Reconstruction of SUSY Lagrangian parameters with Fittino

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Models and their parameters

Standard model (SM)

19 parameters

- 9 fermion masses m_f
- 3 couplings g, $g\prime$, g_S
- Higgs mass m_H, VEV v
- strong CP phase θ_{QCD}
- 3 CKM angles, 1 CKM phase

MSSM-24

24 parameters

- 15 sfermion masses $m_{\tilde{f}}$
- 3 trilinear couplings A_τ, A_b, A_t
- 3 gaugino masses M_1, M_2, M_3
- pseudoscalar Higgs mass m_{A^0}
- Higgsino mass parameter μ
- ratio of 2 Higgs VEVs $\tan\beta = \frac{v_1}{v_2}$

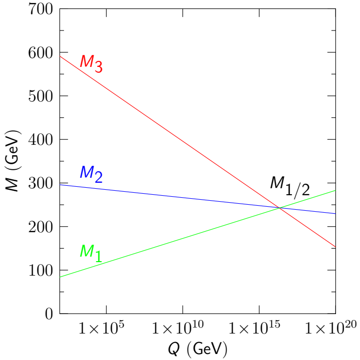
Multiplicity of parameters due to spontaneous symmetry breaking

Unified models

Unification of parameters at high energies

example

universal gaugino mass $M_{1/2}$



unified model: mSUGRA

4 parameters

- universal gaugino mass $M_{1/2}$
- universal scalar mass M_0
- universal trilinear coupling A_0
- $\tan\beta$

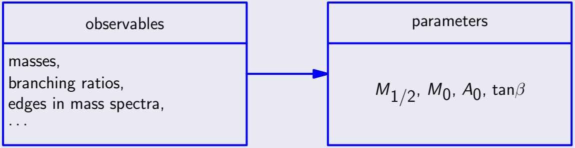
assumed model point: SPS 1a

$M_{1/2} = 250$ GeV, $M_0 = 100$ GeV, $A_0 = -100$ GeV, $\tan\beta = 10$, sign$\mu = 1$

Principles of parameter reconstruction

Principles

- In general: observables $\neq$ parameters
- Reconstruction: mapping observables $\rightarrow$ parameters



- Difficulty: mapping not analytical due to higher order corrections
- But: theory gives mapping parameters $\rightarrow$ observables
- Strategy: vary parameters until predicted and measured observables in agreement

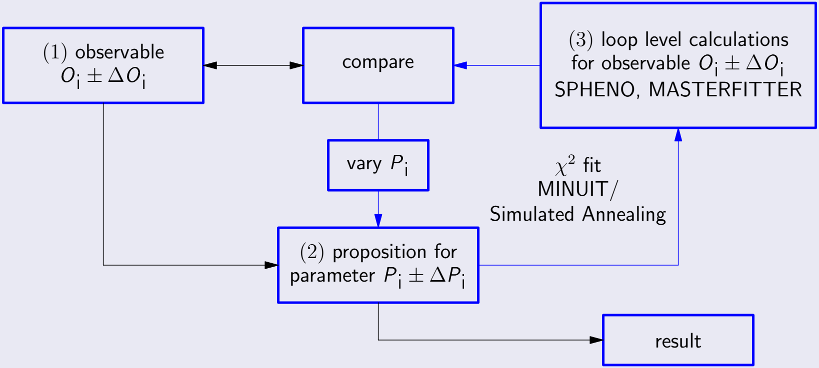
List of observables (excerpt)

LHC observable (1 fb^{-1})	nominal value (GeV)	uncertainty (GeV) stat.	LES (0.2 %)	JES (5 %)	syst.
m_t	170.9	1.1		1.5	
$m_{\tilde{q}_R} - m_{\tilde{\chi}_1^0}$	533.7	19.6		26.7	10.0
$m_{\ell\ell}^{\max}$	80.2	1.7	0.16		
$m_{\tau\tau}^{\max}$	83.2	12.6		4.2	8.3
$m_{\ell\ell q}^{\max}$	454.3	13.9		11.4	
$m_{\ell q}^{\text{low}}$	320.3	7.6		8.0	
$m_{\ell q}^{\text{high}}$	398.3	5.2		10.0	
$m_{\ell\ell q}^{\text{thres}}$	216.2	26.5		5.4	
m_{tb}^{w}	360.9	43.0		18.0	
$\frac{\text{BR}(\tilde{\chi}_2^0 \to \tilde{\ell}\ell) \times \text{BR}(\tilde{\ell} \to \tilde{\chi}_1^0 \ell)}{\text{BR}(\tilde{\chi}_2^0 \to \tilde{\tau}_1 \tau) \times \text{BR}(\tilde{\tau}_1 \to \tilde{\chi}_1^0 \tau)}$	0.08	0.009			0.008

