Status of the standard electron beam diagnostics of the EU-XFEL

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DEELS workshop at DIAMOND, 18. and 19.04.2018

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

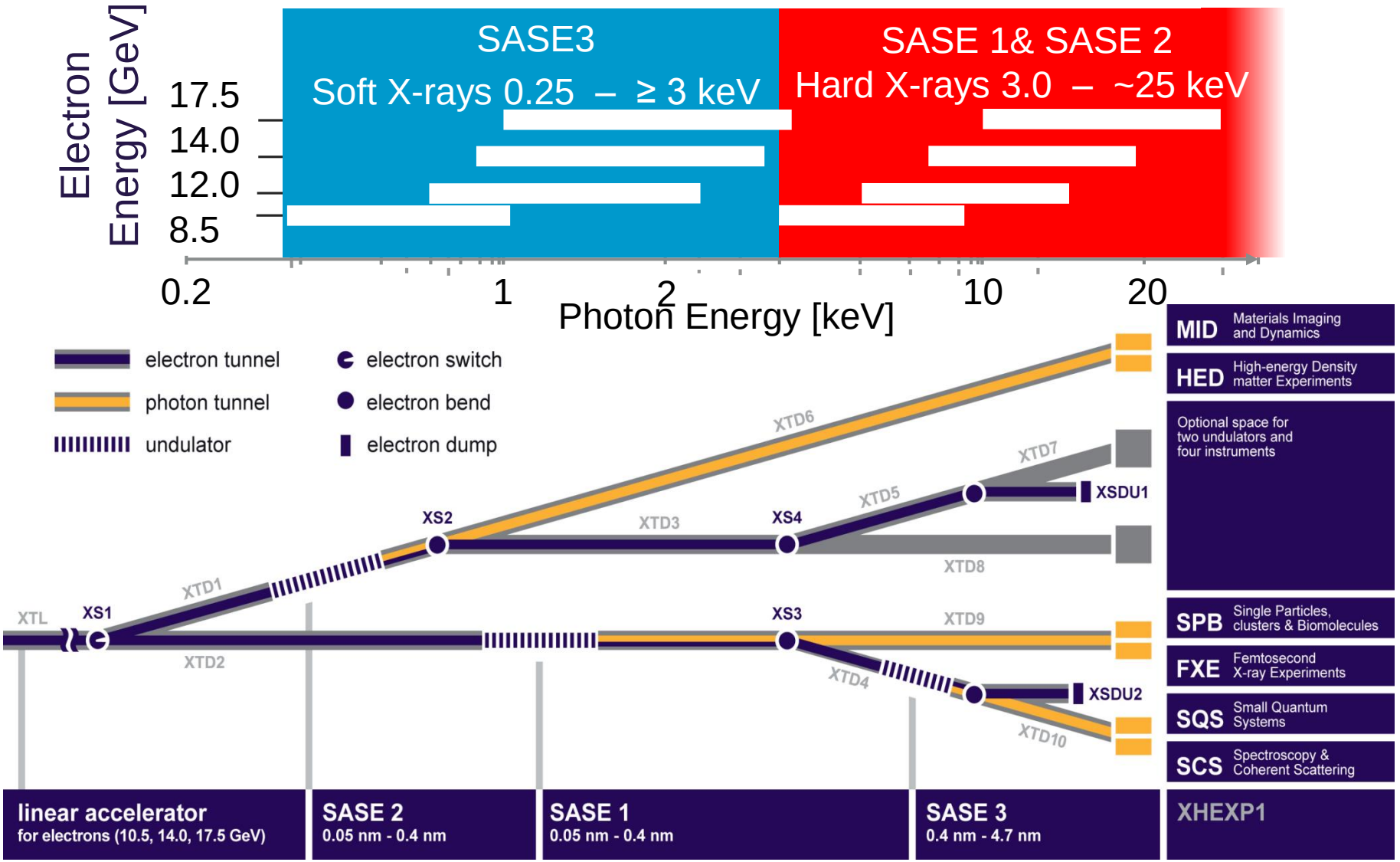
European XFEL

DESY.

Outline

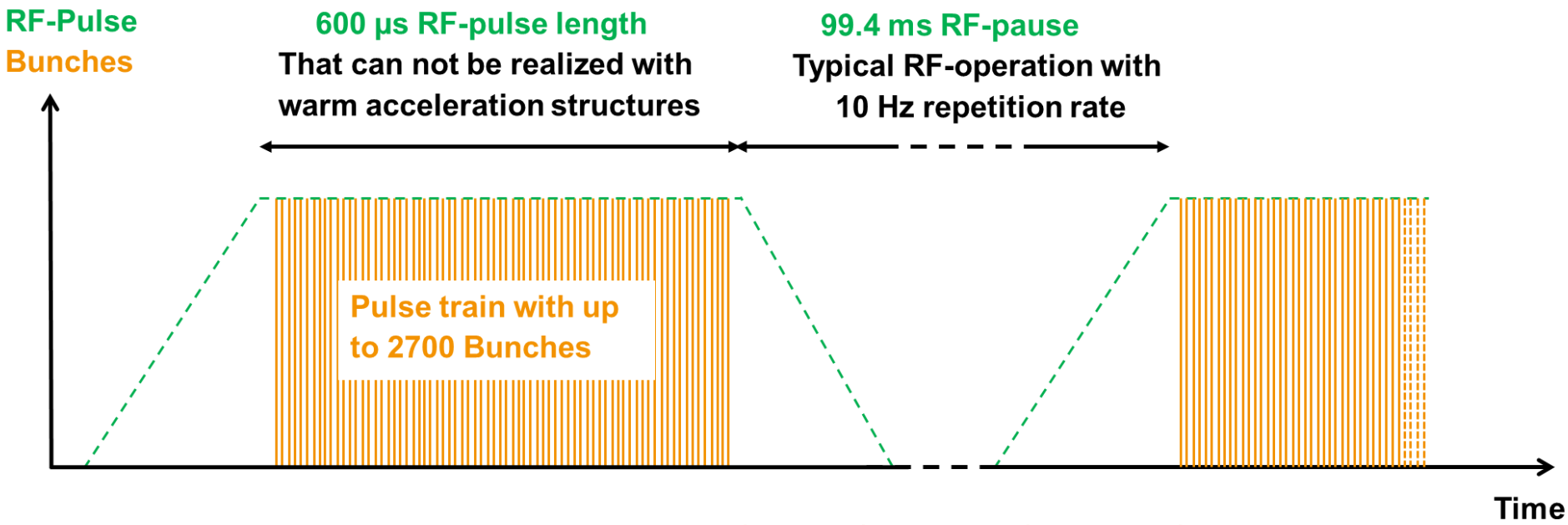
- Setup and status accelerator
- Diagnostics
  - BPMs
  - Toroids
  - Beam Loss Monitors
  - Wirescanner
  - Dosimetry
- Summary

Schematic of SASE beamlines



Courtesy Winfried Decking, DESY

Superconducting accelerator modules and long pulse trains

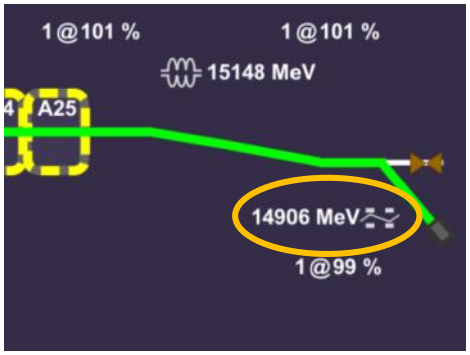


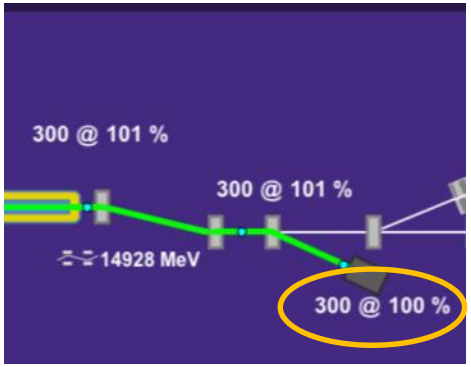
Typical distances between bunches are 220 ns (4.5 MHz) or 880 ns (1.125 MHz).

