

# Measurements of the proton structure at HERA and their impact for LHC

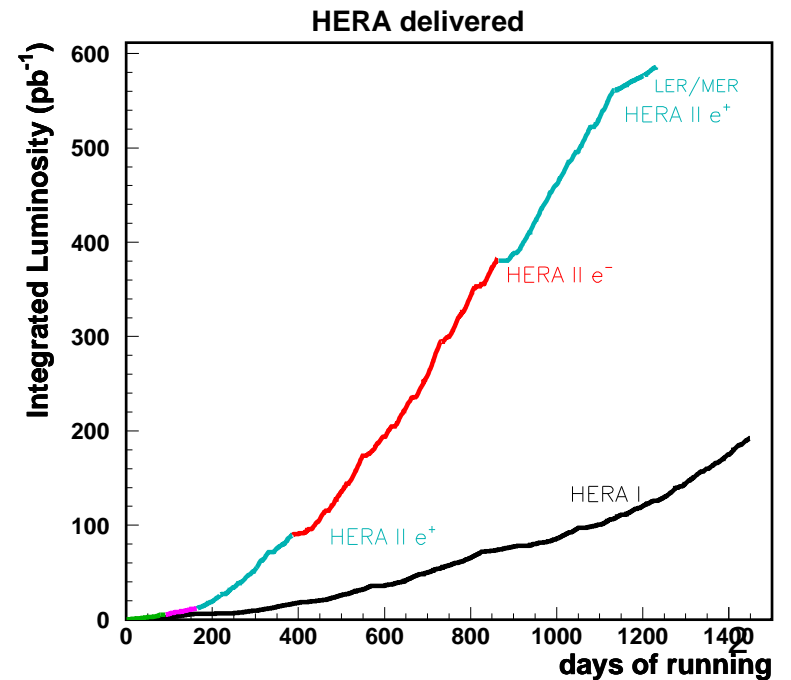
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(on behalf of the [H1](#) and [ZEUS](#) Collaborations)

