The QCD evolution of F_2^p at small–x *

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- The structure function of the proton F_2 in QCD
- Standard χ^2 analysis
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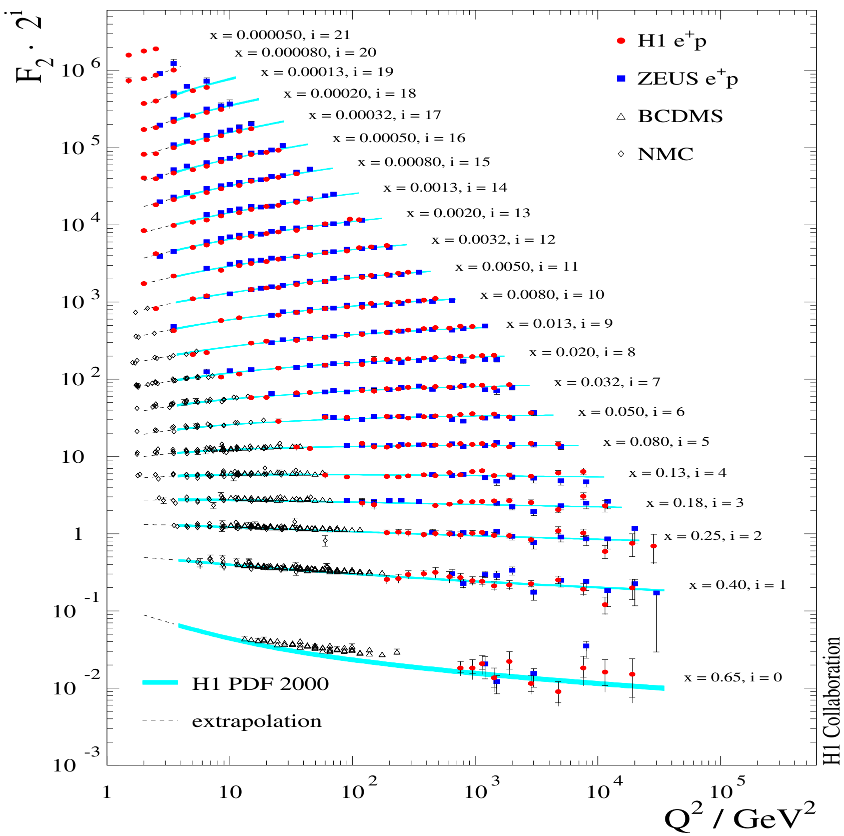
* EPJ C40, 515 (2005); in collaboration with M. Glück and E. Reya

The structure function of the proton F_2 in QCD

- At fixed x and $Q^2 \gtrsim 1$ GeV^2 , the structure function of the proton F_2 appears to depend logarithmically on Q^2



- This behaviour arises from perturbative QCD (pQCD), which dictates the Q^2–evolution of the underlying parton distributions $f(x, Q^2)$, $f = q, \bar{q}, g$
- The parton distributions are fixed at a specific input scale $Q^2 = Q_0^2$, mainly by experiment, only their evolution to any $Q^2 > Q_0^2$ being predicted by pQCD

Standard χ^2 analysis

Does the NLO pQCD Q^2–evolution agree with recent HERA data on F_2 at $x \lesssim 10^{-3}$?

- In order to answer, we adopt two sets of input distributions at $Q_0^2 = 1.5$ GeV^2 with $u_v = u - \bar{u}$, $d_v = d - \bar{d}$, $s = \bar{s}$, $\Delta \equiv \bar{d} - \bar{u}$ taken from GRV98

  best fit set: the sea $\bar{u} + \bar{d}$ and the gluon g GRV distributions are modified in the small–x region to obtain an optimal fit to the data

  $\mathrm{GRV_{mod}}$ set: the $\bar{u} + \bar{d}$ and g GRV distributions are modified as little as possible in the small–x region

