A Two Higgs Doublet Model with Minimal Flavor Violation at the LHC

Wolfgang Altmannshofer

Fermilab

GGI Workshop

Understanding the TeV Scale Through LHC Data,
Dark Matter, and Other Experiments

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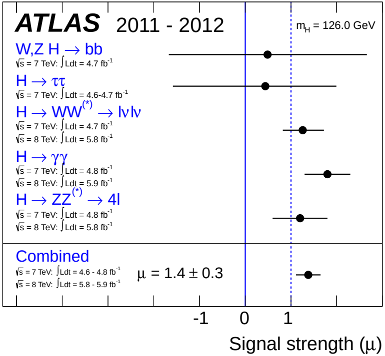
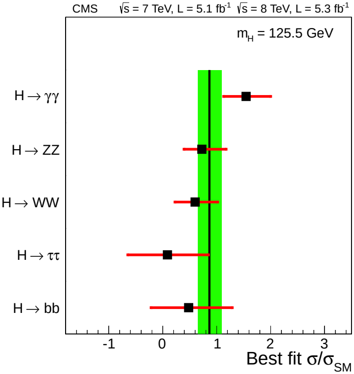
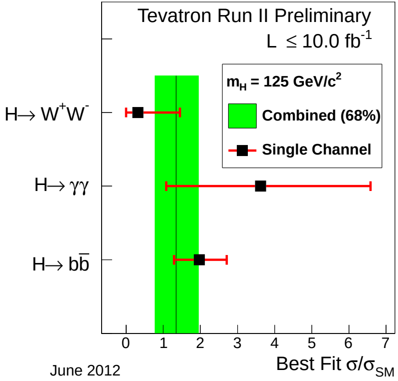
Phys. Lett. B **716**, 30 (2012)





CDF + D0

arXiv:1207.0449 [hep-ex]



Outline

WA, Stefania Gori, Graham Kribs
arXiv:1210.2465 [hep-ph]

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1. A Two Higgs Doublet Model with Minimal Flavor Violation
2. The Light Higgs Boson at the LHC
3. The Heavy Higgs at the LHC
4. Impact of the Charged Higgs Boson
5. Summary

A Two Higgs Doublet Model with Minimal Flavor Violation

A Simple Extension of the SM Higgs Sector

- two Higgs doublets H_1 and H_2 with hypercharges -1/2 and +1/2

$$H_2 = \begin{pmatrix} H_2^+ \\ \frac{1}{\sqrt{2}}(v s_\beta + h_2 + i a_2) \end{pmatrix} \quad , \quad H_1 = \begin{pmatrix} \frac{1}{\sqrt{2}}(v c_\beta + h_1 + i a_1) \\ H_1^- \end{pmatrix}$$

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- 5 physical degrees of freedom: h and H, A, and $H^\pm$

  assuming CP conservation:

$$\begin{pmatrix} G^\pm \\ H^\pm \end{pmatrix} = \begin{pmatrix} s_\beta & -c_\beta \\ c_\beta & s_\beta \end{pmatrix} \begin{pmatrix} H_2^\pm \\ H_1^\pm \end{pmatrix}$$

$$\begin{pmatrix} h \\ H \end{pmatrix} = \begin{pmatrix} c_\alpha & -s_\alpha \\ s_\alpha & c_\alpha \end{pmatrix} \begin{pmatrix} h_2 \\ h_1 \end{pmatrix} \quad , \quad \begin{pmatrix} G \\ A \end{pmatrix} = \begin{pmatrix} s_\beta & -c_\beta \\ c_\beta & s_\beta \end{pmatrix} \begin{pmatrix} a_2 \\ a_1 \end{pmatrix}$$

Generic Couplings to Fermions

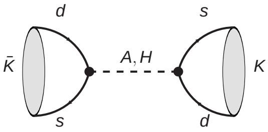
$$\mathcal{L} \supset (y_u)_{ik} \, H_2 \bar{Q}_i U_k + (\tilde{y}_u)_{ik} \, H_1^\dagger \bar{Q}_i U_k$$
$$+ (y_d)_{ik} \, H_1 \bar{Q}_i D_k + (\tilde{y}_d)_{ik} \, H_2^\dagger \bar{Q}_i D_k$$
$$+ (y_\ell)_{ik} \, H_1 \bar{L}_i E_k + (\tilde{y}_\ell)_{ik} \, H_2^\dagger \bar{L}_i E_k \quad + \text{h.c.}$$

- for generic couplings y and $\tilde{y}$, quark masses and Higgs couplings are not aligned, e.g.

$$(m_d)_{ik} = \frac{v}{\sqrt{2}} \left(c_\beta (y_d)_{ik} + s_\beta (\tilde{y}_d)_{ik} \right) , \quad (g_d^A)_{ik} = \frac{1}{\sqrt{2}} \left(s_\beta (y_d)_{ik} - c_\beta (\tilde{y}_d)_{ik} \right)$$

→ tree level FCNCs

→ incredible strong constraints from meson mixing



2HDM type I, II, III, and IV

- Natural Flavor Conservation: no tree level FCNCs if all types of fermions couple only to one Higgs doublet (Glashow, Weinberg '77)
- Can be enforced by:
  (softly broken) continuous symmetries (Peccei-Quinn)
  or discrete symmetries (Z_2)
- 4 possibilities: $(y_u)_{ik}\, H_2 \bar{Q}_i U_k + (\tilde{y}_d)_{ik}\, H_2^\dagger \bar{Q}_i D_k + (\tilde{y}_\ell)_{ik}\, H_2^\dagger \bar{L}_i E_k$

	type I
up quarks	H_2
down quarks	H_2
leptons	H_2

many recent studies of type I-IV in light of LHC data:
Ferreira, Santos, Sher, Silva '11; Blum, D'Agnolo '12; Azatov, Chang, Craig, Galloway '12; Craig, Thomas '12; Alves, Fox, Weiner '12; ...

