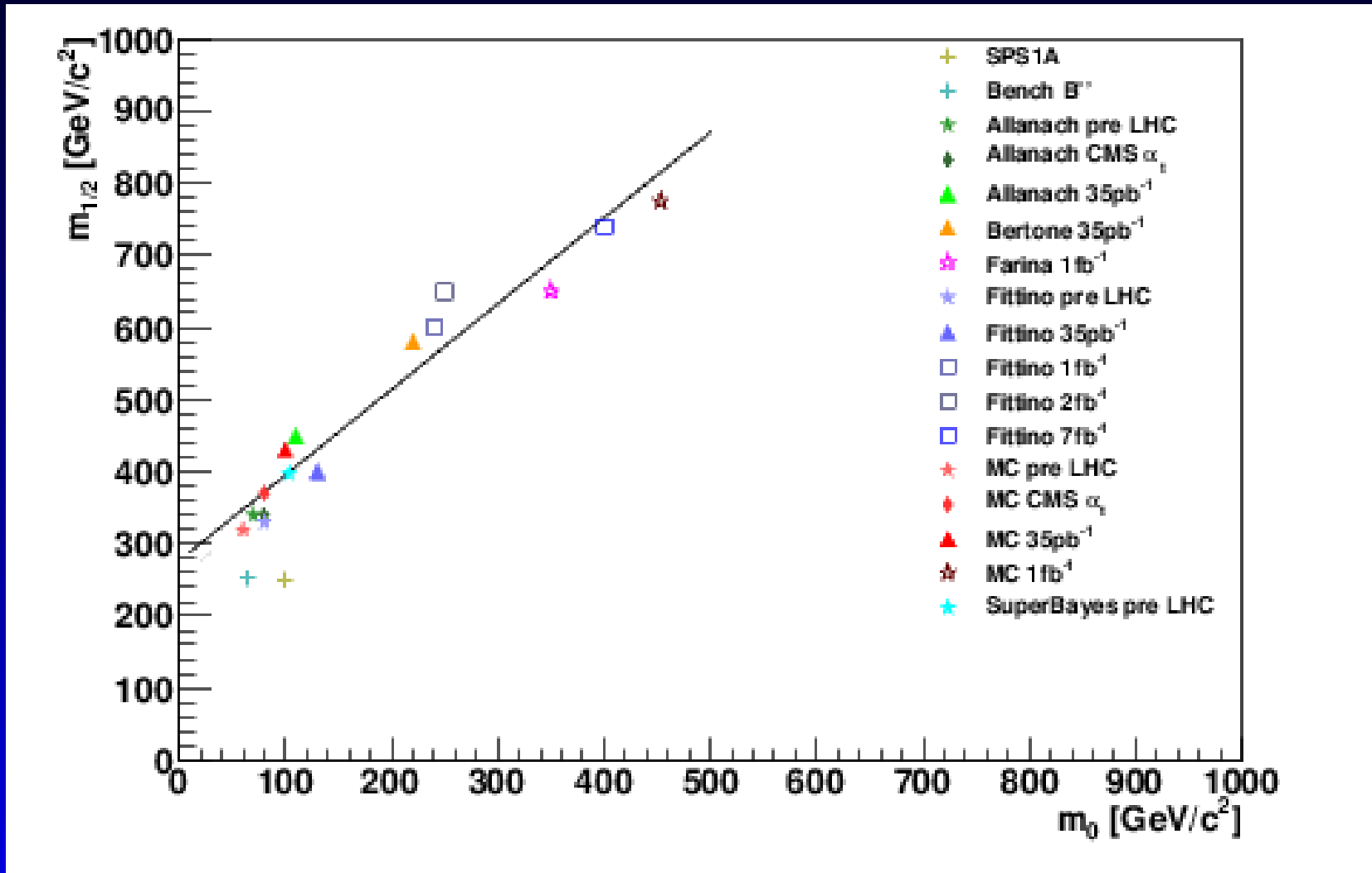
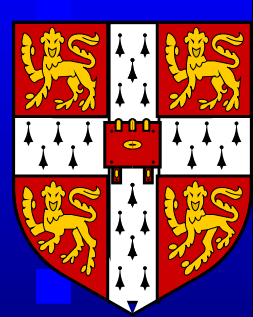
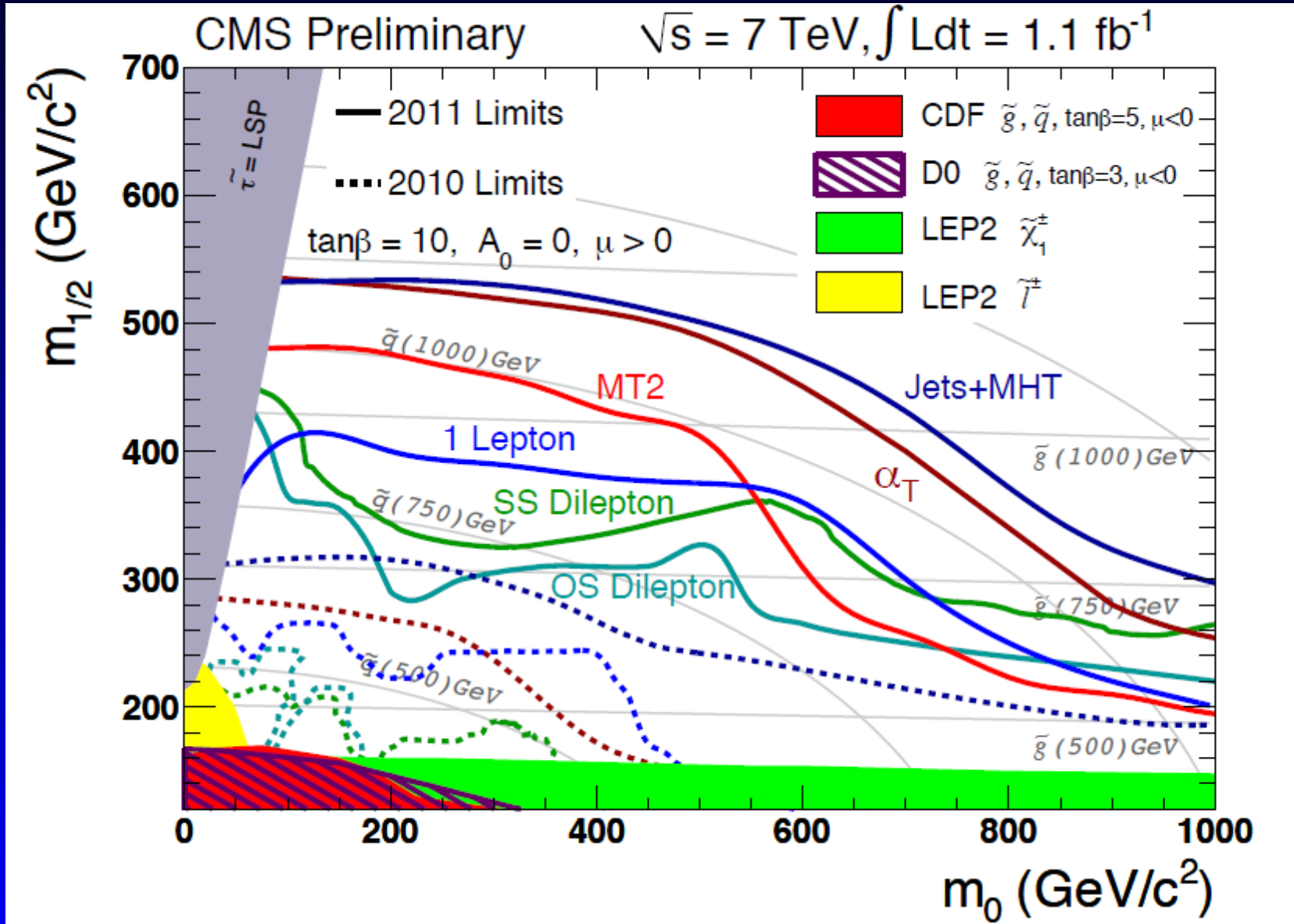
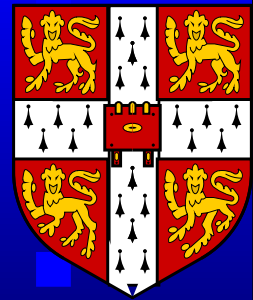


