FAST ORBIT CORRECTION AT THE ESRF

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Orbit stability requirement

- ESRF is a 3rd generation light source:

Energy: 6GeV

Circumference: 844.39m / 32cells

Horizontal and vertical emitance: 4nm and 30pm

- *Position stability must match this emitance figure*
- Stability criterion

Less than 20% emitance growth or:

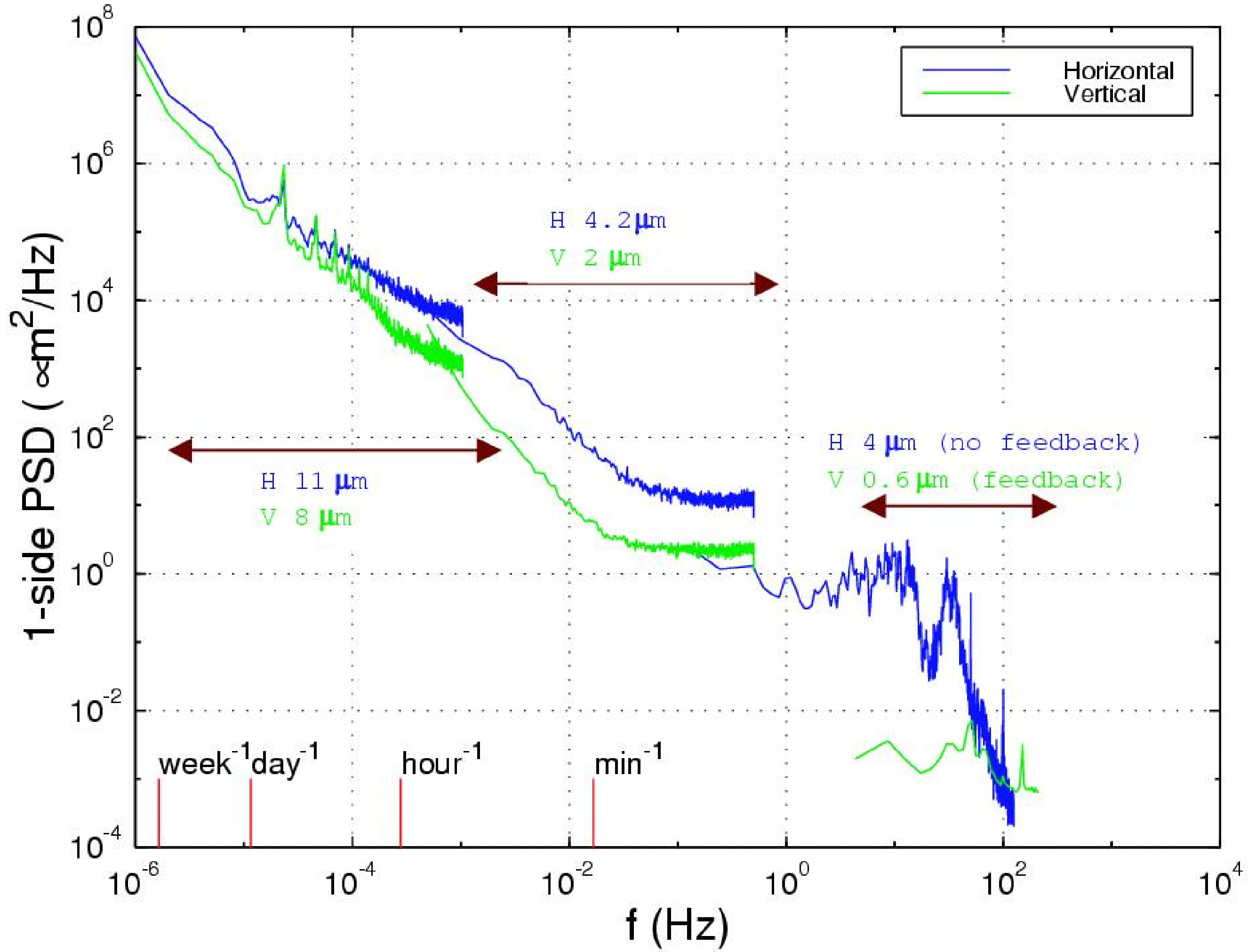
<10% beam size increase

<10 % beam divergence increase

More stringent demands at high frequency from some beamlines

Beam stability at ESRF (until Nov. 2004)

Beam motion on straight sections BPMs
: βx=35.4m, β_z=6.2m
σ_x=360μm, σ_z=15μm



FAST/SLOW correction management:

- **ESRF solution:**
- ***2 independent systems:***
- **Slow system with 224 BPMs/96 correctors from 0 to .1Hz**
- **Fast systems from .2 to 100 Hz**
- **Frequency separation between the slow and fast system**

- **Addition of a feed forward angle corrections during ID gap change on some straight sections to improve the orbit settling time in the .2 to .02 Hz range**
- **Choice due to circumstance, but it works fine**

We have recently upgraded our fast global feedback to damp the horizontal and vertical orbit distortions from .1 to 200Hz

Situation before the global feedback upgrade

- **Vertical global feedback system**

• **Aimed at bringing back the fast vertical motion to less than 10% of the beam size**

•20 nm/Hz$^{1/2}$ BPM resolution (1 μm in 2 KHz BW)
•.1 to 150 Hz feedback bandwidth
• (separation from the slow correction in the frequency domain)
•4.4 KHz sampling and correction rate
•Air cored magnets and 2mm thick stainless steel vessel
•low signal latency in the loop: .6mS

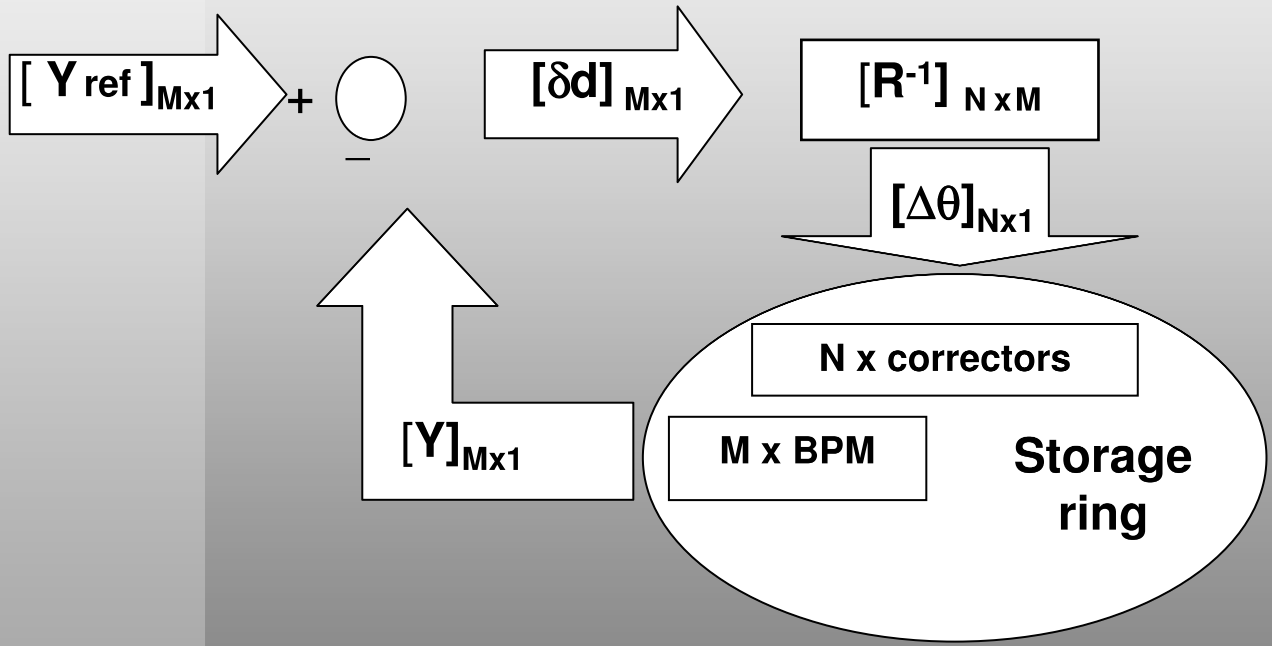
- **4 horizontal local feedback systems**

