Constrained Supersymmetry after two years of LHC data: a global view with Fittino

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Global SUSY fits with LHC exclusions

We have been trying to address to following questions:

- What is the most probable CMSSM (and NUHM1) parameter space after two years of LHC data?
- To what extend are the non-LHC measurements and the LHC non-observation in mutual tension?
- What would be the impact of a light SUSY Higgs boson with $M_h \approx 125$ GeV, and what would be the implication for its couplings?
- What are the implications of the CMSSM fit for direct and indirect searches for WIMP dark matter?

The Fittino CMSSM fits

- For the calculation of non-LHC observables we have used
  - the spectrum generators `SPheno` and `SOFTSUSY`;
  - `FeynHiggs` and `SuperISO` for $(g-2)_\mu$, flavour and electroweak precision observables;
  - `MicrOMEGAs` and `DarkSUSY` for the DM relic density;
  - `AstroFit` for direct and indirect DM detection limits;
  - `HiggsBounds` for the Higgs limits.

- We require that the $\tilde{\chi}_1^0$ is the LSP.

- We then calculate and minimize

$$\chi^2 = (\vec{O}_{\rm obs} - \vec{O}_{\rm th}(\vec{P}))^T \, {\rm cov}_M^{-1} (\vec{O}_{\rm obs} - \vec{O}_{\rm th}(\vec{P})) + \text{limits}$$

  for each point $\vec{P}$ in the CMSSM parameter space using `Fittino`.

The Fittino CMSSM fits without LHC exclusions

We include

- Indirect constraints:

  $\mathrm{BR}(b \to s\gamma)$, $\mathrm{BR}(B_s \to \mu\mu)$, $\mathrm{BR}(b \to \tau\nu)$, Δm_{B_s}, $(g-2)_\mu$, m_W, $\sin^2\theta_{\mathrm{eff}}$

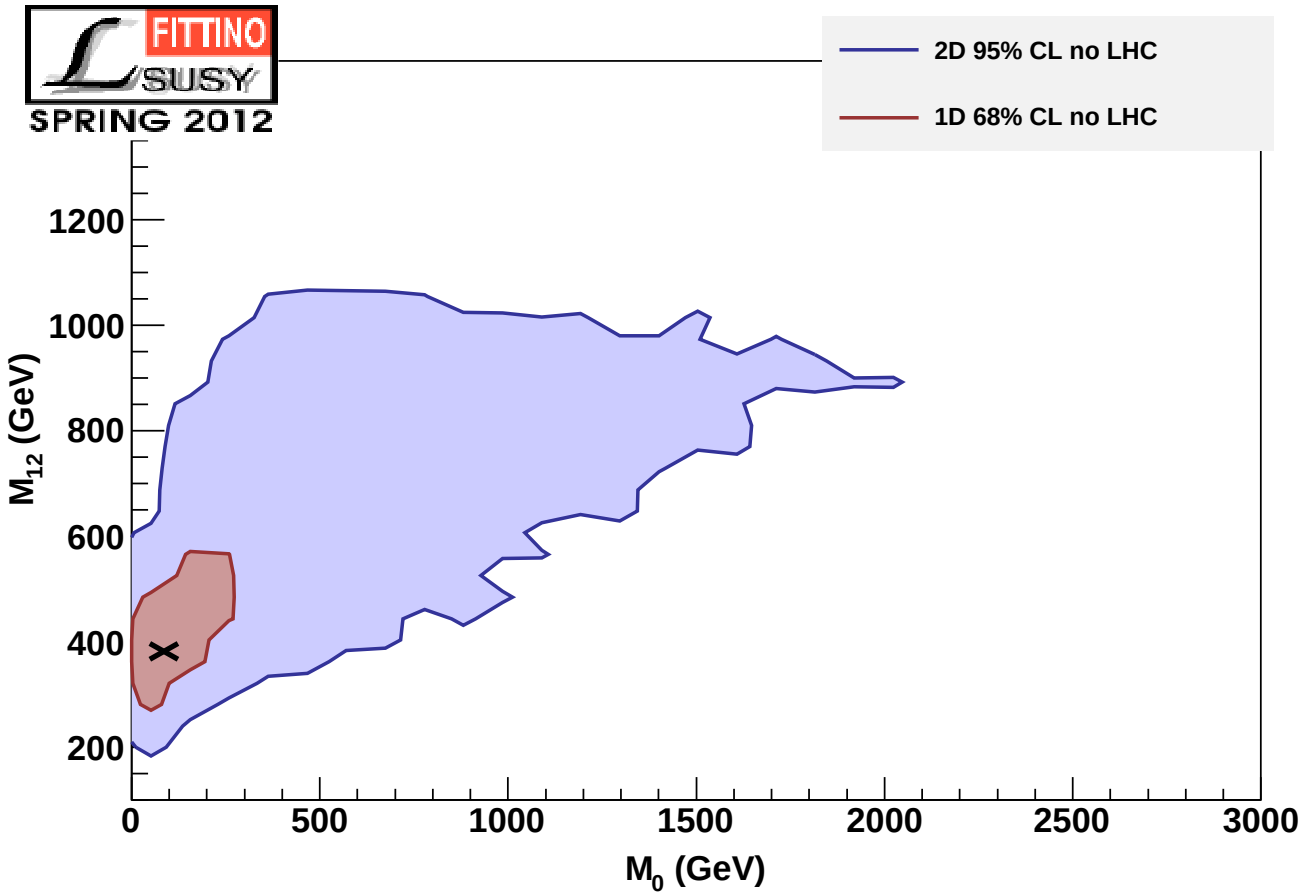
- Constraints from astrophysical observations:

  Ω_{DM}, direct and indirect DM detection limits

- Direct sparticle and Higgs boson search limits from colliders:

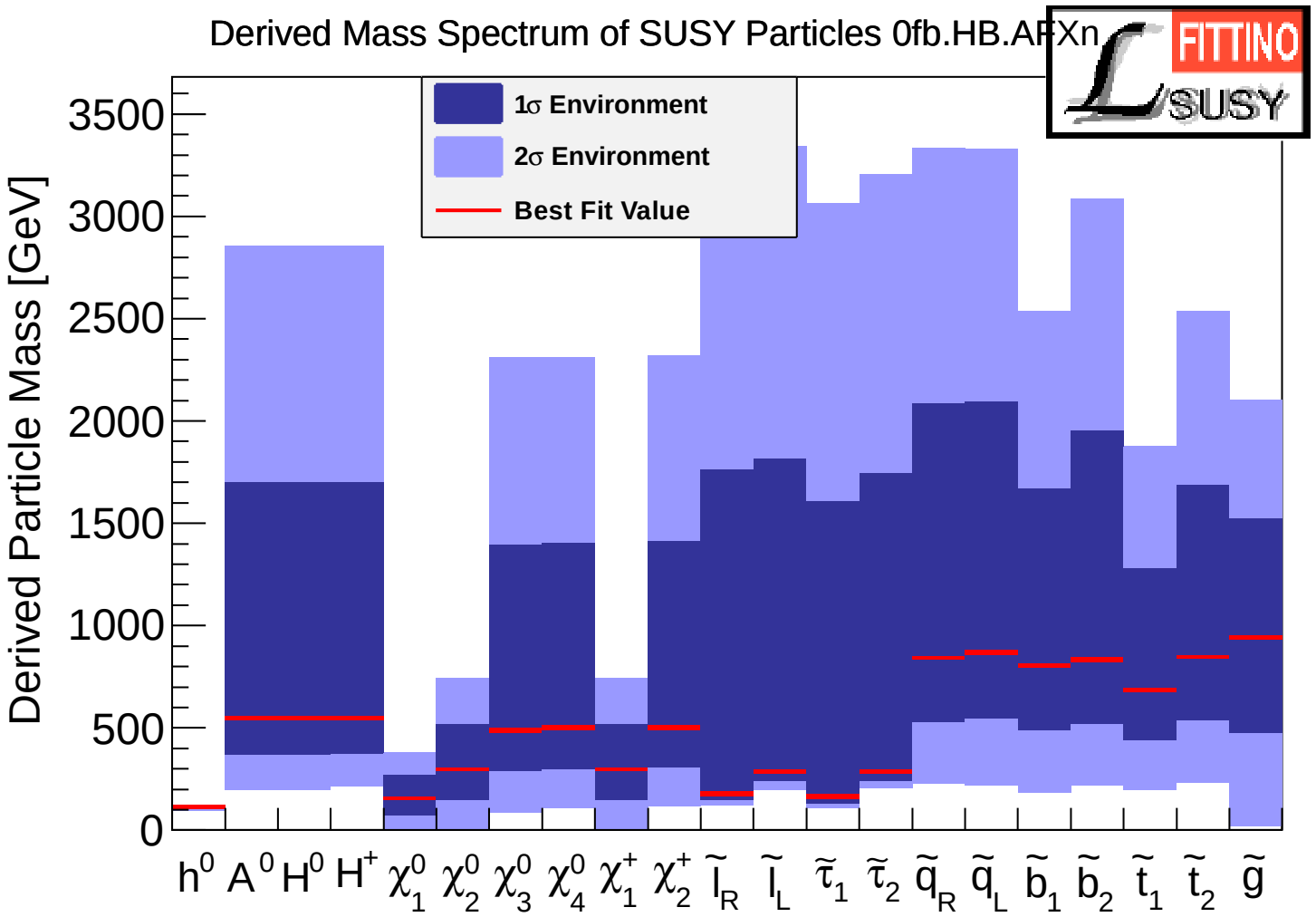
  $m_{\tilde{\chi}^\pm}$, limits on MSSM Higgs boson masses from `HiggsBounds`

The Fittino CMSSM fits without LHC exclusions



Fit	M_0 [GeV]	$M_{1/2}$ [GeV]	$\tan\beta$	A_0	χ^2/ndf
LEO	$85.9^{+139.7}_{-29.9}$	$381.8^{+177.2}_{-97.1}$	$14.9^{+16.1}_{-7.3}$	$184.1^{+846.7}_{-872.1}$	10.2/8

The Fittino CMSSM fits without LHC exclusions



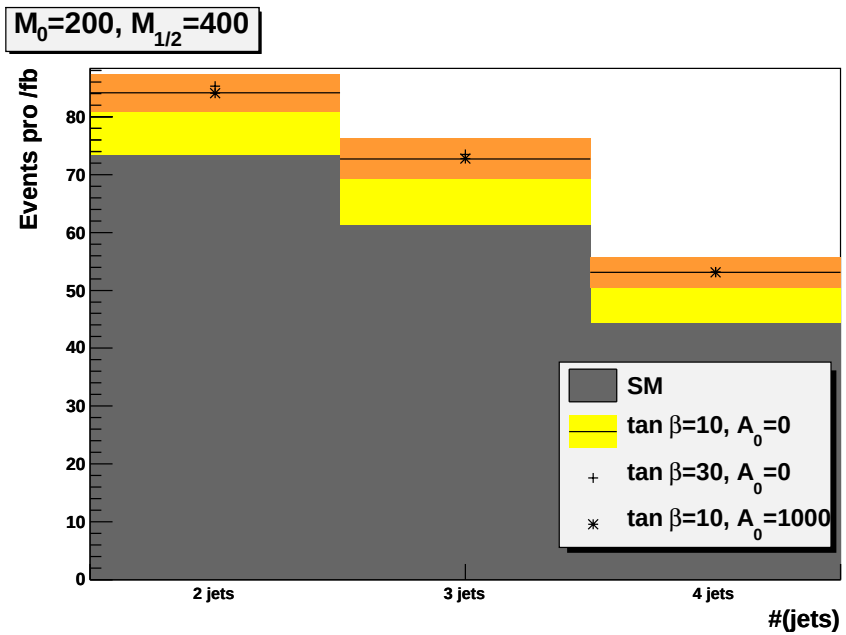
. . . point to light sparticles with $\tilde{m} < 1$ TeV, but with large errors

