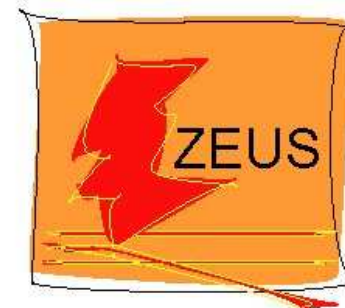




Proton Structure Measurements and the HERAPDF fit



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Lake Louise Winter Institute 2009

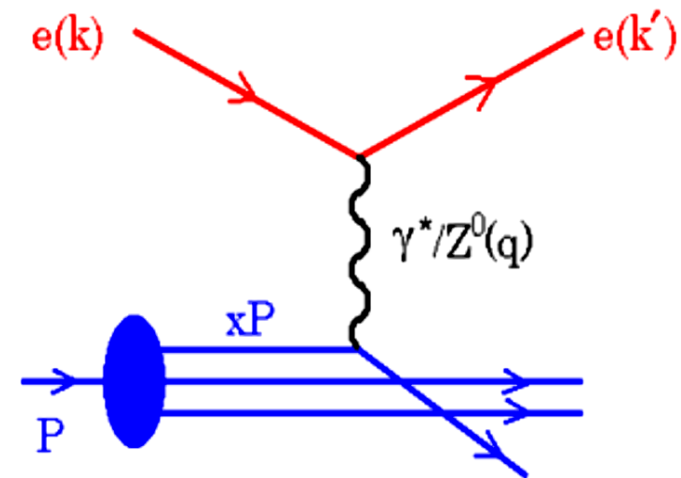
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Introduction

- Kinematics of Deep Inelastic Scattering (DIS) described by Lorentz invariant quantities:
 - Q^2 virtuality/resolving power
 - x Bjorken scaling variable, momentum fraction of the scattered parton
 - y inelasticity
- Related by $Q^2 = xys$, where $\sqrt{s} = 319 \text{ GeV}$ for the HERA experiments
- DIS is a unique tool to
 - Test QCD dynamics: validity of evolution equations, with a wide range of Q^2 and x accessible at HERA
 - Measure the substructure of the proton: quark and gluon content, so called Parton distribution functions (PDFs)
- Precise knowledge of the PDFs is vital for measurements at hadron colliders as the LHC



Inclusive DIS Cross Section

- Three structure functions $F_2(x, Q^2)$, $F_L(x, Q^2)$, $xF_3(x, Q^2)$ parametrise the inclusive NC cross section for $ep \rightarrow e'X$:

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

- Leading contributions of the structure functions relate to the PDFs as

$$F_2 = x \sum e_q^2 (q(x) + \bar{q}(x))$$

$$xF_3 \sim x \sum 2e_q a_q (q(x) - \bar{q}(x))$$

- Additional information is given by the CC cross section for $ep \rightarrow \nu_e X$:

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

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

- The gluon $xg(x, Q^2)$ is constrained by F_2 scaling violations, jet cross sections, and F_L measurement

