Upgraded LHC experiments as a check of the would-be approach to the calculation of SM fundamental parameters

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1. Introduction, non-perturbative physics
2. Compensation approach
3. Weinberg mixing angle and the fine structure constant
4. Experimental implications $p + p \longrightarrow \bar{t}tW^{\pm}(Z)$
5. Conclusion

Introduction, non-perturbative physics

Perturbation expansions diverge.

F.J. Dyson, Phys. Rev. v. 85, p. 631 (1952).
L.N. Lipatov, Sov. Phys. JETP, v. 45, p. 216 (1977).

Non-perturbative contributions are inevitable.

Various approaches:
Analytic, e.g.
D.V. Shirkov, I.L. Solovtsov, Phys. Rev. Lett. v. 79, p. 1209 (1997),
Lattice
Schwinger-Dyson equations
...
Effective interactions (NJL ...)
Compensation approach

Let us take low-momenta $\alpha_s(Q)$ as an important example ($N_f = 3$).

$$\alpha_s(Q) = \frac{4\,\pi}{9\,Ln\left[\frac{Q^2}{\Lambda_{QCD}^2}\right]}. \qquad (1)$$

Here we see (Landau) pole at $Q^2 = \Lambda^2$. What to do?
To use a non-perturbative tool.

The analytic approach:

$$\alpha_s(Q) = \frac{4\,\pi}{9\,Ln\left[\frac{Q^2}{\Lambda_{QCD}^2}\right]} + \frac{4\pi\,\Lambda_{QCD}^2}{9(\Lambda_{QCD}^2 - Q^2)}. \qquad (2)$$

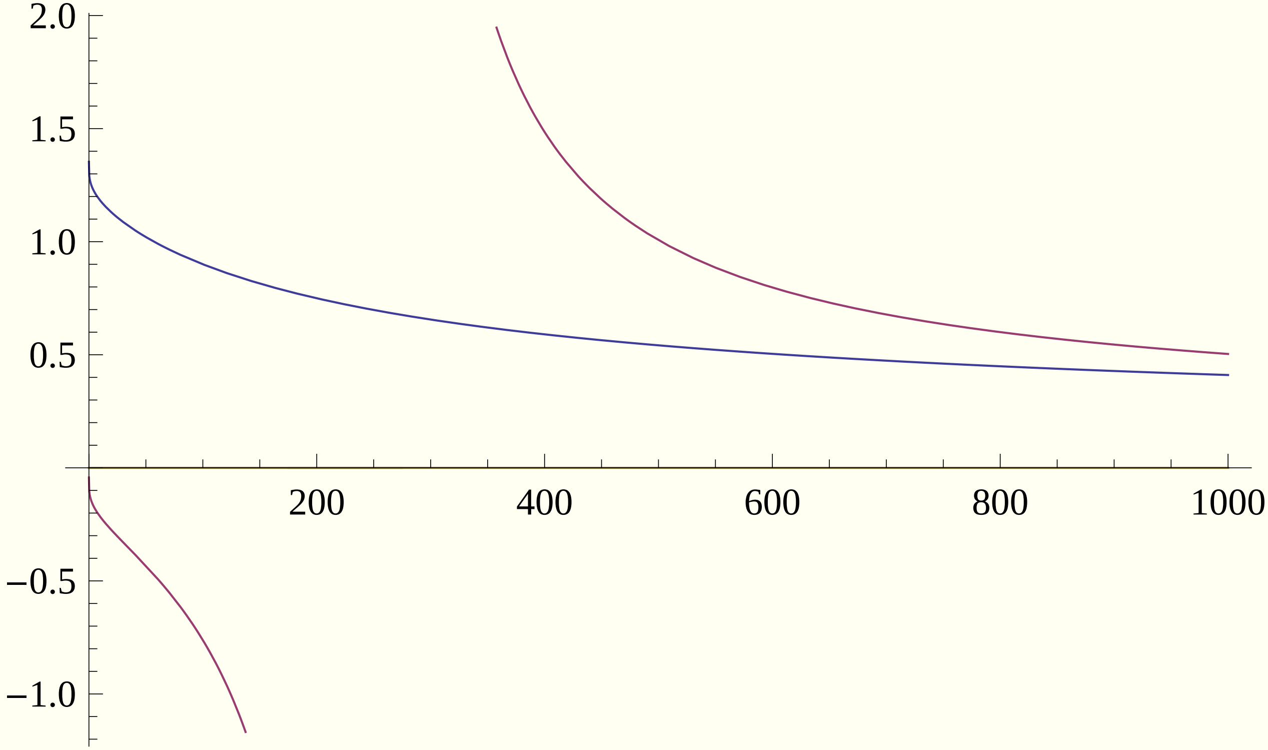

Figure 1: Behavior of $\alpha_s(Q)$ in the analytic approach. The curve with the pole - perturbation expression.

