mSUGRA and NUHM1 prospects including latest SUSY and Higgs search result

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All results still preliminary, paper to come soon

Aachen,Bonn,DESY/UniHH,Dresden,Göttingen,Würzburg

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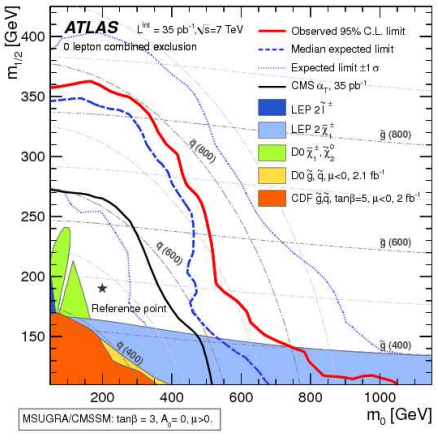
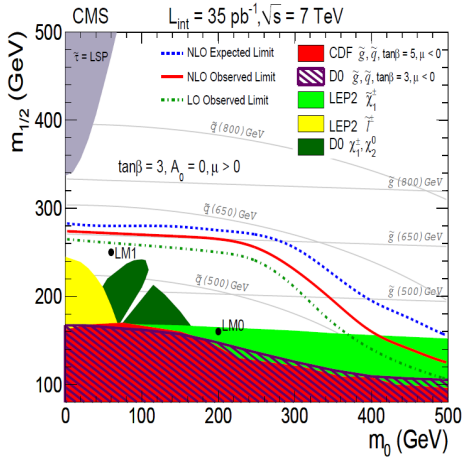
An Incomplete Overview of the Current Situation

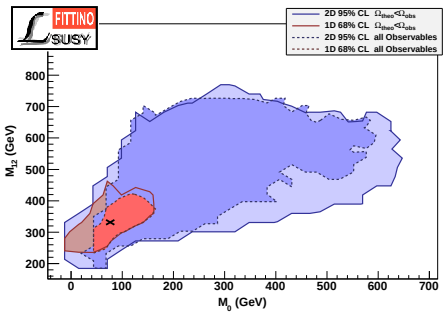
Old slide, but still almost up-to-date!

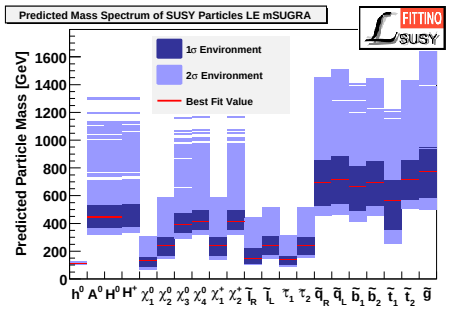


arXiv:1102.5290 [hep-ex]



arXiv:1101.1628 [hep-ex]





e.g. arXiv:0907.2589 [hep-ph]

- Does the non-observation of SUSY in the 2011 LHC searches agree with mSUGRA?
- If mSUGRA-like SUSY is realized, can we expect to discover SUSY in 2011/2012?
- What are the implications for the Higgs and for future colliders?

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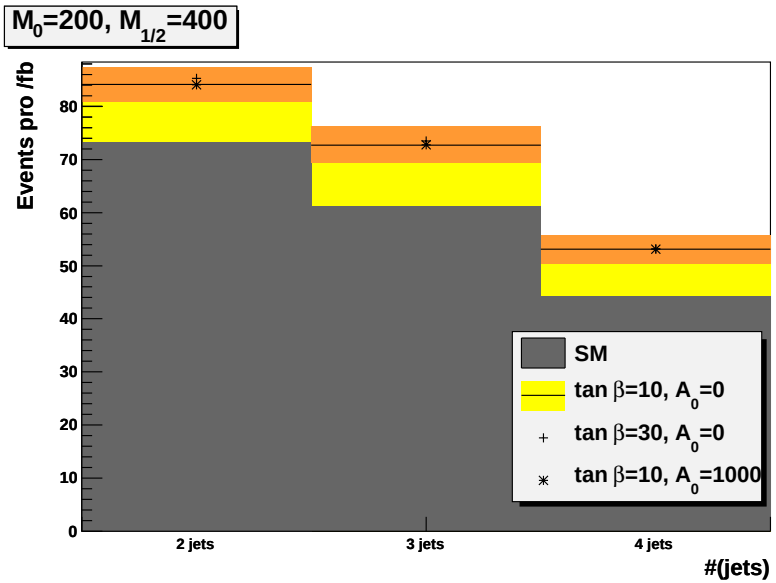
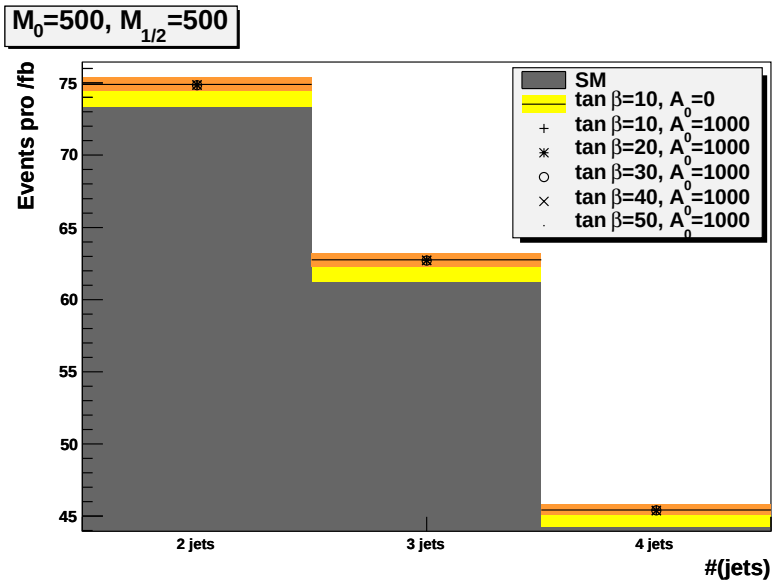
Systematic Check of the MSUGRA Parameter Grid





- Full re-implementation of the ATLAS search on free MC!
  following ATLAS-CONF-2011-086
- Variations of the signal shape for different $\tan\beta$ and A_0 covered by systematic uncertainty
- This is specific for the 0ℓ search – more complicated grids would be necessary for other searches
- Based on the full M_{eff} distribution, calculate CL_{s+b} for the median background hypothesis
- Transfer CL_{s+b} into $\chi^2 = 2[\,\mathrm{erf}^{-1}(1 - 2\,CL_{s+b})]^2$

