STRUCTURE FUNCTIONS from HERA to LHC

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on behalf of ZEUS and H1 collaborations

Outline

- Structure of the proton
- HERAPDF
- Recent results
- Comparison to data

23rd Rencontres de Blois, 1 June 2011

Probe of proton structure at HERA

HERA was an ep collider at DESY (Hamburg, Germany)

- Provides unique data to study the proton structure
- 2 general purpose detectors: H1 and ZEUS
- E_e=27.5 GeV, E_p=920 GeV
- 15 years of successful data taking, 1 fb^{-1} data collected
- 2 periods of running: HERAI and HERAII

T. J. LeCompte's talk on Monday:

'HERA revolutionized our knowledge of parton densities'

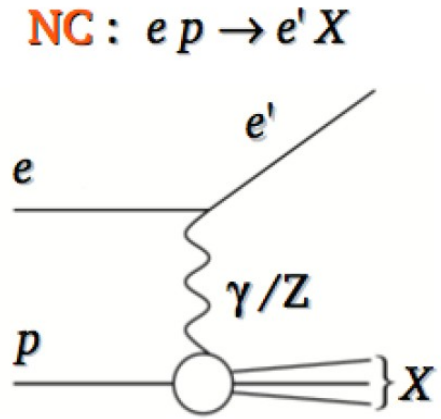
Deep Inelastic Scattering (DIS) kinematics:

x – Bjorken scaling variable

Q^2 – virtuality of the exchanged boson

y – inelasticity

s – centre-of-mass energy

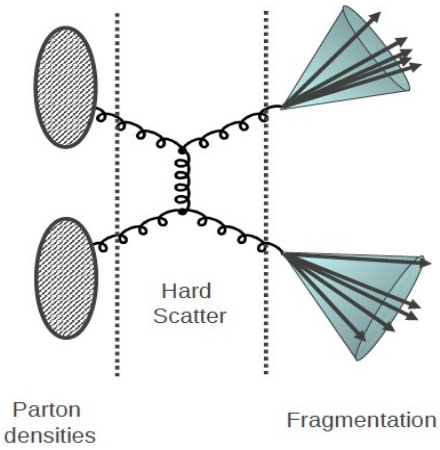


HERA and LHC

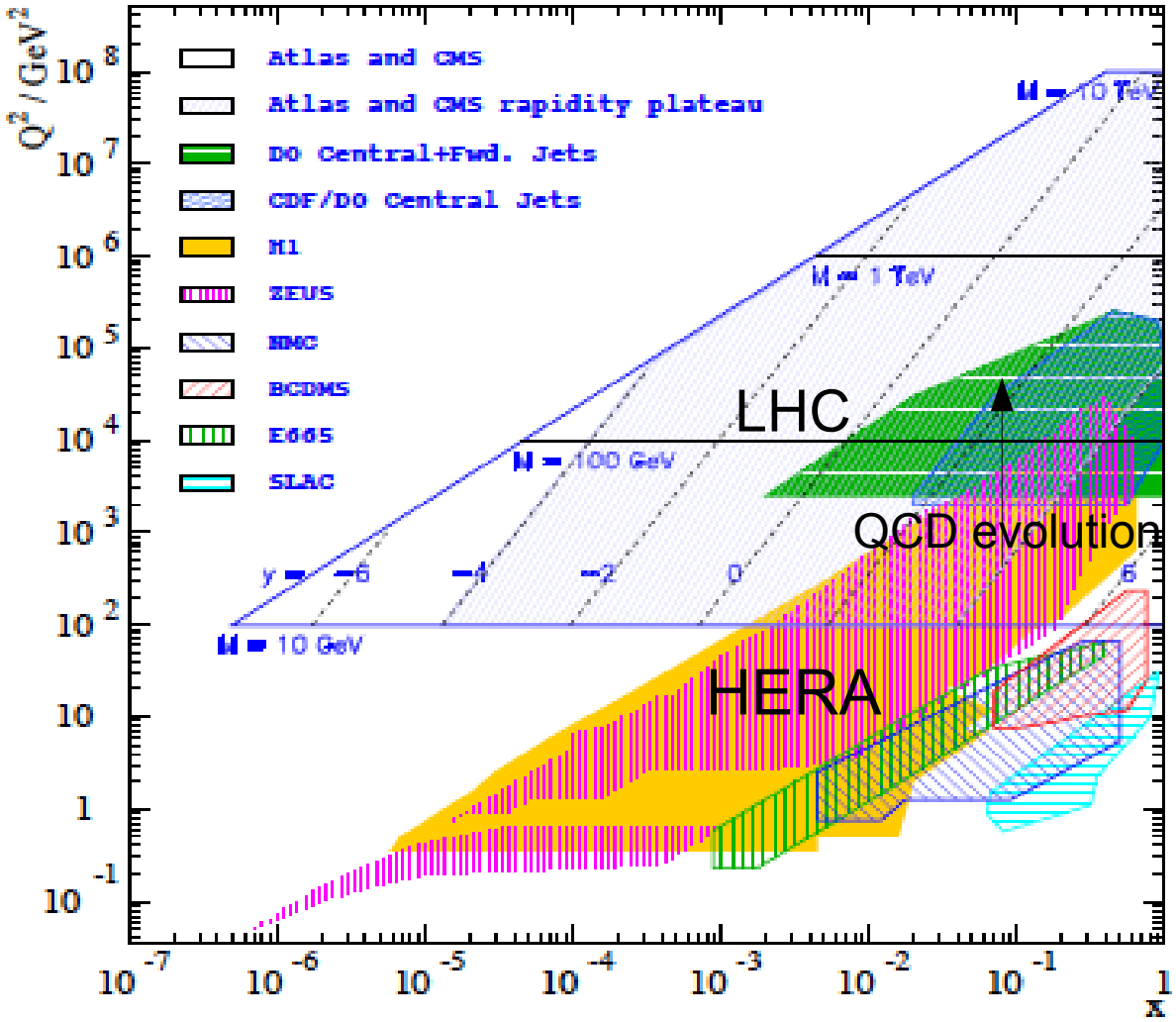
LHC: pp-collisions at 7,10,14 TeV

Predictions for the LHC – use of factorisation:

$$\sigma \approx \hat{\sigma} \otimes \text{PDF}$$



Precision of parton densities (PDFs) is essential

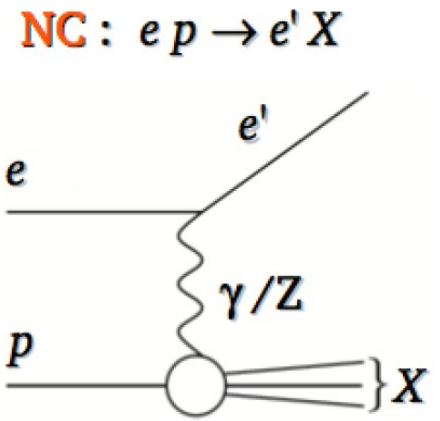


HERA data are unique
access to very low-x, low-Q^2 ,high-x and high-Q^2 regions

Proton structure

Deep inelastic scattering NEUTRAL CURRENT (NC) cross section can be written via *structure functions F_2, F_L and xF_3*:

$$\frac{\mathrm{d}^2\sigma_{NC}^{e^\mp p}}{\mathrm{d}x\mathrm{d}Q^2} = \frac{2\pi\alpha^2 Y_+}{xQ^4}\left(F_2 - \frac{y^2}{Y_+}F_L \pm \frac{Y_-}{Y_+}xF_3\right), \quad Y_\pm = 1 \pm (1-y)^2$$



