# ZEUS High Q2 data from HERA-II +PDF fits

DIS 2009

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There is NEW published data on NC and CC e-p scattering from HERA-II from running in 2005 and 2006

There is preliminary data on NC and CC e+p scattering from HERA-II from running in 2006 and 2007

We have included the double differential cross-section data from these new data sets in the ZEUS-JETS fit formalism to assess their impact on PDFs

## There is NEW published data on NC and CC e-p scattering from HERA-II from running in 2005 and 2006

e- CC 175pb$^{-1}$ compared to 16.4 pb$^{-1}$ from HERA-I

(DESY-08-177) arxiv:0812.4620

e- NC 169pb$^{-1}$ compared to 16.4 pb$^{-1}$ from HERA-I

(DESY-08-202) arxiv:0901.2385

## There is preliminary data on NC and CC e+p scattering from HERA-II from running in 2006 and 2007

e+ NC 113pb-1 compared to 60.9 pb-1 from HERA-I and 23.8pb-1 from early HERA-II running in 2004
ZEUS-prel-08-005
Only single differential cross-sections are presented for these data

e+ CC 136pb$^{-1}$ compared to 60.9 pb$^{-1}$ from HERA-I and 23.8pb$^{-1}$ from early HERA-II running in 2004
ZEUS-prel-09-002

# ZEUS-JETS NLO QCD fit Eur.Phys.C42(2005)1

**Data:**

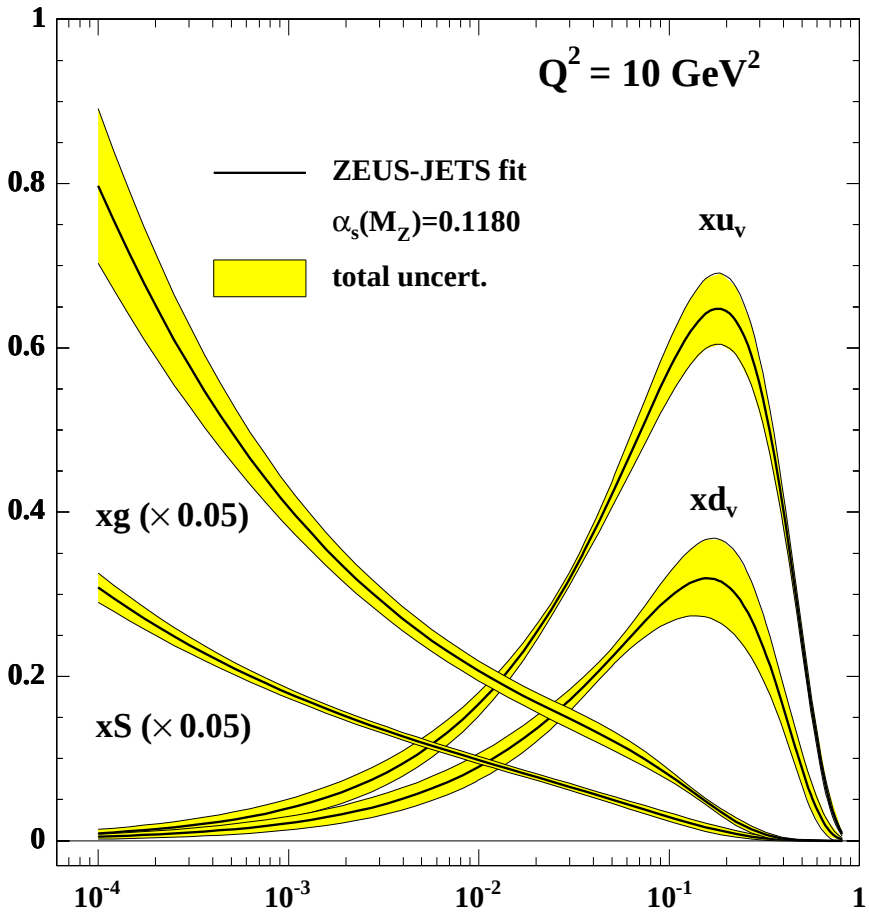
| |
|---|
| all HERA-I ZEUS incl. NC/CC $e^+/e^-$ (94-00) |
| ZEUS inclusive jets in DIS (96-97) |
| ZEUS dijets in photoproduction (96-97) |

**Parameterisation:**

| PDF | Param. at $Q_0^2 = 7$ GeV$^2$ |
|---|---|
| u-val. ($xu_v$) | $A_{uv}\, x^{buv}\, (1-x)^{cuv}\, (1+d_{uv}x)$ |
| d-val. ($xd_v$) | $A_{dv}\, x^{bdv}\, (1-x)^{cdv}\, (1+d_{dv}x)$ |
| total sea ($xS$) | $A_S\, x^{bS}\, (1-x)^{cS}$ |
| gluon ($xg$) | $A_g\, x^{bg}\, (1-x)^{cg}\, (1+d_g x)$ |
| dbar-ubar ($x\Delta$) | $A_\Delta\, x^{b\Delta}\, (1-x)^{c\Delta}$ |

- parameter constraints:
  - momentum and quark number sum rules
  - low-x behaviour of $u_v$ and $d_v$ set equal
  - flavour structure of light quark sea set consistent with Gottfried sum and Drell-Yan
- heavy quarks treated in variable flavour number scheme of Thorne and Roberts

*Correlated systematic errors treated by OFFSET method




We are using this fit formalism to assess the impact of the new data.

ZEUS-prel-09-010

## CC e-p (LO)

$$\frac{d^2\sigma(e^-p)}{dxdy} = \frac{G_F^2 M^4_W}{2\pi x(Q^2+M^2_W)^2}\left[x\,(u+c) + (1-y)^2 x\,(\bar{d}+\bar{s})\right]$$

propagator

reduced cross-section

## CC e+p (LO)

$$\frac{d^2\sigma(e^+p)}{dxdy} = \frac{G_F^2 M^4_W}{2\pi x(Q^2+M^2_W)^2}\left[x\,(\bar{u}+\bar{c}) + (1-y)^2 x\,(d+s)\right]$$

propagator

reduced cross-section

•We can use the reduced cross-sections to learn about PDFs and about the helicity structure of the interaction

The HERA-II data were run with polarised electron and positron beams

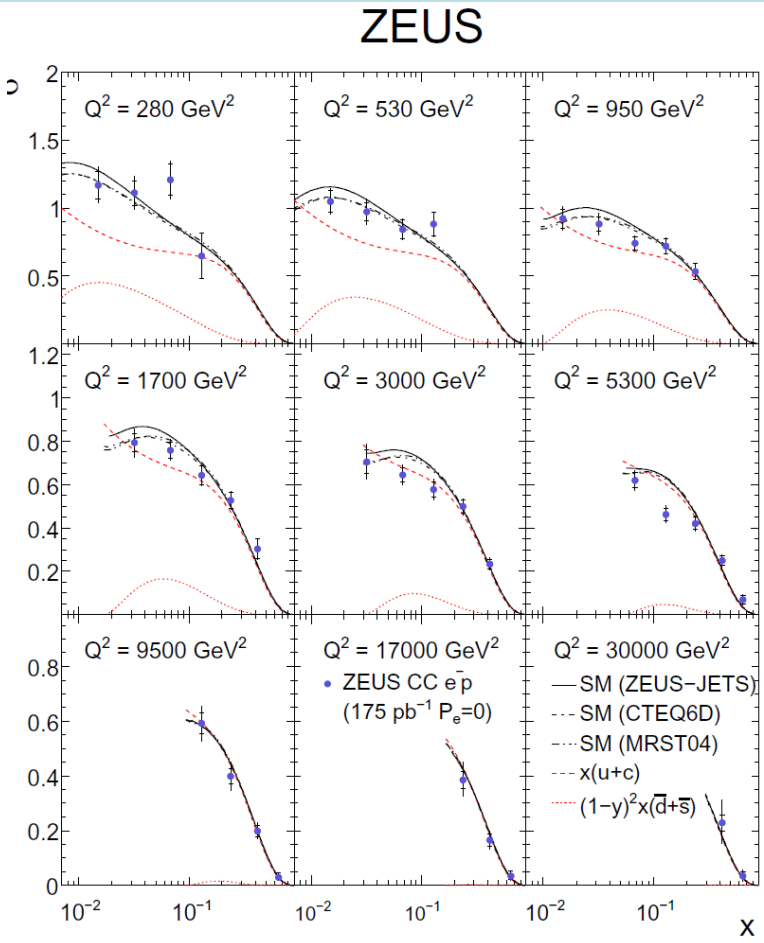
For charged currents this simply modifies the SM cross-sections by the factors

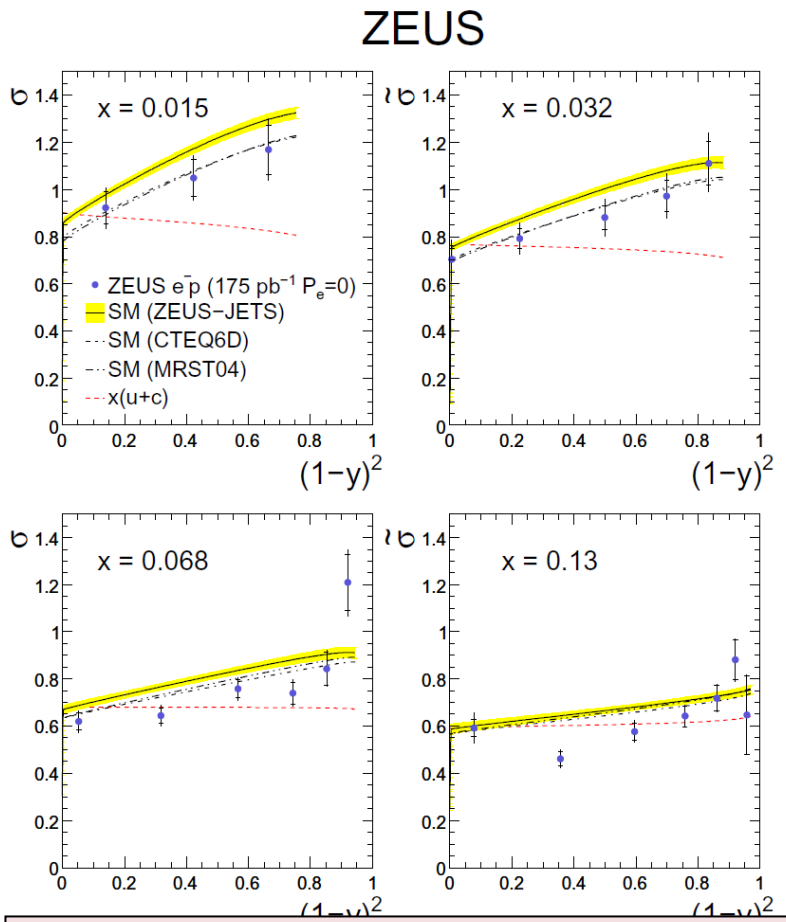
$(1 - P)$ and $(1 + P)$

So we can also test the predictions for polarisation dependence

# 175pb$^{-1}$ NEW CC e- p data: first combine the polarisations to look at unpolarised cross-sections

DESY-08-177



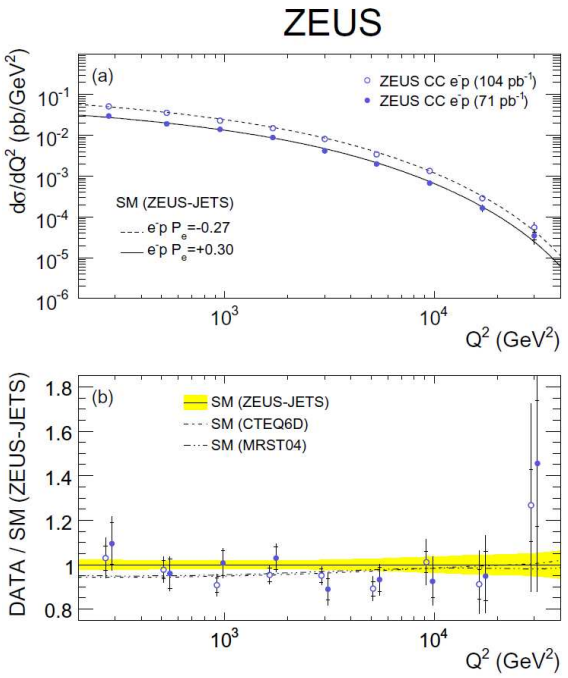

This shows the reduced cross-section vs x in Q2 bins, emphasizing the role of quark and anti-quark PDF flavours. These cross-sections are dominated by u at high-x, Q2

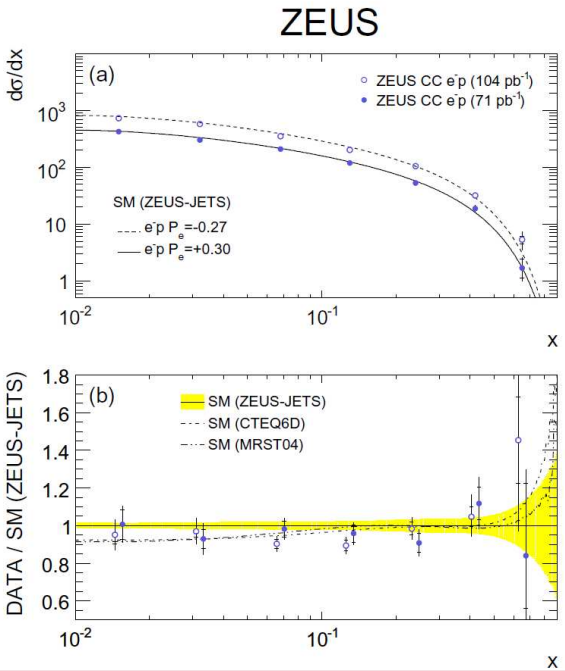
This shows the reduced cross-section vs $(1-y)^2$ in x bins, emphasizing the helicity structure of the interaction

