Discussion of physics studies

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1st Fittino-Workshop
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DESY

Overview

Physics studies performed so far:

- LHC300 + ILC500 with RR,LL,LR,RL at $\sqrt{s}$ = 500 GeV
  + ILC500 with LR, RL at $\sqrt{s}$ = 400 GeV and 1000 GeV
  (Option 1)
- LHC1, LHC10, LHC300 (Option 2)
- LE (Option 3)
- LE+LHC1, LE+LHC10, LE+LHC300 (Option 4)
- LE+LHC300+ILC500 with LR, RL at $\sqrt{s}$ = 500 and 1000 GeV
  (Option 5)

LHC and ILC studies performed for SPS1a/SPS1a'

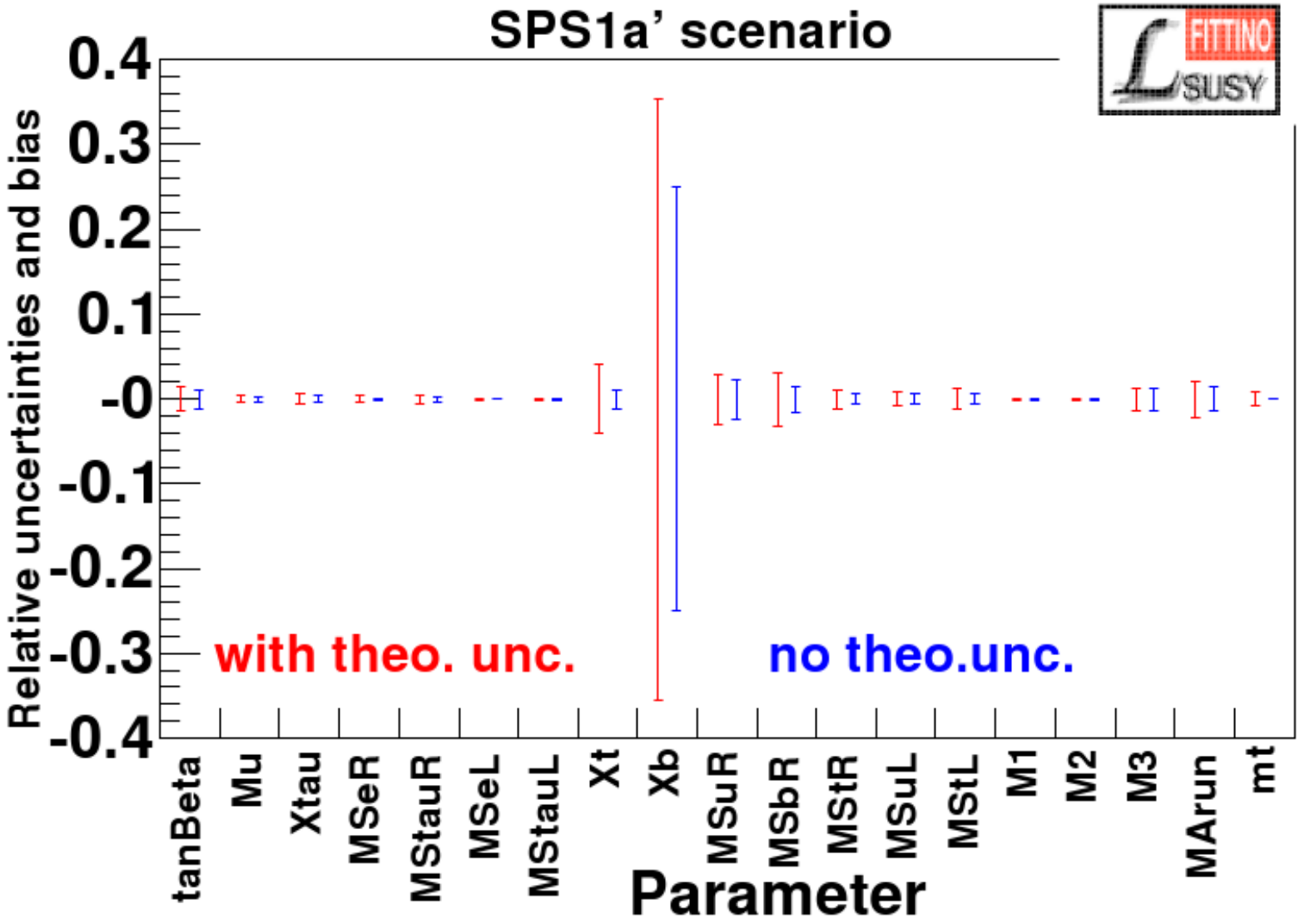
Option 1: Observables

Observable	Value	Exp. uncertainty
m_{W}	80.3371 GeV	0.039 GeV
m_{Z}	91.1187 GeV	0.0021 GeV
m_{t}	178.0 GeV	0.05 GeV
m_{h}	112.888 GeV	0.05 GeV
$m_{\mathrm{A_{pole}}}$	374.228 GeV	1.3 GeV
m_{H}	374.464 GeV	1.3 GeV
$m_{\mathrm{H}^{\pm}}$	383.131 GeV	1.1 GeV
$m_{\tilde{q}_L}$	561.539 GeV	9.8 GeV
$m_{\tilde{q}_R}$	543.35 GeV	11.0 GeV
$m_{\tilde{b}_1}$	502.059 GeV	5.7 GeV
$m_{\tilde{b}_2}$	541.81 GeV	6.2 GeV
$m_{\tilde{t}_1}$	365.819 GeV	2.0 GeV
$m_{\tilde{e}_L}$	190.209 GeV	0.2 GeV
$m_{\tilde{e}_R}$	124.883 GeV	0.05 GeV
$m_{\tilde{\mu}_L}$	190.237 GeV	0.5 GeV
$m_{\tilde{\mu}_R}$	124.837 GeV	0.2 GeV
$m_{\tilde{\tau}_1}$	107.292 GeV	0.3 GeV
$m_{\tilde{\tau}_2}$	195.290 GeV	1.1 GeV
$m_{\tilde{g}}$	603.639 GeV	6.4 GeV
$m_{\tilde{\chi}_1^0}$	97.7662 GeV	0.05 GeV
$m_{\tilde{\chi}_2^0}$	184.345 GeV	0.08 GeV
$m_{\tilde{\chi}_3^0}$	404.134 GeV	4.0 GeV
$m_{\tilde{\chi}_4^0}$	417.037 GeV	2.3 GeV
$m_{\tilde{\chi}_1^{\pm}}$	184.132 GeV	0.55 GeV
$m_{\tilde{\chi}_2^{\pm}}$	418.495 GeV	3.0 GeV
Edge 3 with $m_{\tilde{\chi}_1^0}$, $m_{\tilde{q}_L}$, $m_{\tilde{\chi}_2^0}$	449.679 GeV	4.9 GeV
Edge 3 with $m_{\tilde{\mu}_R}$, $m_{\tilde{q}_L}$, $m_{\tilde{\chi}_2^0}$	390.285 GeV	3.35 GeV
Edge 4 with $m_{\tilde{\chi}_1^0}$, $m_{\tilde{\chi}_2^0}$, $m_{\tilde{\mu}_R}$, $m_{\tilde{q}_L}$	329.831 GeV	4.2 GeV
Edge 5 with $m_{\tilde{\chi}_1^0}$, $m_{\tilde{\chi}_2^0}$, $m_{\tilde{\mu}_R}$, $m_{\tilde{q}_L}$	218.529 GeV	3.44 GeV

