There is plenty of room at the top

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PHYSICS AT THE TERA SCALE
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“Die Frage”

Today there is already quite some work about what we will learn from the LHC if SUSY searches provide a signal.

But so far very little quantitative work on:

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

- How much information does it provide on the possible SUSY parameter space in addition to available “low energy” observables (LEOs)?
- Does it create any tension between LEOs and LHC?
- What are the implications for a future Linear Collider?

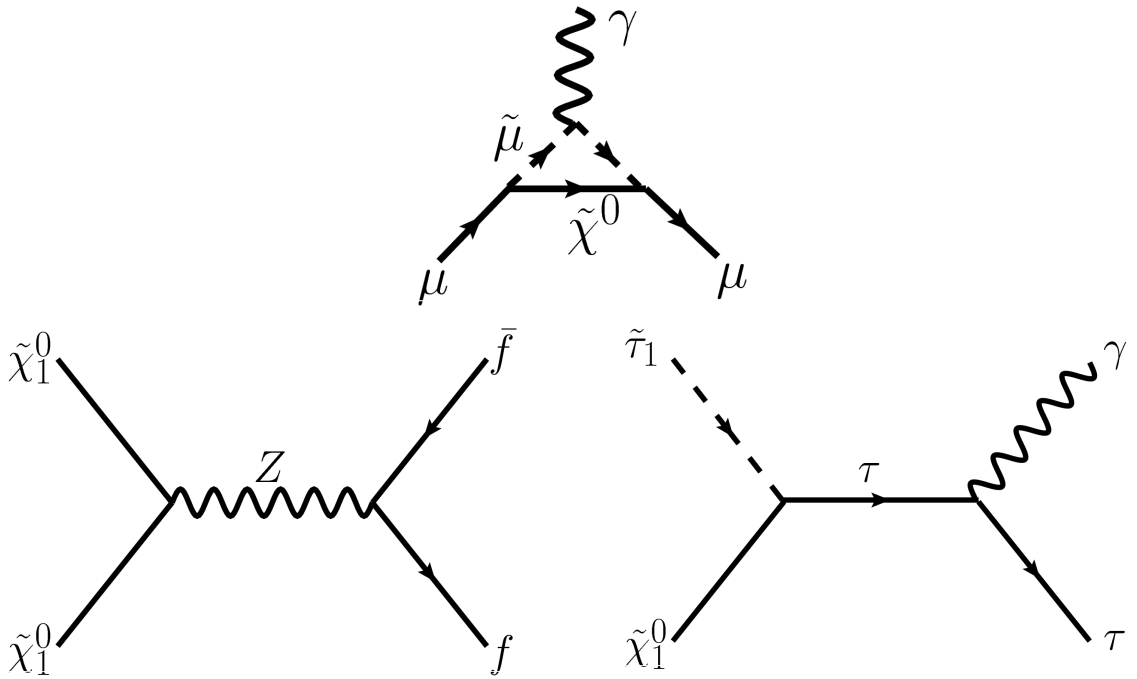
“Low energy” measurements

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

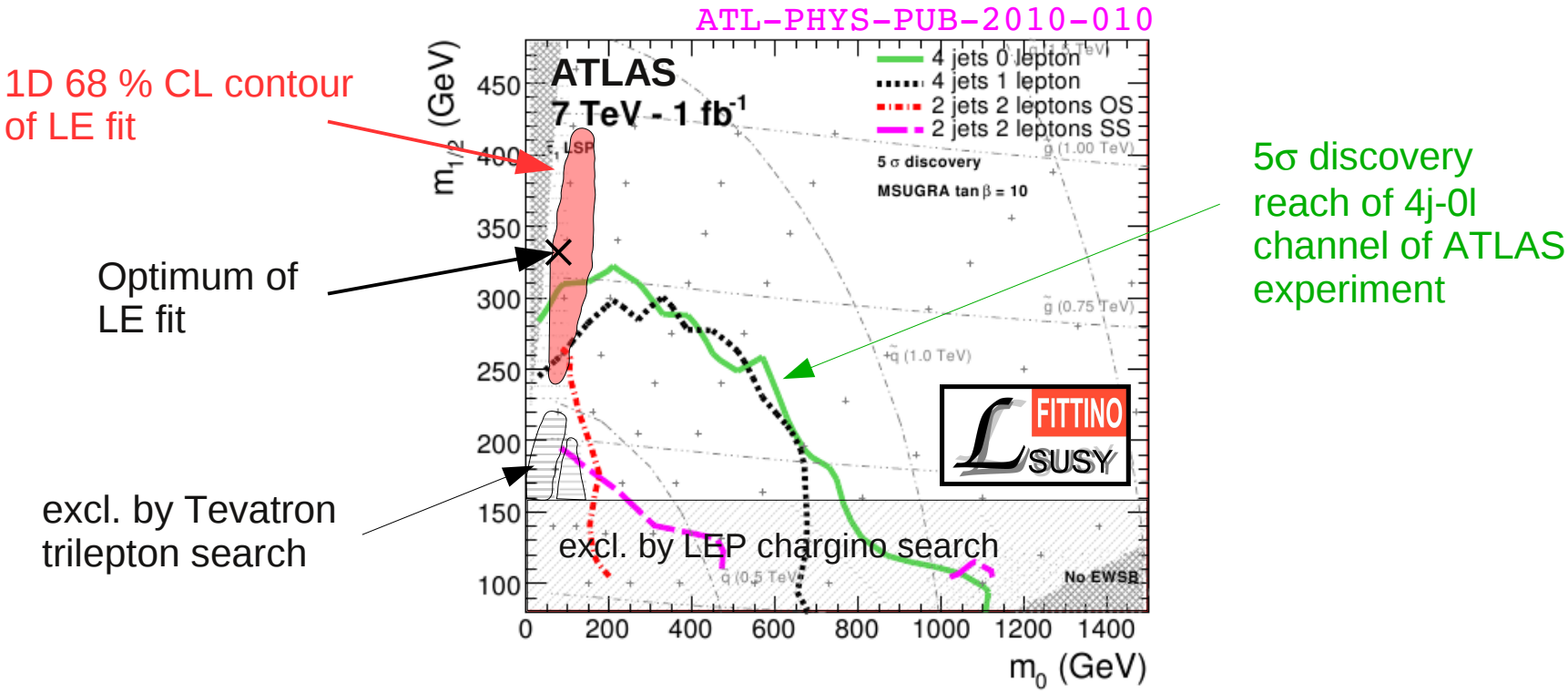
Observable	Experimental Value	Uncertainty stat	Uncertainty syst	Exp. Reference
$\mathcal{B}(B \to s\gamma)/\mathcal{B}(B \to s\gamma)_{\rm SM}$	1.117	0.076	0.096	[47]
$\mathcal{B}(B_s \to \mu\mu)$	$< 4.7\times10^{-8}$			[47]
$\mathcal{B}(B_d \to \ell\ell)$	$< 2.3\times10^{-8}$			[47]
$\mathcal{B}(B \to \tau\nu)/\mathcal{B}(B \to \tau\nu)_{\rm SM}$	1.15	0.40		[48]
