Dynamical origin of the electroweak scale and a 125 GeV scalar

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Outline

1. A brief introduction: strong dynamics and a light scalar

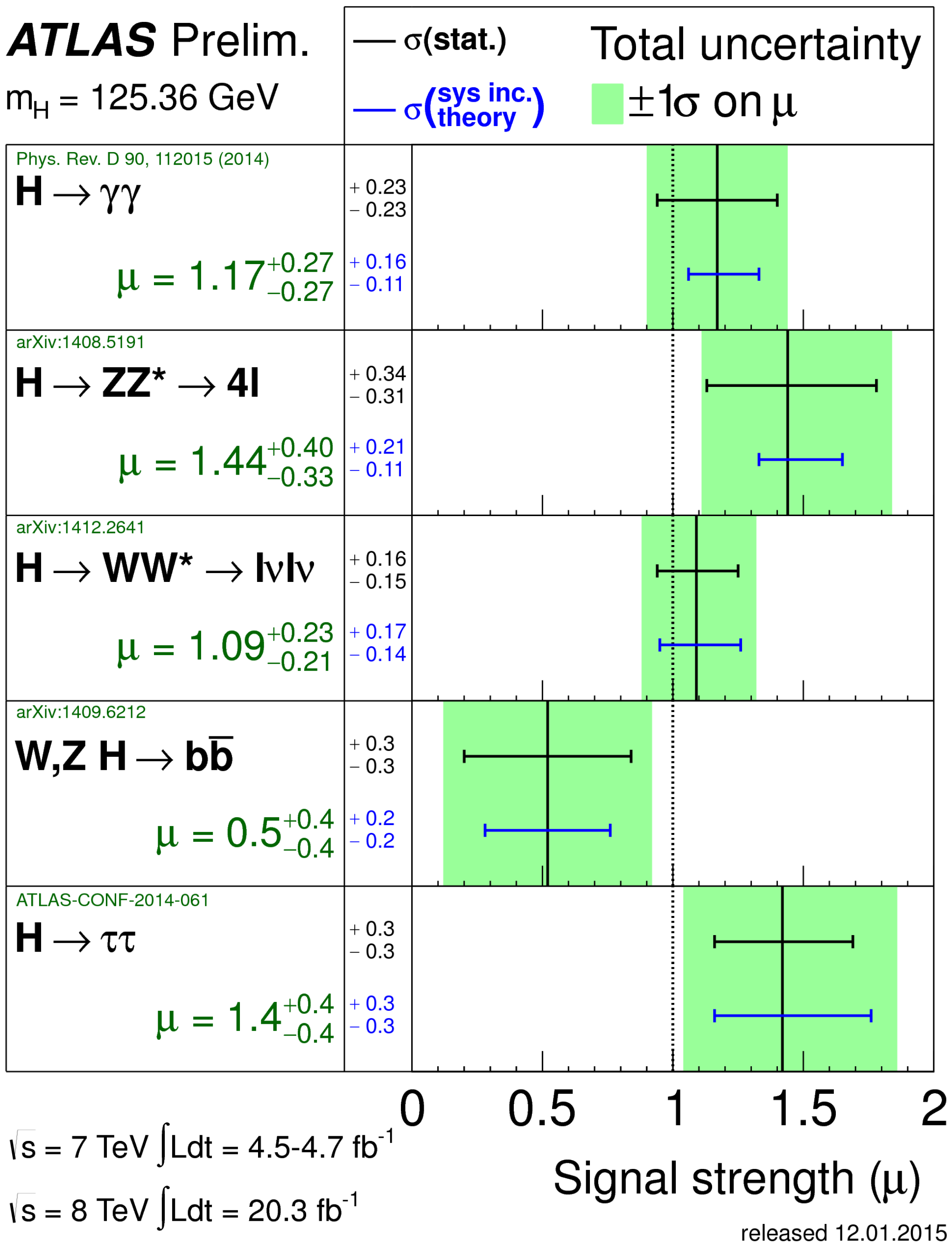
2. A concrete model: masses, couplings and S & T

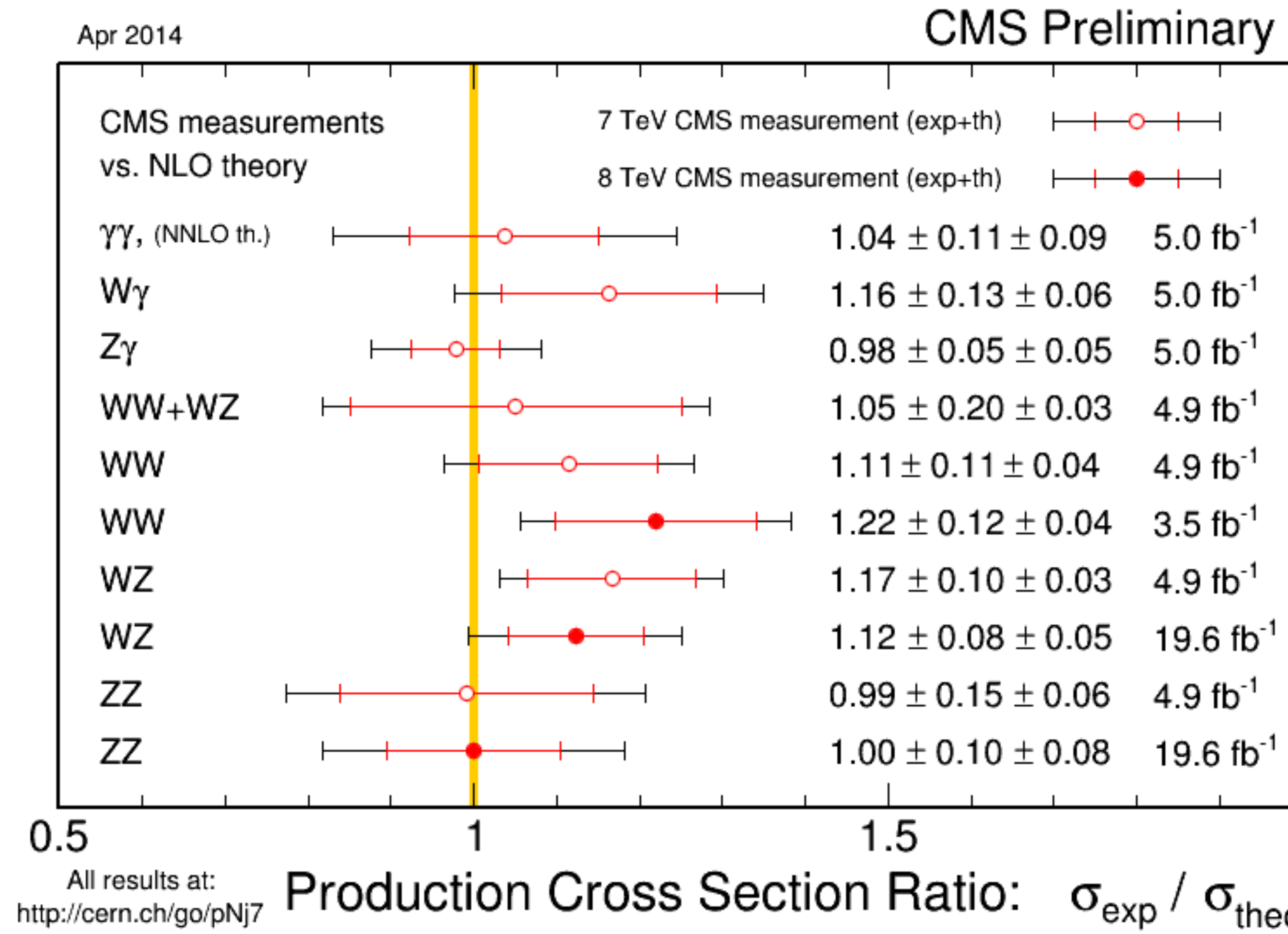
3. Numerical results, conclusions and outlook

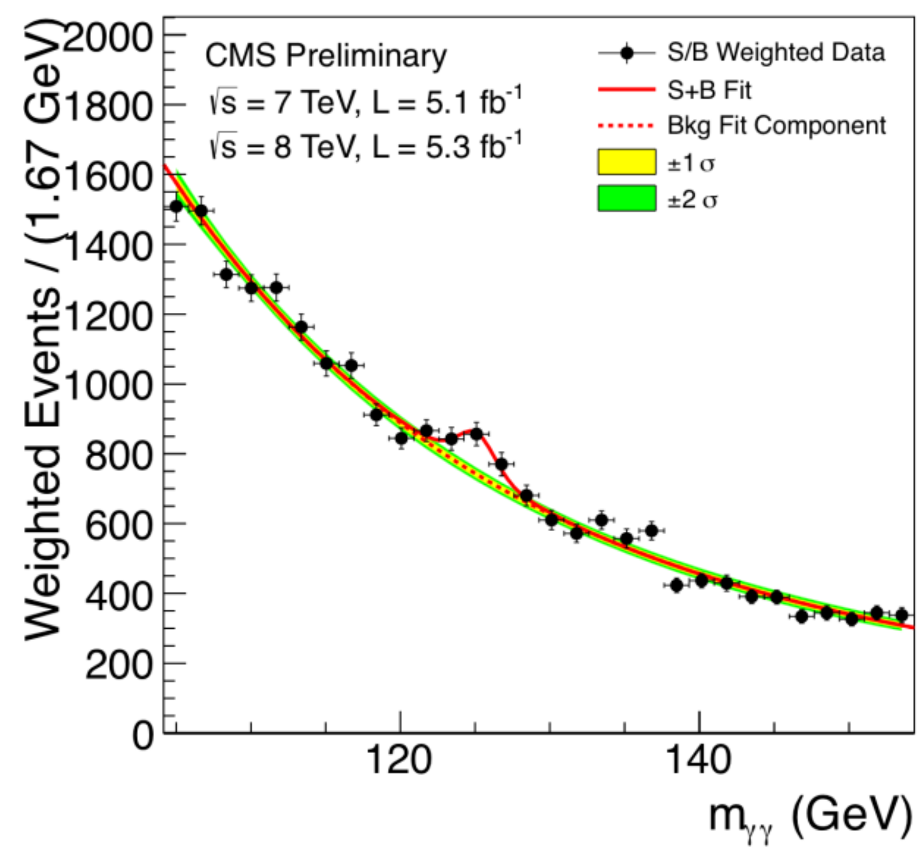
Di Chiara, Foadi, Tuominen 1405.7154
Di Chiara, Foadi, Tuominen, Tähtinen 1412.7835

