Impact of large-x resummation on parton distributions

Gennaro Corcella

CERN TH

1. **Introduction**
2. **Soft resummation in the DIS coefficient function**
3. **Large-x CC and NC data**
4. **Resummed and NLO parton densities**
5. **Conclusions**

In collaboration with L. Magnea (Università di Torino)

Structure functions $\mathcal{F}_i$ in 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 (charged current):

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

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

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

$$\frac{d^2\sigma^{\nu(\bar{\nu})}}{dxdy} = \frac{G_F^2 ME}{\pi(1+Q^2/m_W^2)^2} \left\{ y^2 x F_1 + \left[1 - \left(1+\frac{Mx}{2E}\right) y\right] F_2 \pm y\left(1-\frac{y}{2}\right) x F_3 \right\}$$

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

$$F_1 = \mathcal{F}_1 \qquad F_2 = \frac{2x}{\rho^2}\mathcal{F}_2 \qquad F_3 = \frac{2}{\rho}\mathcal{F}_3 \qquad \rho = \sqrt{1+\left(\frac{2Mx}{Q}\right)^2}$$

CC NLO $\overline{\rm MS}$ coefficient functions: M. Glück, S. Kretzer and E. Reya, PLB 380 (1996) 171

Soft-gluon radiation

Quark-initiated coefficient function contains terms which get large for $x \to 1$ (soft gluons)

$$C^{\rm soft}(x,\mu_F^2,\lambda) = \delta(1-x) + \frac{C_F\alpha_S}{\pi}\left\{\left[\frac{\ln(1-x)}{1-x}\right]_+ + \frac{1}{(1-x)_+}\left(\ln\frac{Q^2}{\mu_F^2} - \frac{3}{4}\right)\right\}$$

$$f_N = \int_0^1 dx x^{N-1} f(x) \qquad \frac{1}{(1-x)_+} \to \ln N \qquad \left[\frac{\ln(1-x)}{1-x}\right]_+ \to \ln^2 N \quad \text{for } N\to\infty$$

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

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

$$\Delta_N = \exp\left\{\int_0^1 dz \frac{z^{N-1}-1}{1-z}\int_{\mu_F^2}^{Q^2(1-x)}\left[\frac{dk^2}{k^2}A\left[\alpha_S(k^2)\right] + \frac{1}{2}B\left[\alpha_S\left(Q^2(1-z)\right)\right]\right]\right\}$$

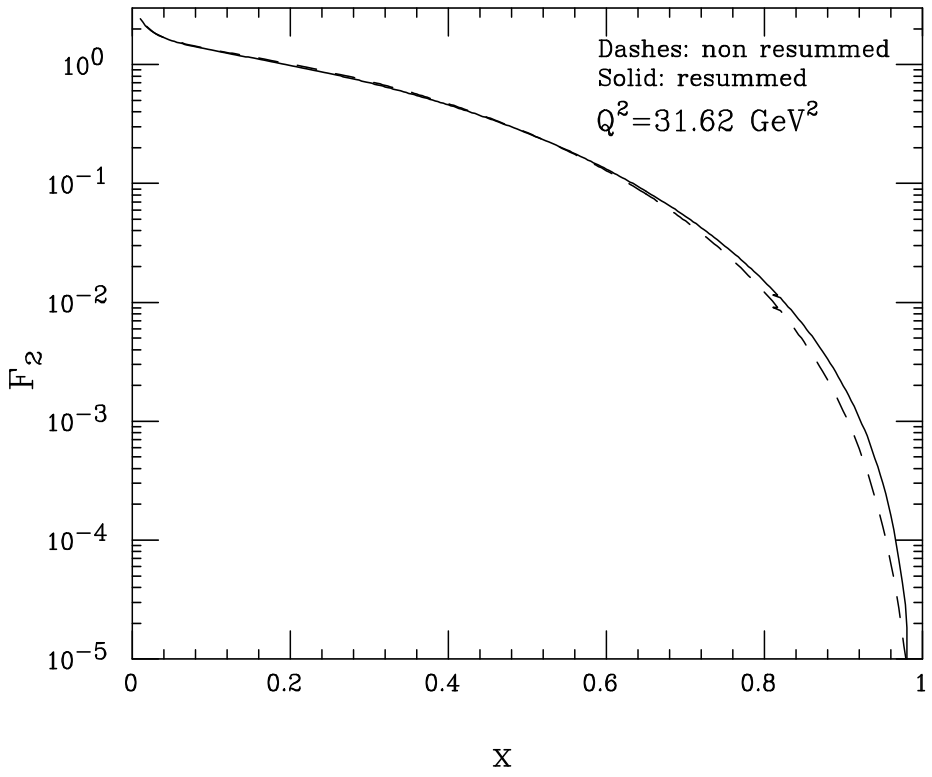
$$A(\alpha_S) = \sum_{n=1}^{\infty}\left(\frac{\alpha_S}{\pi}\right)^n A^{(n)} \;\; ; \;\; B(\alpha_S) = \sum_{n=1}^{\infty}\left(\frac{\alpha_S}{\pi}\right)^n$$

