Preliminary tracking results

L. Soubirou, A. Chance – CEA Saclay

MuCol workshop on RCS, pulsed magnets & powering (15 May 2024, CERN)

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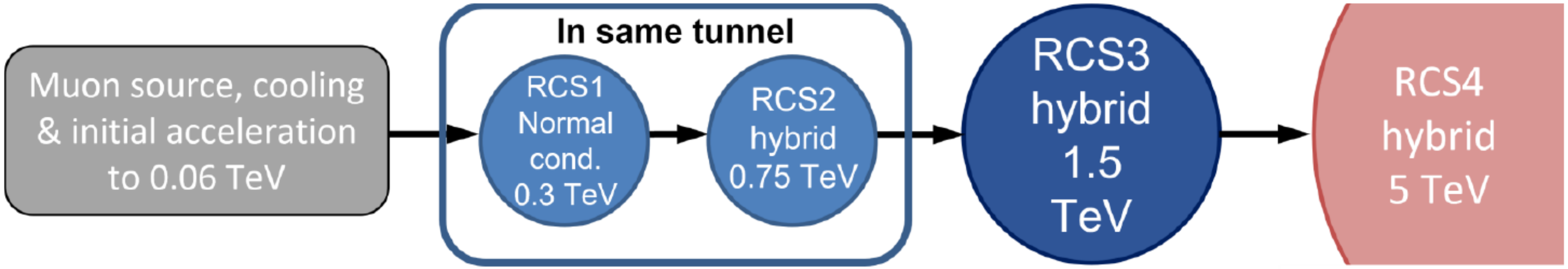
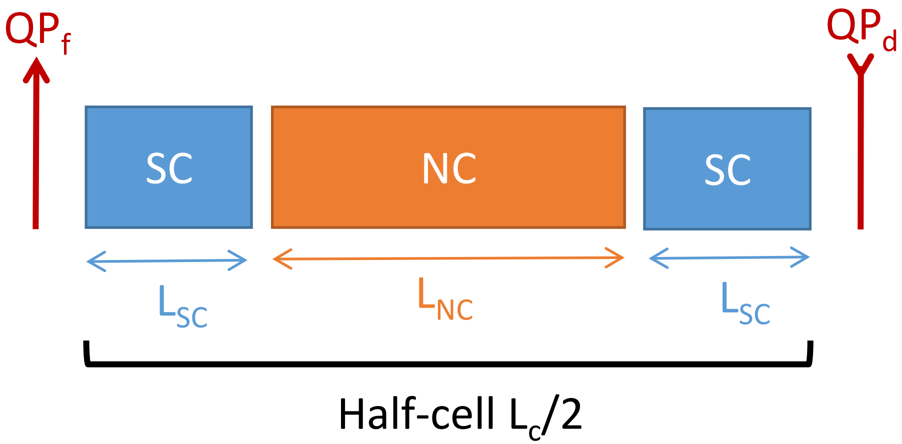
Structure of a RCS

- Chain of RCS



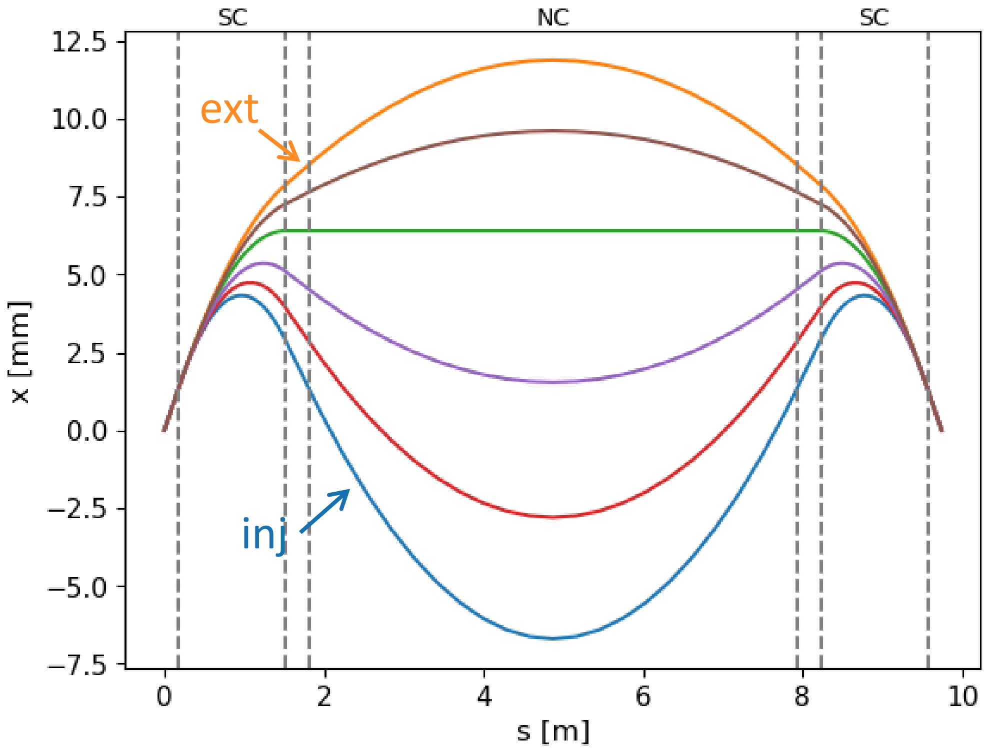
- Study focused on RCS2: hybrid synchrotron
- Structure of RCS: FODO cells with phase advance: μ=90°
- RCS2 geometric parameters:
  - C=5990m
  - n_{arc}=26
  - n_{RF}=26
  - n_c=8 cells per arc



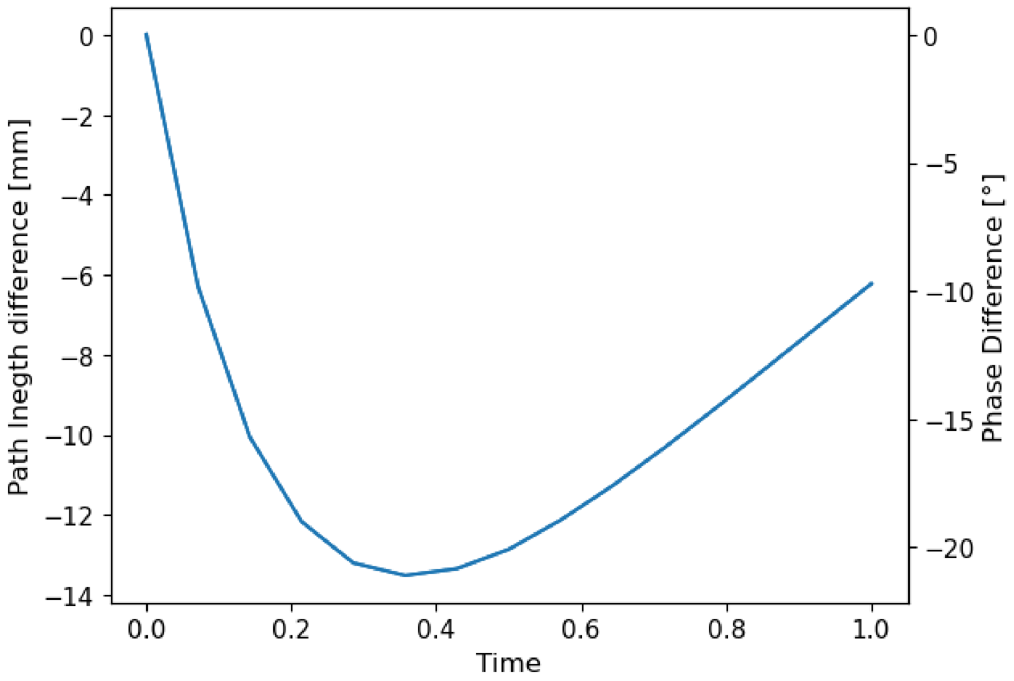
Difference of trajectory during ramping

Results from Xsuite

Trajectories from injection to extraction



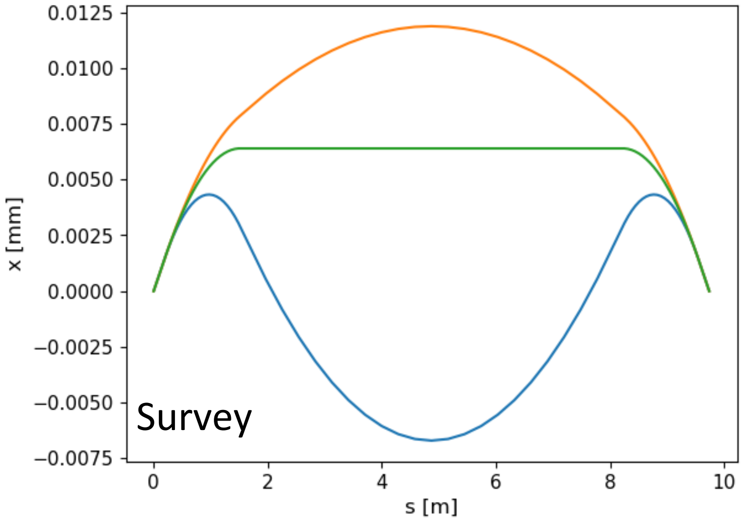
Path length difference from injection



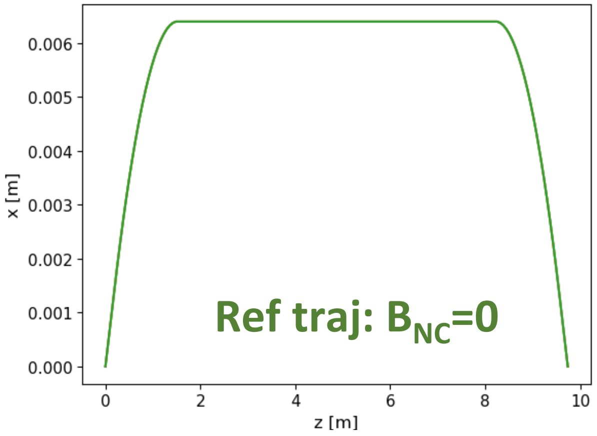
RF tuning ?

