Fast Orbit Feedback (FOFB) at Diamond

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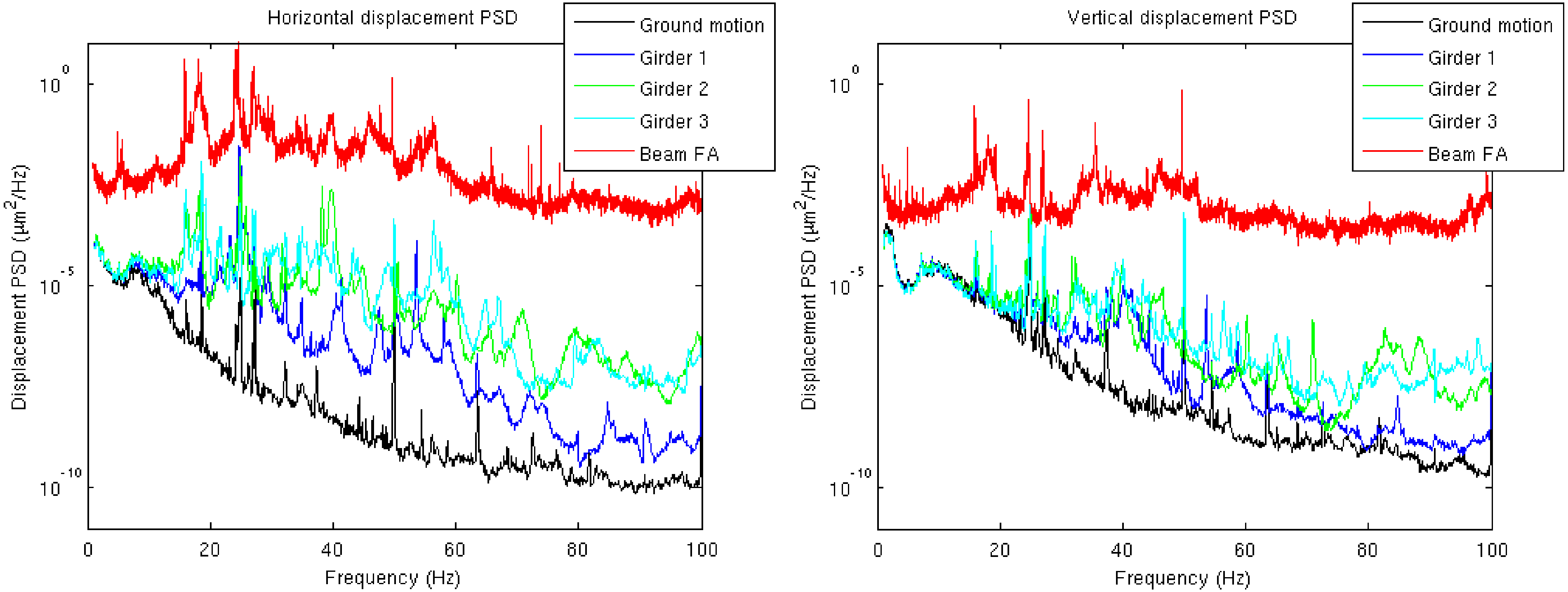
Ground, Girder and Beam Motion



Fast Feedback Design Philosophy

- Low latency:
  - Ensures high bandwidth for feedback, good suppression
  - Major contribution to latency should be unavoidable group delays of filters
- Robust:
  - FOFB has to perform with components failed
  - Try to avoid single point of failure
- Accessible for maintenance / development:
  - Have only what is necessary inside the FPGA
  - Implement feedback algorithm on PowerPC boards
- Truly global:
  - No slow orbit feedback to run in parallel
  - RF frequency correction also to be calculated

Measurement Resolution

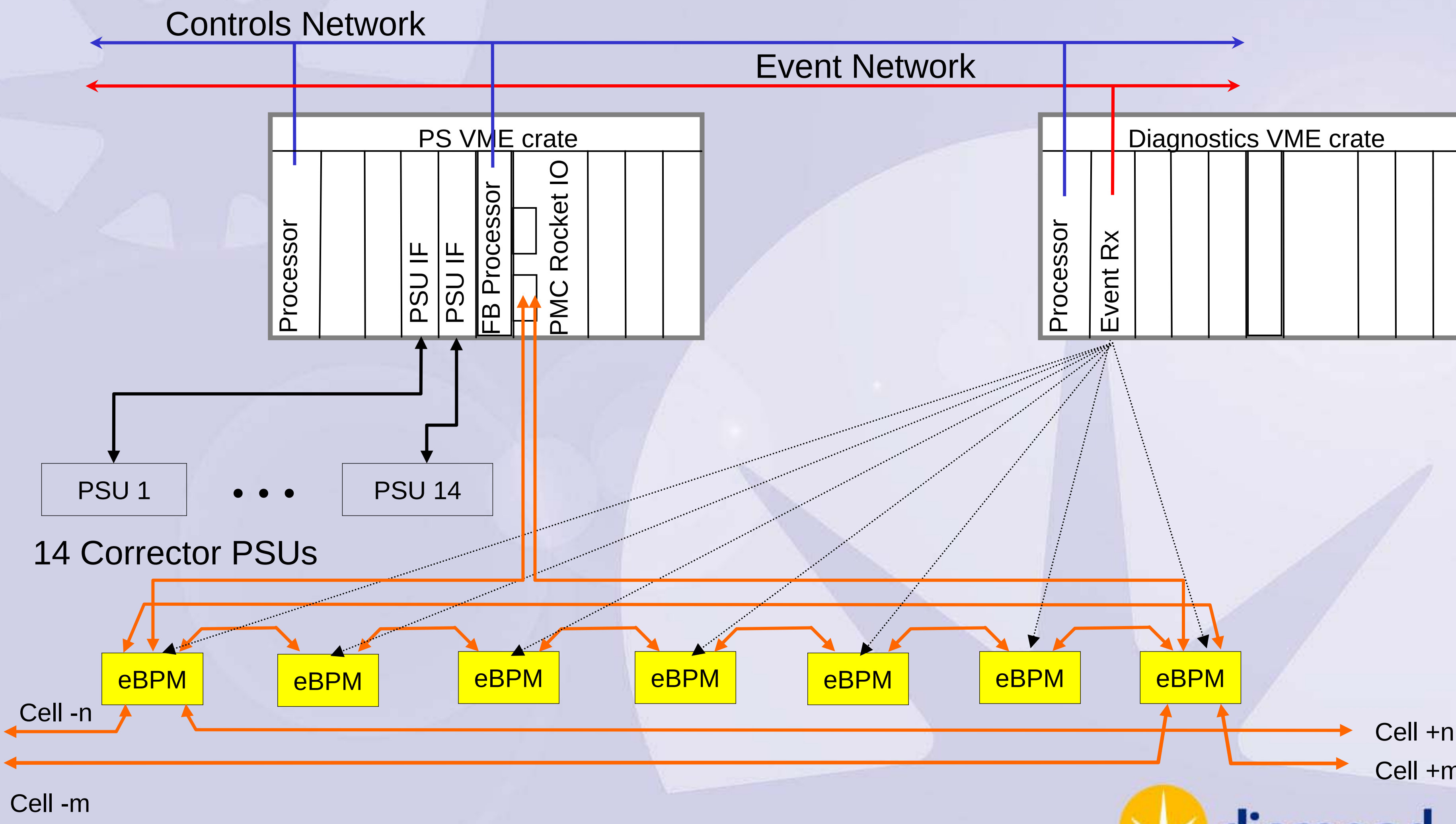
Type	Application	Rate	BW	RMS X	RMS Y
Slow Acq.	Slow orbit feedback, response matrix measurement	10 Hz	4 Hz	45 nm	45 nm
Fast Acq.	Fast orbit feedback	10 kHz	2 kHz	140 nm	190 nm
Turn-by-turn	Tune measurement, betatron amplitude and phase	534 kHz	267 kHz	1.5 µm	3 µm

