Possible compositeness of the 125 GeV Higgs boson

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Abstract

The modification of the top – quark condensation model is suggested.

Higgs boson is composed of all quarks and leptons of the SM.

$$M_h = m_t/\sqrt{2} \approx 125\,\mathrm{GeV}$$

The low energy effective action is calculated using zeta – regularization.

Plan

1. Nambu sum rules.

2. Conventional models of top quark condensation

3. Modification of top – quark condensation scenario

4. Effective action and the Higgs boson mass

5. Experimental constraints

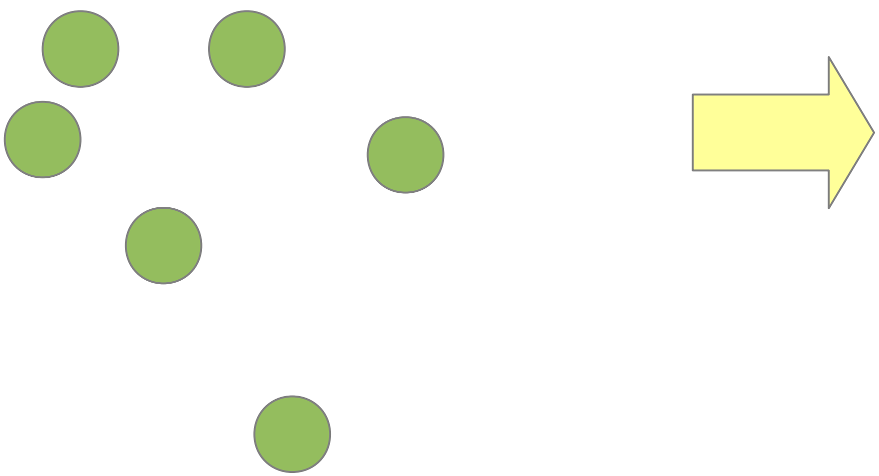
6. Effective U(12)xO(4) model at small distances

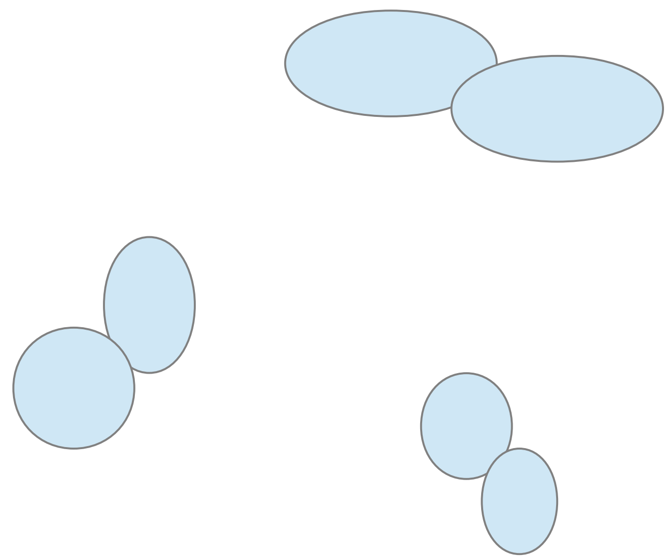
Nambu sum rules in BCS models

Energy gaps of scalar excitations (composed of the given fermion) are related to the energy gap of this fermion

$$\sum M_{H,i}^2 \approx 4M_f^2,$$

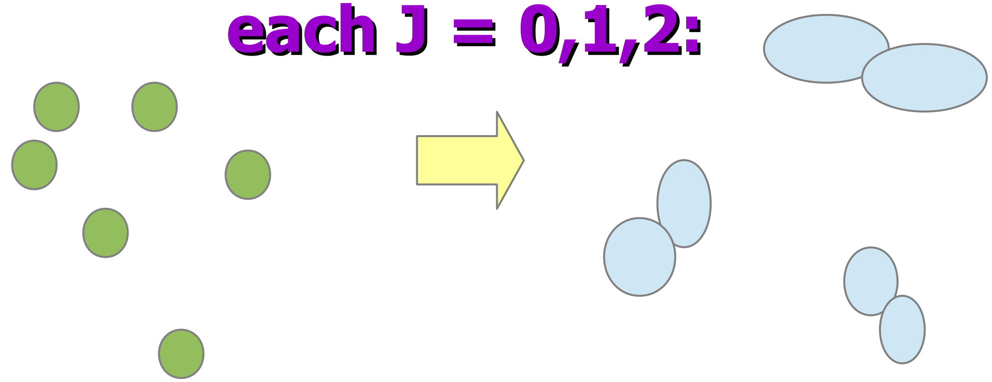
BCS model: fermions ----> composite bosons (cooper pairs)





Example: BCS model of He-3 B

Cooper pairs are classified by the total momentum J. For each J = 0,1,2:



$$[E_u^{(J)}]^2 + [E_v^{(J)}]^2 = 4\Delta^2$$

$$E_1^{(0)} = 0, \quad E_2^{(0)} = 2\Delta$$

$$E_1^{(1)} = 0, \quad E_2^{(1)} = 2\Delta$$

$$E_1^{(2)} = \sqrt{2/5}\,(2\Delta), \quad E_2^{(2)} = \sqrt{3/5}\,(2\Delta)$$

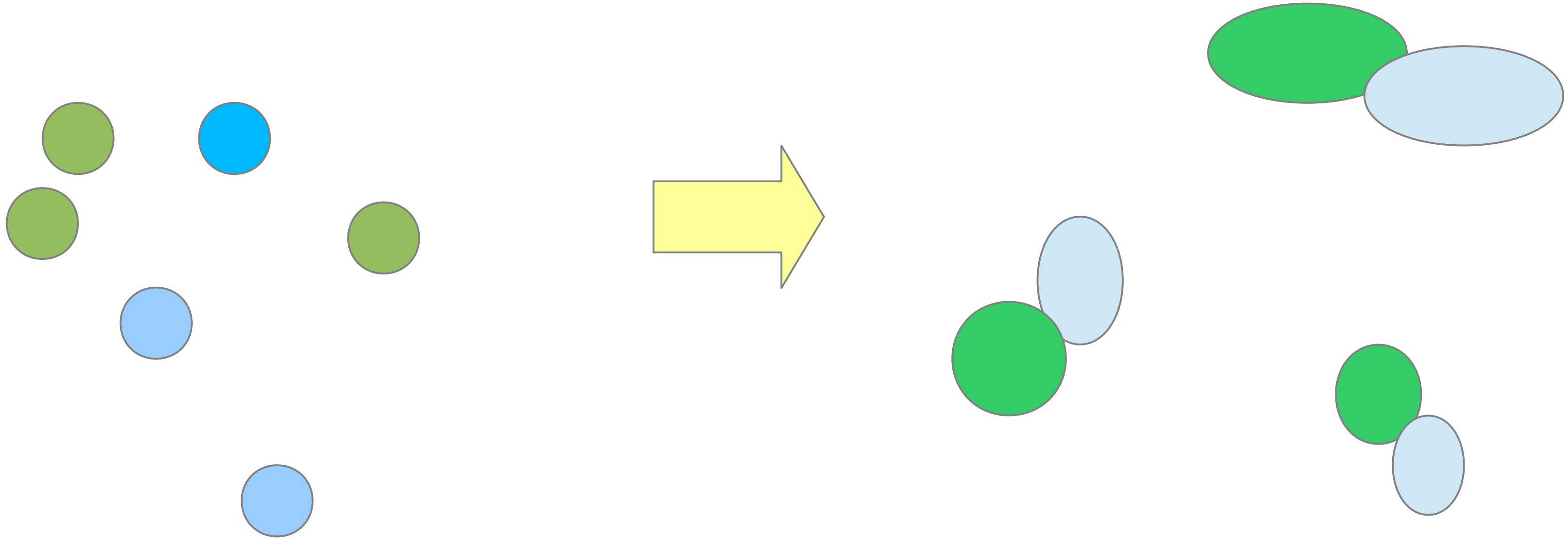
P. N. Brusov and V. N. Popov, "Nonphonon branches of the Bose spectrum in the B phase of systems of the He3 type", JETP **51**, 1217–1222 (1980).