$\mathcal{B}(B_s \to X_s\ell\ell)/\mathcal{B}(B_s \to X_s\ell\ell)_{\rm SM}$	0.99	0.32		[47]
$\Delta m_{B_s}/\Delta m_{B_s}^{\rm SM}$	1.11	0.01	0.32	[49]
$\frac{\Delta m_{B_s}/\Delta m_{B_s}^{\rm SM}}{\Delta m_{B_d}/\Delta m_{B_d}^{\rm SM}}$	1.09	0.01	0.16	[47,49]
$\Delta\epsilon_K/\Delta\epsilon_K^{\rm SM}$	0.92	0.14		[49]
$\mathcal{B}(K \to \mu\nu)/\mathcal{B}(K \to \mu\nu)_{\rm SM}$	1.008	0.014		[50]
$\mathcal{B}(K \to \pi\nu\bar{\nu})/\mathcal{B}(K \to \pi\nu\bar{\nu})_{\rm SM}$	< 4.5			[51]
$a_\mu^{\rm exp} - a_\mu^{\rm SM}$	30.2×10^{-10}	8.8×10^{-10}	2.0×10^{-10}	[52,53]
$\sin^2\theta_{\rm eff}$	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]
$A_{\rm fb}(b)$	0.0992	0.0016		[46]
$A_{\rm fb}(c)$	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]
$A_{\rm fb}(l)$	0.01714	0.00095		[46]
$\sigma_{\rm had}$	41.540 nb	0.037 nb		[46]
m_h	> 114.4 GeV		3.0 GeV	[54,55,56]
$\Omega_{\rm CDM}h^2$	0.1099	0.0062	0.012	[57]
$1/\alpha_{em}$	127.925	0.016		[58]
G_F	$1.16637\times10^{-5}\,{\rm GeV}^{-2}$	$0.00001\times10^{-5}\,{\rm GeV}^{-2}$		[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

