Coordination on LHeC/PERLE/FCC-eh

Strategy

2020 and Beyond

LHeC at HL-LHC

Max Klein, Coordination Meeting 19.December 2019

Strategy Events – what have we done

2018:

Hongkong Meeting

FCC Physics Workshop

DIS Workshop Kobe April: Panel on Future DIS

FCC Week

Orsay Workshop

ICHEP

ERL Workshop

Papers sent to the ESG Update, December
[LHeC, PERLE, Addendum] → 50 GeV
to reduce cost.. LHeC in JPhysG.

2019:

FCC CDR (1,3 with eh)

FCC Physics Workshop

DIS Workshop in Torino April

Granada May

EPS and Lepton-Photon

ERL Workshop Berlin

Chavannes Workshop

IAC Statement

ERL Talk at ECFA, letter 4:
https://ecfa.web.cern.ch

LHeC in(to) the ESG Agenda

2020:

„The LHeC at HL-LHC“

FCC Physics Workshop (ee..)

Bad Honnef (20-24.1.20)

DIS Workshop New York (EIC..)

May Budapest: Strategy Out

IPAC France May

ICHEP Prague (30.7.-5.8.)

ERL Workshop Cornell?

..

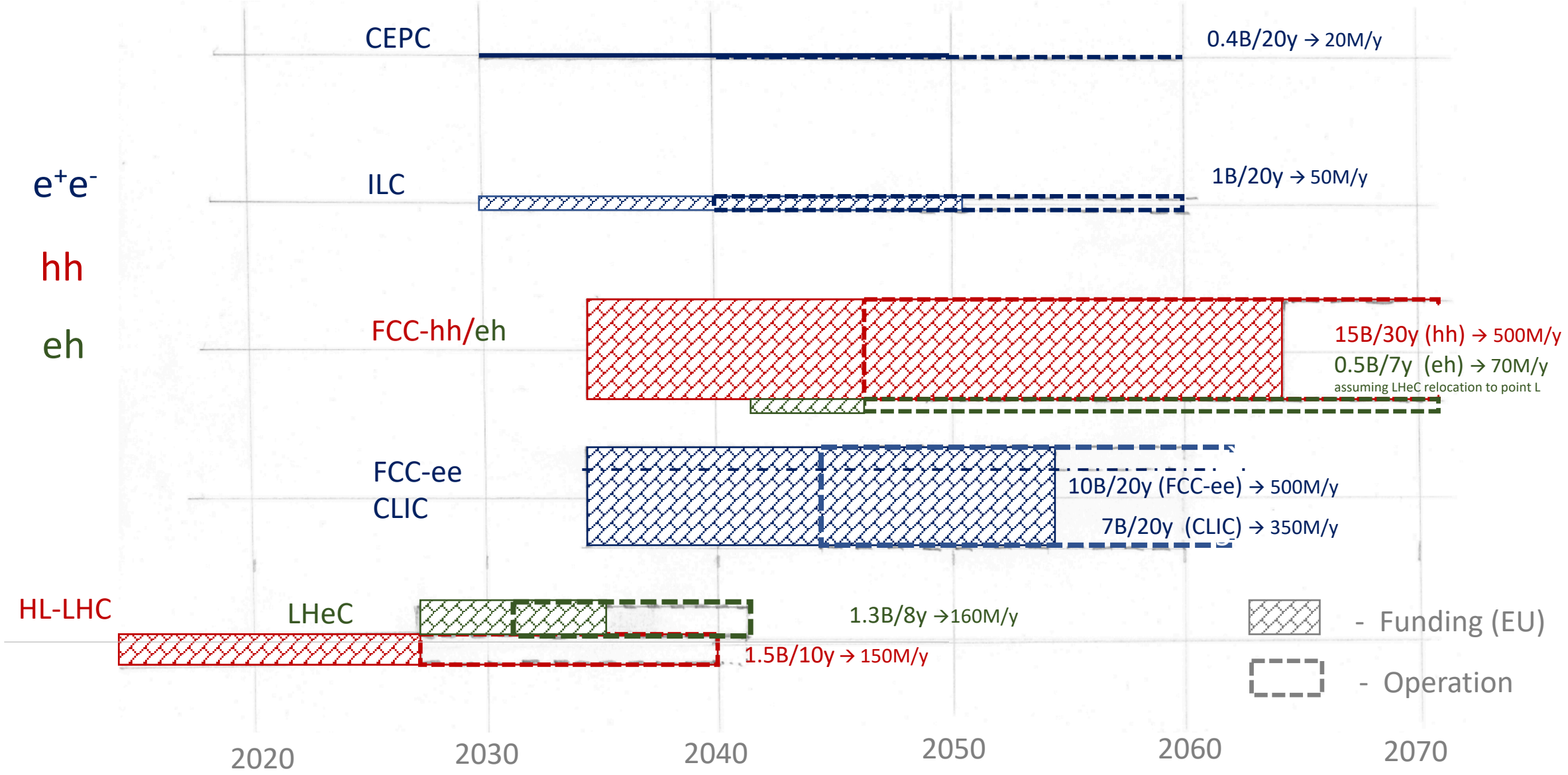
A landscape for colliders in Europe

	2020-2040	2040-2060	2060-2080
