The Proton Structure
as measured at HERA

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- Introduction
- Complete Kinematic plane
- High-Q^2
- Charged Current
- Summary

Intro: PDFs and Structure Functions

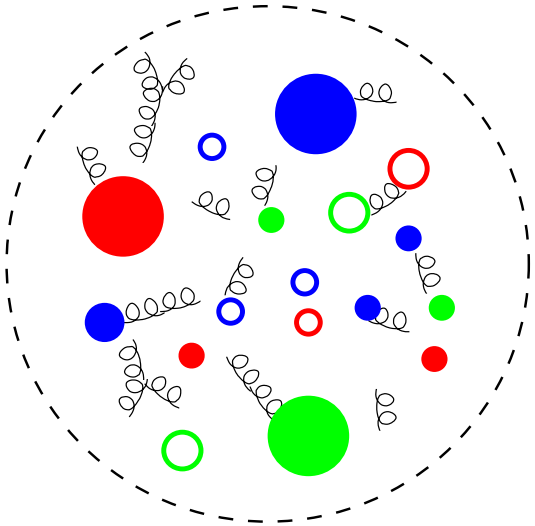
Theory: PDFs

- describe the proton universally
- are not observables

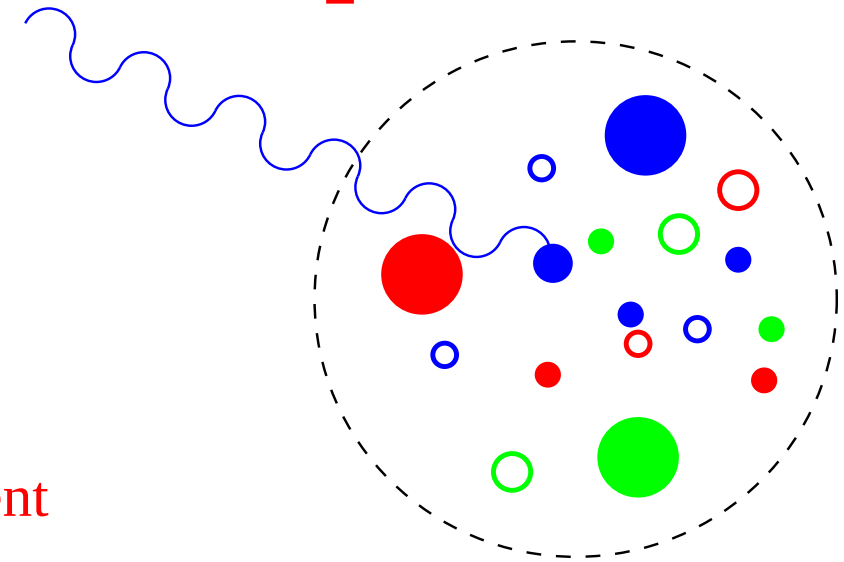
Experiment: Structure Functions

- can be observed
- depend on probing boson

g, u, d, s, ...



F_2^γ ,xF_3^W,...



Goal:

The Measurement

(Parametrization and Evolution of PDFs is not topic)

Intro: Inclusive DIS ep Scattering at HERA

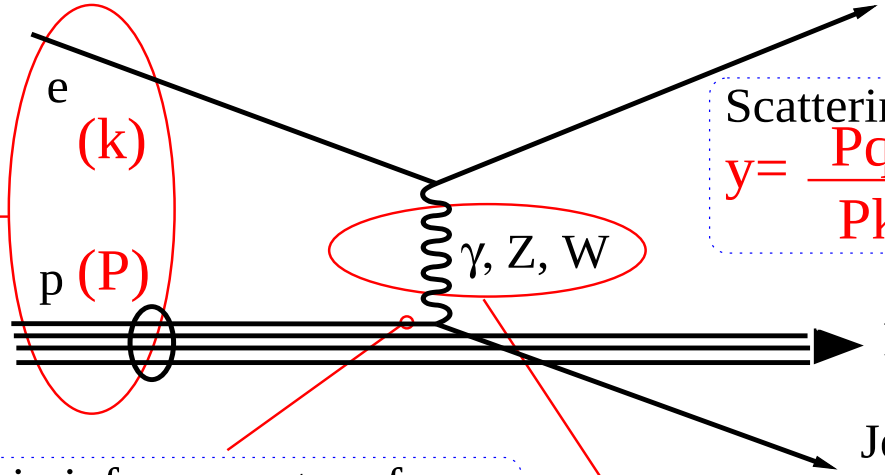
Reactions:

NC: e + p −> e + X
CC: e + p −> ν+ X

Lorentz invariants:

e p−c.m.− energy: $\sqrt{s}$

$s=(P+k)^2$



Scattering angle in eq−c.m. frame

$y=\frac{Pq}{Pk}$

Quark momentum in inf. momentum frame

$x=\frac{Q^2}{2Pq}$

1/Momentum transfer^2 ~Resolved dist.