QCD 2010, Montpellier

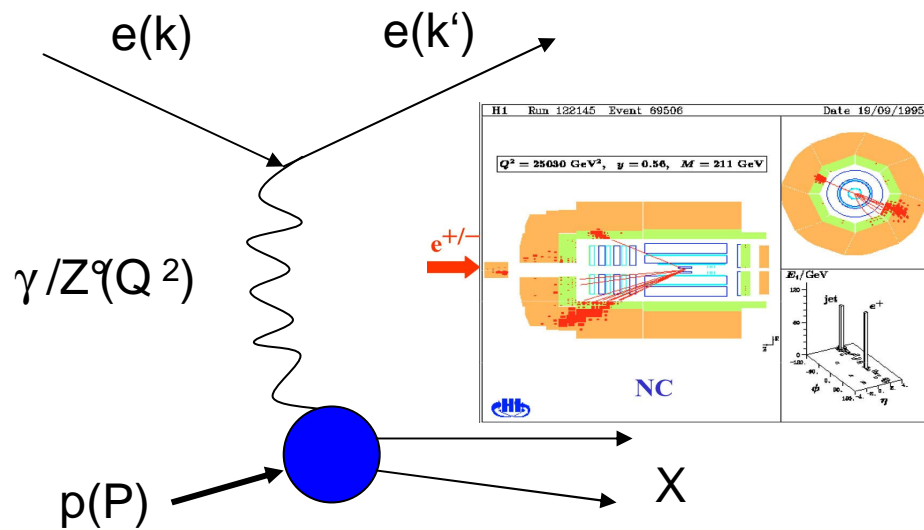
# The $ep$ collider HERA

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

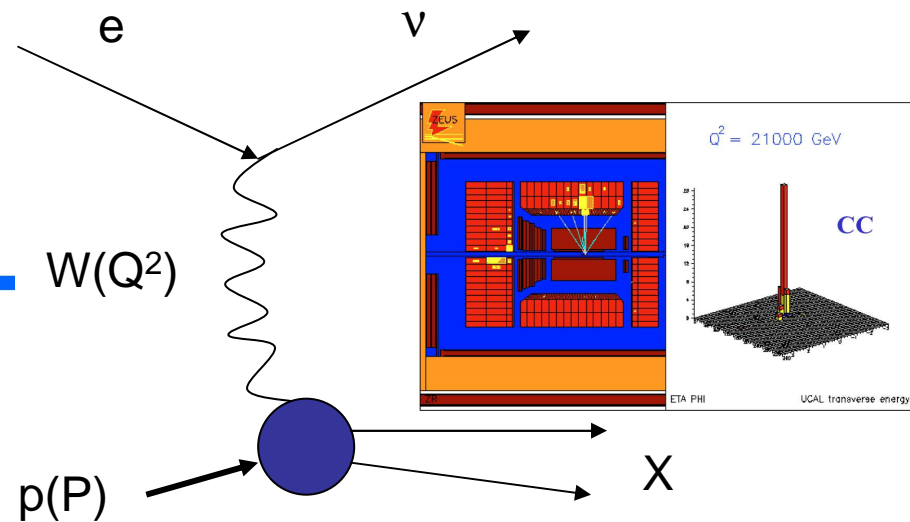


# Inclusive DIS at HERA

## 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:

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

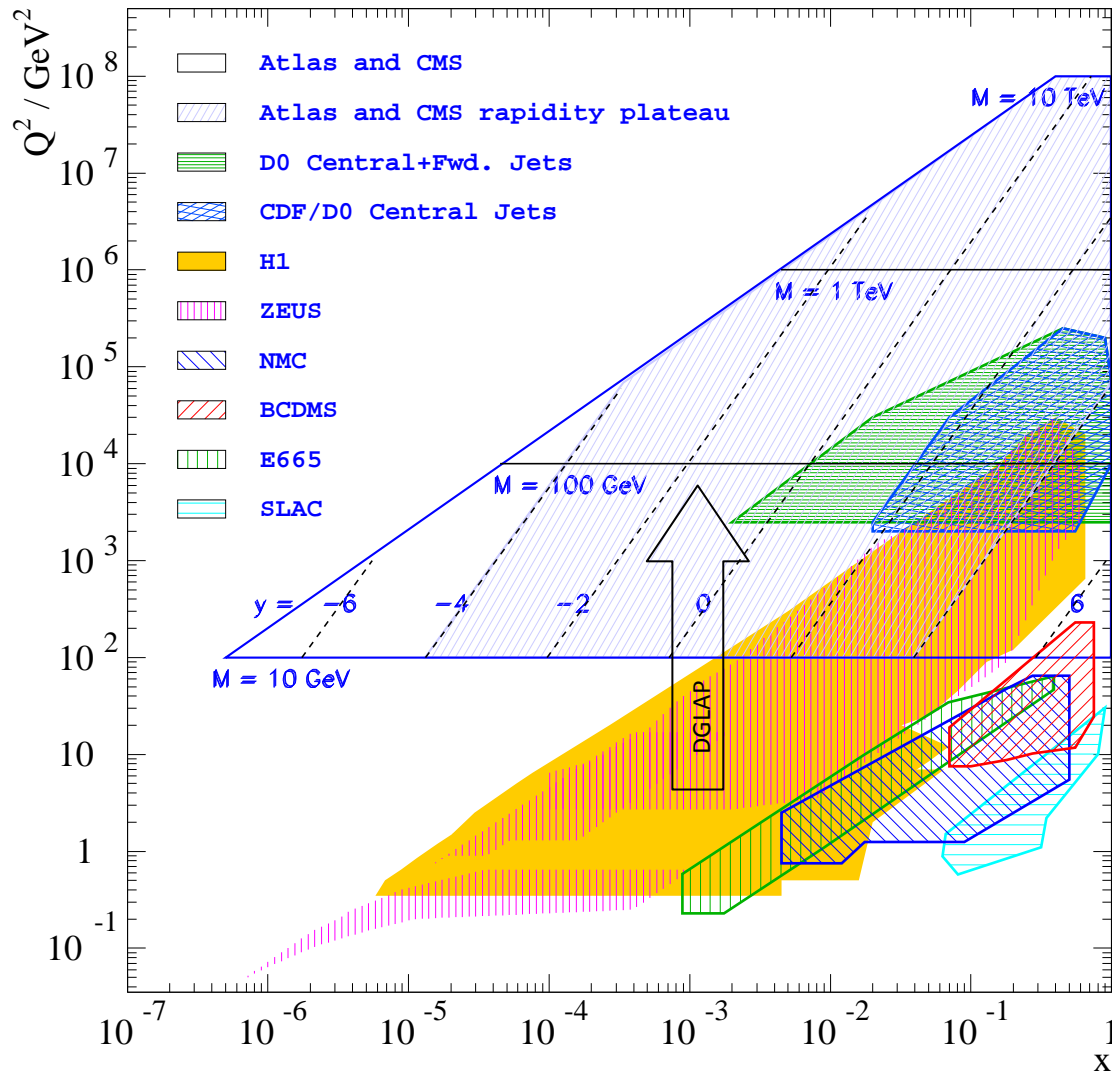
- sum of the (anti)quarks density distributions weighted with their electric charge squared

