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

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(on behalf of the H1 and ZEUS Collaborations)

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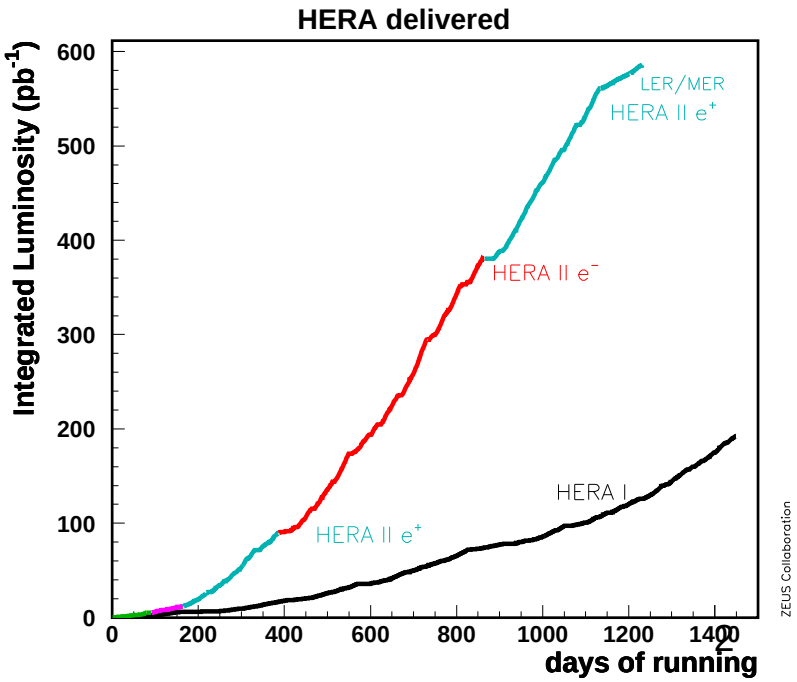
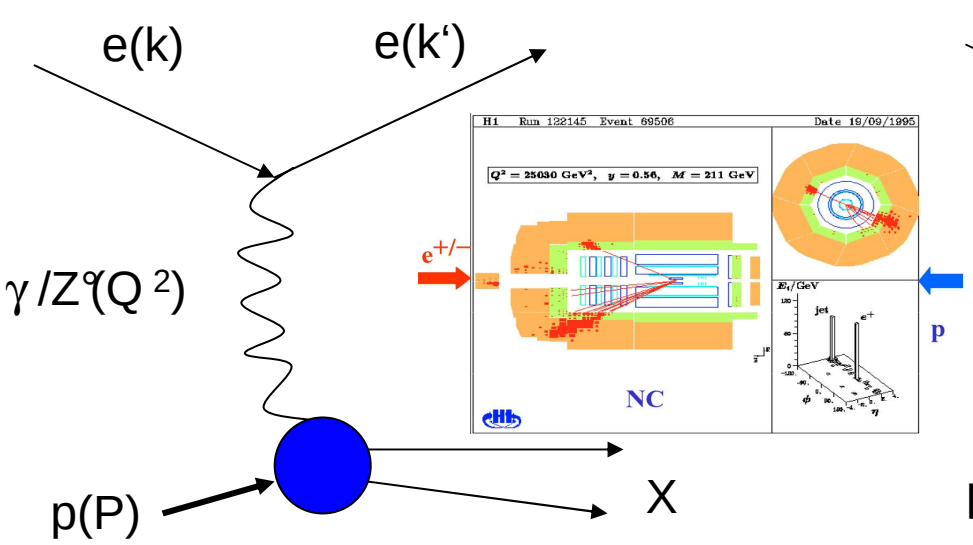
The *ep* collider HERA

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

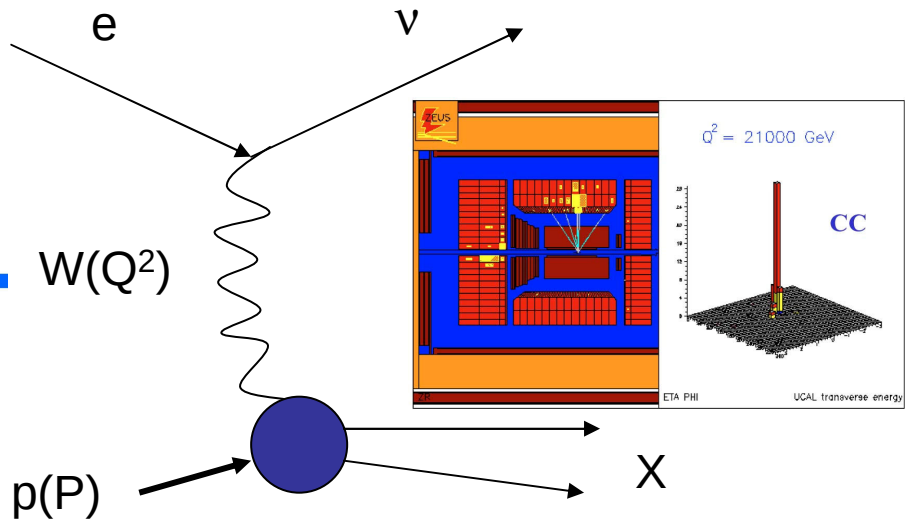


Inclusive DIS at HERA

Neutral current



Charged current



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

$x = \dfrac{Q^2}{2P(k - k')}$ - 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: $\tilde{\sigma}_{NC}(x,Q^2)$

