Ring circumference

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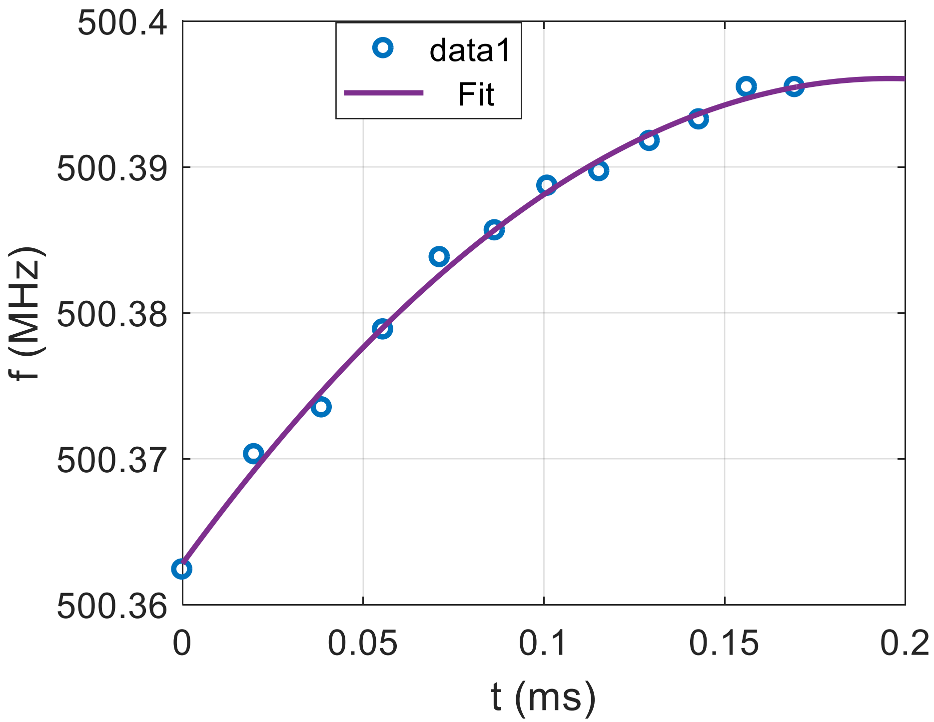
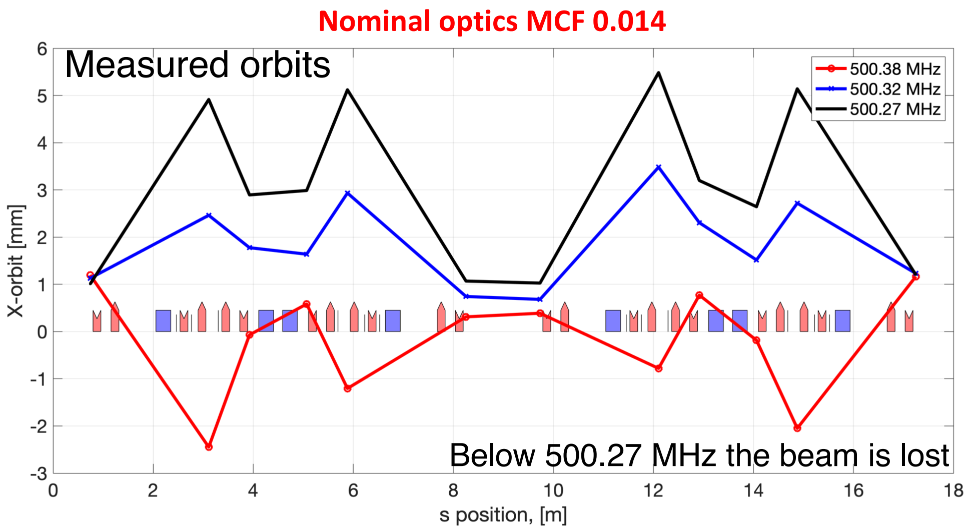
Experimental attempts to measure the ring frequency

Screenshot from 02/08/2023 16:50:56.
Beating frequency between F_{LO} =500.32 MHz and turning frequency of the bunch freely circulating around the ring.

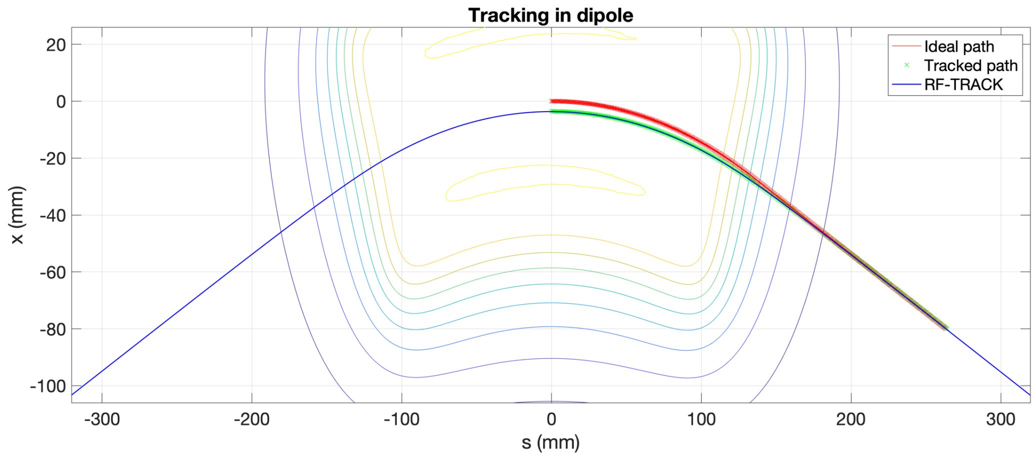


Result of screenshot processing.
Bunch circulating frequency vs time.

Shorter circumference understanding



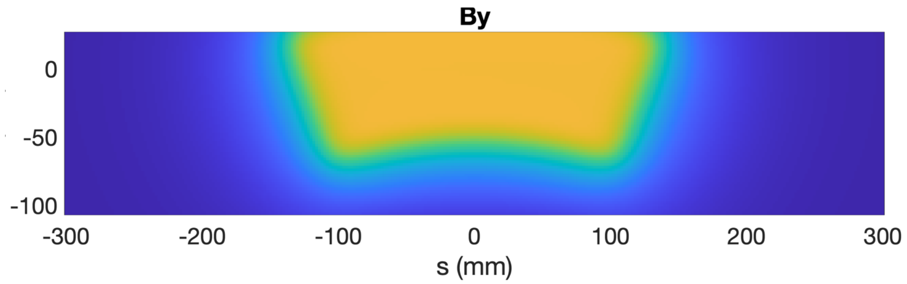
- **The RF frequency is found experimentally to be 0.3 - 0.4 MHz higher than the nominal.**
- **Need explicit simulation!**

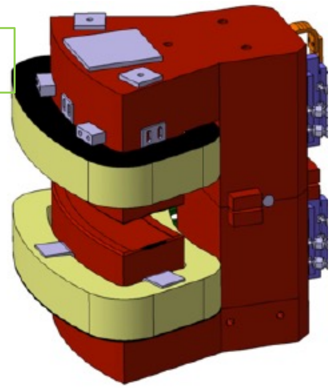


R_{eff} = 377 mm (from the measured effective length of the dipoles)

Features of dipoles	
Quantity	14 + 1 (pre-serie)
Radius of curvature	352 mm
Main field B_0	0.7 Tesla
Gap	42 mm
Good field region	+/- 20mm
Integral of field	184.59 mT.m
Current max.	275 Amp
Beam energy	from 50 to 70 MeV

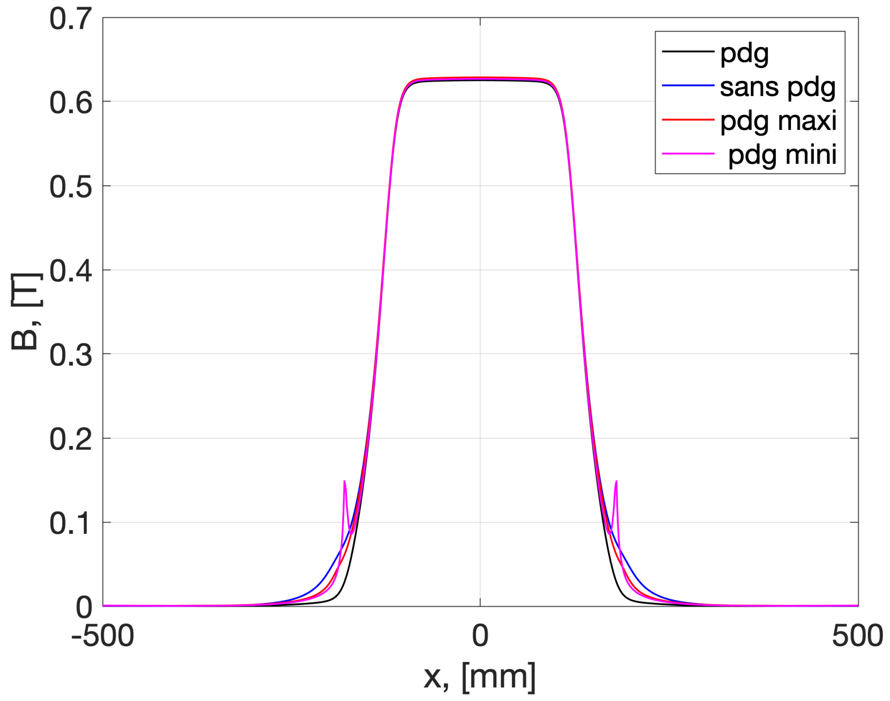
Short and small-radius dipoles, long fringe fields

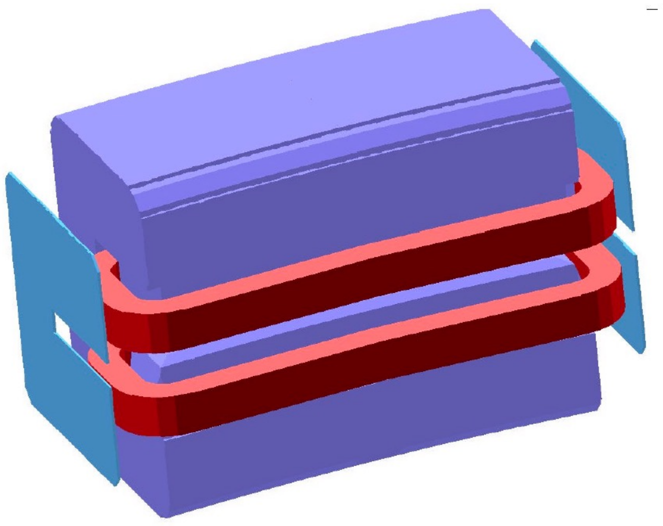




Solution 1: surround dipoles with metallic plates

- **Goal: install the metallic plates for each of the dipole in the ring**
- **Limitation of the fringe field will allow to increase the pathlength in the dipole.**





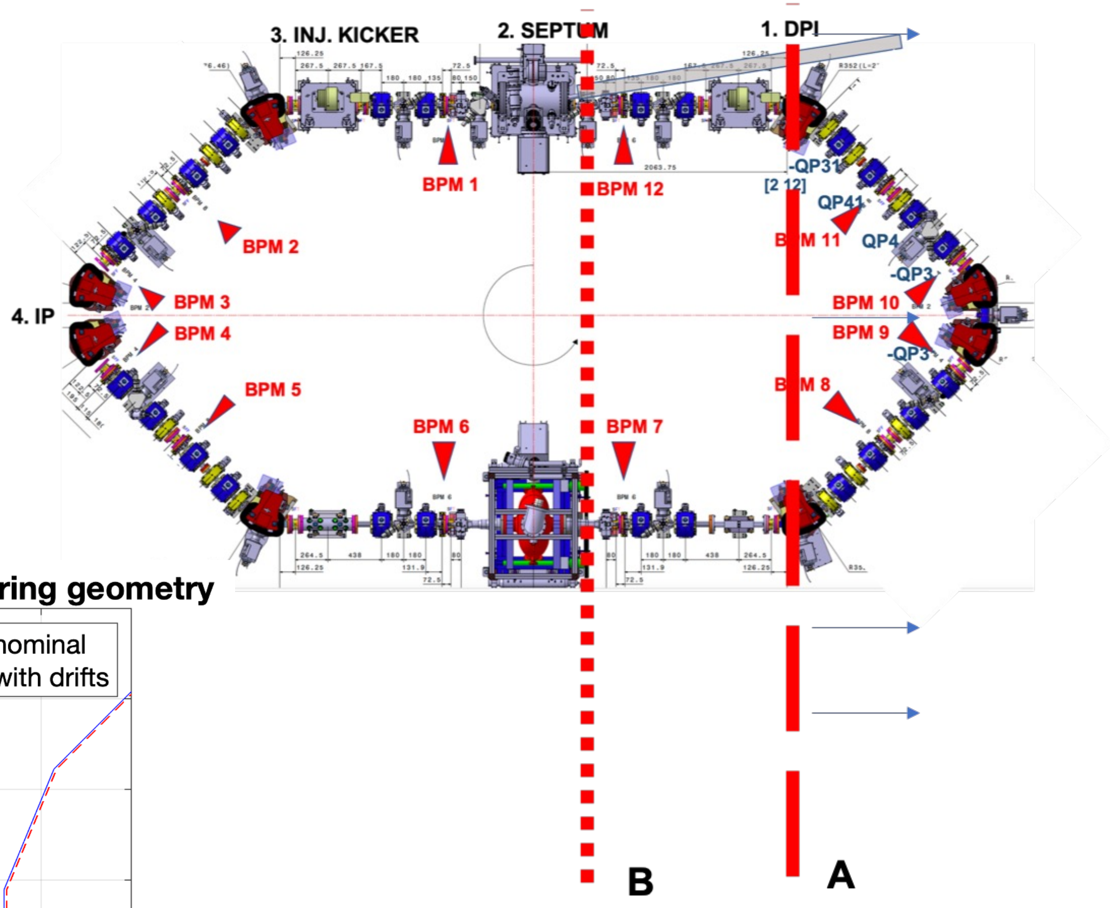
Example: le dipole de l'anneau de soleil.
Etude magnetostatique 3d
n/ref. : dsm/dapnia/sacm/soleil-2002

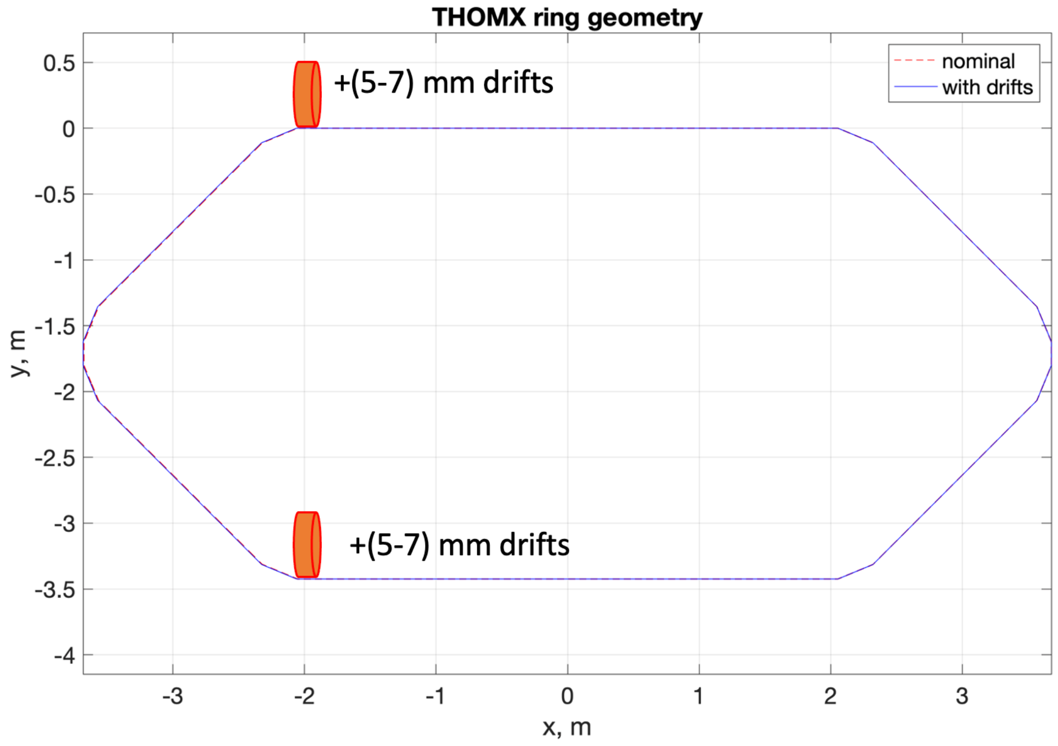
- First "ideal" configuration with correct scaling of magnetic field allows to reduce the ring RF frequency by **~200 kHz.**
- After iteration with Rodolphe ???, the OPERA simulations are performed for more realistic configuration (pdg mini/maxi configuration).
- **According to the received fieldmaps, the expected effect is quite small (not sufficient in our case).**

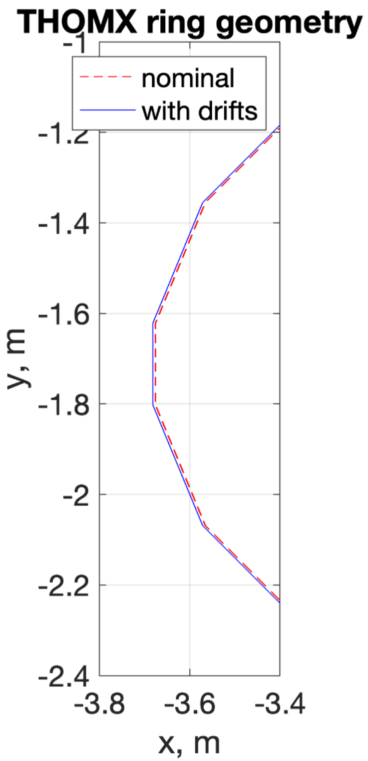
Fieldmaps are provided by Fabrice (SOLEIL)

Solution 2: insert drifts

- **Goal: bring the ring frequency to the nominal (or suitable for timing and FPC systems) one by making the insertions/adding drifts**



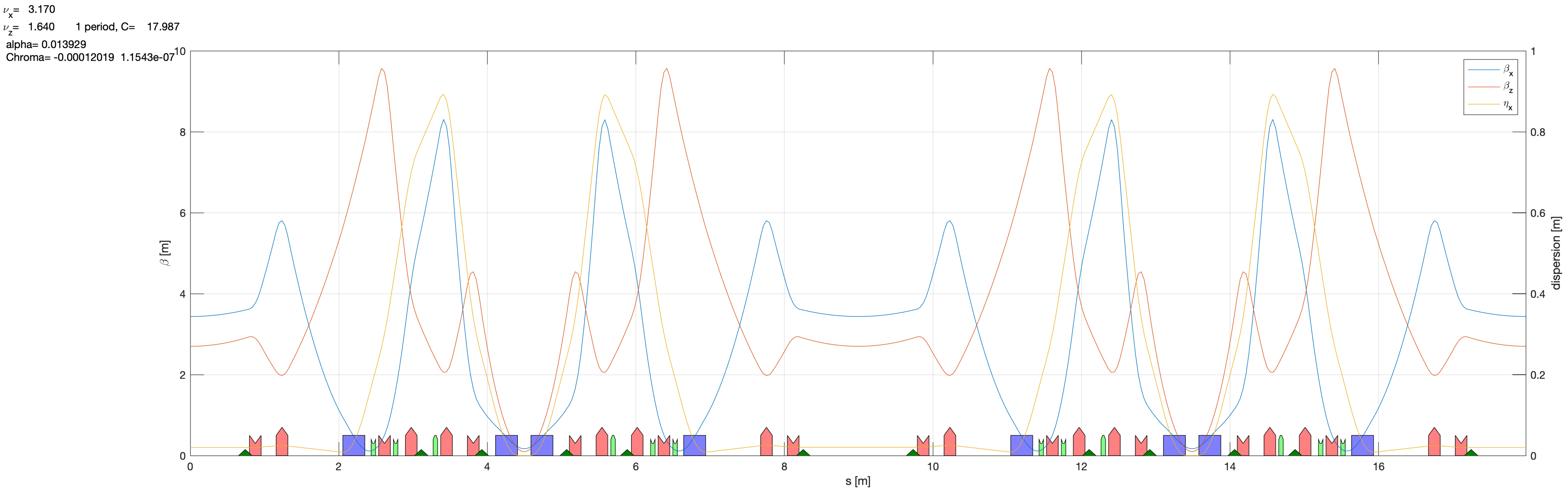




The exact drift length to be adjusted

Updates

Nominal optics



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Injection:

H: beta = 03.437 [m] alpha = -1.6e-10 eta = +0.020 [m] eta' = -3.0e-09

V: beta = 02.700 [m] alpha = -7.7e-08 eta = +0.000 [m] eta' = -3.7e-17

Simulation/matching results (dL = 14 mm)

************* Summary for 'NOMINAL' ************

Energy:	0.05000 [GeV]
Gamma:	97.84756
Circumference:	17.98668 [m]
Revolution time:	59.99711 [ns] (16.66747 [MHz])
Betatron tune H:	0.16999 (2833.35119 [kHz])
V:	0.63999 (10667.06832 [kHz])
Momentum Compaction Factor:	1.39842e-02
Chromaticity H:	+0.00000
V:	+0.00000

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************* Summary for 'LATTICE WITH DRIFTS' ************

Energy:	0.05000 [GeV]
Gamma:	97.84756
Circumference:	18.00068 [m] L_{nom} + 14 mm
Revolution time:	60.04381 [ns] (16.65451 [MHz])
Betatron tune H:	0.17000 (2831.24491 [kHz])
V:	0.64000 (10658.87618 [kHz])
Momentum Compaction Factor:	1.41915e-02
Chromaticity H:	+0.00000
V:	+0.00000

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Matching with all families of QP

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Final variable values:

Name	field	before	after	variation
QP1	PolynomB	-4.63186	-4.67797	-0.0461089
QP2	PolynomB	9.32456	9.34028	0.0157197
QP3	PolynomB	-17.2633	-17.2605	0.00279447
QP4	PolynomB	15.3651	15.3685	0.00345879
QP31	PolynomB	-10.2947	-10.2773	0.0173877
QP41	PolynomB	6.86566	6.85603	-0.00963218

Matching w/o QP1 & QP2 (injection area)

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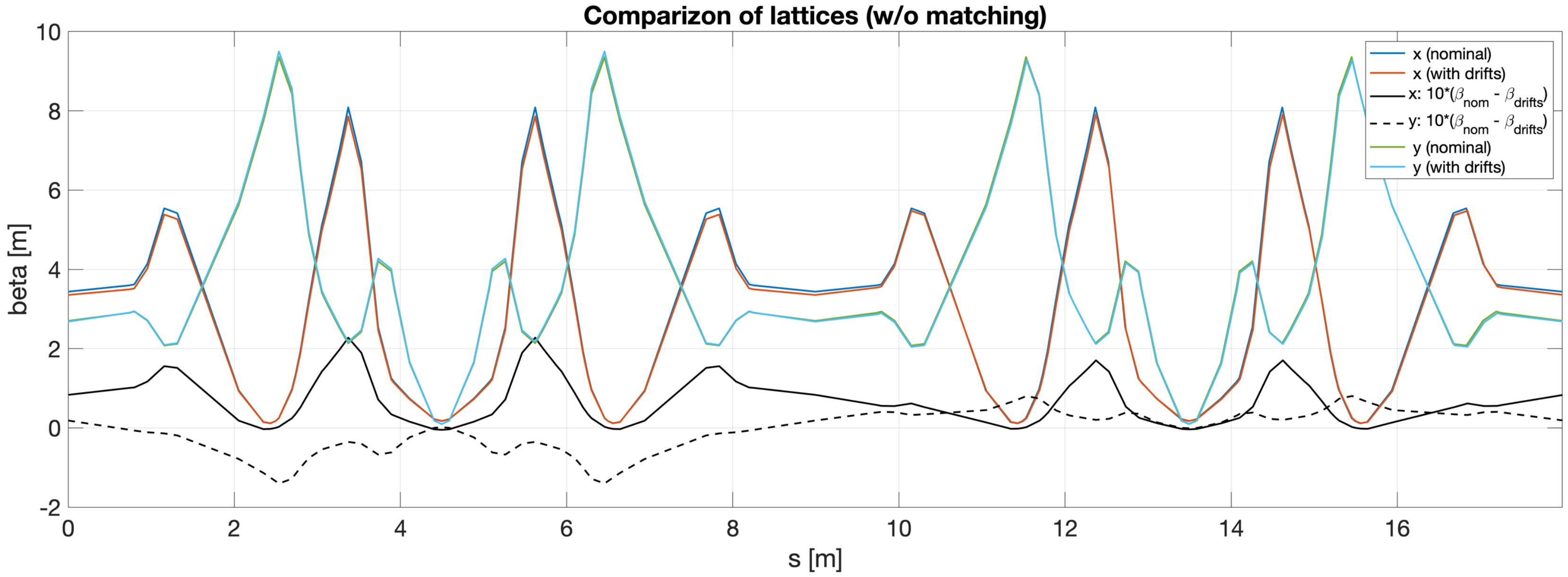
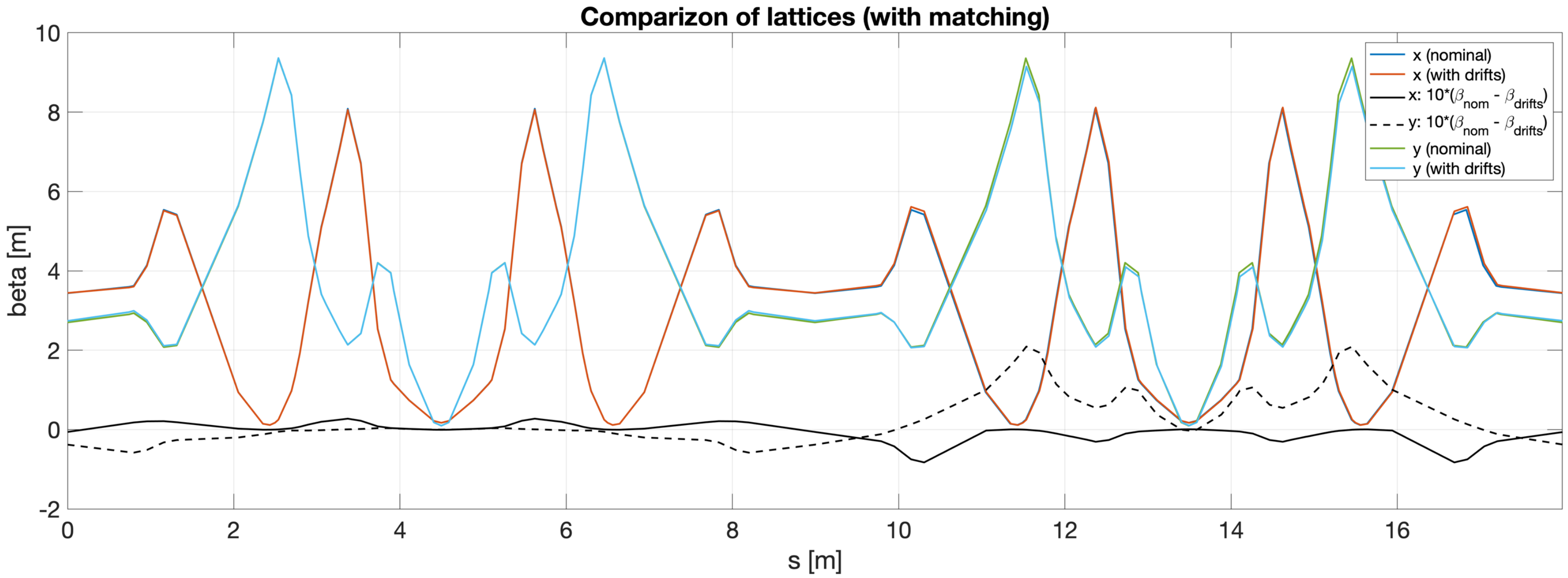
Final variable values:

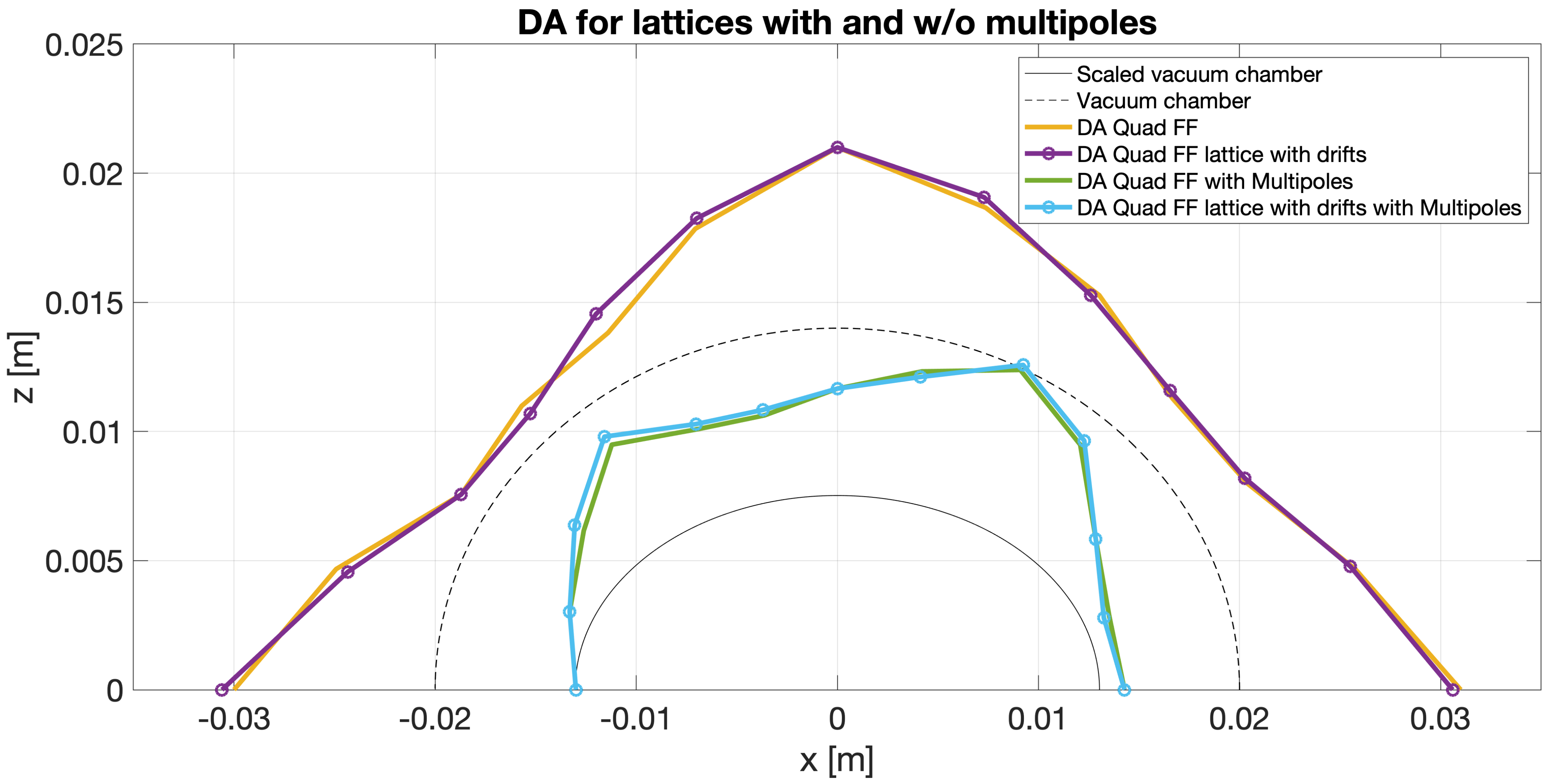
Name	field	before	after	variation
QP3	PolynomB	-17.2633	-17.1371	0.126169
QP4	PolynomB	15.3651	15.2624	-0.102735
QP31	PolynomB	-10.2947	-10.3805	-0.0858206
QP41	PolynomB	6.86566	6.99468	0.129015

Simulation/matching results (dL = 14 mm)

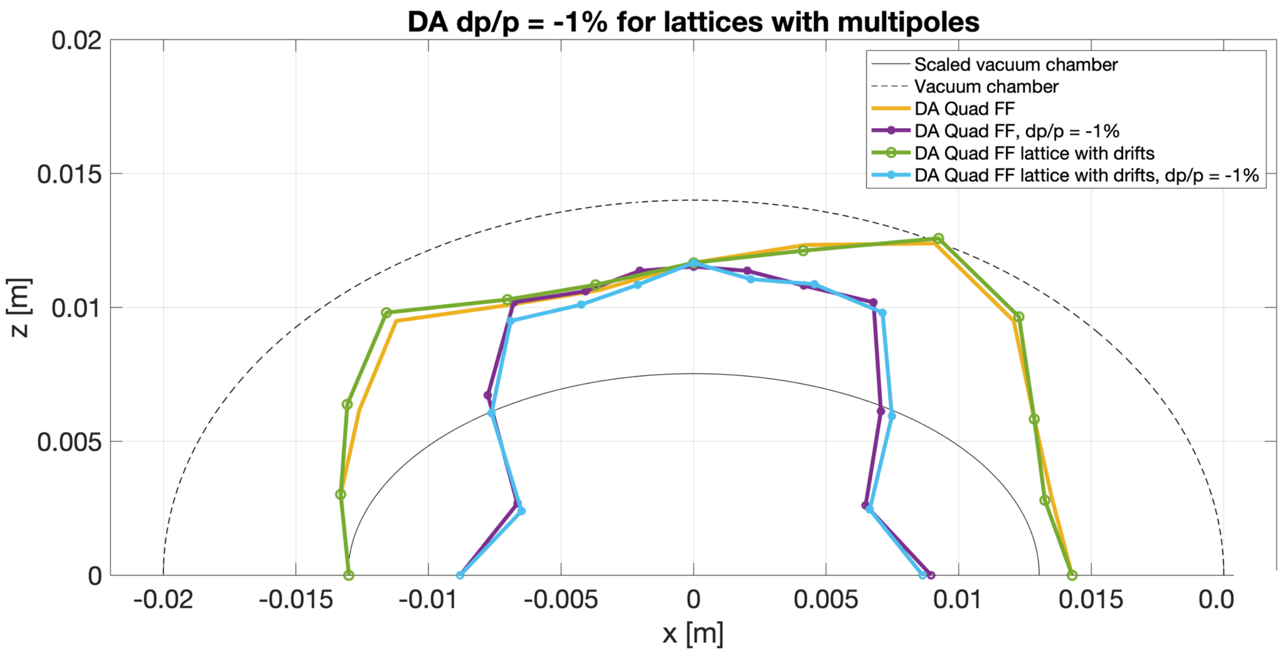


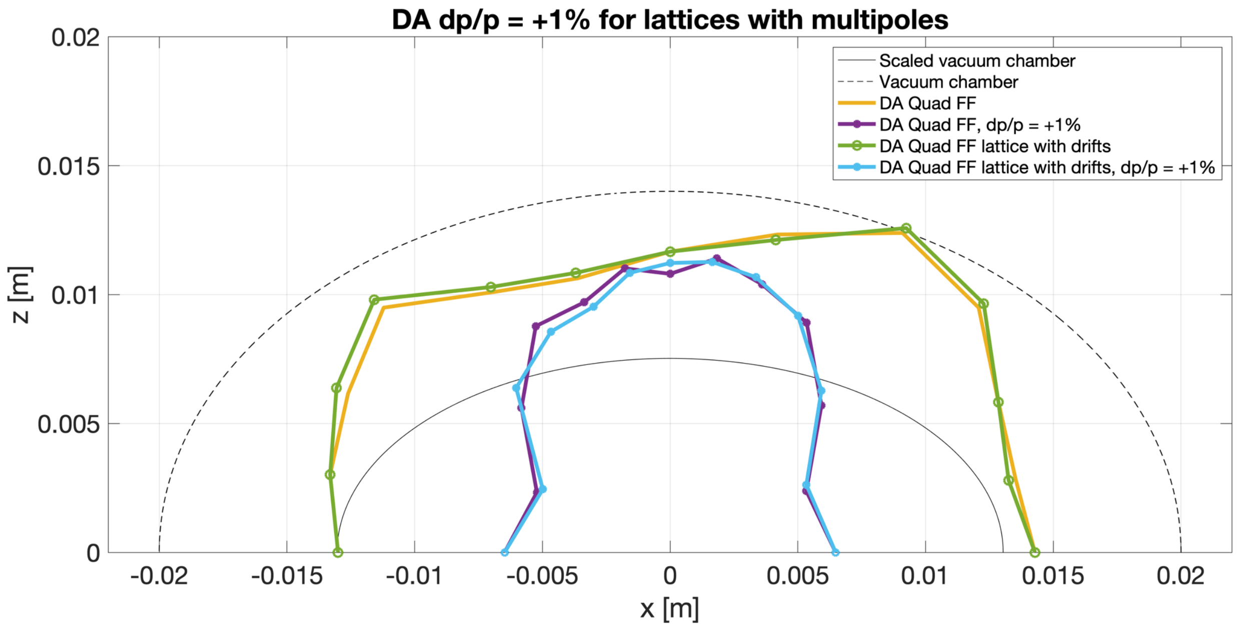


DA comparison: nominal lattice vs. lattice with drifts (dL = 14 mm)



DA ± 1% dp/p : lattice with drifts (dL = 14 mm)