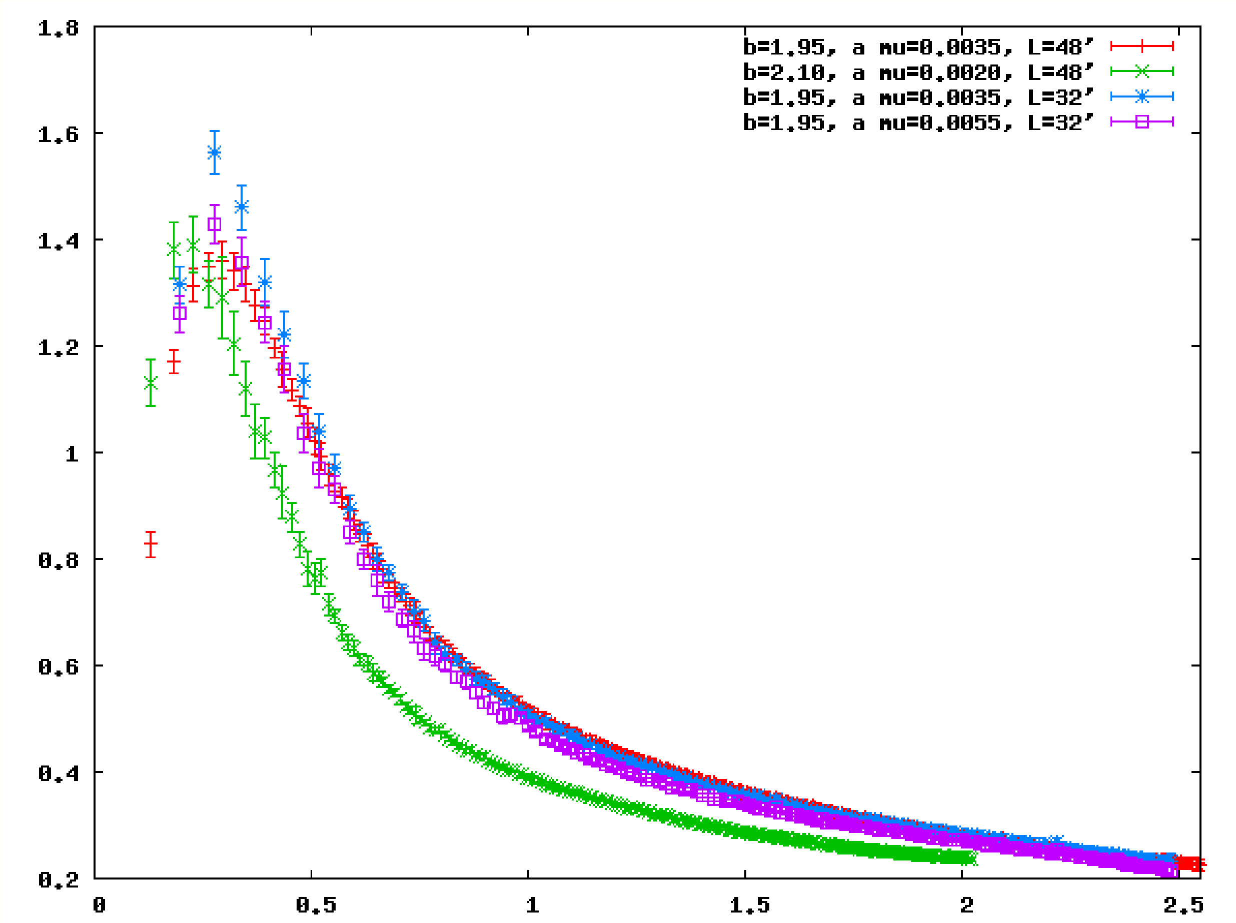

Figure 2: Behavior of $\alpha_s(Q)$ in the lattice approach.

B. Blossier** et al., **Nucl. Phys. Proc. Suppl. v. 234 p. 217 (2013)

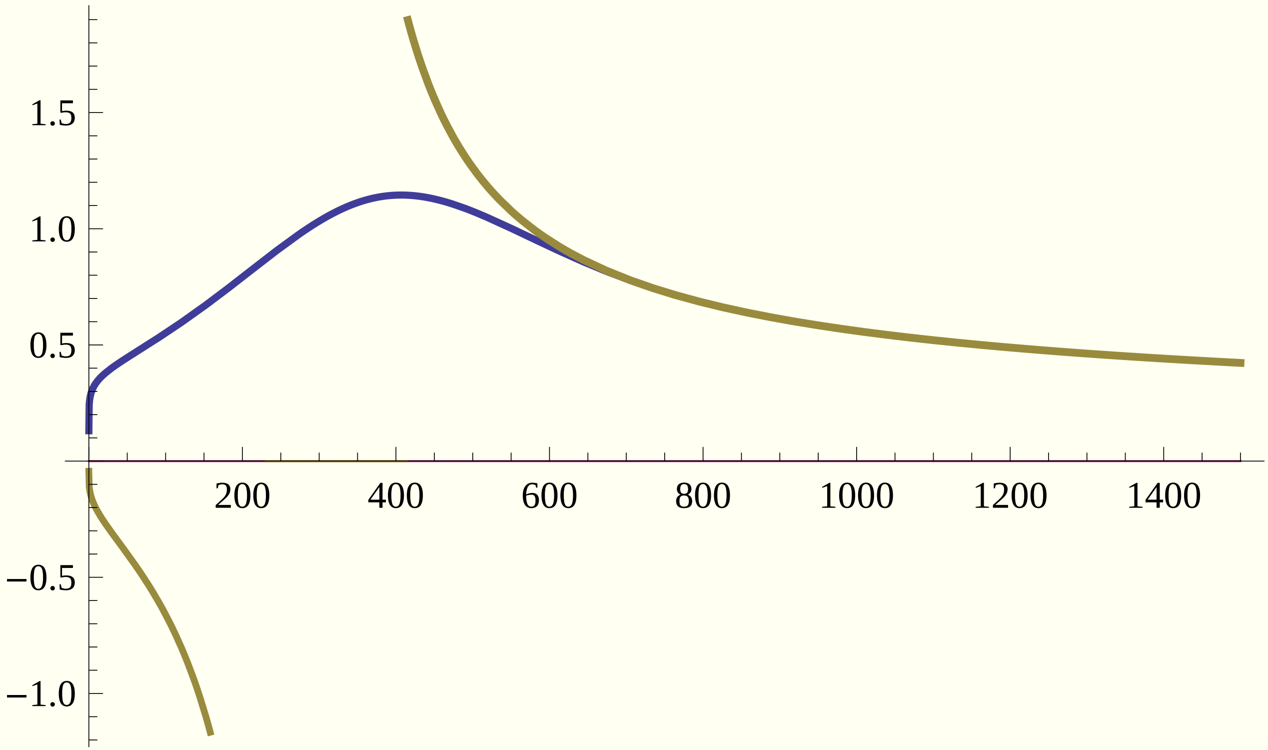

Figure 3: Behavior of $\alpha_s(Q)$ in the compensation approach.

B.A.A.,I.V.Zaitsev, Int. J. Mod. Phys. v. A28: 1350127 (2013)

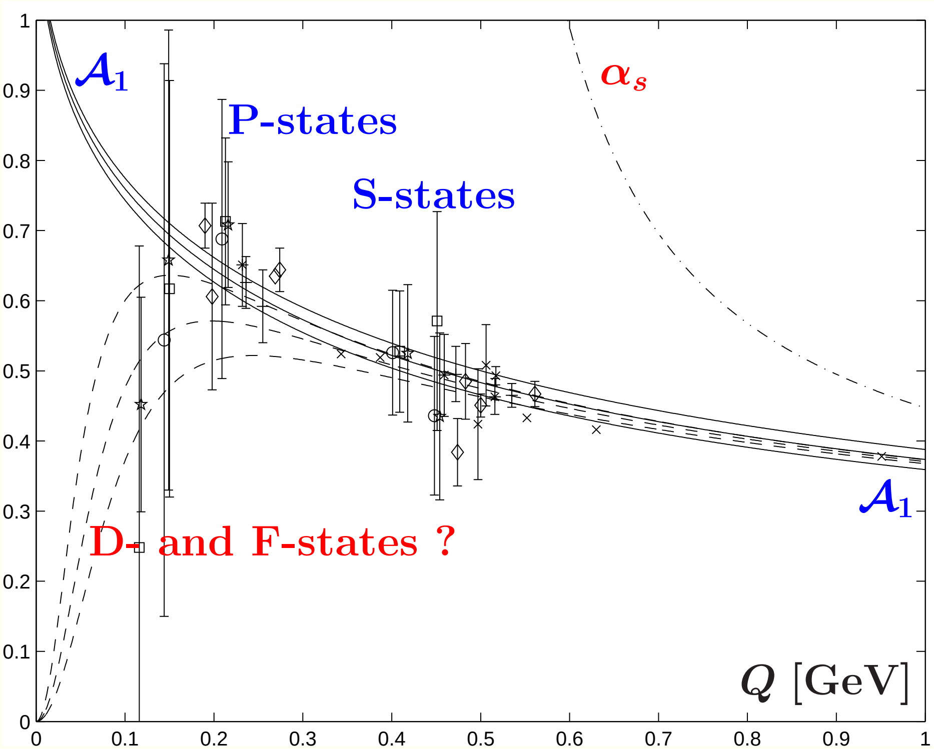

Figure 4: Behavior of $\alpha_s(Q)$ from low mass resonances.

M.Baldicchi *et al.*, ***Phys.Rev.Lett. v.99:242001 (2007)***

A qualitative semblance with both the lattice and the compensation approaches.

Compensation approach

The method of a spontaneous generation of effective non-local interactions, which we shall try to apply in this talk to the problem, was just grown up from N.N. Bogoliubov's compensation conception developed and successfully applied in the superconductivity theory.

N.N. Bogoliubov, ZhETF, v. 34 pp. 58,66,73 (1958).