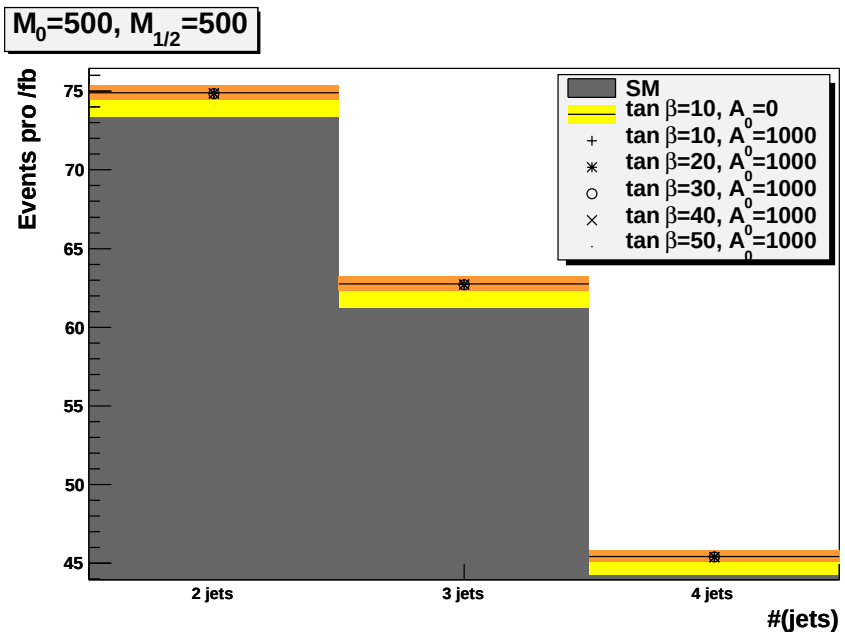
Including LHC SUSY search limits

- We follow a recent ATLAS analysis in the jets+0l+$E_{T\mathrm{miss}}$ signature.
- We have calculated the CMSSM signal for a grid in $(m_0, m_{1/2})$ using
  - the spectrum generator `SPheno`;
  - the MC generator `Herwig++`;
  - NLO+NLL K-factors;
  - the fast detector simulation `Delphes`.

  and have verified the independence of the signal yield from $\tan\beta$ and A_0.
- The SM background is taken from the ATLAS simulation.

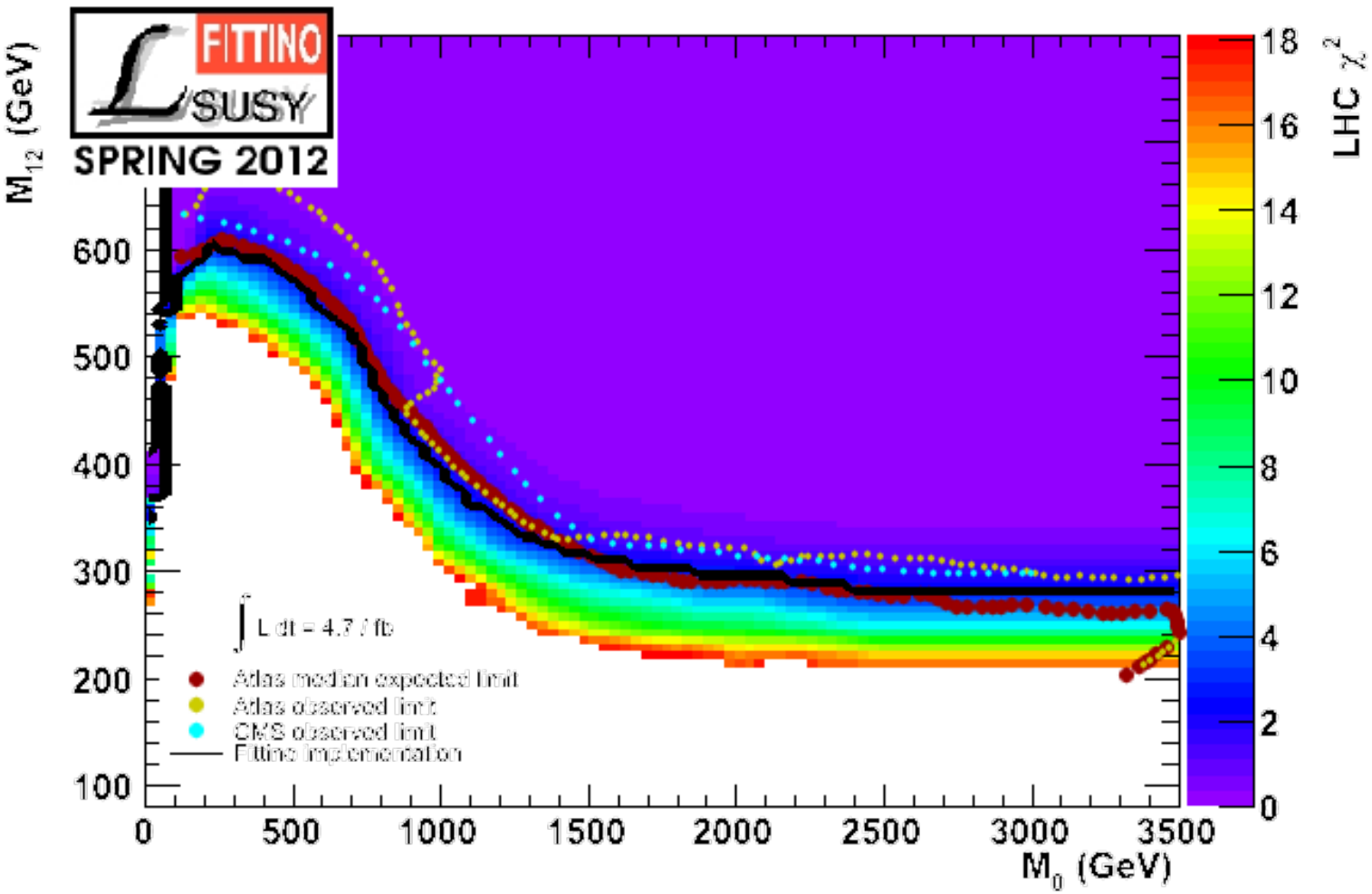
The jets+0l+$E_{T\mathrm{miss}}$ signature is rather independent of tan β and A_0:



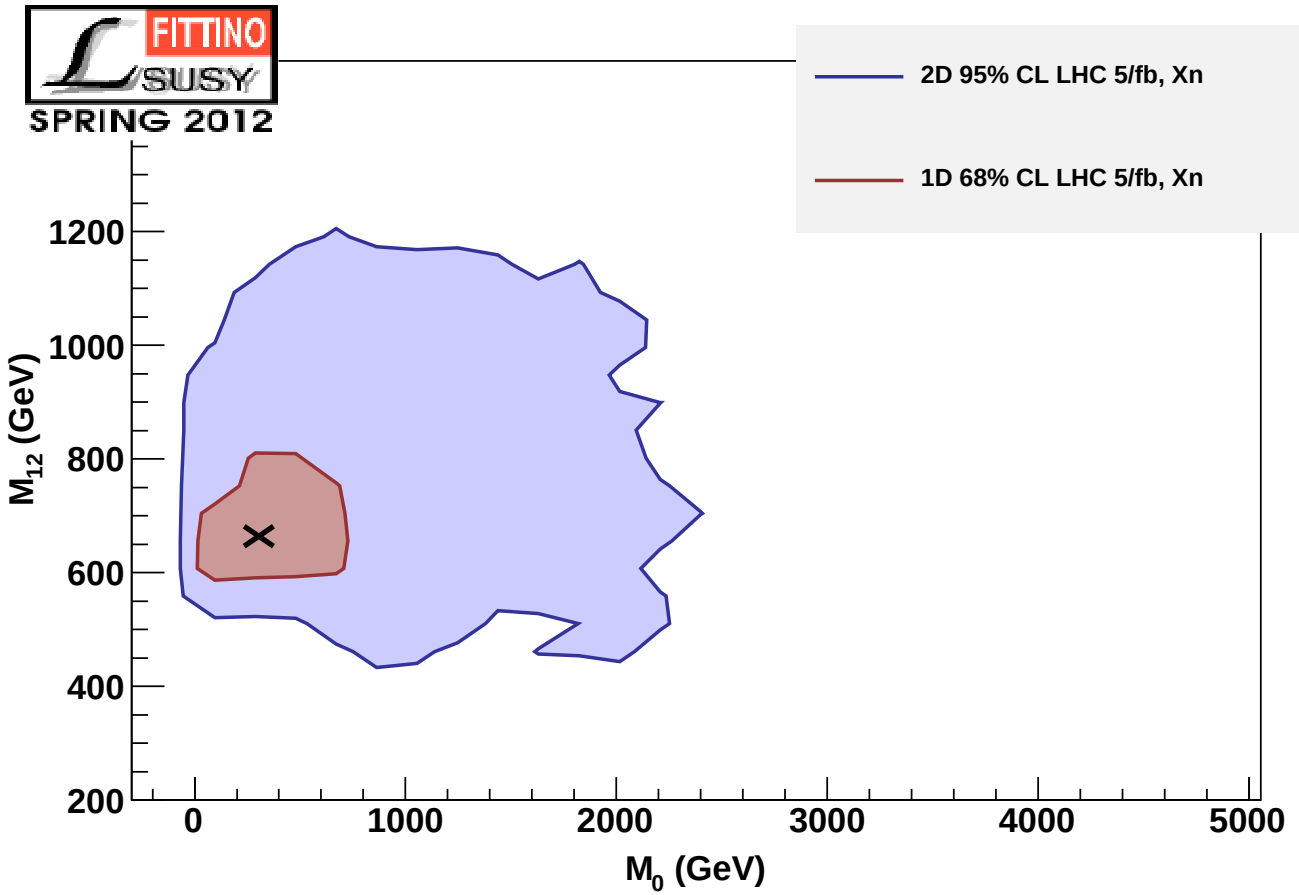


Including LHC SUSY search limits

We find good agreement with the current $5\,\mathrm{fb}^{-1}$ LHC CMSSM limits:



The Fittino CMSSM fits with $5\,\mathrm{fb}^{-1}$ LHC exclusions



Fit	$M_0\,[\mathrm{GeV}]$	$M_{1/2}\,[\mathrm{GeV}]$	$\tan\beta$	A_0	χ^2/ndf
LHC	$304.3^{+373.7}_{-185.2}$	$664.6^{+138.1}_{-70.9}$	$34.4^{+15.3}_{-21.3}$	$884.76^{+1178.0}_{-974.9}$	13.0/9

