Combining low energy measurements with LHC exclusion limits

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Workshop “Global BSM fits and LHC data”
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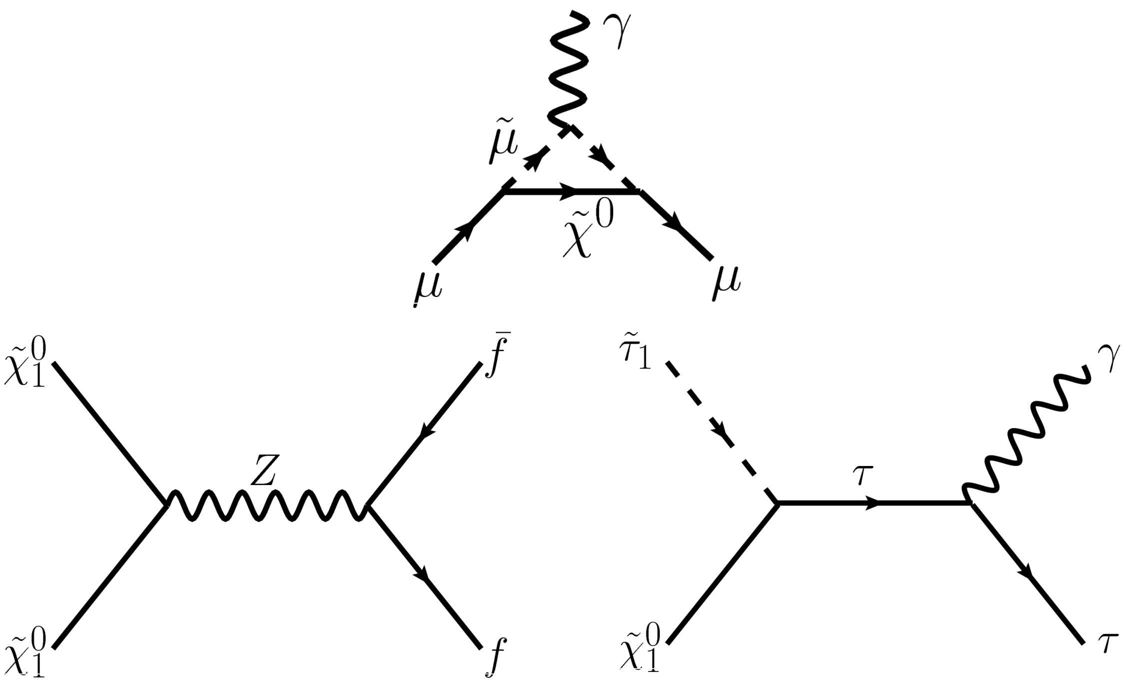
“Low energy” measurements

Wealth of precision measurements from LEP/SLC, from Tevatron, from B/K physics, from $(g\text{-}2)_\mu$ and from astrophysics

Already “low energy” (LE) data exhibits sensitivity to SUSY effects ($\rightarrow$ m_t prediction), in particular:

- $(g-2)_\mu$
- $\Omega_\chi h^2$

Example diagrams:



List of used LE precision measurements

Observable	Experimental Value	Uncertainty stat	Uncertainty syst	Exp. Reference
$\mathcal{B}(B \to s\gamma)/\mathcal{B}(B \to s\gamma)_{\mathrm{SM}}$	1.117	0.076	0.096	[47]
$\mathcal{B}(B_s \to \mu\mu)$	$< 4.7\times10^{-8}$			[47]
$\mathcal{B}(B_d \to \ell\ell)$	$< 2.3\times10^{-8}$			[47]
$\mathcal{B}(B \to \tau\nu)/\mathcal{B}(B \to \tau\nu)_{\mathrm{SM}}$	1.15	0.40		[48]
$\mathcal{B}(B_s \to X_s\ell\ell)/\mathcal{B}(B_s \to X_s\ell\ell)_{\mathrm{SM}}$	0.99	0.32		[47]
$\Delta m_{B_s}/\Delta m_{B_s}^{\mathrm{SM}}$	1.11	0.01	0.32	[49]
$\frac{\Delta m_{B_s}/\Delta m_{B_s}^{\mathrm{SM}}}{\Delta m_{B_d}/\Delta m_{B_d}^{\mathrm{SM}}}$	1.09	0.01	0.16	[47,49]
$\Delta\epsilon_K/\Delta\epsilon_K^{\mathrm{SM}}$	0.92	0.14		[49]
$\mathcal{B}(K \to \mu\nu)/\mathcal{B}(K \to \mu\nu)_{\mathrm{SM}}$	1.008	0.014		[50]
$\mathcal{B}(K \to \pi\nu\bar{\nu})/\mathcal{B}(K \to \pi\nu\bar{\nu})_{\mathrm{SM}}$	< 4.5			[51]
$a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{SM}}$	30.2×10^{-10}	8.8×10^{-10}	2.0×10^{-10}	[52,53]
$\sin^2\theta_{\mathrm{eff}}$	0.2324	0.0012		[46]
Γ_Z	2.4952 GeV	0.0023 GeV	0.001 GeV	[46]
R_l	20.767	0.025		[46]
R_b	0.21629	0.00066		[46]
R_c	0.1721	0.003		[46]
$A_{\mathrm{fb}}(b)$	0.0992	0.0016		[46]
$A_{\mathrm{fb}}(c)$	0.0707	0.0035		[46]
A_b	0.923	0.020		[46]
A_c	0.670	0.027		[46]
A_l	0.1513	0.0021		[46]
A_τ	0.1465	0.0032		[46]
$A_{\mathrm{fb}}(l)$	0.01714	0.00095		[46]
σ_{had}	41.540 nb	0.037 nb		[46]
m_h	> 114.4 GeV		3.0 GeV	[54,55,56]
$\Omega_{\mathrm{CDM}}h^2$	0.1099	0.0062	0.012	[57]
$1/\alpha_{em}$	127.925	0.016		[58]
G_F	$1.16637\times10^{-5}\mathrm{GeV}^{-2}$	$0.00001\times10^{-5}\mathrm{GeV}^{-2}$		[58]
α_s	0.1176	0.0020		[58]
m_Z	91.1875 GeV	0.0021 GeV		[46]
m_W	80.399 GeV	0.025 GeV	0.010 GeV	[58]
m_b	4.20 GeV	0.17 GeV		[58]
m_t	172.4 GeV	1.2 GeV		[59]
m_τ	1.77684 GeV	0.00017 GeV		[58]
m_c	1.27 GeV	0.11 GeV		[46]

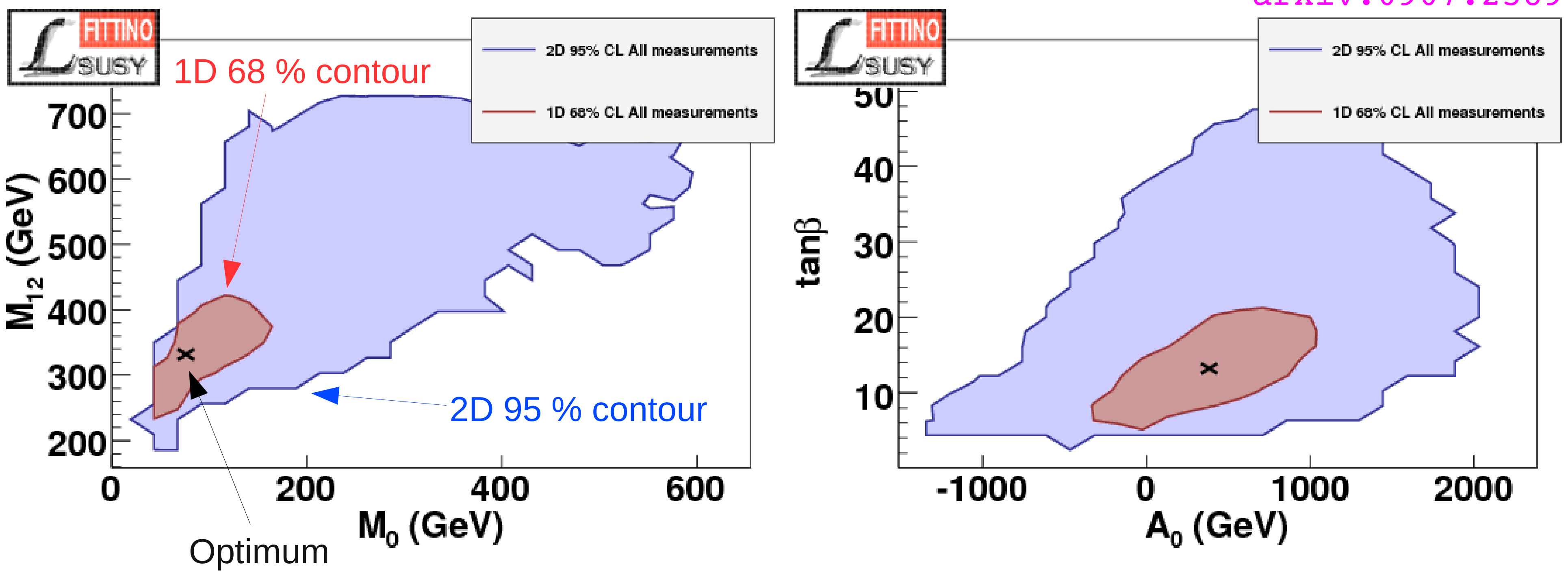
Fit machinery

- Fit to LE data performed using `Fittino` (P. Bechte, K. Desch, PW, et al.)
- Parameter analysis with Markov Chain Monte Carlo (frequentistic interpretation)
- Theory predictions taken from
  - ➔ SPheno (W. Porod)
  - ➔ Mastercode (O. Buchmüller, et al.) for LE observables