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

## CC $e^\pm p$ Cross Sections:

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

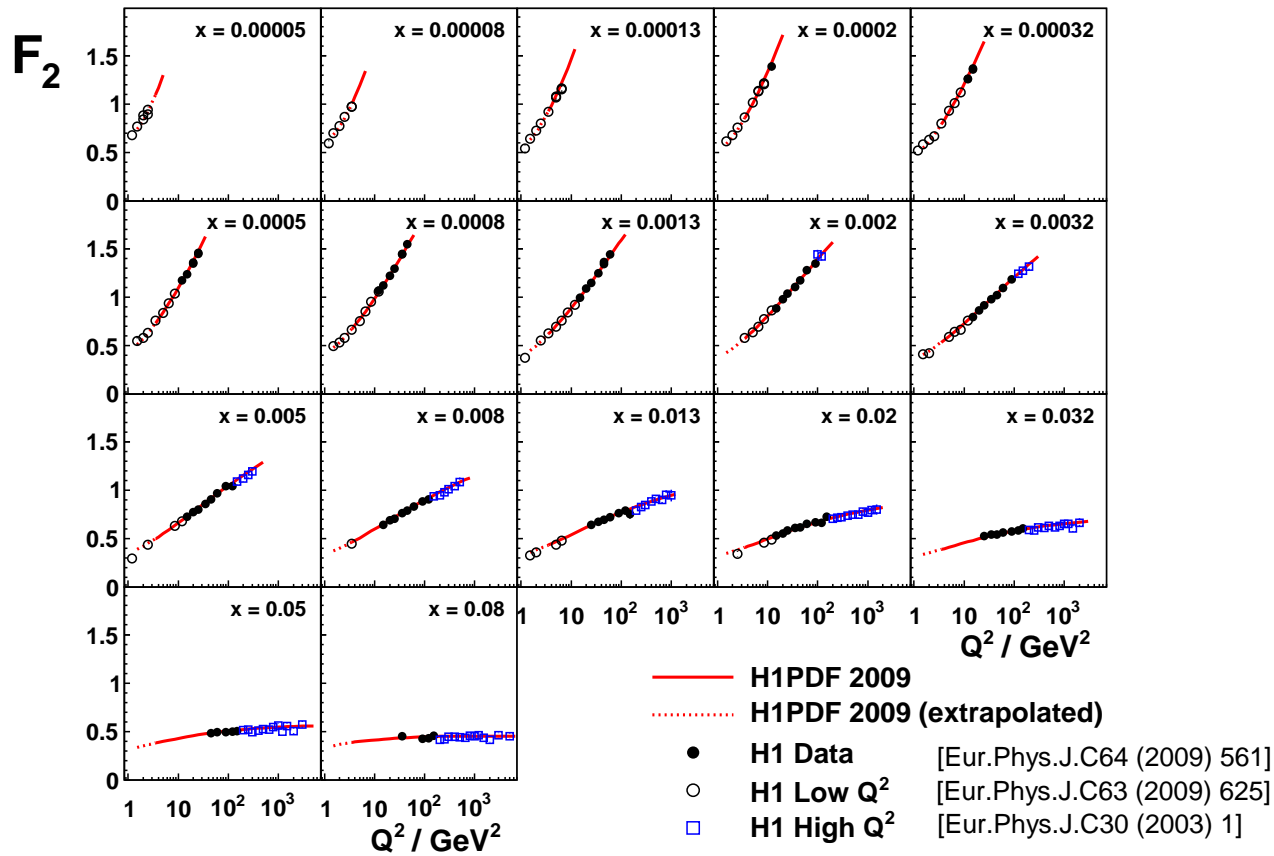
# Kinematic plane



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

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

