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The impact of heavy quark mass effects in the NNPDF global analysis

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We discuss the implementation of the FONLL general-mass scheme for heavy quarks in deep-inelastic scattering in the FastKernel framework, used in the NNPDF series of global PDF analysis. We present the general features of FONLL and benchmark the accuracy of its implementation in FastKernel comparing with the Les Houches heavy quark benchmark tables. We then show preliminary results of the NNPDF2.1 analysis, in which heavy quark mass effects are included following the FONLL-A GM scheme.

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1. FONLL in Mellin space: FastKernel

The NNPDF series of PDF analysis [1–5] has used up to now the ZM-VFN scheme for the treatment of heavy flavours. In this contribution we review progress on the implementation of heavy quark mass effects in the NNPDF analysis and their implications on PDFs and LHC observables. We present preliminary results of the NNPDF2.1 set [7], which updates the global NNPDF2.0 fit with heavy quark mass effects as well as with the addition of the H1 and ZEUS charm structure function data F_2^c.

Recently, the FONLL general-mass scheme, originally formulated for heavy quark hadroproduction, was generalized to deep-inelastic scattering [6]. This scheme has several advantages over other existing GM schemes, such as S-ACOT [9], TR/MSTW08 [10] and BMSN [11]: it can be applied also in general hadronic processes, it can be formulated at any perturbative order, it allows the combination of different perturbative orders in the massless and massive computations, and it can be combined with various prescriptions for the treatment of subleading mass-suppressed terms near threshold, such as χ–scaling or damping factors. In Ref. [6] explicit FONLL implementations are discussed at $\mathcal{O}(\alpha_s)$ (FONLL-A) and at $\mathcal{O}\left(\alpha_s^2\right)$, either within an NLO (FONLL-B) or within a NNLO calculation (FONLL-C).

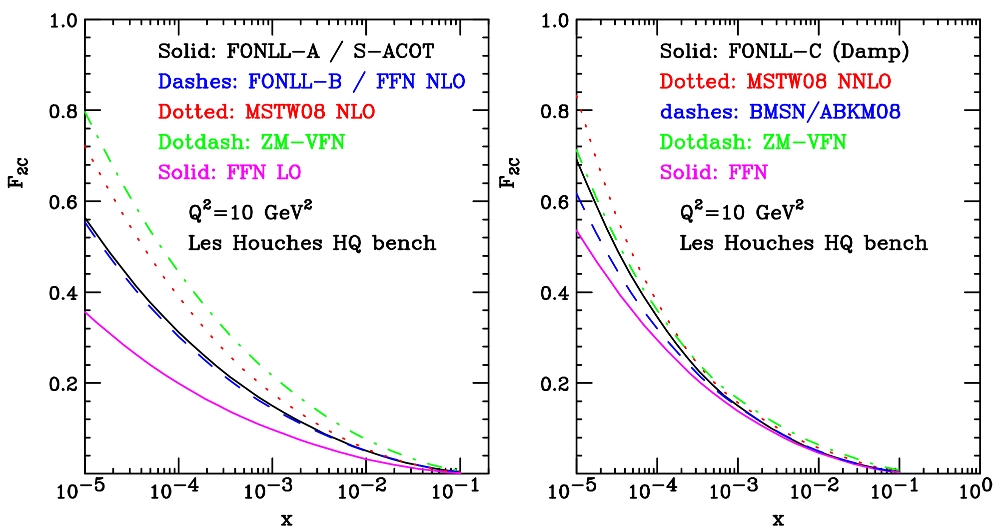

Figure 1: The F_2^c structure function for $Q^2 = 10$ GeV^2 computed at $\mathcal{O}(\alpha_s)$ accuracy (left plot) and $\mathcal{O}\left(\alpha_s^2\right)$ accuracy (right plot) in various GM schemes: FONLL, S-ACOT, MSTW08 and BMSN. The purely massless and massive results are also shown for comparison.