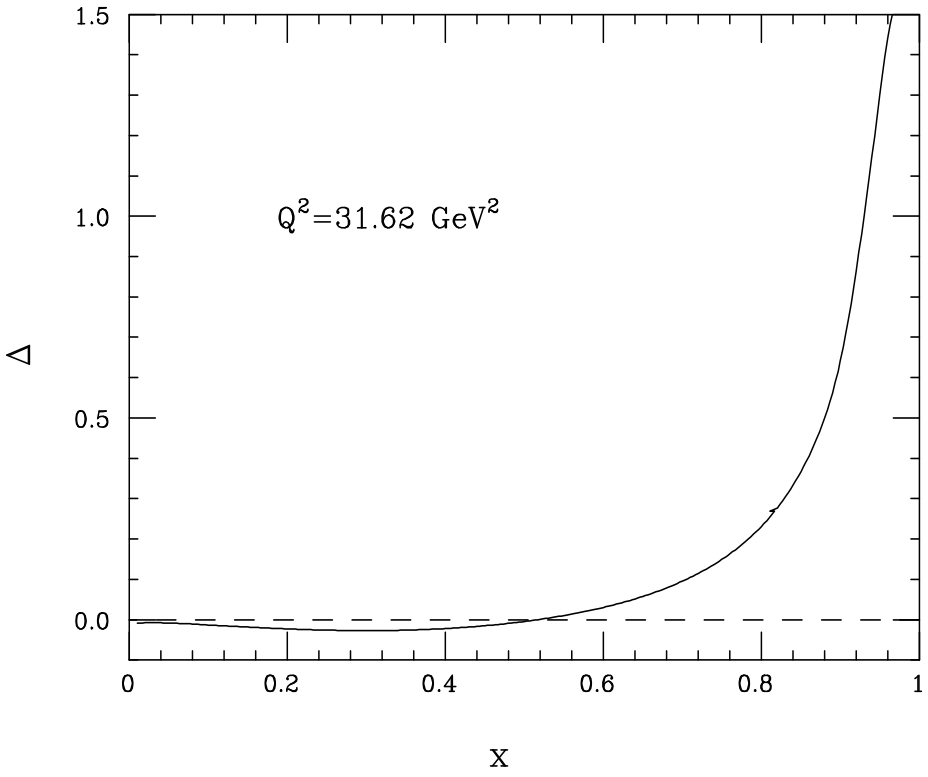
LL $\alpha_S^n \ln^{n+1} N$**:** $A^{(1)}$ **;** **NLL** $\alpha_S^n \ln^n N$**:** $A^{(1)}$, $A^{(2)}$, $B^{(1)}$

E. Laenen and S. Moch, PRD 59 (1999) 034027; G.C. and A. Mitov, NPB 676 (2004) 346:
soft resummation for heavy-quark production in DIS (A. Mitov's talk, heavy-flavour session)

Results for CC structure function F_2 with resummed coefficient function and NLO pdf (CTEQ6M)

