The Elettra Fast Global Orbit Feedback

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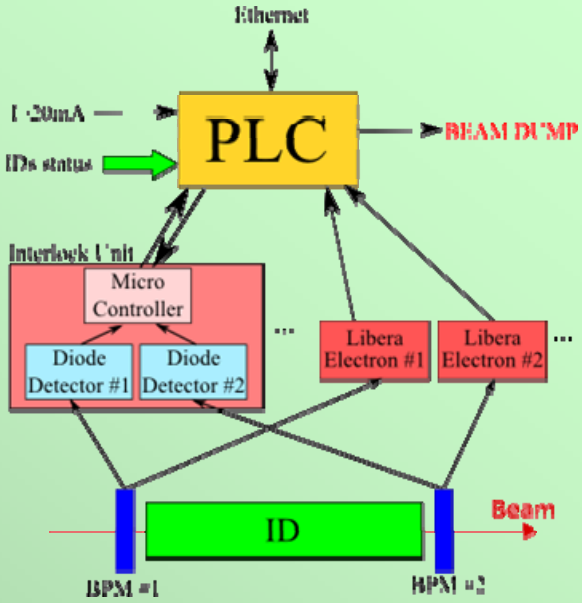
Milestones of the project

- the existing RF BPM detectors have been replaced with Libera Electron:
  - March 2006 - March 2007
- installation of the feedback system: finished February 2007
- loop closed in March 2007
- commissioning of the fast feedback system followed by:
  - optimization of the feedback parameters
  - development of control room panels
  - definition and implementation of the operational procedures
- since beginning of September 2007 the feedback is routinely used during users shifts

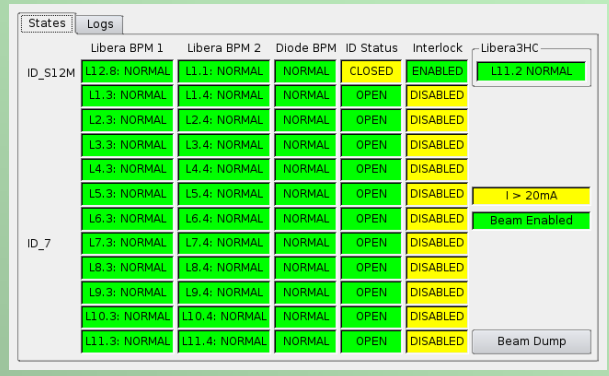
BPM Detectors Upgrade

- Gradual upgrade of 96 BPM detectors with *Libera Electron* performed during dedicated machine shifts
- Negligible inconvenience to machine operations and beam line experiments
- The fast orbit interlock system (protection of the vacuum chamber from synchrotron radiation) based on the old BPM detectors has also been replaced
- The new interlock has a redundant architecture using Libera detectors and newly developed diode detectors all connected to a Programmable Logic Controller (PLC)



