The LHeC

Project Overview
Physics Programme
Accelerator
Detector

Max Klein, University of Liverpool - University of Geneva, 5.12.2012
Colliders explored the Fermi Energy Scale

**Tevatron** to find SUSY and BSM; **LEP/SLC** to find SUSY and the Higgs; **HERA** to find Lepto-Quarks

**NNLO!**

\[ M_Z = 91.1876 \pm 0.0021 \text{ GeV} \]  (PDG2010)

**probable legacy plots/numbers**

Practical end of HERA xg sensitivity
What HERA could not do or has not done

**HERA** in one box

**the first ep collider**

\[ E_p \times E_e = 920 \times 27.6 \text{GeV}^2 \]

\[ \sqrt{s} = 2V E_e E_p = 320 \text{ GeV} \]

\[ L = 1 \times 4 \times 10^{31} \text{cm}^{-2}\text{s}^{-1} \]

\[ \Sigma L = 0.5 \text{fb}^{-1} \]


- Test of the isospin symmetry (u-d) with eD - no deuterons
- Investigation of the q-g dynamics in nuclei - no time for eA
- Verification of saturation prediction at low x – too low s
- Measurement of the strange quark distribution – too low L
- Discovery of **Higgs** in WW fusion in CC – too low cross section
- Study of **top** quark distribution in the proton – too low s
- Precise measurement of **F_L** – too short running time left
- Resolving d/u question at large Bjorken x – too low L
- Determination of **gluon distribution at hi/lo x** – too small range
- High precision measurement of \( \alpha_s \) – overall not precise enough
- Discovering **instantons, odderons** – don’t know why not
- Finding **RPV SUSY** and/or leptquarks – may reside higher up

\[ Q^2 = [0.1 -- 3 \times 10^4] \text{ GeV}^2 \]

-4-momentum transfer

\[ x = Q^2 / (sy) \approx 10^{-4} \ldots 0.7 \]

Bjorken x

\[ y = 0.005 \ldots 0.9 \]

inelasticity

The H1 and ZEUS apparatus were basically well suited
The machine had too low luminosity and running time

HEP needs a TeV energy scale machine with 100 times higher luminosity than HERA to develop DIS physics further and to complement the physics at the LHC. The **Large Hadron Collider p and A beams offer a unique opportunity to build a second ep and first eA collider at the energy frontier [discussed at DIS since Madison 2005]**
60 GeV electron beam energy, $L = 10^{33} \text{ cm}^{-2}\text{s}^{-1}$, $\sqrt{s} = 1.3 \text{ TeV}$: $Q_{\text{max}}^2 \leq 10^6 \text{ GeV}^2$, $10^{-6} < x < 1$.

Recirculating linac (2 * 1km, 2*60 cavity cryo modules, 3 passes, $P < 100 \text{ MW}$, ERL)
Two 10 GeV energy recovery Linacs, 3 returns, 720 MHz cavities
Published 600 pages conceptual design report (CDR) written by 200 authors from 60 Institutes and refereed by 24 world experts on physics, accelerator and detector, which CERN had invited.
“BFKL evolution and Saturation in DIS”

“Critical gravitational collapse”

Circles in a circle
V. Kandinsky, 1923
Philadelphia Museum of Art

5d tiny black holes and perturbative saturation
Talk by A.S.Vera at LHeC Workshop 2008
Project Development

2007: Invitation by SPC to ECFA and by (r)ECFA to work out a design concept

2008: First CERN-ECFA Workshop in Divonne (1.-3.9.08)

2009: 2nd CERN-ECFA-NuPECC Workshop at Divonne (1.-3.9.09)

2010: Report to CERN SPC (June)
      3rd CERN-ECFA-NuPECC Workshop at Chavannes-de-Bogis (12.-13.11.10)
      NuPECC: LHeC on Longe Range Plan for Nuclear Physics (12/10)

2011: Draft CDR (530 pages on Physics, Detector and Accelerator) (5.8.11)
      refereed and being updated

2012: Discussion of LHeC at LHC Machine Workshop (Chamonix)
      Publication of CDR + 2 Contributions to European Strategy [arXiv]
      Chavannes workshop (June14-15, 2012) – CERN: Linac+TDR Mandate
      ECFA final endorsement of CDR

http://cern.ch/lhec
LHC Schedule for the coming decade

Figure 11.1: CERN medium term plan (MTP), draft as of July 2011
as shown by S. Myers at EPS 2011 Grenoble - Principal guidance of CDR [+N years..]
Detector supported by L3 Magnet

**Installation study in CDR** (Herve, Ghaddi): 30 months for removal and installation which is compatible with LHC shutdown for HL-LHC (“LS3”)
High Precision DIS

Q² >> M_{Z,W}², high luminosity, large acceptance
Unprecedented precision in NC and CC
Contact interactions probed to 50 TeV
Scale dependence of sin²θ left and right to LEP

→ A renaissance of deep inelastic scattering ←

Solving a 40 year puzzle:
α_s small in DIS or high with jets?
Per mille measurement accuracy
Testing QCD lattice calculations
Constraining GUT (CMSSM40.2.5)
Charm mass to 3MeV, N^3LO
PDFs from **HERA+LHC** and **LHeC**

QCD fit with free u,d,s, HERA plus ultimate ATLAS and full systematic error simulation on LHeC

**DIS** is the appropriate process to determine PDFs (just compare HERA – Tevatron PDF constraints)

**LHeC**: first time ever to fully determine PDFs, free of symmetry and ad hoc assumptions in huge and unexplored kinematic range

**LHC**: precision Drell-Yan data provide constraints (cf for example the ATLAS determination of s/d)

Yet, high precision (<1%) only achievable at W,Z scale (miss the evolution) and large e/weak-QCD theory uncertainties complicate interpretation

**Direct strange measurement from charged current**

Ws→c in ep→νcX [high lumi, large range, small spot ~7μm²]
LHeC and the HL-LHC (SUSY searches)

With high energy and luminosity, the LHC search range will be extended to high masses, up to 5 TeV in pair production. At correspondingly high $x (> 0.5)$ the PDFs are unknown to a considerable extent [cf $gg$ luminosity $\rightarrow \bar{g}g$ and gluon density from LHeC (10% at $x=0.6$)]

The HL-LHC (search) programme requires a much more precise understanding of QCD, which the LHeC provides (strong coupling, gluon, valence, factorisation, saturation, diffraction..)
Higgs and LHeC

Precision measurements of couplings in WW and ZZ production (so far: bb in CC to 4%)
Measurement of CP properties (J^{PC}=0^{++} in SM; MSSM has 2 CP-even and 1 CP-odd states)
Reduction of theoretical uncertainties for pp measurements

Initial study of WW → H → bb

PGS for detector, cut based analysis, S/N =1, 500 H-bb events for 100fb^{-1}

ICHEP12: J Campbell: ultimate limitation of Higgs measurements from LHC by PDFs/QCD

With high luminosity the LHeC has a huge potential for precision Higgs physics, which is being further evaluated.
Top Quark and Leptoquarks

Leptoquarks (-gluons) are predicted in RPV SUSY, E6, extended technicolour theories or Pati-Salam.

