The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2400-6

Workshop on Strongly Coupled Physics Beyond the Standard Model

25 - 27 January 2012

The 4D Composite Higgs

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The 4D Composite Higgs

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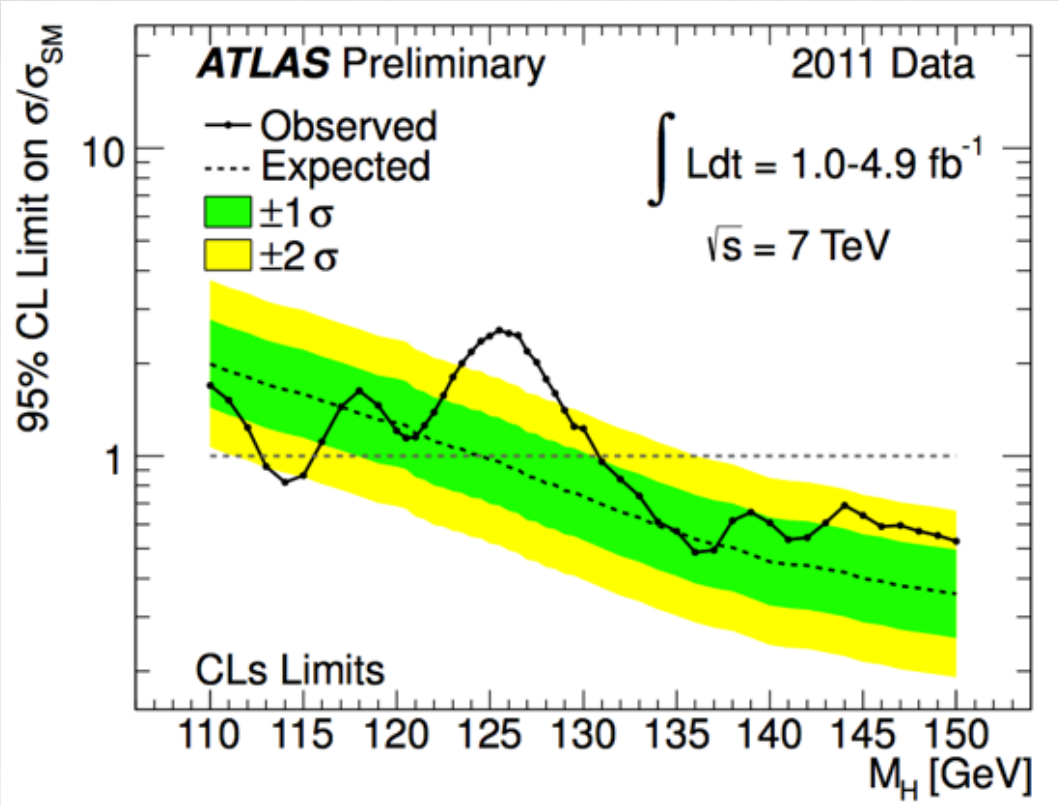
with Stefania de Curtis
and Andrea Tesi
arxiv:1110.1613[hep-ph]
+ work in progress

Trieste, 27 January



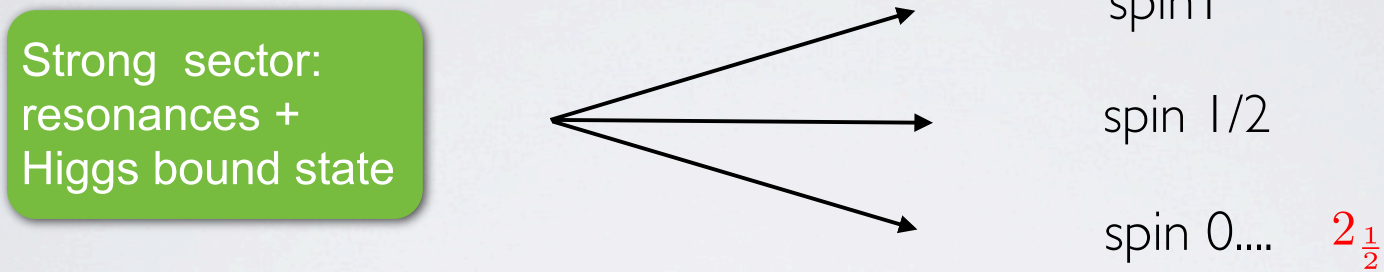
Technicolor:

Light Higgs ok for composite models

COMPOSITE HIGGS

Georgi, Kaplan '80s

Logical possibility:
Higgs doublet is a light remnant of strong dynamics.



Two parameters:

m_ρ $\qquad$ g_ρ $\qquad$ $\left(g_\rho = \frac{4\pi}{\sqrt{N}}\right)$

Relieves hierarchy problem:

$$\delta m_h^2 \sim \frac{3\,\lambda_t^2}{4\pi^2} m_\rho^2$$

Particularly compelling if the Higgs is a Goldstone Boson:

Massless at leading order:

Ex: $\frac{SO(5)}{SU(2)_L \otimes SU(2)_R} \longrightarrow GB = (2,2)$

Agashe , Contino,Pomarol '04

Contino, da Rold, Pomarol, '06

Low energy lagrangian:

$$\mathcal{L} = f^2 \, D_\mu \Sigma^i D^\mu \Sigma^i + \ldots \xrightarrow{SU(2)_L \otimes SU(2)_R} \rho = \frac{m_W^2}{m_Z^2 \cos\theta_W} \approx 1$$

Extended Higgs sectors:

Ex: $\frac{SO(6)}{SO(5)}$ $\frac{SO(6)}{SO(4) \otimes U(1)}$ $\frac{SU(5)}{SU(4) \otimes U(1)}$ $+ \ldots$

Gripaios, Pomarol, Riva, Serra '09

Mrazek, Pomarol, Rattazzi, MR, Serra, Wulzer '11

Main difference from techni-color is that f is not linked to v. Increasing f CH approximates SM.

$$\mathrm{TUNING} \sim \frac{\mathrm{v}^2}{\mathrm{f}^2}$$

Spectrum:

$m_\rho \sim 3\,\mathrm{TeV}$

$m_\rho = g_\rho f$

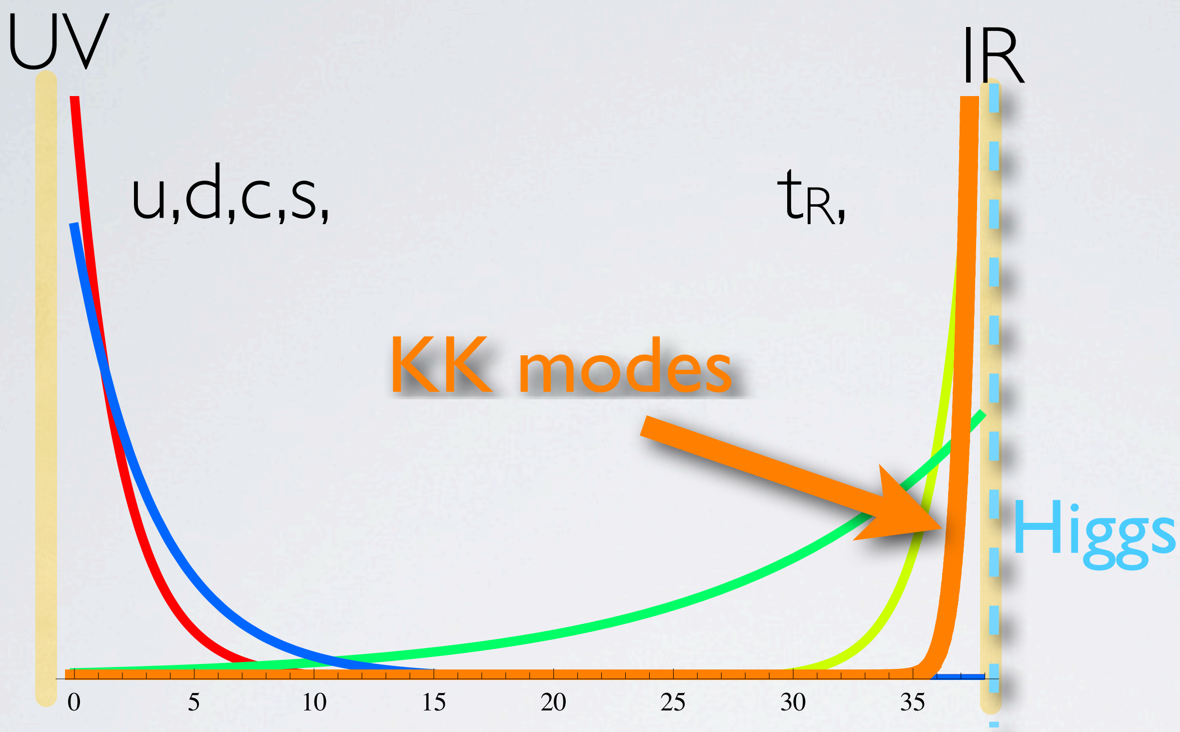
$m_h = ?$

$m_W = 80\,\mathrm{GeV}$

0

Reasonable phenomenology can be obtained for $m_\rho \sim 3\,\mathrm{TeV}$

Recent progress started with Randall-Sundrum constructions.