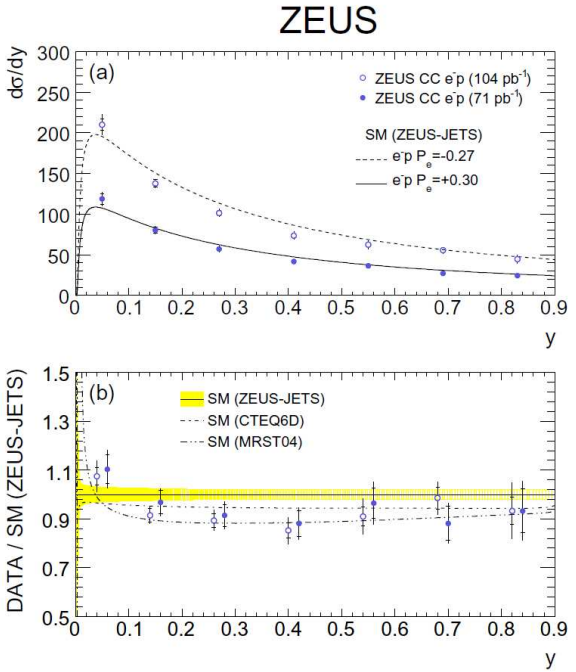
DESY-08-177

# Now consider positive and negative polarisation separately

## CCe-p data: 71pb$^{-1}$ with P = +0.30 and 104pb$^{-1}$ with P = -0.27



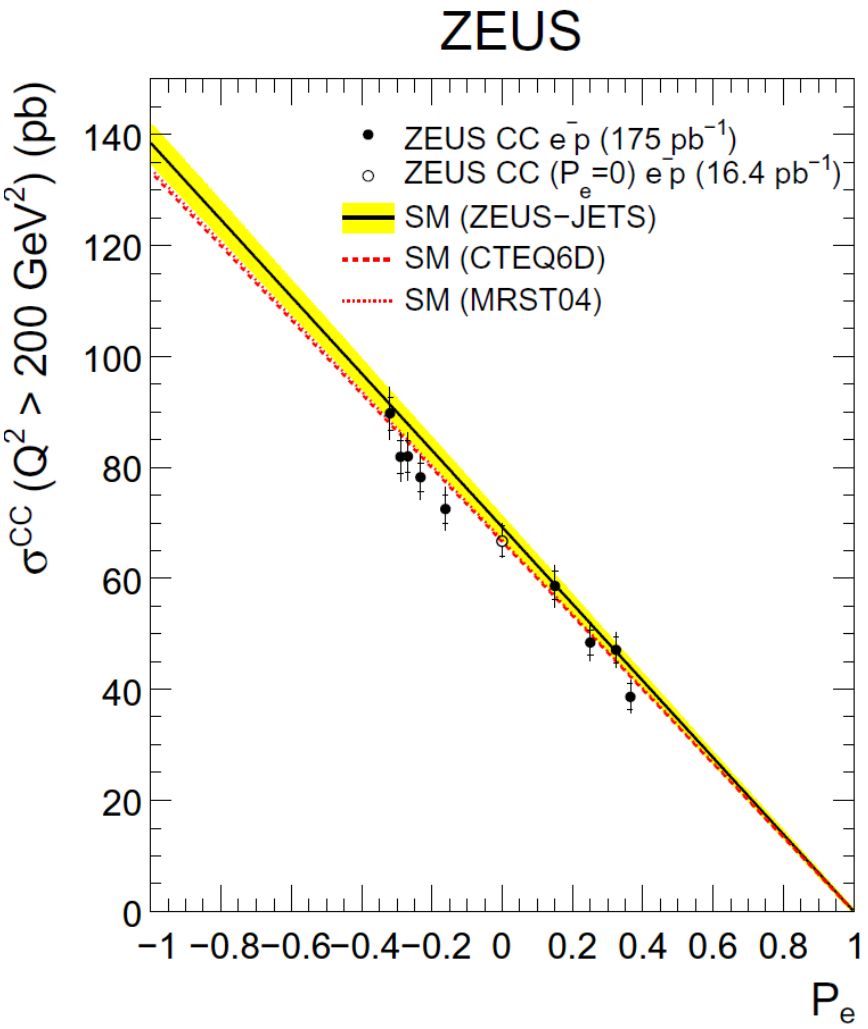




Single differential cross-sections vs $Q^2$, x, y for positively and negatively polarised data are compared to SM predictions calculated using ZEUS-JETS, CTEQ6D and MRST04 PDFs

The total cross-sections can be plotted vs electron polarisation for HERA-I and HERA-II data giving a striking confirmation of SM predictions for the chiral structure of the CC interactions

DESY-08-177



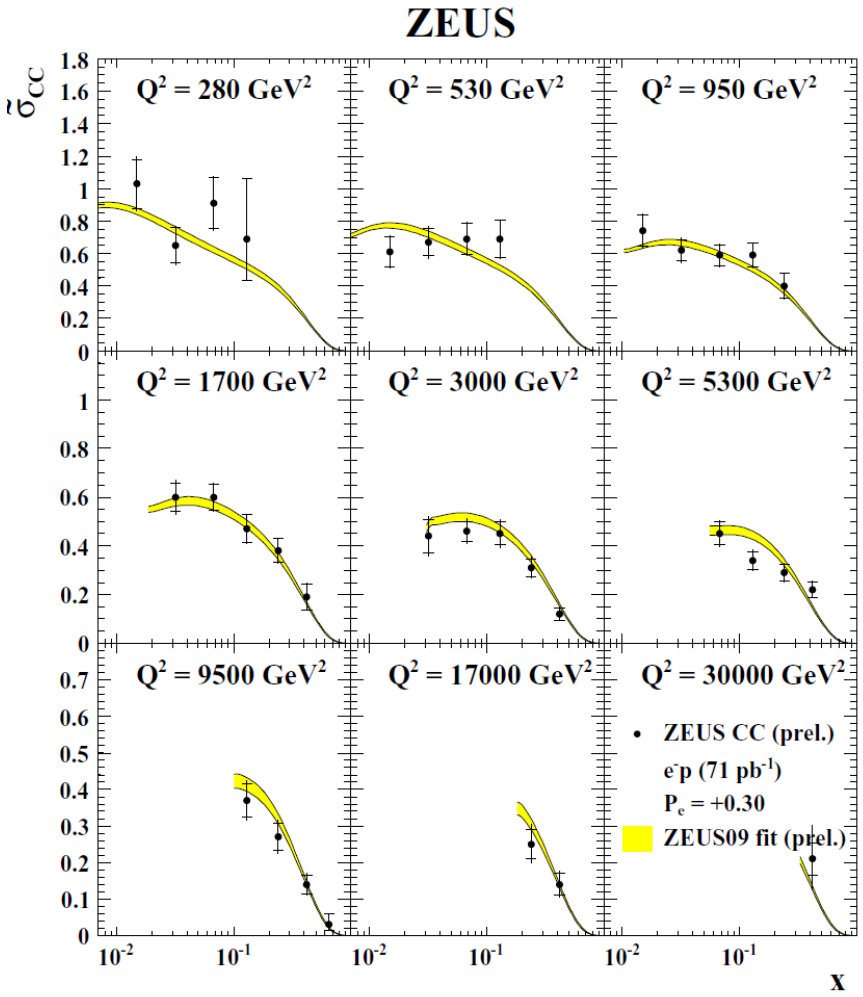
# CCe-p double differential cross-sections for positive and negative polarisation separately:

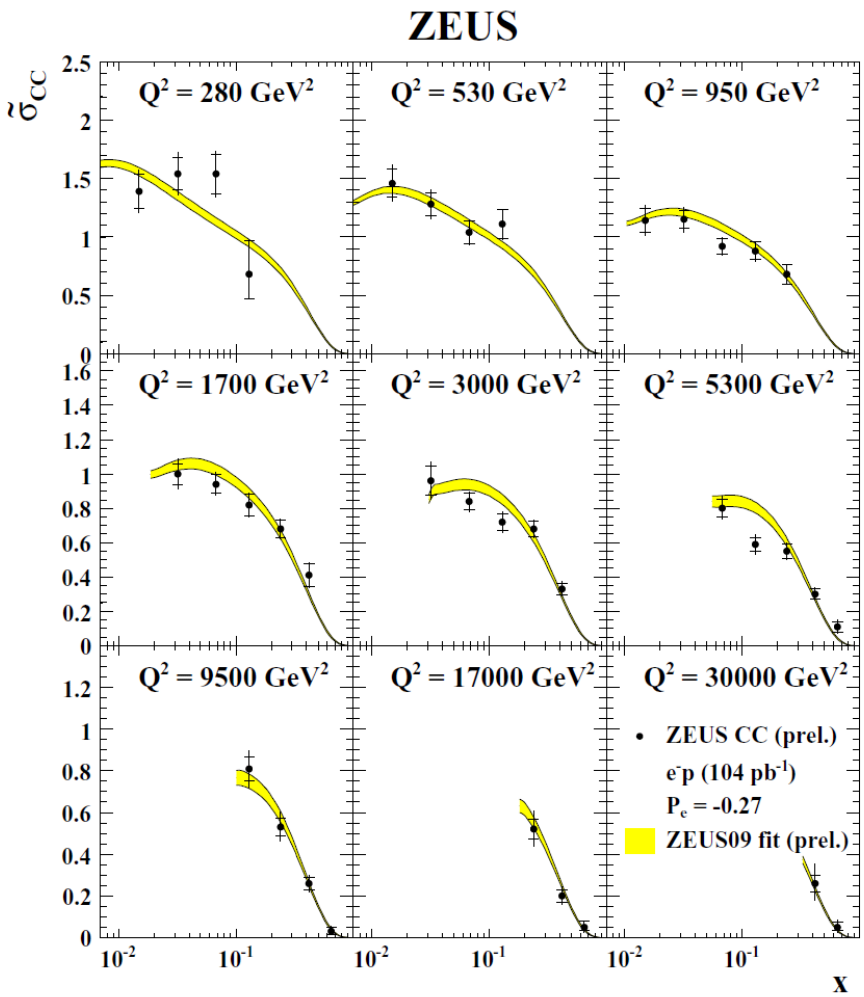
Data: DESY-08-177

71pb$^{-1}$ with P = +0.30 and 104pb$^{-1}$ with P = -0.27

Also showing the new ZEUS PDF fit which includes these data

Fit: ZEUS-prel-09-010




CC e- 04-06 (final) DESY-08-177

# For NC e+ and e-

$$\frac{d^2\sigma(e^{\pm}N)}{dxdy} = \frac{2\pi\alpha^2 s}{Q^4}\, Y_+ \left[ F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2) \pm \frac{Y_-}{Y_+} xF_3(x,Q^2) \right], \quad Y_\pm = 1 \pm (1-y)^2$$

reduced cross-section

## For NC processes unpolarised

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

$xF_3 = - a_e P_Z xF_3^{\gamma Z} + 2 v_e a_e P_Z^2 xF_3^{Z}$

Where $P_Z^2 = Q^2/(Q^2 + M^2_Z)\ 1/\sin^2\theta_W$, and at LO

$[F_2, F_2^{\gamma Z}, F_2^{Z}] = \Sigma_i\ [e_i^2, 2e_i v_i, v_i^2+a_i^2][xq_i(x,Q^2) + \bar{xq}_i(x,Q^2)]$

$[xF_3^{\gamma Z}, xF_3^{Z}] = \Sigma_i\ [e_i a_i, v_i a_i] \qquad [xq_i(x,Q^2) - \bar{xq}_i(x,Q^2)]$

So that $xF_3^{\gamma Z} = 2x[e_u a_u u_v + e_d a_d d_v] = x/3\ (2u_v+d_v)$

Where $xF_3^{\gamma Z}$ is the dominant term in $xF_3$

The difference between e+ and e- cross-sections gives the valence structure function xF3 due to $\gamma$/Z interference and Z exchange

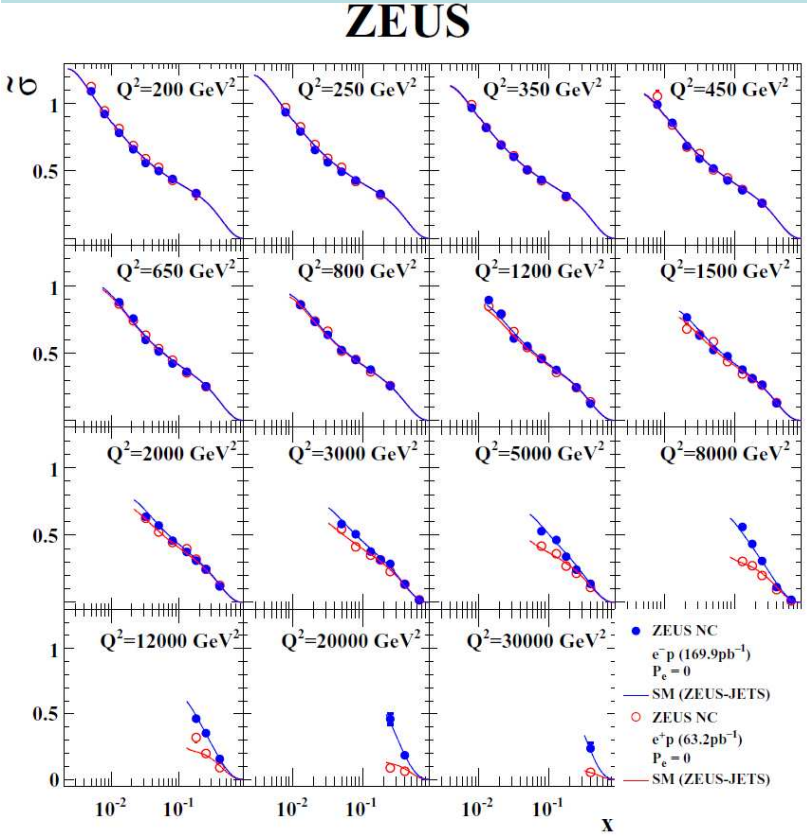
Note this is obtained on a pure proton target so