The LHeC is the appropriate configuration to do their spectroscopy, should they be discovered at the LHC.
Heavy Ion Physics

eA physics is essentially not done yet (no eA at HERA)
LHeC has huge discovery potential for new HI physics
(bb limit, saturation, deconfinement, hadronisation..)
It will put nPDFs on completely new ground and
constrain the initial conditions of the Quark-Gluon Plasma
Saturation – Low x Physics

New phase of matter: small coupling but non-linear parton-parton interactions:

- End of DGLAP? BFKL?
- Access to 10 TeV scale SUSY via BFKL ("DP") arXiv:1205.6713 Kowalski, Lipatov, Ross
- Restoration of unitarity?
- Relevant for UHE neutrino scattering

Precision Measurements of crucial observables ($F_2, F_L, J/\psi$..)
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.

**Candidates for Surprises and Discoveries**

- PDFs ($t$, $s$, $q\cdot q$, $v$, $xg$)
- Odderon
- Instanton
- (no) saturation, QCD
- QGP initial state

**Lev Lipatov in the CDR...**

- Ultra high precision (detector, e-h redundancy)
- Maximum luminosity and much extended range
- Deep relation to (HL-) LHC (precision+range)
- Factorization pp-ep
- LQs, RPV SUSY
- e*
- Higgs CP
- $\alpha_s$ indeed small (GUT)

→ **LHeC brings a substantial enrichment of LHC physics**
Summary of LHeC Physics [arXiv:1211:4831+5102]

The LHeC represents a new laboratory for exploring a hugely extended region of phase space with an unprecedented high luminosity in high energy DIS. It builds the link to the LHC and a future pure lepton collider, similar to the complementarity between HERA and the Tevatron and LEP, yet with much higher precision in an extended energy range. Its physics is fundamentally new, and it also is complementary especially to the LHC, for which the electron beam is an upgrade. Given the broad range of physics questions, there are various ways to classify these, partially overlapping. An attempt for a schematic overview on the LHeC physics programme as seen from today is presented in Tab. 3. The conquest of new regions of phase space and intensity has often lead to surprises, which tend to be difficult to tabulate.

<table>
<thead>
<tr>
<th>QCD Discoveries</th>
<th>$\alpha_s &lt; 0.12$, $q_{sea} \neq \bar{q}$, instanton, odderon, low $x$: (n0) saturation, $\bar{u} \neq \bar{d}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higgs Substructure</td>
<td>$WW$ and $ZZ$ production, $H \rightarrow b\bar{b}$, $H \rightarrow 4l$, CP eigenstate</td>
</tr>
<tr>
<td>New and BSM Physics</td>
<td>Electromagnetic quark radius, $e^<em>, \nu^</em>$, $W^0$, $Z^0$, top?, $H^0$</td>
</tr>
<tr>
<td>Top Quark</td>
<td>Leptoquarks, RPV SUSY, Higgs CP, contact interactions, GUT through $\alpha_s$</td>
</tr>
<tr>
<td>Relations to LHC</td>
<td>Top PDF, $xt = x_lT$, single top in DIS, anomalous top</td>
</tr>
<tr>
<td>Gluon Distribution</td>
<td>SUSY, high $x$ partons and high mass SUSY, Higgs, LQs, QCD, precision PDFs</td>
</tr>
<tr>
<td>Precision DIS</td>
<td>Saturation, $x \simeq 1$, $J/\psi$, $\Upsilon$, Pomeron, local spots?, $F_L, F_2^e$</td>
</tr>
<tr>
<td>Parton Structure</td>
<td>$\delta \alpha_s \simeq 0.1%$, $\delta M_c \simeq 3$ MeV, $\nu_{u,d}$, $a_{u,d}$ to $2 - 3%$, $\sin^2 \Theta(\mu)$, $F_L, F_2^b$</td>
</tr>
<tr>
<td>Quark Distributions</td>
<td>Proton, Deuteron, Neutron, Ions, Photon</td>
</tr>
<tr>
<td>QCD</td>
<td>Valence $10^{-4} \lesssim x \lesssim 1$, light sea, $d/u$, $s = \bar{s}$?, charm, beauty, top</td>
</tr>
<tr>
<td>N$^3$LO, factorisation, resummation, emission, AdS/CFT, BFKL evolution</td>
<td></td>
</tr>
<tr>
<td>Deuteron</td>
<td>Singlet evolution, light sea, hidden colour, neutron, diffraction-shadowing</td>
</tr>
<tr>
<td>Heavy Ions</td>
<td>Initial QGP, nPDFs, hadronization inside media, black limit, saturation</td>
</tr>
<tr>
<td>Modified Partons</td>
<td>PDFs “independent” of fits, unintegrated, generalised, photonic, diffractive</td>
</tr>
<tr>
<td>HERA continuation</td>
<td>$F_L, xF_3, F_2^{\gamma Z}$, high $x$ partons, $\alpha_s$, nuclear structure, ..</td>
</tr>
</tbody>
</table>

Table 3: Schematic overview on key physics topics for investigation with the LHeC.
Accelerator Design: Participating Institutes

CERN
SLAC National Accelerator Laboratory
NTNU Norwegian University of Science and Technology
Jefferson Lab Thomas Jefferson National Accelerator Facility
ANKARA ÜNIVERSİTESİ
The Cockcroft Institute of Accelerator Science and Technology
TOBB ETU
INFN Istituto Nazionale di Fisica Nucleare
DESY
Physique des accélérateurs
EPFL École Polytechnique Fédérale de Lausanne
UNIVERSITY OF LIVERPOOL
BROOKHAVEN NATIONAL LABORATORY
KEK
SIBIRSKOE OTDelenie RAN INSTITUT YADERNOY FIZIKI
im. G.I. Budkera

