

Measurement of Structure Functions at HERA

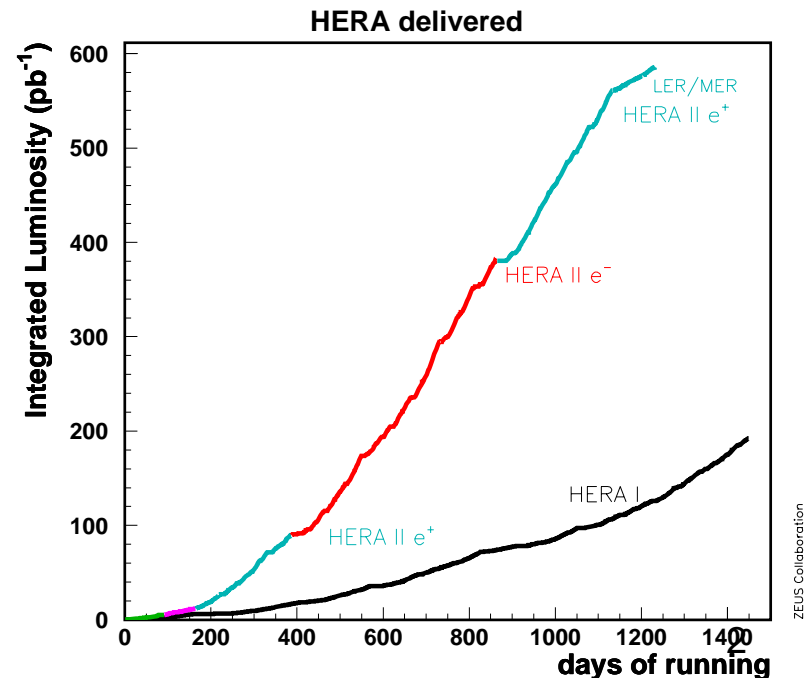
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(on behalf of the H1 and ZEUS Collaborations)

Lake Louise Winter Institute 2010

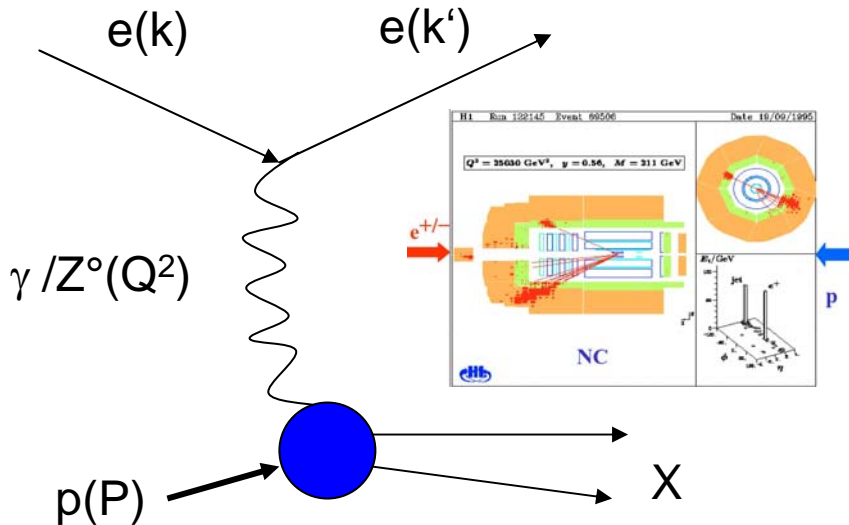
The *ep* collider HERA

- Circumference: 6.3 km
- $27.5 \times 920(820) \text{ GeV}$, $\sqrt{s_{ep}} = 319 \text{ GeV}$
- 4 experimental halls, 2 collider experiments: H1 and ZEUS
- HERA 1: 1992-2000
- Luminosity upgrade: mid 2000 – end 2001
- Higher luminosity: HERA 2 (2003 – 2007)