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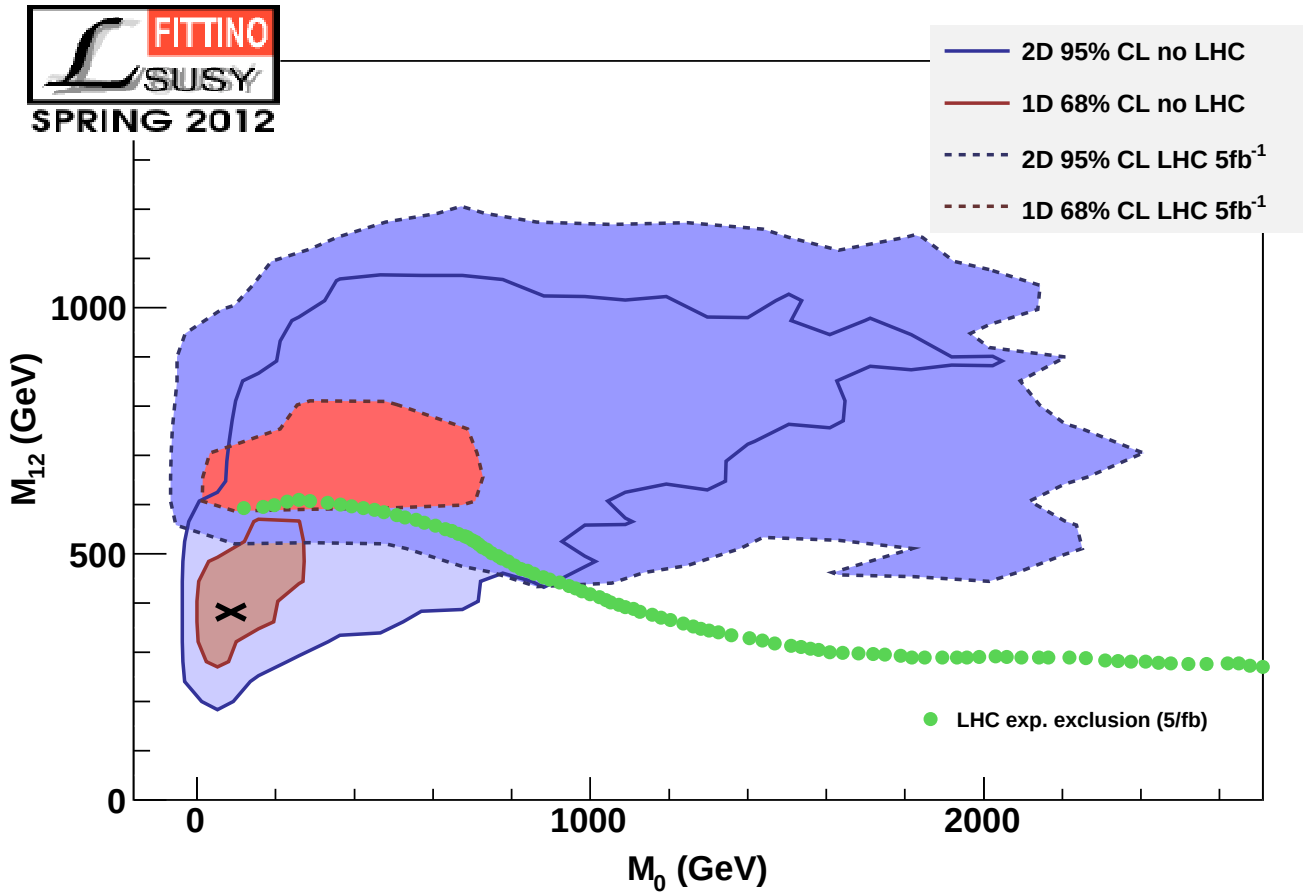

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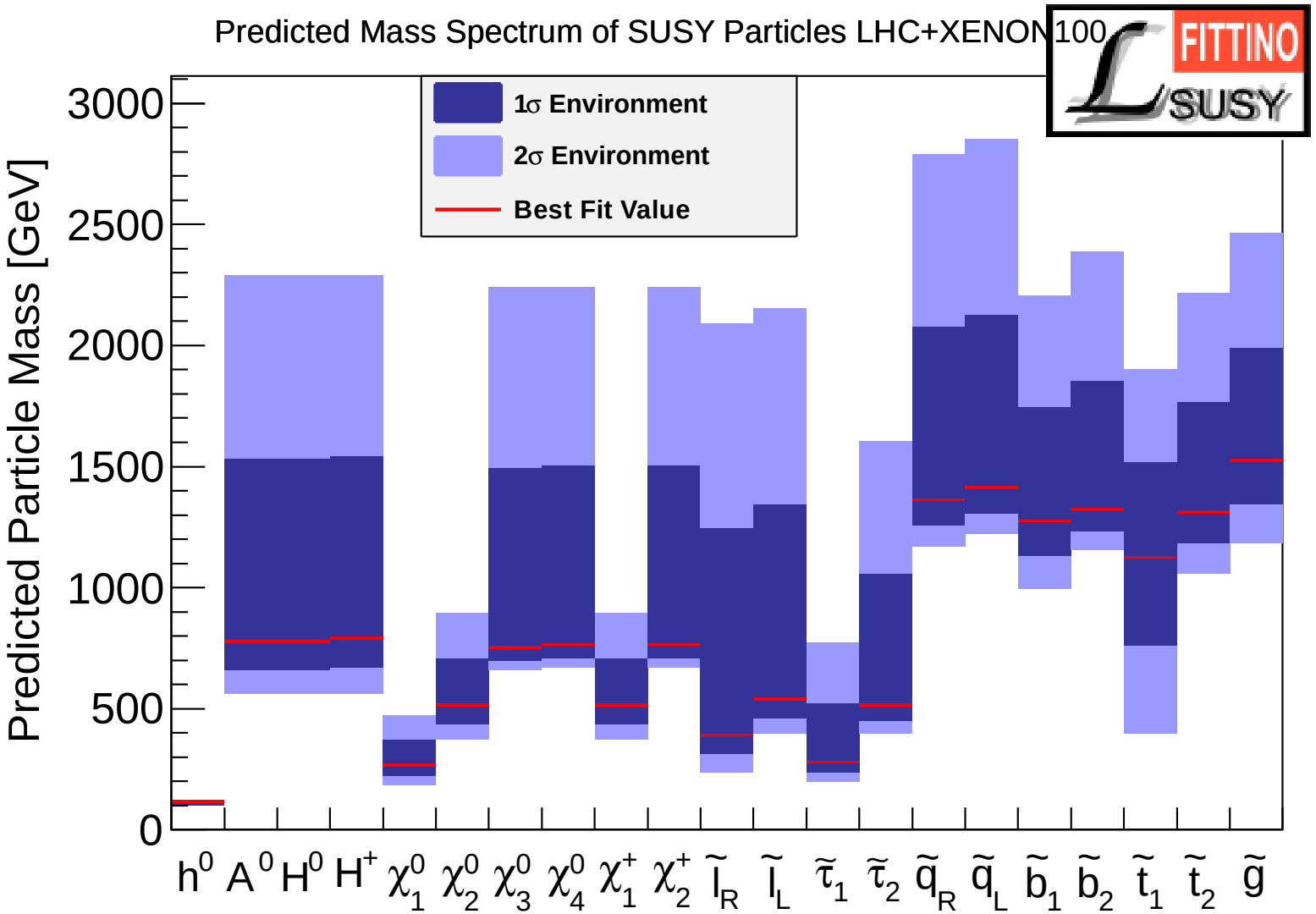

Global SUSY fits with LHC exclusions: is there a tension?

