Chapter 1

Chapter 2

Chapter 3

Figure 3.1 : Total cross sections

Figure 3.2 : Total cross sections *continued*

Figure 3.3 : (a) Exchange of a ladder between two relatively-small hadrons, and (b) the same process viewed as the direct interaction of two larger hadrons

Figure 3.4 : pp elastic scattering data at $\sqrt{s} = 53$ GeV from the CERN ISR[62,63] with (a) the fit that determines the value of $\alpha'_{I\!P}$ and (b) the fit extended to larger values of $|t|$

Figure 3.5 : pp elastic scattering[64] at $\sqrt{s} = 53$ GeV and[65] $\bar{p}p$ at $\sqrt{s} =$ 1800 GeV, together with the curves (3.15) corresponding to $\alpha'_{I\!P} = 0.25$ GeV^{-2}

Figure 3.6 : Data[68,69] for the pion elastic form factor, with the fit (3.22)

Figure 3.7 : πp elastic scattering data[70] at $\sqrt{s} = 19.4$ GeV with the curve (3.21)

Figure 3.8 : Single and double pomeron exchange contributions to $d\sigma/dt$; the arrows indicate how they change as the energy increases

Figure 3.9 : Analytic continuation $s \to se^{i\pi}$

Figure 3.10 : pp elastic scattering data at large t (CHHAV collaboration[64]). The 62 GeV data are multiplied by 10.

Figure 3.11 : Elastic $\alpha\alpha$ scattering[78] at $\sqrt{s} = 126$ GeV

Figure 3.12 : Elastic scattering at $\sqrt{s} = 53$ GeV of antiprotons (upper points) and protons (lower points) on protons[81]

Figure 3.13 : pp elastic scattering data[64,82] at the largest available t, at various energies indicated in the figure as $\sqrt{s}$ in GeV. The line is $0.09\,t^{-8}$.

Figure 3.14 : Energy dependence of pp elastic scattering data at two values

Figure 3.27 : Ratios of number of events with $k_T \leq 0.2$ GeV to the number with $k_T \geq 0.5$ GeV for central production[120] of, from left to right, (a) $f_0(1370), f_0(1500), f_0(1710)$ and (b) $f_2(1270), f_2'(1520), f_2(1910), f_2(1950)$ in pp collisions at $\sqrt{s} = 29.1$ GeV.

Figure 3.28 : A 2^{++} glueball candidate[128], with the line $\alpha(t) = 1.08{+}0.25t$

Figure 3.29 : Deck mechanism for the reaction $\pi^- p \to (\pi^- \pi^+ \pi^-)p$

Figure 3.30 : Deck mechanism followed by rescattering

Chapter 4

Figure 4.1 : Comparison of $p_{\rm Lab}(\sigma^{\rm Tot}(\pi^- p) - \sigma^{\rm Tot}(\pi^+ p))$ with the Regge fit to high energy data

Figure 4.2 : Comparison of the low-energy $\pi^+ p$ and $\pi^- p$ total cross sections with the Regge fits to high energy data

Figure 4.3 : Differential cross section for $\pi^- p \to \pi^0 n$ at, from top to bottom, $p_{\rm Lab} = 3.67$, 5.85 and 13.3 GeV/c.

Figure 4.4 : Data for $\alpha_\rho(t)$ obtained at $t < 0$ from $\pi^- p$ charge-exchange data and the physical states at $t > 0$. The line is $\alpha(t) = 0.5 + 0.9t$ as in the fit of figure 2.8.

Figure 4.5 : $\pi^- p$ and $\pi^+ p$ differential cross sections, multiplied by $e^{b|t|}$ with $b = 7$ GeV^{-2} to make the plots clearer, at $\sqrt{s} = 10.4$ GeV

Figure 4.6 : $\pi^- p$ and $\pi^+ p$ polarisation at $p_{\rm Lab} = 6$ GeV/c (upper figure) and 10 GeV/c (lower figure)

Figure 4.7 : The moduli of the non-flip and flip helicity amplitudes in $\pi^\pm p$ scattering at $p_{\rm Lab} = 6$ GeV/c (upper figure) and 16 GeV/c (lower figure)

Chapter 5

to bottom, $E_\gamma = 6$, 9, 12 and 16 GeV

Figure 5.13 : Effective ω trajectory obtained from the π^0-photoproduction differential cross section. The line is $\alpha(t) = 0.44 + 0.92t$ as in figure 2.13.

