Non-perturbative effects in the electro-weak theory versus LHC and Tevatron data

Boris A. Arbuzov
SINP MSU, Moscow, Russia

Application of Bogoliubov compensation principle to the gauge electro-weak interaction.

1. Compensation equation for anomalous tree-boson interaction.

2. Four-fermion interaction of heavy quarks.

3. Doublet bound state $\bar{\Psi}_L\, T_R$.

4. W-hadrons and CDF Wjj anomaly.

Results: $g(M_W^2) \simeq 0.62$ **and** $m_t\ = \ 177\, GeV$**; very heavy composite Higgs scalar; the indications (CDF and LHC) for state with mass** $\simeq 145\, GeV\ \ \rightarrow\ \ I = 1, J = 1$ **bound state of two** W**.**

Compensation equation for anomalous tree-boson interaction

In works

B.A.A., Theor. Math. Phys., 140, 1205 (2004); Teor. Mat. Fiz., 140, 367 (2004).

B.A. A., Phys. Atom. Nucl., 69, 1588 (2006); Yad. Fiz., 69, 1621 (2006).

B.A. A., M.K. Volkov and I.V. Zaitsev, Int. Journ. Mod. Phys. A, 21, 5721 (2006).

B.A. A., Phys. Lett. B, 656, 67 (2007).

B.A. A., M.K. Volkov and I.V. Zaitsev, Int. Journ. Mod. Phys. A, 61, 51 (2009).

B.A. A., Eur. Phys. J. C, 61, 51 (2009).

B.A. A. and I.V. Zaitsev, arXiv:1107.5164 (hep-ph) (2011).

N.N. Bogoliubov compensation principle was applied to studies *of spontaneous generation of effective non-local interactions in renormalizable gauge theories.*

N.N. Bogoliubov compensation principle:

N.N. Bogoliubov. Soviet Phys.-Uspekhi, 67, 236 (1959); Uspekhi Fiz. Nauk, 67, 549 (1959).

N.N. Bogoliubov. Physica Suppl., 26, 1 (1960).

N.N. Bogoliubov, Quasi-averages in problems of statistical mechanics. Preprint JINR D-781, (Dubna: JINR, 1961).

The first application of Bogoliubov compensation principle to QFT:

B.A.A., A.N. Tavkhelidze and R.N. Faustov, Doclady AN SSSR, 139, 345 (1961).

The main principle of the approach is to check if an effective interaction could be generated in a chosen variant of a *renormalizable theory. In view of this one performs "add and subtract" procedure for the effective interaction with a form-factor. Then one assumes the presence of the effective interaction in the interaction Lagrangian and the same term with the opposite sign is assigned to the newly defined free Lagrangian.*

EW Lagrangian with 3 *lepton and quarks doublets with gauge group* $SU(2)$*.*

$$L = \sum_{k=1}^{3}\biggl(\frac{\imath}{2}\Bigl(\bar\psi_k\gamma_\mu\partial_\mu\psi_k - \partial_\mu\bar\psi_k\gamma_\mu\psi_k\Bigr) + \frac{g}{2}\,\bar\psi_{kL}\gamma_\mu\tau^a W_\mu^a\psi_{kL}\biggr) +$$
$$+\sum_{k=1}^{3}\biggl(\frac{\imath}{2}\Bigl(\bar q_k\gamma_\mu\partial_\mu q_k - \partial_\mu\bar q_k\gamma_\mu q_k\Bigr) + \frac{g}{2}\,\bar q_{kL}\gamma_\mu\tau^a W_\mu^a q_{kL}\biggr) - \qquad (1)$$
$$-\frac{1}{4}\Bigl(W_{\mu\nu}^a W_{\mu\nu}^a\Bigr);\qquad W_{\mu\nu}^a = \partial_\mu W_\nu^a - \partial_\nu W_\mu^a + g\,\epsilon_{abc}W_\mu^b W_\nu^c\,.$$

Bogoliubov procedure add – subtract.

$$
\begin{aligned}
L \;&=\; L_0 + L_{int}\,;\\
L_0 \;&==\; \sum_{k=1}^{3}\Bigl(\frac{\imath}{2}\Bigl(\bar\psi_k\gamma_\mu\partial_\mu\psi_k - \partial_\mu\bar\psi_k\gamma_\mu\psi_k\Bigr) - m_k\bar\psi_k\psi_k +\\
&\frac{\imath}{2}\Bigl(\bar q_k\gamma_\mu\partial_\mu q_k - \partial_\mu\bar q_k\gamma_\mu q_k\Bigr) - M_k\bar q_k q_k\Bigr) -\\
&\frac{1}{4}W^a_{\mu\nu}W^a_{\mu\nu} + \frac{G}{3!}\cdot\epsilon_{abc}\,W^a_{\mu\nu}\,W^b_{\nu\rho}\,W^c_{\rho\mu}\,; \qquad (2)\\
L_{int} \;&=\; \frac{g}{2}\sum_{k=1}^{3}\Bigl(\bar\psi_k\gamma_\mu\tau^a W^a_\mu\psi_k + \bar q_k\gamma_\mu\tau^a W^a_\mu q_k\Bigr) -\\
&\frac{G}{3!}\cdot\epsilon_{abc}\,W^a_{\mu\nu}\,W^b_{\nu\rho}\,W^c_{\rho\mu}\,. \qquad (3)
\end{aligned}
$$

Notation $-\frac{G}{3!}\cdot\epsilon_{abc}\,W^a_{\mu\nu}\,W^b_{\nu\rho}\,W^c_{\rho\mu}$ ***means presence of non-local***

vertex in the momentum space

$$(2\pi)^4\, G\, \epsilon_{abc}\, (g_{\mu\nu}(q_\rho pk - p_\rho qk) + g_{\nu\rho}(k_\mu pq - q_\mu pk) + g_{\rho\mu}(p_\nu qk - k_\nu pq) + q_\mu k_\nu p_\rho - k_\mu p_\nu q_\rho)\, F(p,q,k)\, \delta(p+q+k); \quad (4)$$

where $F(p,q,k)$ is a form-factor and $p,\mu,a;\ q,\nu,b;\ k,\rho,c$ are respectfully incoming momenta, Lorentz indices and weak isotopic indices of W-bosons.

Effective interaction (44) is usually called anomalous three-boson interaction Interaction constant G is connected with conventional definitions

$$G = -\frac{g\,\lambda}{M_W^2}\,. \quad (5)$$

$$\lambda = -0.016^{+0.021}_{-0.023}\,; \qquad -0.059 < \lambda < 0.026\,(95\%\ C.L.)\,. \quad (6)$$

Due to our approximation $\sin^2\theta_W \ll 1$ we use the same M_W for

both charged $W^{\pm}$ and neutral W^0 bosons and assume no difference in anomalous interaction for Z and γ, i.e. $\lambda_Z = \lambda_\gamma = \lambda$.

Compensation conditions (see for details (1)) will consist in demand of full connected three-gluon vertices of the structure (4), following from Lagrangian L_0, to be zero.