1. A brief introduction:
   strong dynamics and a light scalar

SM-like Higgs has been discovered







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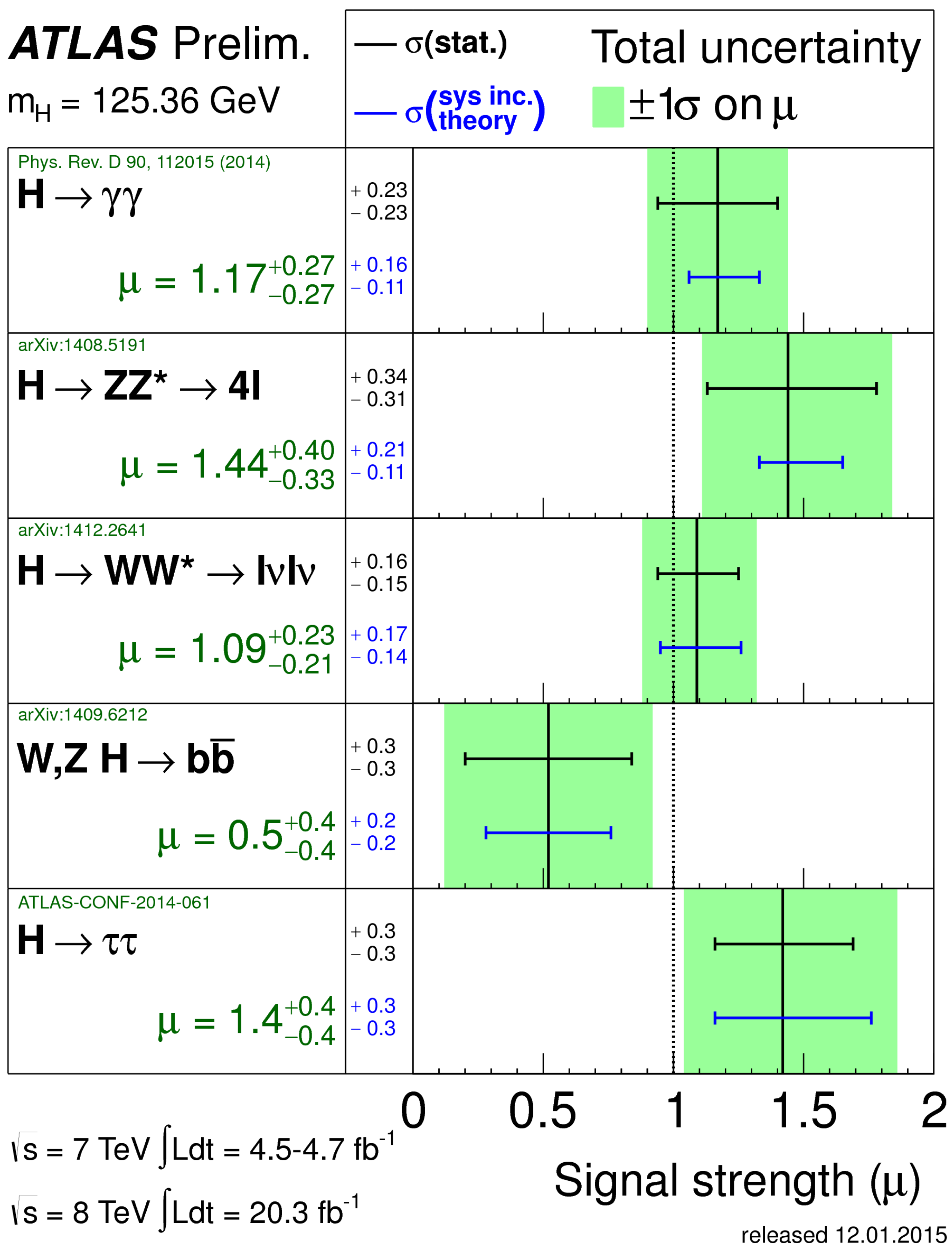
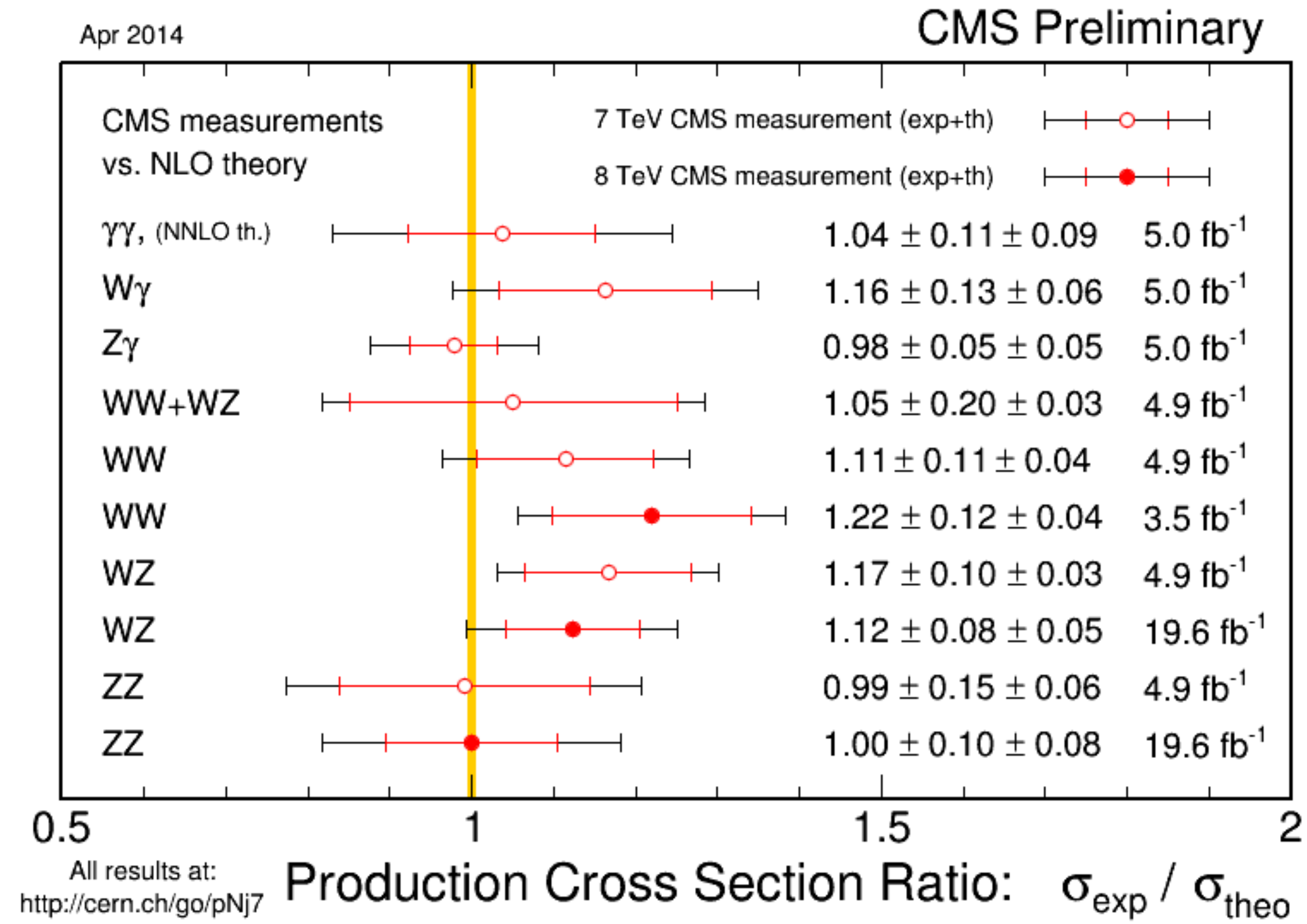
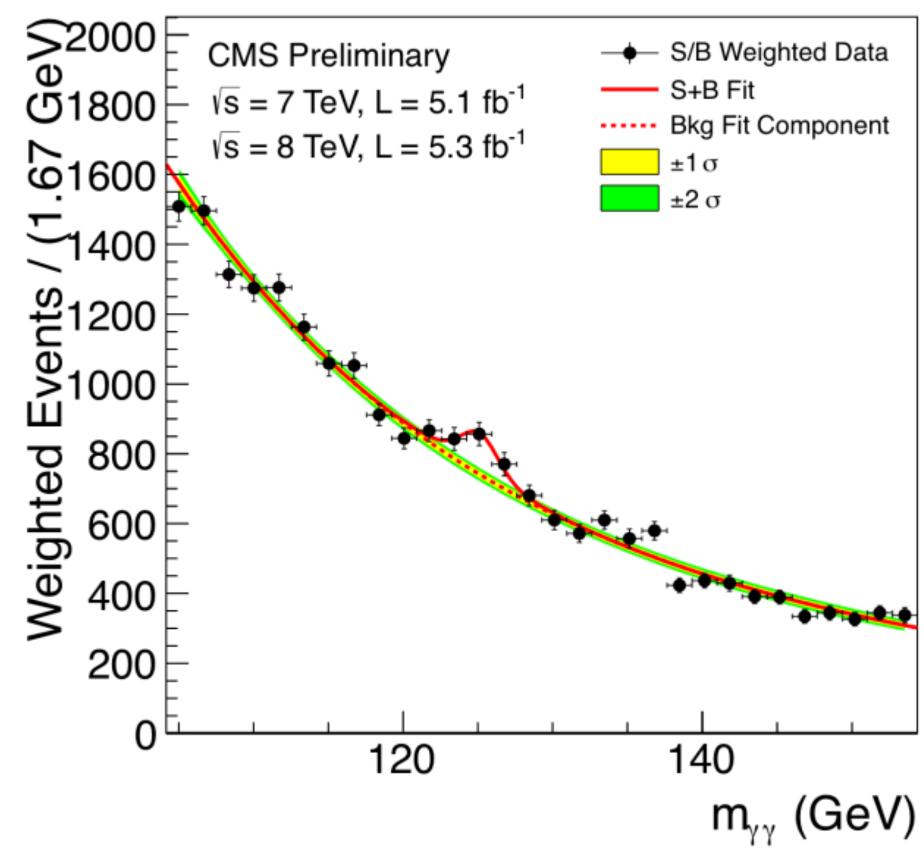




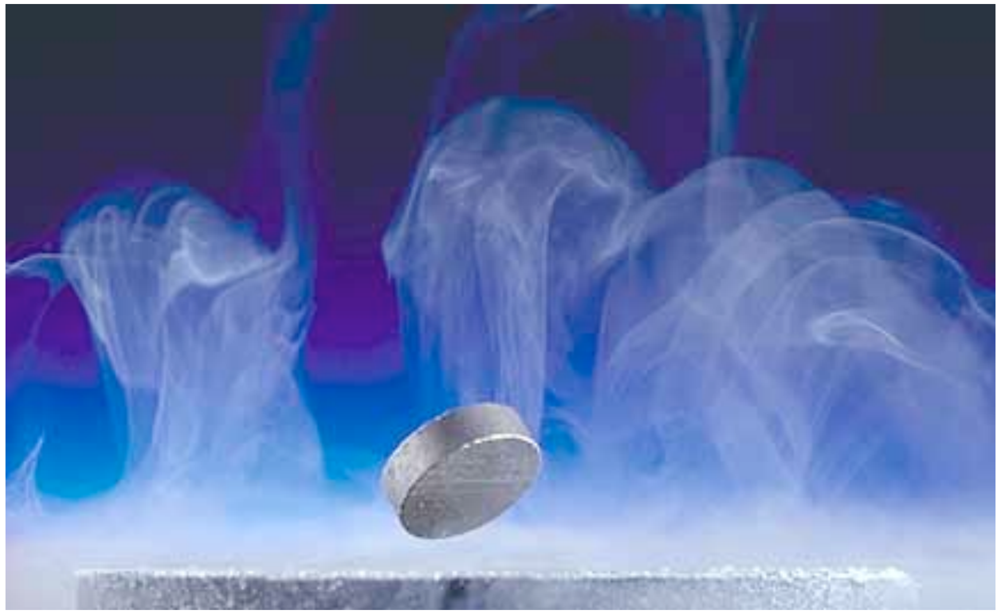


An **avatar** of new physics

(An incarnation, embodiment, or manifestation of a person or idea)

Paradigm: dynamical EWSB

Vintage compositeness:
replicate 2-flavor QCD



Weinberg '79,
Susskind '79

Higgs mechanism as usual from
SSB+gauge symm.

$\langle \bar{Q}_L Q_R \rangle = \Lambda_{\mathrm{TC}}^3, \quad \Lambda_{\mathrm{TC}} \simeq 1 \text{ TeV}$

The Higgs is composite,

$$\pi^{\pm}, \pi^0 \to W_L^{\pm}, Z_L \qquad M_W = \frac{g F_\Pi}{2} \qquad F_\Pi = 246 \, \mathrm{GeV}$$

Pagels-Stokar: $$F_\Pi^2 \simeq 4 N M^2 \ln\left(\frac{\Lambda_{\mathrm{TC}}^2}{M^2}\right)$$

Setting $F_\Pi = 246 \, \mathrm{GeV}$ and $\Lambda_{\mathrm{TC}} \simeq 2 \ldots 10 \, \mathrm{TeV}$, this implies that the dynamical mass is constrained: $M \simeq 0.5 \ldots 1 \, \mathrm{TeV}$

So how to get a 125 GeV scalar?

A light scalar from strong dynamics:

pNGB from chiral symmetry

-Kaplan, Georgi (1984)
-Cacciapaglia, Sannino (2014)

scale invariance

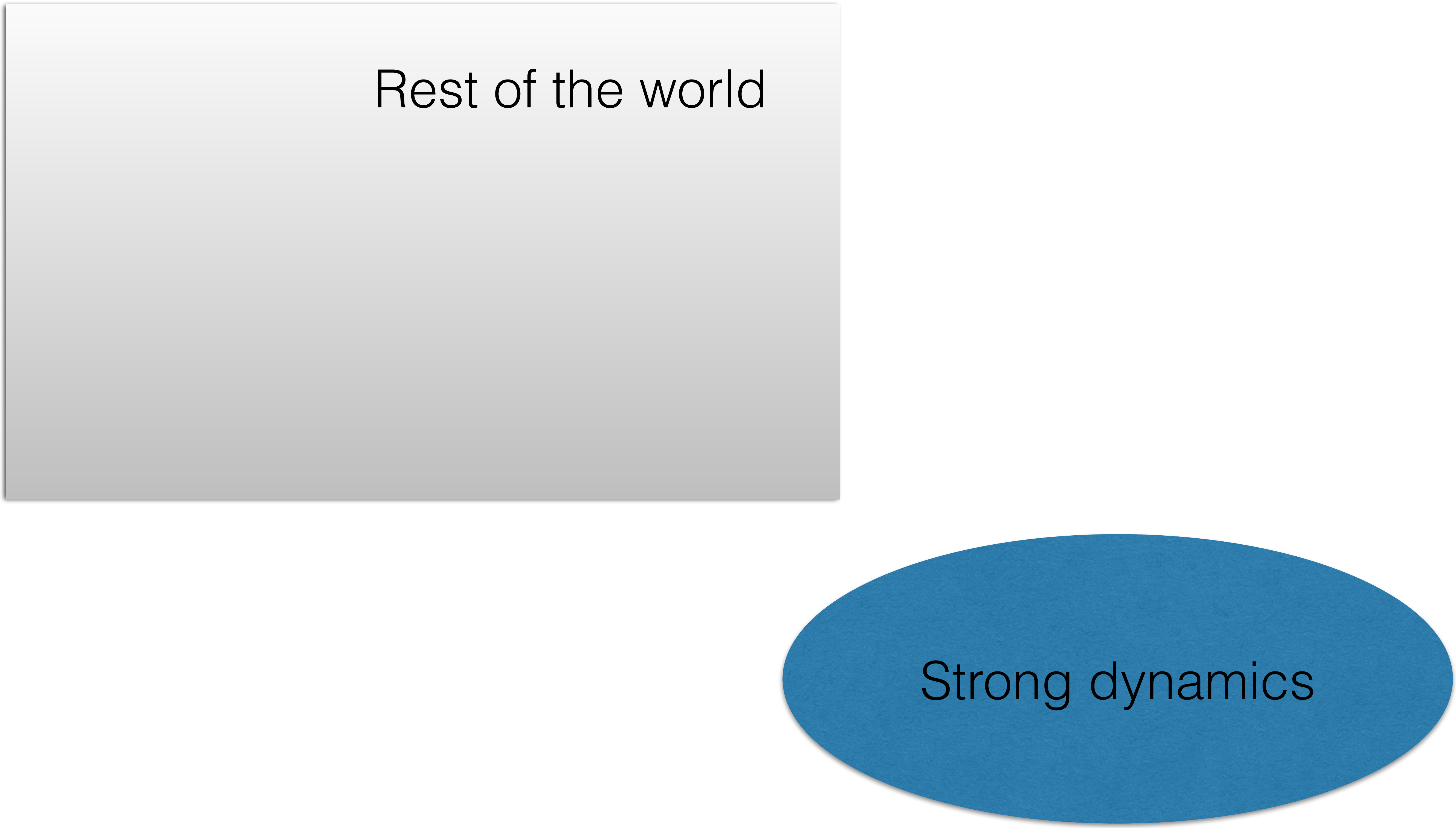
-Yamawaki, Bando, Matumoto (1986)
-Dietrich, Sannino, Tuominen (2005)
-Matsuzaki, Yamawaki (2012)
-Zacko, Misra (2013)

Parametrically light scalar
(near conformal, finely tuned)

Further phenomenological tensions, S-parameter, FCNC, etc. also resolved with walking dynamics.

A recent new development:

Coupling with SM changes properties of strong dynamics from those observed in isolation.



