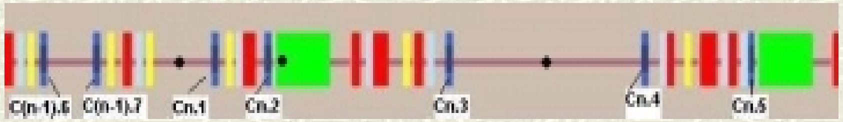
Slow Orbit Feedback at ELETTRA and the performance of a full 7-Bump Correction Algorithm



www.elettra.trieste.it

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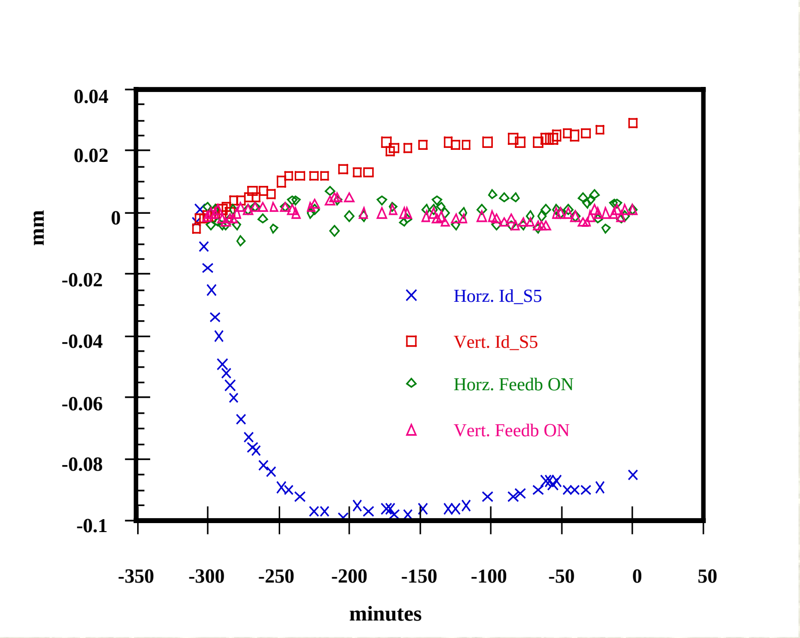
Workshop on Beam Orbit Stabilization, SPRING-8, Japan

The Orbit at ELETTRA is influenced by

- Very slow ground thermal drifts
- Small ground settlements -> The machine will be shortly realigned
- hysterisis effects due to mismatch between injection (1 GeV) and operation (2 and 2.4 GeV) energy (Ramping)
- Thermal load at 2 GeV on the vacuum vessel produces an up to 100 horizontal and up to 30 μm vertical orbit shift in the straight sections within 2 hours after the end of ramping
- Vibrations and mains noise up to some tens of Hz
- Maintenance and too often opening up for new installations
- ID strength / phase changing when the calibrations of the correction coils are no more valid -> comparable to thermal drifts

Biggest effect is the thermal load on the chamber



Worst case local orbit drift for a period of five hours without any feed back at 2 GeV with an initial current of 320 mA. Drifts in angle are less than 9 μrad horizontally

It is apparent that one needs a slow correcting system, a slow Feed Back

Detectors and Correctors

e-detectors: Until recently only 96 beam position monitors multiplexed with 150 μ absolute and 2.5μ relative accuracy (at 1 sec reading rate) attached to the quadrupoles. In practice the relative accuracy is compromised by longitudinal beam excitations to typically 5-10 μ

The Beam Steering system consists of 82 combined H+V iron core correctors 0.22 m long with a 140-130 Gm maximum field strength.

Slow Corrections

The relatively low repeatability has influenced our orbit correction philosophy:

No Golden orbits but every BL station is set to an optimal orbit position and angle and it is kept to it.

- Global corrections with in house developed programs (Gloc and Toca) involving all traditional bpms and any correctors, usually **once per run**.