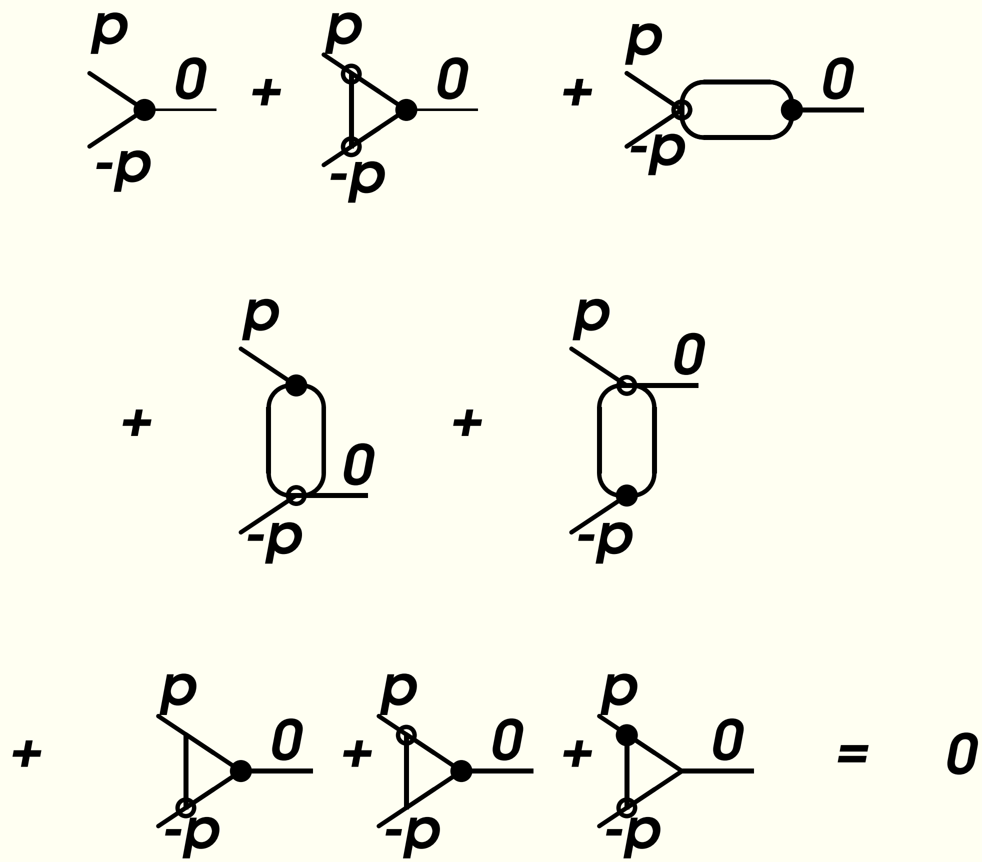

Fig.1. Diagram representation of the compensation equation. Black spot corresponds to anomalous three-gluon vertex with a form-factor. Empty circles correspond to point-like anomalous three-gluon and four-gluon vertices. Simple point corresponds to usual gauge vertex. Incoming momenta are denoted by the corresponding external lines.

$$F(p_1, p_2, p_3) = F\left(\frac{p_1^2 + p_2^2 + p_3^2}{2}\right); \tag{7}$$

$$F(x) = -\frac{G^2 N}{64\pi^2}\left(\int_0^Y F(y) y dy - \frac{1}{12x^2}\int_0^x F(y) y^3 dy + \frac{1}{6\,x}\int_0^x F(y) y^2 dy + \right.$$

$$\left. + \frac{x}{6}\int_x^Y F(y)\, dy - \frac{x^2}{12}\int_x^Y \frac{F(y)}{y}\, dy\right) + \frac{G\, g\, N}{16\,\pi^2}\int_0^Y F(y)\, dy +$$

$$\frac{G\, g\, N}{24\,\pi^2}\left(\int_{3x/4}^x \frac{(3x-4y)^2(2y-3x)}{x^2(x-2y)} F(y)\, dy + \int_x^Y \frac{(5x-6y)}{(x-2y)} F(y)\, dy + \right.$$

$$\frac{3}{4}\left(\int_{3x/4}^x \frac{3(4y-3x)^2(x^2-4xy+2y^2)}{8x^2(2y-x)^2} F(y) dy + \int_x^Y \frac{3(x^2-2y^2)}{8(2y-x)^2} F(y) dy + \right.$$

$$\left.\left.\int_0^x \frac{5y^2-12xy}{16x^2} F(y)\, dy + \int_x^Y \frac{3x^2-4xy-6y^2}{16y^2} F(y)\, dy\right)\right). \tag{8}$$

Here $x = p^2$ and $y = q^2$, where q is an integration momentum,

$N = 2$. ***An effective cut-off Y bounds a "low-momentum" region where our non-perturbative effects act and we consider the equation at interval $[0, Y]$ under condition***

$$F(Y) = 0. \tag{9}$$

We shall solve equation (8) by iterations. The second iterations gives the following equation

$$F(z) = 1 + \frac{85\, g\, \sqrt{N}\, \sqrt{z}}{96\, \pi}\Biggl(\ln z + 4\,\gamma + 4\,\ln 2 + \frac{1}{2}\, G^{31}_{15}\Bigl(z_0\,\Big|^{0}_{0,0,1/2,-1,-1/2}\Bigr) - \frac{595}{336}\Biggr) + \frac{2}{3\,z}\int_0^z F(t)\,t\,dt - \frac{4}{3\sqrt{z}}\int_0^z F(t)\sqrt{t}dt - \frac{4\sqrt{z}}{3}\int_z^{z_0} F(t)\frac{dt}{\sqrt{t}} + \frac{2\,z}{3}\int_z^{z_0} F(t)\frac{dt}{t}; \tag{10}$$

where γ is the Euler constant. Solution (10):

$$F(z) = \frac{1}{2} G^{31}_{15}\left(z\,\middle|^{0}_{1,1/2,0,-1/2,-1}\right) - \frac{85 g \sqrt{N}}{512\pi} G^{31}_{15}\left(z\,\middle|^{1/2}_{1,1/2,1/2,-1/2,-1}\right) +$$
$$C_1 G^{10}_{04}\left(z\,\middle|\,1/2,\,1,\,-1/2,\,-1\right) + C_2 G^{10}_{04}\left(z\,\middle|\,1,\,1/2,\,-1/2,\,-1\right). \quad (11)$$

where

$$G^{nm}_{qp}\left(z\,\middle|^{a_1,\dots,a_q}_{b_1,\dots,b_p}\right);$$

is a Meijer function. We have also conditions

$$1 + 8\int_0^{z_0} F(z)\,dz = \frac{87\,g\,\sqrt{N}}{32\,\pi}\int_0^{z_0} F_0(z)\,\frac{dz}{\sqrt{z}}; \quad (12)$$
$$F(z_0) = 0. \rightarrow \quad (13)$$

$$g(z_0) = 0.60366;\; z_0 = 9.61750;\; C_1 = -0.035096;\; C_2 = -0.051104. \quad (14)$$

One-loop expression for $\alpha_s(p^2)$

$$\alpha_{ew}(x) = \frac{6\,\pi\,\alpha_{ew}(x_0)}{6\,\pi + 5\,\alpha_{ew}(x_0)\ln(x/x_0)}; \quad x = p^2; \tag{15}$$

Normalization

$$\alpha_{ew}(x_0) = \frac{g(Y)^2}{4\,\pi} = 0.0290; \tag{16}$$

Note that value (16) is not far from physical value $\alpha_{ew}(M_W) = 0.0337$. To compare these values properly one needs a relation connecting G and M_W. For example with $|g\,\lambda| = 0.025$, $\alpha_{ew}(M_W) = 0.0312$. The experimental value 0.0337 is reached for $|g\,\lambda| = 0.000003$. For both cases values of λ are consistent with limitations (6). Accuracy of the approximation $\simeq 10\% \longrightarrow$ agreement is valid for all possible values of λ. We shall use experimental value $\alpha_{ew}(M_W) = 0.0337$.