low energy observable	nominal value	uncertainty stat.	syst.
σ_0^h (nb)	41.404	0.037	
R_ℓ	20.788	0.025	
A_{FB}^ℓ	0.01644	0.00095	
A_ℓ(SLD)	0.1481	0.0021	
Ωh^2	0.194	0.009	0.012
R($b \to s\gamma$)	0.915	0.122	
$\Delta(g-2)_\mu$	29.7×10^{-10}	9.0×10^{-10}	

Fittino overview

Fittino



Simulated Annealing

Simulated Annealing

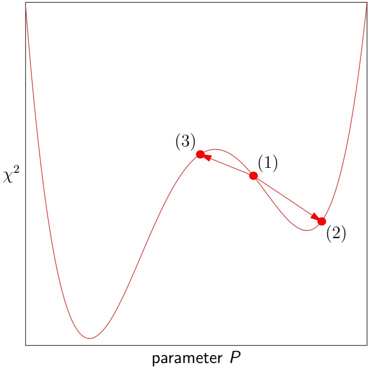
- χ^2 surface is considered as potential
- higher χ^2 is accepted according to Boltzmann distribution to escape from local mimima

$$p < \exp\left(-\frac{\chi^{2(t)} - \chi^{2(t-1)}}{T}\right)$$

with $p \in [0, 1]$

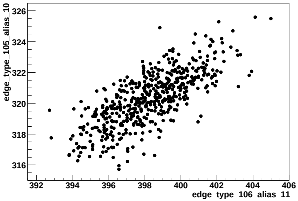
- iterative temperature reduction

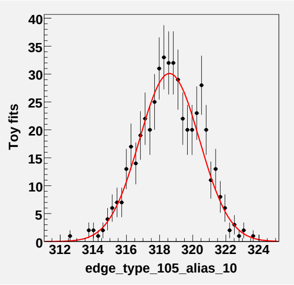
$$T' = rT \qquad 0 < r < 1$$



Principles of MC method

observables

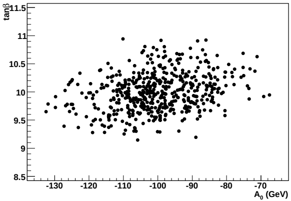


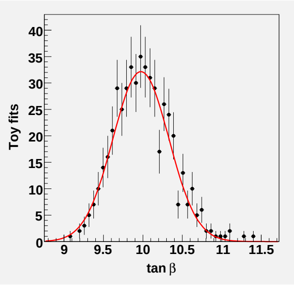


fit

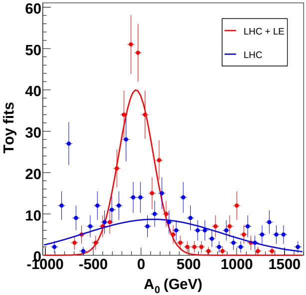
errors given by standard deviation

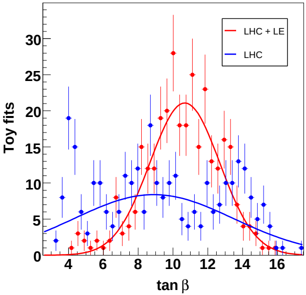
parameters





Results of MC method

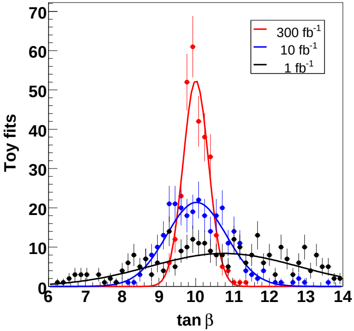


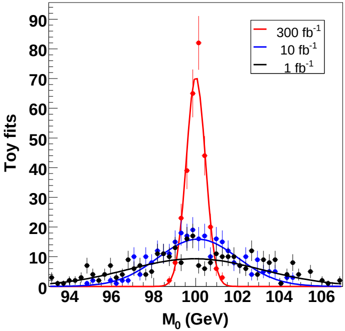


Non-Gaussian behaviour at low luminosities

- mapping: at 1 fb^{-1} deviations from linear approximation