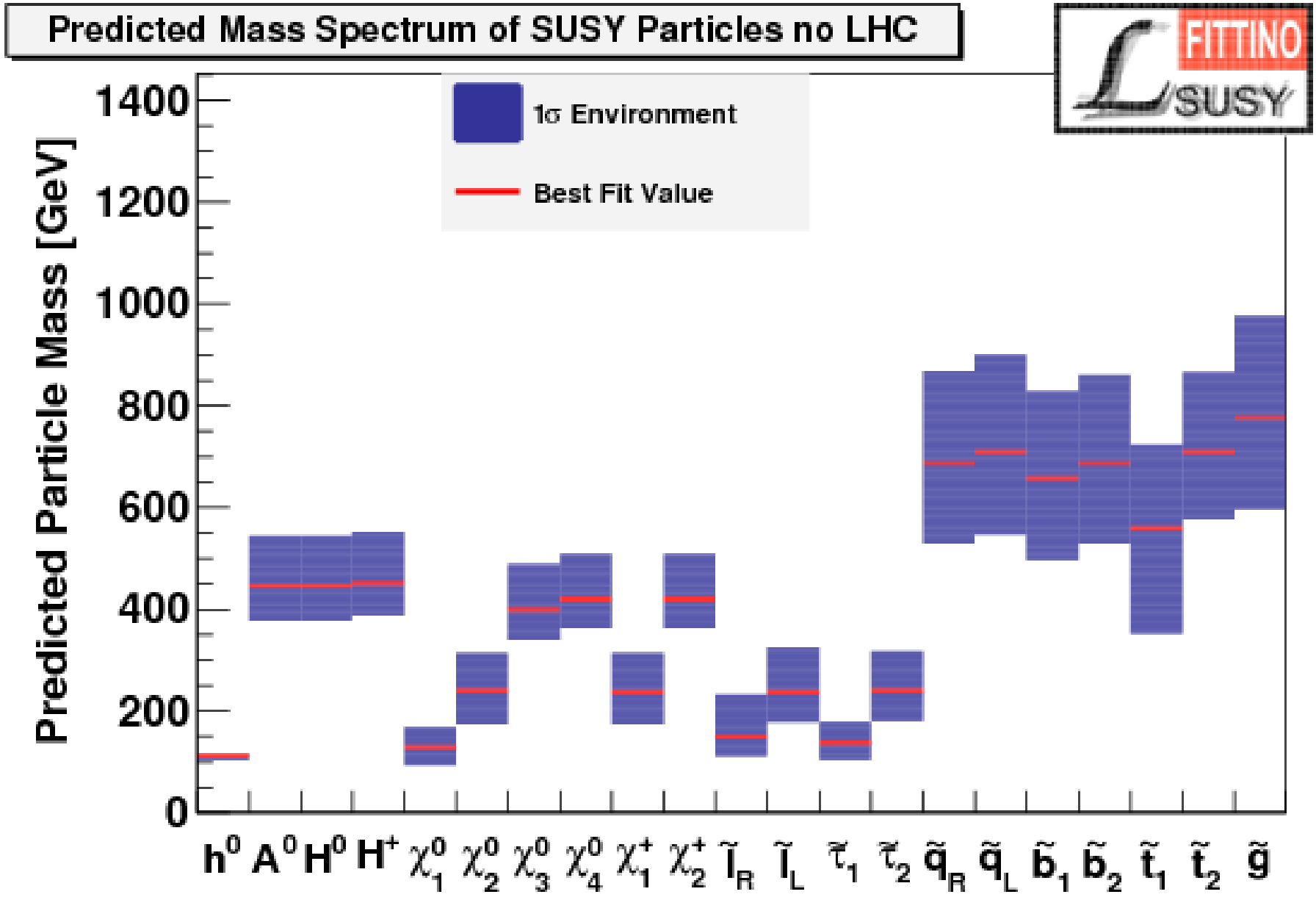
- Using SUSY fitting program **Fittino** (Bechtle, et al.)
- Parameter analysis performed using Markov chain Monte Carlo technique (frequentistic interpretation)
- Fitting code interfaced to dedicated theory codes:
  - Mastercode (Buchmüller et al.) for LE observables
  - HiggsBounds (Bechtle et al.) for Higgs mass limits
  - SPheno (W. Porod)
  - Cross-section library (Dreiner, Krämer, Lindert, O'Leary) for LHC NLO cross-sections (including acceptance)

