ZEUS results on high Q^2 cross-sections and QCD fits

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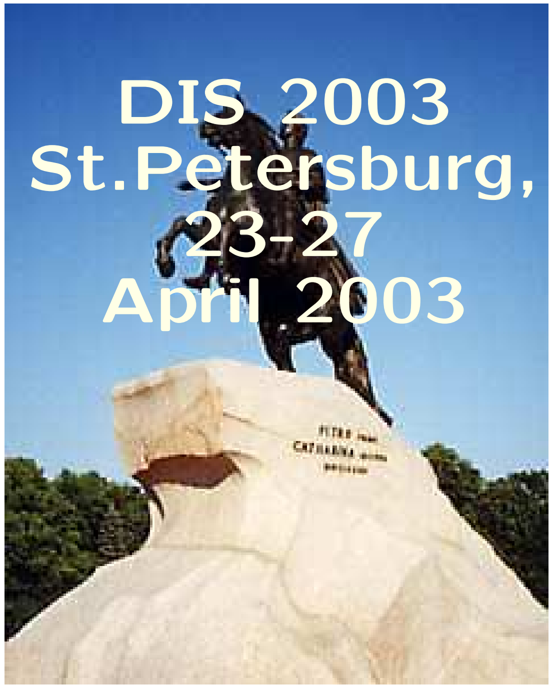
on behalf of the
ZEUS Collaboration



DIS 2003
St.Petersburg,
23-27
April 2003

- QCD NLO fits

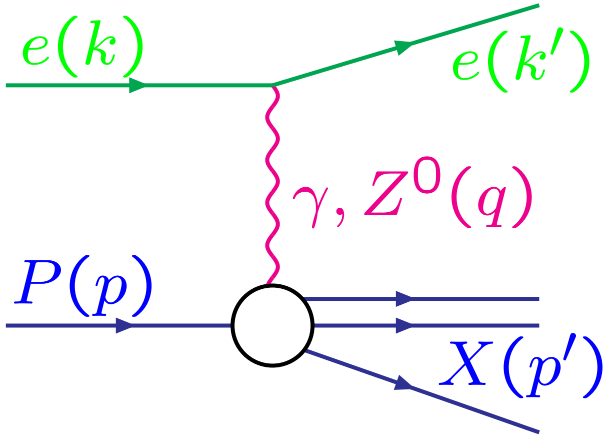
  Phys. Review D67,012007(2003)
- NC e^-p

  Europ.Phys.Journal C;

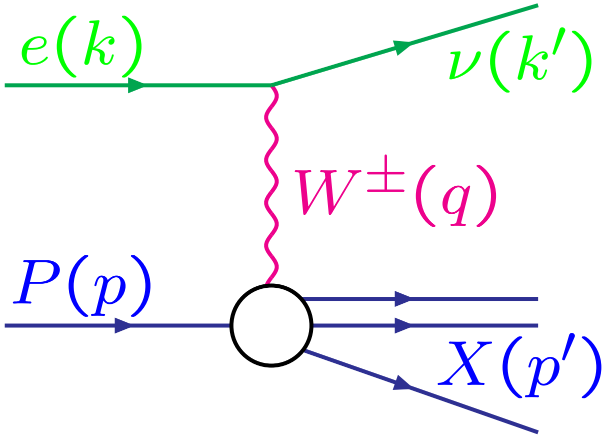
  DOI 10.1140 (2002) 169-187
- CC e^+p

DIS at HERA

Neutral Current (NC)



Charged Current (CC)



negative four-momentum transfer squared	$Q^2 = -q^2 = -(k-k')^2$
fraction of proton momentum	$x = \frac{Q^2}{2p\cdot q}$
inelasticity	$y = \frac{p\cdot q}{p\cdot k}$
squared cms energy	$s = (k+p)^2 = \frac{Q^2}{xy}$

Inclusive cross sections

Neutral Current (NC)

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

$$F_2^{\mathrm{NC}} = x \sum_{q=u\dots b} A_f\,[q+\bar{q}]$$

$$xF_3^{\mathrm{NC}} = x \sum_{q=u\dots b} B_f\,[q-\bar{q}]$$

$$\tilde{\sigma} = \frac{xQ^4}{2\pi\alpha^2 Y_+}\,\frac{d^2\sigma^{\mathrm{NC}}}{dxdQ^2}$$

Charged Current (CC)

$$\frac{d^2\sigma^{e+p}}{dxdQ^2} = \frac{G_F^2}{4\pi x}\left(\frac{M_W^2}{Q^2+M_W^2}\right)^2 \times \left[Y_+ F_2^{\mathrm{CC}} - Y_- xF_3^{\mathrm{CC}} - y^2 F_L^{\mathrm{CC}}\right]$$

$$F_2^{\mathrm{CC}} = x\,[d+s+\bar{u}+\bar{c}]$$

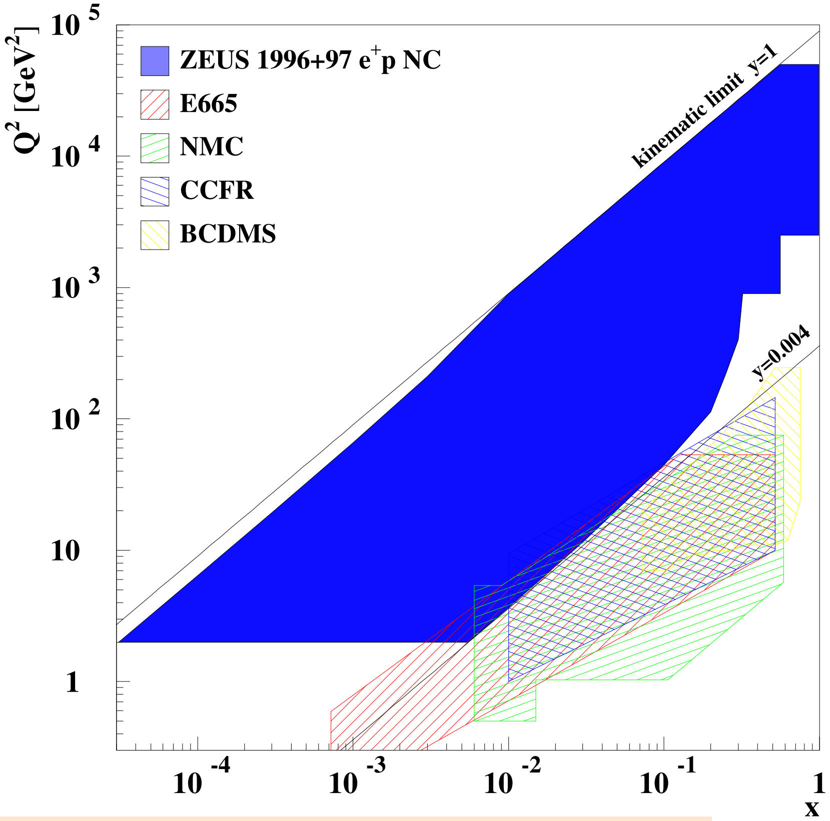
$$xF_3^{\mathrm{CC}} = x\,[d+s-(\bar{u}+\bar{c})]$$

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

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

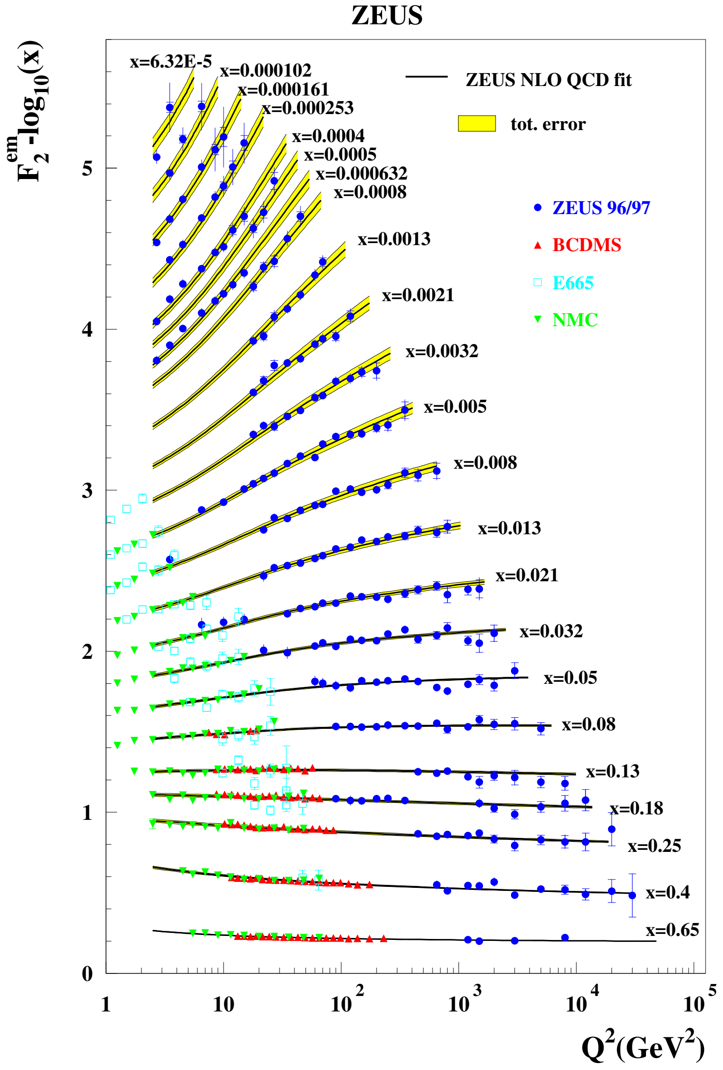
ZEUS-Standard QCD NLO-fit

Data-sets:	ZEUS NC 96-97, E665, NMC, CCFR, BCDMS
Cuts:	$Q^2 > 2.5\,\mathrm{GeV}^2$ $W^2 > 20\,\mathrm{GeV}^2$
Kinematic range:	$6.3 \cdot 10^{-5} < x < 0.65$ $2.5 < Q^2 < 30\,000\,\mathrm{GeV}^2$
DGLAP evolution:	QCDNUM
Factorisation scheme:	$\overline{\mathrm{MS}}$-scheme
Heavy flavour scheme:	TR-VFN
Parametrisation:	$p_1 x^{p_2} (1-x)^{p_3} (1+p_5 x)$
Constraints:	sum-rules, etc.



