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Scaling Violation Analysis of the H1 F_2 Data

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Introduction

- neutral current $ep \to eX$ scattering

$$\frac{d^2\sigma}{dx dQ^2} = \kappa \cdot [F_2(x,Q^2) - \frac{y^2}{Y_+} \cdot F_L(x,Q^2)\ ]$$

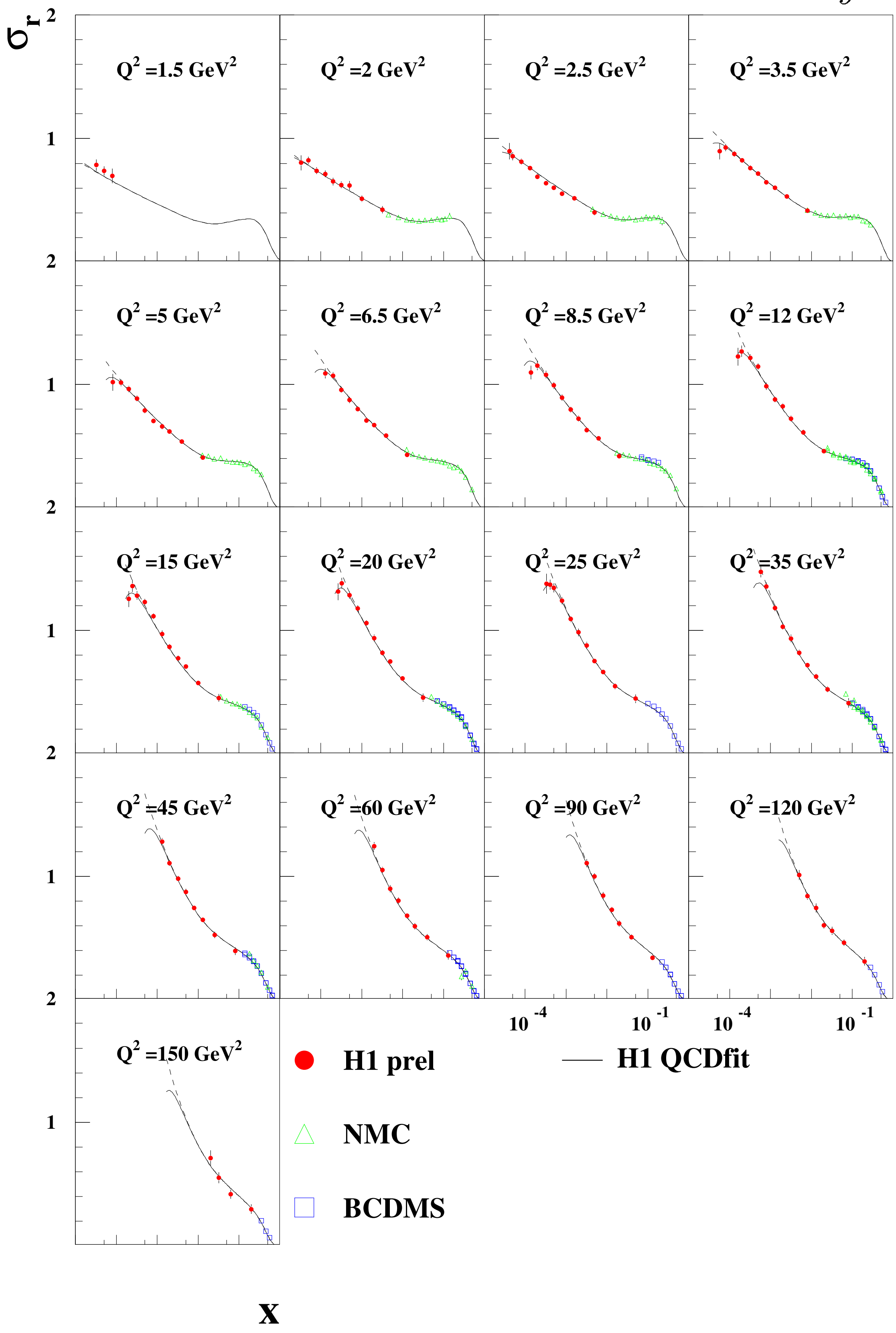
$$Y_\pm = 1 \pm (1-y)^2, \quad \kappa = \frac{2\pi\alpha^2}{Q^4 x} Y_+$$

- $Q^2 \ll M_Z^2 \to \sigma$ dominated by γ exchange
- $F_2 \geq F_L \geq 0$
- at low $y \to \sigma \simeq F_2$
- new H1 backward instrumentation $\to$ extended y-range of the measurement :
  - high $y \to F_L$
  - low $y \to$ overlap with fixed target expts
- precision F_2 and F_L measurements
  $\Rightarrow$ important tests of NLO pQCD
  $\Rightarrow$ parton distribution functions
- F_2 scaling violation studied with
  - local derivatives of F_2
  - NLO QCD fits $\Rightarrow xg(x, Q^2)$

