The Global Electroweak Fit and Constraints on New Physics with Gfitter

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Introduction to Gfitter - 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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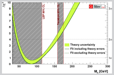
Gfitter SM · Gfitter 2HDM · Gfitter BSM

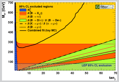
3. Physics Results

- **global electroweak fit** ⇒ constraints on M_H
- determination of α_s

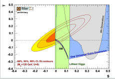


Please refer to main publication, webpage for updated results

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



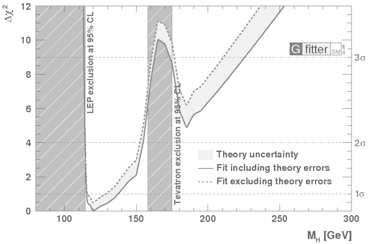
- constraints on **BSM physics** using the oblique parameters



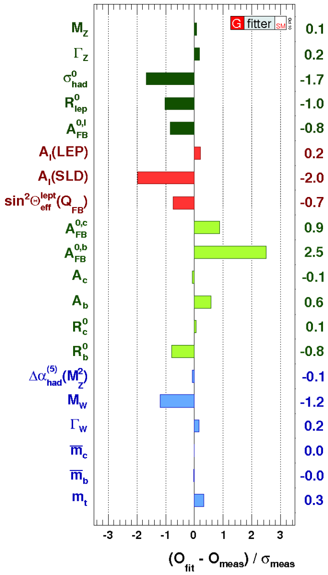
⇒ **Topic of this talk**

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

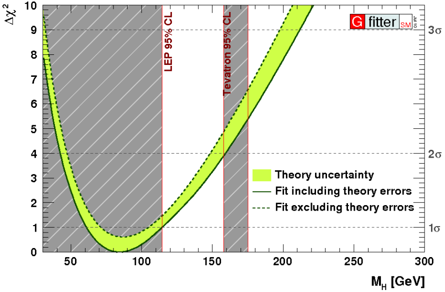


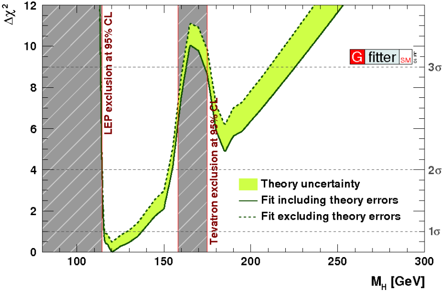
- input: usage of latest experimental results of electroweak precision observables
  - incl. direct Higgs searches (LEP, Tevatron)
  - incl. latest average of m_t =173.3±1.1 GeV (arXiv:1007.3178)
  - incl. latest evaluation of $\Delta\alpha_{had}(M_Z^2)$ (arXiv:1010.4180)
- floating fit parameters: M_Z, M_H, m_t, $\Delta\alpha_{had}^{(5)}(M_Z^2)$, $\alpha_S(M_Z^2)$, $\bar{m}_c$, $\bar{m}_b$
- goodness-of-fit:
  - **excl. direct Higgs searches:** $\chi^2_{min} = 16.6$ $\Rightarrow$ Prob(χ^2_{min},13) = 0.22
  - **incl. direct Higgs searches:** $\chi^2_{min} = 17.5$ $\Rightarrow$ Prob(χ^2_{min},14) = 0.23
- pull values (incl. direct Higgs searches)
  - $A_{FB}^{0,b}$ largest contributor to χ^2_{min}
  - no individual pull exceeds 3σ
  - small contributions from M_Z, $\Delta\alpha_{had}(M_Z)$, m_c, m_b: 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 $\pm 1\sigma$: $M_H = 84^{+30}_{-23}$ GeV
  - 2σ interval: [42, 159] GeV

- M_H from fit also including results from direct Higgs searches at LEP, Tevatron
  - value at minimum $\pm 1\sigma$: $M_H = 120.6^{+17.0}_{-5.2}$ GeV
  - 2σ interval: [114, 155] GeV





