Front-to-end simulations of the Energy Recovery Linac for the LHeC project

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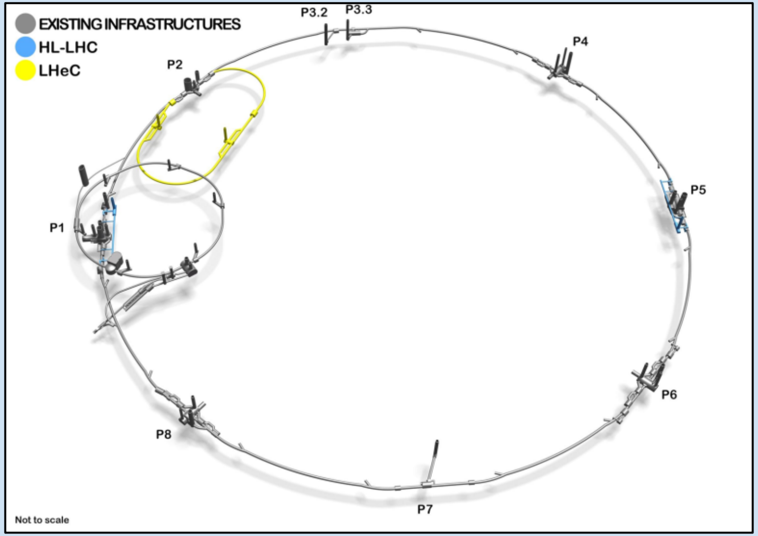
Table 1: Design parameters for the LHeC project

Parameter	unit	proton	electron
Beam energy	GeV	7000	50
Bunch intensity	10^{11}	2.2	0.03
$\gamma\varepsilon_{x,y}$ at IP	mm mrad	2.5	30
$\beta_{x,y}$ at IP	cm	10.00	10.92
Bunch length σ_s	mm	75.5	0.6
b-b parameter ξ	-	1.5×10^{-4}	1.64
Geometric $\mathcal{L}$	$\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$	6.5×10^{33}	

Lepton-hadron collision in the TeV center of mass energy range.

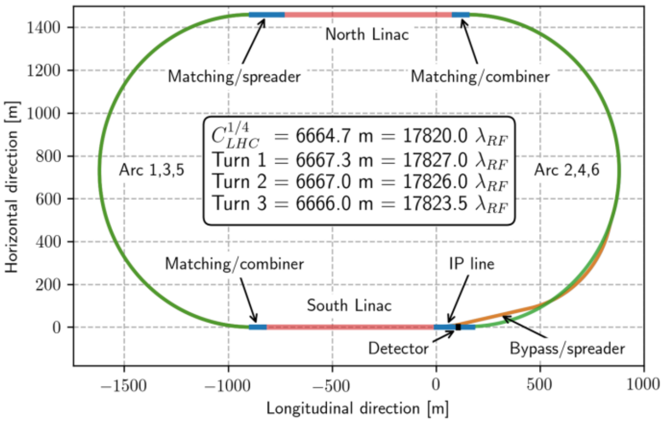


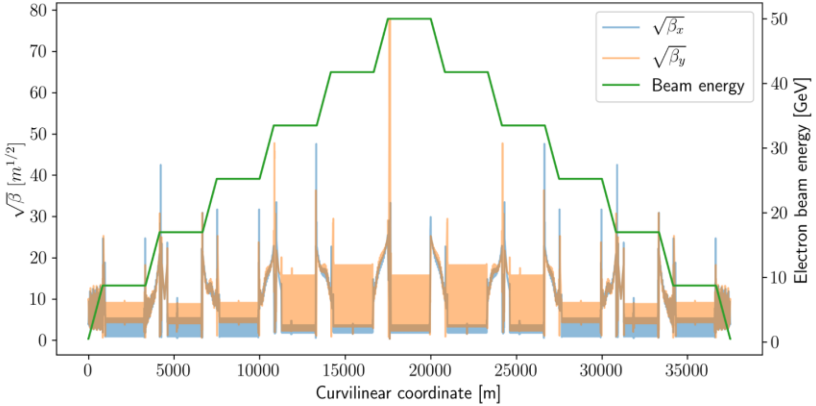
“ The Large Hadron-Electron collider at HL-LHC ”
Published in J.Phys. G. arXiv: 2007.14491, April 2020

ERL lattice and optics design specifics

ERL specifics of the LHeC project

- Arcs (Isochronous and “TME”)
- One-step achromatic vertical deflection
- Linacs with minimized $\int \frac{\beta}{E} ds$
- Particle detector bypass
- Interaction region with 3 beams that provides head-on collision and features an optimised separation scheme