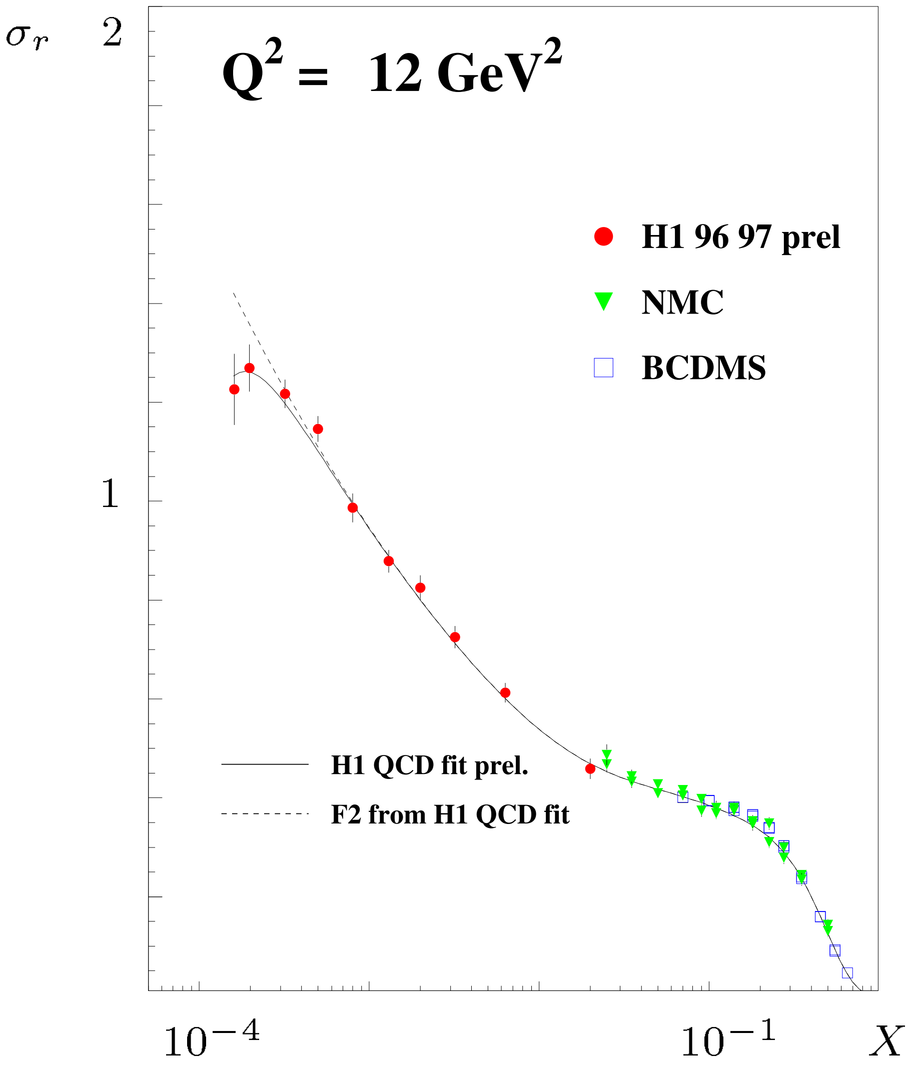
Reduced Cross Section H1 96-97

$$\sigma_r = \frac{1}{\kappa}\frac{d^2\sigma}{dx\,dQ^2} = F_2(x,Q^2) - \frac{y^2}{Y_+}\cdot F_L(x,Q^2)$$

$$\leftarrow y = \frac{Q^2}{sx}$$

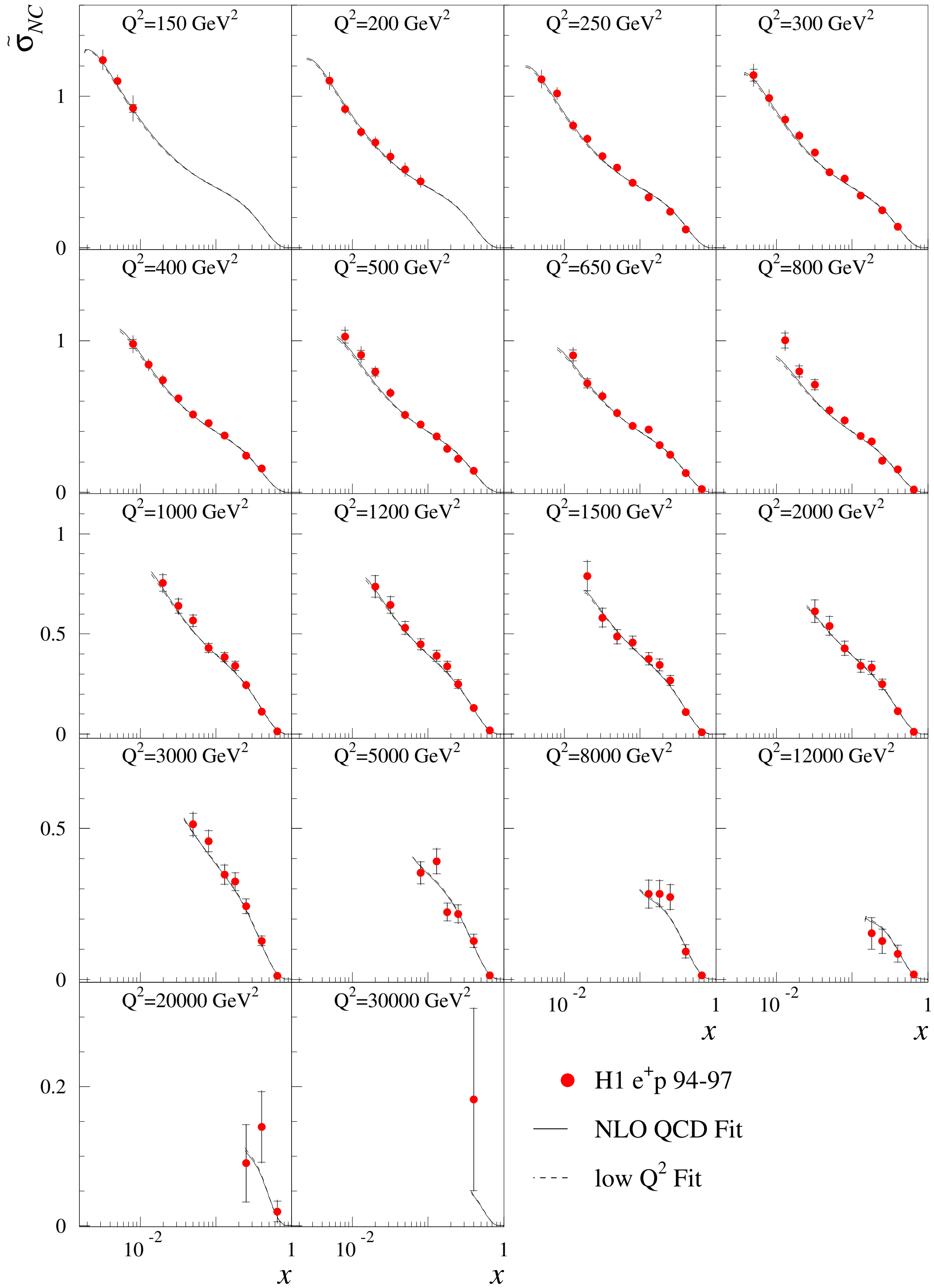


$\mathbf{F_2}$, $\mathbf{F_L}$ Extraction from Cross Section



- σ_r consistent with DGLAP QCD fit
- σ_r dominated by $F_2(x, Q^2)$
  - except at high y-values $\rightarrow$ F_L contribution
- F_2 is fixed over 3 orders of magnitude in x
  $\rightarrow$ extrapolate $\rightarrow$ get F_L
- F_2 determination requires assumption on F_L
  $\Rightarrow$ F_2 extraction restricted to $y \leq 0.6$

