Report to ECFA

Thomas Müller, Institut für Experimentelle Kernphysik, KIT

1. History

- 2006 Idea presented to the Open Symposium on European Strategy, DESY 06-006, by J. Dainton, M. Klein, et al.
- 2008 Presentations at EPAC08, Genoa, Italy
- 2008-10 Three CERN-ECFA-NuPECC workshops on Accelerator, Detector, Physics (New Physics, QCD, EWK and parton densities)
- 2010 Presentations at IPAC10, Kyoto, Japan
- 2011 Status report at PECFA Nov. 2011
- 2012 Conceptual design report (631 pages) delivered: http://arxiv.org/abs/1206.2913
- 2012 CERN-ECFA-NuPECC Workshop in Chavannes (June 2012) https://indico.cern.ch/conferenceDisplay.py?confId=183282

2. Organisation for LHeC CDR

Scientific Advisory Committee

Guido Altarelli (Roma)
Sergio Bertolucci (CERN)
Stan Brodsky (SLAC)
Allen Caldwell (MPI Muenchen) - Chair
Swapan Chattopadhyay (Cockcroft Institute)
John Dainton (Liverpool)
John Ellis (CERN)
Jos Engelen (NWO)
Joel Feltesse (Saclay)
Roland Garoby (CERN)
Rolf Heuer (CERN)
Roland Horisberger (PSI)
Young-Kee Kim (Fermilab)
Aharon Levy (Tel Aviv)
Lev Lipatov (St. Petersburg)
Karlheinz Meier (Heidelberg)
Richard Milner (MIT)
Joachim Mnich (DESY)
Steve Myers (CERN)
Guenther Rosner (Glasgow)
Alexander N. Skrinsky (INP Novosibirsk)
Anthony Thomas (JLab)
Steve Vigdor (Brookhaven)
Ferdinand Willeke (Brookhaven)
Frank Wilczek (MIT)

Steering Committee

Oliver Bruening(CERN)
John Dainton (Liverpool)
Albert De Roeck (CERN)
Stefano Forte (Milano)
Max Klein (Liverpool) - Chair
Paul Laycock (Liverpool)
Paul Newman (Birmingham)
Emmanuelle Perez (CERN)
Wesley Smith (Wisconsin)
Bernd Surrow (MIT)
Katsuo Tokushuku (KEK)
Urs Wiedemann (CERN)
Frank Zimmermann (CERN)

Working Group Convenors

Accelerator Design

Oliver Bruening (CERN)
John Dainton (Liverpool)

Interaction Region

Bernhard Holzer(CERN)
Uwe Schneekloth (DESY)
Pierre van Mechelen (Antwerpen)

Detector Design

Peter Kostka (DESY)
Alessandro Polini (Bologna)
Rainer Wallny (Zurich)

New Physics at Large Scales

Georges Azuelos (Montreal)
Emmanuelle Perez (CERN)
Georg Weiglein (Hamburg)

Precision QCD and Electroweak

Olaf Behnke (DESY)
Paolo Gambino (Torino)
Thomas Gehrmann (Zurich)
Claire Gwenlan (Oxford)

Physics at High Parton Densities

Néstor Armesto (Santiago de Compostela)
Brian A. Cole (Columbia)
Paul R. Newman (Birmingham)
Anna M. Stasto (PennState)

CERN Referees

Ring Ring Design
Kurt Huebner (CERN)
Alexander N. Skrinsky (INP Novosibirsk)
Ferdinand Willeke (BNL)
Linac Ring Design
Reinhard Brinkmann (DESY)
Andy Wolski (Cockcroft)
Kaoru Yokoya (KEK)
Energy Recovery
Georg Hoffstaetter (Cornell)
Ilan Ben Zvi (BNL)
Magnets
Neil Marks (Cockcroft)
Martin Wilson (CERN)
Interaction Region
Daniel Pitzl (DESY)
Mike Sullivan (SLAC)
Detector Design
Philippe Bloch (CERN)
Roland Horisberger (PSI)
Installation and Infrastructure
Sylvain Weisz (CERN)
New Physics at Large Scales
Cristinel Diaconu (IN2P3 Marseille)
Gian Giudice (CERN)
Michelangelo Mangano (CERN)
Precision QCD and Electroweak
Guido Altarelli (Roma)
Vladimir Chekelian (MPI Munich)
Alan Martin (Durham)
Physics at High Parton Densities
Alfred Mueller (Columbia)
Raju Venugopalan (BNL)
Michele Arneodo (INFN Torino)

3. Physics Programme

Why an ep/A Experiment at TeV Energies?