Proton structure functions

F_2 – dominant term, sensitive to quark and gluon

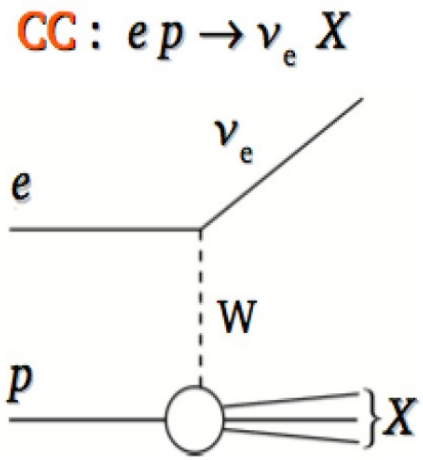
F_L – sensitive to gluon

XF_3 – sensitive to valence quarks

CHARGE CURRENT (CC) data allow to get flavour information

$$\sigma_{e^+p}^{CC} \sim x(\bar{u}+\bar{c}) + x(1-y)^2(d+s)$$

$$\sigma_{e^-p}^{CC} \sim x(u+c) + x(1-y)^2(\bar{d}+\bar{s})$$



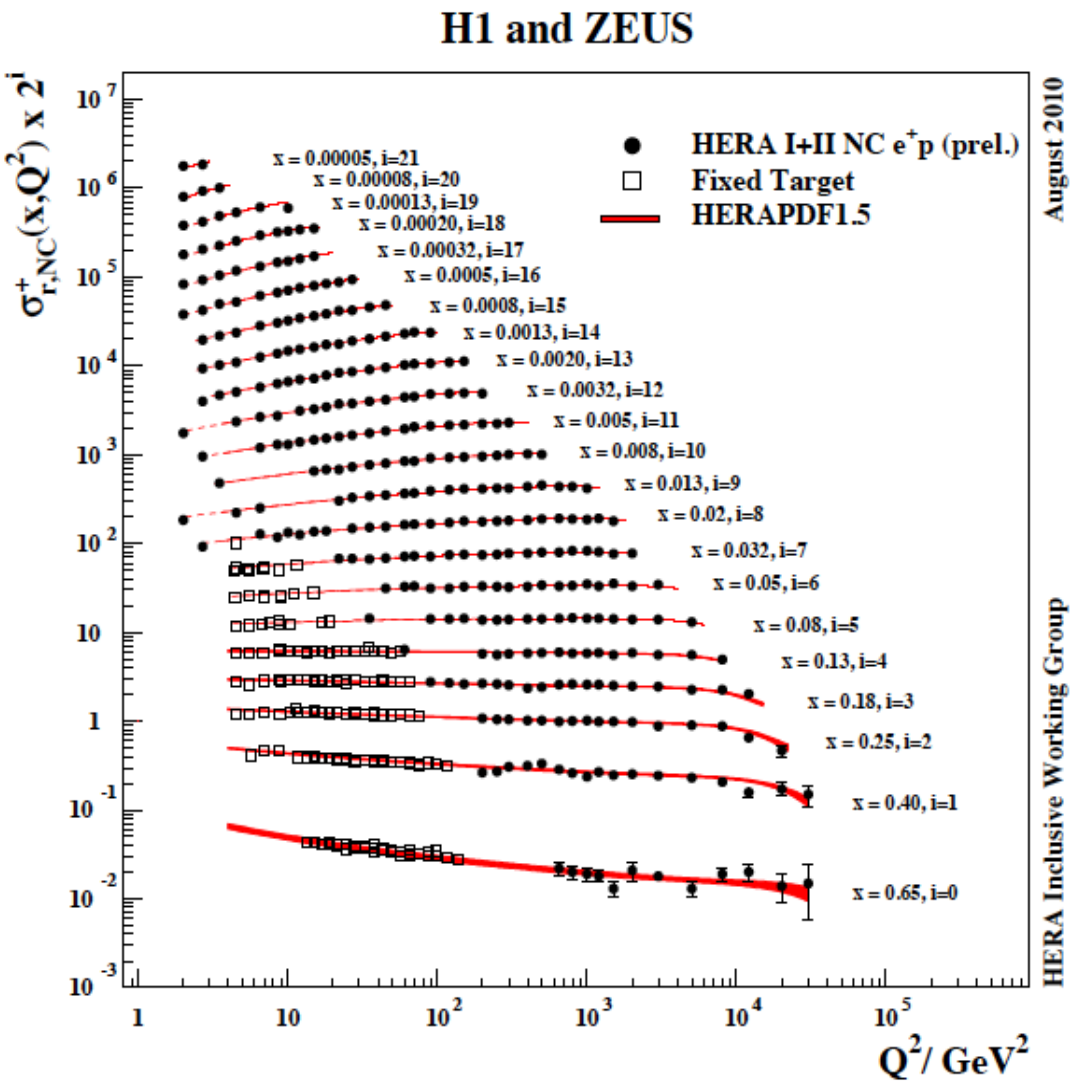
HERAPDF

Input to PDF fits – cross sections
(HERA data: combined ZEUS and H1)

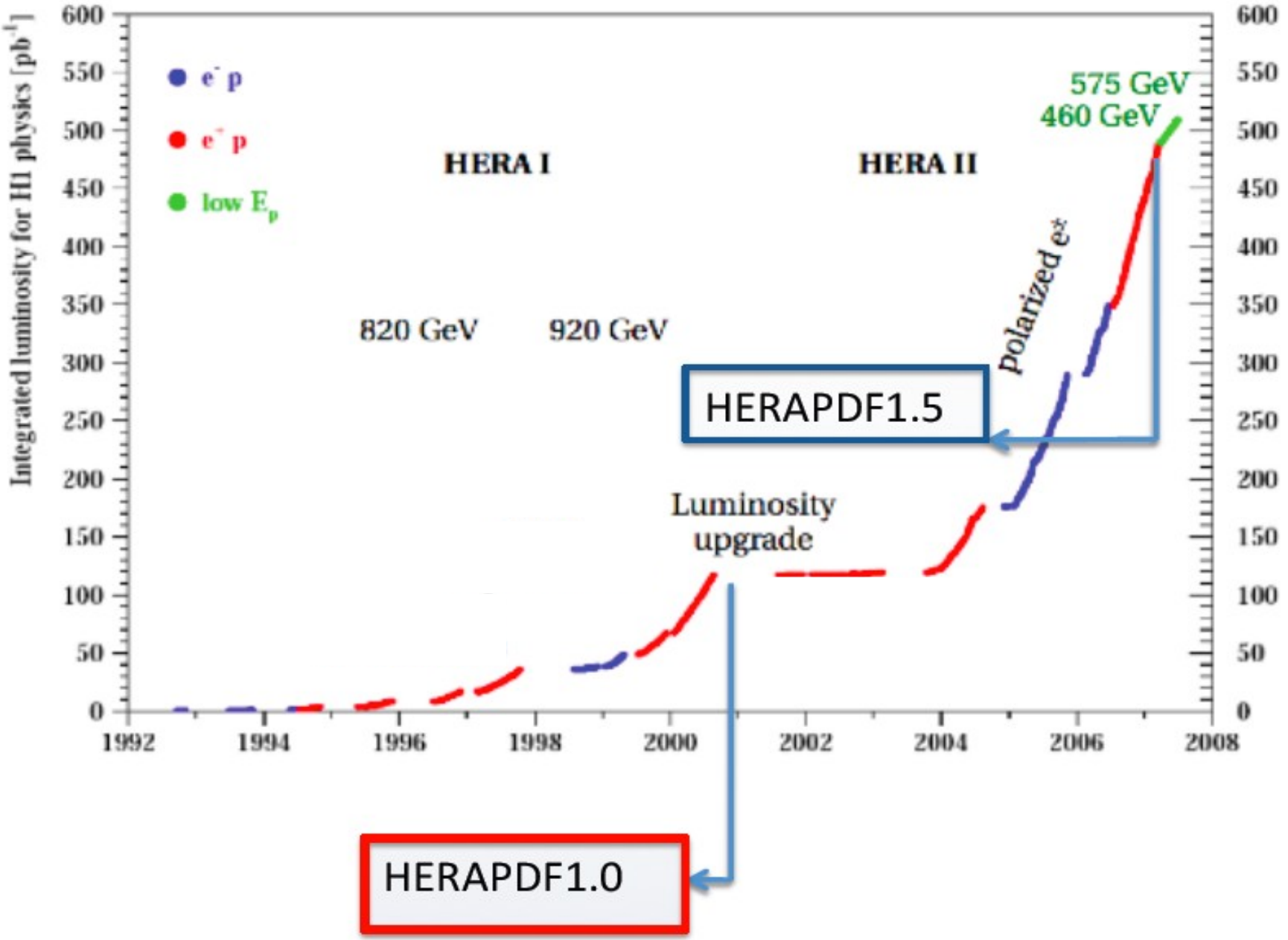
Many groups are doing PDF fits of global data coming from many experiments:
MSTW, CTEQ, NNPDF, ABKM, GJR