Diode Detector unit

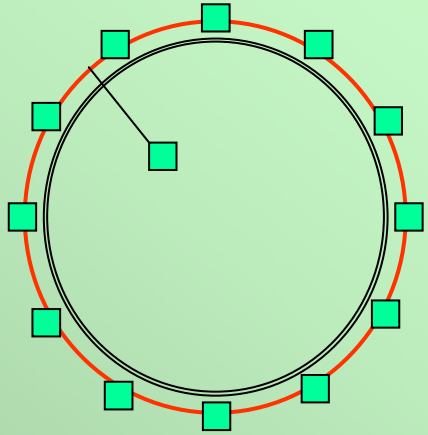
PLC of the orbit interlock system



Supervisor of the orbit interlock system

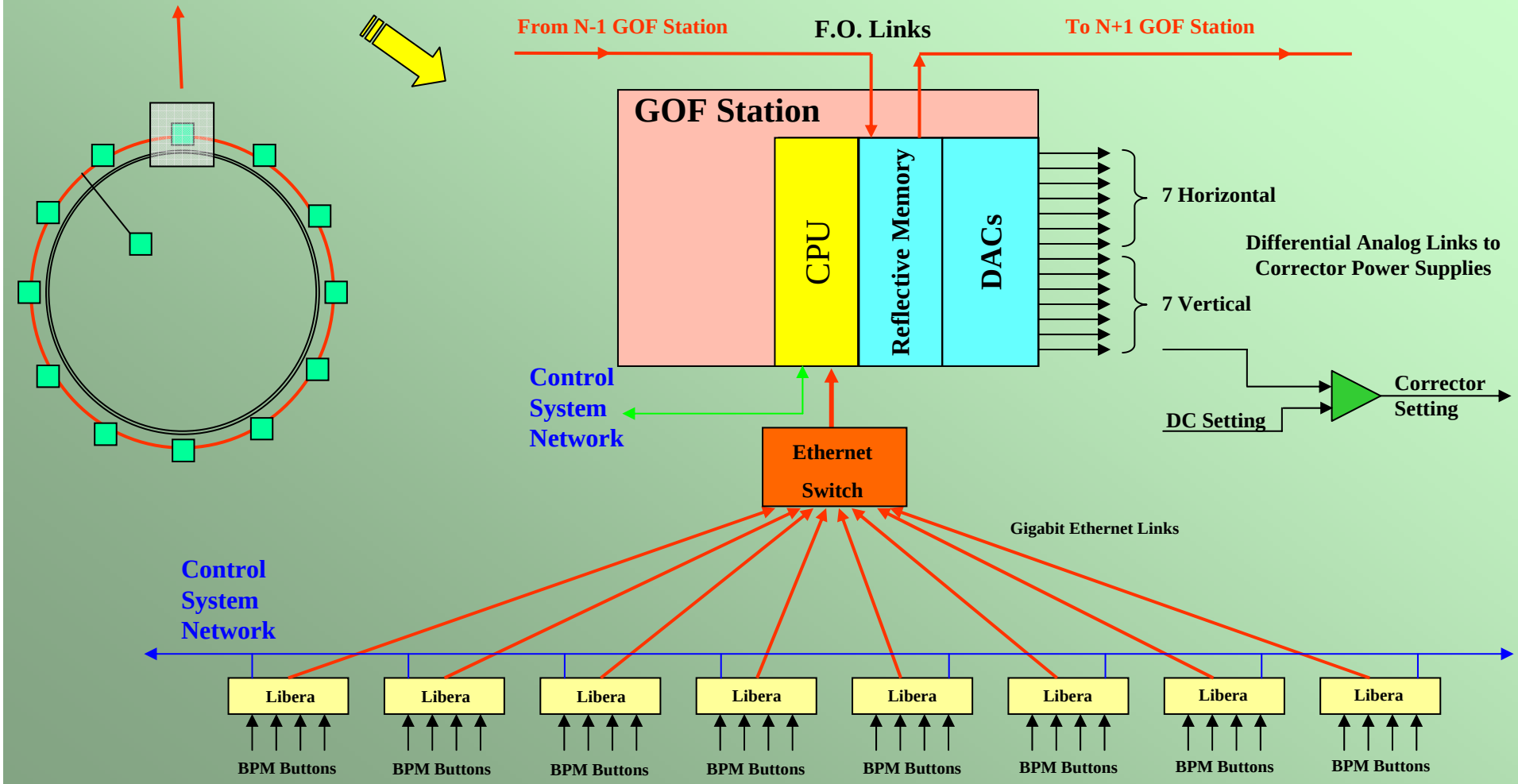
Global Orbit Feedback Architecture

- 96 rohmboidal + 4 low-gap BPMs all equipped with Libera Electron
- 82 corrector magnets per plane
- 12 + 1 VME GOF stations with Motorola 6100 CPU boards running Linux (Tango control system) and RTAI real-time extension (feedback processing)
- Gigabit Ethernet to acquire 10 kHz data from Libera Electron
- Reflective Memory to share data in real-time: 13 PMC modules, fibre optics
- PMC DAC modules to convert corrections to analog
- Event system: 1 EVG, 12 EVR, Libera Clock Splitters and fibre optics to distribute MC, SC, PM and Trigger signals



Global Orbit Feedback Architecture

Schematics of one of the 12 GOF stations



Real-time performance

- Libera latency: 300 μs
- Gigabit Ethernet transmission time: 10 μs
- Ethernet switch latency: 1 μs
- Reflective Memory Latency (BPMs and correctors data): 25 μs
- matrix multiplication and 14 control channels (LP Filter + PID + 10 HS): 21 μs
- DAC settings: 10 μs
- all real-time tasks executed in 60-80 μs

CPU Load (G4 PowerPC @ 1.3 GHz)

- feedback processing under RTAI: 60-70 %
- 8 TANGO servers (25 devices), control system interface, FFT of 10000 samples

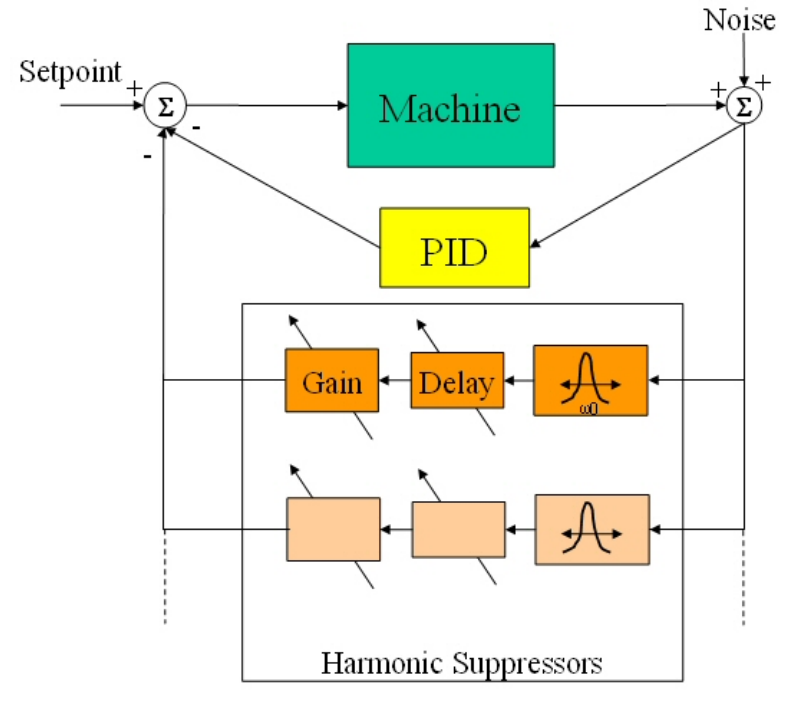
20 times per second with transmission to the client: 20%