Courtesy Matthias Scholz, DESY

Accelerator 2017

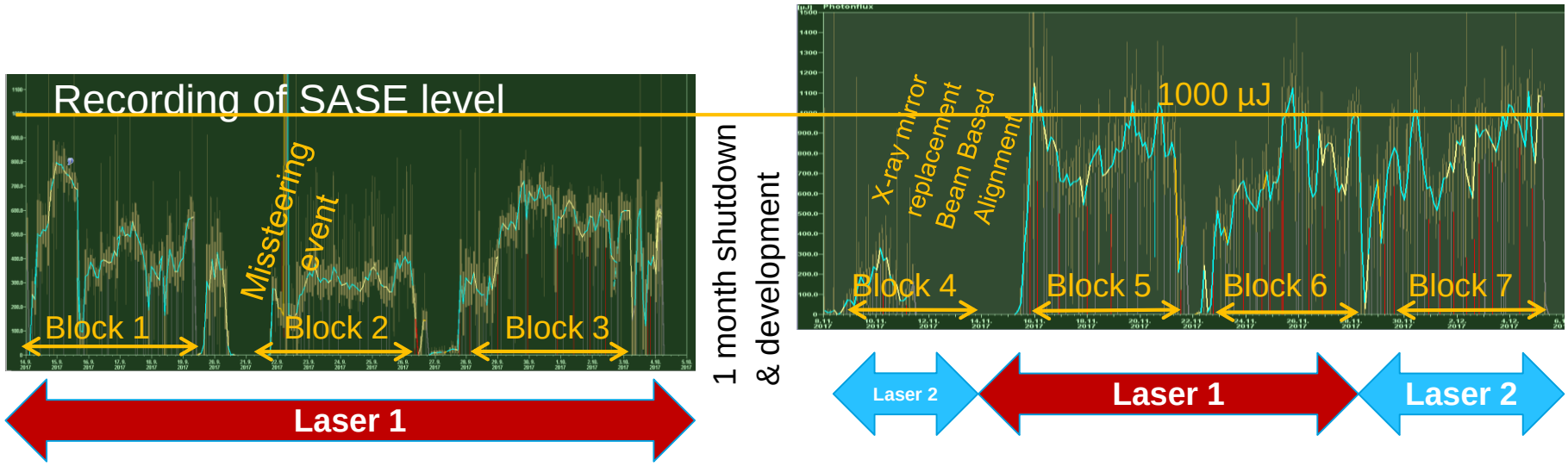
- Accelerator has been commissioned according to schedule and towards expected parameters, about 6400 h of scheduled beam time, always being very close to the commissioning schedule
- **23 out of 25 RF** stations commissioned (last two in CS9, will be ready in Q2/2018)
- Maximum potential final energy obtained during dedicated LLRF studies**16.1 GeV,** maximum beam energy **14.9 GeV**, user operation with **14.0 GeV**
- Routine operation with **300 bunches/second** in user mode
- Test operation in **linac mode** with **3000 bunches/second** (≈ 18 kW beam power) & in **SASE mode** with **1200 bunches/second**





Courtesy Winfried Decking, DESY

Facility performance in user run

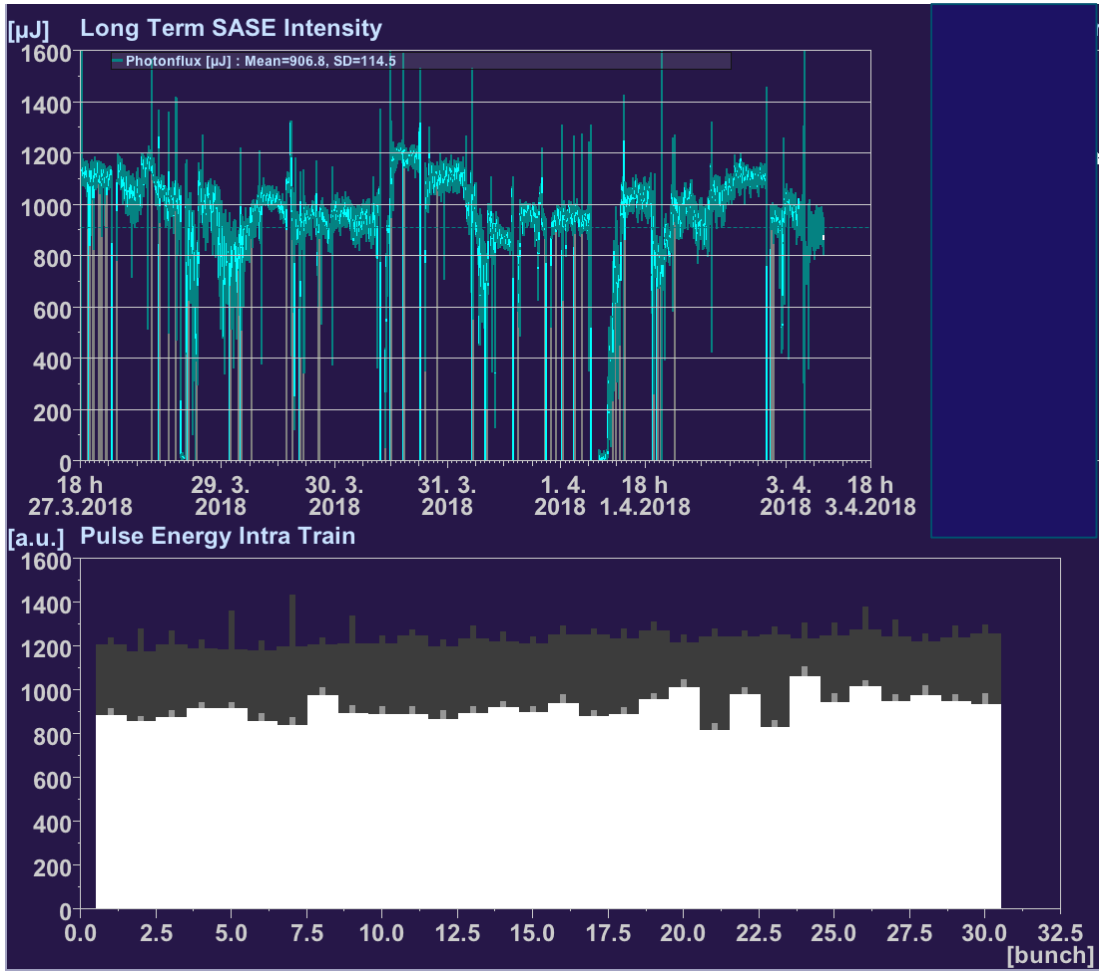


- 7 user blocks, 5 days each, with 2 days in between for set-up & tuning
- 14 GeV, 1-30 bunches, 9.2-9.3 keV
- Availability (= SASE delivery above threshold) between 10% (Block 4) and 97% (Block 6&7)
- Little tuning needed (because of limited flexibility offered), but frequent small wavelength changes and variation of bunch number (1-30)
- Prominent error sources: operation & controls, trips (frequent but speedy recovery), magnets

Courtesy Winfried Decking, DESY

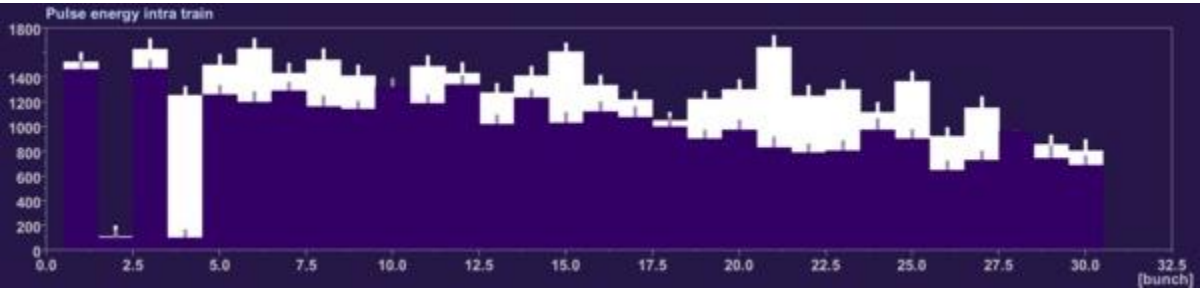
Facility performance in user run

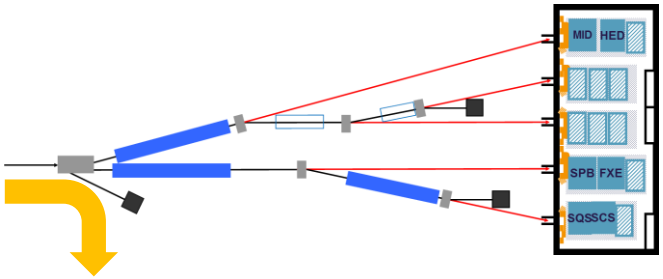
- Last user run in March
- Run with 30 bunches
- Almost equal SASE level for each bunch in train



