Combined Measurements of NC and CC DIS Cross-sections at HERA

R. Yoshida (ANL)
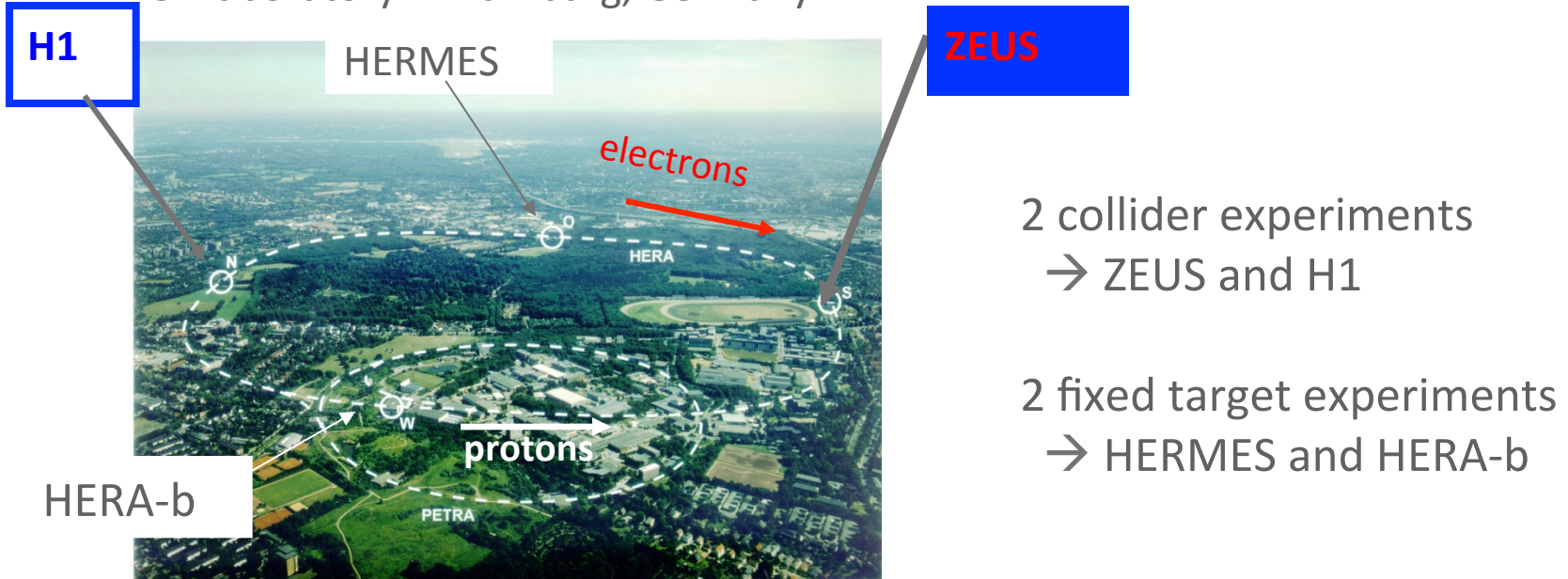
On behalf of the

H1 and ZEUS Collaborations

PANIC 2011, Cambridge, MA , 7/25/2011

HERA electron-proton collider

DESY laboratory in Hamburg, Germany

H1
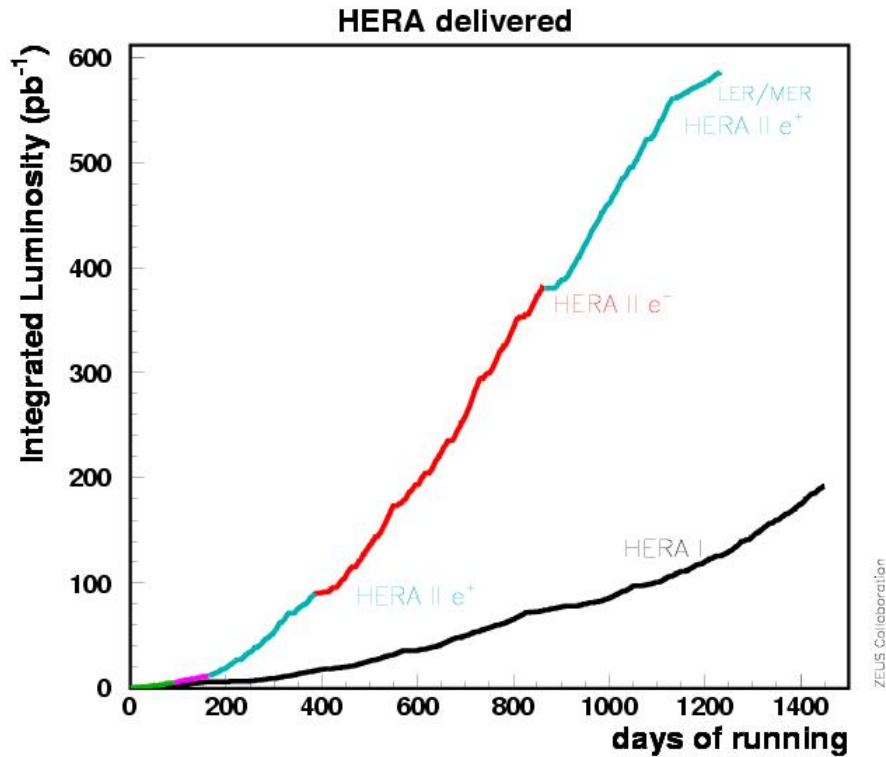
HERMES

ZEUS

electrons

protons

HERA-b

2 collider experiments
→ ZEUS and H1

2 fixed target experiments
→ HERMES and HERA-b

- 920 GeV protons (820 before 1998)
- 27.5 GeV $e^{\pm}$
- 300/318 GeV c.o.m. energy
- 220 bunches, 96ns. crossing time
- 90 mA protons, 40 mA positrons
- Instantaneous luminosity: $1.8 \times 10^{31} cm^2 s^{-1}$

$5.12 \times 10^{31} cm^2 s^{-1}$ after upgrade

HERA delivered

HERA I: 1992-2000
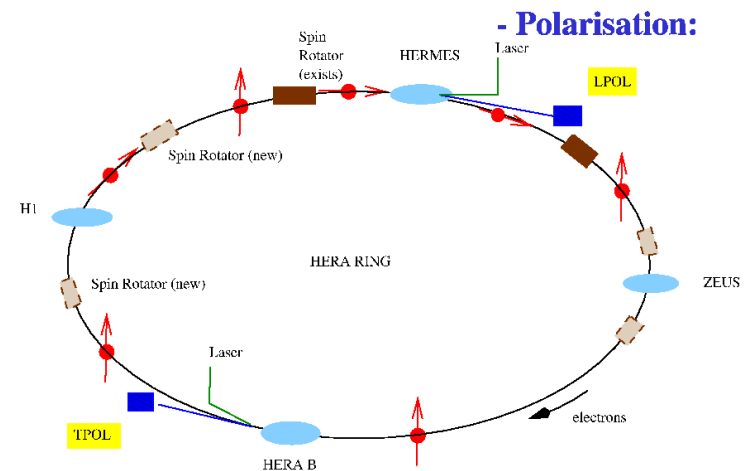~180 pb-1/experiment
delivered. (mostly e⁺)

