Inclusive Deep-Inelastic Scattering at HERA

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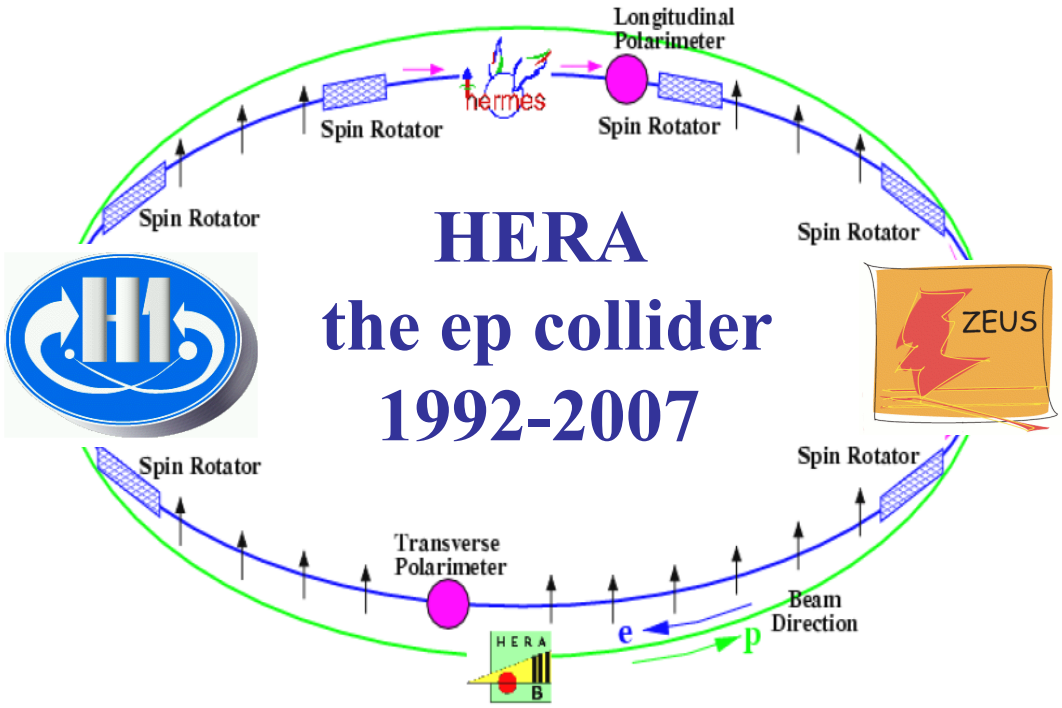
on behalf of the H1 and ZEUS Collaborations



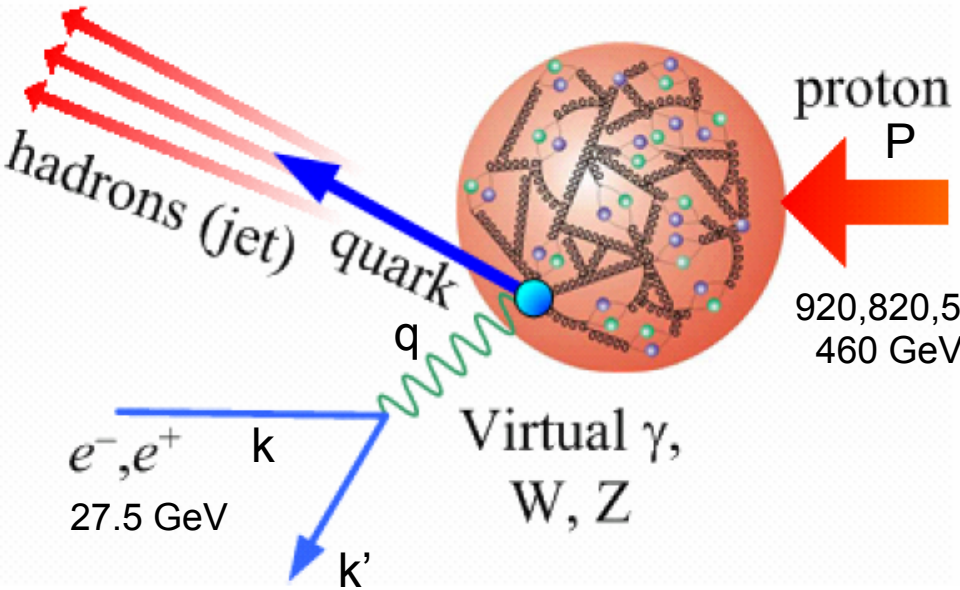
Completion of the HERA inclusive DIS cross section measurements:

1. NC at E_p=460, 575 GeV and model independent F_L measurements

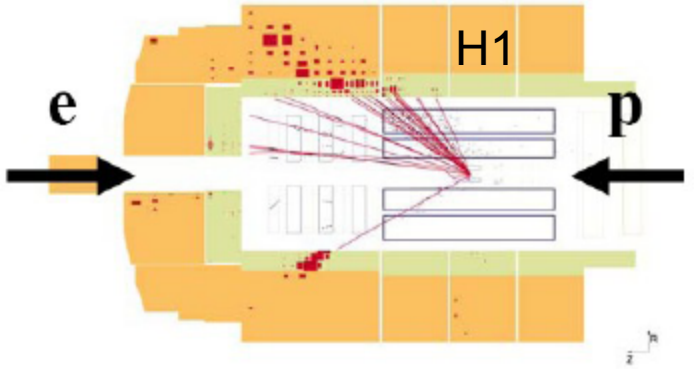
2. NC measurements at highest $x \rightarrow 1$

3. Combination of all HERA I+II NC&CC inclusive measurements (HERAPDF2.0)

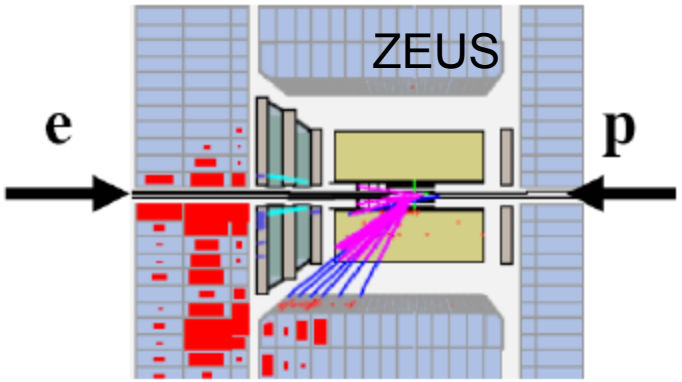
Deep-Inelastic Scattering (DIS)



