Progress with FCC-eh IR design and SR load

R. Martin

Electrons for the LHC Workshop
June 28, 2018

Thanks to:
E. Cruz-Alaniz, B. Holzer, P. Kostka, B. Parker, R. Tomás

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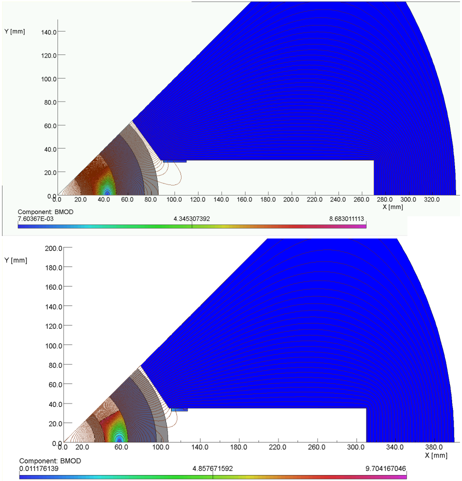
Why new IR for LHeC?

- Final focus magnet design of 2012 CDR was mainly concerned with field free region
- Result: poor field quality of the quadrupole field
- B. Parker: "*The MSQ design for Q1 given in the LHeC CDR is really not suitable for its intended usage.*" LHeC and FCC-eh workshop, Sept. 2017
- Meeting in **May 2018** to come up with new magnet designs that satisfy beam optics need and are realistic
- Update of LHeC CDR by **October 2018**: need for fast results ⇒ start with less ambitious $\beta^* = 10\,\text{cm}$ baseline option

New Magnets

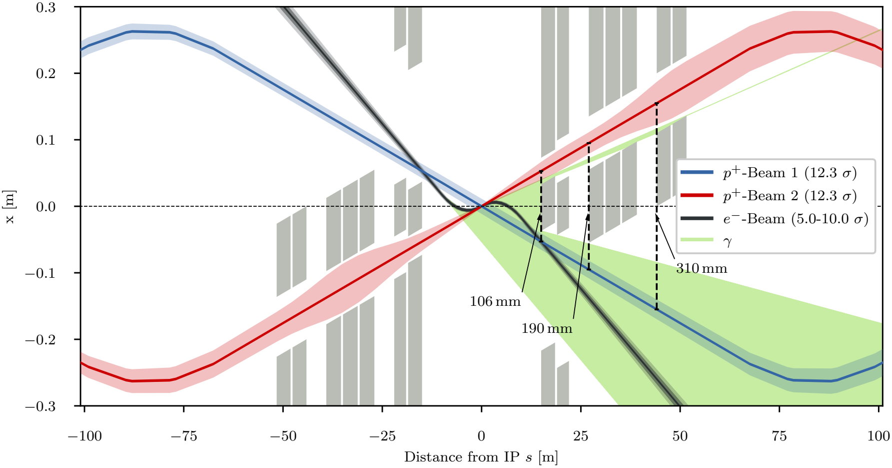
Magnet	Gradient [T/m]	Aperture radius [mm]
Q1a	252	20
Q1b	164	32
Q2	186	40
Q3	175	45

- Larger beam separation in Q1a ⇒ Synchrotron radiation increases
- Increase L^* to 15 m to keep Synchrotron radiation low



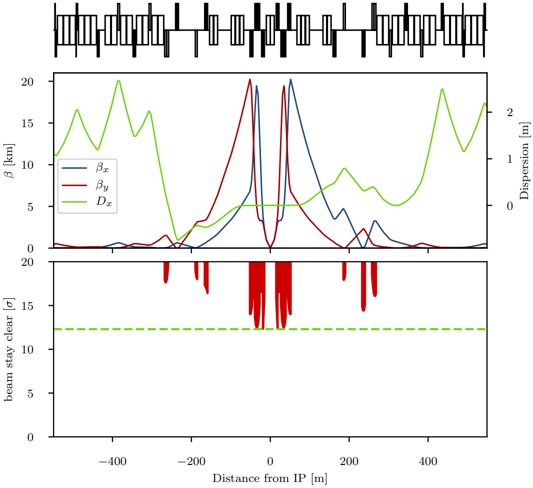
Magnet designs for Q1a and Q1b by B. Parker. See talk this afternoon.

