BSM Perspective on Precision Higgs Physics

Francesco Riva (CERN)

In Collaboration with:

Pomarol, Gupta, Liu, Rattazzi, Falkowski, Biekötter, Knochel, Krämer

(1308.2803, 1405.0181, 1406.7320, 1411.0669,?)

Motivation

Assume New Physics $\Lambda \gg m_t$

- What New Physics can we see indirectly in Higgs precision measurements?

Motivation

Assume New Physics $\Lambda \gg m_t$

- What New Physics can we see indirectly in Higgs precision measurements?

First: what is genuine Higgs Physics?

- Since H=h+v, Higgs physics must be put in perspective with (disentangled from) EW physics

Motivation

Assume New Physics $\Lambda \gg m_t$

- What New Physics can we see indirectly in Higgs precision measurements?

First: what is genuine Higgs Physics?

- Since H=h+v, Higgs physics must be put in perspective with (disentangled from) EW physics

- This can be done in generality using EFT Language

(EFT as the very motivation for precision tests and to quantify results in comparison with other searches FCCee vs FCChh)

Motivation

Assume New Physics $\Lambda \gg m_t$

- What New Physics can we see indirectly in Higgs precision measurements?

First: what is genuine Higgs Physics?

- Since H=h+v, Higgs physics must be put in perspective with (disentangled from) EW physics

- This can be done in generality using EFT Language
  (EFT as the very motivation for precision tests and to quantify results in comparison with other searches FCCee vs FCChh)

Last: Broad BSM Assumptions → Size of EFT effects

PART 1: EFT, In General
(Higgs/EW Interplay)

Notice: all Wilson coefficients evaluated at $\mu \sim m_W$

For running to UV see e.g.
Elias-Miro,Espinosa,Masso,Pomarol'13; (Alonso,Grojean),Jenkins,Manohar,Trott'13,Elias-Miro,Grojean,Gupta,Marzocca'13

EFT Parametrization

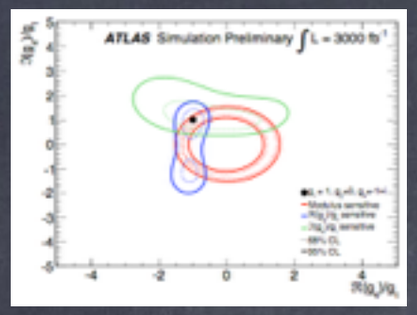
Searches for New Physics

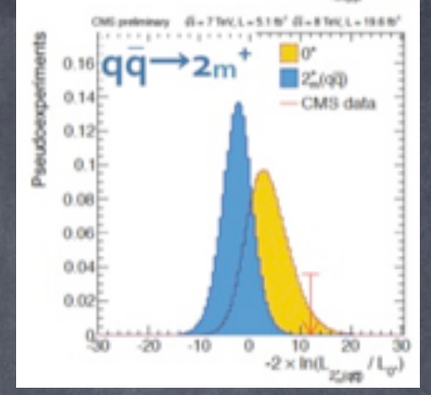
Direct

Precision

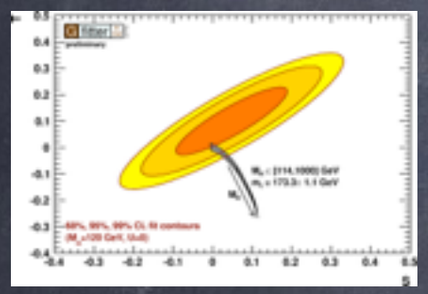
EFT Parametrization

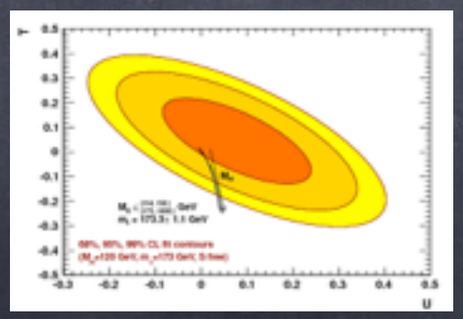
Searches for New Physics

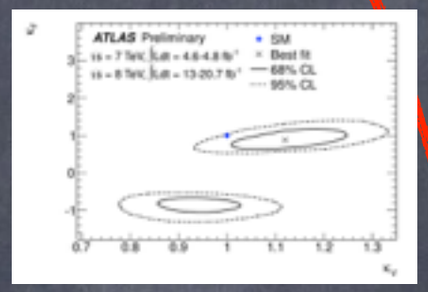


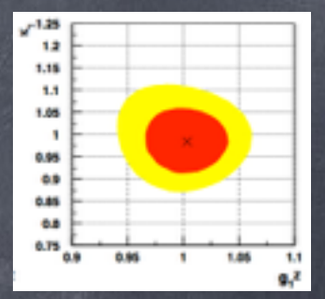


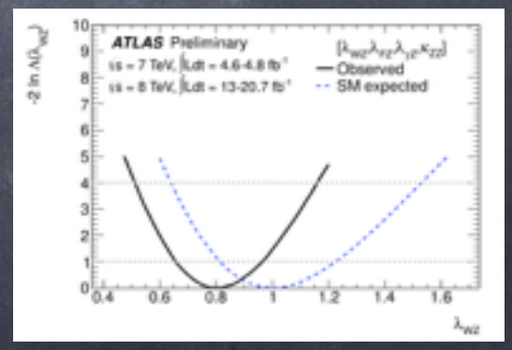
$\mathcal{L}^{SM}$

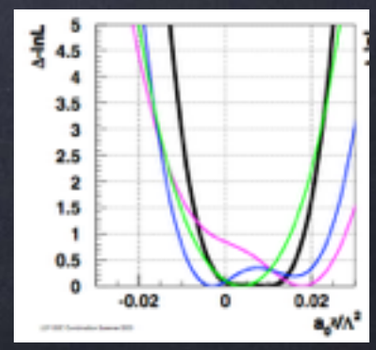






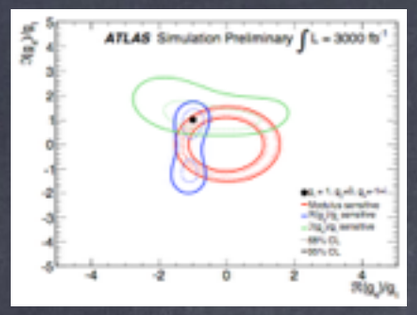


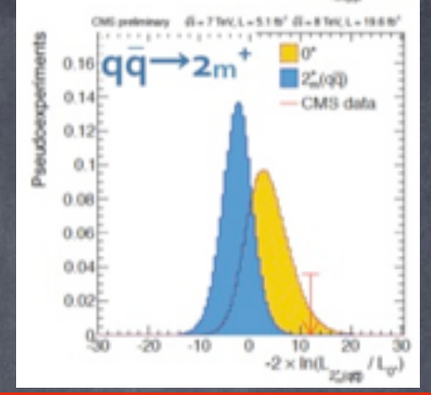




EFT Parametrization

EFT=Organizing Principle





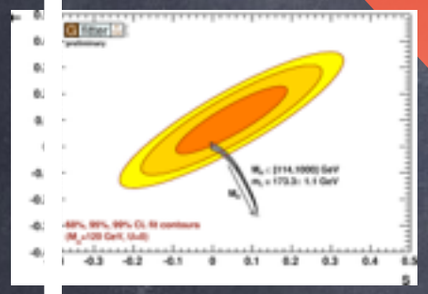
$\mathcal{L}^{SM}$

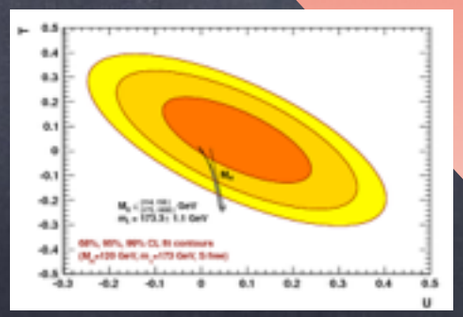
Expansion

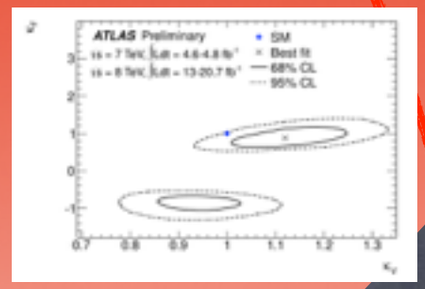
1) E/Λ

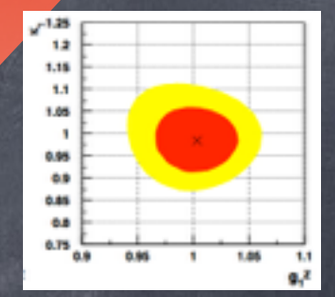
2) H/f

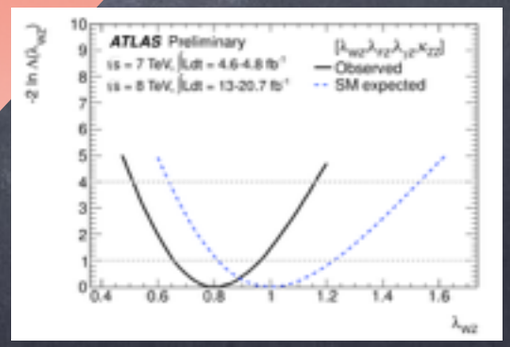
3) Y_U, Y_D, Y_E



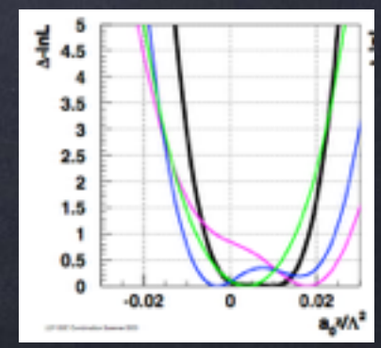






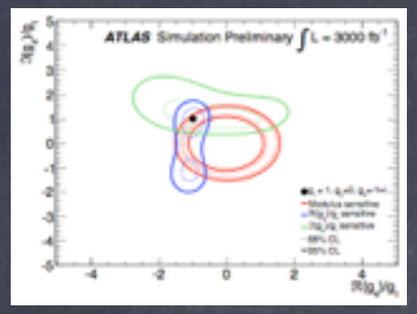


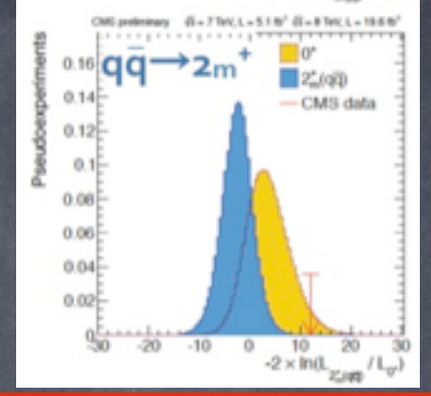
$\mathcal{L}^{UV}$



EFT Parametrization

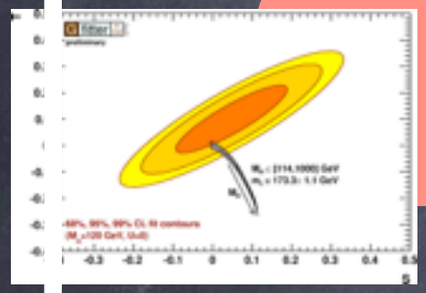
EFT=Organizing Principle

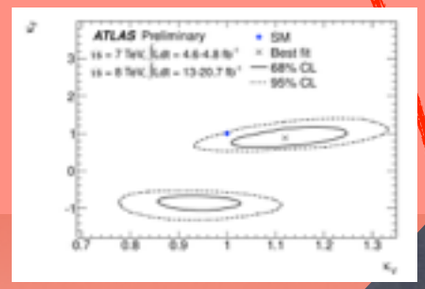


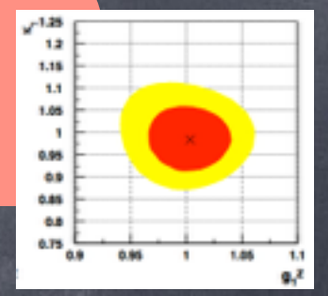


$\mathcal{L}^{SM} \equiv \mathcal{L}^4$

$\mathcal{L}^6$







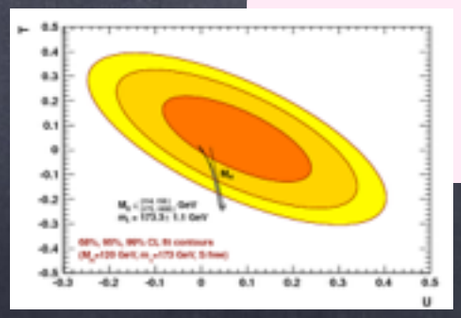
Expansion

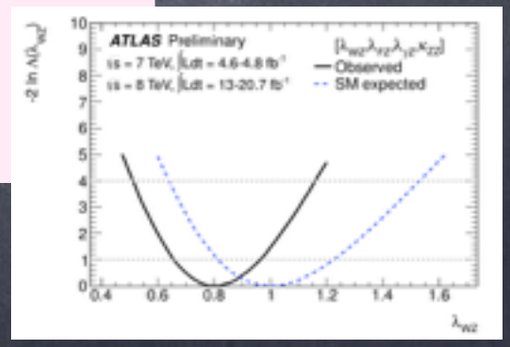
1) E/Λ

2) H/f

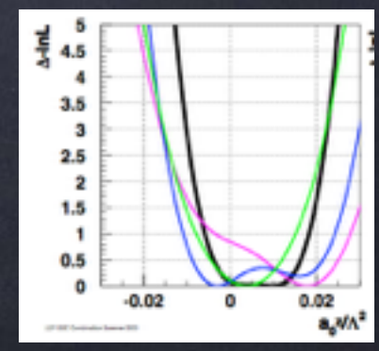
3) Y_U, Y_D, Y_E

$\mathcal{L}^8$



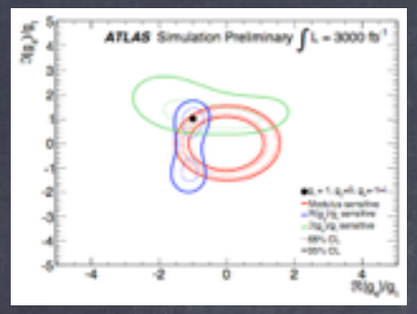


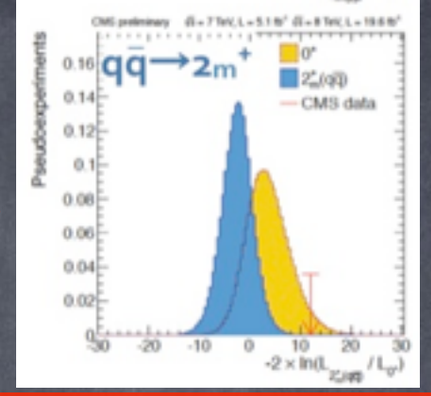
$\mathcal{L}^{UV}$



EFT Parametrization

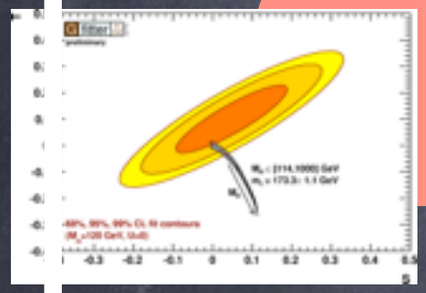
EFT=Organizing Principle

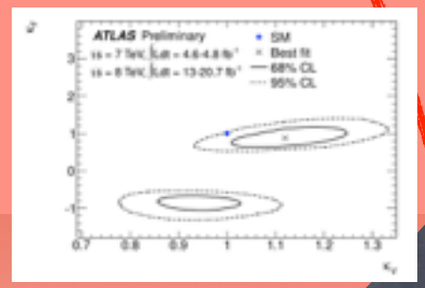


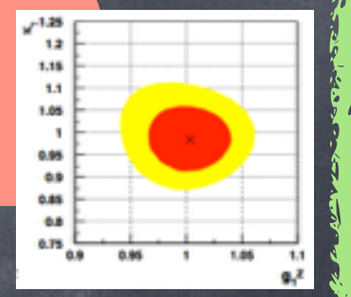


$$\mathcal{L}^{SM} \equiv \mathcal{L}^4$$

$$\mathcal{L}^6$$







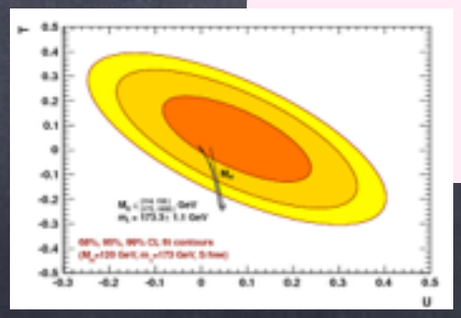
Expansion

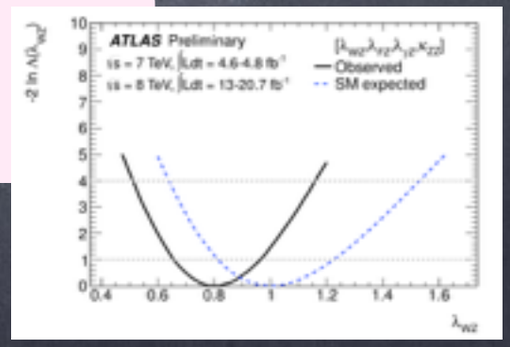
1) E/Λ

2) H/f

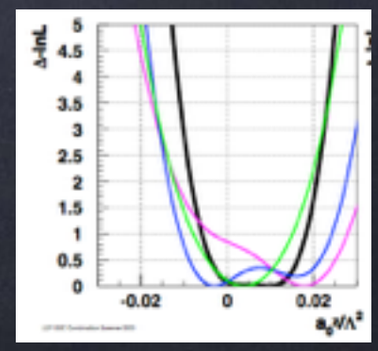
3) Y_U, Y_D, Y_E

$$\mathcal{L}^8$$





$$\mathcal{L}^{UV}$$



Motivation

$$\mathcal{L}_{\rm eff} = \frac{\Lambda^4}{g_*^2}\mathcal{L}\left(\frac{D_\mu}{\Lambda}\,,\ \frac{g_* H}{\Lambda}\,,\ \frac{g_* f_{L,R}}{\Lambda^{3/2}}\,,\ \frac{g F_{\mu\nu}}{\Lambda^2}\right) \simeq \mathcal{L}_4 + \mathcal{L}_6 + \cdots, \qquad \sum_i \frac{c_i}{\Lambda^2}\mathcal{O}_i$$

SM

Buchmuller,Wyler'86;
Giudice et al '07
Grzadkowski et al'10

$$\mathcal{L}^{BSM} \simeq \mathcal{L}^6$$

- What effects can appear in L6?
- How Many? 76 dimension-6 ops.
- What experiments are best to fix them?

