ATLAS-D Meeting

DESY Zeuthen

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Electroweak Fits using

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Outline

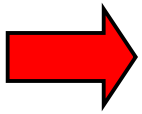
- What / Who is Gfitter?
- Why a new fit of Standard Model?
- Implementation
- Comparison with Zfitter
- Results
  - Higgs mass estimate
  - Goodness of global fit
  - p-value of the SM at different Higgs masses
  - Two-dimensional scans
- Summary

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)

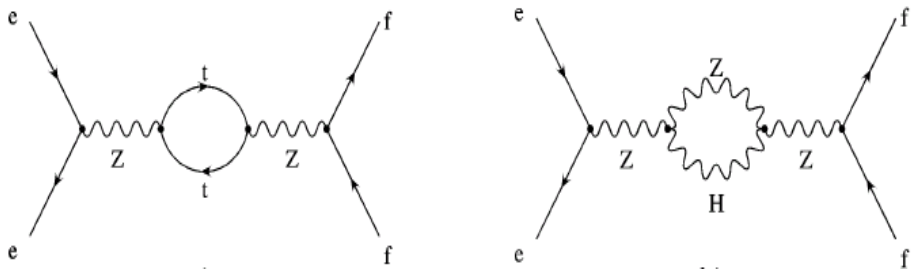
Joerg Stelzer (CERN)

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
  - Present: Quark masses and Fermi constant are fixed