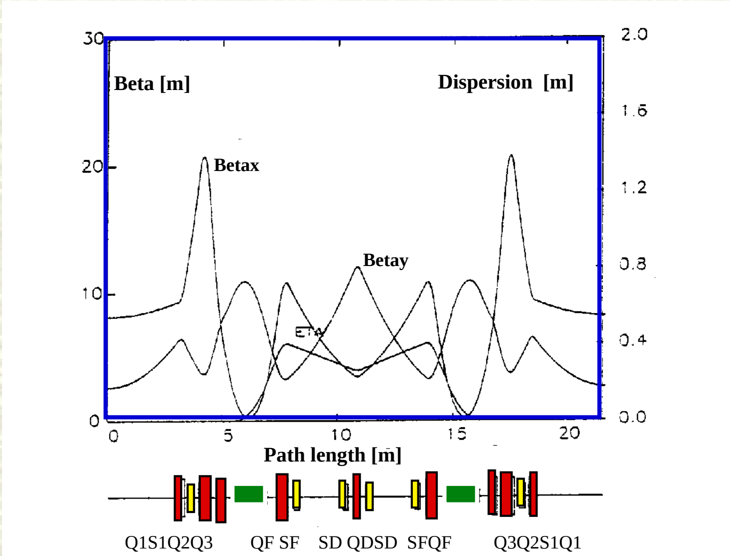
- Local orbit corrections with in house developed programs (SlowFB , OrbitFB and Gloc) usually once every 5 minutes automatically.

Present situation

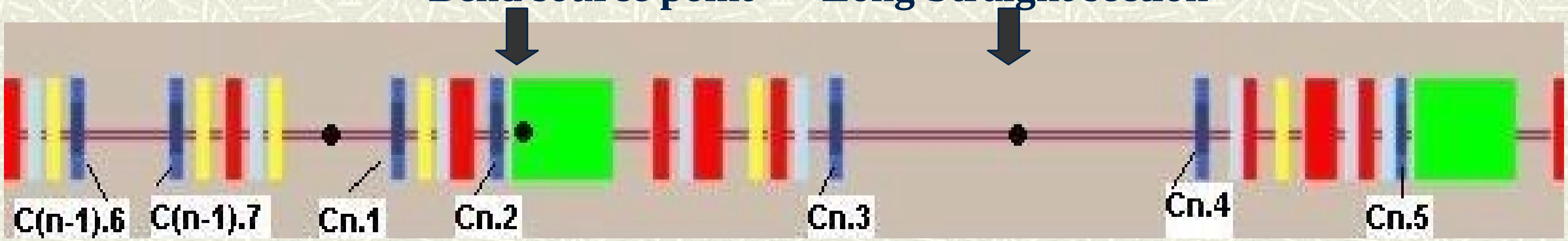
Each of the 11 sections has 7 correctors while the 12th section reserved for injection has 5. Usually a four corrector bump is applied at each active straight section. Whenever the beam angle in the bending magnet source point has to be controlled a five corrector bump is applied instead.

- To complicate matters not all section are corrected to zero position and angle. Some experimental stations have noticed that with the passage of time they have a better performance if they introduce a certain local orbit angle at source point. This is partially due to the fact that ELETTRA after eight years of continuous operations is above the alignment tolerances. A vertical misalignment of 500 μm of a quadrupole magnet can give an angle error of about 100 μrad in the downstream insertion device. Thus in general misalignments between the beam position monitors (that are fixed on the quadrupole magnets) and the insertion devices as well as accidental movement of the insertion device magnets shims can result in the manifestation of strong higher order magnetic multipole components in the insertion device magnets that influence the optics of the machine.
- On the other hand for some insertion devices it is explicitly required a position offset and a certain angle (e.g. 2.5 mm and 1 mrad) if chicane operation is needed.

Optics and layout of a section



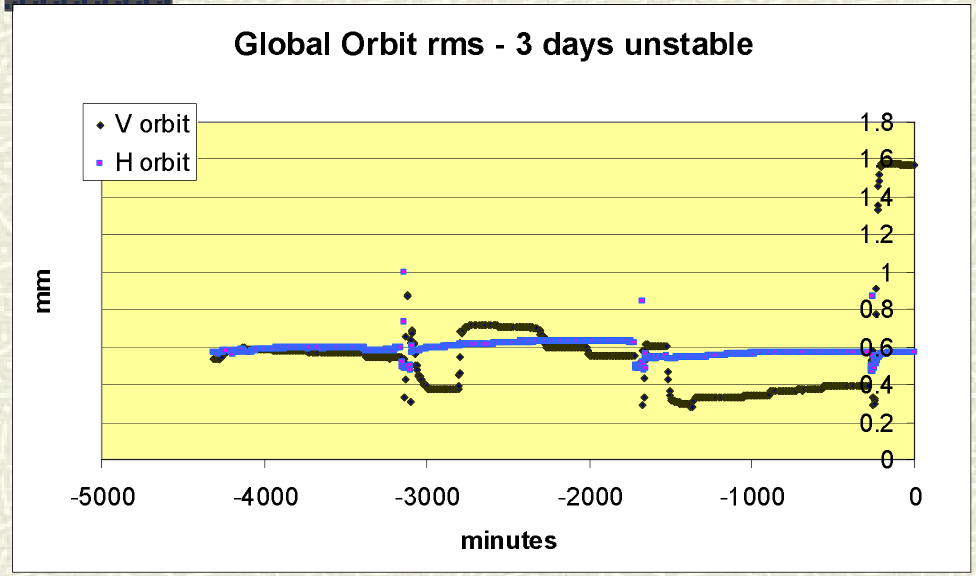
Bend source point **Long Straight section**