Roadmap

Frequency choice strategy

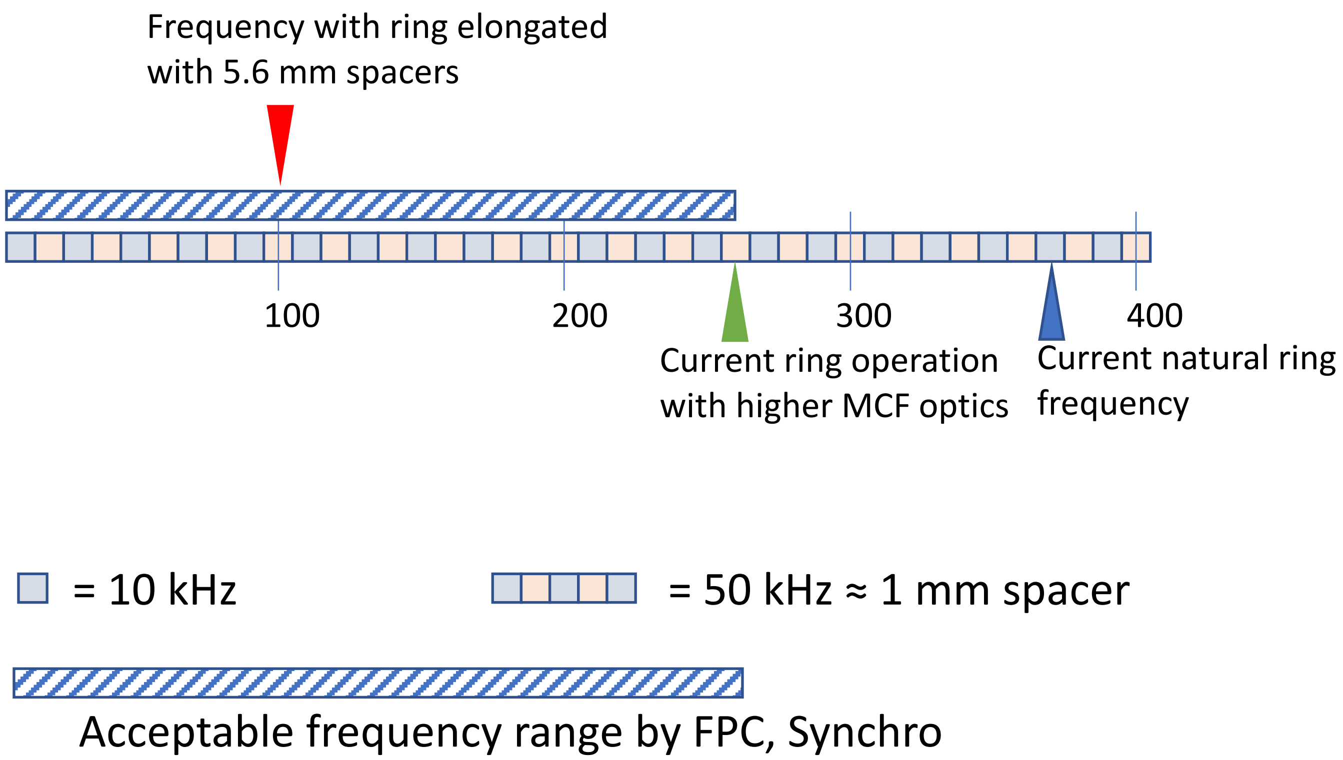


Table 2: Comparison Chart of Long-Term Ring Frequency Correction Solutions.

PROS	CONS
Elongation of the ring • Not many dependencies. Can be done by our mechanical team (in-house). • Requirements: infra team , 4 mechanical engineers, 2-3 weeks. • Studied, understood and explained with simulations with existing models/tools. • Flexible frequency choice. Frequency to be decided before installation of insertions.	**Elongation of the ring** • Vacuum break-up in the sector of intervention. • Slight change in symmetry (< ~6 mm max from each side). Main ring properties are conserved. • Symplectic simulation of strong short dipoles is not fully understood and not implemented in the available tracking codes. • Mechanics: adding new alignment points in the 3D model of the ring. • Need for realignment of displaced elements. • Risk: Break of the RF bellows, costly and very time consuming in case of refabrication. • Risk: vacuum leakage. • Exact ring frequency will be retrieved experimentally with the beam (modelling and installation errors).
Dipole field modification • Non-invasive. Vacuum is not affected. • Ring elements stay at their actual place. No realignment needed. • With available data, tracking in a realistic dipole magnetic field (OPERA) with and w/o plates show ~200 kHz frequency decrease with rescaling of the fieldmap. • Simulation model for dipoles becomes more correct (accurate). Correct physics and survey in the ring model. • Nominal ring optics. • Easily reversible solution.	**Dipole field modification** • Uncertainty on the final frequency. • Q: Thickness of the plates? • Fabrication and installation of the plates. • Need to be done in exactly the same way on all 8 dipoles. • Need to be validated by a magnet expert. And preferably measured at the magnetic test bench (ThomX spare dipole is taken by another experiment). • Require 3D preliminary studies by magnet(?) and mechanical groups. Spacing available for the plates is still not confirmed. • Strong dependency on magnetic expertise (both simulations and measurements). • Time schedule and planning is undefined and difficult to estimate.

- Currently, the potential solution seems to be "Elongation of the ring".
- This is a purely geometrical solution.
- Supervision by mechanical engineer team
  - Ordering the spacers + planning of the intervention
  - 3D modelling
  - Installation and alignment

We will provide all the necessary inputs to mechanical team

Summary

- We developed the methods to simulate the ThomX ring in **AT / MadX / ASTRA / RF-track**. We studied the solutions to elongate the ring. **The studies are accomplished. Next: after intervention, we will recommissioning the ring (injection, first turns, searching for the frequency…)**
- The solution with the metallic plates seems very promising. BUT allowed spacing and realistic geometry studies showed that the expected effect is not sufficient: < 100 kHz.
- Solution 2 ("Elongation of the ring"):
  - The physics studies now are done.
  - The choice of the drift length should be driven by the inputs from synchromization and FPC teams. From beam dynamics studies, the range (1-14) mm seems OK.
- **Once again: the current ring configuration allows the studies/characterization of the X-rays. The elongation of the ring is not a showstopper for the project.**