Group at DESY: *HERAPDF*

- Use only HERA data, *combined ZEUS and H1* results
- Fix α_s, strange fraction, heavy quark masses in standard fit
- Use simple parametrisation with minimum number of parameters
- Uncertainty: experimental, model and parametrisation



HERA data sets

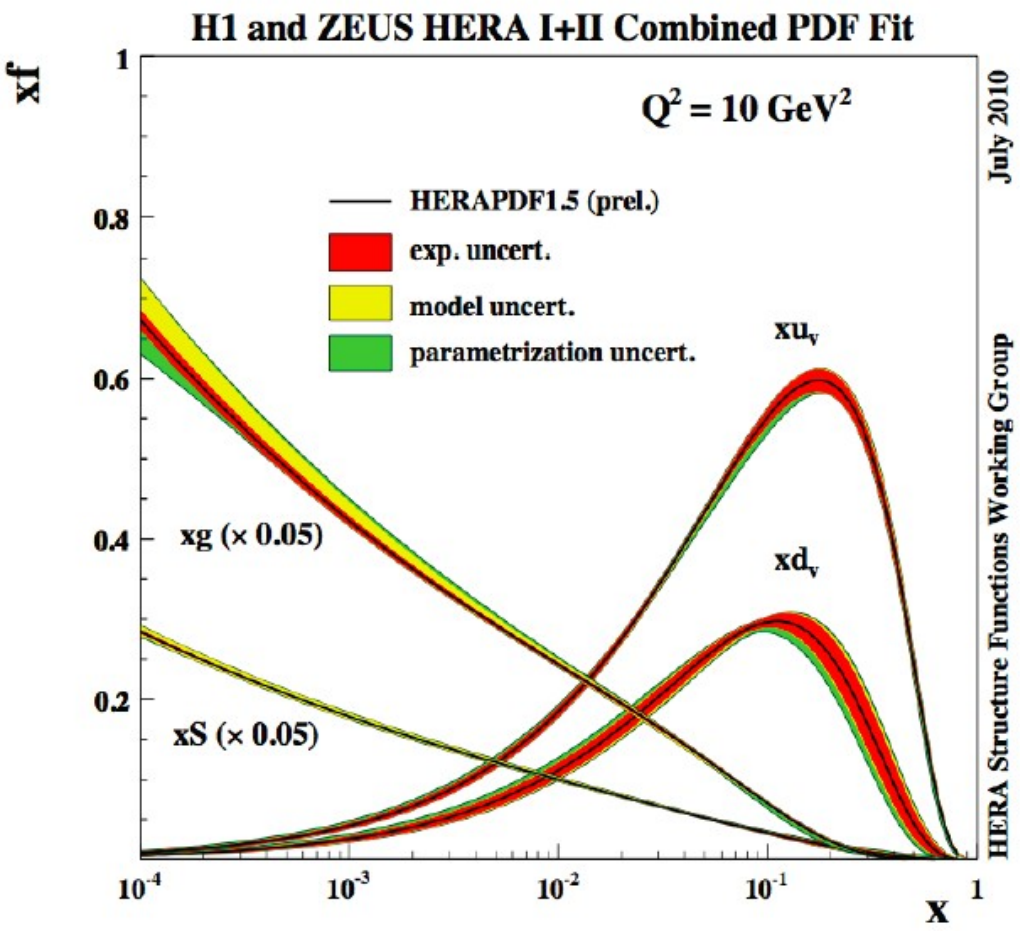


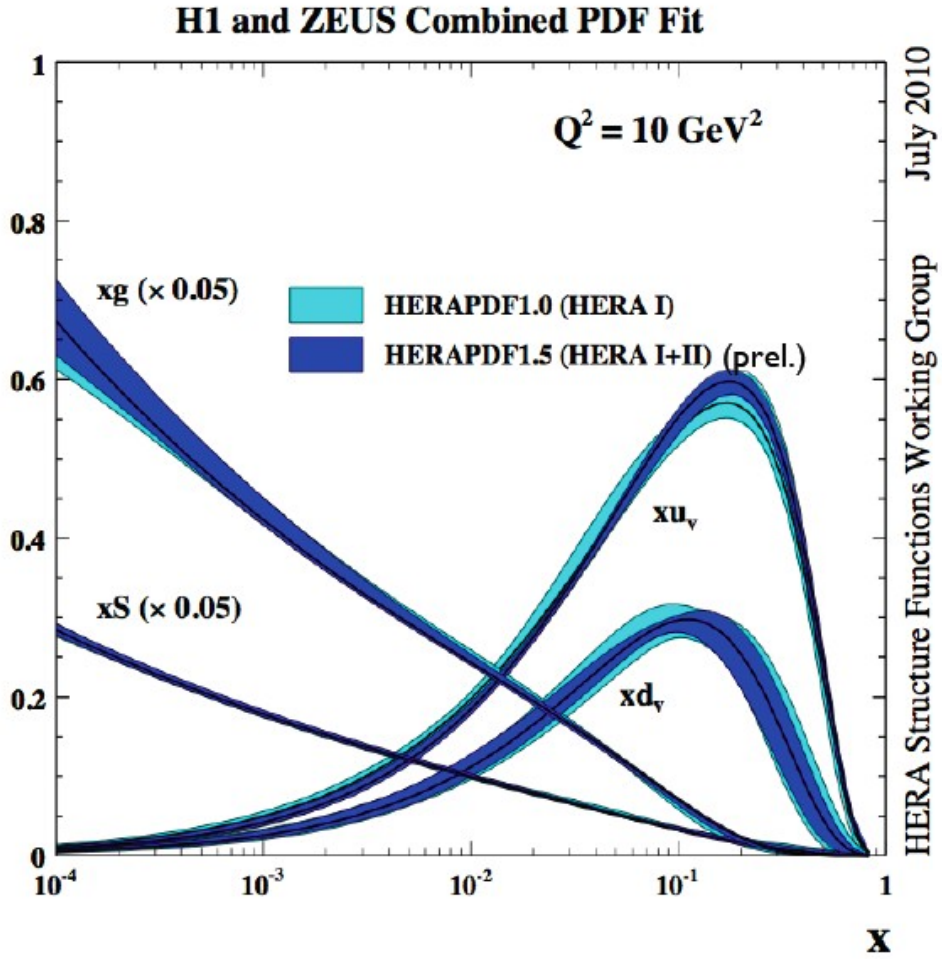
HERAPDF1.5

HERAPDF1.0 – HERAI data

HERAPDF1.5 – HERAI and HERAII high-Q^2 data

$Xg,\ xu_v,\ xu_d,\ xS = x\bar{U} + x\bar{D}$ $(x\bar{U} = xu(+xc),\ xD = xd + xs(+xb))$

