SRUCTURE FUNCTION MEASUREMENTS AT ZEUS

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HEP 2001

- Final reduced cross-section and F_2 data from e^+p run 96/97: $30pb^{-1}$, $2.7 < Q^2 < 30,000 GeV^2$, $6.10^{-5} < x < 0.65$
- NLO QCD fits to extract parton distributions and $\alpha_S(M_Z^2)$

CROSS SECTIONS and STRUCTURE FUNCTIONS

$$\frac{d^2\sigma(e^\pm)}{dxdQ^2} = \frac{2\pi\alpha^2 Y_+}{xQ^4}\left[F_2 - \frac{y^2}{Y_+}F_L \mp \frac{Y_-}{Y_+}xF_3\right] \quad (1)$$

For $Q^2 < 3000 GeV^2$,

$$\sigma_r = F_2 - \frac{y^2}{Y_+}F_L \simeq F_2 \quad (2)$$

F_L is only important for high y, and $F_L = 0$ at LO
$xF_3 \simeq 0$ until Z_0 exchange becomes important

Structure functions are convolutions of QCD calculable coefficient functions with parton distributions

$$\frac{F_2(x, Q^2}{x} = \int_0^1 \frac{dz}{z}\left[\sum_i C_2(\frac{x}{z}, \alpha_s) q_i(z, Q^2) + C_g(\frac{x}{z}, \alpha_s) g(z, Q^2)\right] \quad (3)$$

At LO in QCD

$$F_2 = x\sum_i e_i^2 (q_i(x, Q^2) + \bar{q}_i(x, Q^2) \quad (4)$$

We may use cross-section and structure function measurements to determine parton distribution functions (PDFs)

NLOQCD fits IN DGLAP formalism

- Parametrize PDFs at one $Q^2 = Q_0^2$ value: $xq(x) = p_1 x^{p_2}(1-x)^{p_3}(1+p_4 x)$
- DGLAP equations to evolve PDFs to other Q^2 using NLO splitting functions..depends on α_S
- Convolute PDFs with Coefficient Functions to give Structure Functions and Cross-Sections for all x, Q^2: depends on α_S, depends on heavy quark production scheme
- Fit to ZEUS and fixed target data to extract PDF parameters and $\alpha_S(M_Z^2)$

Parametrize $xu_v, xd_v, xSea, xGluon, x(\bar{d}-\bar{u})$ hence need Sea flavour and Valence information from fixed target data, as well as low x Gluon and Sea information from ZEUS

Choose data sets with full information on CORRELATED systematic errors: ZEUS: NMC p,D ; BCDMS p; E665 p,D: CCFR

- 1263 data points
- 11 PDF parameters plus α_s
- 71 CORRELATED systematic errors including NORMALISATIONS

$W^2 > 20 GeV^2$ to avoid high x higher twist

$M\bar{S}$ scheme, $\mu_R = \mu_F = Q^2$

General mass variable flavour number heavy quark production scheme (Roberts and Thorne)

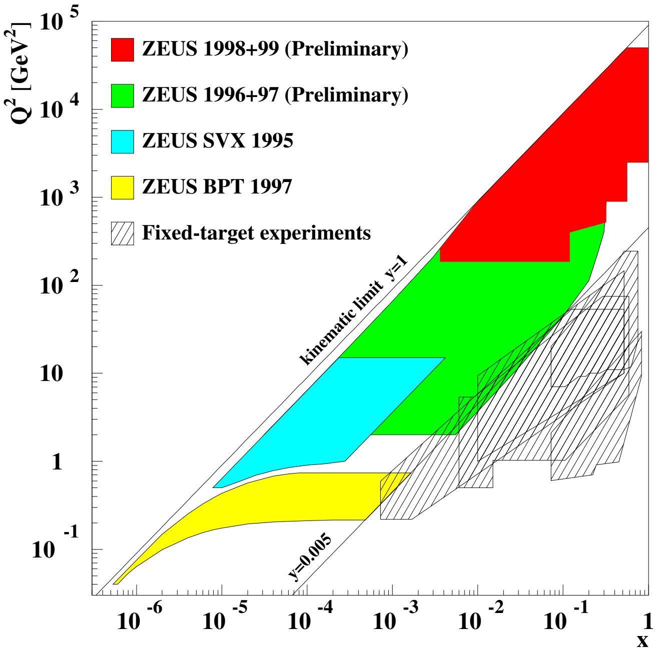
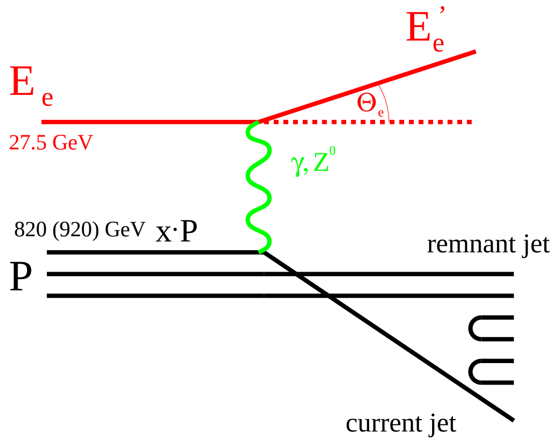


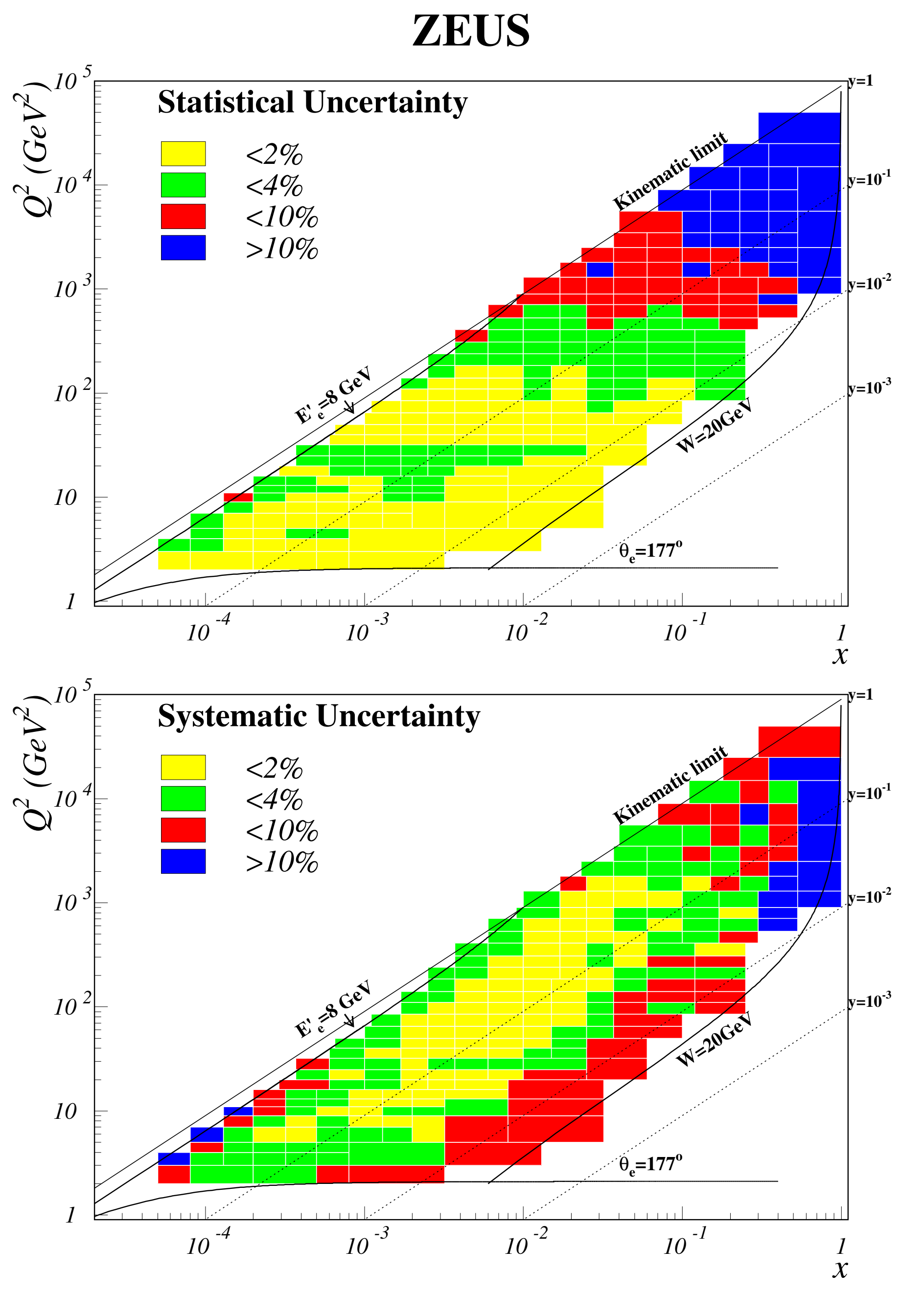
Figure 2: *HERA kinematic plane with the regions covered by different analysis. The data in this paper come from the darkest region (ZEUS 1998+99).*

