

## Particle Physics Homework

### 2. Decays and scattering processes

2023/09/25

(deadline: 2023/10/02)

1. Show that an emission process  $A \rightarrow A B$  is generally forbidden by energy and momentum conservation. Discuss the (unphysical) exceptions.
2. Consider a three-body decay  $X \rightarrow A B C$ . Show that the energy of particle  $A$  obeys the bound

$$E_A \leq \frac{m_X^2 + m_A^2 - (m_B + m_C)^2}{2m_X}.$$

Show that the equality sign holds only if particles  $B$  and  $C$  are at rest in their centre-of-mass frame. What configuration does this correspond to in the rest frame of particle  $X$ ?

3. Consider the scattering of electrons and positrons of energy  $E$  in a circular collider, and the pair-creation processes

$$e^- e^+ \rightarrow X \bar{X},$$

with  $X$  a particle of mass  $m_X$  and  $\bar{X}$  the corresponding antiparticle. Determine the energy and the magnitude of the spatial momentum of  $X$  and  $\bar{X}$  as a function of the lepton energy  $E$ , and determine the minimal lepton energy  $E_{\min}$  for which the pair  $X\bar{X}$  can be created.

#### Hints

Write the energy and momentum conservation relations in terms of four-vectors, rearrange this conveniently if needed, and get Lorentz invariants out of it.