Example 2: BCS model of QCD

Sigma meson mass is related to the dynamical quark mass

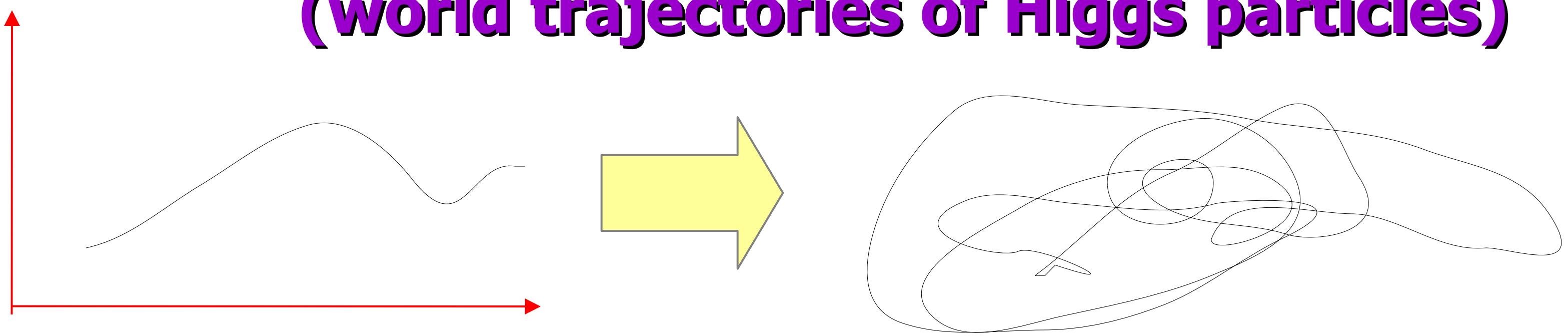
$$M_\sigma \approx 2M_{quark}$$

BCS model: **quarks ----> sigma - mesons**

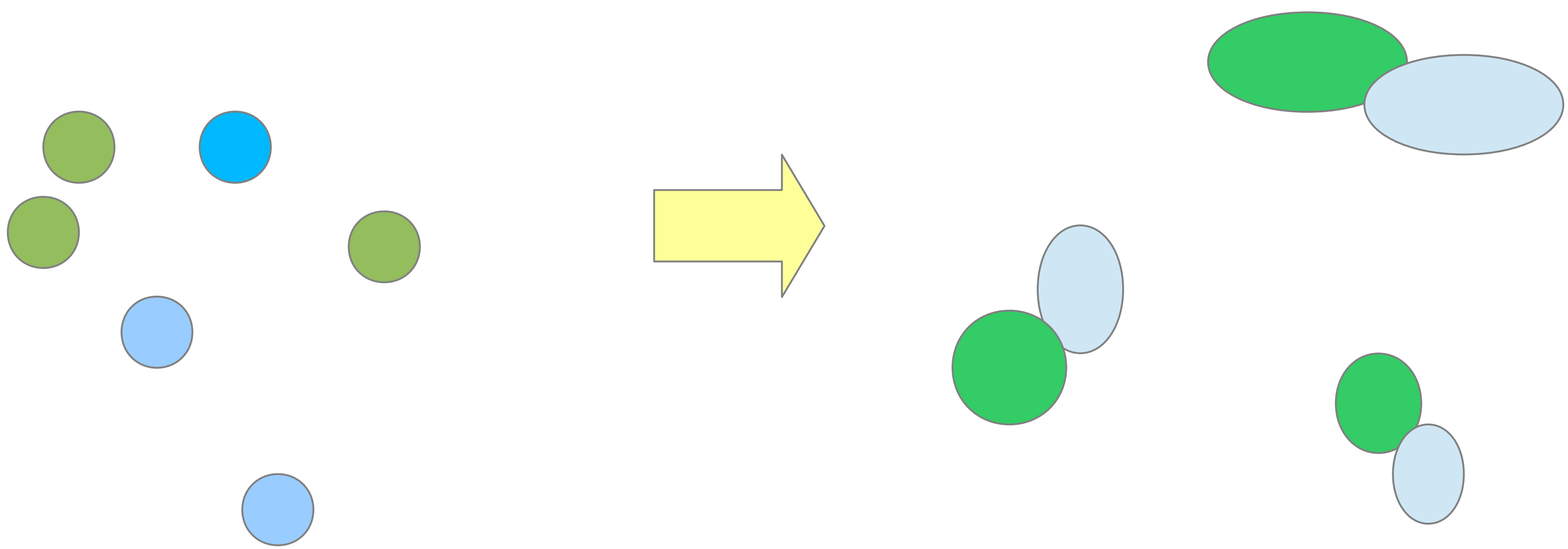


Conventional top quark condensation model

Weinberg – Salam model. Higgs particles are condensed (world trajectories of Higgs particles)



