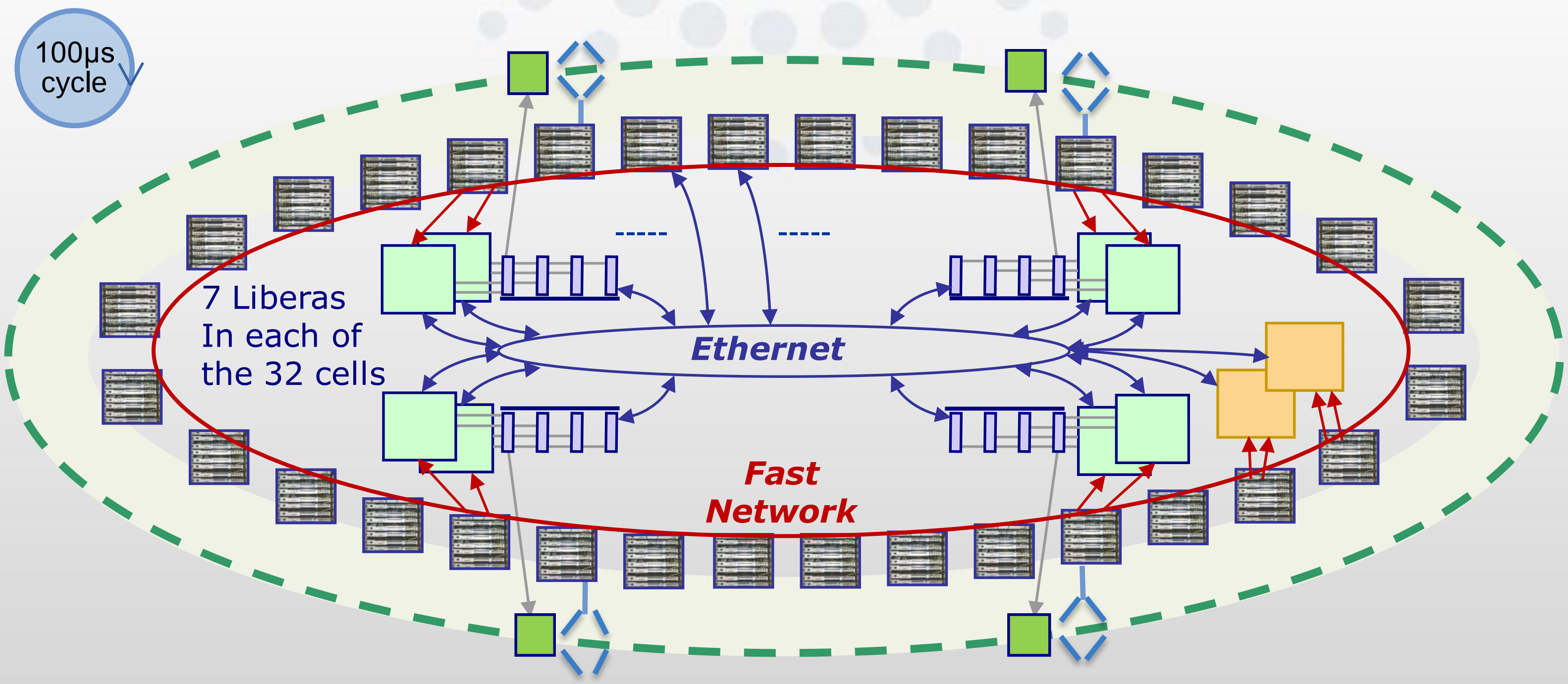
Fast Orbit Feedback upgrade

- ***Architecture***
- ***Preliminary results***
- ***Diagnostics***
- ***Planning***

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

2 sniffers boards

One of the 96 sextupoles housing the steerers

06/10/2011

Why such options?

- As usually such a large system must have to cope with external constraints (standards of the control system, infrastructure, local human resources…)

- This is why there is no perfect ultimate orbit correction system; even when two such systems are implemented on very similar storage rings at about the same time, they there will be significant differences in their design, which will maybe this presentation not too redundant and eventually interesting ….

ESRF constraints and assets

- Corrector magnets already designed and implemented (sextupoles), on a storage ring operated almost permanently =>
- The new correctors power supply had to be connected at the same place than the old ones in order to make the transition as smooth as possible

- Some very efficient control subsystems were available from others institutes (DLS and Soleil):
- DLS Communication Controller
- Power supplies control protocol
- Sniffers

Fast Orbit Feedback

Position measurement → ***Digital B.P.M. Libera Brilliance***

Acquisition:

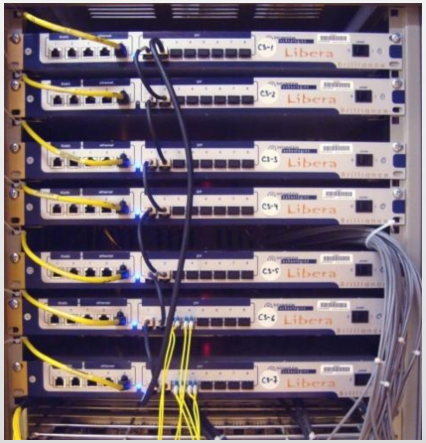
- 224 H & V positions from Libera BPMs grouped by cells (7/cell)

  Position data rate for fast orbit feedback: 10kHz

  There are 2 kinds of communication channels:

Configuration, 10Hz monitoring **Ethernet**

Fast Communication for data exchange at 10kHz **RocketIOs**



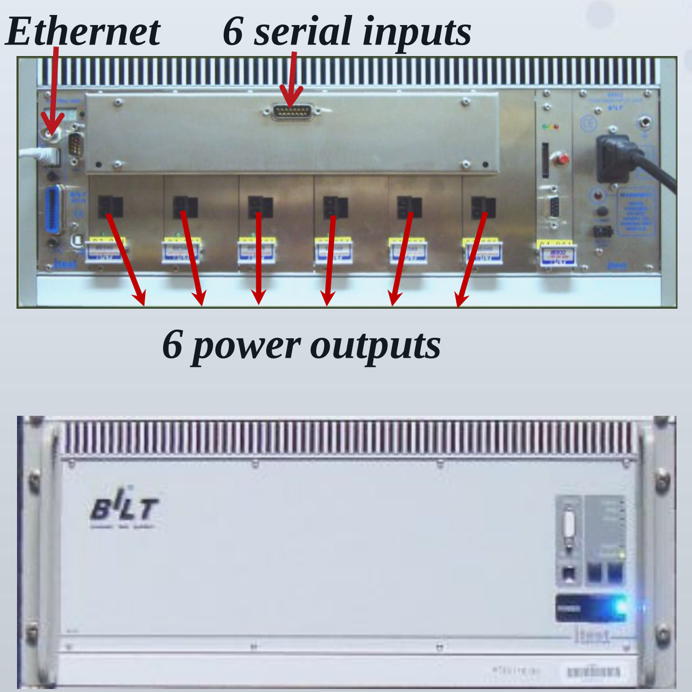
Libera Brilliance. Set-up for one cell

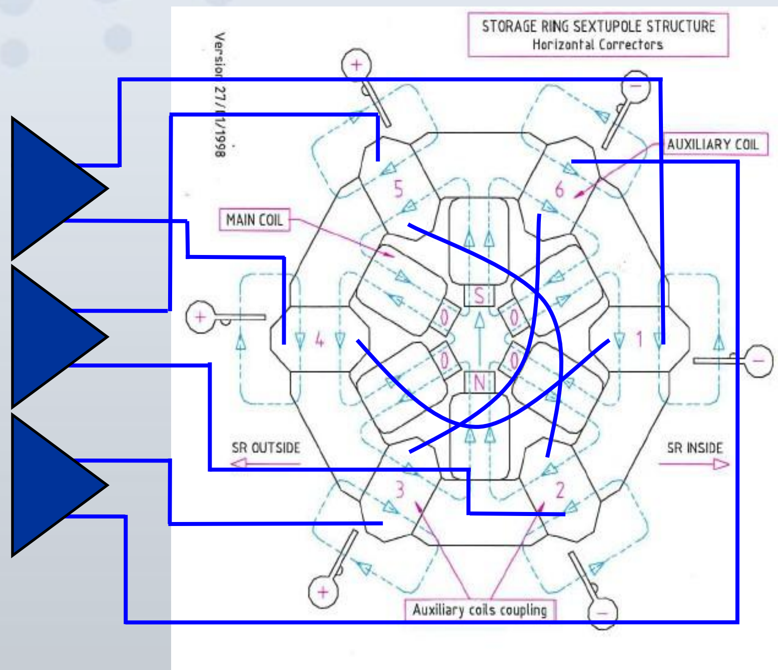
Fast communication:
copper for the very short links within the rack and **optic fiber** for the inter-cells connections →

06/10/2011

Fast Orbit Feedback

Steering magnets power supplies *→288 channels in 48 units*





Horizontal beam steerering configuration

- One crate drives 2 steerers
- 3 channels for one H + V steerer

Fast Orbit Feedback

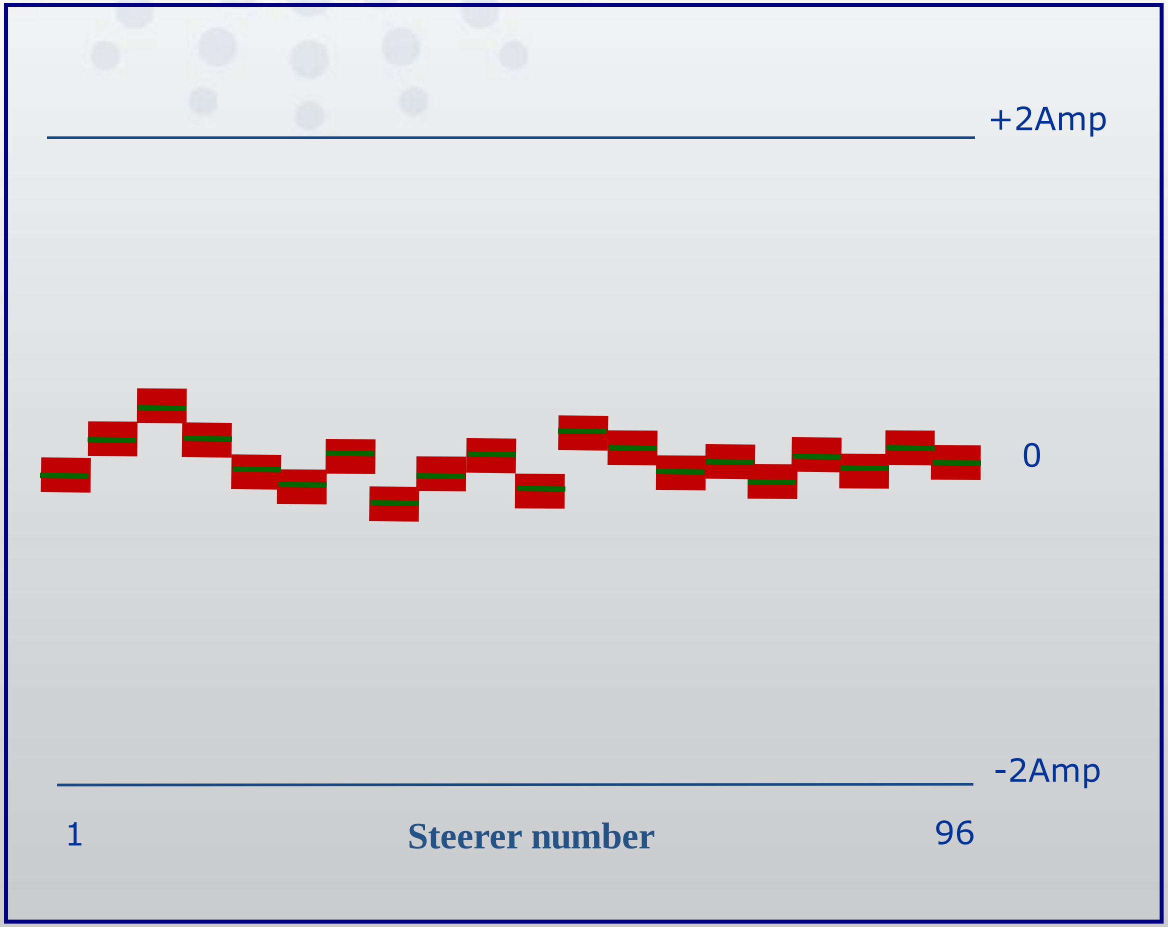
Steering magnets power supplies ***→ Each channel receives its setpoint from two sources***