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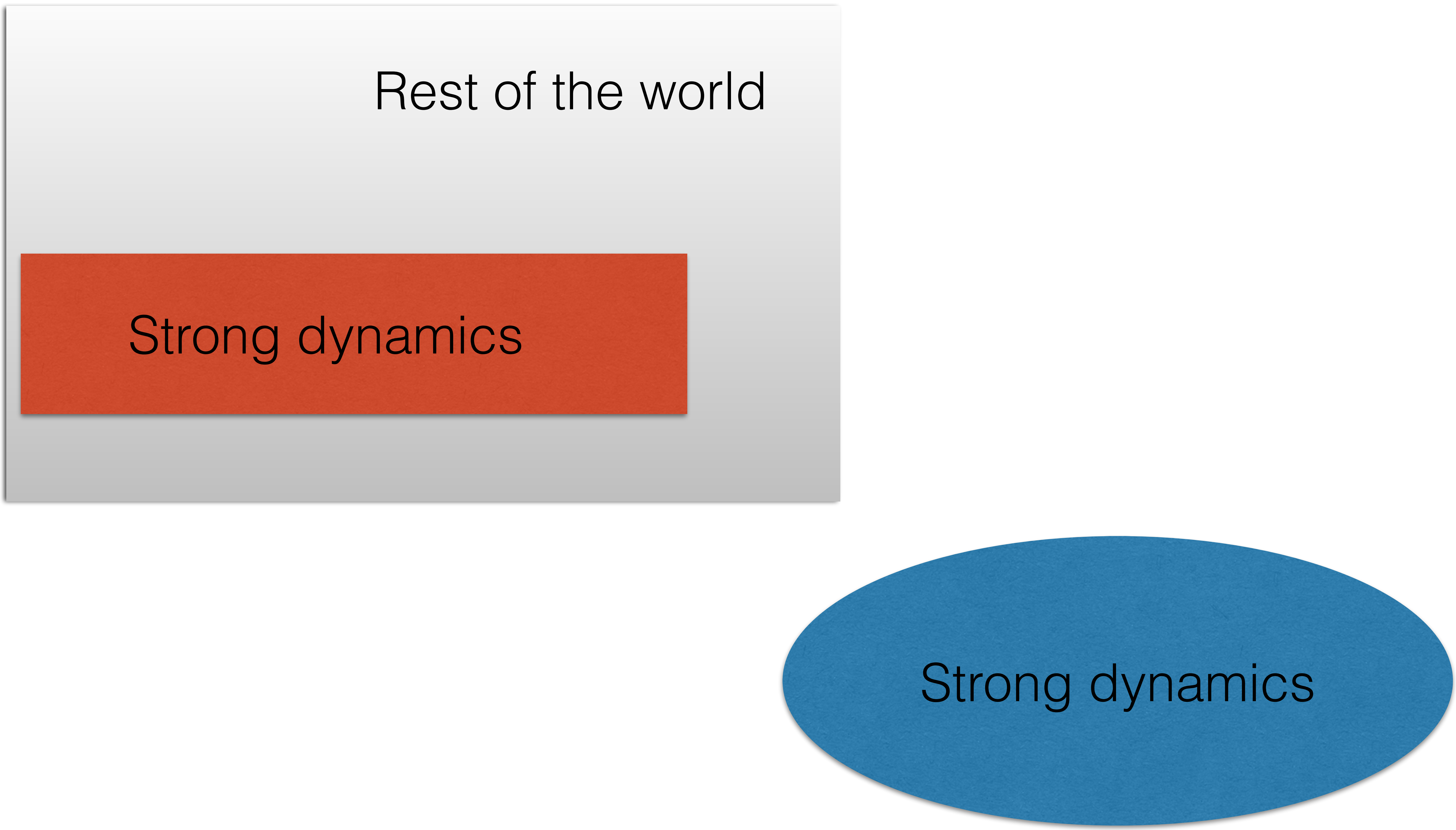
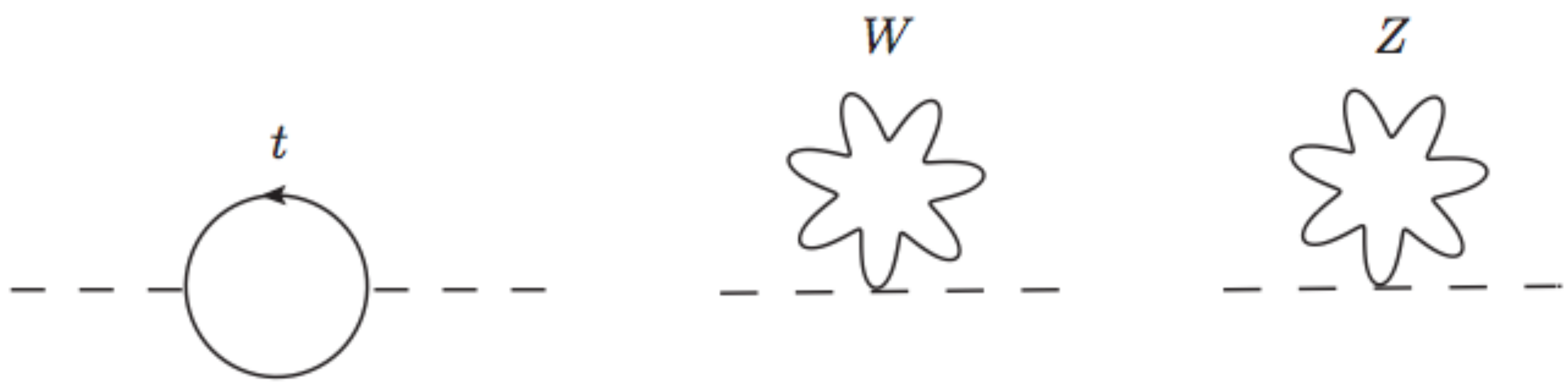


Coupling with SM changes properties of strong dynamics from those observed in isolation.

Example: EM mass splitting of $\pi^{\pm}, \pi_0$

In SM couplings are not small, e.g. top Yukawa
(Foadi, Frandsen, Sannino, 2012)



We will now consider this in a setting where all masses are generated dynamically

(Also important: changes the location of conformal window, Fukano, Sannino (2010))

We will consider:

- New strong dynamics (TC & ETC),
- Two TC fermions in N dim. representation (QCD singlet),
- Only 3rd generation SM quarks,

The main results:

- ETC interactions lead to a 125 GeV scalar,
- The scalar has SM-like couplings to W,Z and fermions,
- Oblique corrections OK,

A toy model (Di Chiara, Foadi, Tuominen (2014))

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \mathcal{L}_{\rm TC} + \mathcal{L}_{\rm ETC}$$

Very simple extended dynamics to generate top mass:

$\mathcal{M} = M_{\rm ETC}$

$$\mathcal{L}_{\rm ETC} = 2G\left(\bar{q}_L t_R \overline{U}_R Q_L + \text{h.c.}\right) \qquad G \sim \frac{1}{M_{\rm ETC}^2}$$

$$\Sigma = \exp(i\Pi^a \tau^a / v)$$

$\Lambda_{\rm TC} \simeq 4\pi F_\Pi$

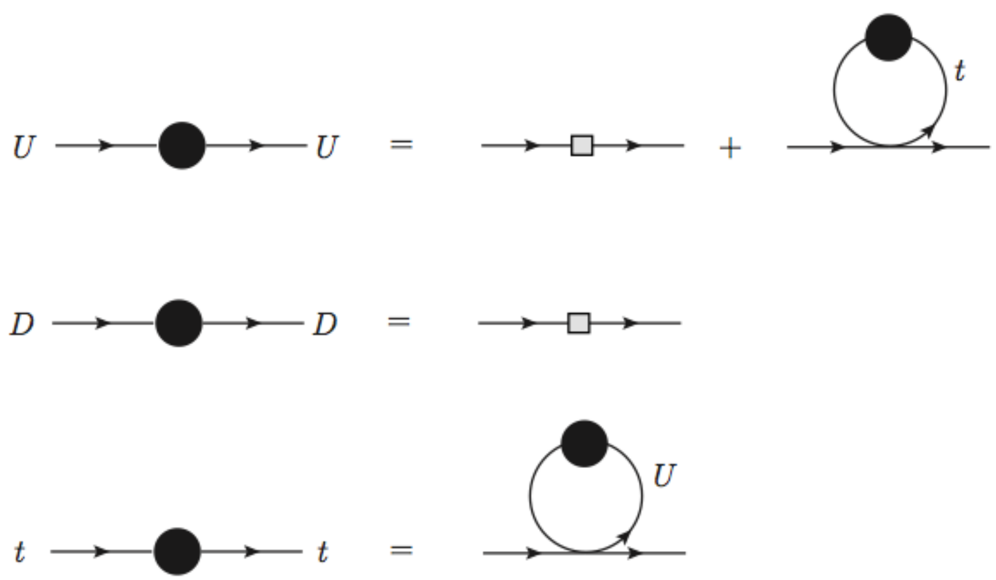
$$\mathcal{L}_{\rm TC} = \overline{Q}_L\ i\not{D} Q_L + \overline{U}_R\ i\not{D} U_R + \overline{D}_R\ i\not{D} D_R$$
$$-M\left(1 + \frac{y}{v}H + \cdots\right)\left(\overline{Q}_L \Sigma Q_R + \overline{Q}_R \Sigma^\dagger Q_L\right) - \frac{m^2}{2}H^2 + \cdots$$

U,D in N dimensional rep. of a new gauge group.

$F_\Pi \simeq 246\,\text{GeV}$

Question: what is the mass of the composite scalar H ?

The masses determined by the gap eqs:



$$M_U = M + \frac{N_c G M_t}{4\pi^2}\left(M_{\mathrm{ETC}}^2 - M_t^2 \ln \frac{M_{\mathrm{ETC}}^2 + M_t^2}{M_t^2}\right)$$

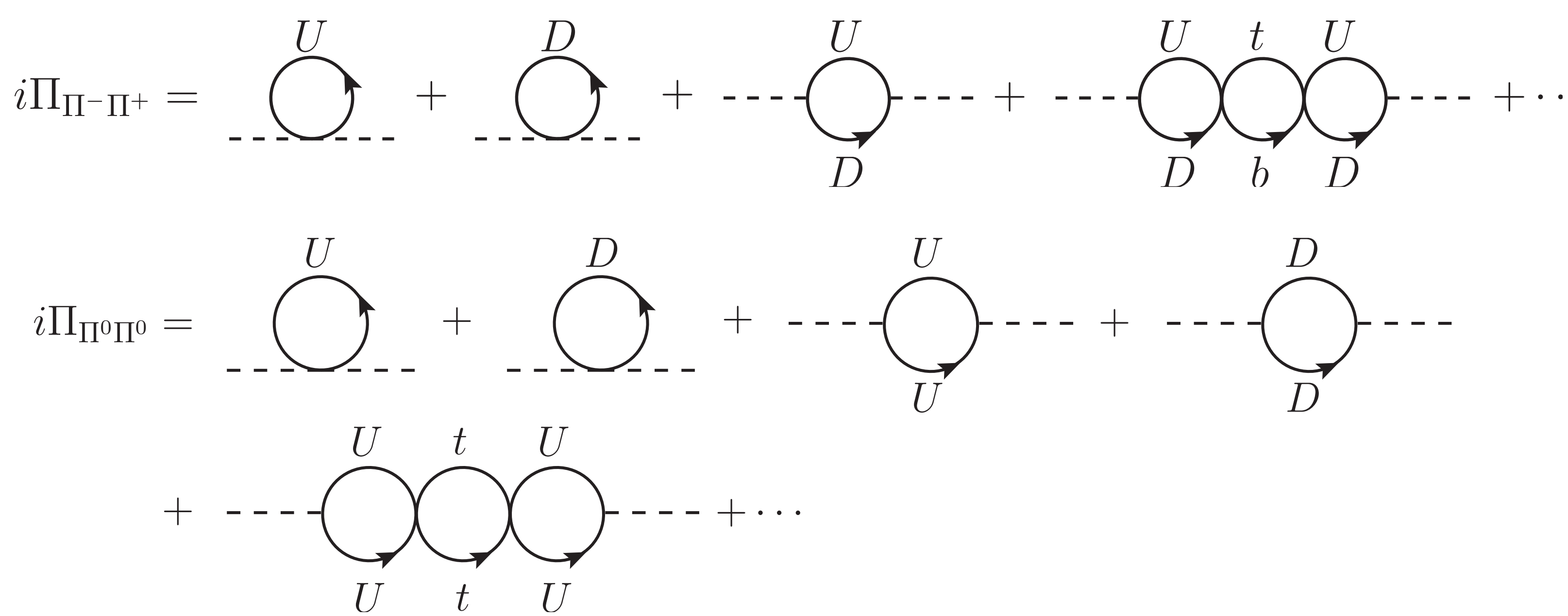
$$M_D = M$$

$$M_t = \frac{N G M_U}{4\pi^2}\left(\Lambda_{\mathrm{TC}}^2 - M_U^2 \ln \frac{\Lambda_{\mathrm{TC}}^2 + M_U^2}{M_U^2}\right)$$

Work to leading order in N and N_c assuming both large and N/N_c finite.

(e.g. Bardeen, Hill & Lindner (1990))

Consistency checks:

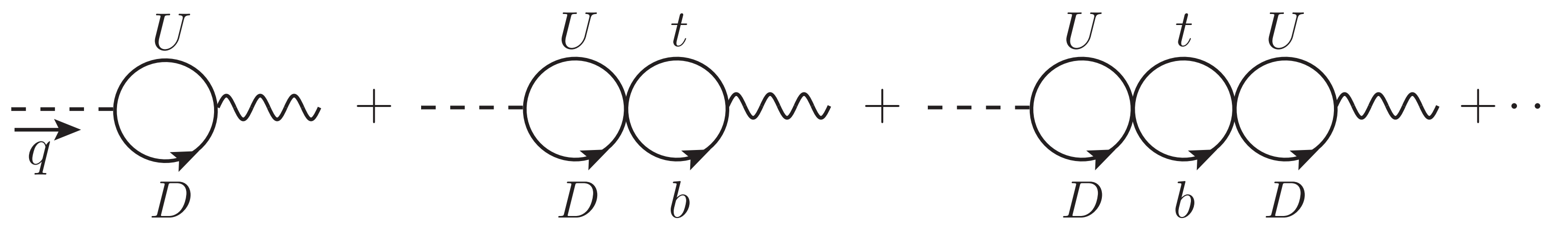


Using the gap equations, one proves $M_{\Pi^0} = M_{\Pi^\pm} = 0$

Also: transversality of W and Z vacuum polarisations can be shown.

Match with EW:

$iq_\mu \mu_{\Pi\mathcal{A}} =$



$$F_\Pi = \lim_{q^2 \to 0} \frac{\mu_{\Pi\mathcal{A}}(q^2)}{\sqrt{\Sigma'_{\Pi^-\Pi^+}(q^2)}}$$

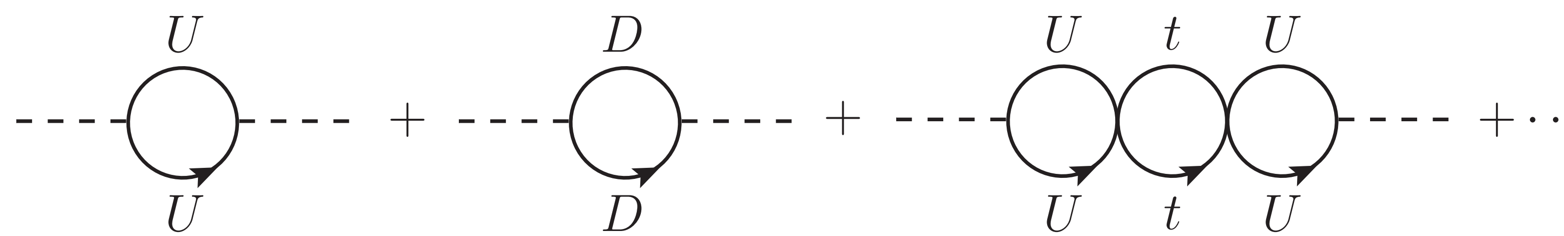
In the limit $G \to 0$ this is just Pagels-Stokar: $F_\Pi^2 \simeq 4NM^2 \ln\left(\frac{\Lambda_{\mathrm{TC}}^2}{M^2}\right)$

Using known values of M_t and F_Π , everything expressed in terms of Λ_{TC} and M_{ETC}

Expect e.g. $\Lambda_{\mathrm{TC}} \simeq 3\,\mathrm{TeV}$ $\qquad M_{\mathrm{ETC}} \simeq 5\,\mathrm{TeV}$

