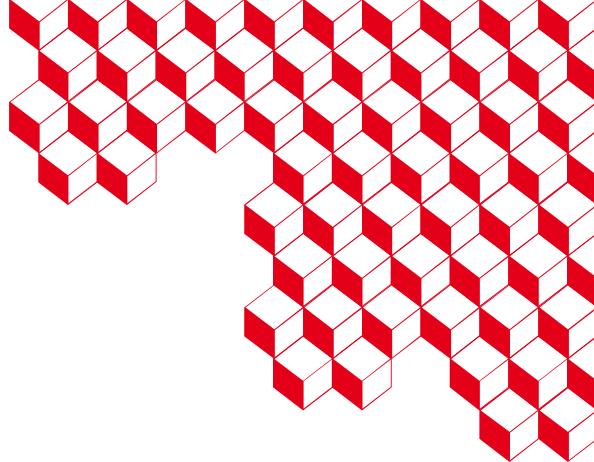




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Orbit correction of the FCC-ee high energy booster

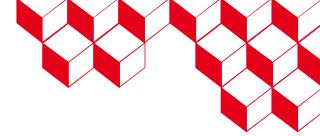
T. Da Silva, B. Dalena, A. Chancé, A. Ghribi, Q. Bruant (CEA irfu and Paris-Saclay University)
A. Mash'al (IPM)

Thanks to: R. Tomas, K. Oide, M. Hostettler, D. Gamba, E. Fol



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Outline



- Motivation
- Orbit Correction Strategy
- Results & discussion
- Conclusion & further steps



MOTIVATION

Goal = Define pre-alignment tolerances of the elements and the orbit correctors specifications for the FCC-ee high energy booster.

The following formulas from [LHC Project Note 43](#) and [LHC Project Note 501](#) are used for the rms orbit estimation:

- For random dipole field error: $\Delta x_{rms} = \frac{\pi}{\sqrt{2} \sin(\pi Q)} \frac{\bar{\beta}}{\sqrt{N_d}} \left(\frac{\Delta B}{B} \right)_{rms}$
- For dipole roll errors: $\Delta y_{rms} = \frac{\pi}{\sqrt{2} \sin(\pi Q)} \frac{\bar{\beta}}{\sqrt{N_d}} (\Delta \theta)_{rms}$
- For quadrupole alignment errors: $\Delta(x, y)_{rms} = \frac{\sqrt{N_q}}{\sqrt{2} \sin(\pi Q) \cos(\mu/2)} (\Delta q_{x,y})_{rms}$
- For BPM alignment errors: $\Delta(x, y)_{rms}^2 = \frac{1/2}{[1 + \sin(\frac{\mu}{2})]^2} (\Delta \sigma_{x,y})_{rms}^2$

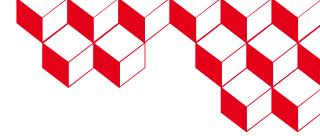
... and for corrector strengths calculation:

-
- $(\delta_x)_{rms} = \sqrt{\frac{\bar{\beta}}{\beta_{max}} \left(n \left[\frac{2\pi}{N_d} \left(\frac{\Delta B}{B} \right)_{rms} \right]^2 + 2(\Delta q)_{rms}^2 K_q^2 L_q^2 \right)}$
 - $(\delta_y)_{rms} = \sqrt{\frac{\bar{\beta}}{\beta_{max}} \left(n \left[\frac{L_d}{\rho} (\Delta \theta)_{rms} \right]^2 + 2(\Delta q)_{rms}^2 K_q^2 L_q^2 \right)}$

Correction Strategy



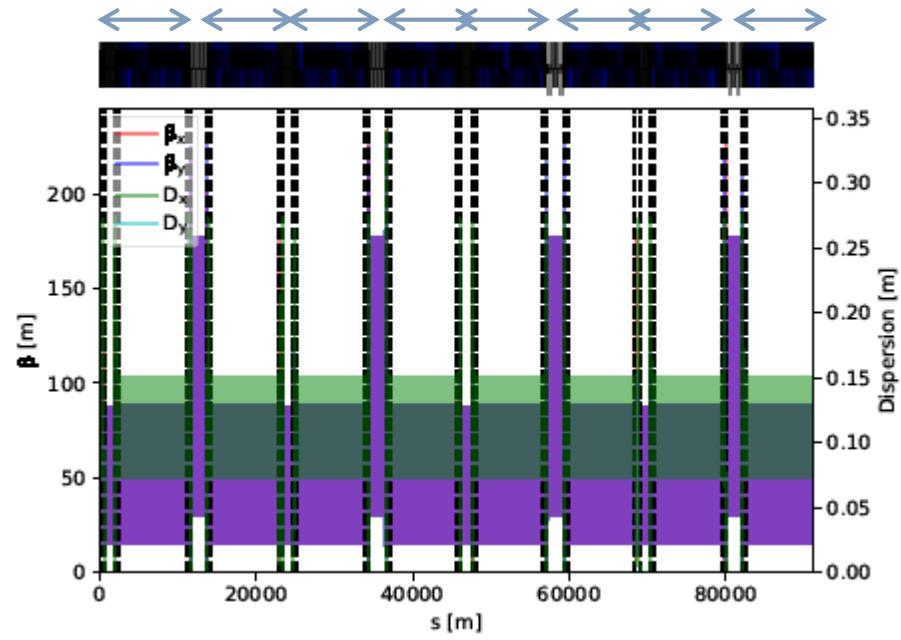
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- Definition of the CORRs and the BPMs:
 - if MQ foc → BPM reads in horizontal and CORR corrects in horizontal
 - if MQ defoc → BPM reads in vertical and CORR corrects in vertical
- Choice CORRs & BPMs for the **segment by segment** (=SbS, done arc by arc):
 - x plane: 1st BPM of the arc, the 2 CORRs before the beginning of the arc and the **3** BPMs and CORRs after the end of the arc
 - y plane: 1st BPM of the arc, the 2 CORRs before the beginning of the arc and the **2** BPMs and CORRs after the end of the arc

Procedure:

- Sextupoles turned **OFF**
 - SbS
 - We use 2 iterations of SVD **in line** on **all arcs**
 - Iterations of SVD in **ring mode**
- Sextupoles turned **ON**
 - 1 iteration of SVD **in ring**