- improvement by constraints from low energy (LE) measurements

Global fits for different luminosities





300fb^{-1} : 10.02 ± 0.34 (3.39 %)

10fb^{-1} : 10.01 ± 0.82 (8.19 %)

1fb^{-1} : 10.68 ± 1.98 (18.54 %)

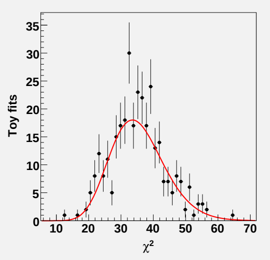
300fb^{-1} : 100.0 ± 0.4 (0.4 %)

10fb^{-1} : 100.3 ± 1.9 (1.9 %)

1fb^{-1} : 99.96 ± 3.15 (3.15 %)

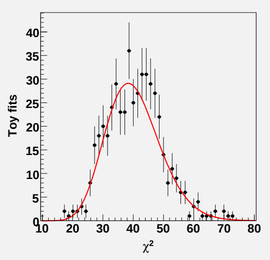
Global fits for different luminosities

1 fb^{-1}



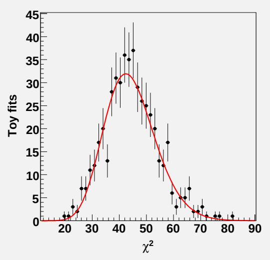
$\text{ndf} = 35.55 \pm 0.52$
(36 expected)

10 fb^{-1}



$\text{ndf} = 40.38 \pm 0.39$
(41 expected)

300 fb^{-1}

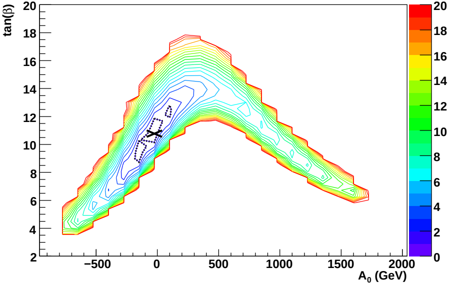


$\text{ndf} = 44.42 \pm 0.45$
(45 expected)

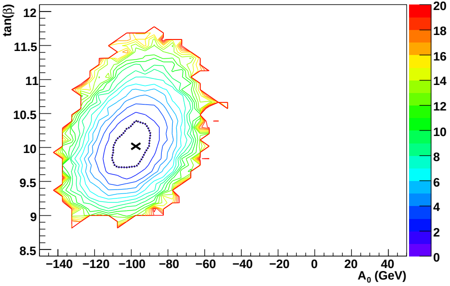
χ^2 distributions

Objective quality criterion: reproduce input number degrees of freedom (ndf)

Global fits for different luminosities



1 fb^{-1}

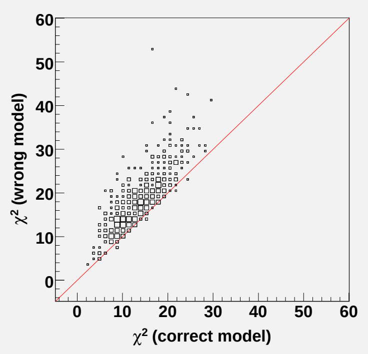


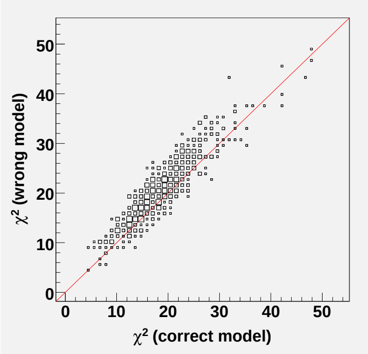
300 fb^{-1}

Alternative view on parameter space: Likelihood maps

- Markov chain with sampling rate proportional to likelihood L that parameter set is realized in data
- plot $2(\ln(L_0) - \ln(L)) = \chi^2$
- reveals substructure (e.g. second order minima)

