Prejudice meets reality, Bonn, August 2012

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

Michael Krämer (RWTH Aachen University)

Work done in collaboration with P. Bechtle, T. Bringmann, K. Desch, H.K. Dreiner, M. Hamer, C. Hensel, N. Nguyen, W. Porod, X. Prudent, B. Sarrazin, M. Uhlenbrock and P. Wienemann, JHEP 06, 098 (2012)

We have been trying to address to following questions:

- What is the most probable CMSSM 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?

SUSY searches: past, present, future

- past: EWK & flavour observables, collider limits, $\Omega_{\rm DM}$
- present: $\oplus$ LHC SUSY exclusions
- present: $\oplus$ LHC Higgs signal
- future: $\oplus$ LHC discoveries…

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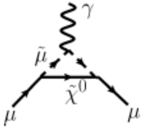
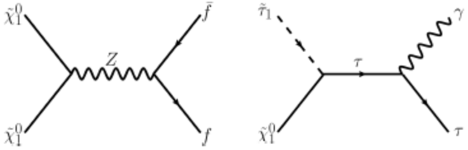
Indirect SUSY searches

There is a wealth of precision measurements including
B physics observables, $(g-2)_\mu$, astrophysics (DM) and collider limits
which show sensitivity to supersymmetry, in particular

- $(g-2)_\mu$



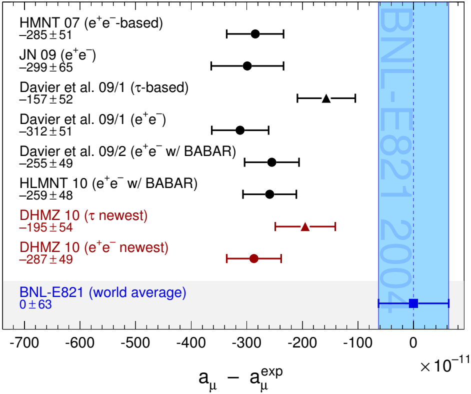
- DM relic abundance



Indirect SUSY searches: $(g-2)_\mu$

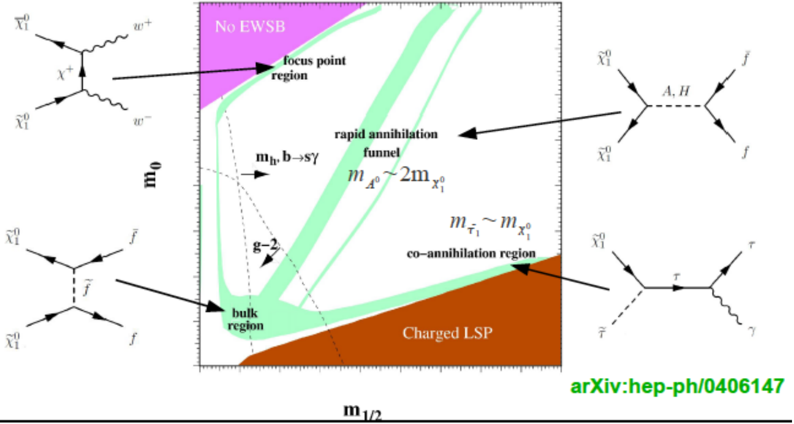
3.6/2.4σ discrepancy between experimental data and SM prediction

Davier, Hoecker, Malaescu, Zhang, arXiv:1010.4180v1



→ SUSY loops: $a_\mu^{\mathrm{SUSY}} \sim \mathrm{sgn}(\mu) \tan\beta \, M_{\mathrm{SUSY}}^{-2}$

Ω_{DM} is too large for large parts of the CMSSM parameter space, special annihilation mechanisms are needed



SUSY framework: the constrained MSSM

SUSY searches are often interpreted in the constrained MSSM, where the breaking is universal at the GUT scale

- universal scalar masses: $M^2_{\tilde{Q}}$, $M^2_{\tilde{U}}$, $M^2_{\tilde{D}}$, $M^2_{\tilde{L}}$, $M^2_{\tilde{E}}$ $\rightarrow M^2_0$ at M_{GUT}
- universal gaugino masses: M_1, M_2, $M_3 \rightarrow M_{1/2}$ at M_{GUT}
- universal trilinear couplings $A^e_{ij}, A^d_{ij}, A^u_{ij} \rightarrow A \cdot h^e_{ij}, A \cdot h^d_{ij}, A \cdot h^u_{ij}$ at M_{GUT}

In addition one has $\tan\beta$ and $\mathrm{sign}(\mu)$

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In addition one has $\tan\beta$ and sign(μ)

In the CMSSM the sparticle masses are strongly correlated, e.g.

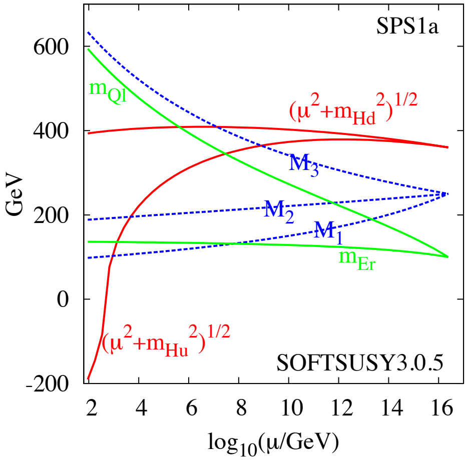
$$M_{\tilde{g}} \simeq 3M_{\tilde{\chi}^\pm} \simeq 3M_{\tilde{\chi}^0_2} \simeq 6M_{\tilde{\chi}^0_1}$$

and

$$\begin{aligned} m^2_{\tilde{u}_L} &\simeq M_0^2 + 6.3\, M^2_{1/2} + D_{\tilde{u}_L} \\ m^2_{\tilde{e}_L} &\simeq M_0^2 + 0.5\, M^2_{1/2} + D_{\tilde{e}_L} \end{aligned}$$

where $D_{\tilde{f}_L} = M_Z^2 \cos(2\beta)(T_{3_f} - Q_f \sin(2\theta_W))$

CMSSM mass spectrum



typical mass pattern e.g. from

$$\frac{M_1(\mu)}{\alpha_1(\mu)} = \frac{M_2(\mu)}{\alpha_2(\mu)} = \frac{M_3(\mu)}{\alpha_3(\mu)}$$

$\rightarrow M_3(M_Z) : M_2(M_Z) : M_1(M_Z)$

$\simeq 7 : 2 : 1$

The Fittino CMSSM fits

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`
- LHC exclusions:
  from jets+$E_{T\mathrm{miss}}$ searches corresponding to $5\,\mathrm{fb}^{-1}$ of data at 7 TeV
- The LHC Higgs signal:
  assuming $m_h = (126 \pm 2\,(\mathrm{exp}) \pm 3\,(\mathrm{theo}))$ GeV