All values are typical for RMS of 10000 samples in lab tests

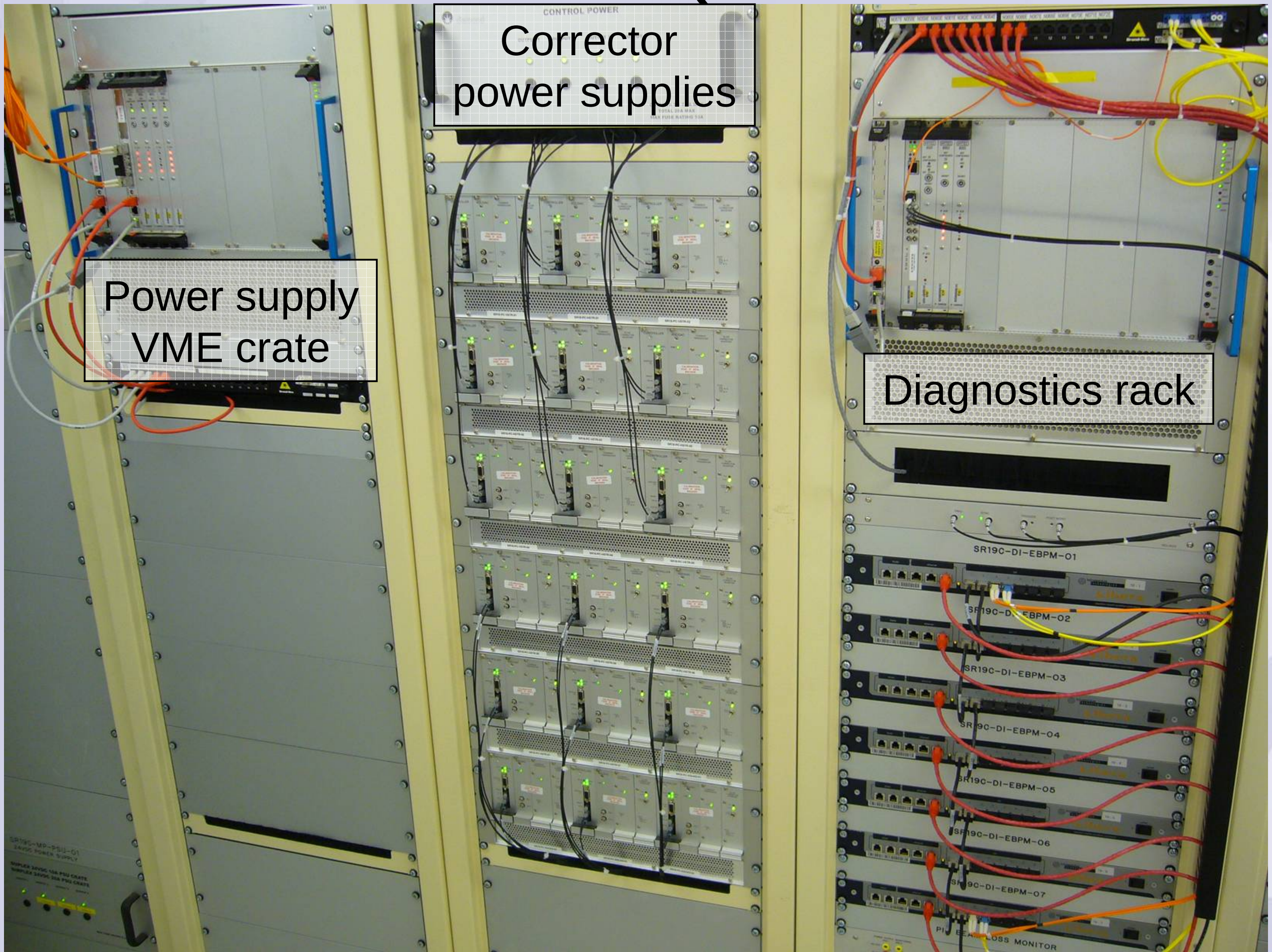
FOFB Overview

- Libera EBPM produces FA data 10072 S/s (2 kHz 3dB bandwidth)
- RocketIO on Libera sends and forwards data at 2.12 Gbit/s using in house developed “Communication Controller”
- Communication is broadcast, no routing information
- PMC card with RocketIO receives data and transfers via DMA to CPU memory
- Dedicated CPU board (1GHz PowerPC MVME5500) performs matrix multiplication and feedback controller
- Resulting corrector PS values are written through VME into PS controller

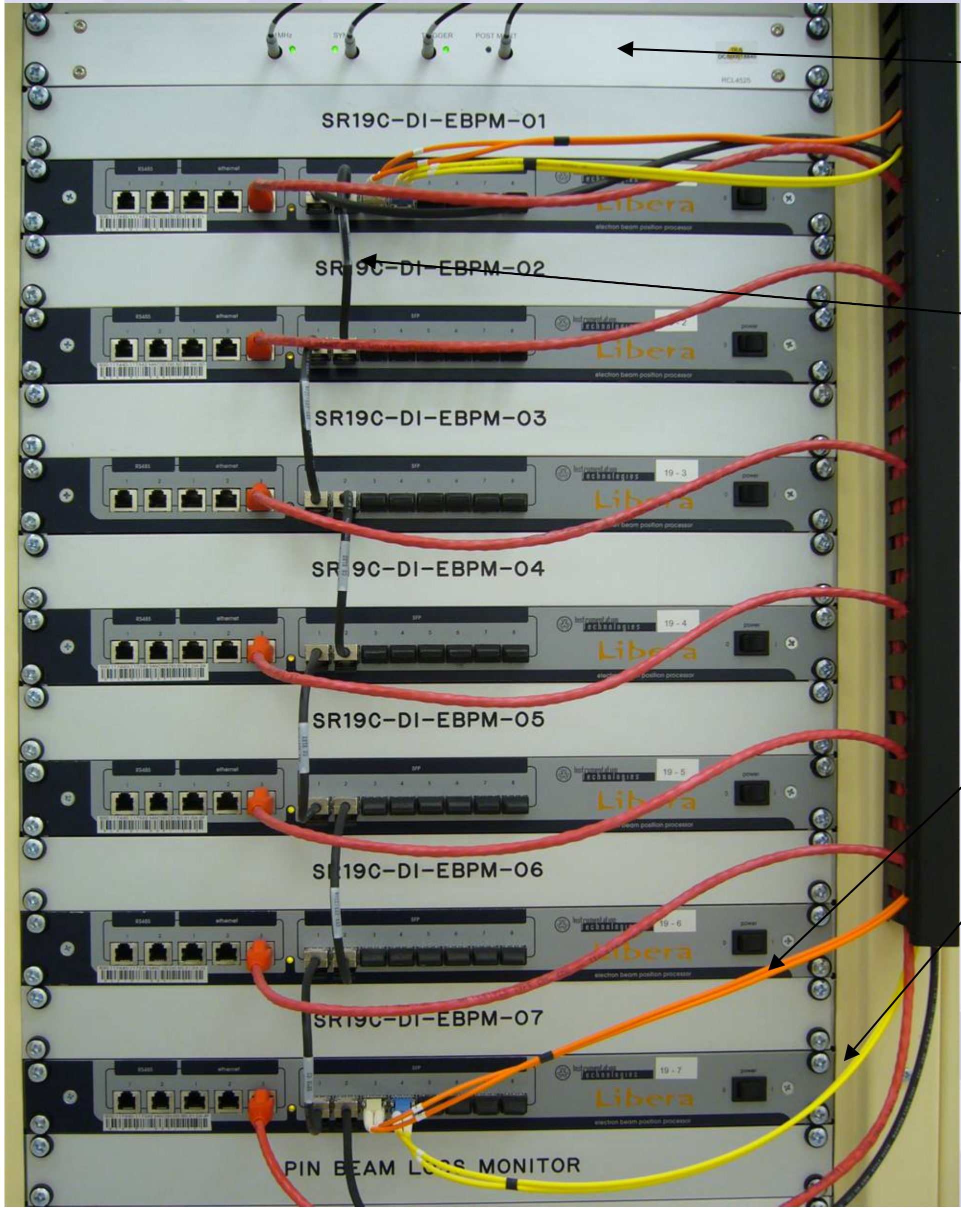
Fast Orbit Feedback



FOFB Installation (one of 24 cells)



