Higgs Physics
&
Extra-Fermions

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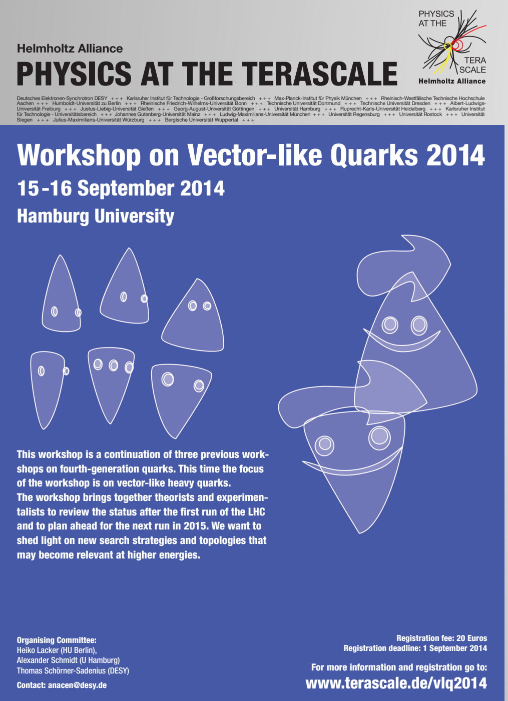
and arXiv:1206.3360 with ***N. Bonne***

DESY / Hamburg University - 16/09/2014 -



Outline

A – Higgs fits with generic Extra-Fermions (EF)

I) Generic Higgs fits

II) Constraining single EF

B – VL quarks to increase Higgs diphoton rates

I) Minimal realistic models of VL quarks

II) Numerical results for the Higgs fits

A – Higgs fits with generic Extra-Fermions

I) Generic Higgs fits

Today : The LHC has **discovered** a resonance of ~ 125 GeV

➡ *it is probably the B.E.Higgs boson => **EWSB** mechanism*

+ Tevatron and LHC provide **~ 60** measurements of the Higgs rates

= new precious source of indirect information on BSM physics

➡ *nature/origin of the EWSB : within the **SM** or **BSM** context !?*

On the theoretical side:

New fermions arise in most *(all?)* of the SM extensions,

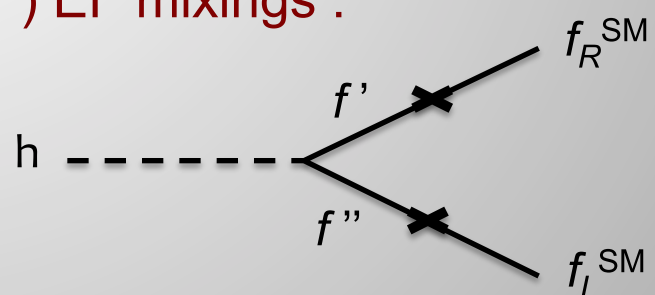
- little Higgs *[fermionic partners]*
- supersymmetry *[gauginos / higgsinos]*
- composite Higgs *[excited bounded states]*
- extra-dimensions *[Kaluza-Klein towers]*
- 4*th* generations *[new families]*
- G.U.Theories *[multiplet components]*
- etc…

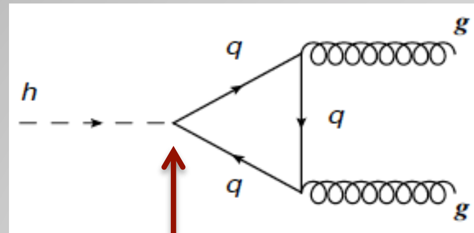
➡ *What are the present* ***constraints on GENERIC Extra-Fermions*** *imposed by all the experimental results in the Higgs sector ?*

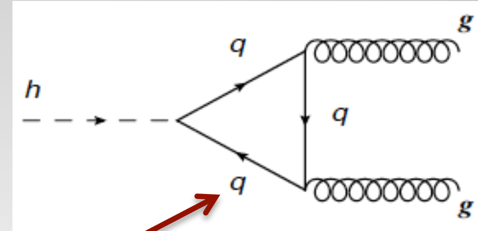
Effective approach : Corrections on the Higgs couplings from **ANY** extra-fermions *(via mixing, new loops)*

$$\mathcal{L}_h = - c_t Y_t \; h \; \bar{t}_L \; t_R \; - c_b Y_b \; h \; \bar{b}_L \; b_R \; - c_\tau Y_\tau \; h \; \bar{\tau}_L \; \tau_R \\ + C_{h\gamma\gamma} \frac{\alpha}{\pi v} \; h \; F^{\mu\nu} F_{\mu\nu} \; + \; C_{hgg} \frac{\alpha_s}{12\pi v} \; h \; G^{a\mu\nu} G^a_{\mu\nu} \; + \; \text{h.c.}$$

Modifications of Y_f Yukawa couplings via (f ’) EF mixings :

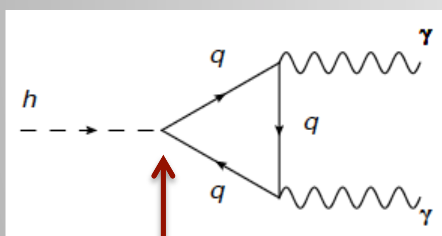


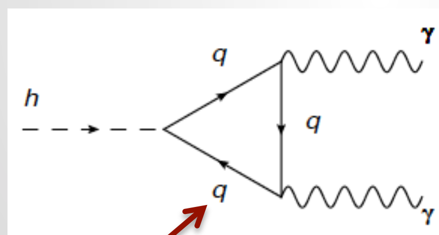




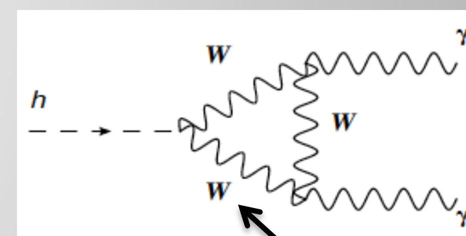
b' , $q_{5/3}$, …

$$C_{hgg} = 2C(t)\ A[\tau(m_t)]\ (c_t + c_{gg}) + 2C(b)\ A[\tau(m_b)]\ c_b + 2C(c)\ A[\tau(m_c)]$$





b' , $q_{5/3}$, …



$$C_{h\gamma\gamma} = \frac{N_c^t}{6} Q_t^2 A[\tau(m_t)]\ (c_t + c_{\gamma\gamma}) + \frac{N_c^b}{6} Q_b^2 A[\tau(m_b)]\ c_b + \frac{N_c^c}{6} Q_c^2 A[\tau(m_c)] + \frac{N_c^\tau}{6} Q_\tau^2 A[\tau(m_\tau)]\ c_\tau + \frac{1}{8} A_1[\tau(m_W)]$$

Higgs production cross sections over their SM expectations :

$$\frac{\sigma_{\mathrm{gg}\to\mathrm{h}}}{\sigma^{\mathrm{SM}}_{\mathrm{gg}\to\mathrm{h}}} \simeq \frac{\left|(c_t + c_{gg})A[\tau(m_t)] + c_b A[\tau(m_b)] + A[\tau(m_c)]\right|^2}{\left|A[\tau(m_t)] + A[\tau(m_b)] + A[\tau(m_c)]\right|^2} \qquad \frac{\sigma_{\mathrm{h}\bar{\mathrm{t}}\mathrm{t}}}{\sigma^{\mathrm{SM}}_{\mathrm{h}\bar{\mathrm{t}}\mathrm{t}}} \simeq |c_t|^2$$

Higgs partial decay widths over the SM predictions (no new channels) :

$$\frac{\Gamma_{\mathrm{h}\to\gamma\gamma}}{\Gamma^{\mathrm{SM}}_{\mathrm{h}\to\gamma\gamma}} \simeq \frac{\left|\frac{1}{4}A_1[\tau(m_W)] + (\frac{2}{3})^2(c_t + c_{\gamma\gamma})A[\tau(m_t)] + (-\frac{1}{3})^2 c_b A[\tau(m_b)] + (\frac{2}{3})^2 A[\tau(m_c)] + \frac{1}{3}c_\tau A[\tau(m_\tau)]\right|^2}{\left|\frac{1}{4}A_1[\tau(m_W)] + (\frac{2}{3})^2 A[\tau(m_t)] + (-\frac{1}{3})^2 A[\tau(m_b)] + (\frac{2}{3})^2 A[\tau(m_c)] + \frac{1}{3}A[\tau(m_\tau)]\right|^2}$$

$$\frac{\Gamma_{\mathrm{h}\to\bar{\mathrm{b}}\mathrm{b}}}{\Gamma^{\mathrm{SM}}_{\mathrm{h}\to\bar{\mathrm{b}}\mathrm{b}}} \simeq |c_b|^2 \qquad \frac{\Gamma_{\mathrm{h}\to\bar{\tau}\tau}}{\Gamma^{\mathrm{SM}}_{\mathrm{h}\to\bar{\tau}\tau}} \simeq |c_\tau|^2$$

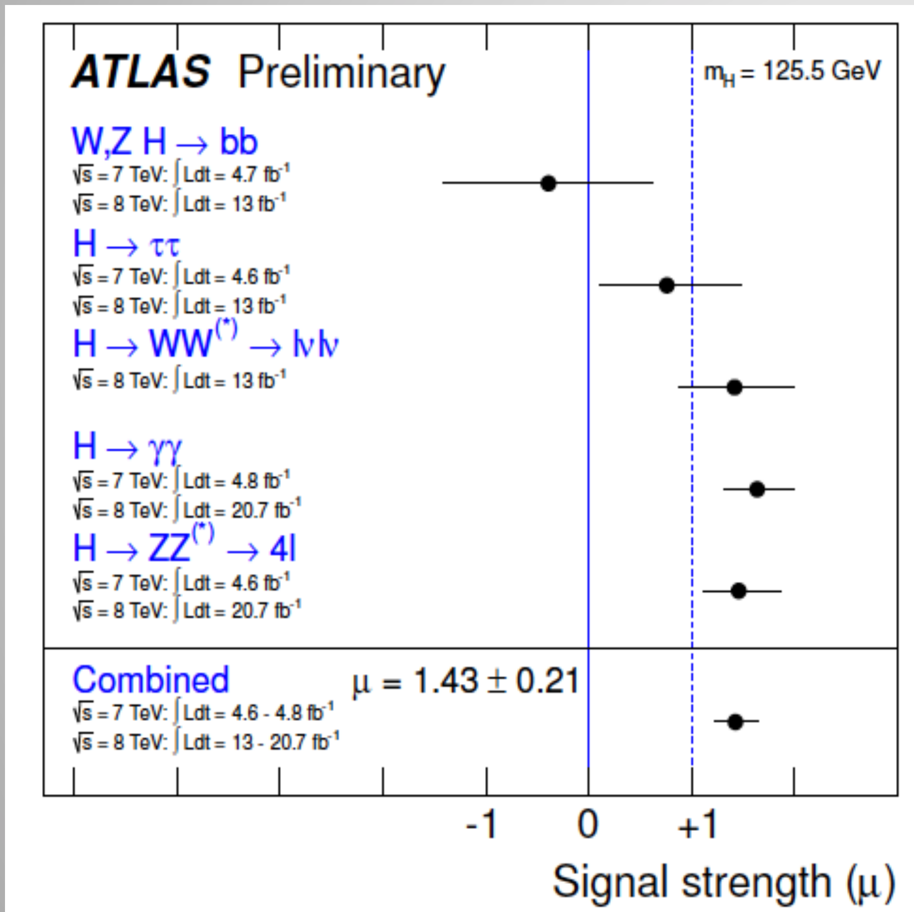
Measured signal strengths all of the form (exp. selection efficiencies) :

