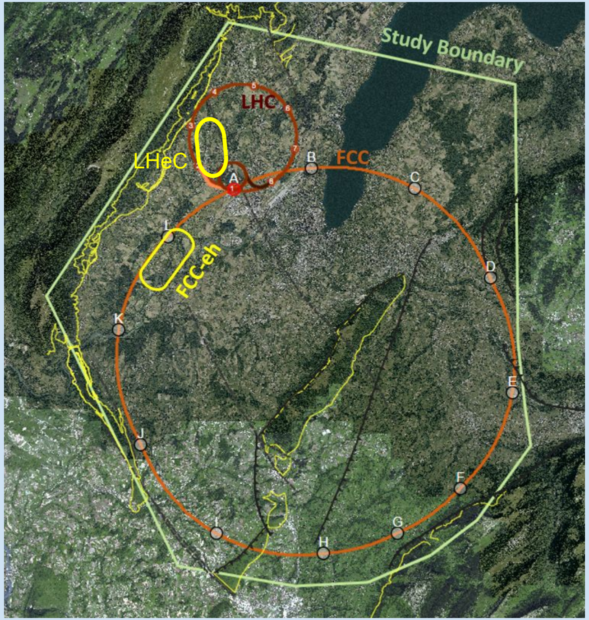
Beam separation scheme and layout of the interaction region for e-h collisions

K.D.J. André, B. Holzer, T. von Witzleben, L. Forthomme for the LHeC study group



Energy frontier electron hadron experiment with a luminosity of up to 10^{34} $cm^{-2}s^{-1}$ to complement the HL-LHC physics program with unprecedented TeV scale DIS physics. Featuring an innovative lepton accelerator design based on the energy recovery technology.

CDR (2012) & CDR (2020)

arXiv:1206.2913

arXiv:2007.14491

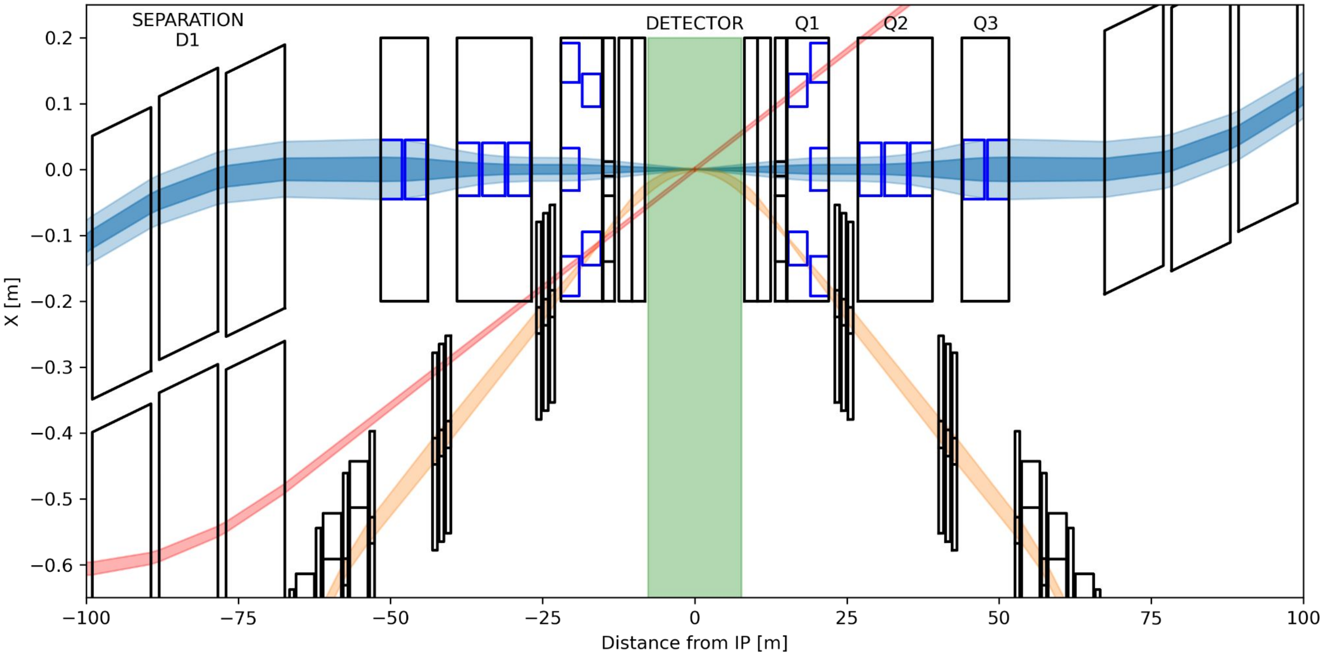
Offshell conference (2021)

Offshell(2021)

EPJC (2022)

EPJC(2022)

Introduction to the LHeC eh interaction region



Three beams crossing the interaction region:

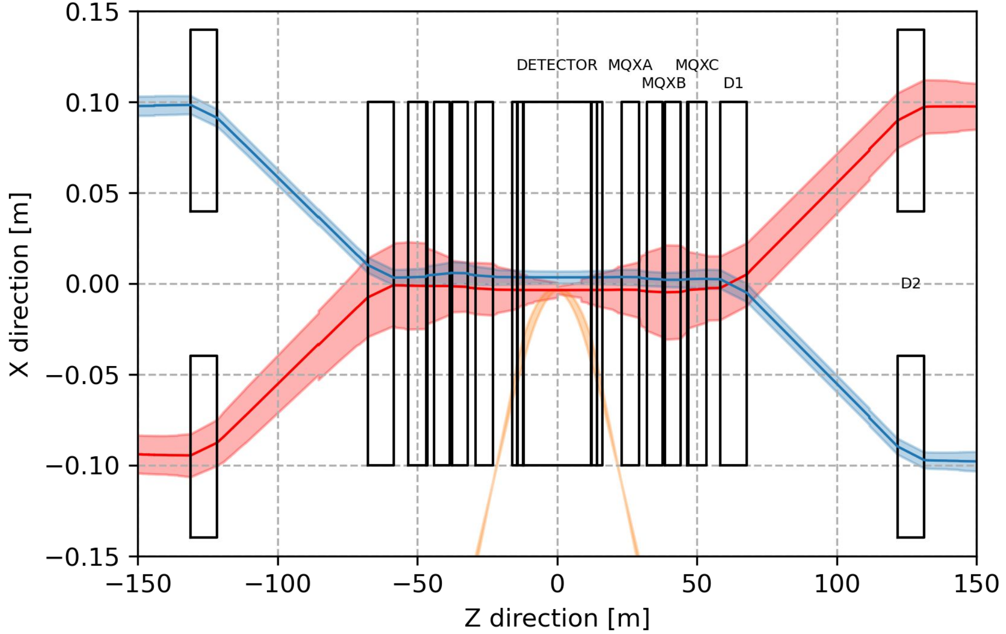
* Colliding electron and proton beams have an optimised separation scheme,

* The non-colliding proton beam is a spectator and both proton beams have a large crossing angle of **7 mrad**,

* Interaction Point (IP) shifted by **Δt/4 = 6.25 ns or 1.88 m**.

proton optics FCC-eh: **L* = 23 m & β* = 30 cm || LHeC L* = 15 m & β* = 10 cm**

Introduction to the LHeC eh interaction region



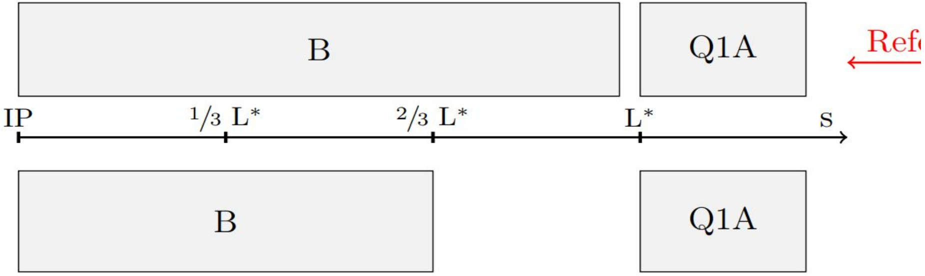
Three beams crossing the interaction region:

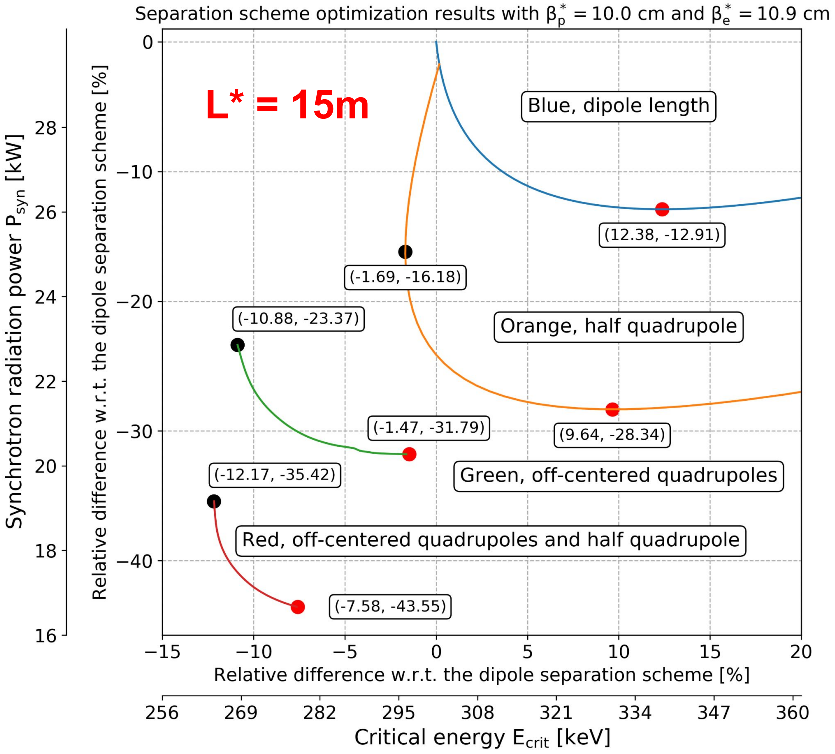
* Colliding electron and proton beams have an optimised beam separation scheme,

* The non-colliding proton beam is a spectator and both proton beams have an **7 mm** orbit bump and a **350 mrad** crossing angle at the IP,

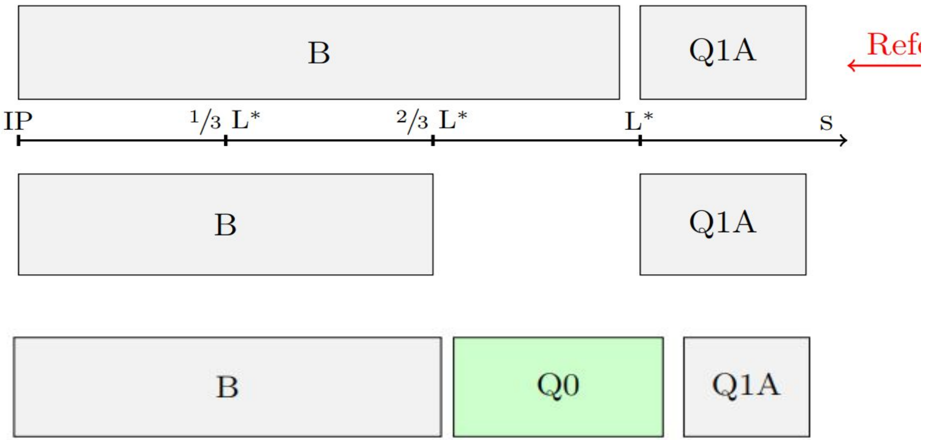
proton optics FCC-eh: **L* = 23 m & β* = 30 cm** || LHeC **L* = 23 m & β* = 20 cm**