Four-fermion interaction of heavy quarks

In the present work we explore the analogous considerations and assume that scalar fields which substitute elementary Higgs fields are formed by bound states of heavy quarks $t,\, b$. This possibility was proposed (1989 – 1990) in works by Y.Nambu, V.Miransky, M.Tanabashi, K.Yamawaki, W.Bardeen, C.Hill, M.Lindner (17, 18, 19) and was considered in a number of publications (see, e.g. review by M.Lindner (20)).Estimates of mass of the t-quark exceeds significantly its measured value. Assume: only the most heavy particles aquire masses, namely W-s and the t-quark while all other ones remain massless. Left doublet $\Psi_L\,=\,(1+\gamma_5)/2\cdot(t,\,b)$ and right singlet $T_R\,=\,(1-\gamma_5)/2\cdot t$. Then we study a possibility of spontaneous generation (1, 2, 3, 5) of the following effective non-local

four-fermion interaction

$$L_{ff} = G_1 \bar{\Psi}^{\alpha}_{L} T_{R\,\alpha} \bar{T}^{\beta}_{R} \Psi_{L\,\beta} + G_2 \bar{\Psi}^{\alpha}_{L} T_{R\,\beta} \bar{T}^{\beta}_{R} \Psi_{L\,\alpha} + \frac{G_3}{2} \bar{\Psi}^{\alpha}_{L} \gamma_\mu \Psi_{L\,\alpha} \bar{\Psi}^{\beta}_{L} \gamma_\mu \Psi_{L\,\beta} + \frac{G_4}{2} \bar{T}^{\alpha}_{R} \gamma_\mu T_{R\,\alpha} \bar{T}^{\beta}_{R} \gamma_\mu T_{R\,\beta}\,. \qquad (17)$$

where α, β are colour indices. In this section $N = 3$ and a kernel term in equations:

$$K \times F = (\Lambda^2 - x\ln\Lambda^2)\int_0^{\bar{Y}} F(y)dy - \ln\Lambda^2 \int_0^{\bar{Y}} F(y)y\,dy + \frac{1}{6x}\int_0^x F(y)y^2 dy + \ln x \int_0^x F(y)y\,dy + x(\ln x - \frac{3}{2})\int_0^x F(y)dy + \int_x^{\bar{Y}} y(\ln y - \frac{3}{2})F(y)dy + x\int_x^{\bar{Y}} \ln y F(y)dy + \frac{x^2}{6}\int_x^{\bar{Y}} \frac{F(y)}{y}dy \qquad (18)$$

Λ is auxiliary cut-off, which disappears from all expressions with all conditions for solutions be fulfilled. The compensation equation corresponds to set of diagrams at Fig.2

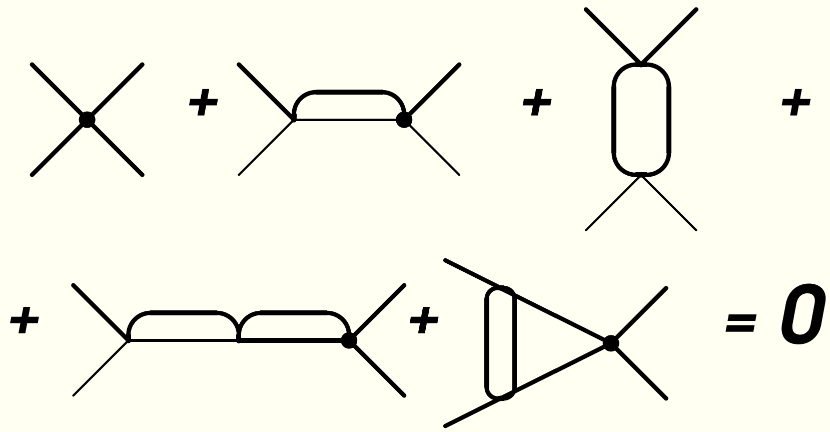

Fig. 2. Diagram representation of the compensation equation for the four-fermion interaction (19). Lines describe quarks. Simple point corresponds to the point-like vertex and black circle corresponds to a vertex with a form-factor.

$$
\Phi(x) = \frac{\Lambda^2((N^2-1)G_1^2 + GG}{8\pi^2(NG_1+G_2)}\left(1 - \frac{NG_1+G_2}{8\pi^2}\int_0^{\bar{Y}}\Phi(y)dy\right) +
$$

$$
\left(\Lambda^2 + \frac{x}{2}\ln\frac{x}{\Lambda^2} - \frac{3x}{4}\right)\frac{GG + 2\bar{G}(N+1)(G_1+G_2)}{32\pi^2(NG_1+G_2)} -
$$

$$
\frac{G_1^2 + G_2^2 + 2NG_1G_2 + 2\bar{G}(N+1)(G_1+G_2)}{2^9\pi^4}K \times \Phi\,; \tag{19}
$$

$$
F_2(x) \;=\; \frac{\Lambda^2 G_2}{8\pi^2}\left(1 - \frac{G_2}{8\pi^2}\int_0^{\bar{Y}}F_2(y)dy\right) +
$$

$$
\left(\Lambda^2 + \frac{x}{2}\ln\frac{x}{\Lambda^2} - \frac{3x}{4}\right)\frac{G_1^2 + G_2^2 + 2\bar{G}(G_1 + G_2(N+1))}{32\pi^2 G_2} -
$$

$$
\frac{G_1^2 + G_2^2 + 2\bar{G}(G_1 + G_2(N+1)}{2^9\pi^4}K \times F_2\,;\; \Phi(\bar{Y}) = F_2(\bar{Y}) = 0\,;
$$

$$
\Phi(x) \;=\; \frac{NG_1F_1 + G_2F_2}{NG_1+G_2}\,;\quad \bar{G} = \frac{G_3+G_4}{2}\,;\quad x = p^2\,;\quad y = q^2\,.
$$

$$GG = G_1^2 + G_2^2 + 2NG_1G_2;$$

Introducing substitution $G_1 = \rho\,\bar{G}$, $G_2 = \omega\bar{G}$ and comparing the two equations (19) we get convinced, that both equations become being the same under the following condition

