Higgs Physics
&
Extra-Fermions

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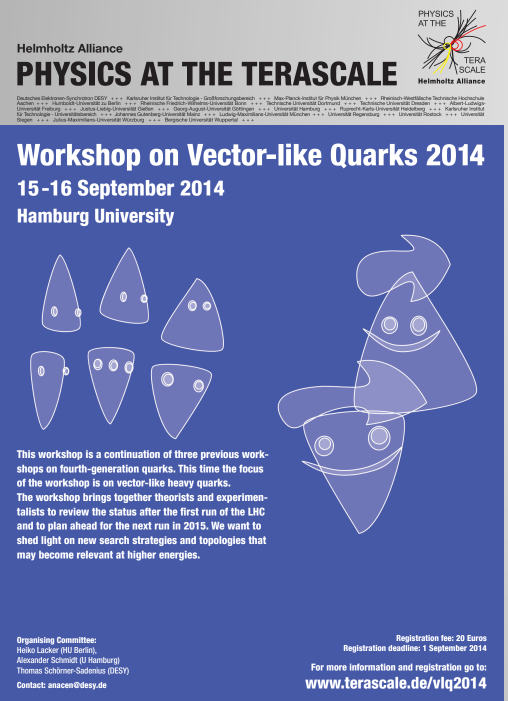
Based on arXiv:1210.3977

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,

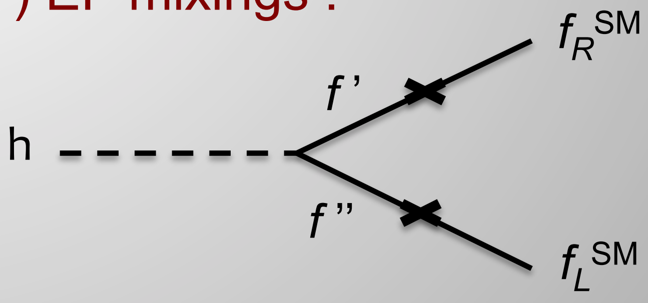
- little Higgs *[fermionic partners]*
- supersymmetry *[gauginos / higgsinos]*
- composite Higgs *[excited bounded states]*
- extra-dimensions *[Kaluza-Klein towers]*
- 4*th* generations *[new families]*
- G.U.Theories *[multiplet components]*
- etc…

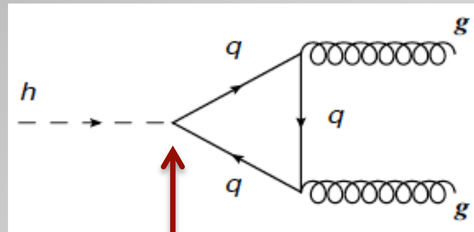
➡ *What are the present **constraints on GENERIC Extra-Fermions** imposed by all the experimental results in the Higgs sector ?*

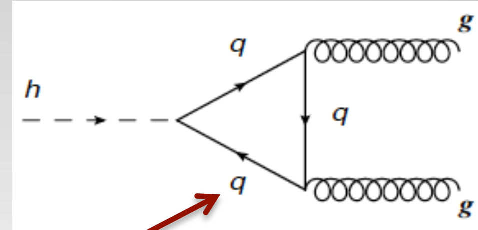
Effective approach : Corrections on the Higgs couplings from **ANY** extra-fermions *(via mixing, new loops)*

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

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

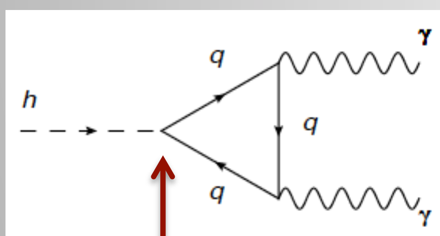


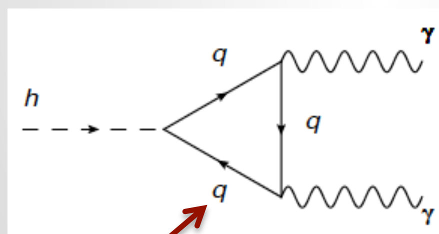




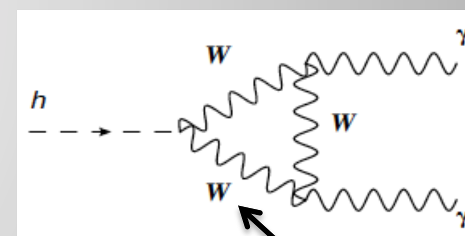
b' , $q_{5/3}$, …

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





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 :

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

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

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

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

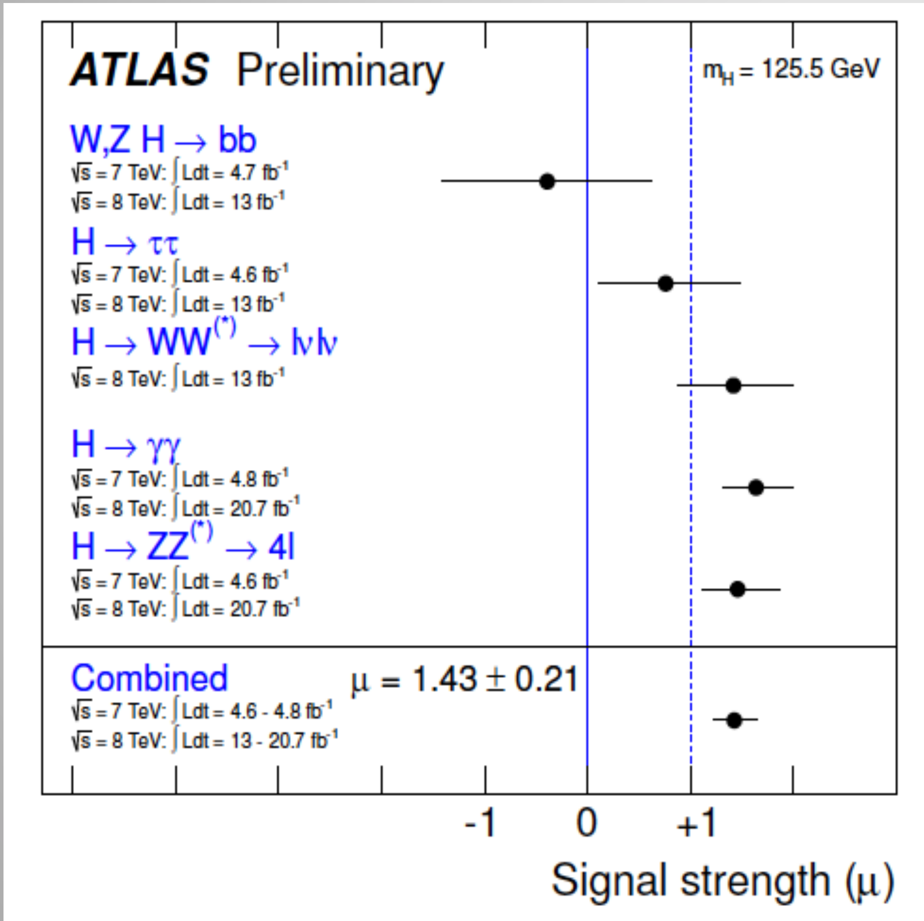
Measured signal strengths all of the form (exp. selection efficiencies) :

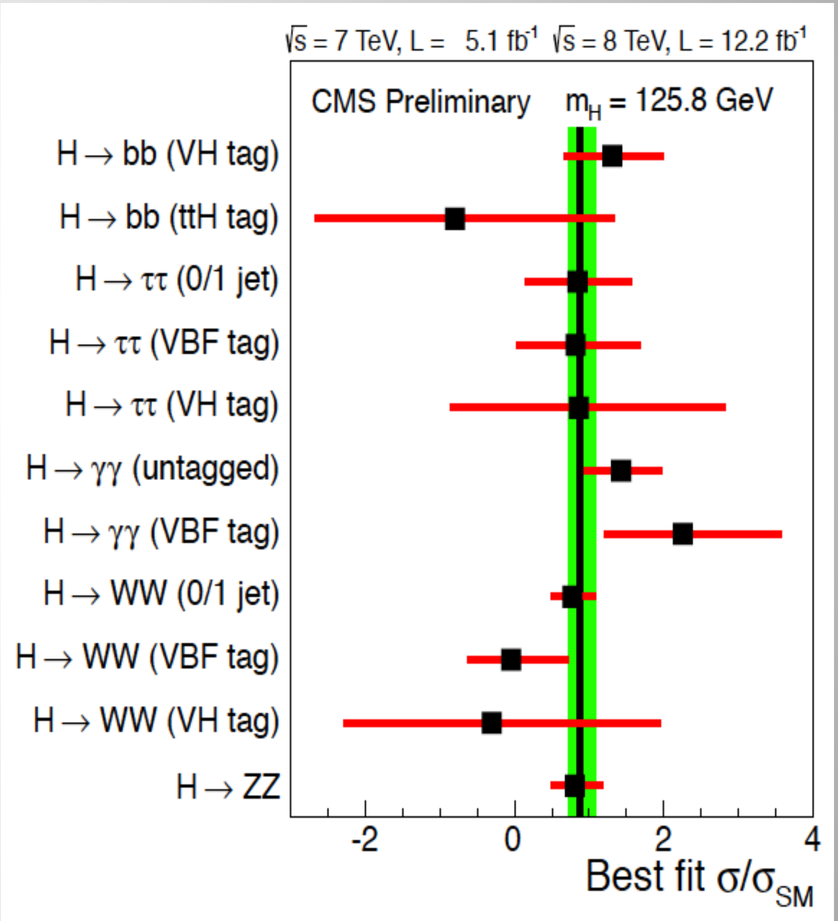
$$\mu^p_{s,c,i} \simeq \frac{\sigma_{\mathrm{gg}\to\mathrm{h}}\big|_s + \frac{\epsilon_{\mathrm{hqq}}}{\epsilon_{\mathrm{gg}\to\mathrm{h}}}\Big|^p_{s,c,i} \sigma^{\mathrm{SM}}_{\mathrm{hqq}}\big|_s + \frac{\epsilon_{\mathrm{hV}}}{\epsilon_{\mathrm{gg}\to\mathrm{h}}}\Big|^p_{s,c,i} \sigma^{\mathrm{SM}}_{\mathrm{hV}}\big|_s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