Neutral Current (NC): $e^{\pm}p \rightarrow e^{\pm}X$



Charged Current (CC): $e^{\pm}p \rightarrow \nu X$



$Q^2 = -q^2 = -(k-k')^2$ virtuality of γ*, Z^0, W

$x = Q^2/2(Pq)$ Bjorken x

$y = (Pq)/(Pk)$ inelasticity

$Q^2 = sxy$ $s=(k+P)^2$

H1+ZEUS in total 1 fb^{-1}

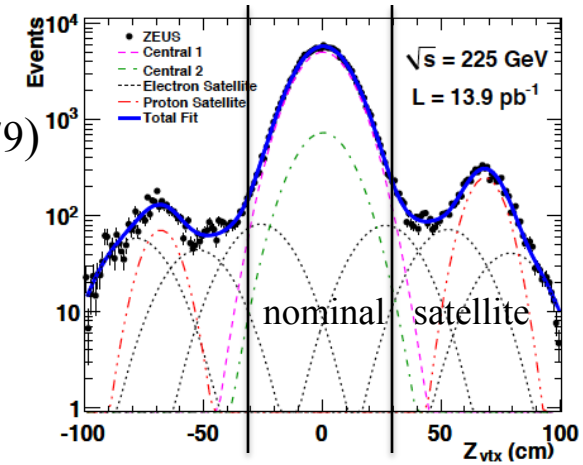
- about equally shared between e^+ and e^-, positive and negative P_e
- special running at low proton energy for F_L

1. NC cross section measurements at high y and low Ep=460, 575 (and 920) GeV

Data Set		x Grid from	x Grid to	Q^2/GeV^2 Grid from	Q^2/GeV^2 Grid to	$\mathcal{L}$ pb^{-1}	e^+/e^-	$\sqrt{s}$ GeV
HERA II E_p = 575 GeV data sets								
H1 NC high Q^2	07	0.00065	0.65	35	800	5.4	e^+p	252
H1 NC low Q^2	07	0.0000279	0.0148	1.5	90	5.9	e^+p	252
ZEUS NC nominal	07	0.000147	0.013349	7	110	7.1	e^+p	251
ZEUS NC satellite	07	0.000125	0.013349	5	110	7.1	e^+p	251
HERA II E_p = 460 GeV data sets								
H1 NC high Q^2	07	0.00081	0.65	35	800	11.8	e^+p	225
H1 NC low Q^2	07	0.0000348	0.0148	1.5	90	12.2	e^+p	225
ZEUS NC nominal	07	0.000184	0.016686	7	110	13.9	e^+p	225
ZEUS NC satellite	07	0.000143	0.016686	5	110	13.9	e^+p	225

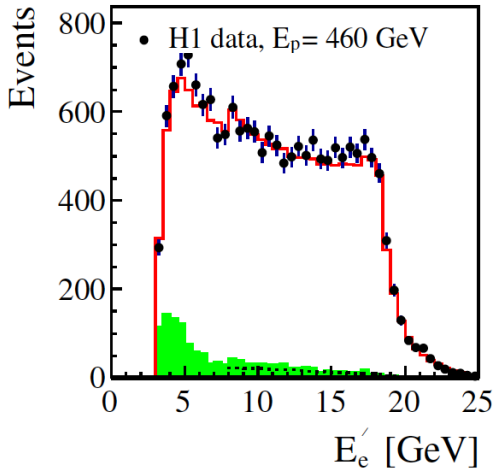
H1: NC high Q2: Eur. Phys. J. C 74 (2014) 2814
(previously published NC low Q2: Eur.Phys.J.C71 (2011) 1579)

ZEUS: NC "nominal" and "satellite": DESY-14-053
measurements at E_p= 460, 575, 920 GeV
→ supersede results of Phys. Lett. B 682 (2009) 8



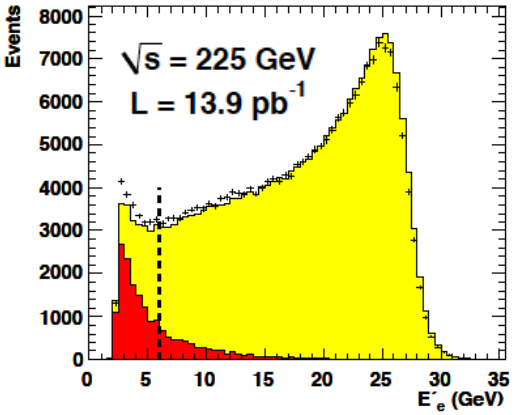
NC at high y for E_p= 460, 575 (and 920) GeV

Experimental challenge: large γp background at high y (low scattered electron energy)



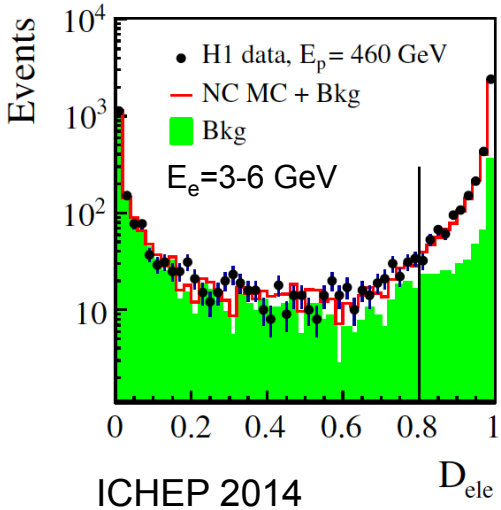
H1:
E_e down to 3 GeV

→ ***"soft electron identification"***:
optimal use of information on shower shape in LAr calorimeter, momentum matching with the track, dE/dx

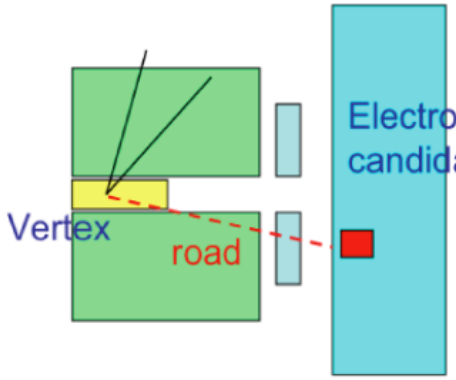


ZEUS:
E_e down to 6 GeV

→ ***"backward tracking"***: use hits in the tracking detectors



→ accept only electron candidates with the *"right electric charge"* and use the *"wrong charge"* events for estimation of remaining background.



