Top-seesaw assisted technicolor model with 126 GeV Higgs

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Based on arXiv:1210.6756, (wtih K.Tuominen)

Outline

1. Introduction (4-pages)

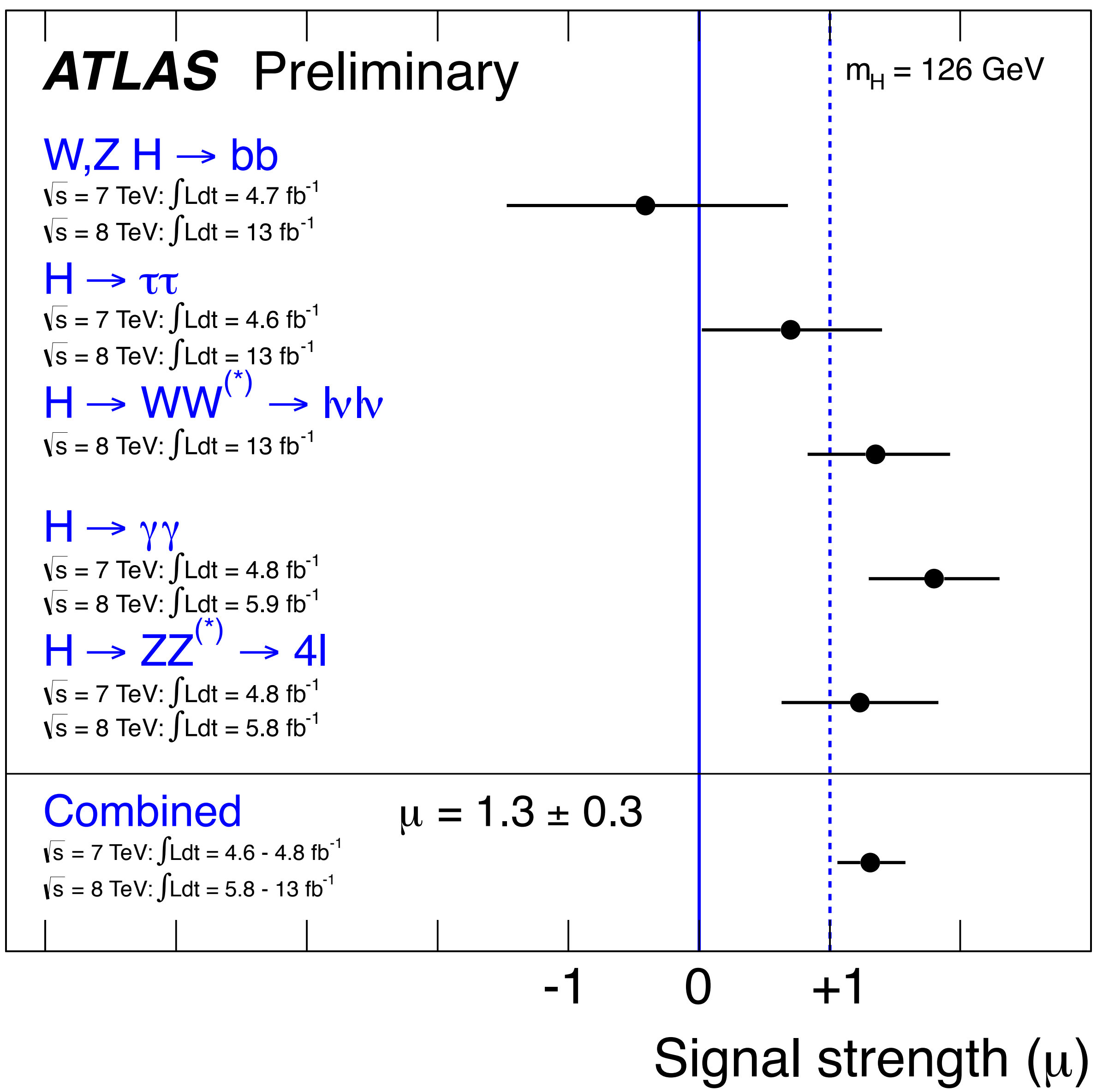
2. Top-seesaw assisted technicolor (8-pages)

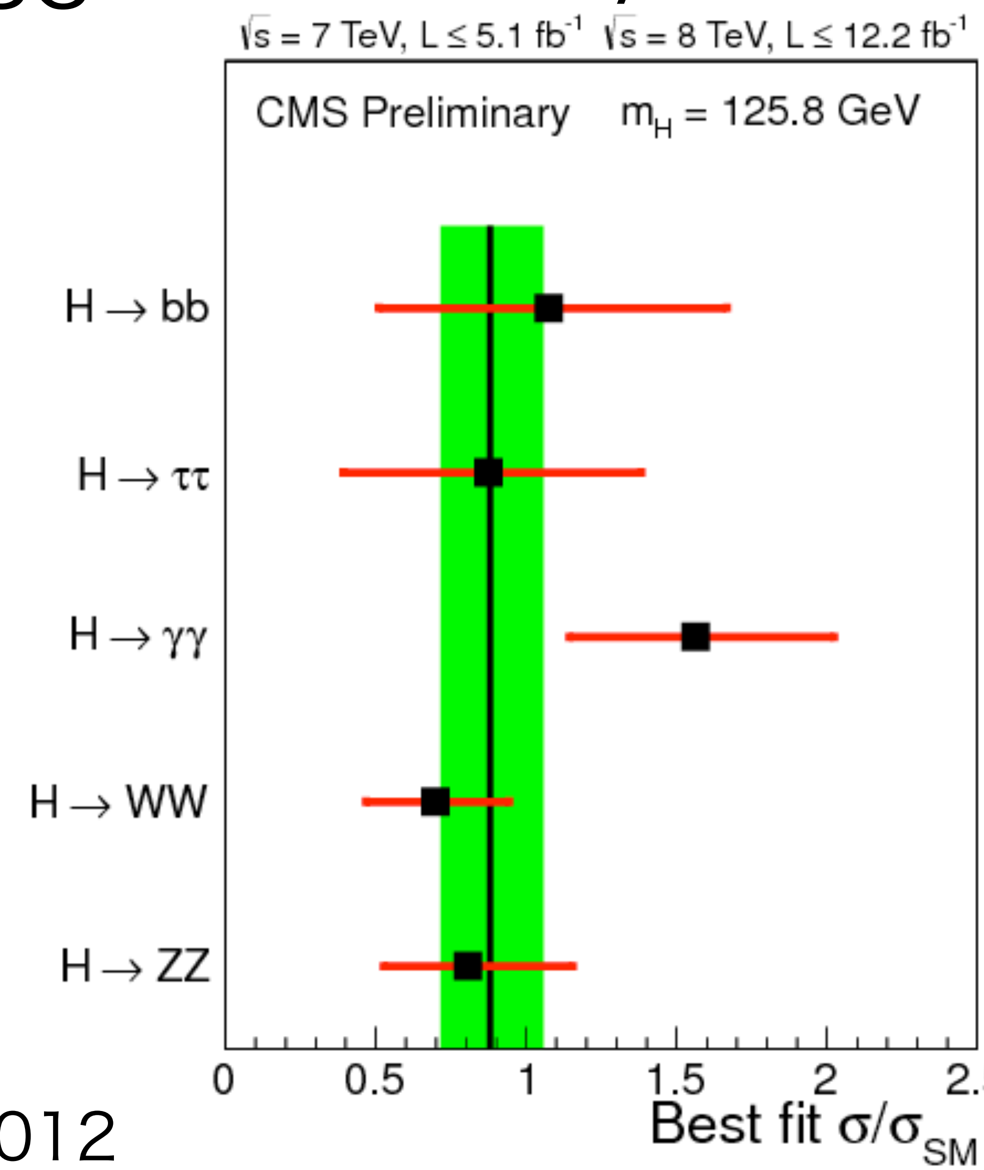
3. 126 GeV Higgs at the LHC (4-pages)

