H1 Status and Prospects, May 2004

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- Data Taking
- Recent Physics Results
- Physics Status and Aims

57th Meeting of the DESY PRC, 27 May 2004
Steady improvement after last vacuum leak (November 2003) . . . pumping takes time
H1 able to run with recent high currents (≈ design) . . . acceptable limits for trackers adjusted
Still suffer from ‘spikes’ in backgrounds
Background conditions remain “harsh” and cause radiation damage . . . FST now inoperational
HERA-II Data Taking: Luminosity

Big improvement on 2003!

> 15 pb$^{-1}$ taken with each lepton polarisation state

Polarisation typically $30 - 40\%$

Small data acquisition deadtimes (H1 active)

Significant HV inefficiencies due to backgrounds / spikes

Only recently reached 2000 level of 85\% HV-on efficiency
Recent H1 Papers

8 papers released since October 2003 PRC . . .

- DESY-03-159 (11/03): Muon Pair Production in $ep$ Collisions
- DESY-03-206 (01/04): Measurement of Dijet Production at Low $Q^2$
- DESY-04-025 (03/04): Search for Squark Production in R-Parity Violating Supersymmetry
- DESY-04-032 (03/04): Measurement of Anti-Deuteron Production
- DESY-04-038 (03/04): Evidence for a Narrow Anti-Charmed Baryon State
- DESY-04-051 (04/04): Forward $\pi^0$ Production and Associated Transverse Energy Flow
- DESY-04-083 (05/04): Measurement of $F_2$ at low $Q^2$ in QED Compton Scattering
- DESY-04-084 (05/04): Search for bosonic stop decays in R-parity violating supersymmetry
Recent and Forthcoming Conferences

At DIS04 there were 30 talks by H1 members summarising work in last year, including newly released data on . . .

- Polarised $\sigma(CC')$ from HERA-II
- High $p_T$ Particle Production at HERA-II
- $F_2$ at low $Q^2$, high $x$ from ISR events
- $\tau$ production
- Forward Jet Production
- $b \rightarrow \mu X$ in low $Q^2$ DIS
- $F_2^b$ and $F_2^c$ at Large $Q^2$

(Almost) all on completely original and new topics!

Preparations for ICHEP04 summer conference are well underway

54 abstracts submitted, summarising work of past two years
Systematic Searches For Anomalies in High $p_T$ Data

Investigation of all final states with isolated $j, e, \mu, \gamma, \nu$  

$(p_T > 20 \text{ GeV}, 10^\circ < \theta < 140^\circ)$

Overall highly impressive agreement with Standard Model predictions ... but $\mu j \nu, e j \nu$?

HERA-I Events

HERA-II Events

H1 General Search

H1 General Search (Hera-II)
Dedicated Studies of Isolated Leptons with Missing $p_T$

Study events with isolated high $p_T$ $\mu$, $e$ or $\tau$, missing $p_T$ and large hadronic $p_T^X$ in $e^+p$ data

Events observed and expected in Standard Model . . .

<table>
<thead>
<tr>
<th></th>
<th>HERA-I (110 pb$^{-1}$)</th>
<th>HERA-II (17 pb$^{-1}$)</th>
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<tbody>
<tr>
<td>$p_T^X &gt; 25$ GeV</td>
<td>$6 / 1.44$</td>
<td>$0 / 0.53$</td>
</tr>
<tr>
<td>$p_T^X &gt; 25$ GeV</td>
<td>$4 / 1.48$</td>
<td>$0 / 0.29$</td>
</tr>
<tr>
<td>$p_T^X &gt; 25$ GeV</td>
<td>$0 / 0.53$</td>
<td>$2 / 0.34$</td>
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$e^+p \rightarrow \mu^+X$

Event MUON-2

$P_T^\mu = 28$ GeV, $P_T^X = 67$ GeV, $P_T^{miss} = 43$ GeV

HERA-II $e^+p \rightarrow e p_T'X$

$P_T^e = 37$ GeV, $P_T^{miss} = 44$ GeV, $P_T^X = 29$ GeV
Possible Interpretations?

**W radiation is dominant SM process . . .**
Excess in HERA-I $e + \mu$ is $\sim 10^{-3}$ fluctuation

**Beyond the Standard Model . . .**
Anomalous single top production?
$R_{p\bar{t}}$ production with $\bar{t} \rightarrow \bar{b}W$?
. . . dedicated searches published

This anomaly can only be clarified with large increases in $e^+p$ luminosity
If current event rate persists, 5σ “discovery” possible with 500 pb$^{-1}$

See also anomalously high H1 yields of multi-electron events in $e^+p$ scattering
SUSY at HERA-I

Search programme with HERA-I data nearing completion

e.g. Recent searches for $R_p$ SUSY $\tilde{q}$ production

Search for e.g. $e^+d \rightarrow \tilde{t}$ via $\lambda'_{131}$, $e^-u \rightarrow \tilde{b}$ via $\lambda'_{113}$

