What if the LHC does not find supersymmetry in the $\sqrt{s} = 7$ TeV run?

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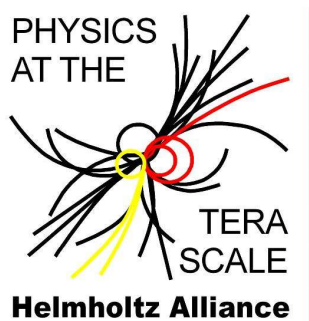
SUSY2011, Fermilab, August 30th, 2011



Outline

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Summary and Outlook

Introduction

Measuring Lagrangian parameters at the LHC: not trivial

- almost every SUSY contribution to experimental measurement depends on many unknown SUSY-breaking parameters
- to get anywhere, use reduced, (over-)simplified set of SUSY Lagrangian parameters
- here: the minimal supergravity-inspired Constrained Minimal Supersymmetric Standard Model
  - common GUT-scale scalar mass M_0
  - common GUT-scale gaugino mass $M_{1/2}$
  - common GUT-scale scalar trilinear coupling A_0
  - ratio of Higgs vacuum expectation values $\tan\beta$
  - sign of Higgs doublet mixing parameter $\mu/|\mu|$
- large amount of observables depending on masses and mixing angles in non-trivial ways $\rightarrow$ set of GUT-scale parameters: very difficult

Fittino

`Fittino`: publically-available program by Philip Bechtle, Klaus Desch and Peter Wienemann (http://www-flc.desy.de/fittino/) (`Fittino 2.0` coming soon!)

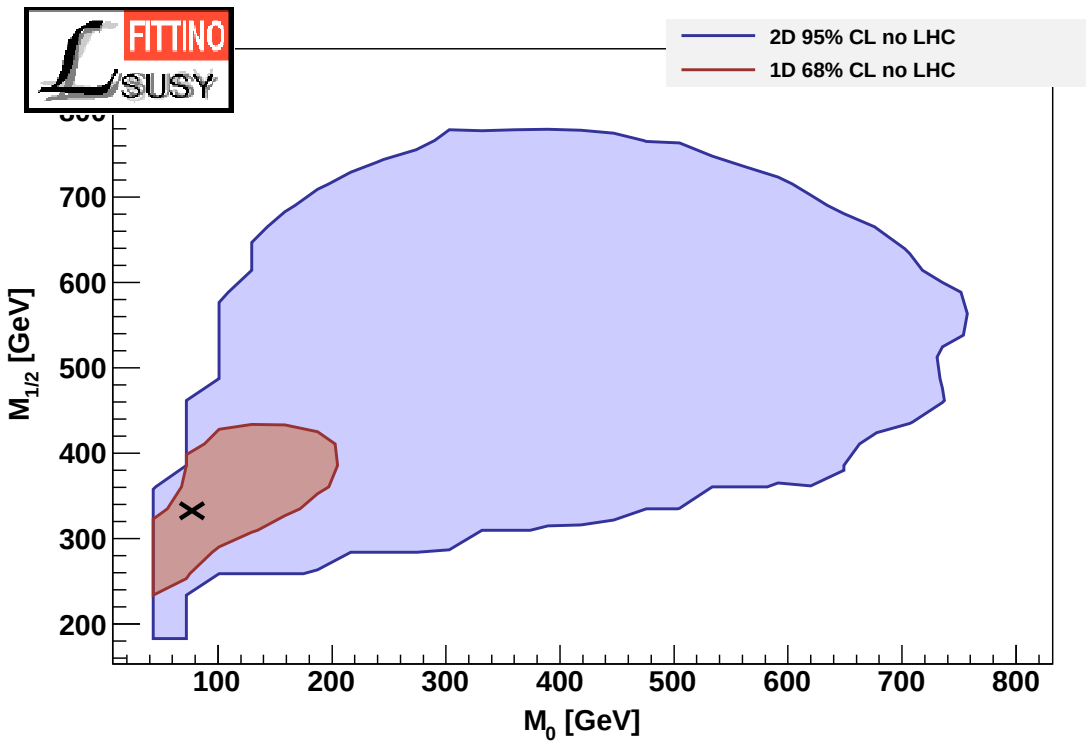
- Explores SUSY parameter space (simulated annealing or Markov chain)
  - can explore LHC-scale Lagrangian parameter space or GUT-scale (uses `SPheno` to run from one scale to the other)
- Calculates χ^2 for each point visited based on supplied observables
- Eventually distills down to a value for the Lagrangian parameters (low scale or high scale) with errors

Best fit pre-LHC

Best fit for CMSSM without LHC data

Expectations were high for early LHC discovery of SUSY: using just

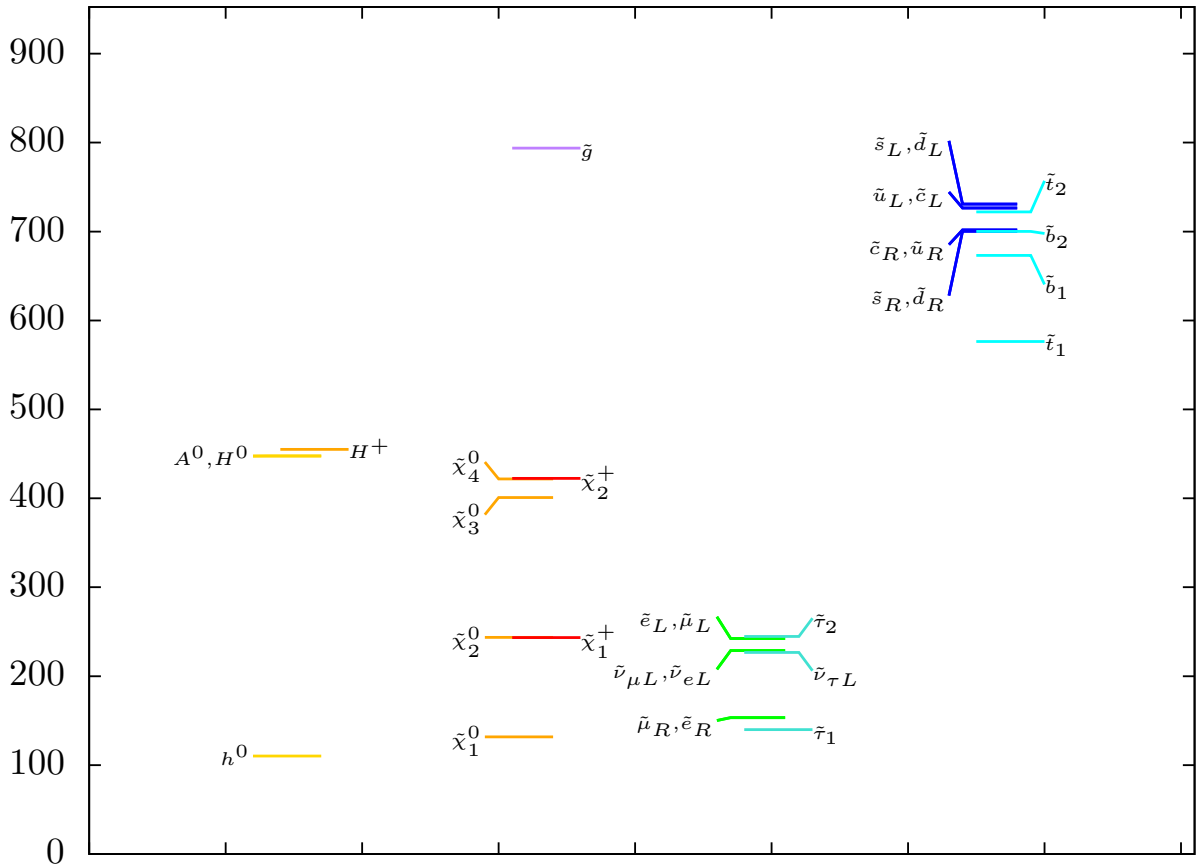
- low energy observables ($b \to s\gamma$, $(g-2)_\mu$, *etc.*)
- LEP precision observables
- dark matter relic density calculations