Figure 2: CMSSM good/best fit-points [arXiv:1109.3859](https://arxiv.org/abs/1109.3859)



Searches and the CMSSM



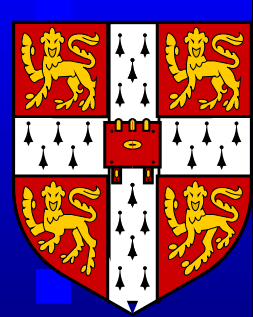


Searches and the CMSSM

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

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
$E_T^{\text{min}}/\sqrt{H_T}$	> $3.5 \text{ GeV}^{1/2}$			

Table 1: Definitions of the four signal regions.



Multijets Method

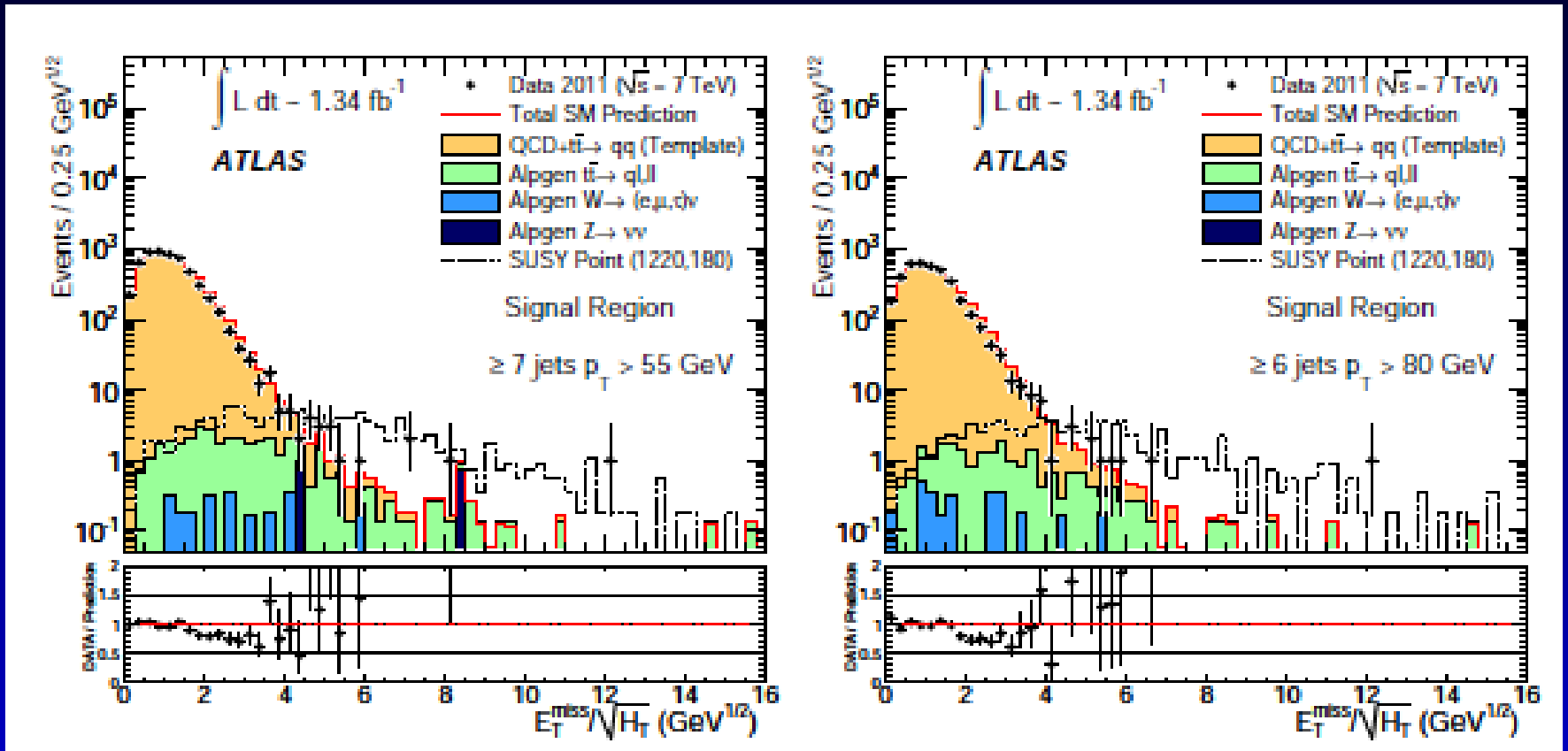
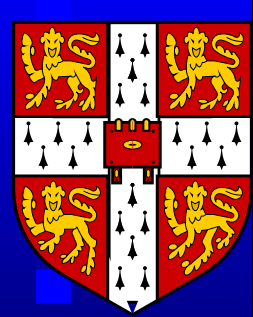
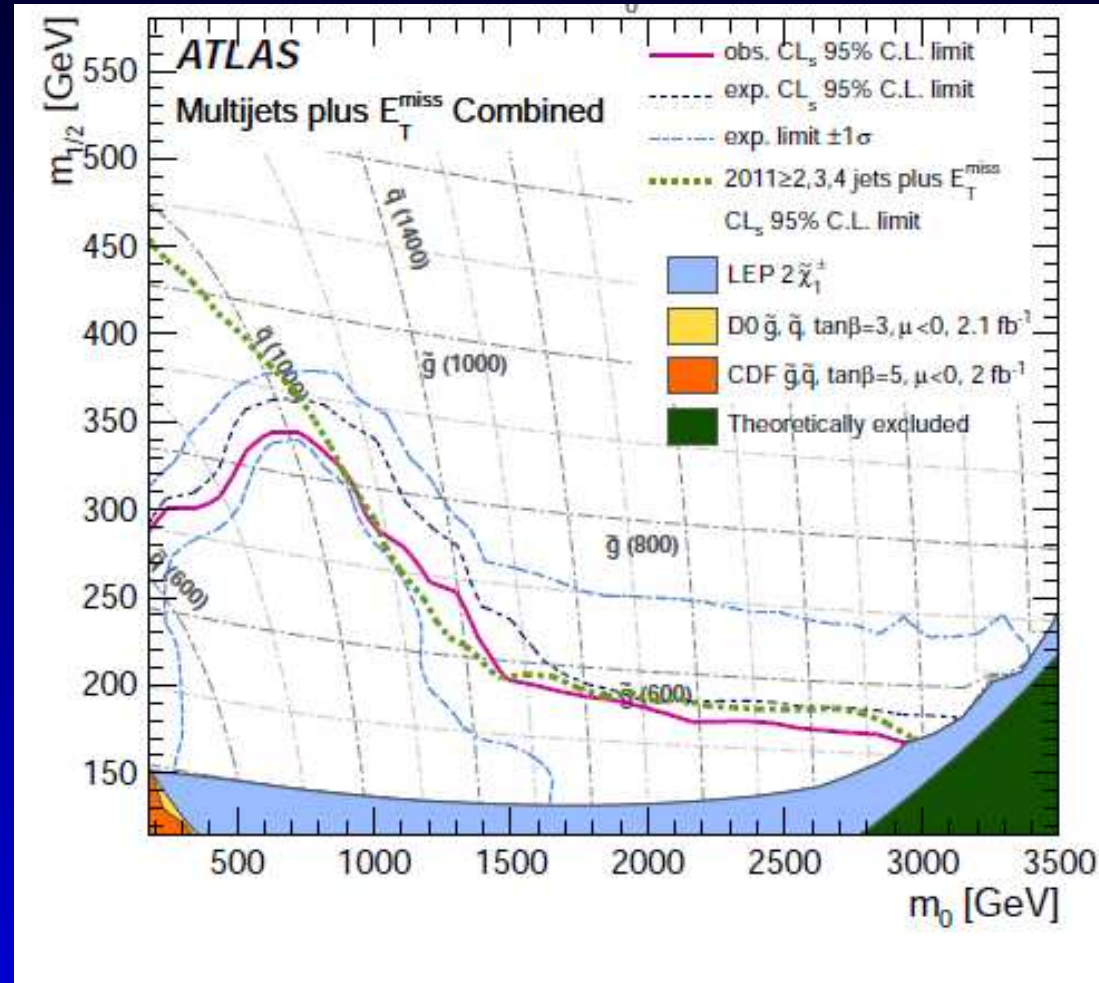
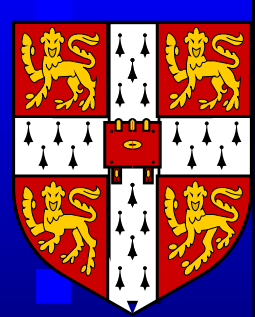


