Tutorial 7

December 14, 2015

In this week's tutorial we will study the invariance of the Standard Model Lagrangian under the C, P and T symmetries. The Higgs, gluon and electromagnetic interactions are independently invariant under C, P and CP (which is equivalent to T, given that CPT is always a symmetry). The neutral-current couplings to the Z boson break C and P but are symmetric under CP.

Here, we will study the charged-current couplings to the W boson, focusing on the Lagrangian term describing the quark interactions,

$$\mathcal{L}_q^W = \frac{ig_2}{2\sqrt{2}} \Big[V_{mn} W_\mu^+ \bar{u}_m \gamma^\mu (1+\gamma_5) d_n + (V^\dagger)_{mn} W_\mu^- \bar{d}_m \gamma^\mu (1+\gamma_5) u_n \Big] . \tag{1}$$

Using

$$\mathcal{C} W_\mu^\pm \mathcal{C}^* = -W_\mu^\mp \qquad \mathcal{P} W_\mu^\pm \mathcal{P}^* = P^\nu{}_\mu W_\nu^\pm \tag{2}$$

$$\mathcal{C} \psi \mathcal{C}^* = (\alpha_\psi)^* C \bar{\psi}^T \qquad \mathcal{P} \psi \mathcal{P}^* = (\alpha_\psi)^* \beta \psi, \tag{3}$$

where ψ is a spinor and

$$C = \begin{bmatrix} -\epsilon & 0 \\ 0 & \epsilon \end{bmatrix}, \qquad \epsilon = i\sigma_2 = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}, \qquad \beta = \begin{bmatrix} 0 & \mathbb{1} \\ \mathbb{1} & 0 \end{bmatrix}, \tag{4}$$

show that:

- $\mathcal{L}_q^W$ is not invariant under C ;
- $\mathcal{L}_q^W$ is not invariant under P ;
- $\mathcal{L}_q^W$ would be invariant under CP if the CKM-matrix were real.