Upgrade: 2001-2002

HERA II: 2002-2007
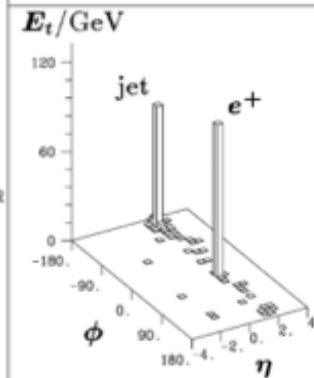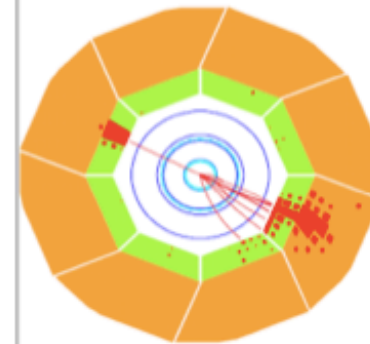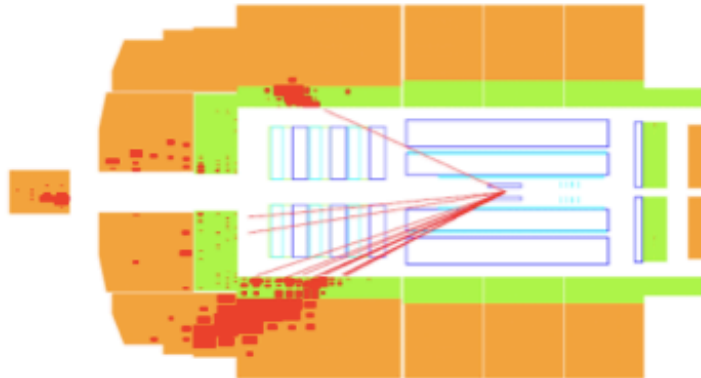~580 pb-1/experiment
delivered. (e⁺ and e⁻)

For HERA II:
 - Luminosity ~x3 (low-β insertion)
 - Long. polarized leptons
 - Some running at lower proton
   energy: 460 and 575 GeV
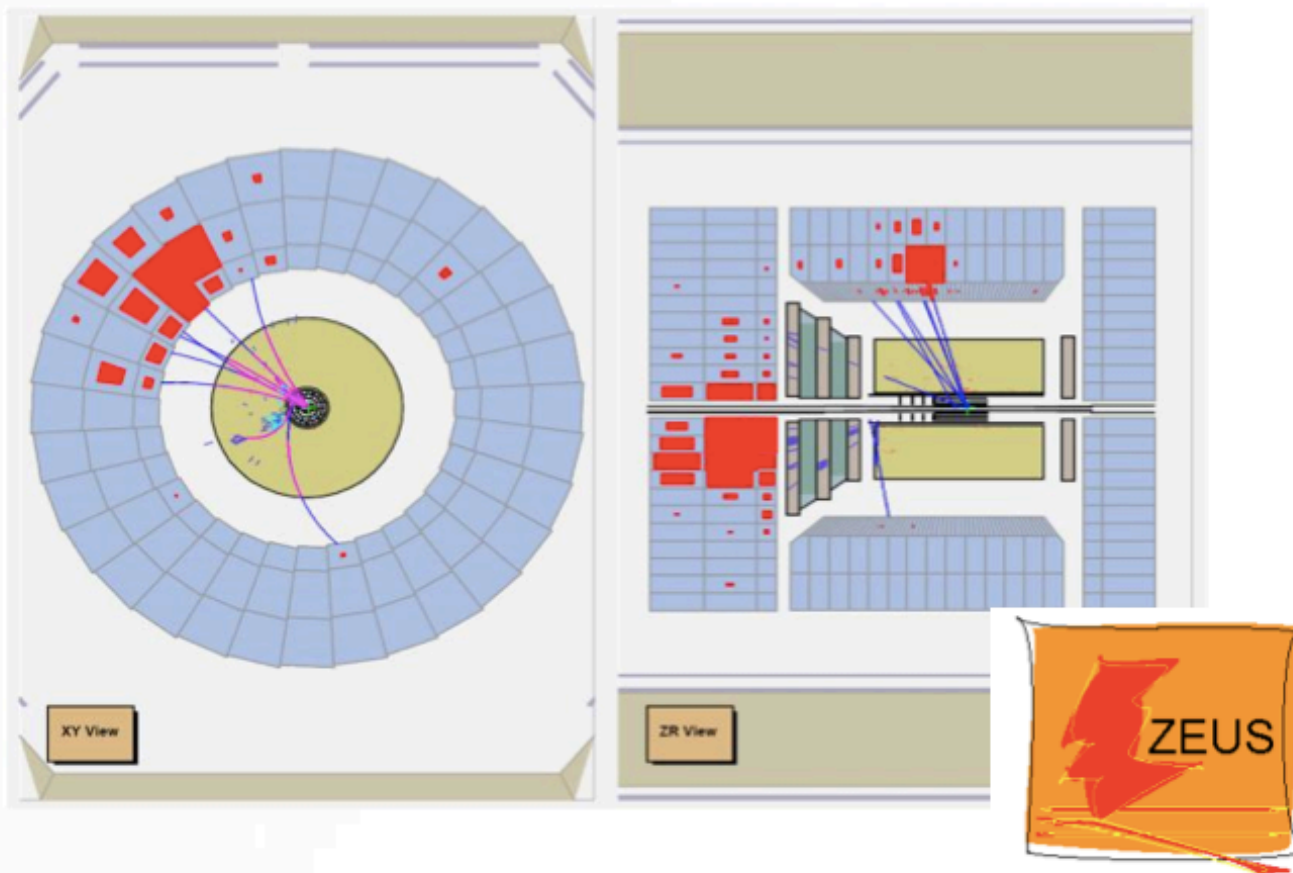
Neutral Current DIS