Defects

- The existing slow local orbit correcting program (slowFB) did not always preserve the global orbit. While in the horizontal plane the rms global orbit does not change appreciably (30-50 μ peak to peak) between refills (24 hours) the vertical global orbit with the increase of the number of corrected sections was becoming unstable and could even change by a factor of 2 although the local readings in the most cases remained within the tolerance limits (i.e. 5 μm, 2 μrad).
- With the increase in the number of bending magnet beam lines and the coming installation of a short ID in the short straight sections where corrections will be needed too, it was evident that this correction procedure had to change.

Occasionally bad orbits



The most requests from users are for the vertical orbit. Thus although the horizontal is usually locally corrected to zero the vertical is set to various positions and angles at each straight section

The vertical orbit occasionally got unstable and slowFB was driving the beam position at the bending magnet source point to high values. Still however the local corrections were successful but the beam quality deteriorated for large values of the vertical orbit rms

What was to be done

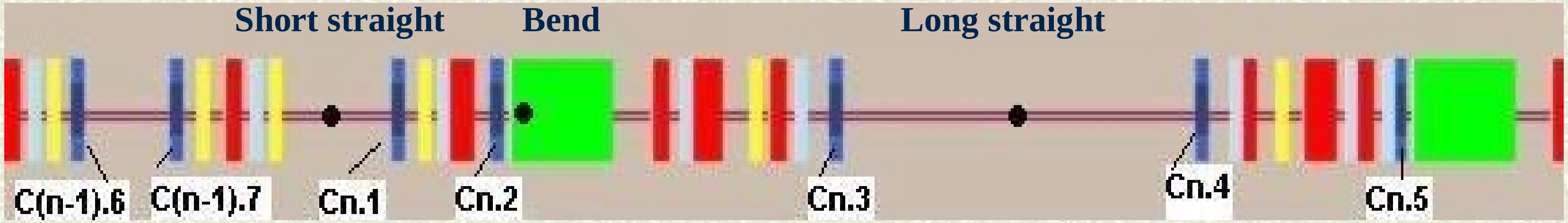
- The effect was attributed to non well closed bump interference with initial conditions and erroneous bpm reading for large orbits. On the other hand the monitors after the bending get all the radiation heating up reaching 130 C at 2 GeV with 320 mA

A seven bump scheme was developed and tested (incorporated in the Gloc program acting in all sections except section 12 where a 5 bump was created instead. This scheme has the advantage that involves all correctors thus giving an enhanced global orbit stability.

Using the 7bump scheme it was also possible to analyze and fix the vertical global orbit problem.

The 7 bump

- Seven correctors, 5 from the current section and 2 from the previous one are used. All bpm readings are translated into positions and angles at three distinct fictitious points per section: middle of the long straight section (between .3 and .4), middle of the short straight section (between .7 and .1) and bending magnet source point (between .2 and .3). The system uses the shown correctors



and corrects position and angle in the short and long sections and angle or position in the bending magnet source point. It is not possible to simultaneously correct position and angle in the bending source point since an eighth corrector is needed that should be positioned after the bending magnet and before the corrector .3. For the present such correction can be done only if the ID section is not corrected.