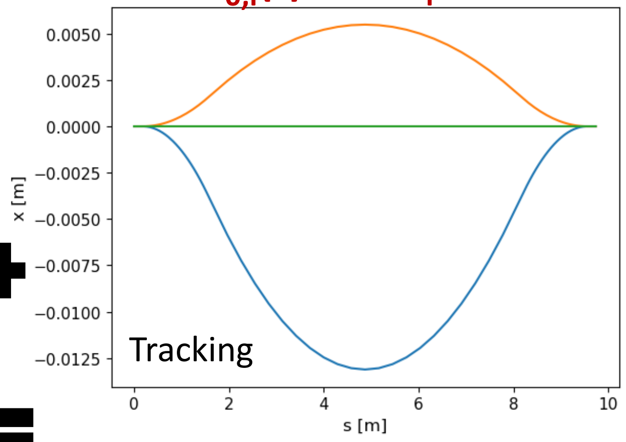
Defining a reference trajectory during ramping

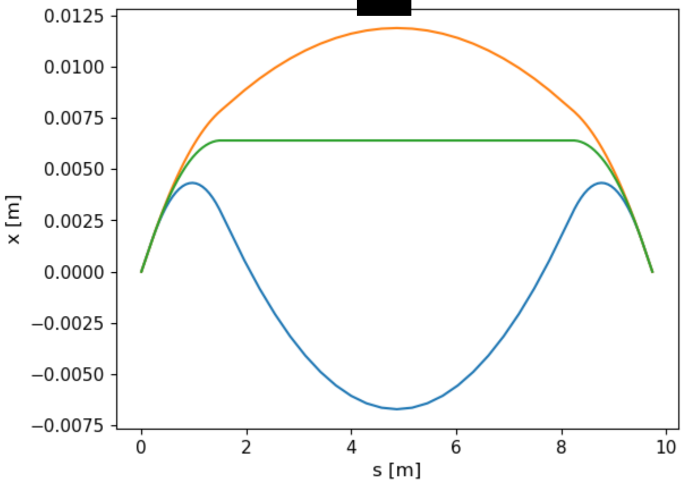
① Reference trajectory is not constant.
Normalized strength and bending of reference trajectory varies together: $k_{0,i}(t) = h_i(t)$



② Reference trajectory is constant
Only normalized strength of dipole varies and bending of reference trajectory is constant: $k_{0,i}(t)$ and $h_i=h^*$

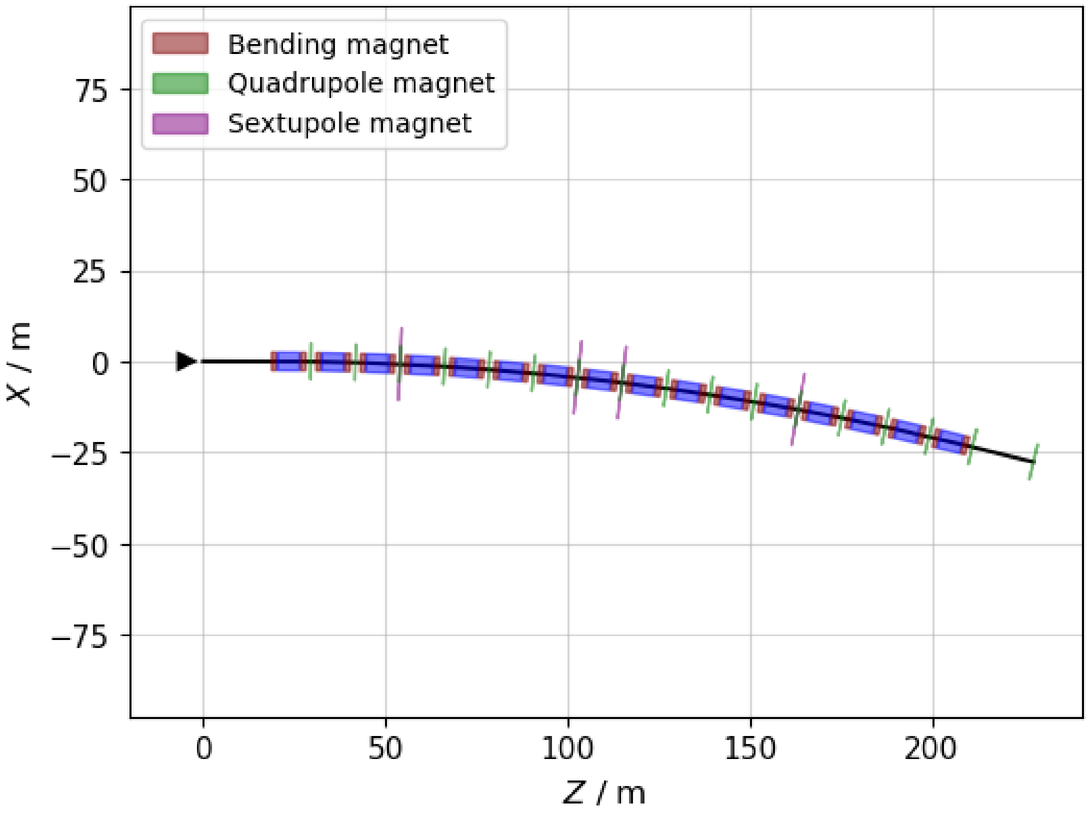


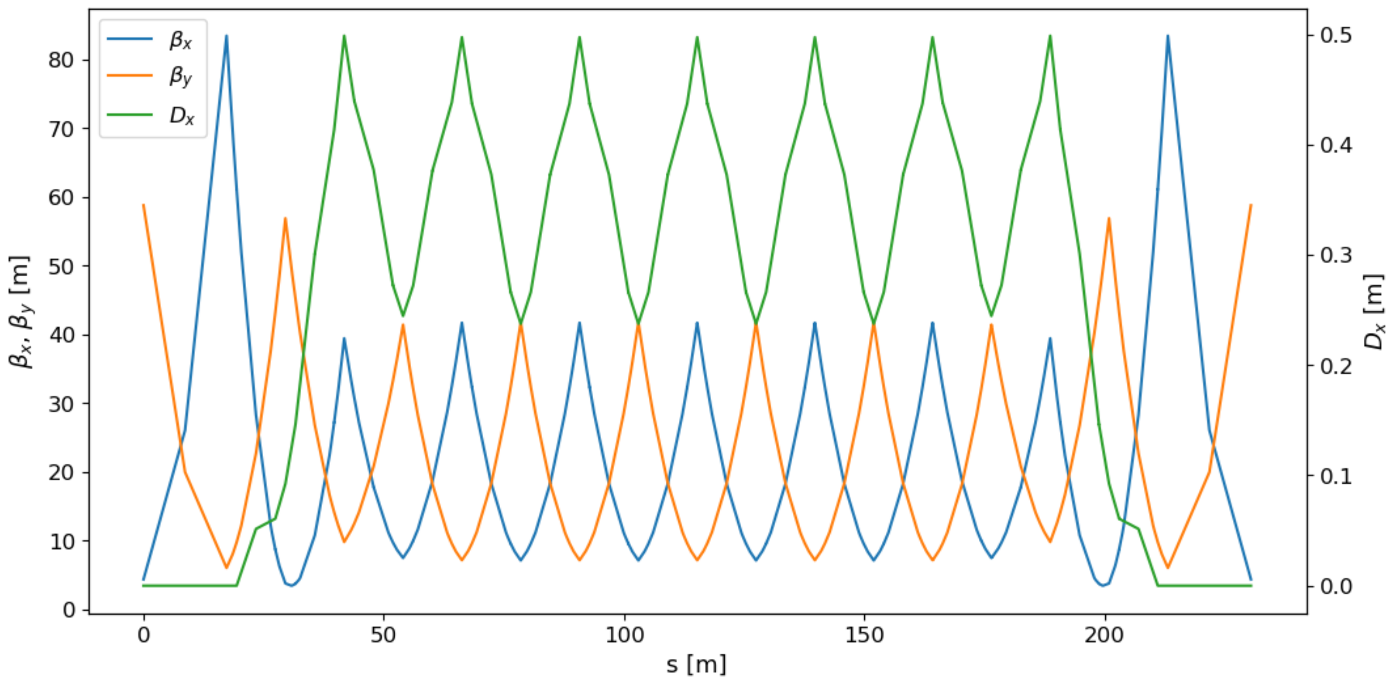




Same trajectories

Structure of an arc and optics





- FODO structure, base of µ=90°
- Dispersion suppressor for RF insertion (cavity + energy kick)
- Quad and Sextupoles: thin multipole approximation
- Dipoles: thick bend, sliced before tracking

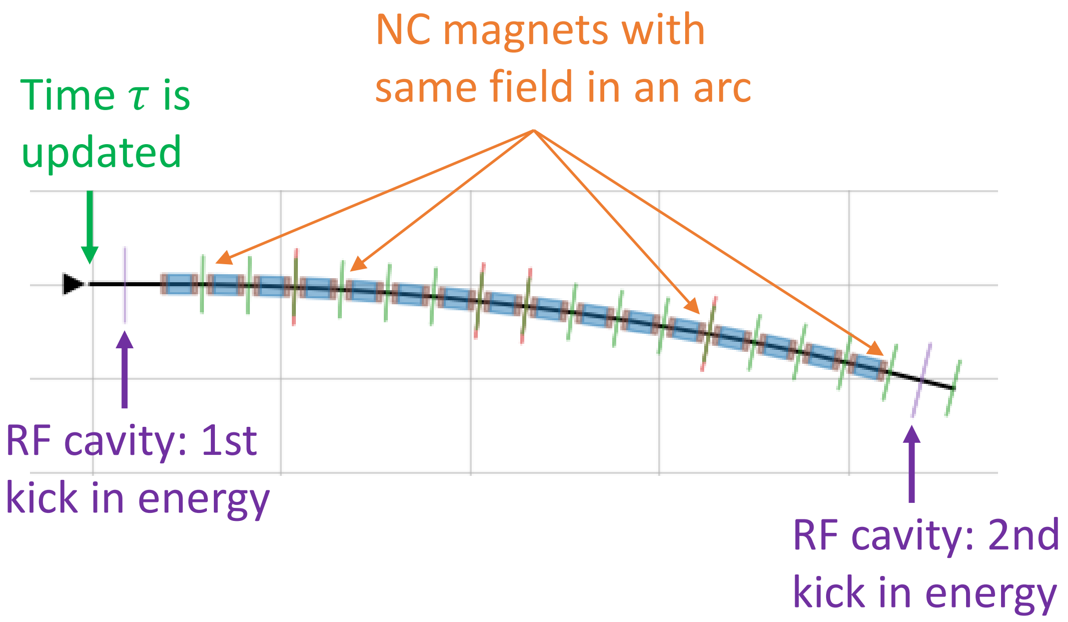
Ramping in Xsuite

- How is ramping done in RCS ?

→ Magnets can include time τ-varying attributes like the normalized strength k_0

→ Time variable τ is updated only at the beginning of the lattice (each arc here): the magnet fields are updated only at the beginning of each arc.

1 arc:

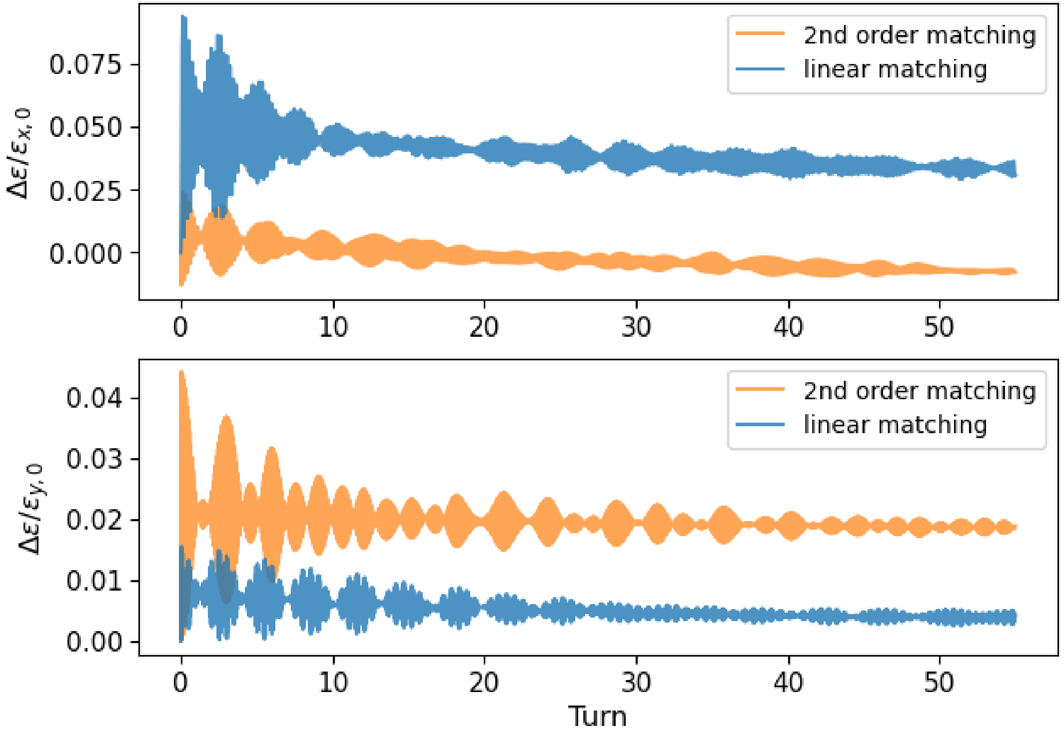


Impact of Montague functions

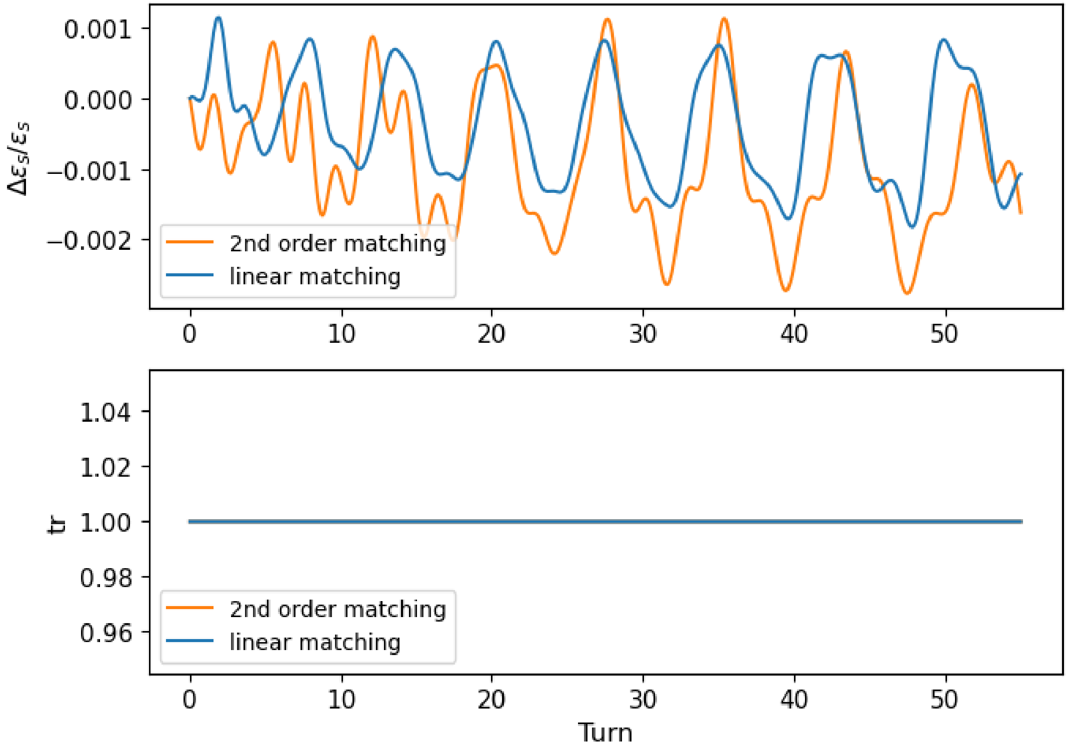
Initial distribution
$\epsilon_n^h = \epsilon_n^v = 25\ \mu m\ rad$
$\sigma_z \sigma_E = 0.025\ eVs$

- Dependence of Twiss parameters on relative energy difference δ: $\beta_x(\delta)$, $\beta_y(\delta)$, $\alpha_x(\delta)$, $\alpha_y(\delta)$
- Beam is linearly adapted but not perfectly adapted (higher order) → emittance growth.
  We superficially get rid of the problem by initially matching the beam to the optics depending on δ → **Work on optics to be done !**

