FCC-hh interaction region optics

R. Martin

FCC week 2019
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On behalf of the EuroCirCol WP3 team

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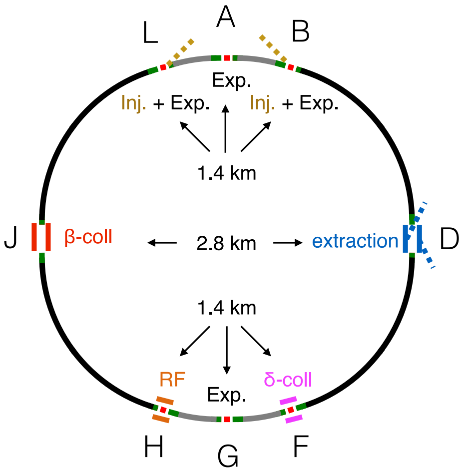
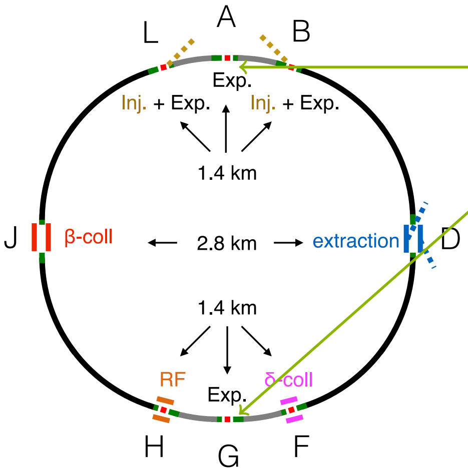
FCC-hh interaction regions



- **High luminosity IRs** in points A and G
- **Low luminosity IRs** in points B and L

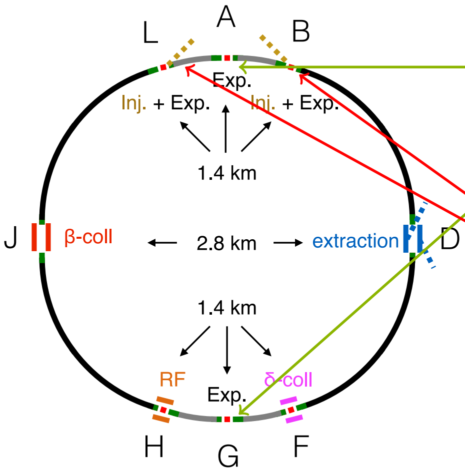
FCC-hh interaction regions



- **High luminosity IRs** in points A and G

Topic of **this** talk

- **Low luminosity IRs** in points B and L



- **High luminosity IRs** in points A and G

Topic of **this** talk

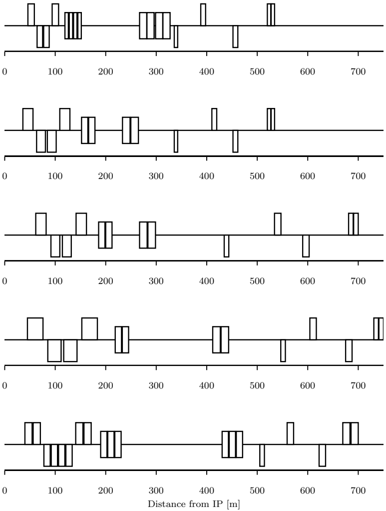
- **Low luminosity IRs** in points B and L

Talk by M. Hofer, next session

FCC-hh parameter overview

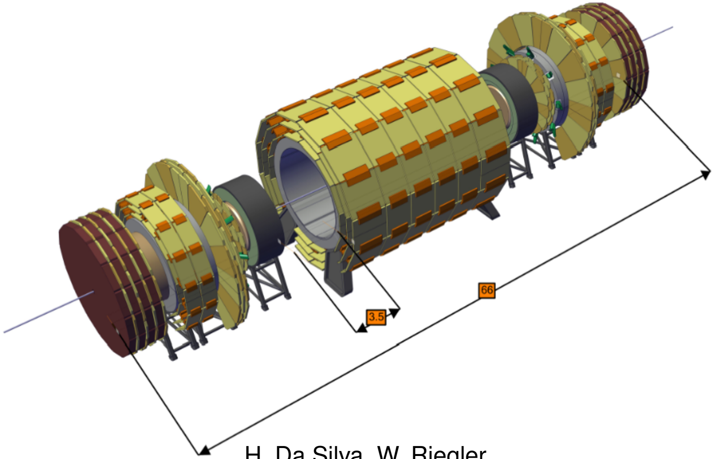
	FCC-hh Baseline	FCC-hh Ultimate
Peak luminosity/IP [10^{34}cm^{-2}s^{-1}]	5	30
Events/crossing	170	1020
Bunch spacing [ns]	25	
Bunch population N_b[10^{11}]	1.0	
Beam current [A]	0.5	
Norm. emittance [µm]	2.2	
IP beta function β^* [m]	1.1	0.3
Transv. emittance damping time [h]	1.1	
Beam beam parameter ξ_{bb}	0.01-0.02	0.03-0.05

- Two parameter sets with same beam current but different luminosity
- **Focus on Ultimate parameters**
- Integrated luminosity target: 17.5 ab^{-1}
- Optionwith 5 ns bunch spacing is considered but not studied so far



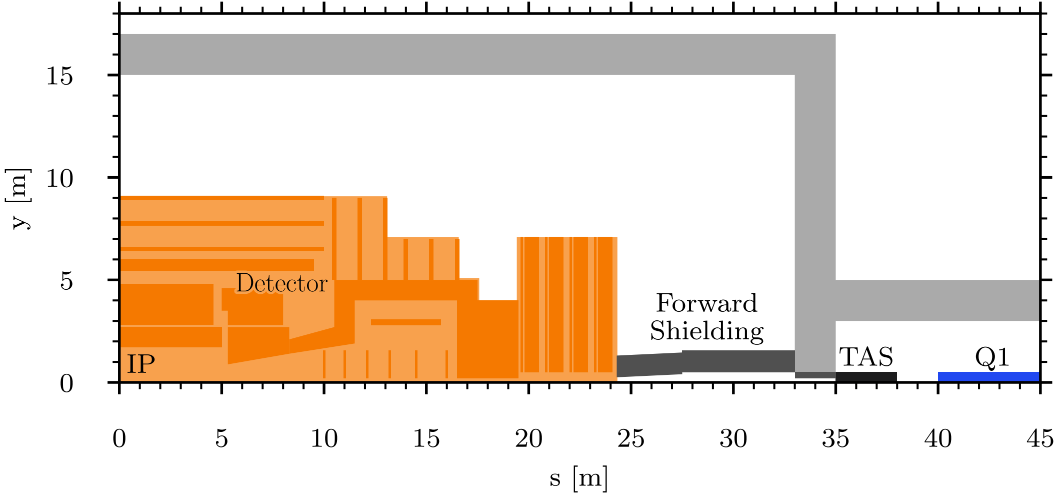
- **2014**: scaled HL-LHC design
- **Late 2014**: improved design, $L^* = 36$ m, longer triplet, minimum β^* below 0.3 m, superconducting separation dipoles
- **2015**: experimenting with longer $L^* = 61$ m, no impact on minimum β^*
- **2016**: From previous experiences: **even longer** triplet, $L^* = 45$ m, normal conducting separation dipoles
- **2017 onward**: realistic magnet lengths, increased separation, finalizing design, shortened L^*

- Shortened **opening scenario**



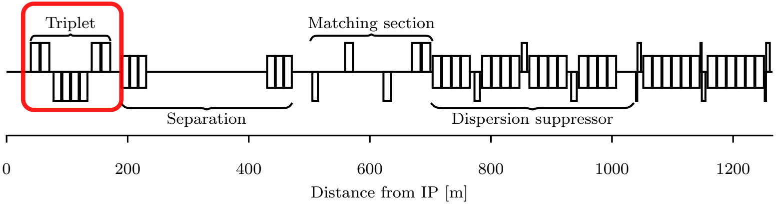
H. Da Silva, W. Riegler

Machine detector interface



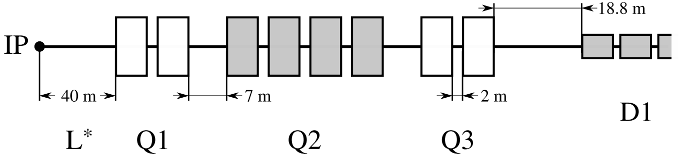
⇒ possible to **shorten L^* to** 40 m

High Luminosity IR optics: Triplet

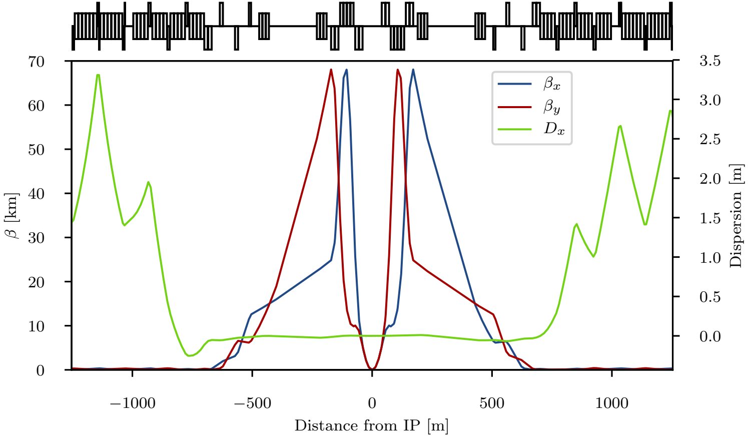


- Large aperture quadrupoles
- Magnet lengths chosen to fit into 15 m cryostats
- Total magnetic length 108 m

Coil Ø [mm]	164	210	210
Gradient [T/m]	130	105	105
Length [m]	14.3	12.5	14.3



Main IR Optics



Main IR optics for $\beta^* = 0.3$ m.

- Peak β function reach up to ≈ 70 km for "ultimate" optics
- Impact on Dynamic Aperture

Talk by E. Cruz-Alaniz, this session

Main IR Optics: Energy deposition in triplet

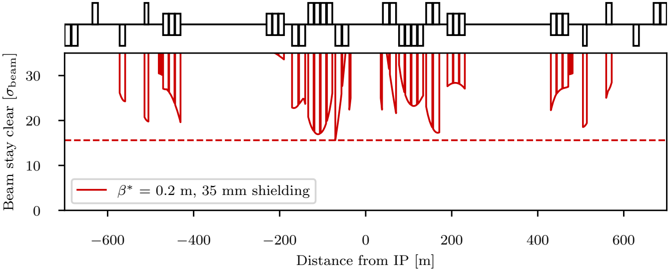
- Triplet magnets are exposed to high levels of radiation from **collision debris**
- Large apertures necessary to house thick shielding inside

See talk by B. Humann, this session

Thick shielding option now default:

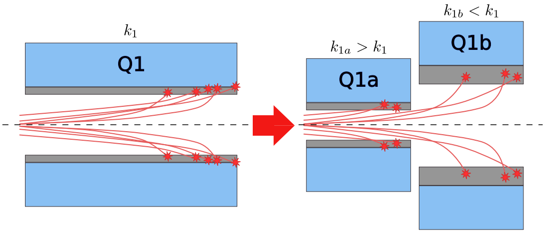
- 35 mm of INERMET180 (Tungsten)
- Aperture large enought to accomodate $\beta^* = 0.2\,\mathrm{m}$

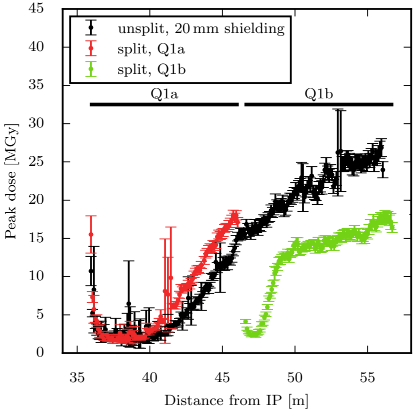
Can reach β^* beyond Ultimate / have comfortable margins



Implementation of the Q1 split

- Originally developed to reduce peak dose at the end of Q1

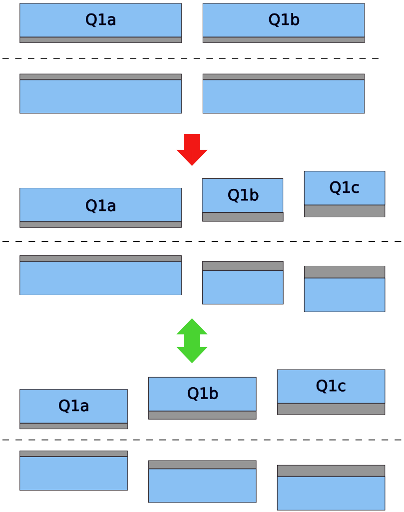




- Proof of concept and fallback solution in case of high doses
- Now implemented to reduce overall heat load on Q1b cold mass

See talk by C. Kotnig on Wednesday, 11:00

Q1 split with 3 Submagnets



Best way to reduce total load on cold mass: **shorten individual magnets**

Two options:

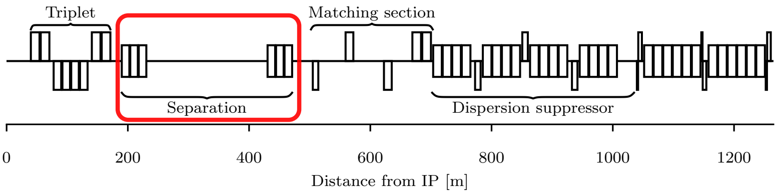
- Keep Q1a at full length, split Q1b in two $\Rightarrow$ best in terms of total power in cryostat

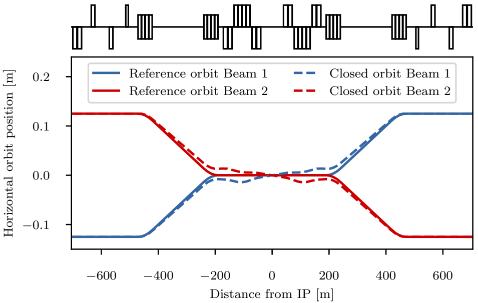
  First iteration in talk by B. Humann, this session

- All submagnets have equal length $\Rightarrow$ shorter Q1a is needed for **k-modulation** to accurately measure β^*

  Needs study

Main IR optics: Separation

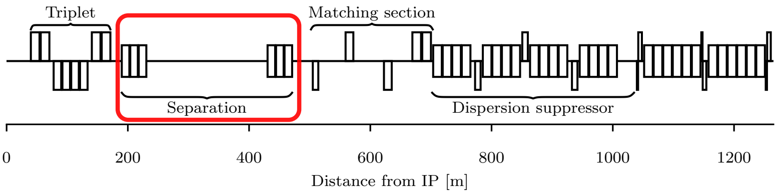




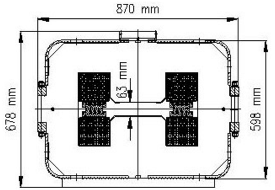
- Separate beams from shared triplet apertures
- Beam separation in arcs 250 mm
- Orbit bumps and crossing angle to avoid **parasitic collisions** and keep **long range beam-beam effect** low enough

Talk by T. Pieloni, this session

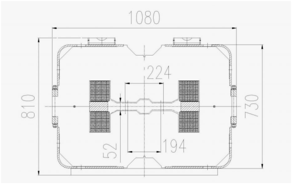
Main IR optics: Separation



- Dipole strengths were close to 2 T
- Use of normal conducting magnets
- Advantages:
  - Robustness in the highly radiative environment
  - Better field quality
- Assuming LHC-like magnet designs

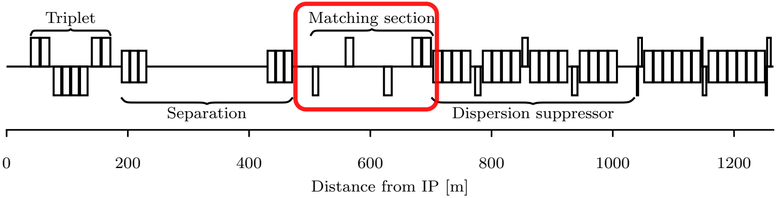


D1 (MBXW design)



D2 (MBW design)

Main IR optics: Matching section



- Total IR length complies with design goal of 1.4 km
- Matched optics found for $\beta^* \geq 0.15$ m (does not fit through triplet)
- **Crab cavities** between recombination dipole and first matching quadrupole
- First studies with varying degrees of orbit leakage:
  - Full crabbing at Ultimate parameters: $V_{\text{crab}} = 13.4$ MV
  - Full crabbing at $\beta^* = 0.15$ m: $V_{\text{crab}} \approx 20$ MV
  - ≈ 20 m of space reserved $\Rightarrow$ expected to be compatible with **full crabbing beyond Ultimate**

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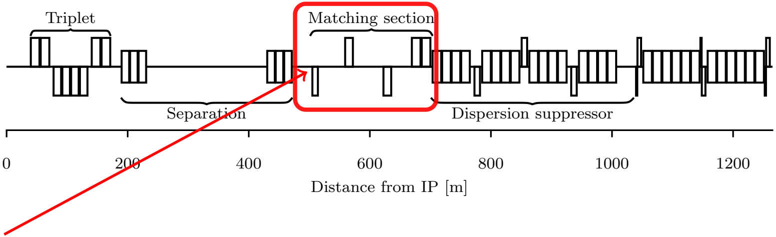

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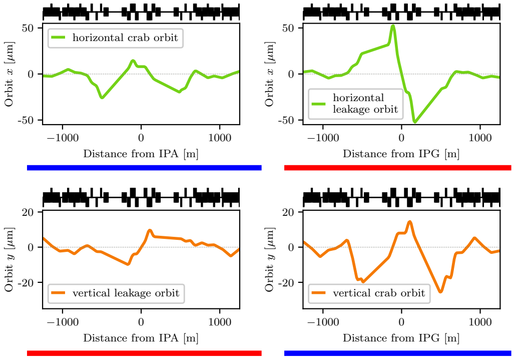
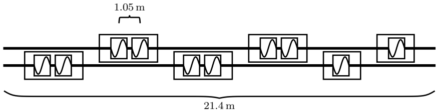
Crab cavities



Crab orbits and orbit leakage into the other high luminosity EIR.

- Orbit leakage still to be solved
- 13.4 MV per IP, per side were determined to suffice for full crabbing at ultimate optics
- Less than 20 MV per IP, per side beyond ultimate optics



- Extrapolating from HL-LHC design 1 MV/m $\Rightarrow \approx$ 22 m of space needed $\Rightarrow$ allocated in lattice

Conclusions & Outlook

Conclusions:

- The main IR design **complies with the allocated length** and the manufacturing and transport **constrains for the cryostats**
- IR design leaves **comfortable margins** for Ultimate parameters ($\beta^*_{\text{min}} = 0.2\,\text{m}$)
- Mitigation measured for radiation implemented / under study
- **Crab cavities** with reasonable parameters

Outlook:

- Optimized running scenarios to make best use of intensity burn-off (crossing angle) and emittance damping
- k-modulation studies and optimized Q1 split
- Achromatic Telescopic Squeezing to improve Chromaticity correction for beyond ultimate β^*
- Flat optics in nominal triplet

Compare next talk by L. van Riesen-Haupt