(Randall-Sundrum '99)

$$ds^2 = e^{-2kry}(-dt^2 + dx^2) + dy^2$$

5D = Effective description of strongly coupled theories

Arkani-Hamed, Porrati, Randall '01

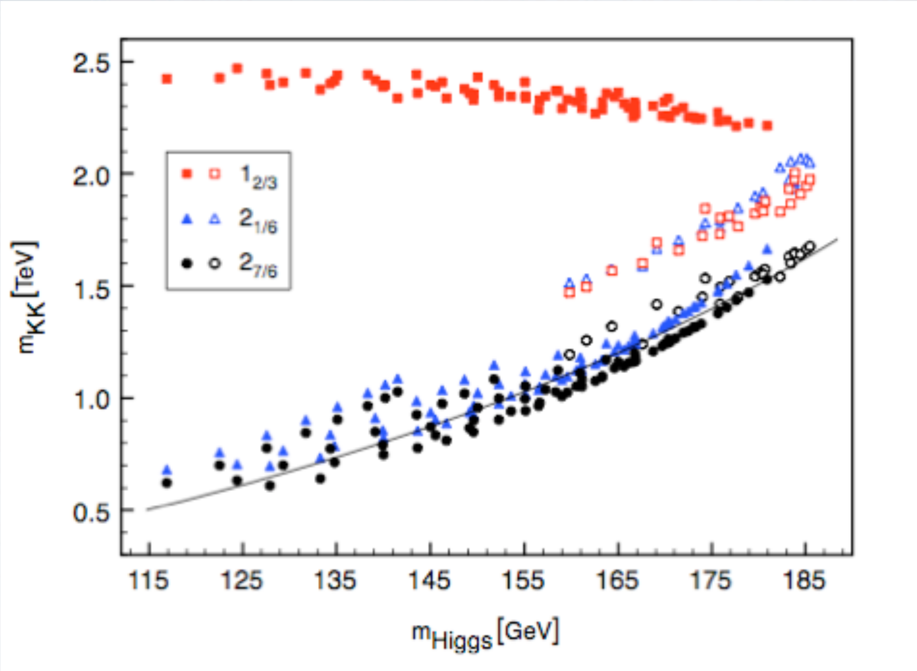
Rattazzi, Zaffaroni '01

Inspired by AdS/CFT but metric not very important.

Panico, Safari, Serone '10

Becciolini, MR, Wulzer '09

When 5D theory weakly coupled (large N), one can compute. CHM5:



(Contino, da Rold, Pomarol '06)

In practice the 5D theory cannot be very weakly coupled

$$\Lambda = \frac{16\pi^2}{g_5^2} \qquad N_{eff} = \frac{\Lambda}{m_\rho} \qquad \hat{S} \sim \frac{N_{eff}}{16\pi^2}\frac{v^2}{f^2}$$

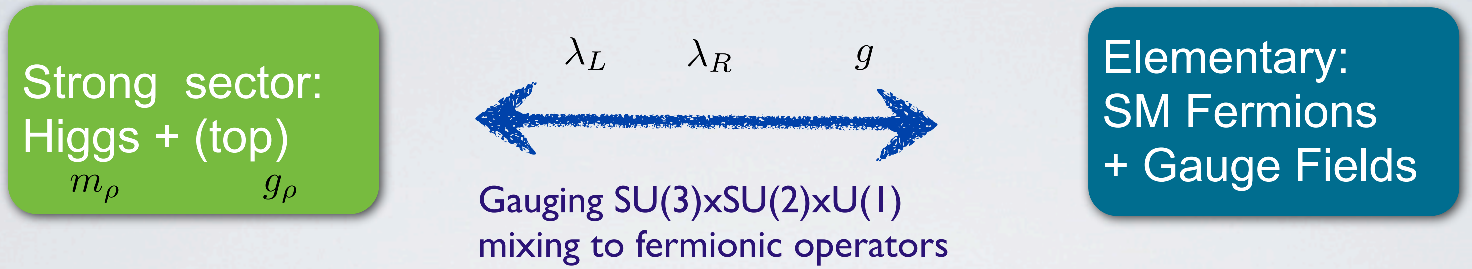
Phenomenologically strong coupling required!

Necessary a useful 4D description:

- theoretical:
  - only very few resonances (1?) weakly coupled
  - relevant physics largely independent of 5D or AdS
  - what are the most general models?

- practical:
  - LHC will at best produce the lightest resonances
  - Simplified model useful for LHC

General picture:



They talk through linear couplings:

$$\mathcal{L}_{gauge} = g\, A_\mu J^\mu$$

$$\mathcal{L}_{mixing} = \lambda_L \bar{f}_L O_R + \lambda_R \bar{f}_R O_R \quad \xrightarrow{\tan\varphi \sim \frac{\lambda}{g_\rho}} \quad y \sim \frac{\lambda_L \lambda_R}{g_\rho}$$

Potential generated at 1-loop:

$$V(H) \propto \frac{m_\rho^4}{g_\rho^2} \frac{\lambda_{L,R}^2}{16\pi^2} \hat{V}\left(\frac{H}{f}\right)$$

Already on the market:

- Simplified two-sector model:

  Contino, Kramer, Son, Sundrum '06 $(f \to \infty)$

- Low energy effects

  Giudice, Grojean, Pomarol, Rattazzi '07

  Barbieri, Bellazzini, Rychkov, Varagnolo '07

- 3-site model

  Panico, Wulzer '11

Take G broken to H. Low energy lagrangian determined by symmetries. CCWZ:

$$U(\Pi) = e^{\frac{i\Pi^{\widehat{a}}T^{\widehat{a}}}{f}} \qquad U(\Pi') = gU(\Pi)h^\dagger(\Pi, g) \quad g \in G, \quad h \in H(x)$$

$$U^\dagger \partial_\mu U = iE_\mu^a T^a + iD_\mu^{\widehat{a}} T^{\widehat{a}}$$

GB lagrangian

$$\mathcal{L} = \frac{f^2}{2} D_\mu^{\widehat{a}} D^{\mu \widehat{a}}$$

Matter couplings,

$$\bar{\psi}\gamma^\mu(\partial_\mu + iE_\mu)\psi$$

Many ways to introduce spin-1 resonances...

We start from G/H

$$\frac{G_L \otimes G_R}{G_{L+R}} \qquad \Omega \to g_L \Omega g_R^\dagger \qquad + \qquad \frac{G}{H}$$

and gauge $G_R + G$

$$\mathcal{L}_{2-site} = \frac{f_1^2}{4} \mathrm{Tr}\, |D_\mu \Omega|^2 + \frac{f_2^2}{2} \mathcal{D}_\mu^{\widehat{a}} \mathcal{D}^{\mu \widehat{a}} - \frac{1}{4 g_\rho^2} \rho_{\mu\nu}^A \rho^{A\mu\nu}$$

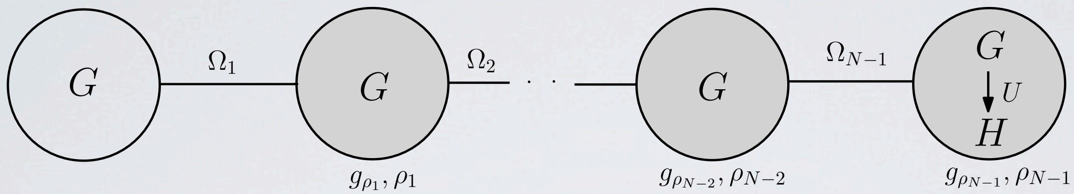
$$D_\mu \Omega = \partial_\mu \Omega - i A_\mu \Omega + i \Omega \rho_\mu$$

Natural to have H and G/H resonances.
In QCD these are vector and axial resonances.

