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

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On behalf of the
H1 and ZEUS Collaborations

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HERA electron-proton collider

DESY laboratory in Hamburg, Germany

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, 96 ns. crossing time
- 90 mA protons, 40 mA positrons
- Instantaneous luminosity: $1.8 \times 10^{31} \text{cm}^2\text{s}^{-1}$

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

27.5 GeV

920 GeV

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

27.5 GeV

Electron

920 GeV

Neutrino
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 $e^+p$ Scattering

- $e^+p \rightarrow \nu X$
- $e^+p \rightarrow \nu X$

- H1 HERA I
- H1 HERA II (prel.)
- ZEUS 06-07
- ZEUS HERA I
- ZEUS 98-06

$Q^2 > 400 \text{ GeV}^2$

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

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

Proton Structure cancels to a good approximation

$$A^\pm \approx \frac{Q^2}{M_Z^2 + Q^2} \frac{Q}{\sin^2 \theta_W}$$
DIS kinematics & cross-section (no electron polarization)

\[ Q^2 = -q^2 = 4\text{-momentum transfer squared} \]

\( x = \) fractional longitudinal momentum carried by the struck parton

\[
\sigma_{r,NC}^{\pm} = \frac{d^2 \sigma_{NC}^{\pm}}{dxdQ^2} \cdot \frac{Q^4 x}{2\pi \alpha^2 Y_+} = \tilde{F}_2 + \frac{Y_-}{Y_+}x\tilde{F}_3 - \frac{y^2}{Y_+}\tilde{F}_L
\]

\[
\sigma_{r,CC}^{\pm} = \frac{2\pi x}{G_F^2} \left[ \frac{M_W^2 + Q^2}{M_W^2} \right]^2 \frac{d^2 \sigma_{NC}^{\pm}}{dxdQ^2}
\]

\[
\sigma_{r,CC}^{\pm} = \frac{Y_+}{2} W_2^{\pm} + \frac{Y_-}{2} xW_3^{\pm} - \frac{y^2}{2} W_L^{\pm}
\]

Structure Functions \(\rightarrow\) extract parton densities using QCD analysis (i.e. PDF fits)
NC and CC measurements at HERA $\rightarrow$ prediction for parton densities at LHC.

DGLAP equations “evolve” parton distributions in $x$ from on $Q^2$ to another $Q^2$.

$\rightarrow$ 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.

χ² / 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)
γZ interference clearly seen
Electron-Proton Charged Current DIS

Mainly sensitive to $u_{\text{valence}}$ distribution
Positron-Proton CC DIS: Mainly sensitive to $d_{\text{valence}}$. 
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.