- The input distributions $f = \bar{u} + \bar{d}$, g at $Q_0^2 = 1.5$ GeV^2 are expressed as

$$xf(x, Q_0^2) = N x^{-a} \left(1 + b\sqrt{x} + c\,x\right) (1 - x)^d$$

  the parameters c, d being kept unchanged and taken from GRV.
  The refitted relevant small–x parameters are

  best fit set: $N_s\,,\ a_s\,,\ b_s\,,\ N_g\,,\ a_g\,,\ b_g$

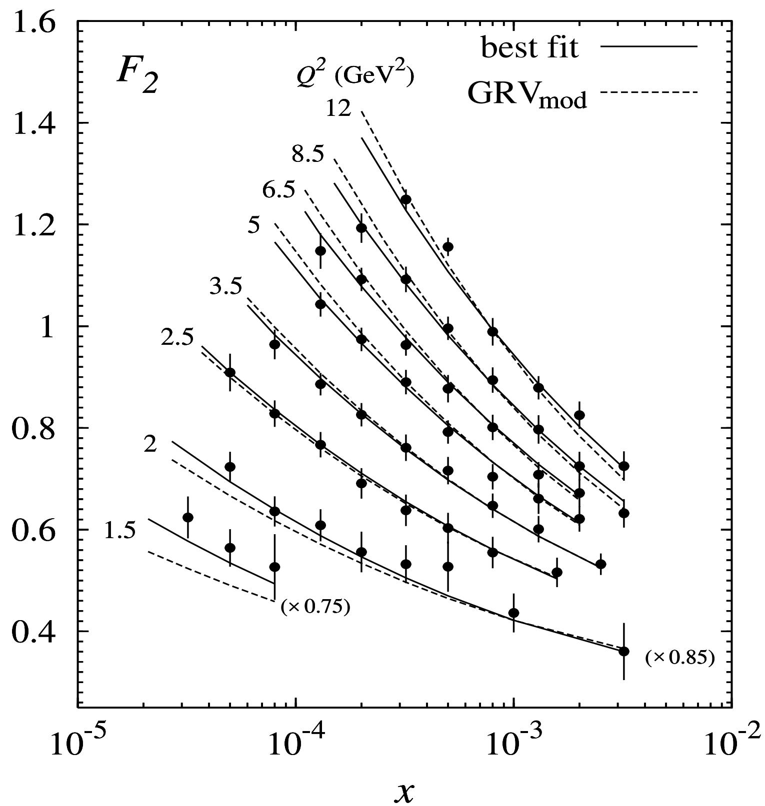
  $\mathrm{GRV_{mod}}$ set: $N_s\,,\ a_s\,,\ b_s\,,\ a_g$

Comparison with the experimental data

- The data considered are restricted to

$$1.5\ \mathrm{GeV}^2 \leq Q^2 \leq 12\ \mathrm{GeV}^2, \qquad 3\times 10^{-5} \lesssim x \lesssim 3\times 10^{-3}$$