1. For resolving the quark structure of the nucleon with p, d and ion beams

   QPM symmetries, quark distributions (complete set from data!), GPDs, nuclear PDFs ..

2. For the development of perturbative QCD

   N^kLO ($k \geq 2$) and h.o. eweak, HQs, jets, resummation, factorisation, diffraction

3. For mapping the gluon field

   Gluon for $\sim 10^{-5} < x < 1$, is unitarity violated? J/ψ, F_2^c, ... unintegrated gluon

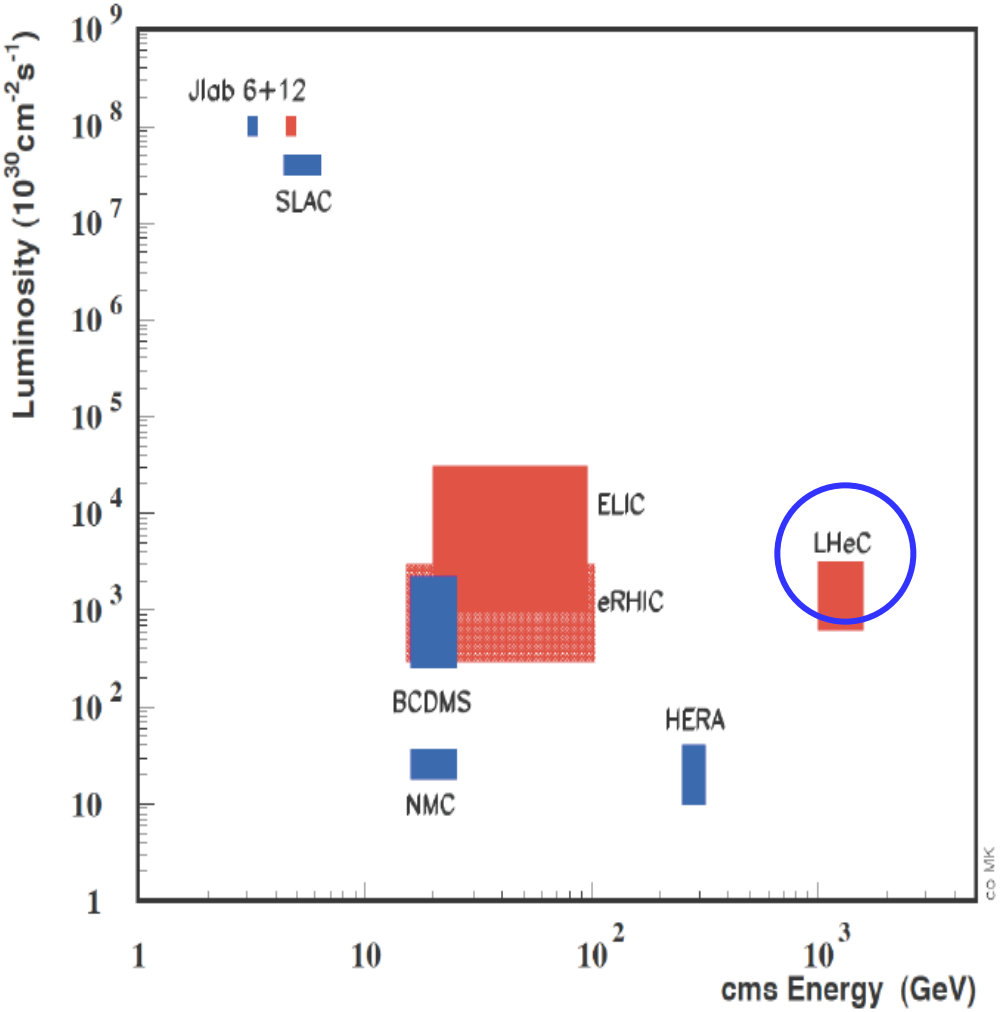
4. For searches and the understanding of new physics