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	type I	type II
up quarks	H_2	H_2
down quarks	H_2	H_1
leptons	H_2	H_1

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	type I	type II	type III	type IV
up quarks	H_2	H_2	H_2	H_2
down quarks	H_2	H_1	H_2	H_1
leptons	H_2	H_1	H_1	H_2

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Another Powerful Protection Mechanism

- largest symmetry group that commutes with the SM gauge group

$$G_F = SU(3)_Q \otimes SU(3)_U \otimes SU(3)_D \otimes SU(3)_L \otimes SU(3)_E \otimes U(1)^5$$

Minimal Flavor Violation

(Chivukula, Georgi '87; Hall, Randall '90; D'Ambrosio et al '02)

- the SM Yukawa couplings are the only spurions that break G_F

$$y_u = 3_Q \times \bar{3}_U \ , \quad y_d = 3_Q \times \bar{3}_D \ , \quad y_\ell = 3_L \times \bar{3}_E$$

$\rightarrow$ the "wrong" Higgs couplings $\tilde{y}$ are functions of the Yukawas y

$\rightarrow$ FCNCs are suppressed by the same small CKM factors as in the SM

$\rightarrow$ protection mechanism holds beyond tree level

MFV Couplings to Fermions

- expansion of the "wrong" Higgs couplings

$$\begin{aligned}
\tilde{y}_u &= \epsilon_u y_u + \epsilon'_u y_u y_u^\dagger y_u + \epsilon''_u y_d y_d^\dagger y_u + \ldots \\
\tilde{y}_d &= \epsilon_d y_d + \epsilon'_d y_d y_d^\dagger y_d + \epsilon''_d y_u y_u^\dagger y_d + \ldots \\
\tilde{y}_\ell &= \epsilon_\ell y_\ell + \epsilon'_\ell y_\ell y_\ell^\dagger y_\ell + \ldots
\end{aligned}$$

MFV Couplings to Fermions

- expansion of the “wrong” Higgs couplings

$$\begin{aligned}\tilde{y}_u &= \epsilon_u y_u + \epsilon'_u y_u y_u^\dagger y_u + \epsilon''_u y_d y_d^\dagger y_u + \dots \\ \tilde{y}_d &= \epsilon_d y_d + \epsilon'_d y_d y_d^\dagger y_d + \epsilon''_d y_u y_u^\dagger y_d + \dots \\ \tilde{y}_\ell &= \epsilon_\ell y_\ell + \epsilon'_\ell y_\ell y_\ell^\dagger y_\ell + \dots\end{aligned}$$

- simplified setup for studying Higgs phenomenology:

$\rightarrow$ drop higher order terms

$$\begin{aligned}\tilde{y}_u &= \epsilon_u y_u \\ \tilde{y}_d &= \epsilon_d y_d \\ \tilde{y}_\ell &= \epsilon_\ell y_\ell\end{aligned}$$

MFV Couplings to Fermions

- expansion of the "wrong" Higgs couplings

$$\begin{aligned}
\tilde{y}_u &= \epsilon_u y_u + \epsilon'_u y_u y_u^\dagger y_u + \epsilon''_u y_d y_d^\dagger y_u + \dots \\
\tilde{y}_d &= \epsilon_d y_d + \epsilon'_d y_d y_d^\dagger y_d + \epsilon''_d y_u y_u^\dagger y_d + \dots \\
\tilde{y}_\ell &= \epsilon_\ell y_\ell + \epsilon'_\ell y_\ell y_\ell^\dagger y_\ell + \dots
\end{aligned}$$

- simplified setup for studying Higgs phenomenology:

→ drop higher order terms

→ consider only real ϵ

$$\begin{aligned}
\tilde{y}_u &= \epsilon_u y_u \\
\tilde{y}_d &= \epsilon_d y_d \\
\tilde{y}_\ell &= \epsilon_\ell y_\ell
\end{aligned}$$

MFV Couplings to Fermions

- expansion of the “wrong” Higgs couplings

$$\begin{aligned}\tilde{y}_u &= \epsilon_u y_u + \epsilon'_u y_u y_u^\dagger y_u + \epsilon''_u y_d y_d^\dagger y_u + \dots \\ \tilde{y}_d &= \epsilon_d y_d + \epsilon'_d y_d y_d^\dagger y_d + \epsilon''_d y_u y_u^\dagger y_d + \dots \\ \tilde{y}_\ell &= \epsilon_\ell y_\ell + \epsilon'_\ell y_\ell y_\ell^\dagger y_\ell + \dots\end{aligned}$$

- simplified setup for studying Higgs phenomenology:

$\rightarrow$ drop higher order terms

$\rightarrow$ consider only real ϵ

$\rightarrow$ choose Higgs basis such that $\epsilon_u = 0$ (without loss of generality)

$$\begin{aligned}\tilde{y}_u &= 0 \\ \tilde{y}_d &= \epsilon_d y_d \\ \tilde{y}_\ell &= \epsilon_\ell y_\ell\end{aligned}$$

- “aligned 2HDM” (see also Pich, Tuzon ’09; Bai, Barger, Everett, Shaughnessy ’12)

$\rightarrow$ Higgs couplings are determined by 4 parameters: $\tan\beta$, α, ϵ_d, and ϵ_ℓ

Higgs Couplings

ξ parametrize the deviations from the SM Yukawas / gauge couplings

	WW/ZZ	top	bottom	tau
h	$\xi_V^h = s_{\beta-\alpha}$	$\xi_u^h = \frac{c_\alpha}{s_\beta}$	$\xi_d^h = \frac{-s_\alpha + \epsilon_d c_\alpha}{c_\beta + \epsilon_d s_\beta}$	$\xi_\ell^h = \frac{-s_\alpha + \epsilon_\ell c_\alpha}{c_\beta + \epsilon_\ell s_\beta}$
H	$\xi_V^H = c_{\beta-\alpha}$	$\xi_u^H = \frac{s_\alpha}{s_\beta}$	$\xi_d^H = \frac{c_\alpha + \epsilon_d s_\alpha}{c_\beta + \epsilon_d s_\beta}$	$\xi_\ell^H = \frac{c_\alpha + \epsilon_\ell s_\alpha}{c_\beta + \epsilon_\ell s_\beta}$
$A, H^\pm$	$\xi_V^{A,\pm} = 0$	$\xi_u^{A,\pm} = \frac{1}{t_\beta}$	$\xi_d^{A,\pm} = \frac{t_\beta - \epsilon_d}{1 + \epsilon_d t_\beta}$	$\xi_\ell^{A,\pm} = \frac{t_\beta - \epsilon_\ell}{1 + \epsilon_\ell t_\beta}$

$\rightarrow$ all four light Higgs couplings are independent ...