PDF	p_1	p_2	p_3	p_5
xu_v	(1.69)	0.5	$4.00 \pm 0.01 \pm 0.08$	$5.04 \pm 0.09 \pm 0.64$
xd_v	(0.96)	0.5	$5.33 \pm 0.09 \pm 0.48$	$6.2 \pm 0.4 \pm 2.3$
xS	$0.603 \pm 0.007 \pm 0.048$	$-0.235 \pm 0.002 \pm 0.012$	$8.9 \pm 0.2 \pm 1.2$	$6.8 \pm 0.4 \pm 2.0$
xg	(1.77)	$-0.20 \pm 0.01 \pm 0.04$	$6.2 \pm 0.2 \pm 1.2$	0
$x\Delta$	$0.27 \pm 0.01 \pm 0.06$	0.5	(10.9)	0

ZEUS-S data comparison



Impacts

Fixed-target:

- quark distributions at high-x
- valence quark distributions
- flavor composition of sea

ZEUS:

- quark distributions at low-x
- gluon distribution

ZEUS-α_s:

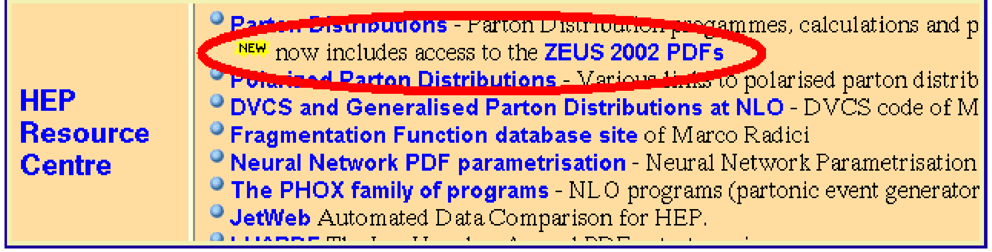
$\alpha_s(M_Z) = 0.1166 \pm 0.0053$

ZEUS-S PDFs

ZEUS-fit compatible with
MRST2001 and CTEQ6M

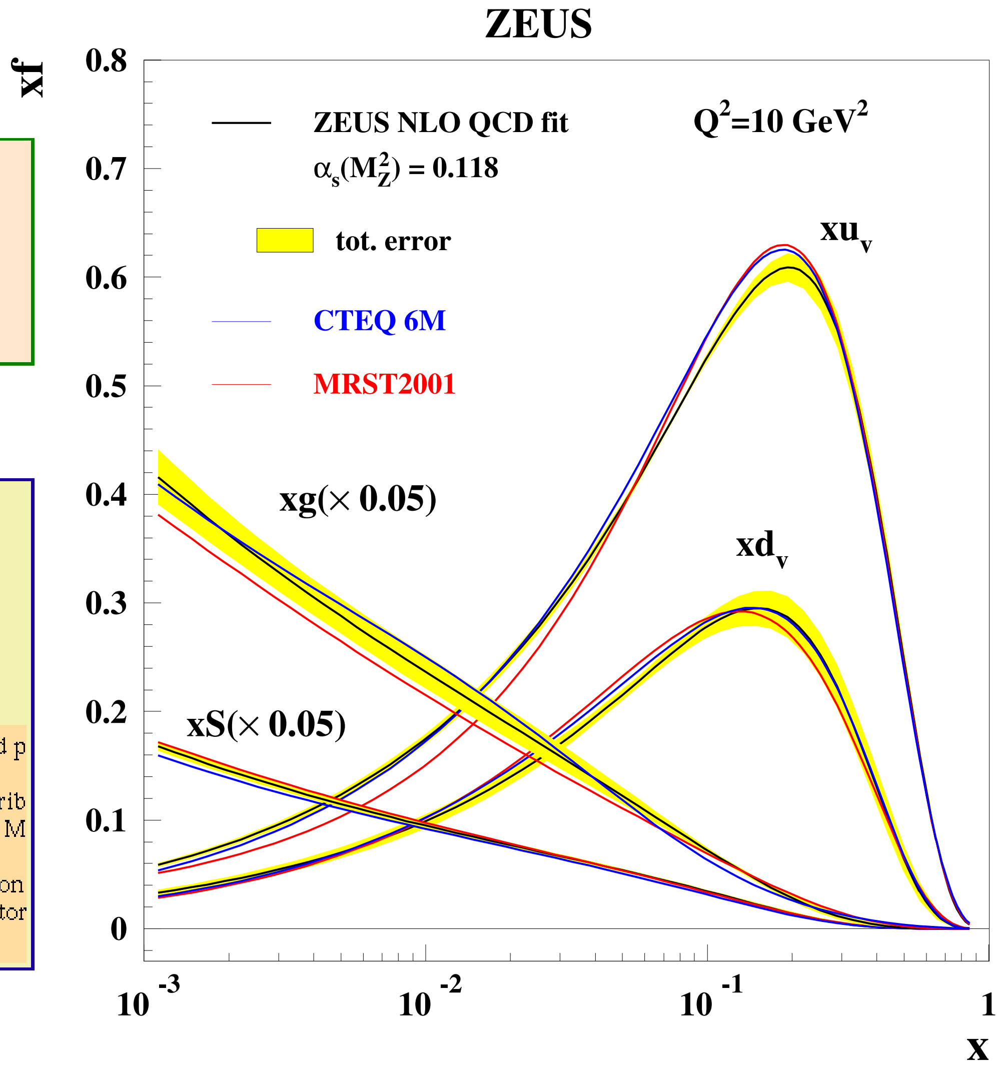
Now available at HEPDATA:

`http:\\durpdg.dur.ac.uk\hepdata`
`\zeus2002.html`

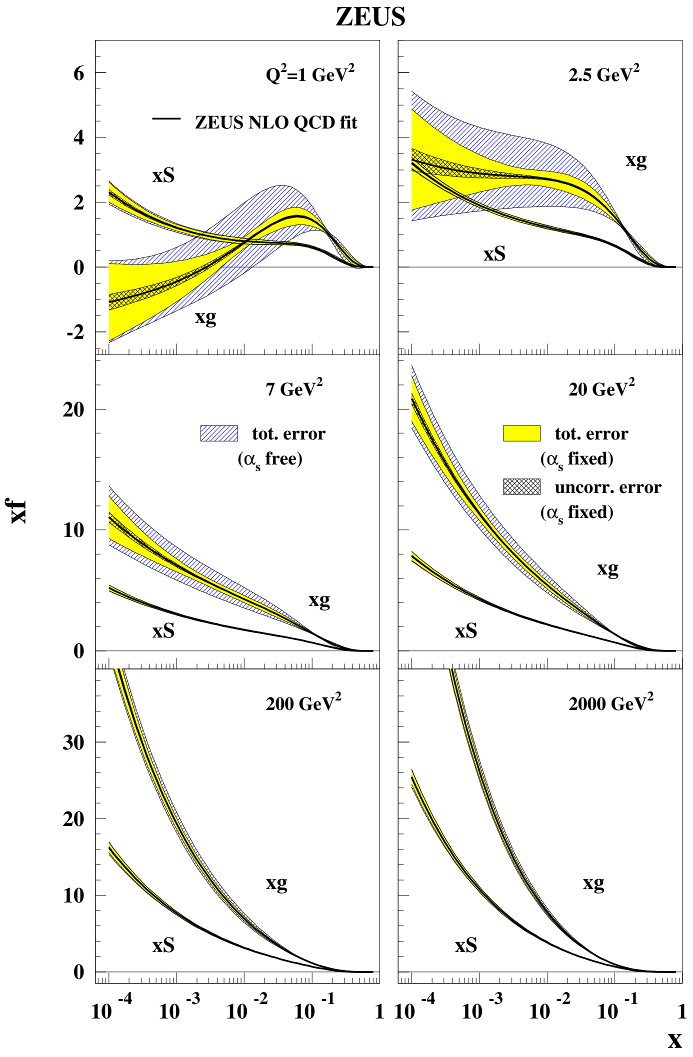


HEP Resource Centre

- **Parton Distributions** - Parton Distribution programmes, calculations and p
  NEW now includes access to the **ZEUS 2002 PDFs**
- **Polarized Parton Distributions** - Various links to polarised parton distrib
- **DVCS and Generalised Parton Distributions at NLO** - DVCS code of M
- **Fragmentation Function database site** of Marco Radici
- **Neural Network PDF parametrisation** - Neural Network Parametrisation
- **The PHOX family of programs** - NLO programs (partonic event generator
- **JetWeb** Automated Data Comparison for HEP.