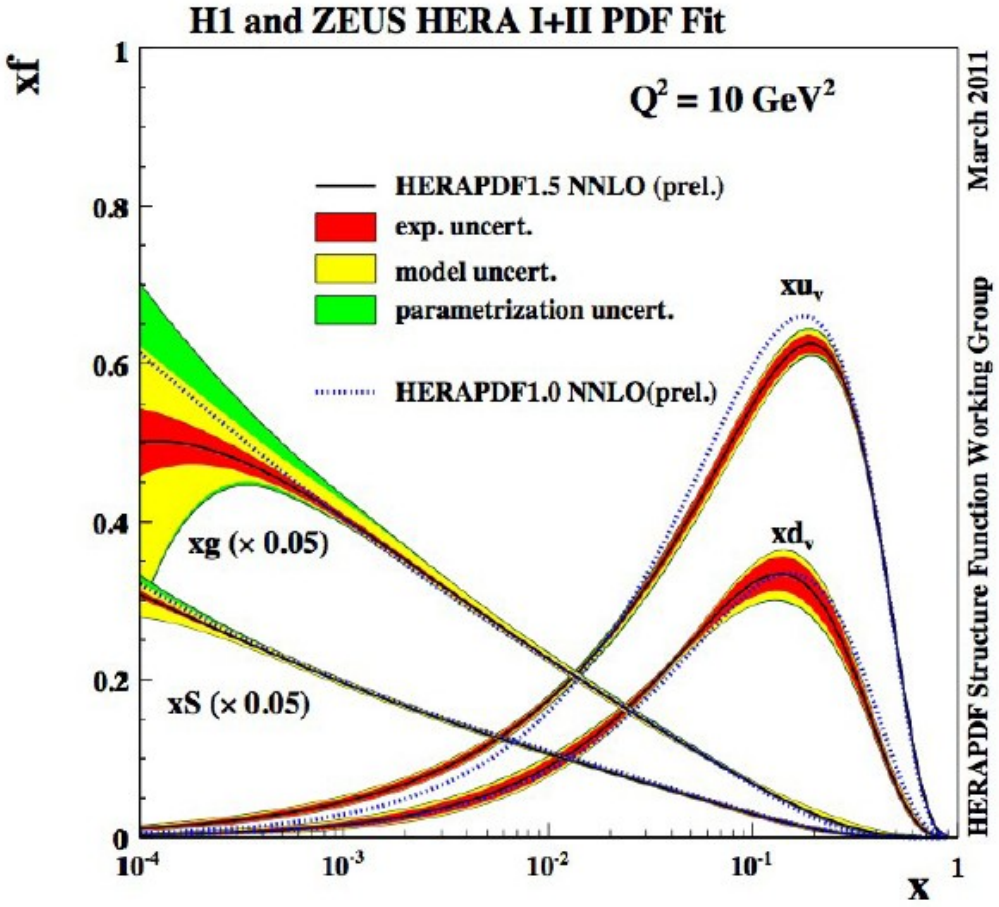


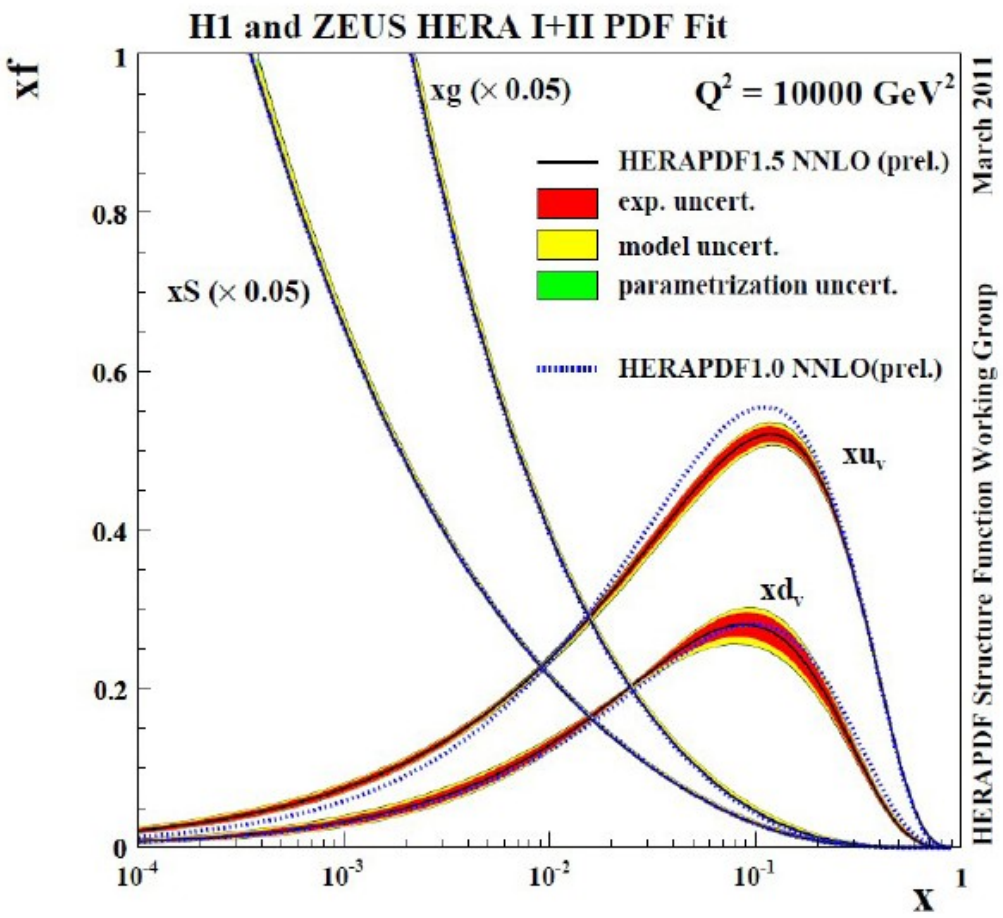


Including HERAII data reduces the uncertainty, especially at high x!

HERAPDF1.5 NNLO

NLO and NNLO HERAPDF available for LHC predictions!

