Next Generation Beam Position Acquisition and Feedback Systems

ALBA Synchrotron, 12-14 November 2018

A fast orbit correction scheme for the ESRF EBS

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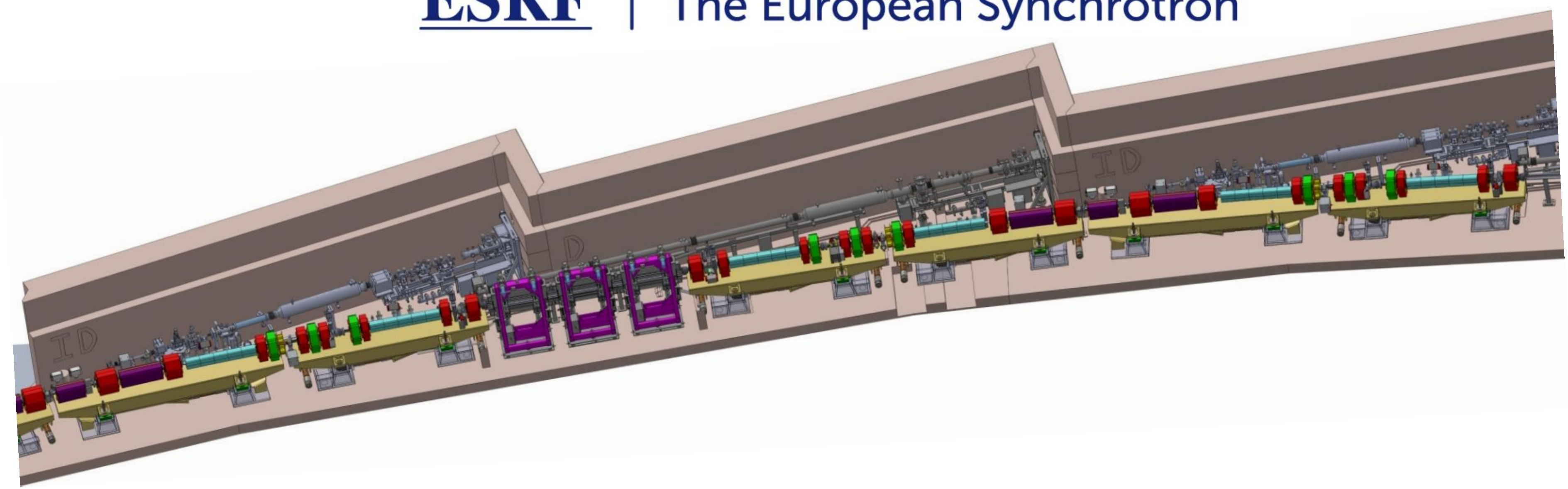
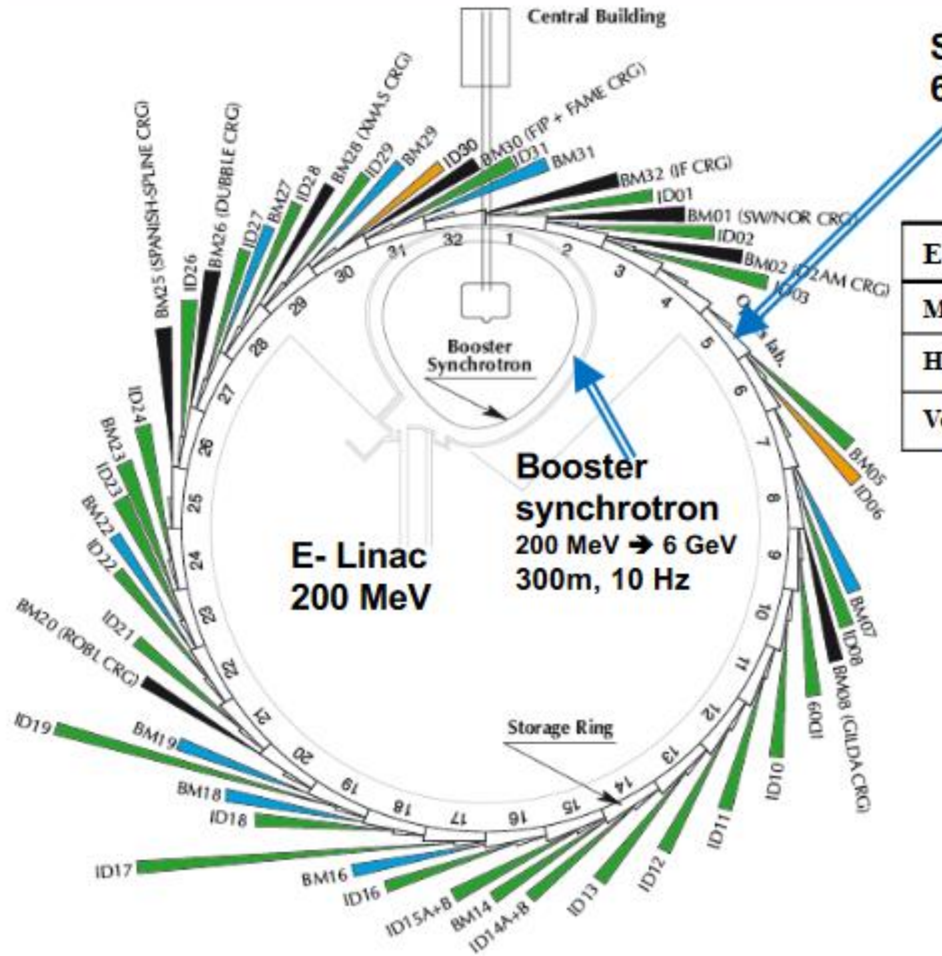
ESRF | The European Synchrotron



ESRF TODAY



Energy	GeV	6.04
Multibunch Current	mA	200
Horizontal emittance	nm	4
Vertical emittance	pm	3.5