4. Summary (1page)

"Higgs" @ LHC (I)

ATLAS and CMS discovered "Higgs" boson w/ 126 GeV





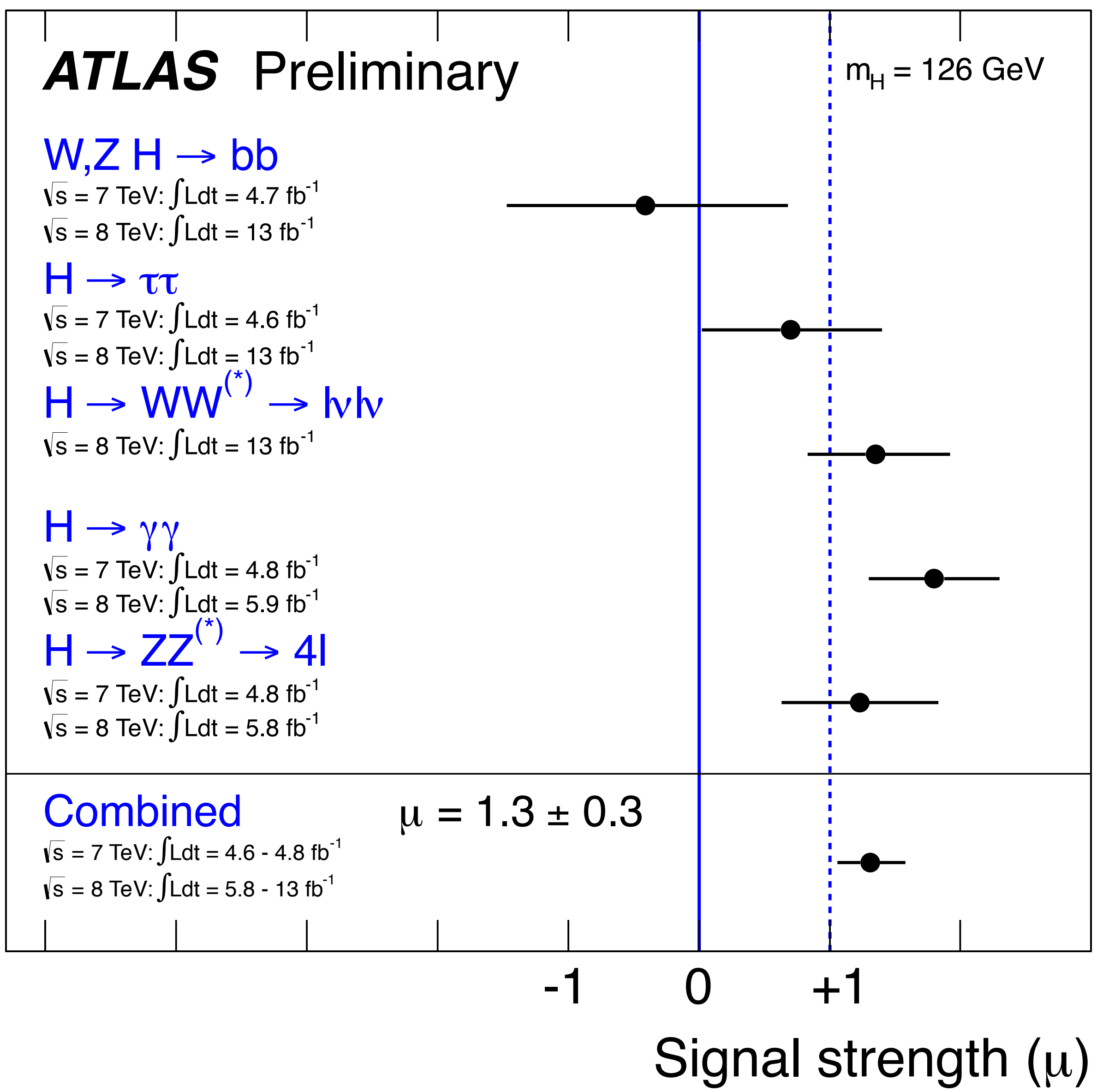
HCP2012

126 GeV "Higgs" in the technicolor

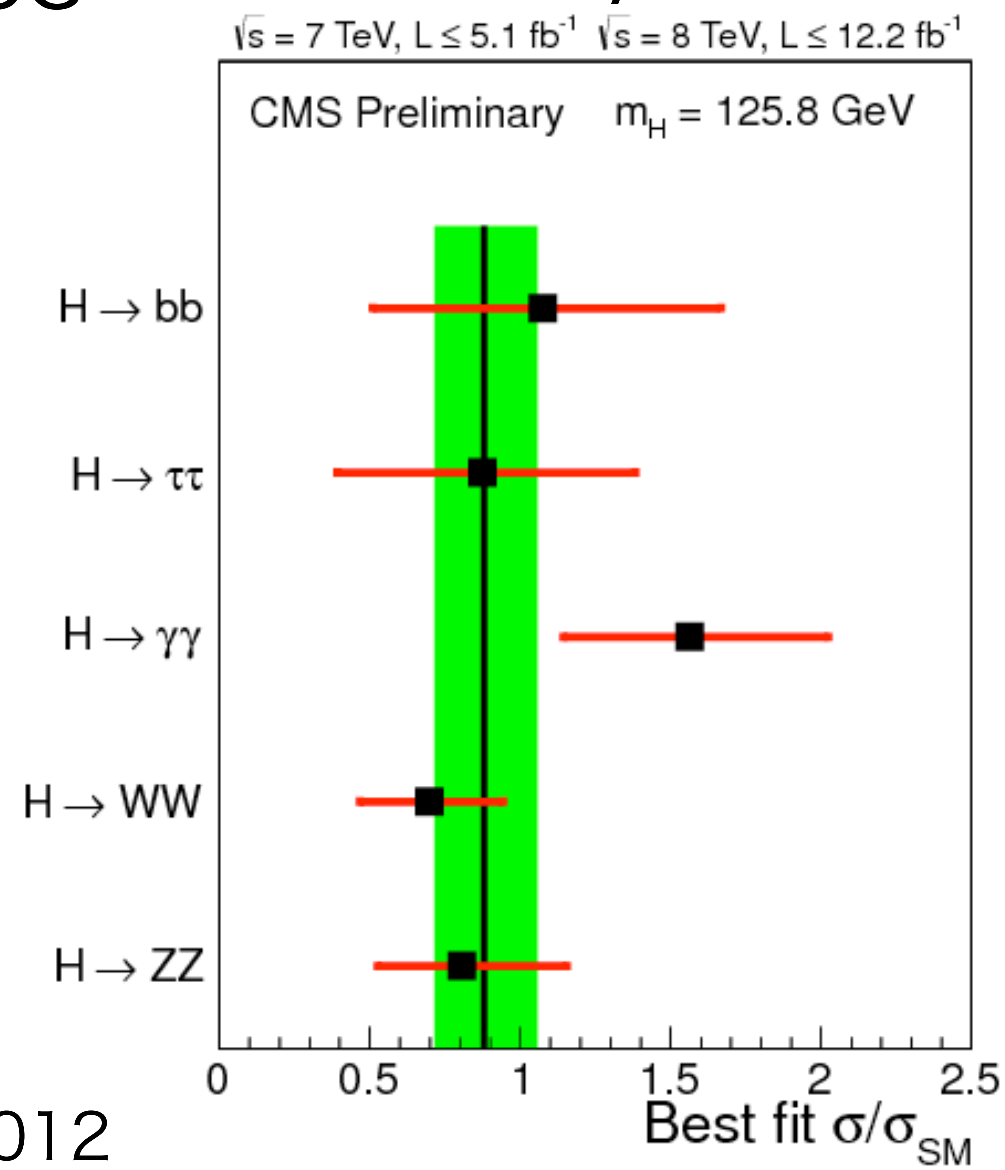
talked by Kuti,Shrock,Sannino,Matsuzaki,Piai,Hong