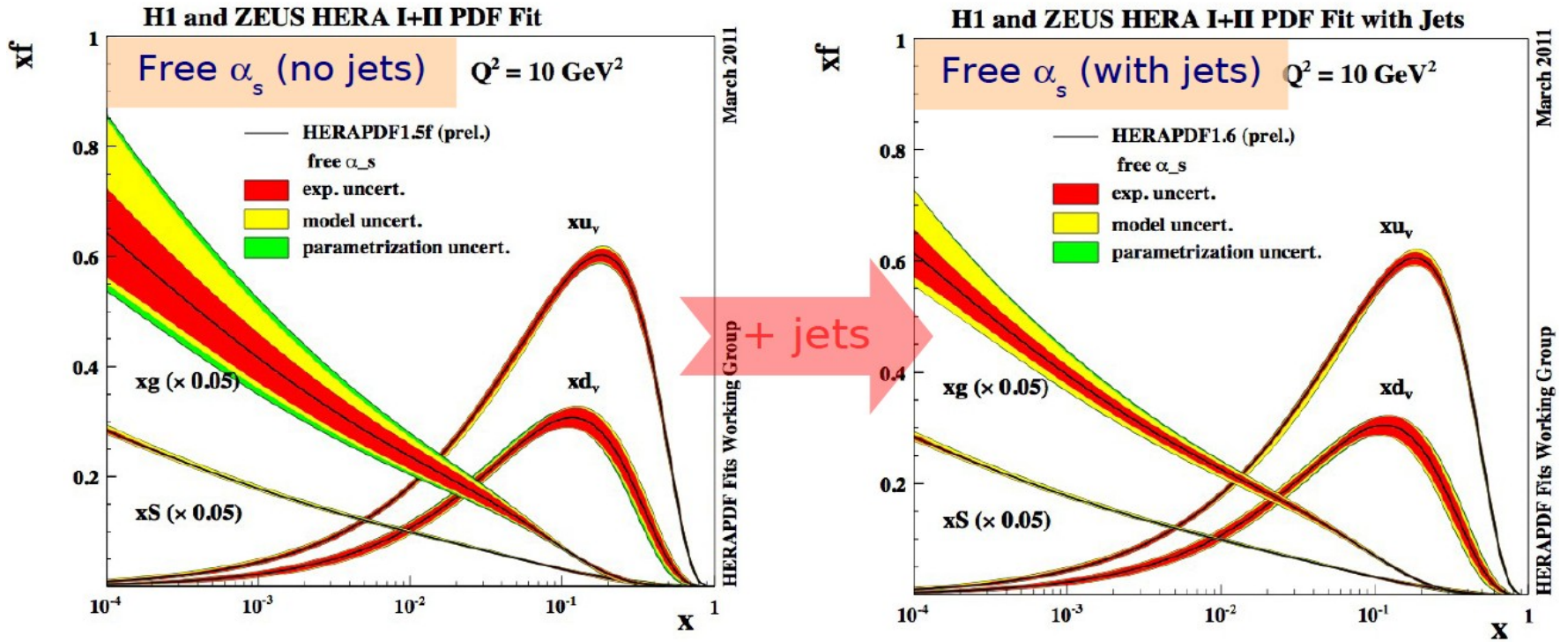




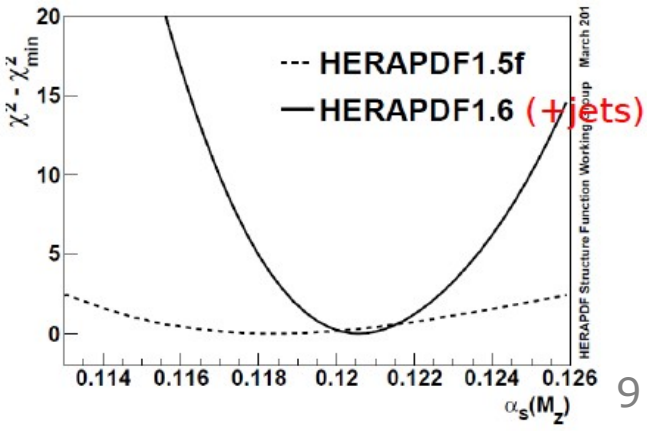
Differences at high-x due mainly to more *flexible parametrisation* (extra term for gluon and valence) used when fitting HERAI+HERAII data

HERAPDF fit including jet data: HERAPDF1.6

In standard fit - fixed α_s, in this fit α_s left free
At low-x α_s and *xg(x)* are strongly correlated



HERA data allow to constrain simultaneously α_s and gluon and improve uncertainty



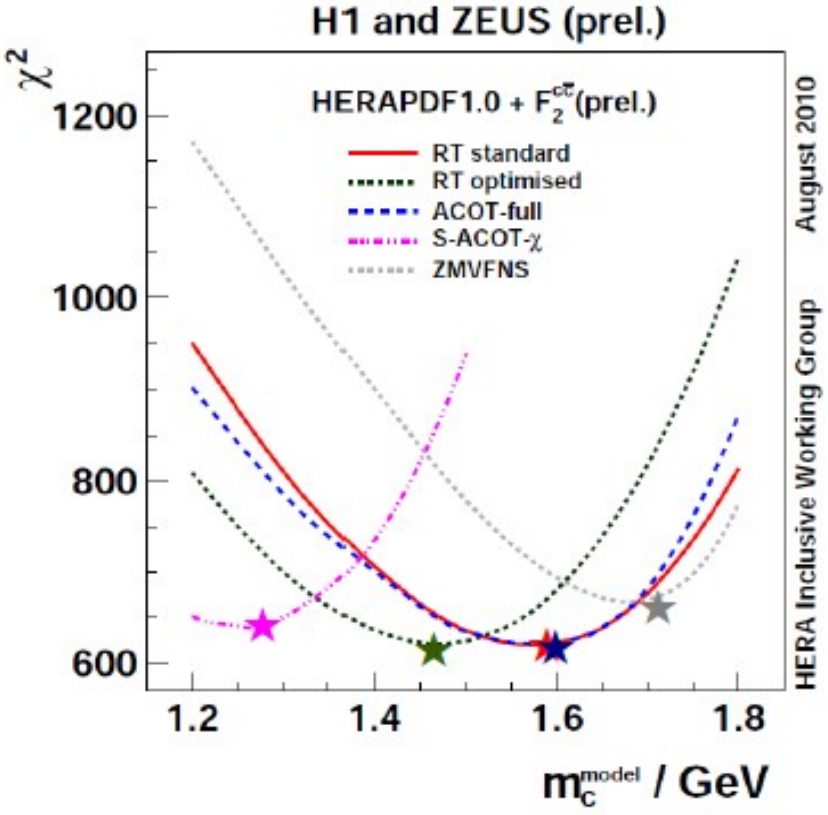
$$\rightarrow \alpha_s(M_Z) = 0.1202 \pm 0.0013(\text{exp}) \pm 0.0007(\text{mod}) \pm 0.0012(\text{had}) \,^{+0.0045}_{-0.0036}(\text{th})$$