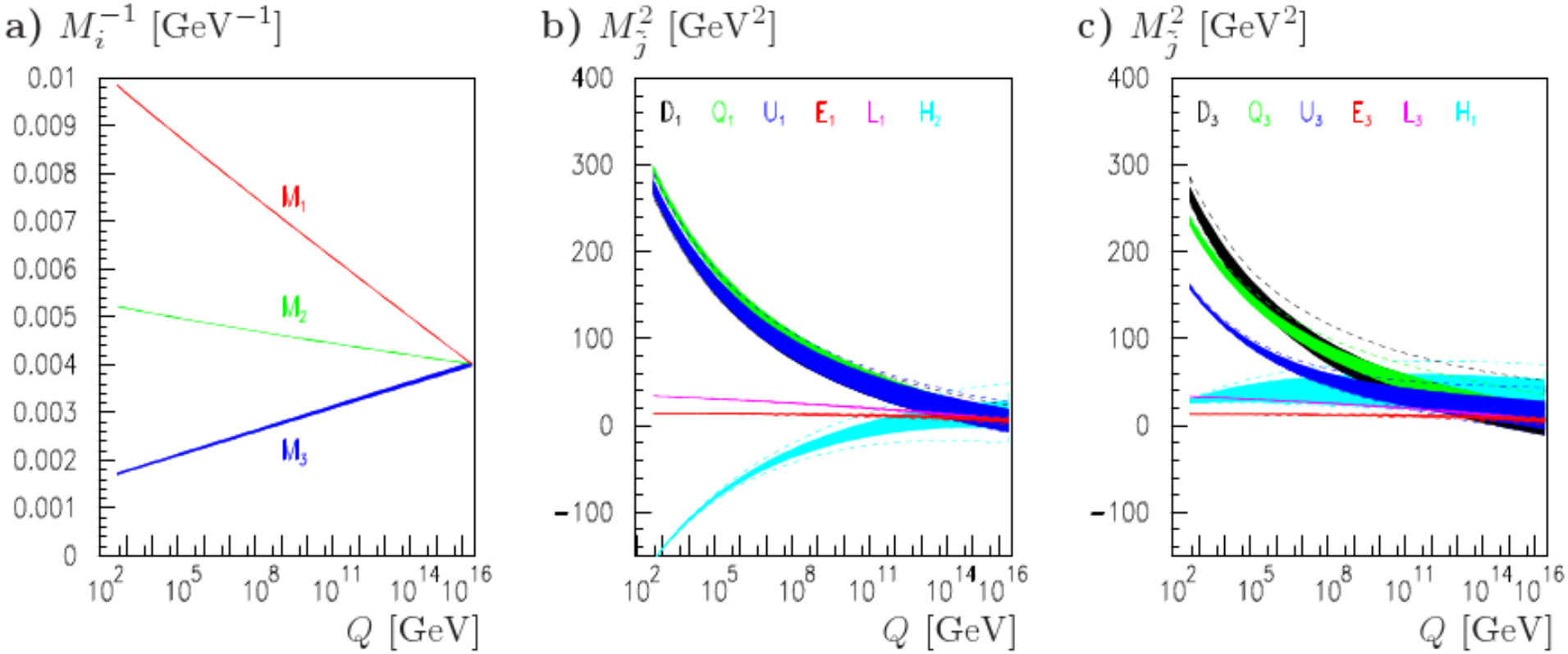
+ theoretical uncertainties

- no obs. correlations
- very few LHC obs.

Option 1: MSSM18 parameters



Option 1: Extrapolation to GUT scale



Easy-to-use machinery to perform extrapolations presently not included in Fittino package

Option 1: mSUGRA parameters

	SPS1a' value	Fitted value	$\Delta_{\text{LHC+ILC}}$	$\Delta_{\text{LHC only}}$
$\tan\beta$	10.000	10.000	0.036	1.3
M_0 (GeV)	70.000	70.000	0.070	1.4
$M_{1/2}$ (GeV)	250.000	250.000	0.065	1.0
A_0 (GeV)	-300.0	-300.0	2.5	16.6

Comparison with Option 3 (LHC300 with more LHC obs.):

Parameter	Best Fit		Uncertainty
sign(μ)	$+1$		
$\tan\beta$	9.98	$\pm$	0.35
A_0 (GeV)	-100.2	$\pm$	11.1
M_0 (GeV)	100.0	$\pm$	0.39
$M_{1/2}$ (GeV)	250.0	$\pm$	0.30

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  (Option 5)

