High Q^2 results
in NC and CC
e^+p and e^-p scattering

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On behalf of the H1 collaboration

Inclusive cross sections with almost the full statistics of HERA-I:

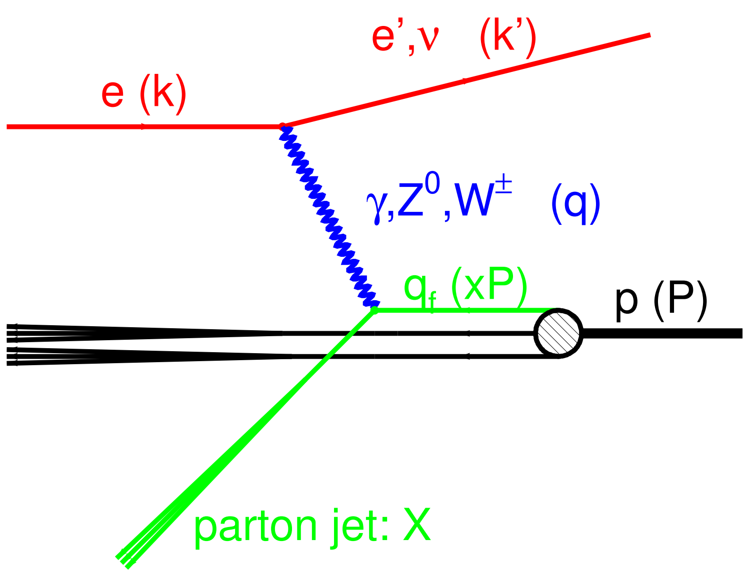
- **NC cross sections**
  - **Structure functions F_2, $x\widetilde{F}_3$ and F_L**
- **CC cross sections**
  - **W propagator mass**
- **Sensitivity to PDFs at high x**

HERA-I and DIS

	98-99	94-97 + 99-00
Beam $\sqrt{s}$	e^-p 318 GeV	e^+p 300+318 $\rightarrow$ 318 GeV
$\int \mathcal{L}\, dt$	16.4 pb^{-1}	35.6+45.9(of$\sim$65) = 81.5 pb^{-1}

Deep Inelastic Scattering at high Q^2:

Neutral current, NC: γ, Z^0 exchange
Charged current, CC: $W^\pm$ exchange



4-mom. transfer sqared:

$$Q^2 = -q^2$$

"Parton mom. fraction":

$$x = \frac{Q^2}{2P\cdot q}$$

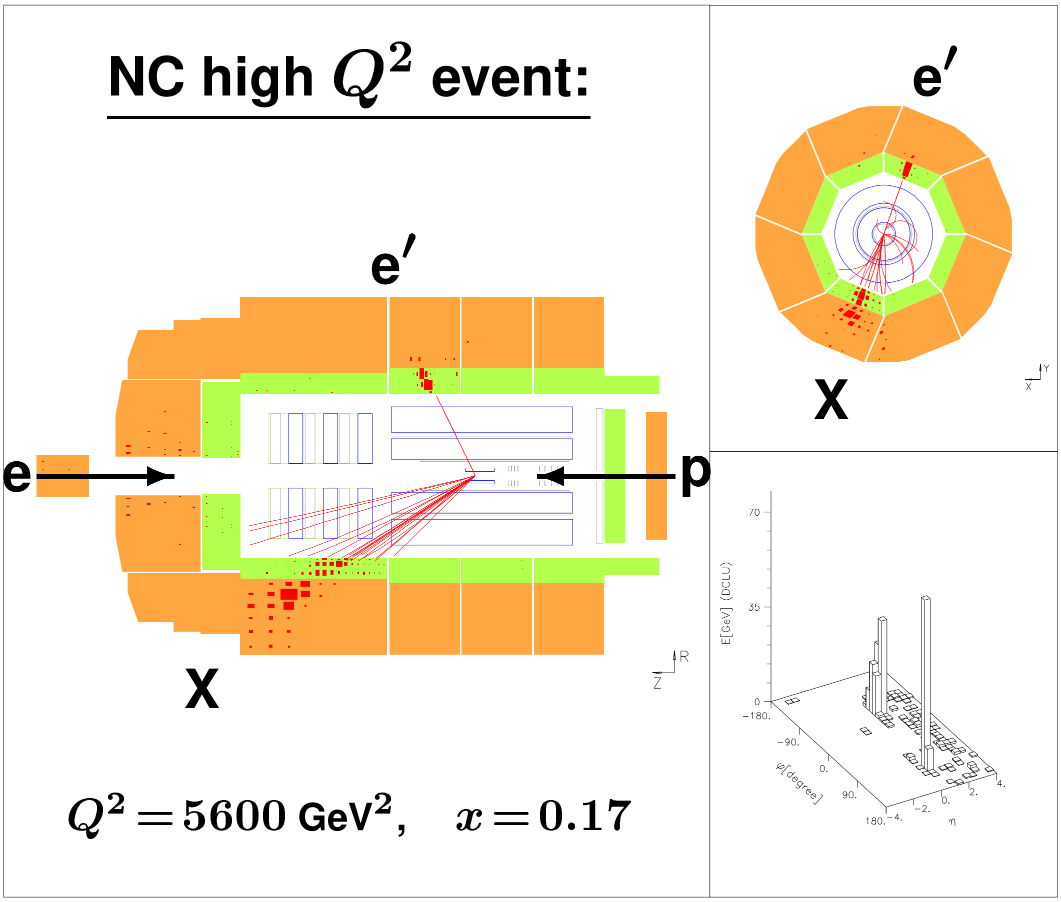
Inelasticity:

$$y = \frac{P\cdot q}{P\cdot k}$$

Redundancy:

$$Q^2 = sxy$$

The H1 detector



Reconstruction of the kinematics:

NC: $ep \to e'X$
- ▷ Clearly identified e′ (em. cluster + track)
- ▷ E_e, θ_e, $[(E-p_z)_{\text{had}}]$

CC: $ep \to \nu X$
- ▷ Missing transverse momentum
- ▷ $(E-p_z)_{\text{had}}$, $p_{T,\text{had}}$

$\Longrightarrow$ Precise LAr energy calibration in situ with NC high statistics data, using the double angle predictions.

$$e: \quad \frac{\delta(E)}{E} = 0.7 - 3\% \qquad \text{had:} \quad \frac{\delta(E)}{E} = 3\%$$

NC cross section: $ep \to e'X$

NC cross section for unpolarized $e^{\pm}p$ scattering:

$$\boxed{\frac{d^2\sigma^{\pm}_{NC}}{dx\,dQ^2} = \frac{2\pi\alpha^2}{x\,Q^4}\left[Y_+ \cdot \widetilde{F}_2 \mp Y_- \cdot x\widetilde{F}_3 - y^2 \cdot F_L\right]}$$

Helicity factors: $Y_{\pm} = 1 \pm (1-y)^2$

Generalized structure functions:

$$\widetilde{F}_2 = F_2 + \frac{Q^2}{Q^2+M_Z^2}\,F_2^{\gamma Z} + \left[\frac{Q^2}{Q^2+M_Z^2}\right]^2 F_2^Z \overset{\text{LO}}{\propto} \sum_q (q+\bar{q})$$

$$x\widetilde{F}_3 = \frac{Q^2}{Q^2+M_Z^2}\,xF_3^{\gamma Z} + \left[\frac{Q^2}{Q^2+M_Z^2}\right]^2 xF_3^Z \overset{\text{LO}}{\propto} \sum_q (q-\bar{q})$$

- F_2 dominates almost the full kinematic range.
- $x\widetilde{F}_3$ contributes significantly at $Q^2 \gtrsim M_Z^2$, sign depends on lepton charge.
- F_L contribution is small at small y.