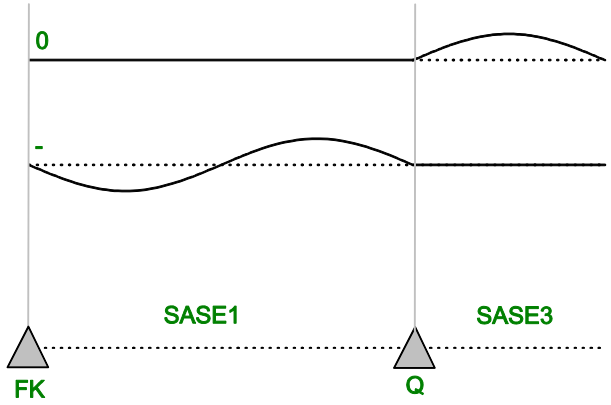
Individual Bunch Pattern: Kick bunches into dump after linac

- Kick bunches into dump after linac





- Operate SASE3: Suppress lasing in SASE1



Courtesy Winfried Decking, DESY

2018 e-beam parameters

Quantity		Project Goal	Achieved	Routine	2018 Goal
electron energy	GeV	8,12.5,14,17.5	6-14.9	14	8/12.5/14/17.5 GeV
bunch repetition frequency within pulse	MHz	Up to 4.5	1.1, 4.5	1.1	1.1
bunch charge	pC	20 – 1000	100, 500	500	200, 500
electron bunch length after compression	fs (FWHM)	2 – 180	20, 90	90	40, 90
beam power	kW	500 kW	18 kW	1.8 kW	50 kW
undulators in operation (lasing)		SASE1-3	SASE1	SASE1	SASE1-3
photon energy (SASE1)	keV	0.25 - 25	1,6,9	9-9.5	6-15
photon pulses / s / undulator		27000	1200	300	3000
saturation power (@ 14 GeV, 500 pC, 9 keV)	mJ	1	1	0.4	1

Courtesy Winfried Decking, DESY

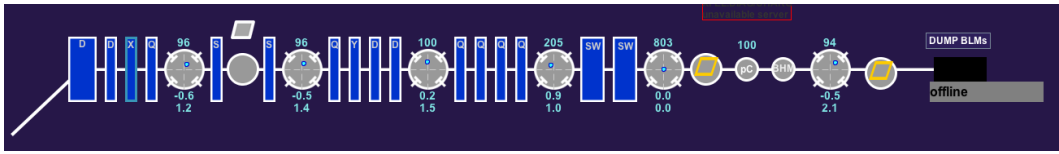
Plans for 2018

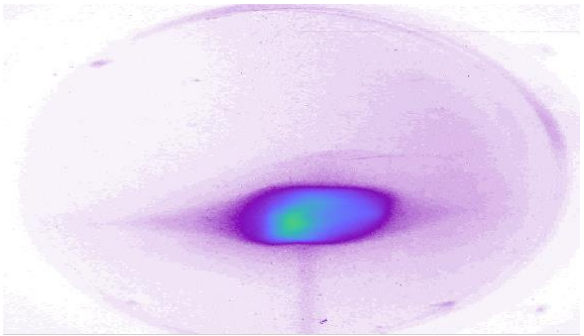
- SASE1: About 1200h experiment commissioning & 1600 h user operation, improve performance and flexibility
- SASE2: First e-beam in March (already done, see next slide), first lasing in May
  - Commission laser and photon systems parallel to user runs
  - Installation of Self-Seeding Chicanes (December)
- SASE3: First lasing in February: already done
  - photon systems commissioning influences SASE1 operation
- Accelerator:
  - 17.5 GeV by July (continue high gradient task force & CS9 installation and commissioning)
  - 3000 bunches/second lasing in SASE1 by mid of the year (Possible limitation: dose rate in undulators)
  - 27000 bunches in XTL by December

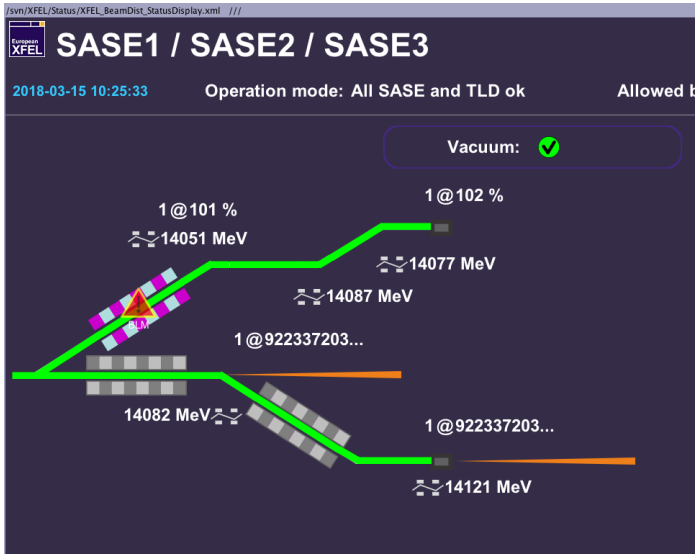
Courtesy Winfried Decking, DESY

SASE2 commissioning

- On 13.03.2018 within few hours transmission is performed, see first beam on screen
- Cavity BPMs are commissioned, phases set, signs identified and set







- On 15.03.2018 first beam on all electron beamlines with the same bunch train

Standard Diagnostics

Systems count in total and per section

- Gun
- Injector
- XTL: the long accelerator with collimator section
- XTD: undulator sections up to dumps

System	Subsystem	Gun	Injector [XTIN]	XTL	XTDs
BPM system	Button	3	7	162	126
~ 460	Cavity Ø 10 mm				103
	Cavity Ø 40.5 mm		3	19	5
	Reentrant		1	23	
	Button Compressor			3	
	HOM		2		
Charge	FCUP	4			
~ 50	DaMon	1	1	7	
	Toroid	1	3	16	15
Screens	Simple	3			
~ 70	Complete		7	26	16
	Dump		1	4	5
	Compressor			3	
Wire scanners				6	6
12					
Loss monitors	BLM	1	18	230	240
~ 490	BHM		1	1	2

BPM setup

BPM types

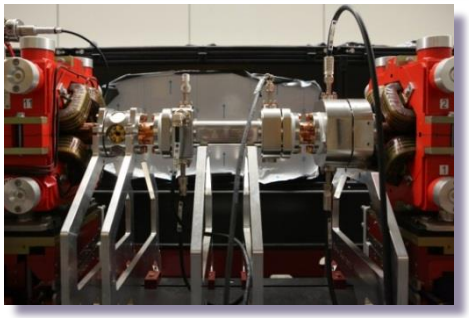
- Button for different beam pipe diameter
- Low Q cavity BPMs with 2 beam pipe diameters
- Reentrant Cavity BPM (30% of cold LINAC)

Collaboration (institutes and tasks)

- CEA Saclay: re-entrant cavity BPM for cold modules including front end electronics
- DESY: button and cavity BPM mechanics
- PSI: front end electronics (button and cavity BPM) and digital back end (all)