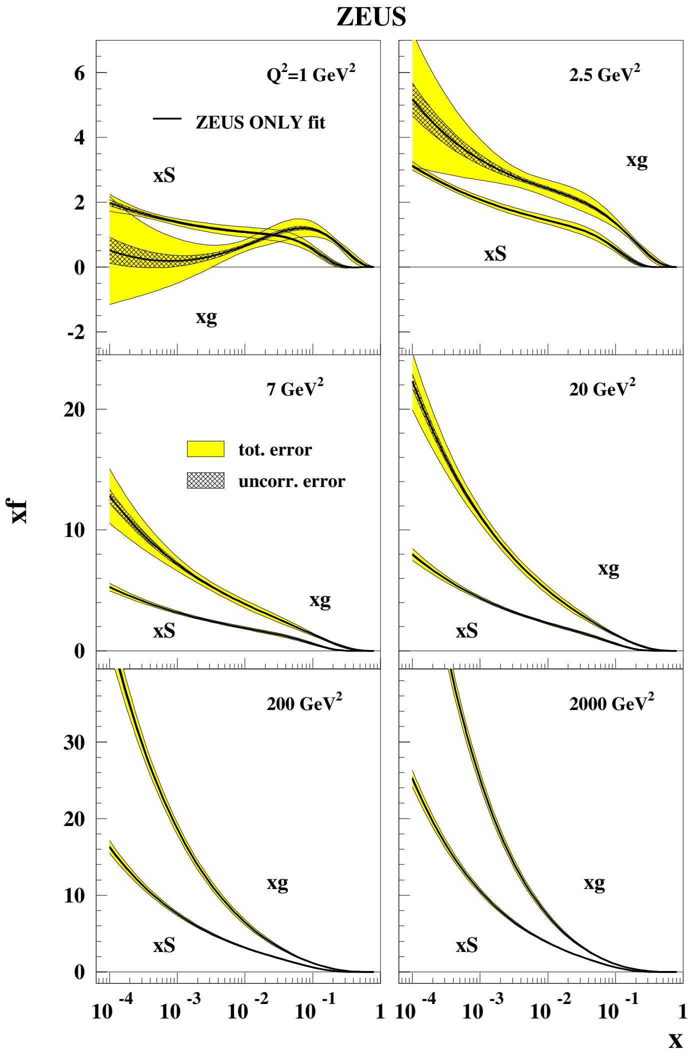
ZEUS-Only xS and xg



Uncertainty dominated by correlated systematics

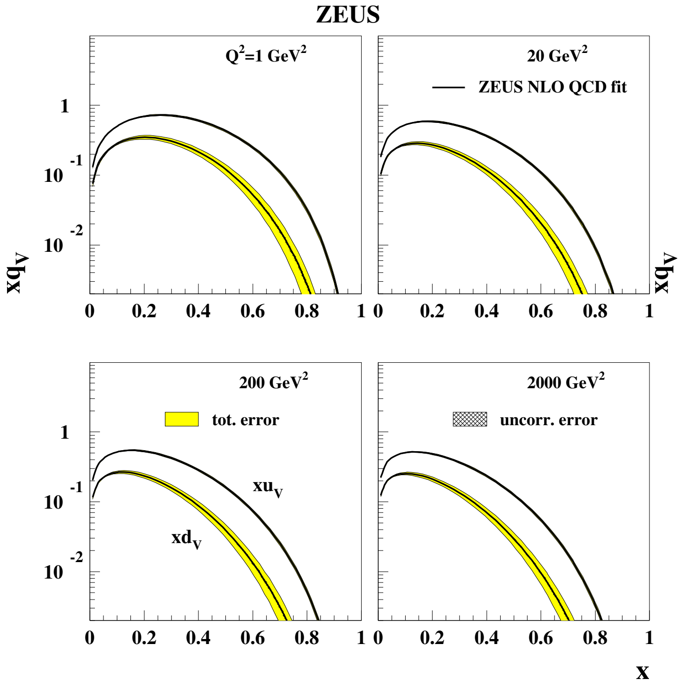
At low-Q^2 the rise of F_2 towards lower x is not dominated by gluons

All ZEUS inclusive cross sections only
NC & CC,
e^+p & e^-p
until 1999

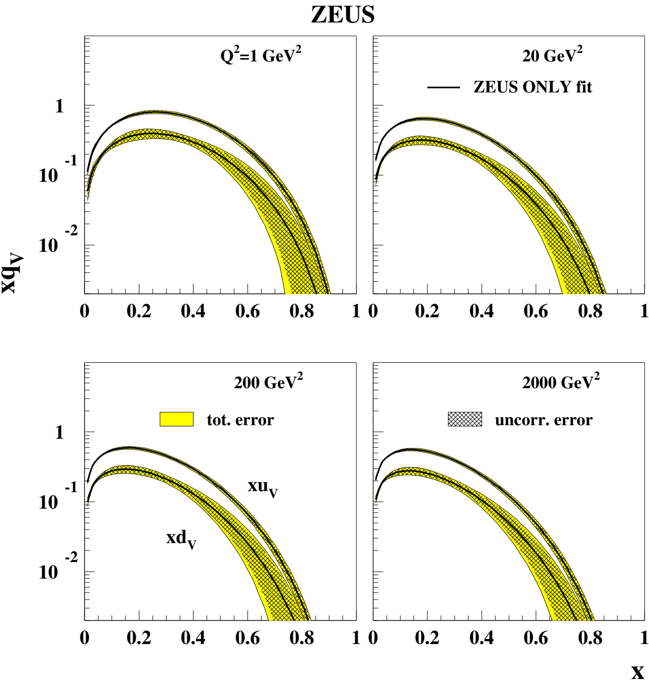


ZEUS-Only valance distributions

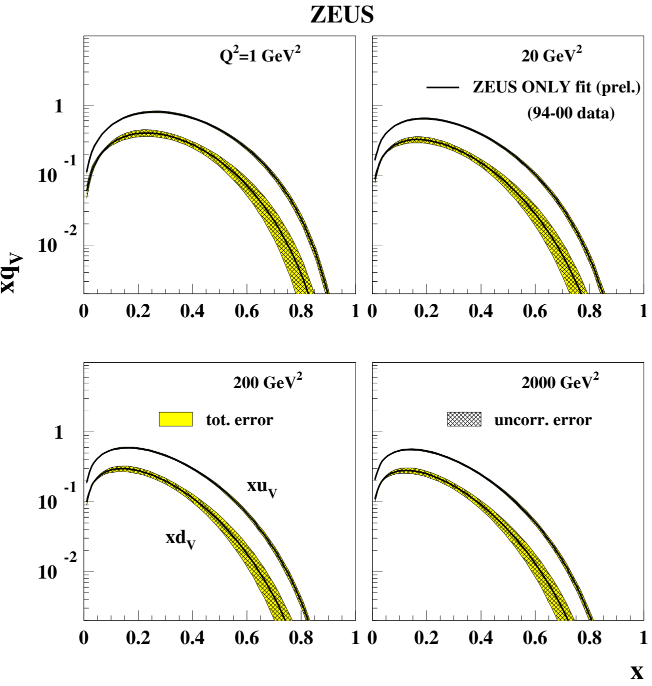
ZEUS-S



ZEUS-Only



ZEUS-Only prel.



Including latest ZEUS data sets
uncertainties become compatible with ZEUS-S

With **all** HERA-I inclusive measurements
NLO QCD-fit (almost) independent of fixed target data.

High-Q^2 NC cross sections from e^-p DIS

Electromagnetic interactions
are invariant under P and C

Weak interactions
do not preserve P or C

for $Q^2 \ll M_Z^2$
γ-only exchange
$\Rightarrow \sigma^{\mathrm{NC}}(e^-p) \approx \sigma^{\mathrm{NC}}(e^+p)$

for $Q^2 \gtrsim M_Z^2$
$|\gamma + Z|$ exchange
$\Rightarrow \sigma^{\mathrm{NC}}(e^-p) > \sigma^{\mathrm{NC}}(e^+p)$

Parity conserving terms of σ^{NC}
are collected in F_2

Parity violating terms of σ^{NC}
are collected in xF_3

Direct test of the EW sector of the SM

NC analysis details

Data set:

- $e^- p$ at $\sqrt{s} = 318\,\text{GeV}$ 1998/99
- $\mathcal{L} = 15.9\,\text{pb}^{-1}$

Kinematic range:

- $185\,\text{GeV}^2 < Q^2 < 50000\,\text{GeV}^2$
- $0.0037 < x < 0.75$

Kinematic reconstruction:

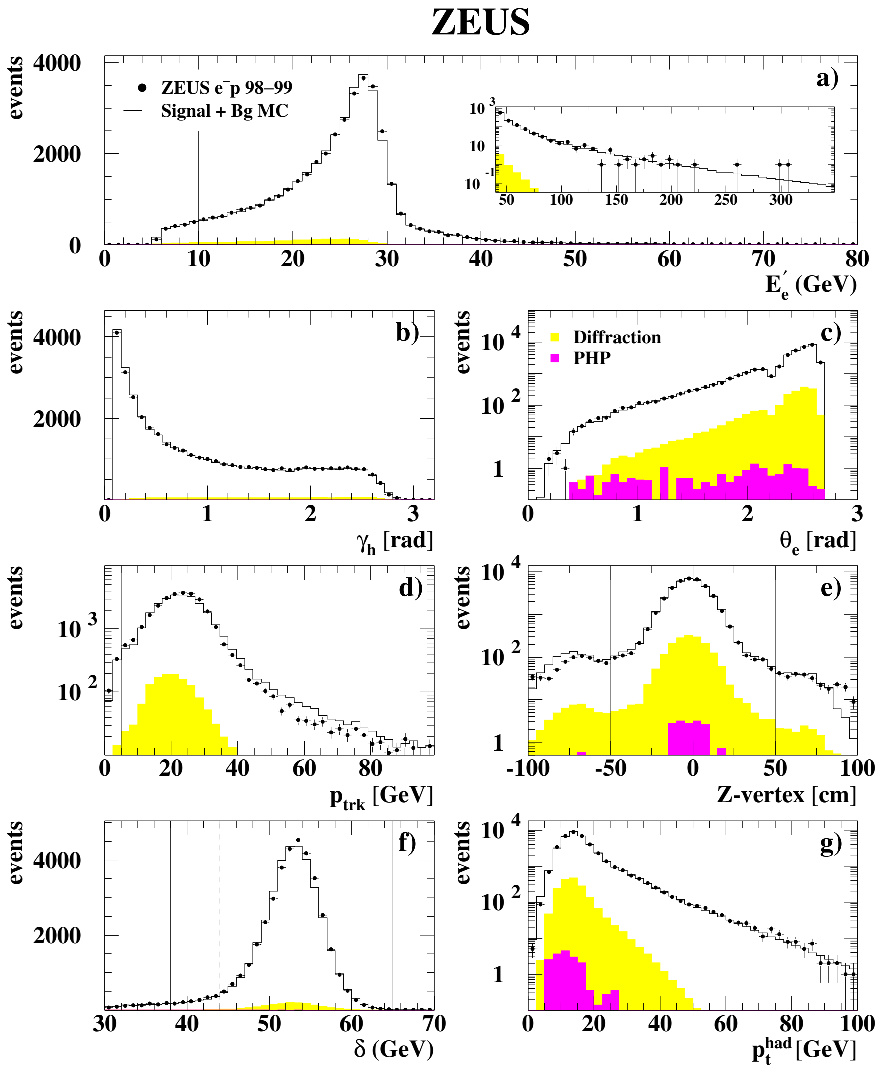
- Double angle method (γ_h, θ_e)

