FCC-eh Interaction Region

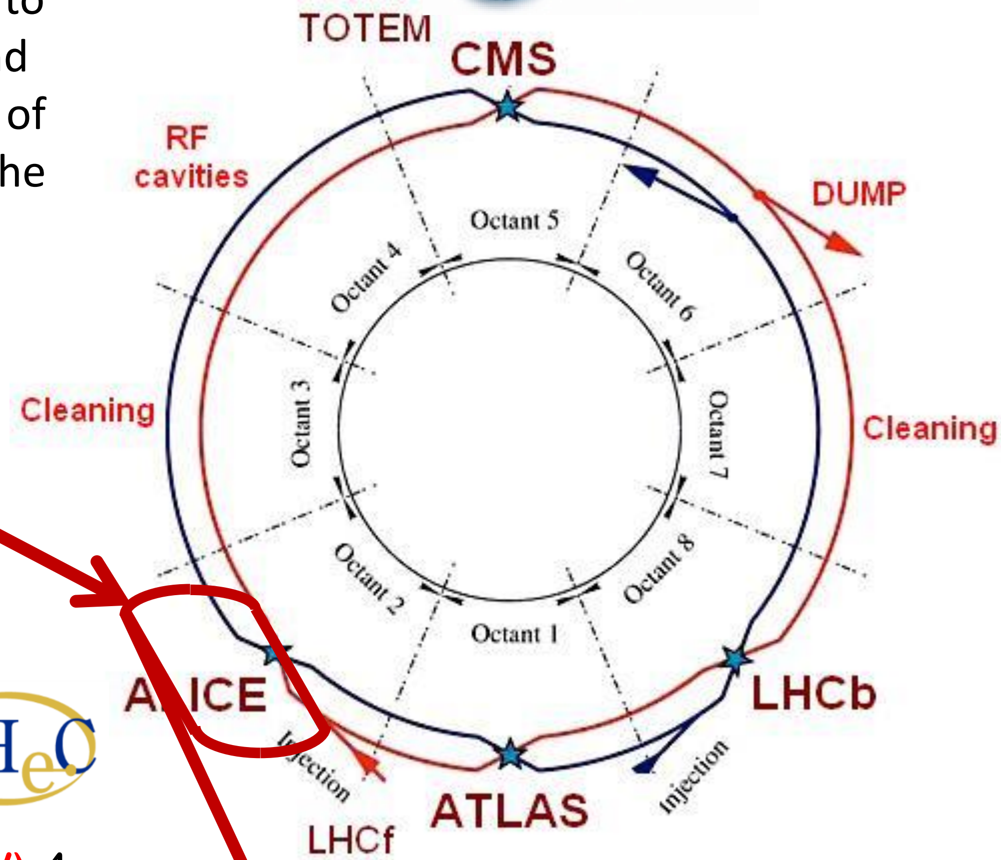
Emilia Cruz

September 21, 2015

LHeC integration into HL-LHC

The LHeC aims to implement a new ERL to circulate electrons and collide them with one of the proton beams of the LHC

Increase Luminosity(5×10^{34} $cm^{-2}s^{-1}$) in IP1 (ATLAS) and IP5 (CMS)



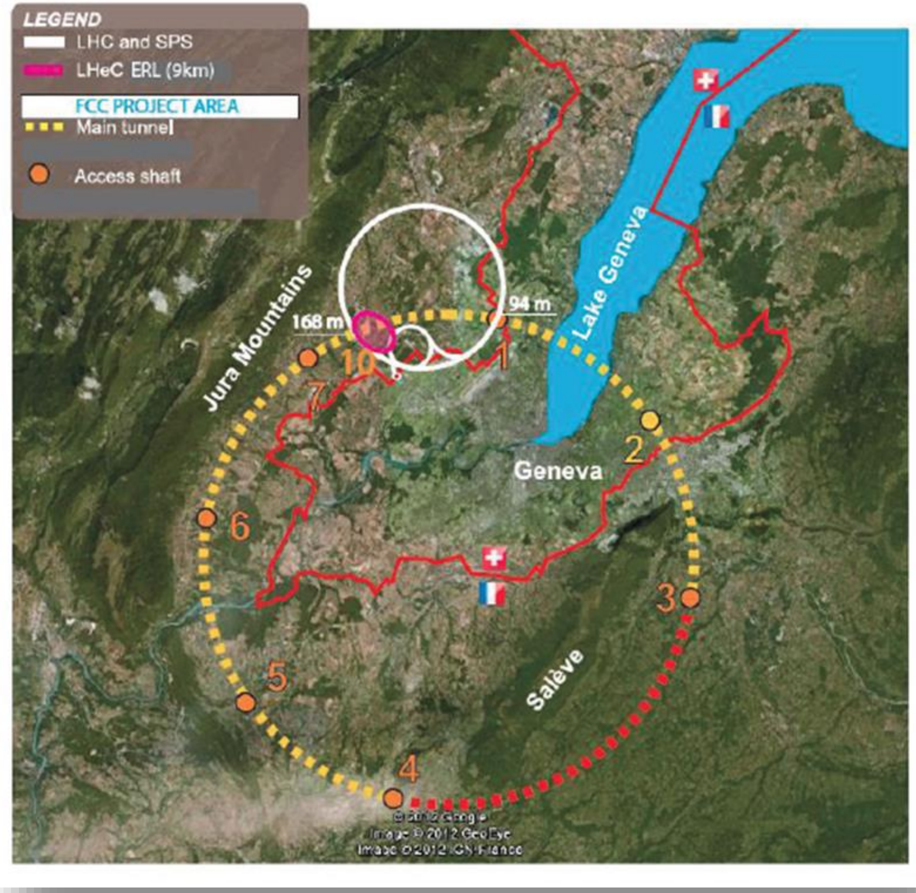
Energy Recover Linac

Energy ($\sqrt{s}$= 1.2 TeV) 4 times higher Luminosity (10^{33} $cm^{-2}s^{-1}$) 100 higher as HERA

FCC-eh

The LHeC ERL in the FCC-eh context:

- Use electron from LHeC ERL to collide with one the proton beams of the FCC.
- FCC-eh aims to work parallel to FCC-hh, just like LHeC aims to works alongside HL-LHC.