relatively light sparticle spectrum gave best fit
(P. Bechtle, K. Desch, M. Uhlenbrock and P. Wienemann, Eur. Phys. J. C **66** (2010) 215 [arXiv:0907.2589 [hep-ph]])

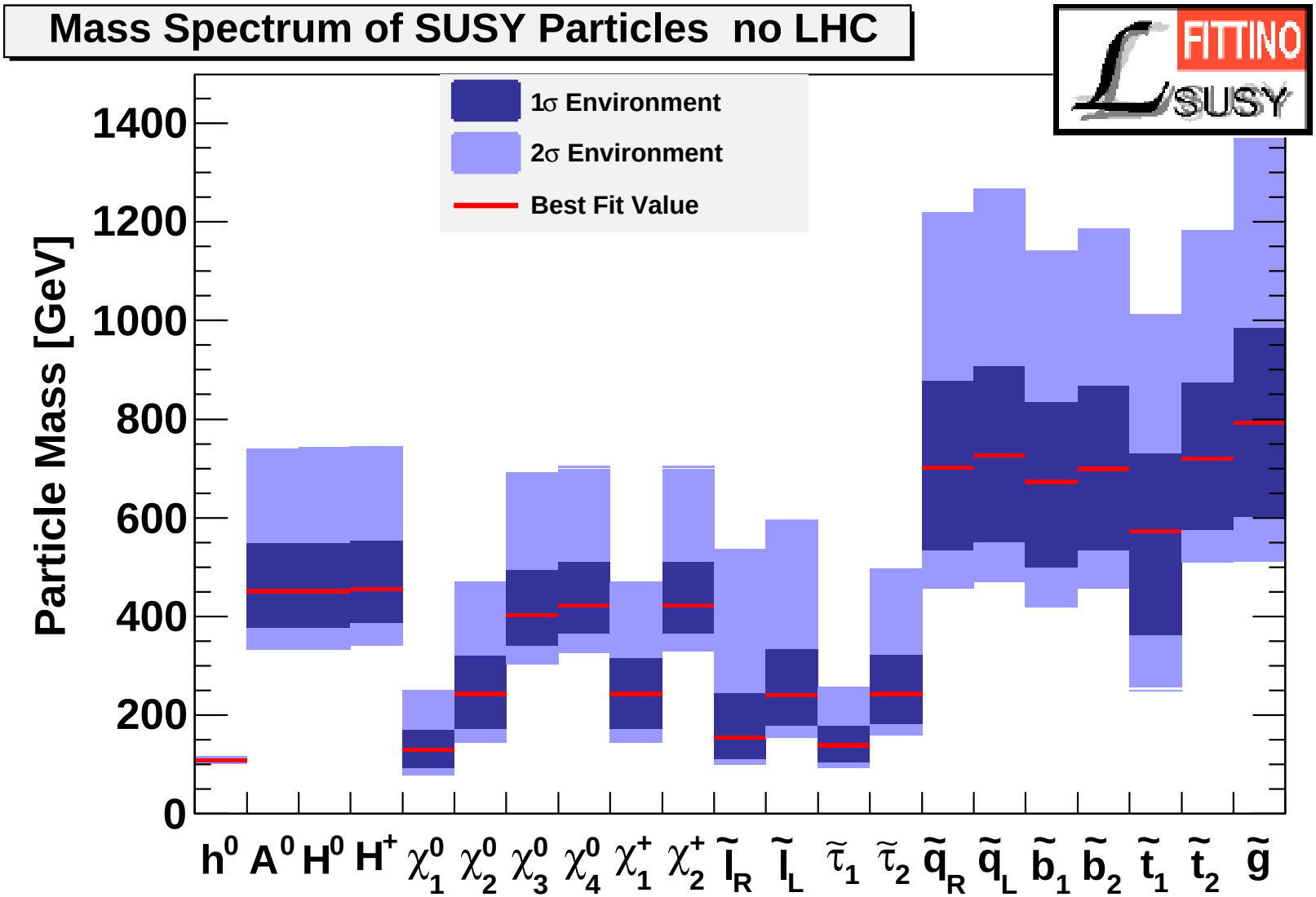
Spectrum at best fit point without LHC data

M_0	:	77 GeV
$M_{1/2}$	:	333 GeV
A_0	:	426 GeV
$\tan\beta$	:	13
$\mu/\lvert\mu\rvert$	:	+1
$\chi 2$	:	18.9
d.o.f.	:	20
$\mathcal{P}$	:	0.531



$(m_{\tilde{\chi}_1^0} = 132 \text{ GeV} < m_{\tilde{\tau}_1} = 140 \text{ GeV})$

