Quark mass generation due to scalar fields with zero dimension from anomaly cancellations

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Introduction. Why composite Higgs?

- The 125 GeV scalar particle is discovered experimentally

- Values of couplings of the discovered scalar particle to the other fields are close to the predictions of the Standard Model

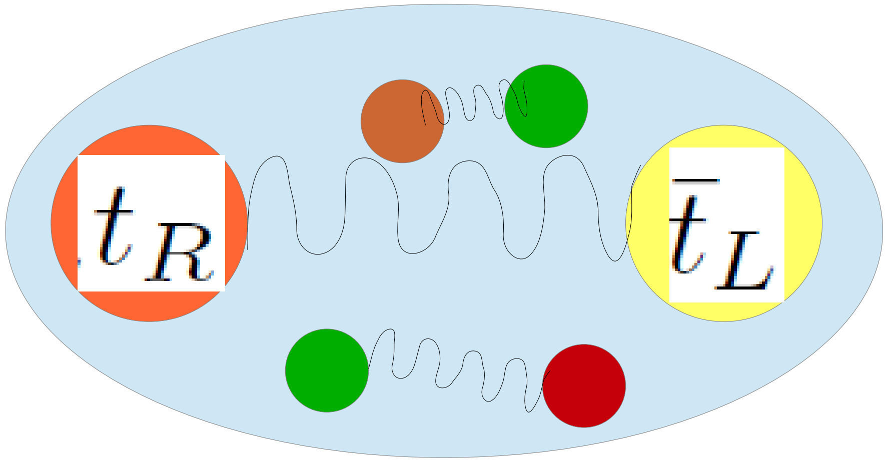
- Nevertheless, **the possibility that this scalar particle is composed of fermions** (like Cooper pairs in superconductors) **is not excluded**

LHC

Working hypothesis

125 GeV Higgs boson is composed **mostly of top quark**

It also consists partially of the other SM fermions



Pre - history

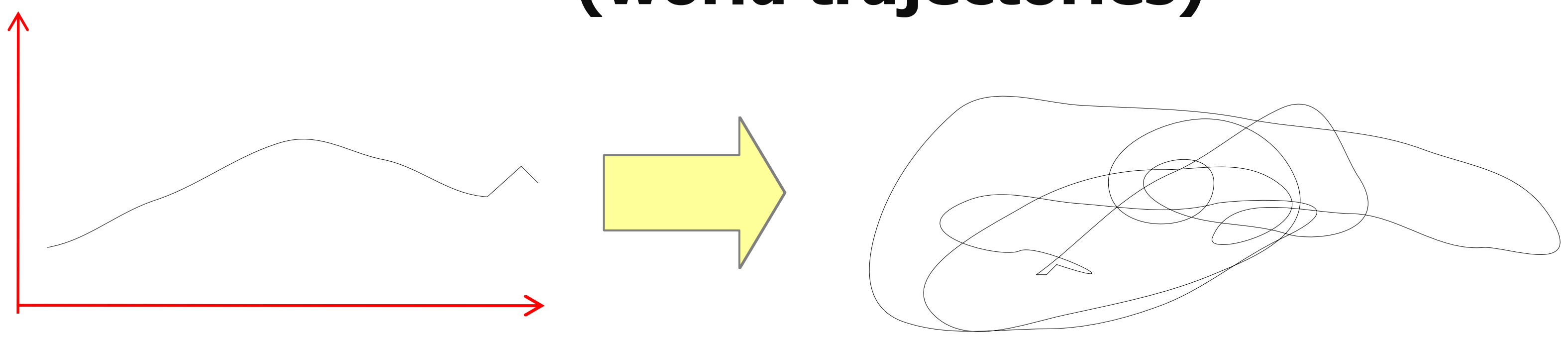
Simplest Top quark condensation model = analogue of BCS model for s-wave superconductor

First proposed in 1977: **H. Terazawa, Y. Chikashige, K. Akama**, Phys. Rev. D 15, 480 (1977); H. Terazava, Phys. Rev. D 22, 2921 (1980); erratum: H. Terazawa, Phys. Rev. D 41, 3541 (1990).

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

Later discussed in 1990: **W. A. Bardeen, C. T. Hill, and M. Lindner**, Phys. Rev. D 41, 1647-1660 (1990);

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



Weinberg – Salam model

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

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

Ginzburg – Landau Model

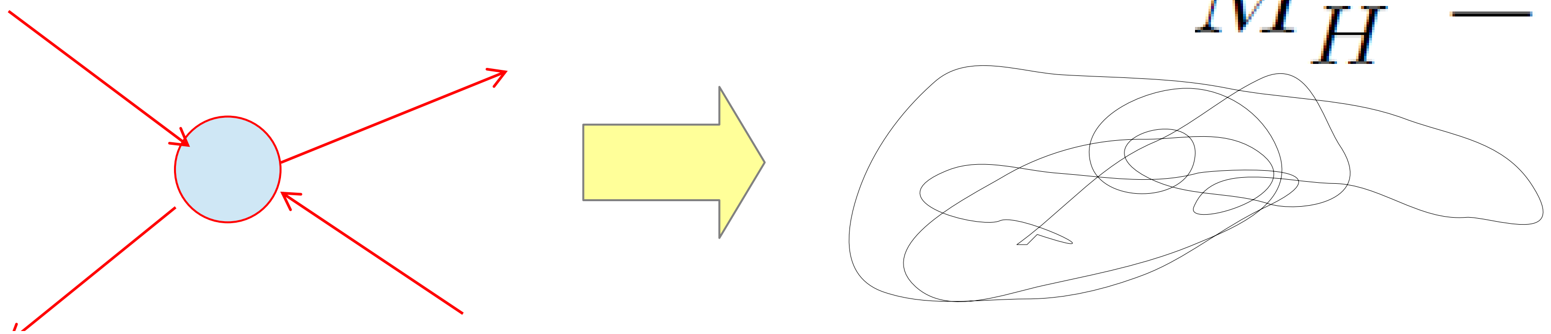
$$L = \frac{1}{2}\int [(\partial_\mu - 2iA_\mu)H]^+ (\partial^\mu - 2iA^\mu) H d^3 x - \frac{\lambda}{4}\int (\|H\|^2 - v^2)^2 d^3 x$$

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

Top quarks ----> Higgs bosons 350 GeV

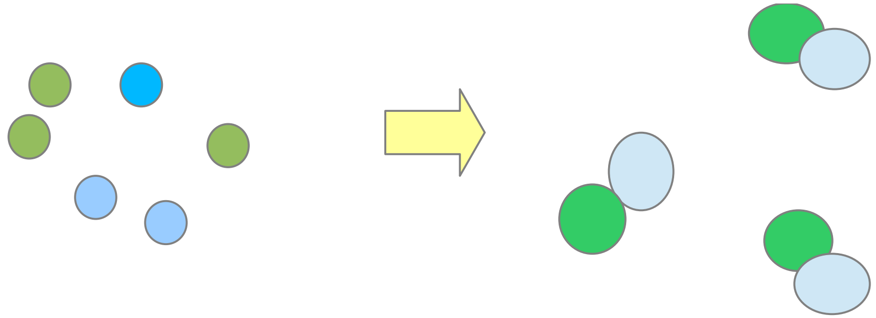
Nambu sum rule

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



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

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



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

Excluded

Experimentally

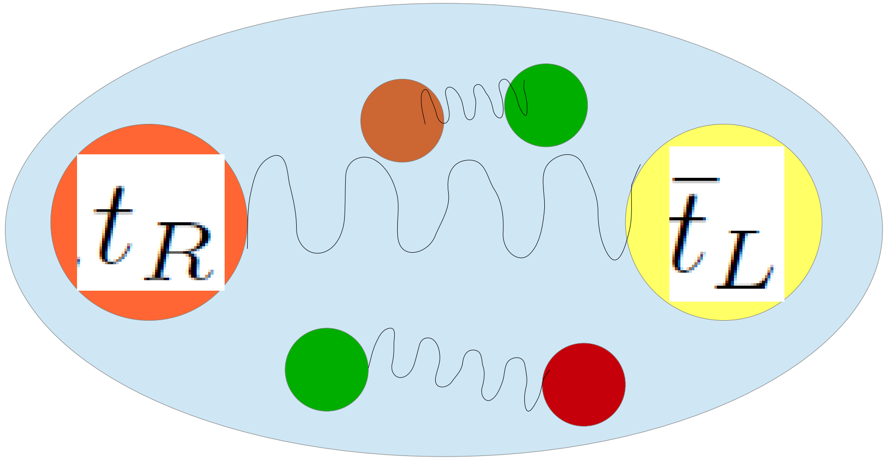
Top quark condensation – superconductivity dictionary