Scaling to FCC parameters

	protons	electrons
beam energy [GeV]	~~7000~~ 50000	60
Luminosity [$10^{33}cm^{-2}s^{-1}$]	~~1~~ 6.8/8.2	
normalized emittance $\gamma\varepsilon_{x,y}$ [μm]	~~3.75~~ 2.2	~~50~~->20/10
IP beta function $\beta^*_{x,y}$ [mm]	~~100~~ 150	~~120~~ -> 36/72
rms IP beam size $\sigma^*_{x,y}$ [μm]	~~7~~ 2.5	~~7~~ 2.5
beam current [mA]	~~860~~ 500	~~6.5~~ 15
bunch spacing [ns]	~~25 (50)~~ 25	~~25 (50)~~ 25
bunch population [10^{10}]	~~17~~ 10	~~0.1 (0.2)~~ 0.23
Effective crossing angle	0.0	

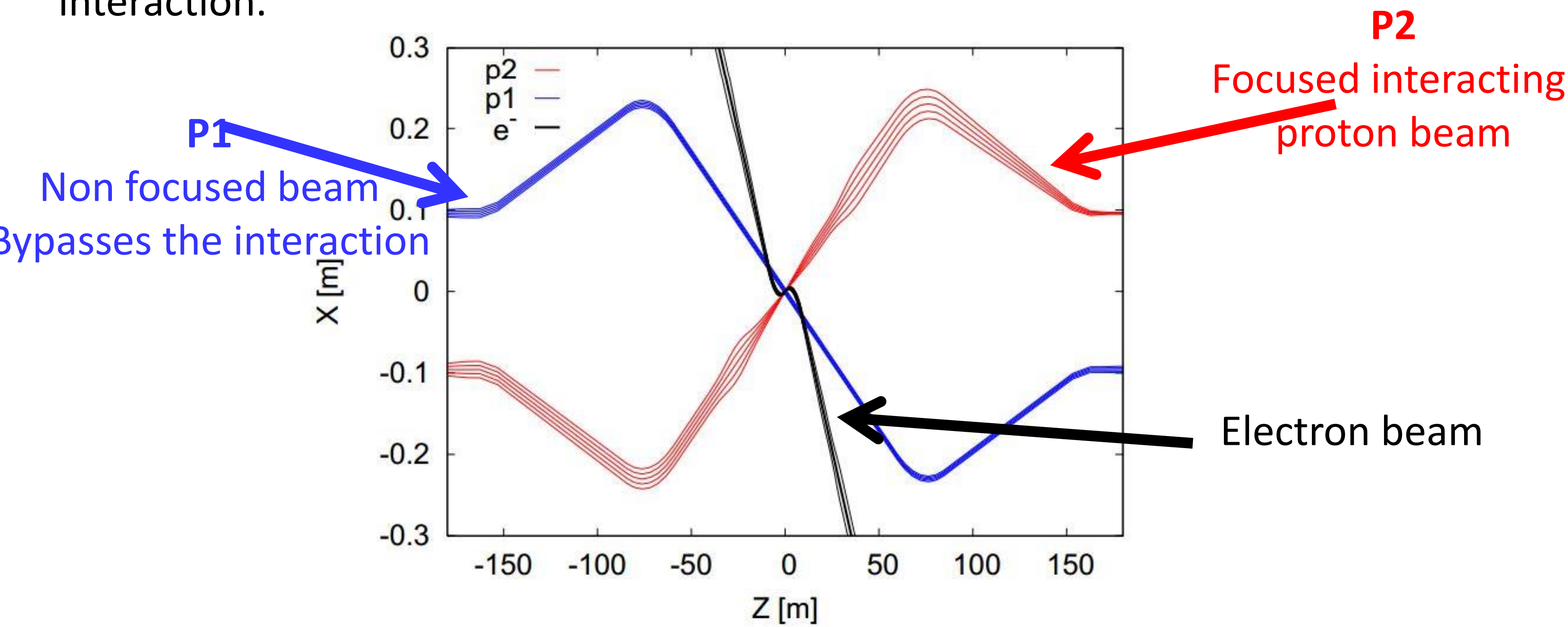
D. Schulte's Talk

IR Design Challenges

- Challenging part of the design of any accelerator. Has to meet requirements from both the detector and the accelerators.
- Smaller beam sizes, tight constraints.
- Competing criteria is found and compromises need to be taken.
- Find the best design that will optimize the luminosity with less impact on the accelerator.