32 straight sections

DBA lattice

42 Beamlines

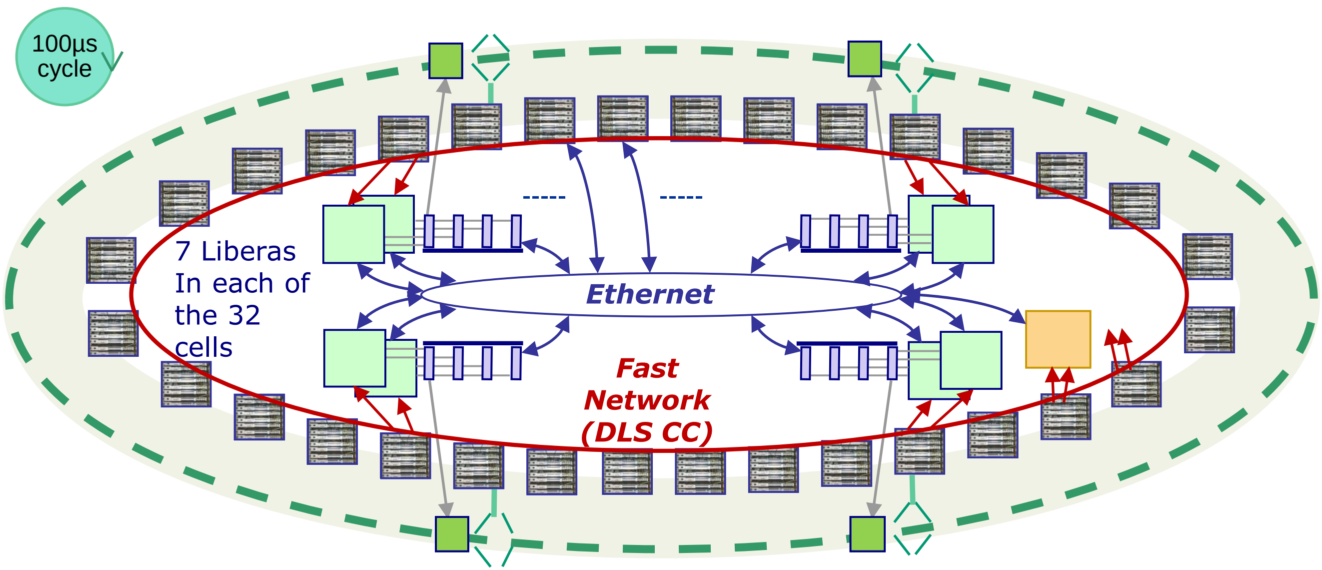
12 on dipoles

30 on insertion devices

72 insertion devices:
55 in-air undulators, 6 wigglers,
11 in-vacuum undulators, including
2 cryogenic

Present ESRF fast Orbit Feedback

Architecture



One of the 224 Beam Position Monitors

Group of 7 Libera BPMs per cell

4 cabinets of 18 Power Supplies each

8 Feedback Processors

DLS fast data archiver

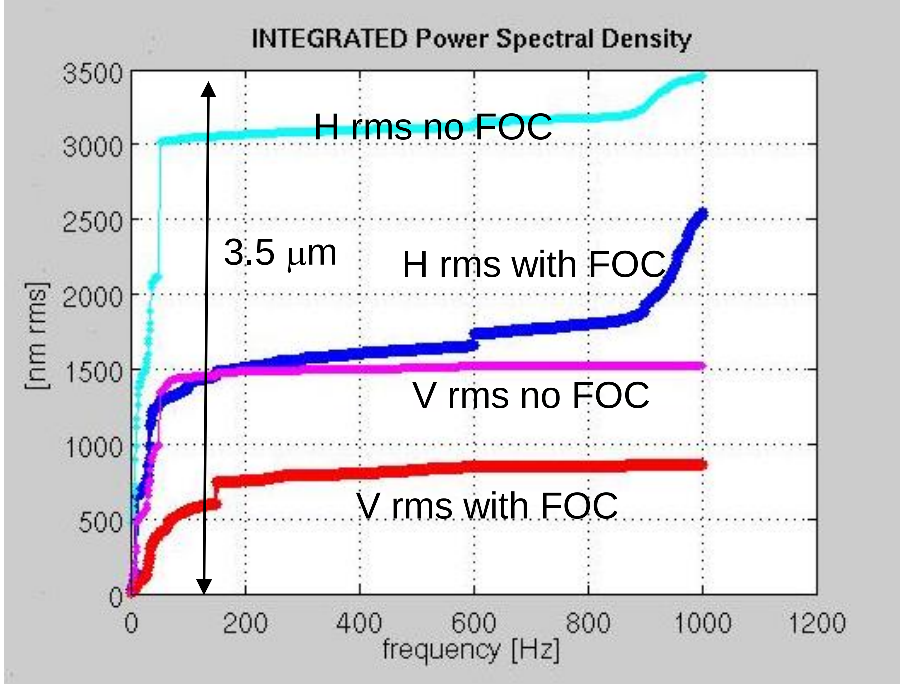
One of the 96 sextupoles housing the steerers

PRESENT FAST ORBIT CORRECTION PERFORMANCE

On our present ring
Vertical emittance: 6pm
Horizontal emittance: 4nm

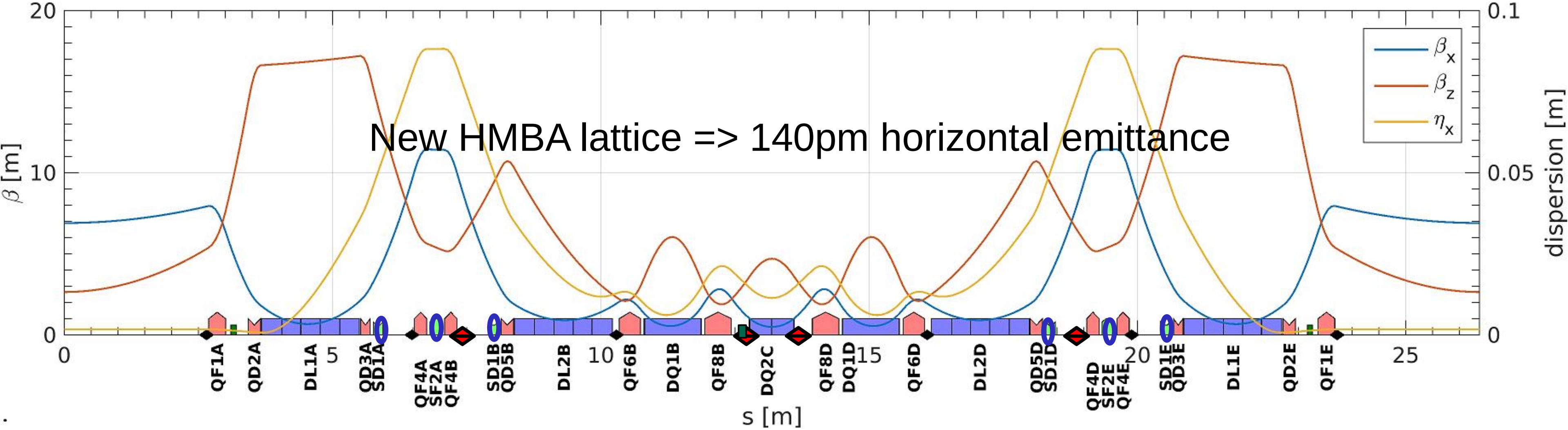
Orbit stability from .01Hz to 1 Hz:
Vertical: .5µm
Horizontal: .8µm