Consider $R_p$ and $R_p$ decays covering most of BR for all $m(\tilde{q})$

Also consider for first time $\tilde{t} \rightarrow \tilde{b}W$

Limits: e.g. $m(\tilde{t}) > 275$ GeV for $\lambda'_{131}$ of em strength
Search Prospects at HERA-II

HERA has unique discovery potential for some time to come in several areas

\( e^+ \) or \( e^- \)

Anomalous \( t u \gamma \)

\( q \) radius / form factor

Contact Interactions

Double charged Higgs

Large Extra Dimensions

\( e^* \)

\( q^* \)

\( e^+ \)

\( F = 0 \) LQ / LFV

\( \tilde{t} \) (\& \( \tilde{c}, \tilde{u} \))

\( e^- \)

\( F = 2 \) LQ / LFV

\( \tilde{b} \) (\& \( \tilde{s}, \tilde{d} \))

\( \nu^* \)

Improvements on current sensitivity require large increases in \( \mathcal{L} \)

... top priority to optimise overall search programme

\( e^+ p \) and \( e^- p \) complementary in some areas, both interesting
\( F^\text{em}_2(x, Q^2) \) and \( u \) at high \( x \)

\[
\tilde{\sigma}_{\text{NC}}^\pm = F_2 \mp \frac{Y_-}{Y_+} x F_3 - \frac{y^2}{Y_+} F_L
\]

\[
F^\text{em}_2(x, Q^2) = x \sum_q e^2_q (q + \bar{q})
\]

...dominates in most of phase space

Measured over huge kinematic range

well matched to LHC predictions via DGLAP

2-3% precision in bulk of phase space

Highest \( x \) region requires much more luminosity (\( e^+ \) or \( e^- \)) and / or reduced \( E_p \rightarrow \) high \( x \), moderate \( Q^2 \)

Beautifully described by QCD fits

→ strongest constraint on \( u, \bar{u} \)

Constrains gluon and \( \alpha_s \)

via \( \frac{\partial F_2}{\partial \ln Q^2} \sim \alpha_s x g(x) \) (LO QCD)
**$e^+p$ Charged Current Cross Section and $d$ at “high” $x$**

**Charged Current**  \((e^+p, 65 \text{ pb}^{-1})\)

- \(Q^2 = 300 \text{ GeV}^2\)
- \(Q^2 = 500 \text{ GeV}^2\)
- \(Q^2 = 1000 \text{ GeV}^2\)
- \(Q^2 = 2000 \text{ GeV}^2\)
- \(Q^2 = 3000 \text{ GeV}^2\)
- \(Q^2 = 5000 \text{ GeV}^2\)
- \(Q^2 = 8000 \text{ GeV}^2\)
- \(Q^2 = 15000 \text{ GeV}^2\)

Promising for $d$ density at $x \sim 0.3$

Higher $x$ Suppressed by \((1 - y)^2\) factor

\[
\tilde{\sigma}_{CC}^+ \sim x(\bar{u} + \bar{c}) + (1 - y)^2 x(d + s)
\]
$$x F_3(x, Q^2) \text{ and } u_v, d_v$$

$$x F_3 = \frac{1}{2y(1-y)} (\tilde{\sigma}_{NC}^- - \tilde{\sigma}_{NC}^+)$$

$$\sim 2u_v + d_v$$

Assumption-free access to valence distributions at largest $Q^2$ ($\tilde{\sigma}_{NC}^- \gg \tilde{\sigma}_{NC}^+$)

$y$ factors suppress highest $x$, kinematics suppress lowest $x$, potentially competitive for $x \sim 0.1$

First “exploratory” HERA-I extractions agree well with predictions

Errors rather insensitive to exact $e^+ / e^-$ sharing within reasonable limits

Total $e^+$ and $e^-$ luminosity most important for significant progress
Gluon only indirectly determined in DGLAP fits

Important to test with jets, charm, \( F_L \ldots \sim \alpha_s x g(x) \) (LO QCD)

\[
\tilde{\sigma} = F_2 - \left( \frac{y^2}{Y_+} \right) F_L
\]

Sensitivity at highest \( y \to 0.9 \) (\( E'_e \to 3 \text{ GeV} \))

\( F_L \) determination spans 3 orders of magnitude in \( Q^2 \)

Distinguishes between DGLAP and other approaches at low \( Q^2 \)

Better measurements from reduced \( E_p \) running \( \rightarrow \) relax \( F_2 \) assumptions and see \( x \) dependence
Polarisation and HERA-II

CC cross section has linear dependence on polarisation in Standard Model

First measurement of influence of lepton helicity on CC interactions in $ep$ scattering