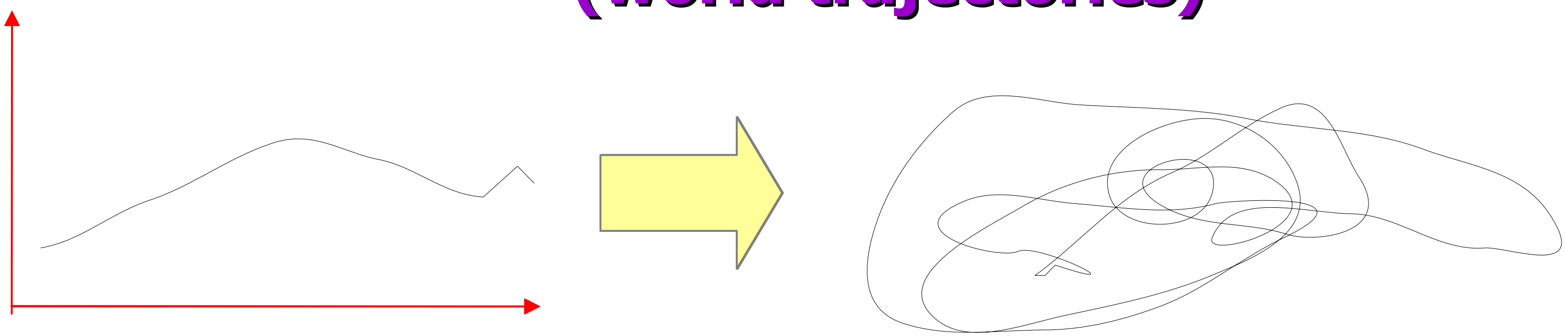
Top quark ----> composite Higgs boson



Top quark condensation – superconductivity dictionary

Standard model	S-wave superconductivity
Weinberg — Salam model $$L=\frac{1}{2}\int[(\partial_\mu-2iA_\mu)H]^+(\partial^\mu-2iA^\mu)Hd^3x-\frac{\lambda}{4}\int(\lvert H\rvert^2-v^2)^2d^3x$$ $$A\in SU(2)\otimes U(1);H=\begin{pmatrix}h_1\\h_2\end{pmatrix}$$	**Ginzburg — Landau model** $$L=\frac{1}{2}\int[(\partial_\mu-2iA_\mu)H]^+(\partial^\mu-2iA^\mu)Hd^3x-\frac{\lambda}{4}\int(\lvert H\rvert^2-v^2)^2d^3x$$
Top — quark condensation model $$S_I'=\frac{1}{M_I^2}\int d^4x\left(\bar{L}_{aK}^{(tb)A}t_{R,K}^A\right)\left(\bar{t}_{R,N}^B L_{aN}^{(tb)B}\right)$$ $$L_{aK}^{(tb)A}=\begin{pmatrix}t_{L,K}^A\\b_{L,K}^A\end{pmatrix}$$ **Composite Higgs boson**	**BCS model** $$L=\int\bar{\psi}\left(i(\partial_\mu-iA_\mu)\gamma^\mu-m+\mu\gamma^0\right)\psi d^3x+L_I$$ $$L_I=\frac{g^2}{M^2}\int(\bar{\psi}i\gamma_5C\bar{\psi}^T)(\psi^Ti\gamma_5C\psi)d^3x;C=i\gamma^0\gamma^2$$ **Cooper pair**

Weinberg – Salam model/Ginzburg – Landau Model
Higgs – bosons/Cooper pairs are condensed
(world trajectories)



Weinberg – Salam model

$$L=\frac{1}{2}\int[(\partial_\mu-2iA_\mu)H]^+(\partial^\mu-2iA^\mu)Hd^3x-\frac{\lambda}{4}\int(|H|^2-v^2)^2d^3x$$

$$A\in SU(2)\otimes U(1);H=\begin{pmatrix}h_1\\h_2\end{pmatrix}$$

Ginzburg – Landau Model

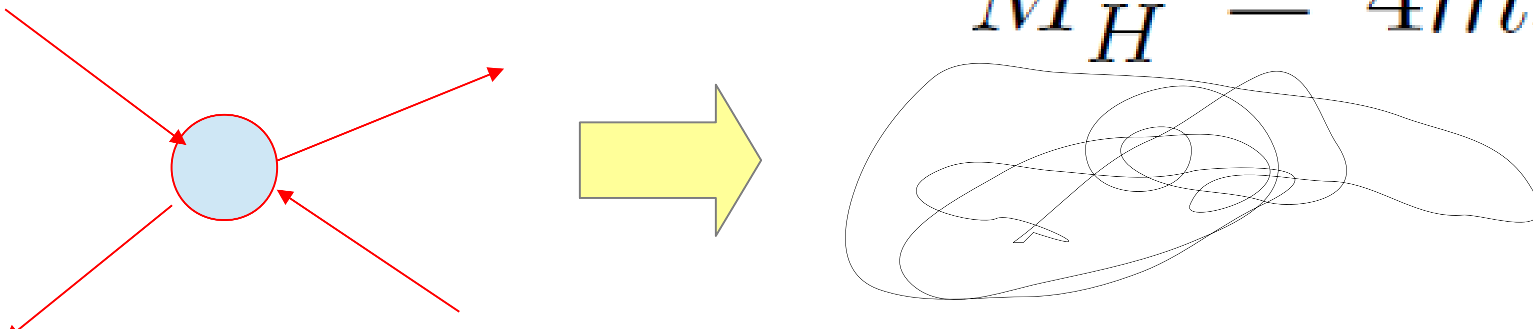
$$L=\frac{1}{2}\int[(\partial_\mu-2iA_\mu)H]^+(\partial^\mu-2iA^\mu)Hd^3x-\frac{\lambda}{4}\int(|H|^2-v^2)^2d^3x$$

Top quark condensation model = analogue of BCS model for s-wave superconductor

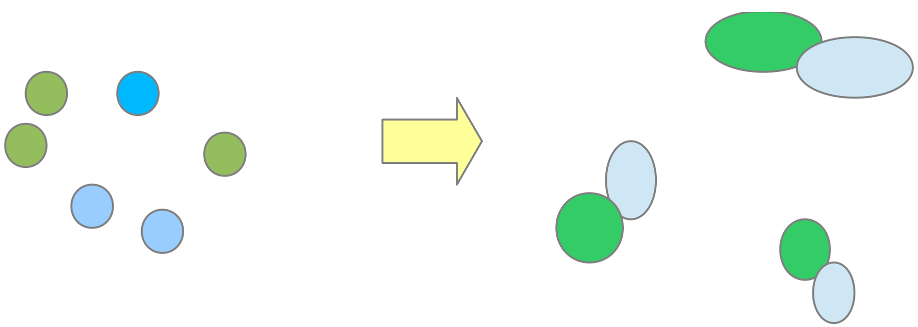
Top quarks ----> Higgs bosons 350 GeV

Nambu sum rule

$$M_H^2 = 4m_t^2$$



$$S_I' = \frac{1}{M_I^2} \int d^4x \left(\bar{L}_{aK}^{(tb)A} t_{R,K}^A \right) \left(\bar{t}_{R,N}^B L_{aN}^{(tb)B} \right) \qquad L_{aK}^{(tb)A} = \begin{pmatrix} t_{L,K}^A \\ b_{L,K}^A \end{pmatrix}$$



