The Global Electroweak Fit and Constraints on New Physics

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for the Gfitter group*

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Introduction to G fitter - A Generic Fitter Project

Goal: provide state-of-the-art model testing tool for LHC era

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- electroweak precision measurements from **LEP, SLD, TeVatron**
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- C++, ROOT, xml
- full statistics analysis (parameter scans, p-values, MC analyses, goodness-of-fit tests)

Gfitter SM   Gfitter 2HDM   Gfitter BSM

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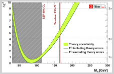
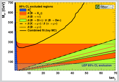
3. Physics Results

- **global electroweak fit** $\Rightarrow$ constraints on M_H
- determination of α_s



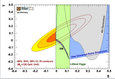
Talk: 313 - M. Goebel - "Status of global fit to ew precisions data, constraints on Higgs boson"

- constraints on $M_{H\pm}$ and $\tan\beta$ in **2HDM**
- observables: K and B sector



Please refer to the main publication

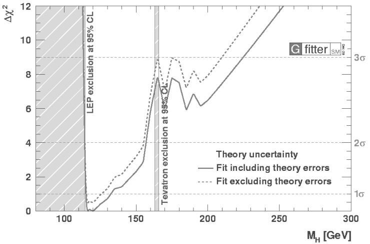
- constraints on **BSM physics** using the oblique parameters



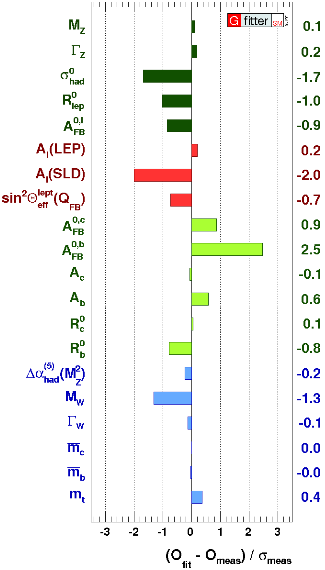
$\Rightarrow$ **Topic of this talk**

Main publication: EPJ C60, 543-583,2009 [arXiv:0811.0009]
http://www.cern.ch/Gfitter

The Electroweak Fit with Gfitter



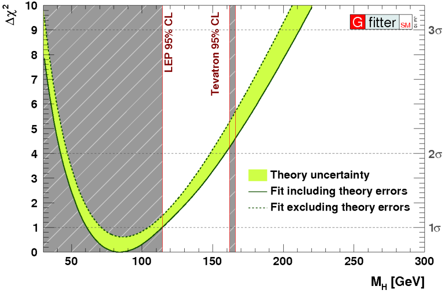
The Electroweak Fit I: SM Fit Results



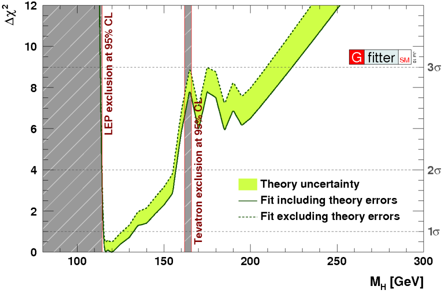
- input: usage of latest experimental results of electroweak precision observables
  - incl. direct Higgs searches (LEP, Tevatron)
  - incl. latest average of m_t =173.3±1.1 GeV (arXiv:1007.3178)
- floating fit parameters: M_Z, M_H, m_t, $\Delta\alpha^{(5)}_{had}(M_Z^2)$, $\alpha_S(M_Z^2)$, $\bar{m}_c$, $\bar{m}_b$
- goodness-of-fit:
  - **excl. direct Higgs searches:** $\chi^2_{min} = 16.4$ $\Rightarrow$ Prob(χ^2_{min},13) = 0.23
  - **incl. direct Higgs searches:** $\chi^2_{min} = 17.8$ $\Rightarrow$ Prob(χ^2_{min},14) = 0.22
- pull values (incl. direct Higgs searches)
  - no individual pull exceeds 3σ
  - $A^{0,b}_{FB}$ largest contributor to χ^2_{min}
  - small contributions from M_Z, $\Delta\alpha_{had}(M_Z)$, m_c, m_b: their input accuracies exceed fit requirements