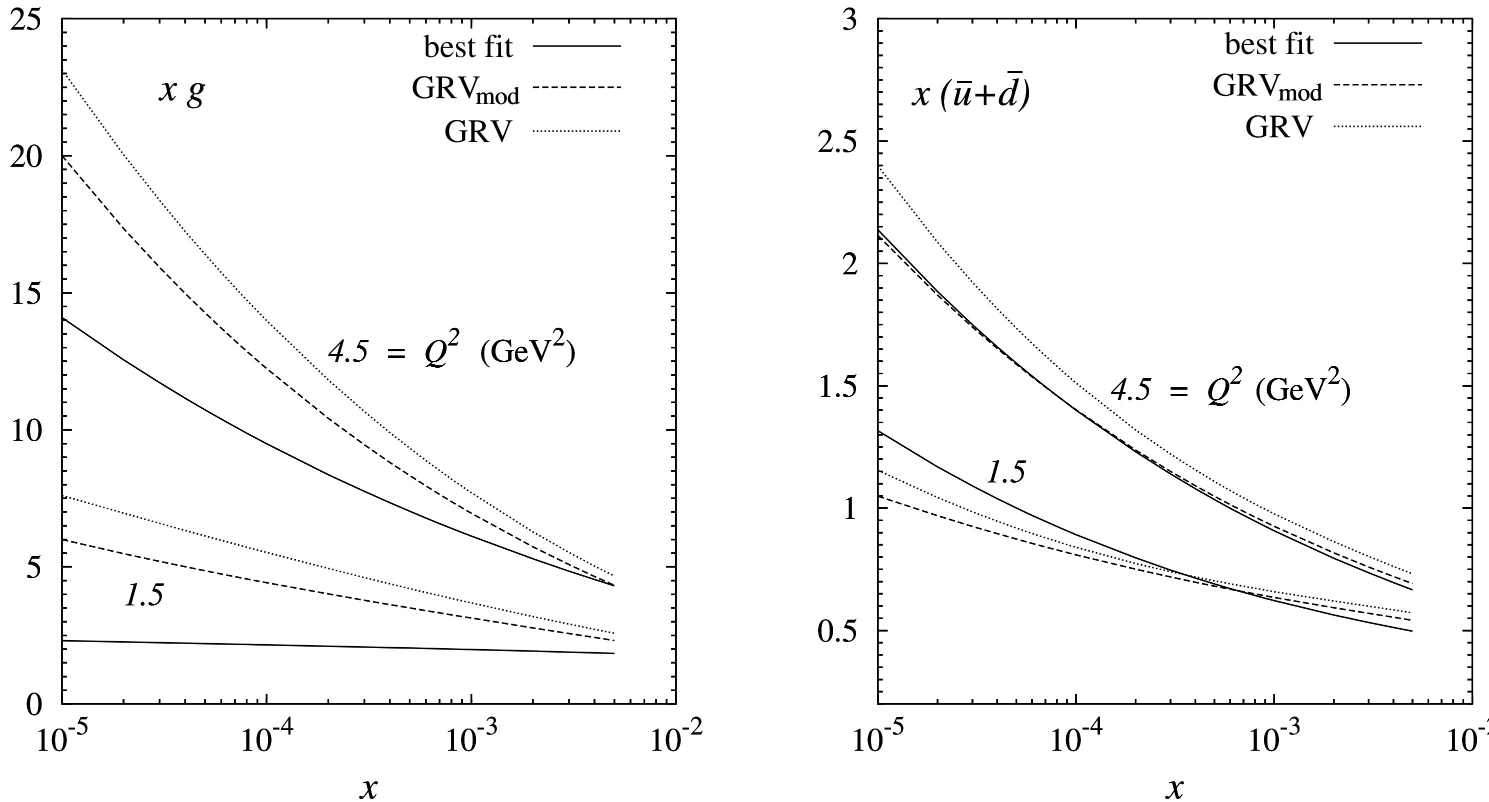
C. Adloff et al., H1 Collab., EPJ C21, 33 (2001)



- Both fits are compatible with the data, yielding comparable χ^2: agreement between the NLO Q^2–evolution of $f(x, Q^2)$ and the measured Q^2–dependence of $F_2(x, Q^2)$

Resulting gluon and sea distributions

- Both of the new small–x gluon distributions at $Q^2 = 4.5$ GeV^2 conform to the rising shape obtained in most available analyses published so far