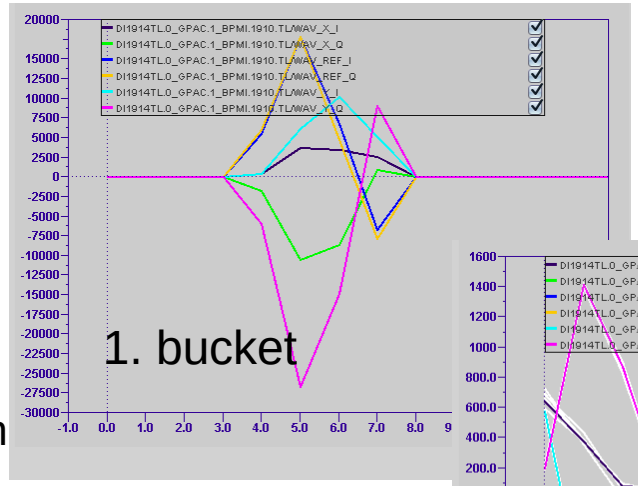
Readout

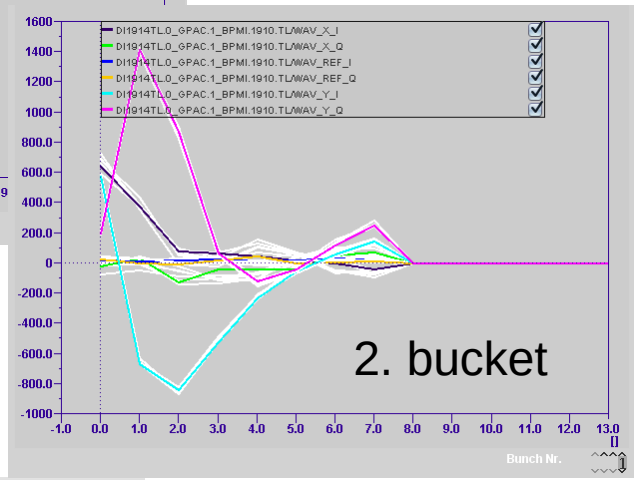
- MBU (Modular BPM Unit)
- Single bunch measurement
- Connection to DOOCS via a FPGA-FPGA bridge with optical fibers.
- Decoding of E-XFEL timing protocol in MBU



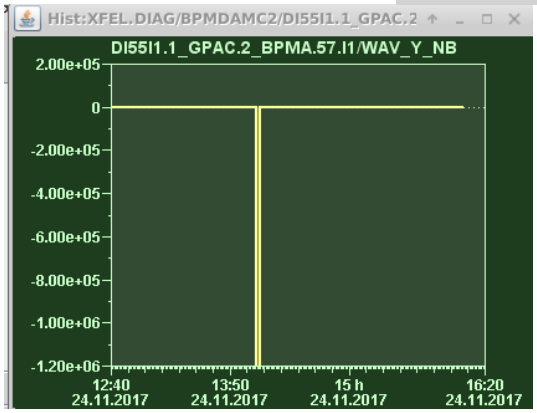
BPM Problems

- Reflections at 2 cavity BPMs with specific cable length caused signal in second bucket. These BPMs used for Intra Bunch Feedback system. Therefore avoid reflected signal. Reason of reflection: maybe at a cable feedthrough on rack. Elongation of cable with 90 ns delay shifted the problem





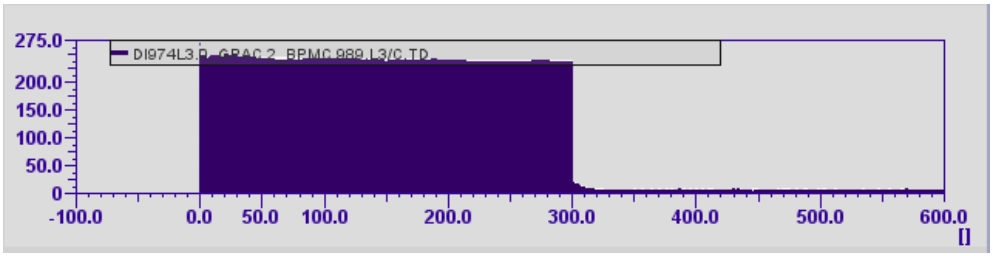
- Sometimes beam measured with unphysical positions; caused trouble in slow feedback; problem in server, solved

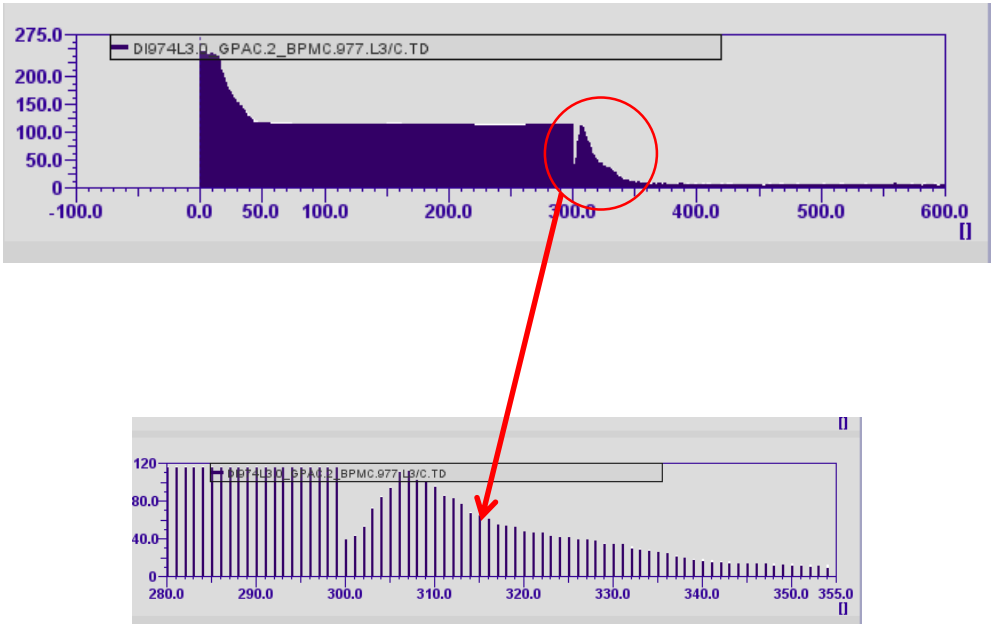


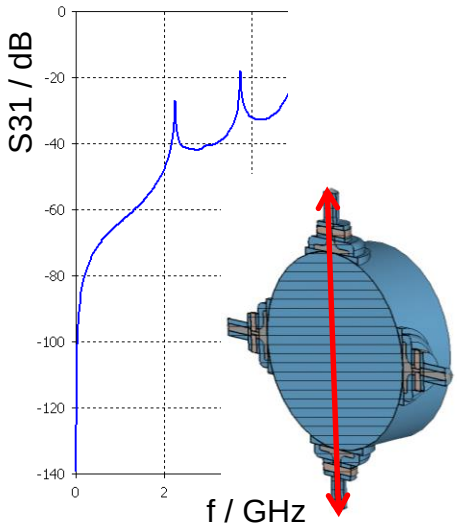
BPM Problems

Crosstalk in cold button BPMs

- Charge along bunch train should be constant
- 17 out of 72 show crosstalk, here most extreme case shown
- Assumption: resonance in button of 2.2 GHz with high quality factor causes the crosstalk
- Under investigation!