$$\rho = 0 \;\rightarrow$$

$$F_2(z) = \frac{\sqrt{\omega^2+8\omega}}{\omega}\sqrt{z}(\ln z - 3) - 16\Bigg[\frac{1}{6\sqrt{z}}\int_0^z F_2(t)\sqrt{t}dt +$$
$$\frac{\ln z}{2}\int_0^z F_2(t)dt + \frac{\sqrt{z}(\ln z-3)}{2}\int_0^z \frac{F_2(t)}{\sqrt{t}}dt + \tag{20}$$
$$\frac{1}{2}\int_z^{\bar{z}_0}(\ln t - 3)F_2(t)dt + \frac{\sqrt{z}}{2}\int_z^{\bar{z}_0}\ln t\frac{F_2(t)}{\sqrt{t}}dt + \frac{z}{6}\int_z^{\bar{z}_0}\frac{F_2(t)}{t}dt\Bigg];$$
$$z = \frac{(\omega^2+8\omega)\bar{G}^2x^2}{2^{14}\pi^4};\, t = \frac{(\omega^2+8\omega)\bar{G}^2y^2}{2^{14}\pi^4};\, \bar{z}_0 = \frac{(\omega^2+8\omega)\bar{G}^2\bar{Y}^2}{2^{14}\pi^4}.$$

$$\left(z\frac{d}{dz}+\frac{1}{2}\right)\left(z\frac{d}{dz}\right)\left(z\frac{d}{dz}\right)\left(z\frac{d}{dz}-\frac{1}{2}\right)\left(z\frac{d}{dz}-\frac{1}{2}\right)\times$$
$$\left(z\frac{d}{dz}-1\right)F_2(z)\,+\,z\,F_2(z)\,=\,0; \tag{21}$$

$$\int_0^{\bar z_0}\frac{F_2(t)}{\sqrt{t}}dt\,=\,\frac{\sqrt{\omega^2+8\omega}}{8\,\omega};\quad F_2(\bar z_0)\,=\,0;$$
$$\int_0^{\bar z_0}F_2(t)\sqrt{t}\,dt\,=\,0;\quad \int_0^{\bar z_0}F_2(t)\,dt\,=\,0. \tag{22}$$

Boundary conditions (22) $\rightarrow$ ***cancellation of*** Λ.

$$F_2(z)\,=\,\frac{1}{2\sqrt{\pi}}G^{40}_{06}\left(z|0,\frac{1}{2},\frac{1}{2},1,-\frac{1}{2},0\right);\quad z_0\,=\,\infty. \tag{23}$$

$F_2(0)=1\,\rightarrow\,\omega=\frac{8}{3}$.

Doublet bound state $\bar{\Psi}_L\, T_R$

$\bar{\Psi}_L\, T_R\, =\, \phi \to$ *a Higgs scalar. Bethe–Salpeter equation (see Fig. 3)*

$$\Psi(x)\, =\, \frac{\bar{G}}{16\pi^2}\int \Psi(y)\, dy + \frac{G_2^2}{2^7\pi^4} K^* \times \Psi\,; \tag{24}$$

K^* *is defined with* $\bar{Y}\, =\, \infty$ *and lower limit of integration* 0 *being changed for the* t*-quark mass* m_t^2*.*

Then we have again differential equation

$$\left(z\frac{d}{dz}-a_1\right)\left(z\frac{d}{dz}-a_2\right)\left(z\frac{d}{dz}\right)\left(z\frac{d}{dz}-\frac{1}{2}\right)\left(z\frac{d}{dz}-\frac{1}{2}\right)\times$$
$$\left(z\frac{d}{dz}-1\right)\Psi(z)-z\Psi(z)=0;\; a_1=-\frac{1+\sqrt{1+64\mu}}{4};$$
$$a_2=-\frac{1-\sqrt{1+64\mu}}{4};\; \mu=\frac{G_2^2m^4}{2^{12}\pi^4}. \qquad (25)$$

$$\int_\mu^\infty \frac{\Psi(t)}{\sqrt{t}}dt\,=\,0;\;\int_\mu^\infty \Psi(t)\sqrt{t}\,dt\,=\,0;$$
$$\int_\mu^\infty \Psi(t)\,dt\,=\,0;\;\;\Psi(\mu)\,=\,1. \qquad (26)$$

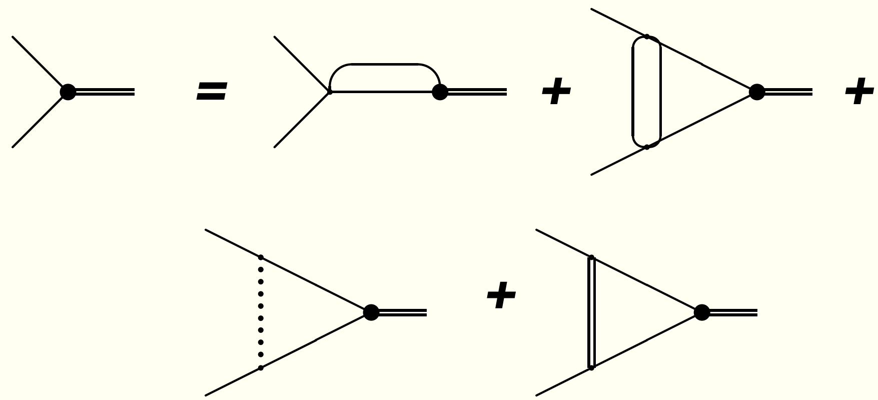

Fig. 3. Diagram representation of the Bethe-Salpeter equation for a bound state of heavy quarks. Double line represent the bound state and dotted line describes a gluon. Black circle corresponds to BS wave function. Other notations are the same as at Fig.2.

Solution:

$$\Psi(z) = C_1\, G^{50}_{06}(z|a_1, a_2, 1/2, 1/2, 1, 0) + C_2\, G^{30}_{06}(z|0, 1/2, 1, a_1, a_2, 1/2$$

$$C_3\, G^{30}_{06}(z|1/2, 1/2, 1, a_1, a_2, 0) + C_4\, G^{50}_{06}(z|a_1, a_2, 0, 1/2, 1, 1/2)\,;$$

We define interaction of the doublet ϕ with heavy quarks

$$L_\phi = g_\phi(\phi^*\bar{\Psi}_L\, T_R + \phi\, \bar{T}_R\, \Psi_L)\,; \qquad (28)$$

Perturbative method $\longrightarrow$

$$m^2_\phi = -\frac{m_t^2\, I_5}{\sqrt{\pi\,\mu}\, I_2}\,; \quad I_2 = \int_\mu^\infty \frac{\Psi(z)^2\, dz}{z}\,; \qquad (29)$$

$$I_5 = \int_\mu^\infty \frac{(16\,\pi\,\alpha_s(z) - g_\phi^2)\, \Psi(z)\, dz}{16\,\pi\, z} \int_\mu^z \frac{\Psi(t)\, dt}{\sqrt{t}}\,.$$

$$m_t = \frac{g_\phi\, \eta}{\sqrt{2}}\,; \quad \eta = 246.2\, GeV\,. \qquad (30)$$

Additional contribution to t mass (Fig. 4).