$$H_a \sim \bar{t}_{R,N}^B L_{aN}^{(tb)B}$$

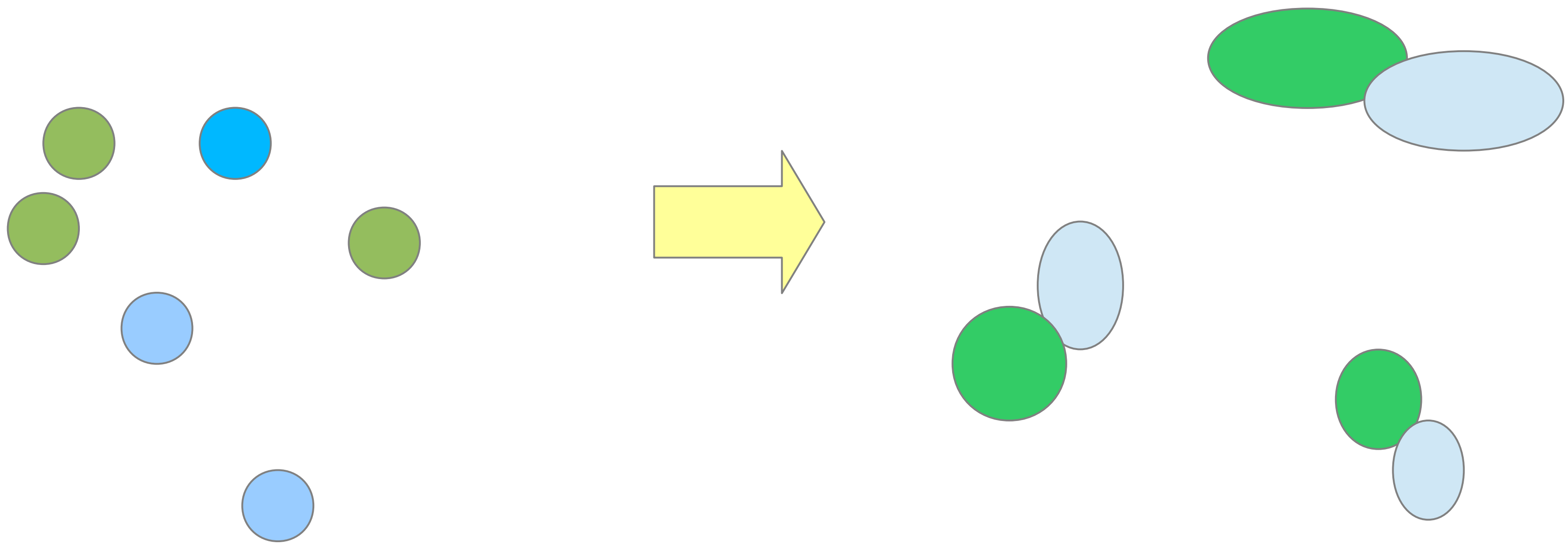
V.A. Miransky, Masaharu Tanabashi, and Koichi Yamawaki, Mod. Phys. Lett. A 4, 1043--1053 (1989); Bardeen 1990

New version of top quark condensation model

Four – fermion interaction
with the non – trivial form – factors

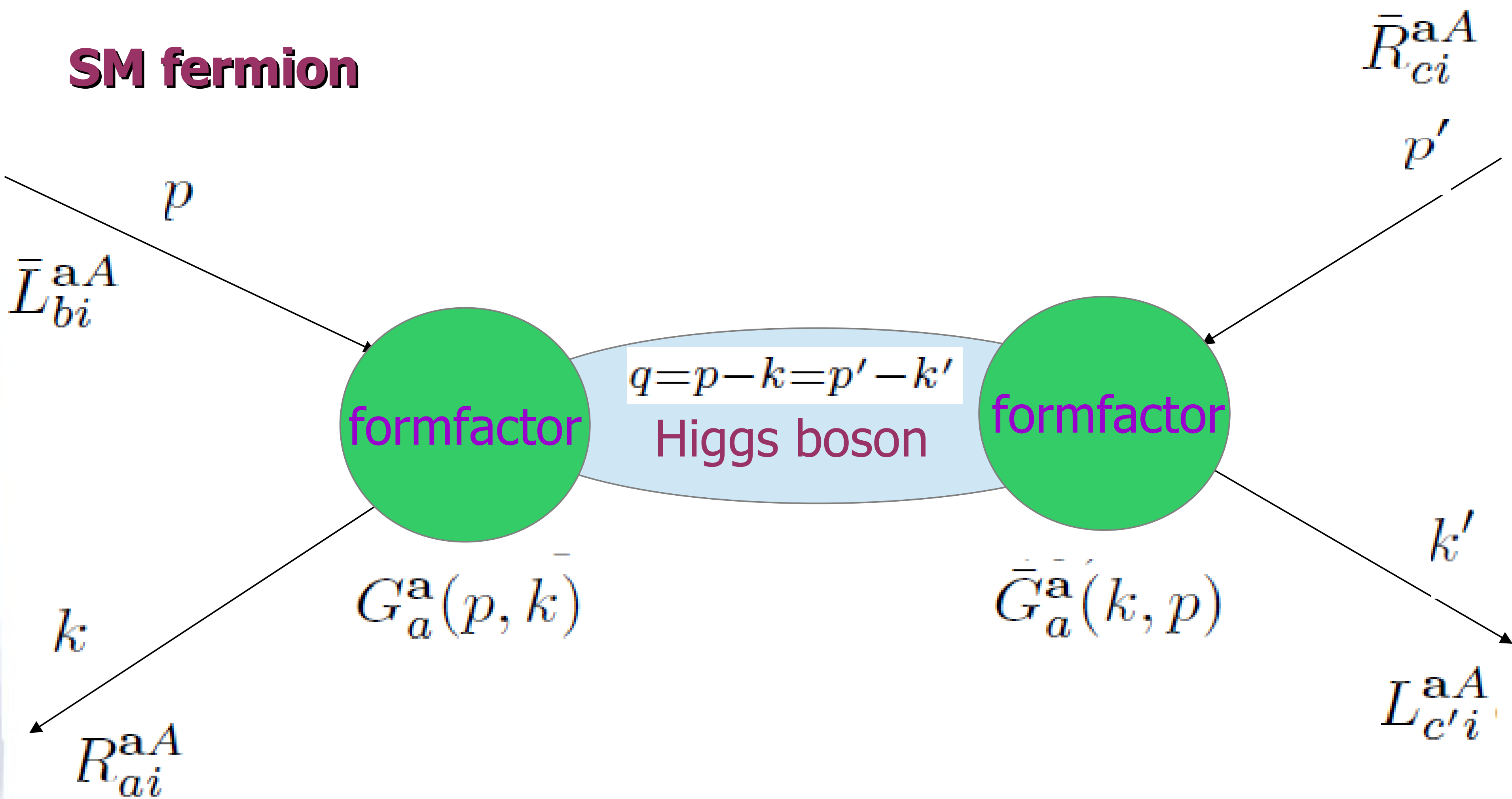
Higgs boson

All leptons and all quarks ----> composite Higgs boson



Four – fermion interaction with the non – trivial form – factors

SM fermion



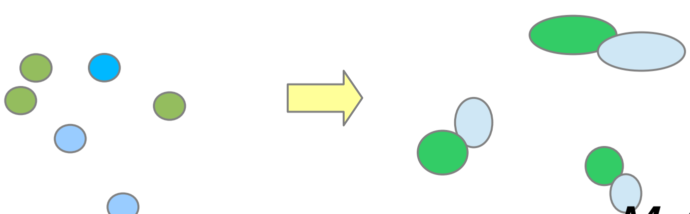
New version of the top quark condensation model

