UNIVERSIDADE DE SÃO PAULO

INSTITUTO DE FÍSICA
CAIXA POSTAL 20516
01000 - SÃO PAULO - SP
BRASIL

publicações

IFUSP/P-333
IFT-P-06/82

FLAVOUR CHANGING HIGGS BOSON COUPLINGS AND THE ELECTRIC DIPOLE MOMENT OF THE NEUTRON

by

C.O. Escobar
Instituto de Física, Universidade de São Paulo

and

V. Pleitez
Instituto de Física Teórica, São Paulo, Brazil

Maio/1982

FLAVOUR CHANGING HIGGS BOSON COUPLINGS AND THE ELECTRIC DIPOLE MOMENT OF THE NEUTRON

C. O. Escobar[*]
Instituto de Física - Universidade de São Paulo, S.Paulo, Brazil.
and
V. Pleitez[**]
Instituto de Física Teórica - São Paulo, Brazil

ABSTRACT - We argue that the existence of flavour changing Higgs boson couplings, within the experimental bounds, is sufficient to increase by many orders of magnitude, the electric dipole moment of the neutron, in the model where CP violation occurs only in the weak charged current.

* - Work supported in part by CNPq.
**- Supported by CAPES.

APRIL/1982

In the minimal Weinberg-Salam model of the electroweak interactions [1], with one Higgs doublet and at least three generations of fermions, the only source of CP violation are the complex couplings in the weak charged current [2]. In this model, it has been shown that the electric dipole moment (EDM) of a quark is strictly zero at the two-loop level [3]. Strong radiative corrections [4,5] modify this result giving however an EDM which is still very small, being of the order of 10^{-33}ecm. Recall that the experimental upper limit is $D_n < 6 \times 10^{-25}$ecm [6]. Another possible mechanism for generating a neutron EDM in the Kobayashi-Maskawa (K.M.) model, has been proposed by several authors [7,8,9] but again, this gives a small EDM, of the order 10^{-33}ecm.

In this letter we would like to point out that the introduction of flavour changing couplings in an extended Higgs sector, has significant effects upon the EDM of a quark calculated at the two-loop level, with CP violation in the charged current.

Let us recall the motivation for enlarging the Higgs sector. Any grand unified model for the strong and electroweak interactions will have a fairly complex Higgs system [10]. It is also desirable to extend the Higgs sector if one wishes to be able to calculate mixing angles and fermion masses in the theory[*1]. A phenomenological analysis of the virtual effects of Higgs particles has been performed by McWilliams and Li [11], who showed that it is possible to have flavour changing couplings consistent with the existent experimental bounds, provided the Higgs particle be quite heavy, with mass greater than 100 GeV.

To appreciate our point, let us consider the diagrams shown in Figures 1 and 2. In the absence of flavour changing couplings ($\alpha \to \beta$; $\sigma \to \alpha$), the charged current couplings are strictly real[*2] and therefore there is no contribution to the EDM. We will assume, as usual [11], that the Higgs couplings are proportional to the fermion masses to which they couple, in which case the diagram in Fig. 1 is less important than the one in Fig. 2[‡3], therefore in the following, we will consider only the latter.

In order to estimate the order of magnitude of the diagram in Fig. 2, we make the following assumptions:

(i) the Higgs-fermion couplings are of the order $(m_\alpha + m_\beta)G_F^{1/2}$,

(ii) the charged current coupling is of the order e times the appropriate matrix element of U,

(iii) the neutral Higgs coupling with the $W^\pm$ is of order $e^2 G_F^{-1/2}$,

(iv) for every loop in the diagram we have a factor of $(8\pi^2)^{-1}$,

with these assumptions we obtain for the EDM of a d-quark the following estimate[‡4],

$$D_d = (8\pi^2)^{-2}\, e^3 (m_b G_F^{1/2})(e^2 G_F^{-1/2}) M^{-2} \;\; s_1 c_2 s_2 c_3 \sin\delta \qquad (1)$$

where M is a mass of the order of the gauge boson mass. We assumed the Higgs boson to have a mass comparable to the W-boson mass [11]. Using in (1), m_b=4.5 GeV, $s_1c_2s_2c_3\sin\delta \sim 0.5\times 10^{-3}$ [13], we obtain,

$$D_d \simeq 6\times 10^{-27}\ \mathrm{ecm} \qquad (2)$$

This would imply an EDM for the neutron of the same order of magnitude.