... as long as one is not in the decoupling regime

$$\alpha = \beta - \pi/2 + O(v^2/M_A^2)$$

MFV Generalizes Types I - IV

$$\epsilon_d \to \infty\ , \quad \epsilon_\ell \to \infty \qquad \text{(Type I)}$$

$$\epsilon_d \to 0\ , \quad \epsilon_\ell \to 0 \qquad \text{(Type II)}$$

$$\epsilon_d \to \infty\ , \quad \epsilon_\ell \to 0 \qquad \text{(Type III)}$$

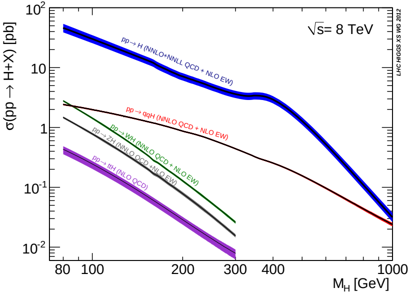
$$\epsilon_d \to 0\ , \quad \epsilon_\ell \to \infty \qquad \text{(Type IV)}$$

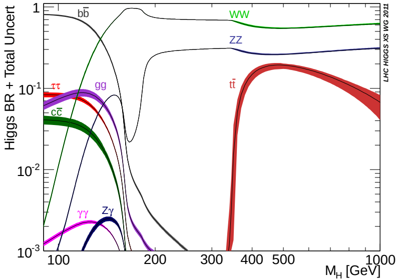
- ϵ parameter allow to interpolate continuously between the type I - IV
- interesting regions of parameter space (never reached by type I - IV)

$$\epsilon_i \sim -1/\tan\beta\ , \quad \epsilon_i \sim \tan\alpha$$

The Light Higgs h

$$\sigma(pp \to h \to X_{\rm SM}) = \sigma(pp \to h) \times \frac{\Gamma(h \to X_{\rm SM})}{\Gamma_{\rm tot}}$$





Higgs Production

- gluon-gluon fusion
  (dominated by top loop)

$$\frac{\sigma(gg \to h)}{\sigma(gg \to h)_{\rm SM}} \simeq (\xi_t^h)^2$$

- Vector boson fusion

$$\frac{\sigma(VBF)}{\sigma(VBF)_{\rm SM}} \simeq (\xi_V^h)^2$$

- production in
  association with vector bosons

$$\frac{\sigma(Wh)}{\sigma(Wh)_{\rm SM}} \simeq \frac{\sigma(Zh)}{\sigma(Zh)_{\rm SM}} \simeq (\xi_V^h)^2$$

- production in
  association with tops

$$\frac{\sigma(tth)}{\sigma(tth)_{\rm SM}} \simeq (\xi_t^h)^2$$

production cross sections depend only on
"ordinary" type I - IV parameter $\tan\beta$ and α

Higgs Decays

- decay widths into gauge bosons

$$\frac{\Gamma(h \to VV)}{\Gamma(h \to VV)_{\text{I-IV}}} \simeq \frac{\Gamma(h \to gg)}{\Gamma(h \to gg)_{\text{I-IV}}} \simeq \frac{\Gamma(h \to \gamma\gamma)}{\Gamma(h \to \gamma\gamma)_{\text{I-IV}}} \simeq 1$$

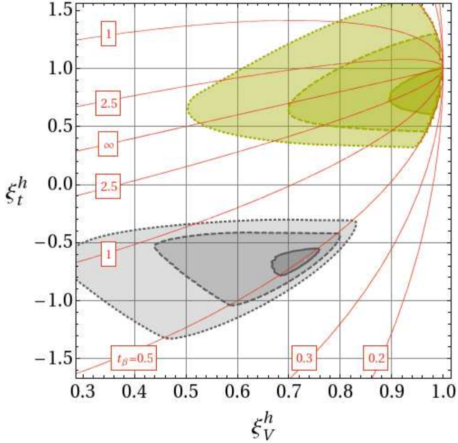
- decay widths into bb and $\tau\tau$

$$\frac{\Gamma(h \to bb)}{\Gamma(h \to bb)_{\text{II}}} \simeq \left(\frac{1 - \epsilon_d / t_\alpha}{1 + \epsilon_d t_\beta}\right)^2 \quad , \quad \frac{\Gamma(h \to \tau\tau)}{\Gamma(h \to \tau\tau)_{\text{II}}} \simeq \left(\frac{1 - \epsilon_\ell / t_\alpha}{1 + \epsilon_\ell t_\beta}\right)^2$$

$\to$ can be modified independently

the 2HDM type MFV is a very
flexible framework to interpret Higgs data

Fit to the Data

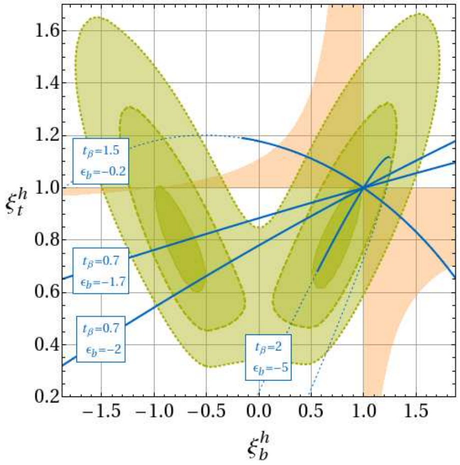


- result of a simple χ^2 fit (imposing $\tan\beta > 0.5$):

  two regions in the ξ_t^h – ξ_V^h plane give an equally good description of the data

