NONLINEAR CORRECTIONS TO THE DGLAP EQUATIONS IN VIEW OF THE HERA DATA

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Outlines

- Nonlinear corrections to the DGLAP equations in view of the HERA data

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  hep-ph/0211239

- Enhancement of charm quark production due to nonlinear corrections to the DGLAP equations

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  hep-ph/0310111

- D-meson enhancement in pp collisions at the LHC due to nonlinear gluon evolution

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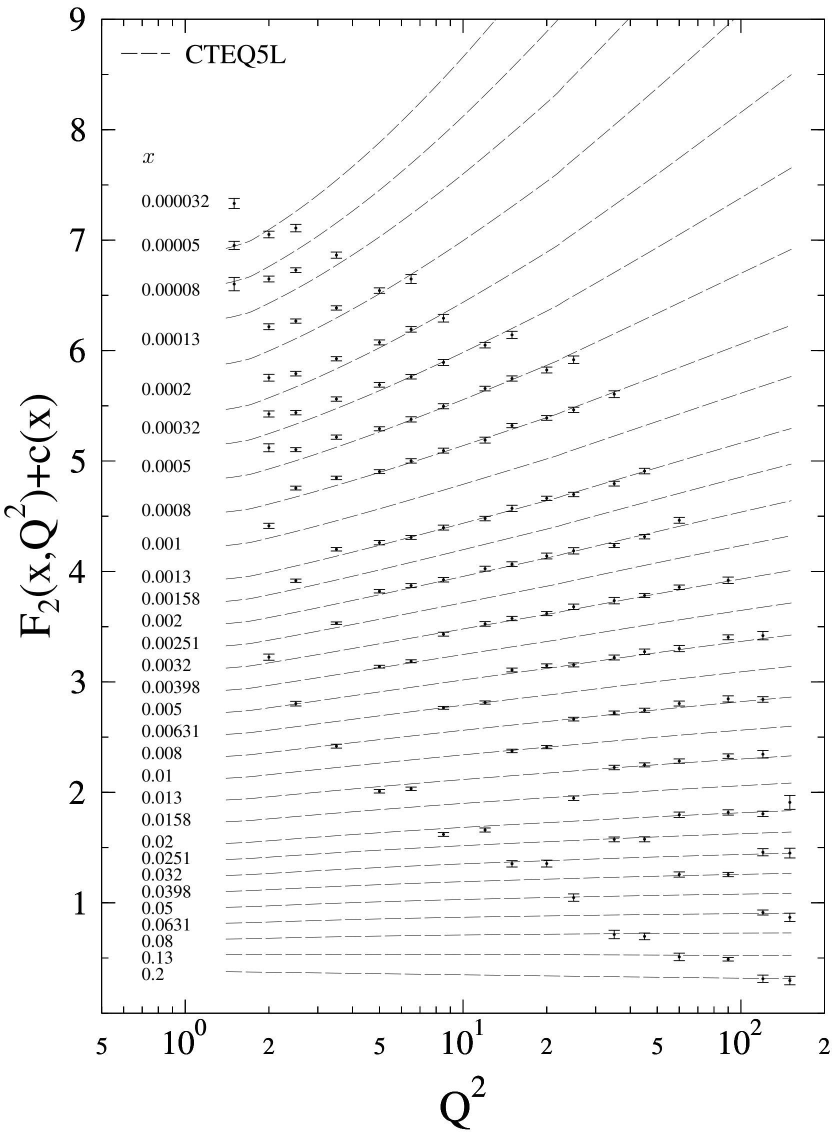
  hep-ph0403098

Motivation

HERA-data: older parton distribution function (PDF) sets do not fit the HERA data adequately at small x and small Q^2.

$$\frac{\partial F_2(x,Q^2)}{\partial \log Q^2} \approx 5\alpha_s \frac{xg(2x,Q^2)}{9\pi}$$