$\rightarrow$ LEOs prefer low mass scales (for non-coloured sector)

$\rightarrow$ LHC prefers high mass scales (for coloured sector)

Is there a tension building up?

Let us look at the best fit points:

	M_0	$M_{1/2}$	$\tan\beta$	A_0	χ^2/ndf
no LHC	$85.9^{+139.7}_{-29.9}$	$381.8^{+177.2}_{-97.1}$	$14.9^{+16.1}_{-7.3}$	$184.1^{+846.7}_{-872.1}$	10.2/8
with LHC	$304.3^{+373.7}_{-185.2}$	$664.6^{+138.1}_{-70.9}$	$34.4^{+15.3}_{-21.3}$	$884.76^{+1178.0}_{-974.9}$	13.0/9

$\rightarrow$ some tension building up, but not enough to exclude the CMSSM

Note: $a_\mu^{\mathrm{SUSY}} \sim \mathrm{sgn}(\mu)\tan\beta\, M_{\mathrm{SUSY}}^{-2}$ and Ω_{DM} require larger $\tan\beta$

Global SUSY fits with LHC exclusions: is there a tension?

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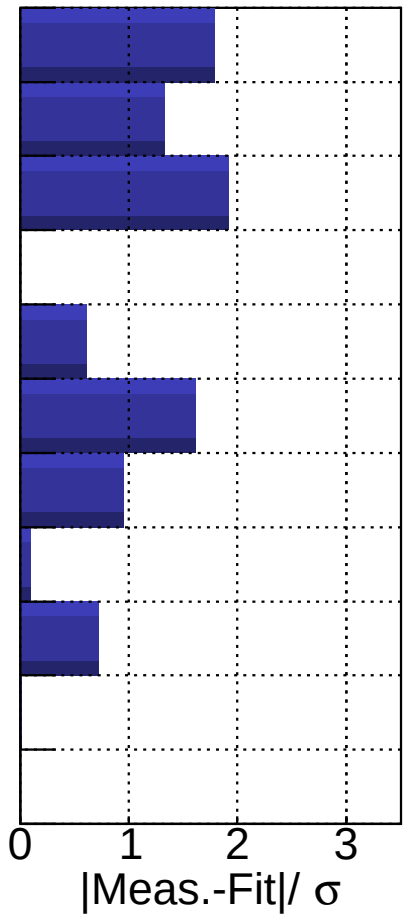
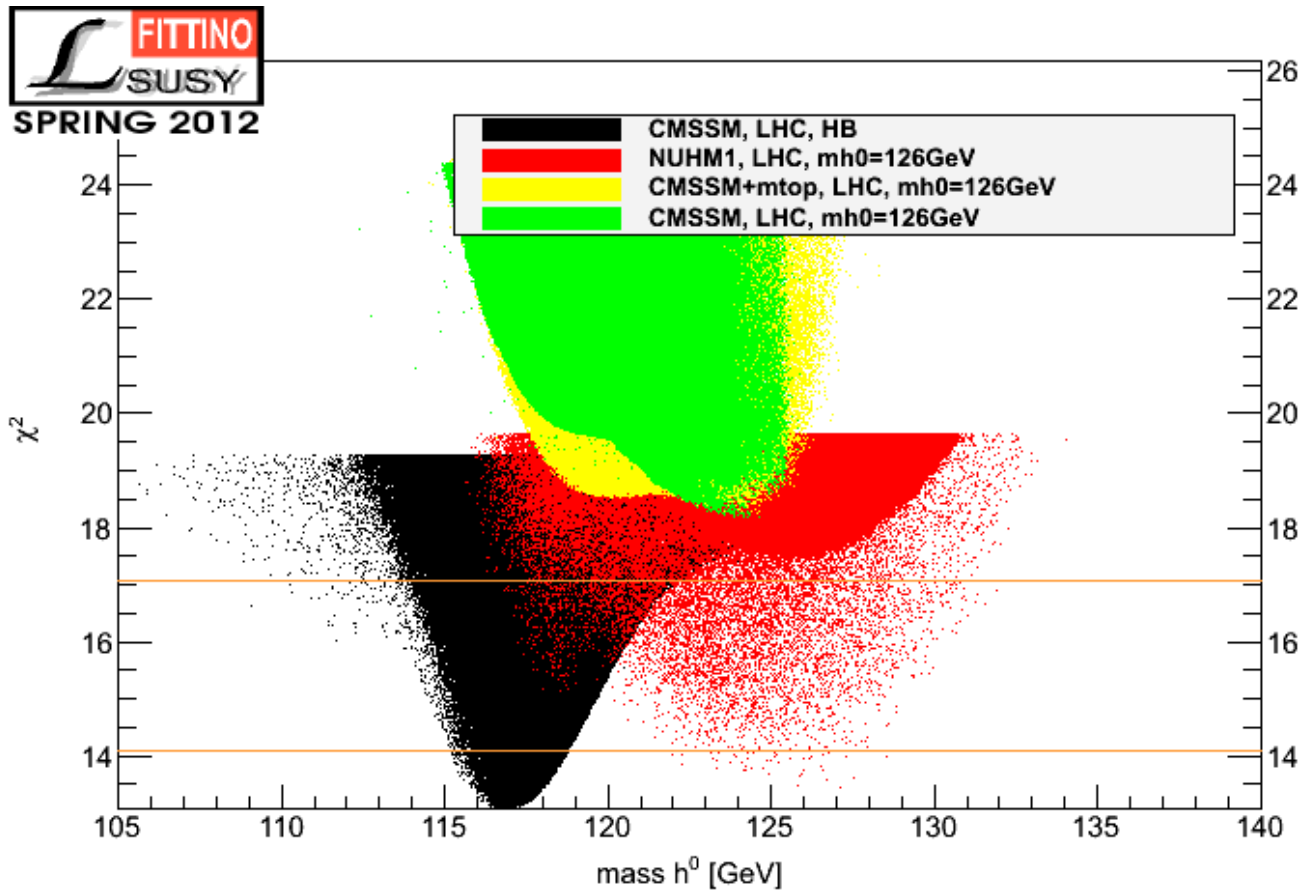
CMSSM, LHC

