High Q^2 neutral current results from ZEUS

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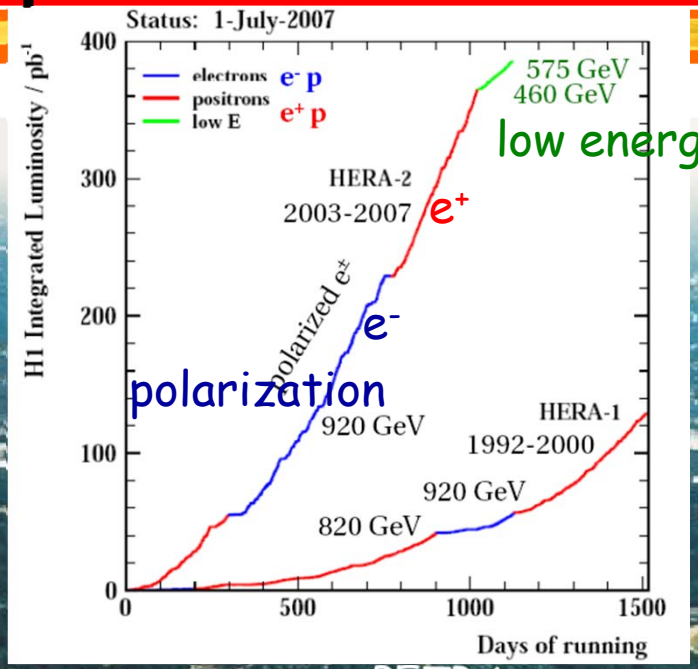
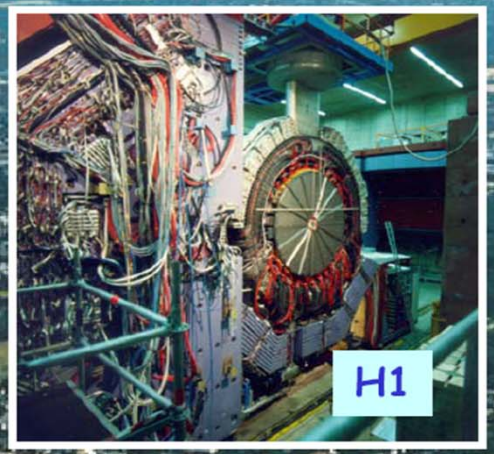
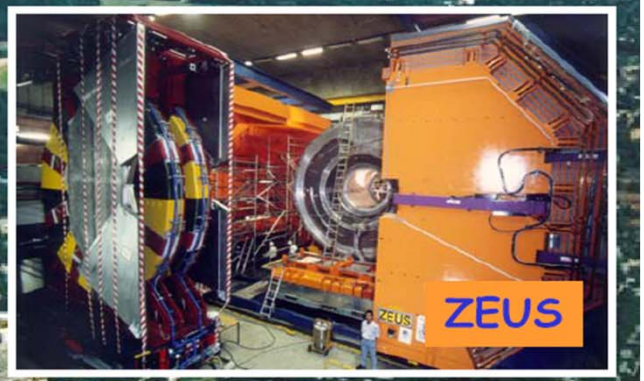
- Introduction
- Latest results on high Q^2 e^+p
- e^+p vs e^-p
- Polarized cross sections
- Summary and conclusions

The HERA ep collider and experiments







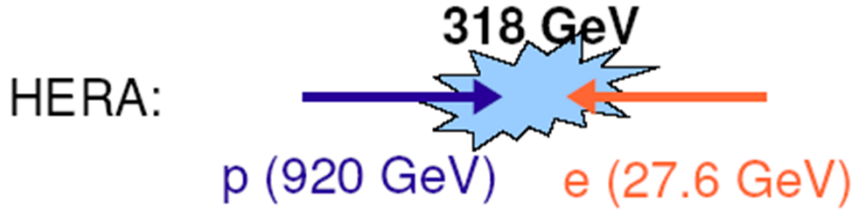
HERA

PETRA

HERA I: ~ 130 pb^{-1} (physics)

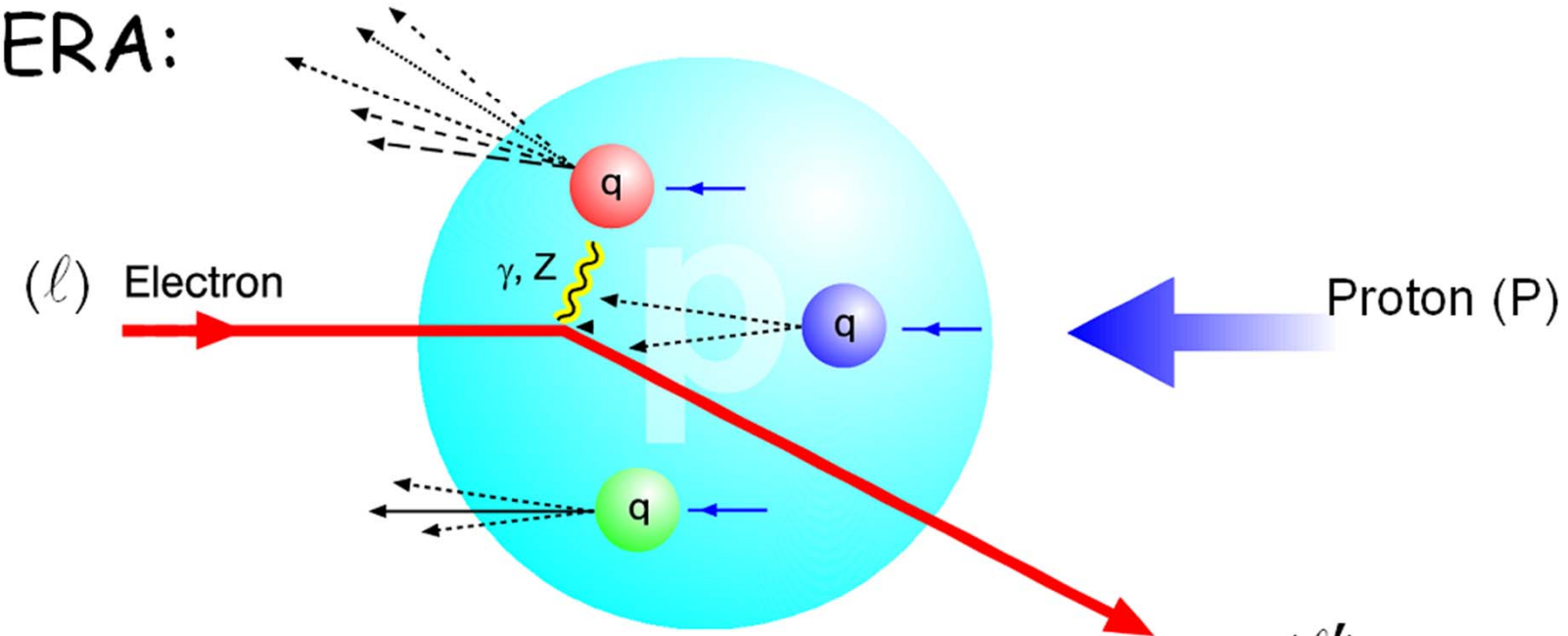
HERA II: ~ 380 pb^{-1}(physics)

combined: ~ 2 x 0.5 fb^{-1}



Kinematics of Deep Inelastic Scattering (DIS)