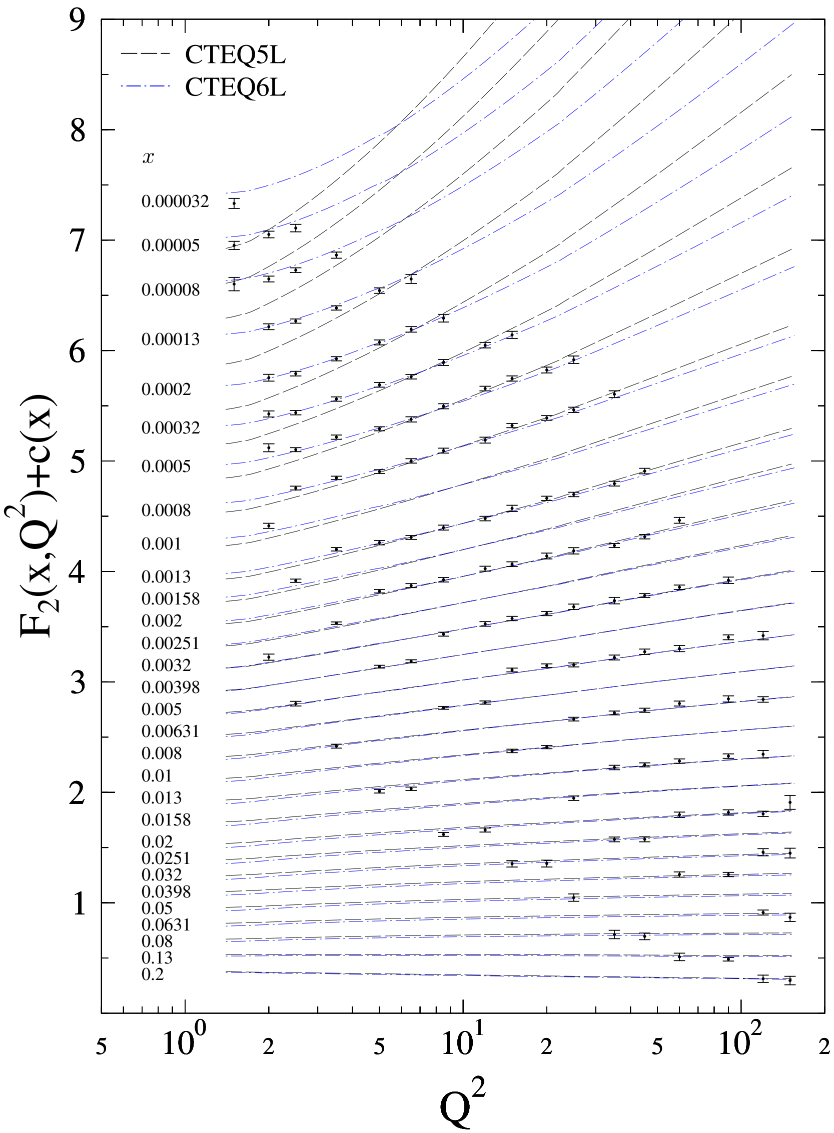
[K. Prytz, Phys. Lett. **B311** (1993) 286]



Motivation

New CTEQ and MRST sets work better. Simultaneous fitting of small ($Q^2 < 4$ GeV^2) and large ($Q^2 > 4$ GeV^2) scales is difficult.

$\rightarrow$ negative NLO gluons at small x, Q^2



Nonlinear evolution equations

By: K.J. Eskola, H.Honkanen, V.J. Kolhinen, J. Qiu & C. Salgado

- At large interaction scales Q^2 the DGLAP equations predict well the scale evolution.

