

ORBIT CONTROL WITH LIBERAS

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On behalf of Diagnostics group



- **Libera modules**
 - Overview
 - Data Flow
 - Principles
 - Performances

- **Orbit Control**
 - Fast Orbit Feedback
 - Interaction with Slow Orbit Feedback

- **Experience with Libera**
 - Reliability
 - Libera users community

- **Electronic modules for Beam Position Monitor**
- **Industrial device**
 - Specified by SOLEIL for light sources
 - Detailed design and construction by Instrumentation Technologies (Solkan, Slovenia)
- Machine equipped with Libera:
 - New machines:
 - SOLEIL
 - DIAMOND
 - Australian Synchrotron
 - ALBA
 - NSRRC
 - SSRF
 - PETRA III
 - Upgrades:
 - ELETTRA
 - ESRF
- Product evolves with the new customers:
 - Libera Electron became Libera Brilliance (new RF board)



Overview

- Outside:**

2 serial RS485 ports

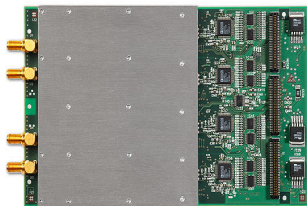
Ethernet link for communication and integration into the control system

8 SFP connectors linked to FPGA Rocket I/Os for fast communication

Timing interface: trigger, clocks, interlock and Postmortem

4 analog inputs from pickups

- Inside:**



Analog Board (4 multiplexed channels)



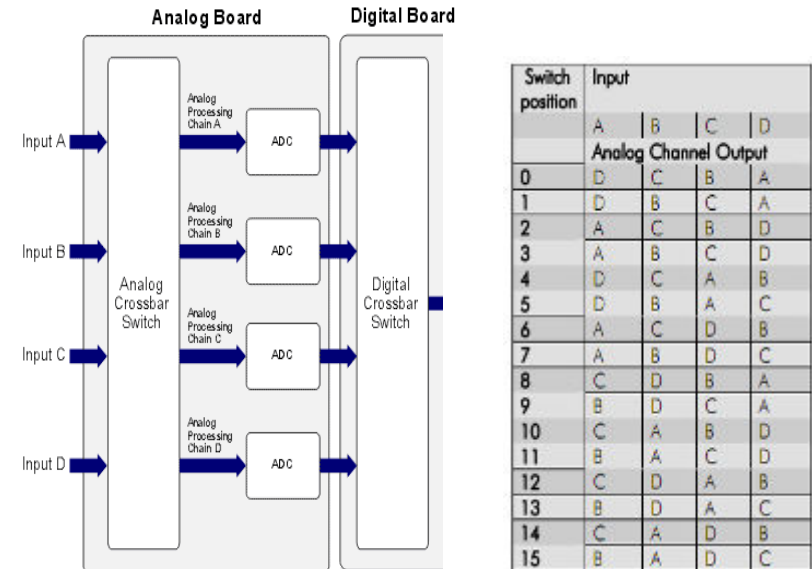
Digital Board (Xilinx V2P FPGA)

Single Board Computer (SBC):

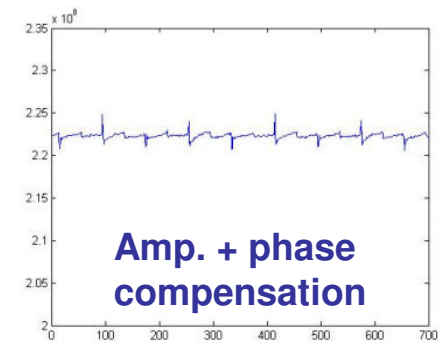
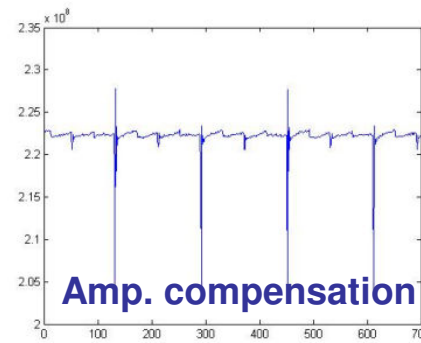
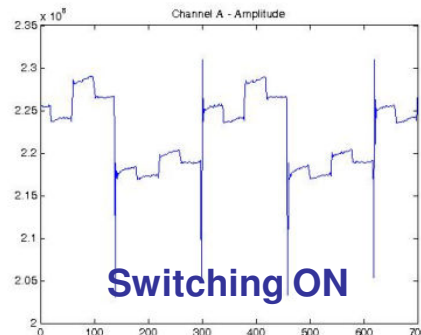
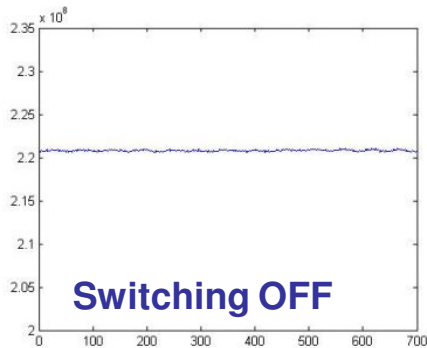
- ARM processor
- Linux
- Some data processing and interface with Control Command

Libera principles: switching

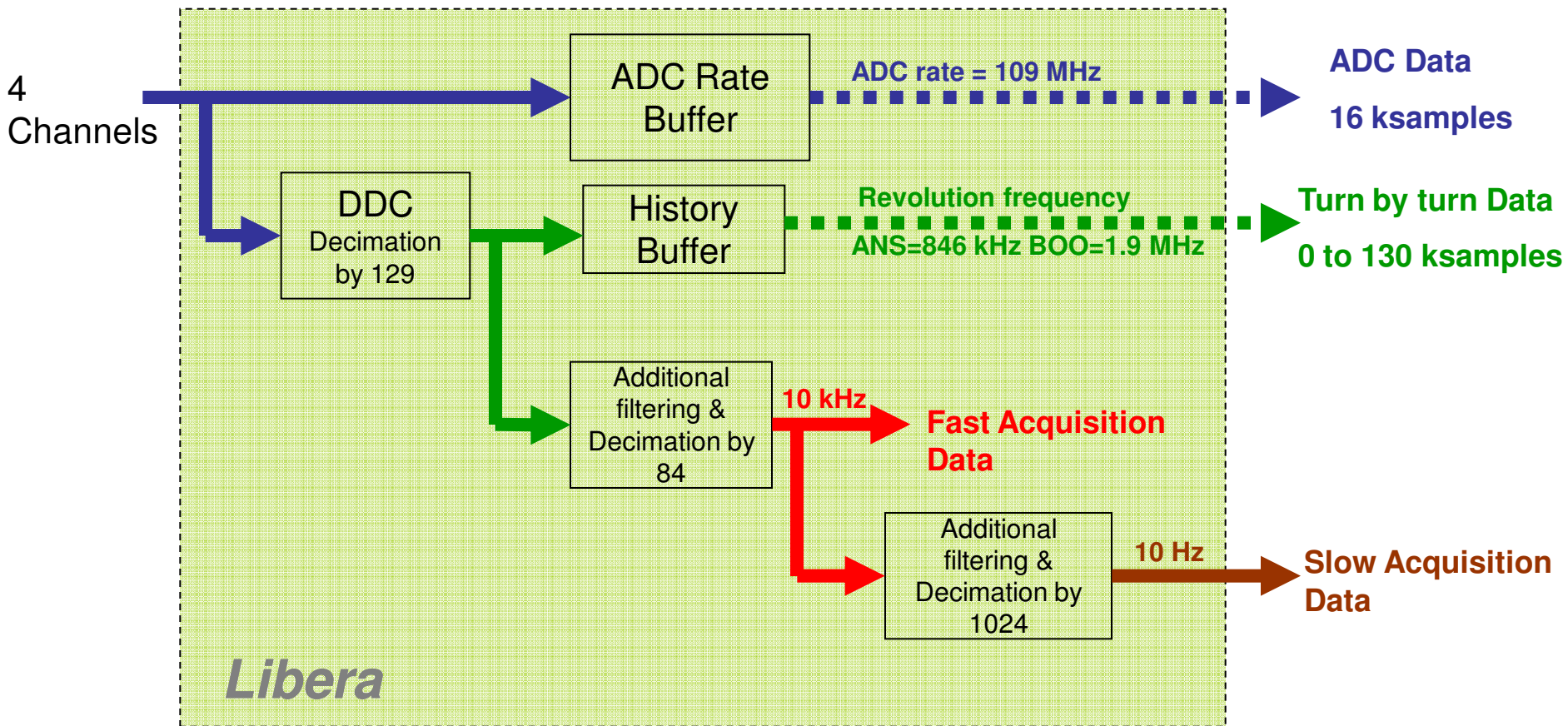
- Takes advantages of the 2 following systems:
 - **4 channels**
 - High sampling rate, Bandwidth
 - High Resolution
 - **Multiplex channel**
 - Temperature dependence
 - Beam current and filling pattern dependence
- Need for a **switching mechanism**
 - Rotation frequency ≈ 13 kHz
 - 8 positions (out of 16 possible)



- **Digital Signal Conditioning** to minimize side effects of switching mechanism:



Libera Data Flow

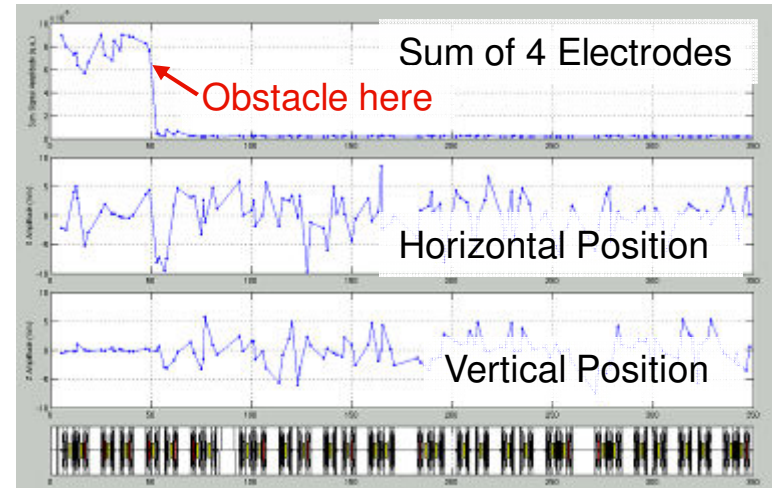


■■■▶ : Data on demand
 —▶ : Continuous data flow

Available on
 Ethernet port

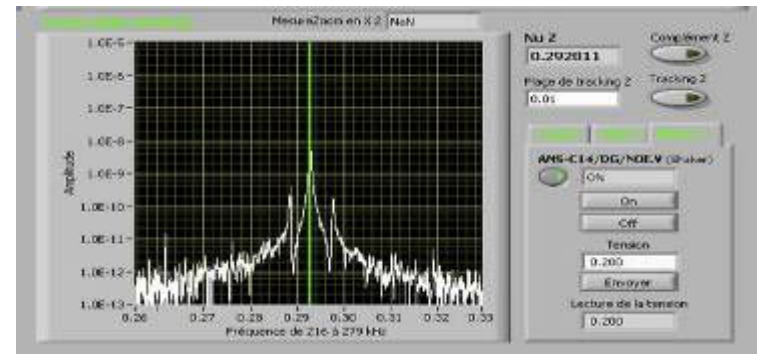
Libera Data Flow: Turn By Turn

- Characteristics:
 - Sampling rate at revolution frequency:
 - 846 kHz for SOLEIL storage ring
 - Buffer of data on demand
 - Recorded automatically or on trigger
 - Va, Vb, Vc, Vd, X, Y, Q and Σ



First Turn

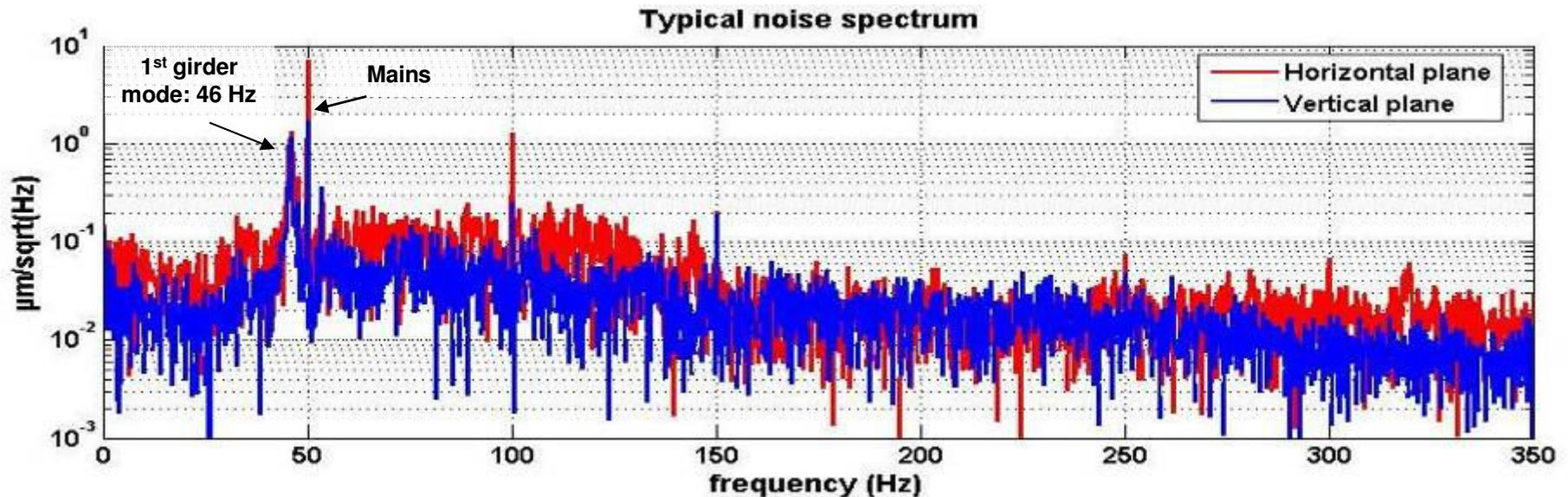
- Applications:
 - Commissioning: first turns
 - Monitoring of booster and transfer lines
 - Machine Physics studies
 - Tune measurements



Tune measurement

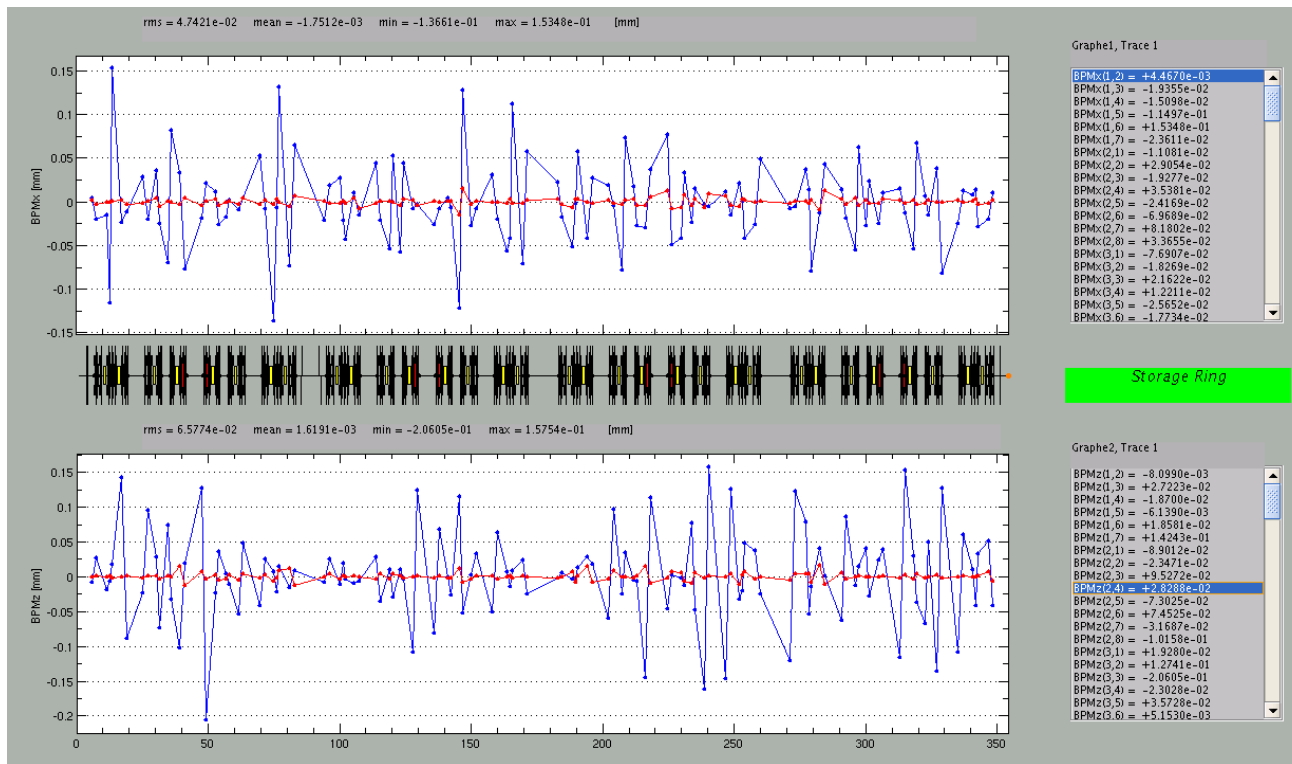
Libera Data Flow: Fast Acquisition

- Continuous data flow at 10 kHz with a bandwidth of ~2 kHz
- Distributed on fast communication dedicated ports
- Purpose:
 - Fast Orbit Feedback System
 - Monitoring of beam position spectra
 - Internal position Interlock feature



Typical noise spectrum BPM + Beam 0 → 350 Hz

- Continuous data flow at 10 Hz
- Purpose:
 - Monitoring the stored beam
 - Data for Slow Orbit Feedback