We recover CCWZ for $f_2 \to \infty$

$$\mathcal{L} = \frac{f^2}{2} D_\mu^{\widehat{a}} D^{\mu \widehat{a}} - \frac{1}{4 g_\rho^2} \rho_{\mu\nu}^a \rho^{\mu\nu a} + \frac{f'^2}{2} (\rho_\mu^a - E_\mu^a)^2$$

In general:



$$\mathcal{L}_{N-sites} = \sum_{n=1}^{N-1} \frac{f_n^2}{4} \mathrm{Tr}\,|D_\mu \Omega_n|^2 + \frac{f_N^2}{2} \mathcal{D}_\mu^{\hat{a}} \mathcal{D}^{\mu \hat{a}} - \sum_{n=1}^{N-1} \frac{1}{4\, g_{\rho_n}^2} \rho_{n,\mu\nu}^A \rho_n^{A\mu\nu}$$

$$D^\mu \Omega_n = \partial^\mu \Omega_n - i\rho_{n-1}^\mu \Omega_n + i\Omega_n \rho_n^\mu, \qquad n = 1, .., N-1$$

GBs are

$$\Omega_n = \exp i \frac{f}{f_n^2} \Pi, \quad n = 1, ..., N \qquad\qquad \sum_{n=1}^{N} \frac{1}{f_n^2} = \frac{1}{f^2}$$

$$\boldsymbol{U'} \equiv \left(\Pi_{n=1}^{N-1} \Omega_n\right) U$$

For N large we recover the 5D theory.
Boundary conditions not rigid for f_N finite.

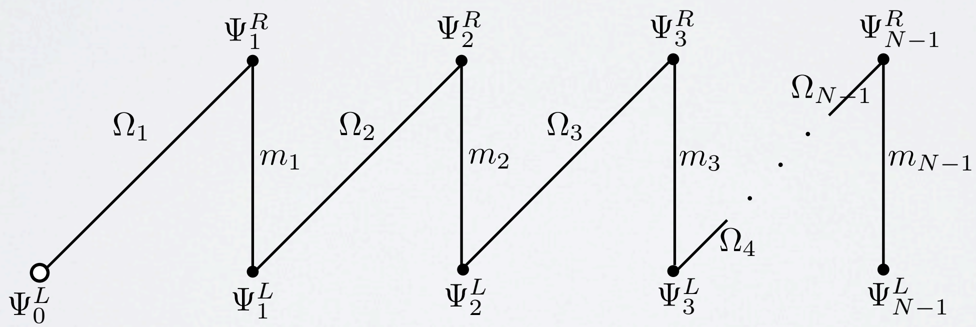
Fermions:

$$\mathcal{L}_{fermions} = \sum_{n=1}^{N-1} \bar{\Psi}_n^{(r)} \left[i \not{D}^{\rho_n} - m_n^{(r)} \right] \Psi_n^{(r)} + \sum_{n=1}^{N-1} \Delta_n^{(r)} \left(\bar{\Psi}_{r,L}^{n-1} \Omega_n \Psi_{r,R}^{n} + h.c. \right)$$

$$D^\mu \Psi_n^{(r)} = \partial^\mu \Psi_n^{(r)} - i \rho_n^\mu \Psi_n^{(r)}$$

$$\mathcal{L}_{\frac{G}{H}} = m_\Psi \sum \bar{\Psi}_L^{(r),N-1} U(\Pi) P_A^{rs} U(\Pi)^\dagger \Psi_R^{(s),N-1} + h.c$$

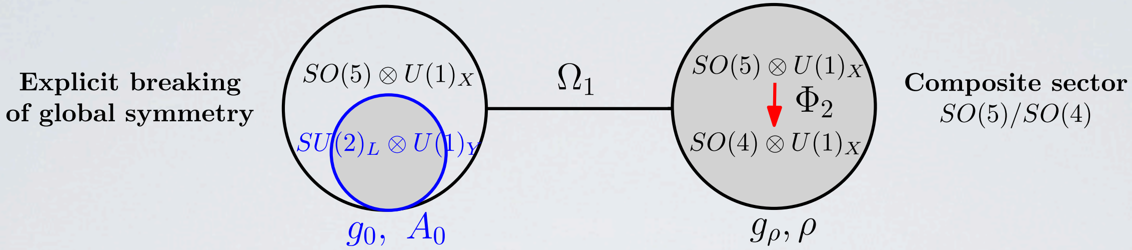
LR structure



Inspired by 5D.

MINIMAL 4D COMPOSITE HIGGS

- One resonance for each SM field



Minimal coset:

$$\frac{SO(5)}{SU(2)_L\otimes SU(2)_R}$$

Extra $U(1)_X$

$$Y = T_{3R} + X$$

Composite spin-1 lagrangian:

$$\mathcal{L}_{gauge} = \frac{f_1^2}{4}\mathrm{Tr}\left|D_\mu\Omega_1\right|^2 + \frac{f_2^2}{2}\left(D_\mu\Phi_2\right)\left(D^\mu\Phi_2\right)^T - \frac{1}{4g_\rho^2}\rho^A_{\mu\nu}\rho^{A\mu\nu}$$

$$\Omega_1 = \mathbf{1} + i\frac{s_1}{h}\Pi + \frac{c_1-1}{h^2}\Pi^2 \qquad \Phi_2 = \phi_0 e^{-i\frac{\Pi}{f_2}} = \frac{1}{h}\sin\frac{h}{f_2}\left(h_1,\ h_2,\ h_3,\ h_4,\ h\cot\frac{h}{f_2}\right)$$

Spectrum:

$$m_\rho^2 = \frac{g_\rho^2 f_1^2}{2}$$
$$m_{a_1}^2 = \frac{g_\rho^2 (f_1^2 + f_2^2)}{2}$$
$$m_{\rho_X}^2 = \frac{g_{\rho_X}^2 f_X^2}{2}$$

SM fields are introduced adding kinetic terms for the sources

$$\mathcal{L}_{gauge}^{el} = -\frac{1}{4g_0^2} F_{\mu\nu}^a F_{\mu\nu}^a - \frac{1}{4g_{0Y}^2} Y_{\mu\nu} Y^{\mu\nu}$$

Physical parameters:

$$\frac{1}{g^2} = \frac{1}{g_0^2} + \frac{1}{g_\rho^2}$$
$$\frac{1}{g'^2} = \frac{1}{g_{0Y}^2} + \frac{1}{g_\rho^2} + \frac{1}{g_{\rho_X}^2}$$

$$m_{\rho_{aL}} = \frac{m_\rho}{\cos\theta_L}, \quad \tan\theta_L = \frac{g_0}{g_\rho}$$

Each SM fermion is associated to a rep of SO(5).

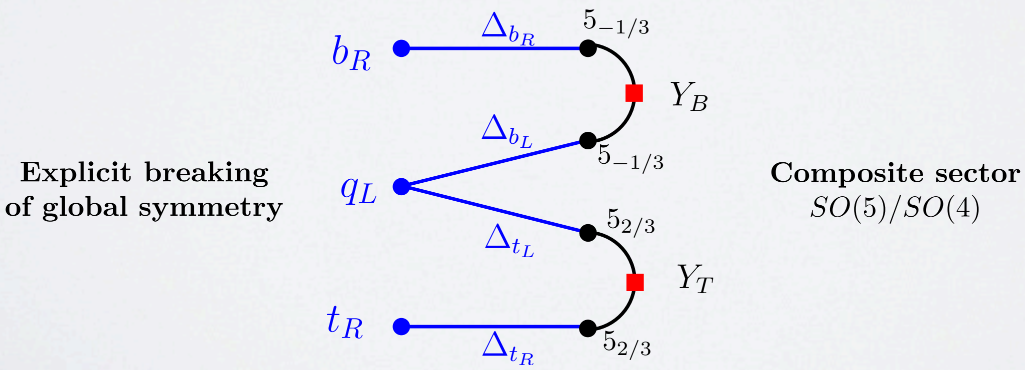
CHM5:

$$\mathbf{5}_{2/3} = (\mathbf{2},\mathbf{2})_{2/3} \oplus (\mathbf{1},\mathbf{1})_{2/3}, \qquad (\mathbf{2},\mathbf{2})_{2/3} = \begin{pmatrix} T & T_{\frac{5}{3}} \\ B & T_{\frac{2}{3}} \end{pmatrix}$$

Left and right components correspond to different 5.

