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Collimation System Optics

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Outline

- Options under considerations for collimation system
- optics for betatron collimation
- Optics for momentum collimation
- First aperture and optimisations

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- **Options under considerations for collimation system**
- *Optics for betatron collimation*
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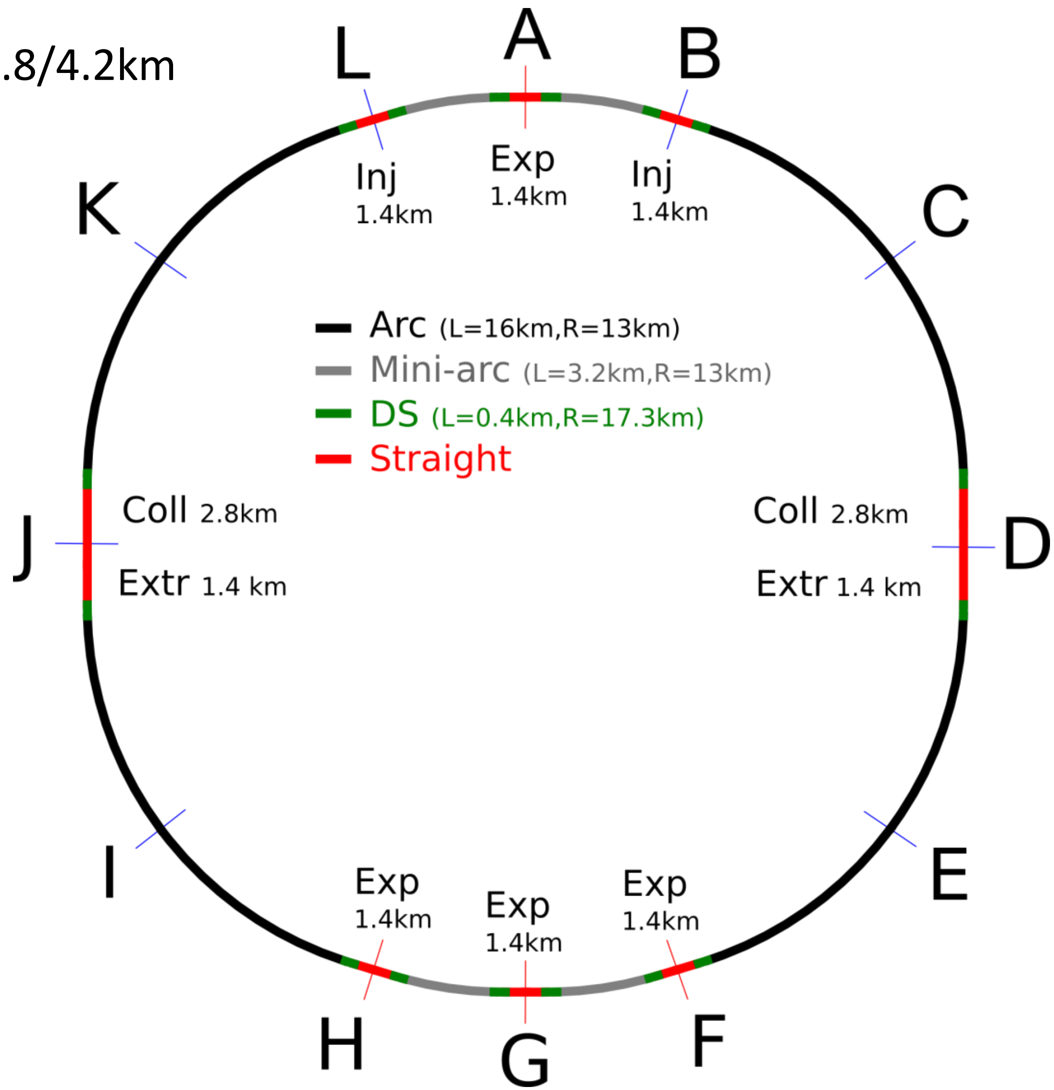
- *General layout of the Straigth Section*

Options under considerations for collimation system

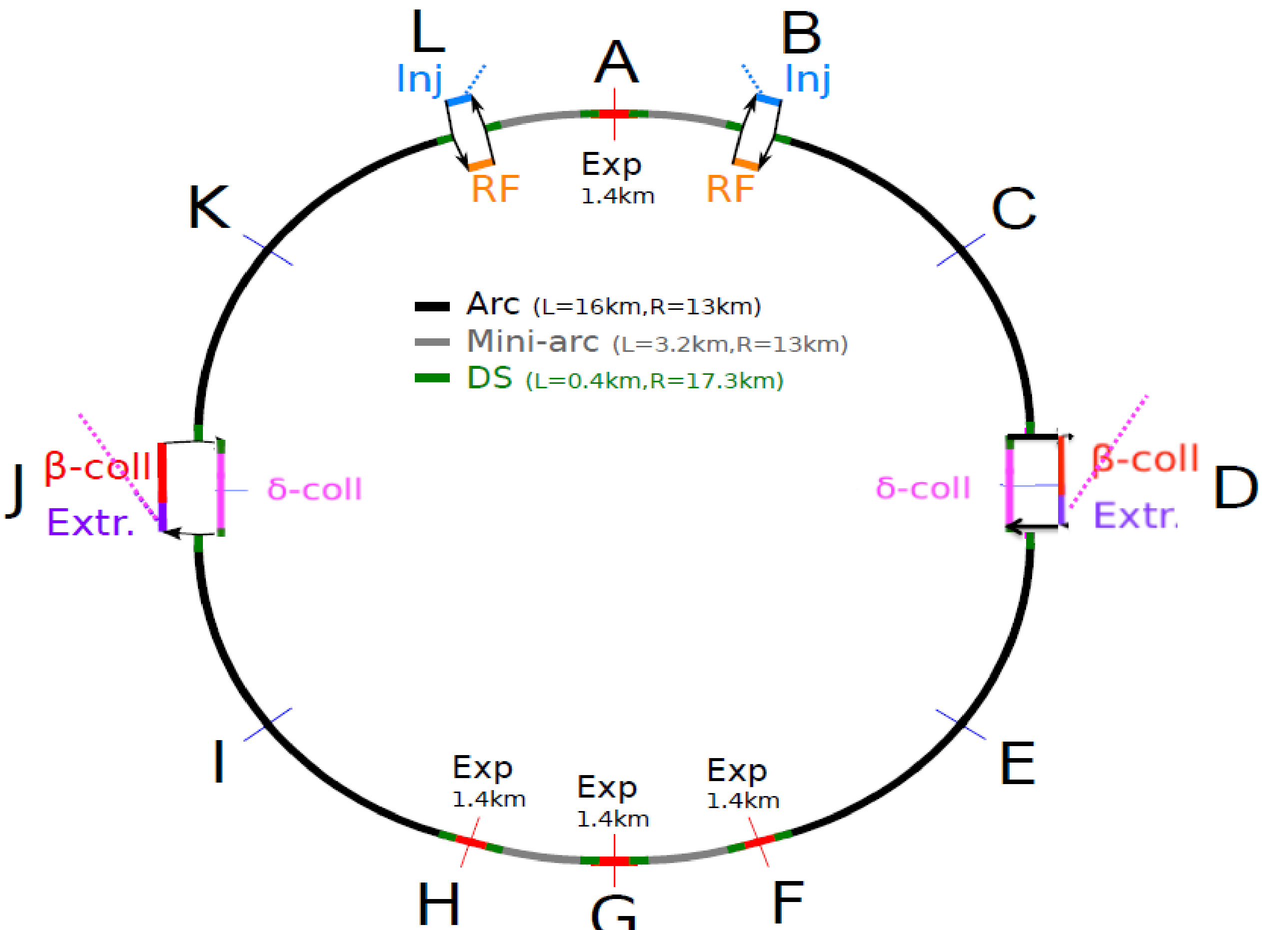
Colllimation system is installed in Extended Straight Sections D and J