N.N. Bogoliubov, Soviet Phys.-Uspekhi, v. 67 p. 236 (1959).

N. N. Bogoliubov, Physica Suppl. (Amsterdam), v. 26, p. 1 (1960).

The light meson physics – Nambu - Iona-Lazinio interaction

Y. Nambu and G. Jona-Lasinio, Phys. Rev., v. 122 p. 345 (1961); ibid v. 124 p. 246 (1961).

Application of the method leads to calculation of main light mesons' properties with good precision using only fundamental QCD parameters.

B. A. Arbuzov, M. K. Volkov and I. V. Zaitsev, Int. J. Mod.Phys. A, v. 21 p. 5721 (2006).

Application to the spontaneous generation of the would-be anomalous three-boson interaction:

B. A. Arbuzov, Eur. Phys. J., v. C61 p. 51 (2009).
B. A. Arbuzov and I. V. Zaitsev, Phys. Rev., v. D85 : 093001 (2012).

The low energy gluon interaction:
B. A. Arbuzov and I.V. Zaitsev, Int. J. Mod. Phys., v. A28 : 1350127 (2013).

The method is described in full in the book

B. A. Arbuzov, Non-perturbative Effective Interactions in the Standard Model*, De Gruyter, Berlin, 2014.*

Compensation equations – non-trivial solutions – phenomenon of a spontaneous generation of effective interactions.
A trivial solution – absence of anything new.
Important: a non-trivial solution exists only provided a number of conditions on parameters of a problem under a study being fulfilled.

A non-trivial solution $\longrightarrow$ a possibility of a determination of fundamental SM parameters with the fine structure constant α taken as an example in this talk.

B.A. Arbuzov and I.V. Zaitsev: arXiv 1505.07269 (hep-ph)

Few formulas for the would-be triple effective interaction of the electro-
weak bosons

$$-\frac{G}{3!}\,F\,\epsilon_{abc}\,W^a_{\mu\nu}\,W^b_{\nu\rho}\,W^c_{\rho\mu}\,; \tag{3}$$

$$W^a_{\mu\nu} = \partial_\mu W^a_\nu - \partial_\nu W^a_\mu + g\,\epsilon_{abc} W^b_\mu W^c_\nu\,;$$

Form-factor $F(p_i)$ is uniquely defined by compensation equations.

Anomalous three-boson interaction (3) was considered for a long time on phenomenological grounds

K. Hagiwara, R. D. Peccei, D. Zeppenfeld and K. Hikasa, Nucl. Phys., v. B282 p. 253 (1987).
K. Hagiwara, S. Ishihara, R. Szalapski and D. Zeppenfeld, Phys. Rev., v. D48 p. 2182 (1993).

Conventional definition:

$$G \;=\; -\,\frac{g\,\lambda}{M_W^2}\,;\; g \approx 0.65. \qquad (4)$$

The best limitations for λ: (PDG)

$$\lambda_\gamma = -\,0.022 \pm 0.019\,;$$
$$\lambda_Z = -\,0.09 \pm 0.06\,. \qquad (5)$$

The conditions for existence of the non-trivial solution $\longrightarrow$

$$g(z_0) = 0.60366\,; \quad z_0 = 9.6175\,; \tag{6}$$
$$|\lambda| = 3.5 \cdot 10^{-6};\; G \;=\; 0.000352\, TeV^{-2}.$$

$$\frac{2\,G^2\,\Lambda_0^4}{1024\,\pi^2} = z_0;\; \Lambda_0 = 7.914 \cdot 10^5\, GeV. \tag{7}$$

In QCD : $g(z_0) = 3.817$*, that gives satisfactory description of the low-momentum behavior of the running strong coupling, including absence of the Landau pole.*

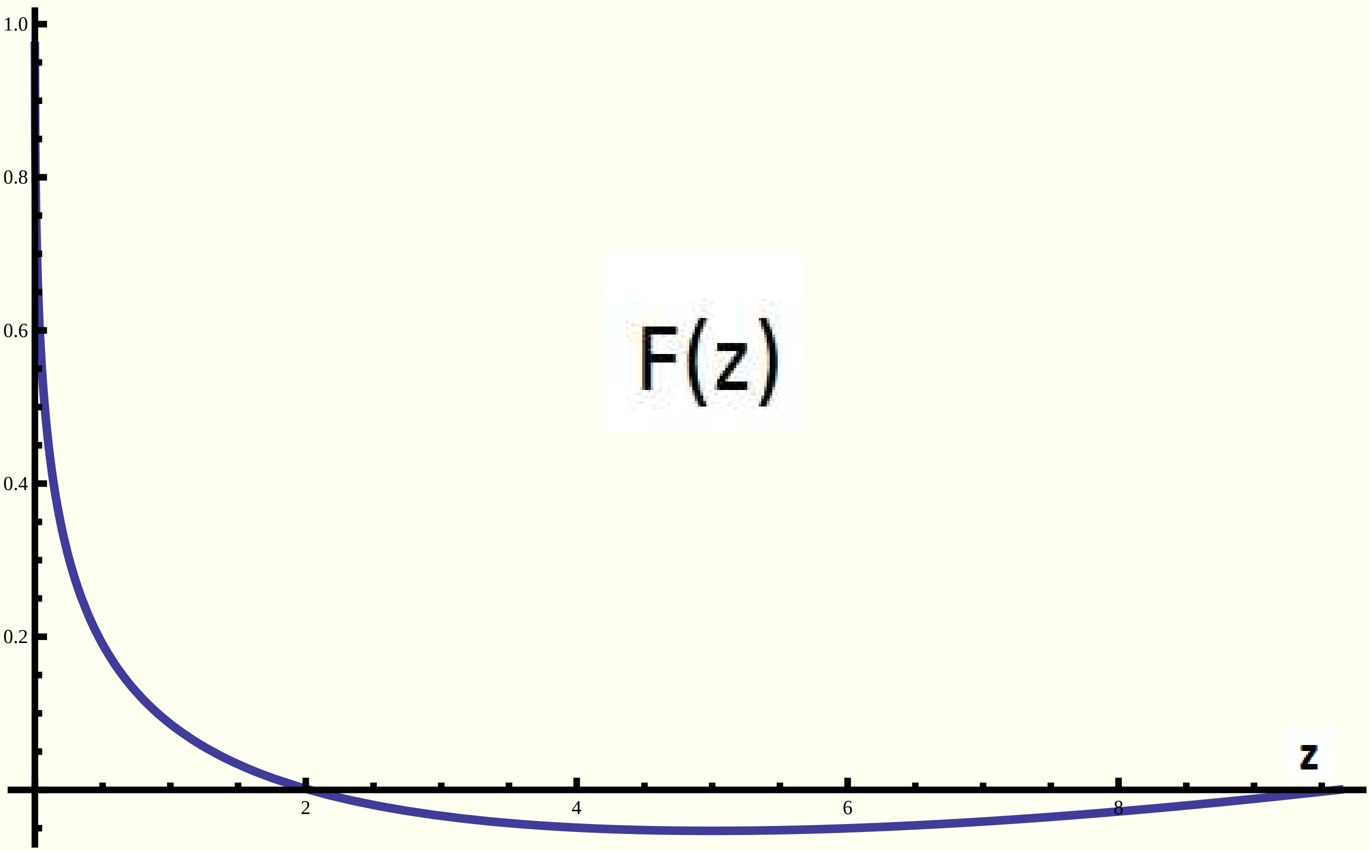

Figure 5: The behavior of the form-factor in EW theory.

$$z = \frac{G^2 p^4}{512 \pi^2}; \; F(z) = 0 \; for \; z > z_0. \qquad (8)$$

Weinberg mixing angle and

the fine structure constant

Let us consider the following effective interaction of electroweak gauge bosons

$$L^W_{eff} = -\frac{G_2}{8} W^a_\mu W^a_\mu W^b_{\rho\sigma} W^b_{\rho\sigma} - \frac{G_3}{8} W^a_\mu W^a_\mu B_{\rho\sigma} B_{\rho\sigma} - \frac{G_4}{8} Z_\mu Z_\mu W^b_{\rho\sigma} W^b_{\rho\sigma} - \frac{G_5}{8} Z_\mu Z_\mu B_{\rho\sigma} B_{\rho\sigma}. \qquad (9)$$

Here index a $(1, 2)$ corresponds to charged W-s, and index b $(1, 2, 3)$corresponds to W in the initial formulation of the electro-weak interaction.