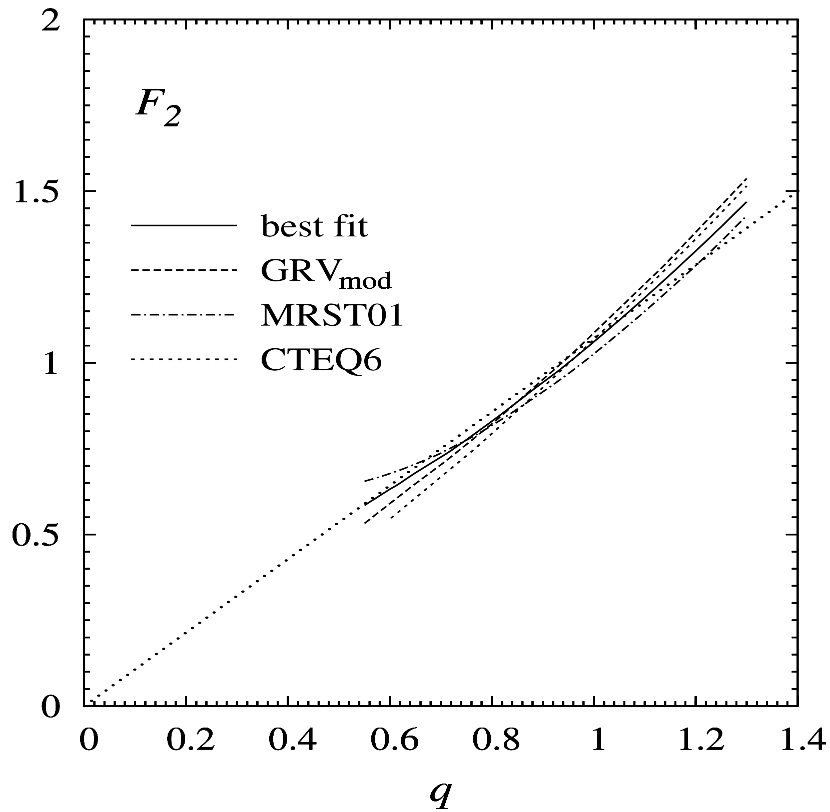
- It is possible to conceive a valence–like gluon at some very–low Q^2 scale, but even in this extreme case the gluon ends up as non valence–like at $Q^2 > 1$ GeV^2, in particular at $Q^2 = 4.5$ GeV^2

Curvature test of F_2

- At $x = 10^{-4}$ most measurements lie along a straight (dotted) line, if plotted versus

$$q = \log_{10}\left(1 + \frac{Q^2}{0.5\,\mathrm{GeV}^2}\right)$$

D. Haidt, EPJ C35, 519 (2004)

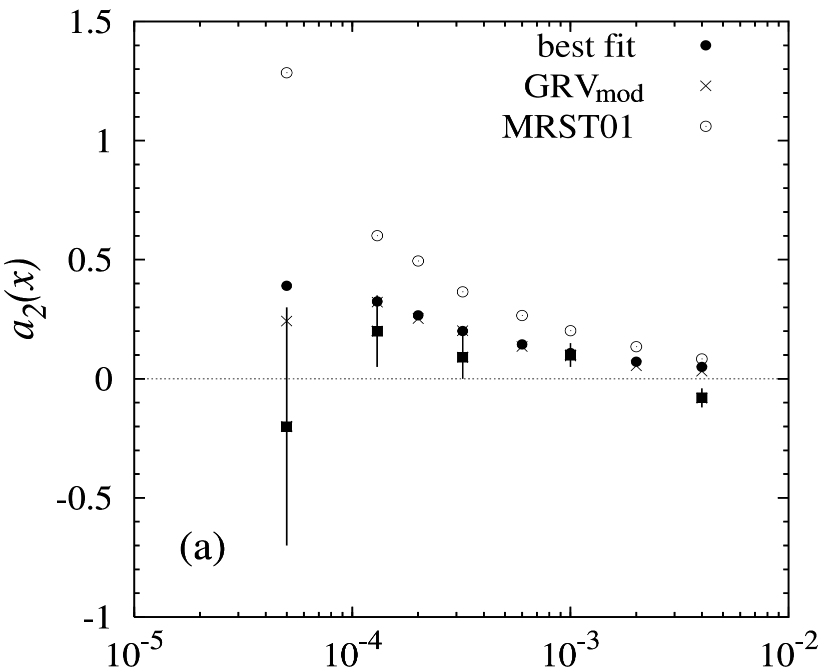


- MRST01 fit: sizable curvature for F_2, incompatible with the data, mainly caused by the valence–like input gluon distribution at $Q_0^2 = 1$ GeV^2