Their length is 2.8/4.2km



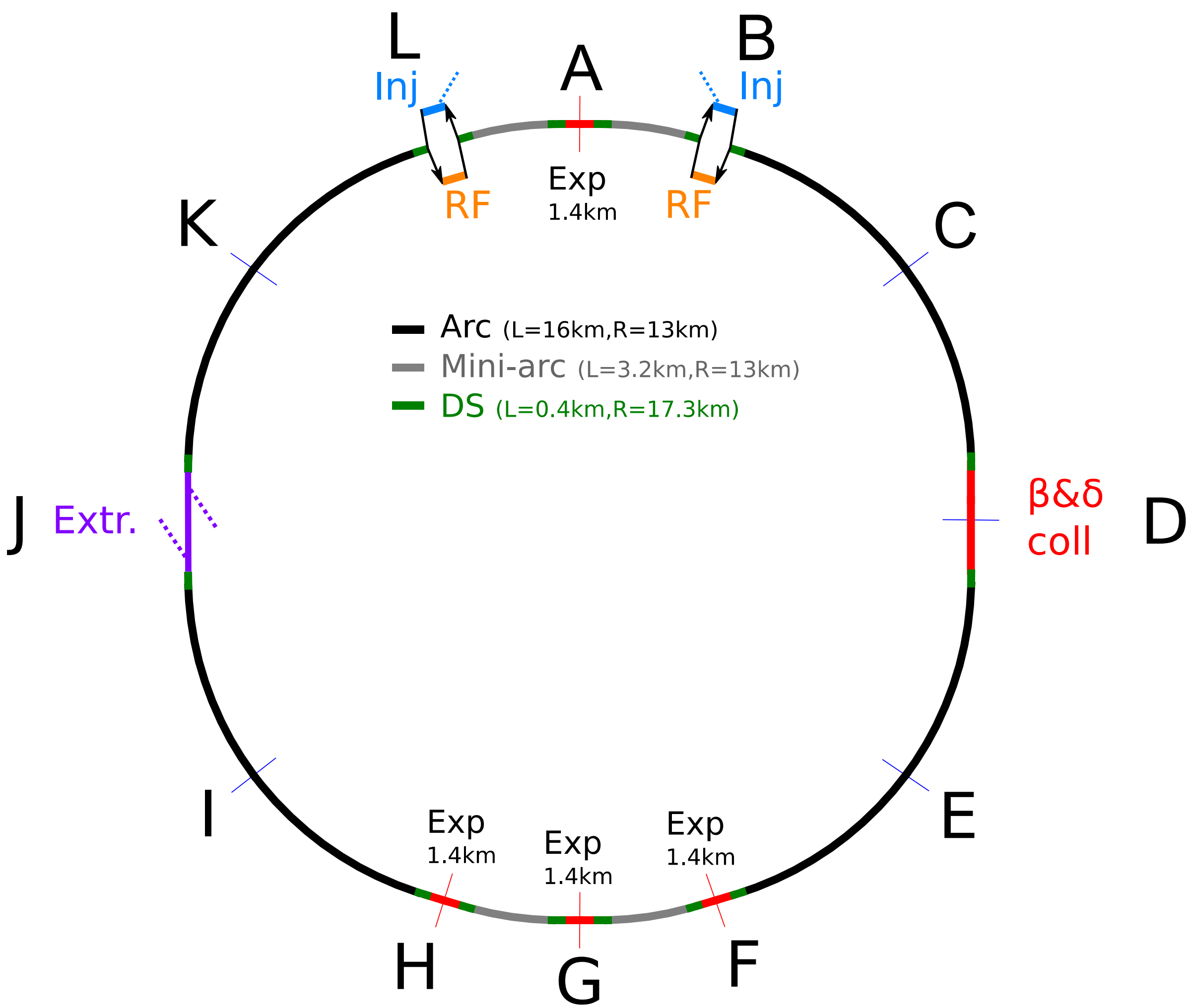
Options under considerations for collimation system (Option 1)

Different options are under consideration for collimation system layout. The first option, called Option 1, consists on betatron collimation installed just after extraction section, to protect machine from badly extracted beam.
Momentum collimation in same SS, for counterclokwise beam.



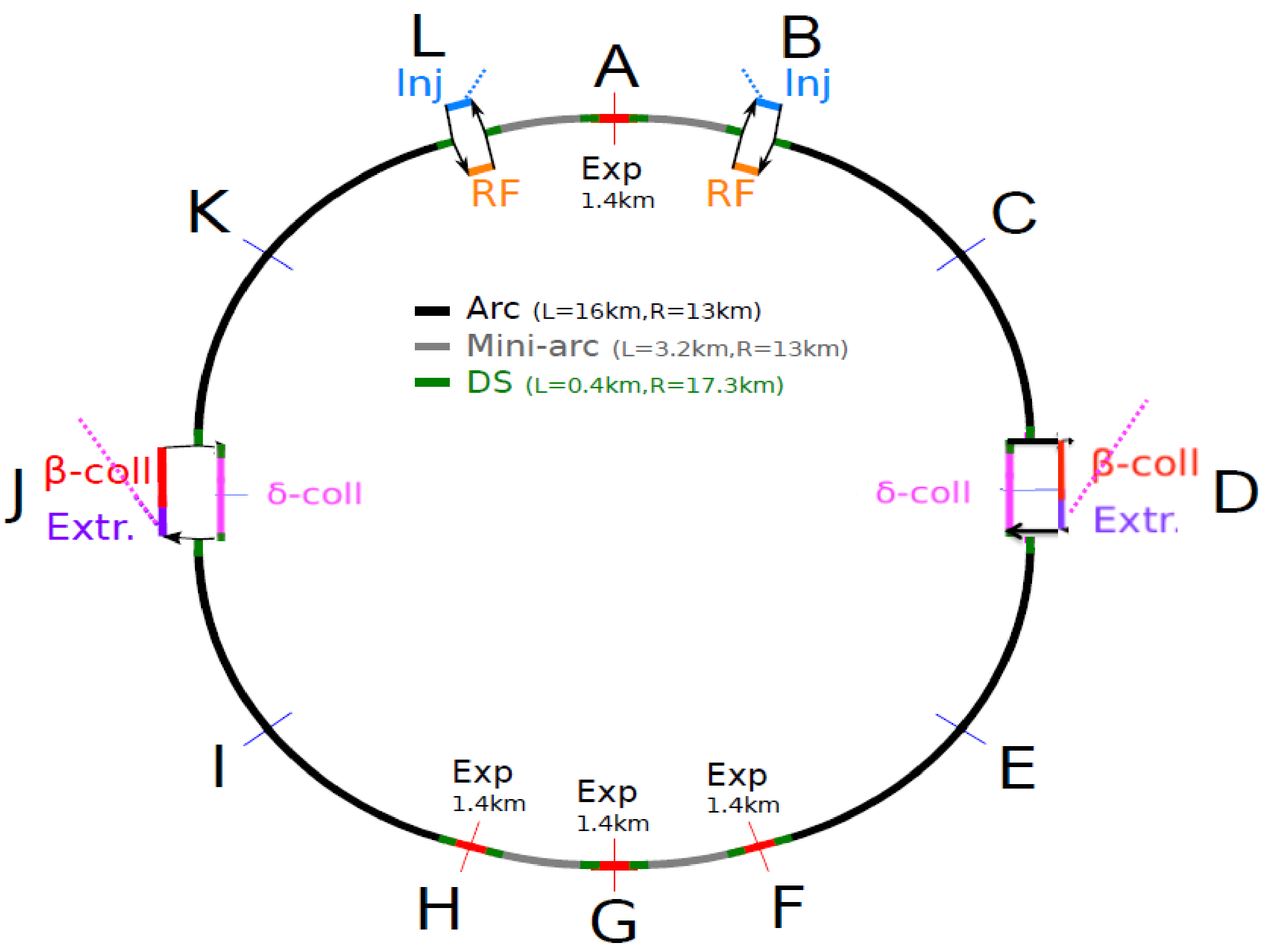
Options under considerations for collimation system (Option 2)

Option 2 : Both extraction lines are installed on the same side of the ring, and both betatron and momentum collimation section are installed on the other side of the ring.



Options under considerations for collimation system (Option 1)

At this time of the study ; the first option has been studied and results will be presented here.
Other options studies will come after Rome.



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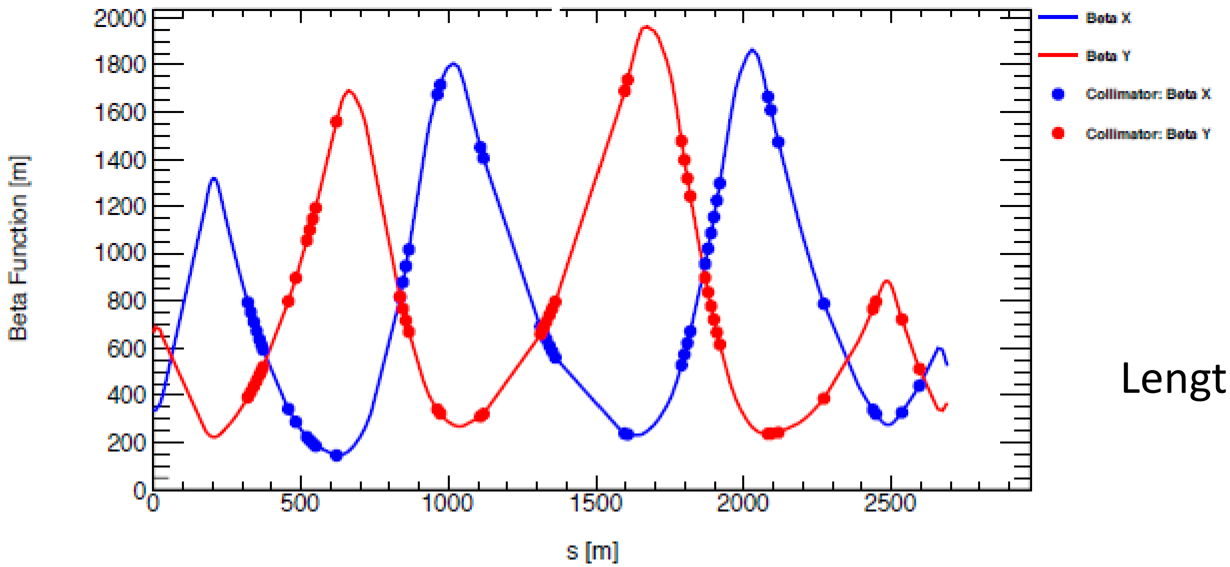
Optics for betatron collimation

Guideline for betatron collimation optics design :
request from collimation team to have collimator gap in FCC similar to collimator gap in LHC. Same magnet sequence has been used for FCC, with beta function (and sequence length) scaled be a factor five to compensate for energy change. Sigma settings have been scaled also to compensate for emittance change.

FCC betatron collimation section



Length 2.5km

Beta functions at location of collimator are multiplied by 5 and phase advances between collimators remain as in LHC.

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Optics for momentum collimation

As for betatron section, collimation team asked to have a starting point which is a scaled version from LHC. Its optical function have been scaled by sqrt(50/7). Its length is 1.4km.

2 different versions have been defined :

- One with same dispersion than LHC at location of primary collimator. (~2.2m)
- One with higher dispersion than LHC at location of primary collimator. (~4m) to improve normalised dispersion.

For both versions same number of collimators than in LHC have been installed :

- 1 primary
- 4 secondaries
- 4 absorbers

They have been installed at same place (phase advance) than in LHC

The dispersion peak has been obtained using natural dispersion coming from arcs and optimised only by quad matching in order to have the peak of normalised dispersion at entrance of the primary collimator.

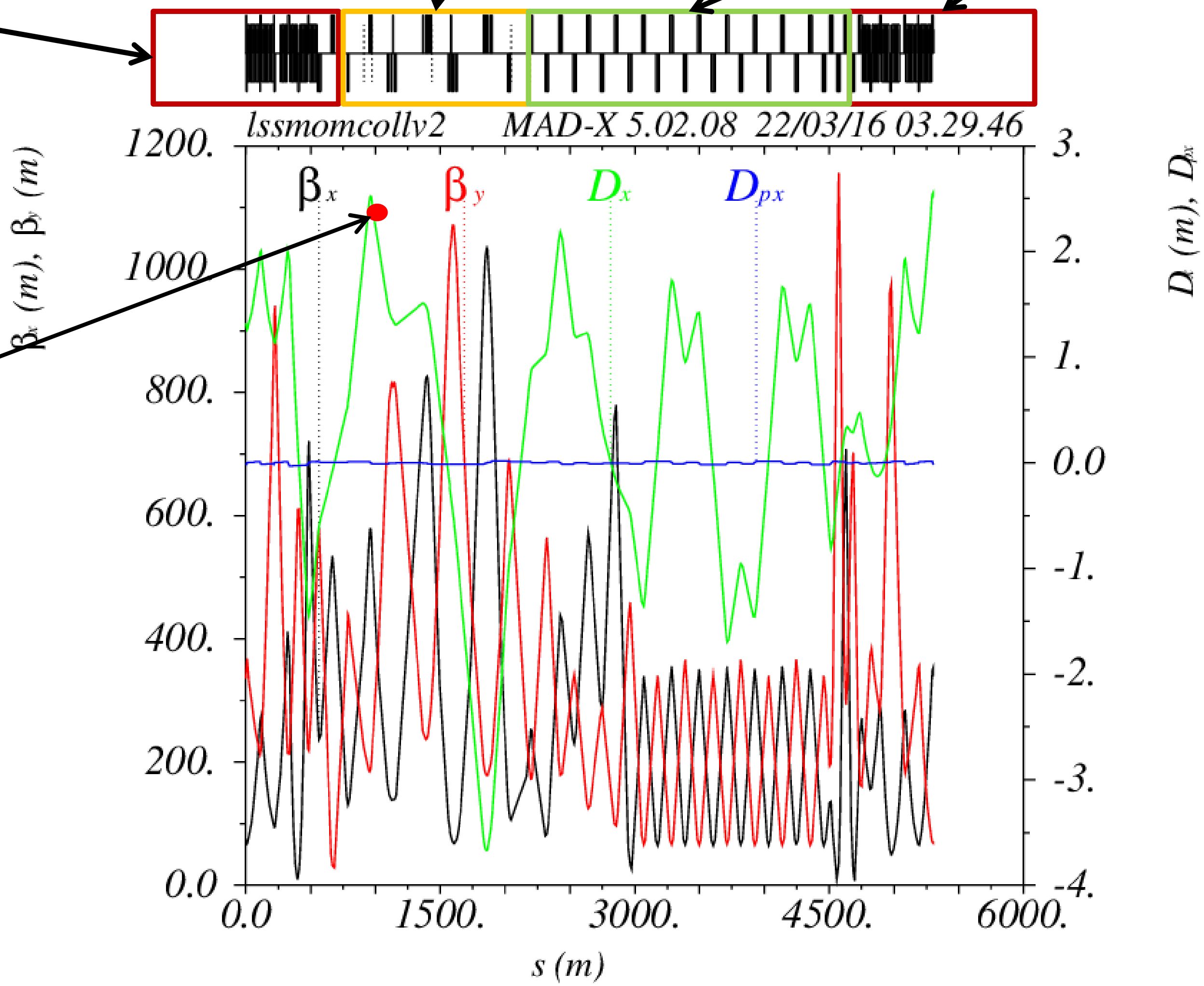
Optics for momentum collimation

Dispersion suppressor

Collimation section

Fodo canal

Dispersion suppressor



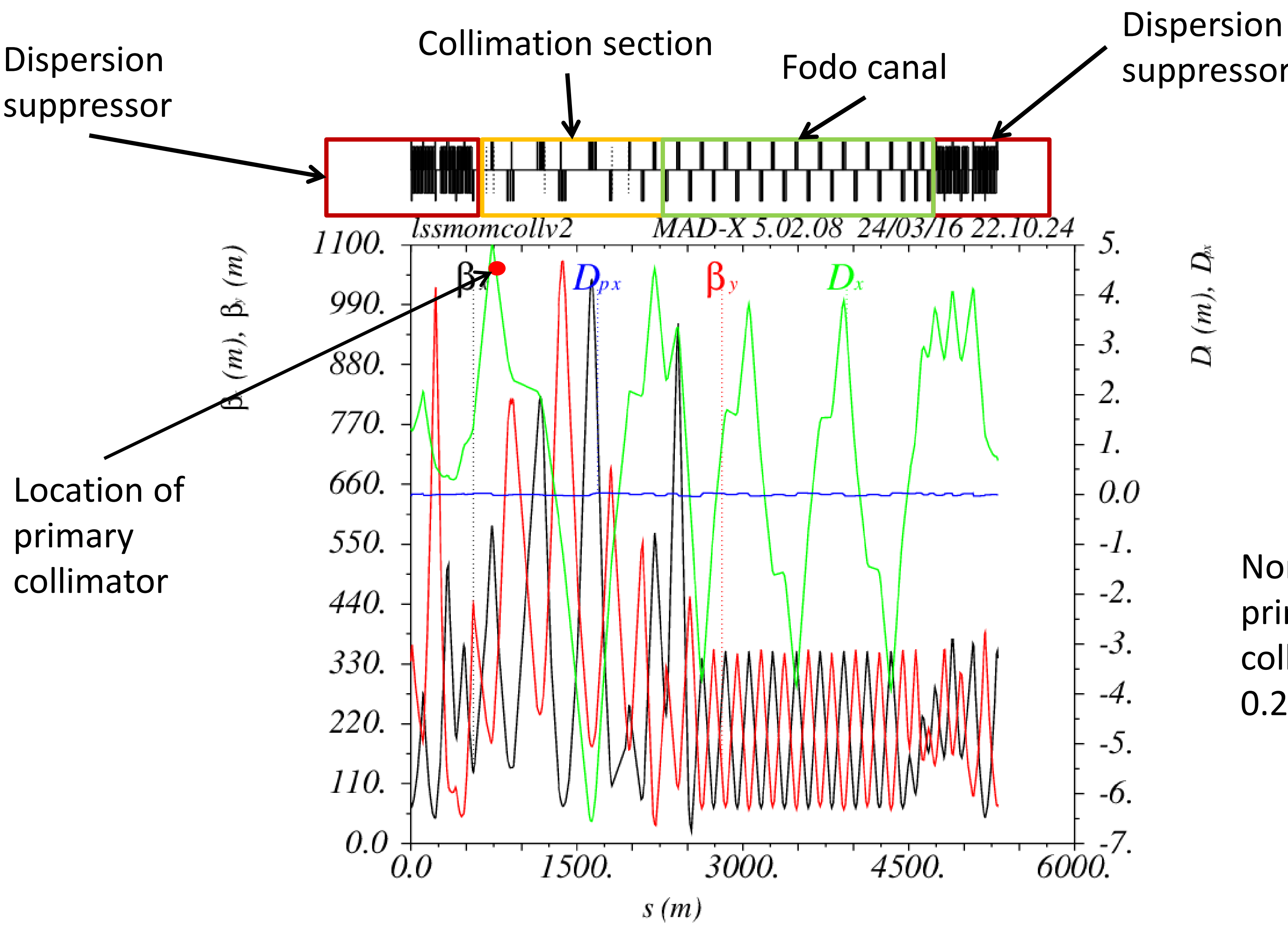
Location of primary collimator

NormDisp at primary collimator : 0.11

Optics for momentum collimation

- In order to test influence of the dispersion a second sequence has been optimised.
- The natural dispersion coming from arc has benn improved in order to obtain an higher .
- Normalised dispersion at location of the primary collimator, with careful check that normalised dispersion peak is located at entance of the primary collimator.
- As for previous case, a fodo canal has been added to fill the 4.2km of the ESS.
- As for previous case collimators have been installed at same phase advance than in LHC.

Optics for momentum collimation



NormDisp at primary collimator : 0.215

Optics for momentum collimation

Using LHC collimation sequence for FCC is a good starting point but why not taking our chance to design a completely new sequence, simple but fully optimised for our purpose ?

in this way another sequence has been developed, only based on fodo cells for momentum collimation.

This sequence is based on warm quads.

The required length to install all collimators is now ~1.1km (ELL length : 4.2km)

As for previous version using LHC scaled optics, it is worth noting that **no additional dipoles** are used, collimation section are pure straight sections.

The value of normalised dispersion at entrance can easely be adjust by quads matching.