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

- 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

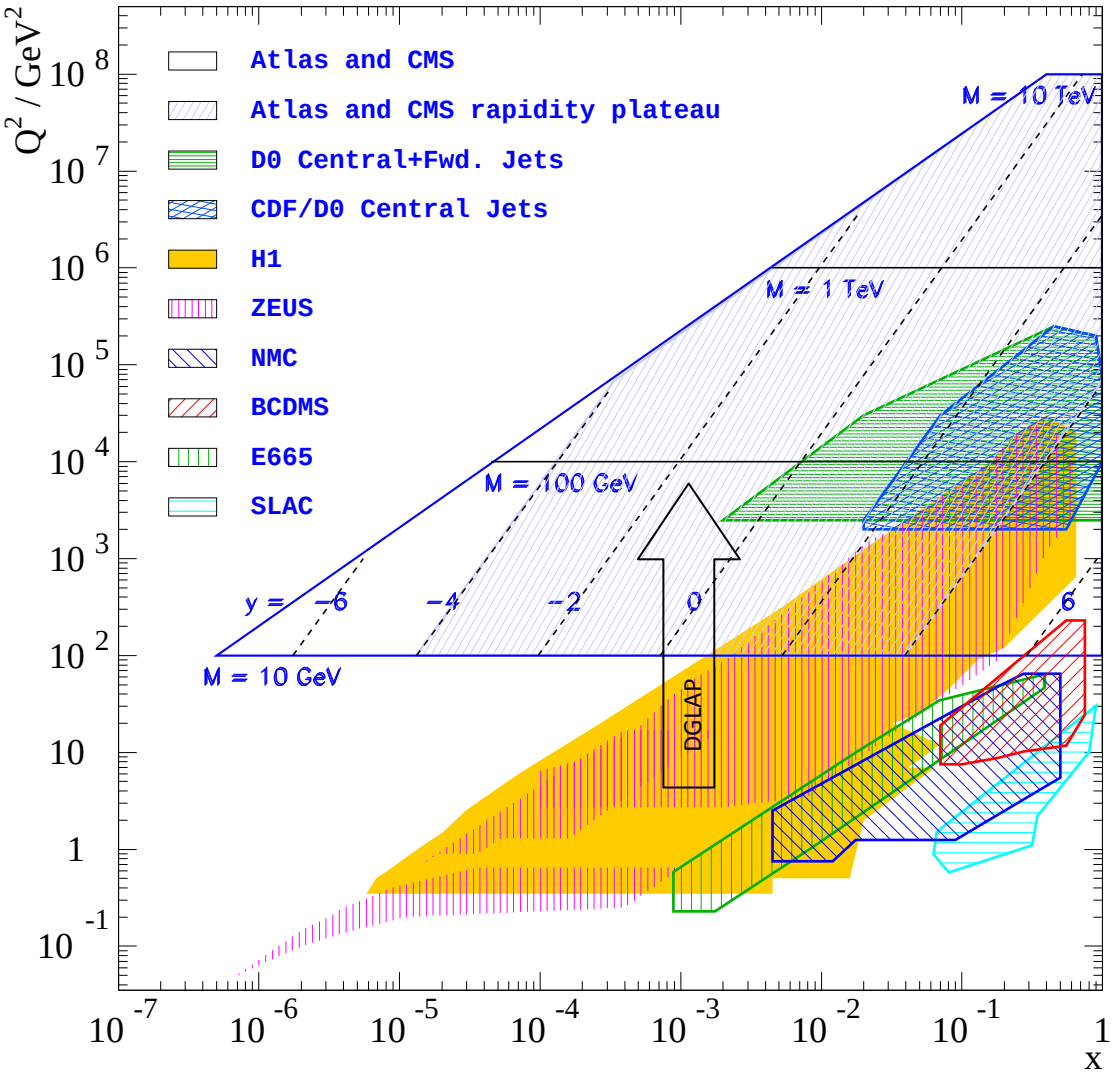
- Structure function F_L ~ gluon density *g(x)* in NLO QCD and 0 in QPM
- $xF_3 \sim 2\sum_i e_i a_i x[q_i(x) - \bar{q}_i(x)]$ - provides info from the valence quark distributions

CC $e^{\pm}p$ Cross Sections:

$$\sigma^+ = x[\bar{u} + \bar{c}] + (1-y)^2 x[d + s]$$
$$\sigma^- = x[u + c] + (1-y)^2 x[\bar{d} + \bar{s}]$$