Modified Nambu Sum rule. All quarks and leptons ----> Higgs bosons 125 GeV

$$N_{\mathrm{total}} M_H^2 = 4 N_c m_t^2$$

$$N_{\mathrm{total}} = 2 \times (N_c + 1) \times N_g = 24,\ N_c = 3 \qquad N_g = 3$$

1. The four – fermion interaction involves all quarks and leptons
2. The four – fermion interaction in nonlocal
3. At small distances it is highly symmetric
4. At large distances it is complicated and produces different masses for different fermions



M.A.Zubkov, Phys. Rev. D 89 (2014), 075012

The fermions of the Standard Model

quarks

$$L^{\mathbf{1}} = \begin{pmatrix} u_L \\ d_L \end{pmatrix}, \quad L^{\mathbf{2}} = \begin{pmatrix} c_L \\ s_L \end{pmatrix}, \quad L^{\mathbf{3}} = \begin{pmatrix} t_L \\ b_L \end{pmatrix}$$

$$R_U^{\mathbf{1}} = u_R, \quad R_U^{\mathbf{2}} = c_R, \quad R_U^{\mathbf{3}} = t_R$$

$$R_D^{\mathbf{1}} = d_R, \quad R_D^{\mathbf{2}} = s_R, \quad R_D^{\mathbf{3}} = b_R$$

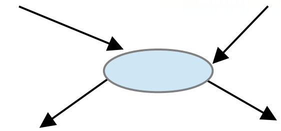
leptons

$$\mathcal{L}^{\mathbf{1}} = \begin{pmatrix} \nu_L \\ e_L \end{pmatrix}, \quad \mathcal{L}^{\mathbf{2}} = \begin{pmatrix} \nu_{\mu L} \\ \mu_L \end{pmatrix}, \quad \mathcal{L}^{\mathbf{3}} = \begin{pmatrix} \nu_{\tau L} \\ \tau_L \end{pmatrix}$$

$$\mathcal{R}_N^{\mathbf{1}} = \nu_R, \quad \mathcal{R}_N^{\mathbf{2}} = \nu_{\mu R}, \quad \mathcal{R}_N^{\mathbf{3}} = \nu_{\tau R}$$

$$\mathcal{R}_E^{\mathbf{1}} = e_R, \quad \mathcal{R}_E^{\mathbf{2}} = \mu_R, \quad \mathcal{R}_E^{\mathbf{3}} = \tau_R$$

Non – local four – fermion interaction



$$S_I = \frac{V}{M_I^2} \sum_{\mathbf{a}} \sum_{q=p-k=p'-k'} \Big(\bar{L}_b^{\mathbf{a}}(p) R_U^{\mathbf{a}}(k) G_U^{\mathbf{a}}(p,k) + \bar{\mathcal{L}}_b^{\mathbf{a}}(p) \mathcal{R}_N^{\mathbf{a}}(k) G_N^{\mathbf{a}}(p,k)$$

$$+ \bar{R}_D^{\mathbf{a}}(p) L_c^{\mathbf{a}}(k) \epsilon_{bc} G_D^{\mathbf{a}}(p,k) + \bar{\mathcal{R}}_E^{\mathbf{a}}(p) \mathcal{L}_c^{\mathbf{a}}(k) \epsilon_{bc} G_E^{\mathbf{a}}(p,k) \Big)$$

$$\Big(\bar{G}_D^{\mathbf{a}}(p',k') \bar{L}_d^{\mathbf{a}}(k') R_D^{\mathbf{a}}(p') \epsilon_{bd} + \bar{G}_E^{\mathbf{a}}(p',k') \bar{\mathcal{L}}_d^{\mathbf{a}}(k') \mathcal{R}_E^{\mathbf{a}}(p') \epsilon_{bd}$$

$$+ \bar{G}_U^{\mathbf{a}}(p',k') \bar{R}_U^{\mathbf{a}}(k') L_b^{\mathbf{a}}(p') + \bar{G}_N^{\mathbf{a}}(p',k') \bar{\mathcal{R}}_N^{\mathbf{a}}(k') \mathcal{L}_b^{\mathbf{a}}(p') \Big),$$

Formfactor for all fermions except for the top quark

$$G_a^{\mathbf{a}}(p,k) = g_a^{\mathbf{a}}(q^2, p^2, k^2) \to 1$$
$$(|q^2|, |p^2|, |k^2| \sim M_Z^2 \sim [90\,\mathrm{GeV}]^2)$$
$$G_a^{\mathbf{a}}(p,k) = g_a^{\mathbf{a}}(q^2, p^2, k^2) \to 0 \quad (|q^2|, |p^2|, |k^2| \ll M_Z^2)$$

for the top quark

$$G_t(p,k) \equiv G_U^{\mathbf{3}}(p,k) \approx 1$$

Distances ~ 1/100 GeV; momenta transfer ~ 100 GeV

$$S_I \;=\; -V \sum_{\mathbf{a}} \sum_{q=p-k} \left[\bar{L}^{\mathbf{a}}_b(p) R^{\mathbf{a}}_U(k) H^b(q) + \bar{\mathcal{L}}^{\mathbf{a}}_b(p) \mathcal{R}^{\mathbf{a}}_N(k) H^b(q) + (h.c.) \right]$$
$$-V \sum_{\mathbf{a}} \sum_{q=p-k} \left[\bar{L}^{\mathbf{a}}_c(k) R^{\mathbf{a}}_D(p) \bar{H}^b(q) \epsilon_{bc} + \bar{\mathcal{L}}^{\mathbf{a}}_c(k) \mathcal{R}^{\mathbf{a}}_E(p) \bar{H}^b(q) \epsilon_{bc} + (h.c.) \right] \Big]$$

$$(|(p-k)^2|, |p^2|, |k^2| \sim M_Z^2)$$

The field of composite Higgs boson H

$$S \;= \text{-}V \sum_p H^+(p) H(p) M_I^2$$

Effective four – fermion interaction is obtained after the integration over H

Distances >> 1/100 GeV; momenta transfer << 100 GeV

$$S_I' = -\int d^4x \left(\bar{L}_{aK}^{(tb)A} t_{R,K}^A H^a + (h.c.) \right)$$

$$L_{aK}^{(tb)A} = \begin{pmatrix} t_{L,K}^A \\ b_{L,K}^A \end{pmatrix}, \quad t_{R,K}^A$$

