Two topics are covered in this paper. In the first part the relation between quark mass matrices and observable quantities in gauge theories. In the second part neutrino masses and mixings in a seesaw framework.
This talk is divided in two parts: Part I deals with quark mass matrices and observable quantities and is based on three papers \[1\]–\[3\]. Part II deals with neutrino masses and mixings in a seesaw framework and is based on another three papers \[4\]–\[6\].

Part I - Quarks

In the standard model (SM), which is a gauge theory with \(SU(3)_c \times SU(2)_L \times U(1)_Y\) as a symmetry group, let us consider the quark mass and charged weak current terms in the Lagrangian:

\[ \bar{u}_L M_u u_R + \bar{d}_L M_d d_R + g \bar{u}_L d_1 W. \]  

(1)

When we diagonalize both mass matrices by biunitary transformations, we get the terms

\[ \bar{u}_L D_u u_R + \bar{d}_L D_d d_R + g \bar{u}_L V_{CKM} d_1 W, \]  

(2)

where \(V_{CKM}\) is the quark mixing matrix \[7\]. There is a clear hierarchy of quark masses: \(m_u \ll m_c \ll m_t\) and \(m_d \ll m_s \ll m_b (m_b \ll m_t)\). Moreover, \(V_{CKM}\) is near the identity and \(V_{ub} \ll V_{cb} \ll V_{us}\).

The following (unitary) transformations have no physical consequences, that is they do not change masses and mixings:

\[ u_L \rightarrow U u_L, \quad d_L \rightarrow U d_L \]  

(3)

\[ u_R \rightarrow V_u u_R, \quad d_R \rightarrow V_d d_R. \]  

(4)

As you see, the left-handed states transform in the same way, while the right-handed states may undergo different transformations. The two mass matrices \(M_u, M_d\) have 36 real parameters while \(D_u, D_d, V_{CKM}\) have 10 real parameters (observable quantities). By using transformations (3),(4) we can go to a basis where the mass matrices contain exactly 10 real parameters. This is called a minimal parameter basis (MPB) \[8\].

However, by using transformations (3),(4) we can get also \(M_u, M_d\) both hermitian \[9\], or \(M_u, M_d\) both in the nearest neighbor interaction (NNI) form \[10\], or \(M_u\) diagonal and \(M_d\) hermitian or containing three zeros \[11\]. In fact, we can diagonalize \(M_u\) by a biunitary transformation, and use the freedom in \(V_u\) to get \(M_d\) hermitian or containing three zeros. There are 54 bases with three zeros, out of 84 possibilities. In this way \(M_u\) has three real parameters and \(M_d\) seven real parameters, six moduli and one phase (but keeping three phases preserves an arbitrary representation for \(V_{CKM}\)).

As an example of a MPB with \(M_u\) diagonal and \(M_d\) with three zeros, we can consider the one studied in ref. \[12\], where

\[ M_d \simeq \begin{pmatrix} 0 & \sqrt{m_d m_s} & 0 \\ \sqrt{m_d m_s} & m_s e^{i \phi} & m_b/\sqrt{5} \\ 0 & m_b/\sqrt{5} & 2m_b/\sqrt{5} \end{pmatrix}. \]  

(5)

There are three simple relations among its elements, and the mixings can be written in terms of down quark masses:

\[ V_{us} \simeq \sqrt{m_d / m_s} \]  

(6)

\[ V_{cb} \simeq \frac{3}{\sqrt{5}} m_s \]  

(7)

\[ V_{ub} \simeq \frac{1}{\sqrt{5}} \frac{m_d m_s}{m_b}. \]  

(8)

Therefore on this basis we have seven independent real parameters (six masses and one phase), instead of ten. We can check also that \(V_{ub} V_{cb} \simeq 3 V_{cb}\). The relation \(|M_{23}| \simeq M_{13}\) is due to the value \(\delta \simeq 75^\circ\) in \(V_{CKM}\).

