индекс 3624

ԵՐԵՎԱՆԻ ՖԻԶԻԿԱՅԻ ԻՆՍՏԻՏՈՒՏ
ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

ЕФИ-403(10)-80

H.M.ASATRYAN, S.G.MATINYAN

NEUTRINO AND t-QUARK MASSES IN THE SO(10) GRAND UNIFICATION SCHEME

ԵՐԵՎԱՆ 1980 ЕРЕВАН

ЕФИ-403(IO)-80

YEREVAN PHYSICS INSTITUTE

H.M.ASATRYAN, S.G.MATINYAN

NEUTRINO AND t-QUARK MASSES IN THE SO(10) GRAND UNIFICATION SCHEME

Yerevan 1980

Attractiveness of the group SO(10) [1] from the view point of the mixing angle calculation problem is due to the fact that, contrary to SU(5) [2], it contains as an electroweak subgroup the product $SU(2)_L \otimes SU(2)_R \otimes U(1)$ with a higher left-right symmetry. This ambidextrous symmetry preserves its traces in the SO(10)-scheme and permits to restrict the Yukawa couplings of Higgs bosons with fermions [3,4].

Left fermions form three families of quarks and leptons $U_\alpha^{r,y,b}$, $D_\alpha^{r,y,b}$, N_α , L_α and corresponding antiparticles (r,y,b are coloured indices, U_α denotes the charge 2/3 quark, D_α is the charge 1/3 quark, N_α is a zero charge lepton, L_α is a charge -1 lepton of α families (α=1,2,3)).

The Higgs scalars that give mass to fermions transformed according to the spinor representation <u>16</u> SO(10) ψ_α have to be chosen from representations <u>10</u>, <u>126</u> and <u>120</u> (<u>16</u> ⊗ <u>16</u> = <u>10</u> ⊕ <u>120</u> ⊕ <u>126</u>).

In connection with the possibility of the presence of nonzero mass neutrino in the SO(10), when restricting ourselves with only representations <u>10</u> for Higgs bosons, we are not able to have massless neutrino and simultaneously obtain reasonable conclusions for the U_a -quark masses.

In this connection, if not introducing for the solution of the neutrino mass problem,, along with spinor representations, the superheavy neutral lepton-singlet of SO(10), whose interaction gives the nonzero mass to right neutrino of the order of 10^{16} GeV and thus effectively isolating it from other fermions [4] , which seems to us rather artificial, then the extension of the Higgs sector (see also [5]) seems unavoidable.

Of course, one may give up at all the strict masslessness of 16-plet neutral leptons, as it was the case in [6], giving the Mayorana mass to the right neutrino.

However, before giving up strict equality to zero of left neutrino masses, one should make sure of the absence of other alternatives.

Such an alternative seems to be a generalization of results of the previous works [4,7], consisting in adding representations 126 to the Higgs sector.

Thus we introduce for the Higgs scalar along with representations 10 , the 126 representations restricting at the same time the arbitrariness in the structure of their Yukawa coupling with the 16-plet fermions ψ_a .The restriction is connected with the requirement [3,4], that mass matrices of a given charge be determined by three parameters only, corresponded to three independent Yukawa couplings for representations 10 and 126, respectively.

The only acceptable structure of the three independent

Yukawa couplings of the Higgs fields ϕ_a from representations 10 [4] and the corresponding three couplings of the Higgs scalars χ_a from self-dual, totally antisymmetric tensor representations 126 of the left fermions ψ_a , has the form:

$$A\bar{\psi}_1^c \phi_1 \psi_2 + B\bar{\psi}_2^c \phi_2 \psi_3 + C\bar{\psi}_3^c \phi_3 \psi_3 + \\ D\bar{\psi}_1^c \chi_1 \psi_2 + E\bar{\psi}_2^c \chi_2 \psi_3 + F\bar{\psi}_3^c \chi_3 \psi_3 + \text{э.с.} \tag{1}$$

where the index c denotes a charge conjugation. It is not difficult to see that the number of parameters that determined the mass matrix of the given charge fermions is equal to three.

Indeed, from (1) for the mass 3x3-matrix of fermions of the given charge $m^f (f \equiv U, D, N, L)$ follows

$$m^f = \begin{pmatrix} 0 , & A(S_1+\alpha P_1)+\beta D(\sigma_1+\alpha\pi_1), & 0 \\ A(S_1+\alpha P_1)+\beta D(\sigma_1+\alpha\pi_1), & 0, & B(S_2+\alpha P_2)+\beta E(\sigma_2+\alpha\pi_2) \\ 0, & B(S_2+\alpha P_2)+\beta E(\sigma_2+\alpha\pi_2), & C(S_3+\alpha P_3)+\beta F(\sigma_3+\alpha\pi_3) \end{pmatrix} \tag{2}$$

where S_a , P_a and σ_a , π_a are, in general, complex numbers defining the vacuum expectation values of electrically neutral colourless components of the Higgs fields ϕ_a and χ_a , respectively, $\alpha = 1$ for $f = U, N$, $\alpha = -1$ for $f = D, L$, $\beta = -1/3$ for $f = D$, $\beta = 1/3$ for $f = U$, $\beta = 1$ for $f = L$, $\beta = -1$ for $f = N$.