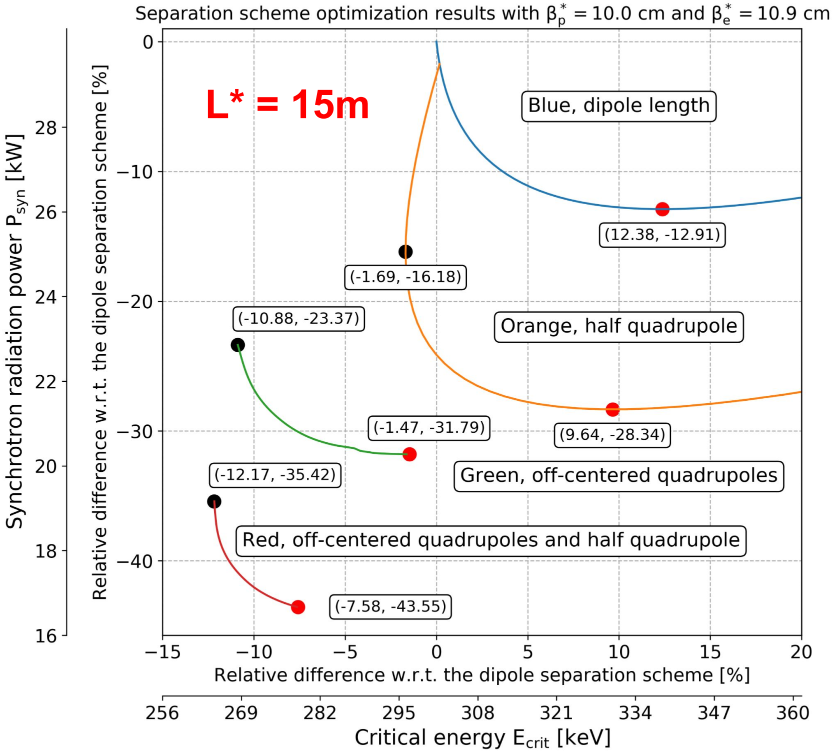
Optimization of the synchrotron radiation in the IR



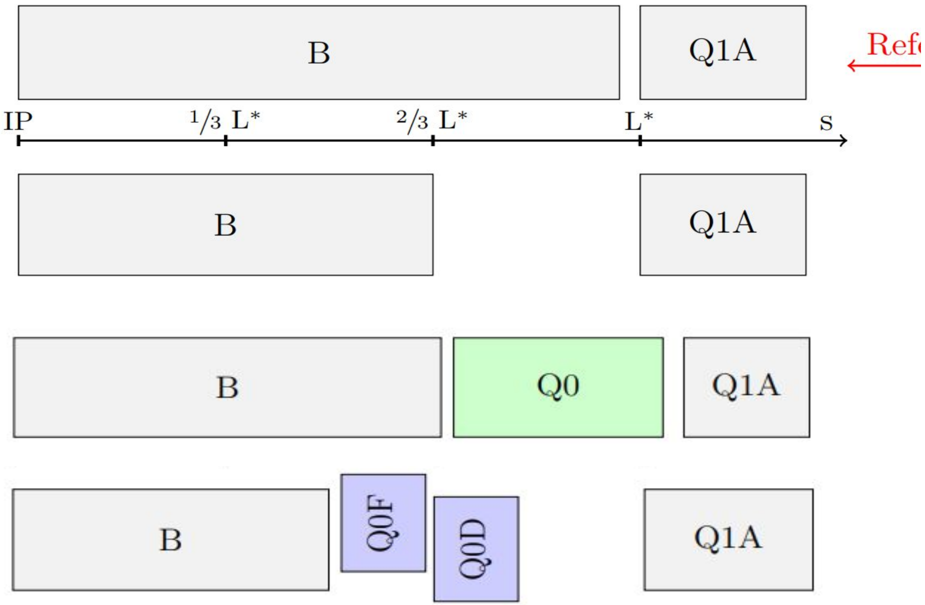


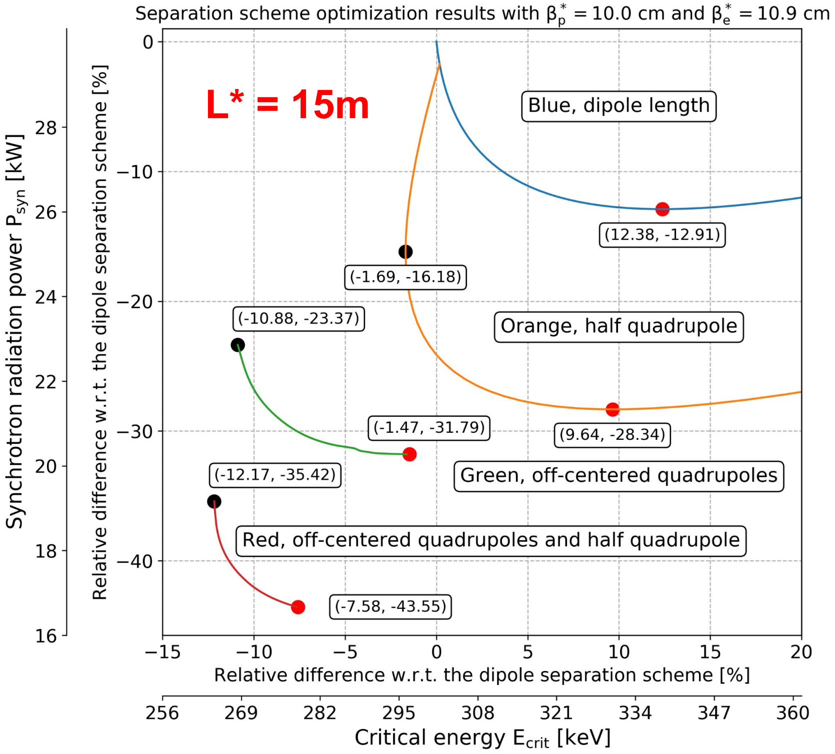
Optimization of the synchrotron radiation in the IR