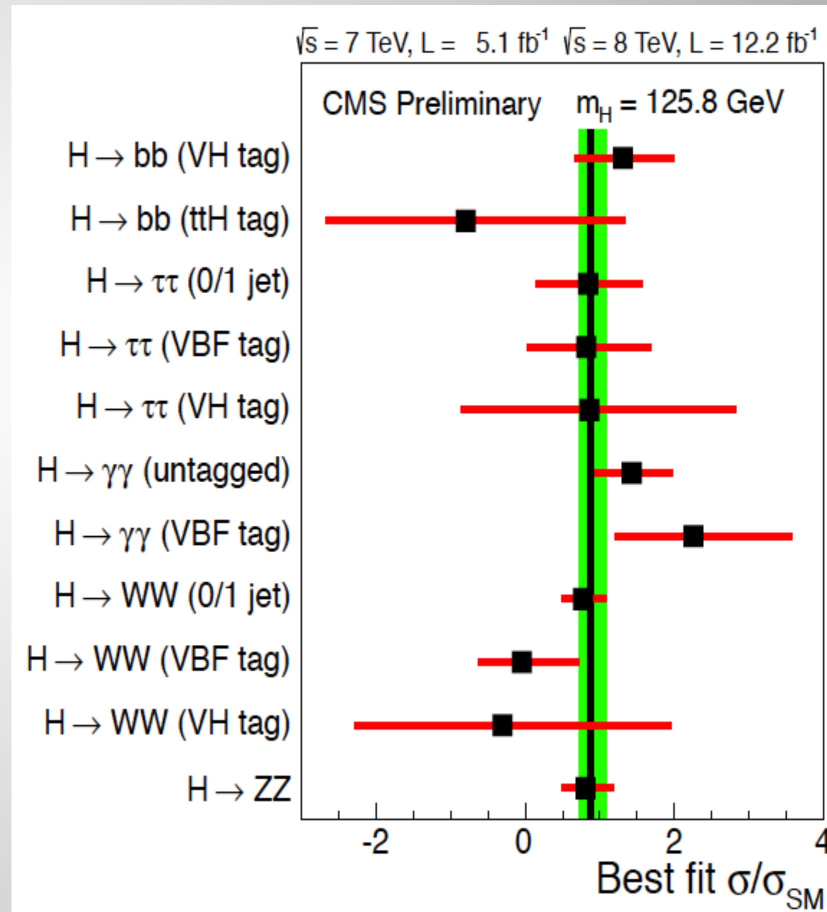
$$\mu^p_{s,c,i} \simeq \frac{\sigma_{\mathrm{gg}\to\mathrm{h}}\big|_s + \frac{\epsilon_{\mathrm{hqq}}}{\epsilon_{\mathrm{gg}\to\mathrm{h}}}\Big|^p_{s,c,i} \sigma^{\mathrm{SM}}_{\mathrm{hqq}}\big|_s + \frac{\epsilon_{\mathrm{hV}}}{\epsilon_{\mathrm{gg}\to\mathrm{h}}}\Big|^p_{s,c,i} \sigma^{\mathrm{SM}}_{\mathrm{hV}}\big|_s + \frac{\epsilon_{\mathrm{h\bar{t}t}}}{\epsilon_{\mathrm{gg}\to\mathrm{h}}}\Big|^p_{s,c,i} \sigma_{\mathrm{h\bar{t}t}}\big|_s}{\sigma^{\mathrm{SM}}_{\mathrm{gg}\to\mathrm{h}}\big|_s + \frac{\epsilon_{\mathrm{hqq}}}{\epsilon_{\mathrm{gg}\to\mathrm{h}}}\Big|^p_{s,c,i} \sigma^{\mathrm{SM}}_{\mathrm{hqq}}\big|_s + \frac{\epsilon_{\mathrm{hV}}}{\epsilon_{\mathrm{gg}\to\mathrm{h}}}\Big|^p_{s,c,i} \sigma^{\mathrm{SM}}_{\mathrm{hV}}\big|_s + \frac{\epsilon_{\mathrm{h\bar{t}t}}}{\epsilon_{\mathrm{gg}\to\mathrm{h}}}\Big|^p_{s,c,i} \sigma^{\mathrm{SM}}_{\mathrm{h\bar{t}t}}\big|_s} \frac{B_{\mathrm{h}\to\mathrm{XX}}}{B^{\mathrm{SM}}_{\mathrm{h}\to\mathrm{XX}}}$$

For the fit analysis, we define a function $\chi^2(c_t, c_b, c_\tau, c_{gg}, c_{\gamma\gamma})$:

$$\chi^2 = \sum_{p,s,c,i} \frac{(\mu^p_{s,c,i} - \mu^p_{s,c,i}|_{\mathrm{exp}})^2}{(\delta\mu^p_{s,c,i})^2}$$

Taking the (latest) experimental results…





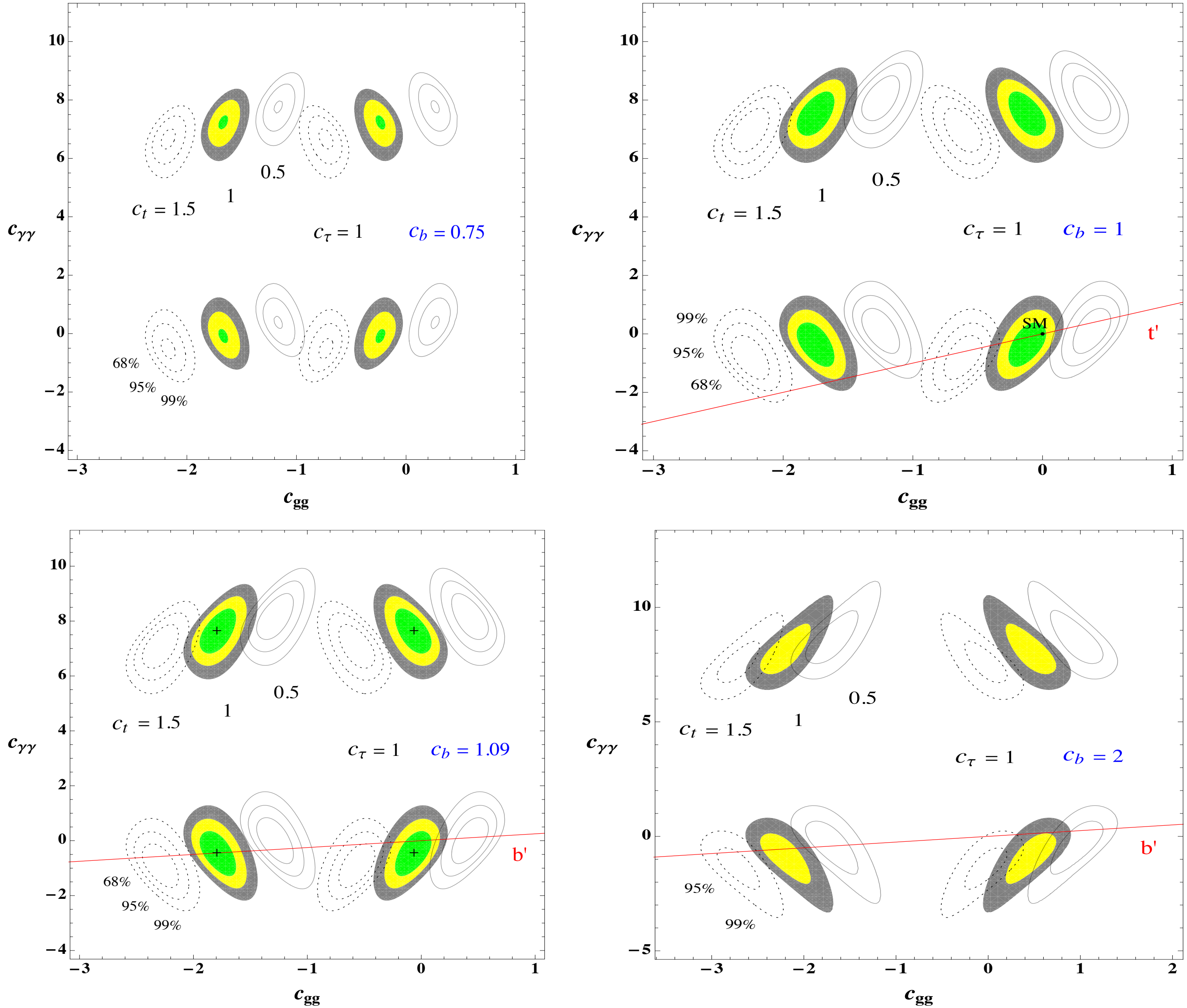
Higgs fit results :

(3 free param.)

AFTER MORIOND 2013...

$$\Delta\chi^2 = \chi^2 - \chi^2_{\rm min}$$

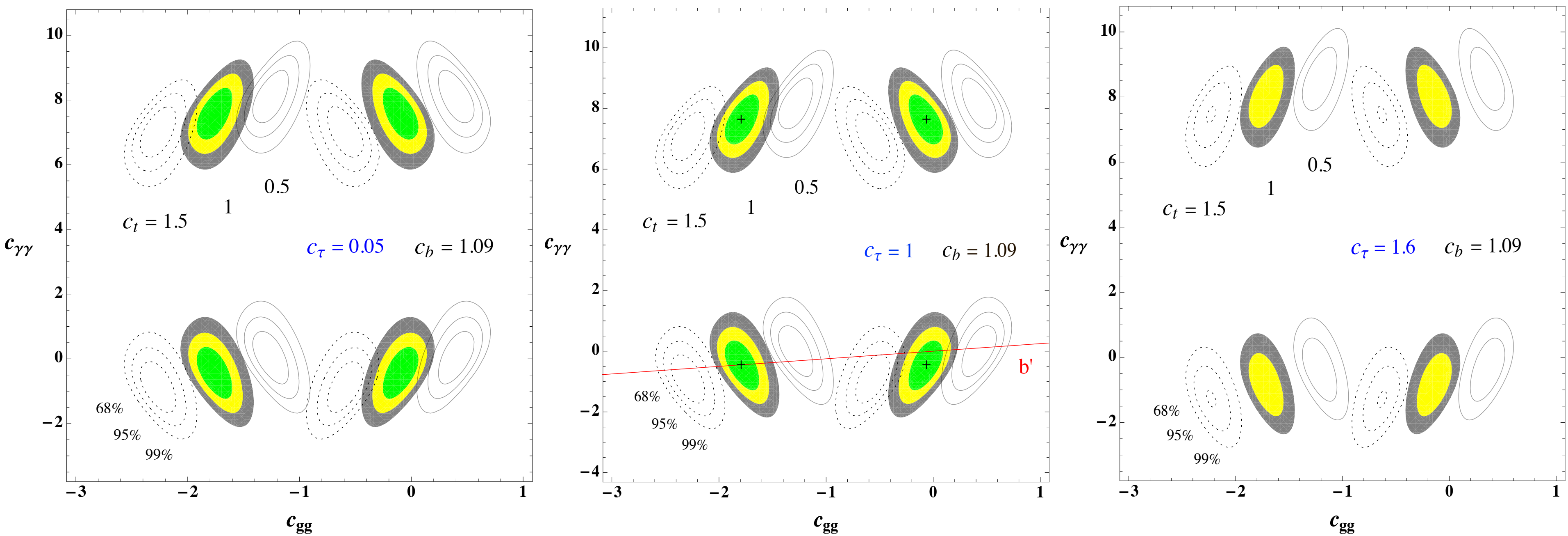
$$\chi^2_{\rm min} = 52.36$$



« 3 conclusions for this generic fit… »