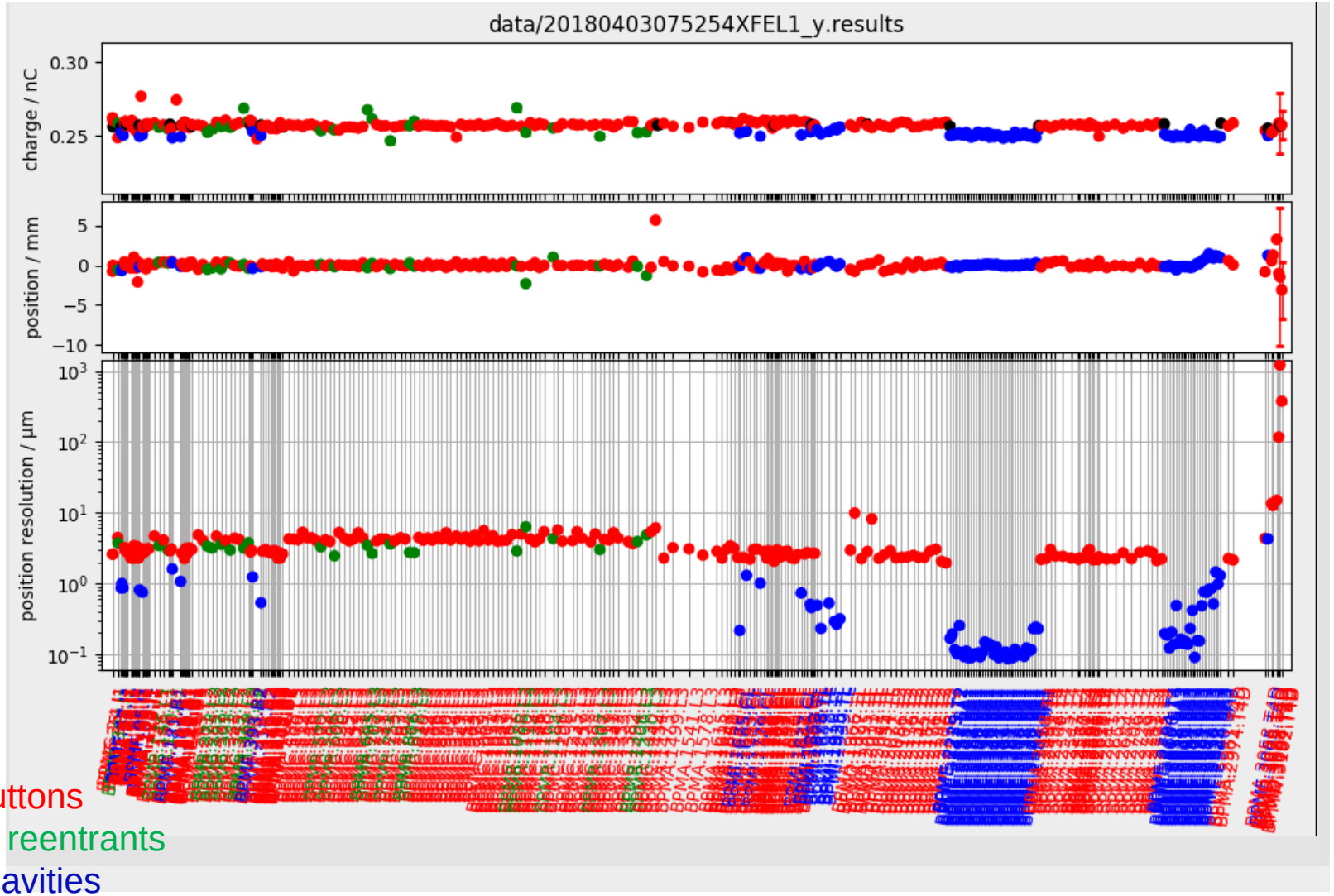






BPM performance

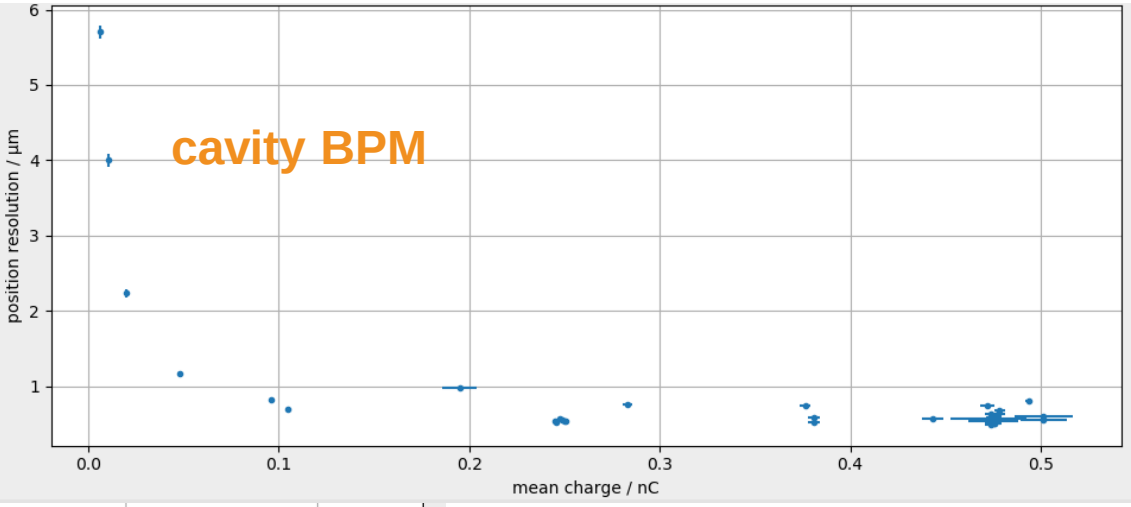
- Resolution during user run

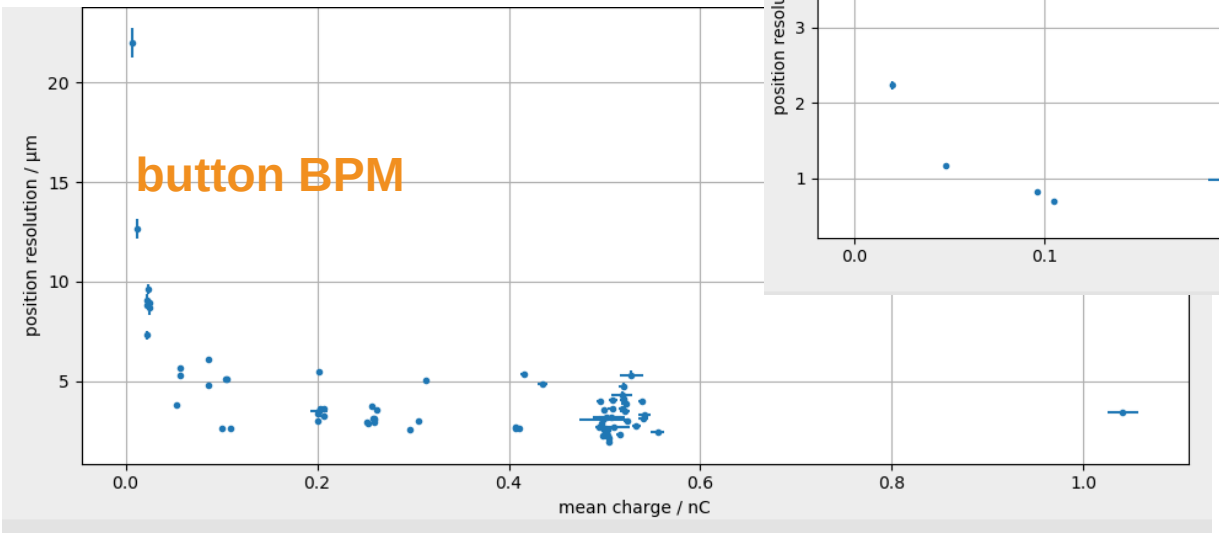


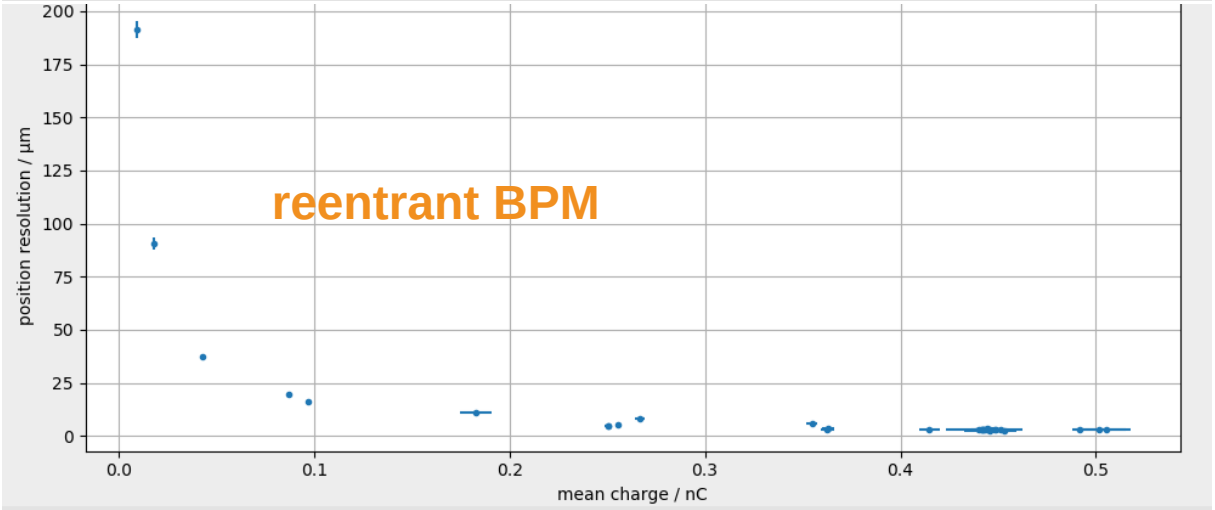
red: buttons
green: reentrants
blue: cavities