LE fit result and LHC discovery potential

- LE fit favours rather small SUSY masses.
- Discovery reach (and exclusion potential) of initial 7 TeV LHC run (years 2010/2011) extends to favoured region



LE fit: Predicted mass spectrum

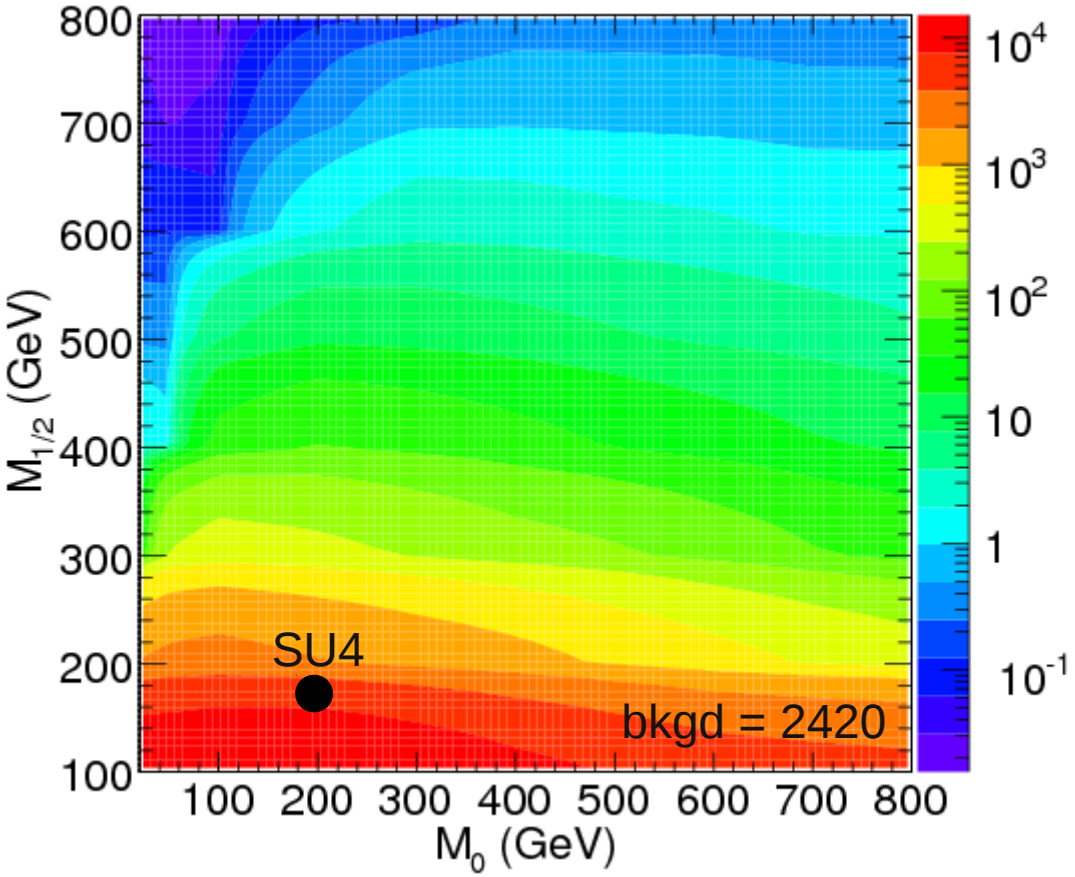


A simple method

As a first attempt, make some simplifying assumptions:

- Only consider most powerful 4j-0l channel
- Only use its *total* cross-section

Number of signal events (NLO) for 1 fb^{-1}:



Good agreement at SU4 point:

- Our expectation: 3750 sig. evts.
- ATLAS analysis: 3810 sig. evts.