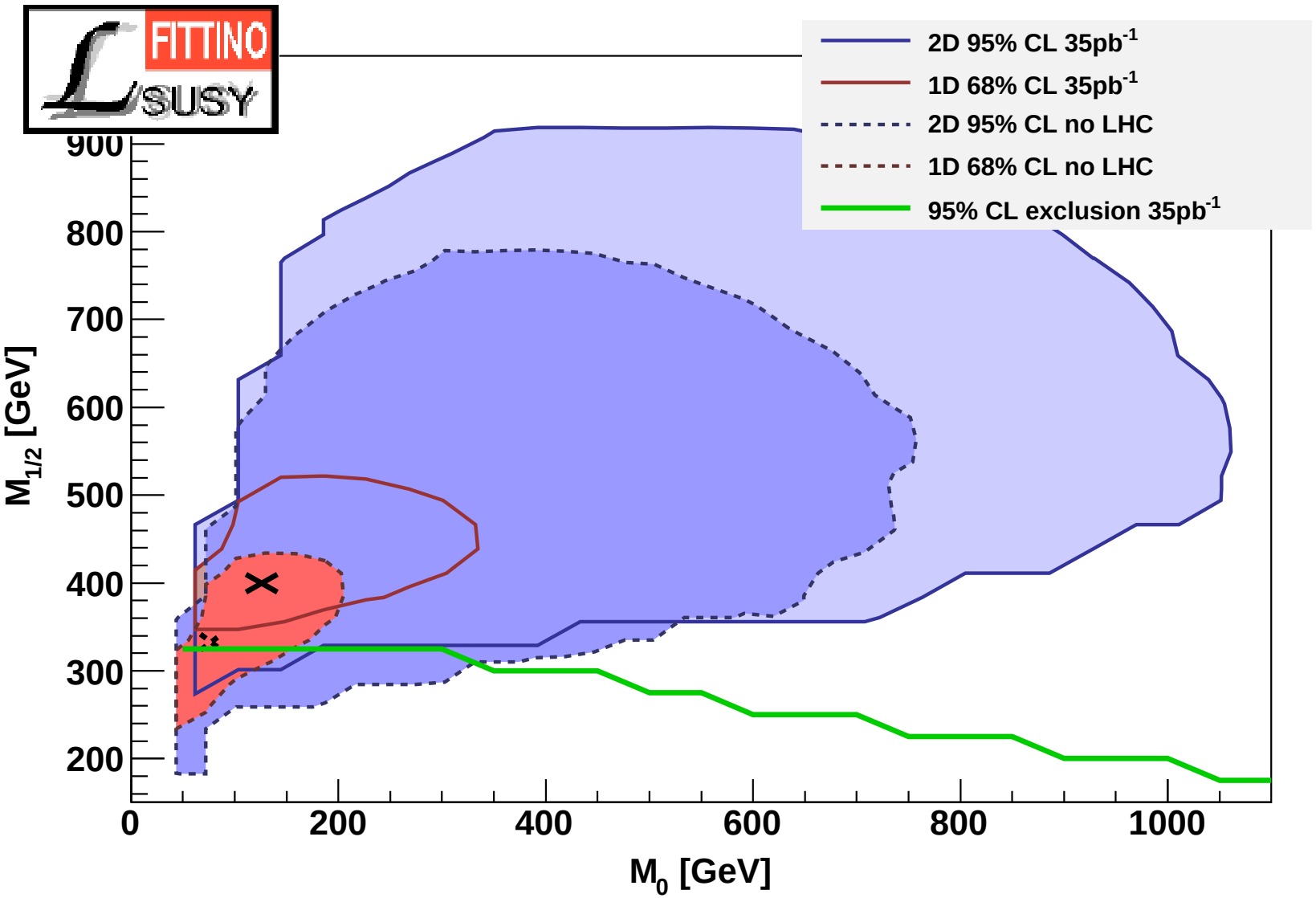
Spectrum range without LHC data



Best fit with recent LHC data (35/pb)

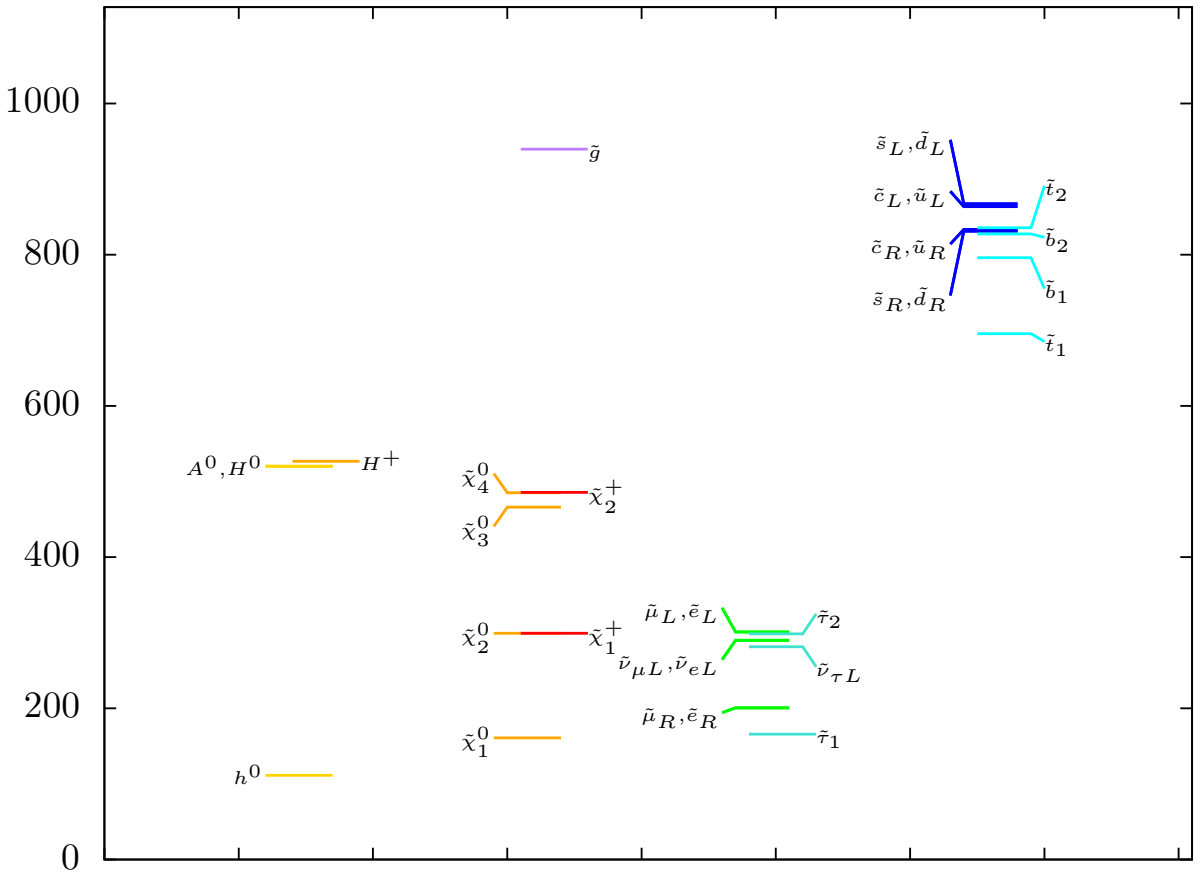
P. Bechtle, B. Sarrazin, K. Desch, H. K. Dreiner, P. Wienemann, M. Kramer, C. Robens, B. O'L., Phys. Rev. **D84** (2011) 011701. [arXiv:1102.4693 [hep-ph]]

