Constrained SUSY after the Higgs discovery

Björn Sarrazin

for the Fittino Collaboration

Rheinische
Friedrich-Wilhelms-
Universität Bonn

DPG Mainz, 24 March 2014

The status of the CMSSM

healthy?

pretty dull?

almost dead?

buried?

Fittino

C++ program for model testing and parameter analysis using

- all kind of available experimental measurements
- public theory codes to calculate predictions
- a χ^2 function to compare measurements and predictions
- an auto-adaptive Markov Chain to sample the parameter space
- frequentist interpretation

Publications:

arXiv:0412012[hep-ph], arXiv:0511006[hep-ph], arXiv:0907.2589[hep-ph], arXiv:0909.1820[hep-ph], arXiv:1102.4693[hep-ph], arXiv:1105.5398[hep-ph], 1204.4199[hep-ph], arXiv:1310.3045 [hep-ph]

The CMSSM

Constrained MSSM reduces 124 parameters of MSSM to 4 and a sign:

M_0	common scalar mass parameter
$M_{1/2}$	common gaugino mass parameter
A_0	common trilinear coupling
$\tan\beta$	ratio of Higgs VEVs
$\mathrm{sgn}\,\mu$	sign of Higgsino mass parameter

We fix $\mathrm{sgn}\,\mu = +1$

We use m_t as additional free fit parameter.

Fitting the CMSSM

CMSSM is experimentally constrained by

- indirect constraints from low energy precision measurements
- SM-like Higgs boson
- direct searches for sparticles and Higgs bosons
- astrophysical observations

To evaluate the corresponding model predictions we use:

- SPheno for spectrum calculation
- FeynHiggs for Higgs properties, $(g-2)_\mu$ & Δm_s
- SuperIso for other B-Physics observables
- Prospino, Herwig++, Delphes for direct sparticle searches
- MicrOMEGAs for dark matter relic density
- DarkSUSY via Astrofit for direct detection cross section

Measurements

Low energy observables

$\mathcal{B}(B_s \to \mu^+\mu^-)$	$(3.20 \pm 1.50 \pm 0.76) \times 10^{-9}$
$\mathcal{B}(B^\pm \to \tau^\pm\nu)$	$(0.72 \pm 0.27 \pm 0.11 \pm 0.07) \times 10^{-4}$
$\mathcal{B}(b \to s\gamma)$	$(3.43 \pm 0.21 \pm 0.07 \pm 0.23) \times 10^{-4}$
Δm_s	$(17.719 \pm 0.043 \pm 4.200)\,\mathrm{ps}^{-1}$
$a_\mu - a_\mu^{\mathrm{SM}}$	$(28.7 \pm 8.0 \pm 2.0) \times 10^{-10}$
m_W	$80.385 \pm 0.015 \pm 0.010$
m_t	$(173.18 \pm 0.94)\,\mathrm{GeV}$
$\sin^2\theta_{\mathrm{eff}}$	0.23113 ± 0.00021

SM-like Higgs boson

- Higgs signals via HiggsSignals

Direct searches for sparticles and Higgs Bosons

- Higgs limits via HiggsBounds
- LEP chargino mass limit
- ATLAS MET + jets + 0 lepton search (20fb^{-1})