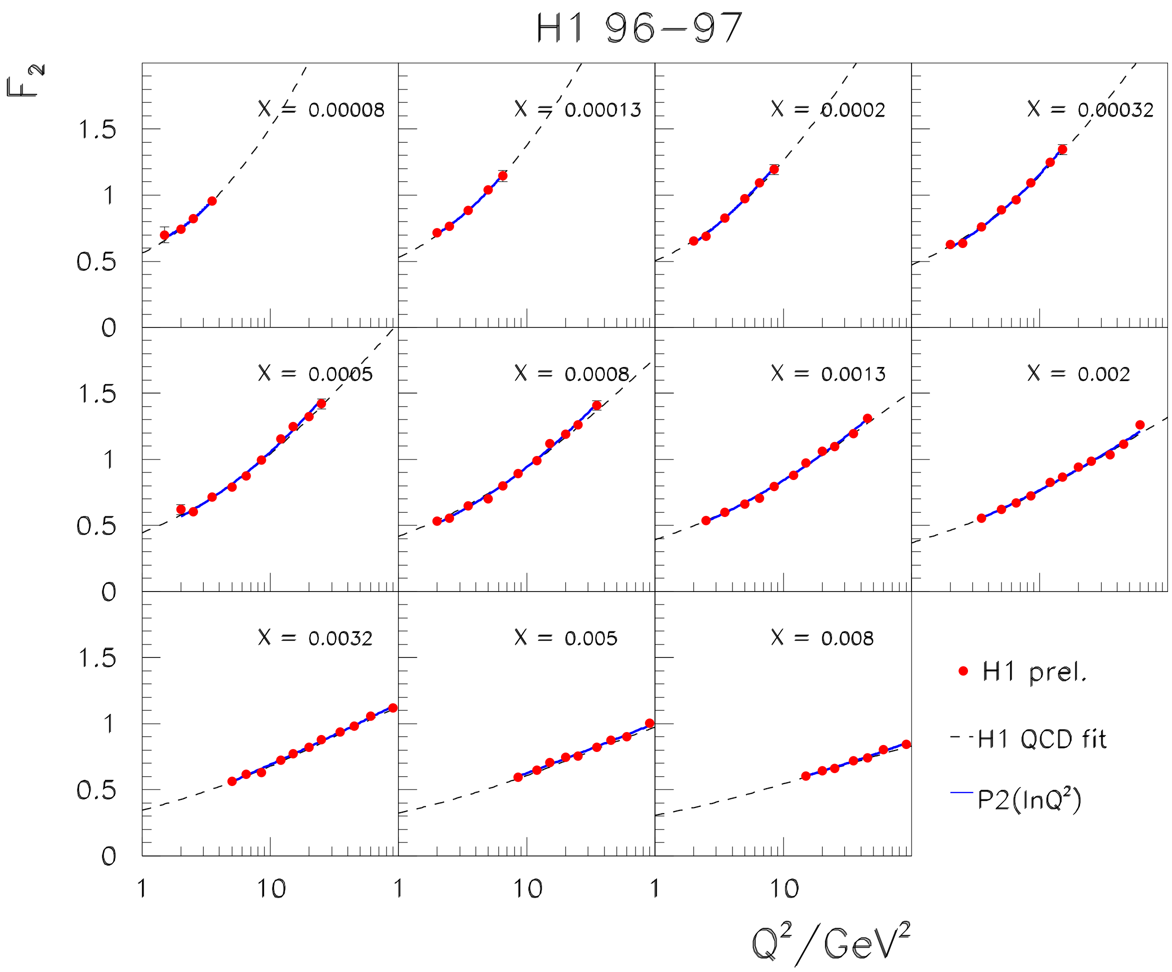
Reduced Cross Section at High Q^2



- fit the whole Q^2- range
- low $Q^2 \leq 150\, GeV^2$ fit extrapolated to high $Q^2 \Rightarrow$ excellent agreement

Nonlinear Parametrization of F_2

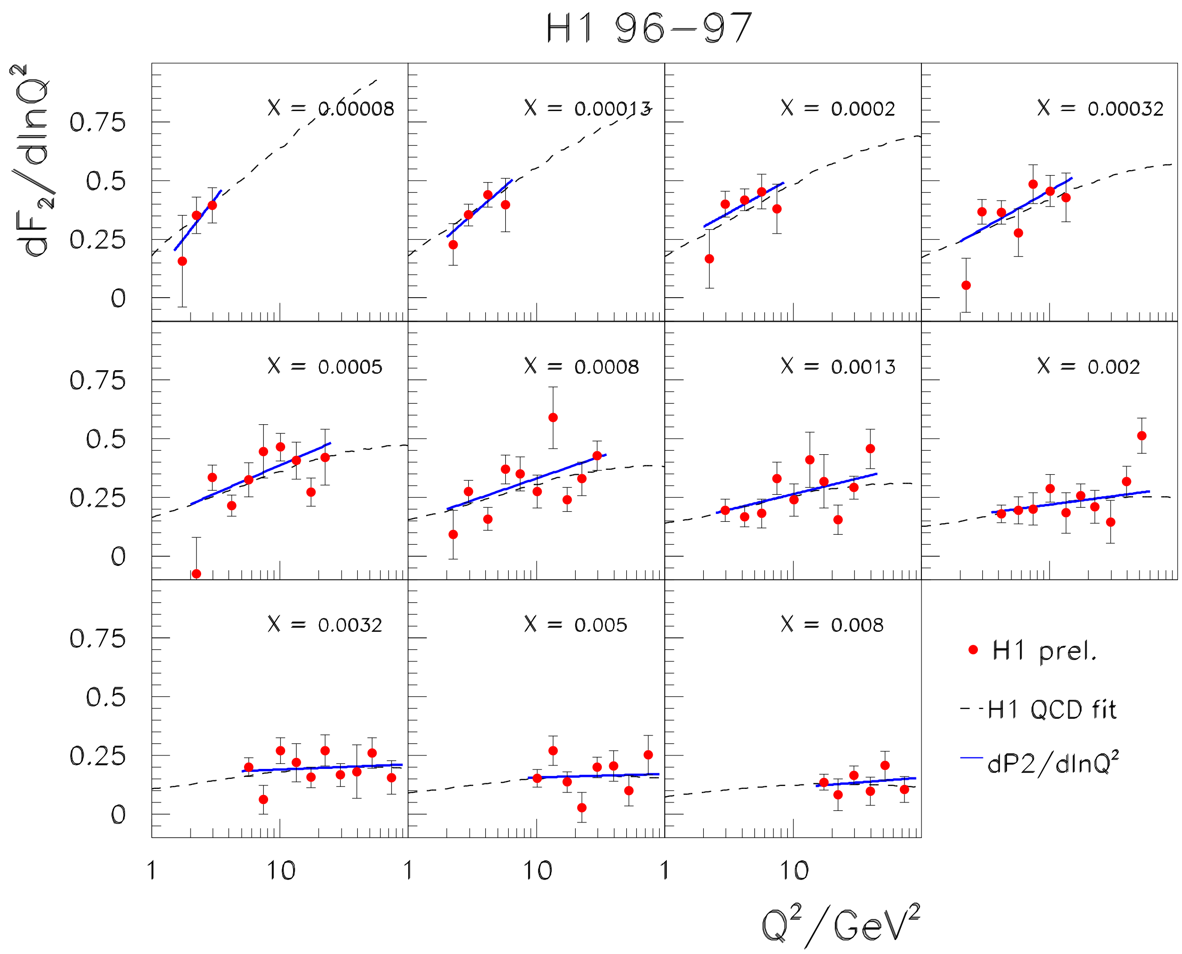
$$F_2 = a + b * lnQ^2 + \frac{c}{2} * (lnQ^2)^2$$