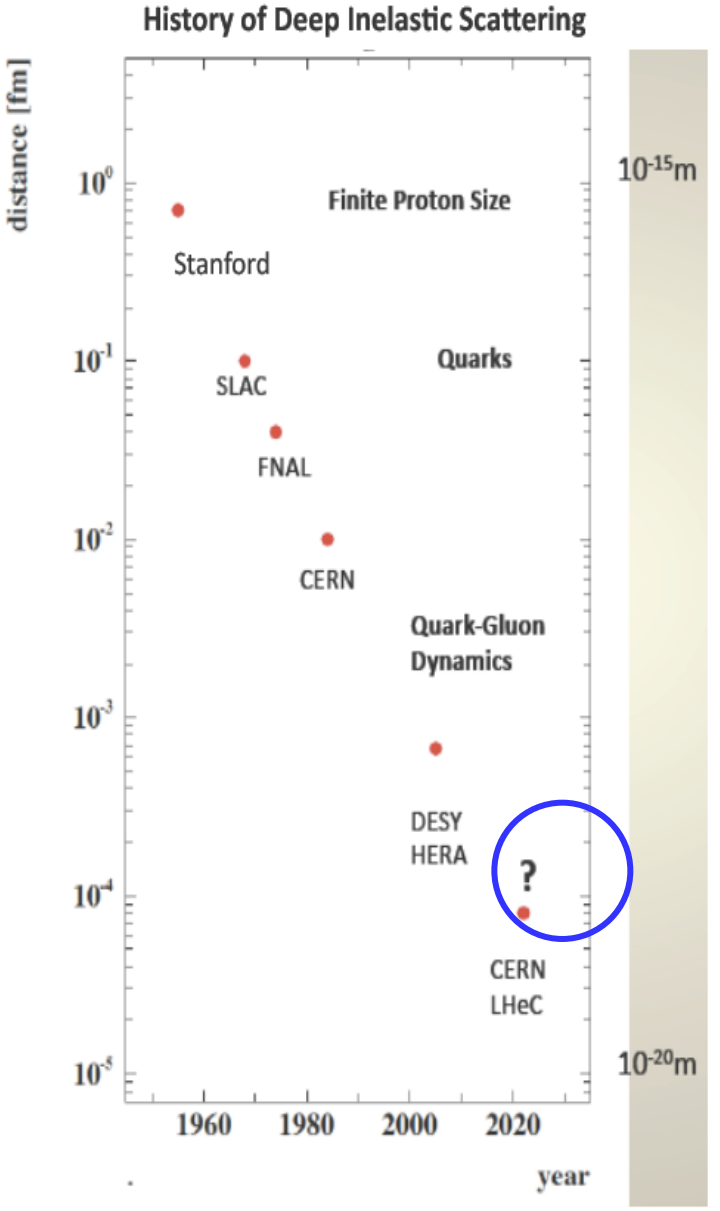
   GUT (α_s to 0.1%), LQs RPV, Higgs (bb, HWW) ... PDFs4LHC... instanton, odderon,..?

5. For investigating the physics of parton saturation

   Non-pQCD (chiral symm breaking, strings), black disc limit, saturation border..

..For providing data which could be of use for future experiments [Proposal for SLAC ep 1967]


Lepton-Proton Scattering Facilities
Luminosity (10^{30}cm^{-2}s^{-1})
Jlab 6+12
SLAC
ELIC
eRHIC
LHeC
BCDMS
HERA
NMC
cms Energy (GeV)


History of Deep Inelastic Scattering
distance [fm]
Finite Proton Size
Stanford
Quarks
SLAC
FNAL
CERN
Quark-Gluon Dynamics
DESY HERA
?
CERN LHeC
10^{-15}m
10^{-20}m
year

Candidates for Surprises and Discoveries

PDFs (t, s, q-$\bar{q}$, val, xg)
Odderon
Instanton
(no) saturation, QCD
QGP initial state