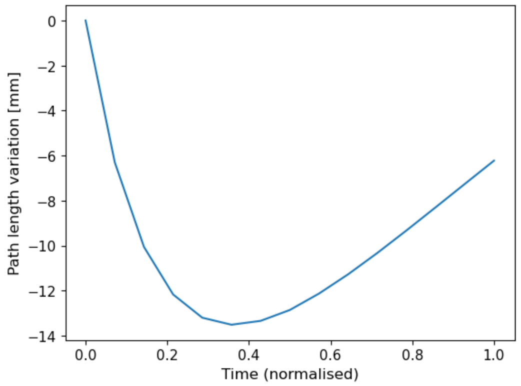
Relative transverse emittance growth



Relative longitudinal emittance growth and transmission

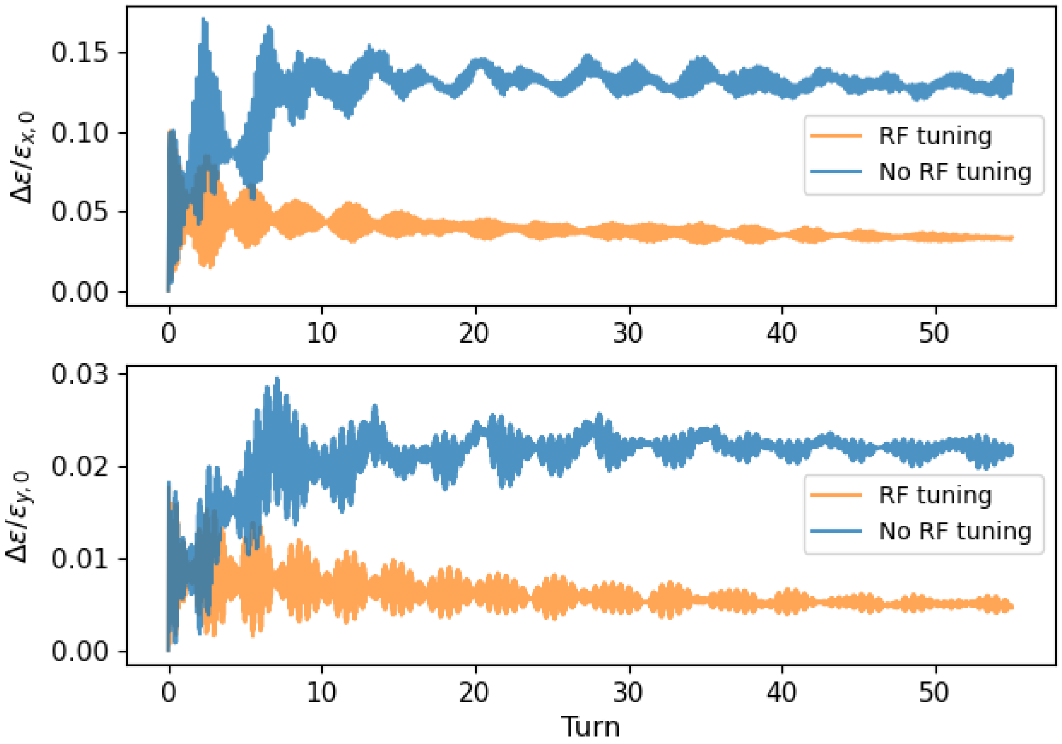


Effect of path length difference and RF tuning



RF tuning ↔ Applies a time shift to the particle when going through the RF cavity equal to the time of flight difference with the reference trajectory.

Relative transverse emittance growth



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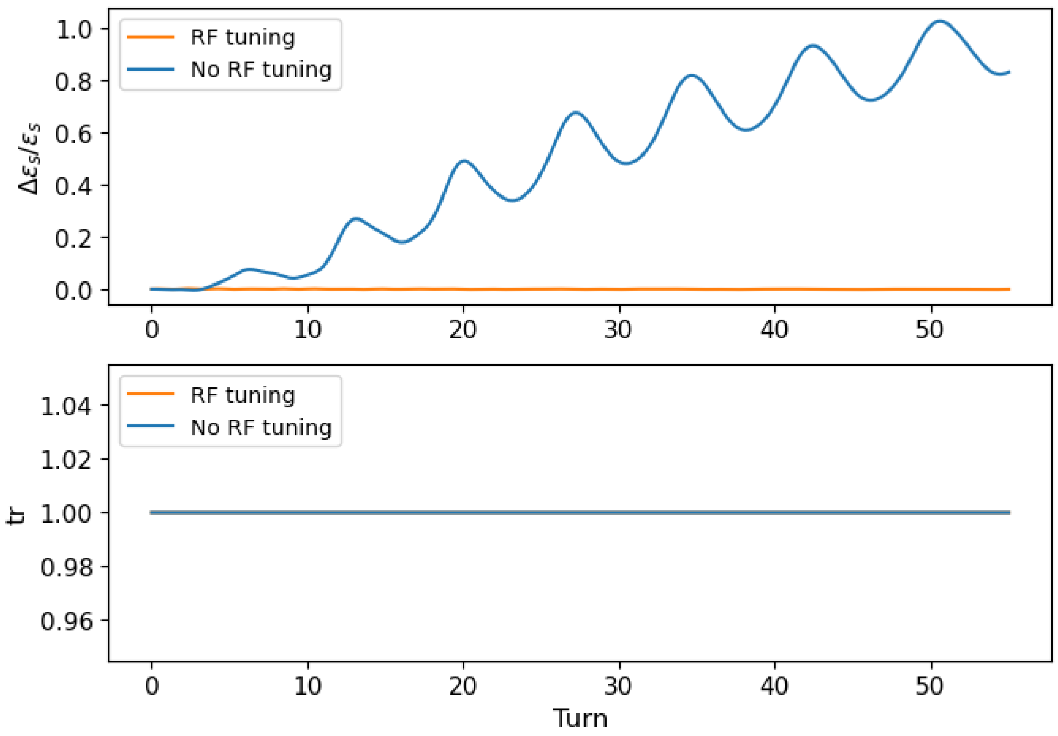
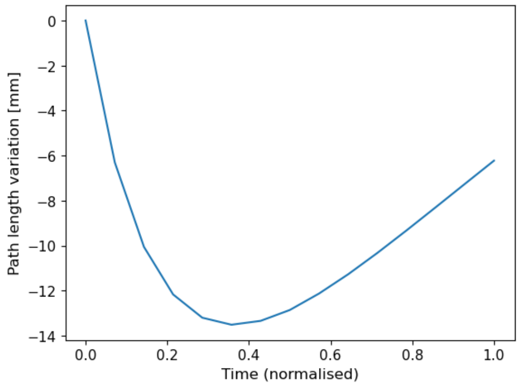
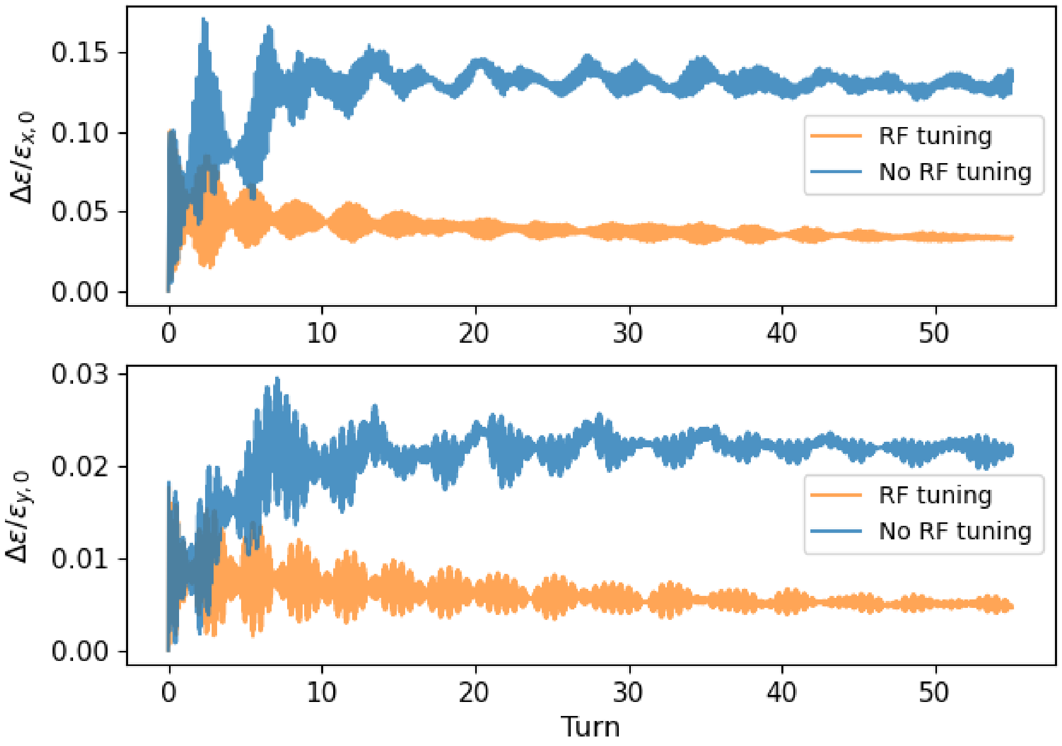


Effect of path length difference and RF tuning

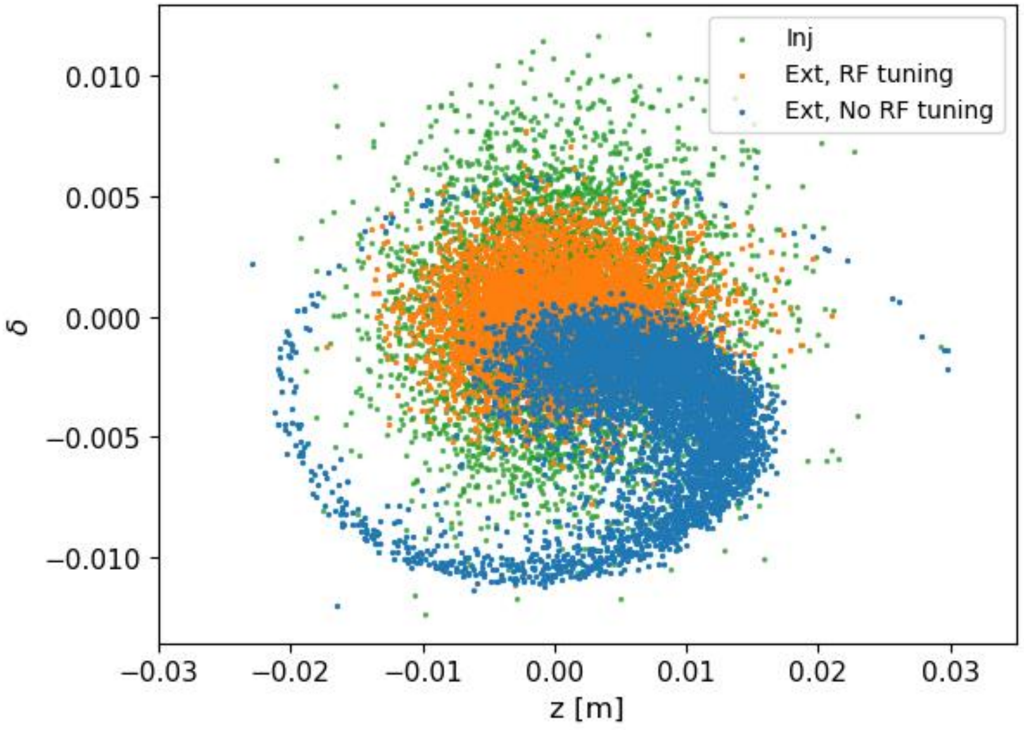


RF tuning ↔ Virtually give a Δz shift to the reference trajectory when going through the RF cavity :

Relative transverse emittance growth



Longitudinal phase-space



Adding higher multipolar component to the dipoles

- So far, dipoles only had b1 component = dipolar component
- No alignment errors, no rolls, no fringe field: « perfect vertical field »
- Include b3 and b5 => systematic errors added to all the SC dipoles
- Different dipole designs: different b3/b5 to be tested
- Correct chromaticity after introducing b3: dqx=5, dqy=5

	2 RTs *	b3 [units]	b5 [units]
(Min V)	1. Minimum Volume	-9.8	-6.3
(Med V)	2, Median Volume	2.5	-3.0
(Best B)	3. Best Field Quality	0.3	-0.8

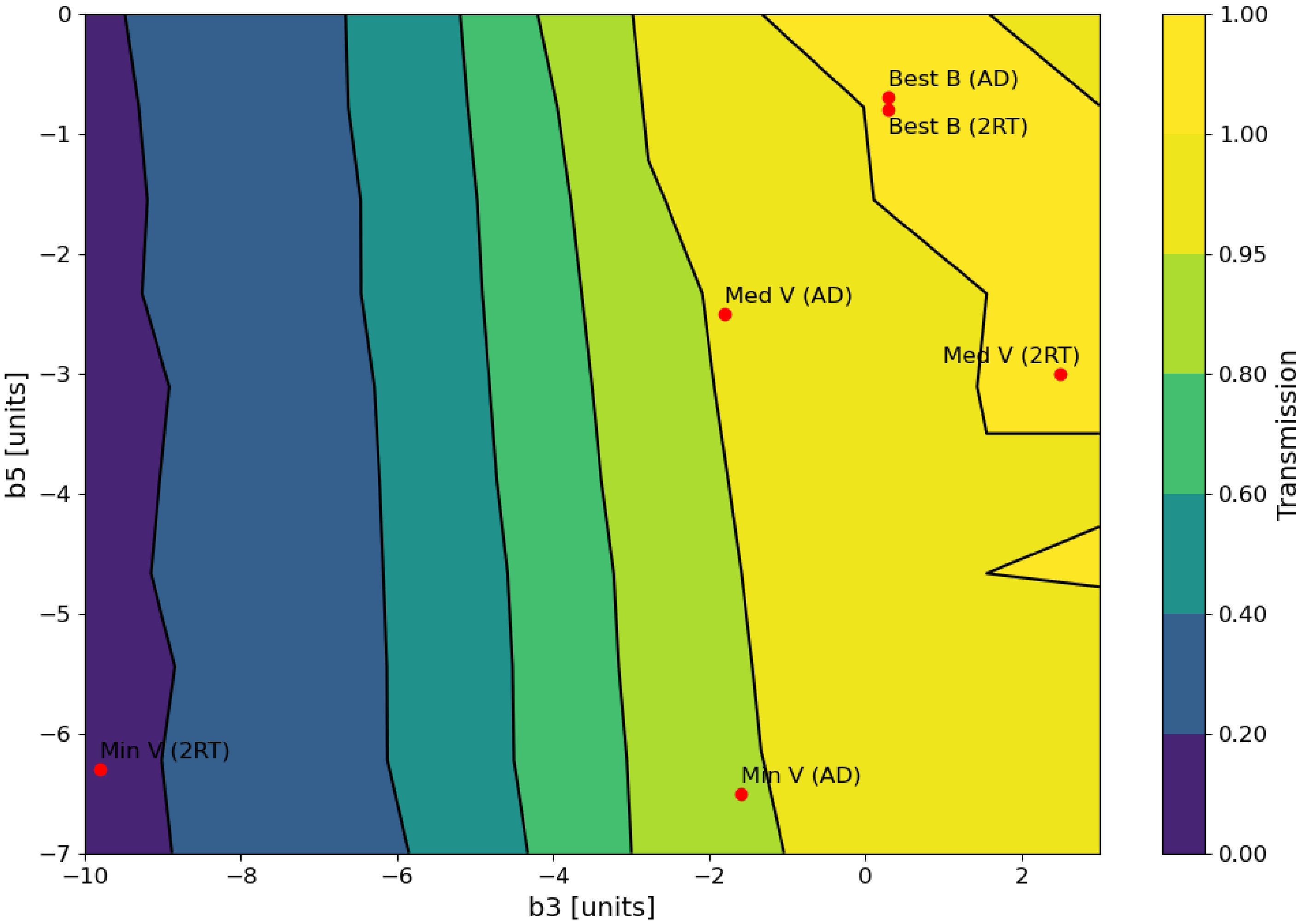
Additional coils (AD) *	b3 [units]	b5 [units]
1. Minimum Volume	-1.6	-6.5
2, Median Volume	-1.8	-2.5
3. Best Field Quality	0.3	-0.7

*** Initial Magnetic Design of Superconducting Dipoles in Acceleration Stage - Siara Fabbri, Luca Bottura (IMCC-MuCol annual meeting 2024)**

Rough scan of b3/b5 component Transmission

Transmission map

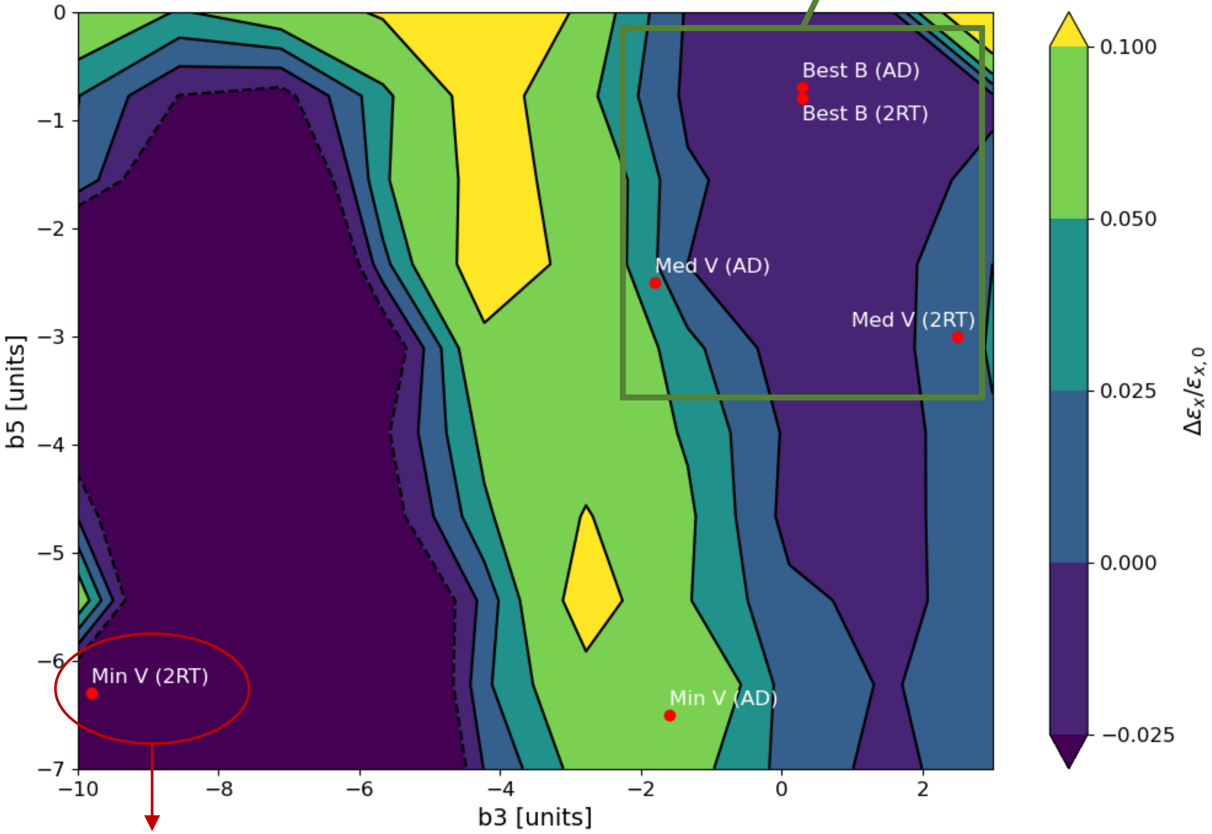
- Rough scan : 10 * 10 points
  → get an idea of the good/bad regions
- Minimum volume (2RT) : not good enough
- Best field + MedV designs are the best
- Optics not yet optimised : could improve those results



Rough scan of b3/b5 component
Emittance growth

Same order of magnitude as without errors : good!

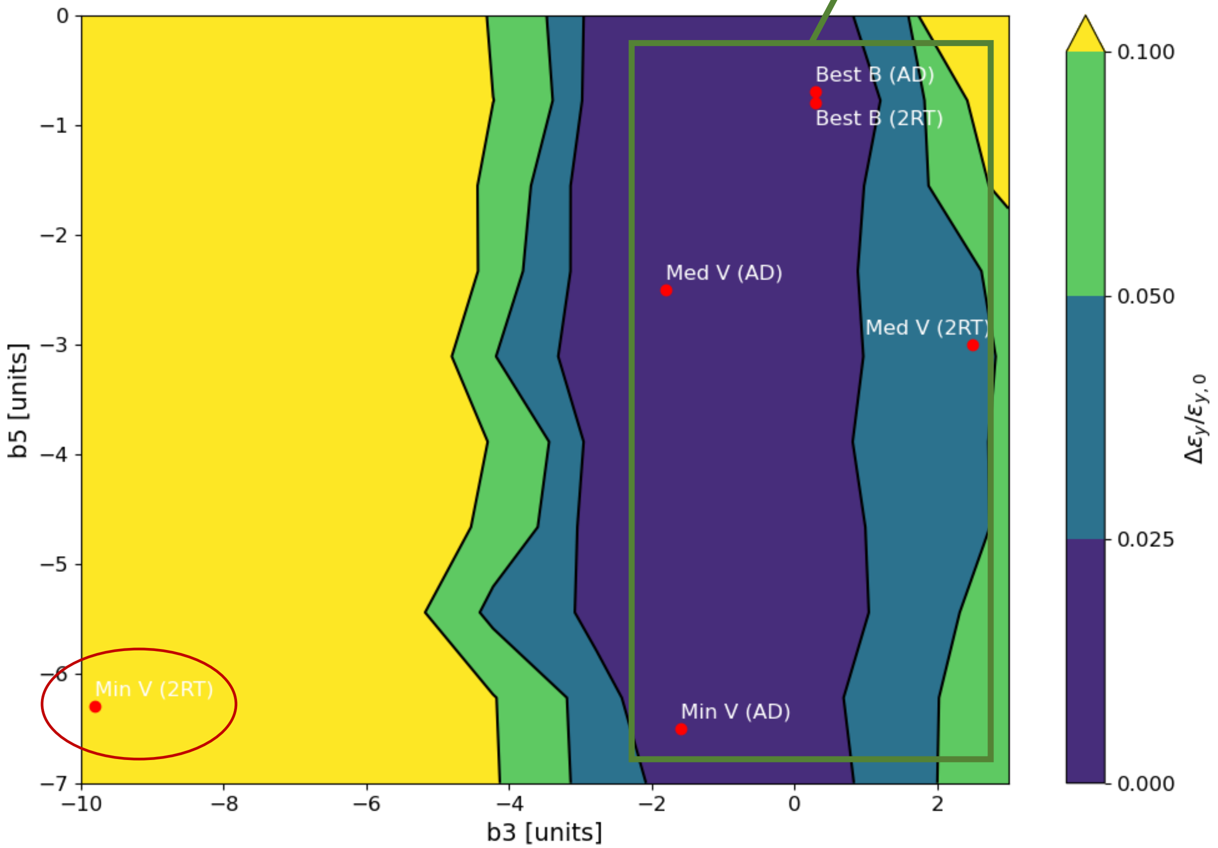
ε_x



Lose a lot of particles

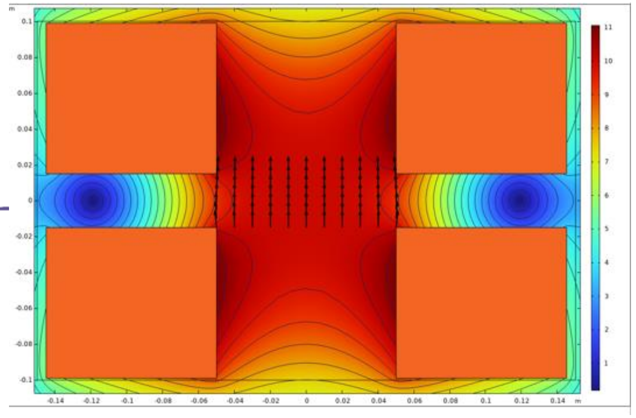
Same order of magnitude as without errors : good!

ε_y

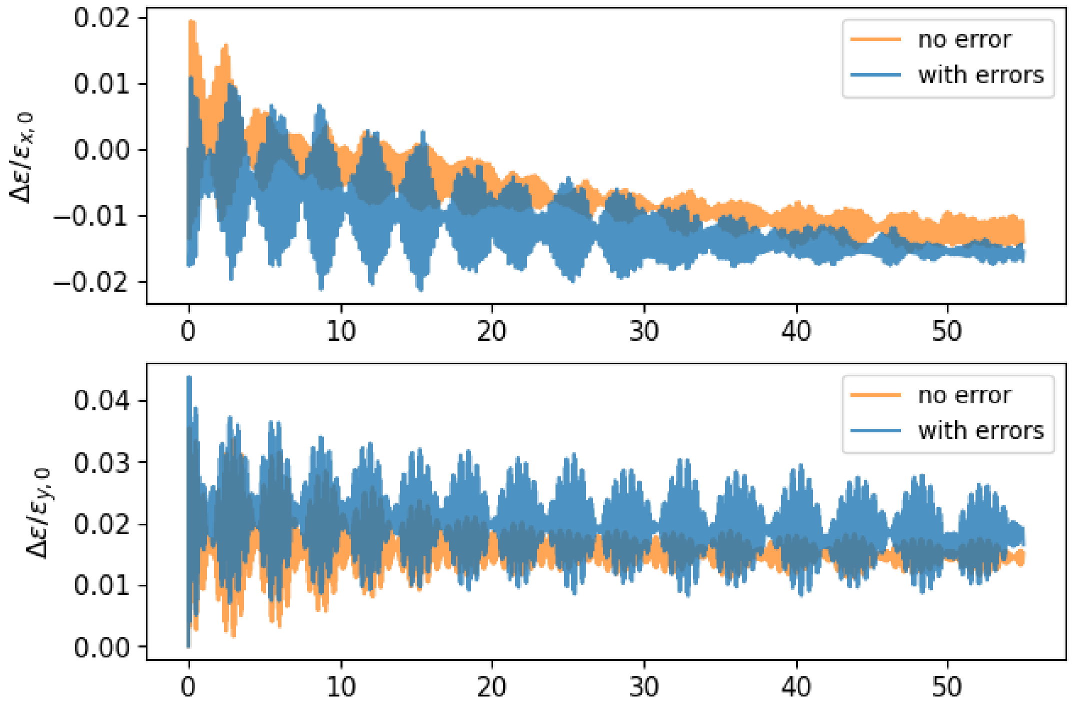


Best Field Quality (2RT)

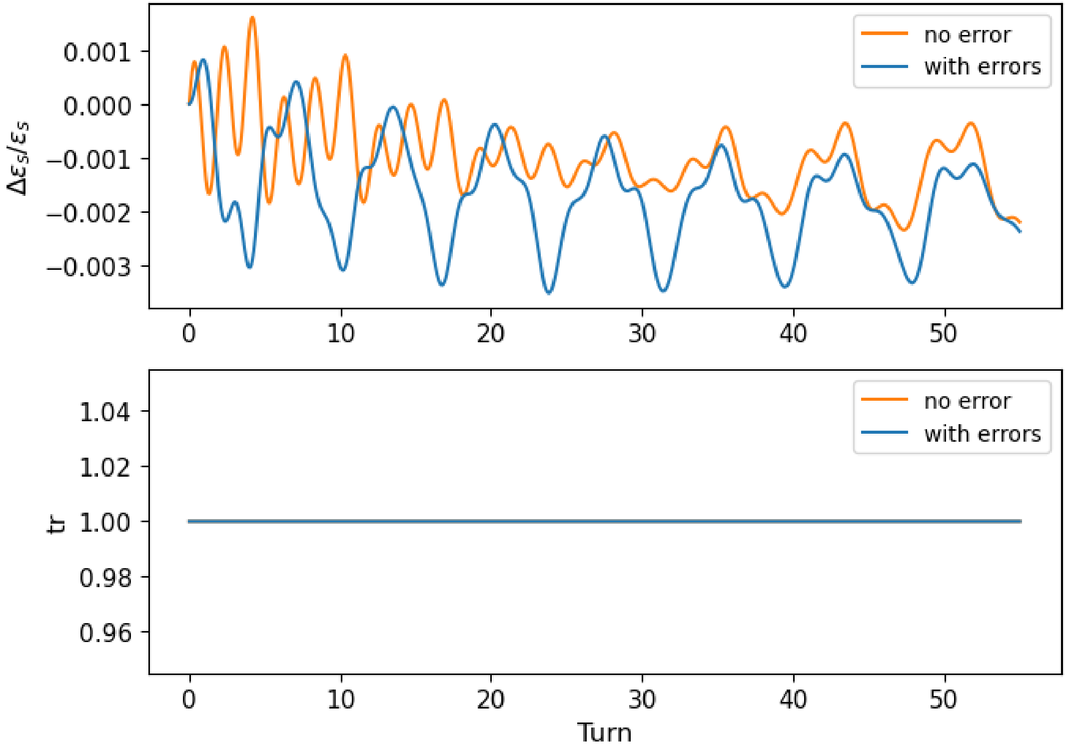
*



- Relative transverse emittance growth

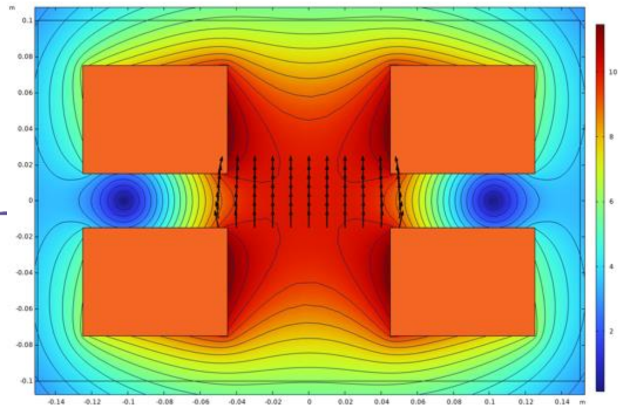


- Relative longitudinal emittance growth and transmission

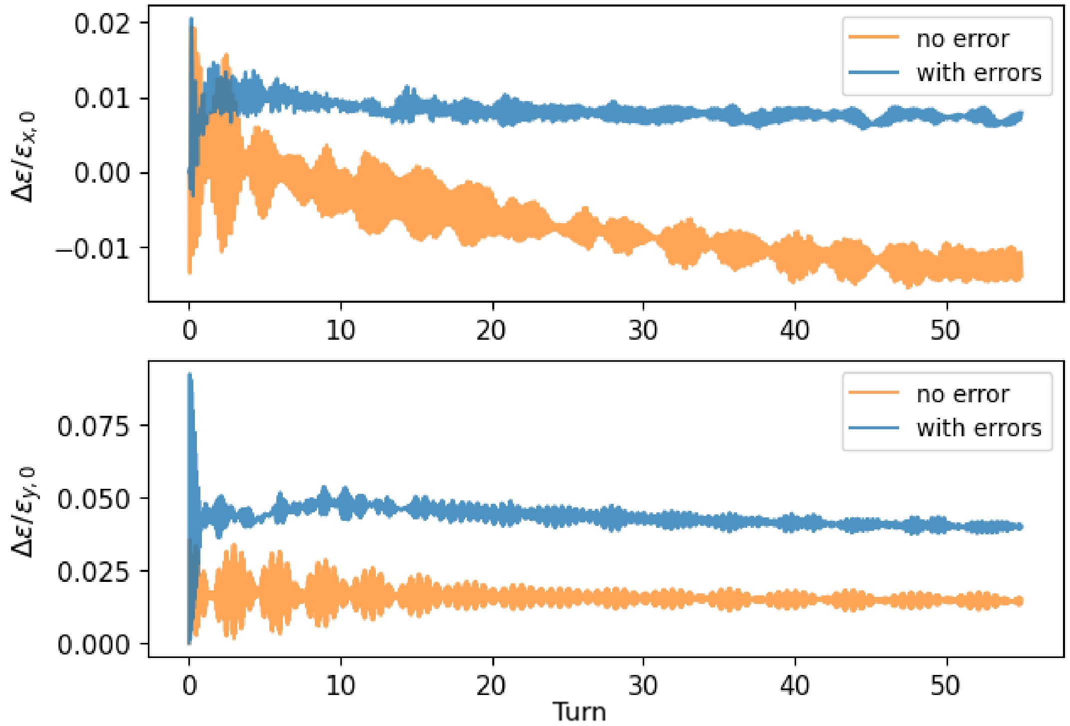


*** Initial Magnetic Design of Superconducting Dipoles in Acceleration Stage - Siara Fabbri, Luca Bottura (IMCC-**

Median Volume (2RT)

*


- Relative transverse emittance growth



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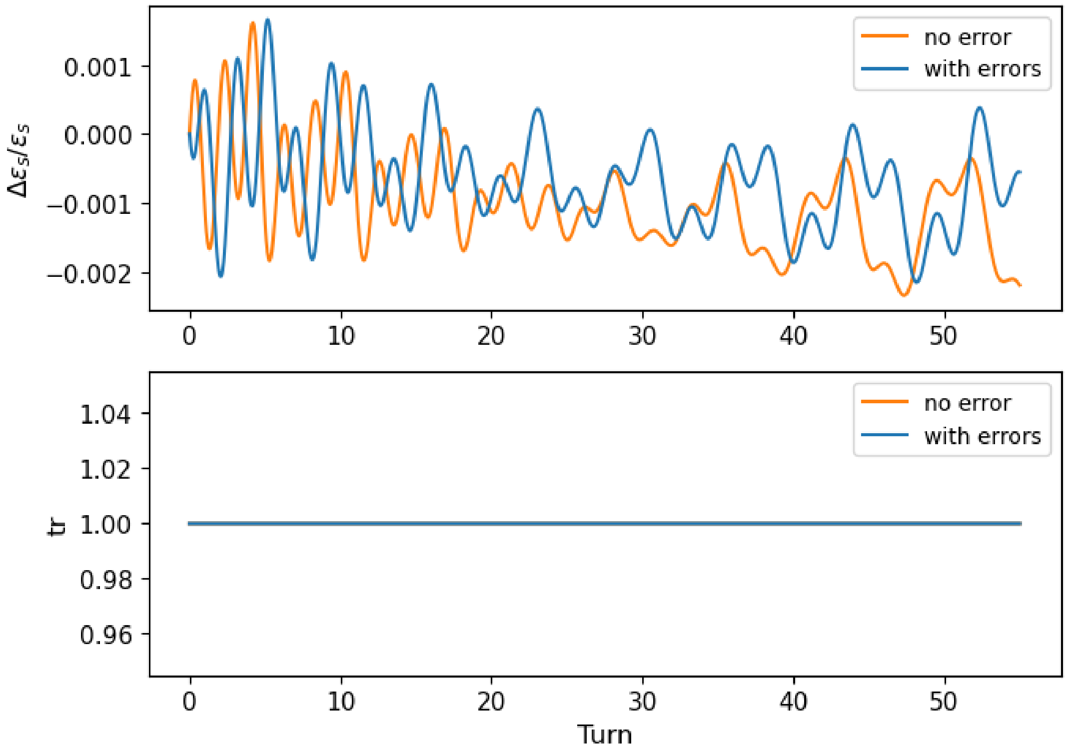
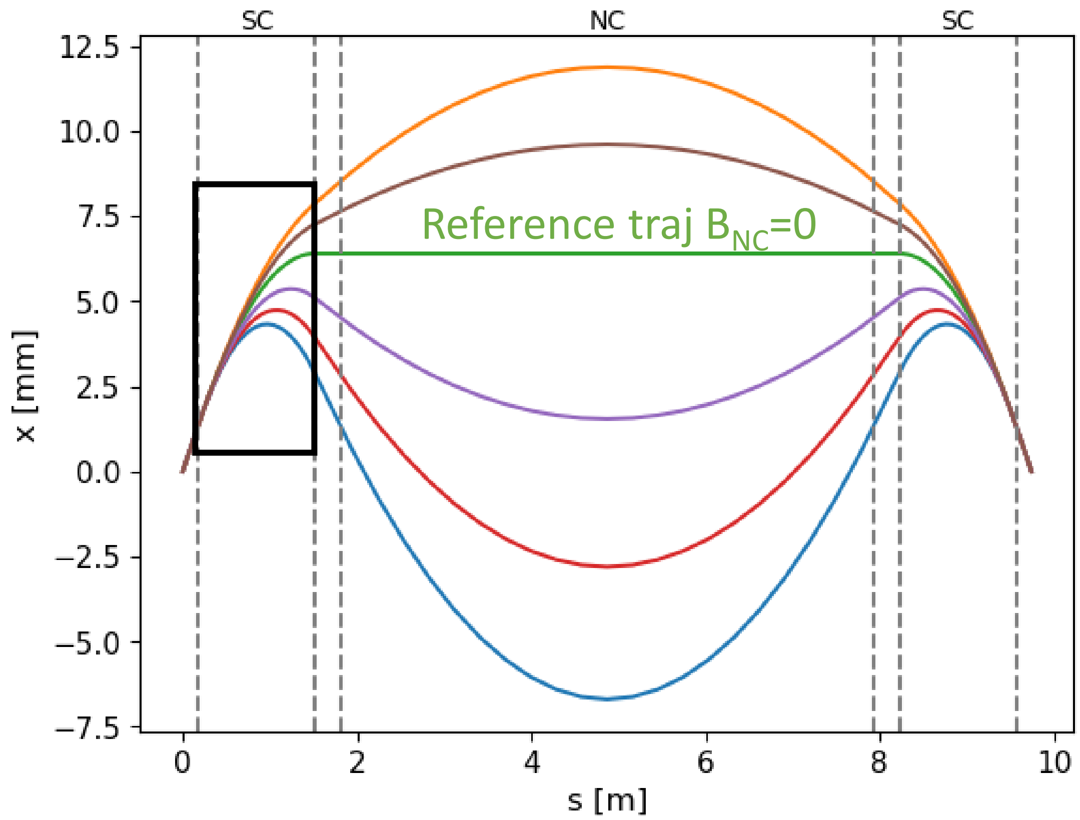


