Reconstruction of SUSY Lagrangian parameters with Fittino

Philip Bechtle, Klaus Desch,
Mathias Uhlenbrock, Peter Wienemann

Physikalisches Institut
University of Bonn

Helmholtz Alliance "Physics at the Terascale"
2nd Annual Workshop
Aachen, November 27, 2008

Table of contents

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 $\tan\beta = \frac{v_1}{v_2}$

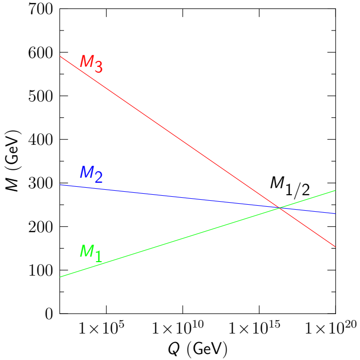
Multiplicity of parameters due to spontaneous symmetry breaking

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
- $\tan\beta$

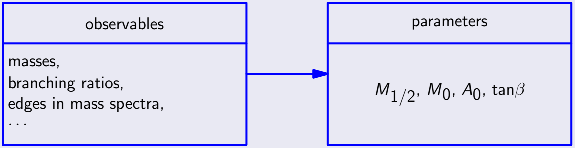
assumed model point: SPS 1a

$M_{1/2} = 250$ 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 $\longrightarrow$ parameters



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

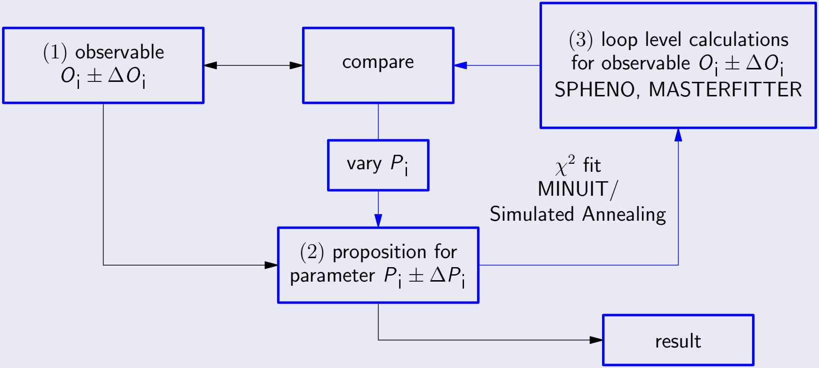
List of observables (excerpt)

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	
$\frac{\mathrm{BR}(\tilde{\chi}_2^0 \to \tilde{\ell}\ell) \times \mathrm{BR}(\tilde{\ell} \to \tilde{\chi}_1^0 \ell)}{\mathrm{BR}(\tilde{\chi}_2^0 \to \tilde{\tau}_1 \tau) \times \mathrm{BR}(\tilde{\tau}_1 \to \tilde{\chi}_1^0 \tau)}$	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

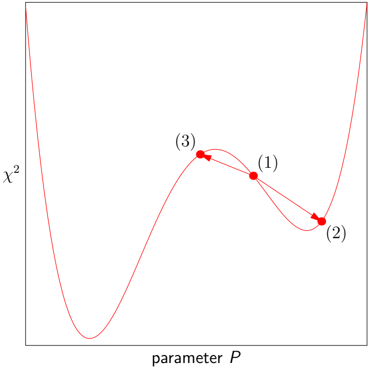
- χ^2 surface is considered as potential
- higher χ^2 is accepted according to Boltzmann distribution to escape from local mimima