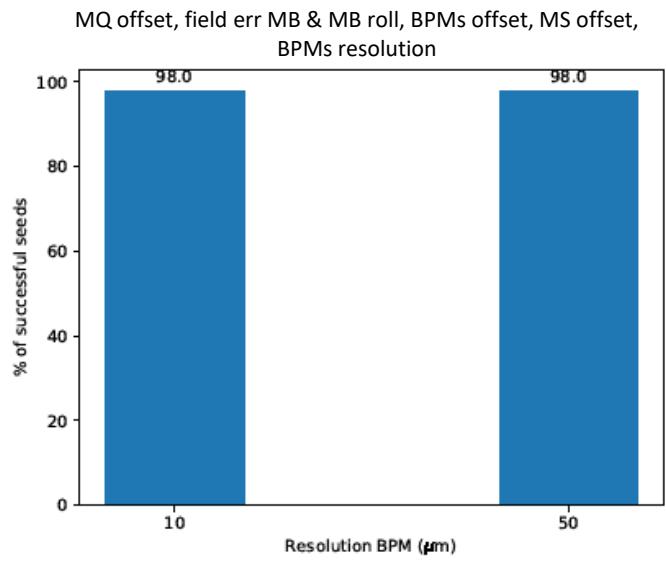
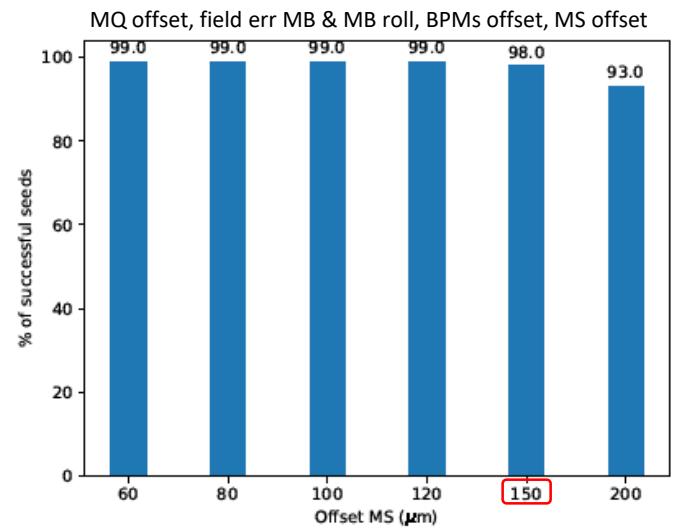
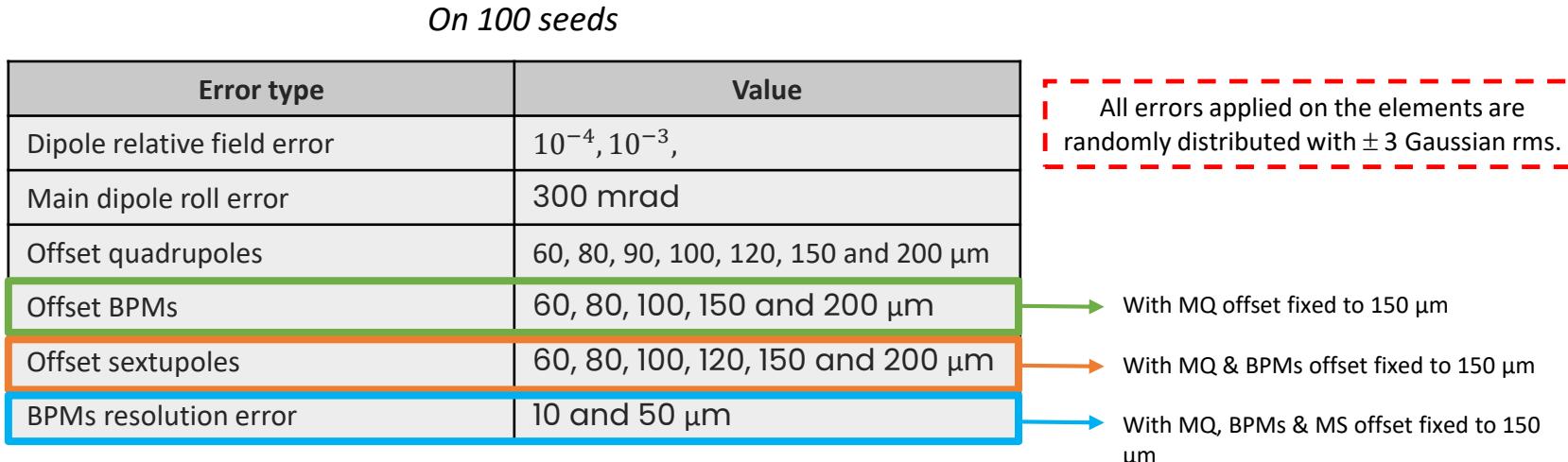
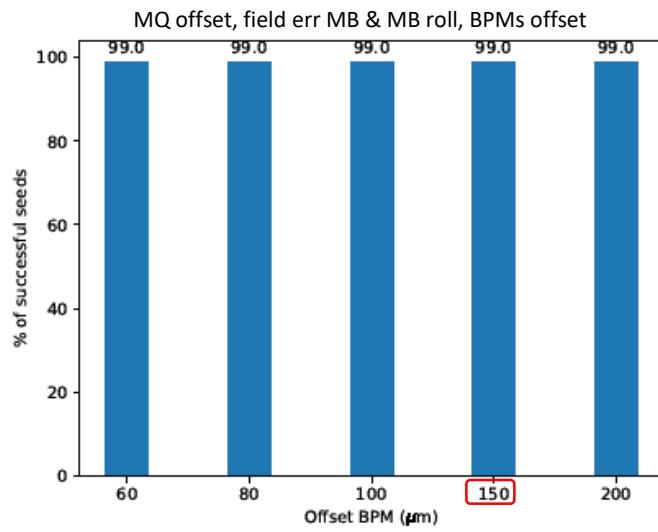
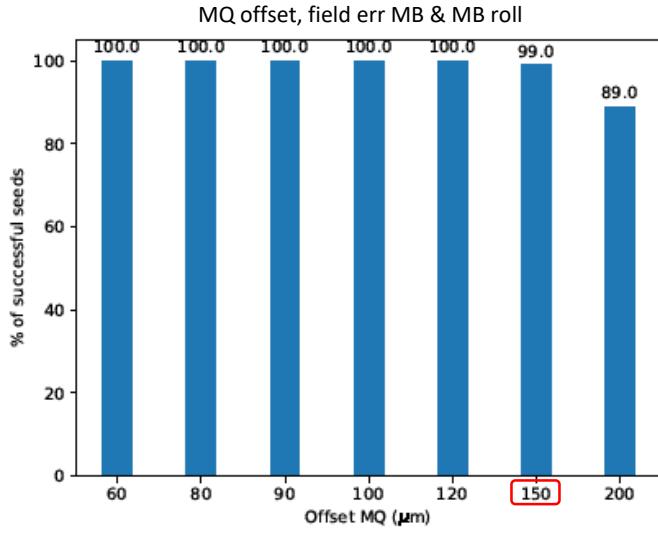


