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 19.8:** The proton structure function $F_2^p$ measured in electromagnetic scattering of electrons and positrons on protons (collider experiments H1 and ZEUS for $Q^2 \geq 2 \text{ GeV}^2$), in the kinematic domain of the HERA data (see Fig. 19.10 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 H1+ZEUS combined binning in $x$ is used in this plot; all other data are rebinned to the $x$ values of these data. For the purpose of plotting, $F_2^p$ has been multiplied by $2^x$, where $i_x$ is the number of the $x$ bin, ranging from $i_x = 1$ ($x = 0.85$) to $i_x = 24$ ($x = 0.00005$). References: H1 and ZEUS—F.D. Aaron et al., JHEP 1001, 109 (2010); BCDMS—A.C. Benvenuti et al., Phys. Lett. B225, 485 (1989) (as given in [78]); E665—M.R. Adams et al., Phys. Rev. D54, 3006 (1996); NMC—M. Arneodo et al., Nucl. Phys. B483, 3 (1997); SLAC—L.W. Whitlow et al., Phys. Lett. B282, 475 (1992).
Figure 19.9: 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, $F_2^d$ has been multiplied by $2^x$, 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. 19.8.
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 and NuTeV) using $F_2^\mu = (5/18)F_2^\nu - x(s + \tilde{s})/6$, 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 and NuTeV $x$ values. 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 ($x = 0.75$) to 7 ($x = 0.175$). For $i_x = 8$ ($x = 0.125$) to 11 ($x = 0.015$), $2c(x)$ has been added. References: NMC—M. Arneodo et al., Nucl. Phys. B483, 3 (1997); CCFR/NuTeV—U.K. Yang et al., Phys. Rev. Lett. 86, 2741 (2001); NuTeV—M. Tzanov et al., Phys. Rev. D74, 012008 (2006).

b) The proton structure function $F_2^p$ mostly at small $x$ and $Q^2$, measured in electromagnetic scattering of electrons and positrons (H1, ZEUS), electrons (SLAC), and muons (BCDMS, NMC) on protons. Lines are ZEUS Regge and HERAPDF parameterizations for lower and higher $Q^2$, respectively. The width of the bins can be up to 10% of the stated $Q^2$. Some points have been slightly offset in $x$ for clarity. References: H1 and ZEUS—F.D. Aaron et al., JHEP 1001, 109 (2010) (data), POS ICHEP 2010, 168 (2010) (HERAPDF parameterization) ZEUS—J. Breitweg et al., Phys. Lett. B487, 53 (2000) (ZEUS Regge parameterization); BCDMS, NMC, SLAC—same references as Fig. 19.8.

Statistical and systematic errors added in quadrature are shown for both plots.
19. Structure functions

Figure 19.11: a) The charm-quark structure function $F_2^{cc}(x)$, 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). For the purpose of plotting, a constant $c(Q) = 0.07iQ^{1.7}$ is added to $F_2^{cc}$ where $iQ$ is the number of the $Q^2$ bin, ranging from 1 ($Q^2 = 2.5$ GeV$^2$) to 12 ($Q^2 = 2000$ GeV$^2$). References: **H1 and ZEUS run I combination**—H. Abramowicz et al., Eur. Phys. J. C73, 2311 (2013); **ZEUS run II**—H. Abramowicz et al., JHEP 05, 023 (2013); H. Abramowicz et al., JHEP 05, 097 (2013); **EMC**—J.J. Aubert et al., Nucl. Phys. B213, 31 (1983).

b) The bottom-quark structure function $F_2^{bb}(x)$. For the purpose of plotting, a constant $c(Q) = 0.01iQ^{1.6}$ is added to $F_2^{bb}$ where $iQ$ is the number of the $Q^2$ bin, ranging from 1 ($Q^2 = 5$ GeV$^2$) to 12 ($Q^2 = 2000$ GeV$^2$). References: **ZEUS**—S. Chekanov et al., Eur. Phys. J. C65, 65 (2010); H. Abramowicz et al., Eur. Phys. J. C69, 347 (2010); H. Abramowicz et al., Eur. Phys. J. C71, 1573 (2011); **H1**—F.D. Aaron et al., Eur. Phys. J. C65, 89 (2010).

For both plots, statistical and systematic errors added in quadrature are shown. The data are given as a function of $x$ in bins of $Q^2$. Points may have been slightly offset in $x$ for clarity. Some data have been rebinned to common $Q^2$ values. Also shown is the MSTW2008 parameterization given at several $Q^2$ values (A.D. Martin et al., Eur. Phys. J. C63, 189 (2009)).
Figure 19.12: 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—F.D. Aaron et al., JHEP 1209, 061 (2012); ZEUS—S. Chekanov et al., Eur. Phys. J. C28, 175 (2003); H. Abramowicz et al., Phys. Rev. D87, 052014 (2013); 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 $c(x) = 0.5(i_x - 1)$ is added to $x F_3$, where $i_x$ is the number of the $x$ bin as shown in the plot. The NuTeV and CHORUS points have been shifted to the nearest corresponding $x$ bin as given in the plot and slightly offset in $Q^2$ for clarity. References: CCFR—W.G. Seligman et al., Phys. Rev. Lett. 79, 1213 (1997); NuTeV—M. Tzanov et al., Phys. Rev. D74, 012008 (2006); CHORUS—G. Önengürt et al., Phys. Lett. B632, 65 (2006).

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

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. C30, 1 (2003).

The H1 results shown in the bottom plot 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 19.14: 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 \((Q^2 \sim 0.3 - 10 \text{ GeV}^2)\), E143 \((Q^2 \sim 0.3 - 10 \text{ GeV}^2)\), E154 \((Q^2 \sim 1 - 17 \text{ GeV}^2)\), E155 \((Q^2 \sim 1 - 40 \text{ GeV}^2)\), JLab E99-117 \((Q^2 \sim 2.71 - 4.83 \text{ GeV}^2)\), HERMES \((Q^2 \sim 0.18 - 20 \text{ GeV}^2)\), CLAS \((Q^2 \sim 1 - 5 \text{ GeV}^2)\) and muons: EMC \((Q^2 \sim 1.5 - 100 \text{ GeV}^2)\), SMC \((Q^2 \sim 0.01 - 100 \text{ GeV}^2)\), COMPASS \((Q^2 \sim 0.001 - 100 \text{ GeV}^2)\), shown at the measured \(Q^2\) (except for EMC data given at \(Q^2 = 10.7 \text{ GeV}^2\) and E155 data given at \(Q^2 = 5 \text{ GeV}^2\)). 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. Rev. D75, 012007 (2007) 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); Jlab-E99-117—X. Zheng et al., Phys. Rev. C70, 065207 (2004); COMPASS—V.Yu. Alexakhin et al., Phys. Lett. B647, 8 (2007), E.S. Ageev et al., Phys. Lett. B647, 330 (2007), and M.G. Alekseev et al., Phys. Lett. B690, 466 (2010); CLAS—K.V. Dharmawardane et al., Phys. Lett. B641, 11 (2006) (which also includes resonance region data not shown on this plot).
Figure 19.15: 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 ($x = 0.9$).