Fittino best fit with 35/pb exclusions



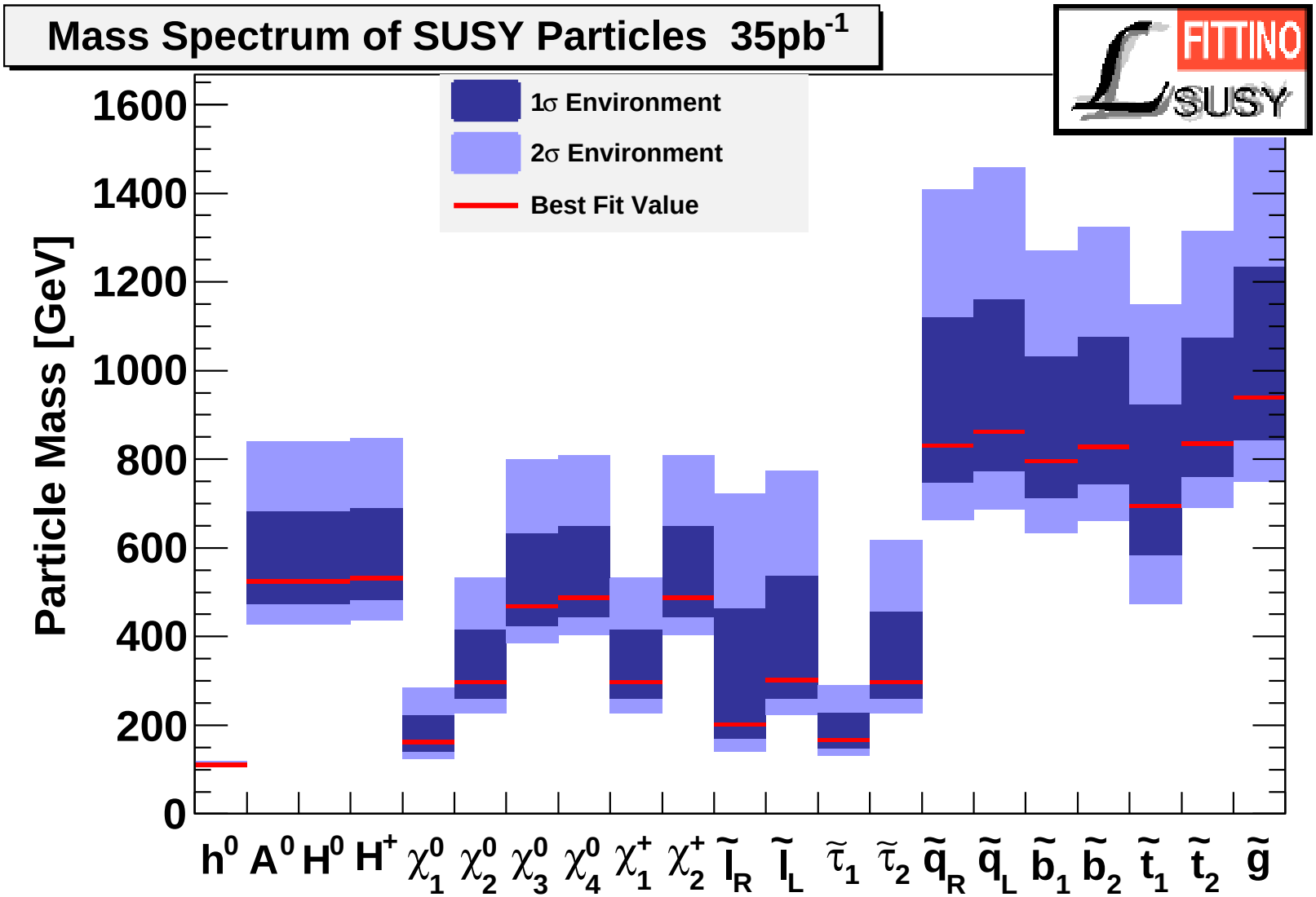
Spectrum at best fit point after 35/pb

M_0	:	126 GeV
$M_{1/2}$	:	400 GeV
A_0	:	742 GeV
$\tan\beta$	:	17
$\mu/\lvert\mu\rvert$	:	+1
$\chi 2$	:	20.4
d.o.f.	:	21
$\mathcal{P}$	:	0.499

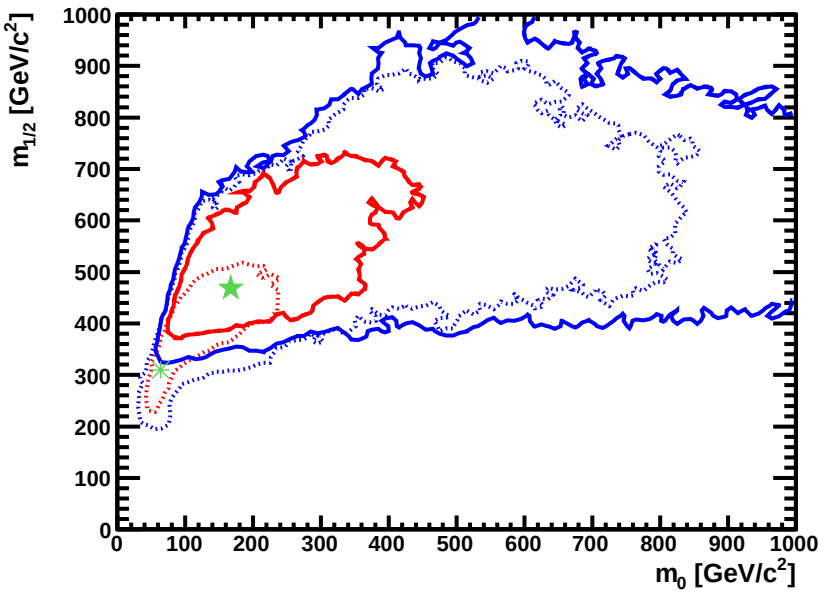


($m_{\tilde{\chi}_1^0} = 161$ GeV $< m_{\tilde{\tau}_1} = 166$ GeV)