HERA:



$q = \ell - \ell'$

kinematic variables:

$Q^2 = -q^2$ photon (or Z) virtuality, squared momentum transfer

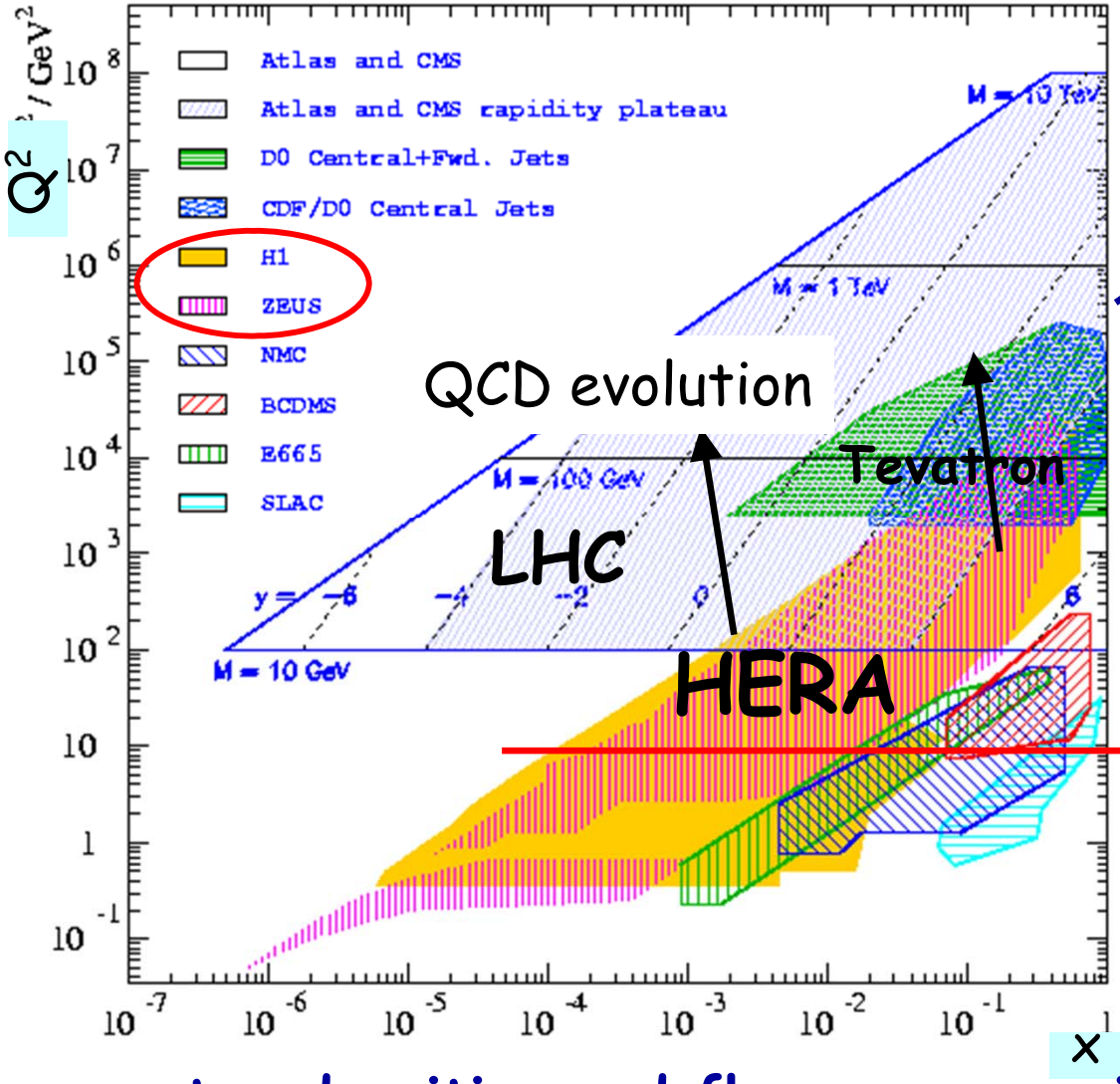
$x = \frac{Q^2}{2Pq}$ Bjorken scaling variable,
for $Q^2 \gg (2m_q)^2$: momentum fraction of p constituent

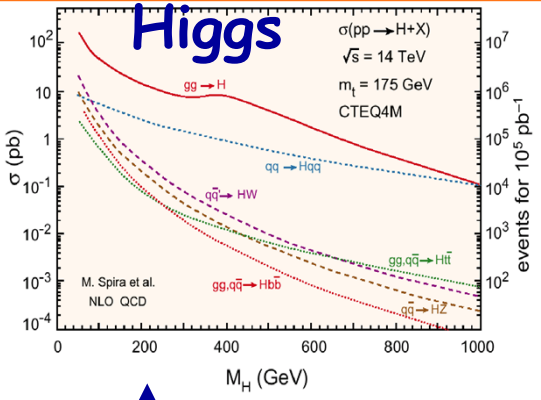
$y = \frac{qP}{\ell P}$ inelasticity,
γ momentum fraction (of e)

$Q^2 \lesssim 1\ GeV^2$: photoproduction

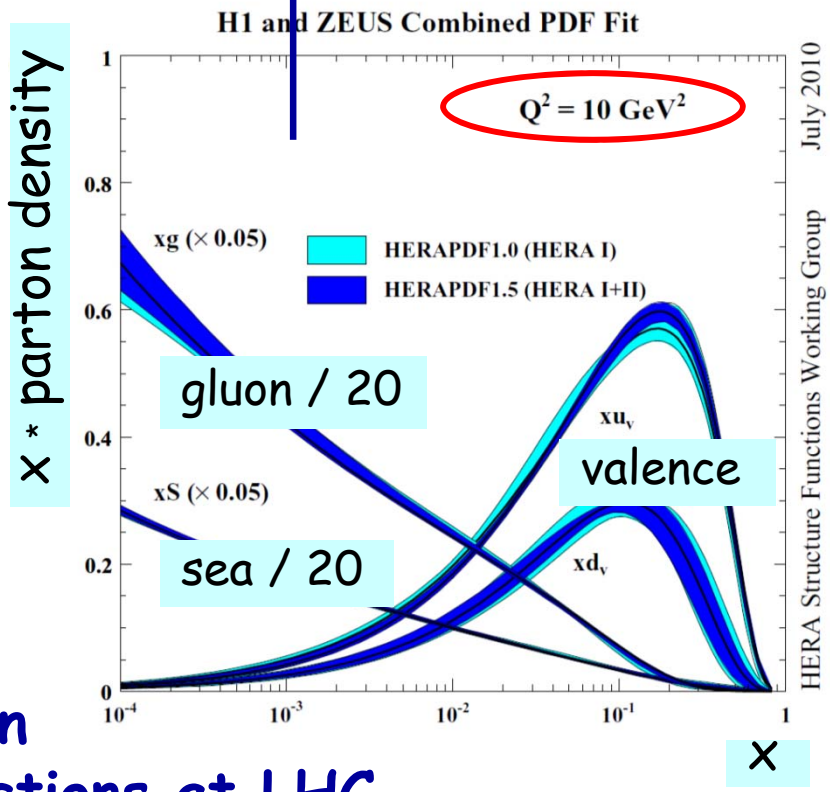
$Q^2 \gtrsim 1\ GeV^2$: DIS

Parton density functions (PDF)