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…





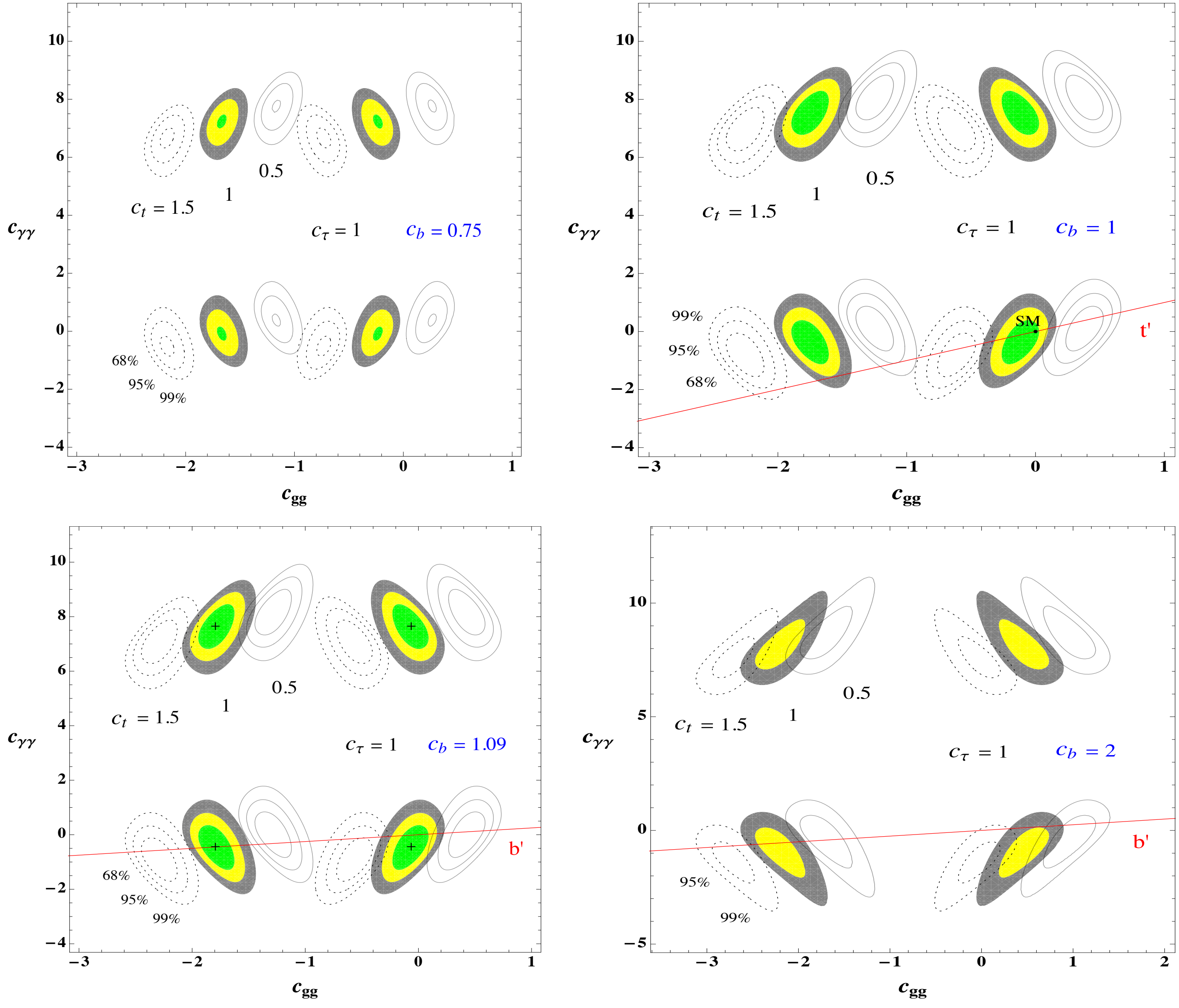
Higgs fit results :

(3 free param.)

AFTER MORIOND 2013...

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

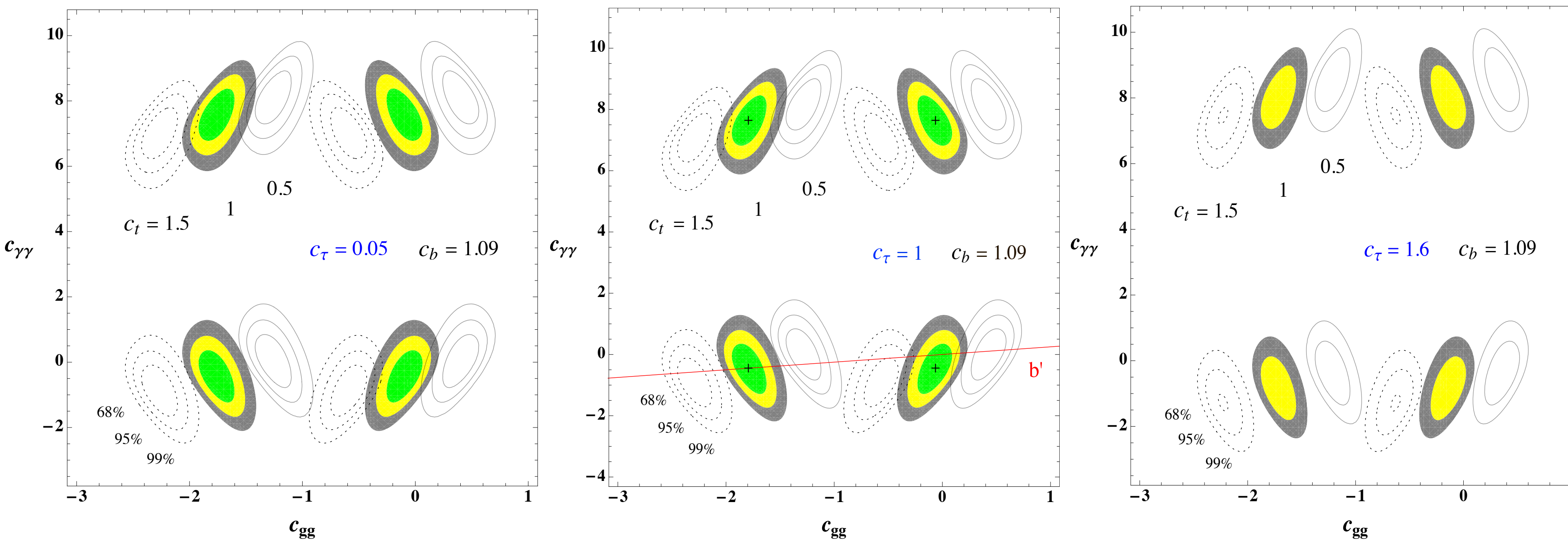
$$\chi^2_{\rm min} = 52.36$$



« 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 :