Kinematics of NC e^+P scattering at HERA

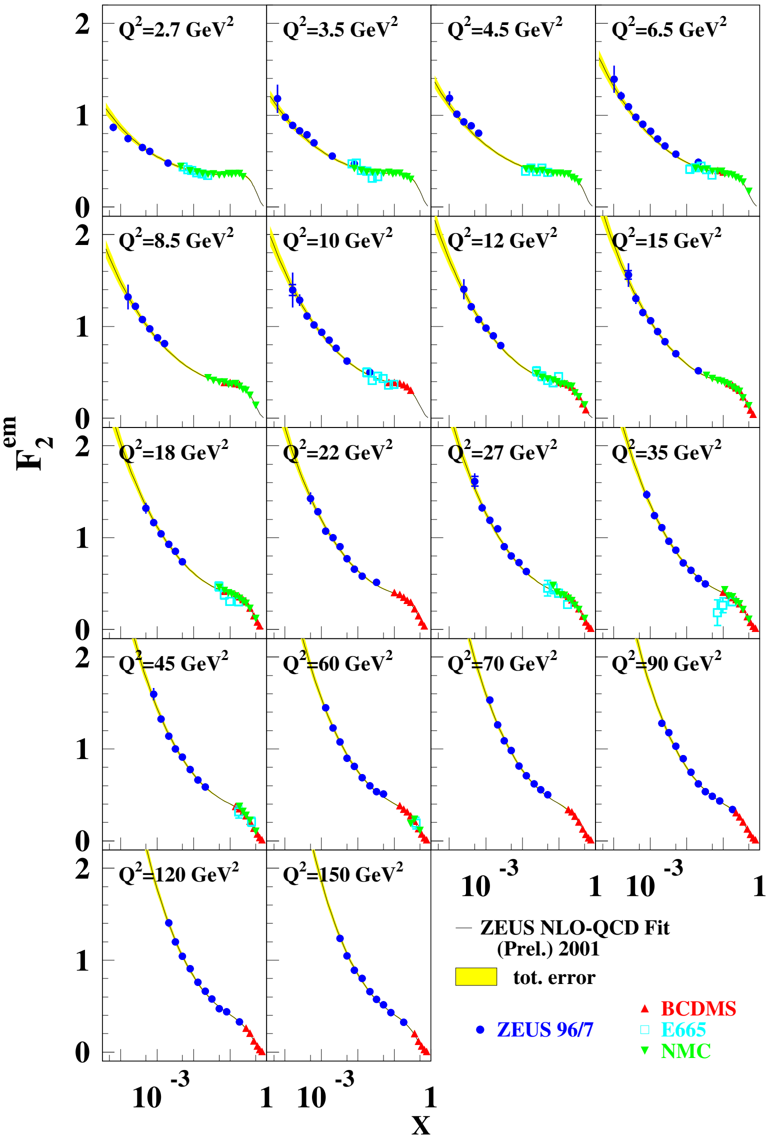


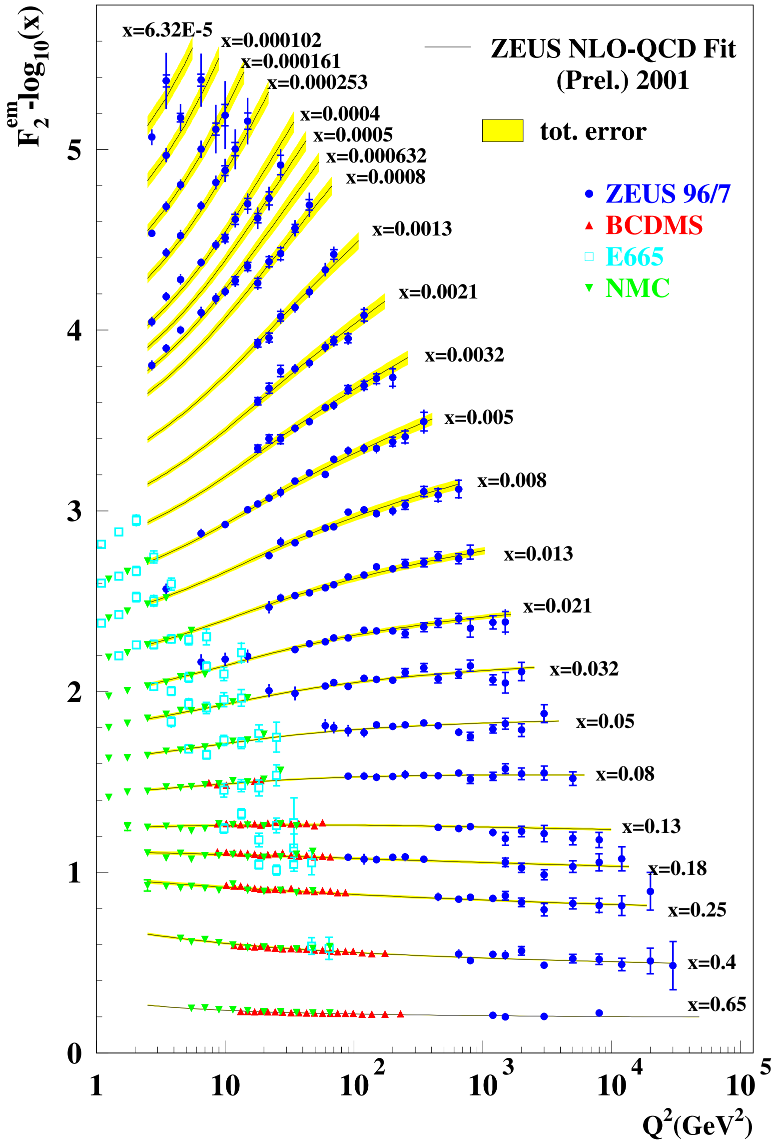
Q^2	$= -q^2 = -(k-k')^2$	squared 4-momentum transfer;
x	$= \frac{Q^2}{2p\cdot q}$	fractional parton momentum $(0 \leq x \leq 1)$
y	$= \frac{p\cdot q}{p\cdot k}$	fractional energy transfer $(0 \leq y \leq 1)$
W^2	$= (q+p)^2 \simeq \frac{Q^2}{x}(1-x)$	$\gamma^* P$ CMS energy^2 energy;
s	$= (k+p)^2 \simeq 4E_eE_P$	e^+P CMS energy^2 $(\sqrt{s} \sim 300(318)$ GeV$)$