Static correction:
+/- 1.8 A maxi

Setpoint from Ethernet :
Golden orbit

Dynamic correction:
+/- 200mA
Resolution = 3ppm

Setpoint at 10kHz from serial line : FOFB



Fast Orbit Feedback
Start and stop

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

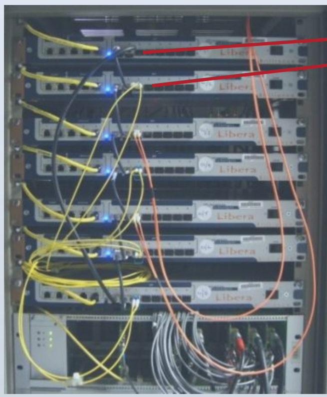
<u>At the start of the fast correction</u>:
the dynamic correction is added to the initial static correction

<u>Every 10 seconds</u>:
The average of the dynamic correction is computed and added to the static correction setting =>the average of the dynamic correction stays low

<u>If the fast correction is stopped</u>:
The orbit is set by the static correction setting, without noticeable orbit jump since the average value of the dynamic correction is very low

Fast Orbit Feedback

From Liberas to steerers power supplies → ***10kHz data flow***



224 Libera BPMs

224 X & Z positions

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

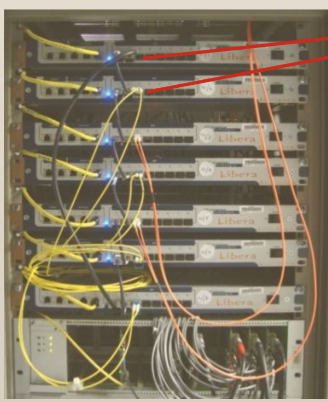
Corrections

Up to 42 corrections

48 Power Supplies Crates,

each driving 2 steerers

96 steerers



Diagnostics

2 FPGA PMCs "sniffers" Store the X & Z positions @ 10kHz for 10s and make the data available to an application

06/10/2011

Orbit Correction processors

- Due to the number of the correctors channels/sextupoles legs, we have to split the power supply control over 8 control boards, using the same boards as DLS and Soleil

These boards houses Virtex 5 FPGA DSPs

Why not to implement the orbit correction on these FPGAs?

Orbit correction on a FPGA

- Advantage:
- We do not need a real time OS

- Drawbacks:
- Debugging of a FPGA model is more tedious as the debugging of a C compiled code
- The 10ns/cycle parallel processing architecture of the Virtex 5 FPGA is not ideally suited to the calculation of an orbit correction at a rate of 10KHz …

Fast Orbit Feedback

Processing *→ PMC module, Multi-Gbit transceivers + Virtex-5 FPGA*

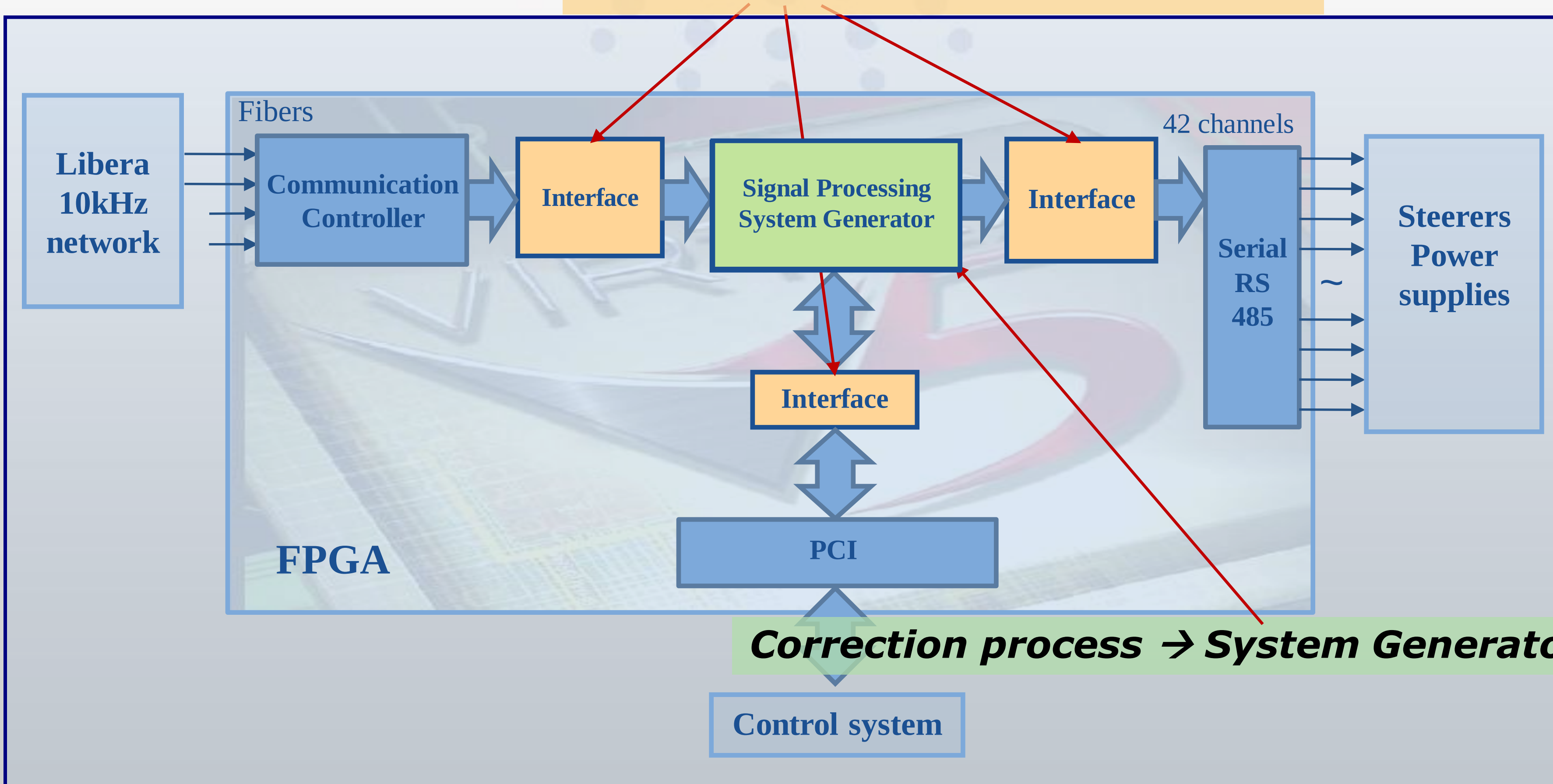
- Commercial card in a PCI, Embedded Communication Controller from Diamond L.S.:
  - Communication node and signal processor, the FPGA embeds the signal processing
    → *Real time inside the FPGA*
  - Transfer of parameters through the PCI interface
    → *Not real time*