"Higgs" @ LHC (II)

ATLAS and CMS discovered "Higgs" boson w/ 126 GeV



HCP2012



126 GeV "Higgs" in a scenario based on the top condensation

Top-seesaw [Dobreascu et.al. 19997, Chivukula et.al.1998]

- a scenario based on the top-condensate

Brief summary

Nambu 1988; Miransky et.al. 1988;Bardeen et.al. 1989

- player : top quark (q) and its vector-like partner ($\chi_{L,R}$)

- mass term

Nambu-Jona-Lasinio (NJL) dynamics for the EWSB : $\langle \bar{q}_L \chi_R \rangle \neq 0$

$$\begin{pmatrix} \bar{q}_L & \bar{\chi}_L \end{pmatrix} \begin{pmatrix} 0 & \Sigma \\ m & M \end{pmatrix} \begin{pmatrix} q_R \\ \chi_R \end{pmatrix} \Rightarrow m_t \bar{t} t + m_T T \bar{T}$$

chiral invariant mass term : $m \bar{\chi}_L q_R + M \bar{\chi}_L \chi_R \ (m < M)$

- seesaw mechanism

$$m_t^2 \simeq \frac{m^2}{M^2} \Sigma^2 \, , \, m_T^2 \simeq M^2 \Leftrightarrow m_t < \Sigma$$

"Higgs" in the top-seesaw

- Decay constant [Pagels et.al. 1979] : $f_\pi^2 = \dfrac{3\Sigma^2}{8\pi^2} \ln \dfrac{\Lambda^2}{\Sigma^2}$
- NJL dynamics result : $m_h = 2\,\Sigma \;(\mathrm{RGE} : m_h \simeq \sqrt{2}\,\Sigma)$
- TSS estimate for $f_\pi = 246/\sqrt{2}(\mathrm{GeV})\,,\; \Lambda \simeq \mathcal{O}(1 - 10\mathrm{TeV})$

$$\Sigma \simeq 400 - 600\mathrm{GeV} \to m_h \simeq 0.8 - 1.2\mathrm{TeV}$$

Not suitable for 126 GeV Higgs...

I would like to talk about .....

- ☐ Can we realize 126 GeV "Higgs" ?
- ☐ Can we explain the observed "Higgs" decay ?
- ☑ Yes, we can !!

Model set-up [TSS-part]

- TSS part in top-seesaw assisted technicolor (TSSTC)

[He et.al. 2002, H.S.F and K.Tuominen,2011,2012]

field	$SU(3)_1$	$SU(3)_2$	$SU(2)_L$	$U(1)_Y$
$Q_L^{(3)}$	3	1	2	1/6
$U_R^{(3)}, D_R^{(3)}$	1	3	1	(2/3 , -1/3)
$U_L^{(4)}, D_L^{(4)}$	1	3	1	(2/3, -1/3)
$U_R^{(4)}, D_R^{(4)}$	3	1	1	(2/3,-1/3)
$Q^{(1,2)}$	1	3	SM	SM

vector-like

anomaly free

$SU(3)_1 \times SU(3)_2 \rightarrow SU(3)_c$: massive gauge boson = coloron

Auxiliary field methods [TSS-part]

NJL interactions in the TSS sector emerges @ Λ

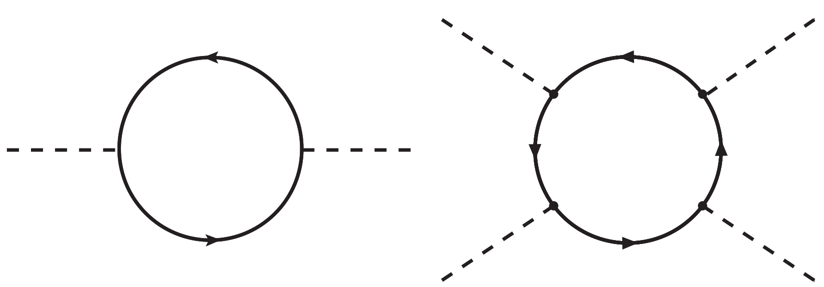
$$\mathcal{L}_\Lambda = G_b \left(\bar{D}_R^{(4)} Q_L^{(3)}\right)^2 + G_t \left(\bar{U}_R^{(4)} Q_L^{(3)}\right)^2 + G_{tb} \left(\bar{Q}_L^{(3)} U_R^{(4)}\right)\left(\bar{D}_R^{(4)c} i\tau_2 Q_L^{(3)c}\right)$$

coloron exchange — top-color instanton

We introduce the auxiliary fields : $\Phi_1^{(0)} \sim \bar{D}_R^{(4)} Q_L^{(3)}$, $\Phi_2^{(0)} \sim \bar{U}_R^{(4)} Q_L^{(3)}$

$$\begin{aligned}\mathcal{L}_\Lambda \;=\; & -M_b^{(0)2}|\Phi_1^{(0)}|^2 - M_t^{(0)2}|\Phi_2^{(0)}|^2 \\ & -M_{tb}^{(0)2}\left[\Phi_1^{(0)\dagger}\Phi_2^{(0)} + \text{h.c.}\right] \\ & -\left[\bar{Q}_L^{(3)}\Phi_1^{(0)}D_R^{(4)} + \bar{Q}_L^{(3)}\tilde{\Phi}_2^{(0)}U_R^{(4)} + \text{h.c.}\right]\end{aligned}$$

$G_{tb} = 0 \to M_{tb}^{(0)2} = 0$



Low energy effective theory (LEFT) for TSS

Low energy effective theory [TSS-part]

LEFT for TSS sector = $\mathcal{L}_{\rm kin} + \mathcal{L}_{\mu<\Lambda}$

- TSS part derives Two Higgs doublet model (2HDM)

$$
\begin{aligned}
\mathcal{L}_\Lambda \to \mathcal{L}_{\mu<\Lambda} \;=\; & -\left[y_1 \bar{Q}_L^{(3)} \Phi_1 D_R^{(4)} + y_2 \bar{Q}_L^{(3)} \tilde{\Phi}_2 U_R^{(4)} + \text{h.c.} \right] \\
& + M_{11}^2 |\Phi_1|^2 + M_{22}^2 |\Phi_2|^2 - M_{12}^2 \left[\Phi_1^\dagger \Phi_2 + \text{h.c.} \right] \\
& - \frac{1}{2}\lambda_1 (\Phi_1^\dagger \Phi_1)^2 - \frac{1}{2}\lambda_2 (\Phi_2^\dagger \Phi_2)^2 \\
& - \lambda_3 (\Phi_1^\dagger \Phi_1)(\Phi_2^\dagger \Phi_2) - \lambda_4 (\Phi_1^\dagger \Phi_2)(\Phi_2^\dagger \Phi_1)
\end{aligned}
$$

- NJL = RGE + compositeness conditions (cc)

cc: $$y^2 \to y^2(\Lambda) = \infty \quad , \quad \frac{\lambda}{y^4} \to \frac{\lambda(\Lambda)}{y^4(\Lambda)} = 0$$