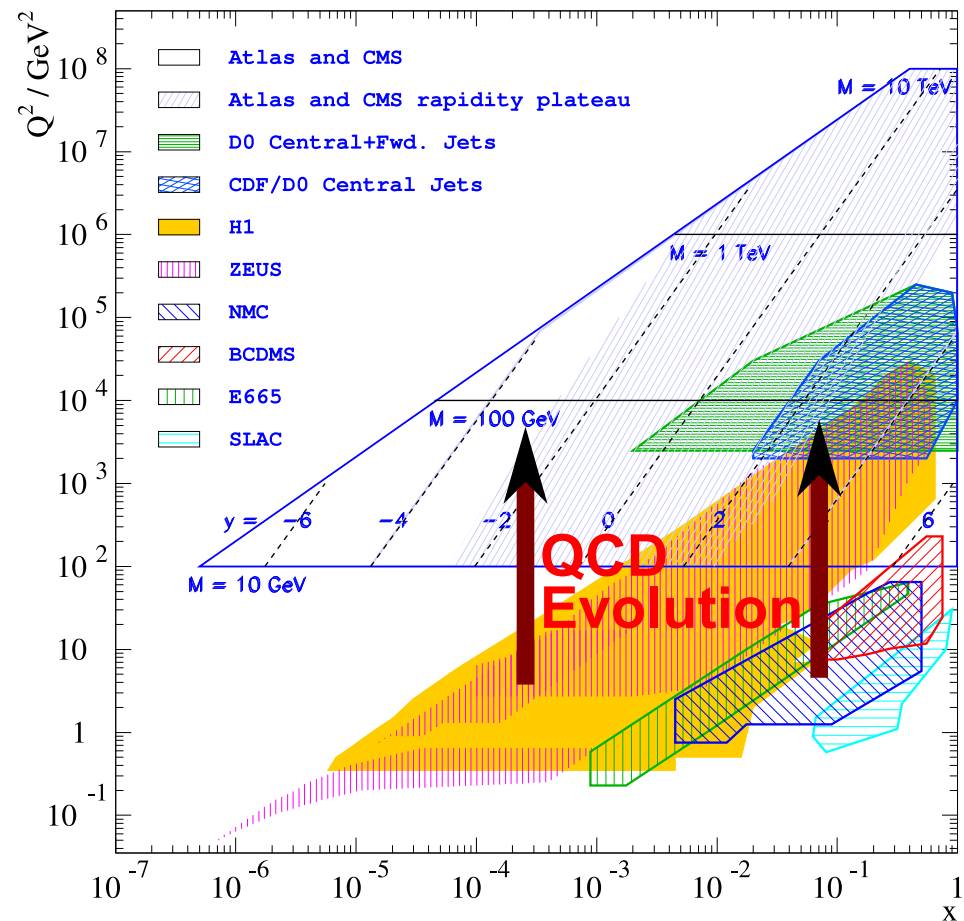
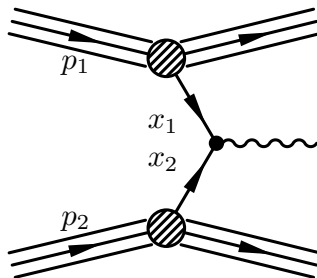
HERA and LHC Kinematics

● Cross Sections at pp collider can be calculated using:

- Universal PDFs
- Hard scattering parton-parton cross section

● Rapidity y of produced particle with mass M is related to the momentum fractions x_1 and x_2 of the partons via

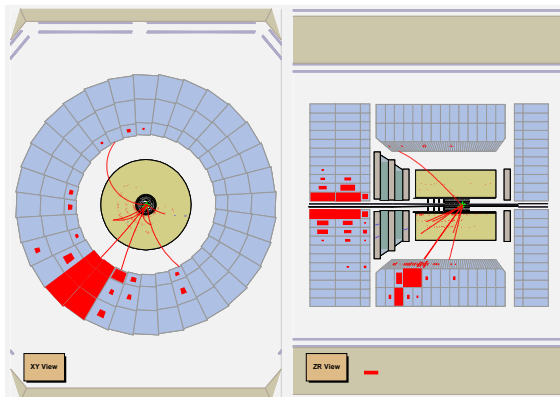
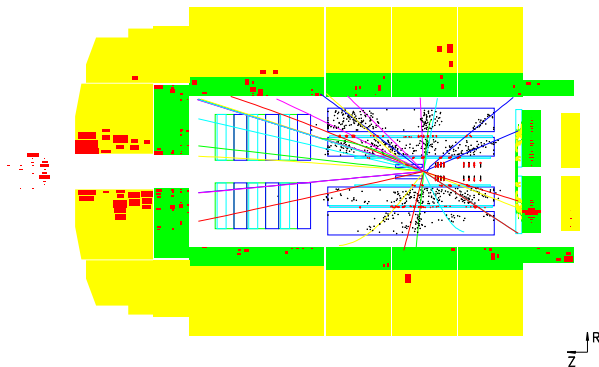
$$x_{1,2} = \frac{M}{\sqrt{s}} \exp(\pm y)$$



The HERA Collider

- HERA: Operation from 1992 until End June 2007
- H1 and ZEUS: general purpose detectors, Measurement of the Proton Structure in full kinematic range one of the prime objectives