The equations

The orbit displacement y and angle y’ created by a corrector j of strength θ_j at a point i are:

$$y_i = A_{ij}\vartheta_j \qquad y'_i = A'_{ij}\vartheta_j$$

where:

$$A_{ij} = \sqrt{\beta_j \beta_i}\ \sin\left(2\pi\left(\varphi_i - \varphi_j\right)\right) \qquad A'_{ij} = \sqrt{\beta_j / \beta_i}\ \left(\cos\left(2\pi\left(\varphi_i - \varphi_j\right)\right) - \alpha_i \sin\left(2\pi\left(\varphi_i - \varphi_j\right)\right)\right)$$

with β,α the twiss functions and ϕ the phase advance. The local seven corrector bump equations can then be written as follows (n is the current section number):

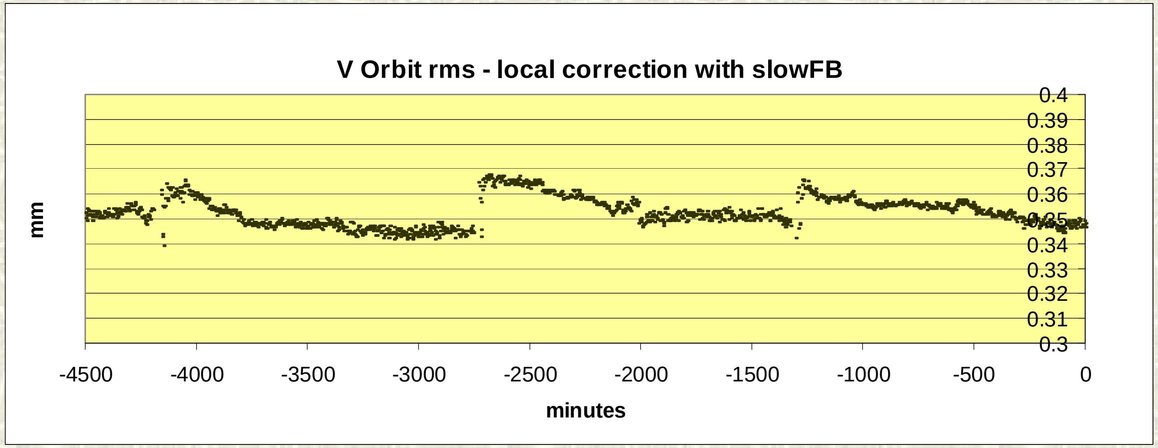
Short straight sections middle: $\sum_{j=(n-1).6}^{(n-1).7} \vartheta_j A_{SSj} = y_{SS}$ $\qquad \sum_{j=(n-1).6}^{(n-1).7} \vartheta_j A'_{SSj} = y'_{SS}$

At the bending magnet source point: $\sum_{j=(n-1).6}^{n.2} \vartheta_j A_{Bj} = y_B$ **or** $\sum_{j=(n-1).6}^{n.2} \vartheta_j A'_{Bj} = y'_B$

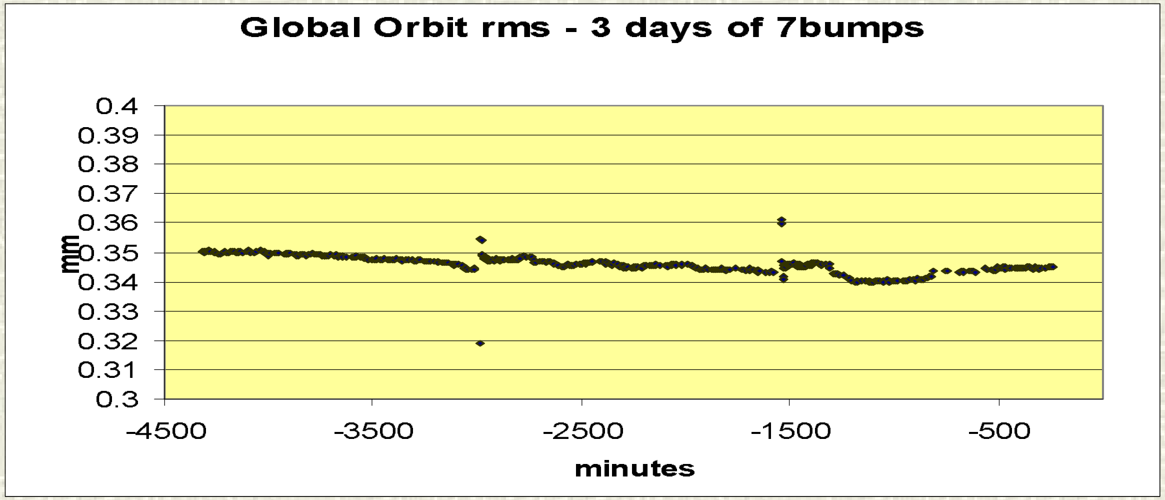
At the long straight sections middle $\sum_{j=(n-1).6}^{n.3} \vartheta_j A'_{LSj} = y'_{LS}$ $\qquad \sum_{j=(n-1).6}^{n.3} \vartheta_j A_{LSj} = y_{LS}$