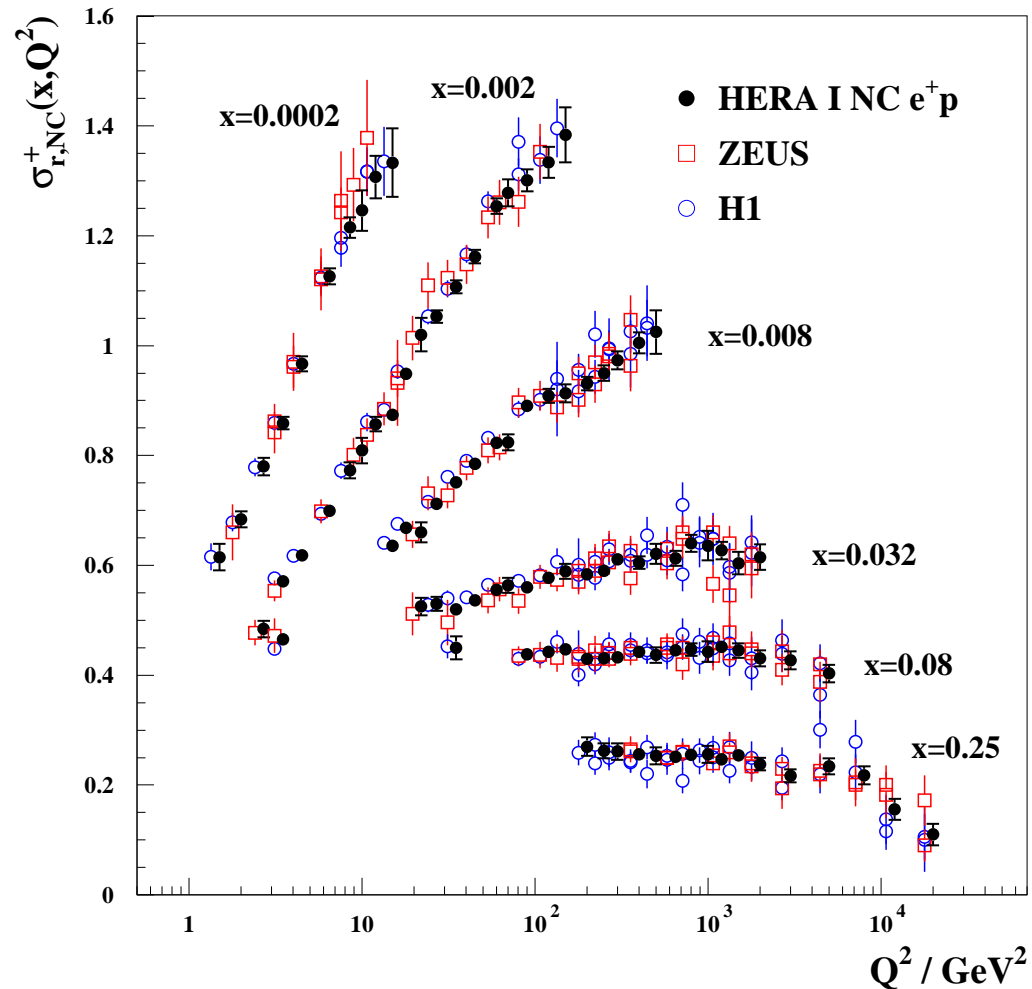
H1 Collaboration



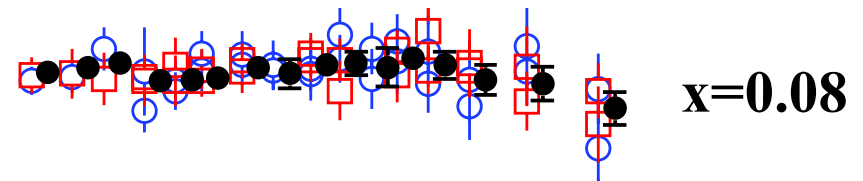
- Combined H1 data in the region of inelasticity  $0.005 < y < 0.6$  with a precision of 1.3-2% , for HERA I period
- Data are compared to NLO QCD fit to the H1 data alone – H1PDF2009