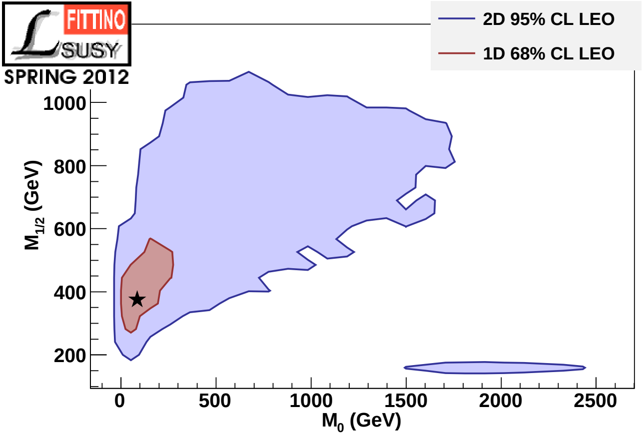
The Fittino CMSSM fits

- 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

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

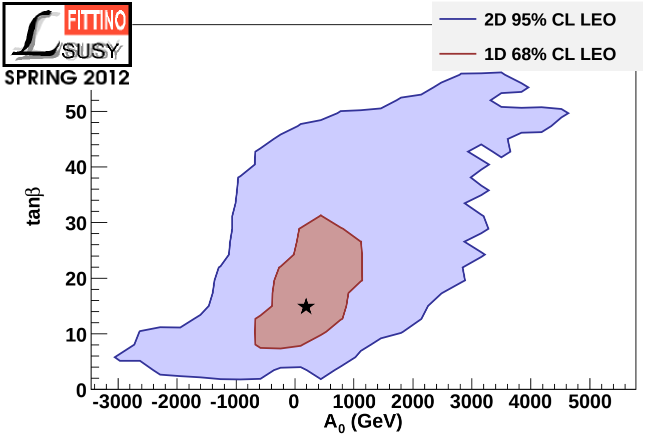
for each point $\vec{P}$ in the CMSSM parameter space using `Fittino`.

The Fittino CMSSM fits without LHC exclusions



Fit	M_0 [GeV]	$M_{1/2}$ [GeV]	$\tan\beta$	A_0	χ^2/ndf
LEO	$84.4^{+144.6}_{-28.1}$	$375.4^{+174.5}_{-87.5}$	$14.9^{+16.5}_{-7.2}$	$186.3^{+831.4}_{-843.7}$	$10.3/8$

The Fittino CMSSM fits without LHC exclusions



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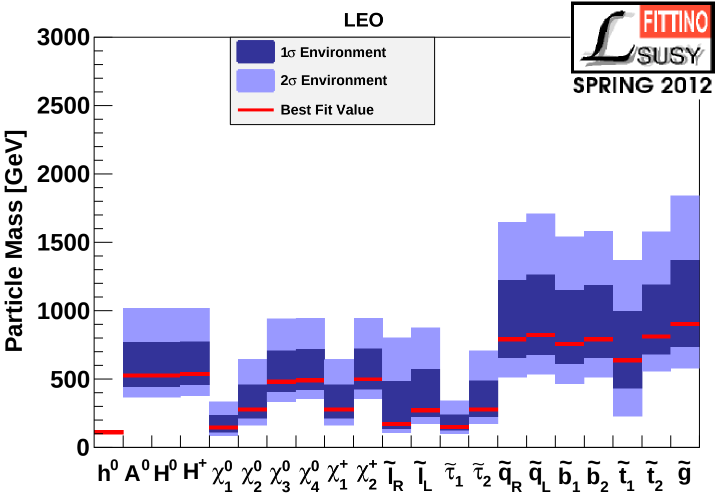

... point to a relatively light sparticle spectrum with $\tilde{m} \lesssim 1\,\text{TeV}$

SUSY searches: past, present, future

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- present: $\oplus$ LHC Higgs signal
- future: $\oplus$ LHC discoveries. . .

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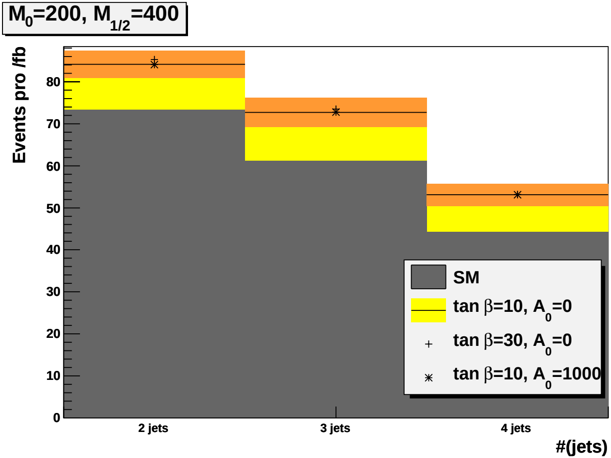
Including LHC SUSY search limits

- 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 from $\tan\beta$ and A_0.
- The SM background is taken from the ATLAS simulation.

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



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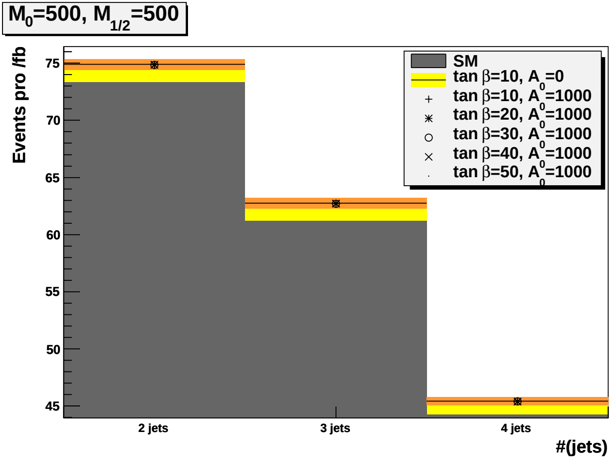
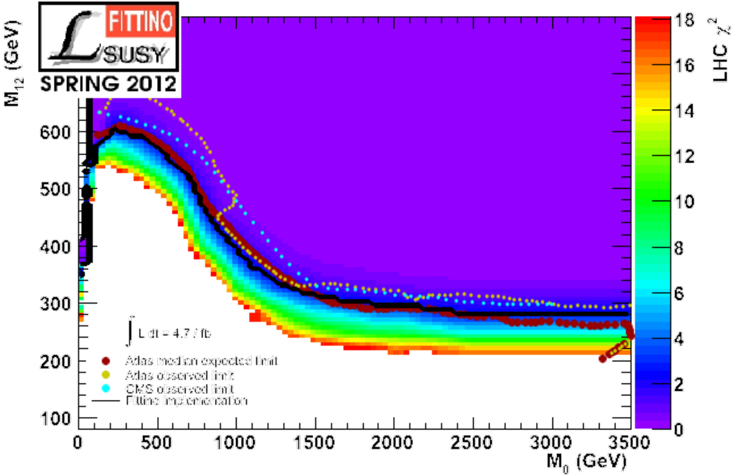
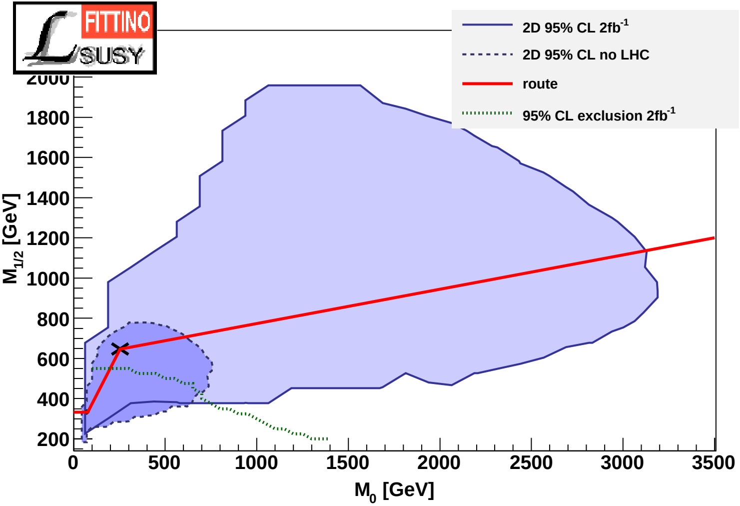