Down quarks

$$\mathbf{5}_{-1/3} = (\mathbf{2},\mathbf{2})_{-1/3} \oplus (\mathbf{1},\mathbf{1})_{-1/3}, \qquad (\mathbf{2},\mathbf{2})_{-1/3} = \begin{pmatrix} B_{-\frac{1}{3}} & T' \\ B_{-\frac{4}{3}} & B' \end{pmatrix}.$$



Third generation:

$$
\begin{aligned}
\mathcal{L}^{\mathrm{CHM}_5} &= \mathcal{L}^{el}_{fermions} \\
&+ \Delta_{t_L}\, \bar{q}^{el}_L \Omega_1 \Psi_T + \Delta_{t_R}\, \bar{t}^{el}_R \Omega_1 \Psi_{\widetilde{T}} + h.c. \\
&+ \bar{\Psi}_T (i \not{D}^\rho - m_T)\Psi_T + \bar{\Psi}_{\widetilde{T}} (i \not{D}^\rho - m_{\widetilde{T}})\Psi_{\widetilde{T}} \\
&- Y_T \bar{\Psi}_{T,L} \Phi_2^T \Phi_2 \Psi_{\widetilde{T},R} - m_{Y_T} \bar{\Psi}_{T,L} \Psi_{\widetilde{T},R} + h.c. \\
&+ (T \to B)
\end{aligned}
$$

→ Explicit SO(5) breaking

→ Composite physics SO(5)/SO(4)

$$\mathcal{L}^{el}_{fermions} = \bar{q}^{el}_L i \not{D}^{el} q^{el}_L + \bar{t}^{el}_R i \not{D}^{el} t^{el}_R + \bar{b}^{el}_R i \not{D}^{el} b^{el}_R$$

Masses:

$$m_t \sim \frac{v}{\sqrt{2}} \frac{\Delta_{t_L}}{m_T} \frac{\Delta_{t_R}}{m_{\widetilde{T}}} \frac{Y_T}{f}$$

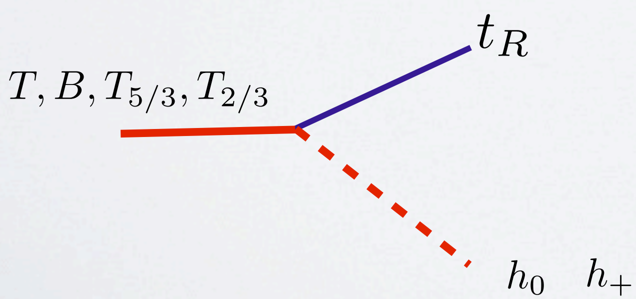
Relation to 2-site picture:

$$\mathcal{L}^{gauge}_{comp} = -\frac{1}{4}\rho^A_{\mu\nu}\rho^{A\mu\nu} + \frac{1}{2}m^2_\rho \rho^a_\mu \rho^{a\mu} + \frac{1}{2}m^2_{a_1}\rho^{\hat{a}}_\mu \rho^{\hat{a}\mu} + \left|\partial_\mu - i g_\rho \rho^a_\mu H\right|^2 \quad + \mathrm{nl\,terms}$$

$$\mathcal{L}_{mix} = \frac{1}{2}m^2_\rho \frac{g_0^2}{g_\rho^2} A^a_\mu A^{a\mu} - m^2_\rho \frac{g_0}{g_\rho} A^a_\mu \rho^{a\mu} + g_0 \frac{f^2}{f_1^2}(\partial^\mu H^\dagger A_\mu H) + \ldots$$

- Non linear GB structure included.
- Correlations of 2-site model removed.

Ex:



$2 - \mathrm{site}: \mathrm{g}_\rho\, \mathrm{c_L s_R}$

We can borrow 5D techniques and write the effective action of SM fields:

Contino, da Rold, Pomarol, '06

$$\begin{aligned}
\mathcal{L}_{\rm eff}^{ferm} &= \bar{q}_L \, \not{p} \left[\Pi_0^q(p^2) + \frac{s_h^2}{2} \left(\Pi_1^{q1}(p^2)\, \widehat{H}^c \widehat{H}^{c\dagger} + \Pi_1^{q2}(p^2)\, \widehat{H}\widehat{H}^\dagger \right) \right] q_L \\
&+ \bar{u}_R \, \not{p} \left(\Pi_0^u(p^2) + \frac{s_h^2}{2}\, \Pi_1^u(p^2) \right) u_R + \bar{d}_R \, \not{p} \left(\Pi_0^d(p^2) + \frac{s_h^2}{2}\, \Pi_1^d(p^2) \right) d_R \\
&+ \frac{s_h c_h}{\sqrt{2}} M_1^u(p^2)\, \bar{q}_L \widehat{H}^c u_R + \frac{s_h c_h}{\sqrt{2}} M_1^d(p^2)\, \bar{q}_L \widehat{H} d_R + h.c.\,.
\end{aligned}$$

$$\begin{aligned}
\mathcal{L}_{\rm eff}^{gauge} &= \frac{1}{2} P_{\mu\nu}^T \left[\left(\Pi_0(p^2) + \frac{s_h^2}{4} \Pi_1(p^2) \right) A_{aL}^\mu A_{aL}^\nu \right. \\
&+ \left. \left(\Pi_Y(p^2) + \frac{s_h^2}{4} \Pi_1(p^2) \right) Y^\mu Y^\nu + 2 s_h^2\, \Pi_1(p^2)\ \widehat{H}^\dagger T_L^a Y \widehat{H}\ A_\mu^{aL} Y_\nu \right]
\end{aligned}$$

Coleman-Weinberg effective potential:

$$V(h)_{fermions} = -2N_c \int \frac{d^4p}{(2\pi)^4} \left[\ln \Pi_{b_L} + \ln\left(p^2 \Pi_{t_L} \Pi_{t_R} - \Pi_{t_L t_R}^2 \right) \right]$$

$$V(h)_{gauge} = \frac{9}{2} \int \frac{d^4p}{(2\pi)^4} \ln \left[1 + \frac{1}{4} \frac{\Pi_1(p^2)}{\Pi_0(p^2)} \sin^2 \frac{h}{f} \right]$$

Form factors are simple functions:

$$\widehat{\Pi}[m_1, m_2, m_3] = \frac{\left(m_2^2 + m_3^2 - p^2\right)}{p^4 - p^2(m_1^2 + m_2^2 + m_3^2) + m_1^2 m_2^2}$$

$$\widehat{M}[m_1, m_2, m_3] = -\frac{m_1 m_2 m_3}{p^4 - p^2(m_1^2 + m_2^2 + m_3^2) + m_1^2 m_2^2}$$

$$\Pi_{gauge}[m_V] = \frac{p^2}{p^2 - m_V^2}$$

Gauge potential:

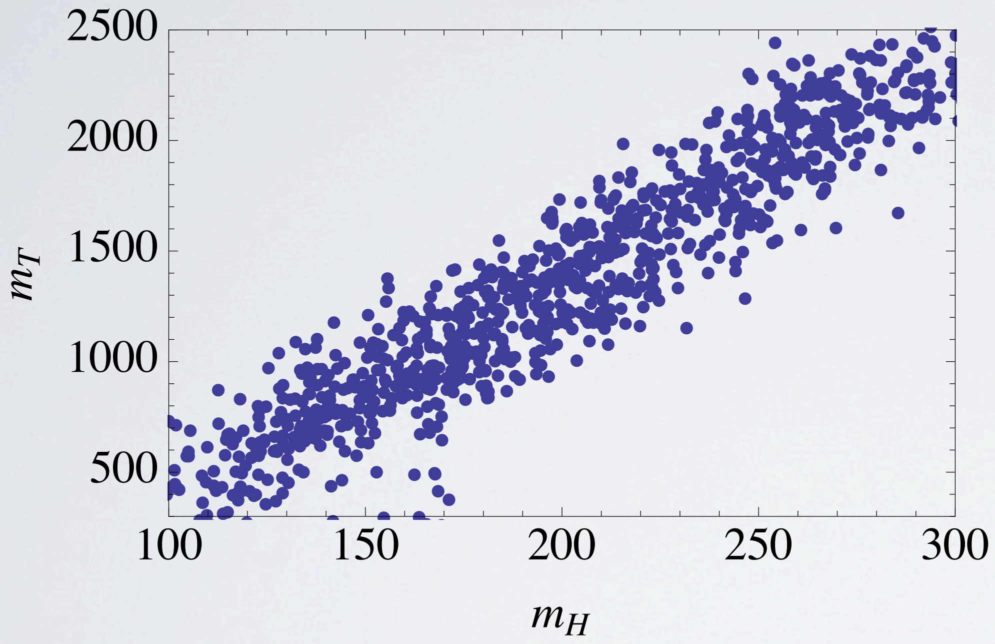
$$\begin{aligned} V(h)_{gauge} &\approx \int \frac{d^4p}{(2\pi)^4} \frac{9}{8} \frac{\Pi_1}{\Pi_0} \sin^2 \frac{h}{f} \\ &= \frac{9}{4} \frac{1}{16\pi^2} \frac{g_0^2}{g_\rho^2} \frac{m_\rho^4 \left(m_{a_1}^2 - m_\rho^2\right)}{m_{a_1}^2 - m_\rho^2(1 + g_0^2/g_\rho^2)} \ln\left[\frac{m_{a_1}^2}{m_\rho^2(1 + g_0^2/g_\rho^2)}\right] \sin^2 \frac{h}{f} \end{aligned}$$

Potential is finite with a single SO(5) multiplet!

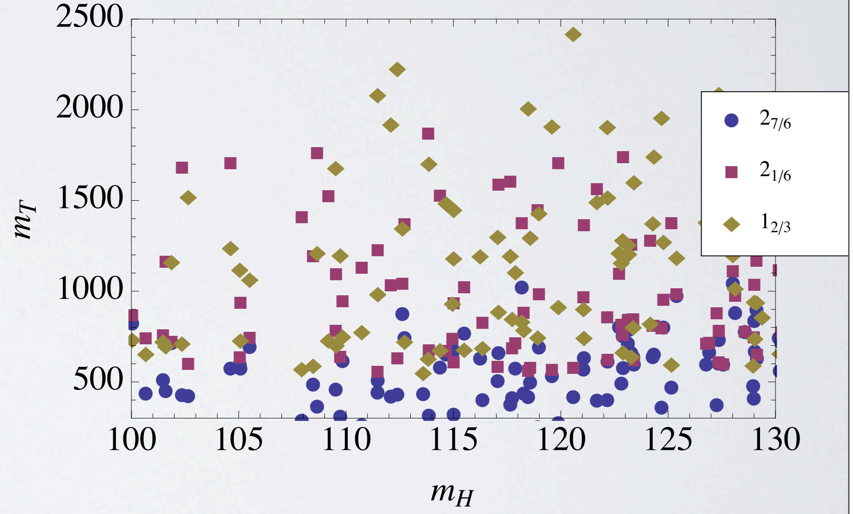
HIGGS MASS

General scan:

$f = 500\,\mathrm{GeV}$



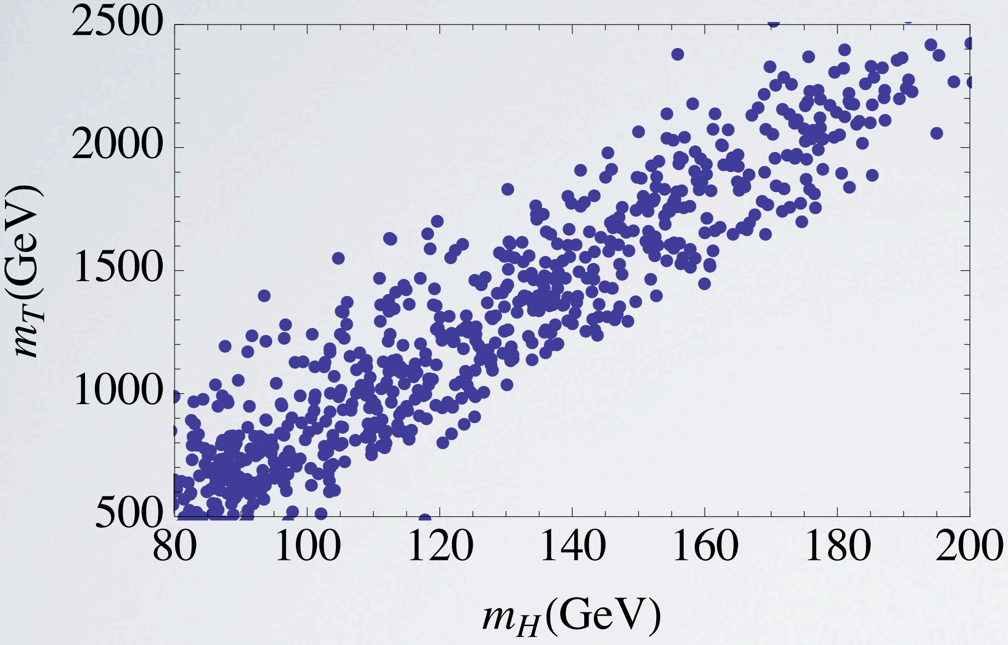
Low mass:



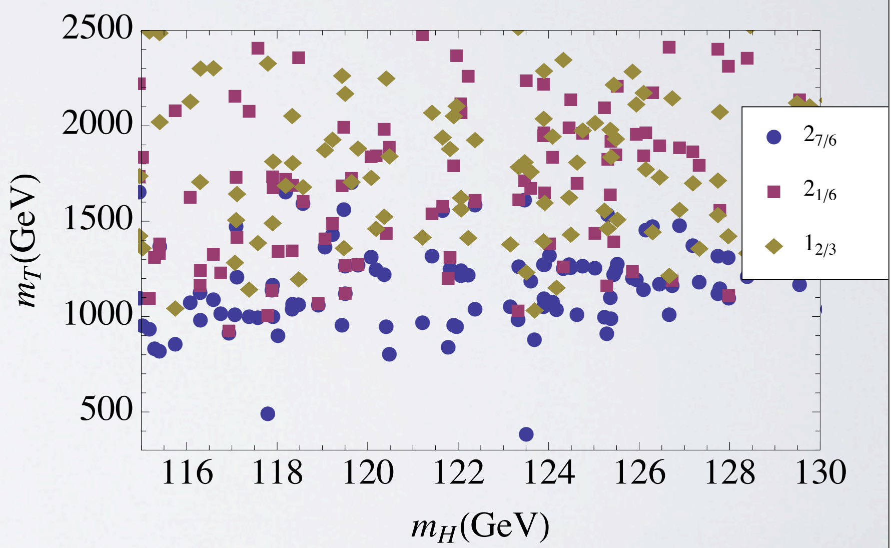
If mH=125 GeV, nearby fermionic partners.

Might be visible at LHC7!