BPM performance

Resolution vs. Charge



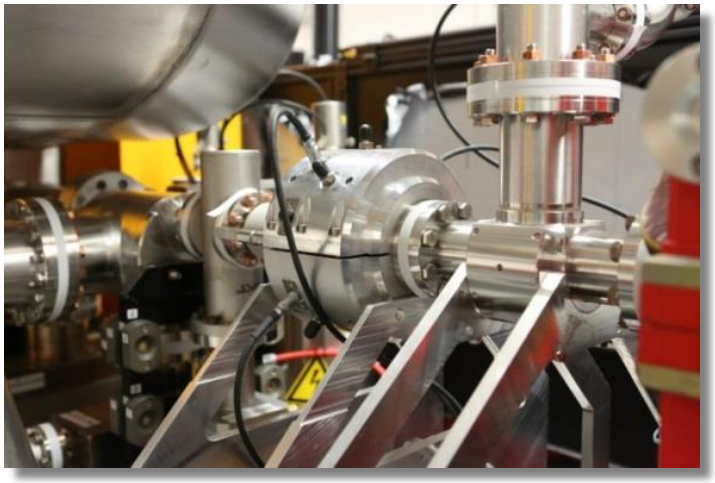




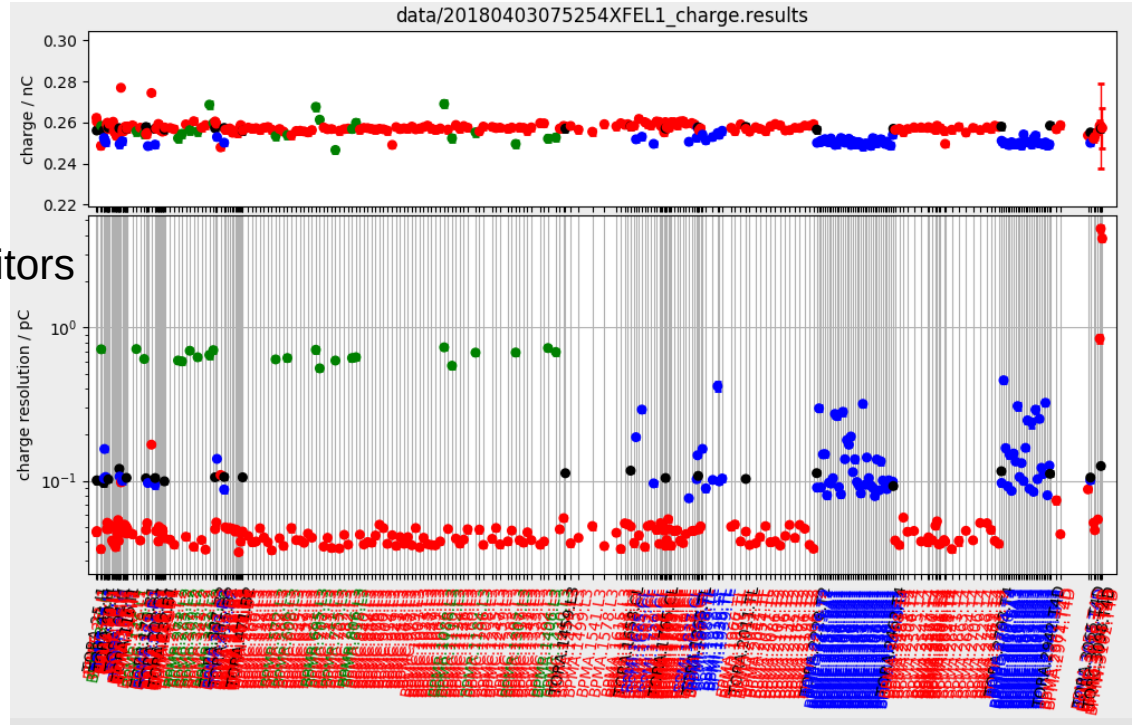
- Automatic Gain control (attenuators) used for button and cavity
- Automatic can be switched off for special purpose but need to take care that ADCs are not saturated by the operators

Toroids

- New calibration signal source with faster rise time: reduces charge difference between two Toroid chambers
- Fast and Slow transmission interlock implemented to prevent uncontrolled beam loss



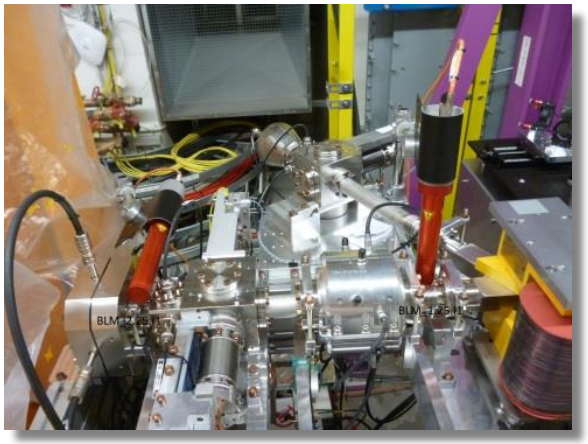
- Charge resolution of all monitors

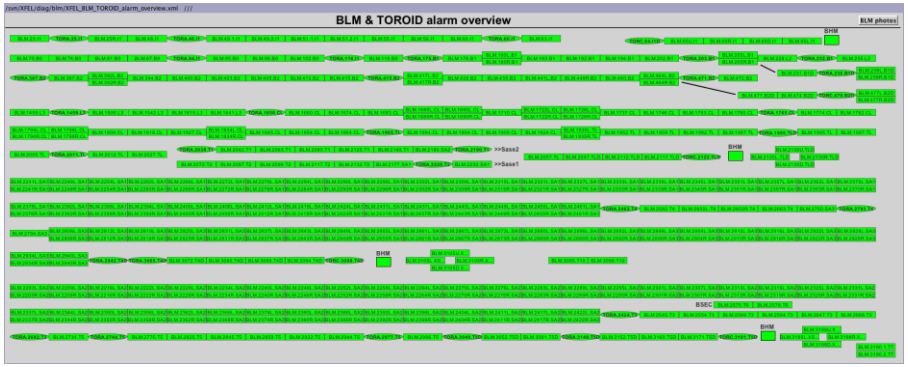


red: buttons
green: reentrants
blue: cavities
black: Toroids

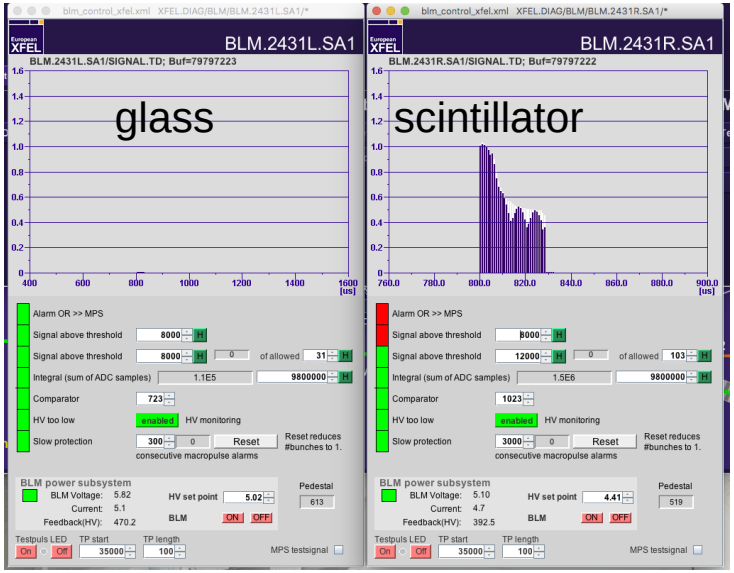
Beam Loss Monitors

- Scintillators with photomultipliers
- Single bunch resolution
- On board HV generation
- Single, multiple bunch and integration alarms to MPS
- Readout by µTCA board with rear transition module, digital interface to MPS system





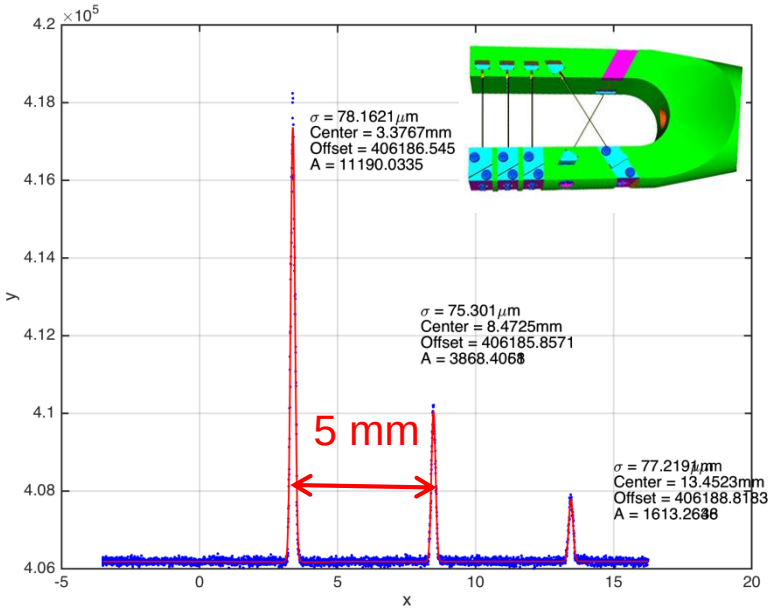
- Operation GUI for identifying loss
- At SASE undulators scintillators sensitive to photons: replacement to glass is ongoing



Wirescanner

Beam core measurement using plastic scintillating fibers with PMT

Beam size measured by different wires (<3% discrepancy), 20 um wire is used for beam core scan and 50 um wire is used for beam halo scan.