FOFB connections



SC/MC/Trigger/PM fan out

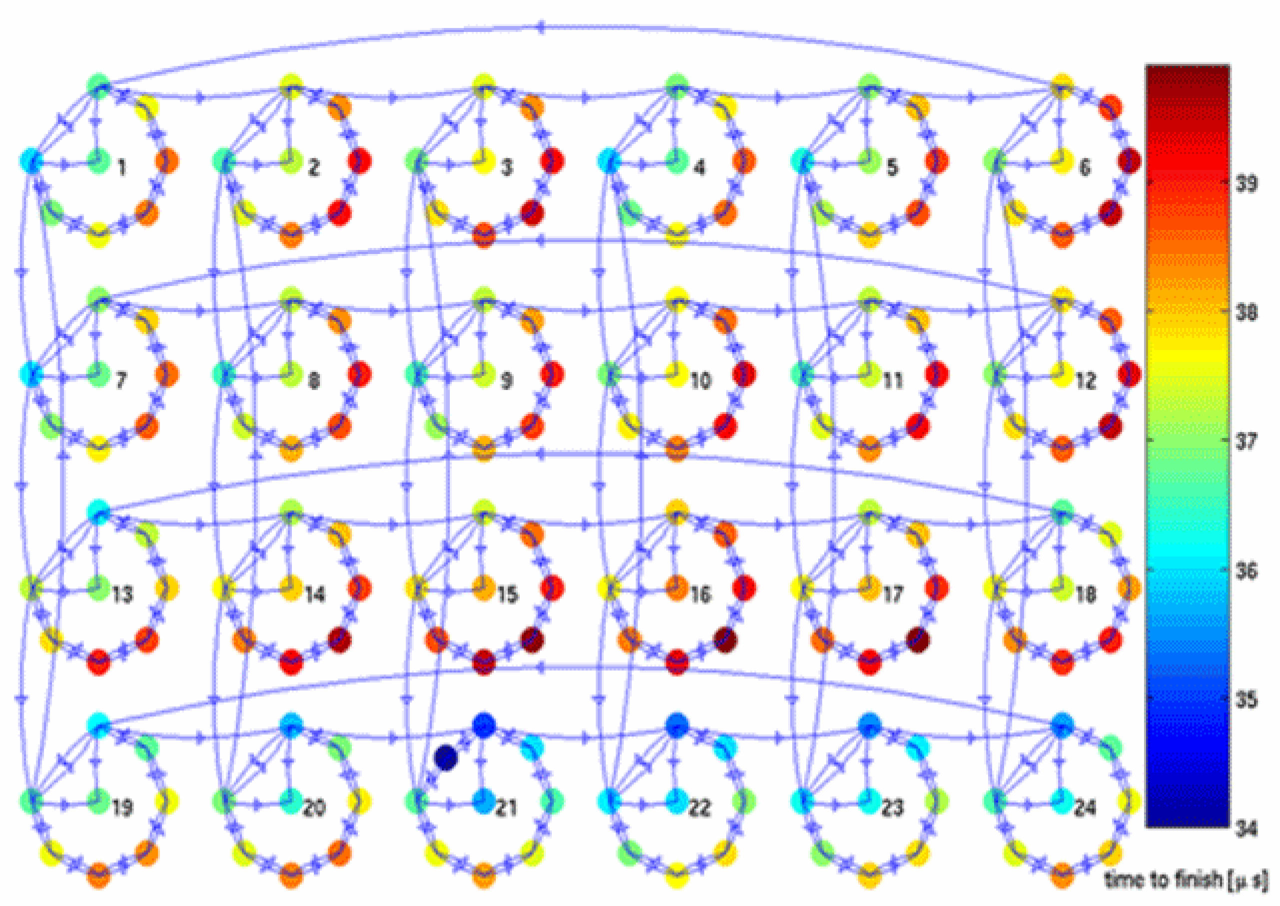
Galvanic SFP connections

Multi mode fibre to PS rack

Single mode fibre to other CIAs

PMC interface to FOFB network

Global Connections of FOFB



FOFB Latencies / Bandwidth

- Group delay of FIR: 148 µs
- Group delay of 2 IIR: <71 µs

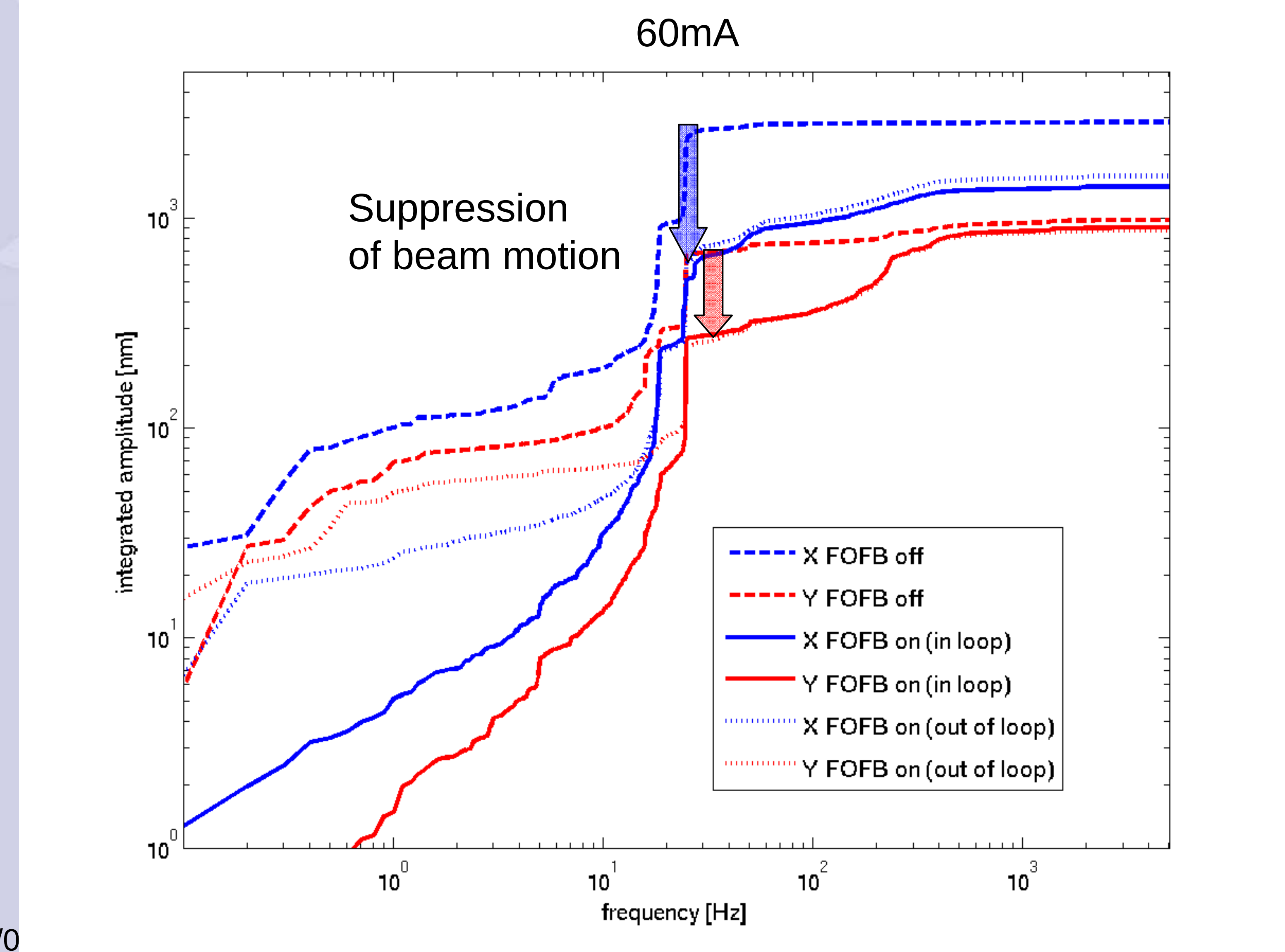
calculated

- Distribution of data around ring: 50 µs
- DMA transfer to CPU: 49 µs
- Conversion integer to float : 5 µs
- Matrix multiplication 2*7*168: 4 µs
- PID controller: 1 µs
- Write into PS controller: 3 µs

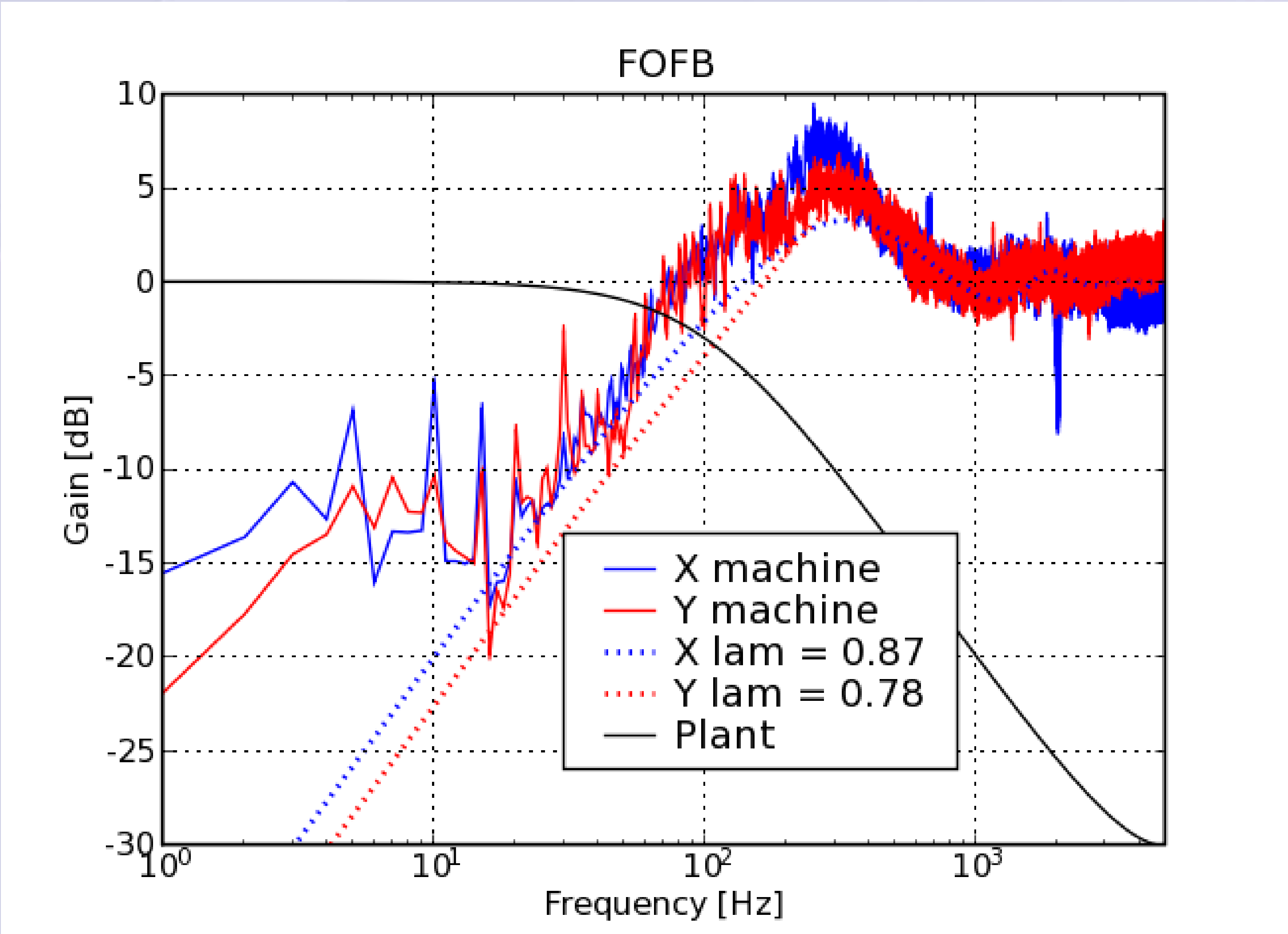
measured

- Total: <331 µs
- Magnet/chamber estimated to have 500 Hz BW
- Bandwidth of PS controller currently limits loop (set to 100Hz, but programmable)

