FLASH2
Extension of the FLASH Facility

FLASH.
Free-Electron Laser
in Hamburg

Commissioning of the FLASH2 Electron Beam Diagnostics in respect to its Use at the European XFEL

N. Baboi, DESY
for the Diagnostics Team

HELMHOLTZ GEMEINSCHAFT

DESY

International Beam Instrumentation Conference
Monterey, California, USA September 14–18, 2014

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FLASH (Free electron LASer in Hamburg)

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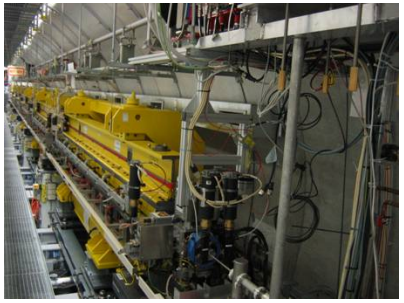
Free-Electron Laser in Hamburg

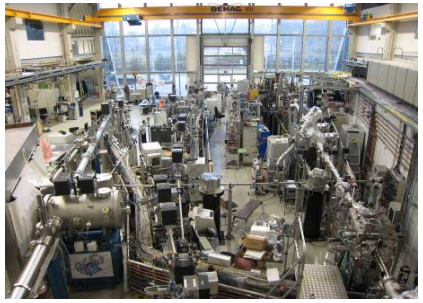
> 3rd harmonic sc module 3.9 GHz

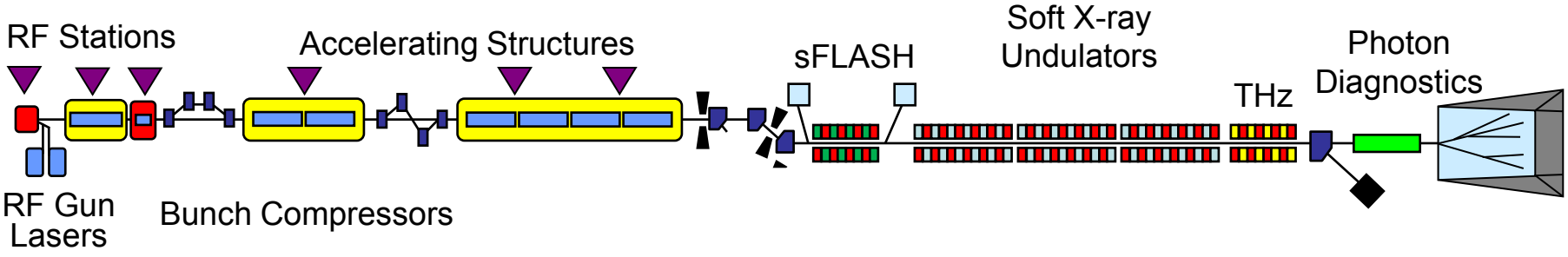
> TESLA type superconducting accelerating modules 1.3 GHz

> FLASH1 fixed gap undulators



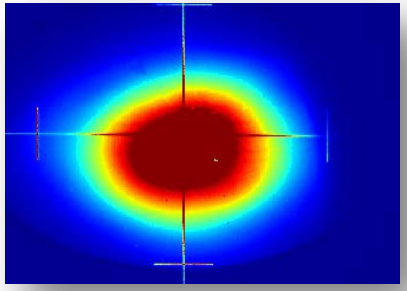
> FLASH1 Experimental Hall





> Normal conducting 1.3 GHz RF gun
> Ce_2Te cathode
> Two Nd:YLF based ps photocathode lasers

- Former TTF, and VUVFEL
- Proof of principle for SASE in XUV
- First Lasing in Feb. 2000



