



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

Contents

1	Foreword	Herwig Schopper	3
2	Executive Summary	Oliver Bruening, Max Klein	4
3	Introduction	Max Klein	5
4	The Large Hadron Collider at High Luminosity	Oliver Bruening	6
4.1	The Accelerator - Parameters and Timeline	Oliver Bruening	6
4.2	Physics Expectations	Monica D’Onofrio	6
5	Main Characteristics of the LHeC	Oliver Bruening, Max Klein	7
5.1	Kinematics and Reconstruction of Final States	Max Klein	7
5.1.1	Nominal Beam Energies		7
5.1.2	Reduced Electron or Proton Beam Energy		7
5.2	ERL Baseline Configuration	Frank Zimmermann	7
5.3	Choice of Electron Energy and Physics	Max Klein	7
5.4	Choice of Electron Energy and Cost	Oliver Bruening	7
5.5	Accelerator and Luminosity Parameters	Frank Zimmermann	7
5.6	Operation Schedule	Oliver Bruening	7
5.7	Summary of Acceptance, Resolution and Calibrations	Peter Kostka	7
6	Precision Standard Model Physics with LHeC	Daniel Britzger, Fred Olness	8
6.1	Resolving the Parton Substructure of the Proton	Claire Gwenlan, Fred Olness	8
6.1.1	Simulated Data	Max Klein	8
6.1.2	PDFs from early LHeC Data	Claire Gwenlan	8
6.1.3	Complete Unfolding of PDFs	Claire Gwenlan	8
6.1.4	Strange Quark Density	Mandy Cooper Sarkar	8
6.2	Discovery through Precision QCD		8
6.2.1	Strong Coupling and Grand Unification	Claire Gwenlan and Daniel Britzger	8
6.2.2	New QCD Dynamics at Small x	Anna Stasto	8
6.2.3	Pinning Down the Low x Gluon with F_2 and F_L Measurements	Max Klein	8
6.2.4	The 3D Structure of the Proton	Anna Stasto	8
6.2.5	Diffraction	Paul Newman	8
6.3	Electroweak Physics	Daniel Britzger	8
6.3.1	Neutral Current Couplings		8
6.3.2	Electroweak Parameters M_W , $\sin^2 \theta_W$, CKM		8
6.4	Top-Quark Physics	Christian Schwanenberger	8
6.4.1	Single and Pair Top Production in DIS		8
6.4.2	Wtq Couplings		8
6.4.3	FCNC Top Quark Couplings		8
6.4.4	Top Quark Measurements and Searches for New Physics		8