- precision measurement of F_2 $\Rightarrow$
- observed nonlinear $ln\,Q^2$ dependence of F_2
  $\rightarrow$ fit with 2^{nd} order polynomial in $ln\,Q^2$
  $\rightarrow$ nearly coincides with NLO QCD fit
- scaling violations conveniently studied with $ln\,Q^2$ derivative of F_2

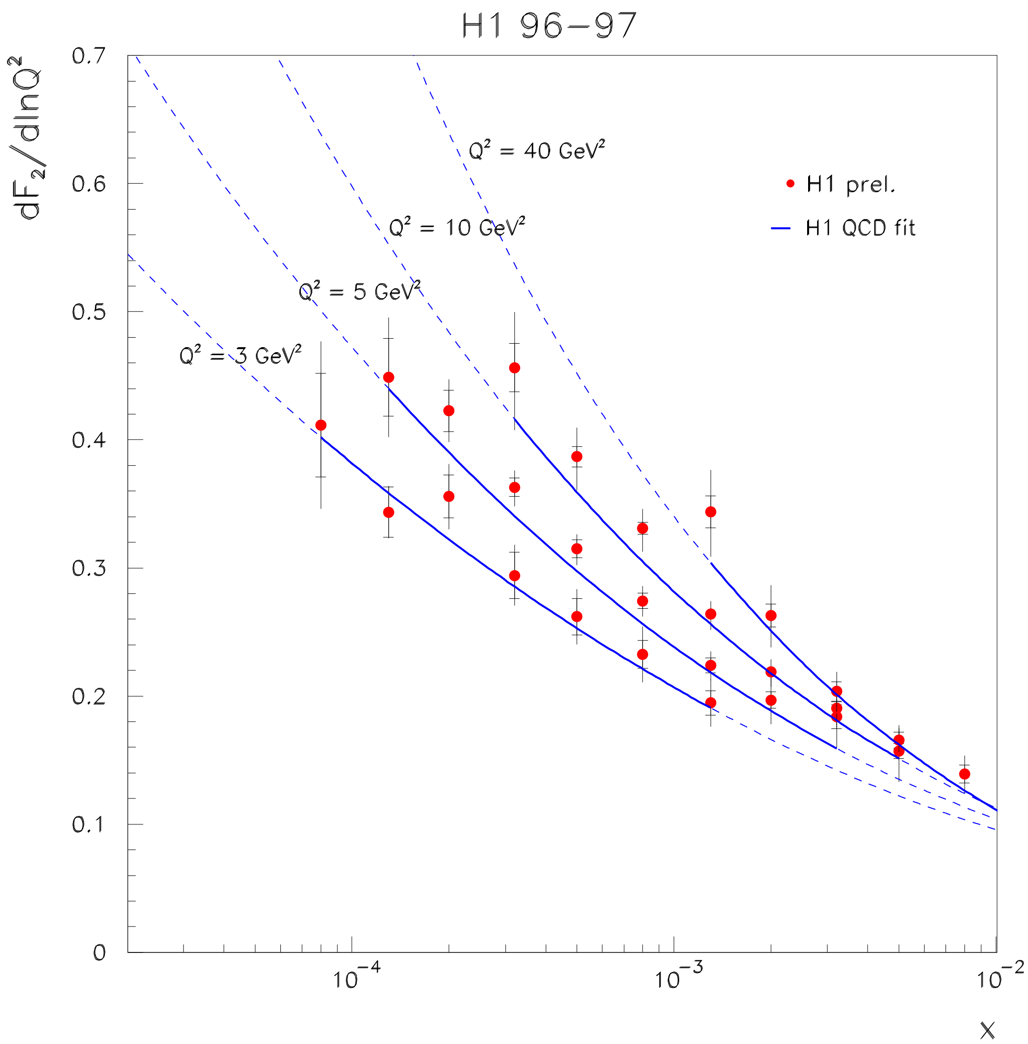
Local Derivatives of $\mathbf{F_2}$

$$\frac{\partial F_2}{\partial lnQ^2}(x, Q^2) = b + c * lnQ^2$$



- local derivatives are determined for each $x-$bin from two F_2 values adjacent in Q^2
- Q^2 is taken in the middle and corrected for the bin center
- local derivatives at fixed low x are not constant in Q^2 $\Rightarrow$ used linear dependence

Logarithmic Derivatives of F_2



- F_2 derivatives from P2 fit parameters
  $\rightarrow$ well described by DGLAP NLO QCD
  $\rightarrow$ rising for $Q^2 \geq 3\ GeV^2$

- at $Q^2 \sim \mathcal{O}(1)\, GeV^2 \rightarrow$ valence-like gluon
  - screening corrections
  - higher twist corrections

- needed precision data at $Q^2 < 3\ GeV^2$
  ($x-$range for fixed Q^2)
  $\rightarrow$ VLQ spectrometer data
  $(0.1\ GeV^2 < Q^2 < 0.4\ GeV^2)$
  $\rightarrow$ low E_e run at HERA ($Q^2 \sim E^2$)