Installed from 1999 to 2001 on sensitive beam lines:

- ID14: Protein cristallography
- ID21: X-ray microscopy
- ID8:soft X ray spectroscopy
- ID24 X ray absorption spectroscopy

Same type of BPMs and steerers as the global feedback

Global closed orbit correction principle



Corrected orbit = ($[Y]_{Mx1}$- $[\ Y\ ref\ ]_{Mx1)}$)-$R_{M\ x N}$ x $[\Delta\theta]_{Nx1}$

$[R^{-1}]_{N\ x\ M}$ is obtained by a SVD method

efficiency

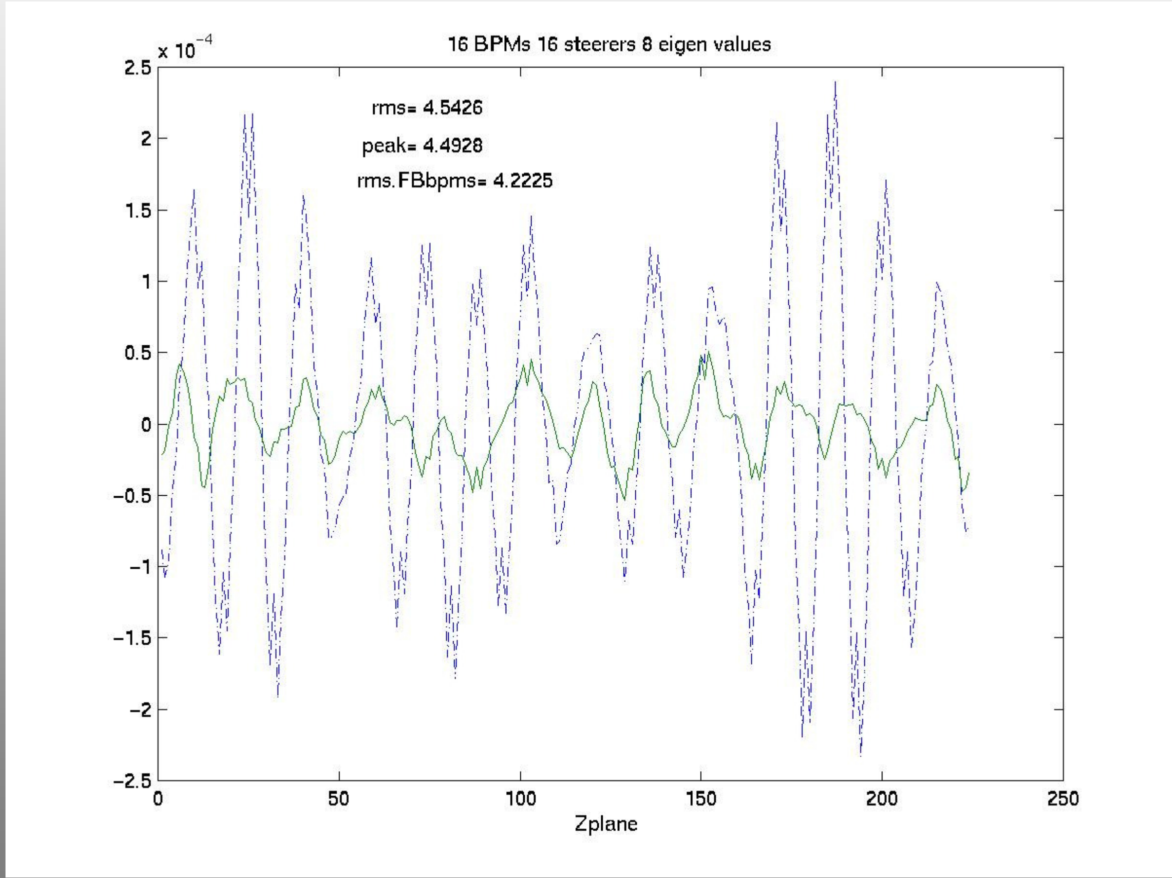
- a limited number of monitors and correctors can correct all the machine =>

  global scheme = undersampling

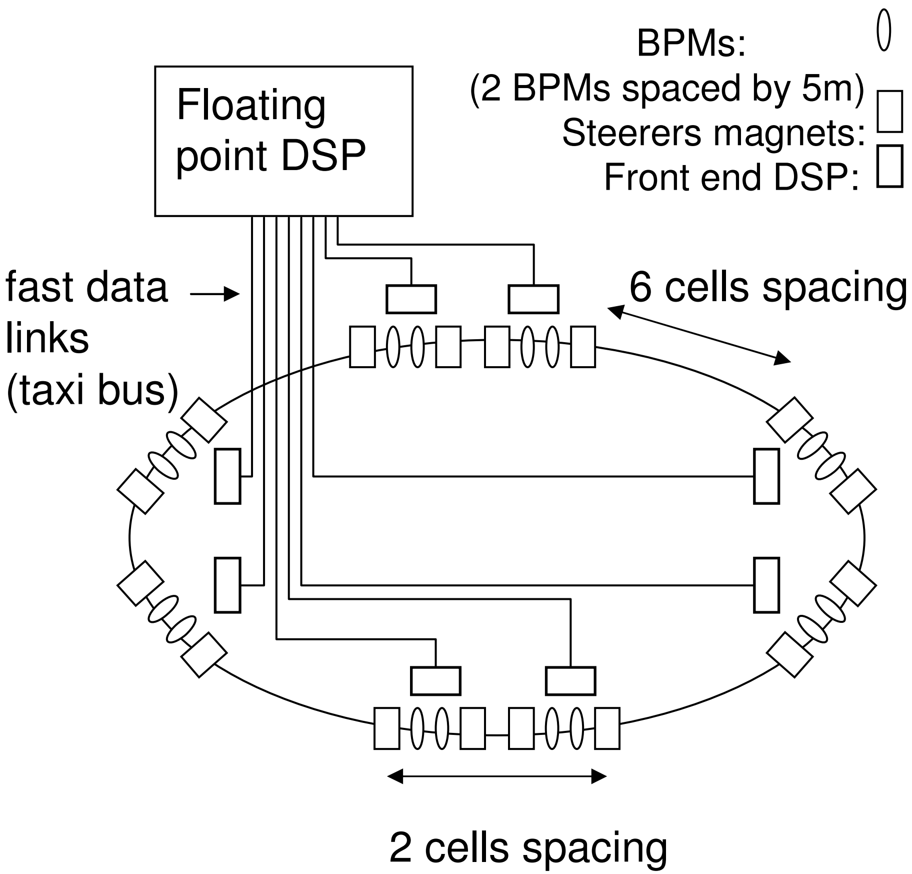
- According to simulations 16 monitors and correctors are enough in the vertical plane (Q=14.39)

