ATLAS-DESY Meeting
DESY Hamburg
1st November 2007

Electroweak Fits using

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Outline

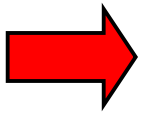
- What / Who is Gfitter?
- Why a new fit of Standard Model?
- Implementation
- Comparison with ZFitter
- Results
  - Higgs mass estimate
  - Treatment of theoretical uncertainties
  - Goodness of global fit
  - p-value of the SM at different Higgs masses
  - STU and epsilon parameters
- Summary

What is Gfitter?

- Gfitter - A Generic Fitter Project for HEP Model Testing
  http://cern.ch/Gfitter
- It is built upon ROOT
- Organized in one core statistic/fitting package, and physics plugin packages
  - SM, Two Higgs Doublet, SUSY, etc.
- Dynamic parameter caching
  - Only Recalculation of parameters when needed
- Goal: Perform fully frequentist analysis
  - Present: goodness of fit by toy-analysis
- Transparent fitting and steering card interpretation
  - Usage of XML format

What / Who is Gfitter?

- In steering card only one type of parameter
  - The chosen actions depend on whether the parameter has an associated prediction or not



This makes Gfitter a flexible tool

- We think it's very user-friendly

Who is Gfitter?

Henning Flächer (CERN)

Martin Goebel (Uni HH / DESY)

Johannes Haller (Uni HH / DESY)

Andreas Hoecker (CERN)

Klaus Mönig (DESY)

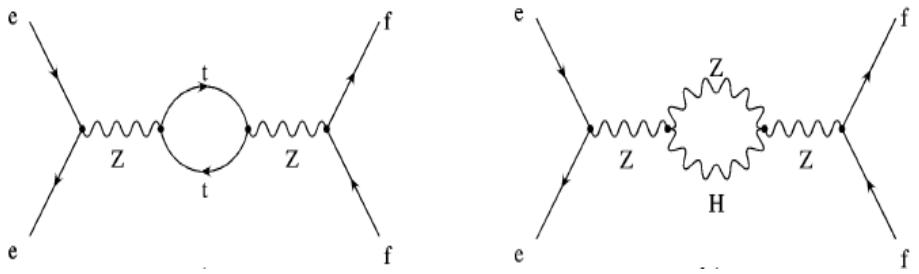
Joerg Stelzer (CERN)

Why a new fit of Standard Model?

- Testing and improving of framework with well-known theory
- Existing SM packages written in Fortran
  - Involved usage
  - Hard to change something or update the code
- Physics aim: Determination of observables which don't match well to the SM (e.g. when the Higgs is measured)
- Usage of EW fit: SM extensions, e.g. 2 Higgs doublet models

Implementation of EW Fit

- Idea: Radiative corrections give precise predictions for ew observables
- Task: Computing all ew observables with five input parameters
- We use the *on-mass-shell (OMS)* scheme (like Zfitter)
  - Complete two loop corrections incl. the known higher order QCD and QED orders for most of the observables
  - Quark masses and Fermi Constant can be varied in the Fit!



5 free parameters in the fit:

$$\Delta\alpha^{(5)}_{had}(m_Z^2), \alpha_S(m_Z^2), m_Z, m_{top}, m_H$$

Which observables are fitted?

All LEP precision measurements:

$M_Z \quad A_f \quad A_{FB}^{0,f} \quad R_f^0 \quad \sigma_{had}^0 \quad \Gamma_Z \quad \sin^2\Theta_{eff}^{lept}$

SLD measurement of the leptonic asymmetry A_{lep}

Tevatron/LEP world averages:

$M_W \quad \Gamma_W \quad m_{top}$

QED and QCD coupling constants at Z pole

$\Delta\alpha_{had}^{(5)}(M_Z) \qquad \alpha_S(M_Z)$

19 observables – 5 free parameters = 14 dof

Comparison with Zfitter

- Compared in detail the calculations of Zfitter and Gfitter
- Reproduction of Zfitter results!
- Small differences completely understood
  - Due to a different treatment of running QCD effects
  - Implementation of 4th order RGE for strong coupling constant and running quark masses

Test with identical input, i.e.

$$\Delta\alpha^{(5)}_{had}(M_Z) = 0.02758 \pm 0.00035 \quad \text{[BP'05]}$$

Gfitter: $\chi^2_{\min} = 18.0$

$M_H = 76.9 + 33.3 - 24.6$ GeV

Zfitter: $\chi^2_{\min} = 18.0$

$M_H = 76.7 + 33.2 - 24.5$ GeV

Global Standard Model Fit

We use the following best estimate for the contribution to α_{QED} at M_Z:

$$\Delta\alpha^{(5)}_{had}(M_Z) = 0.02768 \pm 0.00022 \pm 0.00066 \cdot (0.118 - \alpha_s(M_Z))^{1} \quad \text{[HMNT'07]}$$

[1]Until confirmation by the authors: dependence from α_S estimated from [Davier-Hoeker]

Results for fit parameters:

Parameter Name	Fit Value	Uncertainties		
		$\pm 1\sigma$ (sym.)	$+1\sigma$	-1σ
$\alpha_S(M_Z)$	0.1183	0.0020	0.0020	-0.0021
$\Delta^{(5)}_{had}$	0.02772	0.00022	0.00022	0.00022
M_Z	91.1875	0.0021	0.0021	-0.0021
m_{top}	171.27	1.79	1.80	-1.79
M_H	75.1	25.7	29.6	-22.4

$$\chi^2_{\min} / dof = 17.9/14$$

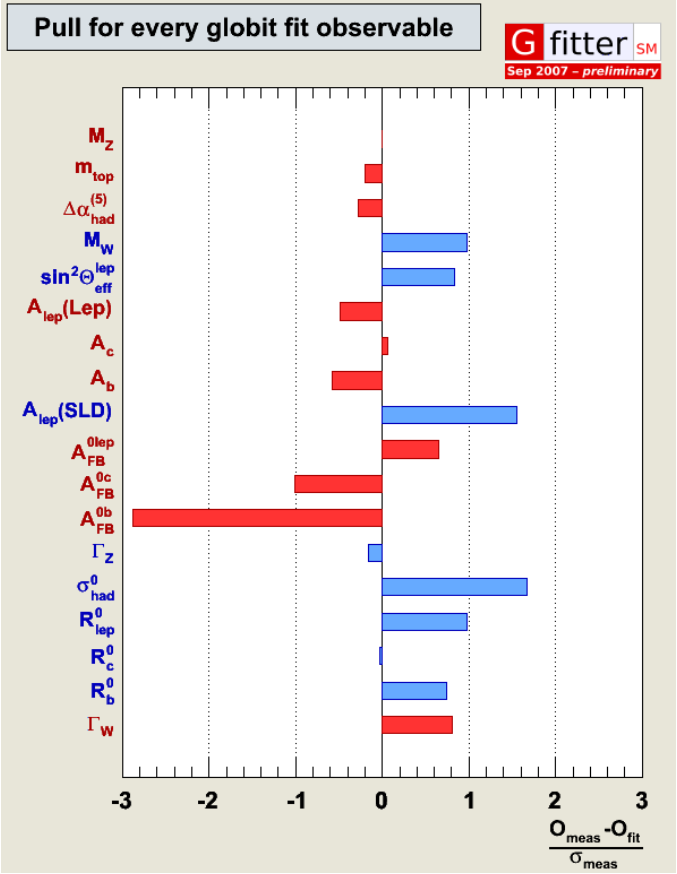
Correlation matrix:

	$\alpha_s(M_Z)$	$\Delta\alpha^{(5)}_{had}$	M_Z	m_{top}	M_H
$\alpha_s(M_Z)$	1	0.206	-0.016	0.020	-0.020
$\Delta\alpha^{(5)}_{had}$		1	-0.005	-0.002	-0.375
M_Z			1	-0.025	0.099
m_{top}				1	0.426
M_H					1