E.g. ***for the first term in (9) the vertex reads***

$$\imath\,\delta^{a_1}_{a_2}\,\delta^{b_1}_{b_2}\,G_2\,g_{\mu\nu}\,(g_{\rho\sigma}(p\,q)\,-\,p_\sigma\,q_\rho)\,; \tag{10}$$

where W^a ***have indices*** μ, ν ***and incoming momenta and indices*** (p,ρ) ***and*** (q,σ) ***refer to fields*** W^b***.***

Remind the well-known relation

$$\begin{aligned} W^0_\mu &= \cos\theta_W\,Z_\mu + \sin\theta_W\,A_\mu; \\ B_\mu &= -\,\sin\theta_W\,Z_\mu + \cos\theta_W\,A_\mu. \end{aligned} \tag{11}$$

Thus in terms of the physical states we have

$$
\begin{aligned}
L_{eff}^{W} = & -\frac{G_2}{2} W_\mu^+ W_\mu^- \, W_{\rho\sigma}^+ W_{\rho\sigma}^- - \frac{G_2}{4} W_\mu^+ W_\mu^- \times \\
& \Big(\cos^2\theta_W Z_{\rho\sigma} Z_{\rho\sigma} + 2\cos\theta_W \sin\theta_W Z_{\rho\sigma} A_{\rho\sigma} + \\
& \sin^2\theta_W A_{\rho\sigma} A_{\rho\sigma} \Big) - \frac{G_4}{4} Z_\mu Z_\mu W_{\rho\sigma}^+ W_{\rho\sigma}^- - \frac{G_4}{8} Z_\mu Z_\mu \times \\
& \Big(\cos^2\theta_W Z_{\rho\sigma} Z_{\rho\sigma} + \sin^2\theta_W A_{\rho\sigma} A_{\rho\sigma} + 2\cos\theta_W \times \\
& \sin\theta_W Z_{\rho\sigma} A_{\rho\sigma} \Big) - \frac{G_3}{4} W_\mu^+ W_\mu^- \Big(\sin^2\theta_W Z_{\rho\sigma} Z_{\rho\sigma} + \\
& \cos^2\theta_W A_{\rho\sigma} A_{\rho\sigma} - 2\cos\theta_W \sin\theta_W Z_{\rho\sigma} A_{\rho\sigma} \Big) - \\
& \frac{G_5}{8} Z_\mu Z_\mu \Big(\sin^2\theta_W Z_{\rho\sigma} Z_{\rho\sigma} + \cos^2\theta_W A_{\rho\sigma} A_{\rho\sigma} - \\
& 2\cos\theta_W \sin\theta_W Z_{\rho\sigma} A_{\rho\sigma} \Big).
\end{aligned} \tag{12}
$$

Interactions of type (12) were earlier introduced on phenomenological grounds in works

G. Belanger and F. Boudjema, Phys. Lett., v. B288 p. 201 (1992).

G. Belanger et al.*, Eur. Phys. J., v. C13 p. 283 (2000).*

A spontaneous generation of interaction (12)? We start with Lagrangian, which describes boson fields W^a, Z, γ and the Higgs field H in the unitary gauge with the usual division into the free and the interaction parts

$$L = L_0 + L_{int} \,. \tag{13}$$

Then we perform the Bogoliubov add-subtract procedure of expression (12)

$$L = L'_0 + L'_{int};$$

$$L'_0 = L_0 - L^W_{eff}; \tag{14}$$

$$L'_{int} = L_{int} + L^W_{eff}. \tag{15}$$

We are to demand, so that in the theory with Lagrangian L'_0 (14), all contributions to four-boson connected vertices (12) are summed up to zero. The interaction term in (14) is compensated. Emphasize, that all SM interactions are included in L'_{int} (15).

The experience of application of the method to the Nambu - Jona-Lazinio interaction. The first approximation for the problem of spontaneous generation of the NJL interaction assumes form-factor $F(p)$, to be unit step function $\Theta(\Lambda^2 - p^2)$ and only horizontal diagrams of the type presented in Fig. 6 are taken into account. The next approximation includes also vertical diagrams and form-factor $F(p)$ is uniquely defined as a solution of a set of compensation conditions. We just use the first approximation.

