Structure Function Results From H1

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On behalf of the H1 Collaboration

Inclusive DIS Data ↔ Partonic Structure & QCD

Main published H1 Data:

1) e^+p (94-97, ~36pb^{-1}, @ 300 GeV) &
2) e^-p (98-99, ~16pb^{-1}, @ 320 GeV) :
   → High Q^2 Neutral Current (NC)+
   Charged Current (CC)
   cross sections

3) e^+p (96-97, ~20pb^{-1}, @ 300 GeV)
   → Precision low Q^2 data

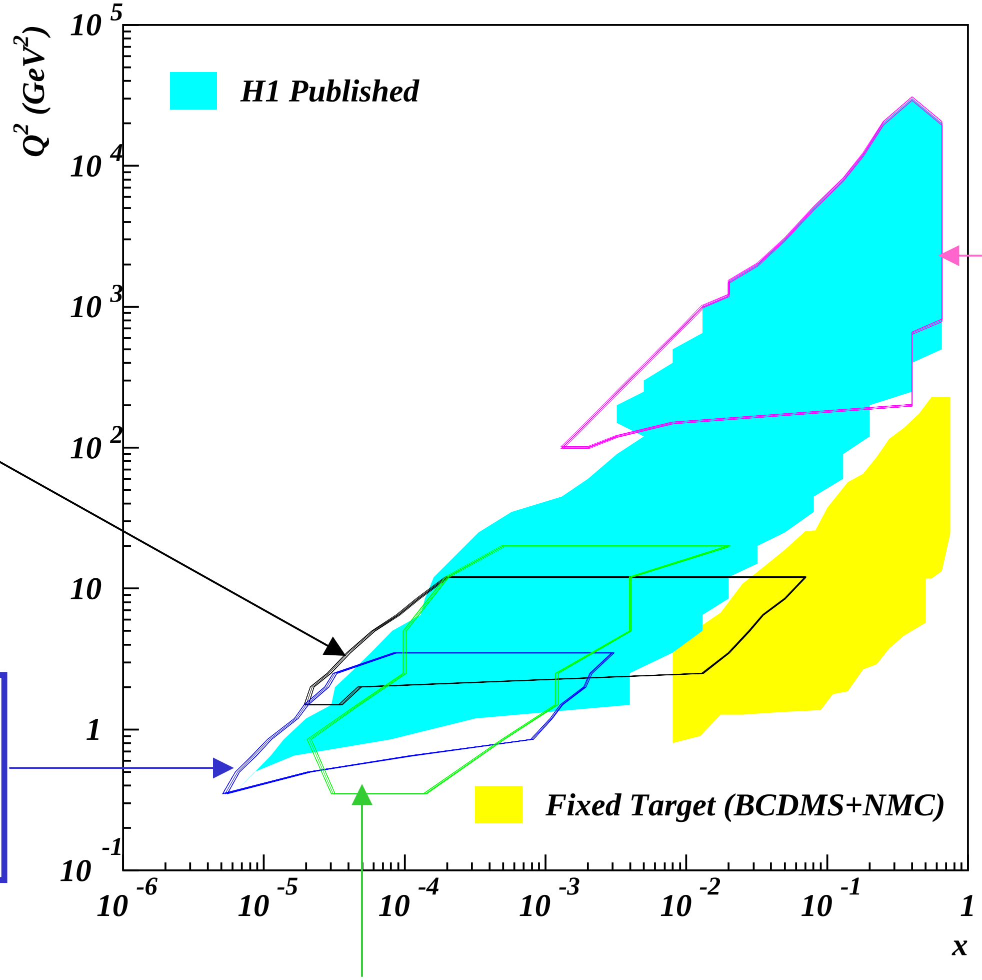
Major input to global fits
(MRST, CTEQ, …)

→Universal Parton Density Functions (PDF)
→Reliable predictions for
  - precision measurements &
  - search for new physics
    @ future hadron machines (LHC)

Questions:

a) What's new?
b) What are the impacts of the HERA I data?
c) Can full HERA I cross sections (structure functions) data be described by QCD (DGLAP evolution equations)?

New Cross Section (σ) Measurements



Dedicated Runs '99 (3pb-1):

→ F_L @ low x

Shifted Vertex '00 (0.6pb-1)

→ insight into DIS/γp

e^+p 99-00 (65pb^{-1}, @ 320GeV):

→ σ_{NC} & σ_{CC}

→ 1st F_L @ high Q^2

Radiative Events '97 → extended phase space

Cross Sections and Structure Functions

NC Cross Section:

$$\frac{d^2\sigma_{NC}(e^\pm p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\, Y_+ \overbrace{\left[\underset{\substack{\uparrow \\ \text{Dominant contribution}}}{\tilde{F}_2} - \frac{y^2}{Y_+}\underset{\substack{\uparrow \\ \text{Sizeable only at high y (y>~0.6)}}}{\tilde{F}_L} \mp \frac{Y_-}{Y_+}\, x\underset{\substack{\uparrow \\ \text{Contribution only important at high } Q^2}}{\tilde{F}_3}\right]}^{\text{NC Reduced cross section: } \tilde{\sigma}_{NC}(x,Q^2)}$$

$$Y_\pm = 1 \pm (1-y)^2$$

CC Cross Section:

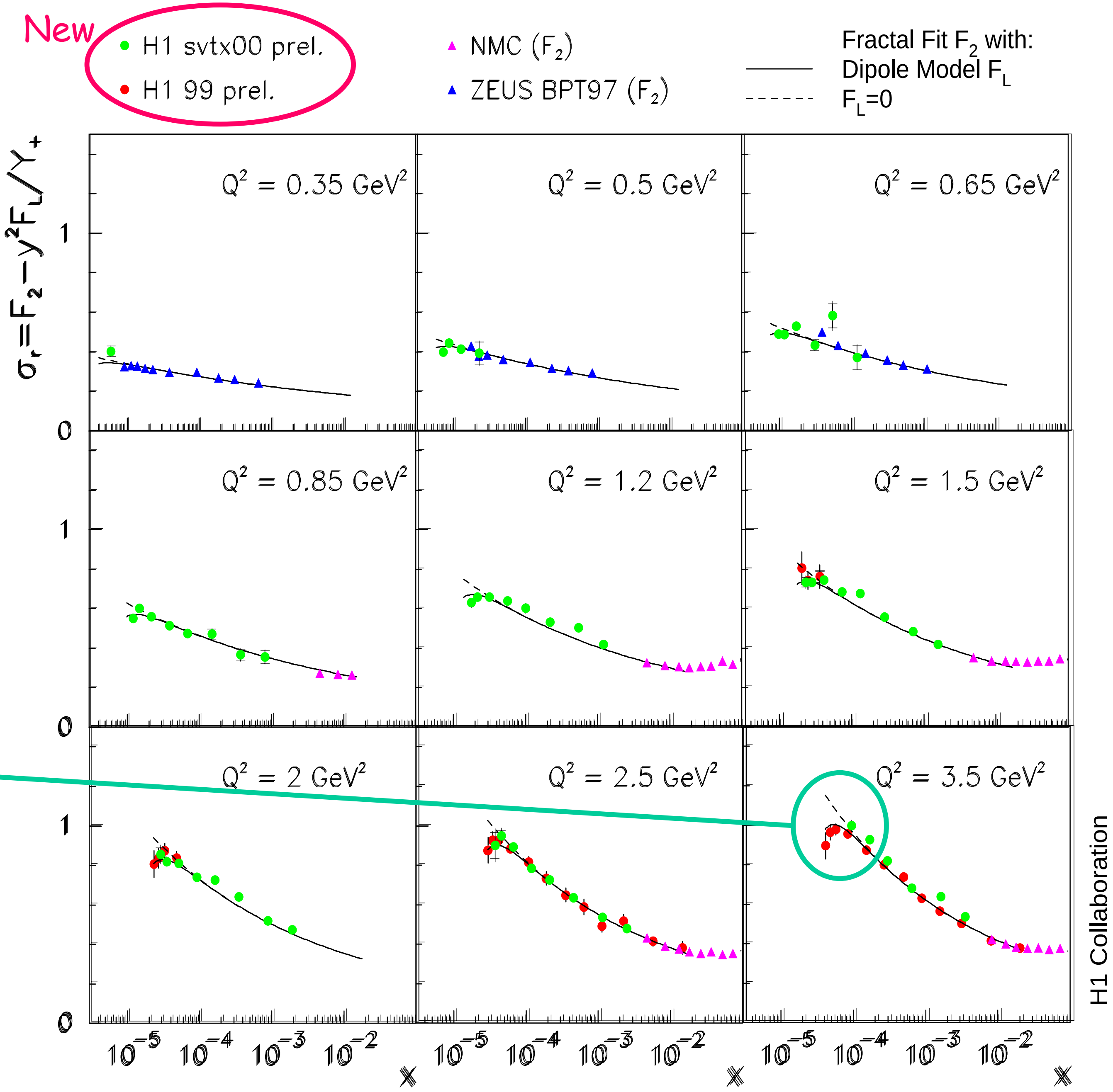
$$\frac{d^2\sigma_{CC}(e^\pm p)}{dxdQ^2} = \frac{G_F^2 M_W^4}{2\pi x}\,\frac{1}{(Q^2+M_W^2)^2}\,\underbrace{\frac{1}{2}\left[Y_+W_2 - y^2W_L \mp Y_- xW_3\right]}_{\text{CC Reduced cross section: } \tilde{\sigma}_{CC}(x,Q^2)}$$

Reduced Cross Section (σ_r) at low Q^2,small x

Extended phase space:

CM: 300→320GeV
Backward silicon tracker
$E_e^{min} \rightarrow 3$GeV or
$z \rightarrow z_{nominal}+70$cm