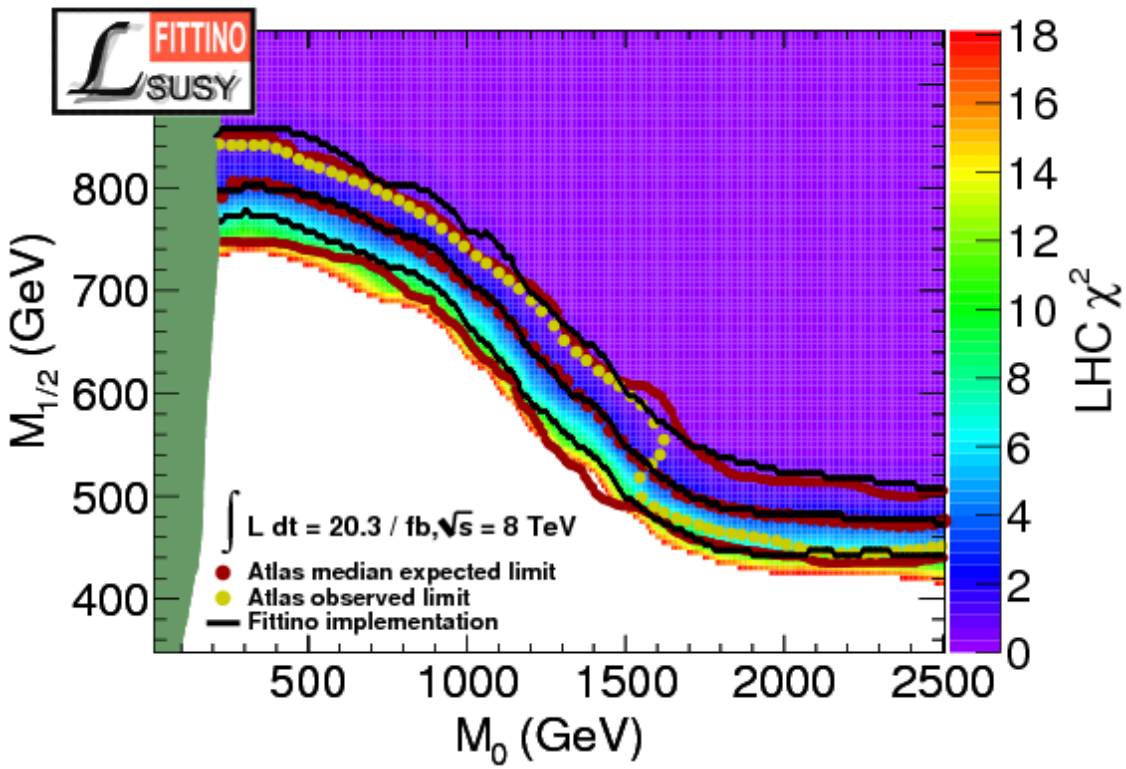
Astrophysical observables

- We require χ_1^0 to be the LSP
- Dark matter relic density:
  $\Omega_{\text{CDM}} h^2 = 0.1187 \pm 0.0017 \pm 0.0119$ (Planck '13)
- Direct detection limit from 225 live days of Xenon100 ('12)

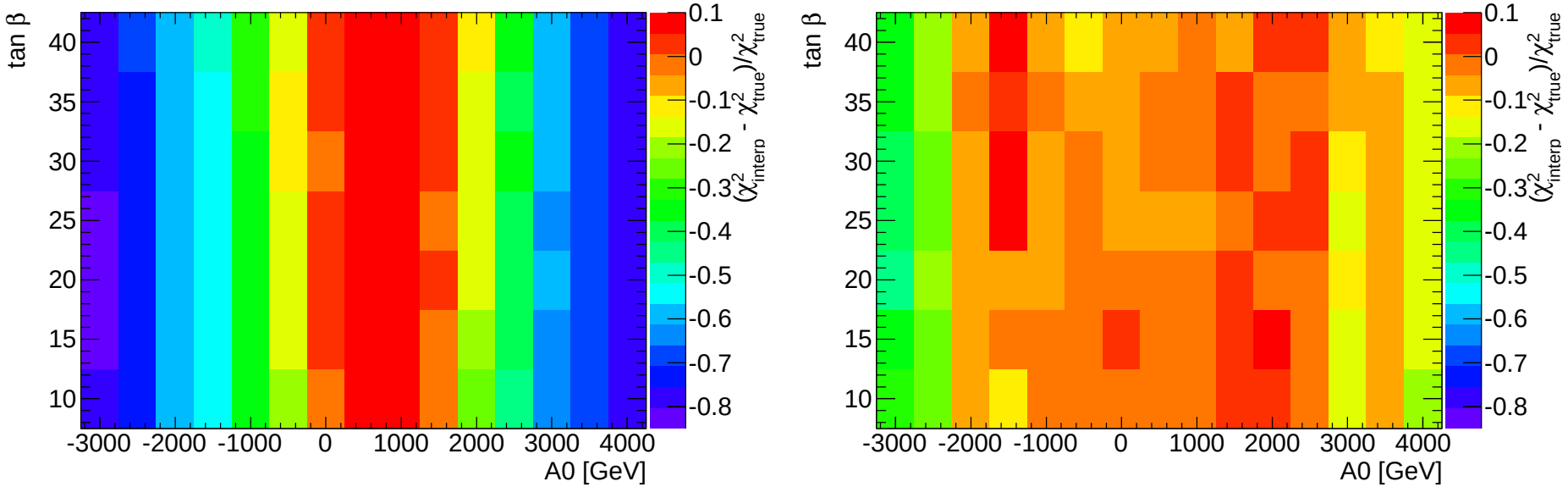
χ^2 contributions

At each parameter point $\vec{P}$ calculate:

$$\chi^2 = \left(\vec{O}_{\text{meas}} - \vec{O}_{\text{pred}}(\vec{P})\right)^T cov^{-1} \left(\vec{O}_{\text{meas}} - \vec{O}_{\text{pred}}(\vec{P})\right) + \chi^2_{\text{limits}}$$