Other interesting bases, with \(M_u\) diagonal and \(M_d\) triangular, are in refs. \[12,13\]. In particular, from ref. \[13\] we get the form

\[ |M_d| \simeq \begin{pmatrix} m_d & m_s V_{us} & m_b V_{cb} \\ 0 & m_s & m_b V_{cb} \\ 0 & 0 & m_b \end{pmatrix}. \]  

(9)

Non diagonal bases include hermitian matrices with no zeros on the diagonal \[14\]. The physical content of such bases can be explained considering that, for example, solution 3 by Ramond, Roberts, Ross \[15\] is obtained setting \(M_{u11} = M_{d11} = 0\) in one of them. Moreover, we have also the basis with hermitian matrices and \(M_{u13} = M_{d13} = 0 \) \[16\], or \(M_{u11} = M_{d11} = M_{d13} = 0 \) \[17\], and the physical content is given by the ansatz with \(M_{11} = M_{13} = 0\) in both matrices (this is contradicted in ref. \[18\], where other hermitian mass matrices are studied and a non parallel structure is found).

Let us now turn to the left-right model (LRM), based on the symmetry \(SU(3)_c \times SU(2)_L \times SU(2)_R \times U(1)\), and consider the part of the Lagrangian containing the quark mass terms and the charged currents:

\[ \bar{u}_L M_u u_R + \bar{d}_L M_d d_R + g_L \bar{u}_L d_1 W_L + g_R \bar{u}_R d_2 d_1 W_R. \]  

(10)

When we diagonalize the mass matrices we obtain

\[ \bar{u}_L D_u u_R + \bar{d}_L D_d d_R + g_L \bar{u}_L V_{L} d_1 W_L + g_R \bar{u}_R V_{R} d_2 d_1 W_R, \]  

(11)

with two mixing matrices \(V_L, V_R\), and \(V_L = V_{CKM}\). The transformations that do not change masses and mixings are now

\[ u_L \rightarrow U u_L, \quad d_L \rightarrow U d_L \]  

(12)
\[ u_R \rightarrow V u_R, \quad d_R \rightarrow V d_R. \]  

(13)

Thus, also the right-handed fields transform in the same way, and if we diagonalize \( M_u \) by a biunitary transformation, then \( M_d \) is fixed: The 54 bases of the SM become strong ansatze in the LRM. To select them we have to look at right-handed mixings \[19\].

As an example, consider the 2-generation case, where we have four SM bases, according to where we put the zero in \( M_d \) (taking \( M_u = D_u, \lambda = 0.22 \)):

\[
M_d \simeq \begin{pmatrix} 0 & \sqrt{m_d m_s} \\ \sqrt{m_d m_s} & m_s \end{pmatrix}, \quad V_R \simeq \begin{pmatrix} -1 & \lambda \\ \lambda & 1 \end{pmatrix}; \quad (14)
\]

\[
M_d \simeq \begin{pmatrix} \sqrt{m_d m_s} & 0 \\ 0 & \sqrt{m_d m_s} \end{pmatrix}, \quad V_R \simeq \begin{pmatrix} \lambda & 1 \\ -1 & \lambda \end{pmatrix}; \quad (15)
\]

\[
M_d \simeq \begin{pmatrix} -m_d & \sqrt{m_d m_s} \\ \sqrt{m_d m_s} & m_s \end{pmatrix}, \quad V_R \simeq \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix}; \quad (16)
\]

\[
M_d \simeq \begin{pmatrix} \sqrt{m_d m_s} & -m_d \\ m_s & 0 \end{pmatrix}, \quad V_R \simeq \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}. \quad (17)
\]

In the 3-generation case we rely on the following considerations. A recent analysis, by T. Rizzo \[20\], of right-handed currents in B decay, within the LRM, suggests that \( V_{cb}^R \) is large and perhaps near unity. From inclusive semileptonic decays of B mesons one has \( V_{cb}^R \gtrsim 0.782 \). Moreover, if as suggested by Voloshin \[21\], right-handed currents can help to solve the B semileptonic branching fraction and charm counting problems, then \( V_{cb}^R \gtrsim 0.908 \).