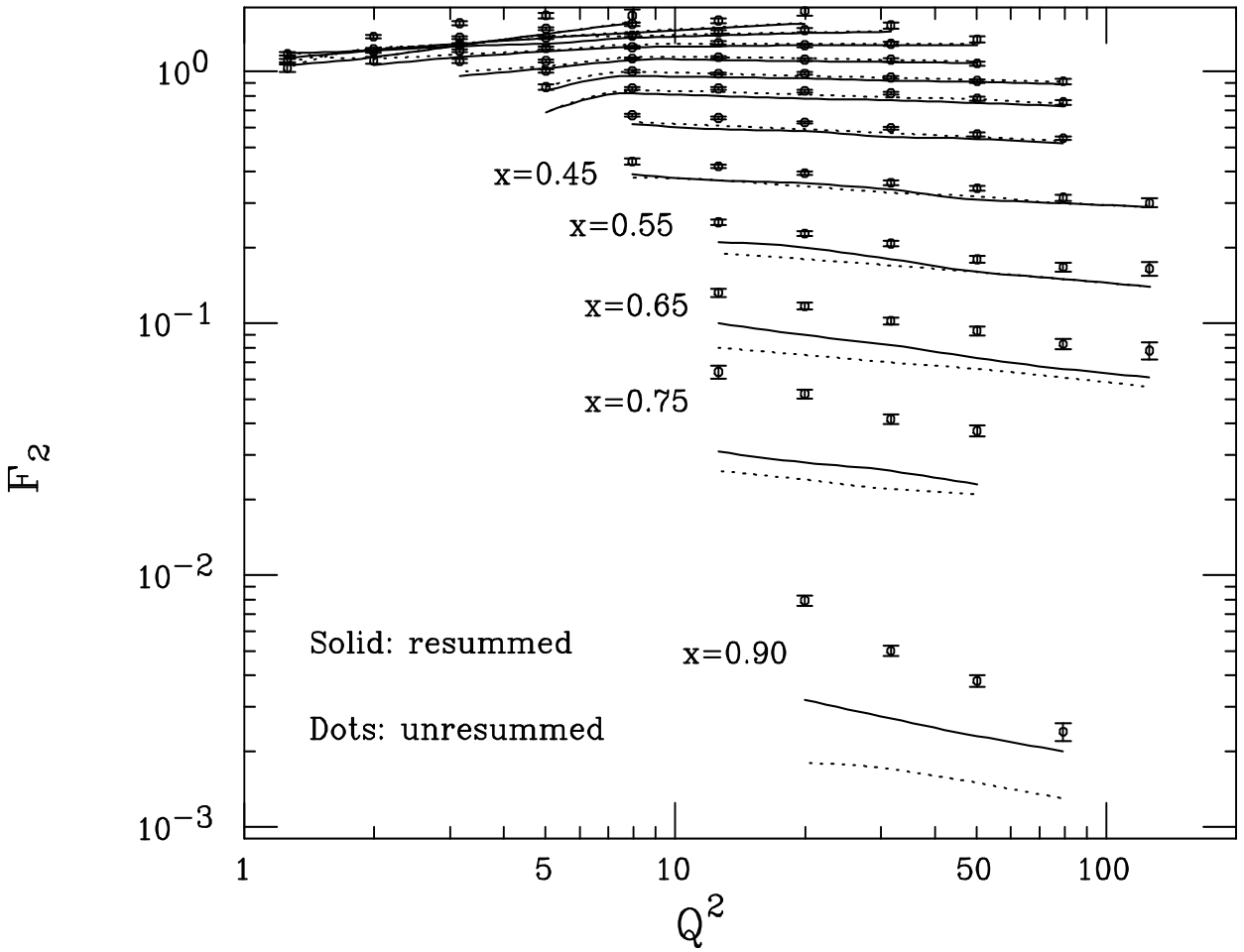
$Q^2 = 31.62$ **GeV^2 (NuTeV),** $\Delta = (F_2^{\rm res} - F_2^{\rm NLO})/F_2^{\rm NLO}$





Remarkable impact of large-x resummation for $x > 0.6$

Comparison with preliminary NuTeV data (CTEQ6M NLO pdf)



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

NuTeV data not included in CTEQ pdfs

Theory curves agree better with CCFR data at large-x, which were used in the fit (D. Naples et al., hep-ex/0307005, proceedings of DIS 2003)

A toy model for large-x resummed parton densities

- NuTeV data on F_2 and F_3 (CC), NMC/BCDMS on F_2 (NC)
- Parametrization of data at fixed values of Q^2
- Resummation is performed in N space: extraction of moments of linear combinations of parton densities
- Determination of valence quark distributions in N-space, with assumptions on gluon and sea densities
- Inversion to x-space