The scalar mass: $\Sigma_{HH}(q^2) = q^2 - m^2 - \Pi_{HH}(q^2)$

$i\Pi_{HH} =$



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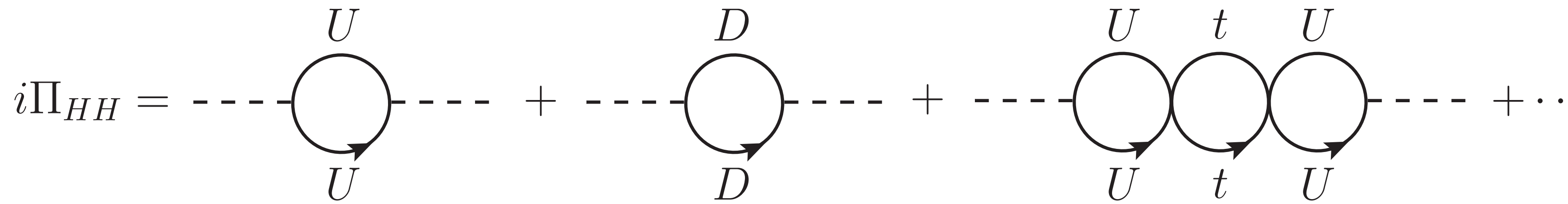

First, set $G = 0$ and trade m with the dynamical mass M_{H0} via

$$\Sigma_{HH}(q^2 = M_{H0}^2) = 0$$

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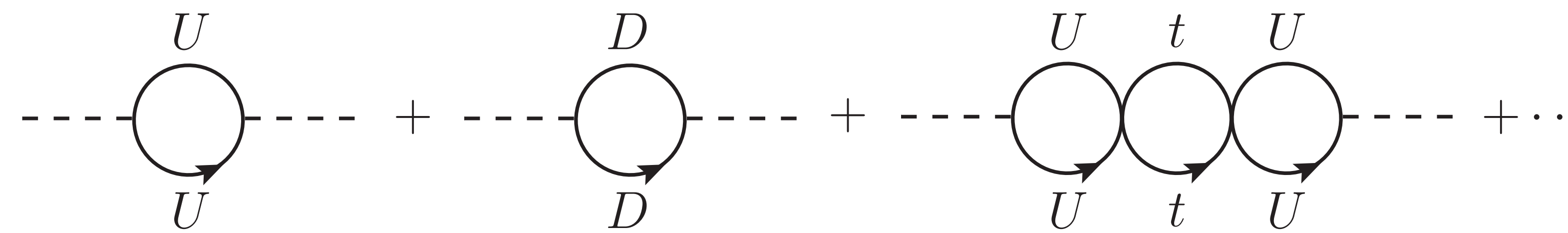

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Then, at $G \neq 0$ solve for M_{H0} by setting

$$\Sigma_{HH}(q^2 = M_H^2) = 0 \quad @ \quad M_H^2 = (125)^2\,\mathrm{GeV}^2$$

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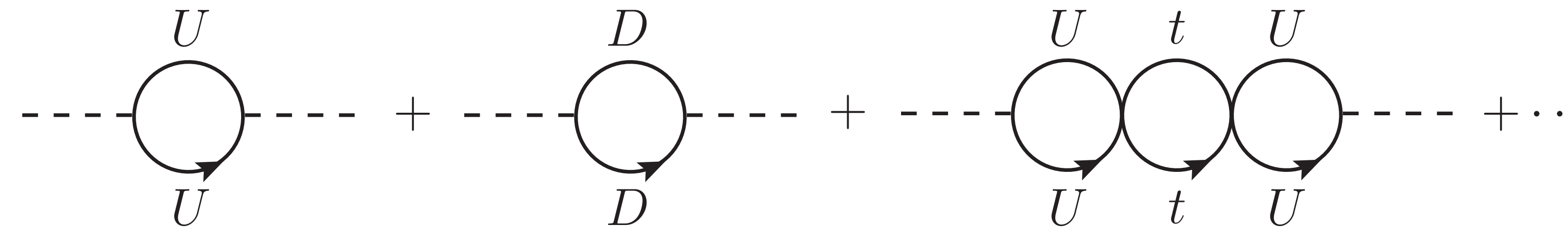

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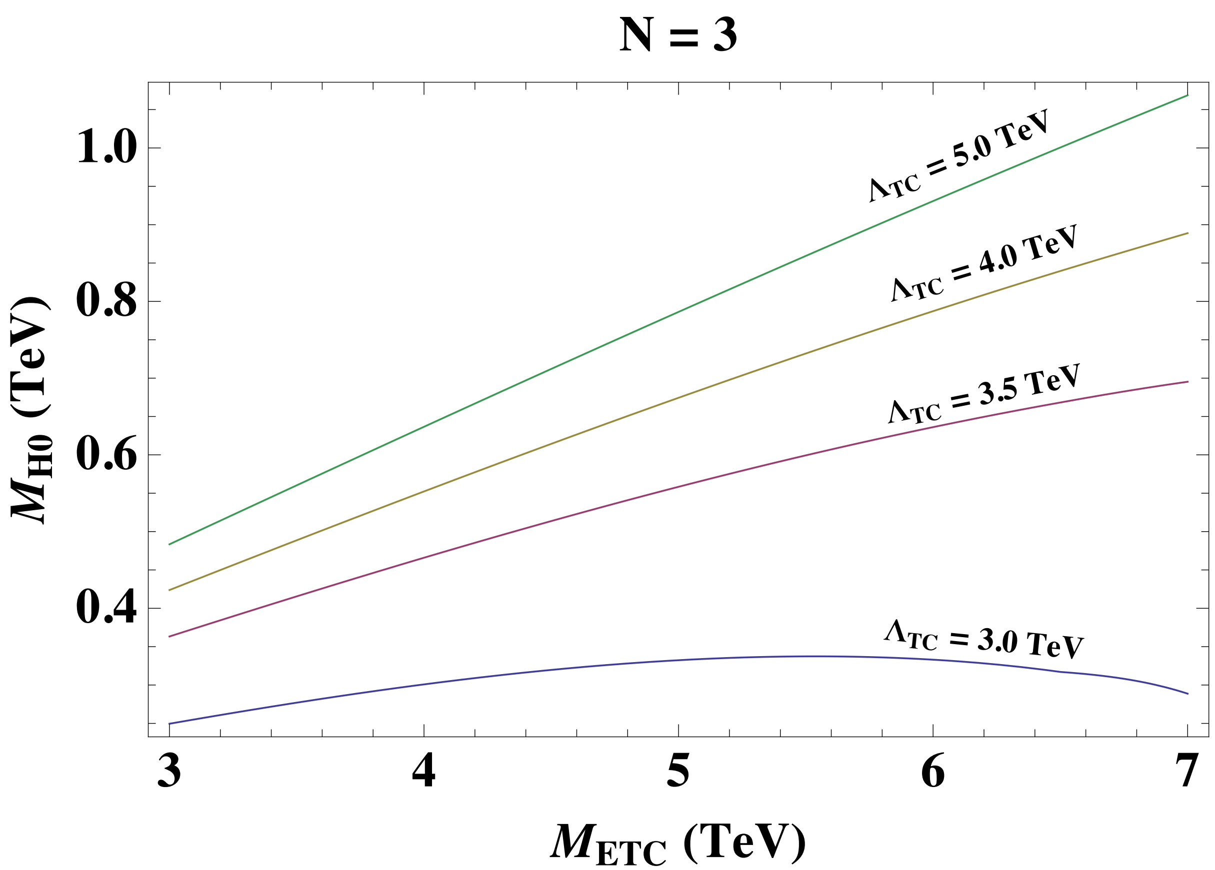
In the limit $M_{H0} \ll \Lambda_{\mathrm{TC}} \ll M_{\mathrm{ETC}}$ the dynamical mass is given by

$$M_{H0}^2 \simeq \frac{1}{\ln(\Lambda_{\mathrm{TC}}^2/M^2)} \frac{\frac{N_c}{N}\frac{M_t^2}{M_U^2}}{1 - \frac{N_c}{N}\frac{M_t^2}{M_U^2}\frac{M_{\mathrm{ETC}}^2}{\Lambda_{\mathrm{TC}}}} M_{\mathrm{ETC}}^2$$

So M_{H0} can be large even if the physical Higgs is light.

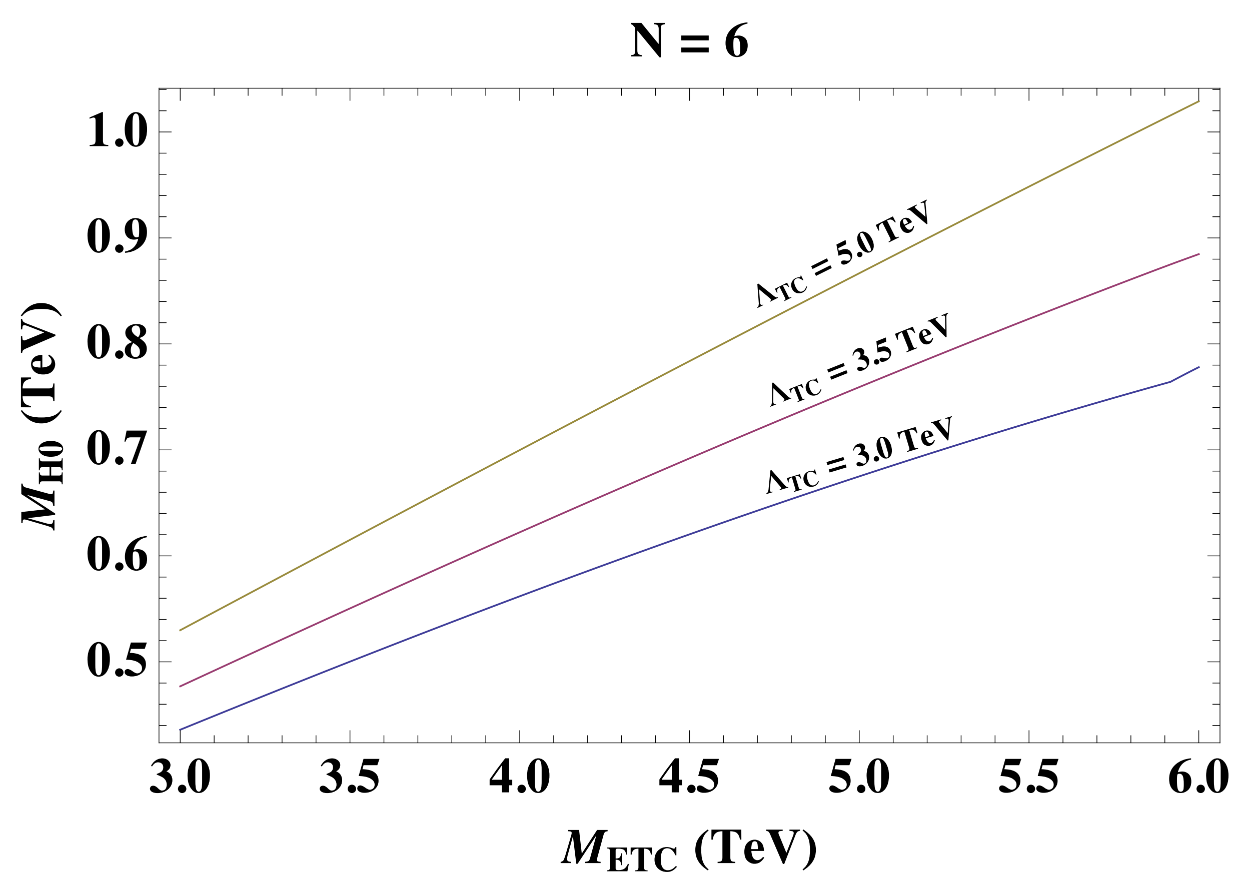
Numerical evaluation:

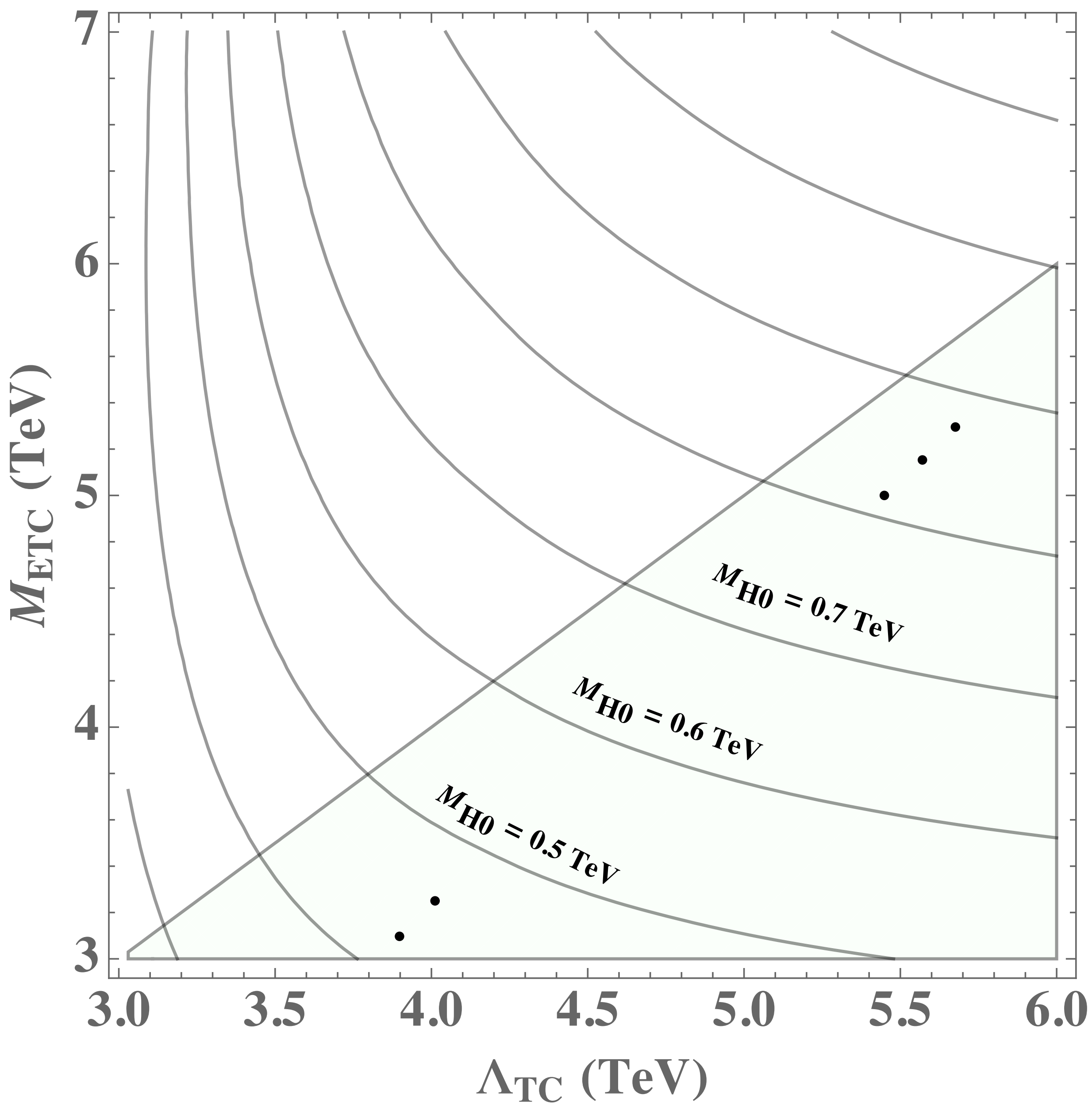


e.g. SU(3) gauge theory and U, D fermions in 3-dim. rep. (Scaled-up QCD)

SU(3) gauge theory and U, D fermions in 6-dim. rep.