W, Z, top, jets, ...



parton densities and flavour composition measured at HERA determine cross sections at LHC

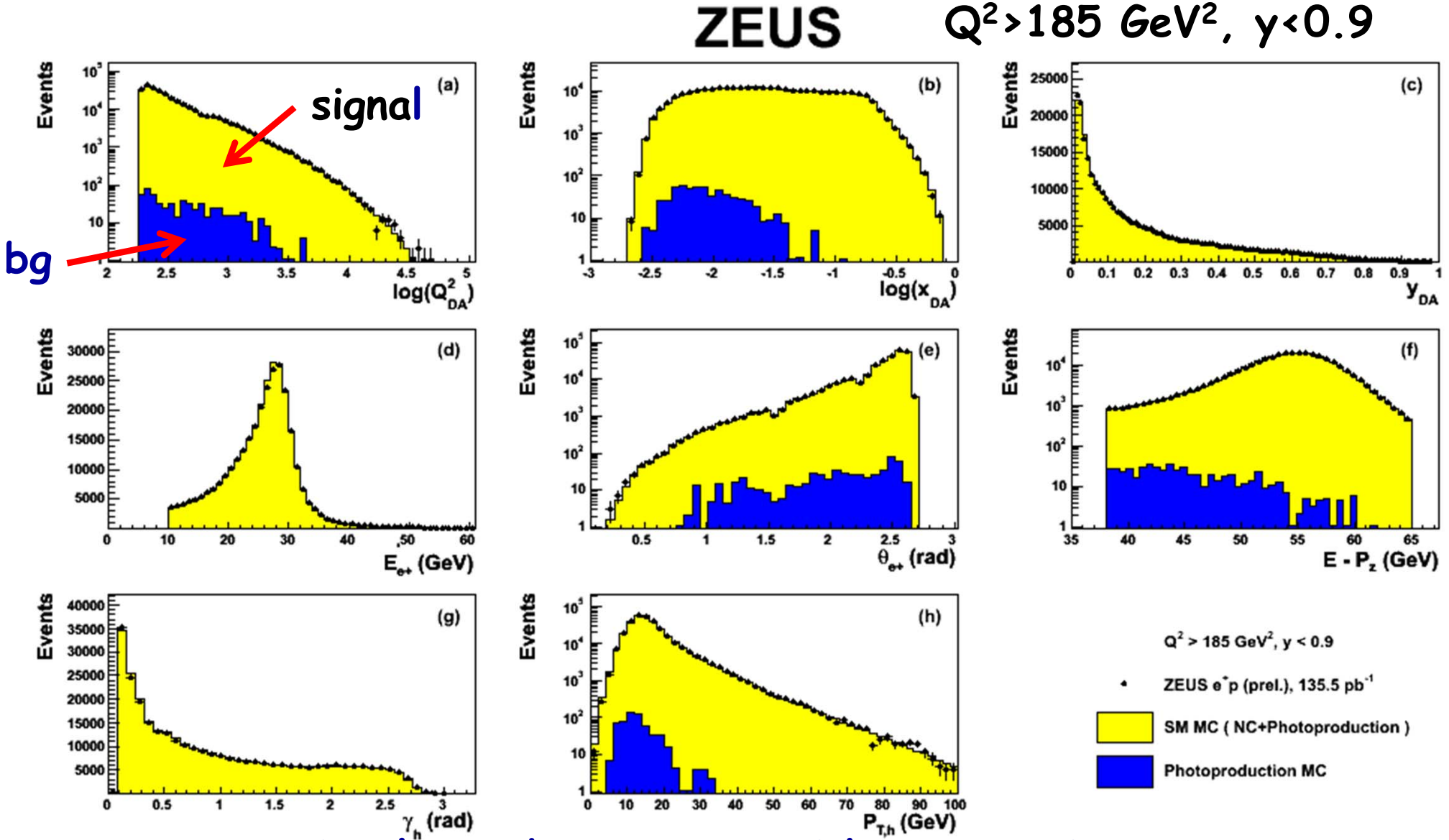
HERA results on high Q^2 NC cross sections

- final results from H1, e^+p, e^-p
  -> previous talk
- ZEUS HERA I results, e^+p, e^-p
  -> JHEP 1 (2010) 1-63 and references therein
- final e^-p results from ZEUS,
  -> EPJ C 62 (2009) 625-658

HERAPDF1.5 (next talk)

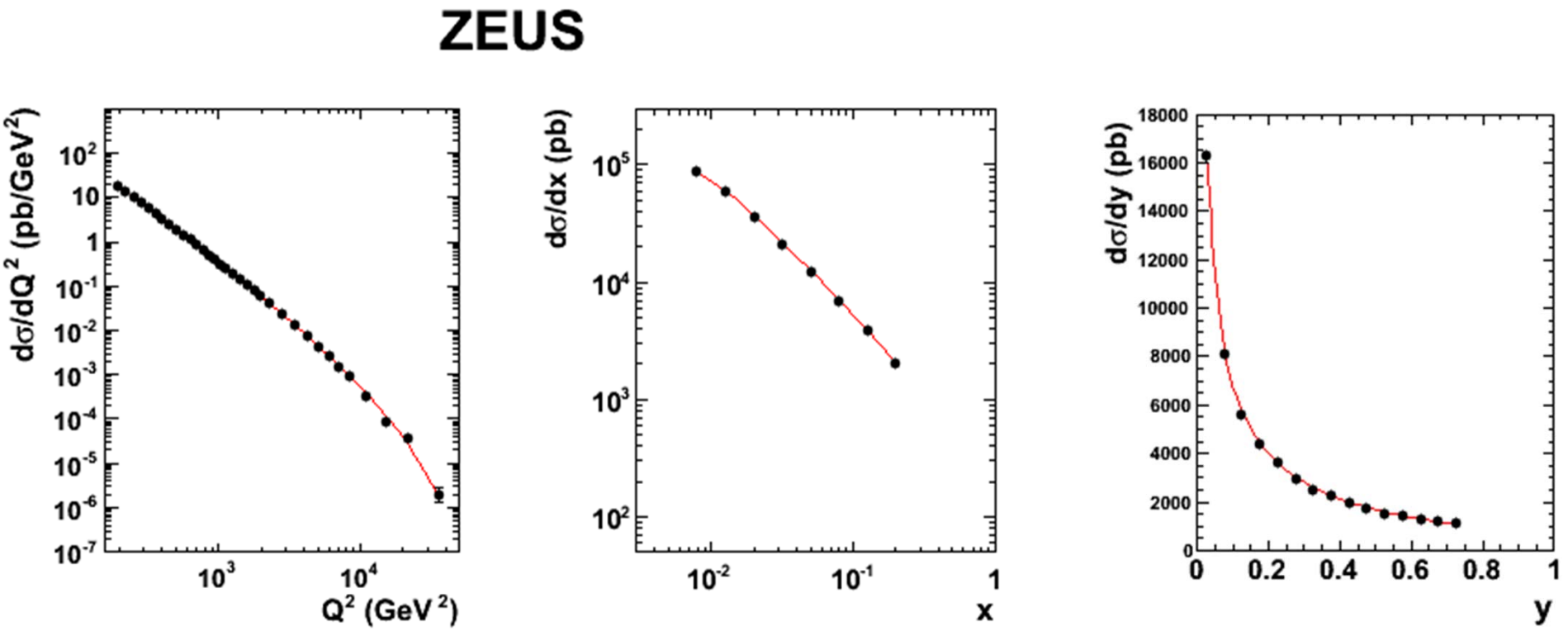
- preliminary e^+p HERA II results from ZEUS,
  -> this talk, NOT included in HERAPDF1.5
  (ZEUS-prel-11-003, final results soon)