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

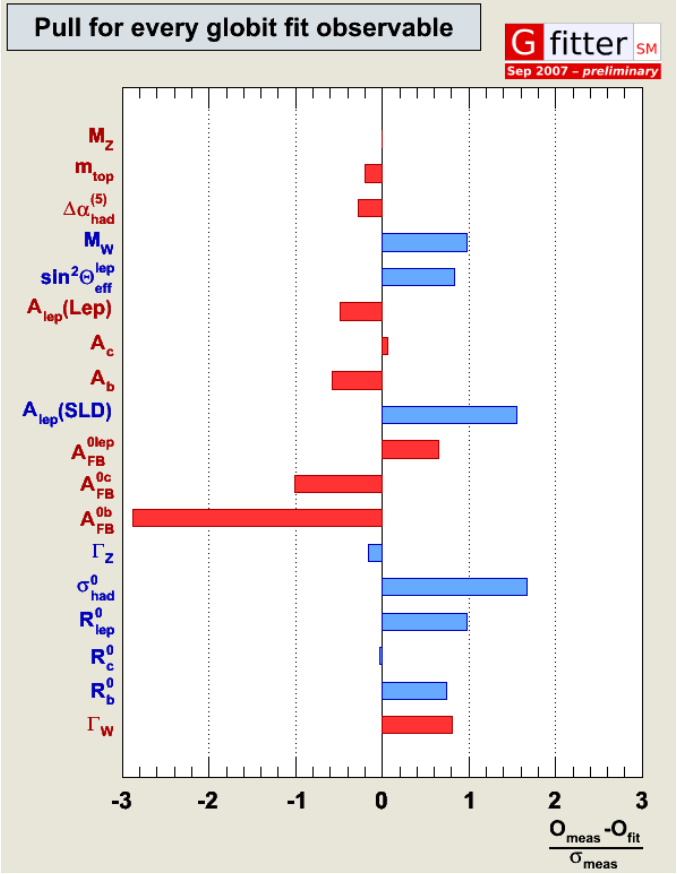
$M_H = 76.9 + 33.3 - 24.6$ GeV

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

$M_H = 76.7 + 33.2 - 24.5$ GeV

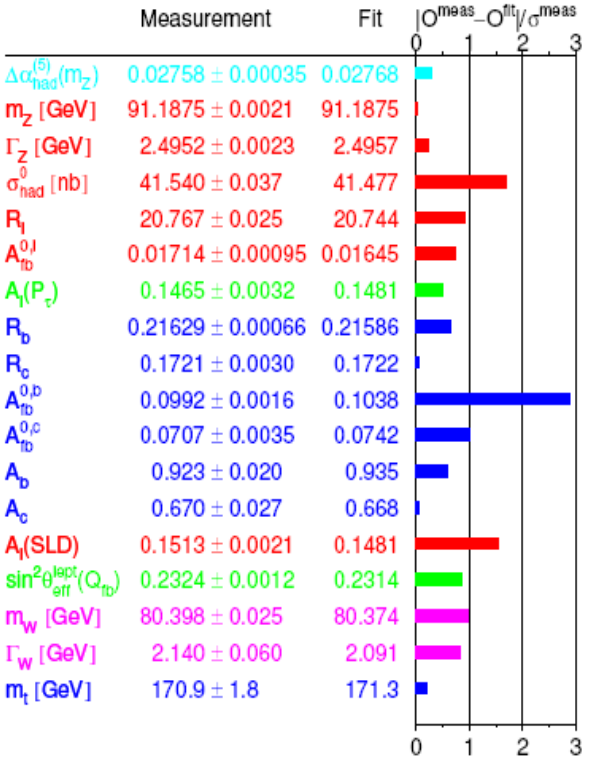
Comparison with Zfitter

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!