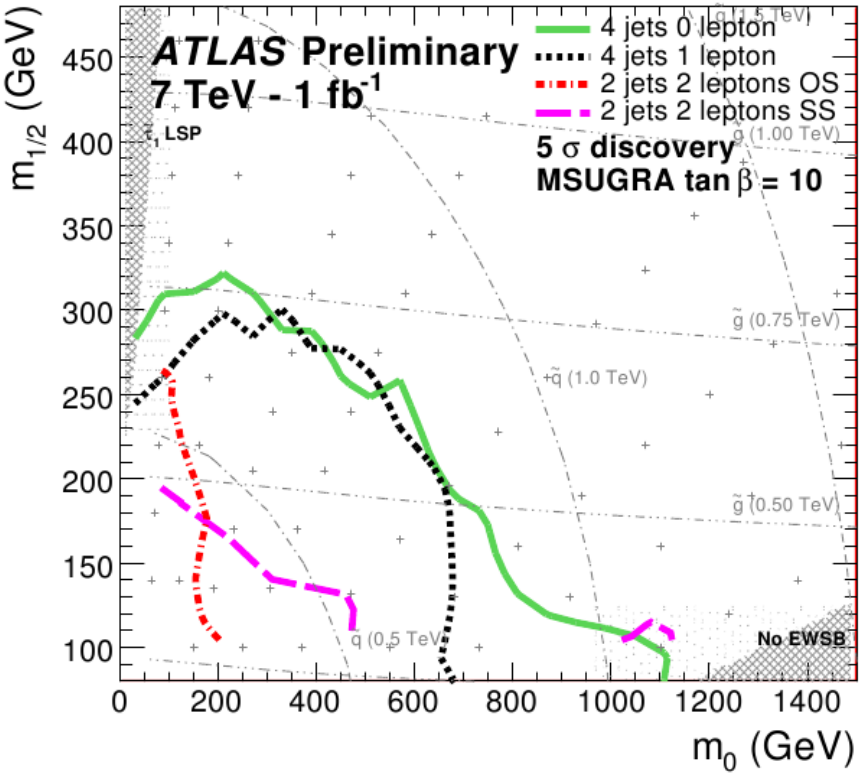
A (too) simple method

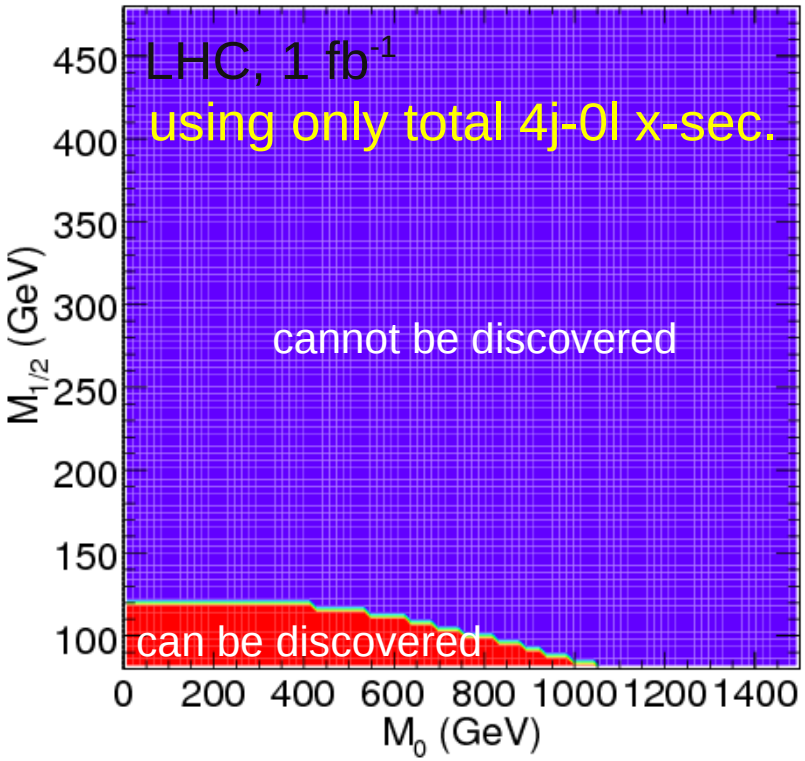
Add x-sec. info to fit by adding additional χ^2 term:

$$\chi^2 = \left(\frac{s}{\sqrt{s+b}} \right)^2$$

Total 4j-0l cross-section has only little statistical power, not sufficient to get even close to discovery reach of ATLAS analysis