7	Nuclear Particle Physics with Electron-Ion Scattering at the LHeC	Nestor Armesto	9
7.1	Introduction	Anna Stasto	9
7.2	Nuclear Parton Densities	Nestor Armesto	9
7.3	Non-conventional Nuclear Partonic Structure	Anna Stasto, Paul Newman	9
7.4	New Dynamics at Small x with Nuclear Targets	Nestor Armesto	9
8	Higgs Physics with LHeC	Uta Klein, Bruce Mellado	10
8.1	Signal Strength and Couplings	Max, Uta Klein	10
8.2	Htt Coupling Measurement	Bruce Mellado	10
8.3	Higgs Decay into Invisible Particles	Masahiro Kuze	10
8.4	ep Measurement Potential in the EFT Framework	Jorge De Blas	10
9	Searches for Physics Beyond the Standard Model	Georges Azuelos, Oliver Fischer	11
9.1	Extension of the SM Higgs Sector	Oliver Fischer	11
9.2	SUSY	Monica D’Onofrio	11
9.3	Heavy Neutrinos and Feebly Interacting Particles	Oliver Fischer	11
9.4	Dark Matter and Dark Sector	Monica D’Onofrio	11
9.5	Contact Interactions and Leptoquarks	Georges Azuelos	11
9.6	Anomalous Triple Gauge Couplings	Orhan Carkir	11
10	The Influence of the LHeC on Physics at HL-LHC	Maarten Boonekamp	12
10.1	Precision Electroweak Measurements at the LHC	Maarten Boonekamp	12
10.2	Higgs Physics		12
10.2.1	Resolving QCD Uncertainties in pp Higgs Physics using LHeC	Max Klein	12
10.2.2	Combined ep and pp Higgs Coupling Determinations	Jorge De Blas	12
10.3	High Mass Searches at the LHC	Uta Klein	12
10.4	Heavy Ion Physics with eA Input	Nestor Armesto	12
11	The Electron Energy Recovery Linac	Erk Jensen, Gianluigi Arduini, Rogelio Tomas	13
11.1	Introduction - Design Goals	Gianluigi Arduini	14
11.2	The ERL Configuration of the LHeC	Alex Bogacz	14
11.2.1	Default Lattice		14
11.2.2	Lattice with one Linac		14
11.2.3	Component Summary		14
11.3	Electron-Ion Scattering	John Jowett	14
11.4	Beam-Beam Interactions	Andrea Latina, Daniel Schulte	14
11.5	Arc Magnets	Pierre Thonet, Cynthia Vallerand	14
11.6	LINAC and SRF	Erk Jensen	14
11.6.1	Choice of Frequency	Frank Marhauser	14
11.6.2	Cavity Prototype	Frank Marhauser	14
11.6.3	Dressed Cavity Design	Rama Calaga	14
11.6.4	Cavity-CryoModule	Sebastien Bousson	14
11.6.5	Sources	Boris Militsyn, Matt Poelker	14
11.6.6	Injector	Oliver Bruening	14
11.6.7	Compensation of Synchrotron Radiation Losses	Alex Bogacz	14
11.6.8	LINAC Configuration and Infrastructure	Erk Jensen	14
11.7	Interaction Region	Gianluigi Arduini, Bernhard Holzer, Rogelio Tomas	14
11.7.1	Layout	Bernhard Holzer, Rogelio Tomas	14
11.7.2	Electrons	Kevin Andre	14
11.7.3	Protons	Emilia Cruz Alanis	14
11.7.4	Triplet Magnet Design	Stefan Russenschuck, Brett Parker	14
11.8	Civil Engineering	Alexandra Tudora, John Osborne	14

12 Experimentation at the LHeC	Paul Newman, Peter Kostka	15
12.1 Introduction	Paul Newman	15
12.2 Main Detector Elements		15
12.2.1 Magnets	Hermann ten Kate	15
12.2.2 Machine-Detector Interface, Beam Pipe and Radiation	Peter Kostka	15
12.2.3 Inner Tracking	Peter Kostka	15
12.2.4 Calorimetry	Peter Kostka	15
12.2.5 Muon Detector	Alessandro Polini	15
12.3 Central Detector Performance	Peter Kostka	15
12.4 Forward and Backward Detectors	Paul Newman	15
12.5 Detector Installation and Infrastructure	Andrea Gaddi	15
13 Conclusions	Oliver Bruening, Max Klein	16
13.1 Summary	Max Klein	16
13.2 Timeline and Future Project Development	Oliver Bruening	16
14 Appendix A: Electron-Hadron Scattering with $E_p=20$ TeV	Monica D’Onofrio	17
14.1 Introduction	Monica D’Onofrio	17
14.2 Performance Parameters	Frank Zimmermann	17
14.3 Physics Interest - Case Studies		17
14.3.1 FCC-hh at 40 TeV: SM and BSM	Maarten Boonekamp, Monica D’Onofrio	17
14.3.2 ep at 2.2 TeV cms: PDFs and Higgs	Claire Gwenlan, Max Klein, Jorge De Blas	17
14.4 Attaching the ERL to a 100 km Hadron Ring		17
14.4.1 Scaling the IR	Bernhard Holzer	17
14.4.2 Civil Engineering around point L	Alexandra Tudora	17
14.5 Scaling the LHeC Detector Design to Higher Proton Energies	Peter Kostka	17
15 Appendix B: ERL Technology and Applications	Alex Bogacz, Walid Kaabi	18
15.1 Development of Energy Recovery Linac Technology - Status and Prospects	Chris Tennant	18
15.2 The ERL Facility PERLE	Walid Kaabi	18
15.3 High Energy Photo-Nuclear Physics with the LHeC	Norbert Pietralla	18