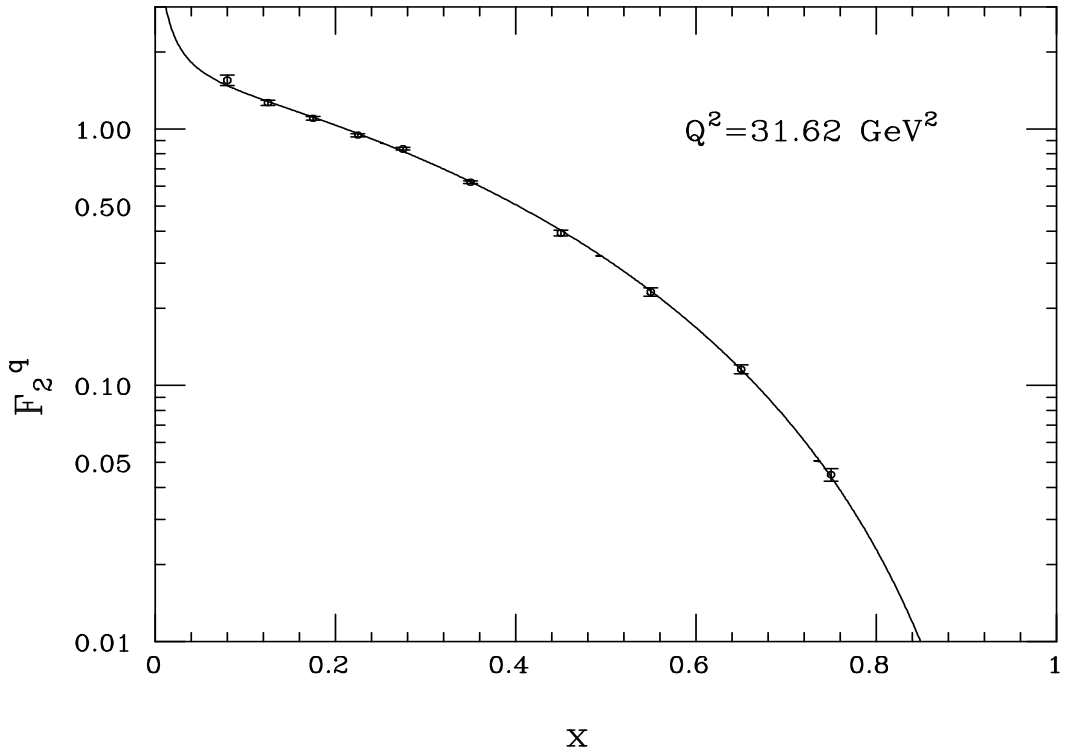
Fits of NuTeV structure function F_2 at $Q^2 = 31.62$ GeV^2 (correlations are neglected)

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

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

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

$$A = 0.17 \pm 0.01,\ \alpha = 0.61 \pm 0.03,\ \beta = 3.00 \pm 0.05,\ b = 17.20 \pm 1.37,\ \ \chi^2/\mathrm{dof} = 7.6/6$$



Similar results when using MRST gluon density

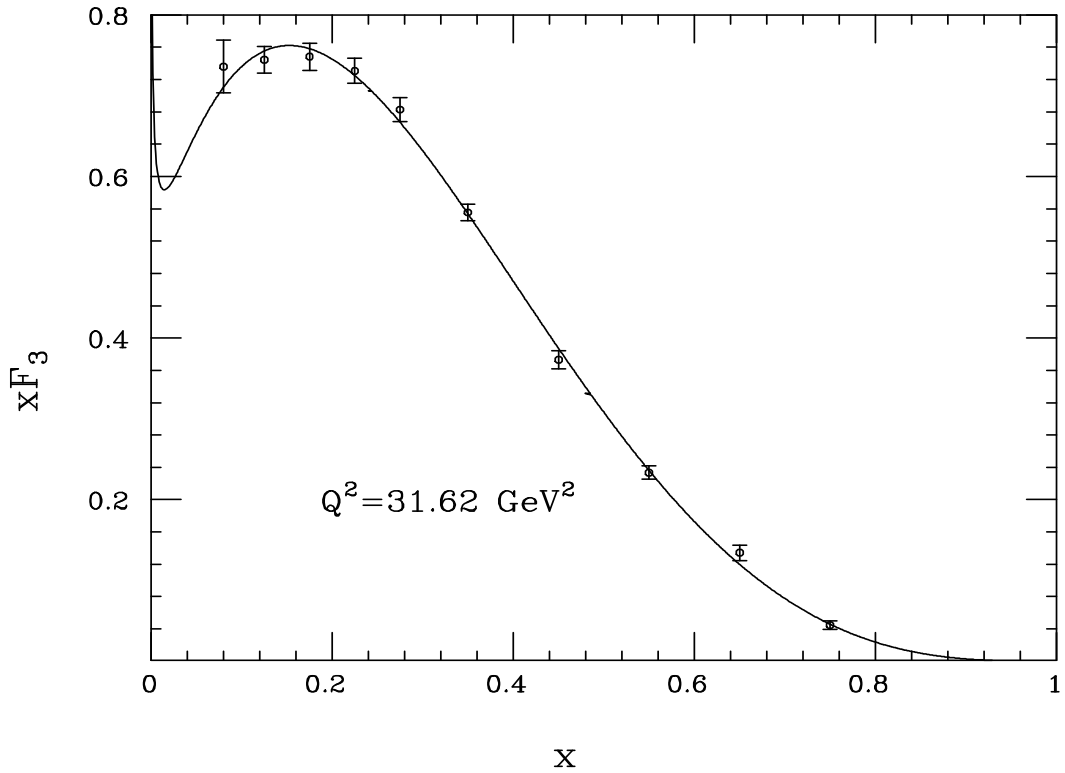
Likewise, for F_3 (NuTeV, CC, $Q^2 = 31.62$ GeV^2):

$$xF_3(x) = 2x\left(F_3^{\nu} - F_3^{\bar{\nu}}\right) = x\left[\sum_{q,q'} |V_{qq'}|^2 (q - \bar{q}) \otimes C_3^q\right]$$

$$F_3(x) = Ax^{-\alpha}(1-x)^{\beta}(1+bx)$$

Best fit values:

$A = 0.17 \pm 0.02$, $\alpha = 0.23 \pm 0.03$, $\beta = 3.17 \pm 0.08$, $b = 25.74 \pm 2.78$, $\chi^2/\text{dof} = 6.8/6$



Neutral current: nonsinglet F_2 from NMC/BCDMS

$$F_2^{\rm NS} = x(u-d) \otimes C_2^q = x f_2^{\rm NS} \otimes C_2^q$$

We use the neural network parametrization of the NNPDF Collaboration to extract $f_2^{\rm NS}$

L. del Debbio, S. Forte, J.I. Latorre, A. Piccioni and J. Rojo, hep-ph/0501067 (J. Rojo's talk)

We obtain a system of three equations:

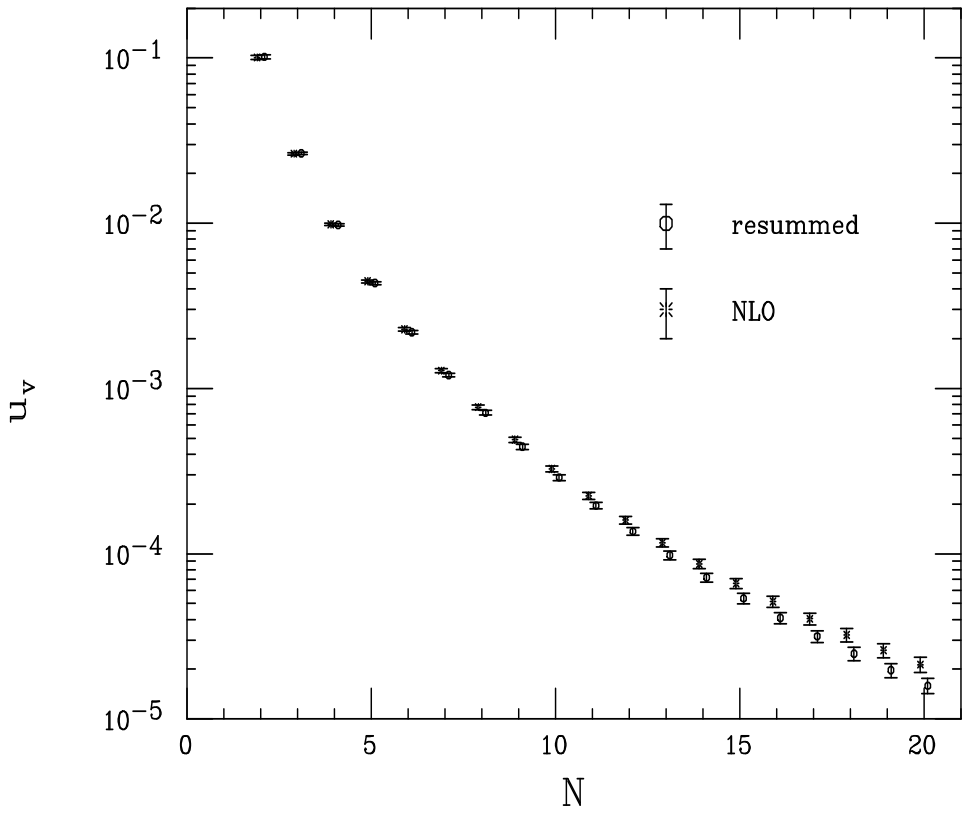
$$\begin{aligned}
f_2^q(CC) &= |V_{ud}|^2(u+d+\bar{u}+\bar{d}) + |V_{us}|^2(u+s+\bar{u}+\bar{s}) + |V_{cs}|^2(c+\bar{c}+s+\bar{s}) + |V_{cd}|^2(d+\bar{d}+c+\bar{c}) \\
f_3(CC) &= |V_{ud}|^2(u+d-\bar{u}-\bar{d}) + |V_{us}|^2(u+s-\bar{u}-\bar{s}) + |V_{cs}|^2(c-\bar{c}+s-\bar{s}) + |V_{cd}|^2(d-\bar{d}+c-\bar{c}) \\
f_2^{\rm NS}(NC) &= u-d
\end{aligned}$$