Orbit stability from 1Hz to 500Hz:
Vertical: 1µm
Horizontal:1.8µm



Integrated spectrum of the orbit perturbation with and without fast orbit correction

EBS NEW LATTICE



10 BPM per cell:

6 Libera Brillance (with fast ouputs)

4 Libera Sparks (no fast ouputs)

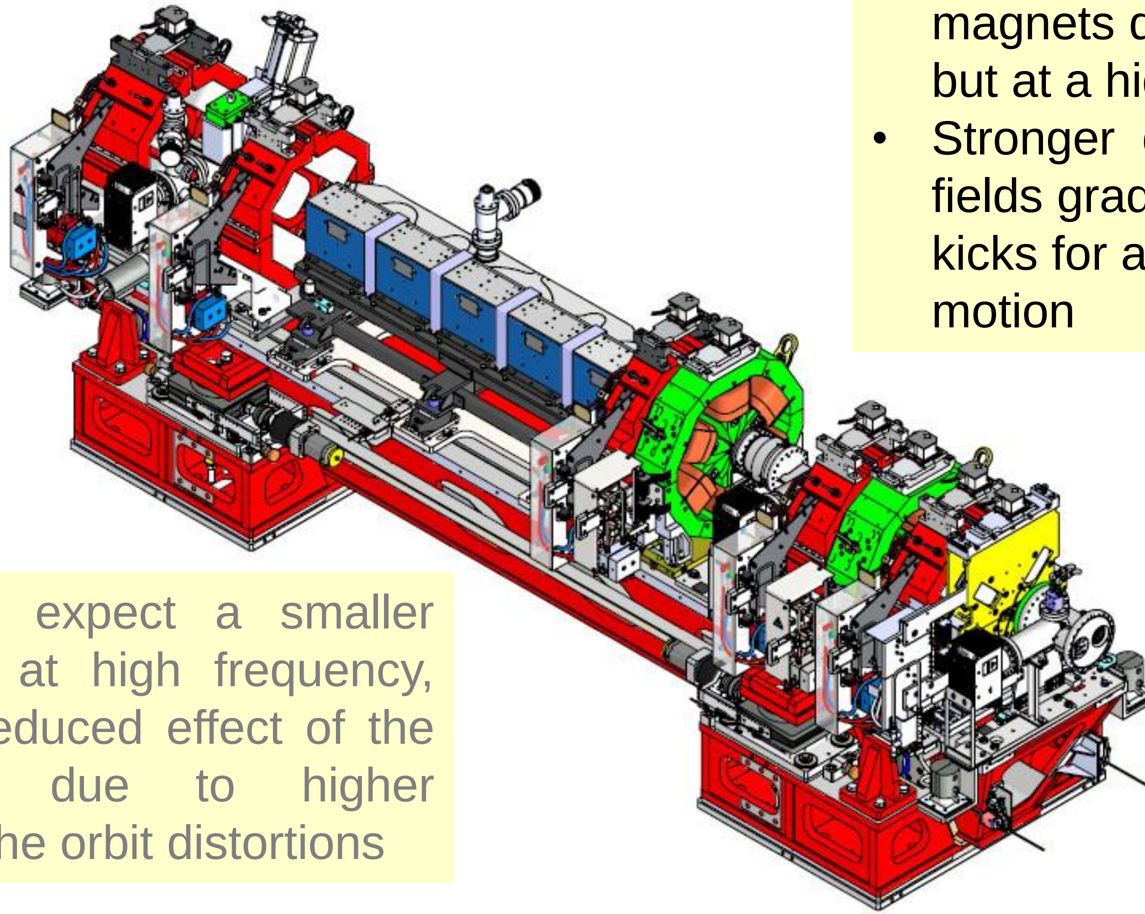
9 correctors per cell:

3 fast correctors (500Hz BW)

6 slow correctors

NEW FAST ORBIT CORRECTION PERFORMANCE

- Stiffer girders: smaller magnets displacement, but at a higher frequency
- Stronger quadrupoles fields gradient => Larger kicks for a given magnet motion



Eventually, we expect a smaller orbit distortion at high frequency, but maybe a reduced effect of the FOC system due to higher frequencies of the orbit distortions

MOTIVATION OF OUR APPROACH

For EBS:

- the vertical emittance will be the same and we aim at reaching the same stability
- The horizontal emittance is much lower but the stability achieved on our present ring would be sufficient

Can we simply reuse our present system without any extra development?

Which means implementing a fast orbit correction using only:

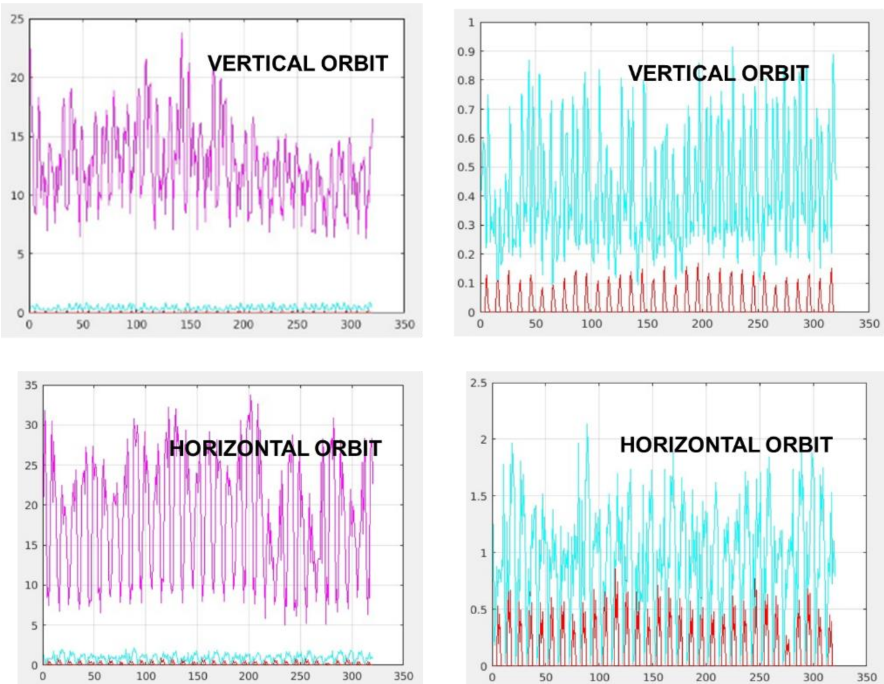
- 6 fast BPM per cell
- 3 fast correctors per cell

