Resummed parton distributions from neutrino data

Gennaro Corcella

CERN TH

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In collaboration with L. Magnea

Structure functions $\mathcal{F}_i$ in CC DIS as convolution of $\overline{\rm MS}$ coefficient functions and parton distribution functions

$$\nu_\mu(k)N(P) \to \mu(k')X(p_X)$$

Hard subprocesses at NLO:

$$q(p_q)W(q) \to q\prime(p_{q\prime})(g(p_g)) \quad ; \quad g(p_g)W(q) \to \bar{q}(p_{\bar{q}})q\prime(p_{q\prime})$$

$$Q^2 = -q^2 \quad ; \quad x = \frac{Q^2}{2P\cdot q} \quad ; \quad \mu_R^2 = \mu_F^2 = Q^2$$

$$\begin{aligned}\mathcal{F}_i(x,Q^2) &= \int_x^1 \frac{d\xi}{\xi}\sum_{q,q'}|V_{qq\prime}|^2\left[C_i^q(\xi,Q^2)q\left(\frac{x}{\xi},Q^2\right)\right.\\ &+ \left. C_i^g(\xi,Q^2)g\left(\frac{x}{\xi},Q^2\right)\right]\end{aligned}$$

Differential cross section in CC DIS is parametrized in terms of three structure functions:

$$\frac{d^2\sigma^{\nu(\bar{\nu})}}{dxdy} = \frac{G_F^2 ME}{\pi(1+Q^2/m_W^2)^2}\left\{y^2xF_1 + \left[1-\left(1+\frac{Mx}{2E}\right)y\right]F_2 \pm y\left(1-\frac{y}{2}\right)xF_3\right\}$$

Relation between F_i and $\mathcal{F}_i$

$$F_1 = \mathcal{F}_1 \qquad F_2 = \frac{2x}{\lambda\rho^2}\mathcal{F}_2 \qquad F_3 = \frac{2}{\rho}\mathcal{F}_3$$

$$\rho = \sqrt{1+\left(\frac{2Mx}{Q}\right)^2} \quad ; \quad \lambda = \frac{Q^2}{Q^2+m^2} \quad ; \quad p_{q\prime}^2 = m^2$$

NLO $\overline{\rm MS}$ coefficient function:

M. Glück, S. Kretzer and E. Reya, PLB 380 (1996) 171

Soft-gluon radiation

Quark-initiated coefficient function contains terms which get large once $x \to 1$ (soft-gluon emission)

$$C^{\rm soft}(x,\mu_F^2,\lambda) = 2C_F\left\{2\left[\frac{\ln(1-x)}{1-x}\right]_+ - \left[\frac{\ln(1-\lambda x)}{1-x}\right]_+ + \frac{1}{4}\left[\frac{1-x}{(1-\lambda x)^2}\right]_+ + \frac{1}{(1-x)_+}\left(\ln\frac{Q^2+m^2}{\mu_F^2}-1\right)\right\}$$

$$f_N = \int_0^1 dx x^{N-1} f(x)$$

$$\frac{1}{(1-x)_+} \to \ln N \qquad \left[\frac{\ln(1-x)}{1-x}\right]_+ \to \ln^2 N \quad \text{for } N\to\infty$$

Massless approximation: $m^2 \ll Q^2$, $\lambda = Q^2/(Q^2+m^2) \simeq 1$, $\lambda x \to 1$

$$C_N^{\rm soft}|_{\lambda=1} = 1 + \frac{\alpha_S(\mu^2)C_F}{\pi}\left\{\frac{1}{2}\ln^2 N + \left[\gamma_E + \frac{3}{4} - \ln\frac{Q^2}{\mu_F^2}\right]\ln N\right\}$$

Resummed coefficient function (Catani, Marchesini, Webber, NPB 349 (1991) 635)

