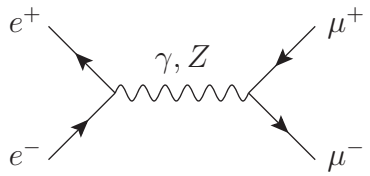
Physics Beyond The Standard Model

Exercise sheet 1

Exercise 1: $\underline{e^+e^- \to \mu^+\mu^-}$



The differential cross section for the scattering process $e^+e^- \to \mu^+\mu^-$ is given by

$$\frac{d\sigma}{d\cos\theta} = \frac{\pi\alpha^2}{2s}\beta\left\{Q_1\ (1+\beta^2\cos^2\theta) + Q_2\ (1-\beta^2) + Q_3\ 2\beta\cos\theta\right\},$$

with charge coefficients

$$\begin{aligned} Q_1 &= \frac{1}{4}\left[|Q_{LL}|^2 + |Q_{RR}|^2 + |Q_{LR}|^2 + |Q_{RL}|^2\right] \\ Q_2 &= \frac{1}{2}\Re e\left[Q_{LL}Q_{RL}^* + Q_{RR}Q_{LR}^*\right] \\ Q_3 &= \frac{1}{4}\left[|Q_{LL}|^2 + |Q_{RR}|^2 - |Q_{LR}|^2 - |Q_{RL}|^2\right], \end{aligned}$$

and helicity amplitudes

$$Q_{ab} = e_\mu e_e + \frac{Q_a^\mu Q_b^e}{\sin^2\theta_W\cos^2\theta_W}\frac{s}{s - M_Z^2 + iM_Z\Gamma_Z},$$

as well as the reduced couplings

$$Q_L^f = I_{3f} - e_f\sin^2\theta_W \qquad\qquad Q_R^f = -e_f\sin^2\theta_W.$$

The relative velocity of the muons is $\beta = \sqrt{1-4m_\mu^2/s}$. Determine the total cross section σ_{tot} and the forward-backward asymmetry

$$A_{FB} = \frac{\int_0^1 d\cos\theta\frac{d\sigma}{d\cos\theta} - \int_{-1}^0 d\cos\theta\frac{d\sigma}{d\cos\theta}}{\sigma_{tot}}.$$

Exercise 2: Two-particle phase space

Calculate the general massive two-particle phase space for a scattering process $f_1(k_1) + f_2(k_2) \to g_1(p_1) + g_2(p_2)$

$$dPS_2 = \frac{d^3p_1}{(2\pi)^3 2p_1^0} \frac{d^3p_2}{(2\pi)^3 2p_2^0} (2\pi)^4 \delta_4(k_1 + k_2 - p_1 - p_2)$$

with massless incoming particles $f_{1,2}$ and $p_i^0 = \sqrt{m_i^2 + \vec{p}_i^2}$. Determine furthermore the phase space in the special case of equal masses ($m_1 = m_2$), one ($m_1 = 0$), respectively two ($m_1 = m_2 = 0$) vanishing masses of the outgoing particles $g_{1,2}$.