⇒ **in SM: light Higgs preferred**

The Electroweak Fit II: Constraints on Higgs mass

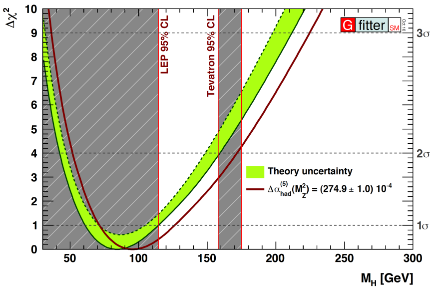
- **latest evaluation of $\Delta\alpha_{had}(M_Z^2)$ shifts fit value of M_H to larger values**

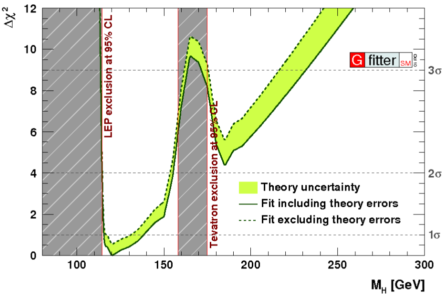
$\Delta\alpha_{had}(M_Z^2) = (276.8 \pm 2.2) \cdot 10^{-4}$ (K. Hagiwara et al., Phys. Lett. B 649: 173-179, 2007)

$\Rightarrow \Delta\alpha_{had}(M_Z^2) = (274.2 \pm 1.0) \cdot 10^{-4}$ (M. Davier et al., arXiv:1010.4180)

- increase of M_H (by 12 GeV) due to negative correlation in the fit
  - value at minimum $\pm 1\sigma$: $M_H = 96^{+31}_{-24}$ GeV
  - 2σ interval: [52, 172] GeV

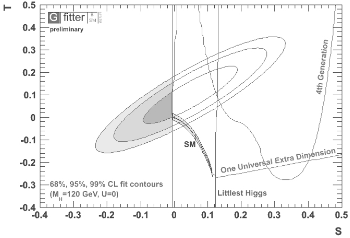
- shift smaller due to inclusion of direct Higgs searches
  - value at minimum $\pm 1\sigma$: $M_H = 120.2^{+18.1}_{-4.7}$ GeV
  - 2σ interval: [114, 155] GeV





$\Rightarrow$ in SM: light Higgs preferred

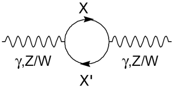
Constraints on New Physics Models



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**

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

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**)

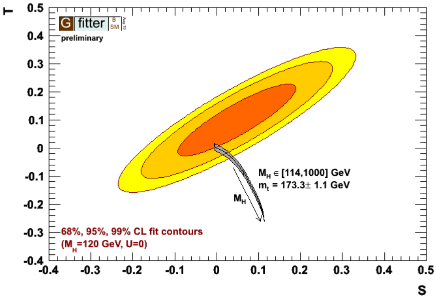
BSM Constraints using the oblique parameters II

- S, T, U derived from fit to electroweak observables
  - SM_{ref} chosen at $m_t = 173.1\,\text{GeV}$, $M_H = 120\,\text{GeV}$
- **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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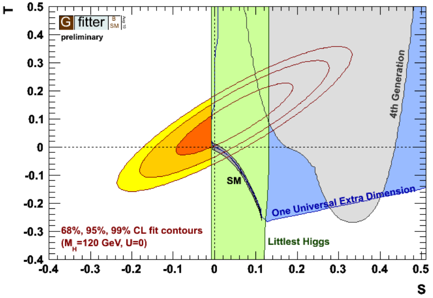
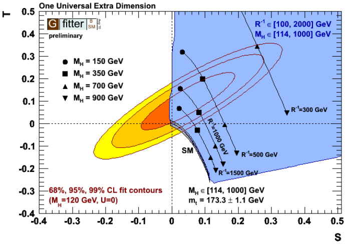
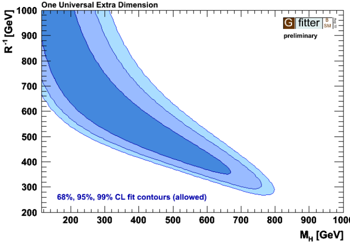


- other models also compatible with the data
  - UED, 4^{th} fermion generation, Littlest Higgs, ...
  - variation of the free parameters allows for large area in ST-plane
  - for some parameter values: large M_H allowed (compensation of effects)

