Problem Sheet 2

3C24

February 23, 2001

1. Draw Feynman Diagrams for the following processes and show that the quantum numbers Baryon number, Lepton (flavour) number, electric charge and colour are conserved at the vertices:

   (i) $K^- \to \pi^0 \mu \bar{\nu_\mu}$

   (ii) $K^- \to \mu \bar{\nu_\mu}$

   (iii) Which of these two decays dominates? Why?

   (iv) From the above argument, which of the following decays would you expect to dominate?

   * $\pi^- \to \mu \bar{\nu_\mu}$
   * $\pi^- \to e \bar{\nu_e}$

   Explain what decay dominates and why.

2. i) Draw the Feynman Diagram for muon decay.

   ii) Write down the relationship between the width, Γ and the invariant amplitude and explain the meaning of all the terms.

   iii) If the muon lifetime is 2.2μsec, what is the width?

   iv) Which is easier to measure?

3. i) Draw the Feynman Diagrams for e^+e^- annihilation.

   ii) Explain why e^+e^- annihilation is such a good microscope on new particles.

   iii) At 9GeV, the weak diagram can be ignored. What should be the value of

$$R = \frac{\sigma(e^+e^- \to q\bar{q})}{\sigma(e^+e^- \to \mu^+\mu^-)} \quad (1)$$

   iv) Why does R tell us about the number of colours?

   v) Write down Q_{EM} for all the fermions

   vi) Show why $R \propto e_q^2$

4. i) In e^+e^- annihilation near a resonance, the expression for the invariant amplitude has to be derived taking into account the time dependence of the particle wave function. Why?

   ii) Starting from

$$\phi(t) = \psi(0)e^{-E_R t}e^{-t/2\tau} \quad (2)$$
$$= \psi(0)e^{-t[iE_R+\Gamma/2]} \quad (3)$$

show that the Invariant Amplitude is proportional to

$$\frac{1}{p^2 - m^2 - \frac{i\Gamma}{2}} \tag{4}$$

at, or very close to, the resonance.

iii) If there were a hypothetical resonance in pp scattering (a beam of protons incident on a stationary target) at p_{beam}=59 GeV, what would the mass of the resonance be?

5. i) Why are neutrinos different from all other fermions?

ii) Why does parity violation in the weak interaction mean that neutrinos must be massless? (At least in the Standard Model framework)

iii) Draw a diagram showing the topology of a muon decay to an electron and two neutrinos for the most energetic electrons

iv) If a lefthanded muon at rest decays, which way will the most energetic electrons emerge? Why?

v) How can you create a left-handed muon at rest?