1st OPAC Topical Workshop

Design of the IR for the LHeC using the ATS scheme

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Abstract

To extend its discovery potential, the Large Hadron Collider at CERN will require major upgrades (HL-LHC) around 2020 to increase its luminosity by a factor of 10 beyond its design value. There is also a proposal to introduce an electron beam to the HL-LHC lattice to exploit the new regime of energy and intensity for lepton nucleon scattering (LHeC). The proposed research will be to investigate and identify optimal solutions to the optics layout to integrate an electron beam with the proposed HL-LHC lattice allowing simultaneous nucleon-nucleon and lepton-nucleon collisions at separate interaction points. There are several tasks to be addressed, this work presents three different aspects, the design lattice proposed for the LHeC aiming to collide proton beam 2 (P2) with the electron beam while proton beam 1 (P1) bypasses the interaction, the implementation of the Achromatic Telescopic Squeezing (ATS) scheme is described and its procedure to reduce the beta function at the interaction point (β*) at the HL-LHC and LHeC interaction points, and finally the trajectory of the proton beams through the proposed quadrupoles is analysed.

Design Layout

A first conceptual design of the LHeC linac-ring Interaction Region (IR) is presented in the LHeC Conceptual Design Report [1]. This design aims to have head-on proton-electron collisions by focusing only proton beam 2 (P2) at very low beta function in the interaction point (β*=10 cm) while having the other proton beam (P1) go through without being focused.

The first design include changing the polarities of the dipoles in the IR D1 and D2 and changing the strength of D1 by 3.43 and D2 by 1.21, allowing a crossing angle of 6.8 mrad between the beams. An implementation of a new triplet of quadrupoles is also proposed consisting of 3 quadrupoles of 9 meters long each, starting at a distance L*=10 m and with strengths Q1= 187 T/m, Q2= 310 T/m and Q3= 182 T/m.

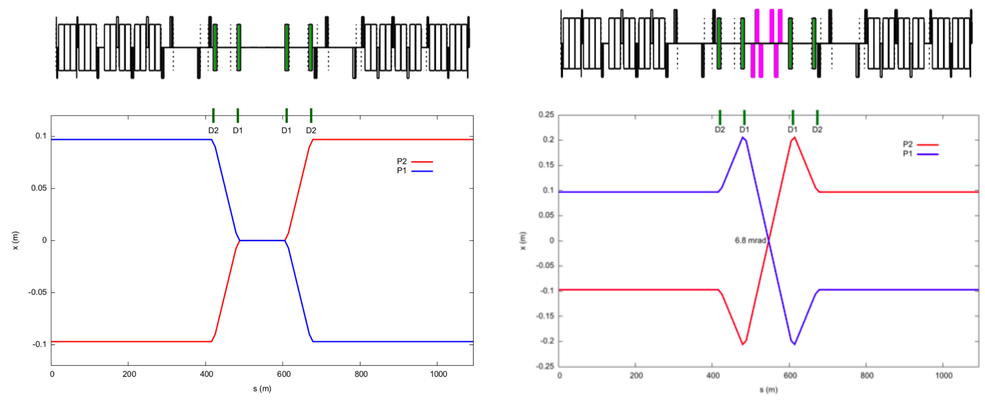

Figure 1. Lattice configuration and proton beam trajectories near IR2 for the current configuration (left) and the LHeC proposed lattice (right).

ATS Scheme

After the insertion and matching of the new triplet, the beta function reaches a value of β*= 44 cm for the IP1 and IP5, and β*=30 cm for the IP2. However, is not possible to diminish this beta further to the desired value due to limitations with the gradient of quadrupoles and strength limits of the arc sextupoles.

The ATS [2] provides a tool to reduce this β* preserving the optics flexibility and guarantying the correct-ability of chromatic aberrations. The idea of this scheme is to make use of the arcs next to the interaction points to generate a beta wave to further reduce the beta and that at the same time, these waves reach their maximum at every other sextupole, drastically increasing their efficiency to reduce the chromatic aberrations. The value of β* reached with this scheme for IR1 and IR5 is β*=15 cm and for IR2 is β*=10 cm [3].

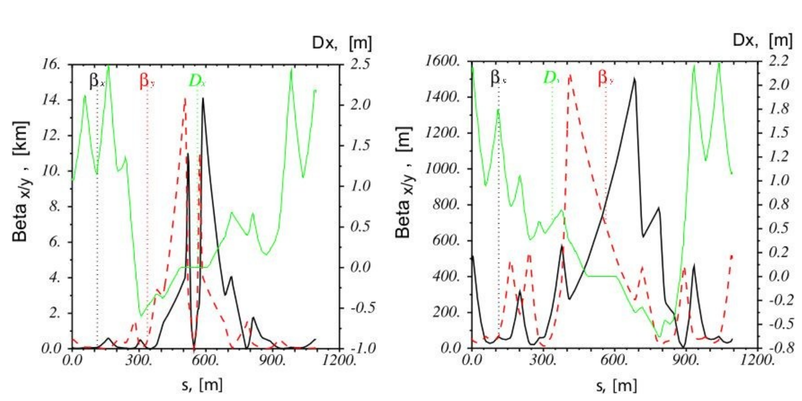

Figure 2. β_x, β_y and D_x near IR2 for proton beam 2 (left) and proton beam 1 (right). [3]

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Beam trajectories

To track the trajectories of the proton beams through the quadrupoles we measure the distance between the beams at the entrance and exit of Q1 and Q2 (Fig. 3).