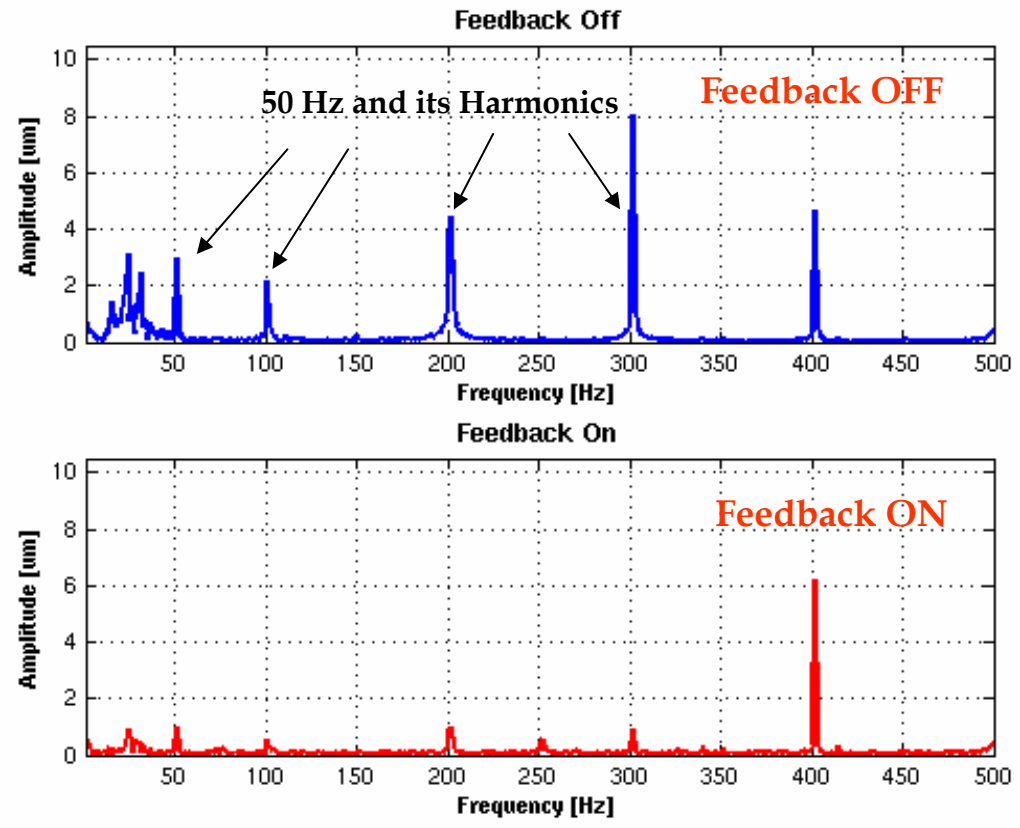
Local Stations

One of the twelve local stations

Correction and Control Algorithms

- SVD algorithm to invert the response matrix (48/24 eigenvalues)
- PID (K_P=3, K_I=0.01, K_D=5, f_c=100Hz), 3dB attenuation point at 150 Hz
- Harmonic Suppressors at: 50, 100, 150, 200, 250 and 300 Hz

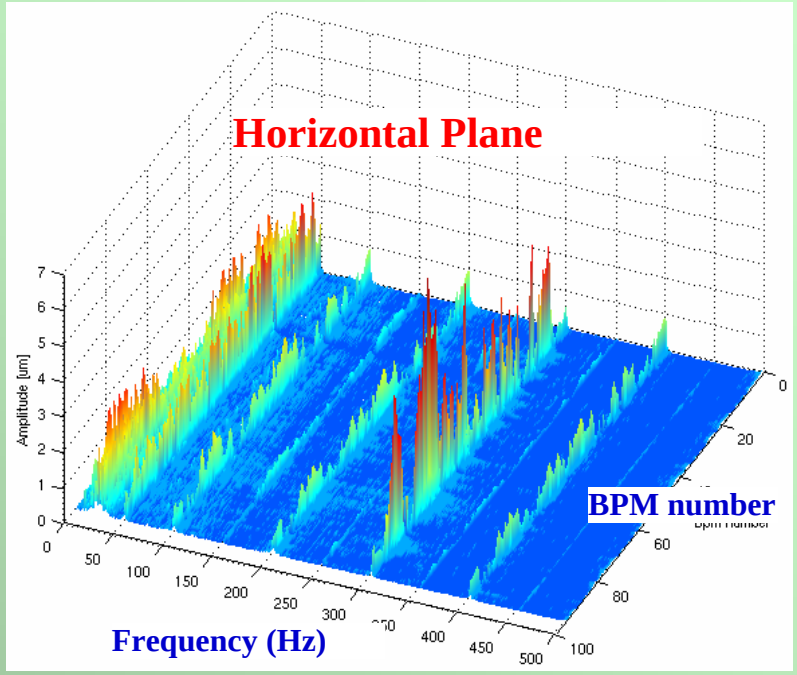




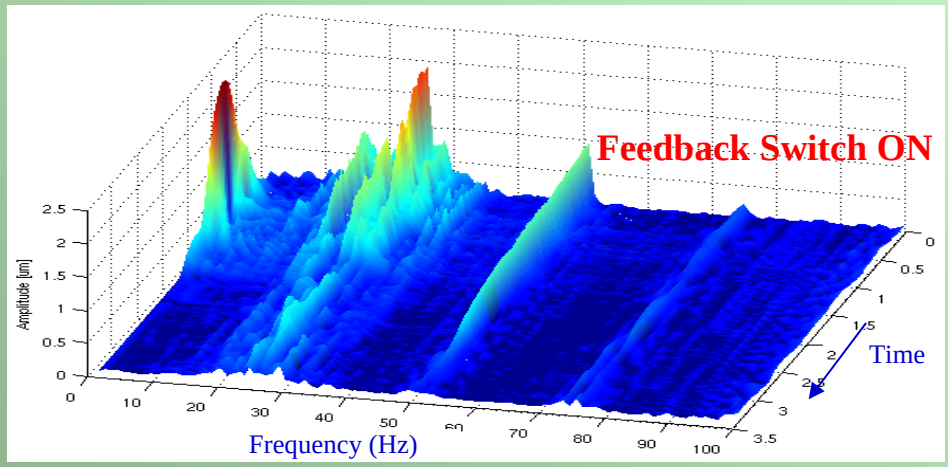
Diagnostic Features

Diagnostic capabilities for machine physics studies, investigation of beam noise sources, searching of malfunctioning machine components

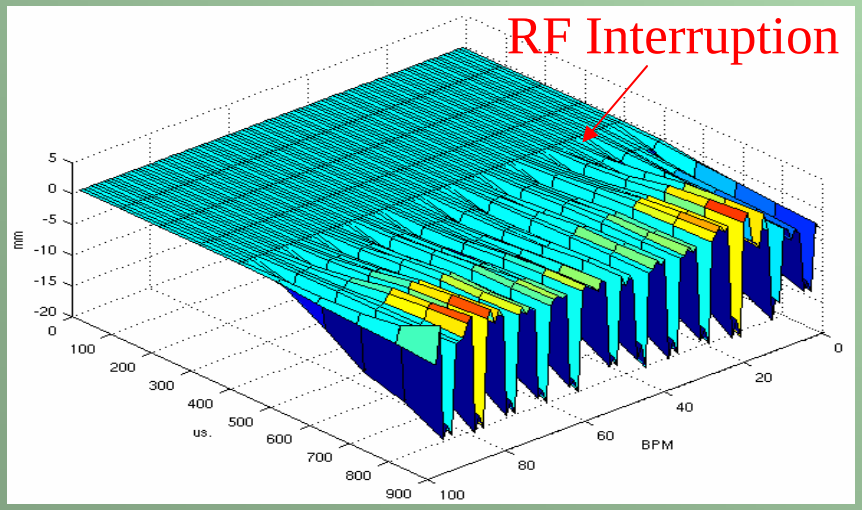
- **Data recording:**
  - *Each local station stores:*
    - 8 seconds of 10kHz data (BPMs and correctors);
    - 5 days of 1Hz data;
  - *Master station stores:*
    - 5 seconds of 10kHz synchronous data of all BPMs and correctors
- **Post Mortem Analysis:** buffers stop automatically under given conditions on BPM signals allowing beam dump detection
- **Arbitrary Waveform generation:** driven by the master station, used to measure the corrector magnets transfer function