- Rule of thumb:

Number of BPM corrector needed = Q



Vertical global feedback layout



Vertical correction only

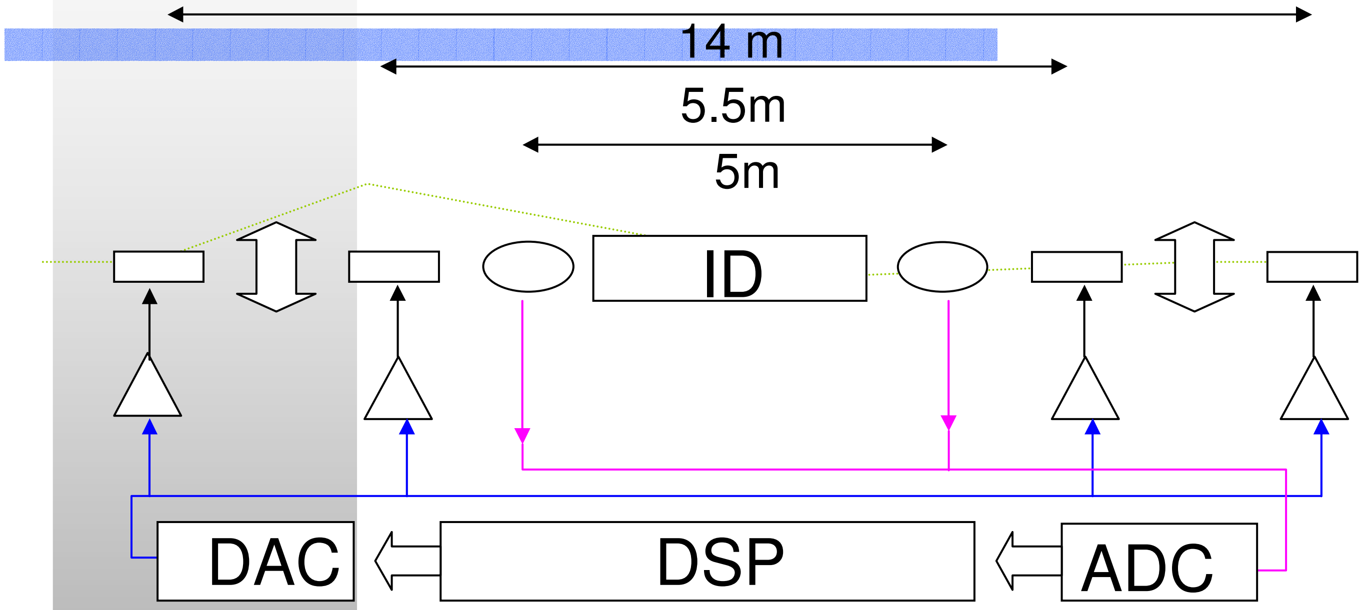
4.4 KHz sampling and correction rate

150 Hz feedback bandwidth

Achieved damping: 2 (.1 to 100 Hz)

Residual movement: 12% of the beam size

Local feedback layout

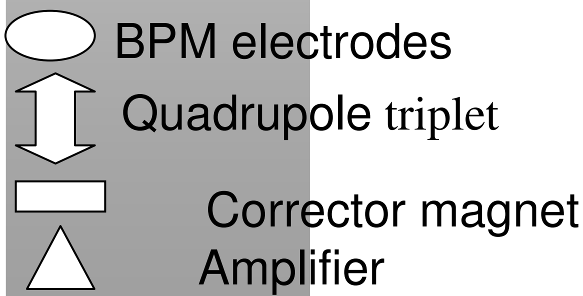


20 nm/Hz$^{1/2}$ BPM resolution (1 μm in 2 KHz BW)

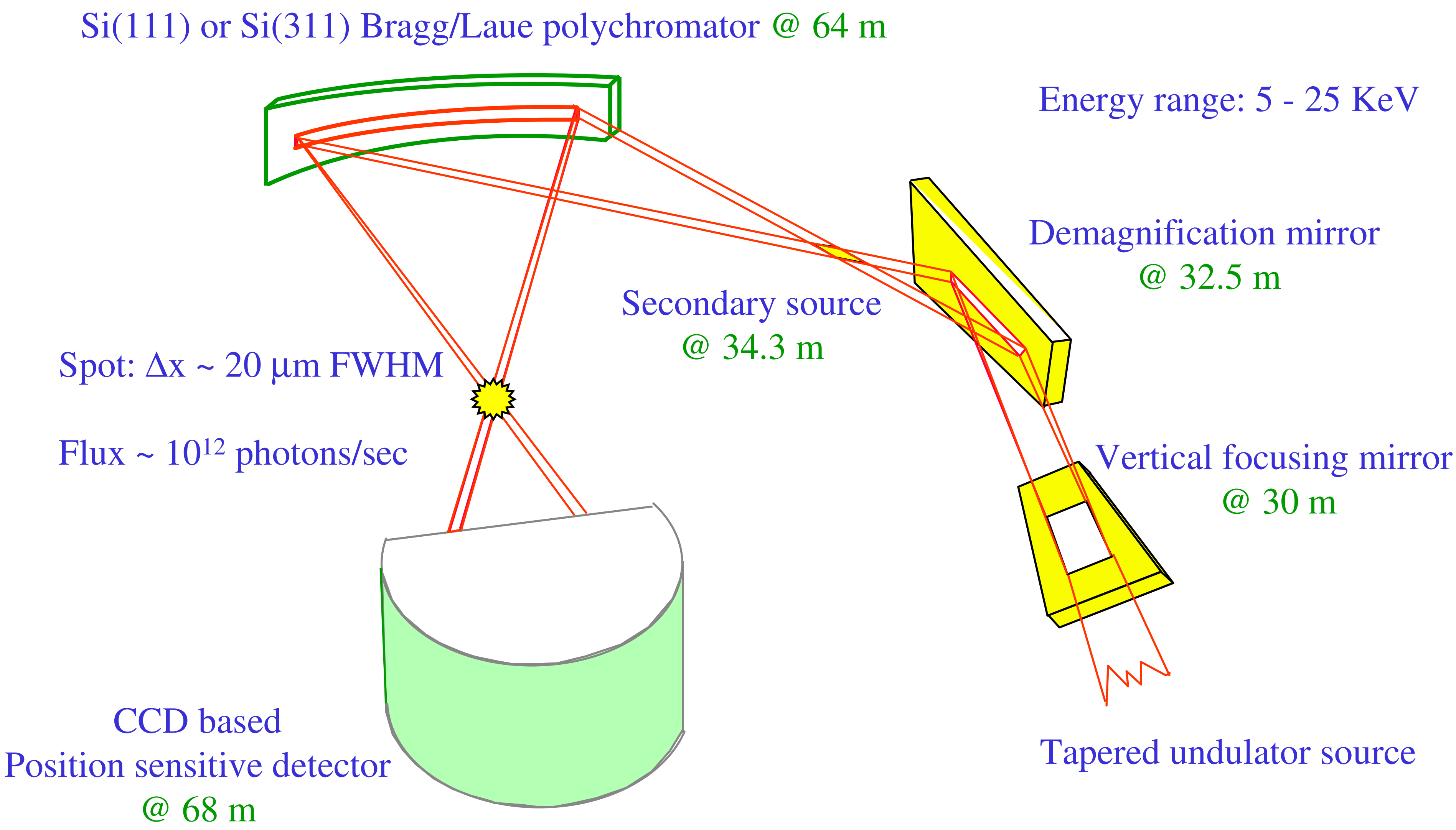
4.4 KHz sampling and correction rate

.1 to 150 Hz feedback bandwidth

Factor 4 damping (with our beam spectrum)