630090 Novosibirsk
## LHeC Parameters

<table>
<thead>
<tr>
<th></th>
<th>Ring</th>
<th>Linac</th>
</tr>
</thead>
<tbody>
<tr>
<td>electron beam 60 GeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$e^- (e^+) \text{ per bunch } N_e [10^9]$</td>
<td>20 (20)</td>
<td>1 (0.1)</td>
</tr>
<tr>
<td>$e^- (e^+) \text{ polarisation } [%]$</td>
<td>40 (40)</td>
<td>90 (0)</td>
</tr>
<tr>
<td>bunch length [mm]</td>
<td>6</td>
<td>0.6</td>
</tr>
<tr>
<td>tr. emittance at IP $\gamma e_{x,y} [\text{ mm}]$</td>
<td>0.59, 0.29</td>
<td>0.05</td>
</tr>
<tr>
<td>IP $\beta$ function $\beta^{*}_{x,y} [\text{ m}]$</td>
<td>0.4, 0.2</td>
<td>0.12</td>
</tr>
<tr>
<td>beam current [mA]</td>
<td>100</td>
<td>6.6</td>
</tr>
<tr>
<td>energy recovery efficiency [%]</td>
<td></td>
<td>94</td>
</tr>
<tr>
<td>proton beam 7 TeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>protons per bunch $N_p [10^{11}]$</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>transverse emittance $\gamma e_{x,y} [\mu m]$</td>
<td>3.75</td>
<td>3.75</td>
</tr>
<tr>
<td>collider</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lum $e^- p (e^+ p) [10^{32}\text{cm}^{-2}\text{s}^{-1}]$</td>
<td>9 (9)</td>
<td>10 (1)</td>
</tr>
<tr>
<td>bunch spacing [ns]</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>rms beam spot size $\sigma_{x,y} [\mu m]$</td>
<td>45, 22</td>
<td>7</td>
</tr>
<tr>
<td>crossing angle $\theta [\text{mrad}]$</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$L_{eN} = A L_{eA} [10^{32}\text{cm}^{-2}\text{s}^{-1}]$</td>
<td>0.45</td>
<td>1</td>
</tr>
</tbody>
</table>

### Source

<table>
<thead>
<tr>
<th>Power [MW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryogenics (linac)</td>
</tr>
<tr>
<td>Linac grid power</td>
</tr>
<tr>
<td>SR compensation</td>
</tr>
<tr>
<td>Extra RF cryopower</td>
</tr>
<tr>
<td>Injector</td>
</tr>
<tr>
<td>Arc magnets</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

**CDR:** Two options for electron beam: Ring or (Racetrack) Linac with E-recovery for $L > 10^{33}\text{cm}^{-2}\text{s}^{-1}$ Synchronous operation of pp and ep in HL-LHC phase. e Ring required bypassing pp experiments.
Civil engineering studied and reviewed by CH company Amber, both for ring and for linac options. Bypass in ring option used to house rf. ~4 years of installation.

Quite some interference with LHC: cryo jumpers (asymmetric FODO), connection of bypasses, access to LHC, proton dump area (point 3), RF (point 4), .. Cf CDR

June workshop, after CDR: RR not preferred, design LR
Two 1km long LINACs connected at CERN territory
Arcs of 1km radius: ~9km tunnel
3 passages with energy recovery
Civil Engineering until 2015

CDR: Evaluation of CE, analysis of ring and linac by Amber Zurich with detailed cost estimate ([linac CE: 249,928 kSF..] and time: 3.5 years for underground works using 2 roadheaders and 1 TBM)

More studies needed for Integration with all services (EL, CV, transport, survey etc). Geology Understanding vibration risks Environmental impact assessment

Tunnel connection in IP2

J. Osborne, Chavannes
### Components and Cryogenics

#### Chapter 9 of CDR

**9 System Design**

9.1 Magnets for the Interaction Region  
9.1.1 Introduction  
9.1.2 Magnets for the ring-ring option  
9.1.3 Magnets for the linac-ring option  
9.2 Accelerator Magnets  
9.2.1 Dipole Magnets  
9.2.2 BINP Model  
9.2.3 CERN Model  
9.2.4 Quadrupole and Corrector Magnets  
9.3 Ring-Ring RF Design  
9.3.1 Design Parameters  
9.3.2 Cavities and klystrons  
9.4 Linac-Ring RF Design  
9.4.1 Design Parameters  
9.4.3 Arc RF systems  
9.5 Crab crossing for the LHeC  
9.5.1 Luminosity Reduction  
9.5.2 Crossing Schemes  
9.5.3 RF Technology  
9.6 Vacuum  
9.6.1 Vacuum requirements  
9.6.2 Synchrotron radiation  
9.6.3 Vacuum engineering issues  
9.7 Beam Pipe Design  
9.7.1 Requirements  
9.7.3 Beampipe Geometries  
9.7.4 Vacuum instrumentation  
9.7.5 Synchrotron Radiation Masks  
9.7.6 Installation and Integration  
9.8 Cryogenics  
9.8.1 Ring-Ring Cryogenics Design  
9.8.2 Linac-Ring Cryogenics Design  
9.8.3 General Conclusions Cryogenics for LHeC  
9.9 Beam Dumps and Injection Regions  
9.9.1 Injection Region Design for Ring-Ring Option  
9.9.2 Injection transfer line for the Ring-Ring Option  
9.9.3 60 GeV internal dump for Ring-Ring Option  
9.9.4 Post collision line for 140 GeV Linac-Ring option  
9.9.5 Absorber for 140 GeV Linac-Ring option  
9.9.6 Energy deposition studies for the Linac-Ring option  
9.9.7 Beam line dump for ERL Linac-Ring option  
9.9.8 Absorber for ERL Linac-Ring option

<table>
<thead>
<tr>
<th></th>
<th>Ring</th>
<th>Linac</th>
</tr>
</thead>
<tbody>
<tr>
<td>magnets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>number of dipoles</td>
<td>3080</td>
<td>3504</td>
</tr>
<tr>
<td>dipole field [T]</td>
<td>0.013 – 0.076</td>
<td>0.046 – 0.264</td>
</tr>
<tr>
<td>number of quadrupoles</td>
<td>968</td>
<td>1514</td>
</tr>
<tr>
<td>RF and cryogenics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>number of cavities</td>
<td>112</td>
<td>960</td>
</tr>
<tr>
<td>gradient [MV/m]</td>
<td>11.9</td>
<td>20</td>
</tr>
<tr>
<td>linac grid power [MW]</td>
<td>49</td>
<td>23</td>
</tr>
<tr>
<td>synchrotron loss compensation [MW]</td>
<td>5</td>
<td>20.8</td>
</tr>
<tr>
<td>cavity voltage [MV]</td>
<td>114</td>
<td>285</td>
</tr>
<tr>
<td>cavity R/Q [Ω]</td>
<td>5.4@4.2 K</td>
<td>30@2 K</td>
</tr>
</tbody>
</table>

Jlab: $4 \times 10^{11}$

![Diagram showing 5-cell 721 MHz cavities in individual 2 K bath]

**Need to develop LHeC cavity (cryo-module)**

Systems will consist of a complex task. Further cavities and cryomodules will require a limited R&D program. From this we expect improved quality factors with respect to today's state of the art. The cryogenics of the L-R version consists of a formidable engineering challenge, however, it is feasible and, CERN disposes of the respective know-how.