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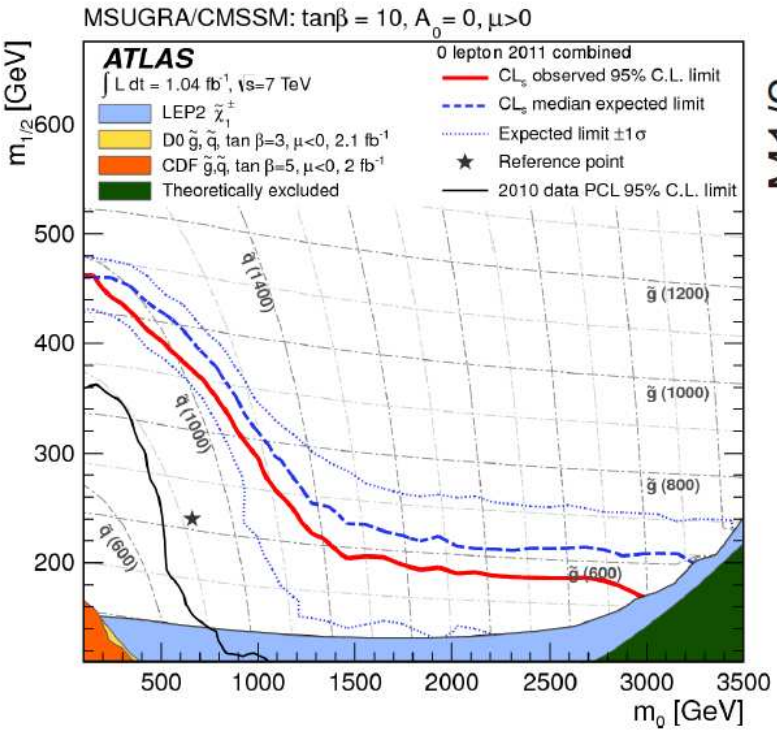
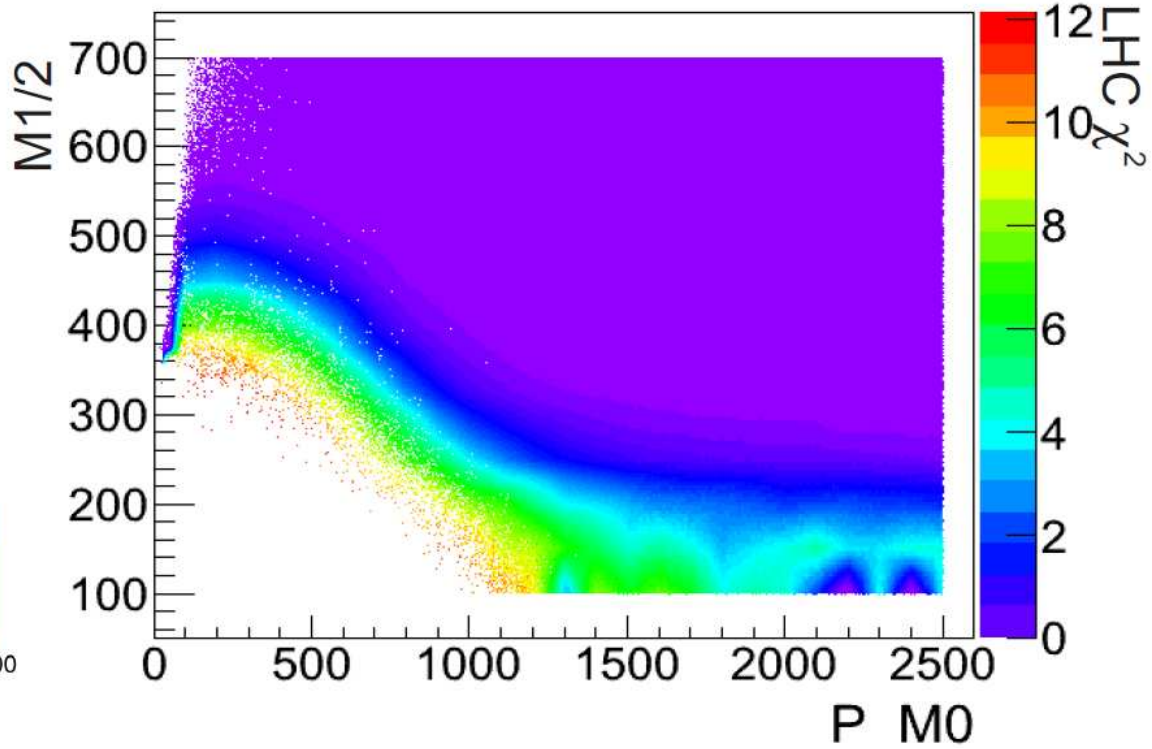
Full re-implementation of an LHC Search

ATLAS, 1.04/fb:



Fittino analysis emulation, 2/fb:

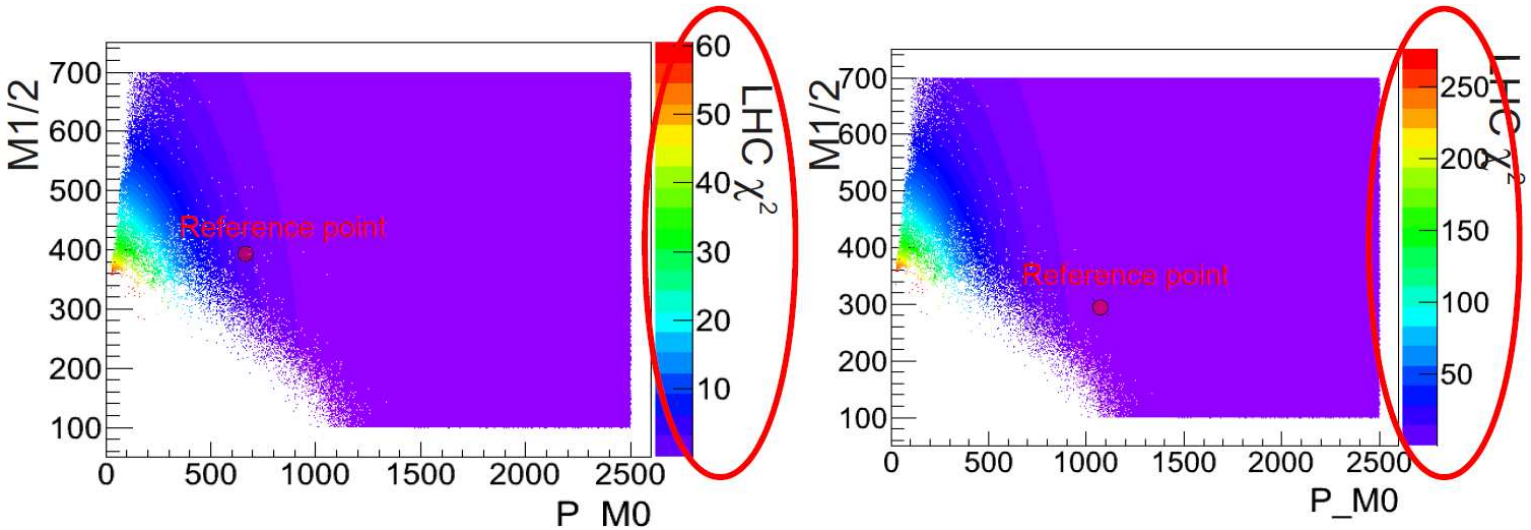


Other implementations are potentially less precise

- Assume following χ^2 scaling:

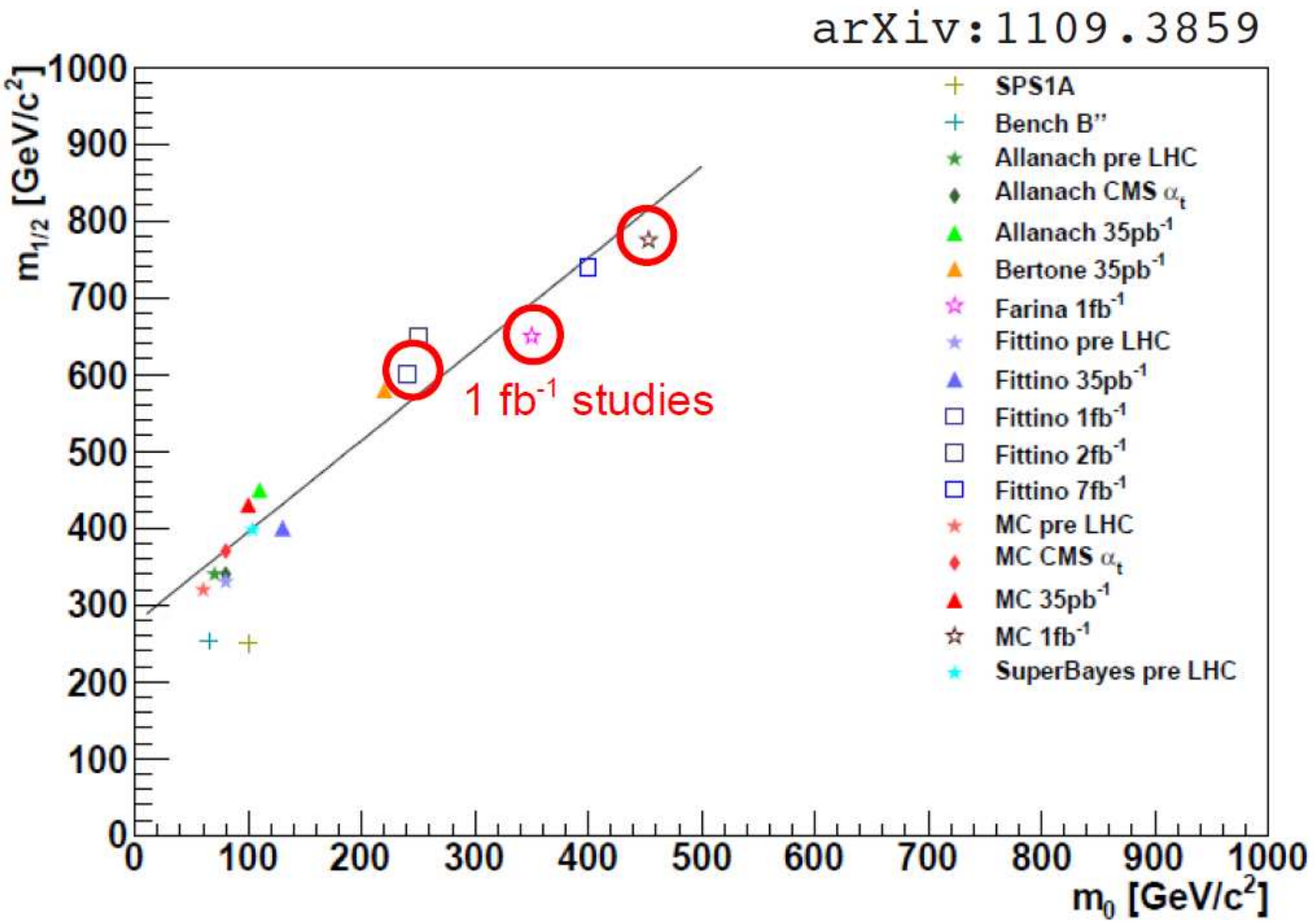
$$\chi^2 = \chi^2_{95\%\mathrm{CL}} \left(\frac{R(M_0, M_{1/2})}{R(M_0^{95\%\mathrm{CL}}, M_{1/2}^{95\%\mathrm{CL}})} \right)^{-4}$$

with $$R(M_0, M_{1/2}) = \sqrt{M_0^2 + M_{1/2}^2}$$



- Practical implementations of this are more detailed (i.e. Mastercode), but the point is:
  An exact parameterization of LHC searches can probably only be done using FastMC

Result of the different level of complexity



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Inputs

$\mathrm{BR}(b \to s\gamma)$	$(3.55 \pm 0.24 \pm 0.09 \pm 0.23) \times 10^{-4}$
$\mathrm{BR}(B_s \to \mu\mu)$	$< (1.6 \pm 0.02) \times 10^{-8}$ @95%*CL*
$\mathrm{BR}(B_s \to \mu\mu)(\mathit{LHCbprojection})$	$(2.0 \pm 0.2)) \times 10^{-9}$
$\mathrm{BR}(B_s \to \mu\mu)(\mathit{CDF})$	$> (4.60 \pm 0.46)) \times 10^{-9}$
$\mathrm{BR}(B \to \tau\nu)$	$(1.67 \pm 0.39) \times 10^{-4}$
Δm_{B_s}	$17.78 \pm 0.12 \pm 5.2$
$a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{SM}}$	$(28.7 \pm 8.0 \pm 2.0) \times 10^{-10}$
$\sin^2\theta_{\mathrm{eff}}$	0.23113 ± 0.00021
m_h via Higgsbounds	$> 114.4 \pm 3.0$ GeV
$\Omega_{\mathrm{CDM}} h^2$	$0.1123 \pm 0.0035 \pm 0.0123$
m_W	$(80.399 \pm 0.023 \pm 0.010)$ GeV

- + LHC exclusion
- + Direct and Indirect Detection of DM via AstroFit (Nguyen, Horns, Bringmann: ''AstroFit: An Interface Program for Exploring Complementarity in Dark Matter Research'')