Low energy effective theory [TSSTC-full]

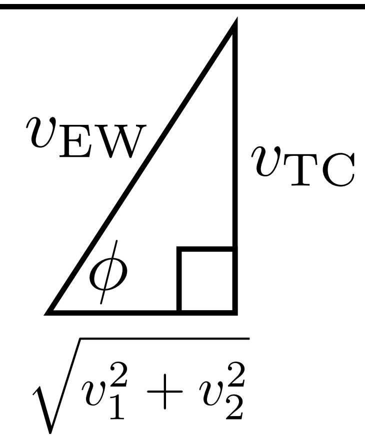
- Besides TSS, TSSTC has TC sector

- EWSB :

$$\underbrace{\langle \mathrm{TC} \rangle}_{\neq 0} + \underbrace{\langle \bar{U}_R^{(4)} Q_L^{(3)} \rangle}_{\neq 0} + \underbrace{\langle \bar{D}_R^{(4)} Q_L^{(3)} \rangle}_{\neq 0} \Rightarrow v_{\mathrm{EW}}^2 = v_{\mathrm{TC}}^2 + v_2^2 + v_1^2$$

def for β, ϕ

$$\tan\beta \equiv \frac{v_2}{v_1} ,$$



- EFT = 1-Higgs“less” doublet + 2HDM w/ cc

TC = electroweak chiral Lagrangian TSS

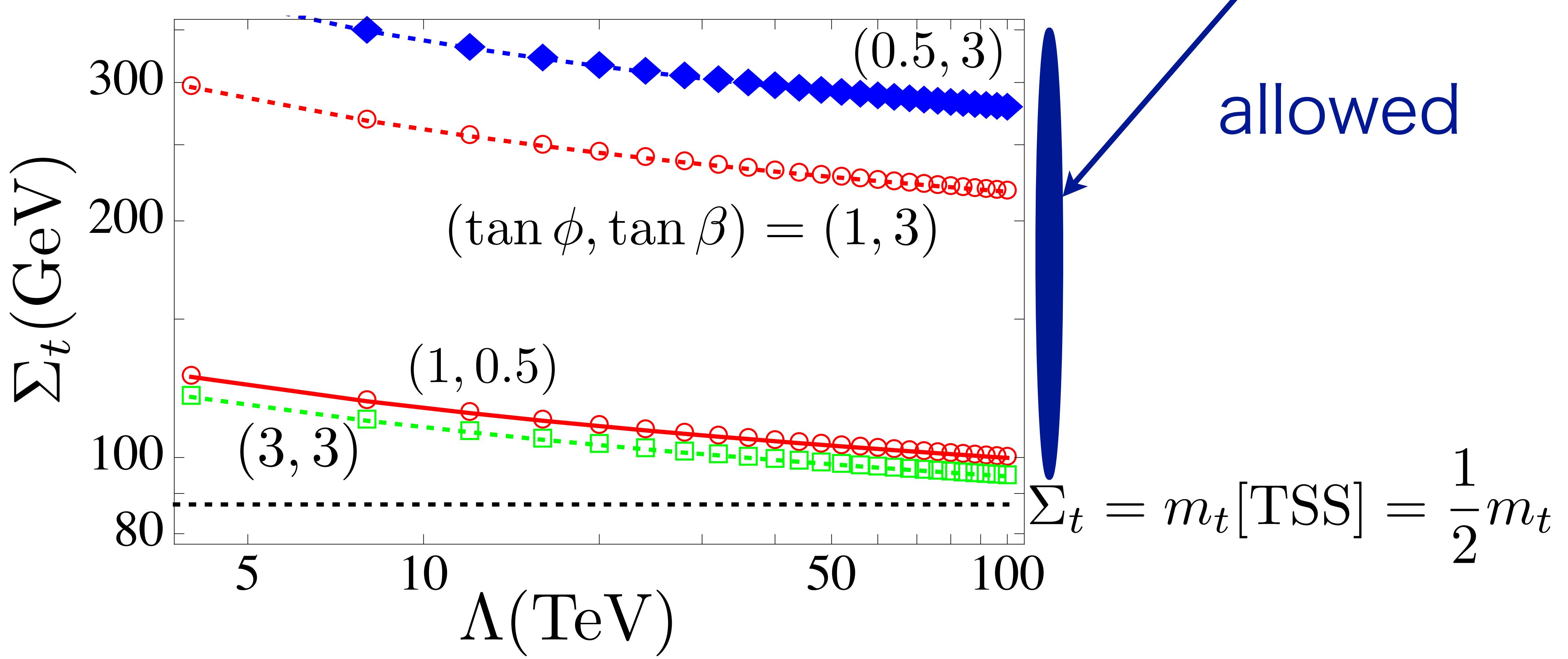
Dynamical results (top sector)

- solution for dynamical top mass

$$\begin{pmatrix}\bar{U}_L^{(3)} & \bar{U}_L^{(4)}\end{pmatrix}\begin{pmatrix}0 & \Sigma_t \\ M_{34} & M_{44}\end{pmatrix}\begin{pmatrix}U_R^{(3)} \\ U_R^{(4)}\end{pmatrix}$$

$\Sigma_t > m_t[\mathrm{TSS}] = (1-\epsilon_t)m_t$
should be satisfied for the seesaw mechanism

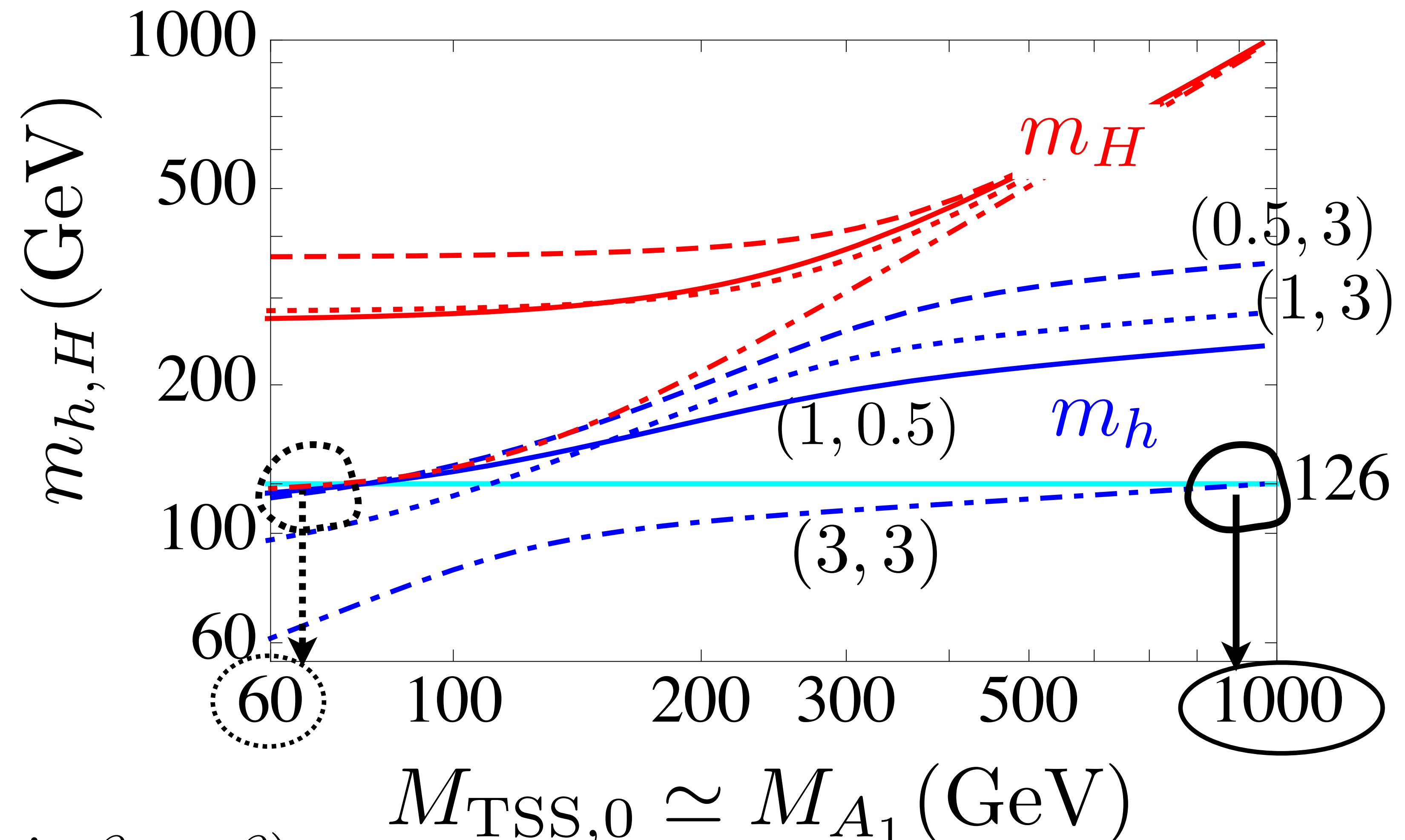
- w/ several sets of $(\Lambda, \tan\phi, \tan\beta)$