Electron identification:

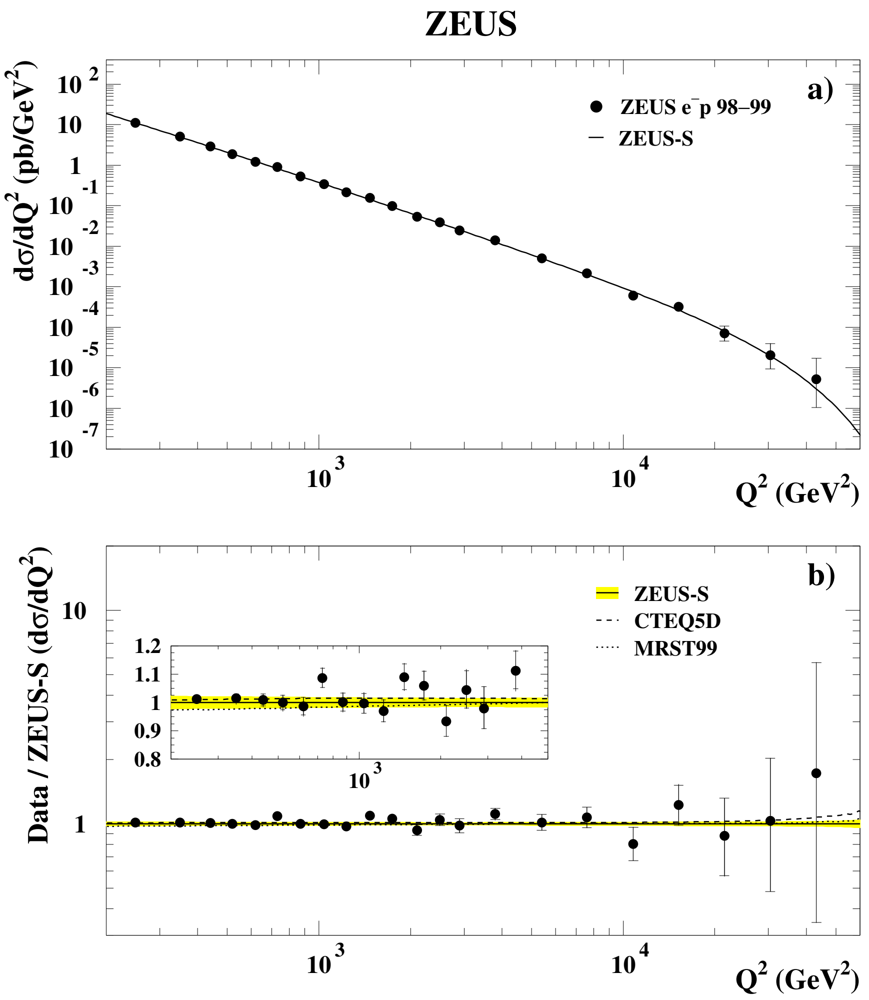
- Electron energy $E_e > 10\,\text{GeV}$
- Isolation
- Track matching
- Transverse momentum

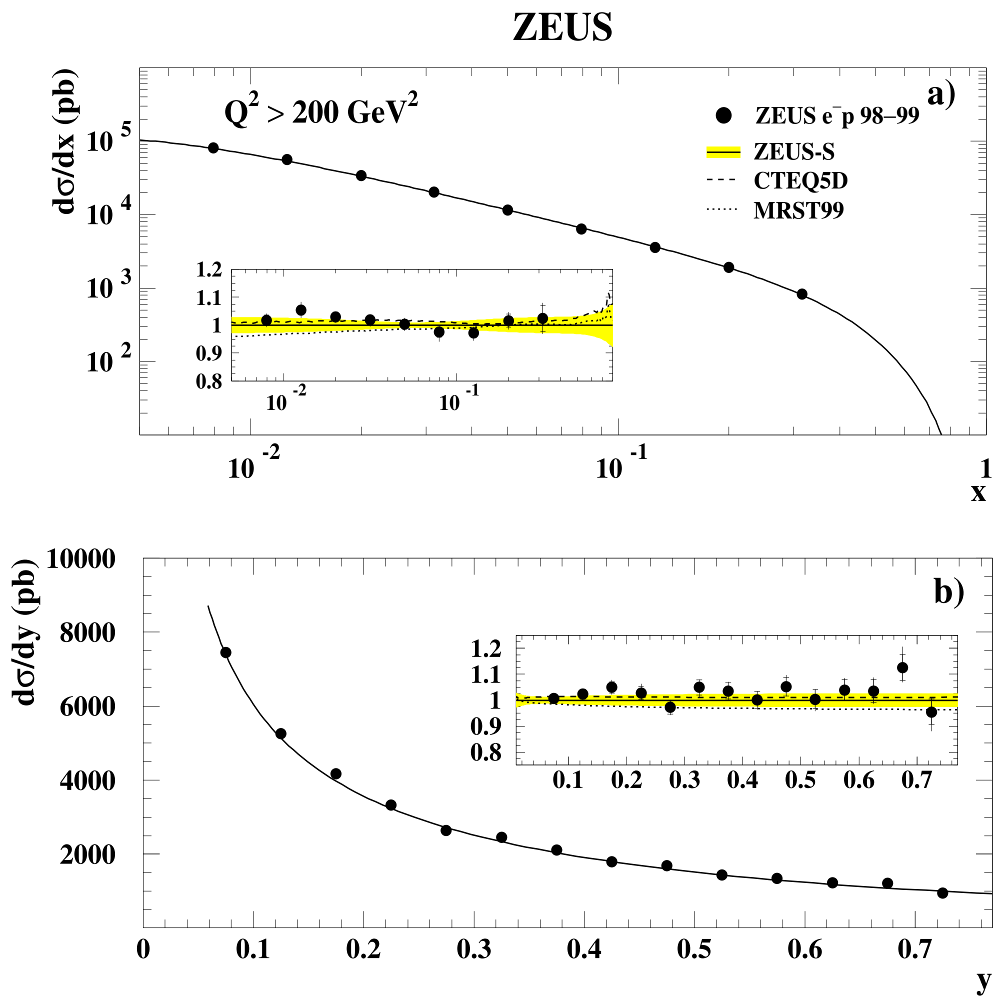
Background supression:

- Tracking vertex
- Transv. momentum conservation
- Long. $E - p_z$ conservation
- Exclude high y $y_E < 0.95$