Optics ttbar: all the machine

ERRORS and STATISTICS

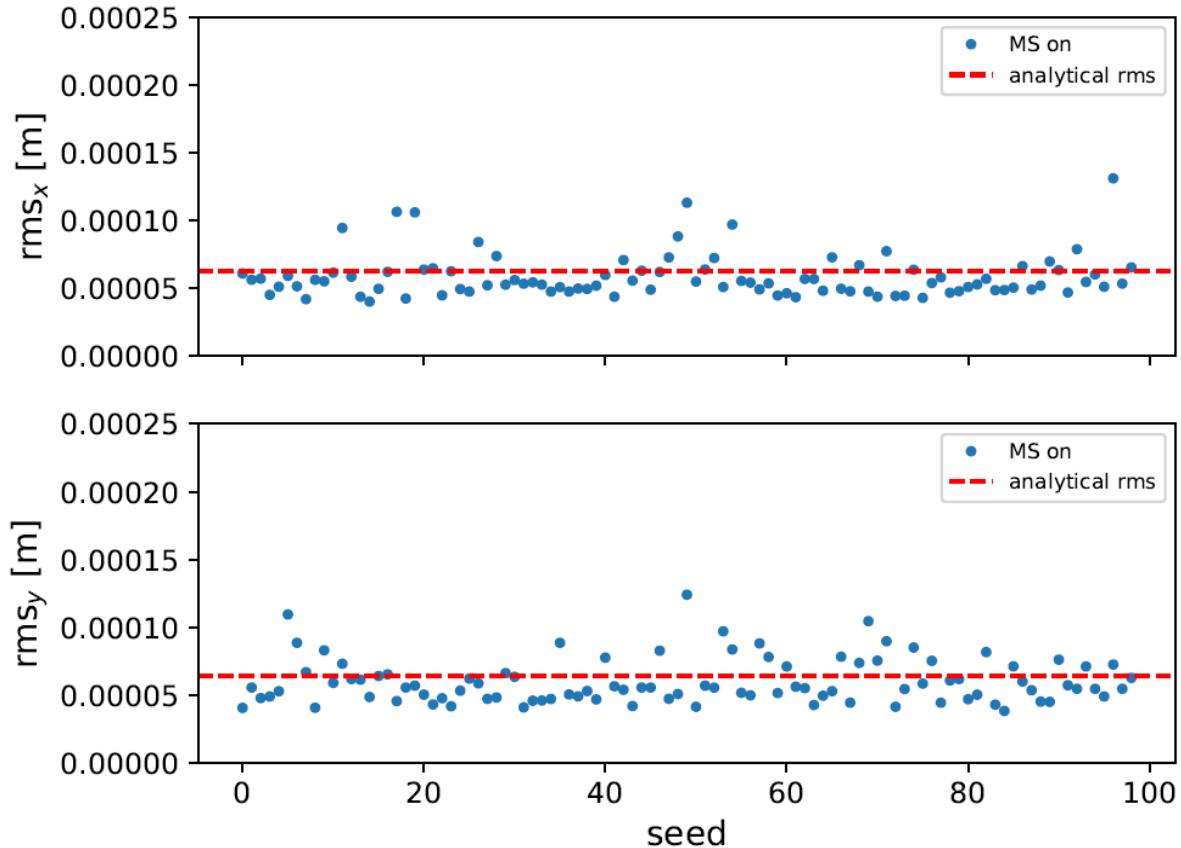
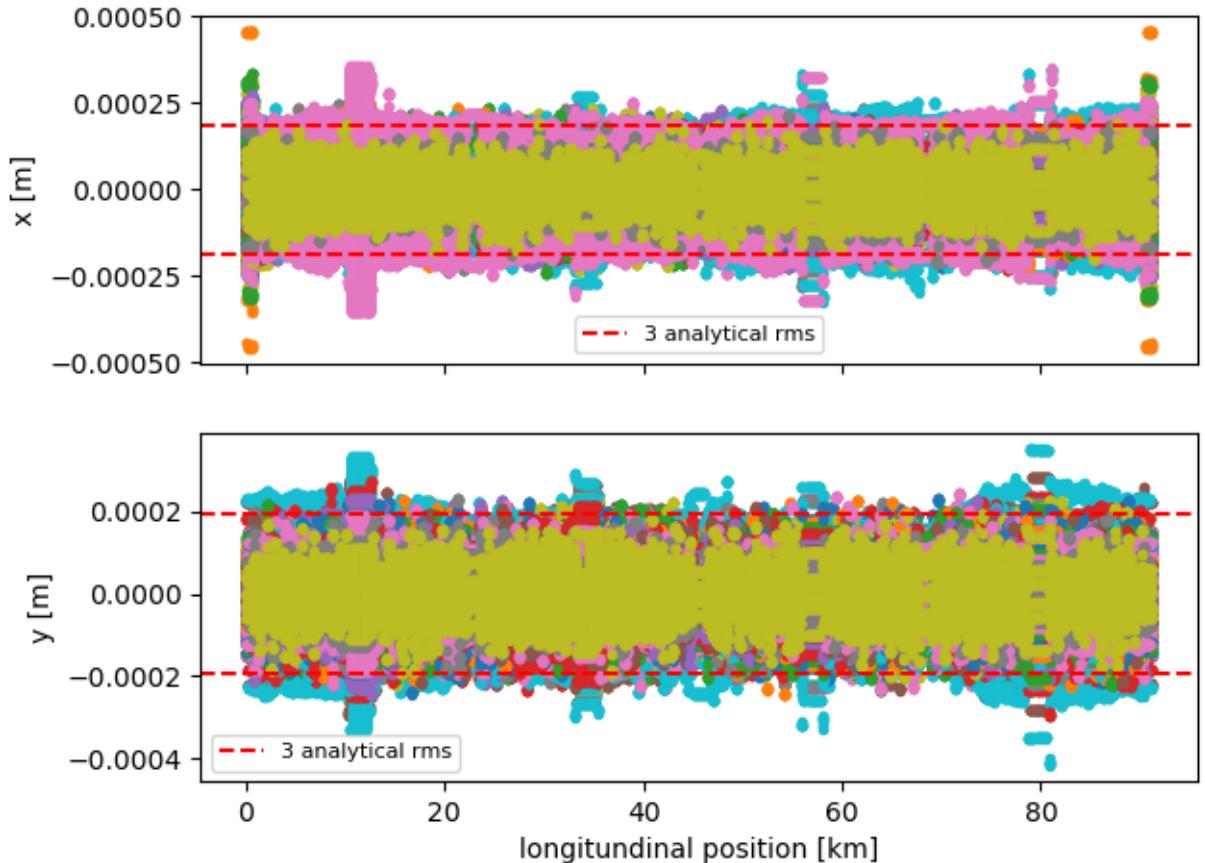