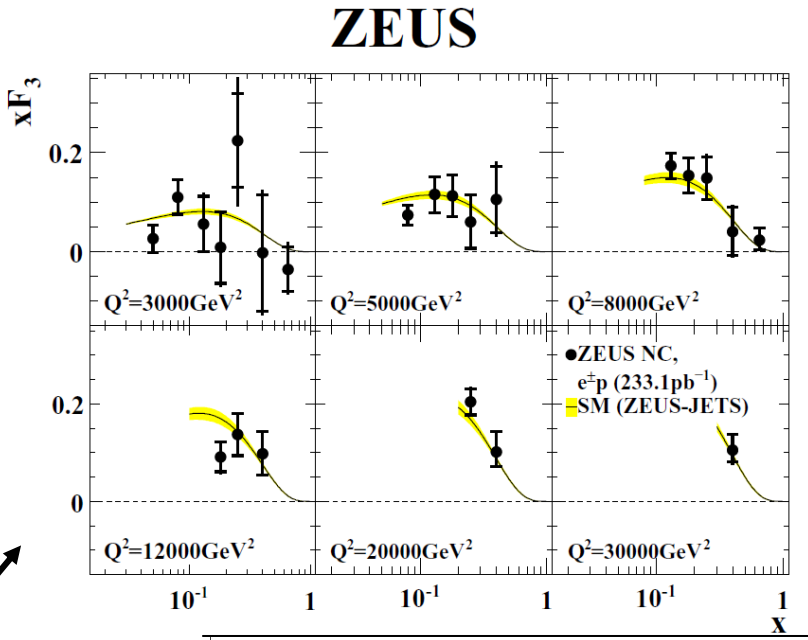
- No heavy target corrections
- No assumptions on strong isospin

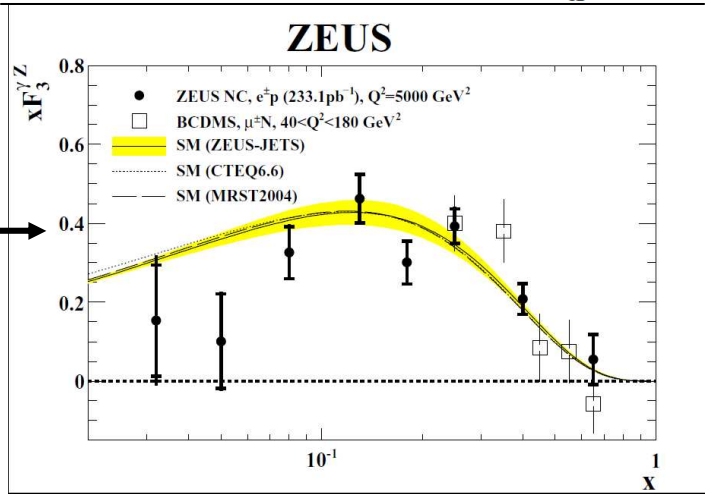
(Unlike xF3 determined from neutrino scattering on heavy isocalar targets)

# 160pb$^{-1}$ NEW NC e-p data: first combine the polarisations to look at unpolarised cross-sections

DESY-08-202




Compare these NEW e- NC data with HERA-I e+ NC data and use these two data sets to extract xF3

Much improved xF3 compared to previous extraction which used only 16.4 pb$^{-1}$ of e- NC data

Measurements from 1500 to 30000 GeV$^2$ have been extrapolated to 5000 GeV$^2$ to measure $xF_3^{\gamma Z}$ and compare to BCDMS at high-x

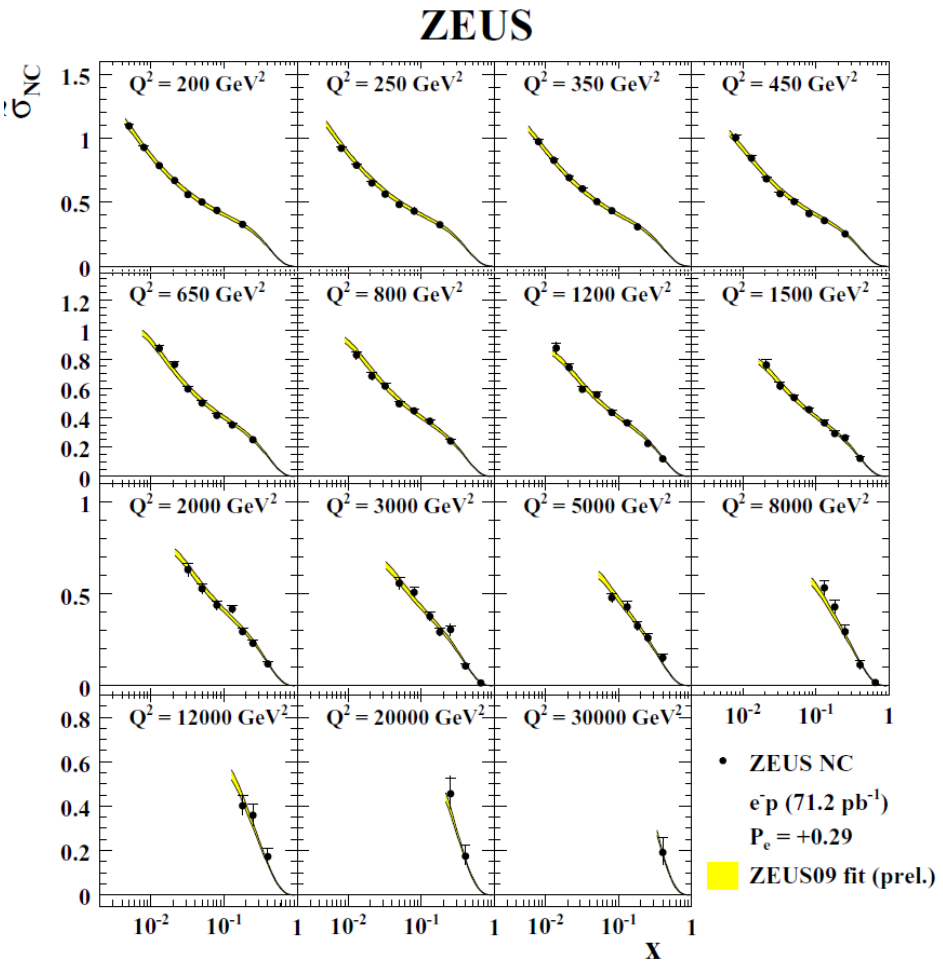
# NCe-p double differential cross-sections for positive and negative polarisation separately.

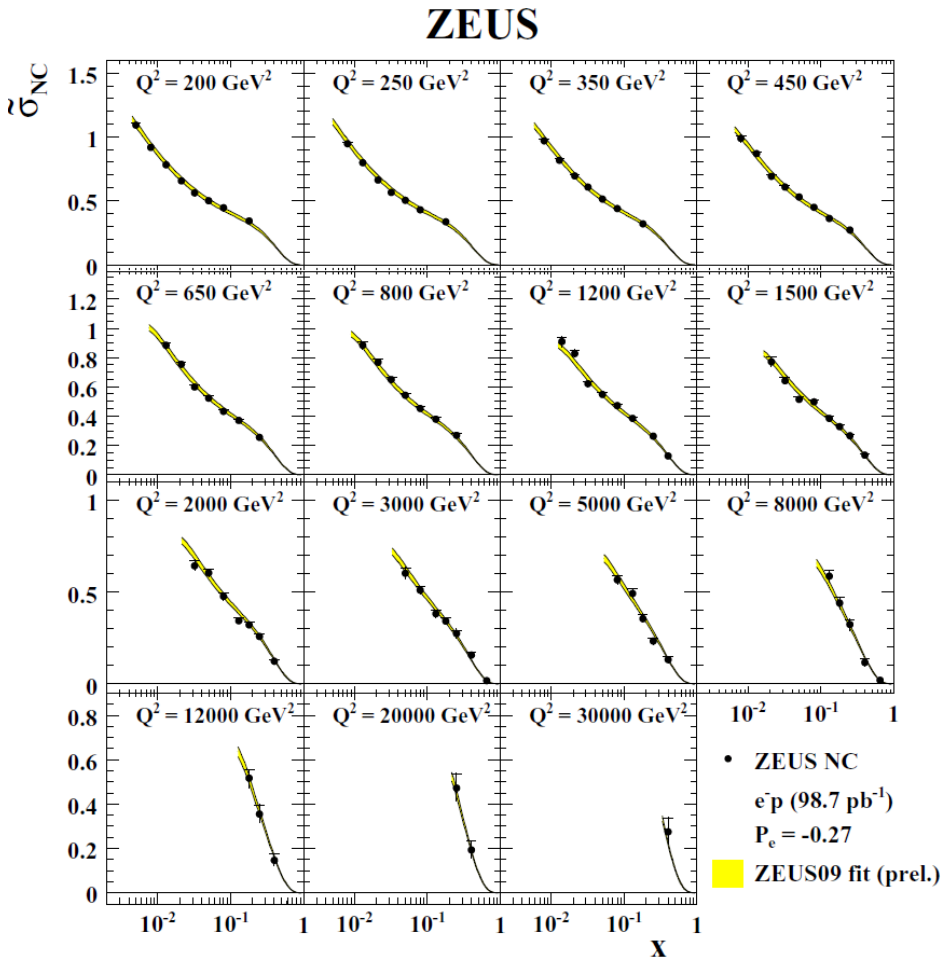
Data: DESY-08-202

71pb$^{-1}$ with P = +0.29 and 99pb$^{-1}$ with P = -0.27

Also showing the new ZEUS PDF fit which includes these data

Fit: ZEUS-prel-09-010




NC e- 05-06 (final) DESY-08-202

For NC processes polarised, polarisation $P=(N_R-N_L)/N_R+N_L)$

$$F_2 = F_2^{\gamma} - (v_e - P\, a_e)\, P_Z\, F_2^{\gamma Z} + (v_e^2 + a_e^2 - 2P\, v_e a_e)\, P_Z^2\, F_2^{Z}$$
$$xF_3 = -(a_e - P\, v_e)\, P_Z\, xF_3^{\gamma Z} + (2v_e a_e - P(v_e^2 + a_e^2)\, P_Z^2\, xF_3^{Z}$$

Where $P_Z^2 = Q^2/(Q^2 + M^2_Z)\ 1/\sin^2\theta_W$, and at LO

$$[F_2, F_2^{\gamma Z}, F_2^{Z}] = \Sigma_i\, [e_i^2, 2e_i v_i, v_i^2 + a_i^2][xq_i(x,Q^2) + x\bar{q}_i(x,Q^2)]$$

$$[xF_3^{\gamma Z}, xF_3^{Z}] = \Sigma_i\, [e_i a_i, v_i a_i] \qquad [xq_i(x,Q^2) - x\bar{q}_i(x,Q^2)]$$

Because $P_Z >> P_Z^2$ and $v_e$ is very small the Polarisation Asymmetry

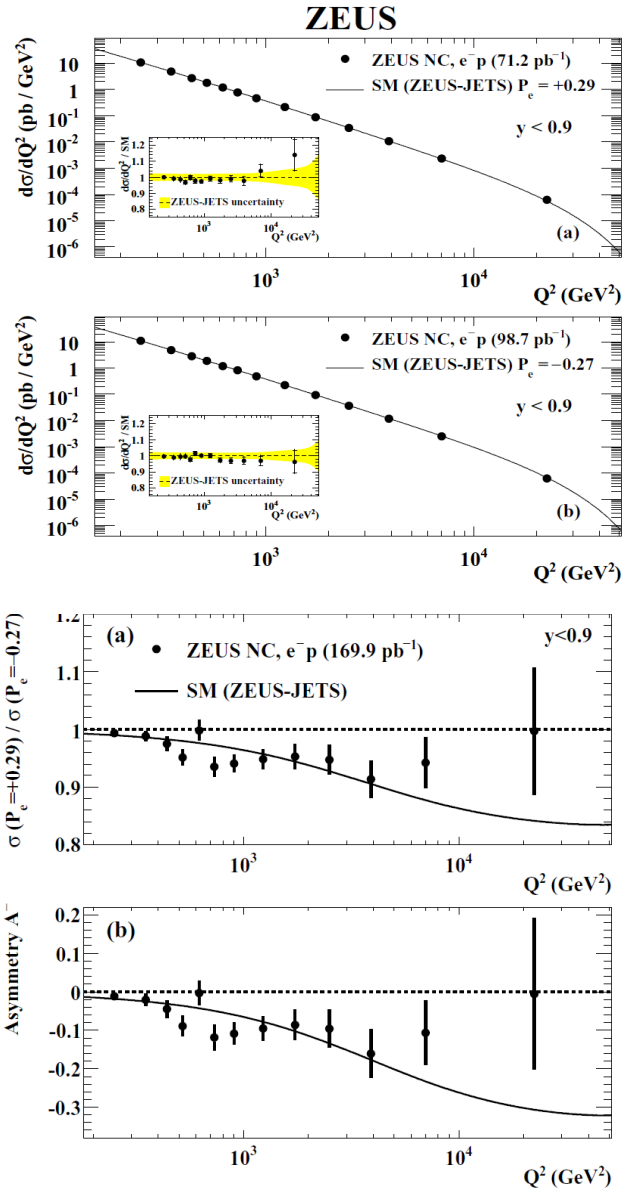
$$A = \frac{\sigma(P=1) - \sigma(P=-1)}{\sigma(P=1) + \sigma(P=-1)} \sim \frac{P_Z\, a_e\, F_2^{\gamma Z}}{F_2^{\gamma}} = \frac{P_Z\, 2a_e v_i e_i}{e_i^2} \sim a_e v_i$$