*from CDR LHeC*
The mandate for the technology development includes studies and prototyping of the following key technical components:

- Superconducting RF system for CW operation in an Energy Recovery Linac, (high Q0 for efficient energy recovery). The studies require design and prototyping of the cavity, couplers and cryostat.
- Superconducting magnet development of the insertion regions of the LHeC with three beams. The studies require the design and construction of short magnet models.
- Studies related to the experimental beam pipes with large beam acceptance in a high synchrotron radiation environment.
- The design and specification of an ERL test facility for the LHeC.
- The finalization of the ERL design for the LHeC including a finalization of the optics design, beam dynamic studies and identification of potential performance limitations.

The above technological developments require close collaboration between the relevant technical groups at CERN and external collaborators.

Given the rather tight personnel resource conditions at CERN the above studies should exploit where possible synergies within existing CERN studies (e.g. SPL and ESS SC RF, HL-LHC triplet magnet development and collaboration with ERL test facility outside CERN).
RF Development

Frequency choice: \( n \times 120.237 \text{ MHz} \)
\( N=6: \ 721 \text{ MHz}, \ n=11: \ 1.3\text{GHz} \ (\text{XFEL}) \)

- Detailed comparison (threshold current, cryo power, Rf power, size, cost, collaboration, synergy..)

- ALICE 1.3 GHz, not CW – only EU ERL facility operational
- Daresbury develops cryomodule for ESS (700 MHz)
- CERN: in house collaboration with SPL, and eRHIC/BNL

Accelerator physics motivation:
- ERL demonstration, FEL, \( \gamma \)-ray source, e-cooling demo!
- Ultra-short electron bunches
- One of the 1\(^{st}\) low-frequency, multi-pass SC-ERL
  synergy with SPL/ESS and BNL activities
- High energies (200 ... 400 MeV) & CW
- Multi-cavity cryomodule layout – validation and gymnastics
- Two-Linac layout (similar to LHeC)
- MW class power coupler tests in non-ER mode
- Complete HOM characterization and instability studies!
- Cryogenics & instrumentation test bed ... E.Jensen

Steps: Design of LHeC ERL TF, cavity-cryo module (hi Q),
lattice, optics, magnets, source, ....
Watch out for surprises as humming bird:
Building international collaboration
(CERN,Daresbury, Jlab, others?)

beam structure at ALICE with 230-kv DC gun voltage
LHeC - ERL-TF

Tentative study of multipass optics and lattice

Development of LHeC Testfacility at CERN in international collaboration (ASTeC, Jlab, +)
Magnets Developments

Prototypes for Ring dipoles
Fabricated and tested by CERN (top) and Novosibirsk

Magnet parameters:
- Flux density in the gaps: 0.264 T, 0.176 T, 0.088 T
- Magnetic length: 4.0 m
- Vertical aperture: 25 mm
- Pole width: 85 mm
- Number of magnets: 584
- Current: 1750 A
- Number of turns per aperture: 1/2/3
- Current density: 0.7 A/mm²
- Conductor material: Copper
- Resistance: 0.36 mΩ
- Power: 1.1 kW
- Total power: 20/40/60 GeV, 642 kW
- Cooling: Air

LR recirculator dipoles and quadrupoles
New requirements (aperture, field)?
Combined apertures?
Combined functions (for example, dipole + quad)?
LR linac quadrupoles and correctors
New requirements (aperture, field)?
More compact magnets, maybe with at least two families for quadrupoles?
Permanent magnets / superconducting for quads?
A. Milanese, Chavannes workshop

1/2m dipole model
Full scale prototype
Quadrupole for Linac

Magnets for ERL test stand

Collaboration of CERN, Daresbury and Budker (Novosibirsk)
Interaction Region Developments

Have optics compatible with LHC and $\beta^* = 0.1\text{m}$
Head-on collisions mandatory $\rightarrow$
High synchrotron radiation load, dipole in detector

**Specification of Q1 – NbTi prototype (with KEK?)**
Revisit SR (direct and backscattered),
Masks+collimators
Beam-beam dynamics and 3 beam operation studies

Optimisation: HL-LHC uses IR2 quads to squeeze IR1
("ATS" achromatic telescopic squeeze) Start in IR3.? R.Tomas et al.

Beam pipe: in CDR 6m, Be, ANSYS calculations

Composite material R+D, prototype, support.. $\rightarrow$ Essential for tracking, acceptance and Higgs
Forward/backward asymmetry in energy deposited and thus in geometry and technology

Present dimensions: \( L \times D = 14 \times 9 \text{m}^2 \) [CMS 21 x 15 m\(^2\), ATLAS 45 x 25 m\(^2\)]

Taggers at -62 m (\( e \)), 100 m (\( \gamma, \text{LR} \)), -22.4 m (\( \gamma, \text{RR} \)), +100 m (\( n \)), +420 m (\( p \))
Detector Magnets

Figure 13.13: Magnetic field of the magnet system of solenoid and the two internal superconducting dipoles at nominal currents (effect of iron ignored). The position of the peak magnetic field of 3.9 T is local due to the adjacent current return heads on top of the solenoid where all magnetic fields add up.

