ep (and eA) Scattering, PRN, 2/9/13

H1: (JB, PRN, PDT)

- Experiment still publishing (e.g. HERA-II PDFs), but ongoing Birmingham analysis ended ~ 2 years ago
- PRN has acted as internal referee for ~ 1 paper / year

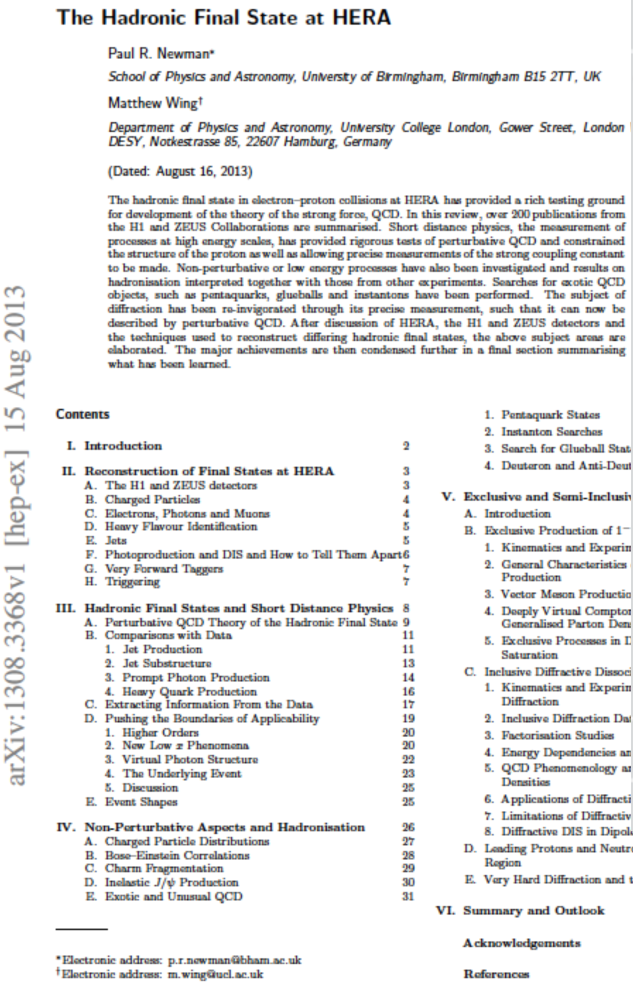
LHeC: (PRN)

- Conceptual Design Report published July 2012.
- Not high on Euro Strategy list, but work still ongoing at CERN and elsewhere on Energy Recovery Linac, magnets …
- Recent UK meeting attended by 11 groups → Not the right time to bid for funding. → Low level ongoing involvement

EIC: (Nobody)

- American project (most plausibly electrons in RHIC to make eA collider at BNL) involves several ex-Birmingham nuclear group members … interest from current Birmingham colleagues

ep (and eA) Papers, PRN, 2/9/13



The Hadronic Final State at HERA

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The hadronic final state in electron–proton collisions at HERA has provided a rich testing ground for development of the theory of the strong force, QCD. In this review, over 200 publications from the H1 and ZEUS Collaborations are summarised. Short distance physics, the measurement of processes at high energy scales, has provided rigorous tests of perturbative QCD and constrained the structure of the proton as well as allowing precise measurements of the strong coupling constant to be made. Non-perturbative or low energy processes have also been investigated and results on hadronisation interpreted together with those from other experiments. Searches for exotic QCD objects, such as pentaquarks, glueballs and instantons have been performed. The subject of diffraction has been re-invigorated through its precise measurement, such that it can now be described by perturbative QCD. After discussion of HERA, the H1 and ZEUS detectors and the techniques used to reconstruct differing hadronic final states, the above subject areas are elaborated. The major achievements are then condensed further in a final section summarising what has been learned.