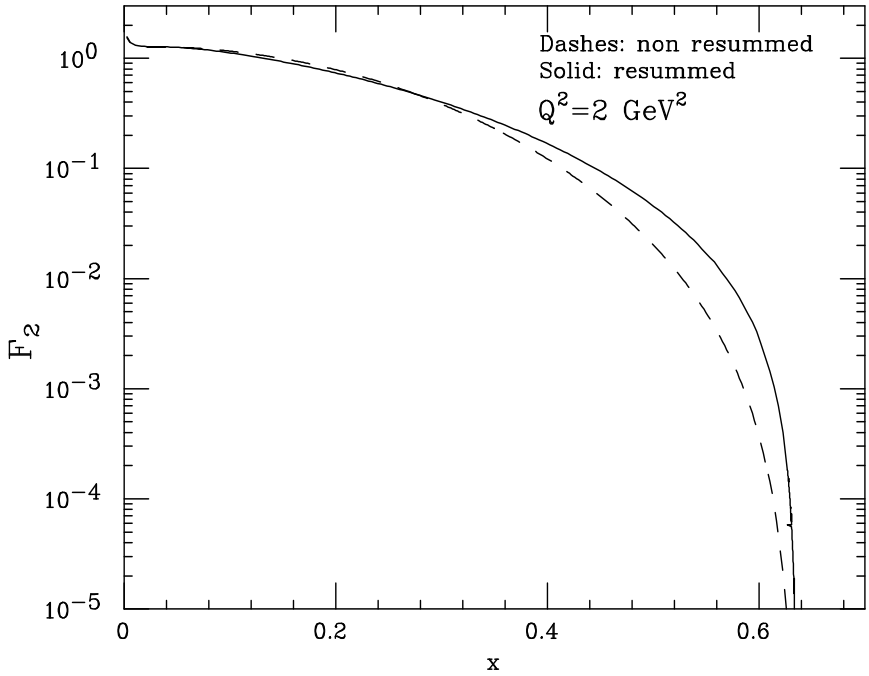
$$\Delta_N|_{m/Q\to 0} = \exp\left\{\int_0^1 dx \frac{x^{N-1}-1}{1-z}\int_{\mu_F^2}^{Q^2(1-x)}\left[\frac{dk^2}{k^2}A\left[\alpha_S(k^2)\right] + \frac{1}{2}B\left[\alpha_S\left(Q^2(1-z)\right)\right]\right\}\right] = \exp\left[\log N g_1 + g_2\right]$$