LHeC interaction region design



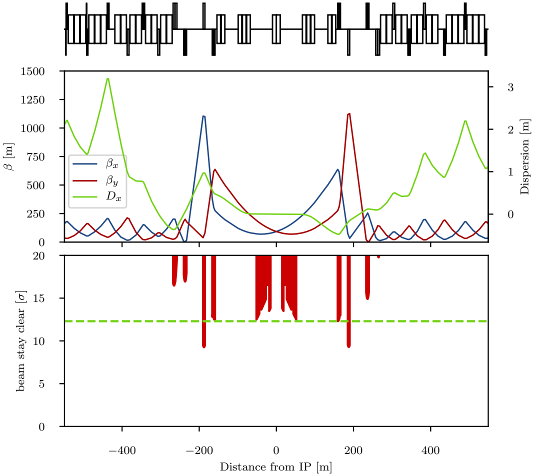
$$P_{\text{synch}} = 27\,\text{kW}, \quad E_{\text{crit}} = 513\,\text{keV} \quad \text{at } 60\,\text{GeV}$$

Beam optics: colliding beam with $\beta^* = 10\,\text{cm}$



- Integrated in HL-LHC (V1.0) lattice
- **Chromaticity correction and dynamic aperture studies** presented by E. Cruz-Alaniz
- Quadrupole strengths according to HL-LHC requirements, except for some tuning quadrupoles
- Recombination dipoles below 5.6 T
- Assumed beam stay clear of 12.3 σ will require local protection and specific phase advances in the ring

Beam optics: non-colliding beam



- Optics for injection and collision energy exist
- Aperture bottleneck in matching quadrupoles can probably be mitigated
- Quadrupole strengths according to HL-LHC requirements
- Dipoles like colliding beam

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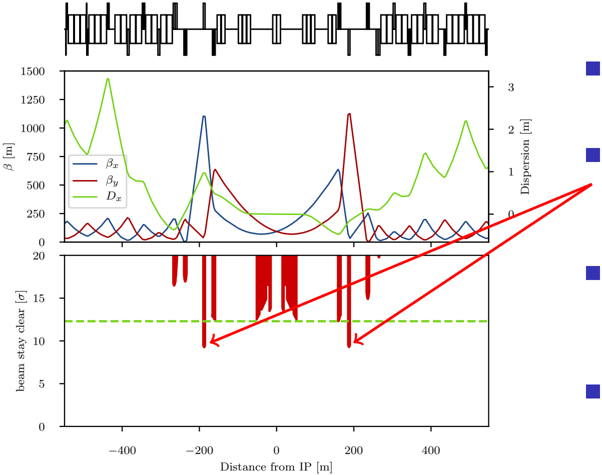

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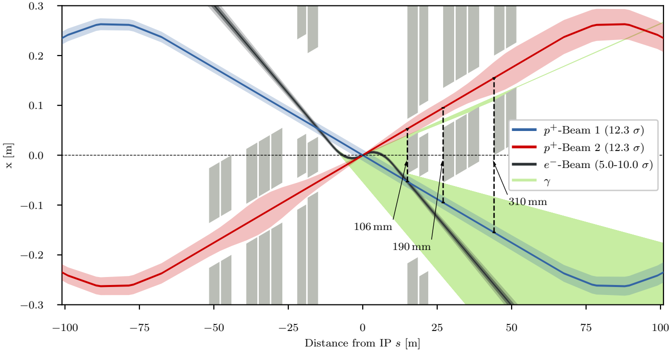
Beam optics: electron beam?

- Many open questions
- Where do we put the final focus system?

- Need input from (NC-) magnet experts
- Basic IR design exists, becomes more challenging if chromaticity correction is neccessary
- Integration in full ERL lattice?



PhD student starting to in September to work on electron beam

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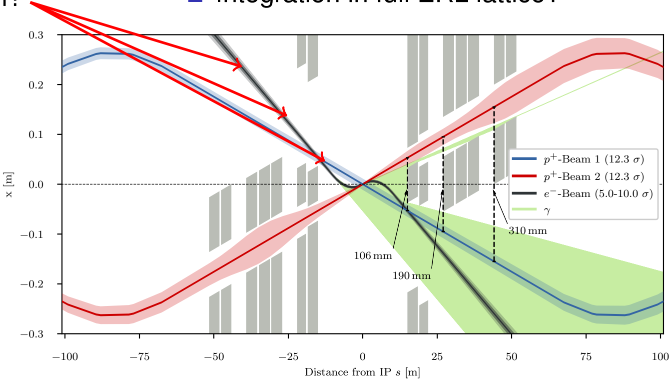