- At small x and Q^2, gluon recombination effects in the parton distribution functions (PDFs) are expected to become significant $\longrightarrow$ nonlinear corrections

- First of these corrections, (GLRMQ terms, by Gribov, Levin and Ryskin, and Mueller and Qiu) have been included in the LO DGLAP evolution

- Goal: to improve fit at small Q^2, while maintaining the good fit at large Q^2

Nonlinear corrections:

General form: [Mueller&Qiu, NP B268 (1986) 427]

$$\frac{\partial xg(x,Q^2)}{\partial \log Q^2} = \frac{\partial xg(x,Q^2)}{\partial \log Q^2}\Big|_{\mathsf{DGLAP}} - \frac{9\pi}{2}\frac{\alpha_s^2}{Q^2}\int_x^1 \frac{dy}{y} y^2 G^{(2)}(y,Q^2)$$

and

$$x^2 G^{(2)}(x,Q^2) = \frac{1}{\pi R^2}[xg(x,Q^2)]^2.$$

We take $R = 1$ fm

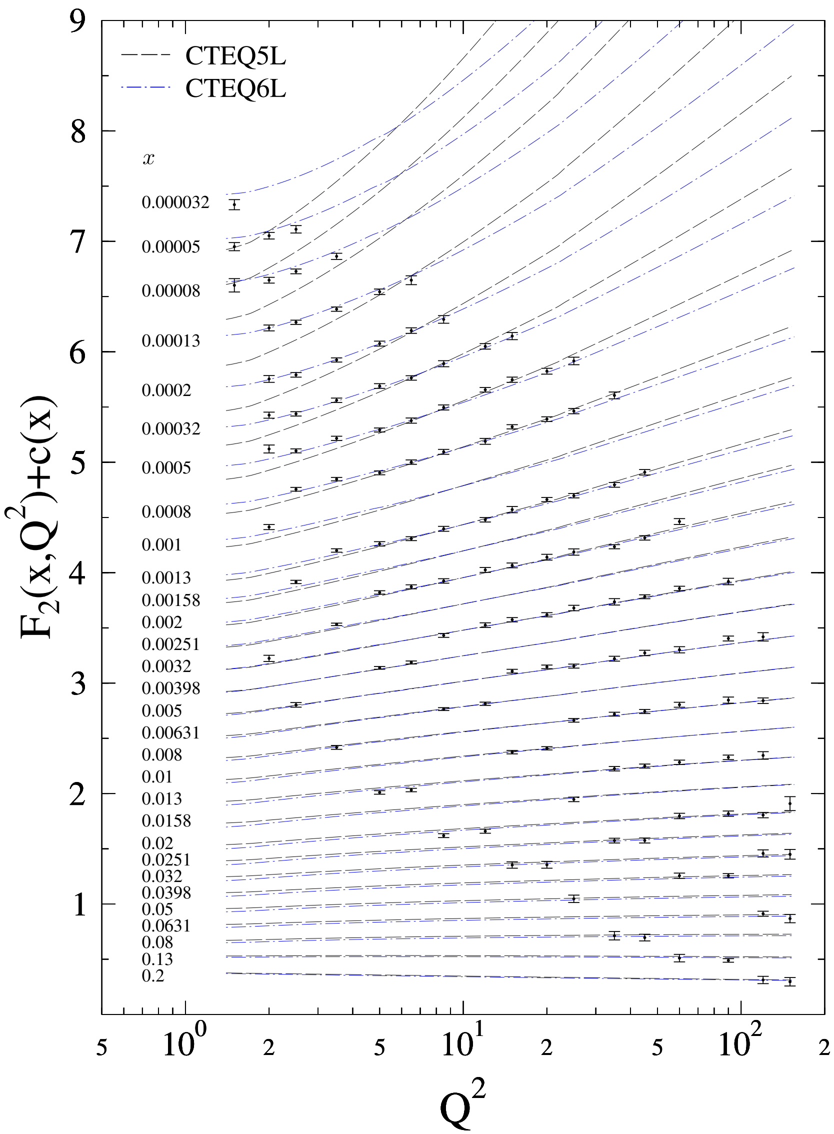
Similarly for sea quarks (valence not modified)

$$\begin{aligned}\frac{\partial xq(x,Q^2)}{\partial \log Q^2} &\approx \frac{\partial xq(x,Q^2)}{\partial \log Q^2}\Big|_{\mathrm{DGLAP}} \\ &- \frac{3\pi}{20}\frac{\alpha_s^2}{Q^2}x^2G^{(2)}(x,Q^2) \\ &+ \ldots G_{\mathrm{HT}}\end{aligned}$$

Assume that $G_{\mathrm{HT}}(x,Q^2)=0$

How to find a suitable initial distribution?