a_μ - a_μ^{SM}	$(2.9 \pm 0.8 \pm 0.2)$E-9	1.4E-9
BR(b$\to$ sγ)	$(3.55 \pm 0.26 \pm 0.23)$E-4	3.09E-4
BR(b$\to \tau\nu$)	(1.67 ± 0.39)E-4	0.92E-4
BR($B_s \to \mu^+\mu^-$)	$<(1.60 \pm 0.02)$E-8	0.38E-8
Δ m_s	$17.78 \pm 0.12 \pm 5.20$	20.97
$\sin^2\theta^l_{eff}$	0.23113 ± 0.00021	0.23147
m_W (GeV)	$80.385 \pm 0.015 \pm 0.010$	80.368
m_h (GeV)		116.8
LHC		
$\Omega_{CDM}h^2$	$0.1123 \pm 0.0035 \pm 0.0123$	0.1125
σ^{SI}		7.28E-10



What is the role of the Higgs sector?

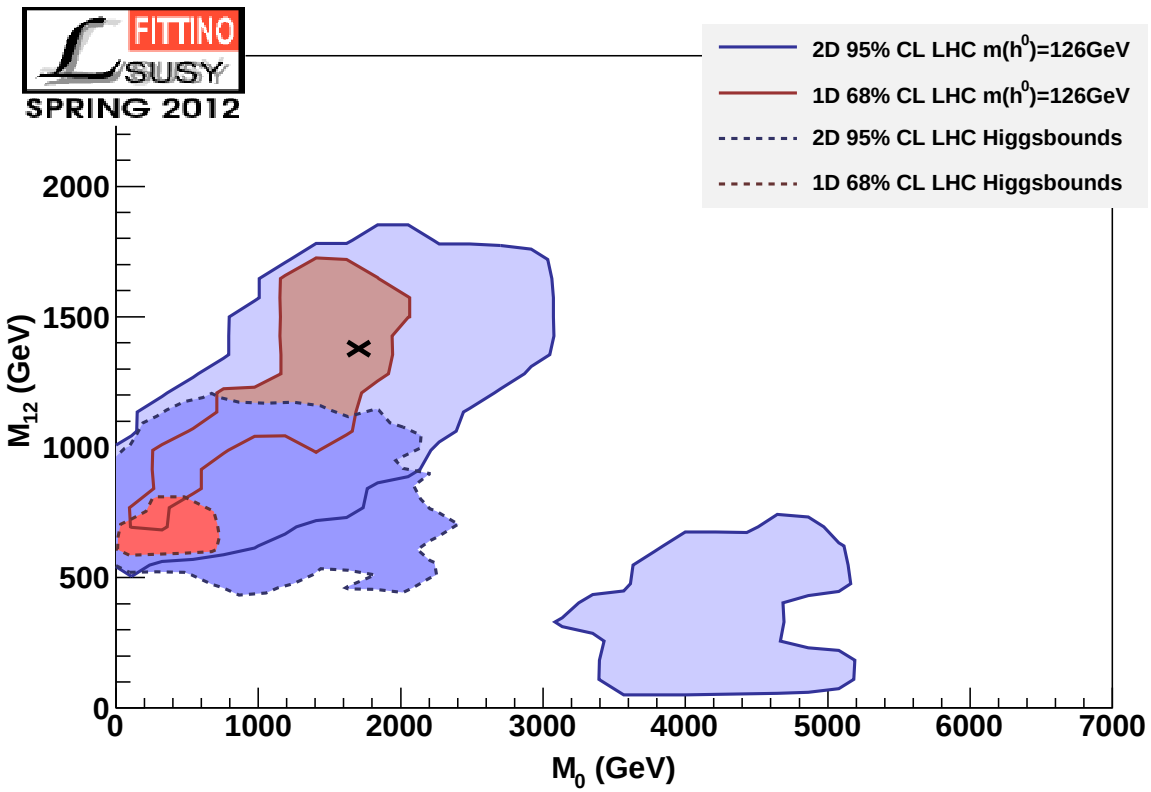
Let us assume that the LHC finds a light Higgs:



$\rightarrow$ Higgs masses $m_h \approx 125$ GeV are hard to accommodate in the CMSSM

What is the role of the Higgs sector?

Let us assume that the LHC finds a light Higgs with $m_h = 126 \pm 3 \pm 2$ GeV



Fit	M_0 [GeV]	$M_{1/2}$ [GeV]	$\tan\beta$	A_0	χ^2/ndf
LHC+m_h=126	$1706.5^{+244.7}_{-1499.3}$	$1378.1^{+328.1}_{-689.9}$	$57.1^{+1.5}_{-49.4}$	$-2015.7^{+3408.3}_{-2019.5}$	18.2/9

What is the role of the Higgs sector?