The Electroweak Fit II: Constraints on Higgs mass

- M_H from fit including all data except results from direct Higgs searches at LEP, Tevatron
  - value at minimum $\pm 1\sigma$: $M_H = 83^{+30}_{-23}$ GeV
  - 2σ interval: [42, 159] GeV

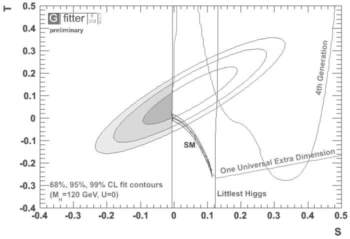


- M_H from fit also including results from direct Higgs searches at LEP, Tevatron
  - value at minimum $\pm 1\sigma$: $M_H = 119.1^{+13.5}_{-4.0}$ GeV
  - 2σ interval: [114, 157] GeV



$\Rightarrow$ **in SM: light Higgs preferred**

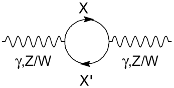
Constraints on New Physics Models



BSM Constraints using the oblique parameters I

[Peskin and Takeuchi, Phys. Rev. D46, 1 (1991)]

1. **assumption**: high-scale BSM physics appears only through **vacuum polarisation corrections** (cf. rad. corr. from m_t, M_H in SM)



2. ew fit sensitive to BSM physics through these **oblique corrections**

3. oblique corrections from New Physics described through **STU parametrization**

$$O_{meas} = O_{SM,ref}(M_H, m_t) + c_S S + c_T T + c_U U$$

4. STU measure deviations from electroweak radiative correction expected in SM_{ref}

- S: new physics contribution to **neutral current processes**
- U: (+S) new physics contribution to **charged current processes**
  - U only sensitive to M_W and Γ_W
  - usually very small in new physics models (often: U=0)
- T: **difference** between neutral and charged current processes (sensitive to **weak isospin violation**)

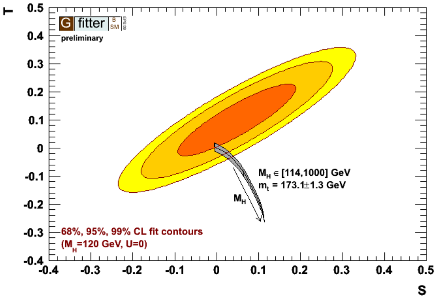
BSM Constraints using the oblique parameters II

- S, T, U derived from fit to electroweak observables
  - SM_{ref} chosen at $m_t = 173.1$ GeV, $M_H = 120$ GeV
- **results** for STU and correlation matrix:

$S = 0.02 \pm 0.11$
$T = 0.05 \pm 0.12$
$U = 0.07 \pm 0.12$

	S	T	U
S	1	0.879	-0.469
T		1	-0.716
U			1

- grey area: SM prediction
  - for SM_{ref}: $S = T = U = 0$
- S, T: logarithmically dependent on M_H
- comparison of data and SM prediction:
  - small M_H compatible with data
  - no need for new physics



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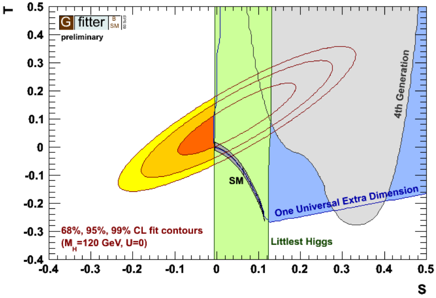
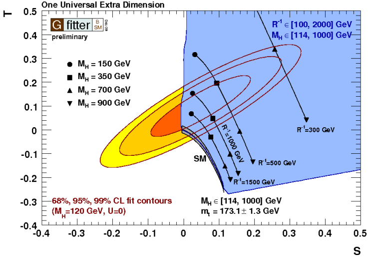
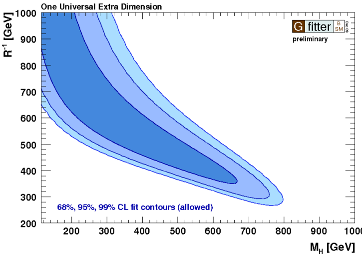


- other models also compatible with the data
  - UED, 4^{th} fermion generation, Littlest Higgs, ...
  - variation of the free parameters allows for large area in ST-plane
  - for some parameter values: large M_H allowed (compensation of effects)