One can see from (2), that confining ourselves to representation 10 for the Higgs scalars ($\mathcal{D} = E = F = 0$) and demanding the zero neutrino masses, we automatically have zero masses for U_a -quarks. Adding representations 126 and demanding a zero mass matrix of neutrino $(m^N_{a\ell} = 0)$ in tree approximation, we do not touch the mass matrices of charged fermions.

To obtain the relations between mass matrices of various fermions, we use for Yukawa coupling (2), as in [4] (see also [7,8]) the $U(1) \otimes U(1) \otimes U(1)$ symmetry relative to ϕ_a , χ_a and ψ_a field phase transformation. This brings to definite relations between various ϕ_a and between various χ_a . A detailed consideration shows that from numerous possibilities providing a required symmetry, only two conditions lead to the reasonable fermion mass relations non-conflicting with the experiment. These conditions are: $\phi_1 = \phi_3$ and $\chi_1 = \chi_3$. A first one gives the following relation between elements of the mass matrix (2)

$$\frac{m^U_{33}}{m^U_{12}} = \frac{3m^{\mathcal{D}}_{33} + m^L_{33}}{3m^{\mathcal{D}}_{12} + m^L_{12}} \qquad (3)$$

the condition $\chi_1 = \chi_3$ gives

$$\frac{m^U_{33}}{m^U_{12}} = \frac{m^{\mathcal{D}}_{33} - m^L_{33}}{m^{\mathcal{D}}_{12} - m^L_{12}} \qquad (4)$$

Confining with representations 10, one may consider all matrix elements in (3), (4) real $(m^L_{a\ell} = m^{\mathcal{D}}_{a\ell})$. For m_t , as is known, we obtain $m_t = 13.6$ GeV[4]. In our case from (3), (4) only the interval of admissible values of m_t can be obtained. Expressing by usual means the matrix elements

in (3), (4) through physical fermion masses, and performing by means of already standard renormalization group procedure (see, e.g. review[9]) transition from symmetry values of masses to fermion masses at the normalization point μ determined by condition $m_q(\mu) = \mu/2$ [10] , we obtain from (3)

7.6 GeV $< m_t <$ 29.3 GeV (Λ =0.34 GeV, $M = 2 \cdot 10^{15}$ GeV)
8.8 GeV $< m_t <$ 22.6 GeV (Λ =0.08 GeV, $M = 0.6 \cdot 10^{15}$ GeV)

Here Λ is a well-known Q.C.D. parameter, M is a unifying mass.

The condition $\chi_1 = \chi_3$ leading to relation (4) gives:

2.9 GeV $< m_t <$ 74.0 GeV (Λ = 0.34 GeV),
2.3 GeV $< m_t <$ 124.7 GeV (Λ = 0.08 GeV).

Thus, one may reach a conclusion that in the SO(10)-symmetry the t-quark mass may be more than 15 GeV.

REFERENCES

1. M.Fritzsch, P.Minkowski, Annals of Phys. (N.Y.) 93, 193, 1975.
2. H.Georgi, S.L.Glashow, Phys.Rev.Lett., 32, 438, 1974.
3. H.Fritzsch, Phys.Lett., 73B, 317, 1978; Nucl.Phys. , B155, 189, 1979.
4. H.Georgi, D.V.Nanopoulos, Nucl.Phys., B155, 52, 1979.
5. M.Yasue, DPNU-25-79.
6. M.Gell-Mann, P.Ramond, R.Slansky, see F.Wilczek, Proceedings of Lepton-Photon Intern.Symp., Batavia, 1978.
7. H.Georgi, D.V.Nanopoulos, Nucl.Phys., B159, 16, 1973.
8. H.Georgi, D.V.Nanopoulos, Phys.Lett., 82B, 392, 1979.
9. S.G.Matinyan, Uspekhi Fiz. Nauk, 130, 3, 1980.
10. H.Georgi, D.Politzer, Phys.Rev., D14, 1829, 1976.

The manuscript was received on the 18 February, 1980

Г.М.АСАТРЯН, С.Г.МАТИНЯН

МАССЫ НЕЙТРИНО И t -КВАРКА В СХЕМЕ $SO(10)$ ВЕЛИКОГО ОБЪЕДИНЕНИЯ

(на английском языке)

Тех. редактор А.С.Абрамян

Заказ 50I ВФ-05095 Тираж 299

Препринт ЕФИ Формат издания 60x84/I6

Подписано к печати 8/IУ-80г. 0,5 уч.изд.л.Ц.4 к.

Издано Отделом научно-технической информации

Ереванского физического института, Ереван-36, пер.Маркаряна 2