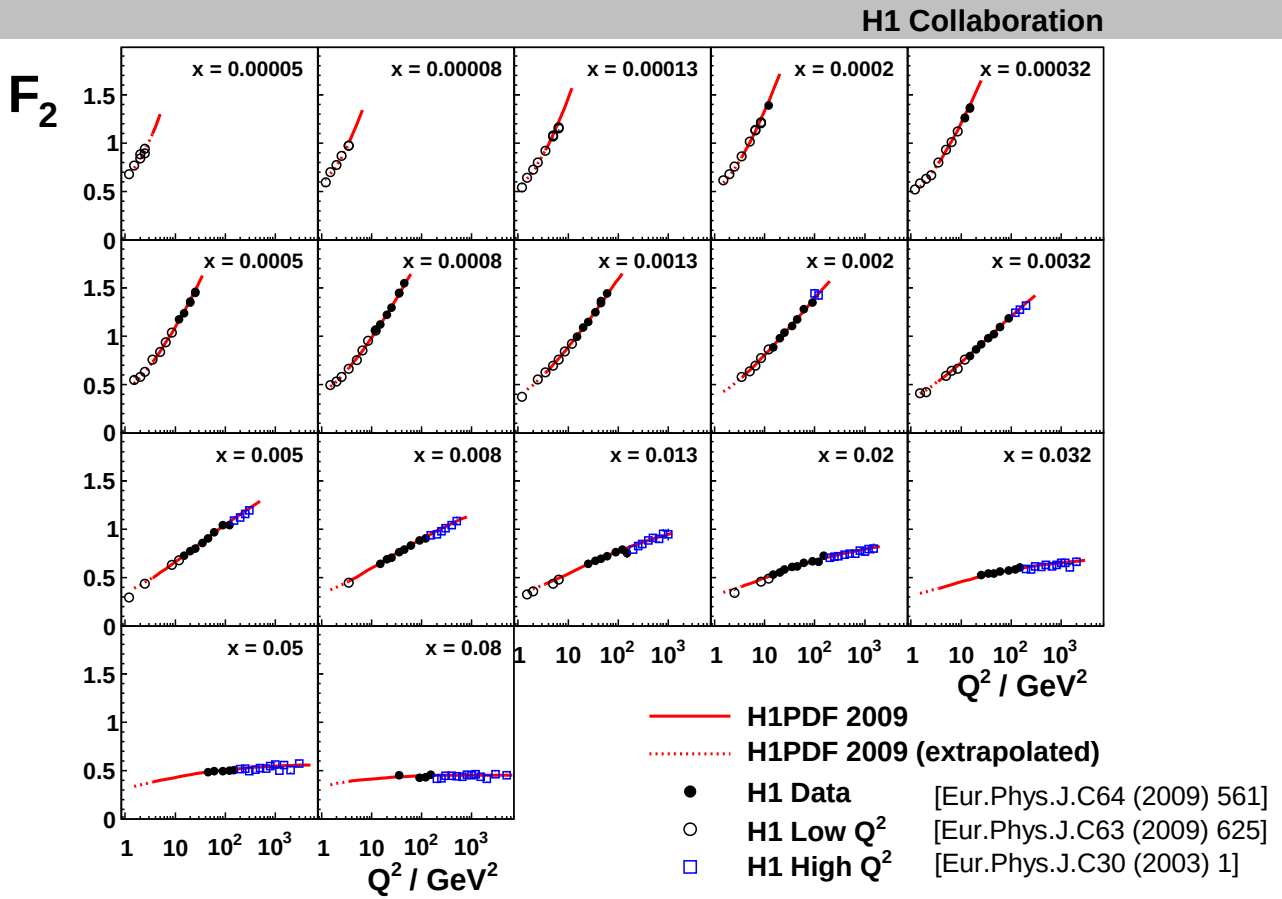
} flavour separation at high *x*

Kinematic plane



- QCD evolution extrapolates HERA measured PDFs to LHC
- HERA data cover LHC central rapidity range for M>100 GeV