LE data: mSUGRA parameter fit

Fit of mSUGRA parameters to 35 LE measurements:

arXiv:0907.2589



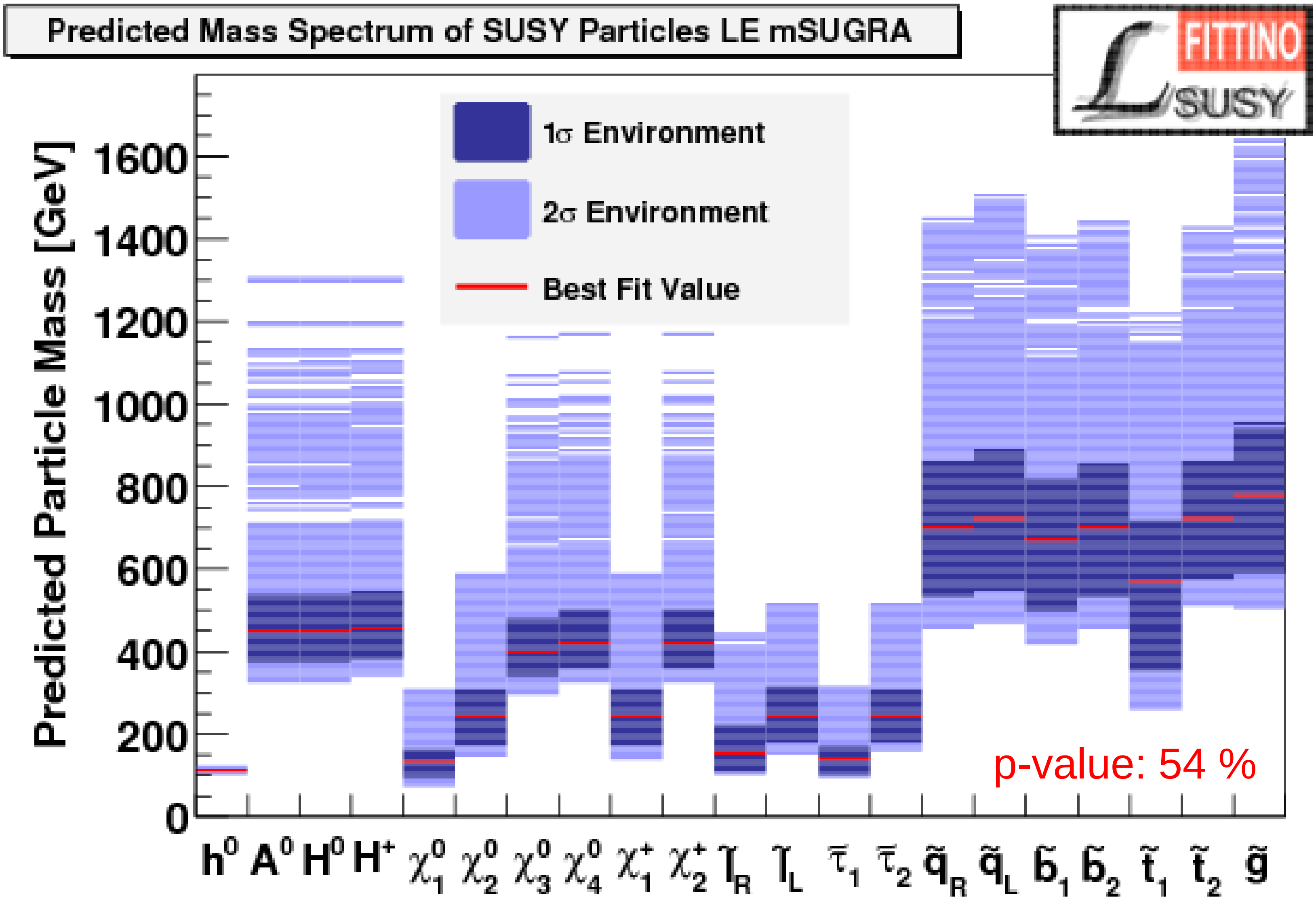
- non-trivial optimum
- M_0 and $M_{1/2}$ already constrained significantly

→ in good agreement with previous findings by
O. Buchmüller et al., arXiv:0808.4128

LE: Expected spectrum from mSUGRA fit

Mass spectrum corresponding to mSUGRA parameter constraints:

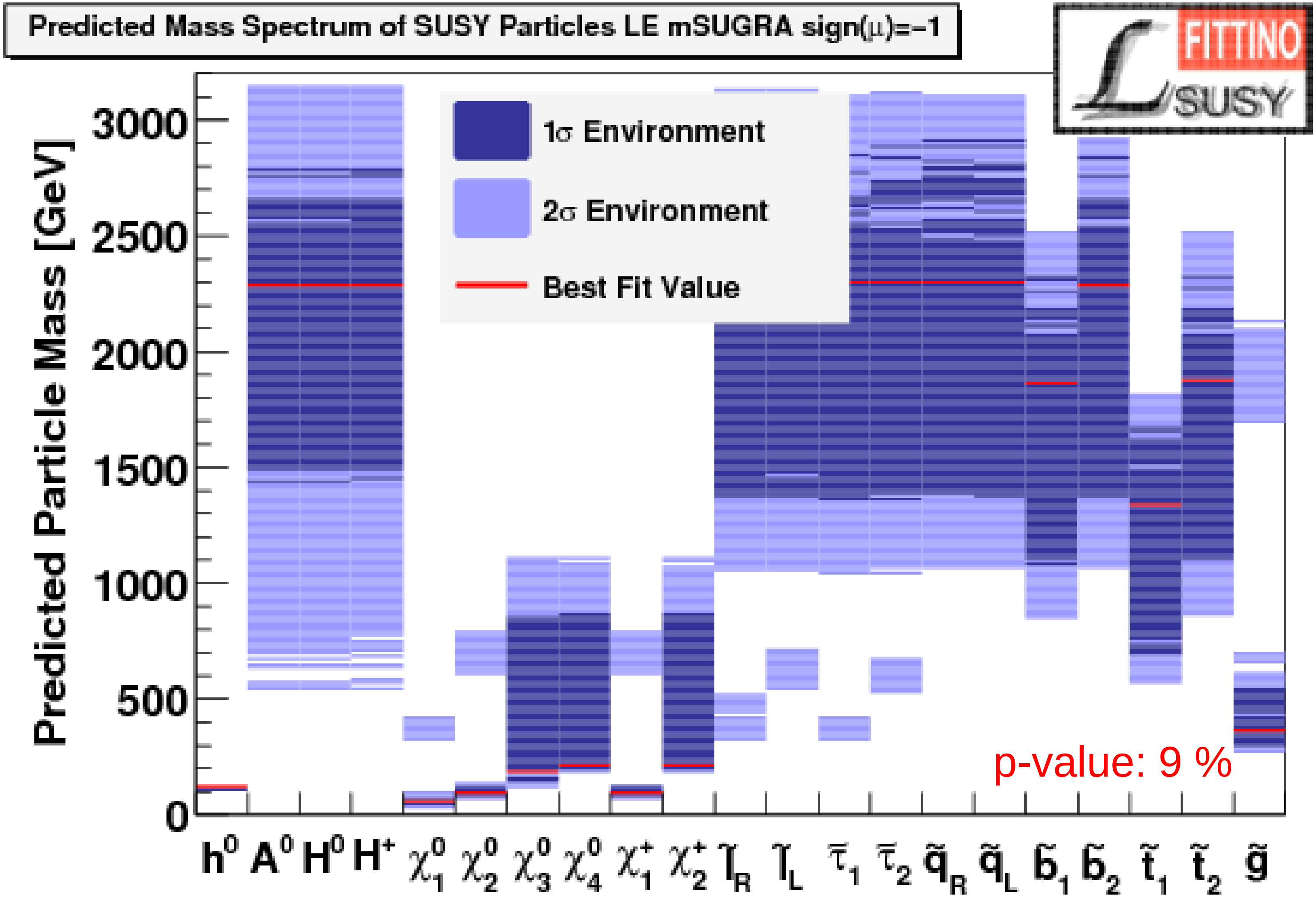
mSUGRA, $\mu>0$:



LE: Expected spectrum from mSUGRA fit

Mass spectrum corresponding to mSUGRA parameter constraints:

mSUGRA, μ<0:

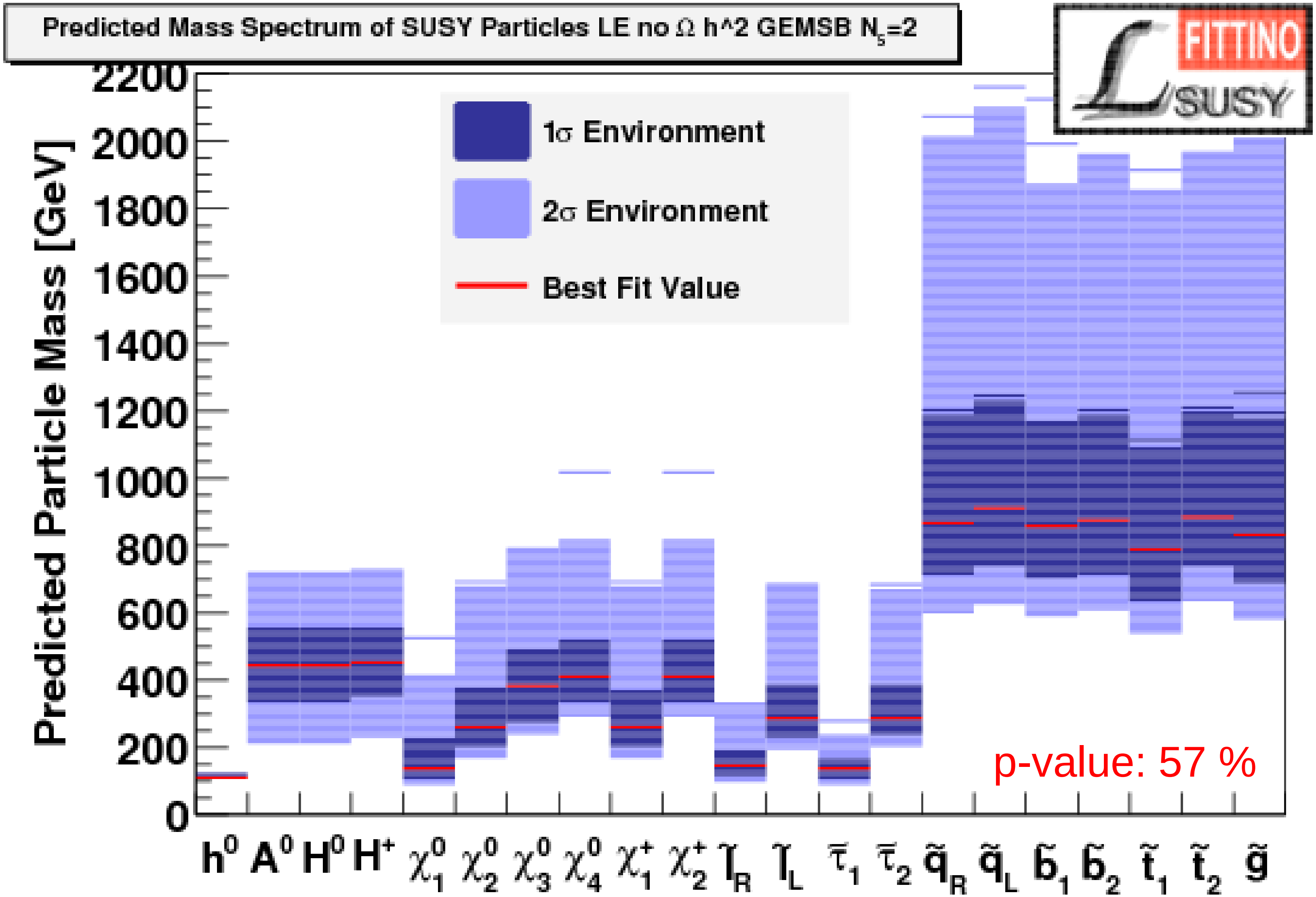


p-value: 9 %

LE: Expected spectrum from GMSB fit

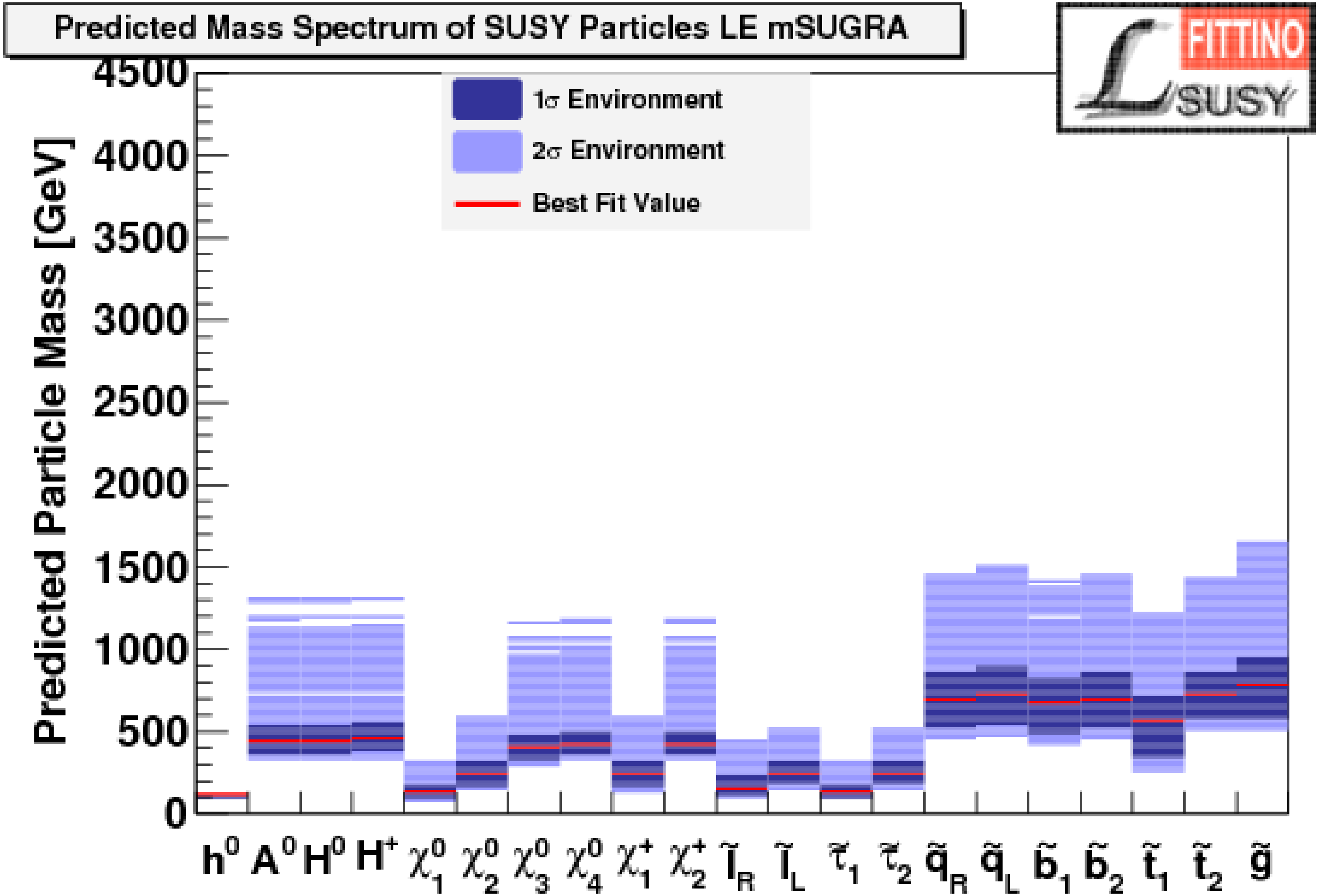
Mass spectrum corresponding to GMSB parameter constraints:

GMSB, μ>0, N_5 = 2:



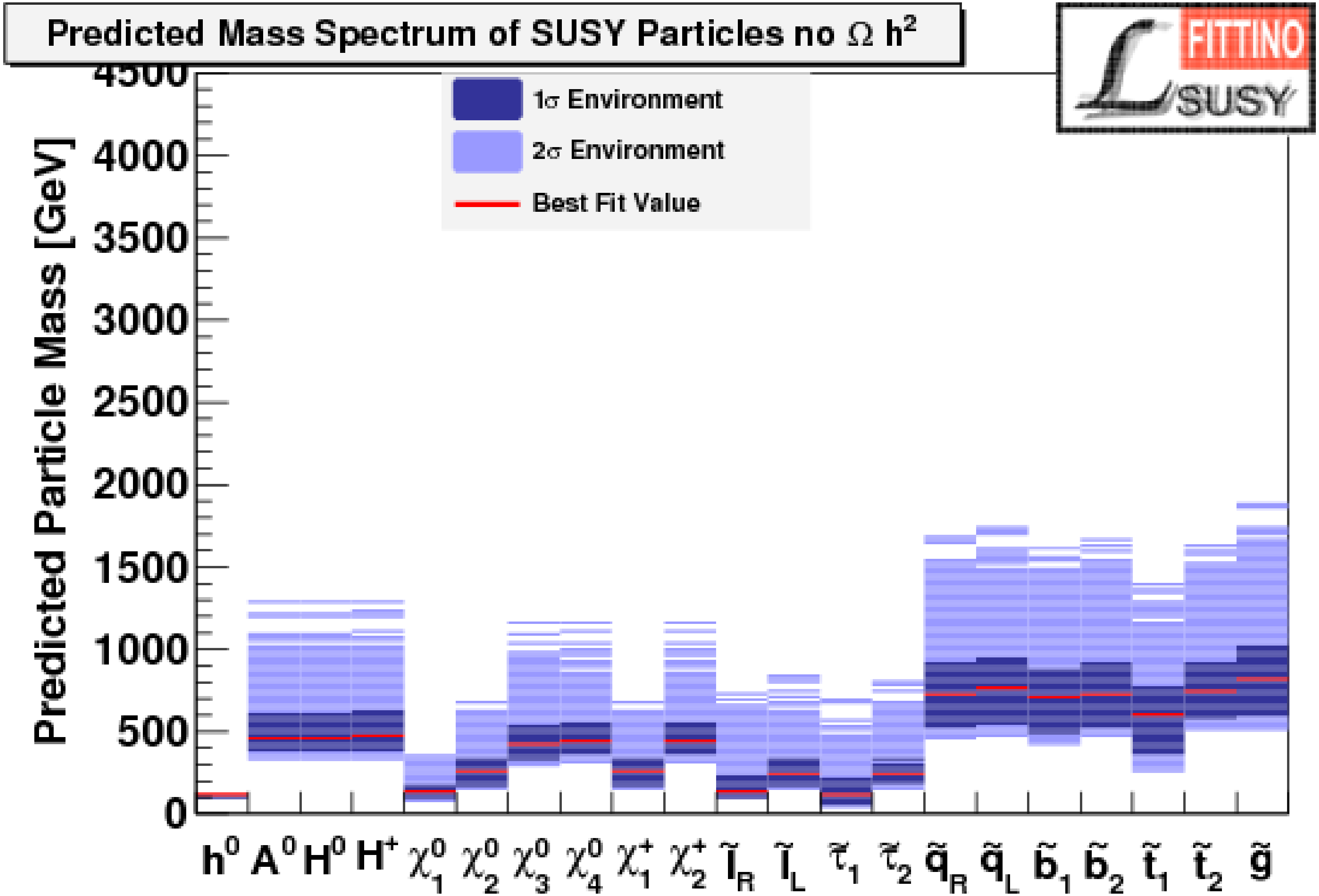
LE: Impact of individual observables

All measurements:



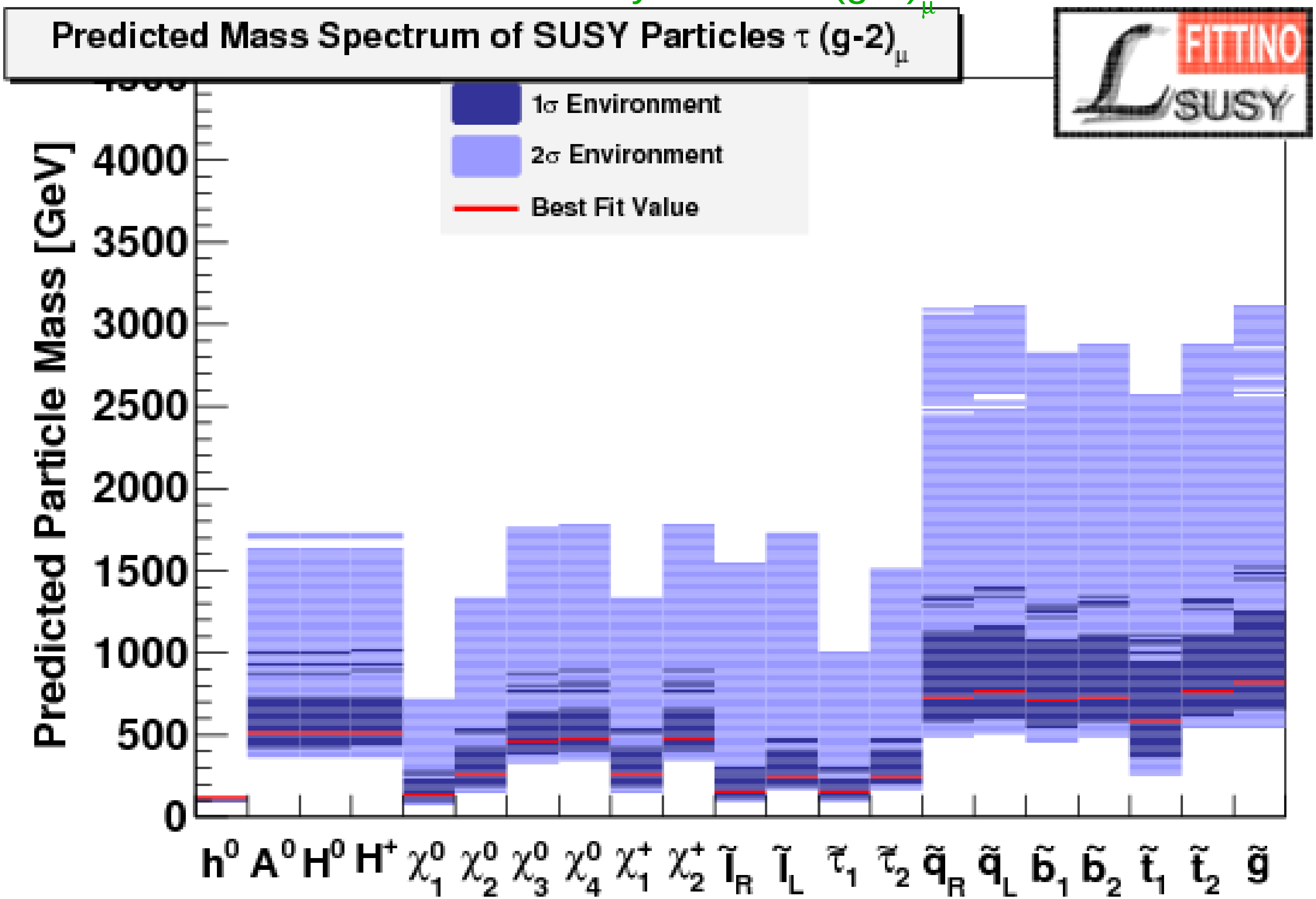
LE: Impact of individual observables

No dark matter density:



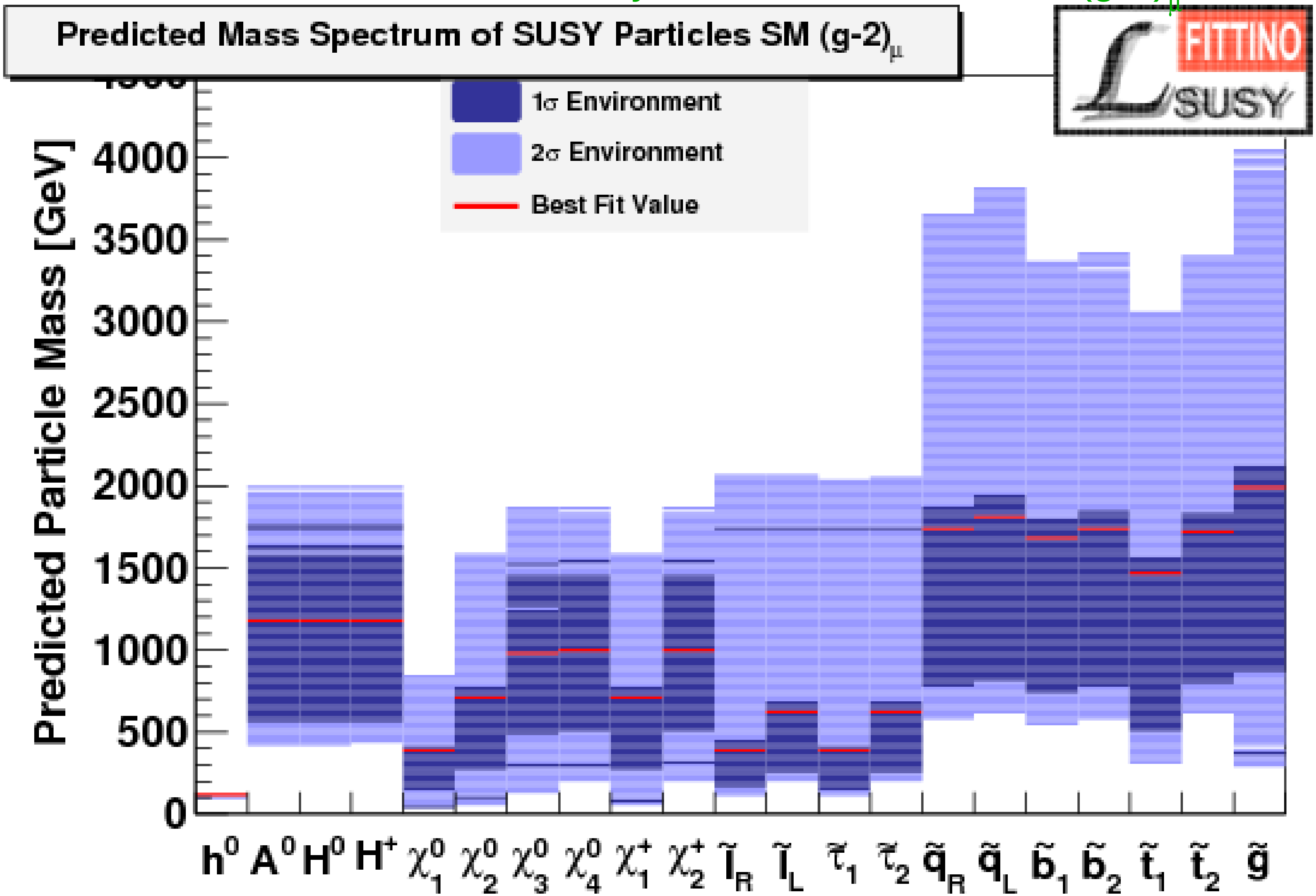
LE: Impact of individual observables

With dark matter density and with $(g-2)_\mu$ from τ data:



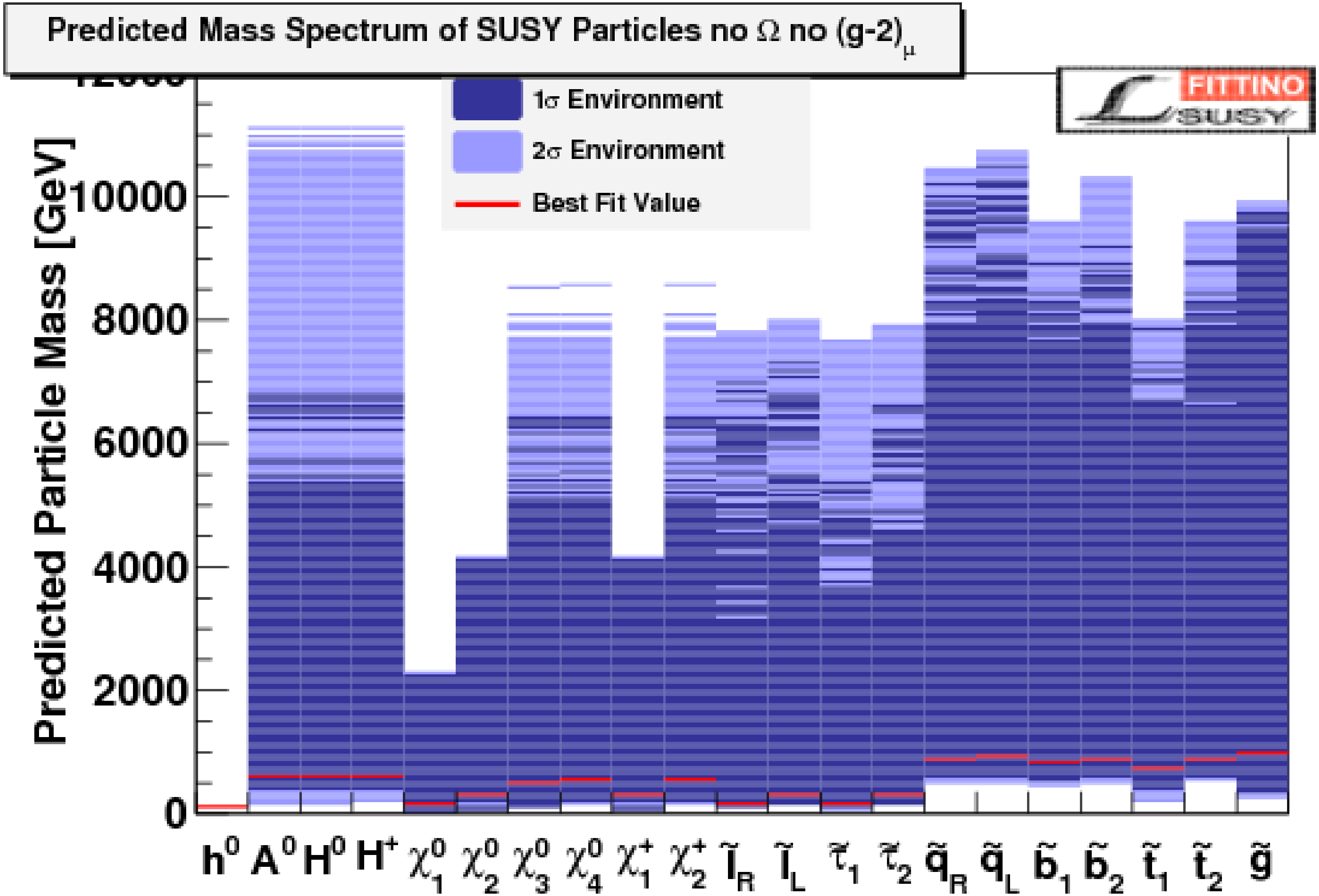
LE: Impact of individual observables

With dark matter density and with SM value for $(g-2)_\mu$:



LE: Impact of individual observables

No dark matter density and no $(g\text{-}2)_\mu$:



Summary of LE fits

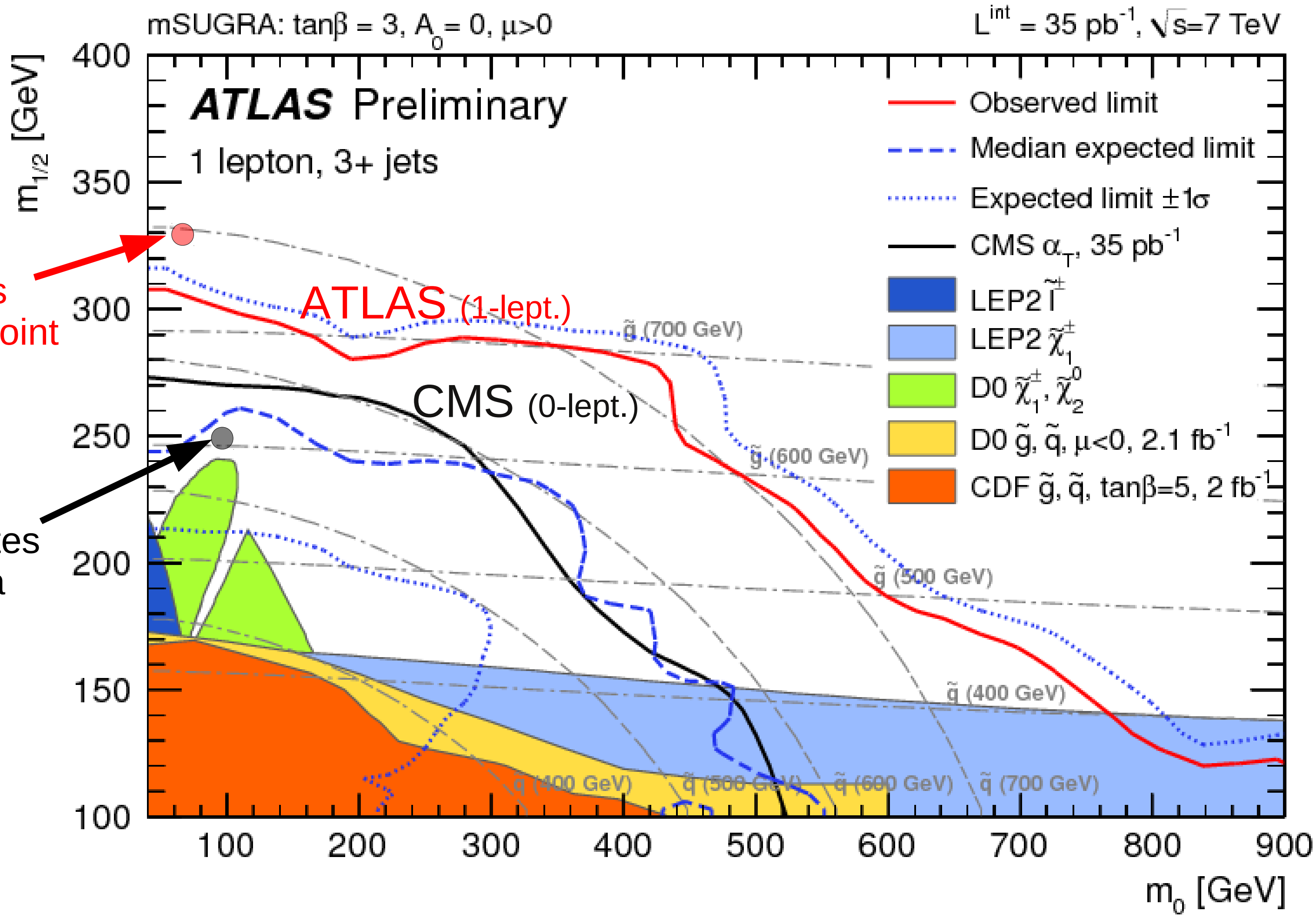
- Available LE data exhibits sensitivity to SUSY parameters
- It favours (at least some) light SUSY masses
- mSUGRA with $\mu > 0$ can describe the data well. $\mu < 0$ disfavoured by $(g-2)_\mu$. But also GMSB is fine (but needs an additional CDM candidate).
- Most constraining measurements are $(g-2)_\mu$ followed by CDM relic density.
- Best-fit point rather stable when removing a single observable
- After removal of $(g-2)_\mu$ *and* relic density almost all sensitivity is lost

First LHC SUSY exclusions

First mSUGRA exclusion limits were just released by LHC collaborations and are pushing up the SUSY mass limits:

(m_0, $m_{1/2}$) coordinates of best-fit point

(m_0, $m_{1/2}$) coordinates of SPS1a



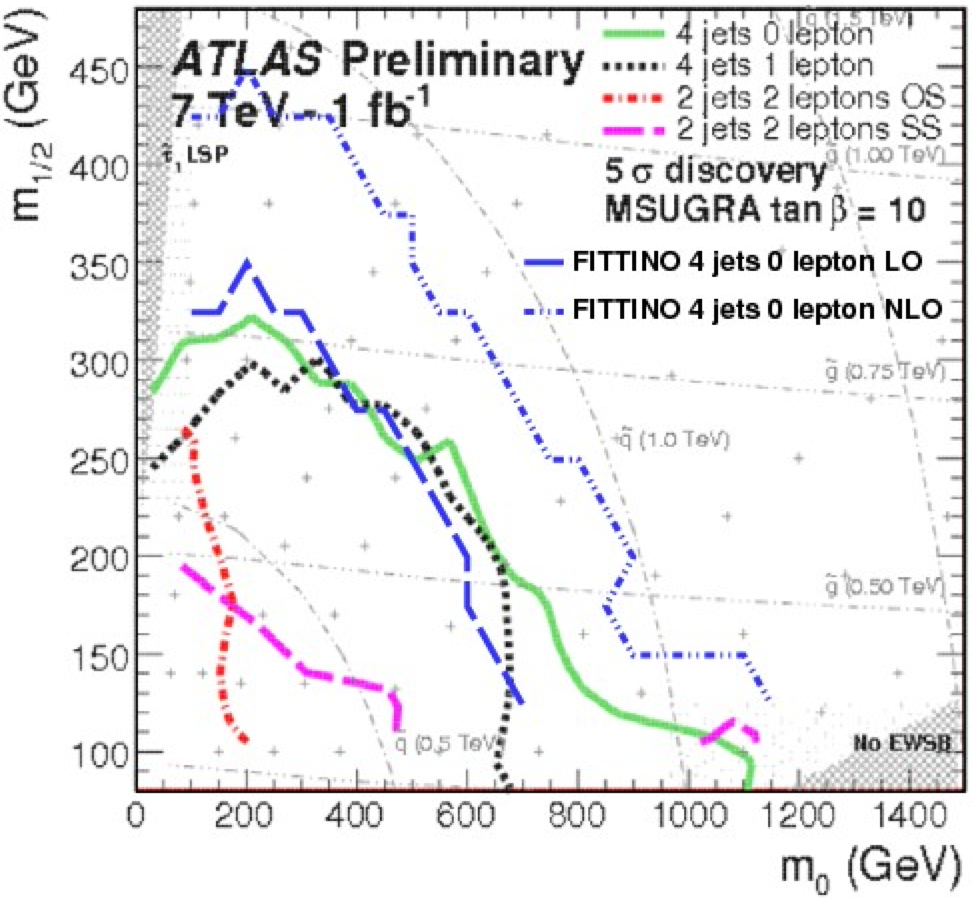
“Die Frage”

What does it mean if the LHC does not find SUSY in the initial 7 TeV run?

- How does the remaining allowed SUSY parameter space look like?
- Does it create any tension between low energy measurements and LHC exclusions?
- What are the implications for a future Linear Collider?

Modelling LHC exclusion potential

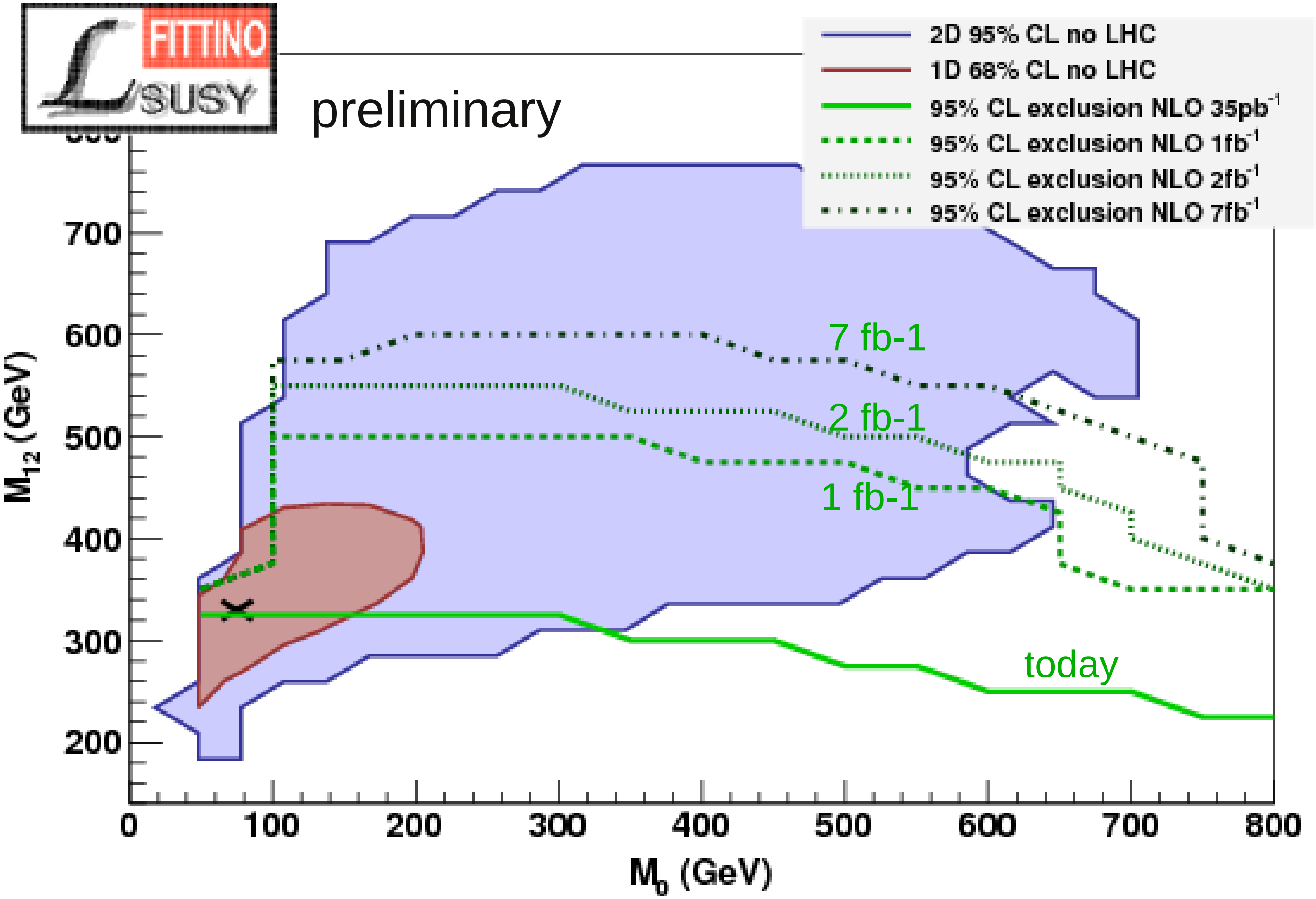
In the quest to answer “die Frage” we use the ATLAS 4-jet + MET + 0 lepton cuts from ATL-PHYS-PUB-2010-010 (7 TeV sensitivity study) and cross-checked our analysis on the discovery reach:



Our analysis nicely reproduces discovery reach of ATLAS sensitivity study (which used LO SUSY cross-section)

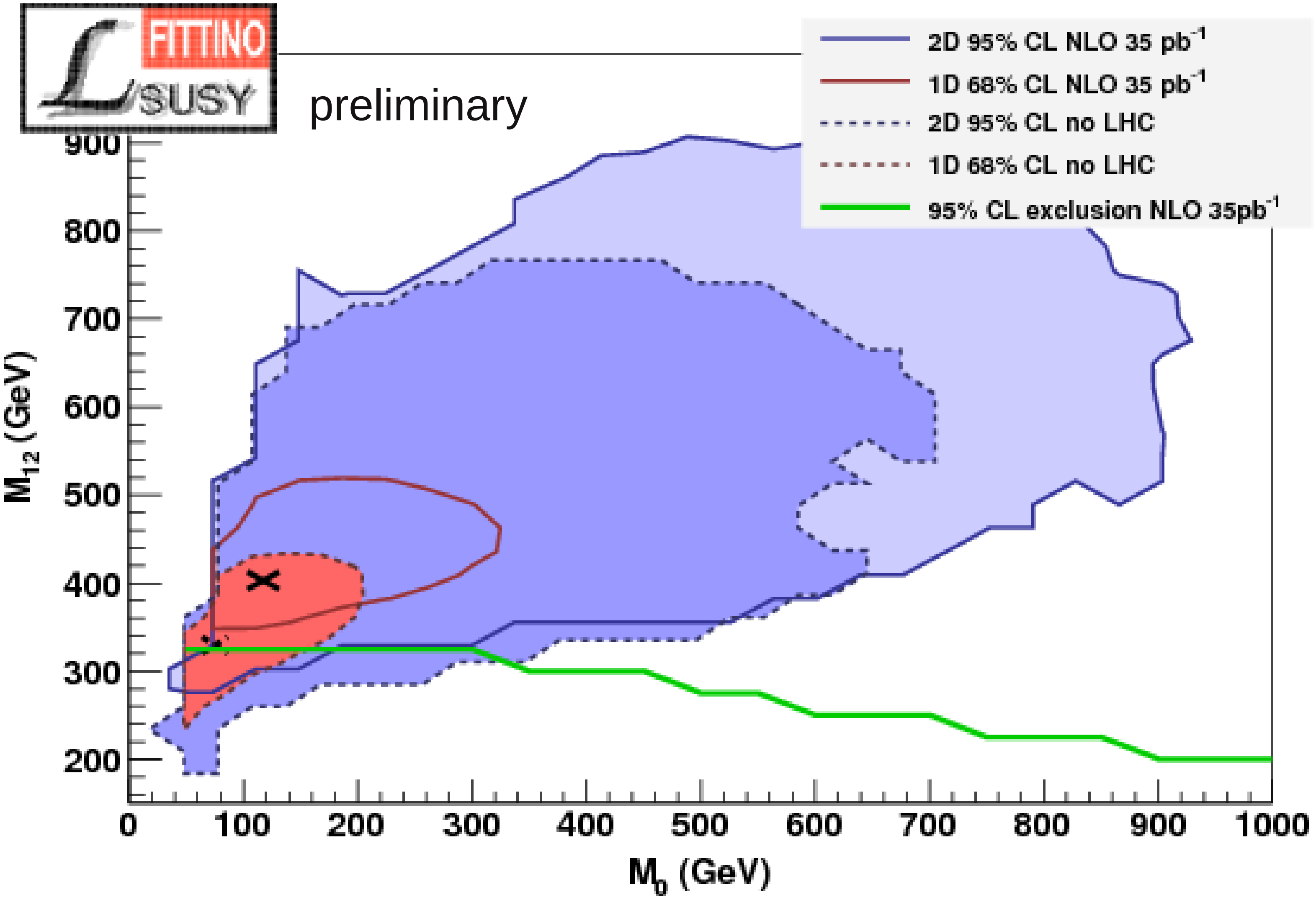
Projection: LE data vs. LHC exclusion

Projection of how the LHC exclusion potential evolves during the 7 TeV run compared to the LE data preferred region:



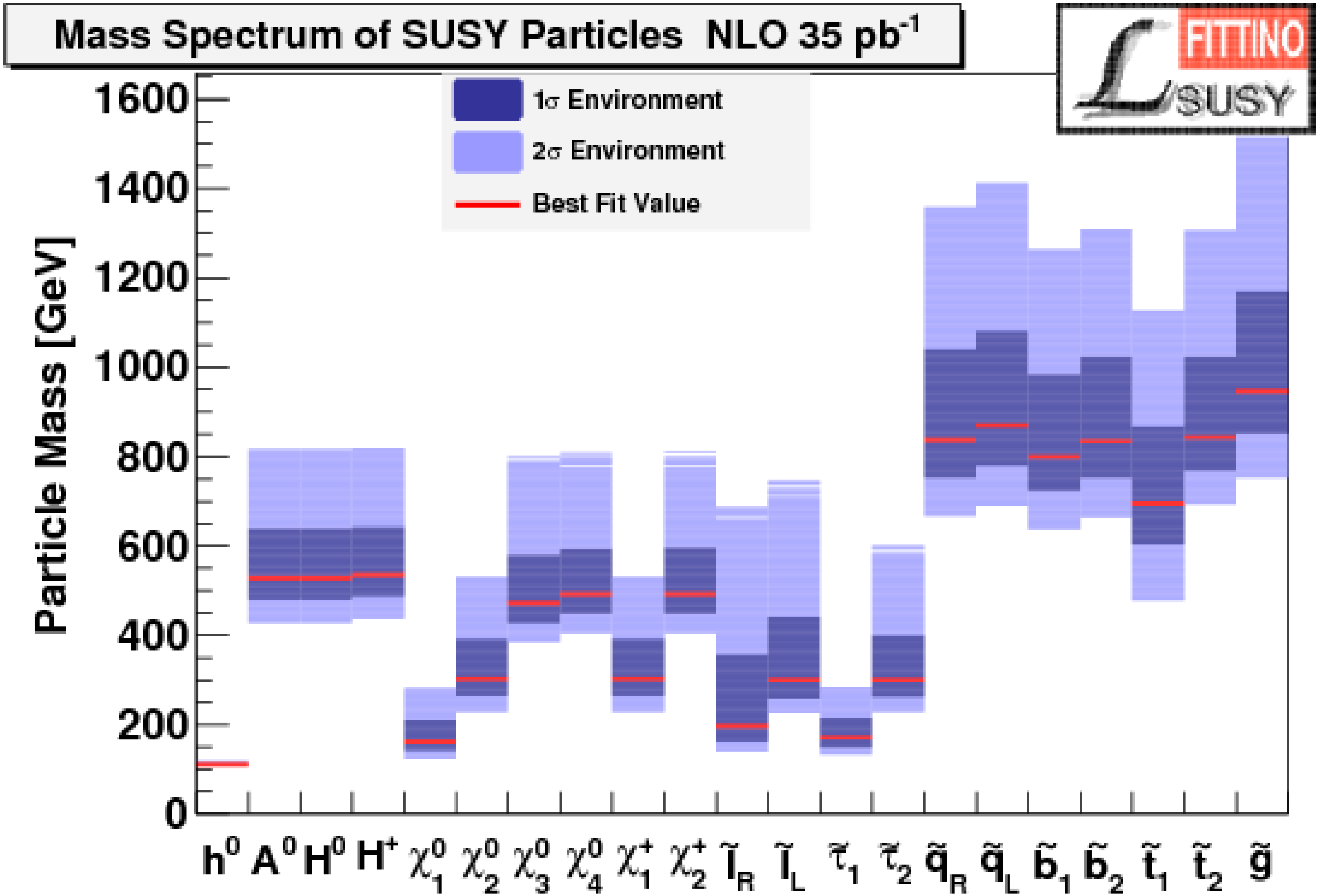
Combined fit of LE data and LHC exclusion