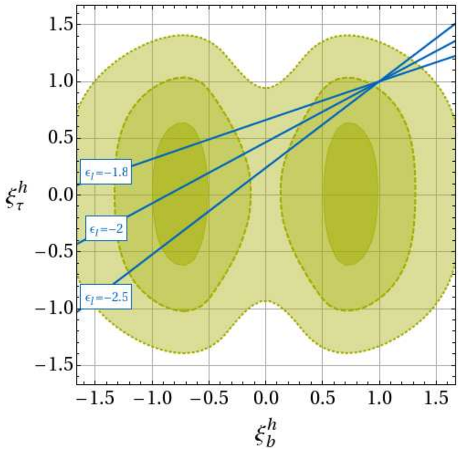
- concentrate on $\xi_t^h > 0$ in the following

Fit to the Data

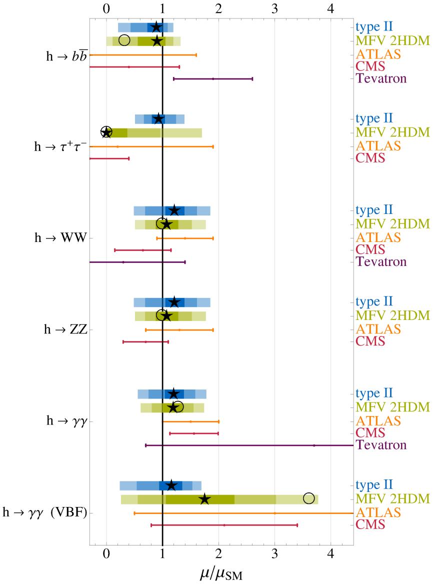


- also two regions in the $\xi_t^h - \xi_b^h$ plane
- sign of the bottom coupling cannot be resolved with light Higgs data
- in orange: region accessible in the type II model

Fit to the Data



- small ξ_τ^h coupling is preferred due to CMS $h \to \tau\tau$ data



main differences
with respect to type II:

1) strongly reduced
   $h \to \tau\tau$ possible

2) strongly enhanced
   VBF $h \to \gamma\gamma$ possible

★ best fit point

$$\xi_V^h = 0.99\ ,\ \xi_t^h = 0.79$$

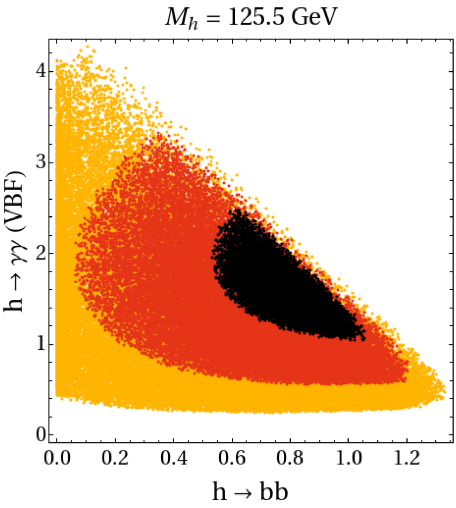
$$\xi_b^h = \pm 0.73\ ,\ \xi_\tau^h = 0$$

◯ strongly enhanced VBF $h \to \gamma\gamma$

$$\xi_V^h = 0.97\ ,\ \xi_t^h = 0.49$$

$$\xi_b^h = \pm 0.33\ ,\ \xi_\tau^h = 0$$

Correlations



- strong enhancement of VBF $h \to \gamma\gamma$ implies upper bound on $h \to bb$

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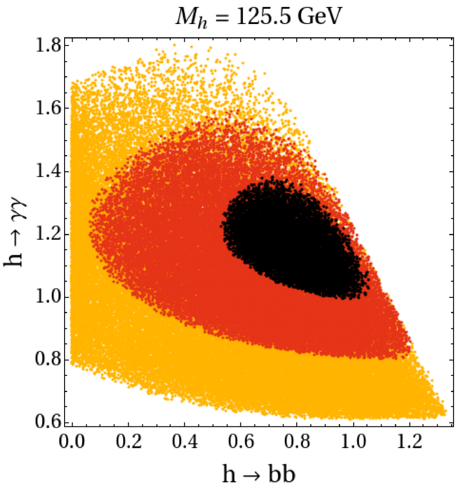
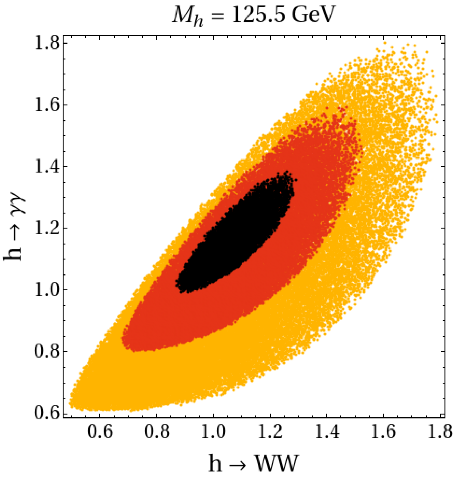


- strong enhancement of VBF $h \to \gamma\gamma$ implies upper bound on $h \to bb$
- enhancement of inclusive $h \to \gamma\gamma$ implies upper bound on $h \to bb$



- strong enhancement of VBF $h \to \gamma\gamma$ implies upper bound on $h \to bb$
- enhancement of inclusive $h \to \gamma\gamma$ implies upper bound on $h \to bb$
- enhancement of inclusive $h \to \gamma\gamma$ implies lower bound on $h \to WW$

“The Quasi Decoupling Limit”

- best fit values for the light Higgs couplings

$$\xi_V^h = 0.99 \ , \quad \xi_t^h = 0.79 \ , \quad \xi_b^h = \pm 0.73 \ , \quad \xi_\tau^h = 0$$