Diagnostic Features



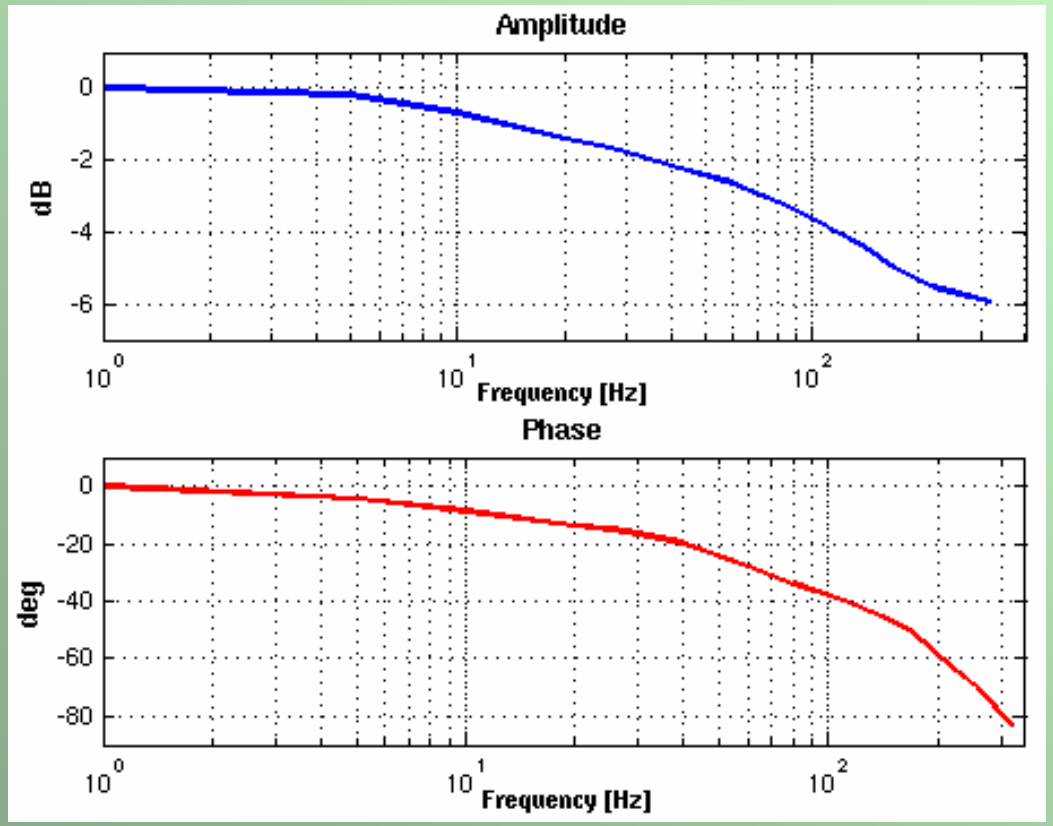
Spectrum of the beam position during a smooth loop closure



Post mortem data displayed in a 3-D plot: evolution of the horizontal closed orbit after interruption of the RF voltage in the accelerating cavities

