Particle Physics – Exercise Sheet 1 – WS 2020/21

Lecturer: Prof. Dr. Hans-Christian Schultz-Coulon
discussed on Friday 13$^{\text{th}}$, November in the exercise groups

1.1 Neutral pion decay

Neutral pions π^0 decay into two photons with a lifetime of $8.4 \cdot 10^{-17}$ s. Consider the case in which the two photons are emitted along the y-axis in the π^0 rest frame (see Fig. 1).

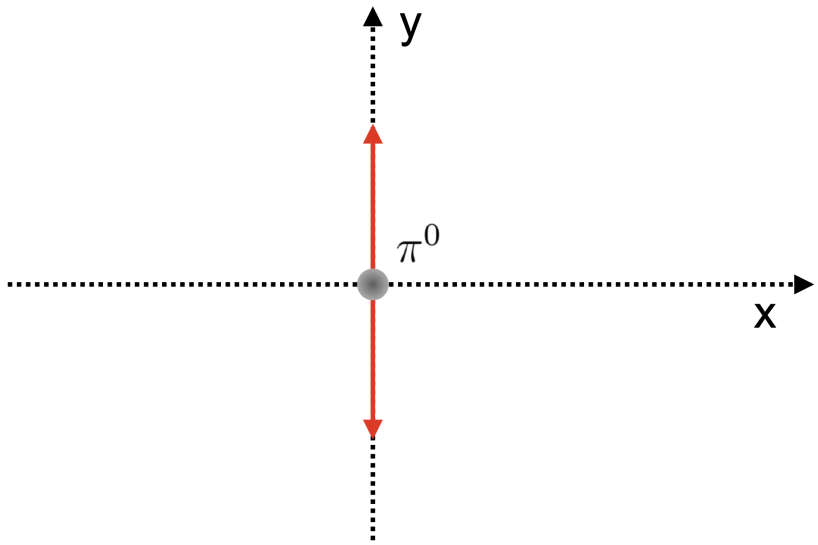

Figure 1: π^0 decay in its center-of-mass frame.

a) Calculate the opening angle of the two photons in the laboratory frame as a function of $\beta\gamma$ of the π^0.

b) An electromagnetic calorimeter is able to separate the showers induced by high-energy photons when the separation angle between the two photons is larger than 5°. The calorimeter is then used to detect π^0's. What is the largest π^0 energy such that any π^0 decay can be reconstructed as a pair of distinct photons?

1.2 β decay of triton

In the period before the discovery of the neutron many people thought that the nucleus consisted of protons and electrons, with the atomic number equal to the excess number of protons. Beta decay seemed to support this idea.

a) Use the position-momentum uncertainty relation to estimate the minimum momentum of an electron confined inside the ^{3}H nucleus (RMS charge radius = 2.15 fm) and calculate its corresponding kinetic energy.

b) Calculate the maximum kinetic energy of electrons emitted in the β decay of triton $^3\mathrm{H} \rightarrow {}^3\mathrm{He} + \mathrm{e}^- + \bar{\nu}_\mathrm{e}$ and compare it with the previous estimate.

Hint: The rest masses of the involved particles are:

m(^{3}H) = 2808.9211306 MeV
m(^{3}He) = 2808.391554 MeV
$\mathrm{m_e}$ = 0.511 MeV

1.3 Conservation laws

Which of the following reactions is allowed and what is the main interaction responsible for the process. Draw the corresponding lowest-order Feynman diagrams for the allowed processes.

a) $\Lambda \rightarrow p + \pi^-$

b) $\Lambda \rightarrow n + \gamma$

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

d) $\pi^0 \rightarrow \tau^+ + \tau^-$

e) $\pi^- + p \rightarrow \pi^0 + \Sigma^0$

f) $\rho^0 \rightarrow \pi^+ + \pi^-$

1.4 Resonance decay width

a) The Δ^{++} resonance ($m = 1.232\ \mathrm{GeV}$) has a full width of Γ = 120 MeV. Estimate the average distance that such a particle travels (decay length) with an energy of E = 200 GeV.

b) Given that the decay width of the W-boson is less than 6.5 GeV, estimate the limit for the corresponding lifetime.