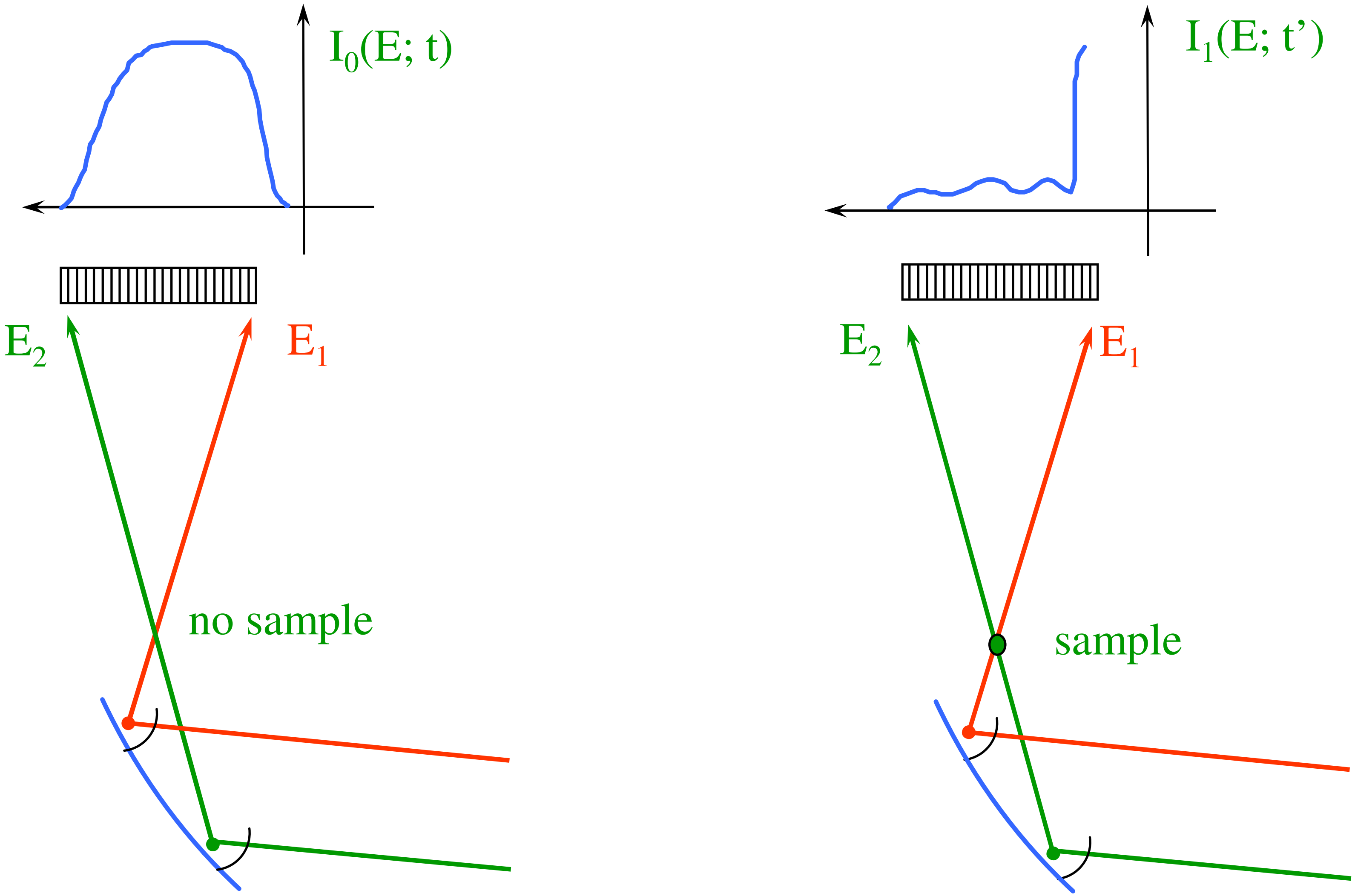
Separation from the slow correction in the frequency domain



Beamline ID24

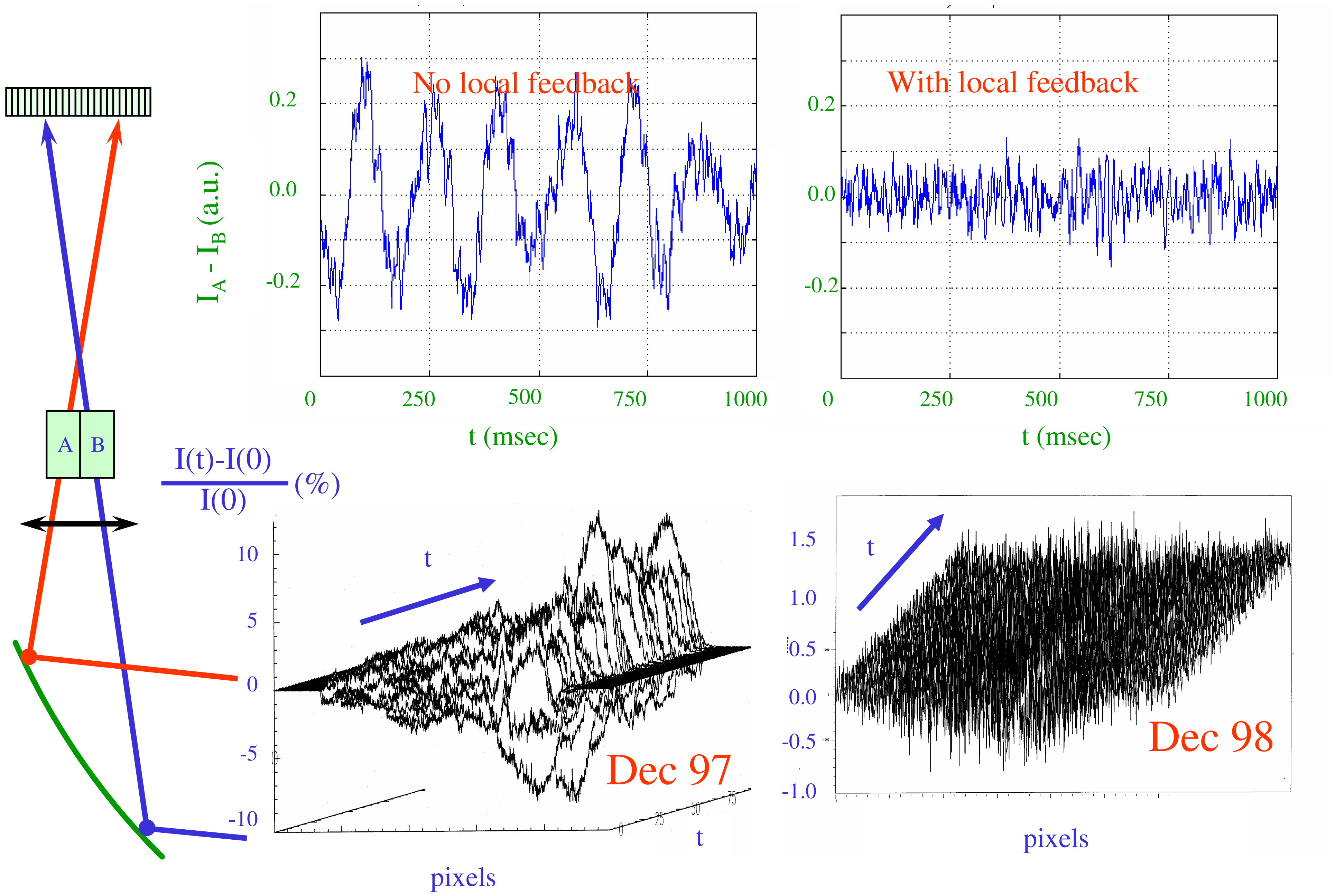
- **X ray Absorption Spectroscopy**
- **All the absorption spectrum is recorded simultaneously thanks to a polychromator**