SOLEIL ORBIT CONTROL

Manual Orbit Correction

H-plane

V-plane

Correct Orbit

Edit BPM, QM Lists

OFB + FOFB interaction

Orbit Feedback

H-plane

V-plane

Slow Orbit Correction

Correct RF Frequency

Start FB Stop FB

Horizontal RMS = 0.0071 mm

Vertical RMS = 0.0085 mm

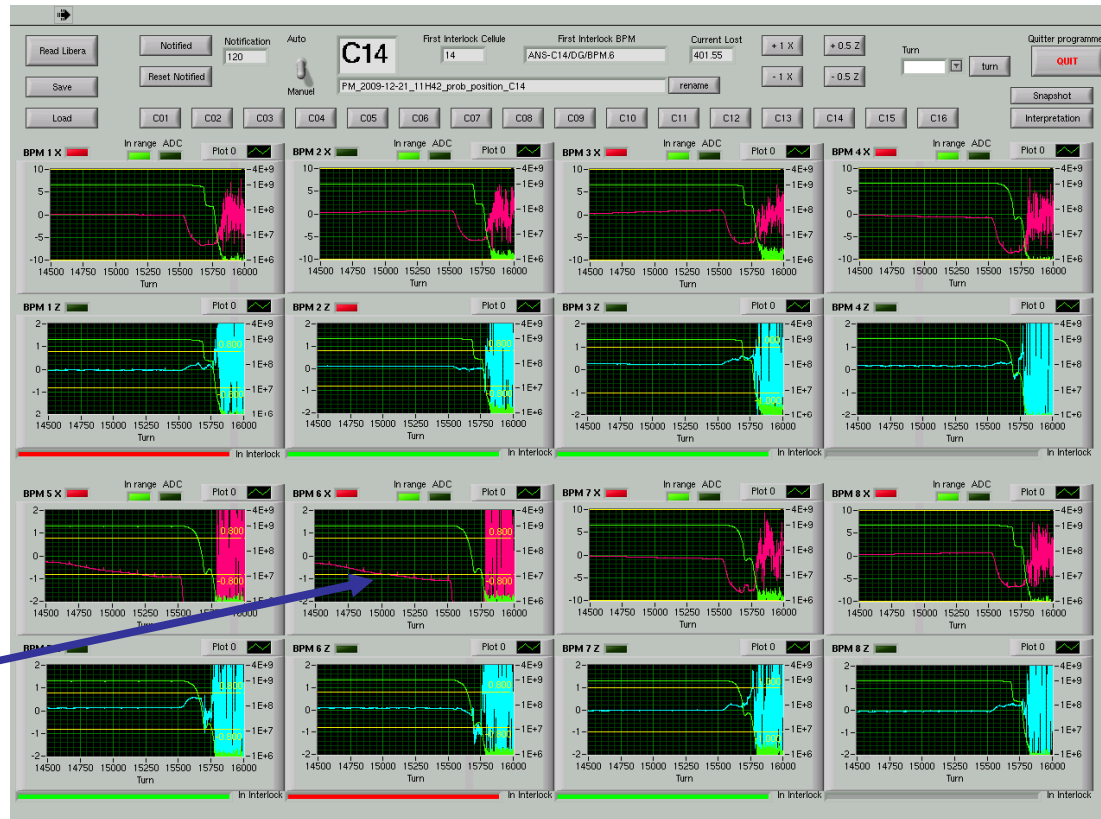
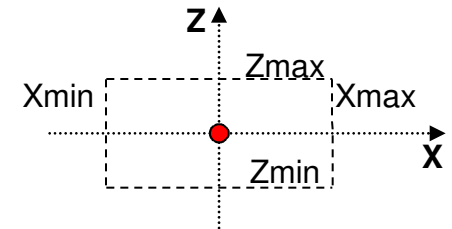
Edit SOFB Setup

Experimental Interface
SOFB Started

FOFB ready for interaction

Close

- **Position Interlock system** embedded in Libera modules
 - Interlock output is triggered if:
 - position measurement outside preconfigured thresholds
 - any ADC saturates (wrong measure of the position in this case)
 - Gain dependant: interlock is inhibited at low current
- **Post-Mortem**
 - A buffer of Turn by Turn Post-mortem data is frozen on user's demand (beam losses)



Interlock here

Libera Electron Performances: Resolution

RF generator

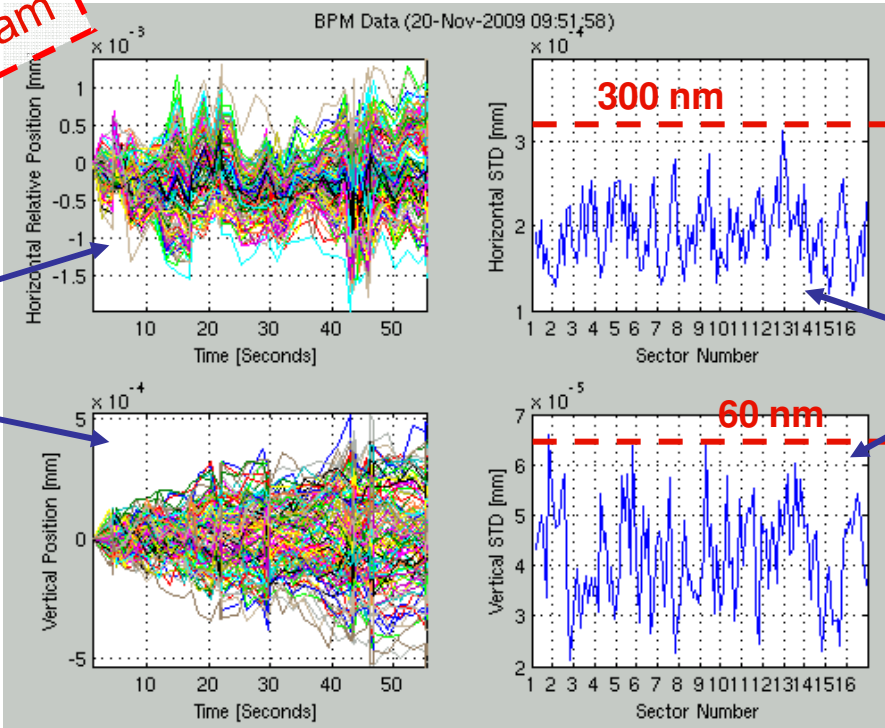
Data type (sampling rate)	RMS Noise (μm)	
	X	Z
Turn by Turn (Revolution frequency: 846 kHz)	2	3
Slow Acquisition (10 Hz)	0.02	0.05