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

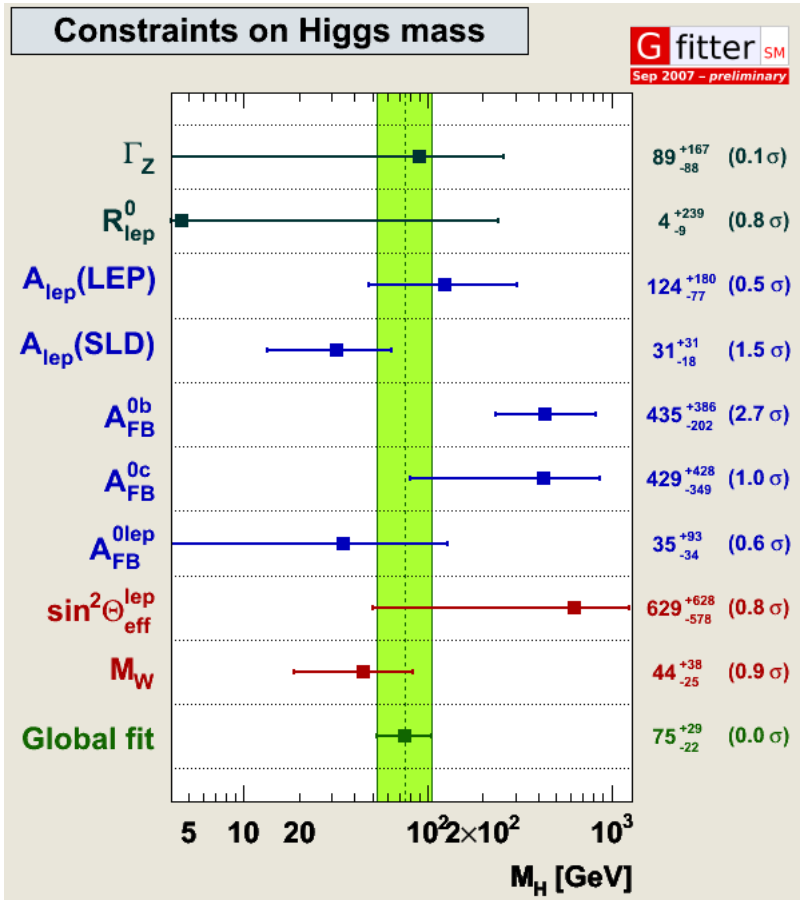
$$\chi^2_{\min} / dof = 17.9/14$$

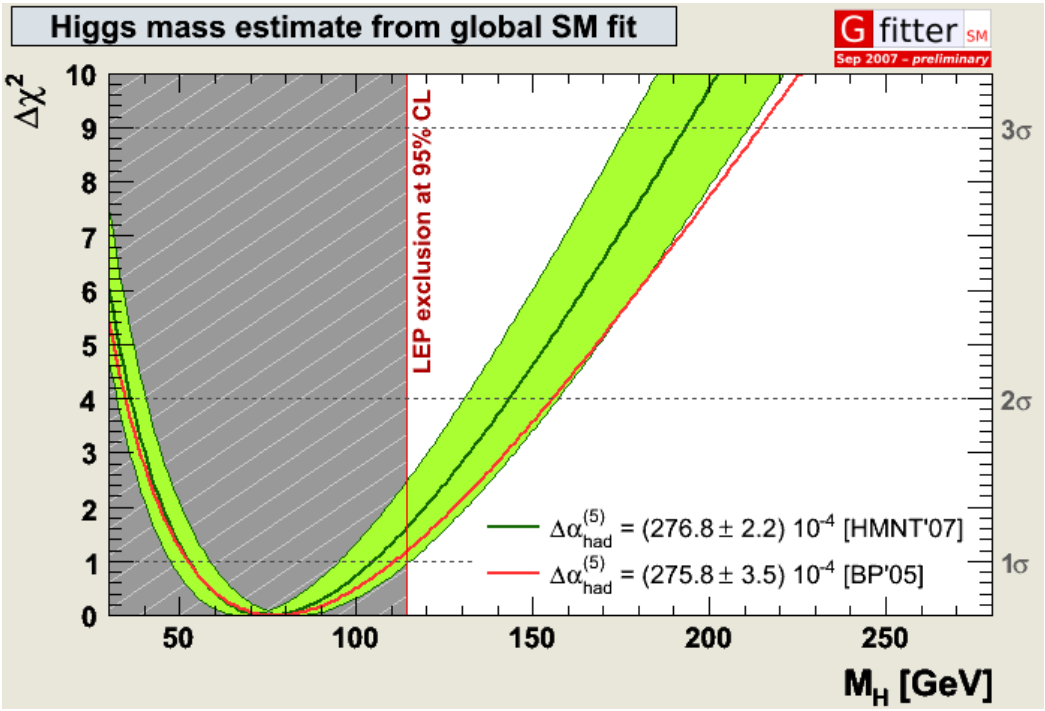
Correlation matrix:

	$\alpha_s(M_Z)$	$\Delta\alpha^{(5)}_{had}$	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