FLASH2: New Undulator Beamline

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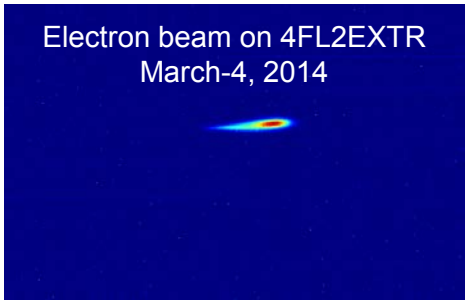
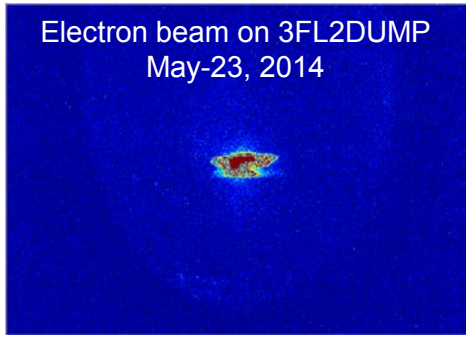
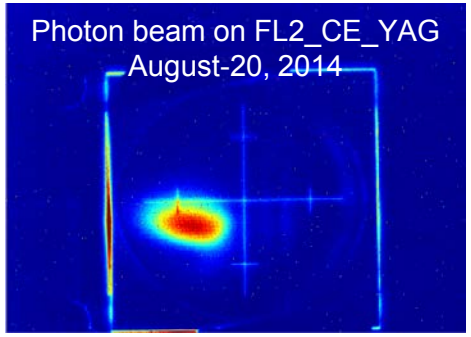
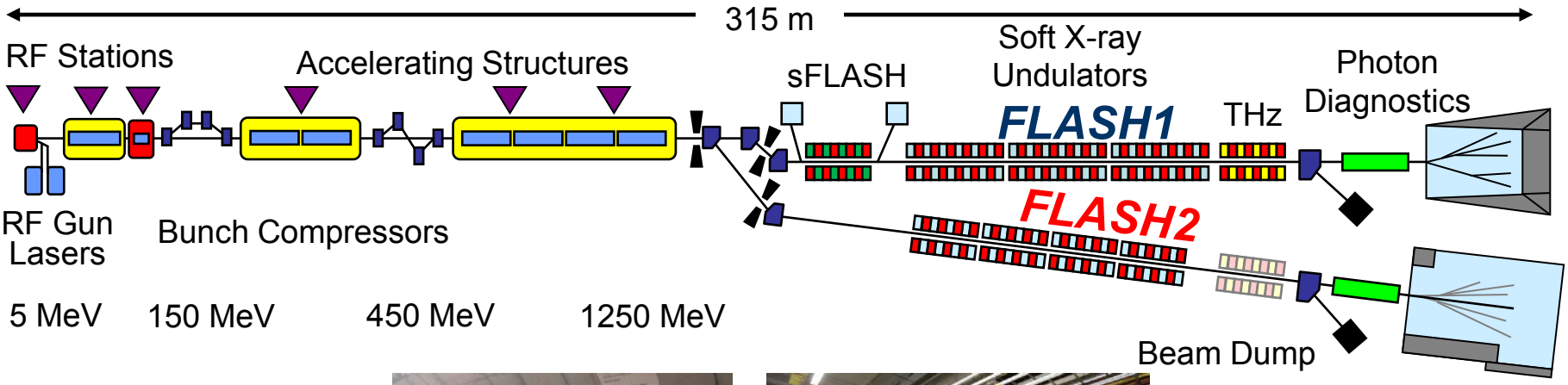
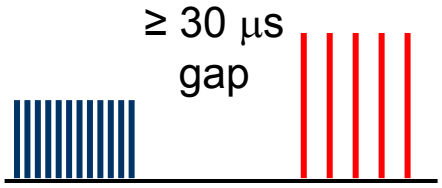








2 lasers



> Extraction to FLASH2

> FLASH2 variable gap undulators

> FLASH2 Experimental Hall

Typical Parameters of European XFEL and FLASH

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	XFEL	FLASH
Max. energy [GeV]	17.5	1.25
Pulse repetition rate [Hz]	10	10*
Max. bunch frequency [MHz]	4.5	1
Max. pulse duration [μm]	600	800
Charge [nC]	0.02 – 1	<0.1 – 1
Photon wavelength [nm]	0.05 - 6	4.2 – 45

* FLASH2 operates often at 1 Hz to reduce activation

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FLASH.
Free-Electron Laser in Hamburg

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  - First Beam
- **Overview of Standard Diagnostics at FLASH2**
  - **General characteristics**
  - **Electronics**
  - **Commissioning**
- Diagnostics monitors at FLASH2
  - Charge monitors / toroids
    Toroid Protection System (TPS)
  - Screens
  - Beam Position Monitors:
    Cavity, Button and Stripline BPMs
  - Beam Loss Monitors (BLM)
    Beam Halo Monitors
- Concluding remarks