		1st gen technology	2nd gen technology
CLIC-all	HL-LHC	**CLIC380-1500**	CLIC3000 / other tech
CLIC-FCC	HL-LHC	**CLIC380**	FCC-h/e/A (Adv HF magnets) / other tech
FCC-all	HL-LHC	**FCC-ee (90-365)**	FCC-h/e/A (Adv HF magnets) / other tech
LE-to-HE-FCC-h/e/A	HL-LHC	**LE-FCC-h/e/A (low-field magnets)**	FCC-h/e/A (Adv HF magnets) / other tech
LHeC-FCC-h/e/A	HL-LHC **+ LHeC**	**LHeC**	FCC-h/e/A (Adv HF magnets) / other tech

- All elements related to the CLIC, FCC and LHeC proposals are discussed in their CDRs.
- The LE-to-HE-FCC-hh(e/A) scenario with the hadron collider version of the FCC moves from initially lower-field magnets to higher-field magnets, potentially HTS magnets.
- The LHeC+FCC-h/e/A scenario includes the LHeC (could be included in all scenarios) and foresees FCC-h/e/A at a later stage directly with high-field magnets.

J de Hondt, ECFA plenary: https://indico.cern.ch/event/847002/

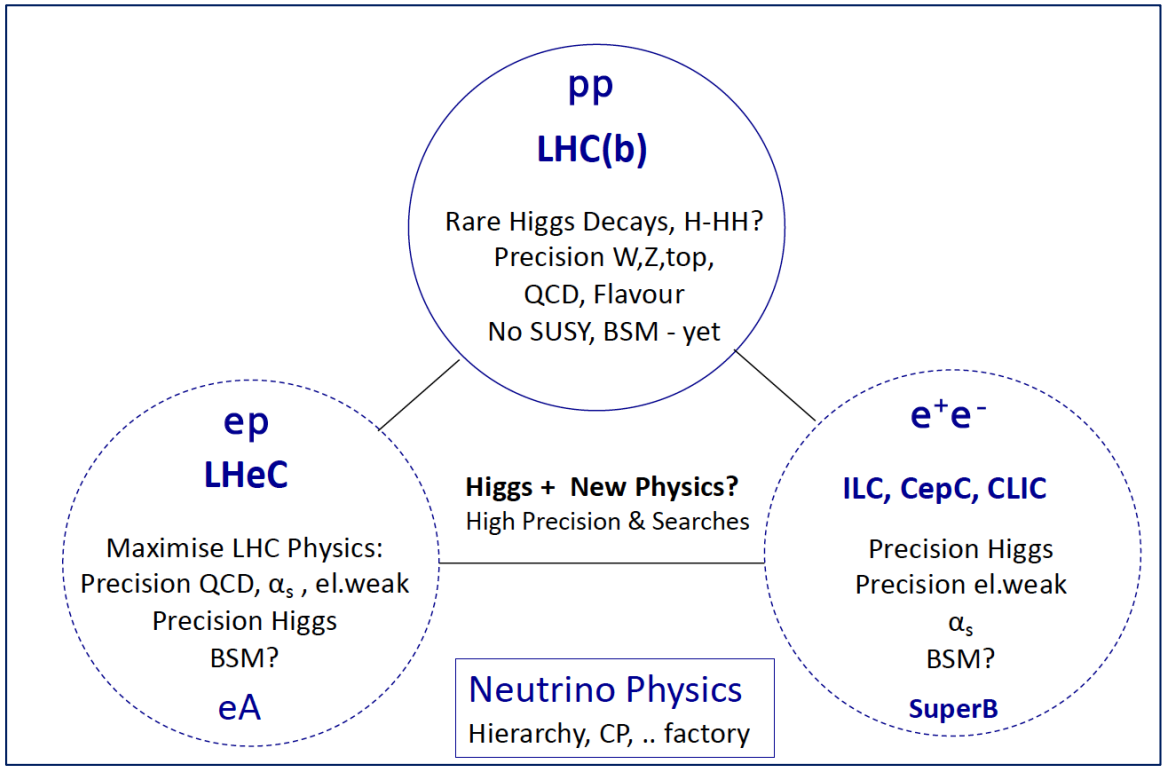
Future Collider Options timelines of funding (cost for Europe) and operation