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

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

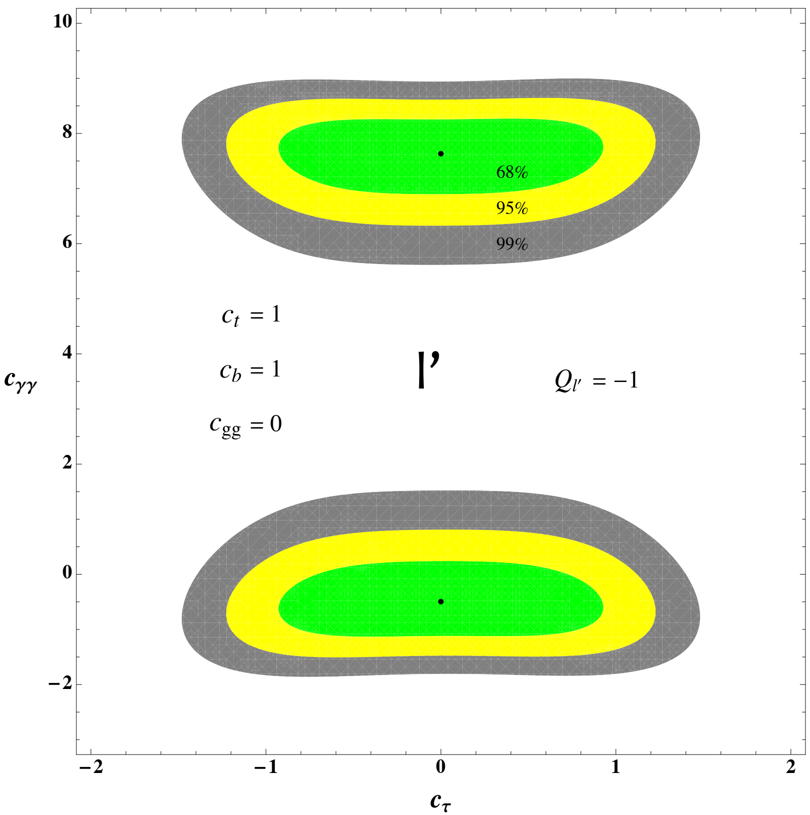
2. **Same color** repres. as the top quark ➡

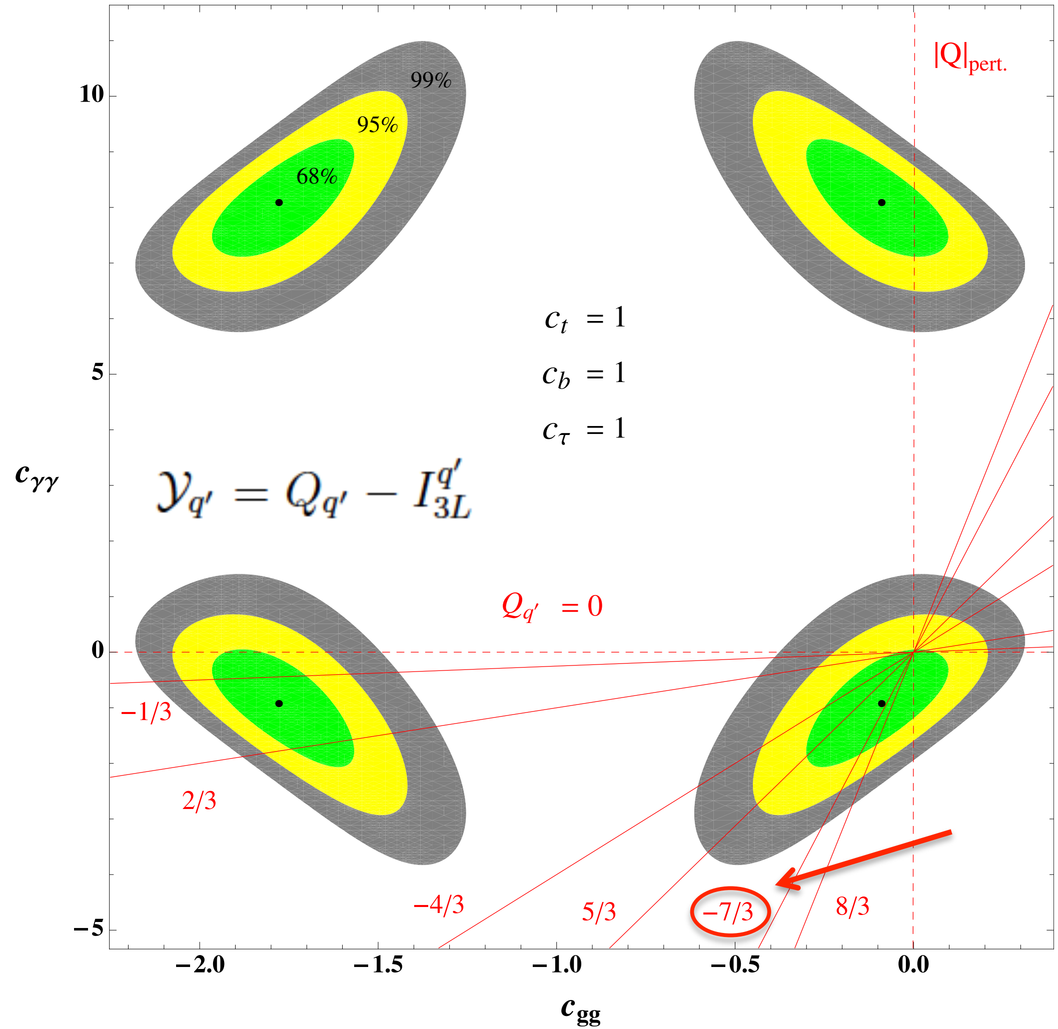
$$\left.\frac{c_{\gamma\gamma}}{c_{gg}}\right|_{q'} = \frac{Q_{q'}^2}{(2/3)^2}$$

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

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

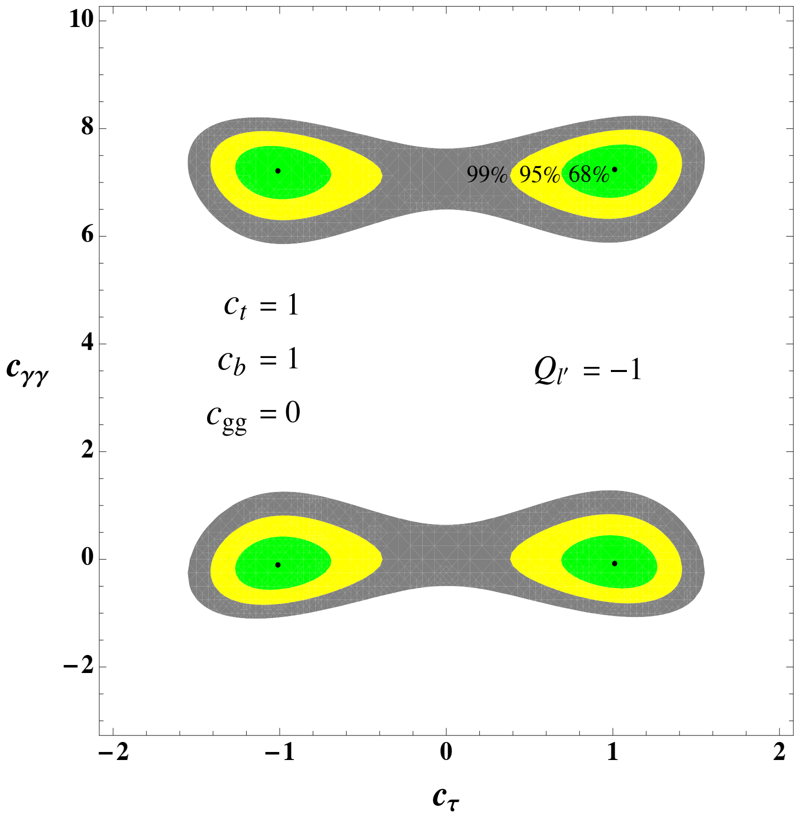
(2 free parameters)