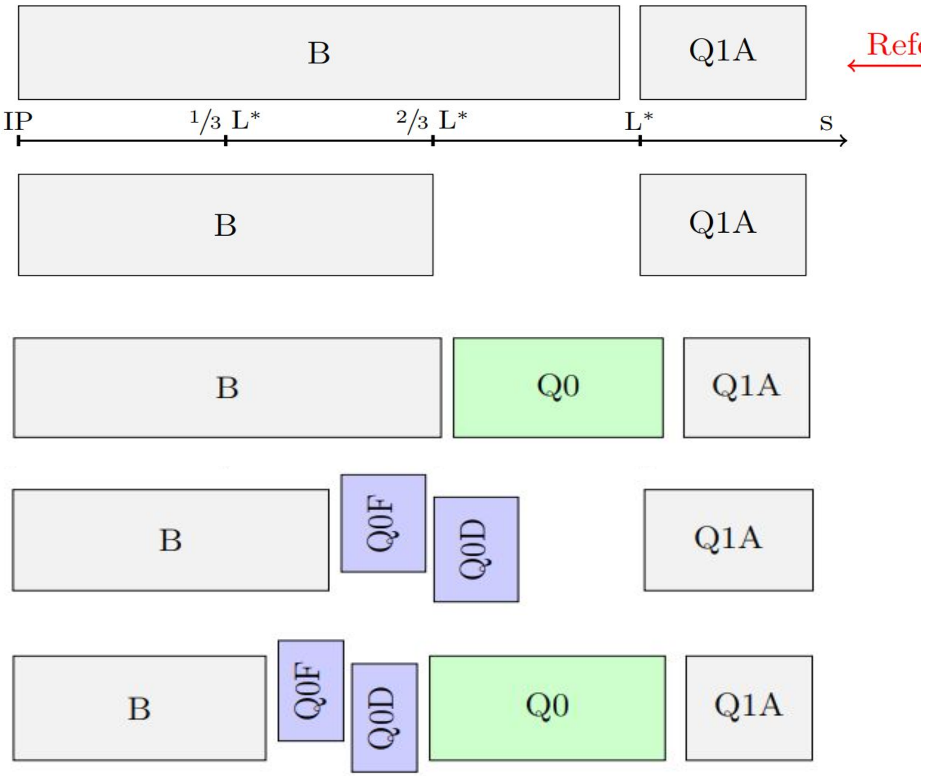


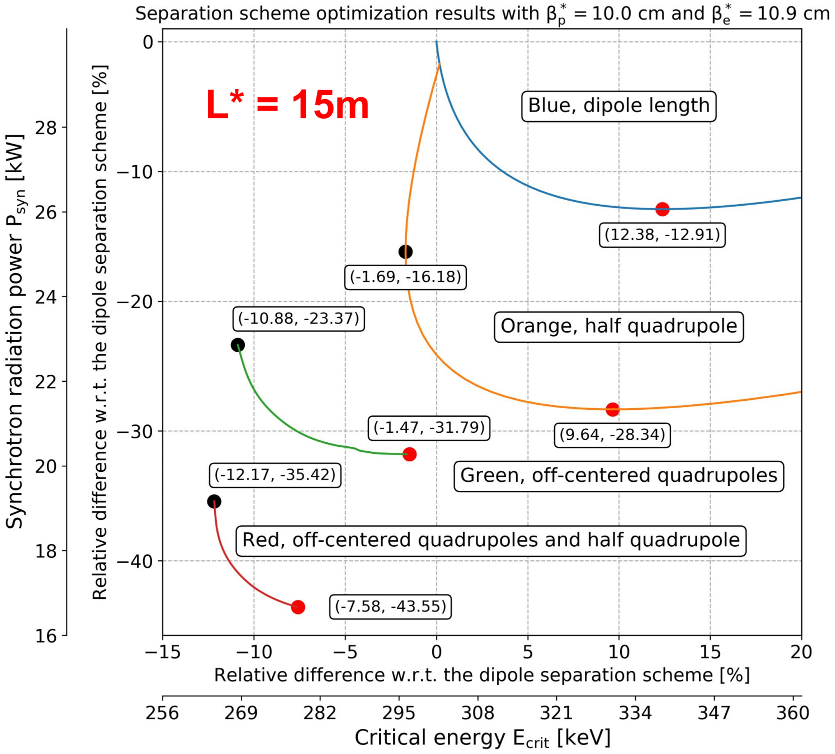
Optimization of the synchrotron radiation in the IR





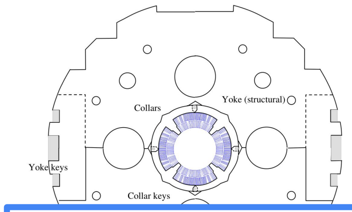
Optimization of the synchrotron radiation in the IR