Tests the EW sector of the SM with minimal sensitivity to parton PDFs

# NC e-

To see the effect of polarisation more clearly compare NCe- and NCe+

# NC e+

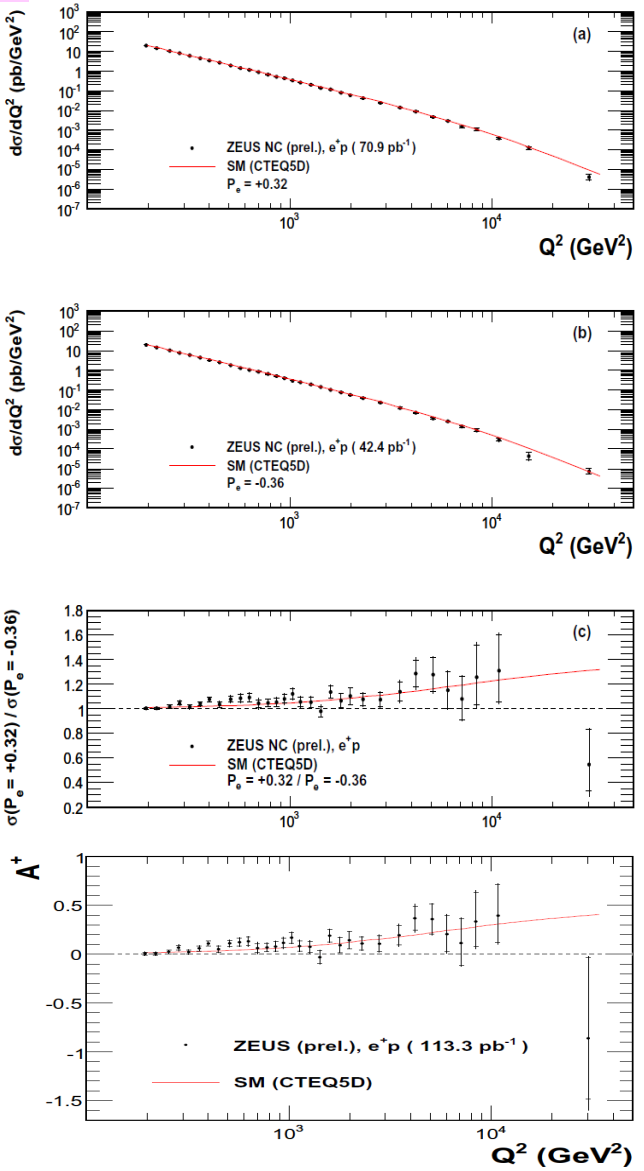



NEW 113pb-1 NC e+ →

71pb$^{-1}$ with P = +0.32

42pb$^{-1}$ with P = -0.36

Look at the single differential cross-section as a function of $Q^2$ for positive and negative polarisations. Compare the ratio and extract the Asymmetry to see the effect of polarisation



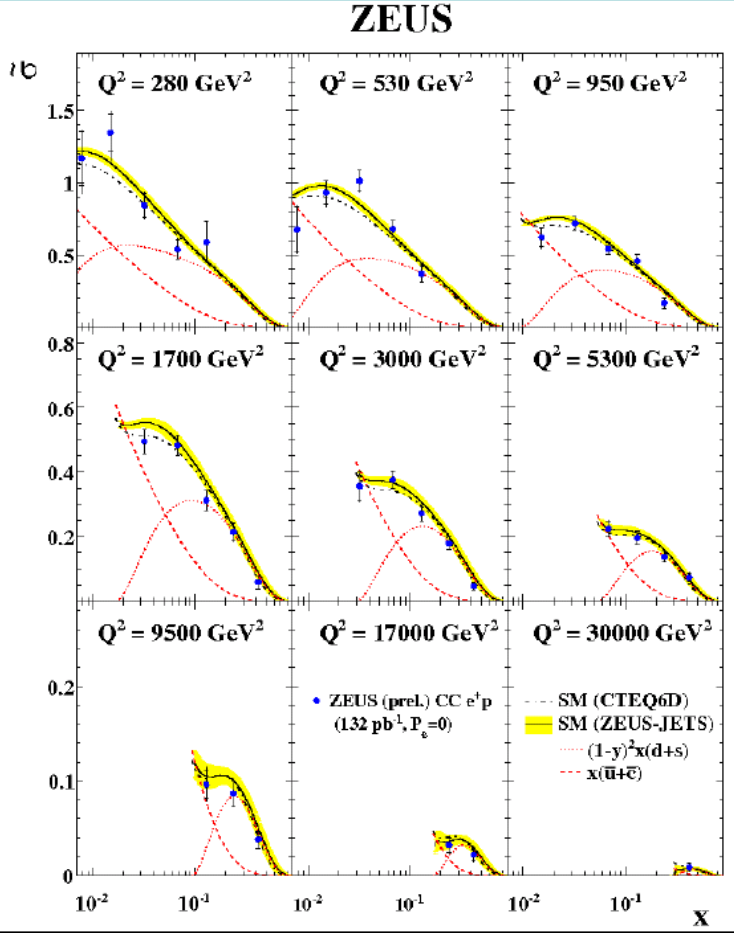

Note the opposite effect of the polarisation comparing e+ and e-

DESY-08-202

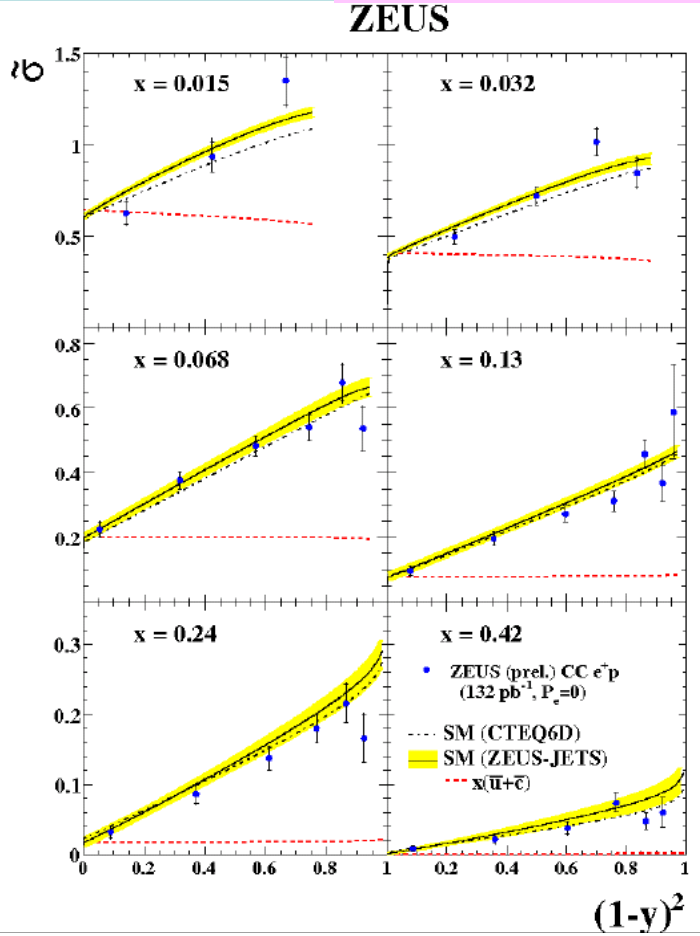
ZEUS-prel-08-005

# HOT OF THE PRESS 132pb$^{-1}$ NEW CC e+ data: first combine the polarisations to look at unpolarised cross-sections

ZEUS-prel-09-002

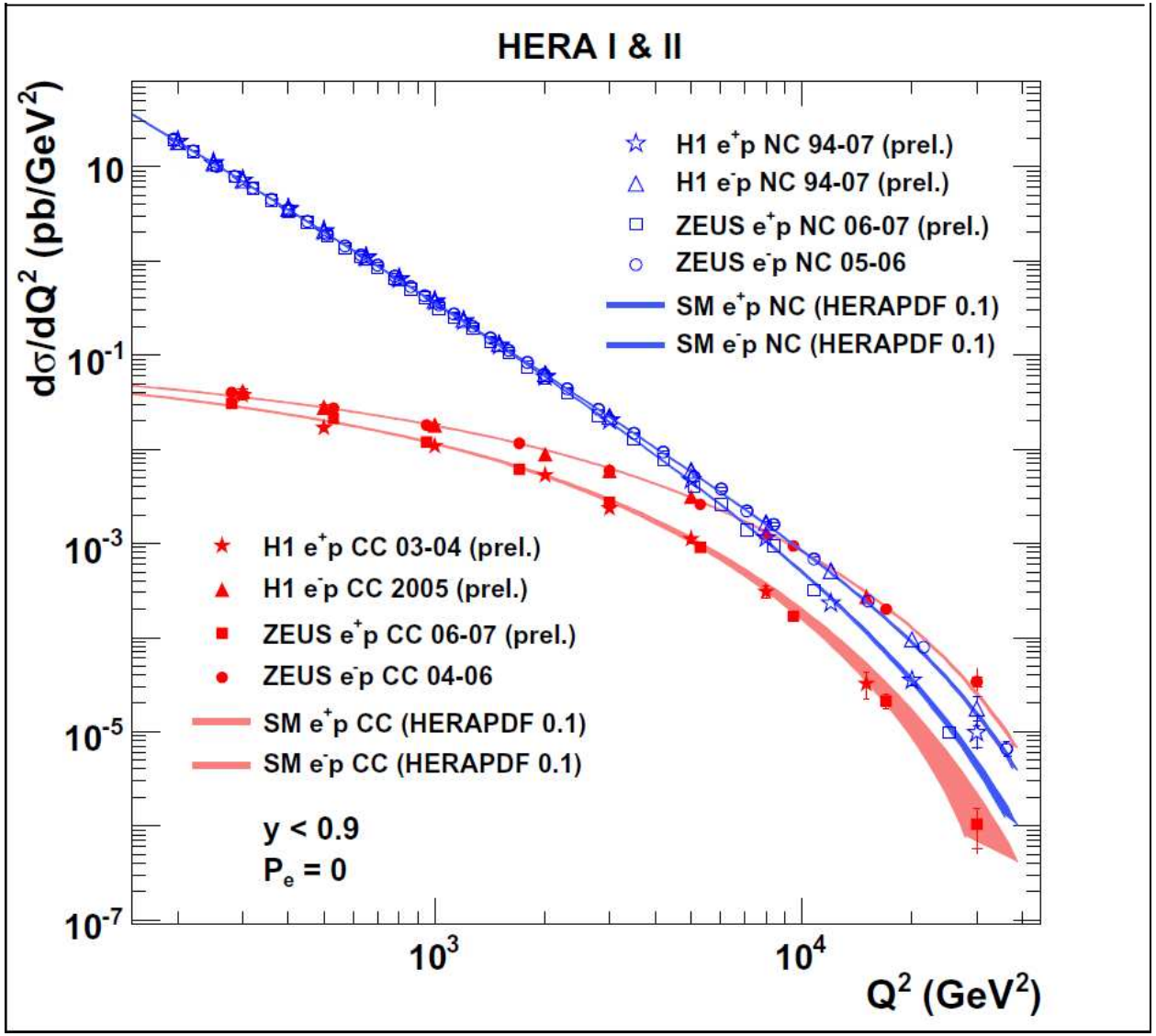



This shows the reduced cross-section vs x in Q2 bins, emphasizing the role of quark and anti-quark PDF flavours. These cross-sections are dominated by d at high-x, Q2




This shows the reduced cross-section vs $(1-y)^2$ in x bins, emphasizing the helicity structure of the interaction

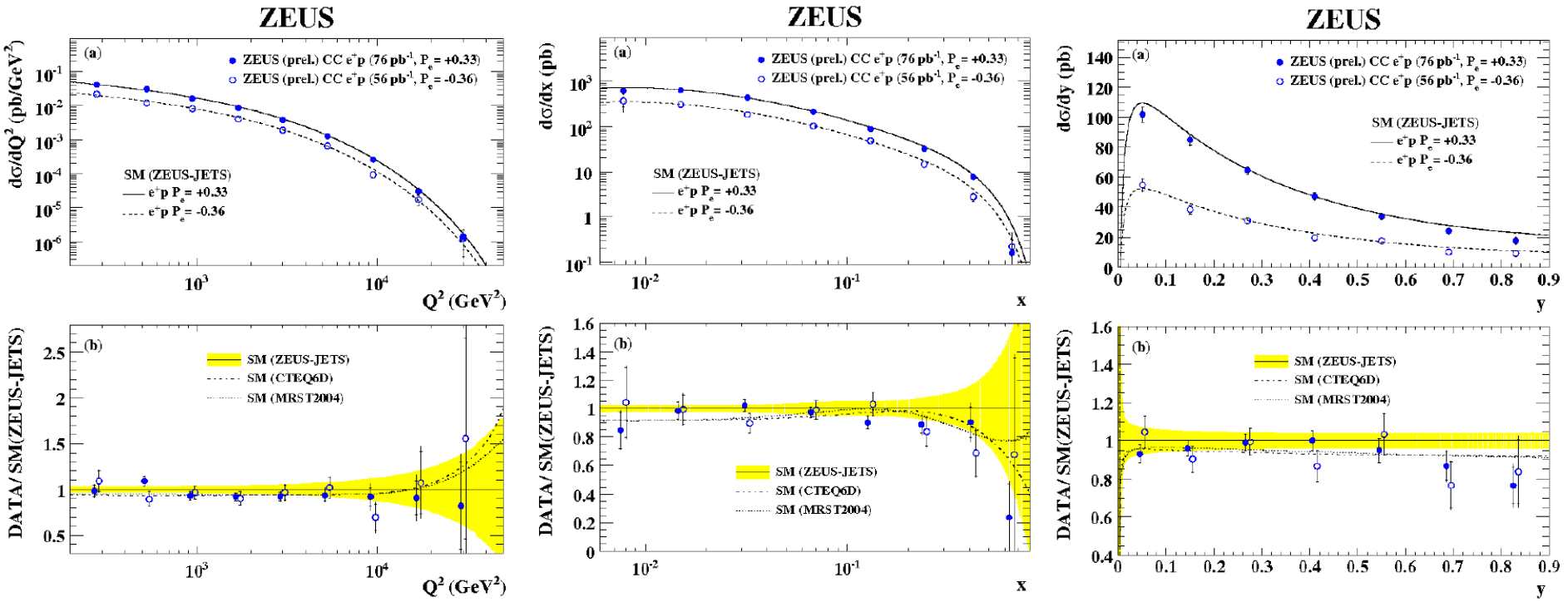
# These data are used to update the HERA $d\sigma/dQ^2$ plot



