Theoretical Particle Physics I

Institut für Theoretische Teilchenphysik

Prof. Dr. Matthias Steinhauser, Dr. Daniel Stremmer, Dr. Marco Vitti, Pascal Reeck

Winter term 24/25 – Sheet 11 Due: 20.01.2025, Discussion: 22.01.2025

Exercise 1: Bhabha Scattering (10 points)

Consider the $2 \to 2$ scattering process

$$e^+(q_1)e^-(q_2) \to e^+(q_3)e^-(q_4),$$

where the electrons and positrons are considered to have a mass of zero.

a) Unlike the process considered in sheet 10, here two Feynman diagrams contribute to the amplitude. Draw them both, and write down the associated matrix elements.

b) Sum the two matrix elements and compute the squared total matrix element, averaging over incoming particle spins and summing over outgoing particle spins. Express your result in terms of the Mandelstam variables.
Think carefully about the relative sign between the matrix elements in their sum.
Hint: It is -1*. Why?*

c) Working in the centre-of-mass frame, write your result in terms of the centre-of-mass energy and the scattering angle between the incoming and outgoing particles, θ.

d) Plot the differential cross section $\mathrm{d}\sigma/\mathrm{d}\Omega$ as a function of θ for a value $\sqrt{s} = 10.58$ GeV, including also curves showing separately the contribution from each Feynman diagram and their interference.

Remark: It is allowed to use `FORM` to solve this exercise.

Exercise 2: Gordon identity

Proof the following equation:

$$\bar{u}(p')\gamma_\mu u(p) = \frac{1}{2m}\bar{u}(p')\Big[(p'+p)_\mu + i\sigma_{\mu\nu}(p'-p)^\nu\Big]u(p)\,,$$

with $\sigma_{\mu\nu} = \frac{i}{2}[\gamma_\mu, \gamma_\nu]$.
