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ABSTRACT

In this note we propose that right handed neutrinos can behave as singlets. Their interaction properties could be revealed through scalar couplings. Signatures and branching ratios for this hypothesis are discussed. In particular we discuss angular asymmetries in $\nu_\mu e \to \nu_e \mu$ due to scalar exchange and z^0 decay in two scalars.

If the ITEP result[1] *on* $m_{\nu_e} \neq 0$ *is confirmed, right handed neutrinos must* find their place in elementary particle physics. *But even if this result is to* be disproved we can ask if the asymmetry between right and left components for the fermionic fields is definitive. Along this line of reasoning, many models have been proposed which include right handed currents[2]. The most simple approach consists of an extension of the standard electroweak model[3] with a right handed leptonic doublet[4]. Then, anomaly cancellation implies right handed charged currents in the quark sector. But, so far, no signal for such effect is known[5].

In this note we propose the inclusion of right handed neutrinos in a different context. Our first step is to postulate a rigorous symmetry between quark and leptons in the following way. As quarks behave as

$$\begin{pmatrix} u \\ d' \end{pmatrix}_L , \quad u_R , \; d'_R , \qquad (1)$$

we postulate that for leptons we have also

$$\begin{pmatrix} \nu \\ e \end{pmatrix}_L , \quad e_R , \; \nu_R \qquad (2)$$

and so on for the other families. A strong objection on this model is that as a right handed neutrino singlet has $Y = 0$ it does not interact with the known gauge vector bosons and would never be detected.

In order to avoid this difficulty, our second step is to consider that this kind of assignement for neutrinos can be meaningful in scalar interactions, with very interesting signatures involving ν_R.

Scalar (and pseudoscalar) interactions are well known to be supressed relative to V-A terms but we can still have residual contributions[6]. Scalars appear quite naturally in the Higgs mechanism and in some supersymmetric models[7]. In our view, the most natural scenario for scalars is in composite models. If the presently known fermions and bosons are to be composite we expect states with spin 3/2 for fermions[8] and spin 0 for bosons[9,10].

The most general scalar interaction lagrangian for the assignement (2) is then

$$L = \frac{g_1}{\sqrt{2}} \bar{e}_R \nu_L \phi^+ + g_2 \bar{e}e \phi_o + \frac{g_3}{\sqrt{2}} \bar{e}_L \nu_R \phi^+ + g_4 \bar{\nu}\nu \phi_o + \text{h.c.} \qquad (3)$$

and analogous terms for the other families. We note that there is no "a priori" link between the four coupling constants. If we impose $SU(2)$ invariance then $g_1 = g_2$ and $g_3 = -g_4$ but g_1 and g_3 are independent. For a Higgs scalar as in the standard model $g_1 = g_3 = 0$ and g_2 and g_4 are very small (related to m_e and m_{ν_e} respectivelly).

We consider in this note scalar isodoublets. This hypothesis in theoretically very appealling since it is known that it maintains the ratio of effective low energy charged to neutral interactions[11]. In the composite approach we expect that the same coupling constants appear for all the families in the case of scalar interactions since we have universality for the vector interactions.

In the composite model we have then[9] three scalar states ϕ^+, ϕ^0, ϕ^- corresponding to the vectors W^+, Z^0, W^- and the possibility of one scalar singlet χ^0 corresponding to the photon. We expect $m_{\phi^0} >> m_{\chi_0}$ and analogous couplings of fermions to ϕ^0 and χ^0 as in equation 3.

A similar scalar interaction was considered recently by Ng[10] with no ν_R

terms which imply different phenomenological consequences.

A stringent bound on charged scalar couplings comes from ordinary muon decay. A, analysis of residual scalar interactions[6] implies the bound

$$\frac{g_1^2}{m_{\phi^+}^2} < 3 \times 10^{-5}\ (\mathrm{GeV}^{-2}) \qquad (4)$$

Contributions to the gyromagnetic factor[12] do not improve this bound. Using the Mark-J data on Bhabha scattering we have the bound[10]

$$\frac{g_2^2}{m_{\phi_0}^2} < 10^{-6}\ (\mathrm{GeV}^{-2}) \qquad (5)$$

Perhaps the clearest signature for scalars is in electron positron annihilation. Neutral scalar exchange occurs in $e^+ e^- \to \mu^- \mu^+$ with cross sections given by many authors[9,10].

Concerning branching ratios we estimate $Br(\phi^0 \to \text{All } \bar{\nu}\nu)$ to be .14 since we have at present only three families. This high branching ratio can only be meaningfull in a model with right handed neutrinos. If no ν_R exists we can still look for other chanels as $\mu^+ \mu^-$. In this case $Br(\phi^0 \to \mu^- \mu^+) = .05$.