Interaction Region

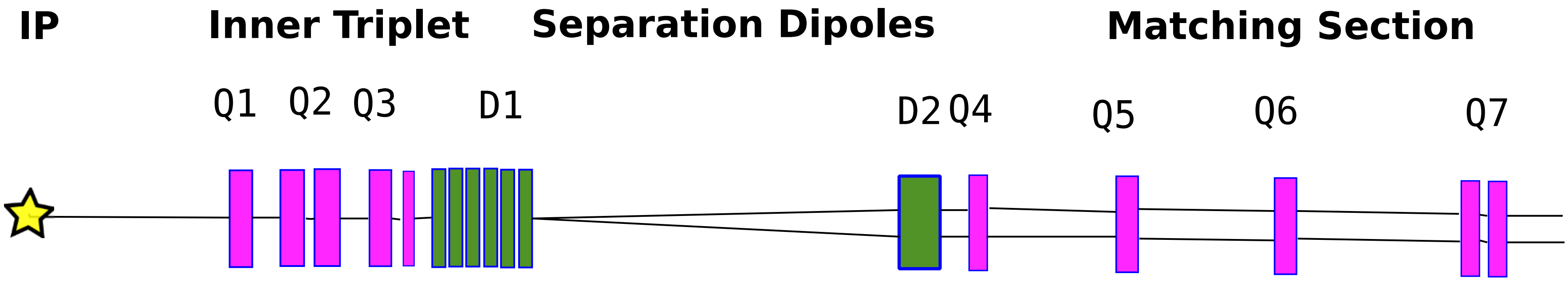
- Aim of the interaction region design: Collide one of the proton beams of the with the electron beam from the ERL while the other proton beam bypasses the interaction.



- LHeC has to work alongside HL-LHC and built on existing IR2, designed for a different experiment.
- FCC-he can be designed for the required purposes.

Interaction Region

General Design of the IR:



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

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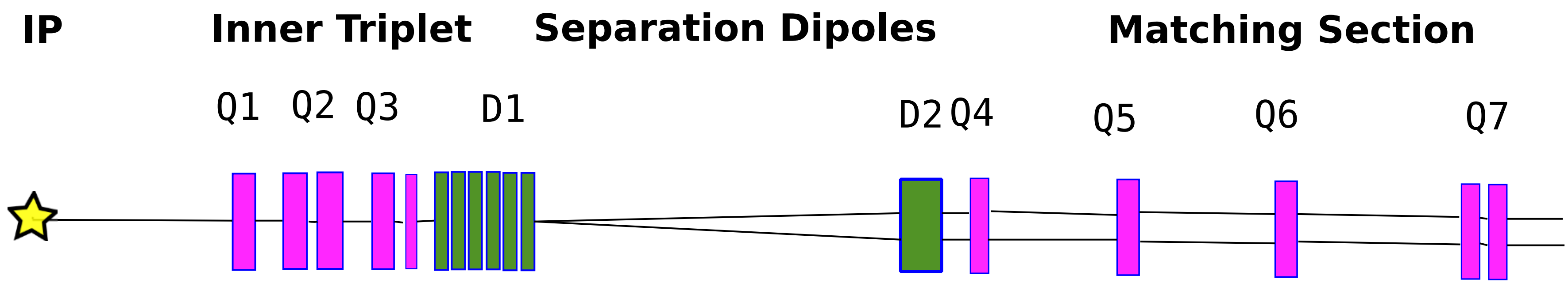

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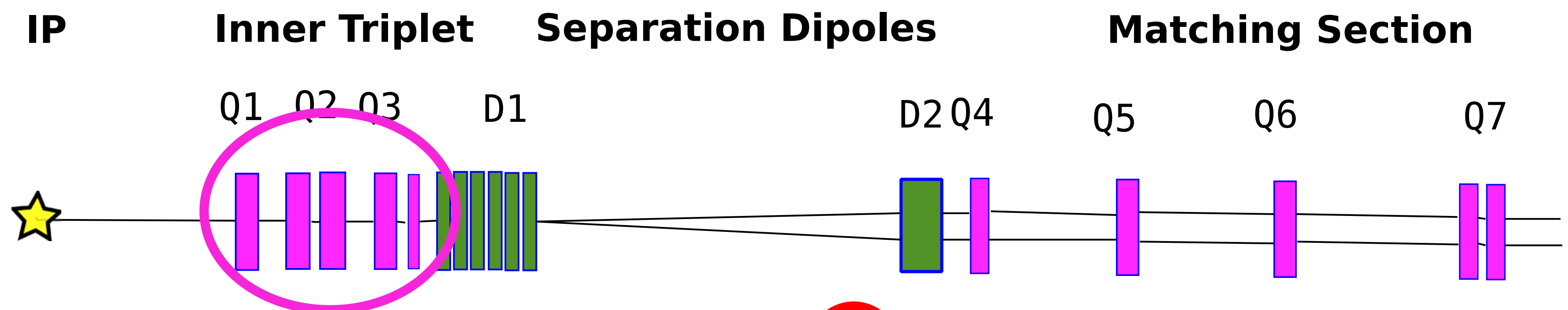

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Implementation of new inner triplet Q1-Q3

Luminosity inversely proportional to the size of the beam of the interaction point.

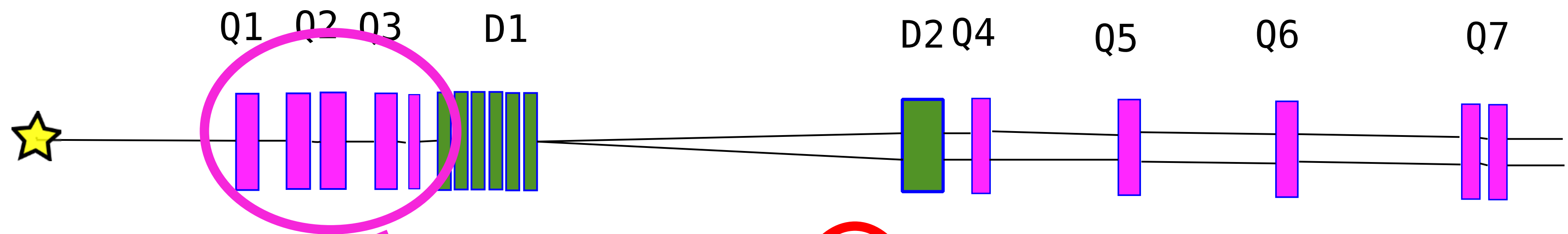
We need:

- β*=10 cm (10^{33} cm^{2}s^{-1})
- β*=5 cm (10^{34} cm^{2}s^{-1})

Interaction Region

General Design of the IR:

IP **Inner Triplet** **Separation Dipoles** **Matching Section**



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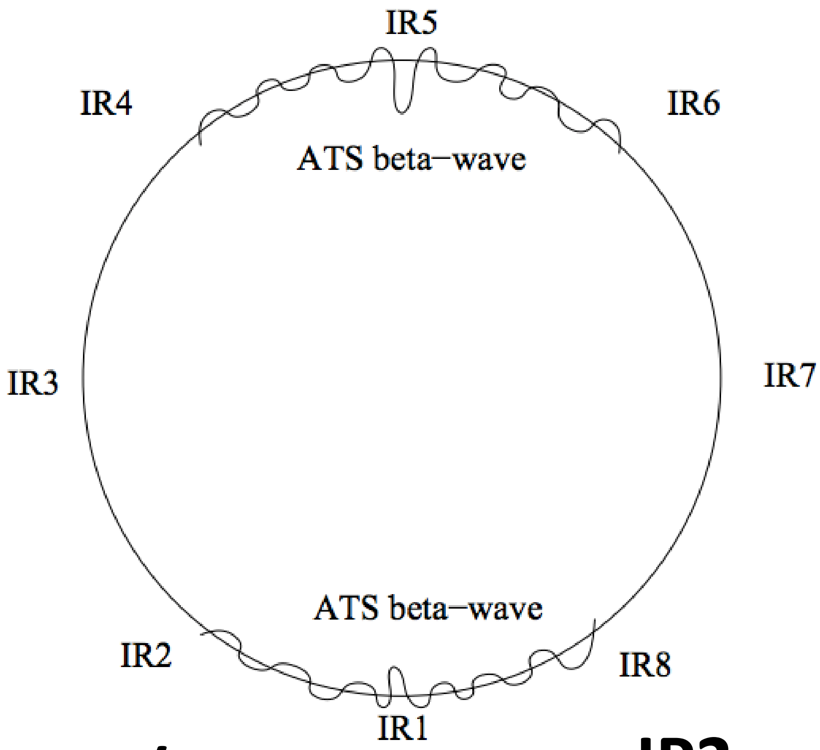
SEVERE LIMITATIONS