NC: Single differential cross sections



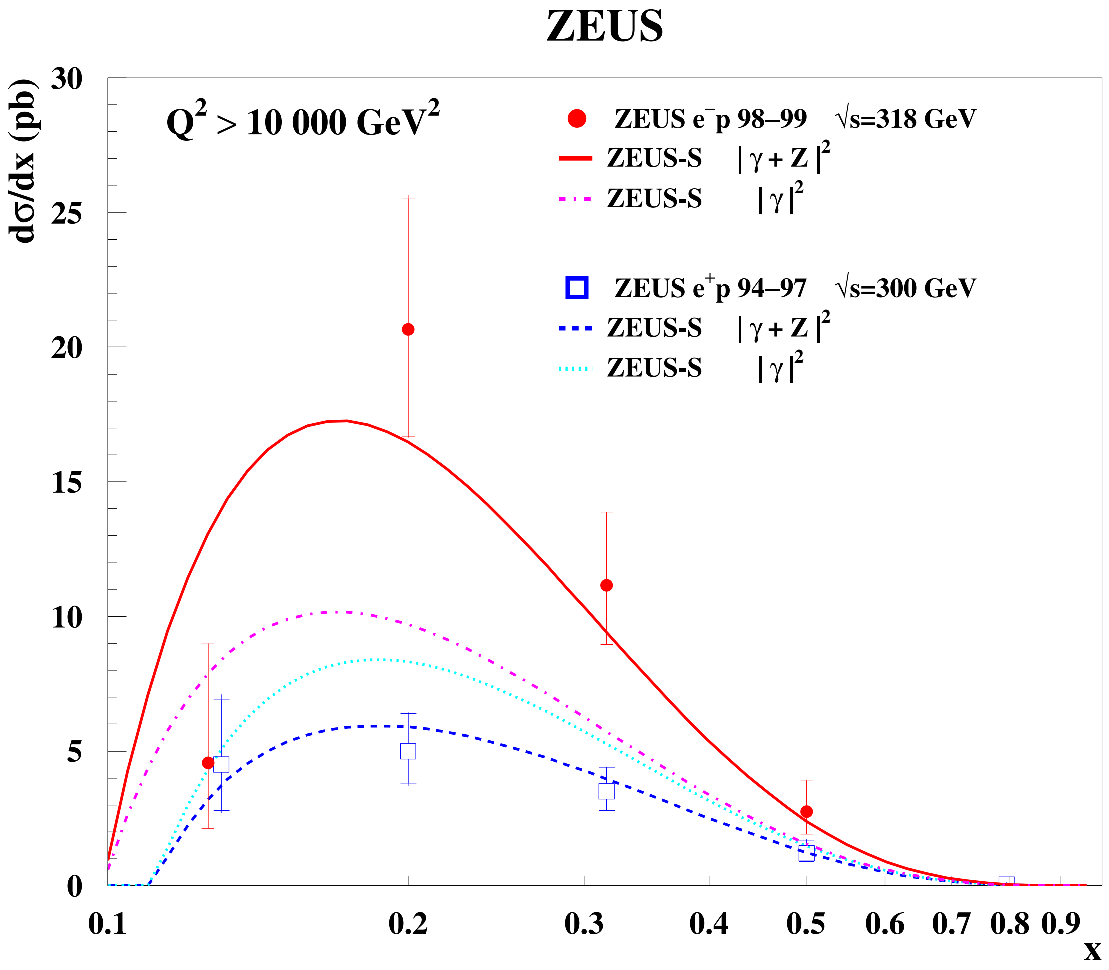


Excellent agreement with SM using ZEUS-S PDFs

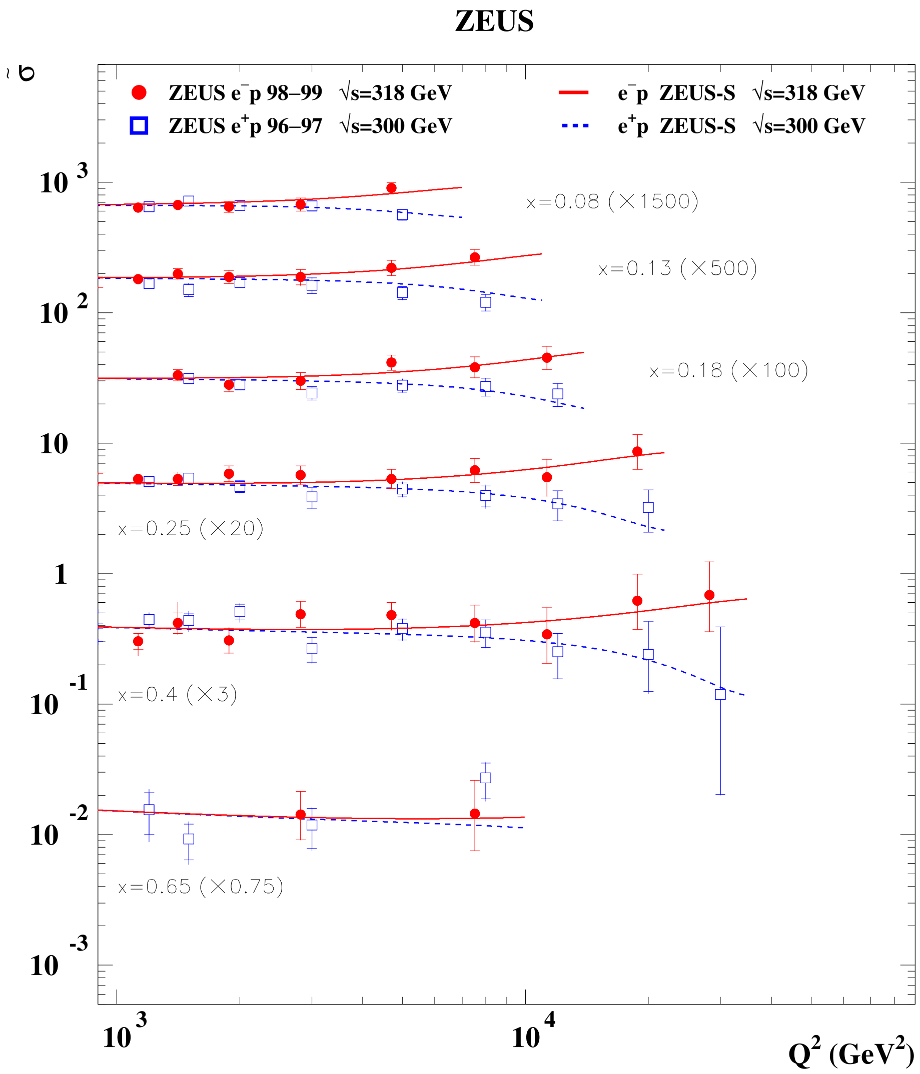
NC: $d\sigma/dx$ at high Q^2

At high Q^2:

- obviously need $|\gamma + Z|^2$ exchange
- σ^{e^+p} reduced by $xF3$
- σ^{e^-p} enhanced by $xF3$



NC: $\tilde{\sigma}$ at fixed x



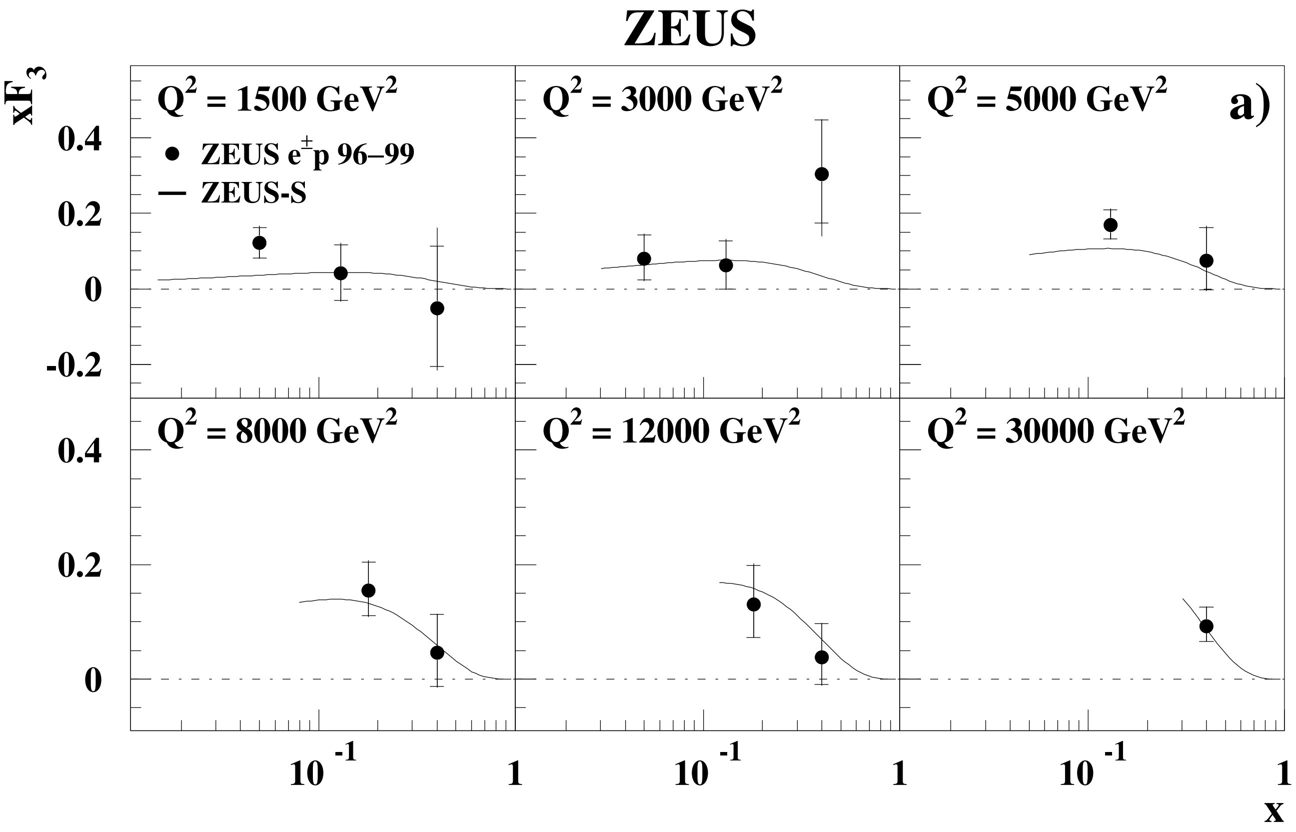
$\tilde{\sigma}$ at fixed x:

- at low Q^2 $\tilde{\sigma}^{e^-p}$ and $\tilde{\sigma}^{e^+p}$ agree
- with rising Q^2 they separate
- directly read off xF3

NC: xF_3

Parity violating xF_3:

- ZEUS measures none-zero xF_3
- Data well described by SM
- Precision limited by low statistics of e^-p sample