Electron

27.5 GeV

920 GeV

γ, Z
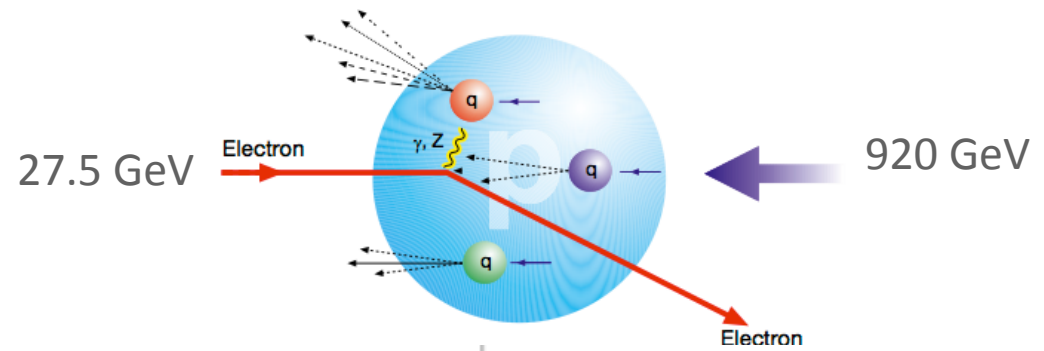
Electron

$Q^2 = 25030 \text{ GeV}^2, \quad y = 0.56, \quad M = 211 \text{ GeV}$

E_t/GeV

jet

$e+$

Charged Current DIS
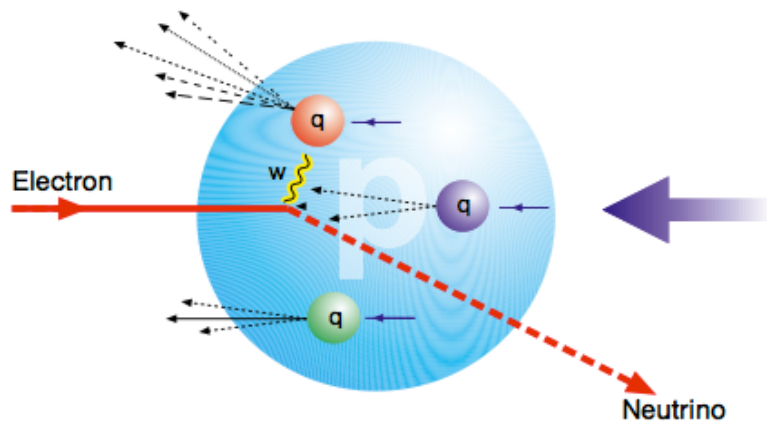
27.5 GeV

920 GeV

Electron

W

q

q

q

Neutrino

XY View

ZR View

ZEUS
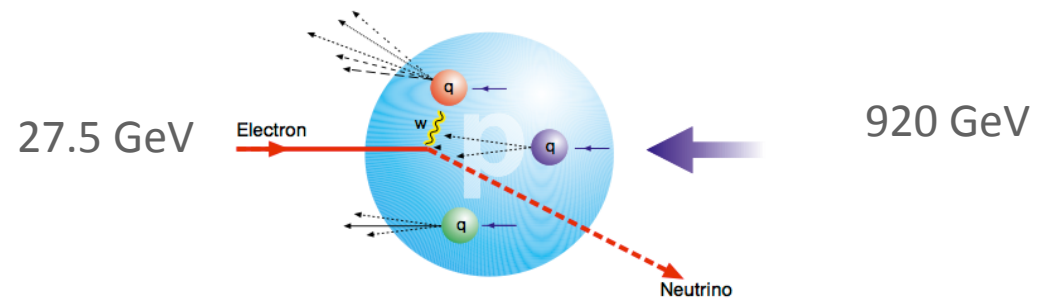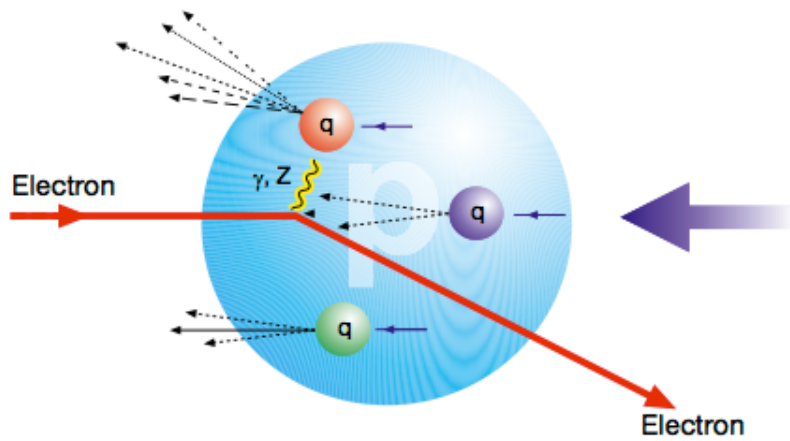
Two types of information

Protons Structure: Parton Distributions.

Structure of the ElectroWeak Sector.

Parity Violation in Charged Current DIS.

$$\frac{d^2\sigma_{pol}^{CC}(e^{\pm}p)}{dx dQ^2} = (1 \pm P)\frac{d^2\sigma_{unpol}^{CC}(e^{\pm}p)}{dx dQ^2}$$

$$P = \frac{N_R - N_L}{N_R + N_L}$$

HERA Charged Current $e^{\pm}p$ Scattering

$e^+p \to \overline{\nu}X$
- ● H1 HERA I
- ○ H1 HERA II (prel.)
- △ ZEUS 06-07
- ▲ ZEUS HERA I