- Baselines used:
  - CTEQ5L & CTEQ6L PDFs; they only use $Q^2 > 4$ GeV^2 data in the fit → avoid some small scale effects entering the PDFs
  - Constraints: HERA DIS data for $F_2^p(x, Q^2)$

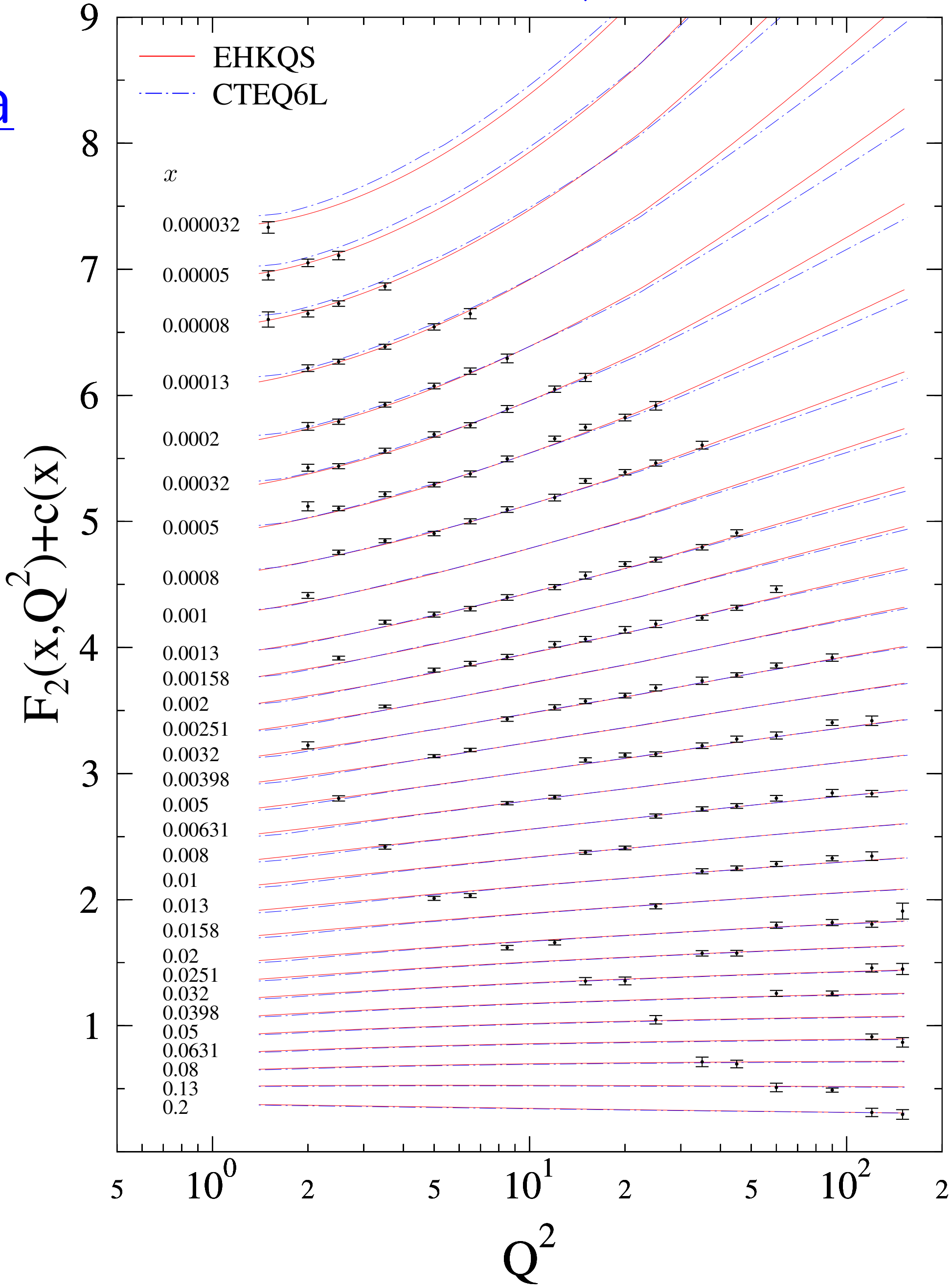


Iteration:

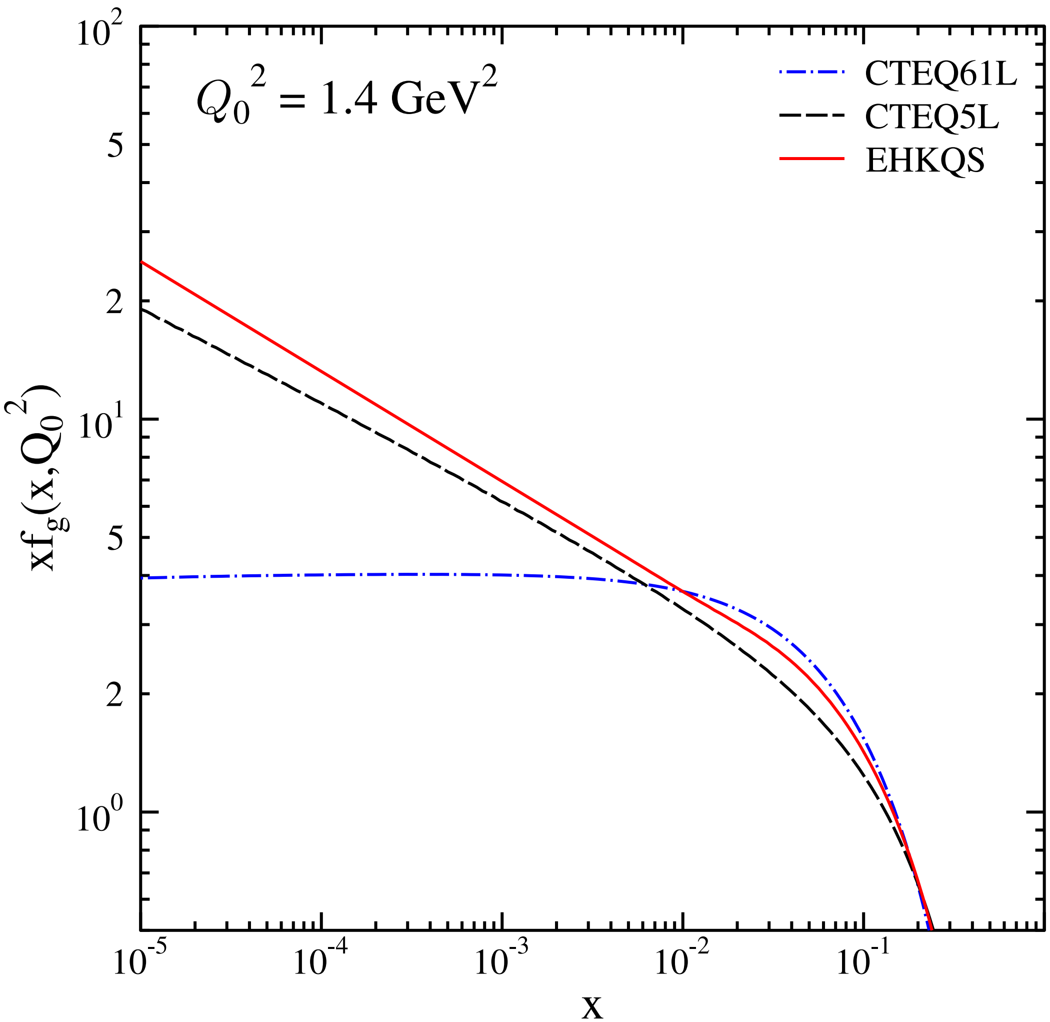
- Take CTEQ5L & 6L at $Q^2 = 3,5,10$ GeV^2 and interpolate to get an initial attempt for distribution
- Evolve down to $Q_0^2 = 1.4$ GeV^2 using DGLAP+GLRMQ to get the initial parametrization
- Evolve upwards using DGLAP+GLRMQ and compare to HERA data