Polarisation $\sim 30\%$, Luminosity $\sim 15$ pb$^{-1}$

Effect established at $\sim 2.3\sigma$ level

Similar luminosity collected with opposite helicity and $\sim 40\%$ polarisation

With larger luminosities, sensitivity to PDFs and electroweak couplings

$F_2^{\gamma Z} \sim \frac{1+d/u}{4+d/u}$

Simulation with $\mathcal{L} = 200$ pb$^{-1}$, $P_e = \pm 0.5$
Hadronic Final State Studies and QCD

Bulk of H1 physics programme concerned with understanding QCD through hadronic final state measurements (89/130 physics papers so far)

- Jet production and properties
- Open charm production
- Open beauty production
- Forward physics & QCD cascade dynamics
- Fragmentation
- Energy flow and particle spectra
- Diffractive cross sections / final states
- Tagged leading protons and neutrons
- Inclusive and exclusive vector mesons, DVCS
- Hadron spectroscopy . . .

Many of these measurements are statistically limited thus far

Theoretical progress → most observables can be compared with NLO calculations

Improvements require highest possible $\mathcal{L}$, independently of beam charge or polarisation
Evidence for a Narrow Anti-charmed Baryon State

Following recent observation of $\theta^+$ pentaquark in $K^0 p$ and $K^+ n$, search for charmed analogue

Use ‘golden’ charm decay channel $D^* - \rightarrow \bar{D}^0 \pi^- \rightarrow K^+ \pi^- \pi^-$ & c.c.
Combine with proton candidates from $dE/dx$ to form $M(D^* p)$

Clear signal with mass $3099 \pm 3$ (stat.) $\pm 5$ (syst.) MeV ... observed in $\gamma p$ and DIS

Background well modelled by wrong charge $K^\pm \pi^\pm$ combinations and $D^*$ Monte Carlo
51 $\pm$ 11 events (75 pb$^{-1}$)
Compatible yields in $D^* - p$ and $D^* + \bar{p}$

As in strange case, width compatible with experimental resolution ($\sim$ 7 MeV)

Minimal constituent quark composition of such a state is $uudd\bar{c}$ ... charmed pentaquark?
Fast Track Trigger Status

Required for continued triggering of interesting low $p_T$ final states with track based signatures at high $\mathcal{L}$

**Level 1**

- Hit finding with 95% efficiency
- Track segment finding operational
- Coarse segment linking to form tracks
- First L1 trigger implemented for exclusive vector mesons in events with no tagged electron

**Level 2/3**

- Later stages of trigger being finalised
- Aiming for full commissioning before shutdown

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<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
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<tbody>
<tr>
<td>2.3 $\mu$s</td>
<td>25 $\mu$s</td>
<td>$\approx$100 $\mu$s</td>
</tr>
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</table>

- QT analysis, Track-Segment-Finding
- Track-Segment-Linking, momenta, momentum sums
- Event reconstruction, jets, invariant masses, $\Delta m$...

First $\rho^0$ signal from short test run

$M_{\pi^+\pi^-}$ (GeV)

Entries 57
Recent Progress in Beauty Cross Sections

$\sigma(e p \rightarrow e \bar{b} b X \rightarrow e \mu j X)$ in DIS

Use sample with muons associated with jets

Evaluate beauty contribution using @D fit to . . .

... muon impact parameter (silicon detector)

... $p^{\text{rel}}_T$ of muon relative to jet

Results consistent with NLO QCD

Inclusive $F^b_2$ (and $F^c_2$) in high $Q^2$ DIS

Inclusive secondary vertex sample from silicon

$b, c$ contributions from fits to signed impact parameter distribution

For $Q^2 \gtrsim 100$ GeV$^2$, minimal extrapolation to inclusive $b$ cross section

New technique!... First $F^b_2$ measurement
Overlaps between different final state signatures give new sensitivities
e.g. test semi-inclusive QCD factorisation by predicting diffractive dijet
and charm rates at NLO using diffractive parton densities from $F^D_2$

Consistent description, but large experimental and theoretical errors
Further progress needs high statistics data at fixed $x_{IP}$ and better systematics
Also improved theoretical errors ... Relax "Regge" factorisation assumption, go to higher scales
2 Roman pot stations near $z = 220$ m

... Efficient triggering and measurement of leading protons in interesting region $|t| < 1 \text{GeV}^2$, $x_{IP} \sim 0.01$

Track reconstruction working ... clear forward peak

First level 1 trigger implemented

Clear $\rho$ peak (untagged $\gamma p$) from short test run
Summary

• Ongoing analysis of HERA-I data
  … Many new measurements and techniques

• Detector in good shape and taking high quality HERA-II data
  … First physics results obtained with polarised leptons

• Top future priority is highest possible luminosity as soon as possible
  … New level of precision in broadest range of physics topics
    Can be realised with $e^+$ running, also necessary to clarify high $p_T$ anomalies
    $e^-$ data of interest for some searches and electroweak physics
    Reduced $E_p$ running required for $F_L$, high $x$, moderate $Q^2$ and $W$ dependences

• H1 Collaboration remains firmly committed to full HERA-II programme