$Q^2=-q^2=-(k-k')^2$

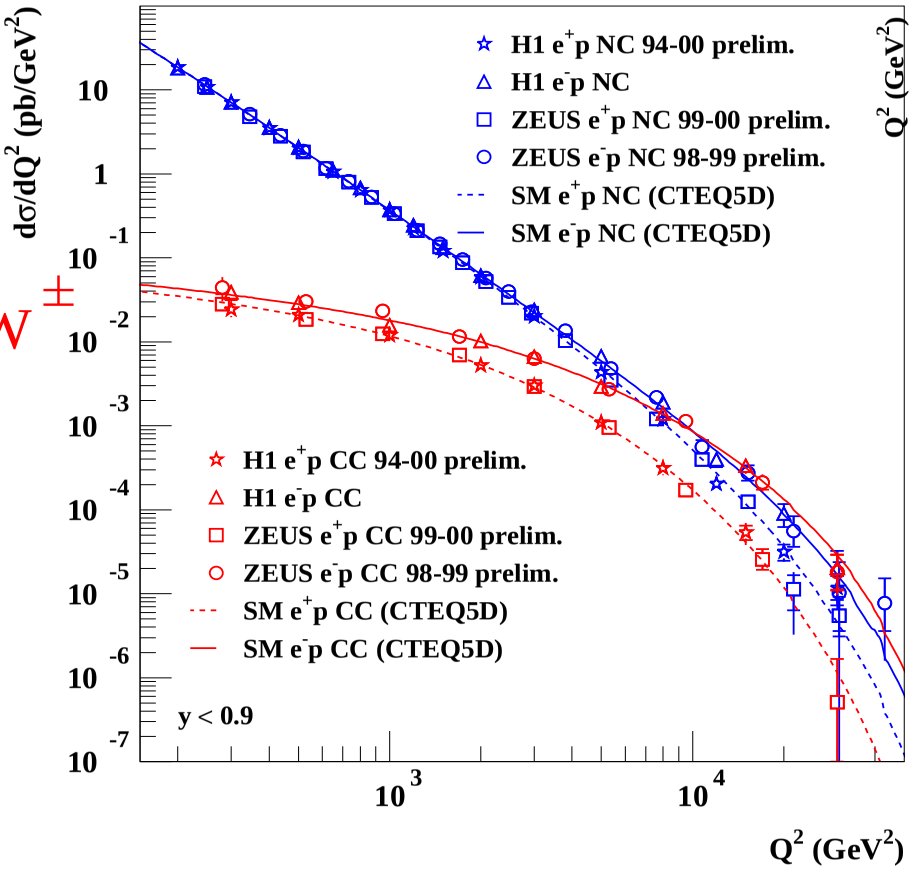
Relation: $Q^2=s\,x\,y$ $(M_p << P)$

Intro: Available Bosons and HERA Kinematic Plane

Bosons:

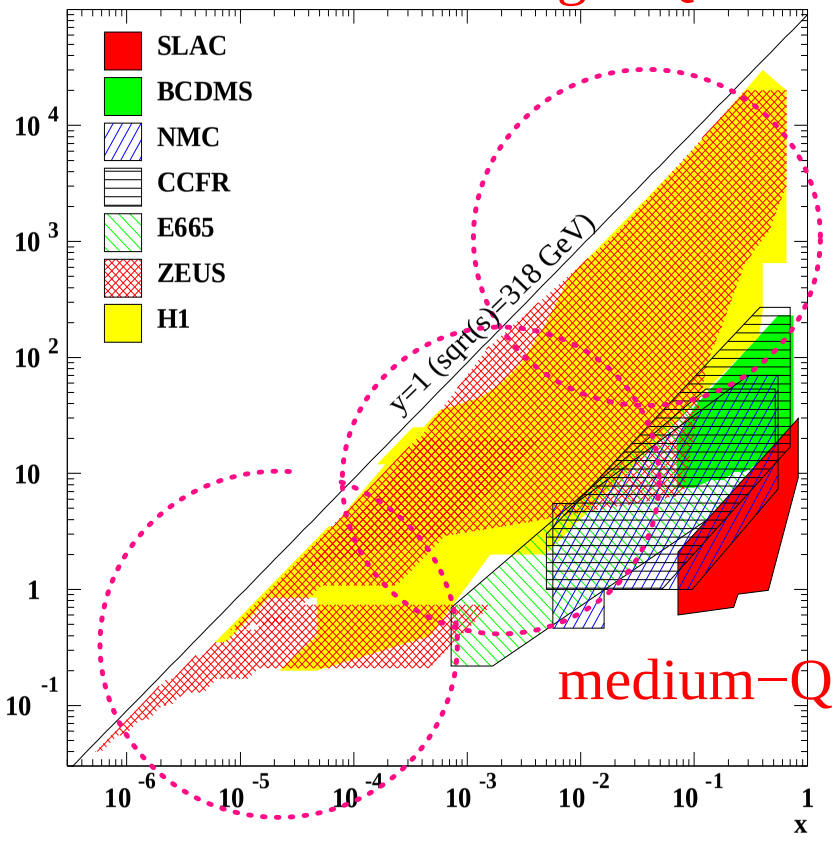
NC: γ , Z

CC: $W^{\pm}$



Kinematics:

high−Q^2



medium−Q^2

low−x

Complete Kinematic Plane: F_2^γ

Generalised Structure Functions:

Parity conserving

Parity violating (small)

$$\frac{d^2\sigma^{NC}(e^\pm p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}[Y_+ F_2^{NC} \mp Y_- xF_3^{NC} - y^2 F_L^{NC}]$$

$$P_Z \equiv \frac{Q^2}{Q^2 + M_Z^2}\,, \qquad Y_\pm \equiv 1 \pm (1-y)^2$$

Longitudinal (small)

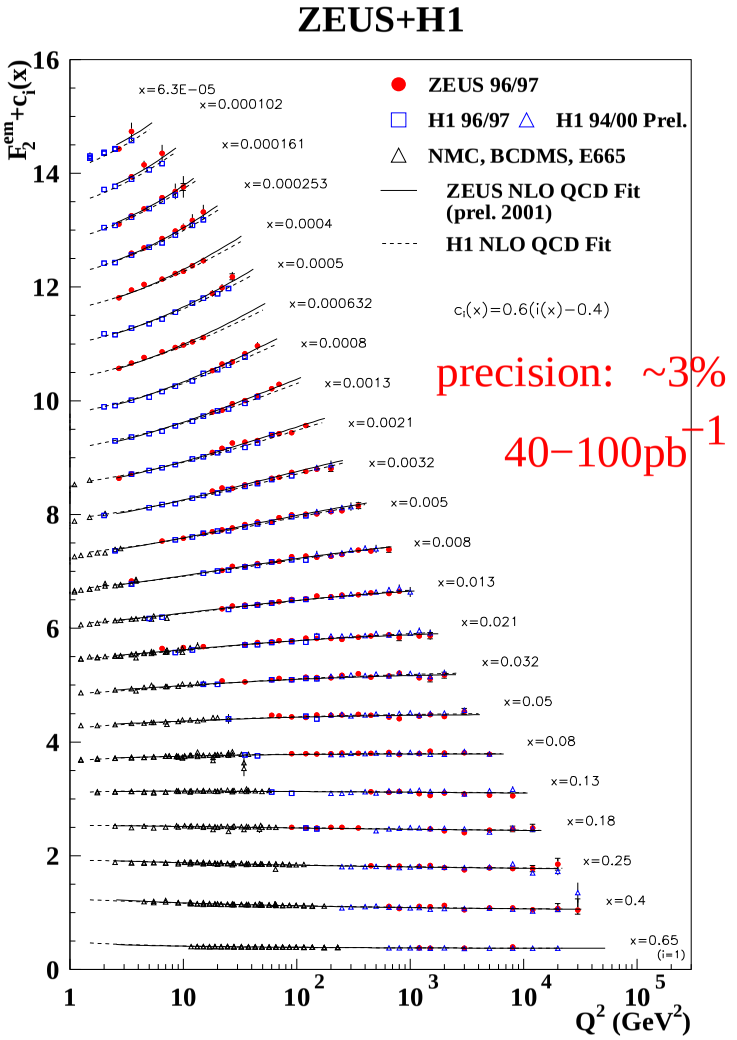
Parity conserving F_2

$$F_2^{NC} = F_2^\gamma - v_e P_Z F_2^{\gamma/Z} + (v_e^2 + a_e^2) P_Z^2 F_2^Z$$

small

Proton Structure viewed with photons: F_2^γ

LO (DIS scheme): $F_2 = \sum q + \bar{q}$



precision: ~3%

$40-100\,pb^{-1}$

High-Q^2: $\tilde{\sigma}$ vs. Q^2

Reduced Cross Section (NC):