Figure 4: QCD template normalised to < 1.5 region. Smaller N_j used for shape in each case.



Searches and the CMSSM

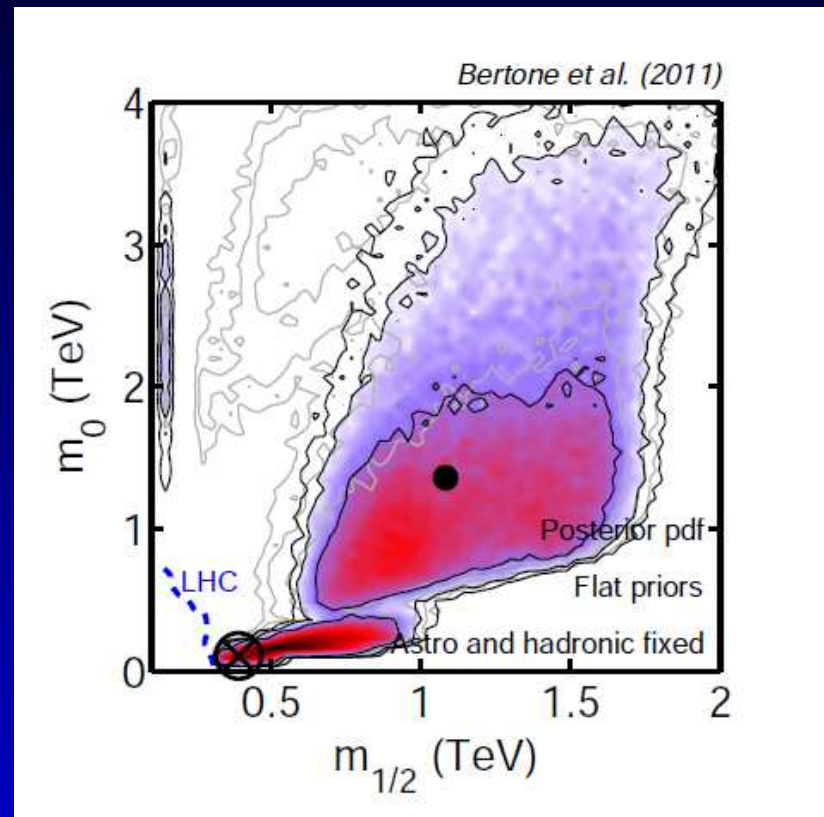
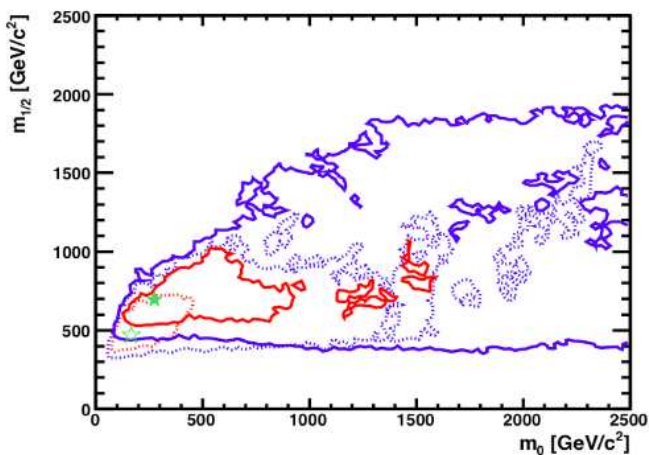


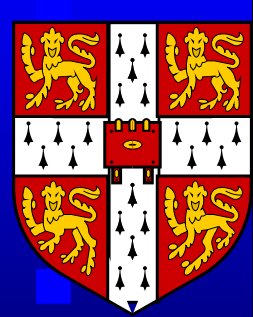


Updated Constraints on CMSSM Data

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

Figure 1: The $(m_0, m_{1/2})$ plane of the CMSSM showing best-fit points (green stars), 68% CL boundaries (red lines) and 95% CL boundaries (blue lines). The dotted (solid) lines are before (after) including the new constraints presented at EPS.



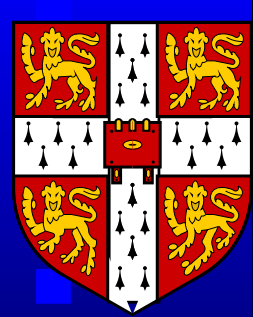


Benchmarks

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.*

^aS.S. AbdusSalam, BCA H. Dreiner, J. Ellis, S. Heinemeyer,
M. Krämer, M. Mangano, K.A. Olive, S. Rogerson, L. Roszkowski,



Benchmarks Example: mAMSB

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

Line: $m_0 = 0.0075m_{\text{aux}}, \tan \beta = 10, \mu > 0$.