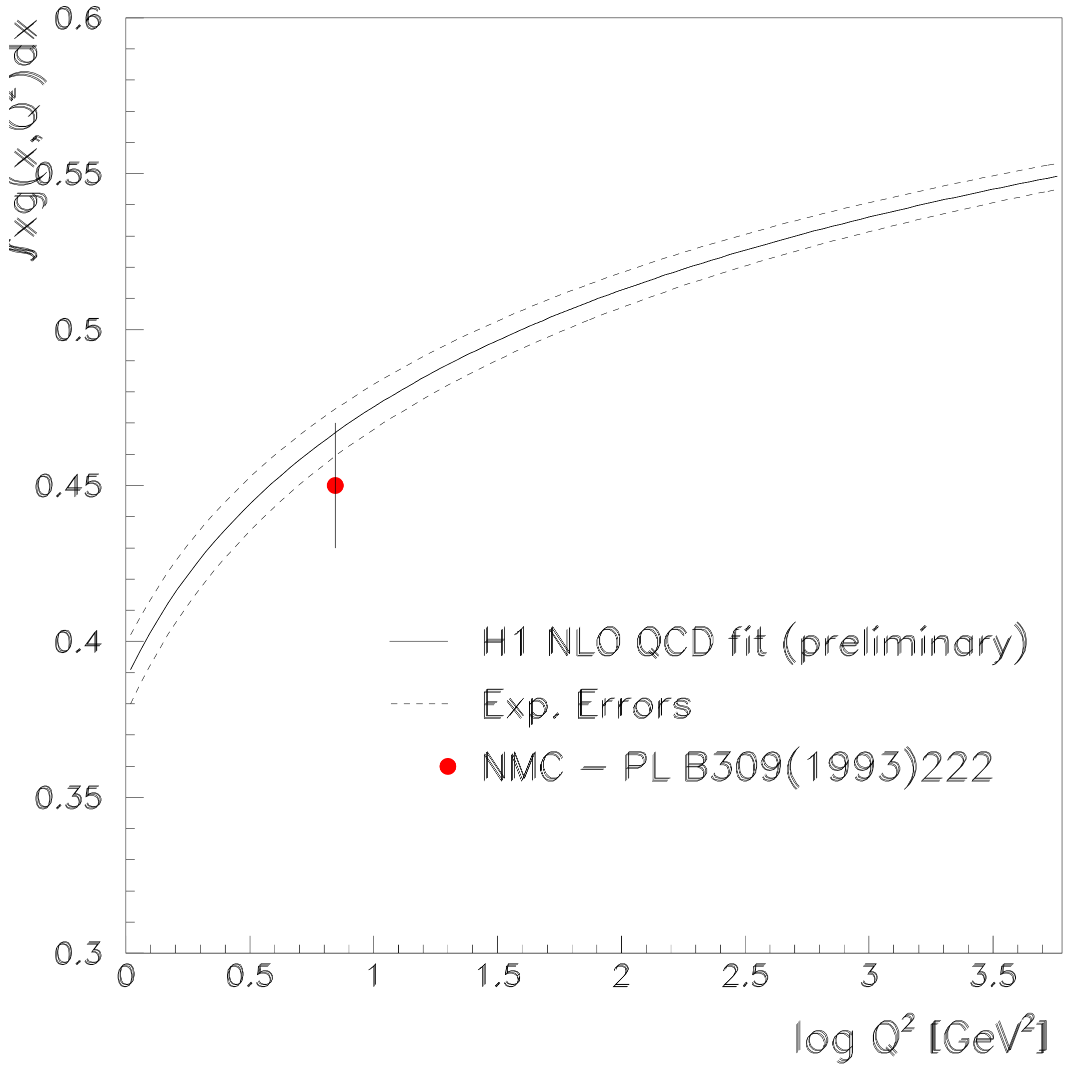
H1 NLO QCD Fit

- Data
  - protons only H1 + NMC
  - $Q^2_{min} \geq 1.5 - 6.5\ GeV^2$, $W^2 \geq 10\ GeV^2$
- Initial Conditions and Assumptions
  - H1 fit program in $x-$space
    (Pascaud,Zomer LAL/95-05)
  - DGLAP in $\overline{MS}$ renormalization scheme
  - u, d, s massless partons
  - c, b contributions from NLO BGF
    (E.Laenen et.al, NP B392(1993)162,
    S.Riemersma et.al, PL B347(1995)143)
  - $m_c = 1.3 \pm 0.1\ GeV$
  - $\alpha_S(M_Z^2) = 0.1175 \pm 0.0030$
  - input parametrizations of $q = g, V, A$
    $xq(x) = A_q x_q^B (1-x)_q^C (1+D_q x+E_q\sqrt{x})$
    gluon: $D_g, E_g = 0$
  - $Q_0^2 \simeq 1.5\ GeV^2$
  - Momentum Sum Rule
  - Quark Counting Rule
  - $\bar{u} = \bar{d} = 2\bar{s}$

Flavour Decomposition of F_2

- u,d,s quarks $\rightarrow F_2 = x \cdot (\frac{4}{9}U + \frac{1}{9}D)$
- where $U = u + \bar{u}$ and $D = d + \bar{d} + s + \bar{s}$
- F_2 in pQCD defined by 2 independent functions $\rightarrow$ in this analysis used V, A
- specific choice of V, A :
  $V = \frac{3}{4}(3U - 2D)$
  $A = \frac{1}{4}(2D - U)$
- symmetric sea : $\bar{u} = \bar{d} = 2\bar{s}$
  $\Rightarrow V = \frac{3}{4}u_v \cdot (3 - 2\frac{d_v}{u_v})$
- for $x < 0.1$ $V \rightarrow 0$
- quark counting rule $\int_0^1 V\,dx = 3$
  $\rightarrow$ profit from the specific V, A definition
- $A = \bar{u} - \frac{1}{4}(u_v - 2d_v)$
  - for small $x \rightarrow A \simeq \bar{u} \rightarrow$ sea distribution