$$M_H = 75.1 + 29.6 - 22.4 \text{ GeV}$$

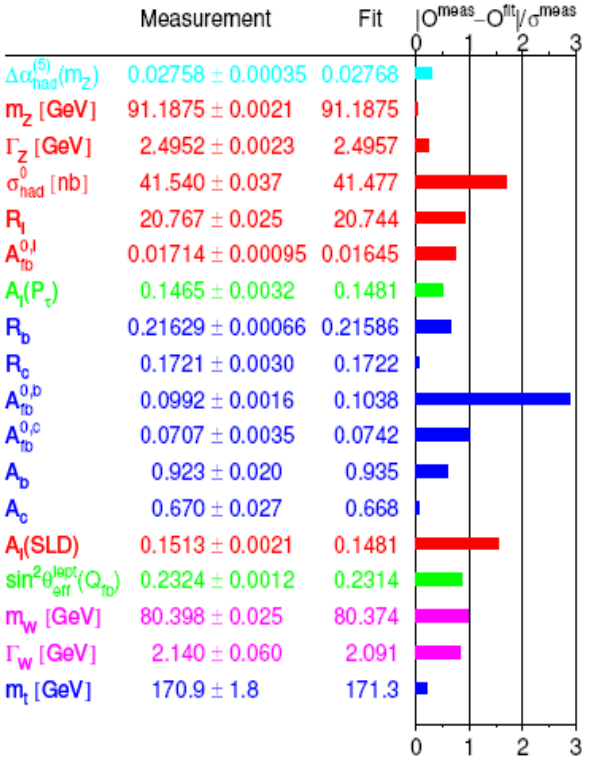
Comparison with Zfitter

Gfitter



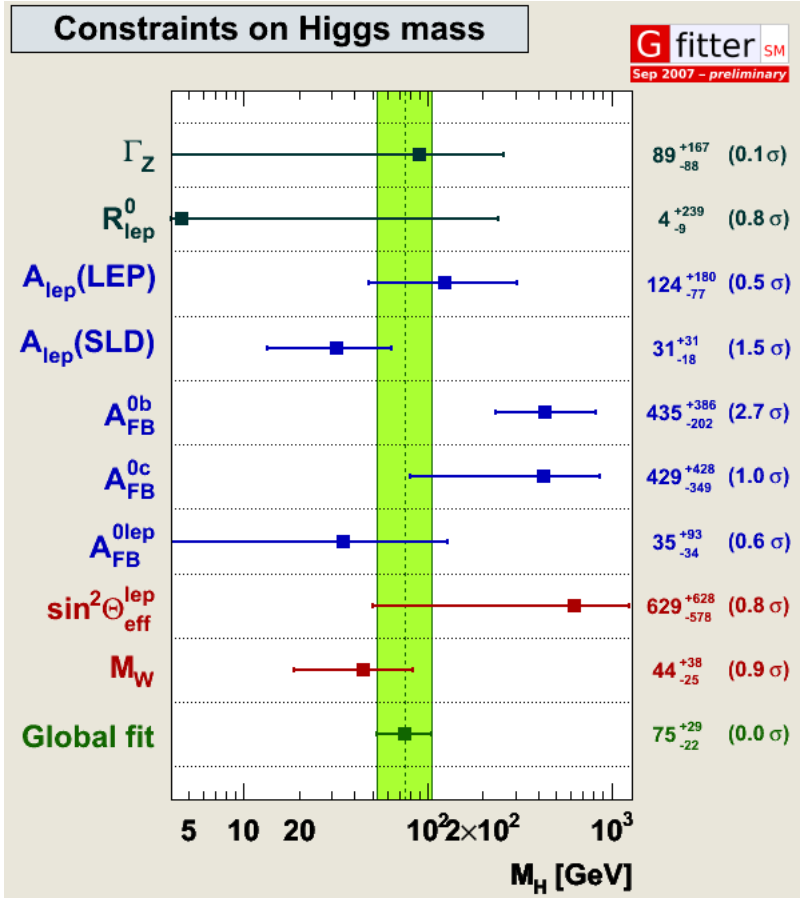
Observable	Measurement	Fit Value
M_Z	91.175 ± 0.0021	91.1875
m_{top}	170.9 ± 1.9	171.3
$\Delta\alpha^{(5)}_{had}$	0.02758 ± 0.00035	0.02768
M_W	80.398 ± 0.025	80.374
$sin^2\Theta^{lep}_{eff}$	0.2324 ± 0.0012	0.2314
$A_{lep}(LEP)$	0.1465 ± 0.0033	0.1481
A_c	0.670 ± 0.027	0.668
A_b	0.923 ± 0.020	0.935
$A_{lep}(SLD)$	0.1513 ± 0.00207	0.1481
A^{0lep}_{FB}	0.0171 ± 0.0010	0.0164
A^{0c}_{FB}	0.0707 ± 0.0035	0.0742
A^{0b}_{FB}	0.0992 ± 0.0016	0.1038
Γ_Z	2.4952 ± 0.0023	2.4956
σ^0_{had}	41.54 ± 0.037	41.478
R^0_{lep}	20.767 ± 0.025	20.743
R^0_c	0.1721 ± 0.00030	0.1722
R^0_b	0.21629 ± 0.000066	0.21580
Γ_W	2.140 ± 0.06	2.091

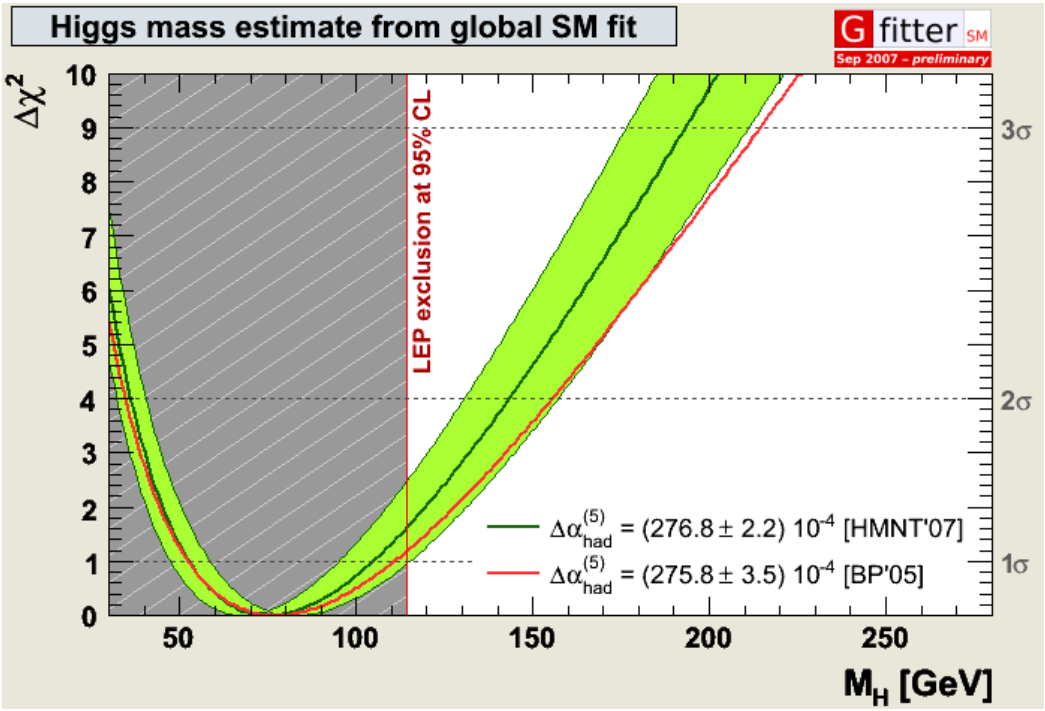
Zfitter



Exact reproduction, up to differences that are understood!