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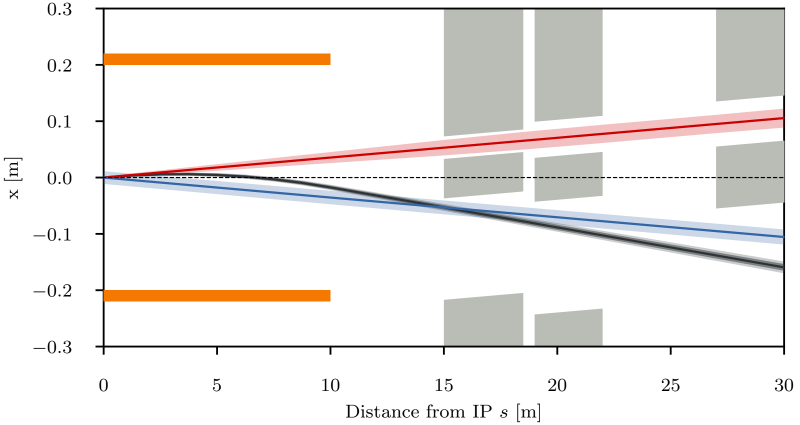
Lower β^*?

- L^* cannot be reduced due to synchrotron radiation
- The magnets were designed to accomodate a beam with $\beta^* = 10\,\text{cm}$
- Lower β^* $\Rightarrow$ Larger aperture needed $\Rightarrow$ lower gradients, potentially larger separation ($\Rightarrow$ Radiation)

$\Rightarrow$ **Need to get everything out of available space**


0.3
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x [m]
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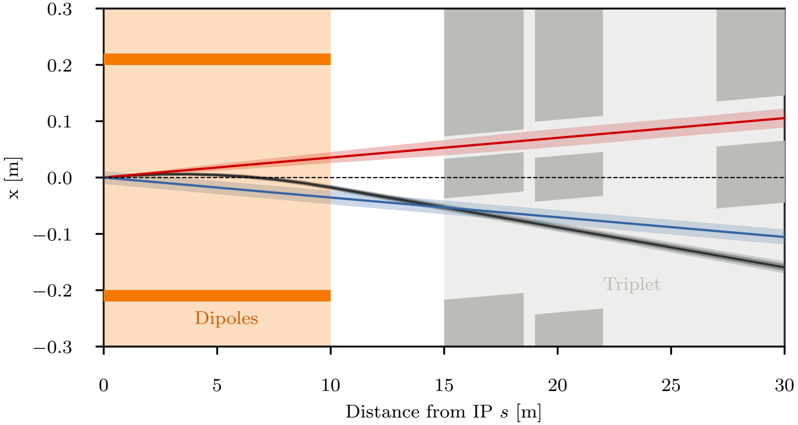
25
30
Distance from IP s [m]

Lower β^*?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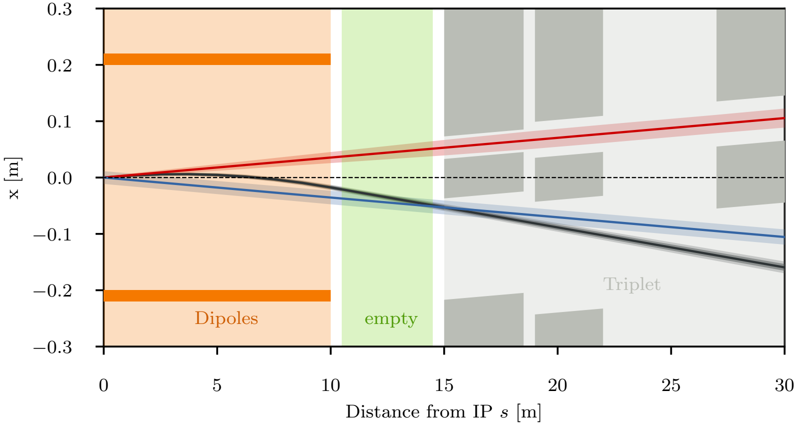
Distance from IP s [m]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Triplet
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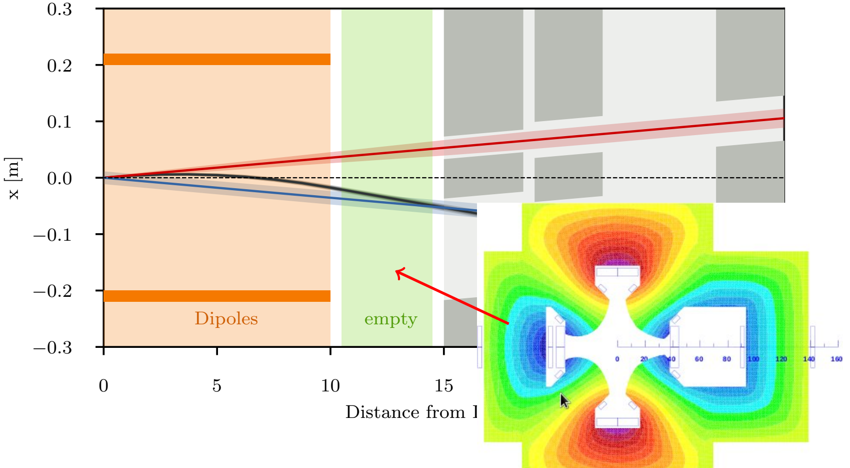
Distance from IP s [m]

Lower β^*?