When the new orbit correction is supposed to require:

- 10BPM per cell
- 9 correctors per cell

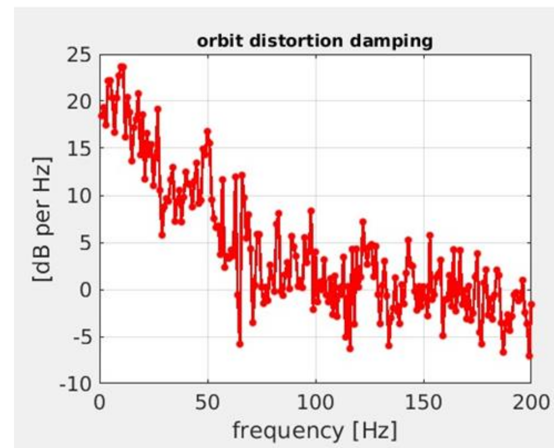
FAST ORBIT CORRECTION PERFORMANCE

10 sets of random quadrupole magnet displacements

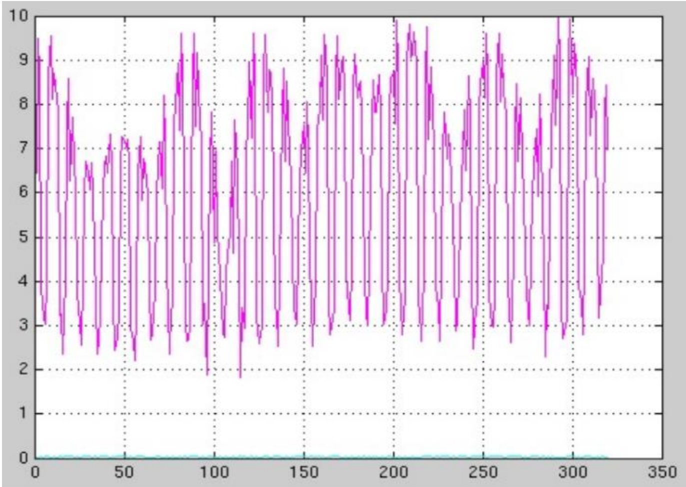


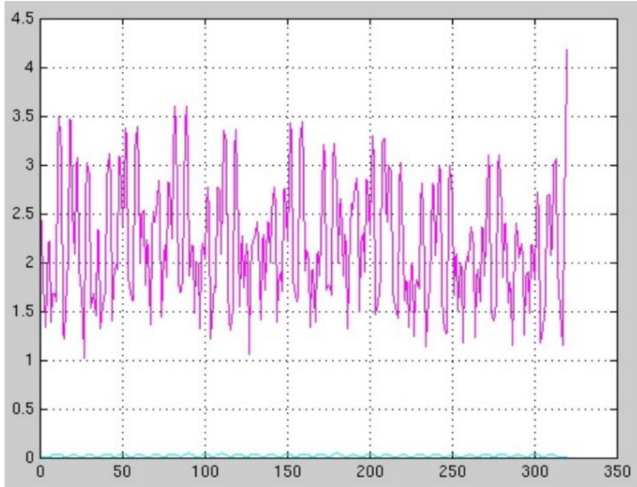
Magenta:
Orbit distortion at the location of the 320 BPMs
Blue:
Orbit measured using 192 BPMs and corrected using 96 fast correctors
Red:
Orbit measured using 320 BPMs and corrected using 288 correctors

When the frequency increases, most of the residual distortion will come from the limited bandwidth of the correction