The study of deep inelastic ep scattering is important for the investigation of the nature of the Pomeron and Odderon, which are Regge singularities of the t-channel partial waves $f_j(t)$ in the complex plane of the angular momentum j. The Pomeron is responsible for a growth of total cross sections with energy. The Odderon describes the behaviour of the difference of the cross sections for particle-particle and particle-antiparticle scattering which obey the Pomeranchuck theorem. In perturbative QCD, the Pomeron and Odderon are the simplest colorless reggeons (families of glueballs) constructed from two and three reggeized gluons, respectively. Their wave functions satisfy the generalized BFKL equation. In the next-to-leading approximation the solution of the BFKL equation contains an infinite number of Pomerons and to verify this prediction of QCD one needs to increase the energy of colliding particles. In the N=4 supersymmetric generalization of QCD, in the t'Hooft limit of large N_c, the BFKL Pomeron is equivalent to the reggeized graviton living in the 10-dimensional anti-de-Sitter space. Therefore, the Pomeron interaction describing the screening corrections to the BFKL predictions, at least in this model, should be based on a general covariant effective theory being a generalization of the Einstein-Hilbert action for general relativity. Thus, the investigation of high energy ep scattering could be interesting for the construction of a non-perturbative approach to QCD based on an effective string model in high dimensional spaces.

Lev Lipatov in the CDR...

Factorization pp-ep
LQs, RPV SUSY
e^*
Higgs CP
α_s indeed small (GUT)

Ultra high precision (detector, e-h redundancy) - new insight
Maximum luminosity and much extended range - rare, new effects
Deep relation to (HL-) LHC (precision+range) - complementarity
→ **LHeC brings a substantial enrichment of LHC physics**

4. The CDR

http://cern.ch/lhec

LHeC Study Group

J.L.Abelleira Fernandez[16,23], C.Adolphsen[57], A.N.Akay[03], H.Aksakal[39], J.L.Albacete[52], S.Alekhin[17,54], P.Allport[24], V.Andreev[34], R.B.Appleby[14,30], E.Arikan[39], N.Armesto[53,a], G.Azuelos[33,64], M.Bai[37], D.Barber[14,17,24], J.Bartels[18], O.Behnke[17], J.Behr[17], A.S.Belyaev[15,56], I.Ben-Zvi[37], N.Bernard[25], S.Bertolucci[16], S.Bettoni[16], S.Biswal[41], J.Blümlein[17], H.Böttcher[17], A.Bogacz[36], C.Bracco[16], G.Brandt[44], H.Braun[65], S.Brodsky[57,b], O.Brüning[16], E.Bulyak[12], A.Buniatyan[17], H.Burkhardt[16], I.T.Cakir[02], O.Cakir[01], R.Calaga[16], V.Cetinkaya[01], E.Ciapala[16], R.Ciftci[01], A.K.Ciftci[01], B.A.Cole[38], J.C.Collins[48], O.Dadoun[42], J.Dainton[24], A.De.Roeck[16], D.d'Enterria[16], A.Dudarev[16], A.Eide[60], R.Enberg[63], E.Eroglu[62], K.J.Eskola[21], L.Favart[08], M.Fitterer[16], S.Forte[32], A.Gaddi[16], P.Gambino[59], H.García Morales[16], T.Gehrmann[69], P.Gladkikh[12], C.Glasman[28], R.Godbole[35], B.Goddard[16], T.Greenshaw[24], A.Guffanti[13], V.Guzey[19,36], C.Gwenlan[44], T.Han[50], Y.Hao[37], F.Haug[16], W.Herr[16], A.Hervé[27], B.J.Holzer[16], M.Ishitsuka[58], M.Jacquet[42], B.Jeanneret[16], J.M.Jimenez[16], J.M.Jowett[16], H.Jung[17], H.Karadeniz[02], D.Kayran[37], A.Kilic[62], K.Kimura[58], M.Klein[24], U.Klein[24], T.Kluge[24], F.Kocak[62], M.Korostelev[24], A.Kosmicki[16], P.Kostka[17], H.Kowalski[17], G.Kramer[18], D.Kuchler[16], M.Kuze[58], T.Lappi[21,c], P.Laycock[24], E.Levichev[40], S.Levonian[17], V.N.Litvinenko[37], A.Lombardi[16], J.Maeda[58], C.Marquet[16], B.Mellado[27], K.H.Mess[16], A.Milanese[16], S.Moch[17], I.I.Morozov[40], Y.Muttoni[16], S.Myers[16], S.Nandi[55], Z.Nergiz[39], P.R.Newman[06], T.Omori[61], J.Osborne[16], E.Paoloni[49], Y.Papaphilippou[16], C.Pascaud[42], H.Paukkunen[53], E.Perez[16], T.Pieloni[23], E.Pilicer[62], B.Pire[45], R.Placakyte[17], A.Polini[07], V.Ptitsyn[37], Y.Pupkov[40], V.Radescu[17], S.Raychaudhuri[35], L.Rinolfi[16], R.Rohini[35], J.Rojo[16,31], S.Russenschuck[16], M.Sahin[03], C.A.Salgado[53,a], K.Sampei[58], R.Sassot[09], E.Sauvan[04], U.Schneekloth[17], T.Schörner-Sadenius[17], D.Schulte[16], A.Senol[22], A.Seryi[44], P.Sievers[16], A.N.Skrinsky[40], W.Smith[27], H.Spiesberger[29], A.M.Stasto[48,d], M.Strikman[48], M.Sullivan[57], S.Sultansoy[03,e], Y.P.Sun[57], B.Surrow[11], L.Szymanowski[66,f], P.Taels[05], I.Tapan[62], T.Tasci[22], E.Tassi[10], H.Ten.Kate[16], J.Terron[28], H.Thiesen[16], L.Thompson[14,30], K.Tokushuku[61], R.Tomás García[16], D.Tommasini[16], D.Trbojevic[37], N.Tsoupas[37], J.Tuckmantel[16], S.Turkoz[01], T.N.Trinh[47], K.Tywoniuk[26], G.Unel[20], J.Urakawa[61], P.VanMechelen[05], A.Variola[52], R.Veness[16], A.Vivoli[16], P.Vobly[40], J.Wagner[66], R.Wallny[68], S.Wallon[43,46,f], G.Watt[16], C.Weiss[36], U.A.Wiedemann[16], U.Wienands[57], F.Willeke[37], B.-W.Xiao[48], V.Yakimenko[37], A.F.Zarnecki[67], Z.Zhang[42], F.Zimmermann[16], R.Zlebcik[51], F.Zomer[42]

