

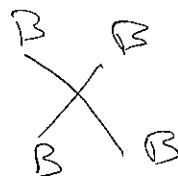
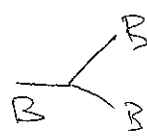
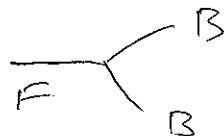
Standard Model

(1)

The version of QFT that 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-7 Tony Mills

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

leptons

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

quarks

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

Spin $\frac{1}{2}$

L & R hand fields

Gauge Bosons Spin 1

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

Spin 0

H

All are assumed to be elementary.

→ No internal structure

Leptons

Quantum Number associated w/ each generation

(8)
(2)

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

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

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

$$\checkmark \quad \sum m_\nu < 10^{-9}$$
$$\begin{pmatrix} m_\nu \\ 10^{-3} \end{pmatrix} \begin{pmatrix} m_\nu \\ 10^{-1} \end{pmatrix} \begin{pmatrix} m_\nu \\ 1.7 \end{pmatrix}$$

\nwarrow ~~thought~~ thought to be 0.

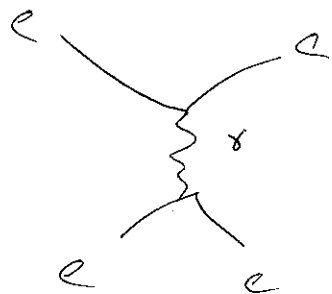
Now known that at least

2 (maybe all) have $m_\nu > 0$

W, Z exchange

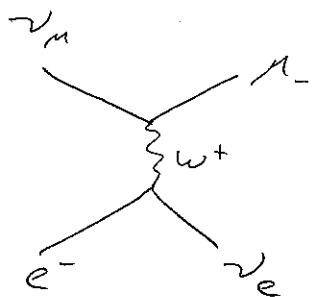
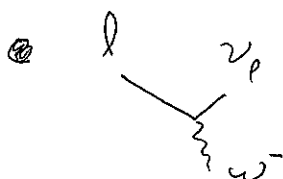
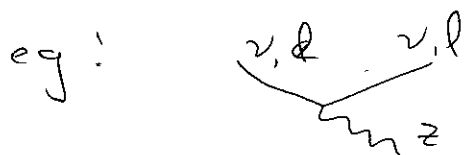
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④
③

EM saw 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.

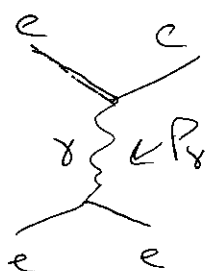


Lepton Universality

All data consistent w/ hypothesis that
interaction of ~~to~~ All generations are
the same (modulo mass differences)

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

Major implication for "range" or effective strength
of interaction



By uncertainty Principle

$$\Delta E \Delta t \sim 1$$

$$\Delta E \Delta x \sim 1$$

$$\Delta x \sim \frac{1}{p_\gamma} \leftarrow \begin{matrix} \text{Can be arbitrarily} \\ \text{large for small } p_\gamma \end{matrix}$$

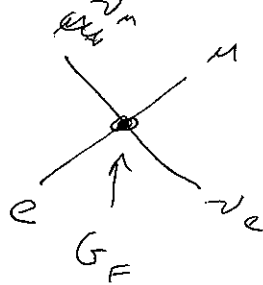
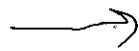
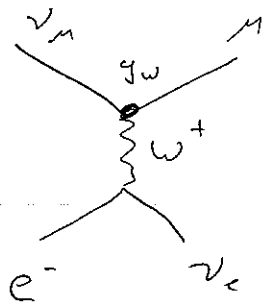
However for weak interaction

$$\begin{matrix} e & e \\ & \diagdown \quad \diagup \\ & Z \\ & \diagup \quad \diagdown \\ & \end{matrix} \quad \times \sim \frac{1}{E} \sim \frac{1}{\sqrt{p_z^2 + m^2}} \sim \frac{1}{m_Z}$$

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 $\frac{1}{m_{W,2}}$

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



by "Fermi constant"

$$G_F \sim 10^{-5} \text{ GeV}^{-2} \\ = \frac{g_w^2}{m_W^2} \\ \sim \frac{4\pi \alpha_w}{M_W^2}$$

$$\alpha_w = 4.26 \times 10^{-3} = 0.5 \alpha$$

Weak & EM interaction of similar strength.

Apparent Difference between Weak & EM interactions is a long-distance illusion

Branching Ratios

$$B_r(z \rightarrow ll) = \frac{\Gamma(z \rightarrow ll)}{\Gamma_{\text{total}}} \quad \leftarrow \text{decay rate } (\Gamma \cong \frac{1}{2E} |M|^2 d\pi_{\text{Lips}})$$

$$\rightarrow \sum_i \Gamma(z \rightarrow i\bar{i})$$

$$\frac{B_r(z \rightarrow ee)}{B_r(z \rightarrow \mu\mu)} = \frac{\Gamma(z \rightarrow ee)}{\Gamma(z \rightarrow \mu\mu)} = \frac{\frac{1}{2E_z} |M(z \rightarrow ee)|^2 d\pi_{\text{Lips}}}{\frac{1}{2E_z} |M(z \rightarrow \mu\mu)|^2 d\pi_{\text{Lips}}} = \frac{|M(z \rightarrow ee)|^2}{|M(z \rightarrow \mu\mu)|^2} = 1$$

By Lep. universality