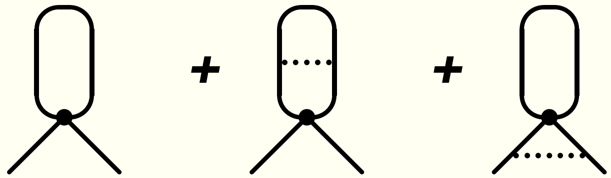

Fig. 4. Diagram representation of additional contribution to the t-quark mass. Dotted lines represent gluons. Other notations the same as at Fig. 2.

$$m_t = \frac{g_\phi\,\eta}{\sqrt{2}} + \Delta M = \frac{g_\phi\,\eta}{f\,\sqrt{2}}. \tag{31}$$

$$\Delta M = -4\,m_t \int_\mu^\infty \frac{F_2(z)\,dz}{\sqrt{z}} \int_\mu^\infty \frac{\alpha_s(z)\,F_2(z)\,dz}{2\,\pi\,z} - \tag{32}$$

$$4\int_\mu^\infty \frac{m_t(z)\,F_2(z)\,dz}{\sqrt{z}}\,;\; m_t(z) = m_t\left(1 + \frac{7\alpha_s(\mu)}{8\pi}\,\ln\frac{z}{\mu}\right)^{-\frac{4}{7}}.$$

$$f = 1 + 4\int_\mu^\infty \frac{F_2(z)\,dz}{\sqrt{z}} \int_\mu^\infty \frac{\alpha_s(z)\,F_2(z)\,dz}{2\,\pi\,z} + 4\int_\mu^\infty \frac{m_t(z)\,F_2(z)\,dz}{m_t\,\sqrt{z}}. \tag{33}$$

Strong coupling $\alpha_s(z)$:

$$\alpha_s(z) = \alpha_s(\mu)\left(1 + \frac{7\alpha_s(\mu)}{8\pi}\ln\frac{z}{\mu}\right)^{-1}. \quad \alpha_s(\mu) = 0.108\,; \tag{34}$$

$\alpha_s(M_Z) = 0.1184 \pm 0.0007.$

Tachyon state ϕ. Higgs mechanism $\rightarrow$

$$Ł_{\phi 4} = \lambda\,(\phi^*\phi)^2. \tag{35}$$

$$\lambda = \frac{3\,g_\phi^4}{16\,\pi^2}\,I_4\,; \quad I_4 = \int_\mu^\infty \frac{\Psi(z)^4\,dz}{z}. \tag{36}$$

From $\eta^2 = -m_\phi^2/\lambda$ and $M_H^2 = -2\,m_\phi^2$ we have

$$\eta^2 = \frac{16\pi\, m_t^2\, I_5}{3\, g_\phi^4\, \sqrt{\mu}\, I_2\, I_4}; \quad M_H^2 = \frac{2\, m_t^2\, I_5}{\pi\, \sqrt{\mu}\, I_2}. \tag{37}$$

From (31) and (37) we have useful relation

$$2 = \frac{16\pi\, I_5}{3\, g_\phi^2\, f^2\, \sqrt{\mu}\, I_2\, I_4}. \tag{38}$$

g_ϕ from a normalization condition (Fig. 5)

$$\frac{3g_\phi^2}{32\pi^2}\left(I_2 + \frac{\alpha_s(\mu)}{4\pi}\left(I_{22}^2 + 2\, I_6\right)\right) = 1; \tag{39}$$

$$I_{22} = \int_\mu^\infty \frac{\Psi(t)\, dt}{t}; \quad I_6 = \int_\mu^\infty \frac{\Psi(z)\, dz}{z\sqrt{z}} \int_\mu^z \frac{\Psi(t)\, dt}{\sqrt{t}}.$$

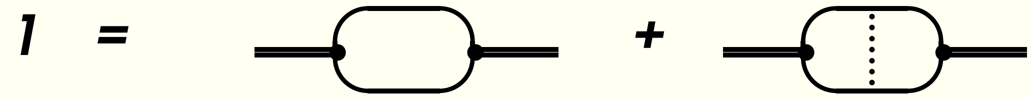

Fig. 5. Diagrams for normalization condition for $H\,\bar{\Psi}_L\,t_R$-vertex. Notations are the same as at Figs. 2 - 4.

For six parameters μ, g_ϕ, η, m_t, M_H, f we have five relations (31, 37, 38, 40) and

$$M_W \;=\; \frac{g_w\,\eta}{2}\,; \tag{40}$$

where g_w is g at W mass (by usual RG evolution) expression (15) from value g at Υ (14). M_W as an input. Thus

$$M_W \;=\; 80.4\,GeV\,; \quad \eta \;=\; 246.2\,GeV\,. \tag{41}$$

$$\mu = 4.0675\,10^{-12}\,; \quad f = 2.034\,; \quad g_\phi = 2.074\,; \qquad (42)$$
$$m_t = 177.0\,GeV\,; \quad M_H = 1803\,GeV\,.$$

The most important result here is the t-quark mass, which is close to experimental value $M_t = 173.3 \pm 1.1\,GeV$ (22). Really, the main difficulty of composite Higgs models (17, 18, 19, 20) consists in too large m_t. Indeed the definition of g_ϕ in such models leads to $g_\phi \simeq 3$ and thus $m_t \simeq 500\,GeV$. In the present work we have all parameters, including inportant parameter f, being defined by selfconsistent set of equations and the unique solution gives results (42), which for m_t is quite satisfactory. The large value for M_H seems to contradict to upper limit for this mass, which follows from considerations of Landau pole in the $\lambda\phi^4$ theory. Emphasize, that this limit corresponds to the local theory and in our case of composite scalar fields is not relevant.

Such large mass of H means, of course, very large width of H

$$\Gamma_H = 3784\,GeV\,; \quad BR(H \to W^+\,W^-) = 51.4\%\,; \qquad (43)$$
$$BR(H \to Z\,Z) = 25.6\%\,; \quad BR(H \to \bar{t}\,t), = 23.0\%\,.$$

Thus our approach predicts, that unfortunately quest for Higgs particle at LHC will give negative result. Maybe one could succeed in registration of slight increasing of cross-sections $p + p \to W^+ + W^- + X,\, p + p \to Z + Z + X,\, p + p \to \bar{t} + t + X$ in region of invariant masses of two heavy particles $1\,TeV < M_{12} < 3\,TeV$. As a matter of fact the most recent LHC data (SMS PAS-HIG-11-022, ATLAS-CONF-2011-135) do not find the SM Higgs in wide interval up to 466 GeV (see also recent ATLAS result (21)).

W-hadrons and CDF Wjj anomaly

Triple interaction

$$-\frac{G}{3!}\cdot\epsilon_{abc}\,W^a_{\mu\nu}\,W^b_{\nu\rho}\,W^c_{\rho\mu}\,; \tag{44}$$

$$W^3_{\mu\nu} = \cos\theta_W\,Z_{\mu\nu} + \sin\theta_W\,A_{\mu\nu}\,;$$

We know form-factor $F(p_i)$*. Effective dimensionless coupling*

$$g_{eff} = \frac{g\,\lambda\,p^2}{M_W^2}\,. \tag{45}$$

In QCD boundary of a strong interaction (non-perturbative region) is around $600\,MeV$ *where* $\alpha_s \simeq 0.5$ *that is coupling* $g_s = \sqrt{4\pi\alpha_s} = 2.5$*. So we have to equate* g_{eff} *(45) to this value and define the typical value* p_{typ} *that gives*

$$p_{typ} = M_W\sqrt{\frac{g_{eff}}{g\,\lambda}} \simeq 650\,GeV\,; \tag{46}$$

λ is maximal value from limitation (6). The lightest hadron – mass $\simeq 140\,MeV$ for typical scale $600\,MeV$ in QCD and for p_{typ} (46) mass of the lightest W-hadron

$$M_{min} = \frac{p_{typ}\,M_\pi}{600\,MeV} \simeq 150\,GeV\,; \tag{47}$$

The excess detected in work (24) is situated just in this region. So one might try to consider interpretation of effect (24) as a manifestation of a W-hadron. Some indications for state with the same mass at LHC are discussed in work (25)(1109.0919 (hep-ph)).