# Combined H1 & ZEUS data

H1 and ZEUS

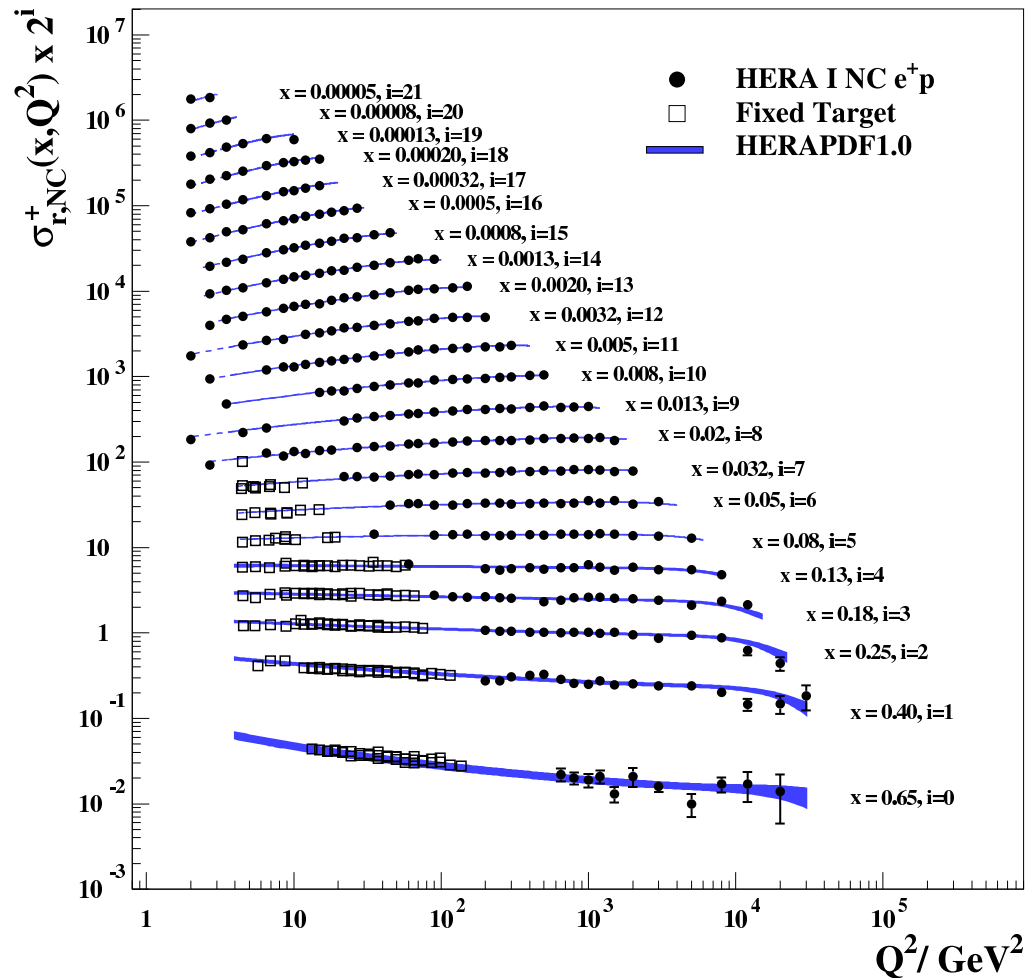


- Combination of H1 & ZEUS HERA I data provides a model independent tool to study consistency of the data and to reduce systematic errors
- New average based on the complete HERA I inclusive DIS data set with a total luminosity of  $L=240 \text{ pb}^{-1}$
- The error reductions after the averaging procedure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