* The SM point ($\chi^2_{\rm SM} = 57.10$) belongs to the 1**σ** region
* Determination of c_{gg} and $c_{\gamma\gamma}$ ***relies*** on the knowledge of $\mathbf{Y_t^{EF}}$ (c_t)
* c_b and c_τ are significatively constrained

Varying the last parameter : c_τ



II) Constraining single Extra-Fermions

1. **Single** Extra-Fermion (starting approximation) => new loop-contributions :

$$c_{gg} = \frac{1}{C(t)A[\tau(m_t)]/v}\left[-C(t')\frac{Y_{t'}}{m_{t'}}A[\tau(m_{t'})]-C(q_{5/3})\frac{Y_{q_{5/3}}}{m_{q_{5/3}}}A[\tau(m_{q_{5/3}})]+\dots\right]$$

$$c_{\gamma\gamma} = \frac{1}{N_c^t Q_t^2 A[\tau(m_t)]/v}\left[-3\left(\frac{2}{3}\right)^2\frac{Y_{t'}}{m_{t'}}A[\tau(m_{t'})]-N_c^{q_{5/3}}\left(\frac{5}{3}\right)^2\frac{Y_{q_{5/3}}}{m_{q_{5/3}}}A[\tau(m_{q_{5/3}})]-Q_{\ell'}^2\frac{Y_{\ell'}}{m_{\ell'}}A[\tau(m_{\ell'})]+\dots\right]$$

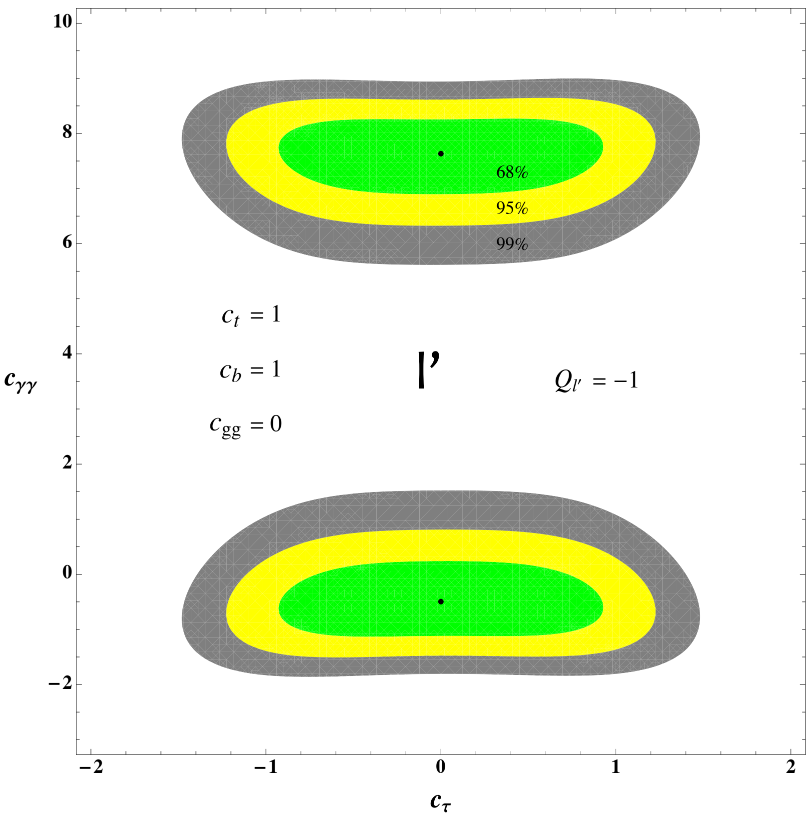
2. **Same color** repres. as the top quark ➡

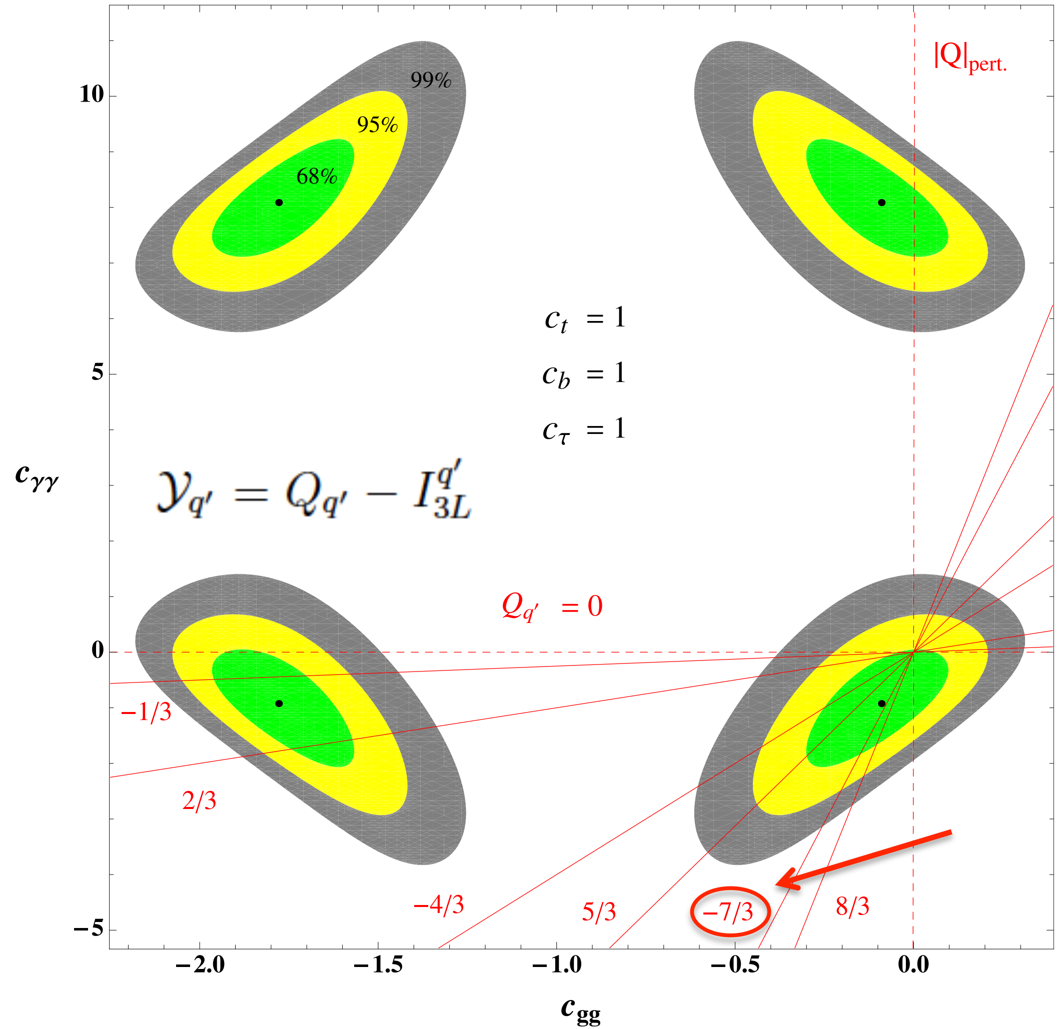
$$\left.\frac{c_{\gamma\gamma}}{c_{gg}}\right|_{q'} = \frac{Q_{q'}^2}{(2/3)^2}$$

2 soft assumptions give quite strong predictions !
(e.g. any b', chiral/VL)

independently of $Y_{q'}$, masses, $SU(2)_L$ repres.

(2 free parameters)