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

with $p \in [0, 1]$

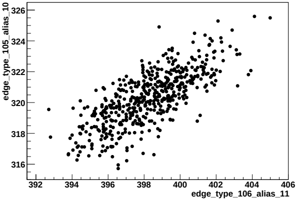
- iterative temperature reduction

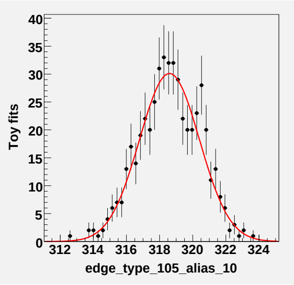
$$T' = rT \qquad 0 < r < 1$$



Principles of MC method

observables

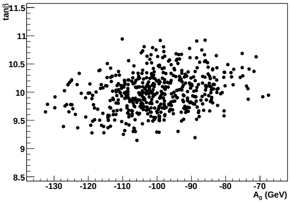


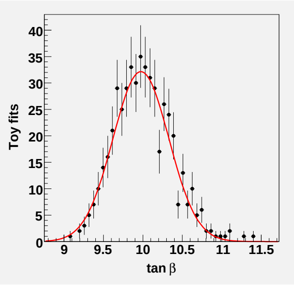


fit

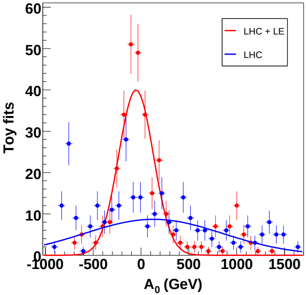
errors given by standard deviation

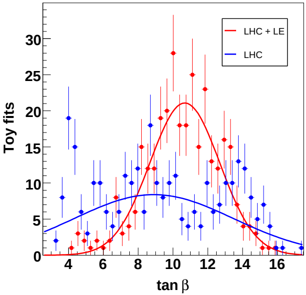
parameters





Results of MC method

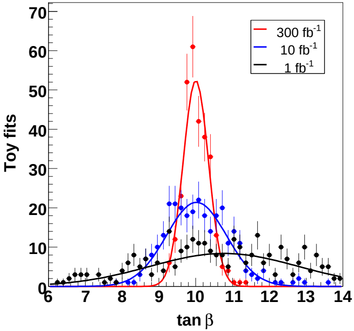


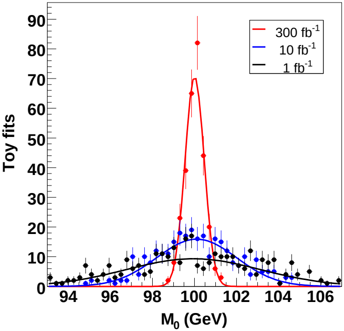


Non-Gaussian behaviour at low luminosities

- 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 %)

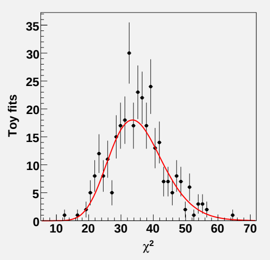
$300fb^{-1}$: 100.0 ± 0.4 (0.4 %)

$10fb^{-1}$: 100.3 ± 1.9 (1.9 %)

$1fb^{-1}$: 99.96 ± 3.15 (3.15 %)

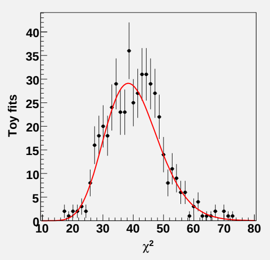
Global fits for different luminosities

$1\ \text{fb}^{-1}$



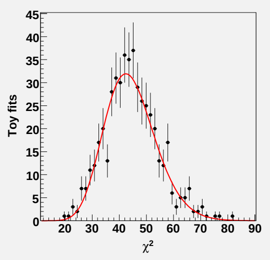
$\text{ndf} = 35.55 \pm 0.52$
(36 expected)

$10\ \text{fb}^{-1}$



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

$300\ \text{fb}^{-1}$

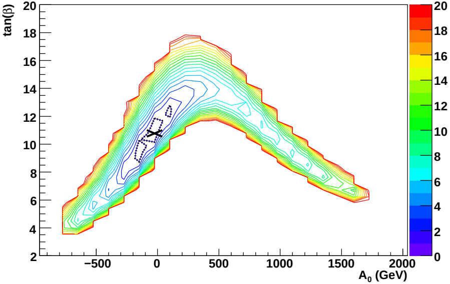


$\text{ndf} = 44.42 \pm 0.45$
(45 expected)

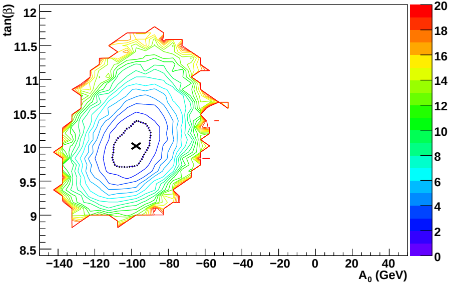
χ^2 distributions

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

Global fits for different luminosities



1 fb^{-1}

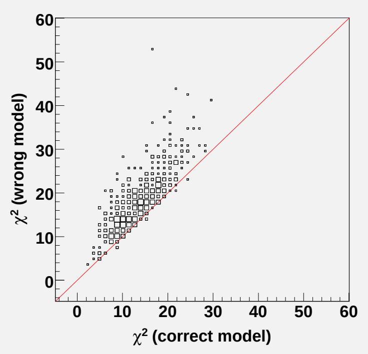


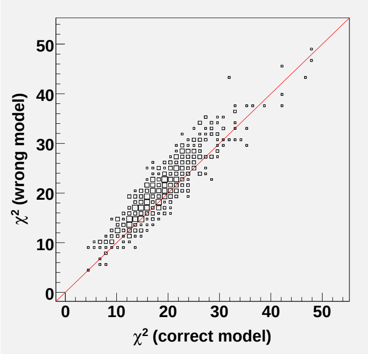
300 fb^{-1}

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 %

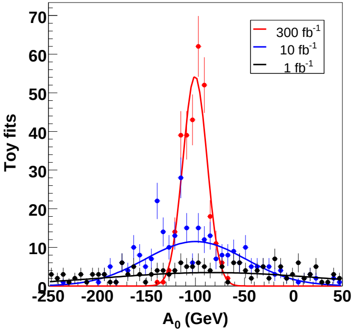
interpretation of mass edge (10 fb^{-1})

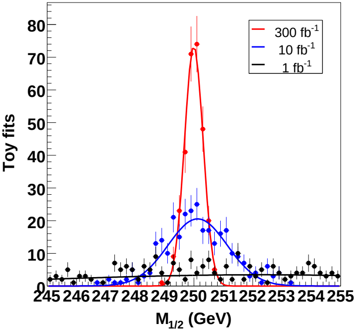
- fit wrongly identified edge in mass spectrum ($m_{\tilde{e}_R} \leftrightarrow m_{\tilde{e}_L}$)
- probability to prefer correct over wrong interpretation: 77 %

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)