Thoughts on FCC-he IR optics

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FCC kick-off meeting, February, 2014
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Example: Nominal LHC IR optics I

- 

Longitudinal location [m]

- 

$\beta_x$, $\beta_y$,

$\beta^* = 0.4\text{m}$,

$L^* = 23\text{m}$

- 

$10^5 \theta/L$

$10^3 K$
Example: Nominal LHC IR optics II

- Longitudinal location [m]
  - dipoles
  - quads

- Max. aper. [cm]
- Field @ beam scr. [T]
Scaling from 7 to 50 TeV

- Scale all lengths by factor $f$,
- all quadrupole gradients by $f^{-2} \frac{50}{7}$,
- quadrupole apertures by $\sqrt{f} \frac{7}{50}$
- peak quadrupole field $f^{-3/4} \sqrt{50/7}$
- dipole angles strongly depend on beam1-beam2 separation ($bs_{50}$)
- dipole field scales with $f^{-2} \frac{50}{7} \times bs_{50}/bs_{7}$
- reasonable range for $f \in [1.5, 3]$
FCC-hh IR from LHC $f = 2$

![Graph showing longitudinal location and field at beam screen for dipoles and quads]
FCC-hh IR from LHC, $f = 2$

$\beta_x$, $\beta_y$

$10^5 \theta/L$, $10^3 K$

$\beta^* = 0.8 m$

$L^* = 46 m$
### LHeC magnets

<table>
<thead>
<tr>
<th>4600 A MQY cable</th>
<th>4900 A MQY</th>
<th>NbTi: 6700 A, 248 T/m at 88% LL</th>
<th>NbTi: 4500 A, 145 T/m, 3.6 T at 87%</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 mm aperture</td>
<td>35 mm (half) app.</td>
<td>Nb3Sn (HFM46): 8600 A, 311 T/m, at 83% LL</td>
<td>Nb3Sn (HFM46): 5700 A, 175 T/m, 4.7 T at 82% on LL (4 layers)</td>
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<tr>
<td>107 mm beam sep.</td>
<td>65 mm beam sep.</td>
<td>23 mm app.</td>
<td>46 mm (half) app.</td>
</tr>
<tr>
<td>0.016 T fringe field in electr. pipe</td>
<td>0.03 T</td>
<td>0.03 T, 3.5 T/m</td>
<td>0.37 T, 18 T/m</td>
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<td></td>
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<td>0.09 T, 9 T/m</td>
<td>0.5 T, 25 T/m</td>
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</table>
Scaling considerations for LHeC

★ reasonable range for $f \in [1.5, 3]$
★ but baseline is to keep e- at 60 GeV
★ $L^*$ between 15-30 m $\rightarrow$ SR power $< 20$ kW and Q1 normal quadrupoles possible
★ Proton beam size between 3.2-4.5 $\mu m$ $\rightarrow$ Electron $\beta$ functions to be reduced to 0.025-0.05 m !!
Aberrations already $\approx 10\%$ for nominal LHeC $\rightarrow$
Likely to increase to 30%-60% for FCC-he (lower $\beta^*$) $\rightarrow$ Need a new design for e-FFS!
Summary and outlook

★ Scaling factor from LHeC between a $[1.5, 3]$

★ FCC-he proton $\beta^* = 0.15-0.3$ m, $L^* = 15-30$ m, normal quads, proton SR power?

★ FCC-he e- $\beta^* = 0.025-0.05$ m, SR power $< 20$ kW

★ Need to assess proton layout and optics and a complete redesign of e-FFS

★ Many critical R&D tasks: magnet feasibility, beams separation, energy deposition from IP debris, technology choice, e-cloud, beam-beam long-range, synchrotron radiation, beam emittances, flat beams, etc.