The different versions of FONLL were compared to other commonly used GM schemes in the Les Houches heavy quark benchmark study [8]. Fig. 1 summarizes the result of this comparison. At $\mathcal{O}(\alpha_s)$, FONLL-A and S-ACOT are formally identical, while FONLL-B cannot be distinguished from the $\mathcal{O}\left(\alpha_s^2\right)$ massive result at this value of Q^2. In Fig. 1, the S-ACOT and FONLL-A curves have been obtained using a threshold damping factor prescription [6], the results with χ–scaling are very close numerically. The MSTW08 result instead has been obtained using the χ_2 version of the $\chi-$scaling prescription [8], which is rather different near threshold. The purely massless and massive results are also shown for illustration. It can be seen that all general-mass schemes interpolate between the massless and massive calculations, and that there are significant differences between them, whose impact in PDF determinations is yet still to be systematically explored.

The FONLL GM scheme has been now implemented in the NNPDF global analysis framework. As discussed in Refs. [2, 5], for the PDF evolution and the computation of physical observables the NNPDF analysis is based on the FastKernel framework, which allows a fast and accurate PDF evolution and evaluation of physical observables, including hadronic processes, without any K–factor approximation at all. The implementation of heavy quark effects in FastKernel has required the computation of the Mellin transforms of the $\mathcal{O}(\alpha_s)$ massive DIS coefficient functions, both in the Neutral Current and in the Charged Current sector. These are not currently available in closed form; complete analytic expressions will be presented in Ref. [7], here we limit ourselves of presenting the results for the accuracy using the Les Houches heavy quark benchmark settings. We summarize the results of the comparison for F_2^c in Table 1. In all cases the accuracy is well below the percent level, accurate enough for precision phenomenology. In Fig. 2 we compare the F_2^c structure function for various heavy quark schemes: ZM, FONLL-A-Damp and the FFN scheme as a function of Q^2 for different values of x. It can easily be seen how FONLL-A-Damp smoothly interpolates between the FFN scheme near threshold and the massless scheme at large Q^2.

	FONLL-A-Damp		
x	FONLLdis	FastKernel	Accuracy
$Q^2 = 4$ GeV^2			
10^{-5}	0.1507	0.1501	0.4%
10^{-4}	0.0936	0.0931	0.5%
10^{-3}	0.0506	0.0504	0.4%
10^{-2}	0.0174	0.0176	0.9%
$Q^2 = 10$ GeV^2			
10^{-5}	0.563	0.561	0.4%
10^{-4}	0.312	0.311	0.3%
10^{-3}	0.1499	0.1495	0.3%
10^{-2}	0.05056	0.05052	0.1%
$Q^2 = 100$ GeV^2			
10^{-5}	2.28636	2.28577	0.02%
10^{-4}	1.12186	1.12082	0.1%
10^{-3}	0.48008	0.47919	0.2%
10^{-2}	0.15207	0.15200	0.04%

Table 1: Results of the benchmark comparison for the $F_{2c}(x,Q^2)$ structure function in the FONLL-A-Damp scheme for the FONLLdis code [6] and for the FastKernel framework. Results are provided at the benchmark kinematical points in x, Q^2 [8].

2. Heavy quark mass effects in the NNPDF global analysis

Here we present preliminary results based on a fit to the NNPDF2.0 dataset [5], supplemented by charm structure function data $F_2^c(x,Q^2)$ from the H1 and ZEUS experiments at HERA: NNPDF2.1. In Fig. 3 we perform a preliminary comparison of the singlet and gluon PDFs at the initial evolution scale $Q_0^2 = 2$ GeV^2 in NNPDF2.1 and NNPDF2.0, normalized to the NNPDF2.0 central values. As expected, including heavy quark mass effects leads to a increase in the singlet at medium and small-x, as well as to a marked increase in the small-x gluon. Note however that

