FITTINO
$\mathcal{L}$ SUSY

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Extracting SUSY parameters from LHC measurements using Fittino

Philip Bechtle[1], Klaus Desch[2], Mathias Uhlenbrock[2], Peter Wienemann[2]

[1]DESY
[2]University of Bonn

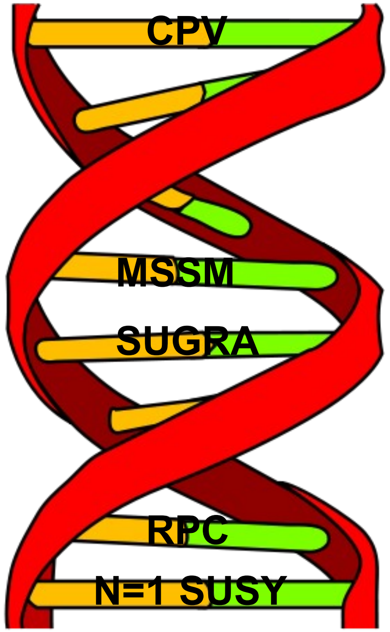
17th International Conference on Supersymmetry and Unification of Fundamental Interactions
June 7, 2009
Boston, USA

The “SUSY Genome Project”

Excess of events ≠ discovery of SUSY

Need to check, whether new physics is truly SUSY and find out the underlying blueprint:

SUSY genes:

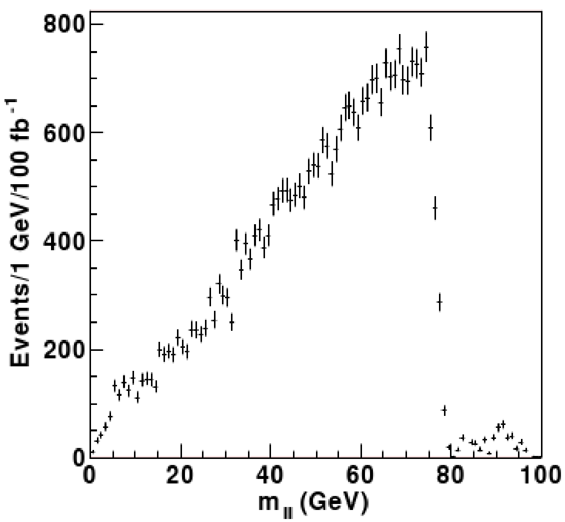


- Particle contents (MSSM, NMSSM, N=1 SUSY, ...)
- SUSY breaking mechanism (SUGRA, GMSB, …)
- R-parity conserved?
- CP violation in SUSY sector?
- Flavour violation?

Check compatibility of measurements with different models and give constraints on their parameters

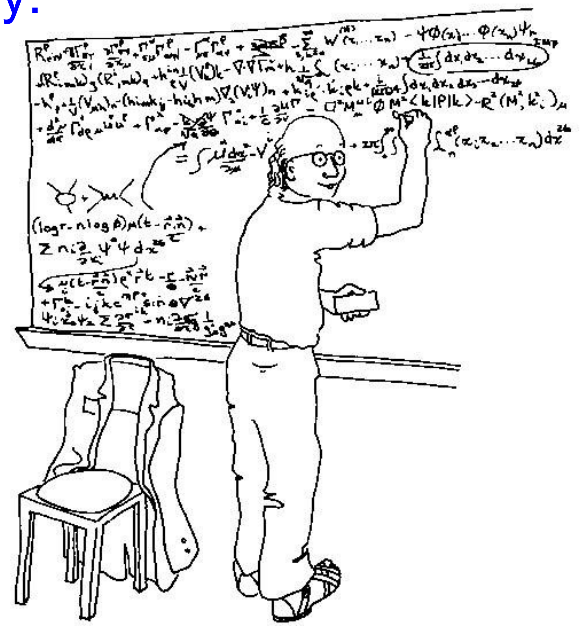
Determination of SUSY parameters

Experiment:



Mapping

Theory:



Observables:

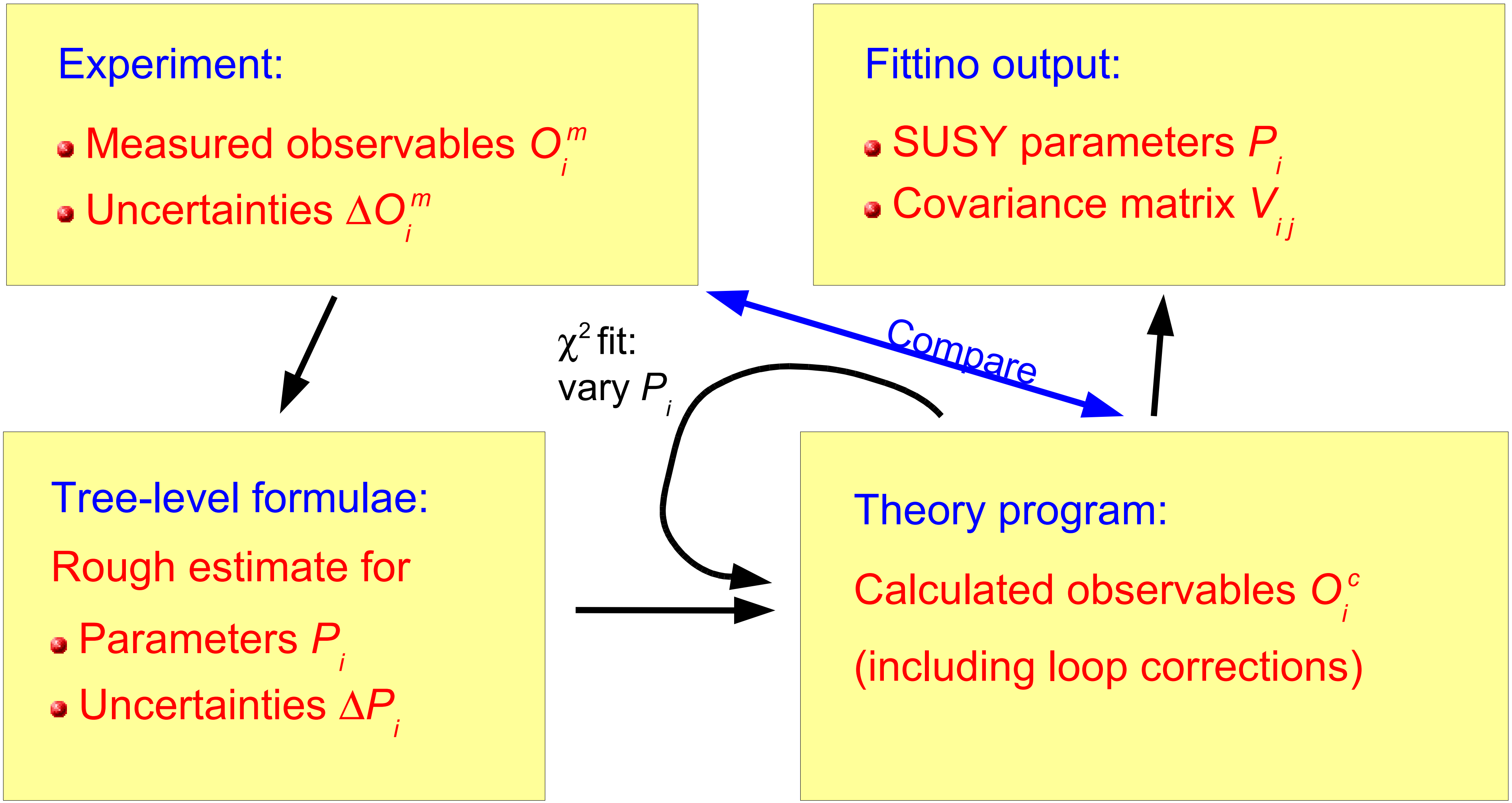
- Endpoints of mass spectra
- cross-sections
- ...