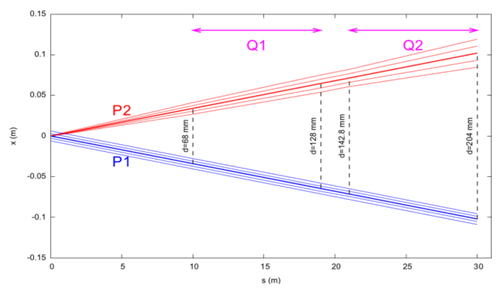

Figure 3. Separation distance between proton beams at the entrance and exit of Q1 and Q2.

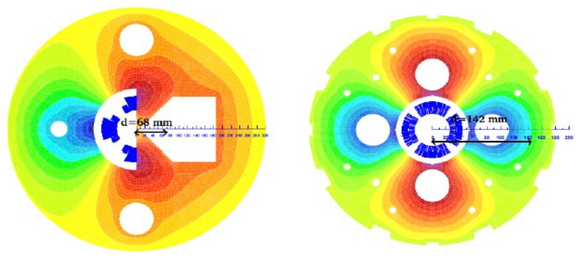

Figure 4. Transverse view of the proposed quadrupoles Q1 (left) and Q2 (right) [1]. The separation distance at the closest point to the IR2 has been overlaid.

The separation distance closest to the IR can be represented in the transverse view of the proposed magnet configurations of Q1 and Q2 (Fig. 4).

Given the beta function we can calculate the size of the proton beam at the entrance and exit of the quadrupoles, and give a representation of the transverse view of the quadrupoles taking into account the beam aperture (Fig. 5).

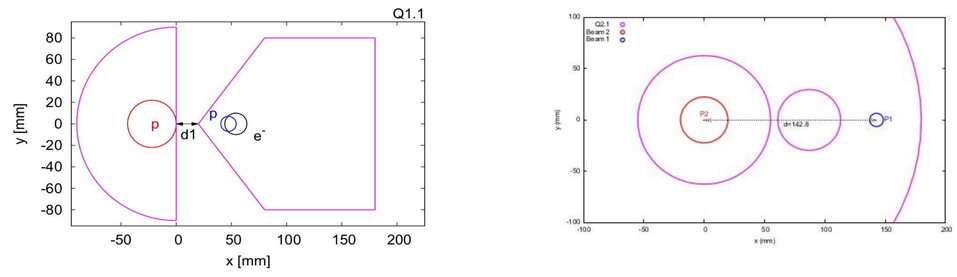

Figure 5. Schematic illustration of the transverse section of the quadrupoles where the aperture of the proton beams at the entrance of Q1 [4] (left) and Q2 (right) is indicated.

With the current configuration we found that having P2 in the centre of the quadrupoles locates P1 going through the field free hole in Q1 but overpasses this zone at the entrance of Q2.

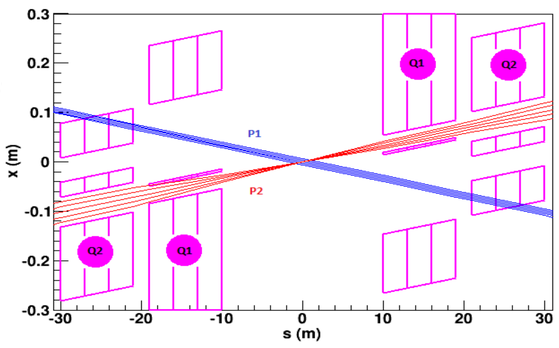

Figure 6. Trajectories of the proton beams near IR2 with the proposed configuration.

Summary

The integration of the LHeC IR with the HL-LHC has been implemented successfully allowing the desired reduction of β* in the interaction points. However this configuration also shows some problems to be addressed, in particular the location of P1 at the entrance of the proposed Q2 which falls out of the free field zone as desired. Other tasks to consider in the study of the LHeC IR include transition optics from injection to collision, beam-beam effects in the IR, dynamic aperture studies, optimisation of the triplet position (L*) and the chromaticity correction.

References

[1] J.L. Abelleira Fernandez et al., *LHeC Conceptual Design Report*, July 2012 http://arxiv.org/abs/1206.2913.

[2] S. Fartoukh, "*An Achromatic Telescopic Squeezing (ATS) Scheme for LHC Upgrade*", in proceedings of IPAC11.

[3] M. Korostelev, "*LHeC IR Optics Design Integrated into the HL-LHC Lattice*" in proceedings of IPAC13.

[4] R. Tomas, "*Interaction Region*" in the Meeting on LHeC with Daresbury group, September 2012: http://indico.cern.ch/conferenceDisplay.py?confId=20766.

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