Incoherent Synchrotron Radiation

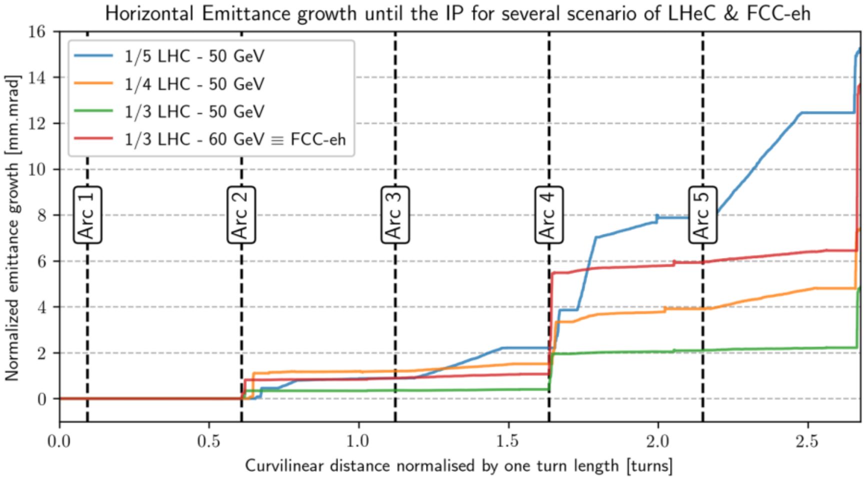
Emission of radiation in the arcs, the particle detector bypass, the spreaders/recombiners and the interaction region in the vicinity of the particle detector.

Extra RF cavities required, especially in arc6

It produces an **emittance growth** and an **energy spread** leading to bunch elongation.

$$\Delta \mathrm{E} = \frac{e^2}{6\epsilon_0}\frac{\gamma^4}{\rho}$$

$$\mathcal{H} = \gamma D^2 + 2\alpha D D' + \beta D'^2$$



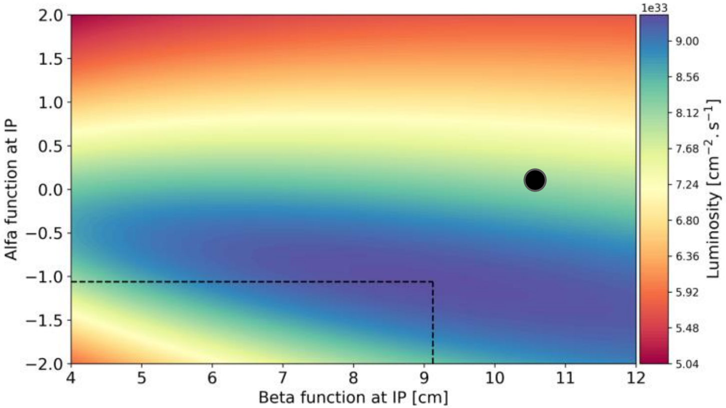
ERL size	1/3	1/4	1/5	unit
$\Delta \mathrm{E}_{\mathrm{losses}}$	1.0	1.5	2.2	GeV
$\mathrm{P}_{\mathrm{losses}}$	20	30	44	MW

Beam-beam interaction and optimisation

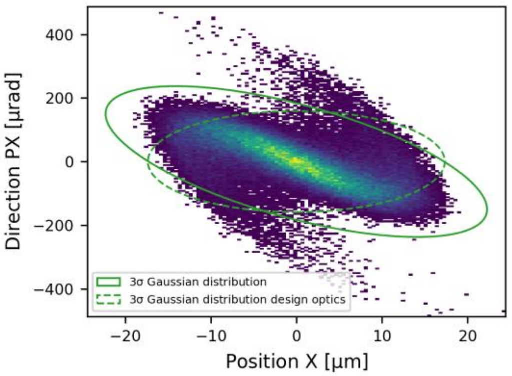
Scenario	Optical matching	Luminosity optimum	unit
Luminosity	8.2×10^{33}	9.3×10^{33}	$\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
$\Delta\gamma\varepsilon$	15	0.1	mm mrad

Optimisation of luminosity, emittance growth and distortion of the phase space. A capture optics improves the transmission.

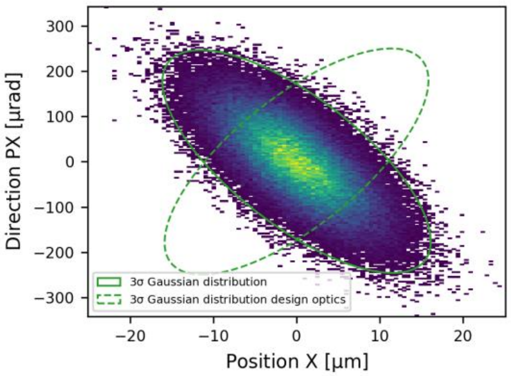
The beam-beam interaction gives the starting conditions for the tracking simulations of the deceleration.



optical matching



luminosity optimum



Tracking results and conclusion

The ERLs have been designed and optimised such that an excellent beam transmission and energy recovery efficiency is achieved, including synchrotron radiation and beam-beam disruption.

ERL size	**1/3 C_{LHC}**	**1/4 C_{LHC}**	**1/5 C_{LHC}**
$\gamma\varepsilon_x^{\mathrm{inj}}$ [µm rad]	25.4	22.7	15.1
$\Delta p/p$ at IP	0.021 %	0.029 %	0.041 %
transmission	99.93 %	98.89 %	98.40 %
energy recovery	97.9 %	96.7 %	95.4 %

Tracking results including beam-beam interaction and synchrotron radiation

Longitudinal phase at the dump