$\boxed{Q^2 \simeq x \cdot y \cdot s}$ $\Rightarrow$ 2 independent variables

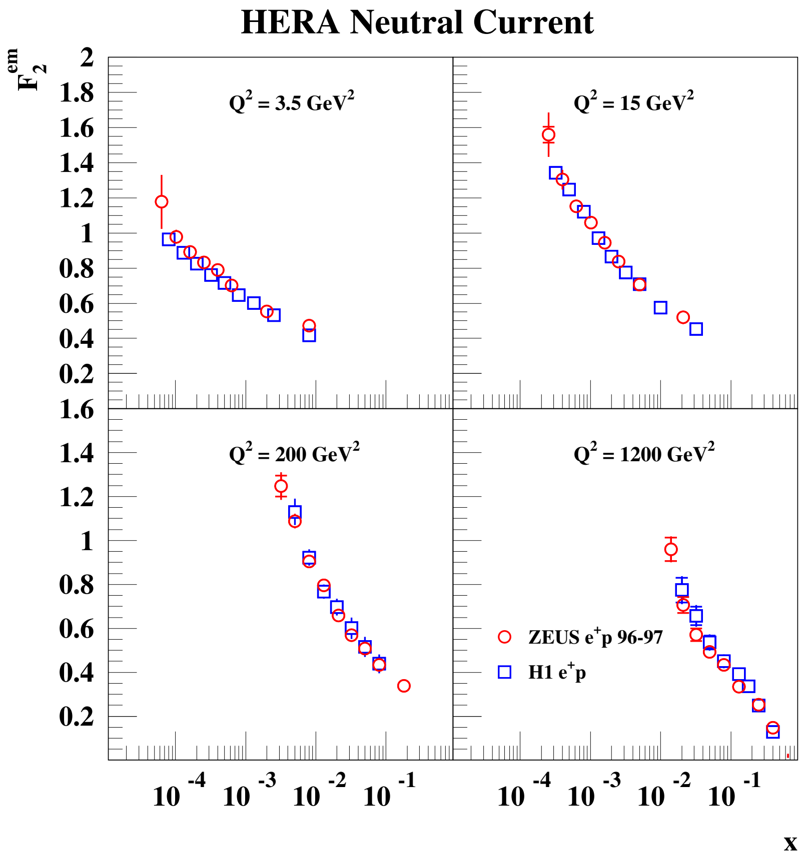


ZEUS
Statistical Uncertainty
<2%
<4%
<10%
>10%
Kinematic limit
E'e=8 GeV
W=20GeV
θe=177°
y=1
y=10^-1
y=10^-2
y=10^-3
Q^2 (GeV^2)
x
Systematic Uncertainty
<2%
<4%
<10%
>10%
Kinematic limit
E'e=8 GeV
W=20GeV
θe=177°
y=1
y=10^-1
y=10^-2
y=10^-3
Q^2 (GeV^2)
x

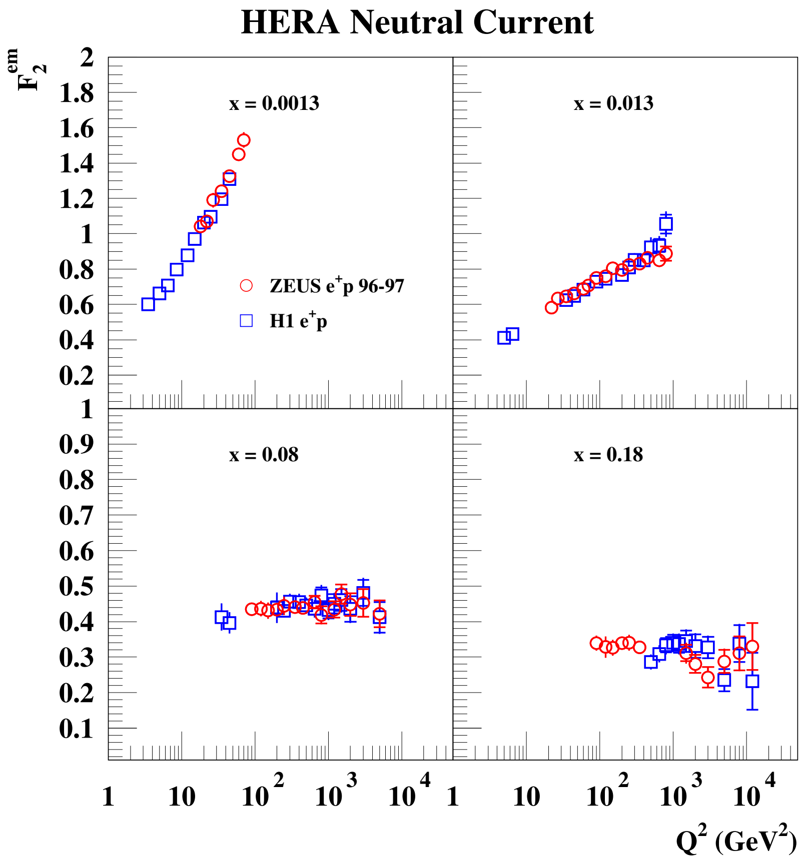

Q²=2.7 GeV²
Q²=3.5 GeV²
Q²=4.5 GeV²
Q²=6.5 GeV²
Q²=8.5 GeV²
Q²=10 GeV²
Q²=12 GeV²
Q²=15 GeV²
Q²=18 GeV²
Q²=22 GeV²
Q²=27 GeV²
Q²=35 GeV²
Q²=45 GeV²
Q²=60 GeV²
Q²=70 GeV²
Q²=90 GeV²
Q²=120 GeV²
Q²=150 GeV²
F₂^em
x
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error
ZEUS 96/7
BCDMS
E665
NMC



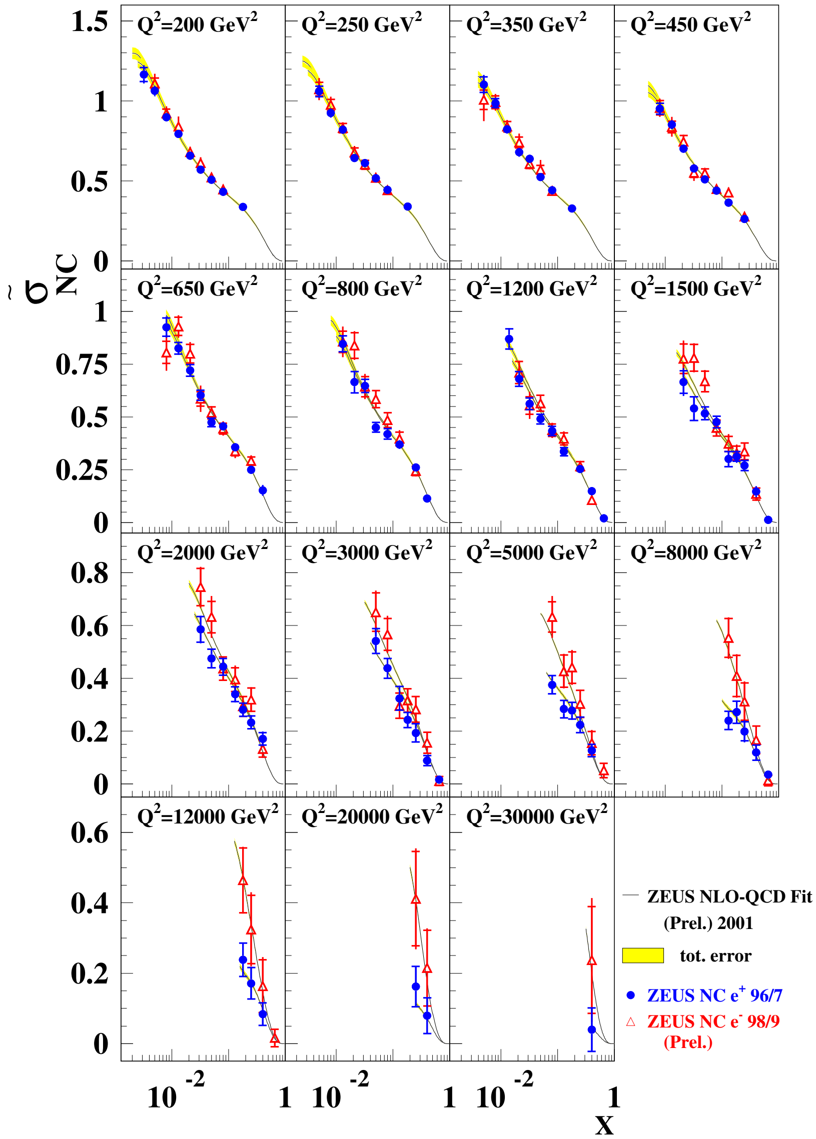
F_2^{em}-$\log_{10}(x)$
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error
ZEUS 96/7
BCDMS
E665
NMC
x=6.32E-5
x=0.000102
x=0.000161
x=0.000253
x=0.0004
x=0.0005
x=0.000632
x=0.0008
x=0.0013
x=0.0021
x=0.0032
x=0.005
x=0.008
x=0.013
x=0.021
x=0.032
x=0.05
x=0.08
x=0.13
x=0.18
x=0.25
x=0.4
x=0.65
Q^2(GeV^2)



