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Electrons and nuclei meet at HERA

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The HERA collider at DESY, Hamburg, has been operating with proton and electron (or positron) beams since it was commissioned in 1991. The possibility of having nuclei in its superconducting proton ring emerged as an interesting option during the 1995-6 workshop 'Future Physics at HERA'.

Such an electron-nucleus collider would explore entirely new domains of Quantum Chromodynamics (QCD) – the field theory of quarks and gluons deep inside protons and nuclei.

Significantly larger quark/gluon densities at very small momentum fractions carried by the struck quark/gluon would be accessible compared to the present electron-proton collisions in HERA or fixed target experiments. This is expected to reveal a new QCD domain where the smallness of the coupling is compensated by a high density of gluons, which leads to novel non-linear dynamics.

Nuclei also provide additional handles to study diffraction and shadowing phenomena, as well as quark/gluon propagation through nuclear media, related to colour phenomena in QCD. The nucleus can also be used as a "femto-detector", giving information on dynamics on the scale of nuclear dimensions.

The physics and accelerator aspects of electron-nucleus collisions at HERA has been investigated during the past three years. The project is considered to be a major future direction for nuclear physics – the Nuclear Working Group of the OECD Megascience Forum endorsed the project as one of three major directions of the electron-nucleus physics (CERN Courier May 1999 p. 21).

To pursue these efforts further, DESY held the workshop 'Physics with HERA as electron-nucleus collider' on May 25-26. About 70 participating theorists, experimentlists and accelerator experts reviewed the latest devlopments and examined the feasibility in terms of accelerator and detector requirements. In the welcome address, then DESY research director, Albrecht Wagner, emphasized the need for a detailed evaluation of the discovery potential of the project.

Review talks covered covered various theoretical, experimental and accelerator aspects. Important recent developments were also reported in many shorter talks. An indication of the problems was given by the review entitled 'Partons, hadrons and theoreticians - Muddling through the QCD vacuum'.

Nevertheless, theorists were confident that the long-sought non-linear QCD effects could be found and studied in a broad kinematic range. The relative rate of so-called diffractive, or rapidity gap, events discovered in electron-proton scattering at HERA a few years ago should be much larger in electron-nucleus collisions and approach 50%! The production of J/ψ and upsilon particles as small quark-antiquark systems that can be used as probes of the nuclear medium they propagate through and reveal strong absorption effects that are characteristic of the new QCD dynamics.

P. Paul, Brookhaven deputy director for Science & Technology, stunned many in the audience by announcing the interest for an electron-nucleus collider at the RHIC machine at Brookhaven, which is now being commissioned. However, the energy would be about a factor ten lower than the energy that could be reached at HERA. It was recognized that the heavy ion collision programmes at RHIC and CERN's LHC have important connections to electron-nucleus physics, for example regarding studies of gluon screening effects and establishing safe signals for the quark-gluon plasma.

Several groups are being formed to study these issues in depth. Regular meetings are planned as well as coordination with studies of the RHIC electron-nucleus option. More information is available at "www.desy.de/heraea".

Figure (from workshop poster): Simulation of a collision between a high-energy nucleus and an electron such as would be seen by an extension of the programme at the HERA collider at DESY, Hamburg.