Let us assume that the LHC finds a light Higgs with $m_h = 126 \pm 3.5$ GeV

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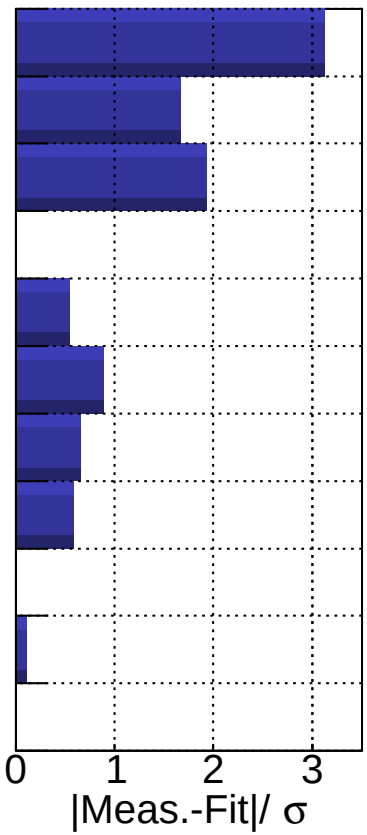
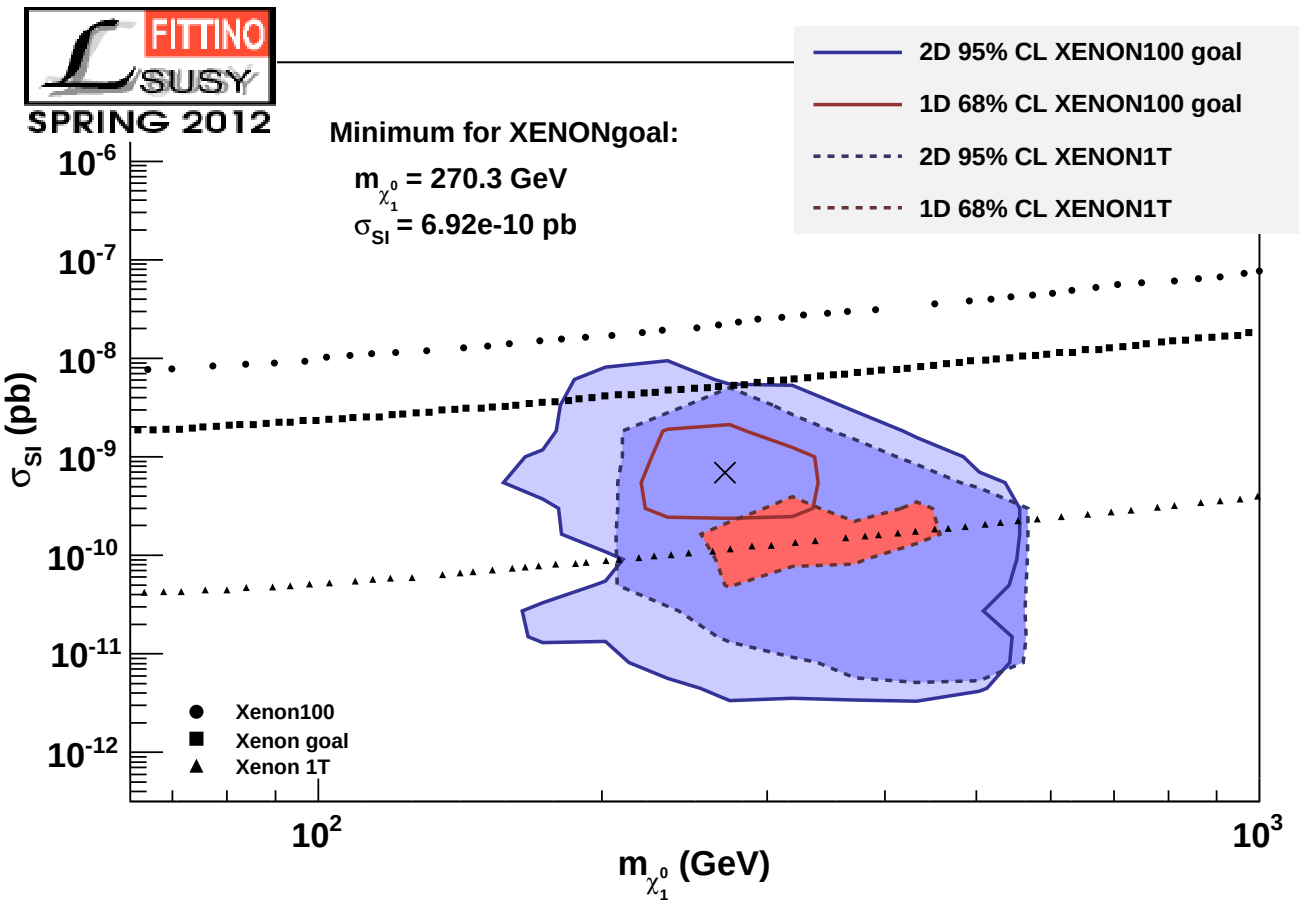
CMSSM, m_h=126 GeV

a_μ - a_μ^{SM}	$(2.9 \pm 0.8 \pm 0.2)$E-9	0.3E-9
BR(b$\to$ sγ)	$(3.55 \pm 0.26 \pm 0.23)$E-4	2.97E-4
BR(b$\to \tau\nu$)	(1.67 ± 0.39)E-4	0.92E-4
BR($B_s \to \mu^+\mu^-$)	$<(1.60 \pm 0.02)$E-8	0.65E-8
Δ m_s	$17.78 \pm 0.12 \pm 5.20$	20.60
$\sin^2\theta^l_{eff}$	0.23113 ± 0.00021	0.23132
m_W (GeV)	$80.385 \pm 0.015 \pm 0.010$	80.397
m_h (GeV)	$126.0 \pm 2.0 \pm 3.0$	123.9
LHC		
$\Omega_{CDM}h^2$	$0.1123 \pm 0.0035 \pm 0.0123$	0.1137
σ^{SI}		2.58E-10



SUSY searches beyond pp $\rightarrow$ jets (+leptons) + MET

- flavour constraints, in particular $B_s \rightarrow \mu\mu$ (LHCb)
- direct dark matter searches



Summary: the Fittino CMSSM fits

fit	M_0	$M_{1/2}$	$\tan\beta$	A_0	χ^2/ndf
no LHC	$85.9^{+139.7}_{-29.9}$	$381.8^{+177.2}_{-97.1}$	$14.9^{+16.1}_{-7.3}$	$184.1^{+846.7}_{-872.1}$	10.2/8
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- including the current LHC exclusion limits leads to tensions within constrained models like the CMSSM
- in particular, Higgs masses $\gtrsim 125\,\mathrm{GeV}$ are hard to accommodate
- essentially, we have to give up on an improved description of low energy data, like $(g-2)_\mu$
- we should move to more general models, but just from exclusions it is hard to constrain a larger set of free parameters