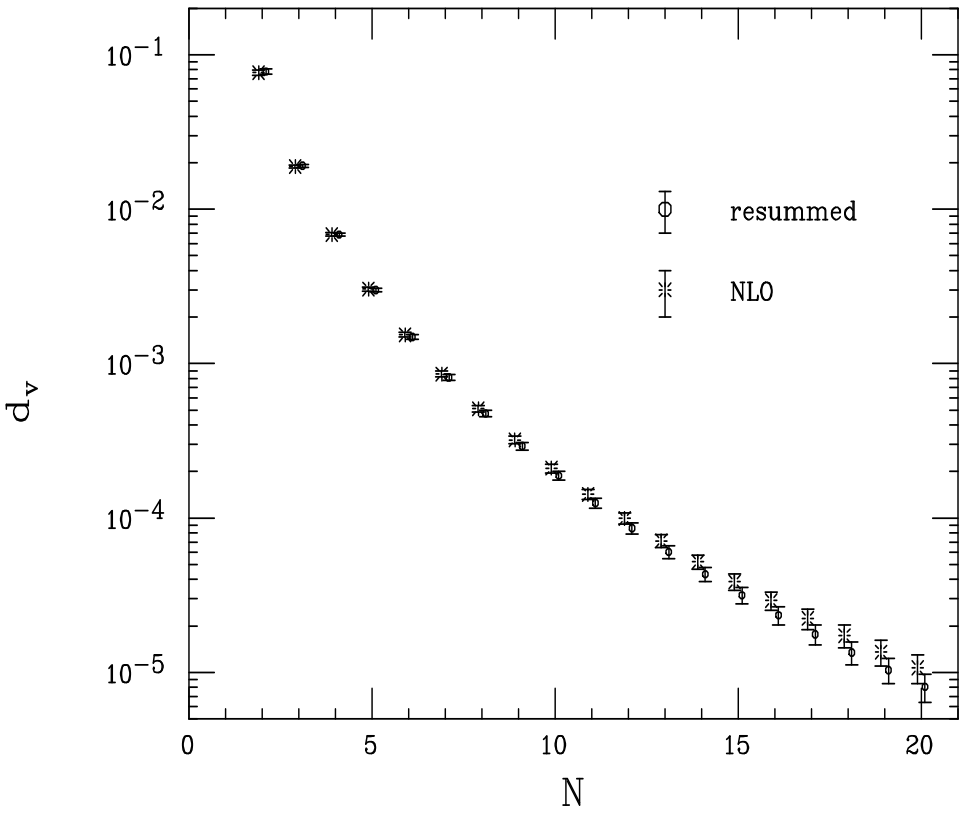
$u = u_V + \bar{u}$, $d = d_V + \bar{d}$

Simplifying assumptions: $s = \bar{s}$, $\bar{u} = \bar{d} = 2s$, $c = \bar{c} = 0$

Extraction of u_V, d_V and s first in moment space, afterwards in x-space

Moments of u_V and d_V distributions at $Q^2 = 31.62$ GeV^2





Effect of the resummation for $N > 7$

s-quark density: the errors are too large for the resummation to have an impact

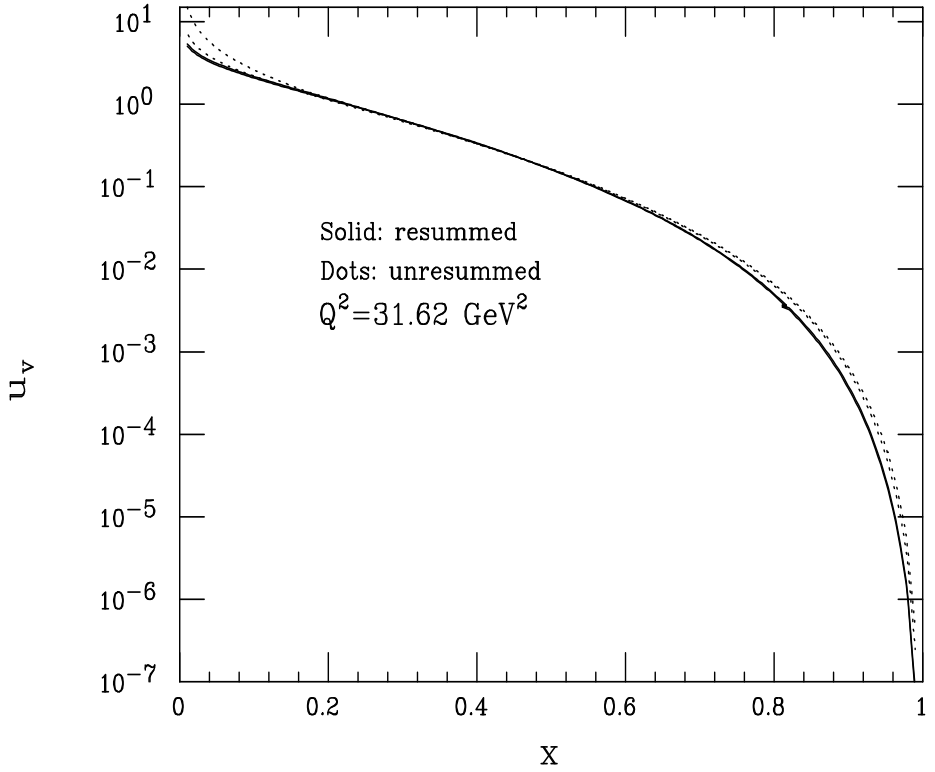
Inversion to x-space: $q(x) = Bx^{-\rho}(1-x)^{\delta}$