1. Quadrupole apertures
2. Quadrupole gradients
3. Limits of the chromatic correction scheme

ATS Scheme HL-LHC+LHeC

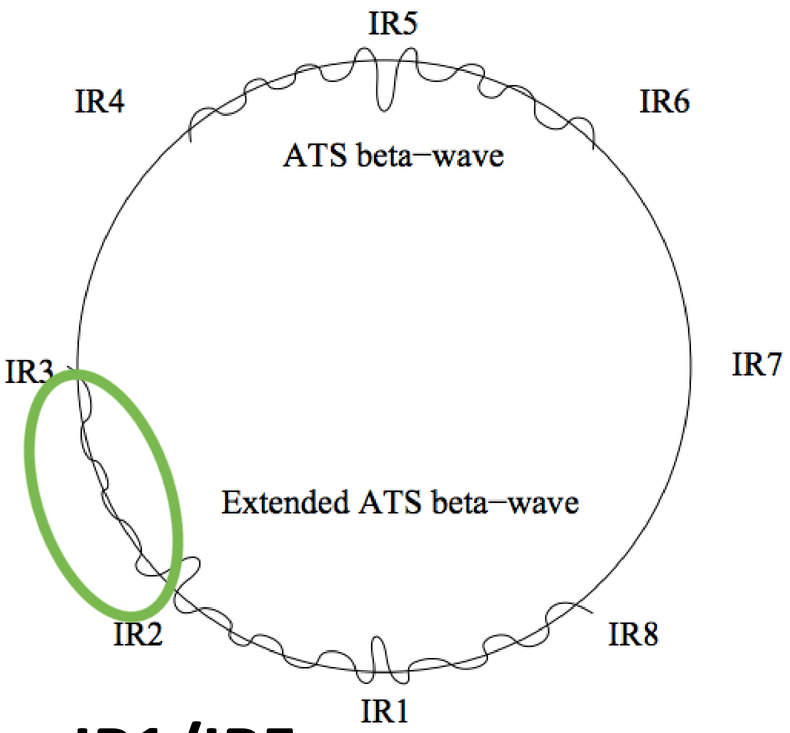
HL-LHC



IP1/IP5
β*=15 cm

IP2
β*=10 m

HL-LHC + LHeC



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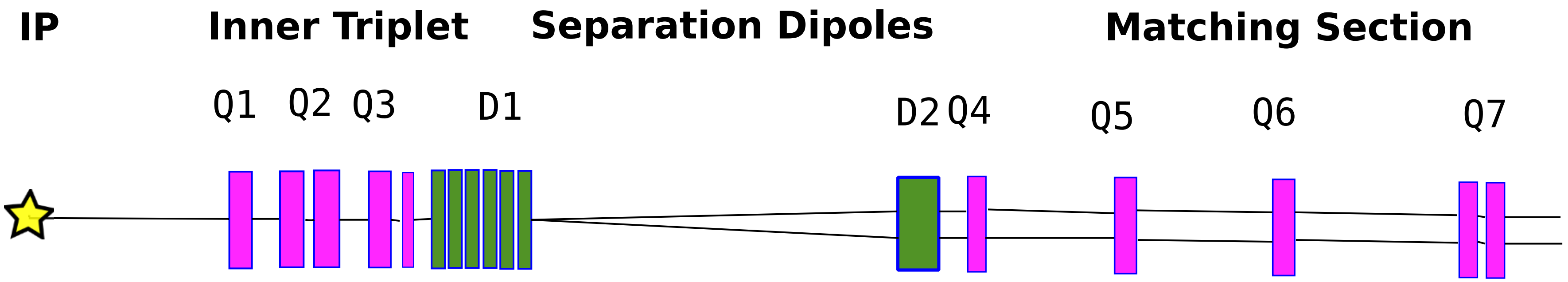
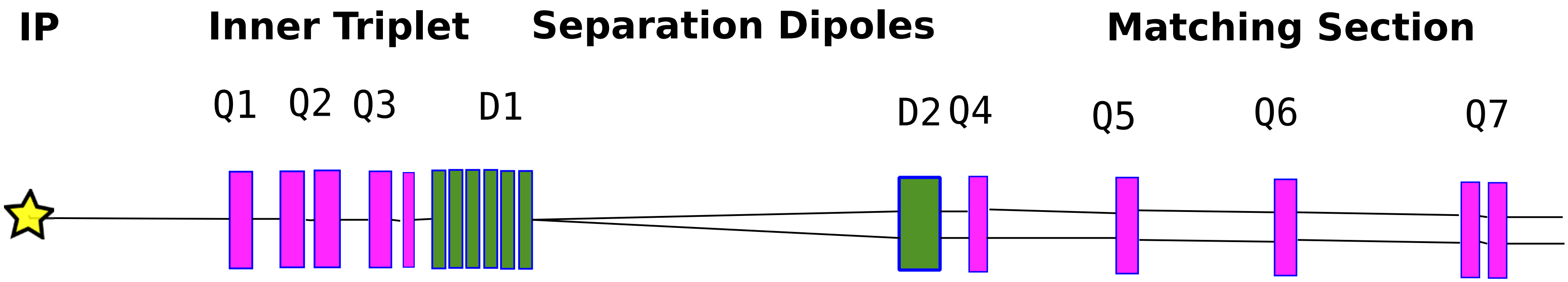
Interaction Region



Fcc-eh design presents some advantages:

1. IR can be design to be adapted to luminosity requirements (Not on a previous design).
2. More relaxed β* (15 cm instead of 10 cm), but higher energy.

Interaction Region



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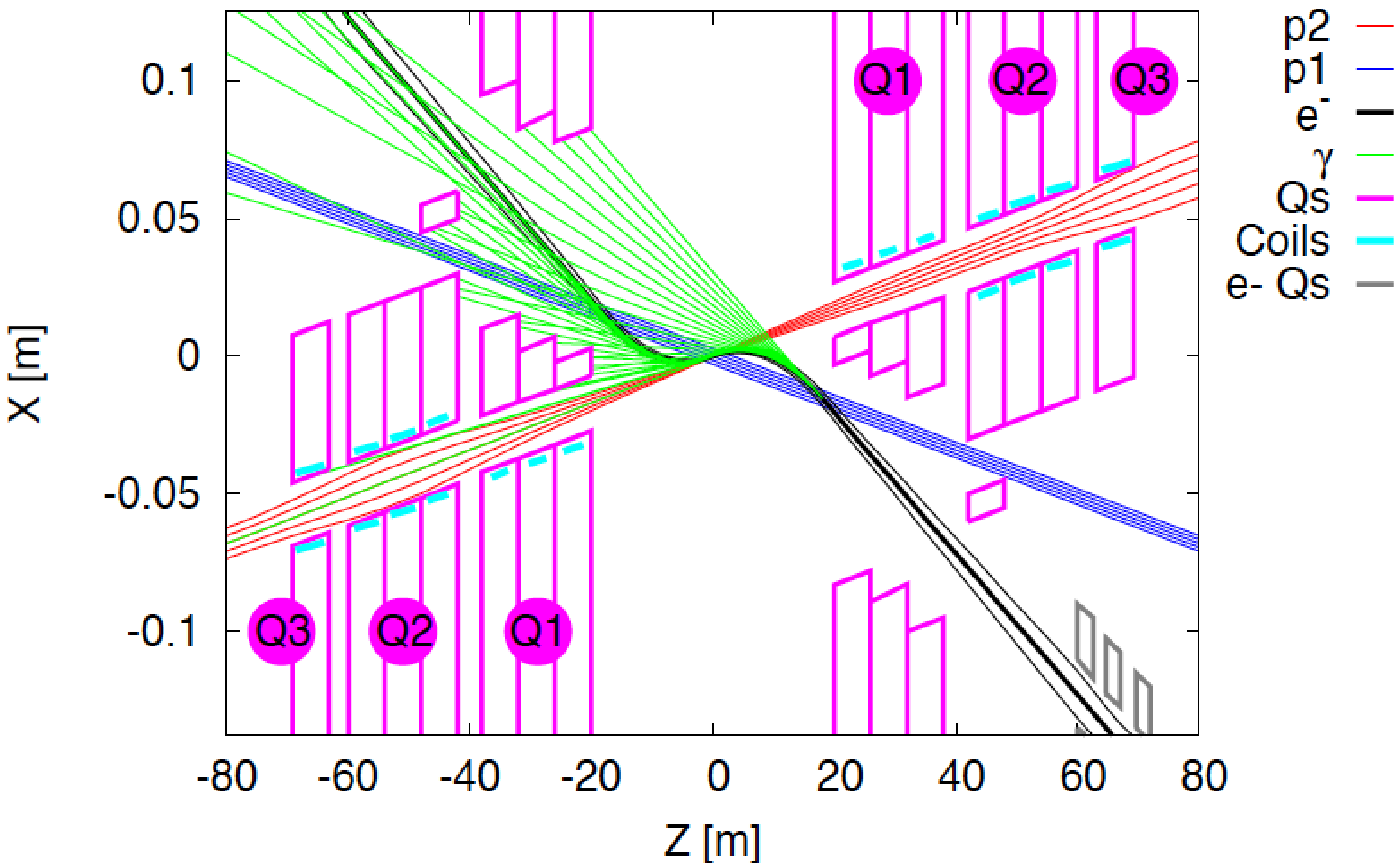
Comparisson with FCC-hh:

R. Martin Talk

On-going work for β* below 20 cm.