06/10/2011

Fast Orbit Feedback

Processing → ***FPGA code development***

From Viveris Technologies → vhdl



Correction process → System Generator

Fast Orbit Feedback

Processing *→ FPGA code production with Xilinx tools*

VHDL
C.C. / RS-485 / PCI

VHDL Interfaces
from Viveris

VHDL Signal processing
from System Generator

Logic **Synthesis**, **Placement** and **Routing**

FPGA
Binary file

Fast Orbit Feedback

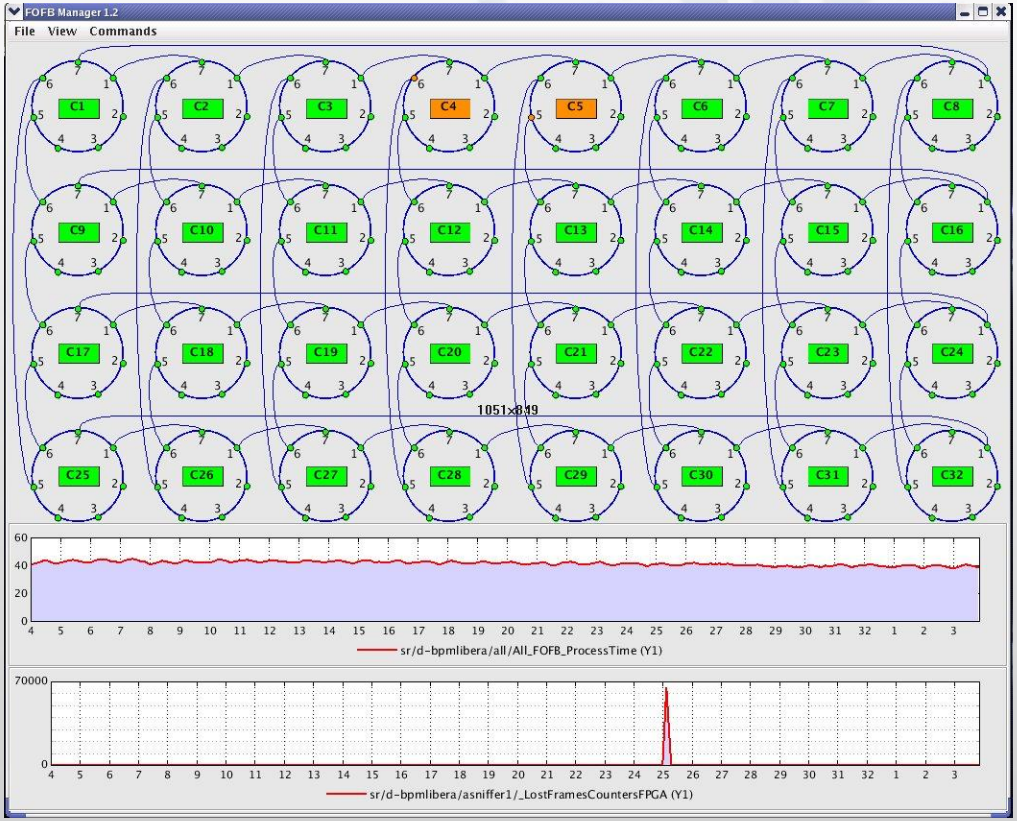
Diagnostics → PMC module (Gbit Ethernet + Virtex-II FPGA)

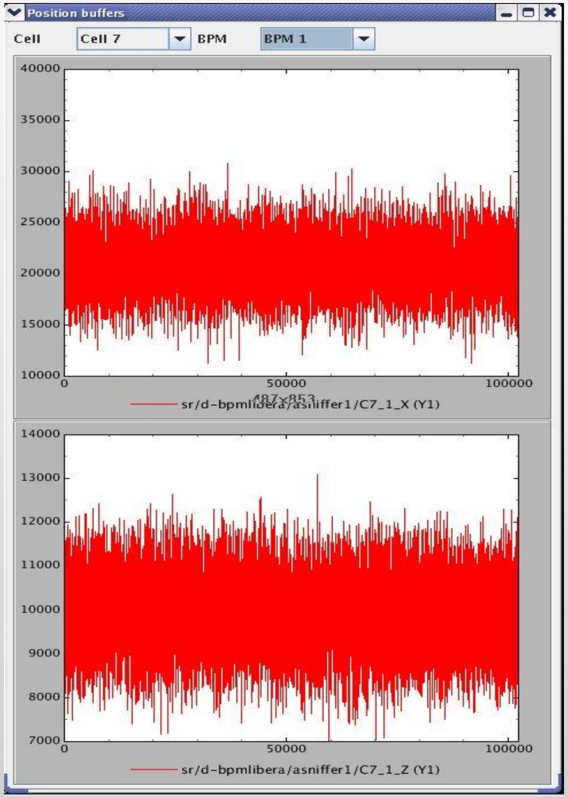
- Commercial card in a PCI, Embedded Communication Controller from Diamond L.S.:
  - Sniffer → communication node and data storage performed with the FPGA
  - Transfer of the beam positions through the PCI interface.

    Continuous data storage for 10s.