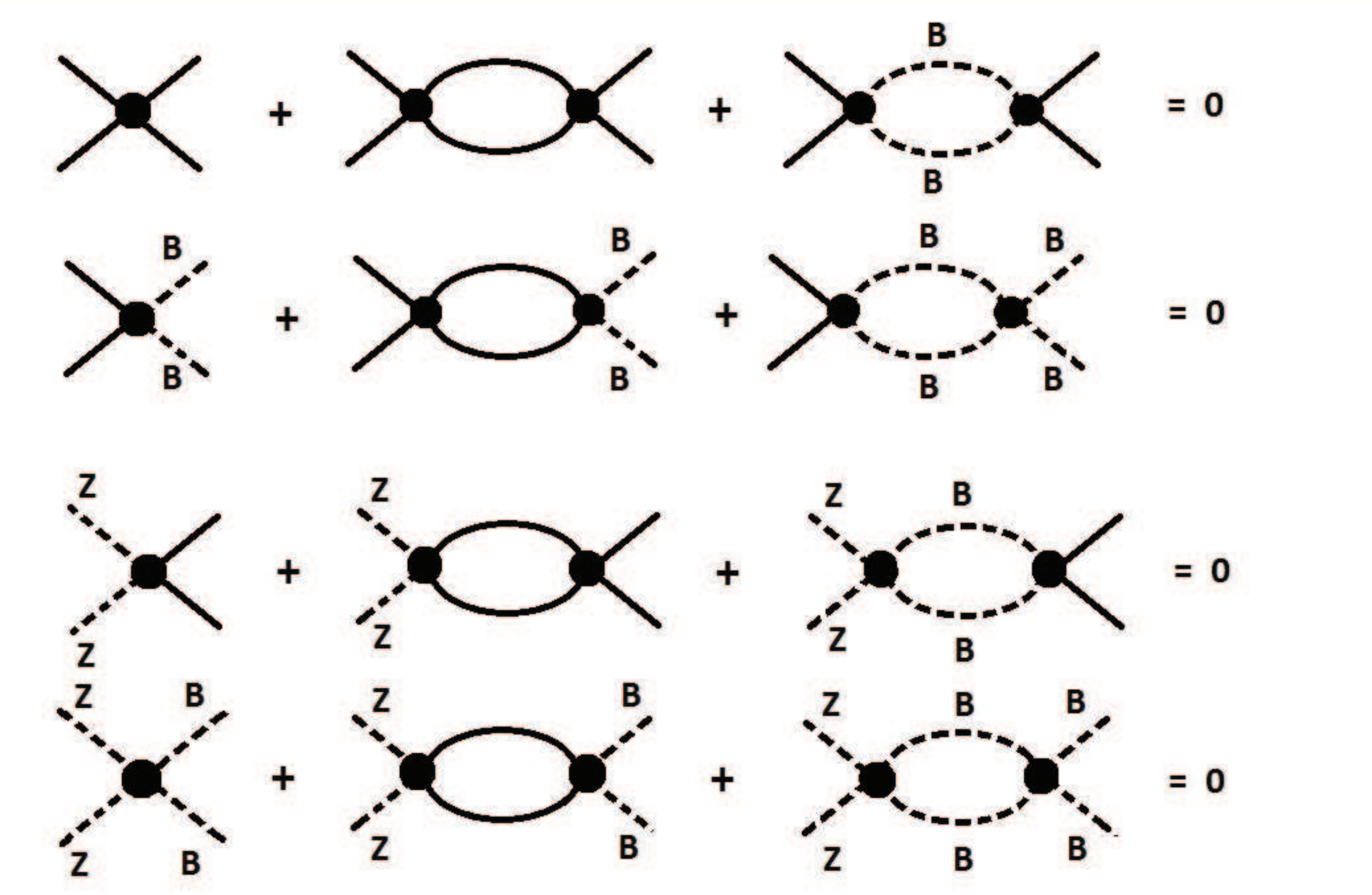

Figure 6: Diagram representation of set (16). Simple lines represent W^a and W^b, dotted lines represent B or Z with indications in the figure. A black spot means effective interaction (12).

Let us introduce effective cut-off Λ and use $\Theta(\Lambda^2 - p^2)$ for the form-factor. The set of compensation equations corresponds to diagrams being presented in FIG. 6

$$
\begin{aligned}
&-x_2 - 2F_W x_2^2 - (1-a^2)F_Z x_3 x_4 - \\
&a^2 F_Z x_2 x_4 = 0;\\
&-x_3 - 2\,F_W\,x_2\,x_3 - a^2 F_Z\,x_2\,x_5 - \\
&(1-a^2)\,F_Z\,x_3\,x_5 \,=\, 0\,;\\
&-x_4 - 2F_W x_2 x_4 - a^2 F_Z x_4^2 - \\
&(1-a^2)F_Z x_3 x_4 = 0;\\
&-x_5 - 2F_W x_3 x_4 - a^2 F_Z x_4 x_5 - \\
&(1-a^2)F_Z x_5^2 = 0;
\end{aligned}
\tag{16}
$$

$$\begin{aligned}
F_W &= 1 - \frac{2M_W^2}{\Lambda^2}\left(L_W - \frac{1}{2}\right);\\
L_W &= \ln\frac{\Lambda^2 + M_W^2}{M_W^2};\\
F_Z &= 1 - \frac{2M_Z^2}{\Lambda^2}\left(L_Z - \frac{1}{2}\right);\\
L_Z &= \ln\frac{\Lambda^2 + M_Z^2}{M_Z^2};
\end{aligned} \tag{17}$$

$$x_i = \frac{3G_i\Lambda^2}{16\pi^2}; \quad a = \cos\theta_W. \tag{18}$$

We have the following solutions of set (16) in addition to the evident trivial one:

$x_2 = x_3 = x_4 = x_5 = 0$

$$x_3 = x_5 = 0;\ x_2 = -\frac{1 + a^2 F_Z x_4}{2\,F_W};* \tag{19}$$

$$x_2 = x_4 = 0;\ x_5 = -\frac{1}{(1-a^2)F_Z};* \tag{20}$$

$$x_2 = x_4 = -\frac{1 + (1-a^2)F_Z x_5}{2\,F_W + a^2\,F_Z};\ x_3 = x_5;* \tag{21}$$

$$x_2 = x_4 = 0;\ x_3 = \frac{a^2}{2(1-a^2)F_W};$$

$$x_5 = -\frac{1}{(1-a^2)F_Z}; \tag{22}$$

$$x_2 = -\frac{1}{2\,F_W};\ x_4 = x_3 = x_5 = 0; \tag{23}$$

$$x_3 = x_5 = 0;\ x_2 = -\frac{1}{2\,F_W};\ x_4 = 0; \tag{24}$$

$$x_2 = x_4 = -\frac{1}{2\,F_W};\ x_3 = \frac{a^2}{2(1-a^2)F_W};$$

$$x_5 = -\frac{1}{(1-a^2)F_Z}; \tag{25}$$

$$x_2 = -\frac{1}{2\,F_W};\ x_4 = 0;\ x_3 = \frac{a^2}{2(1-a^2)F_W};$$

$$x_5 = -\frac{1}{(1-a^2)F_Z}; \tag{26}$$

$$x_2 = -\frac{1}{2\,F_W};\ x_4 = 0;\ x_5 = 0; \tag{27}$$

We assume, that the Higgs scalar corresponds to a bound state consisting of a complete set of fundamental particles. Here we study the would-be effective interaction of the electroweak bosons, so we take into account just these bosons as constituents of the Higgs scalar. Thus corresponding Bethe-Salpeter equations for the bound state are to be fulfilled. Two equations: constituents are either $W^a\,W^a$ *or* $Z\,Z$. *The equations are graphically presented in FIG. 7. Calculations are performed in the unitary gauge.*