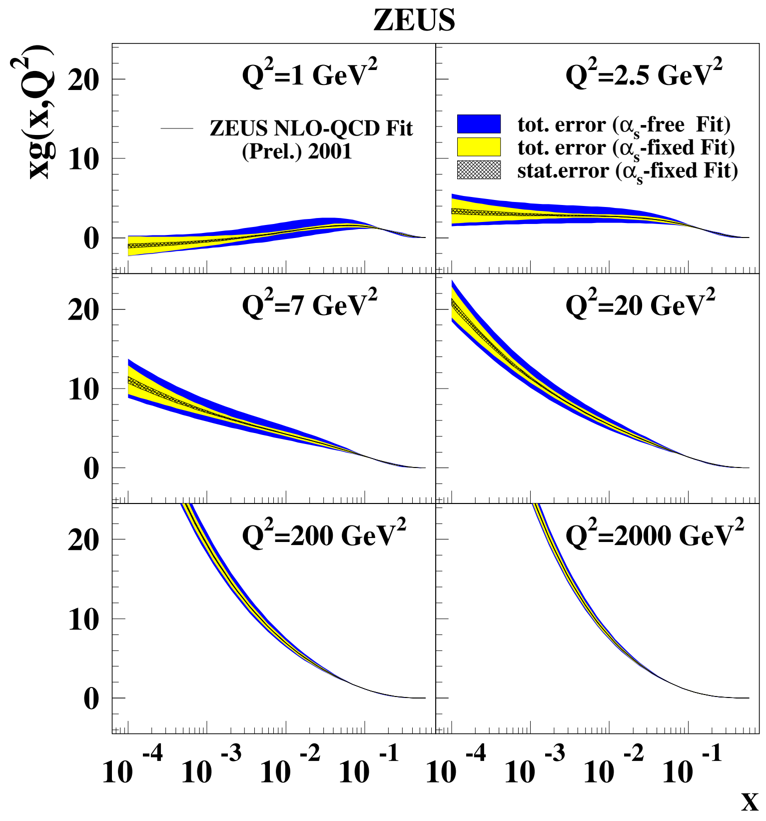
HERA Neutral Current
F_2^{em}
Q^2 = 3.5 GeV^2
Q^2 = 15 GeV^2
Q^2 = 200 GeV^2
Q^2 = 1200 GeV^2
ZEUS e$^+$p 96-97
H1 e$^+$p
x



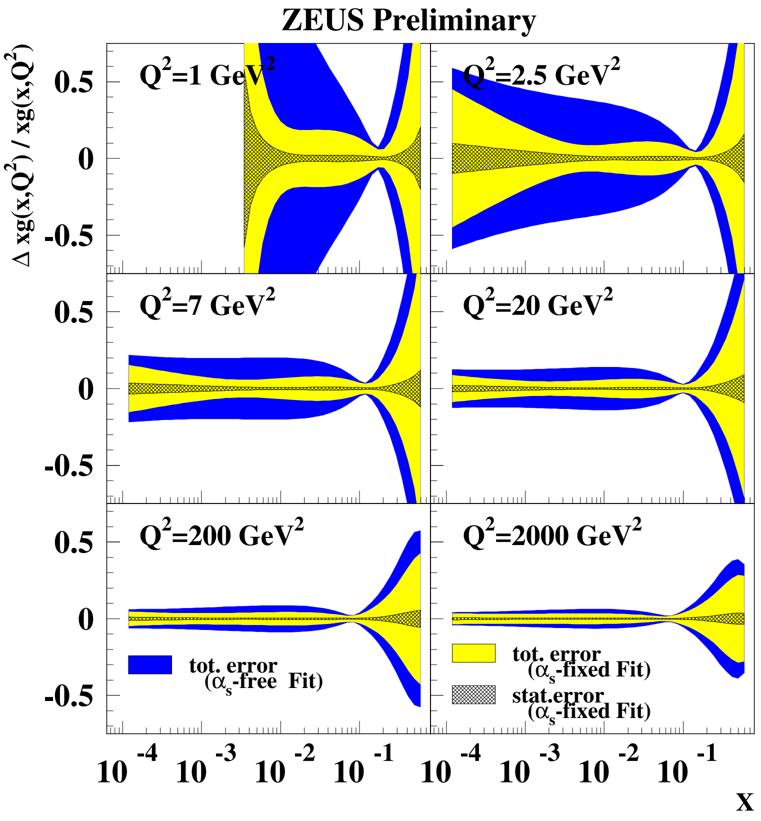
HERA Neutral Current
F_2^{em}
x = 0.0013
x = 0.013
x = 0.08
x = 0.18
ZEUS e^+p 96-97
H1 e^+p
Q^2 (GeV^2)



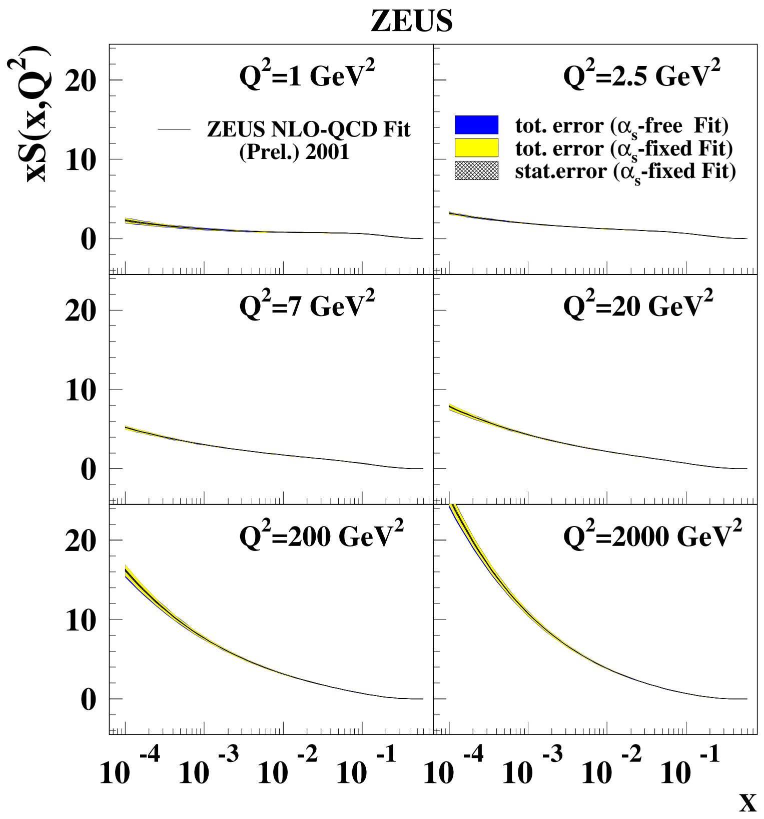
$\tilde{\sigma}_{NC}$
Q^2=200 GeV^2
Q^2=250 GeV^2
Q^2=350 GeV^2
Q^2=450 GeV^2
Q^2=650 GeV^2
Q^2=800 GeV^2
Q^2=1200 GeV^2
Q^2=1500 GeV^2
Q^2=2000 GeV^2
Q^2=3000 GeV^2
Q^2=5000 GeV^2
Q^2=8000 GeV^2
Q^2=12000 GeV^2
Q^2=20000 GeV^2
Q^2=30000 GeV^2
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error
ZEUS NC e^+ 96/7
ZEUS NC e^- 98/9
(Prel.)
10^{-2}
1
x