$e^-p \to \nu X$
- ● H1 HERA I
- ○ H1 HERA II (prel.)
- ▲ ZEUS 98-06

— HERAPDF 1.0

$Q^2 > 400$ GeV^2

$y < 0.9$
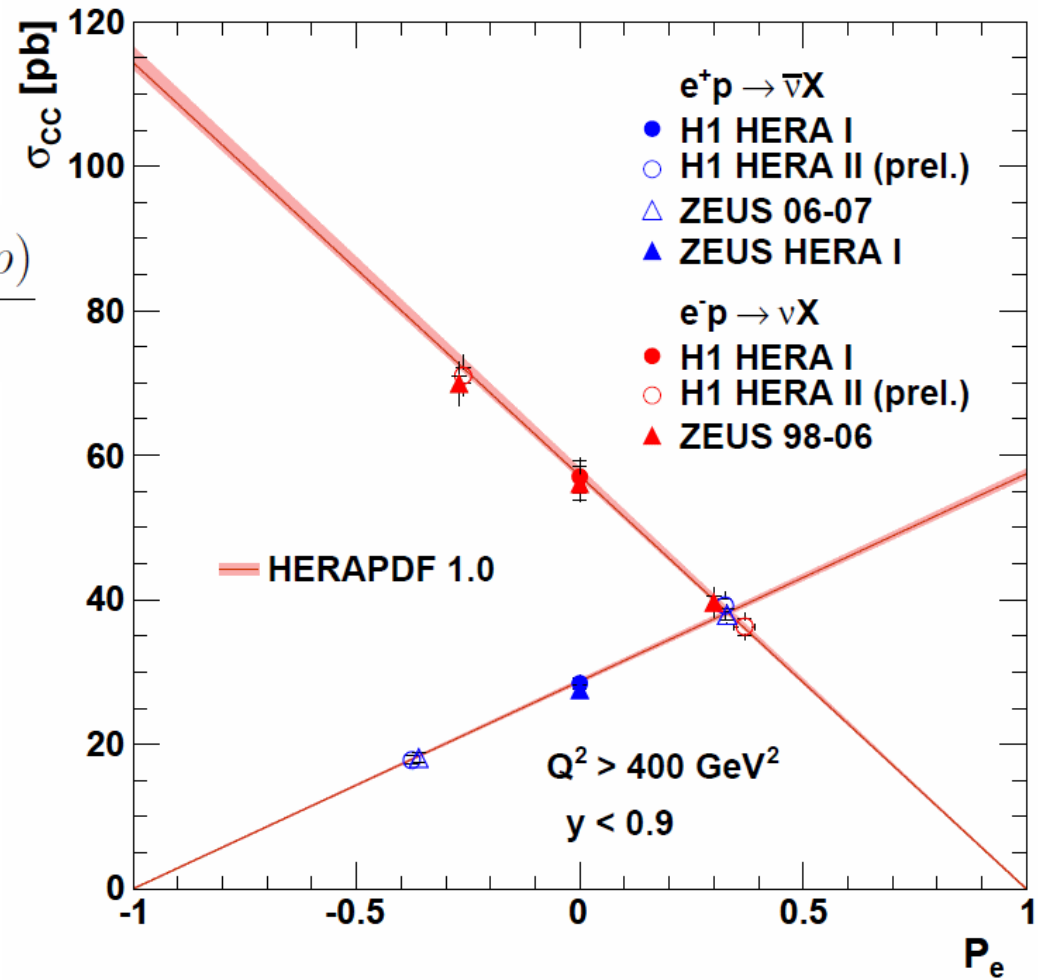
Parity Violation in Neutral Current DIS at
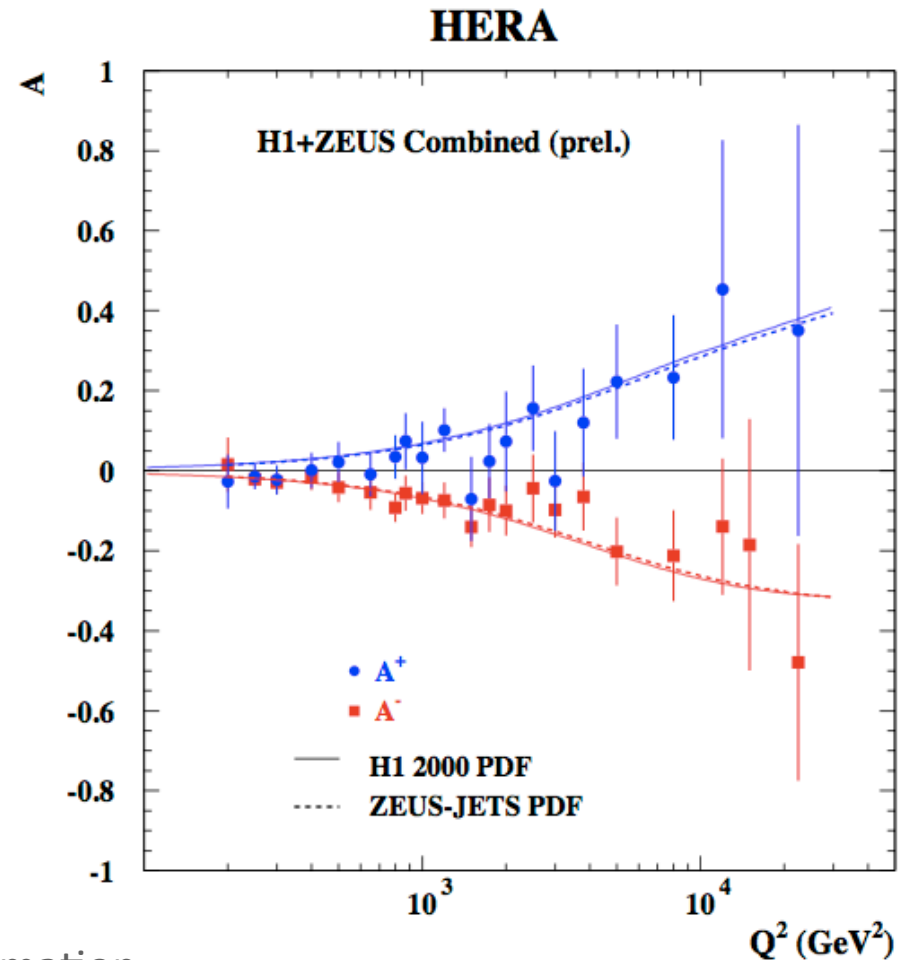High momentum transfer, Q^2

positron and electron (±)

$$A^\pm \equiv \frac{\sigma^\pm (P=+1) - \sigma^\pm (P=-1)}{\sigma^\pm (P=+1) + \sigma^\pm (P=-1)}$$

(e) polarization

Weak couplings
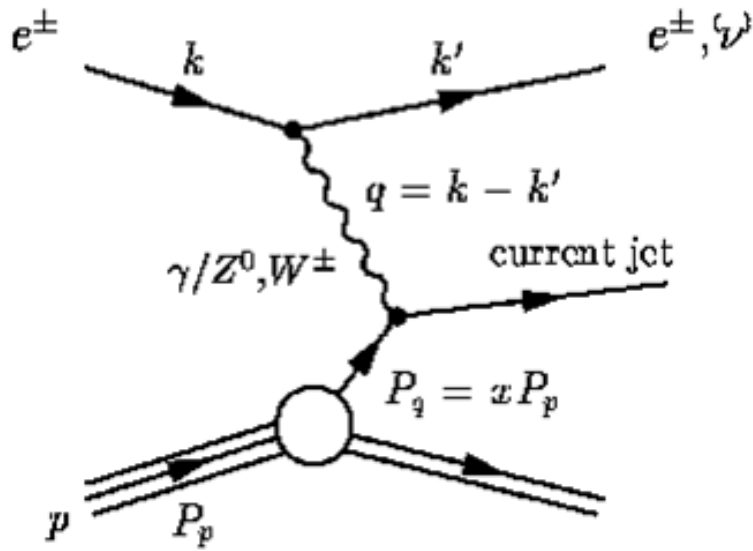
$$A^\pm_{approx} \propto \mp \frac{Q^2}{M_Z^2+Q^2} \frac{a_e v_q}{\sin^2\theta_w}$$

HERA

H1+ZEUS Combined (prel.)

- ● A^+
- ■ A^-

—— H1 2000 PDF
------ ZEUS-JETS PDF

Q^2 (GeV^2)

Proton Structure cancels to a good approximation

DIS kinematics & cross-section (no electron polarization)

$Q^2 = -q^2$ = 4-momentum transfer squared

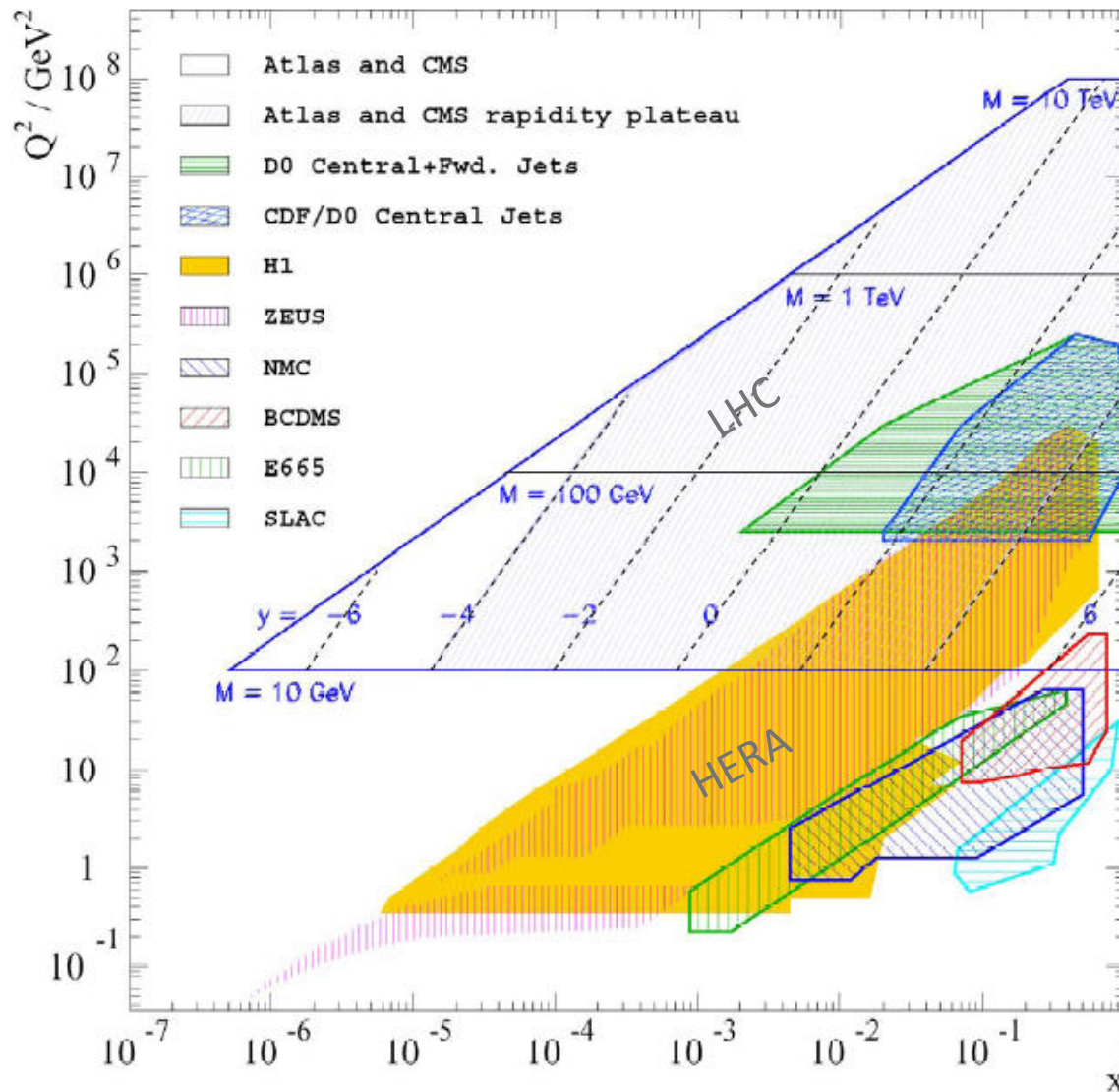x = fractional longitudinal momentum carried by the struck parton