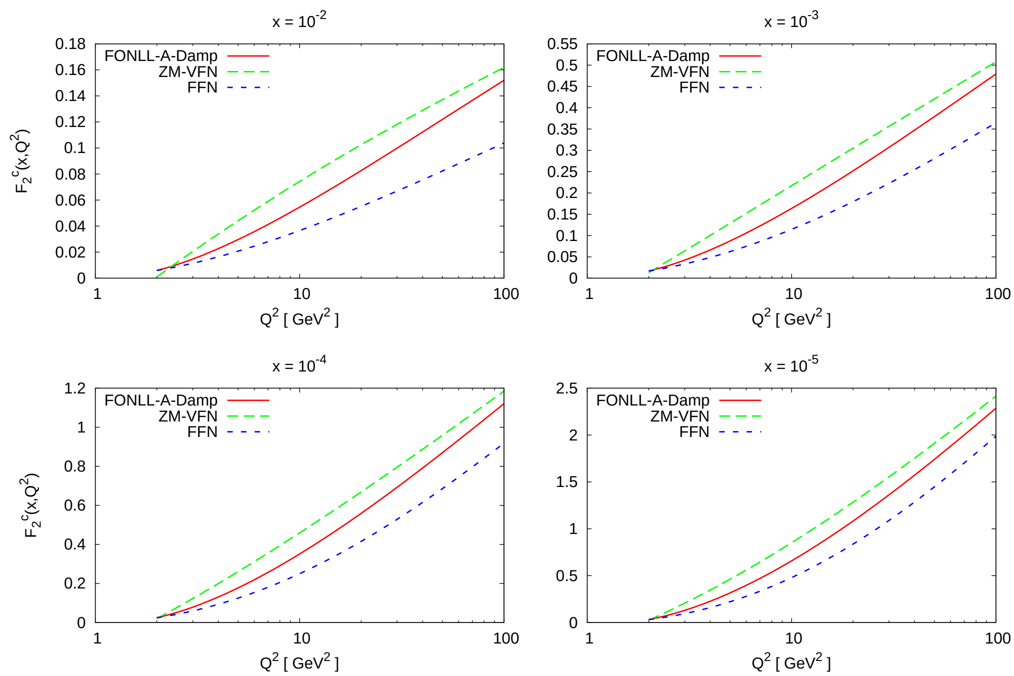

Figure 2: The charm structure functions $F_2^c(x,Q^2)$ as a function of Q^2 for different values of x from $x = 10^{-5}$ to $x = 10^{-2}$ in various heavy quark schemes, computed using the FastKernel method: FONLL-A-Damp, ZM-VFN and the FFN scheme. The PDFs and settings are identical to those of the Les Houches Heavy quark benchmark comparison [8].

differences are always within the PDF uncertainty bands. This implies that heavy quark mass effects should modify the NNPDF2.0 predictions for LHC observables by 1–sigma or so at most. The implications of these results for LHC observables will be discussed in detail in Ref. [7]. This is to be compared with the CTEQ analysis [12], where for example a ~ 2.5–sigma variation on σ_W was obtained in the GM fit based on S-ACOT-χ as compared to the ZM case.

We also show in Fig. 3 the effects of heavy quark mass effects in the triplet and total valence PDFs: as expected their impact is completely negligible. Since processes which depend on valence PDFs, as well as those on the the medium and large-x gluon like Higgs production [13], are unaffected by heavy quark mass effects, the predictions for such processes obtained with NNPDF2.0 will be very close to those of NNPDF2.1.

References

[1] L. Del Debbio, S. Forte, J. I. Latorre, A. Piccione and J. Rojo [NNPDF Collaboration], JHEP **0703** (2007) 039 [arXiv:hep-ph/0701127].

[2] R. D. Ball *et al.* [NNPDF Collaboration], Nucl. Phys. B **809**, 1 (2009) [Erratum-ibid. B **816**, 293 (2009)] [arXiv:0808.1231 [hep-ph]].

[3] R. D. Ball *et al.* [The NNPDF Collaboration], Nucl. Phys. B **823**, 195 (2009) [arXiv:0906.1958 [hep-ph]].

