

Slow Feedbacks

2. Tutorial on basics and operation of slow feedbacks

Raimund Kammering
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Introduction

Many feedbacks (FBs) are around

- RF FBs
- Kicker FBs
- Intra Bunch Train FBs
- slow RF FBs
- orbit FBs
- ...

Area of interest very different – but in general two domains

- intra train
- over several pulses

Introduction

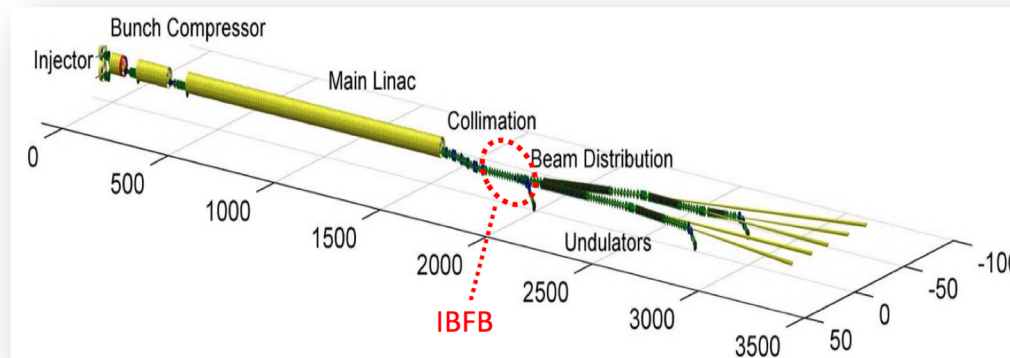
Slow FBs

- main purpose is to **stabilize** and **compensate slow drifts**
- two most important slow FBs are:
 - **Transversal** FB = orbit FB
 - **Longitudinal** FB = slow RF FB
- **DOOCS middle layer server** based
- exact **same software as at FLASH** (just configured differently)
- **same look & feel** as at FLASH (use same panels)
- some differences in underlying interfaces (e.g. magnets)

Introduction

Fast FBs

- most relevant for XFEL: Intra Bunch Train FB (IBFB) – **transversal**
- in-kind contribution from PSI
- uses fast kickers (instead of magnets)
- can feed back on individual bunches
- goal: $< 5 \text{ um}$ beam stability within undulators
- (at FLASH: Fast arrival time FB – **longitudinal**)



Slow and fast FBs

How to get there

The screenshot displays the European XFEL control interface. At the top, a navigation bar includes icons for Status, Operations, Procedures, Feedbacks (highlighted with a yellow arrow), Automation, Diagnostics, and Tools. Below this, a secondary bar contains icons for MPS, Injector, RF, Orbit, Photons, Beam Dynamics, Magnets, Vacuum, Cryo, and Controls. The main area is divided into several sections:

- Feedbacks:** A large section on the left with a green and red circular arrow icon. It contains a list of feedback systems: Long. FB - SASE1, Orbit FB Linac, Orbit FB - SASE, Orbit FB - Dump, and Orbit FB - Overview. Each section has a list of sub-controls: Controls, Charge/BCMs History, BAMs History, Expert, Detector Layout, Response Matrix (GUI), Intra Bunch FB, IBFB Operation, IBFB Expert, and IBFB History.
- Longitudinal:** A section at the bottom left showing the status of various feedback systems. It includes a table with columns for Gun, Charge, BC0, BC1, BC2, SASE1, SASE2, SASE3, T4D, and T5D. Each column has 'Active' and 'Status' indicators.
- Orbit:** A section at the bottom right showing the status of various feedback systems. It includes a table with columns for Injector, L1, L2, L3, TL, SASE1, SASE2, SASE3, T4D, and T5D. Each column has 'Active' and 'Status' indicators.

	Gun	Charge	BC0	BC1	BC2	SASE1	SASE2	SASE3	T4D	T5D
	Amplitude	Phase	BAM	BCM	BAM	BCM	BAM	BCM		
Longitudinal:										
Active:	☐	☐	☒	☒	☐	☒	☐	☐	☐	☐
Status:	☐	☐	☒	☒	☐	☒	☐	☐	☐	☐
Orbit:										
Active:	☐	☐	☒	☒	☒	☒	☐	☒	☐	☐
Status:	☐	☐	☒	☒	☒	☒	☐	☒	☐	☐

Slow and fast FBs

How to get there – how it has been 1 year ago

High Level Controls

European XFEL

Slow Feedbacks – How to get there

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The screenshot displays the XFEL Main Taskbar (XFELMainTaskbar.xml) interface. The top bar contains icons for Status, Operations, Procedures, Feedbacks, Automation, Diagnostics, Tools, MPS, Injector, RF, Orbit, Photons, Beam Dynamics, Magnets, Vacuum, Cryo, and Controls. The Feedbacks section is highlighted with a red box, and the Automation section is also highlighted with a red box. A red arrow points from the Automation icon to the Feedbacks icon. Below the top bar, the Longitudinal and Orbit sections are visible, each with a red box around its controls. The Longitudinal section includes Controls, Mon/Act: Charge, and Expert. The Orbit section includes Overview and Expert. At the bottom, the status 'Longitudinal FBs: running' is displayed.

Longitudinal FBs: running

XFEL Operator Training 8th July 2016

Slow and fast FBs

How to get there

The screenshot displays the European XFEL control interface. At the top, a navigation bar includes icons for Status, Operations, Feedbacks, Diagnostics, and Tools. Below this, a grid of buttons provides access to different feedback systems. A yellow box highlights the 'Long. FB - SASE1' section, which includes buttons for Controls, Charge/BCMs History, BAMs History, Expert, Detector Layout, and Response Matrix (GUI). Another yellow box highlights the 'Orbit FB Linac' section, which includes buttons for Injector Orbit FB, L1 Orbit FB, L2 Orbit FB, L3 Orbit FB, and TL Orbit FB. A third yellow box highlights the 'Orbit FB - SASE' section, which includes buttons for SA1 Orbit FB, SA2 Orbit FB, and SA3 Orbit FB. A fourth yellow box highlights the 'Orbit FB - Dump' section, which includes buttons for T4D Orbit FB and T5D Orbit FB. A fifth yellow box highlights the 'Orbit FB - Overview' section, which includes a button for Orbit FB Overview. A white box labeled 'Longitudinal FBs' points to the 'Long. FB - SASE1' section. A white box labeled 'IBFB' points to the 'Intra Bunch FB' section, which includes buttons for IBFB Operation, IBFB Expert, and IBFB History. A white box labeled 'Transversal FBs' points to the 'Orbit FB - Overview' section. At the bottom, a status bar shows the active and status of various feedback systems, including Gun, Charge, BC0, BC1, BC2, SASE1, SASE2, SASE3, T4D, and T5D.