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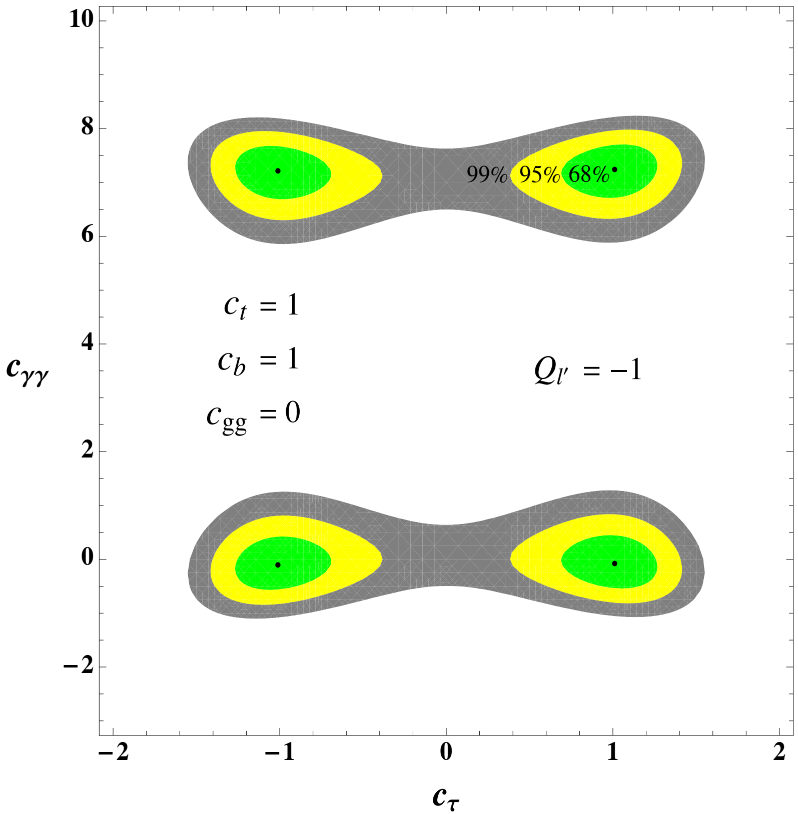
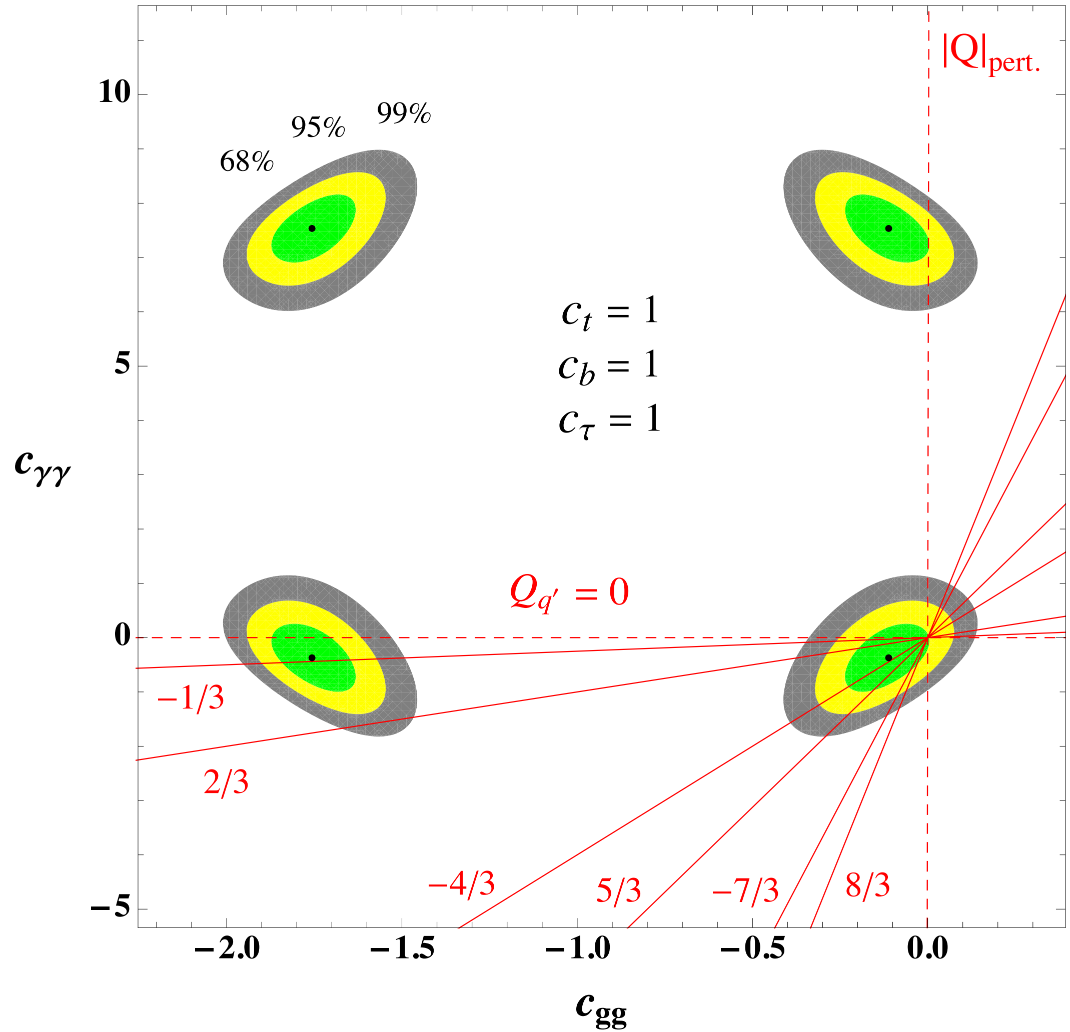
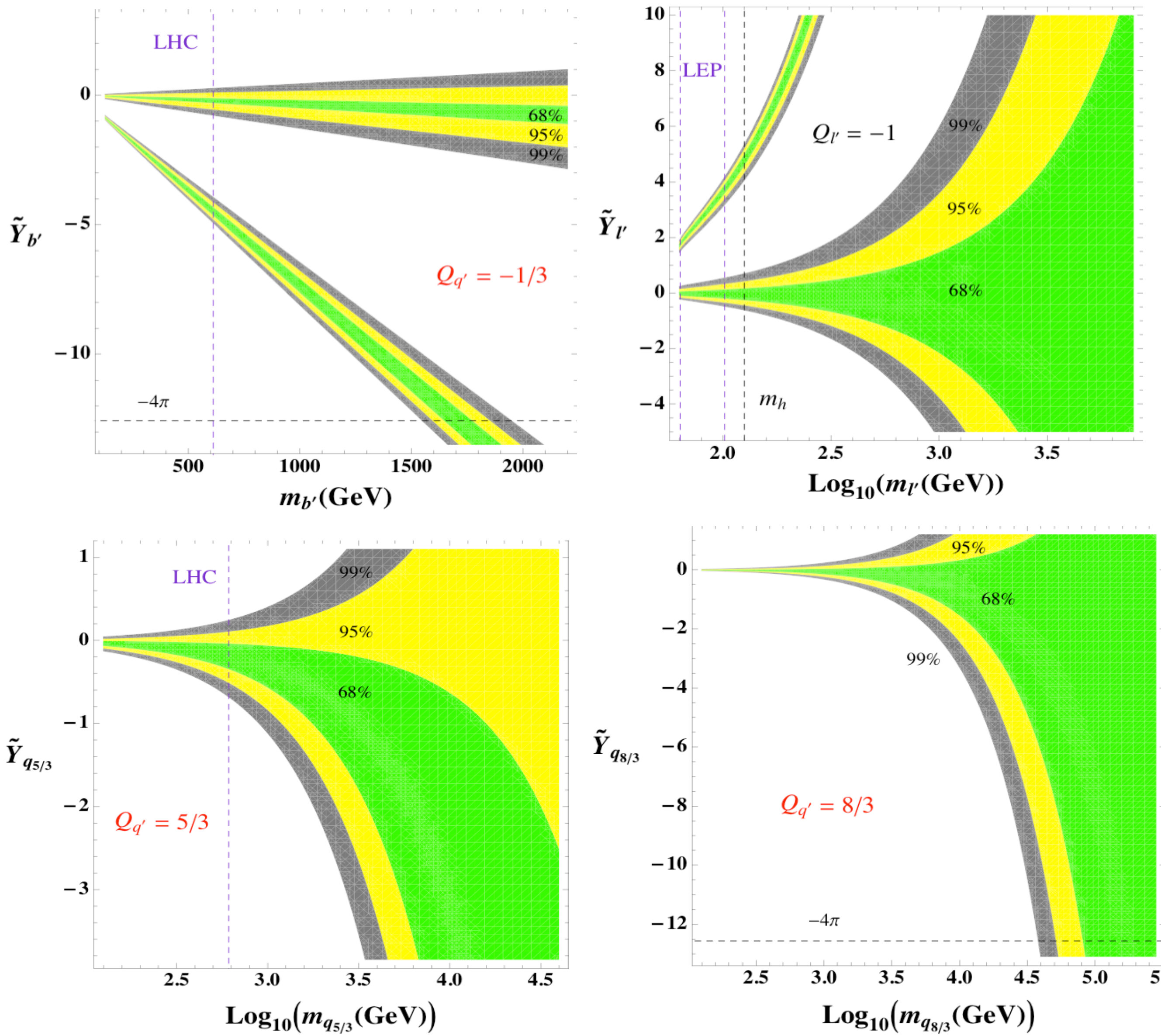
(2 free parameters)

independently of $Y_{q'}$, masses, $SU(2)_L$ repres.





(1 free param.)



For *a* low-charge *q'*, *Extra-dysfermiophilia* :

$$\mathrm{sign}\left(\frac{-Y_{q'}}{m_{q'}}\right) < 0$$

…increasing the diphoton rates – as favored by data.

$q_{5/3} \to tW^+$

$q_{8/3} \to tW^+W^+$

Conclusions (A)

Already ***non-trivial*** & **generic constraints** on extra-fermions from the Higgs rate fit **:**

- Difficult and correlated determinations of the top Yukawa coupling and parameters for the new loop-contributions to hgg , hγγ.

- Interesting theoretical predictions for **single** extra-quarks [same color as the top] - **independently** of *Yukawa's, masses, chiral / VL w.r.t.* $SU(2)_L$

=> Possible electric charge determination in case of deviation w.r.t. SM

=> « *Extra-dysfermiophilia* » prediction for a low-charge extra-quark

The obtained plots can be used for any such scenarios with new fermions…

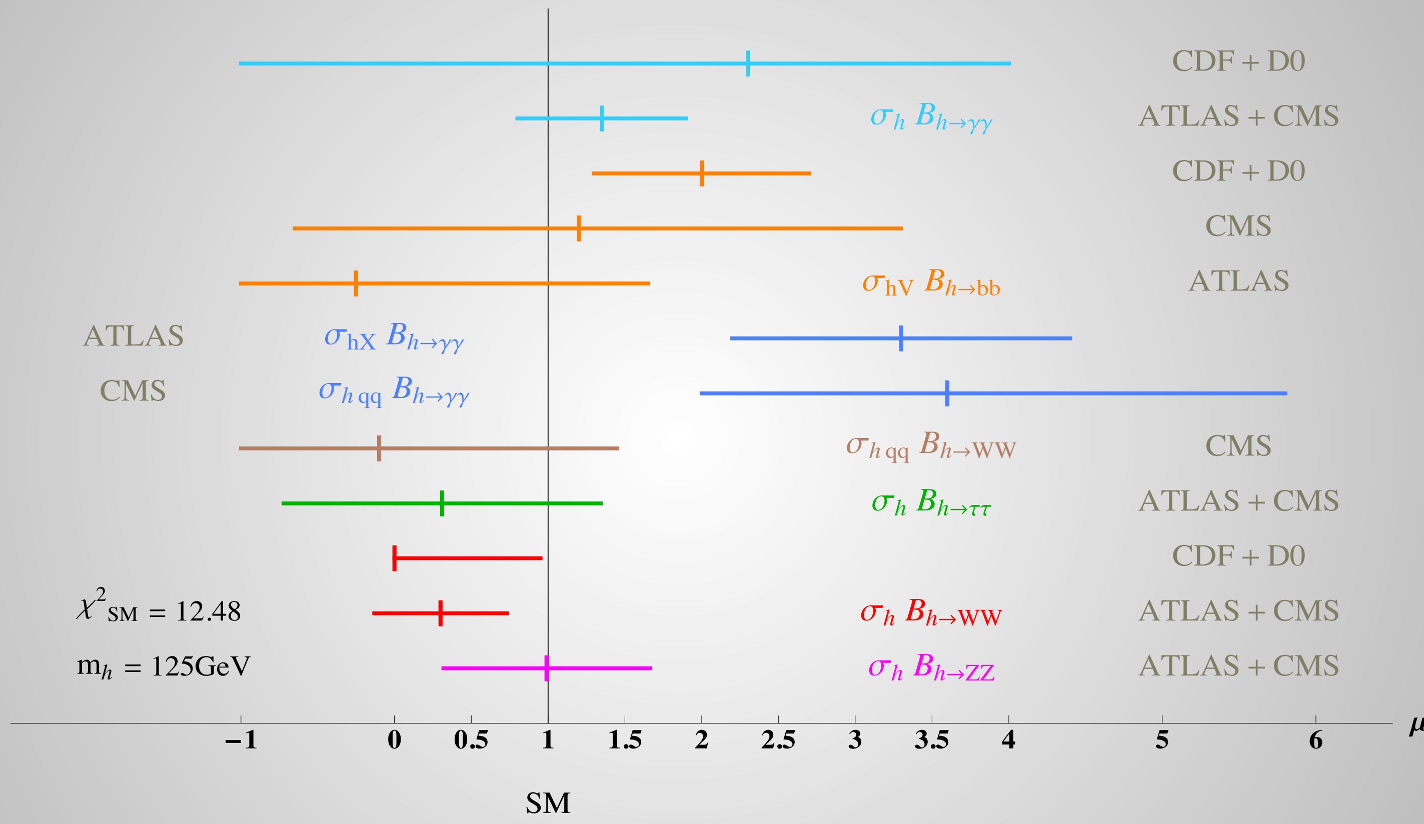
B – VL quarks to increase Higgs diphoton rates

I) Minimal realistic models of VL quarks

Situation in June 2012 :

(a ~ 125 GeV Higgs boson not yet confirmed at 5 *standard deviations*)

Higgs rate **deviations** w.r.t. the SM especially in the diphoton channels..