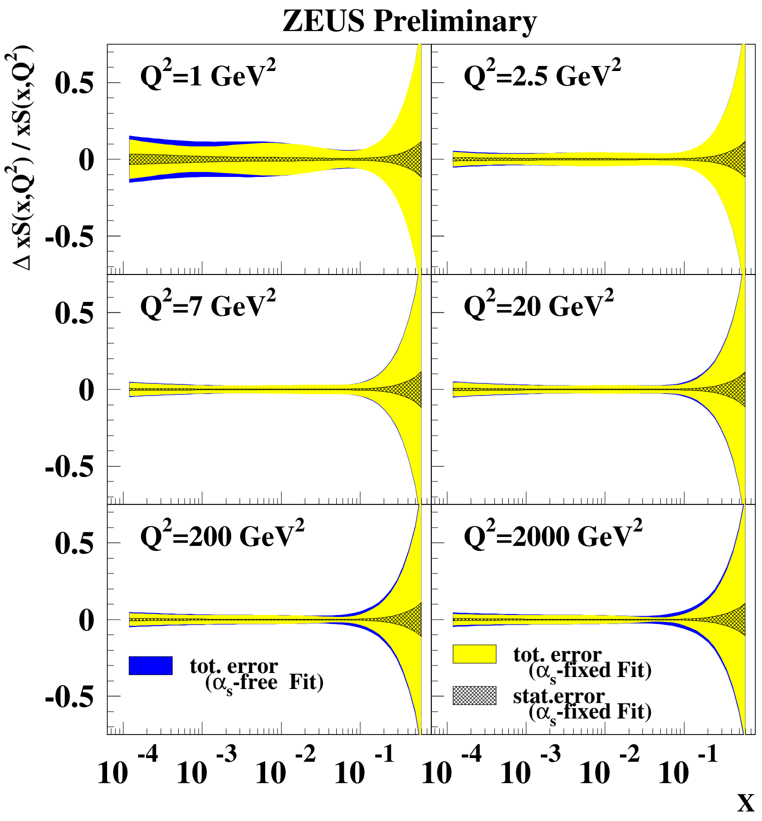


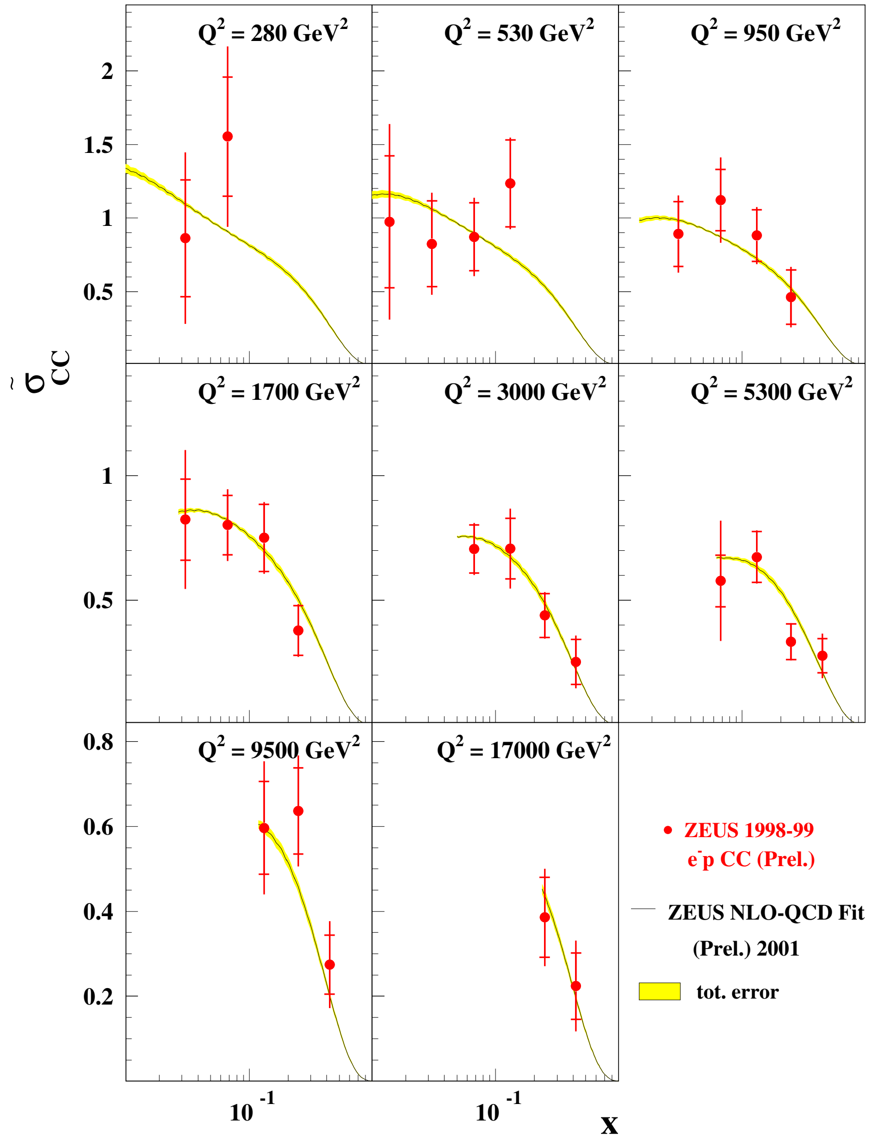
ZEUS
xg(x,Q²)
Q²=1 GeV²
ZEUS NLO-QCD Fit
(Prel.) 2001
Q²=2.5 GeV²
tot. error (αs-free Fit)
tot. error (αs-fixed Fit)
stat.error (αs-fixed Fit)
Q²=7 GeV²
Q²=20 GeV²
Q²=200 GeV²
Q²=2000 GeV²
20
10
0
10⁻⁴ 10⁻³ 10⁻² 10⁻¹
x



ZEUS Preliminary
Δ xg(x,Q²) / xg(x,Q²)
Q²=1 GeV²
Q²=2.5 GeV²
Q²=7 GeV²
Q²=20 GeV²
Q²=200 GeV²
Q²=2000 GeV²
0.5
0
-0.5
tot. error (αs-free Fit)
tot. error (αs-fixed Fit)
stat.error (αs-fixed Fit)
10⁻⁴ 10⁻³ 10⁻² 10⁻¹
X


ZEUS
xS(x,Q^2)
Q^2=1 GeV^2
ZEUS NLO-QCD Fit
(Prel.) 2001
Q^2=2.5 GeV^2
tot. error (α_s-free Fit)
tot. error (α_s-fixed Fit)
stat.error (α_s-fixed Fit)
Q^2=7 GeV^2
Q^2=20 GeV^2
Q^2=200 GeV^2
Q^2=2000 GeV^2
0
10
20
10^-4
10^-3
10^-2
10^-1
x