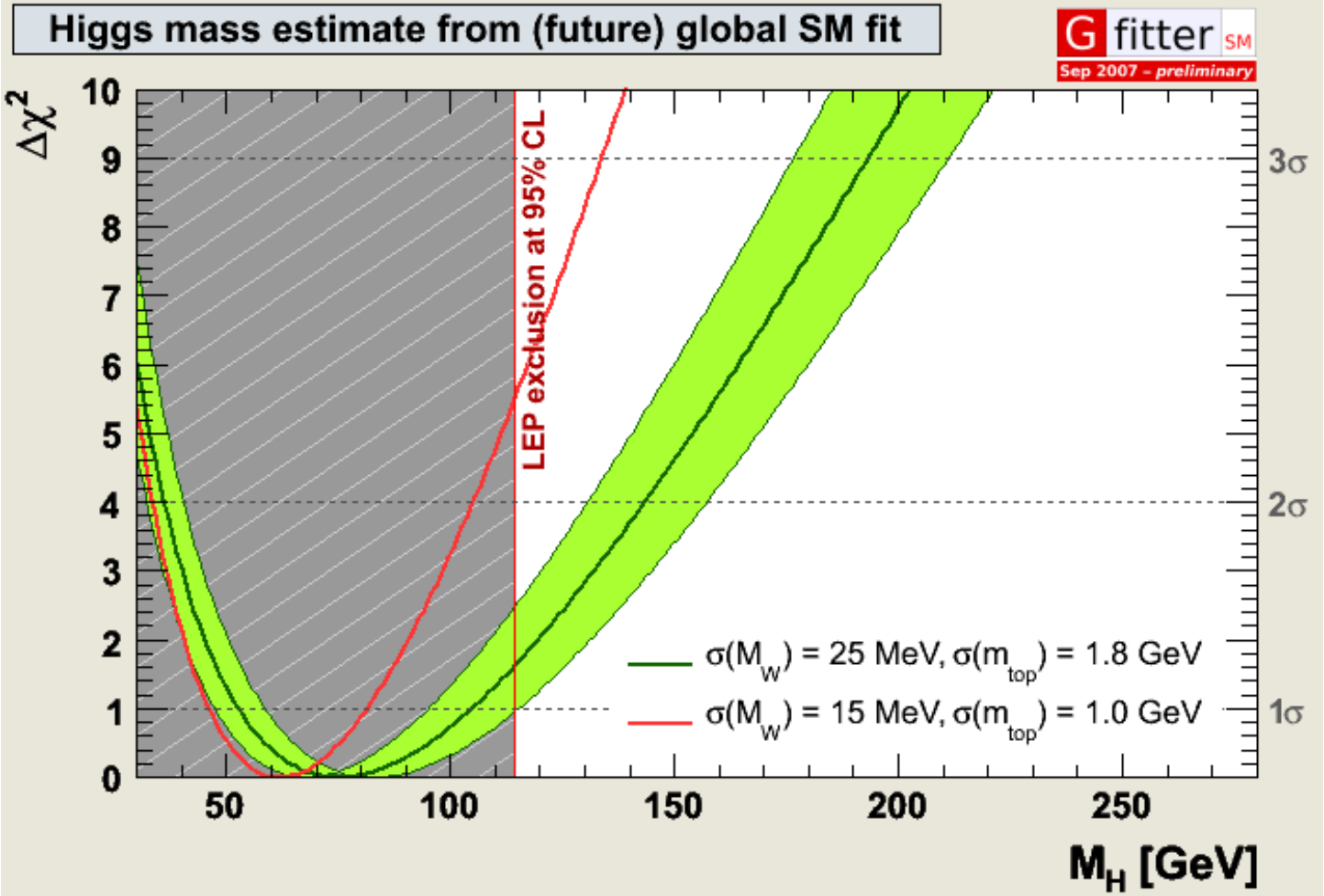
Higgs mass scan





Precision measurements from LHC

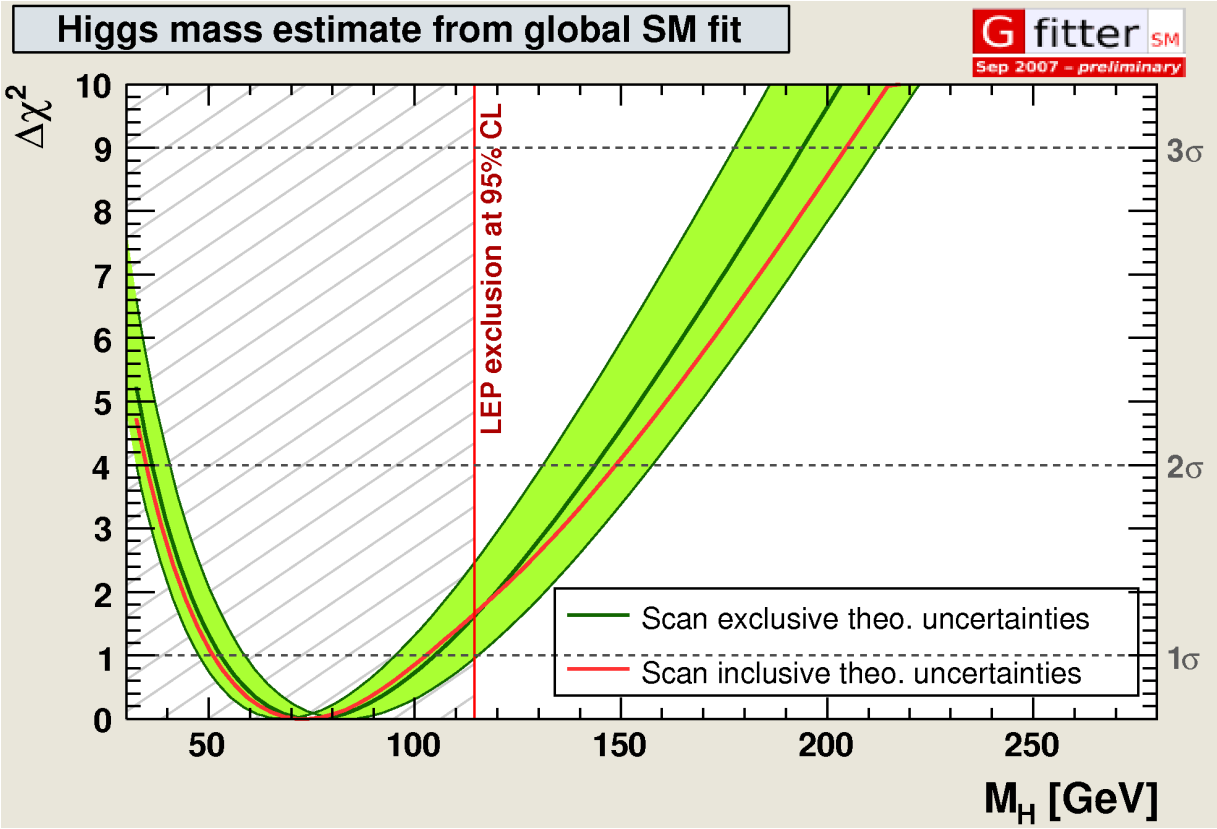
Estimates for top and W mass errors



Band vs. inclusive theo. uncertainties