Dynamical results (CP-even higgs)

- dynamical solution for CP-even higgs in TSS
- w/ previous allowed sets and fixed $M_{\text{coloron}} \simeq \Lambda = 50\text{TeV}$

contribution to T from massive coloron should be small [He et.al. 2002]

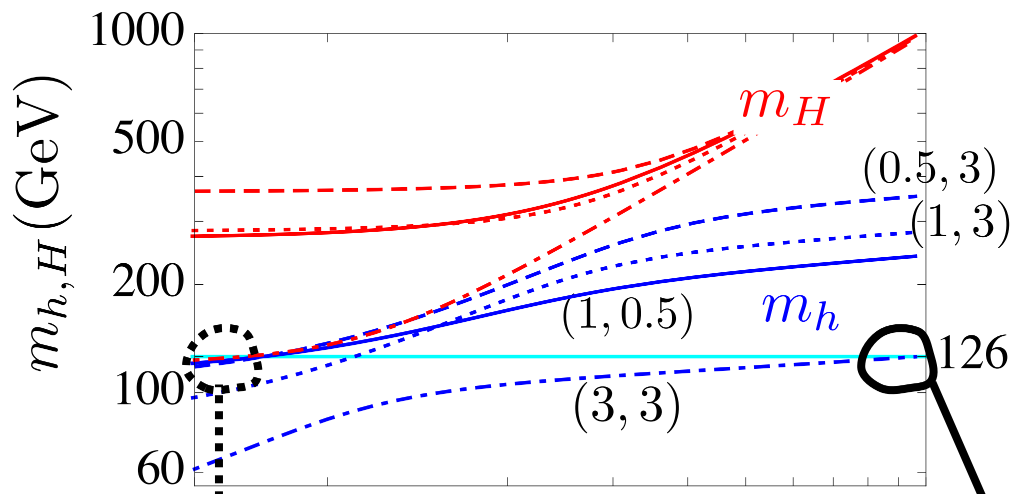


$M^2_{\text{TSS},0} = M^2_{12}/(\sin\beta\cos\beta)$

M_{A_1} : The lightest CP-odd Higgs boson mass

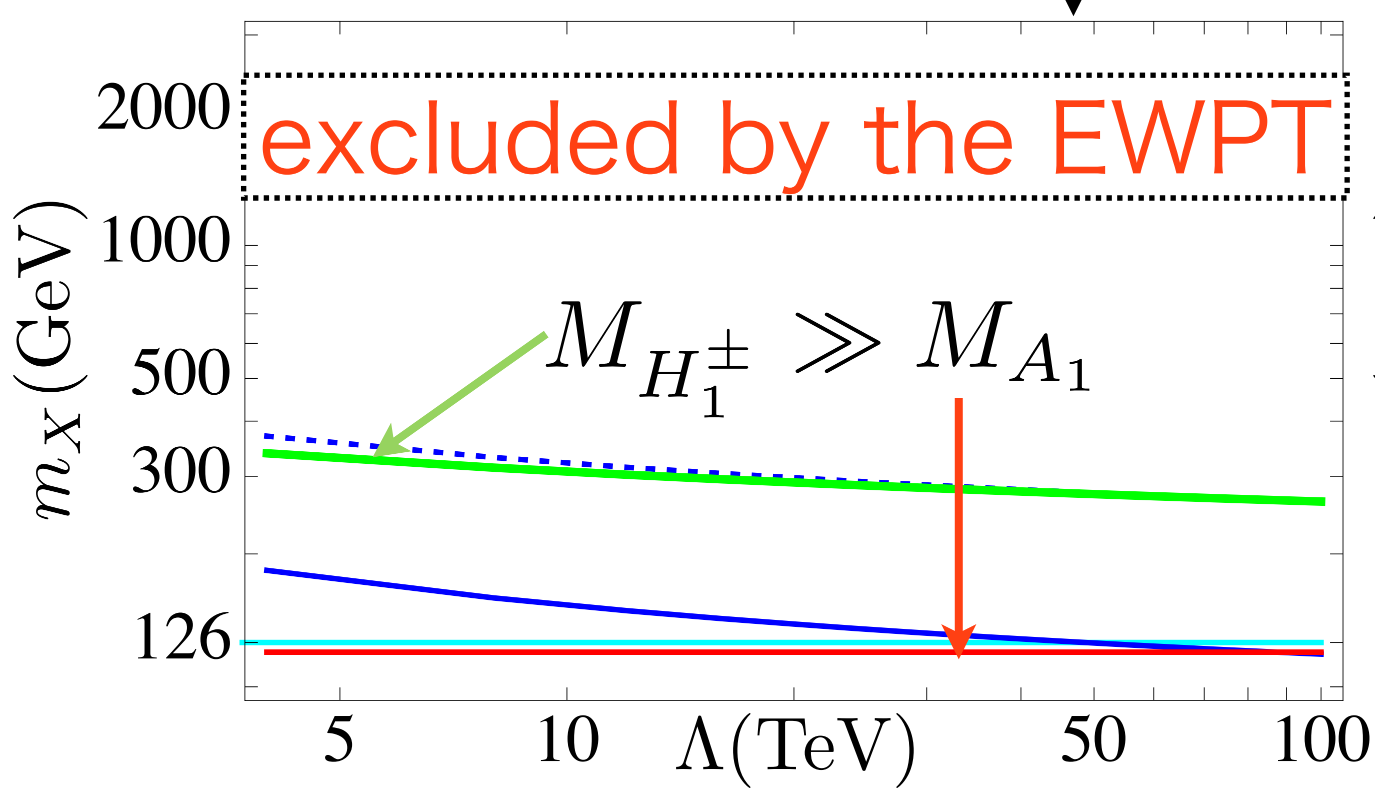
Dynamical results (other Higgs)