Run 270402 Event 120401

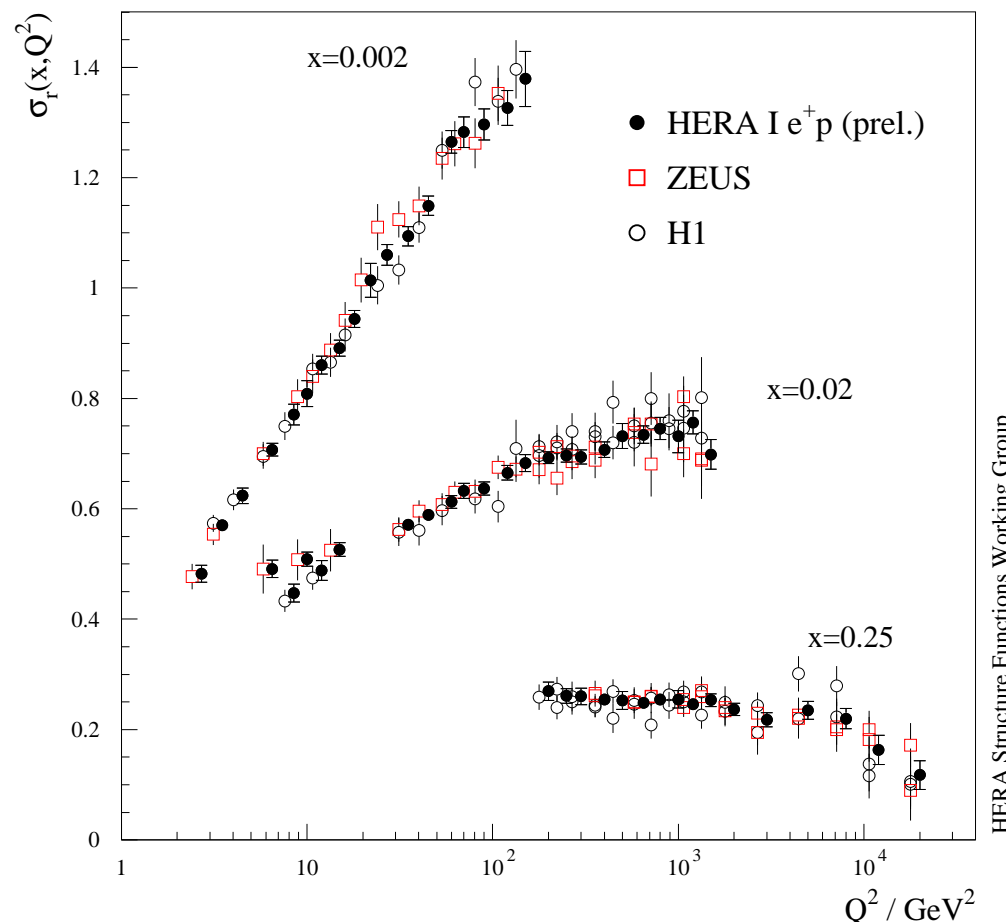


Combination of ZEUS+H1 data

- Average the double differential inclusive NC and CC cross sections by the two HERA experiments without theory assumptions

HERA I e^+p Neutral Current Scattering - H1 and ZEUS

- Fit with consistent treatment of correlated systematic uncertainties
- Improved precision due to reduction of statistical and systematic uncertainties - Cross calibration of the two experiments!
- Provides one data set containing all inclusive HERA results, e.g. for QCD fits