Calculation of the curvature

- The curvature $a_2(x) = \frac{1}{2}\,\partial_q^2 F_2(x,Q^2)$ is evaluated by fitting the predictions for $F_2(x,Q^2)$ at fixed values of x to a (kinematically) given interval of q, as

$$F_2(x,Q^2) = a_0(x) + a_1(x)q + a_2(x)q^2$$



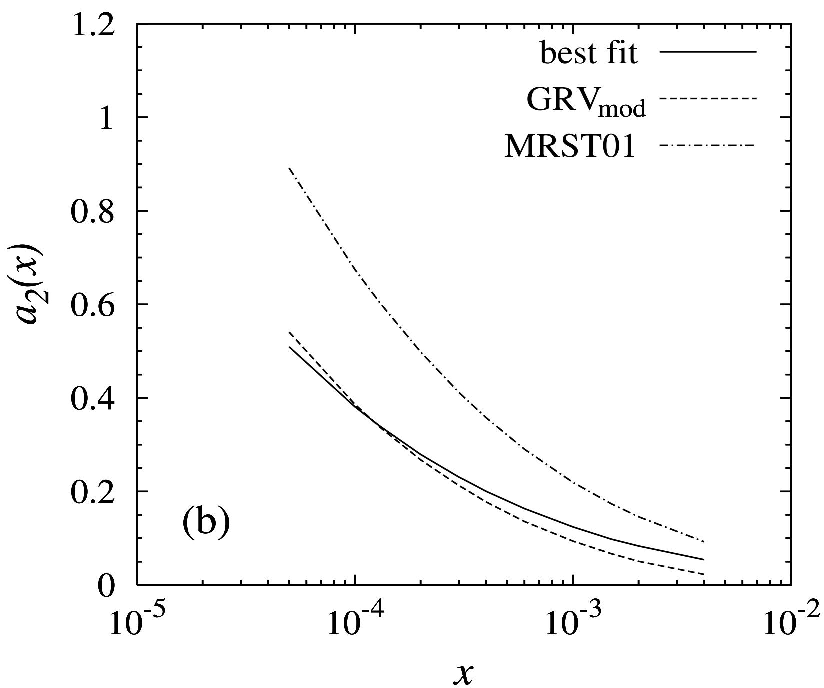
$$0.7 \le q \le 1.4 \quad \text{for} \quad 2\times 10^{-4} < x < 10^{-2}$$
$$0.7 \le q \le 1.2 \quad \text{for} \quad 5\times 10^{-5} < x \le 2\times 10^{-4}$$
$$0.6 \le q \le 0.8 \quad \text{for} \quad x = 5\times 10^{-5}$$

- (a): The average value of q decreases with decreasing x due to the kinematically more restricted Q^2 range accessible experimentally

- Both of our fits agree with the experimental curvatures, as calculated by Haidt using H1 data

Results

- (b): For comparison $a_2(x)$ is also shown for an x–independent fixed q–interval



$$0.6 \leq q \leq 1.4$$
$$(1.5\ \mathrm{GeV}^2 \leq Q^2 \leq 12\ \mathrm{GeV}^2)$$

- Perturbative NLO evolutions result in a positive curvature $a_2(x)$, which increases as x decreases

- This feature is supported by the data; the data point at $x < 10^{-4}$ is statistically insignificant. Future precision measurements in this very small x–region should provide a sensitive test of the range of validity of pQCD evolutions

Summary and conclusions

- A dedicated test of the pQCD NLO parton evolution in the small–x region has been performed

- The Q^2-dependence of $F_2(x, Q^2)$ is compatible with recent high-statistics measurements in that region

- A characteristic feature of perturbative QCD is a positive curvature $a_2(x)$, which increases as x decreases

- Present data are indicative for such a behaviour, but they are statistically insignificant for $x < 10^{-4}$.
  The H1 Collab. has found a good agreement between the perturbative NLO evolution and the slope of F_2, $a_1(x)$, i.e. the first derivative $\partial_{Q^2} F_2$

- Future precision measurements should provide further information concerning the detailed shapes of the gluon and the sea distributions at very small x and perhaps may even provide a sensitive test of the range of validity of pQCD