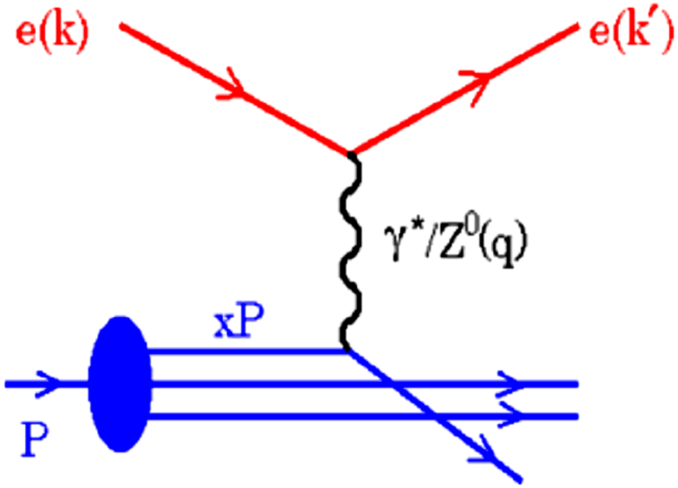
Status of PDFs from HERA

S. Glazov, DESY,
for H1 and ZEUS collaborations
Blois 2010

Proton structure probe



Neutral current Deep Inelastic Scattering (DIS) cross section:

$$\frac{d^2\sigma^\pm}{dx dQ^2} = \frac{2\pi\alpha^2 Y_+}{Q^4 x}\sigma_r^\pm =$$

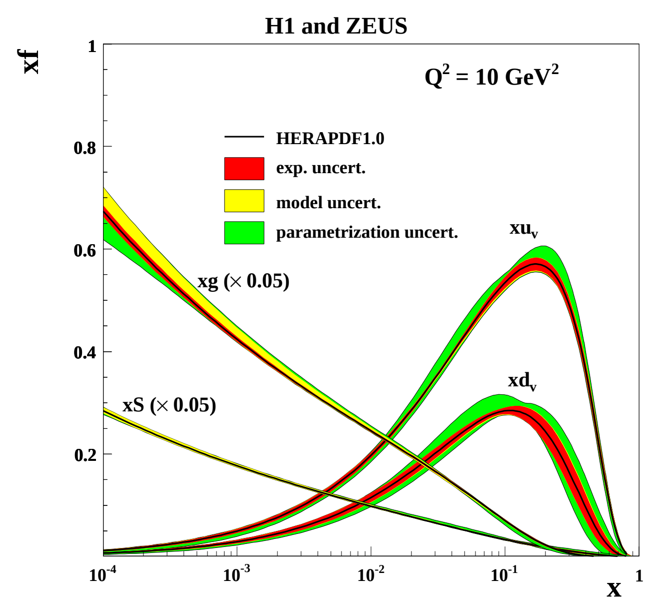
$$= \frac{2\pi\alpha^2 Y_+}{Q^4 x}\left[F_2(x,Q^2) - \frac{y^2}{Y_+}F_L(x,Q^2) \mp \frac{Y_-}{Y_+}xF_3\right]$$

where factors $Y_\pm = 1 \pm (1-y)^2$ and y^2 define polarisation of the exchanged boson and $y = Q^2/(S\,x)$.

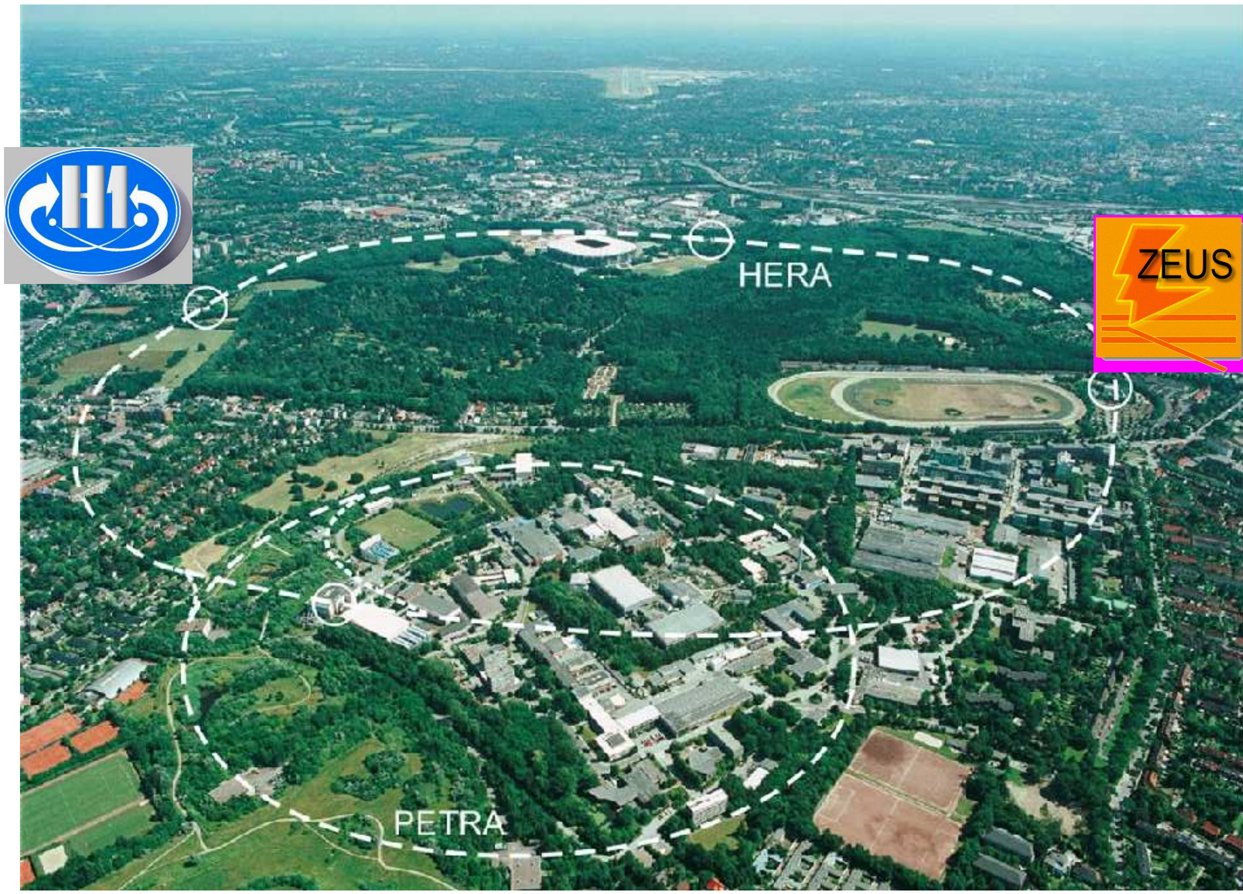
Kinematics is determined by boson virtuality Q^2 and Bjorken x.
At leading order:

$$\begin{aligned} F_2 &= x\sum e_q^2(q(x)+\bar{q}(x)) \\ xF_3 &= x\sum 2e_q a_q(q(x)-\bar{q}(x)) \\ \sigma^+_{CC} &\sim x(\bar{u}+\bar{c}) + x(1-y)^2(d+s) \\ \sigma^-_{CC} &\sim x(u+c) + x(1-y)^2(\bar{d}+\bar{s}) \end{aligned}$$

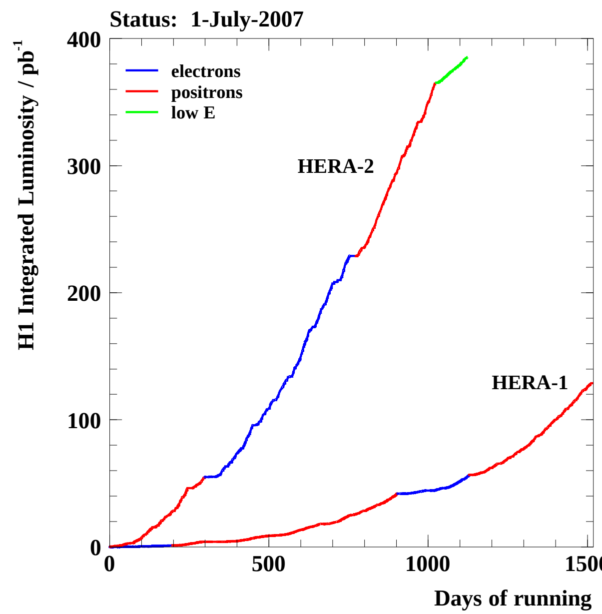
$xg(x)$ — from F_2 scaling violation, jets and F_L



HERA, H1 and ZEUS.

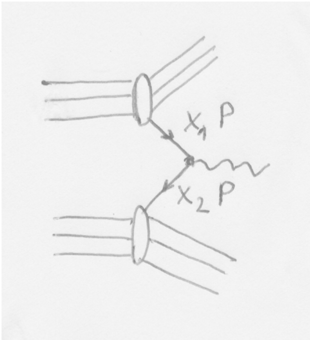


$E_e \times E_p = 27.5 \times 920\,\mathrm{GeV}^2$
$\sqrt{s} = 318\,\mathrm{GeV}$
$\mathrm{L} = 5 \cdot 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
e beam polarisation.



Integrated luminosity: about 500 pb^{-1} per experiment.