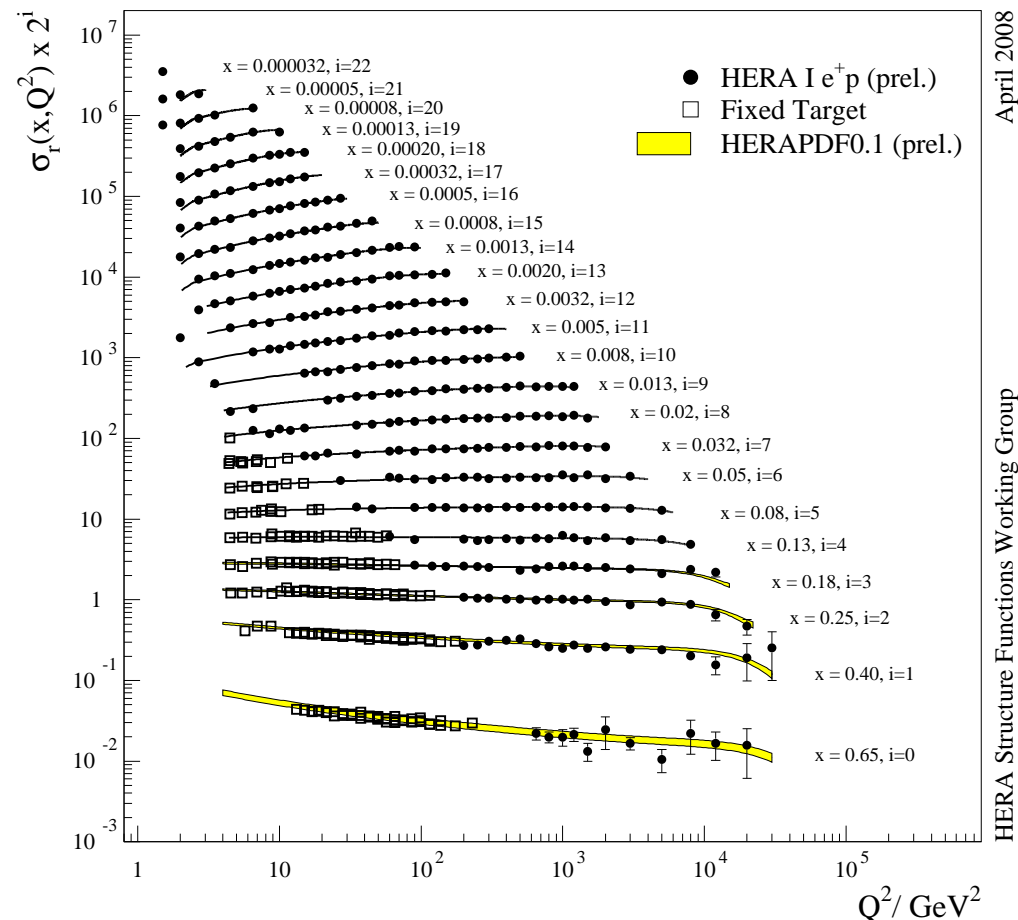


Combined HERA Data

- Using the so far published inclusive measurements by H1 and ZEUS, which employ data taken until the year 2000

