Département de physique nucléaire et corpusculaire
Section de Physique
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ADVANCED PARTICLE PHYSICS II

http://dpnc.unige.ch/∼bravar/PPA2

Exercises - 10^{th} Assignment

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$\nu - e$ **scattering**

1. Draw all possible Feynman diagrams for $\nu_e e^-$, $\bar{\nu}_e e^-$, $\nu_\mu e^-$, and $\bar{\nu}_\mu e^-$ scattering (CC and NC). Sketch the angular dependence of the cross sections for all processes.

2. In deriving the CC invariant neutrino - electron scattering amplitudes ($\nu_\mu e^- \to \mu^- \nu_e$) we ignored the lepton masses. Show that

$$\sigma(\nu_\mu e^- \to \mu^- \nu_e) = \frac{G_F^2}{\pi} \frac{(s - m_\mu^2)^2}{s} \ .$$

3. Assuming that $\nu_e e$ scattering occurs only via the charged current weak interaction $\nu_e e^- \to e^- \nu_e$, estimate the probability that a 10 MeV ν_e (the neutrino could have originated from the Sun) will interact with an e^- in the Earth along a trajectory passing through the center of the Earth (radius = 6400 km, uniform desnity $\rho = 5520\ \mathrm{kg/m^3}$).

4. What would be the angular dependence for

$$\bar{\nu} e^- \to \bar{\nu} e^- \quad \text{and} \quad \nu e^- \to \nu e^-$$

in a vector theory? Sketch it.

5. Perfrom all the steps needed to derive the NC cross section

$$\frac{\mathrm{d}\sigma(\nu_\mu e^- \to \nu_\mu e^-)}{\mathrm{d}y} \qquad \text{and} \qquad \frac{\mathrm{d}\sigma(\nu_\mu e^+ \to \nu_\mu e^+)}{\mathrm{d}y}$$

from the invaraint amplitude M_{fi}.

π^- **decay**

6. Can a π^- decay to a π^0 (draw the corresponding Feynman diagram)? Show that the partial decay rate for the decay $\pi^- \to \pi^0 e^- \bar{\nu}_e$ is given by

$$\Gamma(\pi^- \to \pi^0 e^- \bar{\nu}_e) = \frac{G_F^2}{30\pi^3}(\Delta m)^5 \ ,$$

where $\Delta m = m(\pi^-) - m(\pi^0) = 4.6$ MeV. Compare $\Gamma(\pi^- \to \pi^0 e^- \bar{\nu}_e)$ to $\Gamma(\pi^- \to \mu^- \bar{\nu}_\mu)$ and check the branching ratios in the PDG booklet.

$\nu-$**DIS scattering**

7. Derive the kinematical relations (Q^2, x, y, ν, and W^2) for $\nu_\mu N$ Deep Inelastic Scattering. The measured quantities are E_μ, ϑ_μ, and E_{had}.

8. Let $\sigma(\bar{\nu})/\sigma(\nu) = R$ in ν-nucleon scattering. Show that

$$\frac{\int x\, \bar{Q}(x)\, dx}{\int x\, Q(x)\, dx} = \frac{3R-1}{3-R} \ .$$

Assume an isoscalar target, i.e. a target containing the same number of protons and neutrons.

9. Compare νN to $e^\pm N$ scattering (N is an isoscalar target) and show that

$$\frac{\mathrm{d}\sigma(e^\pm N \to e^\pm N)}{\mathrm{d}x\, \mathrm{d}y} = \frac{2\pi\alpha^2}{q^4} xs \frac{5}{18}[Q(x) + \bar{Q}(x)][1 + (1-y)^2] \ .$$

This is equivalent to write

$$F_2^{\nu n} = \frac{18}{5} F_2^{eN} \ .$$