

Particle Physics: Problem Sheet 2

Quantum Chromodynamics, e^+e^- Annihilation, DIS, Quark Model

1. Discuss evidence for the existence of quarks.
2. The ϕ meson has a mass $m_\phi = 1020 \text{ MeV}/c^2$ and decays as follows:

$$\begin{array}{ll}
 \phi \rightarrow K^+ K^- & 49\% \\
 \rightarrow K^0 \bar{K}^0 & 34\% \\
 \rightarrow \pi^+ \pi^- \pi^0 & 17\%
 \end{array}$$

The masses of the charged and neutral kaons and pions are $m_{K^+} = 493.7 \text{ MeV}/c^2$, $m_{K^0} = 497.7 \text{ MeV}/c^2$, $m_{\pi^+} = 139.6 \text{ MeV}/c^2$, $m_{\pi^0} = 135.0 \text{ MeV}/c^2$, respectively. What are the Q -values, i.e. total available kinetic energies, for these decays? Calculate the momentum of the K^0 in the rest frame of the ϕ meson. Draw Feynman diagrams of the above decays and explain why the decays to kaons is favoured despite the low Q value?

3. At very high beam momenta, $100 \text{ GeV}/c$, the total cross sections for π^+p and pp scattering is dominated by the exchange of a gluon between quarks inside the pions and protons. Draw a Feynman diagram for pp and π^+p scattering. Use the number of possible diagrams to calculate the ratio of cross sections $\frac{\sigma(\pi^+p)}{\sigma(pp)}$.
4. What are the charge, isospin, strangeness and baryon quantum numbers for the \bar{u} , \bar{d} and \bar{s} quarks? What are the quark contents of the Lambda hyperon, Λ^0 , and of the antiproton, \bar{p} ?
5. Which of these processes occur in Nature?

- a) $\pi^- p \rightarrow K^0 \Lambda^0$
- b) $\pi^- p \rightarrow \pi^0 \Lambda^0$
- c) $\pi^- p \rightarrow K^+ \Sigma^-$
- d) $\pi^- p \rightarrow \pi^+ \Sigma^-$

What quantum numbers are needed to solve this question? How are these related to the quark model?

6. Verify the quark model predictions given in the lectures for the masses of the following mesons: π , K , ρ , ω , K^* and ϕ . Assume $m_u = m_d = 310 \text{ MeV}$ and $A = (2m_u)^2 \cdot 160 \text{ MeV}$.