$f = 800\,\text{GeV}$



Low mass:



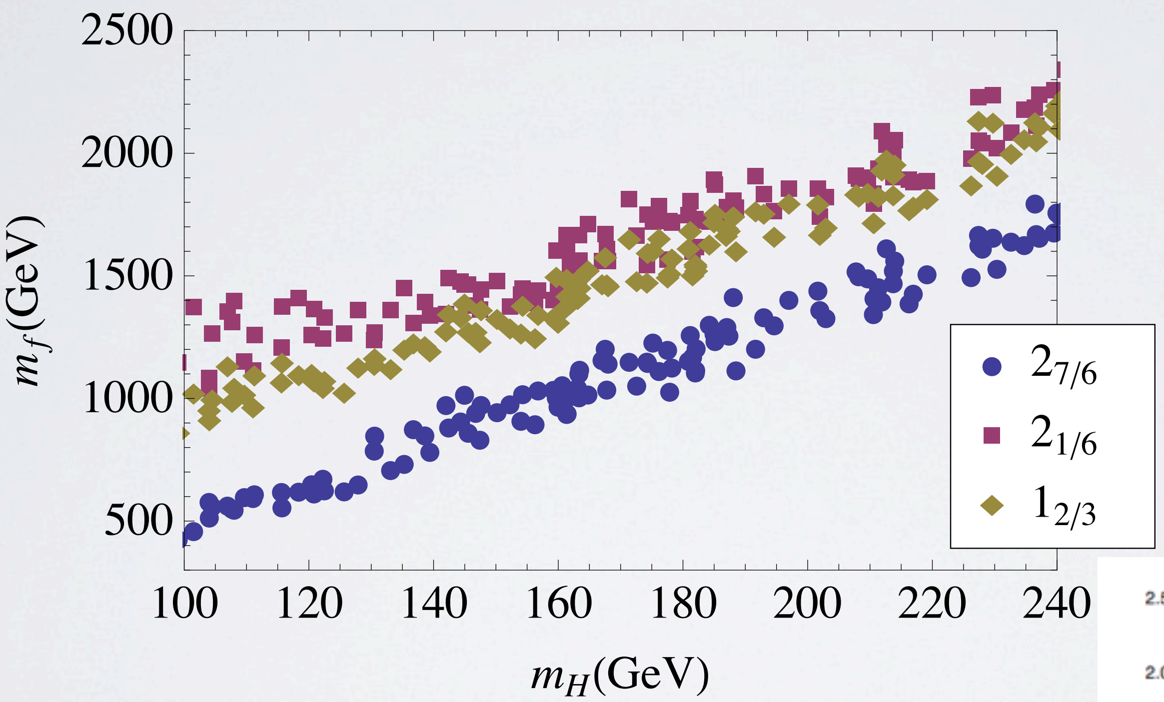
Partners above experimental bound.

Large mixing:

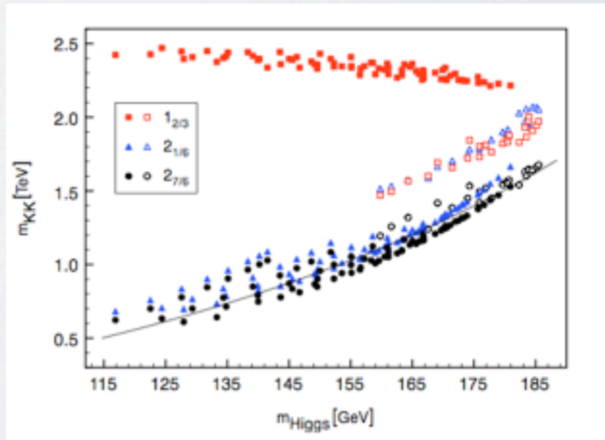
$f = 500\,\mathrm{GeV}$

$1.2 \leq \Delta_{t_L}/m_T \leq 1.8$ $\quad$ $0.7 \leq \Delta_{t_R}/m_{\widetilde{T}} \leq 1.3$

$0.5 \leq Y_T \leq 3$ $\quad$ $-1.2Y_T \leq m_{Y_T} \leq -0.8Y_T$



$5D$

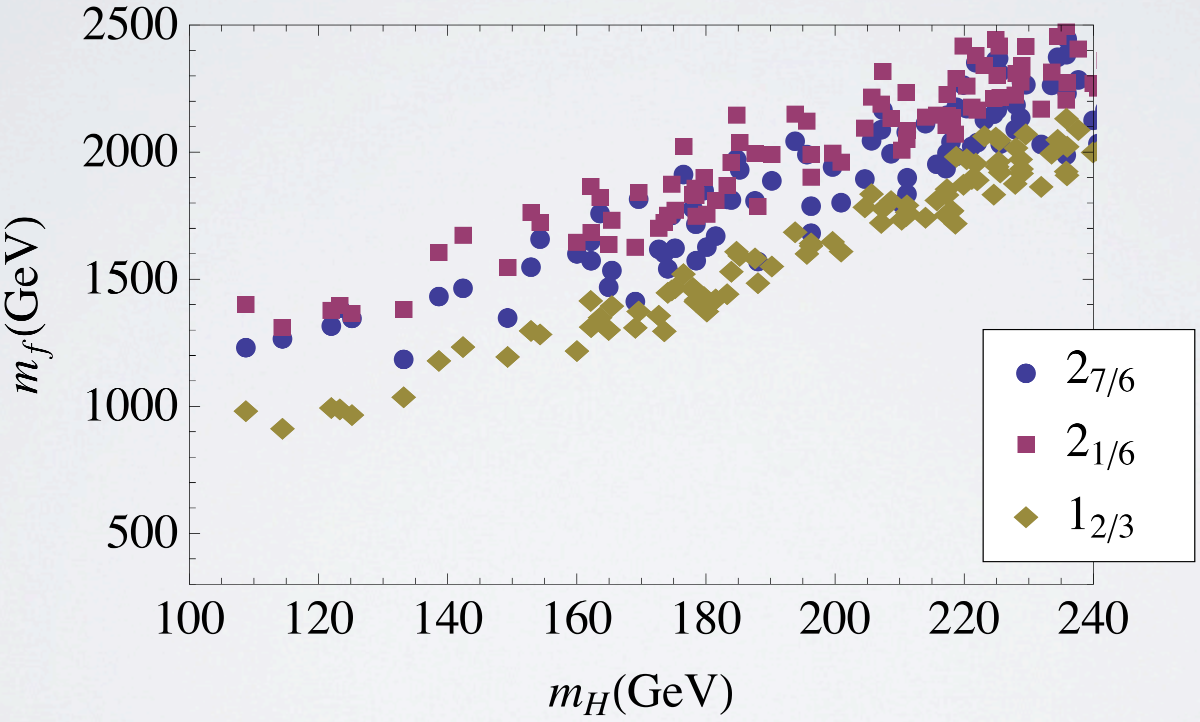


Doublet lightest fermion

Moderate mixing:

$0.6 \leq \Delta_{t_L}/m_T \leq 0.9$ $\qquad$ $0.35 \leq \Delta_{t_R}/m_{\widetilde{T}} \leq 0.7$

$0.5 \leq Y_T \leq 3$ $\qquad$ $-0.5 \leq m_{Y_T} \leq 0.5$



Singlet lightest fermion

Gripaios, Pomarol, Riva, Serra '09

SO(6)/SO(5):

5 GBs:

$$5 = (2,2) + 1$$

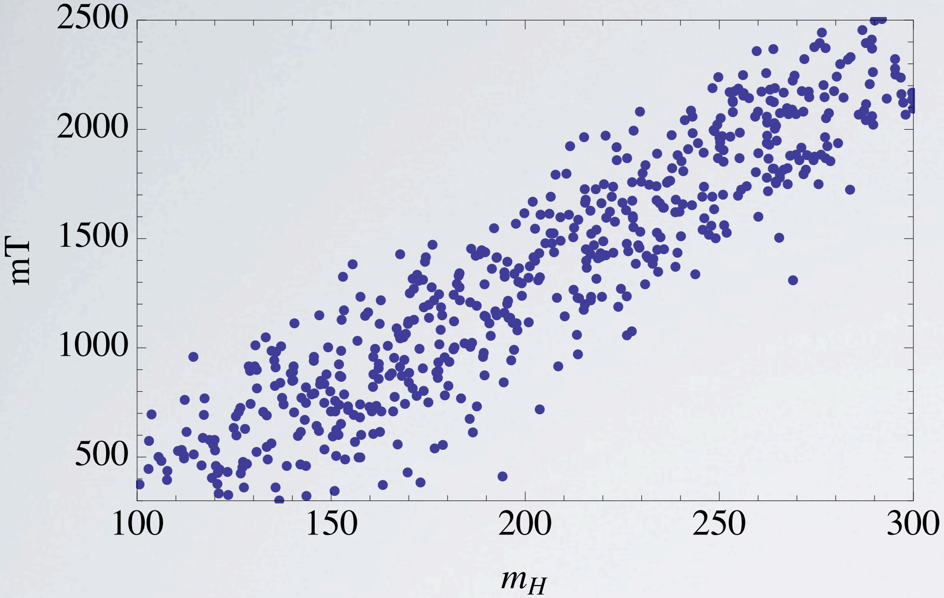
$$\Phi = \sin\frac{\varphi}{f}\left(\frac{h_1}{\varphi}, \frac{h_2}{\varphi}, \frac{h_3}{\varphi}, \frac{h_4}{\varphi}, \frac{s}{\varphi}, \cot\frac{\varphi}{f}\right). \qquad \varphi = \sqrt{\vec{h}^2 + s^2}$$