One Universal Extra Dimensions

[Appelquist et al., Phys. Rev. D67 055002 (2003)] [Gogoladze et al., Phys. Rev. D74 093012 (2006)]





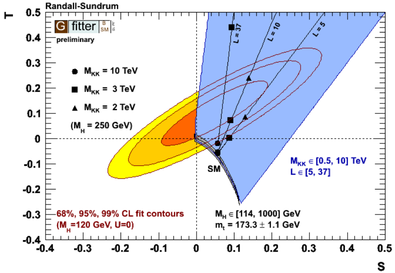
- all SM particles can propagate into ED
- compactification
  $\Rightarrow$ Kaluza-Klein (KK) modes
- conservation of Kaluza-Klein parity
  - similar phenomenology as SUSY
  - lightest KK state stable: CDM
- free parameters of UED model
  - d_{ED}: number of ED (fixed to one)
  - R^{-1}: compactification scale (1/size of extra dimension, $m_{KK} \sim n/R$)

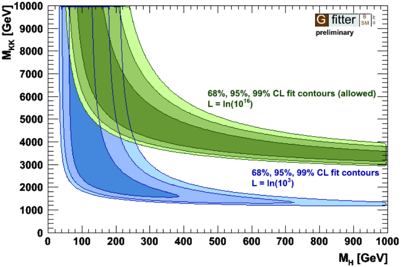
- contribution to vac. polarisation (STU):
  - from KK-top/bottom, KK-Higgs loops
  - dependent on R^{-1}, M_H, m_t
- **results:**
  - large R^{-1}: UED approaches SM (exp.), only small M_H allowed
  - small R^{-1}: UED contribution compensated by large M_H
  - excl.: R^{-1}<300 GeV, M_H>800 GeV

Warped Extra Dimensions

[L.Randall, R.Sundrum, Phys. Rev. Lett. 83, 3370 (1999)],[S. Casagrande et al., JHEP10(2008)094]

- introducing one extra dimension (ED) for solving the **hierarchy problem**
- RS model characterized by one warped ED confined by two three-branes
- one brane contains SM particles
- extension: SM particles allowed to propagate in bulk region
- each SM fermion accompanied by two towers of **heavy KK modes**
- free **parameters**
  - M_{KK}: KK scale
  - L: inverse warp factor, function of compactification radius, explaining big observed hierarchy
- **results:**
  - large L requires large M_{KK}
  - compensation if M_H is large

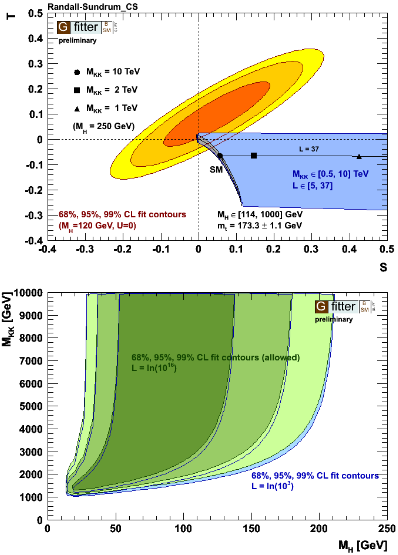




Warped Extra Dimensions with custodial symmetry

[K.Agashe, A.Delgado, M.May, R.Sundrum, , JHEP0308, 050 (2003)],[S. Casagrande et al., JHEP10(2008)094]

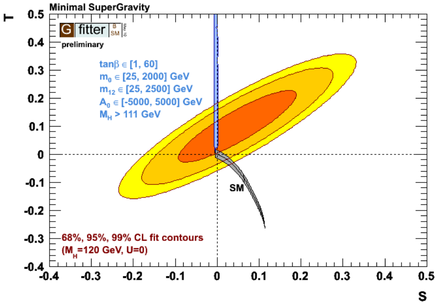
- goal: avoid large T values
- introducing so-called **custodial isospin gauge symmetry** in the bulk
- extension of the hypercharge group to $SU(2)_R \times U(1)_X$
- bulk symmetry group: $SU(3)_C \times SU(2)_L \times SU(2)_R \times U(1)_X$ broken to $SU(3)_C \times SU(2)_L \times U(1)_Y$ on UV brane
- IR brane $SU(2)_R$ symmetric
- right handed fermionic fields occur in doublets
- **results:**
  - almost completely ruled out
  - only small M_H allowed