Assume this CDF excess being due to bound state X of two W with $I = 1$, $J = 1$

$$\frac{G_X}{2}\,\epsilon_{abc}\,W^a_{\mu\nu}\,W^b_{\nu\rho}\,X^c_{\rho\mu}\,\Psi\,; \tag{48}$$

Ψ is a Bethe-Salpeter wave function of the bound state. T(Fig. 6)

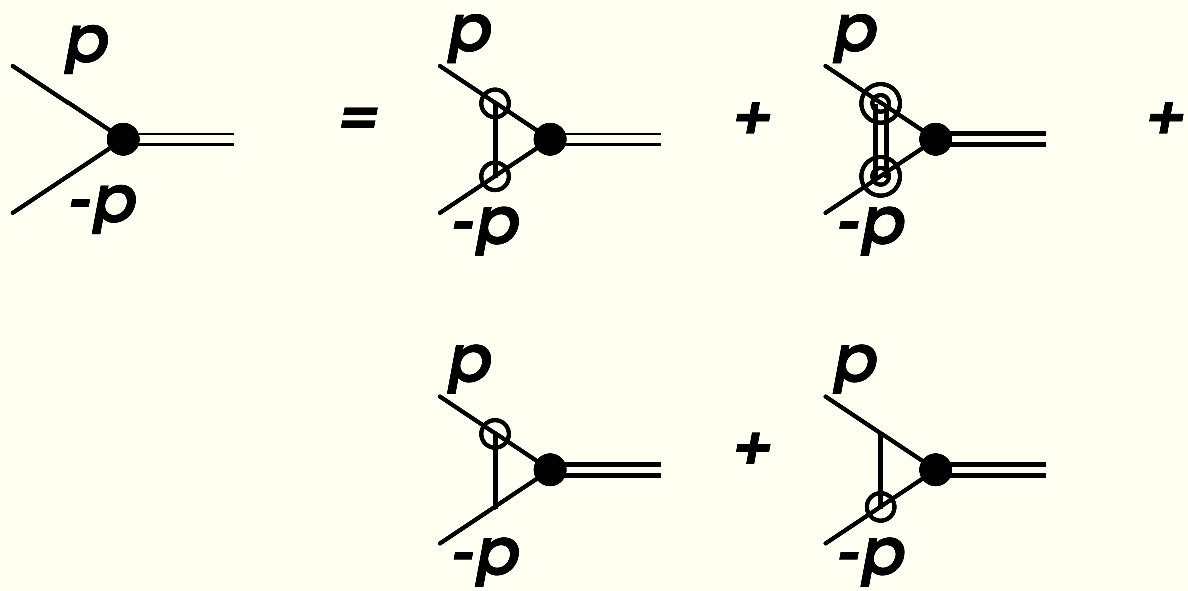

Fig.6 Diagram representation of Bethe-Salpeter equation for W-W bound state. Black spot corresponds to BS wave function. Empty circles correspond to point-like anomalous three-gluon vertex (44), double circle – XWW vertex (48). Simple point – usual gauge triple W interaction. Double line – the bound state

X, simple line – W. Incoming momenta are denoted by the corresponding external lines.

For small mass M_X of state X we expand the kernel of the equation in powers of M_W^2 and M_X^2 and obtain the following equation

$$
\begin{aligned}
\Psi(x) &= \frac{G^2+G_X^2}{32\pi^2}\int_0^{Y_0}\Psi(y)y\,dy - \frac{G^2+G_X^2}{32\pi^2}\Big(\frac{1}{12x^2}\int_0^x \Psi(y)y^3dy - \\
&\frac{1}{6x}\int_0^x\Psi(y)y^2dy - \frac{x}{6}\int_x^{Y_0}\Psi(y)dy + \frac{x^2}{12}\int_x^{Y_0}\frac{\Psi(y)}{y}dy\Big) + \frac{g\,G}{4\,\pi^2}\Big(\int_0^{Y_0}\Psi(y)dy - \\
&\frac{3}{8x^3}\int_0^x\Psi(y)y^3dy + \frac{7}{8x^2}\int_0^x\Psi(y)y^2dy - \frac{1}{2x}\int_0^x\Psi(y)y\,dy + \\
&\frac{x}{8}\int_x^{Y_0}\frac{\Psi(y)}{y}dy - \frac{x^2}{8}\int_x^{Y_0}\frac{\Psi(y)}{y^2}dy)\Big) - \frac{\mu\,\bar{G}\sqrt{2}}{\pi}\Big(\int_0^{Y_0}\Psi(y)dy - \\
&\frac{1}{12x^2}\int_0^x\Psi(y)y^2dy + \frac{1}{6x}\int_0^x\Psi(y)y\,dy + \frac{x}{6}\int_x^{Y_0}\frac{\Psi(y)}{y}dy \qquad (49)\\
&-\frac{x^2}{12}\int_x^{Y_0}\frac{\Psi(y)}{y^2}dy\Big) - \frac{\chi\,\bar{G}\sqrt{2}}{\pi}\Big(\frac{1}{24}\int_0^{Y_0}\Psi(y)dy - \frac{1}{192x^3}\int_0^x\Psi(y)y^3dy + \\
&\frac{1}{64x}\int_0^x\Psi(y)y\,dy + \frac{x}{64}\int_x^{Y_0}\frac{\Psi(y)}{y} - \frac{x^3}{192}\int_x^{Y_0}\frac{\Psi(y)}{y^3}dy\Big).
\end{aligned}
$$

$$
\mu = \frac{\bar{G}\,M_W^2}{16\pi\,\sqrt{2}};\ \chi = \frac{\bar{G}\,M_X^2}{16\pi\,\sqrt{2}};\ \bar{G} = \sqrt{G^2+G_X^2}\,.
$$