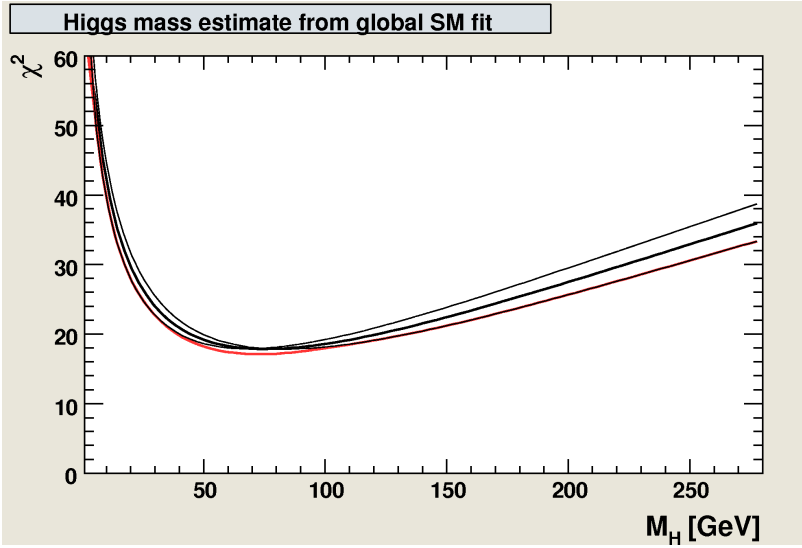
Uncertainties for Theory-Prediction (two main sources)

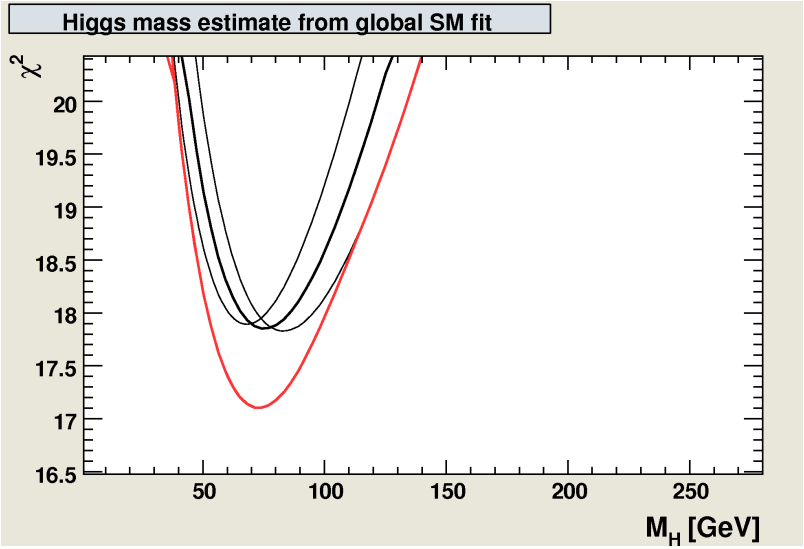
$$M_W \pm \Delta M_W(theo) \qquad \sin^2\Theta^{lept}_{eff} \pm \Delta\sin^2\Theta^{lept}_{eff}(theo)$$