Control distributions, e^+p data



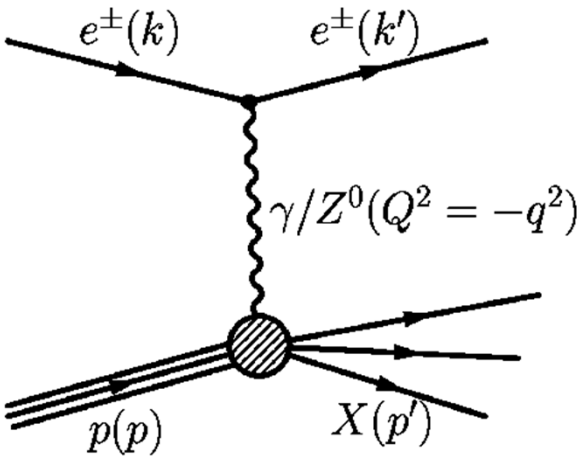
very pure signal, good agreement with expectations

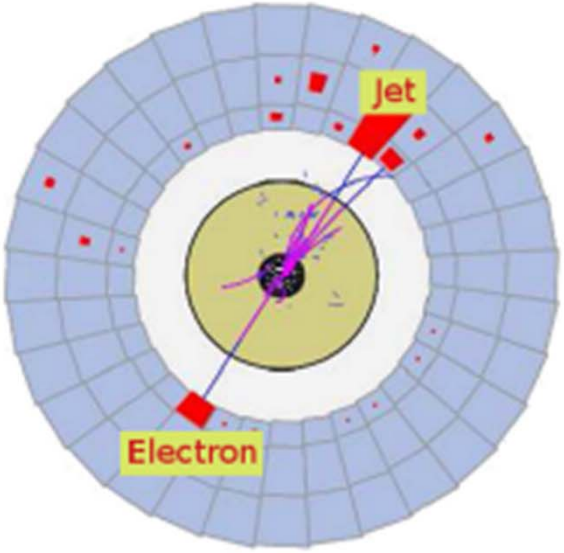
e^+p cross sections without polarization

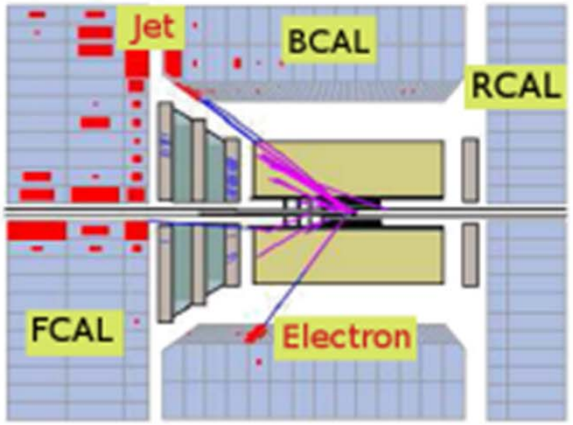


- Standard Model (SM) prediction agrees well with data

Unpolarized high Q^2 Neutral Current scattering







$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha^2}{Q^4 x}\left\{\left[1+(1-y)^2\right]F_2(x,Q^2) - y^2 F_L(x,Q^2) \mp Y_- xF_3\right\}$$

photon-Z interference

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

xF_3 term opposite sign for e^+ and e^-, q and $\bar{q}$ => sensitivity to valence quarks