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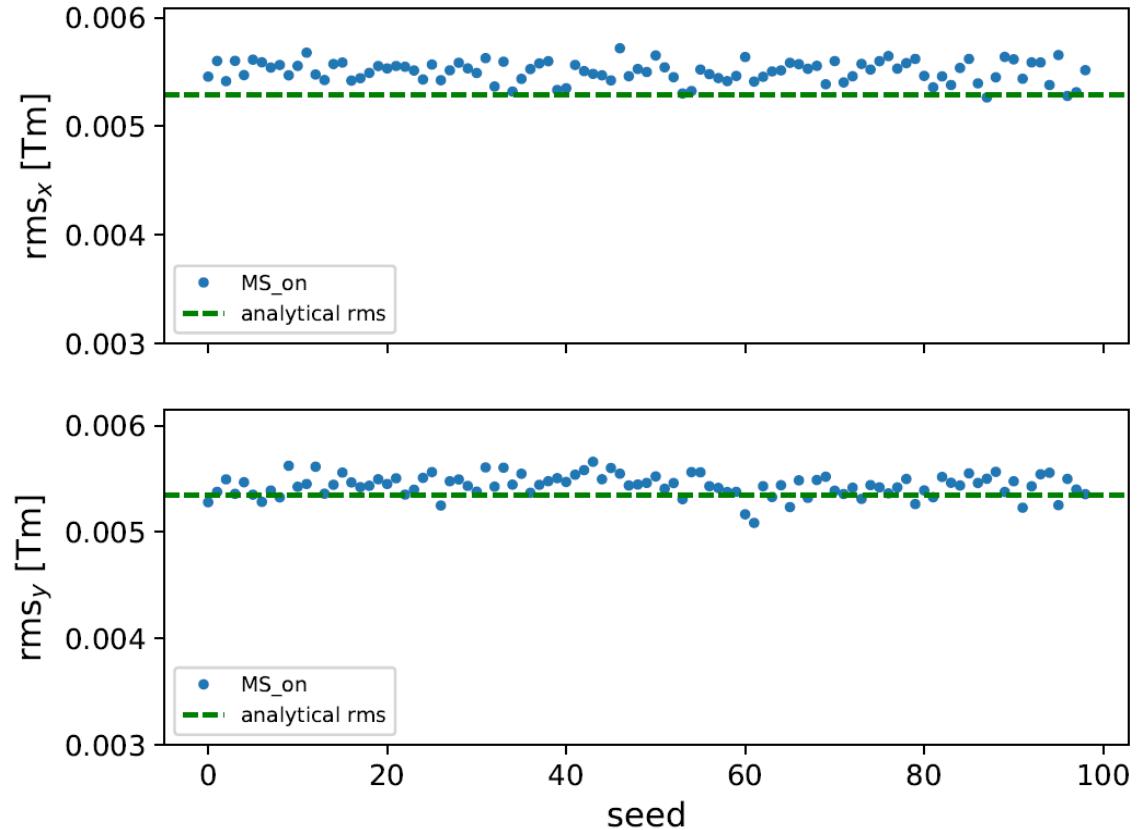
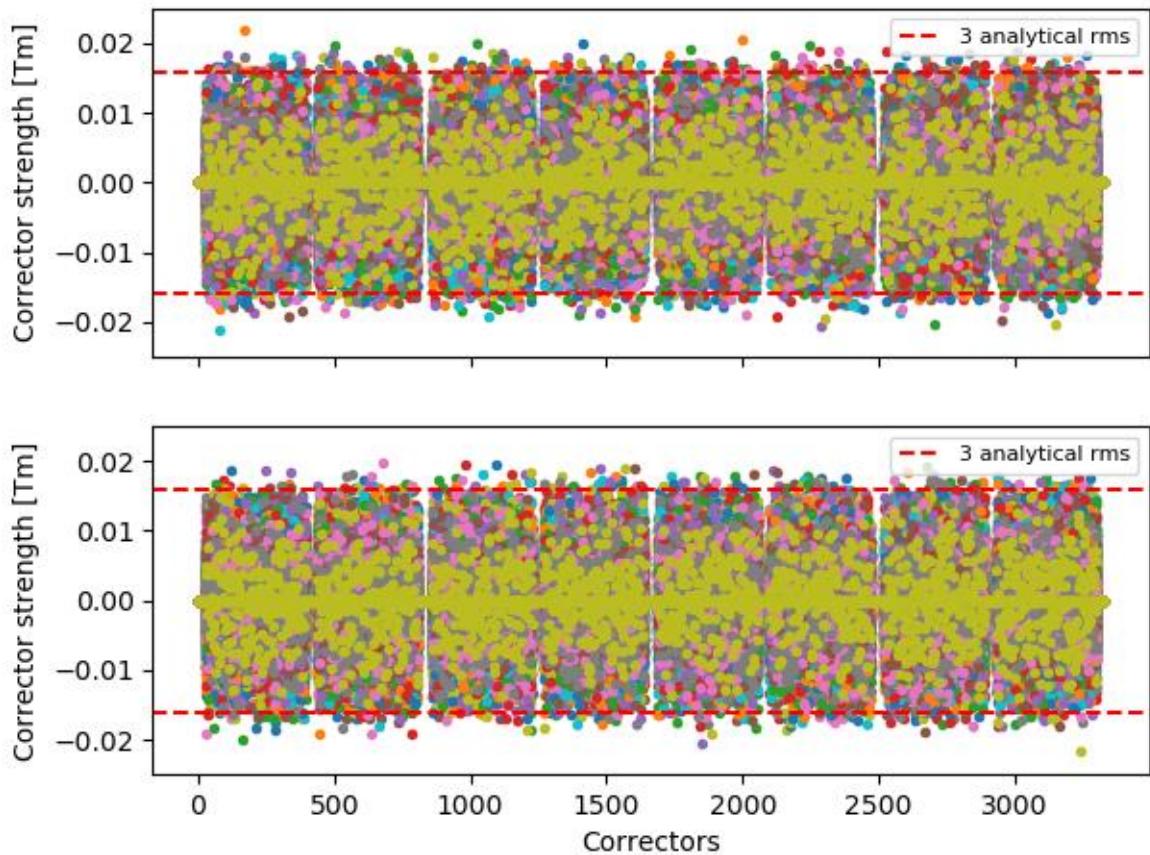
MQ offset = 150 μm , MB field err = 10^{-3} , MB roll = 300 mrad, BPM offset = 150 μm , MS offset = 150 μm , BPM resolution = 50 μm



99 successful seeds

Correctors strength

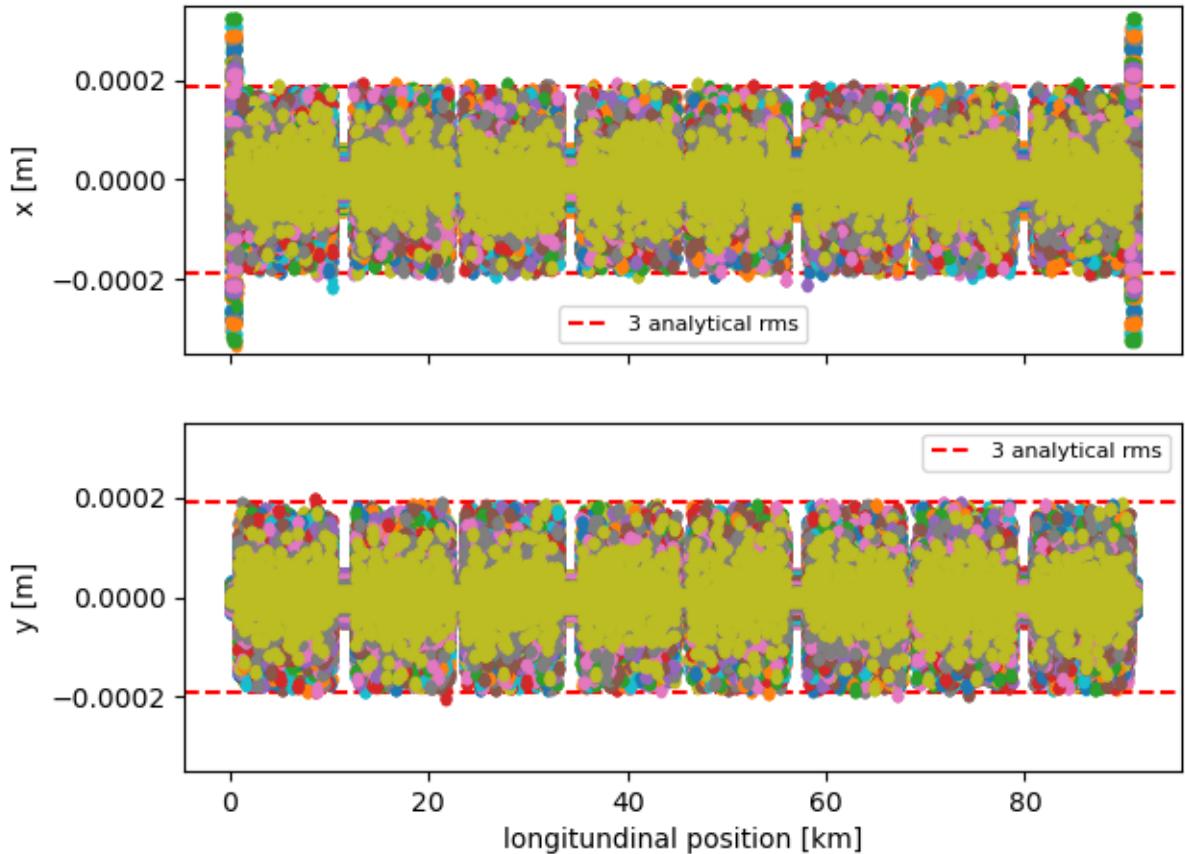
MQ offset = 150 μm , MB field err = 10^{-3} , MB roll = 300 mrad, BPM offset = 150 μm , MS offset = 150 μm , BPM resolution = 50 μm