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

OUR MODIFICATION OF TOP QUARK CONDENSATION SCENARIO

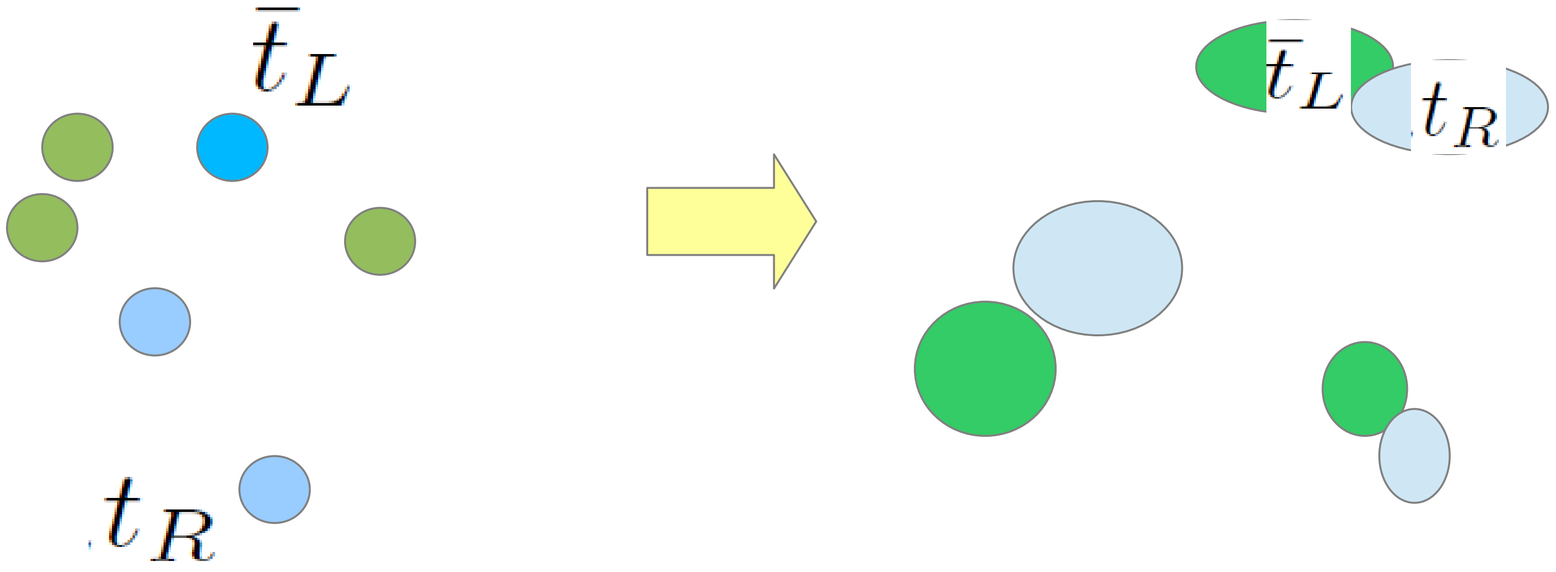
125 GeV Higgs boson is composed **of top quark**

The interactions that provide this condensation are very peculiar

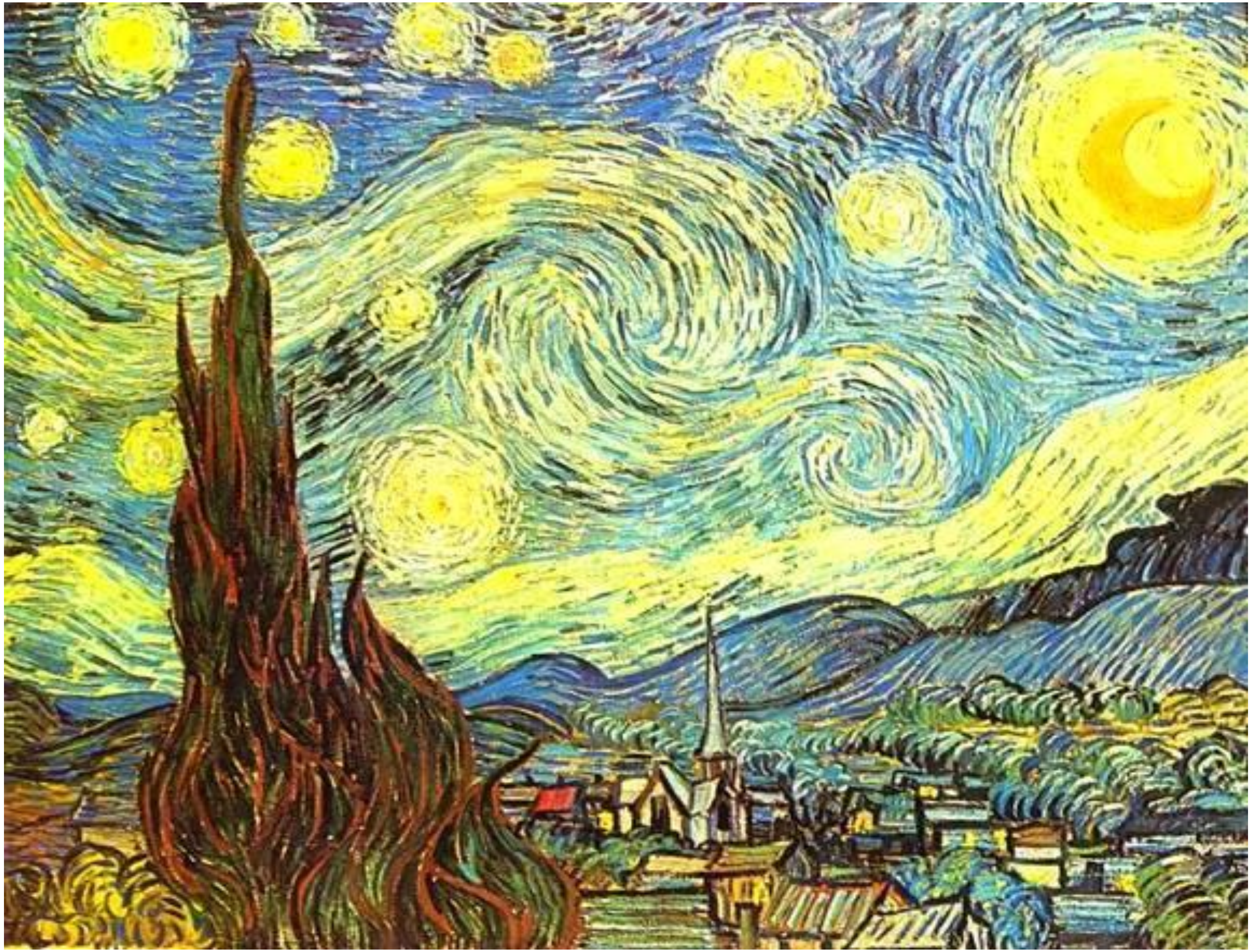


Composite Higgs boson

Top quark + new heavy fermion with quantum numbers of right – handed top ----> composite Higgs boson