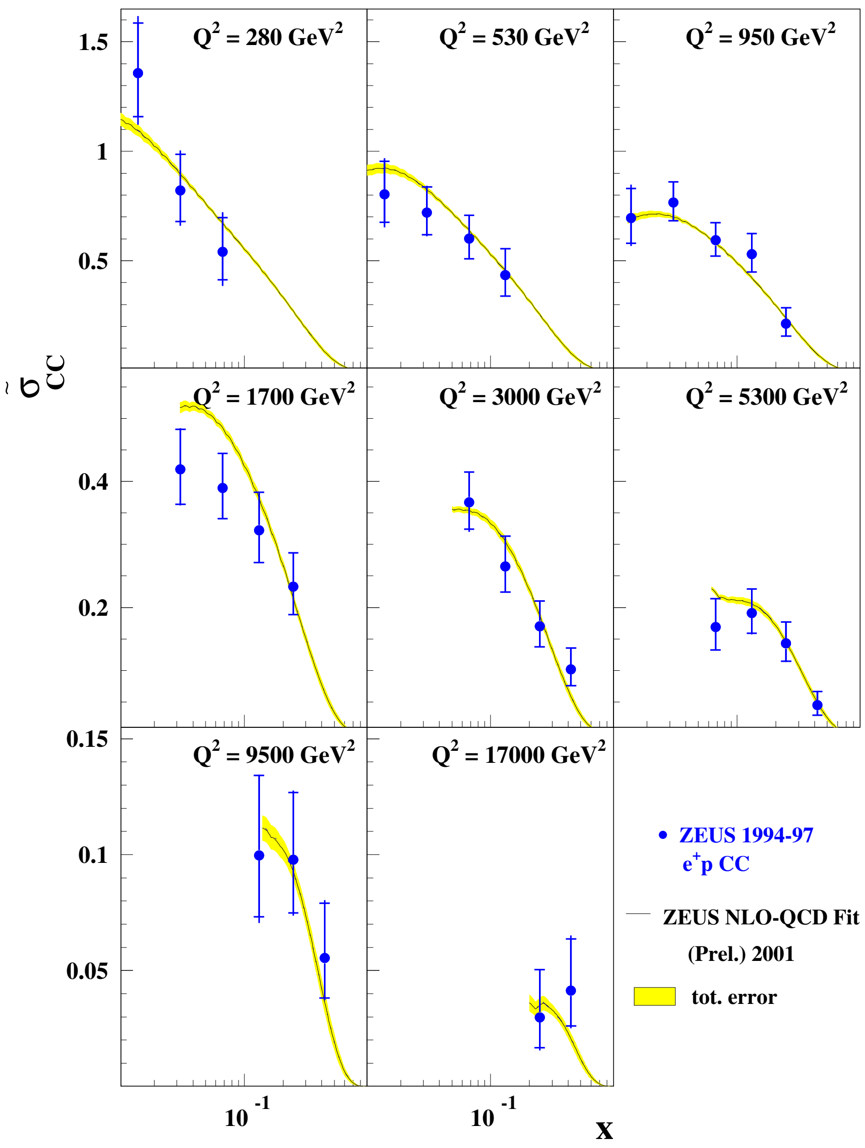

ZEUS Preliminary
Δ xS(x,Q²) / xS(x,Q²)
Q²=1 GeV²
Q²=2.5 GeV²
Q²=7 GeV²
Q²=20 GeV²
Q²=200 GeV²
Q²=2000 GeV²
0.5
0
-0.5
tot. error (αs-free Fit)
tot. error (αs-fixed Fit)
stat.error (αs-fixed Fit)
10⁻⁴ 10⁻³ 10⁻² 10⁻¹
x



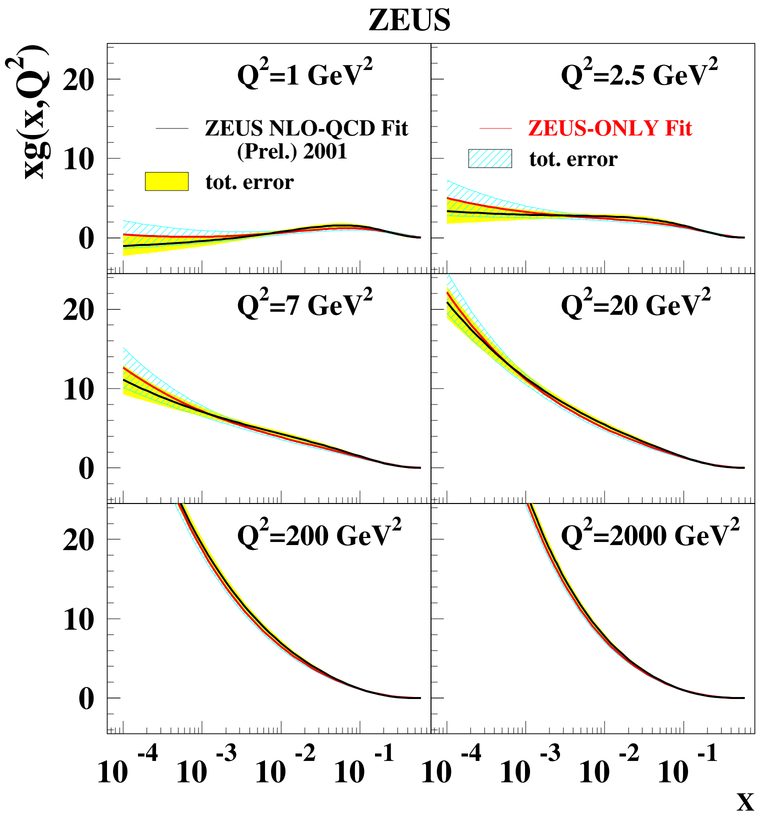
$Q^2 = 280\ GeV^2$
$Q^2 = 530\ GeV^2$
$Q^2 = 950\ GeV^2$
$Q^2 = 1700\ GeV^2$
$Q^2 = 3000\ GeV^2$
$Q^2 = 5300\ GeV^2$
$Q^2 = 9500\ GeV^2$
$Q^2 = 17000\ GeV^2$
$\tilde{\sigma}_{CC}$
x
10^{-1}
ZEUS 1998-99
e^-p CC (Prel.)
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error

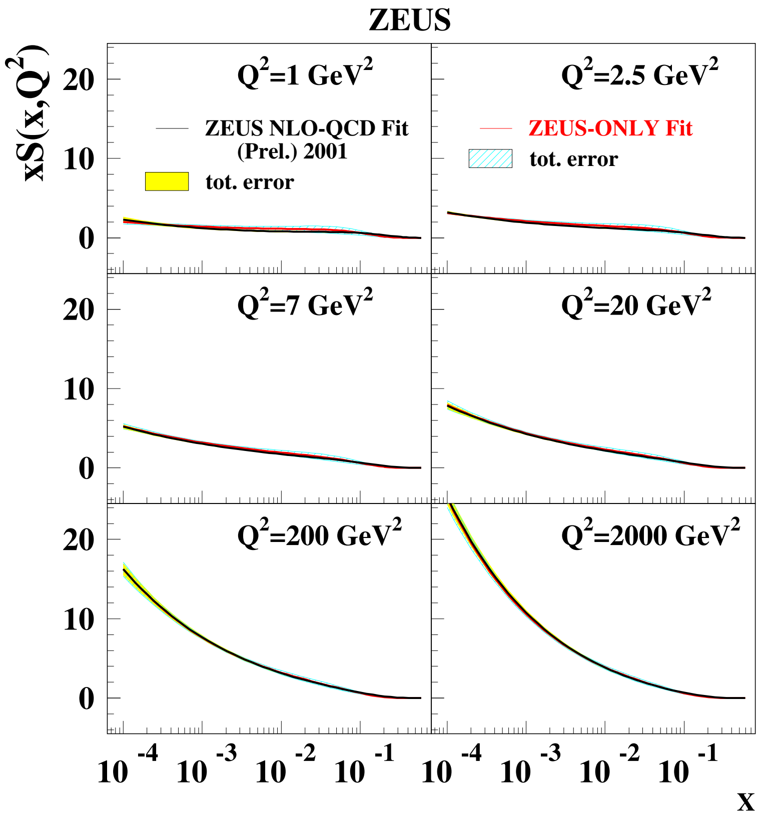
SUMMARY

- Final reduced cross-section and F_2 data from e^+p run 96/97: $30pb^{-1}$, $2.7 < Q^2 < 30,000 GeV^2$, $6.10^{-5} < x < 0.65$
- NLOQCD fit to ZEUS and fixed target data to extract parton distributions and $\alpha_S(M_Z^2)$
- Error Bands on Parton Distributions from CORRELATED systematic errors and NORMALISATIONS
- Lower Q^2 limit of validity of NLOQCD fits $\sim 1GeV^2$
- NLOQCD fit to ZEUS data alone ($e^{\pm}p$, NC/CC) suggests larger d/u ratio at high x than global fit
- $\alpha_S(M_Z^2) =$ $0.1172 \pm 0.0008(stat) \pm 0.0054(sys + norm)$