The measurement of the absorption coefficient $\mu(E)$

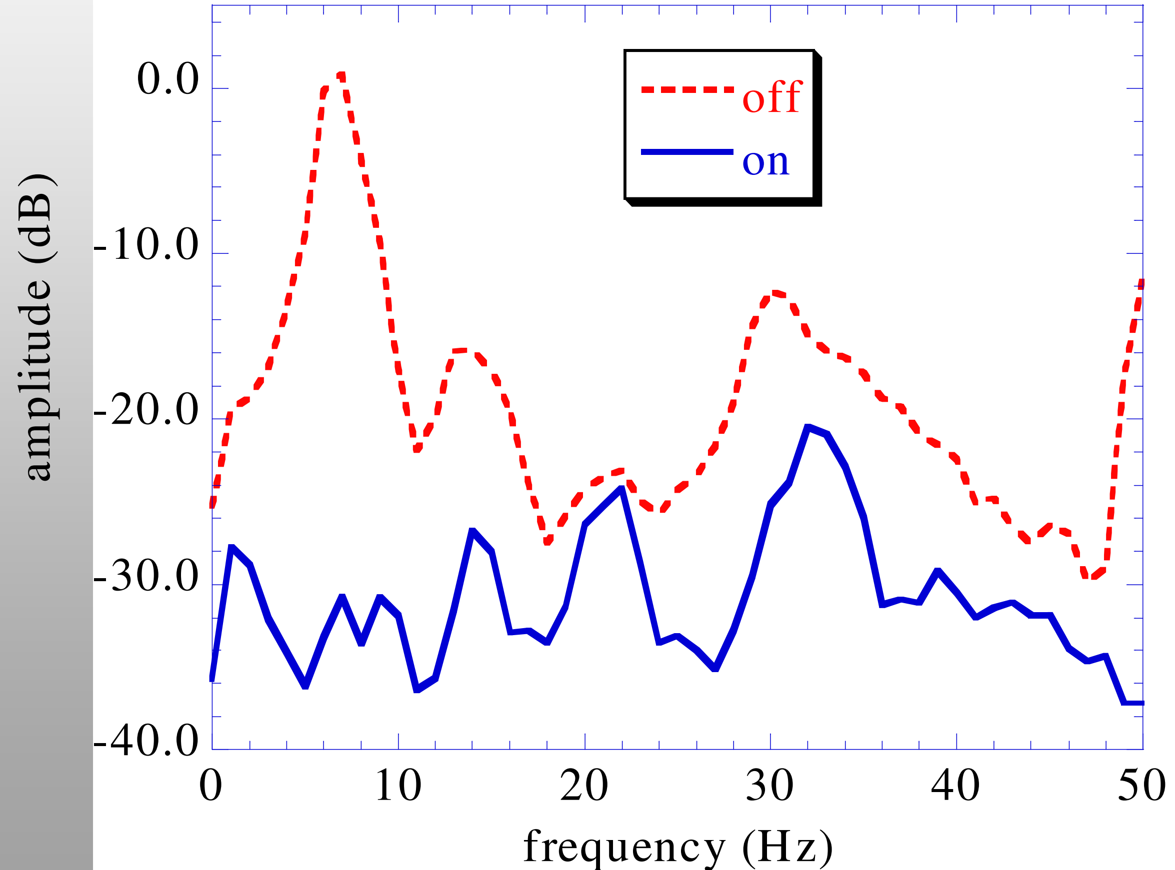


$$I_1(E) = I_0(E)\, e^{-\mu(E)d} \quad \Rightarrow \quad \mu(E)\, d = \ln \frac{I_0(E)}{I_1(E)}$$

EFFECT OF THE LOCAL FEEDBACK

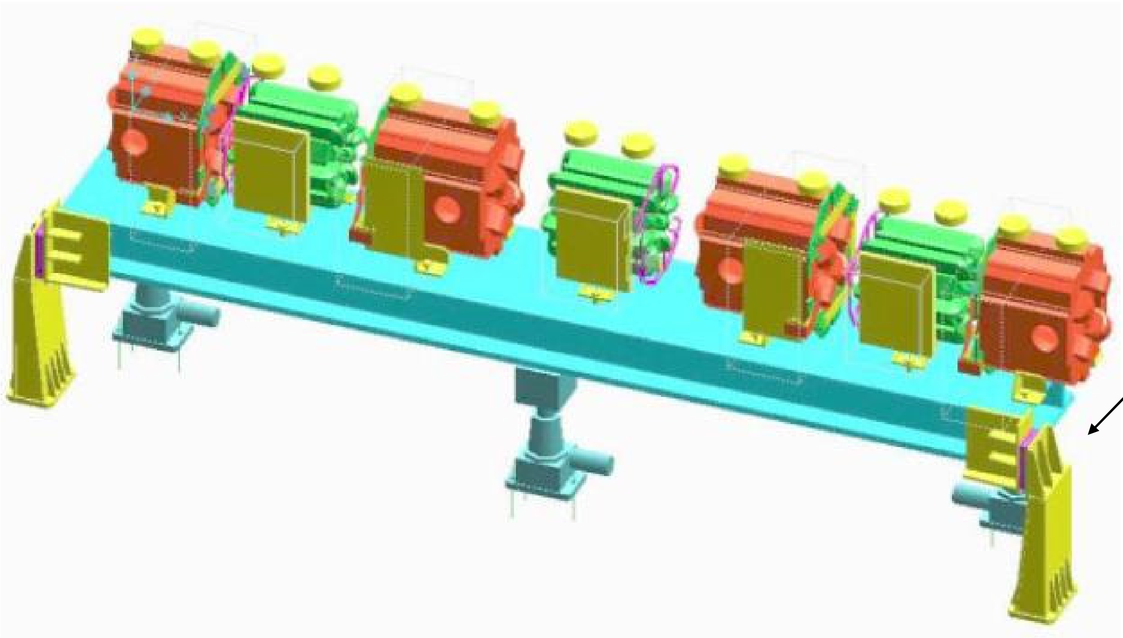


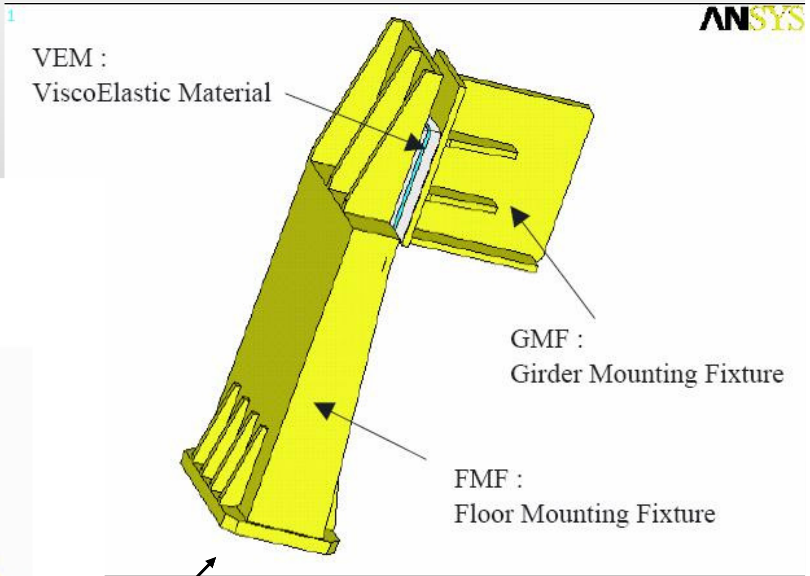
Spectrum of the motion on the sample:



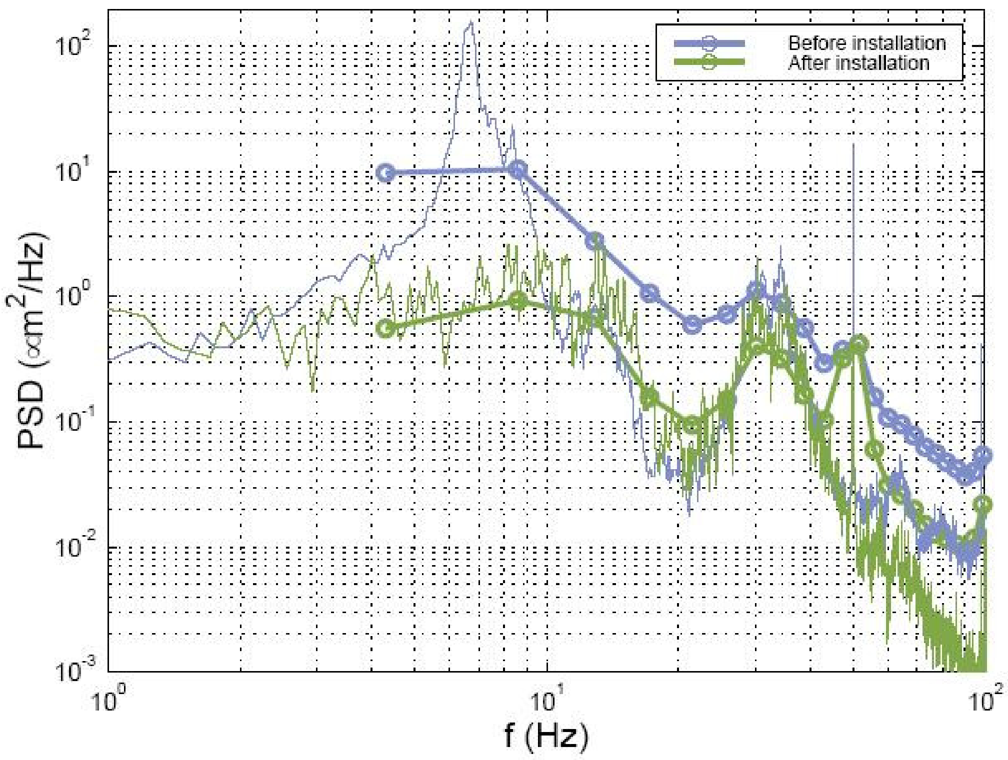
Damping pads on the magnets girders

Damping link design





Damping pads on the magnets girders



Effect of damping links on the horizontal beam motion

- -20dB reduction of the 7Hz
- less reduction of the 30Hz: it is due to the water flow in the quadrupoles coils

Feedforward correction: ID gap dependant CO distortion

- **A good solution for the .03 to 3Hz span without feedback**
- **Used to take care of the transient orbit distortion due to the gap change of some insertion devices:**

- **Measurement of the closed orbit distortion for every ID gap opening values during calibration sessions**
- **Calculation of a correction using 2 correction dipoles at both end of the straight section for every gap opening values**
- **Application of this additional correction as a function of the gap opening in operation (update rate of the correction: 10Hz**

Limitation of our correction system

- **Vertical global feedback system**

Victim of the success of the damping pads installation:

The resolution of the BPMs was now too close to the amplitude of the vertical beam motion without feedback!

- **horizontal local feedback systems**

ID24 X ray Absorption Spectroscopy bealine got the first system

Others beam lines requested horizontal correction:

Eventually crosstalk between the systems due to imperfect bump closure at high frequency started to appear, setting a limit to the number of local feedback systems, but not to the number of beam lines interested by a feedback….

Global feedback upgrade

2001 situation:

- We want to improve the resolution of the vertical orbit distortion measurement
- We wish to have the same low horizontal beam motion amplitude as in the straight sections corrected by the local feedback all over the machine

Solution:

- We need a global feedback in both planes (no more local feedbacks).

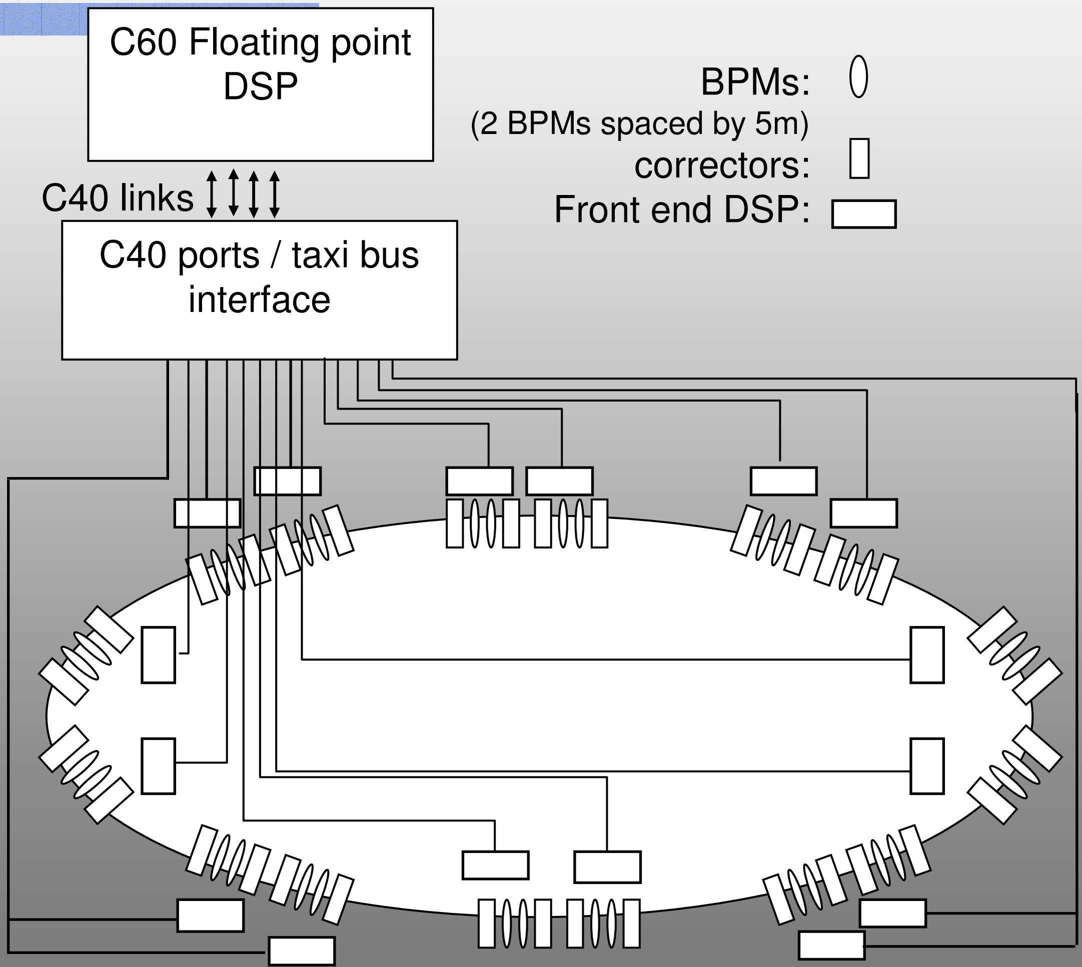
=> We must increase the number of BPMs and correctors (since Qx=36.44) and the DSP processing power

upgraded Global feedback

32BPMs

24 correctors

vertical and horizontal correction



Upgraded system features

- Same components as in the first system:
- RF multiplexing BPMs
- Taxi bus data links
- New DSP: TI C67 in replacement of the TI C40