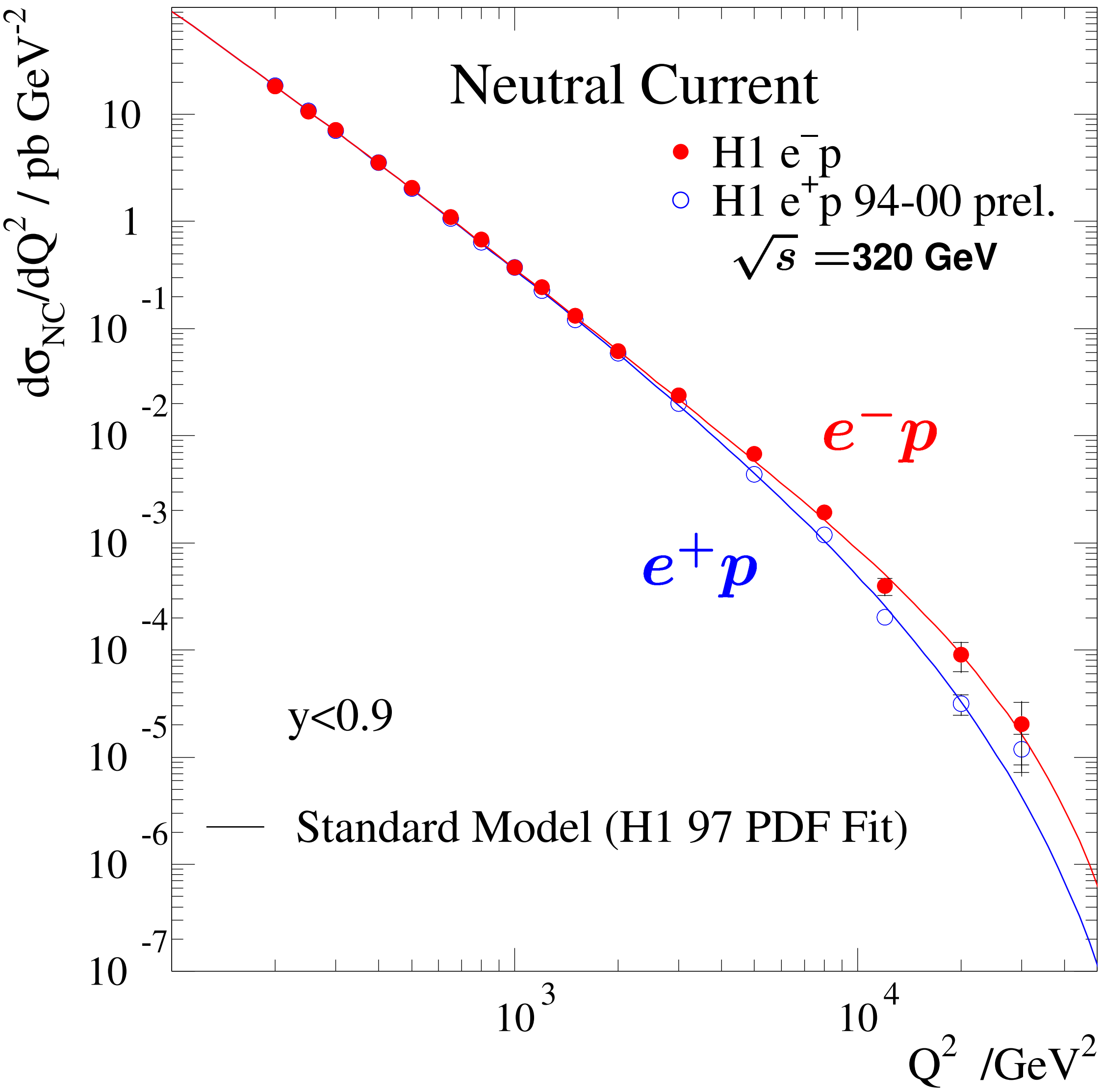
NC reduced cross section:

$$\boxed{\tilde{\sigma}^{\pm}_{NC}(x,Q^2) = \frac{x\,Q^4}{2\pi\alpha^2}\,\frac{1}{Y_+} \cdot \frac{d^2\sigma^{\pm}_{NC}}{dx\,dQ^2}}$$

Standard Model prediction:

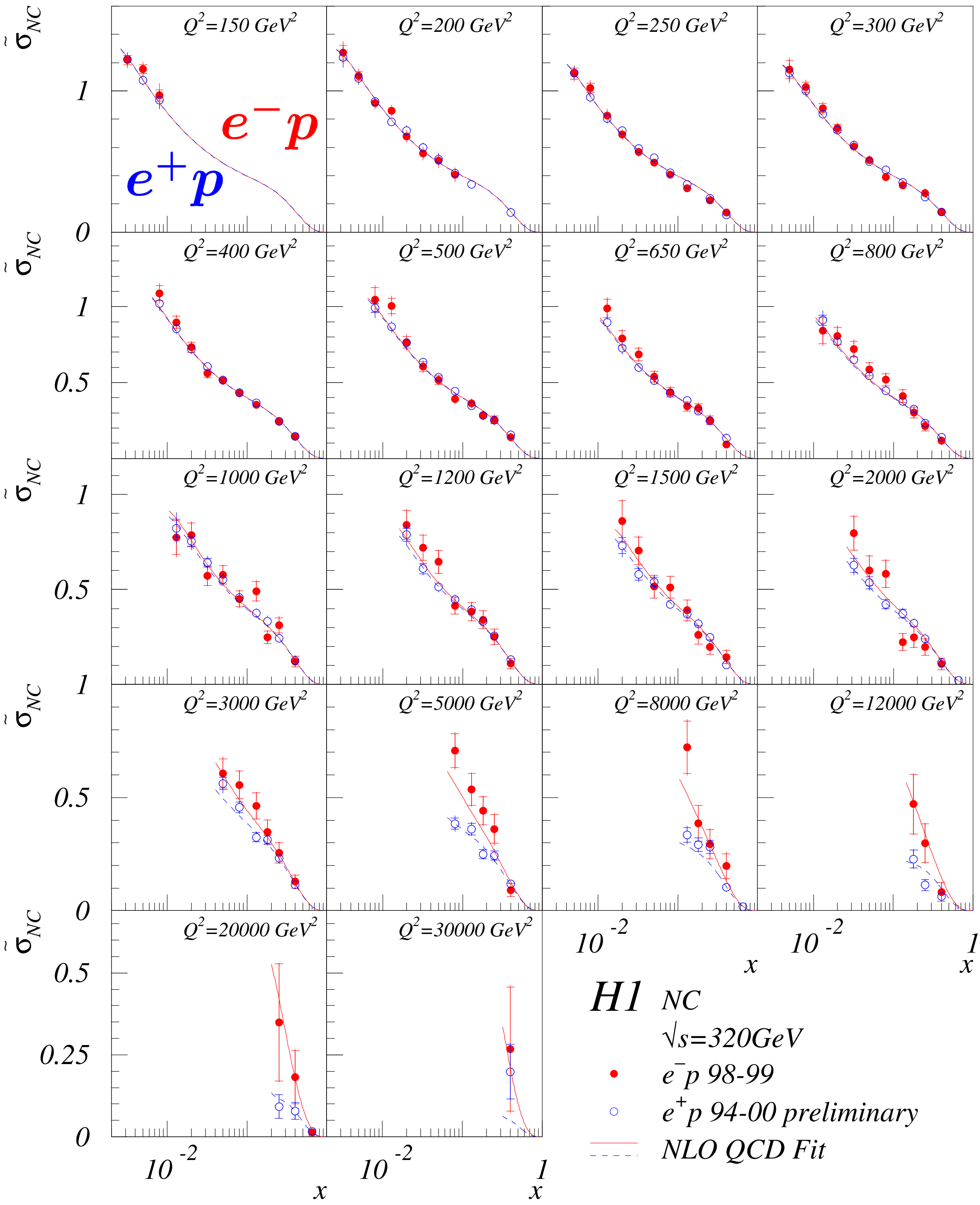
Parton density functions obtained from NLO QCD fit to
- H1 and fixed-target data at low Q^2
- H1 e^+p data from 94-97 at high Q^2

NC cross section $d\sigma/dQ^2$



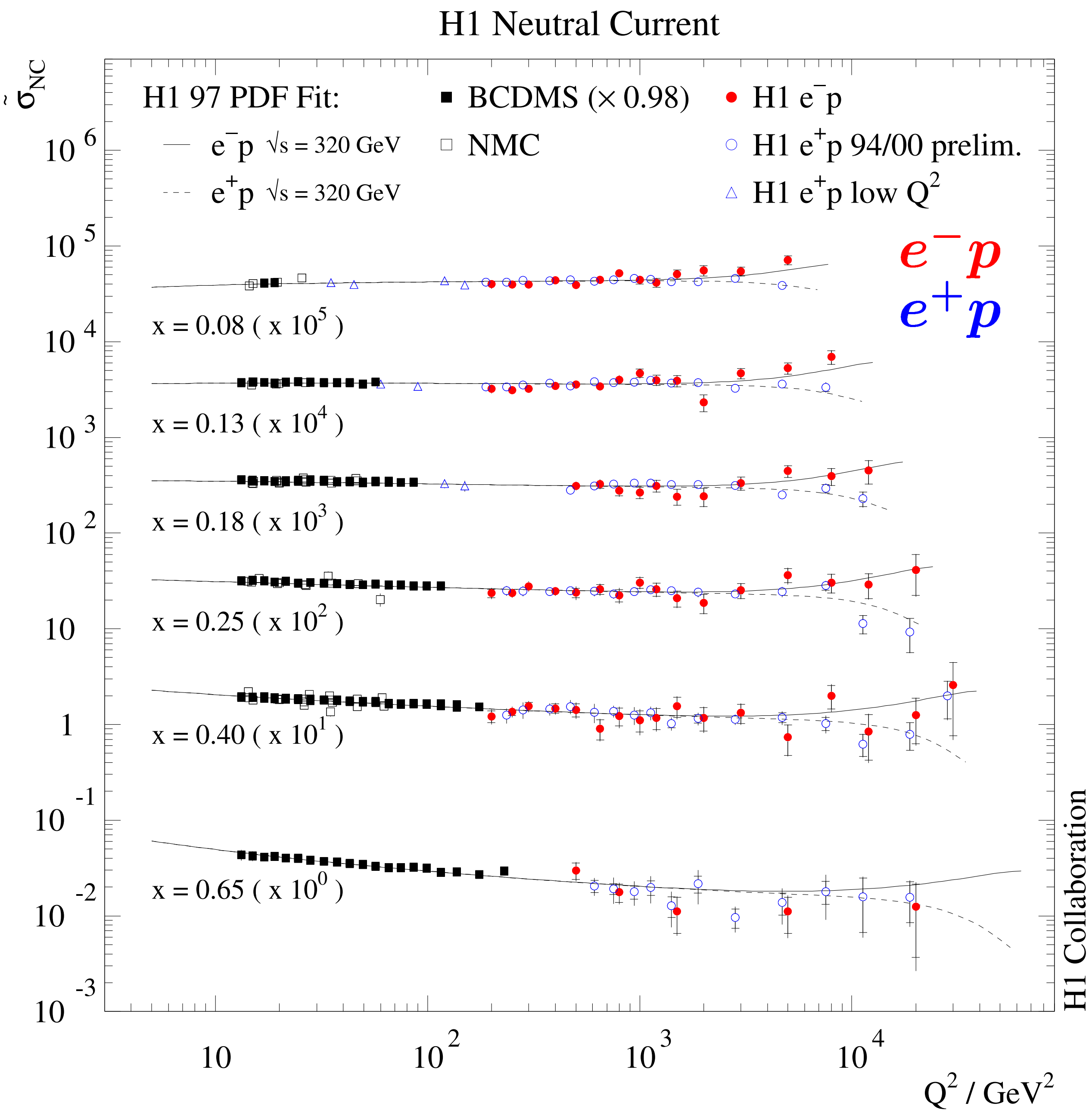
- **Standard Model describes data over 6 orders of magnitude.**
- **Clear effect of $x\widetilde{F}_3$ contribution visible at $Q^2 \gtrsim M_Z^2$.**