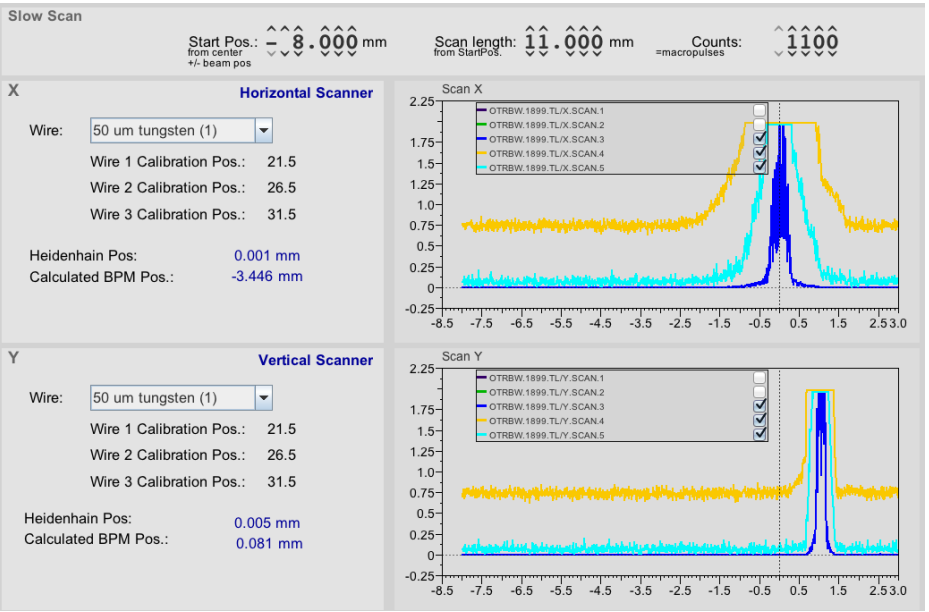
OTRBW.1523.L3 : 50 um, 30 um, 20 um wires

Beam halo measurement done with BLMs

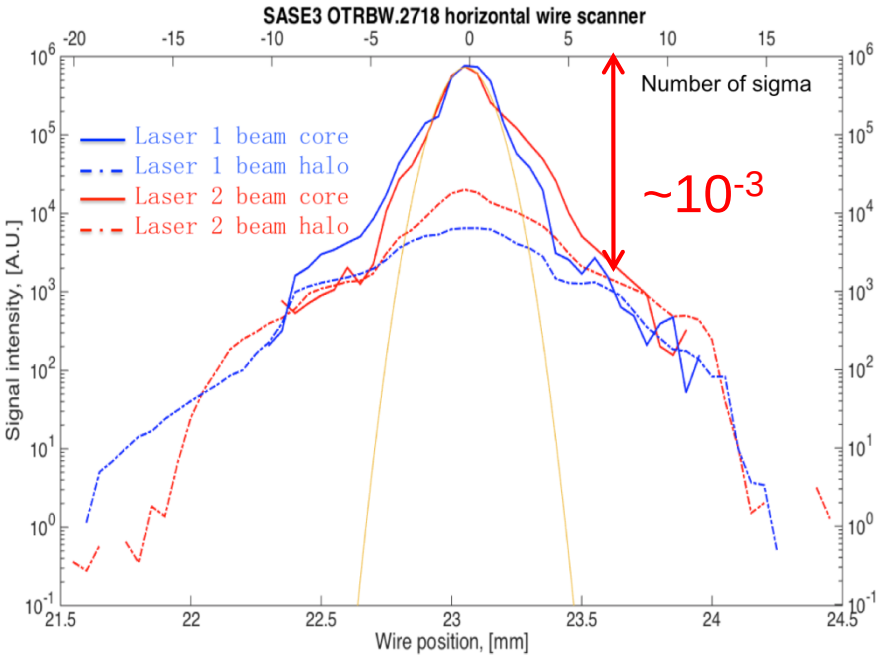
Courtesy Shan Liu, DESY

Wirescanner

- Beam core and beam halo measurements can be done simultaneously using different detectors (fiber and paddle scintillator).

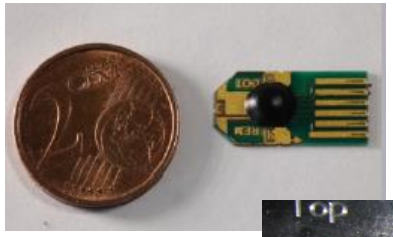


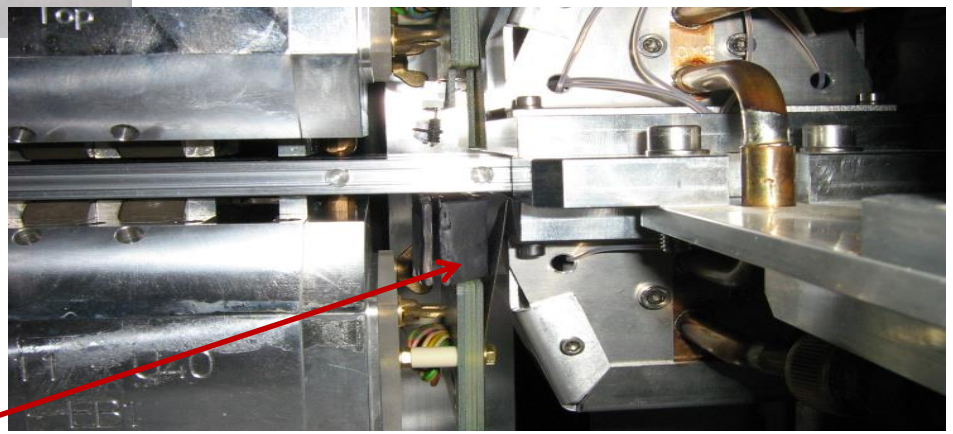
- The combined beam core and beam halo distribution can be used to estimate the beam halo intensity.



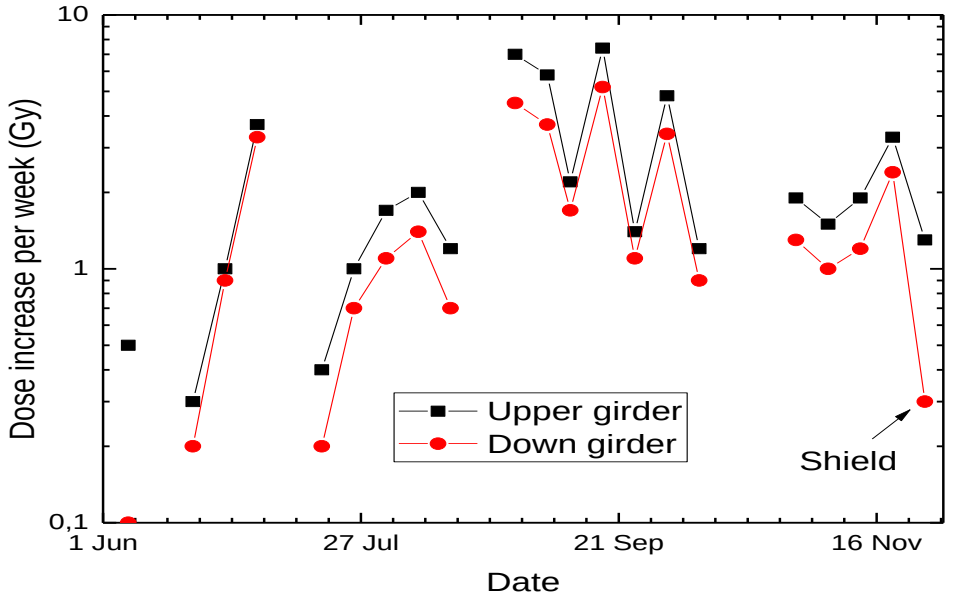
Courtesy Shan Liu, DESY

Dosimetry





- Gamma sensors RadFets for online measurements of accumulated dose
- At undulators high radiation measured
- Shielding with 2 mm lead reduces measured radiation level by about 60%