Beam

60 sec of SA data on the beam

H

V



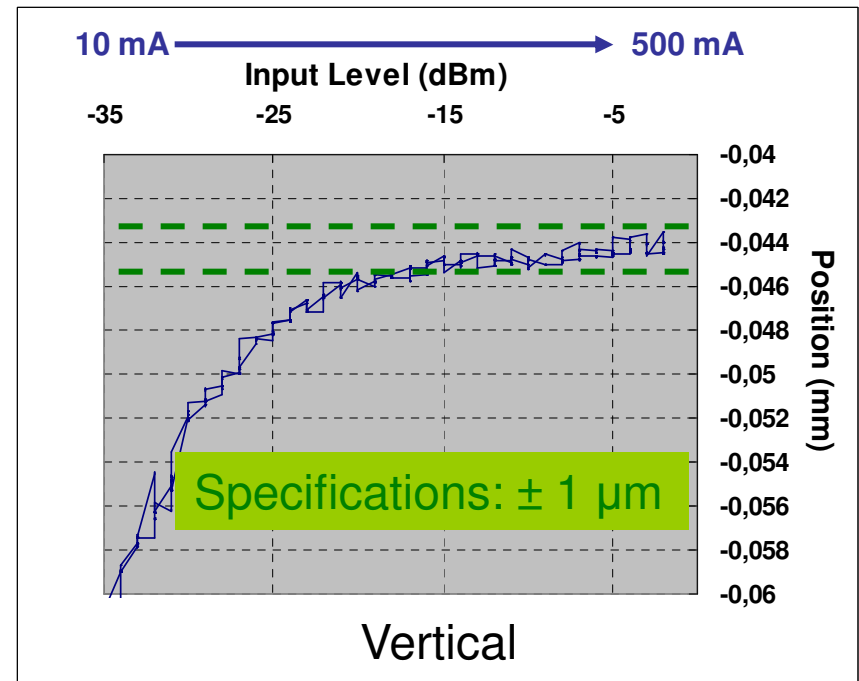
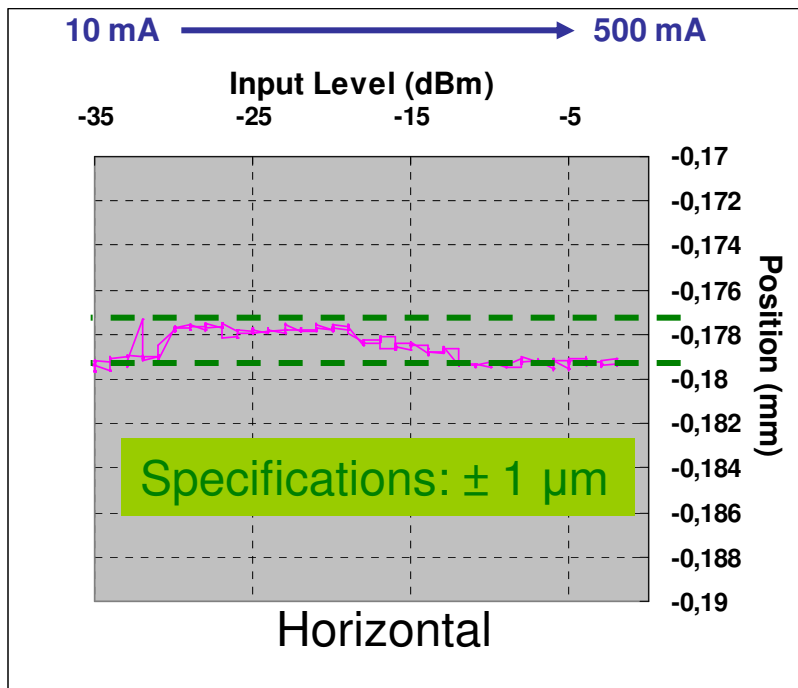
H

V

RMS Noise on 120 BPMs

Libera Electron Performances: Beam current dependence

- Automatic Gain Control:
 - Front-end attenuators values are automatically adjusted to input level
 - Steps $< 1 \mu\text{m}$ at each change of attenuators value



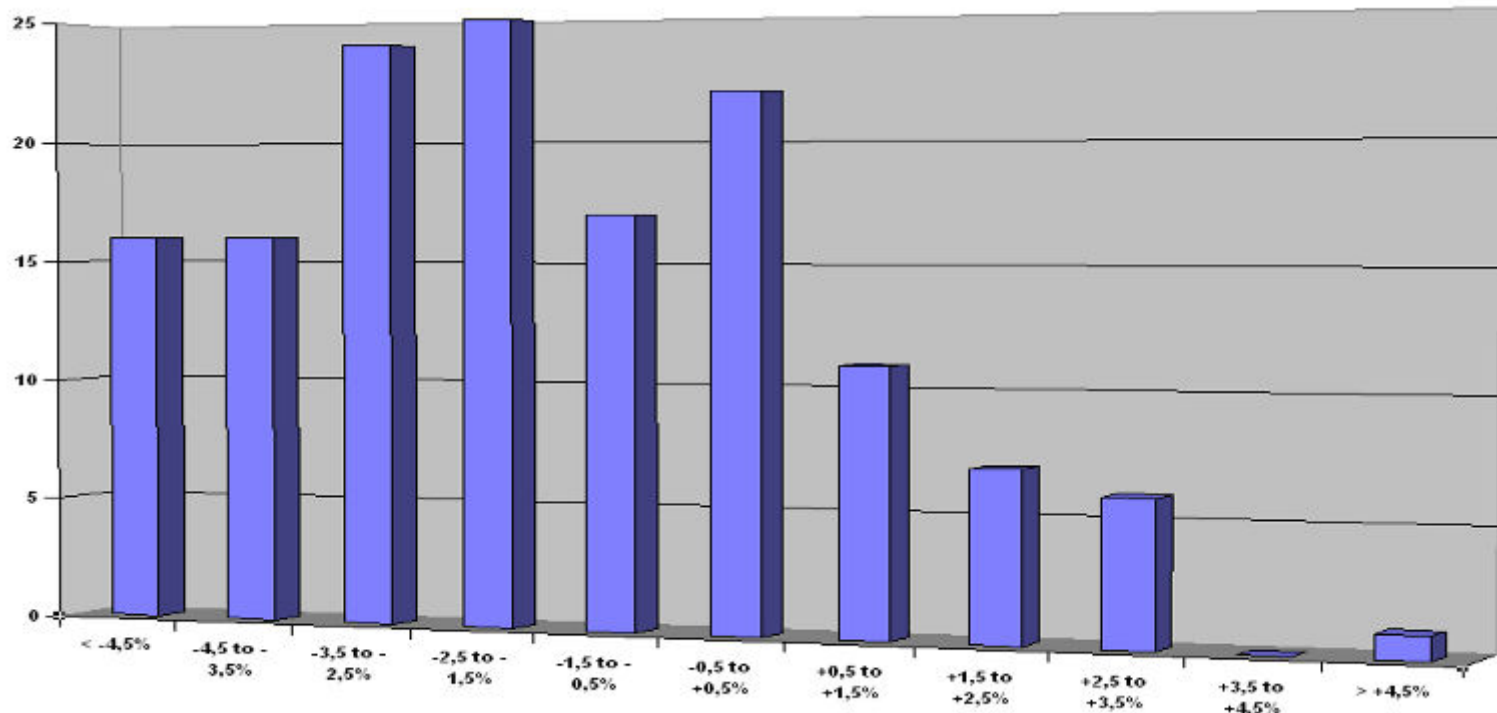
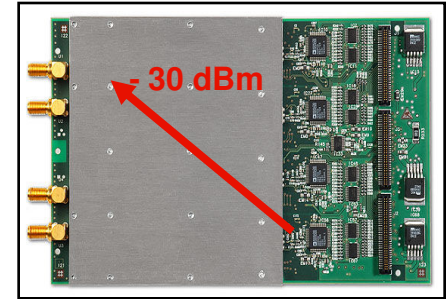
- Correction tables are available to compensate BCD
- Improved (announced $< 1 \mu\text{m}$) with 'brilliance' version of Liberass

Libera Electron Performances: Crosstalk

- **Crosstalk:**

- Due to non perfect isolation between the 4 channels, movements in one plane affect the position measurements in the other plane.
- Crosstalk H->V has been measured on 145 modules.