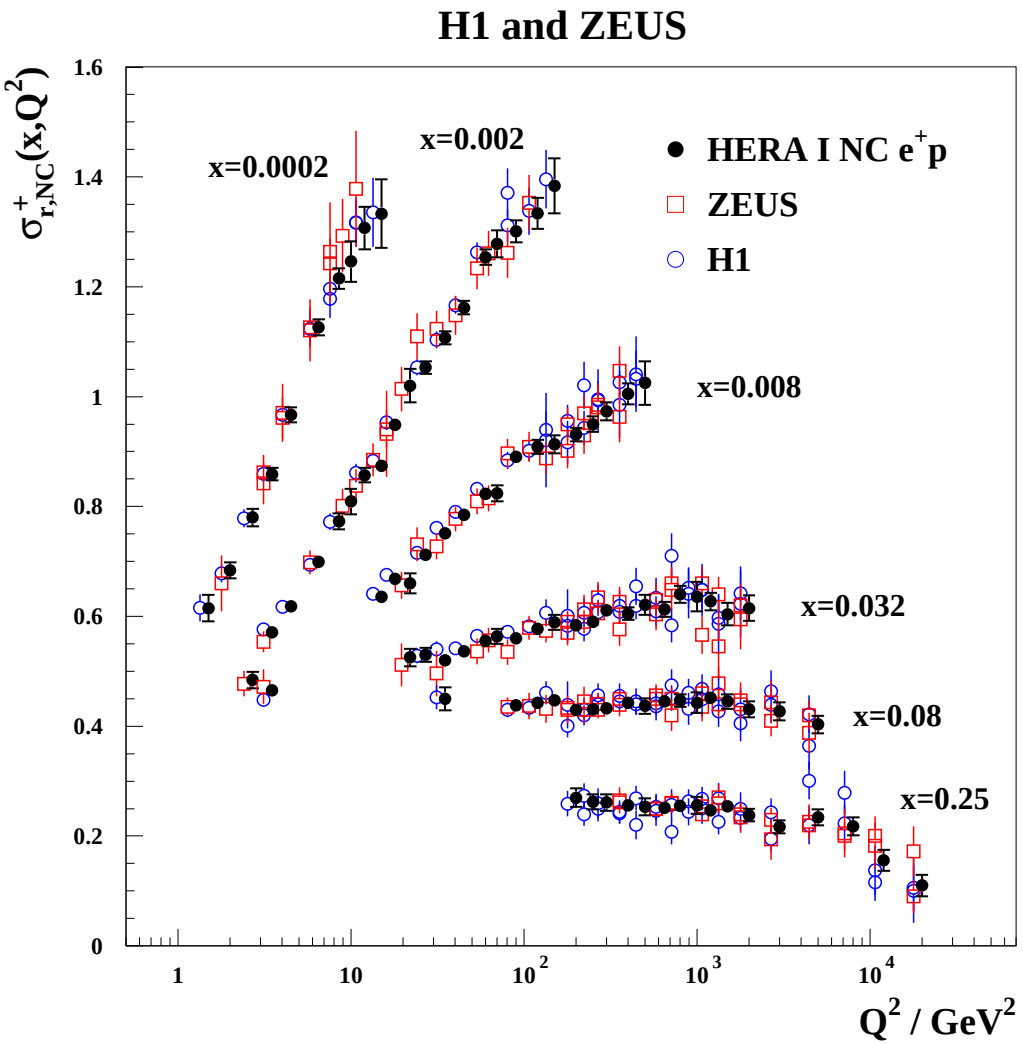
F_2 at $Q^2<150$ GeV^2



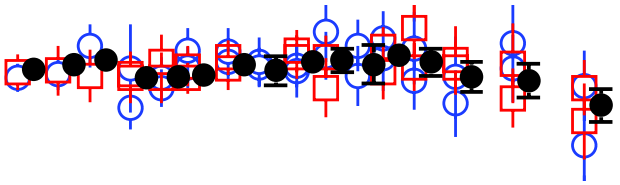
- Combined H1 data in the region of inelasticity $0.005<y<0.6$ with a precision of 1.3-2% , for HERA I period