Points:

Point	m_{aux}	m_0	$m_{\tilde{g}}$	$\langle m_{\tilde{q}} \rangle$	$m_{\tilde{t}_1}$	$m_{\tilde{b}_1}$	BR($\tilde{g} \rightarrow \tilde{t}t$)	BR($\tilde{g} \rightarrow \tilde{b}b$)
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](https://arxiv.org/abs/1109.3859).

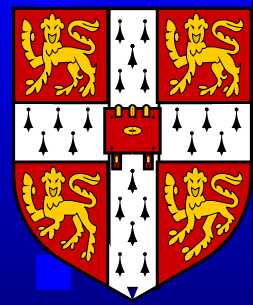
Next point for consideration is *the next one that hasn't been yet ruled out to 95%*

ATLAS 1 fb⁻¹ 0-lepton Search

	≥ 2 jets	≥ 3 jets	≥ 4 jets	≥ 4 jets ^a	High mass
$Pr(J_1)$	> 130 GeV	> 130 GeV	> 130 GeV	> 130 GeV	> 130 GeV
$Pr(J_2)$	> 40 GeV	> 40 GeV	> 40 GeV	> 40 GeV	> 80 GeV
$Pr(J_3)$	–	> 40 GeV	> 40 GeV	> 40 GeV	> 80 GeV
$Pr(J_4)$	–	–	> 40 GeV	> 40 GeV	> 80 GeV
$ p_T^{miss} $	> 130 GeV	> 130 GeV	> 130 GeV	> 130 GeV	> 130 GeV
$\Delta\phi$	> 0.4	> 0.4	> 0.4	> 0.4	> 0.4
p_T^{miss}/m_{eff}	> 0.3	> 0.25	> 0.25	> 0.25	> 0.2
m_{eff}	> 1000 GeV	> 1000 GeV	> 500 GeV	> 1000 GeV	> 1100 GeV
Observed	58	59	1118	40	18
Background	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
$\sigma \times A \times \epsilon/\text{fb}$	22	25	429	27	17

