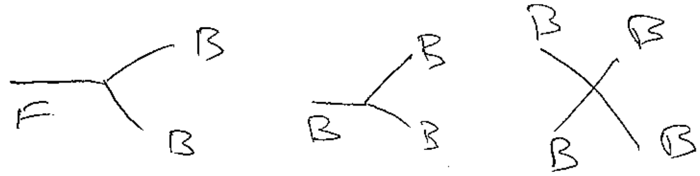
Standard Model

The version of QFT that ~~fits~~ our universe is characterized by.

As we've seen much of the world is fixed by basic principles of QM + L-I.

$0, \frac{1}{2}, 1, \frac{3}{2}, 2$



ect Spin-1 Yang Mills

SM attempt to explain all phenomena of particle physics in terms of small number of particles of 4-types

<u>leptons</u>

$\begin{pmatrix} \nu \\ e \end{pmatrix} \begin{pmatrix} \nu \\ \mu \end{pmatrix} \begin{pmatrix} \nu \\ \tau \end{pmatrix}$

<u>quarks</u>

$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix}$

Spin $\frac{1}{2}$

L & R hand fields

<u>Gauge Bosons</u> Spin 1

$\gamma \quad g \times 8 \quad W^{\pm}\ Z$

<u>Spin 0</u>

H

All are assumed to be elementary.

$\hookrightarrow$ No internal structure

Leptons

Quantum Number associated w/ each generation

$$L_e \equiv N(e^-) - N(e^+) + N(\nu_e) - N(\bar{\nu}_e)$$

All other particles have $L_e = 0$

Conservation of electron number

$\Rightarrow$ electrons (ν_e) need to be created/destroyed in pairs

Corresponding lepton Numbers for

$$L_\mu \quad \& \quad L_\tau$$

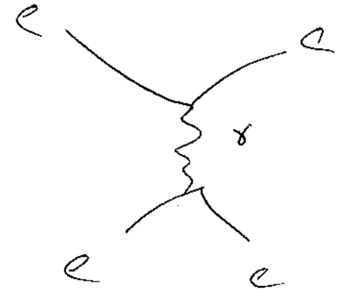
$$\sum m_\nu < 10^{-9}$$

$$\begin{pmatrix} m_\nu \\ 10^{-3} \end{pmatrix} \begin{pmatrix} m_\nu \\ 10^{-1} \end{pmatrix} \begin{pmatrix} m_\nu \\ 1.7 \end{pmatrix}$$

thought to be 0.
Now known that at least 2 (maybe all) have $m_\nu > 0$

W, Z exchange

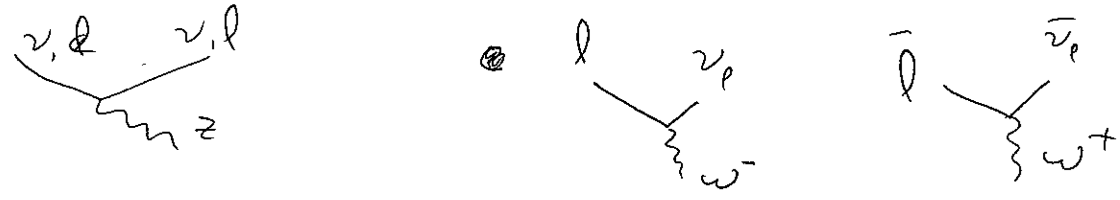
EM seen mediated by exchange of γ

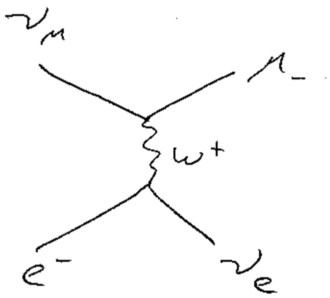


Similarly for weak interaction force mediated by exchange of $W^{+/-}$ or Z

When drawing diagrams, must remember to conserve Lepton numbers & charge.

eg:



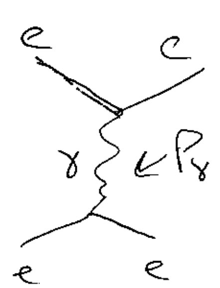


Lepton Universality

All data consistent w/ hypothesis that interaction of all generations are the same (Modulo mass differences)

$m_Z \sim 90$ GeV $\quad m_{W^{\pm}} \sim 80$ GeV $\neq 0$ GeV

Major implication for "range" or effective strength of interaction



By uncertainty Principle

$E\,t \sim 1$

$E\,x \sim 1$

$x \sim \frac{1}{P_\gamma} \leftarrow$ x can be arbitrarily large for small P_γ

However for weak interaction

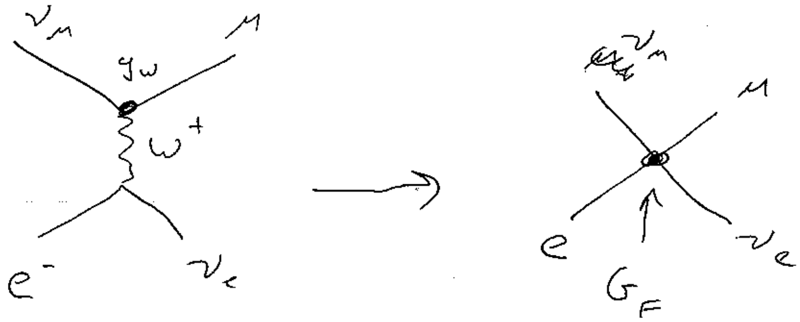
$x \sim \frac{1}{E} \sim \frac{1}{\sqrt{p_Z^2 + m^2}}$

$\sim \frac{1}{m_Z}$

At best can be of range $\frac{1}{m_Z}$.

At low energies the wavelengths of all particles are large compared to range of weak force $\frac{1}{m_{W,Z}}$

Can be approximated by | 0-range "point" interaction whose strength characterized by "Fermi constant"



$$G_F \sim 10^{-5}\ GeV^{-2} = g_W^2/m_W^2 \sim \frac{4\pi\alpha_W}{M_W^2}$$

$$\alpha_W = 4.26\times10^{-3} = 0.5\,\alpha$$

Weak & EM interaction of similar strength,

Apparent Difference between Weak & EM interactions is a long-distance <u>illusion</u>

<u>Branching Ratios</u>

decay rate $\left(\Gamma \approx \frac{1}{2E} |M|^2 d\Pi_{LIPS} \right)$

$$Br(Z\to ll) = \frac{\Gamma(Z\to ll)}{\Gamma_{total}}$$

$$\Gamma_{total} \to \sum_i \Gamma(Z\to x_i^+ x_i^-)$$

$$\frac{Br(Z\to ee)}{Br(Z\to\mu\mu)} = \frac{\Gamma(Z\to ee)}{\Gamma(Z\to\mu\mu)} = \frac{\frac{1}{2E_Z}|M(Z\to ee)|^2 d\Pi_{LIPS}}{\frac{1}{2E_Z}|M(Z\to\mu\mu)|^2 d\Pi_{LIPS}} = \frac{|M(Z\to ee)|^2}{|M(Z\to\mu\mu)|^2} = 1$$

By Lep. universality