PHY 2408 : LONG PROBLEM SET 1

Due: Feb 26th

1- Calculate the cross section for the process $e^+e^- \to Z \to \mu^-\mu^+$ in terms of the vector and axial couplings C_V and C_A, and given that the e^+e^- are unpolarized.

note: we did this in class but try to do it by yourself and if you get stuck, consult the notes

2- the forward-backward asymmetry that can be obtained from the process above can be written as: (see notes)

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} = \frac{3}{4} A_e A_\mu \,,$$

with

$$A_F = \frac{(c_L^e)^2 - (c_R^e)^2}{(c_L^e)^2 + (c_R^e)^2} = \frac{2 c_V^F c_A^F}{(c_V^F)^2 + (c_A^F)^2}$$

$\Rightarrow A_{FB} \propto c_V^2$ and

c_V is small for charged leptons

now $\frac{c_V}{c_A} \propto \sin^2\theta_W$ so given that $A_{Fb} \propto c_V^2$ and c_V is small, the measurement of $\sin^2\theta_W$ will not be as accurate. We can do better with either incoming polarized beams, or by measuring the polarization of the outgoing particles which is possible with τ leptons.

- Let's start with polarized incoming beams. Assume that the electron beam is fully polarized but that the positron beam is unpolarized.

Show that $$A_{LR} = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} = A_e$$

with σ_L as the cross section for a left-handed electron beam, and σ_R is the same for a right-handed beam. the cross section is at the Z^0 resonance.

PROBLEM 3

Now we consider the process $e^+e^- \to Z \to \tau^+\tau^-$

the polarization of the τ leptons can be inferred using the momentum of the τ decay products.

- Show that the average tau polarization: $\frac{N\uparrow - N\downarrow}{N\uparrow + N\downarrow} = -A_\tau$

where $N\uparrow$ and $N\downarrow$ are the number of tau leptons produced in right-handed and left-handed helicity states.

→ this allows a measurement of $\sin^2\theta_W$ with a quantity that involves c_V (and not c_V^2)

→ the measurement is done as a function of $\cos\theta$: $P_{\tau^-}(\cos\theta)$

→ note that at lep, A_{FB} can be extracted using measurements away from the resonance, where its value is not small.

PROBLEM 4

In lecture 9, we saw that the cross section for the process described by the Feynman diagram:

gives a cross section that diverges at high energies.

We know that we were missing a diagram:

Show that the missing diagram will cure the bad energy behaviour