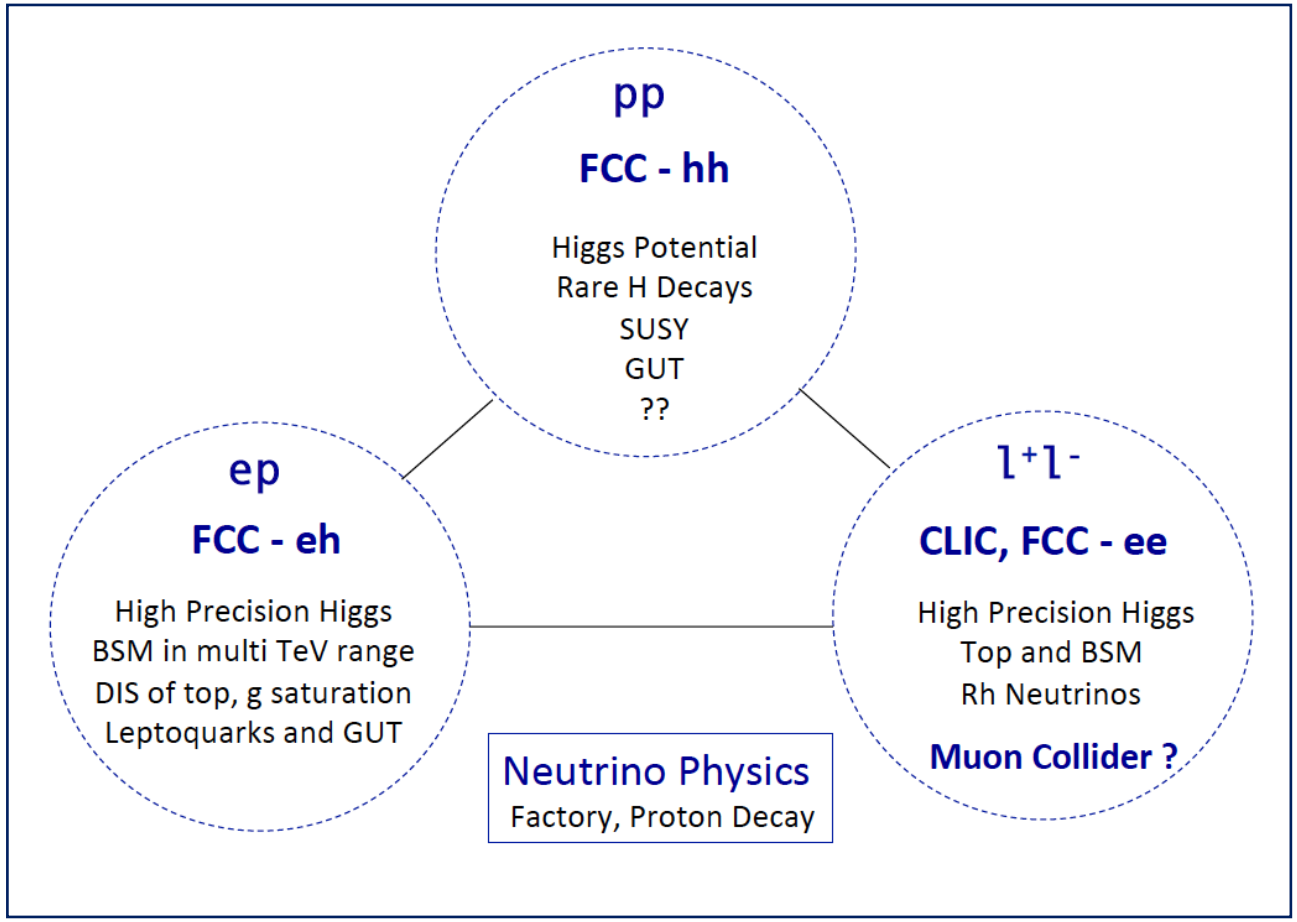


Collider Energy Frontier Physics

TeVatron, LEP and HERA explored the **Fermi scale** and established the SM. Next is the physics BSM, the Higgs mechanism and a new level of scrutiny of the physics of the electroweak and strong interactions.

The TeV scale is being explored now with the LHC. Completion of this program requires next generation e^+e^- and eh colliders. A prime task is to select the next e^+e^- machine, of which only one may be built. The LHeC is the obvious option for eh, provided by the HL-LHC. This is a program for the thirties, possibly into the early 40ies.





The 10 TeV scale requires a post LHC hadron collider. With a next e^+e^- machine built in Asia, CERN may plan for the FCC-hh as its next machine. This may be accompanied by a multi-TeV muon collider and the FCC-eh. If by mid 20ies it is decided that no Asian e^+e^- collider will be built, CERN may rediscuss the question of the relative virtues of an immediate pp/ep vs an initial e^+e^- program.

Strategic Considerations

A The LHC is the base of energy frontier particle physics until ~2040. It has been the largest investment into PP for decades including the HL-LHC. Its maximum exploitation has to be the highest priority for the near and mid-term future. This will be enabled by the luminosity upgrade program. The LHC shall be transformed into a high precision Higgs, QCD and electroweak physics facility with an extended BSM program. This is possible with the addition of the electron ERL (LHeC). The combined program ensures the center of PP stays at CERN.

B A new collider for CERN at the level of O(10) GSF cost should have the potential to change the paradigm of particle physics with direct, high energy discoveries in the ~10 TeV mass range. This may only be achieved with the FCC-hh. It accesses physics to several hundred TeV, assisted by a new level of QCD/DIS input. It is the only collider to measure the Higgs potential as its major goal and thus may not fail. It reaches rare H decays, high