*** Initial Magnetic Design of Superconducting Dipoles in Acceleration Stage - Siara Fabbri, Luca Bottura (IMCC-**

Good field region of SC dipoles



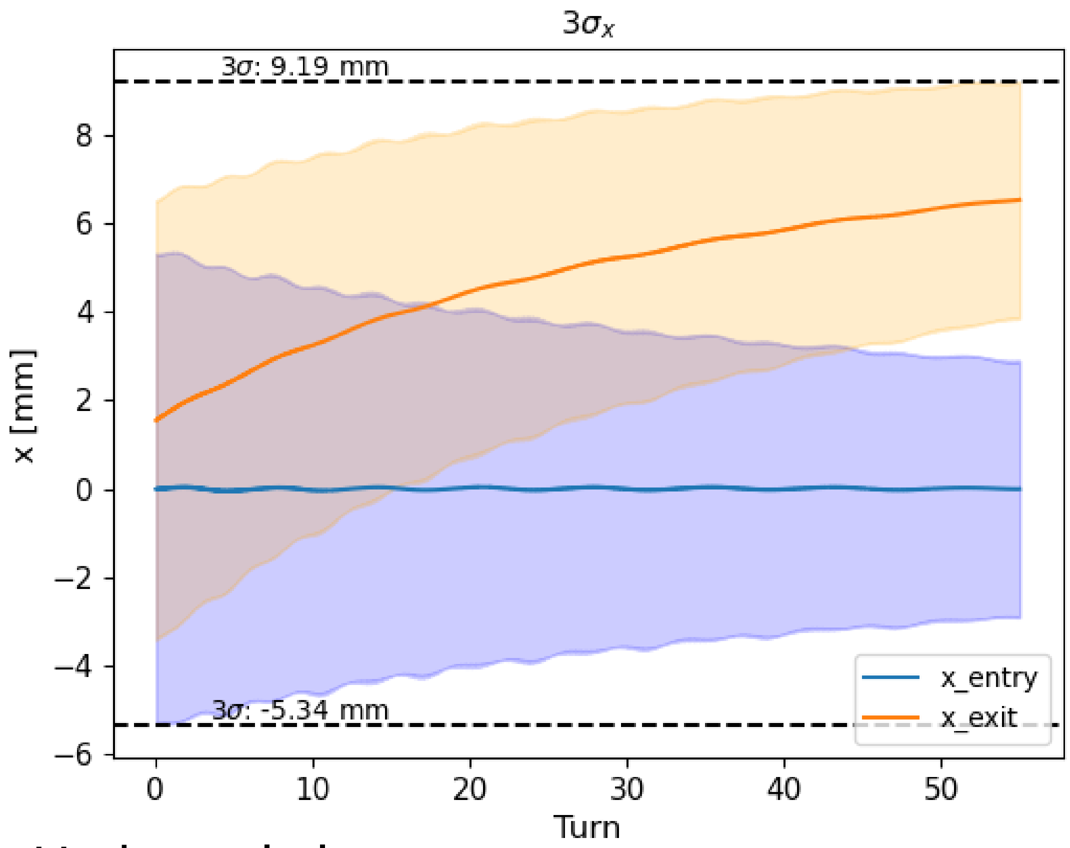
- Estimate the good field region: take into account the excursion of trajectories and the effect of optics

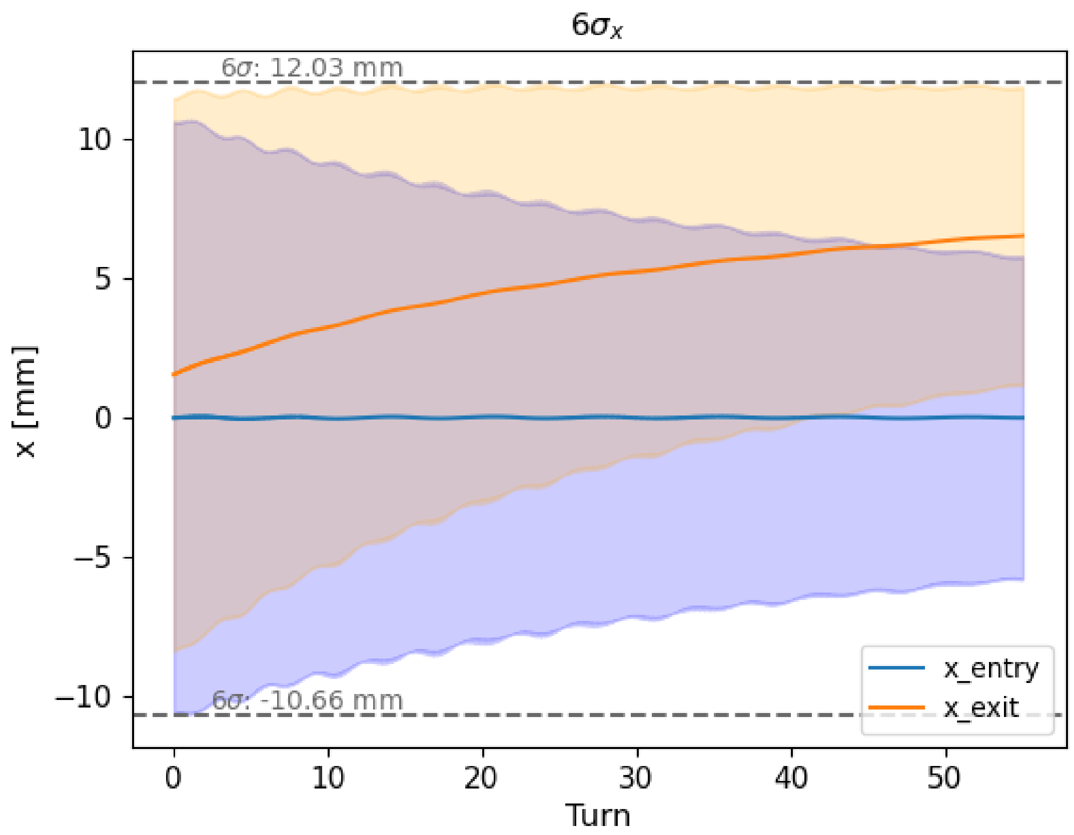
- Choose the reference trajectory
- Tracking in a dipole where β and D are maxima, so we get the « larger beam size » :

$$\sigma_x = \sqrt{\epsilon_x \beta_x + D_x^2 \sigma_\delta^2}$$

- No errors

GFR: Horizontal plane x





Horizontal plane σ_x

- 3σ : ~ 15 mm width
- 6σ : ~ 23 mm width

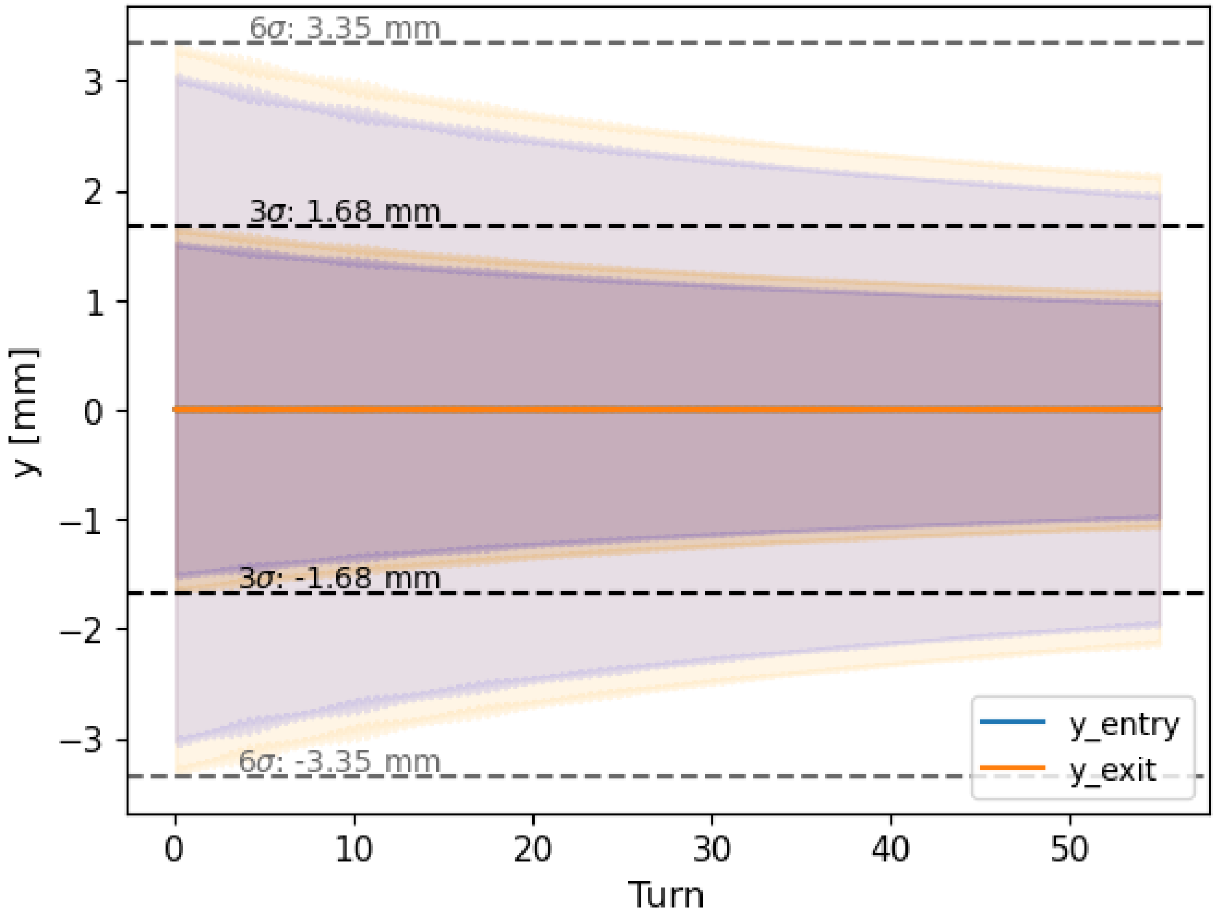
About 20 mm horizontal width for the good field region should be enough → not a lot of travelling in the outer side of GFR

GFR: Vertical plane y

Vertical plane σ_y

- 3σ : ~ 3 mm width
- 6σ : ~ 7 mm width
- No excursion of the trajectory in the vertical plane : much smaller region

GFR x : ~ 20 mm
GFR y: much less needed



Conclusions and perspectives

- First tracking studies conducted
- Impact of preliminary optics and RF tuning
- Tracking integrating systematic errors b3/b5 from dipole designs
  - ➢ Have an idea of which designs could be used
- Get a rough idea of the width of the GFR with tracking studies

- What's next ?
  - ➢ Work on optics
  - ➢ Add misalignment/roll errors and random errors (jitters) on dipoles
  - ➢ Include passive correction schemes

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