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Exploring the Energy Frontier with Deep Inelastic Scattering at the LHC

The Large Hadron Collider determines the energy frontier of experimental collider physics for the next two decades. Following the current luminosity upgrade, the LHC can be further upgraded with a high energy, intense electron beam such that it becomes a twin-collider facility, in which ep operates concurrently with pp. A joint ECFA, CERN and NuPECC initiative led to a detailed conceptual design report (CDR) [1] for the Large Hadron Electron Collider (LHeC) published in 2012. The LHeC uses a novel, energy recovery linear (ERL) electron accelerator which enables TeV energy electron-proton collisions at high luminosity, exceeding that of HERA by nearly three orders of magnitude. The discovery of the Higgs boson and the surprising absence of BSM physics at LHC demand to extend the experimental base of particle physics suitable to explore the energy frontier, beyond pp collisions at the LHC. Following a mandate of the CERN Directorates and guided by an International Advisory Committee, this motivated representatives of more than 100 institutes to proceed, as sketched here, with the development of the accelerator, physics and detector prospects for the LHeC with the intention to publish an update of the CDR in early 2019 [2].

The very high luminosity and the substantial extension of the kinematic range in deep inelastic scattering (DIS) compared to HERA, make the LHeC a uniquely powerful TeV energy collider, which rests on a maximal exploitation of the LHC infrastructure. Realising an "Electrons for LHC"[3] programme would create the cleanest, high resolution microscope accessible to the world, one may term a "CERN Hubble Telescope for the Micro-Universe". It is directed to unravel the substructure of matter encoded in the complex dynamics of the strong interaction, a necessary input for future hadron colliders, including HL- LHC. Being complementary to the LHC and a possible future e+e− machine, the LHeC would scrutinise the Standard Model (SM) deeper than ever before, and possibly discover new physics in the electroweak and chromodynamic sectors. Adding ep transforms the LHC into an outstanding, high precision Higgs facility. Through the extension of the kinematic range by about three orders of magnitude in lepton-nucleus (eA) scattering, the LHeC is the most powerful electron-ion research facility one can build in the next decades, for elucidating the chromodynamic origin of the Quark-Gluon-Plasma and clarifying the partonic substructure and dynamics inside nuclei for the first time.

The LHeC physics programme reaches far beyond any specialised goal, it complements and sustains the physics at HL-LHC by providing new discovery potential in its final phase of operation. The LHeC represents a unique opportunity for CERN and its associated laboratories to build a full, new accelerator using modern technology. The ERL has major future applications, with ep at HE-LHC and FCC-eh, as an injector for FCC-ee, as a $\gamma\gamma$ Higgs facility [4, 5] or, beyond particle physics, as the highest energy XFEL of hugely increased brightness [6]. The main LHeC innovation is the first ever high energy application of energy recovery technology, based on high quality superconducting RF developments, a major contribution to the development of green collider technology. A novel ep experiment enables modern detection technology, such as HV CMOS Silicon tracking, to be further developed and exploited in a new generation, 4π acceptance, no pile-up, high precision collider detector in the decade(s) hence.

This paper focuses on physics providing also an overview on the machine. It is complemented by an Addendum describing further aspects of the LHeC project such as the operation and timelines for the accelerator and the detector. The development of multi-turn, high current, 802MHz ERL technology, required for the LHeC, is described in an accompanying, separate strategy contribution of the PERLE Collaboration [7] on a 500 MeV ERL facility at Orsay, based on its CDR [8] published in 2017.

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