One can imagine the unknown interactions behind this as



Extension of the previous work

Fundamental scalar field with zero dimension from anomaly cancellations

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Plan

1. Nonminimal coupling of gravity to fermions. Introduction of the zero dimension scalar fields of geometric origin.
2. Composite model without Weyl anomaly
3. Toy model with top and bottom quarks
4. Dynamical chiral symmetry breaking and Schwinger – Dyson equation
5. Solution of Schwinger – Dyson equation
6. Relation between ultraviolet cutoff, infrared cutoff, and top quark mass
7. Plans for future

Minimal coupling of gravity to fermions.

$$S = \frac{1}{6}\epsilon_{abcd}\int d^4x\,\theta^a \wedge e^b \wedge e^c \wedge e^d \qquad \theta^a = \frac{i}{2}\left[\bar{\psi}\gamma^a D_\mu\psi - \overline{D_\mu\psi}\gamma^a\psi\right] dx^\mu$$

$$D_\mu\psi = \partial_\mu\psi - \frac{i}{2}\gamma_{ab}\omega^{ab}{}_\mu\psi \qquad \gamma_{ab} = \tfrac{1}{4}[\gamma_a, \gamma_b]$$

Nonminimal coupling of gravity to fermions.

$$S = \frac{1}{6}\epsilon_{abcd}\int d^4x\, \theta^a \wedge e^b \wedge e^c \wedge e^d$$

$$\theta^a = \theta^a_l + \theta^a_q$$

$$\theta^a_q = \frac{i}{2}\Big[\bar{\psi}_q\,(1+\xi_q)\,\gamma^a D_\mu \psi_q - (D_\mu\bar{\psi}_q)\,(1+\xi_q^\dagger)\,\gamma^a \psi_q\Big]dx^\mu$$

ξ_l and ξ_q are the 3×3 complex - valued

$$\theta^a_l = \frac{i}{2}\Big[\bar{\psi}_q\,(1+\xi_l)\,\gamma^a D_\mu \psi_l - (D_\mu\bar{\psi}_l)\left(1+\xi_l^\dagger\right)\gamma^a \psi_l\Big]dx^\mu$$

Nonminimal couplings become scalars.

ξ_l and ξ_q are the 3×3 complex - valued

$$\theta_q^a = \frac{i}{2}\Big[\bar{\psi}_q\,(1+\xi_q)\,\gamma^a D_\mu \psi_q - (D_\mu \bar{\psi}_q)\,(1+\xi_q^\dagger)\,\gamma^a \psi_q\Big] dx^\mu$$

$$\theta_l^a = \frac{i}{2}\Big[\bar{\psi}_q\,(1+\xi_l)\,\gamma^a D_\mu \psi_l - (D_\mu \bar{\psi}_l)\left(1+\xi_l^\dagger\right)\gamma^a \psi_l\Big] dx^\mu$$

$$n_0' = 2_{\text{leps \& qrks}} \times 2_{\text{real \& imag parts}} \times 3_{\text{generations}} \times 3_{\text{generations}} = 36$$

$$S_4[\varphi] = \frac{1}{2}\int d^4x\sqrt{g}\,\varphi\,\Delta_4\,\varphi \qquad \Delta_4 = \Box^2 + 2R^{\mu\nu}\nabla_\mu\nabla_\nu - \frac{2}{3}R\Box + \frac{1}{3}(\nabla^\mu R)\nabla_\mu$$

Weyl anomaly

$$\langle T^\mu_\mu \rangle = cC^2 - aE + \xi \Box R$$

$$C^2 = R^{\alpha\beta\gamma\delta} R_{\alpha\beta\gamma\delta} - 2R^{\alpha\beta} R_{\alpha\beta} + \tfrac{1}{3} R^2$$

$$E = R^{\alpha\beta\gamma\delta} R_{\alpha\beta\gamma\delta} - 4R^{\alpha\beta} R_{\alpha\beta} + R^2$$

$$\sqrt{g}\,\Box R = -\tfrac{1}{6}\, g_{\mu\nu} \frac{\delta}{\delta g_{\mu\nu}} \int \mathrm{d}^4x \sqrt{g}\, R^2$$

$$S_{\text{non-conf}} = S_{\text{conf}} + \frac{\delta'}{12} \int \mathrm{d}^4x \sqrt{g}\, R^2$$

Weyl anomaly

In the presence of zero dimension scalars (Turok and Boyle)

$$\langle T^\mu_\mu \rangle = cC^2 - aE + \xi \Box R$$

$$C^2 = R^{\alpha\beta\gamma\delta} R_{\alpha\beta\gamma\delta} - 2R^{\alpha\beta} R_{\alpha\beta} + \frac{1}{3} R^2$$

$$E = R^{\alpha\beta\gamma\delta} R_{\alpha\beta\gamma\delta} - 4R^{\alpha\beta} R_{\alpha\beta} + R^2$$

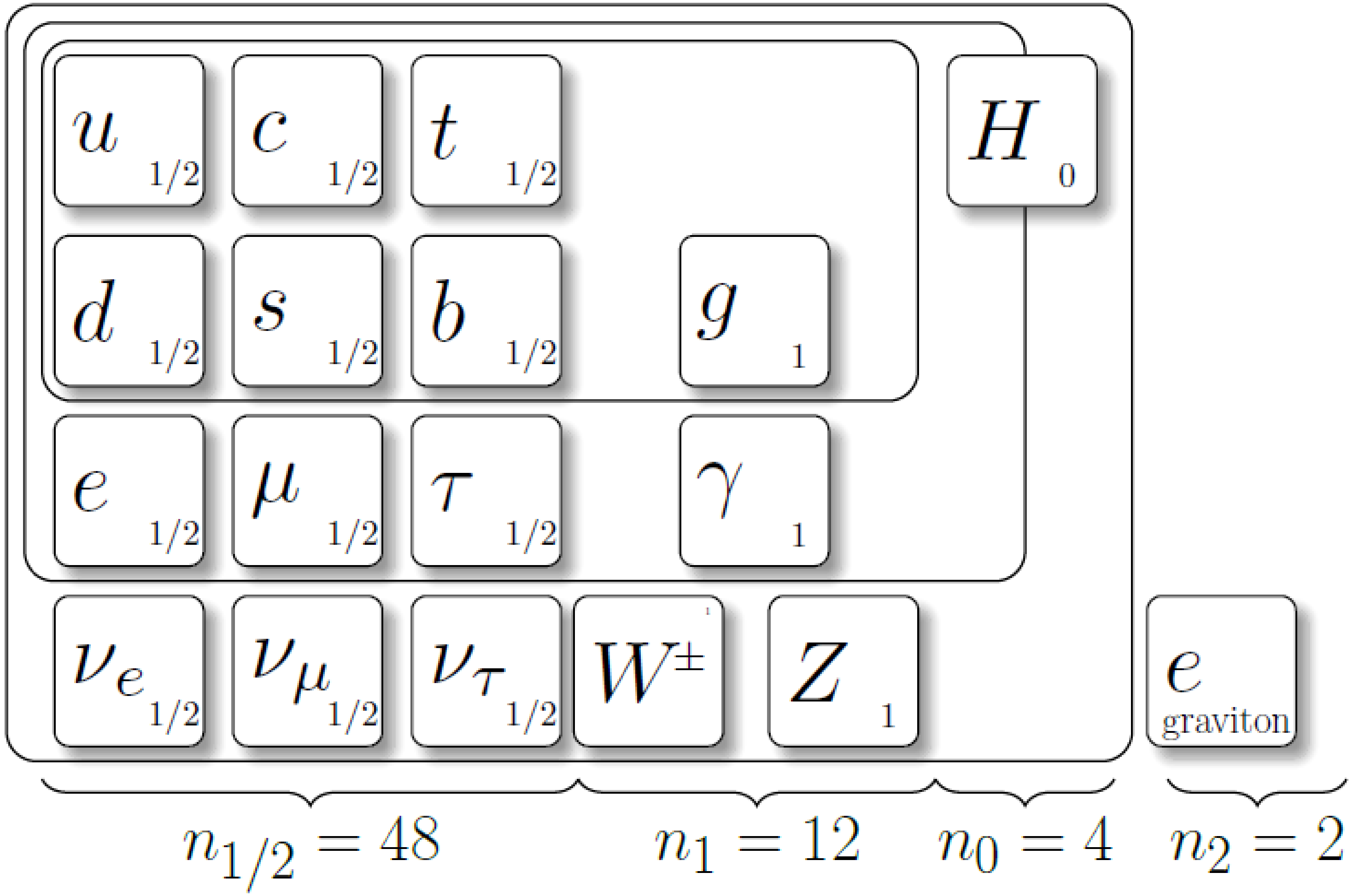
$$a = \frac{1}{360(4\pi)^2}[n_0 + \frac{11}{2} n_{1/2} + 62 n_1 + 1142 n_2 - 28 n_0']$$

$$c = \frac{1}{120(4\pi)^2}[n_0 + 3 n_{1/2} + 12 n_1 + 522 n_2 - 8 n_0']$$

Standard Model

$$a = \frac{1}{360(4\pi)^2}\left[n_0 + \frac{11}{2}n_{1/2} + 62n_1 + 1142n_2 - 28n_0'\right]$$

$$c = \frac{1}{120(4\pi)^2}\left[n_0 + 3\,n_{1/2} + 12n_1 + 522\,n_2 - 8\,n_0'\right]$$