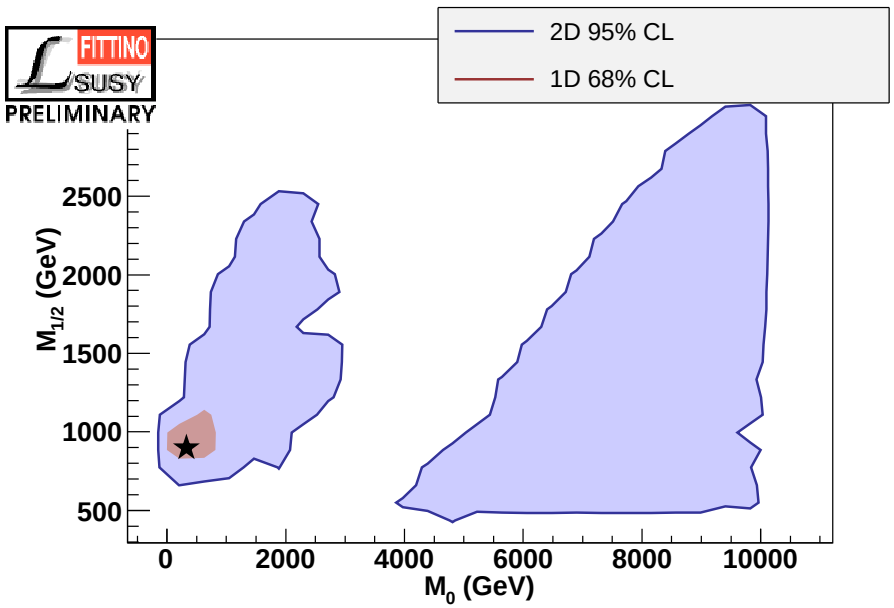
χ^2 contribution from ATLAS SUSY searches

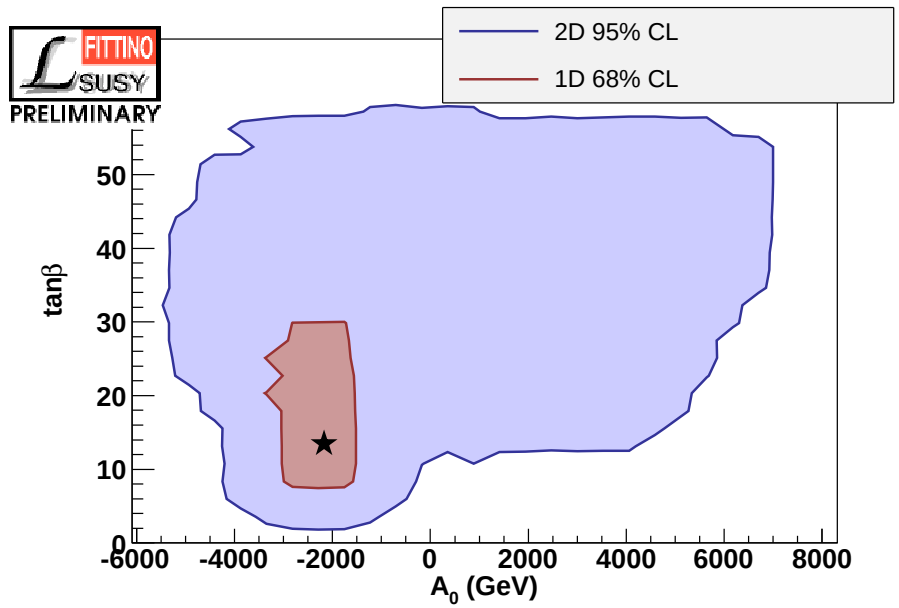


- Depending on value of A_0 and $\tan\beta$ stop-production increases
- Along exclusion line we produced grids of correction factors in A_0-$\tan\beta$