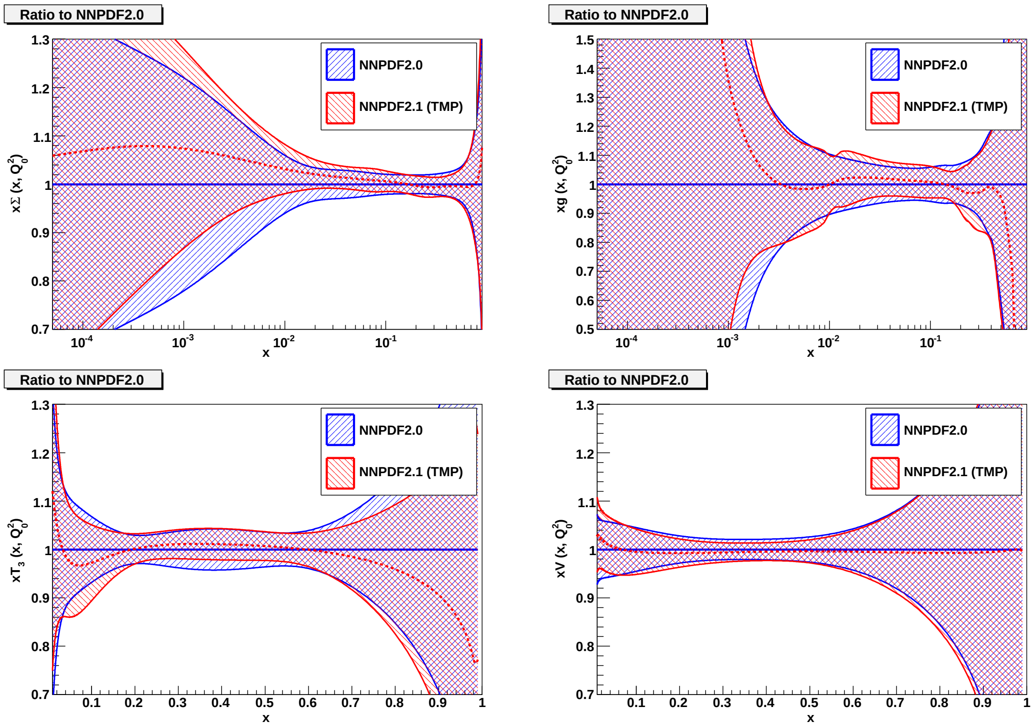

Figure 3: Upper plots: The ratio of the preliminary NNPDF2.1 Singlet (left plot) and gluon PDFs (right plot) to the respective NNPDF2.0 ones, at the initial evolution scale $Q_0^2 = 2$ GeV^2. Error bands are normalized to the NNPDF2.0 central value. Lower plots: same as above for the triplet T_3 and the total valence V.

[4] R. D. Ball, L. Del Debbio, S. Forte, A. Guffanti, J. I. Latorre, J. Rojo and M. Ubiali [NNPDF Collaboration], JHEP **1005** (2010) 075 [arXiv:0912.2276 [hep-ph]].

[5] R. D. Ball, L. Del Debbio, S. Forte, A. Guffanti, J. I. Latorre, J. Rojo and M. Ubiali, arXiv:1002.4407 [hep-ph].

[6] S. Forte, E. Laenen, P. Nason and J. Rojo, Nucl. Phys. B **834** (2010) 116 [arXiv:1001.2312 [hep-ph]].

[7] R. D. Ball, V Bertone, F. Cerutti,L. Del Debbio, S. Forte, A. Guffanti, J. I. Latorre, J. Rojo and M. Ubiali, in preparation.

[8] J. R. Andersen *et al.* [SM and NLO Multileg Working Group], arXiv:1003.1241 [hep-ph].

[9] M. A. G. Aivazis, J. C. Collins, F. I. Olness and W. K. Tung, Phys. Rev. D **50** (1994) 3102 [arXiv:hep-ph/9312319].

[10] R. S. Thorne, Phys. Rev. D **73** (2006) 054019 [arXiv:hep-ph/0601245].

[11] M. Buza, Y. Matiounine, J. Smith and W. L. van Neerven, Eur. Phys. J. C **1** (1998) 301 [arXiv:hep-ph/9612398].

[12] W. K. Tung, H. L. Lai, A. Belyaev, J. Pumplin, D. Stump and C. P. Yuan, JHEP **0702** (2007) 053 [arXiv:hep-ph/0611254].

[13] F. Demartin, S. Forte, E. Mariani, J. Rojo and A. Vicini, arXiv:1004.0962 [hep-ph].