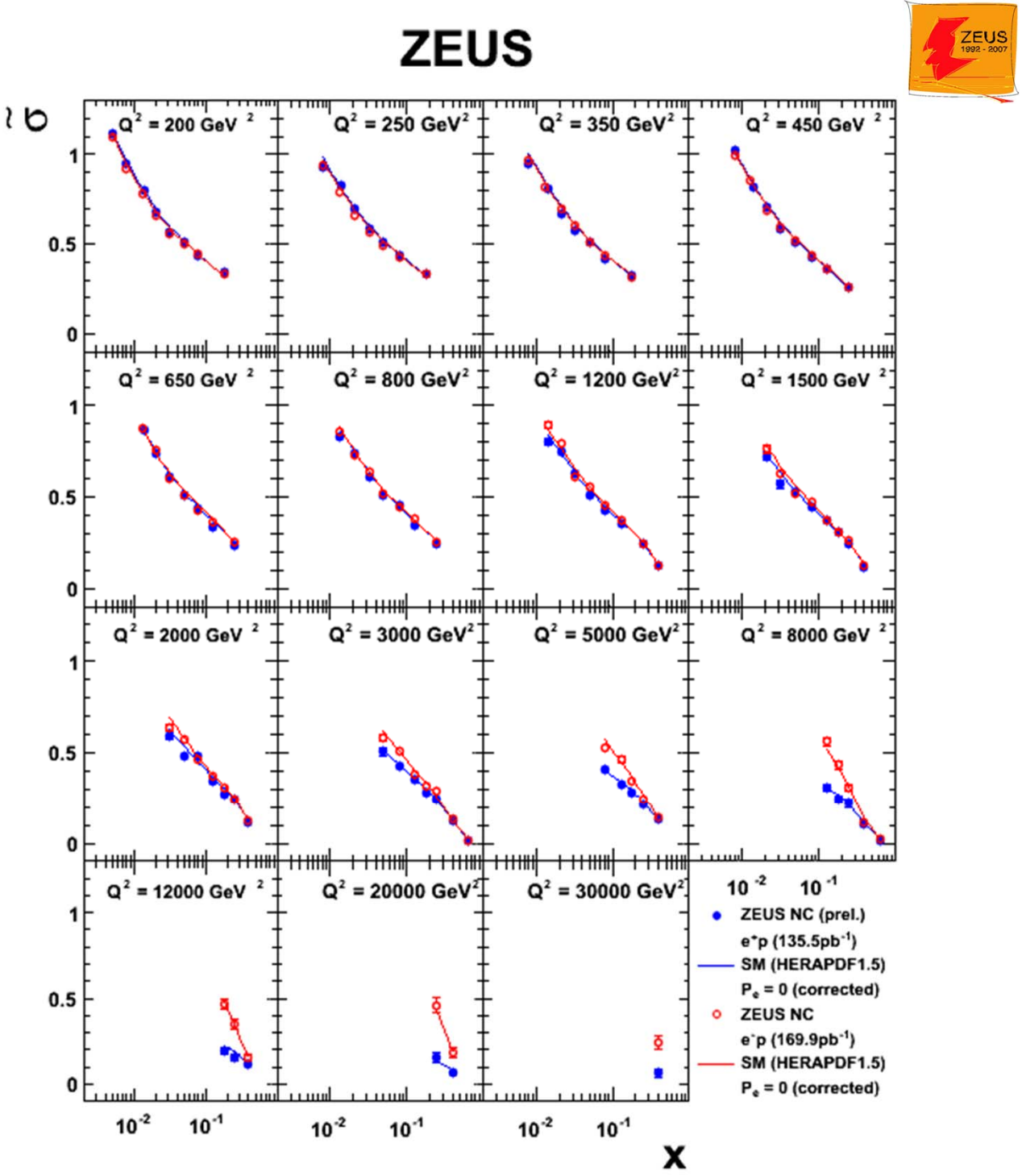
e+ vs. e-

reduced cross section

$$\tilde{\sigma}_{NC}^{e^\pm p} = \frac{xQ^4}{2\pi\alpha^2}\frac{1}{Y_+}\frac{d^2\sigma_{NC}^{e^+p}}{dxdQ^2}$$