Standard Model

$$a = \frac{1}{360(4\pi)^2}[n_0 + \frac{11}{2}n_{1/2} + 62n_1 + 1142n_2 - 28n_0']$$

$$c = \frac{1}{120(4\pi)^2}[n_0 + 3\,n_{1/2} + 12n_1 + 522\,n_2 - 8\,n_0']$$

u	c	t
d	s	b

e	μ	τ
ν	ν	τ

g	γ	W	Z

H

$n_{1/2} = 2 \times 3 \times 6 + 2 \times 6 = 48$

$n_1 = 8 + 1 + 2 + 1 = 12$

$n_0 = 4$

$n_2 = 0,\ n_0' = 0$

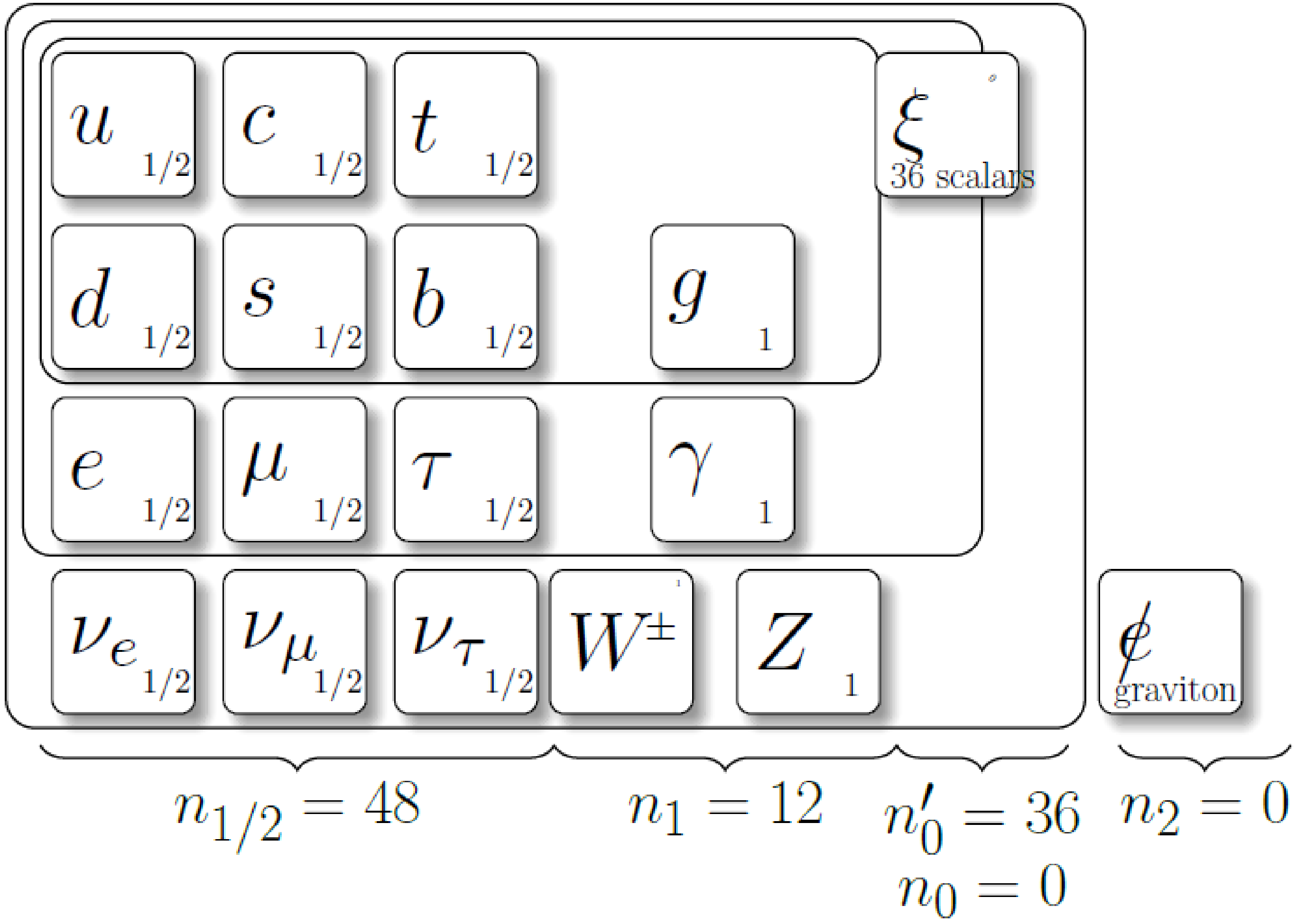
$$a = \frac{1}{360\,(4\,\pi)^2}(4 + 11 \times \frac{48}{2} + 62 \times 12)$$

$$b = \frac{1}{360\,(4\,\pi)^2}(4 + 3 \times 48 + 12 \times 12)$$

Composite Model

$$a = \frac{1}{360(4\pi)^2}\left[n_0 + \frac{11}{2}n_{1/2} + 62n_1 + 1142n_2 - 28n_0'\right]$$

$$c = \frac{1}{120(4\pi)^2}\left[n_0 + 3\,n_{1/2} + 12n_1 + 522\,n_2 - 8\,n_0'\right]$$



Composite Model

$$a = \frac{1}{360(4\pi)^2}[n_0 + \frac{11}{2} n_{1/2} + 62 n_1 + 1142 n_2 - 28 n_0']$$

$$c = \frac{1}{120(4\pi)^2}[n_0 + 3\, n_{1/2} + 12 n_1 + 522\, n_2 - 8\, n_0']$$

u	c	t
d	s	b

e	μ	τ
ν	ν	τ

g	γ	W	Z

ξ

$n_{1/2} = 2 \times 3 \times 6 + 2 \times 6 = 48$

$n_1 = 8 + 1 + 2 + 1 = 12$

$n_0{}' = 36$

$$a = \frac{1}{360\,(4\,\pi)^2}\left(11 \times \frac{48}{2} + 62 \times 12 - 28 \times 36\right) = 0$$

$$b = \frac{1}{360\,(4\,\pi)^2}(3 \times 48 + 12 \times 12 - 8 \times 36) = 0$$

Nonminimal couplings become scalars.

$$S = \frac{1}{6}\epsilon_{abcd}\int d^4x\, \theta^a \wedge e^b \wedge e^c \wedge e^d \qquad \theta^a = \theta_l^a + \theta_q^a$$