Top - quark

Effective action (leading 1/Nc order) using zeta – regularization

M.A.Zubkov, Phys. Rev. D 89 (2014), 075012

Quadratic divergences are absent ; the same for the dimensional regularization ; ordinary cutoff regularization gives different result

$$S[H] = \int d^4x \Big(Z_h^2 \, H^+(x)(-D^2 w(D^2))H(x) - \frac{1}{8}(|H|^2 - v^2)^2 \Big)$$

$$D = \partial + iB \text{ with } B = B^a_{SU(2)}\sigma^a + Y B_{U(1)}$$

$$Z_h^2 \approx \frac{N_{\rm total}}{16\pi^2} \log \frac{\mu^2}{m_t^2} \qquad N_{\rm total} = 2 \times (N_c + 1) \times N_g = 24, \; N_c = 3$$

$$w(-p^2) \to 1 \, (|p^2| \sim [90\,{\rm GeV}]^2);$$
$$w(-p^2) \to N_c/N_{\rm total} = 1/8 \, (|p^2| \ll [90\,{\rm GeV}]^2)$$

$$M_H^2 \approx 4N_c m_t^2/N_{\rm total} = m_t^2/2$$

Scale of the hidden interaction $\mu \sim 5$ TeV

Effective potential for the gauge field

$$\|B\|^2 = -(1,0)B^2(1,0)^T = -\Big((B^3_{SU(2)} - B_{U(1)})^2 + [B^1_{SU(2)}]^2 + [B^2_{SU(2)}]^2\Big)$$

$$V_B \approx \frac{N_{\rm total}}{16\pi^2} m_t^2 \log\frac{\mu^2}{m_t^2}\, w(\|B\|^2)\,\|B\|^2$$

we substitute B ~ 90 GeV

$$w(M_Z^2) \approx 1$$

$$S_B \approx \frac{\eta^2}{2}\|B\|^2 \approx \frac{N_{\rm total}}{16\pi^2} m_t^2 \log\frac{\mu^2}{m_t^2}\,\|B\|^2$$

$$\eta^2 \approx 2Z_h^2 v^2 = \frac{2N_{\rm total}}{16\pi^2} m_t^2 \log\frac{\mu^2}{m_t^2}$$

η should be equal to $\approx$ 246 GeV

Scale of the hidden interaction $\mu \sim 5$ TeV

Branching ratios and Higgs production cross - sections

$$h \rightarrow gg, \gamma\gamma, ZZ, WW, \bar{b}b, \bar{c}c, \bar{\tau}\tau$$

$$L_{eff} = \frac{2m_W^2}{\eta} h W_\mu^+ W_\mu^- + \frac{m_Z^2}{\eta} h Z_\mu Z_\mu + c_g \frac{\alpha_s}{12\pi\eta} h G_{\mu\nu}^a G_{\mu\nu}^a$$
$$+ c_\gamma \frac{\alpha}{\pi\eta} h A_{\mu\nu} A_{\mu\nu} - c_b \frac{m_b}{\eta} h \bar{b}b - c_c \frac{m_c}{\eta} h \bar{c}c - c_\tau \frac{m_\tau}{\eta} h \bar{\tau}\tau$$

SM gives $c_g \simeq 1.03 \,, c_\gamma \approx -0.81$

For the particular form of the form factors (all but the t quark)

$$G_a^{\mathbf{a}}(p,k) = g_a^{\mathbf{a}}(q^2, p^2, k^2) = \begin{cases} 1 \text{ for } |q^2|, |p^2|, |k^2| > M_0^2 \\ \kappa_a^{\mathbf{a}} << 1 \, \text{otherwise} \end{cases}$$

for the top quark

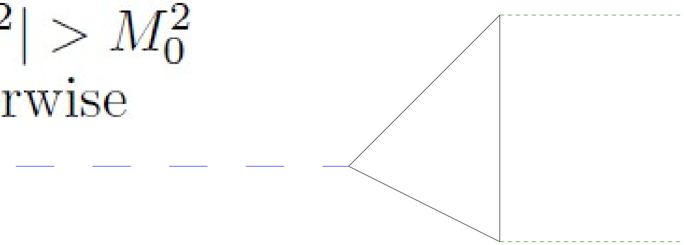
$$G_t(p,k) \equiv G_U^{\mathbf{3}}(p,k) \approx 1$$

$$c_b \approx g(M_H^2, m_b^2, m_b^2)/\kappa_D^{\mathbf{3}}$$
$$c_c \approx g(M_H^2, m_c^2, m_c^2)/\kappa_U^{\mathbf{2}}$$
$$c_b \approx g(M_H^2, m_\tau^2, m_\tau^2)/\kappa_E^{\mathbf{3}}$$

Branching ratios and Higgs production cross - sections

For the particular form of the form factors (all but the t quark)

$$G_a^{\mathbf{a}}(p,k) = g_a^{\mathbf{a}}(q^2,p^2,k^2) = \begin{cases} 1 \text{ for } |q^2|, |p^2|, |k^2| > M_0^2 \\ \kappa_a^{\mathbf{a}} << 1 \,\text{otherwise} \end{cases}$$



corrections

$$\delta c_g^{(f)} = \frac{2m_f}{M_H}\delta r_g^{(f)} \qquad \delta c_\gamma^{(b,c,\tau)} = \left(3(1/3)^2 m_b + 3(2/3)^2 m_c + m_\tau\right)\frac{2}{6M_H}\delta r_g$$