scales and, when combined with ep, it measures the SM Higgs couplings to below percent precision. There is a huge, fundamental program on electroweak and strong interactions, flavour and heavy ions. It is CERN's unique opportunity to build on the ongoing LHC program, for decades ahead. The FCC-hh requires high field dipoles. A strongly supported magnet R+D program shall find an affordable, high field solution, to be selected in the early thirties, and not this time. The size of the FCC-hh, in any case, requires this to be established as a global enterprise.

Truth should not be confused with majority. Jean Cocteau

C A next e^+e^- collider when realized in Asia could come into operation when the HL-LHC and LHeC are still taking data. The then established 3-fold approach to TeV scale physics (pp-ep-ee) represents a fascinating outlook, which puts the accumulation of luminosity with the LHC into a different perspective. Europe would and should take part in an electron-positron program. Page 1 illustrates that the funding for Europe would be a small fraction of what FCC-ee would demand.

D The future PP should support European labs, beyond CERN, and Universities through:

- Development of colliders in a global context: shared technology developments shared goals, joint exploration for/of possibly e^+e^- in Asia and hh/eh at CERN
- Joint detector R+D and establishment of new collaborations, with consent of the GPDs
- Joint HF magnet developments especially with labs in the US
- Joint SRF developments (CERN, US, D, F, UK, Japan..)
- A muon collider demonstrator possibly based in Italy
- An ERL development facility based in Orsay (PERLE)
- A plasma R+D facility at DESY etc , i.e. a programme to be developed and agreed

E Main technology Challenges and Tasks are:

- HF magnet development, including design and prototyping of SC IR magnets
- High gradient/quality SRF developments (for electron accelerators, ee/ep, resp.)
- Development of detector technology: radiation resistance, integration, (no) trigger..