One Universal Extra Dimension

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





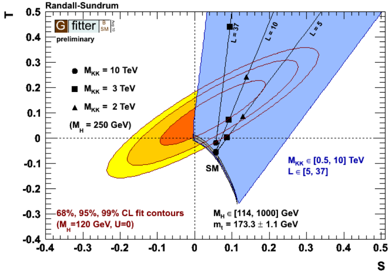
- all SM particles can propagate into ED
- compactification
  $\Rightarrow$ Kaluza-Klein (KK) modes
- conservation of Kaluza-Klein parity
  - similar phenomenology as SUSY
  - lightest KK state stable: CDM
- free parameters of UED model
  - d_{ED}: number of ED (fixed to one)
  - R^{-1}: compactification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

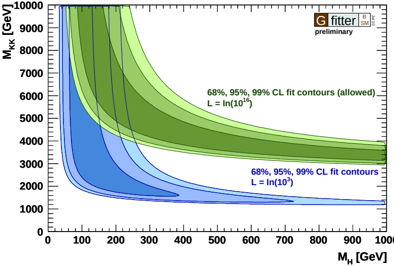
- contribution to vac. polarisation (STU):
  - from KK-top/bottom, KK-Higgs loops
  - dependent on R^{-1}, M_H, m_t
- **results:**
  - large R^{-1}: UED approaches SM (exp.), only small M_H allowed
  - small R^{-1}: UED contribution compensated by large M_H
  - excl.: R^{-1}<300 GeV, M_H>800 GeV

Warped Extra Dimensions

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

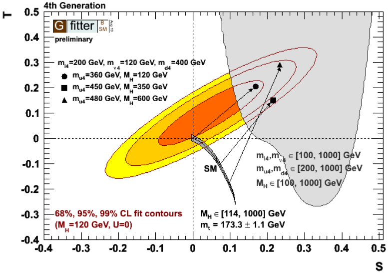
- introducing one extra dimension (ED) for solving the **hierarchy problem**
- RS model characterized by one warped ED confined by two three-branes
- one brane contains SM particles
- extension: SM particles allowed to propagate in bulk region
- each SM fermion accompanied by two towers of **heavy KK 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

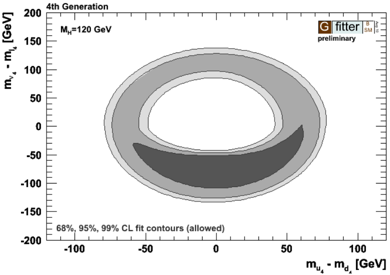




Fourth Family

[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} $m_{\nu 4}$
  - 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, rather than 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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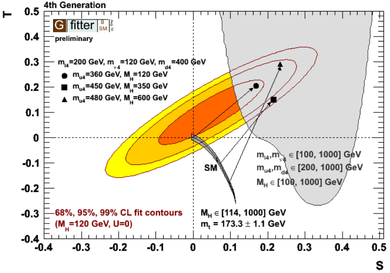

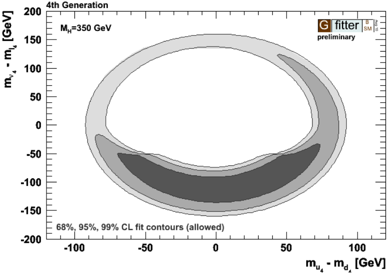

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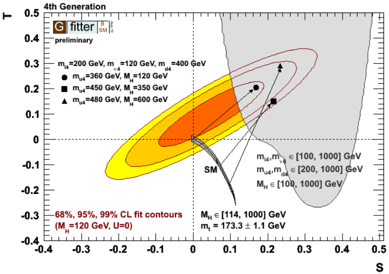

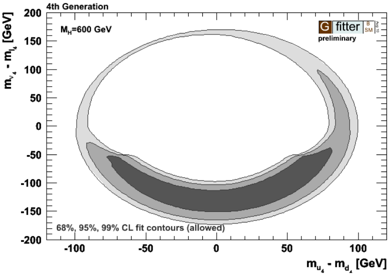

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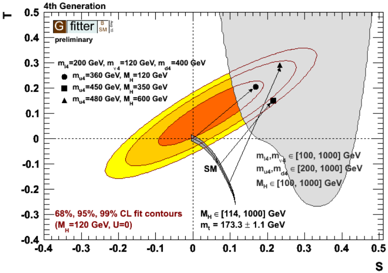