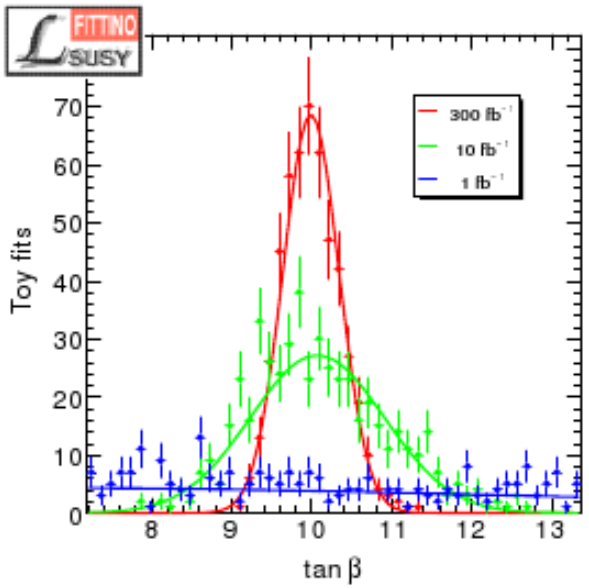
Option 2: Observables

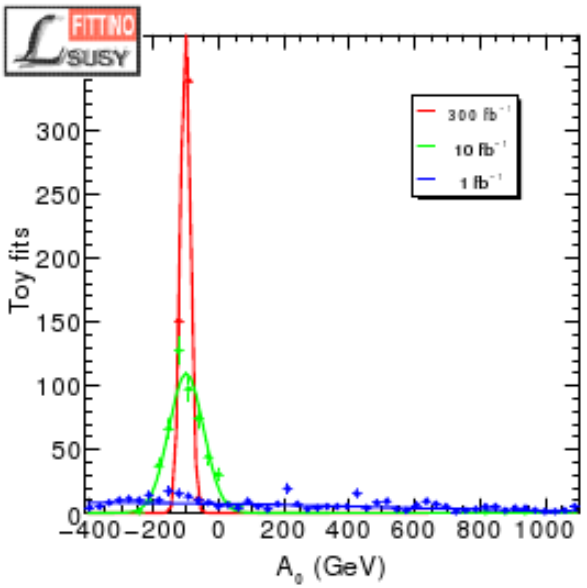
Observable	Nominal Value	Uncertainty							
		1 fb^{-1}	10 fb^{-1}	300 fb^{-1}	LES$_1$	LES$_{10,300}$	JES$_1$	JES$_{10,300}$	syst.
m_h	109.6		1.4	0.1		0.1			
m_t	172.4	1.1	0.05	0.01			1.5	1.0	
$m_{\tilde{\chi}_1^\pm}$	180.2			11.4				1.8	
$\sqrt{m^2_{\tilde{\ell}_L} - 2m^2_{\tilde{\chi}_1^0}}$	148.8			1.7		0.1			6.0
$m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$	507.7		13.7	2.5				5.1	10.0
$\sqrt{m^2_{\tilde{q}_R} - 2m^2_{\tilde{\chi}_1^0}}$	531.0	19.6	6.2	1.1			22.7	4.5	10.0
$m_{\tilde{g}} - m_{\tilde{b}_1}$	88.7			1.5				0.9	
$m_{\tilde{g}} - m_{\tilde{b}_2}$	56.8			2.5				0.6	
$m^{\max}_{\ell\ell}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R})$	80.4	1.7	0.5	0.03	0.16	0.08			
$m^{\max}_{\ell\ell}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_4^0}, m_{\tilde{\ell}_L})$	280.6		12.6	2.3		0.28			
$m^{\max}_{\tau\tau}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\tau}_1})$	83.4	12.6	4.0	0.73			4.2	0.8	5.7
$m^{\max}_{\ell\ell q}(m_{\tilde{\chi}_1^0}, m_{\tilde{q}_L}, m_{\tilde{\chi}_2^0})$	452.1	13.9	4.2	1.4			22.7	4.5	
$m^{\text{low}}_{\ell q}(m_{\tilde{\ell}_R}, m_{\tilde{q}_L}, m_{\tilde{\chi}_2^0})$	318.6	7.6	3.5	0.9			16.2	3.2	
$m^{\text{high}}_{\ell q}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{q}_L})$	396.0	5.2	4.5	1.0			19.9	4.0	
$m^{\text{thres}}_{\ell\ell q}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{q}_L})$	215.6	26.5	4.8	1.6			10.8	2.2	
$m^{\text{thres}}_{\ell\ell b}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{b}_1})$	195.9		19.7	3.6				2.0	
$m^{\text{w}}_{\ell b}(m_t, m_{\tilde{\ell}_1}, m_{\tilde{\chi}_1^\pm}, m_{\tilde{g}}, m_{\tilde{b}_1})$	359.5	43.0	13.6	2.5			18.0	3.6	
$\frac{\mathcal{B}(\tilde{\chi}_2^0 \to \tilde{\ell}_R \ell) \times \mathcal{B}(\tilde{\ell}_R \to \tilde{\chi}_1^0 \ell)}{\mathcal{B}(\tilde{\chi}_2^0 \to \tilde{\tau}_1 \tau) \times \mathcal{B}(\tilde{\tau}_1 \to \tilde{\chi}_1^0 \tau)}$	0.076	0.009	0.003	0.001					0.008
$\frac{\mathcal{B}(\tilde{g} \to \tilde{b}_2 b) \times \mathcal{B}(\tilde{b}_2 \to \tilde{\chi}_2^0 b)}{\mathcal{B}(\tilde{g} \to \tilde{b}_1 b) \times \mathcal{B}(\tilde{b}_1 \to \tilde{\chi}_2^0 b)}$	0.168			0.078					

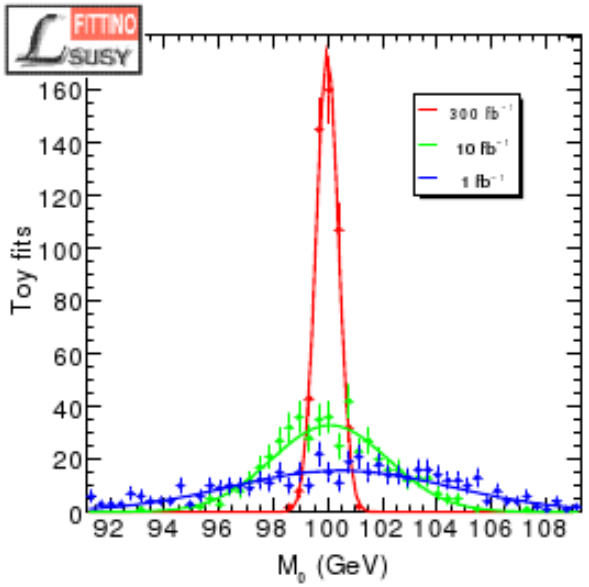
- More comprehensive list of LHC obs.
- Some obs. correlations considered
- No decay chain ambig. considered
- Still missing obs. (rates, ...)
- Theor. unc. (mostly) not considered

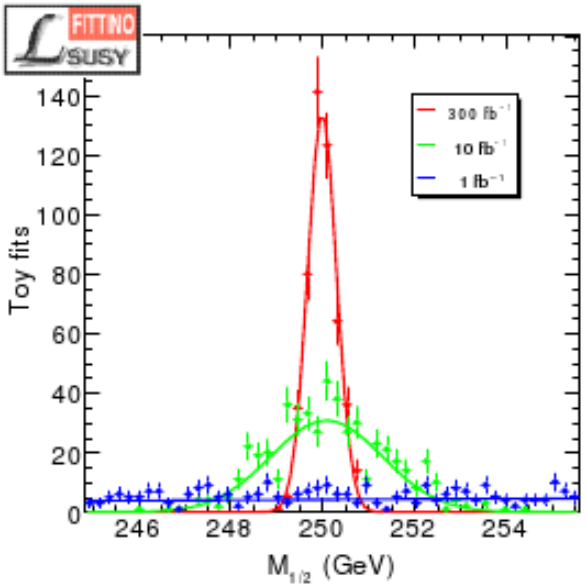
Option 2: mSUGRA parameters

Distribution of fitted parameters for toy fits:



