Keung's class March 17, 2006

Homework 3 Elementary Particle Physics (PHYSICS 552 UIC)

Be creative, and independent. Not think of this a homework, but fun.

Let parton distributions $u(x) = u_v(x) + \xi(x)$, $d(x) = d_v(x) + \xi(x)$, $\bar{u}(x) = \bar{d}(x) = \bar{s}(x) = s(x) = \xi(x)$ be defined for the proton. Note that $\xi(x)$ denotes the ocean quark distribution.

We study the di-lepton pair production $p\bar{p} \to \mu\bar{\nu}_\mu X$ for the invariant mass $m_W \gg m(\mu, \bar{\nu}_\mu) \gg m_N$ so that the W propagator effect is represented by G_F.

Carefully write down the differential cross-section $d\sigma/(dyd\tau)$ in terms of G_F, and $u_v(x), d_v(x)$, and $\xi(x)$

The dominant subprocess is $d + \bar{u} \to \mu + \bar{\nu}_\mu$. The transitional probability is

$$\sum |\mathcal{M}|^2 = 128 G_F^2 (d \cdot \nu_\mu)(\mu \cdot u) = 32 G_F^2 \hat{s}^2 \quad .$$

$$\hat{\sigma}(d\bar{u} \to \mu\bar{\nu}_\mu) = \int \frac{1}{4}\frac{1}{2\hat{s}} \sum |\mathcal{M}|^2 \frac{1}{8\pi}\frac{d\hat{u}}{\hat{s}} = \frac{G_F^2 \hat{s}}{6\pi}$$

$$d\sigma = \frac{1}{3}\left(\frac{G_F \hat{s}}{6\pi}\right) F(x_+, x_-) dx_+ dx_-$$

where the parton luminosity $F(x_+, x_-)$ is given by

$$\begin{aligned} F(x_+, x_-) &= d_p(x_+)\bar{u}_{\bar{p}}(x_-) + \bar{u}_p(x_+) d_{\bar{p}}(x_-) \\ &= d(x_+)u(x_-) + \xi(x_+)\xi(x_-) \\ &= [d_v(x_+) + \xi(x_+)][u_v(x_-) + \xi(x_-)] + \xi(x_+)\xi(x_-) \end{aligned}$$

So far, we ignore the quark mixing and the contribution from the strange quark. The more complete formulas is obtained by

$$\begin{aligned} F(x_+, x_-) = \quad & \cos^2\theta_C \quad \{[d_v(x_+) + \xi(x_+)][u_v(x_-) + \xi(x_-)] + \xi(x_+)\xi(x_-)\} \\ & + \sin^2\theta_C \quad \{\xi(x_+)[u_v(x_-) + \xi(x_-)] + \xi(x_+)\xi(x_-)\} \end{aligned}$$