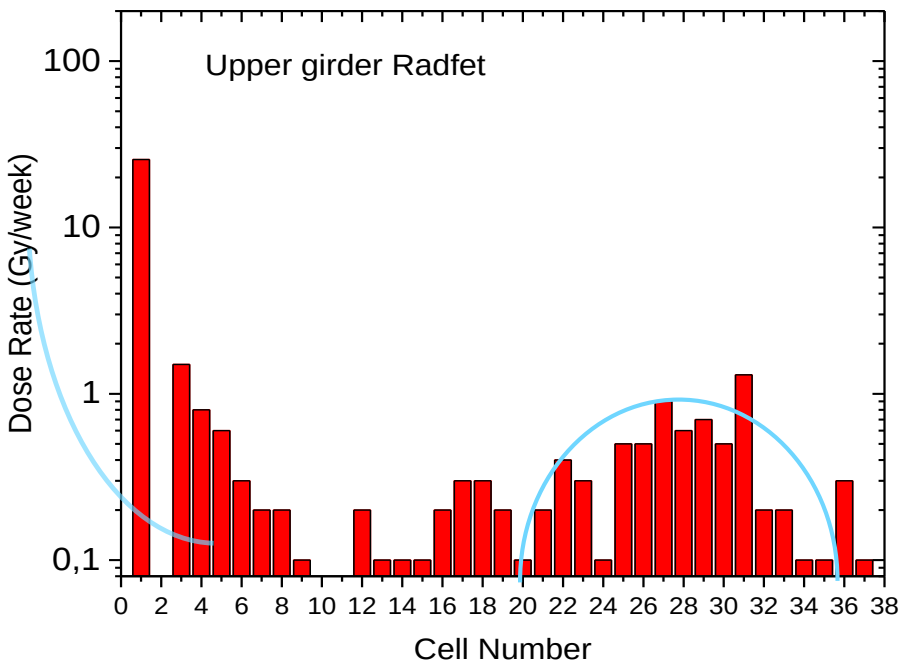


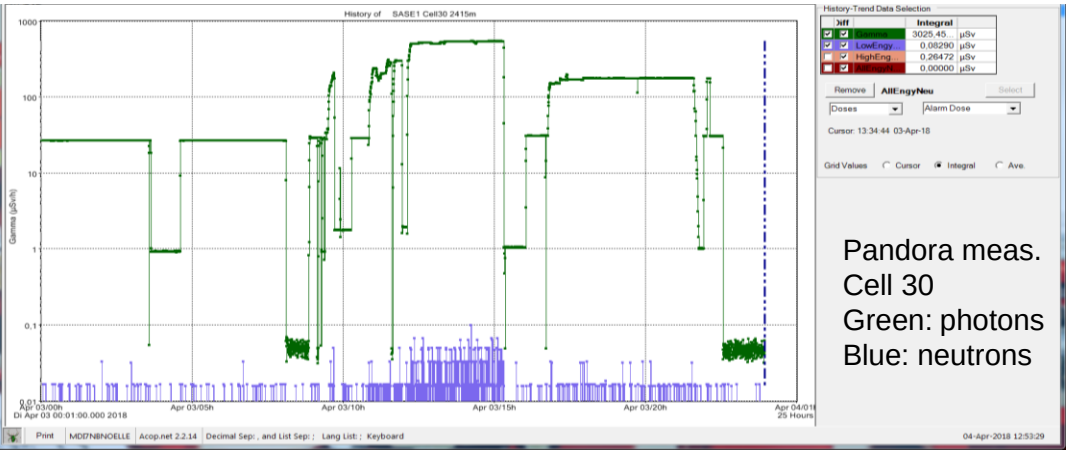
Courtesy: F. Wolff-Fabris, XFEL

Dosimetry

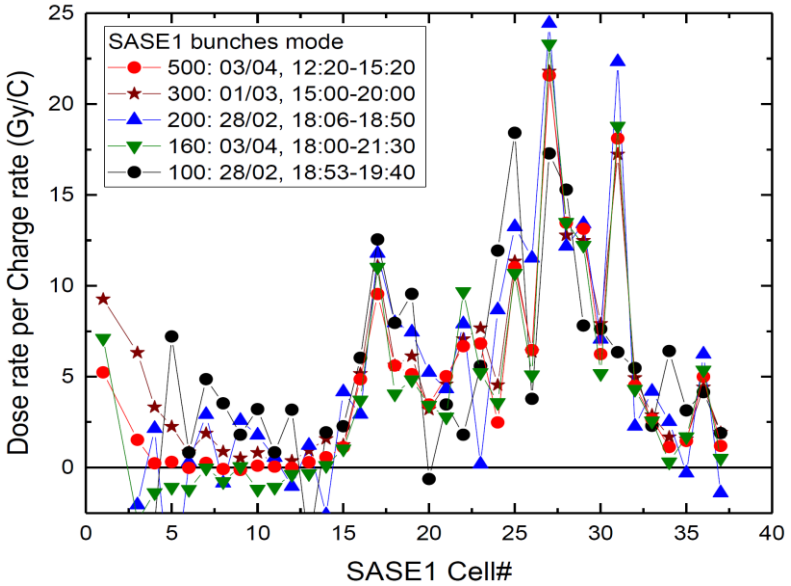
- Exponential Decay in Cells 0 -8
  - Collimation of particle loss
- Bump in last 1/3rd of the Undulator: seems to be fixed, independently of used no. of Undulator, maybe alignment necessary

SASE1 Dose rate on week up to 27th Nov. 2017



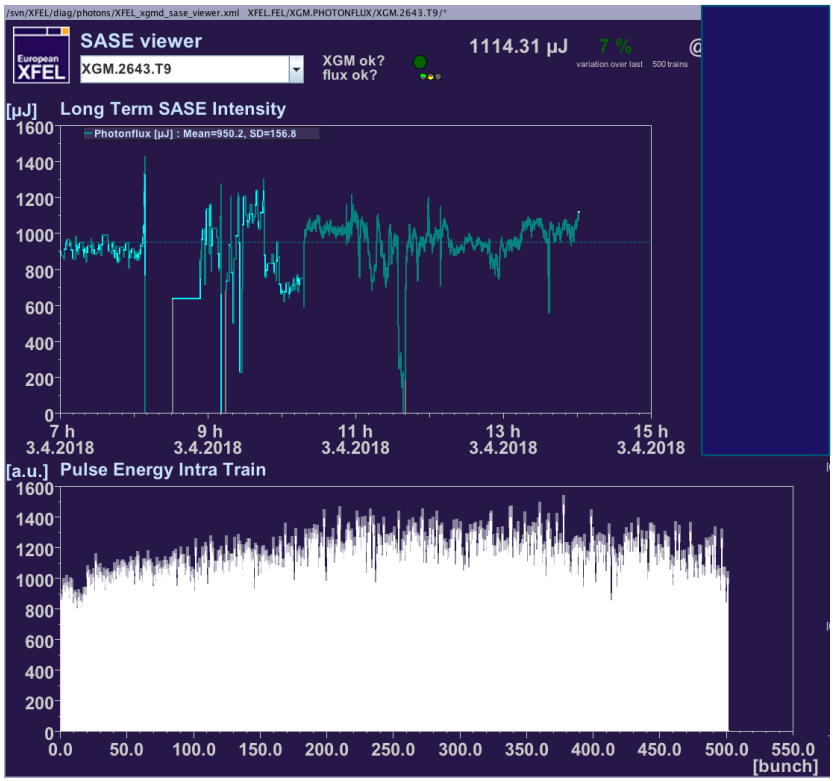


Courtesy: Dirk Nölle



Multibunch operation

500 bunches with IBFB on 03.04.2018



Test with 500 bunches
Feedback with IBFB works, SASE energy above 1 mJ for almost each bunch

Summary

- Status of accelerator
- Setup and status of diagnostics with few recent problems
  - BPM reflections, strange positions and crosstalk
  - BLM sensitive to photons
  - RadFets sensitive to photons as well
  - Higher induced dose in last 1/3 undulator part of SASE1