Lagrange parameters:

- tan β
- M_0
- ...

Mapping complicated if loop corrections are taken into account
(in principle every parameter depends on every observable and vice versa)

Fittino approach



Theory predictions: `SPheno` (W. Porod) and `Mastercode` (Buchmüller et al.)

Fit to "low energy" measurements

Fit of 4 SM + mSUGRA parameters to "low energy" measurements (LEP, SLC, B-factories, WMAP, ...):

Result:

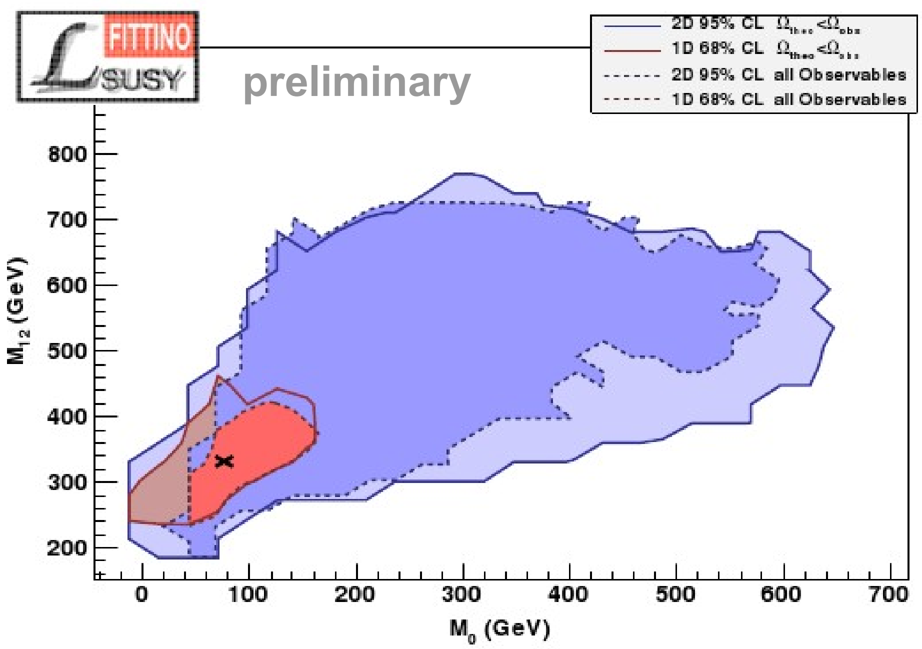
preliminary

Parameter		Best Fit		Uncertainty
signμ		$+1$		
α_s		0.11774	$\pm$	0.00199
$1/\alpha_{em}$		127.924	$\pm$	0.017
m_Z	(GeV)	91.1871	$\pm$	0.0020
m_t	(GeV)	172.4	$\pm$	1.1
$\tan\beta$		13.2	$\pm$	7.2
M_{12}	(GeV)	331	$\pm$	87
M_0	(GeV)	76		$^{+79}_{-29}$
A_0	(GeV)	384	$\pm$	647

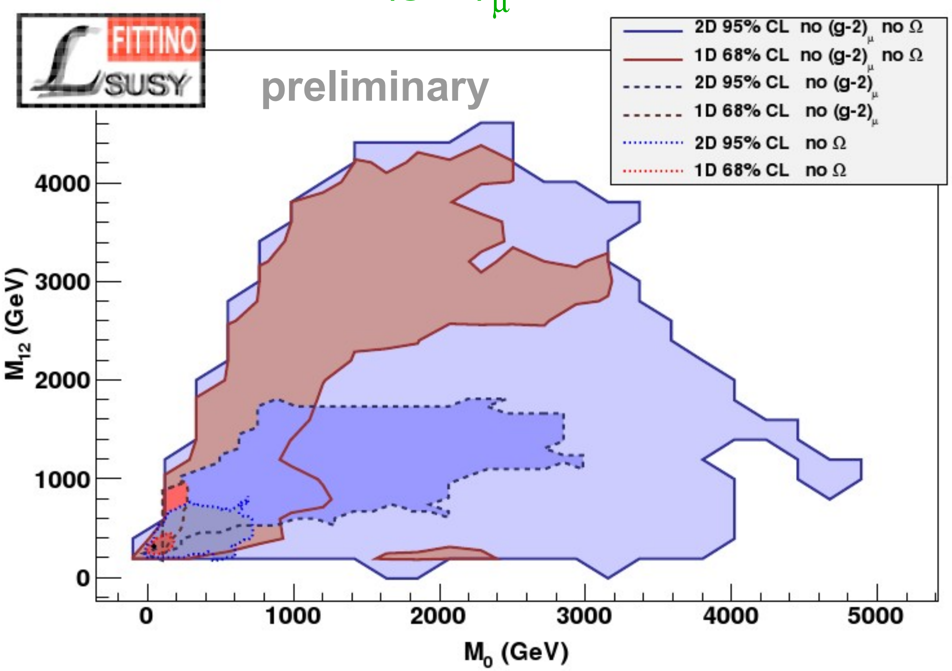
χ^2_{min} = 20.6 (ndof = 22)

Relevance of some observables

Fits using all observables:



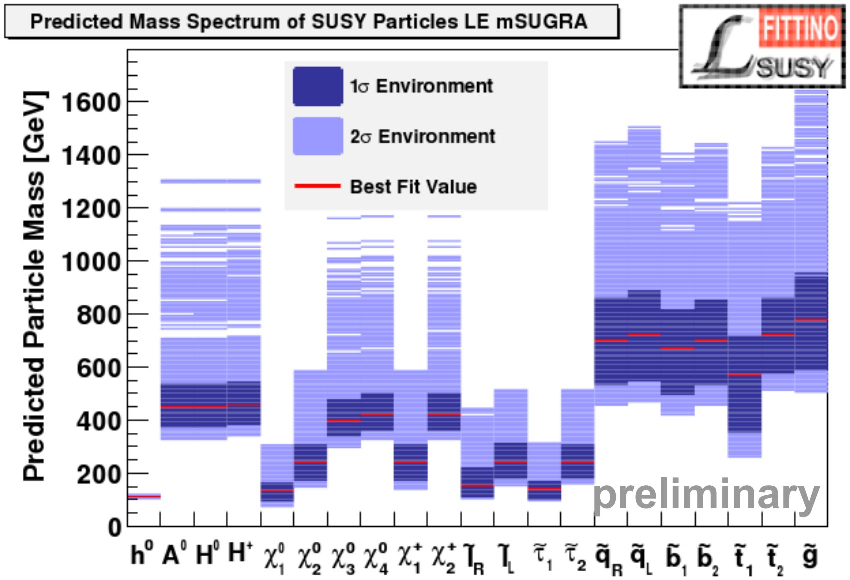
Fits without $(g\text{-}2)_\mu$ or/and Ωh^2:



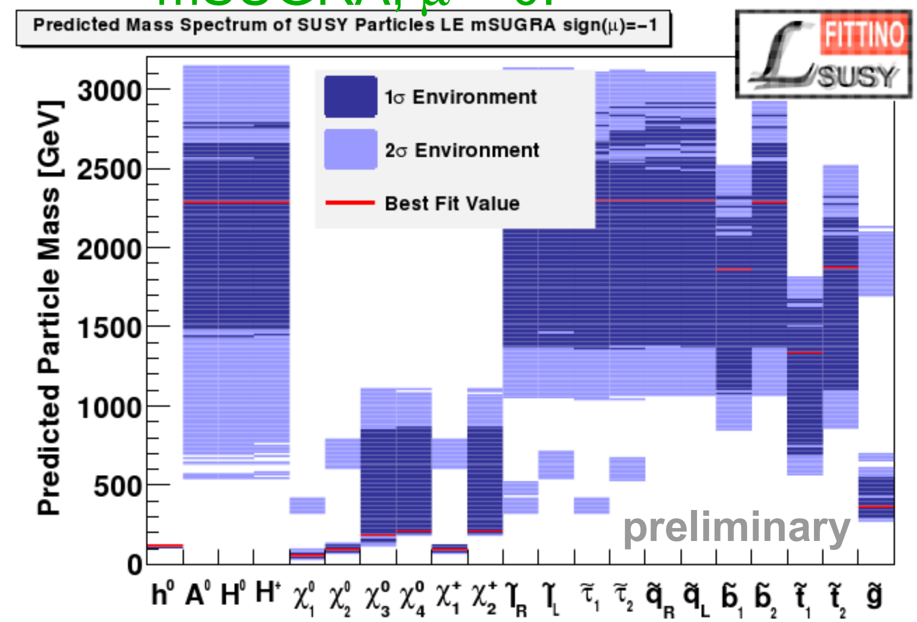
Preferred point rather robust

Mass spectrum from fits to LE data

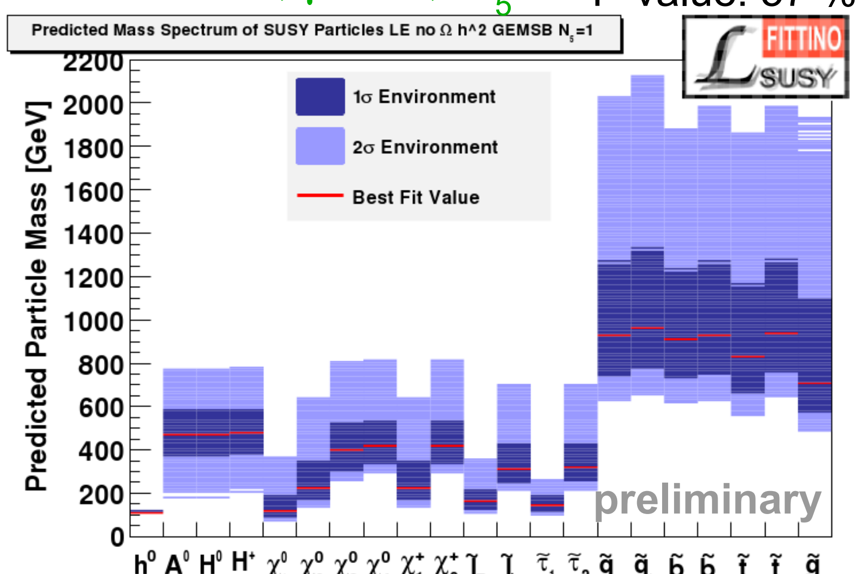
mSUGRA, $\mu > 0$: P-value: 54 %



mSUGRA, $\mu < 0$: P-value: 9 %

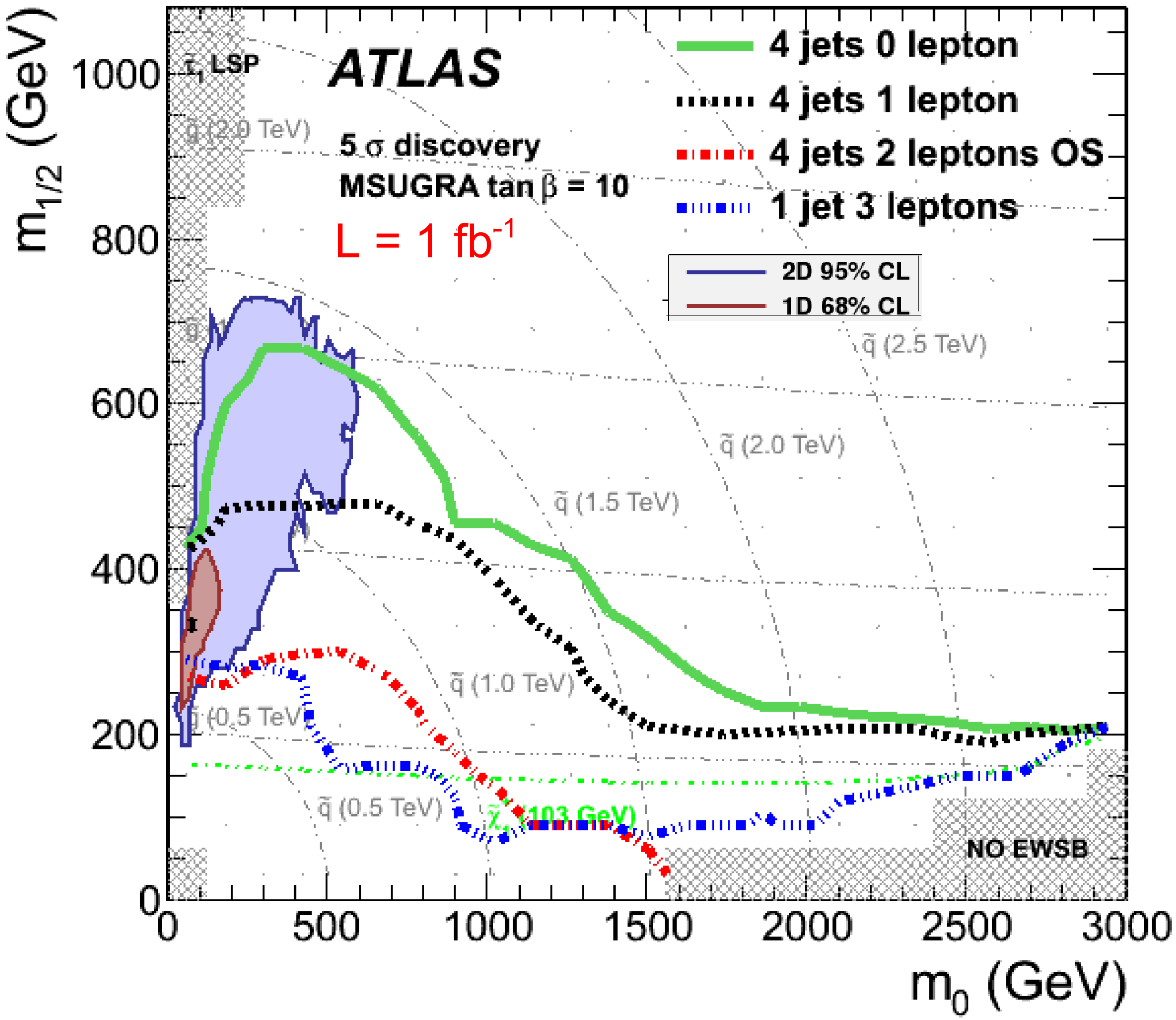


GMSB, $\mu > 0$, $N_5=1$: P-value: 57 %



Light SUSY particles favoured

Comparison with LHC potential



Good prospects for early BSM hints at LHC

Projection to LHC

Fit result of mSUGRA fit to “low energy” data accidentally very close to an experimentally well studied SUSY benchmark point:

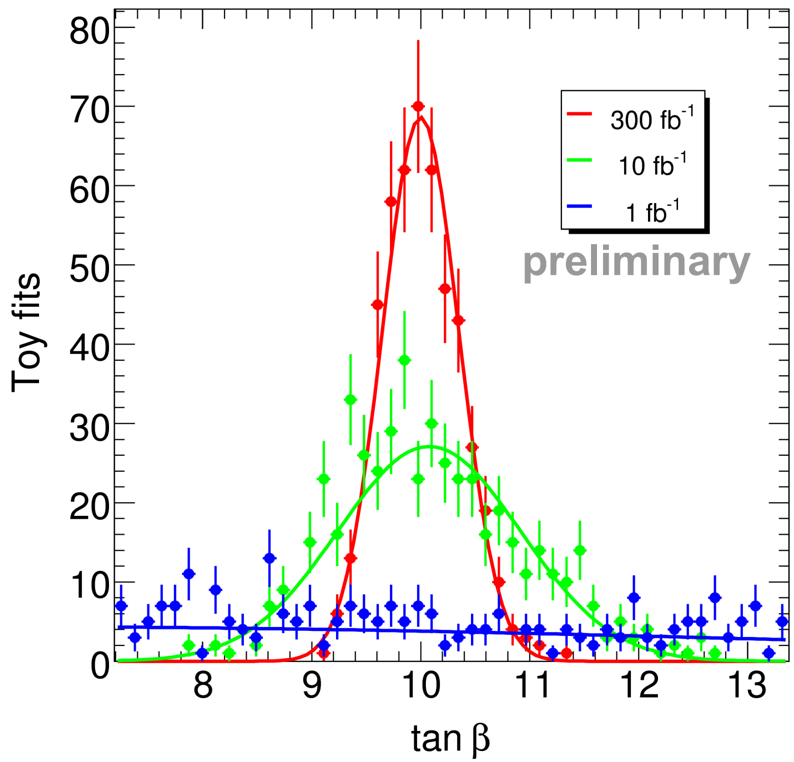
				SPS1a values
$\tan\beta$	13.2	$\pm$	7.2	10
M_{12} (GeV)	331	$\pm$	87	250
M_0 (GeV)	76		$^{+79}_{-29}$	100
A_0 (GeV)	384	$\pm$	647	-100

preliminary

Thus: Experimental SPS1a studies well suited to dare a projection to LHC era and predict evolution of LHC precision on SUSY parameters as function of luminosity

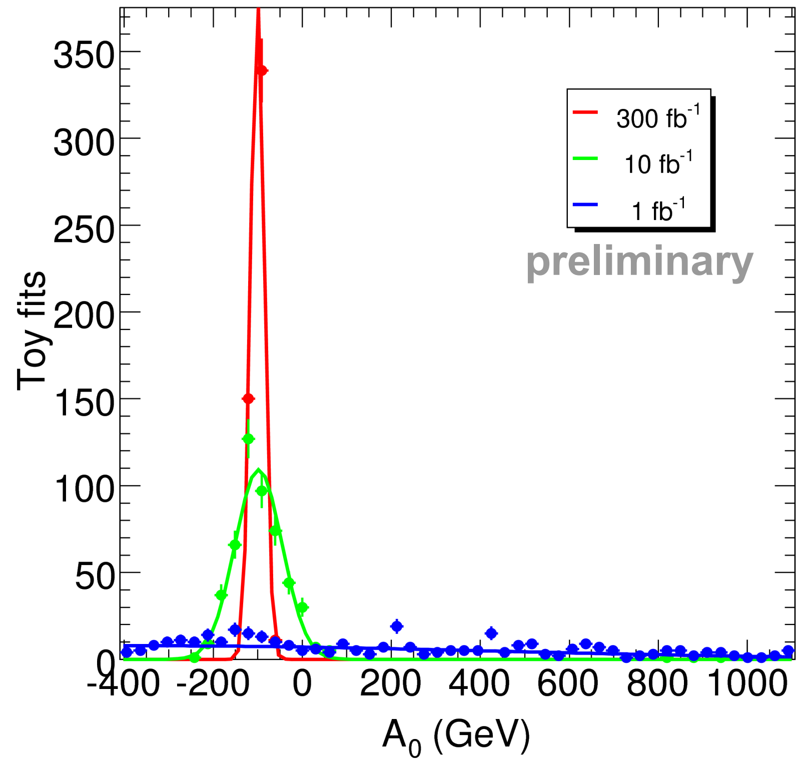
mSUGRA fit to LHC "data"

mSUGRA parameter distributions for toy fits:



Luminosity	Uncertainty
1 fb-1	3.7 (37 %)
10 fb-1	0.8 (8 %)
300 fb-1	0.4 (4 %)

SPS1a: tan β = 10

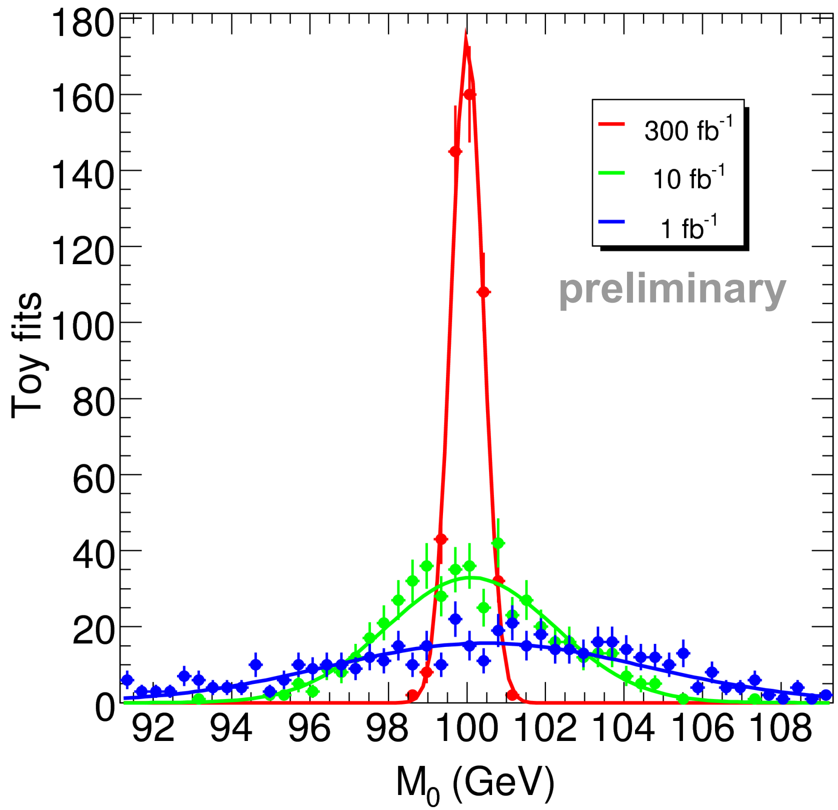


Luminosity	Uncertainty
1 fb-1	742 (742 %)
10 fb-1	53 (53 %)
300 fb-1	11 (11 %)

SPS1a: A_0 = -100 GeV

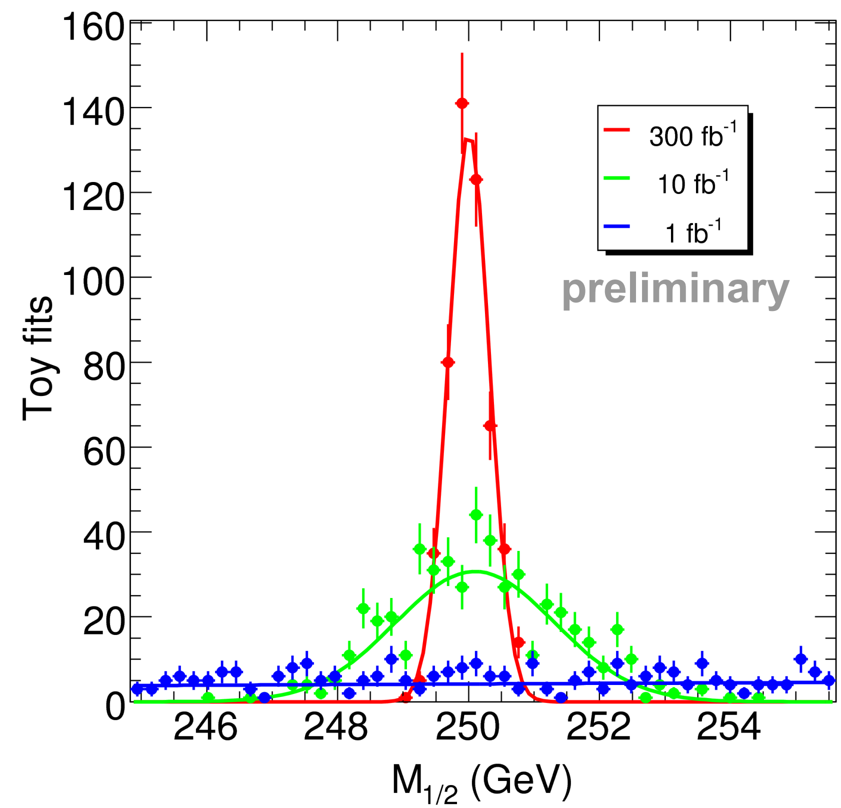
mSUGRA fit to LHC "data"

mSUGRA parameter distributions for toy fits:



Luminosity	Uncertainty
1 fb-1	4.2 (4.2 %)
10 fb-1	2.1 (2.1 %)
300 fb-1	0.39 (0.4 %)

SPS1a: M_0 = 100 GeV



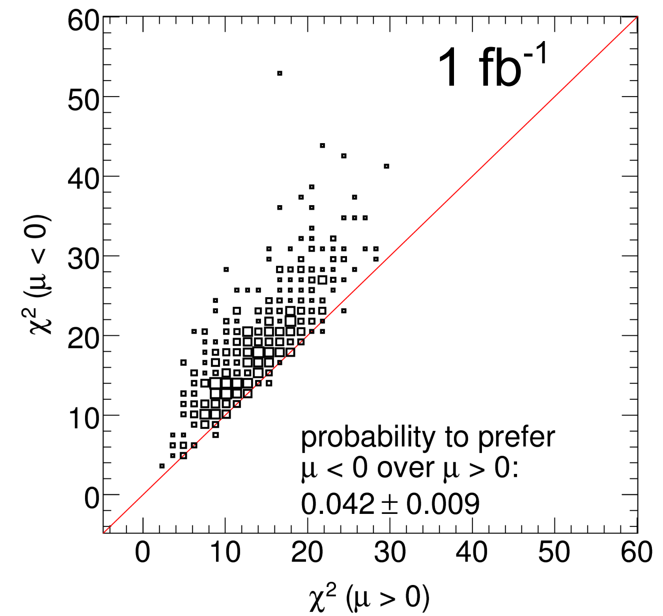
Luminosity	Uncertainty
1 fb-1	6.7 (2.7 %)
10 fb-1	1.2 (0.5 %)
300 fb-1	0.30 (0.1 %)