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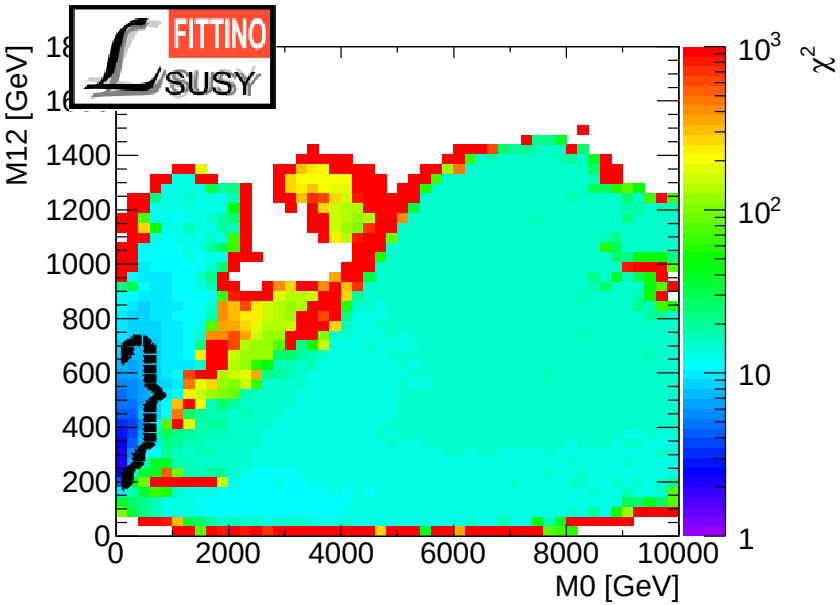
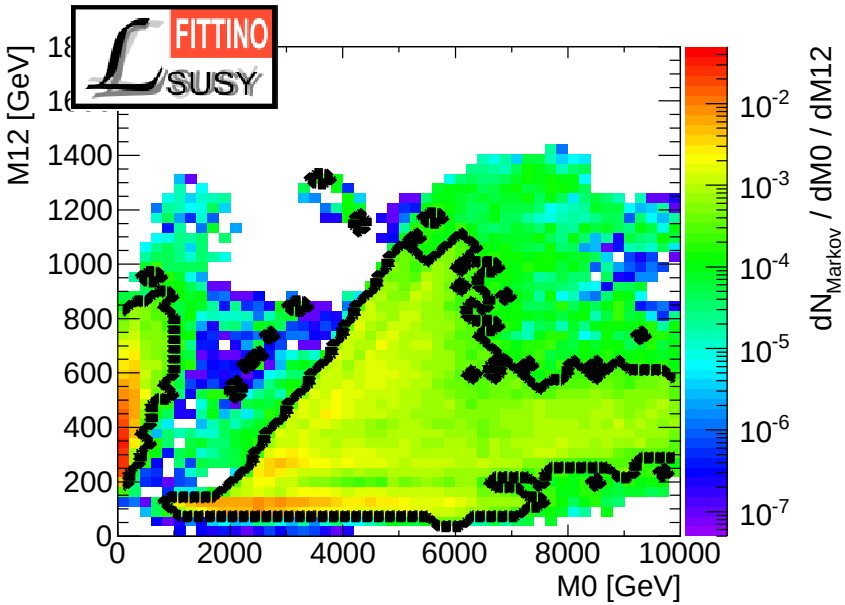
Statistics



Frequentist Profile Likelihood



Bayesian, Flat prior

- More than 40 Million points scanned for each input variable set
- Advanced MCMC scans with automatically adapting proposal density width
- Huge difference between different statistical philosophies
- Frequentist Interpretation chosen for the rest of the plots

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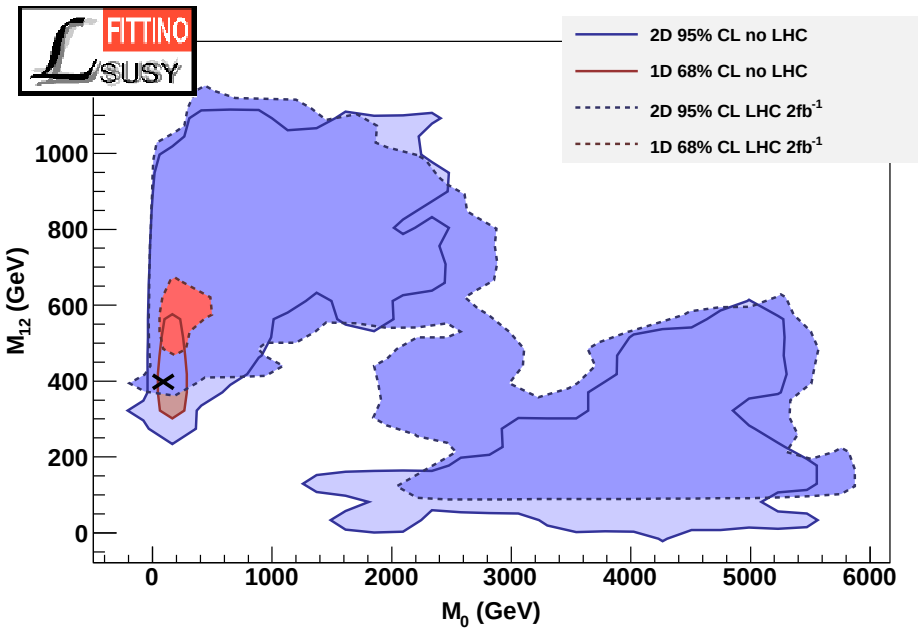
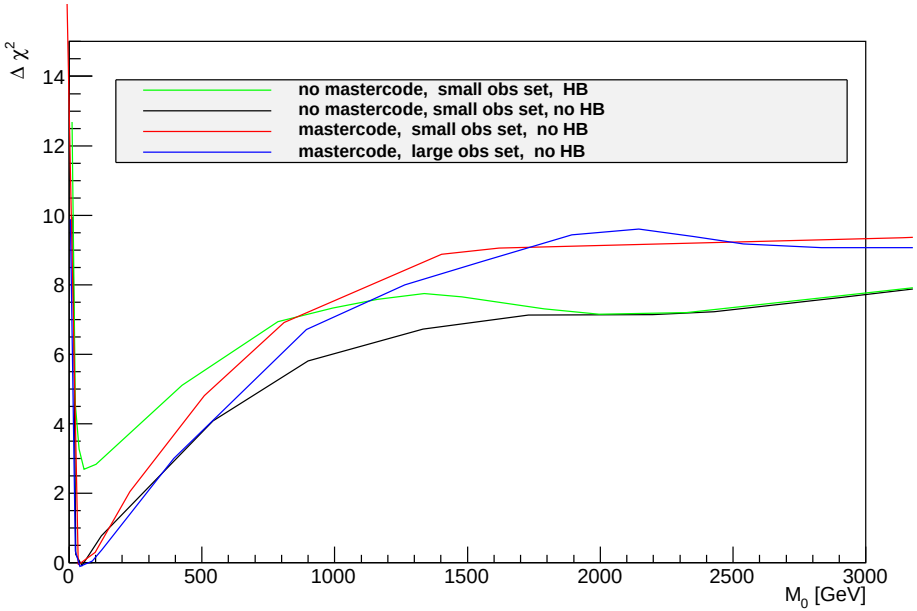
Observable sets and Higgs Limit implementation





- In our previous fits (up to arXiv:1102.4693) there was no focus point region within 2s
- Now it is there. Complex combination of effects from updated measurements and much more precise Higgs Limit implementation via HiggsBounds (arXiv:1102.1898)