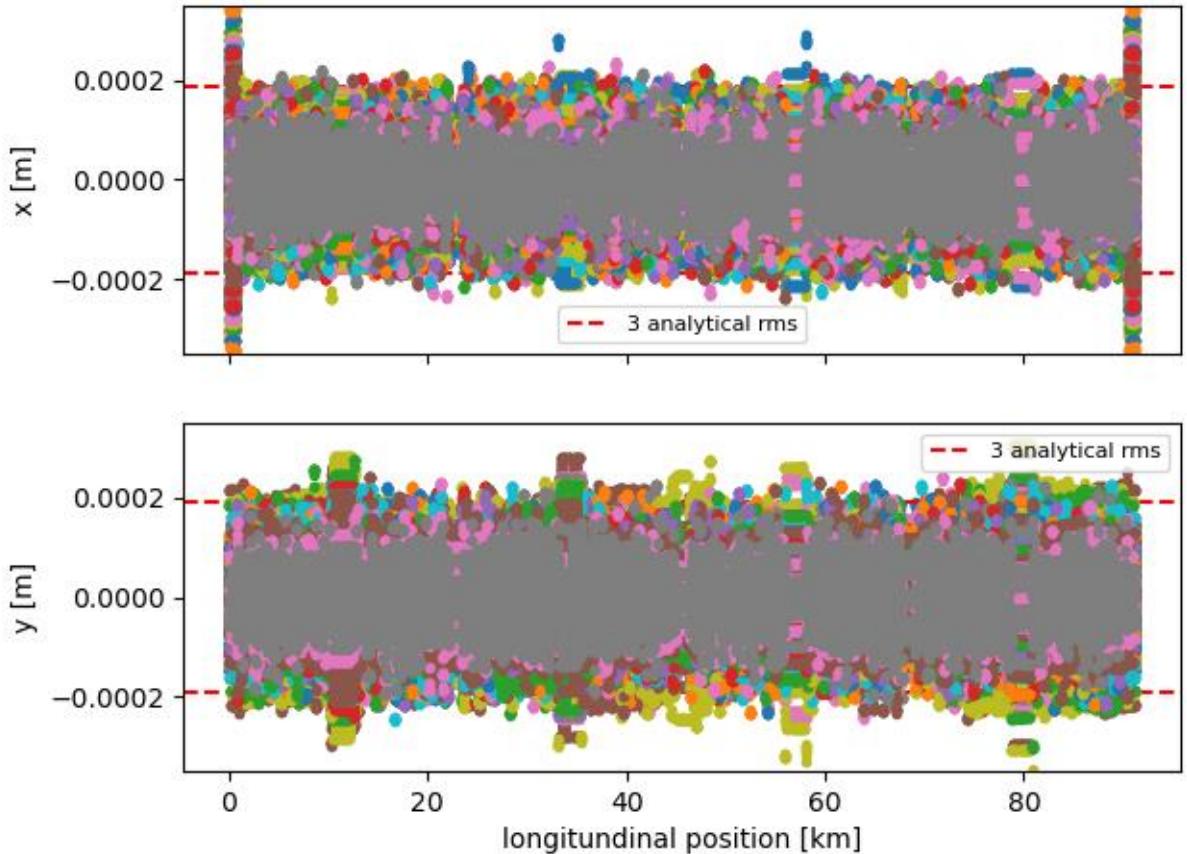
MS offset

MQ offset = 150 μm , **MB field err** = 10^{-4} , MB roll = 300 mrad, BPM offset = 150 μm

