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# HERA UPGRADE AND PROSPECTS*

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The upgrade of HERA offers exciting possibilities to further study electron proton scattering at high energy. The increased luminosity will allow precision measurements of deep inelastic scattering to be extended to the highest $Q^2$. Polarisation will open up many new physics areas, providing increases sensitivity to Standard Model and new physics alike. HERA will have enhanced potential to discover physics beyond the Standard Model in a wide range of new physics scenarios.

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## 1. Introduction

In the years 1999–2000 the $ep$ collider HERA had it most successful running period ever, delivering approximately $70\,\mathrm{pb}^{-1}$ to each experiment at a centre of mass energy of $320\,\mathrm{GeV}$ and bringing the total data delivered since 1992 to about $130\,\mathrm{pb}^{-1}$. Approximately $15\,\mathrm{pb}^{-1}$ of the data was taken in $e^-p$ mode, the rest in $e^+p$ mode. This large data sample has enabled a wealth of physics results such as the observation of a rise in the parton density of the proton at small $x$, scaling violations of the proton structure functions measured up to $Q^2 = 30000\,\mathrm{GeV}$ and numerous searches up to masses of about $200\,\mathrm{GeV}$.

It is clear that in order to build upon the physics results of HERA I a new initiative was required to improve the luminosity of HERA to enable a significant increase in the data sample. A major redesign of HERA including focusing magnets inside the H1 and ZEUS detectors is estimated to yield a luminosity increase by a factor of 3.5, with $240\,\mathrm{pb}^{-1}$ of data per year.

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Another significant improvement in the physics potential of HERA is the introduction of further spin rotators[1] to allow measurements with longitudinally polarised electrons or positrons to be made by H1 and ZEUS.

The upgrade of HERA lasted from winter 2000 to summer 2001. In October 2001 the first collision were recorded at HERA II. In November 2001 the design specific luminosity was reached. Throughout 2002 routine *ep* collisions have been achieved, although there have been numerous problems with the electron and proton machines. The most difficult problem to solve is the large backgrounds experienced in H1 and ZEUS when the machine is run with high currents. Thus, although the machine can deliver luminosity the experiments are unable to turn on their most sensitive detector components. A background task force has been set up to investigate the problems, none of which appear to be intractable.

To get the full benefits from HERA II the experiments H1 and ZEUS have made extensive modifications. Notable upgrades include: a new inner silicon detector in ZEUS; extension of the inner silicon detectors in H1; new forward track detectors (H1 and ZEUS); new luminosity detectors (H1 and ZEUS); and a new track trigger (H1).

## 2. Physics at HERA II

The large increase in luminosity will particularly benefit measurements made at large photon virtuality $Q^2$ and large transverse momentum where the event rates are small. Neutral Current (NC) structure function measurements will yield a measurement of the $u$ quark density of the proton with an error of 2–10% up to Bjorken $x = 0.65$. Inclusive Charge Current (CC) will allow the $d$ density of the proton to be measure with an accuracy of 10% up to $x = 0.4$. An example HERA II structure function measurement is shown in Fig. 1, where running with $e^+$ and $e^-$ beams will allow a measurement of $xF_3$ to be made which will allow the valence quark density to be determined with an accuracy of 10% over the range $0.05 < x < 0.4$.

Included in the running schedule of HERA II is a period where the proton beam energy will be reduced to make cross section measurements at lower centre of mass energies. These will allow enable a direct measurement of the longitudinal structure function $F_{\mathrm{L}}$ for the first time at HERA [1]. Measurements of 15% precision should be achievable.

The advent of longitudinally polarised electrons will allow many new measurements to be made at HERA as well as improving the precision of existing measurements. It is also interesting to note that running with right

[1] At HERA I spin rotators already enable the fixed target experiment HERMES to make polarised structure function measurements. HERA provided polarised beams in routine operation, whilst delivering *ep* collisions to H1 and ZEUS.

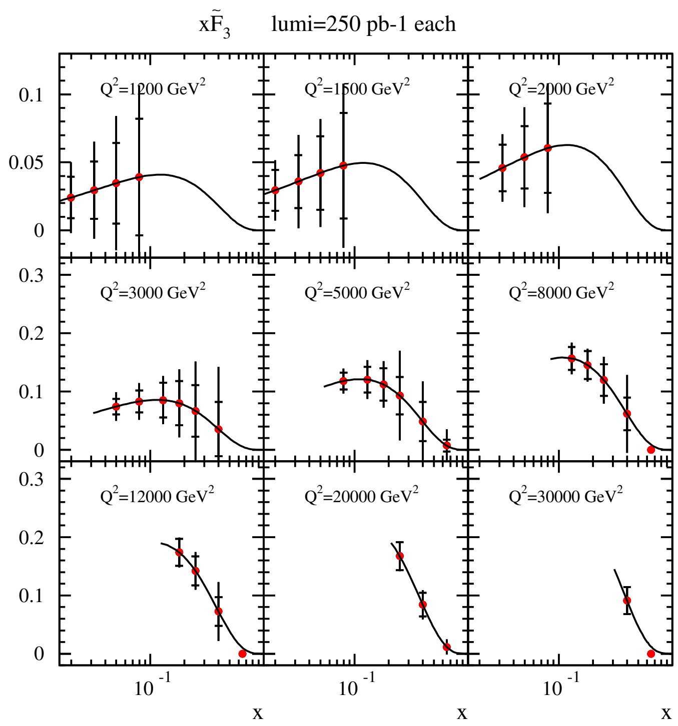


Fig. 1. An estimation of what a measurement of the structure function $xF_3$ may look like after 250 pb$^{-1}$ each of $e^+p$ and $e^-p$ data.