Motivation

$$\mathcal{L}_{\rm eff} = \frac{\Lambda^4}{g_*^2}\mathcal{L}\left(\frac{D_\mu}{\Lambda}\,,\ \frac{g_* H}{\Lambda}\,,\ \frac{g_* f_{L,R}}{\Lambda^{3/2}}\,,\ \frac{g F_{\mu\nu}}{\Lambda^2}\right) \simeq \mathcal{L}_4 + \mathcal{L}_6 + \cdots, \qquad \sum_i \frac{c_i}{\Lambda^2}\mathcal{O}_i$$

SM

Buchmuller,Wyler'86;
Giudice et al '07
Grzadkowski et al'10

$$\mathcal{L}^{BSM} \simeq \mathcal{L}^6$$

- What effects can appear in L6?
- How Many? ~~76~~ 17 dimension-6 ops.
- What experiments are best to fix them?

This Talk: HIGGS PHYSICS
(one family, CP conserving)

Parameters for BSM: Higgs-only

Higgs Physics Only

v	←	$\mathcal{O}_r = \lvert H\rvert^2 (D_\mu H)^\dagger (D^\mu H)$
m_d	←	$\mathcal{O}_{y_d} = y_d \lvert H\rvert^2 \bar{Q}_L H d_R$
m_e	←	$\mathcal{O}_{y_e} = y_e \lvert H\rvert^2 \bar{L}_L H e_R$
m_u	←	$\mathcal{O}_{y_u} = y_u \lvert H\rvert^2 \bar{Q}_L \tilde{H} u_R$
g_s	←	$\mathcal{O}_{GG} = \frac{g_s^2}{4} \lvert H\rvert^2 G^A_{\mu\nu} G^{A\mu\nu}$
g'	←	$\mathcal{O}_{BB} = \frac{g'^2}{4} \lvert H\rvert^2 B_{\mu\nu} B^{\mu\nu}$
g	←	$\mathcal{O}_{WW} = \frac{g^2}{4} \lvert H\rvert^2 W^a_{\mu\nu} W^{a\mu\nu}$
m_h	←	$\mathcal{O}_6 = \lambda \lvert H\rvert^6$

$\approx$ / $\|$ / $\langle h \rangle$

In the vacuum <h>=v, operators $|H|^2 \times \mathcal{L}_{SM}$ only redefine SM parameters! ▸ Observable only in Higgs physics!

$$\frac{1}{g_s^2} G_{\mu\nu} G^{\mu\nu} + \frac{|H|^2}{\Lambda^2} G_{\mu\nu} G^{\mu\nu} = \left(\frac{1}{g_s^2} + \frac{v^2}{\Lambda^2} \right) G_{\mu\nu} G^{\mu\nu} + h \frac{2v}{\Lambda^2} G_{\mu\nu} G^{\mu\nu} + \dots$$

Elias-Miro,Espinosa,Masso,Pomarol'13; Gupta,Pomarol,FR'14

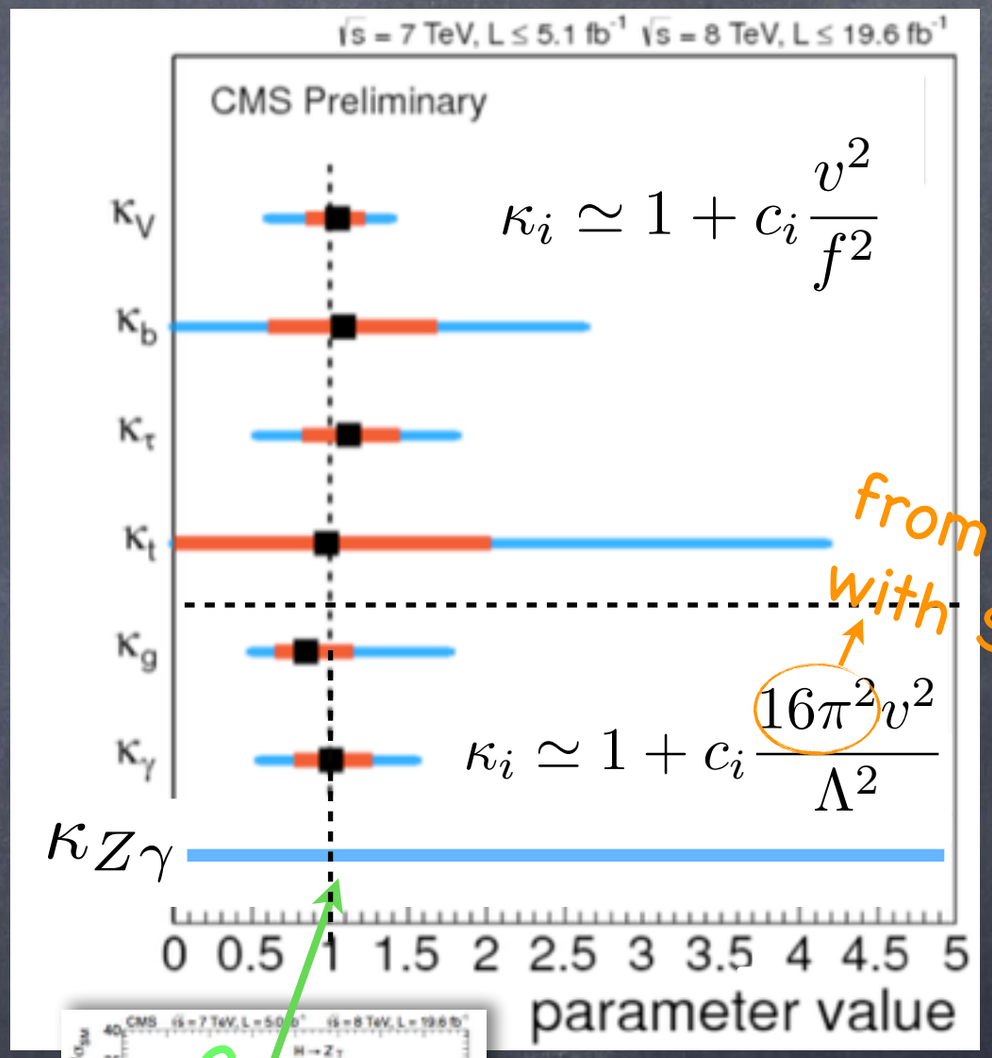
Parameters for BSM: Higgs-only

Higgs Physics Only

$\langle h \rangle = v$

v	$\mathcal{O}_r = \lvert H\rvert^2 (D_\mu H)^\dagger (D^\mu H)$
m_d	$\mathcal{O}_{y_d} = y_d \lvert H\rvert^2 \bar{Q}_L H d_R$
m_e	$\mathcal{O}_{y_e} = y_e \lvert H\rvert^2 \bar{L}_L H e_R$
m_u	$\mathcal{O}_{y_u} = y_u \lvert H\rvert^2 \bar{Q}_L \widetilde{H} u_R$
g_s	$\mathcal{O}_{GG} = \frac{g_s^2}{4} \lvert H\rvert^2 G^A_{\mu\nu} G^{A\mu\nu}$
g'	$\mathcal{O}_{BB} = \frac{g'^2}{4} \lvert H\rvert^2 B_{\mu\nu} B^{\mu\nu}$
g	$\mathcal{O}_{WW} = \frac{g^2}{4} \lvert H\rvert^2 W^a_{\mu\nu} W^{a\mu\nu}$
m_h	$\mathcal{O}_6 = \lambda \lvert H\rvert^6$

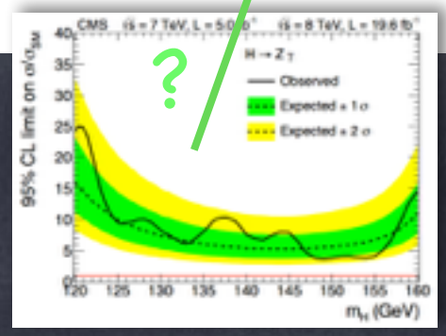
h^3?



$$\kappa_i \simeq 1 + c_i \frac{v^2}{f^2}$$

$$\kappa_i \simeq 1 + c_i \frac{16\pi^2 v^2}{\Lambda^2}$$

from ratio with SM loop



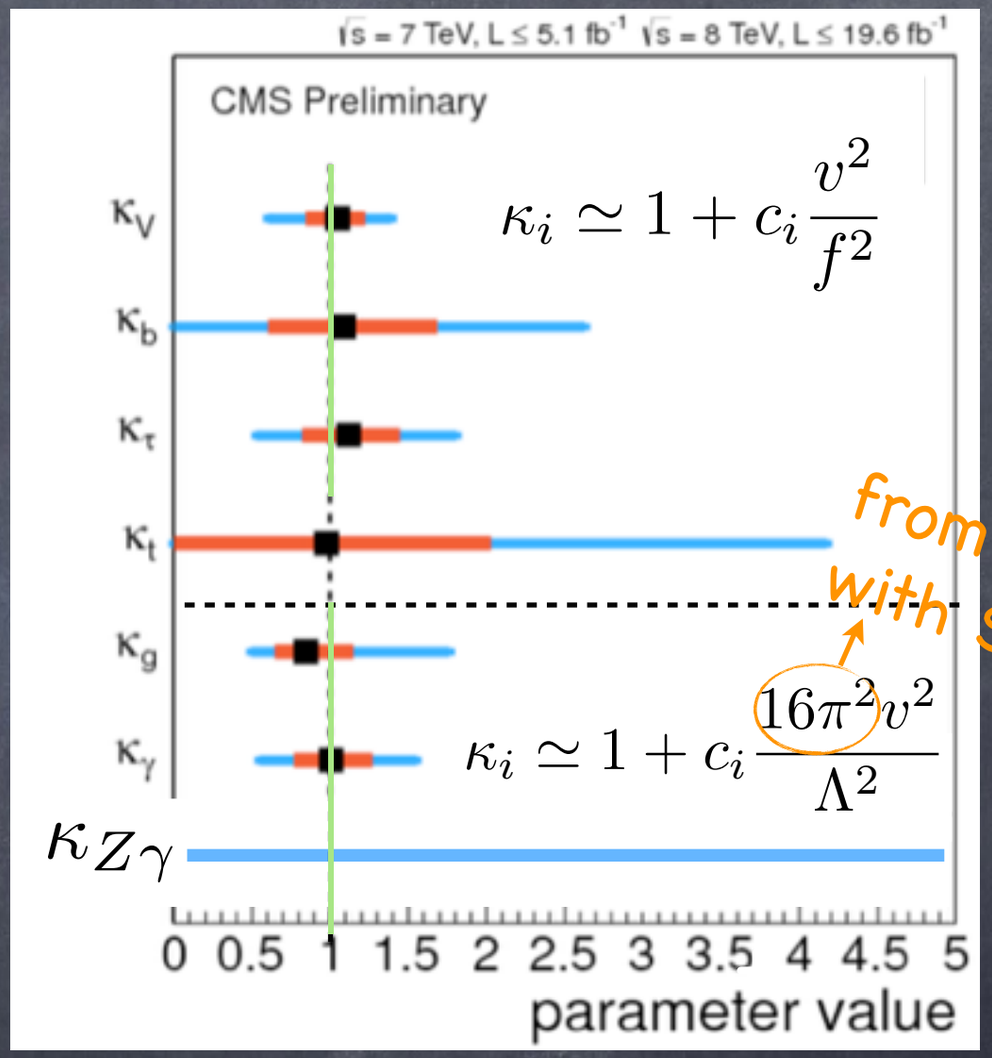
Elias-Miro,Espinosa,Masso,Pomarol13; Gupta,Pomarol,FR'14

Parameters for BSM: Higgs-only

Higgs Physics Only

$\langle h \rangle = v$

v	$\mathcal{O}_r = \lvert H\rvert^2 (D_\mu H)^\dagger (D^\mu H)$
m_d	$\mathcal{O}_{y_d} = y_d \lvert H\rvert^2 \bar{Q}_L H d_R$
m_e	$\mathcal{O}_{y_e} = y_e \lvert H\rvert^2 \bar{L}_L H e_R$
m_u	$\mathcal{O}_{y_u} = y_u \lvert H\rvert^2 \bar{Q}_L \widetilde{H} u_R$
g_s	$\mathcal{O}_{GG} = \frac{g_s^2}{4} \lvert H\rvert^2 G^A_{\mu\nu} G^{A\mu\nu}$
g'	$\mathcal{O}_{BB} = \frac{g'^2}{4} \lvert H\rvert^2 B_{\mu\nu} B^{\mu\nu}$
g	$\mathcal{O}_{WW} = \frac{g^2}{4} \lvert H\rvert^2 W^a_{\mu\nu} W^{a\mu\nu}$
m_h	$\mathcal{O}_6 = \lambda \lvert H\rvert^6$



$$\kappa_i \simeq 1 + c_i \frac{v^2}{f^2}$$

$$\kappa_i \simeq 1 + c_i \frac{16\pi^2 v^2}{\Lambda^2}$$

from ratio with SM loop

These are genuine Higgs physics effects that can be measured at FCC-ee...

... but is there anything else?

Elias-Miro,Espinosa,Masso,Pomarol13; Gupta,Pomarol,FR'14

Parameters for BSM: Higgs+EW

Higgs Physics Only

$\mathcal{O}_r = \lvert H\rvert^2 (D_\mu H)^\dagger (D^\mu H)$
$\mathcal{O}_{y_d} = y_d \lvert H\rvert^2 \bar{Q}_L H d_R$
$\mathcal{O}_{y_e} = y_e \lvert H\rvert^2 \bar{L}_L H e_R$
$\mathcal{O}_{y_u} = y_u \lvert H\rvert^2 \bar{Q}_L \widetilde{H} u_R$
$\mathcal{O}_{GG} = \frac{g_s^2}{4} \lvert H\rvert^2 G^A_{\mu\nu} G^{A\mu\nu}$
$\mathcal{O}_{BB} = \frac{g'^2}{4} \lvert H\rvert^2 B_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_{WW} = \frac{g^2}{4} \lvert H\rvert^2 W^a_{\mu\nu} W^{a\mu\nu}$
$\mathcal{O}_6 = \lambda \lvert H\rvert^6$

EW and Higgs physics

$\mathcal{O}_{WB} = \frac{gg'}{4} (H^\dagger \sigma^a H) W^a_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_T = \frac{1}{2} \left(H^\dagger \overleftrightarrow{D}_\mu H \right)^2$
$\mathcal{O}_R^u = (i H^\dagger \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu u_R)$
$\mathcal{O}_R^d = (i H^\dagger \overleftrightarrow{D}_\mu H)(\bar{d}_R \gamma^\mu d_R)$
$\mathcal{O}_R^e = (i H^\dagger \overleftrightarrow{D}_\mu H)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}_L^q = (i H^\dagger \overleftrightarrow{D}_\mu H)(\bar{Q}_L \gamma^\mu Q_L)$
$\mathcal{O}_L^{(3)\,q} = (i H^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{Q}_L \sigma^a \gamma^\mu Q_L)$
$\mathcal{O}_L = (i H^\dagger \overleftrightarrow{D}_\mu H)(\bar{L}_L \gamma^\mu L_L)$
$\mathcal{O}_L^{(3)} = (i H^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{L}_L \sigma^a \gamma^\mu L_L)$

Parameters for BSM: Higgs+EW

In the vacuum <h>=v, these operators can be measured!

