MEMORANDUM

Comments by RECFA on the CDR Draft for project LHeC

This memorandum bases on the following documents and informations:

- Conceptual Design Report by the LHeC Study Group, LHeC-Note-2011-003 GEN
- Oral presentation to ECFA by Max Klein on Nov. 26, 2011
- Collection of referee reports about LHeC CDR, status 2012:
  CERN-LHeC-Note-2012-001 INT
- Presentations at the 4th Workshop on LHeC in Chavannes, June 14-15, 2012
- Private informations by Max Klein

General:

The Conceptual Design Report (CDR) on the Large Hadron Electron Collider (LHeC) describes the physics programme and the design of a new electron-hadron collider, in which electrons of 60 GeV (with the possibility of up to 140 GeV) collide with LHC protons or of heavy nuclei of 7000 GeV. LHeC is designed to exceed the integrated luminosity collected at HERA by two orders of magnitude and the kinematic range in Q^2 by a factor of twenty. This accelerator facility will enable also collision of positrons with hadrons, albeit at lower luminosities.

The CDR documents a rich LHeC physics programme being capable to perform a set of unique measurements in three areas: precision studies of QCD and the electroweak interaction, physics at high parton densities and searches for phenomena beyond the Standard Model. In these three areas, LHeC will be able to provide a set of unique measurements.

Precision studies of QCD include measurements of the inclusive proton structure function to per-mille accuracy and equally precise measurements of jet and heavy quark cross sections. Combining these measurements provides a determination of parton distributions and of the strong coupling constant to an unprecedented precision. As phrased by one of the expert reviewers, “the LHeC will be the first deep inelastic scattering experiment that is capable to unfold the parton content of the proton for all light flavors” resolving in particular issues related to the antiquark content of the proton (s-sbar, ubar/dbar etc…).

In electroweak physics, new measurements of the couplings of individual light quark flavours and a unique measurement of the running of the weak mixing angle up to the TeV scale in a single experiment are envisaged.

The LHeC would be able to study the high-energy limit of QCD in electron-proton and electron-nucleus interactions, thereby probing the previously inaccessible regime of ultra-high parton densities. Measurements in this regime have important implications for the interpretation of heavy-ion collisions and ultra-high energy cosmic ray interactions.

The LHeC would provide sensitivity to new physics scenarios especially in the lepton sector (excited leptons, first generation leptoquarks, anomalous couplings).

At this stage, there are two competing concepts for LHeC – the ring-ring or the linac-ring option. The CDR also presents a design sketch of a detector and of the physics potential.

The various sections of the CDR (physics, machine, detector) was been reviewed by a panel of independent experts. This review was overall very positive about the proposed project.

Comments

ECFA congratulates the authors of the LHeC CDR for the ingenuity of their design ideas and commends the enormous amount of effort invested into the CDR. We want to refer to the many valuable comments by the referees. From its research programme, LHeC could address fundamental questions both in particle and in nuclear physics. As a facility, it could have the potential to serve a broad community of researchers.

We recognise the presented concept of an electron – proton collider as principally feasible, and the physics programme carried out with LHeC as interesting and important. We, however, point out that a serious consideration of LHeC as a future project at CERN requires an answer to some basic questions and observations:

- **Physics programme**

As a general remark, the interplay of the LHeC physics programme with ongoing (LHC, RHIC) and proposed high-energy collider projects deserves further investigation, particularly taking into account the timeline of the project. For example, it is quite clear that LHeC would be essential to determine the detailed properties of a first generation of leptoquarks. The discovery potential of leptoquarks at LHeC, however, has to be confronted with the projected reach of LHC in the coming years.

Precision measurements in QCD and electroweak physics at LHeC should be confronted with those at high luminosity LHC running, in particular those from W and Z production data. Similarly, the high-energy/high-density QCD programme interplays with forward physics studies at CMS, LHCb and ALICE, and should be confronted with the potential of the p+A and A+A physics programmes at the LHC (and RHIC). We believe that such a comparison is desirable to promote the LHeC physics case by highlighting the uniqueness of its physics programme, and by viewing it in a larger context of physics at the frontiers of highest energy, highest precision and highest densities.

In the preferred design option (the Linac-Ring option, see arguments below), the intensity of the positron beam will be strongly reduced. The impact of this lower luminosity on the three main axes of the scientific program needs to be clarified:

- **Accelerator design**

1. Ring-Ring Concept

From the CDR and the referee's comments, the ring-ring concept projected performance relies on the baseline LHC parameters and on parameters that, for the most parts, have been measured at LEP and HERA. It is however not clear from the report whether the addition of an electron ring on top of the LHC is possible without major modifications of the LHC infrastructure. Before considering seriously this option, the possibility of high hidden costs (for example due to significant civil construction to provide bypasses around the existing experimental hall) and of risks for the existing accelerator have to be assessed. The impact of the LHeC construction on the regular LHC programme needs to be studied. A realistic time schedule must be presented taking into account both the pp and AA programme constraints and the expected lifetime of the proton ring (for this reason, a long follow-up after the termination of the regular LHC programme is probably excluded).

ECFA takes note that in the LHeC workshop in June 2012, the ring-ring option was denoted a fall-back solution only. ECFA recommends dropping the ring-ring option.

2. Linac-Ring Concept

The impact of the linac-ring concept on the LHC programme is smaller than that of the ring-ring concept but not negligible. The necessary time to link the two machines, finalise the e-p interaction region, remove ALICE and install a new experiment must be assessed as well as the corresponding impact on the LHC programme. Unlike for the ring-ring option, here a novel accelerator concept is presented with possible outlook to future accelerator developments. Energy recovery is a vital ingredient to recuperate some of the losses from synchrotron radiation. Therefore, it is necessary to specify and include clearly in the project the schedule and resources needed for R&D. As mentioned above, a drawback is the low achievable positron intensity, which may impact the physics performance.

A realistic cost estimate of the whole project is required.

- **Detector**

A design of the detector was presented for both ring-ring and linac-ring options. It relies on existing and proven technologies, but the required performance is still challenging. Detailed full simulations including a realistic integration scheme of the subdetectors and a realistic material budget are needed to finalize the design, in particular for the linac-ring option where the presence of dipoles that deflect the electron beam complicates the geometry of the calorimeter system.

Summary

The LHeC CDR of a Large Hadron Electron Collider (LHeC) will constitute an important input to the update of the European Strategy in Particle Physics that will take place during 2012-2013.

ECFA acknowledges the large effort, enthusiasm and ingenuity of the LHeC community shown in the CDR.

It is our opinion that only the linac-ring option is viable. We point out that there are still important issues to be addressed concerning the physics potential, the accelerator and the detector.

We regard the design effort carried out on the machine as very valuable also for other projects.

Most important is to assemble a strong community in particle and nuclear physics to push further this challenging project, and to secure resources for the ensuing R&D projects towards the formulation of a TDR.