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

Higgs mass scan





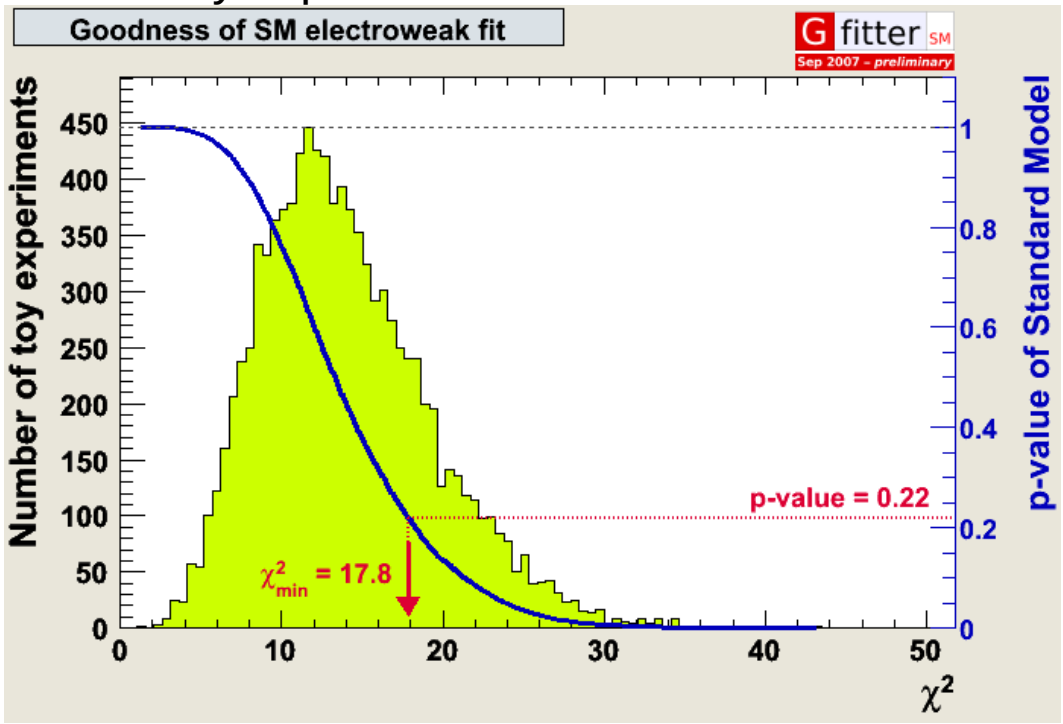
$M_H \leq 165$ GeV within 2σ limit

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

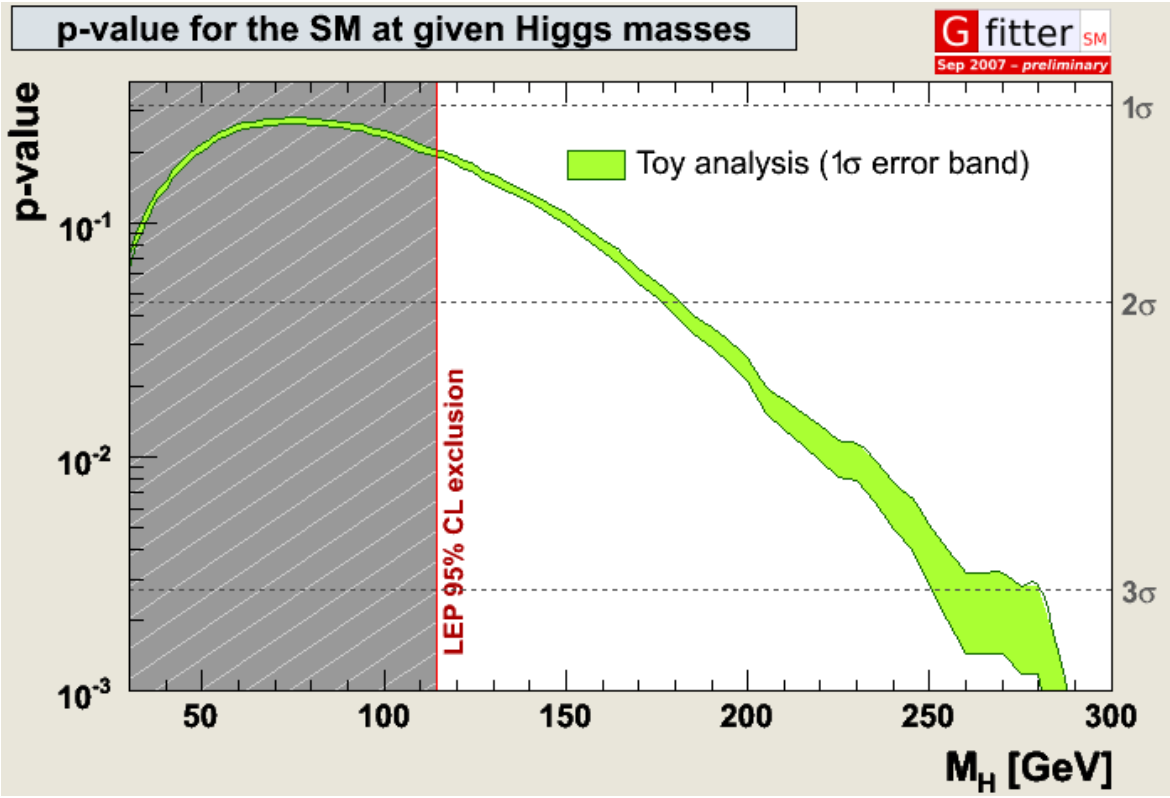
$$p-value \approx 0.22$$

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