We find good agreement with the $5\,\mathrm{fb}^{-1}$ 7 TeV LHC CMSSM limits:



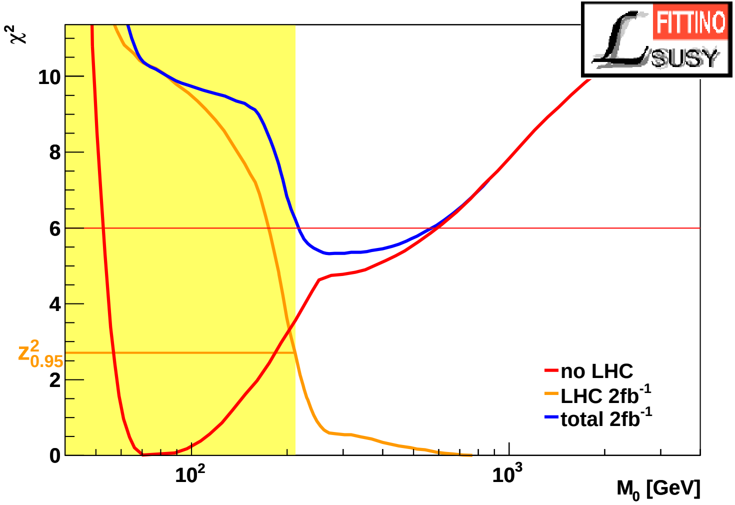
Global SUSY fits: the χ^2 of the LHC exclusions

Let us look at the χ^2 of the LHC exclusions along the red line:

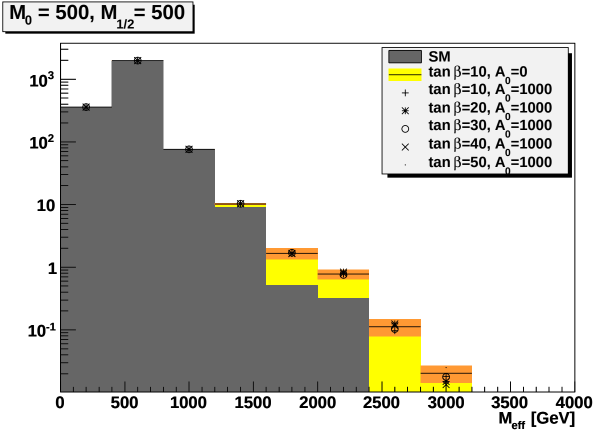


Global SUSY fits: the χ^2 of the LHC exclusions

We find a non-trivial shape of the LHC χ^2:



When we vary m_0 and $m_{1/2}$, both the SUSY rate as well as the shape of the M_{eff} distribution change; SUSY signals with larger rate may become more background-like and thus harder to observe.



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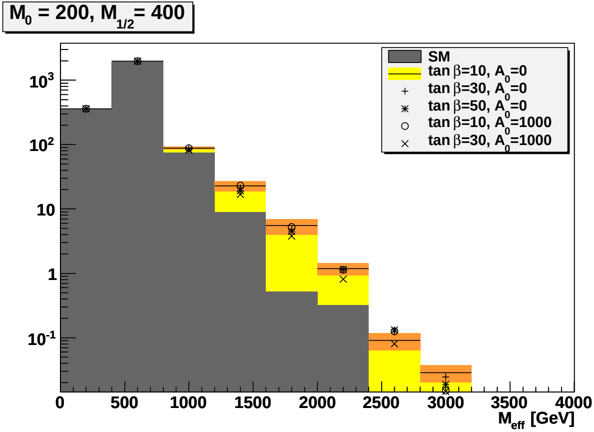
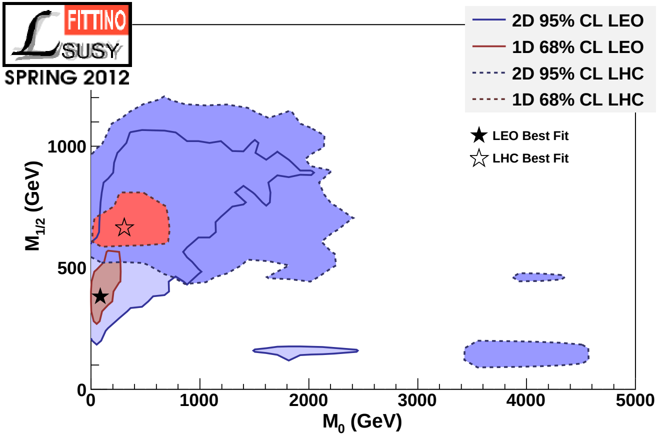
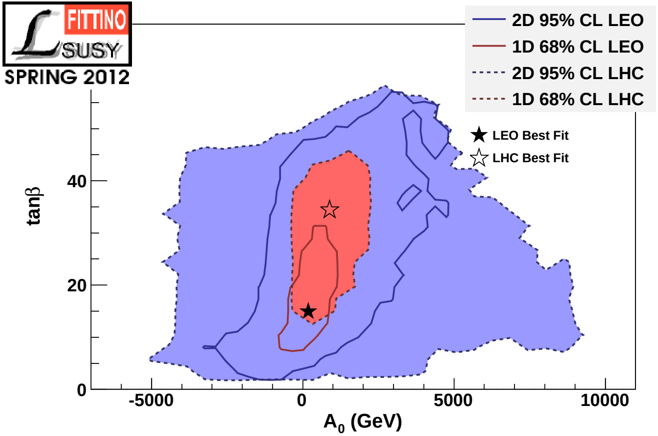


The Fittino CMSSM fits with $5\,\mathrm{fb}^{-1}$ LHC exclusions



Fit	M_0 [GeV]	$M_{1/2}$ [GeV]	$\tan\beta$	A_0	χ^2/ndf
LHC	$304.4^{+373.7}_{-185.2}$	$664.6^{+138.3}_{-70.9}$	$34.4^{+10.9}_{-21.3}$	$884.8^{+1178.0}_{-974.9}$	$13.1/9$