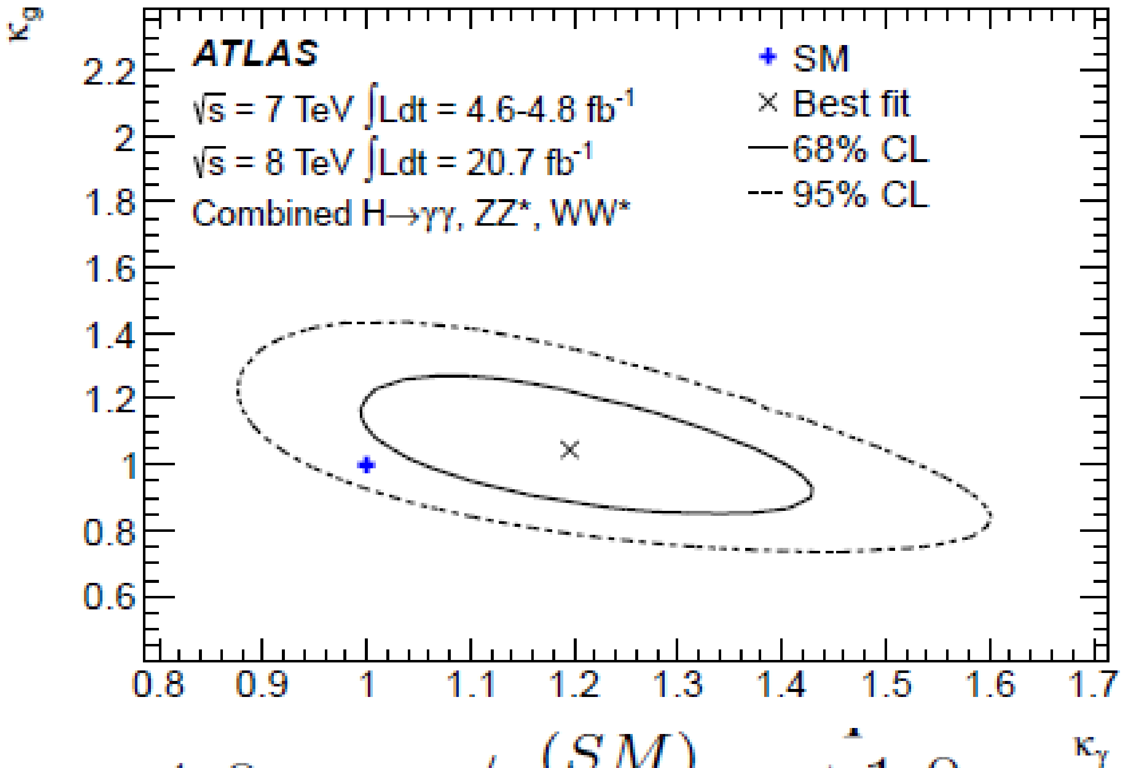
$$\delta r_g^{(f)} \approx \frac{3\sqrt{2}}{\tau_0}\left(\tau_0 - \frac{\tau_0 - 1}{4}\left[\log\left|\frac{\sqrt{1-1/\tau_0}+1}{\sqrt{1-1/\tau_0}-1}\right|\right]^2\right) \qquad \tau_0 = \frac{M_H^2}{4M_0^2}$$

$$-1.0 < c_g/c_g^{(SM)} < +1.0$$

$$M_0 = 10 \text{ GeV} \qquad M_0 = 35 \text{ GeV}$$

$$1.4 > c_\gamma/c_\gamma^{(SM)} > 1.0$$

Branching ratios and Higgs production cross – sections (ATLAS) Phys. Lett. B 726 (2013) 88



Our estimate

$$-1.0 < c_g/c_g^{(SM)} < +1.0$$

$M_0 = 10$ GeV $\qquad M_0 = 35$ GeV.

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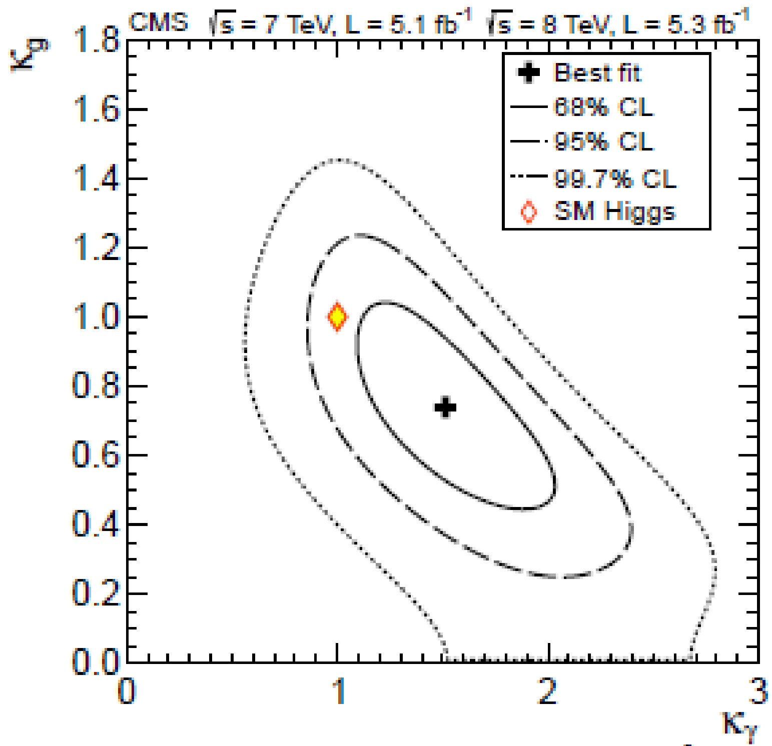
Branching ratios and Higgs production cross – sections (CMS) JHEP 06 (2013) 081



Our estimate

$$-1.0 < c_g/c_g^{(SM)} < +1.0$$

$M_0 = 10$ GeV $\qquad\qquad M_0 = 35$ GeV.

$$1.4 > c_\gamma/c_\gamma^{(SM)} > 1.0$$

Effective theory at small distances ~1/100GeV

quarks

$$L^1 = \begin{pmatrix} u_L \\ d_L \end{pmatrix}, \quad L^2 = \begin{pmatrix} c_L \\ s_L \end{pmatrix}, \quad L^3 = \begin{pmatrix} t_L \\ b_L \end{pmatrix}$$

$$R^1 = \begin{pmatrix} u_R \\ d_R \end{pmatrix}, \quad R^2 = \begin{pmatrix} c_R \\ s_R \end{pmatrix}, \quad R^3 = \begin{pmatrix} t_R \\ b_R \end{pmatrix}$$

leptons

$$\mathcal{L}^1 = \begin{pmatrix} \nu_L \\ e_L \end{pmatrix}, \quad \mathcal{L}^2 = \begin{pmatrix} \nu_{\mu L} \\ \mu_L \end{pmatrix}, \quad \mathcal{L}^3 = \begin{pmatrix} \nu_{\tau L} \\ \tau_L \end{pmatrix}$$

$$\mathcal{R}^1 = \begin{pmatrix} \nu_R \\ e_R \end{pmatrix}, \quad \mathcal{R}^2 = \begin{pmatrix} \nu_{\mu R} \\ \mu_R \end{pmatrix}, \quad \mathcal{R}^3 = \begin{pmatrix} \nu_{\tau R} \\ \tau_R \end{pmatrix}$$

$$L^{\mathbf{a}}_{a,4} = \mathcal{L}^{\mathbf{a}}_a \qquad R^{\mathbf{a}}_{a,4} = \mathcal{R}^{\mathbf{a}}_a$$

At small distances (large momenta transfer)

$$S_I = -\int d^4x \Big(\bar{L}^{\mathrm{a}A}_{1i} R^{\mathrm{a}A}_{1i} h + \bar{R}^{\mathrm{a}A}_{2i} L^{\mathrm{a}A}_{2i} h + (h.c.) \Big)$$

For example, for the quarks of the first generation:

$$S_I^{(ud)} = -\int d^4x \Big(\bar{u}^A_L u^A_R h + \bar{d}^A_R d^A_L h + (h.c.) \Big)$$

All leptons and all quarks ----> composite Higgs boson
All fermions interact in an equal way

