

Vacuum basis:
mass

$$H_{\text{vac}} = \begin{pmatrix} m_1^2/2E & 0 & 0 \\ 0 & m_2^2/2E & 0 \\ 0 & 0 & m_3^2/2E \end{pmatrix}$$

$$\sim \begin{pmatrix} 0 & & \\ & (m_2^2 - m_1^2)/2E & \\ & & \frac{m_3^2 - m_1^2}{2E} \end{pmatrix} \rightarrow \begin{pmatrix} 0 & & \\ & 2\Delta_{21} & \\ & & 2\Delta_{31} \end{pmatrix}$$

Flavour basis

$$H_f = U H_{vac} U^\dagger + \underbrace{\begin{pmatrix} V_c & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}}_V$$

$$|\psi_\alpha(0)\rangle = \sum U_{\alpha j} |\psi_j(0)\rangle$$

$$|\psi_\alpha(t)\rangle = \sum U_{\alpha j} e^{-i\varepsilon_j L} |\psi_j(0)\rangle$$

$$P_{\alpha\beta} = |\langle \psi_\beta | \psi_\alpha(t) \rangle|^2 = \left| \sum U_{\beta j}^* U_{\alpha j} e^{-i\varepsilon_j L} \right|^2$$

$$U \rightarrow U_m \quad \varepsilon_j \rightarrow \text{eigenvalues}$$

eigenvector of
$$\begin{pmatrix} V_c & 0 & 0 \\ 0 & 2s_{23}^2 \Delta & 2s_{23}c_{23} \Delta \\ 0 & 2s_{23}c_{23} \Delta & 2c_{23}^2 \Delta \end{pmatrix} \leftarrow H_0$$



$$\begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \quad \begin{pmatrix} 0 \\ c_{23} \\ -s_{23} \end{pmatrix} \quad \begin{pmatrix} 0 \\ s_{23} \\ c_{23} \end{pmatrix}$$

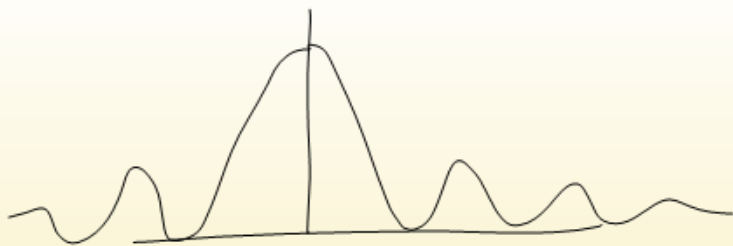
eigenvalues:

$$V_c$$

$$0$$

$$2 \Delta_{31}$$

$$\frac{\sin^2(1-\hat{A})\Delta}{(1-\hat{A})^2}$$



Peak at $\hat{A} = 1$

$$\frac{V_c}{2\Delta_{31}} = 1$$

$$V_c \sim \frac{\Delta m_{31}^2}{2E}$$

$$V_c = \frac{\Delta m^2}{2E} \cos 2\theta$$

$$\sin^2 2\theta_{13} \frac{\sin^2 (1-\hat{A})\Delta}{(1-\hat{A})^2}$$

$$\rightsquigarrow \sin^2 2\theta_{13}^m \cdot \sin^2 \Delta$$

$$V_c = \frac{\Delta m^2}{2E}$$

CP violation :

$$J = \text{Im}(\prod_{\alpha\beta ij})$$

$$= s_{12} c_{12} s_{23} c_{23} s_{13} c_{13}^2 \sin\delta$$

$$\sin(\hat{A}\Delta) = 0$$

$$\sin\left(\frac{V_c}{2\Delta_{31}} \Delta_{31} L\right) = 0$$

$$\sin\left(\frac{V_c L}{2}\right) = 0$$

$$V_c = \sqrt{2G_F n_e}$$

$$V_c L = 2\pi$$

4π, 6π, -

7000 km



$$V_c \sim 10^{-13} \text{ eV}$$

$$\Delta_{31} \sim 10^{-13} \text{ eV}$$

$$\frac{\Delta m_{31}^2}{4E} \sim 10^{-13} \text{ eV}$$

$$E \sim \frac{\Delta m_{31}^2}{4 \times 10^{-13} \text{ eV}} \sim \frac{2.5 \times 10^{-3}}{4 \times 10^{-13}} \text{ eV}$$

$$\sim 10^{10} \text{ eV} \sim \underline{\underline{10 \text{ GeV}}}$$

$$\Delta_{31} L \sim 1$$

$$2.5 \times 10^{-3}$$

$$\sin^2 \left(1.27 \frac{\Delta m^2 L}{E} \right)$$

10 GeV

$L \sim \text{few } 1000 \text{ km}$

$$\frac{1.27 \times 2.5 \times 10^{-3} \times L(\text{km})}{10} \sim 1$$