LHeC IR OPTICS DESIGN INTEGRATED INTO THE HL-LHC LATTICE

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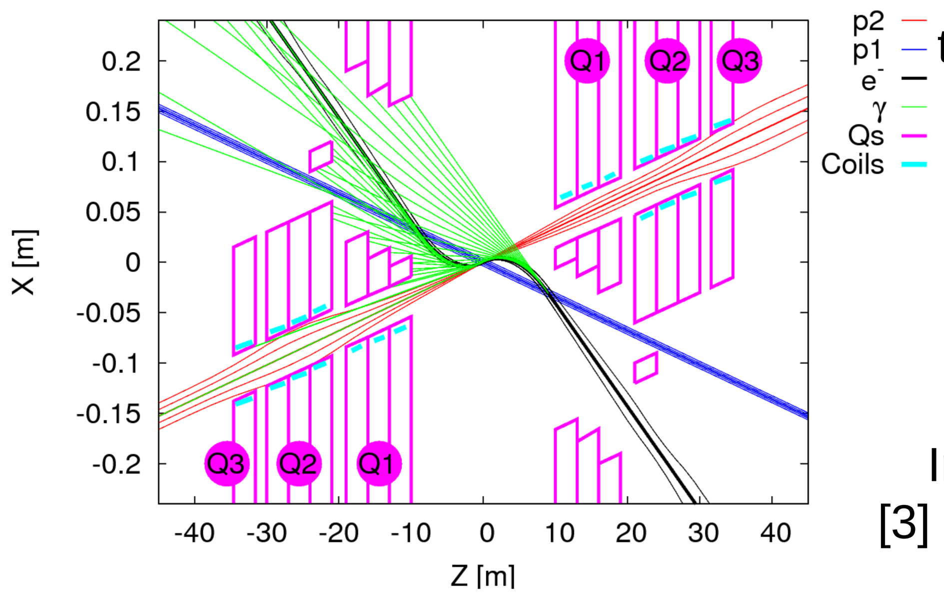
Abstract

The LHeC is a proposed upgrade to the LHC to provide electron-proton collisions and explore the new regime of energy and intensity for lepton-nucleon scattering. This experiment is expected to work alongside the HL-LHC to allow simultaneous nucleon-nucleon and lepton-nucleon collisions at separate interaction points. A first lattice design has been proposed that collides proton beam 2 with the electron beam. The nominal design calls for a β* (β function in the interaction point) of 10 cm using an extended version of the Achromatic Telescopic Squeezing (ATS) scheme, and a L* (distance to the inner triplet) of 10 m. The aim of this work is to explore the flexibility of this design by minimizing β* and increasing L* to find the optimal solution in terms of maximum luminosity while controlling the chromatic aberrations and Synchrotron Radiation (SR).

Nominal Design



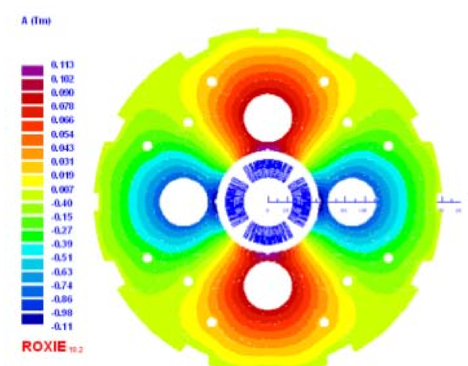
The nominal design presented in the CDR [1] and [2] aims to have head-on proton-electron collisions by focusing only this proton beam at very low **β*=10 cm** while having the other beam go through without being focused.

Changes in IR2:

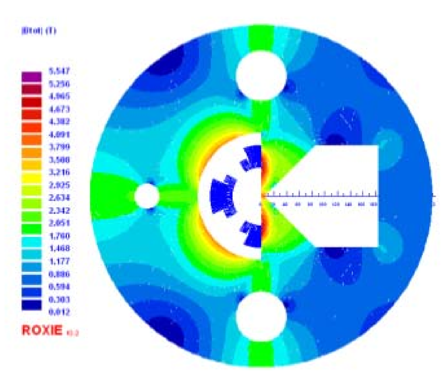
- **New inner triplet** (IT) at L*=10 m with strengths **Q1**= 187 T/m, **Q2**= 310 T/m (Fig. 2) and **Q3**= 182 T/m
- Change polarities of dipoles next to IP (**D1** and **D2**)
- Change strength of **D1** by a factor of 3.43 and **D2** by a factor of 1.21.