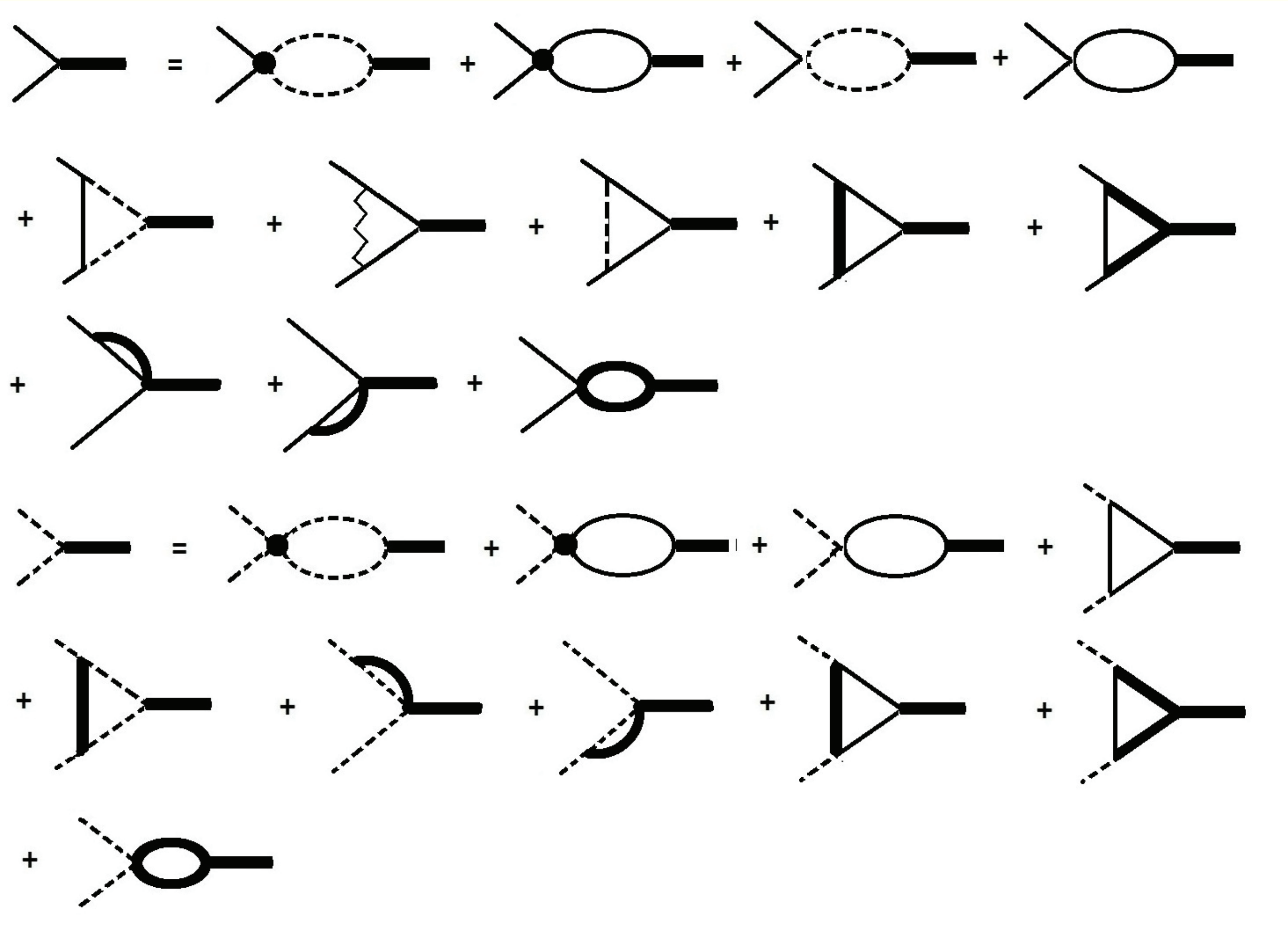

Figure 7: Diagram representation of set of the BS equations. Simple lines - W-s, dotted lines - Z, wave line - γ, thick lines - H. Black spots - effective interaction (12), points - SM EW couplings in the unitary gauge.

$$
\begin{aligned}
&-3\,x_2\,(2\,F_W + a\,F_Z) - \frac{x_3(1-a^2)}{a} - \\
&\frac{3\,\alpha_{ew}}{16\,\pi}\Big[-\frac{a^2(a^6-a^4-5\,a^2+1)}{1-a^2}L_W + \\
&\frac{(1+a^2)(1-3\,a^2)}{a^2(1-a^2)}L_Z - \frac{(1-a^2-a^4)(1-a^2)}{a^2}\Big] + \\
&\frac{3\,\alpha_{ew}\,M_W^2}{32\,\pi}\Big[\frac{3\,M_H^2}{(M_H^2-M_W^2)^2}\ln\Big[\frac{M_H^2}{M_W^2}\Big] - \\
&\frac{3}{M_H^2-M_W^2} - \frac{8}{M_W^2}\Big] = \frac{1}{B_W};
\end{aligned}
\tag{28}
$$

$$
\begin{aligned}
&-x_4(2F_W + aF_Z) - \frac{x_5(1-a^2)}{a} - \frac{\alpha_{ew}a^2}{4\pi} + \\
&\frac{3\alpha_{ew}M_Z^2}{32\pi a^4}\Big[\frac{3M_H^2}{(M_H^2-M_W^2)^2}\ln\Big[\frac{M_H^2}{M_Z^2}\Big] - \frac{8}{M_Z^2} - \\
&\frac{3}{M_H^2-M_Z^2}\Big] = \frac{1}{a^2B_Z};\ .
\end{aligned}
\tag{29}
$$

$$\alpha_{ew} = \frac{\alpha_0}{1 + \frac{5\alpha_0}{4\pi} \ln \frac{\Lambda^2}{M_Z^2}}; \quad \alpha_0 = 0.0337; \tag{30}$$

$$B_W = F_W + \frac{M_H^2}{2\,\Lambda^2}\left(L_W - \frac{13}{12}\right);$$

$$B_Z = F_Z + \frac{M_H^2}{2\,\Lambda^2}\left(L_Z - \frac{13}{12}\right);$$

$$a = \cos\theta_W(\Lambda);\ 1 - a^2 = \frac{\alpha\left(1 + \frac{5\alpha_0}{6\pi} \ln \frac{\Lambda^2}{M_Z^2}\right)}{\alpha_0\left(1 - \frac{5\alpha}{6\pi} \ln \frac{\Lambda^2}{M_Z^2}\right)};$$

$$\alpha = \frac{e^2(M_Z)}{4\,\pi} = \alpha(M_Z) = 0.007756\,.$$

Here we have used the standard one-loop evolution formulas for the running electro-weak coupling α_{ew} and the electromagnetic one α with $N_f = 6$. We have also applied relation $M_W = \cos\theta_W\, M_Z$.

Now we look for solutions of set (16)(four equations), (28), (29) for variables x_2, x_3, x_4, x_5, a, Λ, which give appropriate value for $\alpha(M_Z) = 0.007756$. We use

$$M_W = 80.4GeV, \quad M_Z = 91.2GeV,$$
$$M_H = 125.1GeV. \tag{31}$$

*We have studied solutions of the set of equations. Result: only solutions (19), (20), (21) of set (16) give $\alpha(M_Z) = 0.007756$. These options are marked by * in list (19 – 27).*

For the first option (19) there are two solutions

$$\Lambda = 5.226 \cdot 10^5\, GeV;\; x_2 = -0.3238; \quad (32)$$

$$x_4 = -0.4865;\; x_3 = x_5 = 0;\; a = 0.8511;$$

$$\Lambda = 8.687 \cdot 10^{19}\, GeV;\; x_2 = -0.3160; \quad (33)$$

$$x_4 = -0.7113;\; x_3 = x_5 = 0;\; a = 0.7192;$$

Coupling constants respectively $(G_3 = G_5 = 0)$

$$G_2 = -6.24 \cdot 10^{-5}\, TeV^{-2};$$

$$G_4 = -9.376 \cdot 10^{-5}\, TeV^{-2}; \quad (34)$$

$$G_2 = -2.2045 \cdot 10^{-33}\, TeV^{-2};$$

$$G_4 = -4.962 \cdot 10^{-33}\, TeV^{-2}. \quad (35)$$

From definitions in experimental work

S. Chatrchian** et al. **(CMS Collaboration), Phys. Rev., v. D90: 032008 (2014).

$$L_{eff} = -\frac{e^2 a_0^W}{8\Lambda'^2} A_{\mu\nu} A_{\mu\nu} W_\rho^+ W_\rho^- - \frac{e^2 g^2 k_0^W}{\Lambda'^2} A_{\mu\nu} Z_{\mu\nu} W_\rho^+ W_\rho^- ; \quad (36)$$

we have:

$$\frac{a_0^W}{\Lambda'^2} = \frac{2\,G_2}{g^2}; \quad \frac{k_0^W}{\Lambda'^2} = \frac{G_2 \cos\theta_W}{2\,g^4 \sin\theta_W}. \quad (37)$$

Experimental limitations

$$-21\,TeV^{-2} < \frac{a_0^W}{\Lambda'^2} < 20\,TeV^{-2};$$

$$-12\,TeV^{-2} < \frac{k_0^W}{\Lambda'^2} < 10\,TeV^{-2}; \tag{38}$$

Predictions (39, 40) are deeply inside boundaries of limitations (38).