MS offset = 60 μm



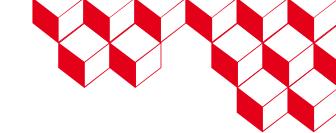
MS offset = 200 μm



BPM resolution

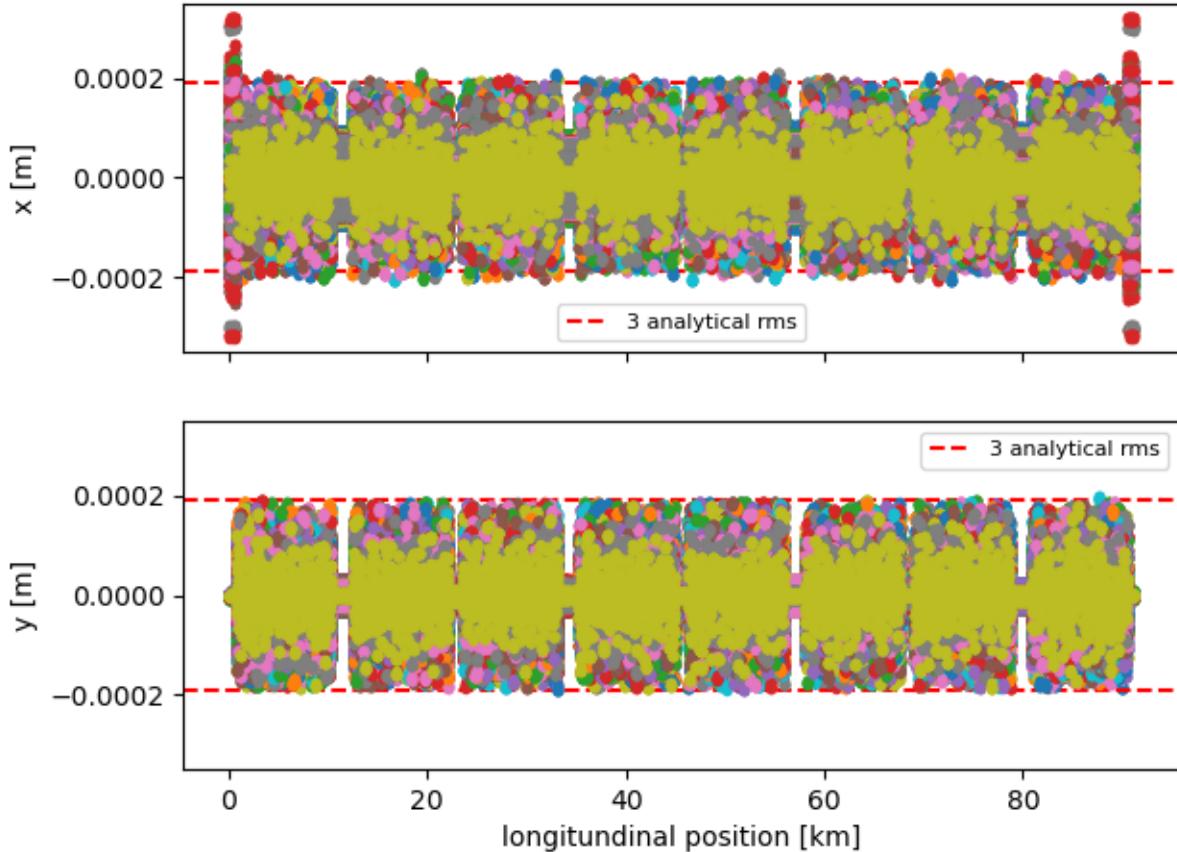


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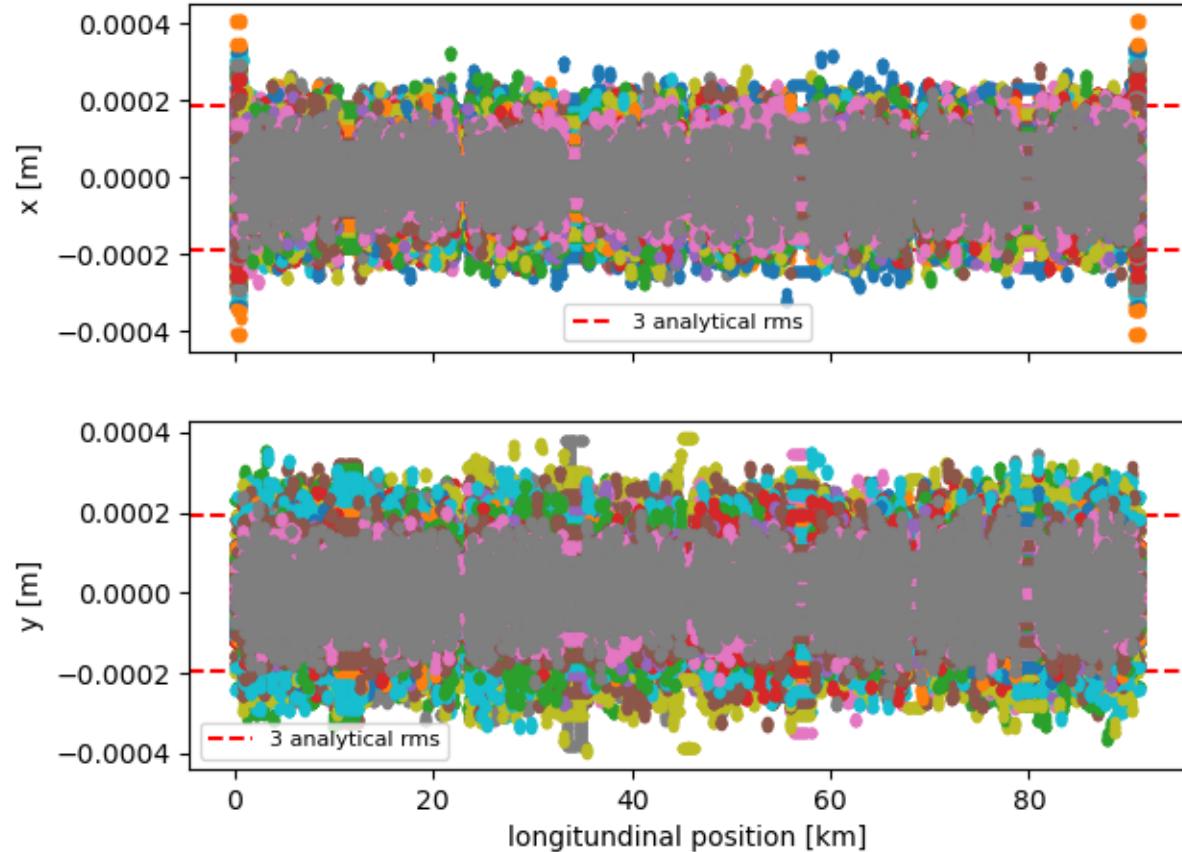


MQ offset = 150 μm , **MB field err** = 10^{-4} , MB roll = 300 mrad, BPM offset = 150 μm , MS offset = 150 μm

BPM resolution = 10 μm



BPM resolution = 50 μm





Conclusion and perspectives

Errors	Case	Plane	3 x Analytical RMS	3 x Mean RMS/seeds
MQ offset = 150 μm MB field err = 10^{-3} MB roll = 300 μmrad BPM offset = 150 μm MS offset = 150 μm BPM resolution = 50 μm	Residual orbit [μm]	x	188	174
		y	192	188
	Correctors strengths [mTm]	x	16	17
		y	16	17

- First specifications of the main **magnets misalignment** of the High Energy Booster arcs cells $\simeq 150 \mu\text{m}$
- **Relative dipole field error 10^{-3}**
- First definition of the **orbit correctors** for the booster $\simeq 20 \text{ mTm}$
- First definition of the orbit correction strategy

Problems:

- Tune match does not work for all the seeds (63/99 successful)
- Convergence of SVD \Rightarrow alternative ?

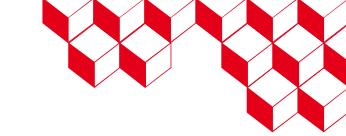
To do:

- Correct β -beating, dispersion and coupling (emittance tuning)
- Impact of booster support vibrations on emittance
- Include the impact of energy ramp during the booster cycle

Back-up slides



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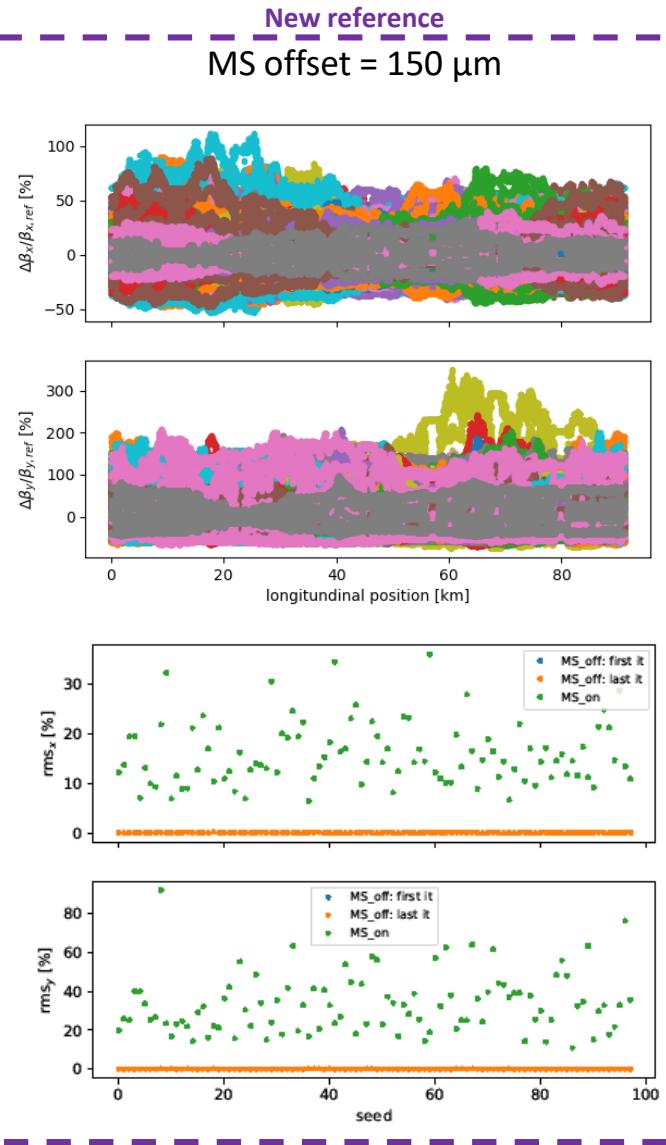
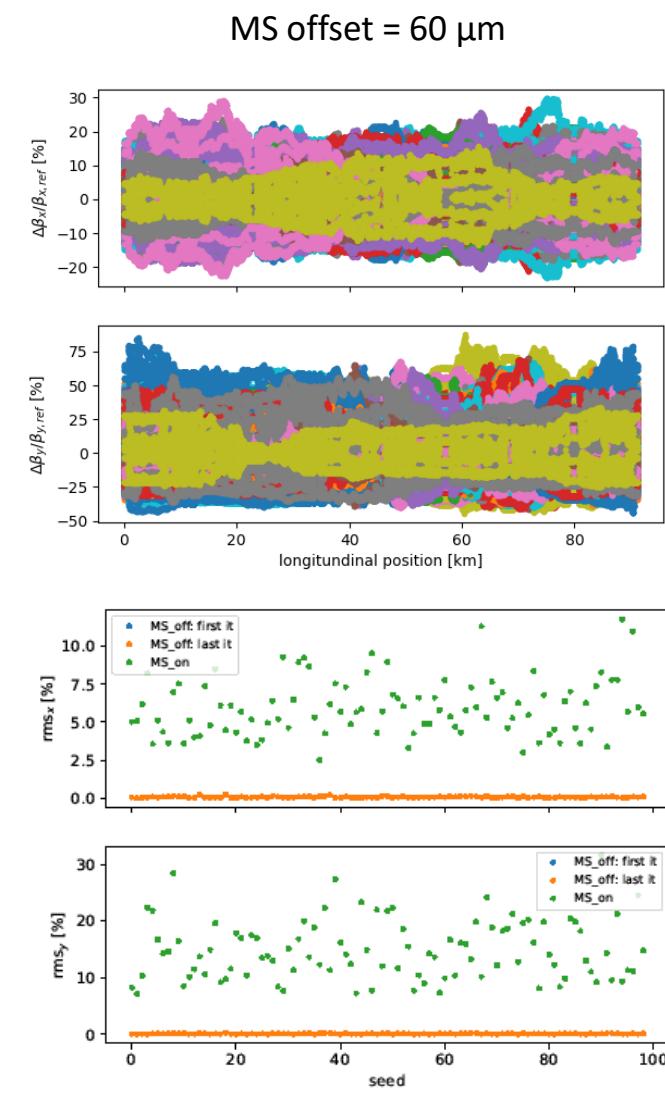
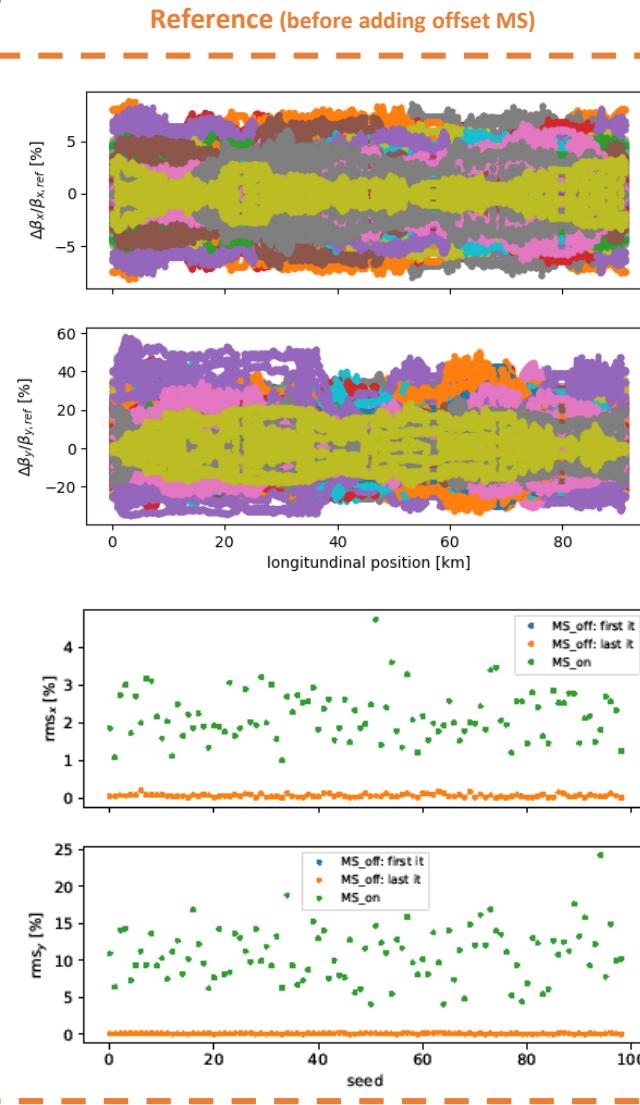