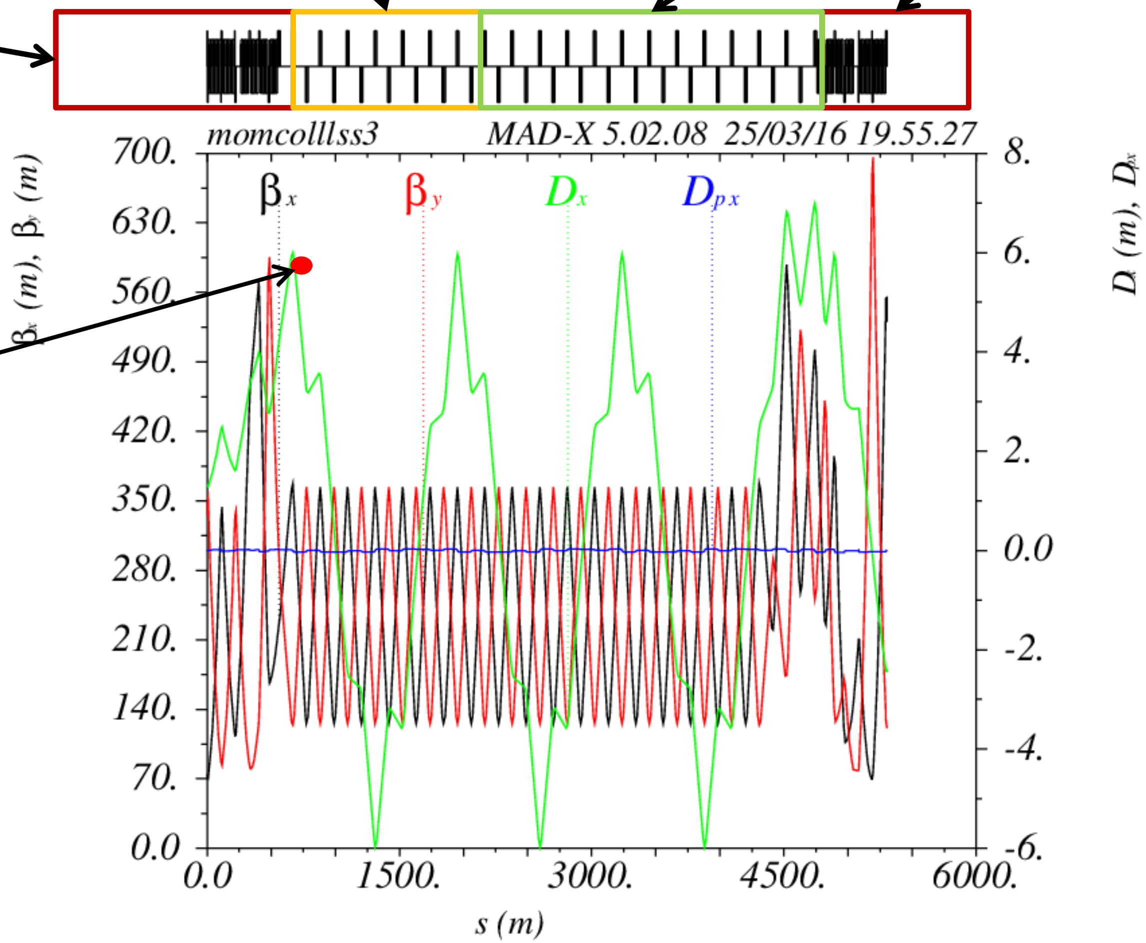
Optics for momentum collimation

Dispersion suppressor

Collimation section

Fodo canal

Dispersion suppressor



Location of primary collimator

NormDisp at primary collimator : 0.314

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First aperture calculations

- First aperture calculations have been done on momentum collimation sections.

- Indeed, the present beam separation is 250mm. and in ESS D and J seqence of each beam will be different so we would like to know if the present beam separation is large enough to install all extraction/collimation elements.

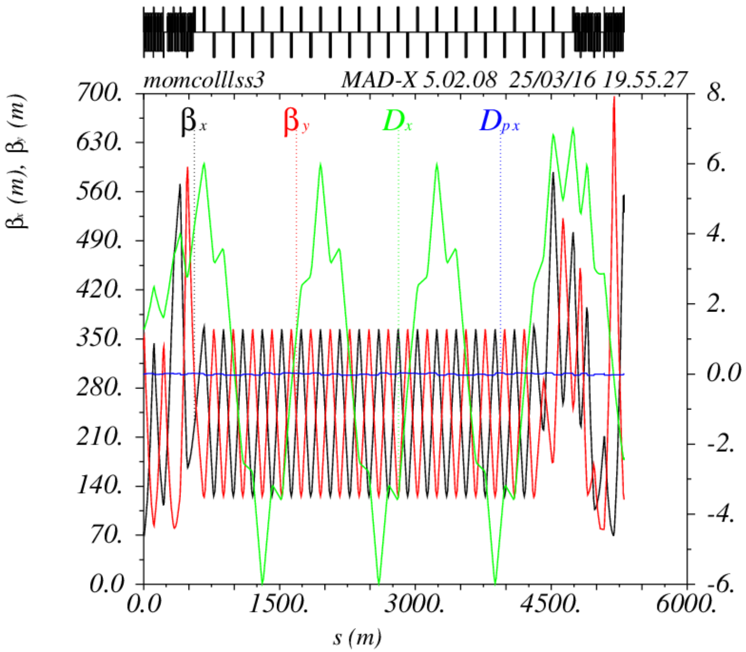
- For that first study I calculated apertue using sigma=18. This nimber corresponds to the minimum guaranted aperture in LHC (at triplet at high energy and in arcs at injection).

- This number also includes off-momentum effects, errors, misalignements, etc..

- I also assumed a vacuum chamber thickness of 2mm.

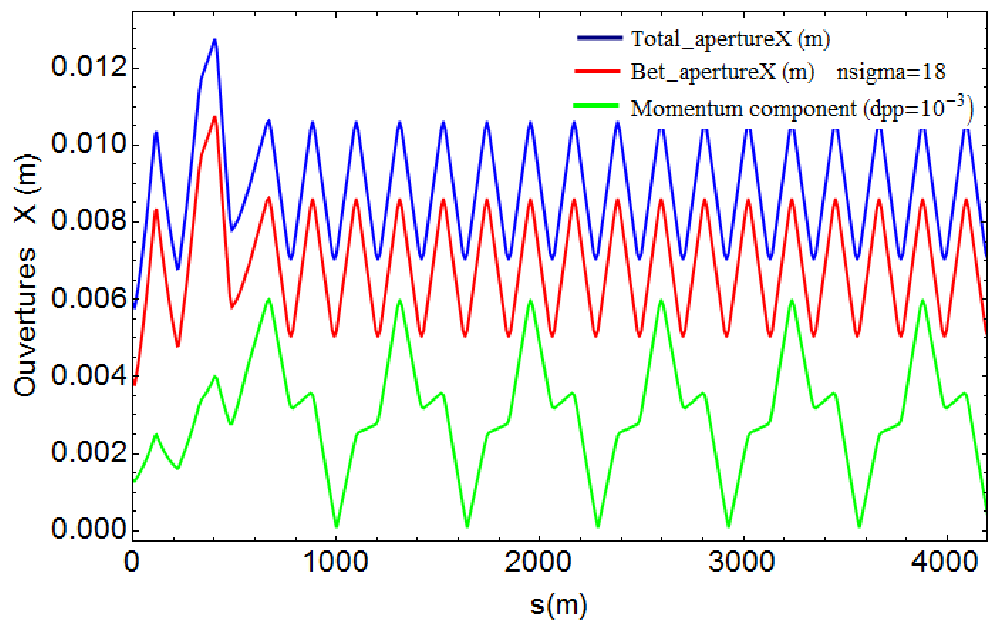
First aperture calculations

First test with pure fodo momentum collimation sequence :



Optical functions of the section

Horizontal beam size for n = 18 sgima et dp/= 10- 3



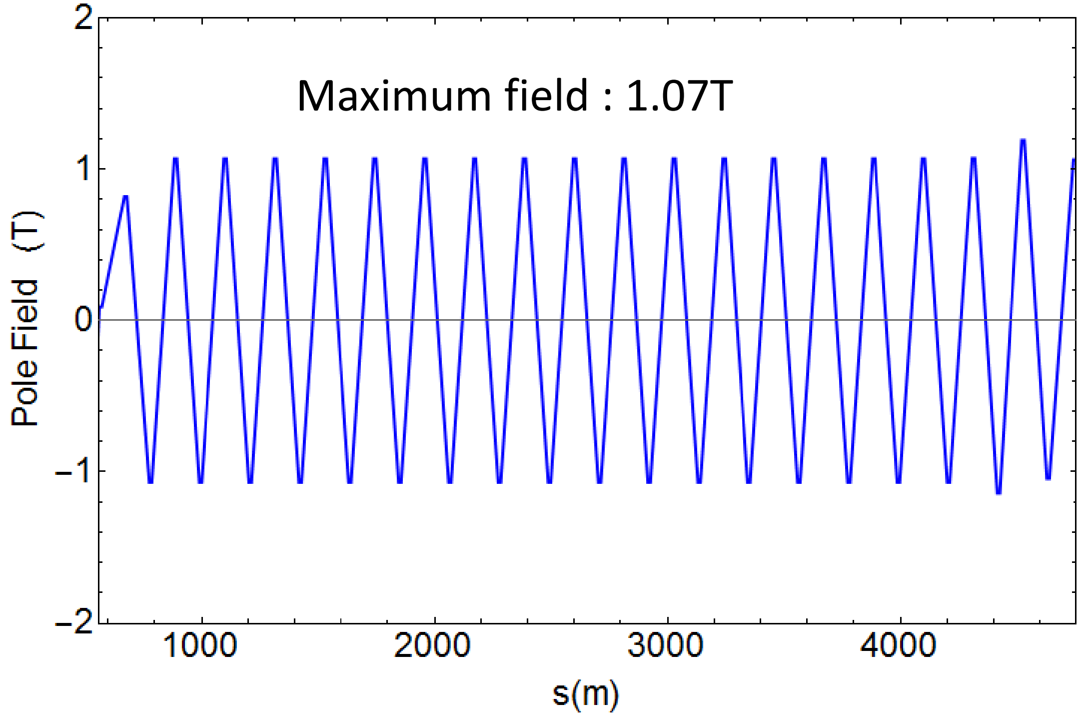
Maximum aperture includin 2mm for chamber thickness 12.7mm

First aperture calculations

One can see that the optcal funtions peaks are located in the Dispersion Suppressors or in the matching section but in the collimation section itself the optical function remains low.

Maximum aperture in the DIS : 12.7mm
Maximum aperture in the collimation section: 10.6mm

Assuming the same aperture for all section magnets the pole field can easely be calculated :

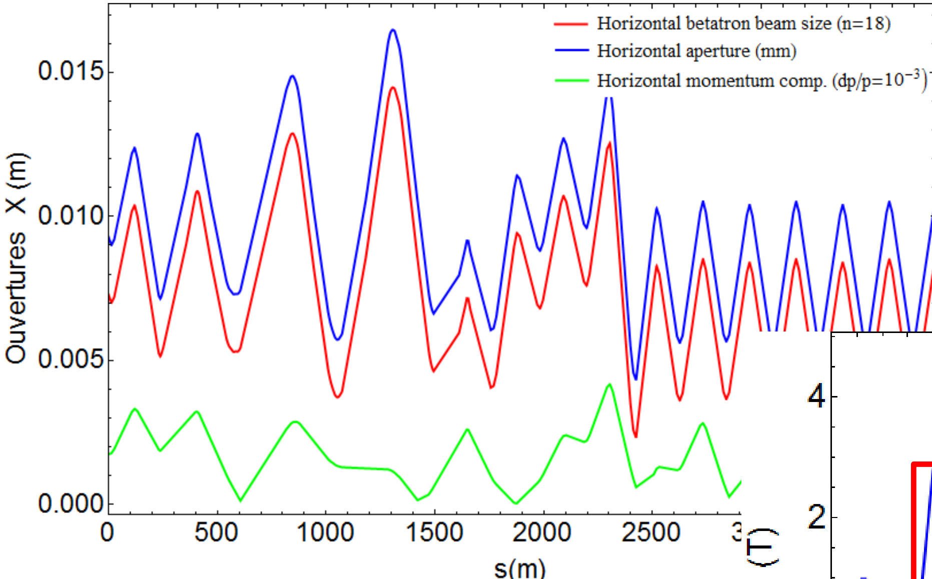


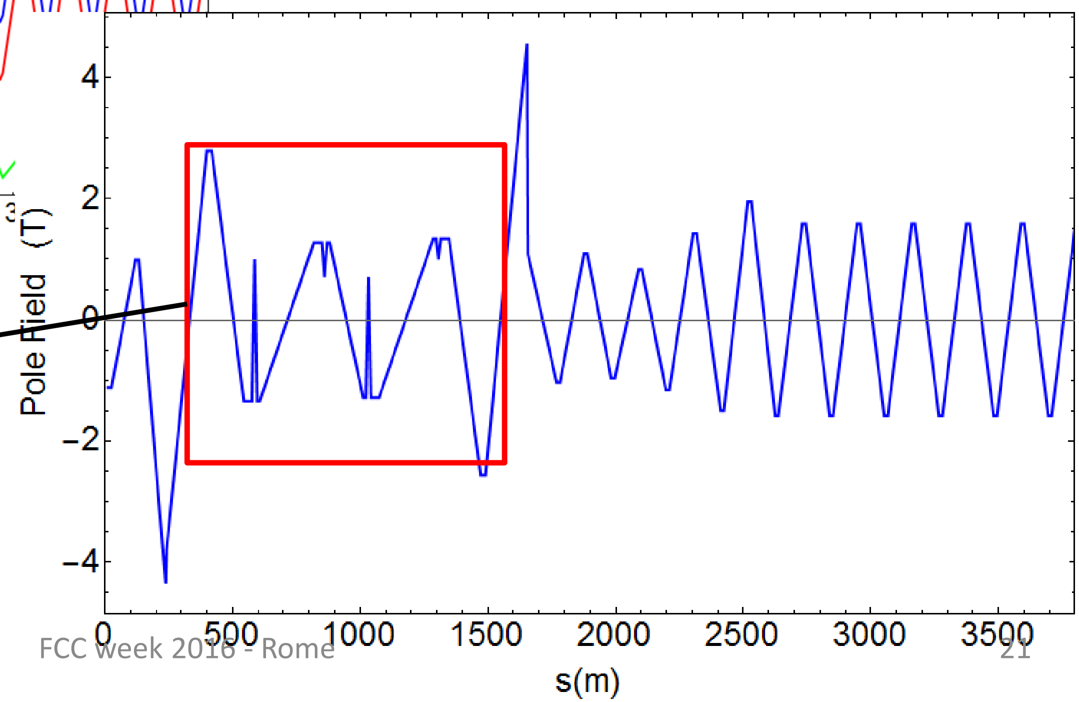
Pole field for quads of the collimation section beased on fodo cells assuming the maximum aperture un the DIS (12.7mm)

If assuming the maximum aperture of the fodo section (10.6mm) the pole field is only 0.9T

First aperture calculations

Same calculation have been made for momentum collimation section based on LHC scaled sequence.
This sequence is more complicated and is composed of much differents quads. First calculation of aperture and pole field shows many fields above 1T.

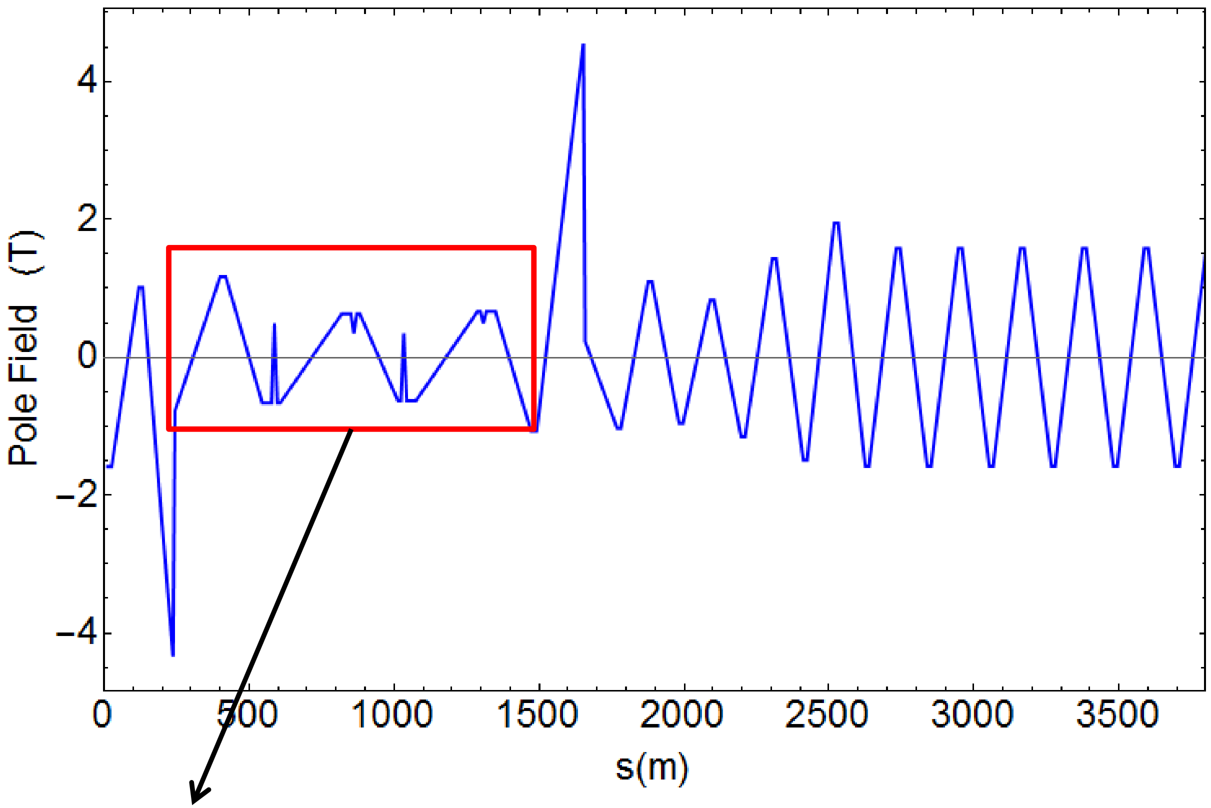




Many pole fields in the collimation section are above 1T (>1.5T)

First aperture calculations

I first improvement of the quads size (length harmonization and increase to limit the pole field) has been made, escpecially in the collimation section wich requires warm quads.
Others quads in th section can remain cold at this time of the study as they are not in the collimation section itself.



All pole field in the collimation section are below or colse to 1T.

Conclusion and Outlook

- The baseline option for FCC-hh collimation system, consisting on extraction followed by betatron collimation for beam one and momentum collimation for beam 2 has been developed.

- Several sequences have been proposed for efficiency simulations, base on LHC collimation sequences or defined using new sequence.

- All these sequences fullfill requirements for collimation at this time of the study and the offer a great variability of parameters (dispersion).

- It is worth noting that all is done WITHOUT any additional dipole in the straigth section, all the dispersion management in done only with quads matching, which represents a clear advantage for ring geometry.

Conclusion and Outlook

- Next step will consists on studying other options for collimation sequence, especially option 2 whitin both momentum and betatron collimation are on same LSS (mixed sequences or not) and both extractions on the other side of the ring.

- First tests for option 2 show that is it technically feasible but with a non-negligible impact on ring geometry.

- According to first tests made for this second option, with first momentum collimation then betatron one in the same LSS. In this case a DS (at least 10 cold dipoles) is needed after momentum collimation in order to have a zero-dispersion area for betatron collimation, inducing a big bend then a change in geometry.
  The length of the LSS is 4.2km, 1.1km is needed for momentum collimation, 2.7km for betatron one.

This leads around 400m (2 cells) to cancel dispersion between momentum and betatron collimation

- Option with first betatron then momentum collimation section would maybe be more easy to integrate. In this case a chcane will be used to create dispersion for the momentum section and a chicane is probably more integrable in terms of geometry than a DS.