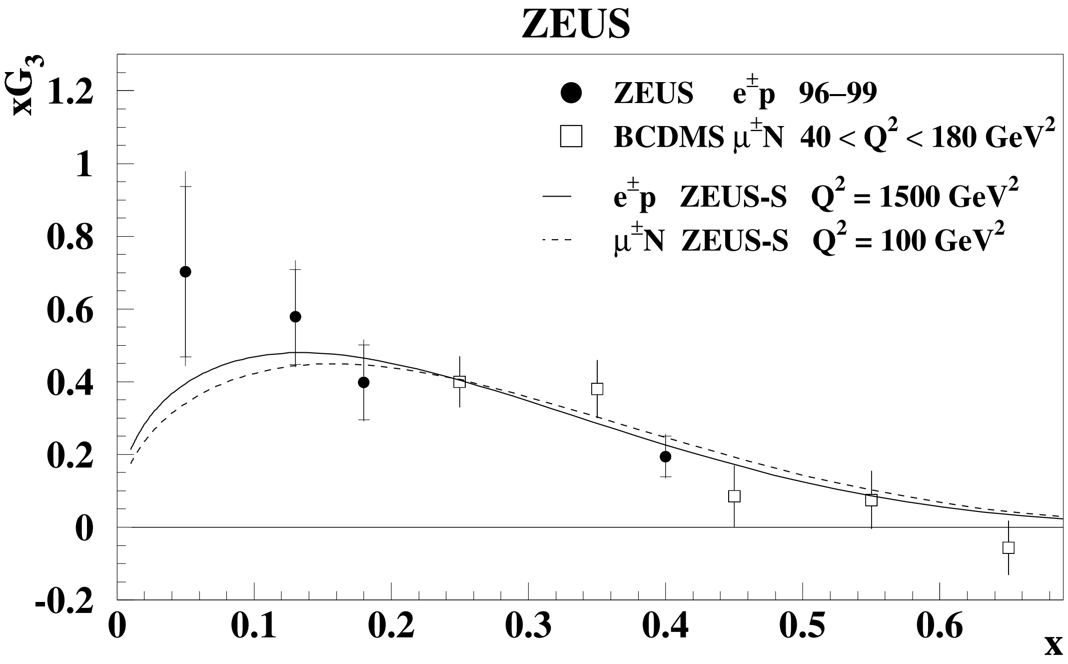


NC: xG_3

composition of xF_3:

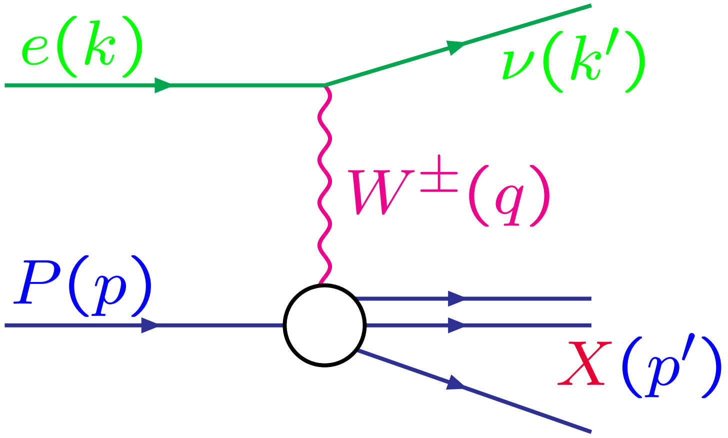
$$xF_3 = -a_e \chi_Z xG_3 + 2 a_e v_e \chi_Z^2 xH_3$$

- xG_3 stems from $\gamma - Z$ interference
- xH_3 arises from pure Z-exchange
- $\chi_Z = \kappa_W \cdot Q^2/(M_Z^2 + Q^2)$
- $2 a_e v_e \chi_Z^2 xH_3$ negligible
- straight forward extract xG_3
- compare to low Q^2 fixed-target BCDMS



ZEUS measurement are in agreement with BCDMS $\mu^{\pm}N$ results though at Q^2 an order of magnitude higher.

CC-process



reconstruction of the kinematics
from angle γ_h and energy E_h
of the hadronic final state X
(Jacquet-Blondel)

$$y_{\text{JB}} = \frac{E_h}{2E_e}(1-\cos\gamma_h)$$

$$Q^2_{\text{JB}} = \frac{{E_h}^2 \sin^2\gamma_h}{1-y_{\text{JB}}}$$

$$x_{\text{JB}} = \frac{Q^2_{\text{JB}}}{s\,y_{\text{JB}}}$$

For e^+p, the W couples only to negatively charged quarks $(d, s, \bar{u}, \bar{c})$
⇒ flavor-specific sensitivity to PDFs

CC: Data set

Data

1999/2000
Positrons @ 27 GeV
Protons @ 920 GeV
$\Rightarrow \sqrt{s} = 318\,\mathrm{GeV}$
$\mathcal{L} = 61\,\mathrm{pb}^{-1}$

Signal-Monte-Carlo

Standard-generators:
DjangoH, Ariadne

PDFs: CTEQ5D

Background-Monte-Carlo

Photoproduction
(direct + resolved)

NC

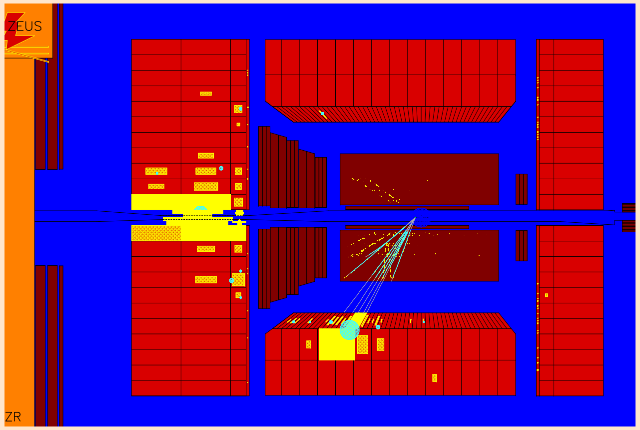
W-production

Di-lepton

CC: Event-selection

Kinematic region:	- $Q^2 > 200GeV^2$ - $y < 0.9$
CC-signature:	- missing p_t - no scattered electron

Large γ_h ($\gamma_h > 0.4\,\text{rad}$)

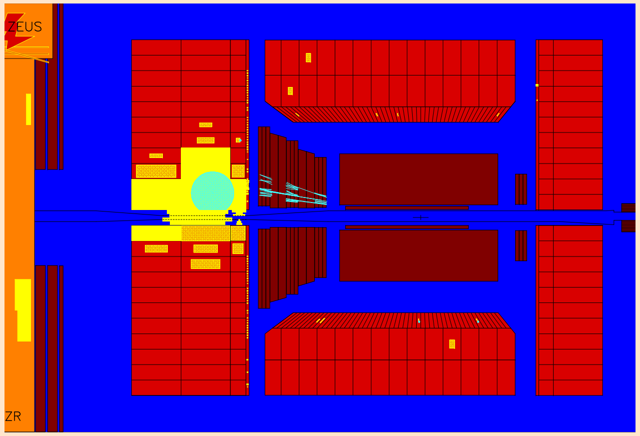


Tracking acceptance (CTD)

Cuts on tracking

Cuts on calorimetry

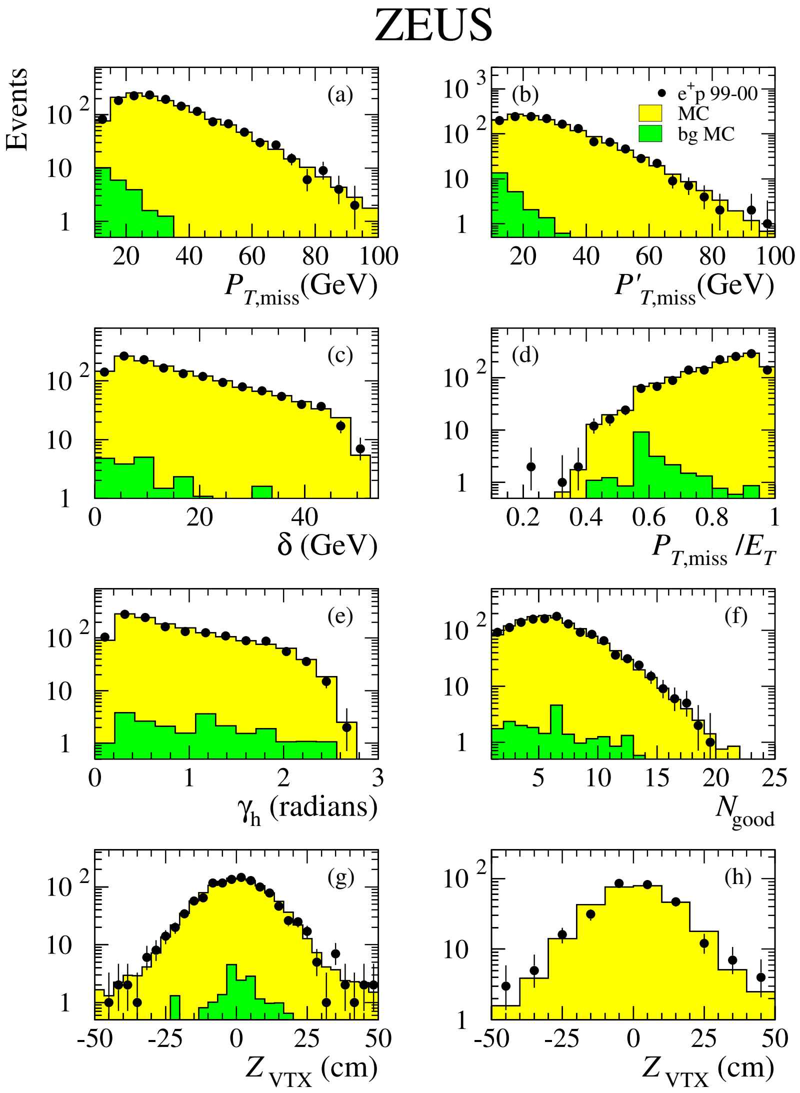
Small γ_h ($\gamma_h < 0.4\,\text{rad}$)