Beta-beating : offset quad, dipole field err & dipole roll, offset BPMs, offset sextupoles

One color = one seed

After SVD ring
with MS on

RMS of the
 β -beating

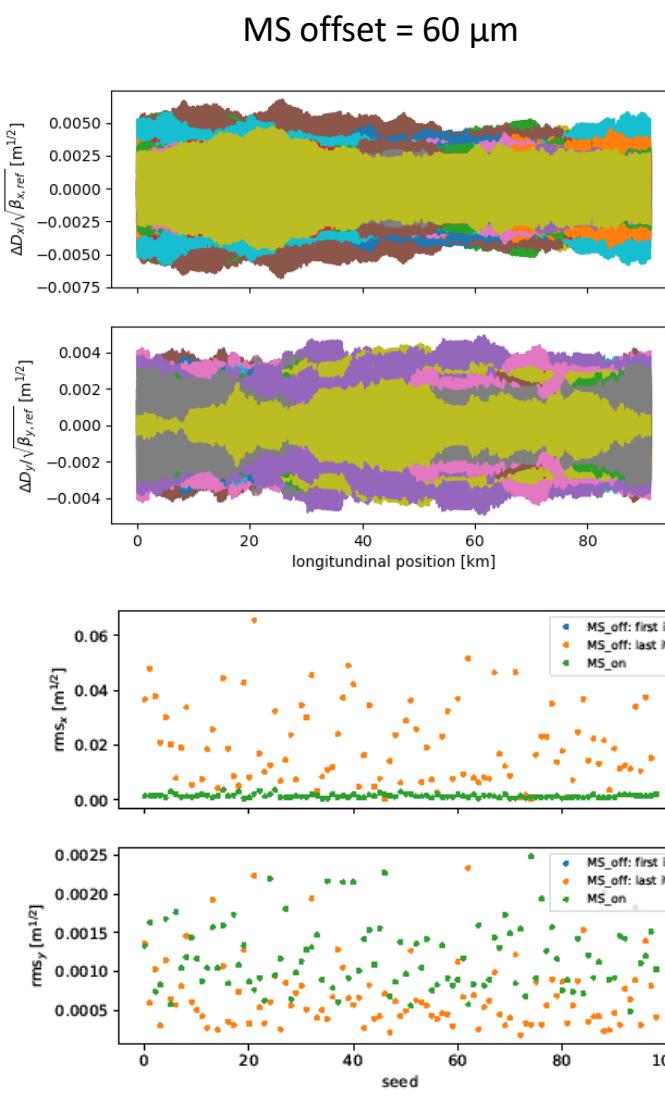
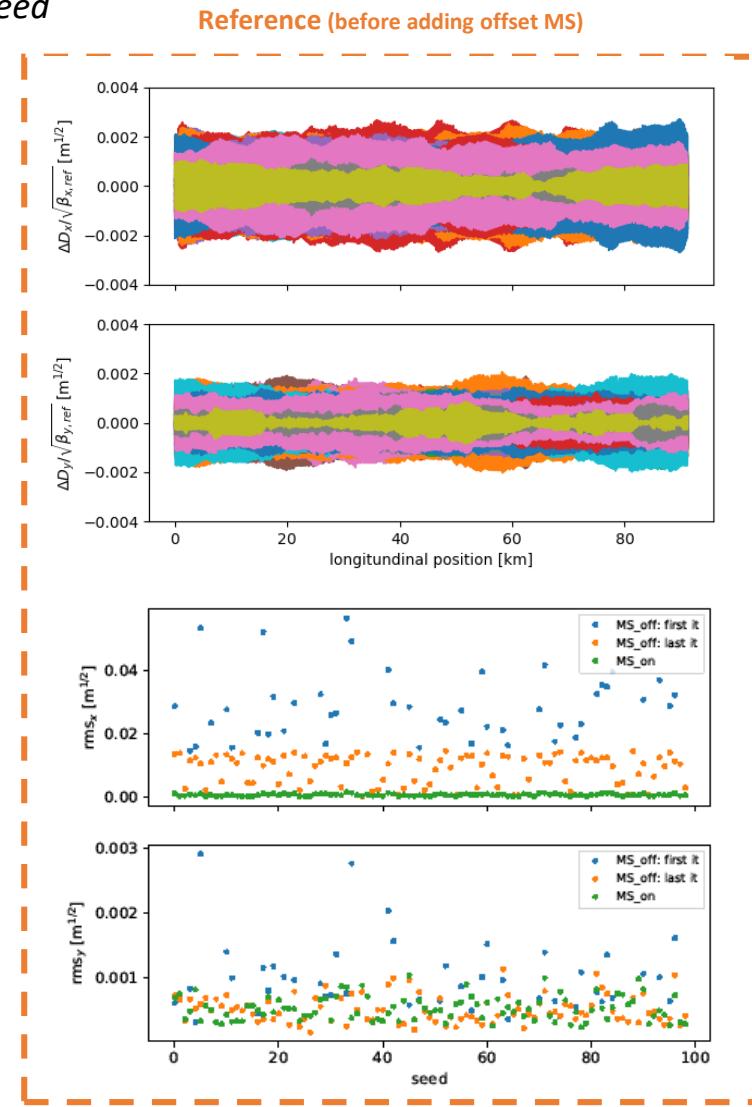