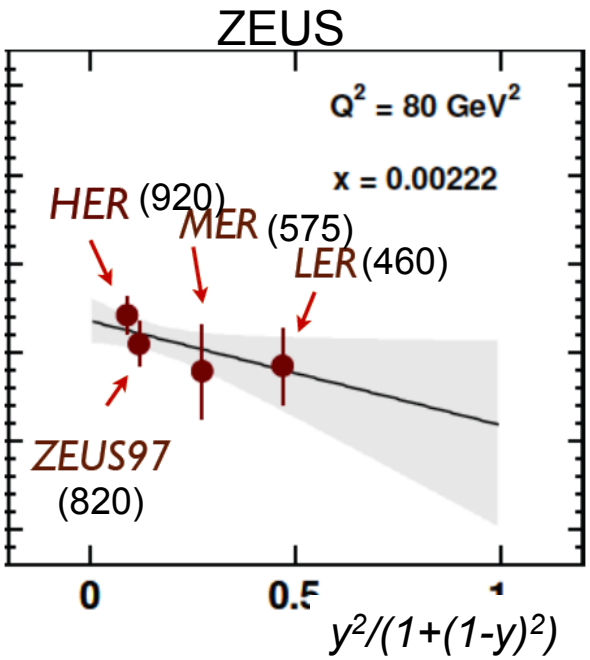
→ remaining bkg is subtracted using MC predictions verified from 6m–tagger and γp enriched sample (agreement within 10%)

A model independent measurement of F_L using data at E_p=460, 575 and 920 (820) GeV

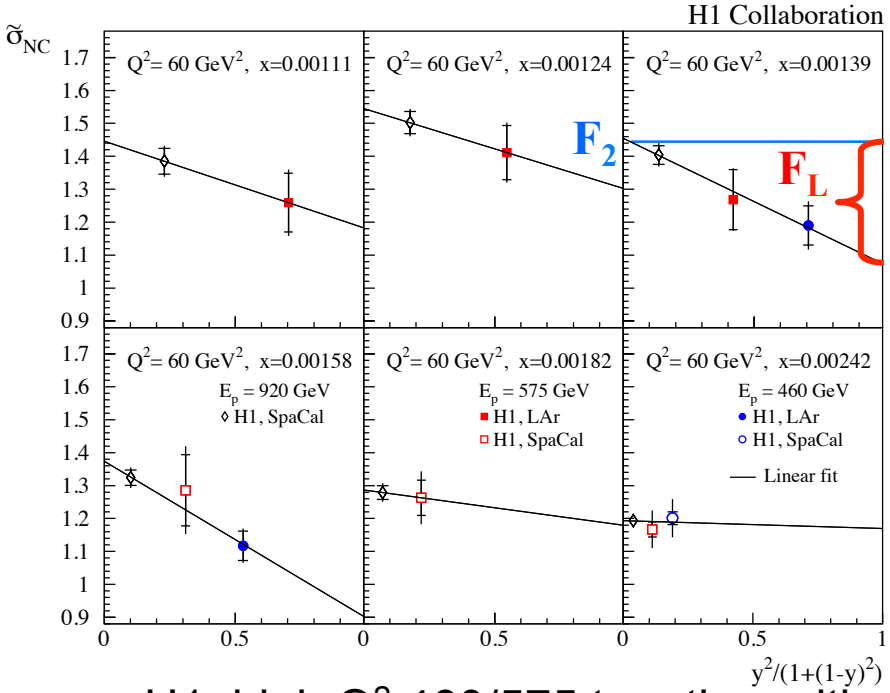
→ F_L and F_2 can be determined in a model independent way at each x and Q^2

$$\sigma_{NC}(x,Q^2,y) = F_2(x,Q^2) - f(y)\, F_L(x,Q^2), \quad f(y)=y^2/(1+(1-y)^2)$$

an example: Q^2=60 GeV^2 and 6 values of x



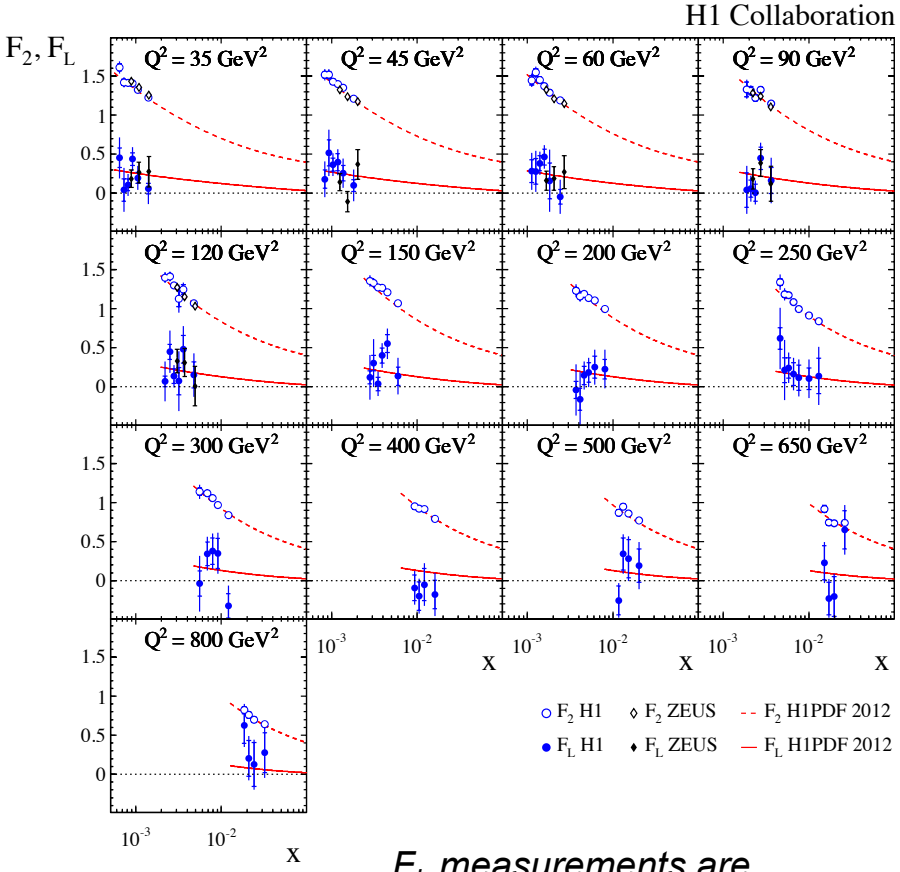
Measurements at E_p=820 GeV (ZEUS97) are included in fits



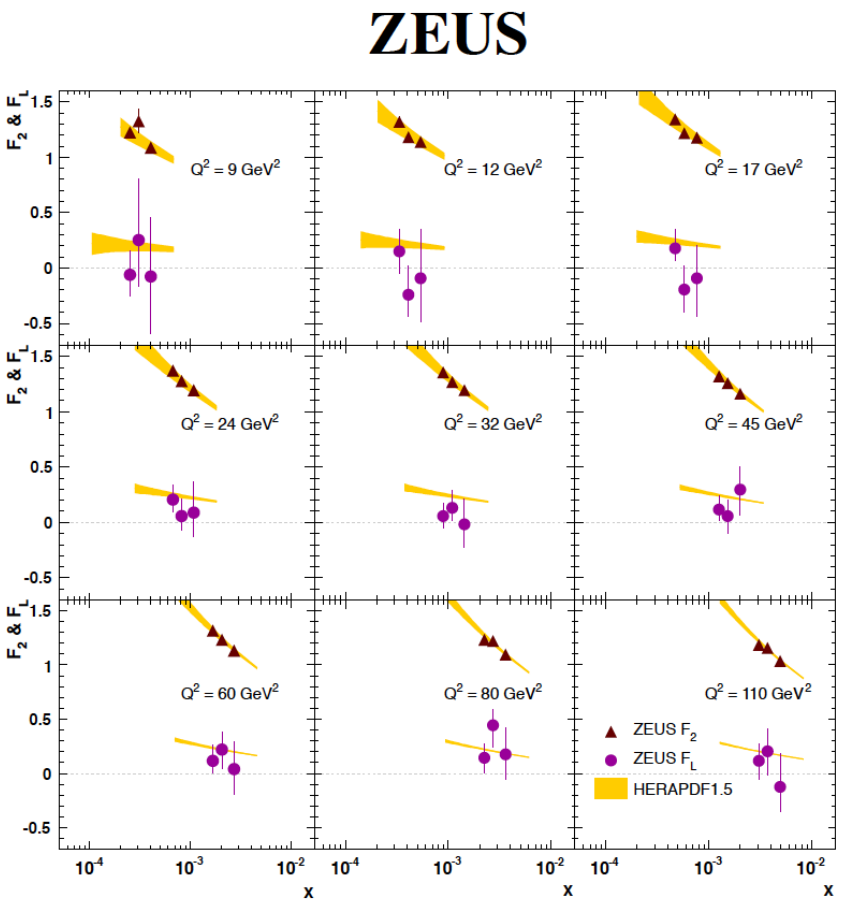
H1: high Q^2 460/575 together with *460/575 data at low Q^2 (Spacal) and 920 e^+p data from HERA II*