MSUGRA I

[G. Weiglein: arXiv:hep-ph/9712226v1][S. Heinemeyer, W. Hollik, G. Weiglein: arXiv:hep-ph/0412214v1]

- **Supersymmetry** may solve many shortcomings of the SM (hierarchy problem, unification of coupling constants, DM candidate)
- mSUGRA: highly constraining **breaking mechanism** at GUT scale
- breaking mediated by **gravitational interaction**



- determined by **5 parameters**
  - $m_{1/2}$: mass of fermions at GUT scale
  - m_0: mass of scalar particles at GUT scale
  - $\tan\beta$: ratio of the two Higgs vacuum expectation values
  - A_0: trilinear coupling of the Higgs
  - sgnμ: sign of Higgsino mass term
- radiative corrections dominated by **weak isospin violation** between $m_{\tilde{b}1}$, $m_{\tilde{t}1}$ and between $m_{\tilde{t}1}$, $m_{\tilde{t}2}$
- by construction of the oblique parameters ⇒ T dominant parameter

Softsusy - [B.C. Allanach, Comput. Phys. Commun. 143 (2002) 305-331]
Feynhiggs - [M. Frank et al., JHEP0702:047,2007]
SuperIso - [F. Mahmoudi, JHEP12 (2007), 026]
microMegas - [G. Bélanger et al., IRFU-10-24, LAPTH-012-10]

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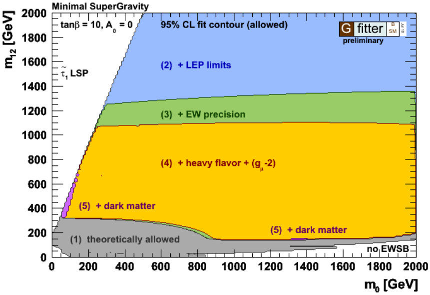

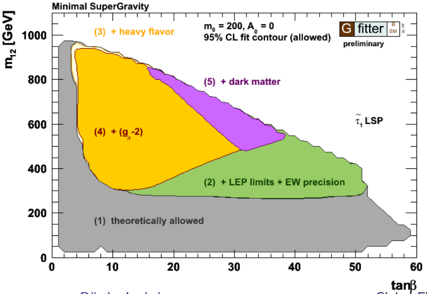

- low m_0 (and large $\tan\beta$) area excluded by requiring a **non-charged LSP**
- limits on m_0, $m_{1/2}$, $\tan\beta$ by including in the fit
  - (2) LEP limits on the Higgs mass, on neutralinos and sleptons
  - (3) electroweak precision observables (STU)
  - (4) constraints from $(g_\mu - 2)$ and from heavy flavor physics
  - (5) from the relic density
- 95% CL fit contours of the allowed regions are shown

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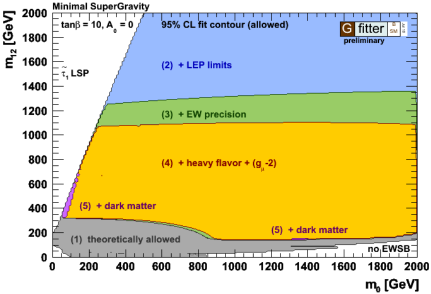

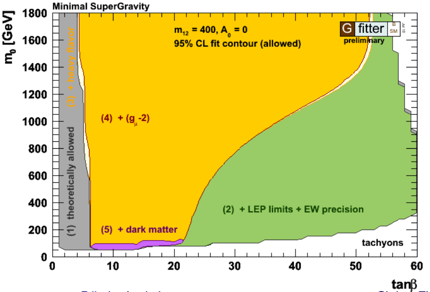

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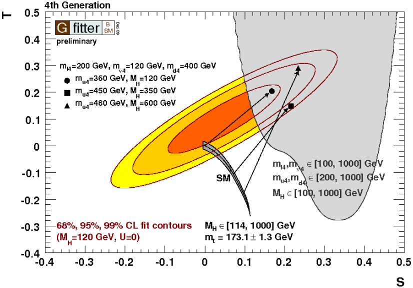
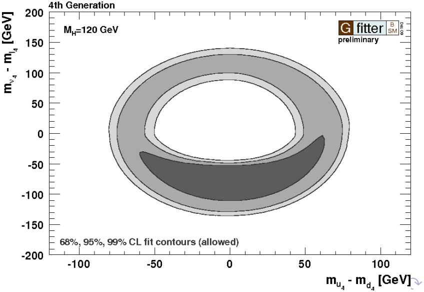
Fourth Family