- Data are compared to NLO QCD fit to the H1 data alone – H1PDF2009

Combined H1 & ZEUS data

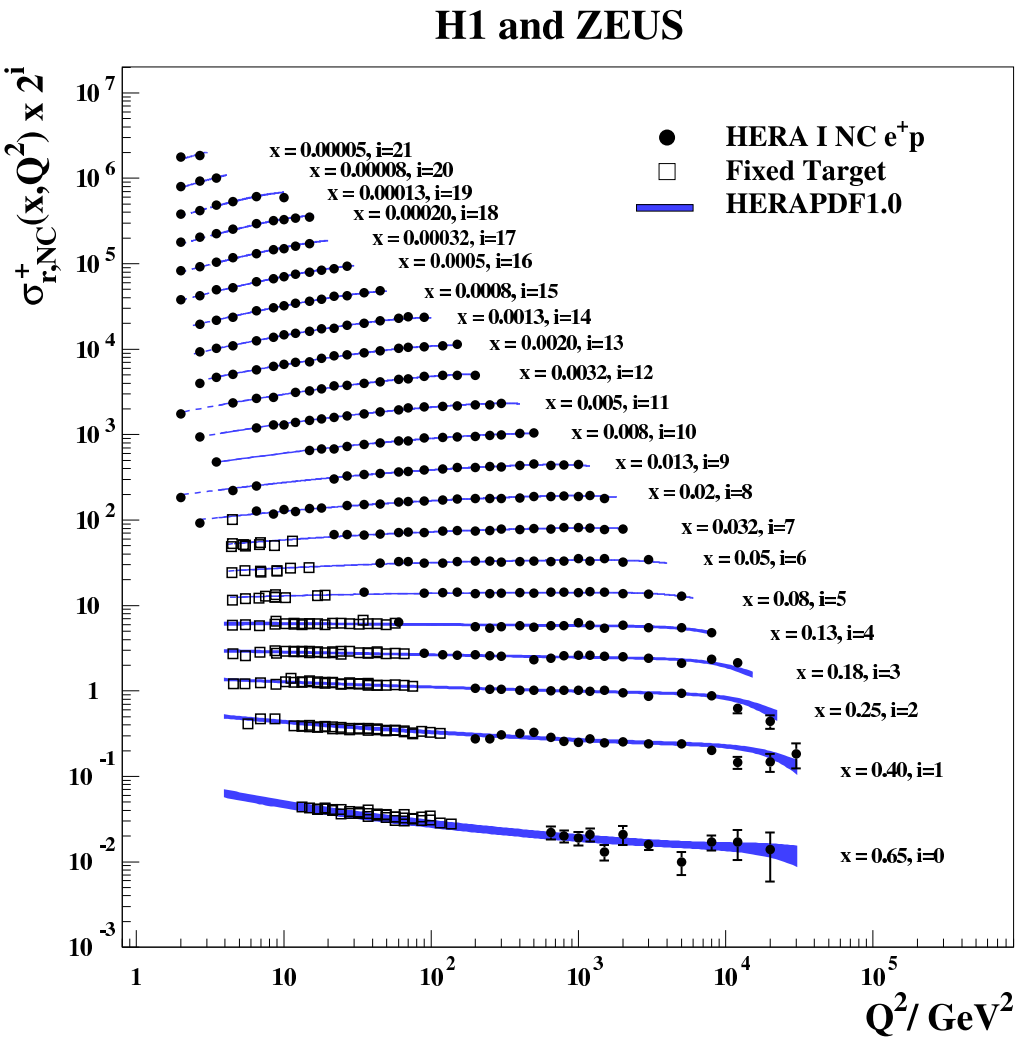


- Combination of H1 & ZEUS HERA I data provides a model independent tool to study consistency of the data and to reduce systematic errors
- New average based on the complete HERA I inclusive DIS data set with a total luminosity of L=240 pb^{-1}
- The error reductions after the averaging procedure are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



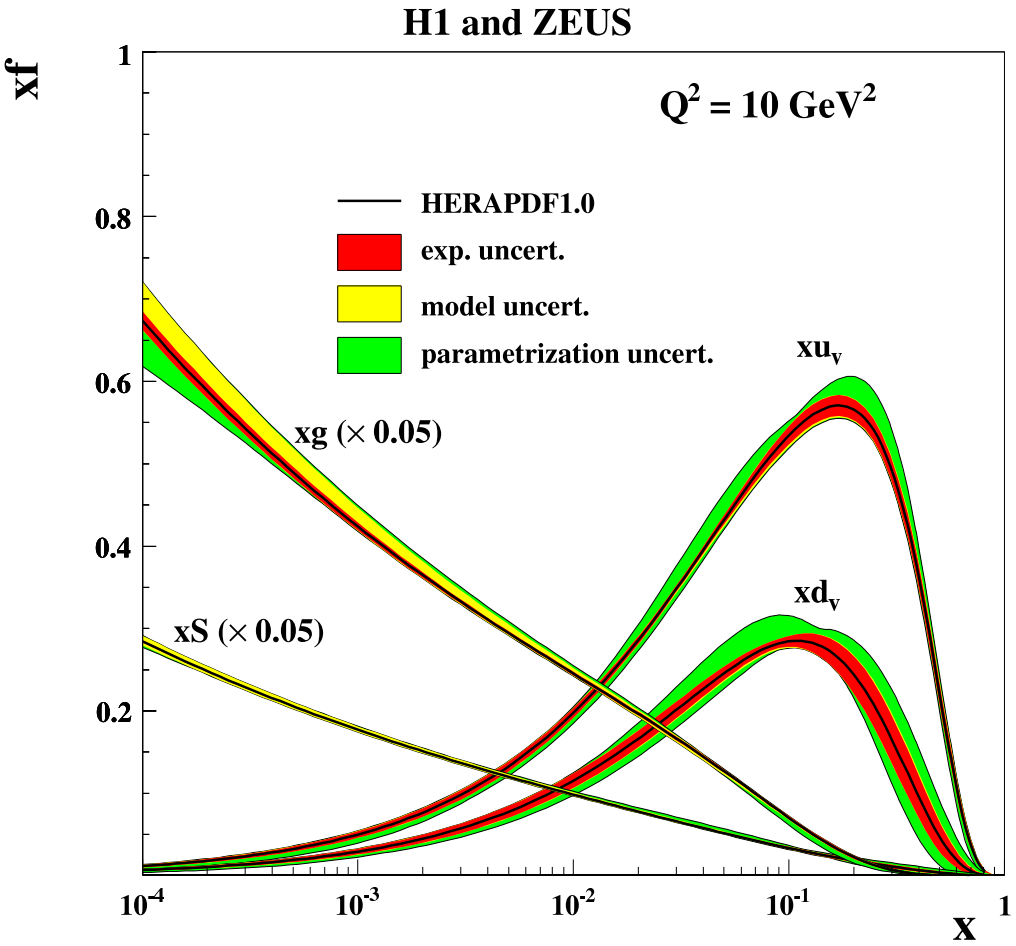
x=0.08

H1 & ZEUS combined results



- 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 χ^2/ndf = 532/582
- Fixed target data are also described by new fit