→ more realistic approach needed

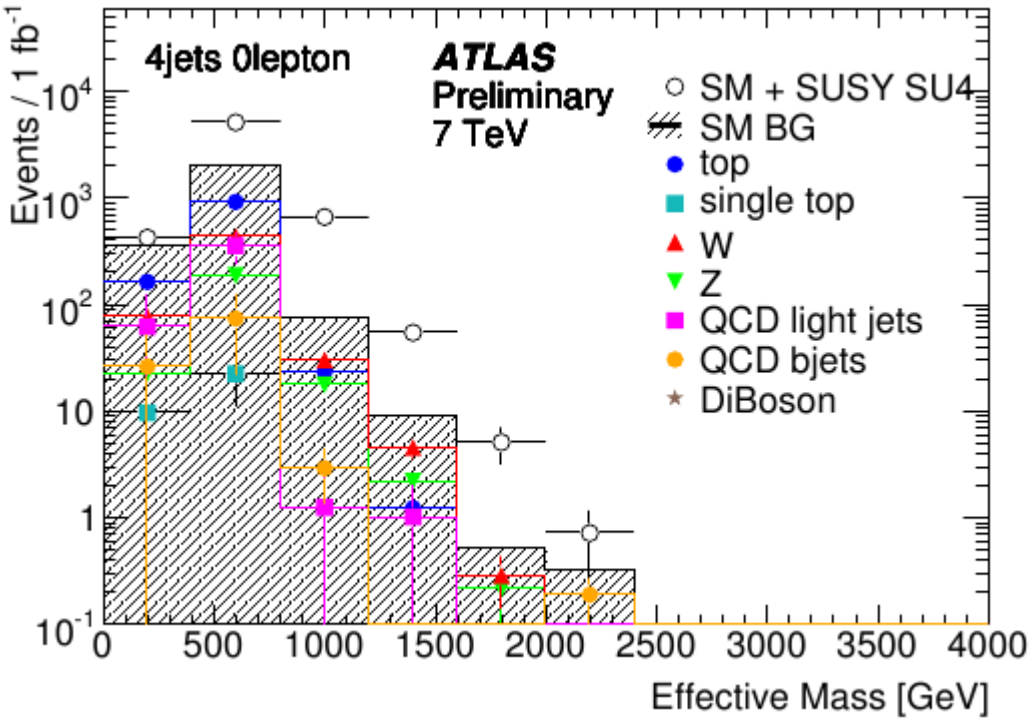




Better method

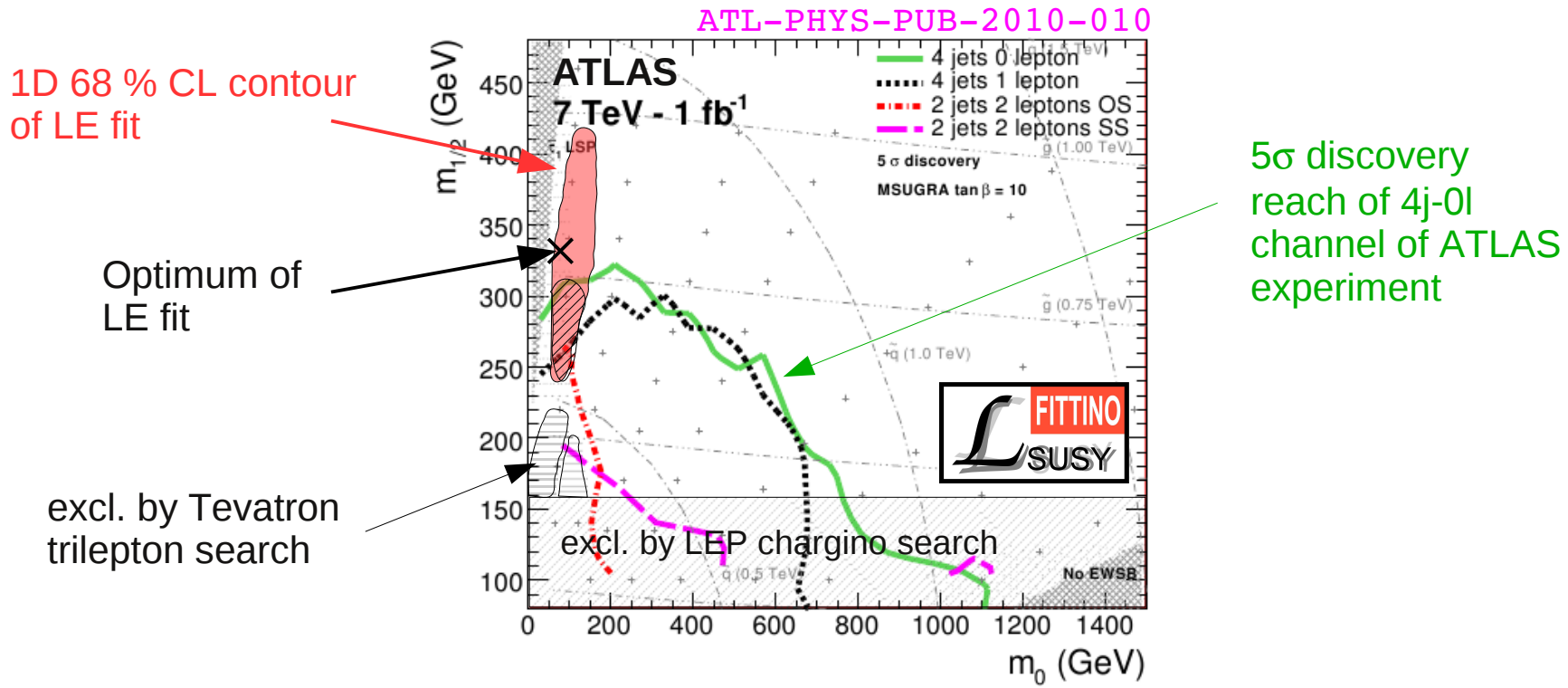
Fully exploit shape information of discriminating variable (like ATLAS analysis does), not only the integral