# H1 & ZEUS combined results

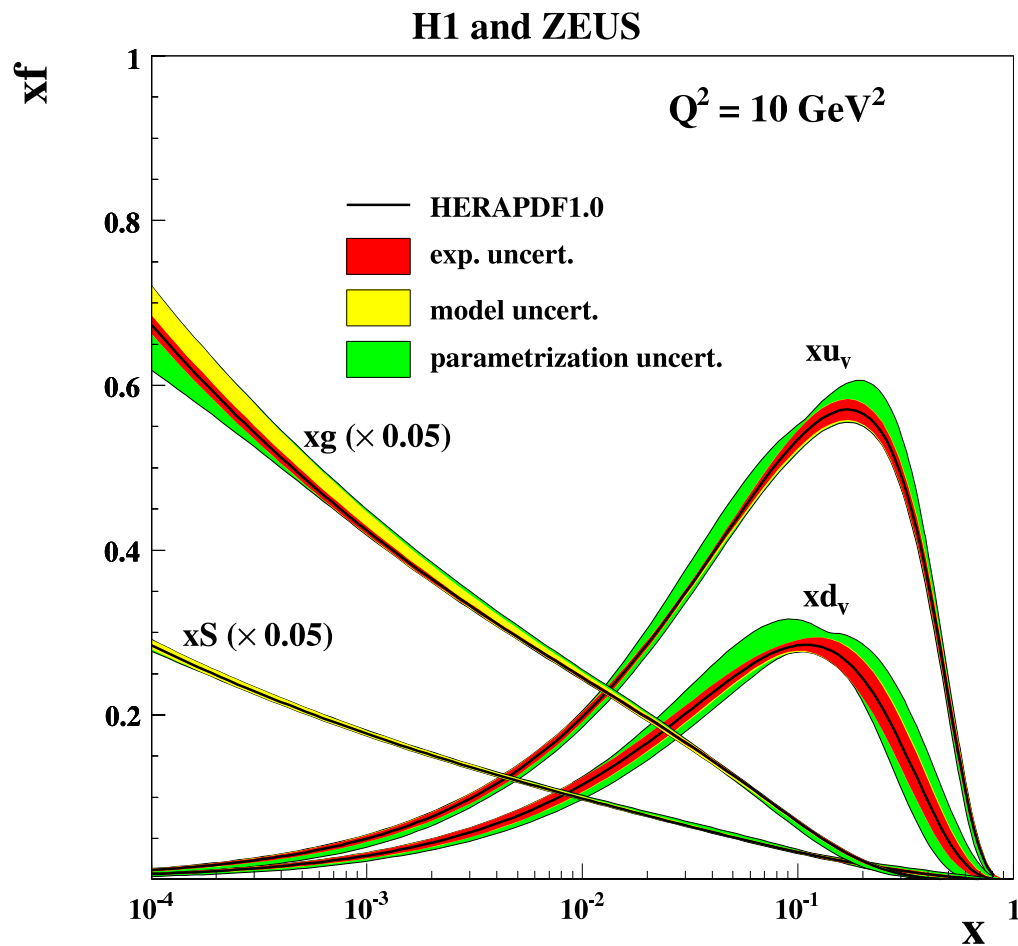
## H1 and ZEUS



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



# HERAPDF1.0 fit

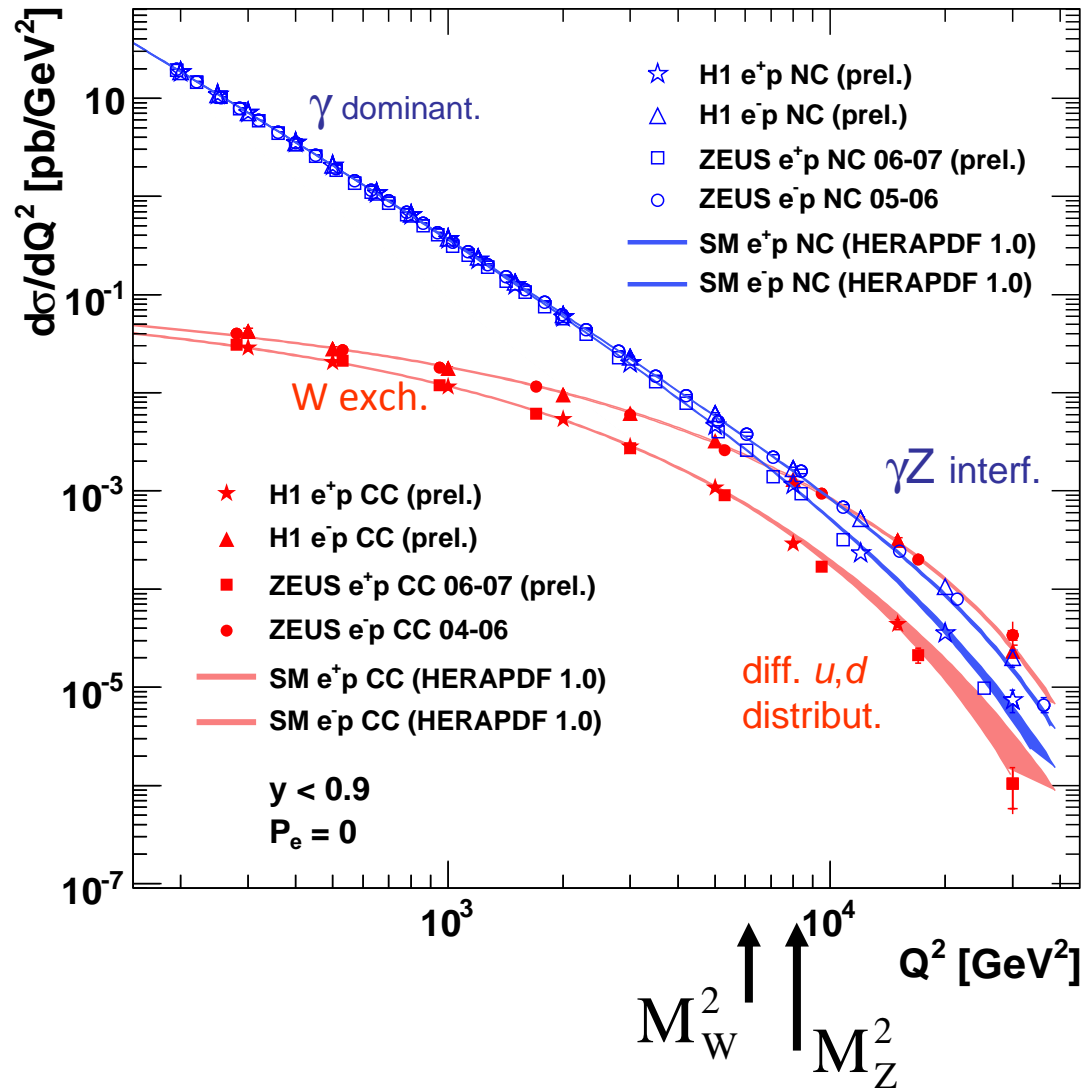


- Due to the precision of the combined data set, the HERAPDF1.0 parameterisation has total uncertainties at the level of a few percent at low  $x$

Sea and gluon distributions are divided by a factor of 20

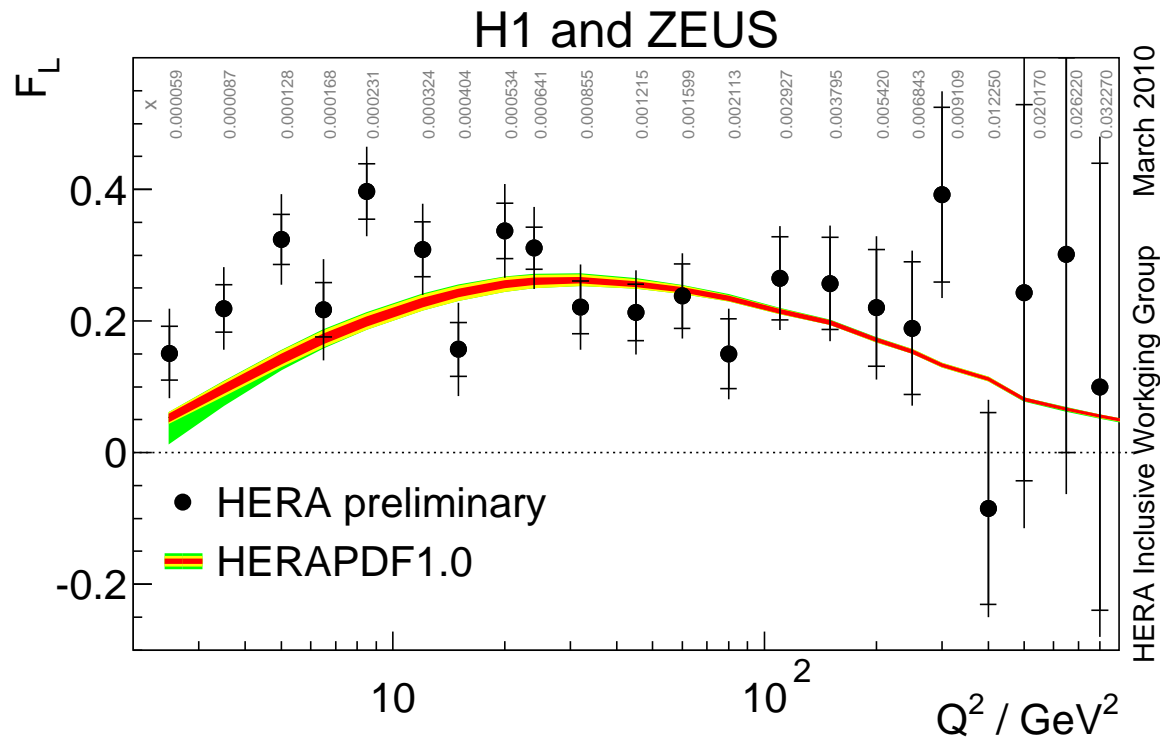
# CC and NC cross section measurements

HERA



- The combined collected luminosity of  $1\text{fb}^{-1}$  by H1 & ZEUS experiments provides a good test of the SM
- Neutral and Charged current cross sections at  $Q^2 \geq M^2(Z/W)$  scale become similar: EW unification
- Agreement between H1, ZEUS and QCD fit over seven orders of magnitude in cross section

# Measurement of $F_L$ by H1 & ZEUS

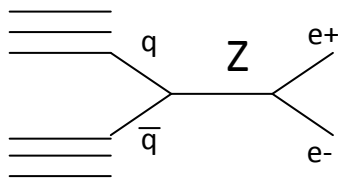
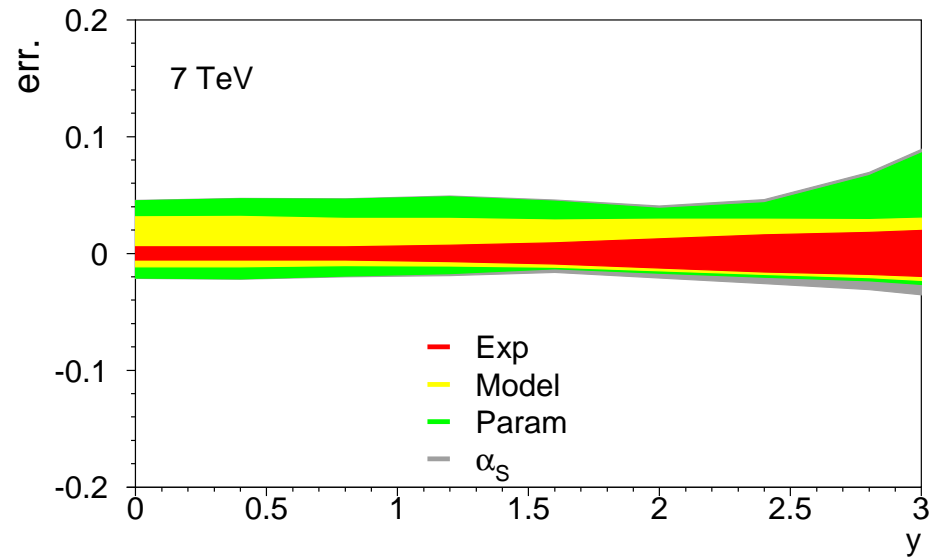
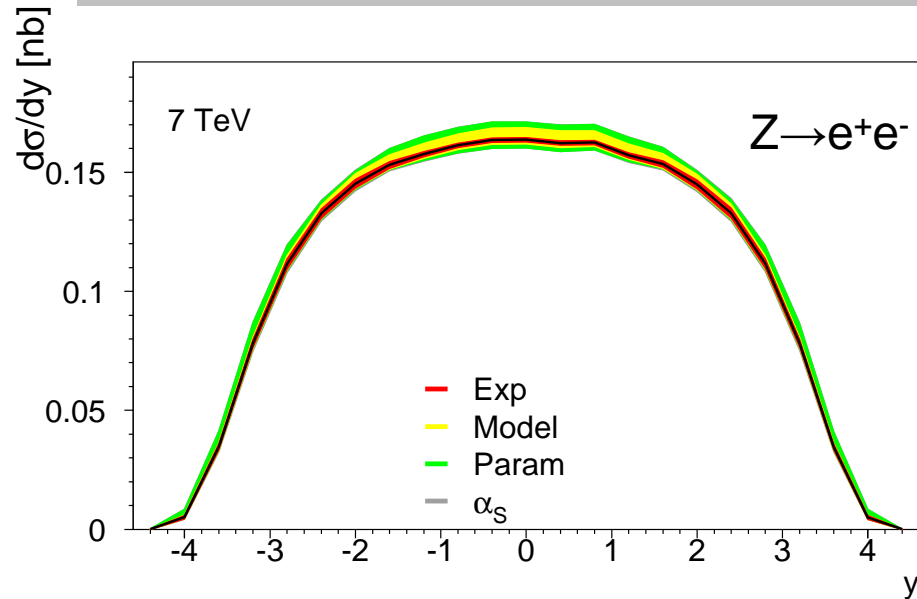