European XFEL

Status

Operations

Feedbacks

Diagnostics

Tools

MPS

Injector

RF

Orbit

Photons

Beam Dynamics

Magnets

Vacuum

Cryo

Controls

Long. FB - SASE1

Orbit FB Linac

Orbit FB - SASE

Orbit FB - Dump

Orbit FB - Overview

Controls

Charge/BCMs History

BAMs History

Expert

Detector Layout

Response Matrix (GUI)

Intra Bunch FB

IBFB Operation

IBFB Expert

IBFB History

Longitudinal FBs

IBFB

Transversal FBs

Gun

Charge

BC0

BC1

BC2

SASE1

SASE2

SASE3

T4D

T5D

Amplitude

Phase

BAM

BCM

BAM

BCM

BAM

BCM

Active:

Status:

Injector

L1

L2

L3

TL

SASE1

SASE2

SASE3

T4D

T5D

Longitudinal:

Orbit:

The Longitudinal FB

Main purpose

- stabilize longitudinal phase space
- main source for disturbances is RF (phase, energy)
 - ➔ control RF phase + energy relevant for bunch compression
 - ➔ monitor bunch compression process

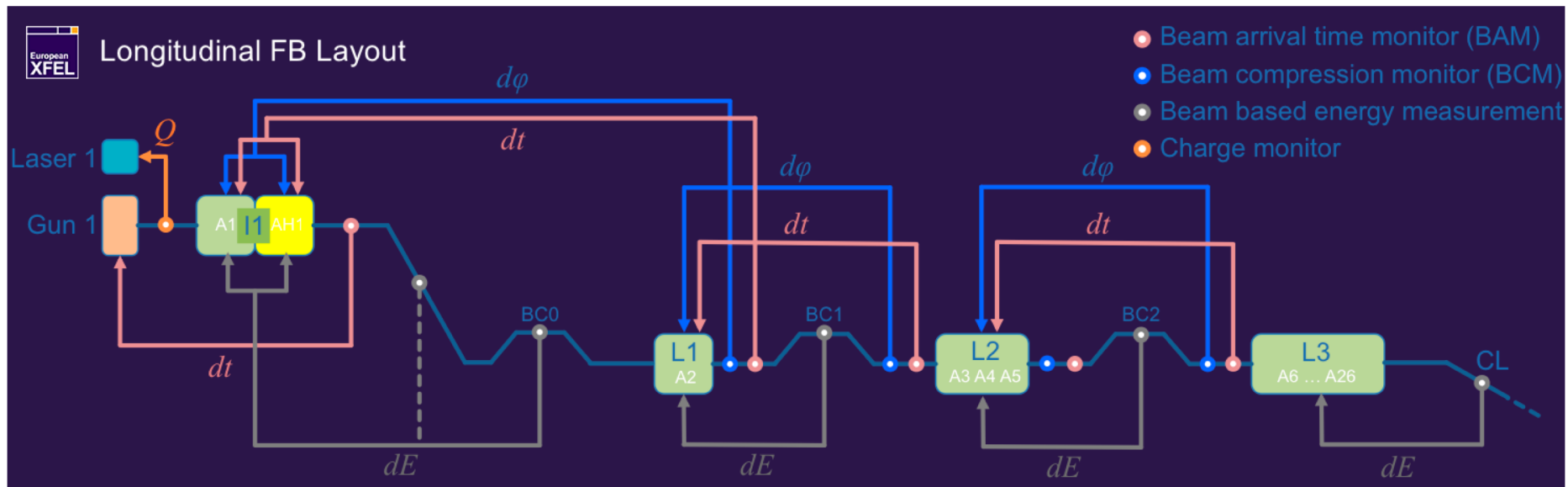
Actuators: RF phases, energy of A1 + AH1, L1, L2, L3

Monitors: Bunch Compression Monitors (BCMs)
Beam Arrival Monitors (BAMs)

- practically linear dependency between actuators and monitors
 - ➔ simple controller is sufficient

The Longitudinal FB

- DOOCS DAQ based middle layer server
- Simple P controller with integrator
- 8 FB loops configured so far (17 monitors and 17 actuators)



[Details see also: ICALEPCS 2013 THPPC121]

The Longitudinal FB – 'under the hood'

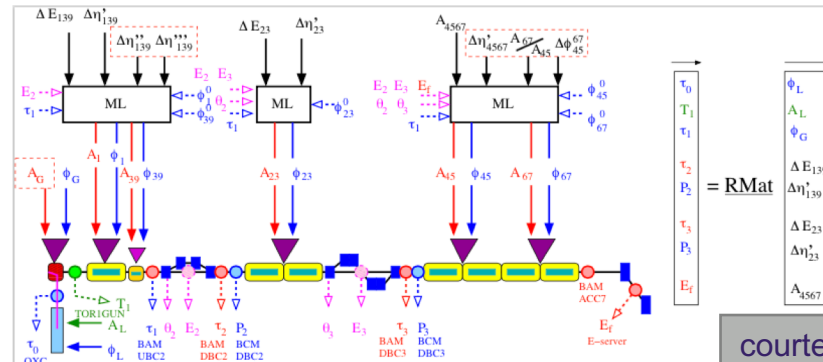
- inverse Response Matrix

$$\delta \mathbf{a} = \mathbf{R}^{-1} \cdot \delta \mathbf{m}$$

- Matrix formalism (GNU Scientific Library + DOOCS MDFA)

$$\begin{pmatrix} \delta \text{ampl}_{ACC1} \\ \delta \text{phase}_{ACC1} \\ \delta \text{ampl}_{ACC39} \\ \delta \text{phase}_{ACC39} \\ \delta \text{ampl}_{ACC23} \\ \delta \text{phase}_{ACC23} \\ \delta \text{ampl}_{ACC45} \\ \delta \text{phase}_{ACC45} \\ \delta \text{ampl}_{ACC67} \\ \delta \text{phase}_{ACC67} \end{pmatrix} = \begin{bmatrix} R_{11} & R_{12} & \dots & \dots & R_{91} \\ & \ddots & & & \\ & & \ddots & & \\ & & & \ddots & \\ & & & & 0 \\ & & & & R_{99} \\ & & & & R_{910} \end{bmatrix} \begin{pmatrix} \delta B_{AM1UBC2} \\ \delta B_{AMBC2} \\ \delta B_{CMBC2}(fine) \\ \delta B_{CMBC2}(coarse) \\ \delta B_{AMBC3} \\ \delta B_{CMBC3}(fine) \\ \delta B_{CMBC3}(coarse) \\ \delta B_{AM18ACC7} \\ \delta Energy_{Dogleg} \end{pmatrix}$$