Result: EHKQS PDF set, with a good fit to the HERA data for $F_2^{\rm p}(x, Q^2)$ at $x > 3 \times 10^{-5}$, $Q^2 > 1.5$ GeV^2

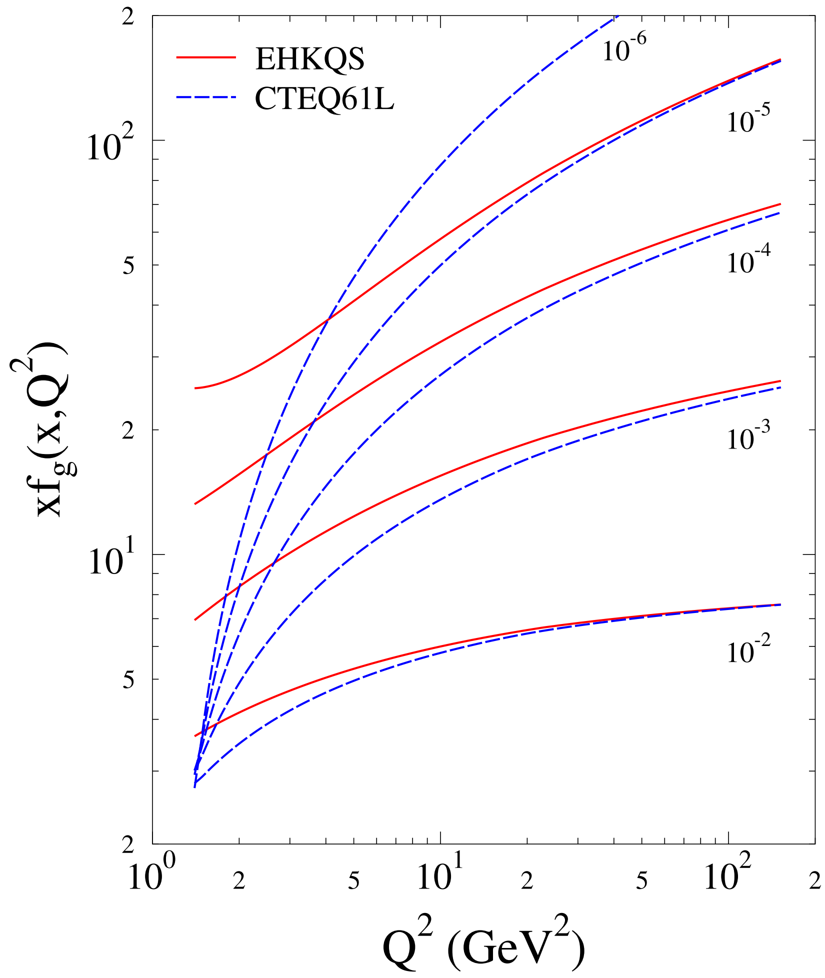
HERA data


EHKQS
CTEQ6L
x
0.000032
0.00005
0.00008
0.00013
0.0002
0.00032
0.0005
0.0008
0.001
0.0013
0.00158
0.002
0.00251
0.0032
0.00398
0.005
0.00631
0.008
0.01
0.013
0.0158
0.02
0.0251
0.032
0.0398
0.05
0.0631
0.08
0.13
0.2
F2(x,Q2)+c(x)
Q2