Green band was done by shifting the predictions by these uncertainties redoing the scan and choosing the worst cases

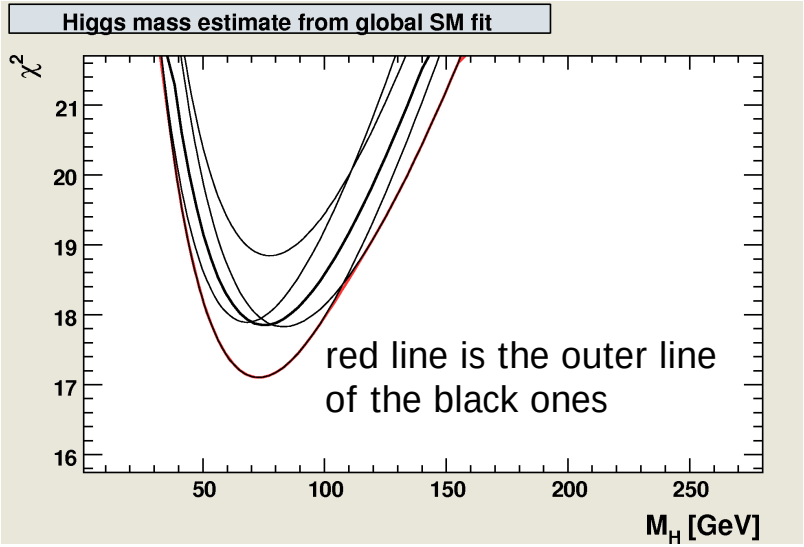
Treatment of theo. uncertainties





Idea: Treat the theoretical errors as Fit-Parameters which are varied in the Fit/Scan (red line)

Old: Predictions are shifted by the the theoretical errors, many possibilities (black lines)

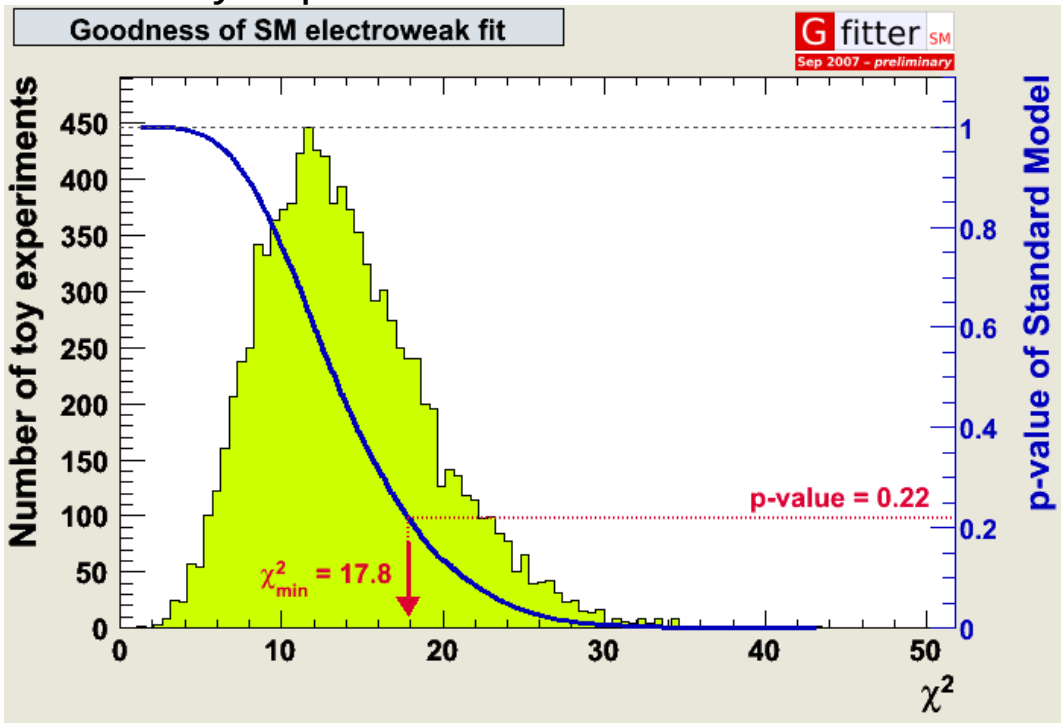


Goodness of global fit

by using toy analysis

- Execute the SM fit
- Generate toy sample by random sampling from Gaussian distributions around initial fit results (Correlations are taken into account)
- Refit with new values for observables, achieve a new χ^2

