The talk covers 3 H1 publications

1) Inclusive deep inelastic scattering at high $Q^2$ with longitudinal polarised lepton beams at HERA
   (arXiv:1206.7007, submitted to JHEP; brand new → focus of the talk)

2) Determination of the integrated luminosity at HERA using elastic QED Compton events
   arXiv:1205.2448, submitted to EPJC

3) Measurement of the inclusive $e^\pm p$ scattering cross section at high inelasticity $y$
   and the structure function $F_L$
**HERA used to be Largest Electron Microscope**

**HERA I:** 1992-2000  
**HERA-II:** 2003-2007

\[ p : 920 \text{ GeV} \]
\[ e^\pm : 27.5 \text{ GeV} \]

\(~ 6.3 \text{ km circumference} \)

\[ 50 \text{ TeV on fixed target} \]
Neutral and Charged Current DIS

NC $e^\pm p$ event

$e \rightarrow e + \gamma + Z$
$p \rightarrow X$

Event kinematics:
$Q^2 = -q^2$
$x$: momentum fraction of struck parton
$Y = Q^2 / s x$: inelasticity

CC $e^\pm p$ event

$e \rightarrow e + W + q + \nu$
$p \rightarrow X$

Final states $e$ & $X$ balanced in transverse plane

Unbalanced due to missing $\nu$
Nominal proton beam energy: 
\[ E_p = 920 \text{GeV} \]

- \( e^- p \) & \( e^+ p \) & Polarized \( e^\pm \) beams & \( \rightarrow 4 \) distinct data sets

| \( e^- p \) & \( e^+ p \) | \( \mathcal{L} \) & \( P_e \) |
|---|---|---|
| \( e^- p \) | \( 47.3 \text{ pb}^{-1} \) | \( +36.0 \pm 1.0 \%) \ |
| \( e^+ p \) | \( 101.3 \text{ pb}^{-1} \) | \( +32.5 \pm 0.7 \%) \ |

Integrated luminosity determined with elastic QED Compton events \((\rightarrow \text{slide 6})\)

Lower energies: 
\[ E_p = 460, 575 \text{ GeV} \]
\( \rightarrow F_L \) measurement
**Direct Measurement of $F_L$**

Based on HERA II data with $E_p=460, 575 \& 920* \text{ GeV}$

Kinematic range: $1.5<Q^2<120\text{GeV}$, $1.9\times10^{-5}<x<0.01$, $y<0.85$

\[
\sigma_r(x, Q^2) \equiv \frac{Q^4 x}{2\pi \alpha^2 [1 + (1 - y)^2]} \cdot \frac{d^2\sigma}{dx \, dQ^2} = F_2(x, Q^2) - \frac{y^2}{1 + (1 - y)^2} F_L(x, Q^2)
\]

Different proton beam energies $\rightarrow$ different inelasticity $y$

Direct $F_L$ measurement in agreement with pert. QCD expectation

Since $F_L \sim xg$

$\Rightarrow$ HERA data @ low $Q^2, x$

provide a direct constraint of gluon density of the proton

*At 920\text{GeV}, it's combined with HERA I

$\Rightarrow$ Combined low $Q^2$ data set (slide 14)

The low $E_p$ data

$\Rightarrow$ Combined low $E_p$ data set (slide 14)
**Luminosity Measurement from QED Compton**

Online lumi measured with BH process with Photon Detector (PD)

\[ \mathcal{L} = \frac{N_{\text{events}}}{\sigma_{ep \rightarrow e\gamma p}} \]

- **Bethe-Heitler (BH) process**: $e, \gamma$ collinear to the beam, high rate (~1MHz) but large syst uncertainty (3.4% for HERA II)

- **Elastic QED Compton process**: $e, \gamma$ at large angles (in main detector) small rate ($10^{-3}$ Hz) but syst similar to cross section measurement

---

Integrated QED Compton lumi:

351.6 pb$^{-1} \pm 0.8\%(\text{stat}) \pm 2.1\%(\text{syst})$

of which theory uncertainty: 1.1%
New High $Q^2$ Cross Section Measurements

Based on full HERA II data at $E_p=920\text{GeV}$

**CC total cross sections**

$Q^2>400 \text{ GeV}^2$, $y<0.9$

**NC & CC single different cross section $d\sigma/dQ^2$**

- **NC**: $200<Q^2<50000 \text{ GeV}^2$, $y<0.9$
- **CC**: $300<Q^2<30000 \text{ GeV}^2$, $y<0.9$

**NC & CC double differential cross sections**

- **NC**: $60<Q^2<50000 \text{ GeV}^2$, $0.0008<x<0.65$
- **CC**: $300<Q^2<30000 \text{ GeV}^2$, $0.008<x<0.4$
**Total CC Cross Sections**