Dipole (for head on LR) and solenoid in common cryostat, perhaps with electromagnetic LAr

3.5 T field at ~1m radius to house a Silicon tracker

Based on ATLAS+CMS experience

<table>
<thead>
<tr>
<th>Property</th>
<th>Parameter</th>
<th>value</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td>Cryostat inner radius</td>
<td>0.900</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>10.000</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>Outer radius</td>
<td>1.140</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>Coil windings inner radius</td>
<td>0.960</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>5.700</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>Thickness</td>
<td>60.0</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td>Support cylinder thickness</td>
<td>0.030</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>Conductor section, Al-stabilized NbTi/Cu + insulation</td>
<td>30.0</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>10.8</td>
<td>km</td>
</tr>
<tr>
<td></td>
<td>Superconducting cable section, 20 strands</td>
<td>12.4</td>
<td>mm²</td>
</tr>
<tr>
<td></td>
<td>Superconducting strand diameter Cu/NbTi ratio = 1.25</td>
<td>1.24</td>
<td>mm²</td>
</tr>
<tr>
<td></td>
<td>Conductor windings</td>
<td>5.7</td>
<td>t</td>
</tr>
<tr>
<td>Masses</td>
<td>Support cylinder, solenoid section + dipole sections</td>
<td>5.6</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td>Total cold mass</td>
<td>12.8</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td>Cryostat including thermal shield</td>
<td>11.2</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td>Total mass of cryostat, solenoid and small parts</td>
<td>24.0</td>
<td>t</td>
</tr>
<tr>
<td>Electromagnetics</td>
<td>Central magnetic field</td>
<td>3.50</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Peak magnetic field in windings (dipoles off)</td>
<td>3.53</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Peak magnetic field in solenoid windings (dipoles on)</td>
<td>3.9</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Nominal current</td>
<td>10.0</td>
<td>kA</td>
</tr>
<tr>
<td></td>
<td>Number of turns, 2 layers</td>
<td>1683</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>Self-inductance</td>
<td>1.7</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>Stored energy</td>
<td>82.0</td>
<td>MJ</td>
</tr>
<tr>
<td></td>
<td>E/m, energy-to-mass ratio of windings</td>
<td>14.2</td>
<td>kJ/kg</td>
</tr>
<tr>
<td></td>
<td>E/m, energy-to-mass ratio of cold mass</td>
<td>9.2</td>
<td>kJ/kg</td>
</tr>
<tr>
<td></td>
<td>Charging time</td>
<td>1.0</td>
<td>hour</td>
</tr>
<tr>
<td></td>
<td>Current rate</td>
<td>2.8</td>
<td>A/s</td>
</tr>
<tr>
<td></td>
<td>Inductive charging voltage</td>
<td>2.3</td>
<td>V</td>
</tr>
<tr>
<td>Margins</td>
<td>Coil operating point, nominal / critical current</td>
<td>0.3</td>
<td>K</td>
</tr>
<tr>
<td></td>
<td>Temperature margin at 4.6 K operating temperature</td>
<td>2.0</td>
<td>K</td>
</tr>
<tr>
<td></td>
<td>Cold mass temperature at quench (no extraction)</td>
<td>~80</td>
<td>K</td>
</tr>
<tr>
<td>Mechanics</td>
<td>Mean hoop stress</td>
<td>~55</td>
<td>MPa</td>
</tr>
<tr>
<td></td>
<td>Peak stress</td>
<td>~85</td>
<td>MPa</td>
</tr>
<tr>
<td>Cryogenics</td>
<td>Thermal load at 4.6 K, coil with 50% margin</td>
<td>~110</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>Radiation shield load width 50% margin</td>
<td>~650</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>Cooling down time / quench recovery time</td>
<td>4 day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use of liquid helium</td>
<td>~1.5</td>
<td>g/s</td>
</tr>
</tbody>
</table>

Table 13.1: Main parameters of the baseline LHeC Solenoid providing 3.5 T in a free bore of 1.8 m.
Silicon Tracker and EM Calorimeter

Transverse momentum $\Delta p_t/p_t^2 \rightarrow 6 \times 10^{-4}$ GeV$^{-1}$
transverse impact parameter $\rightarrow 10 \mu$m

Central Pixel Tracker
- 4 layer CPT:
  - min-inner-R = 3.1 cm
  - max-inner-R = 10.9 cm
  - $\Delta R = 15.0$ cm

Central Si Tracker
- CST - $\Delta R$ 3.5 cm each
  - 1. layer: inner R = 21.2 cm
  - 2. layer: = 25.6 cm
  - 3. layer: = 31.2 cm
  - 4. layer: = 36.7 cm
  - 5. layer: = 42.7 cm

Central Forward/Backward Tracker
- 4 CFT/CBT
  - min-inner-R = 3.1 cm, max-inner-R = 10.9 cm

Forward Si Tracker
- FST - $\Delta Z$= 8.0 cm
  - min-inner-R = 3.1 cm; max-inner-R= 10.9 cm
  - outer R = 46.2 cm
  - Planes 1-5:
    - $z_{1,5} = 370. / 330. / 265. / 190. / 130. cm$

Backward Si Tracker
- BST - $\Delta Z$= 8.0 cm
  - min-inner-R = 3.1 cm; max-inner-R= 10.9 cm
  - outer R = 46.2 cm
  - Planes 1-3:
    - $z_{1,3} = -130. / -170. / -200. cm$

Figure 13.18: Tracker and barrel Electromagnetic-Calorimeter rz view of the baseline detector (Linac-Ring case).

LHeC-LHC: no pile-up, less radiation, smaller momenta apart from forward region
Liquid Argon Electromagnetic Calorimeter

Inside Coil H1, ATLAS experience.

Barrel: Pb, 20 $X_0$, 11$\text{m}^3$

fwd/bwd inserts:
FEC: Si -W, 30 $X_0$, 0.3$m^3$

BEC: Si -Pb, 25 $X_0$, 0.3$m^3$

Figure 13.30: $x$-$y$ and $r$-$z$ view of the LHeC Barrel EM calorimeter (green).

Figure 13.35: View of the parallel geometry accordion calorimeter (left) and simulation of a single electron shower with initial energy of 20 GeV (right).

GEANT4 Simulation

Figure 13.36: LAr accordion calorimeter energy resolution for electrons between 10 and 400 GeV.
Hadronic Tile Calorimeter