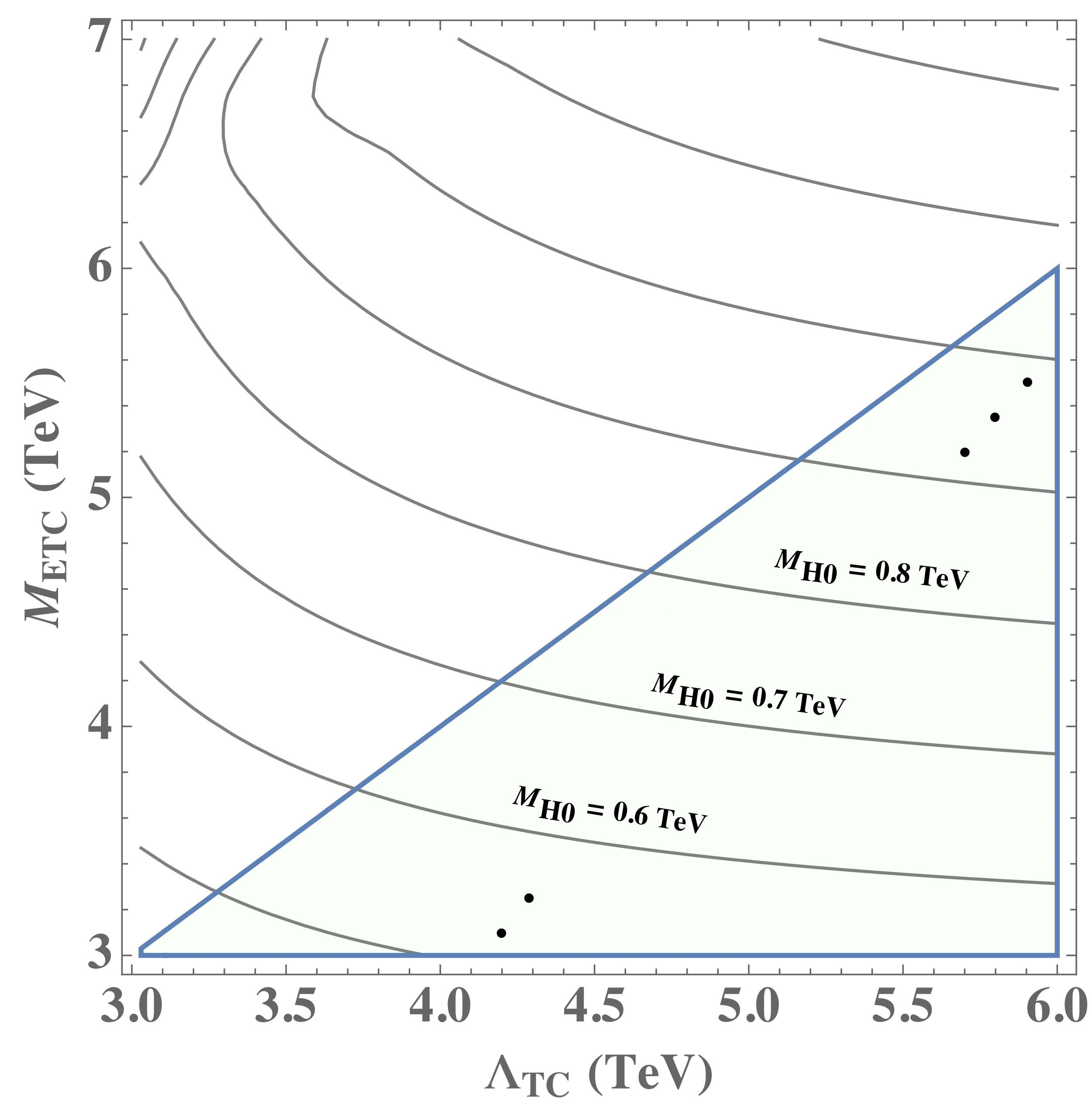
e.g. SU(3)MWT
(see Kuti's talk)





Inside the shaded region

$$M_{\mathrm{ETC}} < \Lambda_{\mathrm{TC}}$$



Can lattice tell which contour are we on?

$$\mathcal{L}_{\mathrm{ETC}} = 2G\left(\bar{q}_L t_R \overline{U}_R Q_L + \mathrm{h.c.}\right)$$

is a simple toy model; leads to large splitting between U and D.

—> large T-parameter.

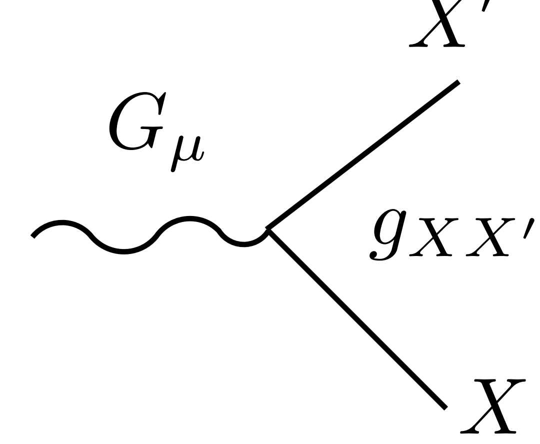
Need to consider more general patterns of ETC couplings:

2. A more realistic model: masses, couplings and S & T

Di Chiara, Foadi, Tuominen & Tähtinen 1412.7835

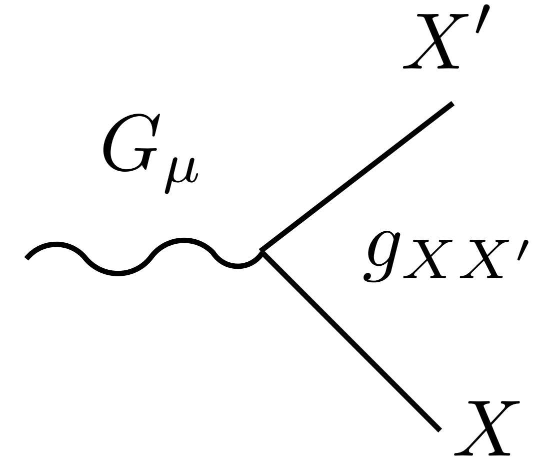
Richer ETC sector

G_μ : (1,1) or (N,N$_c$) -multiplet under (TC,QCD)



Richer ETC sector

G_μ : (1,1) or (N,N$_c$) -multiplet under (TC,QCD)



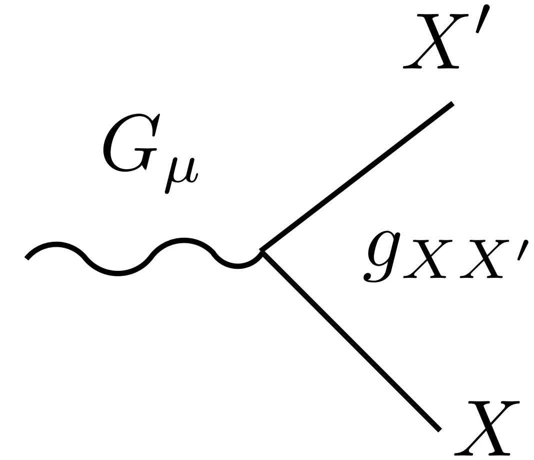
$$\mathcal{L}_{\mathrm{ETC}} \sim -g_{XX'}\overline{X}\gamma_\mu X' G^\mu + \mathcal{M}_G^2 G_\mu G^{\mu *}$$

$$G_\mu \sim -\frac{g_{XX'}}{\mathcal{M}_G^2}\overline{X}\gamma_\mu X'$$

$$\mathcal{L}_{\mathrm{ETC}} \sim -\frac{|g_{XX'}|^2}{\mathcal{M}_G^2}|\overline{X}\gamma_\mu X'|^2$$

Richer ETC sector

G_μ : (1,1) or (N,N$_c$) -multiplet under (TC,QCD)



$$\mathcal{L}_{\rm ETC} \sim -g_{XX'}\overline{X}\gamma_\mu X' G^\mu + \mathcal{M}_G^2 G_\mu G^{\mu *}$$

$$G_\mu \sim -\frac{g_{XX'}}{\mathcal{M}_G^2}\overline{X}\gamma_\mu X'$$

$$\mathcal{L}_{\rm ETC} \sim -\frac{|g_{XX'}|^2}{\mathcal{M}_G^2}|\overline{X}\gamma_\mu X'|^2$$

Assume $g^*_{XY} = g_{XY}$ and a single ETC scale $\mathcal{M}$.

We considered $(1,1)_{Y=0,1}$ and $(N,N_c)_{Y=1/6,5/6,7/6}$, and derived the resulting 4-fermion interactions.

$$\left(Y_{Q_L} = 0, \quad Y_{U_R} = \frac{1}{2}, \quad Y_{D_R} = -\frac{1}{2}\right)$$

$$\mathcal{L}_{\mathrm{ETC}} = 2G_{QqUt}\left[\left(\overline{Q}_L U_R\right)\left(\overline{t}_R q_L\right) + \left(\overline{q}_L t_R\right)\left(\overline{U}_R Q_L\right)\right] + 2G_{QqDb}\left[\left(\overline{Q}_L D_R\right)\left(\overline{b}_R q_L\right) + \left(\overline{q}_L b_R\right)\left(\overline{D}_R Q_L\right)\right]$$
$$+ 2G_{QQUU}\left(\overline{Q}_L U_R\right)\left(\overline{U}_R Q_L\right) + 2G_{QQDD}\left(\overline{Q}_L D_R\right)\left(\overline{D}_R Q_L\right) + 2G_{qqtt}\left(\overline{q}_L t_R\right)\left(\overline{t}_R q_L\right) + 2G_{qqbb}\left(\overline{q}_L b_R\right)\left(\overline{b}_R q_L\right)$$
$$+ \Delta\mathcal{L}_{\mathrm{ETC}}$$

$$G_{QqDb} \equiv \frac{g_{Qq}g_{Db}}{\mathcal{M}^2} \qquad G_{QqUt} \equiv \frac{g_{Qq}g_{Ut}}{\mathcal{M}^2} \qquad \text{etc...}$$

$$\Delta\mathcal{L}_{\mathrm{ETC}} \sim (\overline{X}\gamma_\mu X)^2$$

- Operators in $\Delta\mathcal{L}_{\mathrm{ETC}}$ do not contribute to masses at LO.
- They will contribute to S and T.
- 25 operators.

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + \mathcal{L}_{\mathrm{TC}} + \mathcal{L}_{\mathrm{ETC}}$$

$\mathcal{M} = M_{\mathrm{ETC}}$

$$\begin{aligned}\mathcal{L}_{\mathrm{ETC}} = {} & 2G_{QqUt}\left[\left(\overline{Q}_L U_R\right)\left(\bar{t}_R q_L\right) + \left(\bar{q}_L t_R\right)\left(\overline{U}_R Q_L\right)\right] + 2G_{QqDb}\left[\left(\overline{Q}_L D_R\right)\left(\bar{b}_R q_L\right) + \left(\bar{q}_L b_R\right)\left(\overline{D}_R Q_L\right)\right] \\ & + 2G_{QQUU}\left(\overline{Q}_L U_R\right)\left(\overline{U}_R Q_L\right) + 2G_{QQDD}\left(\overline{Q}_L D_R\right)\left(\overline{D}_R Q_L\right) + 2G_{qqtt}\left(\bar{q}_L t_R\right)\left(\bar{t}_R q_L\right) + 2G_{qqbb}\left(\bar{q}_L b_R\right)\left(\bar{b}_R q_L\right) \\ & + \Delta\mathcal{L}_{\mathrm{ETC}}\end{aligned}$$

$$\Sigma = \exp(i\Pi^a\tau^a/v)$$

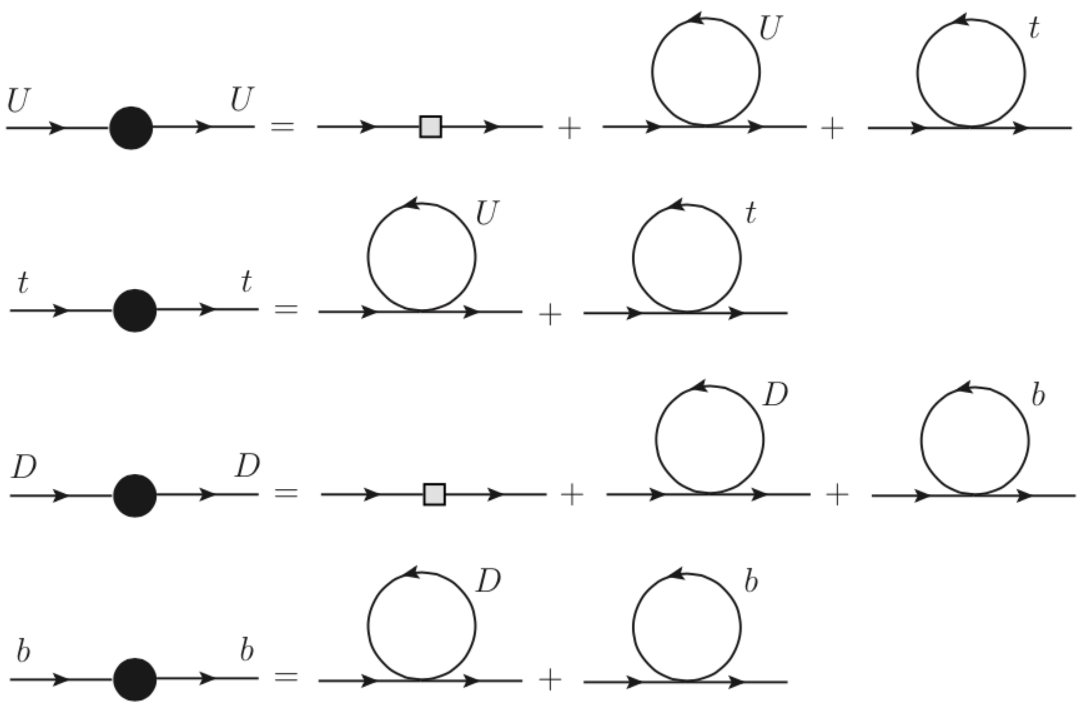
$\Lambda \simeq 4\pi F_\Pi$

$$\begin{aligned}\mathcal{L}_{\mathrm{TC}} = {} & \overline{Q}_L\ i\not{D} Q_L + \overline{U}_R\ i\not{D} U_R + \overline{D}_R\ i\not{D} D_R \\ & - M\left(1 + \frac{y}{v}H + \cdots\right)\left(\overline{Q}_L \Sigma Q_R + \overline{Q}_R \Sigma^\dagger Q_L\right) - \frac{m^2}{2}H^2 + \cdots\end{aligned}$$

U,D in N dimensional rep. of a new gauge group.

