The reaction for eN scattering in the parton model is described in terms of structure functions, W_1, W_2 (E: energy of the scattered electron, θ: scattering angle):

$$\frac{d^2\sigma}{dEd\Omega} = \frac{4\alpha^2 E^2}{Q^4}[2W_1 \sin^2\frac{\theta}{2} + W_2 \cos^2\frac{\theta}{2}]$$

W_1, W_2 describe the probability of finding a parton with longitudinal momentum xP_N inside the nucleon.

In the limit of large Q^2 the structure functions W_1, W_2 only depend on a dimensionless parameter x as follows (assuming only spin $1/2$ partons):

$$2MW_1(\nu, Q^2) = \sum_i Q_i^2 f_i(x) \; ; \; \nu W_2(\nu, Q^2) = x \sum_i Q_i^2 f_i(x)$$

M: nucleon mass, $\nu = pq/M$: energy loss of the scattered electron, Q^2: four-momentum transfer, $x = 2M\nu/Q^2$: Bjorken scaling parameter, Q_i: electric charge of partons

This phenomenon, i.e. that the structure functions only depend on x, is known as *Bjorken scaling*.

NOTE: THE FIGURES IN THIS SECTION ARE INTENDED TO SHOW THE REPRESENTATIVE DATA.
THEY ARE NOT MEANT TO BE COMPLETE COMPILATIONS OF ALL THE WORLD'S RELIABLE DATA.

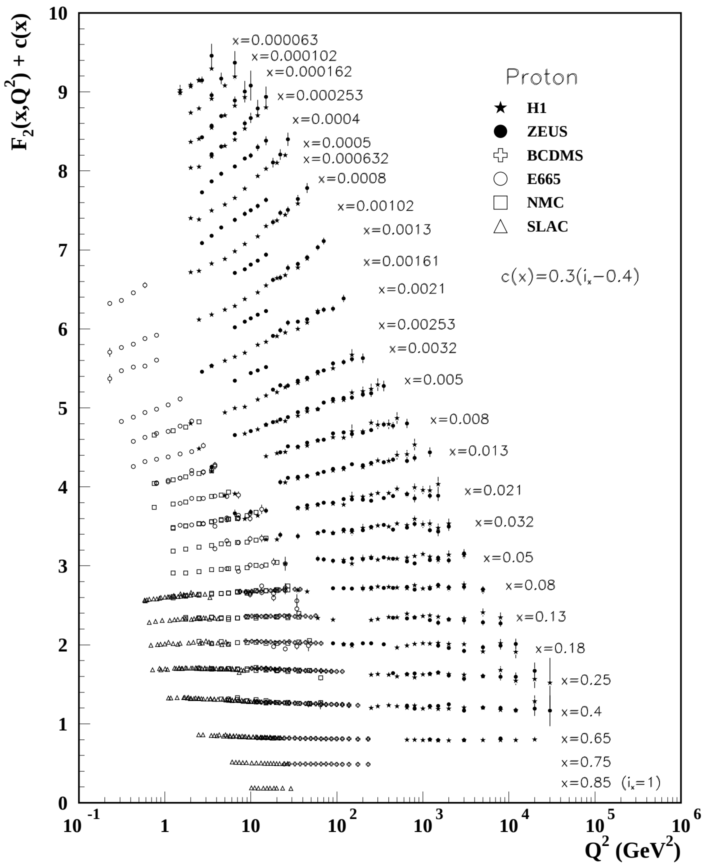

Figure 14.6: The proton structure function F_2^p measured in electromagnetic scattering of positrons on protons (collider experiments ZEUS and H1), in the kinematic domain of the HERA data, for $x > 0.00006$ (*cf.* Fig. 14.9 for data at smaller x and Q^2), and for electrons (SLAC) and muons (BCDMS, E665, NMC) on a fixed target. Statistical and systematic errors added in quadrature are shown. The data are plotted as a function of Q^2 in bins of fixed x. The ZEUS binning in x is used in this plot; all other data are rebinned to the x values of the ZEUS data. For the purpose of plotting, a constant $c(x) = 0.3(i_x - 0.4)$ is added to F_2^p, where i_x is the number of the x bin ranging from $i_x = 1$ ($x = 0.85$) to $i_x = 28$ ($x = 0.000063$). References: **H1**— C. Adloff *et al.*, Eur. Phys. J. **C21**, 33 (2001); C. Adloff *et al.*, Eur. Phys. J. **C13**, 609 (2000); **ZEUS**—S. Chekanov *et al.*, Eur. Phys. J. **C21**, 443 (2001); **BCDMS**—A.C. Benvenuti *et al.*, Phys. Lett. **B223**, 485 (1989) (as given in [46]); **E665**—M.R. Adams *et al.*, Phys. Rev. **D54**, 3006 (1996); **NMC**—M. Arneodo *et al.*, Nucl. Phys. **B483**, 3 (97); **SLAC**—L.W. Whitlow *et al.*, Phys. Lett. **B282**, 475 (1992).

from the Particle Data Group:

http://pdg.lbl.gov/2002/strucfunfigrpp.ps

1970:

Glashow, Iliopoulos and Maiani (GIM) predict the existence of a fourth quark, the charm quark. It has been observed that strangeness-changing neutral currents, $J^{\mu}_{had} = \bar{s}(x)\gamma_{\mu}(v - a\gamma_5)d(x)$, are extremely rare, e.g. $(\Delta S = 1)$

$$\frac{\Gamma(K^{\pm} \to \pi^{\pm}\nu\bar{\nu})}{\Gamma(K^{\pm} \to all)} = 10^{-10}$$

When introducing a fourth quark as follows

$$\begin{pmatrix} u \\ d' \end{pmatrix} ; \begin{pmatrix} c \\ s' \end{pmatrix}$$

with (θ_c : Cabibbo angle, V is unitary)

$$\begin{pmatrix} d' \\ s' \end{pmatrix} = V \begin{pmatrix} d \\ s \end{pmatrix} ; \; V = \begin{pmatrix} \cos\theta_c & \sin\theta_c \\ -\sin\theta_c & \cos\theta_c \end{pmatrix}$$

an additional term arises which at tree-level exactly cancels strangeness-changing neutral currents. In order for the mixing matrix V to cancel in the neutral current an equal number of quarks with charge $-2/3$ and $+1/3$ is needed.

It is recognized that with respect to the electroweak interaction leptons and quarks are intimately connected:

The Weinberg-Salam model is plagued by so-called anomalies (= divergent fermion triangle diagrams which can ruin renormalizability) which can be cured when including the quarks.

The Glashow-Weinberg-Salam (GWS) model also includes the electroweak interaction between quarks which is treated analogous to the one between leptons:
Charged Current (CC) (couples to the $W^{\pm}$ boson):

$$J^{\mu}_{CC} = \bar{\nu}_{e,L}\gamma^{\mu}e_L + \bar{u}_L\gamma^{\mu}V_{ud}d_L + \ldots$$

Neutral Current (NC) (couples to the Z^0 boson):

$$J^{\mu}_{NC} = \bar{e}\gamma^{\mu}(v_e - a_e\gamma_5)e + \bar{d}\gamma^{\mu}(v_d - a_d\gamma_5)d + \ldots$$

This gives rise to quark-induced anomalies, however with opposite sign, which cancel the lepton-induced anomalies.

The GWS model is part of the Standard Model describing the electroweak interaction between quarks and leptons.