Now consider positive and negative polarisation separately

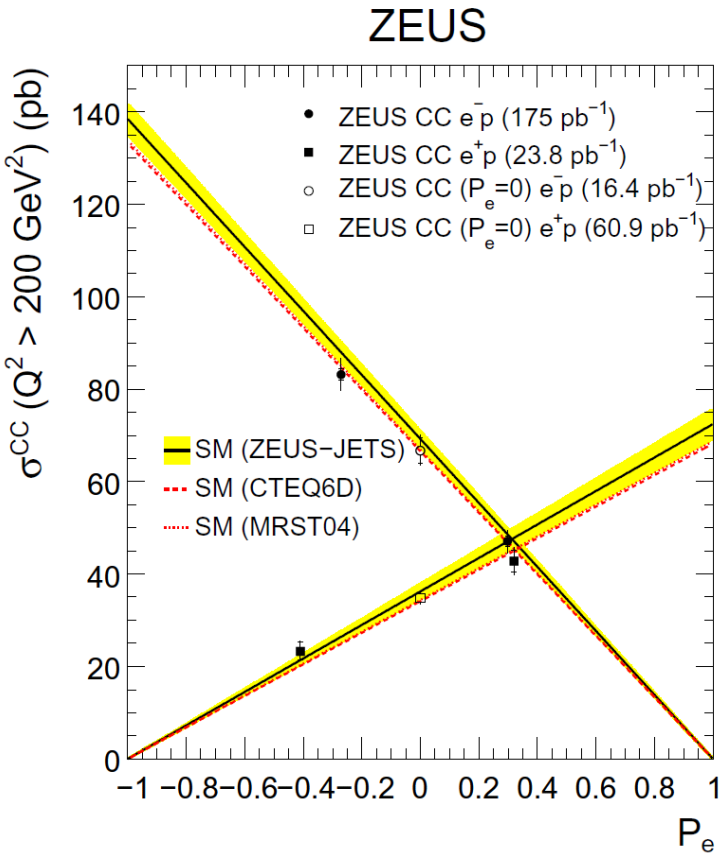
ZEUS-prel-09-002

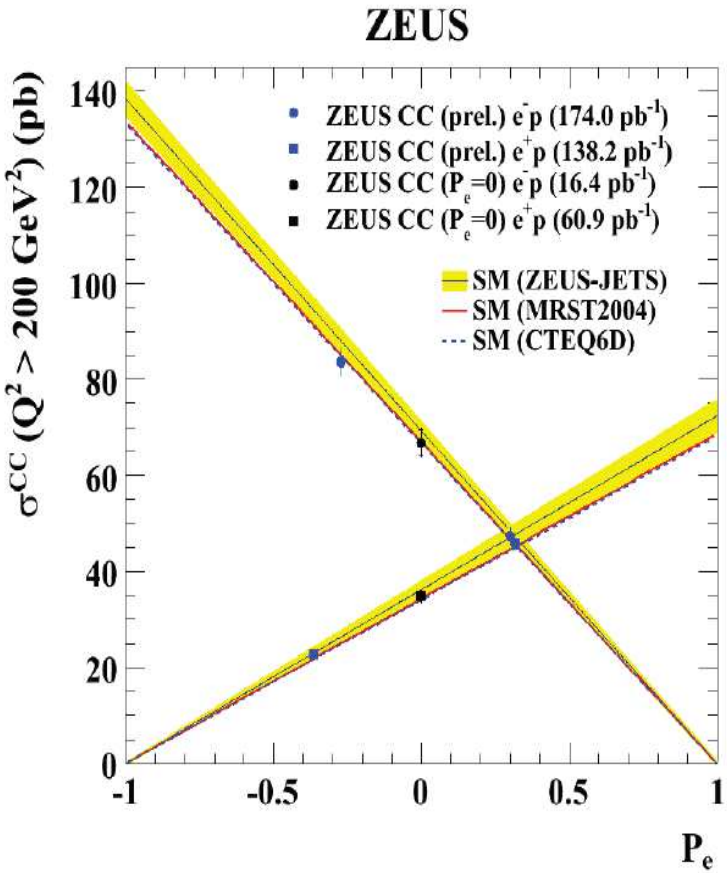
CC e+ data: $76pb^{-1}$ with P = +0.33 and $56pb^{-1}$ with P = -0.36




Single differential cross-sections vs $Q^2$, x, y for positively and negatively polarised data are compared to SM predictions calculated using ZEUS-JETS, CTEQ6D, MRST2004

# These data are used to update the plot of the CC e+ and e- cross-sections vs polarisation




First shown EPS07, not updated

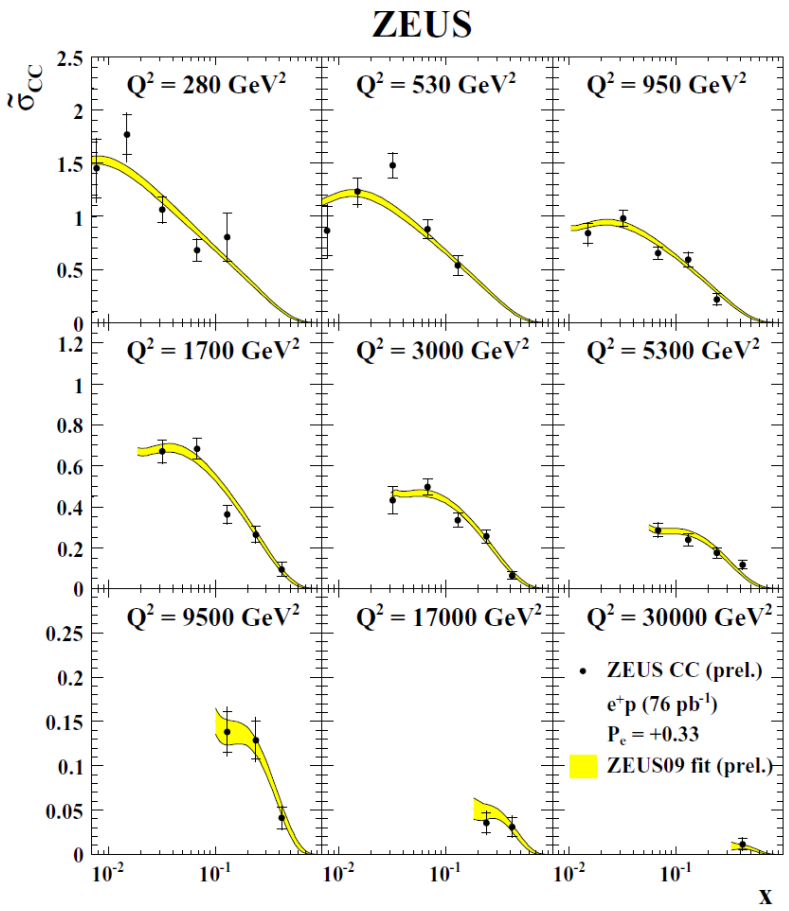
# CCe+p double differential cross-sections for positive and negative polarisation separately.

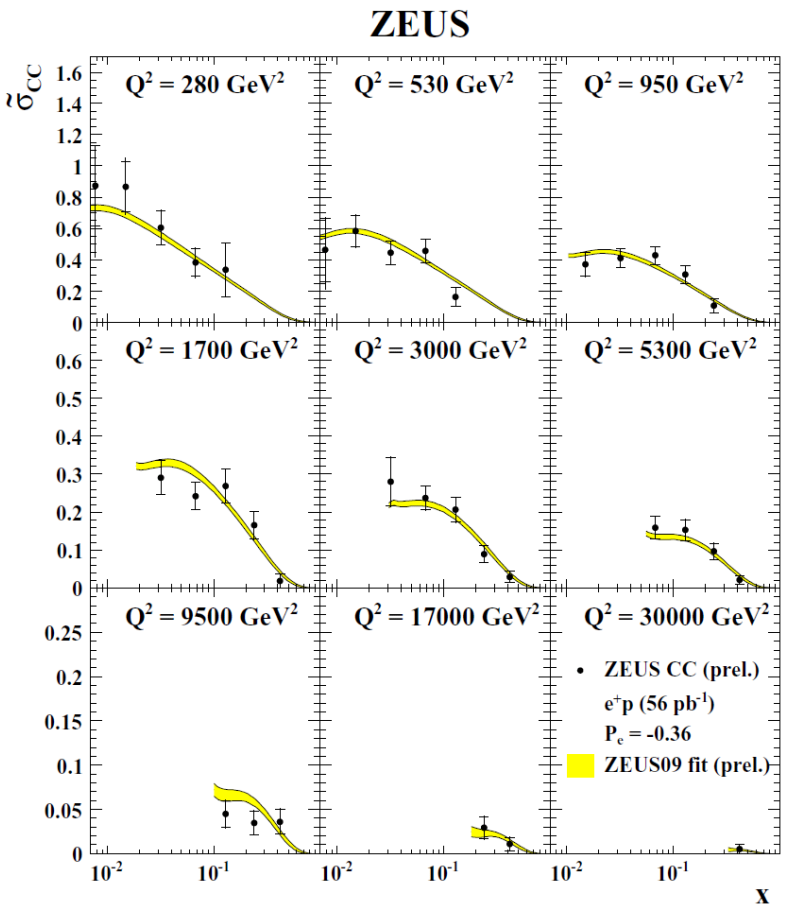
Data: ZEUS-prel-09-002

76pb$^{-1}$ with P = +0.33 and 56pb$^{-1}$ with P = -0.36

Also showing the new ZEUS PDF fit which includes these data

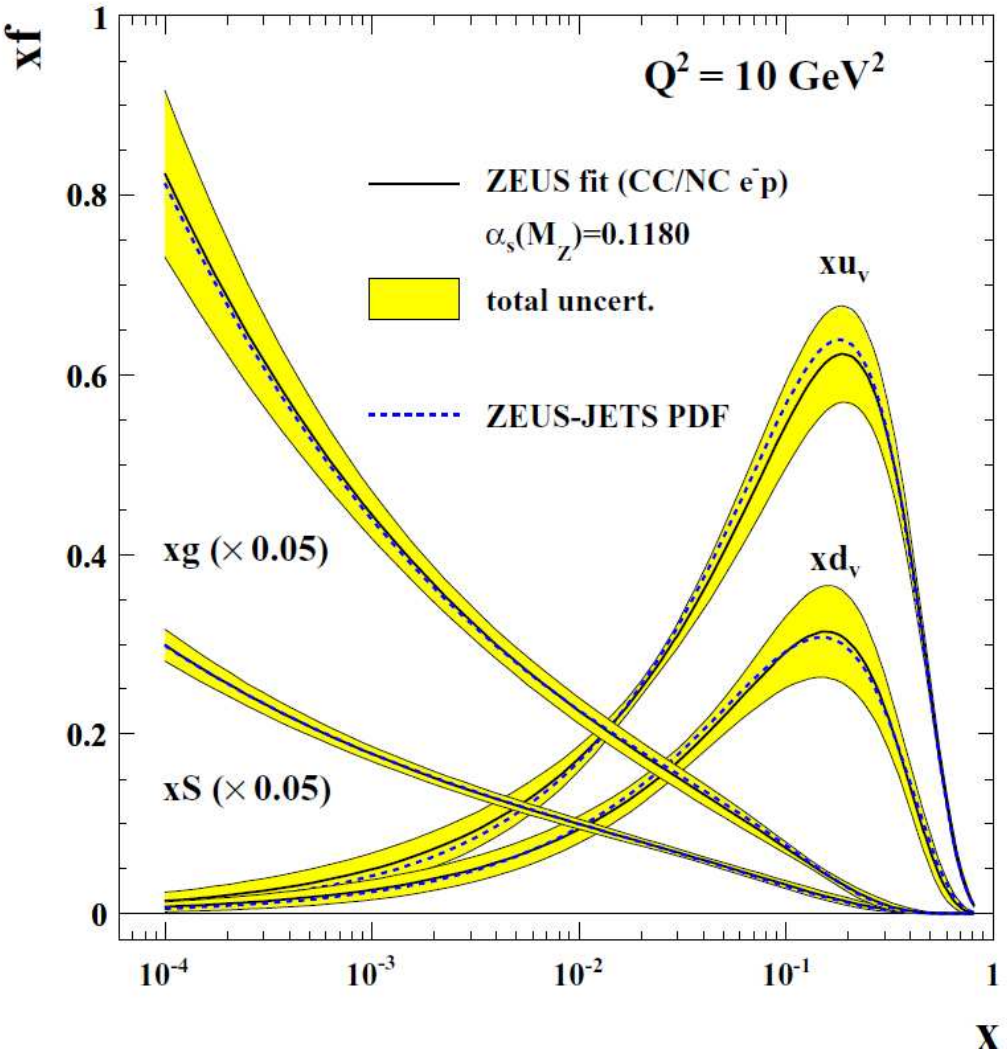
Fit: ZEUS-prel-09-010




CC e+ 06-07 (prel) ZEUS-prel-09-002

# Impact of adding final NEW NC and CCe- data to ZEUS-JETS fit




This takes 577 data points up to 828 data points

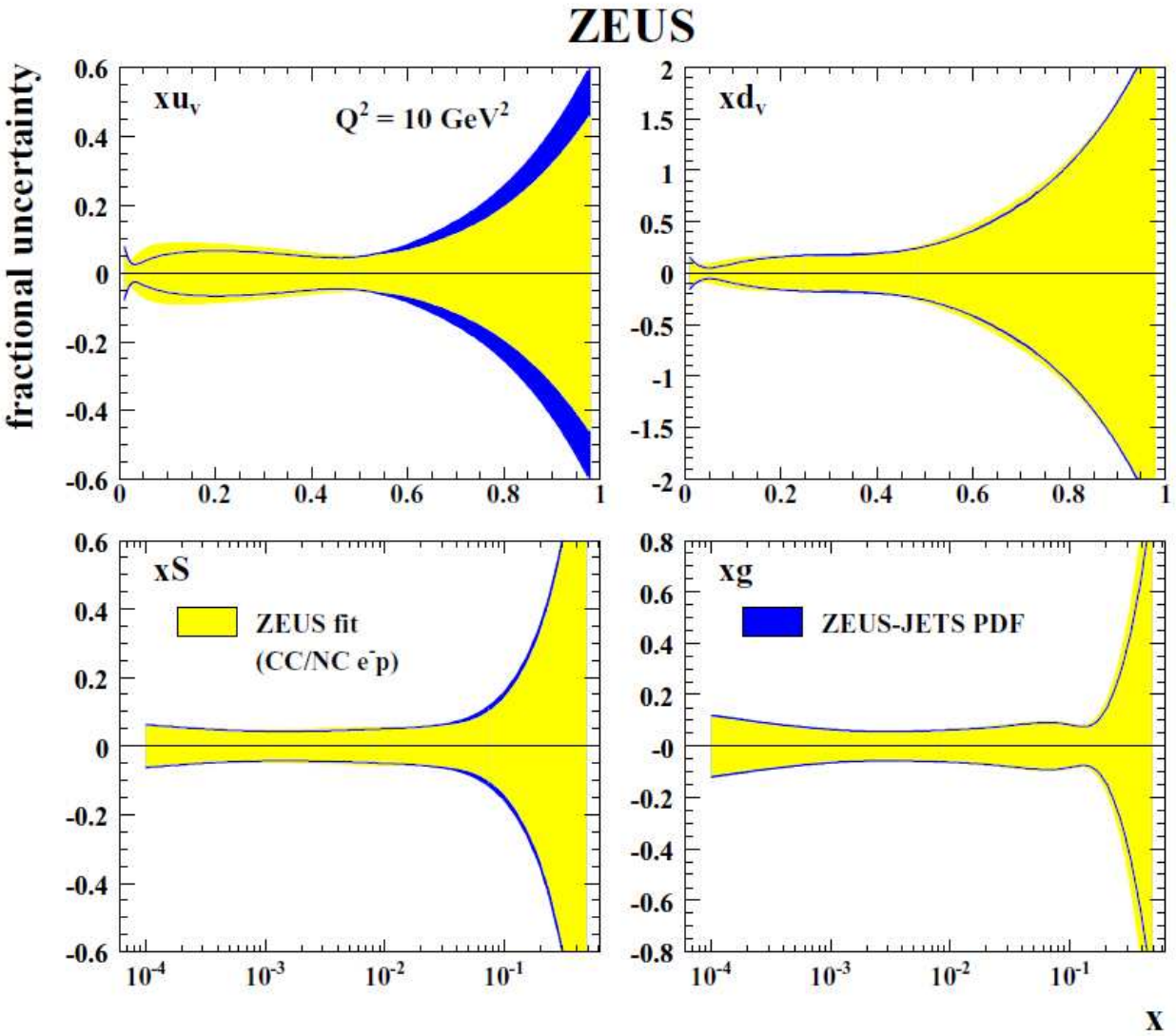
**Quadratic $\chi^2$**

| Dataset | $\chi$2/ndp | ndp |
|---|---|---|
| CC e-p P=- | 1.39 | 37 |
| CC e-p P=+ | 0.97 | 34 |
| NC e-p P=- | 1.00 | 90 |
| NC e-p P=+ | 0.95 | 90 |