$$\sigma_{r,\mathrm{NC}}^{\pm} = \frac{\mathrm{d}^2\sigma_{\mathrm{NC}}^{e^\pm p}}{\mathrm{d}x\mathrm{d}Q^2} \cdot \frac{Q^4 x}{2\pi\alpha^2 Y_+} = \tilde{F}_2 \mp \frac{Y_-}{Y_+} x\tilde{F}_3 - \frac{y^2}{Y_+}\tilde{F}_L$$

$$\sigma_{r,\mathrm{CC}}^{\pm} = \frac{2\pi x}{G_F^2}\left[\frac{M_W^2 + Q^2}{M_W^2}\right]^2 \frac{\mathrm{d}^2\sigma_{\mathrm{CC}}^{e^\pm p}}{\mathrm{d}x\mathrm{d}Q^2}$$

Structure Functions → extract parton densities using QCD analysis (i.e. PDF fits)

$$\sigma_{r,\mathrm{CC}}^{\pm} = \frac{Y_+}{2}W_2^{\pm} \mp \frac{Y_-}{2}xW_3^{\pm} - \frac{y^2}{2}W_L^{\pm}$$
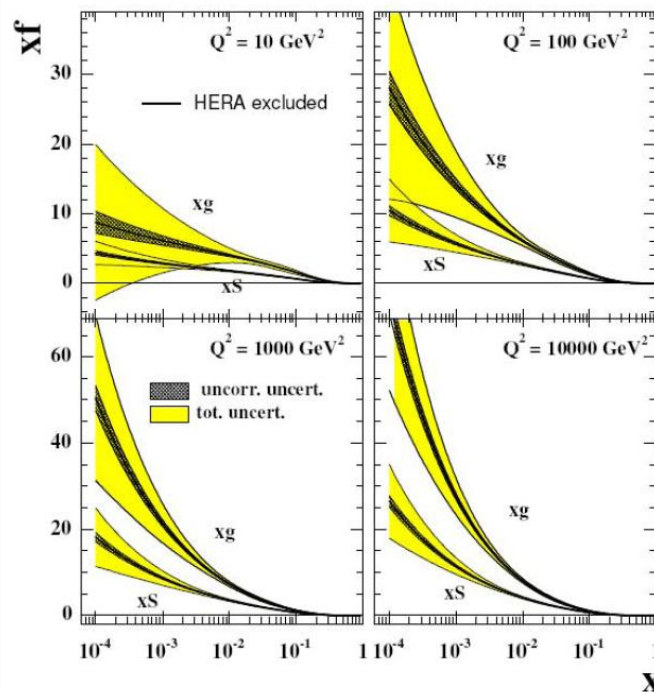
NC and CC measurements at HERA → prediction for parton densities at LHC.

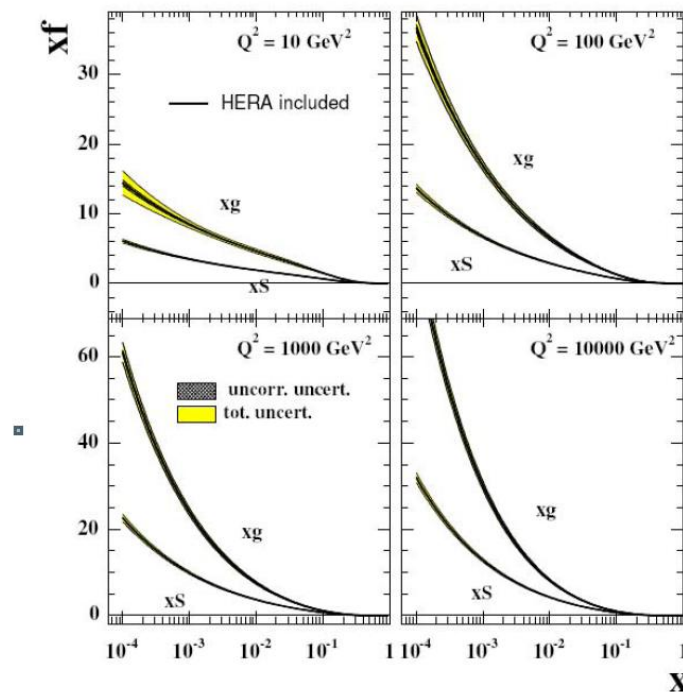DGLAP equations "evolve" patron distributions in x from on Q^2 to another Q^2

→Cross-section predictions for LHC.

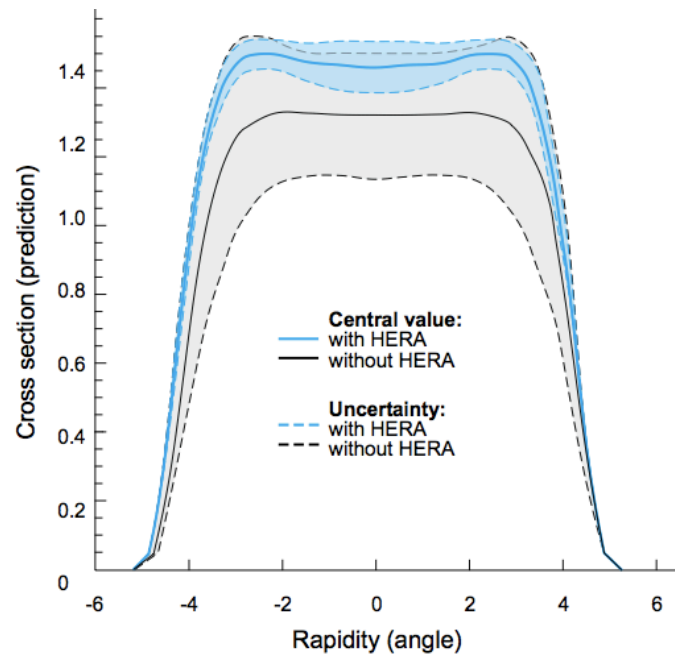HERA DIS data: source of precise predictions of LHC cross-sections

Knowledge of gluon without
HERA data.