F Opportunities for technology applications ("impact") for society, beyond PP

- HF magnet applications (MRI, Hadron Therapy..
- ERL industrial applications (lithography- new chip industry, transmutations..)
- Image reconstruction, novel detector technology
- Big data handling, dealing with distant communication (100km tunnel..)

G Strong investments have to be made in theoretical PP and 'elite' education

Geneva, 4.11.2019

Report by the IAC on the LHeC to the DG of CERN

The development of the LHeC project was initiated by CERN and ECFA, in cooperation with NuPECC. It culminated in the publication of the Conceptual Design Report (CDR), arXiv:1206.2913 in 2012, which received by now about 500 citations. In 2014, the CERN Directorate invited our committee to advise the CERN Directorate, and the Coordination Group, on the directions of future energy frontier electron-hadron scattering as are enabled with the LHC and the future FCC (for the mandate see below). In 2016, Council endorsed the HL-LHC, which offers a higher LHC performance and strengthened the interest in exploring the Higgs phenomenon. In view of the imminent final discussions for the European Road Map for particle physics, a short summary report is here presented.

Main Developments 2014-2019

A series of annual workshops on the LHeC and FCC-eh was held, and this report is given following the latest workshop https://indico.cern.ch/event/835947 , October 24/25, 2019.

Based on recent developments concerning the development of the LHC accelerator and physics, and the progress in technology, a new default configuration of the LHeC and FCC-eh has been worked out with a tenfold increased peak luminosity goal, of 10^{34} $cm^{-2}s^{-1}$, as compared to the CDR. A comprehensive paper, "The LHeC at the HL-LHC", is being finalized for publication this year.

Within this work, it has been shown that the LHeC represents the cleanest, high resolution microscope the world can currently build, a seminal opportunity to develop and explore QCD, to study high precision Higgs and electroweak physics and to substantially extend the range and prospects for accessing BSM physics, on its own and in combination of pp with ep. The LHeC, in eA scattering mode, has a unique discovery potential on nuclear structure, dynamics and QGP physics.

Intense eh collisions with LHeC and FCC-eh are enabled through a special electron-beam racetrack arrangement with energy recovery linac (ERL) technology. If LHeC were to be considered either on its own merits, or as a bridge project to FCC-eh, it seemed important to find a configuration, which could be realised within the existing CERN budget. Several options were studied and found.

Before a decision on such a project can be taken, the ERL technology has to be further developed. Considerable progress has been made in the USA, and a major effort is now necessary to develop it further in Europe. An international collaboration (ASTeC, BINP, CERN, Jefferson Lab, Liverpool, Orsay) has been formed to realise the first multi-turn 10 MW ERL facility, PERLE at Orsay, with its main parameters set by the LHeC and producing the first encouraging results on 802 MHz cavity technology, for the CDR see arXiv:1705.08783.

This radically new accelerator technology, ERL, has an outstanding technical (SRF), physics (nuclear physics) and industrial (lithography, transmutations, ..) impact, and offers possible applications beyond ep (such as a racetrack injector or ERL layout for FCC-ee, a high energy FEL or γγ collider).

In conclusion it may be stated:

- The installation and operation of the LHeC has been demonstrated to be commensurate with the currently projected HL-LHC program, while the FCC-eh has been integrated into the FCC vision;
- The feasibility of the project as far as accelerator issues and detectors are concerned has been shown. It can only be realised at CERN and would fully exploit the massive LHC and HL-LHC investments;
- The sensitivity for discoveries of new physics is comparable, and in some cases superior, to the other projects envisaged;
- The addition of an ep/A experiment to the LHC substantially reinforces the physics program of the facility, especially in the areas of QCD, precision Higgs and electroweak as well as heavy ion physics;
- The operation of LHeC and FCC-eh is compatible with simultaneous pp operation; for LHeC the interaction point 2 would be the appropriate choice, which is currently used by ALICE;
- The development of the ERL technology needs to be intensified in Europe, in national laboratories but with the collaboration of CERN;
- A preparatory phase is still necessary to work out some time-sensitive key elements, especially the high power ERL technology (PERLE) and the prototyping of Intersection Region magnets.