Figure 5.14 : Differential cross section[206] for $\gamma p \to \pi^+ n$ at, from top to bottom, $E_\gamma = 5$, 8, 11 and 16 GeV

Figure 5.15 : Effective trajectory for $\gamma p \to \pi^+ n$

Chapter 6

the function D of (6.68)

Chapter 7

are the hard-pomeron component of the fit to $F_2(x,Q^2)$ shown in figure 7.12, normalised such that the hard pomeron is flavour-blind.

Figure 7.14 : Two-pomeron fit to $F_2(x,Q^2)$ at various values of Q^2 (thick curves), with two-loop unresummed perturbative-QCD fit[317] (broken curves)

Figure 7.15 : Data for $\sigma^{\gamma p}$. The upper curve is the extrapolation to $Q^2=0$ of the curves in figure 7.12; the lower curve omits the hard-pomeron term.

Figure 7.16 : Data for $\sigma^{\gamma\gamma}$. The lower curve is the soft-pomeron/reggeon curve of figure 5.3; the upper curve has an additional hard-pomeron term. The data are explained at the end of section 5.1.

Figure 7.17 : (a) Next-to-leading-order evolution with $\Lambda = 400$ MeV of the hard-pomeron coefficient $f_0(Q^2)$ (solid curve) and the fit (7.36) to the data (broken curve). (b) Evolution of the gluon structure function $xg(x,Q^2)$ at $x=0.01$.

Figure 7.18 : Gluon structure function $xg(x,Q^2)$ at (a) $Q^2 = 20$ and (b) 200 GeV^2. In each case the thick line is the distribution as described in the text and the thin lines are the limits extracted by conventional next-to-leading-order analysis of HERA data[328,324].

Figure 7.19 : $\gamma^*\gamma^*$ scattering

Figure 7.20 : Quark-box contribution to $\sigma^{\gamma^*\gamma^*}$

Figure 7.21 : Data from OPAL[330–332] (black points), L3[333,334] (open points) and ALEPH[335] (crosses) for the photon structure function. The Q^2 values are approximately 2, 5, 10 and 18 GeV^2. The dotted lines are without the hard pomeron and the solid lines with a hard pomeron contribution included.

Figure 7.22 : $\gamma\gamma \to$ charm: data from the L3 collaboration[336] with a fit using a hard pomeron and a reggeon component which are also shown separately

Figure 7.23 : $\sigma^{\gamma^*\gamma^*}$ at $Q_1^2 \approx Q_2^2 \approx 16$ GeV^2 from L3 (black points[342]) and OPAL (open points[343]) with the calculation of the box diagram of

figure 7.20

Figure 7.24 : $\gamma p \to J/\psi\, p$: H1 data[348] for (a) the total cross section and (b) the differential cross section. The fits are (7.66) with $\alpha_{I\!P_0}(0) = 1.44$ and $\alpha'_{I\!P_0} = 0.1\ \mathrm{GeV}^{-2}$.

Figure 7.25 : $\gamma p \to \rho p$: total cross section and differential cross section at $\sqrt{s} = 71.7$ GeV (lower-t data[349]) and 94 GeV (higher-t data[350]). The lower curves correspond to soft-pomeron and f_2, a_2 exchange; the upper curves include also hard-pomeron exchange.

Figure 7.26 : $\gamma p \to \phi p$: total cross section[351] and differential cross section at $\sqrt{s} = 71.7$ GeV (lower-t data[352]) and 94 GeV (higher-t data[350]). In each case the upper curve is the fit with hard and soft-pomeron terms and the lower curve is the soft-pomeron term.

Figure 7.27 : Cross section[353,348] for $\gamma^* p \to \rho p$ at (a), from top to bottom, Q^2 =2, 3, 5, 7, 11 and 20 GeV^2 and (b) at $W = 75$ GeV

Figure 7.28 : (a) Effective trajectory and (b) forward slope parameter for $\gamma^* p \to \rho p$. Data from H1 (black points)[354,355,348] and ZEUS (crosses)[356, 353]

Figure 7.29 : Two-gluon exchange mechanism for $\gamma^* p \to V\, p$

Figure 7.30 : Data[363,364] for σ_L/σ_T in (a) $\gamma p \to J/\psi\, p$ and (b) $\gamma p \to \rho\, p$

Figure 7.31 : Cross section[363] for $\gamma^* p \to J/\psi\ p$ at $Q^2 = 3.5\ \mathrm{GeV}^2$ (upper points) and 10.1 GeV^2 (lower points)

Figure 7.32 : H1 and ZEUS data for $\sigma(\gamma^* p \to Vp)$ with factors 9:1:2:8 removed, plotted against $Q^2 + M_V^2$

Figure 7.33 : Data for $\Gamma^V_{e^+e^-}$ with the factors 9:1:2:8:1 removed. Note the suppressed zero on the vertical scale.