We begin our selection by using \( V_{cb}^R \gtrsim 0.750 \). Setting \( M_u = D_u \), we denote elements in \( M_d \) by

\[
\begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix}.
\]

There are 16 ansatze out of 54 that satisfy our bound. Ten of them are in the following table. We have excluded those giving the particular strange result that some element in \( M_d^\dagger M_d = V_R D_d^2 V_R^\dagger \) is exactly zero.

| zeros | $V_{cb}^R$ | 124.236 146.256 127.128 479.589 467.568 296.896 789.789 914.914 999.999 871.871 |
|-------|-----------|---------------------------------------------------------|

We give now an example of a successful ansatz, namely 124, with

\[
|V_R| \simeq \begin{pmatrix} 1 & \lambda & \lambda \\ \lambda & 2\lambda & 1 \\ \lambda & 1 & 2\lambda \end{pmatrix}.
\]

(19)

Further constraints on the form of \( V_R \) come from the \( K_L - K_S \) mass difference and \( B - \overline{B} \) mixing, reported in ref. \[20\]. Models 128, 479, 589 are reliable, for example 128:

\[
|M_d| = \begin{pmatrix} 0 & 0 & 0.023 \\ 0 & 0.106 & 0.104 \\ 0.541 & 2.687 & 1.213 \end{pmatrix},
\]

(20)

\[
|V_R| \simeq \begin{pmatrix} \lambda & 1 & 2\lambda \\ 2\lambda^2 & 2\lambda & 1 \\ 1 & \lambda & \lambda^5 \end{pmatrix}.
\]

(21)

Of course, other ansatze can be obtained starting from a diagonal \( M_d \). We stress the simple result that, if \( V_{cb}^R \) is really large, then hermitian or symmetric mass matrices are not reliable (remember: for hermitian or symmetric matrices \( |V_R| = |V_L| \)). Notice also that non symmetric mass matrices have important applications in the leptonic sector in connection with the large mixing of neutrinos \[22\].

By using transformations (12),(13) it is possible to change the structure of both \( M_u \) and \( M_d \). Although such forms can be more interesting to discover an underlying theory of fermion masses and mixings, they lead to the same observable parameters in LRM, and we need other observable quantities to make a selection of such models with non diagonal mass matrices. These new physical parameters exist in extensions of the LRM (for example the \( SO(10) \) model). We have here simply attempted to begin with a systematic study, within the LRM, of quark mass matrices which have a general form in the SM. For effects of right-handed mixings in \( SO(10) \) and proton decay see ref. \[23\].

**Part II - Neutrinos**

Let us start from the 1-generation seesaw, where the full neutrino mass matrix is given by

\[
\begin{pmatrix} 0 & m_D \\ m_D & M_R \end{pmatrix},
\]

(22)

with \( m_D \) the Dirac mass and \( M_R \) the right-handed Majorana mass. Assuming \( m_D < \ll M_R, \) we get a small eigenvalue \( m_L \approx m_D^2/M_R \) and a big one, \( m_R \approx M_R. \) Usually \( M_D \sim m_q \) or \( M_D \sim m_{l_l}, \) with \( m_q \) a quark mass and \( m_{l_l} \) a charged lepton mass. In the 3-generation seesaw, we have the matrix

\[
\begin{pmatrix} 0 & M_D \\ M_D & M_R \end{pmatrix},
\]

(23)
with $M_D$ and $M_R$ $3 \times 3$ matrices (we assume $M_D$ to be real symmetric), and an effective light neutrino mass matrix

$$M_L \simeq M_DM_R^{-1}M_D$$

(24)

which can be inverted to give

$$M_R \simeq M_DM_L^{-1}M_D.$$  

(25)

We aim at calculating the scale and the form of $M_R$, because in unified models, where neutrino mass is most natural (SO(10)), this scale is intermediate (around $10^{11}$ GeV) in the non supersymmetric case and of unification ($10^{16}$ GeV) in the supersymmetric case [24].

We rely on quark-lepton symmetry, which in this context means that

$$M_D \simeq \frac{m_\tau}{m_b}\text{diag}(m_u,m_c,m_t),$$  

(26)

and $M_U, M_D, M_L$ also nearly diagonal (see for example ref. [25]). In such a case we can soon obtain $M_L$ from experimental data, by means of the formula

$$M_L \simeq UD_LU^T$$

(27)

with $D_L = \text{diag}(m_1,m_2,m_3)$ and the lepton mixing matrix $U$ [25] given by [26]

$$U = \begin{pmatrix}
    c & s & \epsilon \\
    -\frac{1}{\sqrt{2}}(s + \epsilon c) & \frac{1}{\sqrt{2}}(s - \epsilon c) & \frac{\sqrt{2}}{2} \\
    \frac{1}{\sqrt{2}}(s - \epsilon c) & -\frac{1}{\sqrt{2}}(s + \epsilon c) & \frac{\sqrt{2}}{2}
\end{pmatrix}$$

(28)

where $\epsilon$ is small ($\epsilon^2 \lesssim 0.03$). This form includes the results by Chooz and SuperKamiokande. Since we do not know neutrino masses and mixing so well, our approximations can be considered good.