<table>
<thead>
<tr>
<th>E-Calo Parts</th>
<th>FEC1</th>
<th>FEC2</th>
<th>EMC</th>
<th>BEC2</th>
<th>BEC1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. Inner radius $R$ [cm]</td>
<td>3.1</td>
<td>21</td>
<td>48</td>
<td>21</td>
<td>3.1</td>
</tr>
<tr>
<td>Min. polar angle $\theta$ [°]</td>
<td>0.48</td>
<td>3.2</td>
<td>6.6/168.9</td>
<td>174.2</td>
<td>179.1</td>
</tr>
<tr>
<td>Max. pseudorapidity $\eta$</td>
<td>5.5</td>
<td>3.6</td>
<td>2.8/-2.3</td>
<td>-3</td>
<td>-4.8</td>
</tr>
<tr>
<td>Outer radius [cm]</td>
<td>20</td>
<td>46</td>
<td>88</td>
<td>46</td>
<td>20</td>
</tr>
<tr>
<td>z-length [cm]</td>
<td>40</td>
<td>40</td>
<td>660</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Volume $[m^3]$</td>
<td>0.3</td>
<td></td>
<td>11.3</td>
<td></td>
<td>0.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>H-Calo Parts barrel</th>
<th>FHC4</th>
<th>HAC</th>
<th>BHC4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner radius [cm]</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Outer radius [cm]</td>
<td>260</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>z-length [cm]</td>
<td>217</td>
<td>580</td>
<td>157</td>
</tr>
<tr>
<td>Volume $[m^3]$</td>
<td></td>
<td>121.2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>H-Calo Parts Inserts</th>
<th>FHC1</th>
<th>FHC2</th>
<th>FHC3</th>
<th>BHC3</th>
<th>BHC2</th>
<th>BHC1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. inner radius $R$ [cm]</td>
<td>11</td>
<td>21</td>
<td>48</td>
<td>48</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td>Min. polar angle $\theta$ [°]</td>
<td>0.43</td>
<td>2.9</td>
<td>6.6</td>
<td>169</td>
<td>175.2</td>
<td>179.3</td>
</tr>
<tr>
<td>Max/min pseudorapidity $\eta$</td>
<td>5.6</td>
<td>3.7</td>
<td>2.9</td>
<td>-2.4</td>
<td>-3.2</td>
<td>-5</td>
</tr>
<tr>
<td>Outer radius [cm]</td>
<td>20</td>
<td>46</td>
<td>88</td>
<td>88</td>
<td>46</td>
<td>20</td>
</tr>
<tr>
<td>z-length [cm]</td>
<td>177</td>
<td>177</td>
<td>177</td>
<td>117</td>
<td>117</td>
<td>117</td>
</tr>
<tr>
<td>Volume $[m^3]$</td>
<td>4.2</td>
<td></td>
<td>2.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 13.6: Summary of calorimeter dimensions.
The electromagnetic barrel calorimeter is currently represented by the barrel part EMC (LiAr-Pb module); the setup reaches $X_0 \approx 25$ radiation length) and the movable inserts forward FEC1, FEC2 (Si-W modules ($X_0 \approx 30$) and the backward BEC1, BEC2 (Si-Pb modules; $X_0 \approx 25$).
The hadronic barrel parts are represented by FHC4, HAC, BHC4 (forward, central and backward - Scintillator-Fe Tile modules; $\lambda_f \approx 8$ interaction length) and the movable inserts FHC1, FHC2, FHC3 (Si-W modules; $\lambda_f \approx 10$), BHC1, BHC2, BHC3 (Si-Cu modules, $\lambda_f \approx 8$) see Fig. 13.9.

Outside Coil: flux return
Modular. ATLAS experience.

Combined GEANT4 Calorimeter Simulation

3.37: Accordion and Tile Calorimeter energy resolution for pions with and without 14cm Al block.
Schematic layouts for several potential future projects are shown on this Google Earth view of the Geneva region around CERN:

- CLIC (Compact Linear Collider) at collision energies of 500 GeV and 3 TeV.
- ILC (International Linear Collider) at 500 GeV energy.
- The Linear-Ring Solution of LHeC (A new, electron beam supplied via a 60 GeV
The LHeC is an upgrade of the LHC, to operate with it, and not the next world project.
Summary

The LHeC has a unique physics programme (QCD, Higgs, BSM, HI). It has a rich synergy with the LHC, SPL, ESS.. and links NP and PP. The now published design report moved the dream of a TeV scale electron-hadron collider to the “real axis” (SB). It can be done. The LHeC is the only new collider for CERN which can live with the LHC.

Many thanks to CERN, NuPECC, ECFA and to the expanding LHeC Group

"Energy frontier, Precision, QCD, QGP"
Tatsuya Nakada
Cracow 9/12 ESG
Backup slides
ATLAS Higgs projections

\[ \sqrt{s} = 14 \text{ TeV}: \int L dt = 300 \text{ fb}^{-1}; \int L dt = 3000 \text{ fb}^{-1} \]

\[ \Delta(\sigma \cdot \text{BR}) / \sigma \cdot \text{BR} \]

\[ \Delta(\Gamma_x / \Gamma_y) / \Gamma_x / \Gamma_y \]

ATL-PHYS-PUB-2012-001

Updated in October 2012
### Precision Measurements

<table>
<thead>
<tr>
<th>source of uncertainty</th>
<th>error on the source or cross section</th>
</tr>
</thead>
<tbody>
<tr>
<td>scattered electron energy scale $\Delta E'_e/E'_e$</td>
<td>0.1 %</td>
</tr>
<tr>
<td>scattered electron polar angle</td>
<td>0.1 mrad</td>
</tr>
<tr>
<td>hadronic energy scale $\Delta E_h/E_h$</td>
<td>0.5 %</td>
</tr>
<tr>
<td>calorimeter noise (only $y &lt; 0.01$)</td>
<td>1-3 %</td>
</tr>
<tr>
<td>radiative corrections</td>
<td>0.5%</td>
</tr>
<tr>
<td>photoproduction background (only $y &gt; 0.5$)</td>
<td>1%</td>
</tr>
<tr>
<td>global efficiency error</td>
<td>0.7 %</td>
</tr>
</tbody>
</table>

Table 2: Assumptions used in the simulation of the NC cross sections on the size of uncertainties from various sources. These assumptions correspond to typical best values achieved in the H1 experiment. The total cross section error due to these uncertainties, e.g. for $Q^2 = 100 \text{GeV}^2$, is about 1.2, 0.7 and 2.0 % for $y = 0.84$, 0.1, 0.004.
linac e\(^+\) source options

- recycle e\(^+\) together with energy, multiple use, damping ring in SPS tunnel with \(\tau_\perp \sim 2 \text{ ms}\)  
  (D. Schulte)  
  (Y. Papaphilippou)

- Compton ring, Compton ERL, coherent pair production, or undulator for high-energy beam

- 3-ring transformer & cooling scheme
  (H. Braun, E. Bulyak, T. Omori, V. Yakimenko)

![Diagram](attachment:diagram.png)

- extraction ring (\(N\) turns)
- fast cooling ring (\(N\) turns)
- accumulator ring (\(N\) turns)