7 of these operators modify:

$Z\bar{\nu}\nu \quad Z\bar{e}_L e_L \quad Z\bar{e}_R e_R$

$Z\bar{u}_L u_L \quad Z\bar{u}_R u_R \quad Z\bar{d}_L d_L \quad Z\bar{d}_R d_R$

Already constrained by LEP1 ‰

EW and Higgs physics

$\mathcal{O}_{WB} = \frac{gg'}{4}(H^\dagger \sigma^a H) W^a_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_T = \frac{1}{2}\left(H^\dagger \overleftrightarrow{D}_\mu H\right)^2$
$\mathcal{O}^u_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu u_R)$
$\mathcal{O}^d_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{d}_R \gamma^\mu d_R)$
$\mathcal{O}^e_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}^q_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{Q}_L \gamma^\mu Q_L)$
$\mathcal{O}^{(3)\,q}_L = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{Q}_L \sigma^a \gamma^\mu Q_L)$
$\mathcal{O}_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{L}_L \gamma^\mu L_L)$
$\mathcal{O}^{(3)}_L = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{L}_L \sigma^a \gamma^\mu L_L)$

Parameters for BSM: Higgs+EW

In the vacuum <h>=v, these operators can be measured!

7 of these operators modify:

$$Z\bar{\nu}\nu \quad Z\bar{e}_L e_L \quad Z\bar{e}_R e_R$$

$$Z\bar{u}_L u_L \quad Z\bar{u}_R u_R \quad Z\bar{d}_L d_L \quad Z\bar{d}_R d_R$$

Already constrained by LEP1 ‰

Constraints from FCC-ee?

- Measurements on Z-pole (no E-enhancement)
- Benefits from high luminosity

EW and Higgs physics

$\mathcal{O}_{WB} = \frac{gg'}{4}(H^\dagger \sigma^a H) W^a_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_T = \frac{1}{2}\left(H^\dagger \overleftrightarrow{D}_\mu H\right)^2$
$\mathcal{O}^u_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu u_R)$
$\mathcal{O}^d_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{d}_R \gamma^\mu d_R)$
$\mathcal{O}^e_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}^q_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{Q}_L \gamma^\mu Q_L)$
$\mathcal{O}^{(3)\,q}_L = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{Q}_L \sigma^a \gamma^\mu Q_L)$
$\mathcal{O}_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{L}_L \gamma^\mu L_L)$
$\mathcal{O}^{(3)}_L = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{L}_L \sigma^a \gamma^\mu L_L)$

Parameters for BSM: Higgs+EW

In the vacuum <h>=v, these operators can be measured!

7 of these operators modify:

$$Z\bar{\nu}\nu \quad Z\bar{e}_L e_L \quad Z\bar{e}_R e_R$$

$$Z\bar{u}_L u_L \quad Z\bar{u}_R u_R \quad Z\bar{d}_L d_L \quad Z\bar{d}_R d_R$$

Already constrained by LEP1 ‰

Constraints from FCC-ee:

Preview:

EW and Higgs physics

$\mathcal{O}_{WB} = \frac{gg'}{4}(H^\dagger \sigma^a H) W^a_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_T = \frac{1}{2}\left(H^\dagger \overleftrightarrow{D}_\mu H\right)^2$
$\mathcal{O}^u_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu u_R)$
$\mathcal{O}^d_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{d}_R \gamma^\mu d_R)$
$\mathcal{O}^e_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}^q_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{Q}_L \gamma^\mu Q_L)$
$\mathcal{O}^{(3)\,q}_L = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{Q}_L \sigma^a \gamma^\mu Q_L)$
$\mathcal{O}_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{L}_L \gamma^\mu L_L)$
$\mathcal{O}^{(3)}_L = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{L}_L \sigma^a \gamma^\mu L_L)$

(Gupta),Pomarol,FR'13-14; Falkowski,FR'14, Ellis,Sanz,You'14

Parameters for BSM: Higgs+EW

In the vacuum <h>=v, these operators can be measured!

7 of these operators modify:

$Z\bar{\nu}\nu \quad Z\bar{e}_L e_L \quad Z\bar{e}_R e_R$

$Z\bar{u}_L u_L \quad Z\bar{u}_R u_R \quad Z\bar{d}_L d_L \quad Z\bar{d}_R d_R$

EW and Higgs physics

$\mathcal{O}_{WB} = \frac{gg'}{4}(H^\dagger \sigma^a H) W^a_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_T = \frac{1}{2}\left(H^\dagger \overleftrightarrow{D}_\mu H\right)^2$
$\mathcal{O}^u_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu u_R)$
$\mathcal{O}^d_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{d}_R \gamma^\mu d_R)$
$\mathcal{O}^e_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}^q_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{Q}_L \gamma^\mu Q_L)$
$\mathcal{O}^{(3)\,q}_L = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{Q}_L \sigma^a \gamma^\mu Q_L)$
$\mathcal{O}_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{L}_L \gamma^\mu L_L)$
$\mathcal{O}^{(3)}_L = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{L}_L \sigma^a \gamma^\mu L_L)$

Already constrained by LEP1 ‰

Constraints from FCC-ee:

Preview:

Impact of these operators in H-physics will be irrelevant

(Gupta),Pomarol,FR'13-14; Falkowski,FR'14, Ellis,Sanz,You'14

Parameters for BSM: Higgs+EW

In the vacuum <h>=v, these operators can be measured!

2 of these modify TGCs: $g_Z^1 \quad \kappa_\gamma$

Hagiwara,Hikasa, Peccei,Zeppenfled'87

Already LEP2 constrained $\sim$5%

$e^+e^- \to W^+W^-$

EW and Higgs physics

$\mathcal{O}_{WB} = \frac{gg'}{4}(H^\dagger \sigma^a H) W^a_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_T = \frac{1}{2}\left(H^\dagger \overleftrightarrow{D}_\mu H\right)^2$
$\mathcal{O}_R^u = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu u_R)$
$\mathcal{O}_R^d = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{d}_R \gamma^\mu d_R)$
$\mathcal{O}_R^e = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}_L^q = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{Q}_L \gamma^\mu Q_L)$
$\mathcal{O}_L^{(3)\,q} = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{Q}_L \sigma^a \gamma^\mu Q_L)$
$\mathcal{O}_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{L}_L \gamma^\mu L_L)$
$\mathcal{O}_L^{(3)} = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{L}_L \sigma^a \gamma^\mu L_L)$

Parameters for BSM: Higgs+EW

In the vacuum <h>=v, these operators can be measured!

2 of these modify TGCs: $g_Z^1 \quad \kappa_\gamma$

Hagiwara,Hikasa, Peccei,Zeppenfled'87

Already LEP2 constrained $\sim$5%

$e^+e^- \to W^+W^-$

Constraints from FCC-ee?

- E-enhanced effects!
- FCC-ee perfect for these!

EW and Higgs physics

$\mathcal{O}_{WB} = \frac{gg'}{4}(H^\dagger \sigma^a H) W^a_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_T = \frac{1}{2}\left(H^\dagger \overleftrightarrow{D}_\mu H\right)^2$
$\mathcal{O}_R^u = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu u_R)$
$\mathcal{O}_R^d = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{d}_R \gamma^\mu d_R)$
$\mathcal{O}_R^e = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}_L^q = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{Q}_L \gamma^\mu Q_L)$
$\mathcal{O}_L^{(3)\,q} = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{Q}_L \sigma^a \gamma^\mu Q_L)$
$\mathcal{O}_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{L}_L \gamma^\mu L_L)$
$\mathcal{O}_L^{(3)} = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{L}_L \sigma^a \gamma^\mu L_L)$

Parameters for BSM: Higgs+EW

In the vacuum <h>=v, these operators can be measured!

2 of these modify TGCs: $g_Z^1 \quad \kappa_\gamma$

Hagiwara,Hikasa, Peccei,Zeppenfled'87

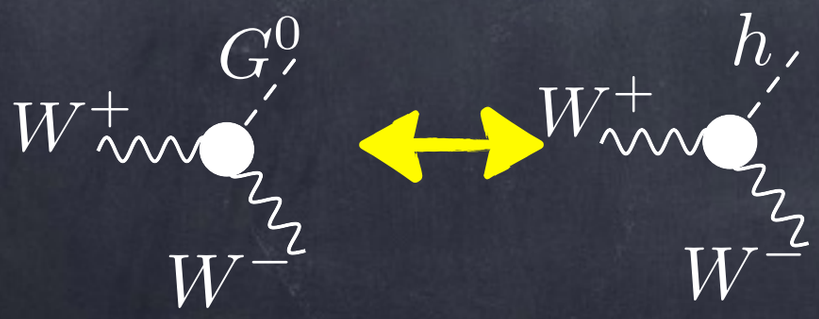
Already LEP2 constrained $\sim$5%

$e^+e^- \to W^+W^-$

Constraints from FCC-ee?

- E-enhanced effects!
- FCC-ee perfect for these!

Preview:



EW and Higgs physics

$\mathcal{O}_{WB} = \frac{gg'}{4}(H^\dagger \sigma^a H) W^a_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_T = \frac{1}{2}\left(H^\dagger \overleftrightarrow{D}_\mu H\right)^2$
$\mathcal{O}_R^u = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu u_R)$
$\mathcal{O}_R^d = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{d}_R \gamma^\mu d_R)$
$\mathcal{O}_R^e = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}_L^q = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{Q}_L \gamma^\mu Q_L)$
$\mathcal{O}_L^{(3)\,q} = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{Q}_L \sigma^a \gamma^\mu Q_L)$
$\mathcal{O}_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{L}_L \gamma^\mu L_L)$
$\mathcal{O}_L^{(3)} = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{L}_L \sigma^a \gamma^\mu L_L)$

Impact of these operators in H-decays irrelevant
Impact in H-production competitive (due to E-enhancement)

EFT Summary

ee->VH and ee->VV
(modify also EW physics, and is E-enhanced)

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

Higgs Physics and Z-Pole
(modify also Z-pole physics)

Higgs Physics Only
(modifications of SM Higgs vertices without E-dependence)

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

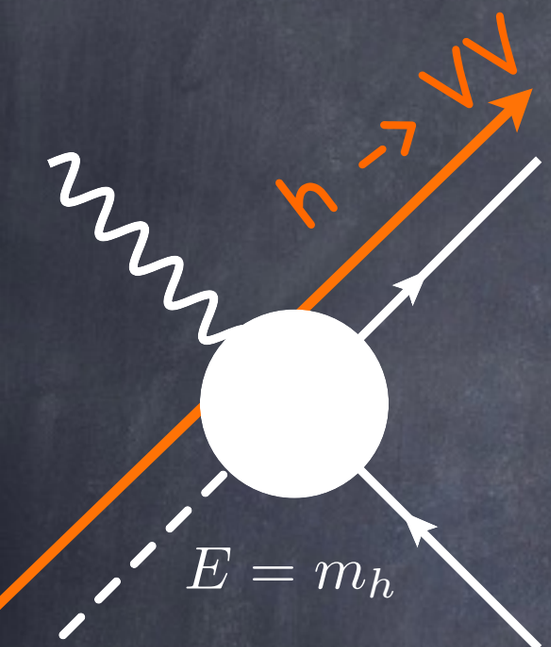
Now: LEP1 < LEP2 < LHC

FCCee: Will this hierarchy of constraints hold?

Or will H-physics improve on some EW measurements?

Implications For Higgs Physics

Decays different. distr. of $h \to Z\bar{f}f$ or $h \to W\bar{f}f$



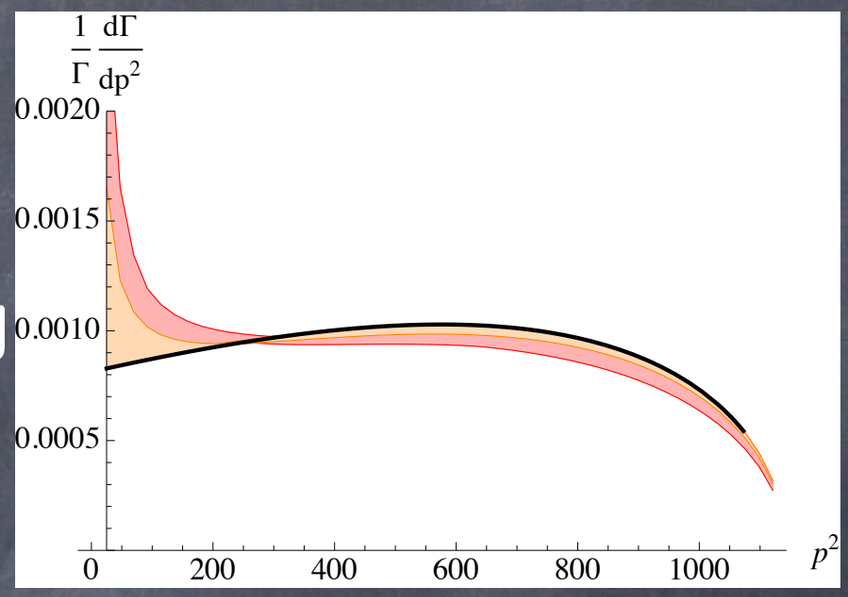
Z-Pole

~~Related with Zff couplings~~

Related to Triple Gauge Coupling

Related with $h \to Z\gamma, \gamma\gamma$

(effect of these operators here small wrt SM)