ξ_l and ξ_q are the 3×3 complex - valued

$$\theta_q^a = \frac{i}{2}\Big[\bar{\psi}_q\,(1+\xi_q)\,\gamma^a D_\mu \psi_q - (D_\mu \bar{\psi}_q)\,(1+\xi_q^\dagger)\,\gamma^a \psi_q\Big] dx^\mu$$

$$\theta_l^a = \frac{i}{2}\Big[\bar{\psi}_q\,(1+\xi_l)\,\gamma^a D_\mu \psi_l - (D_\mu \bar{\psi}_l)\left(1+\xi_l^\dagger\right)\gamma^a \psi_l\Big] dx^\mu$$

$$n_0' \doteq 2_{\text{leps \& qrks}} \times 2_{\text{real \& imag parts}} \times 3_{\text{generations}} \times 3_{\text{generations}} = 36$$

$$S_B = \alpha^{uv}_{ABCD}\int d^4x\, \left(\xi_u^{AB}\right)^* \Box^2 \xi_v^{CD} \qquad \begin{aligned} A, B, C, D &= 1, 2, 3 \\ u, v &= q, l \end{aligned}$$

Nonminimal couplings become scalars + extra couplings.

$$S = \int dx \Big[\alpha^{uv}_{ABCD} \left(\xi^{AB}_u\right)^* \Box^2 \xi^{CD}_v$$
$$+ \frac{i}{2}\bar{Q}_{aL}(1+\beta^{ab}_{cdL}\xi^{cd}_q)\not{D}Q_{bL} - \frac{i}{2}\overline{\not{D}Q_{aL}}(1+\beta^{ba*}_{cdL}\xi^{cd*}_q)Q_{bL}$$
$$+ \frac{i}{2}\bar{U}_{aR}(1+\beta^{ab}_{cdU}\xi^{cd}_q)\not{D}U_{bR} - \frac{i}{2}\overline{\not{D}U_{aR}}(1+\beta^{ba*}_{cdU}\xi^{cd*}_q)U_{bR}$$
$$+ \frac{i}{2}\bar{D}_{aR}(1+\beta^{ab}_{cdD}\xi^{cd}_q)\not{D}D_{bR} - \frac{i}{2}\overline{\not{D}D_{aR}}(1+\beta^{ba*}_{cdD}\xi^{cd*}_q)D_{bR}$$
$$+ \frac{i}{2}\bar{L}_{aL}(1+\gamma^{ab}_{cdL}\xi^{cd}_l)\not{D}L_{bL} - \frac{i}{2}\overline{\not{D}L_{aL}}(1+\gamma^{ba*}_{cdL}\xi^{cd*}_l)L_{bL}$$
$$+ \frac{i}{2}\bar{N}_{aR}(1+\gamma^{ab}_{cdN}\xi^{cd}_l)\not{D}N_{bR} - \frac{i}{2}\overline{\not{D}N_{aR}}(1+\gamma^{ba*}_{cdN}\xi^{cd*}_l)N_{bR}$$
$$+ \frac{i}{2}\bar{E}_{aR}(1+\gamma^{ab}_{cdE}\xi^{cd}_l)\not{D}E_{bR} - \frac{i}{2}\overline{\not{D}E_{aR}}(1+\gamma^{ba*}_{cdE}\xi^{cd*}_l)E_{bR} \Big]$$

Nonminimal couplings become scalars + extra couplings.

Here Q_{aL} is the $SU(2)$ doublet of left - handed quarks $(u,d),(c,s),(t,b)$ (index a takes values $1,2,3$). U_{aR} is the $SU(2)$ singlet of right - handed quarks u,c,t. D_{aR} is the $SU(2)$ singlet of right - handed quarks d,s,b. In a similar way L_{aL} is the $SU(2)$ doublet of left - handed leptons $(\nu,e),(\nu_\mu,\mu),(\nu_\tau,\tau)$. N_{aR} is the $SU(2)$ singlet of right - handed neutrinos ν,ν_μ,ν_τ. E_{aR} is the $SU(2)$ singlet of right - handed leptons e,μ,τ. Tensors β and γ contain coupling constants of the field ξ_q and ξ_l to fermions.

$$
\begin{aligned}
S = \int dx \Big[& \alpha^{uv}_{ABCD} \left(\xi^{AB}_u\right)^* \Box^2 \xi^{CD}_v \\
& + \frac{i}{2}\bar{Q}_{aL}(1+\beta^{ab}_{cdL}\xi^{cd}_q)\not{D}Q_{bL} - \frac{i}{2}\overline{\not{D}Q_{aL}}(1+\beta^{ba*}_{cdL}\xi^{cd*}_q)Q_{bL} \\
& + \frac{i}{2}\bar{U}_{aR}(1+\beta^{ab}_{cdU}\xi^{cd}_q)\not{D}U_{bR} - \frac{i}{2}\overline{\not{D}U_{aR}}(1+\beta^{ba*}_{cdU}\xi^{cd*}_q)U_{bR} \\
& + \frac{i}{2}\bar{D}_{aR}(1+\beta^{ab}_{cdD}\xi^{cd}_q)\not{D}D_{bR} - \frac{i}{2}\overline{\not{D}D_{aR}}(1+\beta^{ba*}_{cdD}\xi^{cd*}_q)D_{bR} \\
& + \frac{i}{2}\bar{L}_{aL}(1+\gamma^{ab}_{cdL}\xi^{cd}_l)\not{D}L_{bL} - \frac{i}{2}\overline{\not{D}L_{aL}}(1+\gamma^{ba*}_{cdL}\xi^{cd*}_l)L_{bL} \\
& + \frac{i}{2}\bar{N}_{aR}(1+\gamma^{ab}_{cdN}\xi^{cd}_l)\not{D}N_{bR} - \frac{i}{2}\overline{\not{D}N_{aR}}(1+\gamma^{ba*}_{cdN}\xi^{cd*}_l)N_{bR} \\
& + \frac{i}{2}\bar{E}_{aR}(1+\gamma^{ab}_{cdE}\xi^{cd}_l)\not{D}E_{bR} - \frac{i}{2}\overline{\not{D}E_{aR}}(1+\gamma^{ba*}_{cdE}\xi^{cd*}_l)E_{bR} \Big]
\end{aligned}
$$

Toy model.

$$S = \int dx \left[\alpha \xi^* \Box^2 \xi \right.$$

$$+ \frac{i}{2} \bar{Q}_L \left(1 + \beta_L \xi\right) \not{D} Q_L - \frac{i}{2} \overline{\not{D} Q_L} \left(1 + \beta_L^* \xi^*\right) Q_L$$

$$+ \frac{i}{2} \bar{t}_R \left(1 + \beta_t \xi\right) \not{D} t_R - \frac{i}{2} \overline{\not{D} t_R} \left(1 + \beta_t^* \xi^*\right) t_R$$

$$Q_L \equiv Q_{3L} = \begin{pmatrix} t_L \\ b_L \end{pmatrix} \qquad \left. + \frac{i}{2} \bar{b}_R \left(1 + \beta_b \xi\right) \not{D} b_R - \frac{i}{2} \overline{\not{D} b_R} \left(1 + \beta_b^* \xi^*\right) b_R \right]$$

Toy model.

$$Q_L \equiv Q_{3L} = \begin{pmatrix} t_L \\ b_L \end{pmatrix}$$

Define the projectors:

Top and bottom:

$$\Pi_t = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}, \qquad \Pi_b = \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$$

Left and right:

$$P_R = \frac{1}{2}(1+\gamma_5) = P_R^\dagger, \quad P_L = \frac{1}{2}(1-\gamma_5) = P_L^\dagger$$

Interaction vertex:

$$\Gamma = \beta_L P_R + (\beta_t \Pi_t + \beta_b \Pi_b)\, P_L\ , \qquad \chi = \beta_L^* P_L + (\beta_t^* \Pi_t + \beta_b^* \Pi_b)\, P_R$$

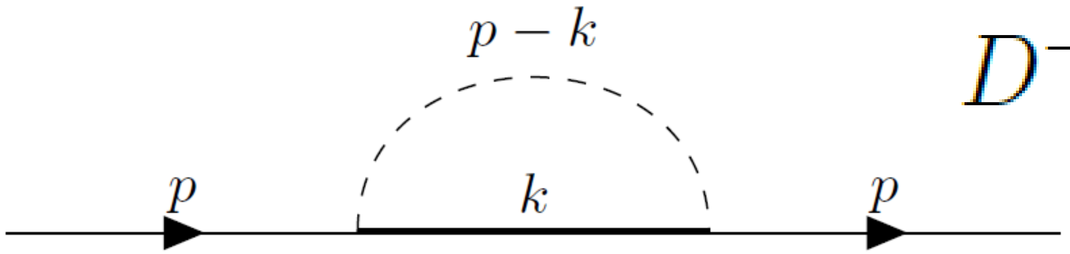
Toy model.