PDFs from a new ZEUS PDF fit including NEW NC/CC e-p data compared to ZEUS-JETS PDFs central values of the PDFs do not change much…..

ZEUS-prel-09-010

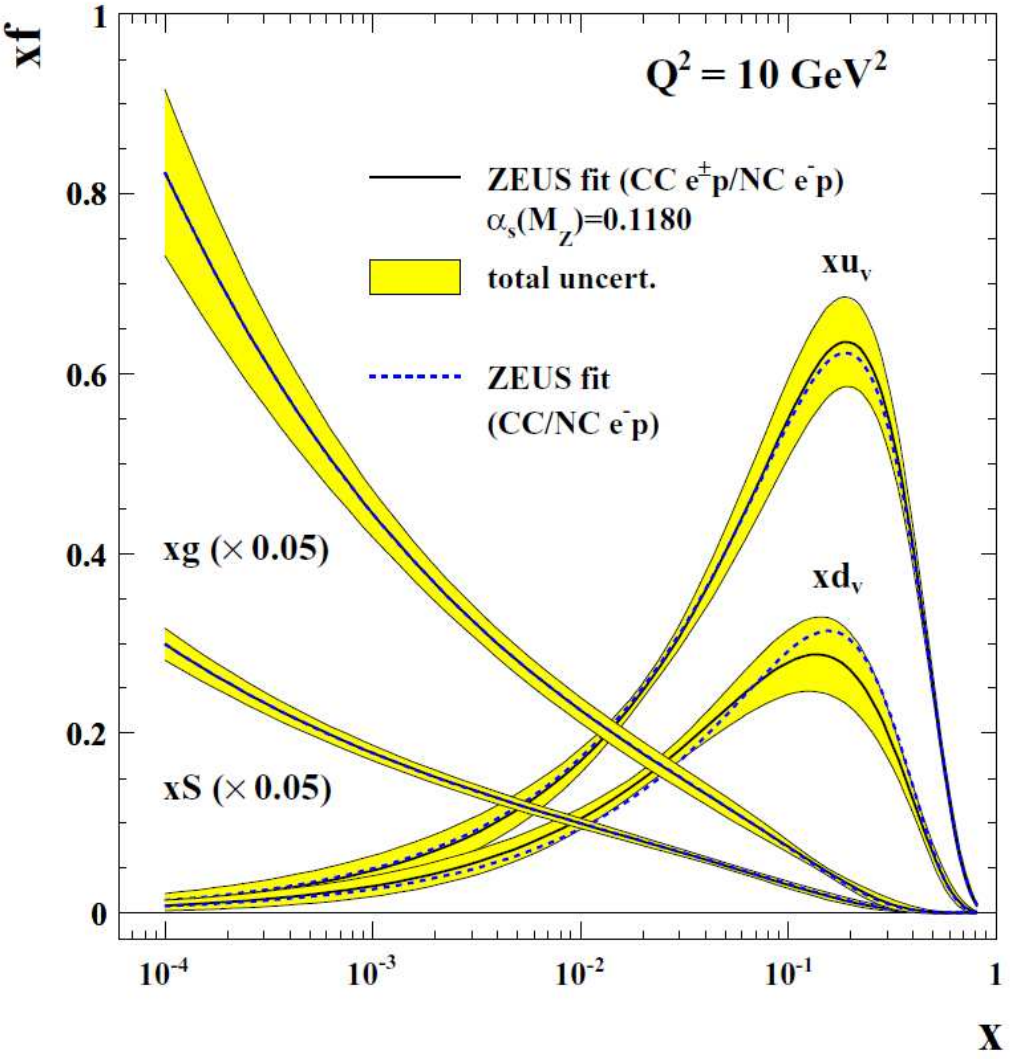
# Impact of adding final NEW NC and CCe- data to ZEUS-JETS fit




The impact is felt on the u-valence PDF at high-x. This is as expected since both CC and NC e- data are u-dominated at high-x and the new data have statistical impact at higher $Q^2$, x

ZEUS-prel-09-010

# Impact of adding preliminary NEW CCe+ data to the fit




This takes 828 data points up to 893 data points

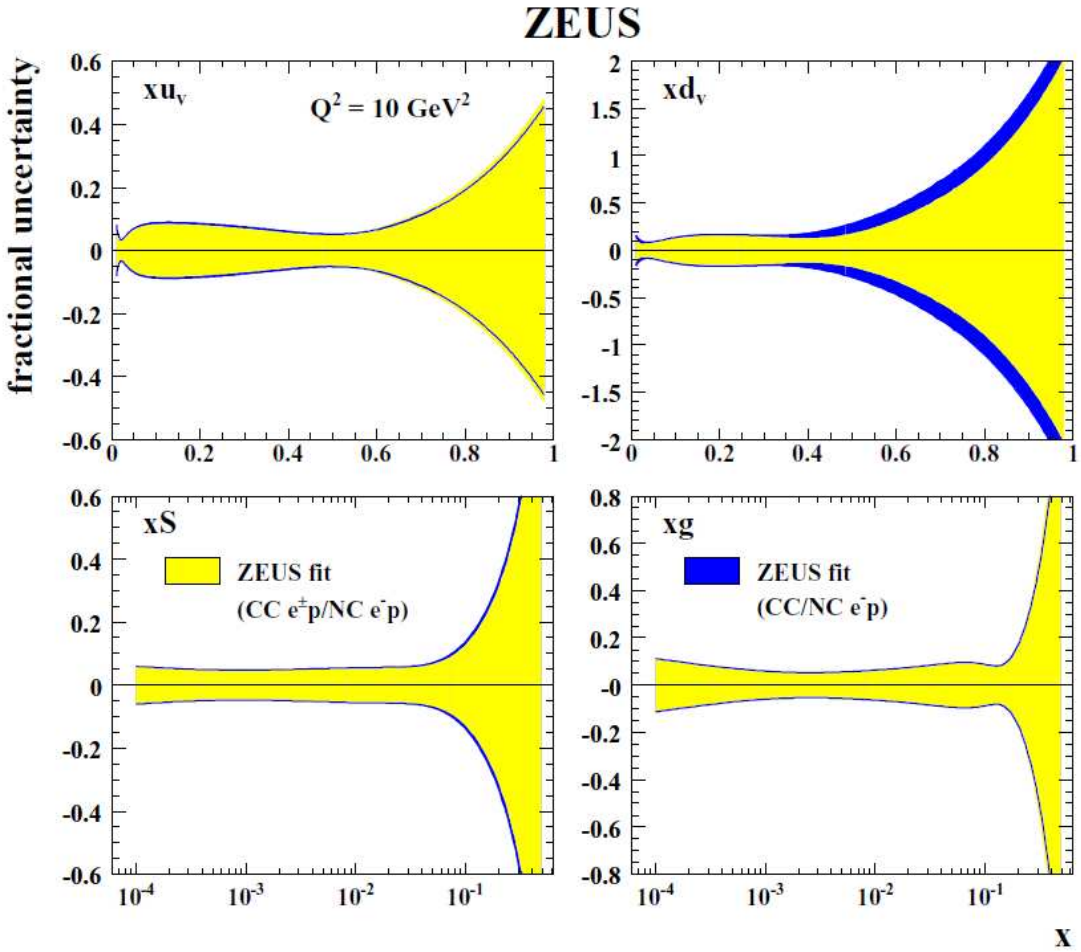
**Quadratic $\chi^2$**

| Dataset | $\chi$2/ndp | ndp |
|---|---|---|
| CC e-p P=- | 1.43 | 37 |
| CC e-p P=+ | 0.99 | 34 |
| NC e-p P=- | 1.00 | 90 |
| NC e-p P=+ | 0.95 | 90 |
| CC e+p P=- | 0.80 | 35 |
| CC e+p P=+ | 1.25 | 35 |

PDFs from a new ZEUS PDF fit including NEW CC e+p data and NC/CCe-p data compared to the fit including only NC/CCe-p data in ZEUS-JETS fit analysis..
central values of d-valence shift a little…..

ZEUS-prel-09-010

# Impact of adding preliminary NEW CCe+ data to the fit




The impact is felt on the d-valence PDF at high-x.

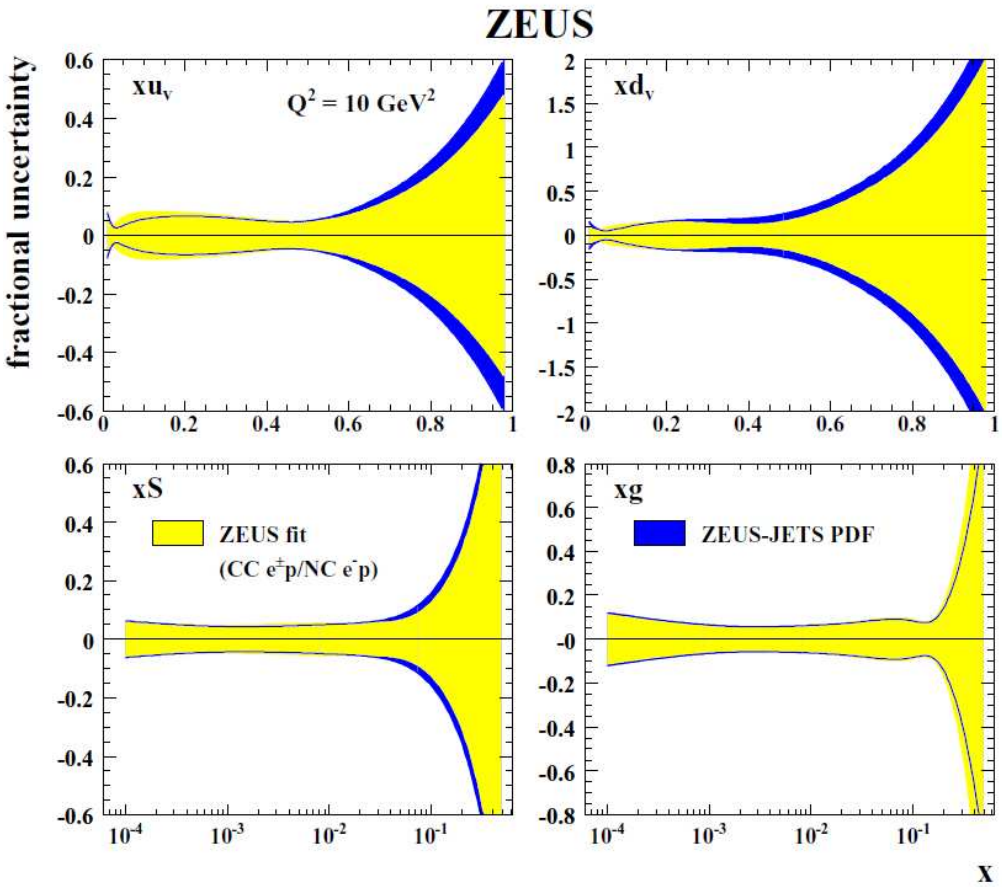
This is as expected since both CC e+ data is d-dominated at high-x and the new data have statistical impact at higher $Q^2$, x

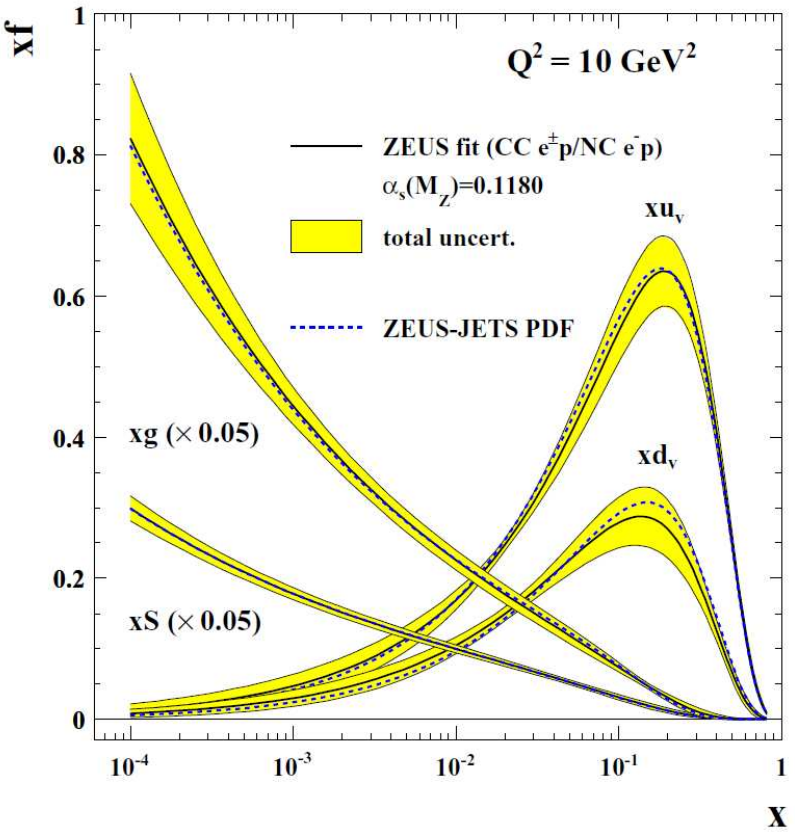
Note this is obtained on a pure proton target so it is a measurement of the d- PDF with