From neutrino oscillation data we have for solar neutrinos [27]

$$\Delta m^2_{sol} \sim 10^{-6}eV^2 (SMA MSW)$$

(29)

$$\Delta m^2_{sol} \sim 10^{-5}eV^2 (LMA MSW)$$

(30)

$$\Delta m^2_{sol} \sim 10^{-10}eV^2 (VO)$$

(31)

and for atmospheric neutrinos

$$\Delta m^2_{atm} \sim 10^{-3}eV^2.$$  

(32)

Then it is clear that $\Delta m^2_{atm} \gg \Delta m^2_{sol}$. We can set

$$\Delta m^2_{sol} = m_2^2 - m_1^2, \ \Delta m^2_{atm} = m_3^2 - m_{1,2}^2$$

(33)

and assuming $m_3 > 0$ there are three possible spectra for light neutrinos [28]:

$$m_3 \gg |m_2|, |m_1| \quad (\text{hierarchical})$$

(34)

$$|m_1| \sim |m_2| \gg m_3 \quad (\text{inverted hierarchy})$$

(35)

$$|m_1| \sim |m_2| \sim m_3 \quad (\text{nearly degenerate}).$$

(36)

We work in a CP conserving framework, but we allow for negative Majorana masses. In a more general approach, two phases in $U$ or $D_L$ connect among the relative signs (see for example ref. [29]). For the sine $s$ of the solar mixing angle one has $s \simeq 0$ in the SMA MSW and $s \simeq 1/\sqrt{2}$ in the LMA MSW or VO.

Hierarchical spectrum. If there was no mixing at all ($U = I$), the scale of $M_R$ would be

$$M_{R33} \sim \frac{k^2 m_l^2}{m_3},$$

with $k = m_\tau/m_b$. For $s \simeq 0$, corresponding to the SMA solution, we get

$$M_R^{-1} \simeq \begin{pmatrix}
    1/m_1 & 0 & 0 \\
    0 & 1/2m_2 & -1/2m_2 \\
    0 & -1/2m_2 & 1/2m_2
\end{pmatrix}$$

(37)

when $\epsilon^2 m_3 \ll m_1$, and the scale is given by

$$M_{R33} \sim \frac{1}{2} \frac{k^2 m_l^2}{m_2},$$

(38)

which is greater or equal to $10^{15}$ GeV, that is near the unification scale. The leading form for $M_R$ is

$$M_R \sim \text{diag}(0,0,1),$$

(39)

similar to the leading form for $M_D$. However, if $\epsilon^2 m_3 \simeq m_1$, then $M_{R33}$ goes to zero and we have a different structure for $M_R$. For $s \simeq 1/\sqrt{2}$ we consider three subcases: $|m_2| \gg |m_1|, m_2 \simeq m_1$ and $m_2 \simeq -m_1$.

1. If there is full hierarchy, we have

$$M_R^{-1} \simeq \begin{pmatrix}
    1 & -1/\sqrt{2} & 1/\sqrt{2} \\
    -1/\sqrt{2} & 1/2 & -1/2 \\
    1/\sqrt{2} & -1/2 & 1/2
\end{pmatrix} \frac{1}{2m_1}$$

(40)

and the scale is

$$M_{R33} \sim \frac{1}{4} \frac{k^2 m_l^2}{m_1}$$

(41)

which gives $10^{16}$ GeV or more in the LMA case and $10^{18}$ GeV or more in the VO case (towards the Planck scale). Again the leading form for $M_R$ is hierarchical and diagonal, reflecting the hierarchy of Dirac masses.