Preferred parameter space

. . . with $m_h = (125.5 \pm 2 \pm 3)$ GeV but without Higgs rates

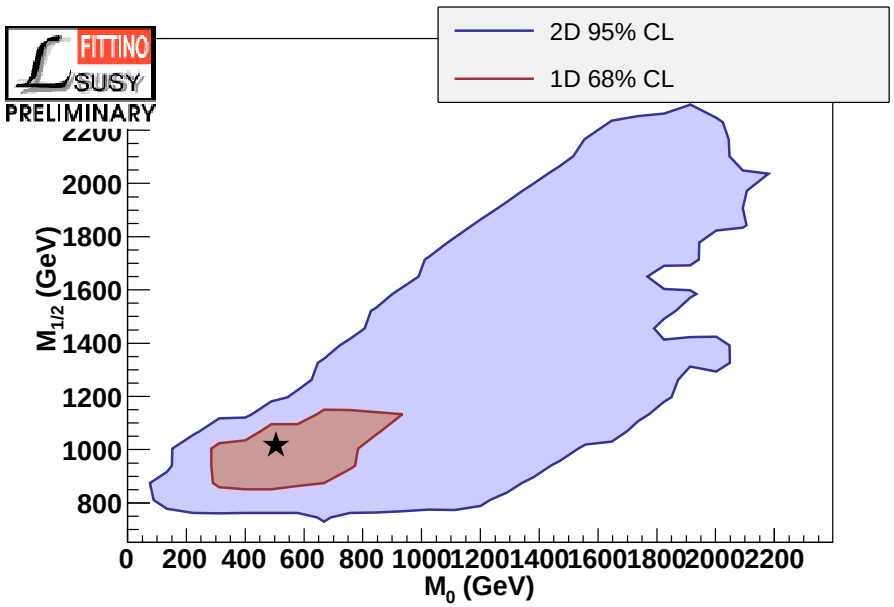


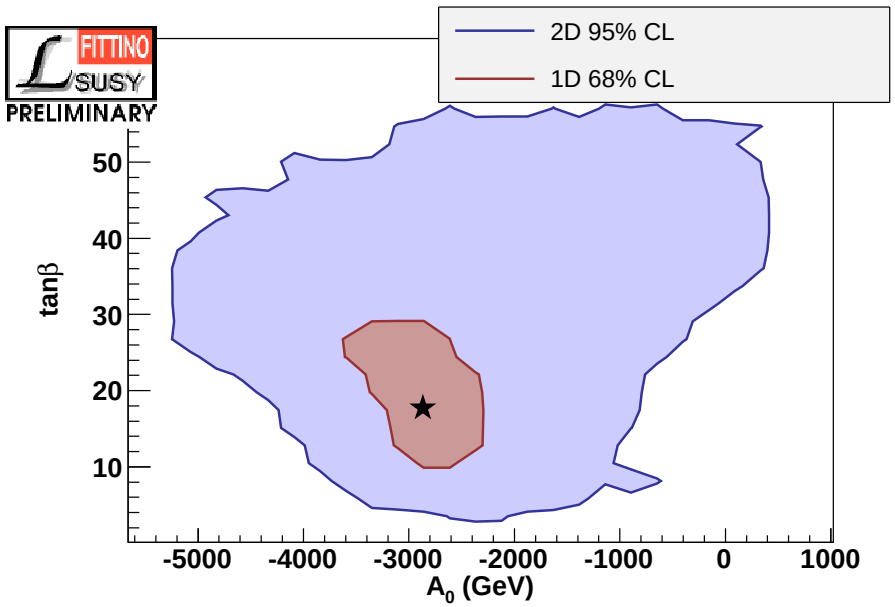


- $\chi^2/\mathrm{ndf} = 13.6/9$
- FP / Higgs funnel region allowed at 2σ

Preferred parameter space