NC reduced cross section $\tilde{\sigma}$



- **Measurement covers large region in x and Q^2.**

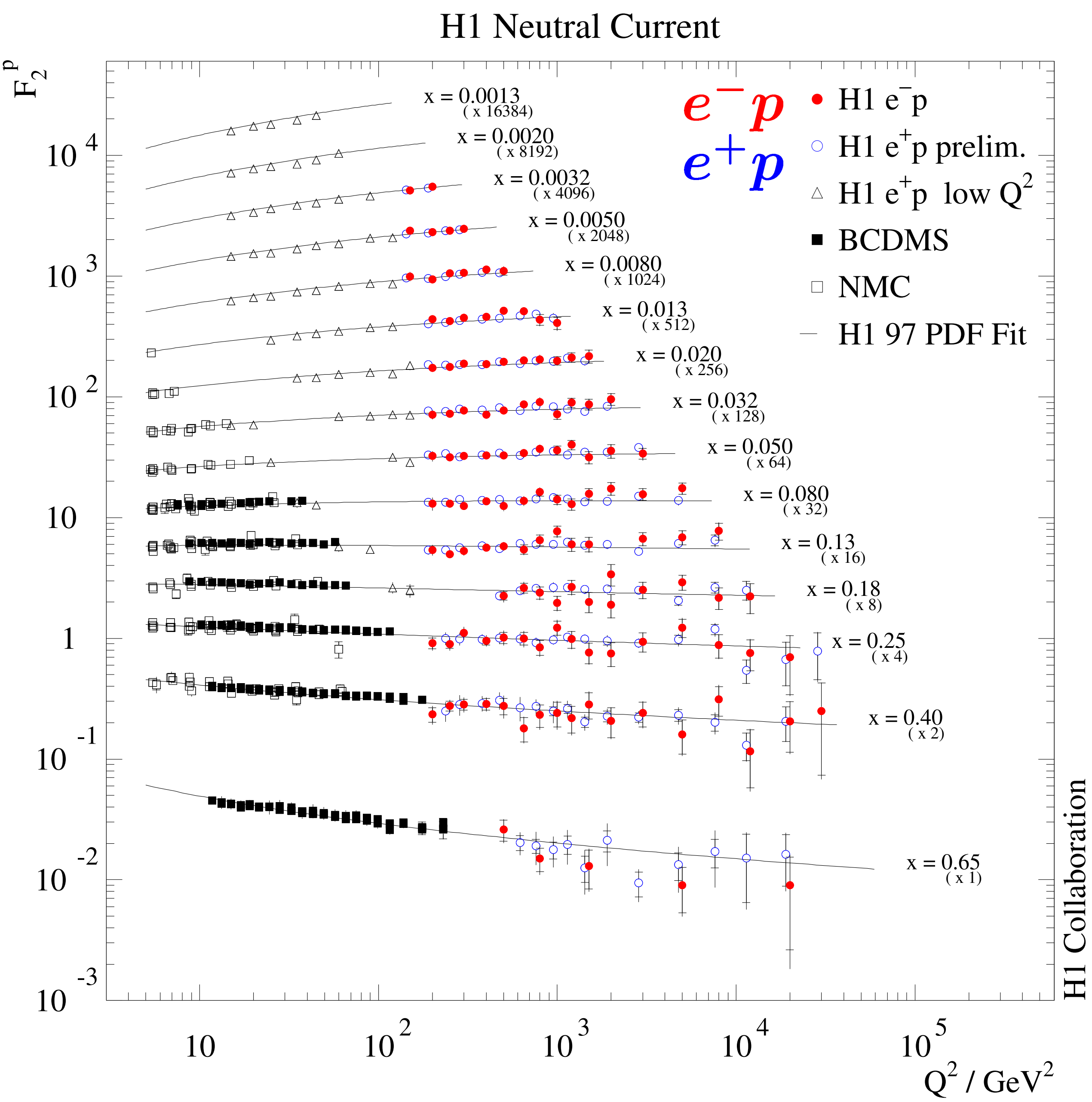
NC reduced cross section $\tilde{\sigma}$ at high x



- Still statistically limited at highest x, Q^2.

Extraction of F_2

$$\tilde{\sigma}_{NC} = F_2 \, (1 + \underbrace{\Delta F_2 + \Delta F_3 + \Delta F_L}_{\text{taken from NLO QCD fit}})$$

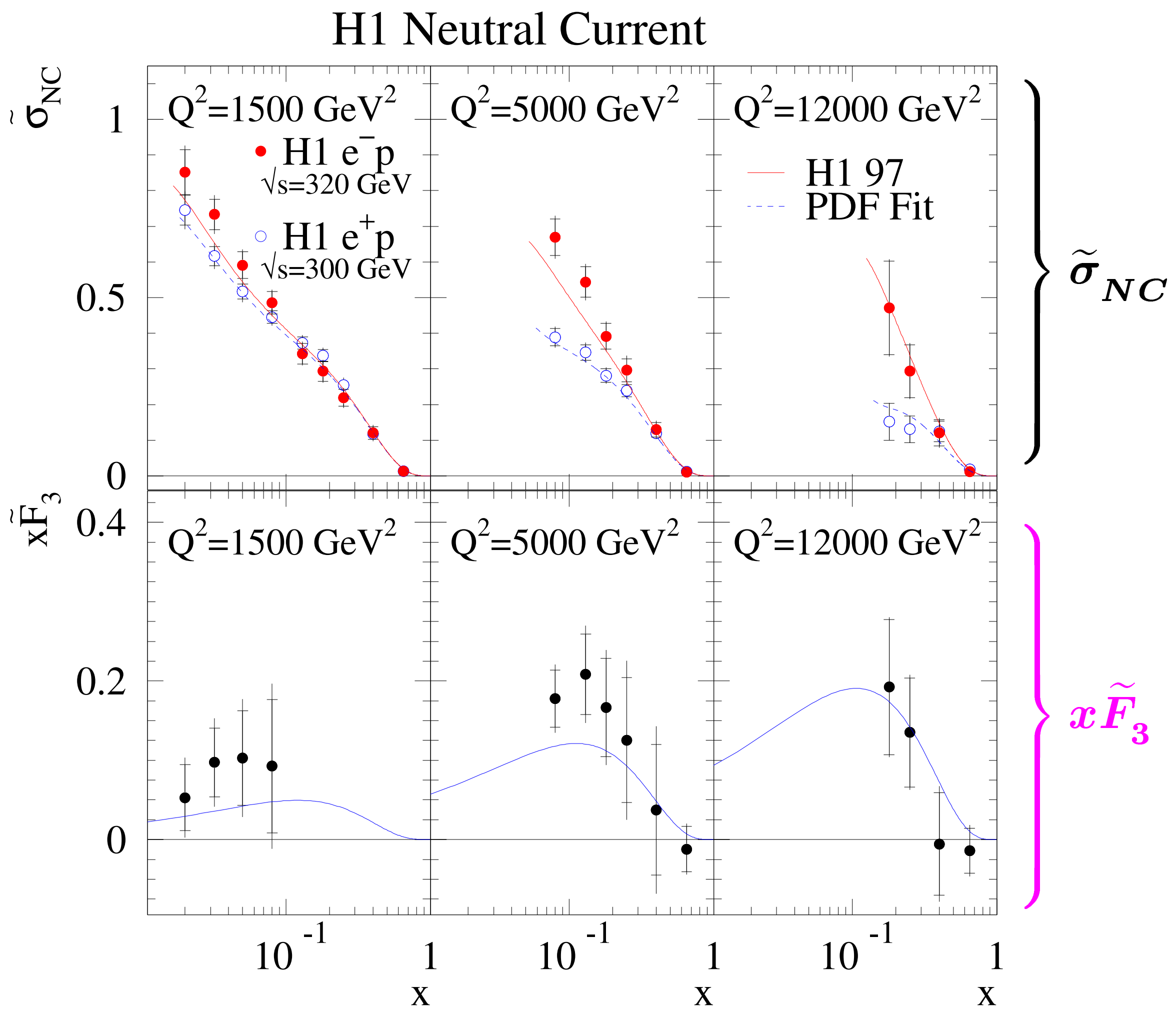


- e^+p and e^-p measurements consistent.