$$k^2 = (p_1+p_g)^2(1-z) = 2E_g^2(1-\cos\theta_{1g}) \simeq E_g^2\sin^2\theta_{1g}$$

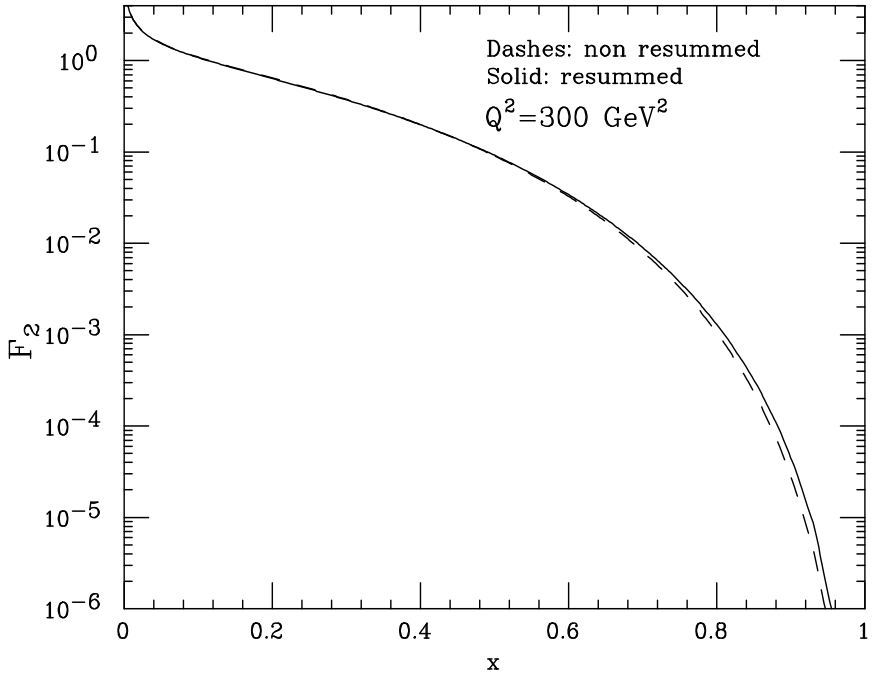
$$A(\alpha_S) = \sum_{n=1}^{\infty}\left(\frac{\alpha_S}{\pi}\right)^n A^{(n)} \;\; ; \;\; B(\alpha_S) = \sum_{n=1}^{\infty}\left(\frac{\alpha_S}{\pi}\right)^n \;\; ; \;\; \text{NLL}: A^{(1)}, A^{(2)}, B^{(1)}$$