F_L and F_2 measurements as a function of Q^2 and x

using a χ^2 minimisation technique accounting for correlations across all measurements



F_L measurements are extended to Q^2 = 800 GeV²

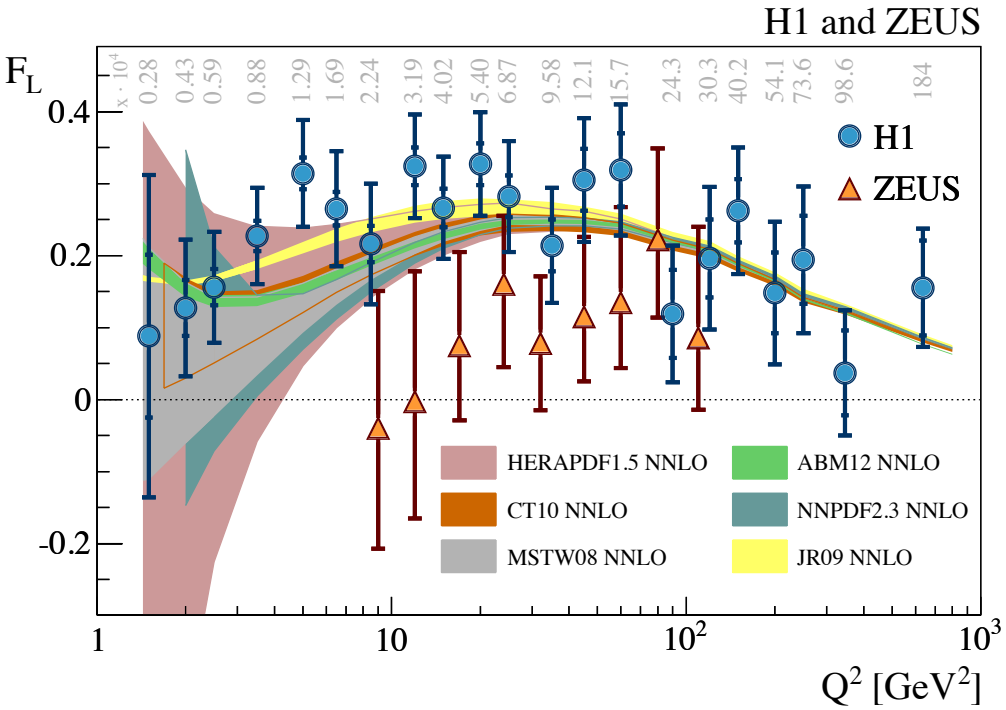


average $F_L(x,Q^2)$ measurements at given Q^2 →

Longitudinal structure function F_L

F_L is a pure QCD effect sensitive to gluon density

$$F_L(x,Q^2) = \frac{\alpha_s}{4\pi} x^2 \int_x^1 \frac{dz}{z^3} \left[\frac{16}{3} F_2 + 8 \sum_q e_q^2 (1 - \frac{x}{z}) \cdot xg \right]$$

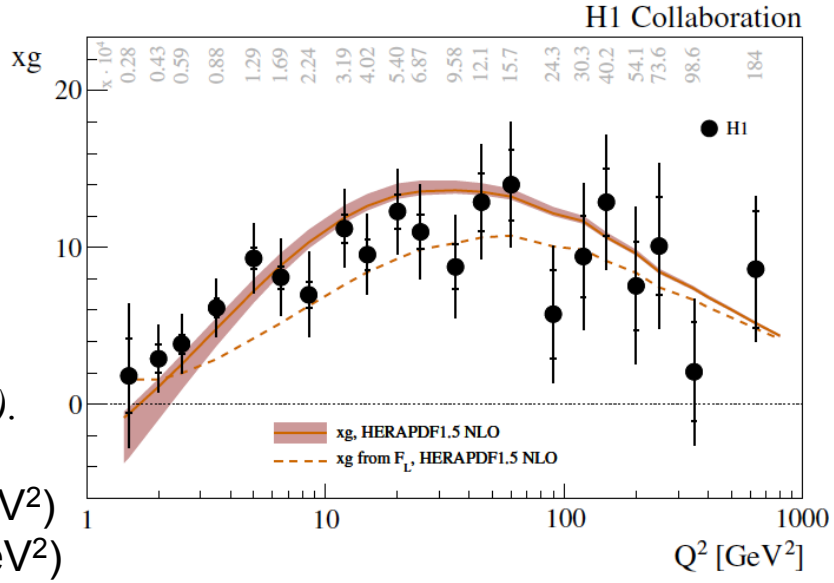


Consistency of the H1 and ZEUS FL data was checked accounting for corr. errors: $\chi^2/ndf=11/8$ (p-value=20%).

approximate relation between F_L and gluon (order of α_s , with a=1)

$$xg(x,Q^2) \approx 1.77 \frac{3\pi}{2\alpha_S(Q^2)} F_L(ax,Q^2)$$

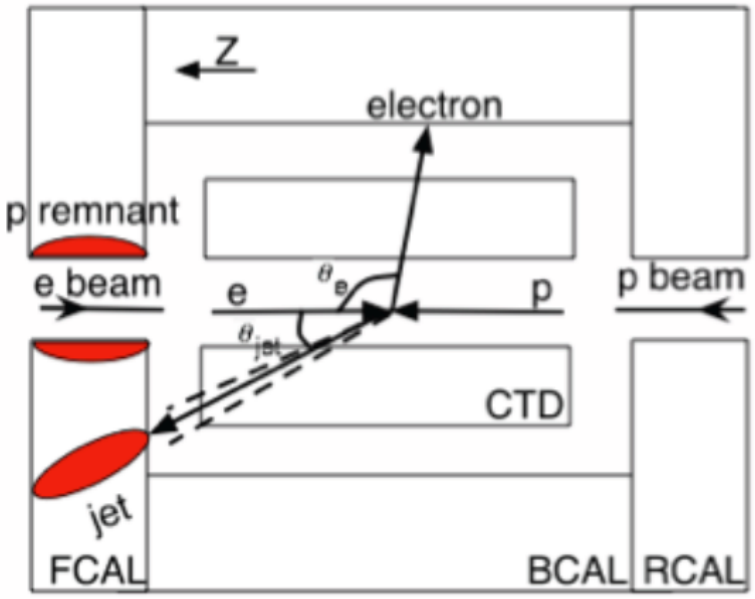
Z. Phys. C39 (1988) 281, Nucl. Phys. B 383 (1992) 525
Eur. Phys. J. C72 (2012) 2221, arXiv:1401.7804



