Kern- und Teilchenphysik II
Spring Term 2016

Exercise Sheet 4

Lecturers: Prof. F. Canelli, Prof. N. Serra
Assistant: Dr. A.de Cosa

1. Electron-positron annihilation

Consider the electron-positron annihilation to $\mu^+\mu^-$ and quarks:

a) Draw the allowed QED Feynman diagram/s for this two processes.

1 pt

b) Use the Feynman rules for QED to calculate the lowest-order matrix element for both the processes.

1 pt

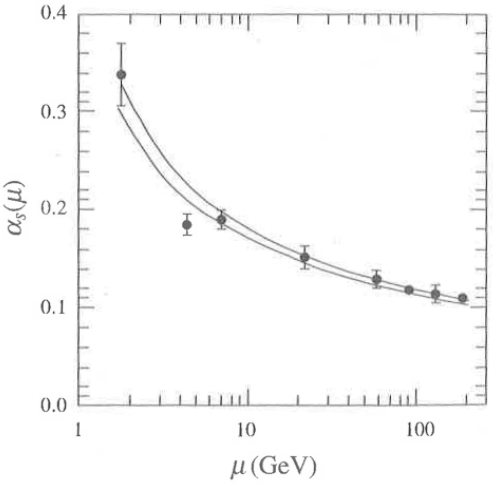
c) Compute the total-cross section for electron-positron annihilation to hadrons and its ratio, R, to $e^+e^- \to \mu^+\mu^-$.

1 pt

d) Corrections of order α_s can be taken into account considering a modification to R ratio:

$$R_s = R(1 + \alpha_s/\pi)$$

Where α_s is the strong running coupling constant, which depends on the interaction scale, μ, as shown in the figure. Assuming that this correction is valid up to high energies, estimate the cross-section ratio R_s at total centre of mass energies $E_{CM} = 2.8, 5$ and 15 GeV. How is going to change R if energy is high enough to produce $t\bar{t}$ pairs (where t is the top quark)?



3 pt

2. Drell-Yan process

At the Large Hadron Collider accelerator at CERN, beams of protons are used to produce hadron-hadron collisions.

a) Draw the diagram for the Drell-Yan process in proton-proton collisions ($pp \rightarrow \mu^+\mu^- X$), and compute its total cross-section.

1 pt

b) Express the cross-section in terms of the valence and sea quark PDFs, for lepton pair production in pp collisions. What does it change if we consider proton-antiproton collisions?

2 pt

c) The cross section of the Drell-Yan production of $\mu^+\mu^- pairs$ with variant mass Q^2 has been measured in $\pi^\pm$ interactions with carbon (equal number of protons and neurons). It was observed that:

$$\frac{\sigma(\pi^+ C \rightarrow \mu^+\mu^- X)}{\sigma(\pi^- C \rightarrow \mu^+\mu^- X)}$$

is approximately unity for small values of Q^2/s and decreases towards $\frac{1}{4}$ when Q^2/s approaches 1.

3 pt

3. Electron-proton inelastic scattering

The electron-proton inelastic scattering is described in terms of the two Lorentz-invariant quantities x and ν:

$$X = \frac{Q^2}{2p_2 \cdot q}$$

and

$$\nu = \frac{p_2 \cdot q}{m_p}$$

satisfying the relation:

$$2m_p\nu = W^2 + Q^2 = m_p^2$$

Show that the variable ν corresponds to the energy variation of the lepton (E-E') in the rest frame of the proton.

2 pt

4. Neutrino scattering

Indicate which of the following processes are not allowed and explain why:

a) $\bar{\nu_\mu} + u \rightarrow \mu^+ + d$

b) $\nu_\mu + d \to \mu^- + u$

c) $\nu_\mu + u \to \mu^+ + d$

d) $\bar{\nu_\mu} + d \to \mu^- + u$

1 pt