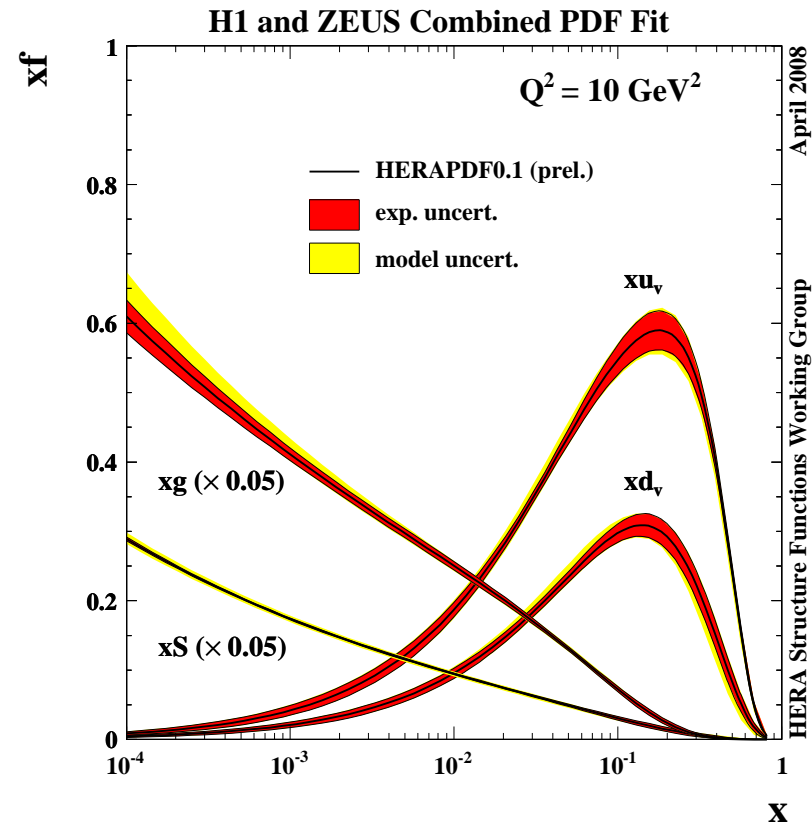
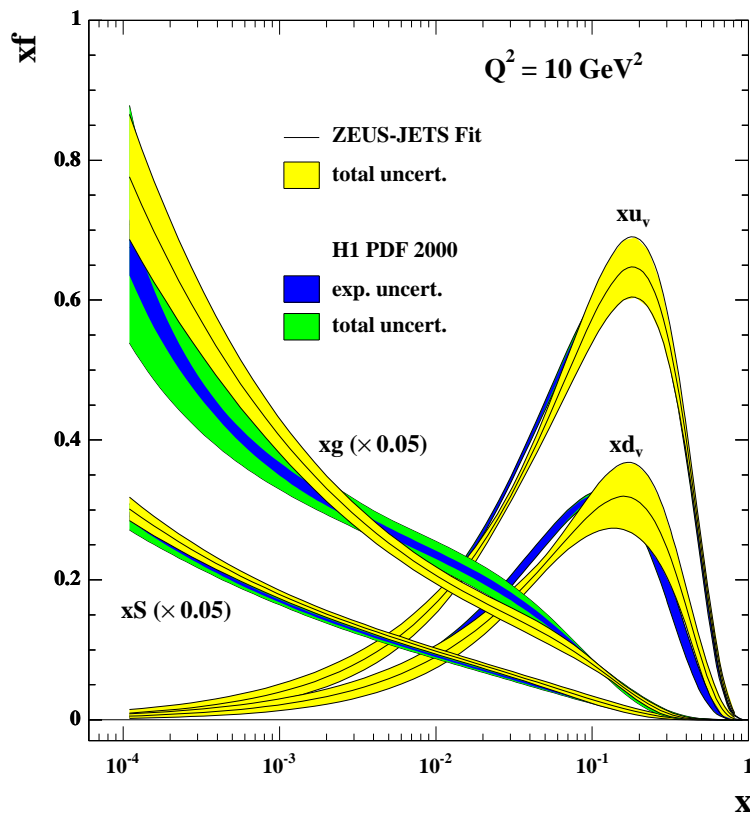
H1 and ZEUS Combined PDF Fit

- Good consistency of the two experiments:
 $\chi^2/\text{n.d.f} = 510/599$
- High precision data over 4 orders of magnitude in x and Q^2 together with the fixed target experiment data provide a stringent test of our understanding of QCD