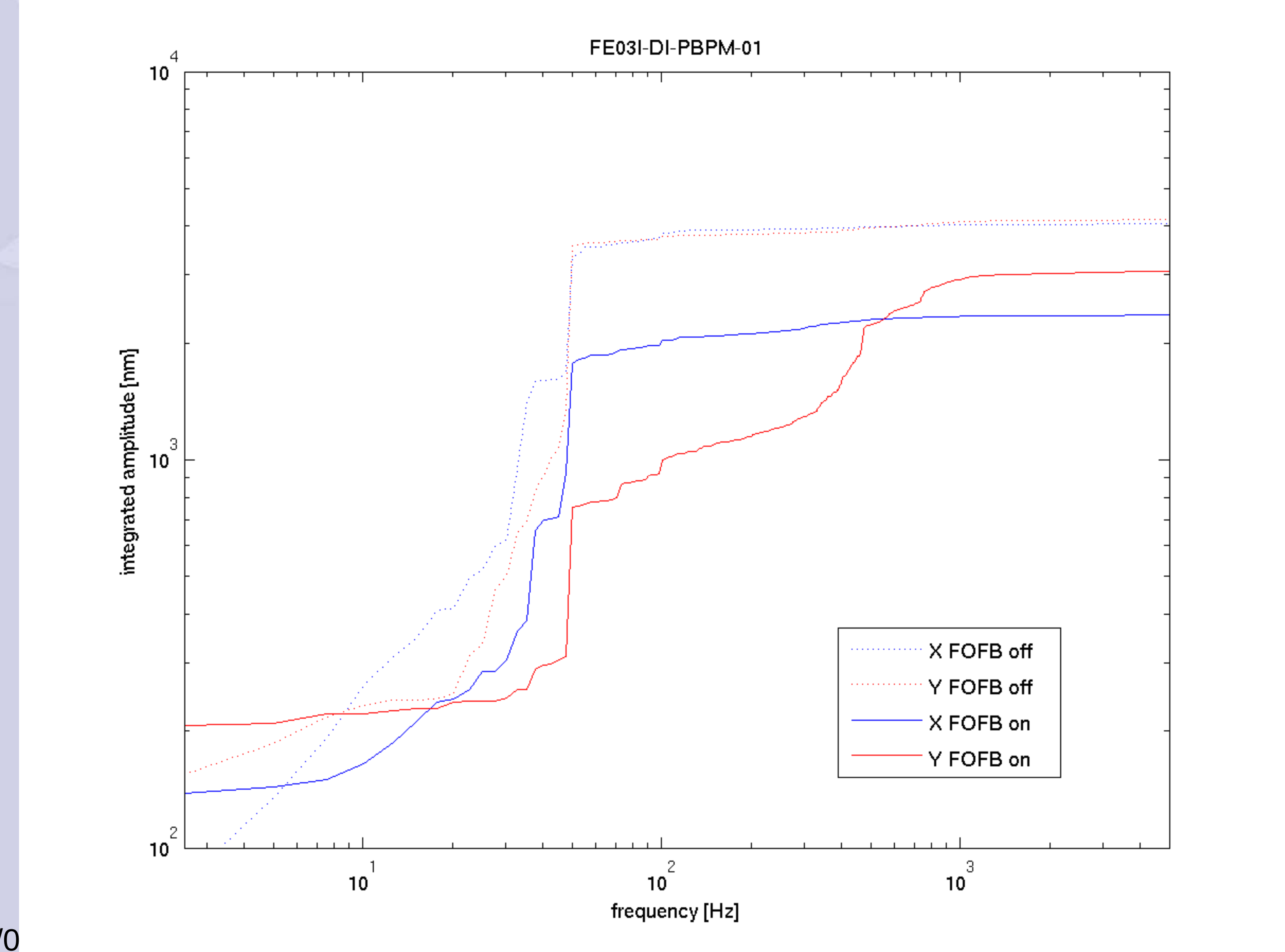
FOFB Performance



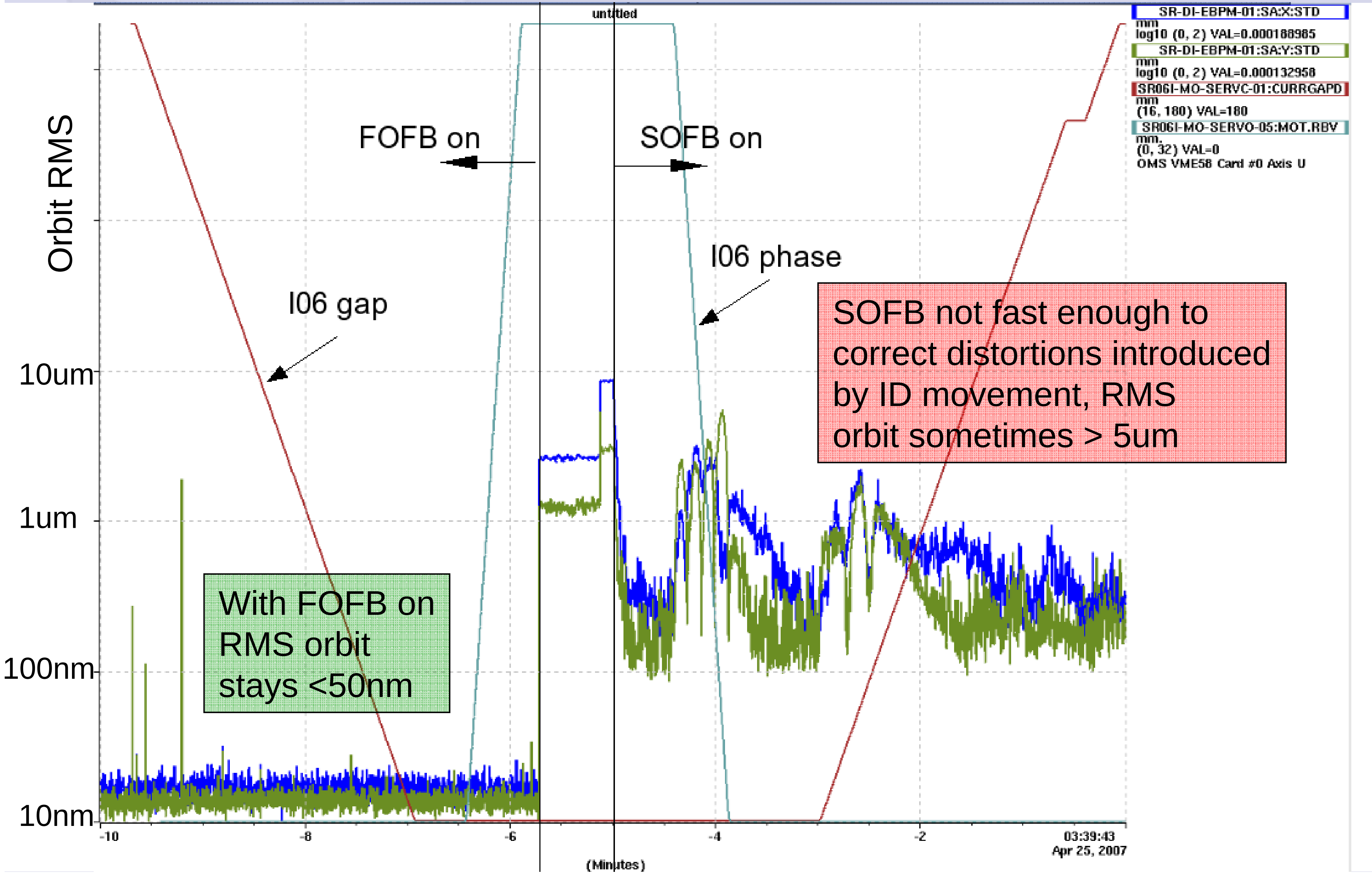
FOFB Suppression



FOFB Performance on XBPM

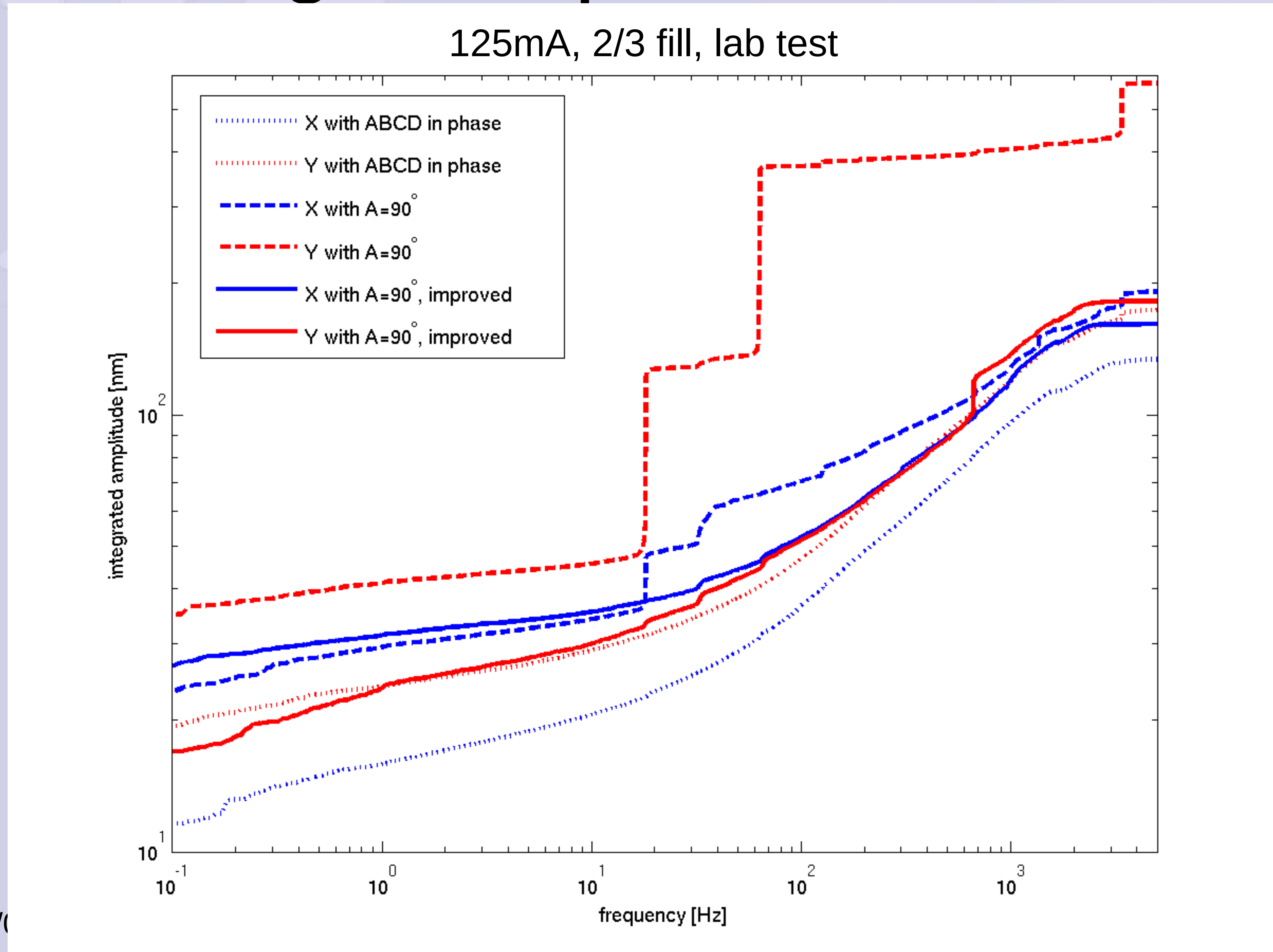


FOFB vs SOFB



untitled
SR-DI-EBPM-01:SA:X:STD
mm
log10 (0, 2) VAL=0.000188985
SR-DI-EBPM-01:SA:Y:STD
mm
log10 (0, 2) VAL=0.000132958
SR06I-MO-SERVC-01:CURRGAPD
mm
(16, 180) VAL=180
SR06I-MO-SERVO-05:MOT.RBV
mm.
(0, 32) VAL=0
OMS VME58 Card #0 Axis U
Orbit RMS
10um
1um
100nm
10nm
FOFB on
SOFB on
I06 phase
I06 gap
SOFB not fast enough to correct distortions introduced by ID movement, RMS orbit sometimes > 5um
With FOFB on RMS orbit stays <50nm
-10
-8
-6
-4
-2
03:39:43
Apr 25, 2007
(Minutes)

