Explaining the W-boson Mass in the Context of the Supersymmetric 331 Model

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Abstract

We present the Minimal Supersymmetric 331 Model as a possibility to resolve the recent excess at the W-boson mass reported by the CDF collaboration, using a new sextet Higgs boson. If this scalar field, S', obtains a vacuum expectation value of a few GeV, we will also analyze the boson masses for all new extra gauge bosons from this model, namely $Z', V^{\pm}$ and $U^{\pm\pm}$ and their mixing. We will show that all the masses of these new gauge bosons are in agreement with current experimental limits.

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1 Introduction

Recently, the CDF Collaboration at Fermilab presented its new high-precision measurement, with an accuracy of $\sim 10^{-4}$, of the W-boson mass [1]

$$(M_W)_{CDF} = (80.4335 \pm 0.0094)\,\mathrm{G}eV, \tag{1}$$

This measurement represents an excess greater than 6 σ in relation to the more precise value (*conservative* scenario) of the Standard Model (SM) which is given by [2]

$$(M_W)_{SM} = (80.3505 \pm 0.0077)\,\mathrm{G}eV. \tag{2}$$

Clearly, if this result presented by the CDF is confirmed by other experimental collaborations, it means a new indication of physics beyond the SM.

From the theoretical point of view, the SM cannot be a fundamental theory since it has so many questions, like that of the number of families, which do not have answers in its context. One of these possibilities to solve this problem is that, at energies of a few TeVs, the gauge symmetry may be

$$SU(3)_C \otimes SU(3)_L \otimes U(1)_N, \tag{3}$$

(or it is more commonly known as 3-3-1 for short) instead of that of the SM [3, 4]. They are intriguing possibilities for the physics at the TeV scale [5, 6].

The supersymmetric version of the 3-3-1 minimal model, more commonly known as MSUSY331, was presented recently [7, 8, 9, 10]. In this model, beyond the anti-sextet S, we need to introduce a Sextet S' Higgs boson to cancel chiral anomalies generated by the superpartners of S in a similar way as we have to add a new doublet scalar in the Minimal Supersymmetric Standard Model (known as MSSM for short). The vacuum expectation value of this new scalar field, S', can explain the shift on the W mass as we will show below. We can decompose our scalar fields into $SU(2)\otimes U(1)$ representations [11, 12, 13]

$$\mathbf{6}_0 \to \mathbf{3}_2 \oplus \mathbf{2}_{-1} \oplus \mathbf{1}_{-4} \tag{4}$$

where

$$\begin{aligned}
S &= \begin{pmatrix} T & \frac{\Phi_S}{\sqrt{2}} \\ \frac{\Phi_S^T}{\sqrt{2}} & H_2^{--} \end{pmatrix} \sim (\mathbf{1}, \mathbf{6}^*, 0), \\
T &= \begin{pmatrix} \sigma_1^0 & \frac{h_1^+}{\sqrt{2}} \\ \frac{h_1^+}{\sqrt{2}} & H_1^{--} \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, +2), \\
\Phi_S &= \begin{pmatrix} h_2^+ \\ \sigma_2^0 \end{pmatrix} \sim (\mathbf{1}, \mathbf{2}, -1), \quad H_2^{--} \sim (\mathbf{1}, \mathbf{1}, -4).
\end{aligned} \tag{5}$$

Φ_S is the Higgs doublet of SM while T was considered at [14].

The changes in the masses of the gauge bosons are:

$$\begin{aligned}
\delta M_W^2 &= \frac{g^2}{4}\left(v_{\sigma_1}^2 + v_{\sigma_1'}^2 + \frac{v_{\sigma_2'}^2}{2}\right), \\
\delta M_Z^2 &= \frac{g^2}{4\cos^2\theta_W}\left(2v_{\sigma_1}^2 + 2v_{\sigma_1'}^2 + \frac{v_{\sigma_2'}^2}{2}\right),
\end{aligned} \tag{6}$$

Therefore, the initial prediction of this model is

$$\delta M_W^2 \neq \delta M_Z^2, \tag{7}$$

we take

$$\left| \sqrt{v_{\sigma_1}^2 + v_{\sigma_1'}^2 + \frac{v_{\sigma_2'}^2}{2}} \right| = 11.19 \mathrm{G}eV, \tag{8}$$

we can explain the anomaly in the W-boson mass.

2 Conclusions

We show that in the context of the Minimal Supersymmetric $SU(3)_C \otimes SU(3)_L \otimes U(1)_N$ Model, MSUSY331, we can explain the recent CDF measure of the W-boson mass.

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Compliance with Ethical Standards is not applicable.

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