If $m_{Z_0} > m_{\phi_0}$ we can have decays as

$$Z^0 \to \chi^0 \; \phi^0, \qquad \phi^0 \to \text{JET}, \qquad \chi^0 \to \nu\bar{\nu} \qquad (6)$$

which appear as events of the type JET + missing energy. This can be the case for the UA_1 events $pp \to \text{JET} + E_{MIS.}$. The hypothesis of a Z^0 decay in two scalars has been recently proposed by Rosner[13]. The general features such as number of events and angular distributions are discussed in this reference but no detail of scalar decays are given. In our model, as we have $BR(\phi^0 \to q\bar{q}) \simeq 5\%$ and $BR(Z^0 \to \chi^0\ \phi^0)$ is not to be larger than 5%[15] we have

$$BR(Z^0 \to 1\,JET + E_{MIS}) \simeq 1\%$$

This model is similar to the Glashow-Manohar model[16] with the important difference that we do not have a stable scalar if $m_{\chi_0} > m_{\nu/2}$. Some of the fermionic channels may be suppressed depending on the m_{χ_0} mass and the branching ratio $BR(Z^0 \to 1\,JET + E_{MIS})$ could be higher than 1%.

There is a recent experimental interest in testing the Glashow-Manohar model in $e^+ e^- \to 1\,JET + E_{MIS}$[17]. As our χ^0 can decay into $\nu\bar{\nu}$, the bound on scalar masses could be significantly higher (for $\frac{\Gamma(Z^0 \to \chi^0\ \phi^0)}{\Gamma(Z^0 \to \mu^-\ \mu^+)} \simeq 1$).

Scalar exchange also occurs in neutrino-lepton scattering. Some of these effects were discussed in reference 10. We point out that an important process which allows the separation between vector and scalar contributions is $\nu_\mu e^- \to \nu_e \mu^-$. As is well known, in the center of mass system the charged lepton angular distribution is isotropic for vector exchange.

But if scalar exchange also happens then this isotropy is destroyed. If we consider the forward-backward asymmetry

$$A = \frac{\sigma(0 \to \pi/2) - \sigma(\pi/2 \to \pi)}{\sigma(0 \to \pi/2) + \sigma(\ /2 \to \pi)} \qquad (7)$$

then only scalar exchange contributes.

In the limit $s >> m_e^2 , m_\mu^2$ but $s << m_\phi^2 , m_W^2$ the angular distribution is

$$\frac{d\sigma}{d\Omega} = \frac{s}{(2\pi)^2} G_F^2 \left[1 + \left(\frac{\sqrt{2}(g_+^2 + g_-^2)}{8\ G_F\ m_\phi^2} \right)^2 \frac{1}{16} (1 - \cos\theta)^2 \right] \qquad (8)$$

where $g_+ = g_3 + g_1$ and $g_- = g_3 - g_1$.

The asymmetry is then

$$A = - \frac{1}{16} \left(\frac{\sqrt{2}(g_+^2 + g_-^2}{8\ G_F\ m_\phi^2} \right)^2 \qquad (9)$$

With the upper bound given by equation 4 we have the following results

Model	Asymmetry
No Scalars	0
Scalar + ν_L	-.5%
Scalar + ν_R	-2.3%

TABLE I

where we consider $g_1 \simeq g_3$ in the case of right handed neutrinos.

We have also a neutral scalar contribution (besides the Z^0), to $\nu_\mu + e^- \to \nu_\mu + e^-$ which gives

$$\frac{d\sigma}{dy} = \frac{G_F^2 m_e E_\nu}{8\pi} \left\{ (g_V + g_A)^2 + (1-y)(g_V - g_A)^2 + \frac{g_2^2\ g_4^2}{G_F^2\ m_{\phi^0}^4}\ y^2 \right\} \qquad (10)$$

where as usual[14] $y = E_e/E_\nu$; $g_V = -1 + 4 \sin^2 \theta_W$ and $g_A = -1$. For antineutrinos we simply change $(g_V + g_A) \leftrightarrow (g_V - g_A)$ in equation 10.

Scalars can be produced in $e^- e^+ \to \chi^0 \phi^0$ but with a small cross section. The reaction $e^+ e^- \to \chi^0 \gamma$ is also possible but it is supressed at present available energies.

In conclusion, the hypothesis of scalar interactions, combined with ν_R singlets leads to very interesting experimental signatures as in $p\bar{p} \to Z^0 \to \chi^0 \phi^0$; a high branching ratio for $(\chi^0, \phi^0) \to \bar{\nu}\nu$ and asymmetries in neutrino-lepton scattering. We stress the fact that our assignement for ν_R leads to no new vector currents.

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