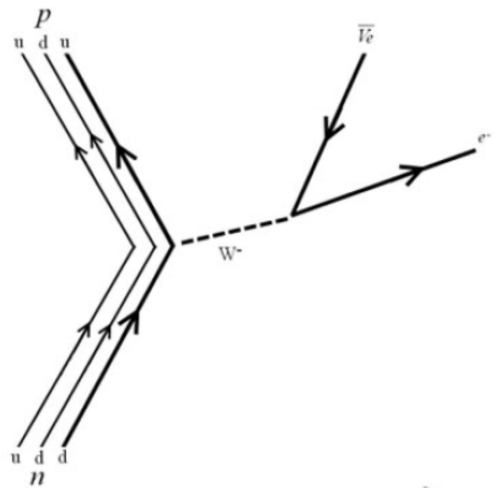
Lecture 9 : **Weak interactions - 2**

Decay of a free neutron : $n \rightarrow p + e^- + \overline{\nu}_e$



For detailed analysis see the Chapter 10 Section 3 of D.Griffiths textbook Int.to Elementary Particles, J.Wiley Pub.

If one treats the proton and neutron as point particles and further assumes that they interact with the W bosons as leptons do, then the total decay rate does not confirm the experimental value for the lifetime of the neutron which is 810 seconds. After performing several corrections on may obtain a better value closer to the experimental data.

Pion decay : $\pi^- \rightarrow l^- + \overline{\nu}_l$

The tree level diagram via W^- exchange leads to the decay rate

$$\Gamma = \frac{f_\pi^2}{\pi \hbar m_\pi^3} \left(\frac{g_w}{4M_W} \right)^4 m_l^2 (m_\pi^2 - m_l^2)^2$$

where f_π is the pion decay constant. The following branching ratio

$$\frac{\Gamma(\pi^- \rightarrow e^- + \overline{\nu}_e)}{\Gamma(\pi^- \rightarrow \mu^- + \overline{\nu}_\mu)} = \frac{m_e^2 (m_\pi^2 - m_e^2)^2}{m_\mu^2 (m_\pi^2 - m_\mu^2)^2} = 1.28 \times 10^{-4}$$

is quite close to the experimental value 1.23 x 10^{-4}.

Charged weak interactions of the quarks :

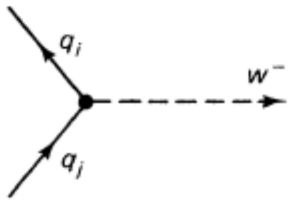
Lepton generations

$$\begin{pmatrix} \nu_e \\ e^- \end{pmatrix} \qquad \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix} \qquad \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}$$

Quark generations

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

The charged weak interaction vertex for the quarks is :



$$\frac{-ig_w}{2\sqrt{2}}\gamma^\mu(1-\gamma^5)U_{ij}$$

Here i = u, c, t quarks and j = d, s, b quarks and U_{ij} represents the Cabibbo-Kobayashi-Maskawa martix elements. 3 x 3 CKM matrix connects the weak interaction flavour and mass eigenstates of the d, s, b quarks :

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = U_{CKM} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Its elements have been experimentally measured (See Particle Data Booklet 2018 PDG http://pdg.lbl.gov/

$$\begin{pmatrix} 0.9745 \text{ to } 0.9760 & 0.217 \text{ to } 0.224 & 0.0018 \text{ to } 0.0045 \\ 0.217 \text{ to } 0.224 & 0.9737 \text{ to } 0.9753 & 0.036 \text{ to } 0.042 \\ 0.004 \text{ to } 0.013 & 0.035 \text{ to } 0.042 & 0.9991 \text{ to } 0.9994 \end{pmatrix}$$

Examples : See the textbook D.Griffiths' Int.to Elementary Particles Wiley Pub. Chapter 10 Section 5.

a) Leptonic decays

b) Semileptonic decays

Homework and Study Problems :

Examine and try to solve some of the problems listed from the same textbook by D.Griffiths.

Solve Problem 10.6

Solve Problem 10.7

Solve Problem 10.8

Solve Problem 10.9

Solve Problem 10.10

Solve Problem 10.11

Solve Problem 10.12

Solve Problem 10.13

Solve Problem 10.14

Solve Problem 10.15