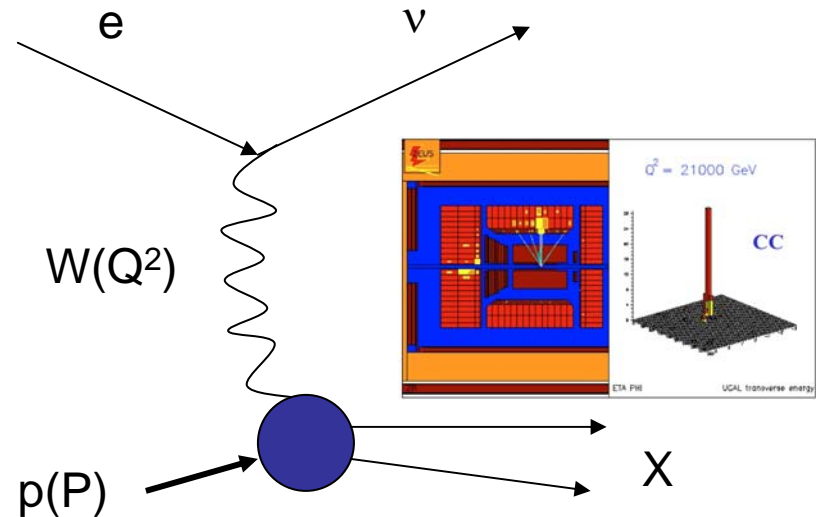


Inclusive Deep Inelastic Scattering at HERA

Neutral current



Charged current



$Q^2 = -(k - k')^2$ - four momentum transfer squared in the reaction

$x = \frac{Q^2}{2P(k - k')}$ - fraction of the proton momentum carried by the parton

$y = Q^2 / sx$ - fraction of the lepton's energy loss

$s = 4E_e E_p$ - center-of-mass energy squared

Cross sections and structure functions

NC Cross Section:

NC Reduced cross section: $\tilde{\sigma}_{NC}(x, Q^2)$

$$\frac{d^2 \sigma_{NC}(e^\pm p)}{dx dQ^2} = \frac{2\pi \alpha^2}{x Q^4} Y_\pm \left[\tilde{F}_2 - \frac{y^2}{Y_+} \tilde{F}_L \mp \frac{Y_-}{Y_+} x \tilde{F}_3 \right] \quad Y_\pm = 1 \pm (1-y)^2$$

- The proton structure function F_2 in QPM:

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

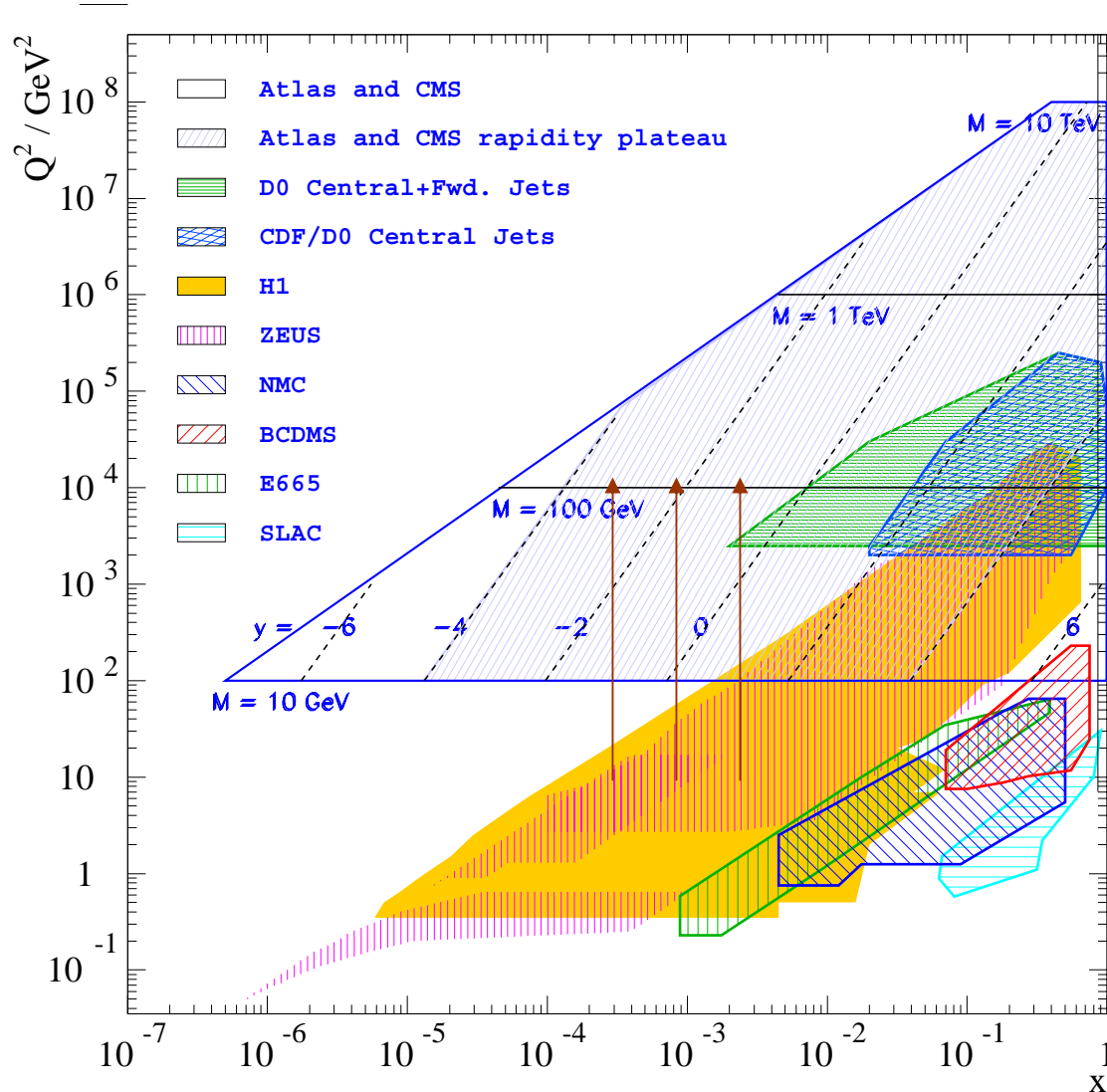
- sum of the (anti)quarks density distributions weighted with their electric charge squared