- couplings to gauge bosons is very SM-like

$$\xi_V^h \simeq 1 - \frac{x^2}{2}$$

$$\xi_u^h \simeq \left(1 - \frac{x^2}{2}\right) + x\xi_u^A$$

$$\xi_{d,\ell}^h \simeq \left(1 - \frac{x^2}{2}\right) - x\xi_{d,\ell}^A$$

$$\xi_V^H \simeq x$$

$$\xi_u^H \simeq -\xi_u^A \left(1 - \frac{x^2}{2}\right) + x$$

$$\xi_{d,\ell}^H \simeq \xi_{d,\ell}^A \left(1 - \frac{x^2}{2}\right) + x$$

“Quasi Decoupling Limit”

$$\alpha = \beta - \pi/2 + x \ , \quad x \ll 1$$

couplings of the light Higgs h to fermions can be modified substantially even for small x

$\Leftrightarrow$ couplings of the pseudoscalar A to fermions are enhanced

$\Rightarrow$ couplings of the heavy Higgs H to fermions are enhanced and “A-like”

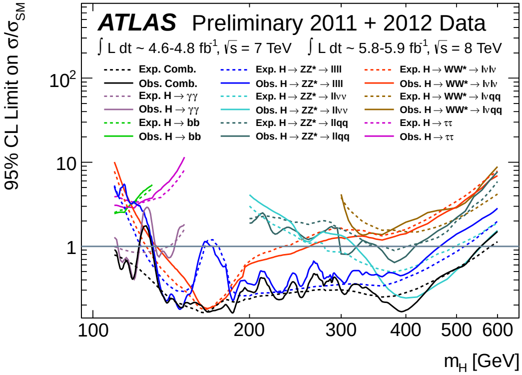
(see also Alves, Fox, Weiner ’12)

The Heavy Higgs H

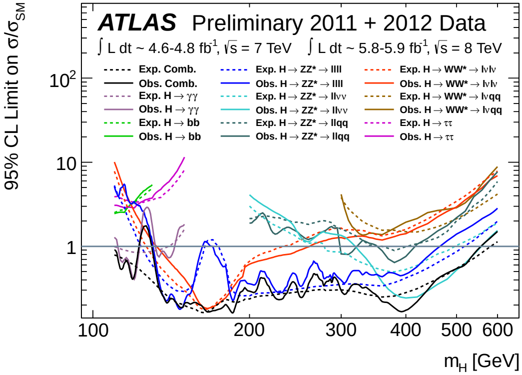
Higgs Coupling Sum Rules

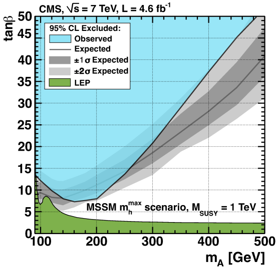
$$
\begin{aligned}
1 + (\xi_u^A)^2 &= (\xi_u^h)^2 + (\xi_u^H)^2 = 1 + \frac{1}{t_\beta^2} \\
1 + (\xi_d^A)^2 &= (\xi_d^h)^2 + (\xi_d^H)^2 = \left(1 + t_\beta^2\right) \frac{1 + \epsilon_d^2}{(1 + \epsilon_d t_\beta)^2} \\
1 + (\xi_\ell^A)^2 &= (\xi_\ell^h)^2 + (\xi_\ell^H)^2 = \left(1 + t_\beta^2\right) \frac{1 + \epsilon_\ell^2}{(1 + \epsilon_\ell t_\beta)^2} \\
1 &= (\xi_V^h)^2 + (\xi_V^H)^2
\end{aligned}
$$

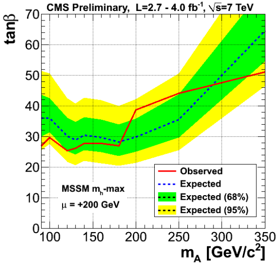
Good prospects to probe the heavy scalar
if the light Higgs is not exactly SM-like



- SM Higgs searches in $h \to WW/ZZ$

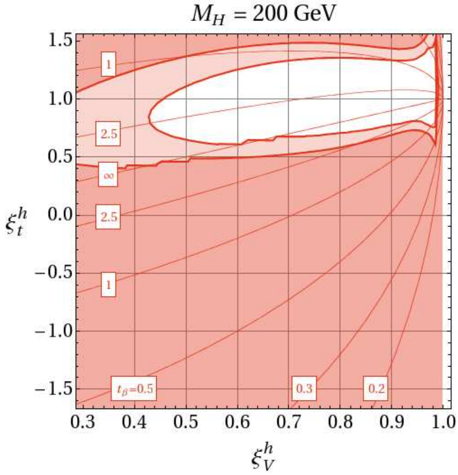






- SM Higgs searches in $h \to WW/ZZ$
- MSSM Higgs searches in $H/A \to bb/\tau\tau$

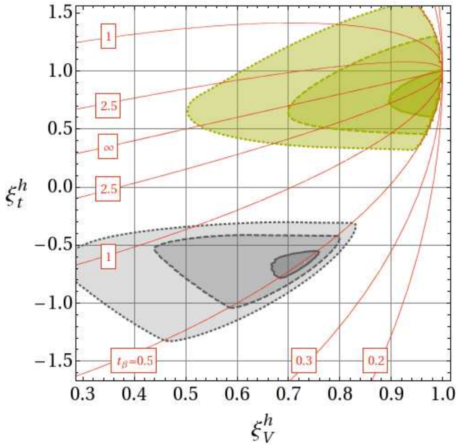
Allowed Parameter Space



red: excluded at 3σ

light red: excluded at 2σ

- large gluon gluon fusion production cross section of H for small tan β
- sizable branching ratio $H \to WW/ZZ$ even for tiny deviations of ξ_V^h from 1