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

p-value vs. Higgs mass

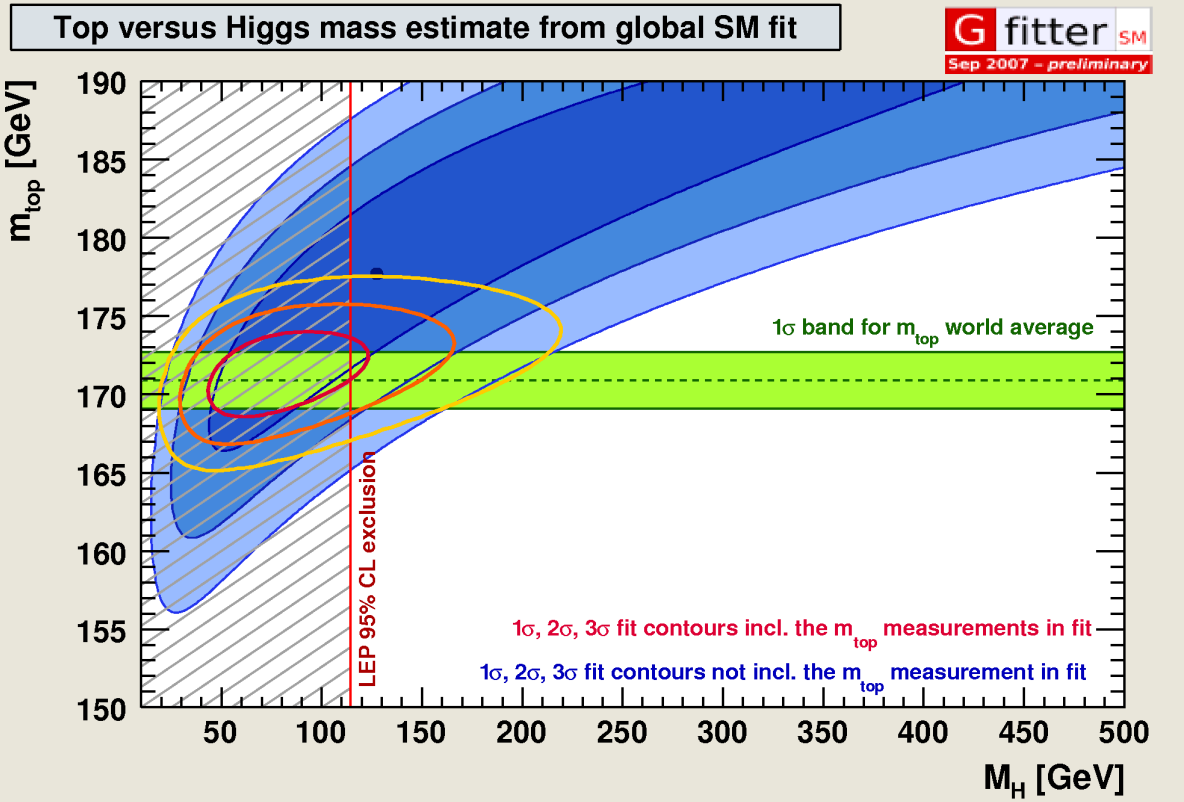
What is the p-value for electroweak fit
for given Higgs masses (negligible errors)?



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

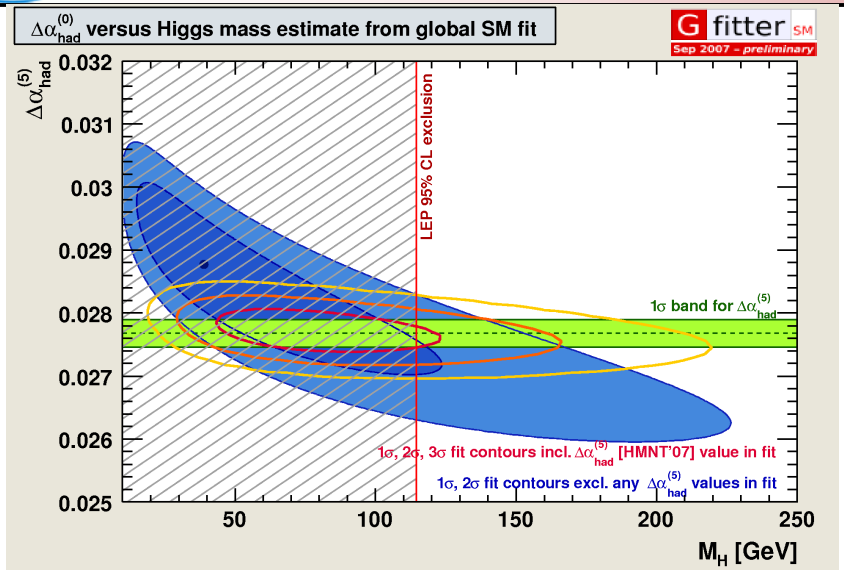
  Higgs mass
  - Only 4 degrees of freedom
  - Higgs mass fixed

