126 GeV Higgs boson and universality relations in the SO(5)xU(1) gauge-Higgs unification

Yutaka Hosotani

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Funatsu, Hatanaka, YH, Orikasa, Shimotani, 1301.1744

HPNP, Toyama, 15 February 2013

126 GeV Higgs boson
and universality relations
in the SO(5)xU(1) gauge-Higgs unification

126 GeV Higgs boson
and universality relations
in the SO(5)xU(1) gauge-Higgs unification

Higgs-like boson at 125-126 GeV

Hint for extra dimensions ?

Gauge-Higgs unification

A_M *in 5 dim.*

Gauge-Higgs unification

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4-dim. components A_μ

4D gauge fields

γ , W , Z

extra-dim. component A_y

4D Higgs fields

H

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Gauge-Higgs unification

A_M *in 5 dim.*

4-dim. components A_μ

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γ , W , Z

extra-dim. component A_y

4D Higgs fields

H

Aharonov-Bohm phase

θ_H

EW symmetry breaking

Hosotani mechanism

Gauge-Higgs unification in RS

input

$$m_Z,\ g_w,\ \sin^2\theta_W$$
$$m_t$$
$$m_H$$

Gauge-Higgs unification in RS

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$$m_t$$
$$m_H$$

Universality

$$\theta_H \ \Leftrightarrow\ m_{\rm KK}\ ,\ \lambda_3^H\ ,\ \lambda_4^H$$

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$m_Z,\ g_w,\ \sin^2\theta_W$

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m_H

Universality

$\theta_H \ \Leftrightarrow \ m_{\rm KK}\ ,\ \lambda_3^H\ ,\ \lambda_4^H$

Higgs production/decay

$H \to \gamma\gamma\ ,\ gg$ close to SM

SO(5)xU(1) gauge-Higgs unification in RS

Model I

Agashe, Contino, Pomarol, 2005
YH, Oda, Ohnuma, Sakamura 2008
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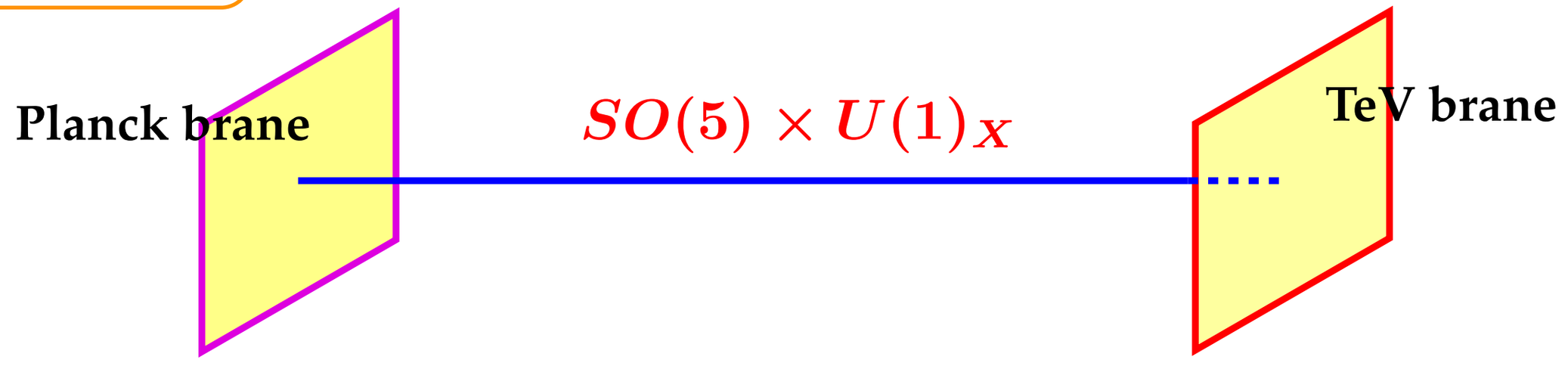

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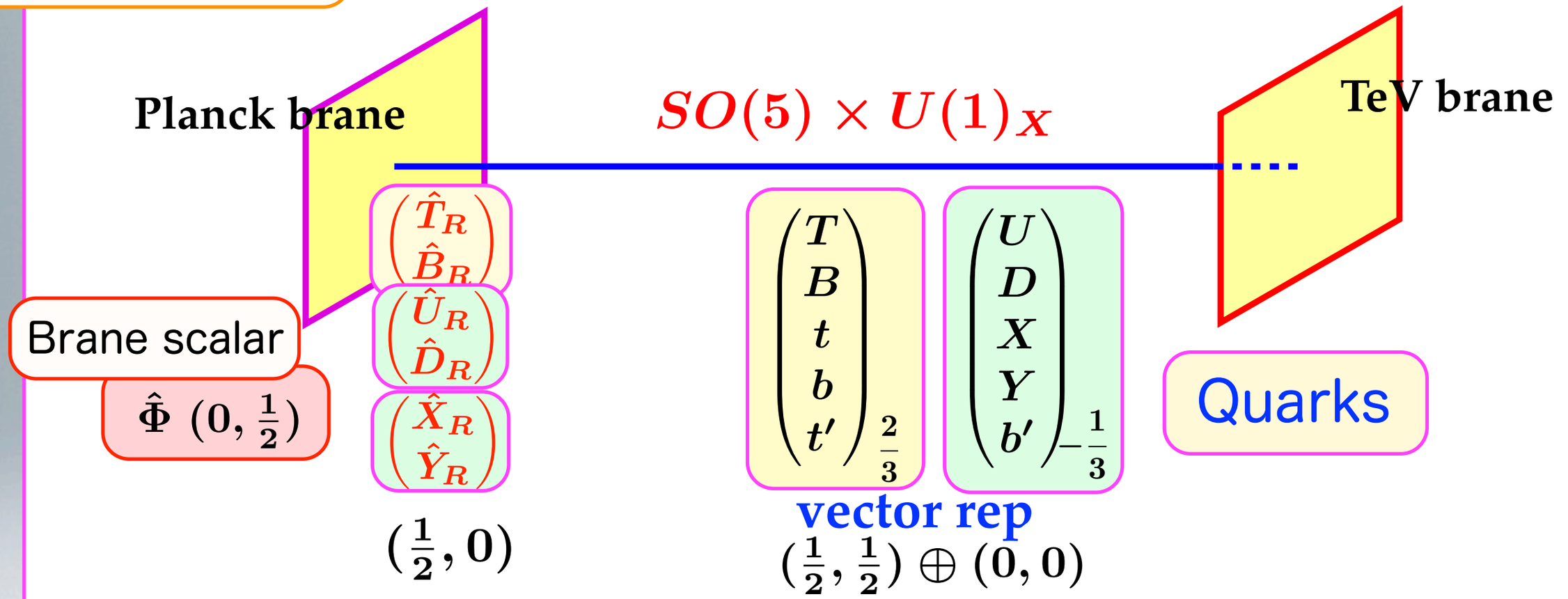

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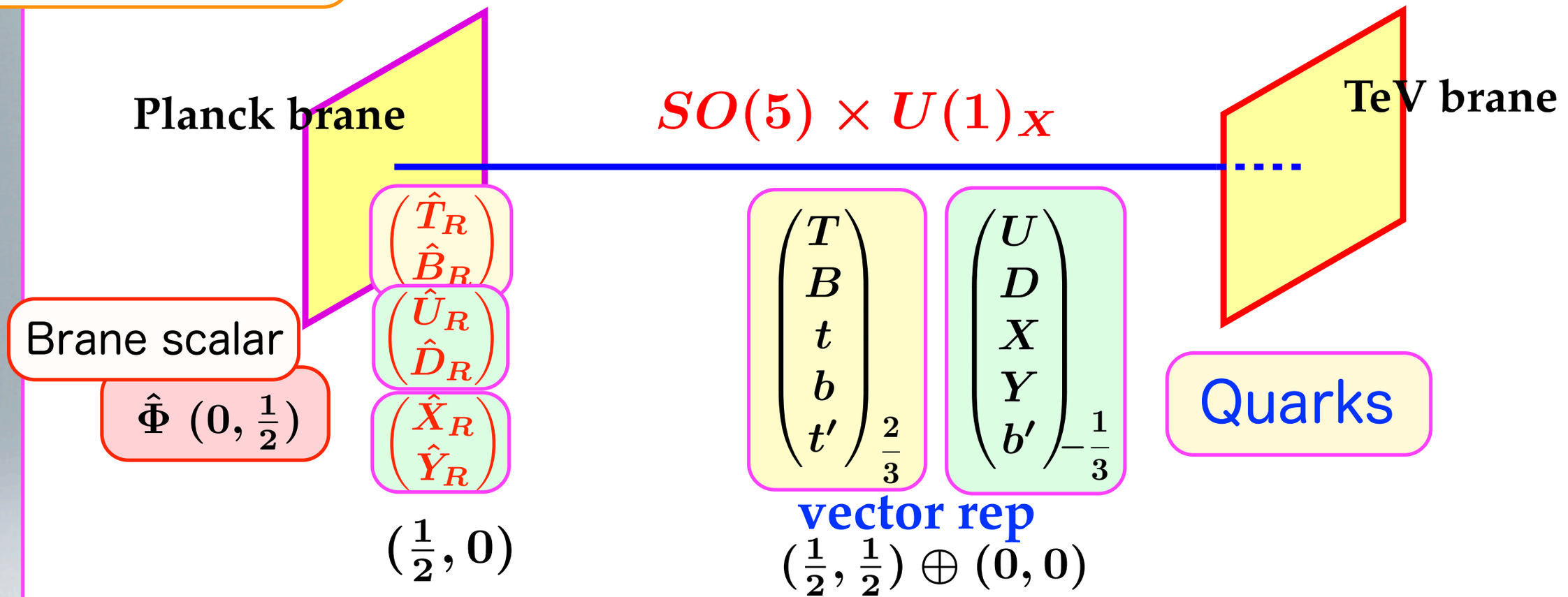