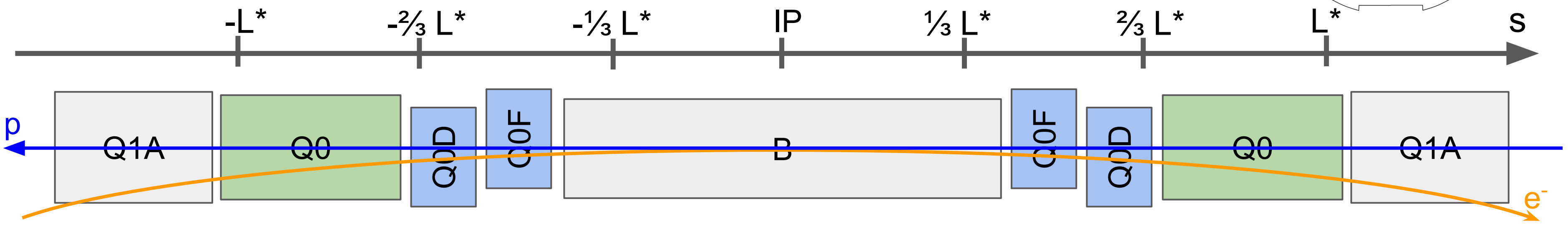


e-p beam separation scheme optimisation

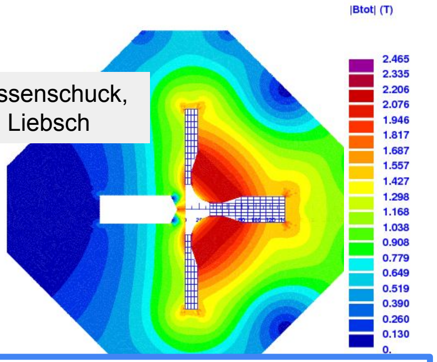
Based on the difference in beam rigidities of the colliding beams.



Q1A magnet design



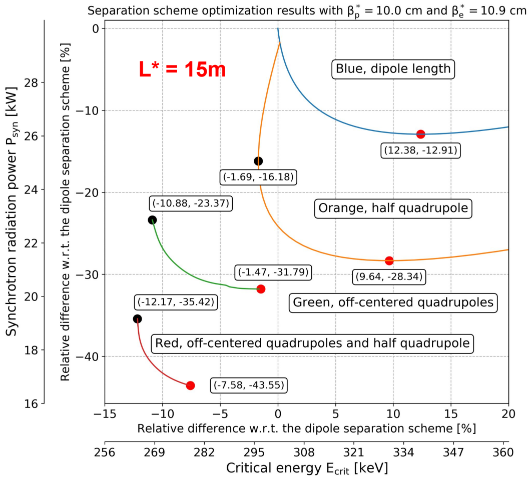
S. Russenschuck, M. Liebsch



Q0 magnet design

* Optimization to **extend the distance to separate the e⁻ beam** inserting Q0

* Optimization to **reduce the electron beam size** at Q1A with Q0F & Q0D

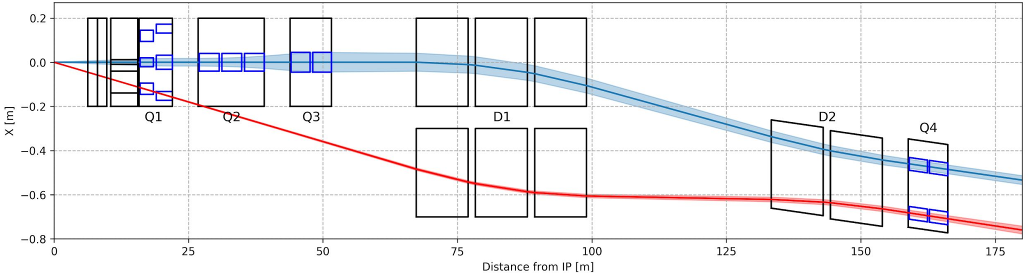


Combined hh|eh interaction region

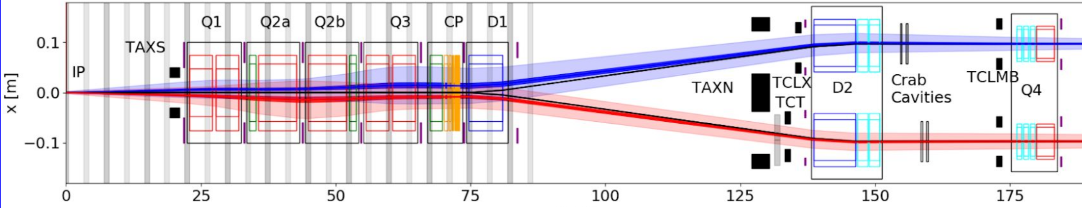
Two modes of operation:

- hh collisions in IP 1, 2, 5 and 8, no e⁻ beam
- eh collisions in IP 2 and hh collisions 1, 5 and 8

HL-LHC with LHeC, L* = 15 m, β* = 10 cm, θ = 7 mrad



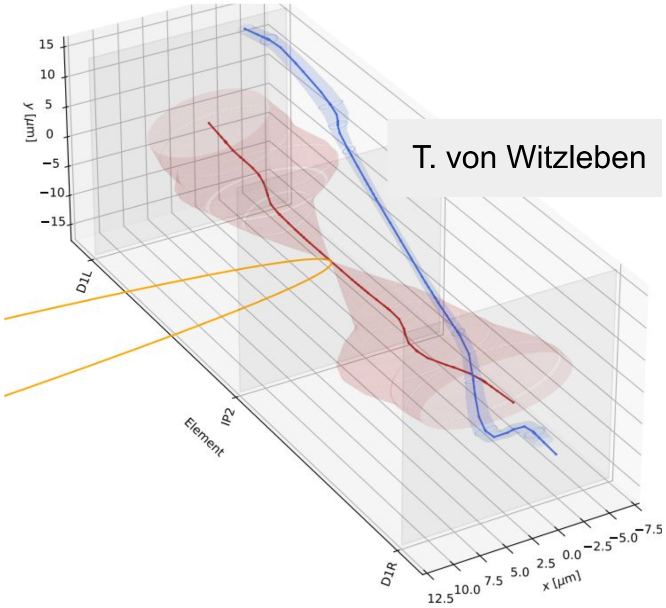
Standard HL-LHC, L* = 23 m, β* = 15 cm, θ = 590 μrad