Model discrimination





model discrimination (1 fb^{-1})

- fit wrong model with signμ = -1
- probability to prefer correct over wrong model: 96 %

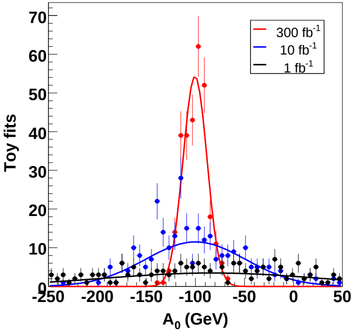
interpretation of mass edge (10 fb^{-1})

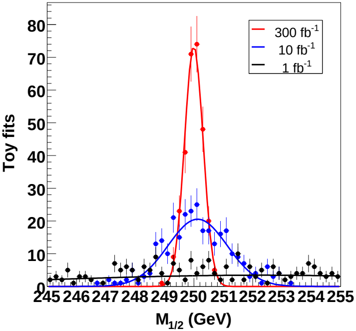
- fit wrongly identified edge in mass spectrum ($m_{\tilde{e}_R} \leftrightarrow m_{\tilde{e}_L}$)
- probability to prefer correct over wrong interpretation: 77 %

Conclusion

1. Supersymmetry breaking parametrized in Lagrangian
2. Reconstruction of mSUGRA point SPS 1a from
   LHC + low energy measurements with Fittino
   using complementing techniques
   - for different luminosities
   - used for model discrimination
3. Expect interesting results from first data

Backup: Global fits for different luminosities





300fb^{-1} : -100.3 ± 11.8 (11.8 %)

10fb^{-1} : -103.6 ± 44.0 (42.5 %)

1fb^{-1} : -57.2 ± 171.6 (300 %)

300fb^{-1} : 250.0 ± 0.3 (0.12 %)

10fb^{-1} : 250.1 ± 1.0 (0.4 %)

1fb^{-1} : 251.6 ± 4.9 (1.9 %)

Backup: Parameter correlations

$\int \mathcal{L} dt = 1\ \text{fb}^{-1}$				
	M_0	$M_{1/2}$	A_0	$\tan\beta$
M_0	1.000(0.000)	-0.249(0.042)	-0.299(0.041)	-0.563(0.031)
$M_{1/2}$	-0.249(0.042)	1.000(0.000)	0.358(0.039)	0.809(0.015)
A_0	-0.299(0.041)	0.358(0.039)	1.000(0.000)	0.435(0.036)
$\tan\beta$	-0.563(0.031)	0.809(0.015)	0.435(0.036)	1.000(0.000)

$\int \mathcal{L} dt = 10\ \text{fb}^{-1}$				
	M_0	$M_{1/2}$	A_0	$\tan\beta$
M_0	1.000(0.000)	0.310(0.040)	-0.528(0.032)	-0.432(0.036)
$M_{1/2}$	0.310(0.040)	1.000(0.000)	0.470(0.035)	0.331(0.040)
A_0	-0.528(0.032)	0.470(0.035)	1.000(0.000)	0.830(0.014)
$\tan\beta$	-0.432(0.036)	0.331(0.040)	0.830(0.014)	1.000(0.000)

$\int \mathcal{L} dt = 300\ \text{fb}^{-1}$				
	M_0	$M_{1/2}$	A_0	$\tan\beta$
M_0	1.000(0.000)	0.346(0.039)	-0.283(0.041)	0.182(0.043)
$M_{1/2}$	0.346(0.039)	1.000(0.000)	0.698(0.023)	0.083(0.044)
A_0	-0.283(0.041)	0.698(0.023)	1.000(0.000)	0.280(0.041)
$\tan\beta$	0.182(0.043)	0.083(0.044)	0.280(0.041)	1.000(0.000)