$$= \tilde{F}_2 \mp \frac{Y_-}{Y_+} x\tilde{F}_3 - \frac{y^2}{Y_+}\tilde{F}_L$$

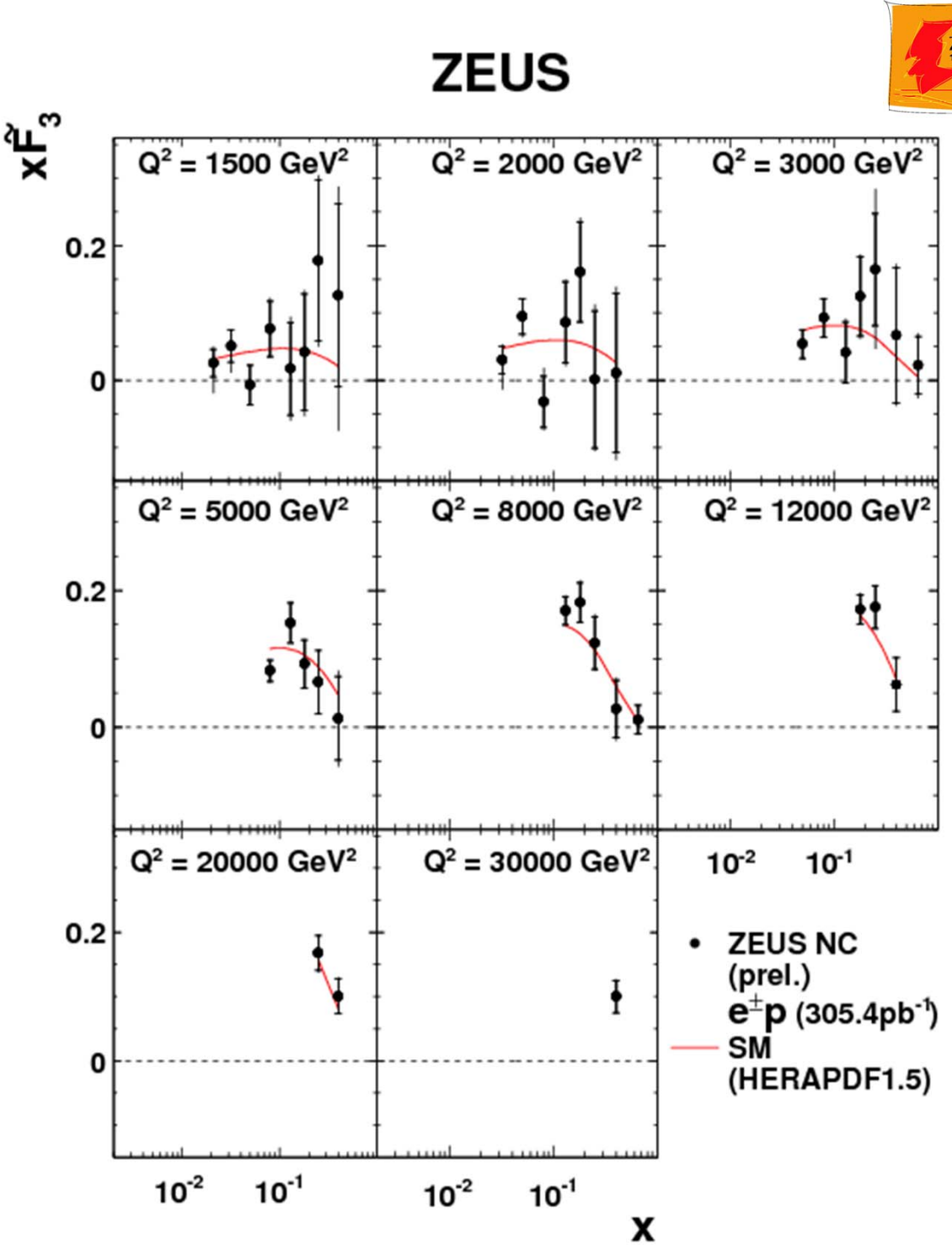
- can use difference to extract xF_3



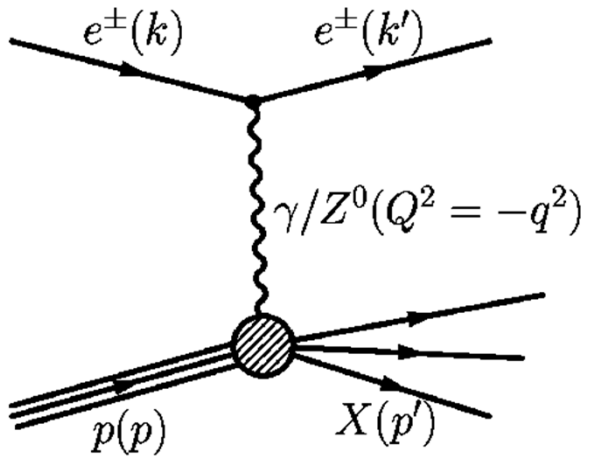
xF_3

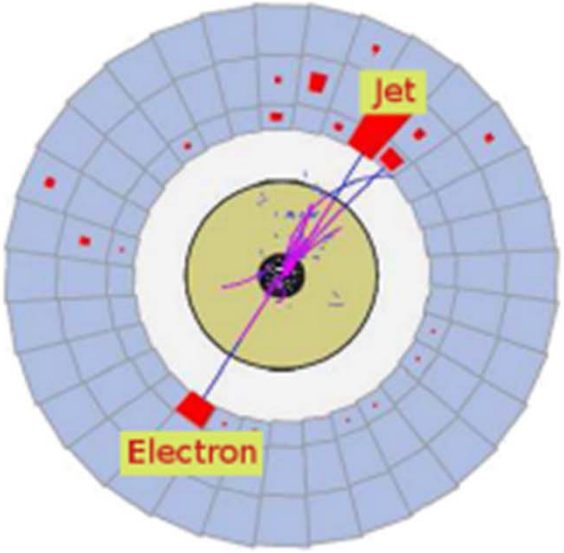
- agrees with expectations

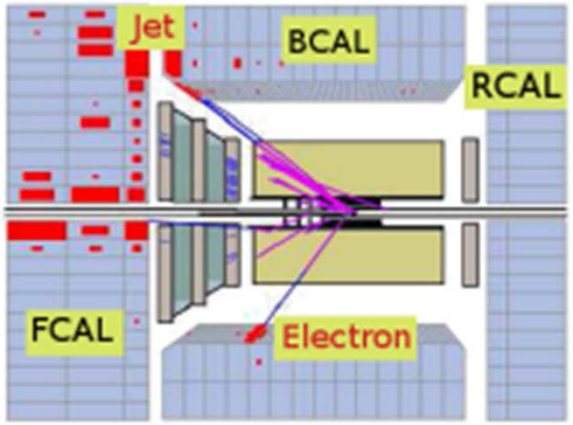
t-channel
weak interaction
contribution and
γZ interference
understood



Polarized Neutral Current Scattering







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

$$F_2^{L,R} = \sum_q [xq(x,Q^2) + x\bar{q}(x,Q^2)]\cdot A_q^{L,R},$$

$$xF_3^{L,R} = \sum_q [xq(x,Q^2) - x\bar{q}(x,Q^2)]\cdot B_q^{L,R}.$$

photon-Z interference

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

$$A_q^{L,R} = Q_q^2 + 2Q_eQ_q(v_e \pm a_e)v_q\chi_Z + (v_e \pm a_e)^2(v_q^2+a_q^2)(\chi_Z)^2,$$

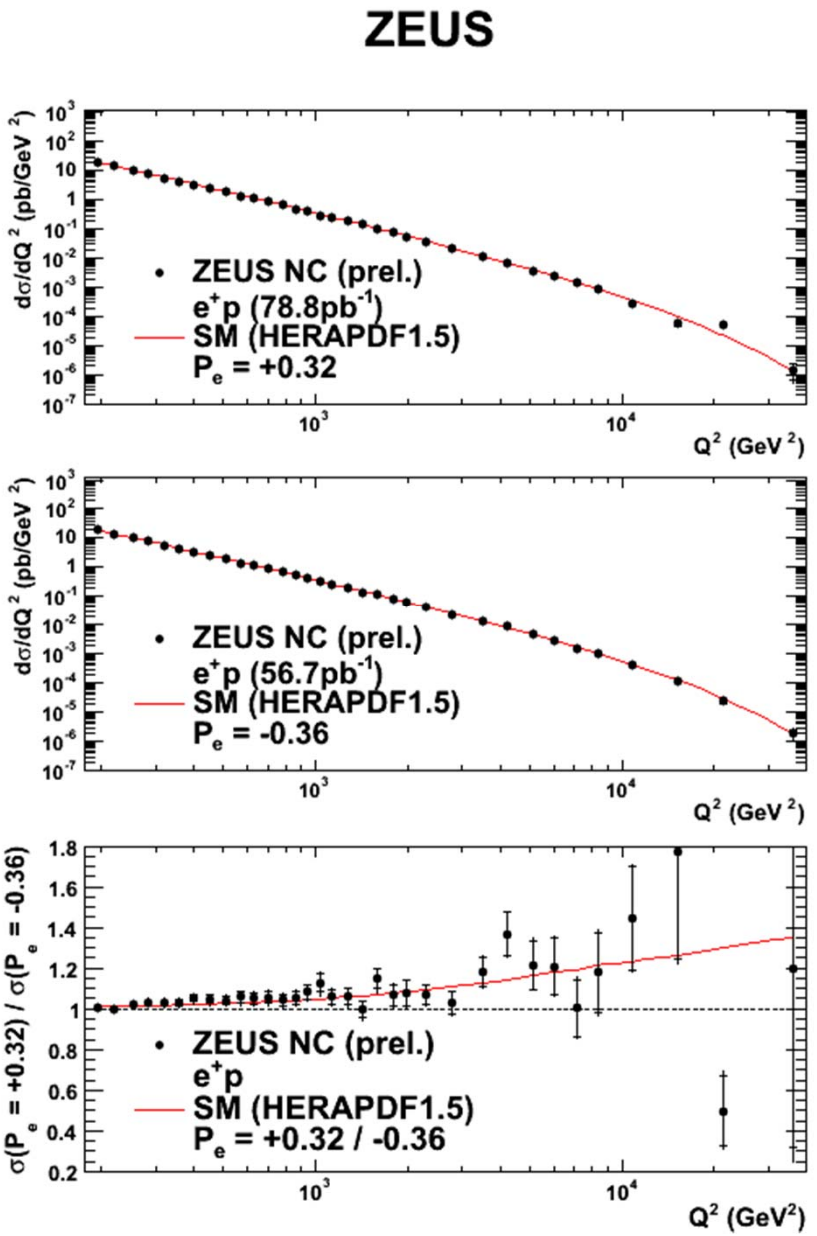
$$B_q^{L,R} = \pm 2Q_eQ_q(v_e \pm a_e)a_q\chi_Z \pm 2(v_e \pm a_e)^2 v_q a_q(\chi_Z)^2,$$

additional polarization dependence

$d\sigma/dQ^2$ with positive/negative e^+ polarization

- positive P_e = +0.32
  (righthanded)
- negative P_e = -0.36
  (lefthanded)
- ratio, deviatation from 1
  due to Z exchange