- Gets complex if all parameters of the longitudinal phase space are considered

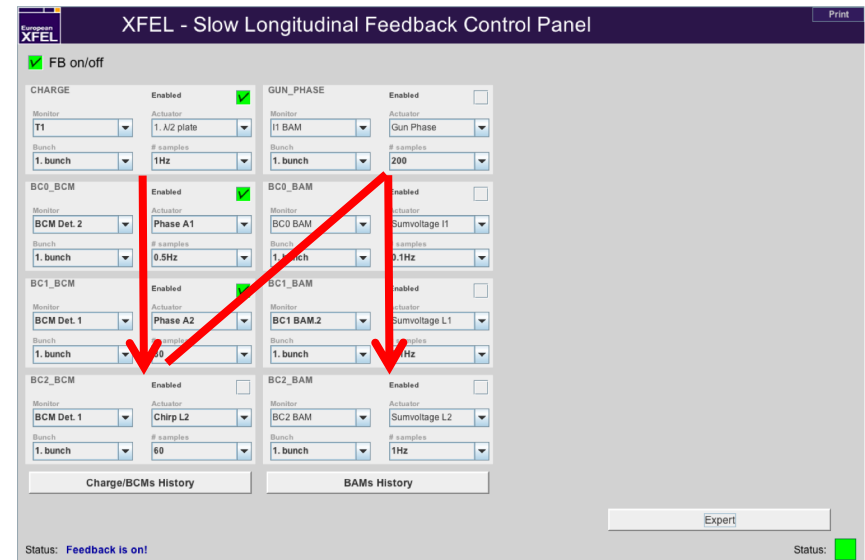


courtesy of M. Vogt

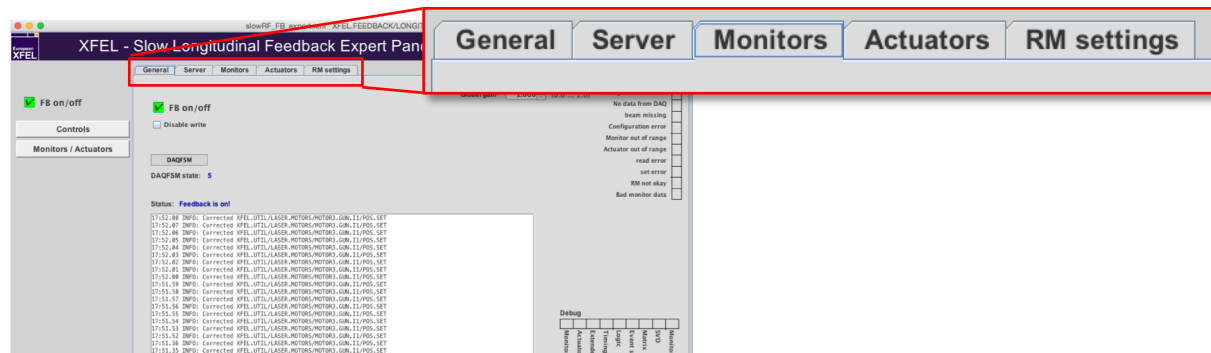
The Longitudinal FB – Operators View

Panels reflect **topology** and **architecture**

- Topology: e.g. INJ to L3 (causality!)



- Architecture: e.g. Monitors, Actuators form 'groups'



The Longitudinal FB – Operators View

The image displays the XFEL - Slow Longitudinal Feedback Control Panel, which is divided into several sections:

- Long. FB - SASE1:** Contains a 'Controls' section with a 'Charge/BChs History' button highlighted in yellow. Below it are 'BAMs History' and 'Expert' buttons, also highlighted in yellow. A yellow arrow points from the 'Expert' button to the 'XFEL - Slow Longitudinal Feedback Expert Panel'.
- Orbit FB Linac:** Contains 'L1 Orbit FB', 'L2 Orbit FB', 'L3 Orbit FB', and 'TL Orbit FB' buttons.
- Orbit FB - SASE1:** Contains 'SA1 Orb', 'SA2 Orb', and 'SA3 Orb' buttons.
- XFEL - Slow Longitudinal Feedback Control Panel:** This panel has a 'FB on/off' checkbox checked. It includes sections for 'CHARGE' (with 'Monitor' and 'Bunch' dropdowns), 'BC0_BCM' (with 'Monitor' and 'Bunch' dropdowns), and 'BC1_BCM' (with 'Monitor' and 'Bunch' dropdowns). It also has 'GUN_PHASE' and 'BC0_BAM' sections.
- XFEL - Slow Longitudinal Feedback Expert Panel:** This panel has a 'FB on/off' checkbox checked. It includes a 'Controls' section with 'Charge/BChs History' and 'BAMs History' buttons. It also has a 'Monitors' section with 'Toroid TORA 25.11', 'BC0 BCM.2', 'BC1 BCM.1', and 'BC2 BCM.1' monitors. It has an 'Actuators' section with 'Laser Attenuator', 'A1 Phase', 'A2 Phase', and 'Chip L2' actuators. A yellow arrow points from the 'Expert' button in the 'Long. FB - SASE1' section to the 'Monitors' section of the 'XFEL - Slow Longitudinal Feedback Expert Panel'.
- Monitors:** This section displays several graphs showing the feedback signal over time. The graphs are labeled 'Toroid TORA 25.11', 'BC0 BCM.2', 'BC1 BCM.1', 'BC2 BCM.1', 'Laser Attenuator', 'A1 Phase', 'A2 Phase', and 'Chip L2'. Each graph shows a mean value, a target value, and a status indicator (e.g., 'Status: ok').
- Actuators:** This section displays several graphs showing the feedback signal over time. The graphs are labeled 'Laser Attenuator', 'A1 Phase', 'A2 Phase', and 'Chip L2'. Each graph shows a mean value, a target value, and a status indicator (e.g., 'Status: ok').
- General:** This section contains a 'Status: Feedback is on!' message and a list of data types (e.g., 'Data Type: A_USTR').
- Debug:** This section contains a table with columns for 'Monitors', 'Actuators', 'Members', 'Generated', 'Timing', 'Logic', 'Event', 'Set', 'Monitor', and 'Data'. It lists various components and their status.
- Monitors Table:**