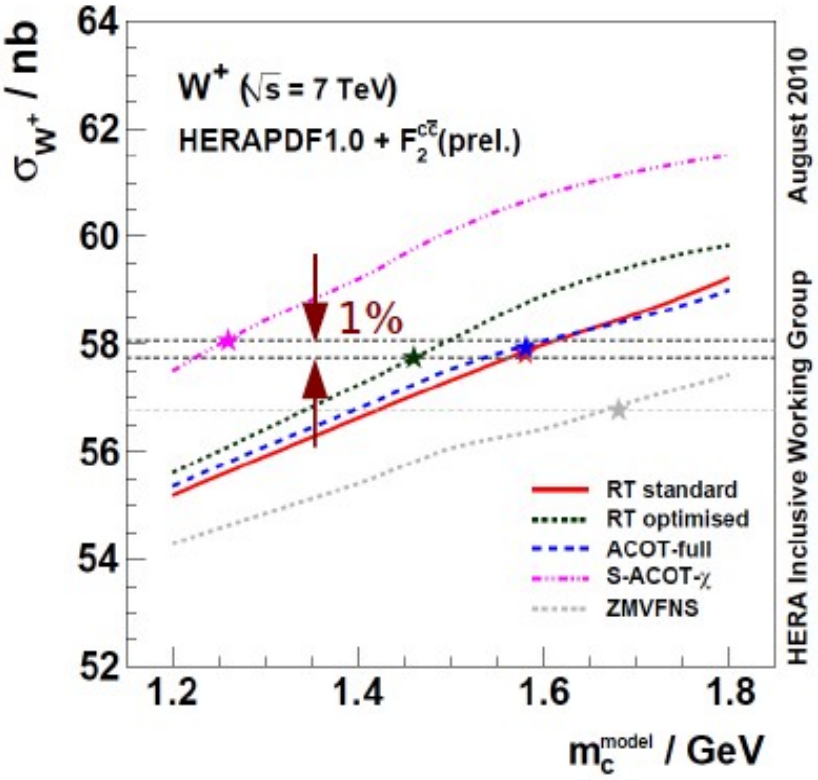
Including charm data in the fit

Heavy quark treatment in PDFs is important, many different existing schemes

Charm mass variation $1.4 < m_c < 1.65$ gives 5% uncertainty on W cross section

HERA charm data allow to constrain charm mass

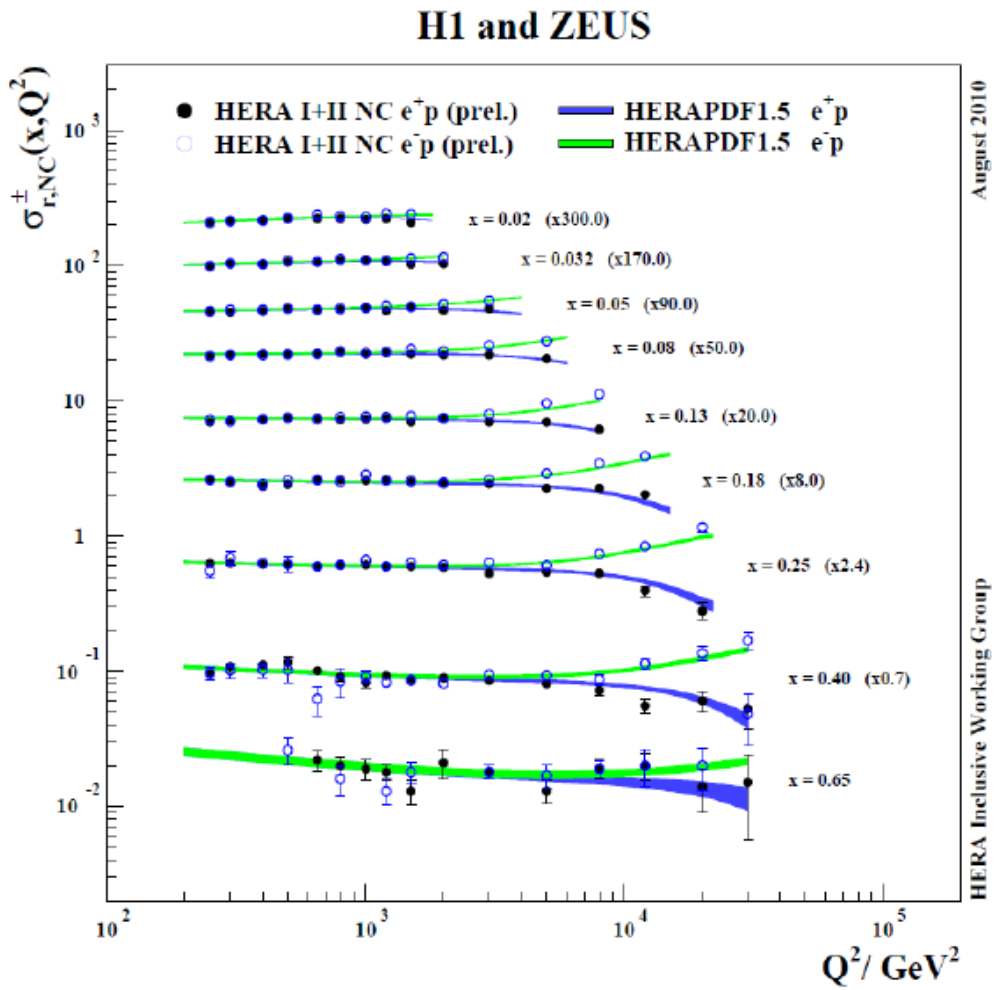




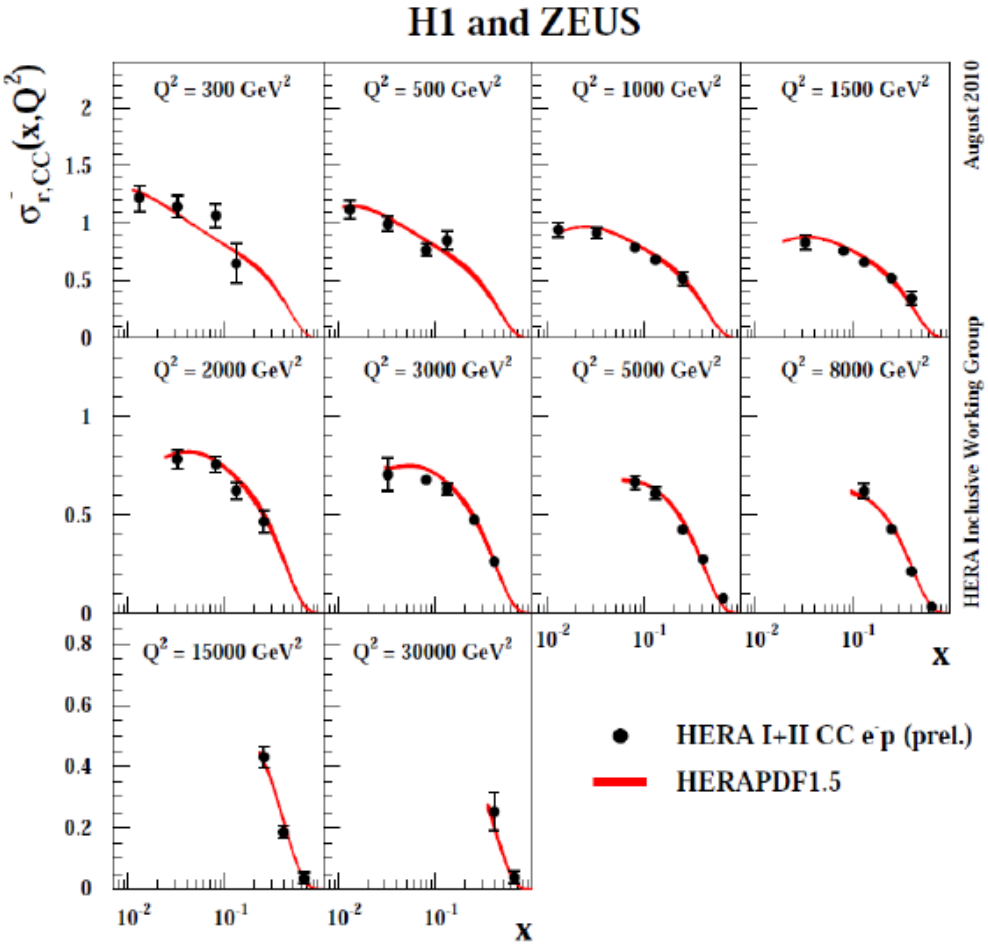
Optimal charm mass determined with HERA data reduces the uncertainty of cross section prediction!