- Structure function $F_L \sim$ gluon density $g(x)$ in NLO QCD and 0 in QPM
- $x F_3 \sim 2 \sum_i e_i a_i x [q_i(x) - \bar{q}_i(x)]$ - determines the valence quark distributions

CC $e^\pm p$ Cross Sections:

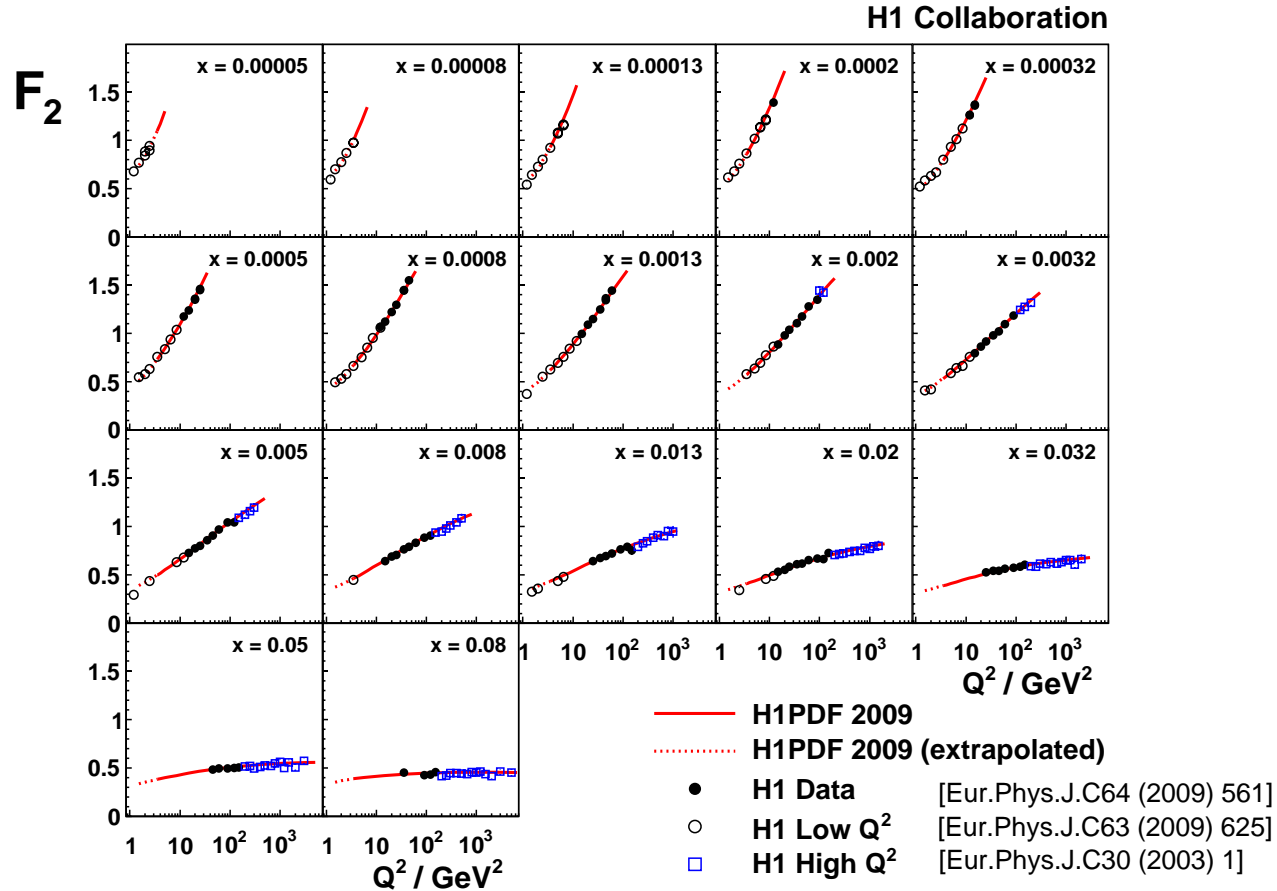
$$\left. \begin{aligned} \sigma^+ &= x[\bar{u} + \bar{c}] + (1-y)^2 x[\bar{d} + s] \\ \sigma^- &= x[u + c] + (1-y)^2 x[\bar{d} + \bar{s}] \end{aligned} \right\} \text{flavour separation at high } x$$