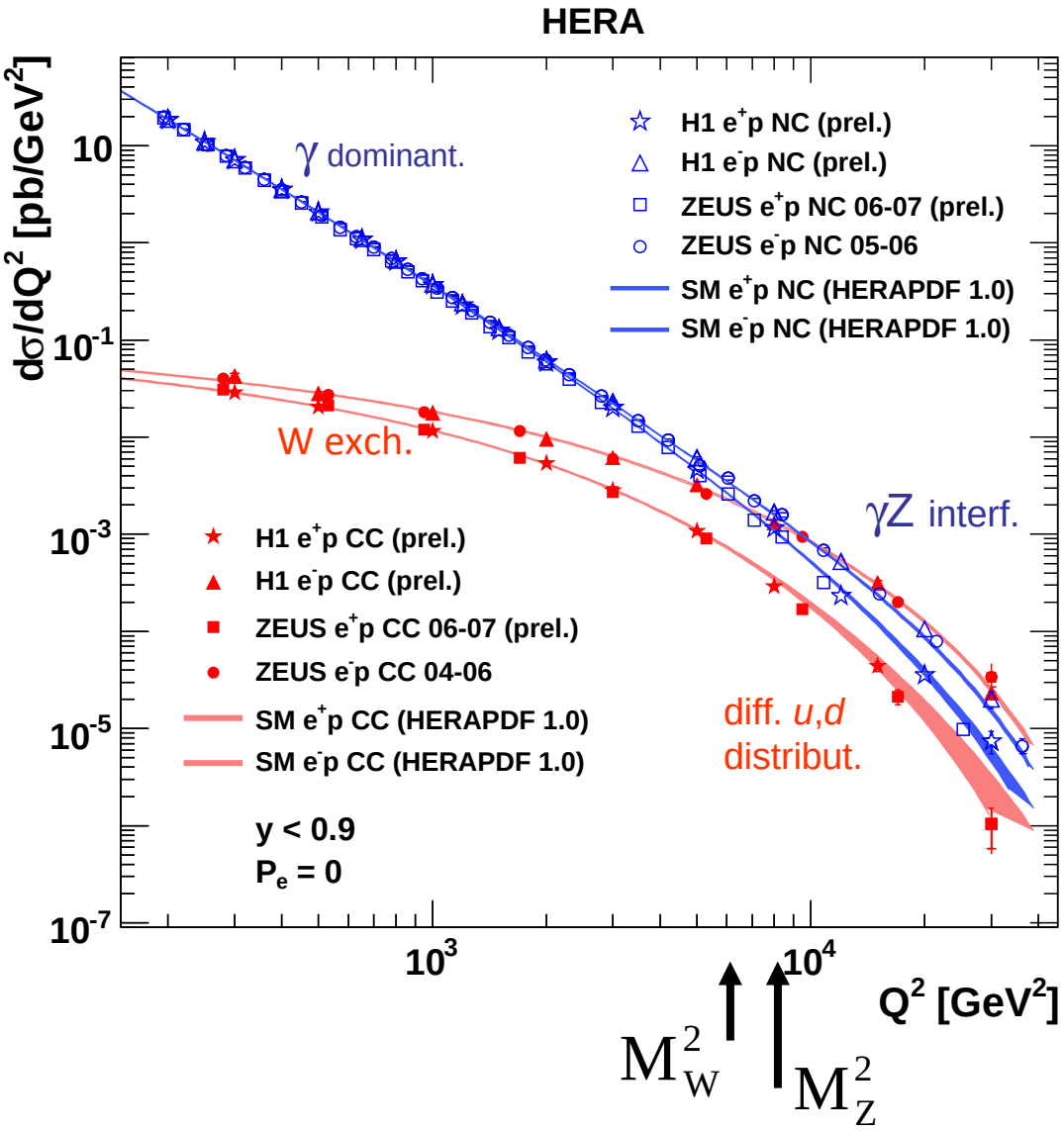
HERAPDF1.0 fit



- 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*

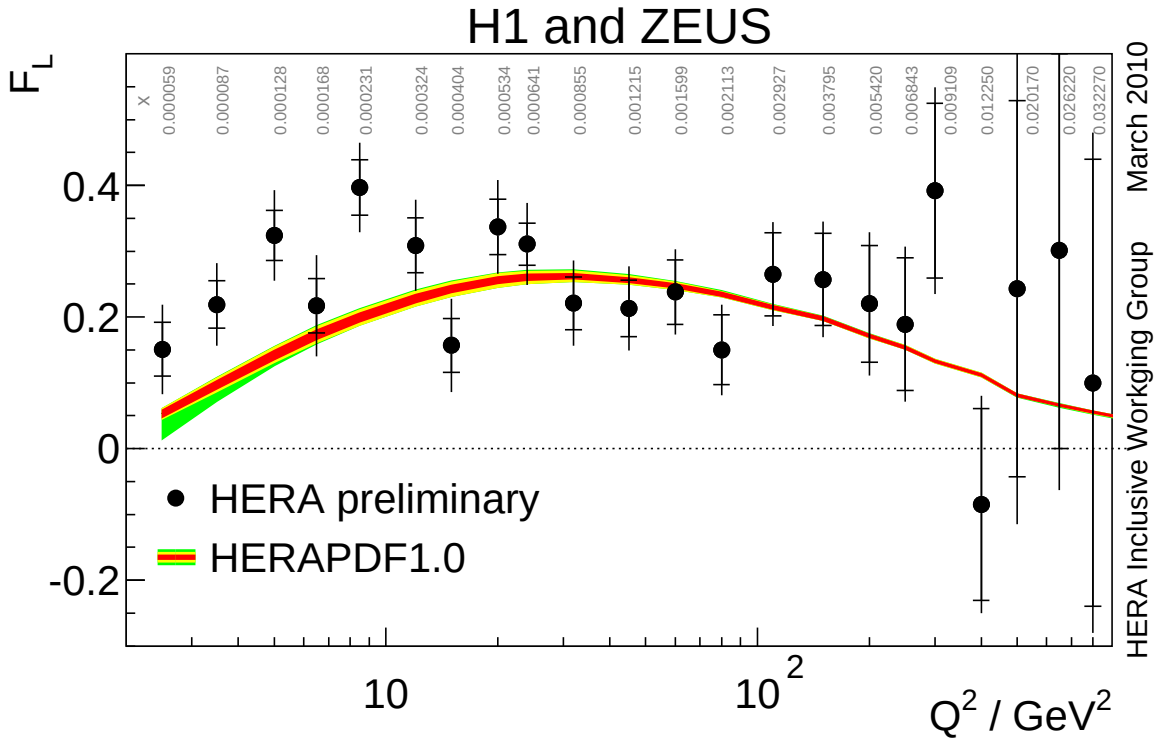
Sea and gluon distributions are divided by a factor of 20

CC and NC cross section measurements