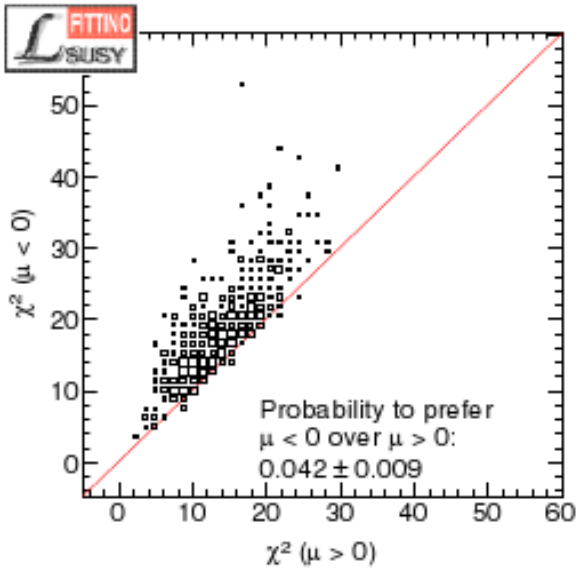


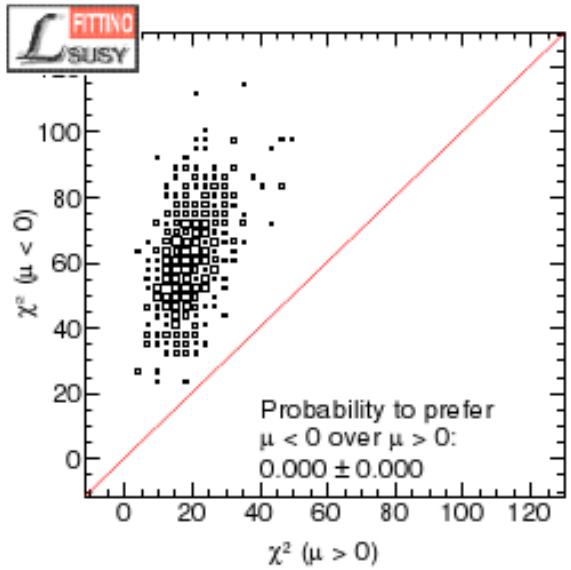


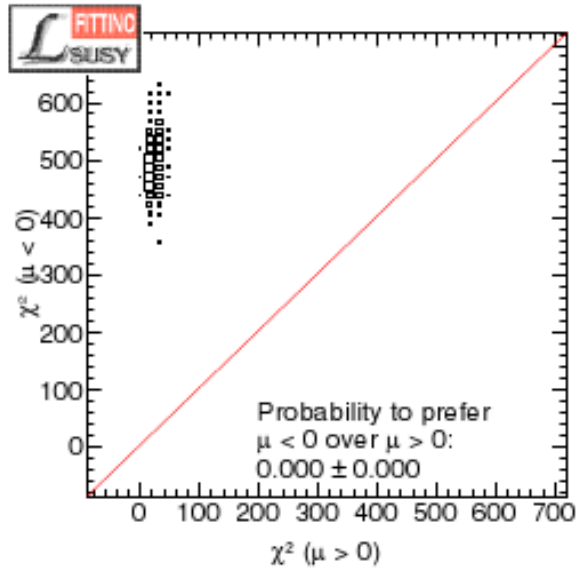


Option 2: sign(μ)

χ^2 correlations for fits with sign(μ) > 0 and sign(μ) < 0:

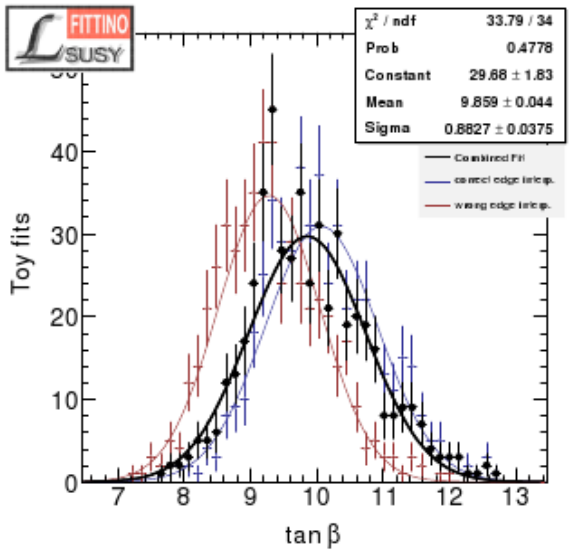


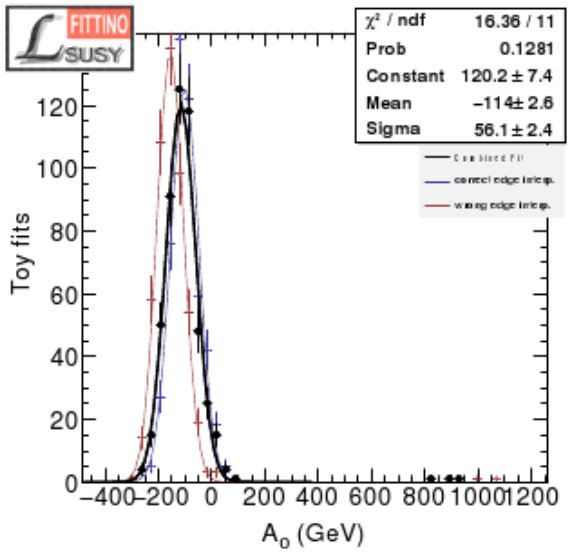


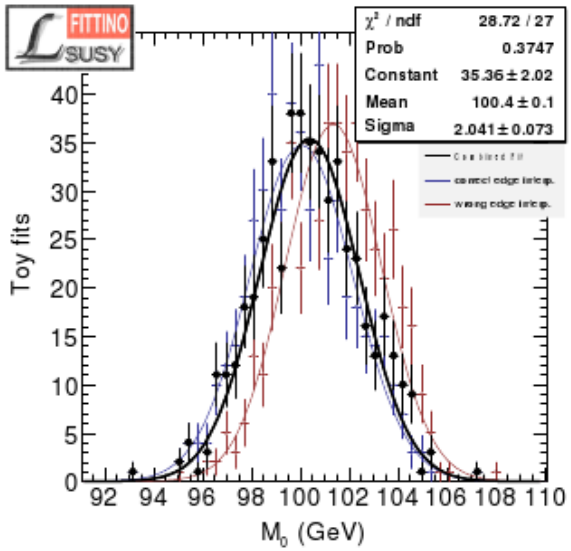


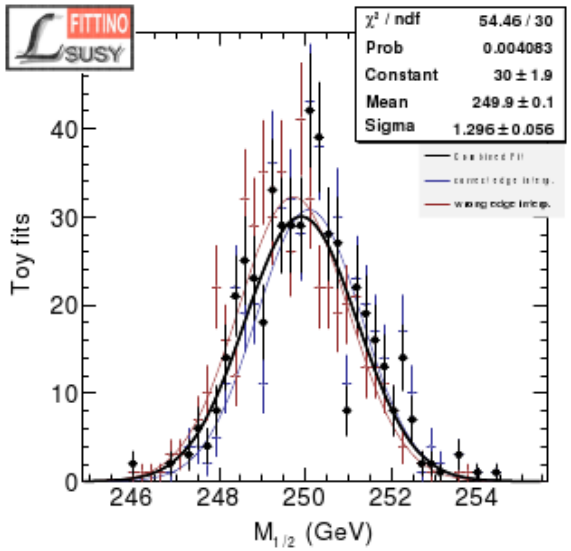
Option 2: First look at ambiguities

Toy fits for all possibilities. For each toy dataset, choose best fit:









Correct interpretation:

$$m_{\ell\ell}^{\max}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_4^0}, m_{\tilde{\ell}_L})$$

Wrong interpretation:

$$m_{\ell\ell}^{\max}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_4^0}, m_{\tilde{\ell}_R})$$

