Département de physique nucléaire et corpusculaire
Section de Physique
Université de Genève

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ADVANCED PARTICLE PHYSICS II

http://dpnc.unige.ch/∼bravar/PPA2

Exercises - 11^{th} Assignment

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1. Draw the lowest order Feynman diagram for the decay

$$\pi^0 \to \nu_\mu \bar{\nu}_\mu$$

   and explain why this decay is effectively forbidden. How would you design an experiment to search for this forbidden decay?

2. Assuming the Standard Model coupling, show that

$$\Gamma(Z \to \nu_e \bar{\nu}_e) = \frac{g_w^2}{96\pi \cos^2 \vartheta_W} M_Z \; .$$

3. Starting from the matrix element, work through the calculation for the $Z \to f\bar{f}$ partial decay rate. Express the decay rate in terms of the vector and axial-vector couplings of the Z boson. Taking $\sin^2 \vartheta_W = 0.2315$, show that

$$R_\mu \approx \frac{\Gamma(Z \to \mu^+\mu^-)}{\Gamma(Z \to \text{hadrons})} \approx \frac{1}{20} \; .$$

4. Calculate the partial width for the $W^+ \to e^+\nu_e$ decay mode. Then repeat the exercise for $W^+ \to \bar{d}u$ and $W^+ \to \bar{s}u$.

5. Predict the total width of the W^+ in the Standard Model.

6. There are ten possible lowest order Feynman diagrms for the process $e^+e^- \to \mu^-\bar{\nu}_\mu u\bar{d}$ of which only three involve a W^+W^- intermediate state. Draw the other seven diagrams (they are all s-channel processes involving a single W).

7. Assuming that the electron beam is 100% polarized and that the positron beam is unpolarized, show that

$$A_{LR} = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} = \frac{(c_L^{(e)})^2 - (c_R^{(e)})^2}{(c_L^{(e)})^2 + (c_R^{(e)})^2} = A_e \; ,$$

   where σ_L and σ_R are the measured cross sections at the Z pole for LH and RH electron beams. What happens if both beams are 100% polarized?

8. Your *new theroy* of weak interactions asserts that the W boson has spin 0 and that the coupling is scalar / pseudoscalar (i.e. always parity violating). In this *new theory* the W propagator and vertex factor become

$$\frac{-i}{q^2 - M_W^2} \approx \frac{i}{M_W^2} \quad \text{and} \quad \frac{-ig}{\sqrt{2}}(1 - \gamma_5) \ ,$$

respectively. Consider the inverse muon decay $\nu_\mu + e^- \rightarrow \nu_e + \mu^-$. Draw the corresponding Feynman diagram and calculate M. Then calculate the spin-avereged amplitude modulo squared $\langle |M|^2 \rangle$. Finally find the differential and total cross sections in the c.o.m. frame.