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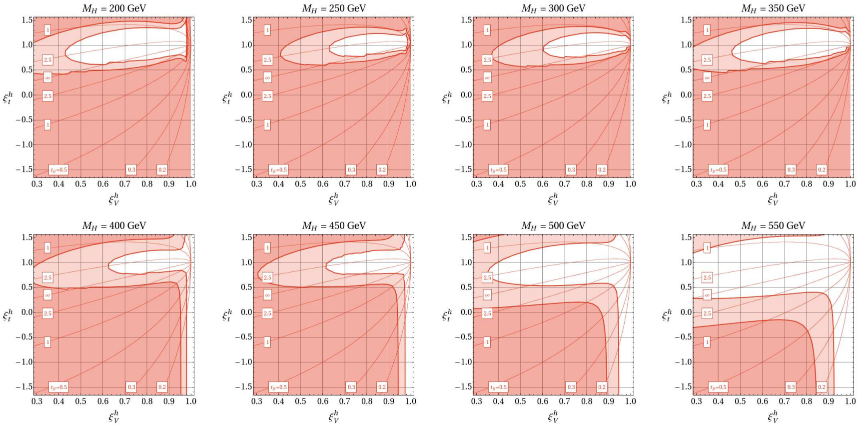
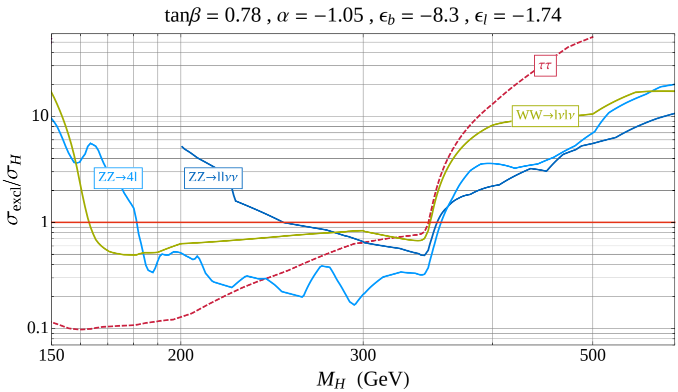
- large gluon gluon fusion production cross section of H for small $\tan\beta$
- sizable branching ratio $H \to WW/ZZ$ even for tiny deviations of ξ_V^h from 1

Allowed Parameter Space



- ► The solution with negative top coupling is excluded up to $M_H < 600$ GeV due to $H \to WW/ZZ$ searches

Predictions for H in the Quasi Decoupling Regime *



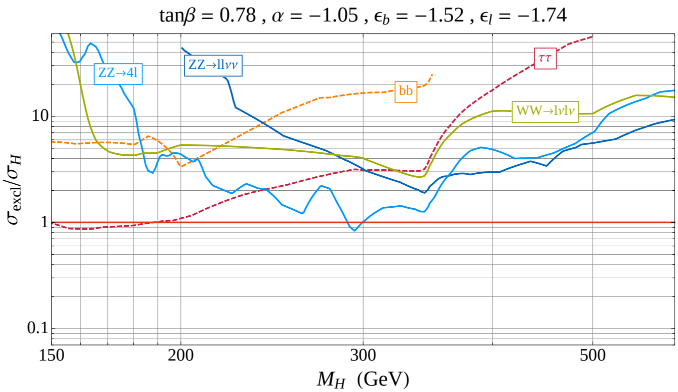
- best fit value with $\xi_b^h > 0$

$$\xi_V^h = 0.99 \ , \quad \xi_t^h = 0.79 \ , \quad \xi_b^h = +0.73 \ , \quad \xi_\tau^h = 0$$

$$\Rightarrow \quad \xi_V^H = 0.14 \ , \quad \xi_t^H = 1.36 \ , \quad \xi_b^H = -1.78 \ , \quad \xi_\tau^H = -7.1$$

* we do not consider sizable $H \to hh$ rates

Predictions for H in the Quasi Decoupling Regime *



- best fit value with $\xi_b^h < 0$

$$\xi_V^h = 0.99 \ , \quad \xi_t^h = 0.79 \ , \quad \xi_b^h = -0.73 \ , \quad \xi_\tau^h = 0$$

$$\Rightarrow \quad \xi_V^H = 0.14 \ , \quad \xi_t^H = 1.36 \ , \quad \xi_b^H = -12.4 \ , \quad \xi_\tau^H = -7.1$$

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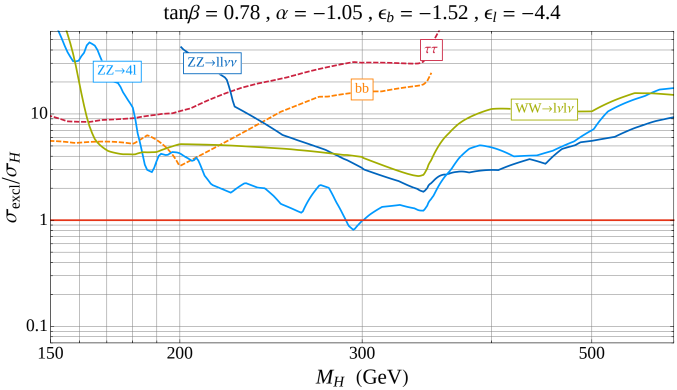
Predictions for H in the Quasi Decoupling Regime *



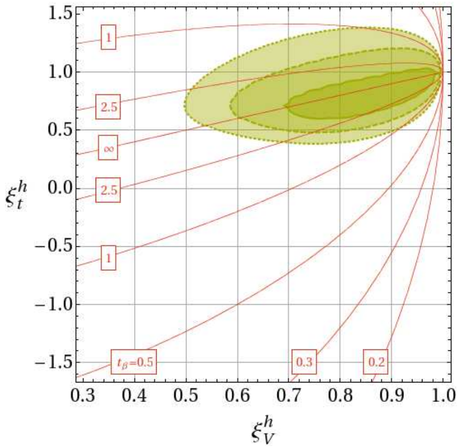
- only 50% suppression of $h \to \tau^+\tau^-$

$$\xi_V^h = 0.99 \ , \quad \xi_t^h = 0.79 \ , \quad \xi_b^h = -0.73 \ , \quad \xi_\tau^h = 0.6$$

$$\Rightarrow \quad \xi_V^H = 0.14 \ , \quad \xi_t^H = 1.36 \ , \quad \xi_b^H = -12.4 \ , \quad \xi_\tau^H = -2.2$$