- Measurement of  $F_L$  can be performed by measuring cross section for the same  $Q^2$ - $x$  but with different proton beam energies (different  $y$ ):

$$\sigma_r = F_2 - f(y)F_L$$

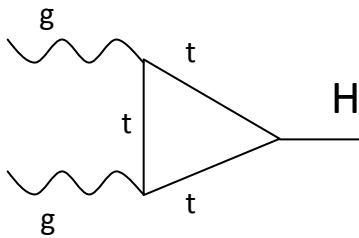
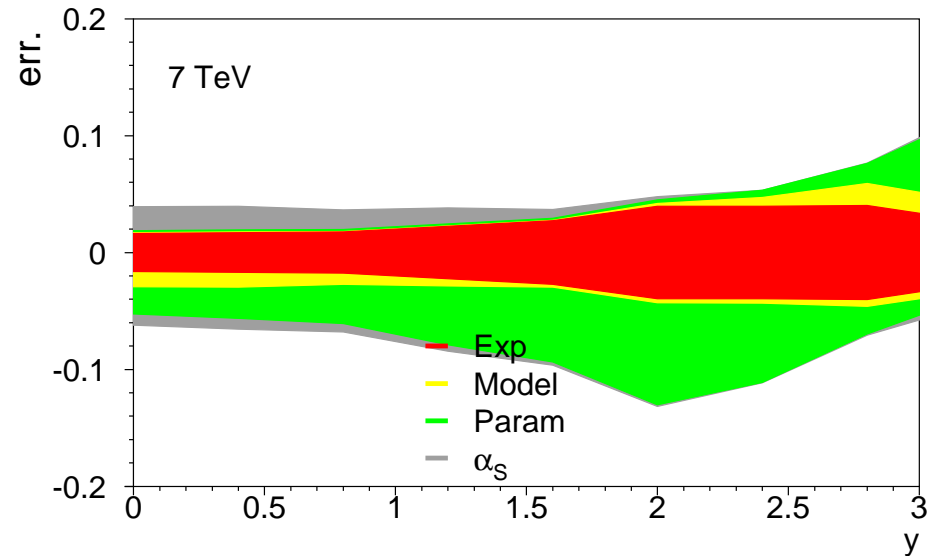
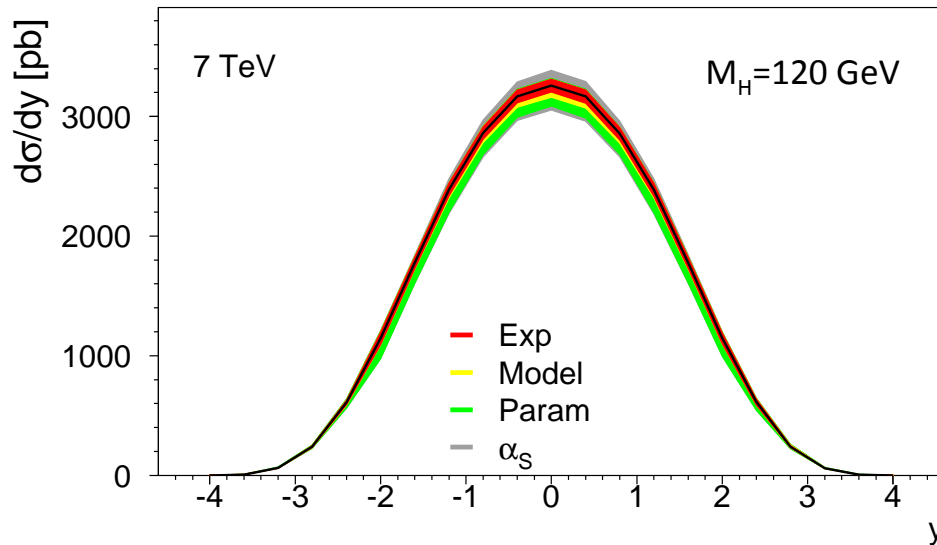
- The new preliminary measurement of  $F_L$  cover the range of  $2.5 \leq Q^2 \leq 800 \text{ GeV}^2$  and  $0.00005 \leq x \leq 0.06$
- Data are in a good agreement with HERAPDF1.0 for  $Q^2 > 10 \text{ GeV}^2$

# HERAPDF1.0 for LHC



- Sea quark dominated process
- Prediction based on HERAPDF1.0 and MCFM 5.7 calculation
- Exp. precision  $<1\%$ , total uncertainty  $<5\%$  for  $y < 2.5$
- Can be used as a luminosity monitor for LHC

# HERAPDF1.0 for LHC



- Gluon dominated process, which is measured at HERA from scaling violation
- Small experimental uncertainties

# 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