For interaction (44) Υ_0 is already defined. Substitutions

$$z = \frac{(G^2 + G_X^2)x^2}{512\pi^2}, \quad t = \frac{(G^2 + G_X^2)y^2}{512\pi^2}; \tag{50}$$

zero approximation:

$$\Psi_{00}(z) = \frac{\pi}{2}\, G_{15}^{21}\left(z\Big|^{0}_{1,0,1/2,-1/2,-1}\right). \tag{51}$$

$$\Psi_0(z) = INH - \frac{2}{3z}\int_0^z \Psi_0(t)\,t\,dt + \frac{4}{3\sqrt{z}}\int_0^z \Psi_0(t)\sqrt{t}\,dt + \frac{4\sqrt{z}}{3}\int_z^{z_0'} \frac{\Psi_0(t)}{\sqrt{t}}dt - \frac{2z}{3}\int_z^{z_0'} \frac{\Psi_0(y)}{y}dy\,; \tag{52}$$

$$INH = 1 - \sqrt{z}\left(\frac{g'\sqrt{2}}{8\,\pi} + \frac{8\,\mu}{3} - \frac{\chi}{4}\right)\left(ln\,z + 4\,\gamma + 4\,ln\,2 + \frac{\pi}{2}\,G_{15}^{21}\left(z_0'\Big|_{0,0,1/2,-1/2,-1}^{0}\right)\right) + \sqrt{z}\left(\frac{g'\sqrt{2}}{48\,\pi} + \frac{68\,\mu}{9} - \frac{25\,\chi}{32}\right);$$

$$1 = 8\int_0^{z_0'} \Psi_0(t)\,dt - \left(\frac{g'\,2\,\sqrt{2}}{\pi} - 16\,\mu + \frac{2\,\chi}{3}\right)\int_0^{z_0'} \frac{\Psi_{00}(t)}{\sqrt{t}}\,dt$$

$$M_X = M_W\sqrt{\frac{\chi}{\mu}}\,; \quad M_W = 80.4\,GeV\,. \tag{53}$$

Solution of (52)

$$
\begin{aligned}
\Psi_0(z) = {} & \frac{\pi}{2}\, G^{21}_{15}\left(z\middle|^{0}_{1,0,1/2,-1/2,-1}\right) + \\
& C_1\, G^{21}_{15}\left(z\middle|^{1/2}_{1/2,1/2,1,-1/2,-1}\right) + \\
& C_2\, G^{20}_{04}\left(z\middle|_{1,1/2,-1/2,-1}\right) + \\
& C_3\, G^{10}_{04}\left(-z\middle|_{1,1/2,-1/2,-1}\right).
\end{aligned}
\tag{54}
$$

"Experimental" $M_X = 145\, GeV \rightarrow$

$$
\begin{aligned}
& C_1 = -\,0.015282\,; \quad C_2 = -3.26512\,; \\
& C_3 = 1.27962\,10^{-11}\,; \quad g' = 0.03932\,; \\
& \chi = 0.0074995\,; \quad z'_0 = 2627.975\,; \\
& \mu = 0.002305\,.
\end{aligned}
\tag{55}
$$

Physical parameters:

$$G = \frac{0.0099}{M_W^2}\,; \quad \lambda = -\frac{G\,M_W^2}{g} = -\,0.0152\,;$$
$$M_X = 145\,GeV\,; \quad |G_X| = \frac{0.1639}{M_W^2}. \tag{56}$$

λ **(56) agrees with restrictions (6). Additional solutions for "radial excitations"** X_i

$$M_{X_1} = 180.7\,GeV\,; \quad |G_{X_1}| = \frac{0.0628}{M_W^2}\,;$$
$$M_{X_2} = 205.1\,GeV\,; \quad |G_{X_2}| = \frac{0.1155}{M_W^2}\,. \tag{57}$$
$$M_{X_3} = 244.2\,GeV\,; \quad |G_{X_3}| = \frac{0.1837}{M_W^2}\,.$$

$$X^{\pm}_{1,2,3} \to W^{\pm} + (Z,\gamma)\,; \quad X^{0}_{1,2,3} \to W^{+} + W^{-}\,; \tag{58}$$

$$\Gamma(X^0_1) = 0.0086\,GeV\,; \quad \Gamma(X^{\pm}_1) = 0.0051\,GeV\,;$$

$$\Gamma(X^0_2) = 0.126\,GeV\,; \quad \Gamma(X^{\pm}_2) = 0.083\,GeV\,;$$

$$\Gamma(X^0_3) = 1.26\,GeV\,; \quad \Gamma(X^{\pm}_2) = 0.89\,GeV\,;$$

$$BR(X^+_1 \to W^+ Z) = 0.44;\; BR(X^+_1 \to W\gamma) = 0.56.$$

$$BR(X^+_2 \to W^+ Z) = 0.80;\; BR(X^+_2 \to W\gamma) = 0.20.$$

$$BR(X^+_3 \to W^+ Z) = 0.91;\; BR(X^+_3 \to W\gamma) = 0.09.$$

X interact with fermion doublets ψ_L (Fig. 7).

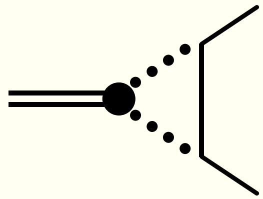

Fig. 7. Diagram for vertex $X\,\bar{q}\,q$. Dotted line – W, double line – bound state X, simple line – a quark. Black spot – the XWW BS wave function.

$$L_{X\psi} \;=\; g_X\, X_\nu^a\, \bar\psi_L\, \tau^a\, \gamma^\nu\, \psi_L; \qquad (59)$$

$$g_X = \frac{g^2\, G_X\, M_X^2}{64\,\pi^2} \int_{\mu^2}^{z_0'} \frac{\Psi_0(t)}{t}\, dt = 0.00067\,.$$

Calculations of decay parameters and cross-sections use CompHEP package (32), each quark $\to$ jet.

$$X^\pm \;\to\; W^\pm + \gamma\,(\simeq 96\%); \quad X^0, \to\; j\,j\;(\simeq 71\%)\,; \qquad (60)$$

X^a necessarily interacts with gauge field W^a with the same

coupling g

$$\Gamma^{abc}_{\mu\nu\rho}(p,q,k) = g\,\epsilon^{abc}\Big(\Phi_\kappa(p,q,k)\,\kappa(g_{\nu\rho}k_\mu - g_{\rho\mu}k_\nu) +$$
$$\Phi_g(p,q,k)\,\big(g_{\mu\nu}(q_\rho - p_\rho) - g_{\nu\rho}q_\mu + g_{\rho\mu}p_\nu\big)\Big); \qquad (61)$$

Φ_i ***– formfactors, in the present approximation*** $\kappa\ =\ 0$***, for TEVATRON*** $\Phi_i \simeq 1$***.***

Estimates for cross-sections for energy $\sqrt{s} = 1960\,GeV$

$$\sigma(p\bar{p} \to W^\pm X^0 + ...) = 1.84\,pb\,;$$
$$\sigma(p\bar{p} \to W^\mp\,X^\pm + ...) = 2.69\,pb\,;$$
$$\sigma(p\bar{p} \to Z\,X^\pm + ...) = 1.32\,pb\,; \qquad (62)$$
$$\sigma(p\bar{p} \to X^0\,X^\pm + ...) = 0.33\,pb\,;$$
$$\sigma(p\bar{p} \to X^\mp\,X^\pm + ...) = 0.24\,pb\,.$$

Branching rations (60) $\rightarrow$

$$\sigma(p\bar{p} \rightarrow W^{\pm} + \gamma + 2\,j + ...) = 0.24\,pb\,;$$
$$\sigma(p\bar{p} \rightarrow W^{\pm} + 2\,j + ...) = 1.43\,pb\,; \qquad (63)$$
$$\sigma(p\bar{p} \rightarrow Z + 2\,j + ...) < 0.06\,pb\,;$$

Total cross-section for $Wjj + Wjj\gamma\ (1.67\,pb)$ occurs to be smaller than result (24) $\sigma(Wjj) = 4.0 \pm 1.2\,pb$ small value for Zjj production agrees with data. Results of $D0$ (27) $\rightarrow$ $\sigma(Wjj) < 1.9\,pb$ (95% C.L.). Our result (63) does not contradict both.