CDF + D0
$\sigma_h\ B_{h\to\gamma\gamma}$
ATLAS + CMS
CDF + D0
CMS
$\sigma_{hV}\ B_{h\to bb}$
ATLAS
ATLAS
$\sigma_{hX}\ B_{h\to\gamma\gamma}$
CMS
$\sigma_{h\,qq}\ B_{h\to\gamma\gamma}$
$\sigma_{h\,qq}\ B_{h\to WW}$
CMS
$\sigma_h\ B_{h\to\tau\tau}$
ATLAS + CMS
CDF + D0
$\chi^2_{SM} = 12.48$
$\sigma_h\ B_{h\to WW}$
ATLAS + CMS
$m_h = 125$GeV
$\sigma_h\ B_{h\to ZZ}$
ATLAS + CMS
−1
0
0.5
1
1.5
2
2.5
3
3.5
4
5
6
μ
SM

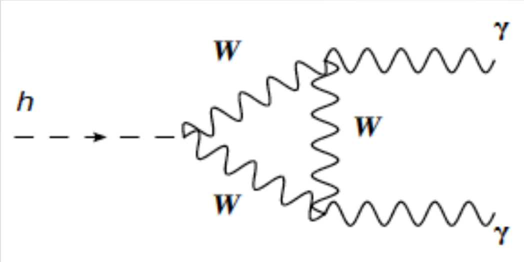
<u>Assessment :</u> on the theoretical side, **Vector-Like quarks** arise in most Supersymmetry alternatives like

– little Higgs
– composite Higgs
– extra-dimensions
– GUT
– …

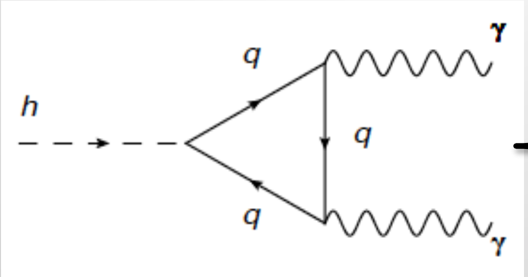
Could VL quarks reduce the largest deviations in the Higgs rates ?

➡ *If yes, which VL quarks and to which goodness-of-fit ?*

– Increase B($h \rightarrow \gamma\gamma$) via $g_{h\gamma\gamma}$
as no g_{hVV} corrections in VBF

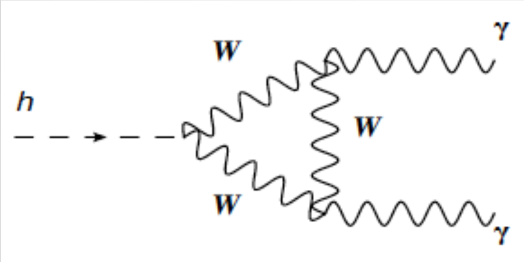


no extra-quark effects

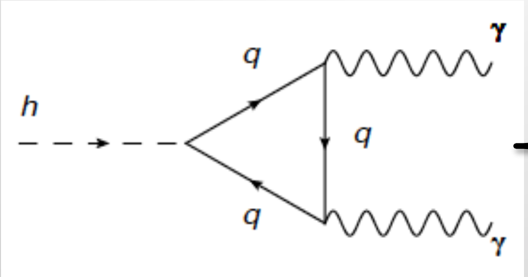


t-t' mix inefficient

– Increase $B(h \rightarrow \gamma\gamma)$ via $g_{h\gamma\gamma}$
as no g_{hVV} corrections in VBF

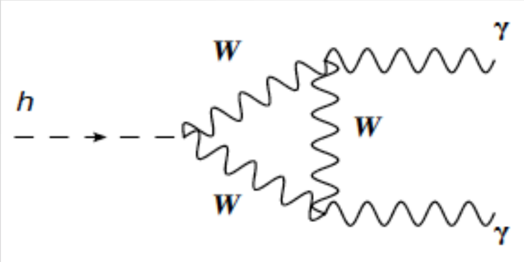


no extra-quark effects

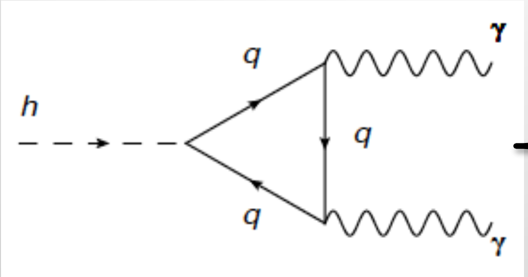


~~t-t' mix inefficient~~ (Y_t ~1)

– Increase $B(h \rightarrow \gamma\gamma)$ via $g_{h\gamma\gamma}$ as no g_{hVV} corrections in VBF



no extra-quark effects

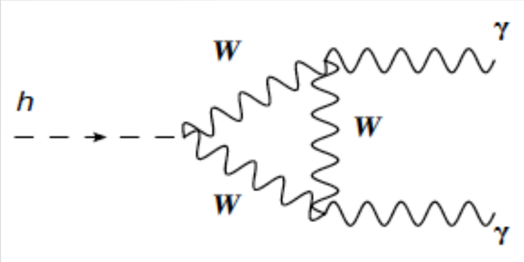


~~t-t' mix inefficient~~ ($Y_t \sim 1$)

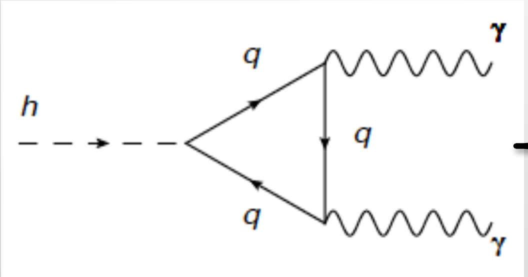
new $q_{5/3}$, $q_{-4/3}$

$$Y = Q_{e.m.} - I_{3L}$$

– Increase $B(h \rightarrow \gamma\gamma)$ via $g_{h\gamma\gamma}$
as no g_{hVV} corrections in VBF



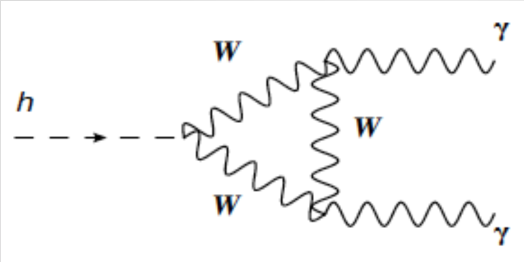
no extra-quark effects



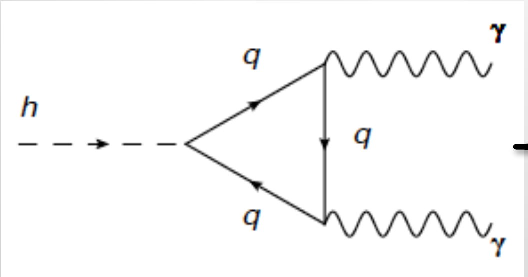
~~t-t' mix inefficient~~ (Y_t ~1)

~~new $q_{5/3}$~~ , $q_{-4/3}$ ($m >\sim 600$GeV)

– Increase B($h \rightarrow \gamma\gamma$) via $g_{h\gamma\gamma}$ as no g_{hVV} corrections in VBF



no extra-quark effects



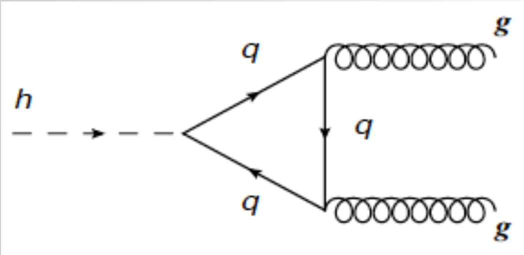
- ~~t-t' mix inefficient~~ (Y_t ~1)
- new ~~$q_{5/3}$~~ , $q_{-4/3}$ (m > ~ 600GeV)
- next one's : $q_{8/3}$, $q_{-7/3}$

– Decrease $\boldsymbol{\sigma}_h$B(h → **WW**)

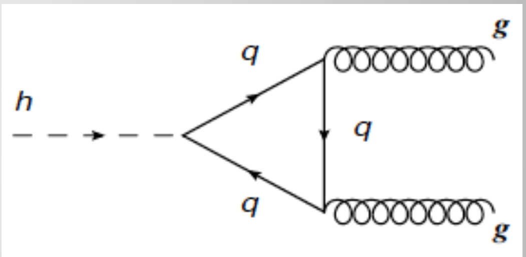
Via production :

Interference…

…destructive



top



$q_{8/3}$, $q_{-7/3}$

[coupled to h]

The induced minimal $SU(2)_L \times U(1)_Y$ *representations :*

I

Doublets

$$(q_{8/3}, q_{5/3})^t_{13/6} \;,\; (q'_{8/3})_{8/3} \;,\; (b')_{-1/3} \;,\; (b'', q_{-4/3})^t_{-5/6}$$

$$(q_{-4/3}, q_{-7/3})^t_{-11/6} \;,\; (q'_{-7/3})_{-7/3} \;,\; (b')_{-1/3} \;,\; (b'', q_{-4/3})^t_{-5/6}$$

Triplets

$$(q_{8/3}, q_{5/3}, t')^t_{5/3} \;,\; (q'_{8/3}, q'_{5/3})^t_{13/6} \;,\; (b')_{-1/3} \;,\; (b'', q_{-4/3})^t_{-5/6}$$

$$(b', q_{-4/3}, q_{-7/3})^t_{-4/3} \;,\; (q'_{-4/3}, q'_{-7/3})^t_{-11/6} \;,\; (b'')_{-1/3} \;,\; (t', b''')^t_{1/6}$$

The induced minimal $SU(2)_L x U(1)_Y$ representations :

I

Doublets

$$(q_{8/3}, q_{5/3})^t_{13/6} \; , \; (q'_{8/3})_{8/3} \; , \; (b')_{-1/3} \; , \; (b'', q_{-4/3})^t_{-5/6}$$

$$(q_{-4/3}, q_{-7/3})^t_{-11/6} \; , \; (q'_{-7/3})_{-7/3} \; , \; (b')_{-1/3} \; , \; (b'', q_{-4/3})^t_{-5/6}$$

Triplets

$$(q_{8/3}, q_{5/3}, t')^t_{5/3} \; , \; (q'_{8/3}, q'_{5/3})^t_{13/6} \; , \; (b')_{-1/3} \; , \; (b'', q_{-4/3})^t_{-5/6}$$

$$(b', q_{-4/3}, q_{-7/3})^t_{-4/3} \; , \; (q'_{-4/3}, q'_{-7/3})^t_{-11/6} \; , \; (b'')_{-1/3} \; , \; (t', b''')^t_{1/6}$$