handed $e^+p$ would reduce the Standard Model NC and CC, thus enhancing sensitivity to new physics. Measurement of the NC cross section as a function of polarisation would allow the determination of the parity violating structure function $G_2$. This would provide an impressive test of electroweak theory and also allow a measurement of the $d/u$ parton densities of the proton. In the Standard Model the CC cross section $e^+p$ ($e^-p$) cross section is directly (inversely) proportional to the polarisation. Thus any measurement of the CC cross section as a function of polarisation that deviates from a straight line is evidence for new physics independent of any QCD or electroweak parameters.

An example of how polarisation can significantly improve measurements is demonstrated in Fig. 2. Here, example measurements of the vector and axial-vector couplings of the $Z^0$ to the light quarks are show together with the improvement of such measurements with polarisation [2]. A factor of 5 improvement in the error on the vector coupling of the $u$ quark if polarisations of 0.5 are achieved. It is interesting to note that although the limits from LEP [3] are better than those estimated for HERA II the HERA data have no heavy quark admixture.

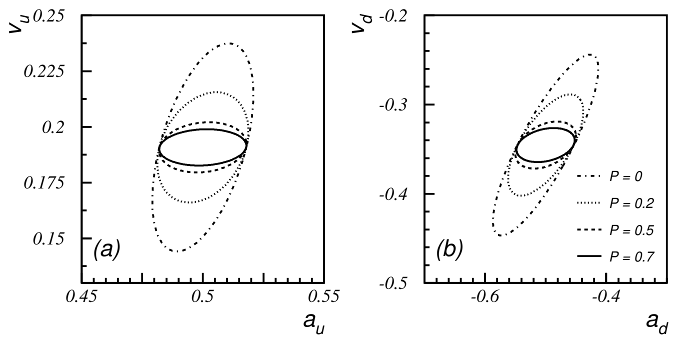


Fig. 2. An estimation of what a measurement of the quark couplings to the $Z^0$ may look like after 250 pb$^{-1}$ of data. Also included in the figure is the impact of polarisation on the measurement.

The large increase in luminosity at HERA II will make it an exciting place to look for new physics. Despite strong competition from the Tevatron $p\bar{p}$ collider HERA will still continue to have the best discovery potential in several new physics scenarios. One such example is shown in Fig. 3 where future sensitivity to scalar leptoquarks (particles that carry both lepton and baryon number) is shown. HERA will have sensitivity up to masses of 290 GeV for couplings $\lambda = 0.05$. Other potential discovery channels are $R$ parity violation supersymmetry where HERA will continue to be competitive particularly at high $\beta$ [4]; excited neutrinos where HERA has sensitivity beyond the reach of LEP; and lepton flavour violation where the main competition to HERA comes from rare $b$ meson decays.

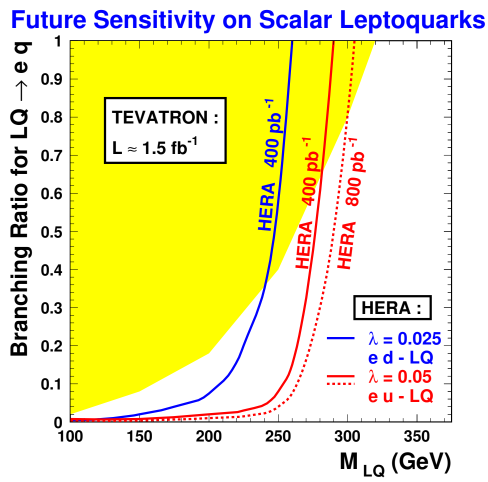


Fig. 3. Examples of the discovery potentials of scalar leptoquarks for in Run II of the Tevatron and HERA II.

One issue that is sure to be resolved at HERA II is the observation of an excess of events with isolated leptons and missing transverse momentum by H1 [5]. If the excess persists at the rate observed in H1 and it is observed by both collaborations, $250\,\mathrm{pb}^{-1}$ would be enough for a $5\sigma$ discovery.

## REFERENCES

[1] L. Bauerdick *et al.*, proceedings of the workshop "Future physics at HERA", p. 77, 1995.

[2] R. Cashmore *et al.*, proceedings of the workshop "Future physics at HERA", p. 163, 1995.

[3] ALEPH, DELPHI, L3, OPAL, "A Combination of Preliminary Electroweak Measurements and Constraints on the Standard Model", CERN-EP/2001-XXX, 2001.

[4] E. Perez *et al.*, proceedings of the workshop "Future physics at HERA", p. 295, 1995.

[5] N. Malden, *Acta Phys. Pol.* **B33**, 3911 (2002), these proceedings.