Pair weak boson production additional contribution

$$\Delta\big(\sigma(p\bar{p} \to W^+W^-) + \sigma(p\bar{p} \to ZW^\pm)\big) = \mathbf{3.2}\,pb;$$
$$\sigma(W^+\,W^-) + \sigma(Z\,W^\pm) = \mathbf{17.4 \pm 3.3}\,pb\,;$$
$$(\sigma(W^+\,W^-) + \sigma(Z\,W^\pm))_{SM} = \mathbf{15.1 \pm 0.9}\,pb\,; \tag{64}$$

Data (26) at TEVATRON.

Predictions for X_i inclusive production at TEVATRON

$$
\begin{aligned}
&\sigma(p\,\bar p \to W^- + X_1^+) \;=\; 0.30\,pb;\\
&\sigma(p\,\bar p \to W^+ + X_1^0) \;=\; 0.21\,pb;\\
&\sigma(p\,\bar p \to Z + X_1^+) \;=\; 0.15\,pb;\\
&\sigma(p\,\bar p \to \gamma + X_1^+) \;=\; 0.12\,pb;\\
&\sigma(p\,\bar p \to W^- + X_2^+) \;=\; 0.87\,pb;\\
&\sigma(p\,\bar p \to W^+ + X_2^0) \;=\; 0.80\,pb;\\
&\sigma(p\,\bar p \to Z + X_2^+) \;=\; 0.42\,pb;\\
&\sigma(p\,\bar p \to \gamma + X_2^+) \;=\; 0.31\,pb;\\
&\sigma(p\,\bar p \to W^- + X_3^+) \;=\; 1.69\,pb;\\
&\sigma(p\,\bar p \to W^+ + X_3^0) \;=\; 1.14\,pb;\\
&\sigma(p\,\bar p \to Z + X_3^+) \;=\; 0.81\,pb;\\
&\sigma(p\,\bar p \to \gamma + X_3^+) \;=\; 0.52\,pb;
\end{aligned}
\tag{65}
$$

At LHC promising process $p + p \longrightarrow W^{\pm} + \gamma + ...$ (see e,g.1106.2829 (hep-ex). Calculation of cross sections needs extensive work.
The results of the last section are obtained by B.A. A. and I.V. Zaitsev.

For calculations CompHEP package (32) was used.

Conclusion

To conclude we would emphasize, that albeit we discuss quite unusual effects, we do not deal with something beyond the Standard Model. We are just in the framework of the Standard Model. What makes difference with usual results are non-perturbative non-trivial solutions of compensation equations. With the present results we would draw attention to two important points. Firstly, the unique determination of gauge electro-weak coupling constant $g(M_W)$ and calculation of the t - quark mass in close agreement with experimental values. These results strengthen the confidence in the correctness of applicability of Bogoliubov compensation approach to the principal problems of elementary particles theory. Secondly, we have seen, that non-perturbative contributions lead to prediction of experimental effects which are investigated at

LHC and TEVATRON. These predictions at least do not contradict to the totality of data. More than that, there are some indications on agreement of several important effects with the predictions (the almost proved absence of Higgs scalar in the most popular region, a possible WW-bound state).

References

(1) ***B.A. Arbuzov, Theor. Math. Phys.,*** 140, ***1205 (2004).***

(2) ***B.A. Arbuzov, Phys. Atom. Nucl., 69, 1588 (2006).***

(3) ***B.A. Arbuzov, M.K. Volkov and I.V. Zaitsev, Int. Journ. Mod. Phys. A,*** 21, ***5721 (2006).***

(4) ***B.A. Arbuzov, Phys. Lett. B, 656, 67 (2007).***

(5) ***B.A. Arbuzov, M.K. Volkov and I.V. Zaitsev, Int. Journ. Mod. Phys. A*** 24, ***2415 (2009).***

(6) ***B.A. Arbuzov, Eur. Phys. J. C,*** 61, ***51 (2009).***

(7) ***N.N. Bogoliubov. Soviet Phys.-Uspekhi, 67, 236 (1959).***

(8) ***N.N. Bogoliubov. Physica Suppl., 26, 1 (1960).***

(9) ***N.N. Bogoliubov,*** *Quasi-averages in problems of statistical mechanics.* ***Preprint JINR D-781, (JINR, Dubna 1961).***

(10) K. Hagiwara, R.D. Peccei, D. Zeppenfeld and K. Hikasa, Nucl. Phys. B, 282, 253 (1987).

(11) B.A. Arbuzov, Phys. Lett. B, 288, 179 (1992).

(12) LEP Electro-weak Working Group, arXiv: hep-ex/0612034v2 (2006).

(13) H. Bateman and A. Erdélyi, *Higher transcendental functions. V. 1* (New York, Toronto, London: McGraw-Hill, 1953).

(14) Y. Nambu and G. Jona-Lasinio, Phys. Rev. 122, 345 (1961).

(15) Y. Nambu and G. Jona-Lasinio, Phys. Rev. 124, 246 (1961).

(16) M.K. Volkov and A. Radzhabov, Phys. Usp. 49, 551 (2006).

(17) Y. Nambu, Enrico Fermi Institute Report No 89-08, 1989.

(18) V.A. Miransky, M. Tanabashi and K. Yamawaki, Phys. Lett B 221, 177 (1989).

(19) W.A. Bardeen, C.T. Hill and M. Lindner, Phys. Rev. D 41, 1647 (1990).

(20) M. Lindner, Int. J. Mod. Phys. A 8, 2167 (1993).

(21) ATLAS Collaboration, arXiv: 1109.3357 (hep-ex) (2011).

(22) Tevatron Electroweak Working Group (CDF and D0 Collaborations), arXiv: 1007.3178 (hep-ex) (2010).

(23) B.A. Arbuzov and I.V. Zaitsev, arXiv:1107.5164 (hep-ph) (2011).

(24) T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett., 106: 171801 (2011); arXiv: 1104.0699(hep-ex) (2011).

(25) R. Foot, A. Kobakhidze, R.R. Volkas, arXiv:1109.0919 (hep-ph) (2011).

(26) T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. D, 82: 112001 (2010).

(27) V.M. Abazov *et al.* (D0 Collaboration), arXiv: 1106.1921 (hep-ex) (2011).

(28) V.M. Abazov et al. (D0 Collaboration), Phys. Rev. Lett., 102: 231801, 2009; arXiv: 0901.1887 (hep-ex) (2009).

(29) The CMS Collaboration, arXiv:1102.5429 (hep-ex) (2011).

(30) D. Majuder (on behalf of the CMS Collaboration), arXiv: 1106.2829 (hep-ex) (2011).

(31) J.M. Campbell and R.K. Ellis, Phys. Rev. D, 60: 113006 (1999).

(32) E.E. Boos et al. (CompHEP Collaboration), Nucl. Instr. Meth. A 534, 250 (2004).