	All	Valid	Enabled	Available
Monitors	17	7	3	3
Actuators	17	17	3	3

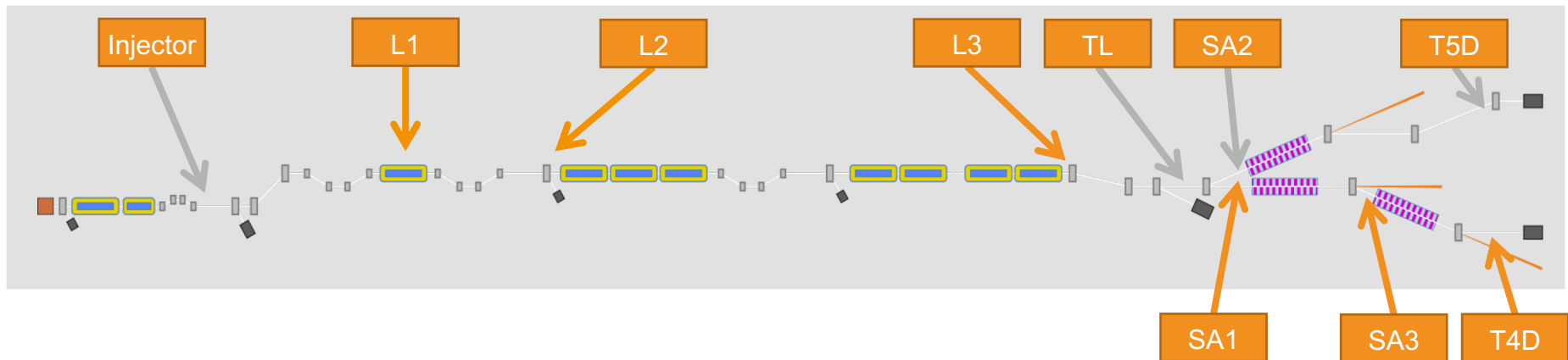
The Transversal FBs

Main objective

- **stabilize** orbit (*trajectory* ;) to a given one ('golden orbit') – slow FB
- equalize trajectory of individual bunches – fast FB
- disturbances: e.g. magnet vibrations, power supply noise, wake-fields, ...

Actuators: Magnetic correctors (slow FB), kickers (fast FB)

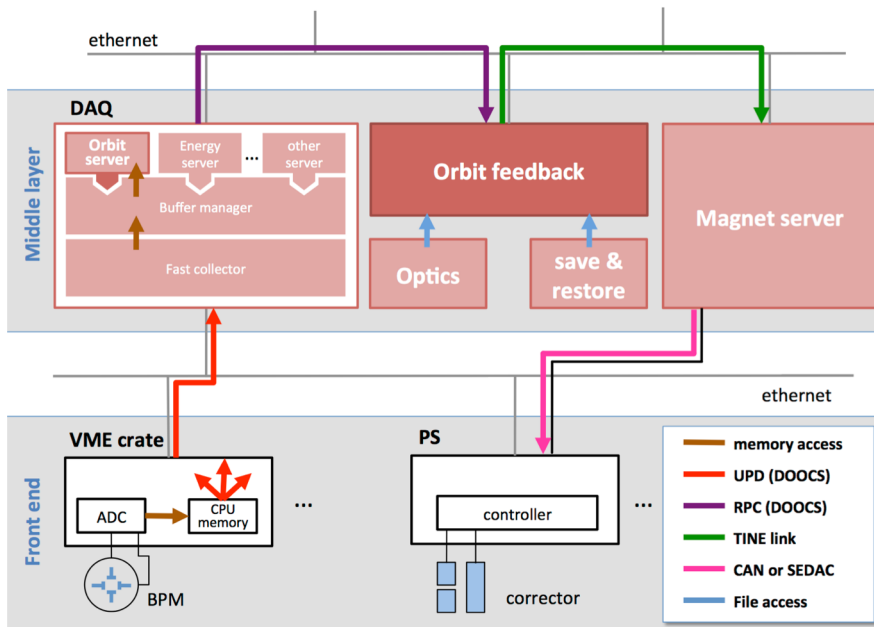
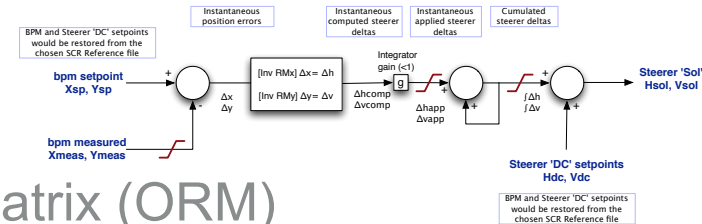
Monitors: Beam Position Monitors (BPMs)



