Physikalisches Institut
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Theoretische Physik

Homework 10
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WS 02/03

Exercises on 'Elementary Particle Physics'

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1. *Muon Decay (Part II)*

   ...but here! To get the decay rate proceed as follows:

   (a) Use *Fermi*'s golden rule to write down the differential decay rate for this process. Which part is the phase space measure?

   (b) Proof that for a four momentum $k = (\omega, \vec{k})$ the relation

   $$\int \frac{d^3k}{2\omega} = \int d^4k\theta(\omega)\delta(k^2) \ ,$$

   where $\theta(\omega)$ is 1 for $\omega > 0$ and zero elsewhere, holds. Use this to integrate out the muon-neutrino momenta from the phase space measure.

   (c) Neglect the electron mass (why?) and show that in the muon rest frame

   $$2(k_1 \cdot p_1)(k_2 \cdot p_2) = (p_1 - k_1)^2(p_1 \cdot k_1) = (m^2 - 2mk_1^0)mk_1^0 \ .$$

   (d) Use your results to show that the differential decay rate in the muon rest frame can now be written as

   $$d\Gamma = \frac{G_F^2}{2m\pi^5}\frac{d^3k_1}{2k_1^0}\frac{d^3k_2}{2k_2^0}mk_1^0(m^2 - 2mk_1^0)\delta(m^2 - 2mk_1^0 - 2mk_2^0 + 2k_1^0k_2^0(1 - \cos\theta)) \ ,$$

   with m the muon mass and θ the angle between the emitted electron and anti-electron-neutrino.

   (e) Rewrite $d^3k_1 d^3k_2$ in terms of the corresponding energies and θ and perform the integration over θ. Which restrictions can you now read off for the values of k_1^0 and k_2^0?

   (f) Compute the decay rate.