CURRENT ISSUES AND CHALLENGES IN GLOBAL ANALYSIS OF PARTON DISTRIBUTIONS *

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A new implementation of precise perturbative QCD calculation of deep inelastic scattering structure functions and cross sections, incorporating heavy quark mass effects, is applied to the global analysis of the full HERA I data sets on NC and CC cross sections, in conjunction with other experiments. Improved agreement between the NLO QCD theory and the global data sets are obtained. Comparison of the new results to that of previous analysis based on conventional zero-mass parton formalism is made. Exploratory work on implications of new fixed-target neutrino scattering and Drell-Yan data on global analysis is also discussed.

1. Introduction

The global QCD analysis of parton structure of the nucleon has made significant progress in recent years. However, there remain many gaps in our knowledge of the parton distribution functions (PDFs). For instance, the uncertainties of the PDFs remain large in both the small-x and the large-x regions—particularly for the gluon; and constraints on the strange, charm and bottom degrees of freedom are either weak or non-existent.

Uncertainties due to the input PDFs will be dominant in many precision measurements (such as the W mass), as well as in studying signals and backgrounds for New Physics searches, at the Tevatron and the LHC. Thus, improving the accuracy of the global QCD analysis of PDFs is a high priority task for High Energy Physics.

In this talk,[a] we apply a new implementation of the general mass PQCD

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[a]Space limitation does not permit the inclusion of full references.

formalism to a precise global analysis of PDFs, including the full HERA I cross section data sets for both NC and CC processes, taking into account all available correlated systematic errors. We also discuss some open issues on PDFs related to two recent fixed target experiments.

2. New Theory Input

The global analysis described in this report is based on a newly finished full implementation of the general mass PQCD formalism of Collins, as discussed separately in the joint Structure Function (SF) and Heavy Flavor (HFL) session. The distinguishing features of this implementation compared to the conventional zero-mass parton calculation are: (i) a clear distinction between the summation over the *scheme-dependent* initial-state parton flavors (either n_f-fixed flavor number scheme or the more general variable flavor number scheme) and the *scheme-independent* summation over final-state flavors (for inclusive cross sections); (ii) attention to kinematic effects on the parton momentum fraction variable (rescaling) due to the restricted final-state phase space associated with heavy flavor production for both neutral current (NC) and charged current (CC) processes; and (iii) consistent implementation of the SACOT approach for calculating the hard cross sections that drastically simplifies the practical calculation beyond leading order (LO) without loss of generality.

3. Full HERA I Cross Section and other Data Sets Included

Previous CTEQ global analyses of PDFs used DIS *structure function* data for all available DIS experiments. By now, both H1 and ZEUS experiments have published detailed *cross section* data from the HERA I runs (1994 - 2000) for both NC and CC processes. We are now able to use these cross section data directly in the global analysis, so that the new analysis will be free from the assumptions that usually go into the intermediate structure function determination. This is important since, in addition to the dominant F_2^γ SF, we can also gain model-independent information on the longitudinal and parity violating structure functions $F_L^{\gamma,\gamma Z}$ and $F_3^{\gamma Z}$ from this more comprehensive study. In this new effort to obtain more accurate PDFs, and to produce more reliable predictions, it is crucial to use the available correlated systematic errors in the global analysis, as we shall do in this work.

The HERA I cross section data sets that are included in this analysis consist of the total inclusive NC and CC DIS measurements, as well as the semi-inclusive DIS processes with tagged final state charm and bottom mesons.[a] They are listed in the following Table:

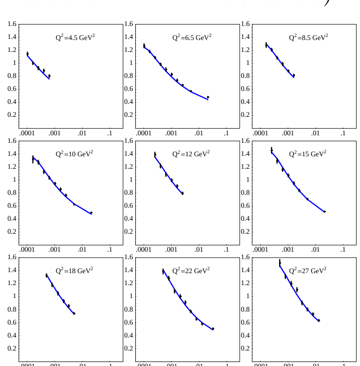
H1			
94-97	e^+p	NC	σ_{tot}
		CC	σ_{tot}
96-97		NC	σ_{tot}
		NC	F_2^c
98-99	e^-p	NC	σ_{tot}
		CC	σ_{tot}
99-00	e^+p	NC	σ_{tot}
		CC	σ_{tot}
		NC	σ_c
		NC	σ_b
	e^-p	NC	σ_{tot}