→ analysis is under way

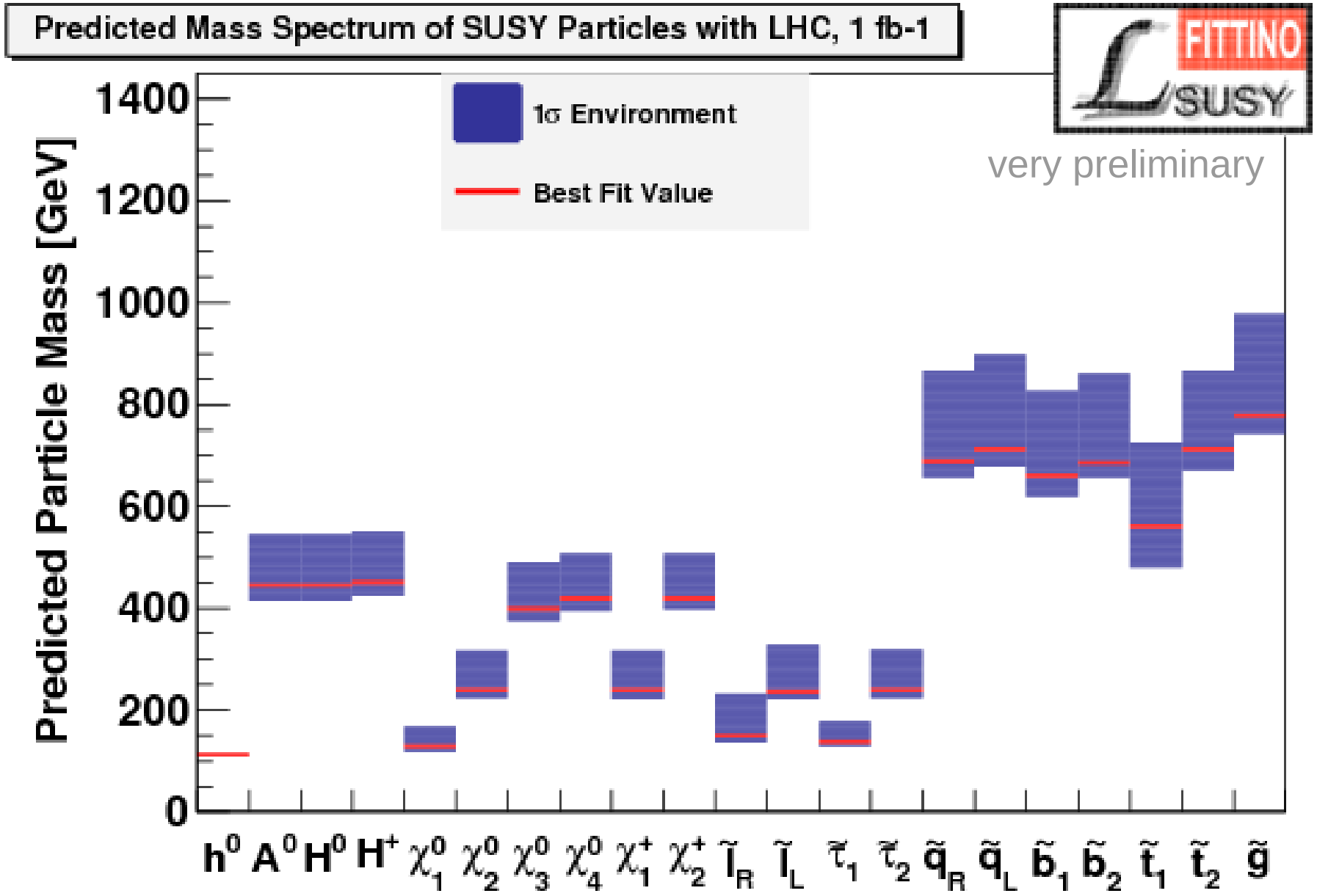


What can we expect?