Kinematic plane



- QCD evolution extrapolates HERA measured PDFs to LHC
- HERA data cover LHC central rapidity range for $M > 100 \text{ GeV}$

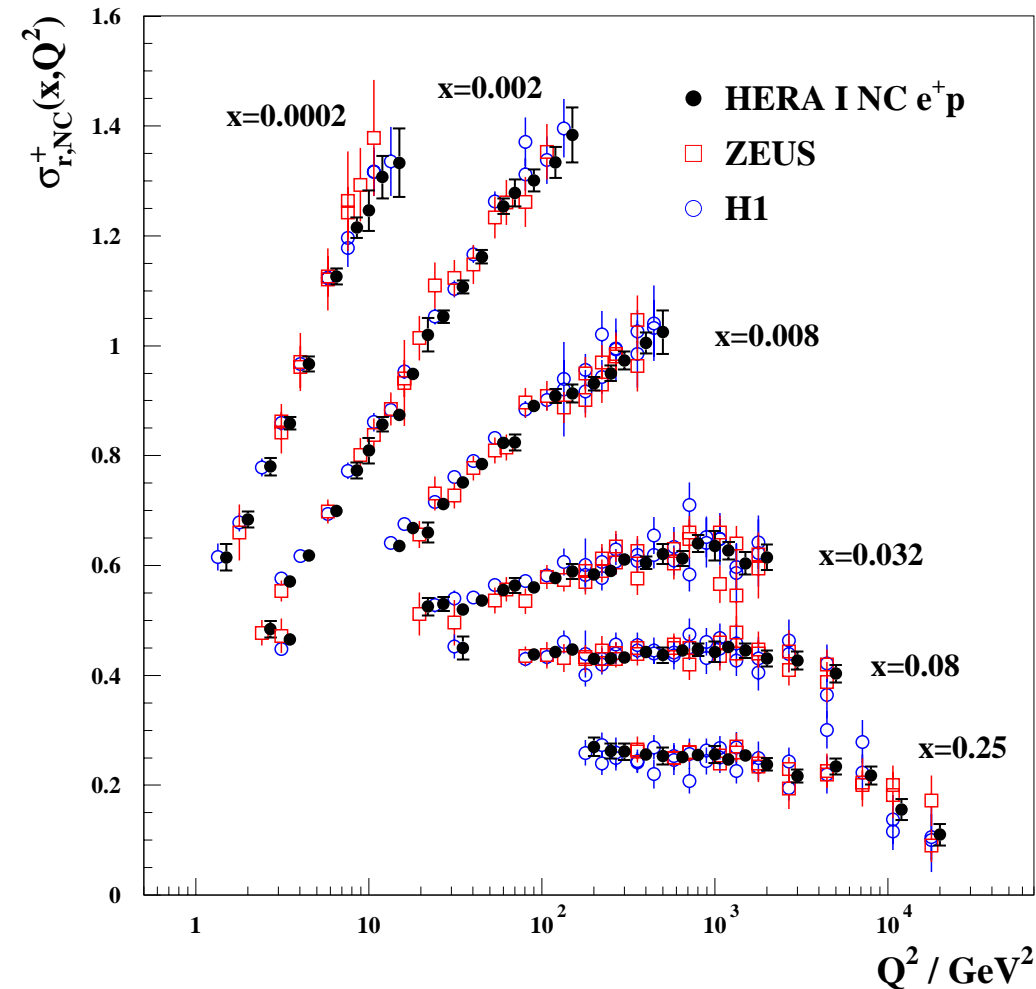
F_2 at $Q^2 < 150 \text{ GeV}^2$



- Combined H1 data in the region of inelasticity $0.005 < y < 0.6$ with a precision of 1.3-2% , for HERA 1 period
- Data are compared to NLO QCD fit to the H1 data alone – H1PDF2009

