Mass vs Flavor Eigenstate Bases in QFT

Robert D. Klauber www.quantumfieldtheory.info October 28, 2024

$\mathcal{L}$ Term	Original Flavor Basis	Mass Eigenstates Basis	Basis I (New Flavors)	Basis II (Yet Different Flavors)
Kinetic	$i\bar{\psi}\not{\partial}\psi$	$i\underset{\sim}{\bar{\psi}}\not{\partial}\underset{\sim}{\psi}$ (same)	$i\bar{\psi}'\not{\partial}\psi'$ (same)	$i\bar{\psi}''\not{\partial}\psi''$ (same)
Non-W interactions	e.g., $e\bar{\psi}\not{A}\psi$	$e\underset{\sim}{\bar{\psi}}\not{A}\underset{\sim}{\psi}$ (same)	$e\bar{\psi}'\not{A}\psi'$ (same)	$e\bar{\psi}''\not{A}\psi''$ (same)
Mass terms	Need to add *h.c.* terms to below $-\frac{v}{\sqrt{2}}\bar{\psi}^L_{\nu_l}{}_B Y_{\nu_l\nu_{l'}}\psi^R_{\nu_{l'}} = -\frac{v}{\sqrt{2}}\times$ $\begin{bmatrix}\bar{\psi}^L_{\nu_e} & \bar{\psi}^L_{\nu_\mu} & \bar{\psi}^L_{\nu_\tau}\end{bmatrix}\begin{bmatrix}Y_{\nu_e\nu_e} & Y_{\nu_e\nu_\mu} & Y_{\nu_e\nu_\tau}\\ Y_{\nu_\mu\nu_e} & Y_{\nu_\mu\nu_\mu} & Y_{\nu_\mu\nu_\tau}\\ Y_{\nu_\tau\nu_e} & Y_{\nu_\tau\nu_\mu} & Y_{\nu_\tau\nu_\tau}\end{bmatrix}_B\begin{bmatrix}\psi^L_{\nu_e}\\ \psi^L_{\nu_\mu}\\ \psi^L_{\nu_\tau}\end{bmatrix}$ Non-diag neutrino mass matrix $\frac{v}{\sqrt{2}}{}_B Y$ $-\frac{v}{\sqrt{2}}\bar{\psi}^L_l{}_A Y_{ll'}\psi^R_{l'} + h.c. = -\frac{v}{\sqrt{2}}\times$ $\begin{bmatrix}\bar{\psi}^L_e & \bar{\psi}^L_\mu & \bar{\psi}^L_\tau\end{bmatrix}\begin{bmatrix}Y_{ee} & Y_{e\mu} & Y_{e\tau}\\ Y_{\mu e} & Y_{\mu\mu} & Y_{\mu\tau}\\ Y_{\tau e} & Y_{\tau\mu} & Y_{\tau\tau}\end{bmatrix}_A\begin{bmatrix}\psi^L_e\\ \psi^L_\mu\\ \psi^L_\tau\end{bmatrix}$ Non-diag charged lepton mass $\frac{v}{\sqrt{2}}{}_A Y$	$m_{\nu_l} = \frac{vg_{\nu_l}}{\sqrt{2}}$ $\quad -m_{\nu_l}\underset{\sim}{\bar{\psi}}_{\nu_l}\underset{\sim}{\psi}_{\nu_l} =$ $-\begin{bmatrix}\underset{\sim}{\bar{\psi}}_{\nu_1} & \underset{\sim}{\bar{\psi}}_{\nu_2} & \underset{\sim}{\bar{\psi}}_{\nu_3}\end{bmatrix}\begin{bmatrix}m_{\nu_1} & & \\ & m_{\nu_2} & \\ & & m_{\nu_3}\end{bmatrix}\begin{bmatrix}\underset{\sim}{\psi}_{\nu_1}\\ \underset{\sim}{\psi}_{\nu_2}\\ \underset{\sim}{\psi}_{\nu_3}\end{bmatrix}$ Diagonal neutrino mass matrix $m_l = \frac{vg_l}{\sqrt{2}}$ $\quad m_l\underset{\sim}{\bar{\psi}}_l\underset{\sim}{\psi}_l =$ $-\begin{bmatrix}\underset{\sim}{\bar{\psi}}_1 & \underset{\sim}{\bar{\psi}}_2 & \underset{\sim}{\bar{\psi}}_3\end{bmatrix}\begin{bmatrix}m_1 & & \\ & m_2 & \\ & & m_3\end{bmatrix}\begin{bmatrix}\underset{\sim}{\psi}_1\\ \underset{\sim}{\psi}_2\\ \underset{\sim}{\psi}_3\end{bmatrix}$ Diagonal charged lepton mass matrix	Need to add *h.c.* terms to below $-\frac{v}{\sqrt{2}}\bar{\psi}'^R_{\nu_l}{}_\nu M_{\nu_l i}P^\dagger_{i\nu_{l'}}\psi'^L_{\nu_{l'}} = -\frac{v}{\sqrt{2}}\times$ $\begin{bmatrix}\bar{\psi}'^L_{\nu_e} & \bar{\psi}'^L_{\nu_\mu} & \bar{\psi}'^L_{\nu_\tau}\end{bmatrix}\begin{bmatrix}MP^\dagger_{\nu_e\nu_e} & MP^\dagger_{\nu_e\nu_\mu} & MP^\dagger_{\nu_e\nu_\tau}\\ MP^\dagger_{\nu_\mu\nu_e} & MP^\dagger_{\nu_\mu\nu_\mu} & MP^\dagger_{\nu_\mu\nu_\tau}\\ MP^\dagger_{\nu_\tau\nu_e} & MP^\dagger_{\nu_\tau\nu_\mu} & MP^\dagger_{\nu_\tau\nu_\tau}\end{bmatrix}\begin{bmatrix}\psi'^L_{\nu_e}\\ \psi'^L_{\nu_\mu}\\ \psi'^L_{\nu_\tau}\end{bmatrix}$ Non-diag neutrino mass matrix $-\frac{v}{\sqrt{2}}MP^\dagger$ $m_l = \frac{vg_l}{\sqrt{2}}$ $\quad m_l\bar{\psi}'_l\psi'_l =$ $-\begin{bmatrix}\bar{\psi}'_e & \bar{\psi}'_\mu & \bar{\psi}'_\tau\end{bmatrix}\begin{bmatrix}m_e & & \\ & m_\mu & \\ & & m_\tau\end{bmatrix}\begin{bmatrix}\psi'_e\\ \psi'_\mu\\ \psi'_\tau\end{bmatrix}$ Diagonal charged lepton mass matrix	$m_q = \frac{vg_q}{\sqrt{2}}$ $\quad -m_q\bar{\psi}''_q\psi''_q =$ $-\begin{bmatrix}\bar{\psi}''_u & \bar{\psi}''_c & \bar{\psi}''_t\end{bmatrix}\begin{bmatrix}m_u & & \\ & m_c & \\ & & m_t\end{bmatrix}\begin{bmatrix}\psi''_u\\ \psi''_c\\ \psi''_t\end{bmatrix}$ Diagonal up type quark (or neutrino) mass matrix $m_q = \frac{vg_q}{\sqrt{2}}$ $\quad -m_q\bar{\psi}''_q\psi''_q =$ $-\begin{bmatrix}\bar{\psi}''_d & \bar{\psi}''_s & \bar{\psi}''_b\end{bmatrix}\begin{bmatrix}m_d & & \\ & m_s & \\ & & m_b\end{bmatrix}\begin{bmatrix}\psi''_d\\ \psi''_s\\ \psi''_b\end{bmatrix}$ Diagonal down type quark (or charged lepton) mass matrix
Mass?	Mass indefinite for all. Flavor definite for all.	Mass definite for all. Flavor indefinite for all.	Mass definite for e,μ,τ, indefinite for ν. Flavor definite for all (but defined differently than original flavor).	Mass definite for all. Flavor definite for all (but defined differently than original flavor)..
W-boson/ lepton interactions	No mixing of generations. e.g., no e^- to ν_μ at W vertex. $-\frac{g}{\sqrt{2}}\bar{\psi}^L_l W^- \psi^L_{\nu_l} =$ $-\begin{bmatrix}\bar{\psi}^L_e & \bar{\psi}^L_\mu & \bar{\psi}^L_\tau\end{bmatrix}\begin{bmatrix}1 & & \\ & 1 & \\ & & \end{bmatrix}W^-\begin{bmatrix}\psi^L_{\nu_e}\\ \psi^L_{\nu_\mu}\\ \psi^L_{\nu_\tau}\end{bmatrix}$	Mixing of generations. e.g., 1 to 2 can occur at W vertex. $-\frac{g}{\sqrt{2}}\underset{\sim}{\bar{\psi}}^L_{l'}P_{l'\nu_l}W^-\underset{\sim}{\psi}^L_{\nu_l} = -\frac{g}{\sqrt{2}}\times$ $\begin{pmatrix}\underset{\sim}{\bar{\psi}}^L_1 & \underset{\sim}{\bar{\psi}}^L_2 & \underset{\sim}{\bar{\psi}}^L_3\end{pmatrix}\begin{bmatrix}P_{11} & P_{12} & P_{13}\\ P_{21} & P_{22} & P_{23}\\ P_{31} & P_{32} & P_{33}\end{bmatrix}W^-\begin{pmatrix}\underset{\sim}{\psi}^L_{\nu_1}\\ \underset{\sim}{\psi}^L_{\nu_2}\\ \underset{\sim}{\psi}^L_{\nu_3}\end{pmatrix}$	No mixing of generations. e.g., no e^- to ν_μ at W vertex. $-\frac{g}{\sqrt{2}}\bar{\psi}'^L_l W^-\psi'^L_{\nu_l} =$ $-\begin{bmatrix}\bar{\psi}'^L_e & \bar{\psi}'^L_\mu & \bar{\psi}'^L_\tau\end{bmatrix}\begin{bmatrix}1 & & \\ & 1 & \\ & & \end{bmatrix}W^-\begin{bmatrix}\psi'^L_{\nu_e}\\ \psi'^L_{\nu_\mu}\\ \psi'^L_{\nu_\tau}\end{bmatrix}$	Mixing of generations. e.g., d to c quark can occur at W vertex. $-\frac{g}{\sqrt{2}}\bar{\psi}''^L_{q_d}V^\dagger_{q_d q_u}W^-\psi''^L_{q_u} = -\frac{g}{\sqrt{2}}\times$ $\begin{bmatrix}\bar{\psi}''^L_d & \bar{\psi}''^L_s & \bar{\psi}''^L_b\end{bmatrix}\begin{bmatrix}V^\dagger_{du} & V^\dagger_{dc} & V^\dagger_{dt}\\ V^\dagger_{su} & V^\dagger_{sc} & V^\dagger_{st}\\ V^\dagger_{bu} & V^\dagger_{bc} & V^\dagger_{bt}\end{bmatrix}W^-\begin{bmatrix}\psi''^L_u\\ \psi''^L_c\\ \psi''^L_t\end{bmatrix}$
Used for	Introducing/developing SM of QFT	Intermediate step to bases at right	Leptons	Quarks