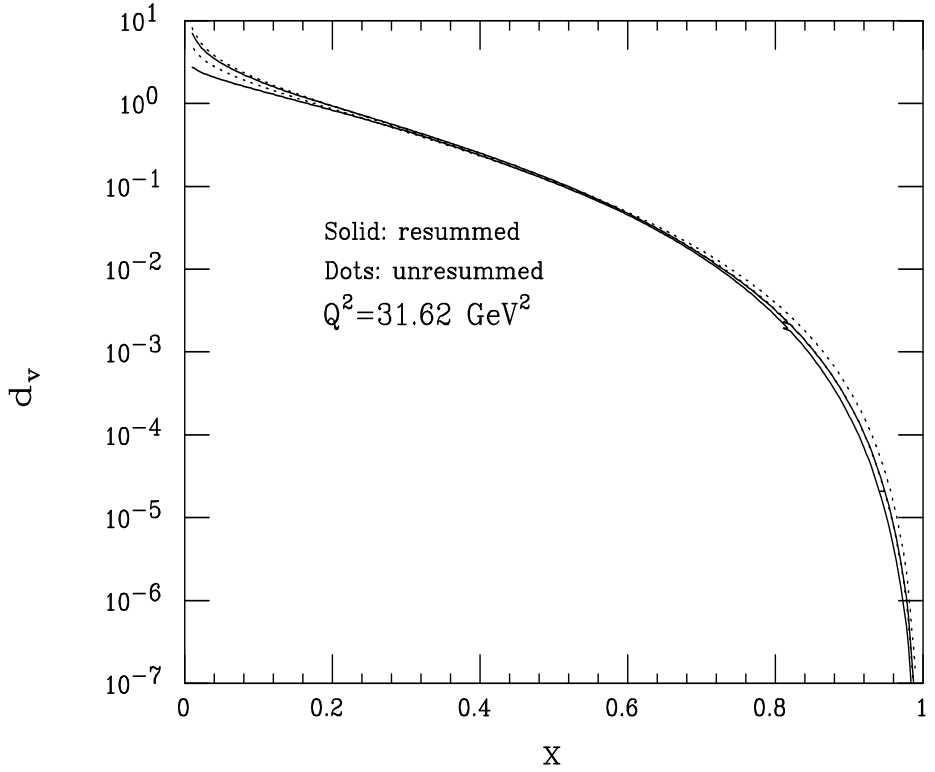
u_V: $B = 1.16 \pm 0.11$, $\rho = 0.47 \pm 0.06$, $\delta = 3.29 \pm 0.06$, $\chi^2/\mathrm{dof} = 0.4/15$ **(NLO)**;

$B = 1.58 \pm 0.17$, $\rho = 0.33 \pm 0.07$, $\delta = 3.61 \pm 0.07$, $\chi^2/\mathrm{dof} = 0.4/15$ **(resummed)**