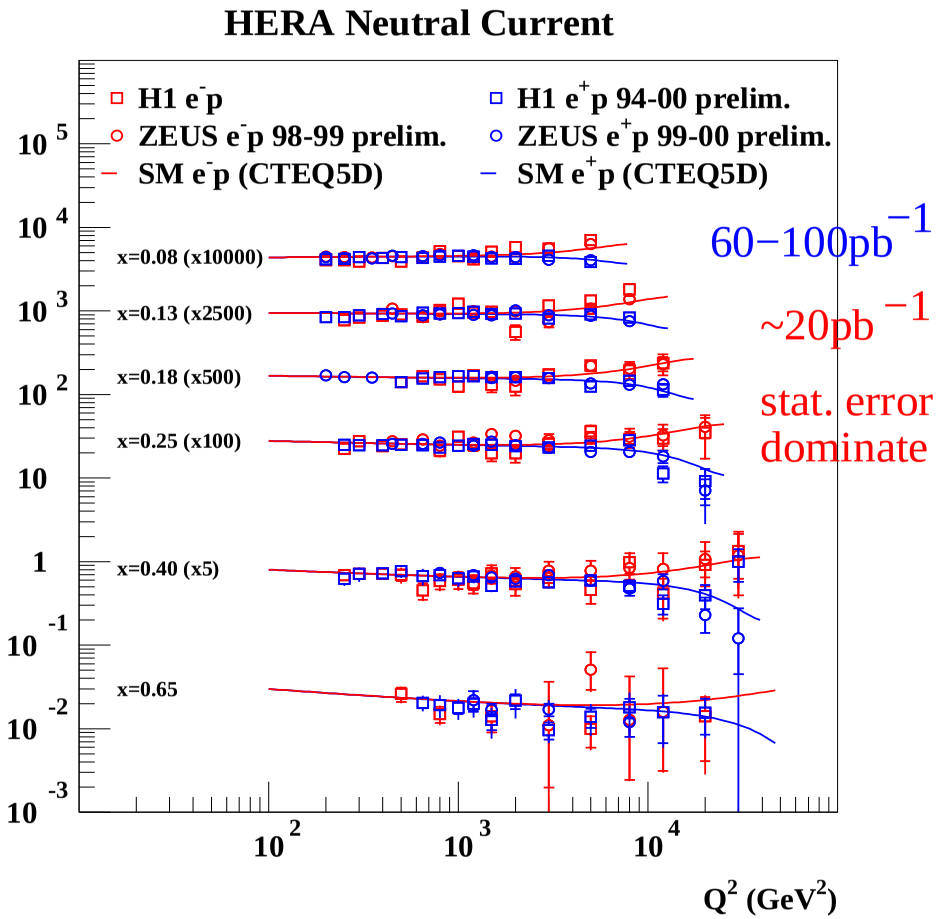
$$\tilde{\sigma}(e^{\pm}p) = F_2^{NC} \mp \frac{Y_-}{Y_+} xF_3^{NC} - \frac{y^2}{Y_+} F_L^{NC}$$

H1 and ZEUS agree well

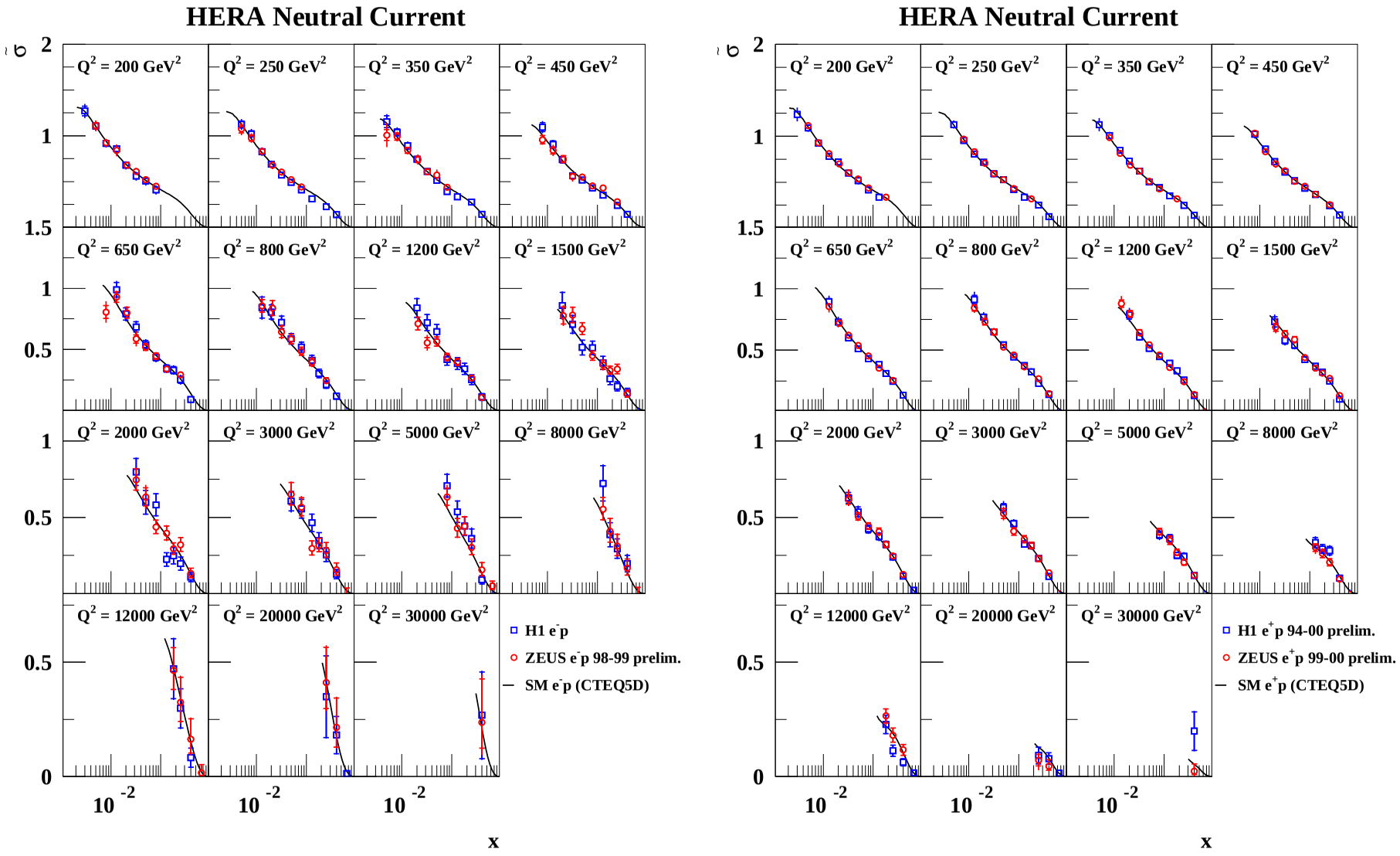
Data well described by theory and parametrisation