FAST ORBIT CORRECTION PERFORMANCE



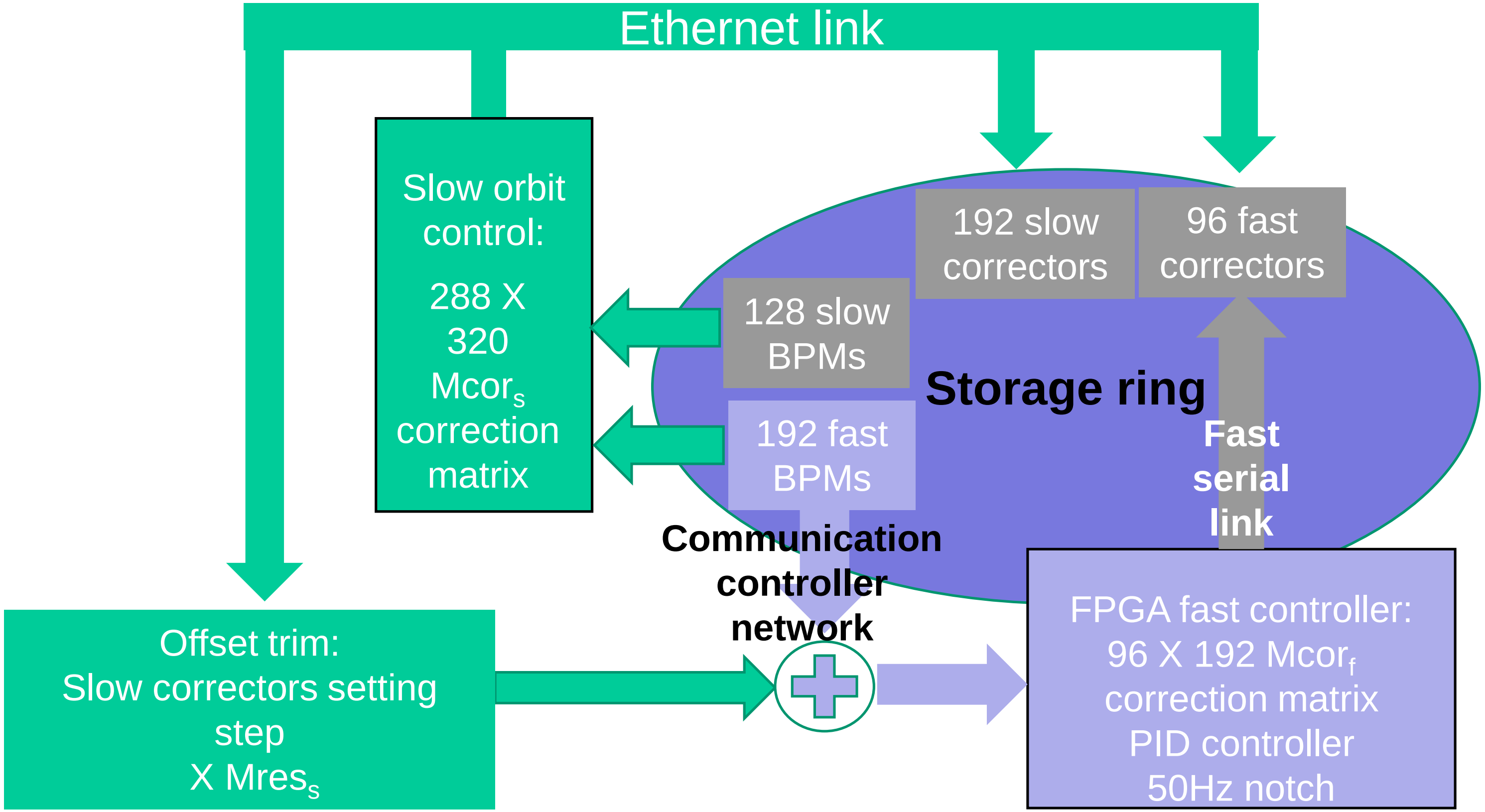


For the BPMs located at he end of the straight section, the correction is nearly perfect

Conclusion

- The 320 BPMs and 288 correctors are required to put the beam optimal orbit in term of coupling, lifetime …
- However small and fast orbit distortion with no DC component can be corrected with a smaller set of BPM and correctors without spoiling the quality of the correction

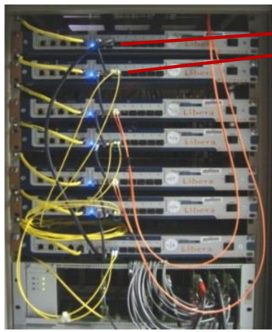
Scheme Implementation



Hybrid slow/fast orbit control flow chart

FAST ORBIT CORRECTION COMPONENTS

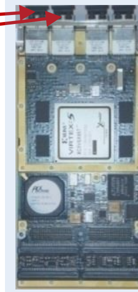
From Liberas to the correctors power supplies ***→ 10kHz data flow***



196 Libera BPMs

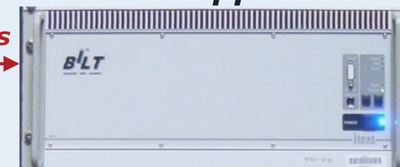
196 X & Z positions

8 FPGA PMCs correctors each driving up to 7 crates (42 channels)



Up to 42 corrections

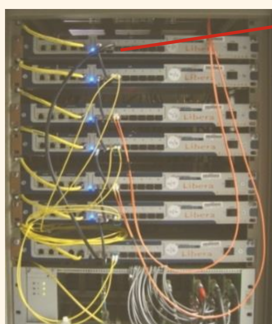
48 Power Supplies Crates,



each driving 2 correctors

Corrections

96 fast correctors



Diagnostics

Fast data archiver developed by DLS:10days buffer of all the data of the FOC

CORRECTORS

192 correctors embedded in the sextupoles;
Slow response (1Hz BW)

92 fast correctors (500Hz BW capability):
Versatile magnets to be used as fast dipoles and skew quadrupole

CORRECTORS POWER SUPPLY CONTROL

Fast correctors magnets power supplies ***→ Each channel receives its setpoint from two sources***

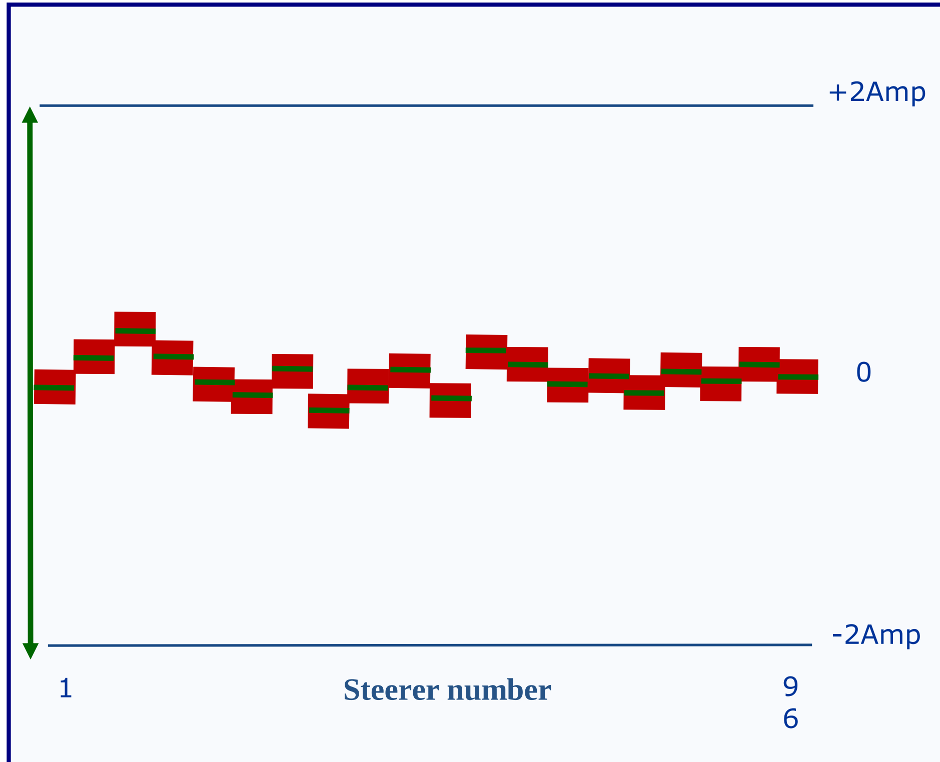
Static correction:
+/- 1.8 A maxi 16bits resolution

Set point from Ethernet :
Golden orbit

Dynamic correction:
+/- 200mA 16 bits resolution

Set point at 10kHz
from serial line : FOFB

Closed loop resolution:
19 bits or 2ppm



Fast power supply design

Fast power supply internal controller:

dI/dt limited =>

50Hz bandwith for the full +/- 100mA swing

500Hz small signal bandwidth

Dual slow/fast inputs advantage:

- By frequently downloading of the average of the fast inputs settings to the slow inputs, the fast stop of the fast correction becomes straightforward…

- 19 bits resolution when the loop is closed, without the constraint of a true 19 bits resolution design