No help from tracking

Tighten cuts on calorimetry

CC: Comparison Data – MC

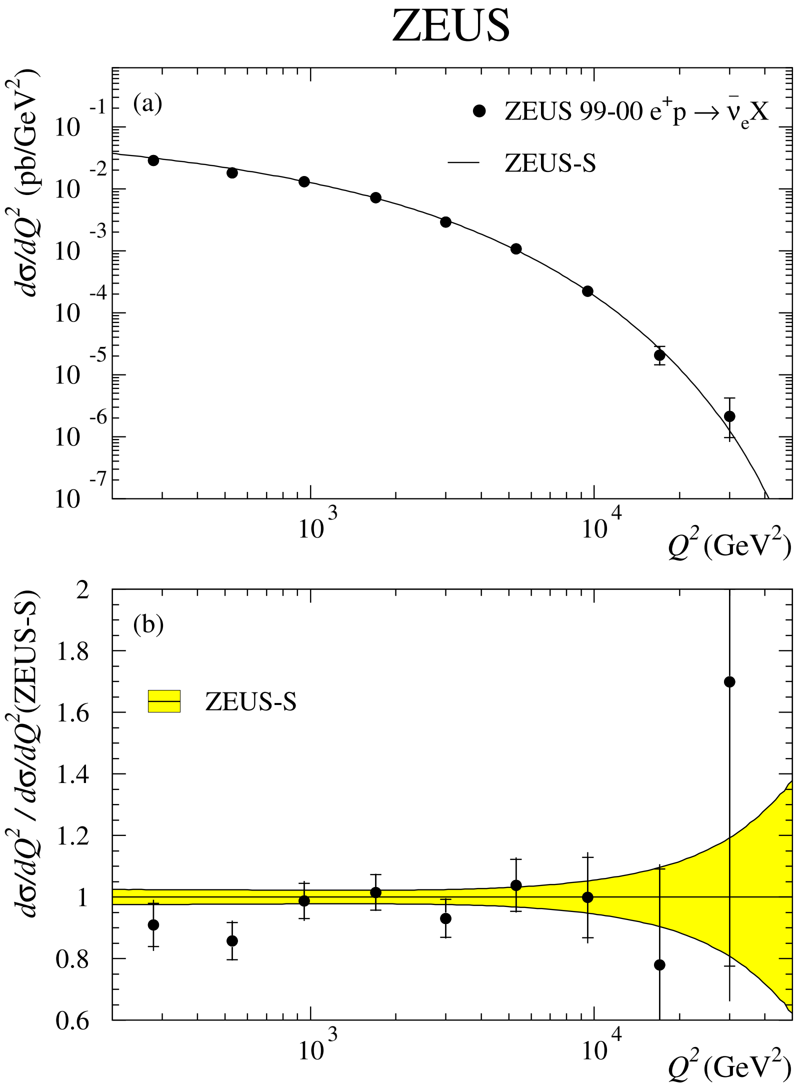


Good decription of data by signal+background MC

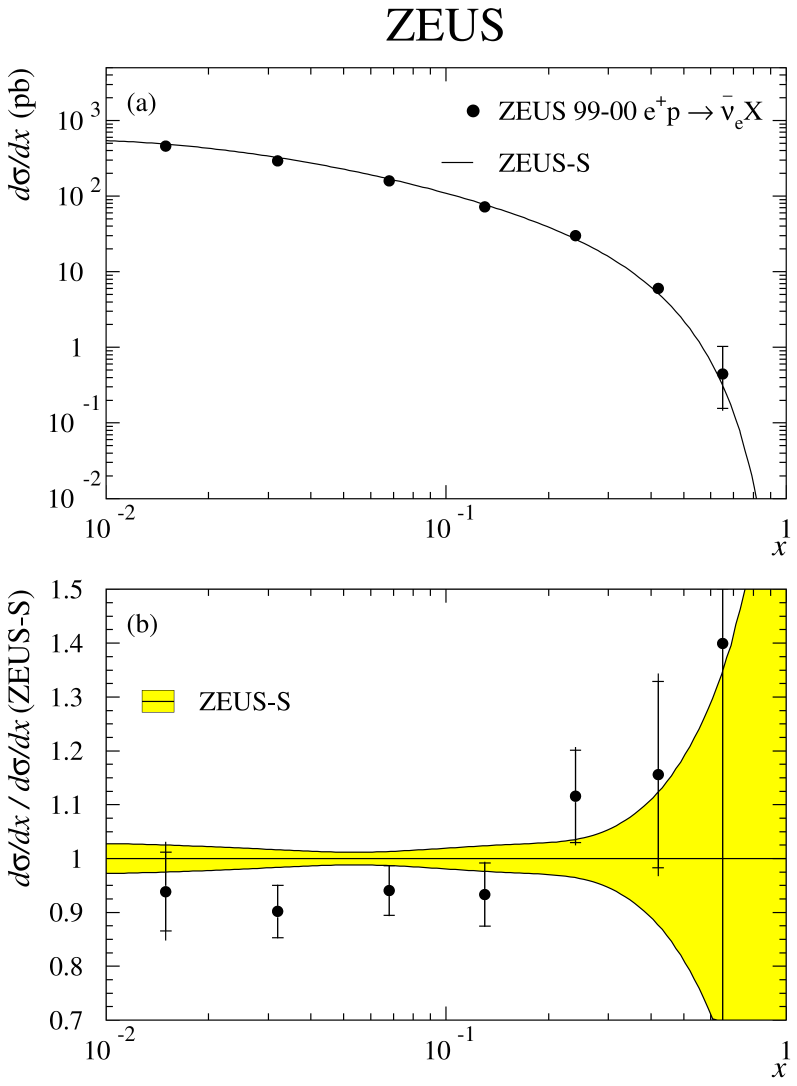
CC: cross section $d\sigma/dQ^2$

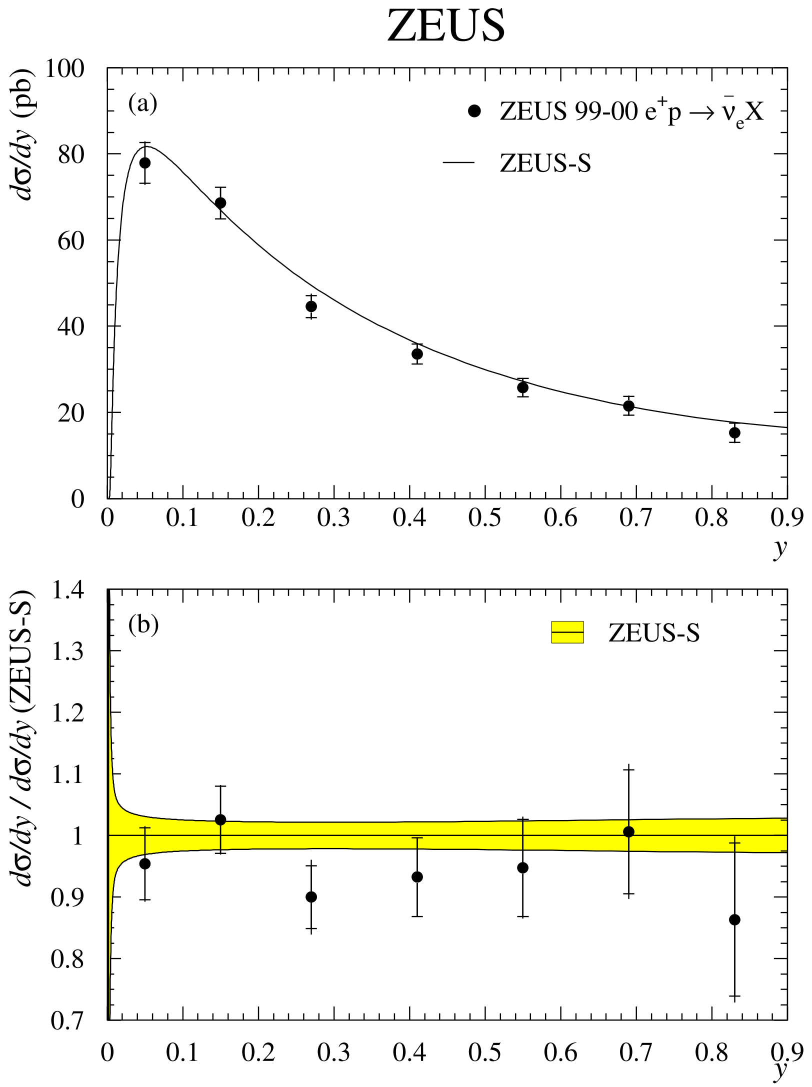
- Bin-by-bin Unfolding
- Correction for radiative effects (HERACLES)

- Well described by SM with ZEUS-S



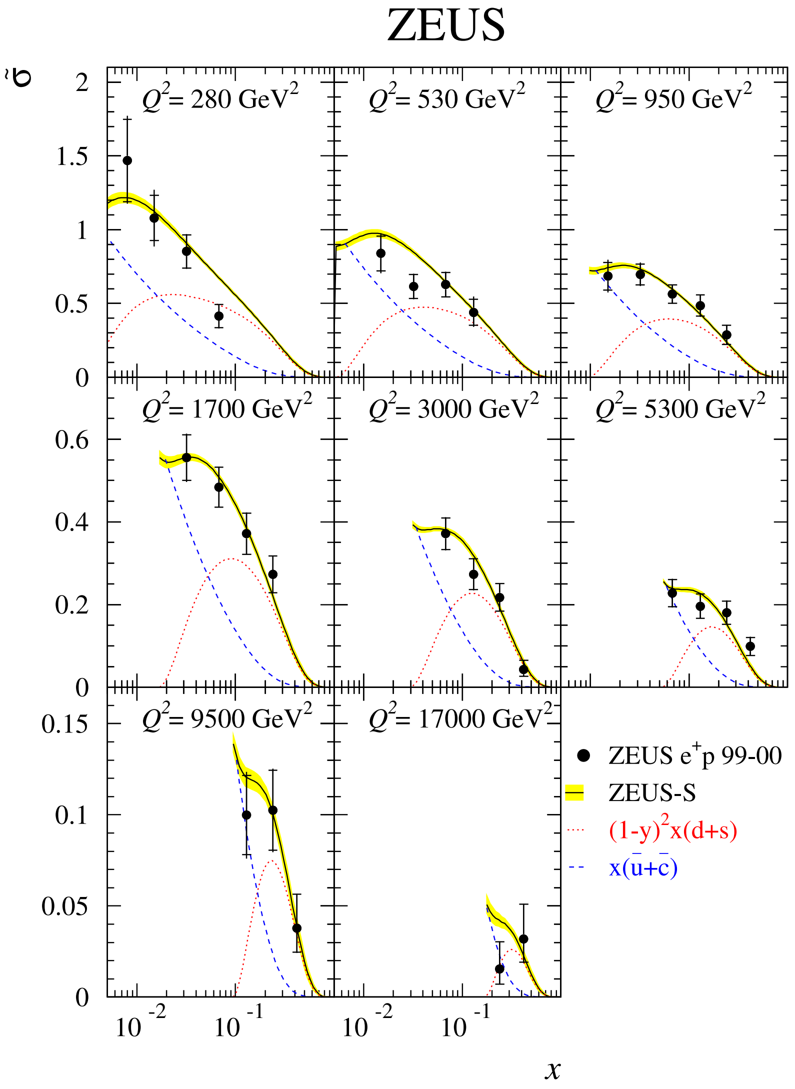
CC: cross sections $d\sigma/dx$ and $d\sigma/dy$