The Fittino CMSSM fits with 5 fb^{-1} LHC exclusions



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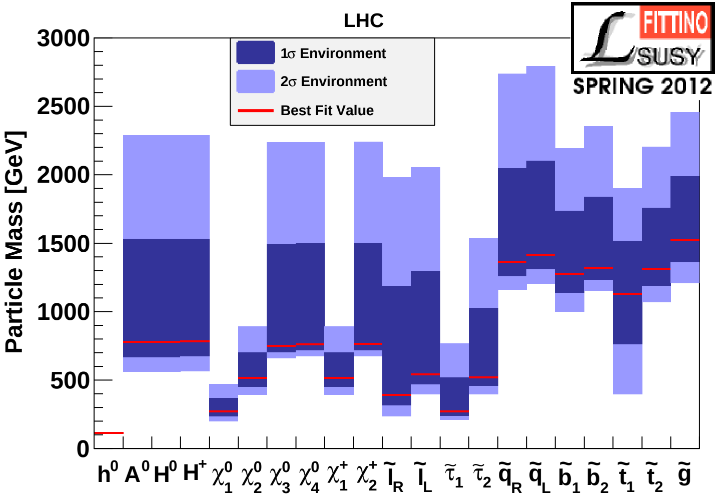

$\rightarrow$ LHC exclusions push up the masses and enlarge the uncertainties

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

→ low energy observables, in particular $(g-2)_\mu$, prefer low mass scales (for the non-coloured sector)

→ LHC prefers high mass scales (for the coloured sector)

Is there a tension building up?

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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	$84.4^{+144.6}_{-28.1}$	$375.4^{+174.5}_{-87.5}$	$14.9^{+16.5}_{-7.2}$	$186.3^{+831.4}_{-843.7}$	10.3/8
with LHC	$304.3^{+373.7}_{-185.2}$	$664.6^{+138.1}_{-70.9}$	$34.4^{+15.3}_{-21.3}$	$884.76^{+1178.0}_{-974.9}$	13.1/9

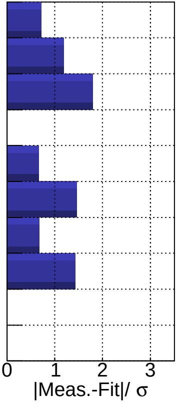
$\rightarrow$ some tension building up, but not enough to exclude the CMSSM

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

FITTINO SUSY
SPRING 2012

CMSSM, LEO

$a_\mu - a_\mu^{SM}$	$(2.9 \pm 0.8 \pm 0.2)$E-9	2.3E-9
BR($b \to s\gamma$)	$(3.55 \pm 0.26 \pm 0.23)$E-4	3.14E-4
BR($B \to \tau\nu$)	(1.67 ± 0.39)E-4	0.97E-4
BR($B_s \to \mu^+\mu^-$)	$<(4.50 \pm 0.30)$E-9	3.08E-9
Δm_s (ps^{-1})	$17.78 \pm 0.12 \pm 5.20$	21.24
$\sin^2\theta^l_{eff}$	0.23113 ± 0.00021	0.23144
m_W (GeV)	$80.385 \pm 0.015 \pm 0.010$	80.373
m_h (GeV)		113.6
$\Omega_{CDM}h^2$	$0.1123 \pm 0.0035 \pm 0.0112$	0.1123
σ^{SI} (pb)		2.04E-9



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

FITTINO SUSY SPRING 2012

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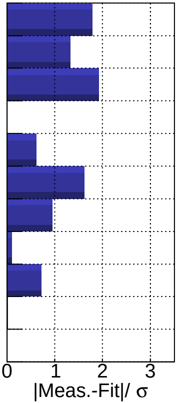
$a_\mu - a_\mu^{SM}$	$(2.9 \pm 0.8 \pm 0.2)$E-9	1.4E-9
$BR(b \to s\gamma)$	$(3.55 \pm 0.26 \pm 0.23)$E-4	3.09E-4
$BR(b \to \tau\nu)$	(1.67 ± 0.39)E-4	0.92E-4
$BR(B_s \to \mu^+\mu^-)$	$<(1.60 \pm 0.02)$E-8	0.38E-8
Δm_s	$17.78 \pm 0.12 \pm 5.20$	20.97
$\sin^2\theta^l_{eff}$	0.23113 ± 0.00021	0.23147
m_W (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



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Including the Higgs

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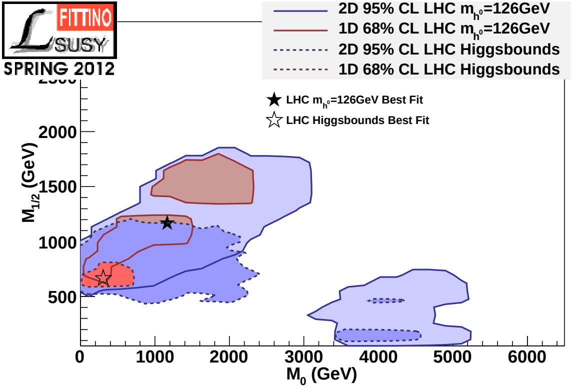

Fit	M_0 [GeV]	$M_{1/2}$ [GeV]	$\tan\beta$	A_0	χ^2/ndf
LHC+m_h=126 GeV	$1163.2^{+1185.3}_{-985.7}$	$1167.4^{+594.0}_{-513.0}$	$39.3^{+16.7}_{-32.7}$	$-2969.1^{+6297.8}_{-1234.9}$	18.4/9

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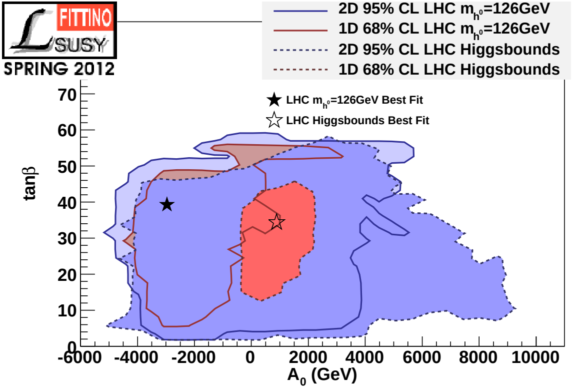