Combined H1 & ZEUS data

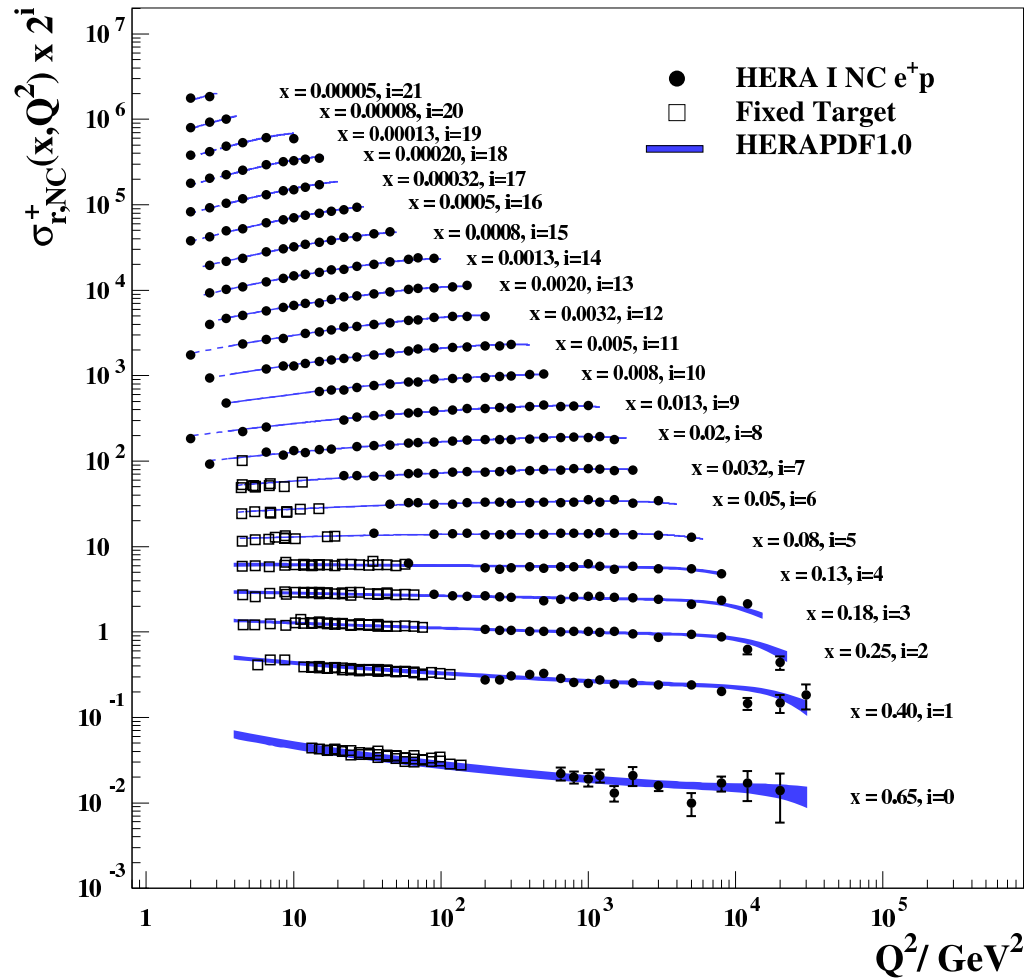
H1 and ZEUS



- Combination of H1 & ZEUS HERA 1 data provides a model independent tool to study consistency of the data and to reduce systematic errors
- New average based on the complete HERA 1 inclusive DIS data set with a total luminosity of $L=240 \text{ pb}^{-1}$
- The error reductions after the averaging procedure and the scaling violation are clearly observed