We conclude that, if in the future, experimentalists find an EDM for the neutron which is much larger than 10^{-33} ecm, this does not rule out CP violation in the charged current ā La Kobayashi-Maskawa, provided we allow, as we have shown in this letter, for small flavour changing couplings in an extended Higgs sector.

FOOTNOTES

[‡1] - We could have, of course, CP violation in such extended Higgs sector coming only from the scalars. We ignore this possibility in the following, our intention is to work with CP violation ā la Kobayashi-Maskawa.

[‡2] - In this case the charged current couplings have the form, $U_{\alpha\delta}U^+_{\delta\alpha}$ which is real. Here U is the Kobayashi-Maskawa matrix [2].

[‡3] - This fact had been noticed before by Bjorken and Weinberg in a different context [12]. Notice that the spin structure of Fig. 1 requires a mass insertion, giving as a net result a dependence on the third power of a fermion mass.

[‡4] - Since we assumed (i), the flavour changing transition which is favoured is d → b, due to relatively large mass of the b-quark. Our simple estimate, eq.(1), does not take into account the t-quark contribution, since its large mass (m_t > 18 GeV) could invalidate our estimate.

FIGURE CAPTIONS

FIG. 1 - A two-loop contribution to the EDM of a quark of flavour α. The subscripts L and R denote the handedness of the fermion. H is the neutral Higgs boson and W the charged gauge boson.

FIG. 2 - Same as Fig. 1. Notice that the spin structure of this diagram does not require a mass insertion, as in Fig. 1.

REFERENCES

[1] - S.Weinberg - Phys.Rev.Lett. 19 (1967) 1264.
A. Salam - Proc. of the 8th Nobel Symposium, Stockholm 1968, ed. N. Svartholm, p.367 (1968).

[2] - M.Kobayashi and T. Maskawa - Progr.Theor.Phys. 49 (1973) 652.

[3] - E.P.Shabalin - Sov. J. Nucl. Phys. 28 (1979) 151.

[4] - J.Ellis and M.K.Gaillard - Nucl.Phys. B150 (1979) 141.

[5] - E.P.Shabalin - Sov. J. Nucl. Phys. 31 (1980) 864.

[6] - I.S.Altarev et al.- Phys. Lett. 102B (1981) 13.

[7] - D.V.Nanopoulos, A.Yildiz and P.H.Cox - Ann. Phys. 127 (1980) 126.

[8]- E.P.Shabalin - Sov. J. Nucl. Phys. 32 (1980) 228.

[9]- B.F.Morel - Nucl. Phys. B157 (1979) 23.

[10]- For a review on Grand-Unification, see: J.Ellis, Lectures presented at the Les Houches Summer School, August 1981 - CERN TH-3174 (1981).

[11]- B.McWilliams and L.F.Li - Nucl.Phys. B179 (1981) 62.

[12]- J.D.Bjorken and S.Weinberg - Phys.Rev.Lett. 38 (1977) 622.

[13]- See, for instance, L.L.Chau Wang, in Weak Interactions as Probes of Unification, AIP Conf. Proceedings nº 72 (1980), ed. G.B.Collins, L.N.Chang and J.R.Ficenec.

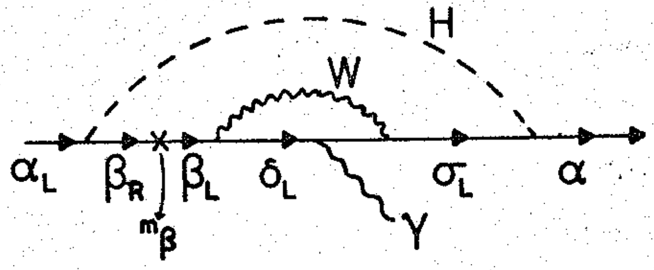
H
W
α_L
β_R
m_β
β_L
δ_L
σ_L
α
γ

FIG. 1

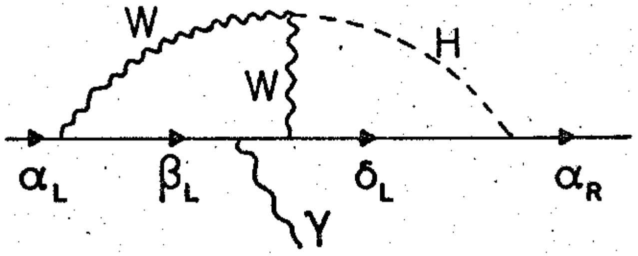
W
W
H
α_L
β_L
δ_L
α_R
γ

FIG. 2