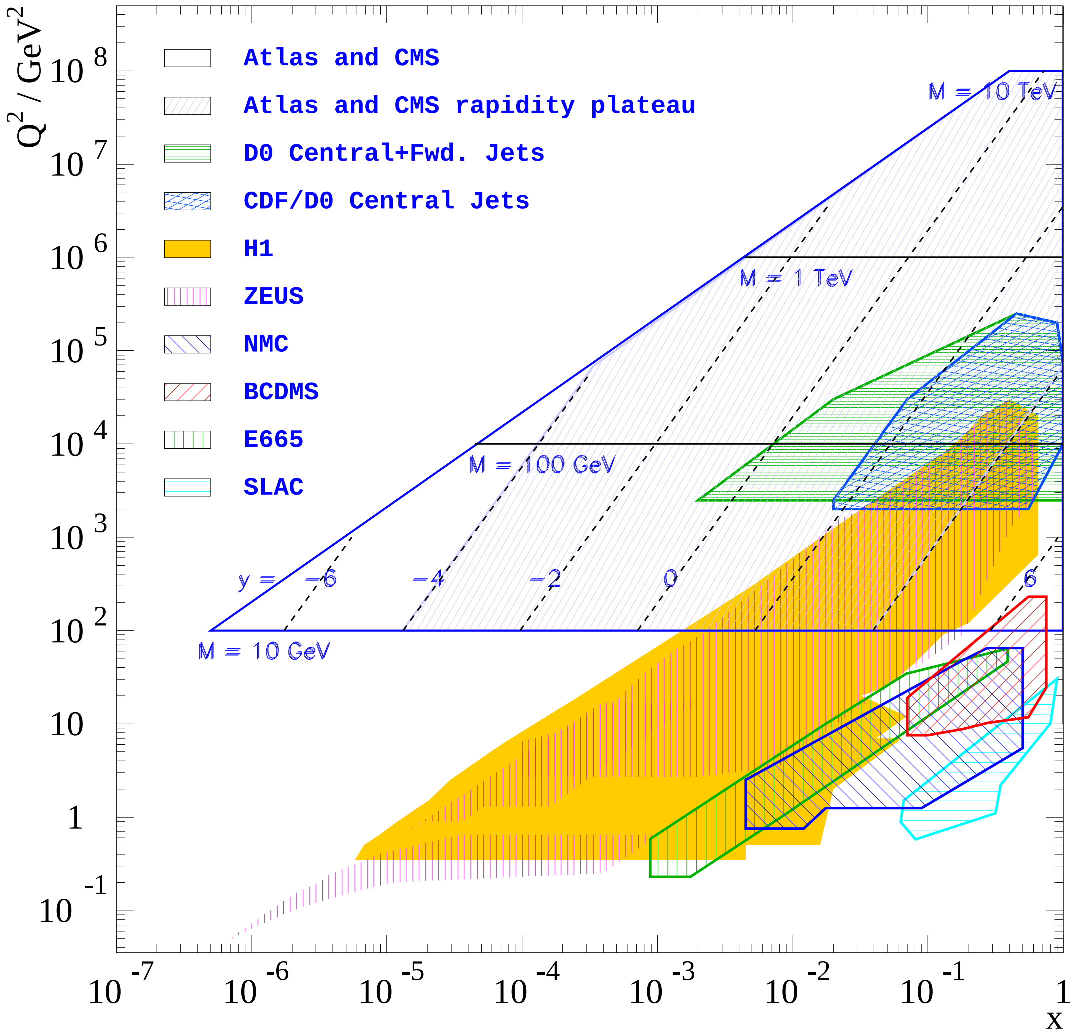
HERA and LHC kinematics



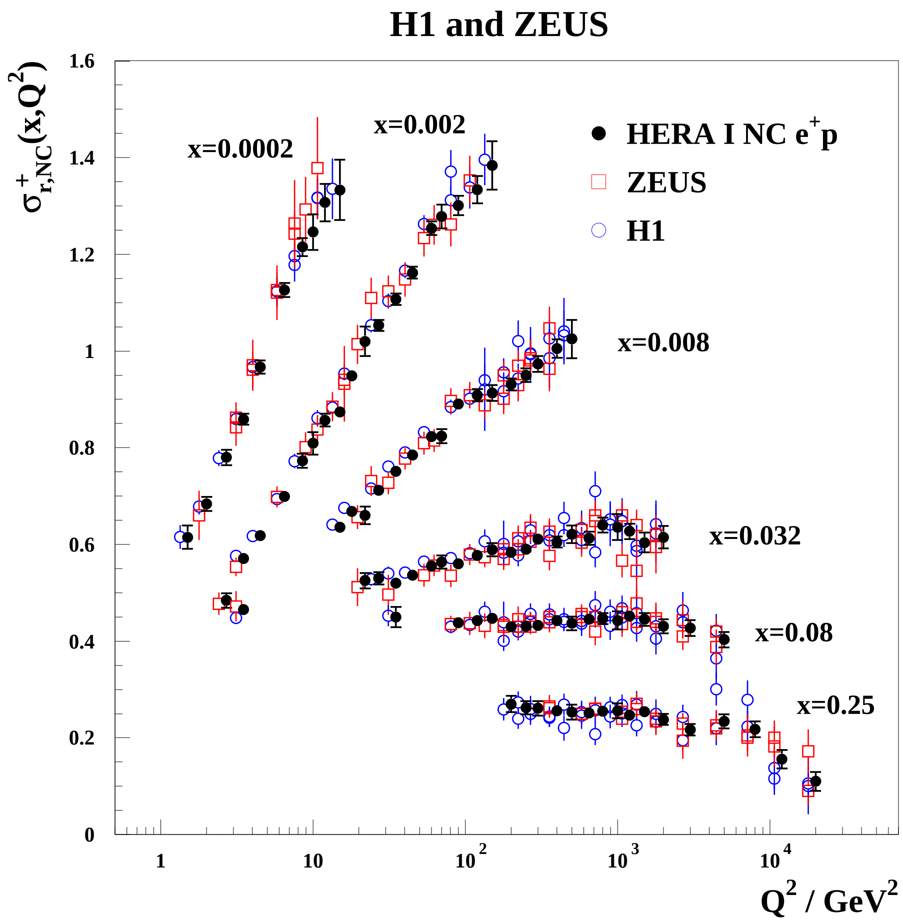
x_1, x_2 are momentum fractions.

Factorization theorem states that cross section can be calculated using universal partons × short distance calculable partonic reaction.

$$x_{1,2} = \frac{M}{\sqrt{S}} \exp(\pm y)$$



Combination of HERA data



Ultimate precision is obtained by combining H1 and ZEUS measurements.

Average H1 and ZEUS data before applying QCD analysis.

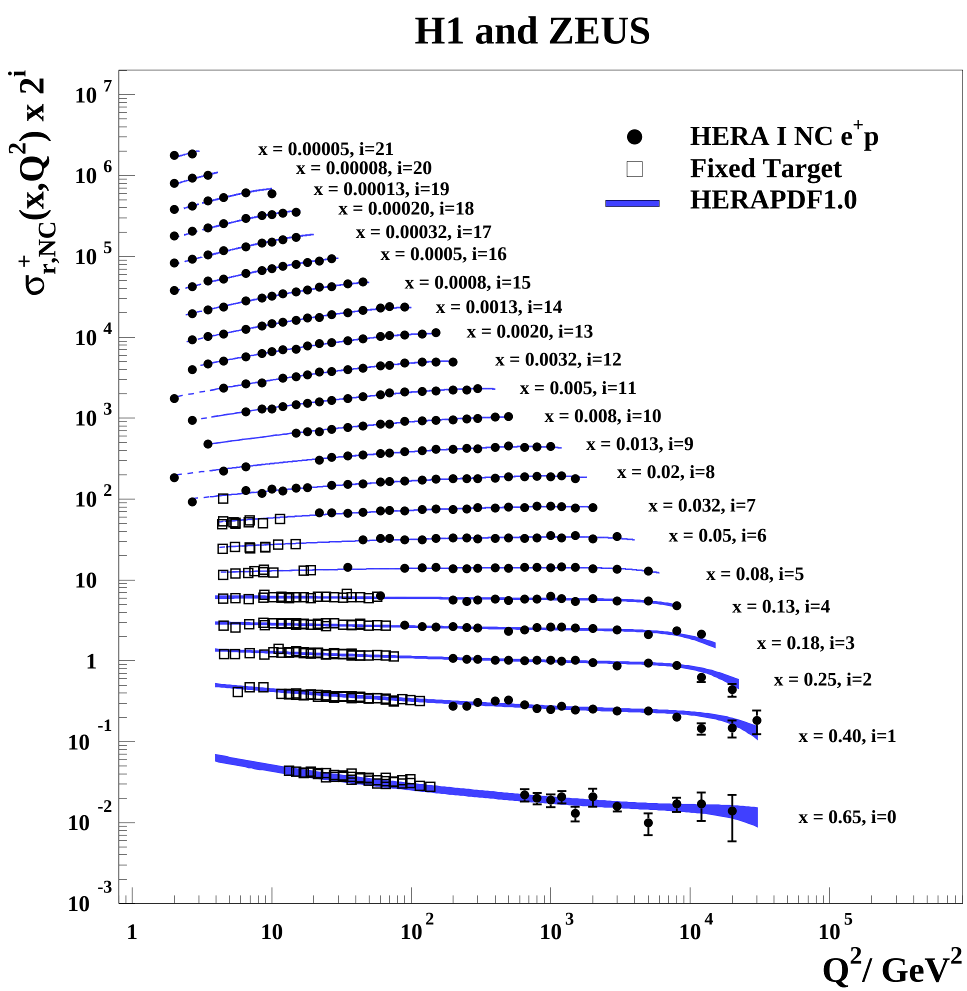
Achieved by fitting σ_r values, global normalisations and the correlated systematic uncertainties.

