A note, to the authors of the LHeC design report and of the LHeC contributions to the European strategy, on the status of the LHeC.

A Conclusion of the ECFA-CERN-NuPECC Study of the LHeC Design

End of November (22nd, 2012,) the plenary ECFA meeting has endorsed its final report on the LHeC, which was prepared by a small committee lead by Thomas Mueller (Karlsruhe) and by restricted ECFA. The three page report acknowledges the impressive work, the importance of and the interest in the publication of the Conceptual Design Report (CDR). It also notes the outcome of the referee process and is encouraging indeed. The ECFA statement recognises that the LHeC should run synchronously with the LHC. It points to two main directions, the desire for a deeper evaluation of the relations of the ep (eA) and pp (AA) programmes, and the importance to assemble a larger community for the realisation of the LHeC project (see the ECFA statement attached).

The November ECFA report marks the conclusion of the few year's period, during which we jointly have developed the LHeC, its physics, its accelerator techniques and its main detector concepts. The LHeC opens the realistic prospect for exploring the TeV energy scale with deep inelastic ep and eA scattering. It is more widely known now as an attractive energy frontier collider project, and it has been taken correspondingly serious in considerations for the future, and in current work. The European nuclear physics community, represented by NuPECC, decided in December 2010 to include the electron-ion collider programme of the LHeC as an integral part of their long range research plan. The CERN directorate, in spring 2012, introduced the LHeC project into the CERN medium term plan and, at the Chavannes workshop in June 2012, it encouraged the formation of international collaborations for the development of key LHeC technologies, such as superconducting cavity and IR magnet prototypes, in order to prepare for a project decision in a few years, when first significant high energy LHC results are expected to become available.

The first phase of the development of the LHeC under the auspices of CERN, ECFA and NuPECC can therefore be considered to have ended successfully. It has ended with the expectation and encouragement to prepare the next phase of the project. I want to convey thanks expressed to all colleagues involved in this, for the efforts and time spent leading to many innovative contributions on the physics programme, the detector development and the accelerator complex.
B Developments since Chavannes and the Publication of the CDR

Following the CDR publication in summer 2012, a number of important developments took place and various questions have been addressed, which are summarised below.

1. European Strategy Process

There were two ~15 page notes submitted to the European strategy process, an introductory note, “The Large Hadron Electron Collider at CERN”, sent in August 2012 to the Cracow meeting and a note “On the Relation of the LHeC and the LHC” added in October. Aspects of the LHeC project were covered in a number of talks at the Cracow workshop (September 2012), and the QCD part of the physics potential was invited to be summarised in the talk by Paul Newman. In the ongoing evaluation process, a number of discussions took place between physicists engaged in the LHeC development with members and the chair of the preparatory group, which is writing the so-called briefing book, an attempt to summarise the discussions and contributions related to the Cracow meeting. The two LHeC notes have been published: http://arxiv.org/abs/arXiv:1211.4831 and 1211.5102. The results of the European strategy process will be summarised at a meeting end of January and can be expected to become available in spring next year. Given the importance of the physics of deep inelastic scattering and based on the reaction to the CDR of ECFA, NuPECC and CERN, including its referees, anything but a clear encouragement for further pursuing the LHeC development would come as a major surprise.

2. The Availability of IP2

A question causing discussions has been the compatibility of the ALICE upgrade plans and the requirement of the LHeC to operate synchronously to the high luminosity phase (HL) of the LHC. This may be summarised as follows. The CDR of the LHeC contains a draft time schedule according to which installation of the LHeC is foreseen during LS3, which tentatively has been scheduled to begin in 2022. This followed a statement by Steve Myers at the EPS Conference at Grenoble, July 2011, which is reproduced in the CDR. The duration of LS3 is currently determined by the machine upgrade and by the need to install major new detectors for ATLAS and CMS within about 2 years. The CDR contains a study, which tentatively concludes that for the removal of the ALICE detector and the installation of the pre-mounted LHeC apparatus one needs 30 months. It is thus possible to install the new detector without adding significant downtime to the LHC. ALICE
has recently proposed an upgrade, which in September this year was endorsed by the LHCC, in which they ask for 10nb$^{-1}$ AA luminosity, which is expected to take about 5-7 months of heavy ion operation time. Given the habit to operate heavy ions for one month annually, ALICE thus may be envisaged to run until 2025. While this may look like a clash with LS3, this yet is resolvable in due time: LS3 only tentatively is to begin in 2022 and with for example a 3month heavy-ion run one may gain two extra years of ALICE operation time.

Discussions between ALICE and LHeC managements before the Cracow meeting, also at a NuPECC meeting in October in Sevilla and informally with CERN directors, pointed to the possibility for commencing a long term collaboration to prepare for a future, in which both the ALICE upgrade programme and the LHeC programme, including its novel eA part, can indeed be realised.

3. LHeC as a Higgs Factory

Given the observation of the 126 GeV boson, world-wide efforts are directed to study and pin down its properties. The LHeC programme focuses on novel and precision QCD and electroweak physics. Yet, already in the CDR, prior to that discovery, it had been noted and worked out to some extent that the LHeC has a unique Higgs potential in the cleanly separable WWH and ZZH production vertices and provides a competitive measurement of the $H \bar{b} \bar{b}$ coupling, to a few per cent precision. The second LHeC note http://arxiv.org/abs/arXiv:1211.5102 submitted to the ESG, provided directions on how the LHeC may possibly achieve a luminosity in excess of $10^{33}$ cm$^{-2}$ s$^{-1}$. An increase of the integrated ep luminosity into the ab$^{1}$ region would provide access with high precision also to rarer decays, such as decays into c\bar{c}, and to possibly exotic phenomena. The LHeC can thus become a competitive and complementary Higgs facility, at modest cost. This also concerns the removal of QCD related uncertainties of pp Higgs measurements with precision LHeC measurements. This will be studied further.