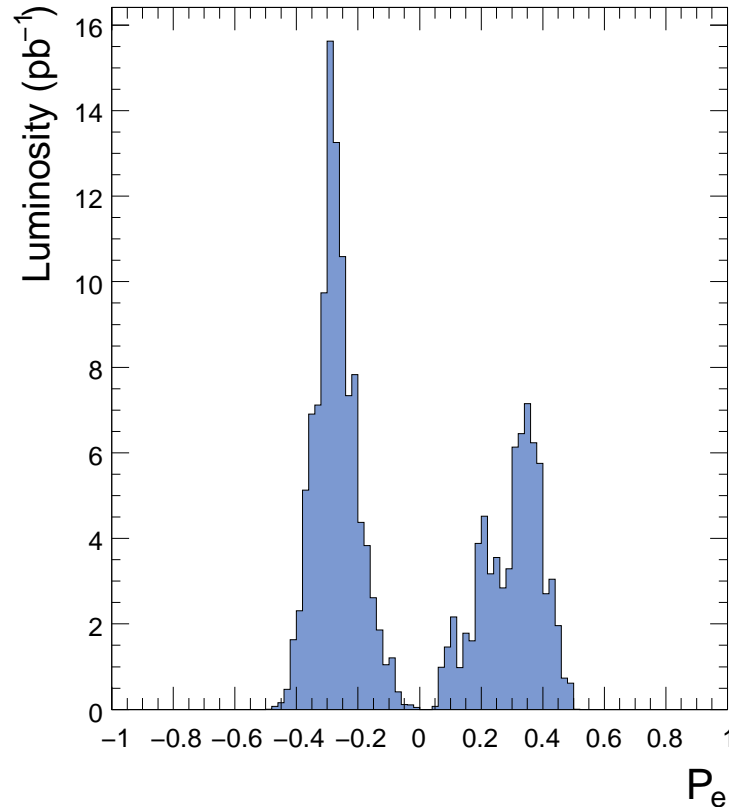
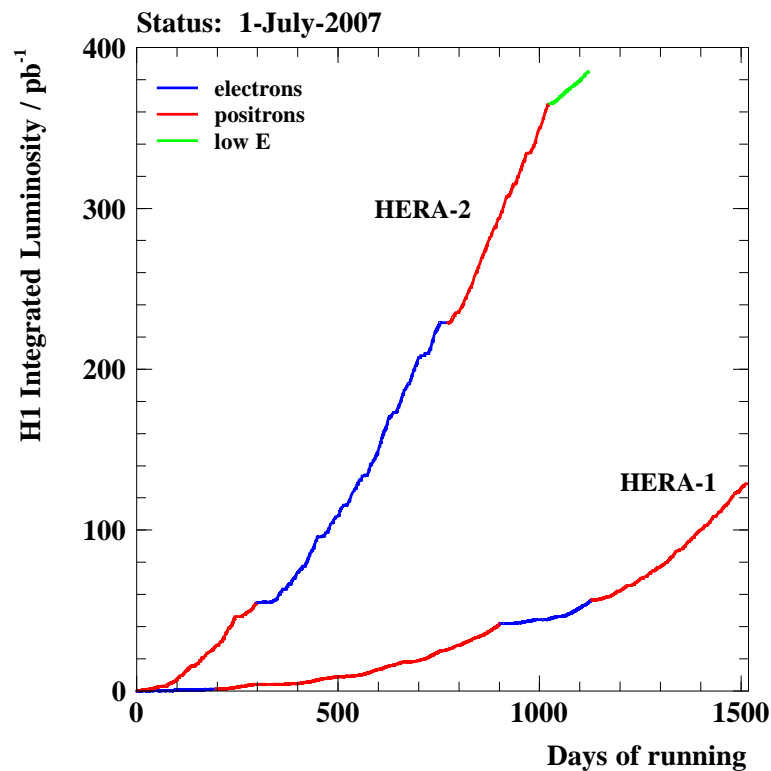


Combined HERA QCD Fit

- Using the combined data, a preliminary combined DGLAP fit, **HERAPDF 0.1**, was performed
- Much reduced PDF uncertainties compared to previous fits, especially for the gluons distribution, which dominates the proton at low x