$$\sigma_r^{\pm} = F_2 - \frac{y^2}{Y_+} \mp \frac{Y_-}{Y_+} xF_3$$

Experiments cross calibrate each other: total uncertainties reduced, sometimes better than $\sqrt{2}$.

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

Combined HERA data



Combination of the published H1/ZEUS data collected at HERA-I for CC,NC, $e^{\pm}p$ mode. 14 publications, 1402 input and 741 output σ_r measurements, 110 correlated experimental error sources. For NC e^+p, $6 \cdot 10^{-7} < x < 0.65$ and $0.045 < Q^2\ 30000\ \text{GeV}^2$.

Combination:

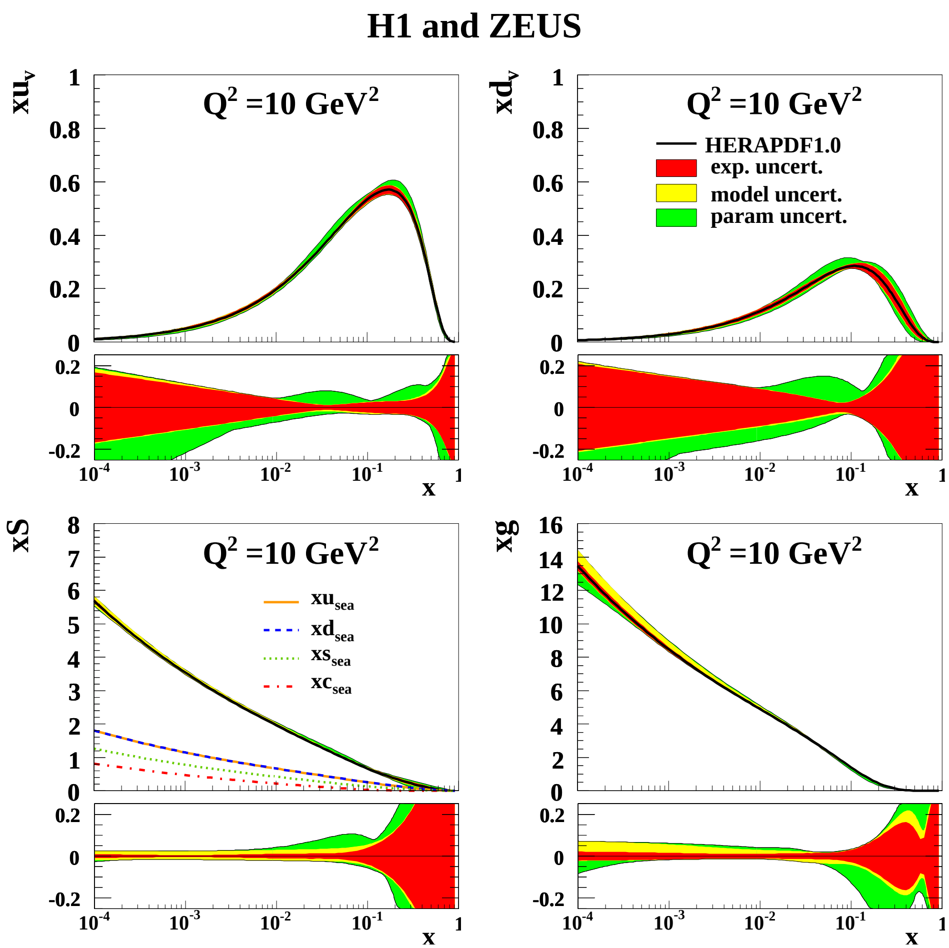
$$\chi^2/dof = 637/656$$

QCD Fit (to the combined HERA data with $Q^2 \geq 3.5\ \text{GeV}^2$):

$$\chi^2/dof = 574/582$$

HERA data precision is similar to fixed target experiments. Good consistency between H1 and ZEUS. Stringent test of DGLAP evolution.

QCD analysis of the HERA combined data



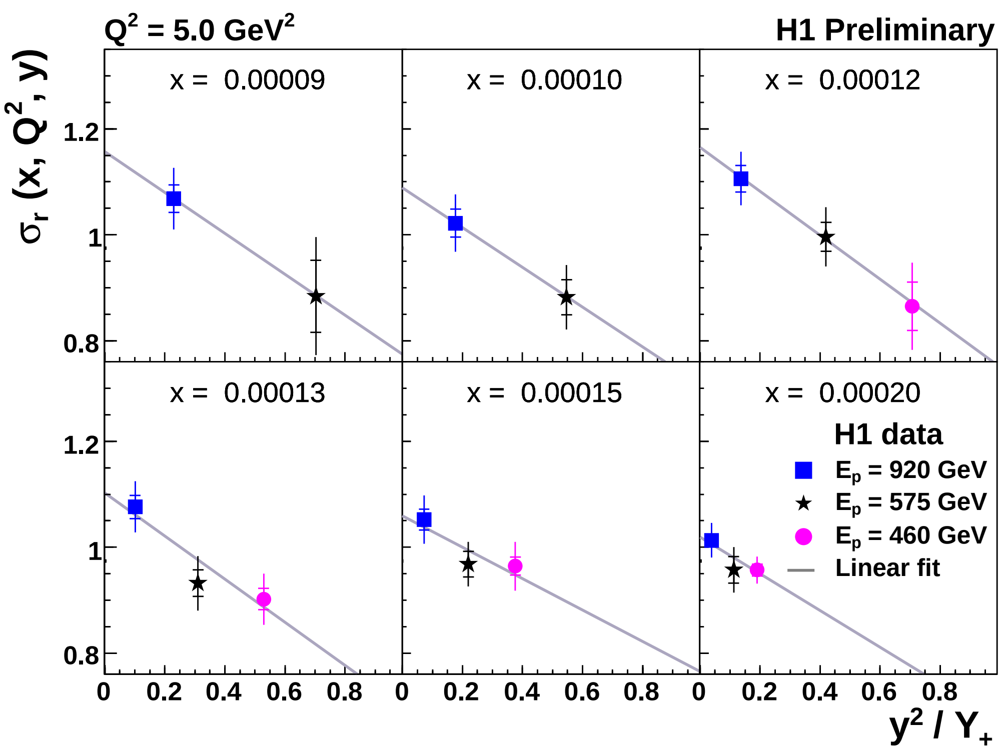
HERAPDF1.0 — NLO QCD analysis of the combined HERA data.