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

- Well decribed by ZEUS-S
- high-x: $d + s$ dominant
- low-x: $\bar{u} + \bar{c}$ dominant



CC e^+p & e^-p: helicity-structure of $\tilde{\sigma}$

e^-q	e^+q
$\Rightarrow$ L.H.+L.H.	R.H.+L.H.
$\Rightarrow$ in CMS $\sum\limits_{e^-,q} S_i = 0$	$= 1$
$\Rightarrow$ isotropic in θ_{CMS}	peaked forward

Down-type (anti-)quarks contribution suppressed by helicity:

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

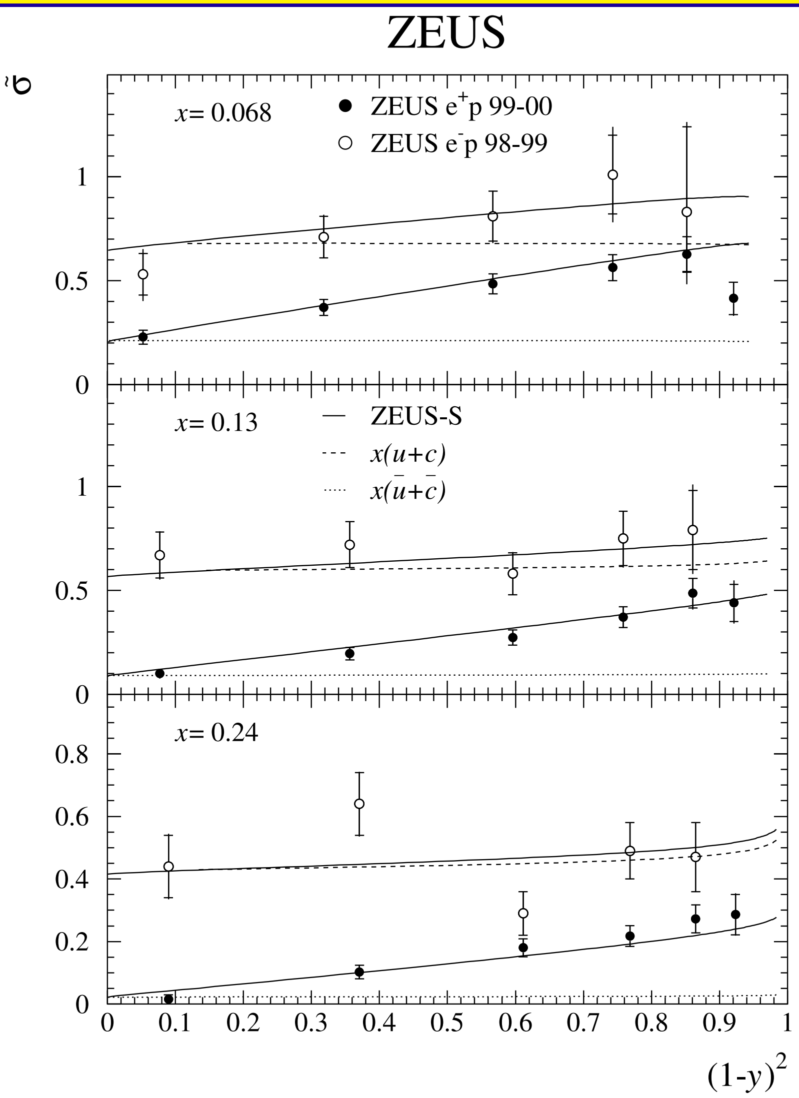
$$\tilde{\sigma}^{e^+p} = x\left[\bar{u}+\bar{c}+(1-y)^2(d+s)\right]$$

Helicity-structure of EW confirmed

Assuming $q_s = \bar{q}_s \Rightarrow$

$$\tilde{\sigma}^{e^-p} - \tilde{\sigma}^{e^+p} = xu_v - (1-y)^2 xd_v$$

$\Rightarrow$ access to valence PDFs

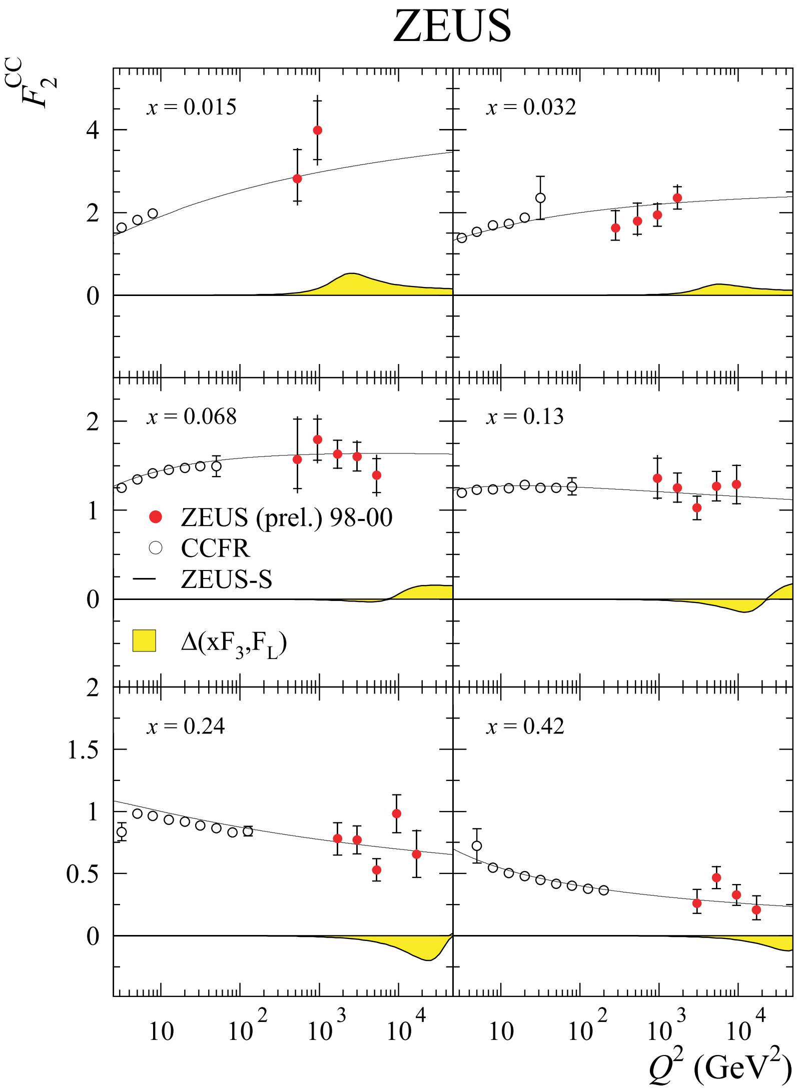


CC e^+p & e^-p: extraction of F_2^{CC}

Extraction from sum:

$$F_2^{CC} = \frac{2}{Y_+}\left(\frac{d^2\tilde{\sigma}^{e^+p}}{dx\,dQ^2} + \frac{d^2\tilde{\sigma}^{e^-p}}{dx\,dQ^2}\right) + \Delta(xF_3, F_L)$$

- Well described by SM with ZEUS-S
- New kinematic area
  (Q^2 two orders of magnitude higher than neutrino-measurements)
- Uncertainty dominated by low statistics of e^-p sample



CC: extraction of M_W

Measure W-mass from its space-like propagator

Fit SM with ZEUS-S to the measured cross section $d\sigma/dQ^2$ with M_W as free parameter and keep G_F fixed to PDG-value

99/00 e^+ ZEUS:

$$M_W = \left(78.9 \pm 2.0(stat.) \pm -1.8(syst.)^{+2.0}_{-1.8}(\text{PDF})\right)\ \text{GeV}$$

98/99 e^- ZEUS:

$$M_W = 80.3 \pm 2.1(\text{stat.}) \pm 1.2(\text{syst.}) \pm 1.0(\text{PDF})\ \text{GeV}$$

94-97 e^+ ZEUS:

$$M_W = 81.4^{+2.7}_{-2.6}(\text{stat.}) \pm +2.0(\text{syst.})^{+3.3}_{-3.0}(\text{PDF})\ \text{GeV}$$

In good agreement with PDG-value:

$M_W = (80.422 \pm 0.047)$ GeV.

Summary

Presented topics:
- ZEUS QCD NLO-fits
- e^-p 98/99 NC, (CC)
- e^+p 99/00 CC, (NC prelim.)

NC e^+p to complete HERA I incl. measurements
HERA I ZEUS QCD NLO-fit

QCD results:
- PDFs
- $\alpha_s(M_Z)$

Additional input e.g. from jet-shapes

EW results:
- propagator
- helicity
- M_W

new quality with long. polarised e in HERA II

But HERA II startup delayed.
Wait for increasing statistics, especially for e^-.