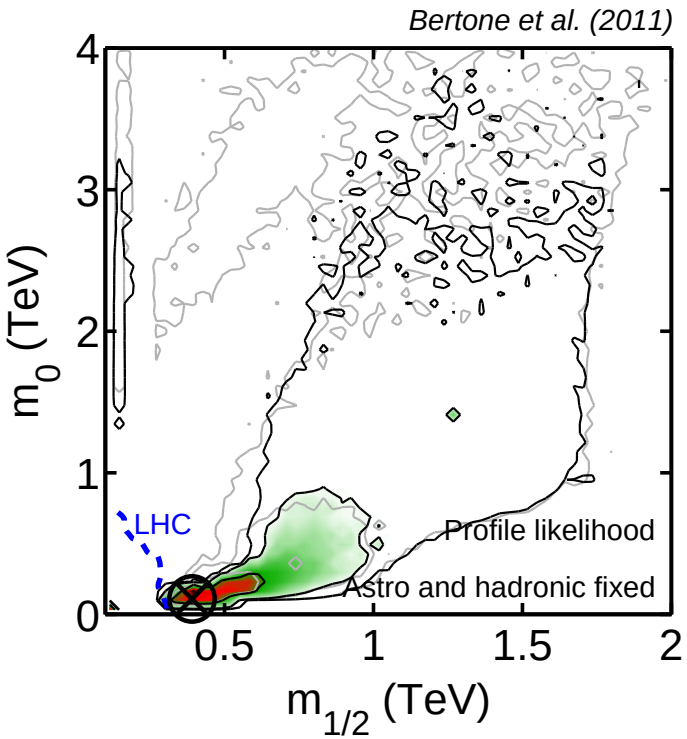
Spectrum range after 35/pb



Comparison with other groups



O. Buchmueller *et al.*, arXiv:1106.2529 [hep-ph]

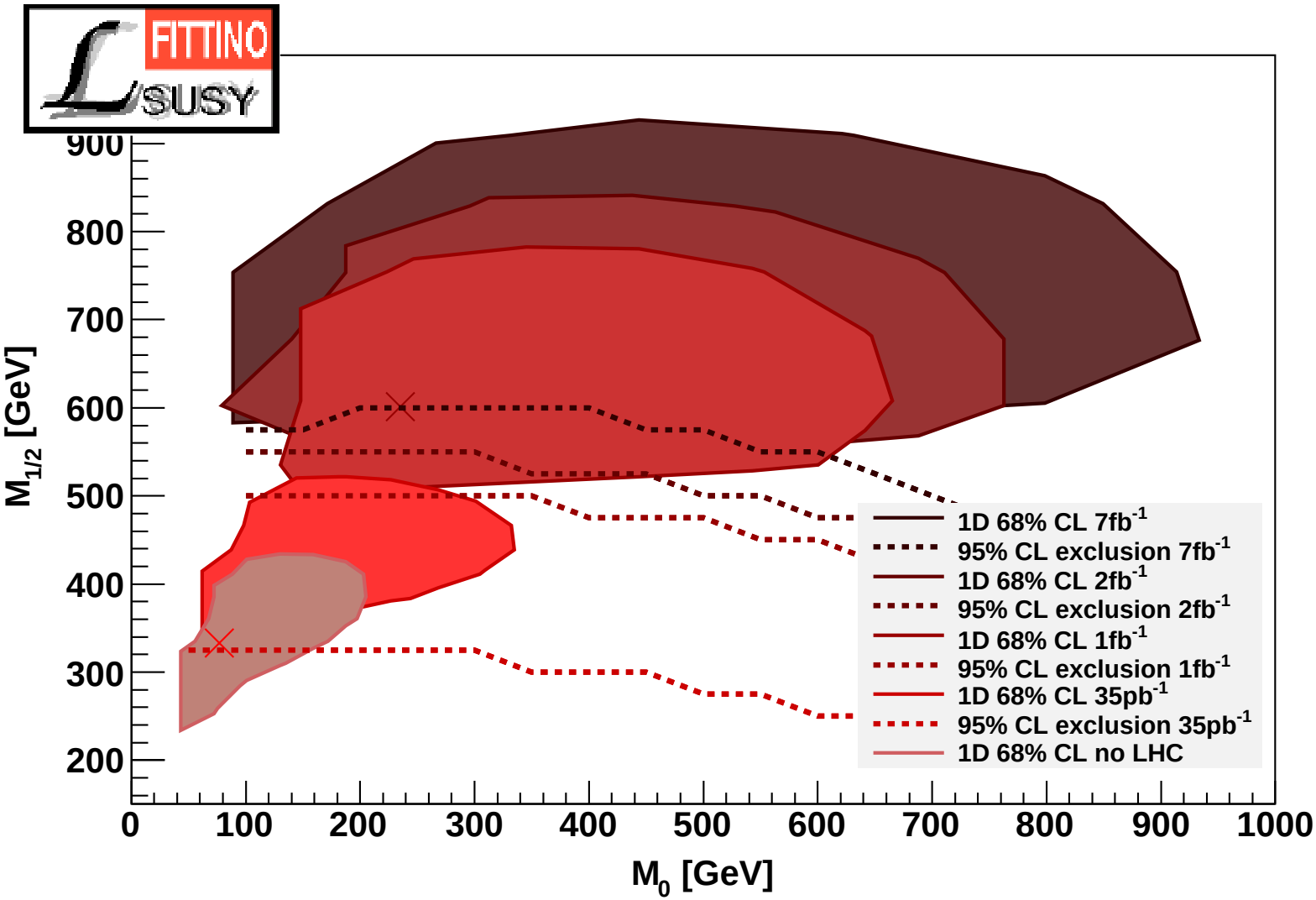


G. Bertone, D. G. Cerdeno, M. Fornasa, R. R. de Austri, C. Strege and R. Trotta, arXiv:1107.1715 [hep-ph]

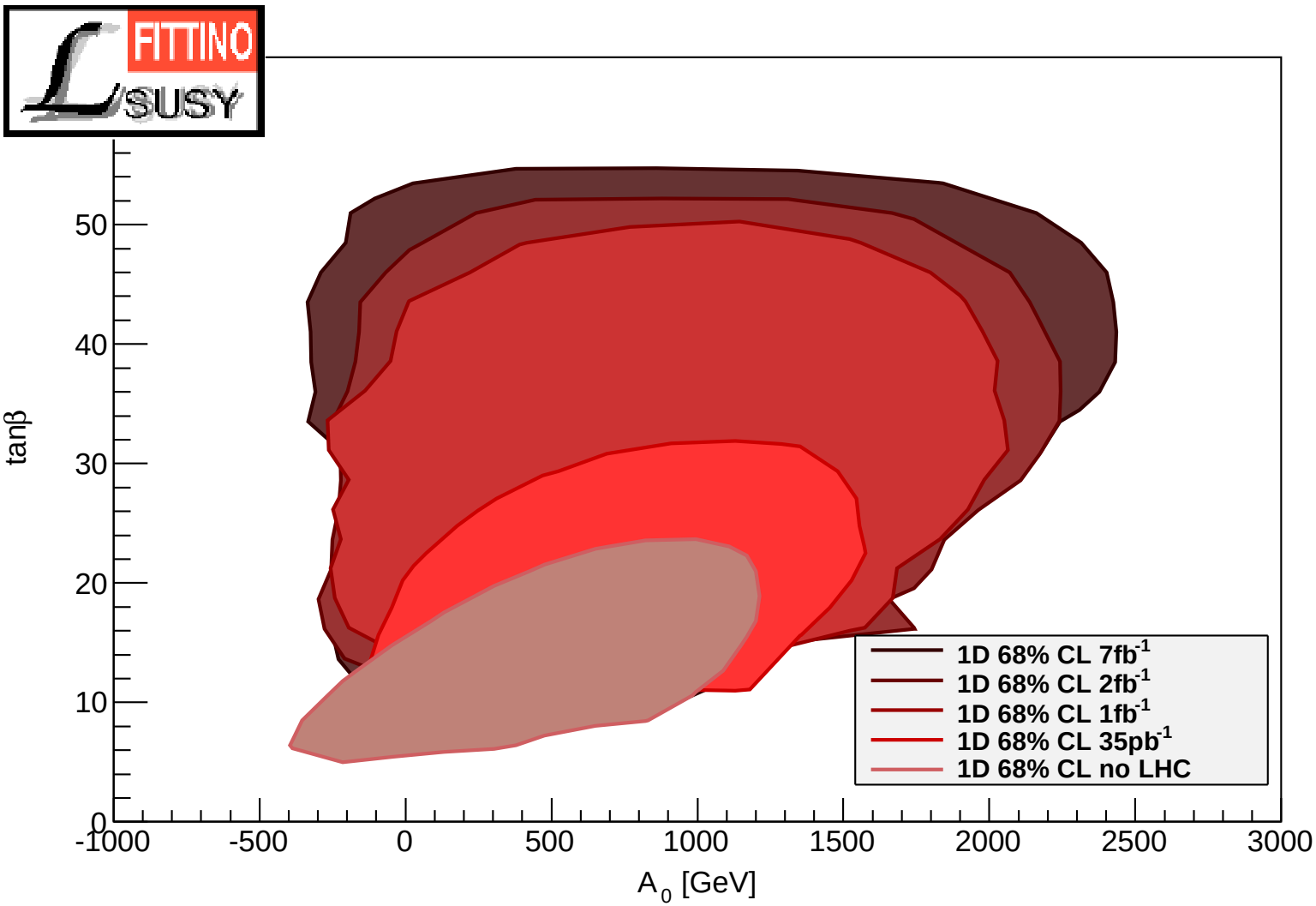