The slow Transversal FB – Architecture

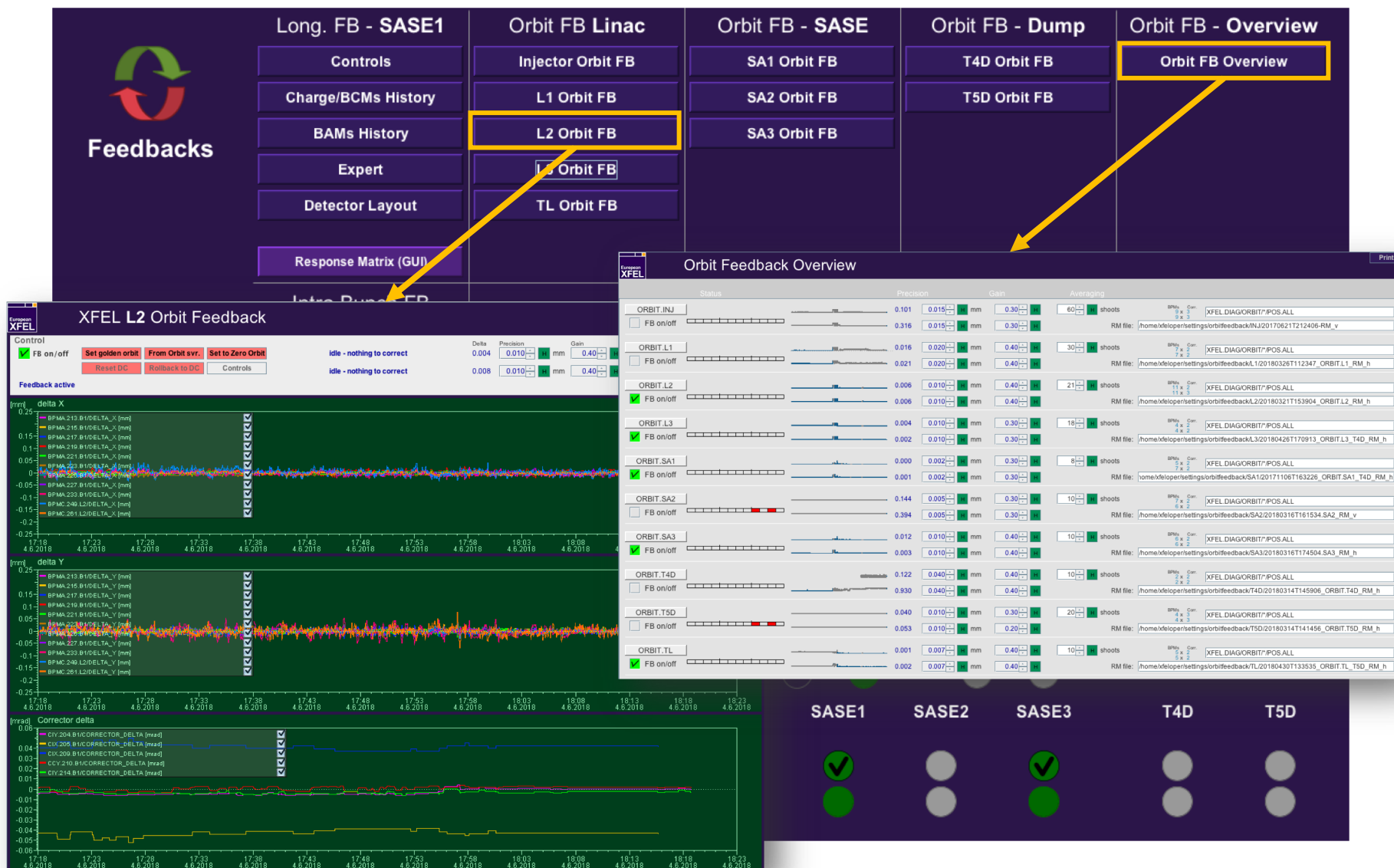
DOOCS Middle layer based FB (J. Carwardine, R. Kammering)

- Systematically designed controller (P-controller with FIR filter)
- Global FB using inverse Orbit Response Matrix (ORM)
- Tight integration into control system (e.g. decoupled from BPM front-ends)

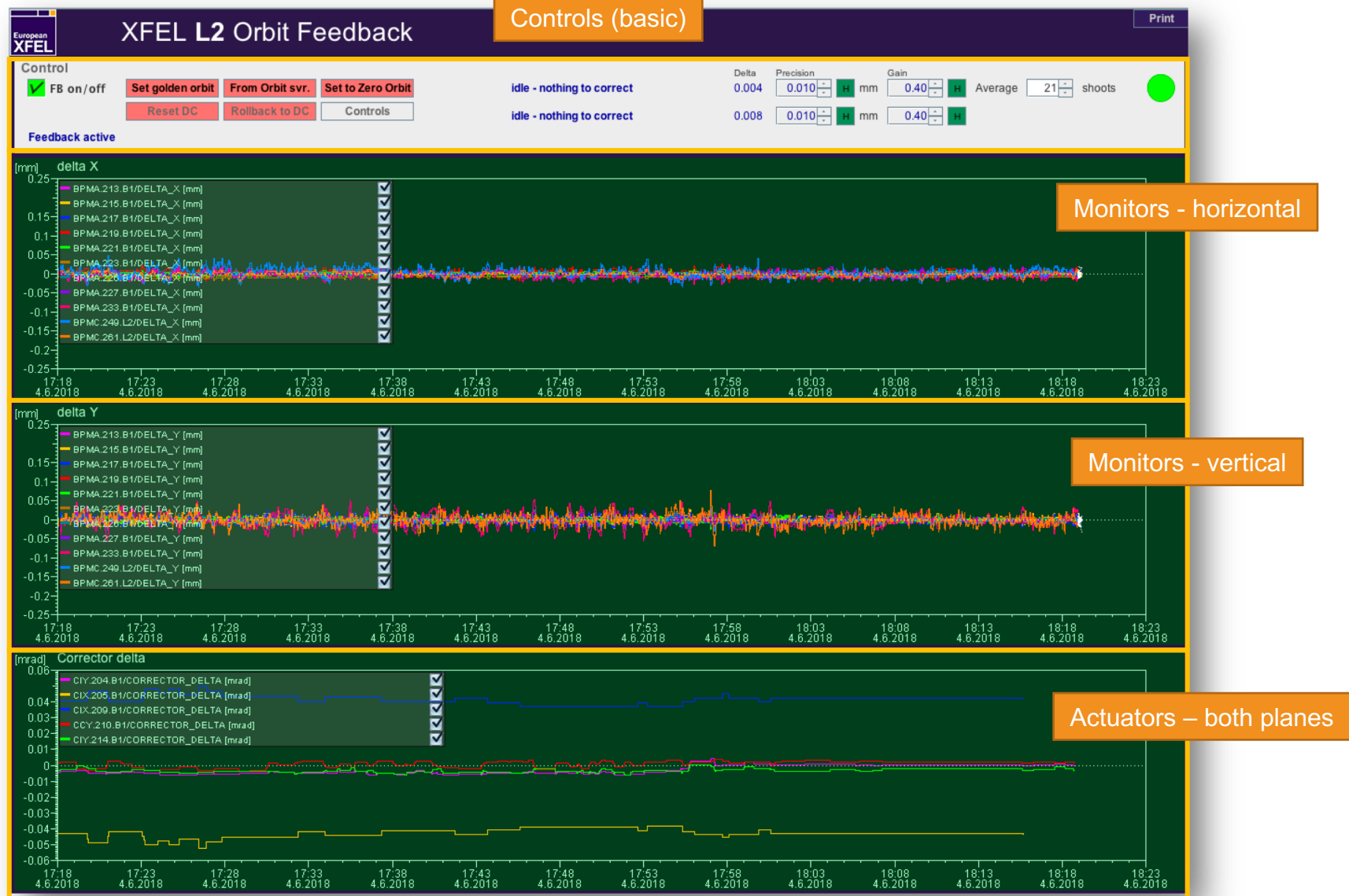


[see: PCAPAC2010 WEPL015]

The Transversal FBs



The Transversal FBs – operation



The Transversal FBs – operation



XFEL L2 Orbit Feedback

Print

☒ FB on/off

Set golden orbit

Reset DC

Rollback to DC

Overview

Mon/Act History

Correctors

ORBIT.L2

GeneralExpertBPMsCorrectorsRM

Controls

	Horiz.		Vert.	
Orbit deviation	0.006	mm	0.005	mm
Allowed	0.010	H mm	0.010	H mm
Gain	0.400	H	0.400	H
delta min	0.0000			
delta max	0.5000			
Averaging	21	macropulses		

inactive BPMs selected

DAQ not okay

beam missing

orbit svr. problem

out of range

delta out of range

read error

set error

no BPMs

no corr.

insuff. corr.