4. Parton Distributions and the LHC

The LHeC provides data which are to change the information on proton and nuclear partons totally. Together with HERA’s data, the LHeC data can be expected to replace all previous PDF sensitive data, which are partially inconsistent and suffer from nuclear and higher twist corrections and their uncertainties. pQCD calculations are projected to be extended to the N$^{3}$LO level eventually. The LHeC therefore essentially removes all QCD related uncertainties which nowadays are significant in the LHC Higgs measurements. It also determines high x partons so well that the HL LHC search potential can be maximally exploited. An example, considering SUSY gluino pair production at the LHC, has been presented in the second LHeC note. In recent months, the question has been raised whether this high precision is indeed required for the LHC given experimental and theoretical uncertainties of pp measurements, and a certain potential to obtain constrains on PDFs
from a number of PDF sensitive processes in Drell-Yan scattering. This question is worth studying further, in collaboration with the ATLAS and CMS Collaborations and theorists, independent of whether one considers the LHeC programme to depend on this or rather not.

5. LHeC Test Facility

The CERN mandate is directed towards the development of a cavity with high Q value and a cavity-cryo module. CERN needs to build an LHeC energy recovery test facility in order to develop the related equipment, to study the ERL process in detail and to acquire the knowledge for mastering the LHeC electron beam challenge. ERL facilities are being built worldwide. Following Chavannes, discussions have taken place with experts from ASTeC and the Cockcroft institute at Daresbury (UK), with Jefferson Laboratory, BNL and others. First studies have been made of the optics and a lattice arrangement for a test facility with 75 MeV per pass, leading to about 300 MeV beam energy, which possibly may serve as an injector to the LHeC. A meeting has been organised for January 2013 for choosing the RF frequency for the LHeC (0.72 or 1.3 GHz), which is important for further technical developments and for the formation of the accelerator and test facility collaboration.

6. Accelerator Developments

Further developments on the LHeC accelerator design are ongoing or being planned. These will be summarised with papers, that have just been submitted to the IPAC13 conference in Shanghai, May 2013. The following papers have been submitted: i) development of the IR in conjunction with a study of the compatibility of the electron beam with the HL LHC (so called ATS) optics; ii) civil engineering of future ‘ring’ colliders at CERN (LHeC, TLEP and SHE-LHC); iii) the LHeC as a Higgs factory; iv) design of the LHeC ERL test facility at CERN; v) RF for the LHeC. Furthermore, a plenary (“oral”) talk was invited to present “The LHeC Project”. There were various occasions where the LHeC was presented at conferences, such as the Positron Workshop at Zeuthen in September or the Higgs facility workshop at Fermilab in November, which took also note of the idea, termed SAPHIRE, to base a photon-photon collider on LHeC technology.

7. Detector and Collaboration

The detector is being further developed, with a current focus on the IR and forward tracking possibilities. First steps are taken to integrate the LHeC IR into the HL-LHC optics. This will affect the placement of magnets and masks. The development of the offline software framework has been initiated, in which the importance of GEANT5 developments was stressed. The LHeC detector will undergo changes when new groups join its development. A number of initial contacts have been established to various groups and many talks and seminars were given recently to prepare the foundation of a detector collaboration.
C  **Goals and Steps for 2013**

A number of questions need to be addressed next year, such as:

- Evaluation of the project cost, possible optimisation of its parameters, and determination of an updated time schedule;
- Deeper study of the physics relation of the LHeC with the LHC, in particular with respect to the Higgs and search programme;
- Further development of the physics programme of the LHeC based on a complete first detector simulation (precision measurement of top quark properties, optimisation of \( b \) and \( c \) tagging in the forward direction, study of the electron-deuteron scattering programme, evaluation of the importance of positrons for the LHeC, etc.);
- Adaptation of the LHeC to the HL-LHC (ATS) optics;
- Optimisation and further specification of the Interaction Region layout;
- Specification of the IR superconducting magnets and proceeding to a prototype fabrication, desirably in collaboration;
- Choice of RF frequency for the electron linac;
- Design of the LHeC test facility and formation of international collaborations (MoU’s) for building it at CERN;
- Studies (accelerator, detector, physics) towards the LHeC as a competitive Higgs facility based on increased luminosity of \( 0(10^{34})\text{cm}^{-2}\text{s}^{-1} \);
- Offline software description of the LHeC detector as a reliable basis for forthcoming analysis studies and the detector design;
- Formation of the LHeC Detector Collaboration, which is able to move the design concept forward towards more detailed component designs;
- Increased (re)presentation of the project towards the international HEP and NP communities, and the public.

The corresponding developments can be expected to lead to strengthening of the international accelerator collaboration, the deeper study of the LHeC physics potential and the foundation of the detector collaboration. This will lead to a new project organisation which may be set up following principal guidance as was provided at Chavannes.

The LHeC promises to become the world’s cleanest microscope and with ep/eA DIS physics based on the LHC a new laboratory for particle physics can be opened as is required to explore TeV energy scale and high parton density physics. It is worth pursuing the project towards its eventual realisation. It sustains the LHC facility’s exploitation and it bridges to a new world HEP project at CERN.

With kind regards + best wishes for a fruitful 2013, Max Klein, Geneva