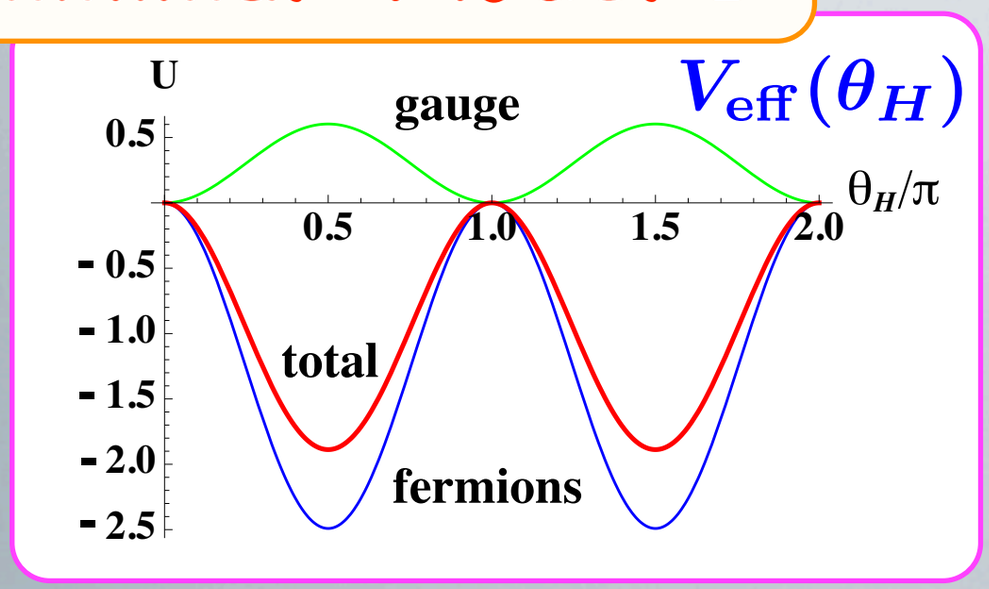
$SO(5) \times U(1)_X$

$\Rightarrow$ B.C. $SO(4) \times U(1)_X$

Hosotani mechanism

$\Rightarrow SU(2)_L \times U(1)_Y \Rightarrow U(1)_{EM}$ ($\theta_H \neq 0$)

"minimal" Model I



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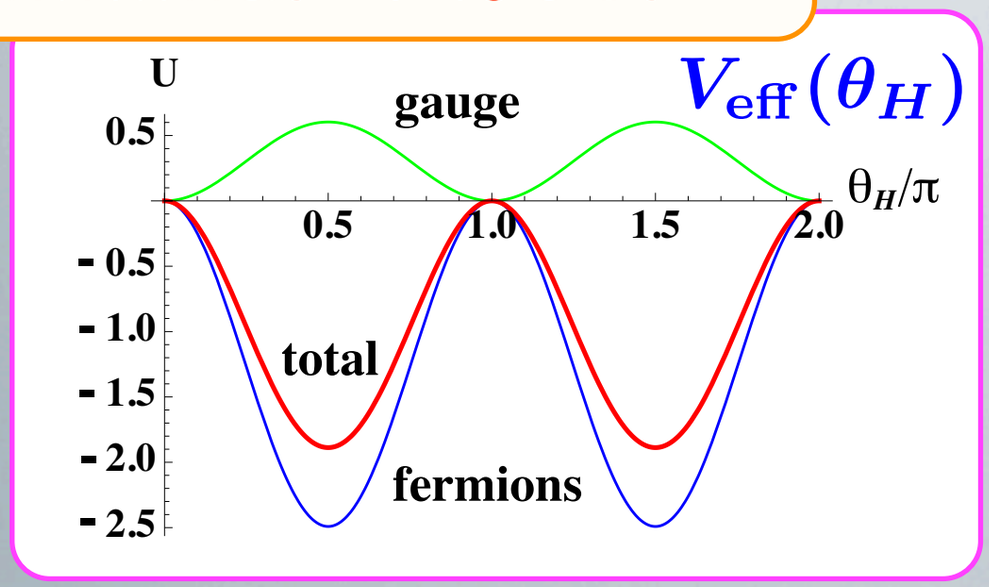

$\theta_H = \dfrac{\pi}{2}$

stable Higgs !?

☹

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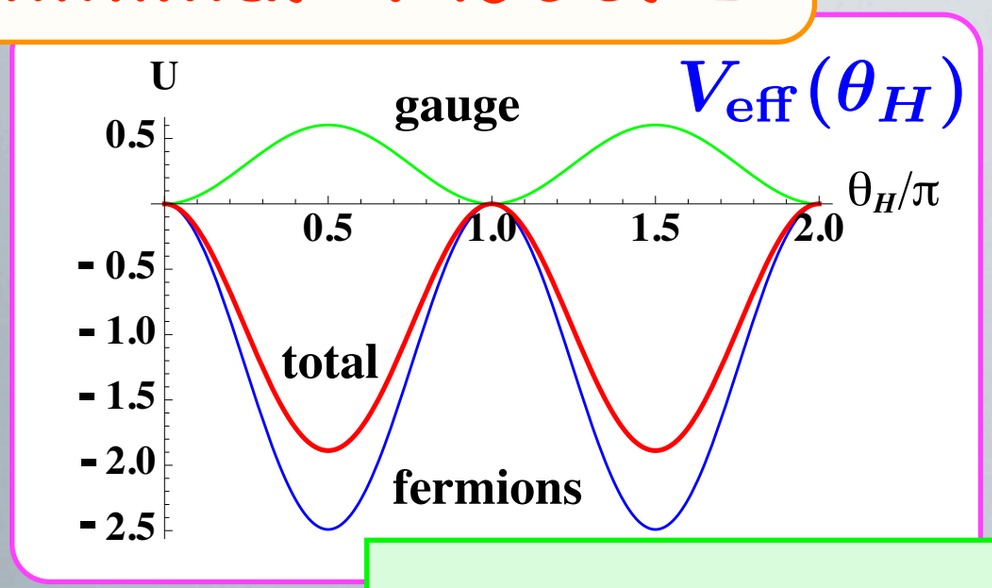

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Need something which breaks H parity.

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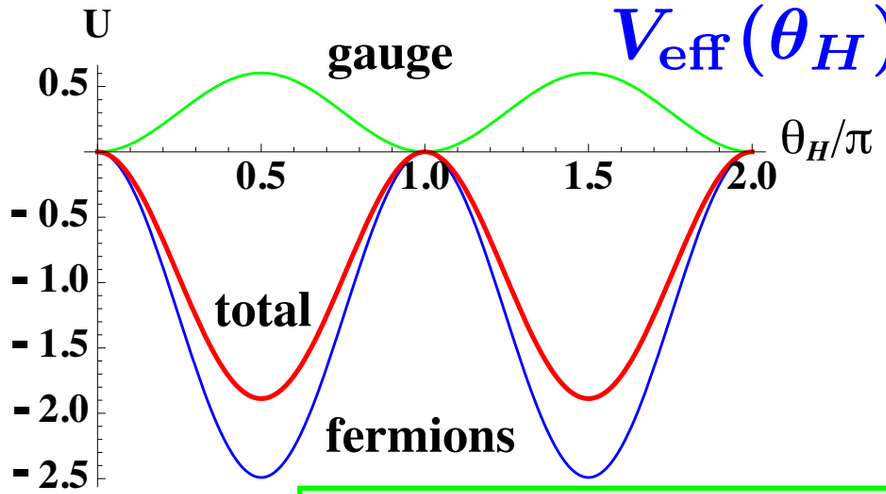

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new Model II

Funatsu, Hatanaka, YH, Orikasa, Shimotani, 1301.1744

Add n_F extra fermions Ψ_F in the spinor rep.

$$\Psi_F(x,-y) = P_0\gamma_5\Psi_F(x,y)$$
$$\Psi_F(x,L-y) = -P_1\gamma_5\Psi_F(x,L+y)$$

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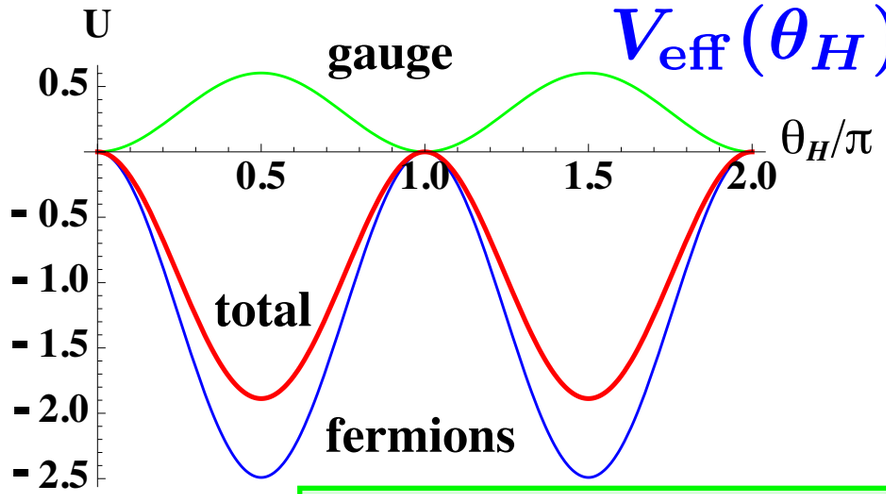

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Physics turns out independent of n_F