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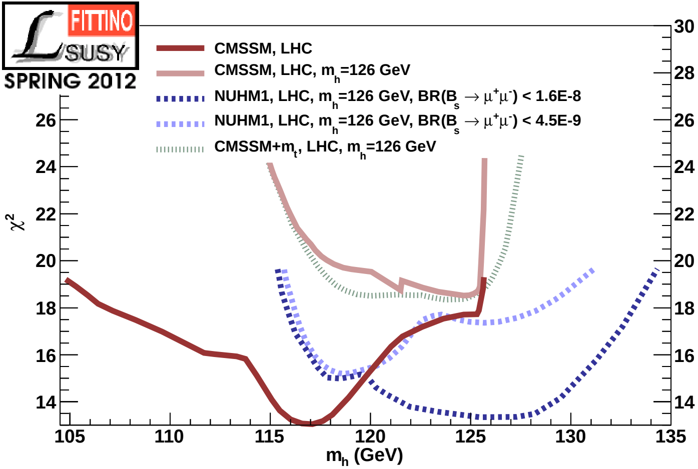
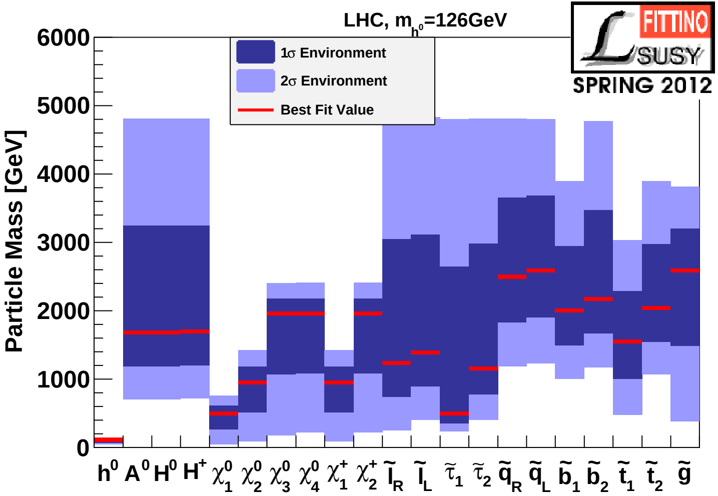
Including the Higgs



$\rightarrow$ $m_h \gtrsim$ 120 GeV is hard to accommodate in the CMSSM

Including the Higgs



→ $m_h \approx 125$ GeV would imply a heavy CMSSM sparticle spectrum

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CMSSM, LHC

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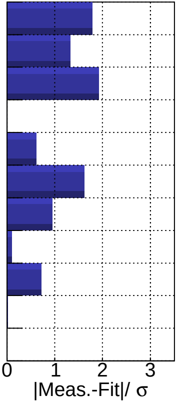

Including the Higgs

FITTINO SUSY SPRING 2012

CMSSM, m_h=126 GeV

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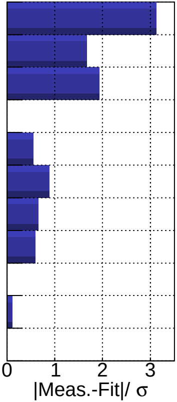
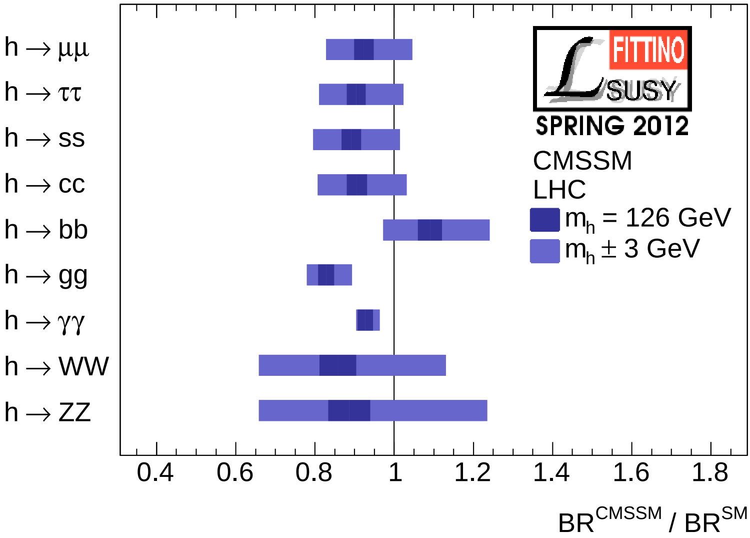
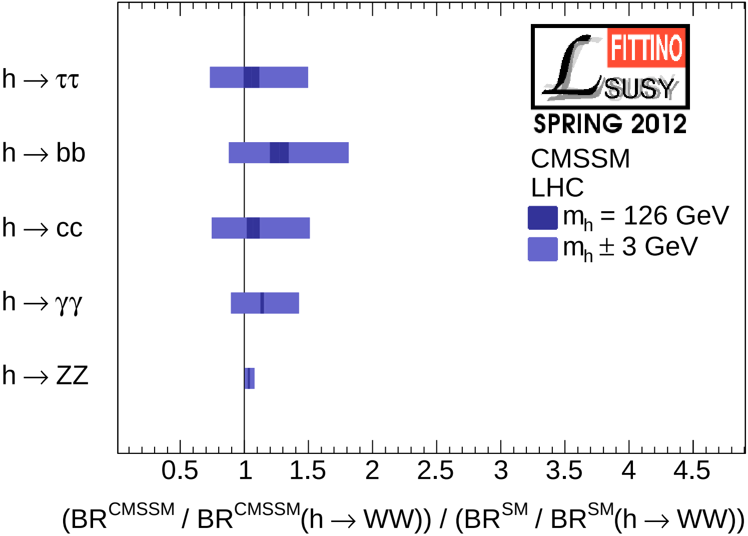
$\sin^2\theta^l_{eff}$	0.23113 ± 0.00021	0.23132
m_W (GeV)	$80.385 \pm 0.015 \pm 0.010$	80.397
m_h (GeV)	$126.0 \pm 2.0 \pm 3.0$	123.9
LHC		
$\Omega_{CDM}h^2$	$0.1123 \pm 0.0035 \pm 0.0123$	0.1137
σ^{SI}		2.58E-10

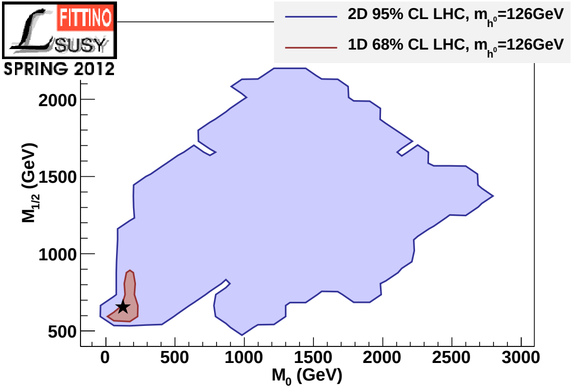



h → μμ
h → ττ
h → ss
h → cc
h → bb
h → gg
h → γγ
h → WW
h → ZZ
FITTINO
SUSY
SPRING 2012
CMSSM
LHC
m_h = 126 GeV
m_h ± 3 GeV
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
BR^CMSSM / BR^SM


h → ττ
h → bb
h → cc
h → γγ
h → ZZ
FITTINO
SUSY
SPRING 2012
CMSSM
LHC
m_h = 126 GeV
m_h ± 3 GeV
0.5
1
1.5
2
2.5
3
3.5
4
4.5
(BR^CMSSM / BR^CMSSM(h → WW)) / (BR^SM / BR^SM(h → WW))