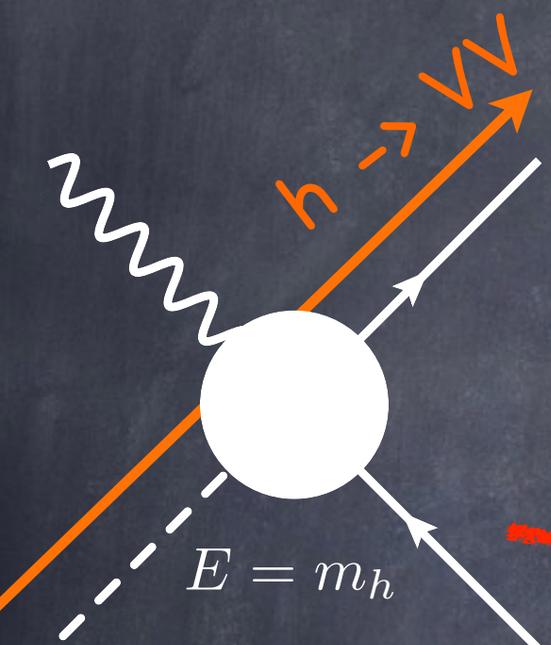


Here Higgs physics at FCCee could improve on EW measurements

Pomarol,FR'13; Beneke,Boito,Wang'14

Implications For Higgs Physics

Decays different. distr. of $h \to Z\bar{f}f$ or $h \to W\bar{f}f$

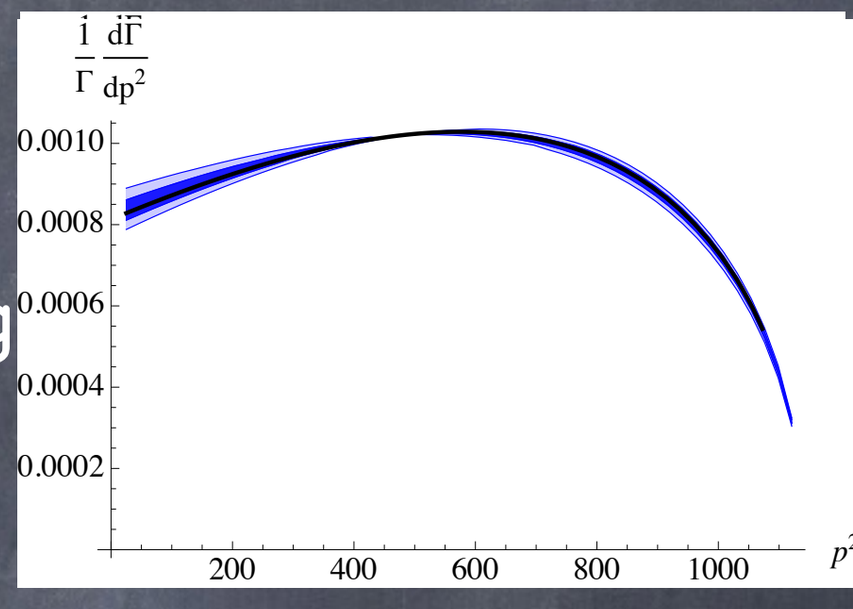


~~Related with Zff couplings~~ Z-Pole

Related to Triple Gauge Coupling

~~Related with~~ $h \to Z\gamma, \gamma\gamma$

~~(effect of these operators here small wrt SM)~~

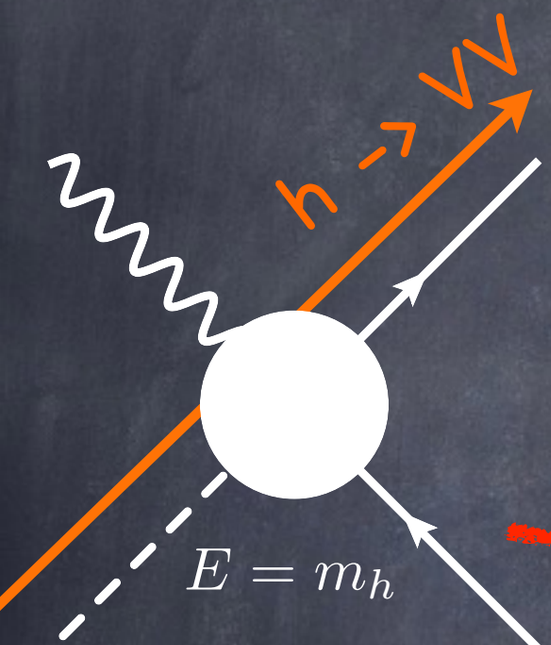


Here Higgs physics at FCCee could improve on EW measurements

Pomarol,FR'13; Beneke,Boito,Wang'14

Implications For Higgs Physics

Decays different. distr. of $h \to Z\bar{f}f$ or $h \to W\bar{f}f$



Z-Pole

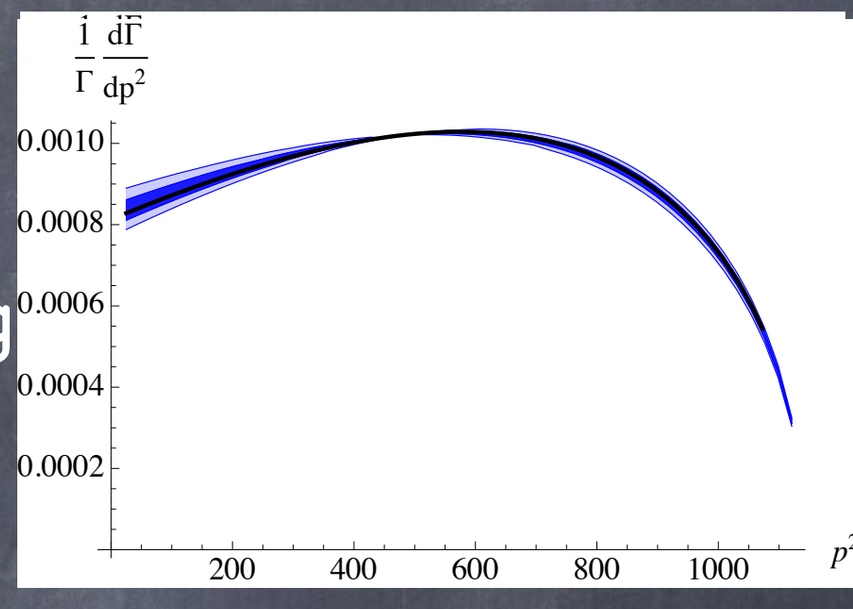
Related with Zff couplings

Related to Triple Gauge Coupling

ee->WW High-E

Related with $h \to Z\gamma, \gamma\gamma$

(effect of these operators here small wrt SM)

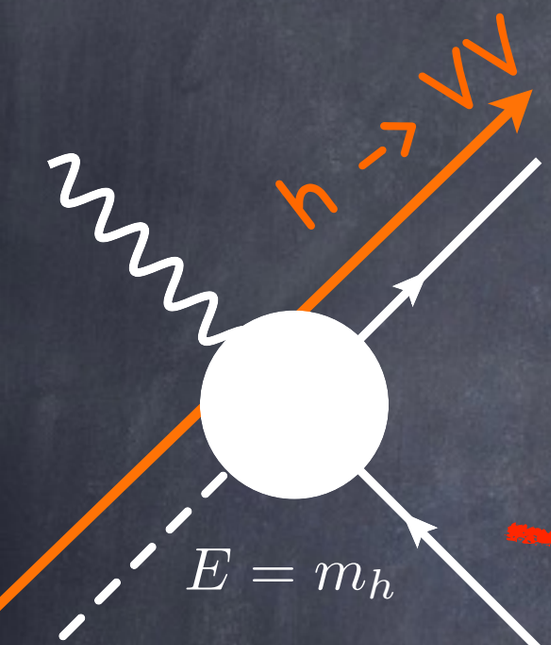


Here Higgs physics at FCCee could improve on EW measurements

Pomarol,FR'13; Beneke,Boito,Wang'14

Implications For Higgs Physics

Decays different. distr. of $h \to Z\bar{f}f$ or $h \to W\bar{f}f$



Z-Pole

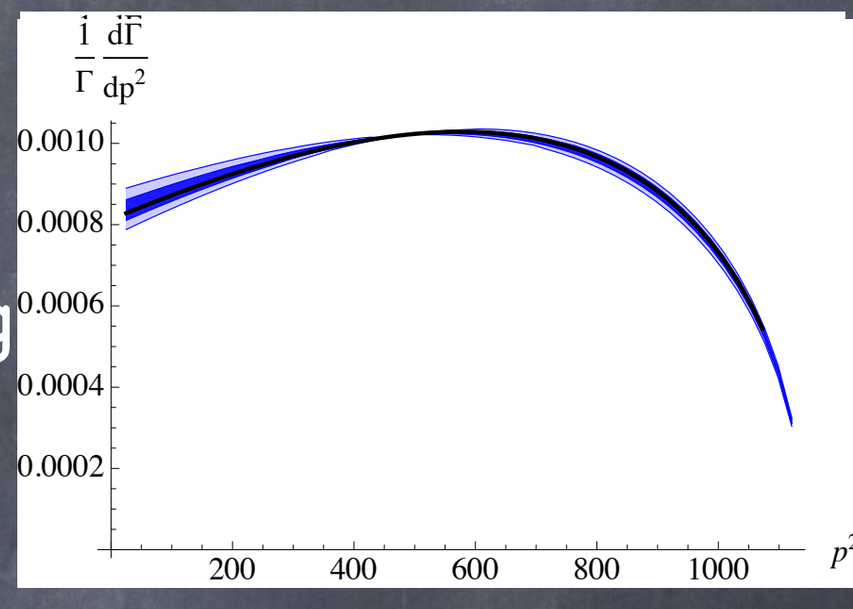
Related with Zff couplings

Related to Triple Gauge Coupling

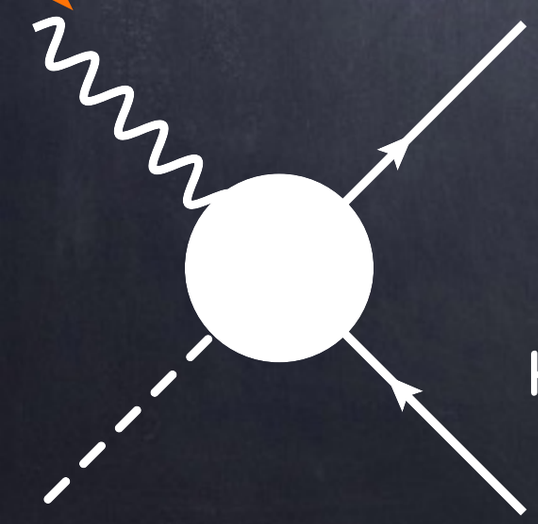
ee->WW High-E

Related with $h \to Z\gamma, \gamma\gamma$

(effect of these operators here small wrt SM)



VH-Associated



At High-E ee->WH competitive with ee->WW

Here Higgs physics at FCCee could improve on EW measurements

Pomarol,FR'13; Beneke,Boito,Wang'14

(angular distributions further enhance sensitivity)

PART 2
BSM Perspective

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H) \partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

Given a BSM scenario, what are the coefficients in front of these operators?

The power of Indirect Searches

- In weakly coupled UV theories?
  Coefficients of order 1 for tree-level effects (no loops)

$$\sigma \simeq \sigma_{SM}\left(1+\frac{E^2}{\Lambda^2}\right)$$

$E \to m_Z, m_H$ for most effects

Can this give access to scales untouched by LHC?

Higgs coupling sensitivity =1% → $\Lambda \approx 1$ TeV

Explicit Examples: MSSM

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

(*Specific regions of parameter space can elude this power counting)

Gupta,Montull,FR'12; Barbieri,Tesi'13; Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: MSSM

R-Parity: no tree-level contributions from sparticles (only H_2)

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

(*Specific regions of parameter space can elude this power counting)

Gupta,Montull,FR'12; Barbieri,Tesi'13; Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: MSSM

R-Parity: no tree-level contributions from sparticles (only H_2)

Weakly coupled: loop effects small unless sparticles very light

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H) \partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

(*Specific regions of parameter space can elude this power counting)

Gupta,Montull,FR'12; Barbieri,Tesi'13; Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: MSSM

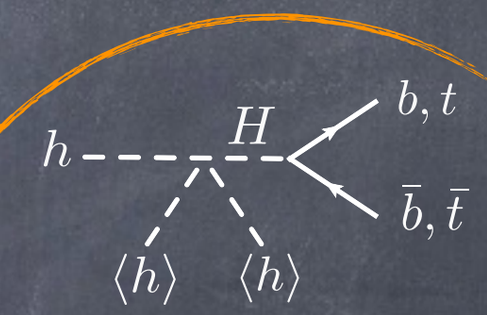
R-Parity: no tree-level contributions from sparticles (only H_2)

Weakly coupled: loop effects small unless sparticles very light

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$



$$c_{y_t} \sim \frac{m_Z^2}{m_H^2} \cot\beta$$

(*Specific regions of parameter space can elude this power counting)

Gupta,Montull,FR'12; Barbieri,Tesi'13; Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: MSSM

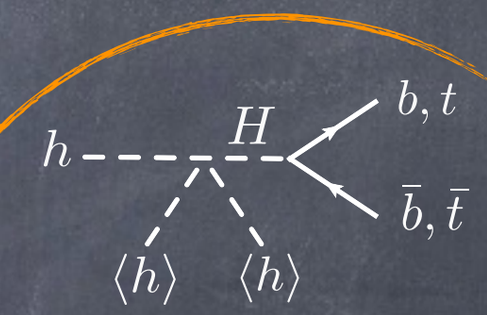
R-Parity: no tree-level contributions from sparticles (only H_2)

Weakly coupled: loop effects small unless sparticles very light

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H) \partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$



$$c_{y_t} \sim \frac{m_Z^2}{m_H^2} \cot\beta$$

$$c_{y_{d,e}} \sim \frac{m_Z^2}{m_H^2} \tan\beta$$

(*Specific regions of parameter space can elude this power counting)

Gupta,Montull,FR'12; Barbieri,Tesi'13; Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: MSSM

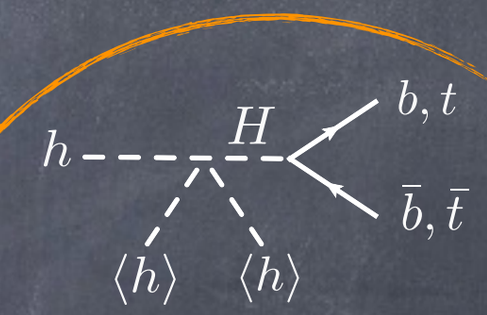
R-Parity: no tree-level contributions from sparticles (only H_2)

Weakly coupled: loop effects small unless sparticles very light

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

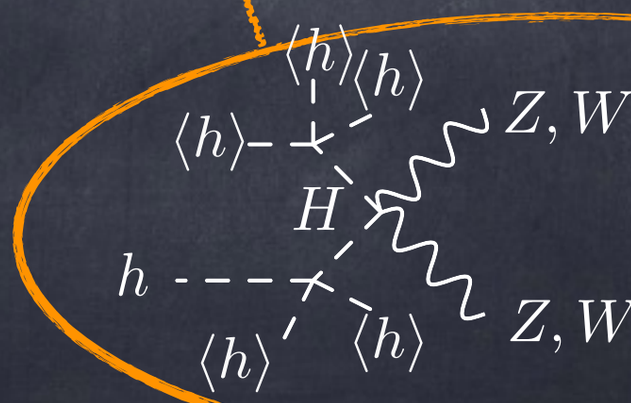
$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H) \partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$



$$c_{y_t} \sim \frac{m_Z^2}{m_H^2} \cot\beta$$

$$c_{y_{d,e}} \sim \frac{m_Z^2}{m_H^2} \tan\beta$$



$$c_H \sim \frac{m_Z^4}{m_H^4}$$

(*Specific regions of parameter space can elude this power counting)

Gupta,Montull,FR'12; Barbieri,Tesi'13; Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: MSSM

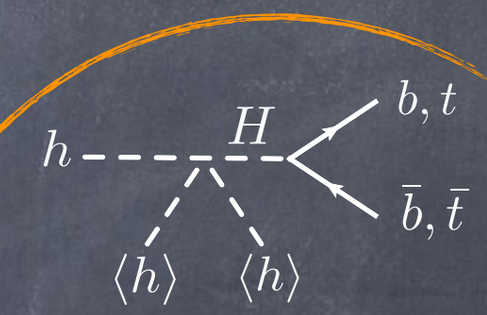
R-Parity: no tree-level contributions from sparticles (only H_2)

Weakly coupled: loop effects small unless sparticles very light

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

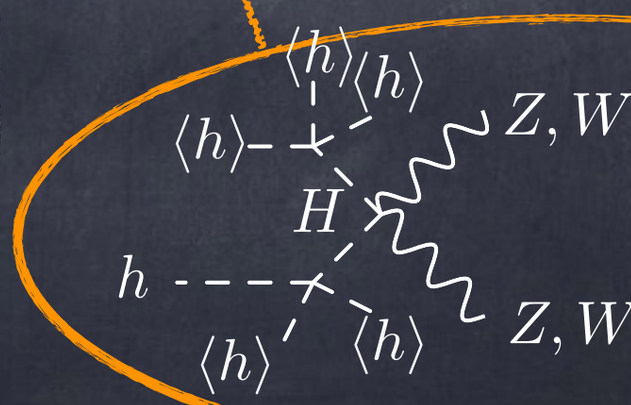
$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H) \partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$



$$c_{y_t} \sim \frac{m_Z^2}{m_H^2} \cot\beta$$

$$c_{y_{d,e}} \sim \frac{m_Z^2}{m_H^2} \tan\beta$$



$$c_H \sim \frac{m_Z^4}{m_H^4}$$

Best Handles*: k_b, k_t

(*Specific regions of parameter space can elude this power counting)

Gupta,Montull,FR'12; Barbieri,Tesi'13; Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: NMSSM

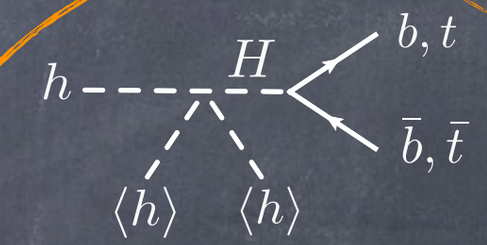
R-Parity: no tree-level contributions from sparticles (only H_2)

Weakly coupled: loop effects small unless sparticles very light

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

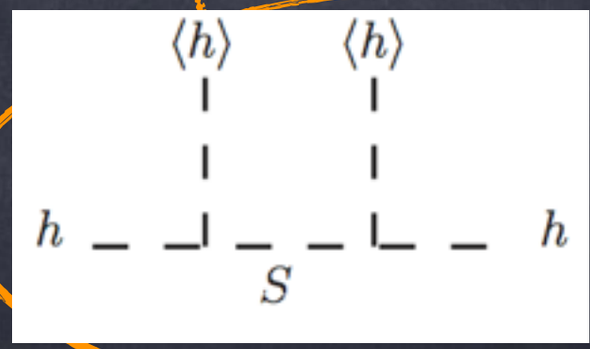
$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$



$$c_{y_t} \sim \frac{m_Z^2}{m_H^2} \cot\beta$$

$$c_{y_{d,e}} \sim \frac{m_Z^2}{m_H^2} \tan\beta$$



$$c_H \sim \frac{m_Z^2}{m_S^2}$$

Gupta,Montull,FR'12; Barbieri,Tesi'13
Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: NMSSM

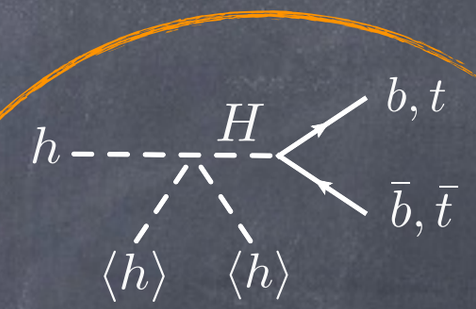
R-Parity: no tree-level contributions from sparticles (only H_2)

Weakly coupled: loop effects small unless sparticles very light

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

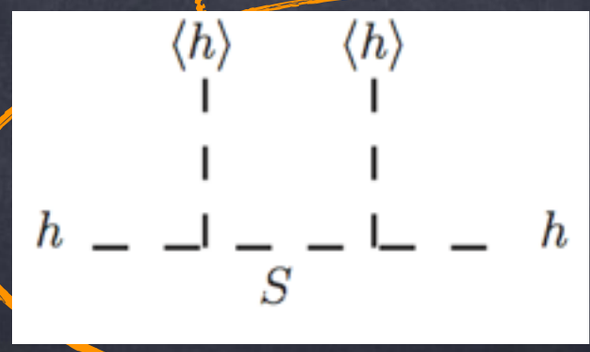
$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$



$$c_{y_t} \sim \frac{m_Z^2}{m_H^2} \cot\beta$$

$$c_{y_{d,e}} \sim \frac{m_Z^2}{m_H^2} \tan\beta$$

Best Handles: k_b, k_t, k_H



$$c_H \sim \frac{m_Z^2}{m_S^2}$$

Gupta,Montull,FR'12; Barbieri,Tesi'13
Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: MSSM

