Electric Charge Breaking in Neutrino Physics

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Breaking the electric charge?

Why?

How?

Consequences?

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Consequences?

- Photon mass, W- and Z-boson mass corrections
- Corrections to the weak mixing angle θ
- Electrons and Neutrinos can mix with each other and form new mass eigenstates with new interactions

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$$\begin{pmatrix} \overline{e_L^-} & \overline{e_L^+} & \overline{\nu_L} \end{pmatrix} \left[\underbrace{\begin{pmatrix} e & & \\ & -e & \\ & & 0 \end{pmatrix}}_{\text{Standard Model}} \longrightarrow \underbrace{\begin{pmatrix} \frac{1}{2}(e_1 + e_2) & \frac{1}{2}(3e_1 + e_2)\,\theta_z & e_2\,\frac{\theta_y + \theta_x}{\sqrt{2}} \\ \frac{1}{2}(3e_1 + e_2)\,\theta_z & -e_1 & \frac{3e_1 - e_2}{2}\,\frac{\theta_y - \theta_x}{\sqrt{2}} \\ e_2\,\frac{\theta_y + \theta_x}{\sqrt{2}} & \frac{3e_1 - e_2}{2}\,\frac{\theta_y - \theta_x}{\sqrt{2}} & \frac{1}{2}(e_1 - e_2) \end{pmatrix}}_{\text{New Basis}} \right] \not{A} \begin{pmatrix} e_L^- \\ e_L^+ \\ \nu_L \end{pmatrix}$$

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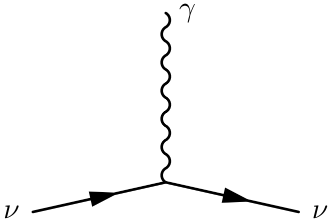
- All lepton-lepton-EW gauge boson interactions are possible on tree-level (with certain scalar representations)

Magnetic Moment

Because there is an explicit neutrino-neutrino-photon coupling, the neutrino has a tree-level magnetic moment.



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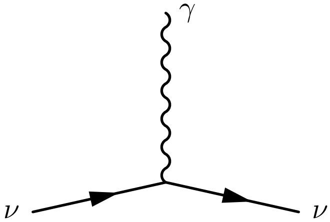

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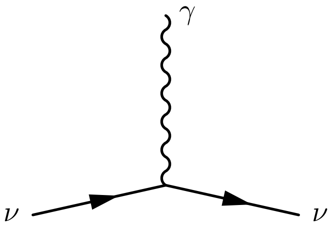
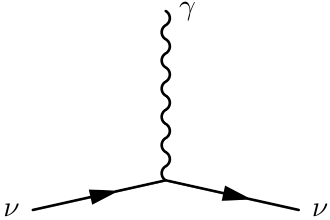
- The tree-level magnetic moment is then

$$|\mu| = \frac{q_{\text{eff}}}{e}\mu_{\text{B}}$$



Photon Decay

The same diagram can also lead to photon decay. This only works if the lightest neutrino is lighter than the photon.



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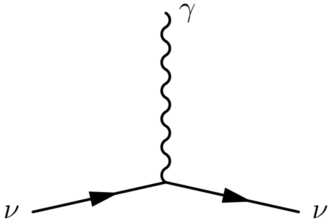
- The lifetime is then

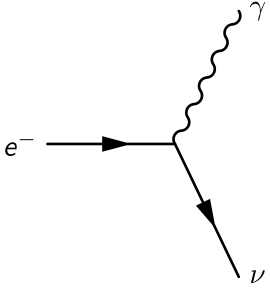
$$\tau_\gamma \approx \frac{96\pi}{q_{\text{eff}}^2 M_\gamma} \frac{M_\gamma^2}{M_\gamma^2 - m_\nu^2}$$

- m_ν is proportional to the vev of $(\mathbf{1},\mathbf{1})_0$, but the formula still holds if it vanishes



Electron Decay

The massive photon has an **additional third polarization** and observables dependent on the photon coupling need not necessarily go smoothly to the SM limit for $M_\gamma \to 0$.



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- The electron now has a lifetime

$$\tau_e \approx 1.4 \cdot 10^{-18}\,\mathrm{s}\,\frac{M_\gamma^2}{M_{\mathrm{LL}}^2 + M_{\mathrm{RL}}^2}$$

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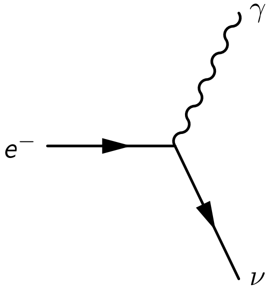

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- This goes to zero for a small photon mass!