- The combined collected luminosity of 1fb^{-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

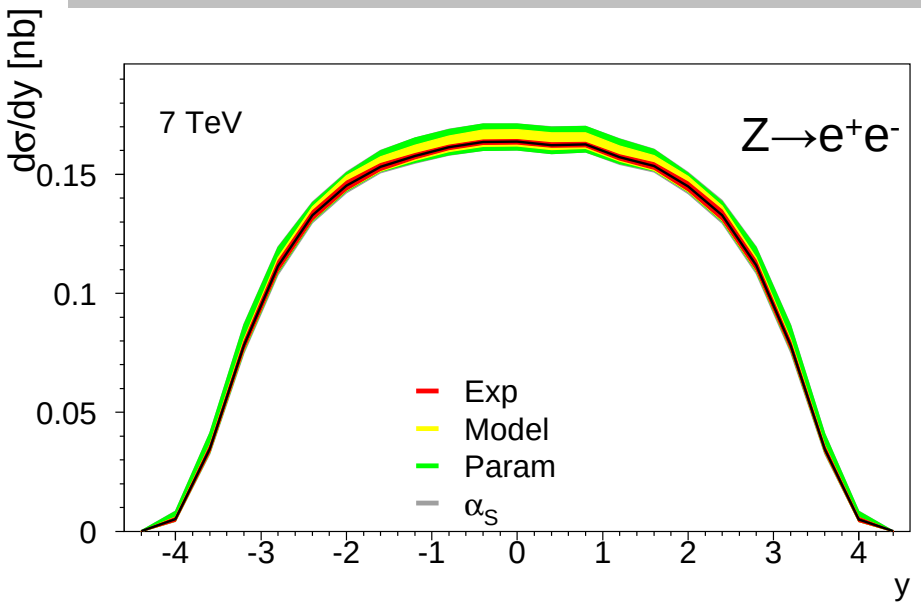


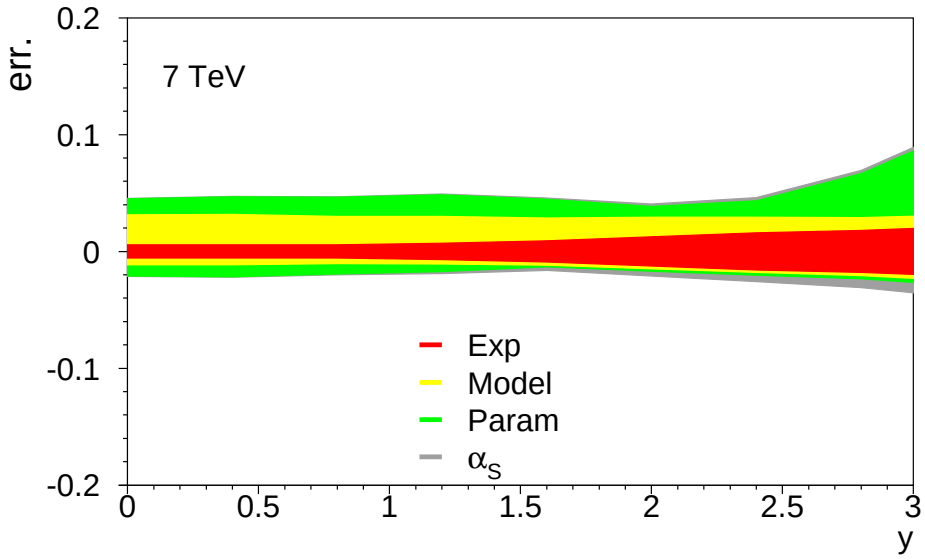
- Measurement of F_L can be performed by measuring cross section for the same Q^2-x but with different proton beam energies (different y):