Fast Orbit Feedback

Diagnostics → Beam Position and communication network



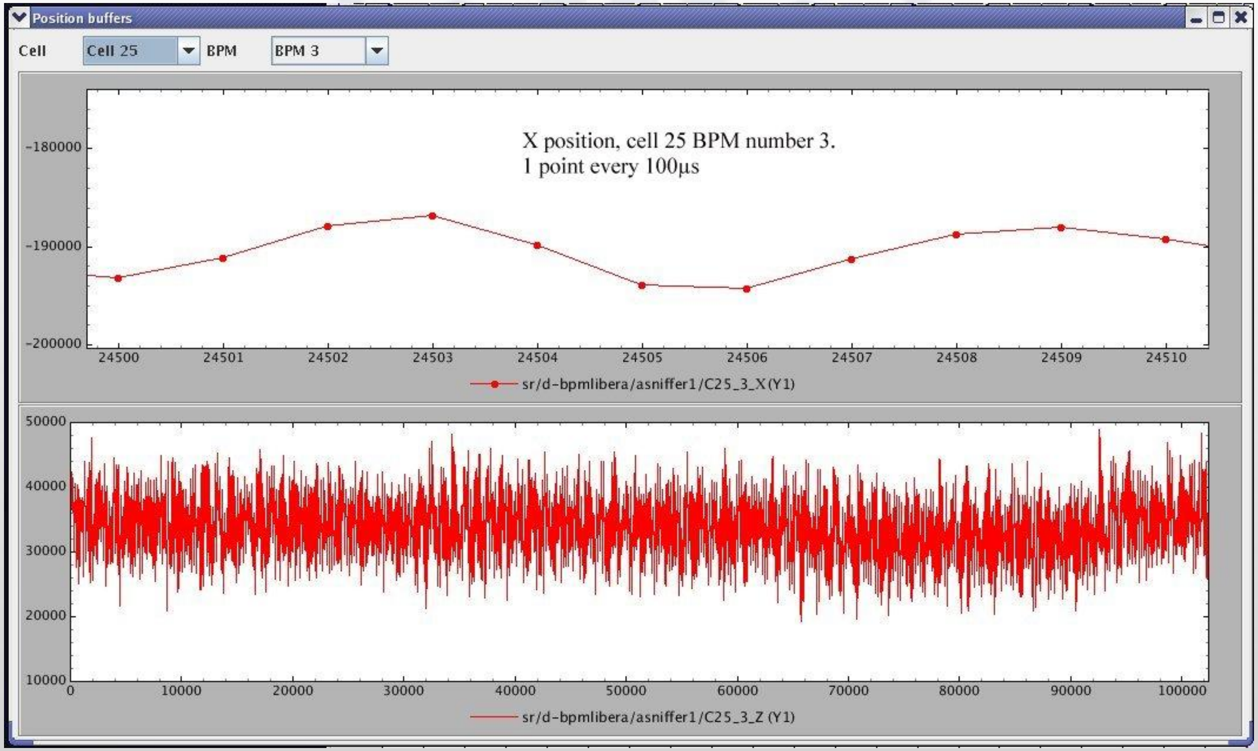


Communication network is monitored from the 224 ***Liberas*** *and one* ***Sniffer.*** *Beam position record is available as well*

The full exchange of 224 positions H & V take a maximum of 50µs even if a connection is broken

Fast Orbit Feedback

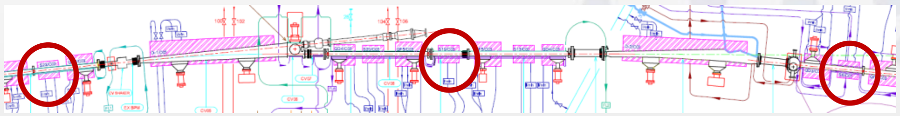
Diagnostics → ***Beam Position recording***



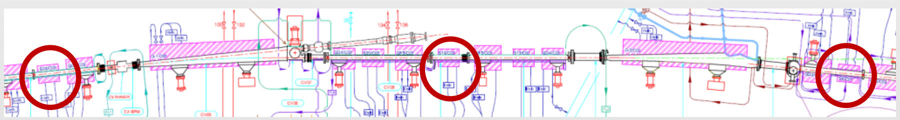
Beam position record is available from a "Sniffer" device connected to the 224 Liberas

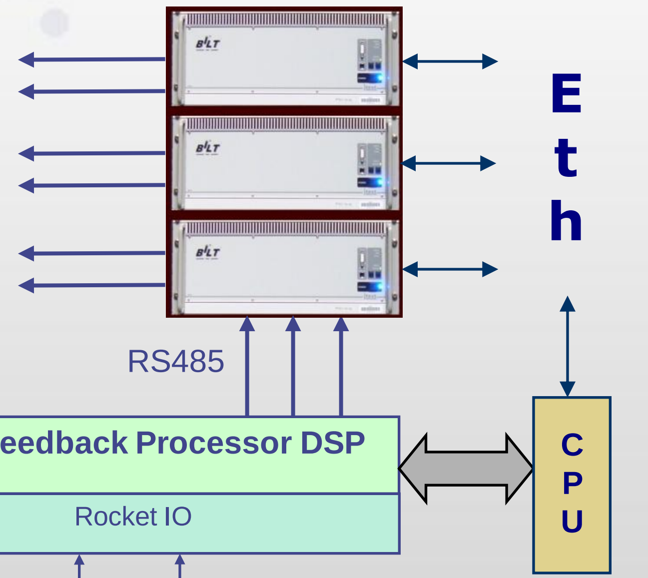
Fast Orbit Feedback

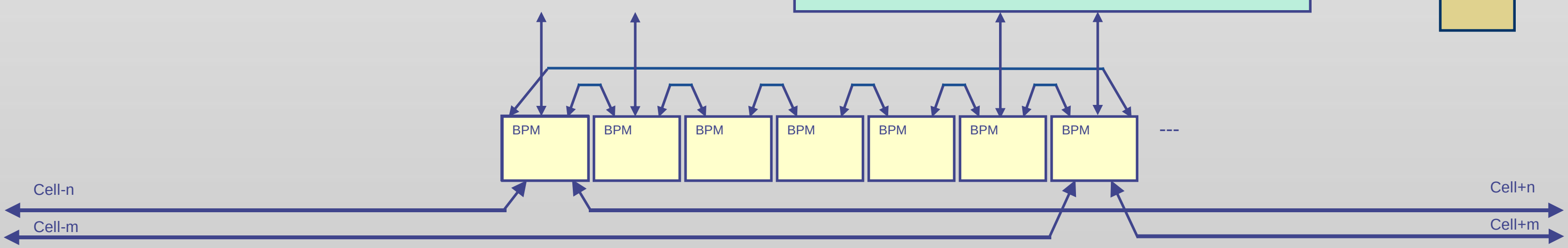
***Preliminary tests** → 224 BPMs / 6 steerers cells 7 and 8*



Partial test setup: 6 steerers cells 7 and 8







Group of 7 Liberas in cells 4

Fast Orbit Feedback

Preliminary tests → ***224 BPMs / 6 steerers cells 7 and 8***

Corrections calculation → example of horizontal corrections cells 7 & 8

Beam position | Correction matrix (***partial for 6 steerers***) | Position errors | Set points P.S.

$$\begin{bmatrix} \Delta x_1 \\ \vdots \\ \Delta x_{224} \end{bmatrix} * \begin{bmatrix} Cx_{1-1} & \cdots & Cx_{224-1} \\ \vdots & & \vdots \\ Cx_{1-6} & \cdots & Cx_{224-6} \end{bmatrix} = \begin{bmatrix} \Delta ex_1 \\ \vdots \\ \Delta ex_6 \end{bmatrix}$$