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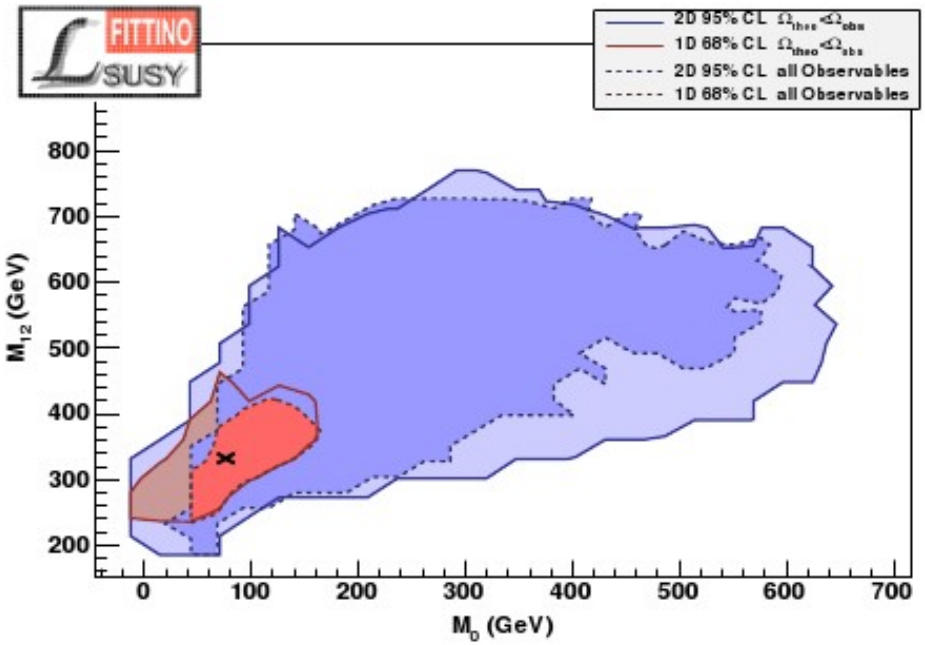
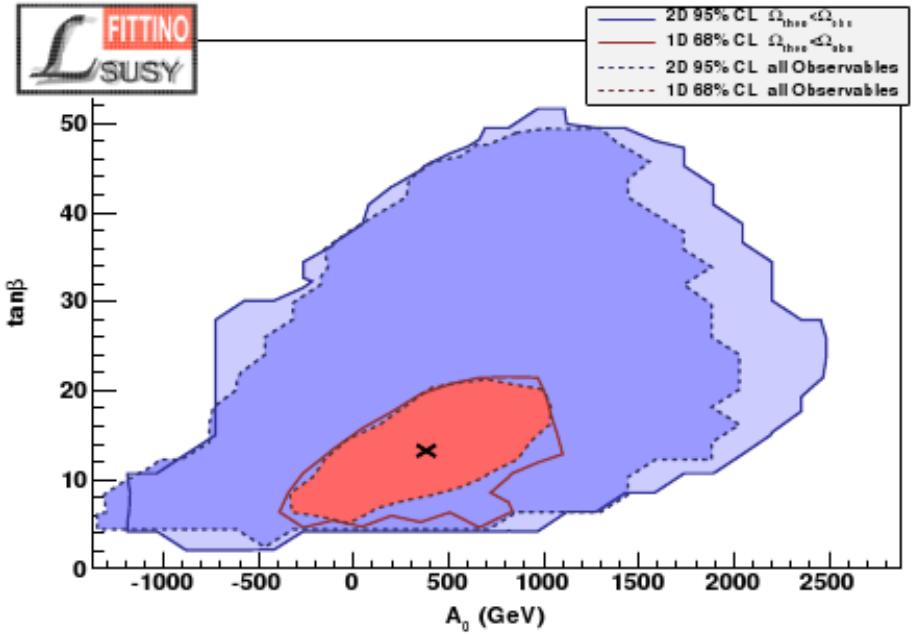
  (Option 5)

Option 3: Observables

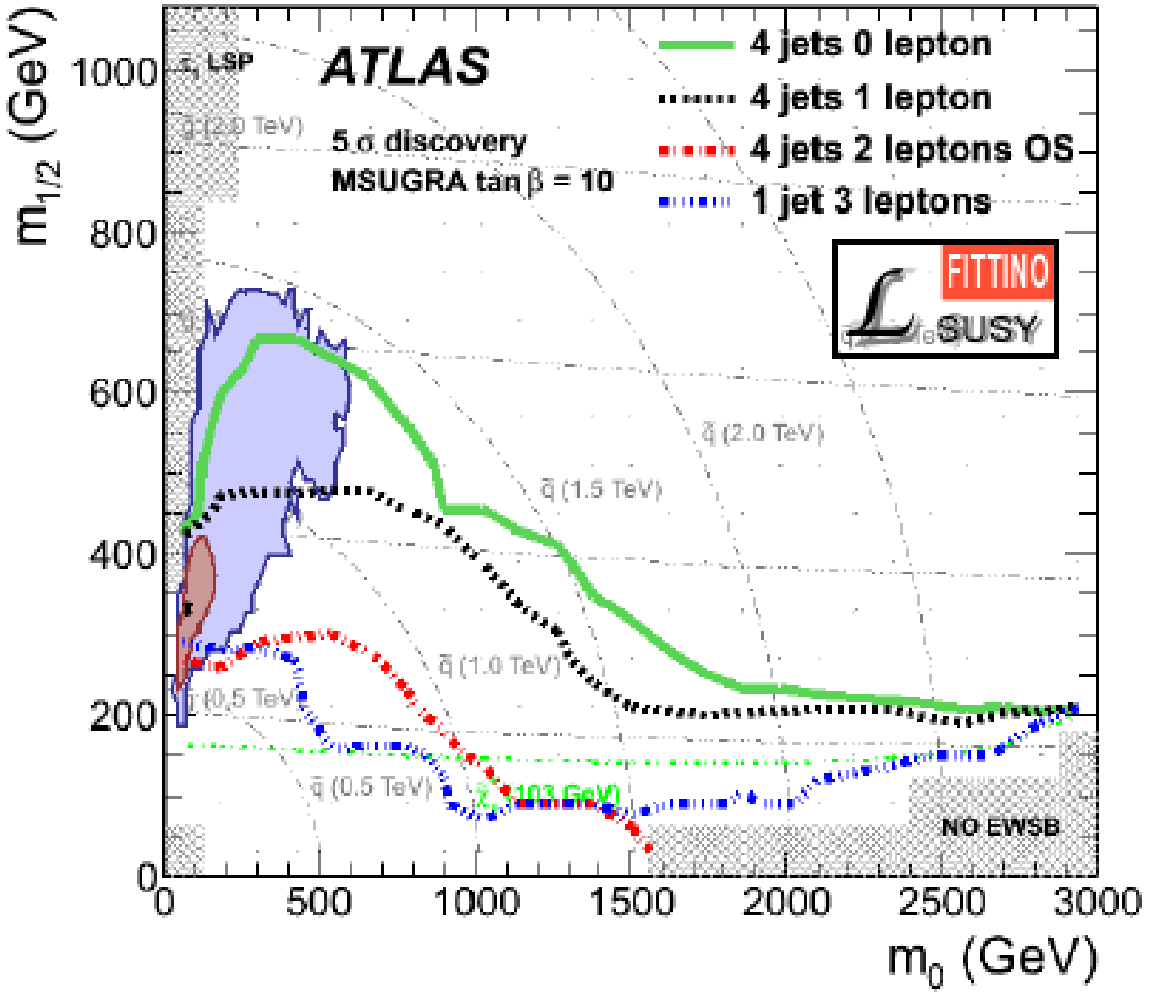
Observable	Experimental Value	Uncertainty stat	Uncertainty syst	Exp. Reference
$\mathcal{B}(B \to s\gamma)/\mathcal{B}(B \to s\gamma)_{\rm SM}$	1.117	0.076	0.096	[47]
$\mathcal{B}(B_s \to \mu\mu)$	$< 4.7\times10^{-8}$			[47]
$\mathcal{B}(B_d \to \ell\ell)$	$< 2.3\times10^{-8}$			[47]
$\mathcal{B}(B \to \tau\nu)/\mathcal{B}(B \to \tau\nu)_{\rm SM}$	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	$1.16637\times10^{-5}\text{GeV}^{-2}$	$0.00001\times10^{-5}\text{GeV}^{-2}$		[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]