$R=\sigma_L/\sigma_T=F_L/(F_2-F_L)$ = 0.23±0.04 (H1, $1.5 \le Q^2 \le 800$ GeV^2)
R=0.105+0.055-0.037 (ZEUS, $9 \le Q^2 \le 110$ GeV^2)

2. Integrated $e^{\pm}p$ NC cross section at high x→1

NC events at high Q^2 have about 100% acceptance and efficiency for the scattered electron but at highest x the hadronic final state disappears in the beam pipe and there are no means to measure x



ZEUS measured the integrated $e^{\pm}p$ NC cross sections at x→1 using events without jets at x above x_{edge}.

$$\int_{x_{\rm edge}}^{1} \frac{d^2\sigma(x,Q^2)}{dxdQ^2}dx$$

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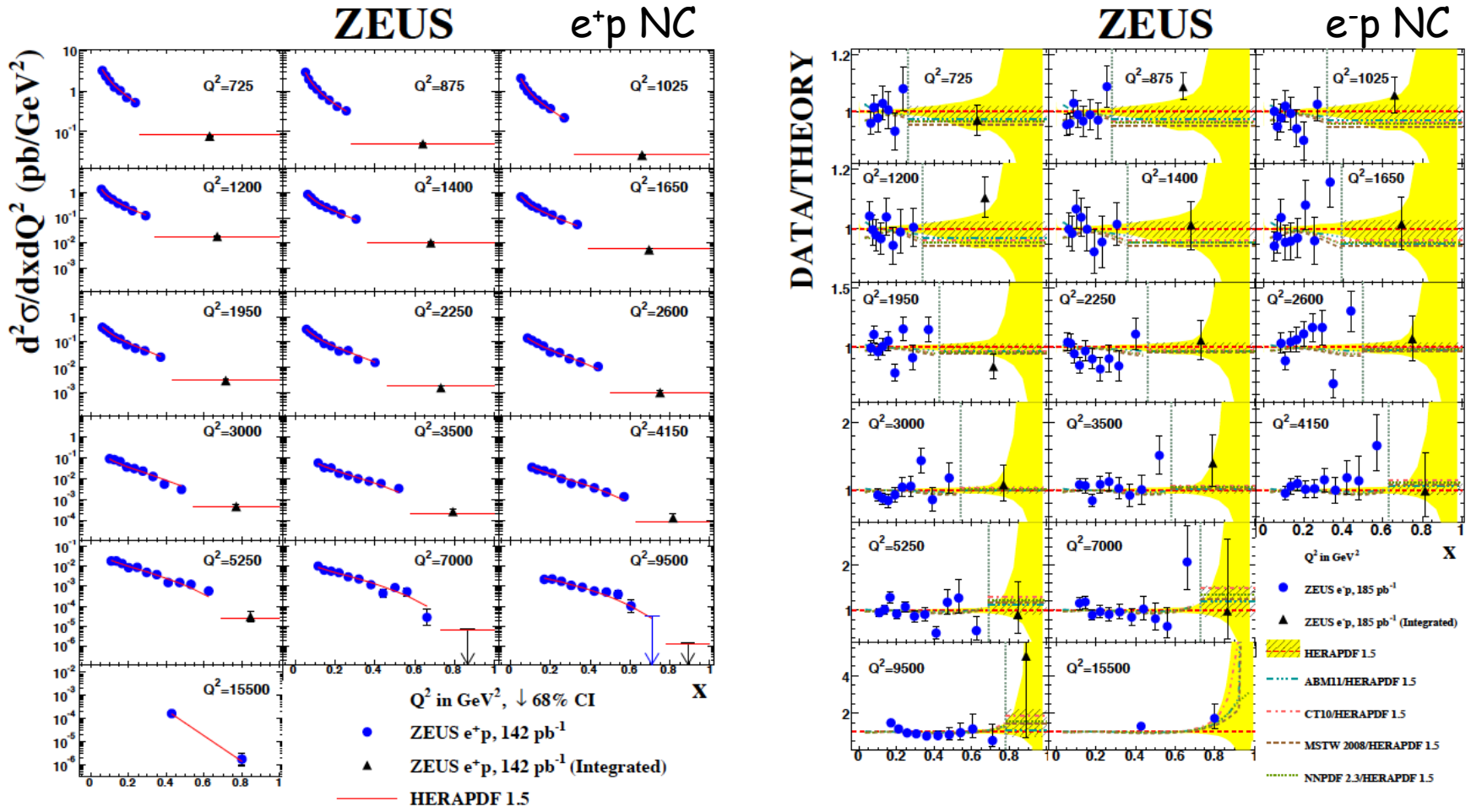
NC $e^{\pm}p$ cross section at highest x

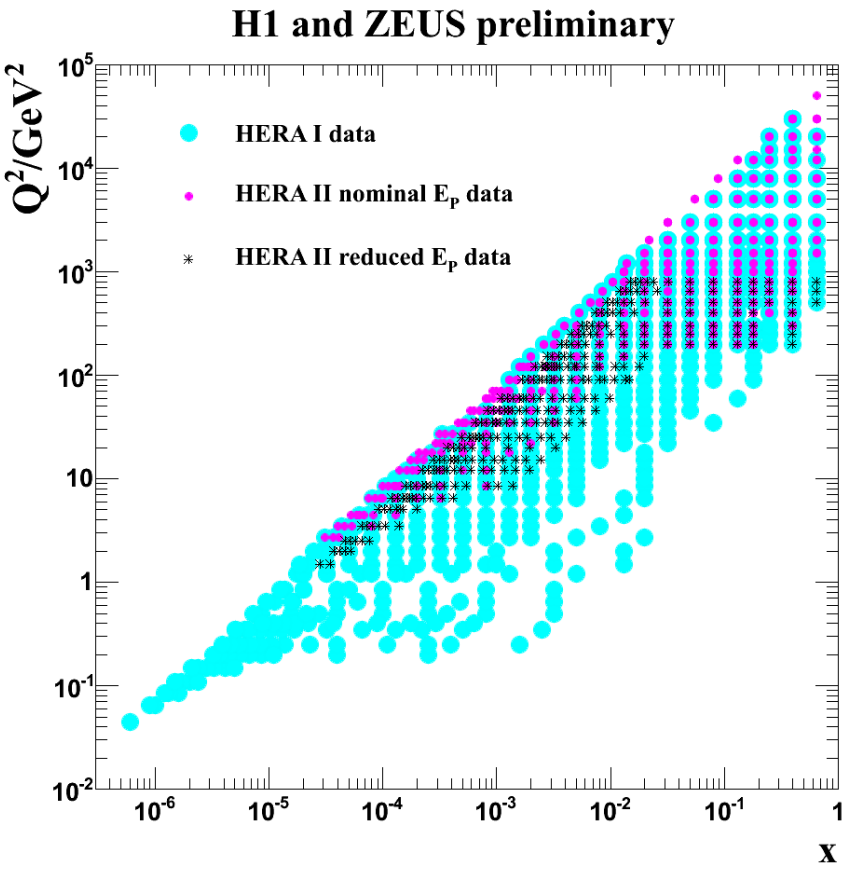


→ there is sensitivity to PDFs at high x→1. These integrated measurements are not used so far in the QCD fits (and in the combination below)