Correctors

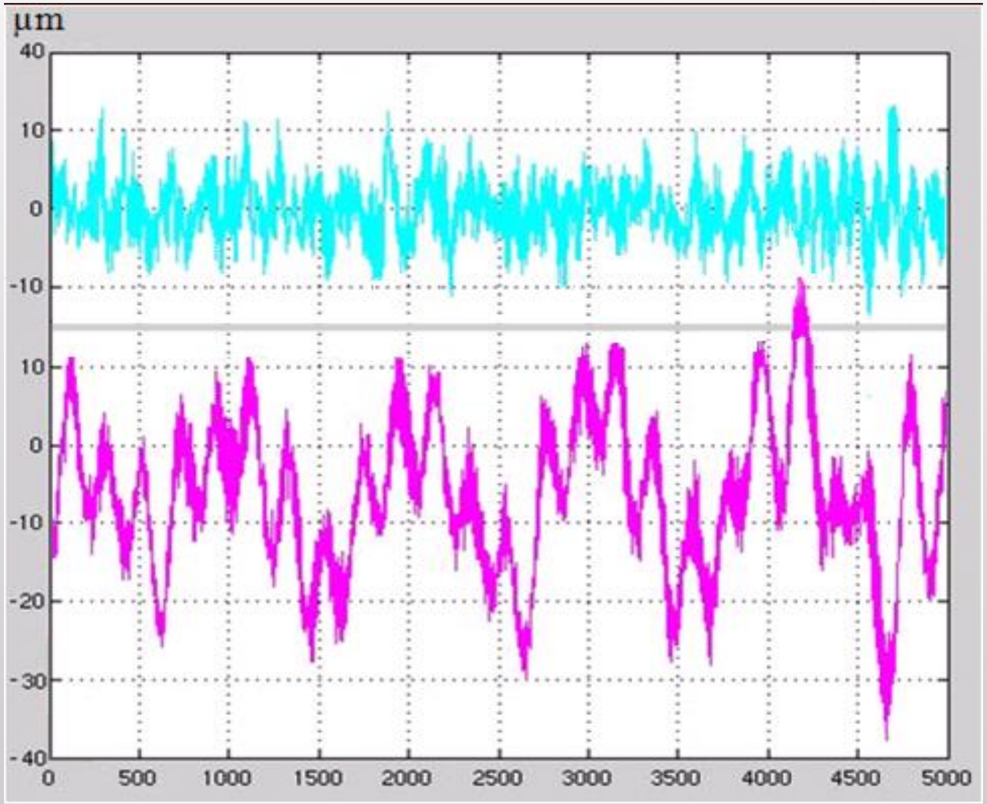
P.I.
+
50Hz
Notch filter

$$\begin{bmatrix} \Delta ix_1 \\ \vdots \\ \Delta ix_6 \end{bmatrix}$$

Fast Orbit Feedback

***Preliminary tests** → 224 BPMs / 6 steerers cells 7 and 8*

Horizontal position in a high beta straight section



Fast correction
P.I. +
50Hz Notch filter

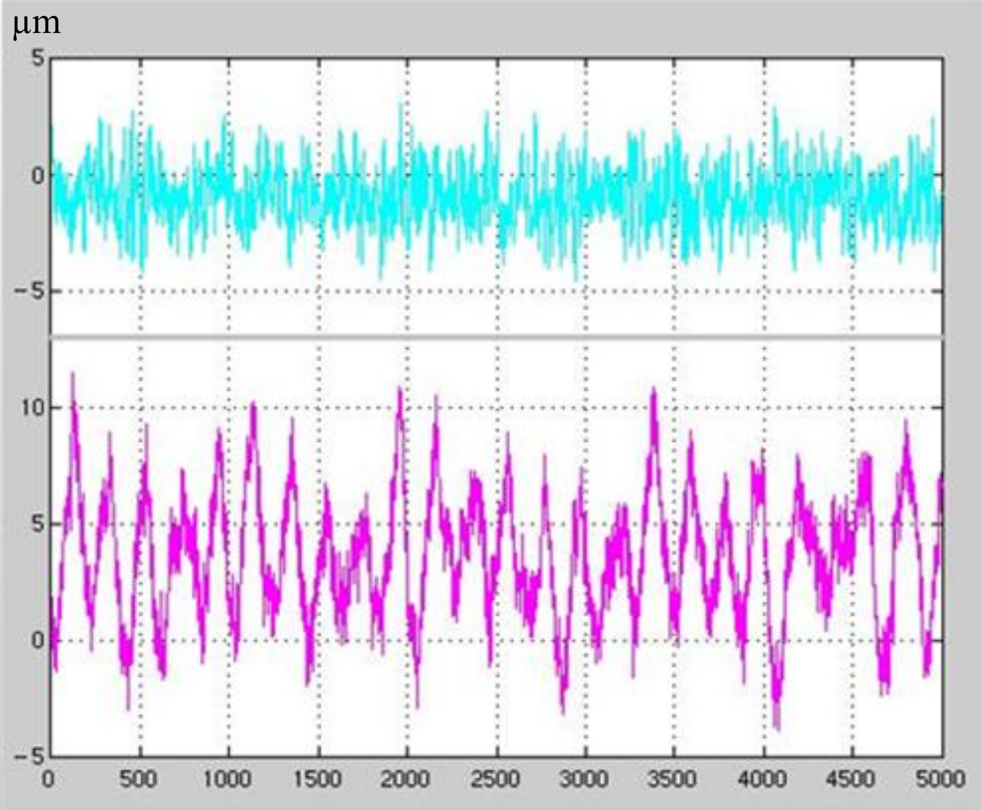
ON

OFF

Fast Orbit Feedback

***Preliminary tests** → 224 BPMs / 6 steerers cells 7 and 8*

Vertical position from an achromat BPM



Fast correction
P.I. +
50Hz Notch filter

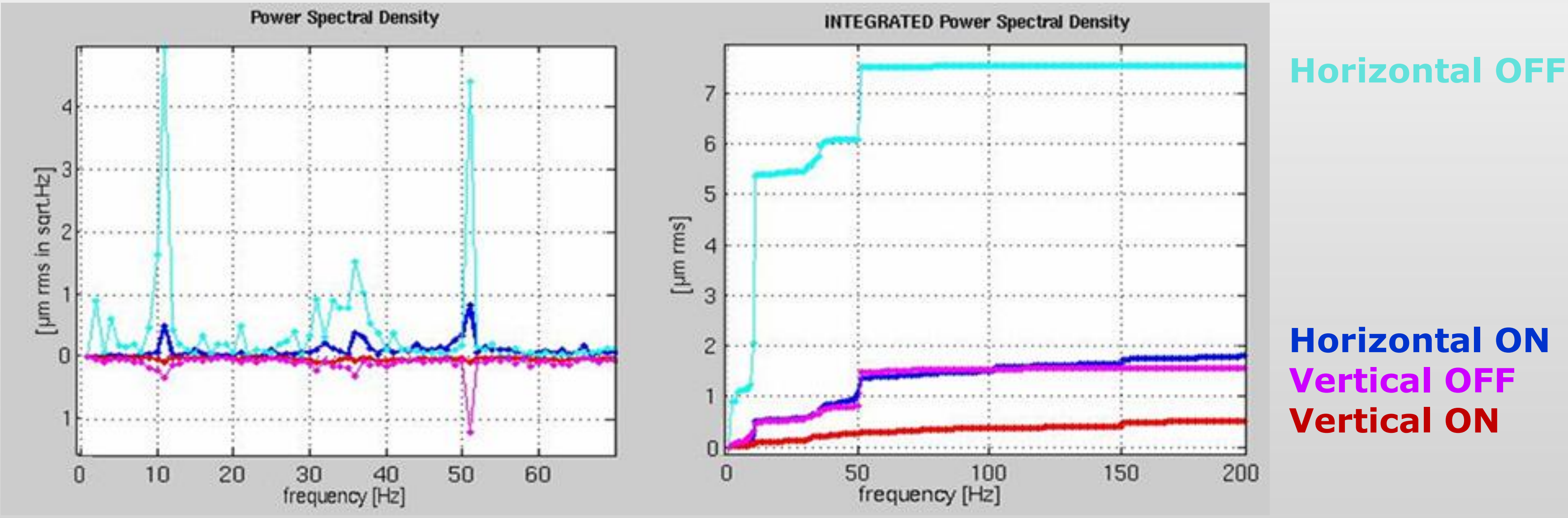
ON

OFF

Fast Orbit Feedback

***Preliminary tests** → 224 BPMs / 6 steerers cells 7 and 8*

Average over 14 BPMs located inside the area covered by the 6 steerers