Integration achieved in [3] using ATS technique [4]:

β*=10 cm in IP2 (LHeC)
β*=15 cm in IP1 And IP5 (HL-LHC)



Q2
Normal quadruple design



Q1
Half-quad design

Luminosity

Aim: 10^{33} cm^{-2} s^{-1}

The **Luminosity** of the e-p collisions is given by:

$$L = \frac{1}{4\pi e}\frac{N_{b,p}}{\epsilon_p}\frac{1}{\beta^*_p} I_e H_{hg} H_D$$

Smaller **β*** results in higher **Luminosity**

Changes and optimization

Principal aim: Explore the flexibility of the design.

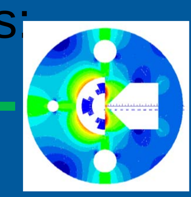
	Disadvantages	Advantages	Cases found
Minimize β*	Increase **Chromatic Aberrations**	Increase **Luminosity**	β* =5-10, 20 cm L* fixed at 10 m
Increase L*	Increase **Chromatic Aberrations**	Minimize **Synchrotron Radiation**	L*=10-20 m β* fixed at 10 cm

Synchrotron Radiation

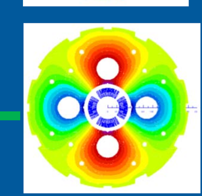
In order to minimize the SR we can minimize the separation d(L) between proton beams in the entrance of Q1.

This minimum separation and it is constrained by the following conditions:

1. d(L)>65 mm for L*<14 m

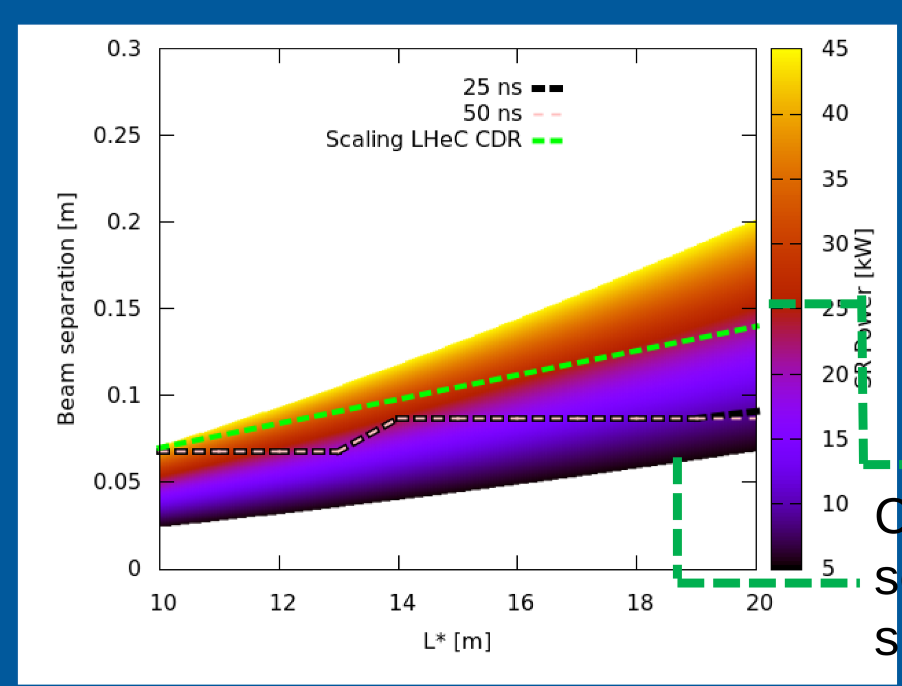


d(L)>87 mm for L*>14 m



2. The separation at the first long-range encounter has to be of at least 12 σ.

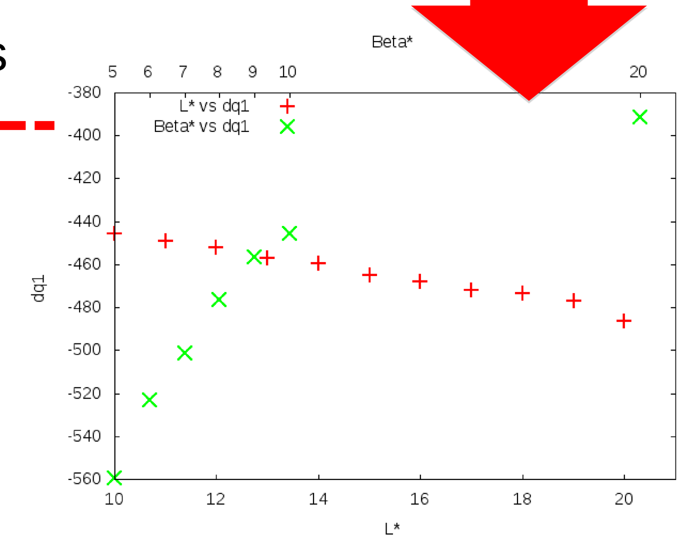
3. The size of the electron beam must physically fit inside the free field hole.