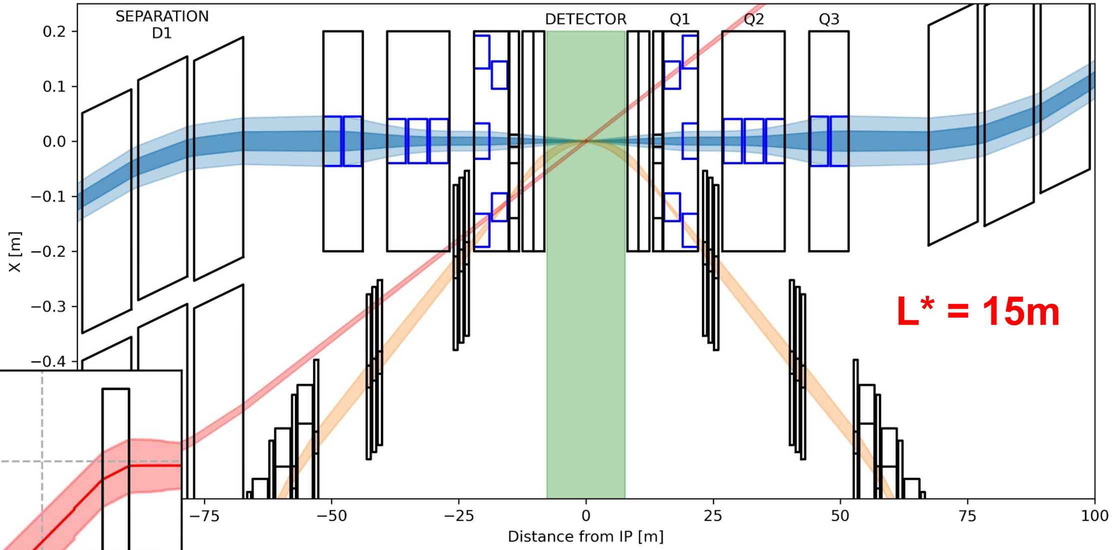
Courtesy from Massimo Giovannozzi (2019)

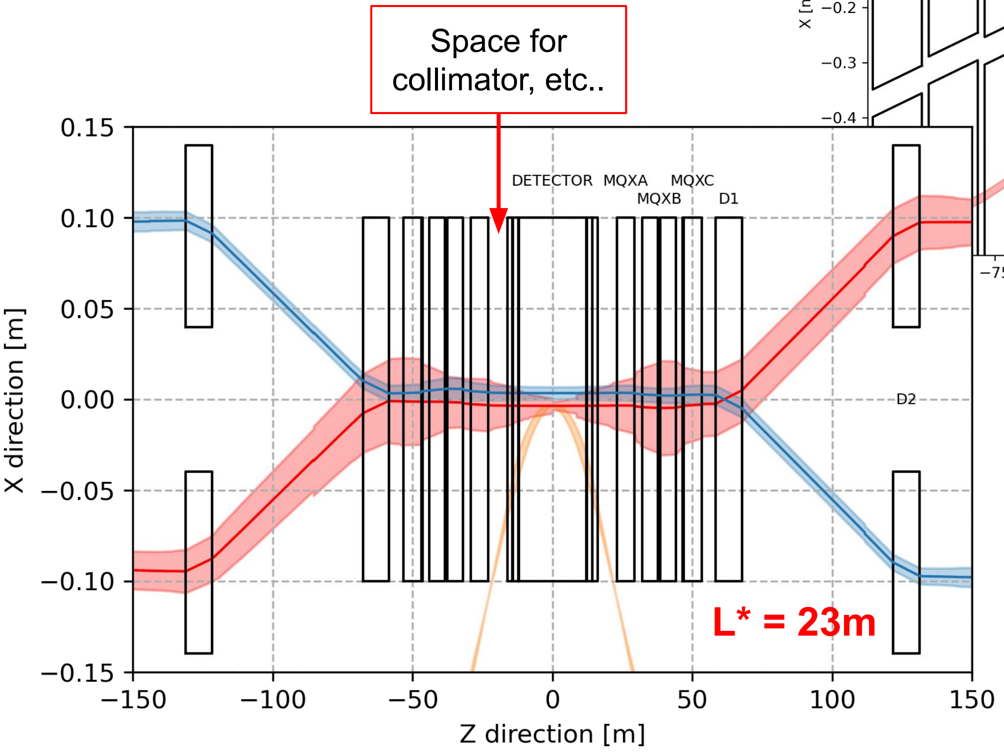
Accelerator considerations to **combine the ALICE and LHeC experiments** at point 2 of the HL-LHC:

- **Flexible interaction region optics and lattice** to provide e-h and h-h alternatively.
- A **beam separation scheme guides the electron beam** after the collision point back to the ERL return arc.