Separation of experimental, model and parameterisation uncertainties.

Accurate xS and xg at low x due to precise measurement of F_2.

Measurement of Structure Function F_L.

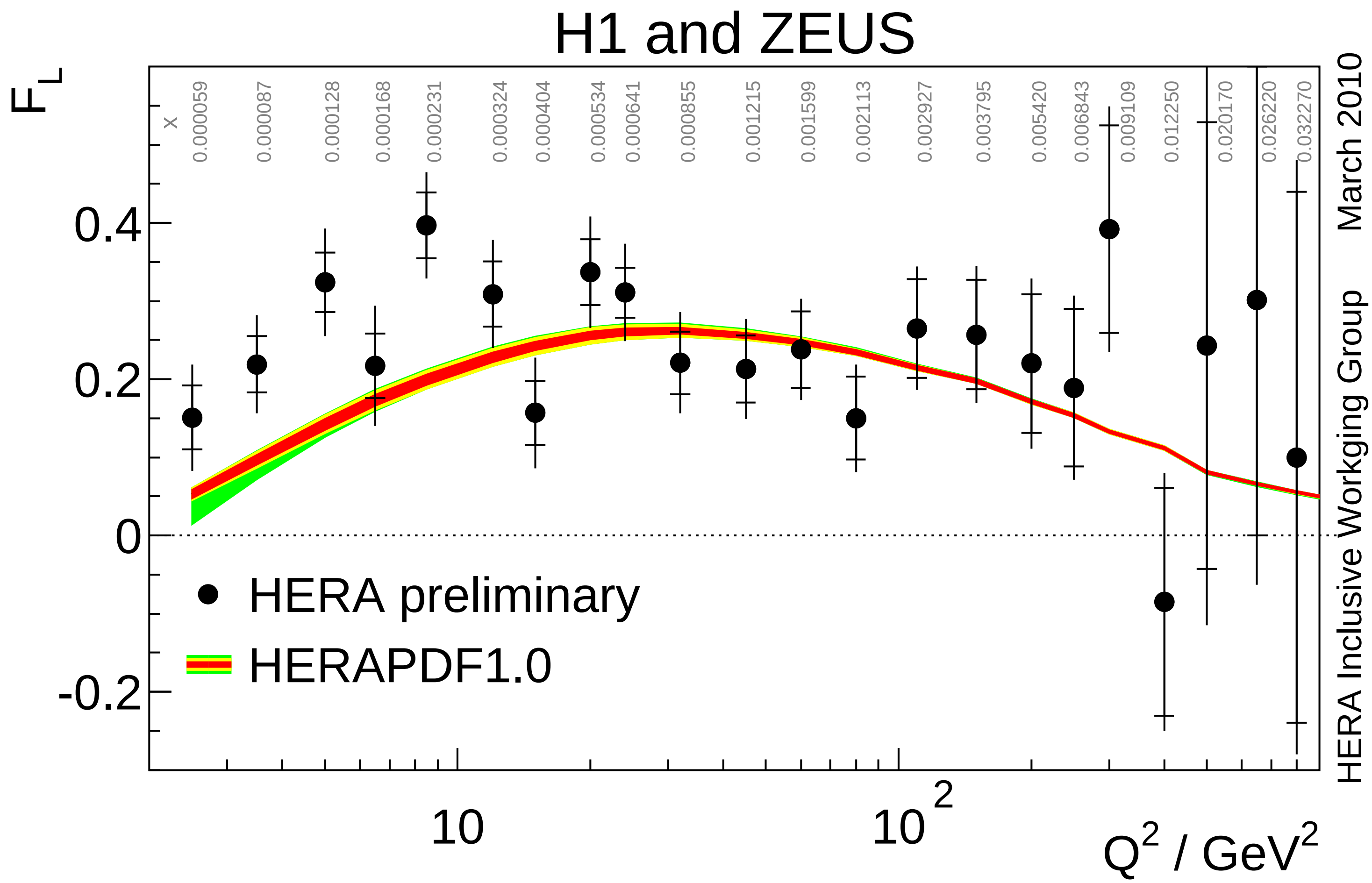
- In quark-parton model $F_L = 0$ for spin 1/2 quarks.
- In QCD $F_L > 0$ due to gluon emission. Large $xg(x)$ at low x implies sizable $F_L \rightarrow F_L$ is crucial test of QCD.
- Reduced proton beam energy runs at the end of HERA operation dedicated to measure F_L.