$V_{\rm eff}(\theta_H)$ & m_H

$V_{\rm eff}(\theta_H)$ & m_H

parameters

$k,\ z_L = e^{kL},\ g_A,\ g_B$

$c_t,\ \tilde{\mu}/\mu_2$

$c_F,\ n_F$

input

$m_Z,\ g_w,\ \sin^2\theta_W$

$m_t,\ m_b$

m_H

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$V_{\rm eff}(\theta_H)$ & m_H

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$k,\ z_L = e^{kL},\ g_A,\ g_B$

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input

$m_Z,\ g_w,\ \sin^2\theta_W$

$m_t,\ m_b$

m_H

$$\theta_H \ :\ \frac{dV_{\rm eff}}{d\theta_H} = 0$$

$$m_H^2 = \frac{1}{f_H^2}\frac{d^2V_{\rm eff}}{d\theta_H^2}\bigg|_{\rm min}$$

$m_H = 126\,{\rm GeV}$

⇓

$\theta_H(z_L, n_F)$

⇓

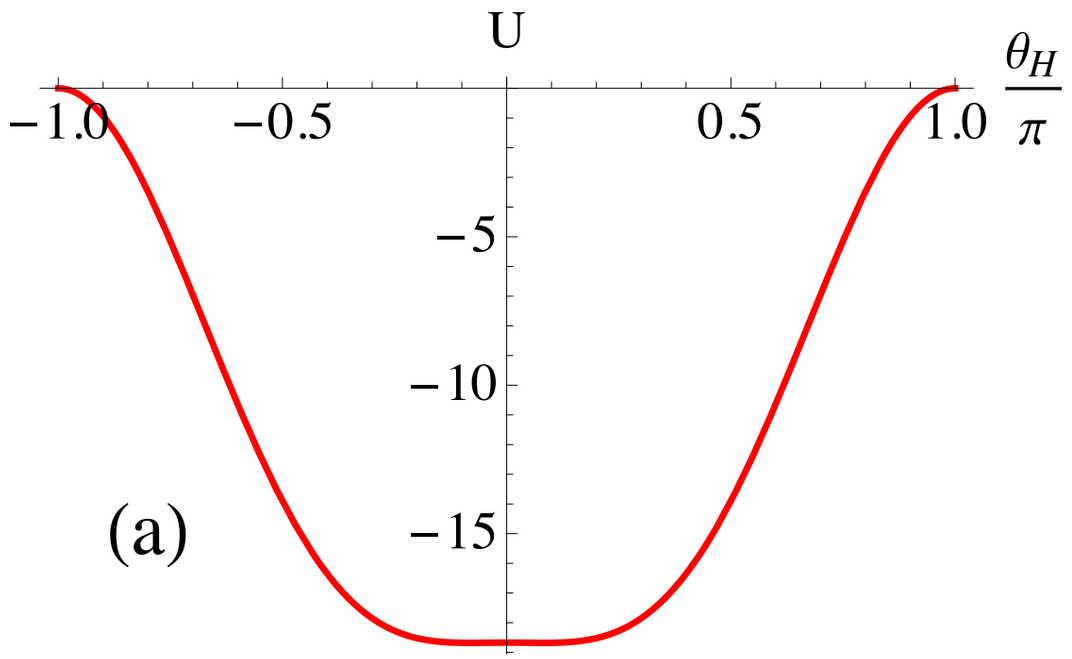
gauge couplings