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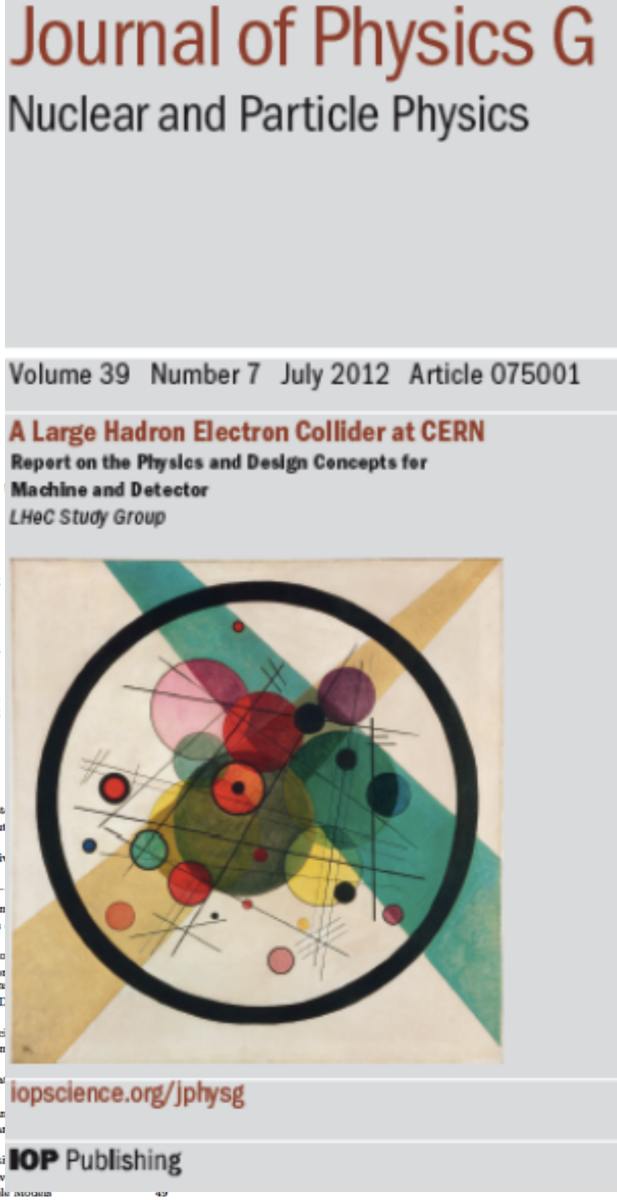

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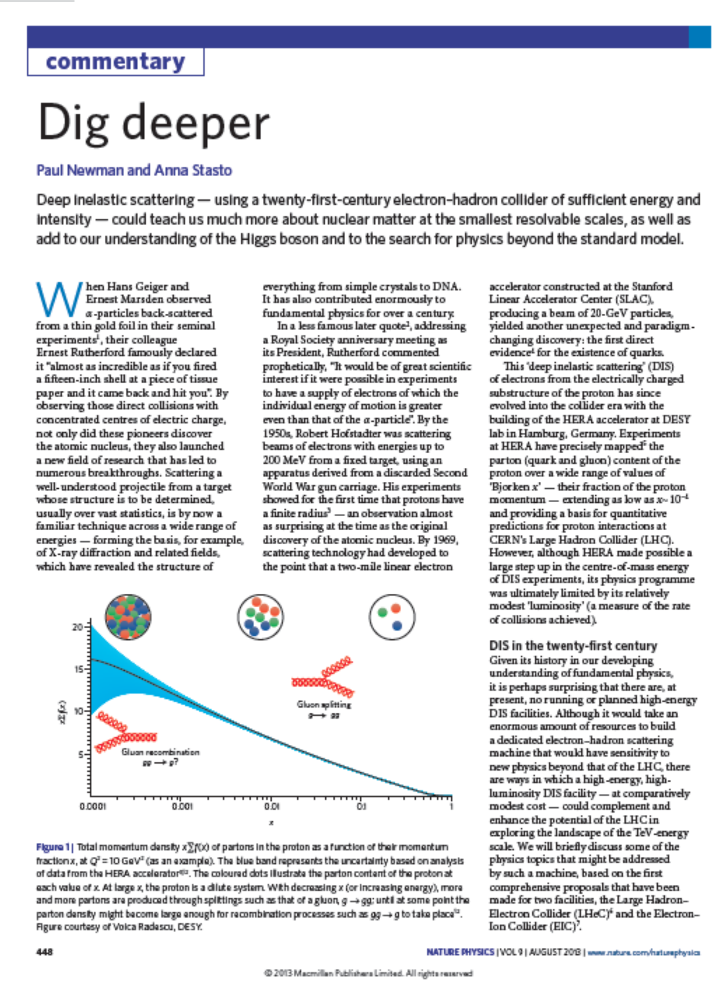
A Large Hadron Electron Collider at CERN

