Name(s) : Group:

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Particle Physics – Exercise Sheet 4 – WS 2011/12

4.1 Bhabha scattering (30P)

In the high energy limit (m=0) the transition amplitudes in the helicity basis as function of the Mandelstam variables (s,t,u) were shown to be:

scattering	M_{fi}/e^2	annihilation	M_{fi}/e^2
$e^-_L\mu^+_R \to e^-_L\mu^+_R$	$-2u/t$	$e^-_L e^+_R \to \mu^-_L\mu^+_R$	$-2u/s$
$e^-_L\mu^+_L \to e^-_L\mu^+_L$	$+2s/t$	$e^-_L e^+_R \to \mu^-_R\mu^+_L$	$-2t/s$
$e^-_R\mu^+_R \to e^-_R\mu^+_R$	$+2s/t$	$e^-_R e^+_L \to \mu^-_L\mu^+_R$	$-2t/s$
$e^-_R\mu^+_L \to e^-_R\mu^+_L$	$-2u/t$	$e^-_R e^+_L \to \mu^-_R\mu^+_L$	$-2u/s$

Using these matrix elements demonstrate that in the CMS the spin averaged cross section for the reaction $e^-e^+ \to e^-e^+$ can be written as:

$$\frac{d\sigma}{d\Omega}(e^-e^+ \to e^-e^+) = \frac{\alpha^2}{2s^2}\left(\frac{s^2+u^2}{t^2} + \frac{2u^2}{ts} + \frac{t^2+u^2}{s^2}\right)$$

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4.2 Muon production at a hadron collider (30P)

Protons with an energy of 30 GeV collide head-on with antiprotons of the same energy. In a simplified picture, the protons (antiprotons) consist of the (anti)quark configuration uud ($\bar{u}\bar{u}\bar{d}$) and the (anti)quarks carry a fraction 1/3 of the proton momentum.

Consider the production of muon pairs ($\mu^+\mu^-$) in these collisions.

a) Draw the leading order QED Feynman diagrams for muon pair production.

b) What is the cross section for muon pair production? Start from the analogous process in e^+e^- collisions and treat all fermions as massless (high energy limit).

4.3 Deep inelastic scattering (40P)

In the e^-p-collider HERA at DESY electrons and protons with an energy of 27.5 GeV and 920 GeV, respectively, were collided.

a) Calculate the four-momentum transfer Q^2 from the measured energy E'_e of the scattered electron and its scattering angle θ relative to the beam direction. (NB: $E'_e >> m_e$)

b) Calculate the four-momentum transfer Q^2 for an event with $E'_e = 166\,\text{GeV}$ and $\theta = 60°$.

c) What is the spatial resolution power for an event as in (b)?