16. Structure functions

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 16.6: 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. 16.9 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 $x$. Some points have been slightly offset in $Q^2$ for clarity. 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, $F_2^p$ has been multiplied by $2^{i_x}$, 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. (accepted for publication) hep-ex/0304003; 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 [54]); 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).
Figure 16.7: The deuteron structure function \( F_2^d \) measured in electromagnetic scattering of electrons (SLAC) and muons (BCDMS, E665, NMC) on a fixed target, shown as a function of \( Q^2 \) for bins of fixed \( x \). Statistical and systematic errors added in quadrature are shown. For the purpose of plotting, \( F_2^p \) has been multiplied by \( 2^{i_x} \), where \( i_x \) is the number of the \( x \) bin, ranging from 1 (\( x = 0.85 \)) to 29 (\( x = 0.0009 \)). References: BCDMS—A.C. Benvenuti et al., Phys. Lett. B237, 592 (1990). E665, NMC, SLAC—same references as Fig. 16.6.
Figure 16.8: The deuteron structure function $F_2$ measured in deep inelastic scattering of muons on a fixed target (NMC) is compared to the structure function $F_2$ from neutrino-iron scattering (CCFR) using $F_2^D = (5/18)F_2^\nu - x(s + \pi)/6$, where heavy target effects have been taken into account. The data are shown versus $Q^2$, for bins of fixed $x$. The NMC data have been rebinned to CCFR $x$ values. Statistical and systematic errors added in quadrature are shown. For the purpose of plotting, a constant $c(x) = 0.05i_x$ is added to $F_2$ where $i_x$ is the number of the $x$ bin, ranging from 0 ($x = 0.65$) to 10 ($x = 0.015$). References: NMC—M. Arneodo et al., Nucl. Phys. B483, 3 (97); CCFR/NuTeV—U.K. Yang et al., Phys. Rev. Lett. 86, 2741 (2001).
Figure 16.9: a) The proton structure function $F_2^p$ mostly at small $x$ and $Q^2$, measured in electromagnetic scattering of positrons (H1, ZEUS), electrons (SLAC), and muons (BCDMS, NMC) on protons. Lines are ZEUS and H1 parameterizations for lower (Regge) and higher (QCD) $Q^2$. Some points are only within 10% of the stated $Q^2$. Some points have been slightly offset in $x$ for clarity. References: ZEUS—J. Breitweg et al., Phys. Lett. B407, 432 (1997); J. Breitweg et al., Eur. Phys. J. C7, 609 (1999); J. Breitweg et al., Phys. Lett. B487, 53 (2000) (both data and ZEUS Regge parameterization); S. Chekanov et al., Eur. Phys. J. C21, 443 (2001); H1—C. Adloff et al., Nucl. Phys. B497, 3 (1997); C. Adloff et al., Eur. Phys. J. C21, 33 (2001) (both data and H1 QCD parameterization); BCDMS, NMC, SLAC—same references as Fig. 16.6.

b) The charm structure function $F_2^c(x)$, i.e. that part of the inclusive structure function $F_2^p$ arising from the production of charm quarks, measured in electromagnetic scattering of positrons on protons (H1, ZEUS) and muons on iron (EMC). The H1 points have been slightly offset in $x$ for clarity. For the purpose of plotting, a constant $c(Q) = 0.03i_Q$ is added to $F_2^c$ where $i_Q$ is the number of the $Q^2$ bin, ranging from $1 (Q^2 = 1.8 \text{ GeV}^2)$ to $8 (Q^2 = 130 \text{ GeV}^2)$. References: ZEUS—J. Breitweg et al., Eur. Phys. J. C12, 35 (2000); H1—C. Adloff et al., Z. Phys. C72, 593 (1996); C. Adloff et al., Phys. Lett. B528, 199 (2002); EMC—J.J. Aubert et al., Nucl. Phys. B213, 31 (1983).

Statistical and systematic errors added in quadrature are shown for both plots. The data are given as a function of $x$ in bins of $Q^2$. 
16. Structure functions

Figure 16.10: The structure function $x F_3^{γZ}$ measured in electroweak scattering of a) electrons on protons (H1 and ZEUS) and b) muons on carbon (BCDMS). The ZEUS points have been slightly offset in $x$ for clarity. References: H1—C. Adloff et al., Eur. Phys. J. (accepted for publication) hep-ex/0304003; ZEUS—S. Chekanov et al., Eur. Phys. J. C28, 175 (2003); BCDMS—A. Argento et al., Phys. Lett. B140, 142 (1984).

c) The structure function $x F_3$ of the nucleon measured in $ν$-Fe scattering. The data are plotted as a function of $Q^2$ in bins of fixed $x$. For the purpose of plotting, a constant $c(x) = 0.12(i_x - 1)$ is added to $xF_3$, where $i_x$ is the number of the $x$ bin as shown in the plot. References: CCFR—W.G. Seligman et al., Phys. Rev. Lett. 79, 1213 (1997).