* we do not consider sizable $H \to hh$ rates

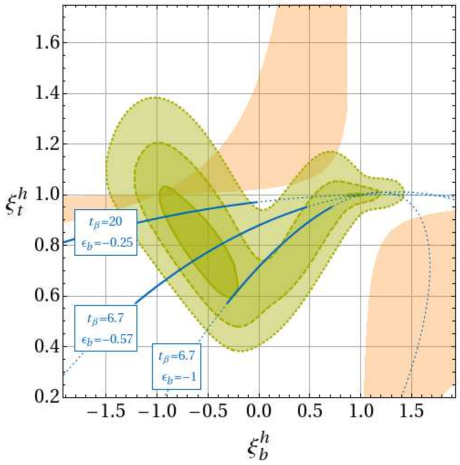
Two light Higgs bosons?



two Higgses at
LHC and Tevatron:

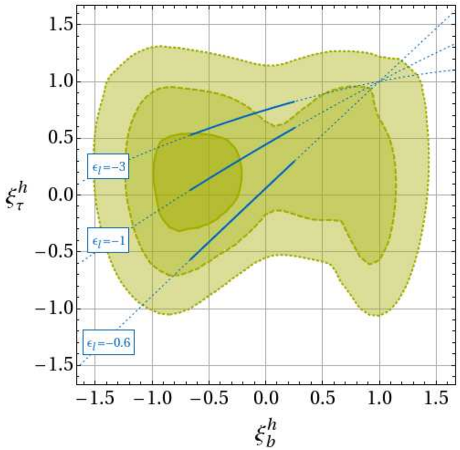
$M_h = 125$GeV, $M_H = 135$GeV
(see also Belanger et al. '12)

- include *H* at 135 GeV directly in the fit
- signals from the 2 Higgs bosons add up in *bb*, $\tau\tau$ and *WW*
- second region with $\xi_t^h < 0$ is automatically excluded

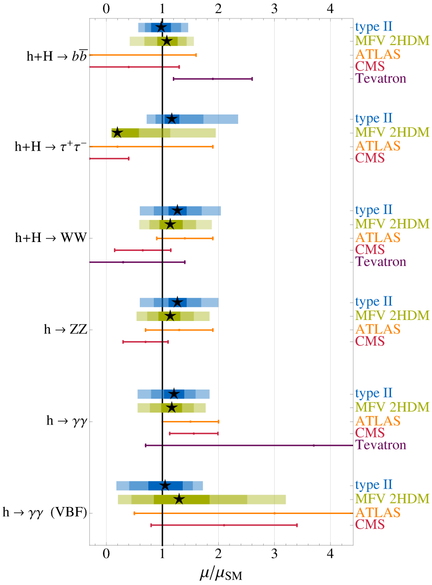


- degeneracy between positive and negative bottom couplings to lighter Higgs is broken
- negative ξ_b^h is preferred because of larger ξ_b^H

Two light Higgs bosons?



- coupling of lighter Higgs to taus is still suppressed



- $h/H \to bb$ can be slightly enhanced
- $h/H \to \tau\tau$ cannot be switched off completely
- difficult to see H in the high resolution channels: $H \to \gamma\gamma/ZZ$ = few% $\times$ SM signal

best fit couplings of h

$$\xi_V^h = 0.85 \; , \; \xi_t^h = 0.77$$

$$\xi_b^h = -0.52 \; , \; \xi_\tau^h = 0.16$$

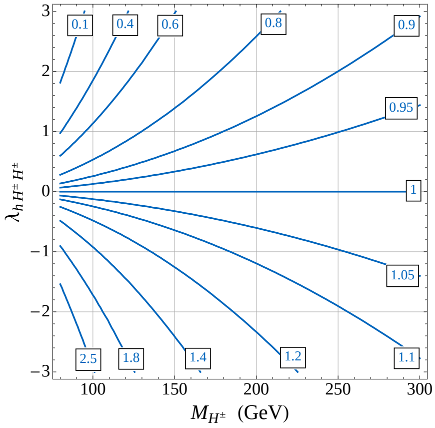
best fit couplings of H

$$\xi_V^H = 0.53 \; , \; \xi_t^H = 0.66$$

$$\xi_b^H = -2.7 \; , \; \xi_\tau^H = -1.6$$

The Charged Higgs Boson

Possible Impact of the Charged Higgs on $h \to \gamma\gamma$



(in the plot $\xi_t^h = \xi_V^h = 1$)

- charged Higgs loops in $h \to \gamma\gamma$

$$\Gamma(h \to \gamma\gamma) \simeq \frac{\alpha^2 m_h^3}{256\pi^3} \frac{1}{v^2} \times$$

$$\times \left| \xi_V^h A_1(x_W) + \frac{4}{3} \xi_u^h A_{1/2}(x_t) + \frac{\lambda_{hH^\pm H^\pm} v^2}{2M_{H^\pm}^2} A_0(x_{H^\pm}) \right|^2$$

Constraints from Vacuum Stability

- coupling with light Higgs determined by quartic couplings

$$\lambda_{hH^\pm H^\pm} = -\lambda_1 s_\alpha s_\beta^2 c_\beta + \lambda_2 c_\alpha c_\beta^2 s_\beta$$
$$+\lambda_3 (c_\alpha s_\beta^3 - s_\alpha c_\beta^3) + \lambda_4 s_{\beta-\alpha} + \lambda_5 s_\beta c_\beta c_{\alpha+\beta}$$
$$+\lambda_6 (c_{\alpha+\beta} s_\beta^2 + 2 s_\beta s_\alpha c_\beta^2) + \lambda_7 (c_{\alpha+\beta} c_\beta^2 + 2 c_\beta c_\alpha s_\beta^2)$$

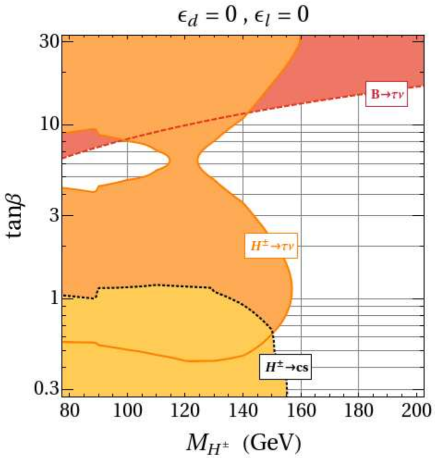
$$\to \lambda_3 + \lambda_4 \qquad \text{for large } \tan\beta \text{ and } \alpha = \beta - \pi/2$$