Combined hh|eh interaction region



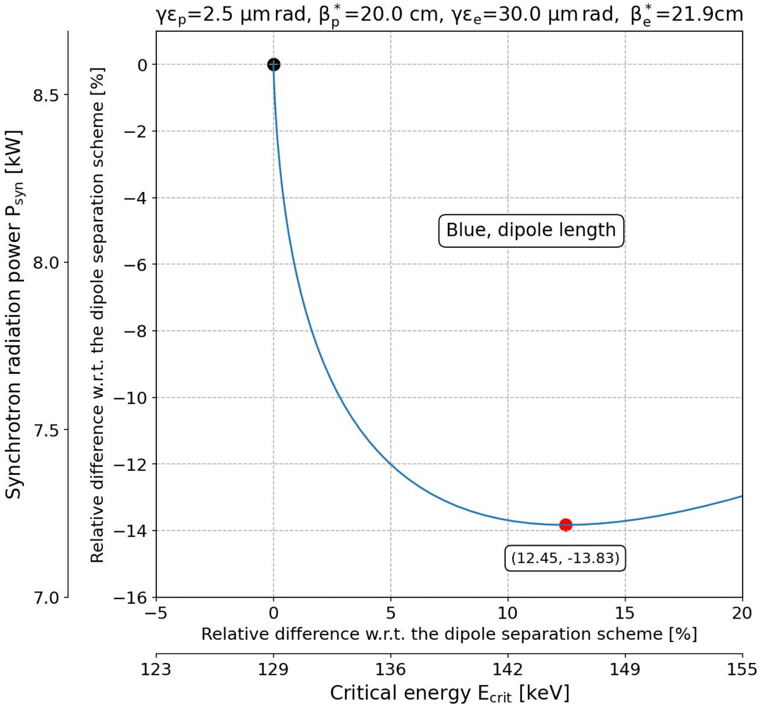


← Standard LHC distance between the IP and Q1A.

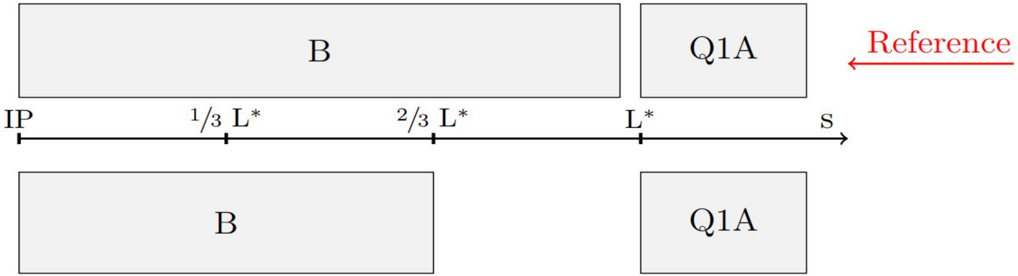
Space for collimators, absorbers, before Q1A (first proton quadrupole).

Possibility to control the electron optical functions with the doublet of off-centered quadrupoles.

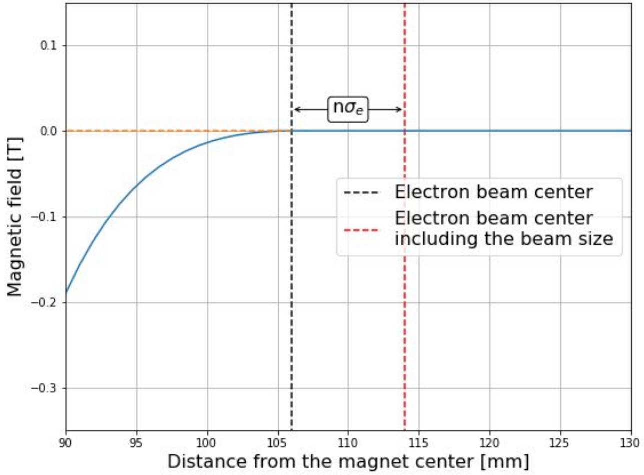
Synchrotron radiation optimization for the combined hh|eh



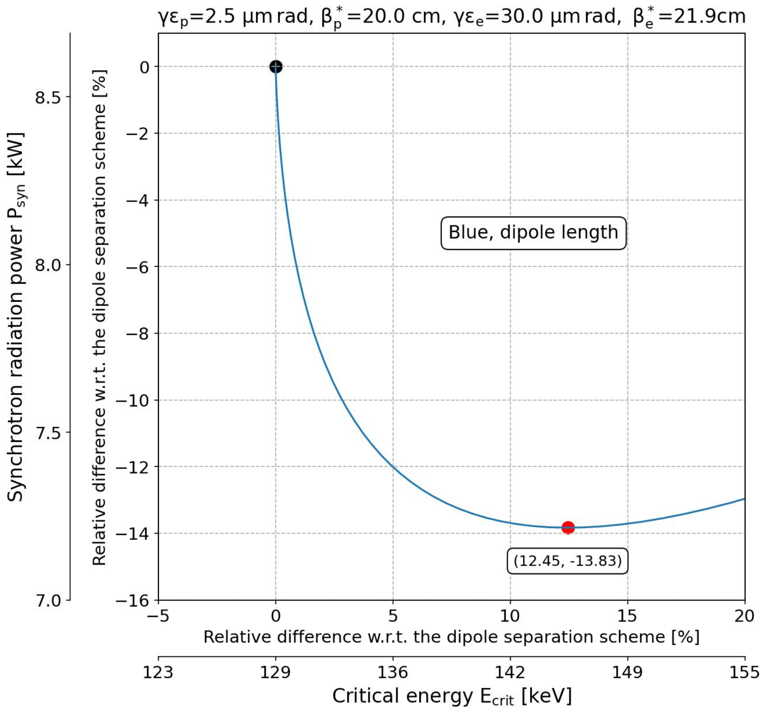
No focusing of the electron beam in the beam separation scheme.