Recommendations

i) It is recommended to further develop the ERL based ep/A scattering plans, both at LHC and FCC, as attractive options for the mid and long term programme of CERN, resp. Before a decision on such a project can be taken, further development work is necessary, and should be supported, possibly within existing CERN frameworks (e.g. development of SC cavities and high field IR magnets).

ii) The development of the promising high-power beam-recovery technology ERL should be intensified in Europe. This could be done mainly in national laboratories, in particular with the PERLE project at Orsay. To facilitate such a collaboration, CERN should express its interest and continue to take part.

iii) It is recommended to keep the LHeC option open until further decisions have been taken. An investigation should be started on the compatibility between the LHeC and a new heavy ion experiment in Interaction Point 2, which is currently under discussion.

After the final results of the European Strategy Process will be made known, the IAC considers its task to be completed. A new decision will then have to be taken for how to continue these activities.

Herwig Schopper, Chair of the Committee

Mandate of the International Advisory Committee (December 2014)

"Advice to the LHeC Coordination Group and the CERN directorate by following the development of options of an ep/eA collider at the LHC and at FCC, especially with: Provision of scientific and technical direction for the physics potential of the ep/eA collider, both at LHC and at FCC, as a function of the machine parameters and of a realistic detector design, as well as for the design and possible approval of an ERL test facility at CERN. Assistance in building the international case for the accelerator and detector developments as well as guidance to the resource, infrastructure and science policy aspects of the ep/eA collider."

Elements of what next?

A: Goals:

PERLE by 2024

LHeC by 2034 (LS4 end)

FCC-eh by 2048 (if FCC-hh comes at CERN)

B: Expectation from Strategy:

Support for ERL and PERLE in particular

Support for SC Magnet and Ring

→ These are the technical means to develop LHeC

C: Hope for Strategy:

Recognition of energy frontier DIS, for LHC and FCC

A reasonable strategy would recognise the unique scientific and technology value of LHeC as the only intermediate, medium size energy frontier proposal

D: Possibly: A Joint ep and AA detector design study (IP2 and L)
→ Needs immediate strengthening of detector activity which is only possible with 3) and requires 2 years at least

E: To Achieve: A clearer understanding by ATLAS+CMS of the role the near ep/A detector has for HL-LHC.
→ This is only rarely understood, it is related to the question of how long HL-LHC is expected to operate, could be 2040.
If/as that develops: plan for an LHeC-HL-LHC workshop in 21?

F: Key: The key is CERN and the strategy. However, there are no presents as the number of possible projects exceeds the available resources and since the long-term future is unclear

In my view, we have reached much more than one could expect and still not enough. The time is only to come where this gets into the programme of energy frontier HEP. We thus need to think together about how to proceed and organise this.

Room for Thoughts

Workshop in 2020?

Topical Meetings (PERLE in spring, Physics?)

Detector proto Collaboration (ECFA, CERN) – needs advanced project status

IAC and Coordination and WG Structure – new discussion with CERN

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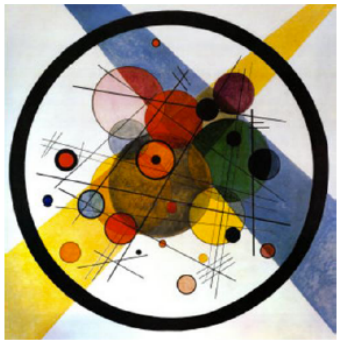
CERN-ACC-Note-2019-XXX
Geneva, December 18, 2019

The Large Hadron-Electron Collider at the HL-LHC

From resolving the partonic structure of matter to Higgs and BSM physics

LHeC Collaboration



Submitted to J.Phys. G

Finalisation of the Paper

At Bad Honnef (20-24.1.20) there will be a discussion on LHeC. It is important that those who are *pro* can point to this paper and those *against* can see what they wish to ignore.