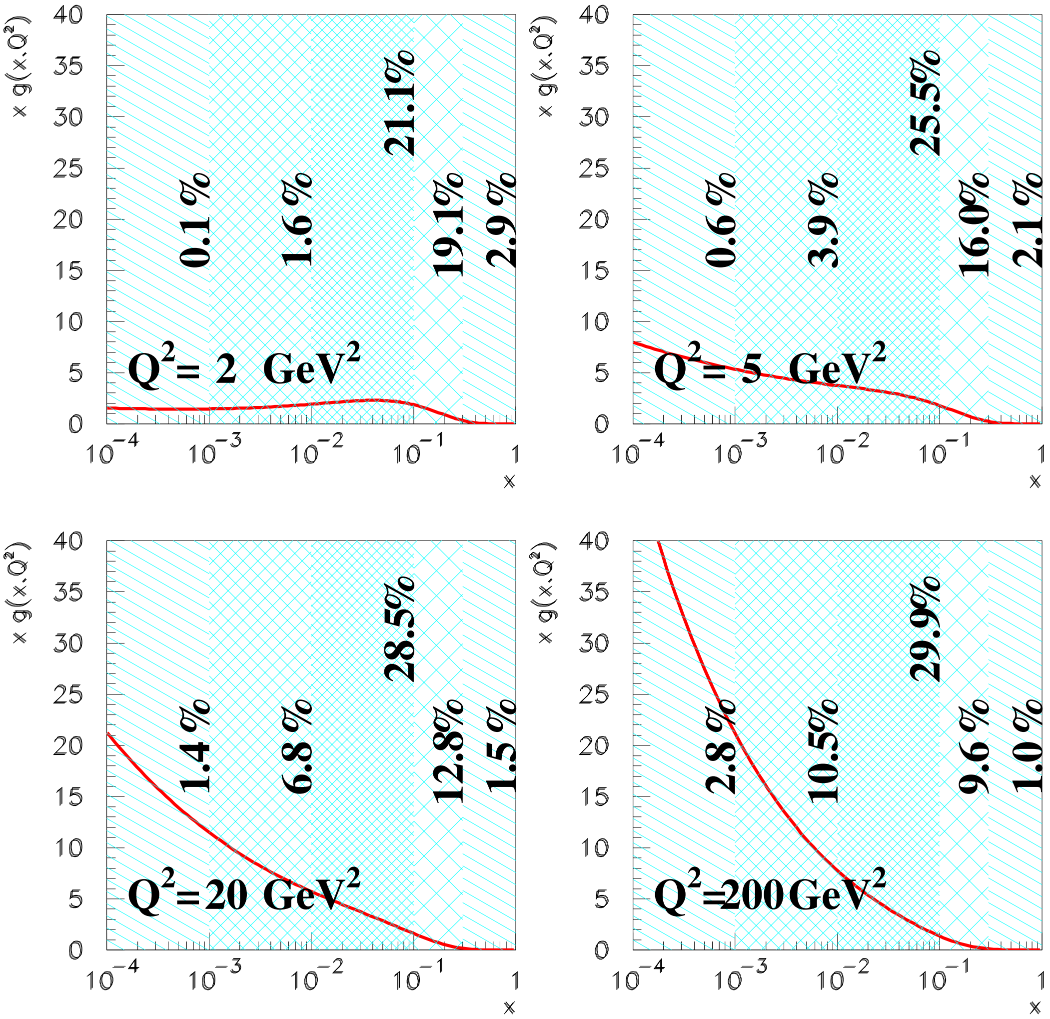
Gluonic Fraction of the Proton Momentum



- gluon momentum with $p-$only data

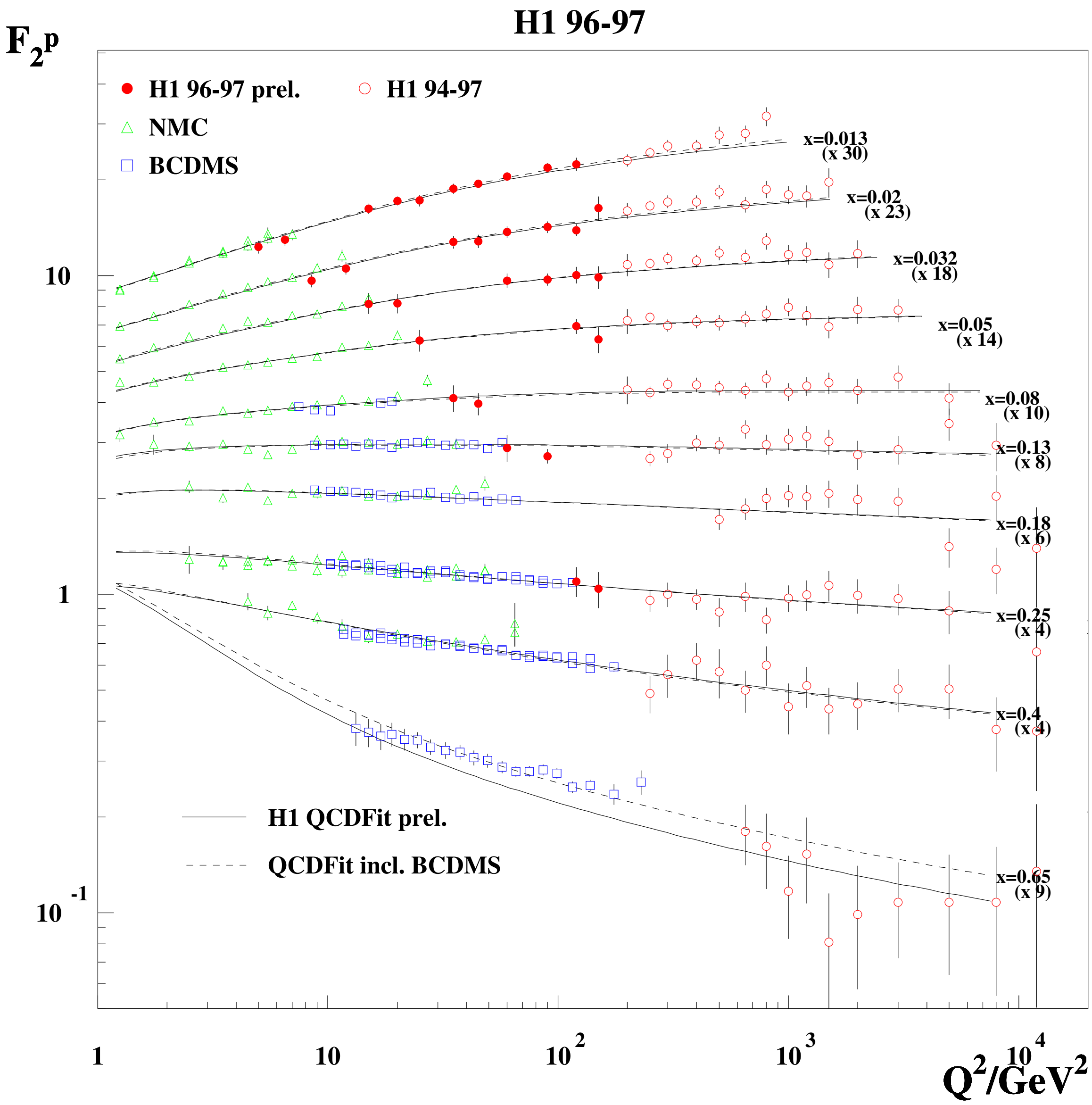
Redistribution of the Gluonic Momentum

$\int_{x_1}^{x_2} x \cdot g(x, Q^2)\, dx$



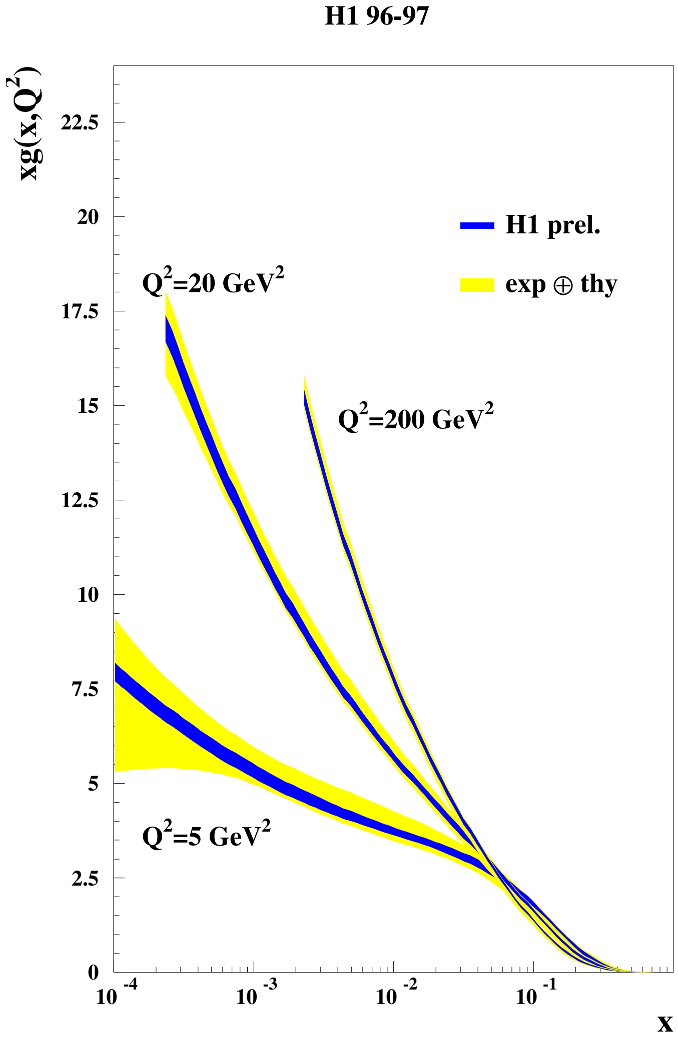
- minimal momentum fraction
  - at very low $x < 10^{-3}$