σ_r changes behavior at high y (small x) for Q^2>~2 GeV^2
→ F_L



Data with Q^2 → 0:
Valuable for studying underlying dynamics of DIS→γp

Determination of F_L

New F_L extends the published one to lower x & higher Q^2

Compare

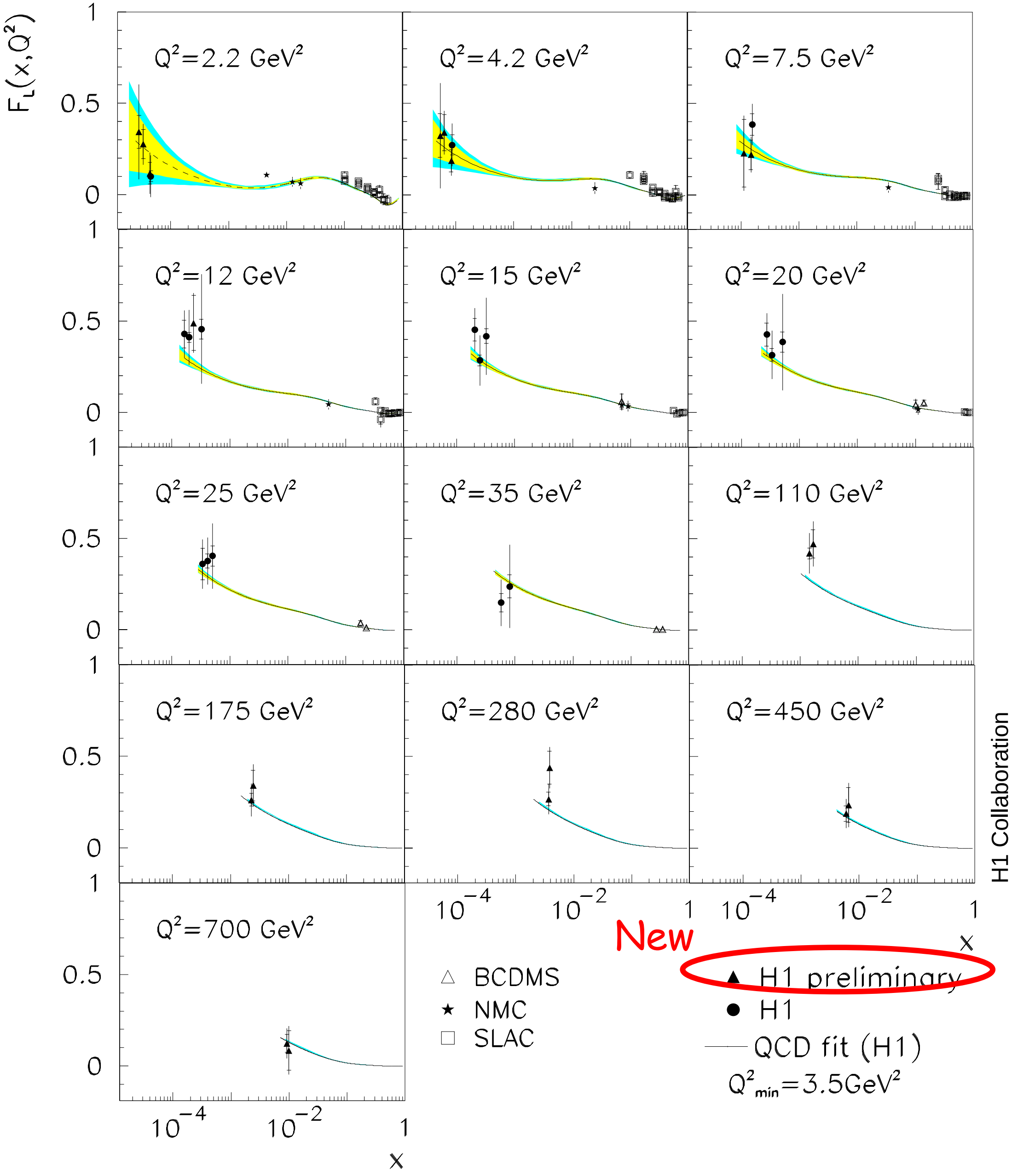
Experimental determination of F_L

with

Theoretical expectation (QCD Fit):