10000 toy experiments



p-value: Probability for getting a χ^2 larger than the χ^2 of the fit

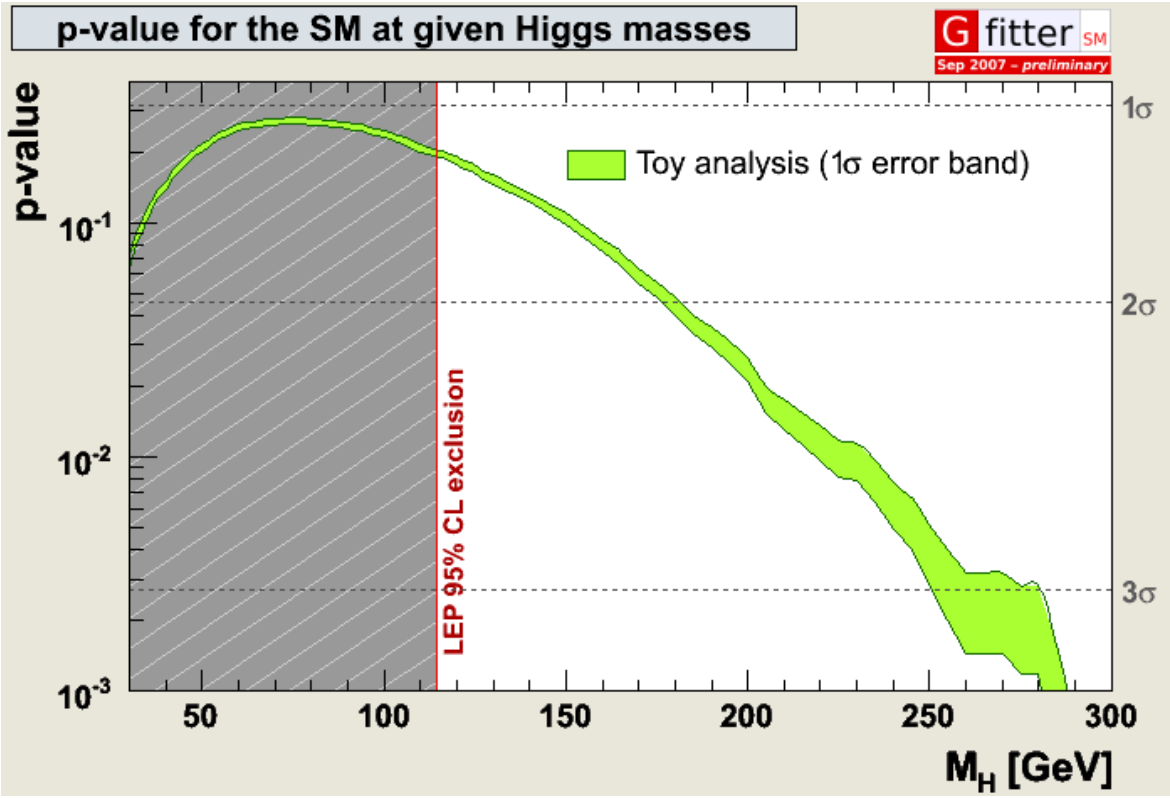
$$p-value \approx 0.22$$

Comparison with ROOT function TMath::Prob(chi2,dof)

$$Prob(17.85,14) \approx 0.21$$

p-value vs. Higgs mass

What is the p-value for electroweak fit
for given Higgs masses (negligible errors)?



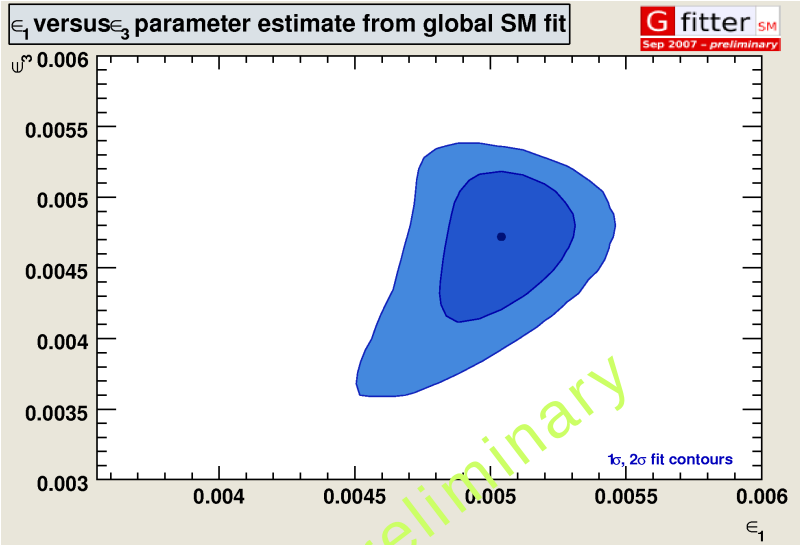
- Compute p-values for fixed Higgs masses using toy-experiment method
- Here: p-value is greater than for a fit with free

  Higgs mass
  - Only 4 degrees of freedom
  - Higgs mass fixed

Epsilon and STU parameters

Epsilon parameters vanish when only pure QCD and QED corrections are taken into account

"Goodness" of the fit and can indicate New Physics



STU parameters:

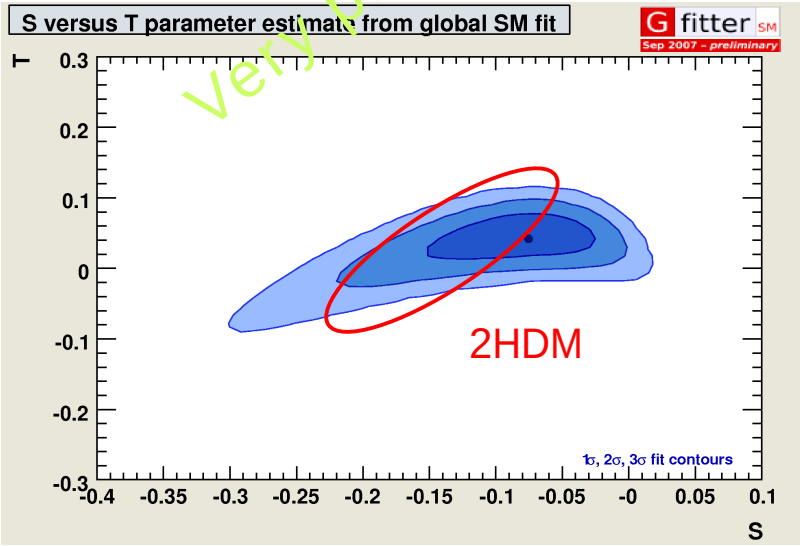
- include all higher order corrections
- related to a reference point (S=T=U=0)

$\Delta\alpha^{(5)}_{had}(M_Z) = 0.02768$ $\alpha_S(M_Z) = 0.118$

$M_Z = 91.1875\ GeV$ $m_{top} = 170.9\ GeV$

$M_H = 170\ GeV$

Can be compared with New Physics models



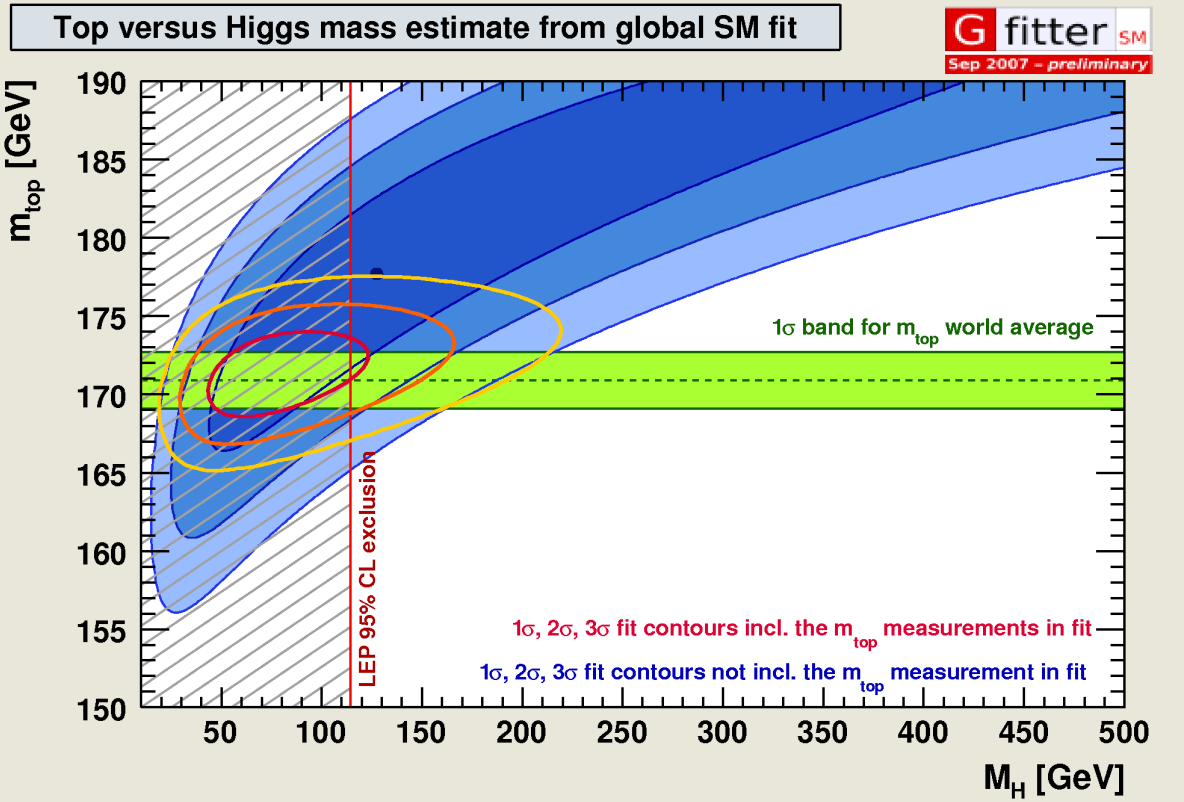
Summary

- Gfitter is very user friendly
- Provides a lot of analysis-tools
- The SM package of Gfitter reproduces the results of Zfitter
  - Because of the C++ environment the SM package is well-organized
  - Easy to use, change or update
- Different treatment of theoretical uncertainties for the theory predictions
- Goodness of Fit: p-value, STU and epsilon parameters
- Next steps: Two Higgs Doublet Models
- Additional information to Gfitter and SM fit can be found on:

http://cern.ch/Gfitter

Additional Information

top mass vs. Higgs mass



- When top mass excluded: allowed band rather big
- For large top masses larger Higgs masses are allowed
- Good constraint if top mass is included
- Looking forward to precise top measurements from ATLAS

Two dimensional scans