This requires: arXiv by Friday 10.1. or the Monday after.

We have now (18.12. 14.40 CET) 193 pages, and many more are drafted or/and being written. Therefore/nevertheless the deadline is very tight.

Who should sign the paper - for discussion: suggest:
All who wish and have contributed to the project in its second phase in a traceable way:
author, talk at workshop or conference, LHeC/PERLE/FCCeh, author of an LHeC related paper, active participant of LHeC/PERLE/FCCeh workshop ..

Nestor and Oliver agreed to help, looking for an acc person

That is NOT by default the CDR 12 authors and we do no collection of names by a too generous invitation mail. The community will grow with the project.

Chapter 1-3

January

Started

May become part of 2
Kine in all detail in CDR

Done, to be read

Exists in Bordy paper,
Plots done by Max last year. coming, Oliver

Chapter 4.1-2

Chapter 4.2-5

All done, to be read

Done (to be read – Anna?)

??

Chapter 5-7 → 5 and 6

Done, integrated into text

Done

Drafted, to be inserted

Promised for early January

Drafted, to be inserted

Not clear (talk on Friday)

Chapter 8,9 → 7,8

All done, being read
LQs being updated?

Plots and tables this week, text over free days

done

Being written

Still being worked on

Being written, new specs for 50 GeV

Supposed to be ready

Supposed to be ready

Being written

Chapter 10 → 9

Basically everything done
See remarks left

A few pages by Louis Rinolfi on positrons likely to come (only invited by Max last week)

Chapter 11 → 10

Done, to be read

Draft by Friday this week, a present for Xmas

Chapter 12,13 → 11,12

Have basic results: tracker + calo tables and plots, needs text. Update on CDR

Drafted by Alessandro

Done

Both to be done

Summary on the Paper

There is a chance to have it ready by 10.1.20

It is crucial that all comes together now.

We will have to read and edit in the New Year.

Frank agreed to read all accelerator part.

J.Phys G has offered the publication

Need to talk with CERN + about hard copies.

Should prepare a CERN seminar on this.

Submit to big conferences (IPAC done, ICHEP)

Thank you all very much.

Merry Christmas

Courtesy: Nathan Readioff

backup

Personal Remarks for Discussion

We see a huge battle for resources, and a lack of guidance from physics and leadership of this Process.

Due to lack of money and unclear Asian situation and HL-LHC to start data taking in 8 years, it is most likely that this time nothing is really decided.

ALL projects struggle for survival and recognition, not just ep

What is important or new for us:

LHeC: The CDR Update: The LHeC at High Luminosity
for discussion later, important to be out in 11/19

PERLE: to really progress

FCC-eh: to keep developing eh as integrated part of hh
new: the option of a 45 TeV FCChh, to which the ERL would ideally fit.

ALICE ends LS4, there is a new proposal by some Members of the Collaboration (cf de Hondt)

The weakest point is the wide support, that is related to the recognition of DIS physics. We are progressing but it remains challenging.

IAC (HS) believes the time for ep will come, Yet the time for LHC moves.

Higgs has given us quite some support and attention, but as well resistance from ee sides.

The biggest potential is in the understanding that future hh needs future high energy eh. That goes with QCD, eweak, BSM, t, ions, and H

We shall keep stressing that this work has been mandated as a service to the community, the ep feature is the lack of resources.