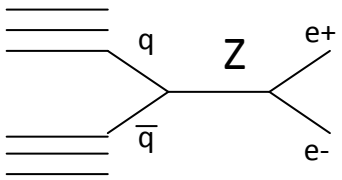
$$\sigma_r = F_2 - f(y)F_L$$

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

HERAPDF1.0 for LHC

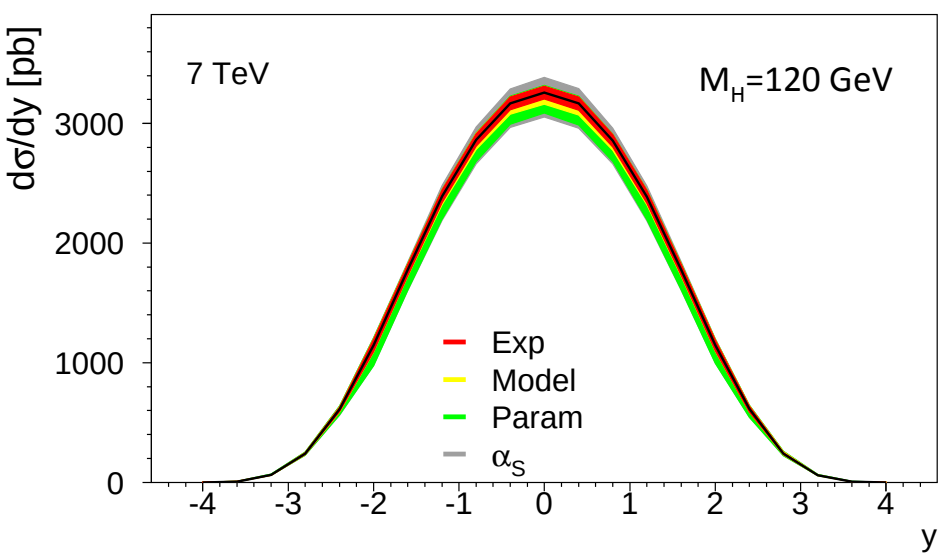


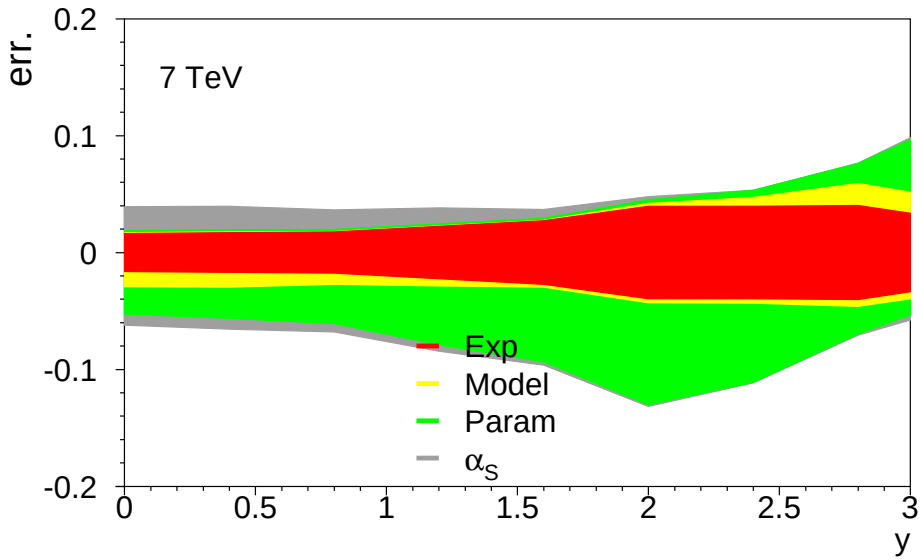


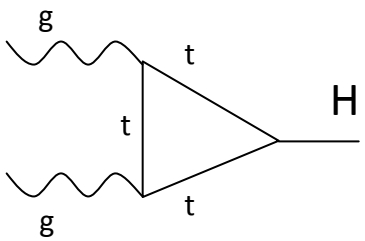


- Sea quark dominated process
- Prediction based on HERAPDF1.0 and MCFM 5.7 calculation
- Exp. precision <1%, total uncertainty <5% for y<2.5
- Can be used as a luminosity monitor for LHC

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 $0.2 \leq Q^2 \leq 30000$ 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