[Hubisz et al., JHEP 0601:135 (2006)]

- models with a fourth generation
  - SM: no explanation for n=3 generations
  - introduction of new states for leptons and quarks ($\Psi_L = (\Psi_1, \Psi_2)_L, \Psi_{1,R}, \Psi_{1,R}$)
- free parameters:
  - masses of new quarks and leptons m_{u_4}, m_{d_4}, m_{e_4} m_{ν_4}
  - assuming: no mixing of extra fermions
  - model-independent
- contribution to STU from new fermions
- sensitivity to mass difference between up-type and down-type fields, not to absolute mass scale
- **results:**
  - with appropriate mass differences: 4^{th} fermion model consistent with data
  - large M_H is allowed
  - data prefer a heavier charged lepton





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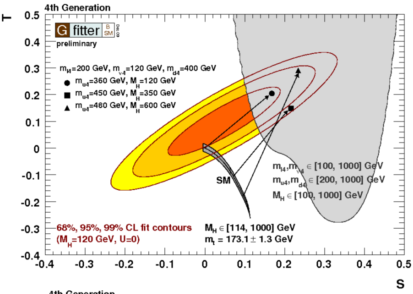

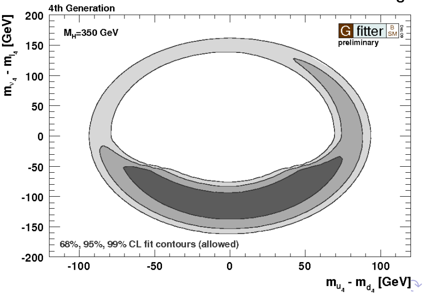

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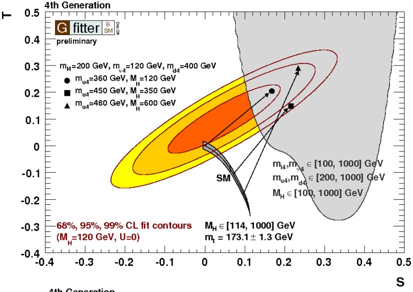

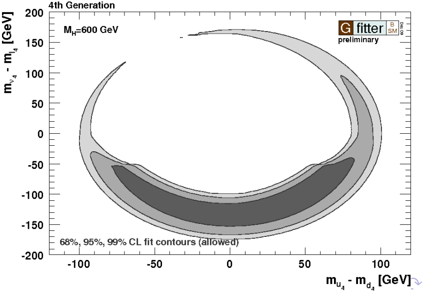

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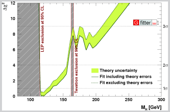

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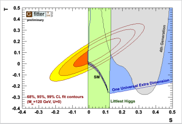
- heavier Higgs boson allowed in various BSM models



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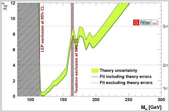

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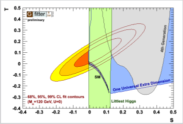

Outlook

- further development of the electroweak fit in line with experimental and theoretical progress ⇒ inclusion of Tevatron updates and of course LHC results !!
- extension of the oblique parameter fit (STU), the 2HDM fit
- further development of the SUSY fit

http://www.cern.ch/Gfitter

Thank you for your attention!