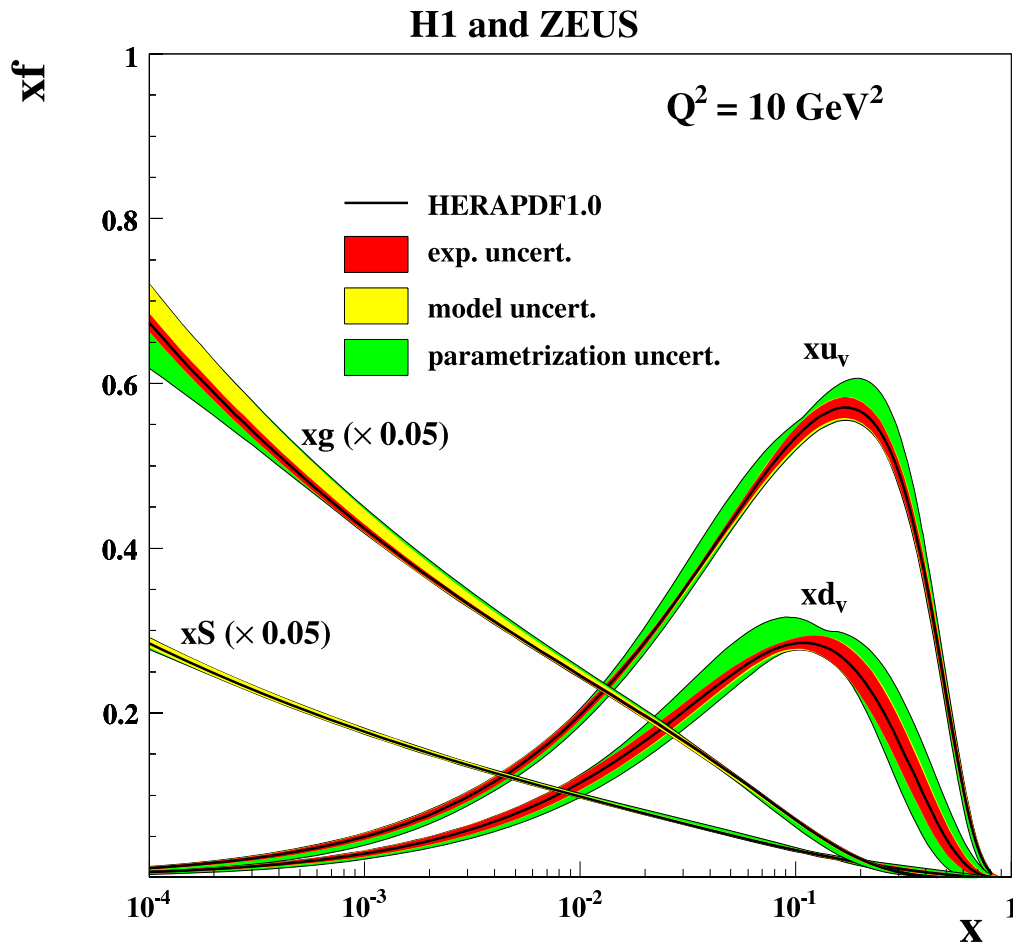
H1 & ZEUS combined results

H1 and ZEUS



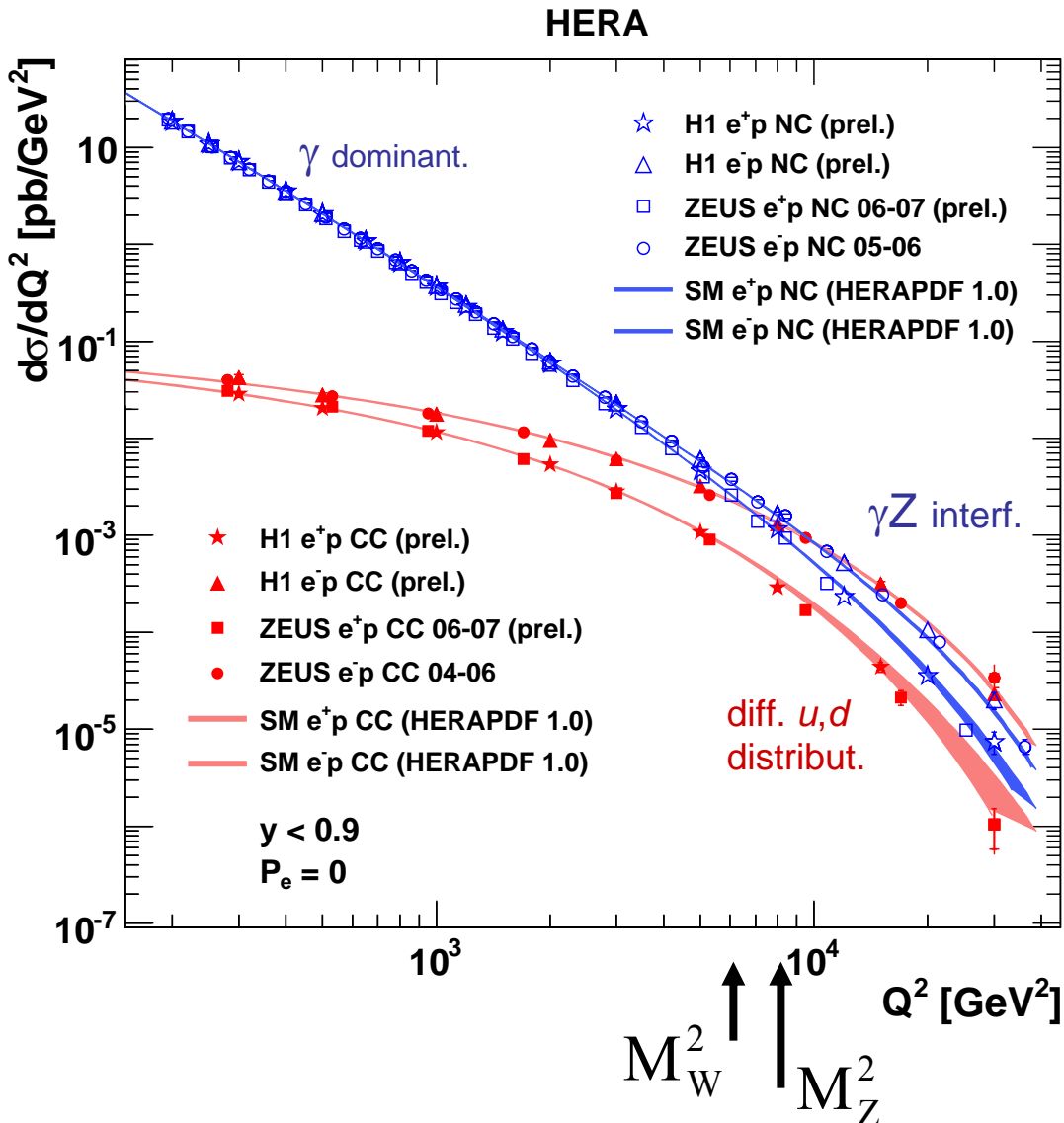
- HERAPDF1.0 is a new NLO QCD fit to the complete inclusive HERA 1 data
- Scaling violation is well described over 4 orders of magnitude in x and Q^2 by the fit with $\chi^2/\text{ndf} = 532/582$

