DOE/ER/70004-273
~~RLO-2230-74-273~~
CONF-800724--62

MASTER

DEPARTURE FROM WEINBERG-SALAM MODEL AND GRANDUNIFICATION *

N.G. Deshpande
University of Oregon, Eugene, OR. 97403

ABSTRACT

The spontaneous breaking of grandunified groups like SO(10) or SU(8) x SU(8) can lead to an extra U(1) group beyond Weinberg-Salam (W-S) SU(2) x U(1). Neutral current data is now shown to depend on two more parameters. We examine the data and put limits on the mass of the extra Z boson. Need for more experiments on parity violation effects in atoms is stressed.

INTRODUCTION

Is proton decay the only direct experimental test for grandunification? The answer in the context of the SU(5) model is unfortunately yes. This is not necessarily true in other models of grandunification. Several models permit low energy group $SU(3)_L$ x $SU(2)_L$ xU(1)xU(1) with two Z-bosons. There should be a characteristic deviation from W-S model in the low energy data which can be saught for. Here we shall examine a class of models that have SU(4) x $SU(2)_L$ x $SU(2)_R$ as a subgroup. Some models that have this subgroup are SO(10),[1] $SU(8)_L$ x $SU(8)_R$[2] and SU(4)[4] of Pati and Salam.[3] By suitable choice of Higgs bosons the low energy group could be (a) $SU(3)_C$ x $SU(2)_L$ x $SU(2)_R$ x U(1), (b) $SU(3)_C$ x $SU(2)_L$ x $(T_3)_R$ x U(1) or (c) $SU(3)_C$ x $SU(2)_L$ x U(1) of W-S. The possibility (a) has been extensively studied in the literature,[4] but recent determination[5] of $x \equiv \sin^2\theta_W$ at a value of $x = .23 \pm .02$ seems to rule this out. The value of x in possibility (a) is restricted to $1/4 < x < 3/8$ and should be close to .28. The possibility (b) has the same constraints as (c) i.e., $1/6 < x < 3/8$, and is consistent with data. The right-handed charged bosons, $W_R^{\pm}$ can be shown to be at least as heavy as 10^9 GeV for this reason. An intermediate scale between the low-energy scale of 10^2 GeV and unification scale at 10^{15} GeV seems to help in raising x from 0.20 to 0.22 thus improving the agreement with experiment. The possibility that the low energy group (b) is realized will be pursued in this talk.

Another way of generating additional U(1) group has recently been pointed out by Barr and Zee.[6] A group SU(N) can break through Higgs in adjoint representation into several extra U(1) groups. The case we consider is a special case of their general case of SU(N) → SU(5) x U(1), with known quarks and lepton having appropriate quantum numbers under U(1).

MODEL

The model we consider,[7] based on $SU(2)_L$ x $(T_3)_R$ x U(1) can be considered in its own right. It is the only model other than W-S model which is free of anomalies and has natural flavor conservation.[8] Right-handed neutrinos play a central role in the model, so if the neutrino oscillations are ever verified, this model could be an interesting alternative. The subgroup $SU(2)_L$ is identical to W-S, $(T_3)_R$ corresponds to the third component of the $SU(2)_R$ and U(1) corresponds to (B-L)/2 where B is the baryon number, and L is the lepton number. The charge Q is given by $Q = T_{3L} + T_{3R} + (B-L)/2$. The neutral current sector is described by the Lagrangian (suppressing the Lorentz index)

$$L_{int} = g_L L\cdot J_L + g_R R\cdot J_R + g_B B\cdot J_B \tag{1}$$

From normalization of the currents, at grandunification scale we find $g_L = g_R$ and $g_B = (3/2)^{\frac{1}{2}} g_R$. The first relation changes at lower scale because the couplings evolve differently, while the second relationship between two U(1) groups is <u>true at all scales</u>. By a change of basis we can rewrite Eq. (1) in the form

$$L_{int} = eA\cdot Q + g_L(\sec\theta_W) Z\cdot J_Z + g_R C\cdot(2J_R - 3J_B)(10)^{\frac{1}{2}} \tag{2}$$

where A is the photon, $\tan\theta_W \equiv (3/5)^{\frac{1}{2}}(g_R/g_L)$, $e = g_L \sin\theta_W$, J_Z is the neutral current W-S model. Z and C are linear combinations of the original gauge fields L, R and B. The first two terms belong to SU(5) while the third is the extra U(1). We now consider the most general mass-mixing of Z-C system

$$M^2 = \begin{matrix} M_Z^2 & M_{Z-C}^2 \\ M_{Z-C}^2 & M_C^2 \end{matrix} \tag{3}$$