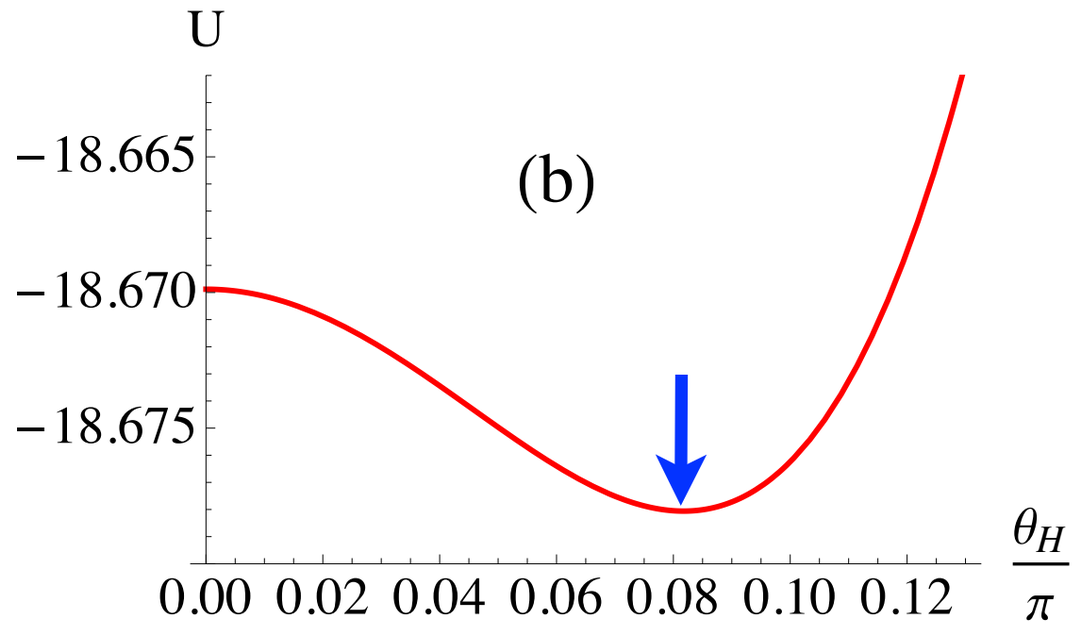
Higgs couplings

KK spectrum

$$V_{\rm eff} = \left(\frac{m_{\rm KK}}{2\pi}\right)^4 U$$

$$n_F = 3\ ,\ z_L = 10^7$$
$$c_t = 0.330\ ,\ c_F = 0.353$$





$$\theta_H = 0.258$$

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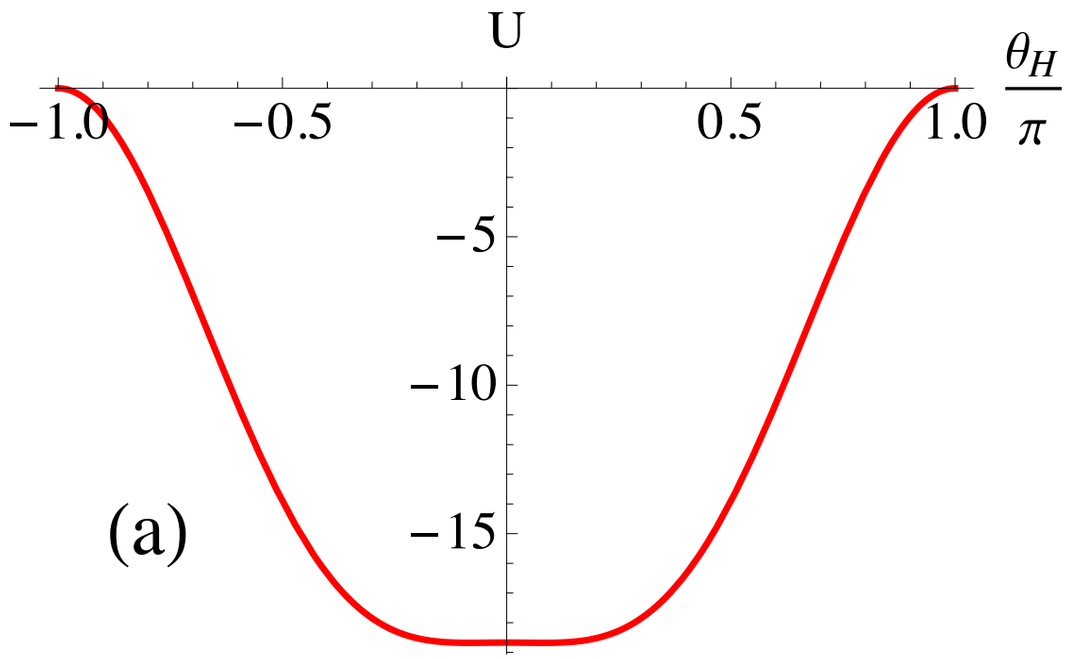
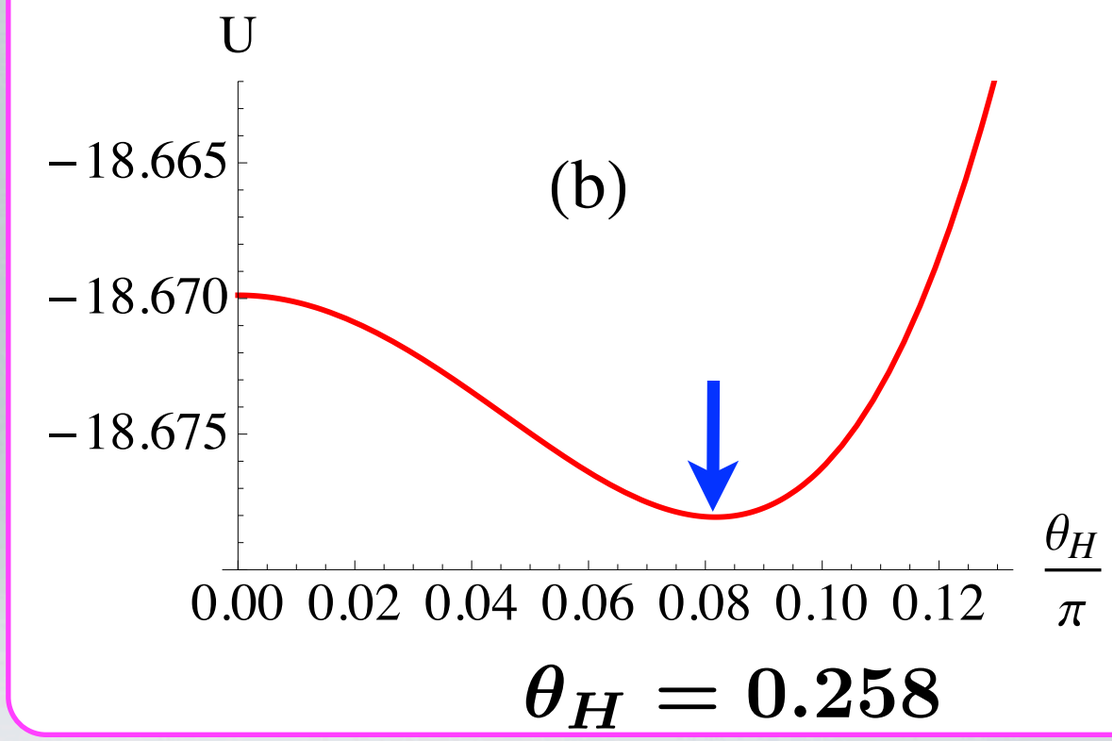
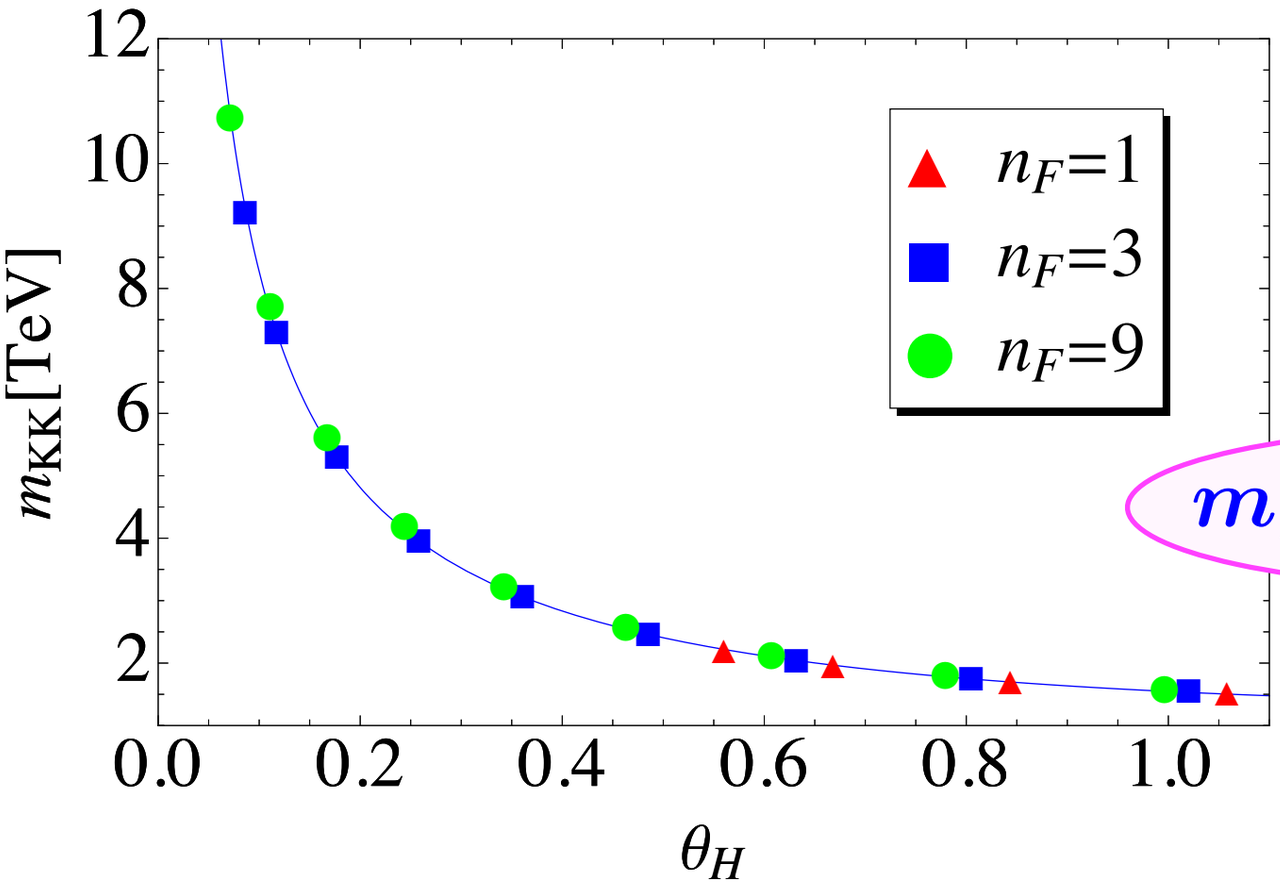




$$\theta_H = 0.258$$

EW symmetry breaking takes place.
Higgs-like boson at 126 GeV.

$\theta_H(z_L, n_F)$ & $m_{\mathrm{KK}}(z_L, n_F)$



input

$m_H = 126\,\mathrm{GeV}$

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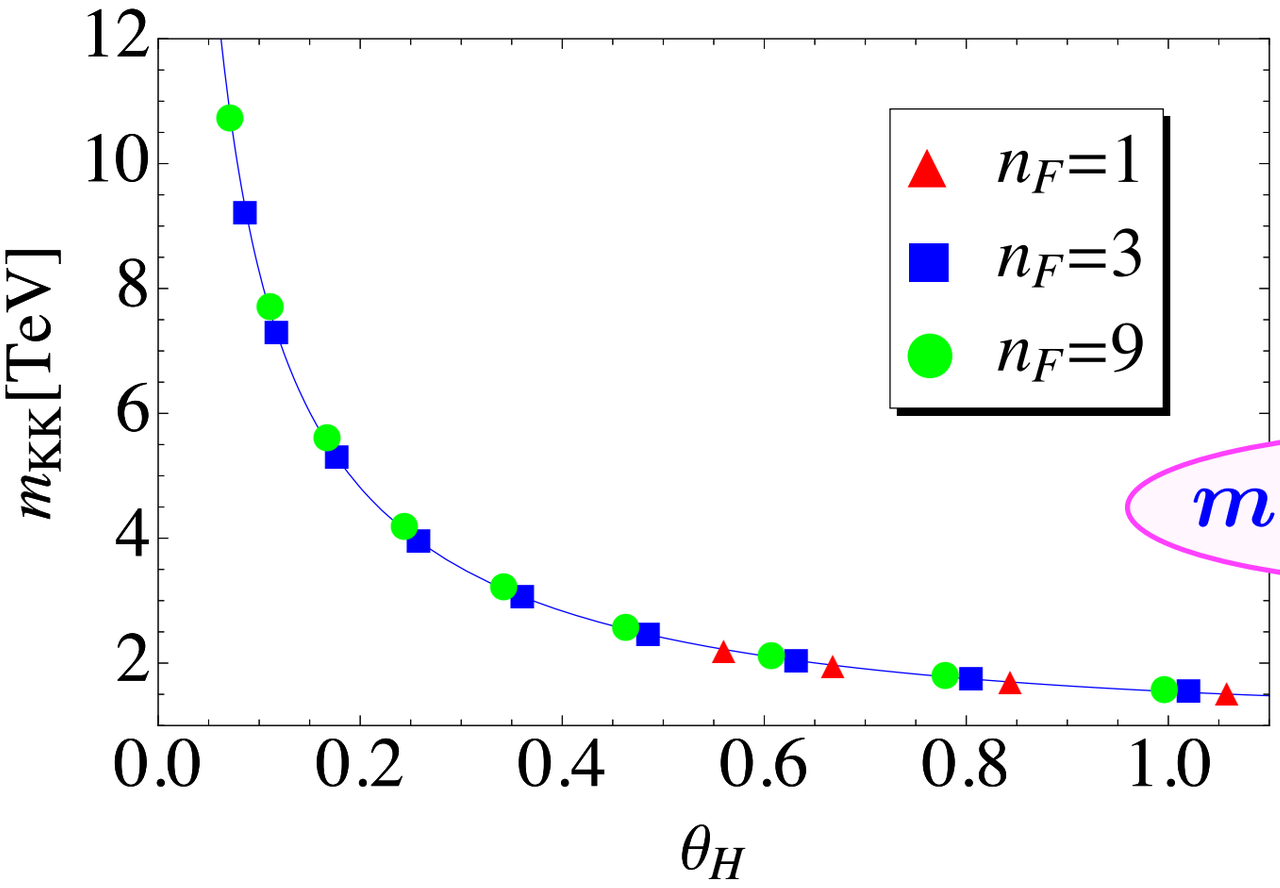
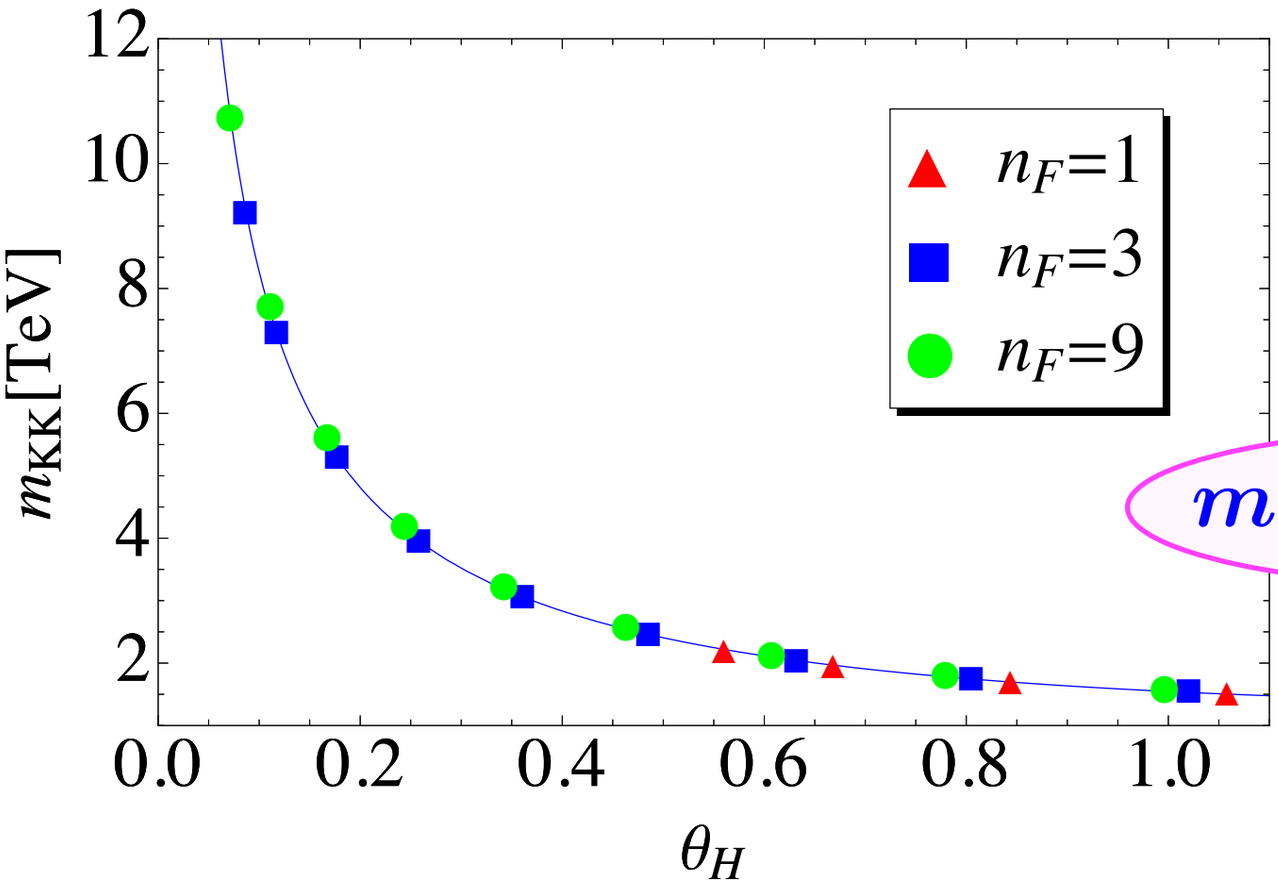