Difference between e^+ and e^- results from xF_3

No high$-Q^2$ excess



High-Q^2: $\tilde{\sigma}$ vs. x

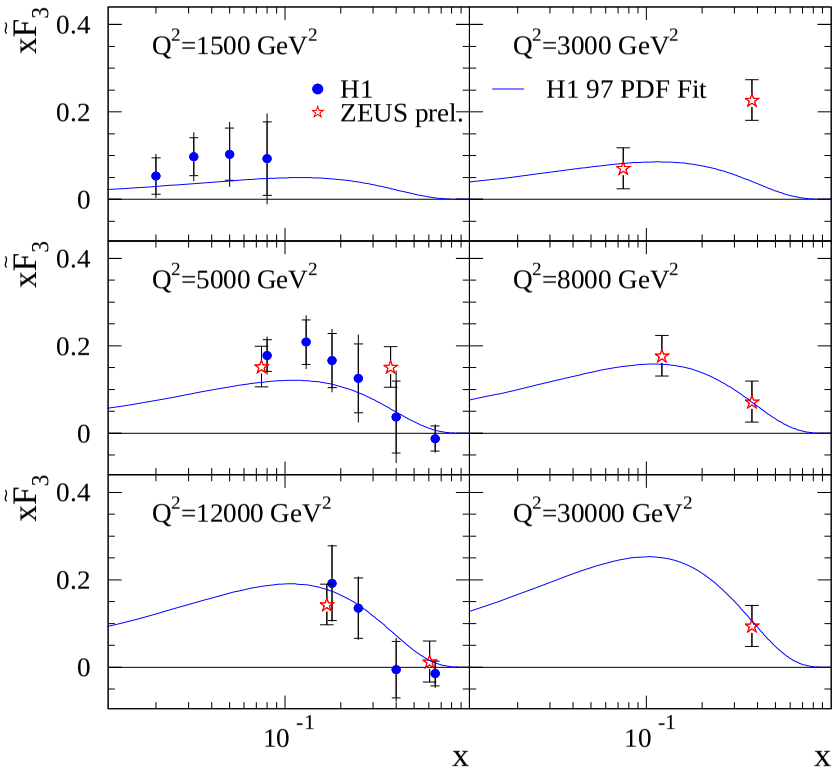


High-Q^2: xF_3^{NC}, $xF_3^{\gamma/Z}$

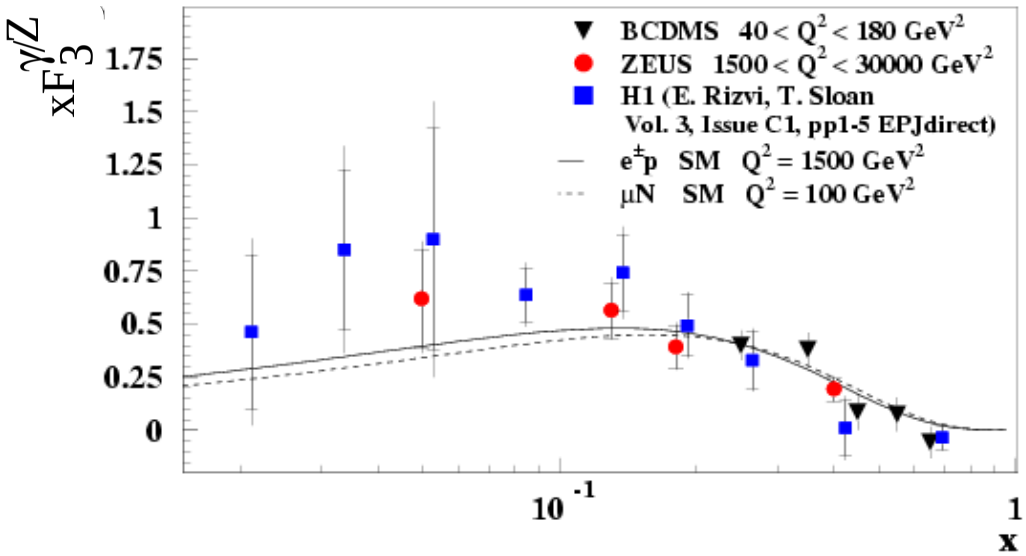
Difference Measurement of e^+ and e^-

=> Measurement of $xF_3^{NC} = -a_e P_Z xF_3^{\gamma/Z} + 2v_e a_e P_Z^2 xF_3^Z$

small



LO (DIS scheme): $xF_3 = \Sigma q - \bar{q} = q_V$



Charged Current Measurement

Reduced Cross Section:

$$\tilde{\sigma}^{\pm} = \frac{4\pi x(Q^2+M_W^2)^2}{G_F^2 M_W^4 Y_+}\frac{d^2\sigma^{CC}(e^{\pm}p)}{dxdQ^2} =$$

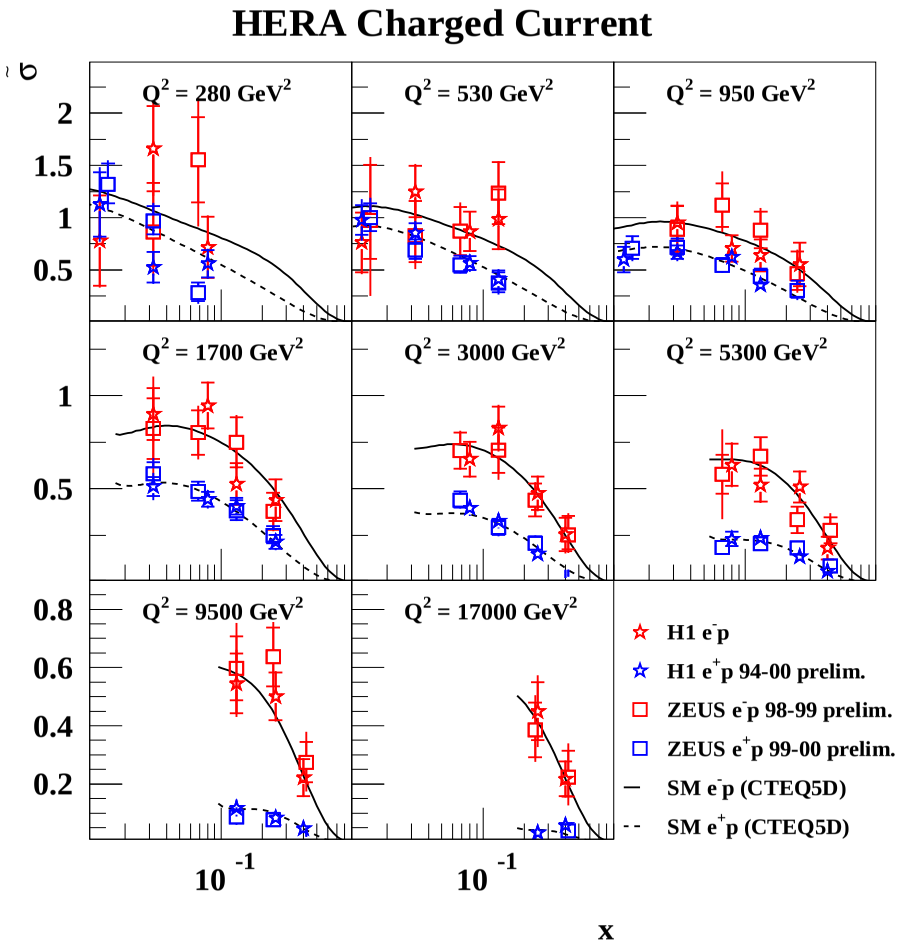
$$F_2^{W^{\pm}} \mp \frac{Y_-}{Y_+} xF_3^{W^{\pm}} - \frac{y^2}{Y_+} F_L^{W^{\pm}}$$

small

LO (DIS scheme):

e.g.: $F_2^{W^+} = u+c + \bar{d} + \bar{s}$

Flavor decomposition possible



Flavor decomposition with CC

Cross Section:

$$\tilde{\sigma}^{\pm} = Y_+ F_2^{W^\pm} \mp Y_- x F_3^{W^\pm} - y^2 F_L^{W^\pm}$$ small