good agreement with expectations

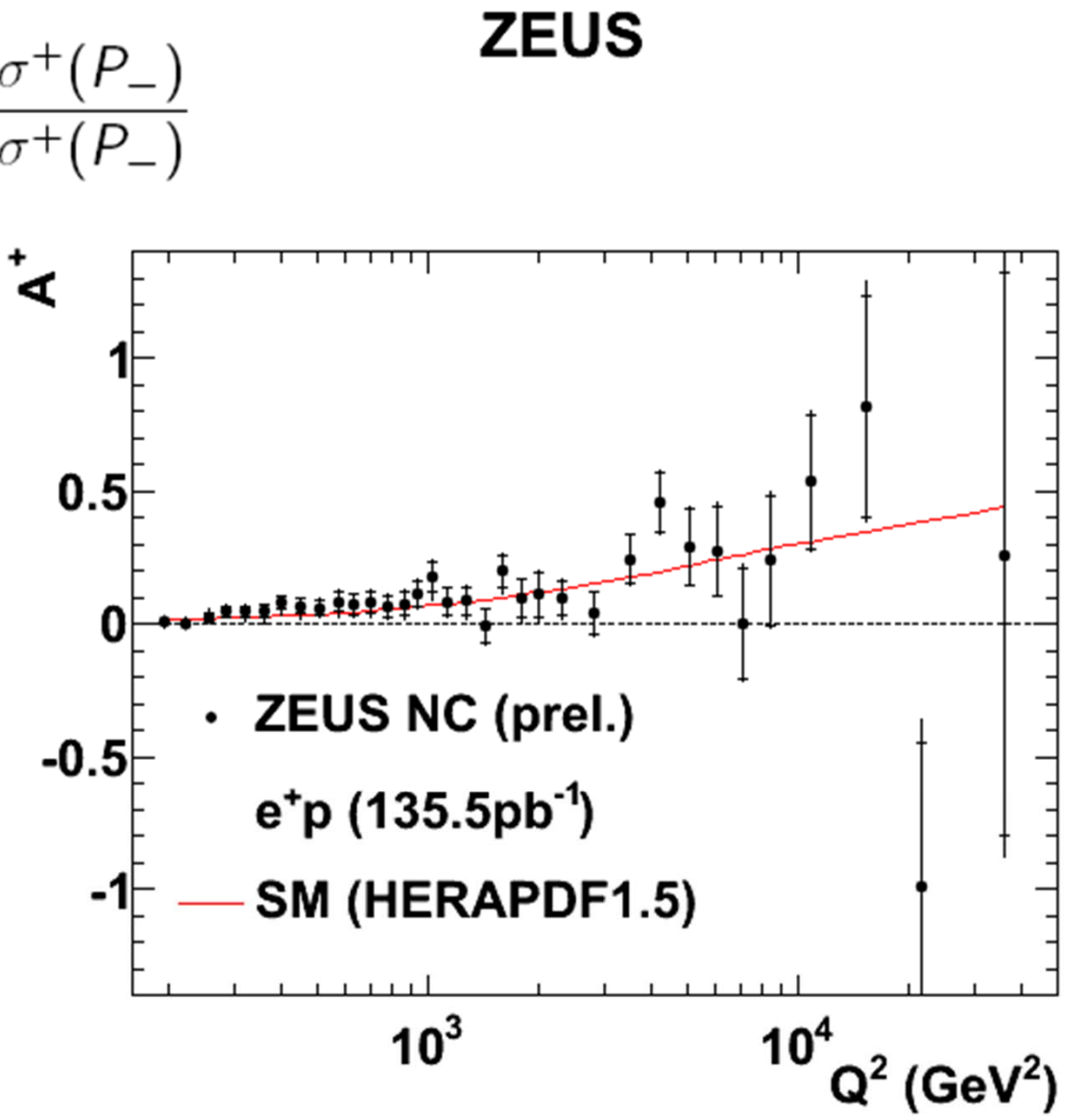


Cross section asymmetry

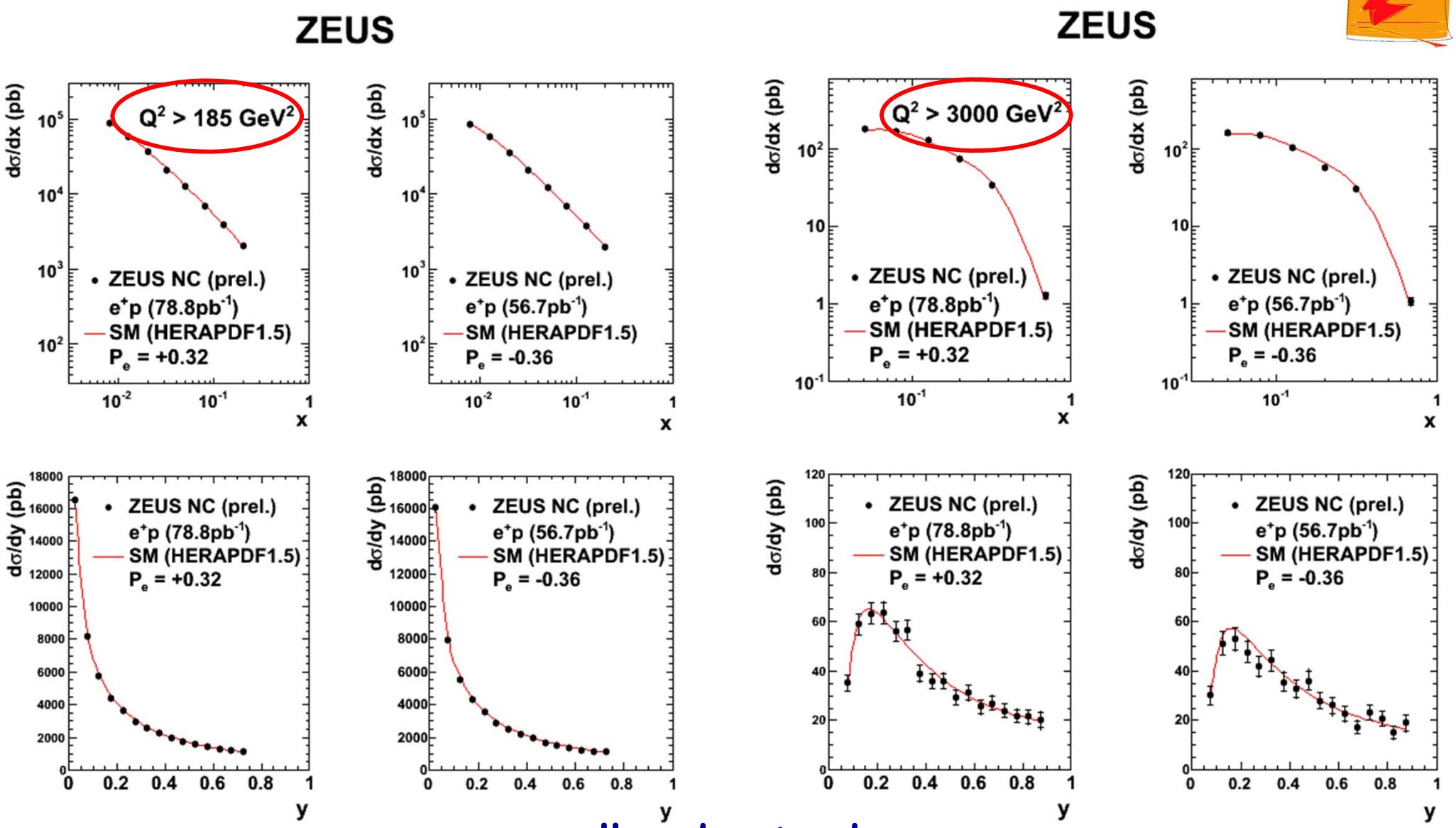
$$A^+ = \frac{2}{P_+ - P_-} \frac{\sigma^+(P_+) - \sigma^+(P_-)}{\sigma^+(P_+) + \sigma^+(P_-)}$$

- increasing Z contribution with increasing Q^2
- -> increasing asymmetry, as expected

(these data not included in prediction)