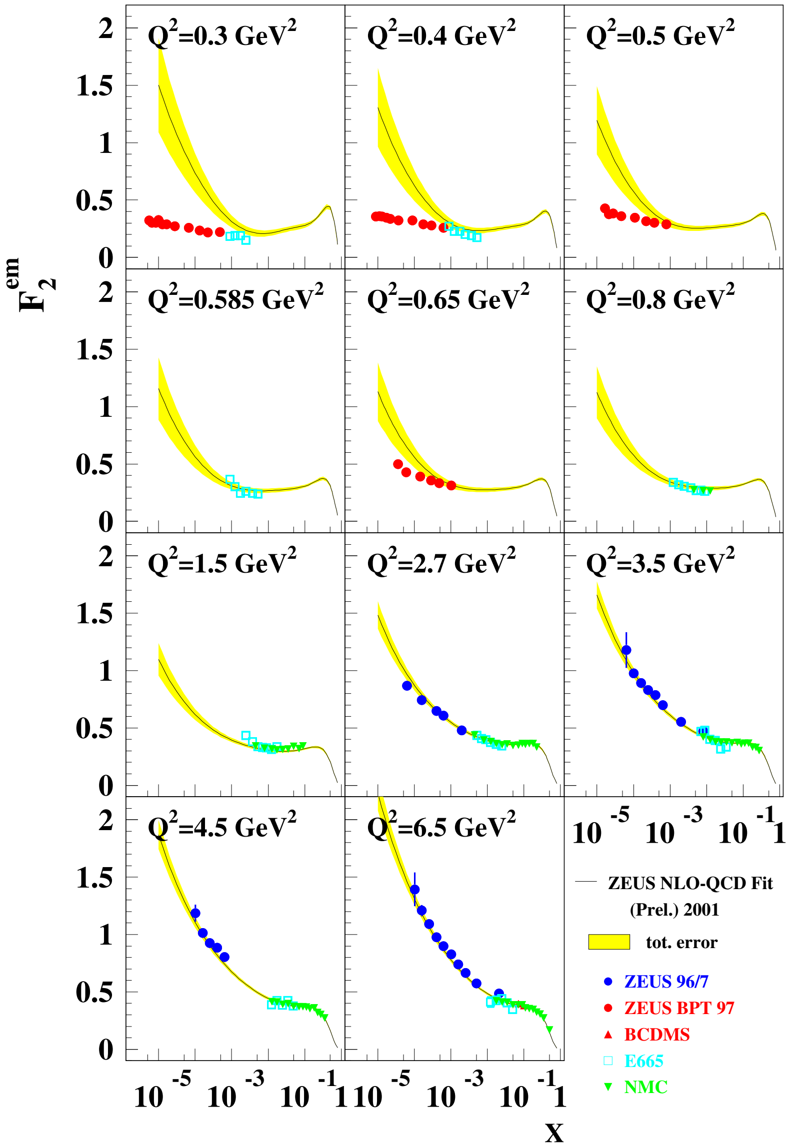


Q^2 = 280 GeV^2
Q^2 = 530 GeV^2
Q^2 = 950 GeV^2
Q^2 = 1700 GeV^2
Q^2 = 3000 GeV^2
Q^2 = 5300 GeV^2
Q^2 = 9500 GeV^2
Q^2 = 17000 GeV^2
1.5
1
0.5
0.4
0.2
0.15
0.1
0.05
10^-1
10^-1
x
σ̃_CC
ZEUS 1994-97
e^+p CC
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error

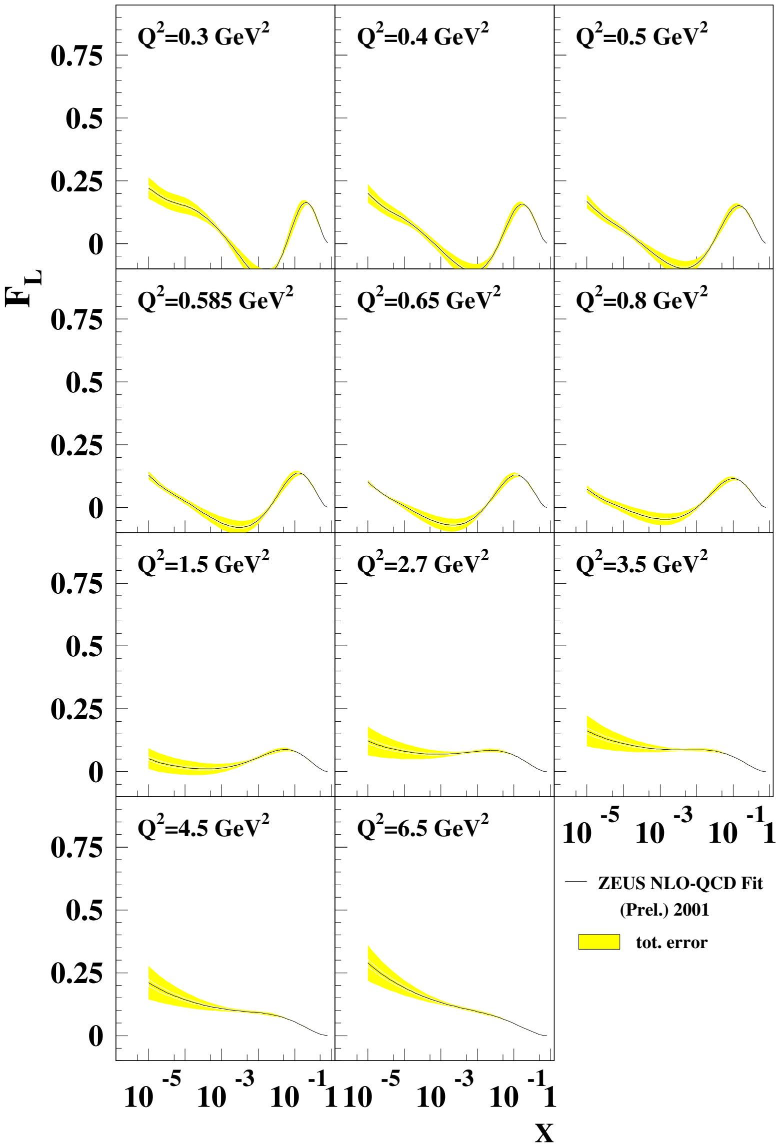

ZEUS
$xg(x,Q^2)$
Q^2=1 GeV^2
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error
Q^2=2.5 GeV^2
ZEUS-ONLY Fit
tot. error
Q^2=7 GeV^2
Q^2=20 GeV^2
Q^2=200 GeV^2
Q^2=2000 GeV^2
20
10
0
10^{-4} 10^{-3} 10^{-2} 10^{-1}
x



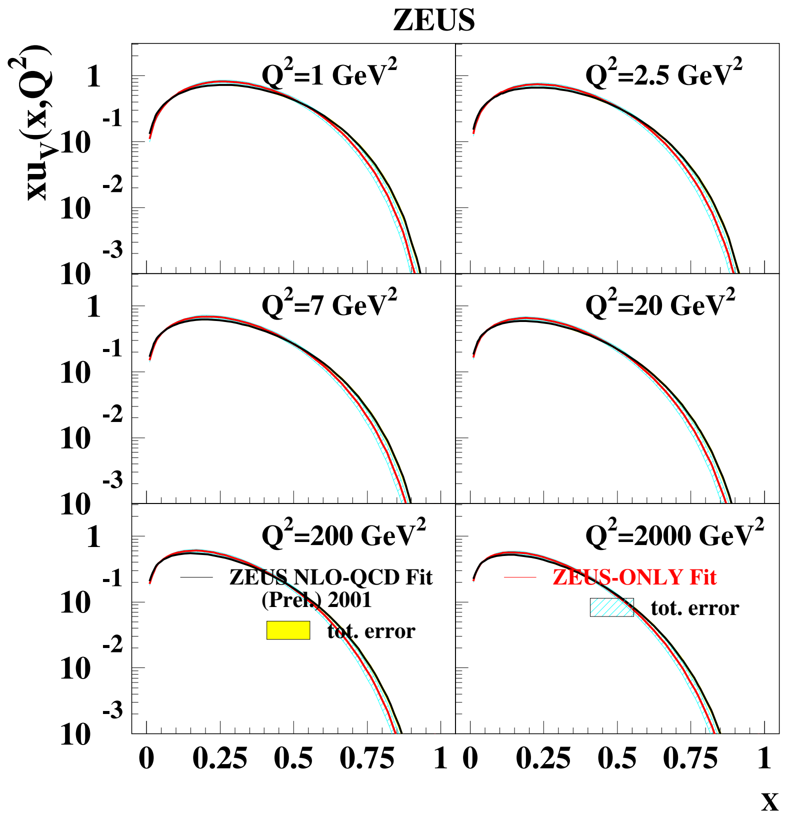
ZEUS
xS(x,Q²)
Q²=1 GeV²
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error
Q²=2.5 GeV²
ZEUS-ONLY Fit
tot. error
Q²=7 GeV²
Q²=20 GeV²
Q²=200 GeV²
Q²=2000 GeV²
20
10
0
10⁻⁴ 10⁻³ 10⁻² 10⁻¹
x