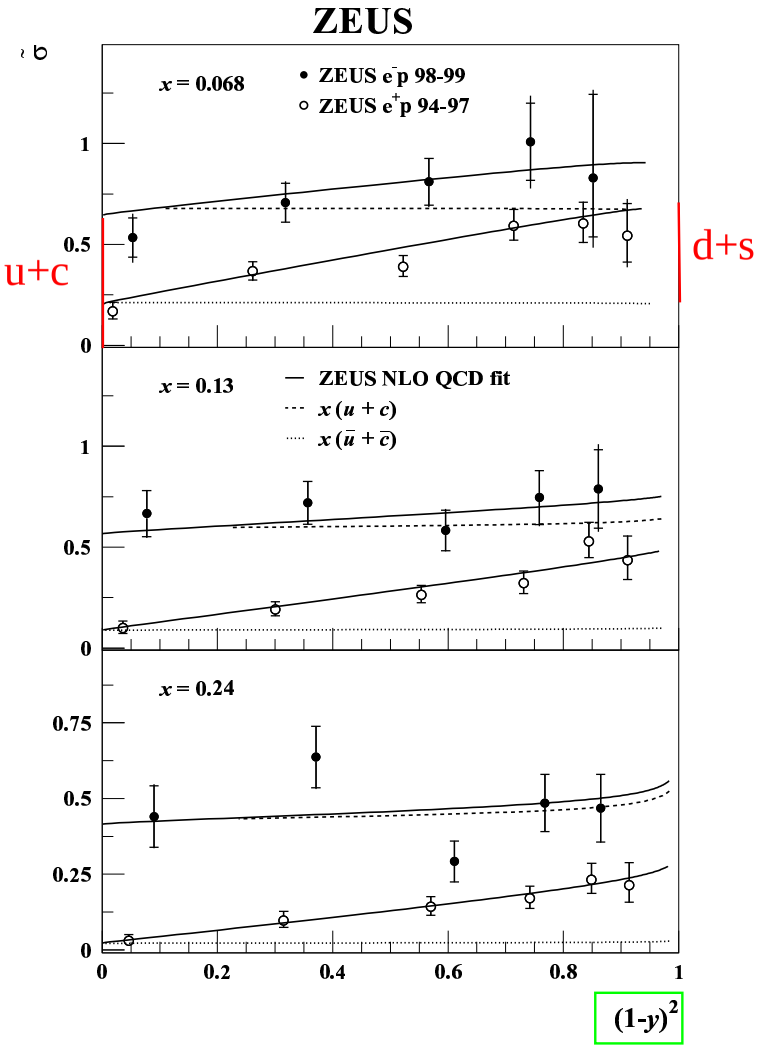
In LO (DIS scheme):

$$\tilde{\sigma}(e^- p \to \nu X) = (1+(1-y)^2)\,(u+c+\bar{d}+\bar{s}) + (1-(1-y)^2)\,(u+c-\bar{d}-\bar{s})$$

