

Exercise Sheet 1 – Particle Physics – Summer 2016

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hand in: Mo 25.4. (in the lecture)

1.1 LHC proton beam energy (3 points)

The LHC proton beam consists of 2808 bunches, each bunch containing $1.15 \cdot 10^{11}$ protons. Calculate the total energy of the beam in Joule if each proton has an energy of 6.5 TeV.

1.2 Muon lifetime (3 points)

The muon is a lepton with mass of 105.7 MeV and lifetime of $2.2 \cdot 10^{-6}$ s. What is the energy and lifetime of a muon traveling with a speed of $0.99 \cdot c$? Calculate the distance the muon will travel before decaying.

1.3 Electrons on fixed target (3 points)

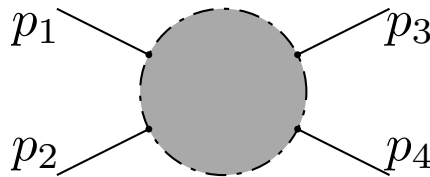
Consider the collision of 100 GeV electrons with a fixed target consisting of protons. Calculate the center-of-mass energy. What are the gamma factors of electrons and protons in the center-of-mass frame?

1.4 Photon emission by an electron in vacuum (3 points)

Show that process $e^- \rightarrow e^- \gamma$, emission of photon by an electron in vacuum, can not occur.

1.5 Mandelstam variables (4 points)

Consider the scattering process with two incoming and two outgoing particles.



The kinematics of the process can be described using Mandelstam variables defined as

1. $s = (p_1 + p_2)^2 = (p_3 + p_4)^2$ - c.m. energy
2. $t = (p_3 - p_1)^2 = (p_4 - p_2)^2$ - momentum transfer
3. $u = (p_4 - p_1)^2 = (p_3 - p_2)^2$

where p_i are four-momenta of the corresponding particles.

Show that $s + t + u = m_1^2 + m_2^2 + m_3^2 + m_4^2$, where m_i are masses of corresponding particles.