Extraction of $x\widetilde{F}_3$

Use published data **94-97** e^+p at $\sqrt{s} = 300$ GeV
and **98-99** e^-p at $\sqrt{s} = 318$ GeV:

$$\boxed{x\widetilde{F}_3 \propto \left(\widetilde{\sigma}^-_{NC} - \widetilde{\sigma}^+_{NC}\right)}$$



- **Direct sensitivity to the valence quarks:** $x\widetilde{F}_3 \overset{\text{LO}}{\propto} \sum_q (q - \overline{q})$

- **Level of agreement quantified by sum-rule:**

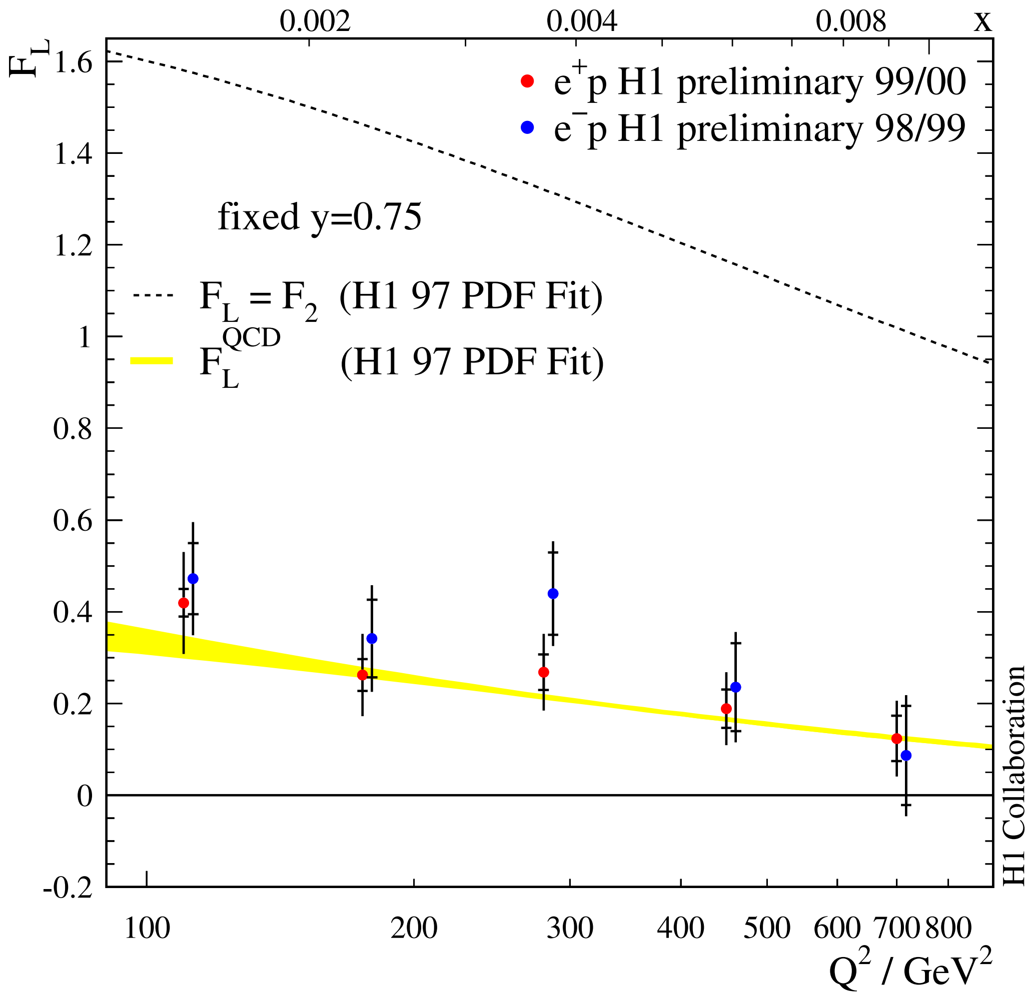
$$\int_{0.02}^{0.65} F_3^{\gamma Z}\,dx = \begin{cases} 1.88 \pm 0.35\text{(stat.)} \pm 0.27\text{(syst.)} & \text{measured} \\ 1.11 & \text{QDC fit} \end{cases}$$

Extraction of F_L

Subtraction method:

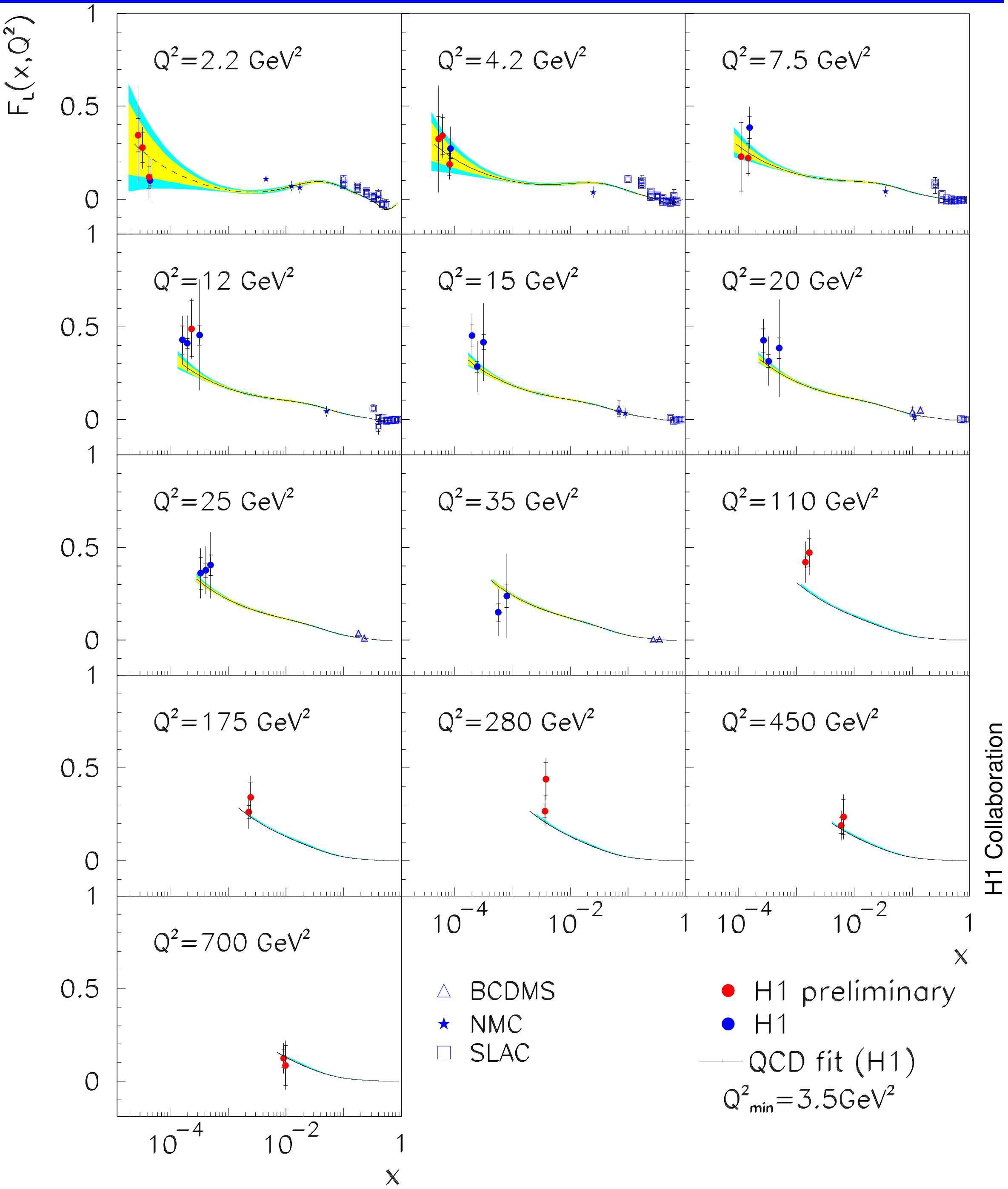
- $Q^2 \ll M_Z^2$: $\tilde{\sigma}_{NC} \approx F_2 - \frac{y^2}{Y_+} F_L$
- need high y, extend measurement to small electron energies
- assume F_2 from NLO QCD fit calculation
- relative normalization a between data and fit (from low y)

$$\boxed{F_L = \frac{Y_+}{y^2}\left(F_2^{\text{fit}} - a\,\tilde{\sigma}_{NC}\right)}$$



- Consistent results from 98/99 e^-p and 99/00 e^+p data.
- Agreement with QCD prediction.

Structure function F_L



- **Extension of F_L measurement to 'high' Q^2.**
- **Agreement with QCD prediction.**

CC cross section: $ep \to \nu X$

CC cross section for unpolarized $e^{\pm}p$ scattering:

$$\boxed{\frac{d^2\sigma^{\pm}_{CC}}{dx\,dQ^2} = \frac{G_F^2}{2\pi x}\left(\frac{M_W^2}{Q^2+M_W^2}\right)^2 \tilde{\sigma}^{\pm}_{CC}}$$

$\tilde{\sigma}^{\pm}_{CC}$: **CC reduced cross section.**

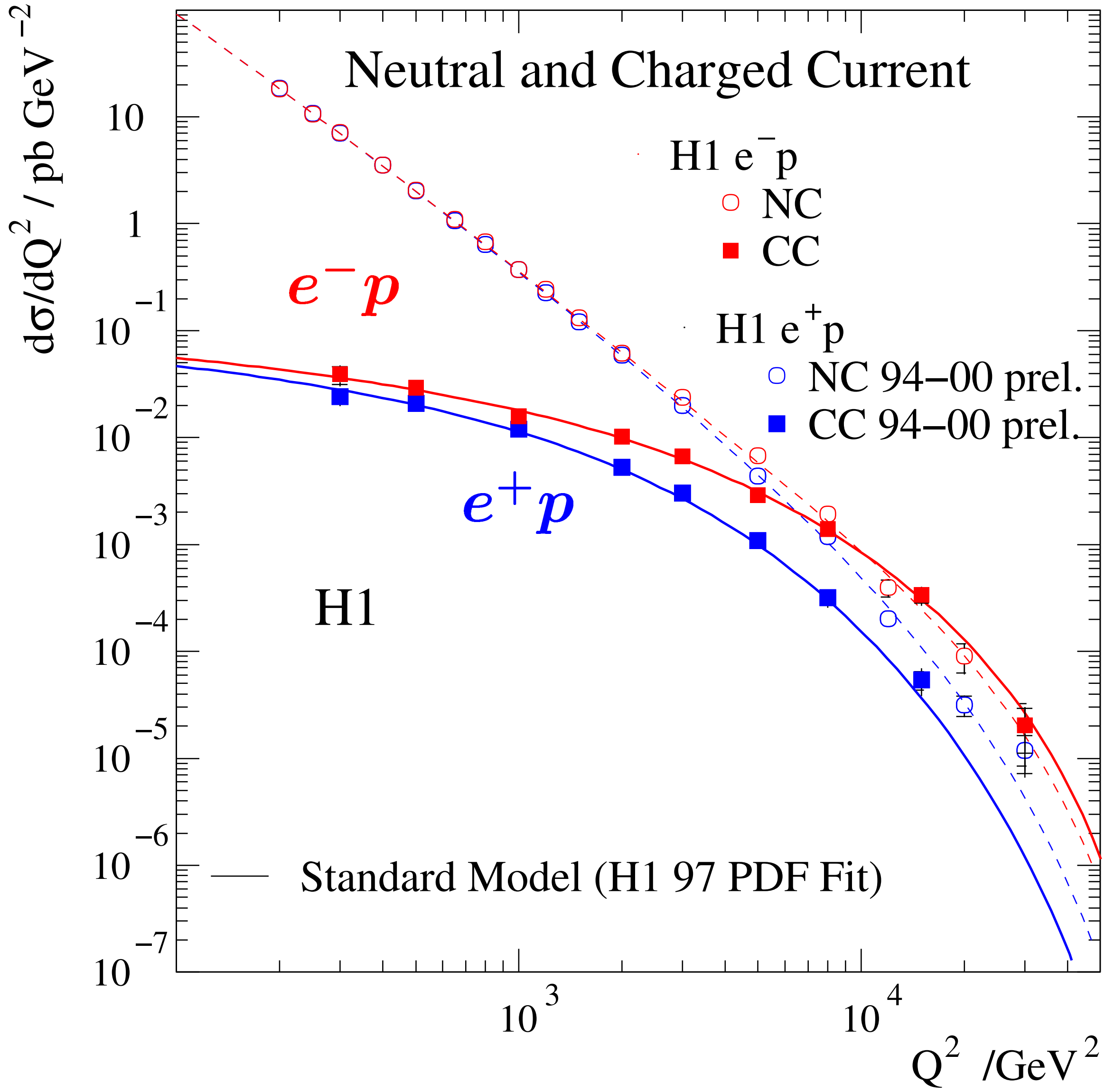
In leading order:

$$\tilde{\sigma}^{+}_{CC} = x\left[(\overline{u}+\overline{c}) + (1-y)^2\,(d+s)\right] \xrightarrow{\text{large } x} (1-y)^2\,x d_v$$

$$\tilde{\sigma}^{-}_{CC} = x\left[(u+c) + (1-y)^2\,(\overline{d}+\overline{s})\right] \xrightarrow{\text{large } x} x u_v$$