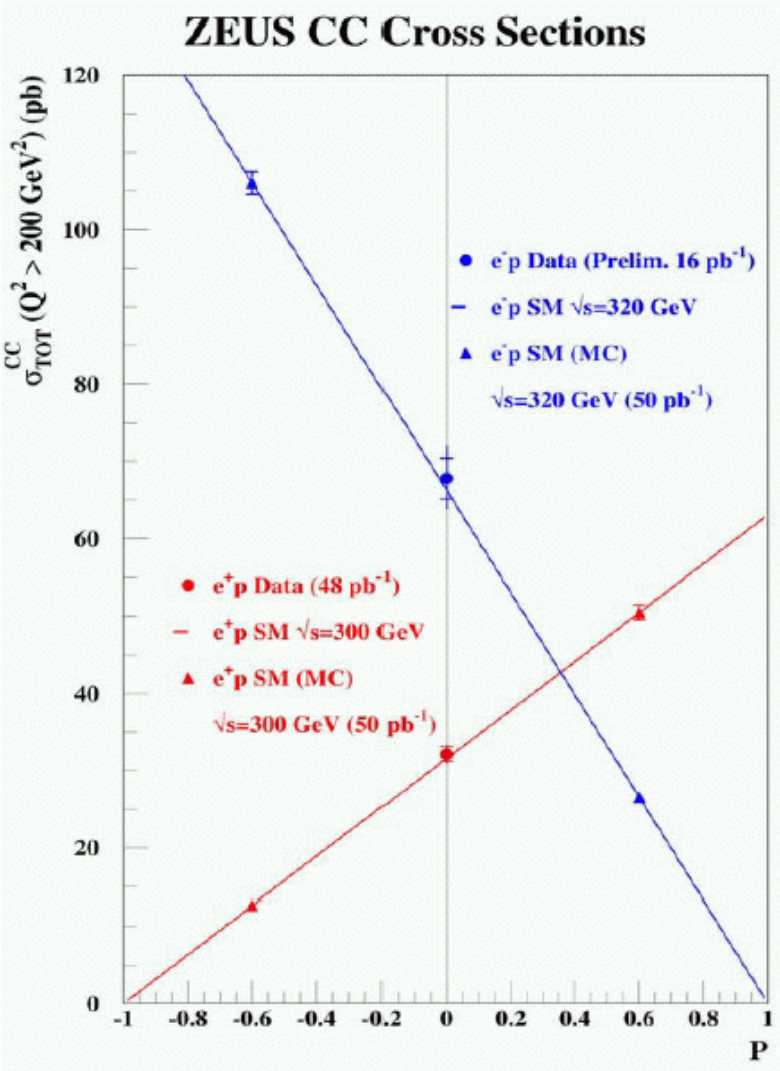
$$= u + c + (1-y)^2(\bar{d}+\bar{s})$$

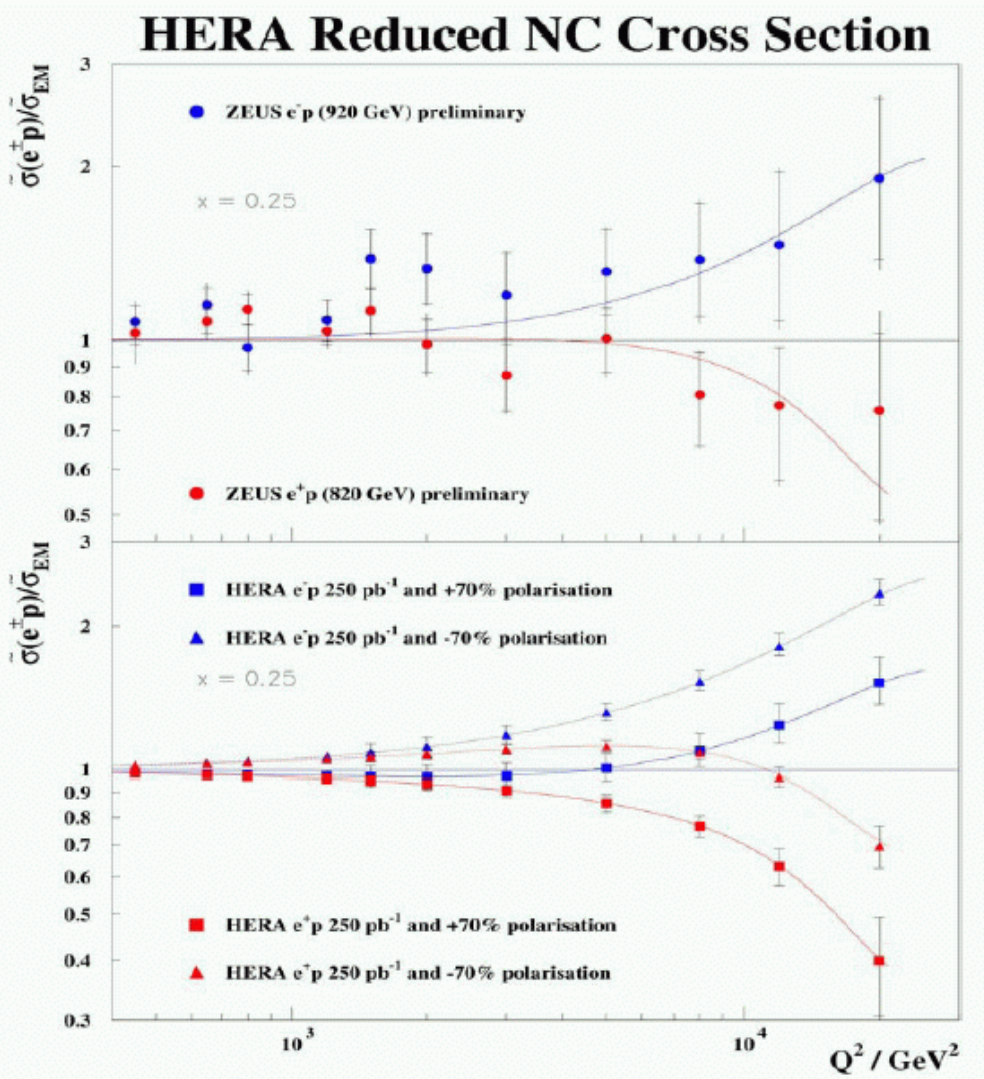
$$\tilde{\sigma}(e^+ p \to \bar{\nu} X) = \bar{u} + \bar{c} + (1-y)^2(d+s)$$

Intercept and slope:
Measurement of individual quark densities



Outlook for HERA II





Summary

- The experimentally observable Structure Functions describe the proton structure dependent on the scattering process.
- At H1 and ZEUS Proton Structure Function measurements have been performed over six orders of magnitude in both x and Q^2 applying γ, Z and $W^{\pm}$ exchange.
- The Structure Functions have been measured with high precision.
- The Structure Functions Measurements of H1 and ZEUS agree well with the SM predictions.
- Outlook: Higher luminosity of HERA II with polarisation for both e^+ and e^-.