HERAPDF1.0 fit



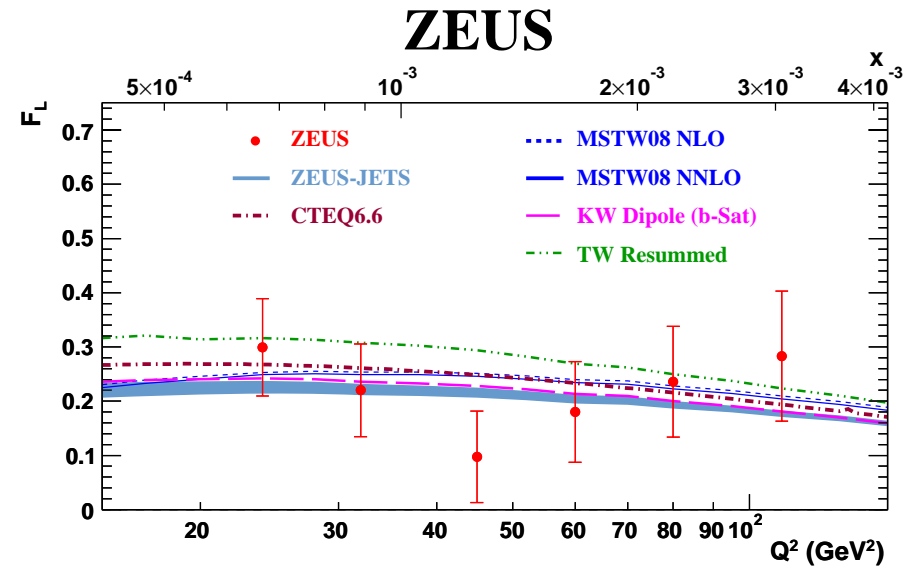
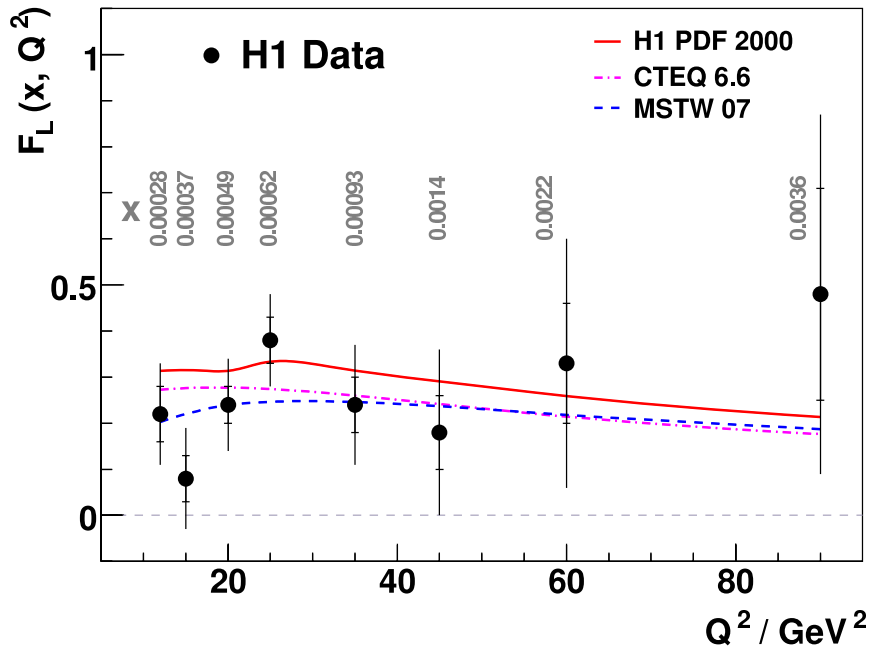
- Due to the precision of the combined data set, the parametrisation HERAPDF1.0 has total uncertainties at the level of a few percent at low x
- Sea and gluon distributions are divided by a factor of 20