- No heavy target corrections
- No assumptions on strong isospin
- (Unlike xF3 determined from neutrino scattering on heavy isocalar targets)

ZEUS-prel-09-010

# Impact of adding all NEW data NC/CC e- and CC e+ to the fit



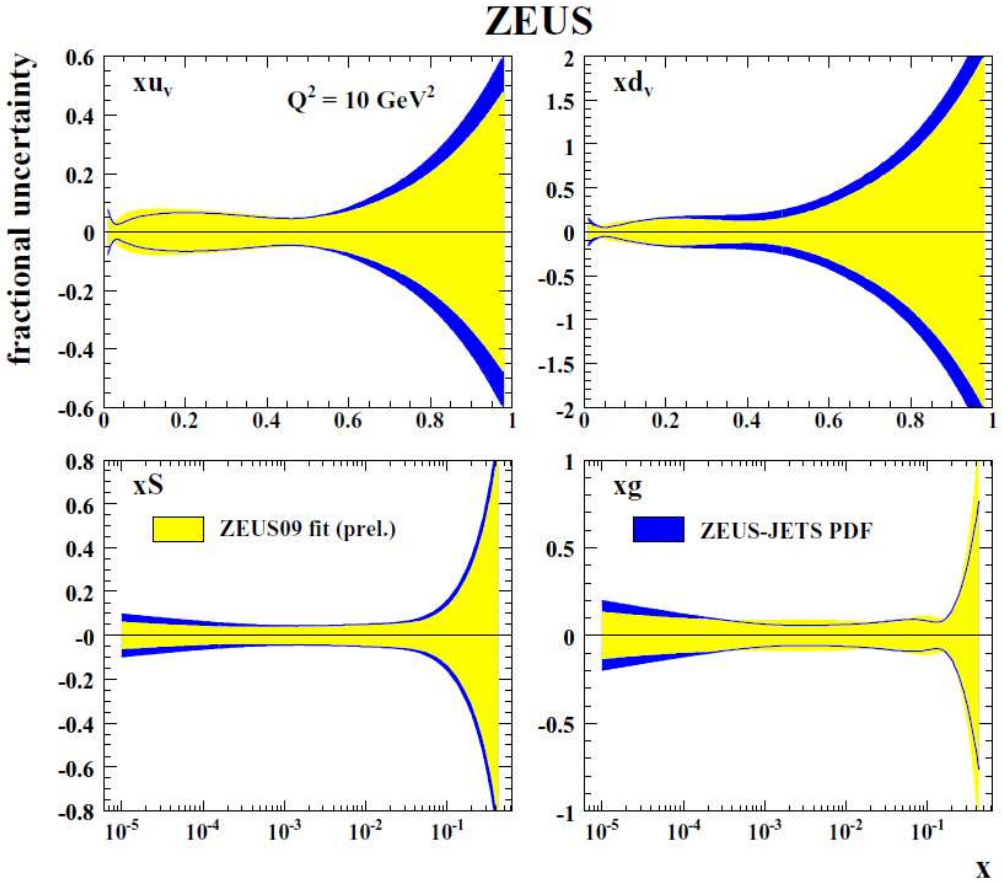



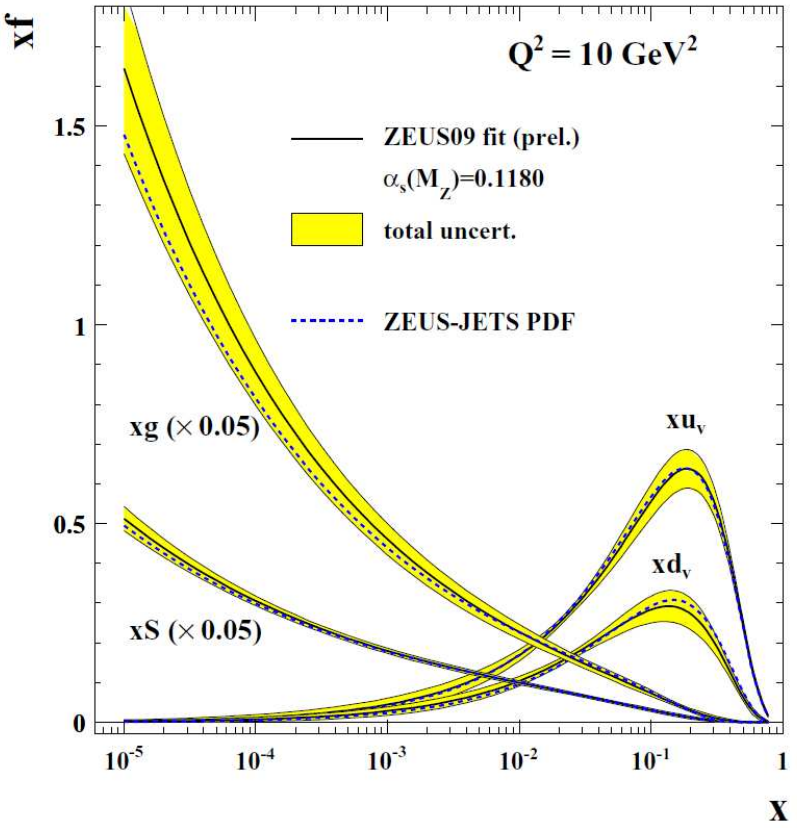

NEW ZEUS PDF fit including new NC e- and CC e- data and prel. CC e+ data compared to ZEUS –JETS PDF fit.

In the talk of J Grebenyuk ([44] 27/04/09) the data from the lower energy 'FL' running (DESY-09-046) are also added to this fit to make the ZEUS09 PDF fit….

ZEUS-prel-09-010

Impact of adding all NEW data: HERA-II NC/CC e-/CC e+ and HER (Ep=920,44.5pb$^{-1}$), MER (Ep=575, 7.1pb$^{-1}$), LER (Ep=460, 14.0pb-1) : NC e+p 'FL' data to the ZEUS-JETS fit




ZEUS-prel-09-010

# Summary

There is NEW published data on NC and CC e-p scattering from HERA-II from running in 2004 and 2005

One can extract xF3 from the combination of this data with older NCe+ data

The effect of electron polarisation is clearly seen

The data have impact on the u-valence PDF

There is preliminary data on NC and CC e+p scattering from HERA-II from running in 2006 and 2007

The effect of positron polarisation is clearly seen

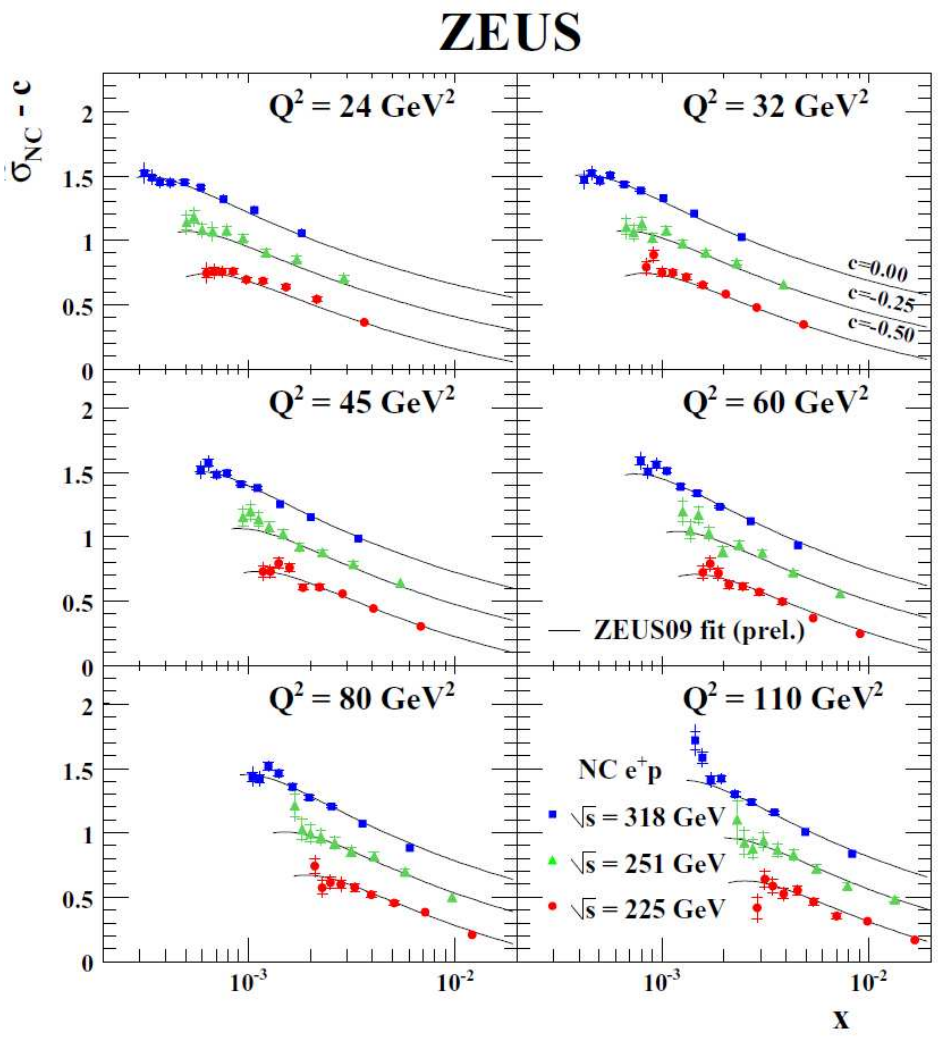
The CC e+ data have impact on the d-valence PDF
This d quark PDF extraction involves no nuclear corrections
or strong isospin assumptions

HER, MER, LER NCe+ data for the FL measurement

have impact on the low-x sea and gluon PDFs

# extras

Adding NC e+ data from HER, MER, LER running to the previous ZEUS-JETS+ HERA-II NC/CCe- and CCe+



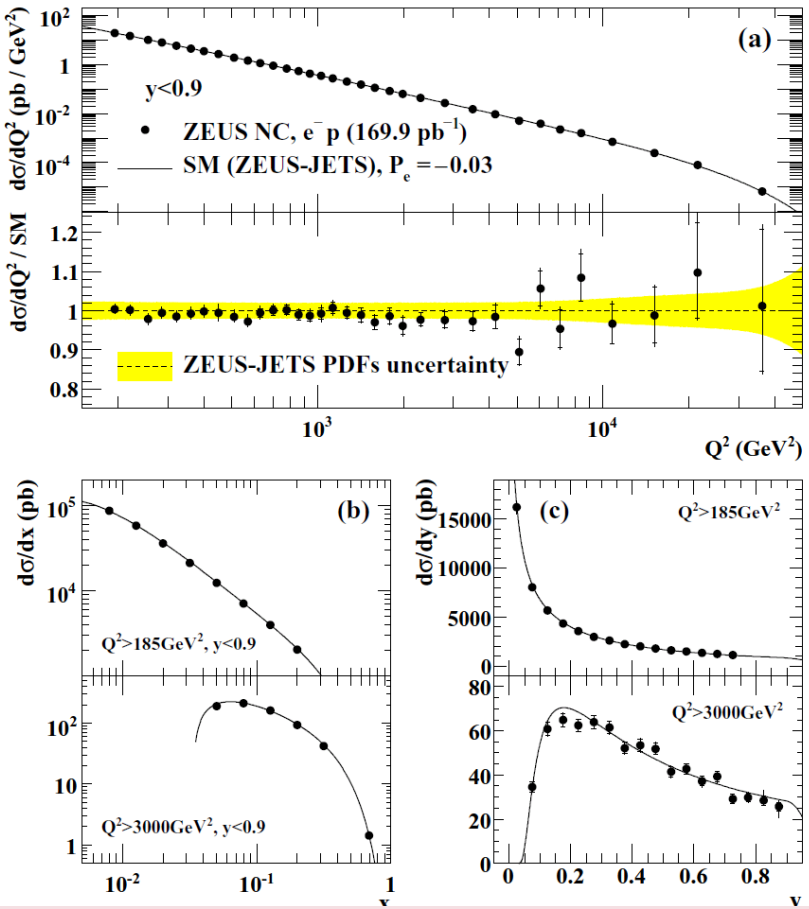

Quality of fit to ZEUS09 HER, MER, LER 'FL' data

This takes 898 data points up to 1060 data points

## Quadratic $\chi^2$

| Dataset | $\chi$2/ndp | ndp |
|---|---|---|
| CC e-p P=- | 1.43 | 37 |
| CC e-p P=+ | 0.99 | 34 |
| NC e-p P=- | 1.00 | 90 |
| NC e-p P=+ | 0.95 | 90 |
| CC e+p P=- | 0.80 | 35 |
| CC e+p P=+ | 1.25 | 35 |
| LER | 0.84 | 54 |
| MER | 0.73 | 54 |
| HER | 0.97 | 54 |