input

$m_H = 126\,\mathrm{GeV}$

Universality

$\theta_H(z_L, n_F)$ & $m_{\rm KK}(z_L, n_F)$



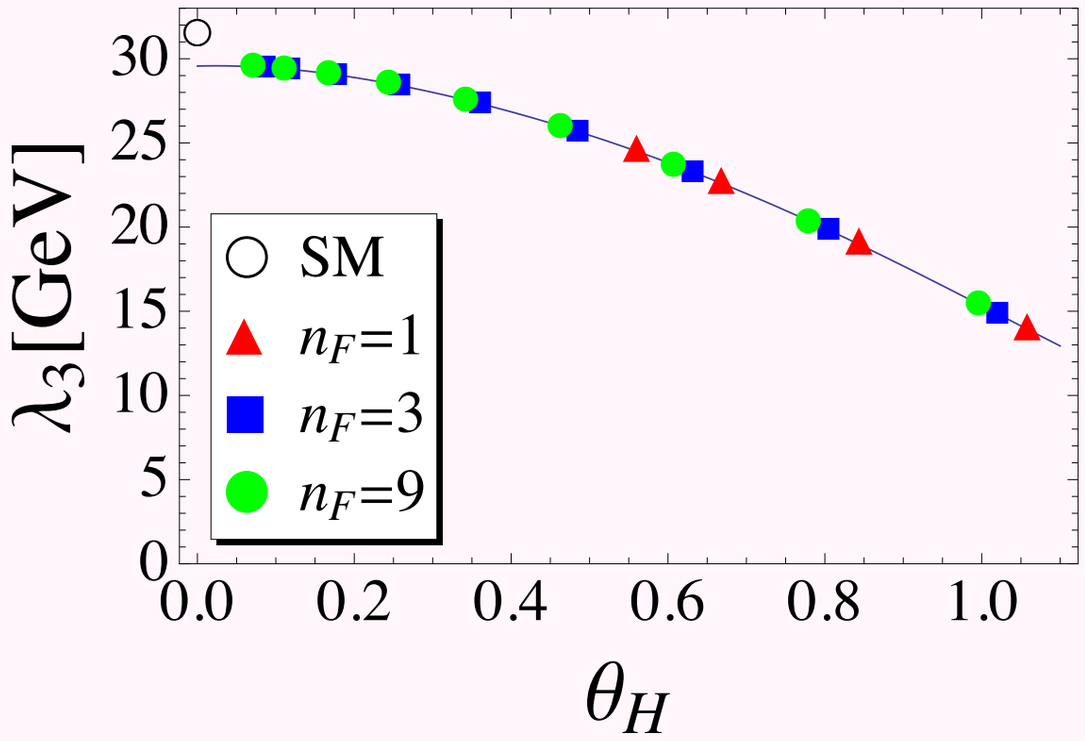
input

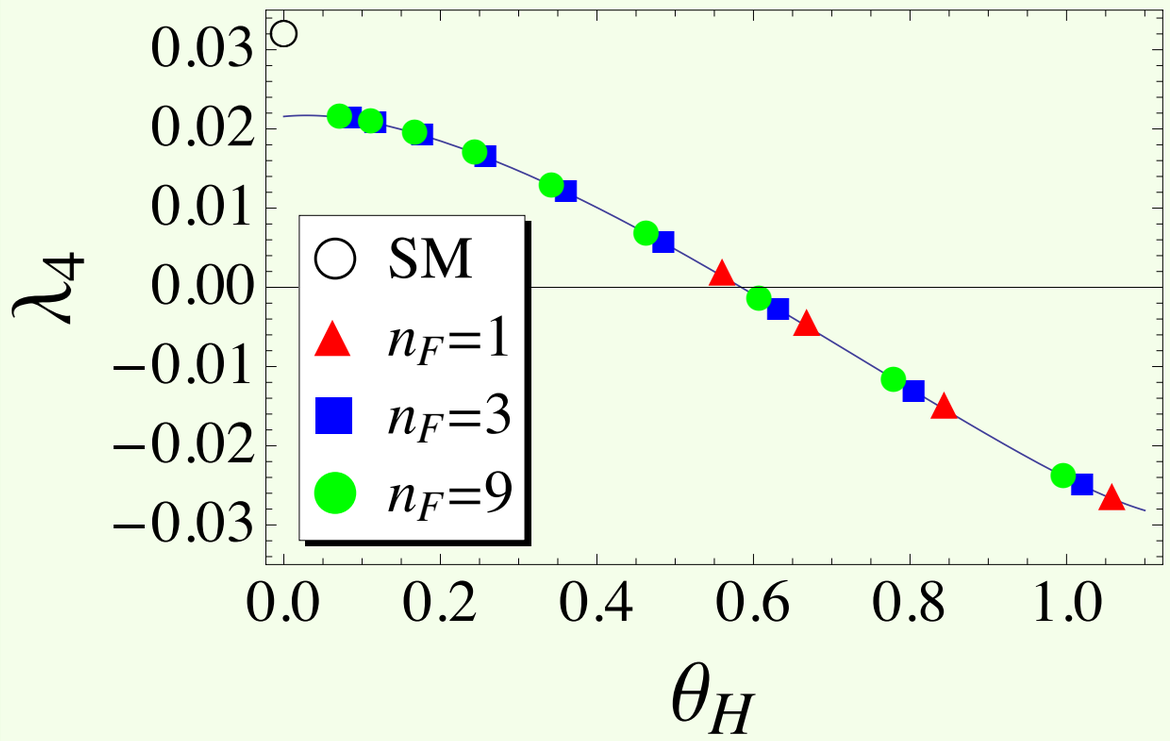
$m_H = 126\,\mathrm{GeV}$

Universality

$$m_{\rm KK} \sim \frac{1350\,\mathrm{GeV}}{(\sin\theta_H)^{0.787}}$$

Higgs self couplings





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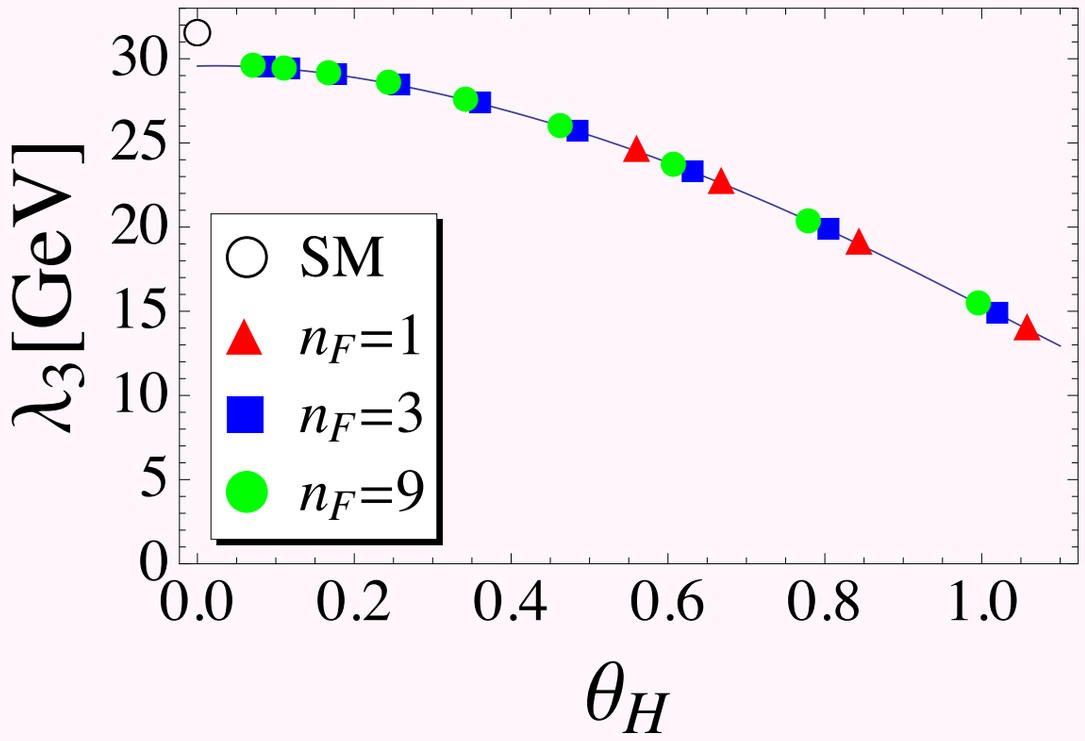