Statistical and systematic errors added in quadrature are shown for all plots.
16. Structure functions

Figure 16.11: Top panel: The longitudinal structure function $F_L$ as a function of $x$ in bins of fixed $Q^2$ measured on the proton (except for the SLAC data which also contain deuterium data). BCDMS, NMC, and SLAC results are from measurements of $R$ (the ratio of longitudinal to transverse photon absorption cross sections) which are converted to $F_L$ by using the BDCMS parameterization of $F_2$ (A.C. Benvenuti et al., Phys. Lett. B223, 485 (1989)). It is assumed that the $Q^2$ dependence of the fix-target data is small within a given $Q^2$ bin. References: H1—C. Adloff et al., Eur. Phys. J. C21, 33 (2001); BCDMS—A. Benvenuti et al., Phys. Lett. B223, 485 (1989); NMC—M. Arneodo et al., Nucl. Phys. B483, 3 (1997); SLAC—L.W. Whitlow et al., Phys. Lett. B250, 193 (1990) and numerical values from the thesis of L.W. Whitlow (SLAC-357).

Bottom panel: Higher $Q^2$ values of the longitudinal structure function $F_L$ as a function of $Q^2$ given at the measured $x$ for $e^+/e^-$-proton scattering. Points have been slightly offset in $Q^2$ for clarity. References: H1—C. Adloff et al., Eur. Phys. J. (accepted for publication) hep-ex/0304003.

The H1 results shown in both plots require the assumption of the validity of the QCD form for the $F_2$ structure function in order to extract $F_L$. Statistical and systematic errors added in quadrature are shown for both plots.
Figure 16.12: The spin-dependent structure function $xg_1(x)$ of the proton, deuteron, and neutron (from $^3$He target) measured in deep inelastic scattering of polarized electrons/positrons: E142 ($Q^2 \sim 0.3 - 10$ GeV$^2$), E143 ($Q^2 \sim 0.3 - 10$ GeV$^2$), E154 ($Q^2 \sim 1 - 17$ GeV$^2$), E155 ($Q^2 \sim 1 - 40$ GeV$^2$), HERMES ($Q^2 \sim 0.8 - 20$ GeV$^2$) and muons: EMC ($Q^2 \sim 1.5 - 100$ GeV$^2$), SMC ($Q^2 \sim 0.01 - 100$ GeV$^2$), shown at the measured $Q^2$ (except for EMC data given $Q^2 = 10.7$ GeV$^2$ and E155 data given at $Q^2 = 5$ GeV$^2$). Note that $g_1^n(x)$ may also be extracted by taking the difference between $g_1^d(x)$ and $g_1^p(x)$, but these values have been omitted in the bottom plot for clarity. Statistical and systematic errors added in quadrature are shown. References: EMC—J. Ashman et al., Nucl. Phys. B328, 1 (1989); E142—P.L. Anthony et al., Phys. Rev. D54, 6620 (1996); E143—K. Abe et al., Phys. Rev. D58, 112003 (1998); SMC—B. Adeva et al., Phys. Rev. D58, 112001 (1998), B. Adeva et al., Phys. Rev. D60, 072004 (1999) and Erratum-Phys. Rev. D62, 079902 (2000); HERMES—A. Airapetian et al., Phys. Lett. B442, 484 (1998) and K. Ackerstaff et al., Phys. Lett. B404, 383 (1997); E154—K. Abe et al., Phys. Rev. Lett. 79, 26 (1997); E155—P.L. Anthony et al., Phys. Lett. B463, 339 (1999) and P.L. Anthony et al., Phys. Lett. B493, 19 (2000).
16. Structure functions

Figure 16.13: The hadronic structure function of the photon $F_2^\gamma$ divided by the fine structure constant $\alpha$ measured in $e^+e^-$ scattering, shown as a function of $Q^2$ for bins of $x$. Data points have been shifted to the nearest corresponding $x$ bin as given in the plot. Some points have been offset in $Q^2$ for clarity. Statistical and systematic errors added in quadrature are shown. For the purpose of plotting, a constant $c(x) = 1.5i_x$ is added to $F_2^\gamma/\alpha$ where $i_x$ is the number of the $x$ bin, ranging from 1 ($x = 0.0055$) to 8 ($x = 0.9$). References: