A FULLY SYMMETRIC FINAL FOCUS SYSTEM FOR FCC-hh

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We present the concept for a new optics for the main Experimental Interaction Region (EIR) of the FCC-hh. This optics is fully symmetric for either side of the IP and for either plane. The luminosity evolution and a schematic of the first quadrupole is shown.

Flat optics for hadron colliders

A flat optics has the following advantages:

- increase the beam separation for the same crossing angle
- Decrease the crossing angle as σ_x is enlarged

The Beam-Beam parameter is one of the main limitations for hadron colliders. For round beams: $\xi = \frac{N r_p}{2\pi\epsilon_N\sqrt{1+\phi^2}}$

ξ increases as ε_N decreases due to damping. After a certain threshold (~0.3) emittance blow up is needed, decreasing luminosity.

A flat optics breaks the antisymmetric properties of the IR for the round optics. There are two options to implement a flat optics:

- Asymmetric optics **k(-s) = -k(s)**
- Symmetric optics **k(-s) = -k(s)**

On top of that, with regard to the beams:

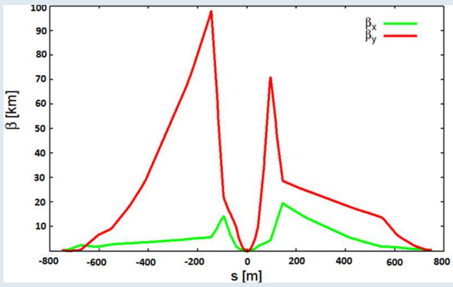
- Antisymmetric beam1/beam2 **k1=k2**
- Symmetric beam1/beam2 **k1= - k2**

Antisymmetric flat optics

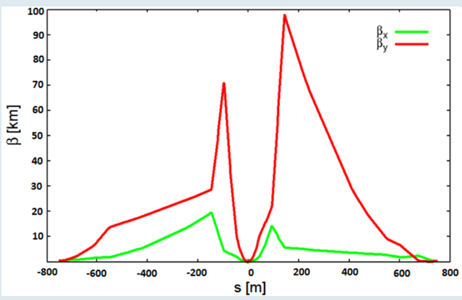
- When the usual double aperture quadrupole is used in an symmetric lattice for flat beams, the symmetries between beams are broken [1,2].
- This is illustrated for the FCC optics [3,4], for beam1 and beam2.

- Betax*=1.0 m
- Betay*= 0.2 m
- Theta=96 μrad

BEAM 1



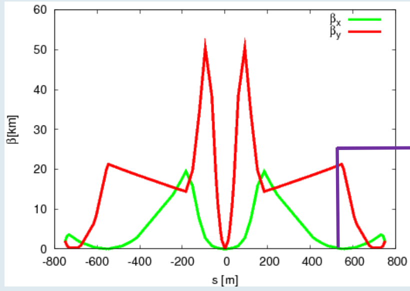
BEAM 2



Symmetric flat optics

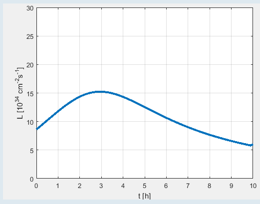
- Betax*=5.0 m
- Betay*= 0.1 m
- Theta=1.0 mrad

BEAM 1/BEAM 2

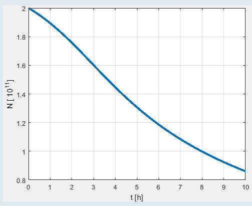


Place for crab-waist sextupoles

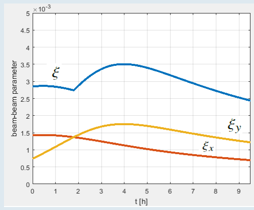
$\Delta\mu_x = \pi$
$\Delta\mu_y = \frac{\pi}{2}$



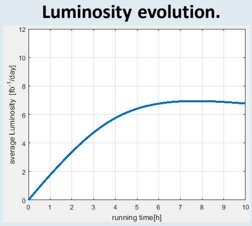
Luminosity evolution.



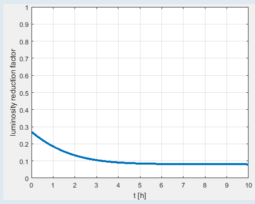
Beam population



Beam-beam parameter.



Average luminosity(4h turnaround).



Luminosity reduction factor

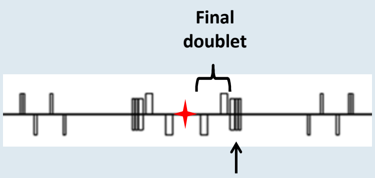
$$\xi = 2max(\xi_x, \xi_y)$$

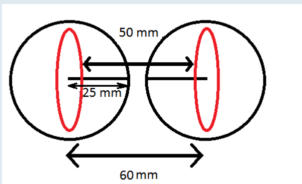
$$\xi_x = \frac{r_p}{2\pi\gamma_r}\frac{N\beta_x^*}{\sigma_x^*\sqrt{1+\phi^2}\left(\sigma_y^*+\sigma_x^*\sqrt{1+\phi^2}\right)}$$

$$\xi_y = \frac{r_p}{2\pi\gamma_r}\frac{N\beta_y^*}{\sigma_y^*(\sigma_y^*+\sigma_x^*\sqrt{1+\phi^2})}$$

Quadrupoles for the symmetric optics

- For the fully symmetric optics, a final quadrupole with double aperture and opposite sign of the gradient is needed.
- A single dipole per side makes the beam separation.





Double aperture Quad1 schematic. Beam size as 15σ.

	g [T/m]	L [m]	a [mm] (15σ)	Beam sep. [mm]
quad1	-111.4	2x15	21.5	62- 93 mm
quad2	63.5	2x15	13.5	152.7-183.5 mm

	B [T]	L [m]	a [mm] (15σ))	Beam sep. [mm]
Dipole sep.	4	21	15	~ 200

Conclusions

- A full symmetric optics for flat beams is proposed for the FCC-hh.
- The optics allows for good integrated luminosity values but with a very smooth instantaneous luminosity and a much lower peak.
- The system operates in a Large Piwinski Angle, allowing for very low tune shifts.
- The system does not require artificial emittance blow up.
- The optics represents a very challenging option, relying in a large beam population and in the design of a new quadrupole with separated apertures for each beam.

References

[1] J. L. Abelleira, "Optics Designs of Final-Focus Systems for Future LHC Upgrades", Ph.D. thesis, 2014.
[2] J. L. Abelleira, F. Zimmermann, "Matching Antisymmetric Arc Optics to Symmetric Interaction Region'', IPAC'13, Shanghai, China.
[3] L. van Riesen-Haupt *et al.*, "Exploring the Triplet Parameter Space to Optimise the Final Focus of the FCC-hh", presented at IPAC'17, Copenhagen, Denmark, May 2017.
[4] J.L. Abelleira *et al.*, "FCC-hh "Final-focus For Flat-beams: Parameters And Energy Deposition Studies", presented at IPAC'17, Copenhagen, Denmark, May 2017.