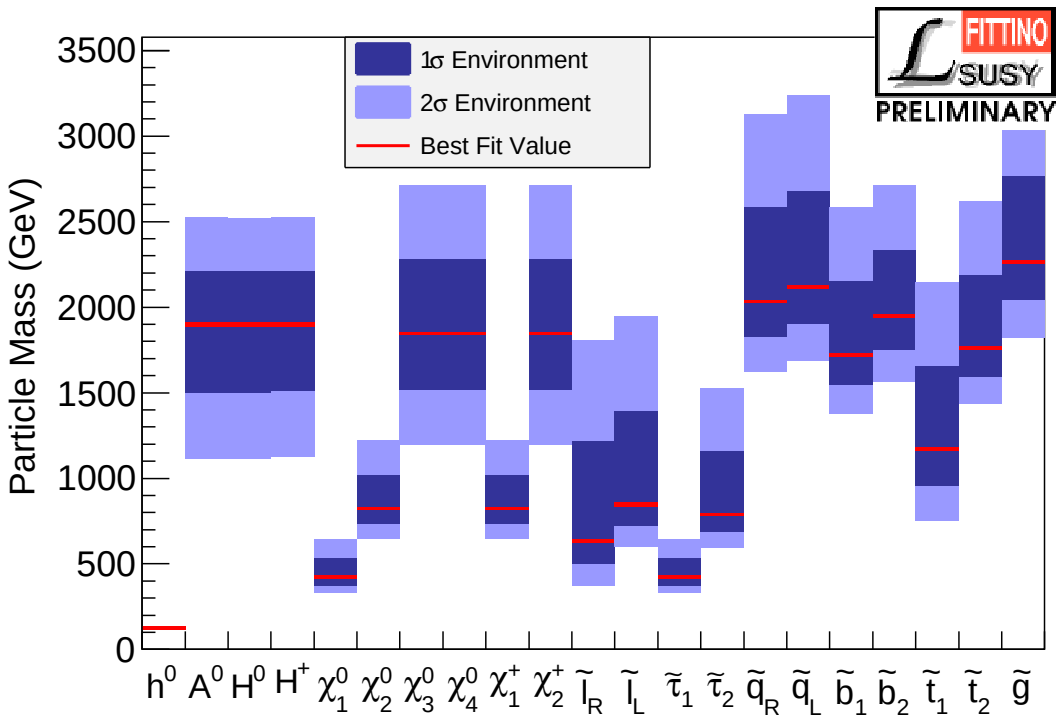
. . . with mass und Higgs rates measurements via HiggsSignals





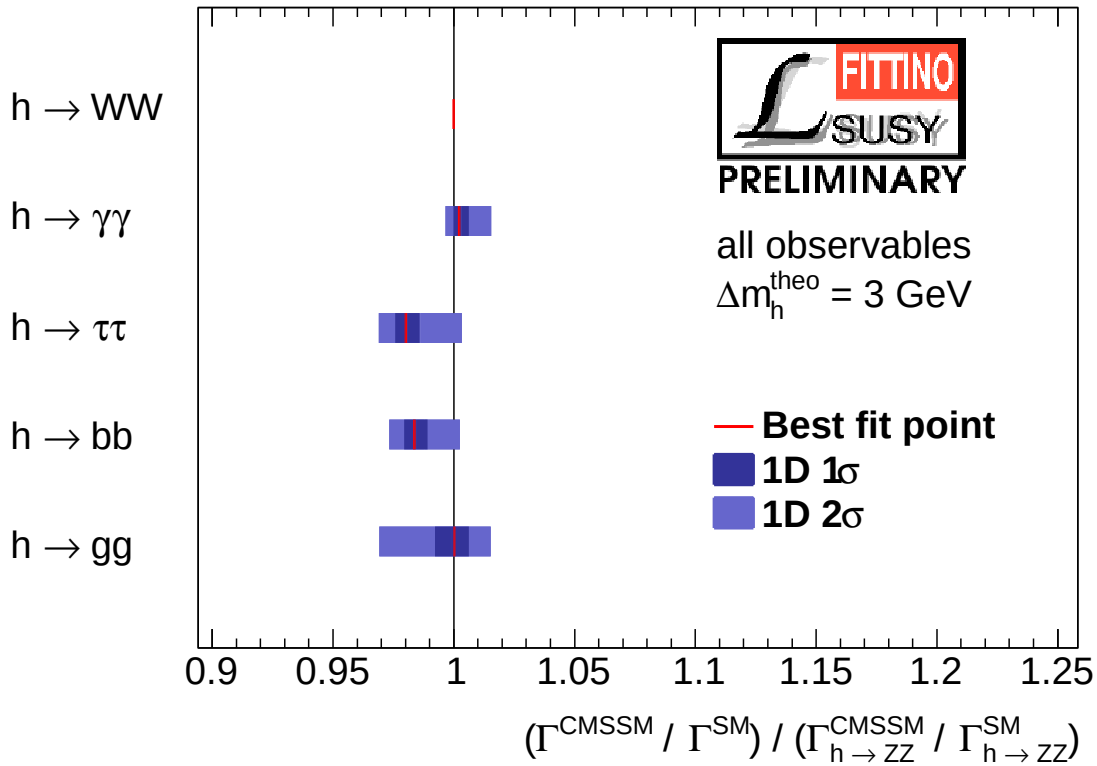
- $\chi^2/\mathrm{ndf} = 49.6/59$: SM-like Higgs well described by CMSSM
- Fit quality seems to improve
- FP / Higgs funnel region disfavored at 2σ