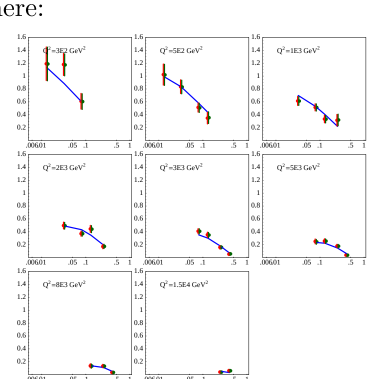
ZEUS			
94-97	e^+p	CC	σ_{tot}
96-97		NC	σ_{tot}
		NC	F_2^c
98-99	e^-p	NC	σ_{tot}
		CC	σ_{tot}
		NC	F_2^c
99-00	e^+p	NC	σ_{tot}
		CC	σ_{tot}

These are supplemented by fixed-target and hadron collider data sets used in the previous CTEQ global fits: BCDMS, NMC, CCFR, E605 (DY), E866 proton-deuteron DY ratio, CDF W lepton asymmetry, and CDF/D0 inclusive jet production.[a] We use the same parametrization of the input parton distribution functions, and adopt the same Q- and W- cuts on experimental data, as in the CTEQ6 papers.[a]

4. Results

We found the global fits obtained with the improved theoretical calculation and experimental data sets to be of even higher quality than the previous (already good) CTEQ6 ones. For a typical fit to $\sim$ 2500 data points, the overall χ^2 is reduced by $\sim$ 50. Two typical data vs. theory plots (ZEUS NC 96-97 and H1 CC 99-00) are shown here:





Similar results are obtained for all other data sets, including the tagged heavy flavor production ones. With correlated systematic errors taken into account, the frequency distributions of (data-theory)—the "pull-plots"—are all normal, providing further assurance that the fits are satisfactory. The new fits (along with fits obtained with input non-perturbative charm described in the companion talk in the joint SF-HFL session) will be presented in subsequent publications.

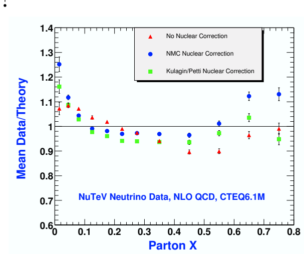
5. Other Recent Developments

In recent years, two new fixed-target experiments have reported results that can potentially affect global QCD analysis, and influence the determination of PDFs. These are the measurement of *pp* and *pd* Drell-Yan cross sections by E866 (cf. results presented at DIS2004 and DIS2005 workshops), and the measurement of sign-selected $\nu/\bar{\nu}$ scattering on iron targets by NuTeV (cf. results presented at DIS2005).[a] They have received considerable attention, since both seem to suggest departure from the standard MRST and CTEQ PDFs; and, interestingly the two experiments appear to pull the parton distributions in opposite directions!

The preliminary results of E866 have, so far, not been formalized in a publication. Small corrections to the original data are anticipated due to the inclusion of radiative correction effects (cf. report by Reimer at APS April Meeting 2006, Dallas, TX).

To understand the implications of the NuTeV total inclusive neutrino data, a crucial issue is the nuclear effect due to the use of heavy (iron) target. What is the appropriate nuclear correction that needs to be applied before one can use the data to reliably extract nucleon parton distributions? Can the previously indicated "discrepancy" with existing PDFs be reduced, or removed, by appropriate nuclear corrections?[b]

Results of comparing different nuclear corrections, using CTEQ6.1M PDFs are shown in the accompanying figure. The difference between data and theory persists in all cases, even if refitting is done. (Results not shown due to lack of space.) More work is obviously needed to clarify the situation.



[b]The following study is done by S. Kuhlmann, F. Olness, J.F. Owens, J. Morfin, D. Stump, and T. Keppel