193 Experimentalists and Theorists from 69 Institutes

Supported by
CERN, ECFA, NuPECC

CDR Model

2008-2012

Scientific Advisory Committee

CERN
ECFA
NuPECC

Steering Group

Accelerator	Interaction Region	Detector	New Physics	QCD and Electroweak	High Parton Densities

Organisation of the LHeC Conceptual Design Report

Issue a): ring on ring vs. linac on ring

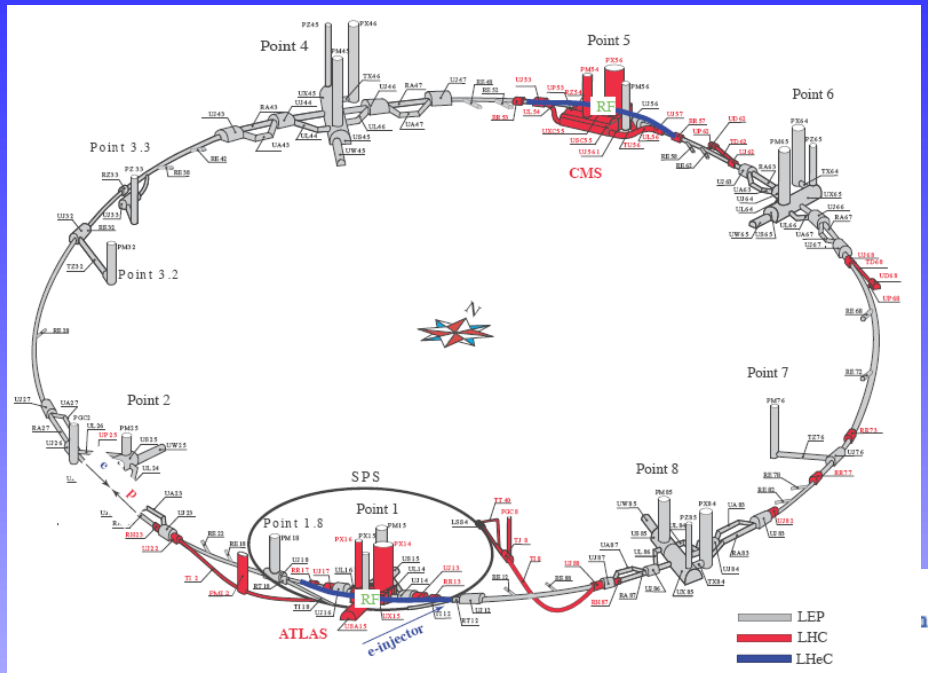


Figure 7.1: Schematic Layout of the LHeC: In grey the LEP tunnel now used for the LHC, in red the LHC extensions. The two LHeC bypasses are shown in blue. The RF is installed in the central straight section of the two bypasses. The bypass around Point 1 hosts in addition the injection.