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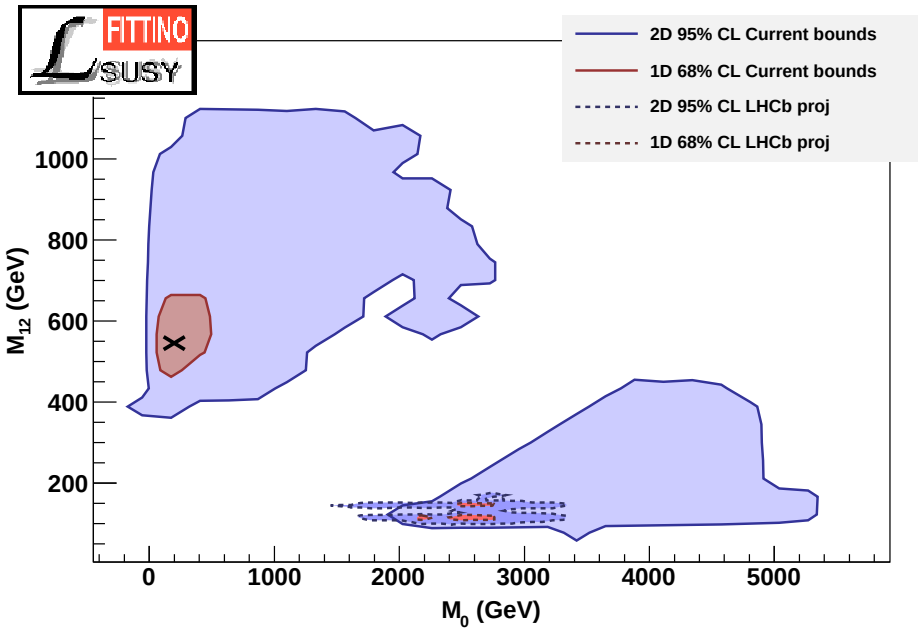
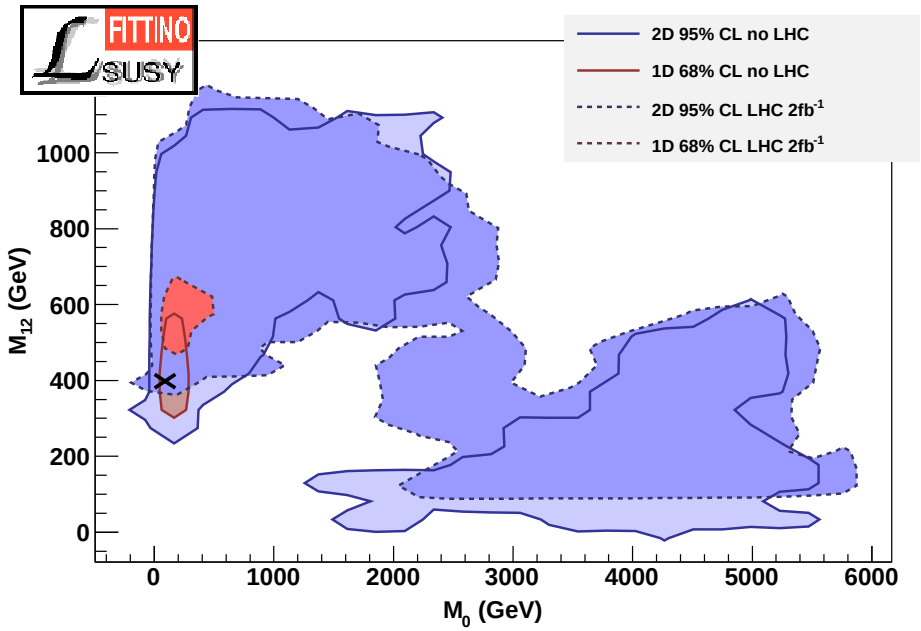
Effect of dfferent Observables





- Future measurements of $\mathcal{B}(B \to \mu\mu) < 2.0 \times 10^{-9}$ (LHCb projection from arXiv:0912.4179) can have tremendous impact on allowed area, much more than direct searches!
- But that conclusion is probably not true for more general SUSY models . . .

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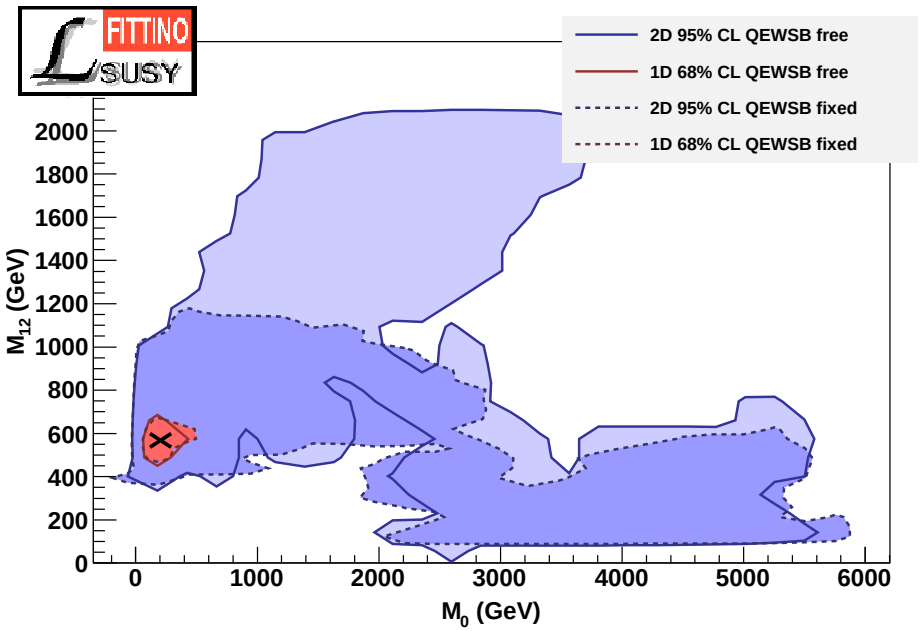
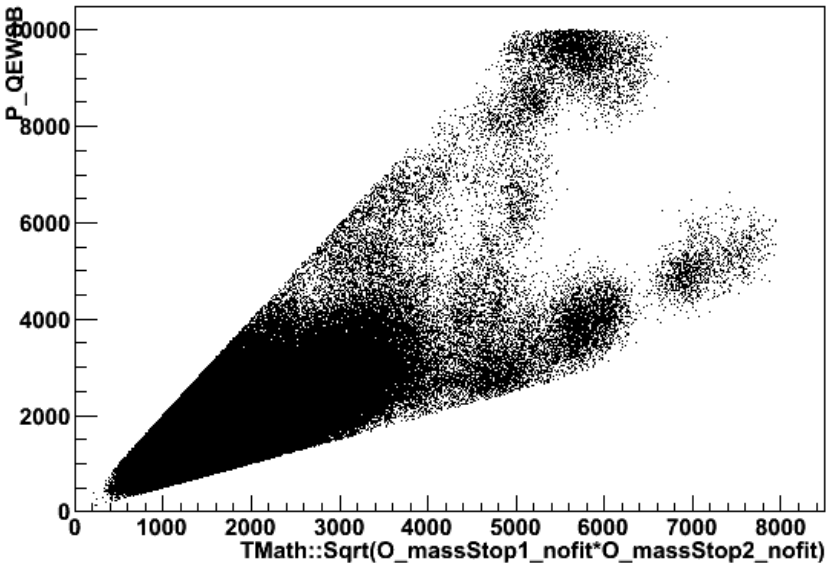
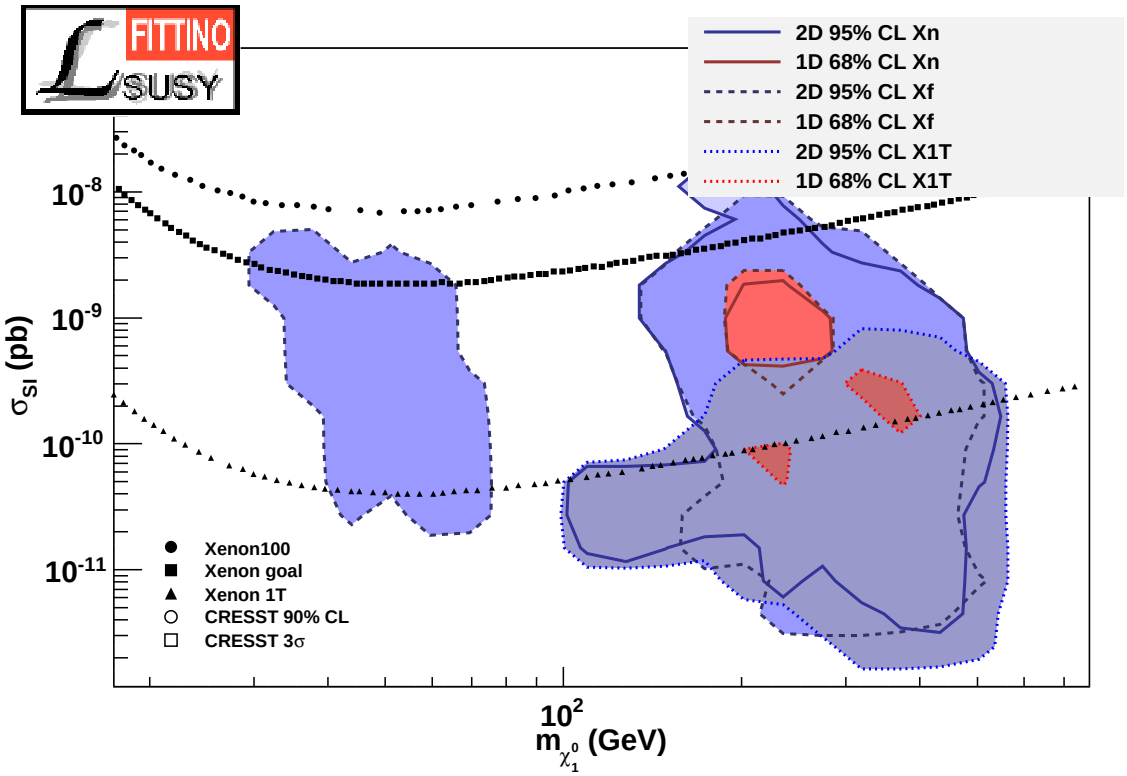
A Nuisance Parameter for RGE Running Uncertainties