Comparisson between this minum separation and the previous results are shown. Reduction of SR power is clearly observed for the cases L*>10 m.

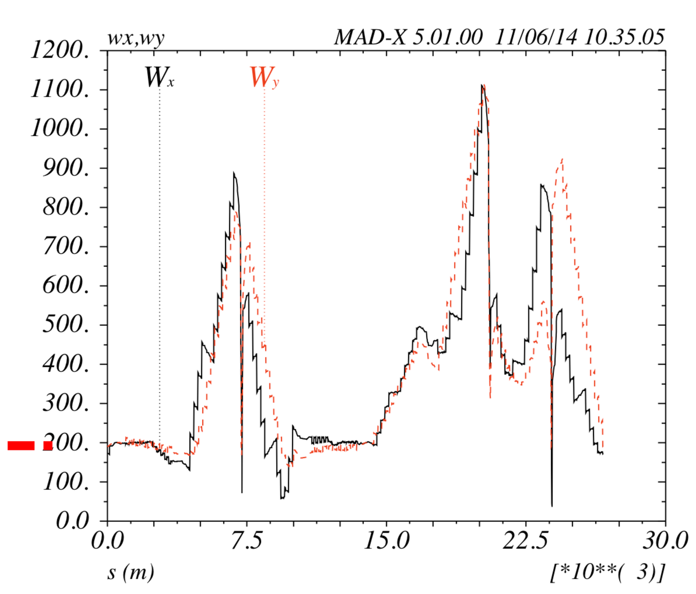
Chromaticity Correction

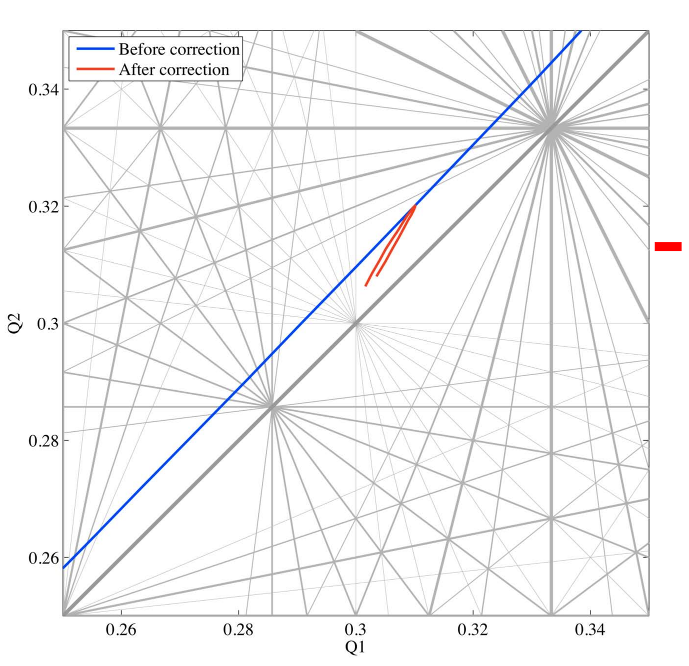
The natural chromaticity of all cases is shown vs L* and β*.



MATCHING PROCEDURE:

Variables: 32 sextupole families
Constraints:
- Horizontal (**dq1**) and vertical (**dq2**) chromaticity to a value of **2**
- Chromatic Amplitude functions (**Wx** and **Wy**) to a value of **200** in IR3 and IR7.





The **tune spread** over a momentum δp=±0.001 was also studied in a frequency map before and after the correction, where chromaticities were avoided up to order 9.

The limit of this correction has been found for a maximum value of L*=18 m with a fixed β*=10 cm , and β*=8 cm with a fixed L*=10 m.

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Conclusion

The flexibility of the integration of the LHeC into the HL-LHC lattice has been explored in terms of minimizing β* to increase the luminosity and increasing L* to reduce the synchrotron radiation. The results show that it is recommended to keep the **β* at 10 cm**, where **luminosity** is still **achievable**, but increase **L* to 14-18 m** which will allow the **chromaticity** to be **corrected** and also give important benefits in terms of the **quadrupole design** and the reduction of **synchrotron radiation**.

References

[1] J. L. Abelleira Fernandez et al. [LHeC Study Group], "A Large Hadron Electron Collider at CERN" J.Phys.G. 39 (2012) 075001, arXiv:1206.2913.
[2] S.~Fartoukh, ``Towards the LHC Upgrade using the LHC well-characterized technology,'' sLHC Project Report 0049.
[3] R.~Tomás, "Interaction Region" in the Meeting on LHeC with Daresbury group, September 2012: http://indico.cern.ch/conferenceDisplay.py?confId=207665
[4] M. Korostelev et al., ``LHeC IR optics design with integration into the HL-LHC lattice'', MOPWO063, IPAC '13 Conference Proceedings.

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