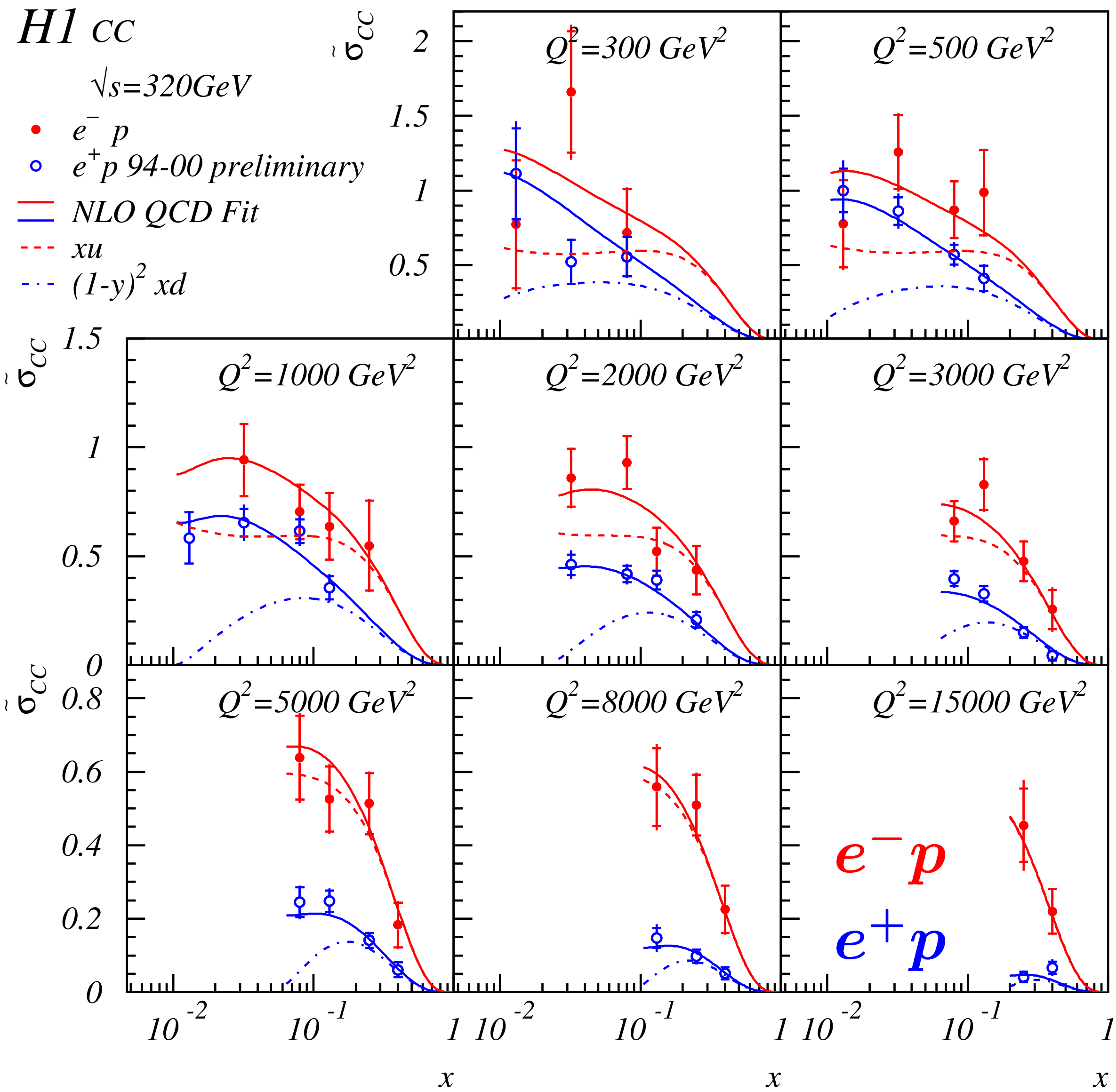
- Q^2 **dependence of the propagator provides access to** M_W.
- **Sensitive to individual parton densities.**
- **Access to valence quark distributions at high** x.

CC cross section $d\sigma/dQ^2$



- CC differences between e^+p and e^-p due to individual parton density contributions.
- Total CC cross section, $Q^2 > 1000$ GeV^2, $Y < 0.9$:
  $\sigma_{\text{tot}}^{\text{CC}}\left(e^-p\right) = 43.08 \pm 1.84\text{(stat.)} \pm 1.74\text{(syst.) pb}$

CC reduced cross section $\tilde{\sigma}$



- Good agreement with Standard Model predictions.
- For $x \to 1$: $\tilde{\sigma}^{+}_{CC} \propto (1-y)^2\, x d$

  $\tilde{\sigma}^{-}_{CC} \propto x u$

W propagator mass

$$\frac{d^2\sigma_{CC}}{dx\,dQ^2} \propto G_{CC}^2 \left(\frac{M_{\text{prop}}^2}{Q^2 + M_{\text{prop}}^2} \right)^2$$

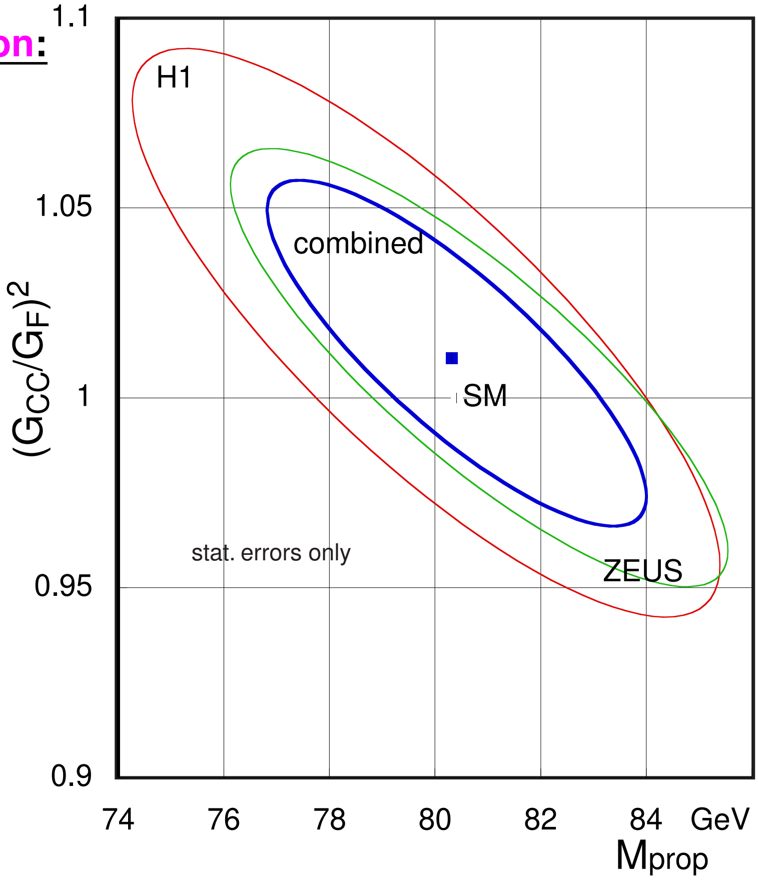
Fit to CC cross section:

Normalization:

$G_{CC}\ (G_F)$

Shape:

$M_{\text{prop}}\ (M_W)$



H1 - constrained fit with $G_{CC} \equiv G_F$:

e^+p: $M_W = 80.9 \pm 3.3\text{(stat.)} \pm 1.7\text{(syst.)} \pm 3.7\text{(pdf)}$ GeV

e^-p: $M_W = 79.9 \pm 2.2\text{(stat.)} \pm 0.9\text{(syst.)} \pm 2.1\text{(pdf)}$ GeV

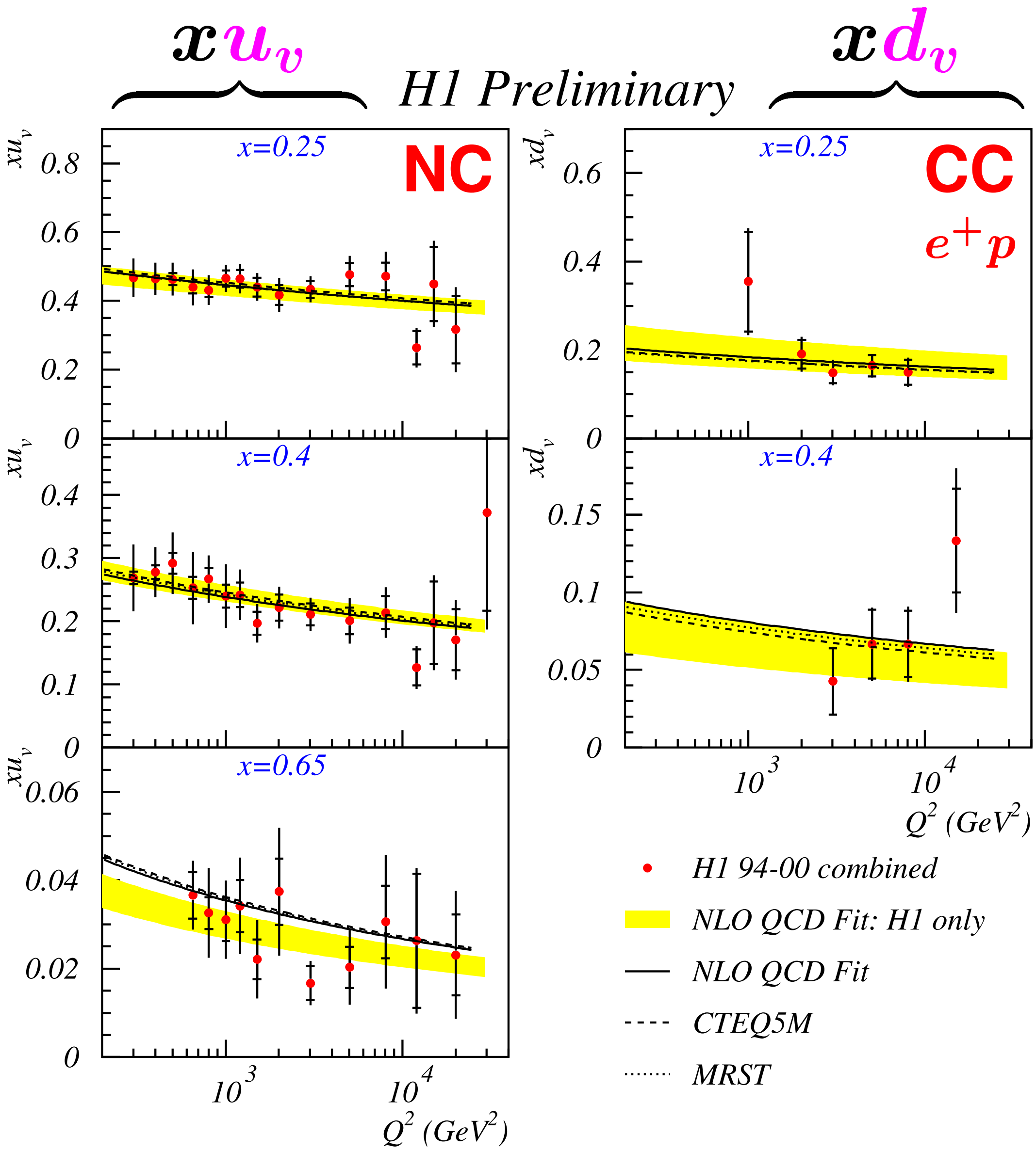
Valence quark PDFs at $x \geq 0.25$

At high x: **NC:** $u:d \approx 2\cdot\frac{4}{9} : 1\cdot\frac{1}{9} = 8:1 \quad \rightarrow x u_v$

CC: $\tilde{\sigma}^+ \propto (1-y)^2\, x d_v, \quad \tilde{\sigma}^- \propto x u_v$

- **QCD fit to H1 NC and CC data alone: precision $\sim$ 6-20 %.**
- **Local extraction method:** $\boxed{x q_v = \sigma_{\text{meas}} \left(\frac{x q_v}{\sigma}\right)_{\text{fit}}}$

$\left(\frac{\sigma(x q_v)}{\sigma}\right)_{\text{fit}} > 0.7$ **minimizes impact of theory uncertainties.**



- **Both methods consistent with global analyses.**
- **Need higher statistics to constrain PDFs at high x.**

Summary

- NC and CC single and double differential cross sections measured in e^+p and e^-p.
- Plenty of measurements allows various tests of QCD and EW parameters.

> High Q^2 results are well described by the Standard Model predictions.
>
> QCD succeeds up to highest Q^2.

Outlook

Complete HERA-I data analysis:

- ⋆ Improved energy calibration, particle ID, tracking...
- ⋆ Results will be ready for the summer conferences.

HERA-Upgrade, HERA-II starts data taking these days:

- ⋆ Increase in luminosity. $\longrightarrow$ Higher statistics.
- ⋆ Polarized $e^\pm$ beam. $\longrightarrow$ Window for new physics.