NON-PERTURBATIVE ASPECTS OF DEEP INELASTIC SCATTERING

Wolodymyr MELNITCHOUK B.Sc.(Hons.)

Thesis submitted for the degree of
Doctor of Philosophy
at
The University of Adelaide
(Department of Physics and Mathematical Physics)
June 1993

Awarded 1994
# Contents

1 INTRODUCTION

2 INCLUSIVE DEEP INELASTIC SCATTERING
   2.1 DIS Structure Functions ........................................ 6
     2.1.1 Quark Parton Model ........................................ 9
     2.1.2 Light-Cone Dominance ...................................... 10
     2.1.3 Operator Product Expansion ................................ 10
     2.1.4 Renormalisation Group Equations ............................. 13
     2.2 The Truncated Hadronic Tensor .................................. 16
     2.2.1 Dirac and Lorentz Structure ................................. 16
     2.2.2 Scaling Properties of the Functions $\bar{W}$ ................ 17
   2.3 Relativistic Model of the Nucleon Structure Function .............. 21
     2.3.1 Relativistic Vertex Functions ............................... 21
     2.3.2 Numerical Results ........................................... 24

3 FLAVOUR CONTENT OF THE PROTON .................................. 29
   3.1 Mesons in the Nucleon — A Model of the Nucleon Sea ............ 30
     3.1.1 Pions — Covariant Formulation .............................. 32
     3.1.2 Pions — TOPT in the IMF ................................... 37
     3.1.3 Heavier Mesons .............................................. 43
     3.1.4 Nucleon Quark Distributions ................................ 51
     3.1.5 Renormalisation, Incoherence ................................ 56
   3.2 Flavour Asymmetry in the Proton Sea ............................ 58
   3.3 Gottfried Sum Rule .............................................. 65

4 SHADOWING IN NUCLEAR DIS ......................................... 75
   4.1 Physics of Shadowing ............................................ 76
     4.1.1 Glauber Multiple Scattering Formalism ....................... 76
     4.1.2 Hadronic Structure of $\gamma^*$ ............................. 79
     4.1.3 Diffractive Scattering from Partons ........................ 81
   4.2 Shadowing in Deuterium ......................................... 86
ABSTRACT

This thesis deals with the consistent description of the quark structure of hadrons and nuclei in deep inelastic scattering, with particular emphasis on the non-perturbative region of QCD. Using a novel new approach based on the expansion of the truncated nucleon tensor, we construct a relativistic quark model which enables the nucleon valence quark distributions to be computed. For the sea quarks we scrutinise a model in which the nucleon has an extended structure due to its virtual meson and baryon components, and discuss tests that may reveal such structure experimentally. For scattering from nuclei, we show how structure functions of composite particles can be calculated from the truncated nucleon tensor, and relativistic nucleon—nucleus vertex functions. This allows for a self-consistent treatment of the off-shell properties of bound nucleons. As a result we can understand for the first time the conditions under which the convolution model of deep inelastic scattering can be justified, however, we find that these are generally not satisfied. On the other hand, within our formalism the traditional convolution approach is bypassed altogether. We also calculate the corrections to nuclear structure functions due to shadowing at small Bjorken-$x$, within a model in which both mesons and partons play distinct roles. Finally, we investigate the possibility of performing (spin-dependent) inclusive hadron leptonproduction experiments as a means of testing directly the relevance of hadronic variables in high energy reactions.