$$Q = \begin{pmatrix} t \\ b \end{pmatrix} \qquad \Gamma = \beta_L P_R + \left(\beta_t \Pi_t + \beta_b \Pi_b\right) P_L \ , \qquad \chi = \beta_L^* P_L + \left(\beta_t^* \Pi_t + \beta_b^* \Pi_b\right) P_R$$

S

$$= \int dx \left[\alpha \xi^* \Box^2 \xi + \frac{i}{2} \bar{Q} \not{D} Q + \frac{i}{2} \bar{Q} \Gamma \xi \not{D} Q - \frac{i}{2} \overline{\not{D} Q} Q - \frac{i}{2} \overline{\not{D} Q} \chi \xi^* Q\right]$$

Schwinger – Dyson equation. Rainbow approximation

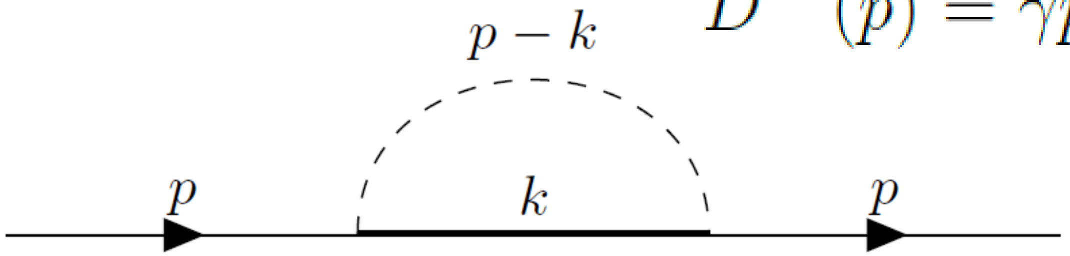


$$D^{-1}(p) = \gamma p - i\Sigma(p)$$

$$\Sigma(p) = \frac{1}{\alpha}\int \bar{d}k \, \Gamma\gamma k \frac{i}{\gamma k - \Sigma(k)} \Gamma\gamma k \frac{1}{(p-k)^4}$$

$$\Gamma = \beta_L P_R + (\beta_t \Pi_t + \beta_b \Pi_b)\, P_L \ , \qquad \chi = \beta_L^* P_L + (\beta_t^* \Pi_t + \beta_b^* \Pi_b)\, P_R$$

Schwinger – Dyson equation. Rainbow approximation



$$D^{-1}(p) = \gamma p - i\Sigma(p) = \hat{A}\gamma p - i\hat{B}\otimes \mathbf{1}_{4\times 4} + \hat{C}\gamma p \gamma_5 - i\hat{D}\gamma_5$$

$$\Sigma(p) = \frac{1}{\alpha}\int đk\, \Gamma\gamma k \frac{i}{\gamma k - \Sigma(k)} \Gamma \gamma k \frac{1}{(p-k)^4}$$

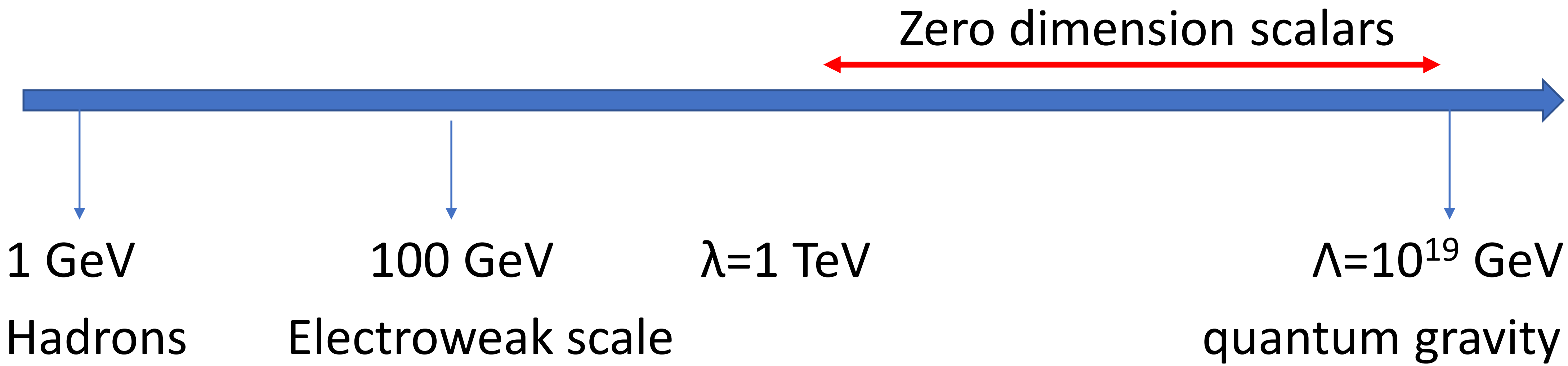
$$\Gamma = \beta_L P_R + (\beta_t \Pi_t + \beta_b \Pi_b)\, P_L\ , \qquad \chi = \beta_L^* P_L + (\beta_t^* \Pi_t + \beta_b^* \Pi_b)\, P_R$$

Cutoffs.

Quantum gravity scale ➔ ultraviolet cutoff $\Lambda=10^{19}$ GeV.

We do not observe extra scalars at the Electroweak scale ➔ infrared cutoff $\lambda=1$ TeV

Cutoffs.


Zero dimension scalars
1 GeV
Hadrons
100 GeV
Electroweak scale
λ=1 TeV
Λ=10^{19} GeV
quantum gravity

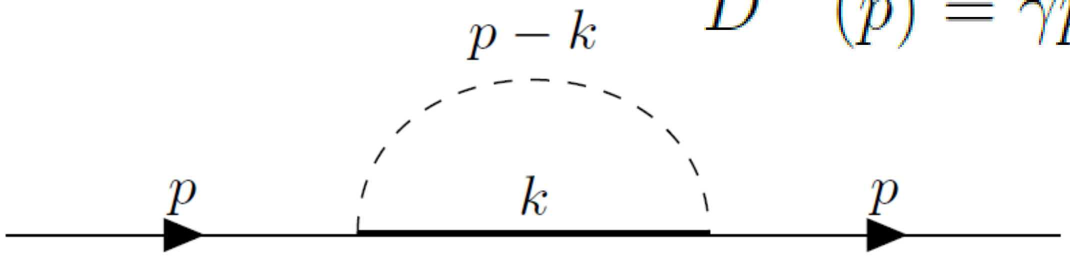
Cutoffs.

Quantum gravity scale ➔ ultraviolet cutoff $\Lambda=10^{19}$ GeV.