A combined global fit of LE data and estimate of present LHC exclusions:



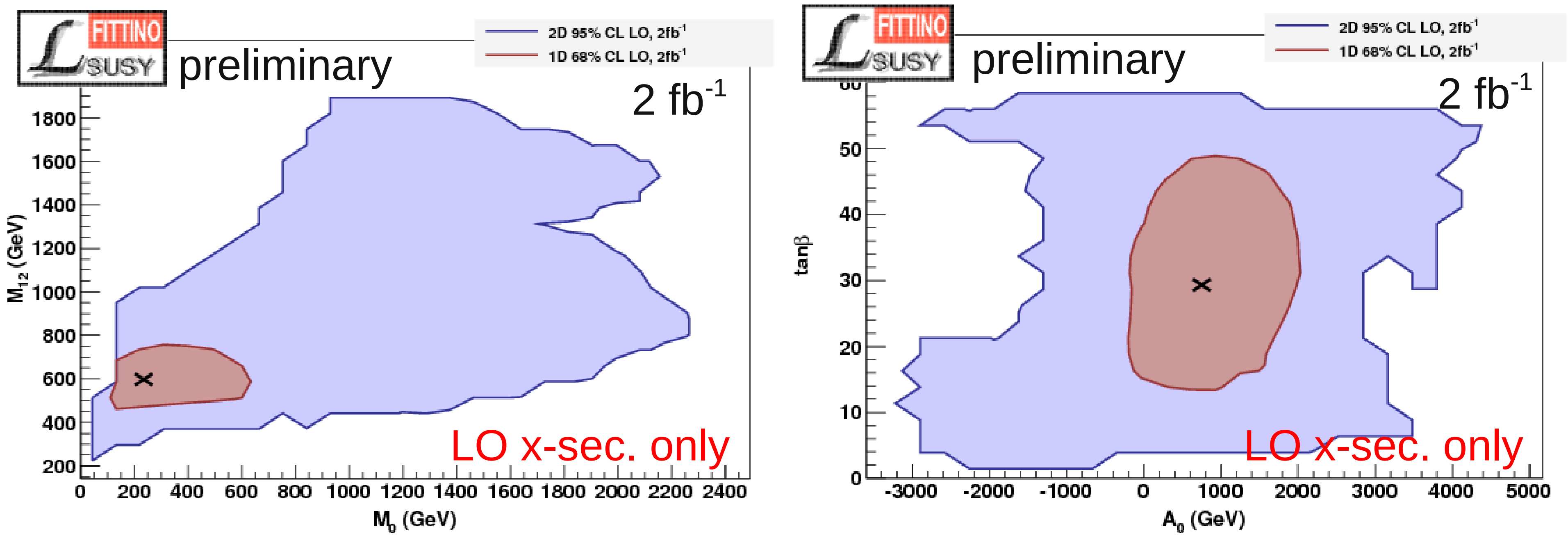
Combined LE+LHC ($35pb^{-1}$) fit: Mass spectrum

Mass spectrum corresponding to mSUGRA parameter constraints:



Comb. fit of LE data and pot. LHC exclusion

A combined global fit of LE data and projected LHC exclusions yields:



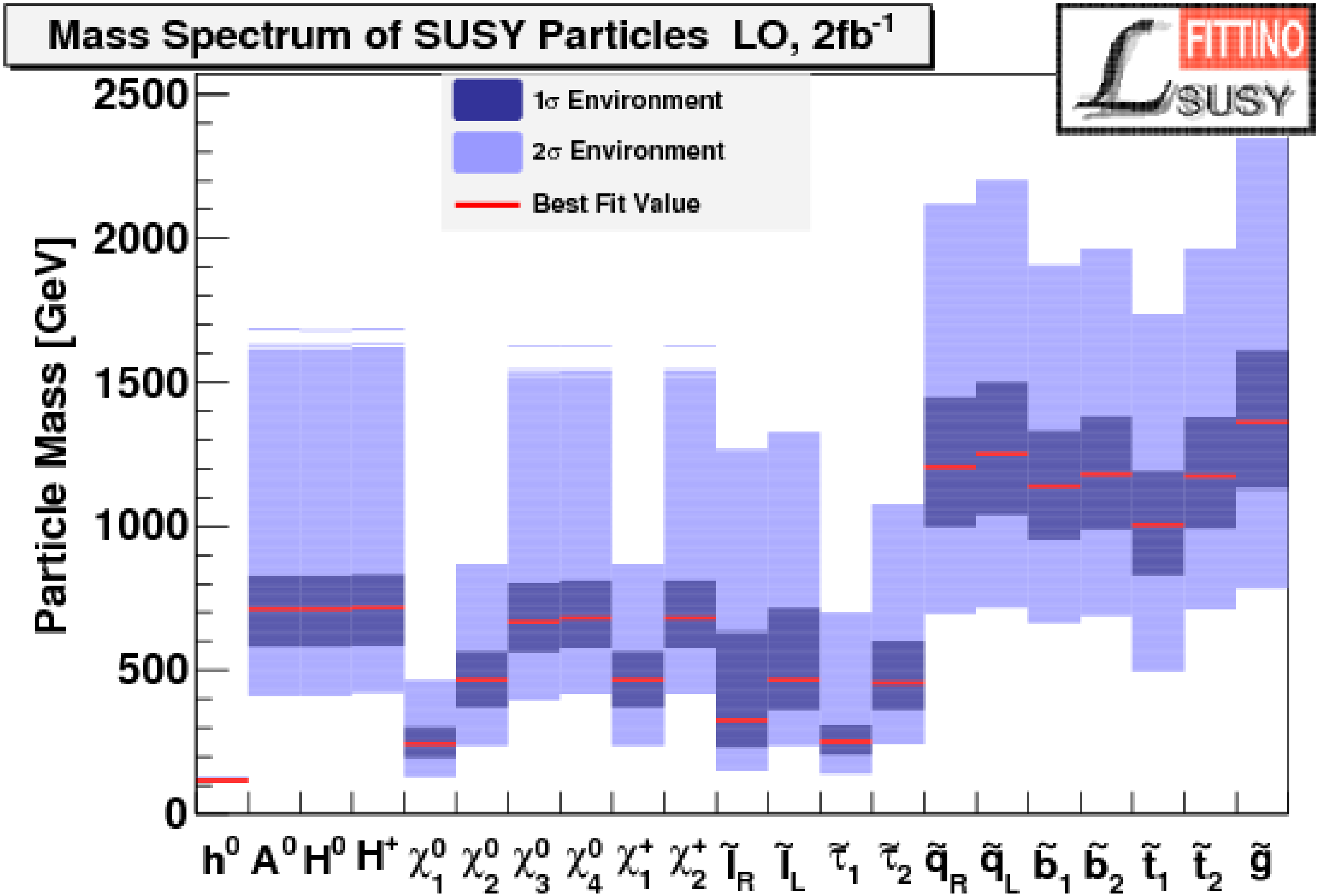
$$\chi^2_{\min}(\text{with LHC}) - \chi^2_{\min}(\text{without LHC}) = 4.9$$

Fits using NLO x-secs. for different LHC lumi assumptions available soon

Peter Wienemann: Die Frage

Combined LE+LHC (2 fb^{-1}) fit: Mass spectrum

Mass spectrum corresponding to mSUGRA parameter constraints:



Summary of combined LE+LHC fit

- LHC has started to probe parameter region favoured by LE mSUGRA fits
- We combine LE data with potential LHC exclusions in a global mSUGRA parameter fit
- M_0, $M_{1/2}$ and $\tan\beta$ are pushed towards larger values with increasing LHC luminosity
- Non-discovery leads to moderate tension between LE data and LHC exclusions (at least up to 2 fb^{-1}) in mSUGRA
- This was an exploratory study. Fit machinery is ready to perform combined fits based on actually observed LHC data. But we need the data in appropriate form from the LHC collaborations.