Note 225(3): Lepton Interaction in Standard or GWS Electroweak Theory

The types of interaction are defined by the lagrangian:

$$\mathcal{L}_1 = i\bar{e}_R \gamma^\mu (\partial_\mu + ig' X_\mu) e_R$$
$$+ i \begin{bmatrix} \bar{\nu}_e & \bar{e}_L \end{bmatrix} \left((\partial_\mu + \frac{i}{2} g' X_\mu) \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} - \frac{ig}{2} \begin{bmatrix} W_\mu^3 & W_\mu^1 - iW_\mu^2 \\ W_\mu^1 + iW_\mu^2 & -W_\mu^3 \end{bmatrix} \right) \begin{bmatrix} \nu_e \\ e_L \end{bmatrix}$$

$$= i\bar{e}_R \gamma^\mu (\partial_\mu + ig' X_\mu) e_R$$
$$+ i \begin{bmatrix} \bar{\nu}_e & \bar{e}_L \end{bmatrix} \gamma^\mu (\partial_\mu + \frac{i}{2} g' X_\mu) \begin{bmatrix} \nu_e \\ e_L \end{bmatrix}$$
$$+ \begin{bmatrix} \bar{\nu}_e & \bar{e}_L \end{bmatrix} \gamma^\mu \frac{g}{2} \begin{bmatrix} W_\mu^3 \nu_e + (W_\mu^1 - iW_\mu^2) e_L \\ (W_\mu^1 + iW_\mu^2)\nu_e - W_\mu^3 e_L \end{bmatrix}$$

$$= -g' X_\mu \bar{e}_R \gamma^\mu e_R + i\bar{e}_R \gamma^\mu \partial_\mu e_R$$
$$+ i\bar{\nu}_e \gamma^\mu (\partial_\mu + \frac{ig'}{2} X_\mu) \nu_e$$
$$+ i\bar{e}_L \gamma^\mu (\partial_\mu + \frac{i}{2} g' X_\mu) e_L \quad -(1)$$
$$+ \bar{\nu}_e \gamma^\mu \frac{g}{2} \left(W_\mu^3 \nu_e + (W_\mu^1 - iW_\mu^2) e_L \right)$$
$$+ \bar{e}_L \gamma^\mu \frac{g}{2} \left((W_\mu^1 + iW_\mu^2) \nu_e - W_\mu^3 e_L \right)$$

2) Therefore there are:

1) Neutrino neutrino interaction energies described by the expectation value $i\bar{\nu}_e\gamma^\mu\left(\partial_\mu + \frac{ig'}{2}X_\mu\right)\nu_e$.

2) Left handed electron left handed electron interactions described by the expectation value $i\bar{e}_L\gamma^\mu\left(\partial_\mu + \frac{i}{2}g'X_\mu\right)e_L$.

3) Neutrino neutrino interactions described by the expectation value $\bar{\nu}_e\gamma^\mu\frac{g}{2}W^3_\mu\nu_e$.

4) Neutrino left handed electron interactions described by the expectation value $\bar{\nu}_e\gamma^\mu\frac{g}{2}(W^1_\mu - iW^2_\mu)e_L$.

5) Left handed electron neutrino interaction described by the expectation value $\bar{e}_L\gamma^\mu\frac{g}{2}(W^1_\mu + iW^2_\mu)\nu_e$.

6) Left handed electron left handed electron interactions described by the expectation value $\bar{e}_L\gamma^\mu\frac{g}{2}W^3_\mu e_L$.

7) Right handed electron right handed electron interactions described by the expectation value $i\bar{e}_R\gamma^\mu(\partial_\mu + ig'X_\mu)e_R$

The Lagrangian (1) may be written as:

3)

$$\mathcal{L}_1 = -g' X_\mu \bar{e}_R \gamma^\mu e_R - \frac{1}{2}\left(g' X_\mu + g W^3_\mu\right) \bar{e}_L \gamma^\mu e_L + \dots \quad -(2)$$

This result suggests that the left handed electron interacts with the left handed electron through a combination $\frac{1}{2}(g' X_\mu + g W^3_\mu)$, in which g', X_μ, g and W^3_μ are a priori unknown. The right handed electron interacts with another right handed electron through $g' X_\mu$, where g' and X_μ are a priori unknown.

There is no interaction between left handed and right handed electron.

The standard model assumes that the following is an electromagnetic potential:

$$A_\mu = \frac{g' W^3_\mu + g X_\mu}{(g^2 + g'^2)^{1/2}} \quad -(3)$$

i.e introduces a normalization.

This is an arbitrary procedure designed to force the theory to "agree" with experimental data.

From eq. (2) it is reasonable to conclude only that g' may be identified with e, the

4) charge on the proton, and that X_μ may be identified with the electromagnetic potential for the interaction of two right handed electrons. For the interaction of two left handed electrons there is an additional gW_μ^3, which violates parity. This can be described by the minimal prescription:

$$p^\mu \to p^\mu - gW^\mu \quad (4)$$

where the superscript 3 has been omitted for clarity.

For the right handed electron:

$$p^\mu \to p^\mu - eA^\mu \quad (5)$$

but for the left handed electron:

$$p^\mu \to p^\mu - eA^\mu - gW^\mu \quad (6)$$

This difference produces effects such as enantiomeric energy inequivalence and optical activity in atoms, but from the fermion equation it will also produce small changes in the Zeeman effect, ESR, NMR, MRI, FMR, spin orbit coupling, Thomas precession and Darwin term. This will be demonstrated in the next note.