ρ PARAMETER IN THE VECTOR CONDENSATE MODEL OF ELECTROWEAK INTERACTIONS

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ABSTRACT

In the standard model of electroweak interactions the Higgs doublet is replaced by a doublet of vector bosons and the gauge symmetry is broken dynamically. This generates masses for the gauge bosons and fermions, as well as it fixes the interactions in the model. The model has a low momentum scale. In this note we show that the model survives the test of the ρ parameter, and to each momentum scale ρ chooses a possible range of vector boson masses.

Although the Higgs mechanism is a very simple realisation of symmetry breaking, alternative realisations [1] are also important, since the Higgs has not yet been seen.

Recently, a model of symmetry breaking has been introduced [2] in such a way that in the standard model of electroweak interactions the Higgs doublet was replaced by a Y=1 doublet of vector fields,

$$B_\mu = \begin{pmatrix} B_\mu^{(+)} \\ B_\mu^{(0)} \end{pmatrix}, \tag{1}$$

and $B_\mu^{(0)}$ forms a nonvanishing condensate,

$$\left\langle B_\mu^{(0)+} B_\nu^{(0)} \right\rangle_0 = g_{\mu\nu} d, \qquad d \neq 0,$$

$$\left\langle B_\mu^{(+)+} B_\nu^{(+)} \right\rangle_0 = 0. \tag{2}$$

This generates mass terms for W and Z, the tree level ρ parameter remains 1 and the photon is massless. Assuming a quartic self-interaction for B_μ , the $B^{+,0}$ particles become massive and the ratio of their bare masses is $(4/5)^{1/2}$.

Fermions can easily be made massive by introducing $\overline{\Psi}_L B_\nu \Psi_R B^{(0)\nu+}$ + h.c. type interactions. Also the Kobayashi-Maskawa mechanism can be built in. Low energy charged current phenomenology shows that $\sqrt{-6d} = 246$ GeV. The fermion-B coupling is $3(2)^{-1/2} m_f G_F$, a $G_F^{\frac{1}{2}}$ factor weaker than the coupling to the Higgs. The model can be considered as a low energy effective model valid up to about $\Lambda \leq 2.6$ TeV, and $m_B \geq 43$ GeV [2].

The aim of this paper is to show that oblique radiative corrections [3] due to B-loops can give arbitrarily small contributions to the ρ parameter, provided the $B^{+,0}$ masses are suitably chosen. The cutoff Λ remains unrestricted.

The contribution $\Delta\rho$ due to B-loops to ρ is

$$\Delta\rho = \alpha T = \varepsilon_1 \tag{3}$$

where T (or ε_1) is one of the three parameters [3] constrained by precision experiments. The analysis in Ref. [4] finds for beyond the standard model $\Delta\rho = -(0.009 \pm 0.25)10^{-2}$ at $m_t = 130$ GeV, $m_H = m_Z$.

The parameter T is defined by

$$\alpha T = \frac{e^2}{s^2 c^2 m_Z^2}\Big(\overline{\Pi}_{WW}(0) - \overline{\Pi}_{WW}(0)\Big) \tag{4}$$

with $s = \sin\theta_W, c = \cos\theta_W$ is calculated in one-B-loop order. $\overline{\Pi}_{ik}$ is expressed by the $g_{\mu\nu}$ terms of the vacuum polarization contributions $\overline{\Pi}_{ik}$ due to B-loops as

$$\Pi_{ZZ} = \frac{e^2}{s^2c^2}\overline{\Pi}_{ZZ}, \quad \Pi_{WW} = \frac{e^2}{s^2}\overline{\Pi}_{WW} \tag{5}$$

The interactions giving rise to W and Z self energies follow from the starting gauge invariant Lagrangian of the $B^{+,0}$ fields [2]. From these only the trilinear ones are important to one-loop order,

$$\begin{aligned}
L\left(B^0\right) &= \frac{ig}{2c}\partial^\mu B^{(0)\nu +}\left(Z_\mu B_\nu^{(0)} - Z_\nu B_\mu^{(0)}\right) + h.c.,\\
L\Big(B^+B^{++}Z\Big) &= -C\cdot L\big(B^0 \to B^+\big), \quad C = c^2 - s^2,\\
L\left(B^0B^+W\right) &= \frac{ig}{\sqrt{2}}\Big[\partial^\mu B^{(+)\nu +}\left(W_\mu^+ B_\nu^{(0)} - W_\nu^+ B_\mu^{(0)}\right) + \\
&\quad + \partial^\mu B^{(0)\nu +}\left(W_\mu^- B_\nu^{(+)} - W_\nu^- B_\mu^{(+)}\right)\Big] + h.c.\ .
\end{aligned} \tag{6}$$