$$\sigma_r(y) = F_2 - \frac{y^2}{1+(1-y)^2} F_L$$

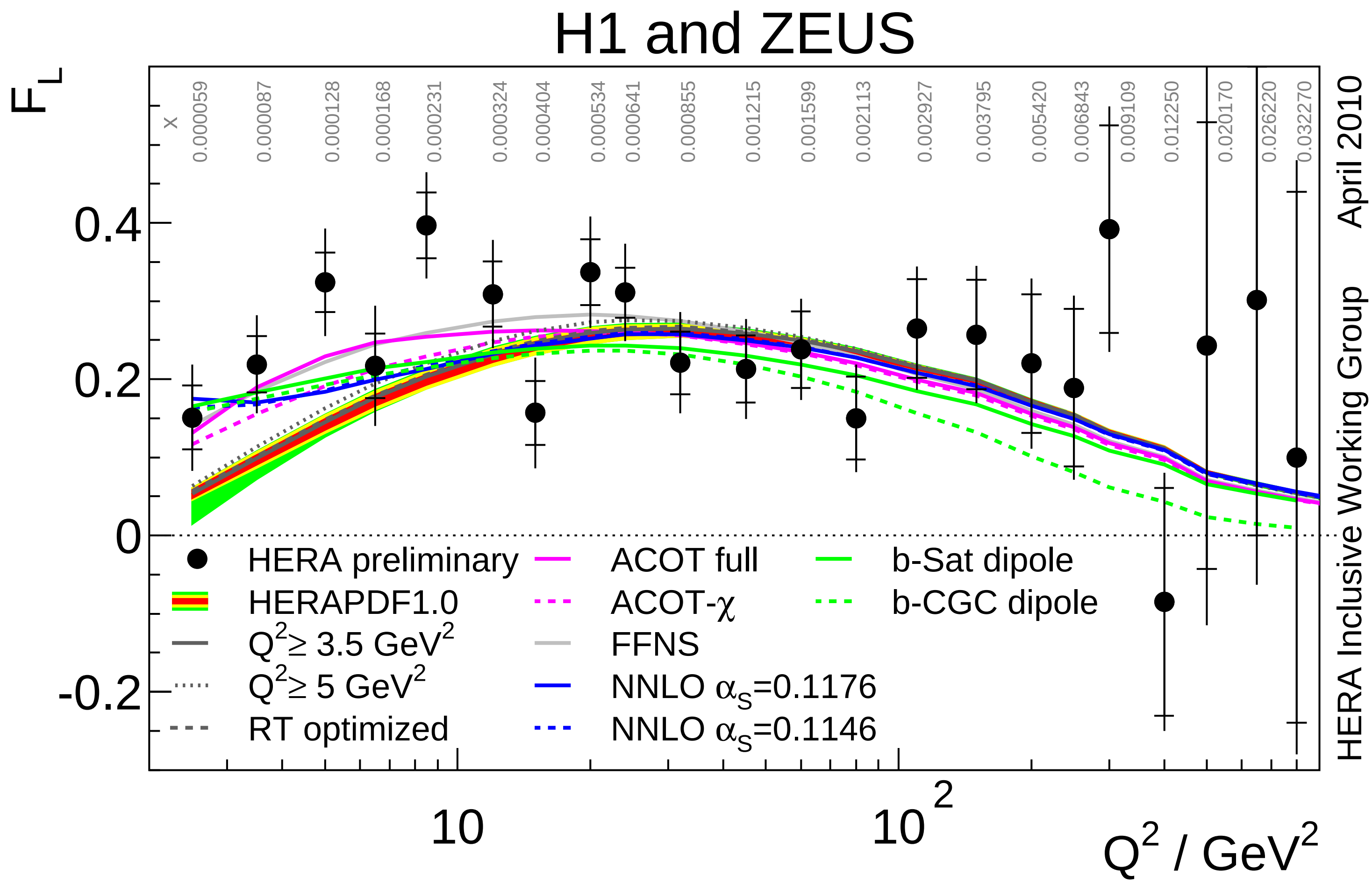
- Linear fit to the data at different centre-of-mass energies to obtain F_2 and F_L
- Relative normalisation from low y data

Combined H1-ZEUS Structure Function F_L



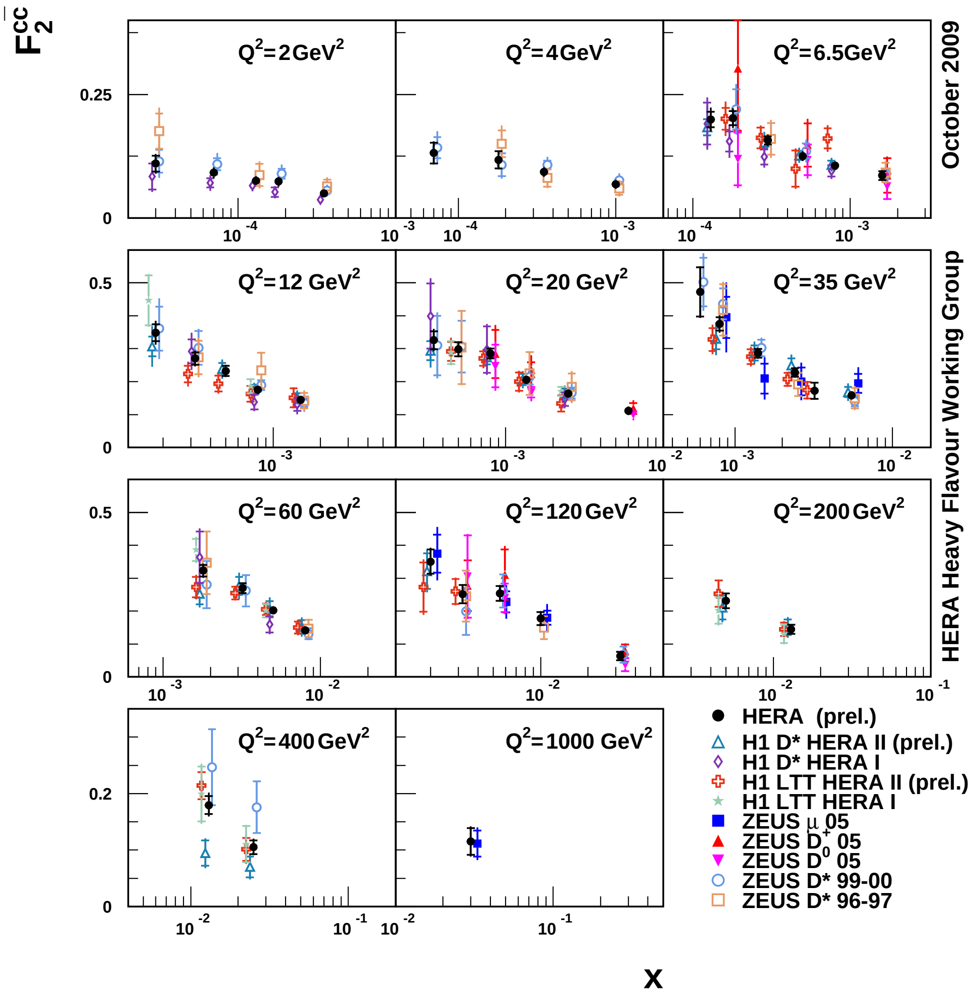
Good agreement with HERAPDF1.0 prediction for $Q^2 \geq 10$ GeV^2, some tension at low Q^2