G.C. and A.D. Mitov, NPB 676 (2004) 346: resummation for heavy quark production in CC DIS

Structure functions with resummed coefficient function and NLO pdf (CTEQ6M)

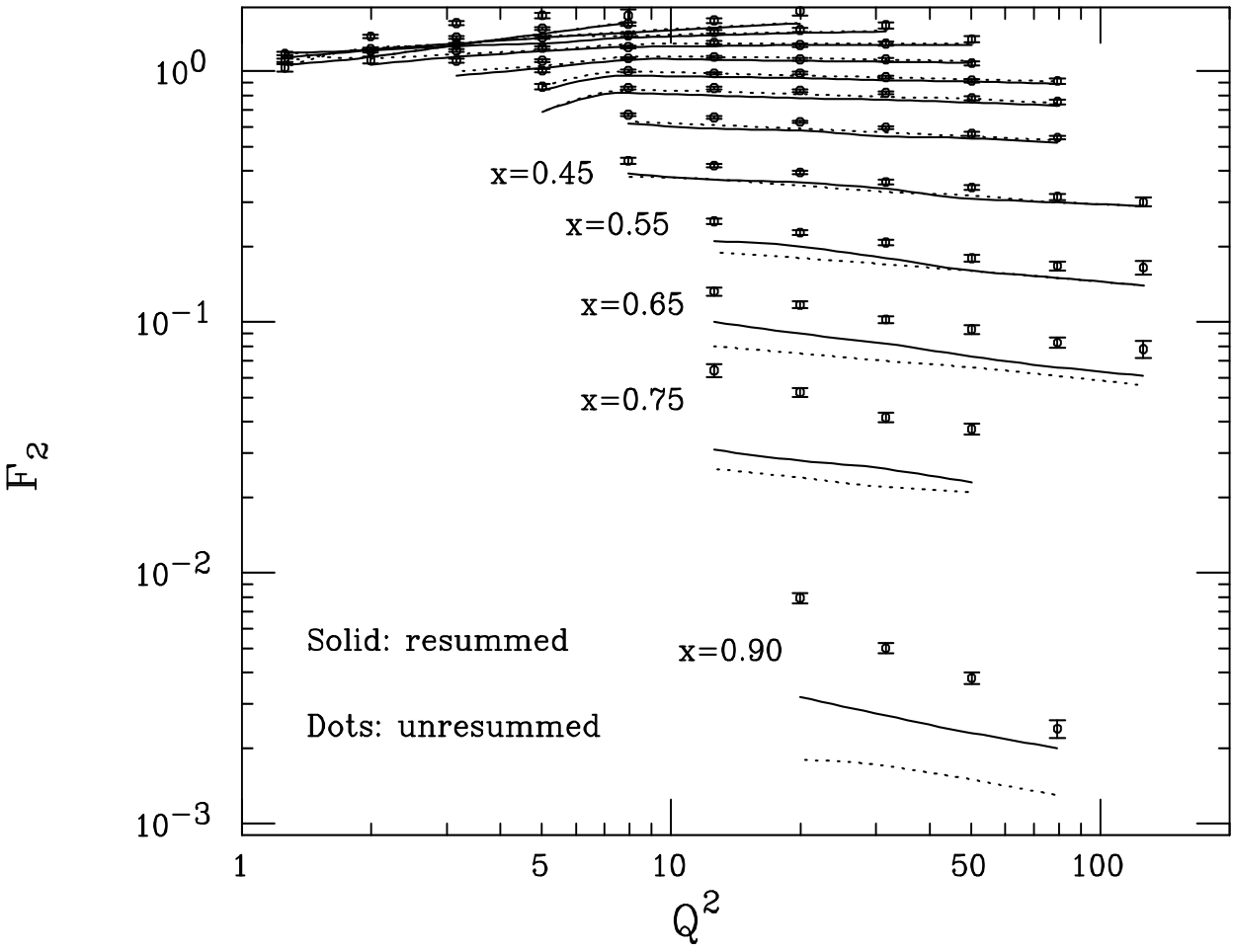


NuTeV: $x = 0.5$ **factor of 2;** $x = 0.6$ **factor of 8**



HERA: $x = 0.8$ 20%**;** $x = 0.9$ 60%

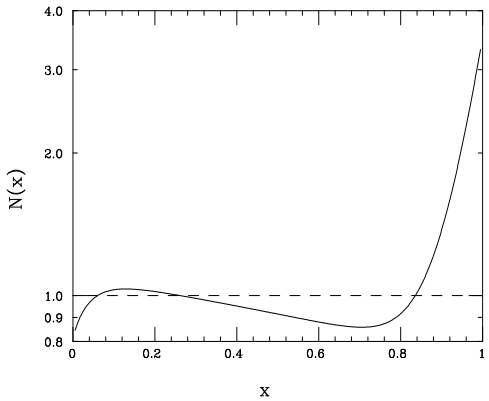
Comparison with NuTeV data (CTEQ6M NLO pdf)



Nuclear correction factor:

$N(x) = 1.10 - 0.36\ x - 0.28 \exp(-21.94\ x) + 2.77\ x^{14.41}$

W. Seligam, Ph.D. Thesis, fit to F_2^{Fe}/F_2^D



Fits of NuTeV structure function F_2

Correlations are neglected

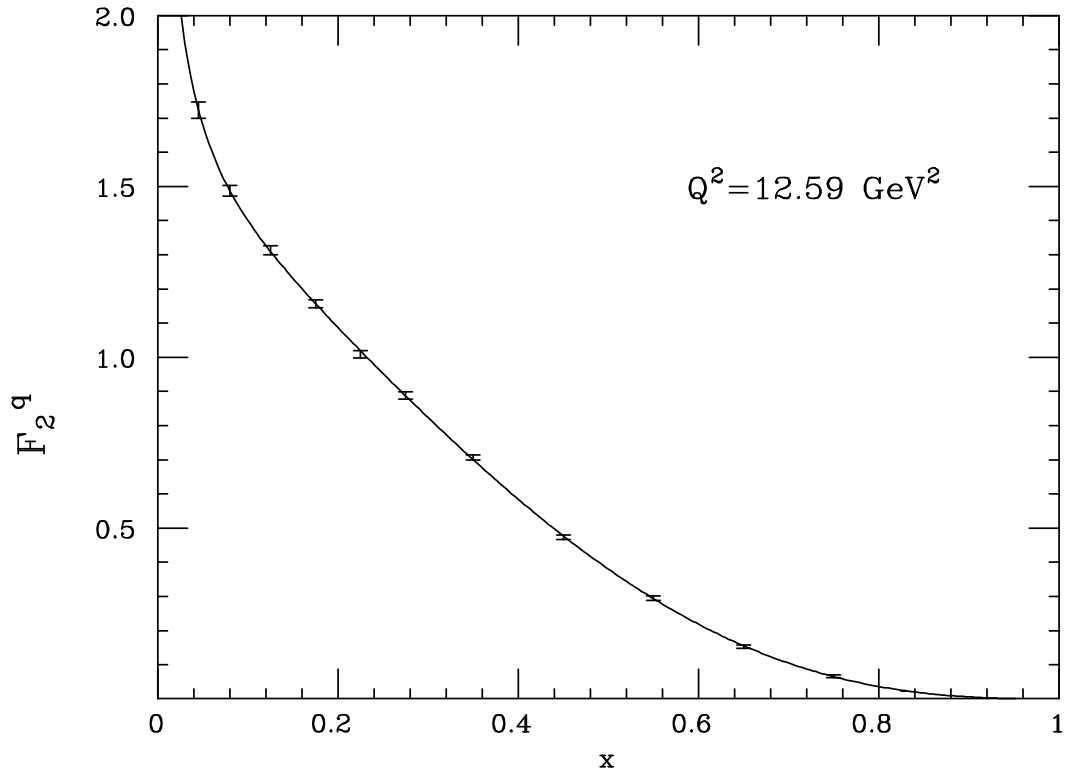
$$F_2 = \frac{1}{2}(F_2^{\nu} + F_2^{\bar{\nu}}) = \sum_{q,q'} |V_{qq'}|^2 \left[(q + \bar{q}) \otimes C_2^q + g \otimes C_2^g\right] = F_2^q + F_2^g$$

We take the gluon pdf from CTEQ6M, compute F_2^g and fit F_2^q

$$F_2(x) - F_2^g(x) = F_2^q(x) = Ax^{-\alpha}(1-x)^{\beta}(1 + bx - cx^2)$$

Best fit values for $Q^2 = 12.59$ GeV^2:

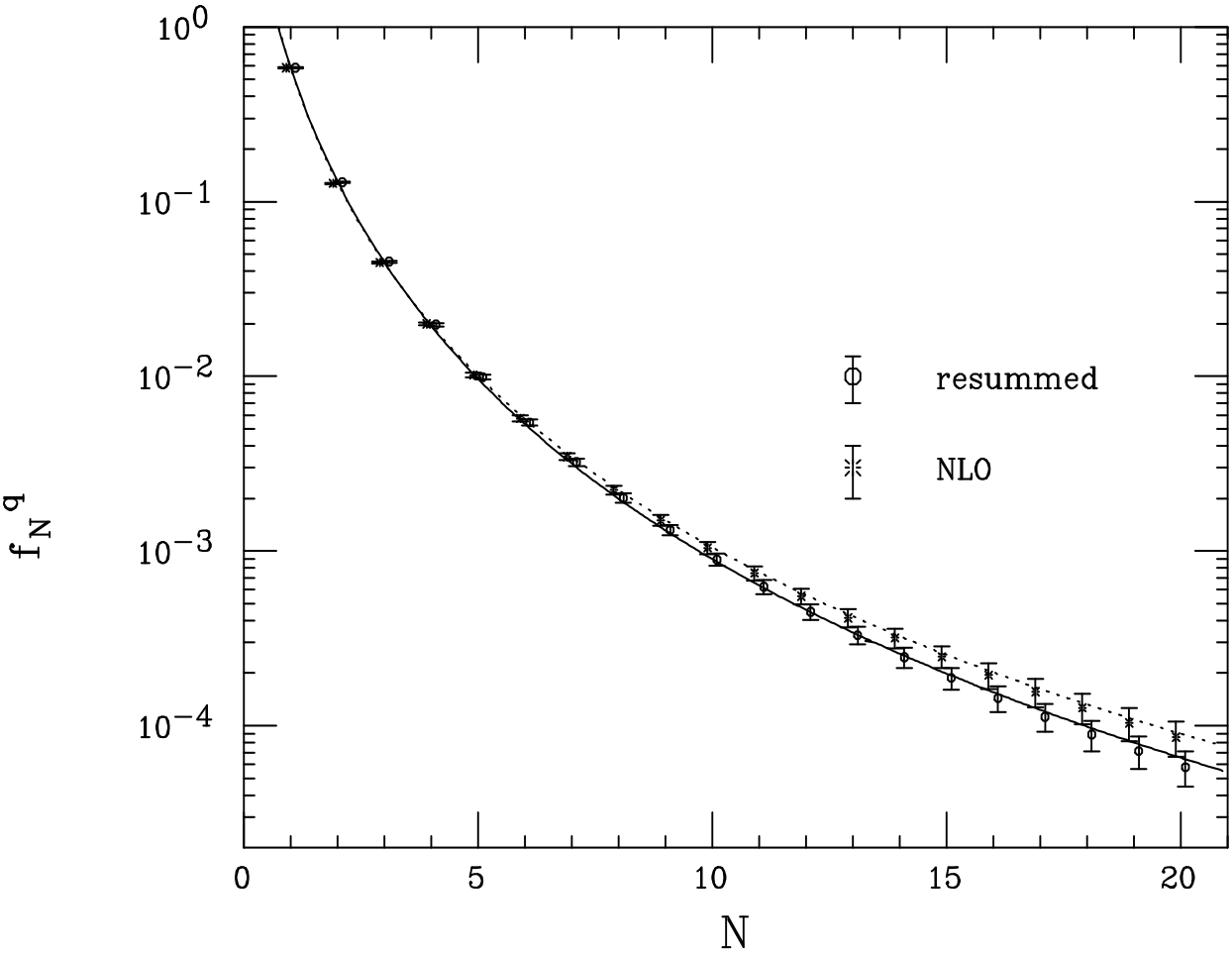
$A = 0.54 \pm 0.02$, $\alpha = 0.34 \pm 0.01$, $\beta = 1.92 \pm 0.12$, $b = 5.06 \pm 0.32$, $c = 5.75 \pm 0.42$, $\chi^2/\text{dof} = 2.54/6$



We compute the central values of the moments $F_2^q(N)$ and estimate the errors using Monte Carlo methods

We extract the moments of resummed and NLO 'parton distribution functions':

$$f^{\rm NLO}(N) = \frac{F_2^q(N)}{C_2^{\rm NLO}(N)} \quad ; \quad f^{\rm res}(N) = \frac{F_2^q(N)}{C_2^{\rm res}(N)}$$