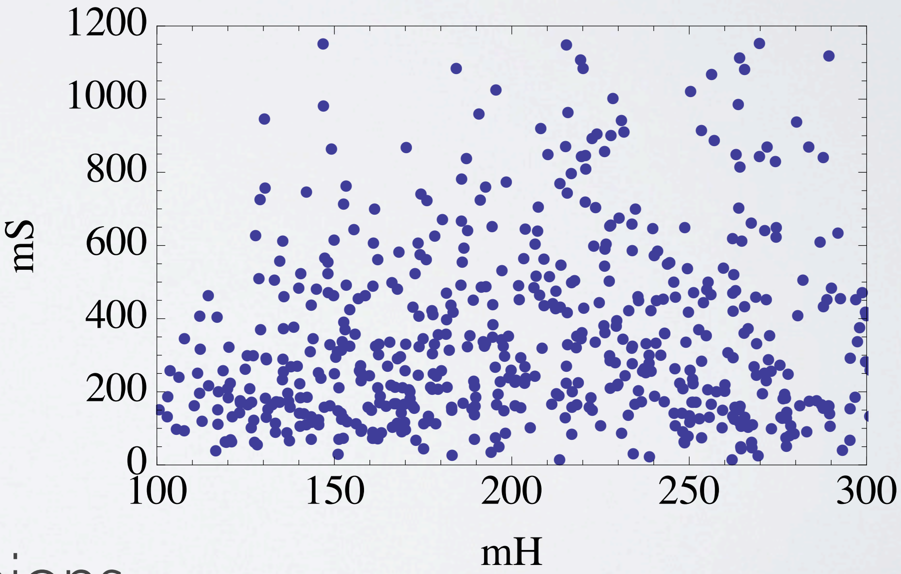
Fermions can be embedded in the 6=(2,2)+2 × 1

$$q_L \to \frac{1}{\sqrt{2}}\begin{pmatrix} b_L \\ -ib_L \\ t_L \\ it_L \\ 0 \\ 0 \end{pmatrix} \qquad t_R \to \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ i\cos\theta\, t_R \\ \sin\theta\, t_R \end{pmatrix}$$

For $\theta = \frac{\pi}{4}$ singlet becomes exact GB.

$$f = 500\,\text{GeV}$$

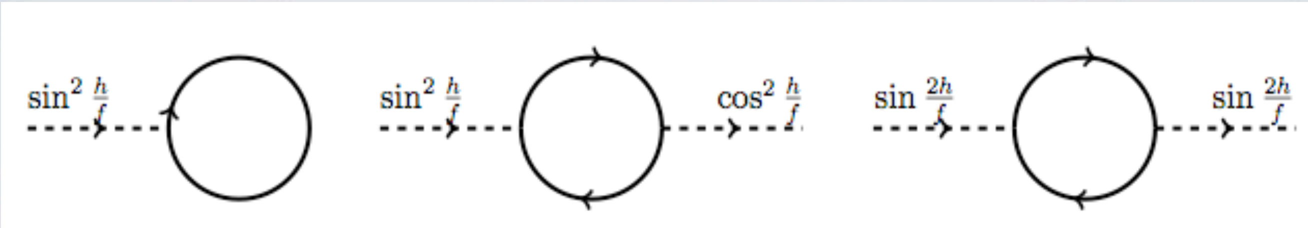




Same correlation Higgs-fermions.

Singlet typically heavier than Higgs unless $\theta \approx \frac{\pi}{4}$

NATURALNESS



$$\mathcal{L}_{Yuk} = y_t f \, \frac{s_h c_h}{h} (\bar{q}_L H^c t_R + h.c.) \longrightarrow V(h)_{Yuk} \sim N_c \frac{y_t^2}{4\pi^2} m_T^2 f^2 \, s_h^2 c_h^2$$

$$\mathcal{L}_{kin} = \frac{y_{t_L}^2}{2 y_T^2} s_h^2 \, \bar{t}_L \, \not{D} t_L + \frac{y_{t_R}^2}{y_{\tilde{T}}^2} c_h^2 \, \bar{t}_R \, \not{D} t_R \longrightarrow V(h)^{(1)}_{kin} \sim N_c \frac{2 y_{t_R}^2 - y_{t_L}^2}{32\pi^2} \frac{m_T^4}{y_T^2} \, s_h^2$$

Potential:

$$V(h) \approx \alpha \, s_h^2 - \beta \, s_h^2 c_h^2$$

Quartic is determined by top Yukawa,

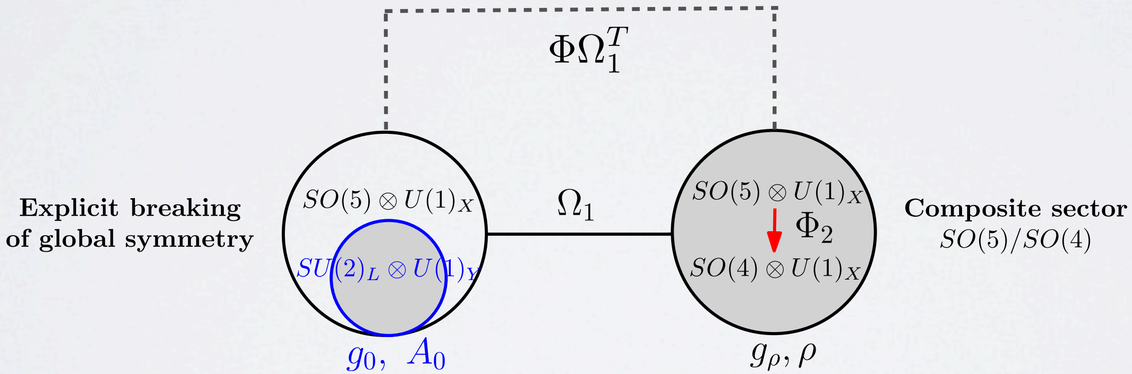
$$m_H \sim 0.3 \, y_t \frac{m_T}{f} v$$

NON MINIMAL TERMS

Most general 2-site lagrangian contains

$$\frac{f_0^2}{2}(D_\mu \Phi)(D^\mu \Phi)^T \qquad \Phi = \Phi_2 \Omega_1^T$$

$$f^2 = f_0^2 + \frac{f_1^2 f_2^2}{f_1^2 + f_2^2}$$



Similar terms are considered in QCD.

Falkowski et al. '11
Contino, Marzocca, Pappadopulo, Rattazzi '11

New term modifies interactions

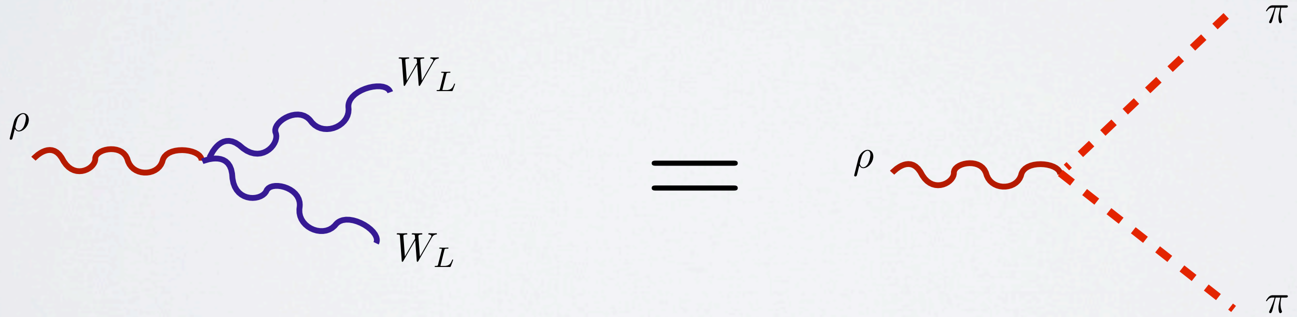
$$g_{\rho\pi\pi} = \frac{f^2 - f_0^2}{2f^2}\, g_\rho$$

$$(m_{a_1} \to \infty)$$

$$m_\rho^2 = 2\frac{f^2}{f^2 - f_0^2}\, g_{\rho\pi\pi}^2\, f^2$$

Coset resonance could give further modifications.