RM not okay

Status

	Available BPMs	Available corr.
Horizontal	11	2
Vertical	11	3

Horiz. correction status

idle - nothing to correct

Vert. correction status

idle - nothing to correct

FB Status

Feedback active

The Transversal FBs – operation



XFEL L2 Orbit Feedback

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Mon/Act History

Correctors

ORBIT.L2

GeneralExpertBPMsCorrectorsRM

Debugging

☐ Disable write

☐ BPMs

☐ Correctors

☐ Extended

☐ Timing

☐ Logic

☐ Extended 2

☐ Matrix

☐ SVD

BPM/corr overview

	BPMs	Enabled BPMs	Available BPMs
Horizontal	26	11	11
Vertical	26	11	11

	Correctors	Enabled corr.	Available corr.
Horizontal	14	2	2
Vertical	14	3	3

BPM data address:

Server performance

Memory size:	1167 Mb	Last start times:	2018-05-15 22:09:42
Resident mem size:	106 Mb		2018-05-15 21:13:06
CPU usage:	4.10 %		2018-05-15 21:10:17
			2018-05-15 21:07:25

The Transversal FBs – operation

European XFEL
XFEL L2 Orbit Feedback
Print

☒ FB on/off

Set golden orbit

Reset DC

Rollback to DC

Overview

Mon/Act History

Correctors

General
Expert
BPMs
Correctors
RM

Name	X	Y	Status
BPMA.206.B1	☐	☐	
BPMA.210.B1	☐	☐	
BPMA.213.B1	☒	☒	
BPMA.215.B1	☒	☒	
BPMA.217.B1	☒	☒	
BPMA.219.B1	☒	☒	
BPMA.221.B1	☒	☒	
BPMA.223.B1	☒	☒	
BPMA.226.B1	☒	☒	
BPMA.227.B1	☒	☒	
BPMA.233.B1	☒	☒	
BPMC.249.L2	☒	☒	
BPMC.261.L2	☒	☒	
BPMR.273.L2	☐	☐	
BPMR.285.L2	☐	☐	
BPMC.297.L2	☐	☐	
BPMR.309.L2	☐	☐	
BPMC.321.L2	☐	☐	
BPMR.333.L2	☐	☐	
BPMC.345.L2	☐	☐	
BPMC.357.L2	☐	☐	
BPMR.369.L2	☐	☐	
BPMR.381.L2	☐	☐	
BPMA.387.B2	☐	☐	
BPMA.390.B2	☐	☐	
BPMF.393.B2	☐	☐	

BPMA.215.B1

BPM Details

Horizontal

Enabled ☒ SP

Weight

X Std

SP Delta

Status

set error
read error
out of range
orbitlsvr. nok
no beam
DAQ not ok

Vertical

Enabled ☒ SP

Weight

Y Std

SP Delta

Status

set error
read error
out of range
orbitlsvr. nok
no beam
DAQ not ok

Common Data

min limit Z position: 221.19

max limit Idx. in RM: 3

The Transversal FBs – operation

European XFEL
XFEL L2 Orbit Feedback
Print

☒ FB on/off

ORBIT.L2

Set golden orbit

Reset DC

Rollback to DC

Overview

Mon/Act History

Correctors

General
Expert
BPMs
Correctors
RM

Name/idx
☒ CIX.205.B1
☒ CIX.209.B1
☐ CIX.213.B1
☐ CIX.216.B1
☐ CFX.223.B1
☐ CFX.226.B1
☐ CCX.232.B1
☐ CX.249.L2
☐ CX.273.L2
☐ CX.297.L2
☐ CX.321.L2
☐ CX.345.L2
☐ CX.369.L2
☐ CCX.388.B2

Currents [A]

idx	SP	Initial	Delta	min	max	Status
0	0.171	0.171	-0.051	-0.76	0.76	calibr.
1	0.257	0.257	0.050	-0.76	0.76	calibr.
2	-0.200	-0.200	0.000	-0.76	0.76	calibr.
3	0.251	0.251	0.000	-0.76	0.76	calibr.
4	-0.065	-0.065	0.000	-10.73	10.72	calibr.
5	0.160	0.160	0.000	-10.73	10.72	calibr.
6	0.057	0.057	0.000	-2.26	2.26	calibr.
7	-0.076	-0.076	0.000	-3.24	3.24	calibr.
8	0.019	0.019	0.000	-2.47	2.47	calibr.
9	0.070	0.070	0.000	-1.94	1.94	calibr.
10	-0.002	-0.002	0.000	-1.58	1.58	calibr.
11	-0.001	-0.001	0.000	-1.36	1.36	calibr.
12	-0.020	-0.020	0.000	-1.19	1.19	calibr.
13	0.091	0.091	0.000	-0.66	0.66	calibr.

Read all

Enabled 2 Avail. 2

CIX.205.B1
☒ Enabled
☐ Update now
☐ Set DC

Feedback:
 SP 0.171
 DC 0.171
 Delta -0.051

Magnet svr.:
 RBV 0.120
 SP 0.120
 max 0.7607
 min -0.7603
 Weight 1.00

Static Infos:
 Idx in RM 0
 Z pos.: 205.14

Status:
☐ set error
☐ read error
☐ delta out of rng
☐ out of range
☐ no beam
☐ DAQ not ok
☐ inactive

Status
ok

DESY.