- Physical Higgs mass in the TSSTC model

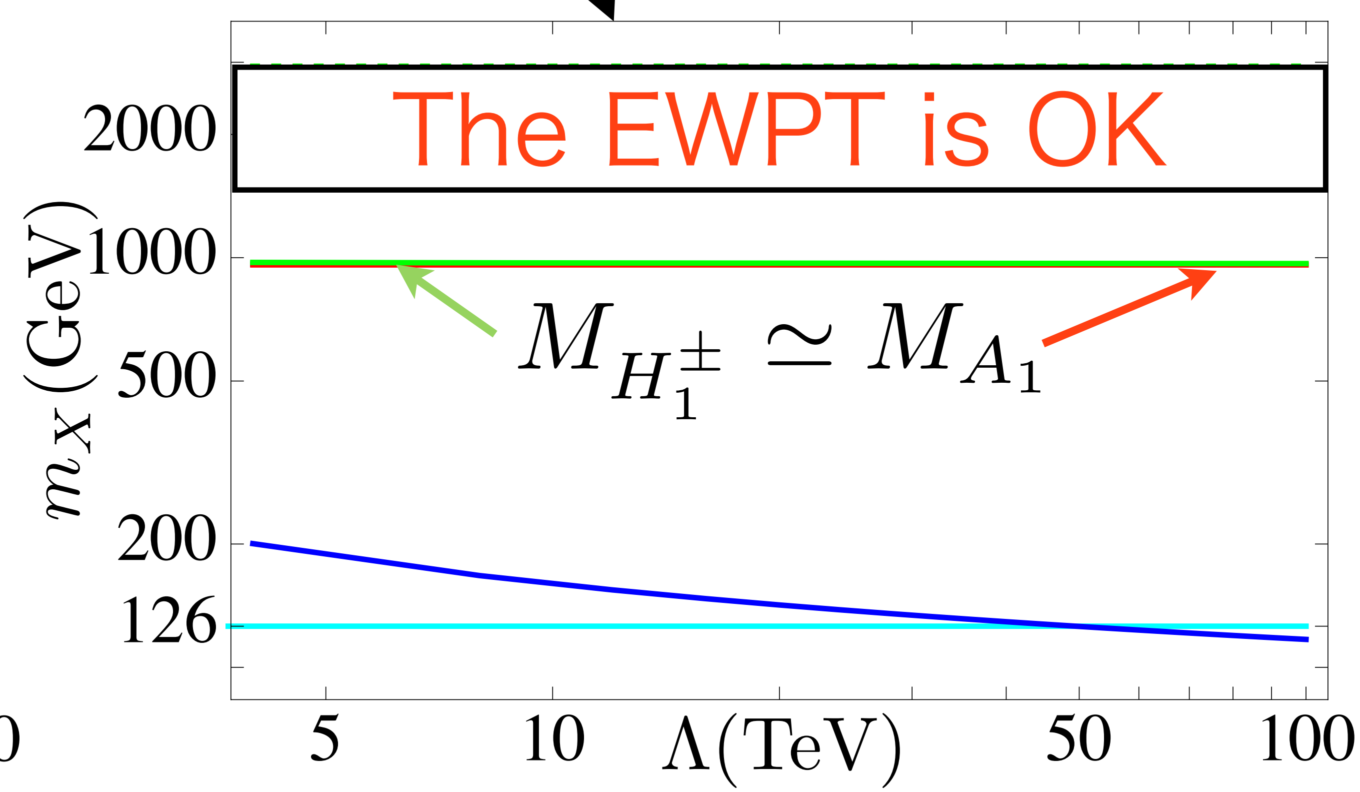


$m_H = 126$ GeV $\Rightarrow m_{H_1^\pm} \simeq 126$ GeV is disfavored by $t \to \Pi_t^\pm b$

For $M_{A_1} \simeq 100$ GeV



For $M_{A_1} \simeq 1000$ GeV



Question and Answer (126 GeV “Higgs” ?)

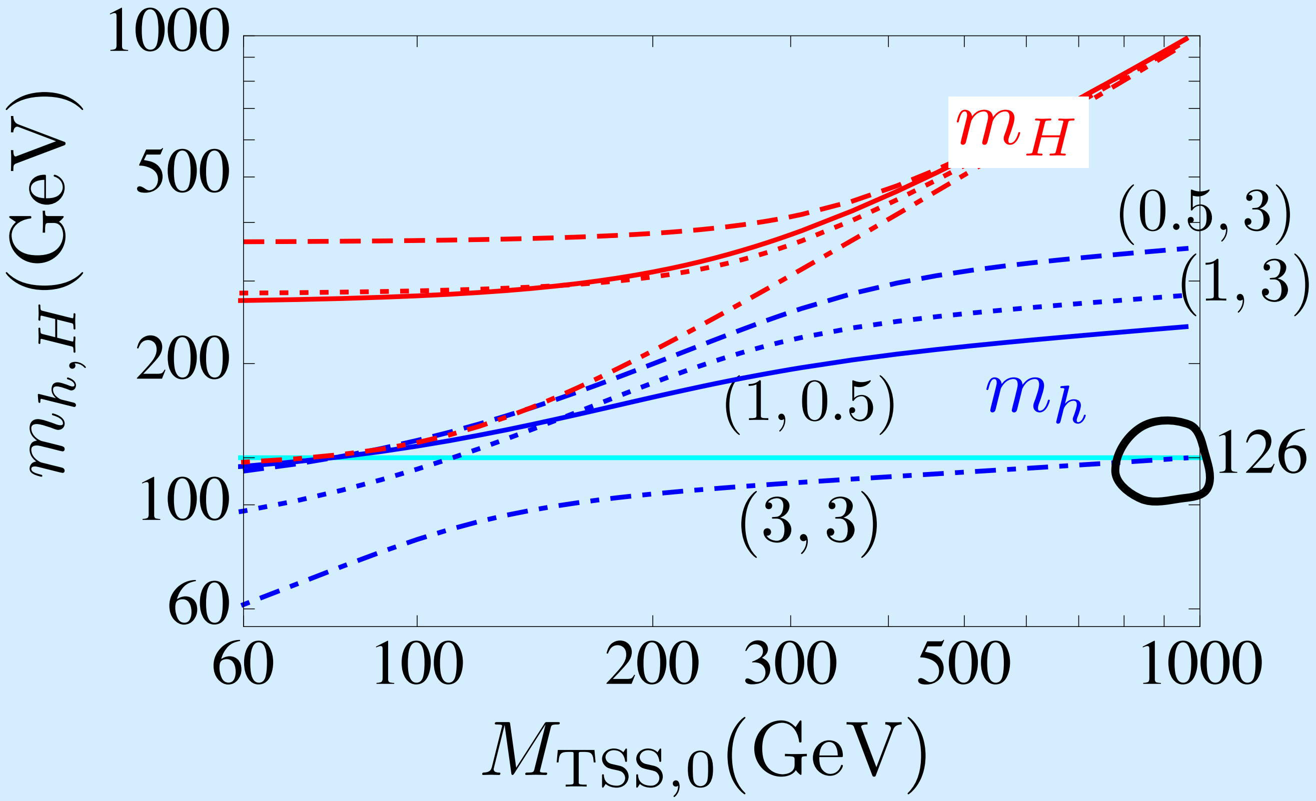
- Can we realize 126 GeV “Higgs” ?

  - ☑ Yes, we can !

    EWPT : OK for

    $\tan\phi = \tan\beta = 3$

    $M_{\mathrm{TSS},0} \simeq M_{A_1} \simeq 1$ TeV



- Can we explain the observed “Higgs” decay ?