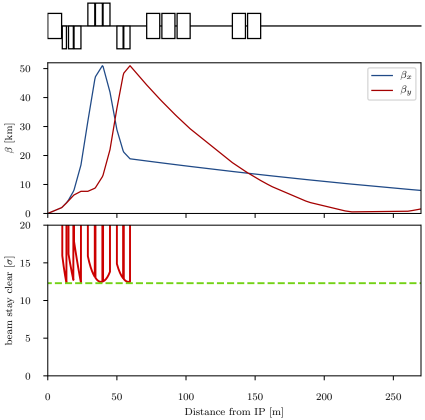
Normal conducting Quadrupole?

$\beta^* = 5\,\text{cm}$?

Magnet	Gradient [T/m]	Aperture radius [mm]
Q0 (nc)	50	20
Q1a	110	27
Q1b	162	37
Q2	123	62
Q3	123	62

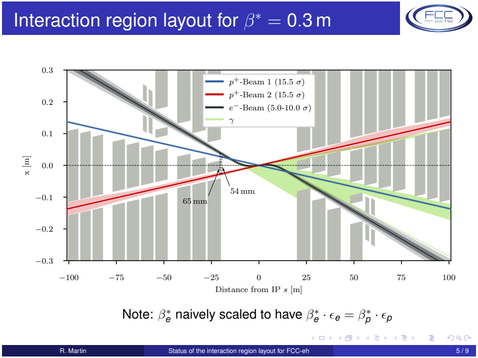
- Might be possible BUT:
  - needs NC septum design
  - SC quadrupole parameters to be approved
  - only realistic once integrated in ring
  - Chromaticity correction for $\beta^* = 5\,\text{cm}$ very challenging, maybe impossible

$\Rightarrow$ Many **IF**s



FCC-eh

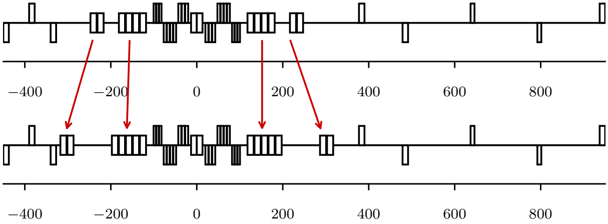
- FCC week 2018: presented first IR design based on some **LHeC magnets** and some **eduacated guesses**



- In most cases we do not want to use LHeC magnets because we need **smaller aperture** but **higher gradients**
- However, if new LHeC magnet designs are somewhat representative, we can make some “guesstimates”

FCC-eh: Guesstimate #1

- **Beam separation** in first quadrupole septum will be **similar to LHeC** $\Rightarrow$ proton crossing angle almost doubled from first LHeC guess (from 27 mrad to 51 mrad)
- Consequently we need more bending strength in recombination dipoles
- Magnetic field already capped at 10 T $\Rightarrow$ need more space
- First calculations show that we will use up almost all reserve space we still had in first design



- ... even though beam separation increased to 250 mm

FCC-eh: Guesstimate #2

- First quadrupole magnet becomes stronger than expected
- Unfortunately Q2 and Q3 will probably become 15 % to 20 % weaker than initially guessed

$\Rightarrow$ **Need more space** (which is scarce)

- FCC-eh design becomes **challenging**
- We need to iterate **FCC-eh specific** magnet designs $\leftrightarrow$ optics calculations from the start
- We need to squeeze out every bit of space we can get (e.g. from redesign of injection section?)

Guess: We will end up somewhere around $\beta^* = 30\,\text{cm}$.

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Possible improvement: save space by redesigning entire injection system of FCC-hh to inject closer to detector, like in LHC

Summary

- **We have optics** for $\beta^* = 10\,\mathrm{cm}$ option in LHeC
  - magnet parameters **realistic**
  - **integrated in ring**
  - chromaticity and dynamic aperture are being studied
  - minor issues to be adressed
- We have ideas on how to get lower β^* but they need lot of work (**Magnets!**)
- Electron IR needs a lot of questions adressed
- New magnet designs require also lots of rework on FCC-eh
- FCC-eh IR is **challenging due to limited space**, β^* around 30 cm looks possible
- If we can **rework the entire injection system**, lower β^* might be possible in FCC-eh