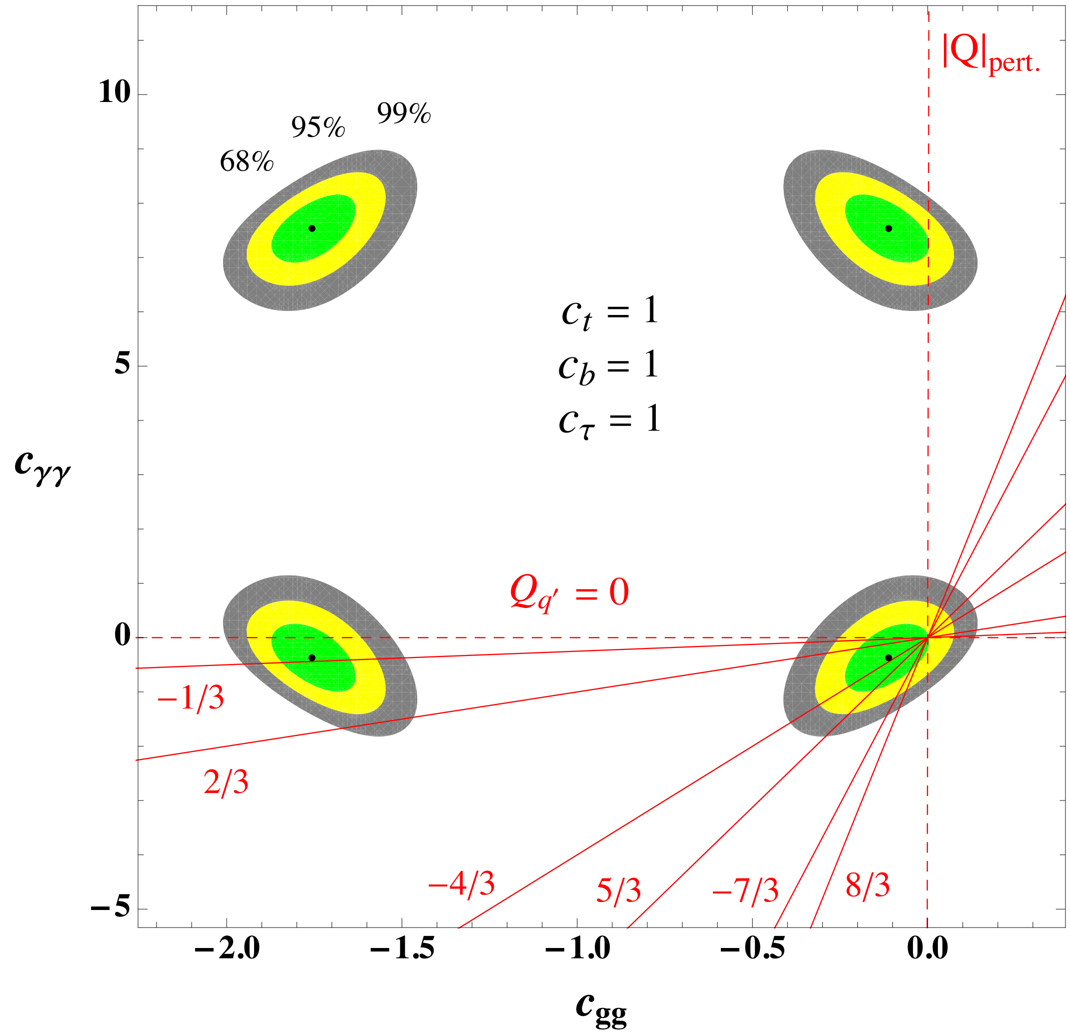


AFTER MORIOND 2013...

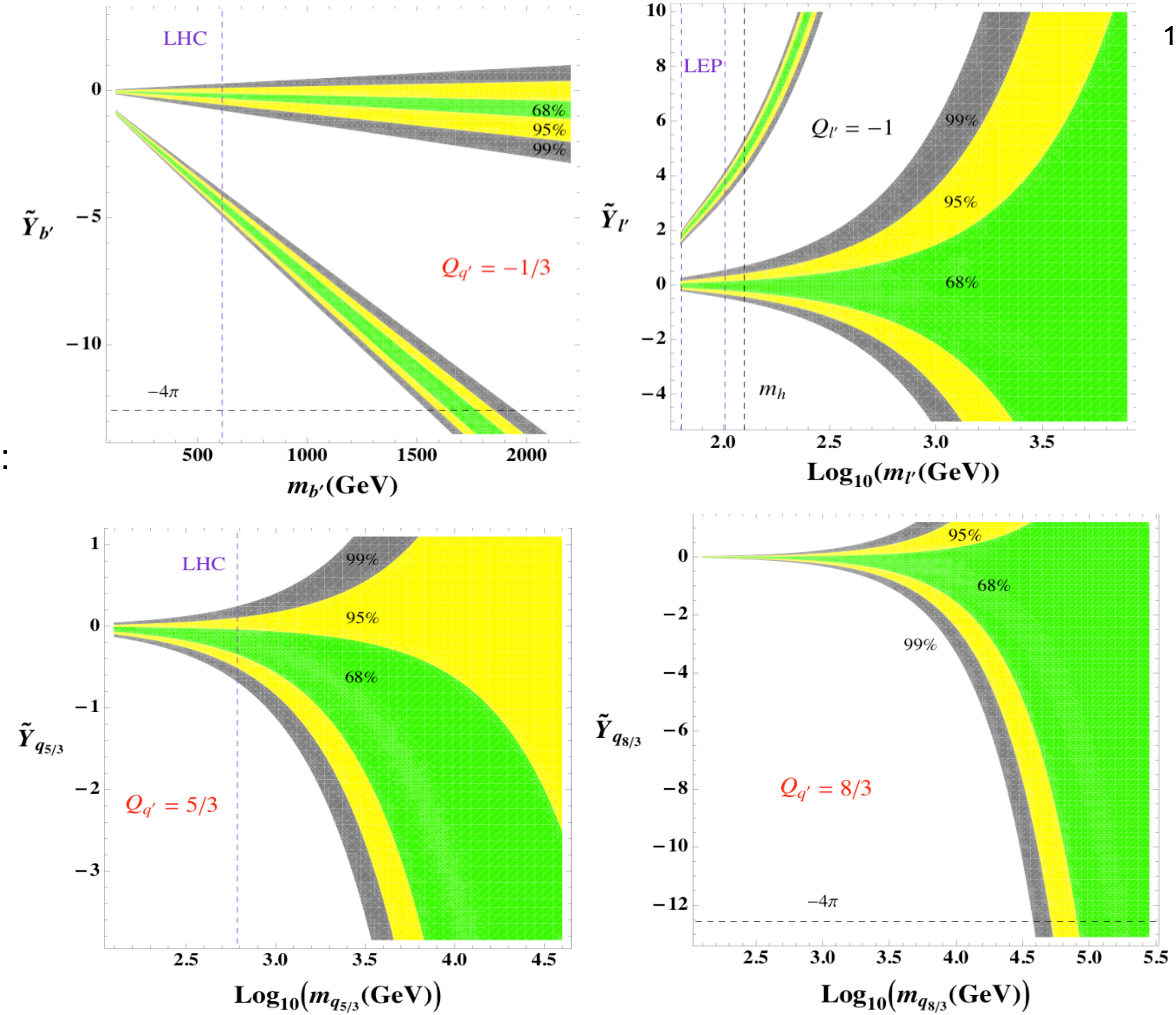
(2 free parameters)



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



(1 free param.)



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

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

…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 , $h\gamma\gamma$.

- 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…

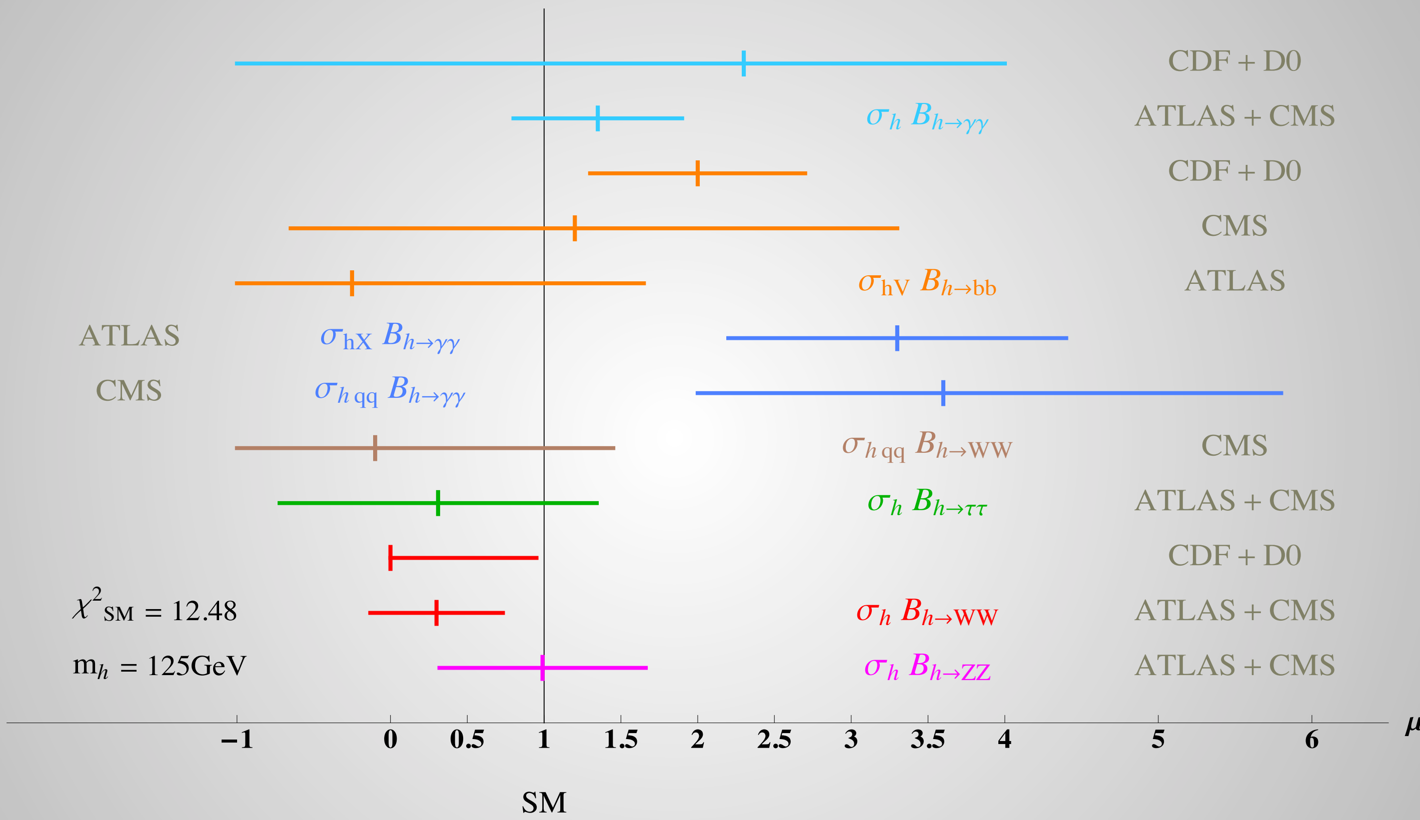
B – VL quarks to increase Higgs diphoton rates