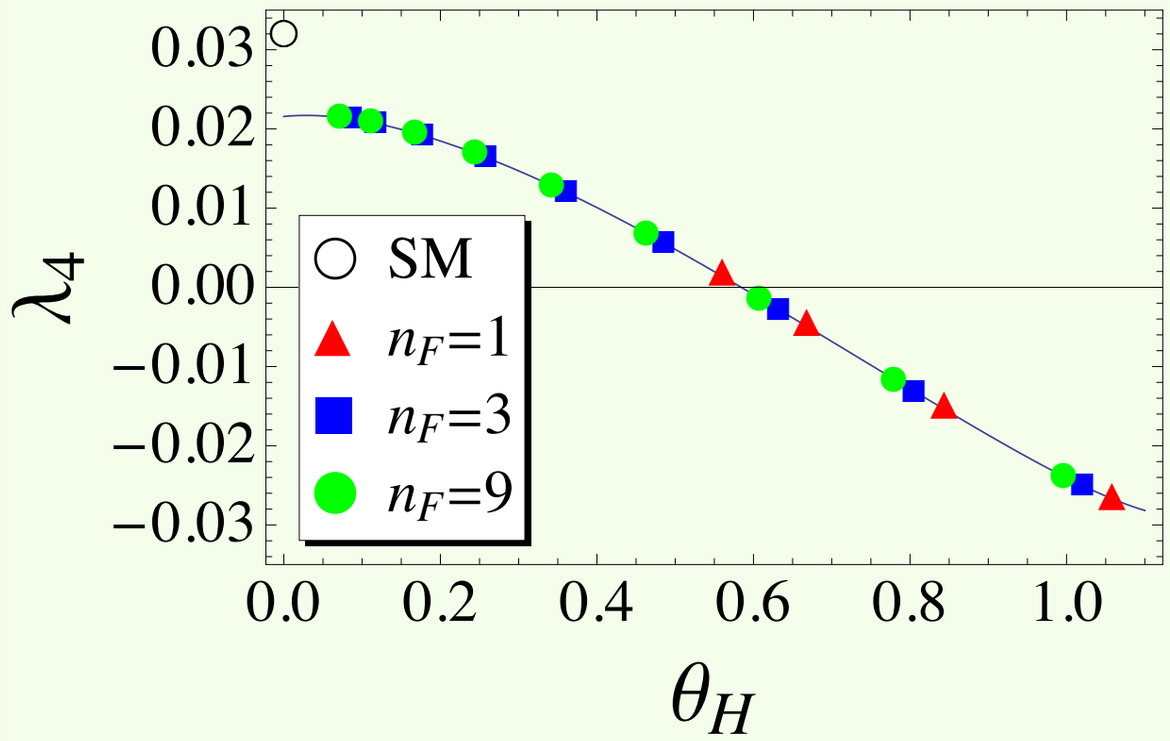

Universality

Higgs boson: Production and decay rates

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$$\left.\begin{matrix} WWH \\ ZZH \\ Yukawa \end{matrix}\right\} = SM \times \cos\theta_H$$

Suppression at tree level

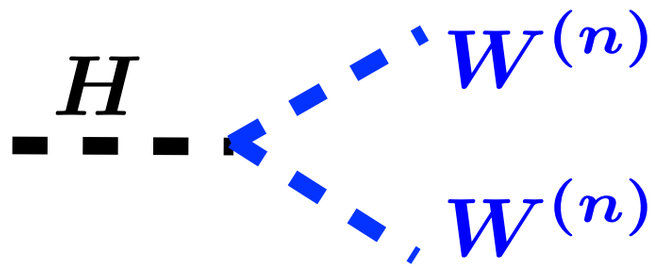
Higgs boson: Production and decay rates

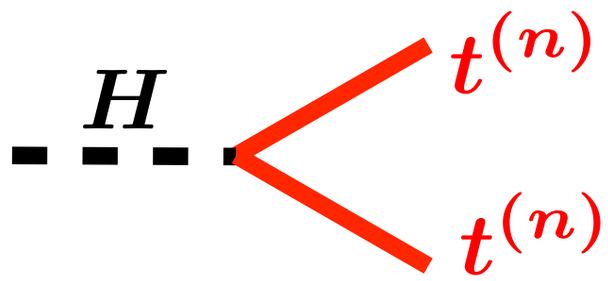
$$\left.\begin{matrix} WWH \\ ZZH \\ Yukawa \end{matrix}\right\} = SM \times \cos\theta_H$$

Suppression at tree level

$$gg \to H \quad , \quad H \to \gamma\gamma \, , \, gg$$

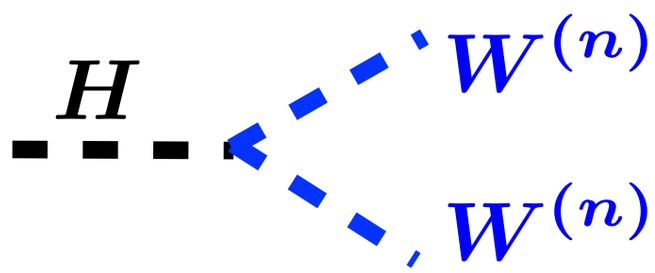
Enhanced ?

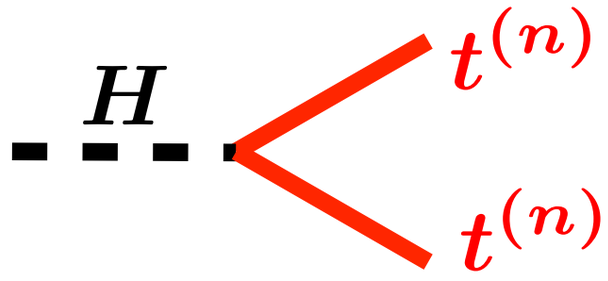




$$I_{W^{(n)}} = \frac{g_{HW^{(n)}W^{(n)}}}{g_w m_{W^{(n)}} \cos\theta_H}$$

$$I_{t^{(n)}} = \frac{y_{t^{(n)}}}{y_t^{\mathrm{SM}} \cos\theta_H}$$





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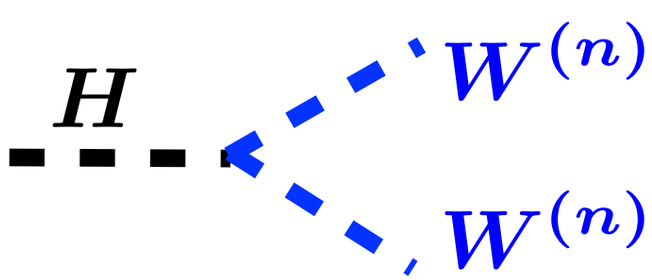
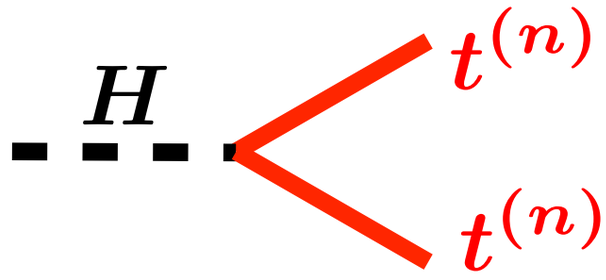
For $\theta_H = 0.360$