  - at very high $x > 0.3$
- $\int_{0.01}^{0.1} x \cdot g(x, Q^2)\, dx \simeq\ 20 - 30\%$

F_2 at High x



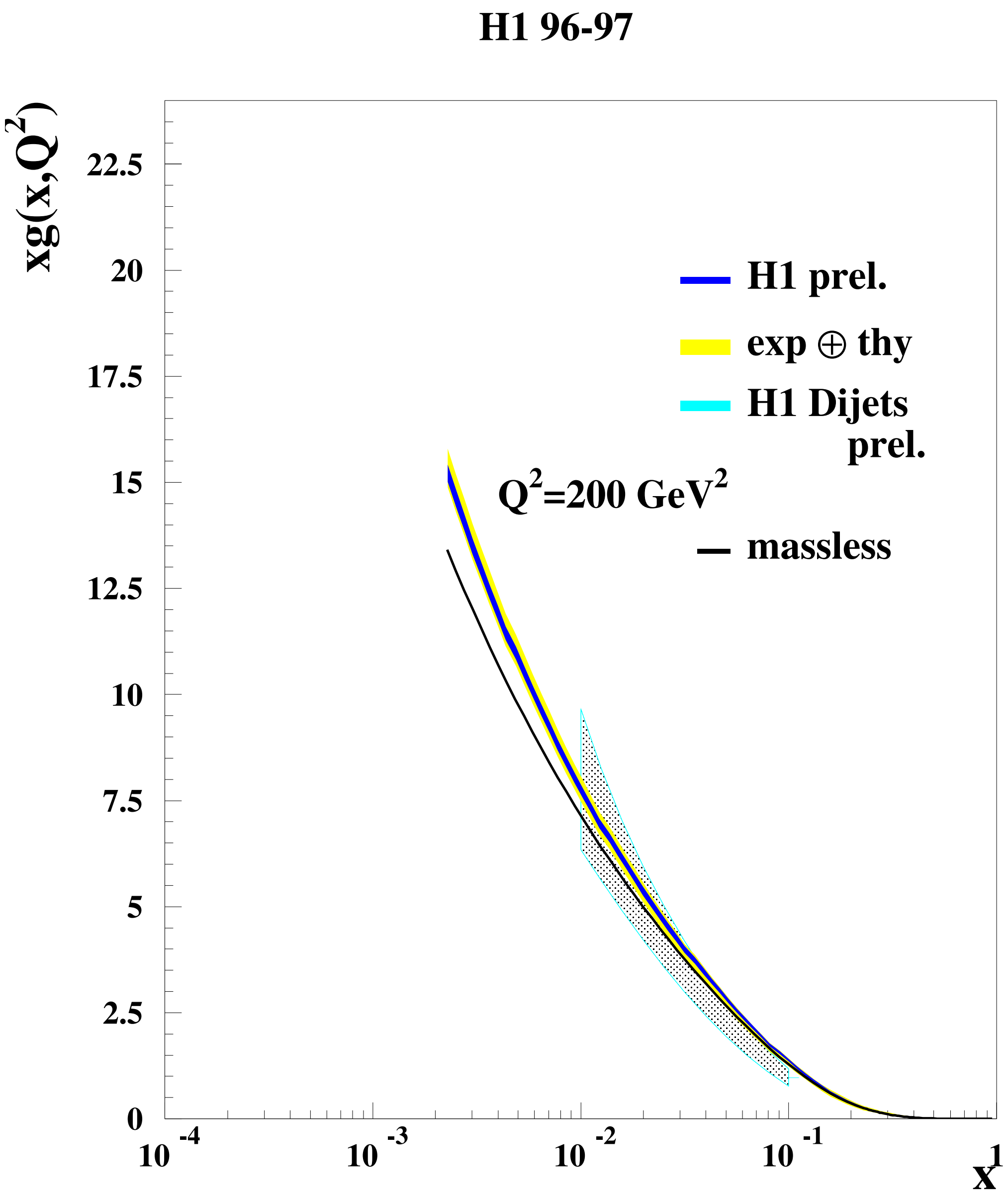
- H1+NMC fit describes data well (including BCDMS - ! but high x, low y)
- high x at HERA requires still higher $\mathcal{L}$ $\Rightarrow$ more data after $\mathcal{L}$ upgrade