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
$m_h = 125GeV$
$\sigma_h\ B_{h\to ZZ}$
ATLAS + CMS
−1
0
0.5
1
1.5
2
2.5
3
3.5
4
5
6
μ
SM

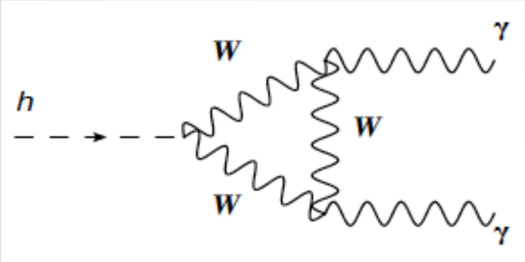
Assessment : on the theoretical side, **Vector-Like quarks** arise in most Supersymmetry alternatives like

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

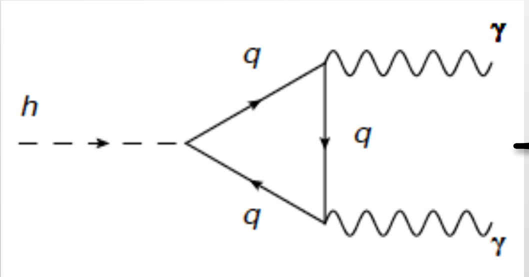
Could VL quarks reduce the largest deviations in the Higgs rates ?

➡ *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

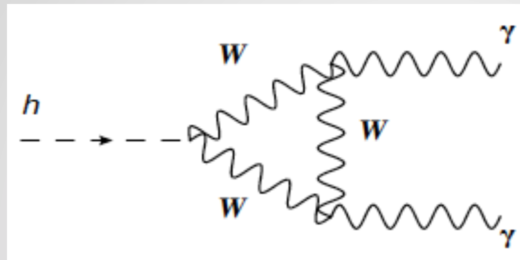


no extra-quark effects



t-t' mix inefficient

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



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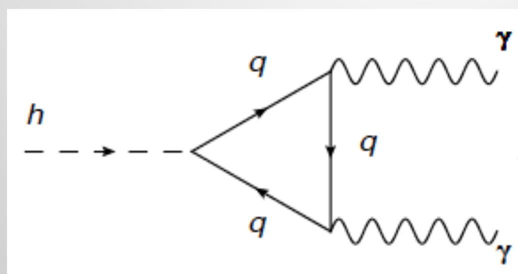
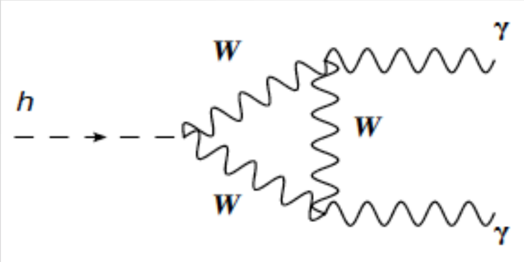
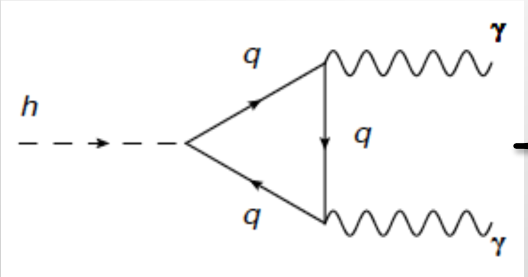


t-t' mix ~~inefficient~~ (Y_t ~1)

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



no extra-quark effects

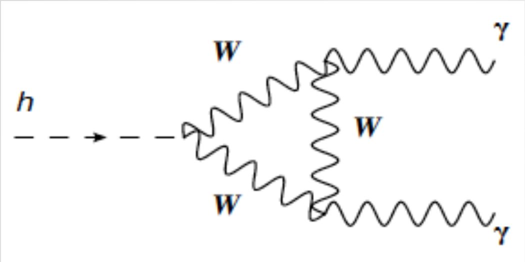


~~t-t' mix inefficient~~ ($Y_t \sim 1$)

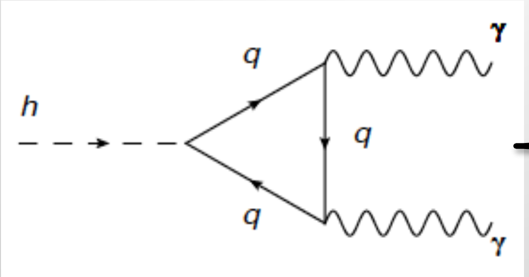
new $q_{5/3}$, $q_{-4/3}$

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

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



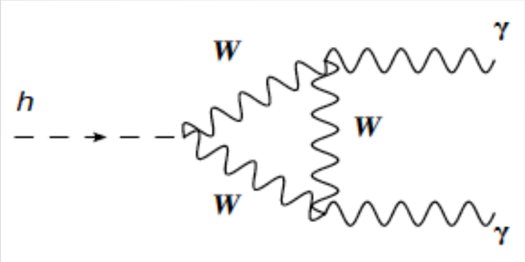
no extra-quark effects



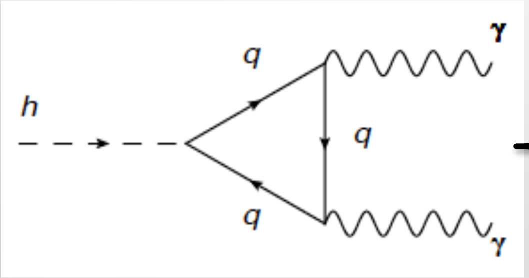
~~t-t' mix inefficient~~ ($Y_t \sim 1$)

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

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



no extra-quark effects



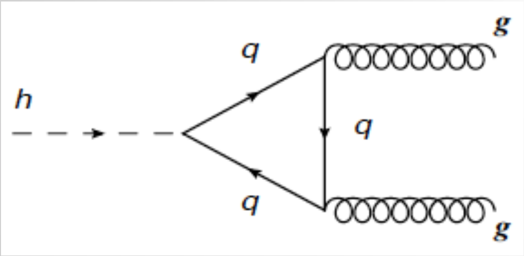
- ~~t-t' mix inefficient~~ (Y_t ~1)
- ~~new $q_{5/3}$, $q_{-4/3}$~~ (m > ~ 600GeV)
- next one's : $q_{8/3}$, $q_{-7/3}$

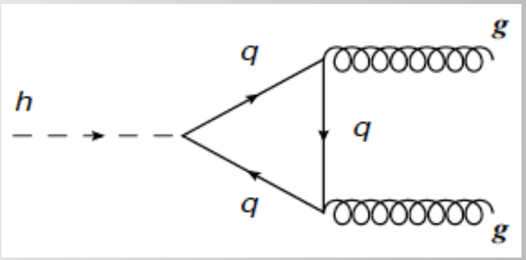
– Decrease $\boldsymbol{\sigma}_h B(h \rightarrow \mathbf{WW})$

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 $SU(2)_L \times U(1)_Y$ 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