$$I_{W^{(0)}} = 1.004$$
$$I_{t^{(0)}} = 1.012$$





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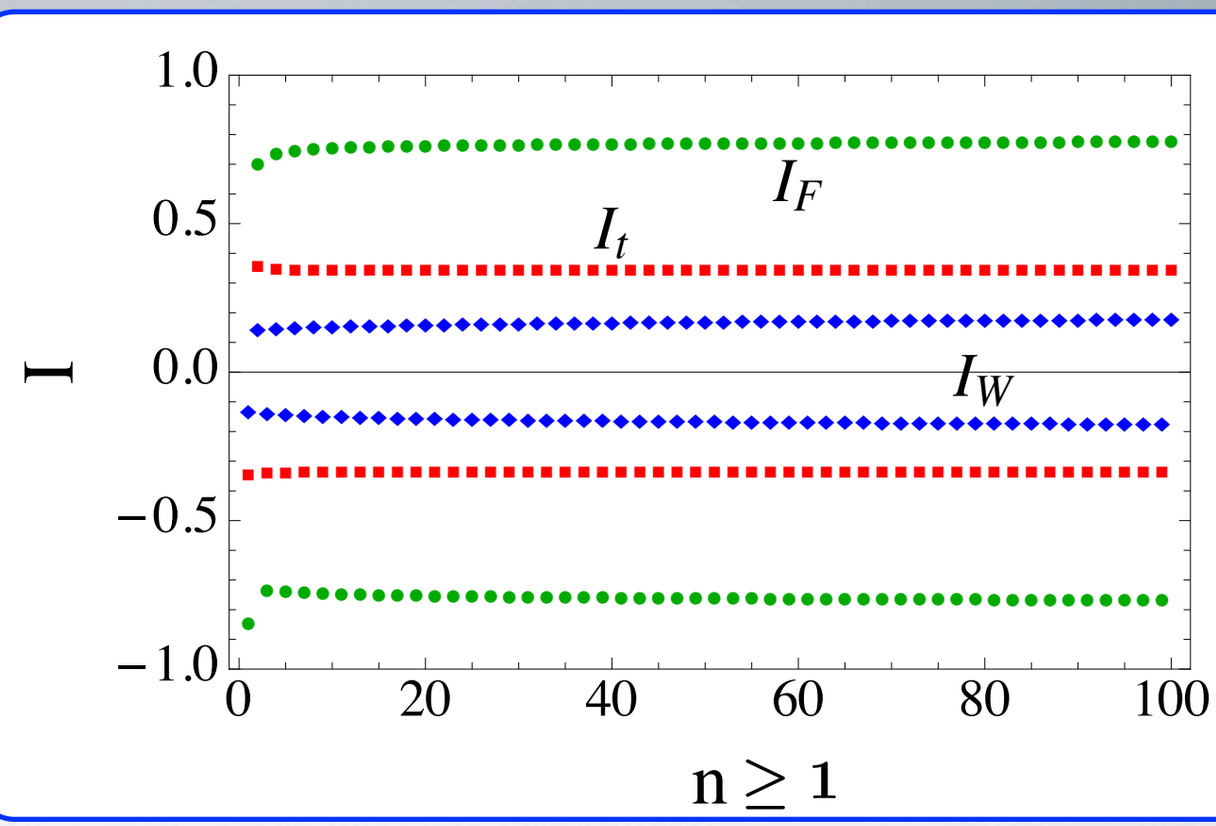

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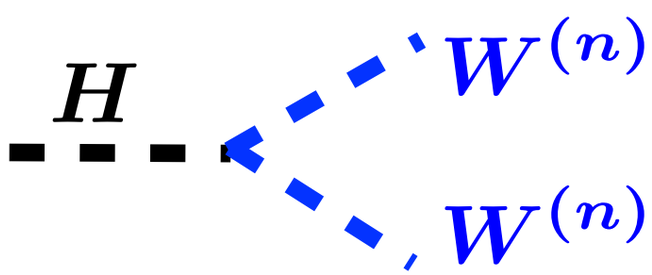

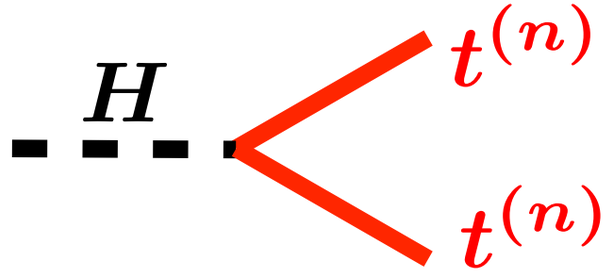

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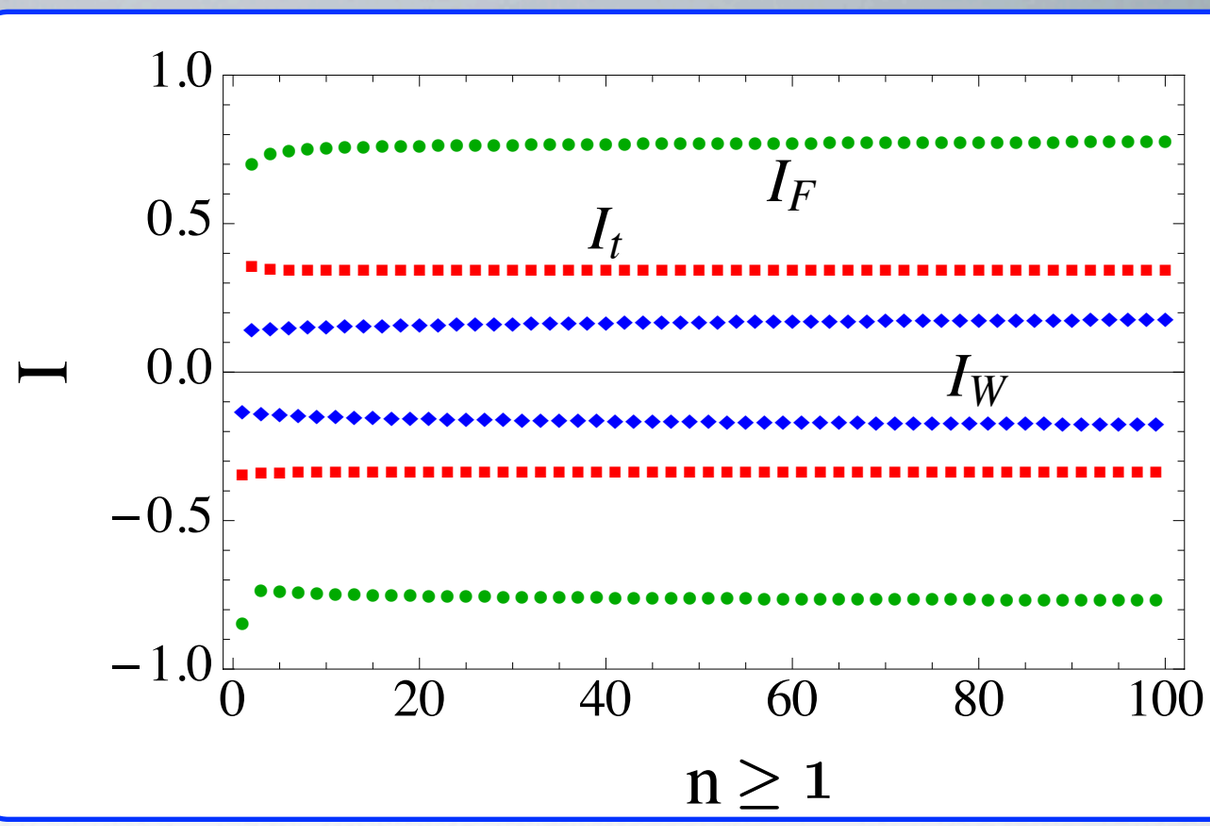
Sign alternates.

$n = 1, 2, 3, \ldots$



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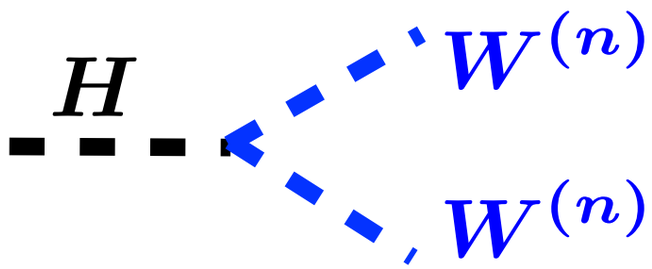

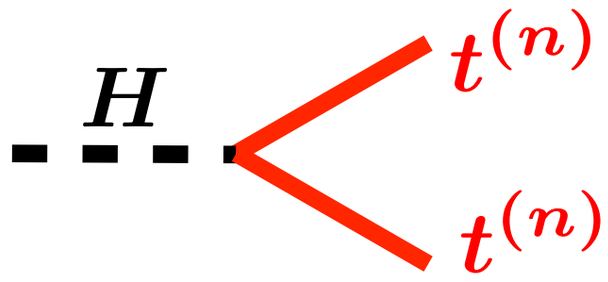

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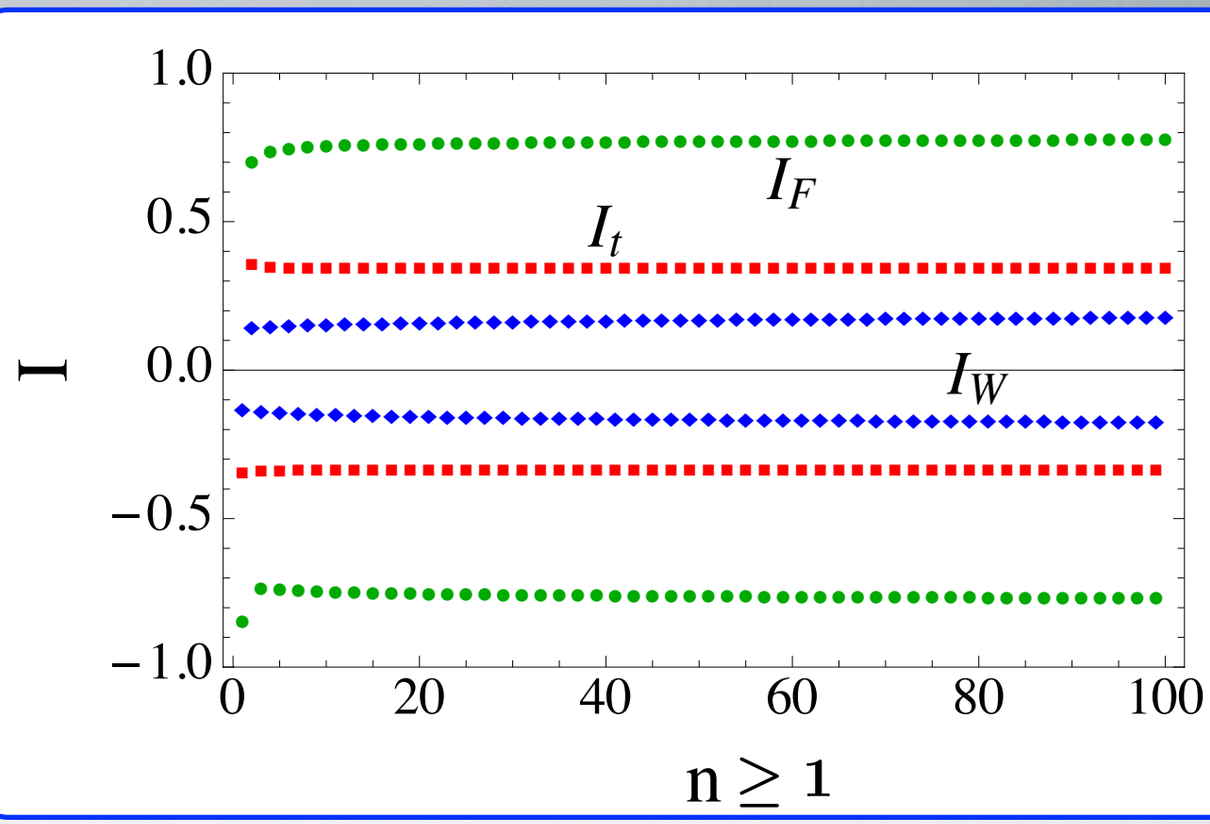
destructive interference