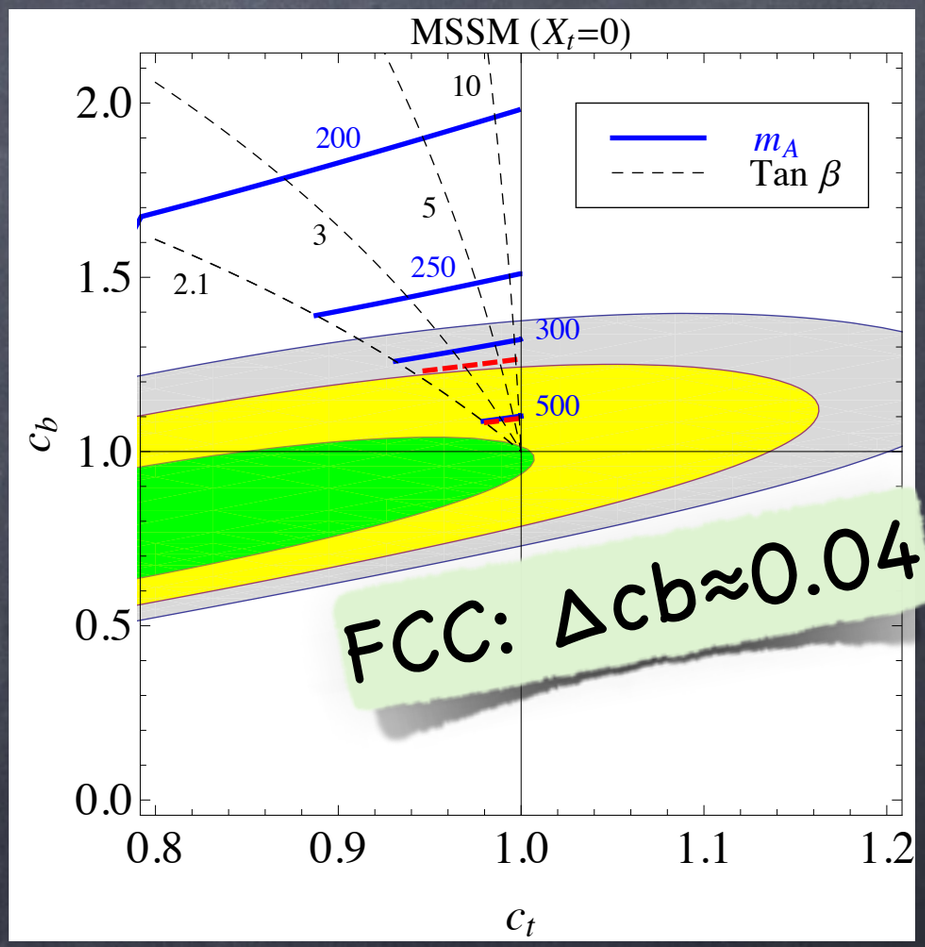
Generally* 2HDM structure:

heavy Higgs ⟷ modified Higgs couplings

Heavy stops,D-terms,F-terms:

$$\Delta V = \delta_\lambda h^4 + \delta h^3 H + \ldots$$

$$m_h^2 \approx m_Z^2 + 16\delta_\lambda v^2$$
$$= (125\text{GeV})^2$$



Blum,D'Agnolo,Fan'12; Azatov,Chang,Craig,Galloway'12
Montull,Gupta, FR, '12

Explicit Examples: MSSM

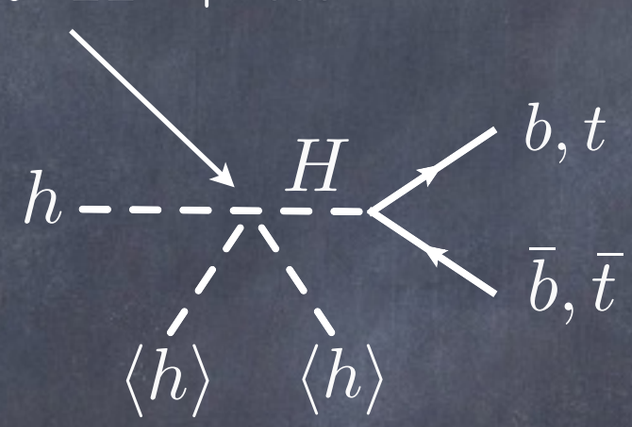
Generally* 2HDM structure:

heavy Higgs ⟷ modified Higgs couplings

Heavy stops,D-terms,F-terms:

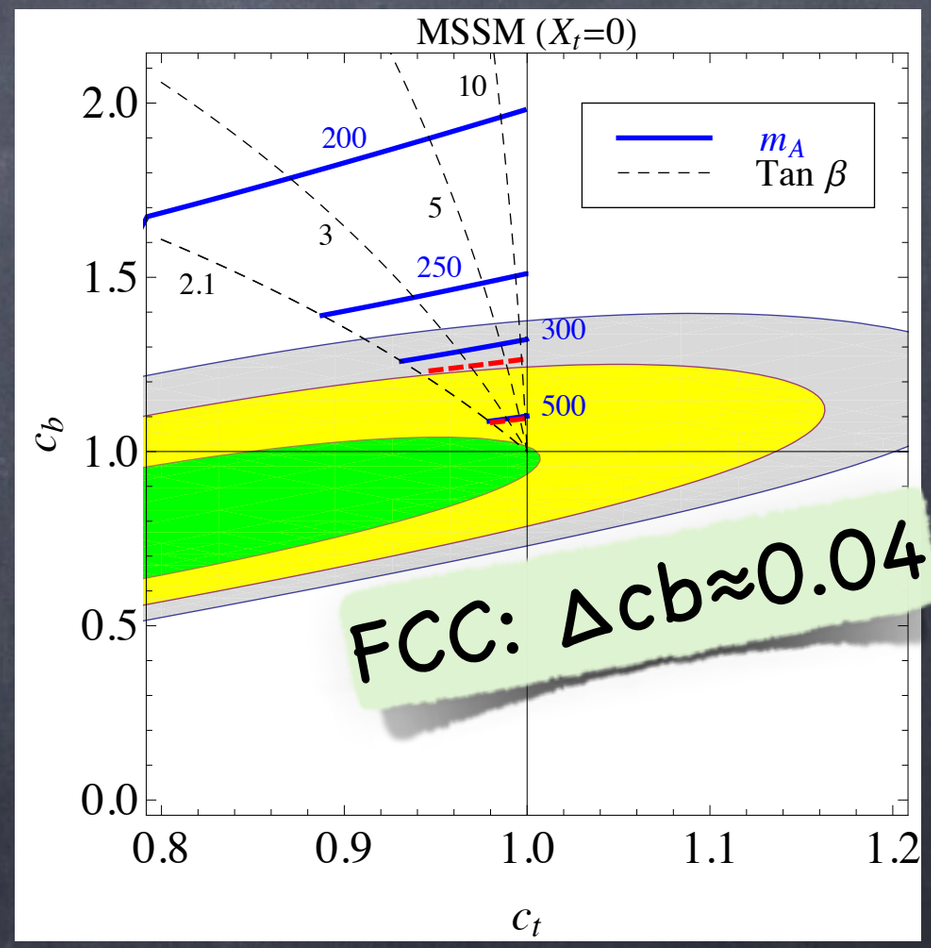
$$\Delta V = \delta_\lambda h^4 + \delta h^3 H + \ldots$$

$$m_h^2 \approx m_Z^2 + 16\delta_\lambda v^2$$
$$= (125\text{GeV})^2$$



$$\frac{y_b}{y_b^{SM}} = 1 - 4\delta \tan\tilde{\beta}\frac{v^2}{m_H^2}$$

$$\frac{y_t}{y_t^{SM}} = 1 + 4\delta \cot\tilde{\beta}\frac{v^2}{m_H^2}$$



Blum,D'Agnolo,Fan'12; Azatov,Chang,Craig,Galloway'12
Montull,Gupta, FR, '12

Explicit Examples: MSSM

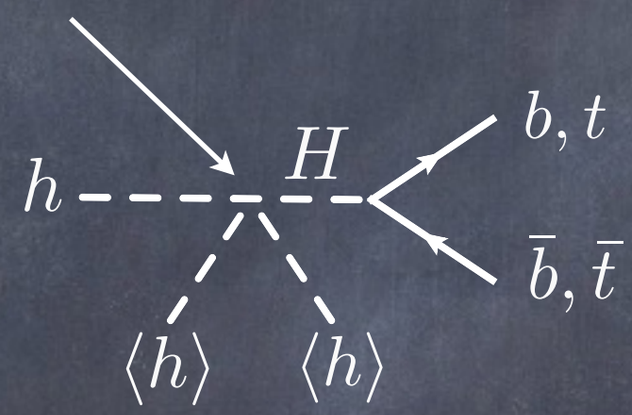
Generally* 2HDM structure:

heavy Higgs ⟷ modified Higgs couplings

Heavy stops,D-terms,F-terms:

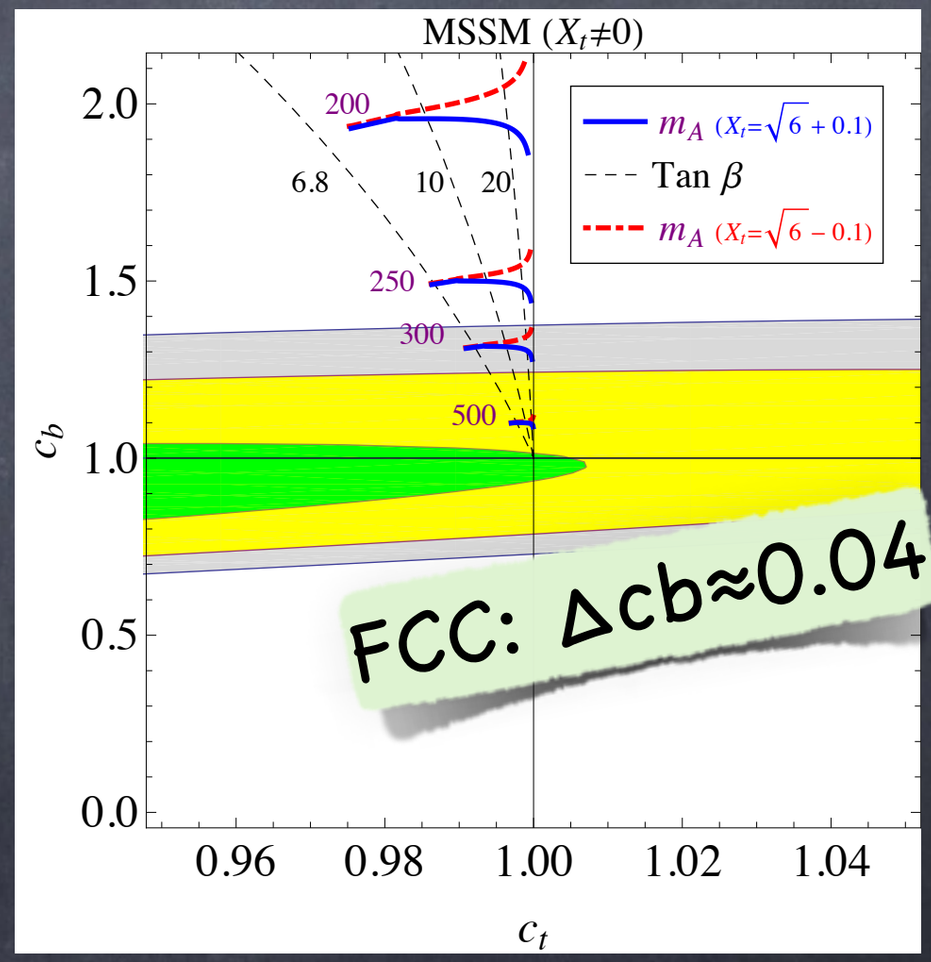
$$\Delta V = \delta_\lambda h^4 + \delta h^3 H + \ldots$$

$$m_h^2 \approx m_Z^2 + 16\delta_\lambda v^2 = (125\text{GeV})^2$$



$$\frac{y_b}{y_b^{SM}} = 1 - 4\delta \tan\tilde{\beta}\frac{v^2}{m_H^2}$$

$$\frac{y_t}{y_t^{SM}} = 1 + 4\delta \cot\tilde{\beta}\frac{v^2}{m_H^2}$$



Blum,D'Agnolo,Fan'12; Azatov,Chang,Craig,Galloway'12
Montull,Gupta, FR, '12

Explicit Examples: MSSM

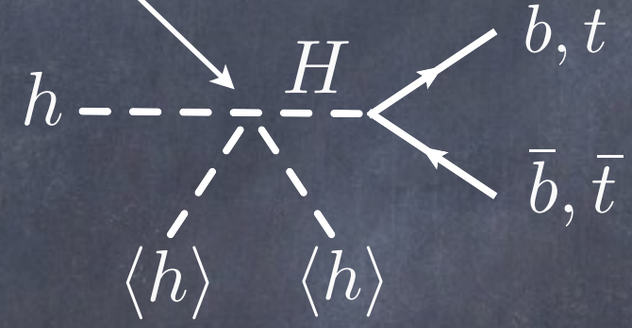
Generally* 2HDM structure:

heavy Higgs ⟷ modified Higgs couplings

Heavy stops, D-terms, F-terms:

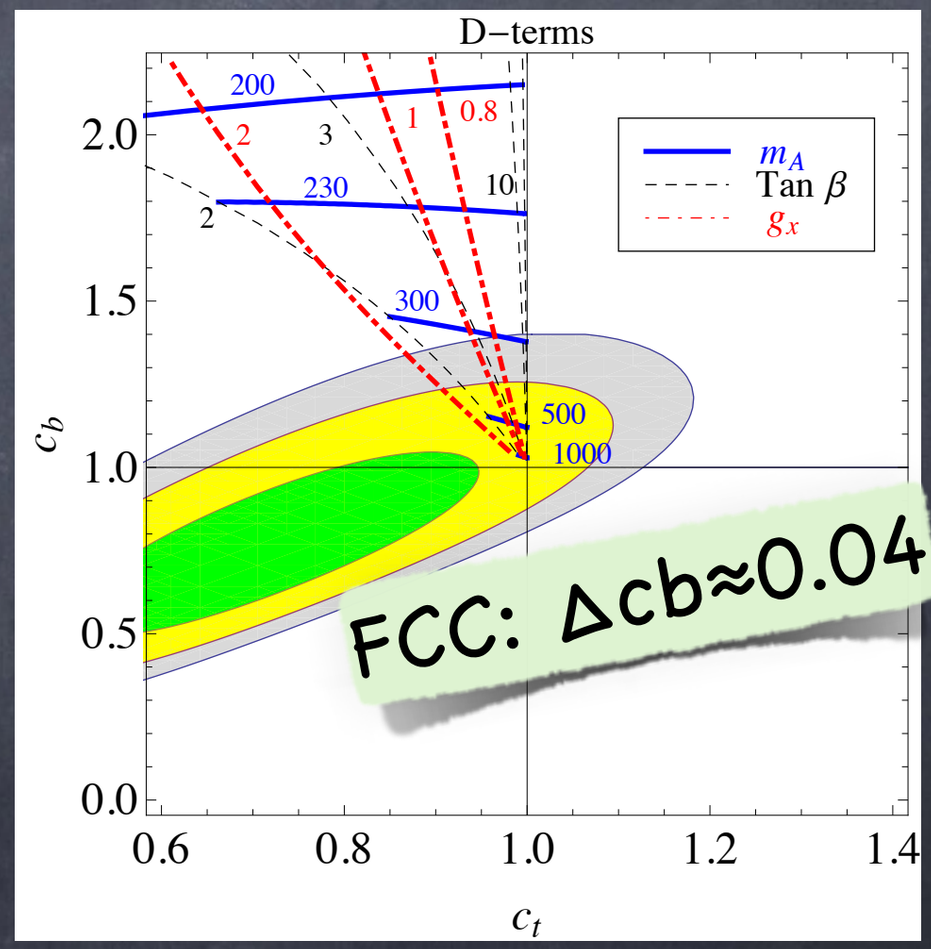
$$\Delta V = \delta_\lambda h^4 + \delta h^3 H + \dots$$

$$m_h^2 \approx m_Z^2 + 16\delta_\lambda v^2 = (125\text{GeV})^2$$



$$\frac{y_b}{y_b^{SM}} = 1 - 4\delta \tan\tilde{\beta}\frac{v^2}{m_H^2}$$

$$\frac{y_t}{y_t^{SM}} = 1 + 4\delta \cot\tilde{\beta}\frac{v^2}{m_H^2}$$



Blum,D'Agnolo,Fan'12; Azatov,Chang,Craig,Galloway'12
Montull,Gupta, FR, '12

Explicit Examples: MSSM

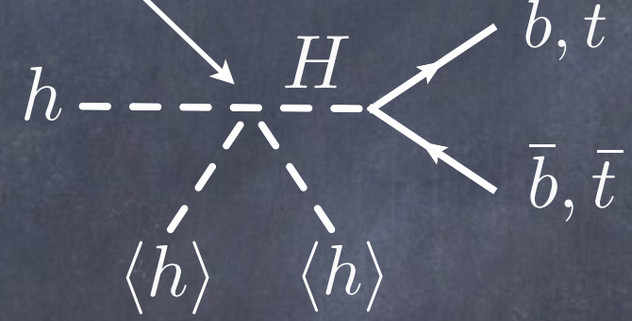
Generally* 2HDM structure:

heavy Higgs ⟷ modified Higgs couplings

Heavy stops, D-terms, F-terms:

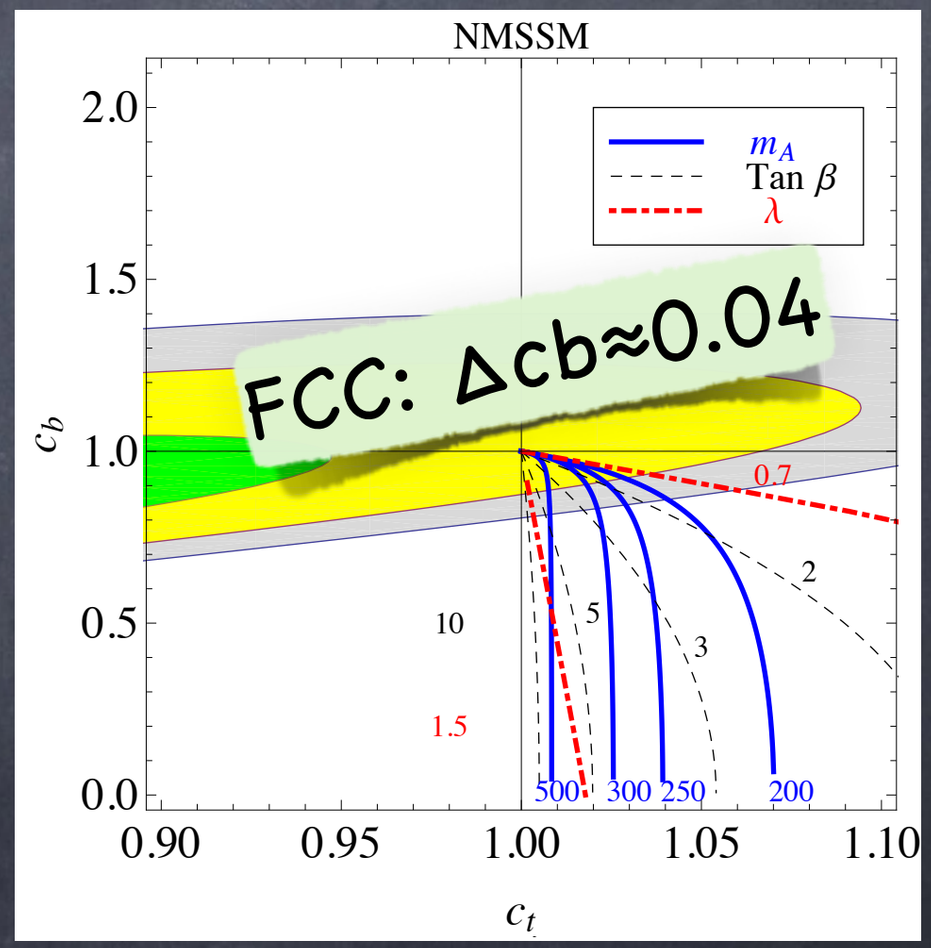
$$\Delta V = \delta_\lambda h^4 + \delta h^3 H + \dots$$

$$m_h^2 \approx m_Z^2 + 16\delta_\lambda v^2 = (125\text{GeV})^2$$



$$\frac{y_b}{y_b^{SM}} = 1 - 4\delta \tan\tilde{\beta}\frac{v^2}{m_H^2}$$

$$\frac{y_t}{y_t^{SM}} = 1 + 4\delta \cot\tilde{\beta}\frac{v^2}{m_H^2}$$



Blum,D'Agnolo,Fan'12; Azatov,Chang,Craig,Galloway'12
Montull,Gupta, FR, '12

Explicit Examples: MSSM

Generally* 2HDM structure:

heavy Higgs ⟷ modified Higgs couplings

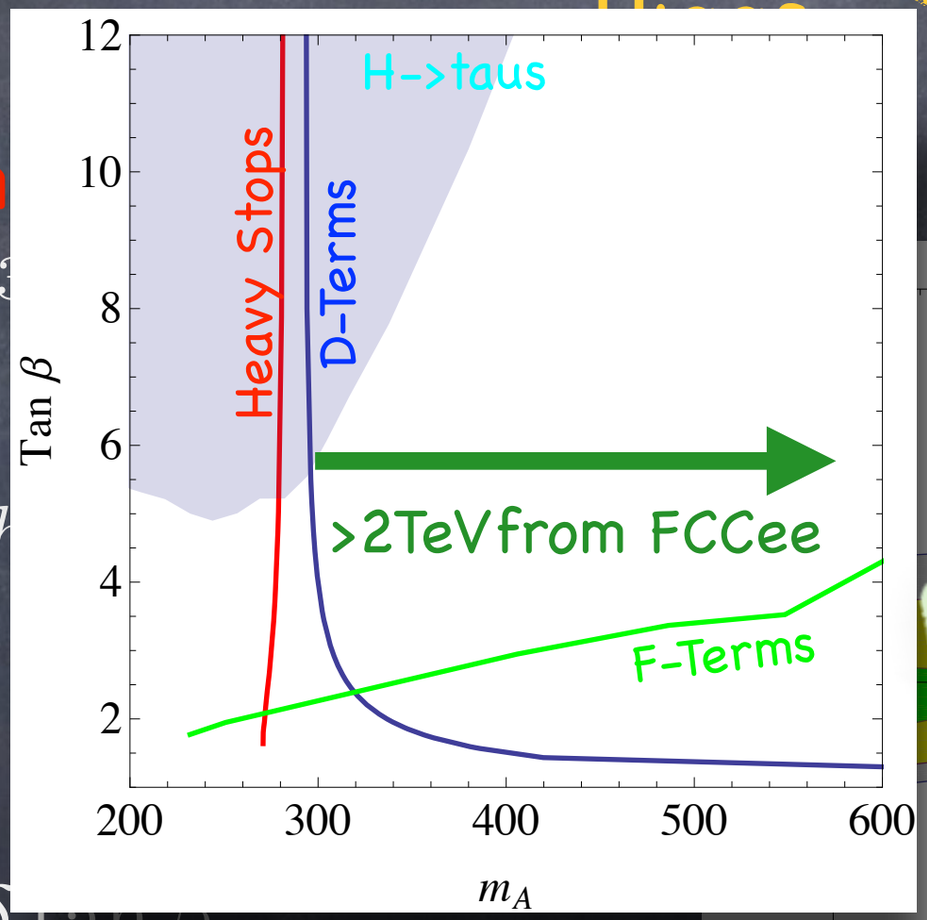
Heavy stops, D-term

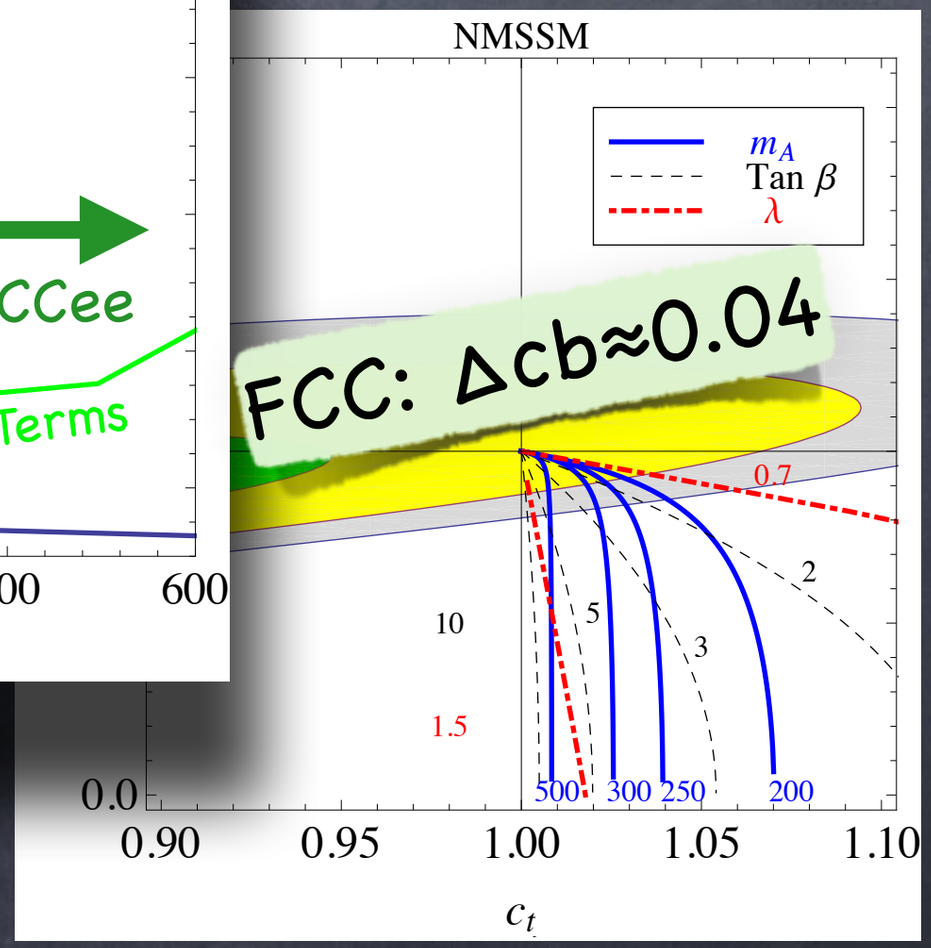
$$\Delta V = \delta_\lambda h^4 + \delta h^3$$

$$m_h^2 \approx m_Z^2 + 16\delta_\lambda v^2 \quad h$$
$$= (125\text{GeV})^2$$

$$\frac{y_b}{y_b^{SM}} = 1 - 4\delta \tan\beta \frac{v^2}{m_H^2}$$

$$\frac{y_t}{y_t^{SM}} = 1 + 4\delta \cot\tilde{\beta} \frac{v^2}{m_H^2}$$





Blum,D'Agnolo,Fan'12; Azatov,Chang,Craig,Galloway'12
Montull,Gupta, FR, '12

The power of Indirect Searches

- In weakly coupled UV theories? Coefficients of order 1

$E \to m_h$ for most effects

$$\sigma \simeq \sigma_{SM}\left(1+\frac{E^2}{\Lambda^2}\right)$$

Can this give access to scales untouched by LHC?

Probably

The power of Indirect Searches

- In weakly coupled UV theories? Coefficients of order 1

$$\sigma \simeq \sigma_{SM}\left(1+\frac{E^2}{\Lambda^2}\right)$$

$E \to m_h$ for most effects

Can this give access to scales untouched by LHC?

Probably

- In Strongly coupled theories? Coefficients enhanced by $g^* \approx 4\pi$

$$\sigma \simeq \sigma_{SM}\left(1+\frac{g_*^2}{g^2}\frac{E^2}{\Lambda^2}\right)$$

Access to scales 10x higher than weakly coupled theories

Surely!

Explicit Examples: Composite Higgs

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H) \partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

Gupta,Montull,FR'12; Barbieri,Tesi'13
Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: Composite Higgs

Custodial symmetry (SO(5)/SO(4) etc)

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

Gupta,Montull,FR'12; Barbieri,Tesi'13
Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: Composite Higgs

Custodial symmetry (SO(5)/SO(4) etc)

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

Shift Symmetry: operators with same symmetry as mass term are suppressed

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

Gupta,Montull,FR'12; Barbieri,Tesi'13
Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: Composite Higgs

Minimal Coupling

$$\frac{g_*^2}{16\pi^2\Lambda^2}$$

Custodial symmetry (SO(5)/SO(4) etc)

Shift Symmetry: operators with same symmetry as mass term are suppressed

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

Gupta,Montull,FR'12; Barbieri,Tesi'13
Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: Composite Higgs

Minimal Coupling

$$\frac{g_*^2}{16\pi^2\Lambda^2}$$

Custodial symmetry (SO(5)/SO(4) etc)

Shift Symmetry: operators with same symmetry as mass term are suppressed

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$

Tree $\frac{1}{\Lambda^2}$

$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H) \partial^\nu B_{\mu\nu}$$

Gupta,Montull,FR'12; Barbieri,Tesi'13
Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: Composite Higgs

Minimal Coupling

$$\frac{g_*^2}{16\pi^2\Lambda^2}$$

Custodial symmetry (SO(5)/SO(4) etc)

Shift Symmetry: operators with same symmetry as mass term are suppressed

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H) \partial^\nu B_{\mu\nu}$$

Tree $\frac{1}{\Lambda^2}$

$\frac{g_*^2}{\Lambda^2}$

Strongly coupled: powers of H enhanced by g*>1 w.r.t. derivatives

Gupta,Montull,FR'12; Barbieri,Tesi'13
Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Explicit Examples: Composite Higgs

Minimal Coupling

$$\frac{g_*^2}{16\pi^2\Lambda^2}$$

Custodial symmetry (SO(5)/SO(4) etc)

Shift Symmetry: operators with same symmetry as mass term are suppressed

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

Tree $\frac{1}{\Lambda^2}$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

$\frac{g_*^2}{\Lambda^2}$

Strongly coupled: powers of H enhanced by g*>1 w.r.t. derivatives

Best Handles: k_f, k_H

Gupta,Montull,FR'12; Barbieri,Tesi'13
Contino,Ghezzi,Muhlleitner,Grojean,Spira'13

Message

- EFT: motivation for SM (Higgs) precision tests
- Part1: precision Higgs measurements at FCCee improve well on Higgs-only effects / very-well on E-enhanced ones (ee->VH)

(competition with ee->VV)

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

Message

- EFT: motivation for SM (Higgs) precision tests
- Part1: precision Higgs measurements at FCCee improve well on Higgs-only effects / very-well on E-enhanced ones (ee->VH)

(competition with ee->VV)

$$\frac{\delta\sigma}{\sigma_{SM}} \approx \frac{E^2}{\Lambda^2}\frac{g_*^2}{g_{SM}^2}$$

- Part2: Reach of precision searches best for strongly coupled BSM scenarios

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

Message

- EFT: motivation for SM (Higgs) precision tests
- Part1: precision Higgs measurements at FCCee improve well on Higgs-only effects / very-well on E-enhanced ones (ee->VH)

(competition with ee->VV)

- Part2: Reach of precision searches best for strongly coupled BSM scenarios

$$\frac{\delta\sigma}{\sigma_{SM}} \approx \frac{E^2}{\Lambda^2}\,\frac{g_*^2}{g_{SM}^2}$$

- In composite Higgs models only g_{hff} and g_{hVV} coupling enhanced

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 \bar{Q}_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

Message

- EFT: motivation for SM (Higgs) precision tests
- Part1: precision Higgs measurements at FCCee improve well on Higgs-only effects / very-well on E-enhanced ones (ee->VH)

(competition with ee->VV)

- Part2: Reach of precision searches best for strongly coupled BSM scenarios

$$\frac{\delta\sigma}{\sigma_{SM}} \approx \frac{E^2}{\Lambda^2}\,\frac{g_*^2}{g_{SM}^2}$$

- In composite Higgs models only g_{hff} and g_{hVV} coupling enhanced

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 Q_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

- In (N)MSSM mainly g_{hbb} (and g_{hVV})

Message

- EFT: motivation for SM (Higgs) precision tests
- Part1: precision Higgs measurements at FCCee improve well on Higgs-only effects / very-well on E-enhanced ones (ee->VH)

(competition with ee->VV)

- Part2: Reach of precision searches best for strongly coupled BSM scenarios

$$\frac{\delta\sigma}{\sigma_{SM}} \approx \frac{E^2}{\Lambda^2}\,\frac{g_*^2}{g_{SM}^2}$$

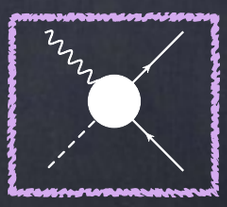
- In composite Higgs models only g_{hff} and g_{hVV} coupling enhanced

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 Q_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

- In (N)MSSM mainly g_{hbb} (and g_{hVV})
- Important effects in difficult in BSM



Liu,Pomarol,Rattazzi,FR'to appear

Message

- EFT: motivation for SM (Higgs) precision tests
- Part1: precision Higgs measurements at FCCee improve well on Higgs-only effects / very-well on E-enhanced ones (ee->VH)

(competition with ee->VV)

- Part2: Reach of precision searches best for strongly coupled BSM scenarios

$$\frac{\delta\sigma}{\sigma_{SM}} \approx \frac{E^2}{\Lambda^2}\,\frac{g_*^2}{g_{SM}^2}$$

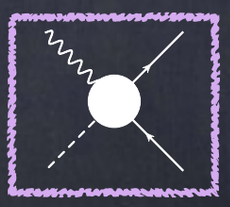
- In composite Higgs models only g_{hff} and g_{hVV} coupling enhanced