Backup Slides

Warped Extra Dimensions

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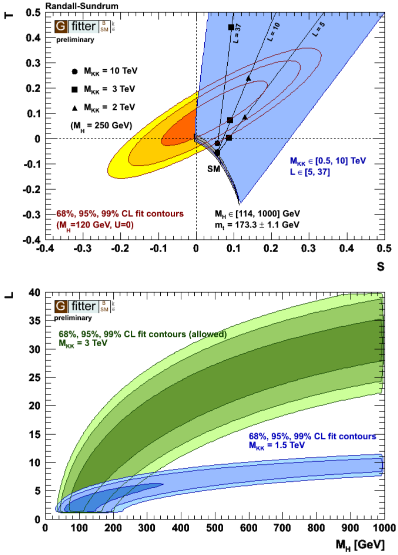

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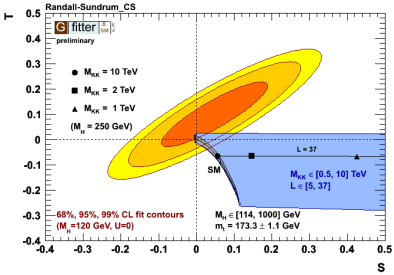
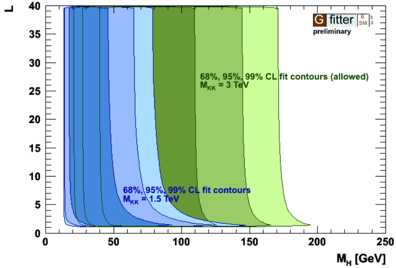
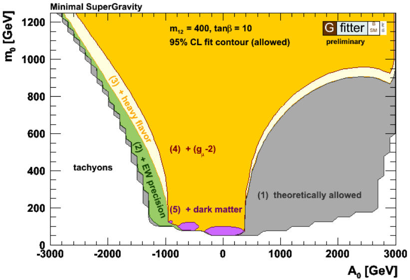
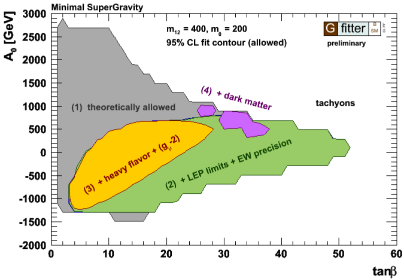


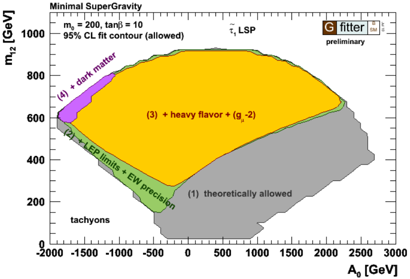


MSUGRA III

[G. Weiglein: arXiv:hep-ph/9712226v1][S. Heinemeyer, W. Hollik, G. Weiglein: arXiv:hep-ph/0412214v1]







- limits on m_0, $m_{1/2}$, $\tan\beta$, A_0 by including in the fit
  - LEP limits on the Higgs mass, on neutralinos and sleptons
  - electroweak precision observables (STU)
  - constraints from $(g_\mu - 2)$ and from heavy flavor physics
  - from the relic density
- 95% CL fit contours of the allowed regions are shown

Littlest Higgs

- Higgs pseudo-Nambu-Goldstone boson
- new fermions and new gauge bosons
  - two new top states (T-odd m_{T-}, T-even m_{T+})
  - LH solves hierarchy problem (new particles cancel SM loops)
- T-parity
  - provide dark matter candidate
  - forbids tree-level contribution from heavy gauge bosons to SM observables

- parameters of LH model
  - f: symmetry breaking scale
  - $s_\lambda \cong m_{T-}/m_{T+}$
- **results:**
  - large M_H can be allowed
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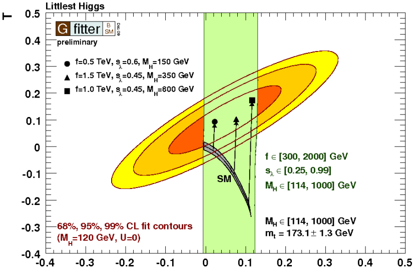

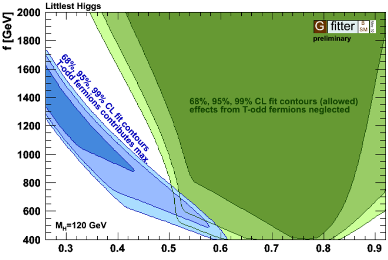

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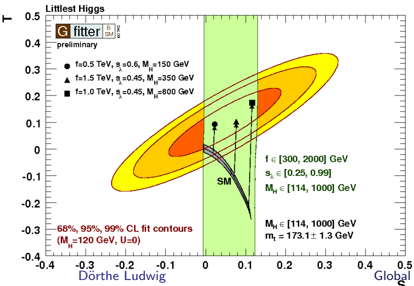