Closure conditions: $\sum_{j=(n-1).6}^{n.5} \vartheta_j A_{n.5\,j} = 0$ $\qquad \sum_{j=(n-1).6}^{n.5} \vartheta_j A'_{n.5\,j} = 0$

Vertical Orbit conservation



During normal local corrections vertical orbit moves at about ± **15** μ

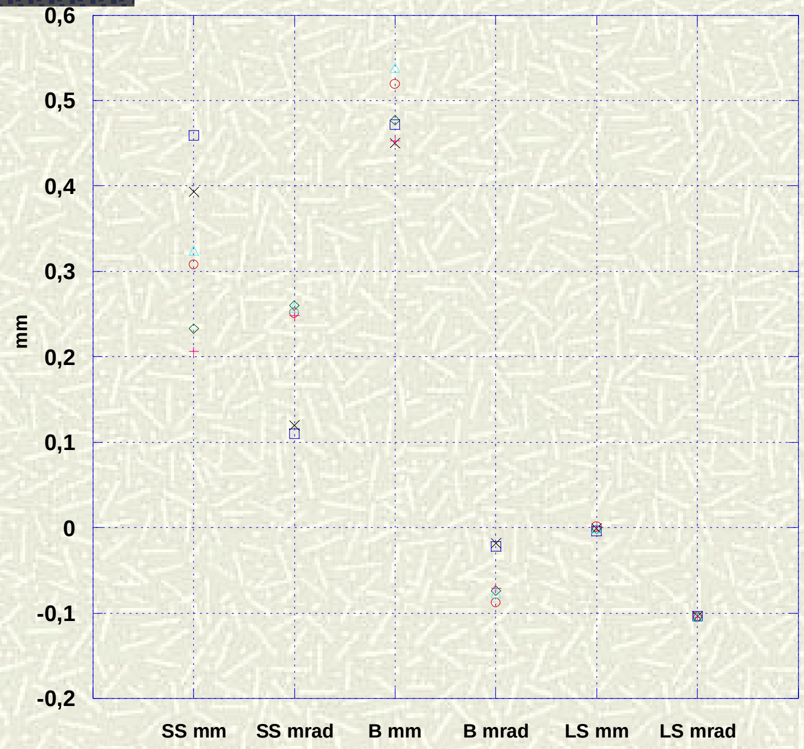


When 7bumps are applied the vertical orbit rms remains stable within the tolerances of the local orbit corrections ± **5** μ

Local reproducibility

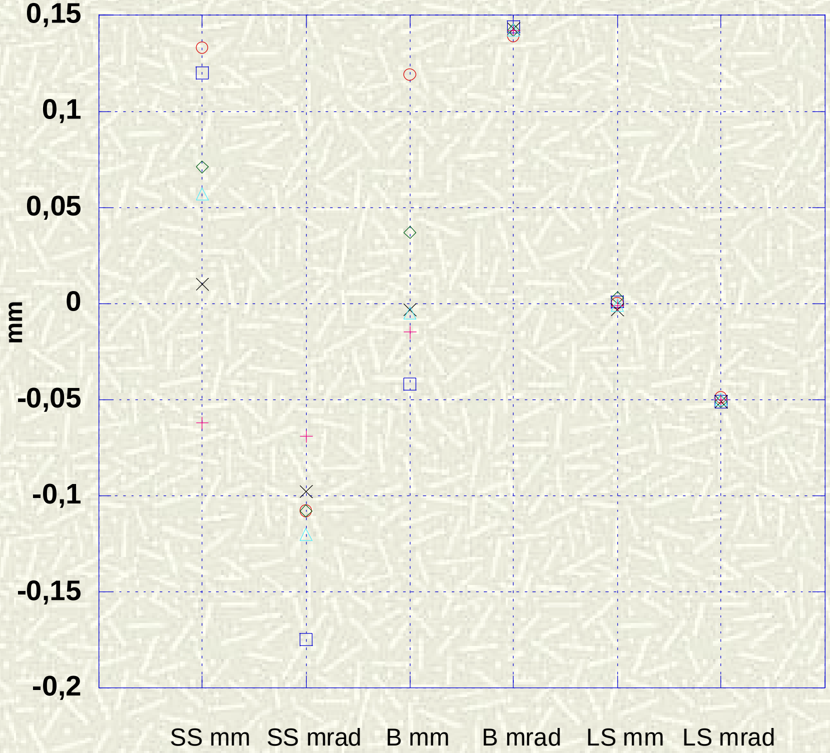
- In order to study the local behaviour of the system a series of controls have been performed. The convergence and the stability was very good, in fact the algorithm converges after a few iterations and corrects always to the set tolerances. To check out the reproducibility of the method on the orbit the position and angle at all three correction points of one section were locally monitored over a 12 day period. In the bending source point the angle was fixed. The program corrected to the preset tolerance of ± 5 μm ± 2 μrad in the LS , ± 5 μrad in the BSy' and ± 5 (μm and μrad) in the SS point. Data were obtained also for 4 and 5 bumps only.

