ELEMENTARY PARTICLE PHYSICS

WS 2016/2017: Exercise sheet 2

5. Which of the suggested following reactions are allowed and which ones are forbidden - why ?

$\mu^+ \to e^+\nu_\mu\nu_e$	$\mu^+ \to e^+\bar{\nu}_\mu\nu_e$	$\mu^+ \to e^+\nu_\mu\bar{\nu}_e$
$\pi^+ \to \mu^+\nu_\mu$	$\pi^0 \to \gamma\gamma$	$\pi^- \to \pi^0 e^-\bar{\nu}_e$
$e^-p \to ne^-\pi^+$	$e^+e^- \to p\bar{p}$	$p\bar{p} \to e^+e^-$
$\mu^+e^- \to e^+\mu^-$	$\bar{\nu}_\mu p \to e^+n$	$\bar{\nu}_\mu p \to \mu^+n$
$\pi^-p \to \Lambda K^-$	$p\bar{p} \to n\pi^+\pi^-$	$\pi^-p \to \Lambda$
$\Delta^0 \to n\rho^0$	$K^+ \to \pi^+\pi^0$	$K^- \to \pi^-\mu^+\nu_\mu$

6. As an example for a 3-body decay we take the decay of a neutron into a proton, an electron and an electron-antineutrino, $n \to pe^-\bar{\nu}_e$.
a) In the rest frame of the neutron, compute the minimal and the maximal electron energy as function of the neutrino energy, setting both electron and neutrino mass to zero.
You may choose the z-direction to be parallel to the e^- momentum and the angle between e^-- and $\bar{\nu}_e$-momentum to be δ to arrive at

$$\begin{aligned} E_e^{min} &= \frac{1}{2}\frac{m_n^2 - m^2}{m_n} - E_\nu \\ E_e^{max} &= \frac{1}{2}\frac{m_n^2 - m^2 - 2m_nE_\nu}{m_n - 2E_\nu} \end{aligned} \tag{1}$$

Here m_n is the neutron and m the proton mass.
b) What is the minimum and the maximum neutrino energy and, by symmetry, the same for the electron ? Especially the minimum energy (can it be zero ?) is more a matter of thinking than computing.
c) Still neglecting the electron mass, how would the maximum electron energy change in the case the neutrino would be massive ?
d) Plot minimum (easy) and maximum (plot routine required) electron energy as function of neutrino energy (with massless neutrino again). In order to do so normalize all energies by the neutron mass so that everything becomes dimensionless and accessible to a computer program.

Such a plot is called a Dalitz plot.
e) Set now the proton mass also to zero. This is of course nonsense for neutron decay but there are 3-body decays with all three decay products being (almost) massless so you will have derived a Dalitz plot for these conditions.

7. Once upon a time it was planned to construct a linear e^+e^- collider, with an electron cannon at DESY in Hamburg and a positron cannon 33 km further north in Pinneberg which both accelerate these particles horizontally locally. The collisions were supposed to take place half way in between in Ellerhoop. What deviations from a straight propagation of the beams would have been necessary for the accelerator physicists to take care of ? Check whether gravity would have played a role ?
(radius of the earth 6378 km, beam energies $E(e^+) = E(e^-) = 500$ GeV)