Report on the Physics and Design Concepts for Machine and Detector

LHeC Study Group

iopscience.org/jphysg

IOP Publishing



commentary

Dig deeper

Paul Newman and Anna Stasto

Deep inelastic scattering — using a twenty-first-century electron–hadron collider of sufficient energy and intensity — could teach us much more about nuclear matter at the smallest resolvable scales, as well as add to our understanding of the Higgs boson and to the search for physics beyond the standard model.

When Hans Geiger and Ernest Marsden observed α-particles back-scattered from a thin gold foil in their seminal experiments[1], their colleague Ernest Rutherford famously declared it "almost as incredible as if you fired a fifteen-inch shell at a piece of tissue paper and it came back and hit you". By observing those direct collisions with concentrated centres of electric charge, not only did these pioneers discover the atomic nucleus, they also launched a new field of research that has led to numerous breakthroughs. Scattering a well-understood projectile from a target whose structure is to be determined, usually over vast statistics, is by now a familiar technique across a wide range of energies — forming the basis, for example, of X-ray diffraction and related fields, which have revealed the structure of everything from simple crystals to DNA. It has also contributed enormously to fundamental physics for over a century.

In a less famous later quote[2], addressing a Royal Society anniversary meeting as its President, Rutherford commented prophetically, "It would be of great scientific interest if it were possible in experiments to have a supply of electrons of which the individual energy of motion is greater even than that of the α-particle". By the 1950s, Robert Hofstadter was scattering beams of electrons with energies up to 200 MeV from a fixed target, using an apparatus derived from a discarded Second World War gun carriage. His experiments showed for the first time that protons have a finite radius[3] — an observation almost as surprising at the time as the original discovery of the atomic nucleus. By 1969, scattering technology had developed to the point that a two-mile linear electron accelerator constructed at the Stanford Linear Accelerator Center (SLAC), producing a beam of 20-GeV particles, yielded another unexpected and paradigm-changing discovery: the first direct evidence[4] for the existence of quarks.

This 'deep inelastic scattering' (DIS) of electrons from the electrically charged substructure of the proton has since evolved into the collider era with the building of the HERA accelerator at DESY lab in Hamburg, Germany. Experiments at HERA have precisely mapped[5] the parton (quark and gluon) content of the proton over a wide range of values of 'Bjorken x' — their fraction of the proton momentum — extending as low as $x \sim 10^{-4}$ and providing a basis for quantitative predictions for proton interactions at CERN's Large Hadron Collider (LHC). However, although HERA made possible a large step up in the centre-of-mass energy of DIS experiments, its physics programme was ultimately limited by its relatively modest 'luminosity' (a measure of the rate of collisions achieved).

DIS in the twenty-first century

Given its history in our developing understanding of fundamental physics, it is perhaps surprising that there are, at present, no running or planned high-energy DIS facilities. Although it would take an enormous amount of resources to build a dedicated electron–hadron scattering machine that would have sensitivity to new physics beyond that of the LHC, there are ways in which a high-energy, high-luminosity DIS facility — at comparatively modest cost — could complement and enhance the potential of the LHC in exploring the landscape of the TeV-energy scale. We will briefly discuss some of the physics topics that might be addressed by such a machine, based on the first comprehensive proposals that have been made for two facilities, the Large Hadron–Electron Collider (LHeC)[6] and the Electron–Ion Collider (EIC)[7].

Figure 1 | Total momentum density $x\sum f(x)$ of partons in the proton as a function of their momentum fraction x, at $Q^2 = 10$ GeV^2 (as an example). The blue band represents the uncertainty based on analysis of data from the HERA accelerator[6,12]. The coloured dots illustrate the parton content of the proton at each value of x. At large x, the proton is a dilute system. With decreasing x (or increasing energy), more and more partons are produced through splittings such as that of a gluon, $g \rightarrow gg$; until at some point the parton density might become large enough for recombination processes such as $gg \rightarrow g$ to take place[12]. Figure courtesy of Voica Radescu, DESY.