Best fits with current (1/fb) and potential future (2/fb, 7/fb) LHC exclusion

P. Bechtle, B. Sarrazin, K. Desch, H. K. Dreiner, P. Wienemann, M. Kramer, C. Robens, B. O'L., Phys. Rev. **D84** (2011) 011701. [arXiv:1102.4693 [hep-ph]] (in case you had forgotten)

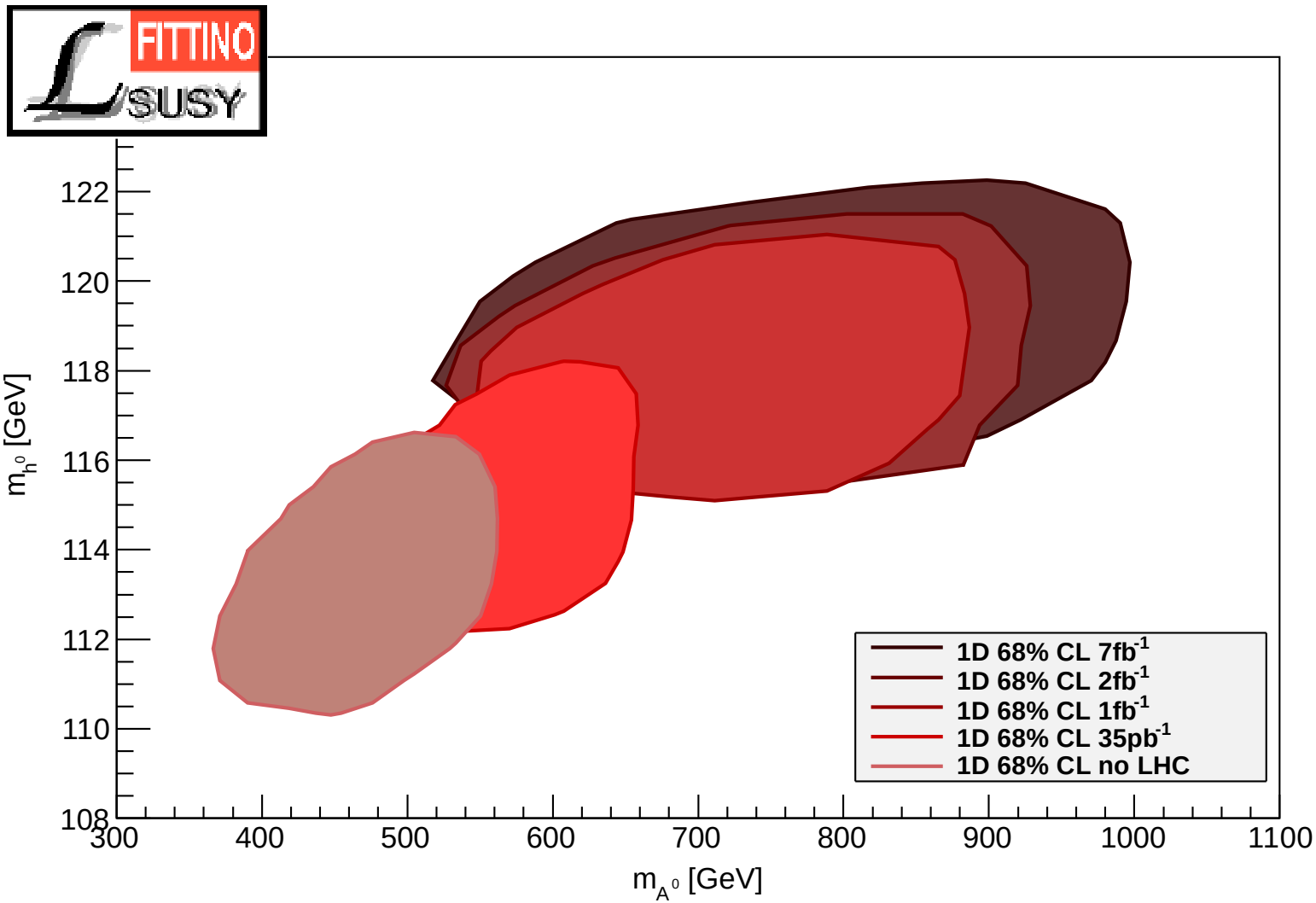
Fittino best fits with 1/fb, 2/fb, 7/fb exclusions - $M_0, M_{1/2}$