FCC-he might provide more flexibility in L* (FCC-hh detector requires L*>45m)

Interaction Region Layout



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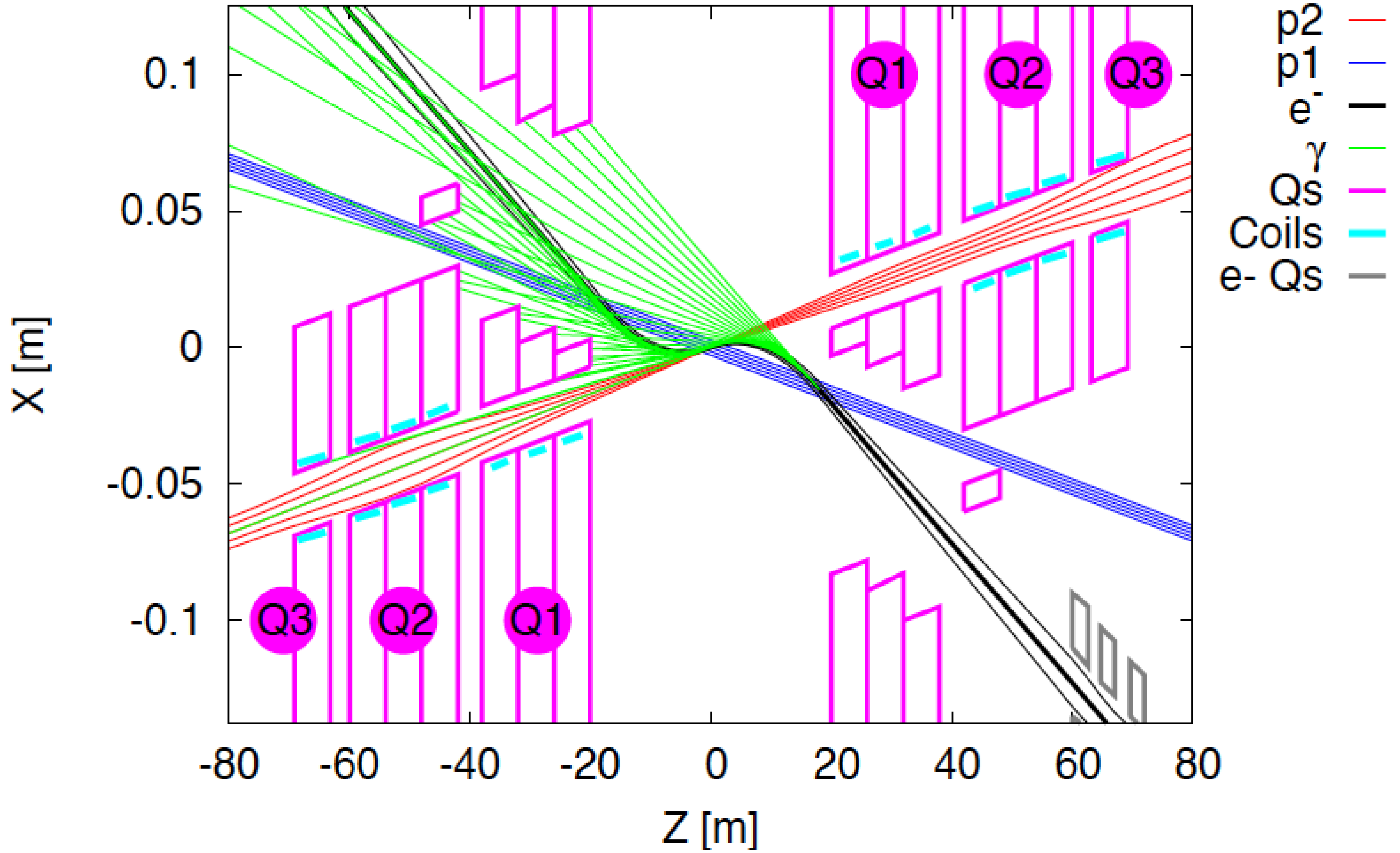
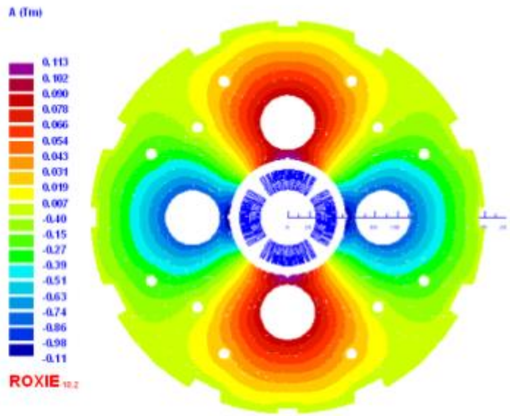


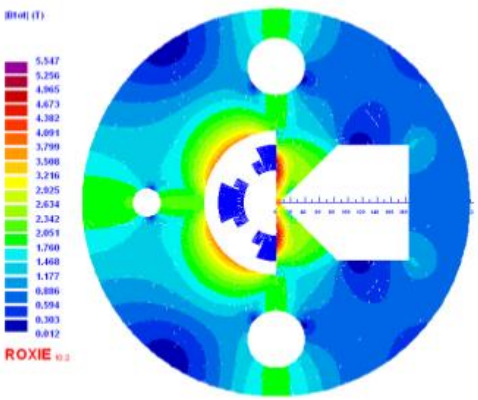
Main considerations for implementing the new inner triplet:

1. Control of the chromaticity → Keep L* small.
2. Synchrotron radiation coming from the electron beam → Careful design of the magnets.