New Inclusive Measurements

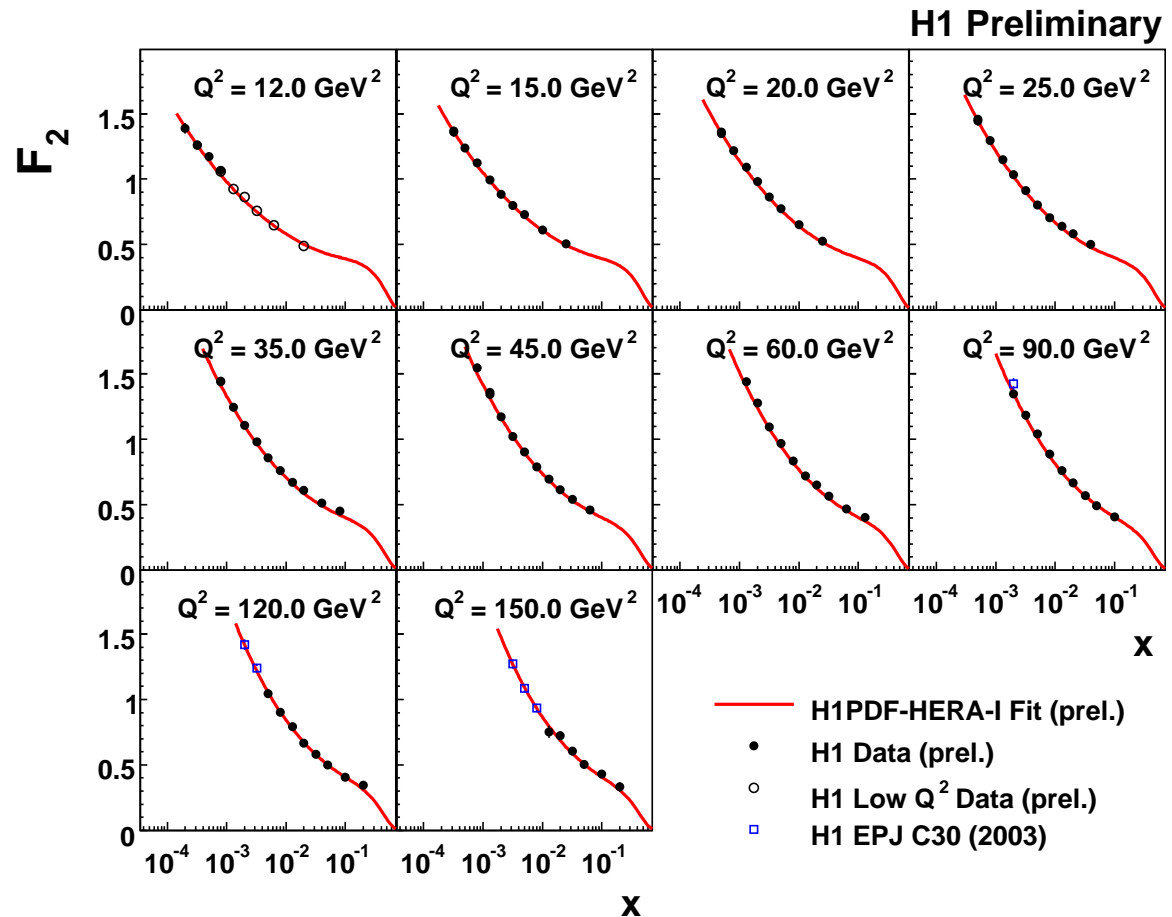


- Final high precision analyses using HERA-I data (low Q^2)
- Analysis of high luminosity samples with polarised e^+ and e^- beams from HERA-II (high Q^2)
- F_L measurement using special low E_p runs

New Results at Low Q^2

New H1 measurements in the region $Q^2 \leq 150 \text{ GeV}^2$

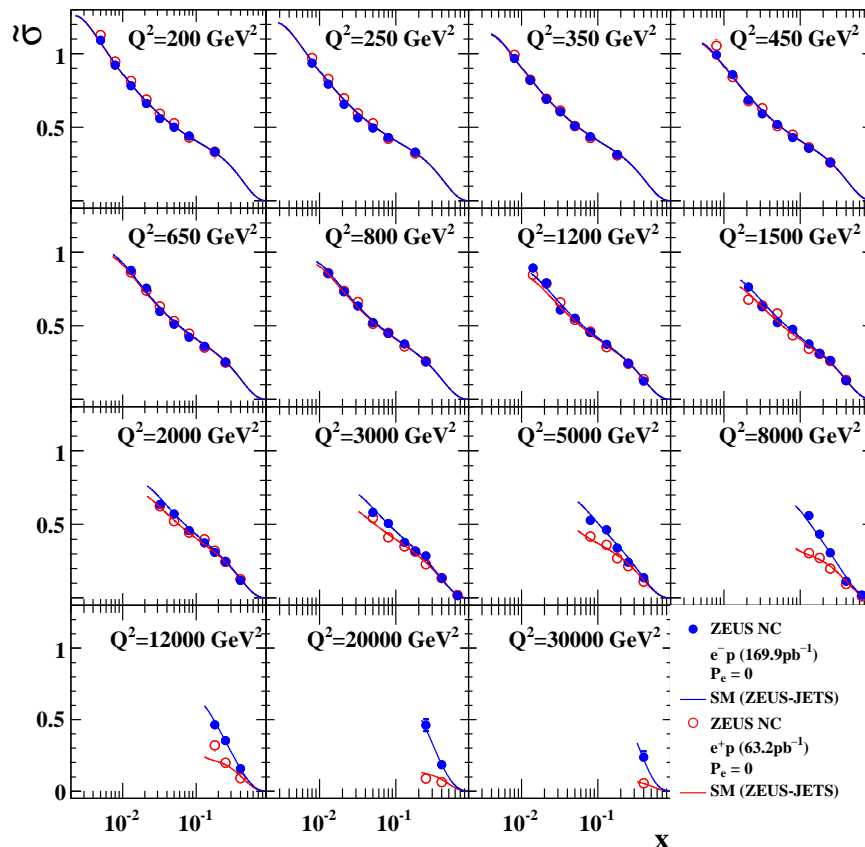
- New measurement for $Q^2 \geq 12 \text{ GeV}^2$ improves precision to $\sim 1.5\%$
- Special experimental techniques for $Q^2 \leq 12 \text{ GeV}^2$, precision $\sim 2\%$