Polarized dσ/dx and dσ/dy for different Q^2



well understood

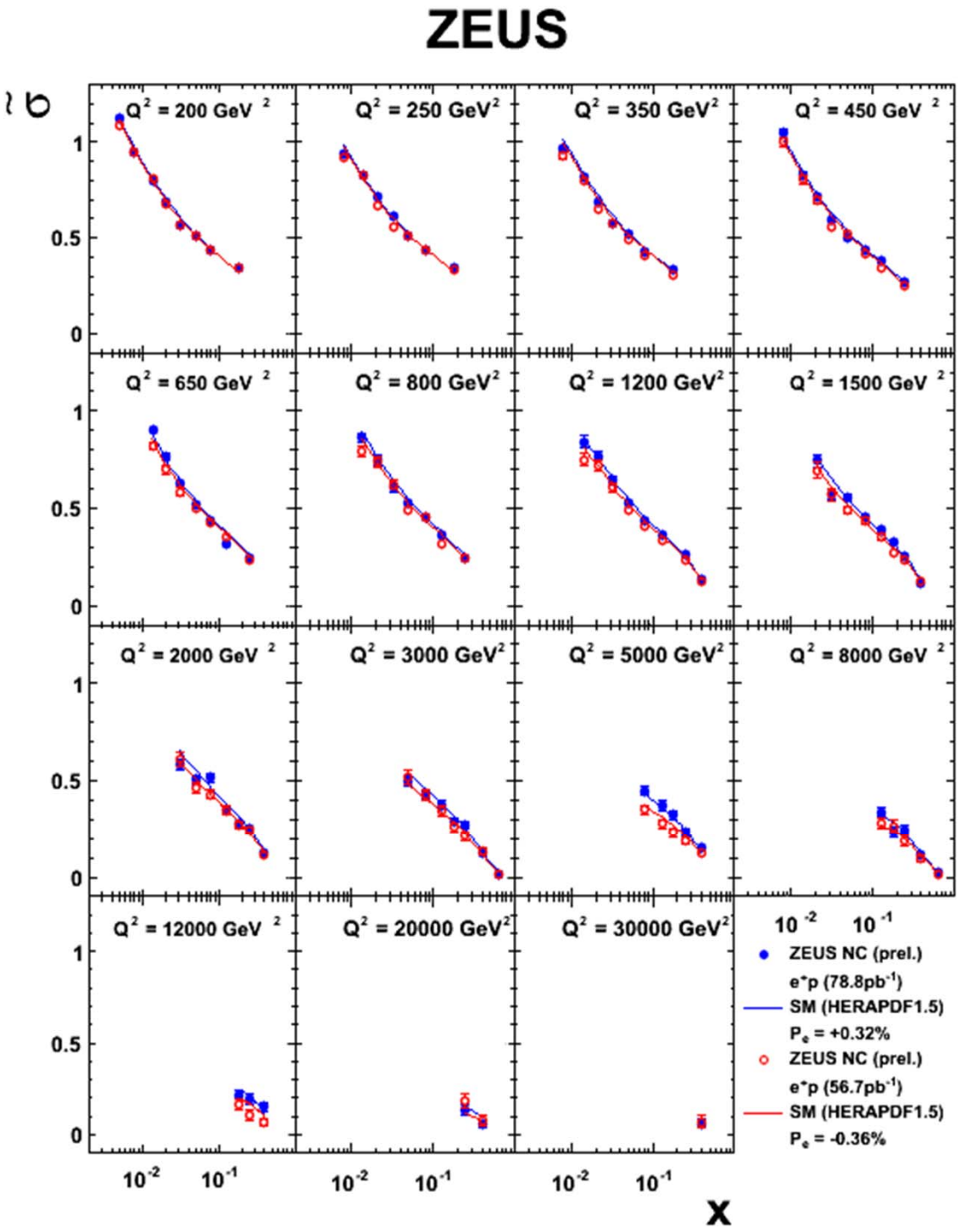
Summary and conclusions

- ZEUS NC e^+p cross sections are well described by Standard Model
- Difference w.r.t. e^-p allows extraction of xF_3
  t-channel weak interaction contribution well described by Standard Model
- Polarized e^+p cross sections are sensitive to vector and axial vector couplings of Z boson
  again well described by Standard Model
- All ZEUS high Q^2 data have been analyzed.

  Final e^+p results and final combination with H1 data in preparation.

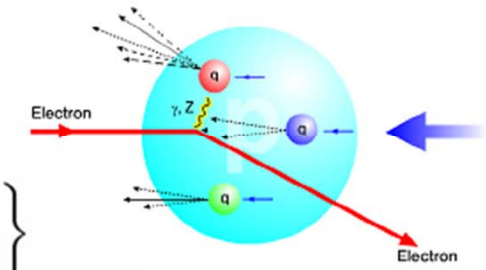
Backup

- Double differential polarized cross sections



The structure of the proton

special HERA run in 2007



- Measure cross section

small

$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha^2}{Q^4 x}\left\{\left[1+(1-y)^2\right]F_2(x,Q^2) - y^2 F_L(x,Q^2) \;+\!-\; Y_-\, xF_3\right\}$$

at high Q^2

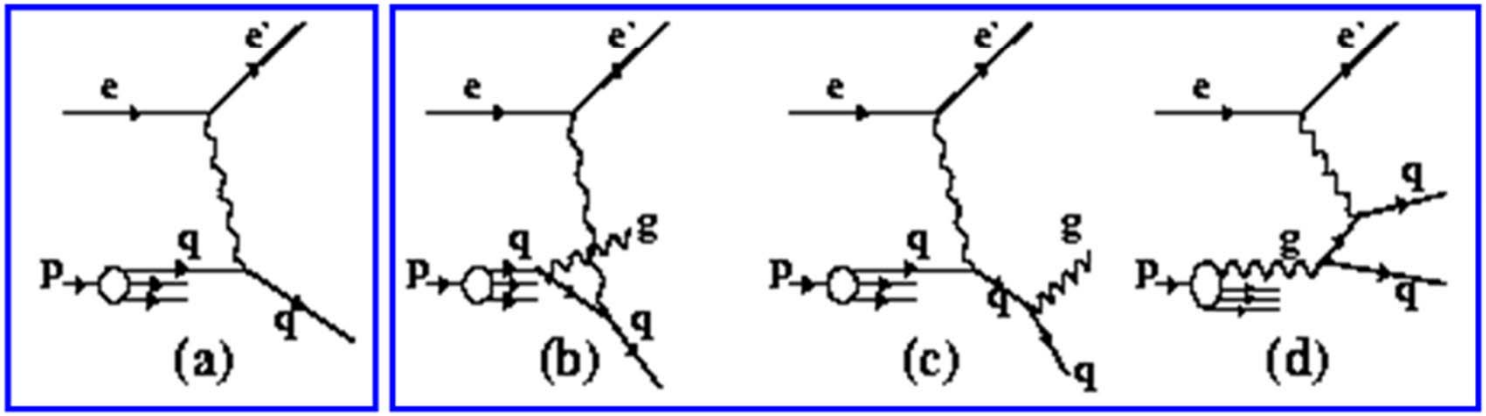
to 0th order QCD (Quark Parton Model, $Q^2 >> m_q^2$):

- Parton distribution functions (PDF) in pQCD

$$F_2^{em}(x,Q^2) = x\sum_i e_i^2\left[q_i(x,Q^2) + \bar{q}_i(x,Q^2)\right]$$

q_i – probability to find quark with flavour i in proton

"higher" order QCD corrections



in general: F_2 structure function is not PDF