QCD analysis of $x F_3$ at NNLO: the theoretical uncertainties

A.L. Kataev$^1$, G. Parente$^2$ and A.V. Sidorov$^3$

$^1$ Institute for Nuclear Research of the Academy of Sciences of Russia, 117312 Moscow, Russia
$^2$ Departamento de Física de Partículas, Universidad de Santiago de Compostela, Spain 15706 Santiago de Compostela
$^3$ Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, 141980 Dubna, Russia

E-mails: gonzalo@fpaxp1.usc.es

Abstract

The next-to-next-to-leading order (NNLO) QCD analysis of the experimental $x F_3$ structure function from CCFR data is performed. The theoretical uncertainties of the analysis are discussed.

The moments in Eq. (1) at the initial scale are $M_n(Q_0^2) = \int_0^1 dx x^{n-2} A(x)(1-x)^\gamma(1+\gamma x)$.

The structure function is reconstructed from its moments by using the expansion in terms of orthogonal Jacobi polynomials:

$$xF_3 = x^\alpha (1-x)^\beta \sum_{n=0}^{N_{\text{max}}} (\sum_{j=0}^{n} c_j^{(n)}(\alpha,\beta)M_{j+2}(Q^2))$$

(2)

where $c_j^{(n)}(\alpha,\beta)$ are combinatorial coefficients given in terms of Euler $\Gamma$-functions of the $\alpha$ and $\beta$ weight parameters which have been fixed to 0.7 and 3 respectively by the reasons given in [4, 7].

Power corrections are included in the analysis using two different approaches. Firstly, in the form given by the Infrared Renormalon Model (IRR) [5] adding in Eq. (1) the contribution $M_n^{IRR} = C(n)M_n(Q_0^2)A_2/Q^2$, with $A_2$ a free scale parameter. Secondly, adding in the r.h.s. of Eq. (2) the term $b(x)/Q^2$, with $b(x)$ a free parameter for each $x$-bin of the data set.

Table 1 summarizes the results of the fits to $x F_3$ CCFR data [6]. For comparison we have applied the same kinematic cuts as in Ref. [9], i.e. $Q^2 > 5$ GeV$^2$, $x < 0.7$ and $W^2 > 10$ GeV$^2$. At NLO the value of $\Lambda^{(4)}_{MS}$ from our fits is in good agreement with that found in Ref. [9] (337±28 MeV) where both, $F_2$ and $x F_3$ structure functions, have been fitted. There is a clear correlation between the effects of the NLO and NNLO approximations and power corrections (see table 1). At NNLO the fits performed with and without power corrections (in
the IRR model) are almost equal. The significant decrease of the magnitude of power corrections in the NNLO fit with IRR model ($A_\lambda$ vanished within statistical errors) is also found with the model $h(x)/Q^2$ (see Fig. 1).

Using the value of $\Lambda$ from the NNLO fit and the running of the coupling up to $M_Z^2$, we obtain $\alpha_s(M_Z^2) = 0.118 \pm 0.002$(stat) $\pm 0.005$(syst) $\pm 0.003$(theory). The theoretical error takes into account the dependence on the initial $Q_0^2$, the influence of the missing higher order terms estimated by Padé approximants and the crossing of the $m_t$ threshold in the calculation of $\alpha_s(M_Z^2)$.

However, in the analysis there are also involved various approximations and shortcuts which could increase this uncertainty. The calculation of $xF_3$ with even-$n$ $F_2$ anomalous dimensions, the interpolation to odd values of $n$, and the effect of the reconstruction method through the parameters $\alpha$, $\beta$ and the number of polynomials $N_{max}$ (see Eq. (2)) are not expected to affect the accuracy of the analysis.

In addition, we have also studied the effect of using in Eq. (1) the original exponentiated formula for the anomalous dimension part (see Eq. (4) in Ref. [4]). We found a change in $\Lambda$ of 2 MeV at NLO and much smaller at NNLO. The effect of nuclear corrections has also been addressed by us although it still deserves a more detailed study. The dependence with the number of active flavors (we work with $n_f = 4$) should also be carefully studied (see Ref. [3]).

Finally, the renormalization and factorization scale dependence (we have fixed both equal to $Q^2$) should also be estimated if one wants to make a meaningful precision test of perturbative QCD. We plan to present this work elsewhere [10].

Acknowledgments

G.P. is grateful to J. Chyła for useful comments and interest on this work. A.L.K. and A.V.S. are supported by RFBR Grant N 99-01-00091. The work of G.P. is supported by CICYT Grant N AE/N96-1773 and Xunta de Galicia Grant N XUGA-20602B98.

References

[1] E.B. Zijlstra and W.L. van Neerven, Nucl. Phys. B383 (1992) 525.
[2] S.A. Larin, T. van Ritbergen and J.A.M. Vermaseren, Nucl. Phys. B427 (1994) 41; S.A. Larin, et al., Nucl. Phys. B492 (1997) 338.
[3] A.L. Kataev, et al., Phys. Lett. B388 (1996) 179; ibid B417 (1998) 374.
[4] A.L. Kataev, G. Parente and A.V. Sidorov, Preprint ICTP IC/99/51, hep-ph/9905310.
[5] G. Parente, A.V. Kotikov and V.G. Krivokhizhin, Phys. Lett. B333 (1994) 190.
[6] J. Santiago and F.J. Yndurain, preprint FTAM 99-8; UG-FT-97/99 (hep-ph/9904344).
[7] J. Chyła and J. Ramez, Z. Phys. C31 (1986) 151. V.G. Krivokhizhin et al., Z. Phys. C36 (1987) 51; Z. Phys. C48 (1990) 347.
[8] M. Dasgupta and B.R. Webber, Phys. Lett. B382 (1996) 273.
[9] CCFR-NuTeV Collab., W.G. Seligman et al., Phys. Rev. Lett. 79 (1997) 1213.
[10] A.V. Kataev et al. work in preparation.