$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$\mathcal{O}_{H\psi} = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{\psi}\gamma^\mu \psi)_{\psi=L,e,Q,u,d}$$
$$\mathcal{O}_T = (H^\dagger \overleftrightarrow{D}_\mu H)^2$$
$$\mathcal{O}_W = ig(H^\dagger \sigma^a \overleftrightarrow{D^\mu} H) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = ig'(H^\dagger \overleftrightarrow{D^\mu} H)\partial^\nu B_{\mu\nu}$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{y_u} = y_u |H|^2 \bar{Q}_L \tilde{H} u_R$$
$$\mathcal{O}_{y_d} = y_d |H|^2 Q_L H d_R$$
$$\mathcal{O}_{y_e} = y_e |H|^2 \bar{L}_L H e_R$$
$$\mathcal{O}_6 = \lambda |H|^6$$
$$\mathcal{O}_H = (\partial^\mu |H|^2)^2$$

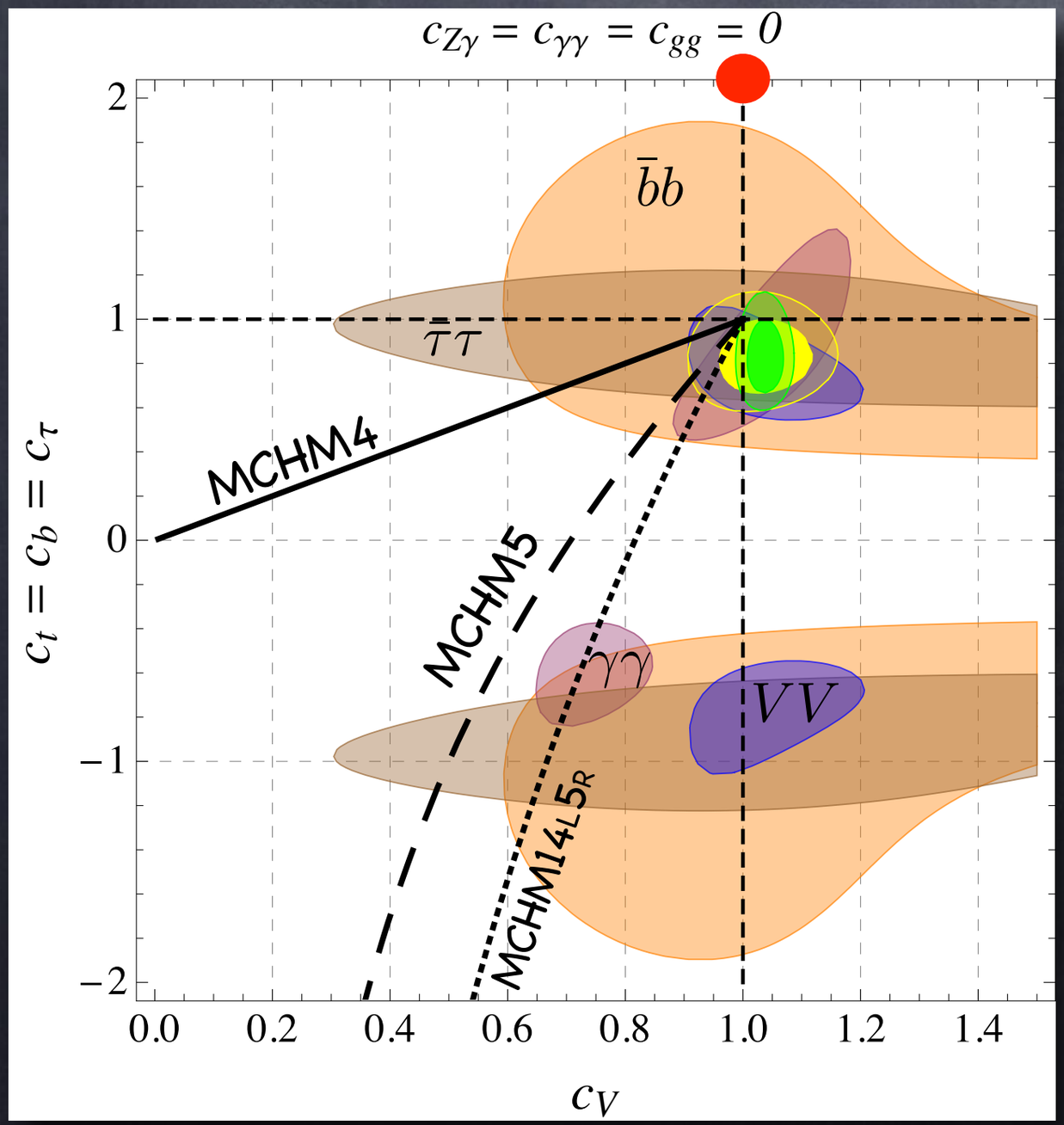
- In (N)MSSM mainly g_{hbb} (and g_{hVV})
- Important effects in difficult in BSM



Liu,Pomarol,Rattazzi,FR'to appear

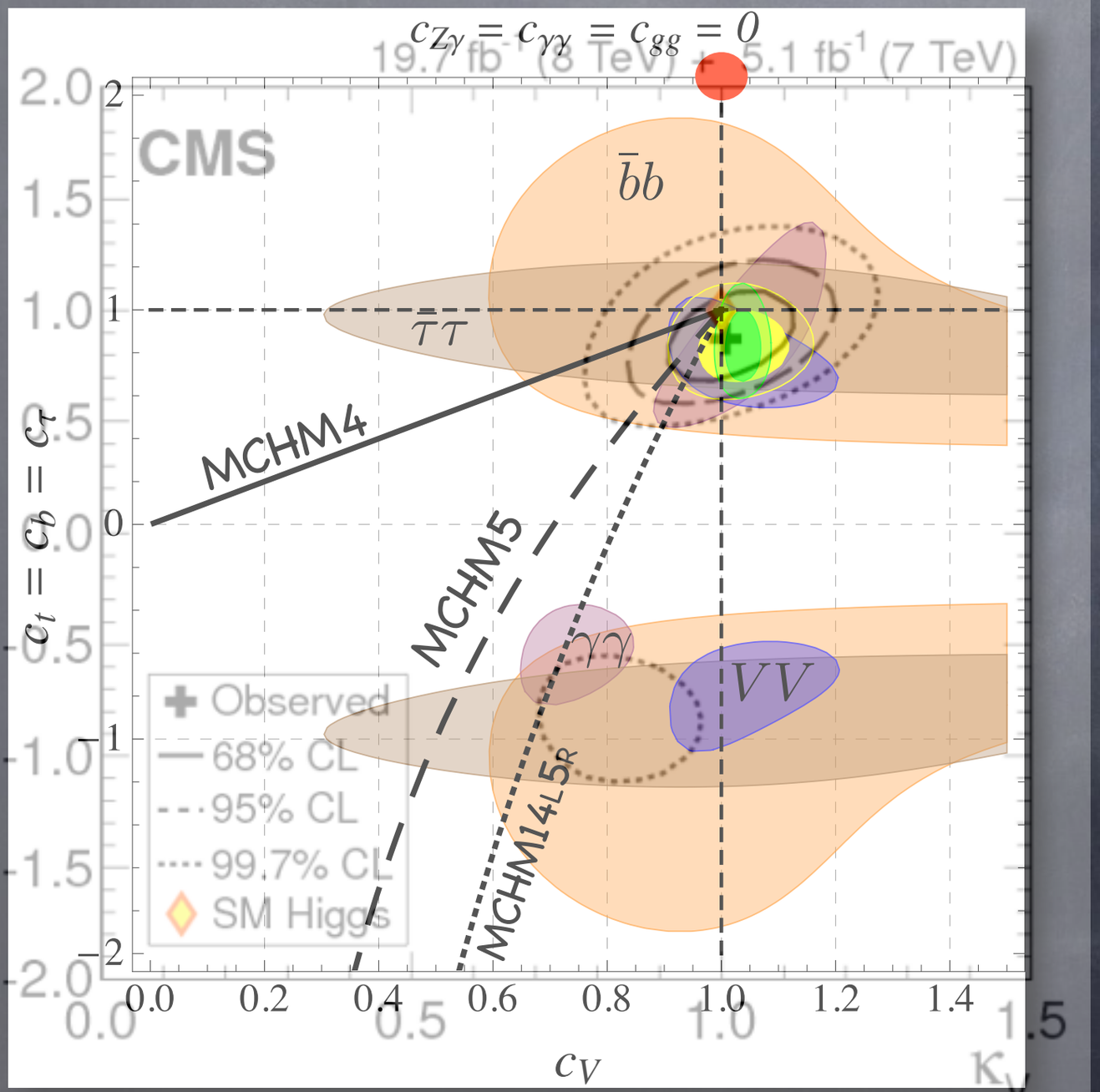
- It would still be interesting to study Higgs/EW complementarity in this context

Explicit Examples: Composite Higgs



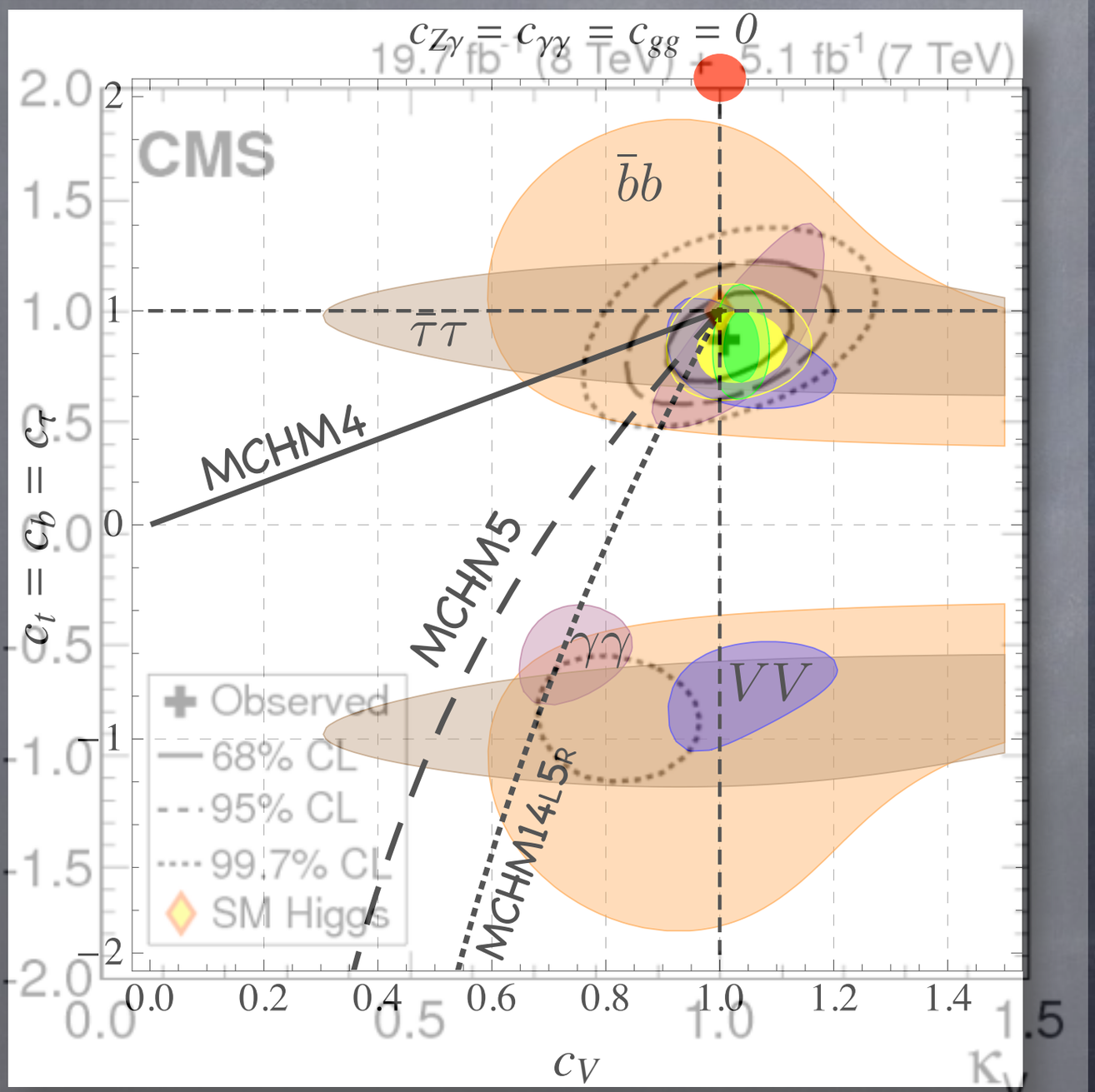
Giudice,Grojean,Pomarol,Rattazzi '07;Barbieri,Bellazzini,Rychkov,Varagnolo'07; Pomarol,FR,'12; Falkowski,FR,Urbano,'13; many more...

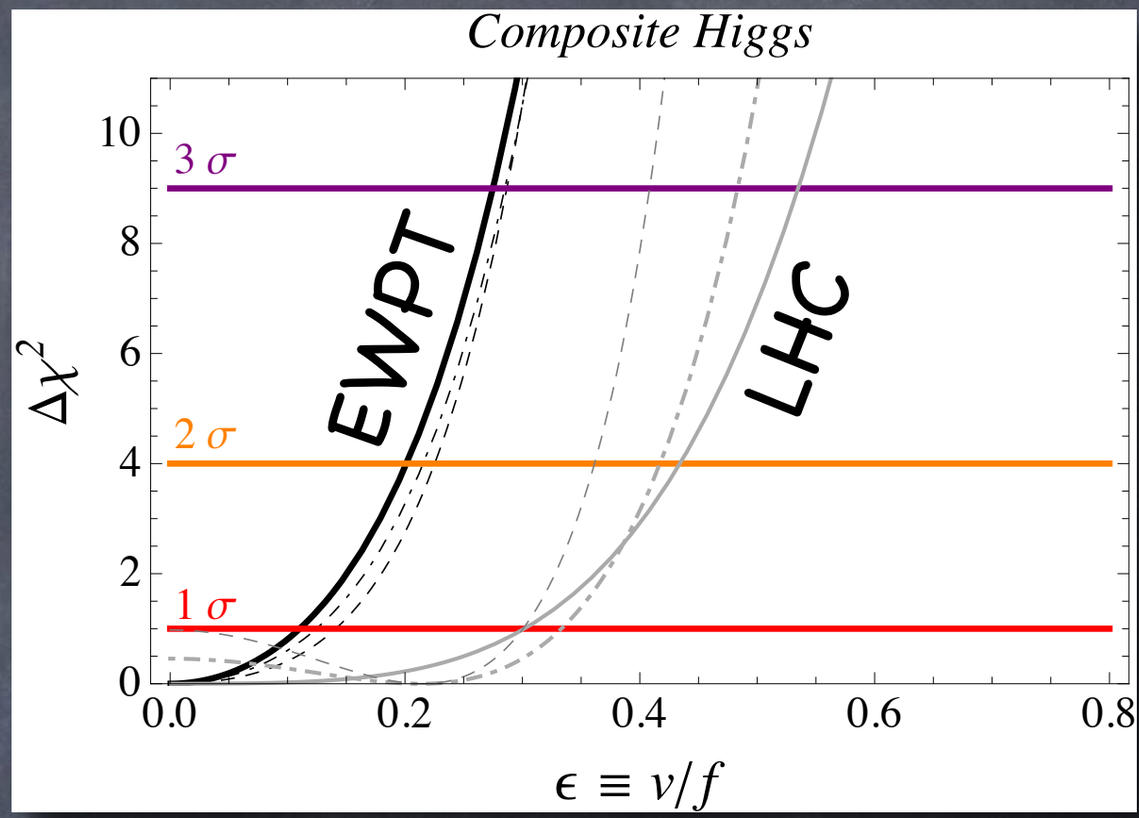
Explicit Examples: Composite Higgs



Giudice,Grojean,Pomarol,Rattazzi '07;Barbieri,Bellazzini,Rychkov,Varagnolo'07; Pomarol,FR,'12; Falkowski,FR,Urbano,'13; many more...