**SM CC:** \( \sigma_{CC}^\pm (P_e) = (1\pm P_e)\sigma_{CC}^\pm (0) \)

- Extrapolated cross sections\(\sim 0 \)
  - at \( P_e=+1 \) for \( e^- \)
  - at \( P_e=-1 \) for \( e^+ \)

\( \Rightarrow \) Only left-hand \( W \) in SM

**Right Handed CC:** \( \sigma_{RHCC}^\pm (P_e) = (1\pm P_e)\sigma_{RHCC}^\pm (0) \)

- If \( g_L=g_R \) & \( \nu_R \) light
  - \( e^-: M_{WR}>214 \text{ GeV} \) (95\%CL)
  - \( e^+: M_{WR}>194 \text{ GeV} \) (95\%CL)
Combined HERA I+II data
→ Typical total precision:
  NC $e^+$: ~1.5%
  NC $e^-$: ~2.0%
  CC $e^\pm$: ~4%

→ Beautiful illustration of unification of electromagnetic and weak interaction strength
A direct measure of parity violation effect in NC DIS

\[ A^\pm = \frac{2}{P_L^\pm - P_R^\pm} \cdot \frac{\sigma^\pm (P_L^\pm) - \sigma^\pm (P_R^\pm)}{\sigma^\pm (P_L^\pm) + \sigma^\pm (P_R^\pm)} \]
NC Double Differential Cross Sections

\[
\hat{\sigma}_{\text{NC}}(x, Q^2) = \frac{d^2\sigma_{\text{NC}}}{dx dQ^2} \frac{1}{2\pi\alpha^2} = \left(\tilde{F}_2^\pm + \frac{Y_\tau}{Y_+} x\tilde{F}_3^\pm - \frac{y^2}{Y_+} \tilde{F}_L^\pm\right) (1 + \Delta_{\text{NC}}^{\text{weak}}) \hspace{1cm} Y_\pm = 1 \pm (1 - y)^2
\]

\[P_e = -25.8\% \hspace{1cm} \text{HERA II} \]

\[P_e = +36.0\% \hspace{1cm} \text{H1 Collaboration} \]

\[P_e = +32.5\% \hspace{1cm} \text{H1 PDF 2012} \]

\[P_e = -37.0\% \hspace{1cm} \text{H1 NC e^-} \]

ICHEP’12, July 4-11, Melbourne

Zhiqing Zhang (LAL, Orsay)
Different CC cross sections for left and right handed polarised CC cross sections provide unique flavor decomposition of proton
Structure Functions $F_2^{γZ}$, $xF_3^{γZ}$

**First measurement $F_2^{γZ}$ extracted from polarized NC cross sections**

**Improved $xF_3^{γZ}$ using combined HERA I+II data**

$x$ dependence of $F_2^{γZ}$ and $xF_3^{γZ}$ reflects their parton compositions

$F_2^{γZ} \sim q+q\bar{q}$

$xF_3^{γZ} \sim xq_v$
The data cover ~5 orders of magnitude in $Q^2$ and $x$
**Impact of the New HERA II Data**

HERAFitter based on
QCDNUM (v17.04)
NLO, MSbar scheme
RT heavy flavor mass scheme

5 sets of PDFs with 13 free parameters with quark number and momentum sum rules:

\[
\begin{align*}
\frac{1}{x}g(x) &= A_g x^{R_g} (1 - x)^{C_g} - A'_g x^{R'_g} (1 - x)^{25}, \\
\frac{1}{x}u(x) &= A_u x^{E_u} (1 - x)^{C_{u,c}} (1 + E_{x,u_x} x^2), \\
\frac{1}{x}d(x) &= A_d x^{D_d} (1 - x)^{C_{d,c}}, \\
\frac{1}{x}U(x) &= A_U x^{R_U} (1 - x)^{C_U}, \\
\frac{1}{x}D(x) &= A_D x^{R_D} (1 - x)^{C_D}.
\end{align*}
\]

- Improvement in precision for all PDFs in full \(x\) range
  - in particular for down-type quarks \(xD\)

\(Q^2 = 1.9\ \text{GeV}^2\)

Zhiqing Zhang (LAL, Orsay)
Summary

- New and Final NC + CC high $Q^2$ cross section for HERA II ready
- Integrated luminosity measurement at 2.3% with QED Compton
- With the polarized lepton beams at HERA II, parity violation effects observed/confirmed with improved precision
- Absence of right-handed CC $W$ boson
- First $F_2^{\gamma Z}$ and improved $xF_3^{\gamma Z}$ determinations
- Direct $F_L$ measurement in extended kinematic region
- These data valuable for further constraining PDFs
- H1+ZEUS HERA II combination will come soon
Extra Slides
At weak boson mass scale (LHC kinematic region), gluon density is by far the dominant contribution.