- SUSY breaking scale Q Should be included in all future fits as nuisance parameter

No strong effect yet from direct detection of DM



- Newest results also include direct and indirect detection (e.g. arXiv:1107.2155)
- Yes to make a strong impact on the fit, but XENON1T sensitivity is very interesting!

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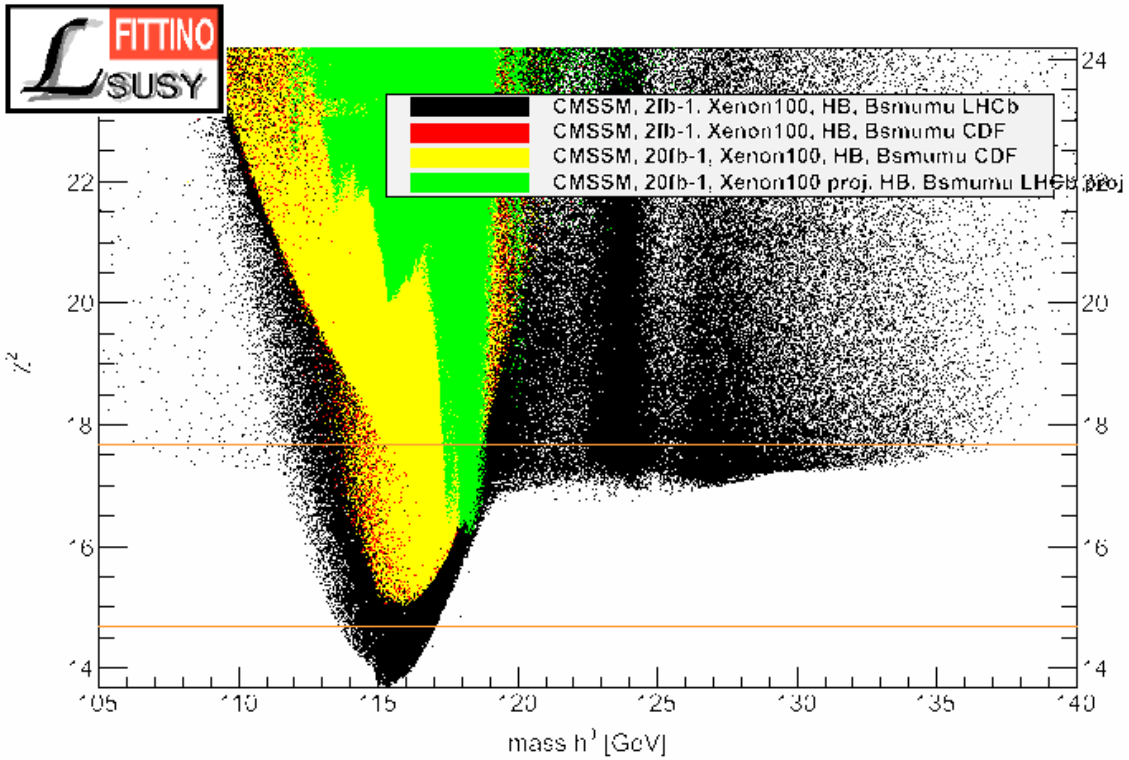
How easy is it to accomodate $m_h = 125\,\text{GeV}$?



- $m_h \approx 125\,\text{GeV}$ is possible but not preferred in the CMSSM
- A combination of a measurement of $\mathcal{B}(B \to \mu\mu) < 2 \times 10^{-9}$ and a Higgs mass measurement would really nail those highly constraint models!
- NUHM1 has much less preassure than CMSSM, but not much more convincing χ^2/ndf

