27) Higgs Mechanism

Gauge invariance does not allow an explicit mass term. We modify the Lagrangian to give mass to W^± and Z^0, but U(1) cannot be broken, so the vacuum must be neutral.

\[ \phi = \left( \begin{array}{c} \phi^+ \\ \phi^0 \end{array} \right) \] Higgs doublet

\[ L_0 = \bar{\psi} \gamma^\mu \partial_\mu \psi + V(\phi^+ \phi) + \frac{1}{2} \overline{\psi} \gamma^\mu \gamma^5 \frac{g}{2} \gamma^\mu \psi \]

\[ \overline{\psi} \gamma^\nu \frac{i}{2} \gamma^\mu \frac{\partial_\mu}{\sqrt{2}} \psi + \frac{1}{2} \bar{\psi} \gamma^5 \frac{\partial_\mu}{\sqrt{2}} \psi \]

\[ \langle \phi \rangle = \frac{\nu}{\sqrt{2}} \]

A nonzero expectation value of \( \langle \phi \rangle \) gives mass to \( W^\pm \) and \( Z^0 \), but \( U(1) \) cannot be broken, so the vacuum must be neutral.

\[ \phi = \left( \begin{array}{c} \phi^+ \\ \phi^0 \end{array} \right) \Rightarrow Y_\phi = 1 \]

\[ \Rightarrow \langle \phi \rangle_0 = \left( T_3 + \frac{i}{2} Y \right) \left( \frac{\nu}{\sqrt{2}} \right) = 0 \]

The other generators of the gauge group become massive.