3. Combination of all inclusive NC and CC $e^{\pm}p$ data from H1 an ZEUS

41 data sets from H1 and ZEUS (1 fb^{-1}): $0.045 \le Q^2 \le 50000$ GeV^2, $6\ 10^{-7} \le x \le 0.65$

21 data sets from HERA I (E_p=920 and 820 GeV) and
20 data sets from HERA II (12/4/4 sets for E_p= 920/575/460 GeV)



Combination of the H1 & ZEUS incl. unpolarized NC and CC data include expert knowledge in the treatment of the correlations between individual data sets.

→ precise, complete and easy in use
→ reduction of stat. and syst. uncertainties

1. HERA I data: JHEP 1001:109,2010 HERAPDF 1.0
2. HERA I and preliminary HERA II data HERAPDF 1.5

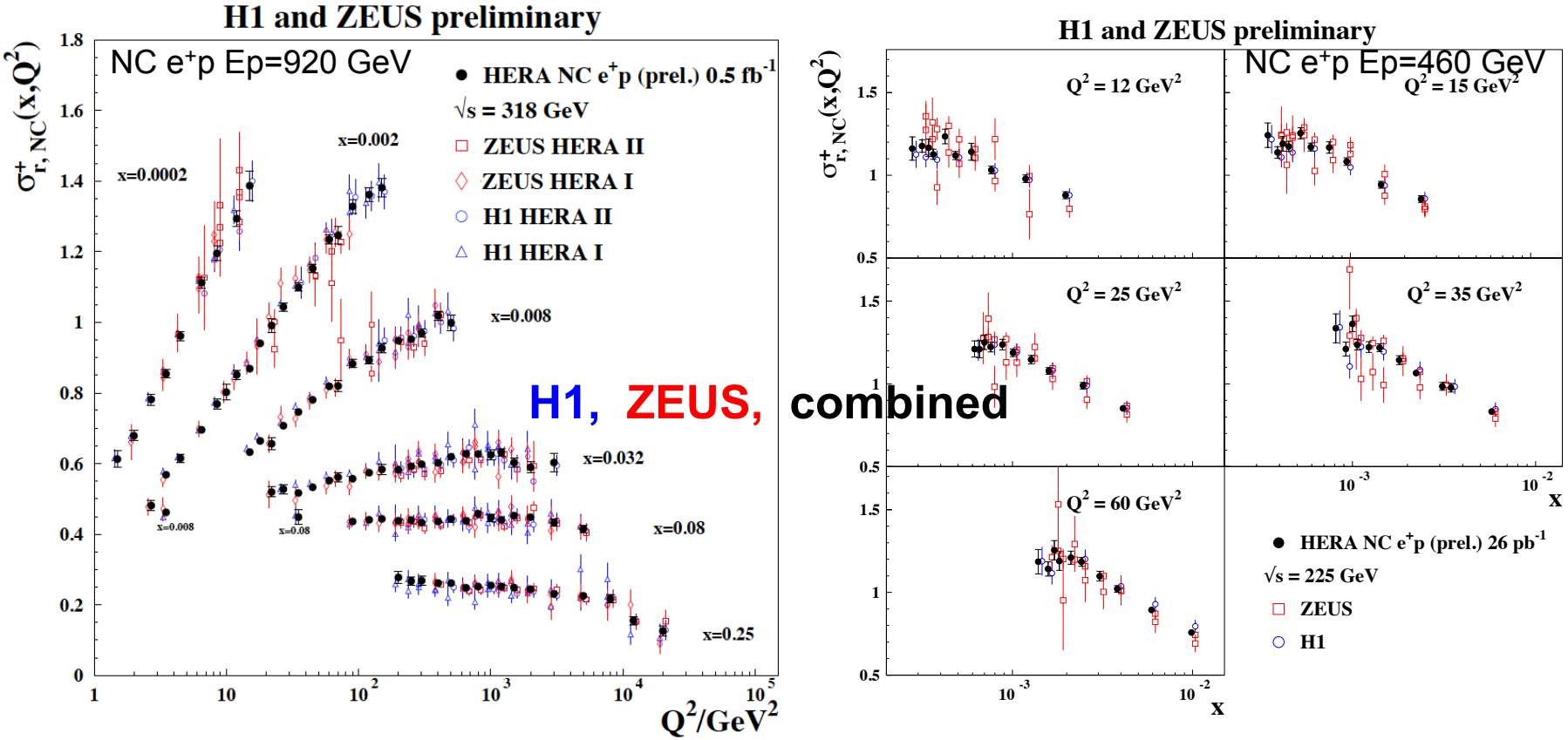
HERAverager (wiki-zeuthen.desy.de/HERAverager) is used for the cross section averaging,
162 corr. syst. sources are treated as multiplicative,
the following χ^2 definition is used:

$$\chi^2_{\text{exp},ds}(\boldsymbol{m},\boldsymbol{b}) = \sum_{i,ds} + \sum_{j,b} = \sum_{i} \frac{\left[m^i - \sum_j \gamma^i_j m^i b_j - \mu^i\right]^2}{\delta^2_{i,\text{stat}}\,\mu^i\left(m^i - \sum_j \gamma^i_j m^i b_j\right) + \left(\delta_{i,\text{uncor}}\, m^i\right)^2} + \sum_j b_j^2$$

Three additional procedural errors :
- multiplicative vs. additive
- correlation over all data sets of photoproduction bkg and hadronic energy scale uncertainties

Averaging of all NC and CC HERA I+II data

2927 cross sections are combined to 1307 points with 165 correlated systematic errors



