Particle Physics - Exercises
06.01.2011

4.1 The Weak Interaction

Start with the important exercises 1, 6 and 7, then solve 2, 3 and 5.
We will discuss 4 together.

1. If the following weak decays and reactions are allowed draw the Feynman diagrams (including spectator quarks)! For forbidden processes give the violated quantity!

$n \rightarrow p\, e^-\, \bar{\nu}_e$

$\Sigma^- \rightarrow n\, \pi^-$ **[2]**
$\Sigma^+ \rightarrow n\, \pi^+$ **[2]**

$D^-(\bar{c}d) \rightarrow K^-\, \pi^+\, \pi^-$ **[2]**

$\nu_e\, p \rightarrow e^+\, n$ **[2]**

2. Why is the ratio of the partial decay widths $\Gamma(\Sigma^+ \rightarrow n\, e^+\, \nu_e) / \Gamma(\Sigma^- \rightarrow n\, e^-\, \bar{\nu}_e) < 5\ 10^{-3}$ so small? **[2]**

3. The Earth atmosphere is constantly bombarded by high energetic cosmic radiation consisting mainly of protons. These protons interact strongly in the upper atmosphere and produce large showers of hadrons which decay weakly into muons which on their turn decay to electrons through the decay chain $\pi^+ \rightarrow \mu^+\, \nu_\mu$, $\mu^+ \rightarrow \bar{\nu}_\mu\, e^+\, \nu_e$. Calculate the approximate ratio $R = (\nu_\mu + \bar{\nu}_\mu) / (\nu_e + \bar{\nu}_e)$ of muon to electron neutrinos in the GeV energy range in cosmic radiation at sea level! **[2]**

4.2 Interaction Strength and Cross sections

4. Consider the decay widths and lifetimes of the following Σ decays:

$\Sigma^{*0}(1385) \rightarrow \Lambda^0(1116)\,\pi^0$	$\Gamma \sim 36$ MeV
$\Sigma^0\ (1193) \rightarrow \Lambda^0\,\gamma$	$\tau \sim 10^{-19}$ s
$\Sigma^+\ (1189) \rightarrow n\,\pi^+,\ p\,\pi^0$	$\tau \sim 10^{-10}$ s.

a) Which interactions mediate these decays?
Draw the Feynman diagrams! **[3]**

b) What is the relative strength of these interactions? **[3]**

c) The fine structure or electromagnetic coupling constant is $\alpha = 1/137$.
What follows for the strength α_S of the strong interaction? **[2]**

5. At which mass becomes the gravitation between two identical charged particles equal to the Coulomb force? **[2]**

6. Calculate the cross section $\sigma = G_F^2\, s\, /\pi$ for the scattering of neutrinos on electrons and nucleons as a function of the neutrino energy E_ν! To achieve that: **[4]**
- Calculate the total reaction energy **s** in the reaction centre-of-mass system!
- Calculate the coupling constant G_F^2/π in units of $\hbar c$!

7. What is the mean free path of neutrinos with an energy of 1 GeV through the Earth ($M = 6\ 10^{24}$ kg, $R = 6400$ km)? Assume $\sigma(\nu N \rightarrow eN) = 10^{-38}\ cm^2\ (E_\nu/GeV)$. **[3]**