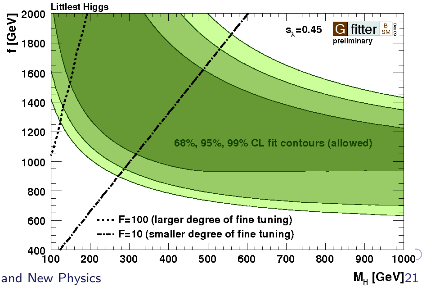

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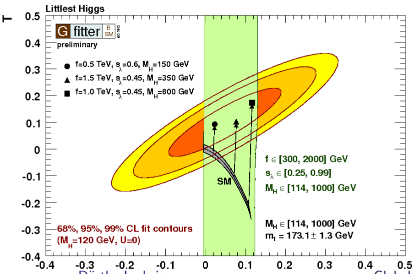

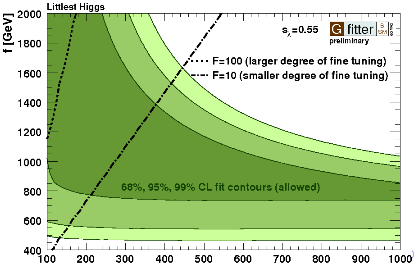

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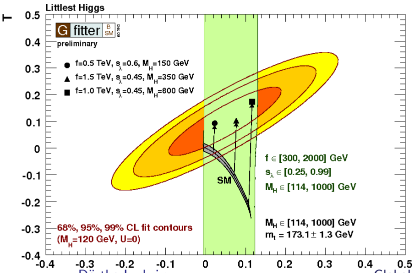

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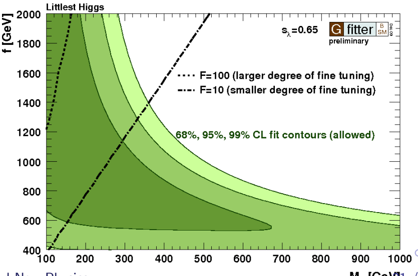

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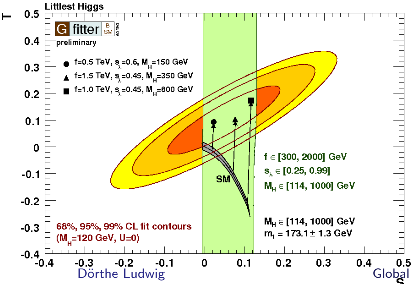
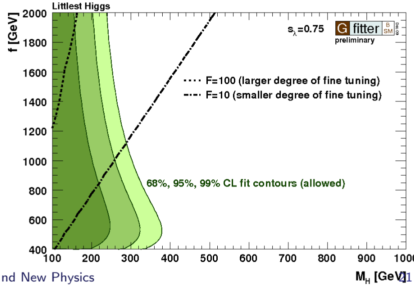
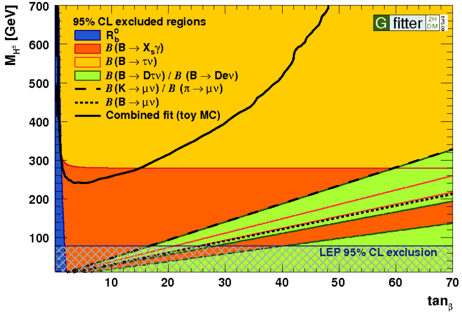




2 Higgs Doublet Model

- Type-II
- additional Higgs doublet
- one doublet couples to up-type, one doublet couples to down-type fermions



- 6 free parameters $\Rightarrow$ $M_{H^\pm}$, M_{A^0}, M_{H^0}, M_h, $\tan\beta$, $|\alpha|$
- looked at processes sensitive to charged Higgs $\Rightarrow$ $M_{H^\pm}$, $\tan\beta$
- overlay of individual 95% CL excluded regions
  - assuming ndof=1 and 2-sided limits
- combined fit:
  - ndof ambiguity resolved by MC toy study assuming 2-sided limits
- excluded at 95% CL:
  - small $\tan\beta$
  - for all $\tan\beta$: $M_H < 240$ GeV
  - for $\tan\beta$=70: $M_H < 780$ GeV