We do not observe extra scalars at the Electroweak scale ➔ infrared cutoff $\lambda=1$ TeV

The approximation with $A = A_0 = \text{const}$, $B = B_0 = \text{const}$, it works at $m \approx p \ll \lambda \ll \Lambda$

Leading order approximation. One of the solutions.



$$D^{-1}(p) = \gamma p - i\Sigma(p) = \hat{A}\gamma p - i\hat{B}\otimes \mathbf{1}_{4\times 4} + \hat{C}\gamma p\gamma_5 - i\hat{D}\gamma_5$$

$$\hat{A}_0 = 1 - \frac{1}{16\pi^2\alpha}\Gamma\hat{A}_0\frac{1}{\hat{A}_0^2}\int_{\lambda^2}^{\Lambda^2} dk^2 \frac{1}{k^2+M^2}\tilde{\Gamma} \,,$$

$$\mathbb{1}_{2\times 2} = \frac{1}{16\pi^2\alpha}\Gamma\frac{1}{\hat{A}_0^2}\int_{\lambda^2}^{\Lambda^2} dk^2 \frac{1}{k^2+M^2}\tilde{\Gamma} \,,$$

$$\hat{C}_0 = 0 \,,$$

$$\hat{D}_0 = 0 \,.$$

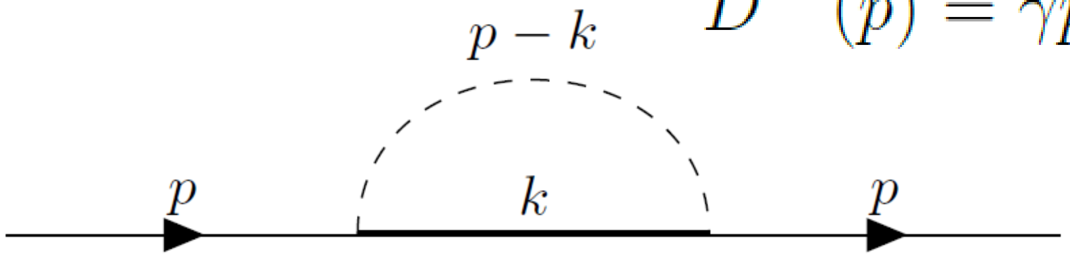
$$\tilde{\Gamma} = \begin{pmatrix} \beta_L P_L + \beta_t P_R & 0 \\ 0 & \beta_L P_L + \beta_b P_R \end{pmatrix}$$

$$\Gamma = \begin{pmatrix} \beta_L P_R + \beta_t P_L & 0 \\ 0 & \beta_L P_R + \beta_b P_L \end{pmatrix}$$

$$M = \begin{pmatrix} m_t & 0 \\ 0 & m_b \end{pmatrix}$$

Leading order approximation. One of the solutions.

$$D^{-1}(p) = \gamma p - i\Sigma(p) = \hat{A}\gamma p - i\hat{B} \otimes \mathbf{1}_{4\times 4} + \hat{C}\gamma p \gamma_5 - i\hat{D}\gamma_5$$



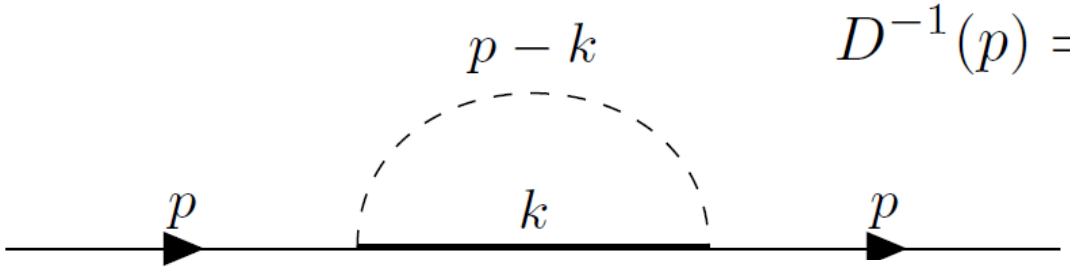
$$\hat{A}_0 = \begin{pmatrix} A_t & 0 \\ 0 & A_b \end{pmatrix},$$

$$\hat{C}_0 = 0$$

$$\hat{B}_0 = \begin{pmatrix} B_t & 0 \\ 0 & B_b \end{pmatrix} = \begin{pmatrix} m_t A_t & 0 \\ 0 & m_b A_b \end{pmatrix}$$

$$\hat{D}_0 = 0$$

Approximation m ≈ p << λ << Λ.



$$D^{-1}(p) = A(p^2)\gamma p - iB(p^2) = \gamma p - i\Sigma(p)$$

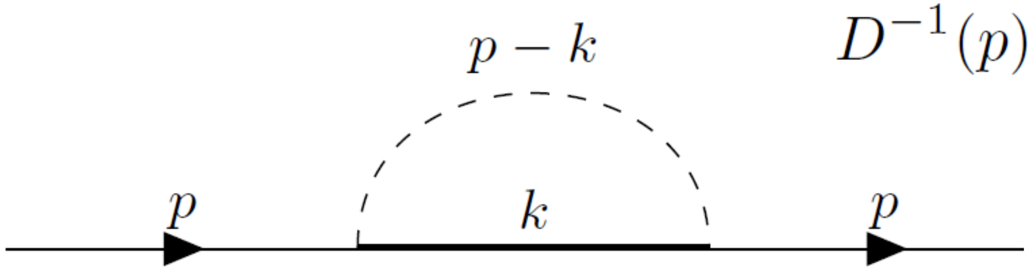
$$\hat{A}_0 = \begin{pmatrix} A_t & 0 \\ 0 & A_b \end{pmatrix},$$

$$\hat{B}_0 = \begin{pmatrix} B_t & 0 \\ 0 & B_b \end{pmatrix} = \begin{pmatrix} m_t A_t & 0 \\ 0 & m_b A_b \end{pmatrix}$$

$$A_t = 1 - \frac{1}{16\pi^2\alpha}\beta_L\beta_t A_t \frac{1}{A_t^2}\int_{\lambda^2}^{\Lambda^2} dk^2 \frac{1}{k^2+m_t^2};$$

$$A_b = 1 - \frac{1}{16\pi^2\alpha}\beta_L\beta_b A_b \frac{1}{A_b^2}\int_{\lambda^2}^{\Lambda^2} dk^2 \frac{1}{k^2+m_b^2}$$

Approximation m ≈ p << λ << Λ.



$$D^{-1}(p) = A(p^2)\gamma p - iB(p^2) = \gamma p - i\Sigma(p)$$

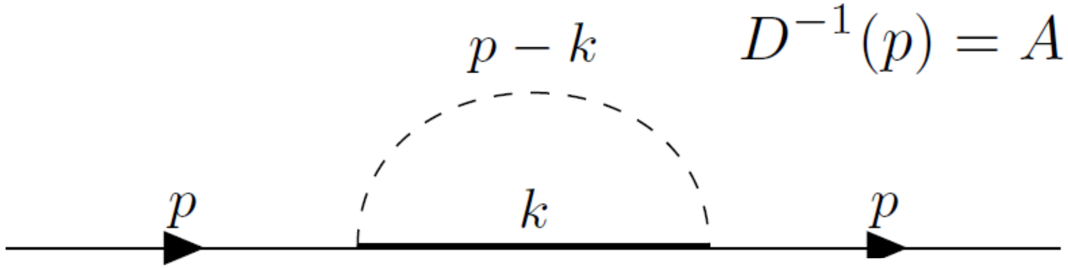
$$\hat{A}_0 = \begin{pmatrix} A_t & 0 \\ 0 & A_b \end{pmatrix},$$

$$\hat{B}_0 = \begin{pmatrix} B_t & 0 \\ 0 & B_b \end{pmatrix} = \begin{pmatrix} m_t A_t & 0 \\ 0 & m_b A_b \end{pmatrix}$$

$$1 = \frac{1}{16\pi^2\alpha}\beta_L\beta_t\frac{1}{A_t^2}\int_{\lambda^2}^{\Lambda^2} dk^2\frac{1}{k^2+m_t^2}$$

$$1 = \frac{1}{16\pi^2\alpha}\beta_L\beta_b\frac{1}{A_b^2}\int_{\lambda^2}^{\Lambda^2} dk^2\frac{1}{k^2+m_b^2}$$

Gap equations. Approximation m ≈ p << λ << Λ.



$$D^{-1}(p) = A(p^2)\gamma p - iB(p^2) = \gamma p - i\Sigma(p)$$

$$\hat{A}_0 = \begin{pmatrix} A_t & 0 \\ 0 & A_b \end{pmatrix}, \qquad A_t = \frac{1}{2} \qquad A_b = \frac{1}{2}$$

$$1 = \frac{1}{4\pi^2\alpha_t} \ln\left(\frac{\Lambda^2 + m_t^2}{\lambda^2 + m_t^2}\right) \qquad 1 = \frac{1}{4\pi^2\alpha_b} \ln\left(\frac{\Lambda^2 + m_b^2}{\lambda^2 + m_b^2}\right)$$

$$\hat{B}_0 = \begin{pmatrix} B_t & 0 \\ 0 & B_b \end{pmatrix} = \begin{pmatrix} m_t A_t & 0 \\ 0 & m_b A_b \end{pmatrix}$$

$$\alpha_t = \frac{\alpha}{\beta_L \beta_t} . \qquad \alpha_b = \frac{\alpha}{\beta_L \beta_b} .$$

Approximation m ≈ p << λ << Λ.