Magnet Design

The design of the magnets for the LHeC included a normal-aperture to focus the proton beam and a field-free aperture for the electron and unfocussed proton beam.





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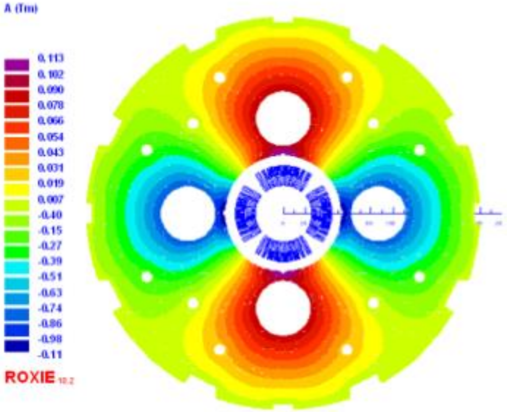
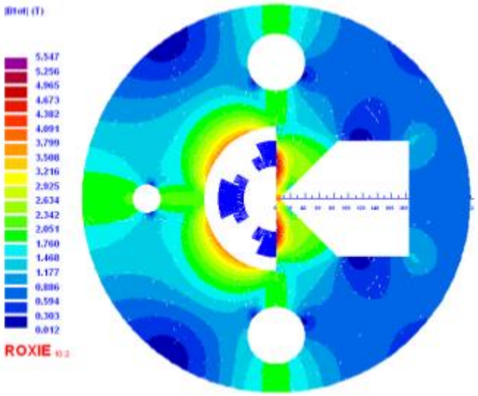
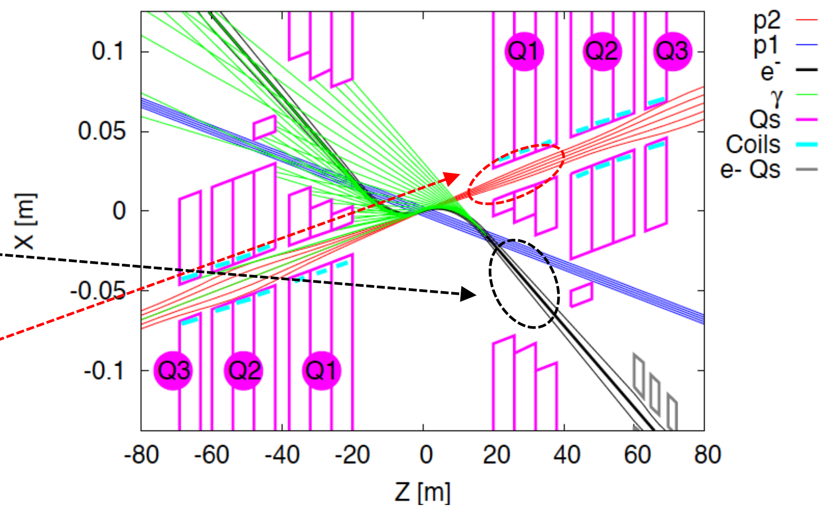


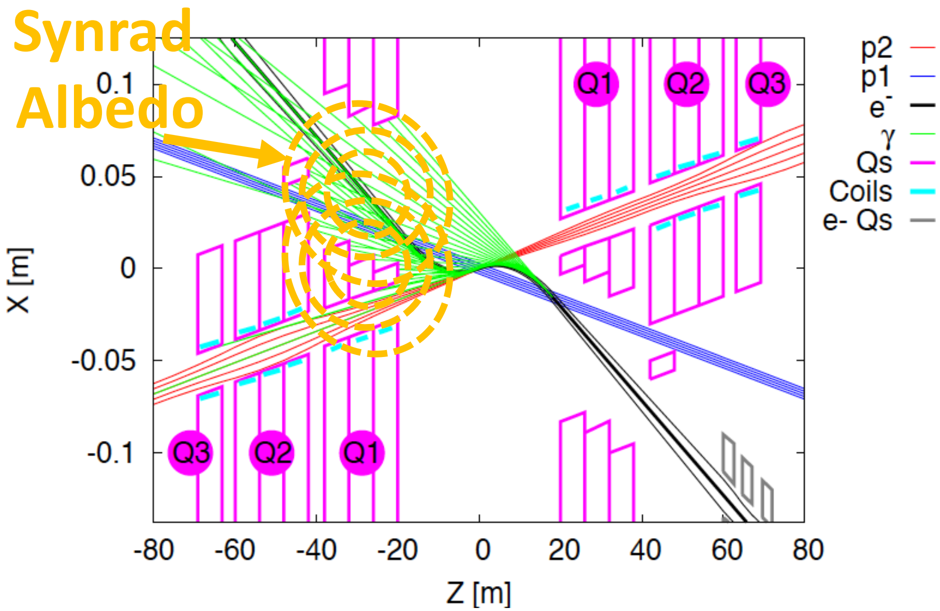


Consideration of the magnets for the LHeC included the design of a half quadrupole for Q1 given the short distance between the proton beam and the electron beam

This design presents stray fields in the 'field-free' region difficulting to match the **electron beam**. Also, beam is off-axis so there is a deflection on the focussed proton beam.