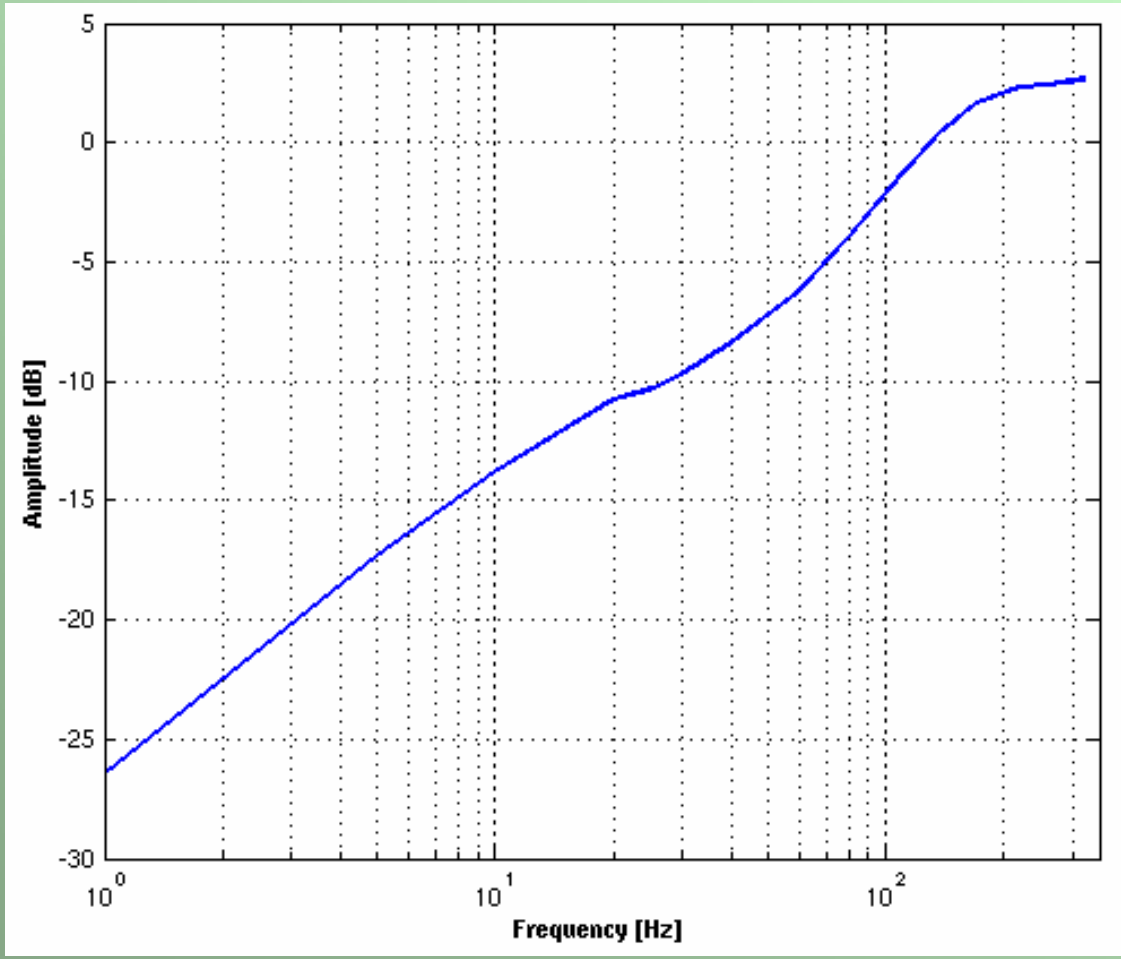
Corrector Magnets Performance

Amplitude and phase response of a corrector magnet measured by exciting it with sinus waves at different frequencies



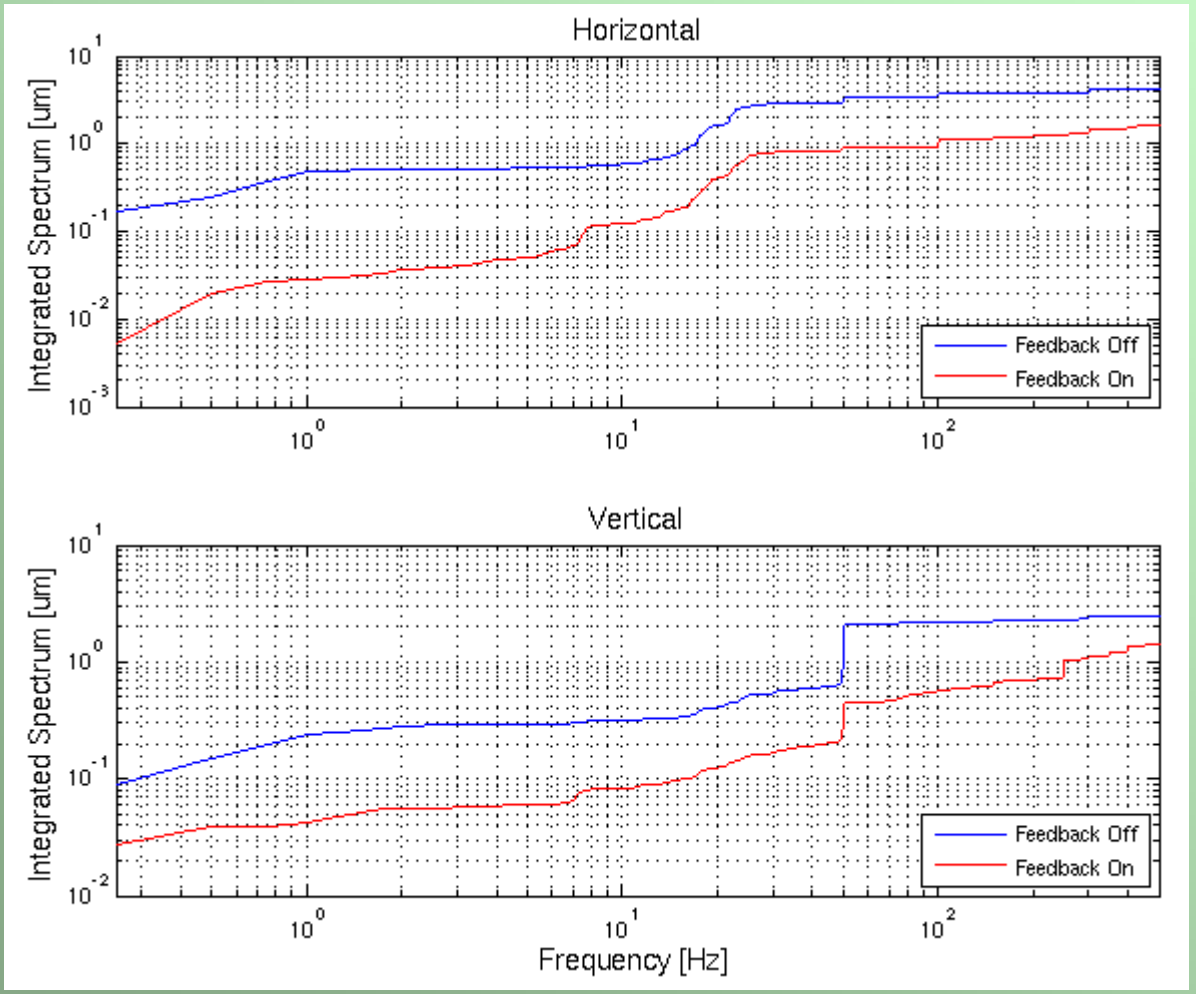
Closed Loop Noise Attenuation

Closed loop transfer function (sensitivity function) showing the attenuation of noise components as a function of frequency



Closed Loop Performance

Integrated amplitude spectrum of the beam position noise measured by a BPM with feedback off and on