Page 20

The Transversal FBs – operation

XFEL L2 Orbit Feedback

Print

☒ **FB on/off**

ORBIT.L2

Set golden orbit

Reset DC

Rollback to DC

Overview

Mon/Act History

Correctors

General
Expert
BPMs
Correctors
RM

General
H matrix
inv H matrix
V matrix
inv V matrix
control matrix

BPMs

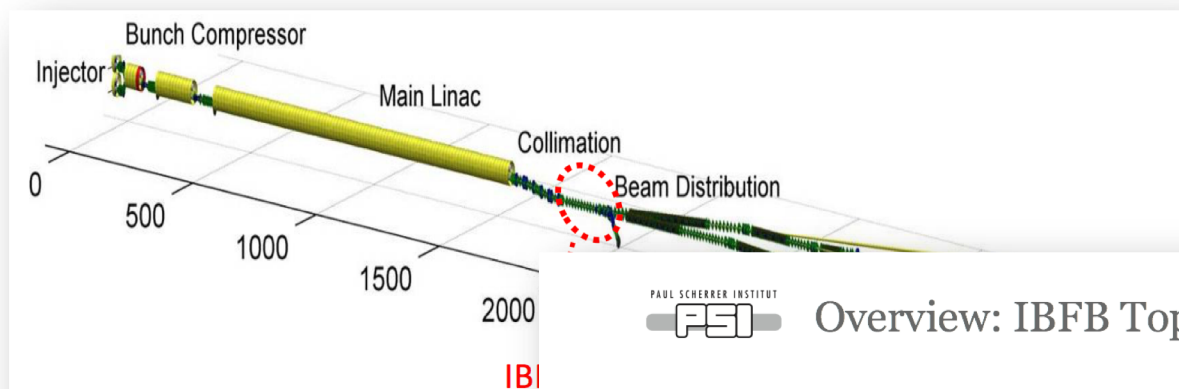
Correctors														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
0	1.543	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	3.170	0.429	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	6.648	4.304	0.230	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	4.915	4.042	1.903	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	4.686	5.174	4.475	1.363	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	7.473	9.674	10.002	4.212	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	2.154	3.482	4.281	2.208	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	-3.165	-1.829	0.334	1.467	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	-5.344	-6.071	-5.446	-1.798	2.705	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	-7.833	-9.544	-9.285	-3.562	4.756	0.230	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	-5.290	-8.052	-9.508	-4.709	5.180	3.717	1.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	10.408	6.539	-0.042	-4.072	1.202	13.311	19.935	0.085	0.000	0.000	0.000	0.000	0.000	0.000
12	9.298	8.738	5.800	0.514	-2.473	5.471	10.973	11.351	0.000	0.000	0.000	0.000	0.000	0.000
13	16.382	18.099	15.665	4.780	-7.667	3.649	12.957	30.521	0.085	0.000	0.000	0.000	0.000	0.000
14	7.595	9.798	10.098	4.233	-5.277	-1.427	2.686	19.627	11.603	0.000	0.000	0.000	0.000	0.000
15	7.226	11.916	14.835	7.746	-8.198	-7.109	-3.566	28.773	32.361	0.085	0.000	0.000	0.000	0.000
16	-1.787	-0.346	1.573	1.813	-1.158	-4.008	-5.257	3.010	13.374	11.845	0.000	0.000	0.000	0.000
17	-12.009	-11.422	-7.763	-0.858	3.360	-6.767	-13.855	-15.187	15.110	38.098	0.085	0.000	0.000	0.000
18	-7.423	-8.373	-7.445	-2.413	3.685	-1.271	-5.464	-14.501	-1.455	17.556	11.940	0.000	0.000	0.000
19	-13.440	-17.009	-17.206	-7.018	8.936	1.796	-5.530	-33.452	-17.829	23.354	38.350	0.085	0.000	0.000
20	2.684	2.396	1.420	-0.032	-0.559	1.859	3.466	2.786	-4.662	-9.228	1.396	11.884	0.000	0.000
21	19.550	21.954	19.411	6.214	-9.585	3.565	14.622	37.808	3.027	-46.684	-30.558	33.027	0.085	0.000
22	15.103	17.564	16.213	5.666	-8.144	1.415	9.871	31.560	7.303	-33.310	-29.074	18.331	11.932	0.000
23	19.933	23.523	22.086	7.968	-11.167	1.111	12.221	42.982	12.446	-42.404	-41.463	20.130	22.459	0.000
24	14.381	17.122	16.237	5.964	-8.241	0.469	8.463	31.596	10.213	-29.909	-31.274	12.738	19.154	1.829
25	13.113	15.767	15.119	5.661	-7.705	0.082	7.348	29.415	10.594	-26.559	-29.927	9.759	20.528	4.773