SR and Magnets

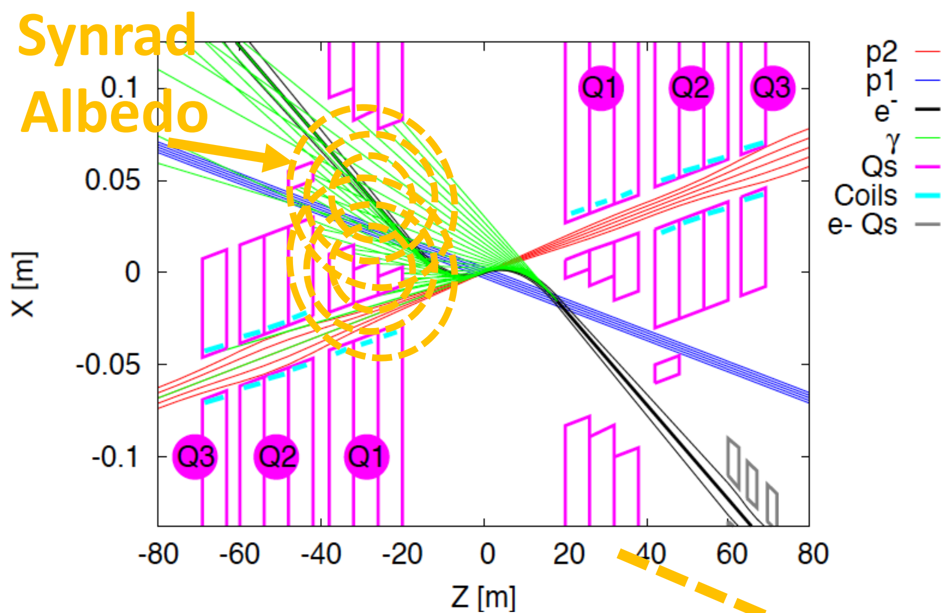


The albedo backscatter radiation from sufficiently high critical energy synchrotron radiation is very difficult to collimate close to the detector.

Experience from HERA -> Luminosity was limited by tolerable limits of experimental backgrounds in the detectors

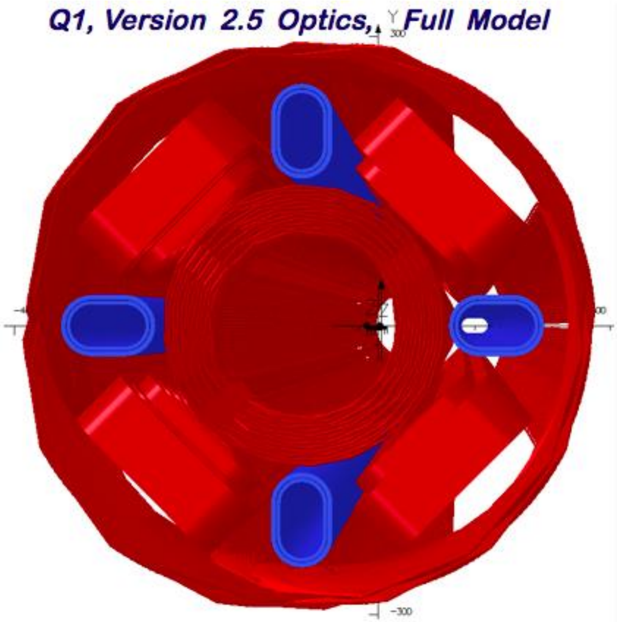
B. Parker

SR and Magnets



Magnet design planned for eRHIC IR.

With the use of outer coils a reduced field region is created inside the quadrupole -> Sweet Spot.

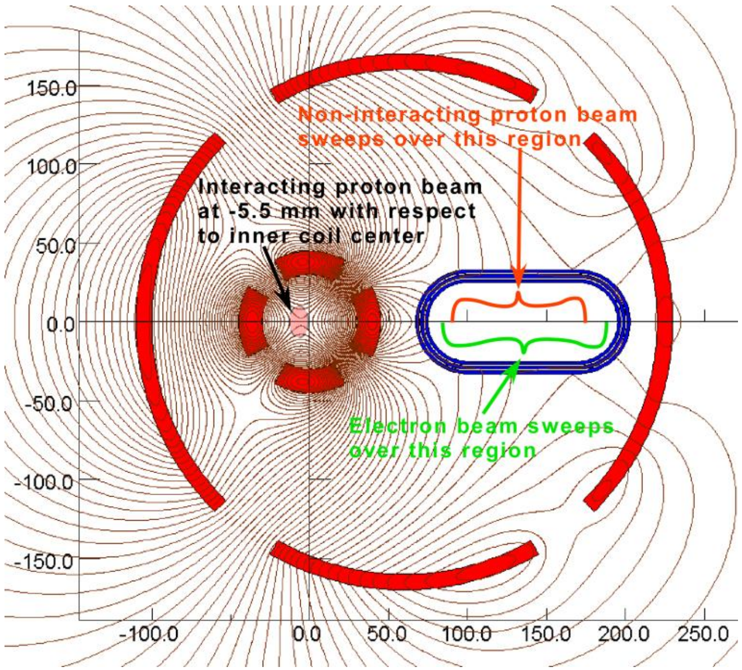


Possible new design for the Q1

Poster TUPMB042, "Sweet Spot Designs for Interaction Region Septum Magnets in IPAC 2016.

SR and Magnets

The sweet spot quadrupole has double the gradient for a given aperture, or double the aperture for the same gradients. Leaving more space to put masks through the whole length of Q1.



Design by B. Parker

The baseline LHeC IR geometry is particularly challenging as it requires very wide Sweet Spot regions to locate both the electron and proton beams.

B. Parker, LHeC Workshop, Chavannes, 2015.

Conclusions

- FCC-eh could work parallel to FCC-hh to have a complementary set of experiments.
- The IR can be designed to accommodate luminosity requirements. More versatility than the LHeC.
- The synchrotron radiation coming from bending the electron could be reduce by increasing L*.
- A new design for the Q1 proposed by B. Parker would allow to increase the aperture to control the backscattering radiation; however, it does become difficult to create a low-field Sweet Spot over too large a horizontally extended region.

Thank you!