CC and NC cross section measurements



- The combined collected luminosity of 1fb⁻¹ by H1 & ZEUS experiments provides a good test of the SM
- Neutral (γZ) and Charged (W[±]) cross sections at Q² ≥ M²(Z/W) scale get similar: EW unification
- Agreement between H1, ZEUS and QCD fit over seven orders of magnitude in cross section

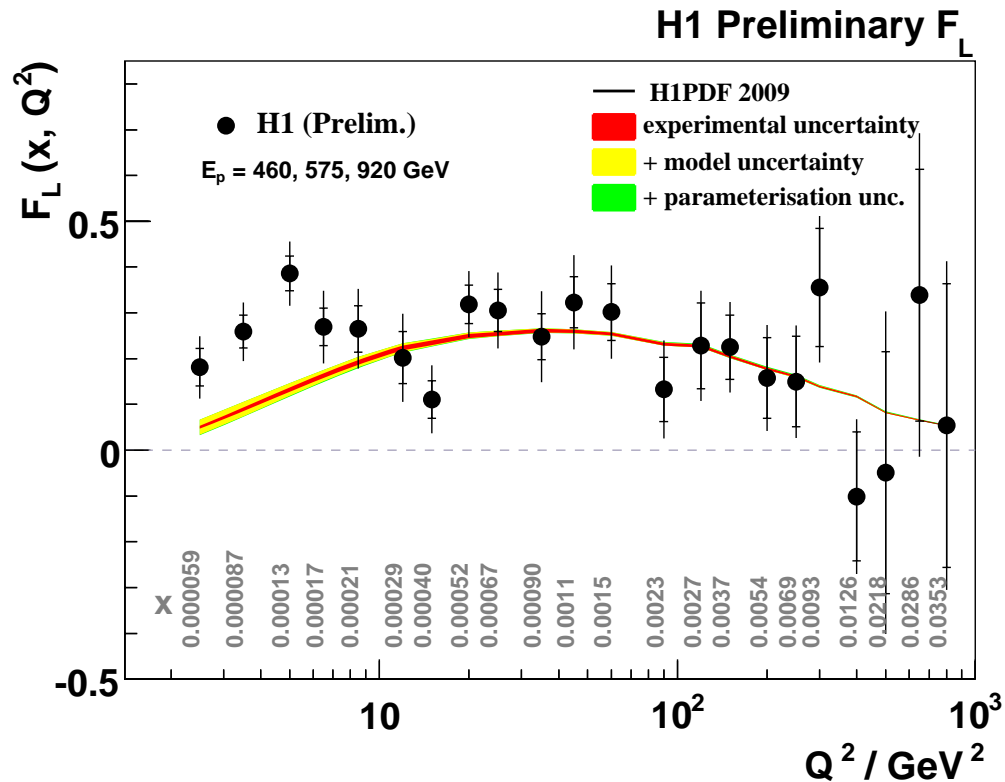
Measurements of F_L by H1 & ZEUS



- The first direct measurement of the structure function F_L at HERA

- A non-zero F_L is observed in the kinematic region of $20 < Q^2 < 130 \text{ GeV}^2$ and $0.0005 < x < 0.007$

Measurement of F_L by H1



- The new preliminary measurement of F_L extend the results to low Q^2 and cover the range of $2.5 \leq Q^2 \leq 800 \text{ GeV}^2$ and $0.00005 \leq x \leq 0.06$
- Data are in a good agreement with H1PDF2009 for $Q^2 > 10 \text{ GeV}^2$

Summary

- Recent structure function results from the H1 and ZEUS Collaborations are presented
- The combined data set covers the wide kinematic range of $0.2 \leq Q^2 \leq 30000 \text{ GeV}^2$ and $5 \cdot 10^{-6} < x < 0.65$
- The combined measurements are analysed in a NLO QCD fit, and a set of parton density functions, HERAPDF1.0, is extracted from these data alone
- The high precision of presented data is essential for predictions of physics at the LHC