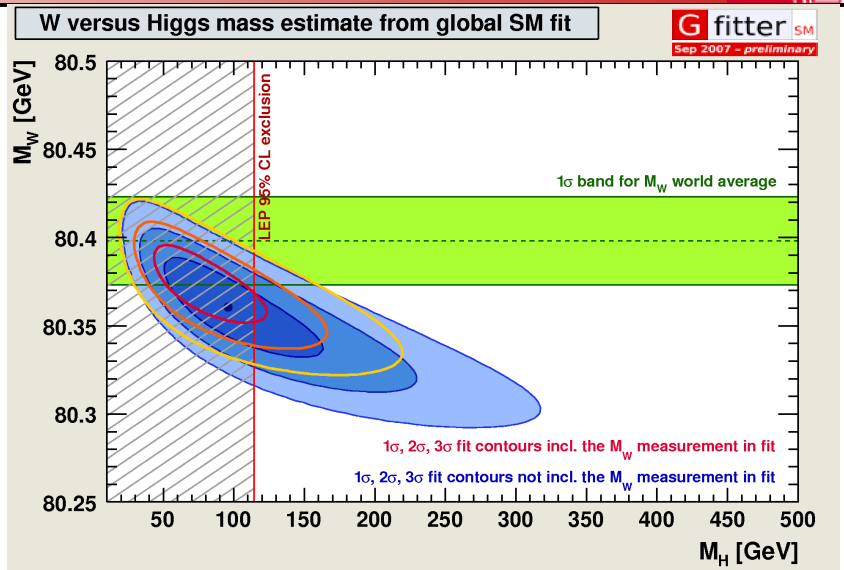
top mass vs. Higgs mass

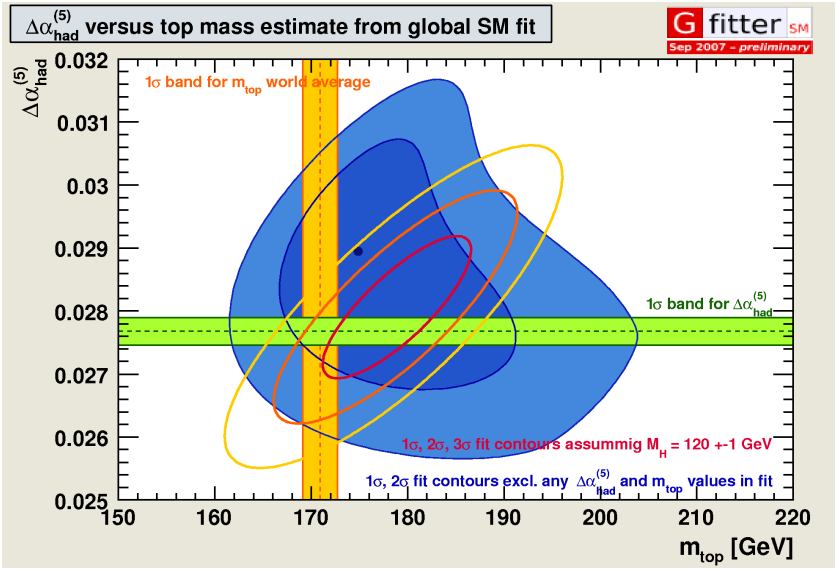


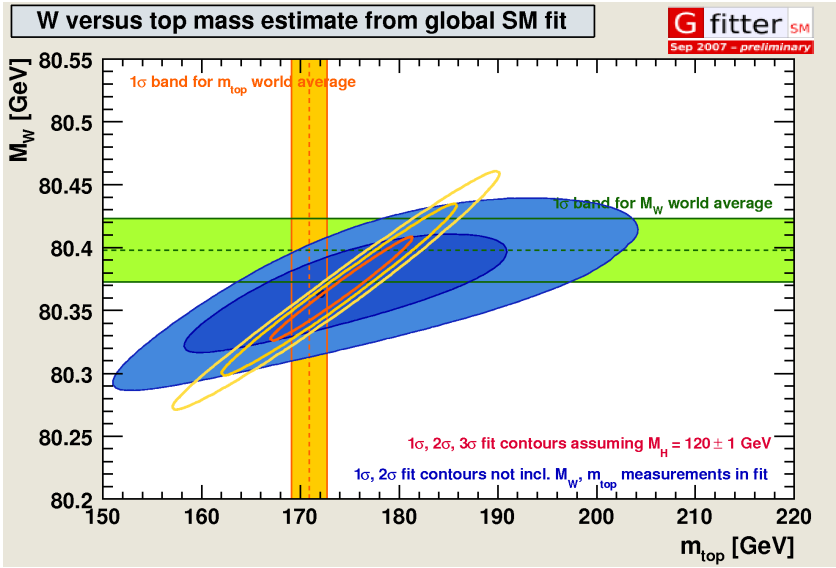
- When top mass excluded: allowed band rather big
- For large top masses larger Higgs masses are allowed
- Good constraint if top mass is included
- Looking forward to precise top measurements from ATLAS

Two dimensional scans









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
- p-value of SM fit from toy-analysis is 0.22
- Next steps: Two Higgs Doublet Models
- Additional information to Gfitter and SM fit can be found on:

http://cern.ch/Gfitter

Precision measurements from LHC

Estimates for top and W mass errors