Combined H1-ZEUS Structure Function F_L



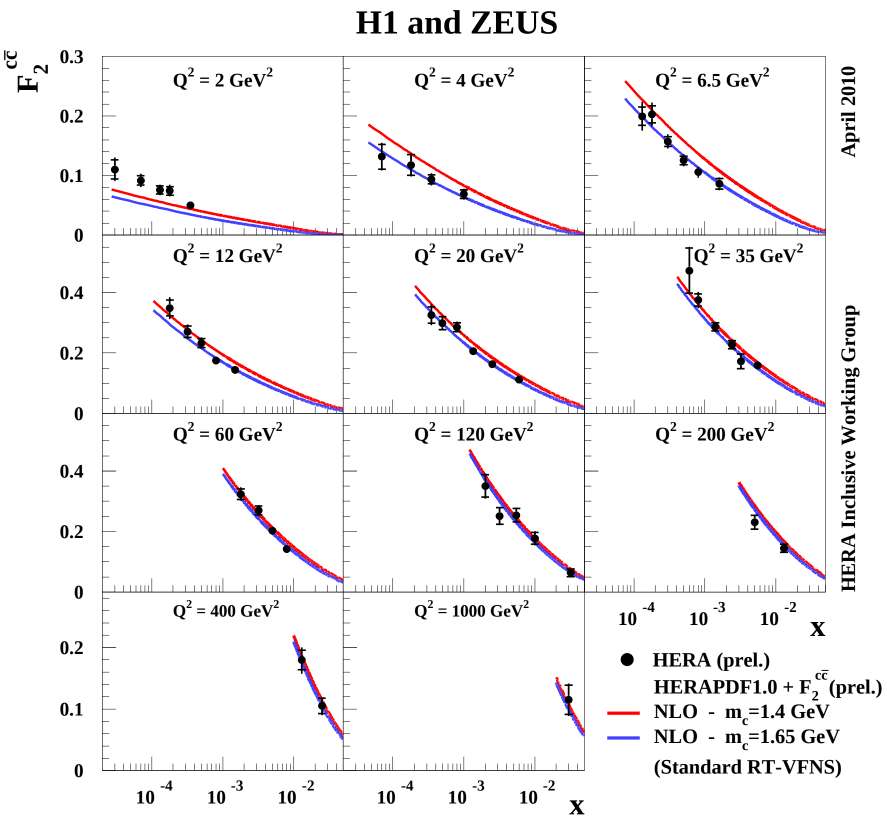
Several models provide better description at low Q^2. In particular, ACOT schemes and dipole models.

Charm data



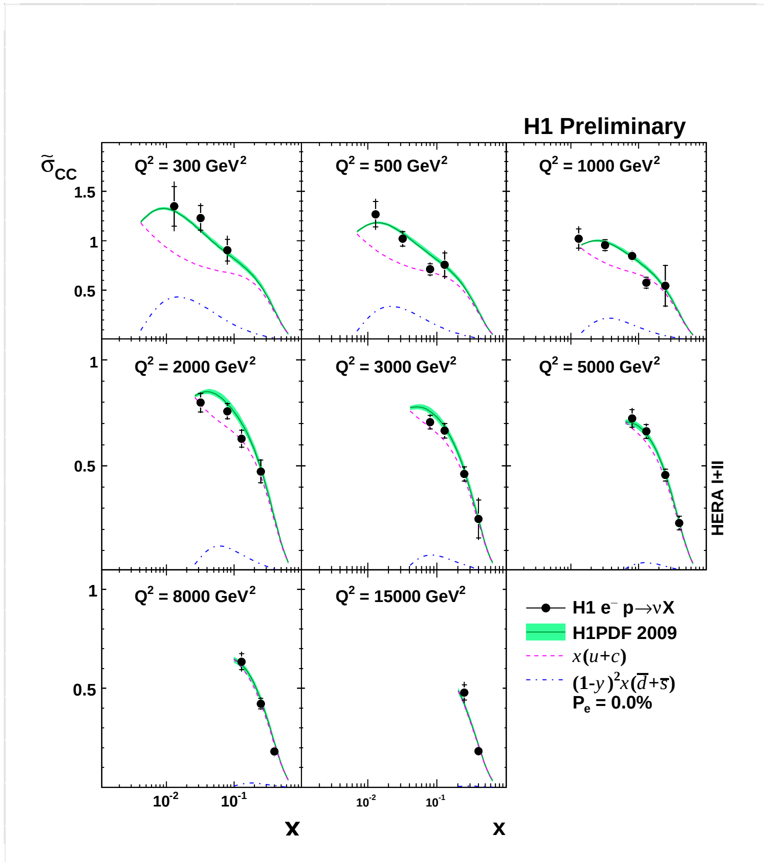
- Many measurements of $F_{2,c}$ using different methods from H1 and ZEUS.
- Average, taking into account different experimental and theoretical uncertainties.