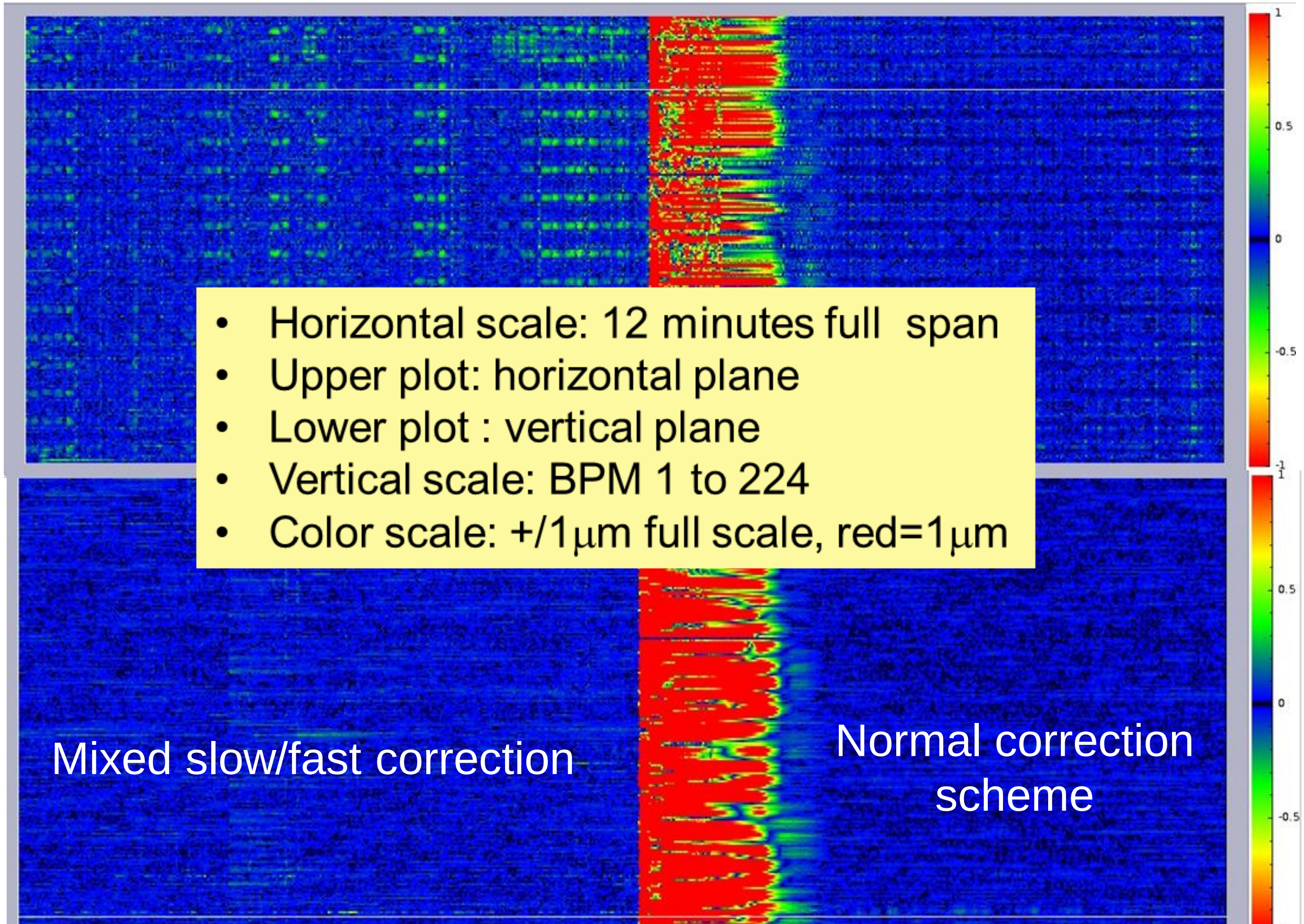
TEST OF THE EBS FAST ORBIT CORRECTION SCHEME

ON THE PRESENT ESRF STORAGE RING

We used only 5 BPMs and 2 correctors per cell for the Fast Orbit Correction

We used the full set of 7 BPMs and 3 correctors per cell for slow orbit corrections (one correction every 5 seconds)

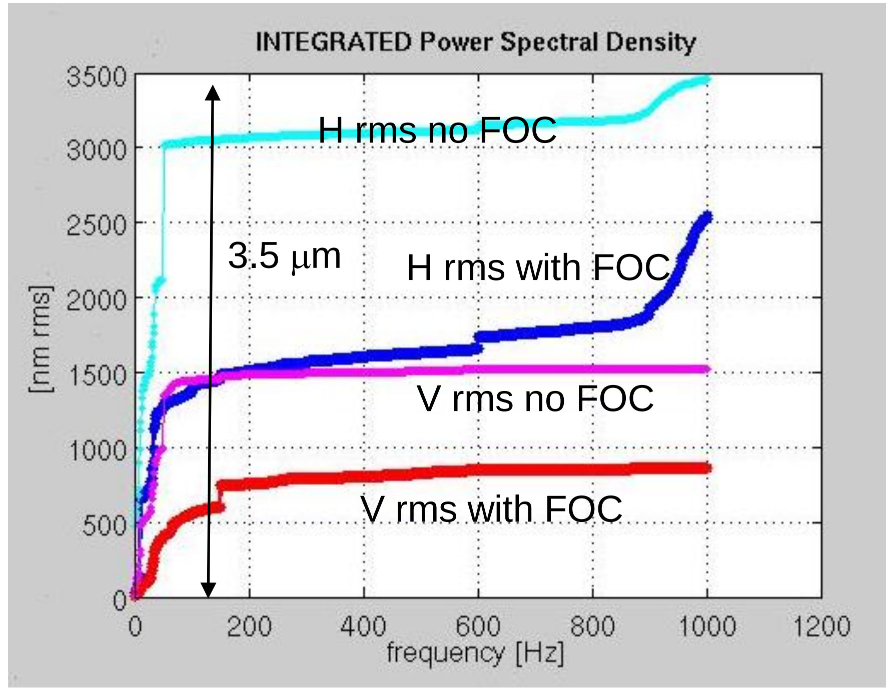
FAST ORBIT CORRECTION PERFORMANCE



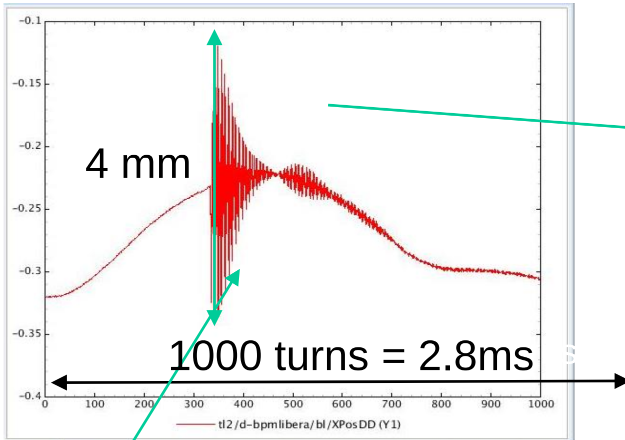
- Horizontal scale: 12 minutes full span
- Upper plot: horizontal plane
- Lower plot : vertical plane
- Vertical scale: BPM 1 to 224
- Color scale: +/1μm full scale, red=1μm

