Teoria do Campo – Problem Series 2

Curso de Engenharia Física Tecnológica – 2016/2017

`Due on the 26/5/2017`

`Version of 29/03/2017`

2.1 Show that for the decay, $P \to q_1 + q_2$, the expression for the total width can be written, in the rest frame of the decaying particle, as

$$\frac{d\Gamma}{d\Omega} = \frac{1}{32\pi^2} \frac{|\vec{q}_{1\text{cm}}|}{M^2} \left\langle |\mathcal{M}_{fi}|^2 \right\rangle$$

where $P^2 = M^2$.

2.2 Evaluate the traces necessary for Compton scattering (Eqs. (5.11), (5.12) e (5.13))

$$\sum_{s,s'} |\mathcal{M}_1|^2 = \text{Tr}\left[(\not{p}' + m)\Gamma_1(\not{p} + m)\overline{\Gamma}_1\right]$$

$$\sum_{s,s'} |\mathcal{M}_2|^2 = \text{Tr}\left[(\not{p}' + m)\Gamma_2(\not{p} + m)\overline{\Gamma}_2\right]$$

$$\sum_{s,s'} (\mathcal{M}_1\mathcal{M}_2^\dagger + \mathcal{M}_1^\dagger\mathcal{M}_2) = \text{Tr}\left[(\not{p}' + m)\Gamma_1(\not{p} + m)\overline{\Gamma}_2\right] + \text{Tr}\left[(\not{p}' + m)\Gamma_2(\not{p} + m)\overline{\Gamma}_1\right]$$

and show that the final result, Eq. (5.52), can be written as

$$\frac{1}{4}\sum_{s,s'}\sum_{\lambda,\lambda'}\{|\mathcal{M}_1|^2 + |\mathcal{M}_2|^2 + \mathcal{M}_1\mathcal{M}_2^\dagger + \mathcal{M}_1^\dagger\mathcal{M}_2\} = 2e^4\left[\left(\frac{k}{k'}\right) + \left(\frac{k'}{k}\right) - \sin^2\theta\right]$$

Note: These are complicated traces. You should learn how to use FeynCalc to evaluate these traces.

2.3 Consider in the SM of electroweak interactions the following processes:

$i)\ e^-e^+ \to \nu_e\overline{\nu}_e$ $\qquad ii)\ e^-e^+ \to \nu_\mu\overline{\nu}_\mu$

$iii)\ e^-e^+ \to e^-e^+\gamma$ $\qquad iv)\ e^-e^+ \to ZZ$

a) Use the program QGRAF to find the diagrams that contribute in lowest order. Do not neglect the Higgs interactions with fermions.

b) **Draw** the diagrams and indicate the relative signs among the diagrams. Do not do any calculations.

2.4 Consider the process $e^-(p_1) + e^+(p_2) \to \nu_e(p_3) + \overline{\nu}_e(p_4)$ in the SM.

a) Evaluate the differential cross section in the CM frame, as a function of the center of mass energy, $\sqrt{s}$, and scattering angle θ defined as the angle between the incoming electron and outgoing ν_e. Neglect the fermion masses.

b) Make a plot of the total cross section as a function of $\sqrt{s}$, for 10 GeV$< \sqrt{s} < 200$ GeV.

c) Use CalcHEP to evaluate this same process. Superimpose the points from CalcHEP on your plot. **Note**: You should check that the physical constants are the same in both cases.