Gluon Density from Scaling Violations



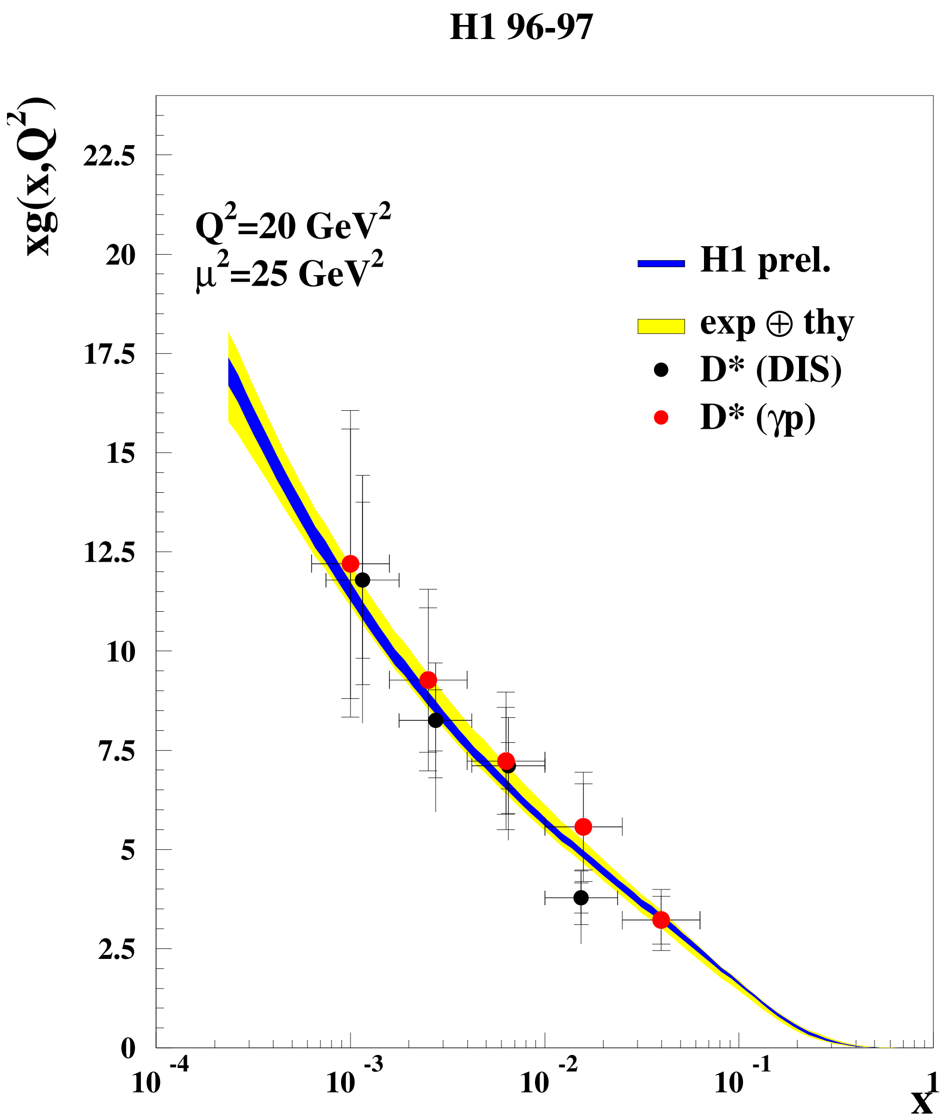
- scaling violation driven by $x \cdot g(x, Q^2)$
- exp. uncertaintes of a few %
- at low Q^2 more sensitive to fit parameters
- in progress detailed systematic study of the $xg(x, Q^2)$ dependence on :
  - α_S, Q_0^2, Q_{min}^2
  - datasets and parametrizations

Gluon Density from Dijets



- $(2+1)$ jet cross section in LO :
  $\sigma_{2+1} \propto \alpha_S(A \cdot g + B \cdot q)$
- fit in the Mellin space $\rightarrow$ dijet gluon
- $xg(x, Q^2)$ from dijets consistent with gluon from scaling violation

Gluon Density from Charm



- $\mathcal{L} = 9.7\, pb^{-1}$ (data 95 – 96)
- measured D^* production cross section in DIS and photoproduction (γp)
  $\Rightarrow$ xg unfolded from F_2^c in DIS and γp
- good agreement with xg from the QCD fit to inclusive DIS cross section

Summary

- F_2 data in accord with DGLAP QCD evolution over 4 orders of magnitude in Q^2

- precision of F_2 data permits determination of derivatives in (x, Q^2)

- $\partial F_2 / \partial ln Q^2 \sim \alpha_s \cdot xg(x, Q^2)$
  $\rightarrow$ rising and described by NLO QCD

- NLO QCD fit possible with proton data only
  $\Rightarrow$ gluon distribution function extracted
  $\Rightarrow$ gluonic momentum fraction in agreement with NMC determination

- gluons from charm and dijets consistent with the more precise $x \cdot g$ from scaling violations

- search for new dynamics $(ln\, 1/x)$ needs highest possible precision
  - data at low Q^2 still to come
  $\rightarrow$ VLQ and low E_e run at HERA