- necessary conditions for vacuum stability

$$\lambda_1,\, \lambda_2 > 0 \ , \quad \lambda_3 > -\sqrt{\lambda_1 \lambda_2}$$
$$\lambda_3 - |\lambda_5| > -\sqrt{\lambda_1 \lambda_2}$$
$$\frac{\lambda_1 + \lambda_2}{2} + \lambda_3 + \lambda_5 - 2|\lambda_6 + \lambda_7| > 0$$

- do not exclude large negative $\lambda_{hH^\pm H^\pm}$

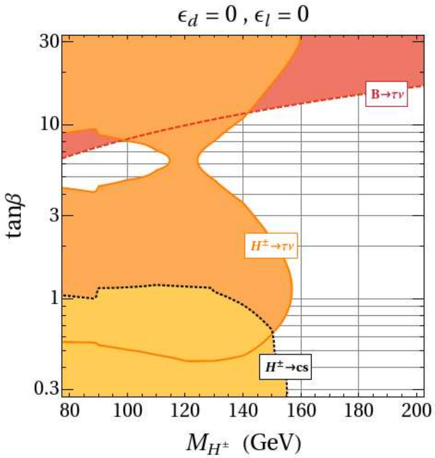
Constraints from Top Decays and Flavor Observables



The case of 2HDM type II

- tree level charged Higgs contributions to $B \to \tau\nu$

$$\frac{\text{BR}(B \to \tau\nu)}{\text{BR}(B \to \tau\nu)_{\text{SM}}} = \left(1 - \frac{m_B^2}{M_{H^\pm}^2} t_\beta^2\right)^2$$



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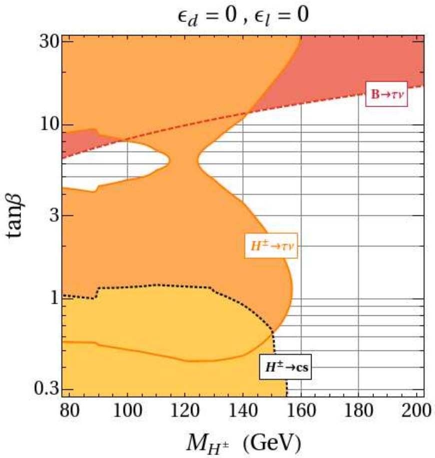
- top decays $t \to bH^\pm$, $H^\pm \to \tau\nu/cs$

$$H^+ \bar{t} \left(\frac{m_t}{v} \frac{1}{t_\beta} P_L + \frac{m_b}{v} t_\beta P_R \right) b$$



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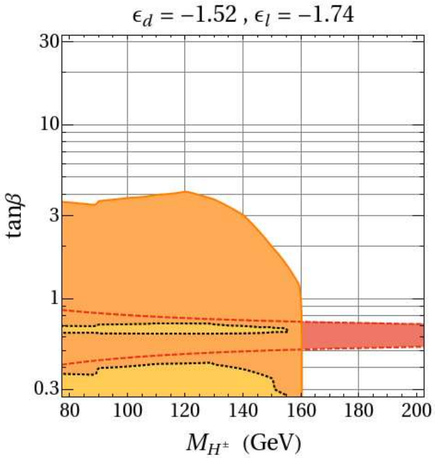
- loop induced FCNCs: $b \to s\gamma$

$$M_{H^+} \gtrsim 380 \text{ GeV}$$

(Herrmann, Misiak, Steinhauser '12)

Constraints from Top Decays and Flavor Observables



The case of 2HDM type MFV

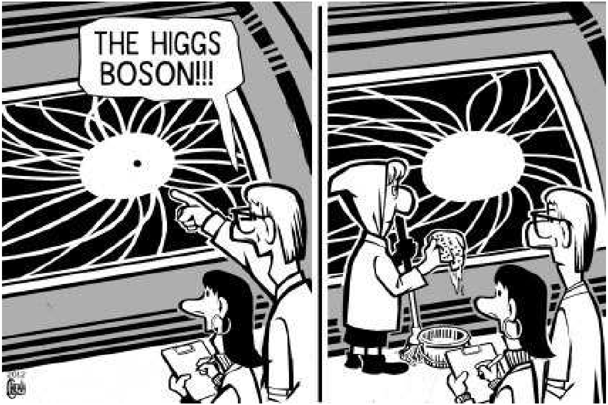
- loop induced FCNCs like $b \to s\gamma$ depend strongly on higher order terms in the Yukawa expansion
  $\to$ independent of Higgs collider pheno
- couplings to t_R and b_R become independent
- parameter space opens up considerably

Summary

- the 2HDM type MFV generalizes the 2HDMs type I - IV
- it is a flexible framework to interpret Higgs data:
  light Higgs couplings to W/Z bosons, top, bottom and tau
  can be modified independently
- prospects for heavy Higgs searches are excellent
  as long as the light Higgs is not exactly SM like

$\rightarrow$ keep searching both in SM and MSSM search channels

- a light charged Higgs can be made compatible with all constraints and can enhance (or suppress...) $h \rightarrow \gamma\gamma$


THE HIGGS BOSON!!!

Back Up

Most General Higgs Potential

$$\begin{aligned} V &= m_{H_1}^2 H_1^\dagger H_1 + m_{H_2}^2 H_2^\dagger H_2 \\ &+ \frac{\lambda_1}{2}(H_1^\dagger H_1)^2 + \frac{\lambda_2}{2}(H_2^\dagger H_2)^2 \\ &+ \lambda_3 (H_1^\dagger H_1)(H_2^\dagger H_2) + \lambda_4 (H_2^\dagger H_1)(H_1^\dagger H_2) \\ &+ \Big(B\mu (H_2 H_1) + \frac{\lambda_5}{2}(H_2 H_1)^2 \\ &\quad - \lambda_6 (H_2 H_1) H_1^\dagger H_1 - \lambda_7 (H_2 H_1) H_2^\dagger H_2 \ + \ h.c. \Big) \end{aligned}$$