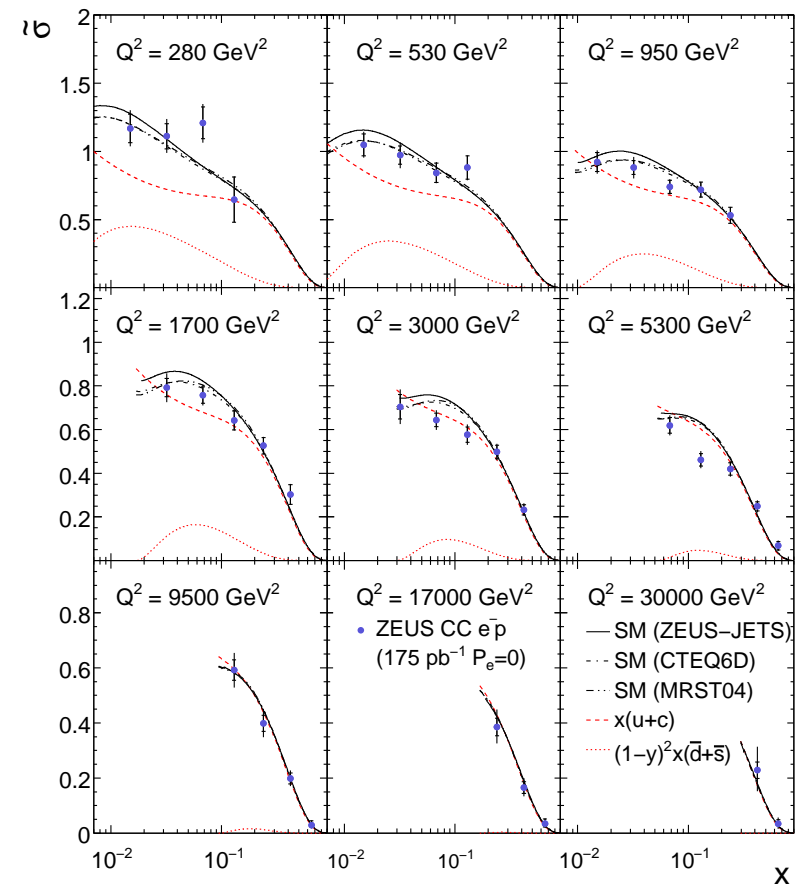
New Results at High Q^2

New NC and CC cross sections by ZEUS using the full dataset of e^-p data for $Q^2 \geq 200 \text{ GeV}^2$: NC cross sections reaching $\sim 2\%$ systematic uncertainty

NC ZEUS



CC ZEUS



Conclusions

- The HERA experiments measure the proton structure in a wide range of x and Q^2 , providing stringent tests of QCD and valuable input for the LHC
- A new procedure combines the already published data to obtain one HERA data set with improved uncertainties
- A combined QCD fit, **HERAPDF 0.1**, is able to describe the data and provides PDFs with much reduced uncertainties
- New measurements of H1 and ZEUS are available or close to publication, which significantly reduce the measurement uncertainties w.r.t to the published measurements

Additional Slides



Combined HERA QCD Fit

- Reasonable comparison to global fits, improved precision, however the error treatment also differs
- Preliminary **HERAPDF 0.1** available in LHAPDF with full uncertainties