Knowledge of gluon with
HERA

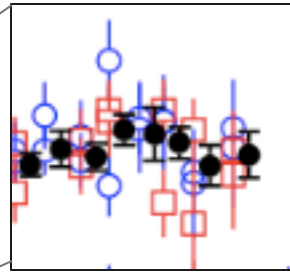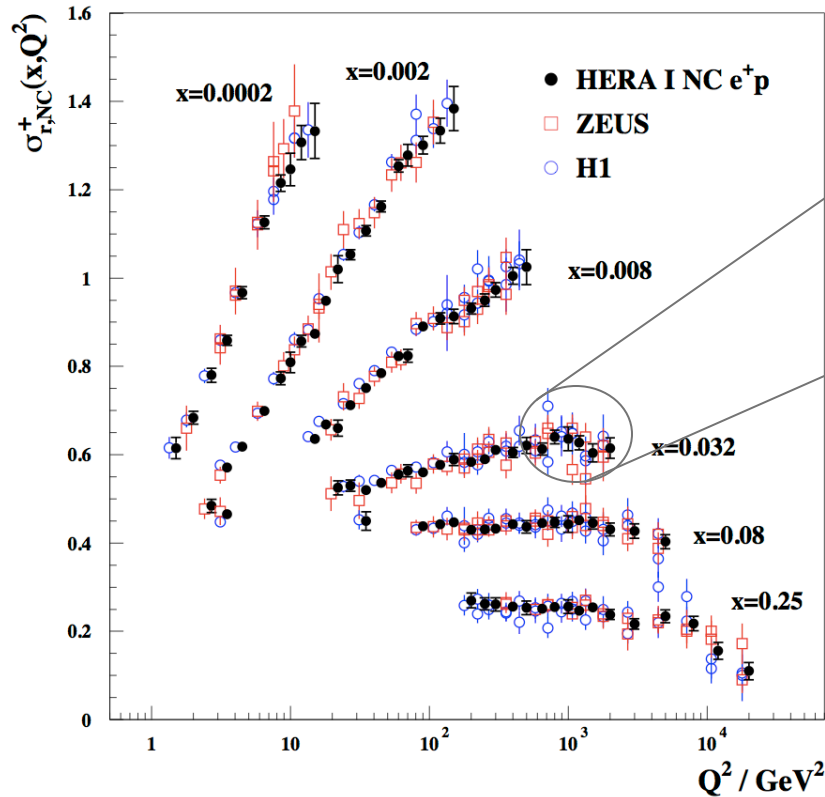Cooper-Sarkar et al. : HERA-LHC workshop 2009

An example

Prediction for
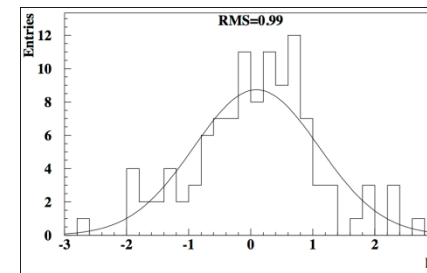W^+ cross-section at LHC,
with and without HERA data.

Obviously, more precise the data, better the prediction.
Combine H1 and ZEUS data.→

Published: HERA I H1 and ZEUS data combined [JHEP01(2010)109]:
cross-section data are combined point by point with no QCD assumptions
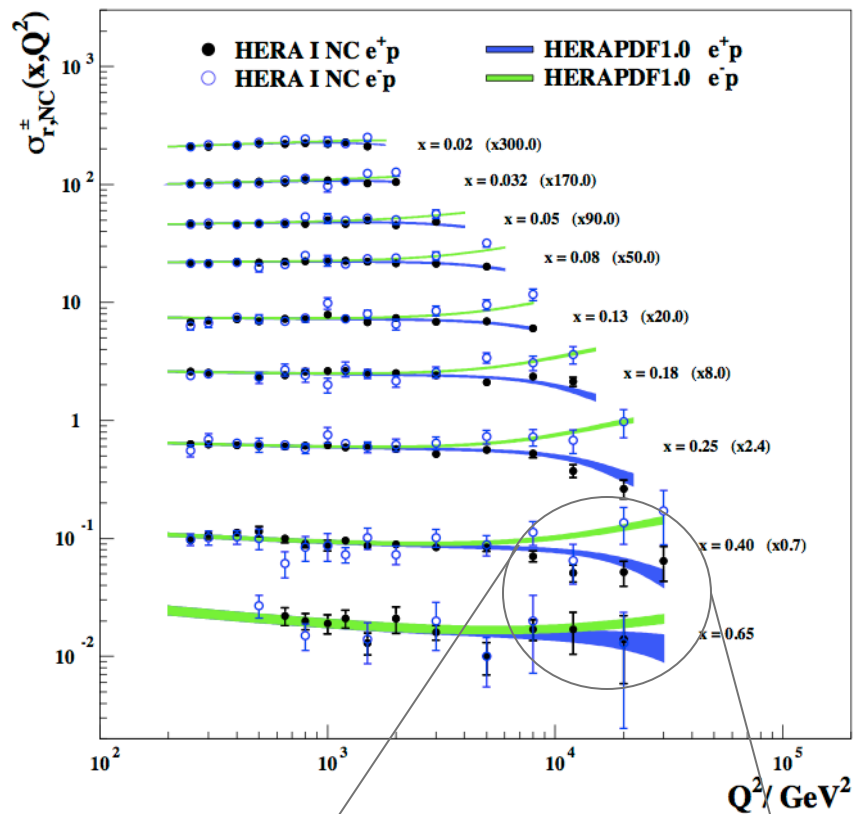

Uncorrelated systematics
cancel between H1 and ZEUS.