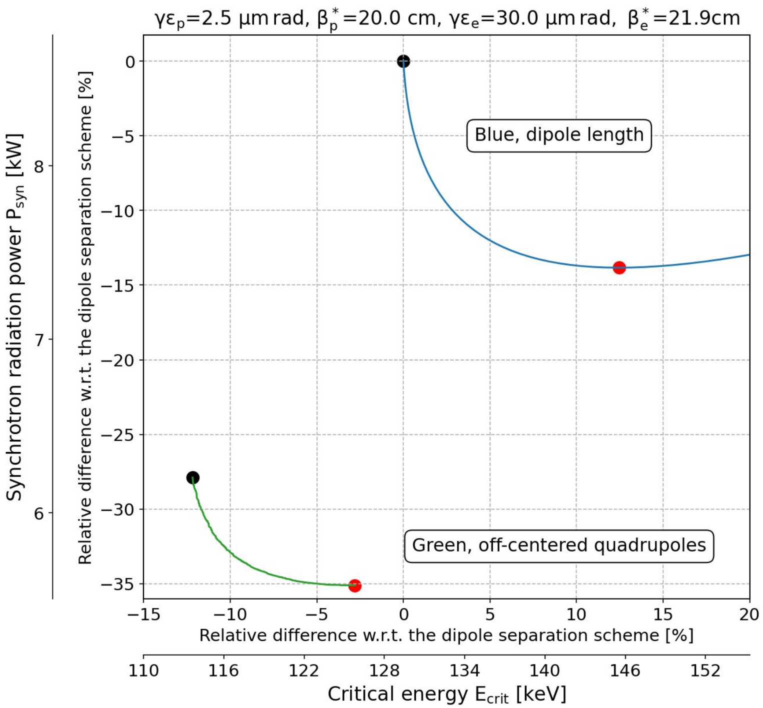


106 mm separation at Q1A + 13 mm (≡ $20\sigma_e$) from the half transverse width of the electron beam.



Synchrotron radiation optimization for the combined hh|eh





No focusing of the electron beam in the beam separation scheme.

Focusing of the electron beam before Q1A.
Pole tip field of quadrupoles below 1T.

Summary

* LHeC: **50 GeV** electron beam from an ERL colliding with one **7 TeV** proton beam from the LHC alongside the HL-LHC hadron-hadron operation and enables the alternate operation of eh and hh physics at IP2.

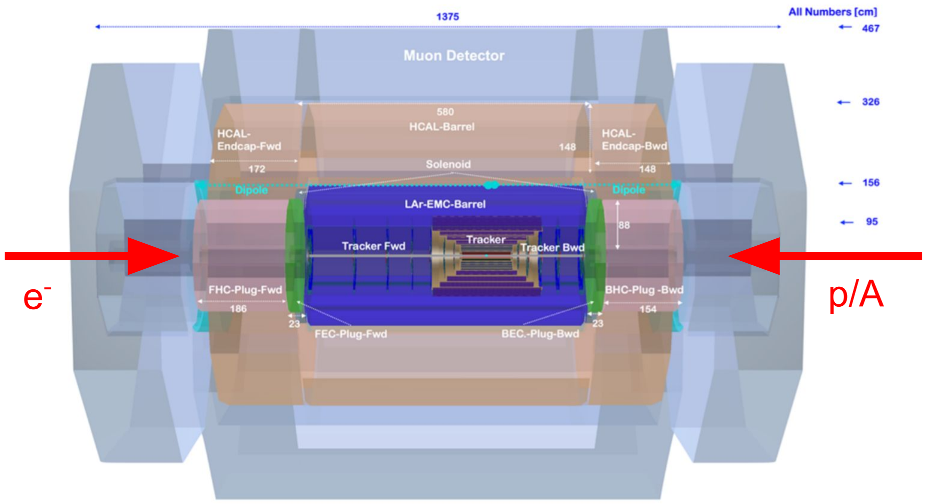
* Ongoing studies led by **T. von Witzleben** to realise a proton lattice and optics design with an interaction region enabling alternate e-h & h-h operations.

* **L. Forthomme** is addressing the machine-detector interface challenges with collimation studies of the synchrotron radiation in the interaction region.

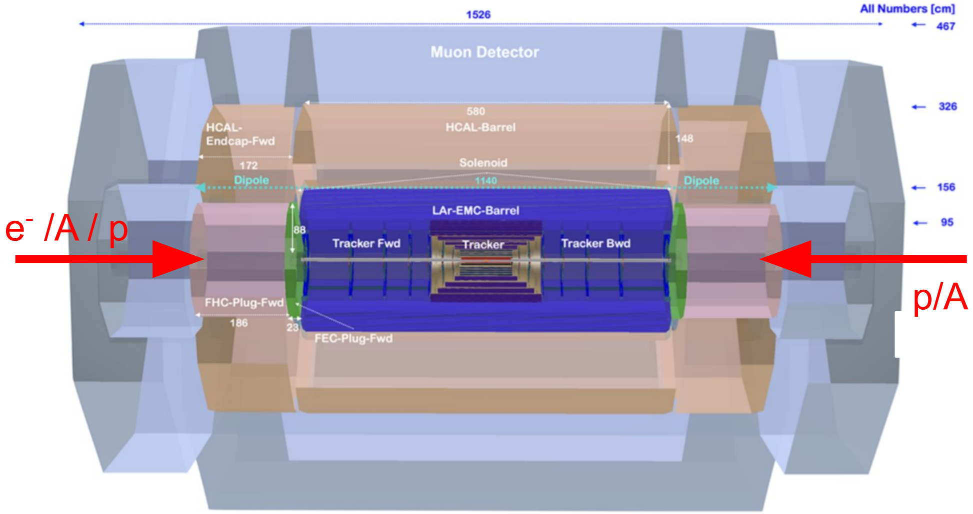
* The symmetrisation of the detector design would make possible the study of **eh and hh** physics at IP2. The combination of the LHeC and ALICE upgrades could significantly expand the energy frontier for electron-ion collisions.

Detector design - EPJC

e-h detector design for the LHeC



e-h & h-h detector design for the LHeC



Silicon tracker, surrounded by an electromagnetic (LAr) calorimeter and a combined solenoid and dipole magnets enclosed by a hadronic calorimeter and muon system. Need of forward-backward symmetry to include hadron-hadron physics.