Phenomenology modified



$$\Gamma(\rho^3 \to Zh) = \Gamma(\rho^3 \to W^+W^-) = \frac{g_{\rho\pi\pi}^2}{192\pi} m_\rho$$

New term modifies S-parameter:

$$S = 4\pi v^2 \left(\frac{1}{m_\rho^2} + \frac{1}{m_{a_1}^2} \right) \frac{f^2 - f_0^2}{f^2}$$

S can vanish

$$f_0 = f$$

H and G/H resonances degenerate and do not participate to unitarization.

In QCD:

$$f_0^2 \sim -f^2$$

General?

CONCLUSIONS

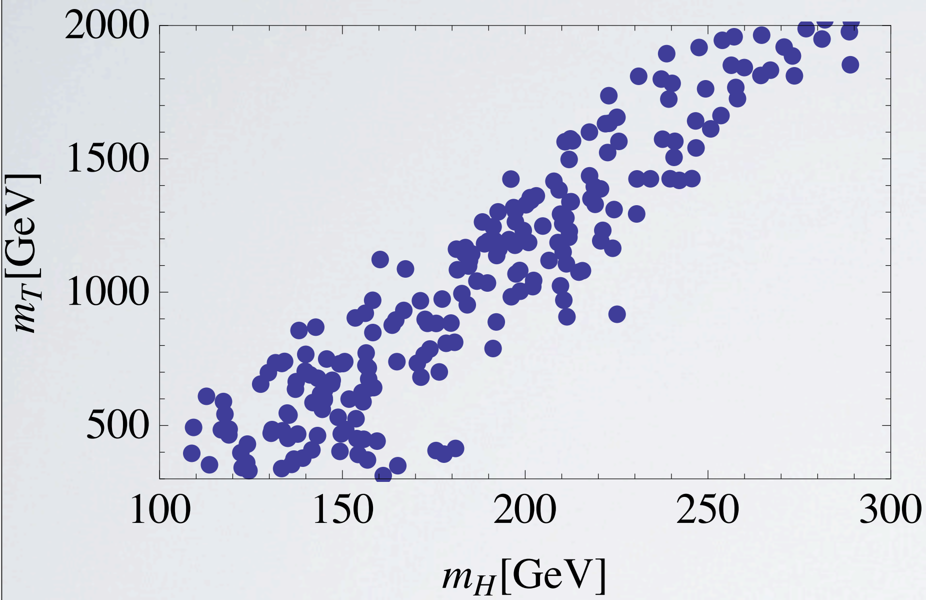
- All relevant features of CHM can be reproduced from a 4D point view. First resonance sufficient for theory & LHC.

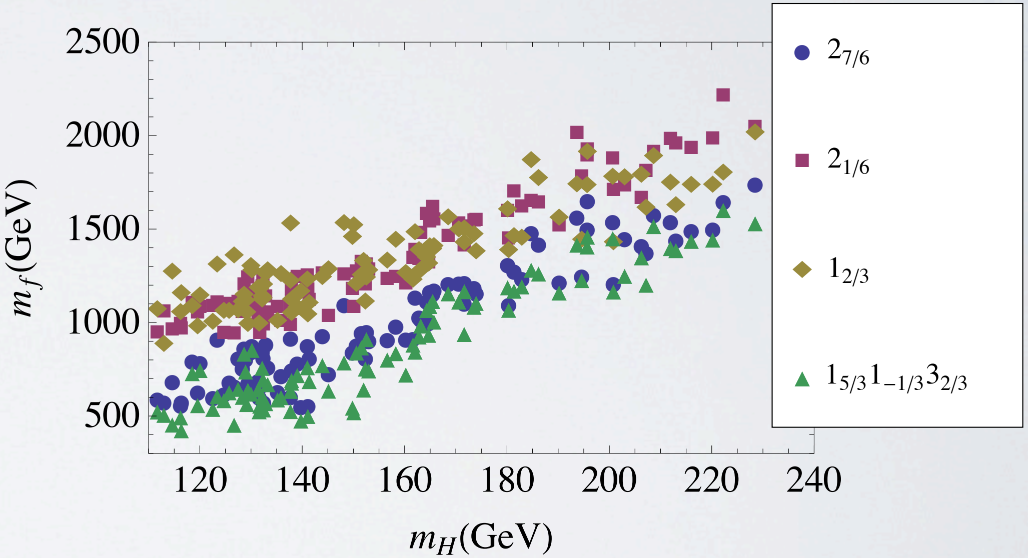
- In general a light Higgs requires light fermionic partners.

- More general models can be considered in 4D than 5D. Contributions to S and modified couplings.

CHM10

$$f = 500\,\mathrm{GeV}$$



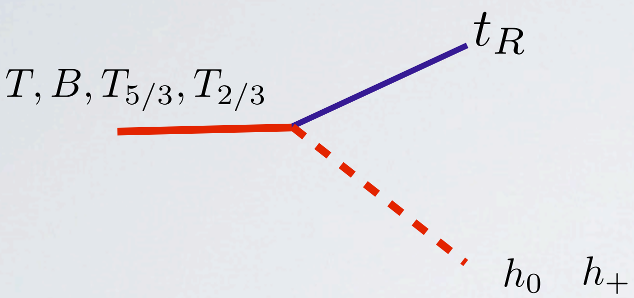


$$0.7 < \frac{\Delta_{t_L}}{m_T} < 1.6\,, \qquad 0.7 < \frac{\Delta_{t_R}}{m_{\tilde{T}}} < 1.5$$

$$-0.4 < M_Y < -2.5\,, \qquad 0.5 < Y_T < 6$$

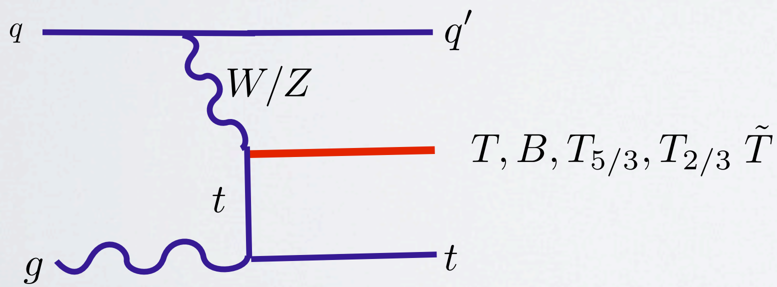
Correlations of 2 site model are modified:

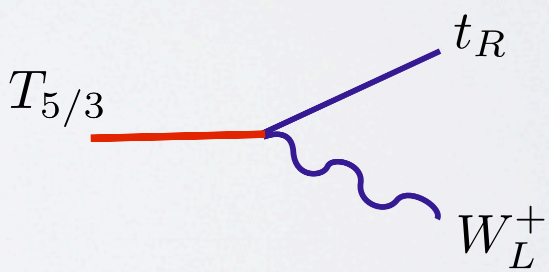
$$Y_T \bar{\Psi}_{T,L} \Phi_2^T \Phi_2 \Psi_{\tilde{T},R} \longrightarrow \frac{Y_T}{2h} \sin \frac{2hf}{f_2^2} Tr \left[\left(\begin{array}{cc} T & T_{\frac{5}{3}} \\ B & T_{\frac{2}{3}} \end{array} \right)_L \cdot \left(\begin{array}{cc} h_0^\dagger & h_+ \\ h_+^\dagger & h_0 \end{array} \right) \right] \tilde{T}_R$$



$$\sim \frac{Y_T f}{f_2^2} c_L s_R \qquad \left(2-\mathrm{site}: \frac{\mathrm{Y_T}}{\mathrm{f}} \mathrm{c_L s_R} \right)$$

Production and decay can be very different from 2 site





Relevant phenomenologically!