

- 1) Three-body decay. A muon at rest decays into an electron and two neutrinos (mass less):

$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$$

In which direction are the neutrinos moving when the electron has its highest energy? Determine the maximal momentum and energy of the electron.

- 2) Neutrino beam. For neutrino oscillation experiments high energy neutrino beams are required which are produced by the decay of high energy pions and kaons:

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$K^+ \rightarrow \mu^+ + \nu_\mu$$

- a) Which fraction of the pions and kaons in a beam of energy 200 GeV decays over a distance of 100 m?
- b) How large are the minimal and maximal neutrino energies in each case. For this purpose derive first an expression for the dependence of the neutrino energy on the angle between the beam direction (momentum direction of pions and kaons) and the neutrino momentum. Assume the neutrino mass is zero.