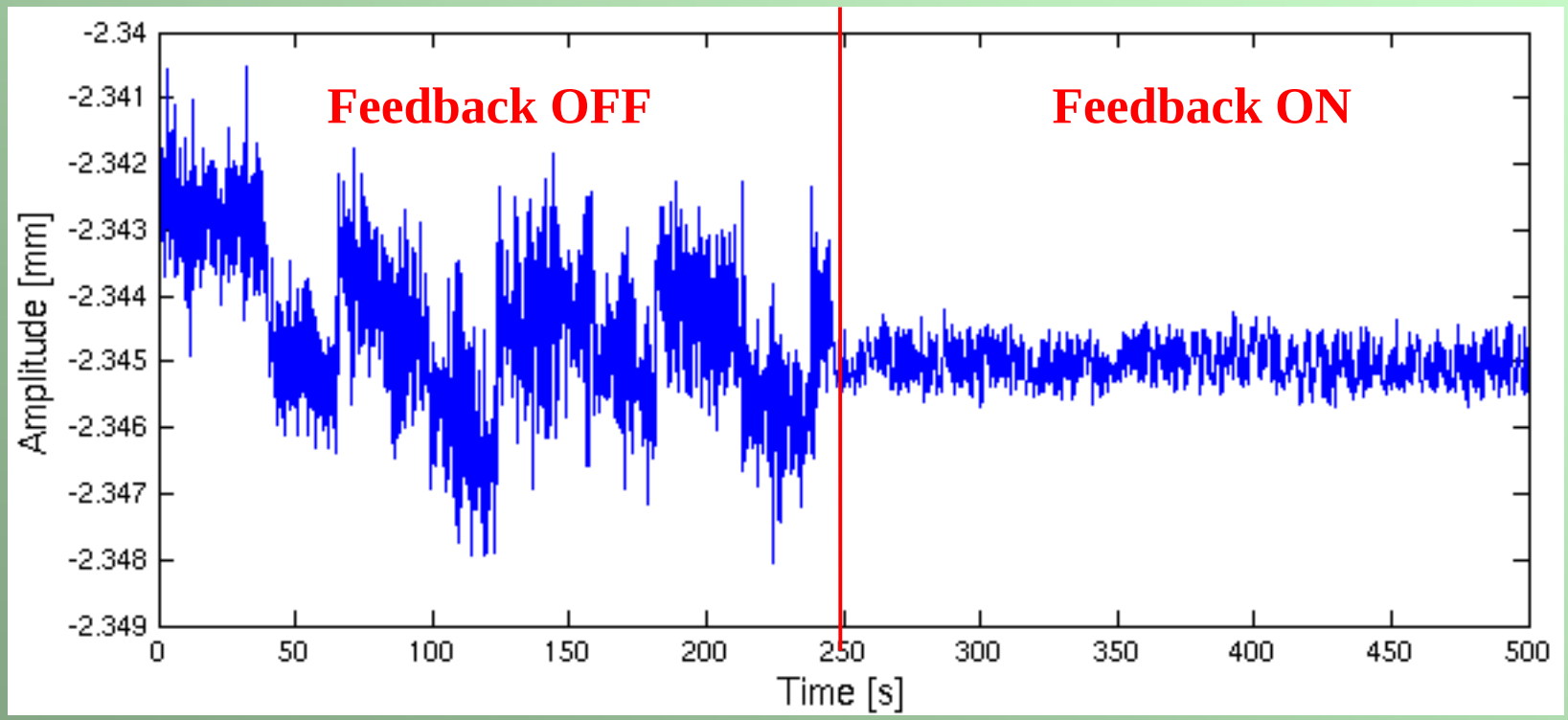
Closed Loop Performance

Average BPM rms in μm in the 0-5 Hz and 0-200 Hz frequency range with feedback off/on

	0 - 5 Hz	0 - 5 Hz	0 - 200 Hz	0 - 200 Hz
	Horizontal	Vertical	Horizontal	Vertical
FB off	0.4	0.15	3.5	2.1
FB on	0.1	0.06	1.1	0.7