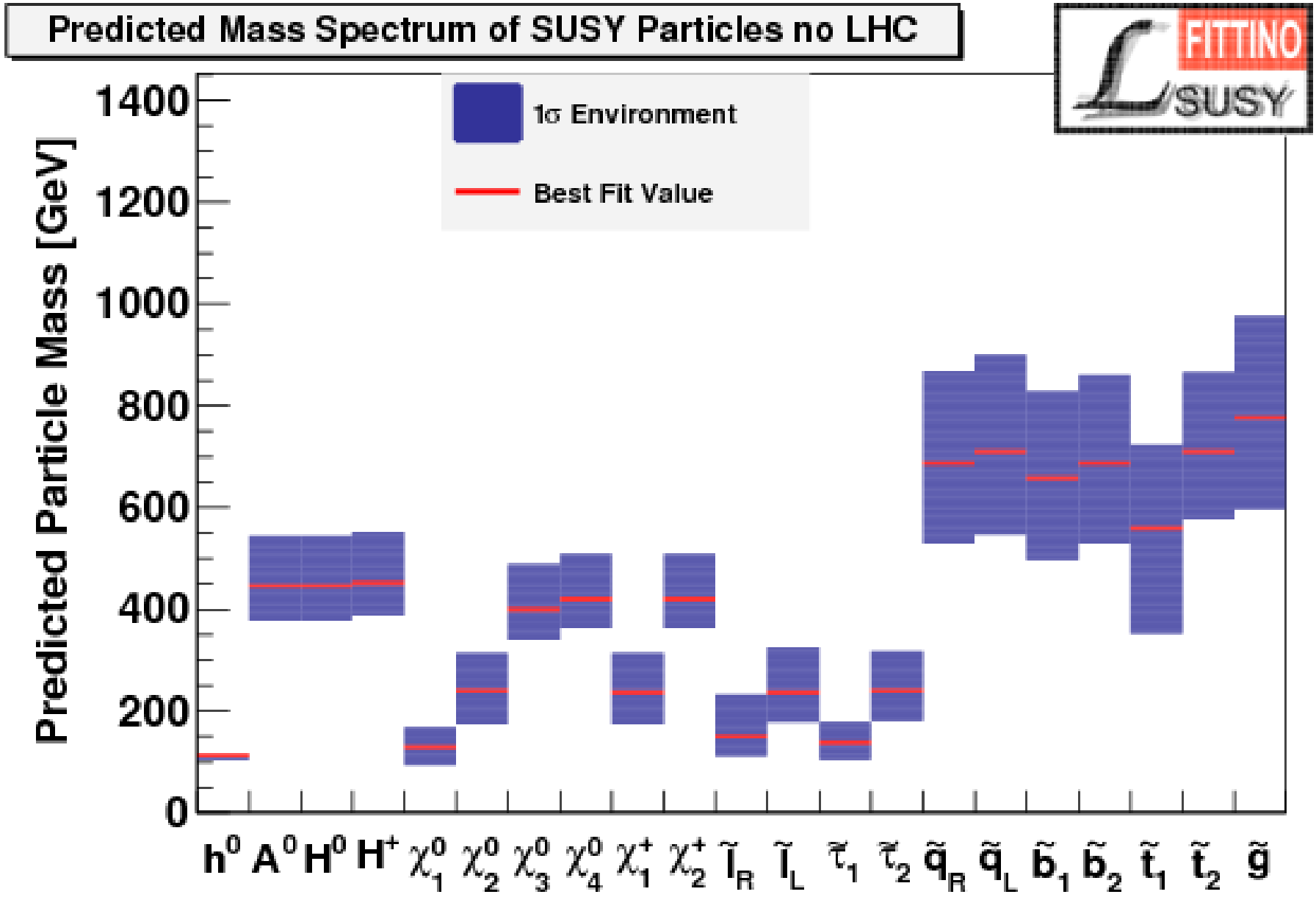
Can already estimate mass spectrum from a (still due) combined LE+LHC fit for the non-observation case by removing Markov chain elements which would lead to discovery (equivalent to adding “large” number to χ^2)



LE fit "+ LHC": Mass spectrum



LE fit: Mass spectrum



Summary

- LE data favour light SUSY
- Discovery potential of initial LHC run at 7 TeV extends to preferred mSUGRA parameter space
- Nevertheless a non-observation of SUSY by the end of the 2011 LHC run probably still leaves a lot of room for interesting SUSY measurements at a Linear Collider (including ILC!)
- More results concerning “die Frage” are under way