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Exame de Teoria do Campo

Curso de Física Tecnológica - 2013/2014

To hand in until 4/06/2014, 18h

The problems are in the framework of the Standard Model of electroweak interactions. The couplings are in the textbook. The values of the masses and widths can be found in the *Particle Data Group* site at `http://pdg.lbl.gov/`.

I

Consider the process

$$\nu_e(p_1) + e^-(p_2) + \rightarrow \nu_e(p_3) + e^-(p_4)$$

a) Use the program **qgraf** to verify that at tree level the relative sign between the two diagrams is negative.

b) Use the technique of the *spinor products* to write the helicity amplitudes for the process. Neglect all the lepton masses.

c) Using the helicity amplitudes make a plot of the cross section in the center of mass frame for $\sqrt{s} \in [100, 500]$GeV. Express the cross section in picobarn (pb).

d) Use `CalcHEP` to evaluate this process and superimpose the points from `CalcHEP` on the curve that you have drawn in the previous section. Do not forget to verify if the constants have the same values in both programs.

II

Consider the process

$$H^0(p) \rightarrow W^+(k) + \tau^-(q_1) + \overline{\nu_\tau}(q_2)$$

in the standard model. **In all calculations neglect the neutrino and the τ masses, but not the W mass**.

1) Write the amplitude(s) for this process.

2) Calculate the decay width of the Higgs boson H in this channel. Take $M_H = 125$ GeV. Compare with the main decay channel for this mass, $H \rightarrow b\overline{b}$.

3) For $M_H = 125$ GeV, make a plot of the energy spectra of the W^+ boson, that is,

$$\frac{d\Gamma}{dE_W}$$

as a function of the energy of the W^+, E_W, in the rest frame of the Higgs boson.

4) In the frame where the W^+ moves with velocity $\vec{\beta}$, the longitudinal polarization vector can be written as

$$\varepsilon_L^\mu(k) = (\gamma\beta, \gamma\hat{\beta})$$

satisfying $\varepsilon_L(k) \cdot \varepsilon_L(k) = -1$ e $\varepsilon_L(k) \cdot k = 0$, where $\vec{\beta} = \vec{k}/E$, $\gamma^{-1} = \sqrt{1-\beta^2}$ and $\hat{\beta} = \vec{\beta}/\beta$.

Assume that we can measure the longitudinal polarization of the W^+ boson. Evaluate the decay width of the Higgs boson for this case, known as longitudinal width, Γ_L. Calculate the fraction of W^+ bosons that have this polarization, that is

$$R = \frac{\Gamma_L}{\Gamma_L + \Gamma_T}$$

Discuss the results. Note that you do not need to evaluate the longitudinal polarization Γ_T, because $\Gamma_{\text{Total}} = \Gamma_L + \Gamma_T$ and you have evaluated Γ_{Total} in the previous section.

NOTES

1. Do not try to make analytical integrations, do the integrations numerically.
2. The text `http://porthos.ist.utl.pt/CTQFT/files/RealExample.pdf` can help with the phase space of three particles in the final state.