Predicted mass spectrum



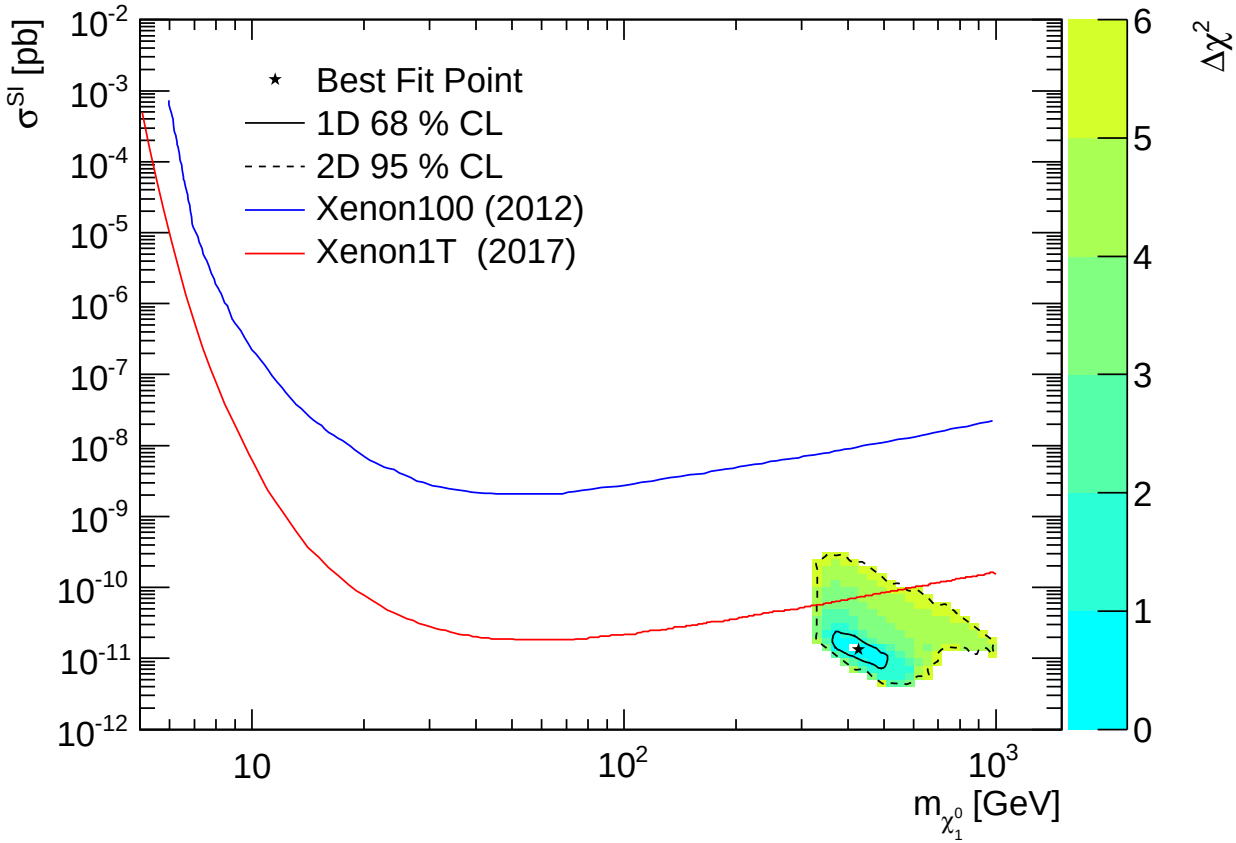
- Lower bound of 1 TeV on heavy Higgs bosons
- Relative light $\tilde{\tau}_1$ because of coannihilation region
- Relative light $\tilde{t}_1$ because of large stop mixing
- $\tilde{q}$ and $\tilde{g}$ masses at best fit point about 2 TeV