χ^2 / DOF = 637/656

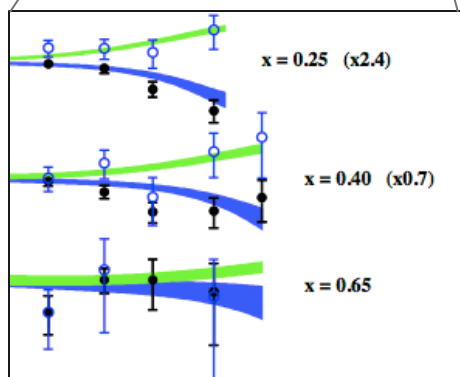Preliminary: HERA II H1 and ZEUS data (as well as HERA I data) combined.
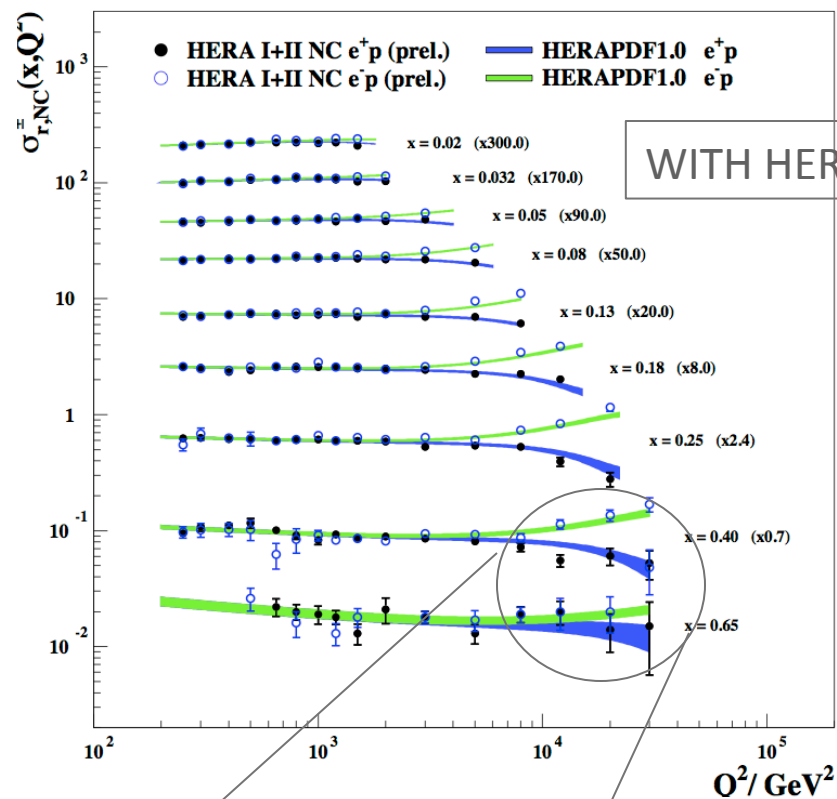
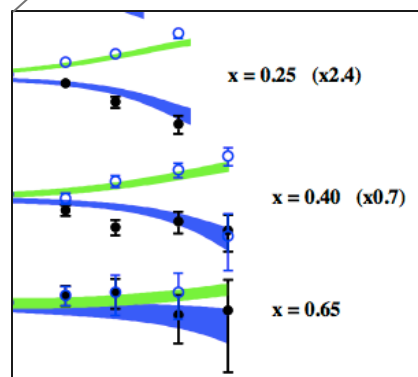~1 fb-1 data added: (e polarization corrected to 0)

H1 and ZEUS

$\sigma_{r,NC}^{\pm}(x,Q^2)$

- HERA I NC e^+p
- HERA I NC e^-p
- HERAPDF1.0 e^+p
- HERAPDF1.0 e^-p

$x = 0.02$ (x300.0)
$x = 0.032$ (x170.0)
$x = 0.05$ (x90.0)
$x = 0.08$ (x50.0)
$x = 0.13$ (x20.0)
$x = 0.18$ (x8.0)
$x = 0.25$ (x2.4)
$x = 0.40$ (x0.7)
$x = 0.65$

Q^2 / GeV^2

H1 and ZEUS

$\sigma_{r,NC}^{\pm}(x,Q^2)$

June 2010

- HERA I+II NC e^+p (prel.)
- HERA I+II NC e^-p (prel.)
- HERAPDF1.0 e^+p
- HERAPDF1.0 e^-p

$x = 0.02$ (x300.0)
$x = 0.032$ (x170.0)
$x = 0.05$ (x90.0)
$x = 0.08$ (x50.0)
$x = 0.13$ (x20.0)
$x = 0.18$ (x8.0)
$x = 0.25$ (x2.4)
$x = 0.40$ (x0.7)
$x = 0.65$

Q^2 / GeV^2

HERA Structure Functions Working Group

WITH HERA II

γZ interference
clearly seen

$x = 0.25$ (x2.4)
$x = 0.40$ (x0.7)
$x = 0.65$

$x = 0.25$ (x2.4)
$x = 0.40$ (x0.7)
$x = 0.65$

Electron-Proton Charged Current DIS
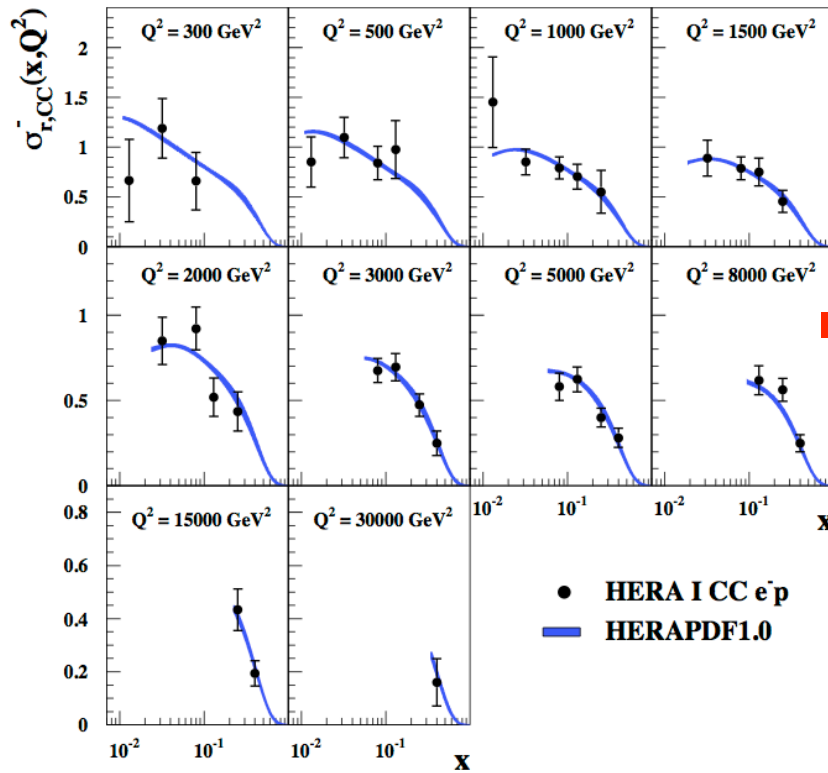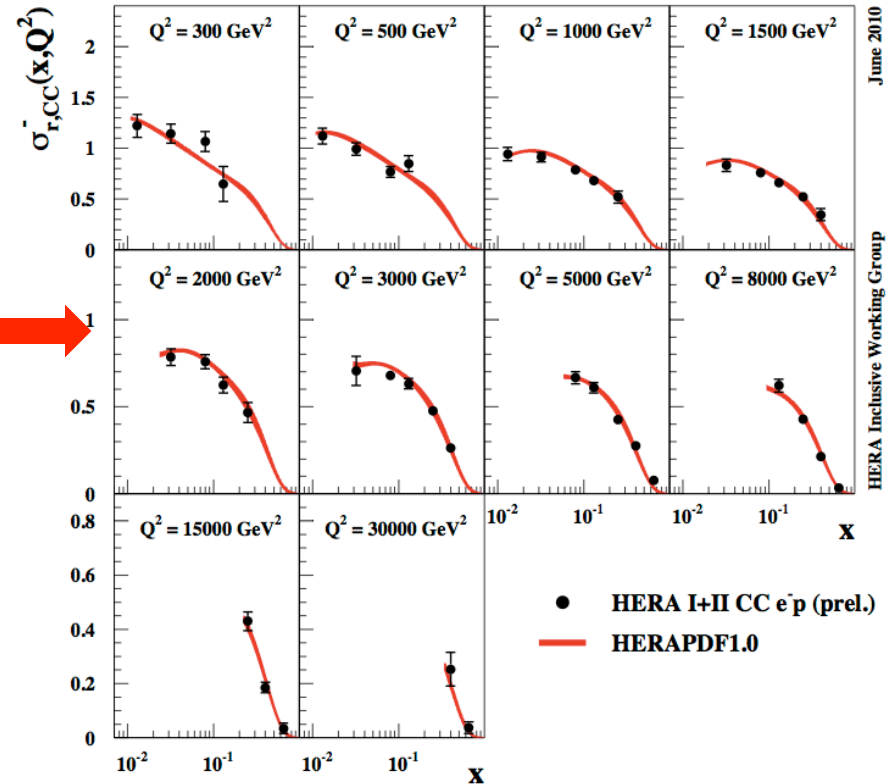
Mainly sensitive to u_valence distribution

