

Homework 1 Elementary Particle Physics (PHYSICS 552 UIC)

In the homework of the first semester, we work out the matrix element for the process $e^-e^+ \rightarrow \tilde{\mu}^- \tilde{\mu}^+$,

$$\sum |\mathcal{M}|^2 = 16e^4(e^- \cdot \tilde{\mu}^+)(e^- \cdot \tilde{\mu}^-)/(e^- \cdot e^+) = 8e^4 ut/s^2 = 2e^4(1 - \cos \theta_{\text{CM}}) .$$

First review this formula from your returned homework, and verify that

$$d\sigma(e^-e^+ \rightarrow \tilde{\mu}^- \tilde{\mu}^+) = \frac{1}{8s} 2e^4(1 - \cos \theta_{\text{CM}}) \frac{1}{8\pi} \frac{d \cos \theta_{\text{CM}}}{2} .$$

After getting familiar with above algebra, we switch our attention to a hypothetical structure that the charged parton in the nucleon is spin-0 scalar quarks \tilde{q} . Convince yourself that

$$\sum |\mathcal{M}|^2(e\tilde{q} \rightarrow e'\tilde{q}') = -8e^4 e_{\tilde{q}}^2 \hat{s} \hat{u} / t^2 .$$

Work out the x, y dependence as follows,

$$\frac{d\sigma}{dQ^2 dx} = \sum_{\tilde{q}} \frac{e^4 e_{\tilde{q}}^2}{8\pi(Q^2)^2} 2(1-y) \tilde{q}(x) ,$$

where $s = (e + P)^2 = 2Em_N$, $y = (E - E')/E$, $Q^2 = -(e - e')^2$, $x = Q^2/[2m_N(E - E')]$, and the function $\tilde{q}(x)$ gives the probability density of the scalar quark at the fractional momentum x . Experimental measurements agrees with the spin- $\frac{1}{2}$ pattern $1 + (1 - y)^2$, disagrees totally with this scalar-quark form of y dependence $2(1 - y)$ and hence rule out the scalar quarks inside nucleon.