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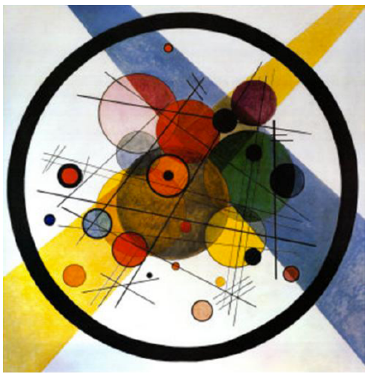
A Large Hadron Electron Collider at CERN

Report on the Physics and Design Concepts for Machine and Detector

LHeC Study Group



The Kandinsky painting, “Circles in a circle” (1923), is taken from a talk on gluon saturation and $5D$ black hole duality as presented at the first CERN-ECFA-NuPECC Workshop on the LHeC held at Divonne near to CERN in September 2008 [1]. We thank the Philadelphia Museum of Art, USA, for the permission to reproduce it here.
Kreise im Kreis, 923 (R.702), Vassily Kandinsky
Oil on canvas, 38 7/8 x 37 5/8 inches (98.7 x 95.6 cm)
Philadelphia Museum of Art: The Louise and Walter Arensberg Collection, 1950

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Abstract

The physics programme and the design are described of a new collider for particle and nuclear physics, the Large Hadron Electron Collider (LHeC), in which a newly built electron beam of 60 GeV, to possibly 140 GeV, energy collides with the intense hadron beams of the LHC. Compared to the first *ep* collider, HERA, the kinematic range covered is extended by a factor of twenty in the negative four-momentum squared, Q^2, and in the inverse Bjorken x, while with the design luminosity of $10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ the LHeC is projected to exceed the integrated HERA luminosity by two orders of magnitude. The physics programme is devoted to an exploration of the energy frontier, complementing the LHC and its discovery potential for physics beyond the Standard Model with high precision deep inelastic scattering measurements. These are designed to investigate a variety of fundamental questions in strong and electroweak interactions. The LHeC thus continues the path of deep inelastic scattering (DIS) into unknown areas of physics and kinematics. The physics programme also includes electron-deuteron and electron-ion scattering in a $(Q^2,\ 1/x)$ range extended by four orders of magnitude as compared to previous lepton-nucleus DIS experiments for novel investigations of neutron's and nuclear structure, the initial conditions of Quark-Gluon Plasma formation and further quantum chromodynamic phenomena. The LHeC may be realised either as a ring-ring or as a linac-ring collider. Optics and beam dynamics studies are presented for both versions, along with technical design considerations on the interaction region, magnets including new dipole prototypes, cryogenics, RF, and further components. A design study is also presented of a detector suitable to perform high precision DIS measurements in a wide range of acceptance using state-of-the art detector technology, which is modular and of limited size enabling its fast installation. The detector includes tagging devices for electron, photon, proton and neutron detection near to the beam pipe. Civil engineering and installation studies are presented for the accelerator and the detector. The LHeC can be built within a decade and thus be operated while the LHC runs in its high-luminosity phase. It so represents a major opportunity for progress in particle physics exploiting the investment made in the LHC.

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