II

$$(q_{8/3}, q_{5/3}, t')^t_{5/3} \; , \; (q'_{8/3}, q'_{5/3})^t_{13/6} \; , \; (q''_{5/3}, t'')^t_{7/6} \; , \; (b')_{-1/3} \; , \; (t''', b'')^t_{1/6} \text{ or } (b'', q_{-4/3})^t_{-5/6}$$

predicted phenomenology : $q^1_{8/3} \to q^{1(\star)}_{5/3} W^+ \to t_1 W^+ W^+$

III

$$(b', q_{-4/3}, q_{-7/3})^t_{-4/3} \; , \; (q'_{-4/3}, q'_{-7/3})^t_{-11/6} \; , \; (b'', q''_{-4/3})^t_{-5/6} \; , \; (b''')_{-1/3} \text{ and/or } (t', b'''')^t_{1/6}$$

main decay mimics b' : $q^1_{-7/3} \to q^{1(\star)}_{-4/3} W^- \to b_1 W^- W^-$

An explicit example : the Model II Lagrangian

$$\mathcal{L}_{\rm II} \;=\; Y\overline{\begin{pmatrix} t \\ b \end{pmatrix}}_L H^\dagger t^c_R + Y'\overline{\begin{pmatrix} q''_{5/3} \\ t'' \end{pmatrix}}_L H t^c_R + Y_{8/3}\overline{\begin{pmatrix} q'_{8/3} \\ q'_{5/3} \end{pmatrix}}_{L/R} H \begin{pmatrix} q_{8/3} \\ q_{5/3} \\ t' \end{pmatrix}_{R/L} + Y_{5/3}\overline{\begin{pmatrix} q''_{5/3} \\ t'' \end{pmatrix}}_{L/R} H^\dagger \begin{pmatrix} q_{8/3} \\ q_{5/3} \\ t' \end{pmatrix}_{R/L}$$

$$+ Y_b\overline{\begin{pmatrix} t \\ b \end{pmatrix}}_L H b^c_R + Y'_b\overline{\begin{pmatrix} t \\ b \end{pmatrix}}_L H b'_R + Y''_b\overline{\begin{pmatrix} b'' \\ q_{-4/3} \end{pmatrix}}_L H^\dagger b^c_R + Y_{-1/3}\overline{\begin{pmatrix} b'' \\ q_{-4/3} \end{pmatrix}}_{L/R} H^\dagger b'_{R/L} + m\;\bar{b}'_L b^c_R + m'\;\bar{b}'_L b'_R$$

$$+ m_{-4/3}\overline{\begin{pmatrix} b'' \\ q_{-4/3} \end{pmatrix}}_L \begin{pmatrix} b'' \\ q_{-4/3} \end{pmatrix}_R + m_{5/3}\overline{\begin{pmatrix} q''_{5/3} \\ t'' \end{pmatrix}}_L \begin{pmatrix} q''_{5/3} \\ t'' \end{pmatrix}_R + m'_{8/3}\overline{\begin{pmatrix} q'_{8/3} \\ q'_{5/3} \end{pmatrix}}_L \begin{pmatrix} q'_{8/3} \\ q'_{5/3} \end{pmatrix}_R + m_{8/3}\overline{\begin{pmatrix} q_{8/3} \\ q_{5/3} \\ t' \end{pmatrix}}_L \begin{pmatrix} q_{8/3} \\ q_{5/3} \\ t' \end{pmatrix}_R + \text{H.c.}$$

Similar quark configurations as in *warped/composite* frameworks…

II

$$(q_{8/3}, q_{5/3}, t')^t_{5/3} \;,\; (q'_{8/3}, q'_{5/3})^t_{13/6} \;,\; (q''_{5/3}, t'')^t_{7/6} \;,\; (b')_{-1/3} \;,\; (t''', b'')^t_{1/6} \text{ or } (b'', q_{-4/3})^t_{-5/6}$$

SU(2)$_L$xSU(2)$_R$xU(1)

$$[T3] \qquad q^{1cp} = (\mathbf{2}, \mathbf{3})_{7/6} = \begin{bmatrix} Y_1^{cp'} & X_1^{cp''} & U_1^{cp} \\ X_1^{cp'} & U_1^{cp'} & D_1^{cp} \end{bmatrix} ,$$

$$t^{cp} = (\mathbf{1}, \mathbf{4})_{7/6} = \begin{bmatrix} Y_t^{cp'} & X_t^{cp'} & U_t^{cp} & D_t^{cp'} \end{bmatrix} ,$$

with Y' being exotic fermions with $Q = 8/3$.

FROM *L. Da Rold,* arXiv:1009.2392

Similar quark configurations as in *warped/composite* frameworks…

II

$$(q_{8/3}, q_{5/3}, t')^t_{5/3}\ ,\ (q'_{8/3}, q'_{5/3})^t_{13/6}\ ,\ (q''_{5/3}, t'')^t_{7/6}\ ,\ (b')_{-1/3}\ ,\ (t''', b'')^t_{1/6} \text{ or } (b'', q_{-4/3})^t_{-5/6}$$

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[T3] $$q^{1cp} = (\mathbf{2}, \mathbf{3})_{7/6} = \begin{bmatrix} Y_1^{cp'} & X_1^{cp''} & U_1^{cp} \\ X_1^{cp'} & U_1^{cp'} & D_1^{cp} \end{bmatrix} ,$$

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SU(2)$_L$xSU(2)$_R$xU(1)

$$[T3] \qquad q^{1cp} = (\mathbf{2},\mathbf{3})_{7/6} = \begin{bmatrix} Y_1^{cp'} & X_1^{cp''} & U_1^{cp} \\ X_1^{cp'} & U_1^{cp'} & D_1^{cp} \end{bmatrix},$$

$$t^{cp} = (\mathbf{1},\mathbf{4})_{7/6} = \begin{bmatrix} Y_t^{cp'} & X_t^{cp'} & U_t^{cp} & D_t^{cp'} \end{bmatrix},$$

with Y' being exotic fermions with $Q = 8/3$.

FROM *L. Da Rold,* arXiv:1009.2392

III

$$(b', q_{-4/3}, q_{-7/3})^t_{-4/3}\ ,\ (q'_{-4/3}, q'_{-7/3})^t_{-11/6}\ ,\ (b'', q''_{-4/3})^t_{-5/6}\ ,\ (b''')_{-1/3}\ \text{and/or}\ (t', b'''')^t_{1/6}$$

$$\{Q_{2L}\} \equiv (\mathbf{2},\mathbf{3})_{-5/6} = \begin{pmatrix} t_{2L} & b'_L & q''_{(-4/3)L} \\ b_{2L} & q'_{(-4/3)L} & q'_{(-7/3)L} \end{pmatrix} \quad \{b^c_R\} \equiv (\mathbf{3},\mathbf{2})_{-5/6} = \begin{pmatrix} t^{c\prime\prime}_R & b^{c\prime\prime\prime}_R \\ b^c_R & q^{c\prime\prime}_{(-4/3)R} \\ q^{c\prime\prime\prime}_{(-4/3)R} & q^{c\prime}_{(-7/3)R} \end{pmatrix}$$

FROM *C.Bouchart et al.,* arXiv:0807.4461

II) Numerical results for the Higgs fits

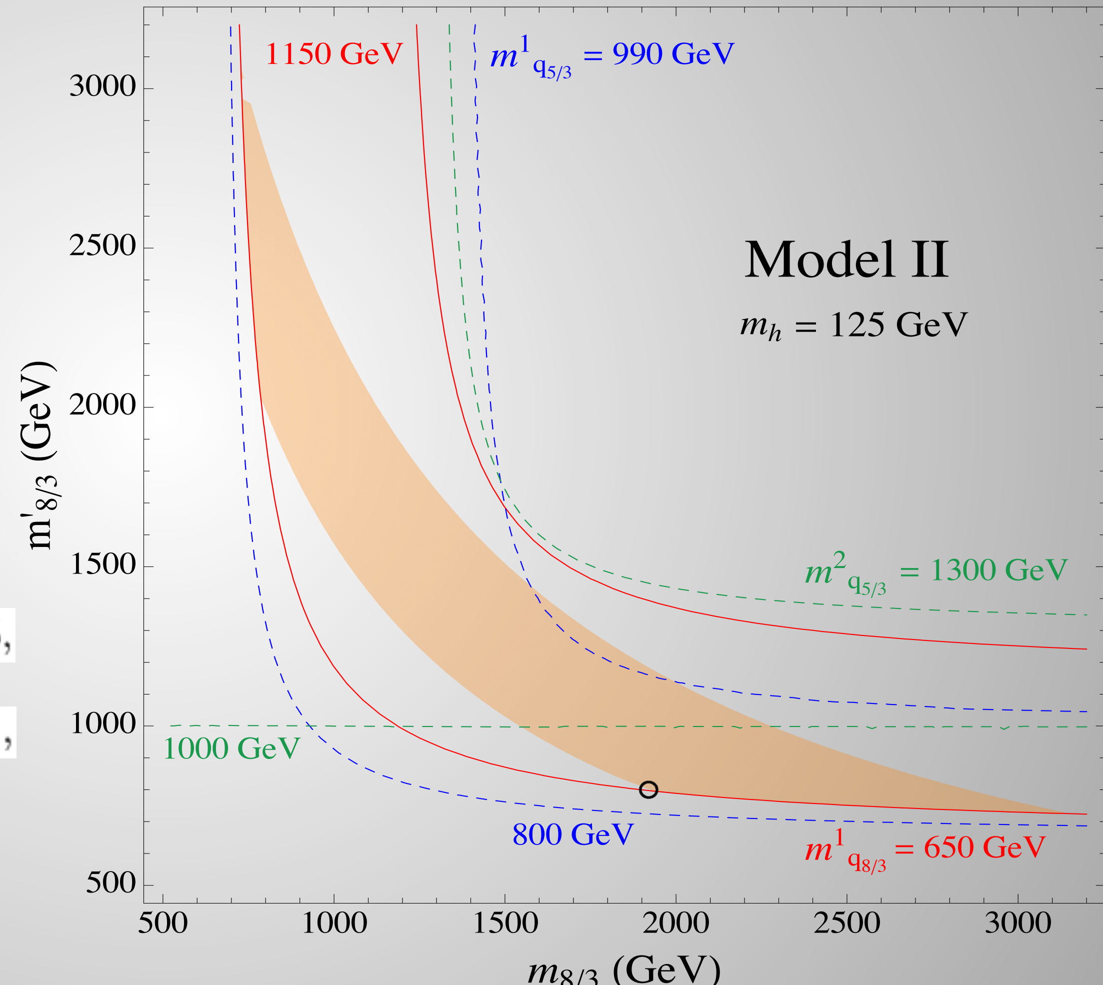
All the Higgs boson rates @ **1σ** in a large parameter space :