Excuse: The adaptive orbit FB



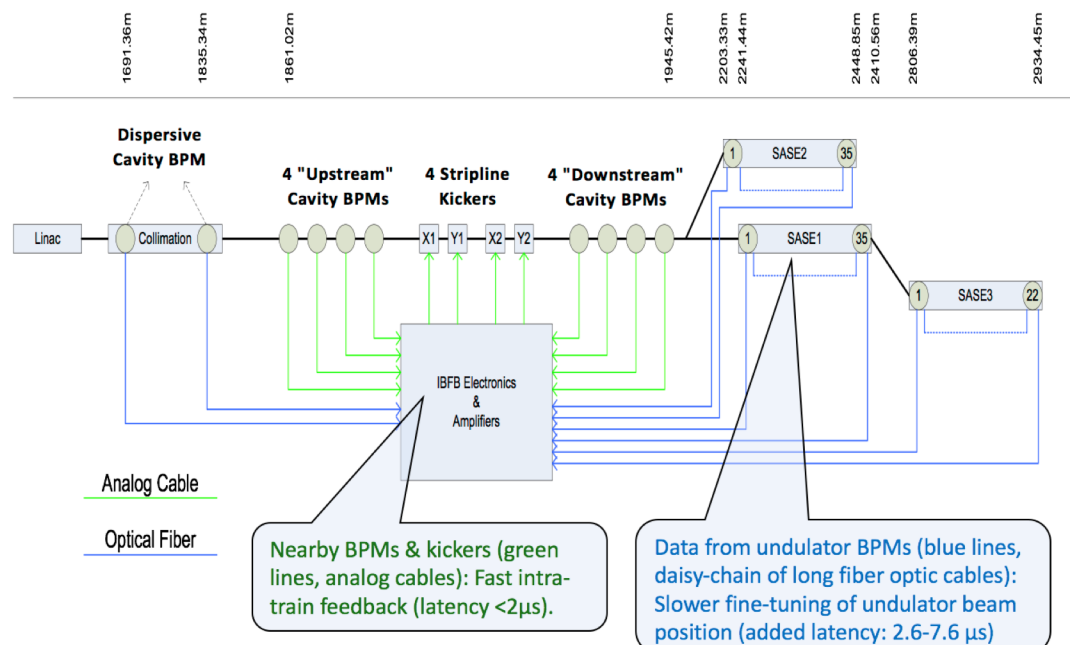
for details: Sergey Tomin

The IBFB

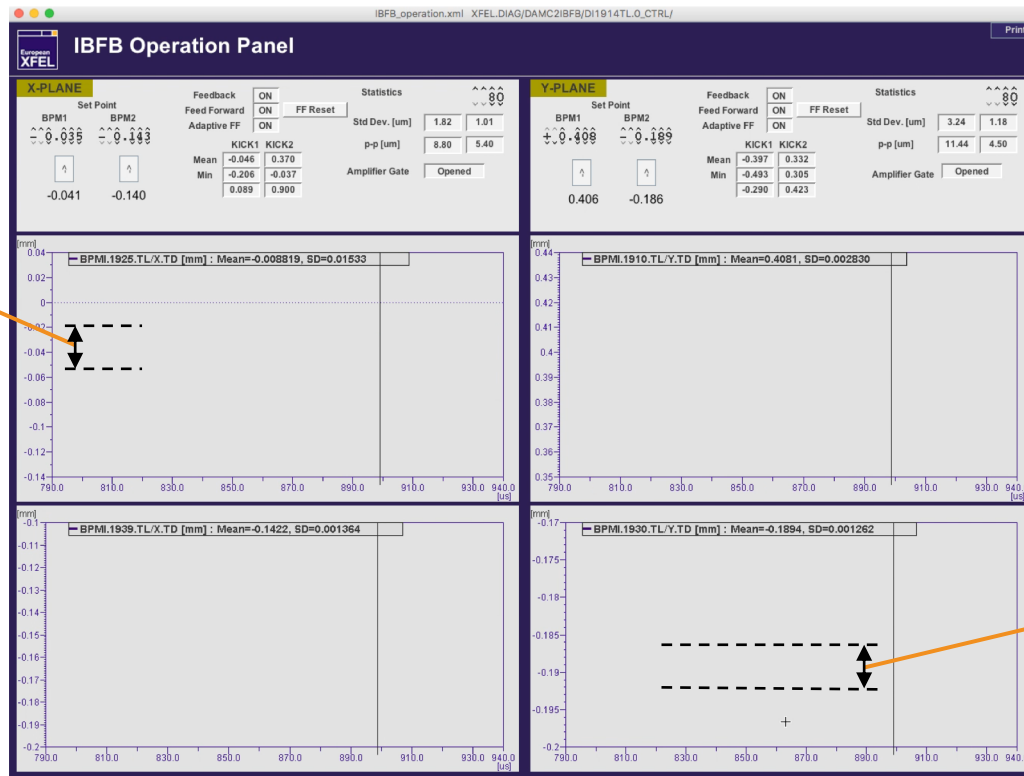


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Overview: IBFB Topology



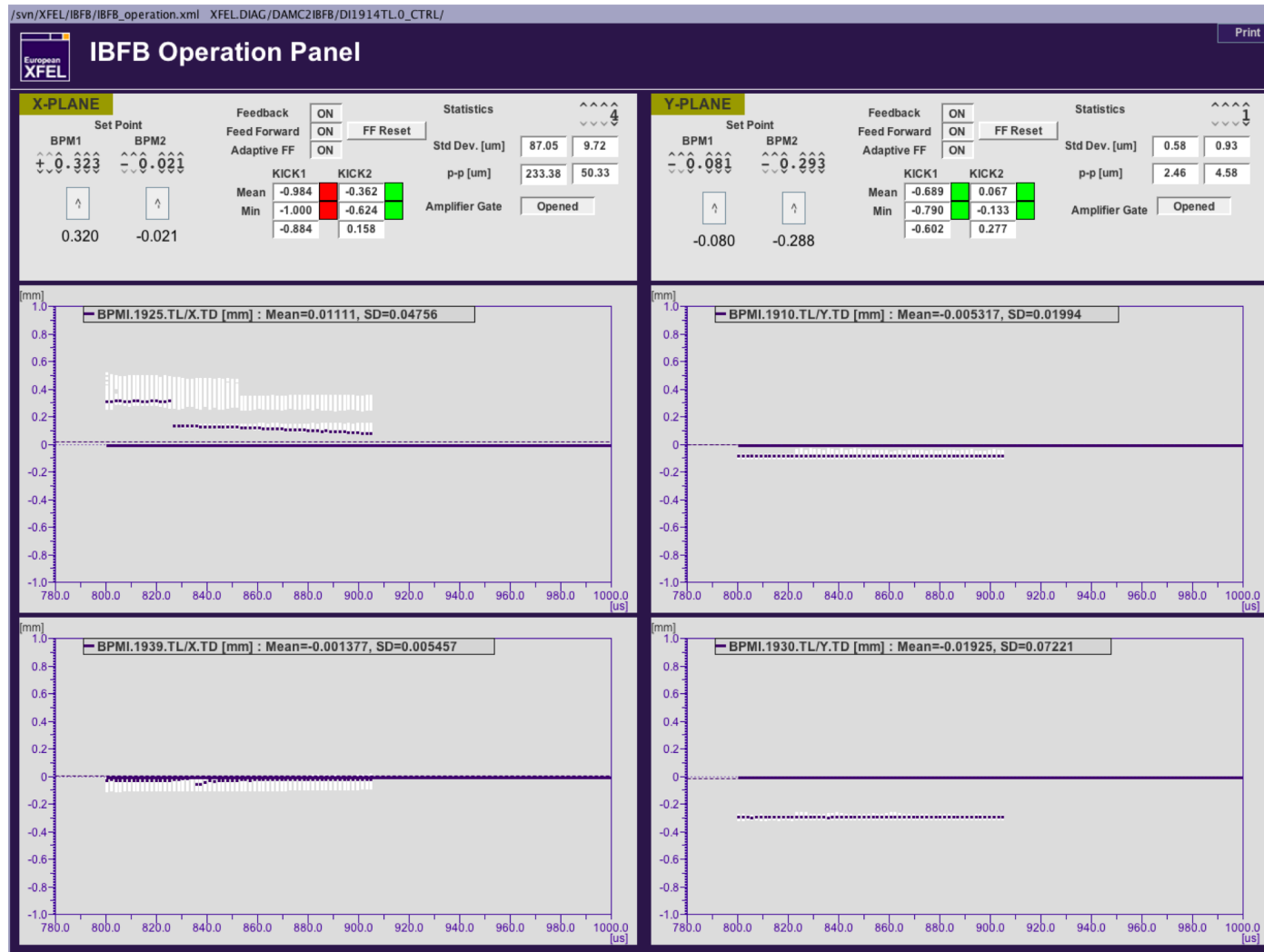
The IBFB – in action



pk2pk ~ 30 μ m

pk2pk ~ 6 μ m

The IBFB – in action



Thank you