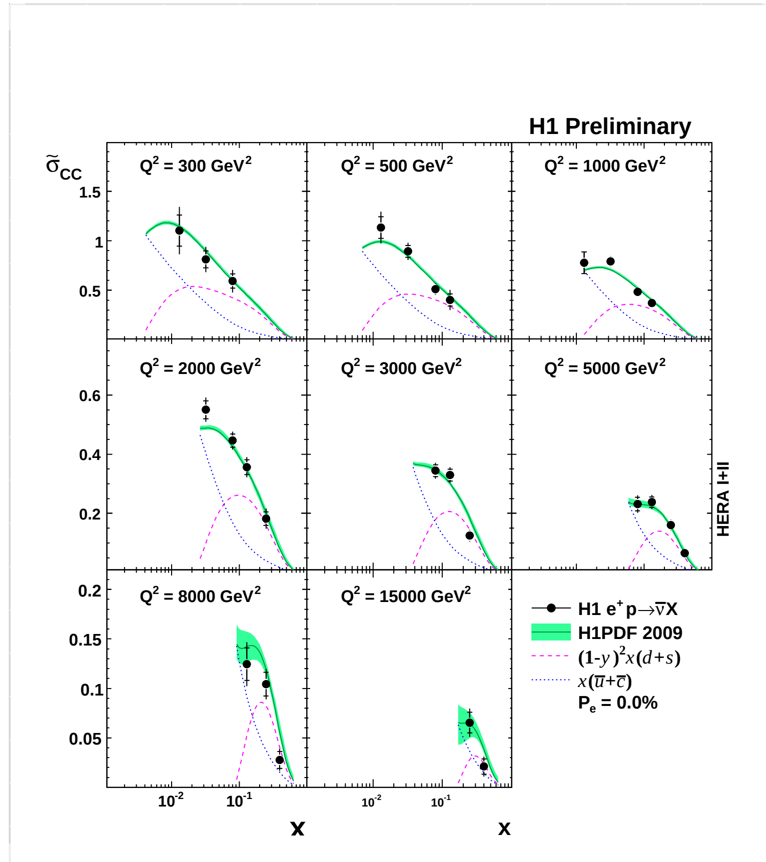
Fit including Charm data



- QCD analysis including charm data using various heavy flavour schemes and different values of m_C at $Q^2 \geq 3.5$ GeV^2.
- For RT scheme, data prefers m_C=1.65 GeV.

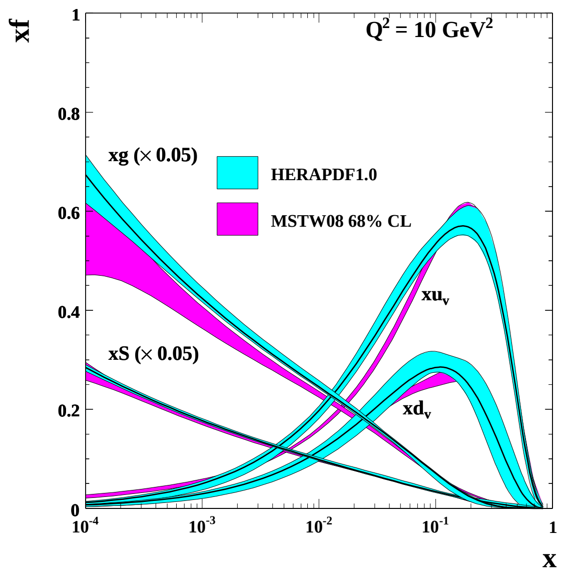
HERA-II data at High $Q^2 - x$

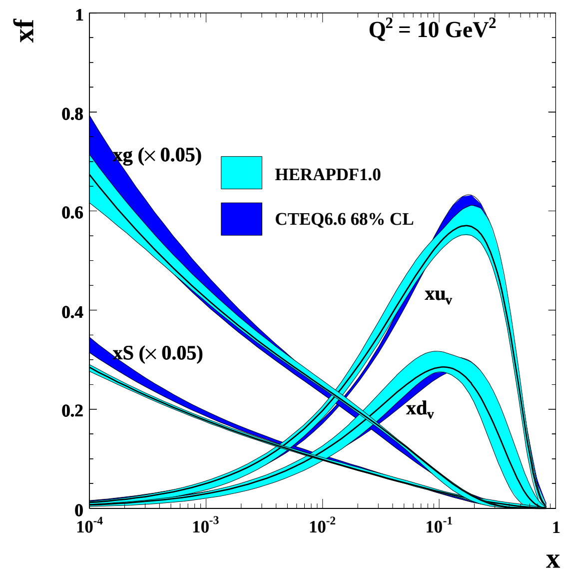


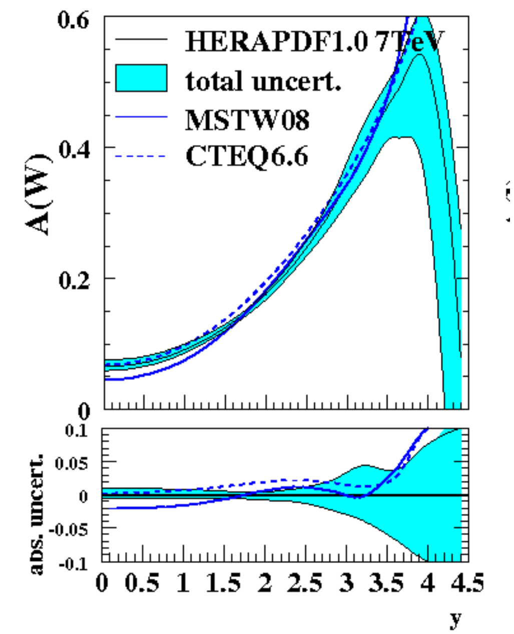


- Analysis of high Q^2 data being finalised by H1 and ZEUS. Almost tenfold increase in $e^- p$ luminosity compared to HERA-I
- CC data allows to decompose contributions of u_v, d_v and $\bar{U}, \bar{D}$ at medium-high x.

HERAPDF, other fits and LHC predictions







- HERAPDF1.0 has similar precision but somewhat different shape for PDFs compared to other fits (MSTW08, CTEQ6.6)
- This reflects in predictions for the LHC: W asymmetry, $A = (\sigma_{W_+} - \sigma_{W_-})/(\sigma_{W_+} + \sigma_{W_-})$ data should allow to constraint valence PDFs better at small x.

Summary

- Many new results from HERA during last year
- Combination of the H1 and ZEUS data brings ultimate precision for PDFs.
- Combined F_L measurement provides important check of the QCD evolution.
- Combined charm data allows to check heavy flavour models, restricts parameter variation.
- New coming HERA-II data improves precision at high x, in particular for u_v.