Update on the FCC-hh Interaction Region Design

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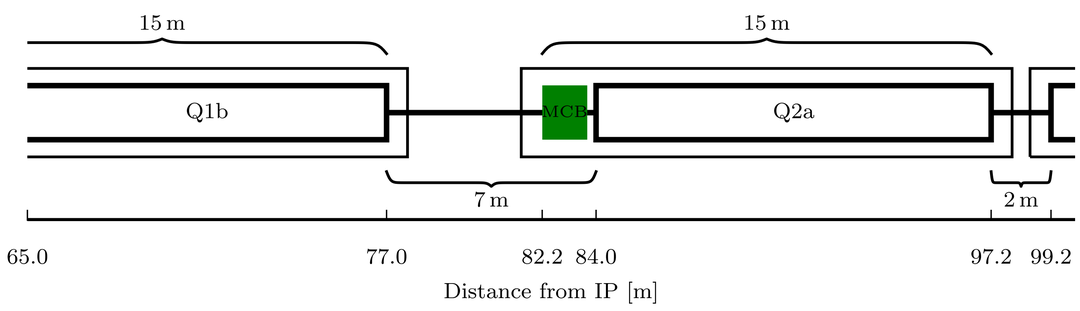
Abstract

The interaction region lattice with $L^* = 45\,\text{m}$ and a long, large aperture triplet has become the reference design for the FCC-hh project with significant margins to the performance goals in terms of β^*. After encouraging results of dynamic aperture studies with triplet errors, some old issues of the baseline interaction region lattice need to be addressed. These issues include realistic lengths of the final focus quadrupoles that exceeded 30 m, as well as the total length of the straight section that exceeded the specified 1400 m by 100 m. Furthermore, a first look is taken at the requirements for crab cavities.

Triplet

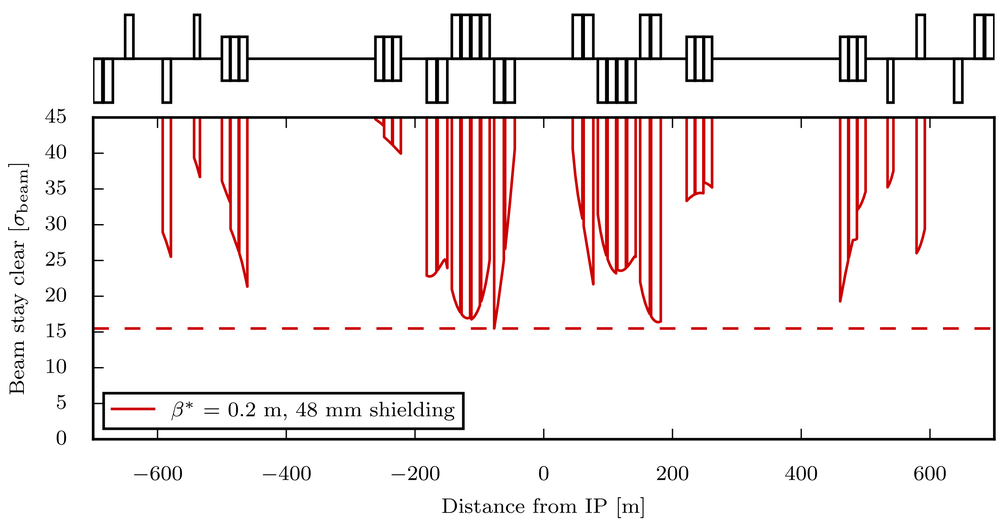


Magnet	Length [m]	Maximum gradient [T/m]	Inner Diameter [mm]
Q1	15	115	190
Q2	13.2	94	240
Q3	15	94	240

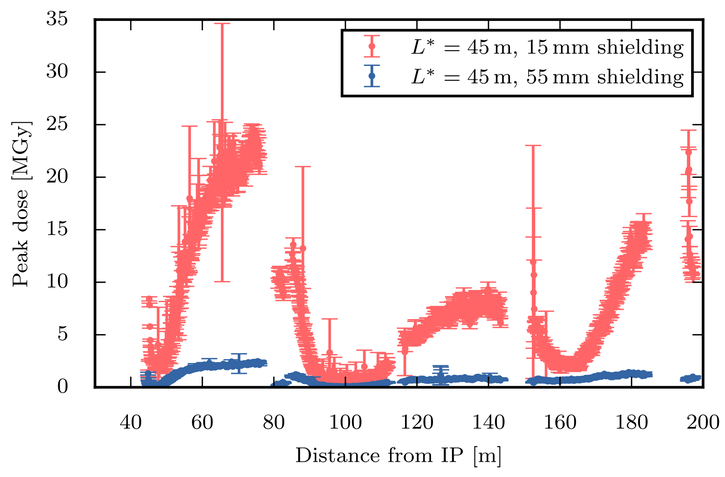
- Lengths of triplet quadrupoles were adopted to maximum of 15 m
- To keep overall magnet length, 2-4-2 scheme was adopted
- 2 m spacing between submagnets and 7 m spacing between main magnets for BPMs, vacuum equipment, orbit correctors
- No separate cryostat for orbit correctors ⇒ shared cryostat with Q2a/Q2d
- Assuming spacing of 0.5 m ⇒ 1.3 m orbit corrector length, equals 3.9 Tm per plane (nested)
- Implications of gaps in shielding between submagnets to be studied