(E. Bulyak)
## ERL Test Facilities

<table>
<thead>
<tr>
<th>IHEP ERL-TF</th>
<th>HZB BERLinPro</th>
<th>BINP</th>
<th>Peking FEL</th>
<th>BNL ERL-TF</th>
<th>KEK cERL</th>
<th>Daresbury ALICE</th>
<th>JAERI</th>
<th>CERN ERL-TF</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 MeV</td>
<td>100 MeV</td>
<td>11-40 MeV</td>
<td>30 MeV</td>
<td>20 MeV</td>
<td>245 MeV</td>
<td>10 MeV</td>
<td>17 MeV</td>
<td>300 MeV</td>
</tr>
<tr>
<td>1.3 GHz 9 cell</td>
<td>1.3 GHz</td>
<td>180 MHz</td>
<td>1.3 GHz 9-cell</td>
<td>704 MHz 5-cell</td>
<td>1.3 GHz 9-cell</td>
<td>1.3 GHz 9-cell</td>
<td>500 MHz</td>
<td>721 MHz 2x4x5 cell</td>
</tr>
<tr>
<td>10 mA</td>
<td>100 mA</td>
<td>30 mA</td>
<td>50 mA</td>
<td>50-500 mA</td>
<td>10-100 mA</td>
<td>13 µA</td>
<td>5-40 mA</td>
<td>2-6 mA</td>
</tr>
<tr>
<td>60 pC</td>
<td>10-77 pC</td>
<td>0.9-2.2 nC</td>
<td>60 pC</td>
<td>0.5-5 nC</td>
<td>77 pC</td>
<td>80 pC</td>
<td>400 pC</td>
<td>500 pC</td>
</tr>
<tr>
<td>1 pass</td>
<td>1-2 pass</td>
<td>4 passes</td>
<td>1 pass</td>
<td>1 pass</td>
<td>2 passes</td>
<td>1 pass</td>
<td>1 pass</td>
<td>2 passes</td>
</tr>
<tr>
<td>under construction</td>
<td>planned / construction</td>
<td>operating</td>
<td>under construction</td>
<td>under construction</td>
<td>operating</td>
<td>operating</td>
<td>first ideas</td>
<td></td>
</tr>
</tbody>
</table>

---

E.Jensen
CDR - Time Schedule*)

Detector installation study for IP2, reuse of L3 magnet as support for LHeC. Estimated 30 months

LHeC is to operate synchronous with HL-LHC

LS3 requires 2-3 years for ATLAS+. It is the one extended time period, which will allow installation and connection of LHeC

*) LS3 → schedule most likely shifted by +2 years
In-medium Hadronisation

The study of particle production in eA (fragmentation functions and hadrochemistry) allows the study of the space-time picture of hadronisation (the final phase of QGP).

Low energy ($\nu$): need of hadronization inside.
Parton propagation: $p_t$ broadening
Hadron formation: attenuation

High energy ($\nu$): partonic evolution altered in the nuclear medium.

LHeC:
+ study the transition from small to high energies in much extended range wrt. fixed target data
+ testing the energy loss mechanism crucial for understanding of the medium produced in HIC
+ detailed study of heavy quark hadronisation ...
High-gradient SC IR quadrupoles based on Nb₃Sn for colliding proton beam with common low-field

**Table: Quadrupoles Specifications**

<table>
<thead>
<tr>
<th>Quadrupole Type</th>
<th>Length (μm)</th>
<th>Gradient (T/m)</th>
<th>Field (T) at 8% LL</th>
<th>Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nb₃Sn (HFM46)</td>
<td>46 mm (half) ap.</td>
<td>0.5 T, 25 T/m</td>
<td>0.09 T, 9 T/m</td>
<td>23 mm ap., 87 mm beam sep.</td>
</tr>
<tr>
<td>Nb₃Sn (HFM46)</td>
<td>8600 A, 311 T/m</td>
<td>0.09 T, 9 T/m</td>
<td>0.09 T, 9 T/m</td>
<td>23 mm ap., 87 mm beam sep.</td>
</tr>
</tbody>
</table>