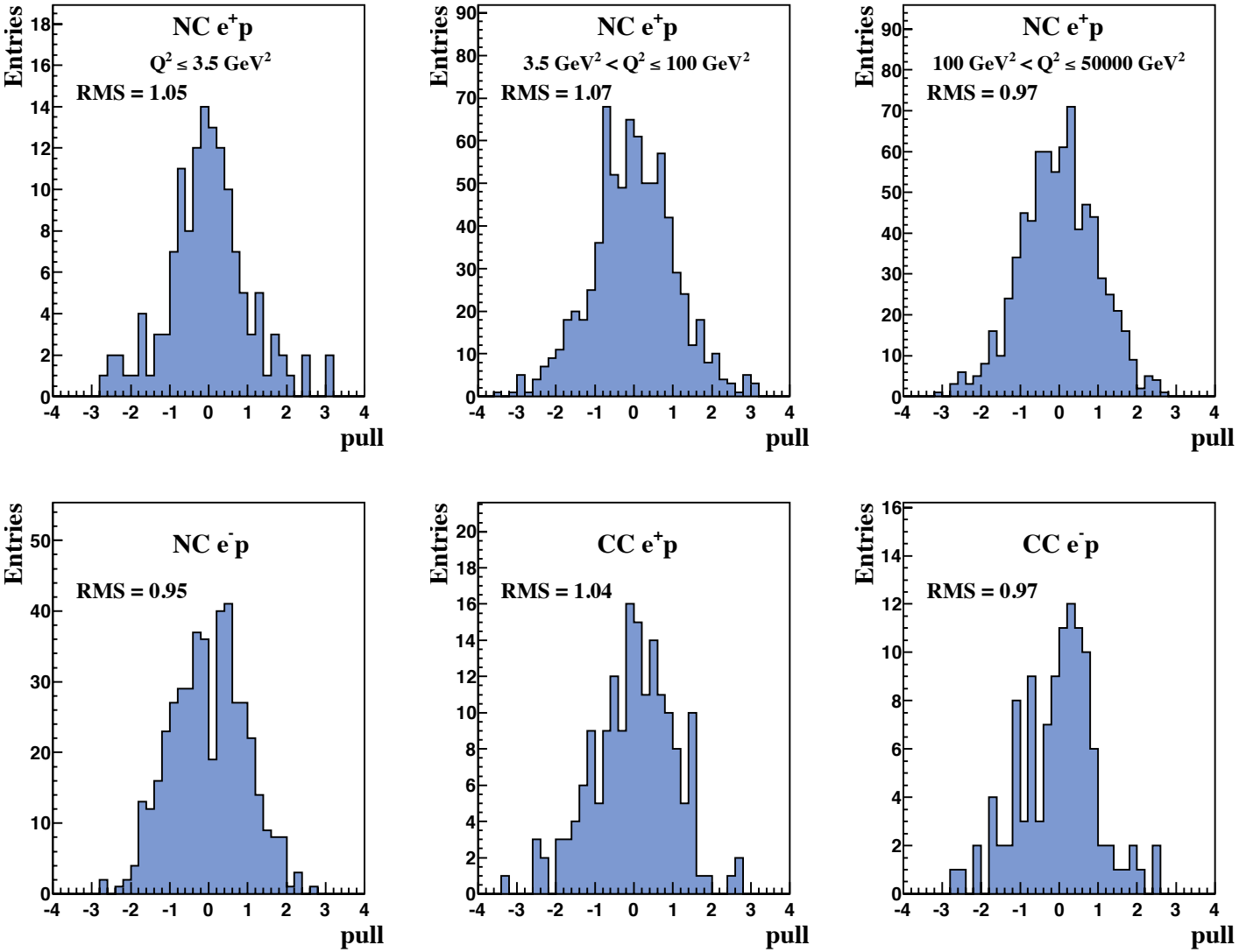
→ up to 6 measurements are combined into one averaged point

→ good consistency of the input data sets ($\chi^2/ndf = 1685/1620$)

Pulls for different samples

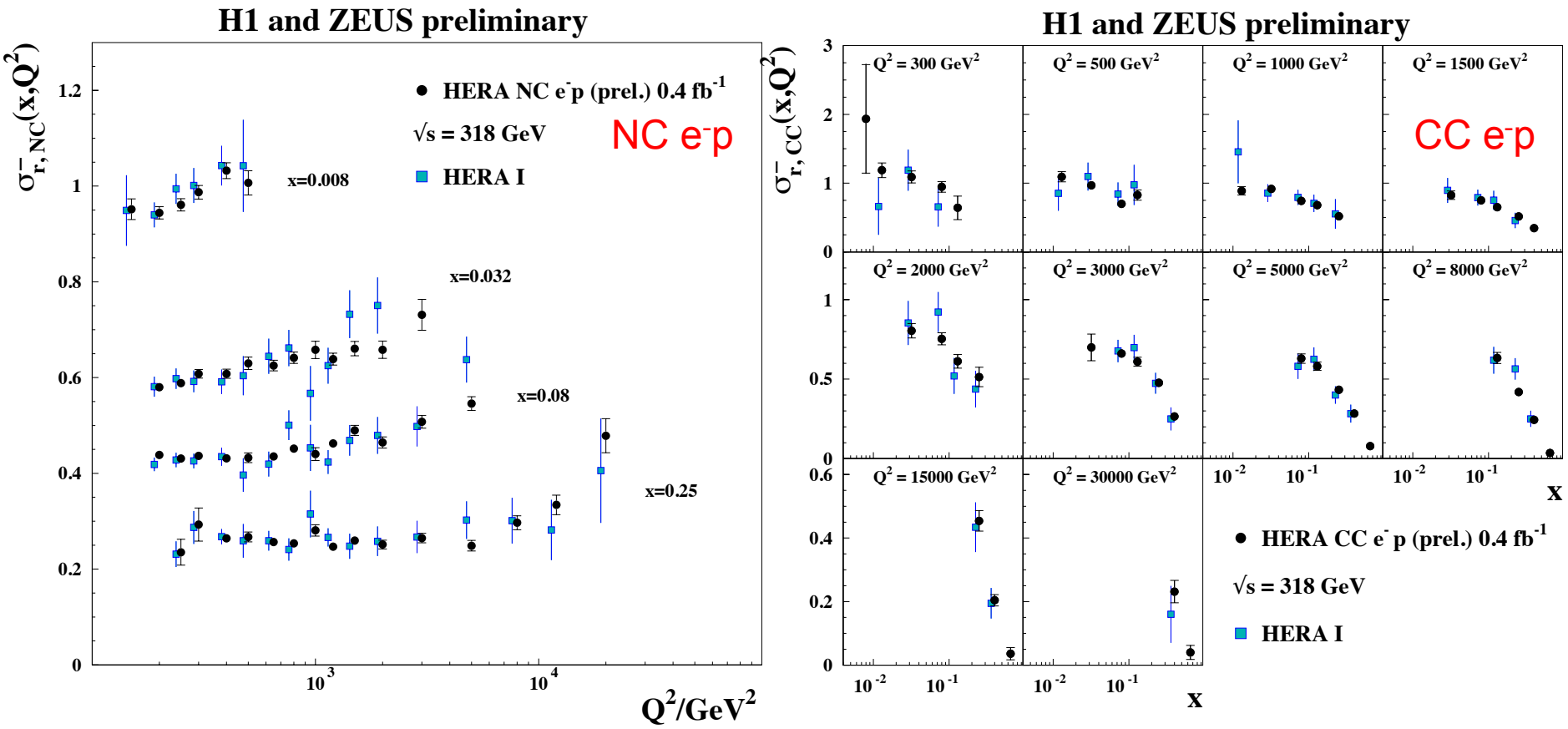
$$p^{i,k} = \frac{\mu^{i,k} - \mu^{i,\text{ave}}\left(1 - \sum_j \gamma_j^{i,k} b_{j,\text{ave}}\right)}{\sqrt{\Delta_{i,k}^2 - \Delta_{i,\text{ave}}^2}}$$