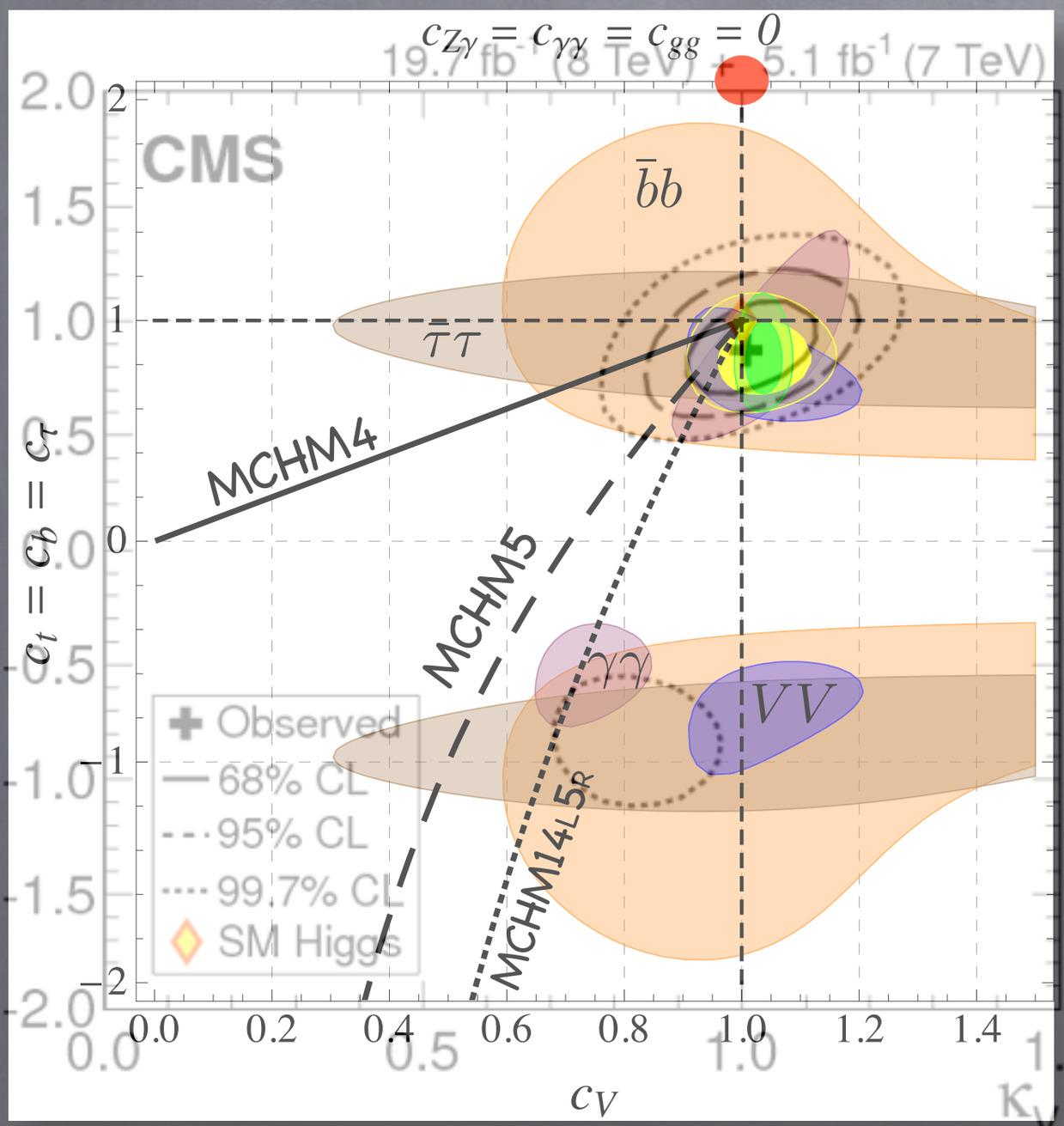
Explicit Examples: Composite Higgs

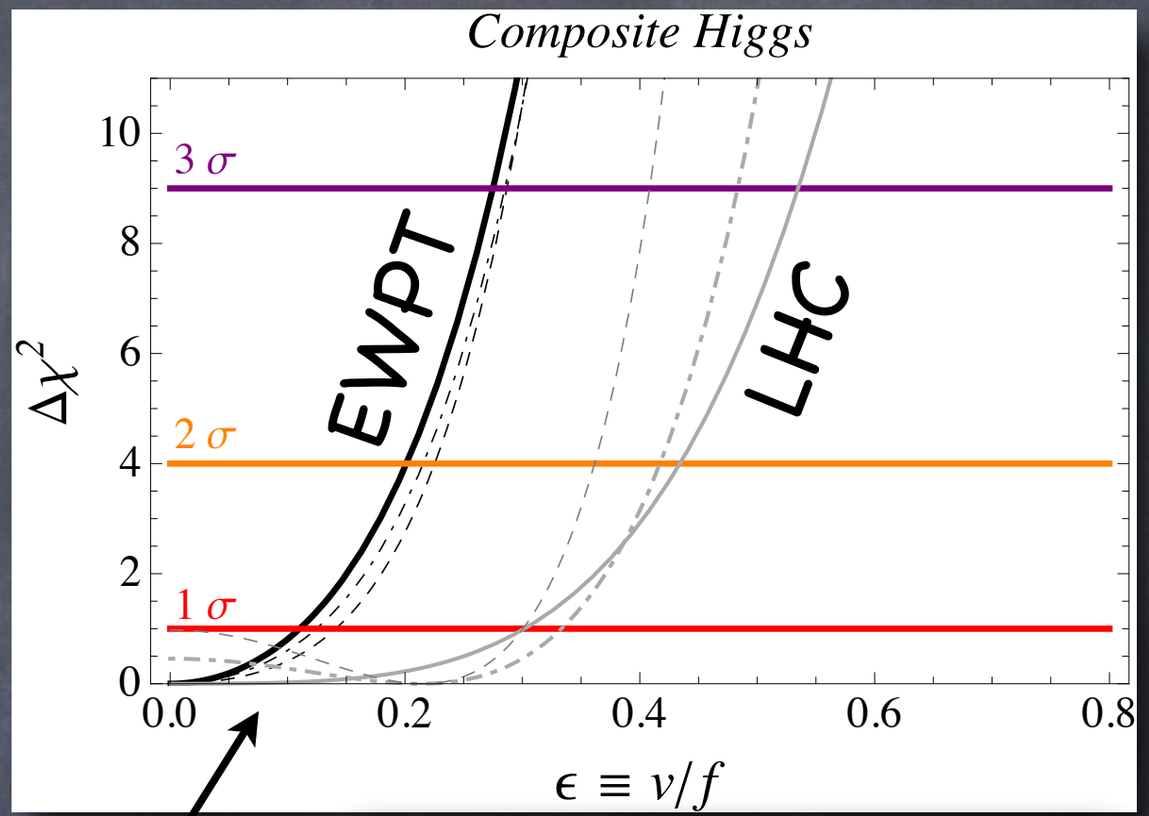




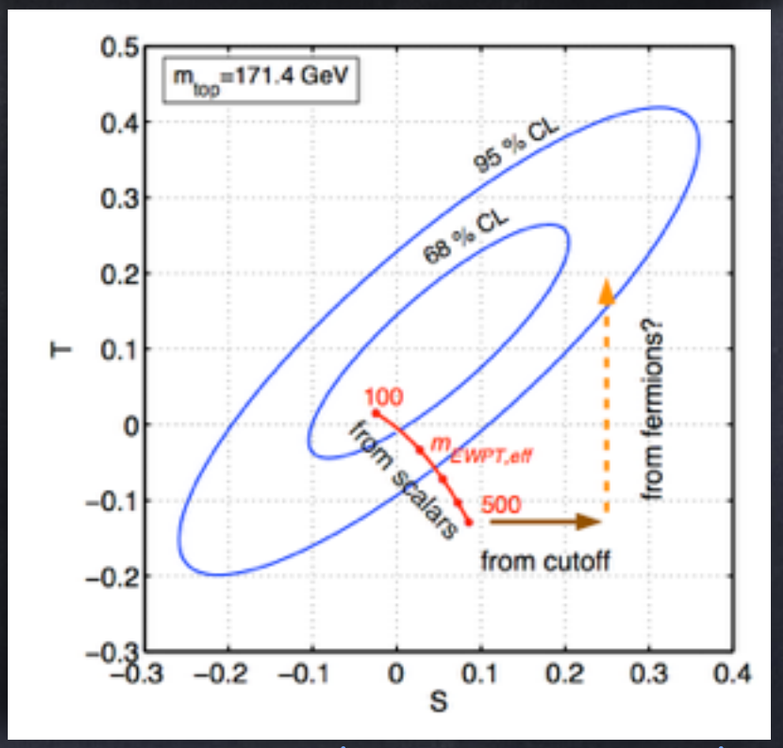
Giudice,Grojean,Pomarol,Rattazzi '07;Barbieri,Bellazzini,Rychkov,Varagnolo'07; Pomarol,FR,'12; Falkowski,FR,Urbano,'13; many more...

Explicit Examples: Composite Higgs



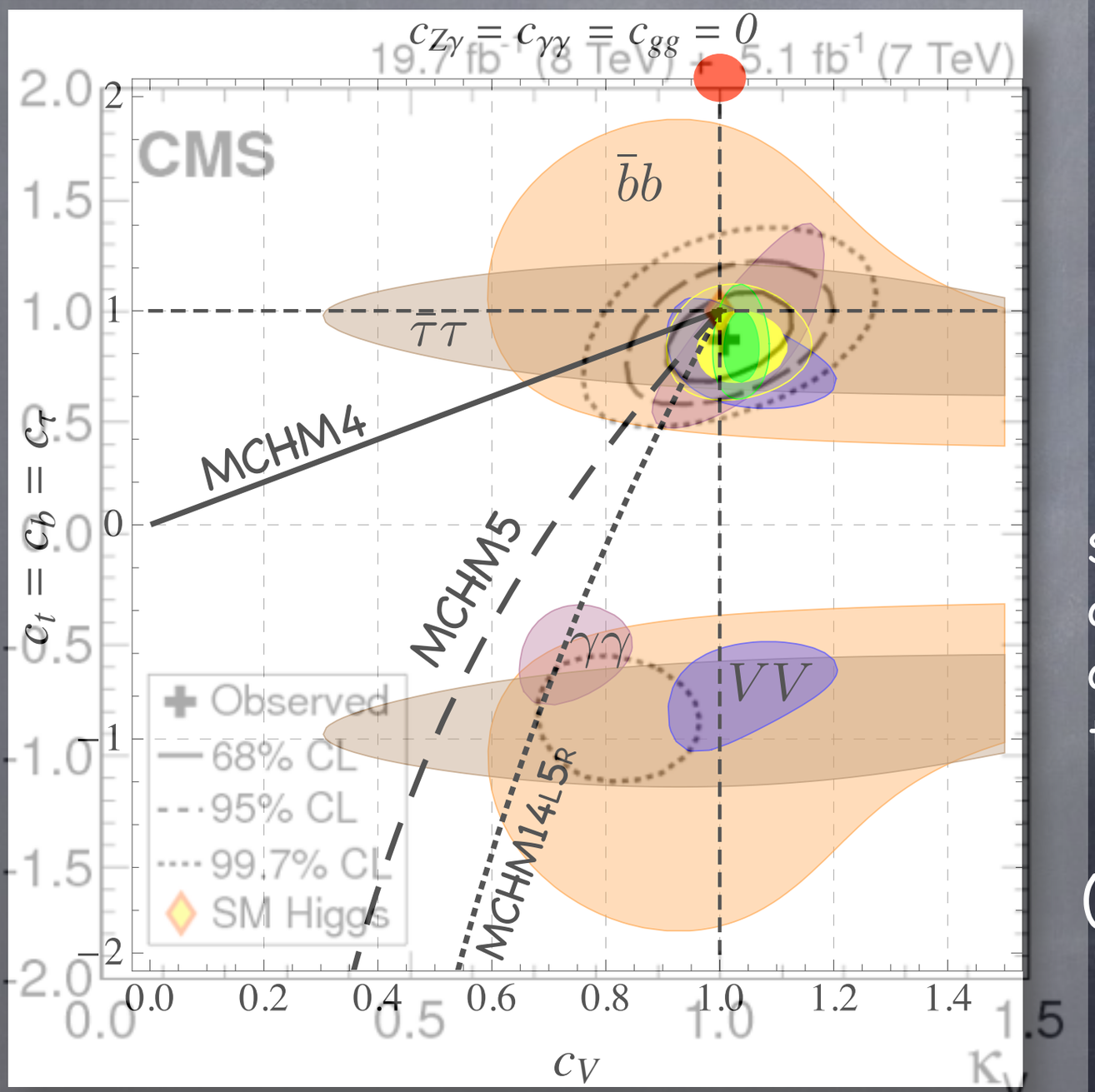


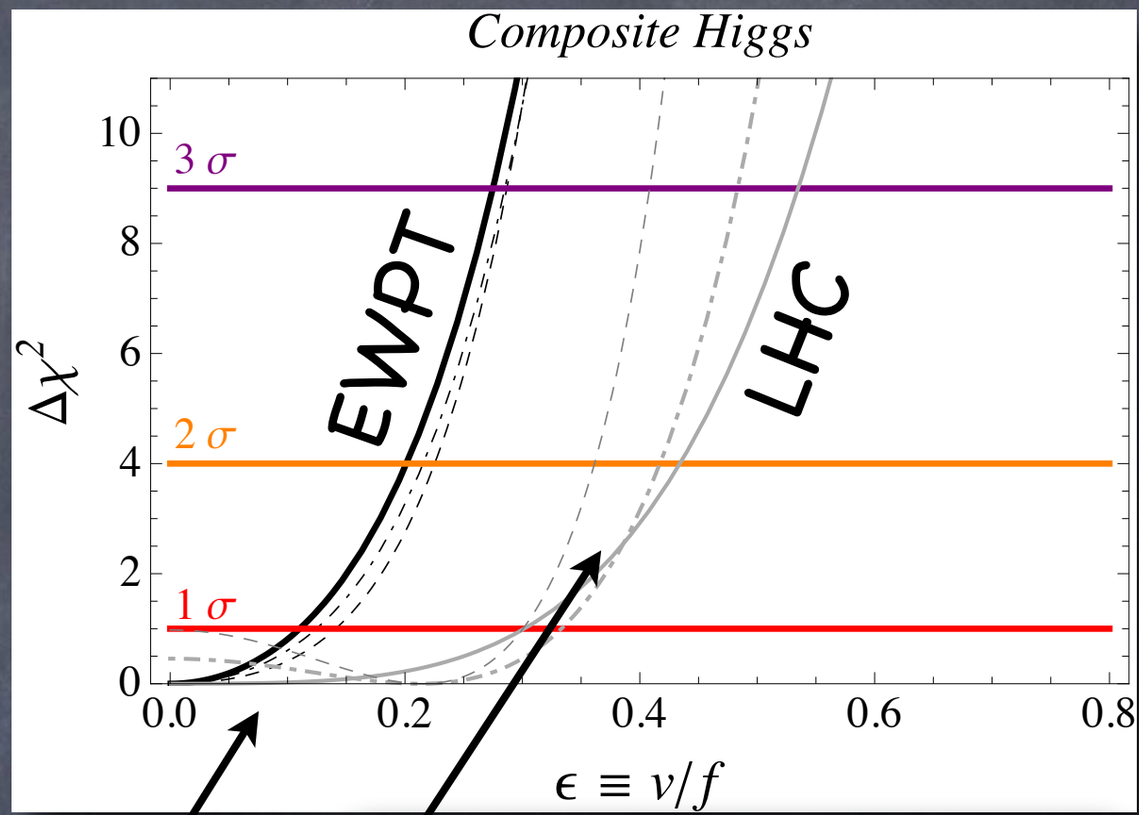
Strong sector contributions can weaken this bound



Giudice,Grojean,Pomarol,Rattazzi '07;Barbieri,Bellazzini,Rychkov,Varagnolo'07; Pomarol,FR,'12; Falkowski,FR,Urbano,'13; many more...

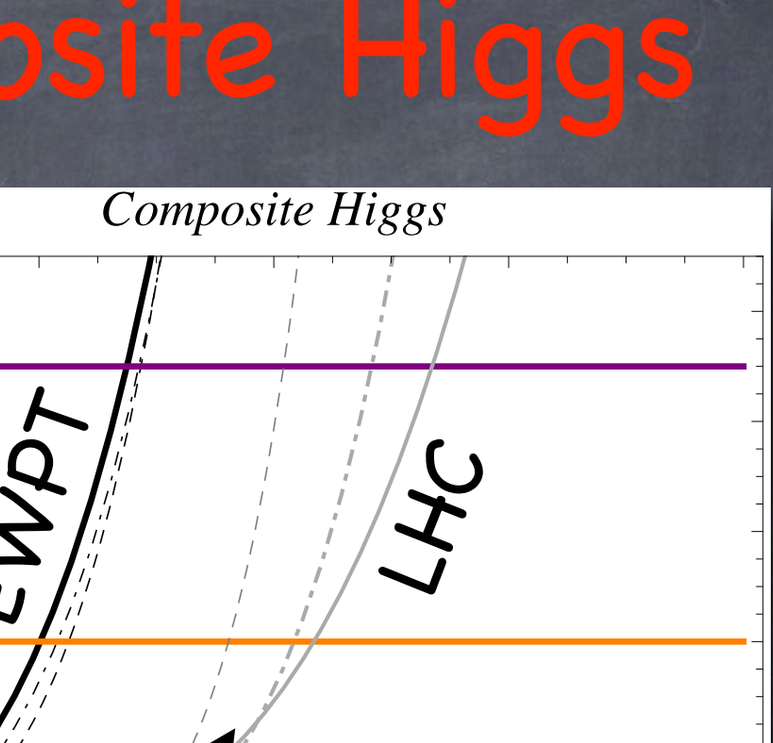
Explicit Examples: Composite Higgs





Strong sector contributions can weaken this bound

(not this)



Giudice,Grojean,Pomarol,Rattazzi '07;Barbieri,Bellazzini,Rychkov,Varagnolo'07; Pomarol,FR,'12; Falkowski,FR,Urbano,'13; many more...