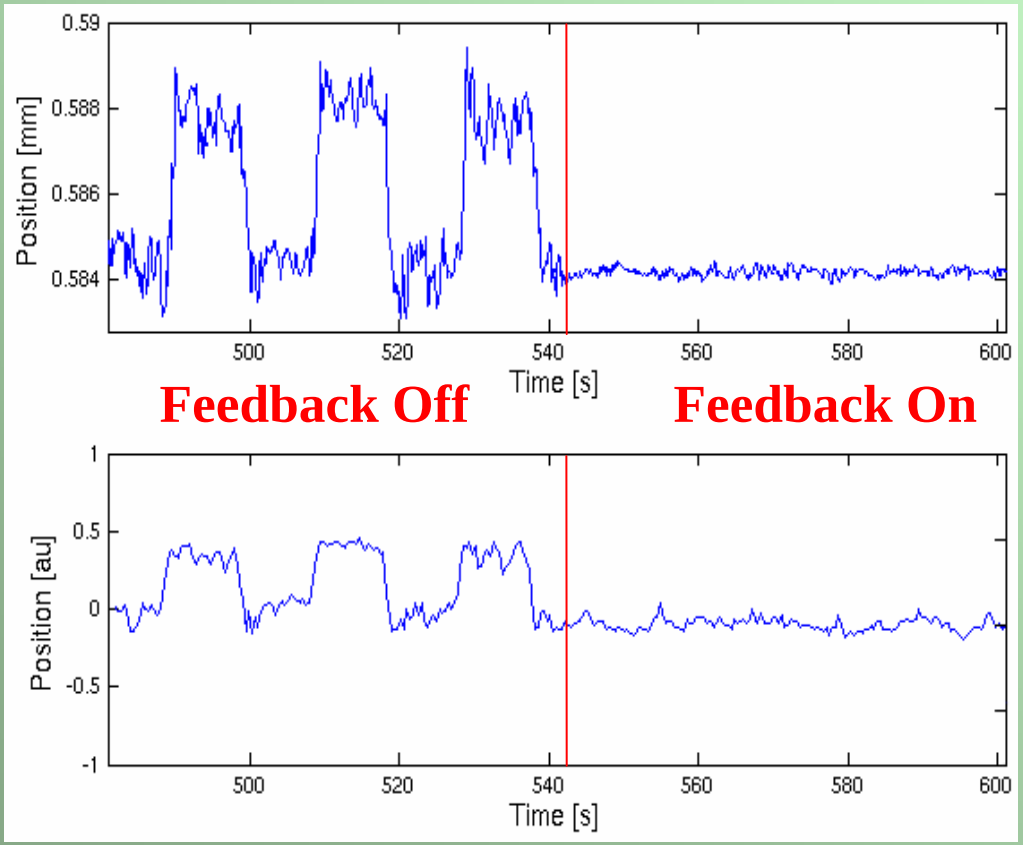
Closed Loop Performance

Horizontal beam position measured by a low-gap BPM with feedback off/on

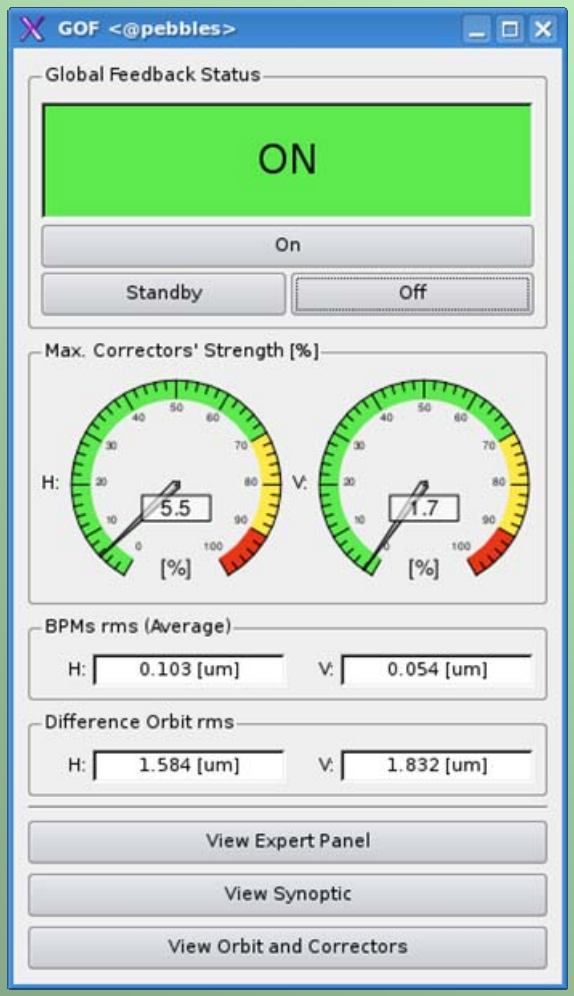


Closed Loop Performance

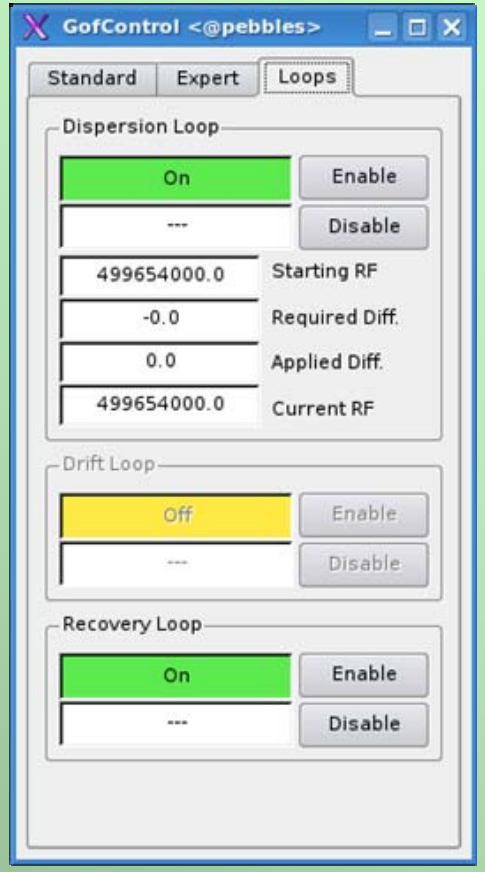
Effect of the feedback in the vertical plane measured by an electron (top) and a photon (bottom) BPM. The beam orbit is perturbed by the operations of the electromagnetic elliptical wiggler