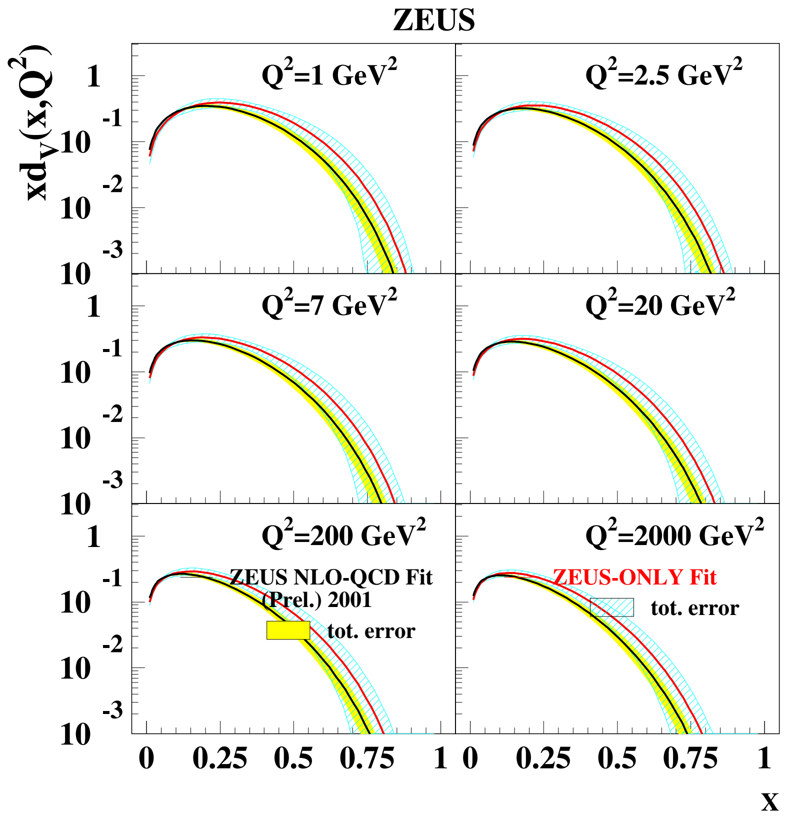
F_2^{em}
Q^2=0.3 GeV^2
Q^2=0.4 GeV^2
Q^2=0.5 GeV^2
Q^2=0.585 GeV^2
Q^2=0.65 GeV^2
Q^2=0.8 GeV^2
Q^2=1.5 GeV^2
Q^2=2.7 GeV^2
Q^2=3.5 GeV^2
Q^2=4.5 GeV^2
Q^2=6.5 GeV^2
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error
ZEUS 96/7
ZEUS BPT 97
BCDMS
E665
NMC
x



Q^2=0.3 GeV^2
Q^2=0.4 GeV^2
Q^2=0.5 GeV^2
Q^2=0.585 GeV^2
Q^2=0.65 GeV^2
Q^2=0.8 GeV^2
Q^2=1.5 GeV^2
Q^2=2.7 GeV^2
Q^2=3.5 GeV^2
Q^2=4.5 GeV^2
Q^2=6.5 GeV^2
F_L
x
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error



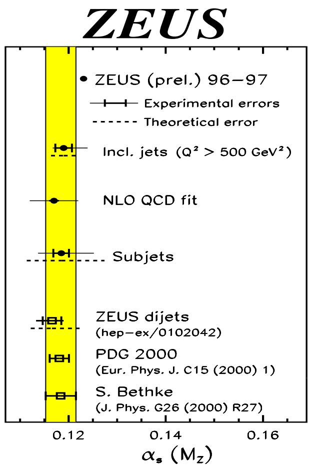
ZEUS
$xu_V(x,Q^2)$
Q^2=1 GeV^2
Q^2=2.5 GeV^2
Q^2=7 GeV^2
Q^2=20 GeV^2
Q^2=200 GeV^2
Q^2=2000 GeV^2
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error
ZEUS-ONLY Fit
tot. error
1
10^{-1}
10^{-2}
10^{-3}
0
0.25
0.5
0.75
1
x

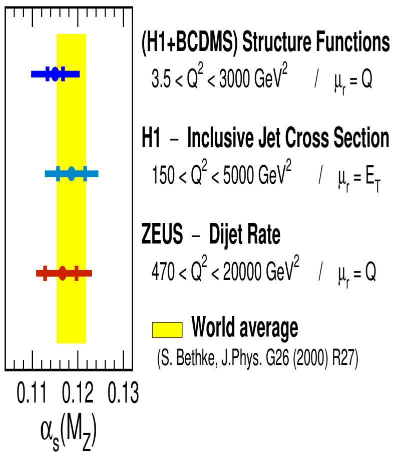


ZEUS
$xd_V(x,Q^2)$
Q^2=1 GeV^2
Q^2=2.5 GeV^2
Q^2=7 GeV^2
Q^2=20 GeV^2
Q^2=200 GeV^2
Q^2=2000 GeV^2
ZEUS NLO-QCD Fit
(Prel.) 2001
tot. error
ZEUS-ONLY Fit
tot. error
1
10^{-1}
10^{-2}
10^{-3}
0
0.25
0.5
0.75
1
x

α_s comparison [H1 and ZEUS]

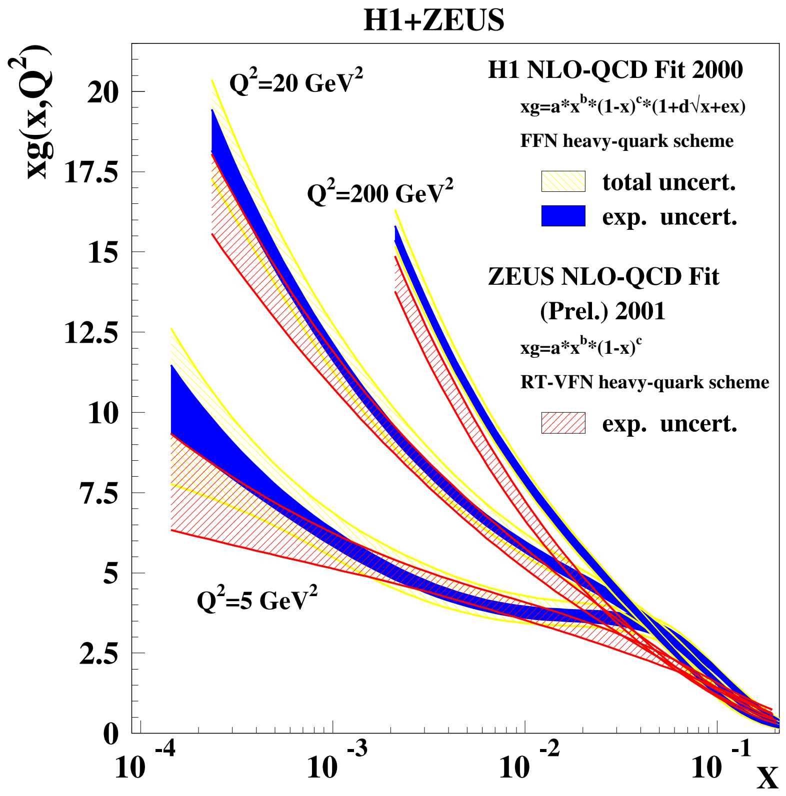
	ZEUS (prelim.)	H1
α_s	0.1172	0.1150
experimental error	± 0.0008 (stat.) ± 0.0054 (syst.) ± 0.0055 (exp.)	± 0.0017 (exp.)
model error		$^{+0.0009}_{-0.0005}$
scale uncertainty		~ 0.005





- The α_s both from H1 and ZEUS are consistent with world average and also with those obtained from jets.
- The α_s error due to experimental errors is different between H1 and ZEUS.

  $\Rightarrow$ different treatment of correlated syst.errors.



H1+ZEUS
$xg(x,Q^2)$
Q^2=20 GeV^2
Q^2=200 GeV^2
Q^2=5 GeV^2
H1 NLO-QCD Fit 2000
xg=a*x^b*(1-x)^c*(1+d√x+ex)
FFN heavy-quark scheme
total uncert.
exp. uncert.
ZEUS NLO-QCD Fit
(Prel.) 2001
xg=a*x^b*(1-x)^c
RT-VFN heavy-quark scheme
exp. uncert.
0
2.5
5
7.5
10
12.5
15
17.5
20
10^{-4}
10^{-3}
10^{-2}
10^{-1}
X