IN THE NAME OF GOD

CALCULATION OF THE PROTON STRUCTURE FUNCTIONS IN NEUTRAL CURRENT DEEP INELASTIC SCATTERING ELECTRON +PROTON $\rightarrow$ ELECTRON + X

BY

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Dedicated To My wife

For her patience, forbearance and encouragement

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Abstract

Calculation of the structure functions in neutral current deep inelastic Scattering electron + proton → electron + X

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High energy,i.e. deep-inelastic electron-proton collision, is the cleanest way to study the inner structure of the proton. The electron can probe the proton an its constituents via the electromagnetic interaction, much in the spirit of the famous Rutherford experiment which established the modern picture of the atom. The electrons thereby send virtual photons towards the proton scanning its internal structure like an electron microscope which renders the image of an object. The unknown proton structure is measured by two functions F_2 and F_L, which correspond to different polarization states of the exchanged virtual photon. While the structure function F_2 in a large part of the measured kinematic region is identical to the deep-inelastic scattering cross section itself the determination of F_L is experimentally much more challenging. The photons which mediate the electromagnetic interaction do not couple directly to electrically neutral gluons but to charged quarks. However the presence of gluons inside the proton can be felt by the struck quark. At large quark momenta x, quarks loose momentum by radiating gluons prior to the interaction with the virtual photon. Gluons can produce pairs of sea quarks which enhances the amount of quarks available for interaction with the proton at low momenta x. These processes can be resolved if the resolution of the photon probe, determined by its virtuality Q^2 is sufficiently large. The amount of quark scattering partners is thus expected to increase with Q^2, i.e. at low x the structure function $F_2(x,Q^2)$ should rise with Q^2, and this rise is determined by the gluon momentum distribution. These so-called scaling violations are indeed observed and they are well described by the theoretical calculation using QCD. In this thesis, a method to obtain an approximate relation between the reduced cross section derivative and the $F_2(x,Q^2)$ scaling violations at low-x is presented. The resulting formula can be used to determine the structure function F_2 from the HERA data taken at low -x. This new approach can determine the structure function F_2 with reasonable precision and an approximate analytical form of the gluon distribution function from the derivative of F_2 proton structure function data at low -x. We use the Leading order A-P evolution equation in our analysis, and test its validity by comparing it with that of QCD analysis at low - x regime.

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Chapter 1

Structure Functions

1.1 Introduction

Scattering electrons off an atomic nucleus is a very effective way of investigating the electric charge and magnetization densities of the nucleus. The experiment is shown schematically in fig.1.1; an electron with four-momentum $k = (E, \mathbf{k})$ scatters off the nucleus at rest and emerges at an angle θ with momentum $k' = (E', \mathbf{k}')$.

The effective probe of the structure within the nucleus is the exchanged virtual photon with momentum $q = k - k'$ with $q^2 = -Q^2$ where $Q^2 > 0$. The resolving power of this probe is the *wavelength* $\hbar/Q$ and so the degree of structure revealed increases with Q^2 which depends on the energy E and the scattering angle θ. In the lab frame, the energy of the virtual photon is $\nu = E - E'$.

For low values of $Q^2(\sim 0.01\ GeV^2)$ the nucleus tends to recoil as a