2. If $m_2 \simeq m_1$, then
\[ M_L^{-1} \simeq \begin{pmatrix} 2 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & -1 & 1 \end{pmatrix} \frac{1}{2m_2}, \] (42)

assuming \( \epsilon^2 m_3 \ll m_2 \), and the scale is
\[ M_{R33} \sim \frac{1}{2} \frac{k^2 m_t^2}{m_2}, \] (43)

which gives \( 10^{15} \) GeV or more, near or above the unification scale. The leading \( M_R \) is hierarchical and diagonal, unless \( \epsilon^2 m_3 \simeq m_2 \), when \( M_{R33} \) goes to zero.

3. For \( m_2 \simeq -m_1 \) there are some possibilities:
\[ M_L^{-1} \simeq \begin{pmatrix} 0 & -\sqrt{2}/m_2 & \sqrt{2}/m_2 \\ -\sqrt{2}/m_2 & -1/2m_3 & -1/2m_3 \\ \sqrt{2}/m_2 & -1/2m_3 & -1/2m_3 \end{pmatrix}, \]

\[ M_L^{-1} \simeq \begin{pmatrix} 0 & -1/\sqrt{2} & 1/\sqrt{2} \\ -1/\sqrt{2} & 2\epsilon & 0 \\ 1/\sqrt{2} & 0 & 0 \end{pmatrix} \frac{1}{m_2}, \] (44)

giving \( M_R \) around the unification scale. An interesting case is \( \epsilon m_3 \simeq -m_2 \), when \( m_2 < 0 \), \( m_1, m_3 > 0 \), and
\[ M_L^{-1} \simeq \begin{pmatrix} 0 & -1/\sqrt{2} & 1/\sqrt{2} \\ -1/\sqrt{2} & 2\epsilon & 0 \\ 1/\sqrt{2} & 0 & 0 \end{pmatrix} \frac{1}{m_2}, \] (44)

with the leading form
\[ M_R \sim \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix}, \] (45)

and a scale given by the element
\[ M_{R13} \sim \frac{1}{\sqrt{2}} \frac{k^2 m_t m_t}{m_2}, \] (46)

yielding \( 10^{11} \) GeV or above, near the intermediate scale of a \( SO(10) \) model. This last form is similar to the one studied in ref. [30].

\[ M_R \sim \begin{pmatrix} 0 & \sigma^2 & 1 \\ \sigma^2 & \sigma^2 & 0 \\ 1 & 0 & 0 \end{pmatrix} M_0, \] (47)

with \( \sigma^2 = m_c/m_t \) and \( M_0 = 10^{12} \) GeV. For other forms at the intermediate scale see refs. [31, 33].

For inverted hierarchy, generally we have
\[ M_{R33} \sim \frac{k^2 m_t^2}{m_3}, \] (48)

and the hierarchical and diagonal leading form with a scale at the unification scale or above.

For nearly degenerate spectrum with \( m_0 \simeq 2 \) eV, the scale is intermediate and depends on \( 1/m_0 \). However, in this case there are instabilities with respect to small entries [24]. Moreover, this spectrum is hard to obtain in the seesaw mechanism [23].

We give now a summary on neutrinos. There are few leading forms for \( M_R \). The diagonal form
\[ M_R \sim \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}, \] (49)

leads to the unification scale or above; in particular, for the VO solution and full hierarchy we go near the Planck scale. The off-diagonal forms [43]
\[ M_R \sim \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix}, \] (50)

are consistent with the intermediate scale of non supersymmetric models. In such cases the structure of \( M_R \) is very different from that of \( M_D \sim \text{diag}(0, 0, 1) \). From the point of view of the effective parameters \( m_1, \epsilon \) this is due to some suitable cancellations, but there could be an underlying theory. Of course, the relation \( M_D \sim M_t \) reduces scales by almost three orders [4], so the unification scale can become the intermediate scale.

We finish with a brief comment on neutrinos and dark matter. From inflation and CMB experiments [34] we can argue that \( \Omega = 1 \). The old paradigm about the content of the universe was \( \Omega_B \simeq 0.1 \) (baryons), \( \Omega_{HDM} = \Omega_\nu \simeq 0.2 \) (hot dark matter), \( \Omega_{CDM} \simeq 0.7 \) (cold dark matter) and \( \Omega_\Lambda = 0 \) (vacuum energy). New results from high-z supernovae and other hints lead to \( \Omega_\Lambda \simeq 0.7 \) [35]. Then \( \Omega_{CDM} \simeq 0.2 \) for structure formation and we are left with \( \Omega_\nu \simeq 0 \). Thus, we would like to stress that the hierarchical spectrum for light neutrinos leads just to \( \Omega_\nu \simeq 0 \), while the degenerate spectrum to the old position \( \Omega_\nu \simeq 0.2 \) [24]. Therefore, it seems that the new results support the hierarchical spectrum.