Scaling violation of $F_2 \rightarrow xg \rightarrow F_L$

Good agreement thus provides a non-trivial consistency test



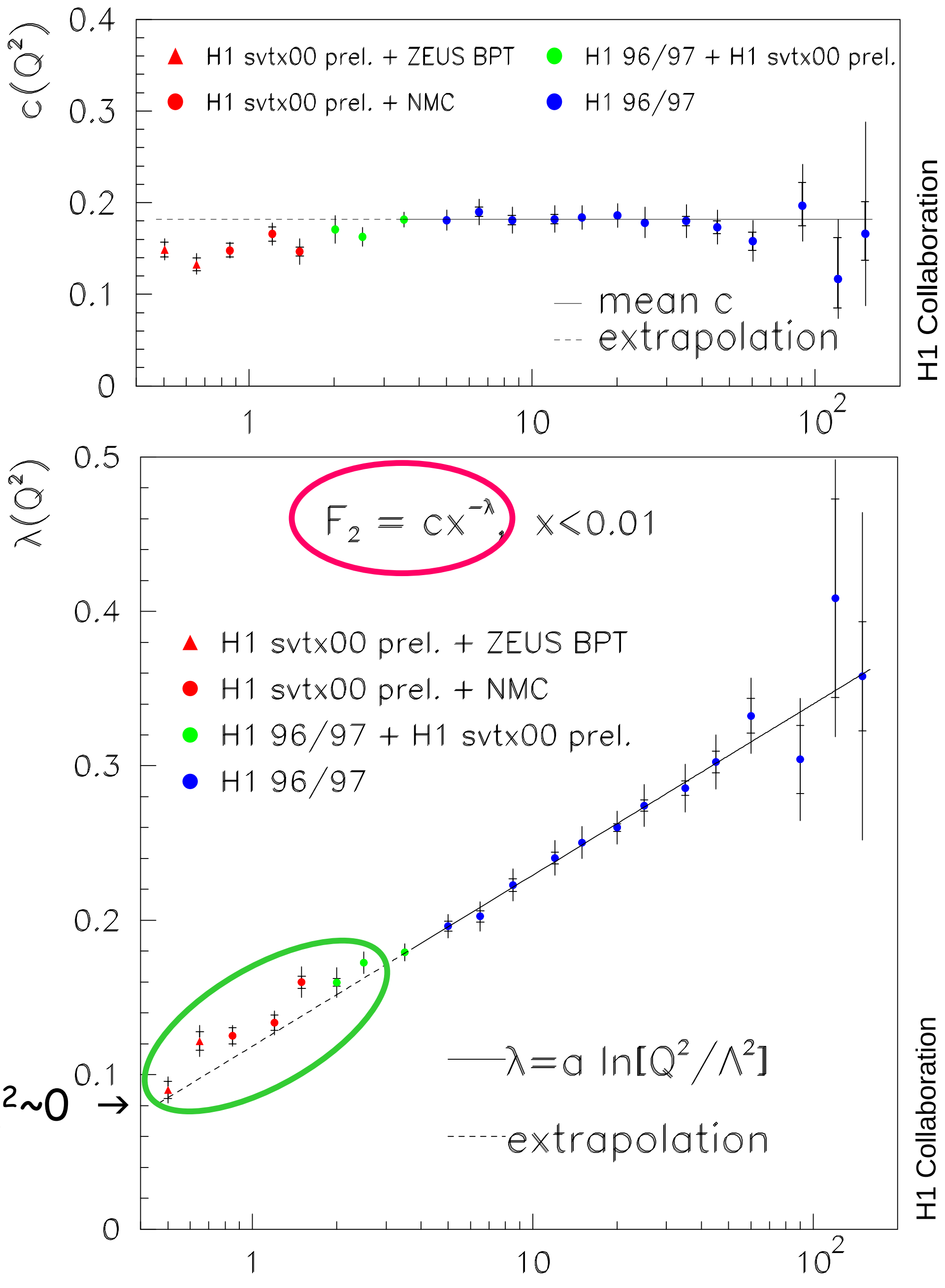
Rise of F_2 Towards Low x

Measured $d\ln F_2(x,Q^2)/d\ln x=-\lambda(x,Q^2)$
consistent with constant for x<0.01
→ $F_2 \propto x^{-\lambda}$ for fixed Q^2

Deviation observed at Q^2~1GeV^2
in $\lambda(Q^2)$
with respect to linear behavior
in $\ln(Q^2)$
when the new H1 data is combined
with other data (H1, ZEUS, NMC)

Hint on a change of strong interaction
dynamics at low x for Q^2~1GeV^2 ?

Regge prediction: 0.08 @ Q^2~0 →

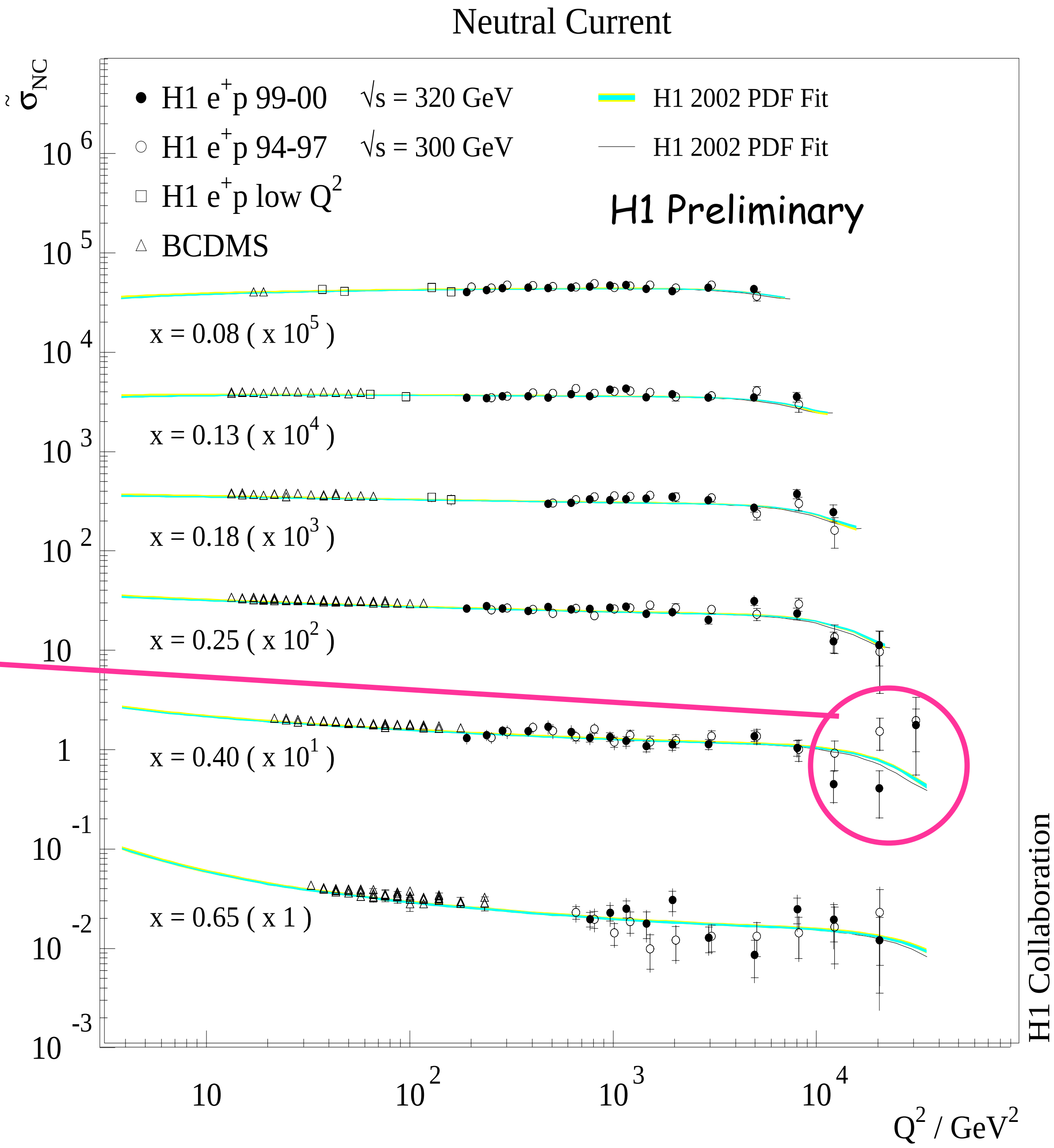


NC Reduced Cross Sections (σ^r_{NC}) at High Q^2 & Large x

Compare
new cross sections @ 320GeV
with
the published ones @ 300GeV

Previously observed "excess"
at Q^2>10 000GeV^2, x~0.4
not confirmed by new data

The measured scaling variation
well described by H1 QCD Fit
(see below)



NC vs. CC & e^+p vs. e^-p

NC e^+p vs. e^-p:

$\sigma(e^+p)=\sigma(e^-p)$ at low Q^2

⇔ γ exchange

$\sigma(e^+p)<\sigma(e^-p)$ at high Q^2

⇔ Z contribution (γZ interf.)