Predicted Higgs properties



- SM-like Higgs boson
- not much room left for deviations

Predicted direct detection cross section

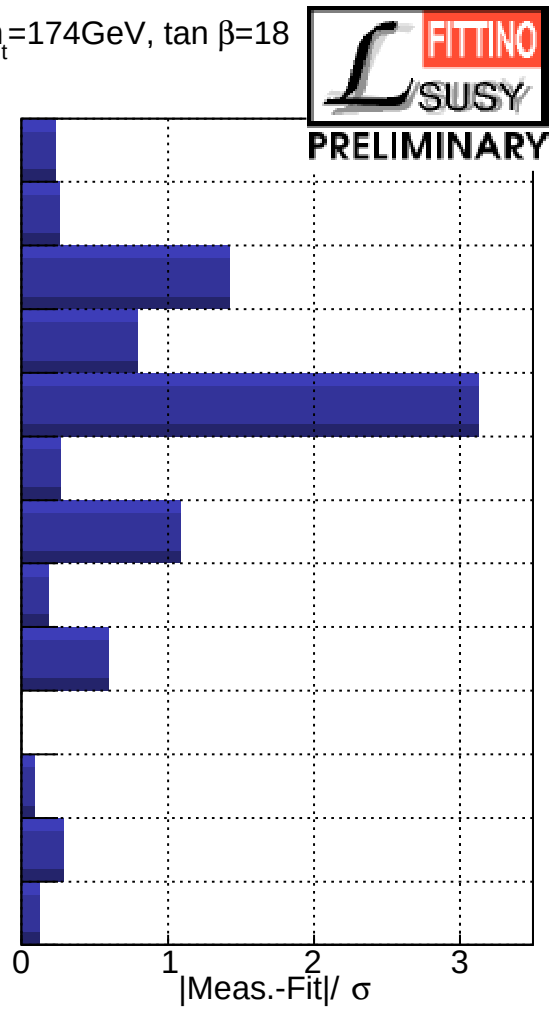


- Xenon 100 currently not sensitive
- Xenon1T will start to probe 2σ region

Agreement of observations with model predictions

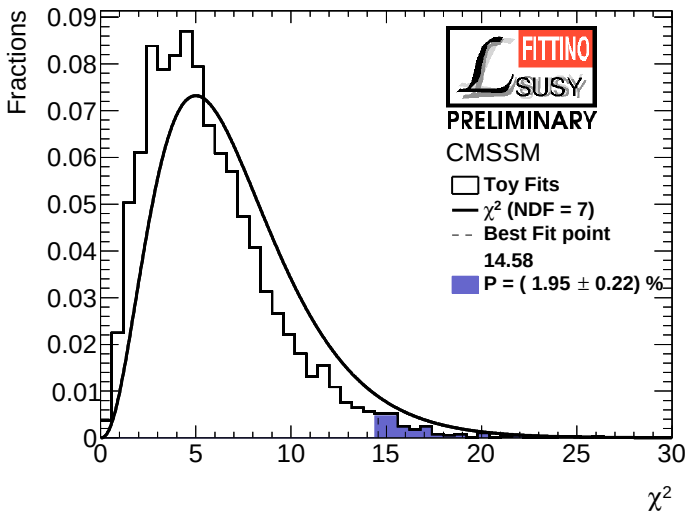
M_0=504GeV, $M_{1/2}$=1016GeV, A_0=-2870GeV, m_t=174GeV, tan β=18

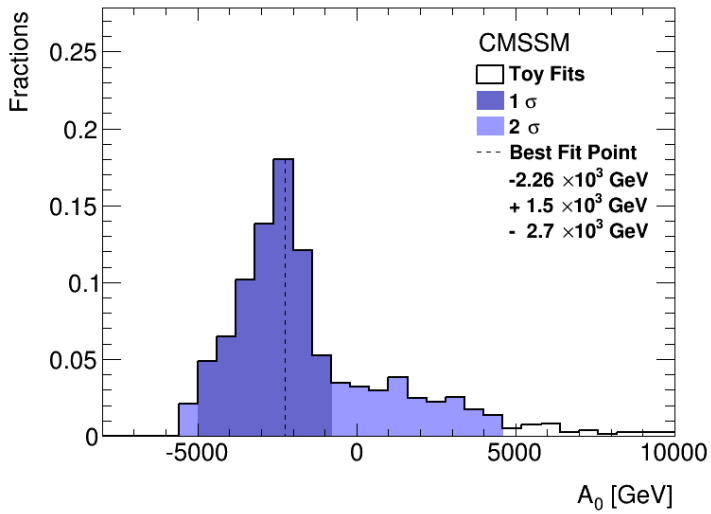
$BR(B_s \to \mu^+\mu^-) / 10^{-9}$	3.20 +- 1.50+- 0.76	3.59
$BR(b \to \tau\nu) / 10^{-4}$	0.72 +- 0.27 +- 0.11+- 0.07	0.80
$BR(b \to s\gamma) / 10^{-4}$	3.43 +- 0.21 +- 0.07+- 0.23	2.97
Δm_s / ps^{-1}	17.719 +- 0.043+- 4.200	21.058
$(a_\mu - a_\mu^{SM}) / 10^{-10}$	28.7 +- 8.0+- 2.0	2.9
m_W / GeV	80.385 +- 0.015+- 0.010	80.390
$\sin^2\theta^l_{eff}$	0.23113 +- 0.00021	0.23136
$\Omega_{CDM}h^2$	0.1187 +- 0.0017+- 0.0119	0.1165
m_t	173.18 +- 0.94	173.74
σ^{SI} / pb		1.3e-11
LHC		
m_h / GeV		125.2
μ_h		