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

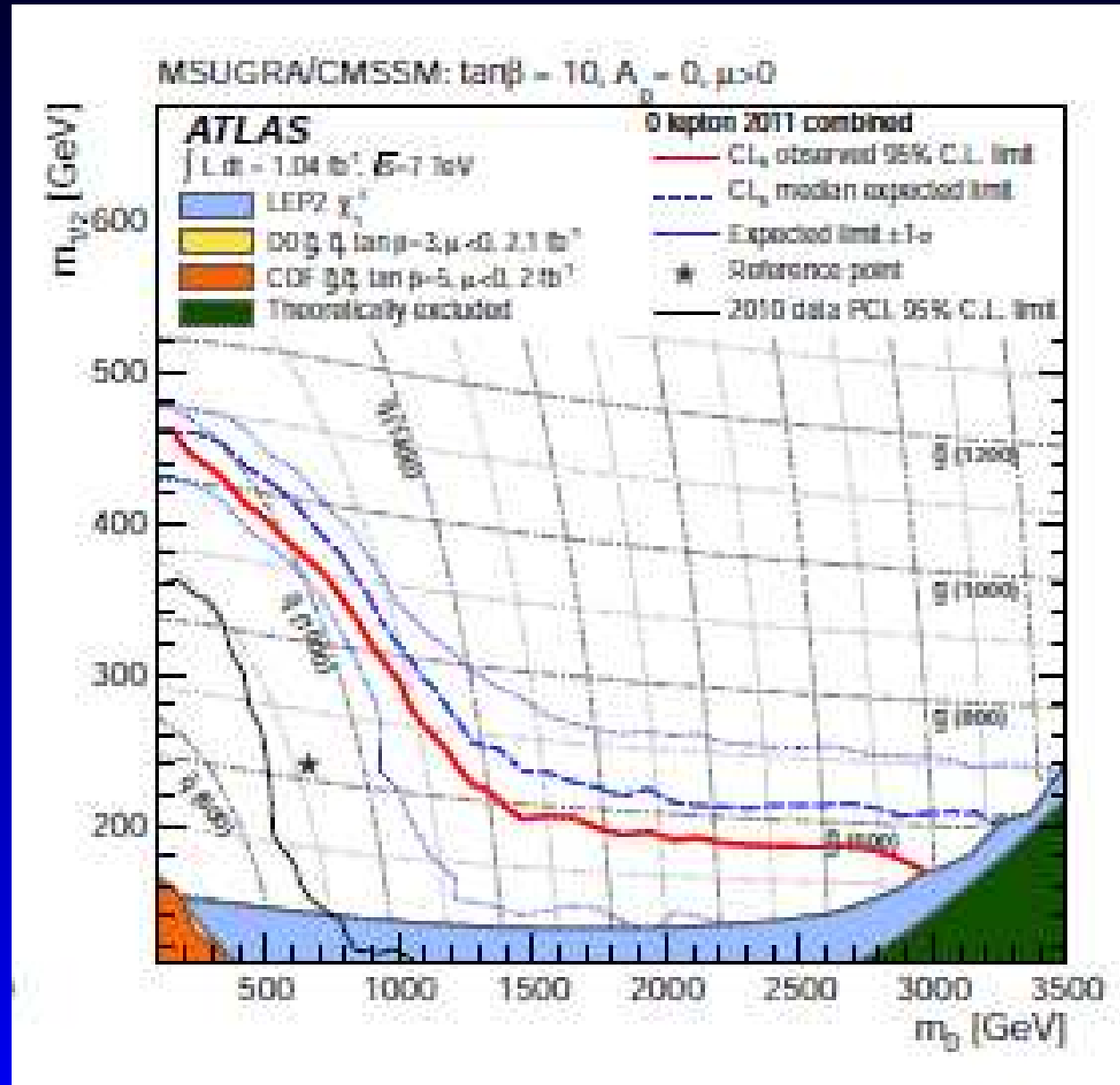
^aATLAS, arxiv:1109.6572

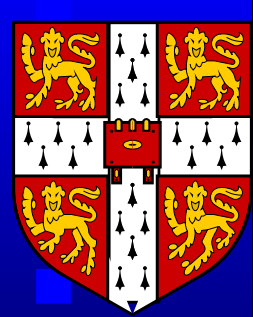


Results

Science & Technology
Facilities Council

Supersymmetry
Cambridge
Working group

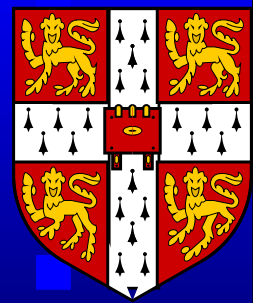




Intepretation

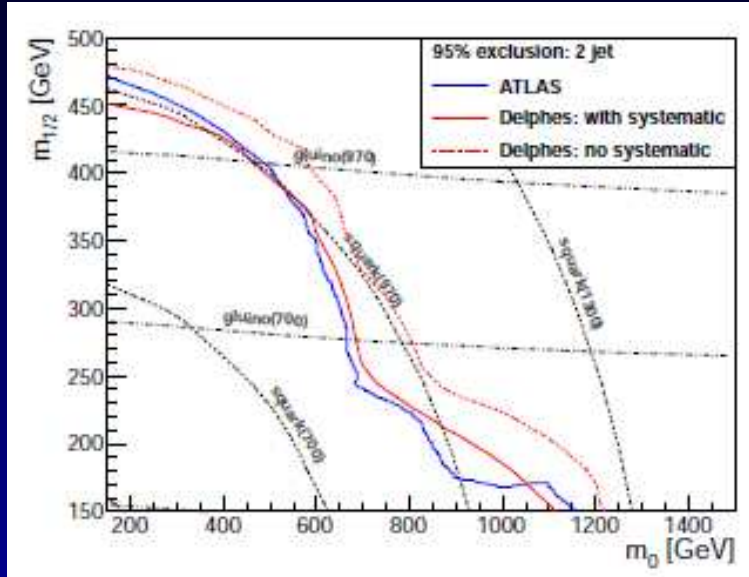
The results give a lower limit of 1020 GeV for $m_{\tilde{g}} = m_{\tilde{q}}$ in the CMSSM. We wish to *reinterpret* the search in mAMSB, to find the exclusion there (and study if mAMSB evades the search). We simulate *signal* only, with HERWIG++-2.5.1, and use ATLAS' upper limits on $\sigma \times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