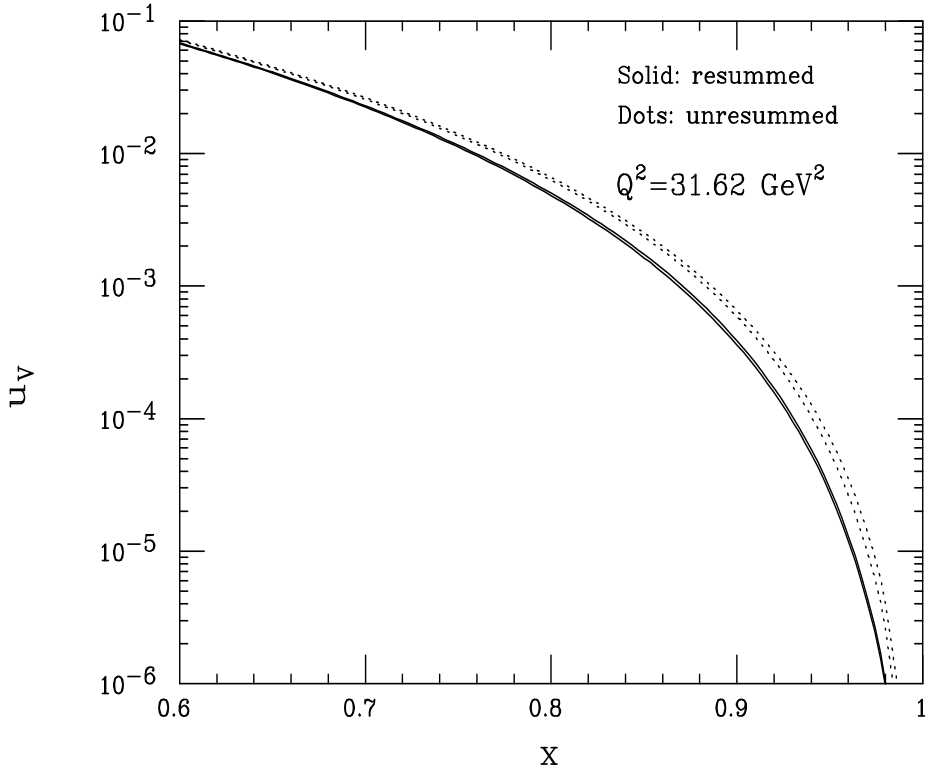
d_V: $B = 0.91 \pm 0.13$, $\rho = 0.47 \pm 0.08$, $\delta = 3.48 \pm 0.90$, $\chi^2/\mathrm{dof} = 1.7/15$ **(NLO)**;

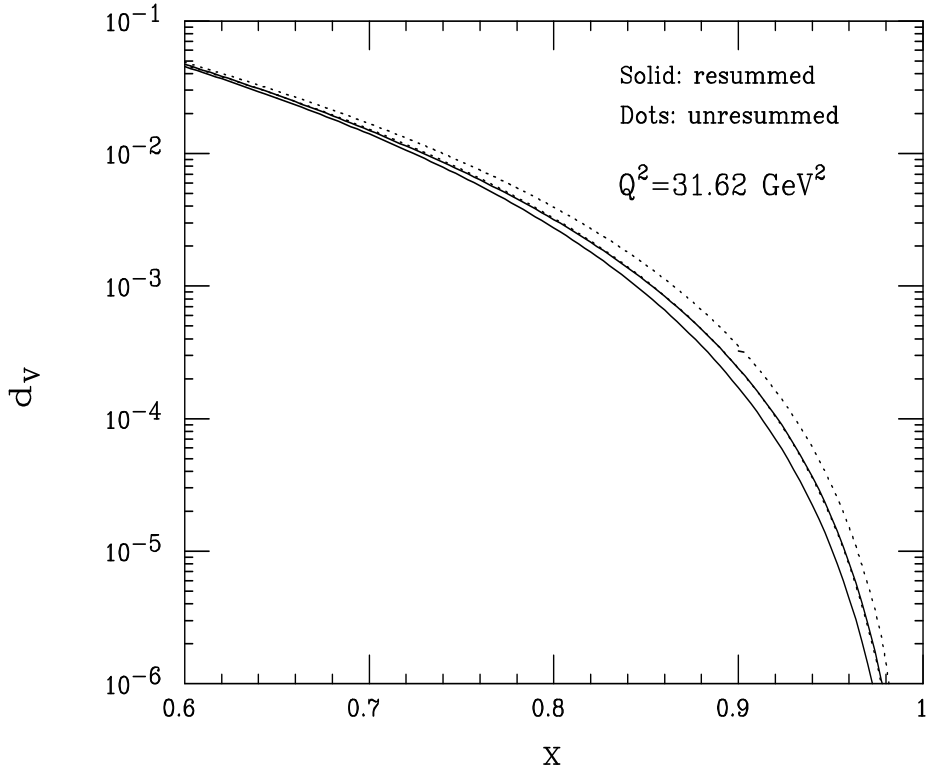
$B = 1.25 \pm 0.19$, $\rho = 0.34 \pm 0.09$, $\delta = 3.79 \pm 0.10$, $\chi^2/\mathrm{dof} = 1.5/15$ **(resummed)**





Large-x behaviour of up and down distributions





Big effect of the resummation on the u_V parton density

u_V: **impact of** 25% **at** $x = 0.8$ **;** 40% **at** $x = 0.9$

Conclusions

Soft resummation in DIS coefficient function with NLL accuracy

Relevant effect of resummation on structure functions at large x

Fits of NuTeV data on CC F_2 and F_3 at 31.62 GeV^2

Use of NNPDF work to get the NC nonsinglet F_2

Extraction of resummed and NLO u_V and d_V parton densities in moment and x-space

Remarkable impact of the resummation, especially on the u_V distribution

In progress:

Implementation of DGLAP evolution and application to Tevatron and LHC physics