It is convenient to define three equivalent parameters $\rho = M_W^2 + /M_Z^2\cos^2\theta_W$, $\alpha^2 = M_{Z-C}^4/\det M^2$ and $\beta = -(5\sin\theta_W/\sqrt{6})(M_Z^2/M_{Z-C}^2)$. We shall see that ρ and β take simple values when the Higgs structure is simple. The low energy Lagrangian now takes the form[7]

$$L_{eff} = -(8G_F/\sqrt{2}) \ \{J_Z^2 + \alpha\,[J_Z + (\beta/5)(2J_R - 3J_B)]^2\} \tag{4}$$

Low energy neutral current phenomena can be described by ten parameters. We adopt the standard definition where $u_{L,R}$ and $d_{L,R}$ stand for left and right handed couplings of u and d quarks to the left-handed neutrinos. The neutrino-electron vector and axial couplings are described by g_V and g_A respectively. For parity violation electron-quark coupling we follow Bjorken convention[9] which differs in sign from the convention used in Ref. 5.

---

*Invited talk presented at XX International Conference in High Energy Physics at Madison, Wisconsin, July, 1980. Work supported by DOE under contract no. EY-76-5-06-2230, TA4, Mod. A008.

MGW

DISCLAIMER

Neutrino-Scattering

$u_L = (1/2x/3)\rho_1 - z$

$u_R = (-2x/3)\rho_1 + z$

$d_L = (-1/2+x/3)\rho_1 - z$

$d_R = (x/3)\rho - 3z$

$g_v = (-1/2+2x)\rho_1 + 4z$

$g_A = (-1/2)\rho_1 + 2z$

where $x = \sin^2\epsilon_W$

$\rho_1 = \rho[1+\alpha^2(1+3\beta/5)]$

$z = \rho\alpha^2\beta(1+3\beta/5)/10$

Electron=Scattering

$\epsilon_{VA}(e,\ ) = (1/2-2x)\rho_2 - z$

$\epsilon_{VA}(e,d) = \epsilon_{VA}(e,u)$

$\epsilon_{VA}(e,u) = (1/2-4x/3)\rho_2$

$\epsilon_{AV}(e,d) = (-1/2+2x/3)\rho_2 - z'$

where $x = \sin^2\theta_W$

$\rho_2 = \rho[1+\alpha^2(1-2\beta/5]$

$z' = 2\rho\alpha^2\beta(1-2\beta/5)/5$

We note that if symmetry is broken only by Higgs doublets and singlets, $\rho=1$. Further if $\beta=5/2$ there is deviation only in neutrino-scattering. If $\beta=-5/3$, there is deviation only in electron scattering. We consider these two cases separately.

SPECIAL CASES

Case I. $\rho=1$ and $\beta=5/2$

This can be accomplished by choosing a doublet and a singlet of Higgs, with the doublet having (B-L)=0. The electron-quark sector is the same as W-S. In the neutrino sector we have two parameters, α^2 and x. From the analysis of Ref. 5, we have $u_L = .351 \pm .034$, $u_R = -.180 \pm .028$, $d_L = -.415 \pm .028$, $d_R = -.011 \pm .046$, $g_V = .043 \pm .066$ and $g_A \cong -.545 \pm .045$. We then find

$$x = .24 \pm .02$$

$$\alpha^2 = .016 \pm .012$$

The central value of α^2 corresponds to $M_{Z_1} = .99\ M_W\sec\theta_W$ and $M_{Z_2} = 2.6\ M_W\sec\theta_W$. From $\alpha^2 < .028$ we have $M_{Z_2} > 1.6\ M_W\sec\theta_W$.