Production cross section

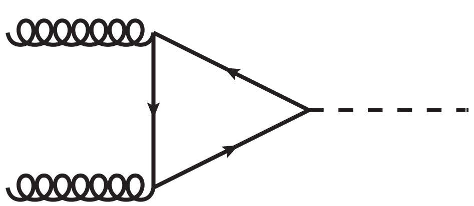
- Production cross section of Higgs

$$\frac{\sigma_{\text{ggF + VBF + VH}}[\text{TSSTC}]}{\sigma_{\text{ggF + VBF + VH}}[\text{SM}]} \simeq 2 - 2.5$$

  - Main production process is gluon fusion

$$\frac{\sigma_{\text{ggF}}[\text{TSSTC}]}{\sigma_{\text{ggF}}[\text{SM}]} \simeq 2.3 - 2.8$$

  - This enhancement is mainly from top quark contribution



(not vector-like top partner)

feature in the TSS

$$t \text{ in triangle} \sim \left[\underbrace{(y_2/y_t^{\text{SM}})}_{\sim 2} \underbrace{c_L^t}_{\sim 1} \underbrace{s_R^t}_{\sim 0.9} \underbrace{\cos\alpha}_{\sim 0.9} \right]^2 \simeq 2.6$$

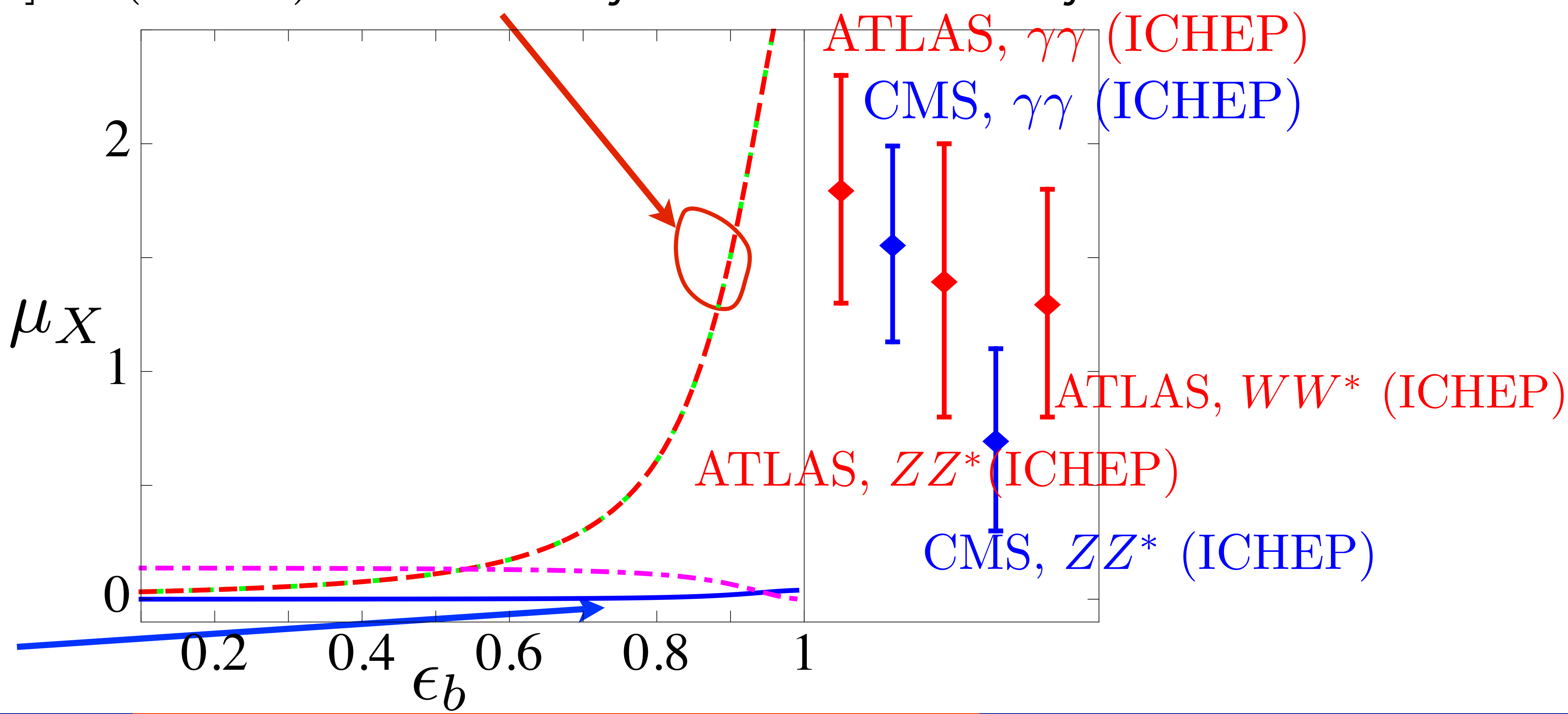
$$T \text{ in triangle} \sim \left[\frac{y_2}{\sqrt{2} m_T / v_{\text{EW}}} s_L^t c_R^t \cos\alpha \right]^2 \ll 1$$

The signal strength (I)

- signal strength of 126 GeV “Higgs”
  (renormalized respect to the SM Higgs)
  - $\mu_{\tau\tau} = 0$ (No Higgs coupling to tau)
  - $\mu_{bb}^{\mathrm{VH}} \simeq 0.1$ (small VH production)

$\mu_{VV^*} \simeq 1 - 1.5$ (for $\epsilon_b \simeq 0.8 - 0.9$)

$m_b[\mathrm{TSS}] = (1-\epsilon_b) m_b$: has very small effect on dynamical results



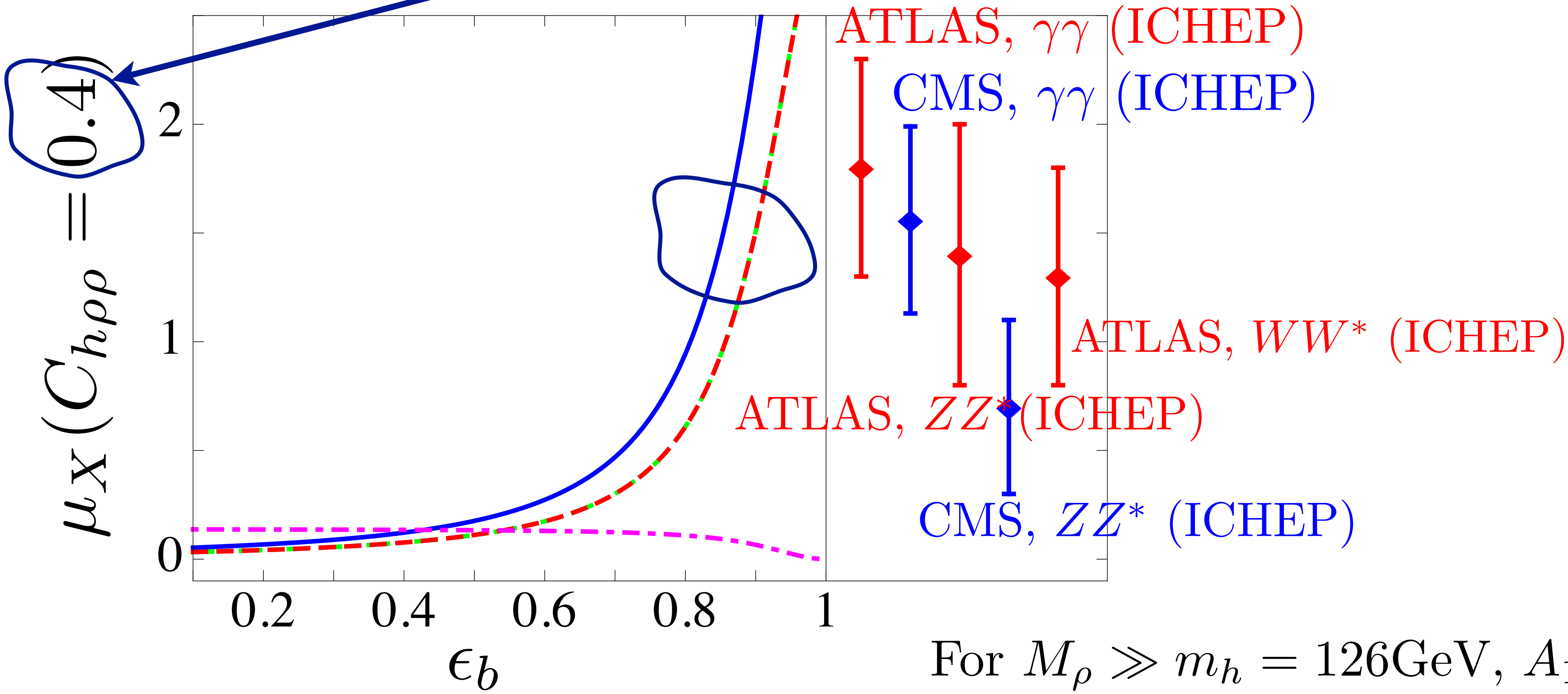
BAD...