Figure 7.34 : Data for J/ψ photoproduction; the solid curve corresponds to the two-pomeron fit (see figure 7.24a), and the thin curve to a calculation[368] of (7.71)

Figure 7.35 : Data for the r^5_{00} matrix element for $\gamma^* p \to \rho p$ from H1 (black

points)[364] and ZEUS (open points)[373]

Figure 7.1 : s-channel helicity-matrix elements in ρ^0 electroproduction[364, 373] showing that (7.77) is satisfied. The first ZEUS entry is from the low-Q^2 data, the second from the high-Q^2 data; see the text.

Figure 7.36 : Theoretical curves[379] for large-t photoproduction of ρ (upper curve) , ϕ (dashed curve) and J/ψ (thick curve)

Figure 7.37 : Diffractive electroproduction factorised as in (7.82)

Figure 7.38 : H1 data[382] for the diffractive structure function $F_2^{D(3)}$ at $\beta = 0.65$ and Q^2 ranging from 7.5 to 45 GeV^2

Figure 7.39 : H1 data[381] for forward proton production (black points) and neutron production (crosses) at $(x, Q^2) = (0.00010, 2.5), (0.00033, 4.4), (0.00104, 7.5)$ and $(0.00329, 13.3)$

Figure 7.40 : pp collisions with a very fast proton in the final state: production of (a) a high-P_T jet pair and (b) W boson.

Figure 7.41 : Diffractive dijet and trijet production

Figure 7.43 : Diffractive dijet production[400]: Q^2, p_T, M_X, W, β and ξ distributions. The histograms are described in the text.

Figure 7.44 : $C = -1$ exchange in $\gamma^*\gamma^* \to \eta_c + \eta_c$

Figure 7.45 : Ladder diagrams contributing to the perturbative odderon

Chapter 8

Figure 8.12 : pp scattering at $\sqrt{s} = 23$ GeV; the solid curve is obtained with parameter set (8.114). Experimental points are from [62].

Figure 8.1 : Values for the string tension σ_q and the vacuum parameters $\langle g^2 FF \rangle, \kappa, a$ obtained with four methods. Underlined numbers are input. Errors on the other numbers are estimated to be about 10%.

Figure 8.13 : Differential cross section[436] for $\gamma^* + p \to \rho + p$ at $Q^2 = 6$ GeV^2 and $\sqrt{s} \approx 20$ GeV with data[449]

Figure 8.14 : Data[450,451] for $e^+e^- \to \pi^+\pi^-$ and[452] $\gamma\, p \to \pi^+\pi^-\, p$ as a function of the invariant mass of the two pions. The curve is from [436].

Figure 8.15 : (a) The function $f(M)$ of (8.115). The dashed line is for the choice $c_{\rho(770)} = 1$, $c_{\rho(1450)} = -0.1$, $c_{\rho(1700)} = +0.1$ and the solid line for $c_{\rho(770)} = 1$, $c_{\rho(1450)} = +0.1$, $c_{\rho(1700)} = -0.1$. (b) In arbitrary units, the dipole-proton scattering amplitude (solid line) and products $R\psi^*_{2S}(R)\psi_\gamma(Q^2, 0.5, R)$ of a $2S$ wave function and the photon wave function for various values of the photon virtuality Q^2: long dash $Q^2 = 0$; short dash $Q^2 = 1$ GeV^2; dots $Q^2 = 20$ GeV^2.

Figure 8.16 : A next-to-leading-order contribution to the gluon ladder, the nonperturbative part of which gives rise to a soft-pomeron intercept larger than 1

Figure 8.17 : Forward-slope parameter $b = b(s, 0)$ for $\bar{p}p$ elastic scattering. The solid curve is from the model of section 8.5, using the parameter set (8.112), and the dashed curve is from Regge theory with a linear pomeron trajectory (3.19). The experimental points are triangle[472], star[473], and box[52].

Chapter 9

the hard pomeron (solid lines) and the soft pomeron (dashed lines)

Figure 9.11 : The longitudinal proton structure function[328] $F_L(x, Q^2)$ for $Q^2 = 12$, 15, 25 and 35 GeV^2. The solid line is the full result and the dashed line the hard-pomeron contribution.

Figure 9.12 : Integrated cross section for the reaction $\gamma^* p \to \gamma p$. (a) at $\langle W \rangle = 75$ GeV; (b) at $\langle Q^2 \rangle = 4.5$ GeV^2. The data are from [507].