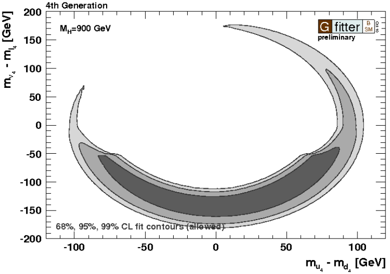

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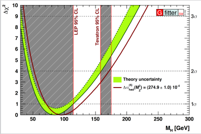
Conclusions

Standard model

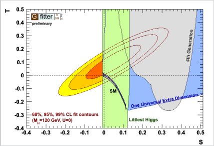
- global fit of the electroweak SM
- inclusion of latest $\Delta\alpha_{had}(M_Z^2)$ evaluation (M. Davier et al., arXiv:1010.4180)



- no evidences for physics beyond SM
- inclusion of direct Higgs searches
  $\Rightarrow$ Higgs mass strongly constrained
  $\Rightarrow$ light Higgs preferred by SM

New physics

- test compatibility of BSM models with electroweak precision data via the oblique parameters (universal/ warped extra dimensions, 4^{th} generation, ...)



- set constraints on BSM model parameters
- heavier Higgs boson allowed in various BSM models

http://www.cern.ch/Gfitter

Thank you for your attention!

Backup Slides

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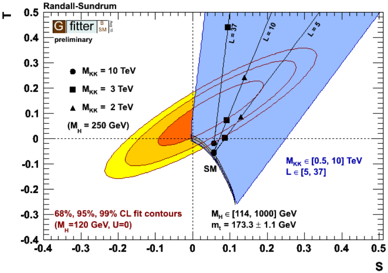
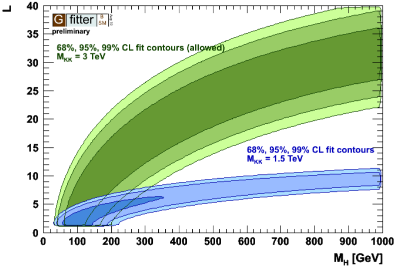
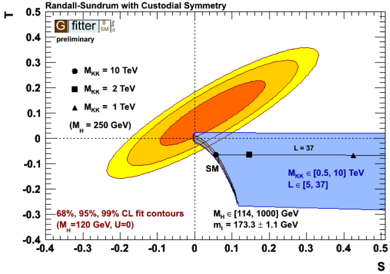


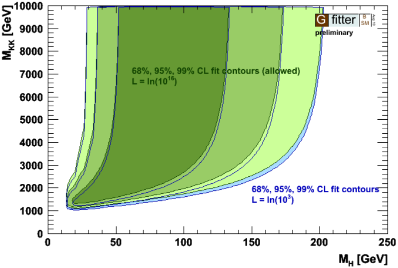


Warped Extra Dimensions with custodial symmetry

[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





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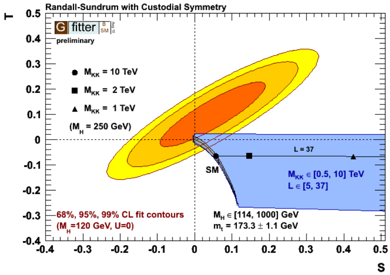
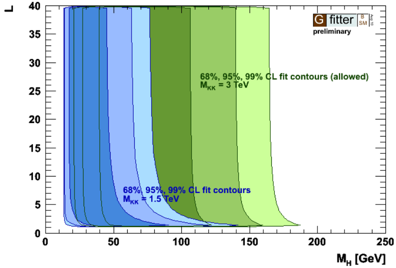
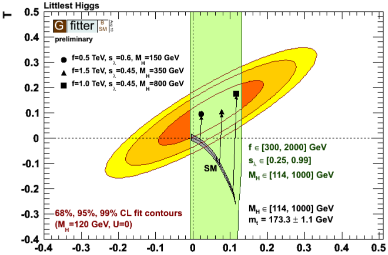


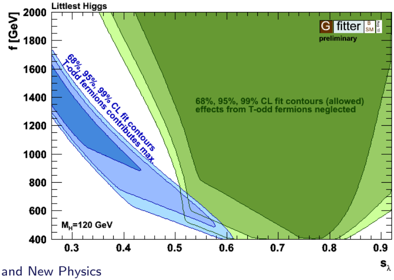


Littlest Higgs

- 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
  - dependent on s_λ:
    - large f: LH approaches the SM prediction and SM MH constraints
    - smaller f: M_H can be large
  - no absolute exclusion limits due to s_λ dependence