$\mu_{\gamma\gamma} \simeq 0$

The signal strength (II)

- a modification to the diphoton channel
- add the vector meson - Higgs coupling

$$\mathcal{L}_{h\rho\rho} = C_{h\rho\rho}(gM_W) \cdot h\rho^{+\mu}\rho^-_\mu$$



For $M_\rho \gg m_h = 126\text{GeV}$, $A_1 \to -7$

$$\Gamma(h \to \gamma\gamma) = \frac{\alpha^2 g^2}{1024\pi^3}\frac{m_h^3}{M_W^2}\left| C_{hWW} A_1\left(\frac{4M_W^2}{m_h^2}\right) + C_{h\rho\rho} A_1\left(\frac{4M_\rho^2}{m_h^2}\right) + \cdots \right|^2$$

Question and Answer ("Higgs" decay mode?)

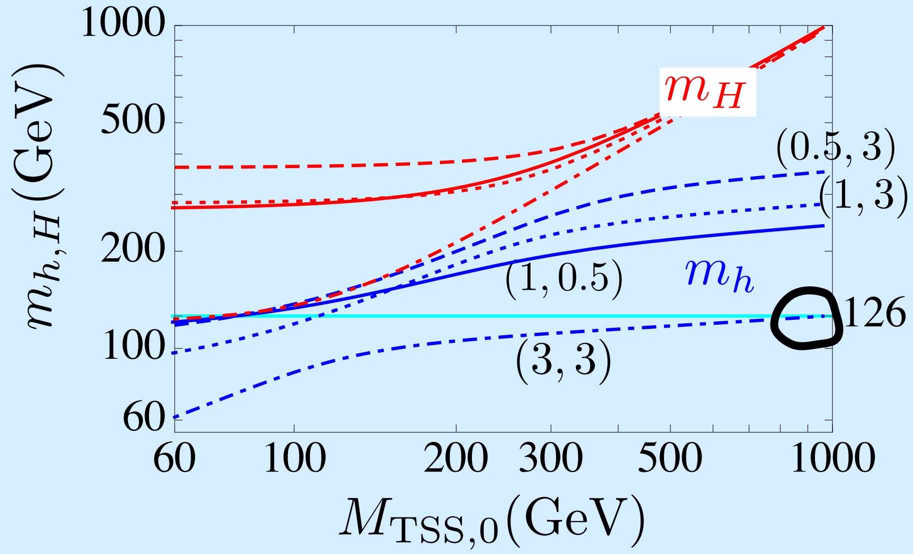
- Can we realize 126 GeV "Higgs" ?

  - ☑ Yes, we can !

    EWPT : OK for

    $\tan\phi = \tan\beta = 3$

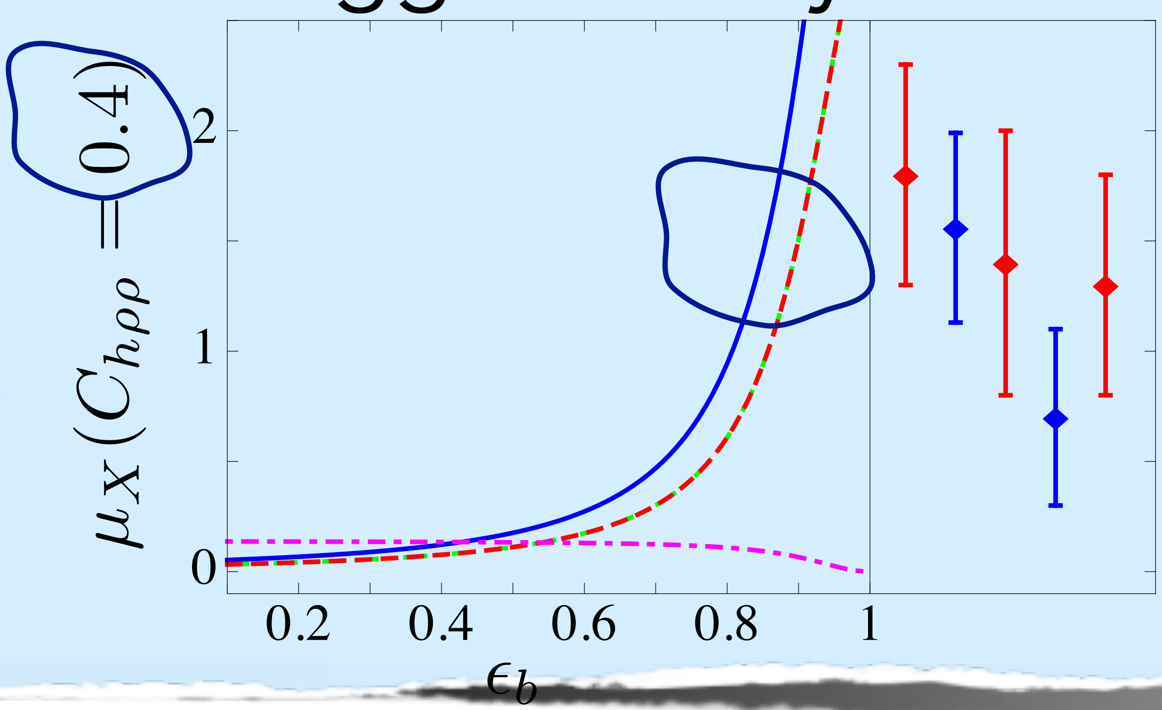
    $M_{\rm TSS,0} \simeq M_{A_1} \simeq 1$ TeV



- Can we explain the observed "Higgs" decay ?

  - ☑ Yes, we can !

    We need new vector meson



4. Summary (1/1)

- 126 GeV "Higgs" V.S.
  Higgs boson in Top-seesaw assisted technicolor
- Signal strength can be consistent
  with results reported at ICHEP
- We should check vector meson for completeness
  (e.g. EWPT, Zbb, ...)
- We should take into account tau-Higgs coupling
  to compare to results reported on HCP

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Thank you very much !!

Electroweak precision test

- vector-like fermion contributions : small
- coloron contribution : too small for $M_{\rm coloron} \simeq \Lambda = 50{\rm TeV}$
- main contribution = Higgs

Minimal Walking TC (MWT) :
SU(2) adjoint TC w/ 4th leptons