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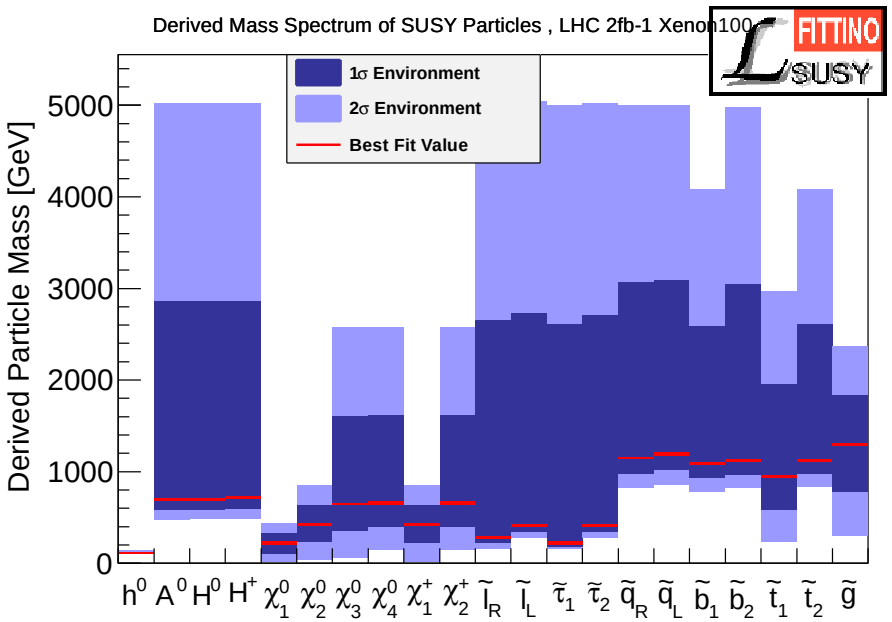
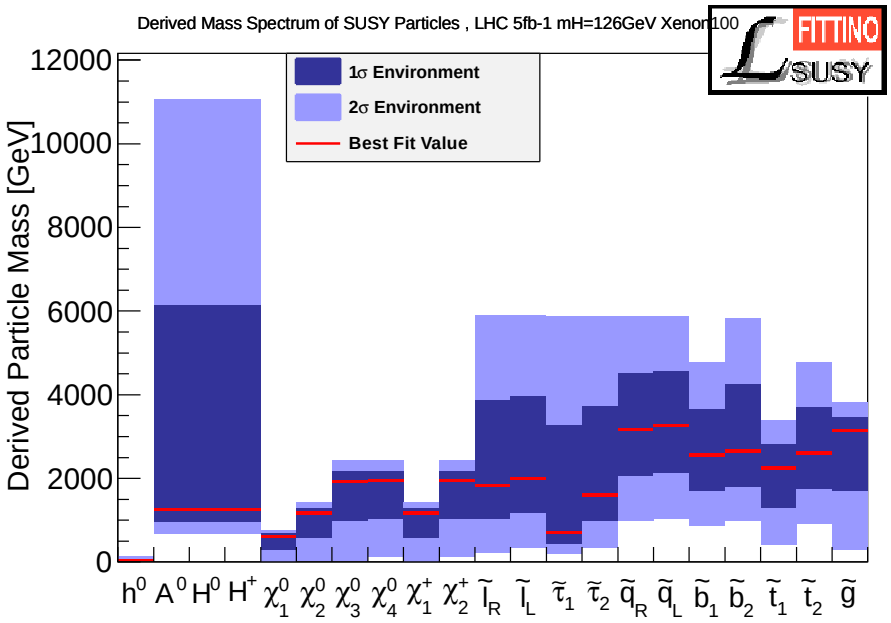
Predicted CMSSM Mass Spectra





Incl. ATLAS 0l SUSY results

$+m_h = 126 \pm 2 \pm 3\,\text{GeV}$

- Still enough room for light sparticles for the ILC
- But also a lot of room for very heavy ones!

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Fit Comparison

description	M_0 [GeV]	$M_{1/2}$ [GeV]	$\tan\beta$	A_0	χ^2/ndf
LEO (12)	$85.9^{+137.7}_{-32.0}$	$381.8^{+171.9}_{-99.6}$	$14.9^{+16.1}_{-7.5}$	$184.1^{+832.0}_{-968.6}$	12.7/5
LEO + AF	$89.4^{+136.9}_{-32.5}$	$397.9^{+183.5}_{-87.6}$	$14.7^{+13.7}_{-6.8}$	$407.8^{+731.0}_{-900.8}$	12.7/7
LHC2	$178.4^{+177.0}_{-74.6}$	$555.7^{+112.4}_{-63.8}$	$23.6^{+11.1}_{-10.3}$	$711.3^{+772.3}_{-770.2}$	13.7/8
LHC20+AF1T	$347.5^{+0}_{-203.0}$	$893.1^{+0}_{-369.6}$	$34.5^{+1.8}_{-29.0}$	$-171.8^{+930.7}_{-2178.6}$	14.6/8
LHC2+Cresst	$2516.5^{+2183.4}_{-332.5}$	$114.0^{+335.5}_{-14.0}$	$45.9^{+4.2}_{-38.4}$	$1793.6^{+990.1}_{-1866.2}$	17.5/8
LHC2+Cogent	$2541.3^{+597.2}_{-155.6}$	$143.8^{+52.3}_{-43.8}$	$46.2^{+5.7}_{-14.4}$	$691.6^{+490.2}_{-1909.4}$	141.9/8
LHC5+MH126	$4041.3^{+1141.8}_{-2694.5}$	$100.3^{+1565.2}_{-0.3}$	$23.4^{+33.9}_{-14.3}$	$2487.4^{+876.0}_{-5406.7}$	18.2/8

- A heavier Higgs around 125 GeV would clearly prefer the Focus Point region
- Fit quality not so great anymore, but $\mathcal{P}$-values practically very difficult to determine due to huge computing needs

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Main Messages

- Highly constraint models like mSUGRA/CMSSM are loosing attractivity due to growing χ^2/ndf
- $m_h \approx 125\,\text{GeV}$ can just still be incorporated in the CMSSM, but already highly penalized
- Still room for light gauginos and sleptons even in very constraint models
- Even very constraint models leave room for precision measurements of Higgs BF
- $\mathcal{B}(B \to \mu\mu) < 2 \times 10^{-9}$ and direct detection of DM can soon make a huge impact!
- Everthing of the above is even more interesting for more complex SUSY models, but they come with a huge difficulty in the parametrization of LHC exclusions!
- Many more results to come very soon (including new ideas on FT)

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Backup Slides

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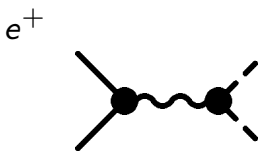
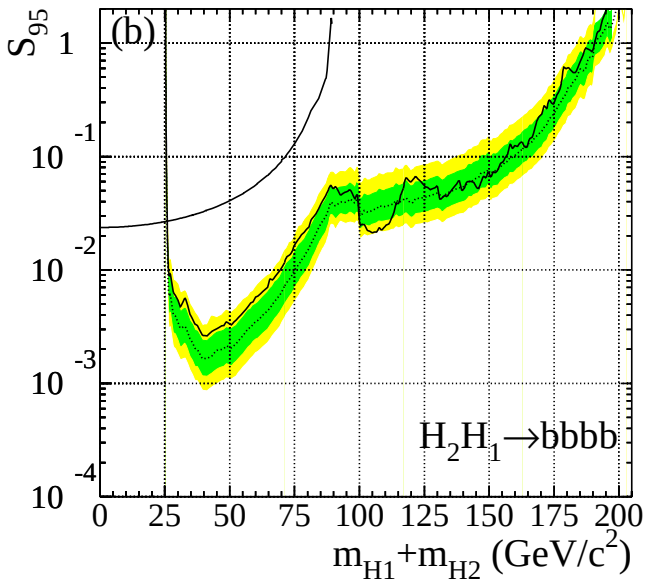
Why SUSY is different than e.g. the Higgs-Sector