As shown by F. Zimmermann at Chamonix12
LHeC Study Group

J. Abelleira Fernandez$^{10,15}$, C. Adolphsen$^{39}$, S. Alekhin$^{40,11}$, A.N. Akai$^{01}$, H. Aksakal$^{30}$, P. Allport$^{17}$, J.L. Albacete$^{37}$, V. Andreev$^{25}$, R.B. Appleby$^{23}$, E. Arikian$^{30}$, N. Armesto$^{38}$, G. Azuelos$^{26}$, M. Bai$^{47}$, D. Barber$^{11,17,23}$, J. Bartels$^{12}$, J. Behr$^{11}$, O. Behnke$^{11}$, S. Belyaev$^{10}$, I. BenZvi$^{47}$, N. Bernard$^{16}$, S. Bertolucci$^{10}$, S. Bettoni$^{10}$, S. Biswal$^{32}$, J. Bluemlein$^{11}$, H. Boettcher$^{11}$, H. Braun$^{48}$, S. Brodsky$^{39}$, A. Bogacz$^{28}$, C. Bracco$^{10}$, O. Bruening$^{10}$, E. Bulyak$^{08}$, A. Bunyatian$^{11}$, H. Burkhardt$^{10}$, I.T. Cakir$^{54}$, O. Cakir$^{53}$, R. Calaga$^{47}$, E. Ciapala$^{10}$, R. Ciftci$^{01}$, A.K. Ciftci$^{01}$, B.A. Cole$^{29}$, J.C. Collins$^{46}$, J. Dainton$^{17}$, A. De Roeck$^{10}$, D. d’Enterria$^{10}$, A. Dudarev$^{10}$, A. Eide$^{43}$, R. Enberg$^{58}$, E. Ergol$^{45}$, K.J. Eskola$^{14}$, L. Favart$^{06}$, M. Fitterer$^{10}$, S. Forte$^{24}$, P. Gambino$^{42}$, T. Gehrmann$^{50}$, C. Glasman$^{22}$, R. Godbole$^{27}$, B. Goddard$^{10}$, T. Greenshaw$^{17}$, A. Guffanti$^{09}$, V. Guzev$^{28}$, C. Gwenlan$^{34}$, T. Han$^{36}$, Y. Hao$^{47}$, F. Haug$^{10}$, W. Herr$^{10}$, B. Holzer$^{10}$, M. Ishitsuka$^{41}$, M. Jacquet$^{33}$, B. Jeanneret$^{10}$, J.M. Jimenez$^{10}$, H. Jung$^{11}$, J.M. Jowett$^{10}$, H. Karadeniz$^{54}$, D. Kayran$^{47}$, F. Kocac$^{45}$, A. Kilic$^{45}$, K. Kimura$^{41}$, M. Klein$^{17}$, U. Klein$^{17}$, T. Kluge$^{17}$, G. Kramer$^{12}$, M. Korostelev$^{23}$, A. Kosmicki$^{10}$, P. Kostka$^{11}$, H. Kowalski$^{11}$, D. Kuchler$^{10}$, M. Kuze$^{41}$, T. Lappi$^{14}$, P. Laycock$^{17}$, E. Levichev$^{31}$, S. Levonian$^{11}$, V.N. Litvinenko$^{47}$, A. Lombardi$^{10}$, C. Marquet$^{10}$, B. Mellado$^{07}$, K.H. Mess$^{10}$, A. Milanese$^{10}$, S. Moch$^{11}$, I.I. Morozov$^{31}$, Y. Muttoni$^{10}$, S. Myers$^{10}$, S. Nandi$^{26}$, P.R. Newman$^{03}$, T. Omori$^{44}$, J. Osborne$^{10}$, Y. Papaphilippou$^{10}$, E. Paoloni$^{35}$, C. Pascaud$^{33}$, H. Paukku$^{38}$, E. Perez$^{10}$, T. Piiloni$^{15}$, E. Pilicer$^{45}$, B. Pire$^{55}$, A. Polini$^{04}$, V. Ptitsyn$^{47}$, Y. Pupkov$^{31}$, V. Radescu$^{13}$, S. Raychaudhuri$^{27}$, L. Rinolfi$^{10}$, R. Rohini$^{27}$, J. Rojo$^{24}$, S. Russenschuch$^{10}$, C.A. Salgado$^{38}$, K.J. Sampeil$^{41}$, R. Sassot$^{57}$, E. Sauvan$^{19}$, M. Sahin$^{01}$, U. Schneekloth$^{11}$, T. Schoerner Sadenius$^{11}$, D. Schulte$^{10}$, A.N. Skrinsky$^{31}$, W. Smith$^{20}$, H. Spiesberger$^{21}$, A.M. Stasto$^{46}$, M. Strikman$^{46}$, M. Sullivan$^{39}$, B. Surrow$^{05}$, S. Sultansoy$^{01}$, Y.P. Sun$^{39}$, L. Szymanski$^{56}$, I. Tapan$^{45}$, P. Taels$^{02}$, E. Tassi$^{52}$, H. Ten Kate$^{10}$, J. Terron$^{22}$, H. Thiesen$^{10}$, L. Thompson$^{23}$, K. Tokushuk$^{44}$, R. Tomas. Garcia$^{10}$, D. Tommasini$^{10}$, D. Trbojevic$^{47}$, N. Tsoupas$^{47}$, J. Tuckmantel$^{10}$, S. Turkoz$^{53}$, K. Tywoniuk$^{18}$, G. Unel$^{10}$, J. Urakawa$^{44}$, P. Van Mechelen$^{02}$, A. Variola$^{37}$, R. Veness$^{10}$, A. Vivoli$^{10}$, P. Vobly$^{31}$, R. Wallny$^{51}$, S. Wallon$^{59}$, G. Watt$^{10}$, G. Weiglein$^{12}$, C. Weiss$^{28}$, U.A. Wiedemann$^{10}$, U. Wienands$^{39}$, F. Willeke$^{47}$, V. Yakimenko$^{47}$, A.F. Zarnecki$^{49}$, F. Zimmermann$^{10}$, F. Zomer$^{33}$

About 180 Experimentalists and Theorists from 60 Institutes

Tentative list of those who contributed to the CDR

Supported by
CERN, ECFA, NuPECC

http://cern.ch/lhec
Topics of joint interest and priority
Meeting ASTEC/CI 5.9.12 at CERN

Electron source for TF
Design of IR, Optics for p beams, synrad tracking
Test facility design (OPAC fellow)
Sc cavity design, coupler, HOM damper, tuner..
Instrumentation for TF...
With only somewhat reduced priority: beam dynamics, positron source, magnets..

Preparation of MoU, with view also to other partners

The LHeC represents a unique opportunity for the Daresbury Campus (ASTEC and CI), but also for the wider UK accelerator community (A.Seryi co-author of CDR) to be at the forefront of accelerator developments, building on their unique expertise, a very welcome strong expression of interest, and its strong links to Universities, CERN and industry.

Deepa Angal-Kalinin\textsuperscript{1}, Robert Appleby\textsuperscript{5}, Ian Bailey\textsuperscript{3}, Steve Buckley\textsuperscript{1}, Graeme Burt\textsuperscript{3}, Neil Bliss\textsuperscript{2}, Swapan Chattopadhyay\textsuperscript{3,4,5}, Jim Clarke\textsuperscript{1}, Peter Corlett\textsuperscript{1}, Philippe Goudket\textsuperscript{1}, Andy Goulden\textsuperscript{1}, Joe Herbert\textsuperscript{1}, Kai Hock\textsuperscript{4}, Frank Jackson\textsuperscript{1}, Steve Jamison\textsuperscript{1}, James Jones\textsuperscript{1}, Lee Jones\textsuperscript{1}, Alexander Kalinin\textsuperscript{1}, Oleg Malyshnev\textsuperscript{1}, Neil Marks\textsuperscript{1}, Peter McIntosh\textsuperscript{1}, Julian McKenzie\textsuperscript{1}, Keith Middleman\textsuperscript{1}, Boris Militsyn\textsuperscript{1}, Andy Moss\textsuperscript{1}, Bruno Muratori\textsuperscript{1}, David Newton\textsuperscript{4}, Tim Noakes\textsuperscript{1}, Shrikant Pallalwar\textsuperscript{1}, Yuri Saveliev\textsuperscript{1}, Ben Shepherd\textsuperscript{1}, Susan Smith\textsuperscript{1}, Rob Smith\textsuperscript{1}, Trina Thakker\textsuperscript{1}, Luke Thompson\textsuperscript{5}, Reza Valizadeh\textsuperscript{1}, Carsten Welsch\textsuperscript{4}, Alan Wheelhouse\textsuperscript{1}, Peter Williams\textsuperscript{1}, Andy Wolski\textsuperscript{4}

\textsuperscript{1}ASTeC/STFC, \textsuperscript{2}TD/STFC, \textsuperscript{3}University of Lancaster, \textsuperscript{4}University of Liverpool, \textsuperscript{5}University of Manchester
ATLAS and LHeC Silicon Trackers

Tentative designs as of 2012

LHeC: no pile-up, less radiation, smaller momenta apart from forward region