Results ($\Delta Z_{\text{perturbated}} / \Delta X_{\text{movement}}$) gives:



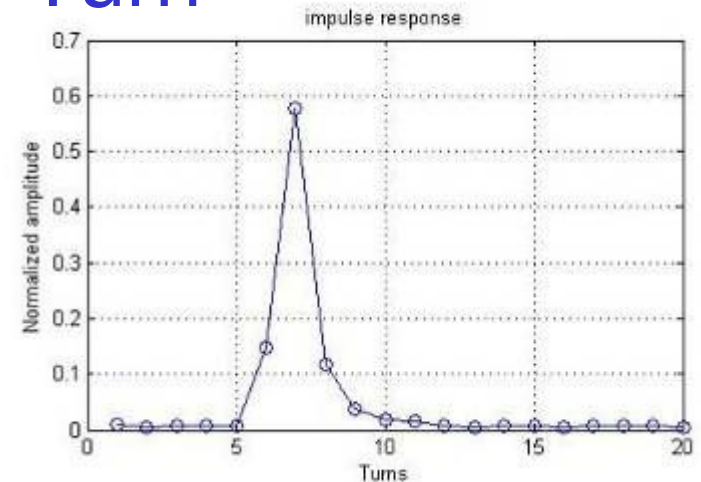
- Has been improved with 'Brilliance' version of Liberass (-45 dBm instead of -30 dBm for 'Electron' version)

Libera Electron Performances: Turn by Turn

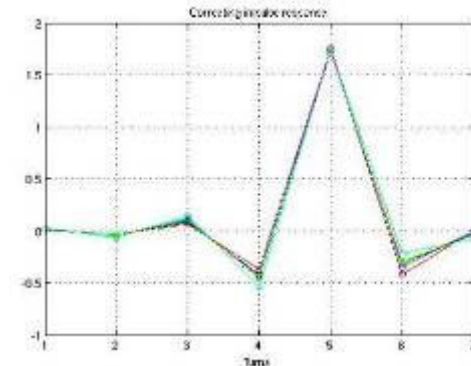
- **Digital filtering for TbT data introduces:**
 - Smearing between turns
 - Frequency dependant amplitude attenuation
 - **Problematic for Machine Physic studies (FMA,...)**

- **2 Solutions are investigated:**
 - **New filtering**
 - Moving average filter (MAF)
 - Filter configuration depend on the filling pattern
 - Not satisfying at the moment (poor resolution for short pulses)

 - **Offline data processing**
 - Deconvolution of standard TbT data
 - Most promising solution



acquisition window with adjustable length and delay

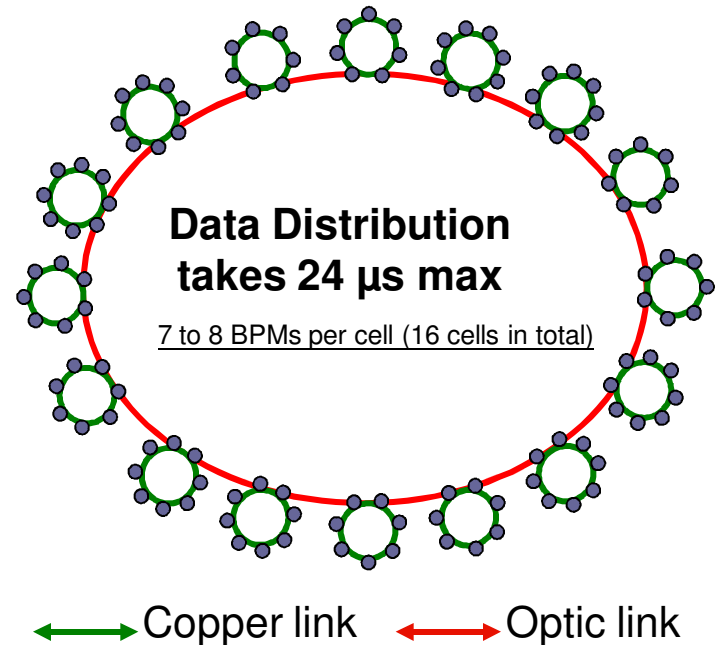
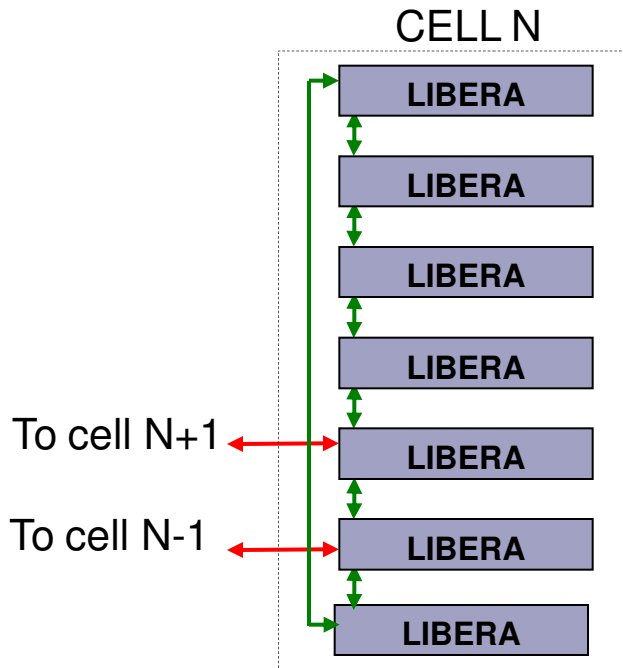


Libera and Orbit Feedbacks

- **2 sets of data used for orbit stabilization**

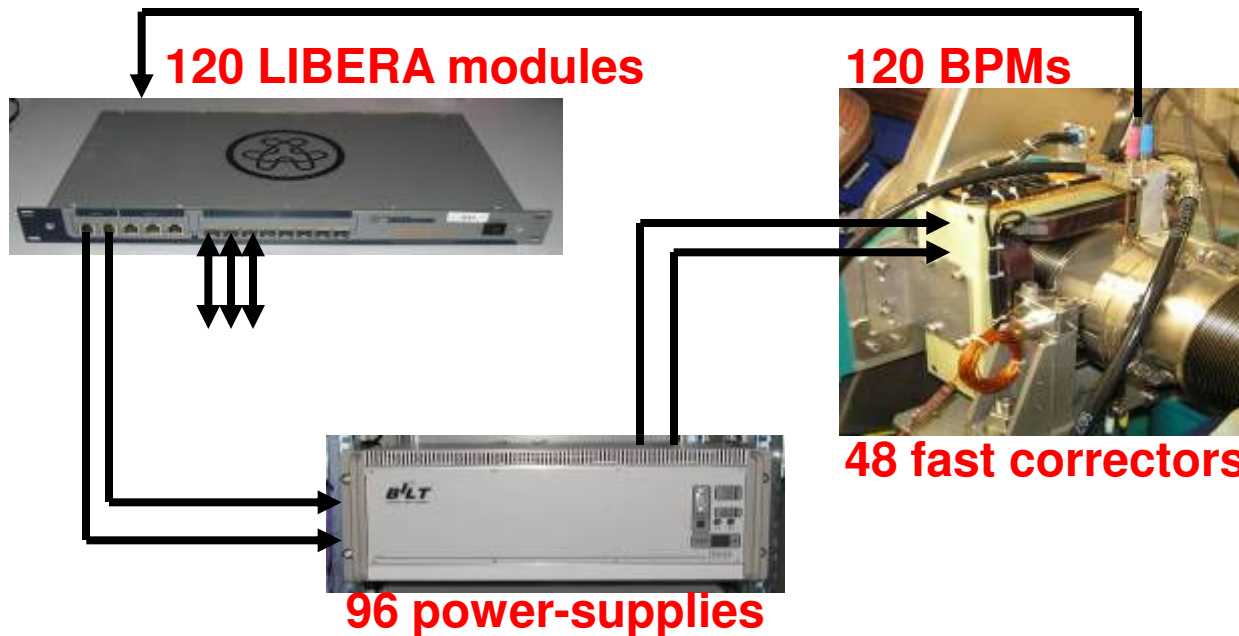
- **Slow Acquisition Data (10 Hz)** → Ethernet network to control command
 - Correct closed orbit
 - Slow Orbit Feedback (56 slow and strong correctors)
- **Fast Acquisition Data (10 kHz)** → Dedicated network for data distribution
 - Fast Orbit Feedback (48 fast but weak correctors)

Dedicated network topology for FA data distribution:



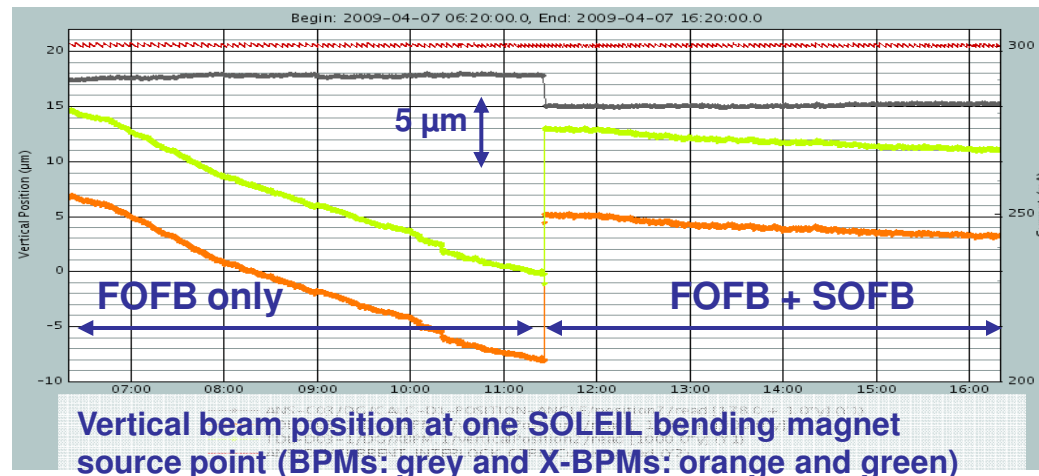
FOFB Architecture

- **FOFB algorithm is embedded in the LIBERA FPGA code**
 - Matrix multiplication split and distributed
 - One Libera process only one line of the inverse response matrix
 - 48 Libera (out of 120) are calculating correction data for FOFB
 - New correction set points are sent to fast power-supplies at 10 kHz