Results (34,35):

$$\frac{a_0^W}{\Lambda'^2} = -0.000147\,TeV^{-2};$$
$$\frac{k_0^W}{\Lambda'^2} = -0.000142\,TeV^{-2}; \tag{39}$$

$$\frac{a_0^W}{\Lambda'^2} = -1.044 \cdot 10^{-32}\, TeV^{-2};$$
$$\frac{k_0^W}{\Lambda'^2} = -1.13 \cdot 10^{-32}\, TeV^{-2}. \qquad (40)$$

for the two solutions respectively.

The second solution (40) gives a negligible small value, whereas the first one (39) for a possibility of its checking needs five orders of magnitude of an improvement of the precision.

The second and the third solutions (20,21) of the set of compensation equations gives too low values for the effective cut-off

$$\Lambda_2 = 364.5845\,GeV;$$
$$\Lambda_3 = 106.7934\,GeV;$$

which contradict experimental limitations and so they are to be rejected.
Thus we are rested with two solutions:
(32) and (33) with the following cut-offs.

$$\Lambda = 5.226 \cdot 10^5 GeV;$$
$$\Lambda = 8.687 \cdot 10^{19} GeV;$$

Solution (33) corresponds to the cut-off being of the order of magnitude of the Planck mass $M_{Pl} = 1.22 \times 10^{19}\,GeV$. This possibility in case of its realization may serve as an explanation of hierarchy problem

E. Gildener, Phys. Rev., v. D14 p. 1667 (1976).

Value of Λ (32) is close to boundary value (7) in the problem of anomalous triple W interaction (3)

$$\Lambda_0 \,=\, 7.91413 \cdot 10^5\, GeV\,. \tag{41}$$

This value is close to value $5.2262 \cdot 10^5\, GeV$ in solution (32).

Now we have two interesting values for possible cut-off Λ. Low value (41), which follows from previous results, and the Planck mass.

Let us consider our set of equations for these values of the cut-off. Earlier we have fixed actual value for electromagnetic constant $\alpha(M_Z)$ and calculated values for cutoff (32,33). Now we fix Λ and calculate $\alpha(M_Z)$. In this way for values (41) and the Planck mass we obtain respectively

$$\alpha(M_Z)_{41} = 0.00792;$$
$$\alpha(M_Z)_{Pl} = 0.00790. \qquad (42)$$

Both values differ from actual value $\alpha(M_Z) = 0.007756$ by 2%.
Thus it might be possible to interpret results (42) just as a calculation of the value of α.

Of course, there is the trivial solution of set (16): all $x_i = 0$, which gives no additional information. We have also non-trivial solutions.

The problem of the choice of the genuine solution is undoubtedly essential. The answer is to be connected with the problem of a stability of solutions. The problem needs extensive additional studies.

In the talk we undertake to show the way to decide if the non-trivial solution (32,34) really exists from experiments at the upgraded LHC.

Experimental implications

Effective interaction (12) directly leads to effects in reactions

$$p + p \longrightarrow W^+ + W^- + W^\pm(Z,\gamma). \tag{43}$$

With values G_2, G_4 (34,35) no hope for the necessary precision.
An enhancement of the effect in processes involving t-quarks. Consider contribution of (12) with couplings (34) to vertex

$$\frac{G_{W\bar{t}t}}{4}\,\bar{t}t\,W^b_{\mu\nu}\,W^b_{\mu\nu}\,;\; b = \overline{1,3}. \tag{44}$$

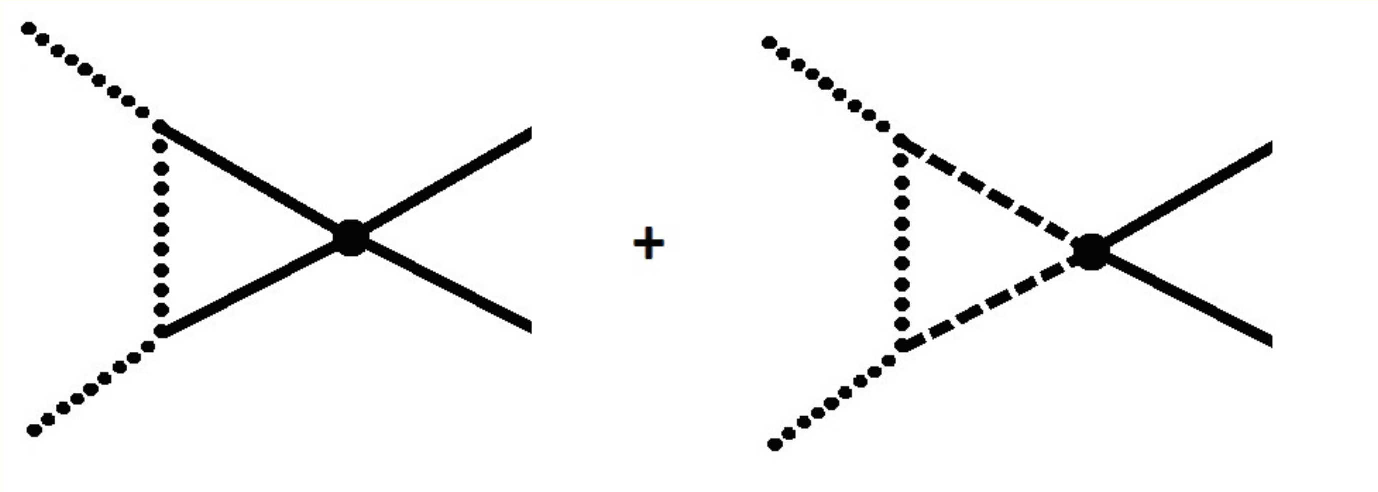

Figure 8: Diagram representation of $\bar{t}tWW$ vertex. Continuous lines represent W, dotted line represents Z and dotty lines at the left of each diagram represent the t-quarks. Notations for vertices are the same as in FIG. 7

We have to bear in mind effective form - factor $\Theta(\Lambda^2 - p^2)$ in interaction (12).

With account of definitions of x_i (18) we obtain

$$G_{W\bar{t}t} = -\frac{g^2(\Lambda)\,M_t(\Lambda)}{24 M_W^4}\Big(2\,x_2 + a^2(\Lambda)\,x_4\Big).$$

where we take $g(\Lambda) = \sqrt{4\pi\alpha_{ew}}$ with use of (29) and

$$M_t(\Lambda) \;=\; \frac{M_t}{\left(1 + \frac{7\alpha_s(M_t)}{4\pi}\,\ln\left[\frac{\Lambda^2}{M_t^2}\right]\right)^{\frac{4}{7}}};$$

where $M_t = 173.2\,GeV$ (PDG).