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[1] D. Falcone and F. Tramontano, Phys. Rev. D 59 (1999) 017302
[2] D. Falcone, Mod. Phys. Lett. A 14 (1999) 1989
[3] D. Falcone and F. Tramontano, Phys. Rev. D 61 (2000) 113013
[4] D. Falcone, Phys. Rev. D 61 (2000) 097302
[5] D. Falcone, Phys. Lett. B 475 (2000) 92
[6] D. Falcone, Phys. Lett. B 479 (2000) 1
[7] N. Cabibbo, Phys. Rev. Lett. 10 (1963) 531
  M. Kobayashi and T. Maskawa, Prog. Theor. Phys. 49 (1973) 652
[8] Y. Koide, Phys. Rev. D 46 (1992) 2121
  Y. Koide, Mod. Phys. Lett. A 12 (1997) 2655
[9] P.H. Frampton and C. Jarlskog, Phys. Lett. B 154 (1985) 421
[10] G.C. Branco, L. Lavoura and F. Mota, Phys. Rev. D 39 (1989) 3443. The famous Fritzsch ansatz consists in taking hermitian matrices: H. Fritzsch, Phys. Lett. B 73 (1978) 317; 70 (1977) 436
[11] E. Ma, Phys. Rev. D 43 (1991) 2761
[12] R. Haussling and F. Scheck, Phys. Rev. D 57 (1998) 6656
[13] T.K. Kuo, S.W. Mansour and G.H. Wu, Phys. Rev. D 60 (1999) 093004
[14] M. Baillargeon, F. Boudjema, C. Hamzaoui and J. Lindig, hep-ph/9809207
[15] P. Ramond, R.G. Roberts and G.G. Ross, Nucl. Phys. B 406 (1993) 19
[16] H. Fritzsch and Z.Z. Xing, Phys. Lett. B 413 (1997) 396
[17] G.C. Branco, D. Emmanuel-Costa and R. Gonzalez-Felipe, Phys. Lett. B 477 (2000) 147
[18] S.H. Chiu, T.K. Kuo and G.H. Wu, hep-ph/003224
[19] Y. Achiman, JHEP proceedings, Corfu 1998
[20] T.G. Rizzo, Phys. Rev. D 58 (1998) 055009; 58 (1998) 114014
[21] M.B. Voloshin, Mod. Phys. Lett. A 12 (1997) 1823
[22] K. Hagiwara and N. Okamura, Nucl. Phys. B 548 (1999) 60
  Z. Berezhiani and A. Rossi, JHEP 03 (1999) 002
  G. Altarelli and F. Feruglio, Phys. Lett. B 451 (1999) 388
[23] Y. Achiman and C. Merten, hep-ph/0004023
  Y. Achiman and S. Bielegfeld, Phys. Lett. B 412 (1997) 320
[24] S.A. Bludman, D.C. Kennedy and P.G. Langacker, Phys. Rev. D 45 (1992) 1810
  N.G. Deshpande, E. Keith and P.B. Pal, Phys. Rev. D 46 (1992) 2261
  N.G. Deshpande and E. Keith, Phys. Rev. D 50 (1994) 3513
[25] Z. Maki, M. Nakagawa and S. Sakata, Prog. Theor. Phys. 28 (1962) 870. In this paper some like a quark mixing is also considered.
[26] E.Kh. Akhmedov, Phys. Lett. B 465 (1999) 219
[27] M. Jezabek and Y. Sumino, Phys. Lett. B 440 (1999) 327
[28] E.Kh. Akhmedov, G.C. Branco and M.N. Rebelo, Phys. Lett. B 478 (2000) 215
[29] M. Abud and F. Buccella, hep-ph/0006029
[30] P. de Bernardis, Nature 404 (2000) 955
[31] M.S. Turner, astro-ph/9912211