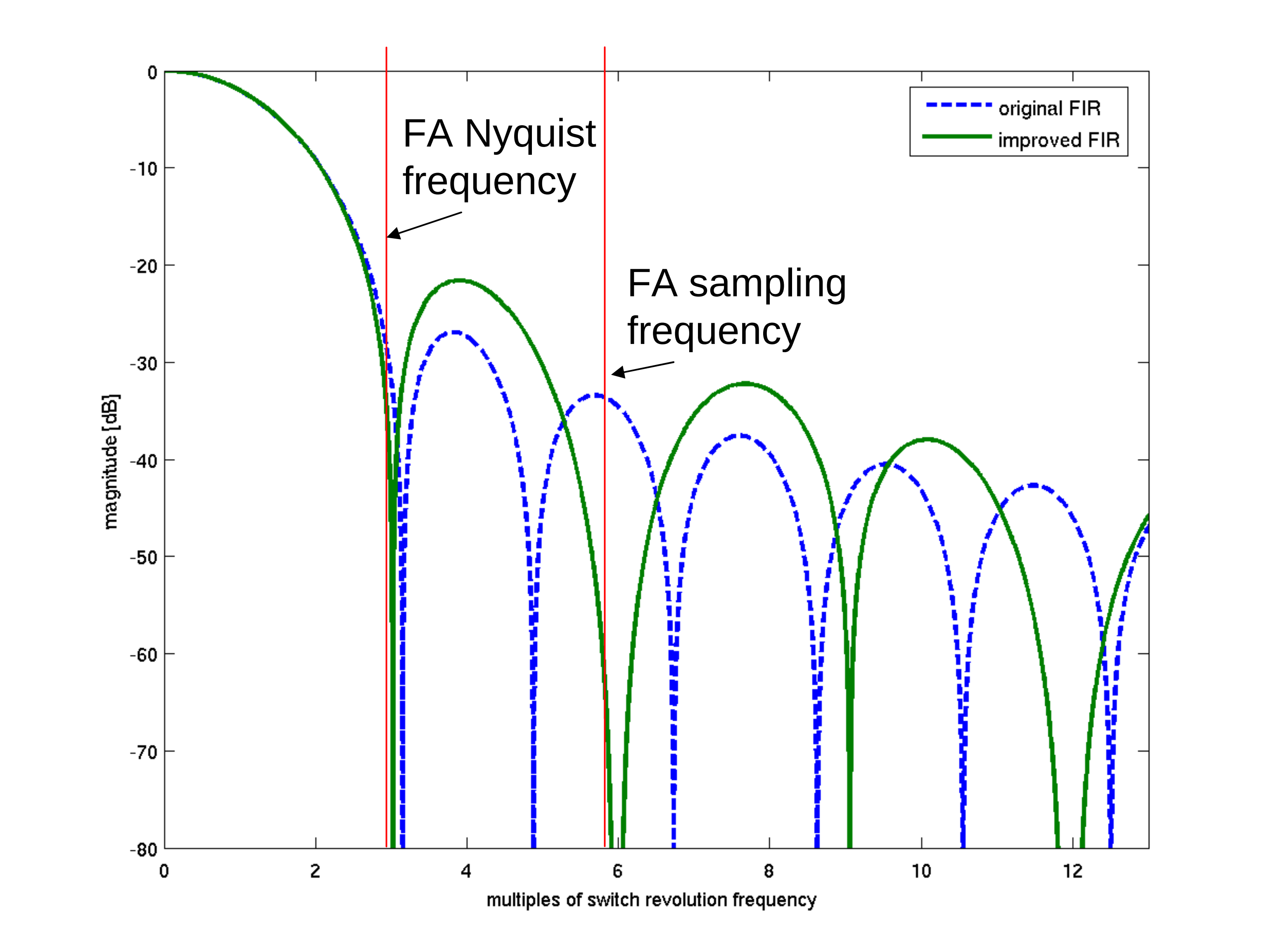
Integrated position noise



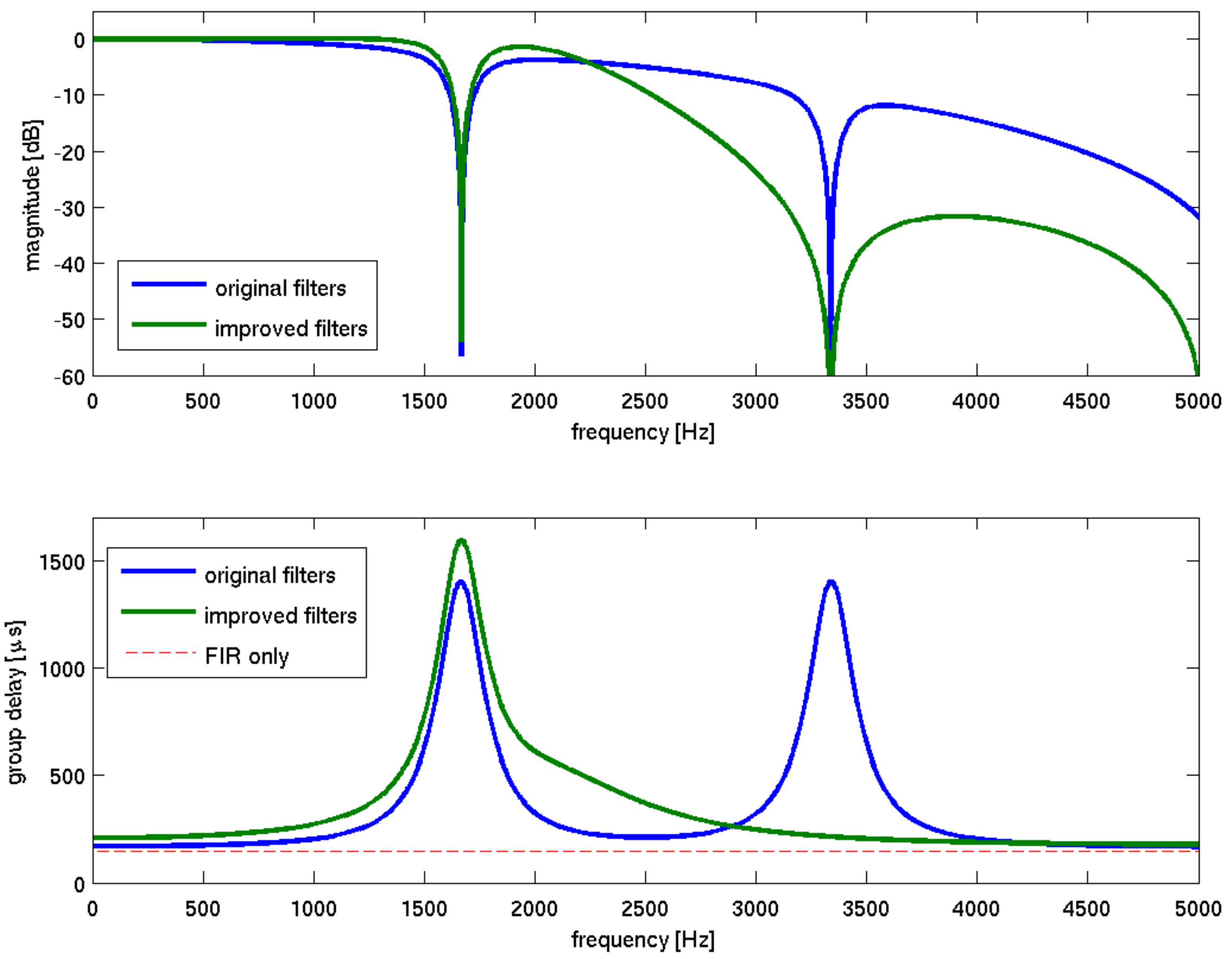
Libera Tuning

- Libera is a complex system with many clocks interacting
- Clocks and ratios can be adjusted or routed from different sources
- Some things can be done purely in software (e.g. FIR and IIR filters in FA data processing), others require FPGA changes (e.g. sync switching with external MC)
- Instrumentation Technologies take experience and solutions from Diamond on board, if slowly