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
  - dependent on s_λ:
    - large f: LH approaches the SM prediction and SM MH constraints
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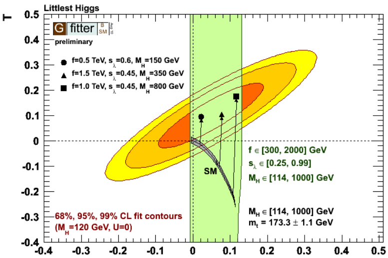
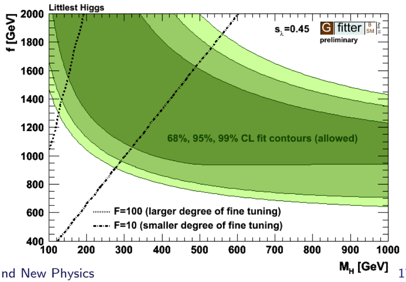
  - no absolute exclusion limits due to s_λ dependence





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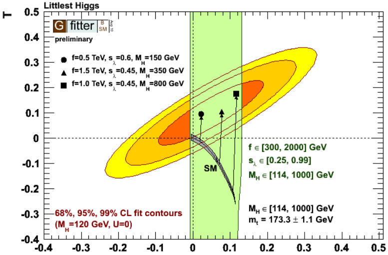

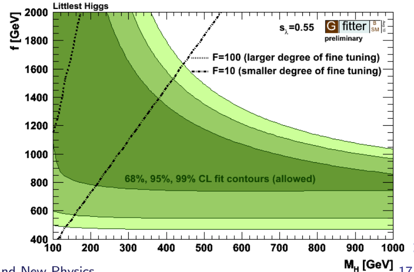

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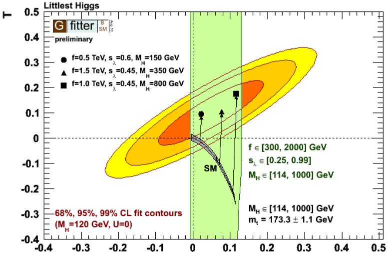

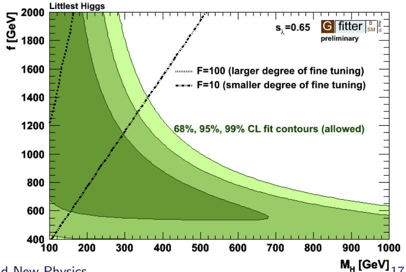

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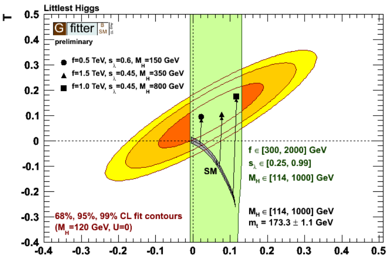
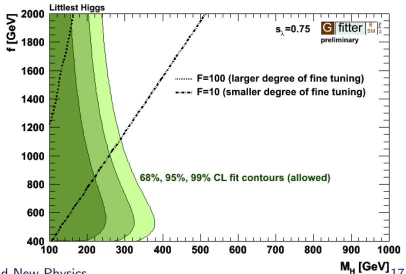
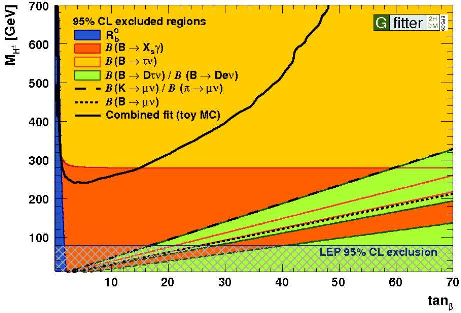




2 Higgs Doublet Model

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



- 6 free parameters ⇒ $M_{H^\pm}$, M_{A^0}, M_{H^0}, M_h, tanβ, $|\alpha|$
- looked at processes sensitive to charged Higgs ⇒ $M_{H^\pm}$, tanβ
- 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 tanβ
  - for all tanβ: $M_H < 240$ GeV
  - for tanβ=70: $M_H < 780$ GeV