$Y = 1.01,\ Y' = 1,\ Y_{8/3} = 2.5,\ Y_{5/3} = -0.5,$

$Y_b = -0.053,\ Y_b' = 1,\ Y_b'' = 1,\ Y_{-1/3} = 1,$

$m' = 1200\ \text{GeV},\ m_{-4/3} = 900\ \text{GeV},$

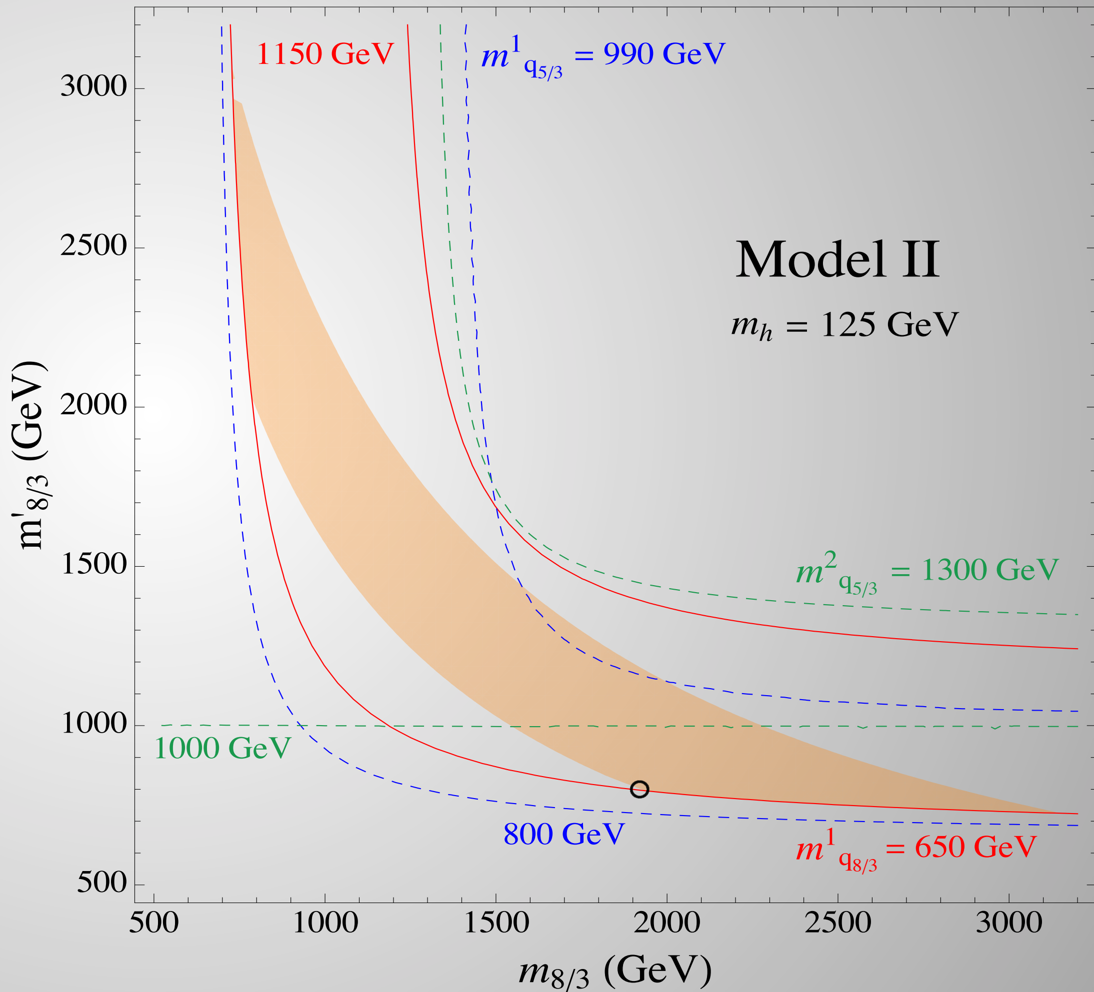
$m_{5/3} = 1000\ \text{GeV}$



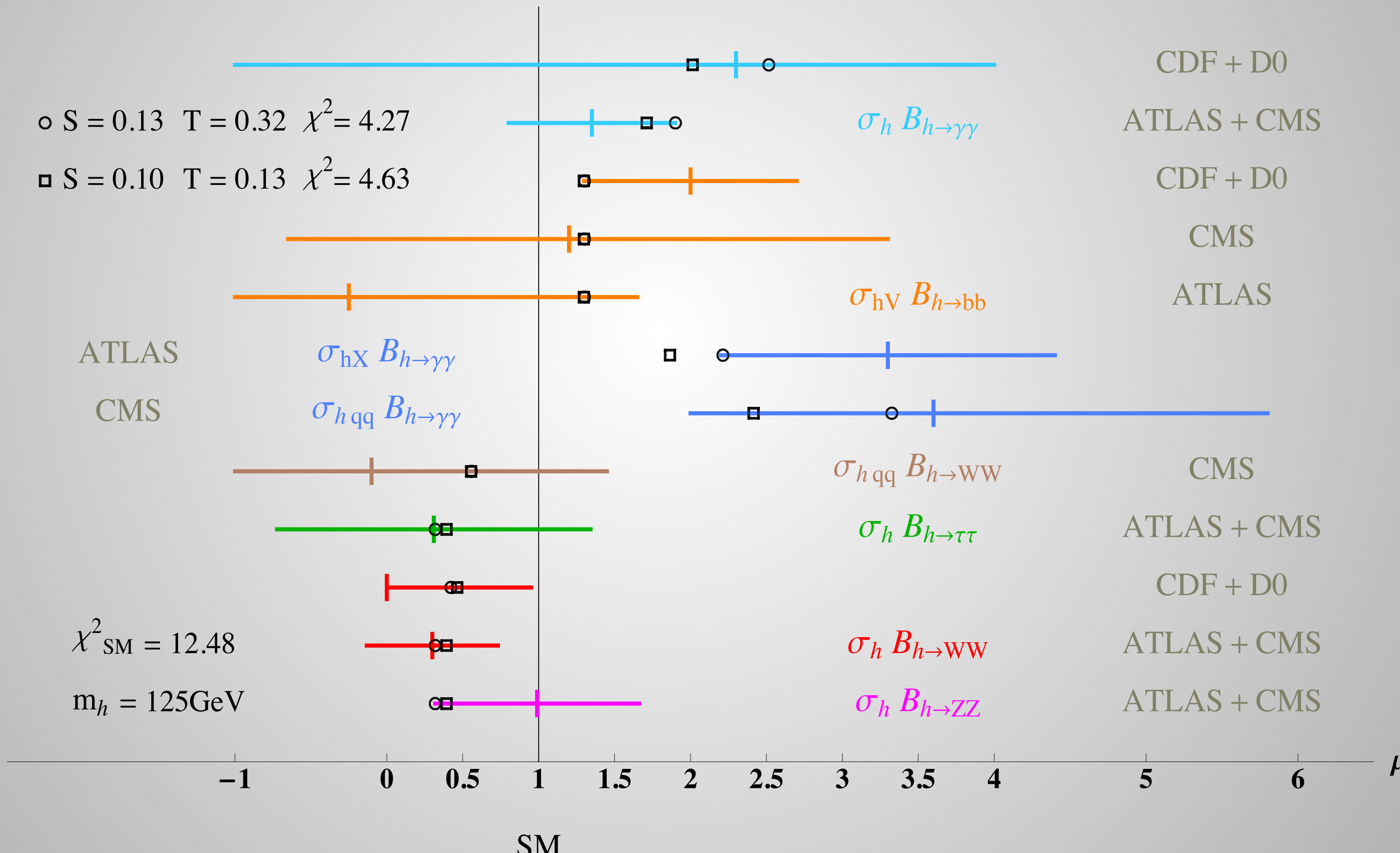
II) Numerical results for the Higgs fits

All the Higgs boson rates @ **1σ** in a large parameter space :

$$m_{b_2} > 611 \text{ GeV} \quad (B_{b_2 \to t_1 W} = 1)$$
$$m_{q^1_{5/3}} > 611 \text{ GeV} \quad (B_{q^1_{5/3} \to t_1 W} \simeq 1)$$
$$m_{t_2} > 560 \text{ GeV} \quad (B_{t_2 \to b_1 W} = 1)$$
$$m_{q^1_{-4/3}} > 560 \text{ GeV} \quad (B_{q^1_{-4/3} \to b_1 W} \simeq 1)$$

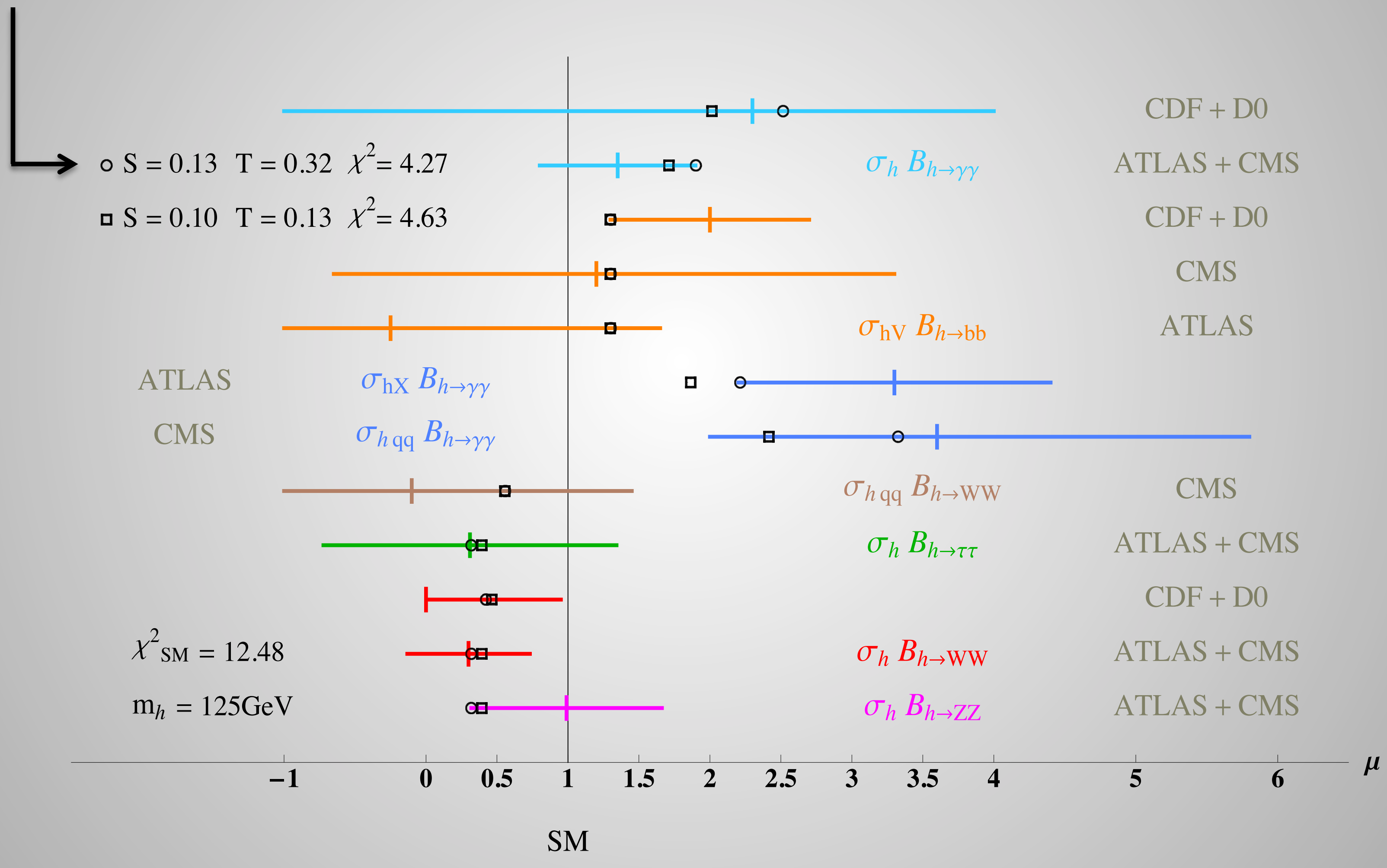


$$m_{b_2} \approx 840 \text{ GeV}$$
$$m_{q^1_{-4/3}} \approx 900 \text{ GeV}$$
$$m_{t_2} \approx 900 - 1010 \text{ GeV}$$