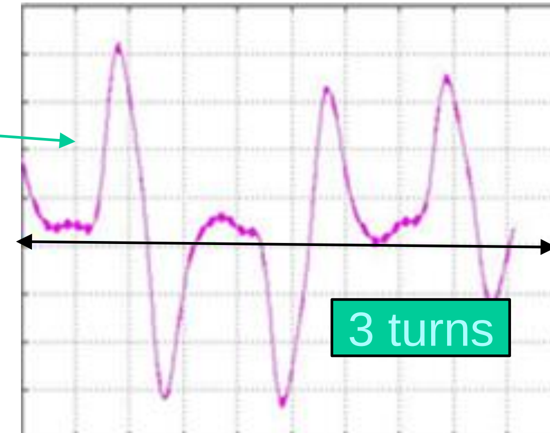
FAST ORBIT CORRECTION PERFORMANCE AT HIGH FREQUENCY

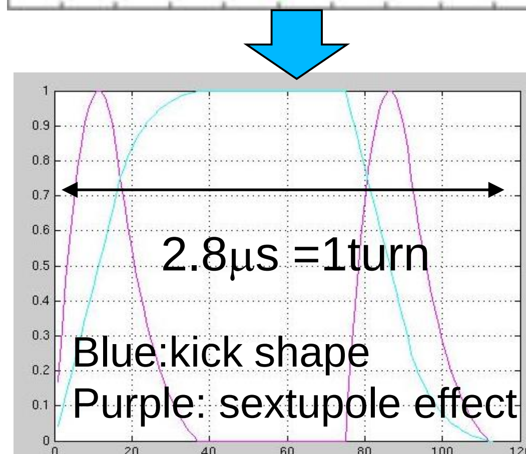
Integrated spectrum of the orbit perturbation with and without fast orbit correction



PERTURBATION OBSERVED ON THE HORIZONTAL BEAM POSITION







Scale for the fast oscillation signal on the right plot due to a BPM bandwidth limitation

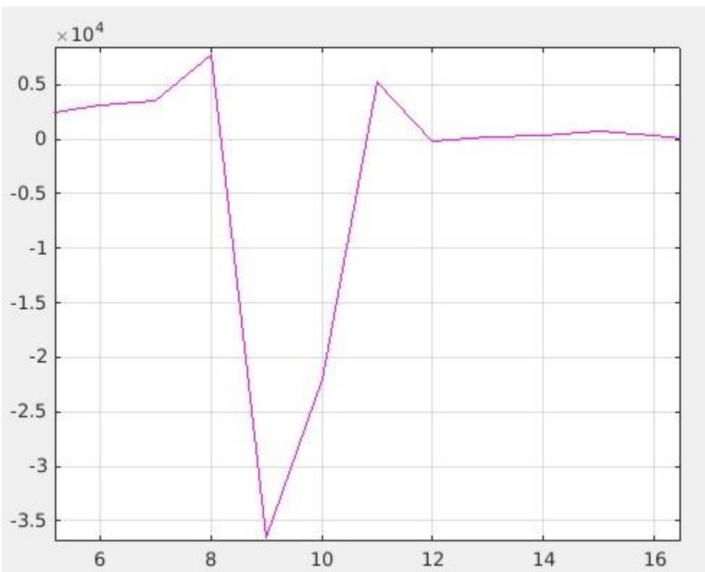
Normal Fast Orbit Correction effect:

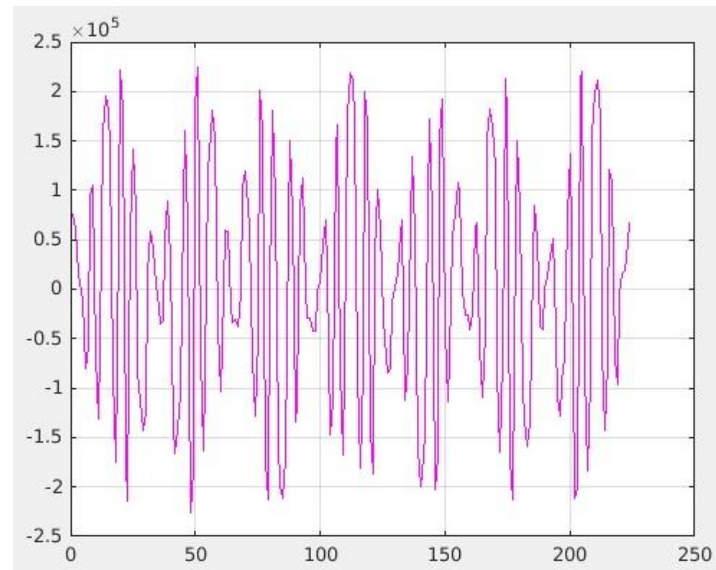
Correction calculated with the normal orbit correction matrix :

- Will use mostly two correctors

The feedback bandwidth is 150Hz:

- The correction will be produced with a delay of about 2ms => no effect!





EFFECT OF THE FAST ORBIT CORRECTION ON THE KICK DUE TO THE SEPTUM

Orbit Correction Feedback bandwidth: 150Hz
Corrector strength:
Parasitic kick strength:
The correction signal results in overshoot without real reduction of the perturbation peak amplitude.
Sometime the orbit correction stops due to an excessive demand on the corrector strength

The corrector bandwidth is 500Hz which is enough to generate a correction signal, so how can we use it more efficiently?