$F_\Pi \simeq 246\,\mathrm{GeV}$

Masses:



$$M_U = M_Q + 4\,N\,G_{QQUU}\,M_U\,I_U + 4\,N_c\,G_{QqUt}\,M_t\,I_t$$

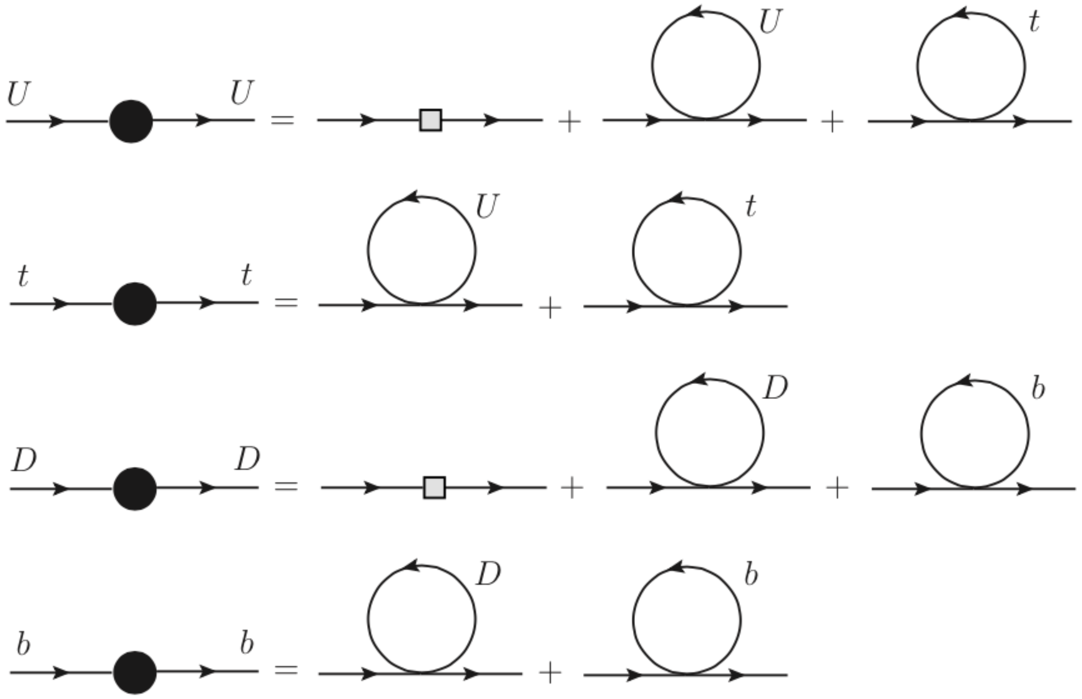
$$M_t = 4\,N\,G_{QqUt}\,M_U\,I_U + 4\,N_c\,G_{qqtt}\,M_t\,I_t\ ,$$

$$M_D = M_Q + 4\,N\,G_{QQDD}\,M_D\,I_D + 4\,N_c\,G_{QqDb}\,M_b\,I_b$$

$$M_b = 4\,N\,G_{QqDb}\,M_D\,I_D + 4\,N_c\,G_{qqbb}\,M_b\,I_b\ .$$

$$I_X \equiv i\int \frac{d^4k}{(2\pi)^4}\,\frac{1}{k^2 - M_X^2}$$

Masses:



$$M_U = M_Q + 4\,N\,G_{QQUU}\,M_U\,I_U + 4\,N_c\,G_{QqUt}\,M_t\,I_t$$

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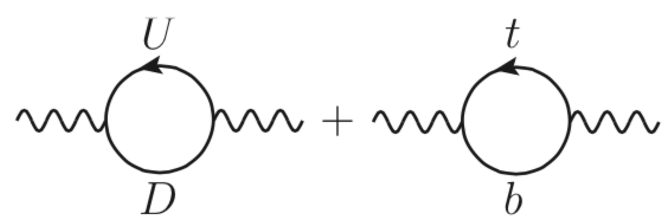
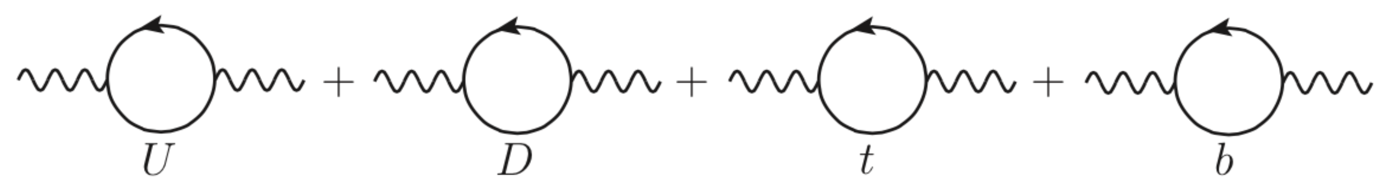
$$M_D = M_Q + 4\,N\,G_{QQDD}\,M_D\,I_D + 4\,N_c\,G_{QqDb}\,M_b\,I_b$$

$$M_b = 4\,N\,G_{QqDb}\,M_D\,I_D + 4\,N_c\,G_{qqbb}\,M_b\,I_b\ .$$

$$I_X \equiv i\int \frac{d^4k}{(2\pi)^4}\,\frac{1}{k^2 - M_X^2}$$



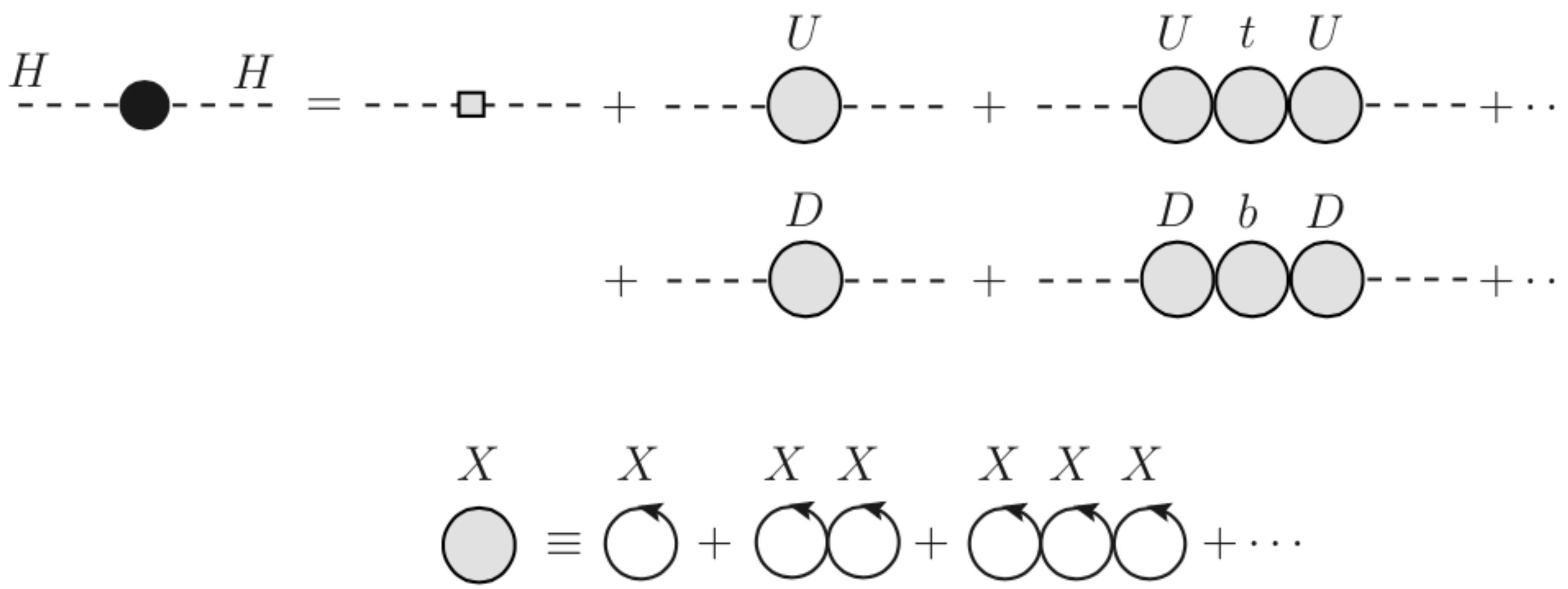
$$\Pi^{\mu\nu}_{WW}(q) = \Pi_{WW}(q^2)\left(g^{\mu\nu} - \frac{q^\mu q^\nu}{q^2}\right)$$



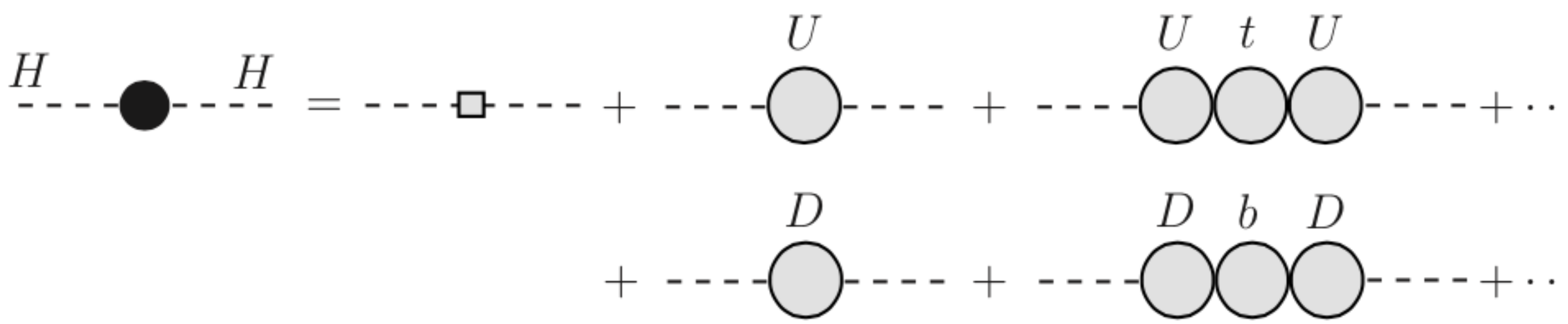
$$K_{XY} = -i\int_0^1 dx \int \frac{d^4\ell}{(2\pi)^4}\,\frac{1}{(\ell^2 - xM_X^2 - (1-x)M_Y^2)^2}$$

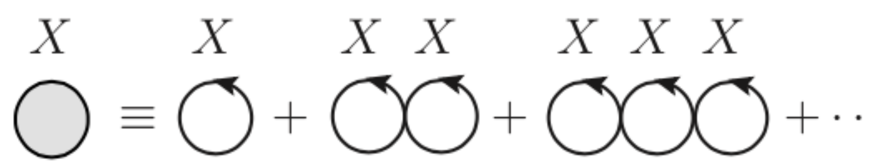
$$\frac{1}{\sqrt{2}G_F} = 4\left[N M_U^2 K_{UD} + N M_D^2 K_{DU} - N_c M_t^2 K_{tb} + N_c M_b^2 K_{bt}\right]$$

(Pagels-Stokar)



$$\Sigma_{HH} = -M^2 + N y^2 \left[\frac{\mathcal{I}^{SS}_{UU}}{1 - N\, N_c\, G^2_{QqUt}\, \mathcal{I}^{SS}_{UU}\, \mathcal{I}^{SS}_{tt}} + \frac{\mathcal{I}^{SS}_{DD}}{1 - N\, N_c\, G^2_{QqDb}\, \mathcal{I}^{SS}_{DD}\, \mathcal{I}^{SS}_{bb}} \right]$$

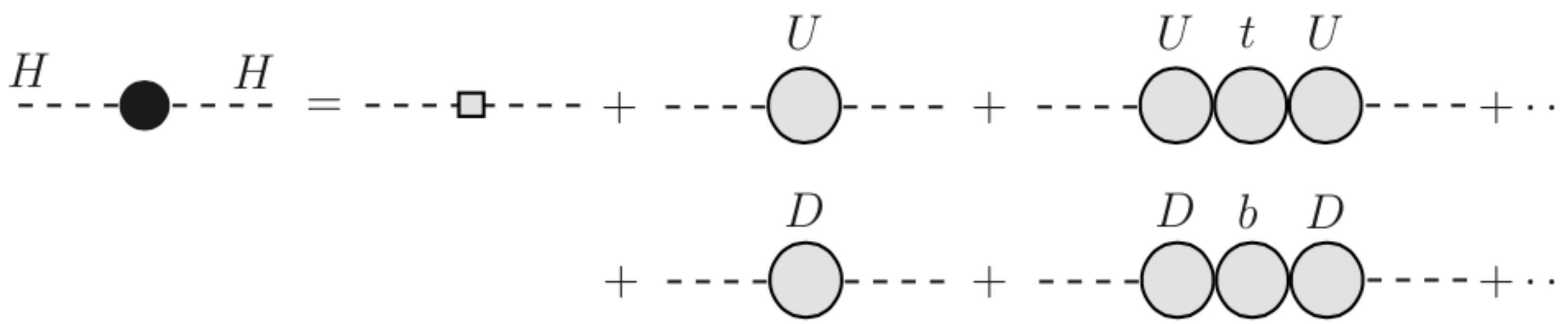


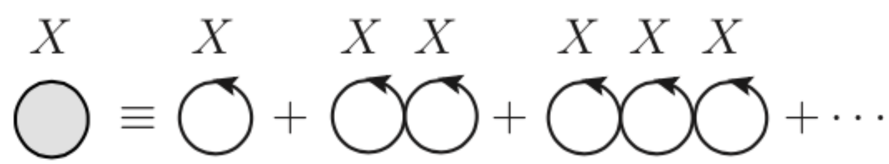


$$\Sigma_{HH} = -M^2 + N y^2 \left[\frac{\mathcal{I}^{SS}_{UU}}{1 - N N_c\, G^2_{QqUt}\, \mathcal{I}^{SS}_{UU}\, \mathcal{I}^{SS}_{tt}} + \frac{\mathcal{I}^{SS}_{DD}}{1 - N N_c\, G^2_{QqDb}\, \mathcal{I}^{SS}_{DD}\, \mathcal{I}^{SS}_{bb}} \right]$$

Again, trade M^2 for the dynamical mass M_{H0} at G=0,

and solve M_{H0} from $\Sigma_{HH}(M_H^2 = 125\,\mathrm{GeV}) = 0 \quad (G \neq 0)$





$$\Sigma_{HH} = -M^2 + Ny^2\left[\frac{\mathcal{I}^{SS}_{UU}}{1 - N N_c\, G^2_{QqUt}\, \mathcal{I}^{SS}_{UU}\, \mathcal{I}^{SS}_{tt}} + \frac{\mathcal{I}^{SS}_{DD}}{1 - N N_c\, G^2_{QqDb}\, \mathcal{I}^{SS}_{DD}\, \mathcal{I}^{SS}_{bb}}\right]$$