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

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

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

$$
\begin{aligned}
\mathcal{L}_{\rm II} \;=\; & Y \overline{\begin{pmatrix} t \\ b \end{pmatrix}}_L H^\dagger t_R^c + Y' \overline{\begin{pmatrix} q''_{5/3} \\ t'' \end{pmatrix}}_L H t_R^c + Y_{8/3} \overline{\begin{pmatrix} q'_{8/3} \\ q'_{5/3} \end{pmatrix}}_{L/R} H \begin{pmatrix} q_{8/3} \\ q_{5/3} \\ t' \end{pmatrix}_{R/L} + Y_{5/3} \overline{\begin{pmatrix} q''_{5/3} \\ t'' \end{pmatrix}}_{L/R} H^\dagger \begin{pmatrix} q_{8/3} \\ q_{5/3} \\ t' \end{pmatrix}_{R/L} \\
& + Y_b \overline{\begin{pmatrix} t \\ b \end{pmatrix}}_L H b_R^c + Y'_b \overline{\begin{pmatrix} t \\ b \end{pmatrix}}_L H b'_R + Y''_b \overline{\begin{pmatrix} b'' \\ q_{-4/3} \end{pmatrix}}_L H^\dagger b_R^c + Y_{-1/3} \overline{\begin{pmatrix} b'' \\ q_{-4/3} \end{pmatrix}}_{L/R} H^\dagger b'_{R/L} + m\ \bar{b}'_L b_R^c + m'\ \bar{b}'_L b'_R \\
& + m_{-4/3} \overline{\begin{pmatrix} b'' \\ q_{-4/3} \end{pmatrix}}_L \begin{pmatrix} b'' \\ q_{-4/3} \end{pmatrix}_R + m_{5/3} \overline{\begin{pmatrix} q''_{5/3} \\ t'' \end{pmatrix}}_L \begin{pmatrix} q''_{5/3} \\ t'' \end{pmatrix}_R + m'_{8/3} \overline{\begin{pmatrix} q'_{8/3} \\ q'_{5/3} \end{pmatrix}}_L \begin{pmatrix} q'_{8/3} \\ q'_{5/3} \end{pmatrix}_R + m_{8/3} \overline{\begin{pmatrix} q_{8/3} \\ q_{5/3} \\ t' \end{pmatrix}}_L \begin{pmatrix} q_{8/3} \\ q_{5/3} \\ t' \end{pmatrix}_R + \text{H.c.}
\end{aligned}
$$

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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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

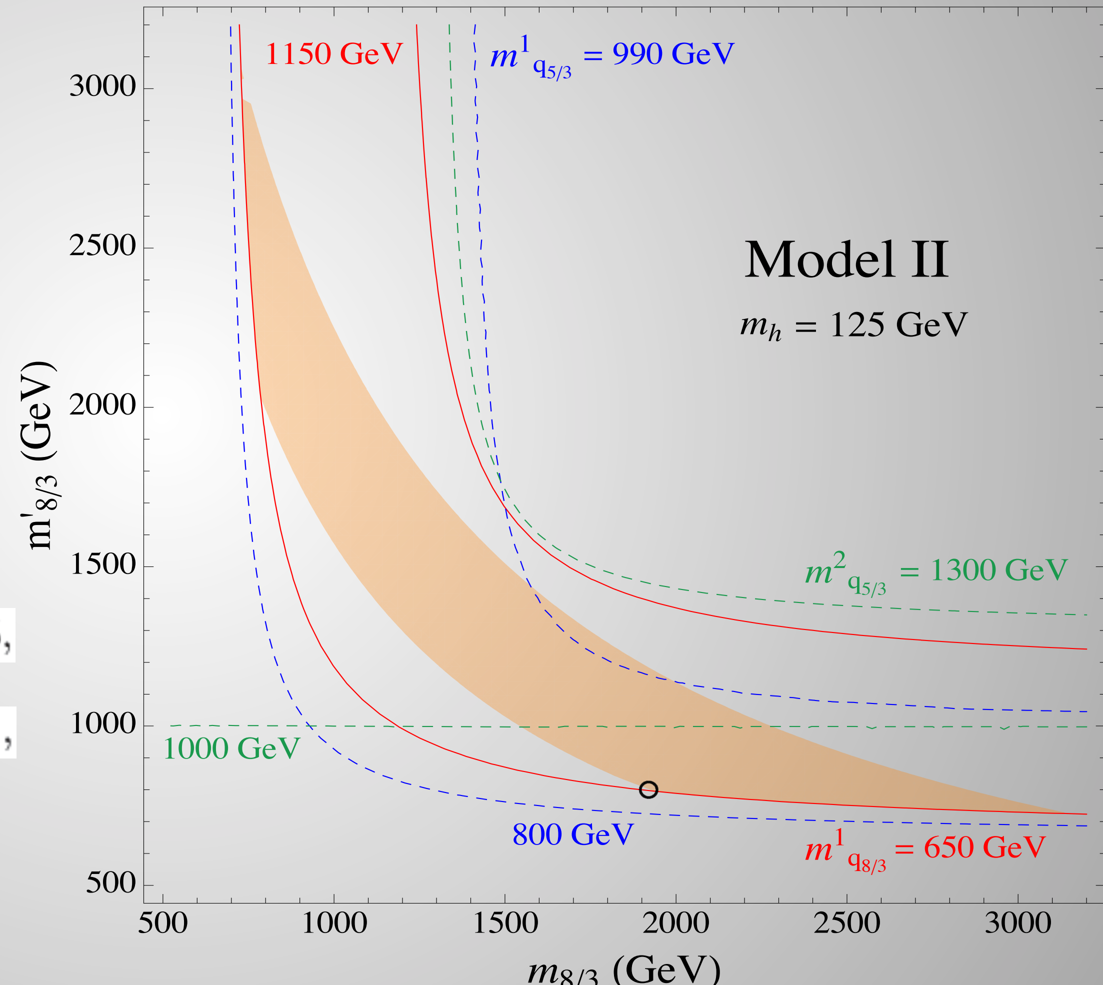
All the Higgs boson rates @ **1σ** in a large parameter space :

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

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

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

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



II) Numerical results for the Higgs fits

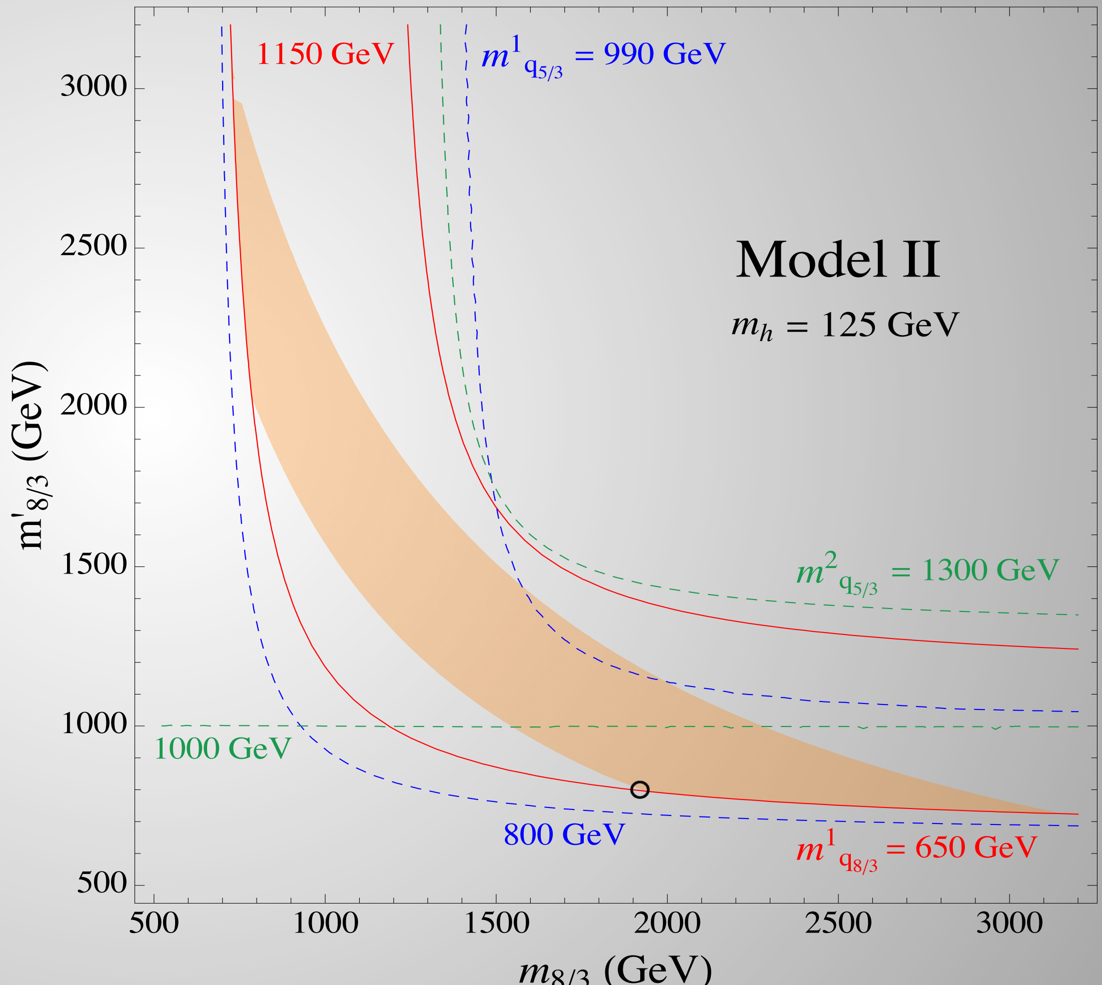
All the Higgs boson rates @ **1σ** in a large parameter space :