DESY-08-202

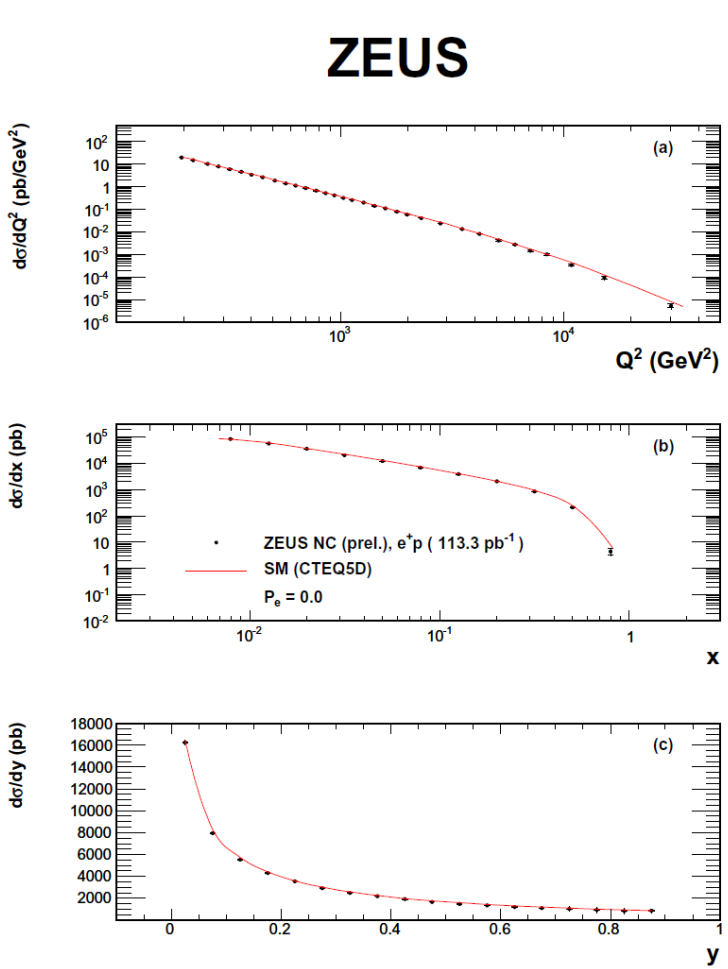


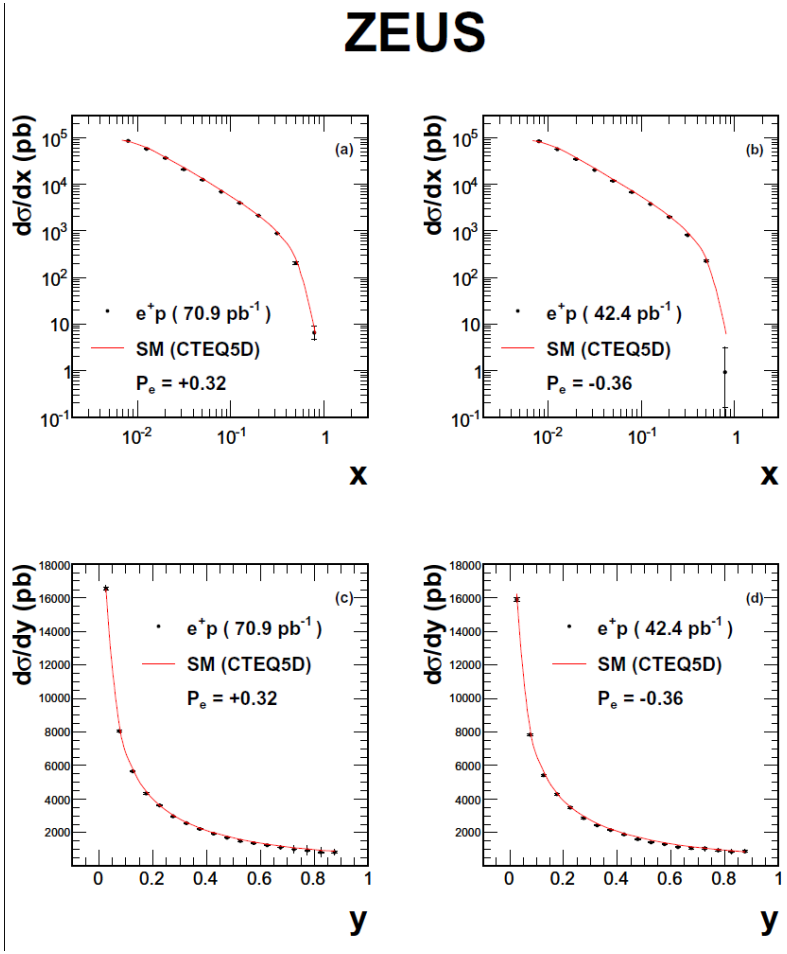

NEW NC e- single differential cross-sections vs $Q^2$, x, y data with net polarisation P = -0.03 compared to SM predictions calculated using ZEUS-JETS

Note that these data are not included in the PDF fits

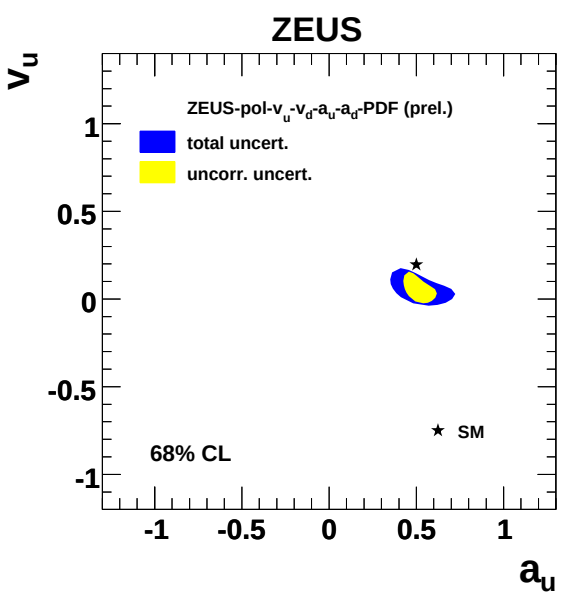
ZEUS-prel-08-005

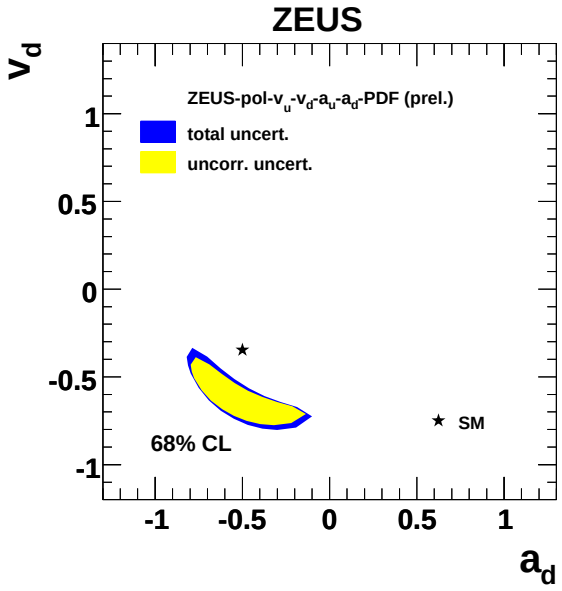
NEW 113pb$^{-1}$ NC e+ single differential cross-sections vs $Q^2$, x, y data with no net polarisation compared to SM predictions calculated using CTEQ5D

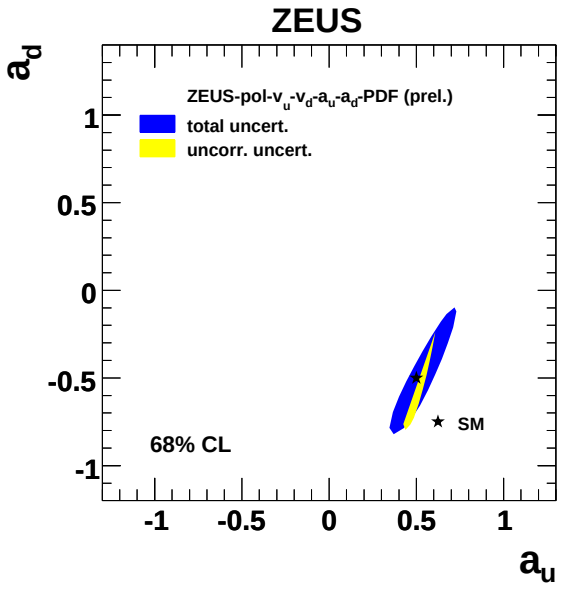


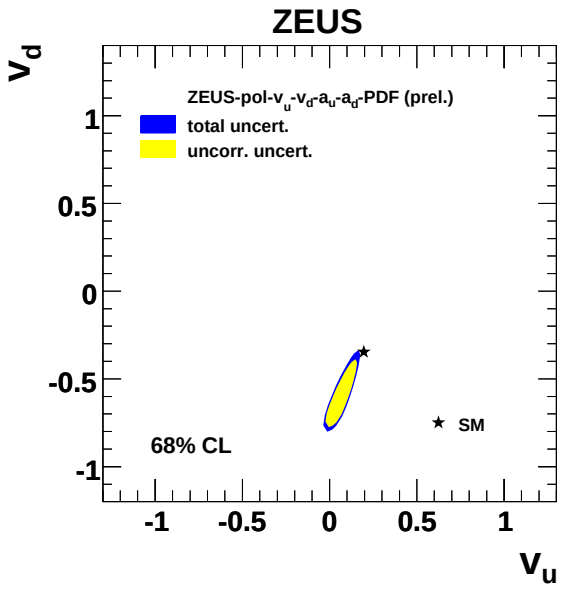



# au/vu ad/vd au/ad vu/vd contours: Prel Hera-II e-



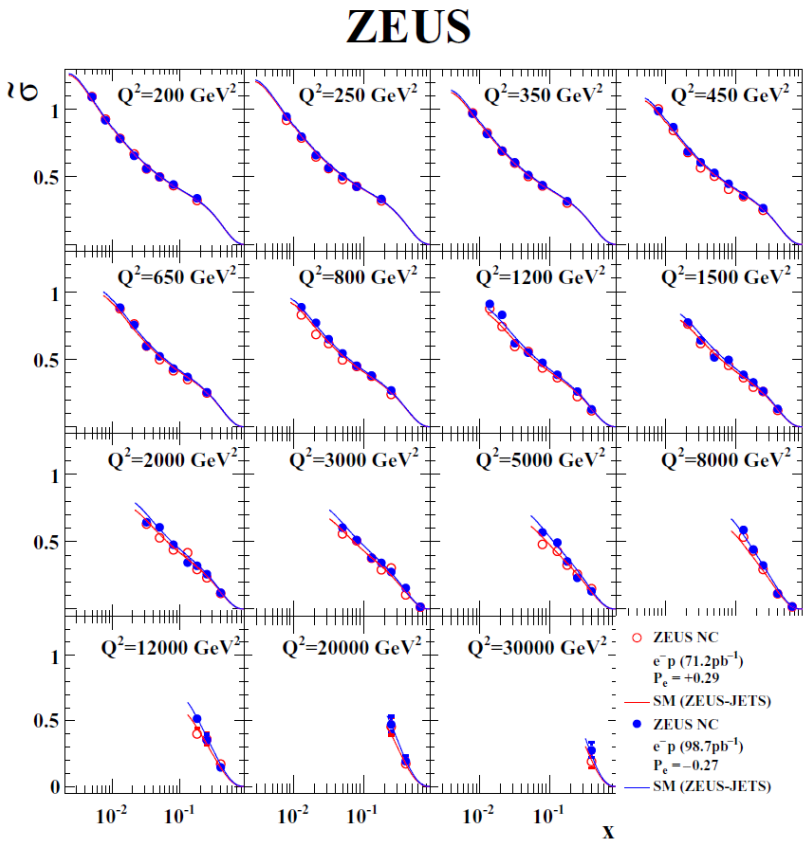



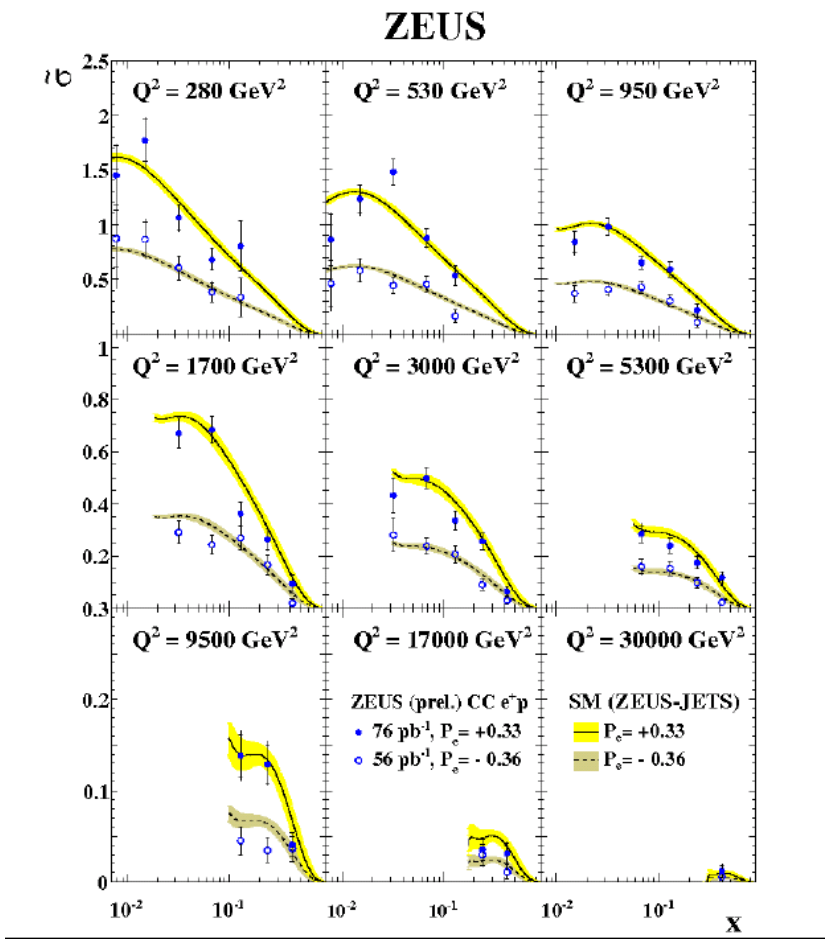




No update to this for DIS09

DESY-08-202

ZEUS-prel-09-002




These plots show the reduced cross-section vs x in Q2 bins for positive and negative polarisations separately compared to the ZEUS-JETS PDF fit for both NCe- and new CCe+. They come from the papers- I have replaced them in the talk by versions with the new fit on