SPS1a: $M_{1/2}$ = 250 GeV

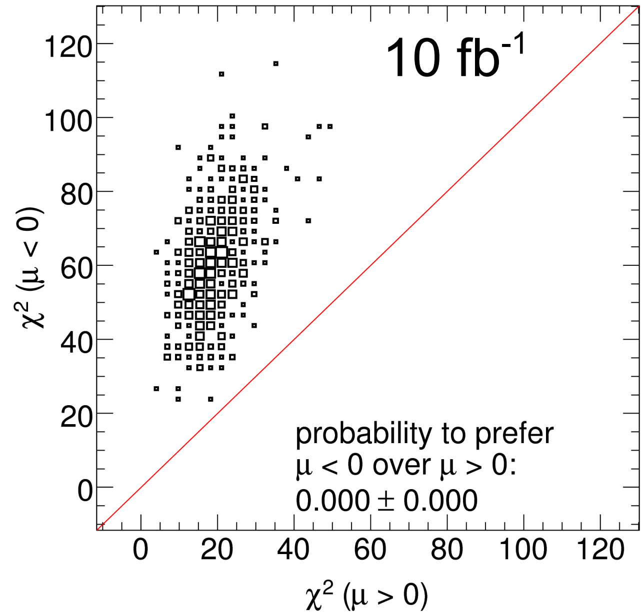
sign(μ)

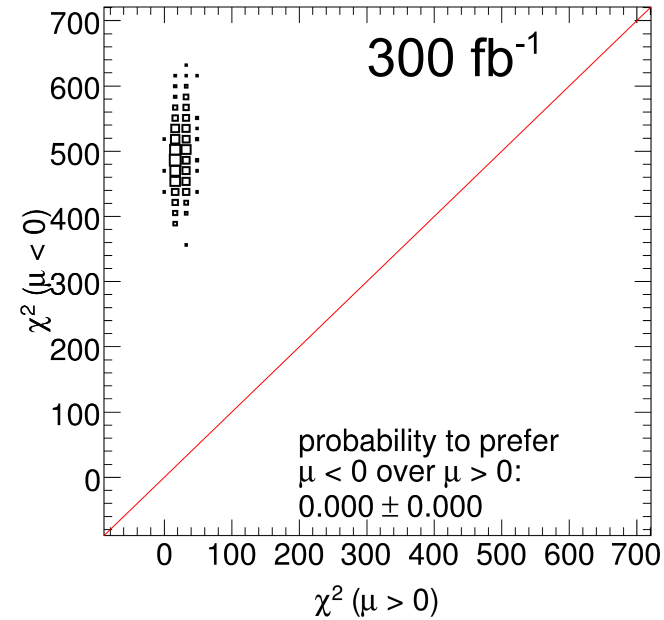
Performed two fits (with $\mu>0$ and $\mu<0$) for each toy data set smeared around best fit values and compared χ^2 values

SPS1a: $\mu>0$



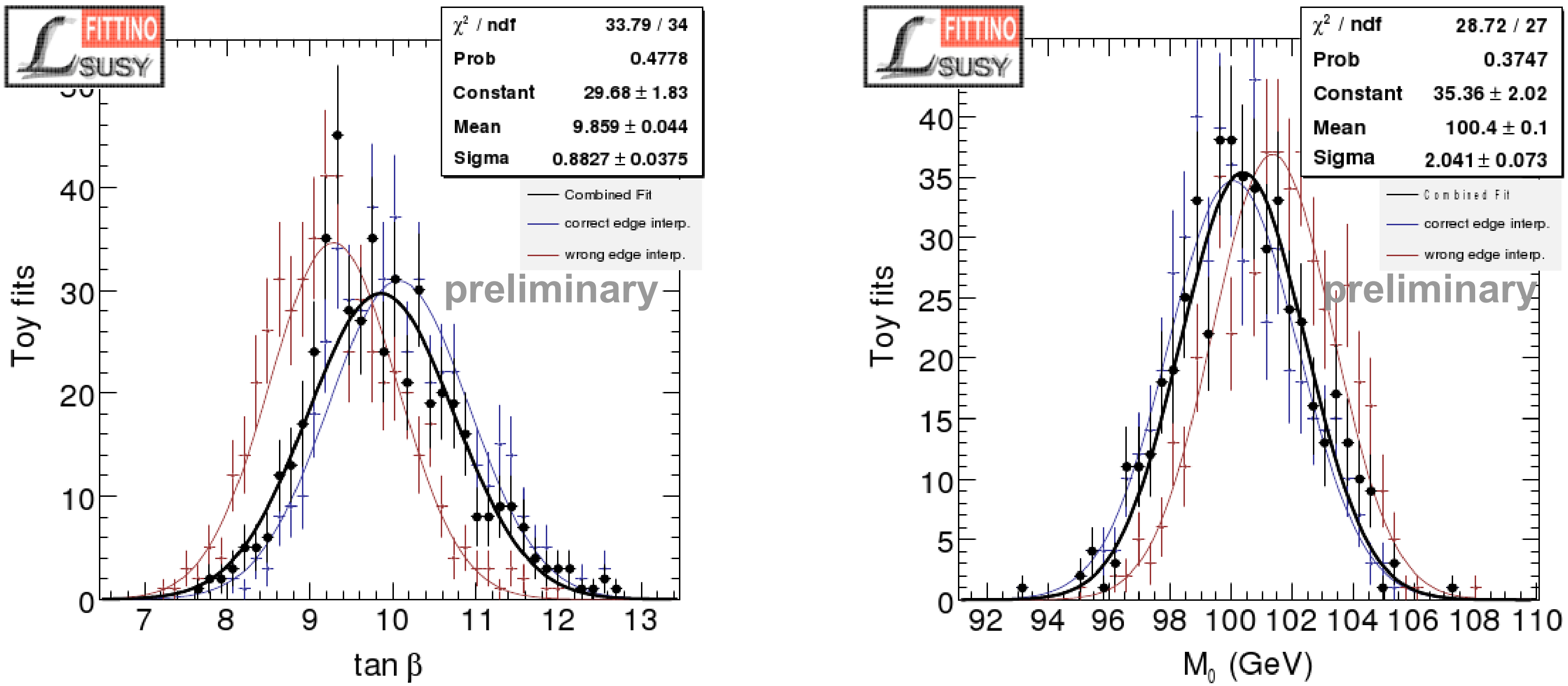
preliminary





Chain ambiguities

Full combinatorics for chain ambiguities not yet considered in analysis.
Exemplarily looked at impact of one possible misinterpretation of one single observable to test methodology:



Perform fit to same toy data for each possible interpretation and choose result with smallest χ^2

LE + LHC combination

	Luminosity	Uncertainty LHC	Uncertainty LHC+LE
$\tan\beta$	1 fb-1	3.7 (41 %)	2.5 (25 %)
	10 fb-1	0.8 (8 %)	0.8 (8 %)
	300 fb-1	0.4 (4 %)	0.3 (3 %)

	Luminosity	Uncertainty LHC	Uncertainty LHC+LE
A_0 (GeV)	1 fb-1	742 (742 %)	169 (169 %)
	10 fb-1	53 (53 %)	48 (48 %)
	300 fb-1	11 (11 %)	12 (12 %)

preliminary

	Luminosity	Uncertainty LHC	Uncertainty LHC+LE
M_0 (GeV)	1 fb-1	4.2 (4.2 %)	3.3 (3.3 %)
	10 fb-1	2.1 (2.1 %)	1.9 (1.9 %)
	300 fb-1	0.39 (0.4 %)	0.44 (0.4 %)

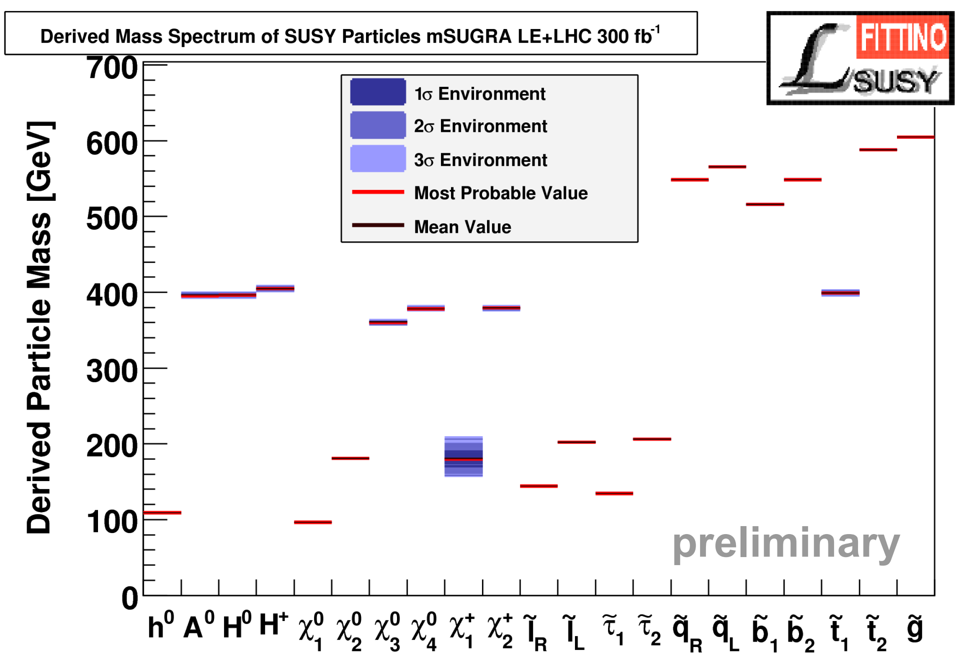
	Luminosity	Uncertainty LHC	Uncertainty LHC+LE
$M_{1/2}$ (GeV)	1 fb-1	6.7 (2.7 %)	4.9 (2.0 %)
	10 fb-1	1.2 (0.5 %)	1.1 (0.4 %)
	300 fb-1	0.30 (0.1 %)	0.32 (0.1 %)

LE observables set to nominal SPS1a values for this combination

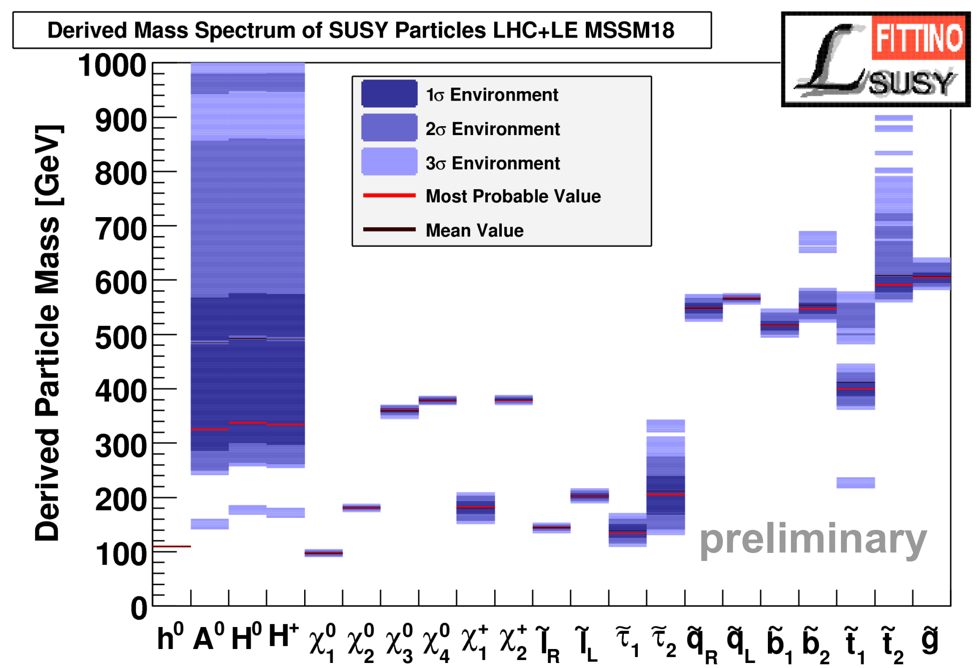
SUSY mass spectra

SUSY mass spectra derived from “low energy” and LHC (300 fb^{-1}) observables for different model assumptions:

mSUGRA



MSSM18



Summary

- “Low energy” data favour light SUSY particles
- New physics might be found with early LHC data
- Finding out its origin is probably more challenging and time consuming
- High scale unification models can be tested early on at the LHC
- More general scenarios can be checked and constrained as LHC accumulates more luminosity
- Just have to exercise a bit more patience until we can test our machinery on *real* LHC data

BACKUP

“Low energy” measurements

Numerous “low energy” measurements by past and present experiments:

- LEP, SLC
- B factories
- WMAP
- ...