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Convergence of the series requires:

$$N\, G_{QQUU}\, \Lambda^2 < 4\pi^2\,, \quad N\, G_{QQDD}\, \Lambda^2 < 4\pi^2$$

Expanding to $\mathcal{O}(M_X^2/\Lambda):$

$\mathcal{O}(1\,\mathrm{TeV})$

$$M_H^2 \simeq M_{H0}^2 - \frac{(G_{QQUU}+G_{QQDD})\Lambda^2}{2\pi^2} \frac{\Lambda^2}{\ln\frac{\Lambda^2}{M_U^2}+\ln\frac{\Lambda^2}{M_D^2}-2}$$

$\mathcal{O}(1\,\mathrm{TeV})$

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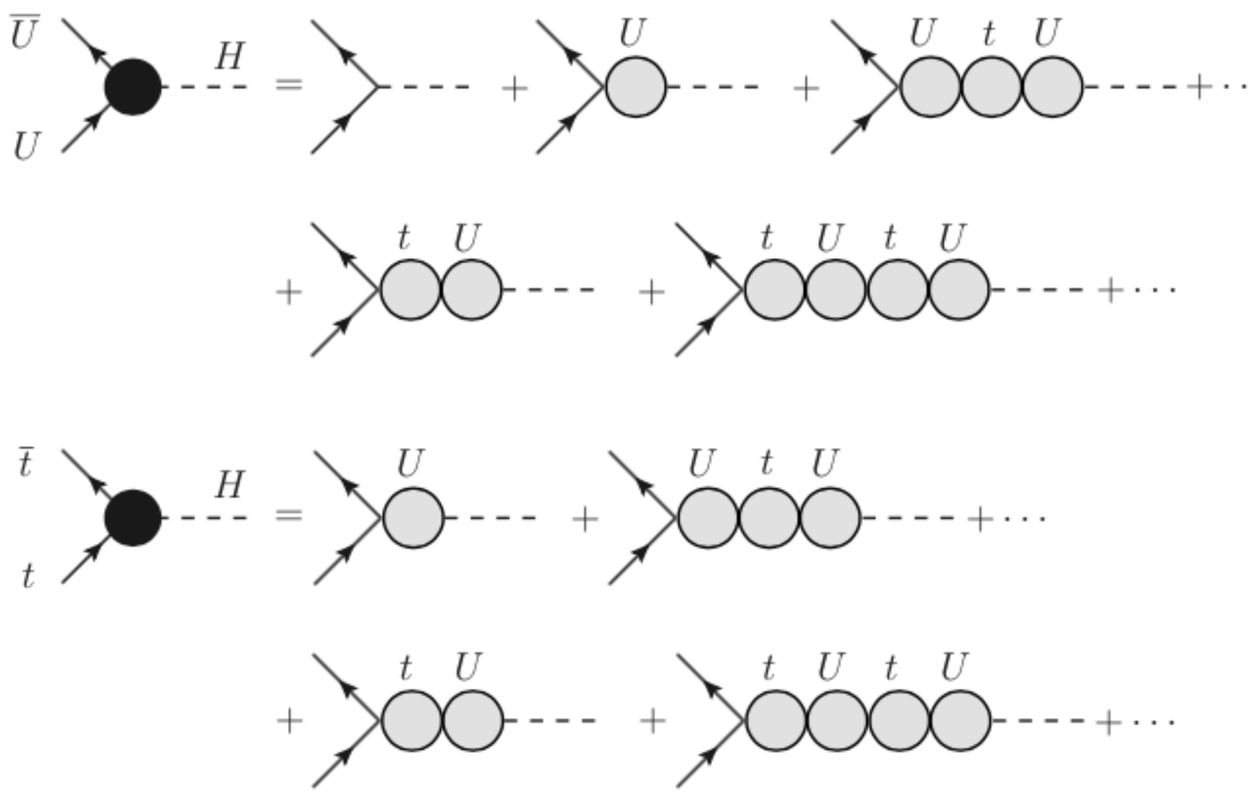
$$\mathrm{FT} = \frac{M_H^2}{M_{H0}^2} = 2\ldots 4\%,\ \text{for}\ M_{H0} \simeq 1\,\mathrm{TeV}\ \ldots M_{H0} \simeq 600\,\mathrm{GeV}$$

Couplings

$$\mathcal{L}_{\text{Yukawa}} = -y_U\,\overline{U}\,U\,H - y_D\,\overline{D}\,D\,H - y_t\,\bar{t}\,t\,H - y_b\,\bar{b}\,b\,H$$



Use gap Eqs. and

expand to $\mathcal{O}(M_X^2/\Lambda^2)$

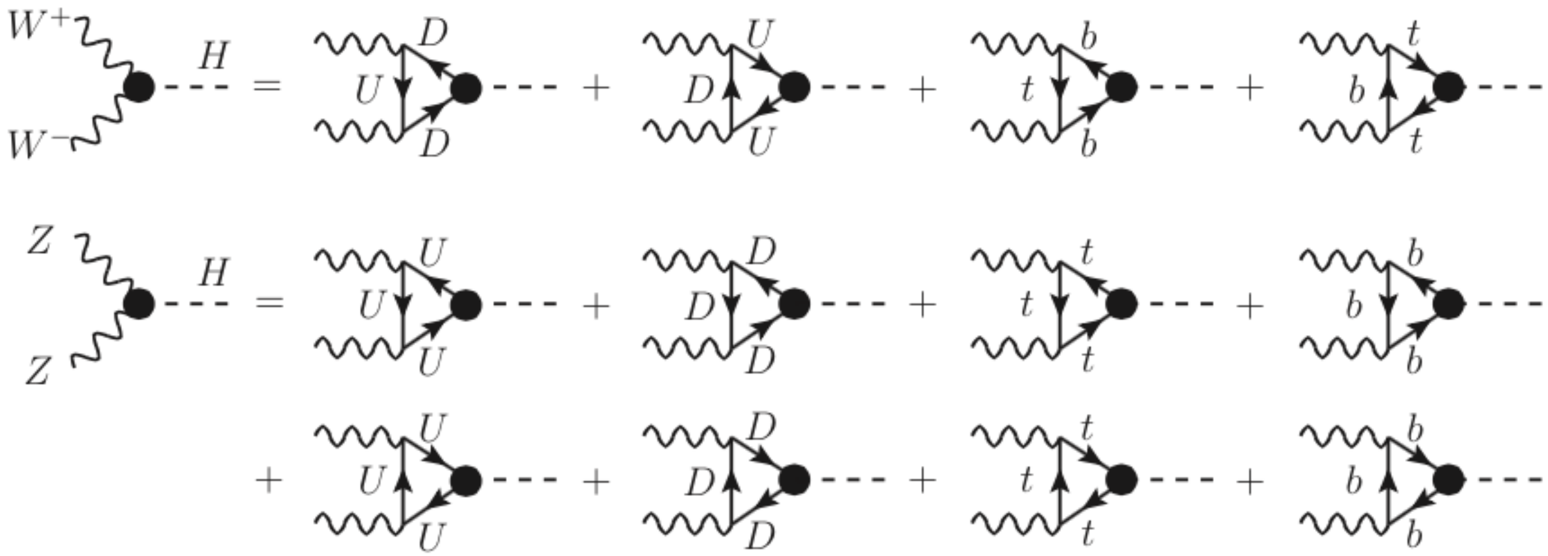
$$y_D \simeq \left(\sqrt{2}\,G_F\right)^{1/2} M_D\,, \quad y_b \simeq \left(\sqrt{2}\,G_F\right)^{1/2} M_b\,,$$

$$y_U \simeq \left(\sqrt{2}\,G_F\right)^{1/2} M_U\,, \quad y_t \simeq \left(\sqrt{2}\,G_F\right)^{1/2} M_t\,,$$

$\boxed{\text{SM-like Yukawa couplings.}}$

Couplings

$$\mathcal{L}_{HWW} = 2\,M_W^2\left(\sqrt{2}G_F\right)^{1/2} a_W\, H\, W_\mu^+\, W^{-\mu} + M_Z^2\left(\sqrt{2}G_F\right)^{1/2} a_Z\, H\, Z_\mu\, Z^\mu$$



$$a_W = \quad 4\left(\sqrt{2}G_F\right)^{1/2}(N y_U M_U K_{UD} + N y_D M_D K_{DU} + N_c y_t M_t K_{tb} + N_c y_b M_b K_{tb}\Big)$$

$$\simeq \sqrt{2}G_F 4\left(N M_U^2 K_{UD} + N M_D^2 K_{UD} + N_c M_t^2 K_{tb} + N_c M_b^2 K_{bt}\right) \;\simeq 1.$$

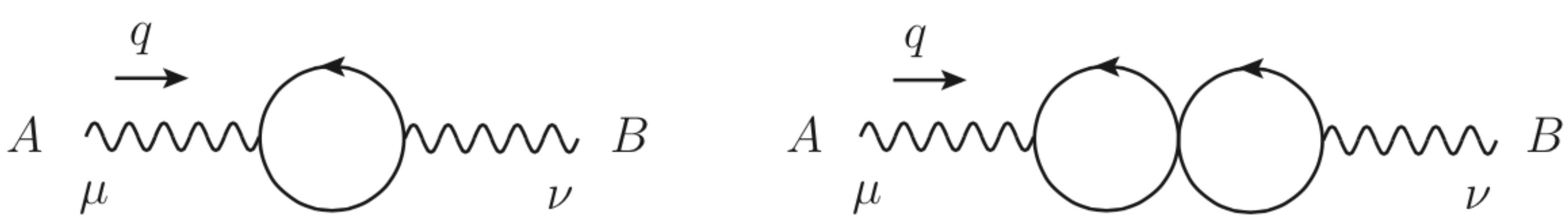
$$K_{XY} = -i\int_0^1 dx \int \frac{d^4\ell}{(2\pi)^4}\,\frac{1}{(\ell^2 - xM_X^2 - (1-x)M_Y^2)^2}$$

SM like couplings to W and Z.

Oblique corrections:

$$S = \frac{16\pi}{g\,g'}\,\Pi'_{W^3B}(0)\,,$$

$$T = \frac{1}{\alpha M_W^2}\left[\Pi_{W^3W^3}(0) - \Pi_{W^+W^-}(0)\right]$$



$$\begin{aligned}\mathcal{L}_{\mathrm{ETC}} = {} & 2G_{QqUt}\left[\left(\overline{Q}_L U_R\right)\left(\bar{t}_R q_L\right) + \left(\bar{q}_L t_R\right)\left(\overline{U}_R Q_L\right)\right] + 2G_{QqDb}\left[\left(\overline{Q}_L D_R\right)\left(\bar{b}_R q_L\right) + \left(\bar{q}_L b_R\right)\left(\overline{D}_R Q_L\right)\right] \\ & + 2G_{QQUU}\left(\overline{Q}_L U_R\right)\left(\overline{U}_R Q_L\right) + 2G_{QQDD}\left(\overline{Q}_L D_R\right)\left(\overline{D}_R Q_L\right) + 2G_{qqtt}\left(\bar{q}_L t_R\right)\left(\bar{t}_R q_L\right) + 2G_{qqbb}\left(\bar{q}_L b_R\right)\left(\bar{b}_R q_L\right) \\ & + \Delta\mathcal{L}_{\mathrm{ETC}}\end{aligned}$$

3. Numerical results, conclusions and outlook

After fixing $\alpha,\, G_F,\, M_Z,\, M_H,\, M_t,\, M_b$
the model has 14 parameters.

$N,\ \Lambda,\ \mathcal{M}$, and 11 ETC couplings.

- We consider N=4 and N=6

- To fix Λ, scale up from QCD: $$f_\pi^2 = \frac{N_c}{16\pi^2} m_\sigma^2 \ln \frac{\Lambda_{\rm QCD}^2}{m_\sigma^2/4}$$

$$\Lambda = \sqrt{\frac{N_c}{N}} \frac{F_\Pi}{f_\pi} \Lambda_{\rm QCD} \qquad \Rightarrow \Lambda \simeq \begin{cases} 2.7\,\mathrm{TeV} & N=4 \\ 2.2\,\mathrm{TeV} & N=6 \end{cases}$$

- Keep $\mathcal{M}$ as free parameter.

To avoid large contributions to T, set

$$g_{UU} = g_{DD}$$

$$g_{tt} = g_{bb}$$

$$g_{UD} = g_{tb} = 0$$

- Large enough couplings to reduce scalar mass to 125 GeV

- Further constraints from S and T

$$\pi/3 \leq |g_{QQ}|, |g_{UU}|, |g_{Qq}|, |g_{Dt}|, |g_{Ub}| \leq 2\pi$$

$$-2\pi \leq |g_{qq}|, |g_{tt}| \leq 2\pi$$

For each value of Λ and $\mathcal{M}$, generate 25 000 models

By construction, all points have

$m_h = 125\,\mathrm{GeV}$

Fine tuning on a few % level

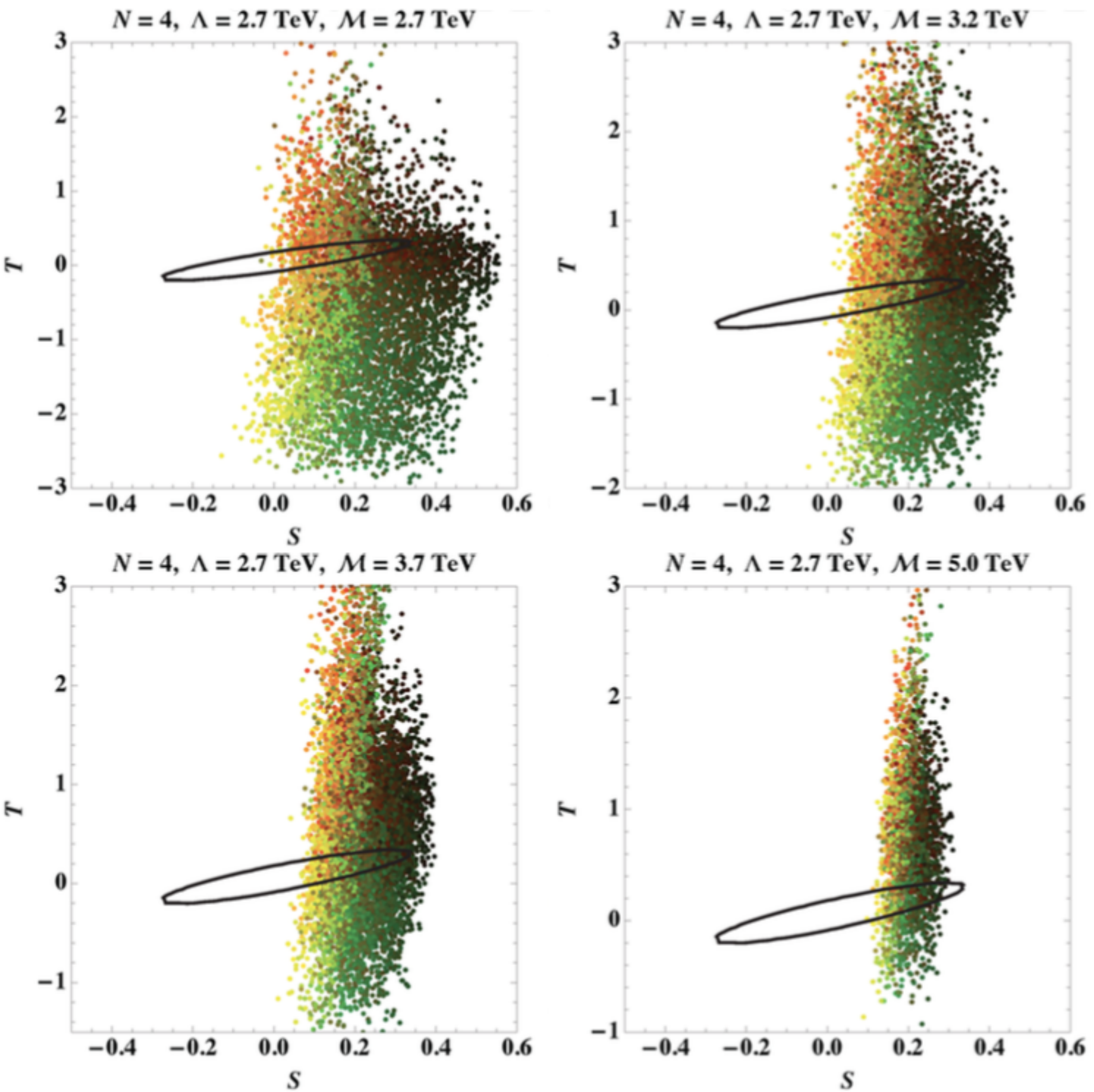
Select only the points which satisfy

$$0.5 m_\sigma \frac{F_\Pi}{f_\pi}\sqrt{\frac{N_c}{N}} < M_{H0} < 1.25 \underbrace{m_\sigma \frac{F_\Pi}{f_\pi}\sqrt{\frac{N_c}{N}}}_{\mathcal{O}(1\,\mathrm{TeV})}$$

$$N = 4: \qquad 500\,\mathrm{GeV} < M_{H0} < 1300\,\mathrm{GeV}$$

$$N = 6: \qquad 400\,\mathrm{GeV} < M_{H0} < 1000\,\mathrm{GeV}$$

All points have Higgs couplings within 10% of SM values.