Critical coupling constant $$\alpha^{(c)} = \frac{1}{4\pi^2} \ln\left(\frac{\Lambda^2}{\lambda^2}\right) \sim 1.866405176474873$$

$$\alpha_t < \alpha^{(c)} \qquad \alpha_b < \alpha^{(c)}$$

$$m_t = \Lambda e^{-2\pi^2\alpha_t}\sqrt{1 - e^{4\pi^2(\alpha_t - \alpha^{(c)})}} \qquad m_b = \Lambda e^{-2\pi^2\alpha_b}\sqrt{1 - e^{4\pi^2(\alpha_b - \alpha^{(c)})}}$$

Approximation $m \approx p \ll \lambda \ll \Lambda$.

Masses $m_t = 175\,\mathrm{GeV}$ $m_b = 4.18\ \mathrm{GeV}$

Are generated, for example, if

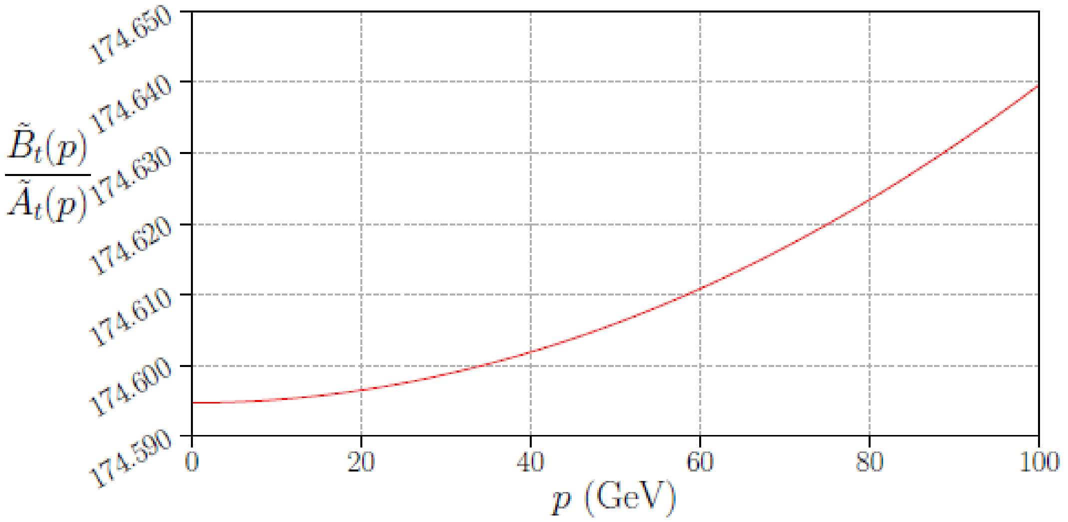
$$\beta_L = \alpha = 1/2; \quad \beta_b = 0.53578946829590691109\ , \quad \beta_t = 0.53600878111265624799$$

Check.

$$\tilde{A}_t(p) = 1 + \frac{1}{16\pi^2\alpha_t}\int_{\lambda^2}^{\Lambda^2} dk^2 \frac{A_{t0}k^4}{A_{t0}^2k^2 + B_{t0}^2}\frac{1}{(p^2 - k^2)} \; ,$$

$$\tilde{B}_t(p) = \frac{1}{16\pi^2\alpha_t}\int_{\lambda^2}^{\Lambda^2} dk^2 \frac{B_{t0}k^2}{A_{t0}^2k^2 + B_{t0}^2}\frac{1}{(k^2 - p^2)} \; ,$$

$$A_{t0} = \frac{1}{2} \text{ and } B_{t0} = \frac{m_t}{2} = 87.5 \text{ GeV}$$

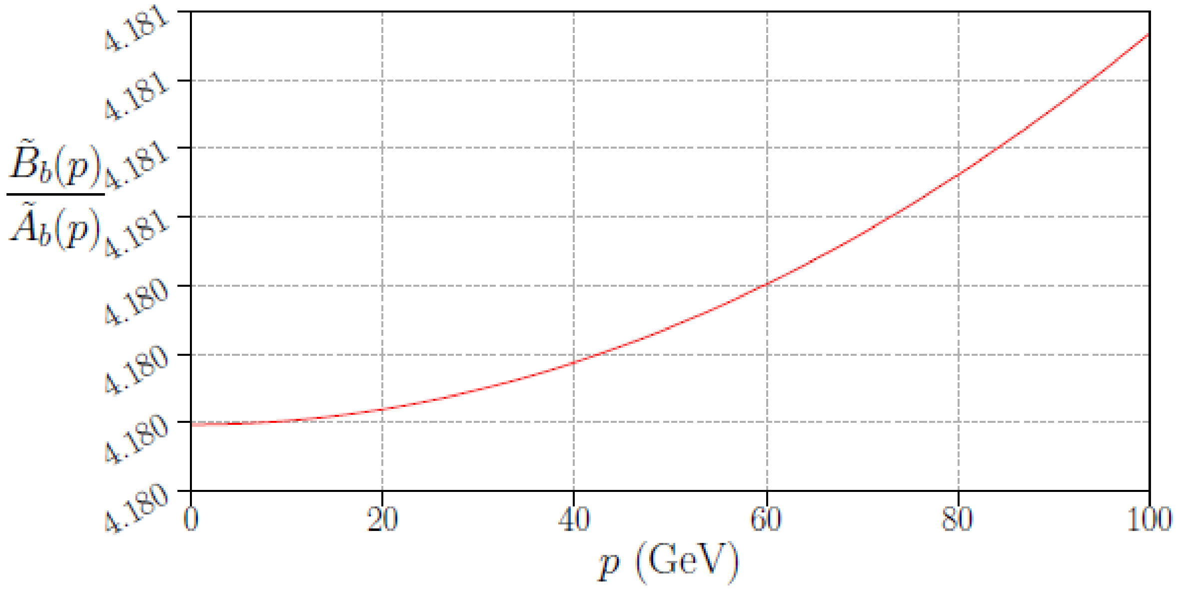


Check.

$$\tilde{A}_b(p) = 1 + \frac{1}{16\pi^2\alpha_b}\int_{\lambda^2}^{\Lambda^2} dk^2 \frac{A_{b0}k^4}{A_{b0}^2k^2 + B_{b0}^2}\frac{1}{(p^2-k^2)} ,$$

$$\tilde{B}_b(p) = \frac{1}{16\pi^2\alpha_b}\int_{\lambda^2}^{\Lambda^2} dk^2 \frac{B_{b0}k^2}{A_{b0}^2k^2 + B_{b0}^2}\frac{1}{(k^2-p^2)}$$

$$A_{b0} = \frac{1}{2} \text{ and } B_{b0} = \frac{m_b}{2} = 2.09 \text{ GeV}$$



Conclusions.

1. Coupling constants in non – minimal coupling of fermions to gravity

36 zero dimension scalars

Weyl anomaly vanishes

2. Composite Higgs model (36 zero dim. scalars, no fundamental Higgs)

Interactions are present at the energies between 1TeV and 10^{19} GeV

Toy model with top and botton quarks of realistic masses 175 GeV and 4.18 GeV

Future prospects.

1. Composite Higgs boson mass(es) is(are) to be calculated
2. Inclusion of the remaining quarks and leptons
3. Evaluation of the cross – sections and branching ratios for realistic processes to be compared with experiment

5. Improvement of the calculation scheme to take into account the NLO corrections (out of the rainbow approximation)