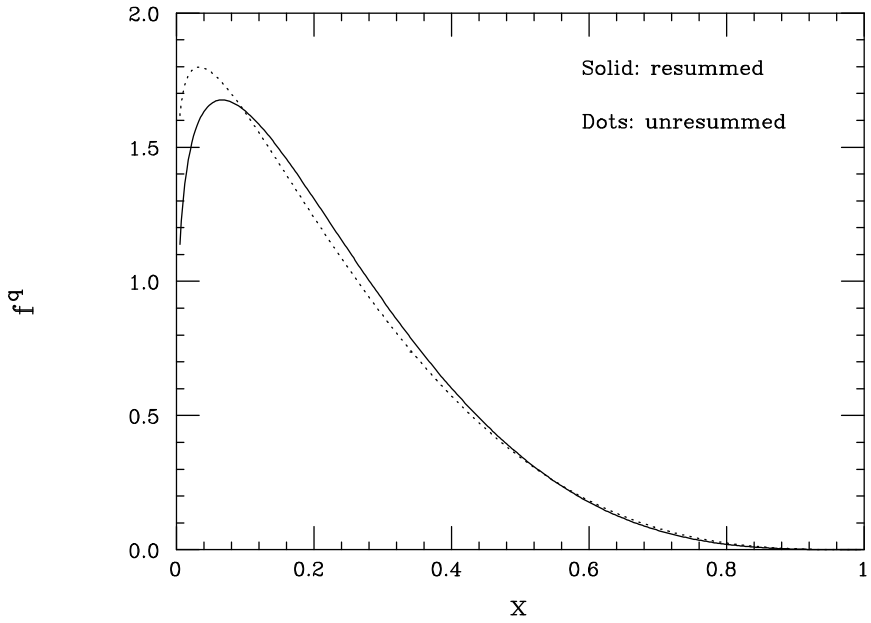
Effect of resummation for $N > 10$

Fits to: $f^q(x) = Ax^\alpha(1-x)^\beta \qquad Q^2 = 12.59$ **GeV**^{2}

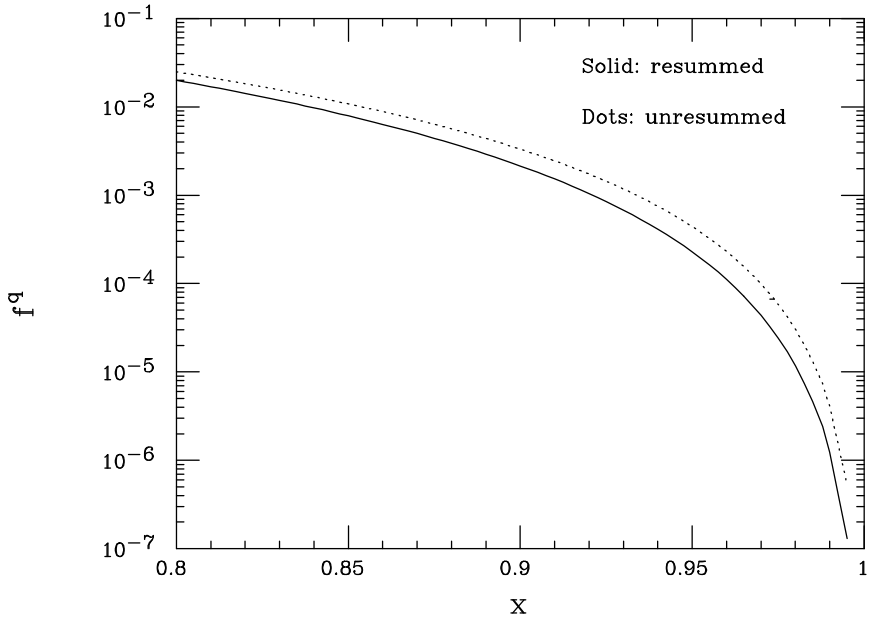
NLO: $A = 2.79 \pm 0.15$, $\alpha = 0.10 \pm 0.02$, $\beta = 2.92 \pm 0.04$, $\chi^2/\text{dof} = 1.7/17$

Resummed:

$A = 3.91 \pm 0.22$, $\alpha = 0.23 \pm 0.02$, $\beta = 3.25 \pm 0.05$, $\chi^2/\text{dof} = 6.4/17$



Large-x behaviour:



Conclusions and outlook

Soft-gluon resummation in CC DIS coefficient function to NLL accuracy

Effect of resummation on structure functions especially at small Q^2

Current pdf sets unable to fit NuTeV data at large x

Fits of moments of NuTeV data on F_2

Extraction of resummed and NLO 'parton distributions' in N and x spaces

Remarkable impact of soft resummation in the coefficient function on the fits

In progress:

Inclusion of correlations among data points and uncertainties on gluon parton densities

Investigation of other functional forms for $f^q(x, Q^2)$

Same analysis for F_3 and several Q^2 values

Studies of NC parton densities using the NNPDF work