Case II. $\rho=1$, $\beta=-5/3$

The Higgs here must satisfy the Georgi-Weinberg condition, namely the doublet with large expectation value must be neutral under $(T_3)_R$ as in ν_L. We find for the electron-deuteron asymmetry

$$A^{ed}/Q^2 = -3G_F/(10\sqrt{2}\ \pi\alpha)\{(3/2-10x/3)+\delta^2(1/2-2x)$$
$$+ 3f(y)[(1/2-2x) + \delta^2(7-12x)/10]$$

where $\delta^2 = \alpha^2\beta^2$. We note that for $x \approx .25$, y independent part is the same as W-S theory. Further y dependent part is small if $\delta^2 < .4$. For $\delta^2 = .4$ we have compared the theory with experiment, and find the fit as good as the S-W model (see Fig. 1). The expression for the parity violation in atoms is rather sensitive to δ^2. Thus for Bismuth $Q_W = -126+192\delta^2$. If $\delta^2 = .4$, we have for $Q_W = -49$ which is a value much smaller than given by W-S model. Similarly parity violation in Hydrogen will also be different from the standard model. Another test is the elastic scattering of electrons off deuterium. For details of these processes see Ref. 7 This value of δ^2 corresponds to $M_{Z_1} = .9\ M_Z$ and $M_{Z_2} = 1.78\ M_Z$, where $M_Z = M_W\ \sec\theta_W$.

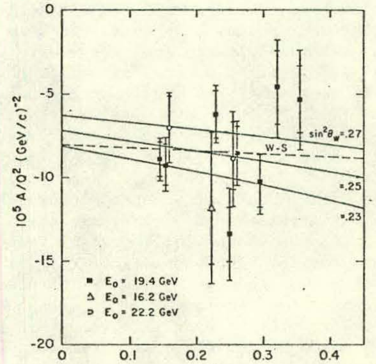

Fig. 1. The asymmetries in the SLAC e–d deep-inelastic scattering as a function of y. The predictions of WS model (dashed lines) as well as the predictions of our model for $\delta^2 = 0.4$ and various values of $\sin^2\theta_W$ are shown.

GENERAL CASE

Barr and Zee[6] have observed that if the combination $R=2U_L-U_R+2d_L$ and $S=U_L+2U_R+d_L+5d_R$ are plotted on y and x axis respectively, W-S model is at the origin. All SU(5)xU(1) models lie on straight lines through the origin. The model we have considered lies on the line R = S/3. A general SU(N) → SU(5)xU(1) breaking will lie on R = 2S. The data favors R = S/3 to W-S model, though the errors have to be considerably reduced for definitive conclusion (see Fig. 2).

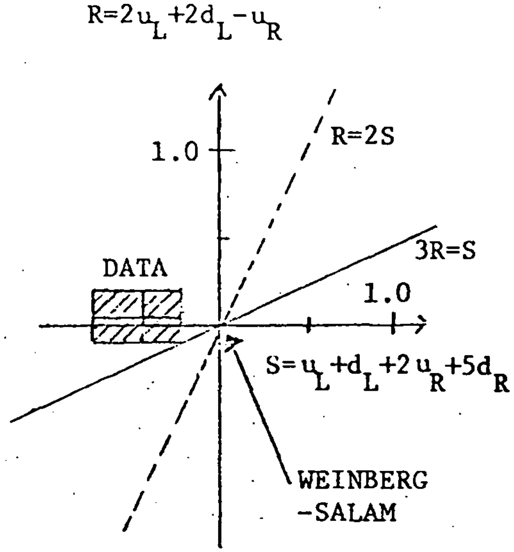

Figure 2

REFERENCES

1. H. Fritzsch and P. Minkowski. Ann. of Physics. 93. 193 (1974) and Nuclear Phys. B103, 61 (1976).
2. N.G. Deshpande and P. Mannheim. Phys. Lett. (1980) and University of Oregon preprint OITS 143.
3. J. Pati and A. Salam. Phys. Rev. D10, 275 (1974).
4. R.N. Mohapatra and J.C. Pati. Phys. Rev. D11, 566, 2558 (1975) G. Senjanovic and R.N. Mohapatra. Phys. Rev. D12, 1502 (1975).
5. P. Langacker et al. Univ. of Pennsylvania preprint COO-3071-243, to be published in Neutrino-79.
6. S.M. Barr and A. Zee. Phys. Lett. 92B 297 (1980).
7. N.G. Deshpande and D. Iskandar. Nuclear Physics B167 223 (1980) and Phys. Lett 87B, 383 (1979).
8. M.S. Chanowitz, J. Ellis and M.K. Gaillard, Nuclear Physics B128, 506 (1977).
9. J.D. Bjorken. Phys. Rev. D18 3239 (1978).