Physikalisches Institut
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Theoretische Physik

Homework 3
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WS 02/03

Exercises on 'Elementary Particle Physics'

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1. Some kinematics

   Here are some smaller exercises to supplement the lectures.

   (a) It was shown that the incident flux in the lab is given by $\vec{F} = (\vec{v}_A - \vec{v}_B) 2E_A 2E_B$. Show that for antiparallel collisions between particles A and B:

   $$|\vec{F}| = 4(|\vec{p}_A| E_B + |\vec{p}_B| E_A) = 4\left((p_A \cdot p_B)^2 - m_A^2 m_B^2\right)^{1/2} \ .$$

   Is the flux *Lorentz* invariant? Comment your answer.

   (b) For spinless electron-muon scattering we found in the lecture that

   $$|\mathcal{M}|^2 = \frac{e^4}{q^4}[(p_A + p_C) \cdot (p_B + p_D)]^2 \ .$$

   Assume that $m_i = 0$ and verify that in the CMS

   $$\left.\frac{d\sigma}{d\Omega}\right|_{\text{CM}} = \frac{\alpha^2}{4s}\left(\frac{3 + \cos\theta}{1 - \cos\theta}\right)^2 \ ,$$

   where $\alpha = \frac{e^2}{4\pi^2}$.

   (c) The *Mandelstam* variables are defined by

   $$\begin{aligned} s &= (p_A + p_B)^2 \ , \\ t &= (p_A - p_C)^2 \ , \\ u &= (p_A - p_D)^2 \ . \end{aligned}$$

   Prove that $s + t + u = m_A^2 + m_B^2 + m_C^2 + m_D^2$.

   (d) Consider a decay $A \to B_1 + B_2$. Use the results of the lecture to show that

   $$\Gamma(A \to B_1 + B_2) = \frac{p_f}{32\pi^2 m_A^2} \int |\mathcal{M}|^2 d\Omega \ .$$