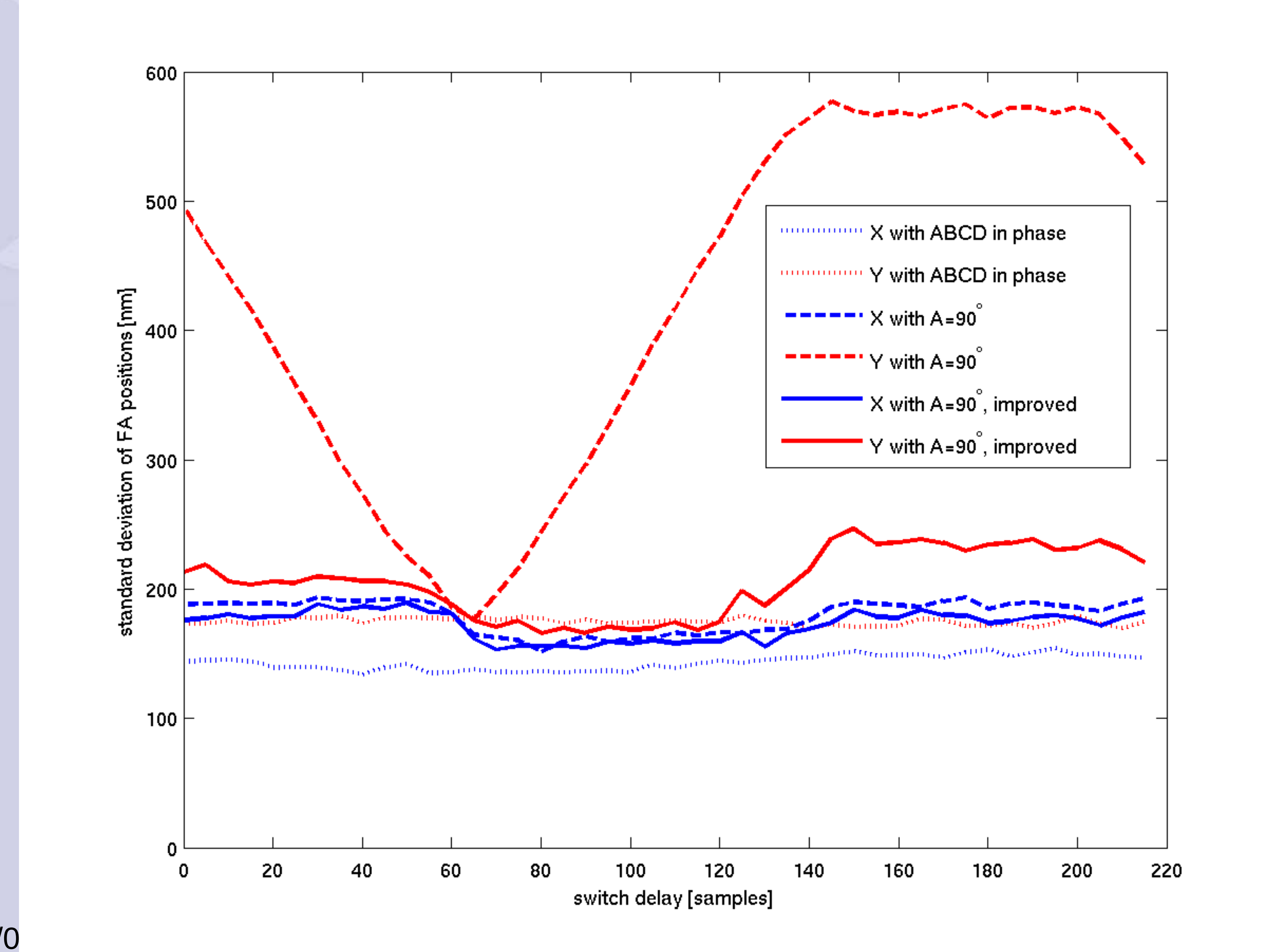
FIR filter improvement



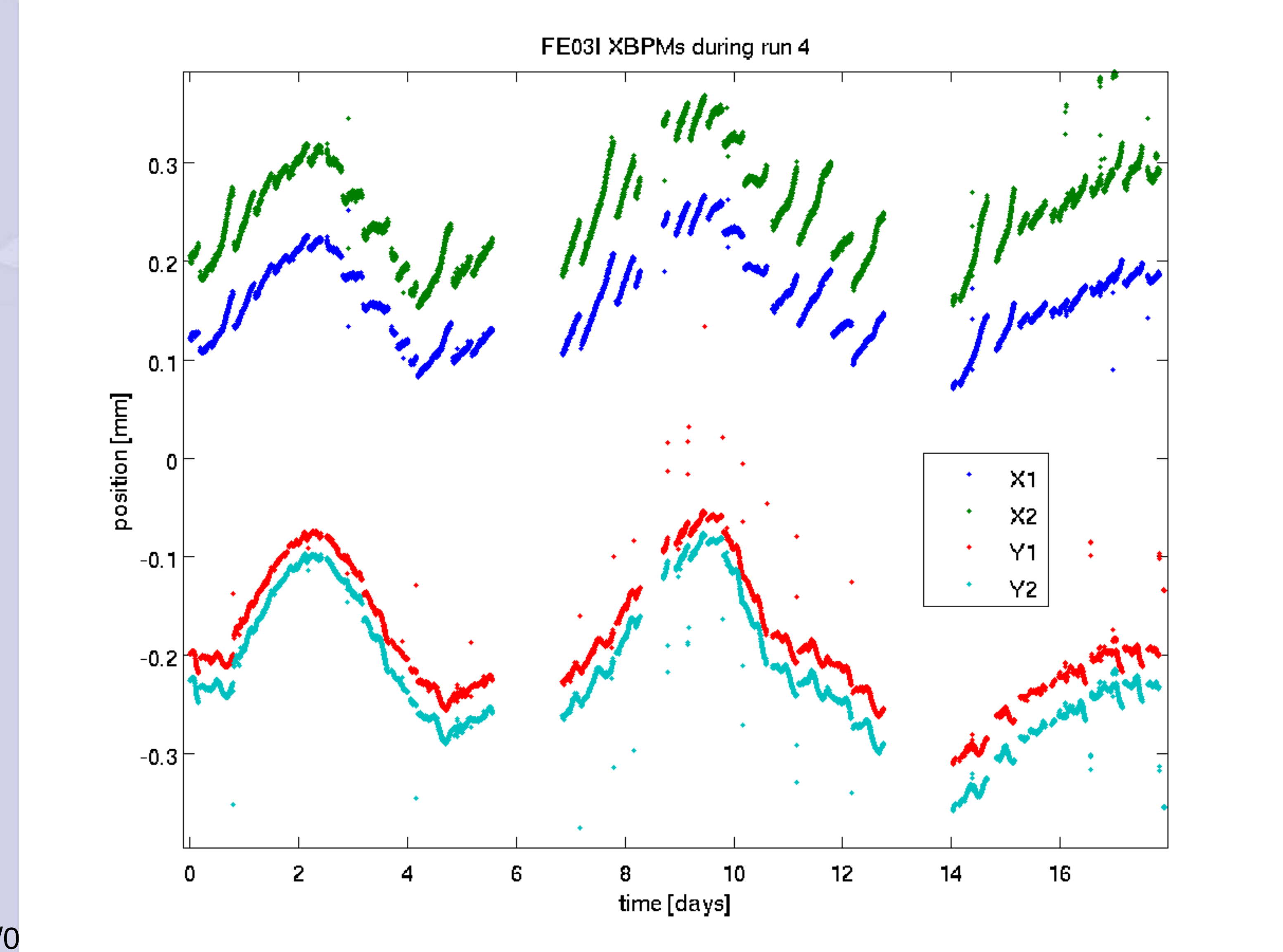
Total filter response (FIR+IIRs)