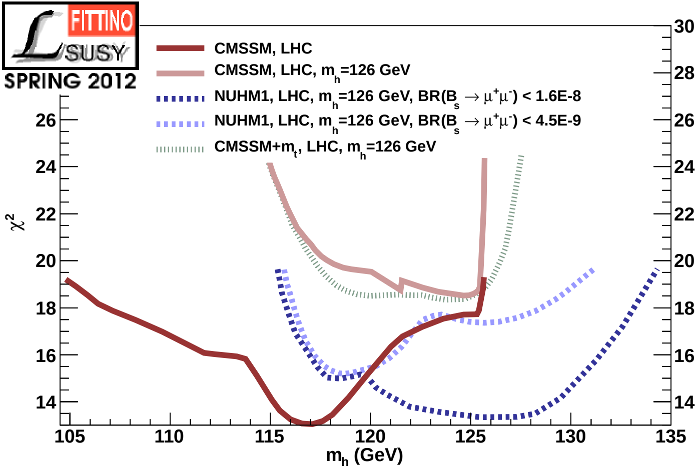
Beyond the CMSSM: non-universal Higgs mass models

- we consider the NUHM1 with $M_{H_u} = M_{H_d} = M_H \neq M_0$



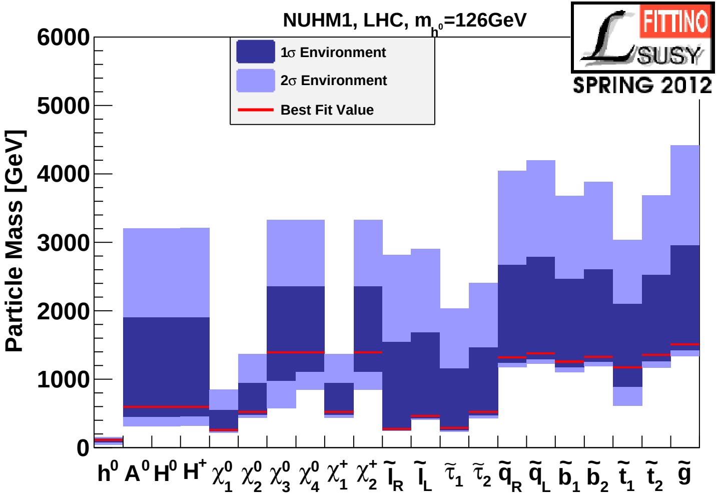
Fit	M_0 [GeV]	$M_{1/2}$ [GeV]	M_H^2 [GeV^2]	tan β	A_0	χ^2/ndf
NUHM1+m_h	$124.3^{+95.2}_{-16.8}$	$655.5^{+218.0}_{-65.0}$	$(-1.7^{+0.5}_{-2.7}) \times 10^6$	$29.4^{+3.3}_{-7.8}$	$-511.2^{+574.7}_{-988.6}$	15.3/8

Including the Higgs



→ $m_h \gtrsim$ 120 GeV is easier to accommodate in the NUHM1

Including the Higgs

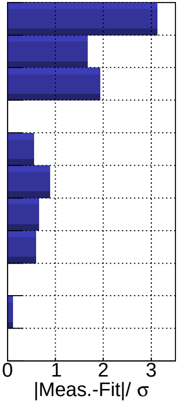


$\rightarrow$ the NUHM1 would imply a lighter sparticle spectrum than the CMSSM

FITTINO SUSY SPRING 2012

CMSSM, m_h=126 GeV

$a_\mu - a_\mu^{SM}$	$(2.9 \pm 0.8 \pm 0.2)$E-9	0.3E-9
$BR(b \to s\gamma)$	$(3.55 \pm 0.26 \pm 0.23)$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
Δm_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

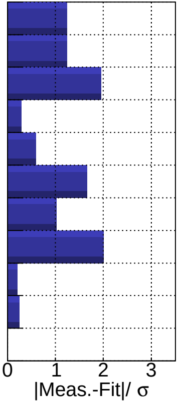


Including the Higgs

SPRING 2012

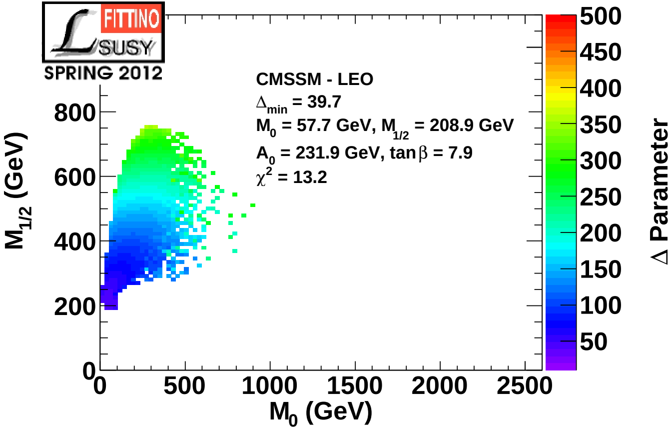
NUHM1, LHC, m_h=126 GeV

$a_\mu - a_\mu^{SM}$	$(2.9 \pm 0.8 \pm 0.2)$E-9	1.8E-9
BR($b \rightarrow s\gamma$)	$(3.55 \pm 0.26 \pm 0.23)$E-4	3.12E-4
BR($B \rightarrow \tau\nu$)	(1.67 ± 0.39)E-4	0.91E-4
BR($B_s \rightarrow \mu^+\mu^-$)	<(4.50 ± 0.30)E-9	4.59E-9
Δm_s (ps^{-1})	$17.78 \pm 0.12 \pm 5.20$	20.88
$\sin^2\theta^l_{eff}$	0.23113 ± 0.00021	0.23148
m_W (GeV)	$80.385 \pm 0.015 \pm 0.010$	80.367
m_h (GeV)	$126.0 \pm 2.0 \pm 3.0$	118.8
LHC		
$\Omega_{CDM}h^2$	$0.1123 \pm 0.0035 \pm 0.0112$	0.1094
σ^{SI} (pb)		1.81E-10



Fine tuning

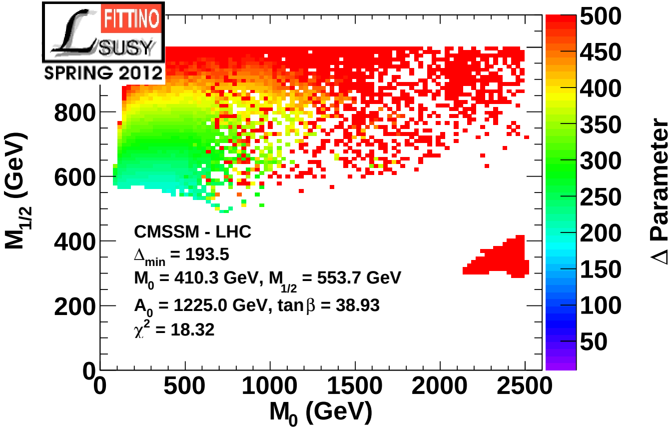
we consider $\Delta = \max_i[c(a_i)]$ with $c(a_i) = \left|\frac{a_i}{m_Z^2}\frac{\partial m_Z^2(a_i)}{\partial a_i}\right|$ [Barbieri, Giudice]