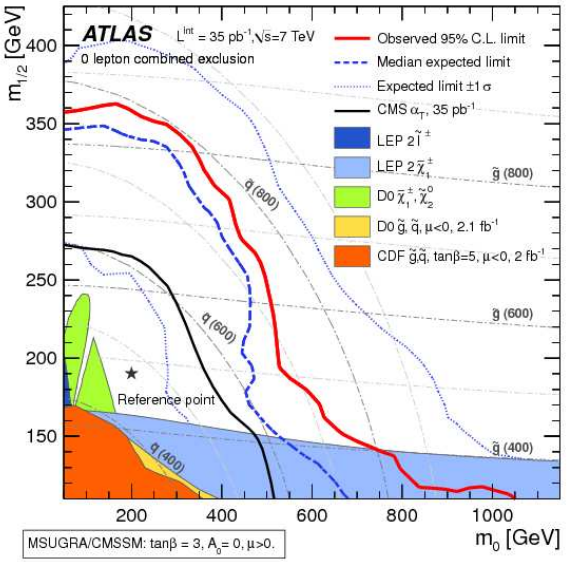


$S_{95} \equiv$

$\max(\cos^2(\beta - \alpha)$

$\times \mathcal{B}(H_i \to b\bar{b}))$





- Higgs Searches (at least at LEP) could be presented in terms of S_{95} for each signature separately, because the signatures can be nicely isolated experimentally: $hZ \to b\bar{b}\ell\ell$, $hA \to b\bar{b}\,b\bar{b}\ldots$
- Higgs: Only very few parameters: $m_h, m_A, \cos^2(\beta - \alpha)$, model-independent comparison with all possible models e.g. in
  PB et al. arXiv:0811.4169 [hep-ph]
- SUSY: incredibly complicated signatures possible, many masses and relations of couplings

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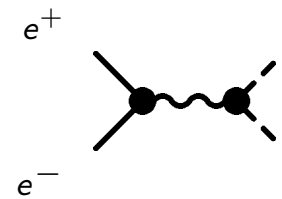

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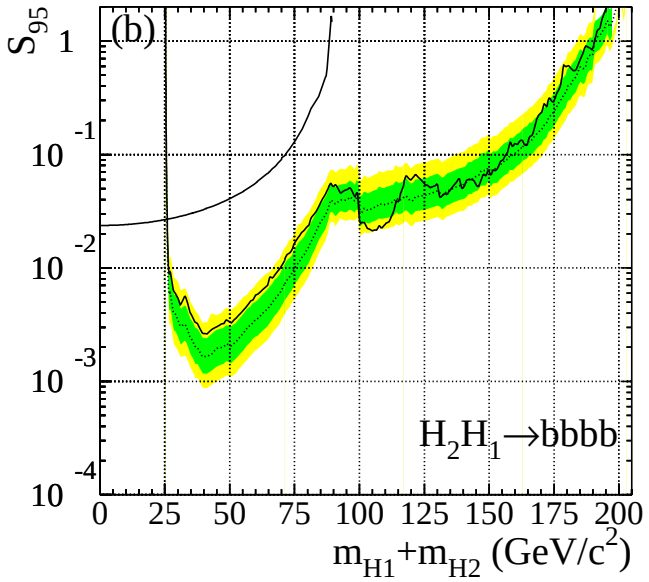

	Signal region A
QCD	$7\ ^{+8}_{-7}$[u+j]
W+jets	50 ± 11[u] $^{+14}_{-10}$[j] $\pm$ 5[$\mathcal{L}$]
Z+jets	52 ± 21[u] $^{+15}_{-11}$[j] $\pm$ 6[$\mathcal{L}$]
$t\bar{t}$ and t	10 ± 0[u] $^{+\ 3}_{-\ 2}$[j] $\pm$ 1[$\mathcal{L}$]
Total SM	118 ± 25[u] $^{+32}_{-23}$[j] $\pm$ 12[$\mathcal{L}$]
Data	87

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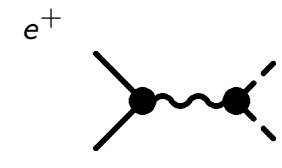

H_2

H_1

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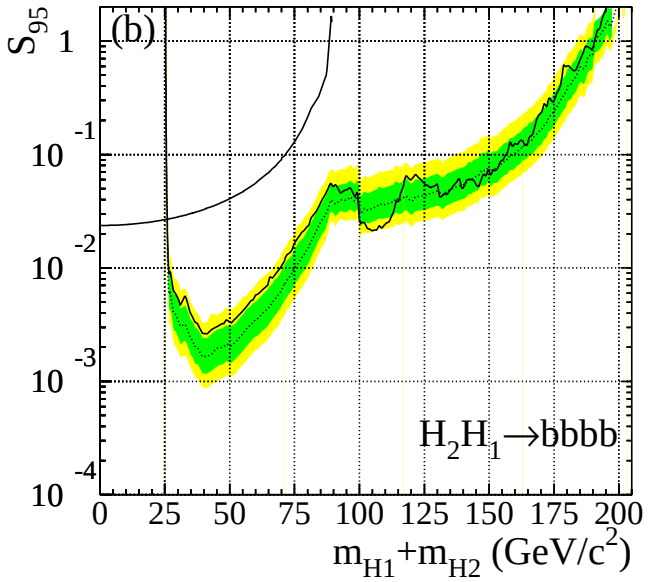

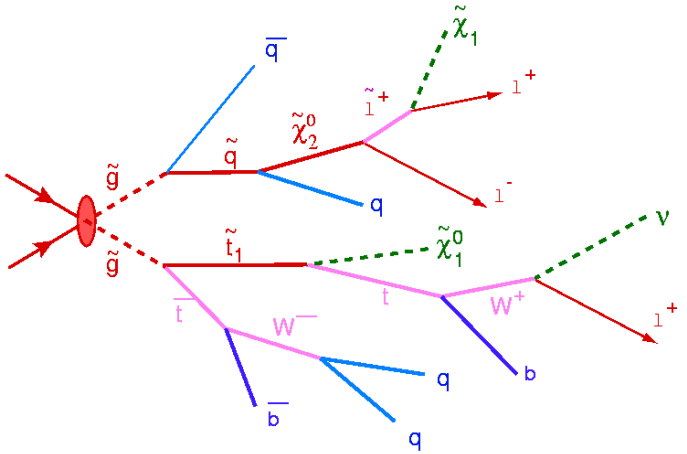

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Other Approaches to Parametrizations of Searches

- Obvious: For model independent results, everything has to be presented in terms of (pseudo)observables (e.g. M_{eff}, masses, couplings, ...)

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- Obvious: For model independent results, everything has to be presented in terms of (pseudo)observables (e.g. M_{eff}, masses, couplings, ...)
- 95 % CL Limit on $\sigma \times \prod_i \mathcal{B}_i$ for a given signature (For some reason specific signatures are sometimes called "simplified model")
  - 95 % CL not very useful for global fits $\rightarrow$ need full CL_{s+b} space
  - Very high dimensional binning is needed (many masses)
  - Much less sensitive for discovery or exclusion, since only a small part of the possible decay chains is probed at a time
- 95 % CL Limit on the number of events for a given selection
  - Simulation needed to determine number of events for any model prediction
- Distributions of b, d in discriminating variables corrected for detector effects, acceptances
  - Sounds nice, but probably impossible: Correction depends on many factors (many masses, couplings)

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