CC e^+p vs. e^-p:

$\sigma(e^+p)<\sigma(e^-p)$

⇔ different partons
different helicity factors

$\sigma(e^+p)\sim(u+c)+(1-y)^2(d_{bar}+s_{bar})$

$\sigma(e^-p)\sim(u_{bar}+c_{bar})+(1-y)^2(d+s)$

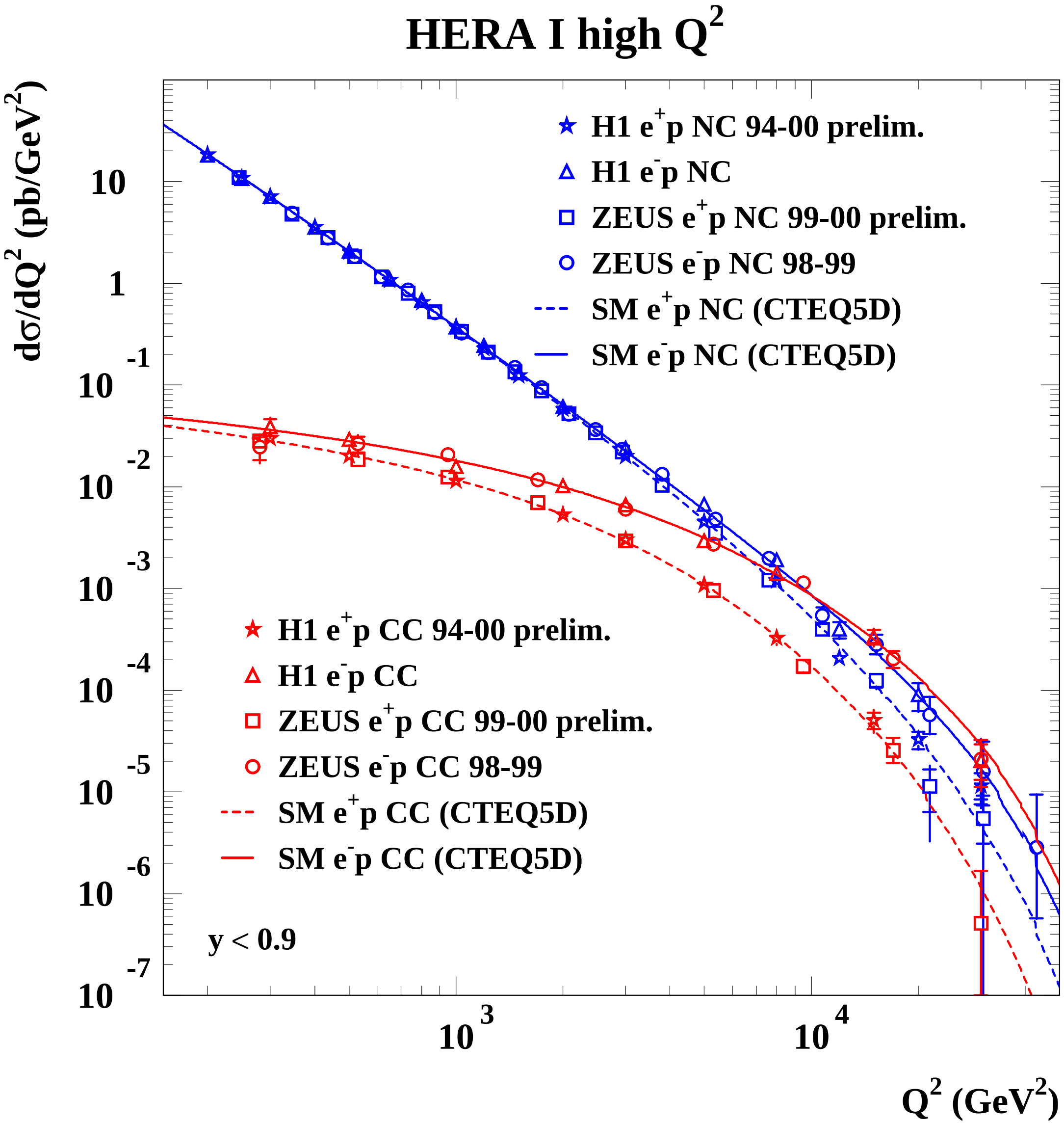
→ constraints on u & d type quarks

NC vs. CC:

$\sigma_{NC}=\sigma_{CC}$ at high Q^2

⇔ Electroweak unification

Good agreement between H1, ZEUS, and Global Fit (CTEQ)