$|g_{Dt}|$ **increases**

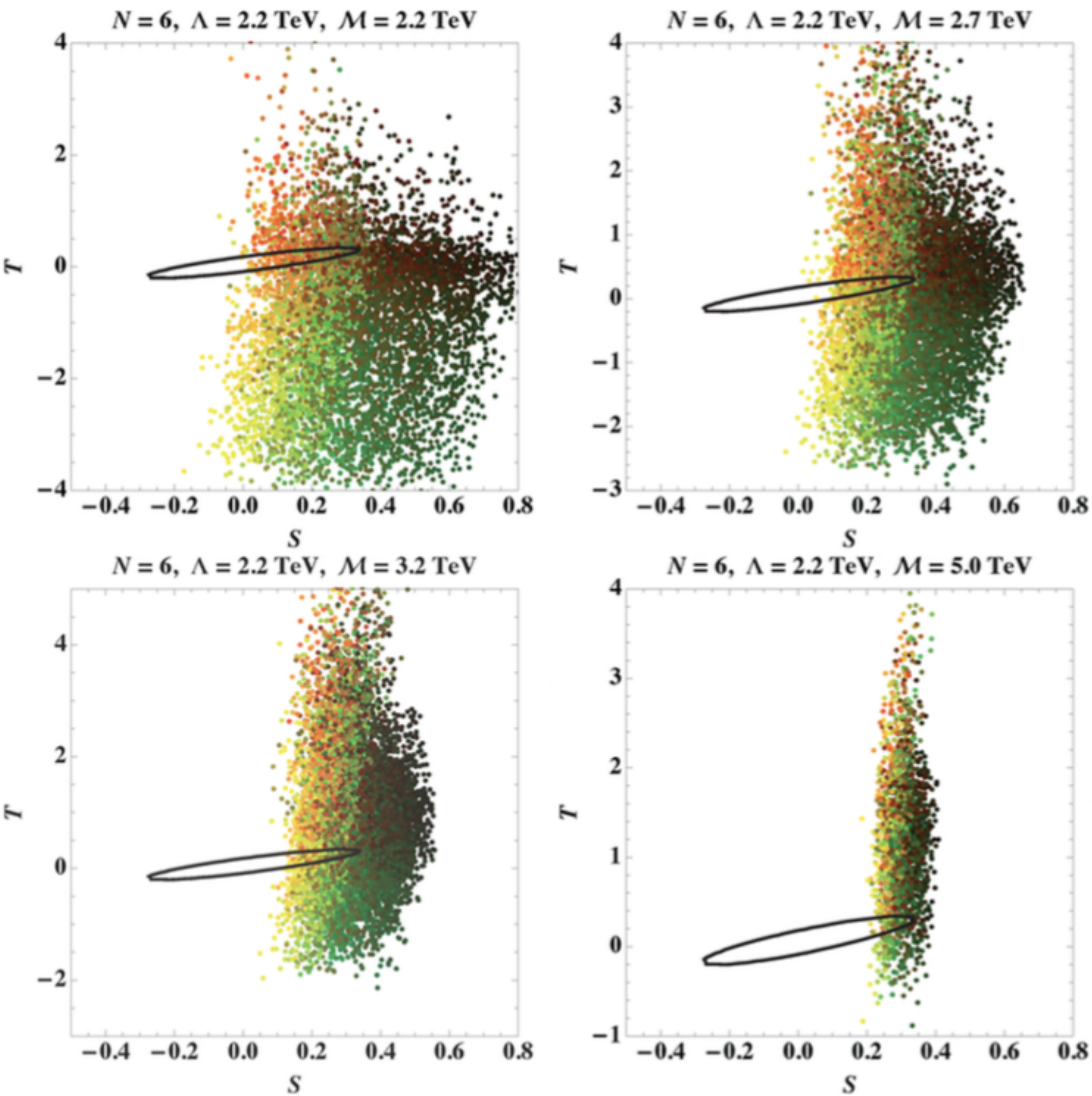
$|g_{Ub}|$ **increases**

$|g_{Qq}|$ increases to right

Larger $\mathcal{M}$,

larger $M_U - M_D$ splitting,

$\Rightarrow$ positive T.



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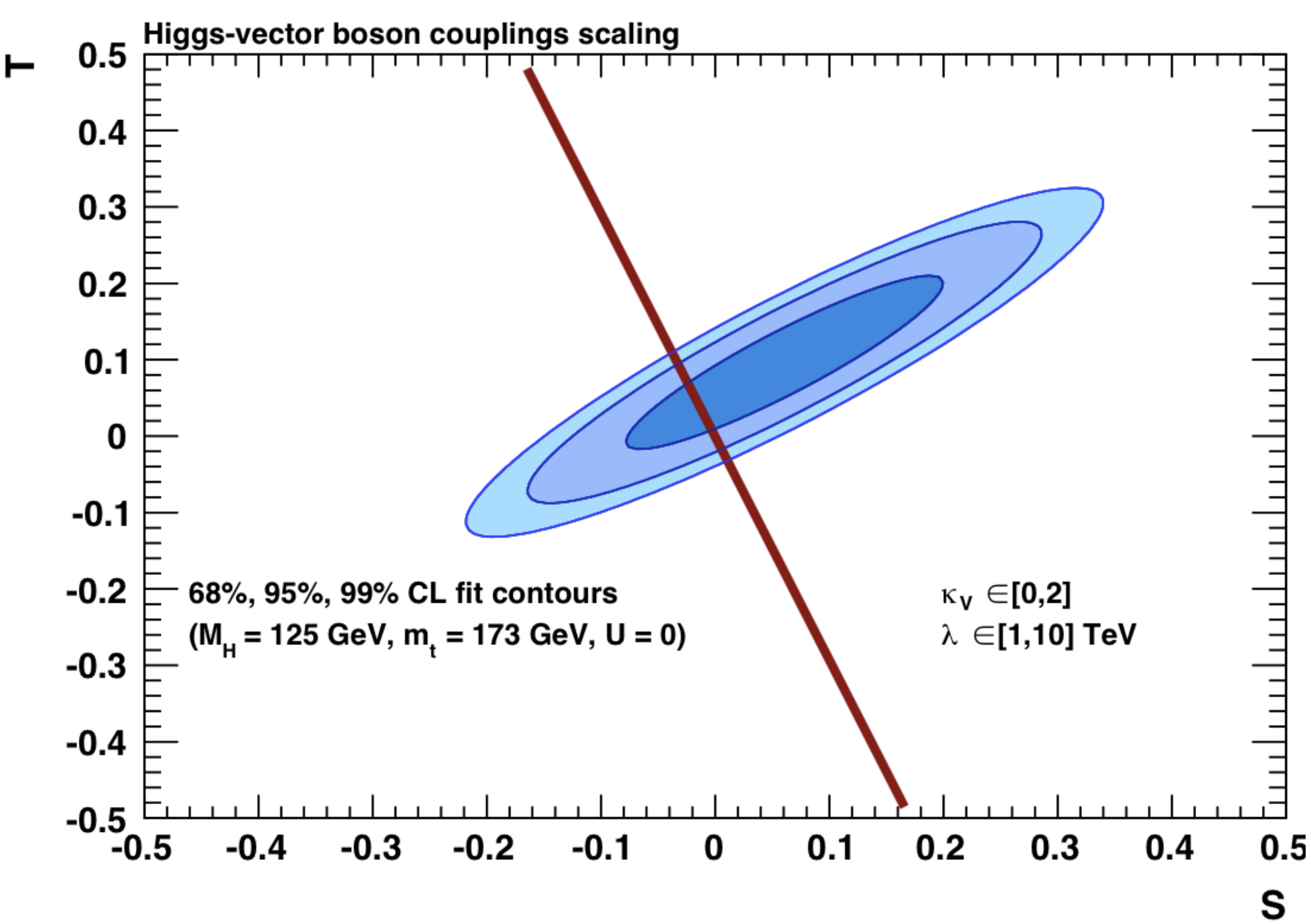
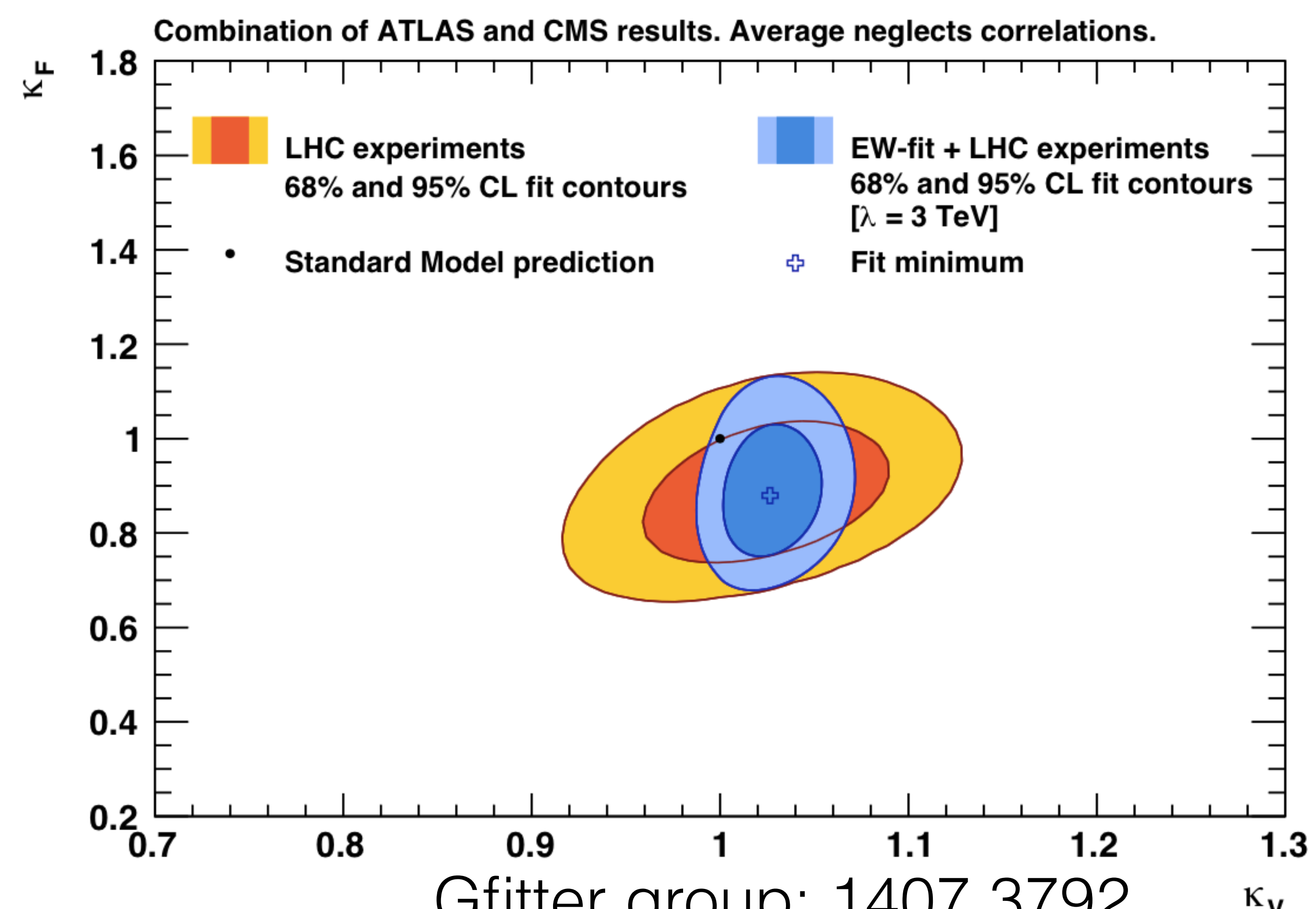
Average over points within 3sigma in S and T:

N, Λ, $\mathcal{M}$ values	$\tilde{y}_t$	$\tilde{y}_b$	$\tilde{g}_{HWW}$	$\tilde{g}_{HZZ}$	S	T
N=4, Λ=2.7, $\mathcal{M}$=3.7	0.92	1.04	1.08	1.07	0.18 ± 0.04	0.18 ± 0.05
N=4, Λ=2.7, $\mathcal{M}$=3.2	0.93	1.03	1.08	1.07	0.17 ± 0.05	0.18 ± 0.05
N=4, Λ=2.7, $\mathcal{M}$=2.7	0.93	1.01	1.09	1.08	0.15 ± 0.06	0.17 ± 0.06
N=6, Λ=2.2, $\mathcal{M}$=3.2	0.92	1.04	1.08	1.07	0.2 ± 0.03	0.2 ± 0.04
N=6, Λ=2.2, $\mathcal{M}$=2.7	0.92	1.03	1.09	1.08	0.18 ± 0.04	0.19 ± 0.05
N=6, Λ=2.2, $\mathcal{M}$=2.2	0.92	1.02	1.09	1.08	0.15 ± 0.06	0.16 ± 0.07





Gfitter group: 1407.3792

Conclusions and Outlook

1. Strong dynamics coupled with SM:
   - 125 GeV scalar,
   - few % fine tuning
   - SM- like couplings

2. Further directions
   - Compare with lattice results,
   - ETC models,
   - Phenomenology