Fittino best fits with 1/fb, 2/fb, 7/fb exclusions - tan β, A_0



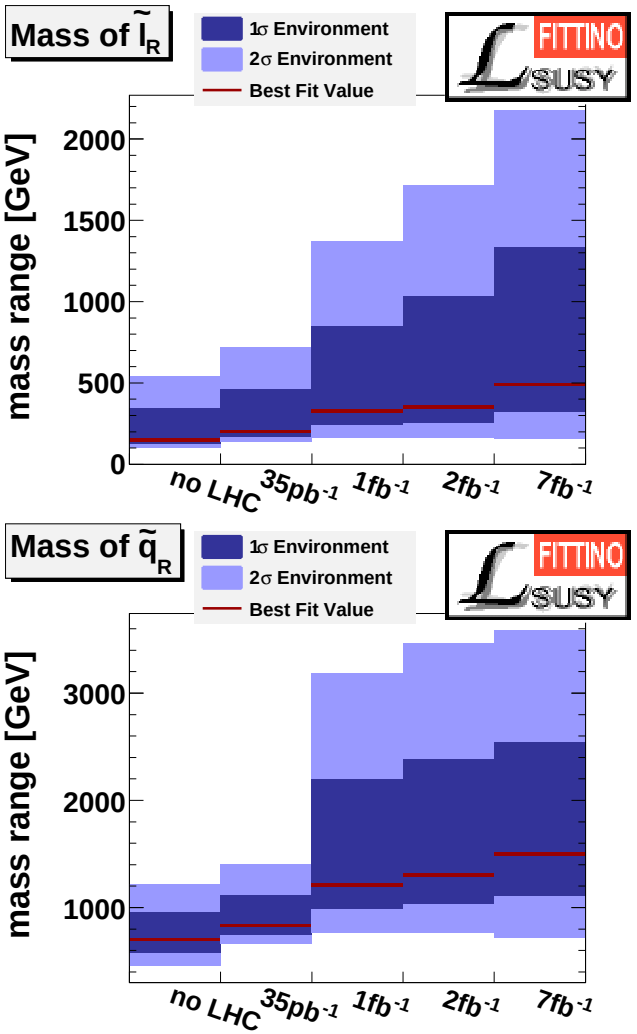
Fittino best fits with 1/fb, 2/fb, 7/fb exclusions - m_{h^0}, m_{A^0}



Best fit points with 1/fb, 2/fb, 7/fb exclusions

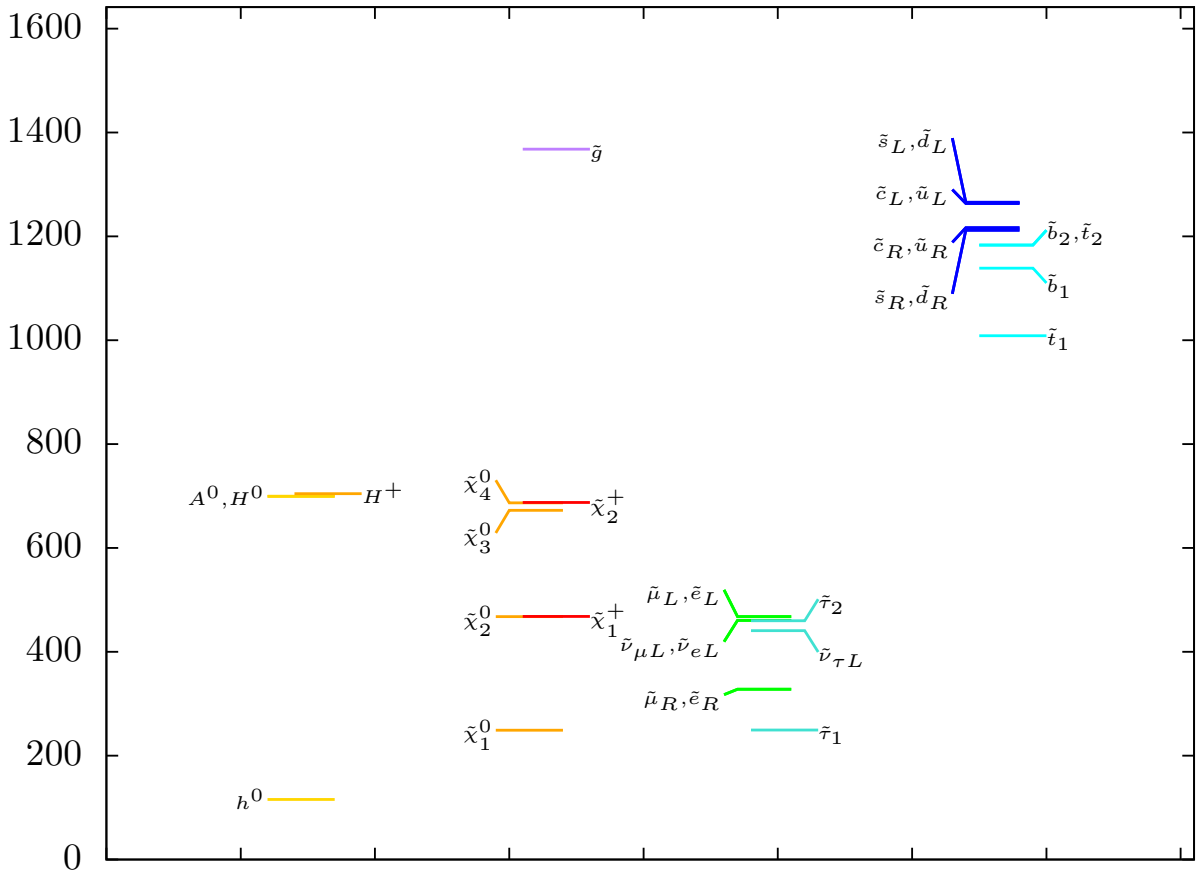
$\mu/|\mu| = +1$

	1/fb	2/fb	7/fb
M_0/ GeV	235	254	403
$M_{1/2}$/ GeV	601	647	744
A_0/ GeV	627	770	781
$\tan\beta$	31	32	43
$\chi 2$	23.7	24.6	25.0
d.o.f.	21	21	21
$\mathcal{P}$	0.309	0.283	0.246