→ $\Delta \gtrsim 40$ without LHC exclusions

Fine tuning

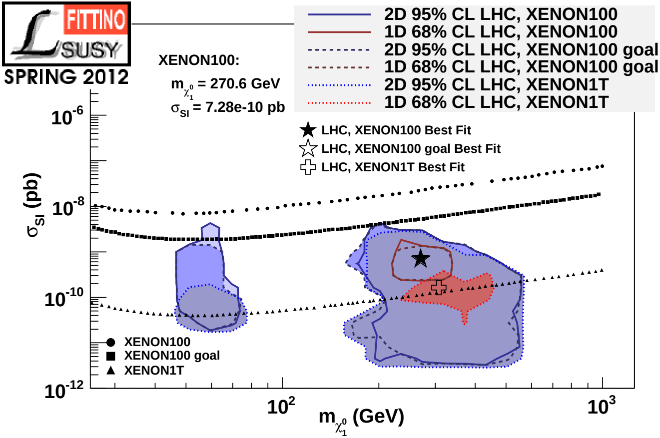
we consider $\Delta = \max_i[c(a_i)]$ with $c(a_i) = \left|\frac{a_i}{m_Z^2}\frac{\partial m_Z^2(a_i)}{\partial a_i}\right|$ [Barbieri, Giudice]



$\rightarrow \Delta \gtrsim 200$ with LHC exclusions

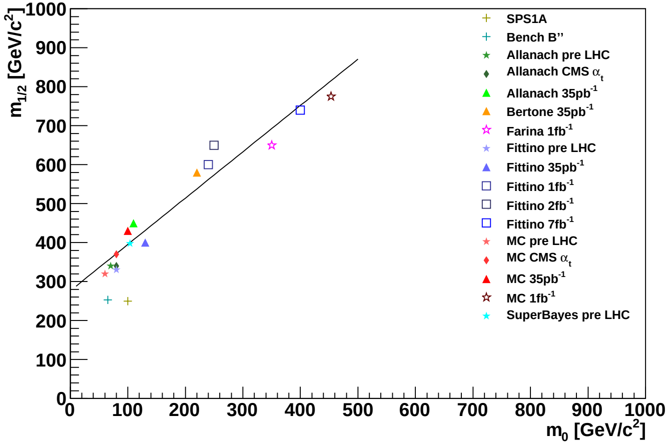
SUSY searches beyond pp $\rightarrow$ jets (+leptons) + MET

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



Comparison of global CMSSM fits with and without LHC exclusions

There has been a lot of activity recently (see e.g. the discussions in arXiv:1109.3859, arXiv:1206.0264 and arXiv:1207.7315)



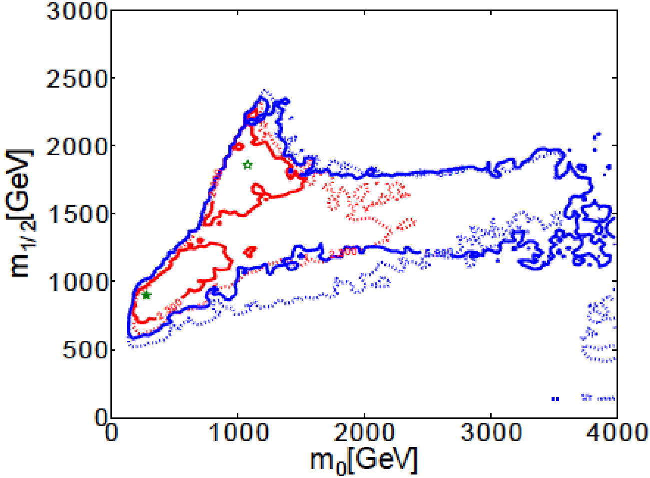
→ there is some spread in the results when including LHC limits

The Mastercode fits

see Buchmueller et al., arXiv:1207.7315

- based on `MasterCode` compilation of codes: private code by Heinemeyer et al. for electroweak observables, `SoftSUSY`, `FeynHiggs`, `SuFla`, `MicoOMEGAs`, `SSARD`, ...
- includes
  - low energy observables;
  - DM relic density;
  - ATLAS SUSY exclusions from 5/fb data at 7 TeV;
  - $B_s \to \mu\mu$ constraints from ATLAS, CDF, CMS and LHCb;
  - recent XENON100 data;
  - CMS exclusions of $H/A \to \tau\tau$;
  - a Higgs signal at $m_h = (125 \pm 1\,(\mathrm{exp}) \pm 1.5\,(\mathrm{theo}))$ GeV.
- LHC exclusions based on `Pythia` and `Delphes` simulation together with parametrization of signal event number $\propto 1/\mathcal{M}^4$, where $\mathcal{M} \equiv \sqrt{m_0^2 + m_{1/2}^2}$

see Buchmueller et al., arXiv:1207.7315

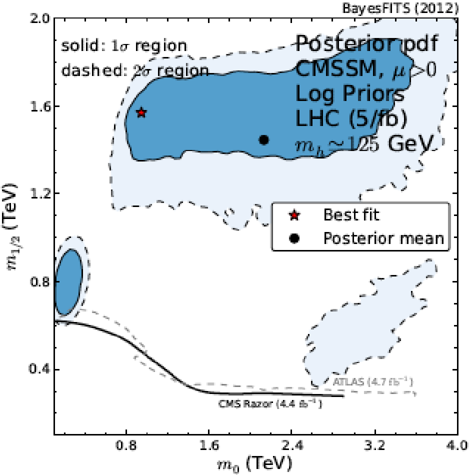


The BayesFITS

see Fowlie et al., arXiv:1206.0264

- uses Baysian statistics
- based on `SoftSUSY`, `FeynHiggs`, `SuperIso`, `MicoOMEGAs` codes
- includes
  - low energy observables;
  - DM relic density;
  - CMS SUSY razor exclusions from 4.4/fb data at 7 TeV;
  - $B_s \to \mu\mu$ constraints from LHCb;
  - CMS exclusions of $H/A \to \tau\tau$;
  - a Higgs signal at $m_h = 125\,\text{GeV}$
    (error included in the calculation of the likelihood).
- LHC exclusions based on `Pythia` and `PGS4` simulation

see Fowlie et al., arXiv:1206.0264



Summary: the Fittino CMSSM fits

fit	M_0	$M_{1/2}$	$\tan\beta$	A_0	χ^2/ndf
no LHC	$84.4^{+144.6}_{-28.1}$	$375.4^{+174.5}_{-87.5}$	$14.9^{+16.5}_{-7.2}$	$186.3^{+831.4}_{-843.7}$	10.3/8
with LHC	$304.3^{+373.7}_{-185.2}$	$664.6^{+138.1}_{-70.9}$	$34.4^{+15.3}_{-21.3}$	$884.76^{+1178.0}_{-974.9}$	13.1/9
LHC+m_h=126	$1163.2^{+1185.3}_{-985.7}$	$1167.4^{+594.0}_{-513.0}$	$39.3^{+16.7}_{-32.7}$	$-2969.1^{+6297.8}_{-1234.9}$	18.4/9

- including the current LHC exclusion limits leads to tensions within constrained models like the CMSSM
- in particular, Higgs masses $\gtrsim 125$ GeV are hard to accommodate
- essentially, in the CMSSM with $m_h \approx 125$ GeV we obtain a very heavy sparticle spectrum and have to give up on an improved description of low energy data, like $(g-2)_\mu$

Outlook

We will

- update our analysis as new LHC SUSY search results become available;
- include the measured Higgs couplings in our fits;
- calculate the p-value by using toy fits;
- move to more general models, in particular those with a different connection between the coloured and uncoloured sparticle sector;
- include a larger set of LHC observables and proper combinations of different analyses.