Commissioning during 2004, now in operation

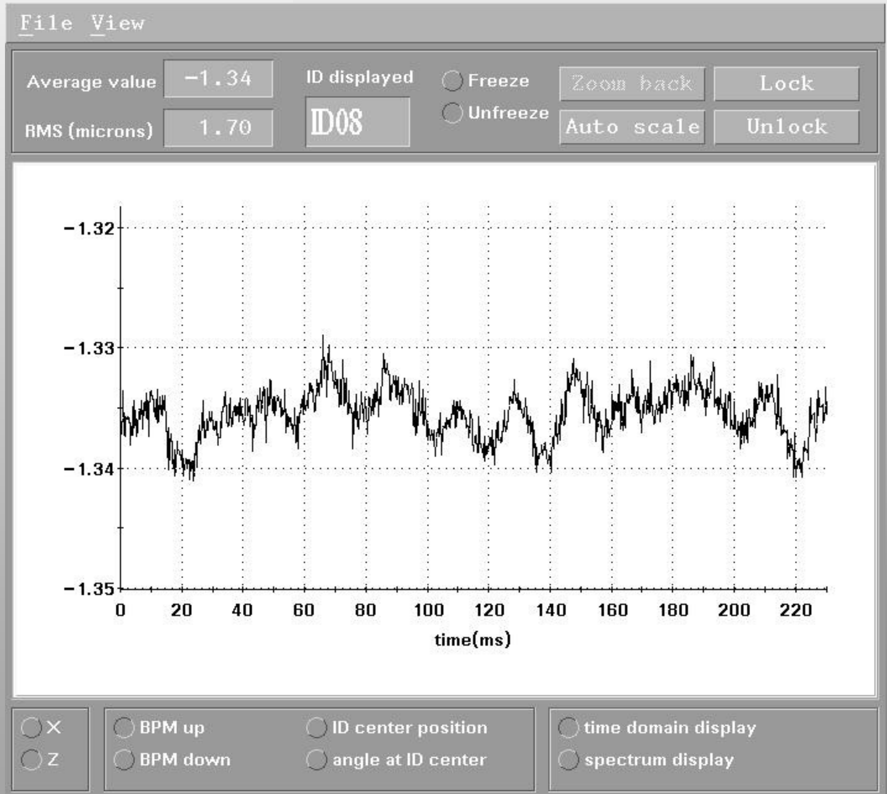
Feedback efficiency

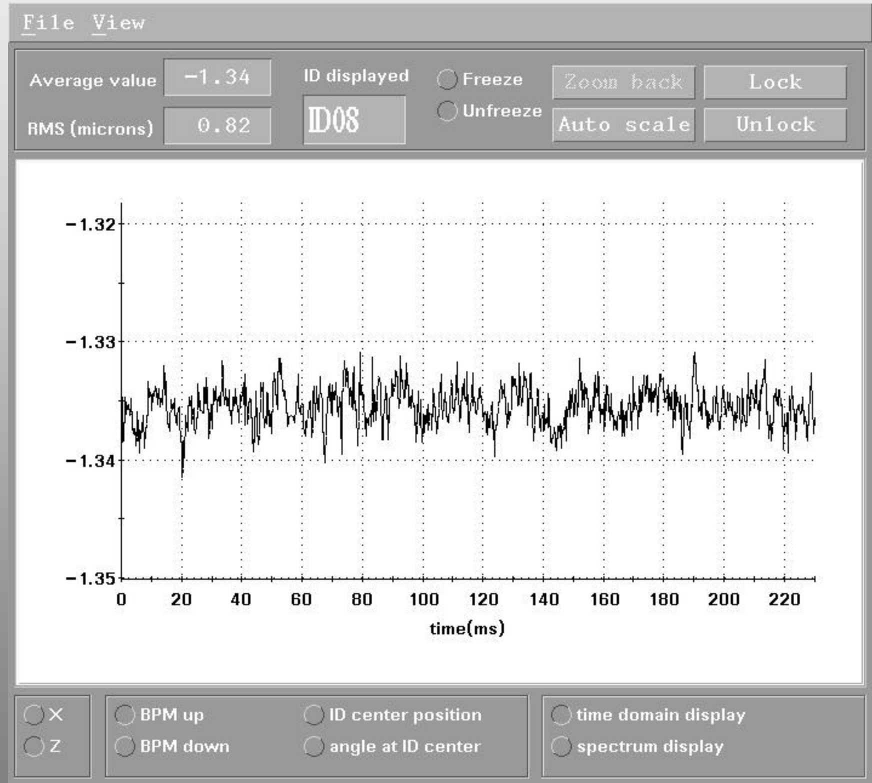
measured at the end of high horizontal β straight section

	β (in m)	rms motion without feedback (in μm, .1 to 200Hz)	rms motion with feedback (in μm, .1 to 200Hz)	rms motion/ rms size
H plane	36	5 to 12 (depending on BPM)	1.5 to 2.5 (depending on BPM)	.004 to .006
V plane	6.5	1.5 to 2.5 (depending on BPM)	.8 to 1.2 (depending on BPM)	.1

Feedback bandwidth: .1Hz to 150 Hz
Beam H and V emitance: 4nm and .03nm

V plane results:

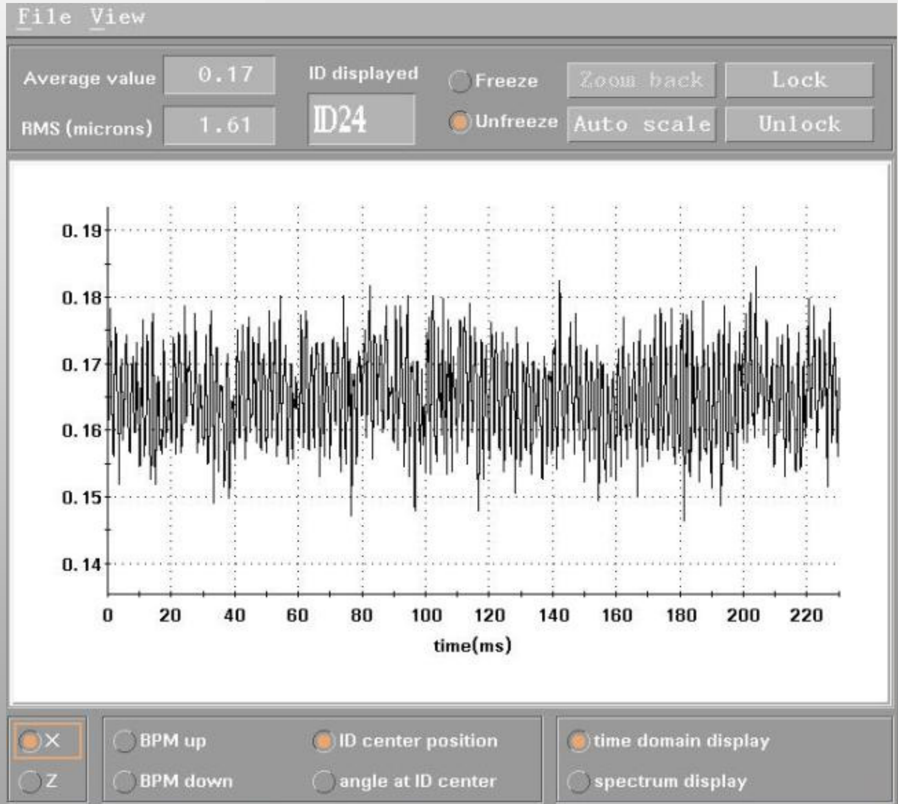


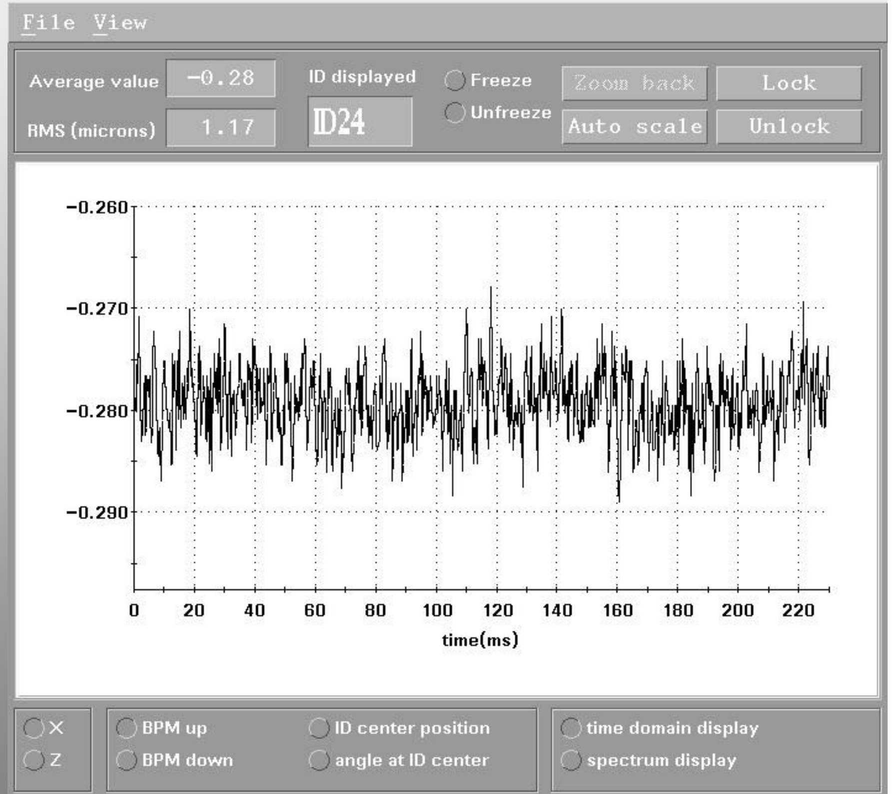


Left: feedback OFF **Right: feedback ON**

rms value: integrated from .1 to 200Hz

H plane results: correction better than with the local feedback at the feedback BPM locations

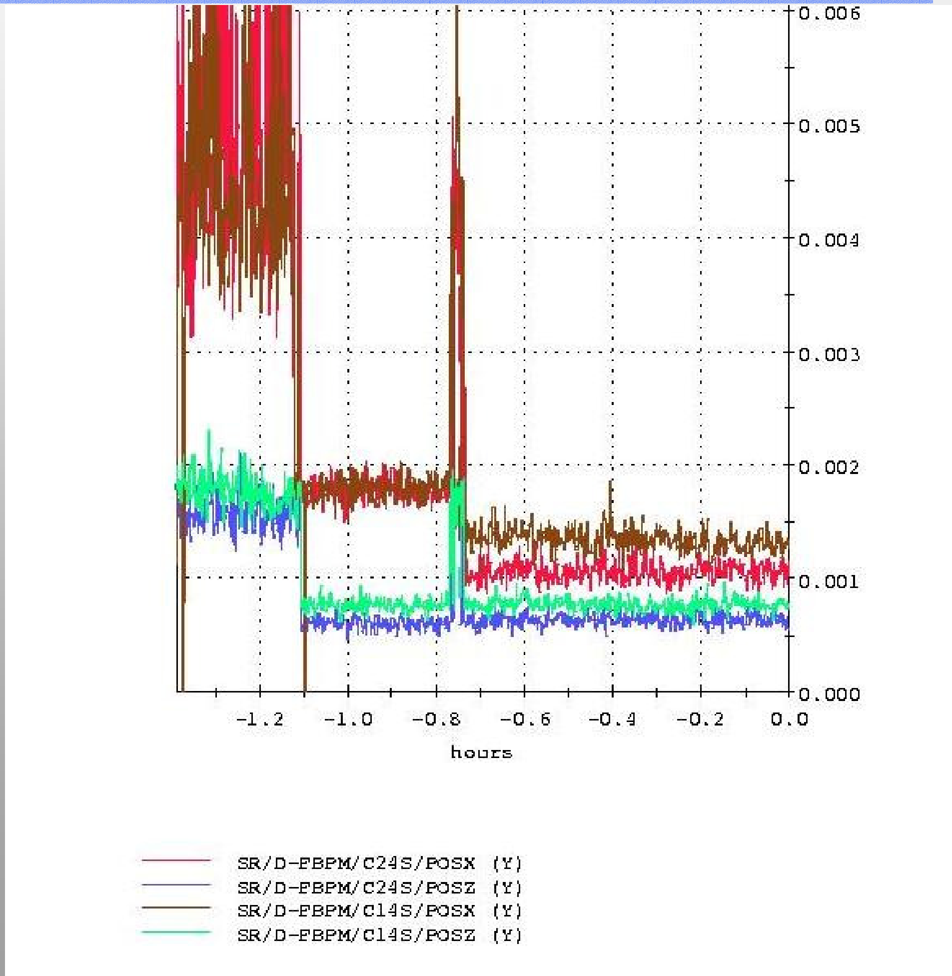




local feedback ON (left), global feedback ON (right)

rms value: integrated from .1 to 200Hz

Feedback efficiency



rms stability in 2 sensitive ID straight sections:

Left : no feedback
Right: both feedbaclk applied

<u>red and brown:</u>
horizontal rms position variation
<u>blue and green:</u>
horizontal rms position variation

Integrated from .1 to 200Hz

Next steps

- Addition of a selective damping of the 50Hz line in the DSP algorithm
- Addition of more diagnostics functions (triggering of the BPMs recording on external events…)

Conclusion

- **With a mix of feedforward action on the orbit perturbations, passive damping of the vibration of the magnets, and a fast orbit correction with a global feedback, we manage to still have a state of the art beam stability (even if our BPMs are now a bit outdated…).**

System size for fast global correction:

All you need is:

- **4 KHz sampling for 200Hz BW**
- **BPM and correctors number roughly equal to the integer of the tune value**