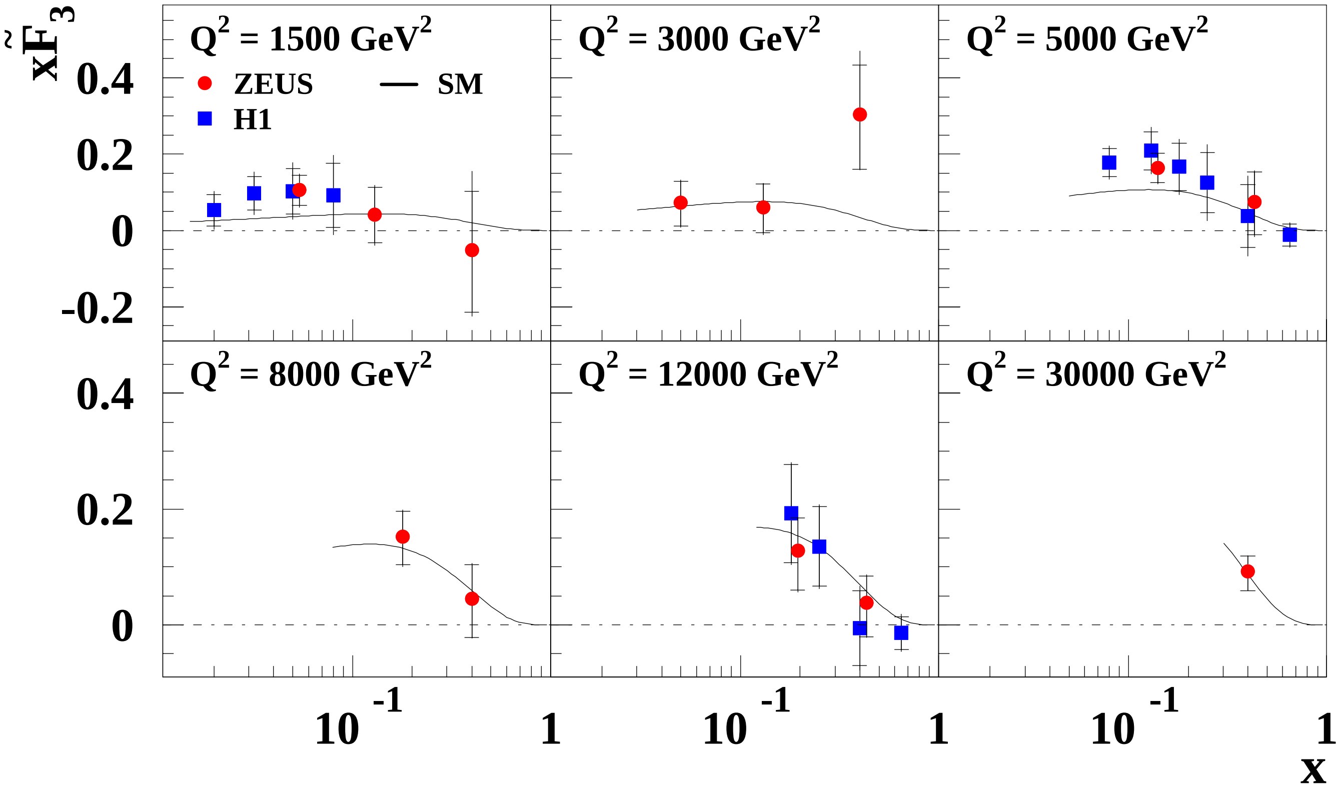


Parity Violating Structure Function xF_3

$$\tilde{\sigma}^{\pm}_{NC}=\tilde{F}_2 - \frac{y^2}{Y_+}\tilde{F}_L \mp \frac{Y_-}{Y_+}x\tilde{F}_3 \qquad x\tilde{F}_3 \approx x\tilde{F}_3^{\gamma Z} \sim 2u_v+d_v$$

1st xF_3 at High Q^2:

When precisely measured, xF_3 will provide important constraint on u,d valence quark densities @ large x

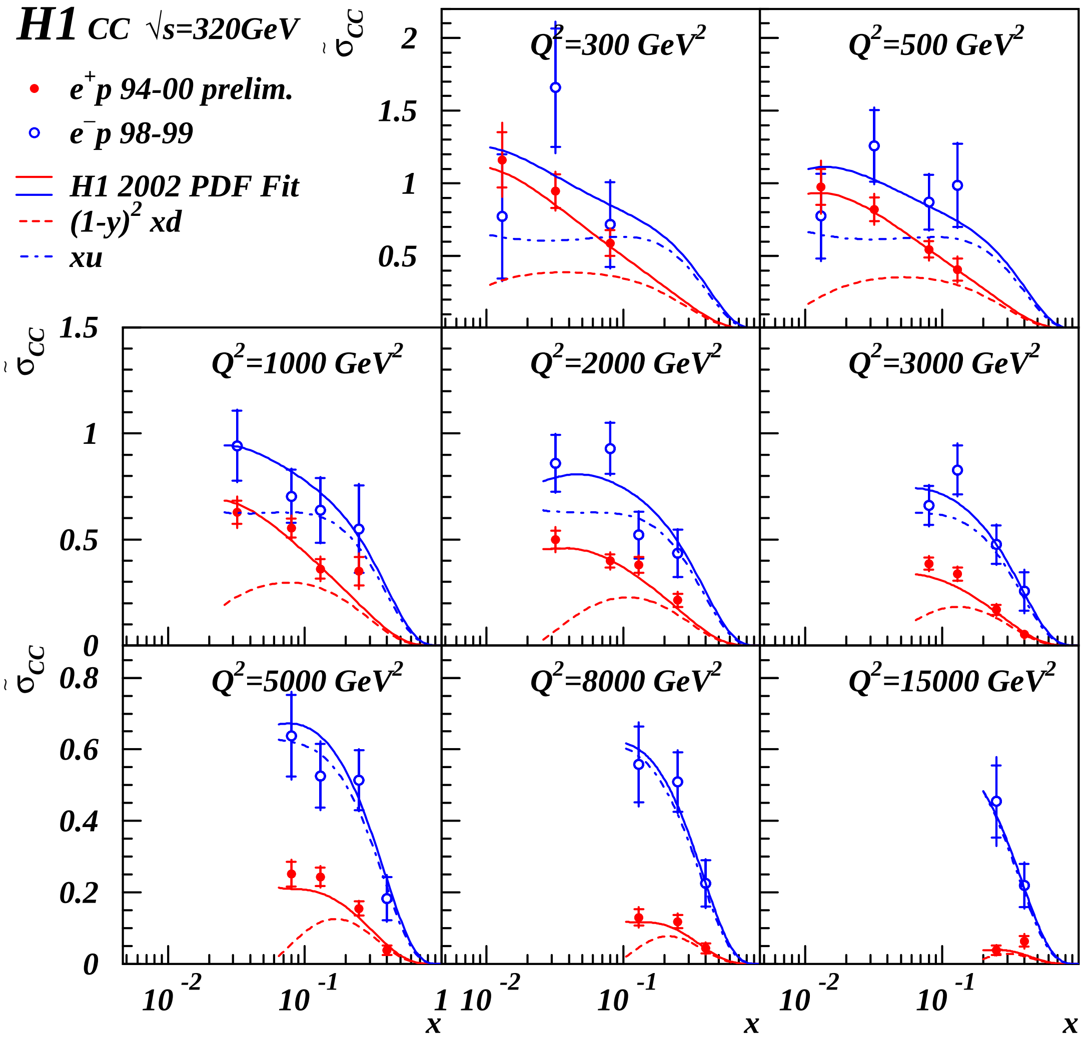


CC Reduced Cross Sections: e^+p vs. e^-p

The e^+p cross sections

differ from

the e^-p cross sections



CC e^+p (e^-p) cross sections are unique for constraining d (u) quark density

NLO QCD Analyses & Impact of HERA I Data

Several Fits with different emphases:

Common features: DGLAP Evolution Equations, NLO, MS_{bar}, $Q^2_0=4GeV^2$, $Q^2_{min}=3.5GeV^2$
Syst. error correlation & relative normalization unc. properly considered

1) Gluon density xg(x) @ small x & α_s:

Eur. Phys. J. C21 (2001) 33, hep-ex/0012053

H1 data only (Q^2<3000GeV^2):

$\delta(xg(x))$~3%(exp) @ $Q^2=20GeV^2$,
$x=3.10^{-4}-0.1$

H1 data + BCDMS(μp) ($y_\mu>0.3$):

$\alpha_s(M^2_Z)=0.1150$ +- 0.0017 (exp)
\+ 0.0009-0.0005 (model)
+- 0.005 (th)

Needs NNLO to improve scale(th) uncertainty

2) Fits for F_L determination

H1 data only at low y (<0.35)

3) General PDF fits

Use all H1 data of HERA I
(e^+p, e^-p, NC, CC, high & low Q^2)
with/without
BCDMS μp & μD ($y_\mu>0.3$)

Up-, down-type quark & gluon densities simultaneously determined

Quarks & Gluon Densities from H1 2002 PDF Fit

$xq(x)=A_q x^{B_q}(1-x)^{C_q}[1+D_q x^{0.5}+E_q x+F_q x^2]$

$xU=x(u+c)$
$xD=x(d+s)$: $F_U=0$
xUbar: $D_{Ubar}=0$, $F_{Ubar}=0$
xDbar: $D_{Dbar}=0$, $E_{Dbar}=0$, $F_{Dbar}=0$
xg: $F_g=0$

H1+BCDMS Fit:

$\chi^2=917/(1014-13)=0.92$

Exp. precision: $\delta q(x)$~a few %

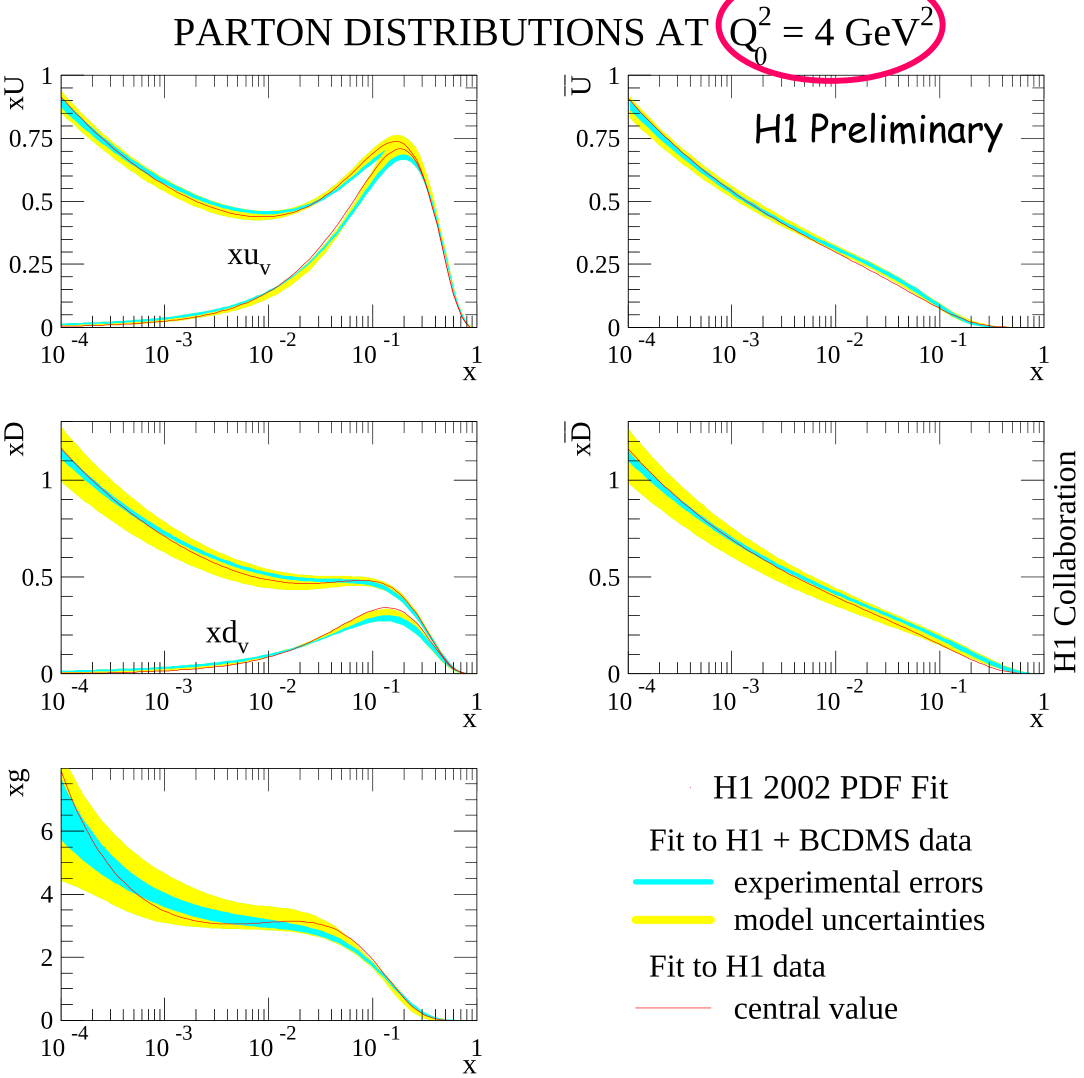
Model uncertainty includes:

Variations of Q^2_0, Q^2_{min}, α_s, heavy quark mass threshold & momentum fraction

H1 only Fit:

$\chi^2=548/(621-11)=0.90$

It is the 1st time, PDFs can be constrained with HERA data only!



u & d Quark Densities

From H1 2002 PDF Fit:

Best optimum precision of PDF without local fluctuation

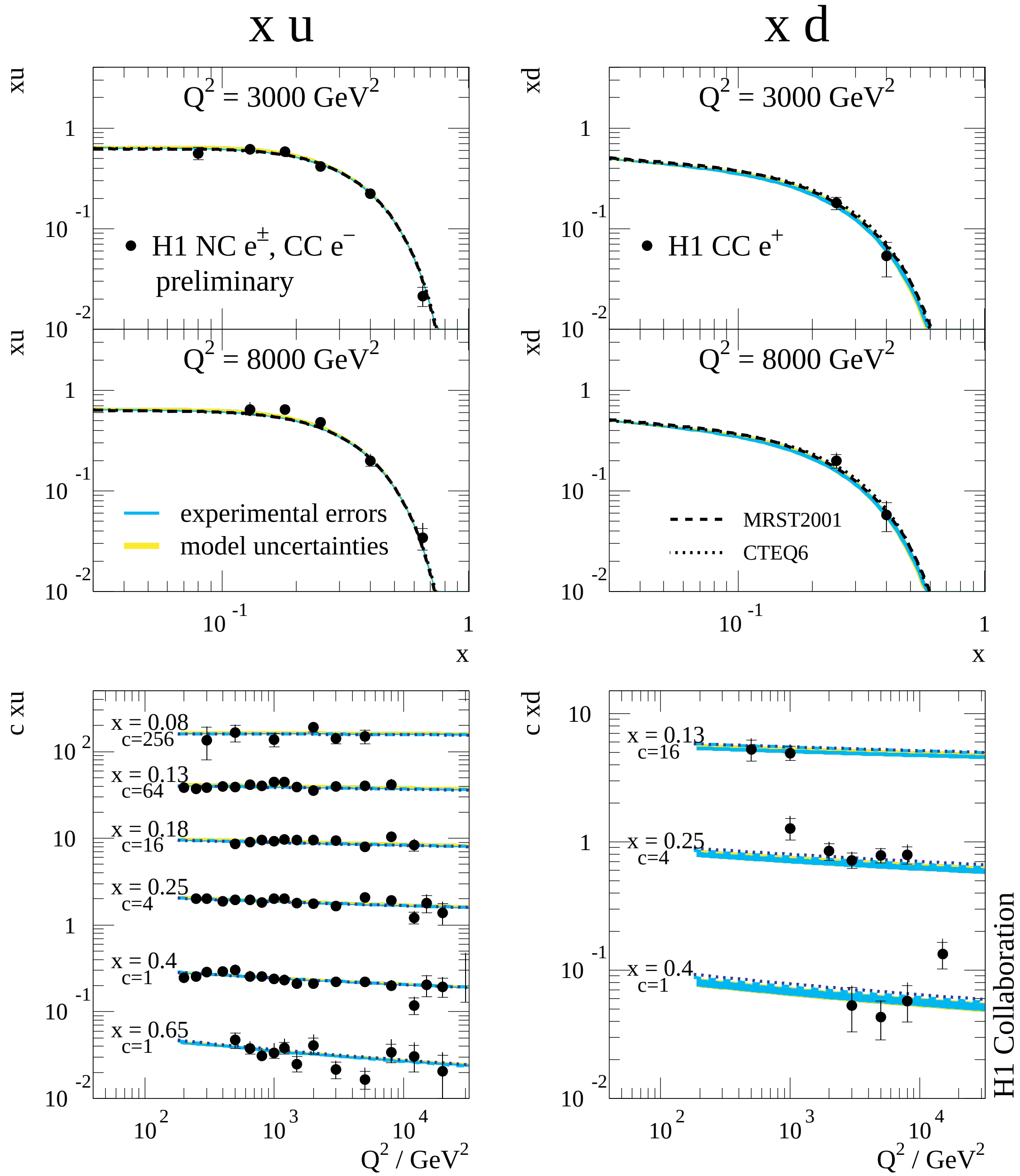
From Local Extraction Method:

$xq=\sigma_{meas}\,(xq/\sigma)_{th}$

Free from nuclear corrections

Two methods are complementary

HERA data start to constrain the u, d quark densities at large x



Summary and Outlook

- With the increased proton beam energy (820→920GeV),
  the new detector: backward silicon tracker
  the improved ability to trigger lower energy electrons
  Special dedicated runs
  The HERA kinematical phase space has been substantially extended

- The inclusive DIS data at HERA are confronted with NLO QCD analyses
  QCD (the DGLAP equations) are able to describe
  all the cross section data: e^+p, e^-p, NC, CC
  all the structure functions: F_2, F_L, xF_3
  in a huge kinematical range: both Q^2 & x covering 5 orders of magnitude

- Perspective @ HERA II:
  Luminosity per experiment: 1fb^{-1} by 2006
  longitudinally polarized e^+ or e^-
  QCD will be tested in DIS to a higher level of accuracy @ NNLO
  New possibilities for precision measurements of electroweak parameters