In a renormalizable theory T is finite. In the present model, however, it is a function of the cutoff Λ which cannot be removed. After lengthy calculations we get

$$\begin{aligned}
-64\pi^2\overline{\Pi}_{ZZ}(0) = &-\frac{5}{4}\left(\frac{1}{m_0^2} + \frac{C}{m_+^2}\right)\Lambda^4 + \frac{11}{2}(1+C)\Lambda^2 - \frac{17}{2}m_0^2\ln\Big(1 + \frac{\Lambda^2}{m_0^2}\Big) - \\
&-\frac{17}{2}Cm_+^2\ln\Big(1 + \frac{\Lambda^2}{m_+^2}\Big) + 3(m_0^2 + Cm_+^2) - \frac{3m_0^4}{\Lambda^2 + m_0^2} - \frac{3Cm_+^4}{\Lambda^2 + m_+^2}
\end{aligned} \tag{7}$$

and

$$\begin{aligned}
-\left[\frac{1}{256\pi^2}\left(\frac{1}{m_0^2} + \frac{1}{m_+^2}\right)\right]^{-1}\overline{\Pi}_{WW}(0) = &-5\Lambda^4 + 11(m_0^2 + m_+^2)\Lambda^2 - \frac{(m_0^2 - m_+^2)^2}{m_0^2 + m_+^2}\Lambda^2 - \\
&-\frac{1}{4}\left[17(m_0^2 + m_+^2)^2 + 3(m_0^2 - m_+^2)^2\right]\ln\left(1 + \frac{\Lambda^2}{m_0^2}\right)\left(1 + \frac{\Lambda^2}{m_+^2}\right) + \\
\frac{1}{2}\left[-\frac{15}{2}(m_0^2 + m_+^2)(m_0^2 - m_+^2) + \frac{1}{2}\frac{(m_0^2 - m_+^2)^3}{(m_0^2 + m_+^2)} - 3\frac{(m_0^2 + m_+^2)^3}{(m_0^2 - m_+^2)}\right]&\ln\frac{1 + \frac{\Lambda^2}{m_0^2}}{1 + \frac{\Lambda^2}{m_+^2}}
\end{aligned} \tag{8}$$

where $m_+(m_0)$ is the physical mass of $B^+(B^0)$.

From (3), (4), (7), (8) it follows that $\Delta\rho$ cannot be small for $\Lambda^2 \gg m_0^2, m_+^2$ and there is no compensation for $\Lambda^2 \sim m_0^2 \gg m_+^2$ or $\Lambda^2 \sim m_+^2 \gg m_0^2$. There exists, however, a compensation between the vacuum polarizations if Λ, m_0, m_+, are not very different. This is seen in Fig.1 showing $\Delta\rho$ as the function of m_0 at various Λ's for $m_+ = 0.8m_0$. Similar curves can be drawn for not very different m_+/m_0 , but at higher Λ the sensitivity to m_+/m_0 increases (Fig.2). For instance, if $\Lambda = 2$ TeV and $m_+ = 0.9m_0 \pm 10$ % , then $m_0 = 1557 \pm 50$ GeV at $\Delta\rho = 0$. We have checked numerically the compensation up to $\Lambda = 15$ TeV. Increasing Λ $m_0(\Delta\rho = 0)$ grows and the m_0 interval corresponding to $\Delta\rho_{exper.}$ shrinks. For instance, for $m_+ = 0.9m_0$ and at $\Lambda = (0.8, 1.4, 2, 4)$ TeV $m_0(\Delta\rho = 0) = (623, 1090, 1557, 3115)$ GeV and from $\Delta\rho_{exper.}$ the m_0 interval is (619- 630, 1088-1094, 1556-1560, 3114-3116) GeV, etc.

In conclusion, the vector condensate model does not contradict to the experimental ρ parameter and even $\Delta\rho_{exper.} = 0$ can be included, but this is possible only if the B particle is heavy.

This work is supported in part by OTKA I/3, No. 2190.

REFERENCES

1. Proceedings of LHC Workshop, Aachen 1990, CERN 90-10, Eds. G.Jarlskog and D.Rein, Vol. 2, p.757. M.Lindner, Int. Journal of Mod. Phys. A8 (1993) 2167. R.Casalbuoni, S.De Curtis and M.Grazzini, Phys. Lett. B 317 (1993) 151.

2. G.Pócsik, E.Lendvai and G.Cynolter, Acta Phys. Polonica B 24 (1993) 1495.

3. D.Kennedy and B.W.Lynn, Nucl. Phys. B 322 (1989) 1. M.E.Peskin and T.Takeuchi, Phys. Rev. Lett. 65 (1990) 964. G.Altarelli and R.Barbieri, Phys. Lett. B 253 (1990) 161. M.E.Peskin and T.Takeuchi, Phys. Rev. D 46 (1992) 381.

4. J.Ellis, G.L.Fogli and E.Lisi, Phys. Lett. B 292 (1992) 427.

FIGURE CAPTIONS

Fig. 1 $\Delta\rho$ vs. m_0 at various Λ's for $m_+ = 0.8m_0$.

Fig. 2. $\Delta\rho$ vs. m_0 at various Λ's for $m_+ = m_0$.