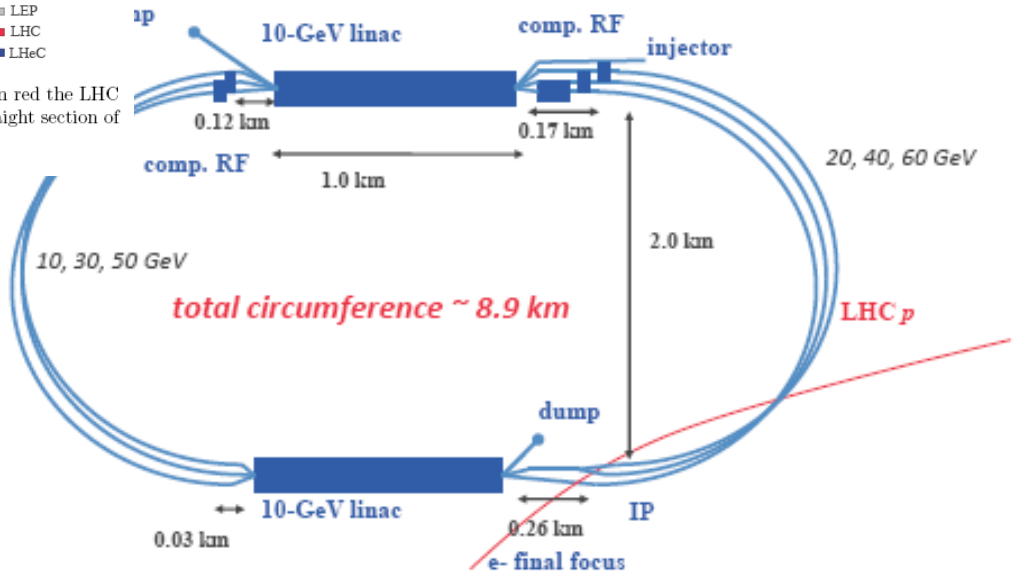


Figure 8.5: LHeC ERL layout including dimensions.

Table 1: Parameters of the RR and RL Configurations

	Ring	Linac
electron beam		
beam energy E_e	60 GeV	
e^- (e^+) per bunch N_e [10^9]	20 (20)	1 (0.1)
e^- (e^+) polarisation [%]	40 (40)	90 (0)
bunch length [mm]	10	0.6
tr. emittance at IP $\gamma\epsilon^e_{x,y}$ [mm]	0.58, 0.29	0.05
IP β function $\beta^*_{x,y}$ [m]	0.4, 0.2	0.12
beam current [mA]	131	6.6
energy recovery intensity gain	–	17
total wall plug power	100 MW	
syn rad power [kW]	51	49
critical energy [keV]	163	718
proton beam		
beam energy E_p	7 TeV	
protons per bunch N_p	$1.7 \cdot 10^{11}$	
transverse emittance $\gamma\epsilon^p_{x,y}$	3.75 μm	
collider		
Lum e^-p (e^+p) [10^{32}cm^{-2}s^{-1}]	9 (9)	10 (1)
bunch spacing	25 ns	
rms beam spot size $\sigma_{x,y}$ [μm]	30, 16	7
crossing angle θ [mrad]	1	0
$L_{eN} = A\, L_{eA}$ [10^{32}cm^{-2}s^{-1}]	0.3	1