FEEDFORWARD APPROACH FOR THE FAST ORBIT CORRECTION:

Correction signal stored in a look up table :

- Efficient use of the corrector bandwidth:
  - No loop stability problem
  - Allows some bandwidth extension by pre emphasis of the signal

- Better use of the available correction strength:
  - Correction spread over 6 correctors instead of 2 when the correction is calculated by the feedback loop using the standard SVD derived correction matrix

Orbit correction: feedforward correction

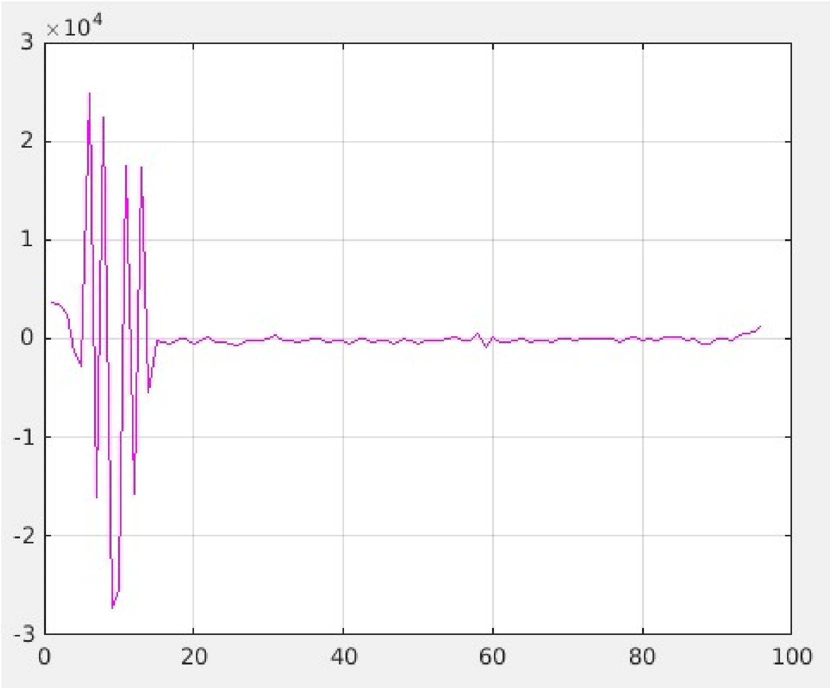
We can use more correctors :

- 6 correctors are available between the two ID straight sections surrounding the injection straight section

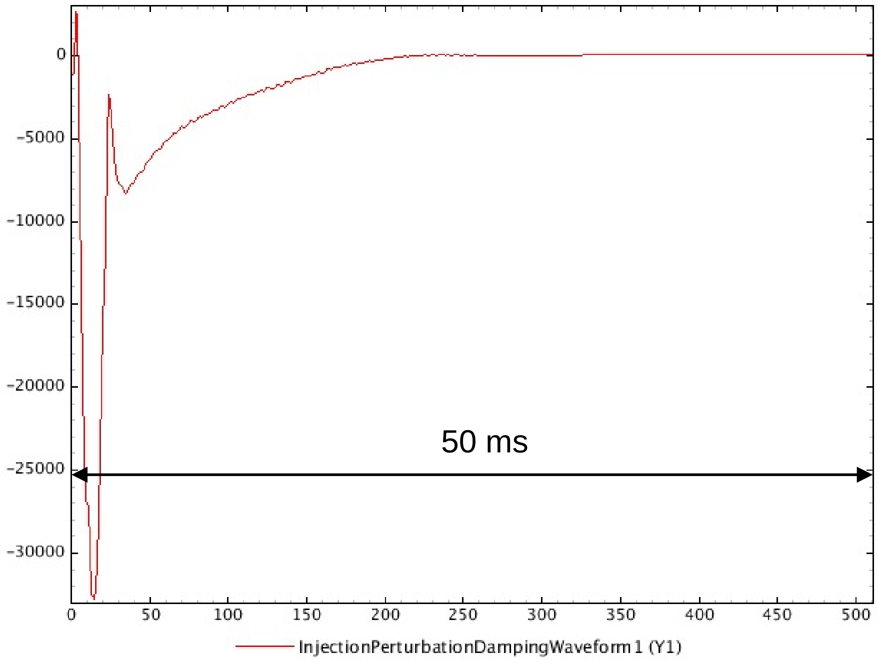
The correction generation is triggered by the injection timing

- no delay
- Correction signal generation is fully using the 500Hz correctors bandwidth

Orbit correction: feedforward correction

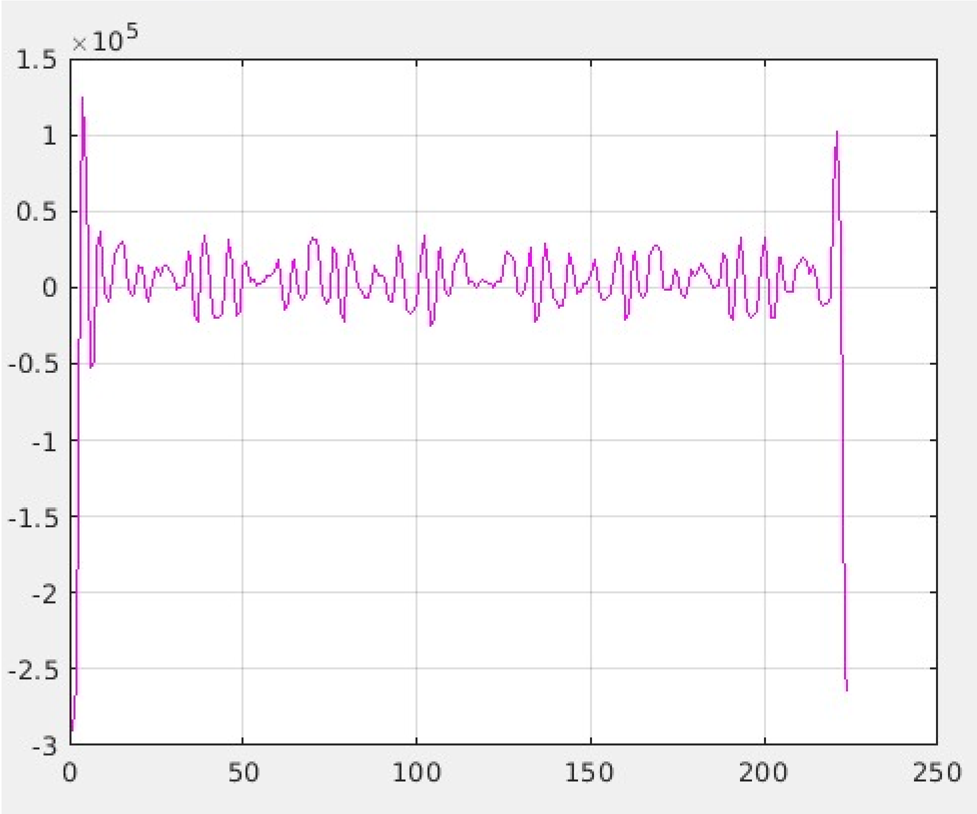


CORRECTION KICKS
CANCELLING THE SEPTUM LEAK



TIME DOMAIN WAVEFORM USED TO
MODULATE THE CORRECTION KICKS

Orbit correction: feedforward correction



MAXIMUM ORBIT PERTURBATION DURING THE SEPTUM PULSE

THANKS FOR YOUR ATTENTION