Maru, Okada, 2008
Falkowski, 2008



in sharp contrast to UED

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$H \to \gamma\gamma$

$$\Gamma(H \to \gamma\gamma) = \frac{\alpha^2 g_w^2}{1024\pi^3} \frac{m_H^3}{m_W^2} \left| \mathcal{F}_{\text{total}} \right|^2$$

$$\mathcal{F}_{\text{total}} = \mathcal{F}_W + \frac{4}{3}\mathcal{F}_t + \frac{1}{2} n_F \mathcal{F}_F$$

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θ_H	0.117	0.360
$\mathcal{F}_{W^{(0)}}$	8.330	7.873
$\mathcal{F}_W/\mathcal{F}_{W^{(0)}}$	0.9996	0.998
$\mathcal{F}_{t^{(0)}}$	-1.372	-1.305
$\mathcal{F}_t/\mathcal{F}_{t^{(0)}}$	0.998	0.990
$\mathcal{F}_F/\mathcal{F}_{t^{(0)}}$	-0.0034	-0.033
$\mathcal{F}_{\rm total}$	6.508	6.199
$\mathcal{F}_{\rm total}/(\mathcal{F}_{W^{(0)}} + \mathcal{F}_{t^{(0)}})$	1.001	1.011

Corrections due to KK W and top :

0.1 % - 1 % for θ_H = 0.1 - 0.3.

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All decay rates $\Gamma(H \to b\bar{b}, c\bar{c}, \cdots, WW, ZZ, \gamma\gamma, gg)$

$$\sim \Gamma^{\rm SM} \times \cos^2 \theta_H$$

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Branching fraction $B(H \to j) \sim B^{\rm SM}(H \to j)$

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$$\sigma^{\rm prod}(H) \cdot B(H \to \gamma\gamma) \sim ({\rm SM}) \times \cos^2 \theta_H$$

$$0.99 \sim 0.91$$

Corrections due to KK W and top :

0.1 % - 1 % for θ_H = 0.1 - 0.3.

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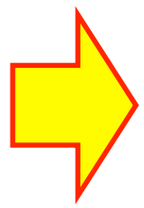
S parameter
Tree unitarity
Z′ search



$$\theta_H < 0.3$$

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Summary

Gauge-Higgs unification with m_H 126GeV

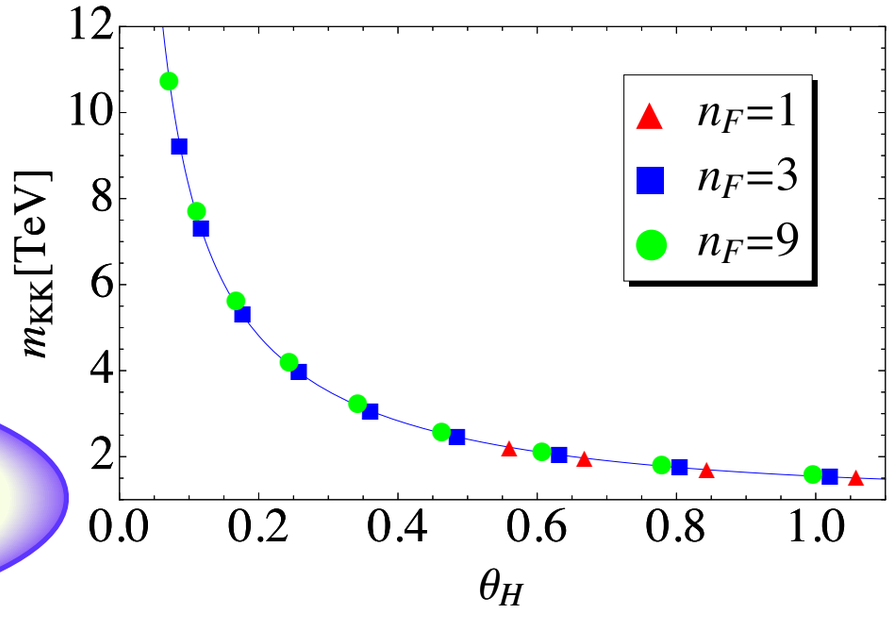
Summary

Gauge-Higgs unification with m_H 126GeV

Universality

$$\theta_H, m_{\rm KK}, \lambda_3^H, \lambda_4^H, m_{Z^{(1)}}$$

$$m_{\rm KK} \sim \frac{1350\,{\rm GeV}}{(\sin\theta_H)^{0.787}}$$



Summary

Gauge-Higgs unification with m_H 126GeV

Universality

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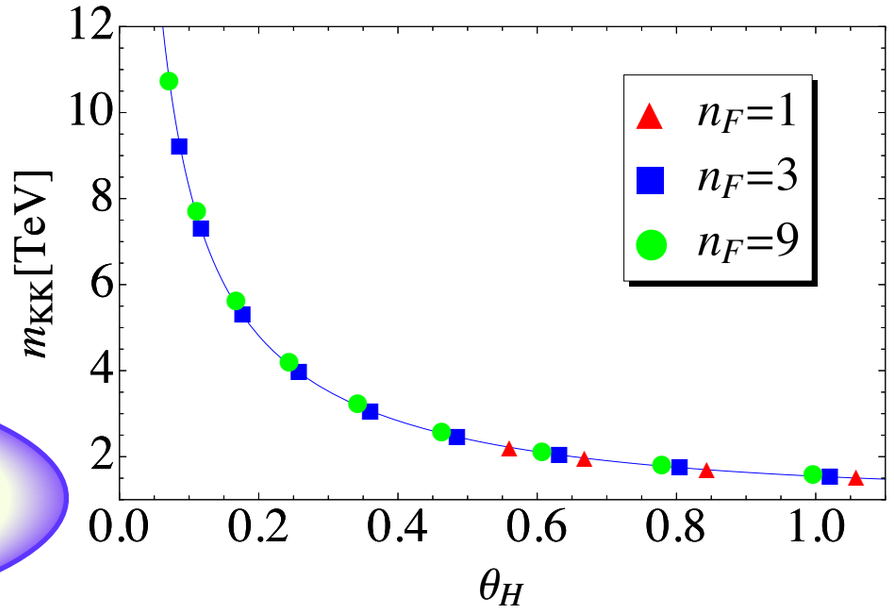

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Low energy physics : close to SM

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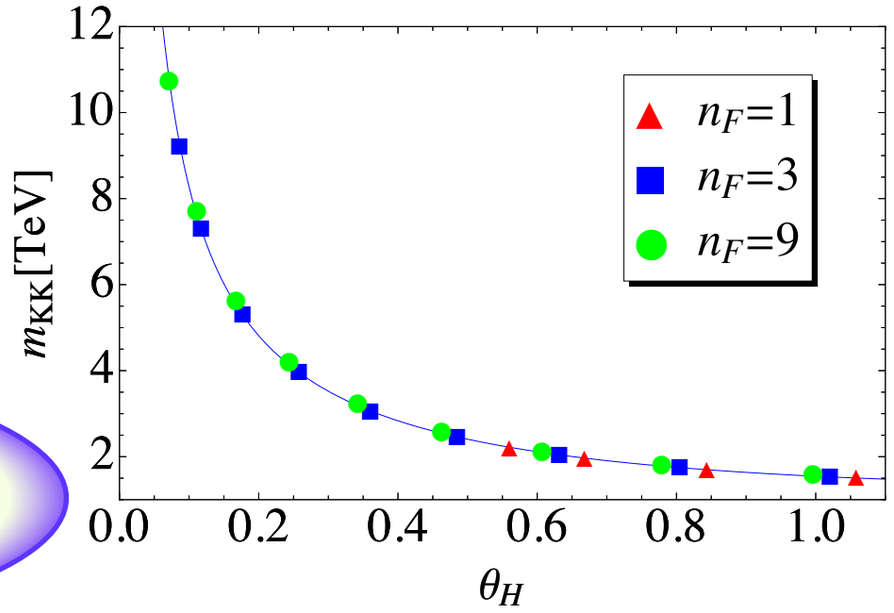

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Signals

$Z^{(1)}$: $5.9 \sim 2.4\,{\rm TeV}$
$(\theta_H : 0.12 \sim 0.36)$

λ_3^H , λ_4^H

$F^{(1)}$, $\bar{F}^{(1)}$: stable
$({\rm exp} : m_{F^{(1)}} > 0.5\,{\rm TeV})$