Chapter 7

Conclusions

In this thesis, we solved the QCD evolution equation for F_L structure function in next-next-to-leading order (NNLO) at small values of Bjorken variable x using Taylor expansion method. The same evolution equation is used to study the behaviour of F_L structure function up to NLO at small-x using Regge like behaviour of structure function. We determined t and x-evolutions of proton longitudinal structure function F_L for both the cases. Of course in most of the cases we look into gluon dominated longitudinal structure function F_L^g as at small-x, gluon contribution dominates over the quark contribution to F_L structure function. At small-x F_L structure function is directly related to the gluon distribution inside the proton. We have determined an approximate relation between the F_L structure function and gluon distribution function in NNLO approximation using Taylor expansion method. Here in our analysis, we have used the Altarelli-Martinelli equation for F_L structure function in terms of co-efficient functions. The x-evolution of F_L structure function is studied using this relation. We have calculated the t- and x-evolutions of the gluon dominating longitudinal structure function F_L up to NNLO approximation using the gluon distribution function obtained as a result of solution of the DGLAP evolution equation for gluon distribution using Regge behaviour of structure function at small-x. Along with the light flavour structure function we have also analysed the behaviour of heavy flavour (charm and beauty) structure function $F_k^h(k = 2, L; h = c, b)$, their ratio R^h and the heavy quark reduced cross section σ_r^h with respect to x for different values of Q^2 using both Taylor expansion and Regge theory approach. The results obtained in all the cases are compared with the available experimental data, theoretical prediction of different parameterizations, results of model fit and results with numerical method with satisfactory phenomenological success. We have also presented a comparative analysis of the our results obtained by both the methods Taylor expansion and Regge theory. All the results show good agreement with the experimental data, model fit and parameterizations and can be described within the framework of pQCD, i.e., all the structure functions increases towards small values of x and high-Q^2.

We have observed that t- and x-evolution results of F_L structure function obtained as a solution of QCD evolution equation for F_L structure function using both Taylor expansion method and Regge behaviour of structure function are in good agreement with H1, ZEUS data, results of DL model and theoretical predictions of MSTW08, CT10, ABM11 and NNPDF2.3 parameterizations. From the comparative study of evolution of F_L structure function predicted by Regge theory approach and Taylor expansion method it is observed that results obtained by both the methods are in good agreement with data and parameterizations. The evolutions of F_L structure function obtained using the approximate relation between F_L and gluon distribution function shows similar behaviour with the data and results of model fit, parameterizations. The calculated results of t- and x-evolutions of F_L structure function using the gluon distribution function obtained as a solution of the DGLAP evolution equation show compatibility with the experimental data and results of model fit and parameterizations. We have also analysed the behaviour of DIS cross section ratio R with respect to x which shows that it is independent of x irrespective of Q^2 values at small-x. The comparative study of the F_L structure function results obtained by these two method also reflects similar behaviour with the data and other results. The behaviour of the heavy quark (charm and beauty quark) structure function with respect to x shows similar behaviour with the experimental H1, ZEUS data and results of DL, CD model, MSTW08 parameterization. To confirm our method and behaviour of these structure functions we have also analysed the behaviours of the ratio of the heavy quark structure function R^h and heavy quark reduced cross section σ_r^h with respect to x which reflect good agreement with the data. The ratio of heavy quark structure function with respect to x is also independent of x for the Q^2 values which shows that it is independent of the distribution of gluons in the proton. The heavy quark content to the F_L structure function with respect to x increases with Q^2 towards small values of x. In our analysis, while solving the evolution equations we have considered two numerical parameters T_0 and T_1, such that $T^2(t) = T_0.T(t)$ and $T^3(t) = T_1.T(t)$ with $T(t) = \dfrac{\alpha_s(t)}{2\pi}$. These two parameters are chosen in such a way that the difference between $T^2(t)$, $T_0.T(t)$ and $T^3(t)$, $T_1.T(t)$ are negligible in our required range of Q^2. Thus both the methods used in our analysis are simple ones and less time consuming on the numerical calculations with less number of numerical parameters compared to the other methods where several parameters are included in the input function. So, these methods may be a good alternative to other methods.

In DIS, at moderate values of x, the linear QCD evolution equation led to a good description of the behaviour of gluon distribution function. But at small values of x and low-Q^2, the problem is more complicated as recombination of the gluon in a dense system has to be taken into account. This region is better explained by non-linear evolution equations. So as future directives with the help of non-linear evolution equations one can explain the behaviour of structure functions at very small-x and thus predicts a range of onset of parton recombination. There are different theoretical models based on parton recombination and saturation which describe low-x and low-Q^2 region well. But till today this saturated gluon density regime has not been clearly observed. With the help of a new collider, Electron Ion Collider (EIC), physicist from different parts of the world try to explain the unanswered questions about the structure of matter. The main unanswered questions are: What are the nuclear gluon and sea quark densities? To what extent are they modified by nuclear binding, quantum-mechanical interference, and other collective effects? These questions are the key to understanding the QCD origins of the nucleon-nucleon interaction at different energies, the role of non-nucleonic degrees of freedom, and the approach to a new regime of high gluon densities and saturation at high energies. This collider would be the first ever high-energy electron-nucleus collider and open up qualitatively new possibilities to study QCD in the nuclear environment. It would represent the natural next step after the high-luminosity fixed-target ep/eA experiments and the high-energy HERA ep collider. □