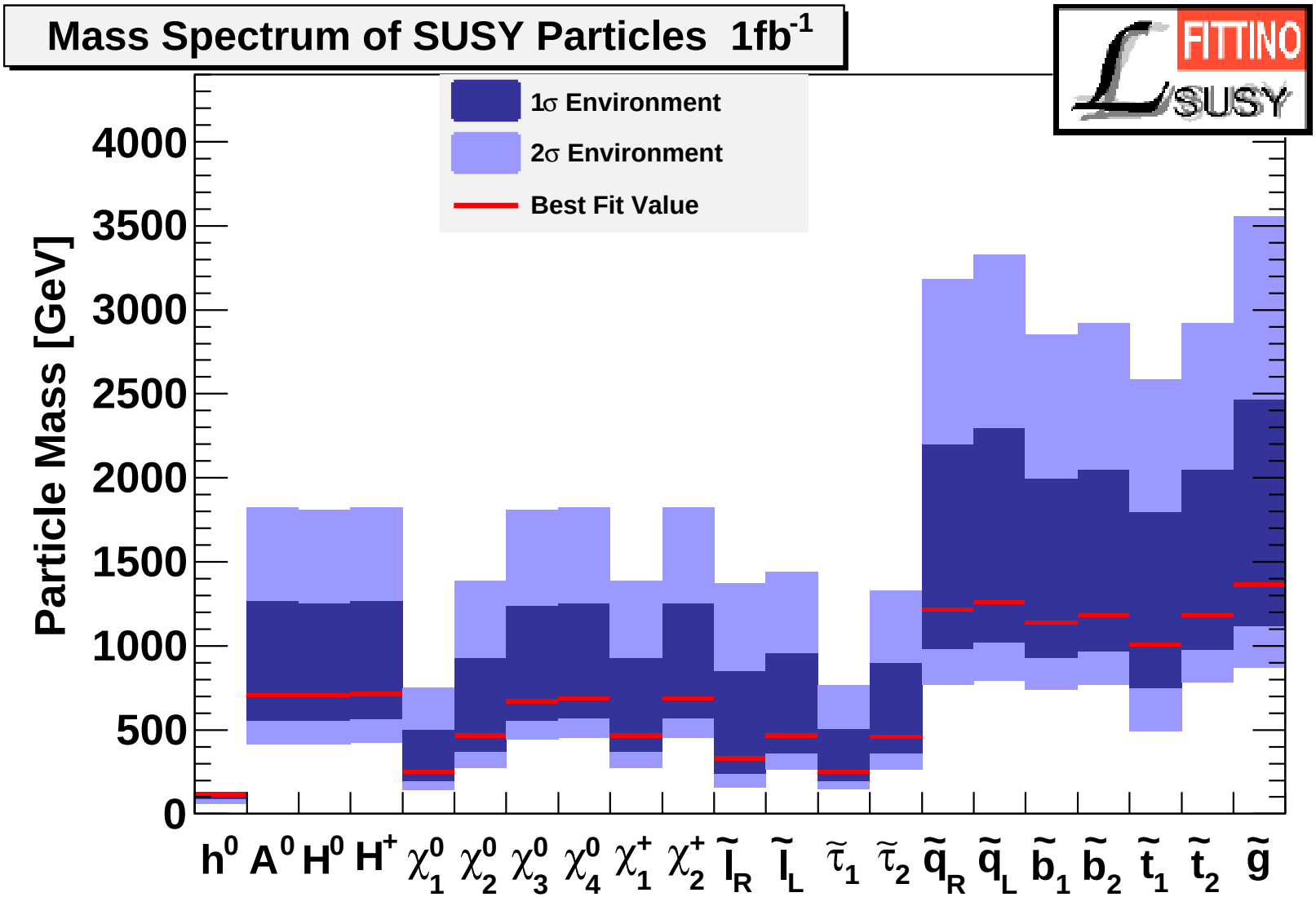
Spectrum at best fit point after 1/fb

M_0	:	235 GeV
$M_{1/2}$	:	601 GeV
A_0	:	627 GeV
$\tan\beta$	:	31
$\mu/\lvert\mu\rvert$	:	+1
$\chi 2$	:	23.7
d.o.f.	:	21
$\mathcal{P}$	:	0.309



($m_{\tilde{\chi}_1^0} = 249.0$ GeV $< m_{\tilde{\tau}_1} = 249.4$ GeV)

Spectrum range after 1/fb



Summary and Outlook

Summary and Outlook

Summary:

- mSUGRA-style CMSSM Lagrangian parameters can be measured
- LHC exclusion limits can be incorporated
- $M_0, M_{1/2}$ increase because of LHC, $\tan\beta, A_0$ increase to compensate for $(g-2)_\mu$
- tension is building, but "CMSSM still not a bad fit"

Outlook:

- further exclusion $\rightarrow$ worse $\chi^2/$ d.o.f.
- 2/fb and even 7/fb may not be very conclusive, may need to go to much higher integrated luminosities to convincingly rule out mSUGRA-style CMSSM

Thank you for your attention

Backup Slides

Used observables 1

obs.	val.	stat.	syst
$a_\mu^{\text{exp.}} - a_\mu^{\text{SM}}$	30.2E-10	$\pm 8.8E-10$	$\pm 2E-10$
Ωh^2	0.1099	± 0.0062	± 0.012
$(\Delta m_{B_s}/\Delta m_{B_s}^{\text{SM}})/$ [same for B_d]	1.09	± 0.01	± 0.16
$\Delta\epsilon_K/\Delta\epsilon_K^{\text{SM}}$	0.92	± 0.14	
$\sigma(Z \to \text{hardrons}$	41.540	± 0.037	
m_{h^0}	> 114.4		
A_{FB}^{ℓ}	0.0171	± 0.0010	
$\mathcal{A}_\ell$	0.1513	± 0.0021	
$\mathcal{A}_\tau$	0.1465	± 0.0032	
R_ℓ	20767	± 0.025	
R_b	0.21629	± 0.00066	
R_c	0.1721	± 0.003	
A_{FB}^{b}	0.0992	± 0.0016	
A_{FB}^{c}	0.0707	± 0.0035	
$\mathcal{A}_b$	0.923	± 0.020	
$\mathcal{A}_c$	0.670	± 0.027	
$m_{W^\pm}$	80.398	± 0.025	
$\sin\theta_{eff.}$	0.2324	± 0.0012	
Γ_Z	2495.2	± 2.3	

Used observables 2

obs.	val.	stat.	syst
$BR(B \to s\gamma)/BR(B \to s\gamma)^{\mathrm{SM}}$	1.117	± 0.076	± 0.096
$(\Delta m_{B_s}/\Delta m_{B_s}^{\mathrm{SM}})$	1.11	± 0.01	± 0.32
$BR(B \to \tau\nu)/BR(B \to \tau\nu)^{\mathrm{SM}}$	1.15	± 0.40	
$BR(B_s \to X_s\ell\ell)/BR(B_s \to X_s\ell\ell)^{\mathrm{SM}}$	0.99	± 0.32	
$BR(K \to \mu\nu)/BR(K \to \mu\nu)^{\mathrm{SM}}$	1.008	± 0.014	

$\Rightarrow 24 - 4 = 20$ degrees of freedom (4 CMSSM parameters)
$+1$ for LHC exclusion

Spectrum range after 7/fb