Comment on "New Model of b-Quark Interactions: A Superstring Alternative"

In a recent Letter,[1] Ma proposed a model where the b quark is not paired with the t quark. This model is inspired by the possible particle content of the heterotic superstring, with two matter supermultiplets in **27** representations of E_6, and the low-energy gauge group

$$G_1 = SU(3)_c \otimes SU(2)_1 \otimes SU(2)_2 \otimes U(1)_H$$

(we use the same notation as Ma). The purpose of this Comment is to draw attention to some phenomenological problems of this model.

The group G_1 cannot arise directly after compactification; therefore it must be obtained by the spontaneous symmetry breaking at an intermediate scale M_I of a larger subgroup G of E_6.[2] This kind of model leads to quite bad predictions for $\sin^2\theta_W$ and R^{-1}. From the general analysis of Dine *et al.*,[3] we extract that the most plausible model is (other models give worse predictions for these parameters)

$$E_6 \to SU(3)_c \otimes SU(2)_1 \otimes SU(2)_2 \otimes U(1)_1 \otimes U(1)_2 \to SU(3)_c \otimes SU(2)_1 \otimes SU(2)_2 \otimes U(1)_H.$$

If we want to decouple the extra gauge boson from the low-energy physics, we will need that $M_I \gg M_W$. The natural way to get this hierarchy is by adding mirror representations $H(\mathbf{1},\mathbf{1},\mathbf{1};1/\sqrt{3},-1\sqrt{3})$+c.c. of G. If no other mirror representations are added, then we get $\sin^2\theta_W \sim 0.27$ and $R^{-1} \sim 10^{25}$ GeV.[4] Thus, in order to get acceptable values for $\sin^2\theta_W$ and R^{-1}, extra mirror representations are needed. It can be shown that at least two, $F(\mathbf{1},\mathbf{1},\mathbf{2};1/\sqrt{3},1/2\sqrt{3})$+c.c., must be added. With this matter content, we obtain $\sin^2\theta_W \sim 0.22$ and $R^{-1} \sim 8\times10^{19}$ GeV.

In order to break $SU(2)_1 \otimes SU(2)_2 \otimes U(1)_H$ to $U(1)_{em}$, the scalars in

$$E_0 \equiv \begin{pmatrix} \nu_E & E^c \\ E & N_E^c \end{pmatrix}_L \sim (\mathbf{1},\mathbf{2},\mathbf{2};0)$$

and in F must have nonzero vacuum expectation value. Consequently, if we ignore mixing between families, the following tree-level relations are obtained:

$$m_u/m_d = m_{\nu_\mu}/m_\mu = m_{\nu_e}/m_e. \qquad (1)$$

From the phenomenological point of view, this prediction is catastrophic, and cannot be avoided unless we add $E(\mathbf{1},\mathbf{2},\mathbf{2};-1/2\sqrt{3},1/2\sqrt{3})$+c.c. These new fields, which are useful for the mass generation at the electroweak scale, spoil the prediction for $\sin^2\theta_W$ leading again to the value ~ 0.27. These wrong predictions could only be solved with the inclusion of an even larger number of mirror multiplets. For instance, if we add

$$[(\mathbf{3},\mathbf{1},\mathbf{1};-1/\sqrt{3},0)+\text{H.c.}] + 3(F+\bar{F}) + (E+\bar{E}) + (H+\bar{H}),$$

we get $\sin^2\theta_W \sim 0.23$, $R^{-1} \sim 10^{16}$ GeV. However, this possibility sounds rather artificial.

To conclude, in the low-energy superstring-inspired model proposed by Ma it seems very hard to obtain acceptable phenomenology for $\sin^2\theta_W$, R^{-1}, and fermionic masses.

The Centro Atómico Bariloche is associated with the Comisión Nacional de Energía Atómica. The Instituto Balseiro is associated with the Comisión Nacional de Energía Atómica and Universidad Nacional de Cuyo. One of us (C.E.M.W.) is a Fellow of Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET).

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Received 5 December 1986
PACS numbers: 12.15.Cc, 12.10.Gq, 12.15.Ff

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[4]The calculations of $\sin^2\theta_W$ and R^{-1} were made with use of the renormalization-group equations [K. Inoue, A. Kakuto, H. Konatsu, and S. Makeshita, Prog. Theor. Phys. **67**, 1889 (1982)], and assuming $M_I = (M_W R^{-1})^{1/2}$, $\alpha_c(M_W) = \frac{1}{9}$, and that the two **27**$\oplus$mirror representations acquire mass $\sim M_W$. Another value of M_I, $\alpha_c(M_W)$, or the supersymmetric partner masses m_{ss}, e.g., $m_{ss} \sim 1$ TeV, would change slightly the predictions for $\sin^2\theta_W$ and R^{-1}, but the conclusion would be the same.