Option 3: mSUGRA parameters



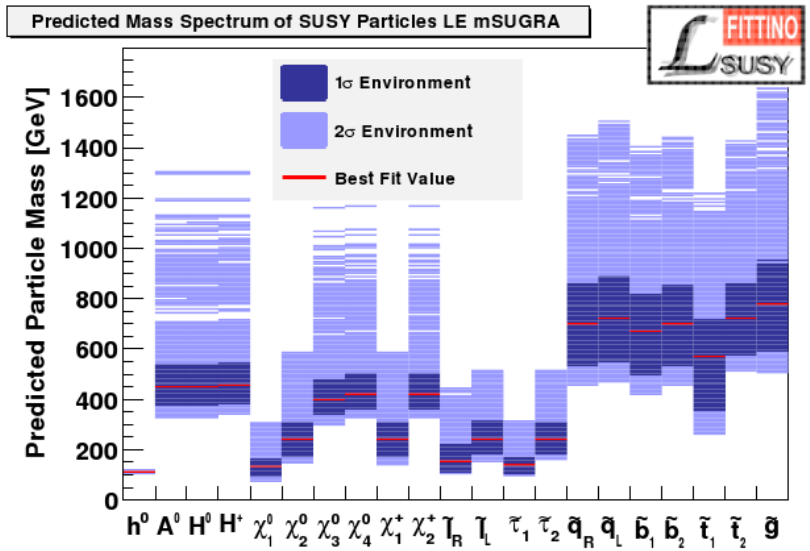


Option 3: Comparison with LHC potential

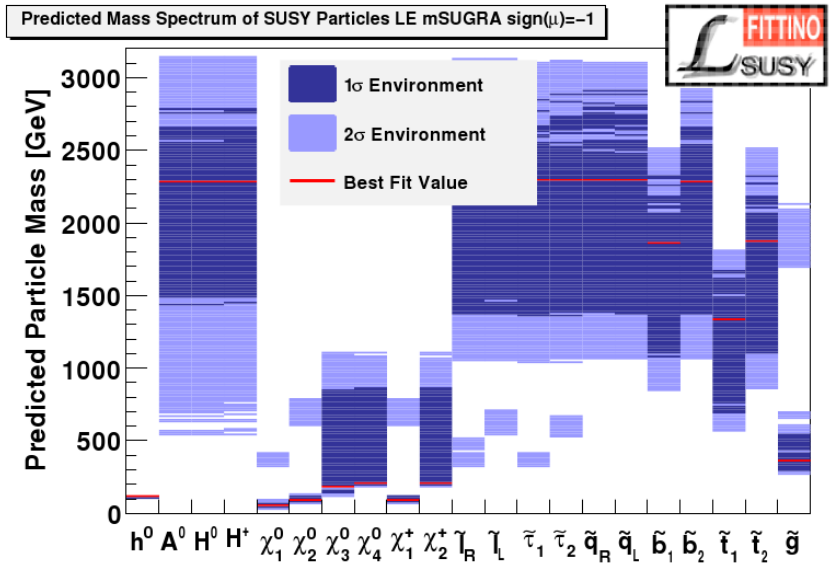


Option 3: Mass spectra

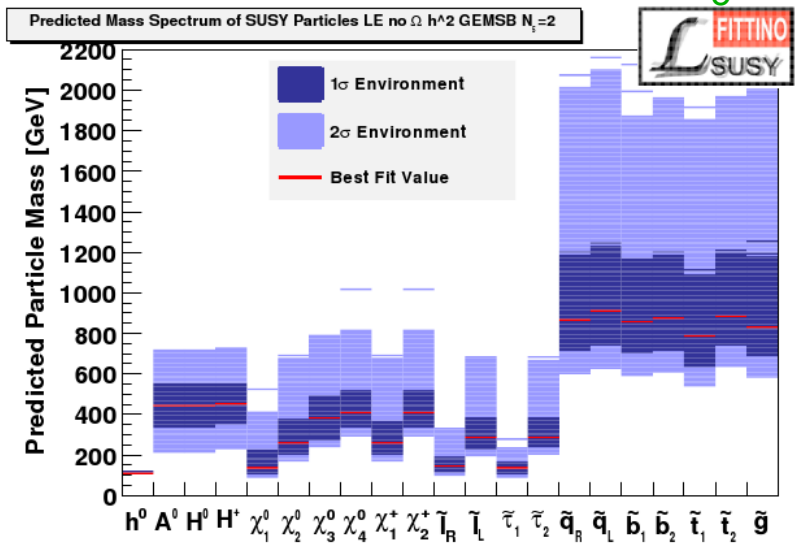
mSUGRA, sign(μ)>0:



mSUGRA, sign(μ)<0:

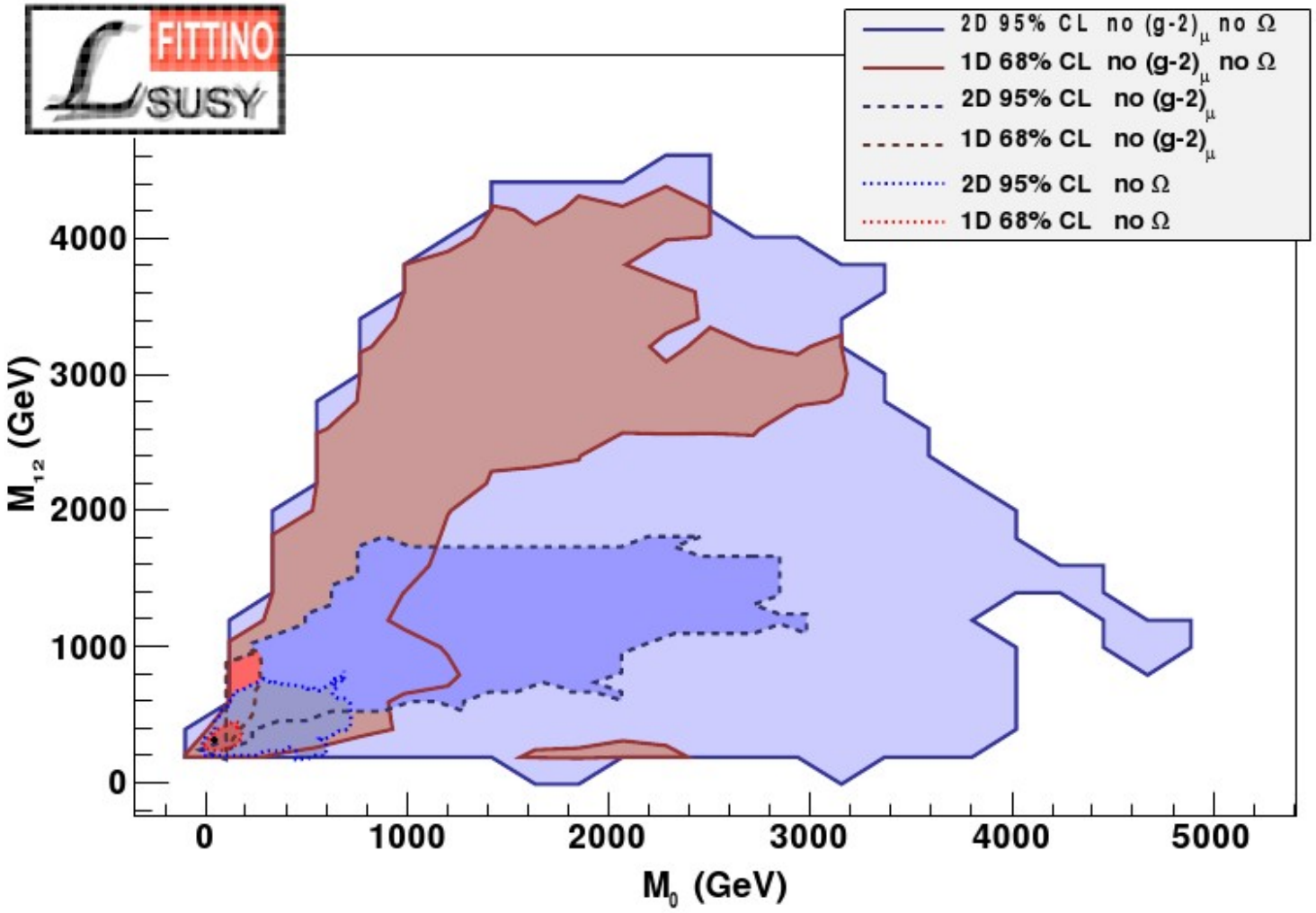


GMSB, sign(μ)>0, N_5 = 2:



Tested different model hypotheses

Option 3: Impact of observables



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Option 4: mSUGRA parameters

LHC1:

Parameter	Best Fit		Uncertainty
sign(μ)	+1		
tan β	9.1	$\pm$	3.7
A_0 (GeV)	−131.8	$\pm$	742.1
M_0 (GeV)	100.2	$\pm$	4.2
$M_{1/2}$ (GeV)	249.7	$\pm$	6.7

LE+LHC1:

Parameter	Best Fit		Uncertainty
sign(μ)	+1		
tan β	10.2	$\pm$	2.3
A_0 (GeV)	−76.3	$\pm$	184
M_0 (GeV)	100.6	$\pm$	3.4
$M_{1/2}$ (GeV)	250.2	$\pm$	5.3

LHC300:

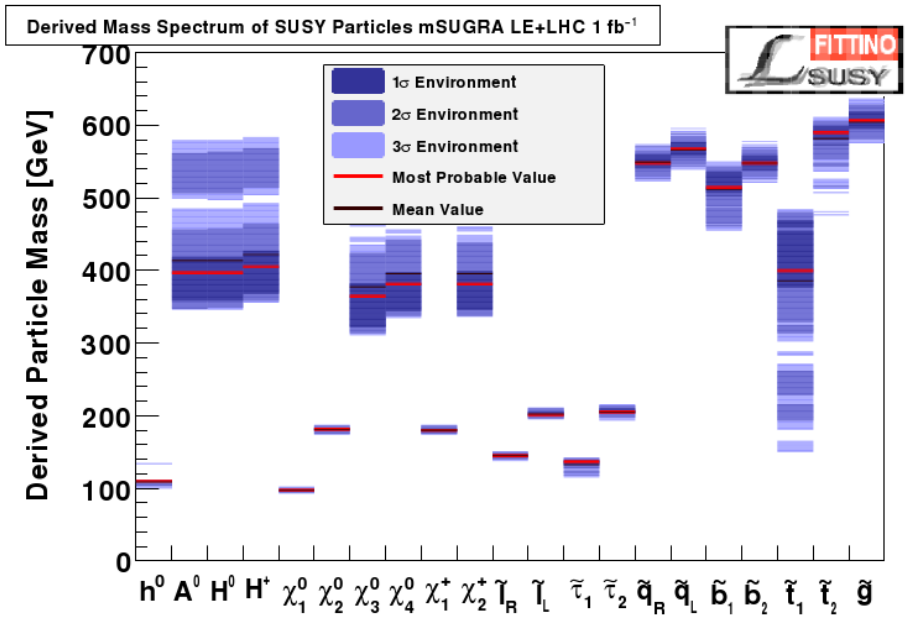
Parameter	Best Fit		Uncertainty
sign(μ)	+1		
tan β	9.98	$\pm$	0.35
A_0 (GeV)	−100.2	$\pm$	11.1
M_0 (GeV)	100.0	$\pm$	0.39
$M_{1/2}$ (GeV)	250.0	$\pm$	0.30

LE+LHC300:

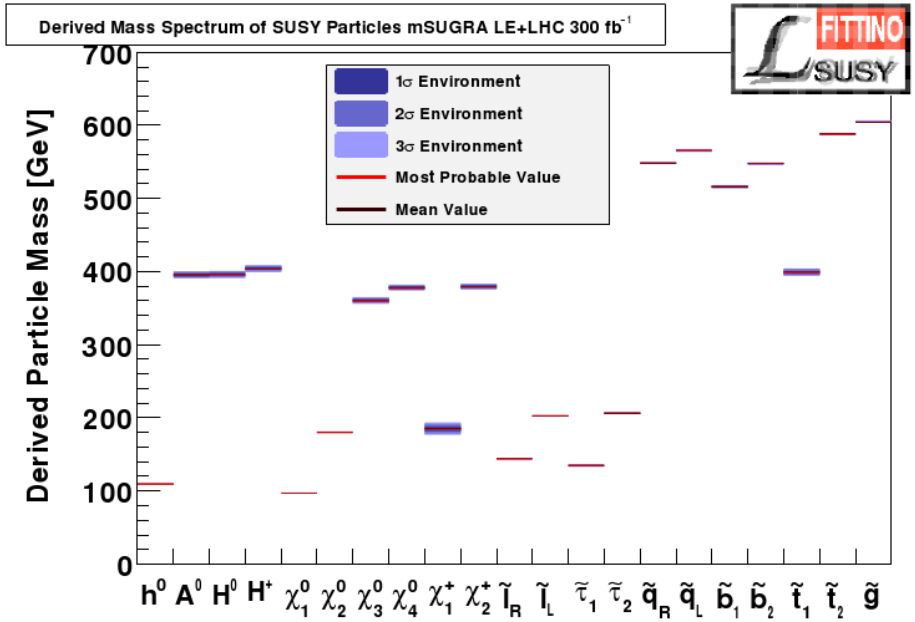
Parameter	Best Fit		Uncertainty
sign(μ)	+1		
tan β	10.00	$\pm$	0.36
A_0 (GeV)	−99.1	$\pm$	12.0
M_0 (GeV)	100.00	$\pm$	0.39
$M_{1/2}$ (GeV)	250.01	$\pm$	0.33

Option 4: Mass spectra

mSUGRA, LE+LHC1:



mSUGRA, LE+LHC300:



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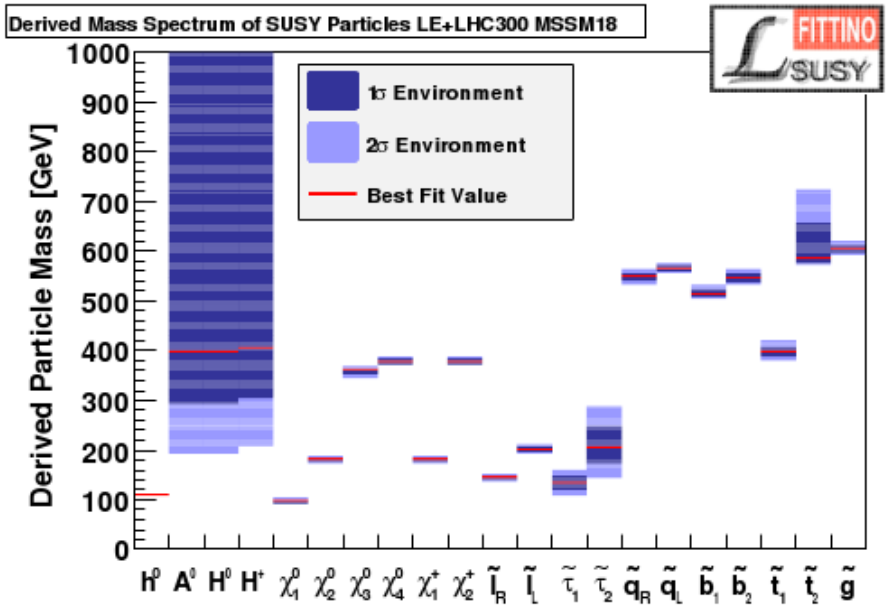
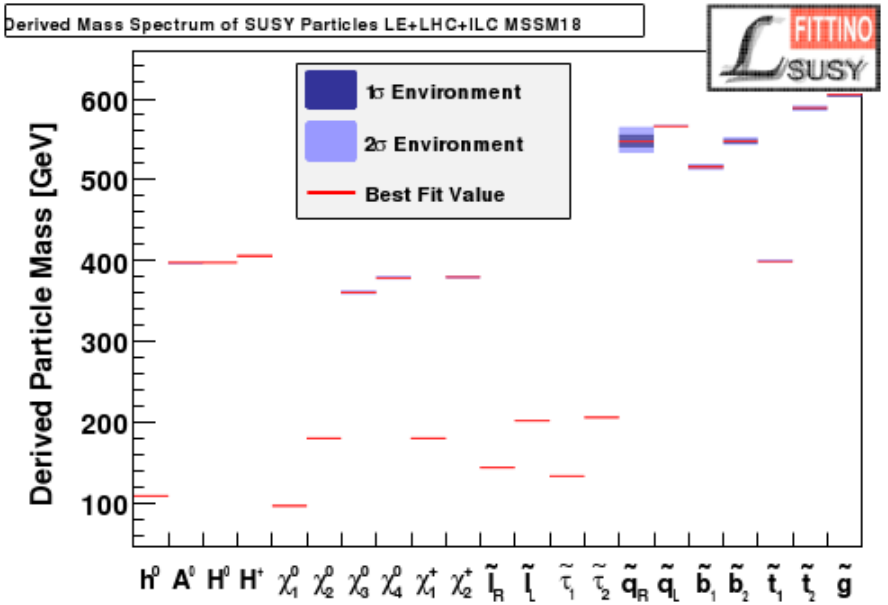
Option 5: Mass spectra

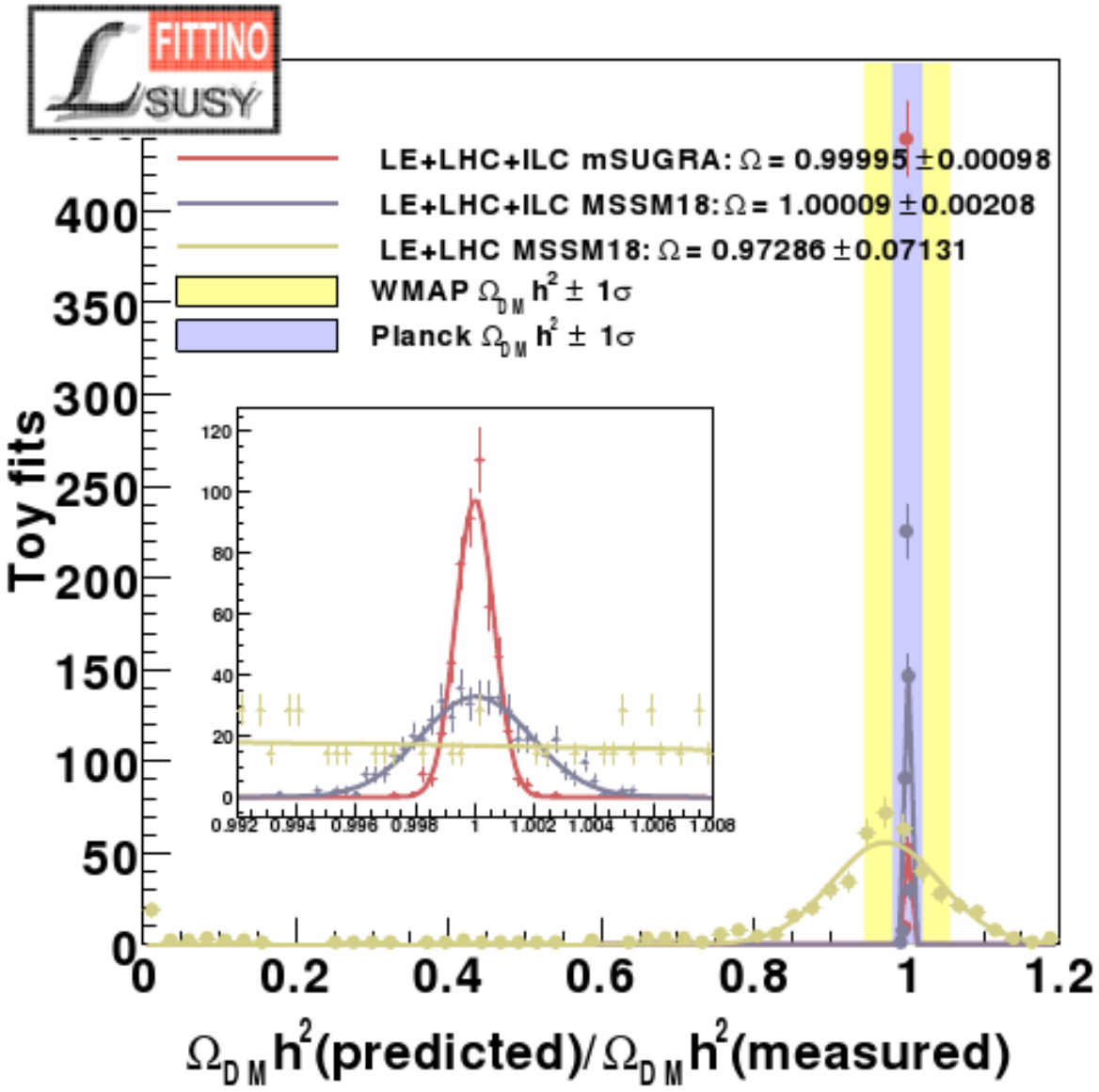
MSSM18, LE+LHC300:



MSSM18, LE+LHC300+ILC:



Option 5: CDM relic density



Conclusions

Quite some work has been done,

but still a lot to do in order to fully exploit upcoming data