However,

- just from exclusions it is hard to constrain a larger set of SUSY parameters;
- we need fast and accurate implementations of the LHC results.

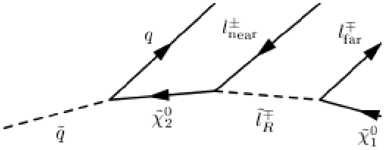
backup

SUSY searches: past, present, future

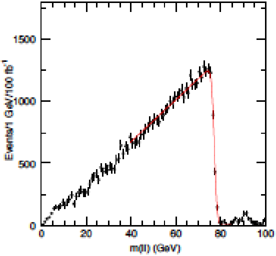
- past: EWK & flavour observables, collider limits, Ω_{DM}
- present: $\oplus$ LHC SUSY exclusions
- present: $\oplus$ LHC Higgs signal
- future: $\oplus$ LHC discoveries. . .

SUSY parameter determination at the LHC

Mass measurements from cascade decays, e.g.



Allanach et al.

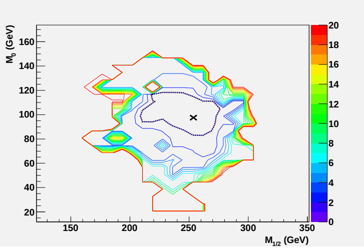


$\rightarrow$ kinematic endpoints sensitive to masses:

$$
\begin{aligned}
(m^2_{ll})^{\rm max} &= (m^2_{\tilde{\chi}^0_2} - m^2_{\tilde{l}_R})(m^2_{\tilde{l}_R} - m^2_{\tilde{\chi}^0_1})/m^2_{\tilde{l}_R} \\
(m^2_{qll})^{\rm max} &= (m^2_{\tilde{q}_L} - m^2_{\tilde{\chi}^0_2})(m^2_{\tilde{\chi}^0_2} - m^2_{\tilde{\chi}^0_1})/m^2_{\tilde{\chi}^0_2} \\
(m^2_{ql,{\rm min}})^{\rm max} &= (m^2_{\tilde{q}_L} - m^2_{\tilde{\chi}^0_2})(m^2_{\tilde{\chi}^0_2} - m^2_{\tilde{l}_R})/m^2_{\tilde{\chi}^0_2} \\
(m^2_{ql,{\rm max}})^{\rm max} &= (m^2_{\tilde{q}_L} - m^2_{\tilde{\chi}^0_2})(m^2_{\tilde{l}_R} - m^2_{\tilde{\chi}^0_1})/m^2_{\tilde{l}_R}
\end{aligned}
$$

SUSY parameter determination with cross sections

How well could we do at 7 TeV and 1 fb^{-1}? [Dreiner, MK, Lindert, O'Leary]



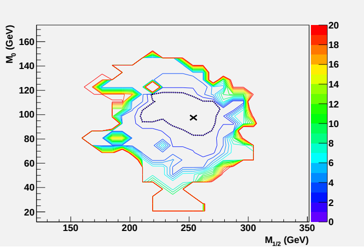
SPS1a with 4 kinematic edges only

→ no stable fit

→ add cross sections:
sensitive to masses and spins

SUSY parameter determination with cross sections

How well could we do at 7 TeV and 1 fb^{-1}? [Dreiner, MK, Lindert, O'Leary]



SPS1a with 4 kinematic edges only

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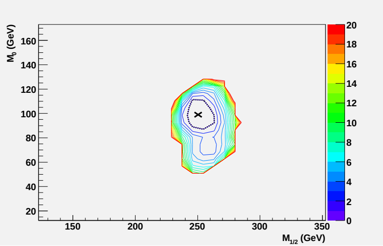
sensitive to masses and spins

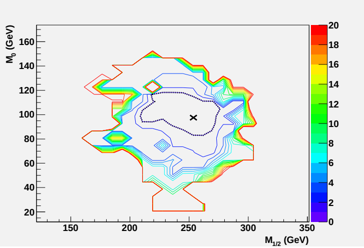


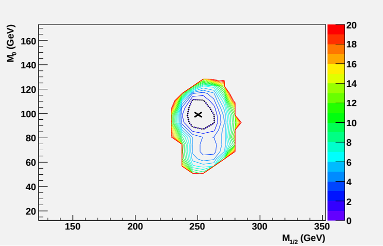
kinematic edges ⊕ cross sections

$$\rightarrow m_0 = 99 \pm 9 \text{ GeV}$$
$$m_{1/2} = 250 \pm 7 \text{ GeV}$$
$$\tan\beta = 11 \pm 6$$

SUSY parameter determination with cross sections

How well could we do at 7 TeV and 1 fb^{-1}? [Dreiner, MK, Lindert, O'Leary]





SPS1a with 4 kinematic edges only

$\rightarrow$ no stable fit

$\rightarrow$ add cross sections:
sensitive to masses and spins

kinematic edges $\oplus$ cross sections

$$\rightarrow m_0 = 99 \pm 9 \text{ GeV}$$

$$m_{1/2} = 250 \pm 7 \text{ GeV}$$

$$\tan\beta = 11 \pm 6$$

$\rightarrow$ cross sections are crucial to determine BSM parameters

SUSY parameter determination with cross sections

Beyond mSUGRA: explore mirage mediation models

[Choi, Nilles, Falkowski, Ratz, Loewen and many others]

$\rightarrow$ characteristic pattern of soft SUSY-breaking terms

$M_1 : M_2 : M_3 \simeq (1 + 0.66\alpha) : (2 + 0.2\alpha) : (6 - 1.8\alpha)$

$\rightarrow$ relative size of modulus and anomaly mediation controlled by α

How well can we determine α from future LHC data?

Beyond mSUGRA: explore mirage mediation models

[Choi, Nilles, Falkowski, Ratz, Loewen and many others]

→ characteristic pattern of soft SUSY-breaking terms

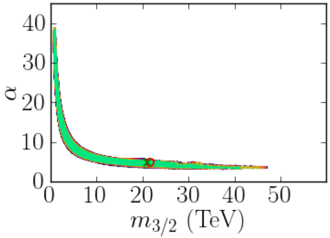
$M_1 : M_2 : M_3 \simeq (1 + 0.66\alpha) : (2 + 0.2\alpha) : (6 - 1.8\alpha)$

→ relative size of modulus and anomaly mediation controlled by α

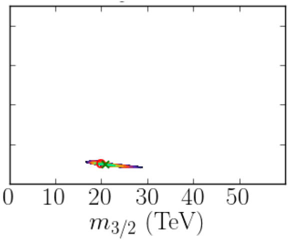
How well can we determine α from future LHC data?

Assume LHC @ 14 TeV with 1 fb^{-1}

[Conley, Dreiner, Glaser, MK, Tattersall]



kinematic edges only



kinematic edges ⊕ cross sections

$\to \alpha \;=\; 5 \pm 0.3$