M.Klein at IPAC11

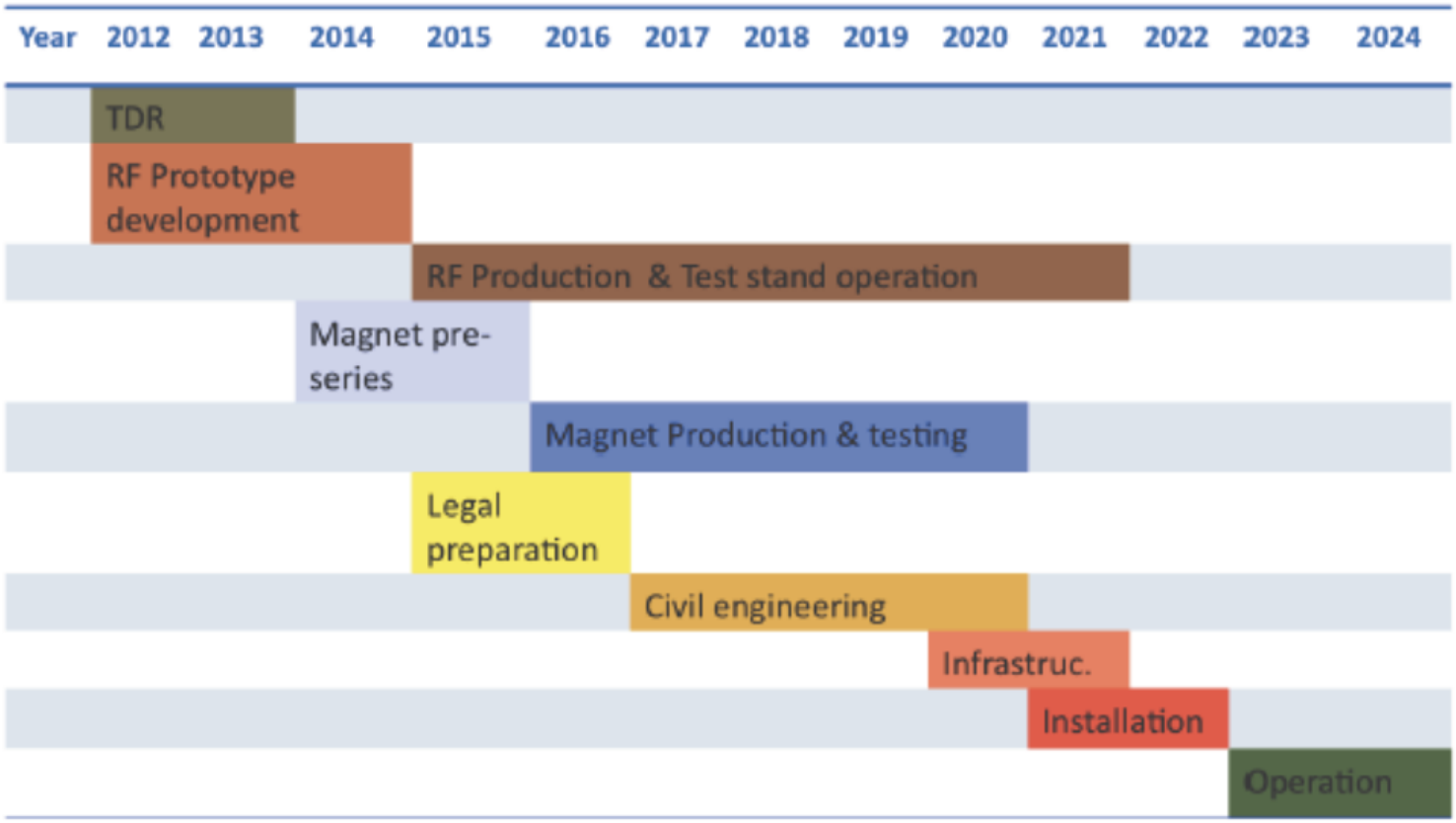
Caveats:

Linac solution:
- high cost
- small e^+- lumi

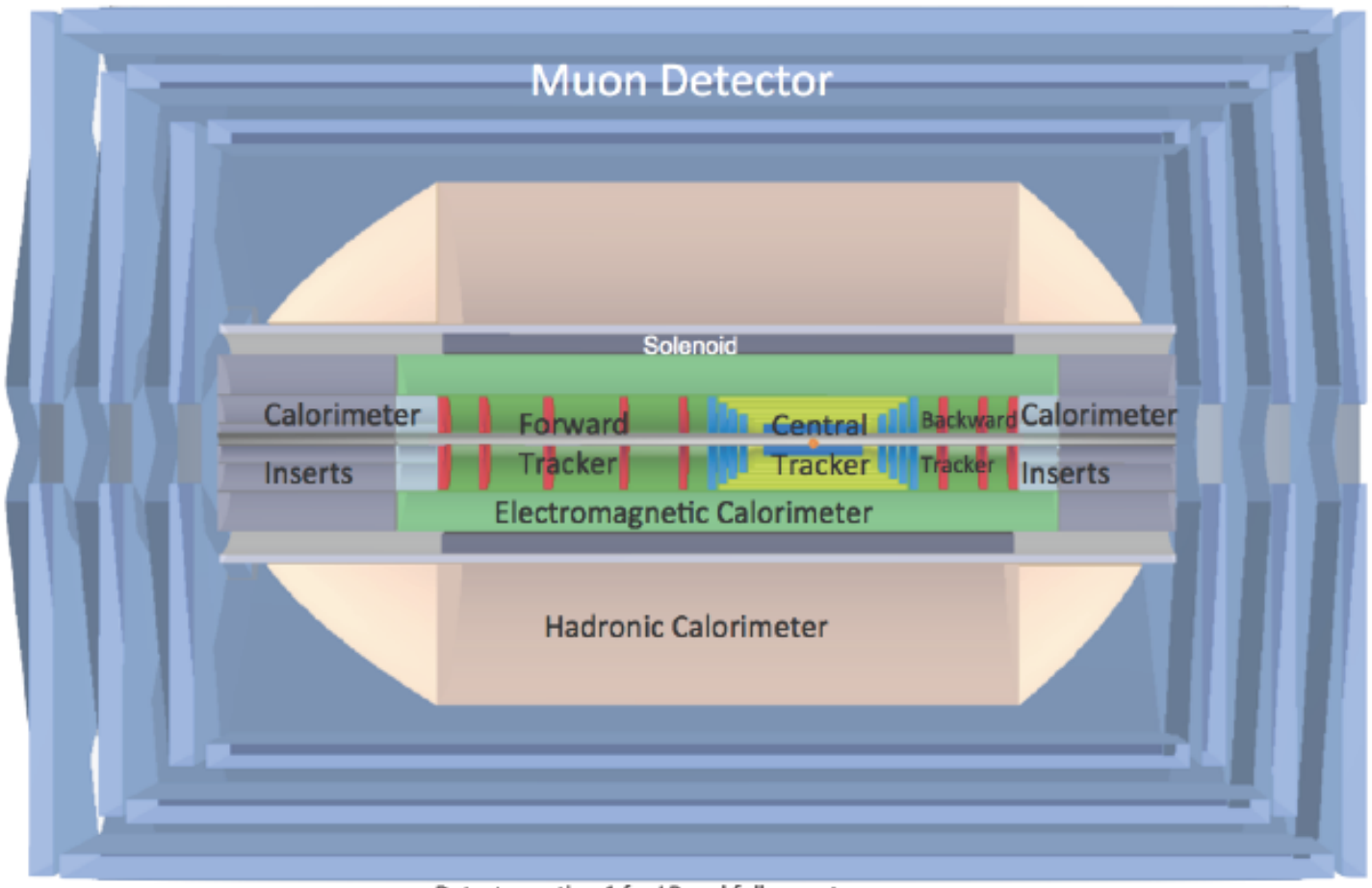
Ring-ring solution:
- unclear impact on LHC programme

Issue b): potential disturbance of LHC programme

Tentative Time Schedule



Issue c): assembly of detector – presence of dipoles



Detector option 1 for LR and full acceptance coverage

Forward/backward asymmetry in energy deposited and thus in geometry and technology
Present dimensions: LxD =14x9m^2 [CMS 21 x 15m^2 , ATLAS 45 x 25 m^2]
Taggers at -62m (e),100m (γ,LR), -22.4m (γ,RR), +100m (n), +420m (p)

5. Comments by RECFA

ECFA congratulates the authors of the *Large Hadron Electron Collider* (LHeC) *Conceptual Design Report* (CDR) for the ingenuity of their design ideas and commends the enormous amount of effort which went into it.

This CDR constitutes an important input to the update of the European Strategy in Particle Physics, which will take place in 2012-2013.

Of the two options ("*ring-ring*" versus "*lineac-ring*"), ECFA considers only the lineac-ring option realistic. In particular the impact of relatively low attainable luminosity in the lineac-ring scenario on the positron-proton programme needs to be quantified. Furthermore there are important open issues identified and remarks made by the expert referees reviewing this CDR, which the community must address.

Once resolved, the community could proceed towards a detailed design, cost estimate and schedule of the project. This also will depend on the outcome of the update of the European Strategy in Particle Physics. To continue the LHeC project, a strong and large enough community, based in particle and nuclear physics, must be gathered to support the project.