

PARTICLE PHYSICS 1 : EXERCISE 11

1) Spin and structure functions

If quarks were spin-0 particles, why would $F_1^{ep}(x)/F_2^{ep}(x)$ be zero?

2) Proton parton distribution functions

What is the expected value of $\int_0^1 (u(x) - \bar{u}(x)) dx$ for the proton?

3) Experimental measurements of the structure functions

Figure 1 shows the raw measurements of the structure function $F_2(x)$ in low-energy electron-deuterium scattering. When combined with the measurements of $F_2(x)$ for electron-proton scattering in Figure 2, it is found that :

$$\frac{\int_0^1 F_2^{eD}(x) dx}{\int_0^1 F_2^{ep}(x) dx} \simeq 0.84.$$

Write down the quark-parton model prediction for this ratio and determine the relative fraction of the momentum of proton carried by down/anti-down quarks compared to that carried by the up/anti-up quarks, f_d/f_u .

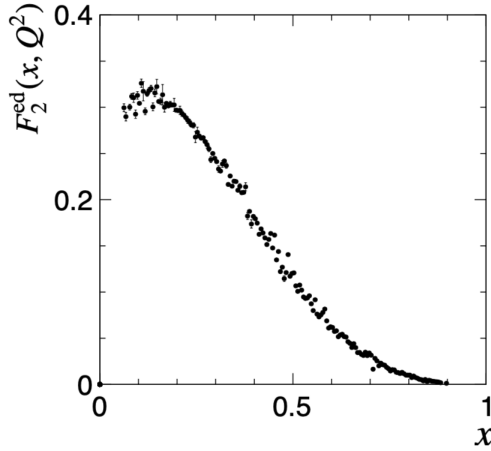


FIGURE 1 – SLAC measurements of $F_2^{eD}(x, Q^2)$ for $2 < Q^2 / \text{GeV}^2 < 30$.

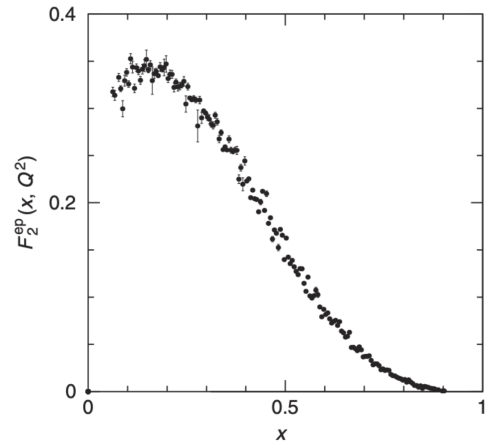


FIGURE 2 – SLAC measurements of $F_2^{ep}(x, Q^2)$ for $2 < Q^2 / \text{GeV}^2 < 30$. Data from Withlow et al. (1992).

4) Parton distribution functions in terms of valence and sea quarks

Including the contributions from strange quarks :

(a) show that $F_2^{ep}(x)$ can be written :

$$F_2^{ep}(x) = \frac{4}{9}x[u(x) + \bar{u}(x)] + \frac{1}{9}x[d(x) + \bar{d}(x) + s(x) + \bar{s}(x)]$$

where $s(x)$ and $\bar{s}(x)$ are the strange quark parton distribution functions of the proton.

(b) Find the corresponding expression for $F_2^{en}(x)$ and show that

$$\int_0^1 \frac{[F_2^{ep}(x) - F_2^{en}(x)]}{x} dx \approx \frac{1}{3} + \frac{2}{3} \int_0^1 [\bar{u}(x) - \bar{d}(x)] dx$$

and interpret the measured value of 0.24 ± 0.03 .

5) Kinematic variables in e^-p DIS

At the HERA collider, electrons of energy $E_1 = 27.5$ GeV collided with protons of energy $E_2 = 820$ GeV. In deep inelastic scattering at HERA, show that Bjorken x is given by

$$x = \frac{E_3}{E_2} \left[\frac{1 - \cos \theta}{2 - (E_3/E_1)(1 + \cos \theta)} \right]$$

where θ is the angle through which the electron has scattered and E_3 is the energy of the scattered electron. Estimate x and Q^2 for the event shown in Figure 3 assuming that the energy of the scattered electron is 250 GeV.

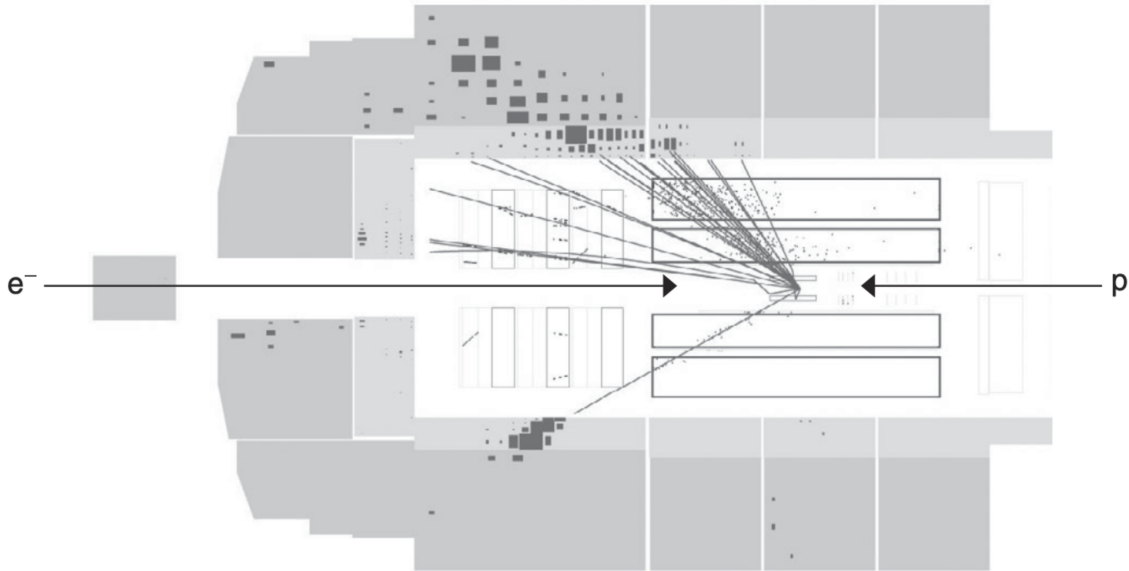


FIGURE 3 – A high-energy electron-proton collision in the H1 detector at HERA. In this event the electron (particle recorded in the lower part of the detector) is scattered through a large angle and the hadronic system from the break up of the proton forms a jet of particles.