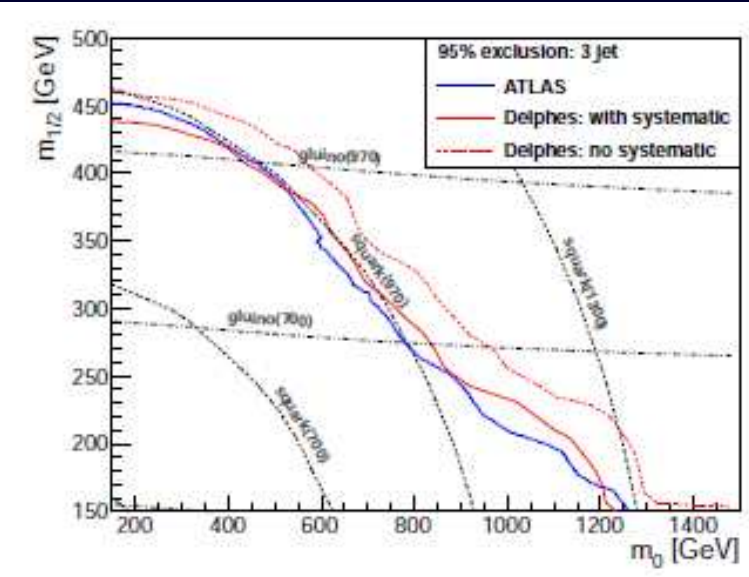


ATLAS Validation

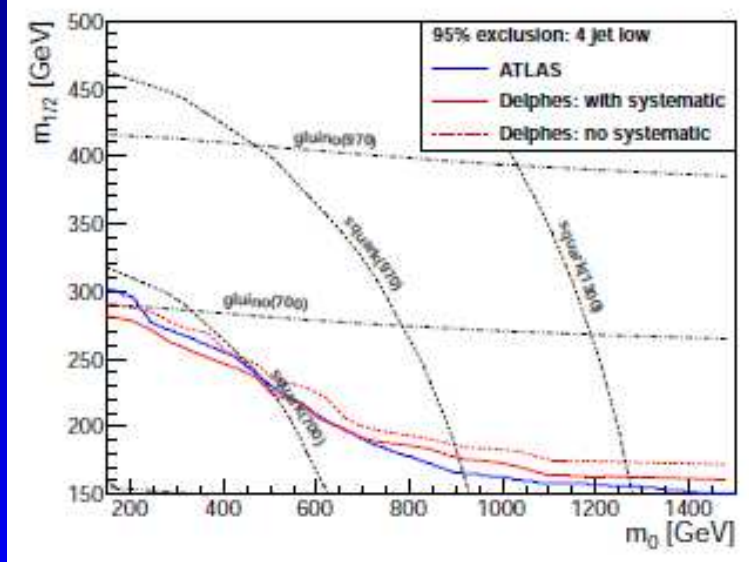
Science & Technology
Facilities Council



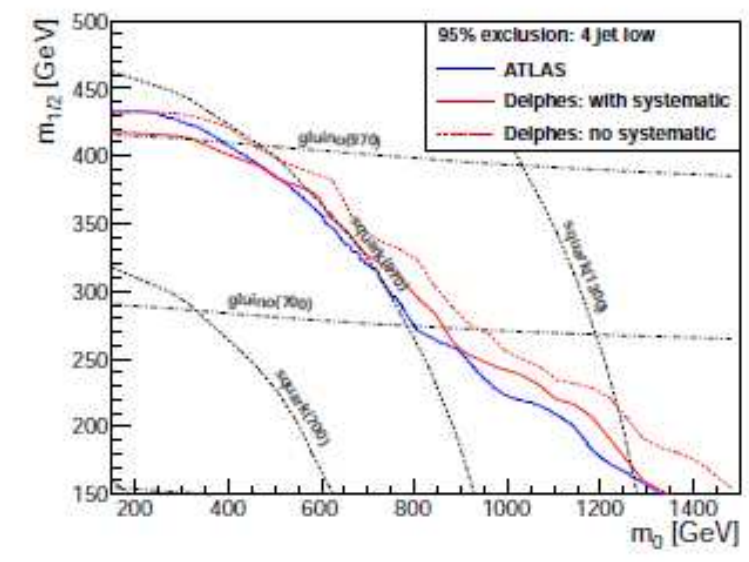
(a) 2 jets



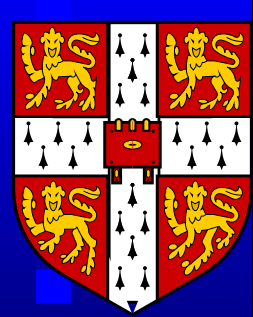
(b) 3 jets



(c) 4 jets

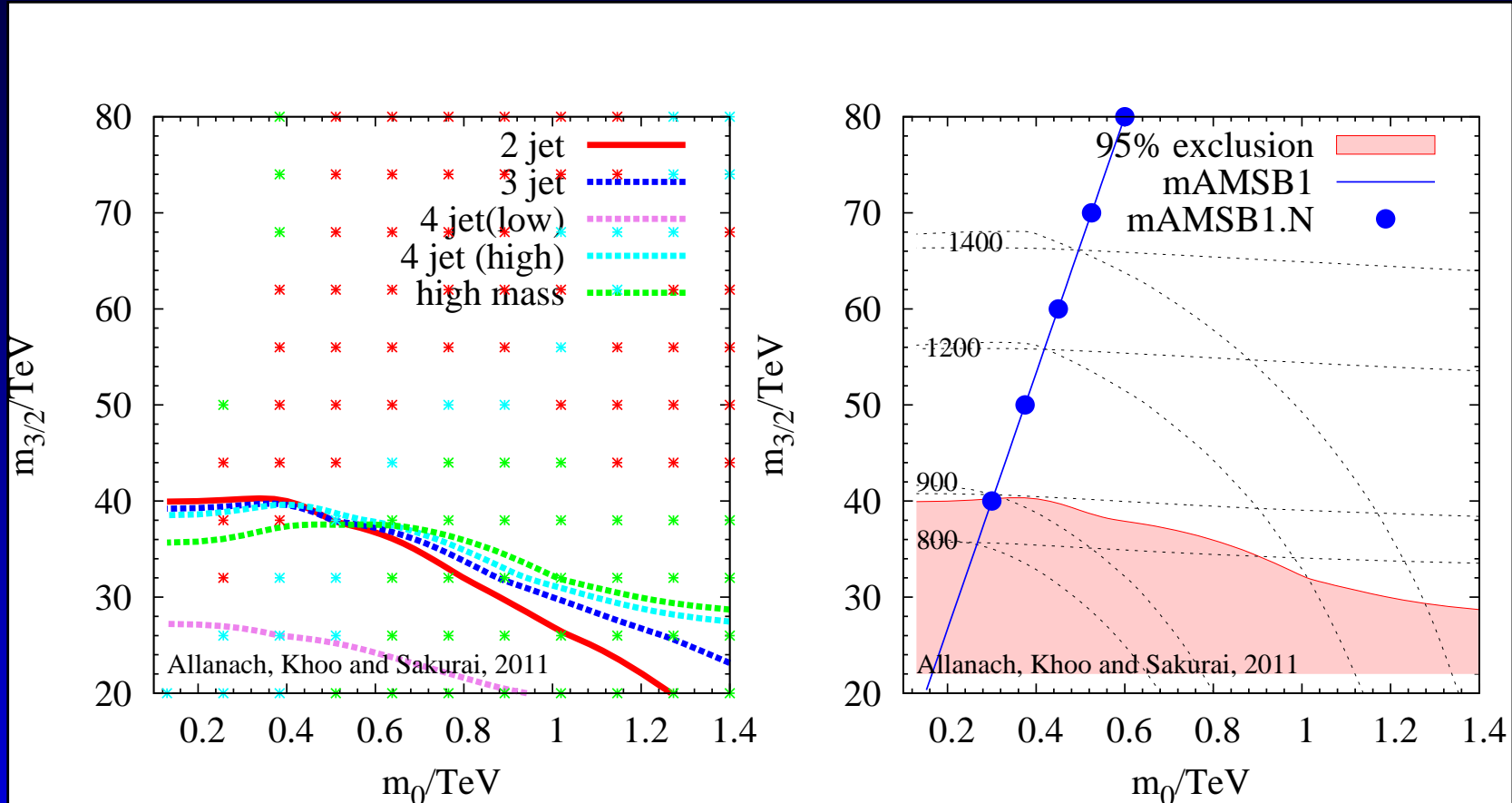


(d) 4 jets'



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

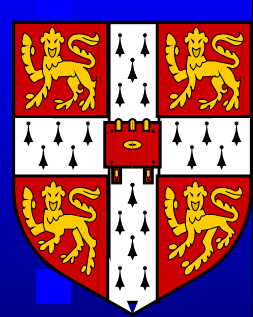


Shopping List II

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

Ancillary Files in arXiv Submission



The screenshot shows a Mozilla Firefox browser window with the following details:

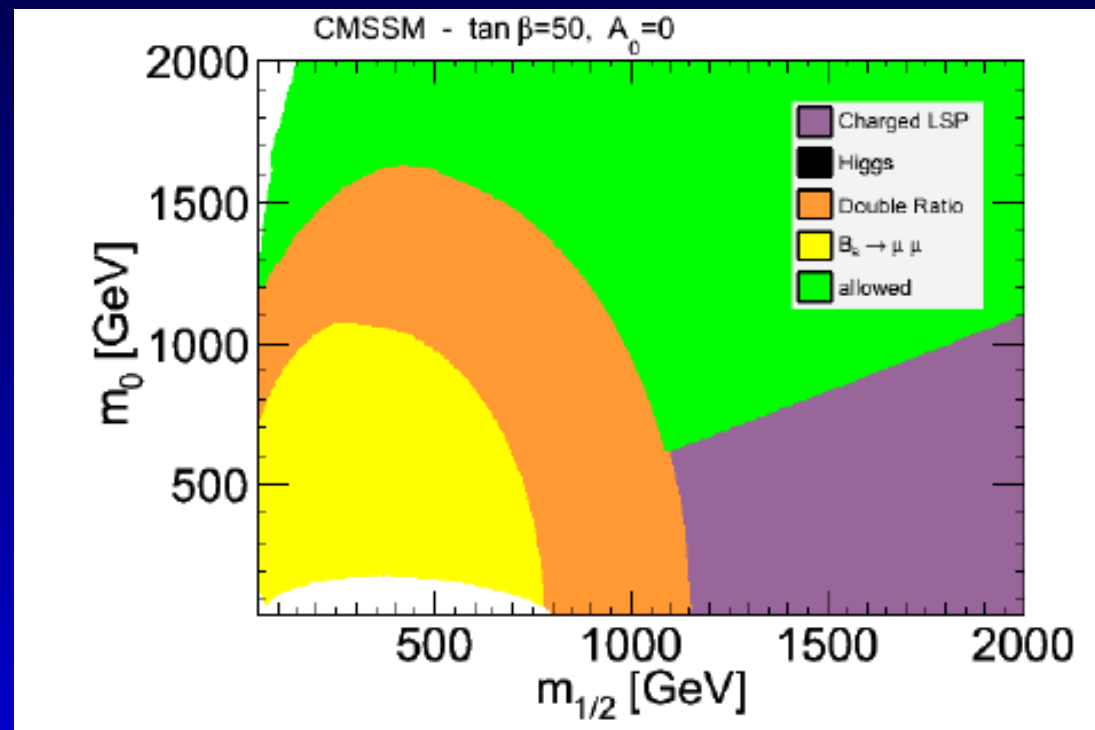
- Tab: arXiv.org help - Ancillary files
- Address bar: http://arxiv.org/help/ancillary_files
- Navigation bar: Google Mail - Inbox - ben.all..., DAMTP laptop, archives, media, Homepg, LHC - Dashboard
- Page title: **Ancillary files**
- Text: arXiv is primarily an [archive and distribution service for research articles](#). There are limited facilities for including ancillary files of modest size (up to a few MB) with articles. Such ancillary files might include:
 - Raw data for tables and plots in the article
 - Program code
 - Additional images or movies
 - Workbooks and spreadsheets
- Text: arXiv accepts ancillary material only in support of research articles submitted.
- Section header: **Submission of ancillary files**
- Text: Ancillary files are included with an arXiv submission by placing them in a directory `anc` at the root of the submission package. For example, if the submission has one TeX file, one image, and C++ program the submission package might be:

```
/article.tex
/figure1.pdf
/anc/my_program.cpp
```
- Text: Ancillary files are stored with a particular version of an article and thus cannot be changed independently from the article. Different ancillary files may appear with each version. Please note that ancillary files are not supported with [PDF submissions](#) at this time.
- Bottom bar: ABP icon

B decays

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

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.