For solutions (32) and (33) we have respectively

$$G_{W\bar{t}t} = \mathbf{4.25 \cdot 10^{-8}}\, GeV^{-3}; \tag{45}$$

$$G_{W\bar{t}t} = \mathbf{1.506 \cdot 10^{-8}}\, GeV^{-3}. \tag{46}$$

Let us consider processes $p + p \longrightarrow \bar{t}\, t\, W^{\pm}(Z) + X$. *With values (45,46) we have additional contributions of the new effective interaction (44) to cross sections* $\Delta\sigma_{\bar{t}tW}$, $\Delta\sigma_{\bar{t}tZ}$ *of the processes.*

$$p + p \,\longrightarrow\, \bar{t} + t + W^{\pm} + X; \tag{47}$$

$$p + p \,\longrightarrow\, \bar{t} + t + Z + X; \tag{48}$$

The results for $\Delta\sigma$ are obtained with the use of the CompHEP package and are presented in Tables1, 2. The results for SM values are obtained in a number of works, for example
J. M. Campbell and R. K. Ellis, JHEP v. 1207 p. 052 (2012);
M. V. Garzelli, A. Kardos, C. G. Papadopulos and Z. Trocsanyi, JHEP v. 1211 p. 056 (2012);
J. Alwall et al., JHEP v. 1407 p. 079 (2014).

Table 1: SM results for cross-sections of processes $p + p \to \bar{t}tV$ at $\sqrt{s} = 8TeV$ and predictions for additional contribution due to effective interaction (44) with solutions (32) and (33). Values for effective $\bar{t}tWW$ coupling are shown in subscripts.

channel	$\sigma_{SM}\ fb$	$\Delta\sigma_{45}\ fb$	$\Delta\sigma_{46}\ fb$
$\bar{t}tW^+$	161^{+19}_{-32}	103.5 ± 20.7	13.0 ± 2.6
$\bar{t}tW^-$	71^{+11}_{-15}	28.0 ± 5.6	3.5 ± 0.7
$\bar{t}tZ$	197^{+22}_{-25}	47.2 ± 9.4	5.9 ± 1.2

Recent CMS result at $\sqrt{s} = 8\ TeV$:

$$\sigma_{\bar{t}tW^+}(8TeV) = 170^{+110}_{-100}\ fb;$$
$$\sigma_{\bar{t}tZ}(8TeV) = 200 \pm 90 fb; \qquad (49)$$

S. Chatrchian et al. (CMS Collaboration), Eur. Phys. J. v. C74 p. 3060 (2014). ***Results for*** $\sqrt{s} = 7\,TeV$ ***:*** *S. Chatrchian et al. (CMS Collaboration), Phys. Rev. Lett, v. 110: 172002 (2013).*

Results (49) are compatible with wouldbe additional contributions in Table 1 for both values (45, 46) and with the Standard Model.

However $\Delta\sigma(\bar{t}tW, Z)$ ***increases with the energy increasing and for the updated LHC*** $\sqrt{s} = 14\,TeV$ ***we show predictions in Table 2.***

Table 2: SM results for cross-sections of processes $p + p \to \bar{t}tV$ at $\sqrt{s} = 14 TeV$ and predictions for additional contribution due to effective interaction (44) with solutions (32) and (33). Values for effective $\bar{t}tWW$ coupling are shown in subscripts.

channel	$\sigma_{SM}\ fb$	$\Delta\sigma_{45\ fb}$	$\Delta\sigma_{46\ fb}$
$\bar{t}tW^+$	507^{+147}_{-111}	1257 ± 251	158 ± 32
$\bar{t}tW^-$	262^{+81}_{-60}	355 ± 71	45 ± 9
$\bar{t}tZ$	760^{+74}_{-84}	578 ± 116	73 ± 15

For $\sqrt{s} = 13\,TeV$ calculated values for $\Delta\sigma$ are to be divided by ≈ 1.38. For the upgraded LHC the most promising process is $p + p \to \bar{t}\,t\,W^{\pm}$.

According to Table 2 the total additional contribution to the production of the charged W with the top pair for the first solution (45) is around $1.6\,pb$, that exceeds the corresponding total SM value by factor 3 (2.2 for $\sqrt{s} = 13\,TeV$).

Thus the effect is quite pronounced. On the other hand such wouldbe significant effect guaranties the reliable disproof of an existence of interaction (44) with coupling (45) and thus the rejection of a realization of solution (32,34) in case of a disagreement with the prediction.

In case of absence of such significant effect, connected with low cut-off solution (32) there remains the possibility of the high cut-off solution (33). However, we see from Table 2 that the effect, could be around 30% *at the upgraded LHC. For example, additional contribution* $\Delta\sigma$ *for process* $p + p \longrightarrow \bar{t}tW^+ + X$ *is now* $158 \pm 32\, fb$ *with SM value* $507^{+147}_{-111}\, fb$*. So the reliable study of effects of this solution needs more precise calculations of the SM value and an improvement of the experimental accuracy.*

Note, that we do not include in the Tables process $p + p \longrightarrow \bar{t}\, t\, \gamma$, because the effect here is significantly less pronounced. Namely, for $\sqrt{s} = 13\, TeV$ we have $\sigma_{SM} = 1.744 \pm 0.005\, pb$, whereas the effect of interaction (44) with coupling (45) is calculated to be $\Delta\sigma = 0.125\, pb$. We have looked for other possible observable effects and have not succeeded in this. For example, effects in pair Higgs scalar production accompanied by W or Z are not significant for solutions (32,33).

Conclusion

To conclude let us draw attention to the the results in view of the compensation approach to the problem of a spontaneous generation of an effective interaction. We would emphasize that the existence of a non-trivial solution of compensation conditions always impose strong restrictions on parameters of the problem. We see such restrictions in both problems of the spontaneous generation of the Nambu – Jona-Lazinio interaction and the triple anomalous weak boson interaction being mentioned above.

Here we have considered consequences of the existence of nontrivial solutions of compensation conditions for a spontaneous generation of the anomalous four-boson interaction.

The most interesting result is just relation (42). Indeed, we see, that the adequate value of the fine structure constant is achieved in two cases. The first case corresponds to the electro-weak scale $\simeq 10^2\, TeV$ and the second case corresponds to the Planck mass scale. We have two phases and may assume, that these phases occur in different stages of the Universe evolution.

Under some conditions there may be a phase transition between them. For example, it might be, that at the very early stage of the evolution the Planck scale solution (33) is realized. Then in the course of expanding of the Universe the phase transition occurs to the low cut-off solution (32) with the electro-weak scale. In the contemporary Universe we would observe just this solution. This point of view could be confirmed provided the effects presented in Tables 1,2 would be discovered. Thus it would be possible to understand such tremendous gap between the electro-weak scale and the gravity scale.

In case of a confirmation of results under the discussion, the following consequences might become clear.

1. The first non-perturbative effect in the electro-weak interaction would be established.

2. The efficiency of the compensation approach to description of the phenomenon of spontaneous generation of an effective interaction would be ascertained.

3. The restrictive nature of compensation conditions would be confirmed.
4. The last but not the least result consists in the successful calculation of the fine structure constant α (42), that already could be considered as a sound argument on behalf of the compensation approach.

The talk mostly corresponds to work:
B.A. Arbuzov and I.V. Zaitsev: arXiv 1505.07269 (hep-ph)

Thanks for the attention

We have studied a dependence of two interesting solutions on value of the Higgs scalar mass M_H. The high cut-off solution depends on M_H quite weakly and Λ remains to be close to the Planck mass for the wide interval, for example

$$100\,GeV < M_H < 100\,TeV.$$

The low cut-off the solution exists only for M_H being limited from above by value $\approx 6.8\,TeV$. At the boundary $\Lambda = 4.008 \cdot 10^5\,GeV$.