HERAPDF for CC and NC data

Charge Current



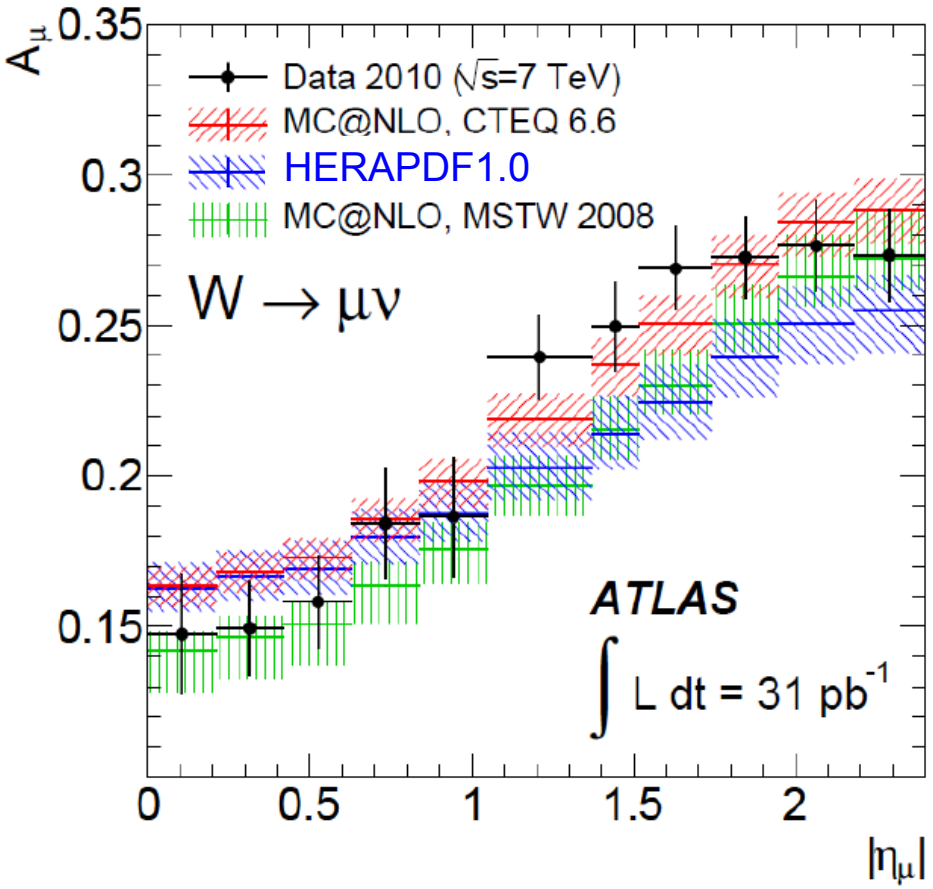
Neutral Current

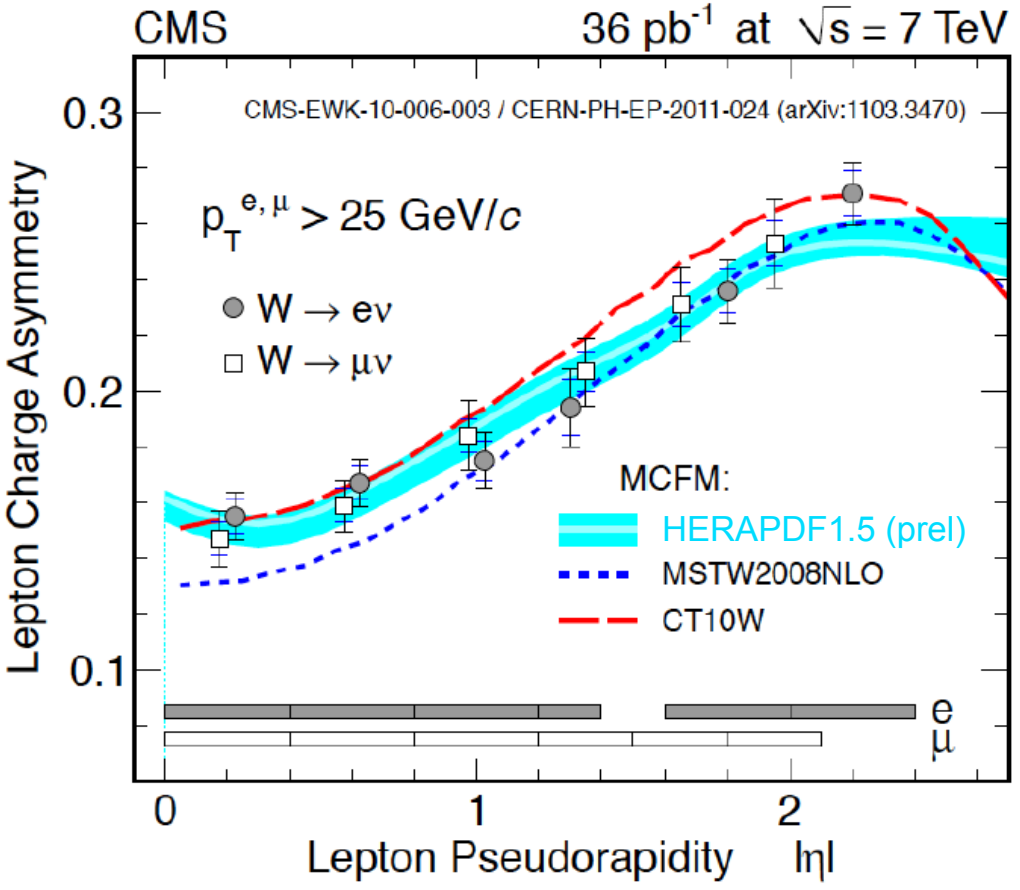


HERAPDF describe NC and CC data well

HERAPDF predictions W lepton asymmetries at LHC

W lepton asymmetry is sensitive to differences between u and d: $A_W \approx \frac{u_v - d_v}{u_v + d_v + 2u_{sea}}$