Beam stay clear and thick shielding option

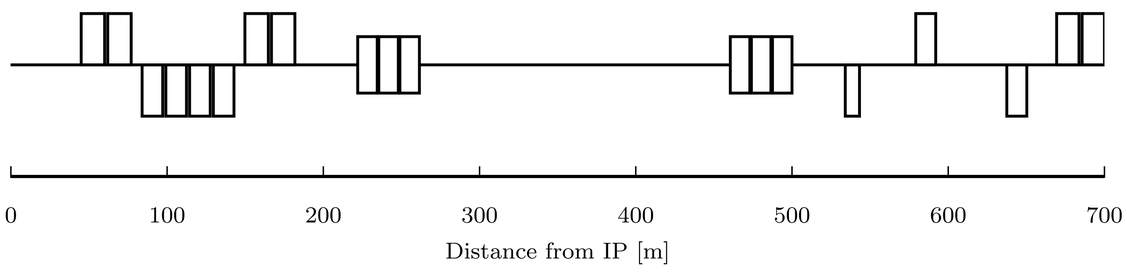
- Triplet aperture still allows for β^* below 0.1 m at beam stay clear of $15.5\,\sigma$ and with 15 mm thick shielding inside quadrupole apertures
- Alternative option with very thick shielding of 48 mm still allows to reach $\beta^* = 0.2\,\text{m}$



- Very thick shielding has shown to reduce peak doses enough to not exceed technical limit of 30 MGy even for integrated luminosities of $17\,500\,\text{fb}^{-1}$

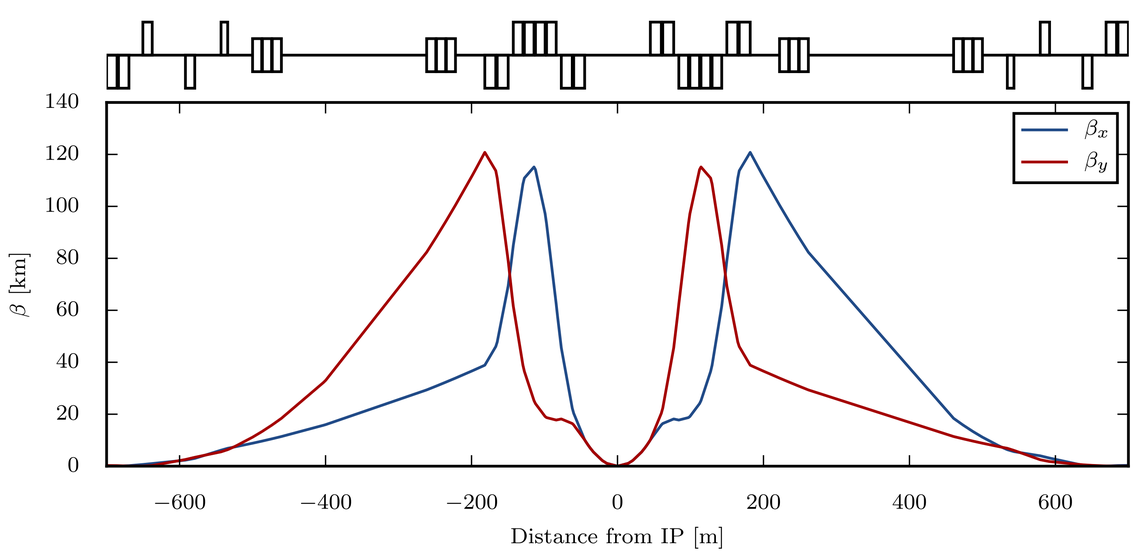


- Damage caused by neutron flux still to be studied in detail



Separation and recombination dipoles

- The successive reduction of the intra-beam spacing to 204 mm significantly reduced strengths of D1 and D2
- With some modifications the strengths could be reduced below 2 T
- Currently normal conducting magnets are foreseen to ease design and radiation protection



Matched optics for $\beta^* = 0.2\,\text{m}$.

Matching section

- Shortening of the matching section posed significant challenge for the arc integration
- Biggest issue was Q7 exceeding the gradient limit by factor of 3
- New preliminary optics were found to match $\beta^* = 0.15\,\text{m}$ to 9 m without exceeding gradient limits (gradient ranges to be checked)
- For smaller β^* and ATS scheme similar to HL-LHC might be possible

Crab cavities

- Large crossing angle at small β^* will require crab cavities to reduce luminosity reduction factor
- First studies with old IR lattice suggest 10.4 MV integrated voltage for full crabbing at $\beta^* = 0.3\,\text{m}$
- Preliminary goal: full crabbing at $\beta^* = 0.1\,\text{m}$ in one plane
- Scaling with crossing angle ⇒ 18 MV
- Assuming HL-LHC technology: 1 MV/m including cryostats and space for crab cavities of other beam ⇒ 20 m of space have been allocated for crab cavities between D2 and Q4
- Required voltage to be checked again with integrated optics
- Crossing angle gymnastics for radiation mitigation will require a hardware exchange of the crab cavities