They constrain possible SUSY parameter space

observable	meas. value	constraint	theo. uncert.
α_{em}	127.925	$\pm$ 0.016	
α_{S}	0.1176	$\pm$ 0.0020	
G_F (GeV^{-2})	1.16637 $\times 10^{-5}$	$\pm$ 0.00001 $\times 10^{-5}$	
m_Z (GeV)	91.1875	$\pm$ 0.0021	
m_W (GeV)	80.399	$\pm$ 0.025	$\pm$ 0.010
m_c (GeV)	1.27	$\pm$ 0.11	
m_b (GeV)	4.20	$\pm$ 0.17	
m_t (GeV)	172.4	$\pm$ 1.2	
m_τ (GeV)	1.77684	$\pm$ 0.00017	
m_h (GeV)	$>$ 114.4		$\pm$ 3.0
Γ_Z (MeV)	2495.2	$\pm$ 2.3	$\pm$ 1.0
Δa_μ	30.2 $\times 10^{-10}$	$\pm$ 8.8 $\times 10^{-10}$	$\pm$ 2.0 $\times 10^{-10}$
σ^0_{had} (nb)	41.540	$\pm$ 0.037	
R_ℓ	20.767	$\pm$ 0.025	
R_b	0.21629	$\pm$ 0.00066	
R_c	0.1721	$\pm$ 0.003	
A^ℓ_{FB}	0.01714	$\pm$ 0.00095	
A^b_{FB}	0.0992	$\pm$ 0.0016	
A^c_{FB}	0.0707	$\pm$ 0.0035	
A_ℓ(SLD)	0.1513	$\pm$ 0.0021	
$A_\ell(P_\tau)$	0.1465	$\pm$ 0.0032	
A_b	0.923	$\pm$ 0.020	
A_c	0.670	$\pm$ 0.027	
$\sin^2\theta^\ell_{\mathrm{W}}(Q_{\mathrm{fb}})$	0.2324	$\pm$ 0.0012	
Ωh^2	0.1099	$\pm$ 0.0062	$\pm$ 0.012
BR($B_d \to \mu^+\mu^-$)		$<$ 2.3 $\times 10^{-8}$	$\pm$ 0.01$\times 10^{-9}$
BR($B_s \to \mu^+\mu^-$)		$<$ 4.7 $\times 10^{-8}$	$\pm$ 0.02$\times 10^{-8}$
R($b \to s\gamma$)	1.117	$\pm$ 0.076 $\pm$ 0.082	$\pm$ 0.050
R($B \to \tau\nu$)	1.15	$\pm$ 0.40	
R($B \to X_s\ell\ell$)	0.99	$\pm$ 0.32	
R($K \to \mu\nu$)	1.008	$\pm$ 0.014	
R($K \to \pi\nu\bar{\nu}$)		$<$ 4.5	
R(Δm_{B_s})	1.11	$\pm$ 0.01	$\pm$ 0.32
R(Δm_{B_s})/R(Δm_{B_d})	1.09	$\pm$ 0.01	$\pm$ 0.16
$R(\Delta\epsilon_K)$	0.92	$\pm$ 0.14	

LHC "measurements"

Observable	Nominal Value	Uncertainty							
		1 fb^{-1}	10 fb^{-1}	300 fb^{-1}	LES_1	$\text{LES}_{10,300}$	JES_1	$\text{JES}_{10,300}$	syst.
m_h	109.1		1.4	0.1		0.1			
m_t	170.9	1.1*	0.05	0.01			1.5*	1.0	
$m_{\tilde{\chi}_1^\pm}$	179.9			11.4				1.8	
$m_{\tilde{\ell}_L} - m_{\tilde{\chi}_1^0}$	105.4			1.7		0.1			6.0
$m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$	510.2		13.7	2.5				5.1	10.0
$m_{\tilde{q}_R} - m_{\tilde{\chi}_1^0}$	454.0	19.6	6.2	1.1			22.7	4.5	10.0
$\langle m_{\tilde{g}} - m_{\tilde{b}_{1,2}} \rangle$	522.6		5.4					5.2	
$m_{\tilde{g}} - m_{\tilde{b}_1}$	89.0			1.5				0.9	
$m_{\tilde{g}} - m_{\tilde{b}_2}$	56.7			2.5				0.6	
$m_{\ell\ell}^{\text{max}} = \epsilon_1(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R})$	80.2	1.7	0.5	0.03	0.16	0.08			
$m_{\ell\ell}^{\text{max}} = \epsilon_1(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_4^0}, m_{\tilde{\ell}_L})$	279.1		12.6	2.3		0.28			
$m_{\tau\tau}^{\text{max}} = \epsilon_1(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\tau}_1})$	83.2	12.6	4.0	0.73			4.2	0.8	5.7
$m_{\ell\ell q}^{\text{max}} = \epsilon_1(m_{\tilde{\chi}_1^0}, m_{\tilde{q}_L}, m_{\tilde{\chi}_2^0})$	454.3	13.9	4.2	1.4			22.7	4.5	
$m_{\ell q}^{\text{low}} = \epsilon_1(m_{\tilde{\ell}_R}, m_{\tilde{q}_L}, m_{\tilde{\chi}_2^0})$	324.2	7.6	3.5	0.9			16.2	3.2	
$m_{\ell q}^{\text{high}} = \epsilon_2(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{q}_L})$	398.3	5.2	4.5	1.0			19.9	4.0	
$m_{\ell\ell q}^{\text{thres}} = \epsilon_3(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{q}_L})$	216.2	26.5	4.8	1.6			10.8	2.2	
$m_{\ell\ell b}^{\text{thres}} = \epsilon_3(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{b}_1})$	196.4		19.7	3.6				2.0	
$m_{tb}^{\text{w}} = \epsilon_4(m_t, m_{\tilde{t}_1}, m_{\tilde{\chi}_j^\pm}, m_{\tilde{g}}, m_{\tilde{b}_i})$	360.9	43.0	13.6	2.5			18.0	3.6	
$\frac{\text{BR}(\tilde{\chi}_2^0 \to \tilde{\ell}\ell) \times \text{BR}(\tilde{\ell} \to \tilde{\chi}_1^0 \ell)}{\text{BR}(\tilde{\chi}_2^0 \to \tilde{\tau}_1 \tau) \times \text{BR}(\tilde{\tau}_1 \to \tilde{\chi}_1^0 \tau)}$	0.08	0.009	0.003	0.001					0.008
$\frac{\text{BR}(\tilde{g} \to \tilde{b}_2 b) \times \text{BR}(\tilde{b}_2 \to \tilde{\chi}_2^0 b)}{\text{BR}(\tilde{g} \to \tilde{b}_1 b) \times \text{BR}(\tilde{b}_1 \to \tilde{\chi}_2^0 b)}$	0.16			0.078					