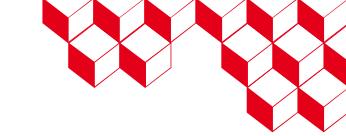
Normalized dispersion : offset quad, dipole field err & dipole roll, offset BPMs, offset sextupoles

One color = one seed

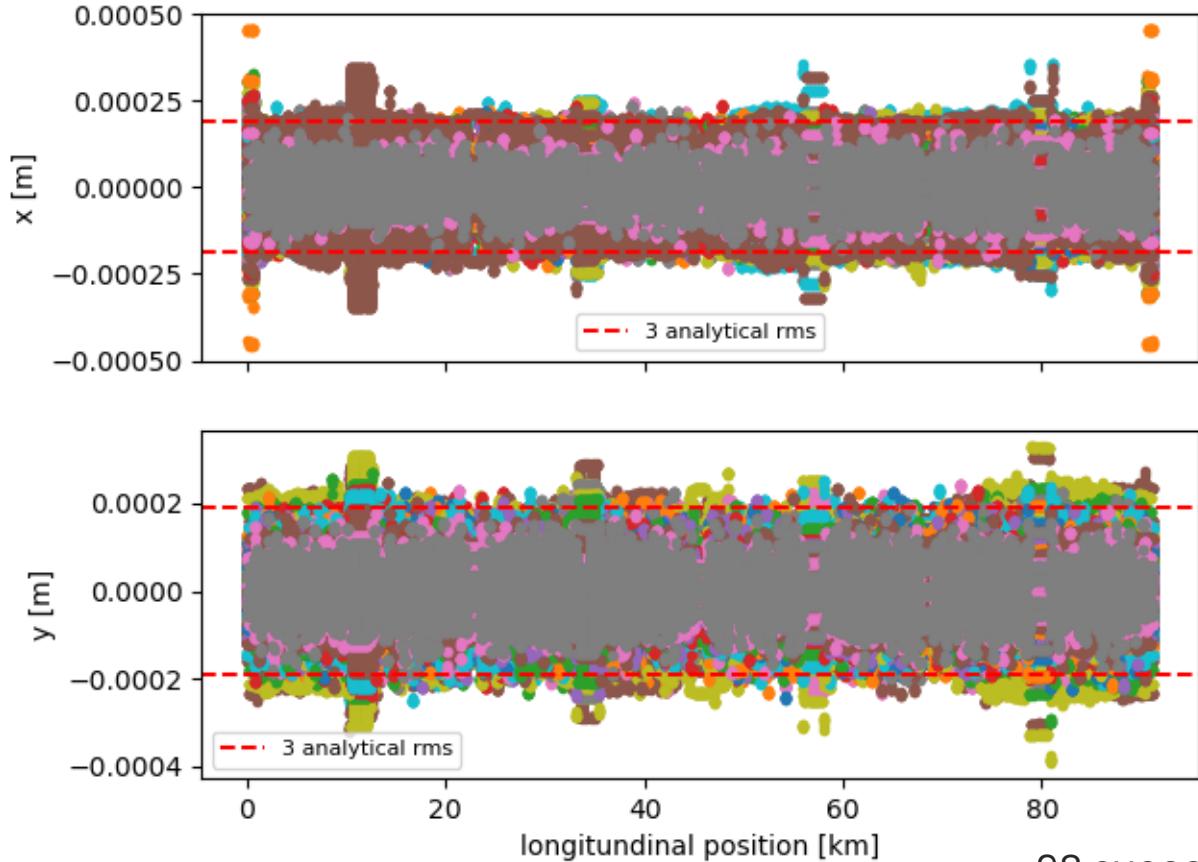
After SVD ring
with MS on

RMS of the
normalized
dispersion

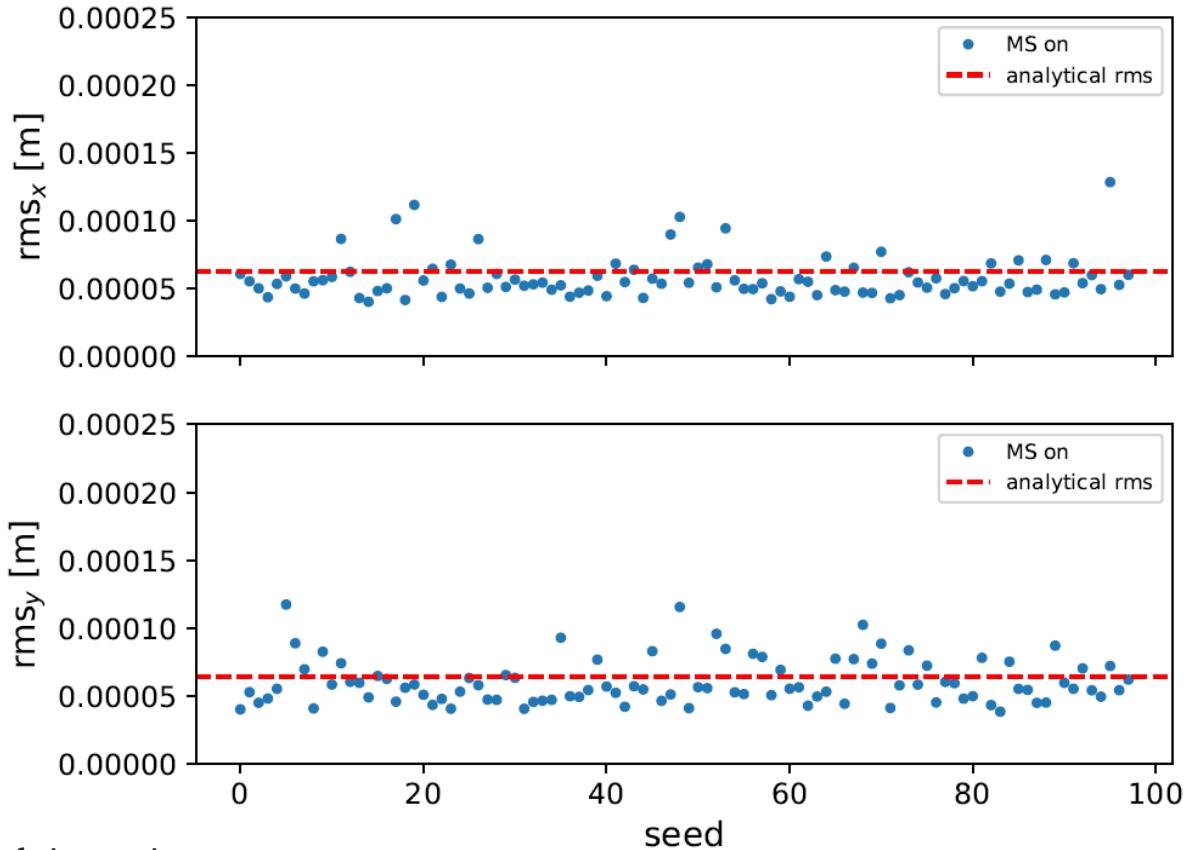




MQ offset = 150 μm , **MB field err = 10^{-4}** , MB roll = 300 mrad, BPM offset = 150 μm , MS offset = 150 μm , BPM resolution = 50 μm



98 successful seeds



Correctors



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MQ offset = 150 μm , **MB field err** = 10^{-4} , MB roll = 300 mrad, BPM offset = 150 μm , MS offset = 150 μm , BPM resolution = 50 μm

