F Homework exercises III

This set of exercises should be completed and submitted via **Brightspace** by **Wednesday 31st of January 2018** before 17h.

1) In all known interactions between elementary particles, the conservation of electric charge, individual leptonic number, and baryon number applies. Taking these considerations into account, indicate which of the following processes are possible and which are impossible. In each case, provide a motivation for your choice. For those processes which are not possible, indicate the conservation rules that are not satisfied. For the physically allowed processes, discuss which of the three fundamental interactions (strong, weak, and/or electromagnetic) might mediate each process.

a) $\mu^+ \to e^+ + \nu_e$
b) $n \to p + e^- + \bar{\nu}_e$
c) $\pi^- + p \to n + \pi^0$
d) $p \to e^+ + \pi^0 + \nu_e$
e) $\Delta^0 \to p + \pi^-$
f) $p + \mu^- \to n + \bar{\nu}_\mu$
g) $e^+ + e^- \to \nu_\mu + \bar{\nu}_\mu$
h) $\nu_\tau + n \to p + \tau^-$

2) A Σ^- baryon at rest decays into a neutron and a π^-, that is, $\Sigma^- \to n + \pi^-$. Describe this decay process at the quark level, including drawing the corresponding diagram, and discuss which interaction might be responsible for it.

Calculate the energy that is released in the $\Sigma^- \to n + \pi^-$ decay process. Discuss what happens with this energy. Who receives more energy, the neutron or the pion? Compute the speed of the outgoing pion, explaining any assumptions that you might have used.

3) Draw the Feynman diagrams, including the particles that mediate the fundamental interactions, for the following processes:

a) $J/\psi \to e^+ + e^-$
b) $\pi^+ \to \mu^+ + \nu_\mu$
c) $e^+ + e^- \to b + \bar{b}$
d) $b \to c + \tau^- + \bar{\nu}_\tau$

Take into account how quantum numbers change between the initial and final state in order to determine which interaction is mediating the process.

4) Consider a very high energy muon neutrino ν_μ (with $E_\nu \gg 1$ GeV) that is traveling in water. The neutrino interacts with either the proton or the neutron of a water molecule by means of the following reaction, $\nu_\mu + X \to \mu^- + Y$, where X stands by either the proton or the neutron. Write the corresponding Feynman diagrams for these reactions (including the particles that mediate the interactions), and determine what is Y both when X is a proton and when it is a neutron. Which interactions has a higher likelihood to happen, $\nu_\mu + p$ or $\nu_\mu + n$?