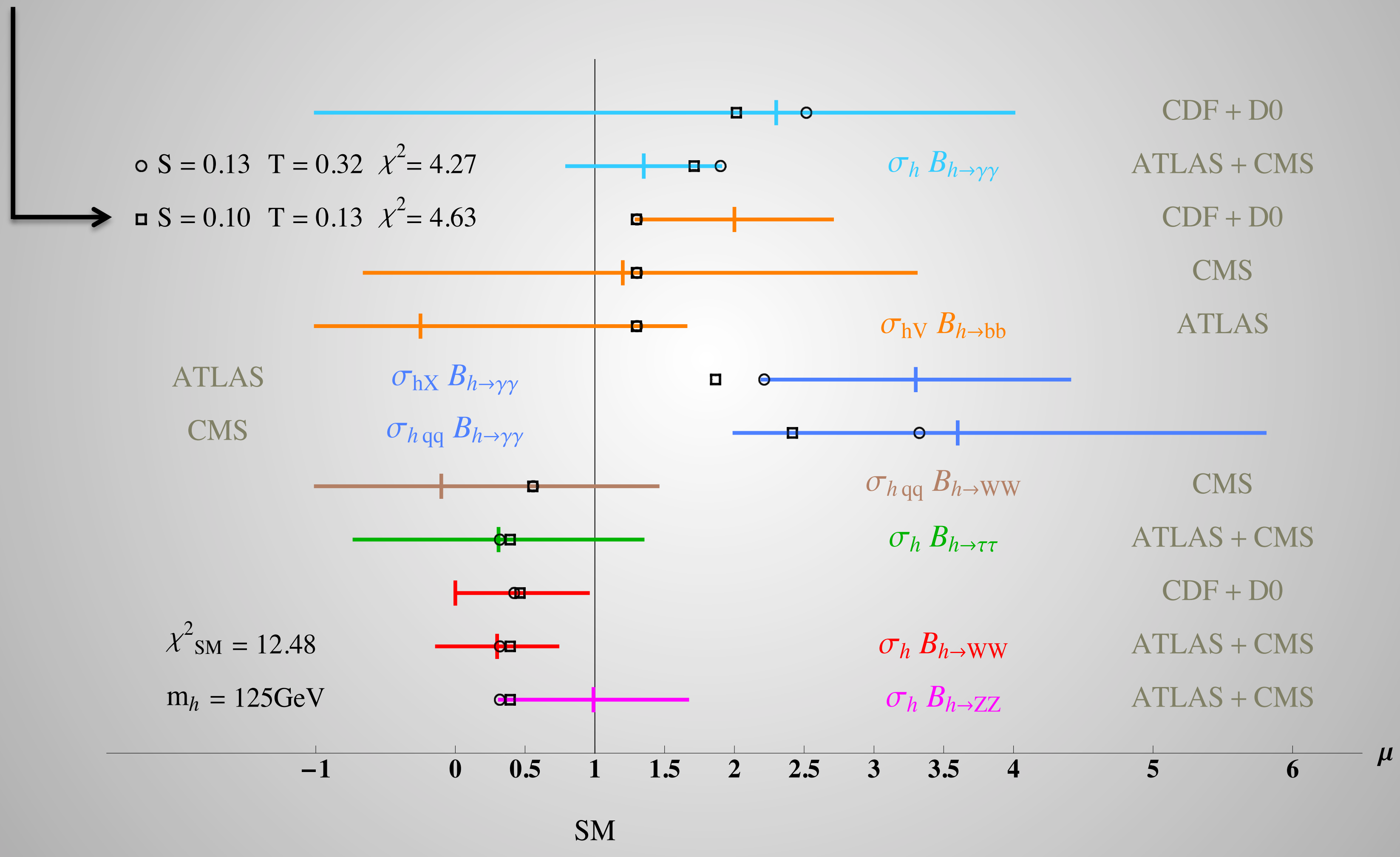


CDF + D0
∘ S = 0.13 T = 0.32 χ^2 = 4.27
□ S = 0.10 T = 0.13 χ^2 = 4.63
$\sigma_h B_{h\to\gamma\gamma}$
ATLAS + CMS
CDF + D0
CMS
$\sigma_{hV} B_{h\to bb}$
ATLAS
ATLAS
$\sigma_{hX} B_{h\to\gamma\gamma}$
CMS
$\sigma_{h\,qq} B_{h\to\gamma\gamma}$
$\sigma_{h\,qq} B_{h\to WW}$
CMS
$\sigma_h B_{h\to\tau\tau}$
ATLAS + CMS
CDF + D0
χ^2_{SM} = 12.48
$\sigma_h B_{h\to WW}$
ATLAS + CMS
m_h = 125GeV
$\sigma_h B_{h\to ZZ}$
ATLAS + CMS
−1
0
0.5
1
1.5
2
2.5
3
3.5
4
5
6
μ
SM

Model also reasonable w.r.t. indirect EW Precision Tests (LEP) :



Optimizing the oblique parameters : $\chi^2_{SM}/8=1.6$ $\chi^2_{VL}/(8-3)=0.9$



Other scenarii for improving the Higgs rate fits at that time…

- VL leptons : smaller masses => larger effects *M.Carena et al.,* arXiv:1206.1082
- Little Higgs non-trivially constrained *D.Carmi et al.,* arXiv:1202.3144
- Minimal Composite Higgs Models constrained *J.Ellis et al.,* arXiv:1204.0464
  A.Azatov et al., arXiv:1202.3415, arXiv:1204.4817
- Type II see-saw : welcome H^{++} exchanged in the $h\gamma\gamma$ loop
  A.Arhrib et al., arXiv:1112.5453
- Extra fermions in exotic $SU(3)_c$ multiplets can help (effective coupling level)
  V.Barger et al., arXiv:1203.3456
- Higgs sector breaking the custodial symmetry accommodates B_{ZZ} versus B_{WW}
  M.Farina et al., arXiv:1205.0011
- Fermiophobic Higgs : increase $B(h \to \gamma\gamma)$ but fermion masses from TC ?
  E.Gabrielli et al., arXiv:1202.1796
- SUSY : problematic correlation between the WW and $\gamma\gamma$ channels
  P.P.Giardino et al., arXiv:1203.4254
- 4^{th} generation, radion, dilaton : difficulties to enhance the diphoton channels
  arXiv:1107.1490, arXiv:1112.4146
- …

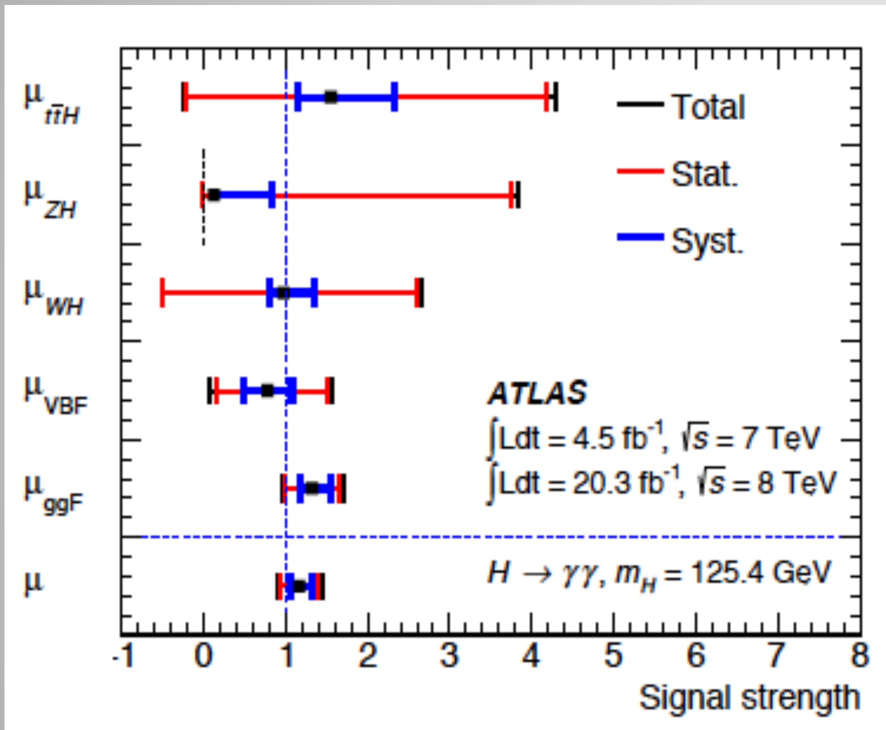
Conclusions (B)

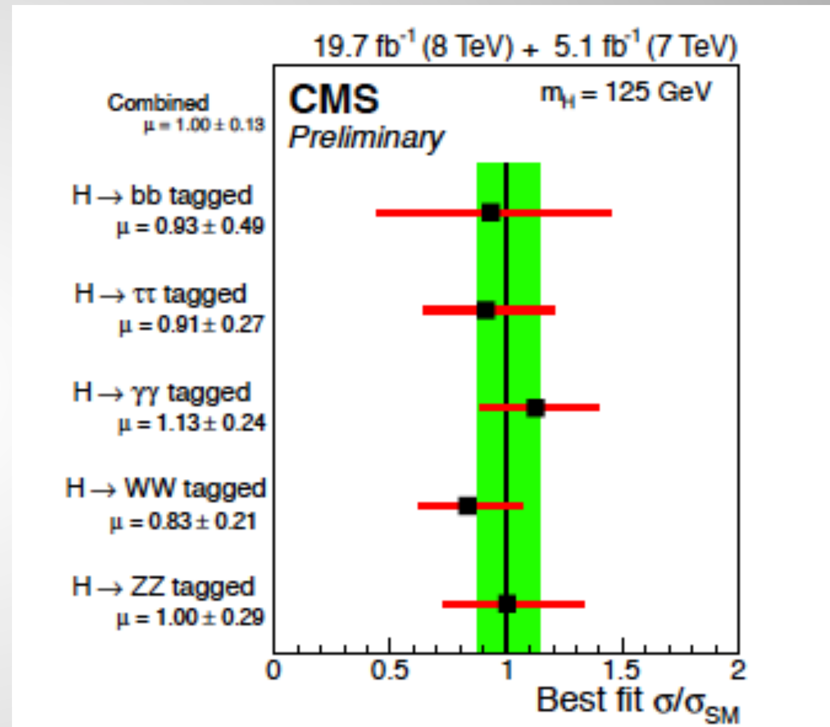
We've presented the list of minimal field contents of VL quarks allowing to :

- induce a **large enhancement** of the Higgs diphoton channels
- with an acceptably small tension (between EWPT and the Higgs fit).

Therefore, VL quarks could certainly induce increases of the Higgs diphoton rates in case of future **(smaller) excesses** in data w.r.t. SM.

Back up





(last exp. results – 08/2014)

LHC Signatures of Warped-space Vectorlike Quarks

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Abstract

We study the LHC signatures of TeV scale vectorlike quarks b', t' and χ with electromagnetic charges $-1/3$, $2/3$ and $5/3$ that appear in many beyond the standard model (BSM) extensions. We consider warped extra-dimensional models and analyze the phenomenology of such vectorlike quarks that are the custodial partners of third generation quarks. In addition to the usually studied pair-production channels which depend on the strong coupling, we put equal emphasis on single production channels that depend on electroweak couplings and on electroweak symmetry breaking induced mixing effects between the heavy vectorlike quarks and standard model quarks. We identify new promising gg-initiated pair and single production channels and find the luminosity required for discovering these states at the LHC. For these channels, we propose a cut that allows one to extract the relevant electroweak couplings. Although the motivation is from warped models, we present many of our results model-independently.

1 Introduction

The standard model (SM) of particle physics suffers from the gauge hierarchy and flavor hierarchy problems and many beyond the standard model (BSM) extensions have been proposed to solve these problems. The extra particles in these BSM extensions are being

$$\epsilon_t c_t = \frac{\text{sign}(m_t)}{\text{sign}(m_t^{\text{EF}})} c_t = \frac{\text{sign}(m_t)}{\text{sign}(m_t^{\text{EF}})} \frac{\text{sign}(-Y_t^{\text{EF}})}{\text{sign}(-Y_t)} |c_t| = \frac{\text{sign}(-Y_t^{\text{EF}})}{\text{sign}(m_t^{\text{EF}})} |c_t| = \text{sign}\left(\frac{-Y_t^{\text{EF}}}{m_t^{\text{EF}}}\right) \left|\frac{Y_t^{\text{EF}}}{Y_t}\right|$$