

## Exercises for "Phenomenology of Particle Physics I"

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sheet 2

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[http://www.itp.phys.ethz.ch/education/lectures\\_hs08/PPPI](http://www.itp.phys.ethz.ch/education/lectures_hs08/PPPI) returned: 14.10.2008

### Exercise 3

Calculate the following for a  $2 \rightarrow 2$  scattering process ( $1 + 2 \rightarrow 3 + 4$ )

- (i) the energy  $E_i^*$  of the particles and their momenta  $|\vec{p}|$  and  $|\vec{p}'|$ . Determine the asymptotic behaviour of these quantities for  $s \gg m_i^2$ .
- (ii) Show that the scattering angle  $\Theta^*$  is given by

$$\cos \Theta^* = \frac{s(t - u) + (m_1^2 - m_2^2)(m_3^2 - m_4^2)}{\sqrt{\lambda(s, m_1^2, m_2^2)} \sqrt{\lambda(s, m_3^2, m_4^2)}}$$

where

$$\lambda(s, m_1^2, m_2^2) = (s - m_1^2 - m_2^2)^2 - 4m_1^2 m_2^2$$

(show also that  $s$ ,  $t$  and  $u$  are not independent because they satisfy  $s + t + u = \sum_i m_i^2$ ).

- (iii) Use the region of validity for the scattering angle formula to determine  $t_{\min}$  and  $t_{\max}$  and compute the asymptotic ( $s \gg m_i$ ) behaviour of  $t_{\min}$  for the general case ( $m_i \neq m_{i'}$ ) and for  $m_2 = m_4$ .

### Exercise 4

Consider the following process in the rest frame of the laboratory:

$pp \rightarrow ppp\bar{p}$ ; i.e. a proton collides with a proton at rest, afterwards there should be one additional proton and one additional antiproton.

- (i) How big is the threshold energy for this process in the center of mass frame, i.e. how big does the total energy of the protons need to be so this process can take place?
- (ii) How big is therefore the energy of the incident proton in the lab frame?

– please turn over –

### Exercise 5

The PEP2 storage ring (BABAR experiment) at the SLAC collides  $e^-$  with an energy of 9.0 GeV with  $e^+$  with an energy of 3.1 GeV to produce a  $B^0 - \bar{B}^0$  pair ( $m_{B^0} = m_{\bar{B}^0} = 5.280$  GeV). The  $B^0$  and the  $\bar{B}^0$  have a lifetime of  $\tau = 1.542 \cdot 10^{-12}$  s. How far do the  $B^0$  and the  $\bar{B}^0$  move between creation and decay (in the lab frame)?