Reproducibility of 4 and 5 bumps



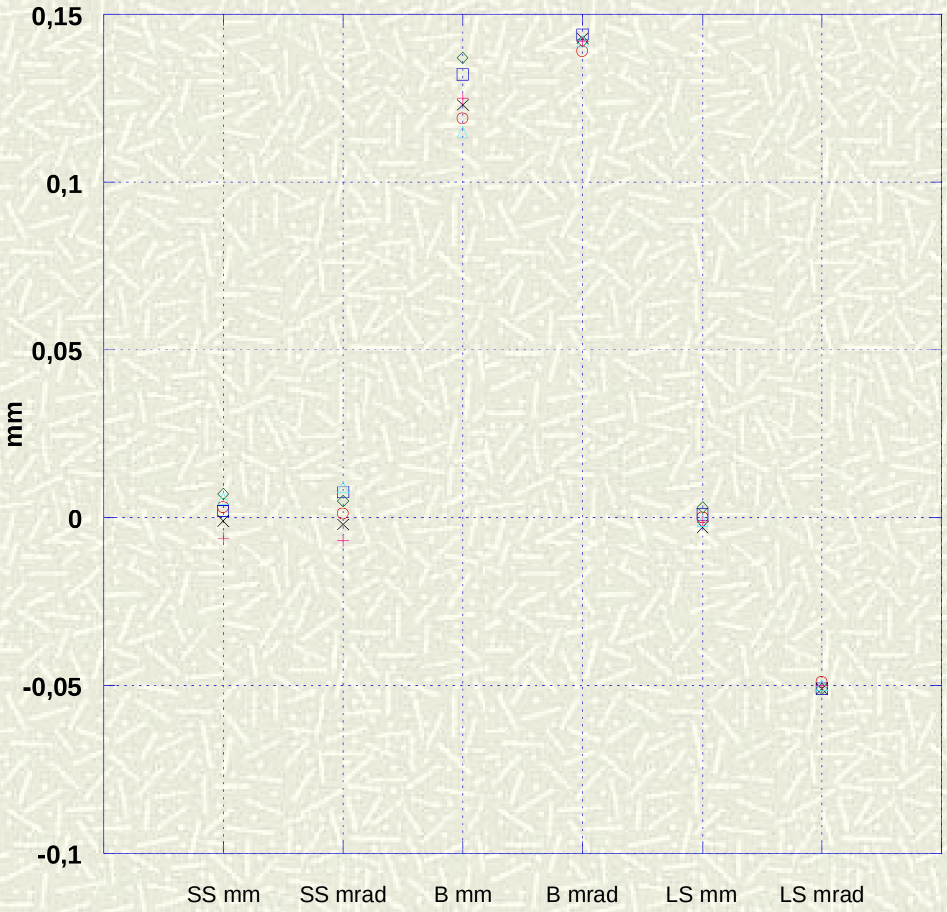
Corrected only LS , 4 bumps

Note that the above are initial conditions and not orbit shifts



Corrected only LS and bending magnet angle - 5 bumps

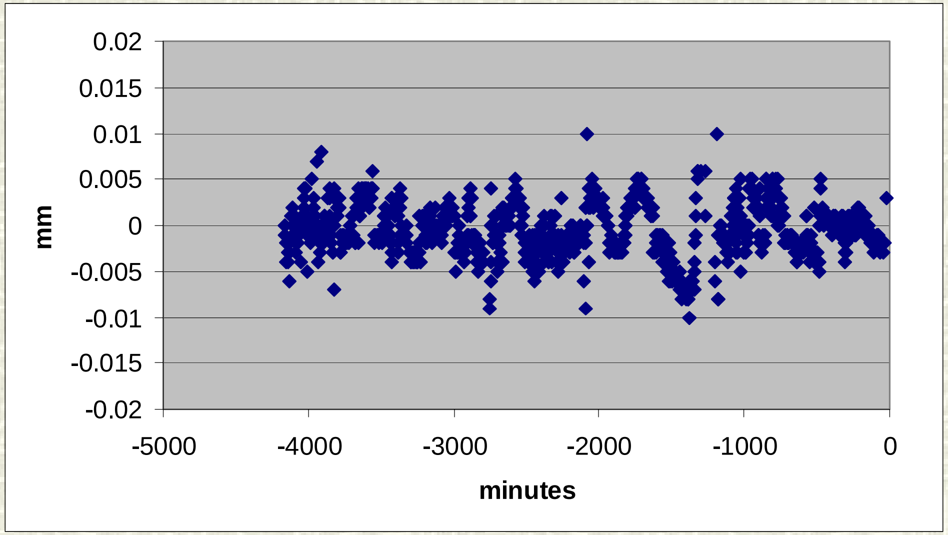
Reproducibility of 7 bumps

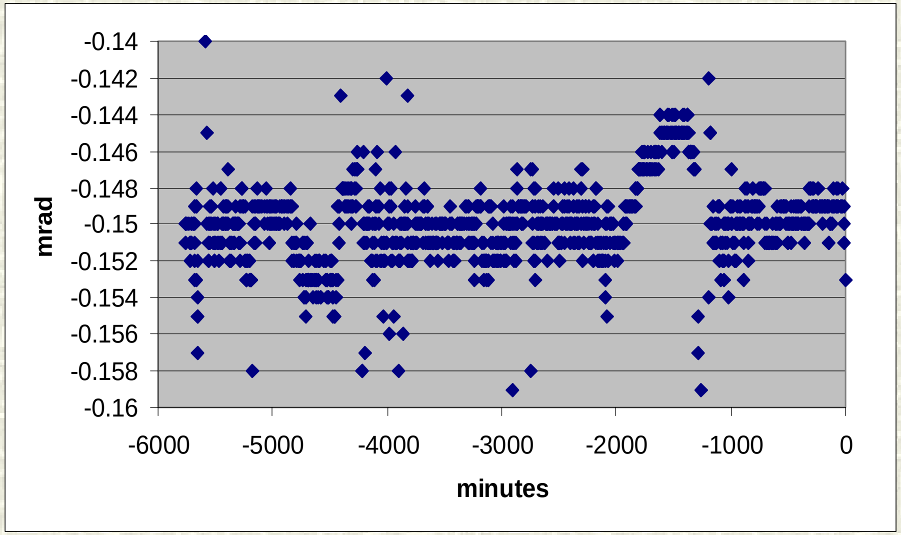


The monitoring confirmed the set tolerances. The position of the beam in the Bending magnet (uncontrolled) is about ± 10 μ very close to slow weekly drift

Correction efficiency

It greatly depends upon the detector and the corrector efficiency





At present the orbit is locally stable in the range of ± 5 μ and ± 2 μrad which is the best we can do for the moment!

Conclusions

The relatively low orbit reproducibility of ELETTRA for reasons explained before has obliged us to control beam position and angle in the middle of the insertion devices long straight sections almost since the beginning of the experimental activities. The chicane operation of a dedicated section (S9) needs special position and angle settings too. The near future plan to operate an already installed short insertion device in a short straight section of ELETTRA, the prospect of having more of those devices in the future and some specific demands from bending magnet beam lines for special source point angles, have pushed us towards the development of a fully fledged local orbit control algorithm. It has been shown that it is possible by means of this algorithm to both control position and angle in the short and long straight sections of ELETTRA as well as angle or position in the bending magnet source points. To control both angle and position at all three points, ELETTRA would need an additional corrector per section. The corrections maintain their preset local accuracy (e.g. $\pm$ 5 μm, $\pm$ 2 μrad) and keep the global orbit constant (within $\pm$ 5 μm rms) enhancing thus the reproducibility of the beam orbit.