High Q^2 Proton Structure

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Photon 2003, Frascati
7^{th} April 2003

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- **Neutral Current Interactions**
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DIS Kinematics

- Q^2: Resolving Power of the exchange boson.

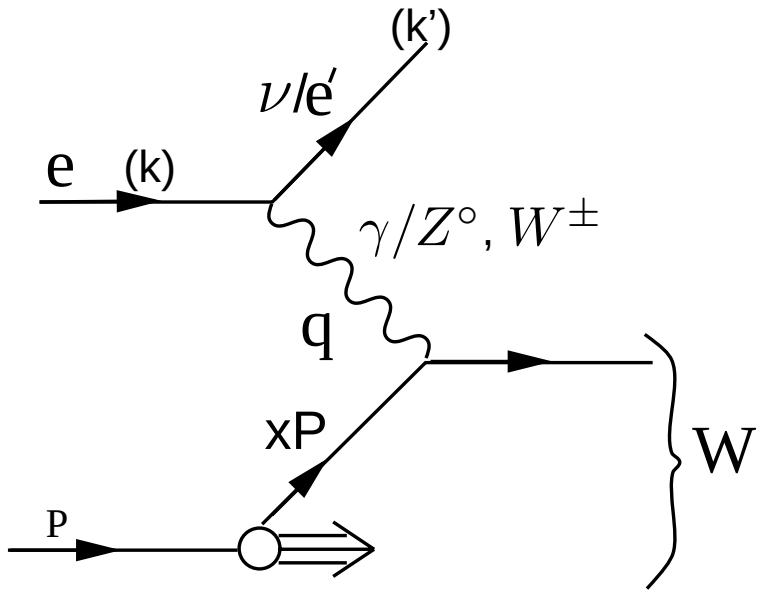
$$Q^2 = -q^2$$

- Bjorken x: Thought of as the Fraction of Proton momentum carried by Quark.

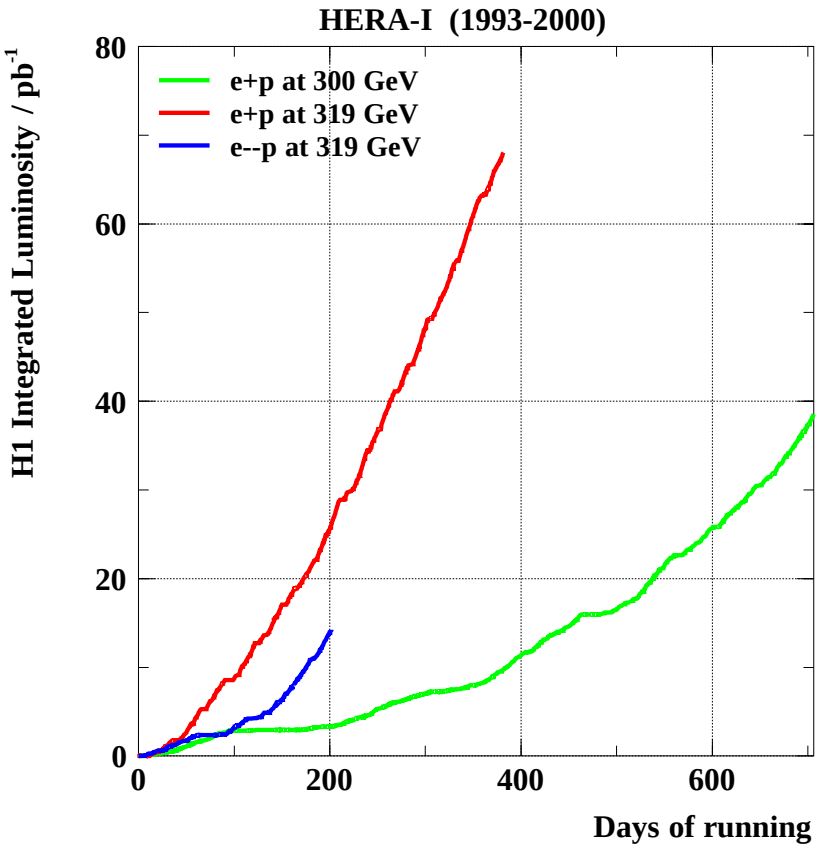
$$x = \frac{Q^2}{2P \cdot q}$$

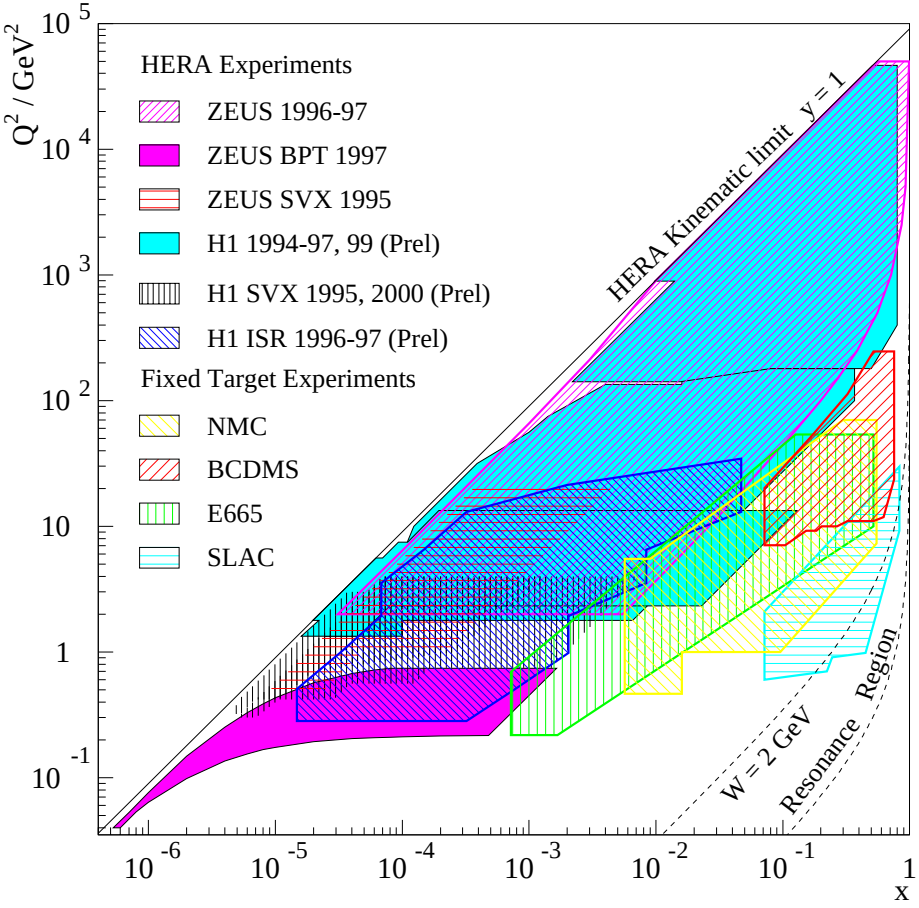
- y: Inelasticity, Fraction of lepton momentum carried by exchange.

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



HERA


HERA-I (1993-2000)
H1 Integrated Luminosity / pb-1
e+p at 300 GeV
e+p at 319 GeV
e--p at 319 GeV
Days of running
0
20
40
60
80
0
200
400
600


Q2 / GeV2
HERA Experiments
ZEUS 1996-97
ZEUS BPT 1997
ZEUS SVX 1995
H1 1994-97, 99 (Prel)
H1 SVX 1995, 2000 (Prel)
H1 ISR 1996-97 (Prel)
Fixed Target Experiments
NMC
BCDMS
E665
SLAC
HERA Kinematic limit y = 1
W = 2 GeV
Resonance Region
x

Parton Distributions

NC and CC cross sections are sensitive to the Parton Distribution Functions (PDFs)

via the proton structure functions

We measure Cross Sections $\Rightarrow$ Structure Functions

$\hookrightarrow$ access to [PDFs(x)]

Evolution in Q^2 predicted by DGLAP

(in perturbative range)

Neutral Current Cross Section

$$\frac{d^2\tilde{\sigma}(e^{\mp}p)}{dx\ dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+\tilde{F}_2(x,Q^2) - y^2\tilde{F}_L(x,Q^2) \pm Y_- x\tilde{F}_3(x,Q^2)\right]$$

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

$\tilde{F}_2$: generalized structure function

$\tilde{F}_L$: longitudinal structure function

x$\tilde{F}_3$: term from Z° exchange

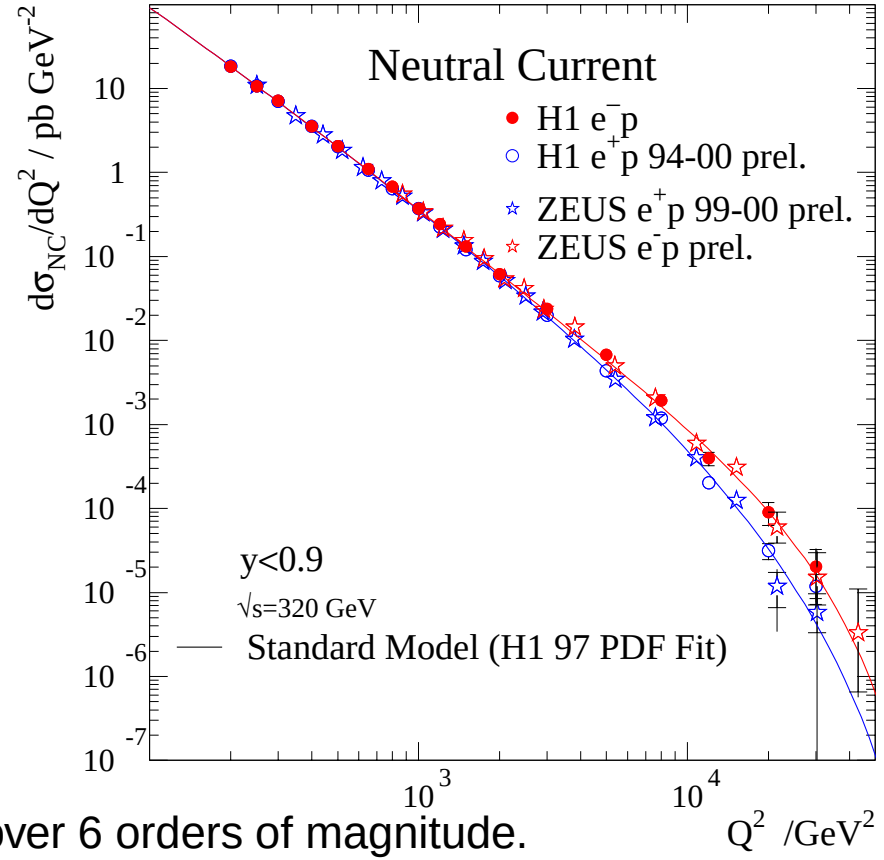
In Leading Order:

$$\tilde{F}_2 \propto \sum_i (xq_i + x\bar{q}_i)$$

$$x\tilde{F}_3 \propto \sum_i (xq_i - x\bar{q}_i)$$

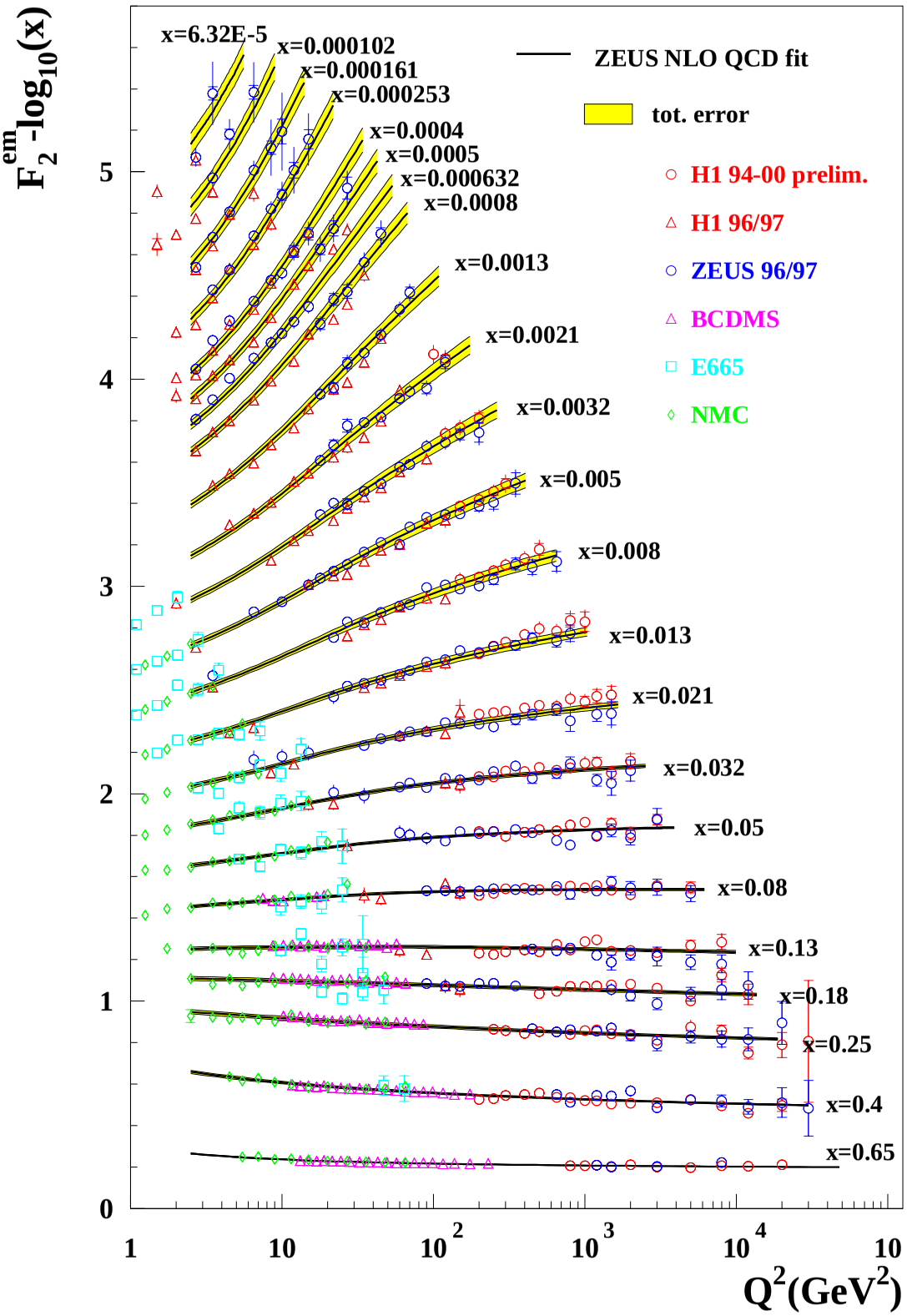
And write Reduced Cross Section as:

$$\tilde{\sigma}^{\pm}_{NC} \equiv \left[\tilde{F}_2 \mp \frac{Y_-}{Y_+} x\tilde{F}_3 - \frac{y^2}{Y_+}\tilde{F}_L\right]$$



- Visible High Q^2 effect (Z^o contribution).
- Good agreement with the Standard Model over 6 orders of magnitude.

F_2^{em}

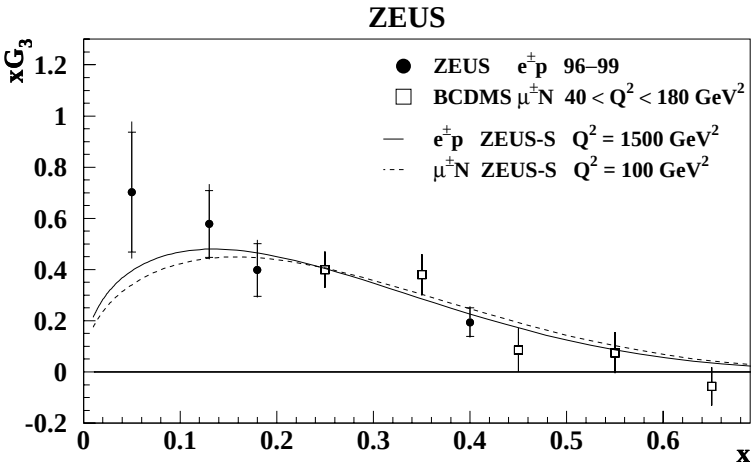


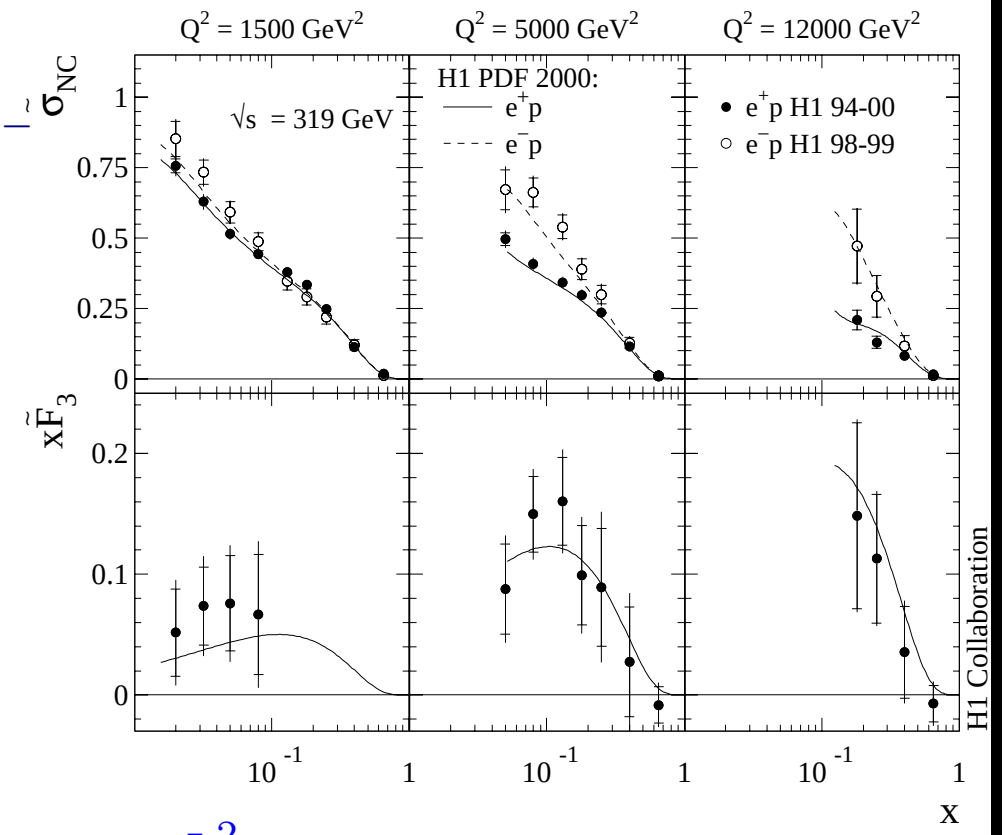
$$\tilde{F}_2 \equiv F_2^{em} - \nu_e \frac{\kappa_w Q^2}{Q^2+M_Z^2} F_2^{\gamma Z} + (\nu_e^2 + a_e^2) \left[\frac{\kappa_w Q^2}{Q^2+M_Z^2} \right]^2 F_2^{Z}$$

$x\tilde{F}_3$

$$\tilde{\sigma}^{\pm}{}_{NC} \approx \left[\tilde{F}_2 \mp \frac{Y_-}{Y_+} x\tilde{F}_3\right]$$

- $x\tilde{F}_3$ measured by subtracting $\tilde{\sigma}^+$ from $\tilde{\sigma}^-$
- Require $Q^2 \simeq M_Z^2$ ($10^4 GeV^2$)
- Direct sensitivity to valence quarks





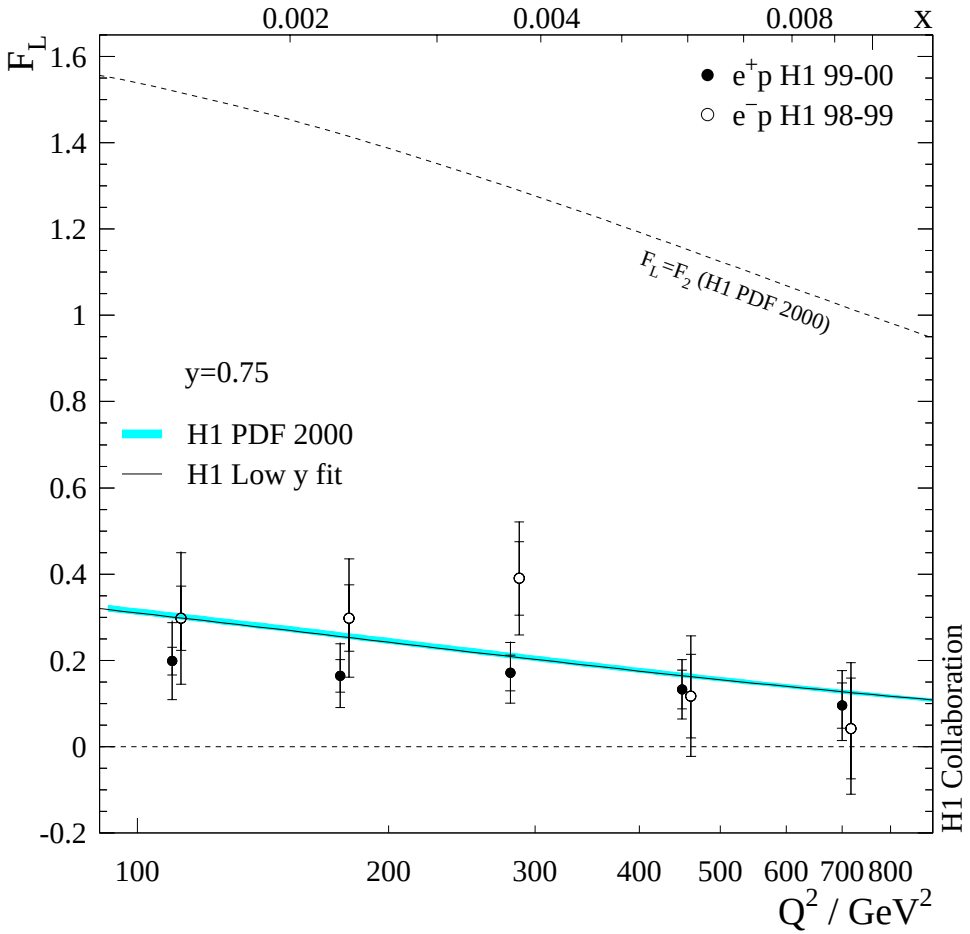
$$x\tilde{F}_3 \equiv -a_e \frac{\kappa_w Q^2}{Q^2 + M_Z^2} xF_3{}^{\gamma Z} + (2\nu_e a_e) \left[\frac{\kappa_w Q^2}{Q^2 + M_Z^2}\right]^2 xF_3{}^{Z}$$

$\tilde{F}_L$

$$\tilde{\sigma} \approx \left[\tilde{F}_2 - \frac{y^2}{Y_+} \tilde{F}_L \right]$$

$$\tilde{F}_L \sim xg$$

- Extracted at high y (and low Q^2)
- Assume $\tilde{F}_2$ from NLO QCD Model
  - e+ and e− data consistent
- Agreement with QCD prediction
- Inconsistent with $\tilde{F}_L$ = 0 and $\tilde{F}_L$ = $\tilde{F}_2$



Charged Current DIS

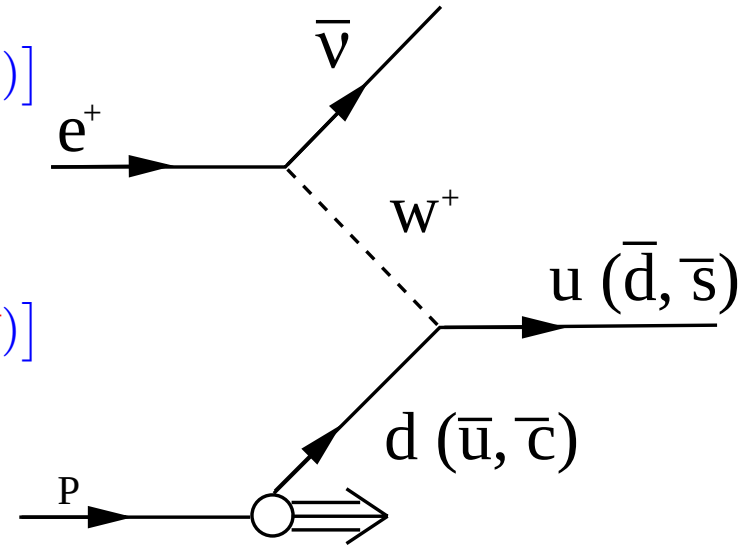
- $e^+p \longrightarrow \bar{\nu}X$: Probe d valence at high x

$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{G_F^2}{2\pi}\left[\frac{Q^2}{Q^2+M_W^2}\right]^2\left[\bar{u}+\bar{c}+(1-y)^2(d+s)\right]$$

- $e^-p \longrightarrow \nu X$: Probe u valence at high x

$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{G_F^2}{2\pi}\left[\frac{Q^2}{Q^2+M_W^2}\right]^2\left[u+c+(1-y)^2(\bar{d}+\bar{s})\right]$$

- Sensitivity to separate parton densities
- Sensitive to sea quarks at low x

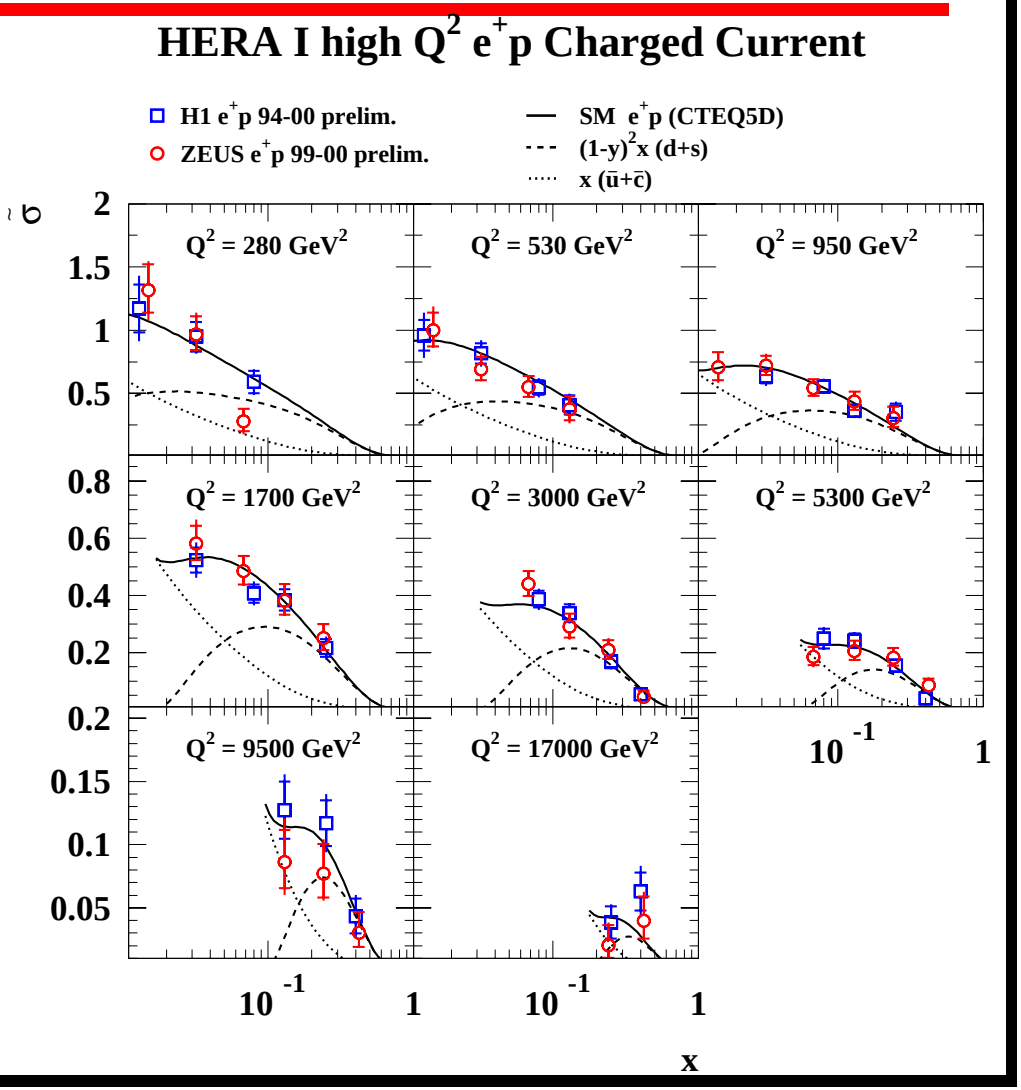


Define $u + c$ = U and $d + s$ = D

$\tilde{\sigma}_{CC}$

$$\tilde{\sigma}^{+}_{CC} = x \cdot \left[\bar{u} + \bar{c} + (1-y)^2(d+s)\right]$$
$$\tilde{\sigma}^{-}_{CC} = x \cdot \left[u + c + (1-y)^2(\bar{d}+\bar{s})\right]$$

- PDF agrees with Data points
- 2 Orders of Magnitude in Q^2 and 2 Orders of Magnitude in x
- At high x, D contribution dominates



Extraction of the PDFs

Parton Distribution Functions are parametrised depending on x

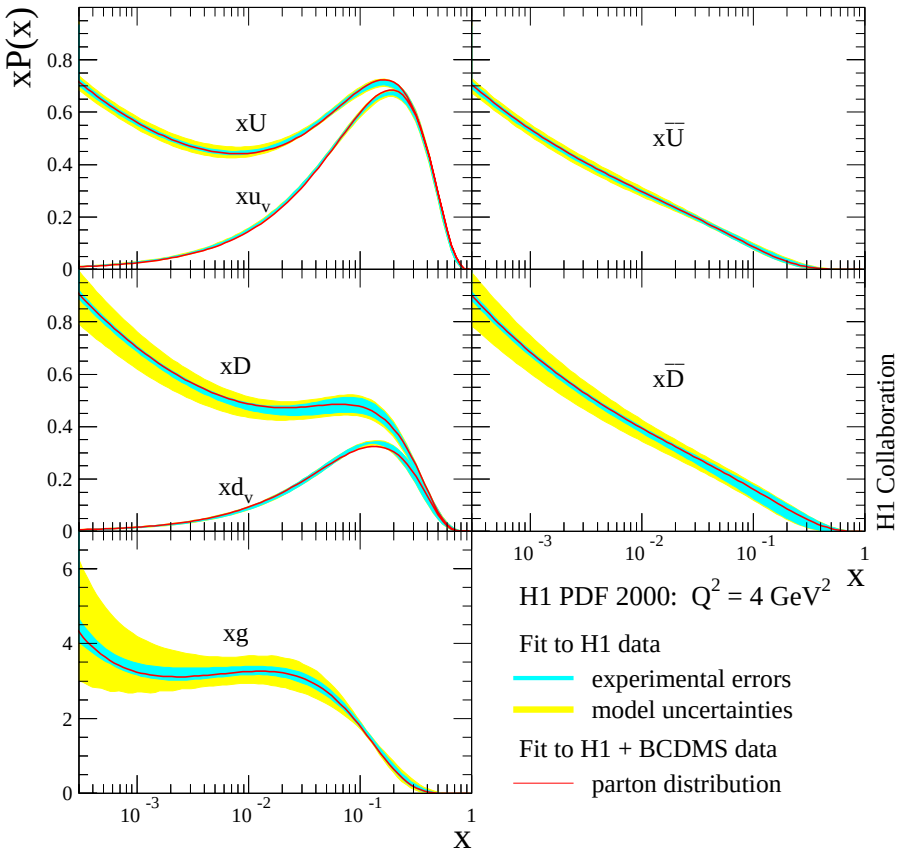
H1	ZEUS
Use only H1 Data	Both Zeus only data and World data
cross check with BCDMS	cross check with NMC, BCDMS, E665, CCFR
Q^2_0= 4 GeV^2	Q^2_0= 7 GeV^2
Data 3.5$< Q^2 <$30,000 GeV^2	Data 2.5$< Q^2 <$ 30,000 with W $>$ 20 GeV^2
parametrisation of combinations:	'classical' parametrisation:
xg, xU, xD, x$\bar{U}$, x$\bar{D}$	xg, xSea, u_v, d_v, $(\bar{u} - \bar{d})$
U = u +c, D = d + s	sum rules,

several assumptions, e.g. on sea distributions

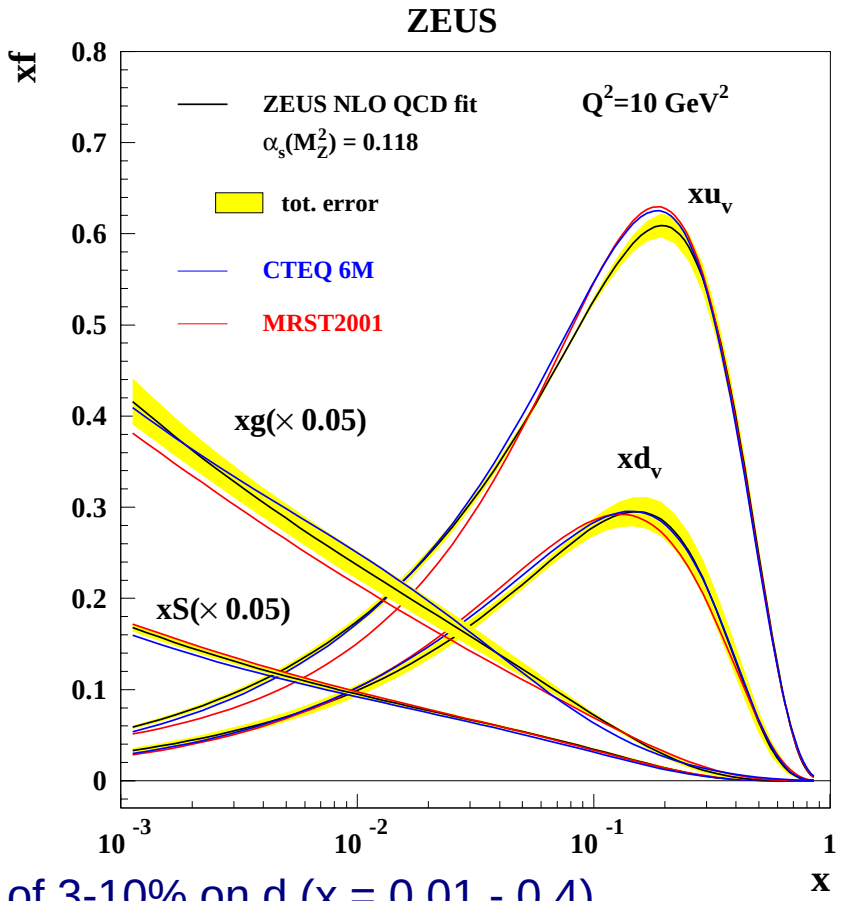
$\Rightarrow$ 13 free parameters	$\Rightarrow$ 11 free parameters

PDFs from NLO QCD Fits

PDFs at Q^2= 4GeV^2



Zeus + Fixed Target fit compared to global fits:



- Error of 1-2% on u (x = 0.01 - 0.4)
- Error of 3-10% on d (x = 0.01 - 0.4)

xu and xd at large x

H1 local extraction of data points:

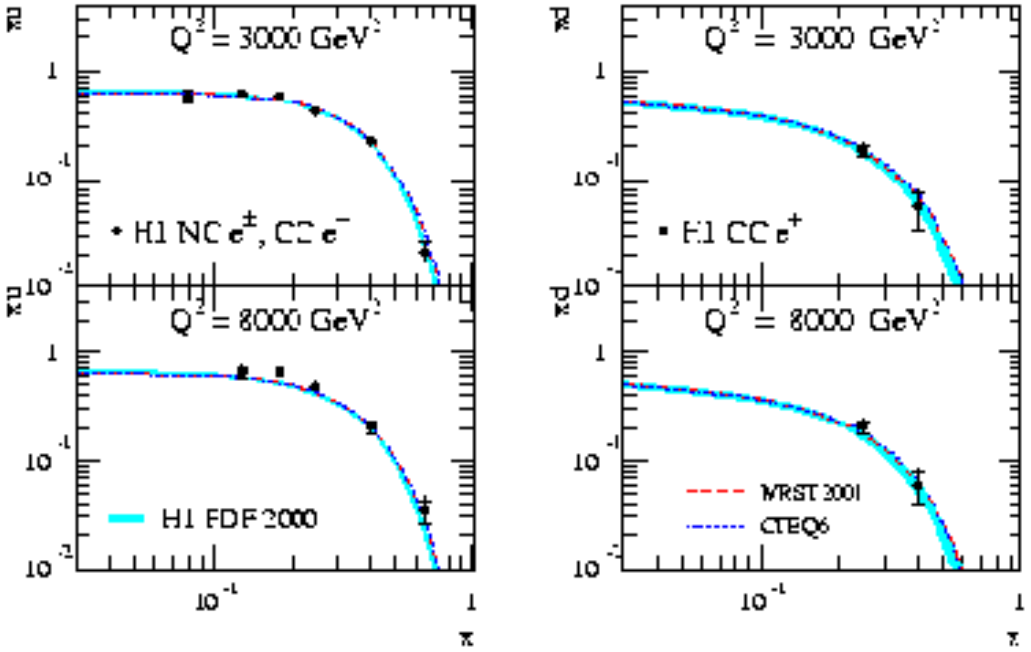
$$xq_{ex} = \tilde{\sigma}_{meas} \times \frac{xq_{th}}{\tilde{\sigma}_{th}}$$

- Ingredients:

▷ QCD assumptions on u and d (70% at high x)

▷ local NC and CC cross section measurement for quark separation

⇒ less sensitive to assumptions in other regions of phase space



Summary

- $\tilde{\sigma}_{NC}$ and $\tilde{\sigma}_{CC}$ well Measured
- $\tilde{F}_2$ errors to 2%
- $\tilde{F}_3$ errors statistically dominated

(reduced with Hera II running)

- $\tilde{F}_L$ Measured with Hera II low energy running
- Hera PDFs Consistent with global fits
- Do not rely on global fits
- Error on u 1%(x=0.01) - 2%(x=0.4) [H1]
- Error on d 3%(x=0.01) - 10%(x=0.4) [H1]
- Error on quark sea ~5 % (x≤0.1) [Zeus]
- Error on gluon ~10 % (x≤0.1) [Zeus]