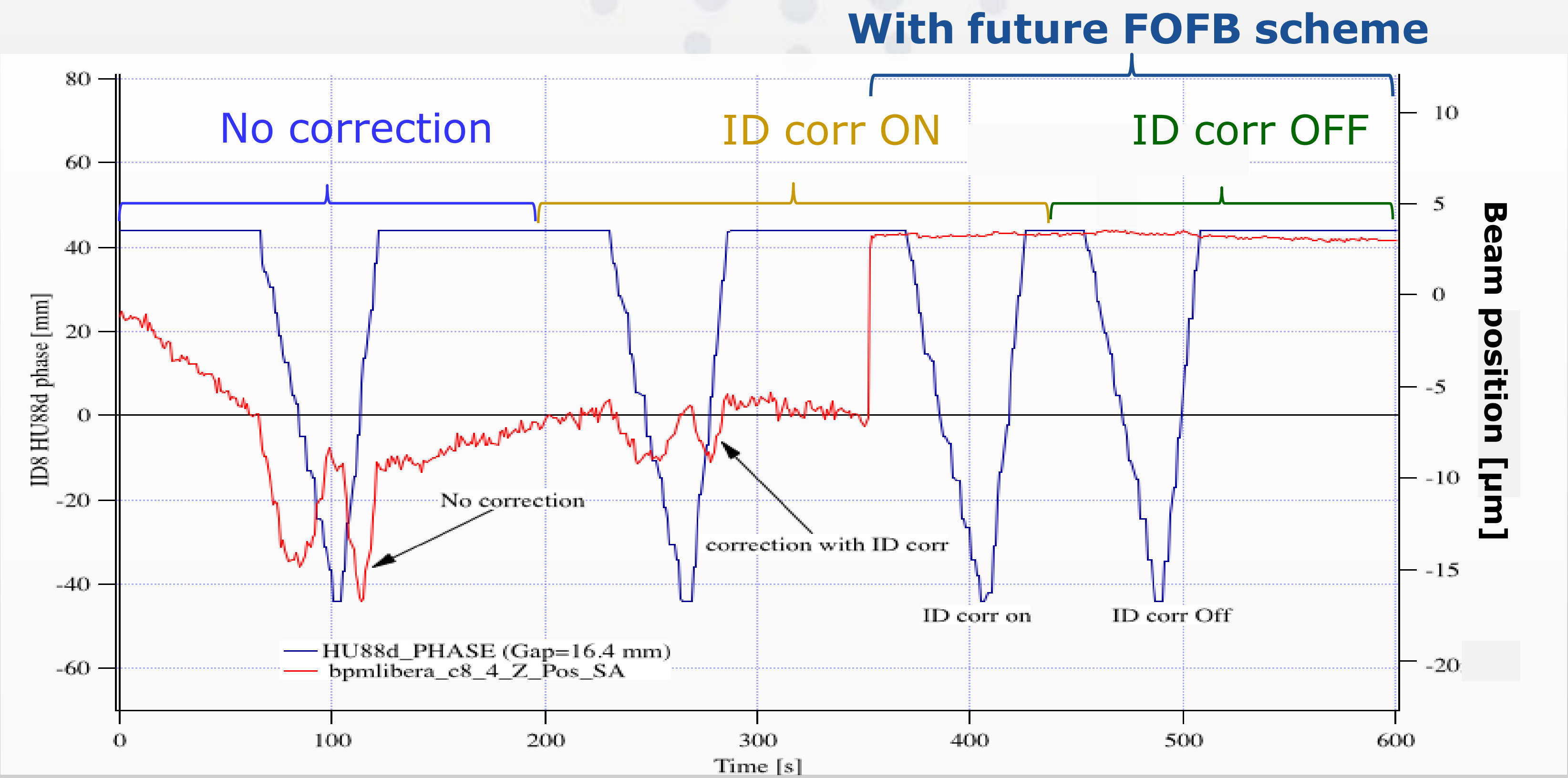


Plots produced using K.Scheidt Matlab tools

Fast Orbit Feedback

Preliminary tests *→ 224 BPMs / 6 steerers cells 7 and 8*

Phase changes in ID8 HU88d:



Graph from Joel Chavanne

Fast Orbit Feedback

Diagnostics *→ Presents & future developments*

Already available

"Sniffer" → 10s record at 10kHz of 224 X & Z positions and corrections *

_ Application rolling buffer in live…

_Diagnostic & status of the communication controller

Future development

Response matrix measurements → The FPGA dedicated to the corrections can also be used to drive a sine excitation to the power supplies while an extra board will analyze the position and correction data available through the Communication Controller

