

Mass vs Flavor Eigenstate Bases in QFT

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

<u>\mathcal{L} Term</u>	<u>Original Flavor Basis</u>	<u>Mass Eigenstates Basis</u>	<u>Basis I (New Flavors)</u>	<u>Basis II (Yet Different Flavors)</u>
Kinetic	$i\bar{\psi} \not{\partial} \psi$	$i\bar{\tilde{\psi}} \not{\partial} \tilde{\psi}$ (same)	$i\bar{\psi}' \not{\partial} \psi'$ (same)	$i\bar{\psi}'' \not{\partial} \psi''$ (same)
Non-W interactions	e.g., $e\bar{\psi} \not{A} \psi$	$e\bar{\tilde{\psi}} \not{A} \tilde{\psi}$ (same)	$e\bar{\psi}' \not{A} \psi'$ (same)	$e\bar{\psi}'' \not{A} \psi''$ (same)
Mass terms	<p>Need to add <i>h.c.</i> terms to below</p> $-\frac{v}{\sqrt{2}} \bar{\psi}_{\nu l}^L Y_{\nu l \nu l} \psi_{\nu l}^R = -\frac{v}{\sqrt{2}} \times$ $\begin{bmatrix} \bar{\psi}_{\nu e}^L & \bar{\psi}_{\nu \mu}^L & \bar{\psi}_{\nu \tau}^L \end{bmatrix} \begin{bmatrix} Y_{\nu e \nu e} & Y_{\nu e \nu \mu} & Y_{\nu e \nu \tau} \\ Y_{\nu \mu \nu e} & Y_{\nu \mu \nu \mu} & Y_{\nu \mu \nu \tau} \\ Y_{\nu \tau \nu e} & Y_{\nu \tau \nu \mu} & Y_{\nu \tau \nu \tau} \end{bmatrix} \begin{bmatrix} \psi_{\nu e}^L \\ \psi_{\nu \mu}^L \\ \psi_{\nu \tau}^L \end{bmatrix}$ <p>Non-diag neutrino mass matrix $\frac{v}{\sqrt{2}} {}_B Y$</p> $-\frac{v}{\sqrt{2}} \bar{\psi}_l^L Y_{ll'} \psi_{l'}^R + h.c. = -\frac{v}{\sqrt{2}} \times$ $\begin{bmatrix} \bar{\psi}_e^L & \bar{\psi}_\mu^L & \bar{\psi}_\tau^L \end{bmatrix} \begin{bmatrix} Y_{ee} & Y_{e\mu} & Y_{e\tau} \\ Y_{\mu e} & Y_{\mu\mu} & Y_{\mu\tau} \\ Y_{\tau e} & Y_{\tau\mu} & Y_{\tau\tau} \end{bmatrix} \begin{bmatrix} \psi_e^L \\ \psi_\mu^L \\ \psi_\tau^L \end{bmatrix}$ <p>Non-diag charged lepton mass $\frac{v}{\sqrt{2}} {}_A Y$</p>	$m_{\nu_l} = \frac{vg_{\nu_l}}{\sqrt{2}} \quad -m_{\nu_l} \bar{\tilde{\psi}}_{\nu l} \tilde{\psi}_{\nu l} =$ $-\begin{bmatrix} \bar{\tilde{\psi}}_{\nu 1} & \bar{\tilde{\psi}}_{\nu 2} & \bar{\tilde{\psi}}_{\nu 3} \end{bmatrix} \begin{bmatrix} m_{\nu 1} & & \\ & m_{\nu 2} & \\ & & m_{\nu 3} \end{bmatrix} \begin{bmatrix} \tilde{\psi}_{\nu 1} \\ \tilde{\psi}_{\nu 2} \\ \tilde{\psi}_{\nu 3} \end{bmatrix}$ <p>Diagonal neutrino mass matrix</p> $m_l = \frac{vg_l}{\sqrt{2}} \quad m_l \bar{\tilde{\psi}}_l \tilde{\psi}_l =$ $-\begin{bmatrix} \bar{\tilde{\psi}}_1 & \bar{\tilde{\psi}}_2 & \bar{\tilde{\psi}}_3 \end{bmatrix} \begin{bmatrix} m_1 & & \\ & m_2 & \\ & & m_3 \end{bmatrix} \begin{bmatrix} \tilde{\psi}_1 \\ \tilde{\psi}_2 \\ \tilde{\psi}_3 \end{bmatrix}$ <p>Diagonal charged lepton mass matrix</p>	<p>Need to add <i>h.c.</i> terms to below</p> $-\frac{v}{\sqrt{2}} \bar{\psi}_{\nu l}^R M_{\nu l i} P_{i\nu l}^\dagger \psi_{\nu l}^L = -\frac{v}{\sqrt{2}} \times$ $\begin{bmatrix} \bar{\psi}_{\nu e}^L & \bar{\psi}_{\nu \mu}^L & \bar{\psi}_{\nu \tau}^L \end{bmatrix} \begin{bmatrix} MP_{\nu \nu e}^\dagger & MP_{\nu \nu \mu}^\dagger & MP_{\nu \nu \tau}^\dagger \\ MP_{\nu \mu \nu e}^\dagger & MP_{\nu \mu \nu \mu}^\dagger & MP_{\nu \mu \nu \tau}^\dagger \\ MP_{\nu \tau \nu e}^\dagger & MP_{\nu \tau \nu \mu}^\dagger & MP_{\nu \tau \nu \tau}^\dagger \end{bmatrix} \begin{bmatrix} \psi_{\nu e}^L \\ \psi_{\nu \mu}^L \\ \psi_{\nu \tau}^L \end{bmatrix}$ <p>Non-diag neutrino mass matrix $-\frac{v}{\sqrt{2}} MP^\dagger$</p> $m_l = \frac{vg_l}{\sqrt{2}} \quad m_l \bar{\psi}_l' \psi_l' =$ $-\begin{bmatrix} \bar{\psi}_e' & \bar{\psi}_\mu' & \bar{\psi}_\tau' \end{bmatrix} \begin{bmatrix} m_e & & \\ & m_\mu & \\ & & m_\tau \end{bmatrix} \begin{bmatrix} \psi_e' \\ \psi_\mu' \\ \psi_\tau' \end{bmatrix}$ <p>Diagonal charged lepton mass matrix</p>	$m_q = \frac{vg_q}{\sqrt{2}} \quad -m_q \bar{\psi}_q'' \psi_q'' =$ $-\begin{bmatrix} \bar{\psi}_u'' & \bar{\psi}_c'' & \bar{\psi}_t'' \end{bmatrix} \begin{bmatrix} m_u & & \\ & m_c & \\ & & m_t \end{bmatrix} \begin{bmatrix} \psi_u'' \\ \psi_c'' \\ \psi_t'' \end{bmatrix}$ <p>Diagonal up type quark (or neutrino) mass matrix</p> $m_q = \frac{vg_q}{\sqrt{2}} \quad -m_q \bar{\psi}_q'' \psi_q'' =$ $-\begin{bmatrix} \bar{\psi}_d'' & \bar{\psi}_s'' & \bar{\psi}_b'' \end{bmatrix} \begin{bmatrix} m_d & & \\ & m_s & \\ & & m_b \end{bmatrix} \begin{bmatrix} \psi_d'' \\ \psi_s'' \\ \psi_b'' \end{bmatrix}$ <p>Diagonal down type quark (or charged lepton) mass matrix</p>
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	<p>No mixing of generations. e.g., no e^- to ν_μ at W vertex.</p> $-\frac{g}{\sqrt{2}} \bar{\psi}_l^L W^- \psi_{\nu l}^L =$ $-\begin{bmatrix} \bar{\psi}_e^L & \bar{\psi}_\mu^L & \bar{\psi}_\tau^L \end{bmatrix} \begin{bmatrix} 1 & & \\ & 1 & \\ & & 1 \end{bmatrix} W^- \begin{bmatrix} \psi_{\nu e}^L \\ \psi_{\nu \mu}^L \\ \psi_{\nu \tau}^L \end{bmatrix}$	<p>Mixing of generations. e.g., 1 to 2 can occur at W vertex.</p> $-\frac{g}{\sqrt{2}} \bar{\tilde{\psi}}_l^L P_{l\nu l} W^- \tilde{\psi}_{\nu l}^L = -\frac{g}{\sqrt{2}} \times$ $\begin{bmatrix} \bar{\tilde{\psi}}_1^L & \bar{\tilde{\psi}}_2^L & \bar{\tilde{\psi}}_3^L \end{bmatrix} \begin{bmatrix} P_{11} & P_{12} & P_{13} \\ P_{21} & P_{22} & P_{23} \\ P_{31} & P_{32} & P_{33} \end{bmatrix} W^- \begin{bmatrix} \tilde{\psi}_{\nu 1}^L \\ \tilde{\psi}_{\nu 2}^L \\ \tilde{\psi}_{\nu 3}^L \end{bmatrix}$	<p>No mixing of generations. e.g., no e^- to ν_μ at W vertex.</p> $-\frac{g}{\sqrt{2}} \bar{\psi}_l^L W^- \psi_{\nu l}^L =$ $-\begin{bmatrix} \bar{\psi}_e^L & \bar{\psi}_\mu^L & \bar{\psi}_\tau^L \end{bmatrix} \begin{bmatrix} 1 & & \\ & 1 & \\ & & 1 \end{bmatrix} W^- \begin{bmatrix} \psi_{\nu e}^L \\ \psi_{\nu \mu}^L \\ \psi_{\nu \tau}^L \end{bmatrix}$	<p>Mixing of generations. e.g., d to c quark can occur at W vertex.</p> $-\frac{g}{\sqrt{2}} \bar{\psi}_q^{nL} V_{qd}^\dagger W^- \psi_{qu}^{nL} = -\frac{g}{\sqrt{2}} \times$ $\begin{bmatrix} \bar{\psi}_d^{nL} & \bar{\psi}_s^{nL} & \bar{\psi}_b^{nL} \end{bmatrix} \begin{bmatrix} V_{du}^\dagger & V_{cu}^\dagger & V_{tu}^\dagger \\ V_{su}^\dagger & V_{bc}^\dagger & V_{bt}^\dagger \\ V_{bu}^\dagger & V_{bc}^\dagger & V_{bt}^\dagger \end{bmatrix} W^- \begin{bmatrix} \psi_u^{nL} \\ \psi_c^{nL} \\ \psi_t^{nL} \end{bmatrix}$
Used for	Introducing/developing SM of QFT	Intermediate step to bases at right	Leptons	Quarks