NEUTRINO OSCILLATIONS -THEORETICAL DATA

CVAVB.CHANDRA RAJU,DEPT OF PHYS. OSMANIA UNIVERST HYDERABAD-500007, TELENGANA ,INDIA,cvavbcmail.com

Using Cabibbo type of mixing, theoretical data is presented for obtaining the probability of neutrino oscillations.

The mass eigenstates of the neutrinos must be mixing in a way similar to the Cabbibo type of mixing in the quark sector. The absolute masses of the neutrinos are obtained by them through their interaction with the Higgs field ,[1].Let the mass matrix of the electron and its neutrino be given by, M_e, where ,

$$M_e = \begin{pmatrix} 0 & \sqrt{m_e m_1} \\ \sqrt{m_e m_1} & m_e - m_1 \end{pmatrix} \quad , \qquad (1)$$

Where m_e is the electron mass and m_1 is the mass of its neutrino. The mass matrix M_e is diagonalized by the orthogonal matrix O_e Where ,

$$O_e = \begin{pmatrix} cos\phi_1 & -sin\phi_1 \\ sin\phi_1 & cos\phi_1 \end{pmatrix} \quad , \qquad (2)$$

Where $\tan\phi_1 = \sqrt{\frac{m_1}{m_e}}$. (3)

In Ref.[1], we have shown that, $m_1 = 2.12098\ eV$. (4)

With this value for the mass of electron- neutrino from, Eq.(3) we find that ,

$\phi_1 = 0.116729$ degrees. (5)

The mass matrix for the muon and its neutrino is given by M_μ where

$$M_\mu = \begin{pmatrix} 0 & \sqrt{m_\mu m_2} \\ \sqrt{m_\mu m_2} & m_\mu - m_2 \end{pmatrix} \quad , \qquad (6)$$

This mass matrix is diagonlized by the orthogonal matrix O_μ where

$$O_\mu = \begin{pmatrix} cos\phi_2 & -sin\phi_2 \\ sin\phi_2 & cos\phi_2 \end{pmatrix} \ . \qquad (7)$$

Again the angle ϕ_2 is given by, $\tan\phi_2 = \sqrt{\frac{m_2}{m_\mu}}$. (8)

From Ref.[1] we note that the mass of the muon-neutrino is given by ,

$m_2 = 2.154\ eV$. (9)

The angle $\phi_2 = 0.008181\ degrees$. (10)

Like the quark mixing the electron-neutrino and the muon -neutrino mix and the mixing angle is given by $\vartheta_1, REf.[2]$, where ,

$\vartheta_1 = \phi_1 - \phi_2$ =0.10855 degrees. (11)

The neutrino mixed states are given by ,

$$\nu_e' = \upsilon_e cos\vartheta_1 - \upsilon_\mu sin\vartheta_1 \tag{12}$$

$$\nu_\mu' = \upsilon_e sin\vartheta_1 + \upsilon_\mu cos\vartheta_1 \quad . \tag{13}$$

In view of the mixing of $\nu_e and \nu_\mu$ with the mixing angle ϑ_1 the relative Phase of $\nu_e and\ \nu_\mu$ changes because of the mass difference so that a Neutrino originating as ν_e' has a nonzero probability of being detected As ν_μ'.If an electron type neutrino is propagating with momentum,P at time t=0 ,it will have a probability of oscillation, $P_{\nu\mu}$ where,

$$P_{\nu_{eto}\mu} \approx sin^2 2\vartheta_1 sin^2 \left[\frac{\Delta m^2 L}{4E_1}\right] \tag{14}$$

Where ϑ_1 is given by Eq.(11) ,and ,

$$\Delta m^2 = m_2^2 - m_1^2 \ . \tag{15}$$

The definition of L and other details can be found from Ref.[2].

A similar procedure can be followed to find the electron-neutrino and the Tau-neutrino mixing. The mass matrix in this case is given by ,

$$M_\tau = \begin{pmatrix} 0 & \sqrt{m_\tau m_3} \\ \sqrt{m_\tau m_3} & m_\tau - m_3 \end{pmatrix} \tag{16}$$

Where m_τ is the mass of the charged Tau-lepton and m_3 is the mass of its neutrino. This mass matrix is diagonalized by the orthogonal matrix $O_{\tau,}$ that is similar to Eq.(7),and

$$tan\phi_3 = \sqrt{\frac{m_3}{m_\tau}} \quad . \tag{17}$$

The Tau- neutrino mass is given by,Ref.[1],

$$m_3 = 12.825\, MeV \quad , \qquad \text{and} \tag{18}$$

$$m_\tau = 1.777 GeV \; . \tag{19}$$

The angle ϕ_3 =4.8559 degree . (20)

The electron-neutrino and tau- neutrino mixing angle is given by ϑ_2

Where,

$$\vartheta_2 = \phi_3 - \phi_1 = 4.739 \text{ degree} \quad . \tag{21}$$

The mixed neutrino states are given by,

$$v_e' = v_e cos\vartheta_2 - v_\tau sin\vartheta_2 \quad , \tag{22}$$

$$v_\tau' = v_e sin\vartheta_2 + v_\tau cos\vartheta_2 \quad . \tag{23}$$

The probability of an electron-neutrino oscillation into a Tau-neutrino is given by,

$$P_{vetor} \approx sin^2 2\vartheta_2 sin^2 \left[\frac{\Delta m^2 L}{4E_1}\right] \quad , \tag{24}$$

Where,

$$\Delta m^2 = m_3^2 - m_1^2 \; . \tag{25}$$

And ϑ_2 is given by Eq.(20). Another possibility is that a muon-neutrino may oscillate into a Tau- neutrino through the following

mixing,

$$\nu'_\mu = \nu_\mu cos\vartheta_3 - \nu_\tau sin\vartheta_3 \quad , \tag{26}$$

$$\nu'_\tau = \upsilon_\mu sin\vartheta_3 + \upsilon_\tau cos\vartheta_3 \quad . \tag{27}$$

The angle ϑ_3 is given by ,

$$\vartheta_3 = \phi_3 - \phi_2 = 4.8477\ degrees. \tag{28}$$

It should be noted that this mixing angle of muon-neutrino to the Tau-

Neutrino is very nearly equal to the mixing angle of the electron-neutrino to the Tau- neutrino ,given by ,Eq.(21).In this case the parameter for the oscillations is given by,

$$P_{\nu\mu to\tau} \approx sin^2 2\vartheta_3 sin^2 \left[\frac{\Delta m^2 L}{4E_\mu}\right] \tag{29}$$

Where E_μ is the initial energy of the muon-neutrino, and ,

$$\Delta m^2 = m_3^2 - m_2^2 \quad . \tag{30}$$

With this data it should be possible to verify the present mixing ,Ref.[2]

[1].Cvavb.Chandra Raju,http://viXra.org/abs/2106.0011v1

[2].Cvavb.Chandra Raju,http://viXra.org/abs/1706.0130