H1 and ZEUS (left figure) — HERA I CC e⁺p, HERAPDF1.0

H1 and ZEUS (right figure) — HERA I+II CC e⁺p (prel.), HERAPDF1.0, WITH HERA II
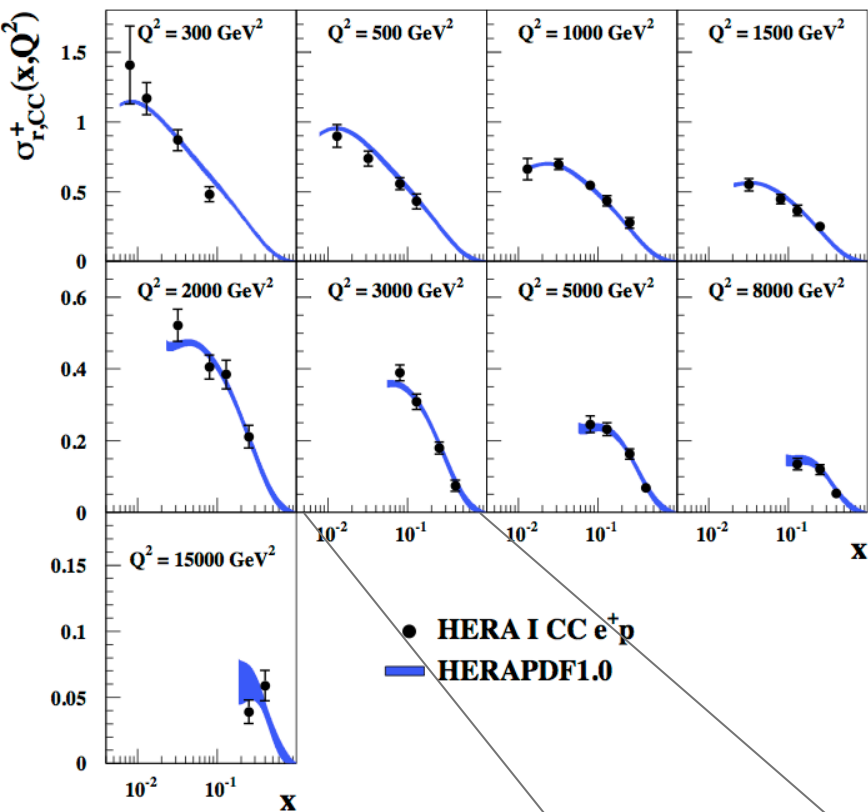
Positron-Proton CC DIS: Mainly sensitive to d_valence.
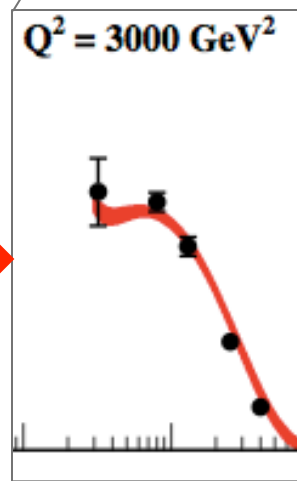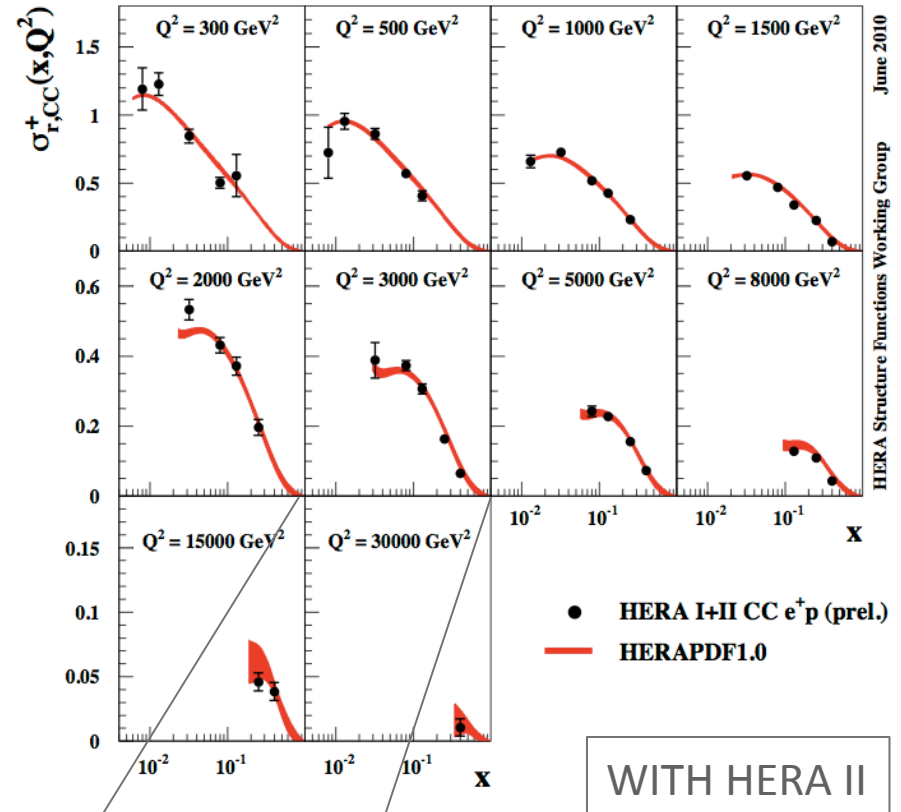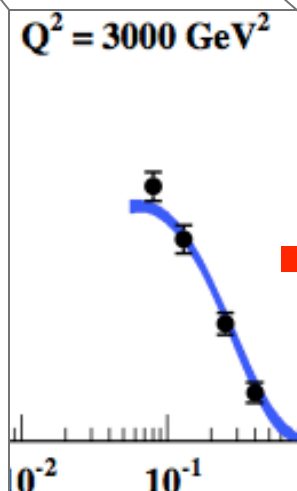
Summary

- Parity violation seen clearly at HERA at high Q^2 in Neutral and Charged current DIS.

- HERA provides only measurement in the low-x range where it is essential for predicting LHC cross-sections. Used in all PDF's (CTEQ, MRST, HERAPDF etc.)

- H1 and ZEUS combination dramatically improves the uncertainty, particularly in the region dominated by systematic uncertainties.   Combination for HERA I data has been published.

- Preliminary H1 and ZEUS combination data using HERA I and HERA II has been released.   There is a dramatic improvement particularly at high-x (>0.05).

- These have been used in new Parton Distribution Fits.   This will be presented by G. Grindhammer later this afternoon in parallel session 2b.