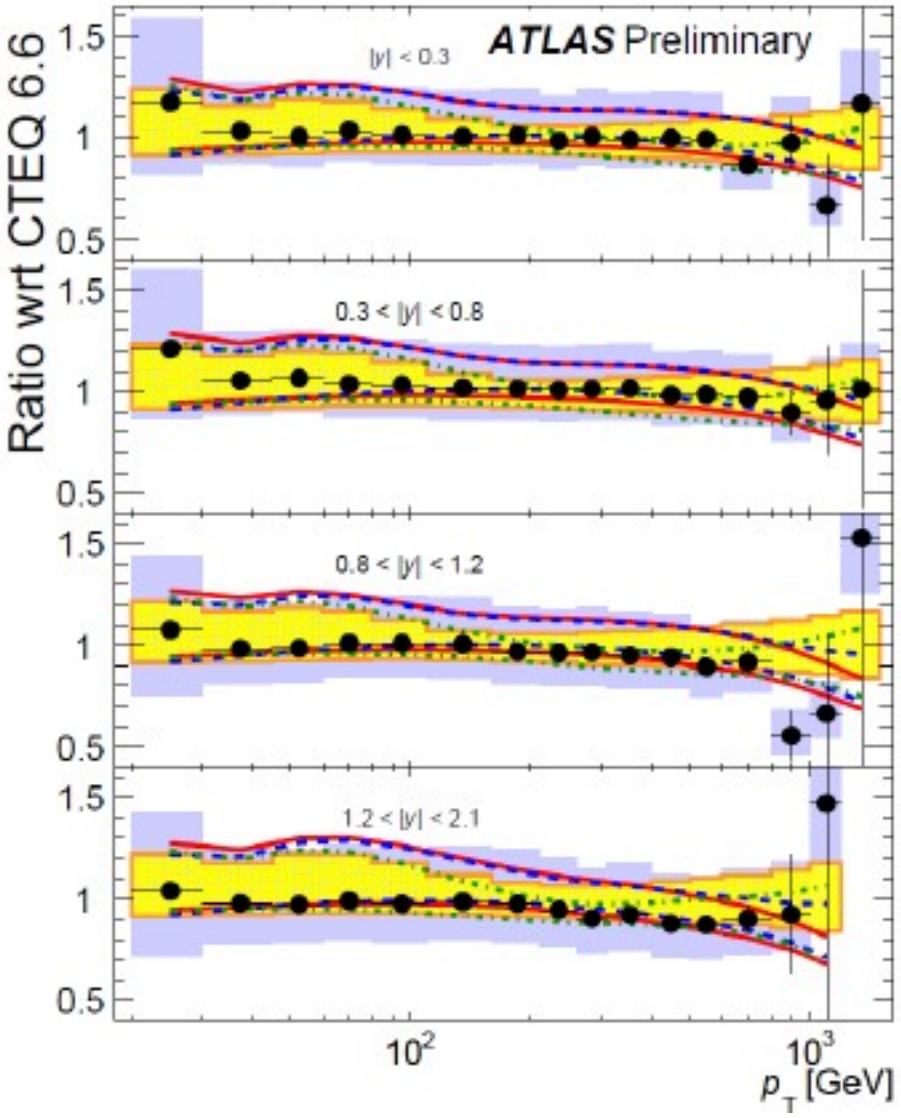


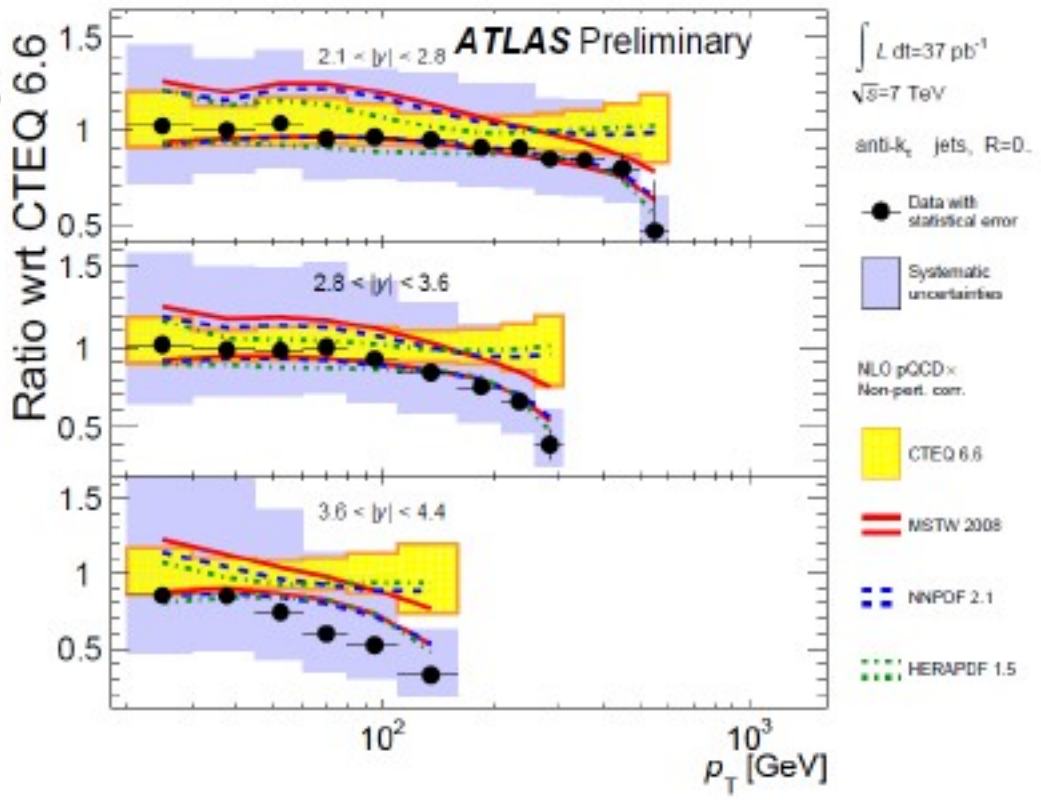


HERAPDF provide good description of LHC data

HERAPDF predictions for jets at LHC

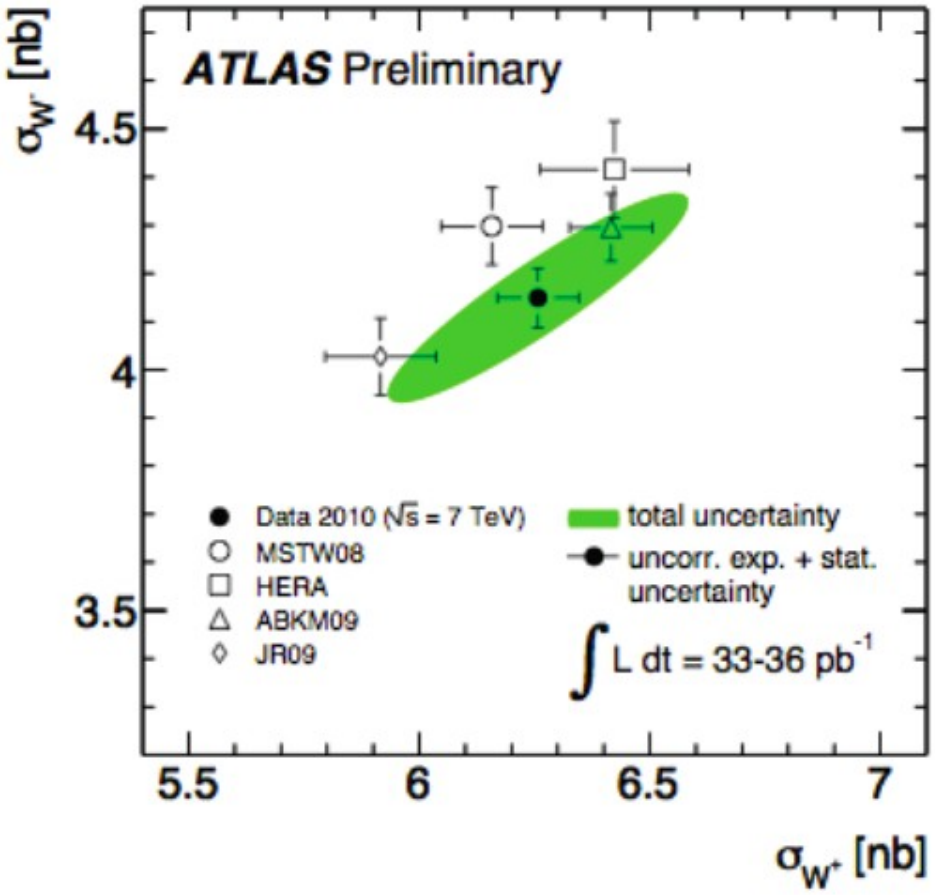
Inclusive jet cross section as a function of jet p_T in different regions of pseudorapidity

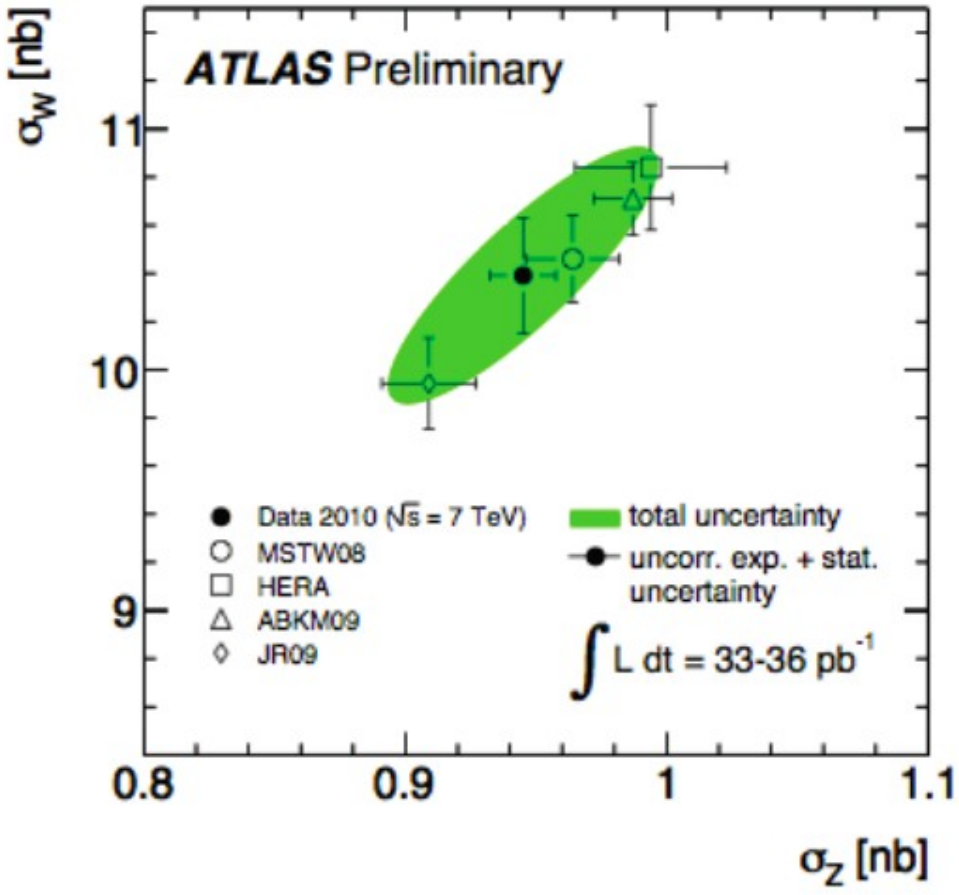




HERAPDF provide good description of LHC data

Predictions for W, Z cross sections at LHC





HERAPDF provide reliable predictions

Summary

HERA provide unique data to study the structure of the proton

New HERAPDF available based on combined HERAI and HERAII data

- Strong constraints on PDFs
- Available at NLO and NNLO
- Inclusion of jet data allows simultaneous determination of the strong coupling and gluon
- Inclusion of charm data allows constraints for the optimal value of the charm mass

HERAPDF provide very reliable predictions for LHC!