Standard Model fermions as components of Majorana spinor

Nambu – Gorkov spinor

$$\mathbf{L}^{\mathbf{a}A}_{aiU} = \begin{pmatrix} L^{\mathbf{a}A}_{ai} \\ \bar{L}^{\mathbf{a}B}_{c'i}\epsilon_{c'a}\epsilon^{BA} \end{pmatrix}, \; \mathbf{R}^{\mathbf{a}A}_{aiU} = \begin{pmatrix} \bar{R}^{\mathbf{a}B}_{bi}\epsilon_{ba}\epsilon^{BA} \\ R^{\mathbf{a}A}_{a,i} \end{pmatrix}$$

Spinor representation of O(4) = SU(2)xSU(2)

$$\Psi^{\mathbf{a}}_{i} = \begin{pmatrix} \mathbf{L}^{\mathbf{a}}_{ai} \\ \mathbf{R}^{\mathbf{a}}_{ai} \end{pmatrix} \qquad \bar{\Psi}^{\mathbf{a}}_{i} = \left(\Psi^{\mathbf{a}}_{i}\right)^{T} i\gamma^{2}\gamma^{5}\gamma^{0}\Gamma^{4}\Gamma^{2}\Gamma^{5}$$

$$\bar{\mathbf{L}}^{\mathbf{a}}_{ai} = \epsilon_{ab}\left(\mathbf{L}^{\mathbf{a}}_{bi}\right)^{T} i\gamma^{2}\gamma^{5}\gamma^{0}, \; \bar{\mathbf{R}}^{\mathbf{a}}_{ai} = \epsilon_{ab}\left(\mathbf{R}^{\mathbf{a}}_{bi}\right)^{T} i\gamma^{2}\gamma^{5}\gamma^{0}$$

The Standard Model gauge group

$$e^{i\theta} \in U(1)_Y \subset SU(2)_R, \; U^{(L)} \in SU(2)_L$$

$$U^{(R)} = \begin{pmatrix} e^{i\theta} & 0 \\ 0 & e^{-i\theta} \end{pmatrix} \in SU(2)_R \qquad Q \in SU(3)$$

$$V = \begin{pmatrix} Qe^{i\theta/3} & 0 \\ 0 & e^{-i\theta} \end{pmatrix} \in SU(4)_{\text{Pati Salam}} \subset U(12)$$

Action on the spinor

$$\Psi_i^{\mathbf{a}} \to \left(V_{ij} \frac{1+\Gamma^5\gamma^5}{2} + \bar{V}_{ij} \frac{1-\Gamma^5\gamma^5}{2} \right) \begin{pmatrix} U^{(L)} & 0 \\ 0 & U^{(R)} \end{pmatrix} \Psi_j^{\mathbf{a}}$$

Global symmetry group is O(4)xU(12) = SU(2)xSU(2)xU(12)

Distances ~ 1/100 GeV; momenta transfer ~ 100 GeV

$$S_K = \frac{i}{2}\int d^4x \left(\bar{\Psi}_i^{\mathbf{a}} \gamma^\mu \nabla_\mu \Psi_i^{\mathbf{a}} \right)$$

$$\bar{\Psi}_i^{\mathbf{a}} = \left(\Psi_i^{\mathbf{a}} \right)^T i\gamma^2\gamma^5\gamma^0\Gamma^4\Gamma^2\Gamma^5$$

The field of composite Higgs boson $\mathbf{H} = \sum_{K=1,2,3,4} \mathbf{h}_K \Gamma^K$

$$S_I = \frac{1}{2}\int d^4x \left(\bar{\Psi}_i^{\mathbf{a}} \gamma^5 \Gamma^5 \mathbf{H} \Psi_i^{\mathbf{a}} \right)$$

$$g_H M_I \gg 100 \text{ GeV}$$

$$S_H = \int d^4x \Big[\frac{1}{4g_H^2} \mathrm{Tr}\,(\nabla \mathbf{H})^2 - \frac{M_I^2}{4} \mathrm{Tr}\,\mathbf{H}^2 \Big]$$

Effective four – fermion interaction is obtained after the integration over H $S_I = \frac{1}{M_I^2}\int d^4x \left(\bar{\mathbf{L}}_a \gamma^5 \mathbf{R}_b \right) \left(\bar{\mathbf{R}}_b \gamma^5 \mathbf{L}_a \right)$

Unitary gauge fixing

$$\bar{\Psi}^{\mathbf{a}}_i = \left(\Psi^{\mathbf{a}}_i\right)^T i\gamma^2\gamma^5\gamma^0\Gamma^4\Gamma^2\Gamma^5$$

$$S_I = \frac{1}{2}\int d^4x\left(\bar{\Psi}^{\mathbf{a}}_i\gamma^5\Gamma^5\mathbf{H}\Psi^{\mathbf{a}}_i\right)$$

$$S_I = -\frac{1}{2}\int d^4x\left(\bar{L}^{\mathbf{a}A}_{bi}R^{\mathbf{a}A}_{ai}H_{ab} + \bar{R}^{\mathbf{a}A}_{ci}L^{\mathbf{a}A}_{c'i}\epsilon_{c'b}\epsilon_{ca}H_{ab} + (h.c.)\right)$$

The field of composite Higgs boson

$$H_{ab} = \mathbf{h}^4\delta_{ab} + i\sum_{K=1,2,3}\mathbf{h}^K\tau^K_{ab} = H\,U_{\mathbf{h}}$$

$$L^{\mathbf{a}A}_{ai} \to [U_{\mathbf{h}}]_{ab}L^{\mathbf{a}A}_{bi}$$

$$U_{\mathbf{h}} = \left[\hat{\mathbf{h}}^4\mathbf{1} + i\sum_{K=1,2,3}\hat{\mathbf{h}}^K\tau^K\right]_{ab} \in SU(2)$$

$$H_{ab} = H\delta_{ab}$$

$$H = v + h \in \mathcal{R}$$

$$H = \sqrt{\sum_{k=1,2,3,4}\mathbf{h}^2_k}, \quad \hat{\mathbf{h}}^K = \frac{1}{H}\mathbf{h}^K$$

Effective interaction between fermions and the h - boson

$$S_I = -\int d^4x\left(\bar{L}^{\mathbf{a}A}_{1i}R^{\mathbf{a}A}_{1i}h + \bar{R}^{\mathbf{a}A}_{2i}L^{\mathbf{a}A}_{2i}h + (h.c.)\right)$$

Due to the unknown strong dynamics the Higgs boson is composed of the known leptons and quarks

The interaction between the composite Higgs boson and the SM fermions is U(12)xO(4) symmetric at small distances ~ 1/[100GeV]

$$M_h = m_t/\sqrt{2} \approx 125 \text{ GeV},$$

(cancellation of quadratic divergences is required)

At large distances the new interaction is complicated and results in the hierarchy of fermion masses

More detailed view of how this unknown hidden interaction might look like