* at a reduced rate of 10KHz/7

Diagnostics: Coupling Matrix Measurement

- **Beam position resolution:**
- **250nm for a bandwidth of 2KHz (beam noise +Libera noise)**

Horizontal beam size: +/- 300μm to 100μm

Vertical beam size: +/- 12μm to 4μm

depending of the β value

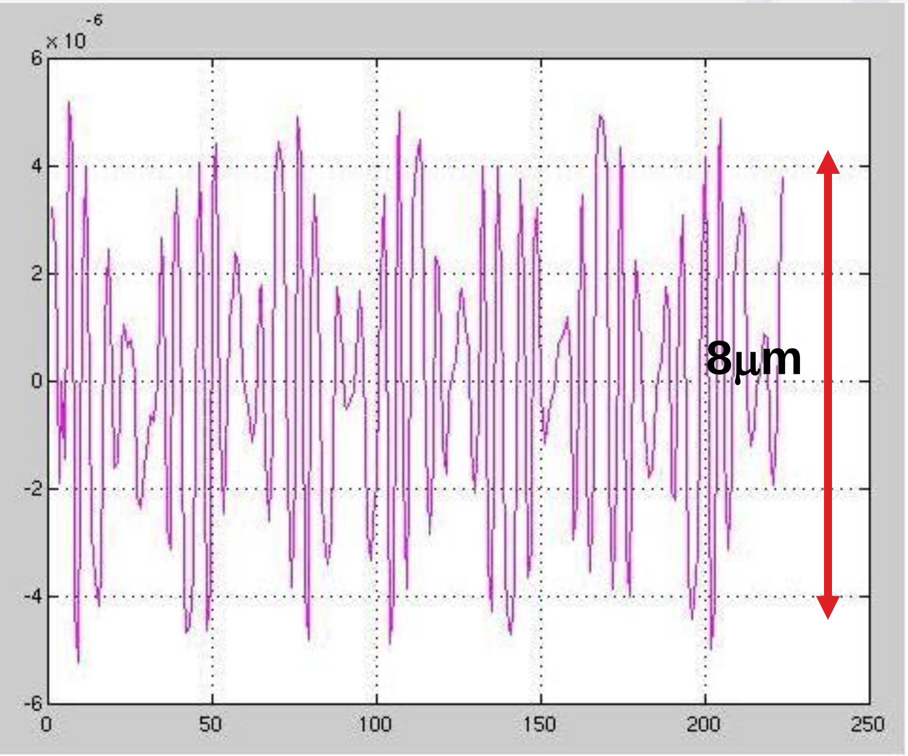
=> Storage ring parameters (orbit response matrix)

are measurable during operation without disturbance for the users

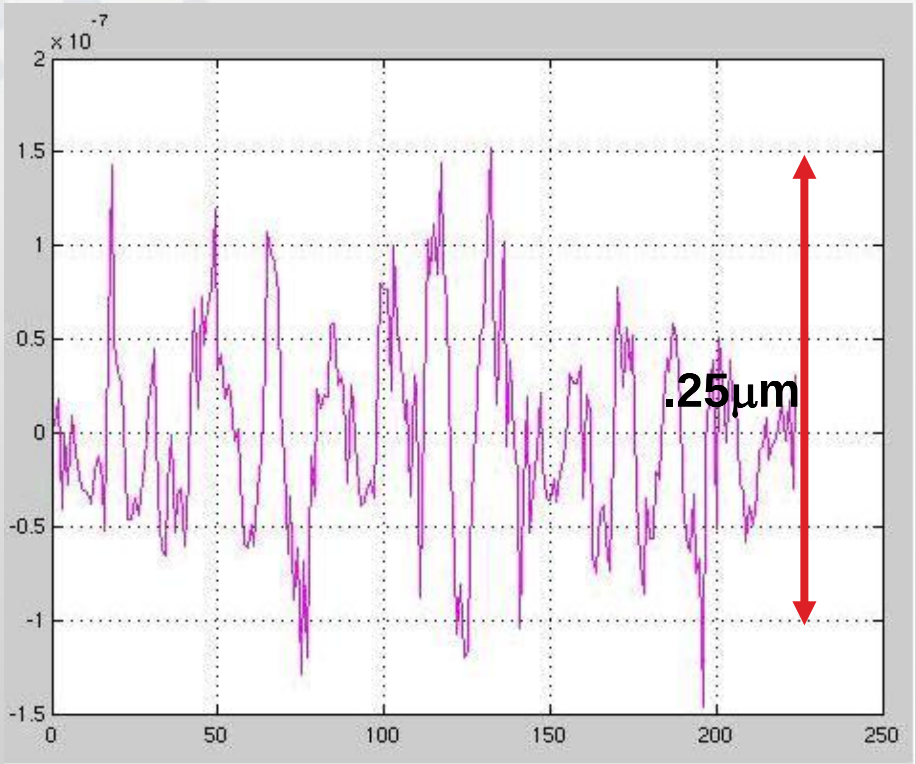
Our main focus:

Measurement of the H/V coupling changes to maintain the lowest emittance during the ID parameters changes…..

Exemple of measured response



Right: H response



Left: V to H coupling response

Method

- **Sine excitation of the beam at a frequency where the beam noise is minimal using a sufficient number of steerers**

- **Synchronous detection demodulation over one second of all the position and correction data***

- **We need to remove the effect on the closed orbit of the correctors driven by the orbit correction if the orbit correction is active**

=>We will implement this diagnostic on an extra Virtex 5 board used as a super sniffer

*** as tested at DNL**

Fast Orbit Feedback

Planning

✓ 1) Optic fibers for the dedicated network

✓ 2) Communication Controller on Liberas and one PMC-FPGA processor

✓ 3) AC Power Converter production validation

✓ 4) Server for diagnostics, basis of the server for the correction processors

✓ 5) First tests of a partial fast orbit correction 224 BPMs / 6 steerers
December 2010

✓ 6) AC Power Converters installed for DC corrections only *(Remote access through Ethernet)* fast correction based on air coil correctors remains active ***Winter shutdown 2010 / 2011***

✓ 7) Implementation of the fast orbit correction on 8 PMC-FPGAs
Summer shutdown 2011 and full commissioning before the long shutdown

Acknowledgements

Nicolas Hubert (Soleil)
Nicolas Leclercq (Soleil)
Michael Abbott (Diamond Light Source)
Guenther Rhem (Diamond Light Source)
Isa Uzun (Diamond Light Source)
Francis Epaud
Jens Meyer
Kees Scheidt
Stéphane Lagarde
Pascal Vidal
Pierrick Sallamand

Thanks for your attention!