Switch Delay Optimisation

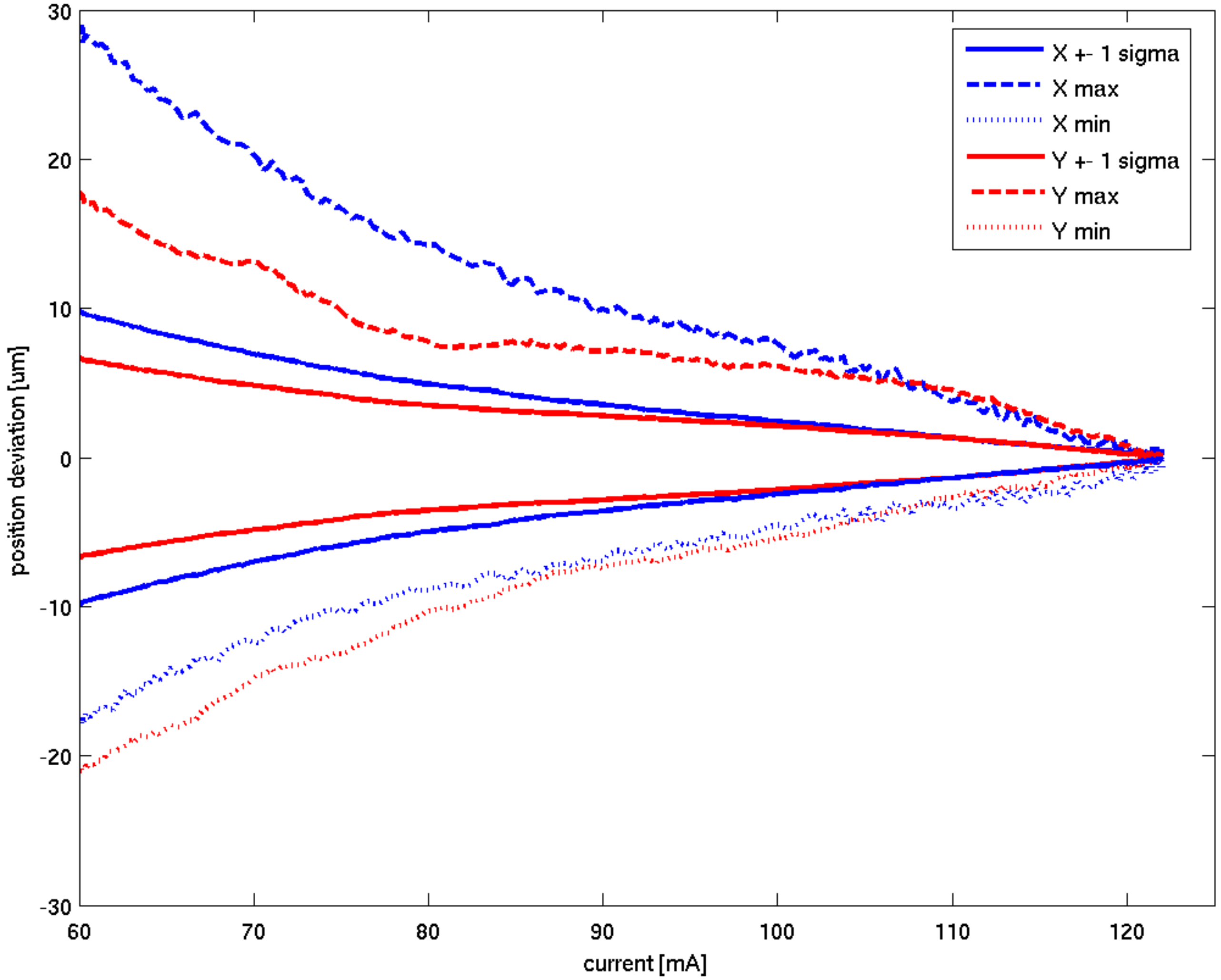


BCD and ? on XBPMs



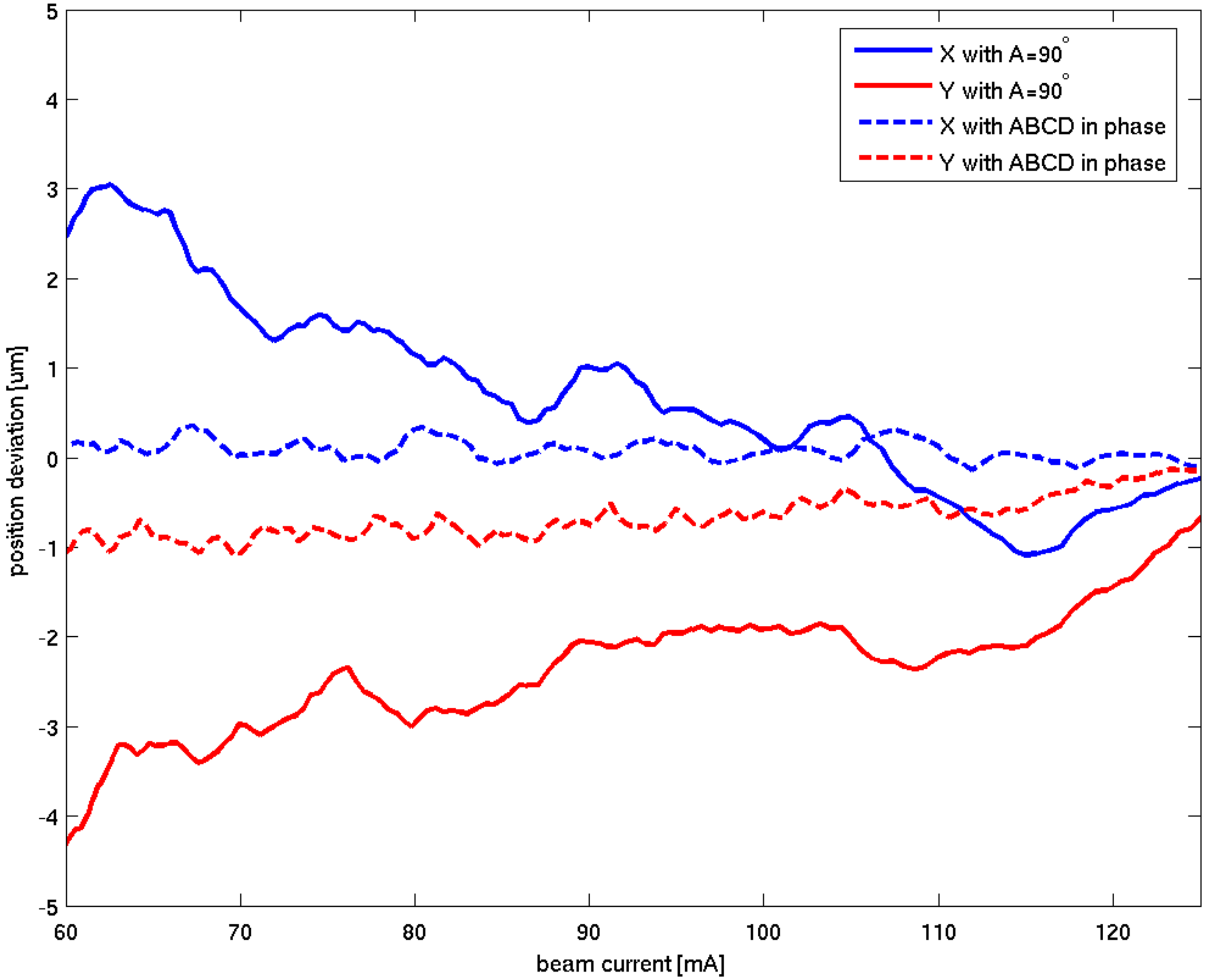
BCD with “real” beam

Measured on 48 primary EBPMs

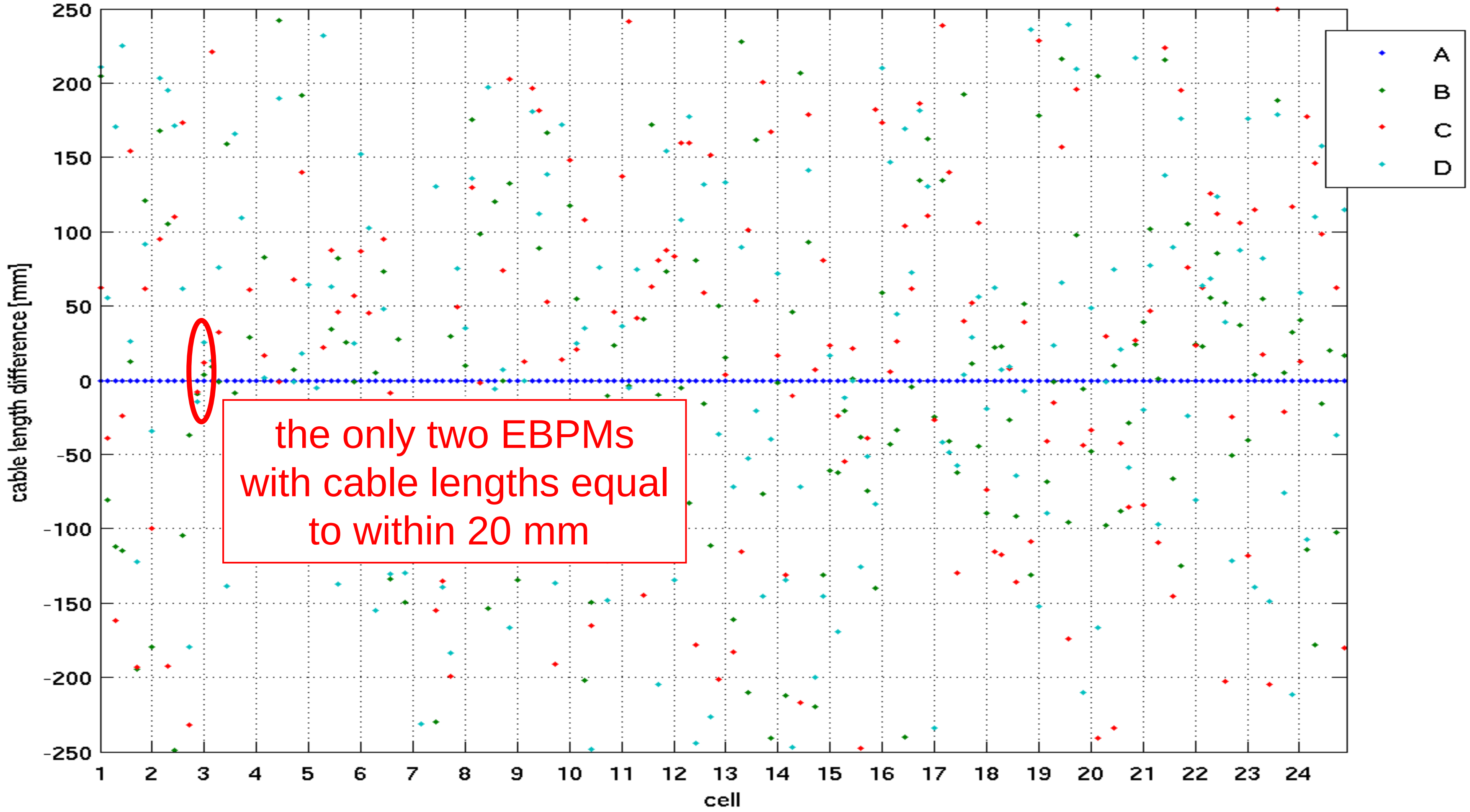


BCD with phase shift of one input

Measured on one BPM in the lab (35 dB attenuation)



Cable Length Differences



Synchronisation of FA data

- All Liberas have to produce FA data synchronously
- As FA is decimated from sample clock, all sample clocks need to be same frequency and decimation needs to be aligned
- Sample clocks are locked to externally supplied revolution clock using software daemon (lmtd)
- Synchronisation is achieved by announcing through control interface and supply a single start trigger on trigger input.
- Same method is used to start output (and time frame counter) of FA data on fast network synchronously