Initial gluon distribution

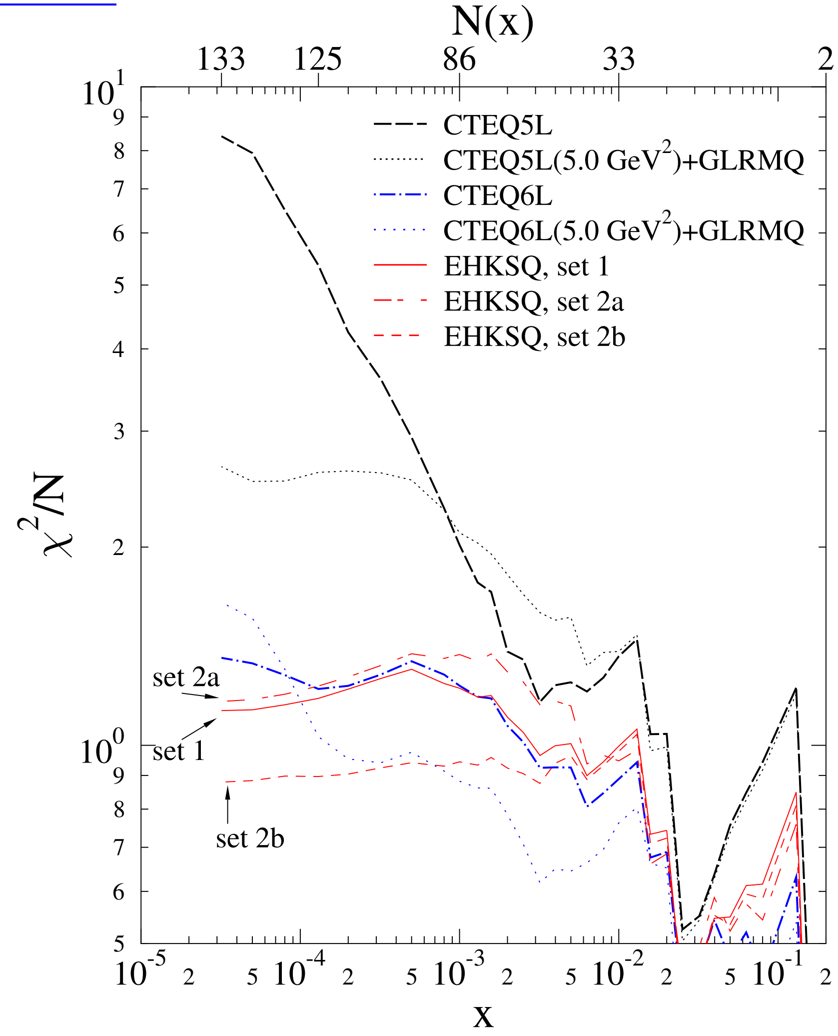


Gluon evolution



χ^2 of the fit

	$Q^2 < 4.0$ GeV^2 $N = 29$	$Q^2 > 4.0$ GeV^2 $N = 104$	all Q^2 $N = 133$
CTEQ5L	31.8	1.18	7.86
CTEQ6L	2.72	0.93	1.32
MRST2001	0.59	2.06	1.74
This work:			
Set 1: $Q_c < \sqrt{1.4}$ GeV	1.75	0.96	1.13
Set 2a: $Q_c = 1.3$ GeV	1.58	1.05	1.17
Set 2b: $Q_c = \sqrt{1.4}$ GeV	0.95	0.86	0.88



Conclusions

Nonlinear corrections have been included into the LO DGLAP evolution equations.

As a result, a higher gluon distribution can be allowed at small x, small Q^2 while still maintaining a good fit to the HERA data.

As HERA data alone cannot tell whether nonlinear terms should be included. More probes are needed $\rightarrow$ enhancement in charm quark production (talk by Andrea Dainese).