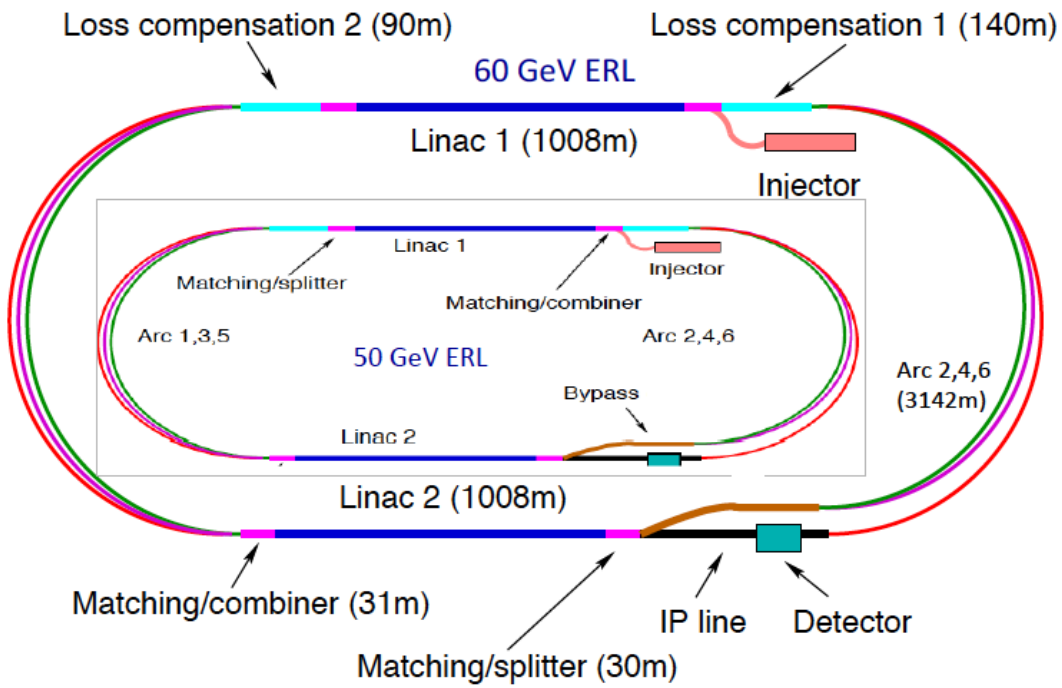
Slide from Coordination Group Meeting in June 19

CERN-ACC-NOTE-2018-0084
December 18, 2018

Exploring the Energy Frontier with Deep Inelastic Scattering at the LHC

A Contribution to the Update of the European Strategy on Particle Physics

LHeC and PERLE Collaboration



From the addendum

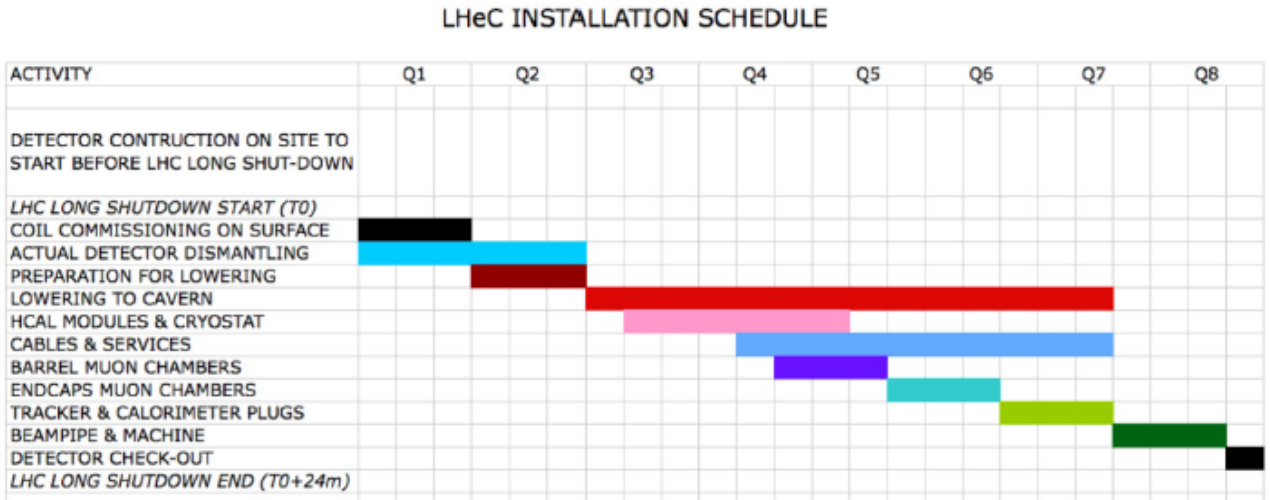


Figure 4: LHeC detector installation sequence in 8 quartals Qi.

3 documents sent of high quality: need further distribution. offer by Jphys for publication (need help to take this up)

Slide from Coordination Group Meeting in June 19