Control Room Panels

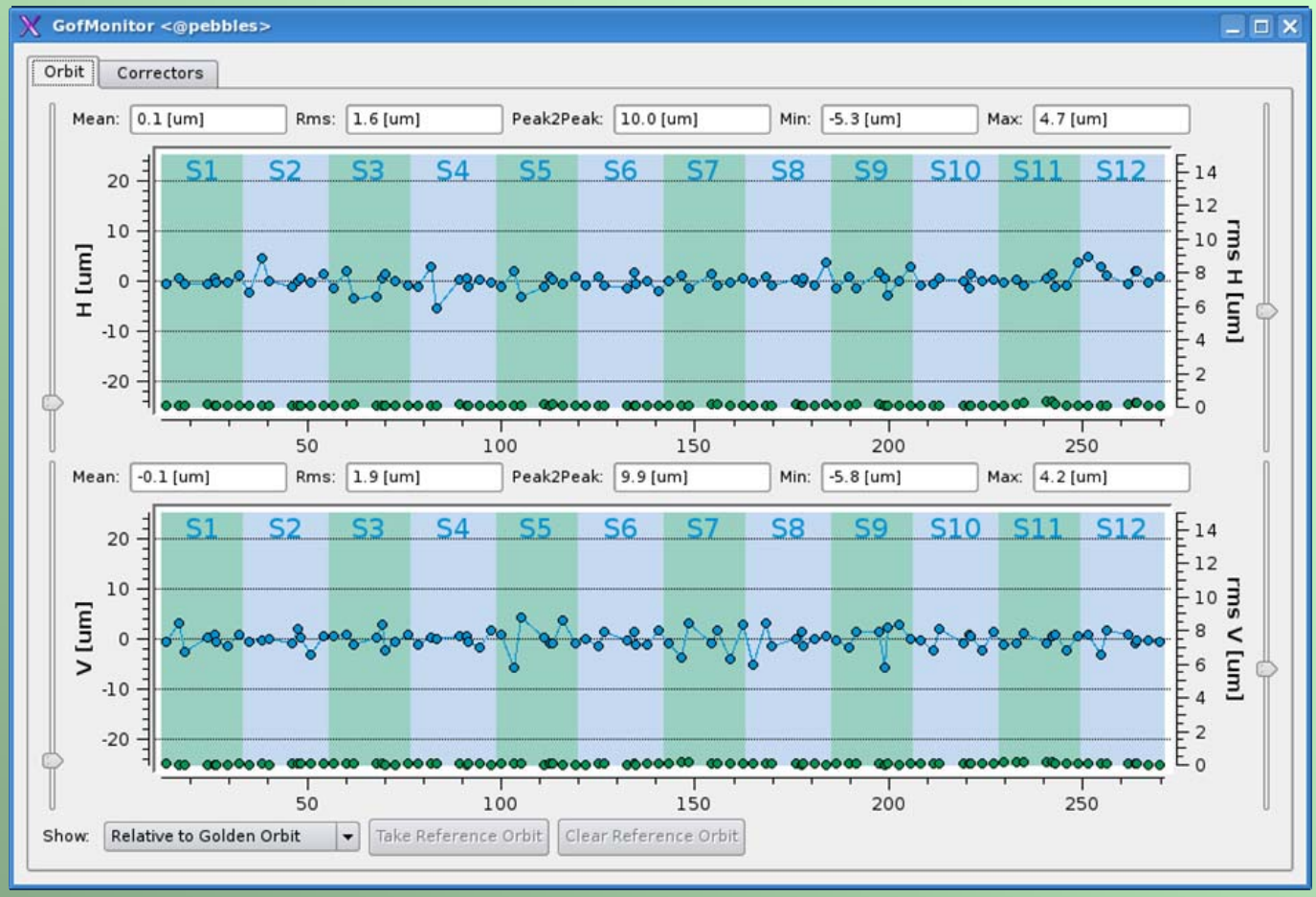


Control Room Operator Panel



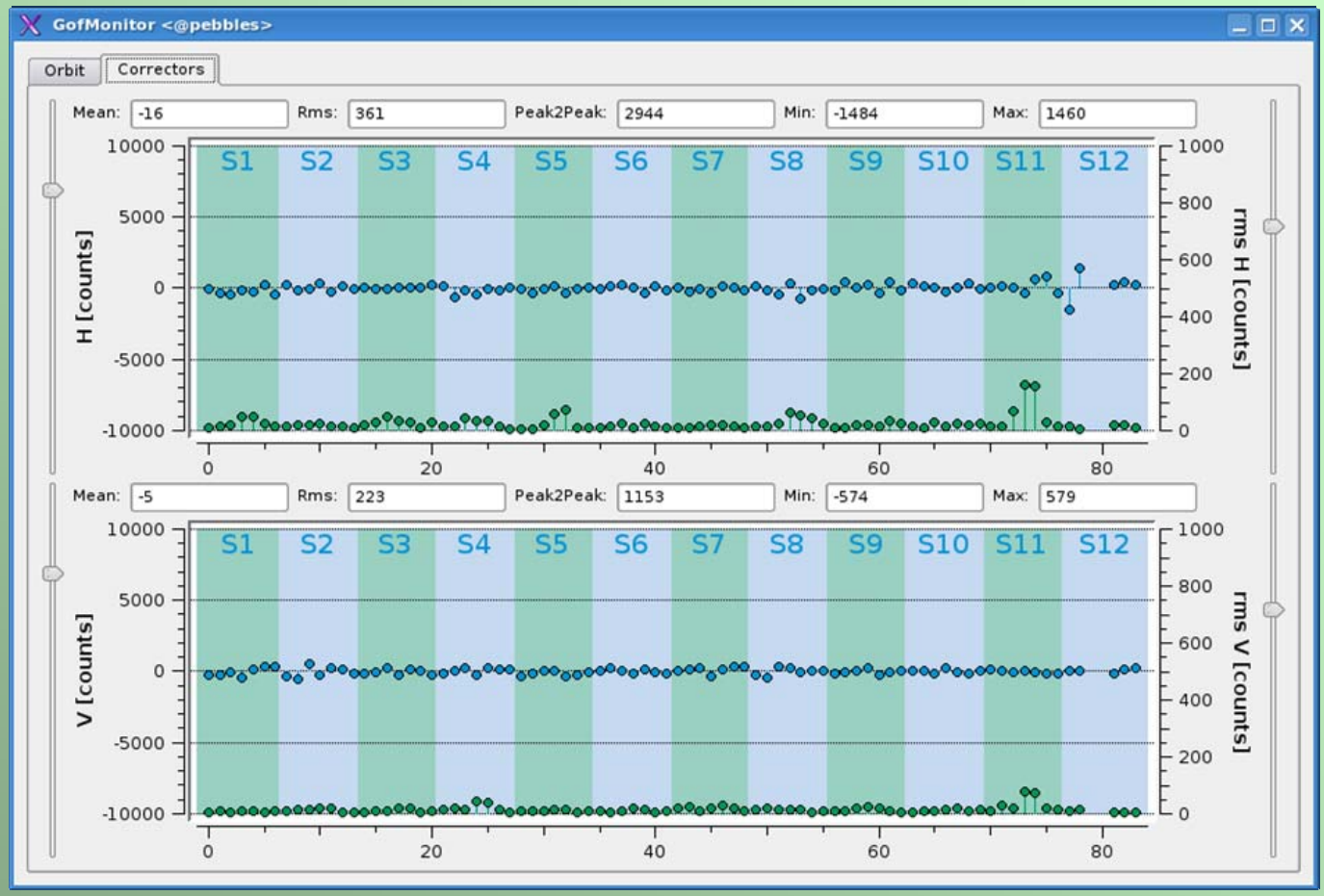
Expert Panel

Control Room Panels



Orbit Survey Panel

Control Room Panels



Correctors Survey Panel

Libera at Elettra

- 107 Libera Electron purchased in 2006, 100 installed
- Release 1.42 presently used, 1.60 received and partially tested in laboratory
- Embedded Tango Device Server running in the SBC on top of the Generic Server (still not possible without it)
- Gigabit Ethernet interface defined together with I-Tech works fine: straightforward commissioning, reliable operation, negligible jitter
- After the first difficulties following the delivery (middle 2006) due to young software/firmware and a few hardware bugs, now Libera Electron is stable and with acceptable performance for Elettra
- A list of new features and improvements agreed with other Libera users have been delivered to I-Tech

Closed Loop BPM *rms*

An annoying problem still to be solved is the change in position readings when the attenuators are switched: steps ranging from 0 to 5 μm

Problem momentarily bypassed by disabling the ACG when the feedback is activated