Contents

Deep Inelastic Scattering

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The book gives an introduction to the ideas and results of deep inelastic scattering in the context of high energy particle physics. Both fixed target and the more recent collider experiments are covered. The advances in the understanding of QCD made possible by deep inelastic scattering are explained and prospects for electroweak physics at large momentum transfer are explored. Particular attention is paid to a clear exposition of the formalism that will be required to analyse the results from the high luminosity, high momentum transfer data expected from the upgrade of the HERA ep collider. The importance of accurate parton distribution functions for advances in hadron collider physics at the Tevatron and LHC is outlined. The book is intended for graduate students and others new to the field, but parts of it will also be relevant for advanced undergraduate courses in particle physics. The audience is similar to that of Renton (Renton 1990).

[*Initials after the chapter headings indicate the lead author. At the moment we are assuming a guidline of roughly 20pages/chapter.*]

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Outline

1.1 Chapter 1 – Introduction (RD)

The basic idea of scattering experiments as a probe of spatial structure. Relation between the spatial distribution of the target and the Fourier transform or momentum space ‘form factor’ or ‘structure function’. Illustrated by the example of spinless non-relativistic scattering of a point-like particle from a fixed potential. Momentum transfer and spatial resolution. Brief discussion of the experiments by Hofstadter on nuclei, including smearing of the quasi-elastic electron-nucleon peak in high-resolution electron-nucleus scattering. [*Similar to account in Perkins (Perkins 1987) ch. 6*] An historical route into the structure of the book is provided via a description of the SLAC (quarks) and Gargamelle (neutral current) experiments which introduces some of the key ideas.

1.2 Chapter 2 – The quark-parton model (AD)

The basic diagram and formulae for the high energy electromagnetic scattering of two spin $\frac{1}{2}$ point-like particles (either $e\mu$ or eq) - discussion of the essentials of the Feynman diagram (coupling, propagator, angular factors from external spin wave-functions) [*Appendix for details and definition of conventions.*]. Extend to lepton scattering off quarks in a proton by introducing parton momentum distribution functions (pdfs) - ignore masses and transverse momentum - to give the expression for $d^2\sigma/dxdy$ or $d^2\sigma/dxdQ^2$ with $F_L = 0$. Explain how this can give a model for deep inelastic scattering provided all final state hadronic particles are summed over - ie ignoring fragmentation because it has probability one. Either here or in Ch.3 a discussion of the different time-scales involved. Similarly for the basic formulae for neutrino scattering. Identification of partons with quarks - the quark-parton model (QPM). Scaling and basic results for u d s and fact that momentum does not add up so there must be something missing. Other QPM sum rules. [*Plenty of examples: Bowler (1989), Chs 9 & 10, Close (1979) Ch 9 & 11, Halzen & Martin (1984) Ch 9*]

1.3 Chapter 3 – QCD and scaling violations (RD)

Exact scaling of F_2 must be violated if the quarks are bound. An outline of QCD. Gluons. Discuss the QCD Compton and BGF diagrams. Idea of the running coupling constant, asymptotic freedom, confinement. Factorisation and scales. Renormalisation schemes. Splitting and coefficient functions. The QCD improved QPM. Prediction of the Q^2 dependence of scaling violations at LO and NLO, DGLAP equations for pdfs. Brief account of predictions for small x, DLLA, BFKL, other resummations and Catani-Thorne ideas. [*Follow Ellis et al (1996) Ch 4, extensive detail in Cooper-Sarkar et al (1998).*]

1.4 Chapter 4 – Formalism for lepton induced DIS (AD)

Full formalism for μN, $\nu(\bar{\nu})N$ and $e^{\pm}p$ at high energies, both NC & CC. Give the general expressions for $d^2\sigma/dxdy$ for the various DIS processes in terms of the structure functions (F_2, F_L and xF_3). Relying heavily on others (Roberts 1990, Ellis et al 1996, HERA Workshops) - give a careful account of how the structure functions for NC ($e^{\pm}p \to e^{\pm}X$ via γ^*, Z^0 exchange), CC ($e^{\pm}p \to \bar{\nu}(\nu)X$ via $W^{\pm}$ exchange) are related to the quark pdfs through the electroweak couplings. Include polarised $e^{\pm}$. Discussion of which structure functions are important where. Discussion of QED radiative corrections by analogy with QCD corrections.

1.5 Chapter 5 –ℓDIS, experiments and data (RD)

Summary of the key fixed target experiments (BCDMS, NMC, E665, CCFR), ditto for HERA (H1, ZEUS). Brief account of kinematics, basic detector techniques, resolutions, trigger. Comment on strengths and weaknesses. Summary of what has been measured (mainly F_2, some F_L), kinematic region covered by the data. Precision and consistency. [*Abbreviate and update relevant sections of CDD review (Cooper-Sarkar et al 1998, secs. 4, 5) and Doyle (1998).*] Summary of nuclear effects - Fermi motion, shadowing, EMC effect. Comment on use of nuclear targets for various QCD studies. Importance of various corrections to obtain nucleon data used as input for accurate pdfs.

1.6 Chapter 6 – Hadronic final states (AD)

Dijets - Discuss the QCD Compton and BGF singularities in the final state. Extension of kinematic variables from 2 to 5. Introduce x_p and z by analogy to x and y of eq scattering and mention ϕ dependence. Measurement of α_S. Forward jets as a handle on BFKL. QCD instantons and their hadronic final state characteristics. Introduce rapidity plateau in non-diffractive processes and exponential suppression of gaps. Inclusive diffractive processes and extension of formalism to $F_2^{D(4)}$ (+ mention ϕ dependence). Quasi-elastic processes such as vector meson production and relation to the gluon and the transition region.

1.7 Chapter 7 – Hadron induced DIS (RD)

The generic formula for hard hadronic processes via the convolution of parton densities with the cross-section for the hard partonic interaction. The additional complications of jet measurement, fragmentation dependence and scale uncertainties. Drell-Yan processes including W and Z. High p_T jets. Direct photon production. Outline of other theoretical problems. Summary of recent experiments and data. [*Refer to Ellis et al (1996) for more theoretical details.*]

1.8 Chapter 8 – Extraction of parton densities (AD)

Principles of what has to be done. Input data choices. Outline of NLO fitting procedures using x space and improved methods using moments space. The parameterisation of the parton densities at Q_0^2 and such constraints as there are. Include input from Regge at low x and lattice gauge theory for lower moments at high x. Introduce the transition region. Discussion of results using recent MRS and CTEQ global fits. Valence, sea and gluon pdfs, discussion of general behaviours - compare with expectations from QCD (as outlined in Ch 3). Heavy flavours and F_2^c. Problem of estimating errors. Universality of pdfs and importance for future experiments, both colliders (HERA, tevatron and LHC) and high energy astroparticle physics.

1.9 Chapter 9 – Polarised DIS and the enigma of nucleon spin (both)

Brief account of the formalism and definition of polarised pdfs for virtual photon exchange. Outline of the SLAC, SMC and HERMES experiments and data. The enigma of what is carrying the nucleon's spin. DGLAP evolution for polarised pdfs. Summary of NLO fits - lack of knowledge of gluon - problem of extrapolation to small x. Sum rules. Semi-inclusive measurements. Prospects for future experiments, including an outline of the formalism needed for a fully polarised HERA ep collider. [*There are quite a number of good reviews.*]

1.10 Chapter 10 – Beyond the Standard Model (both)

Start with the SM. Separate uncertainties on EW parameter and pdf extraction. Accuracy of cross-section predictions at high Q^2 and large x. Discussion of eq contact interactions and input from $e^+e^- \to$ hadrons, Tevatron, Drell Yan and atomic parity violation experiments - how they affect the cross-sections. Ditto leptoquarks. Sensitivity to TeV scale extra space-time dimensions...

Appendices (both)

Summary of our conventions for metrics, Feynman diagrams etc. Summary of QCD and EW Lagragians, or whatever is needed to establish notation for couplings in the cross-section formulae. Put some of the heavier calculations here if we think we should outline them at all. Ditto accounts of the various ways of calculating x, Q^2 at HERA. Exercises should be available for each chapter and solutions or hints provided in the appendix.

Bibliography

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