$m_{b_2} > 611$ GeV $\quad (B_{b_2 \to t_1 W} = 1)$

$m_{q^1_{5/3}} > 611$ GeV $\quad (B_{q^1_{5/3} \to t_1 W} \simeq 1)$

$m_{t_2} > 560$ GeV $\quad (B_{t_2 \to b_1 W} = 1)$

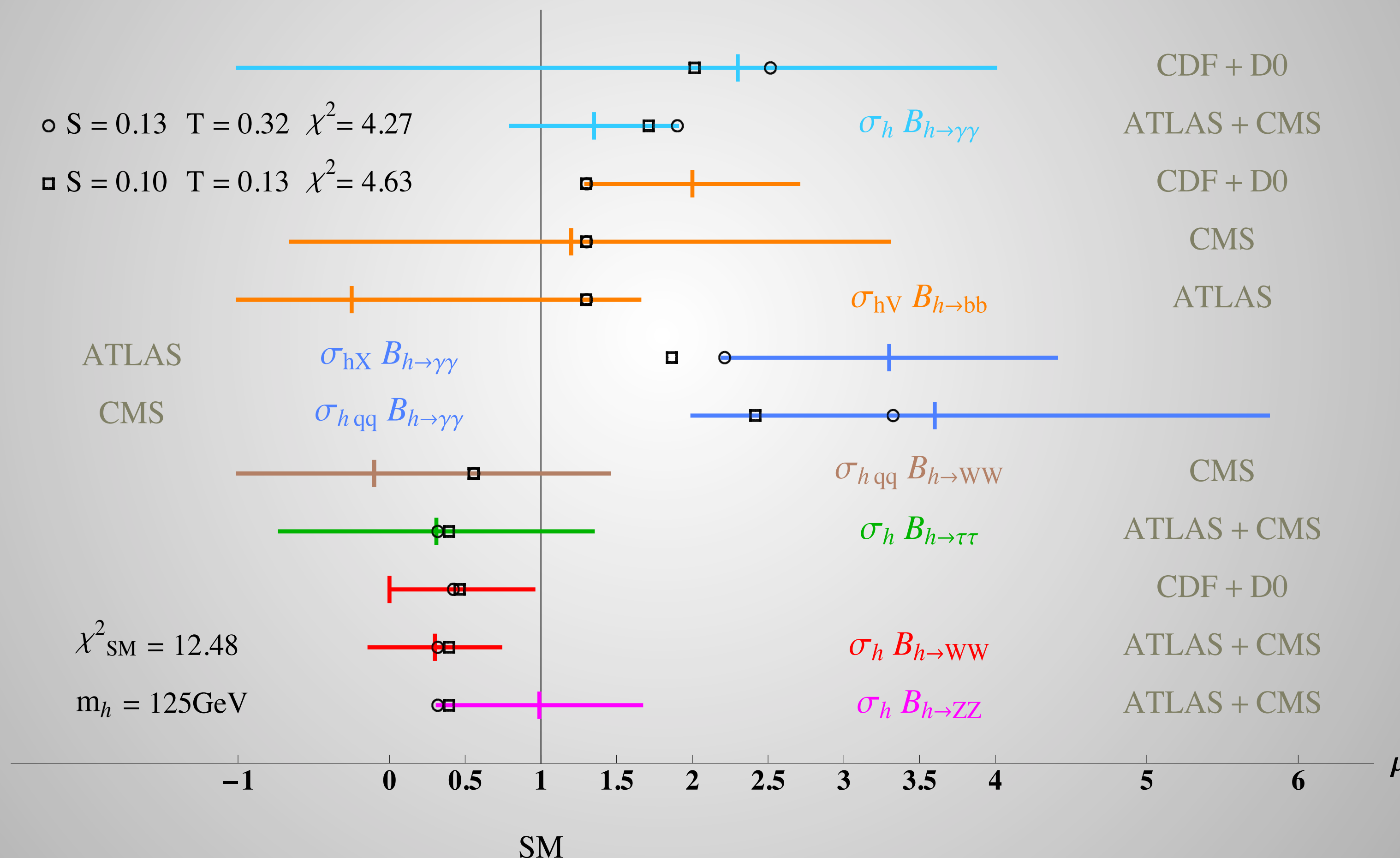
$m_{q^1_{-4/3}} > 560$ GeV $\quad (B_{q^1_{-4/3} \to b_1 W} \simeq 1)$



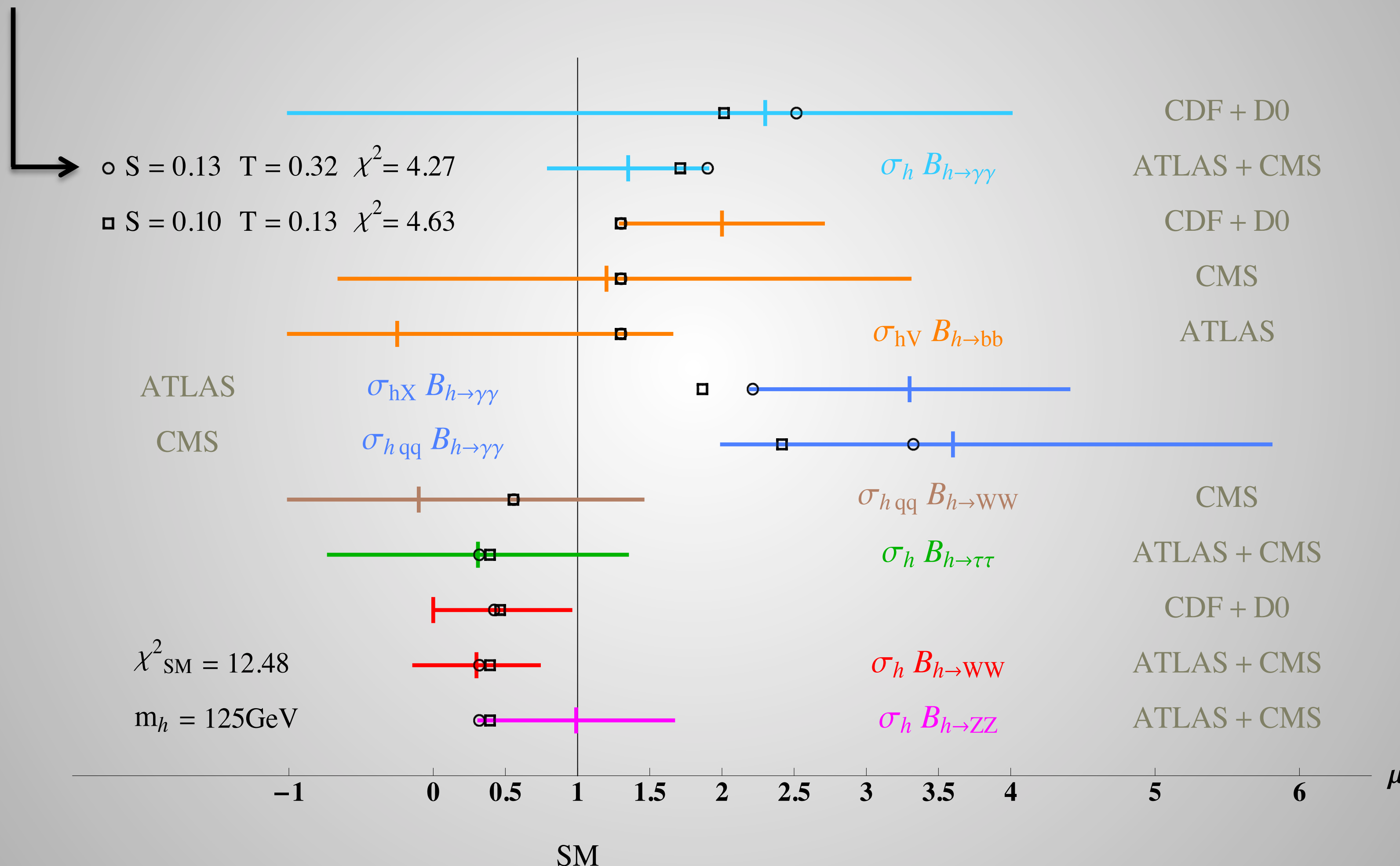
$m_{b_2} \approx 840$ GeV

$m_{q^1_{-4/3}} \approx 900$ GeV

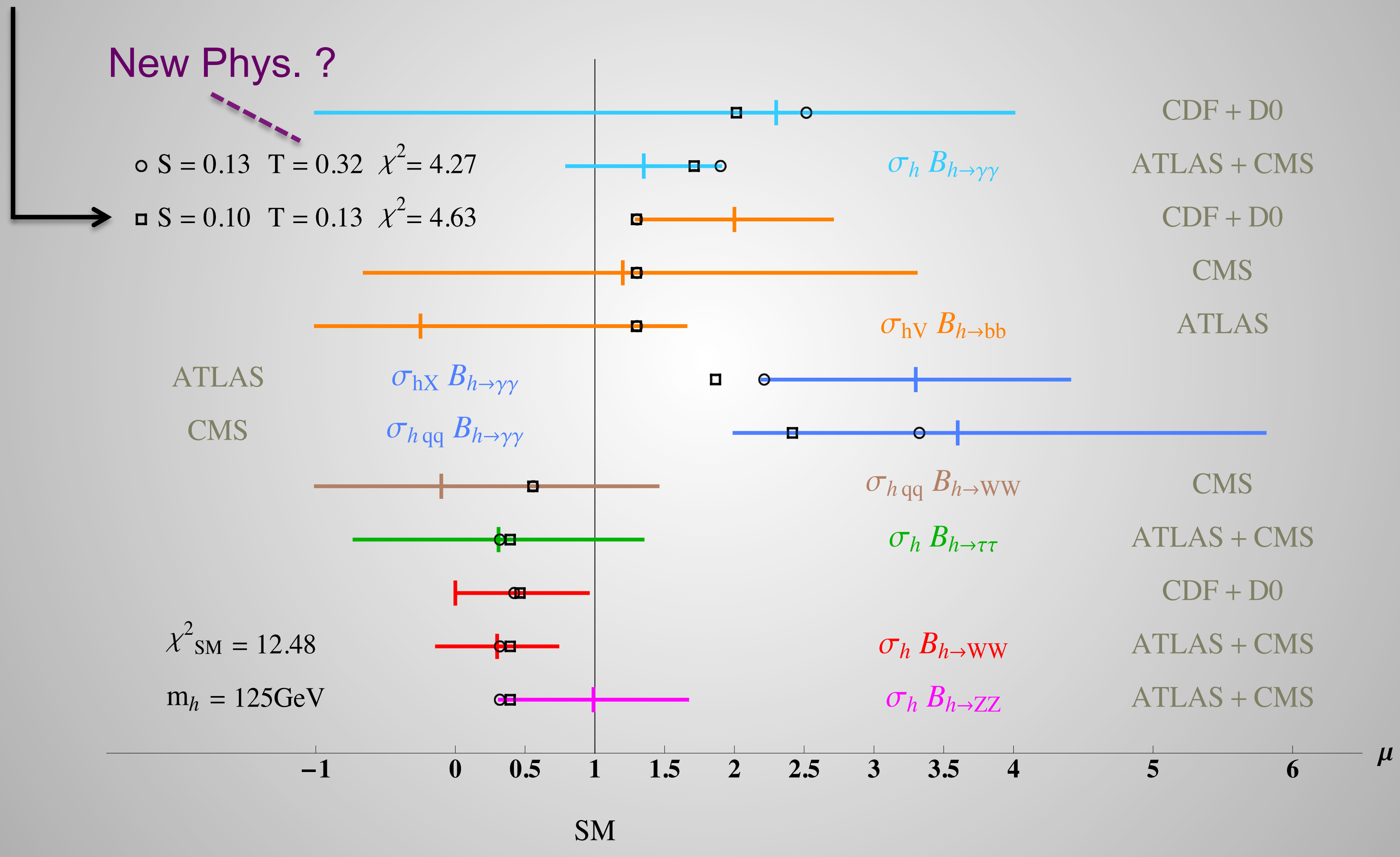
$m_{t_2} \approx 900 - 1010$ GeV


CDF + D0
○ S = 0.13 T = 0.32 χ² = 4.27
□ S = 0.10 T = 0.13 χ² = 4.63
σh Bh→γγ
ATLAS + CMS
CDF + D0
CMS
σhV Bh→bb
ATLAS
ATLAS
σhX Bh→γγ
CMS
σh qq Bh→γγ
σh qq Bh→WW
CMS
σh Bh→ττ
ATLAS + CMS
CDF + D0
χ²SM = 12.48
σh Bh→WW
ATLAS + CMS
mh = 125GeV
σh Bh→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 $\rightarrow\gamma\gamma$) 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)

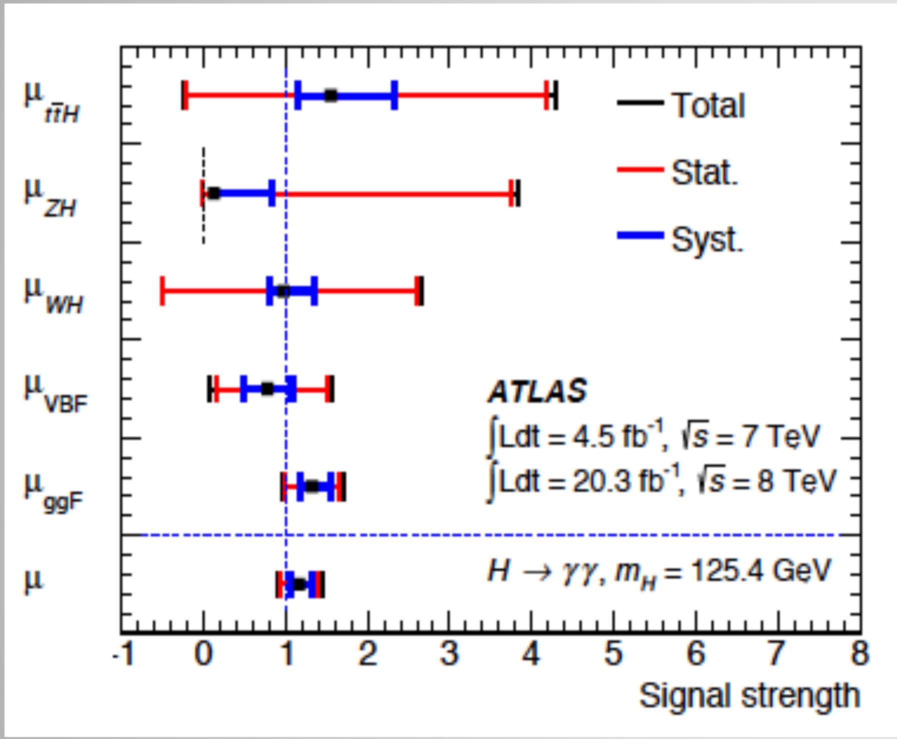
We've presented the list of minimal field contents of VL quarks allowing to :

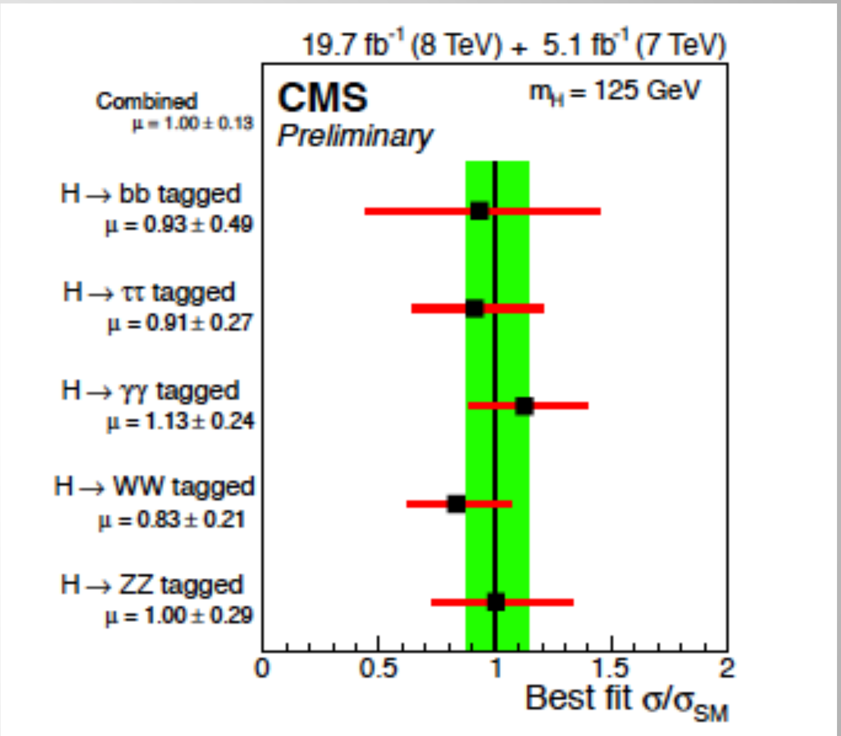
- induce a **large enhancement** of the Higgs diphoton channels
- with an acceptably small tension (between EWPT and the Higgs fit).

↓

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)

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