- SM like region of parameter space
- SUSY is losing its advantage in prediction of $g-2$

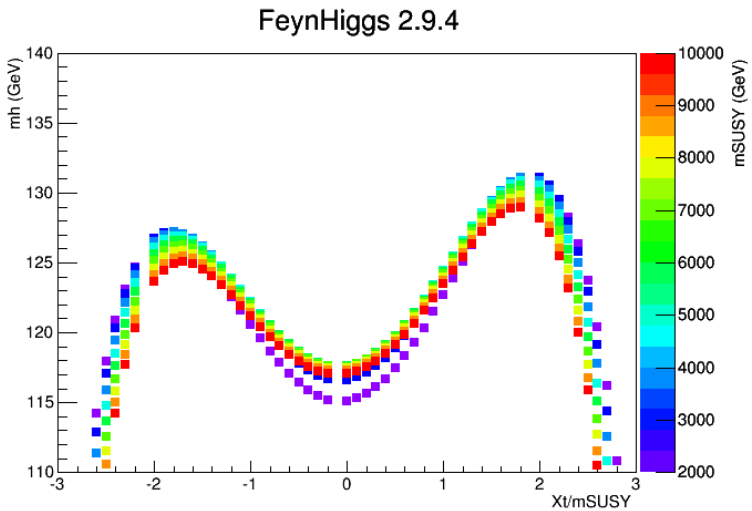
Goodness of fit: Toy toys

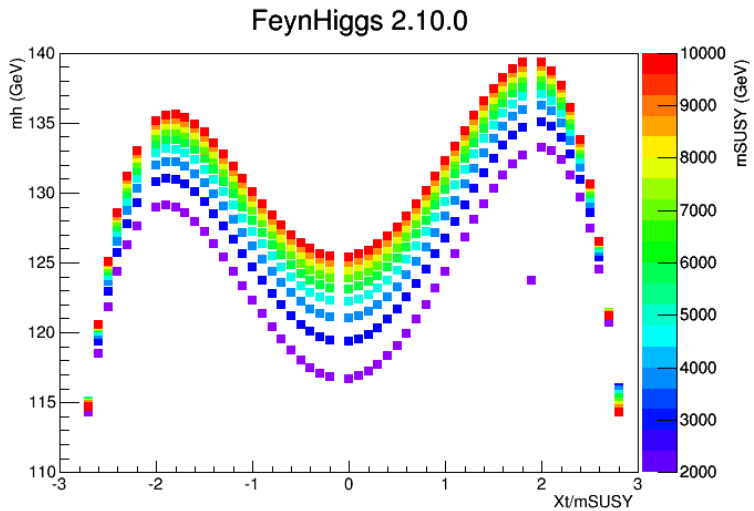




- χ^2 function only guaranteed to be χ^2-distributed if
  - uncertainties are Gaussian
  - observables depend linearly on parameters
- χ^2/ndf might overestimate the goodness of fit
  - here: proof of principle using (toy) toy fits
- bonus: toy distributions of parameters and observables

Why all results are preliminary





- Shown results use FeynHiggs 2.9.4
- The Higgs mass calculations used are not designed to work well for large values of mSUSY
- This has been improved in FeynHiggs 2.10.0

Summary & Outlook

Summary:

- Best fit region of the CMSSM is very SM like
- CMSSM $\sim$ SM + DM
- Difficult to distinguish them experimentally
- But: Relative light $\tilde{\tau}_1$, $\tilde{t}_1$ predicted
- To judge over the CMSSM, toy fits are needed

Outlook:

Stay tuned for results using

- Higgs mass calculation from FeynHiggs 2.10.0
- toy fits including Higgs rate measurements for calculation of $\mathcal{P}$-values