Python Synchronisation Script

commands to all
24 event receivers

commands to all
168 EBPMs

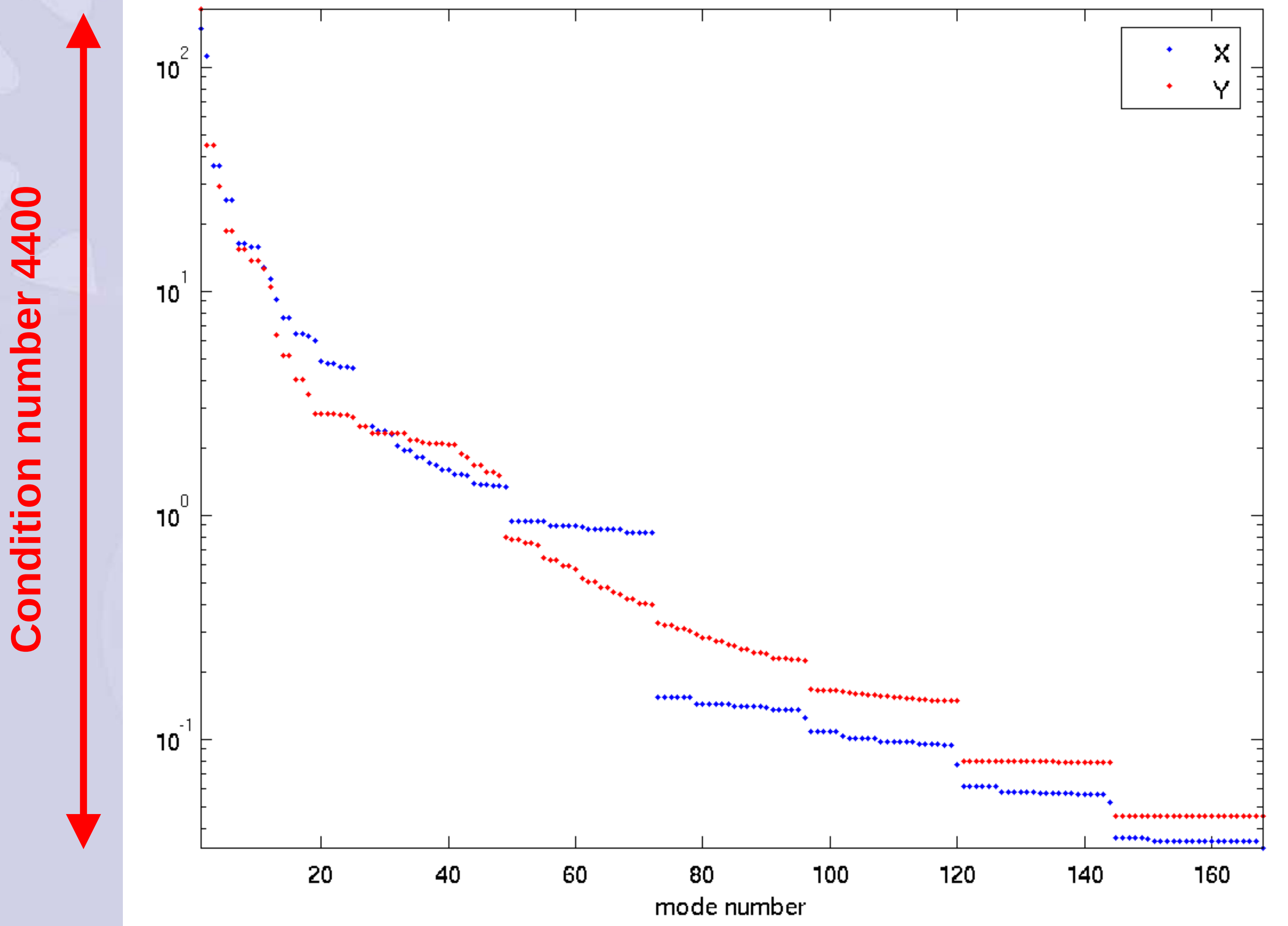
Starting and Stopping FOFB

- Calculations run distributed on 24 CPUs
- Synchronous starting / stopping is essential as otherwise correction is applied on part of correctors for some time
- All feedback CPUs communicate status (stopped, ready, running) through fast network
- When **all** are ready, feedback starts on next cycle
- When **any** is stopped, all stop on next cycle
- Stopping can be caused by:
  - command
  - out of limits for total corrector current
  - out of limits for corrector current step (around 2 s average)
  - out of limits for beam position

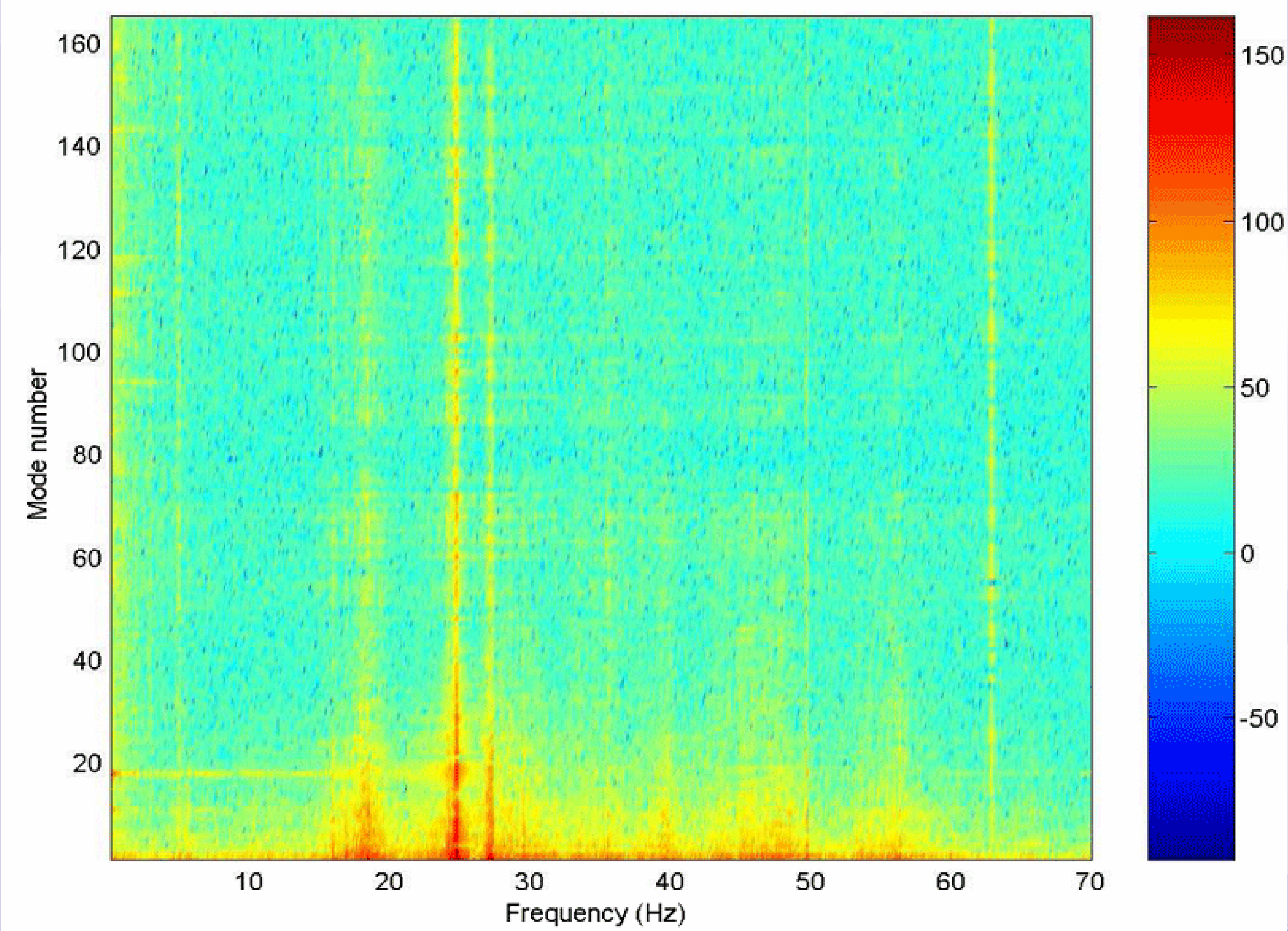
Calculating a Pseudo Inverse Response Matrix

- In principle, Diamond has 168 EBPMs and 168 correctors each plane, so decoupled response matrices are 168x168
- Square matrices could be directly inverted
- However, system should also work with fewer EBPMs or correctors
- Use singular value decomposition for pseudo inversion
- Orbit motion can then be transformed into “mode space”

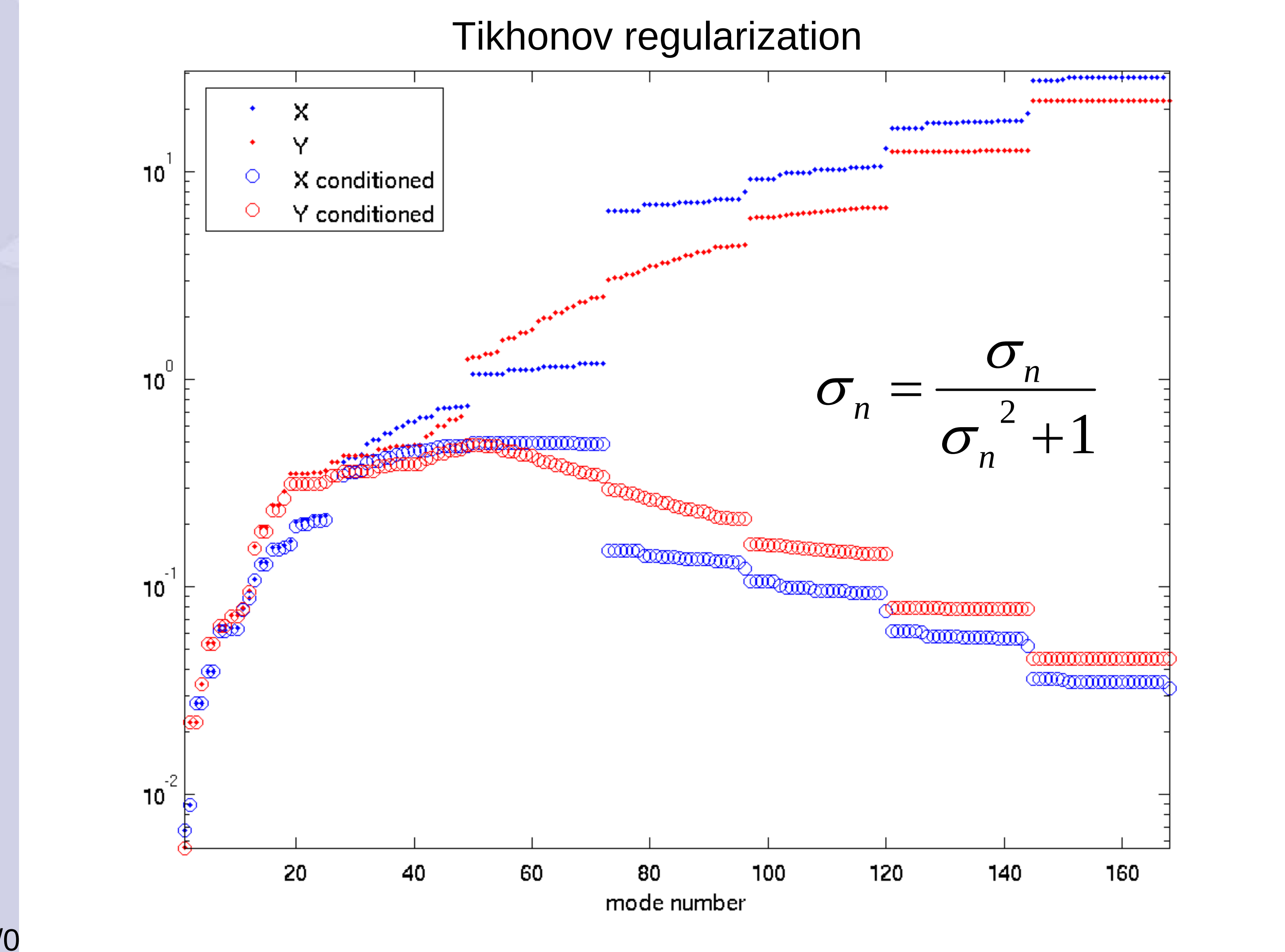
Response Matrix Eigen Values



Orbit Motion in Mode Space



Inversion and Conditioning



Summary

- Libera integrates well into a FOFB system
- Communication Controller performs reliably and without additional hardware
- Feedback calculations on CPU have been relatively easy to commission
- Effective suppression of orbit motion demonstrated
- Running in user mode since 22 July

Acknowledgements

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- External: Stephen Duncan (OU), Andrej Terebilo (SLAC), Leo Breuss (SCS)