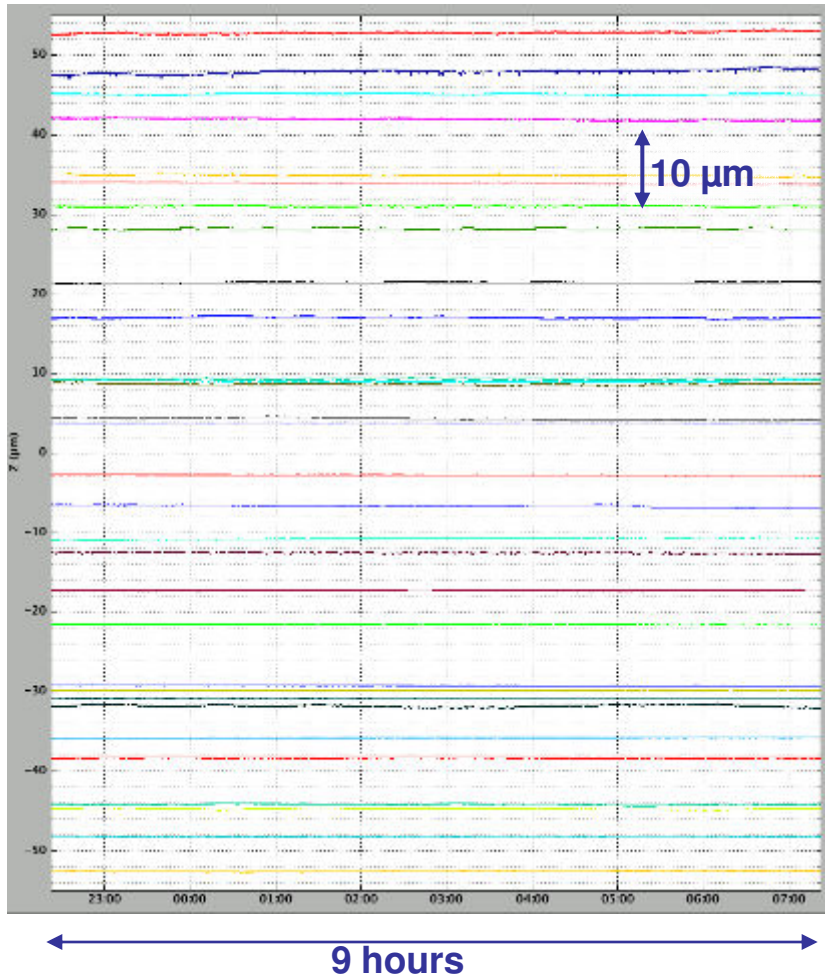
Libera and Orbit Feedbacks

- **SOFB and FOFB are running together without frequency deadband (down to DC)**
 - **Interaction between slow and fast systems**
 - SOFB cancels DC part of the Fast Correctors
 - SOFB calculates a new reference for FOFB by predicting movement caused by its next correction. This new reference orbit is continuously updated on all LiberAs.
 - **Benefits of both systems efficiency**
 - Suppression of perturbations at high frequencies but also caused by insertion devices with FOFB
 - Long term stabilization with SOFB

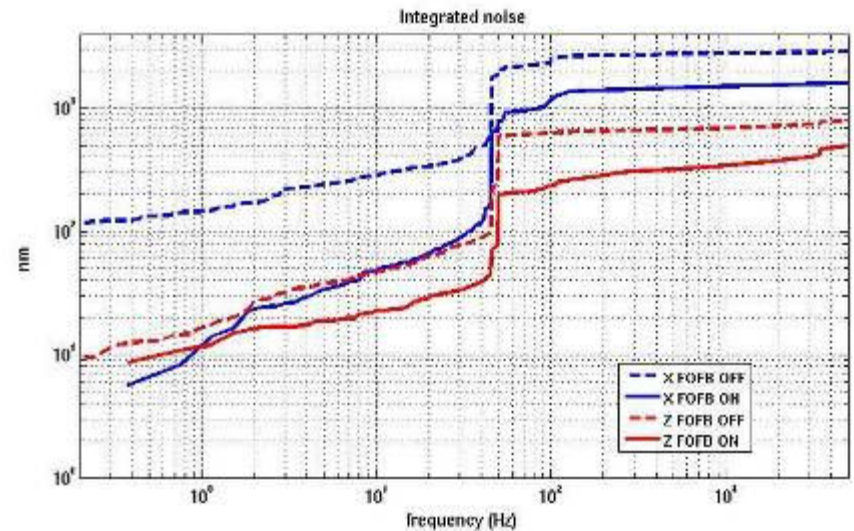


Libera and Orbit Feedbacks

- Vertical position stability at source points



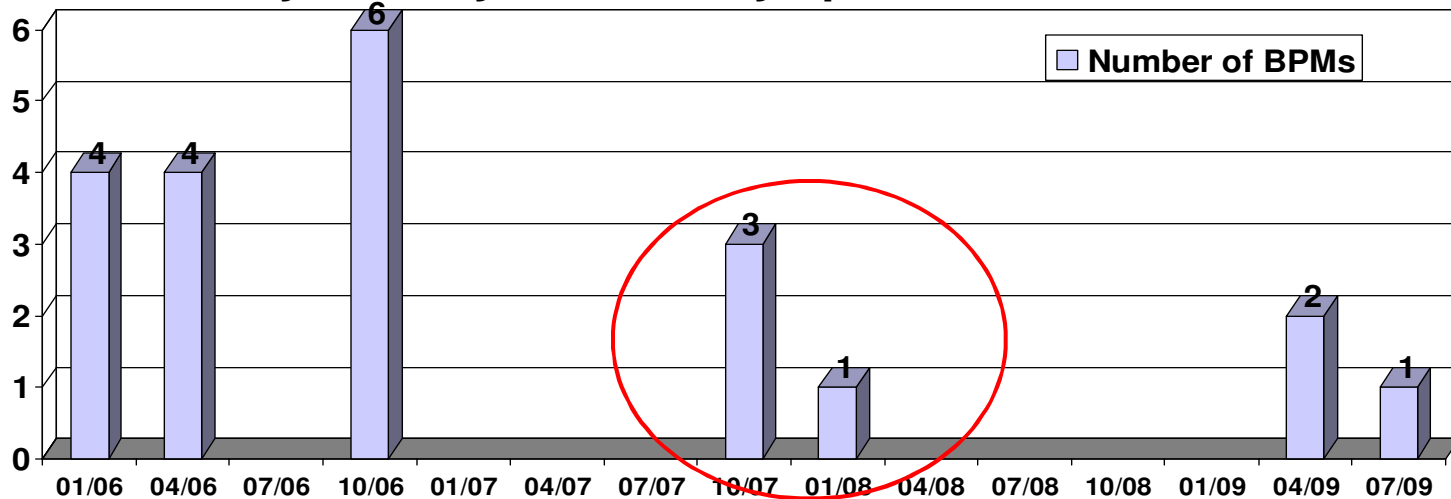
- FOFB efficiency



SOLEIL cumulated PSD in a straight

- **161 modules at Soleil in operation since 2006 (120 on the storage ring)**
 - **Systems rebooted twice a year**
 - **1 or 2 system crashes per year**

- **Failures history over 4 years of daily operation:**



Youth defaults
(components,
soldering, SBC)

Components deficient from the
beginning but not tested until
that time

First 'real' breakdowns
2 analog boards
1 SBC

Libera Users Community

- **Libera are based on programmable ships**
 - Functionalities can be improved with software/firmware upgrades.
 - Based on users demands, Instrumentation Technologies produces 1 upgrade per year.
- **Users community**
 - For all Libera users
 - Meets once a year (May/June)
 - Discuss Libera issues
 - Present new developments
 - Have a practical session on a 'real machine'
 - Elaborate a 'wish list' for the next software release
- **Don't hesitate to join this meeting if you are interested in using Liberass**



THANK YOU FOR YOUR ATTENTION !