H1 and ZEUS preliminary



→ everywhere consistent with expected one sigma gaussian

Comparison of combinations HERA I+II vs. HERA I

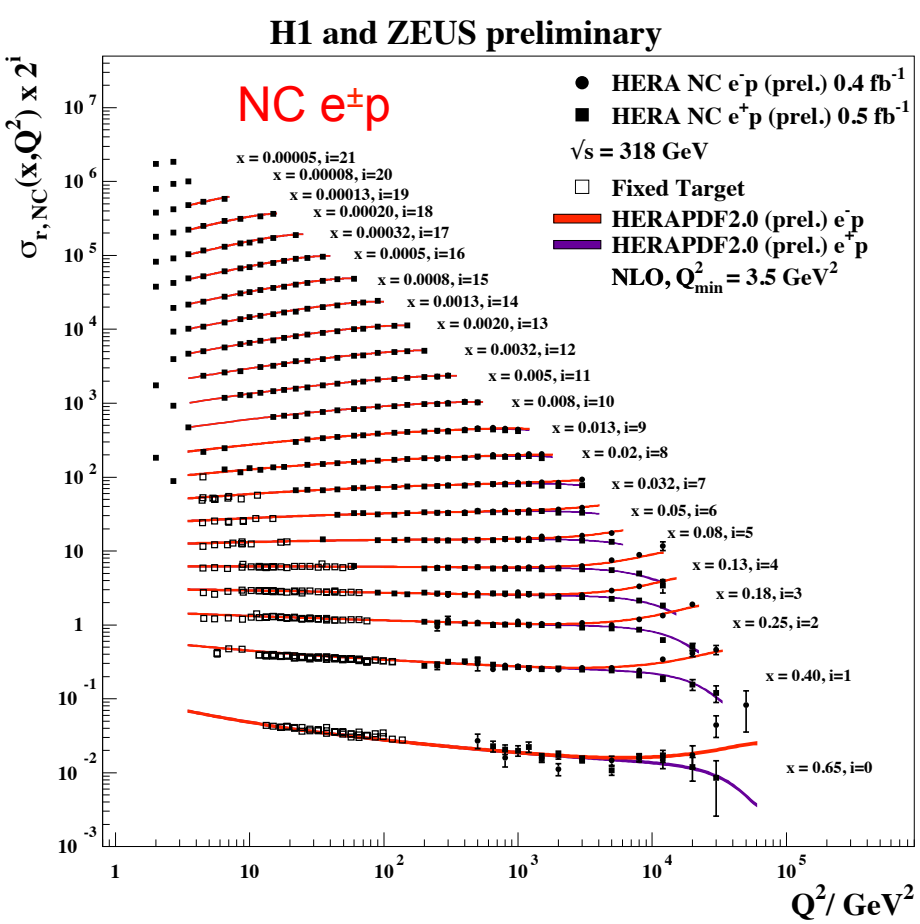


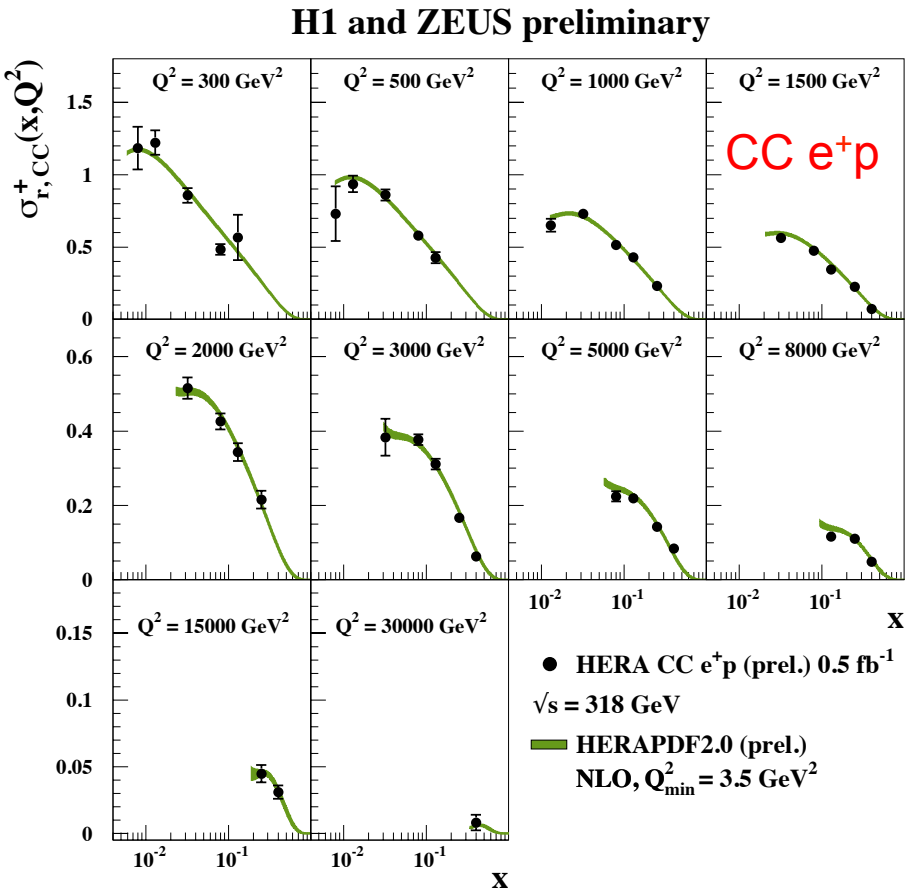
→ significant improvements in precision at high Q^2 (especially for e⁻p NC&CC) and at high y: about 1% precision in the best measured regions

Combined NC and CC data set from HERA (HERAPDF2.0)

$e^{\pm}p$ NC&CC (E_p=920 GeV), $e^{+}p$ NC (E_p = 820, 575, 460 GeV), corresponding to 1 fb^{-1}

→ 165 correlated syst. err.; $0.045 \leq Q^2 \leq 50000\ GeV^2$, $6\ 10^{-7} \leq x \leq 0.65$





→ for QCD analysis of the combined data (HERAPDF2.0) see talk of Katarzyna Wichmann

Conclusions

H1 and ZEUS completed inclusive DIS cross section measurements at HERA

- *e^+p NC cross sections measurements at low E_p=460 and 575 GeV and a model independent determination of F_L.*
- *ZEUS $e^\pm p$ NC measurements at high $x \rightarrow 1$*

All inclusive $e^\pm p$ NC and CC cross sections at E_p=920, 820, 575 and 460 GeV are combined in one coherent HERA data set which is used as a sole input to the HERAPDF 2.0 QCD fits