Overview of Standard Diagnostics at FLASH2

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- Most monitors were designed for the European XFEL
  - Make use of synergies given by the similar time line
  - Some have been designed specially for FLASH(2) or have a temporary solution
- Deliver bunch by bunch measurements, with few exceptions
- Generally based on MTCA-technology
  - Modular architecture, high availability, redundant power, well defined management.
  - 9 MTCA crates for diagnostics installed at FLASH2
- Challenges
  - MTCA previously not fully developed
    x2timer, power supplies
  - Low charge
  - Different charge for FLASH1 and FLASH2 within the same pulse
  - Different rep-rate of bunch trains FLASH1 and FLASH2 (10 vs 1 Hz)

FLASH2 Tunnel and Technical Corridor

FLASH.
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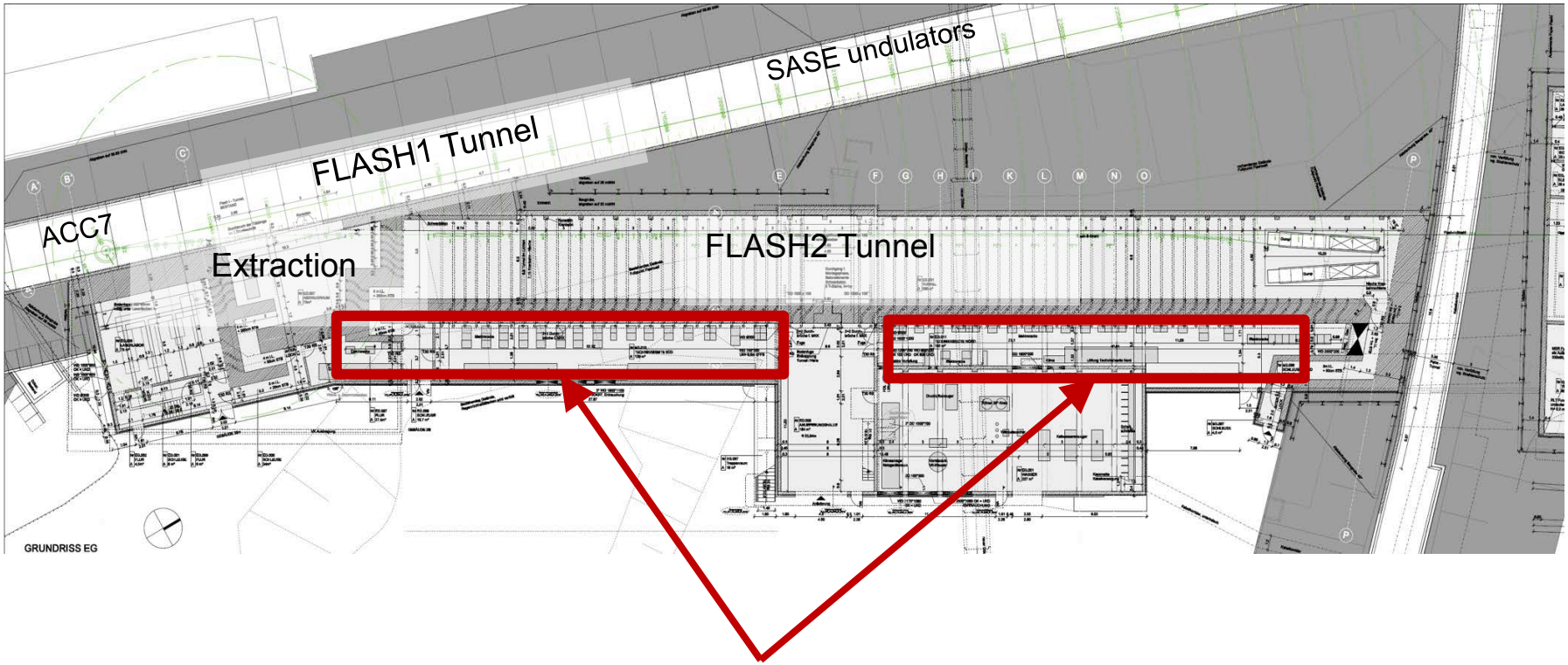

- Electronics installed in technical corridor, parallel to tunnel
  - At the XFEL: everything has to be installed in the tunnel

New Standard Diagnostics at XFEL and FLASH2

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	Pipe Ø (mm)	XFEL[&]	FLASH2[%]	FLASH
Toroids	*40.5 & 100*	36	5	
Screens	*40.5 & 96*	64	7	
Screen on dump-window		3	1	
Cavity BPMs (10 mm)	*10*	101	17	3 (for test)
Button BPMs	*10 - 96*	>300[#]	12	4*
Stripline BPMs	*34 & 44*	-	4	
BLMs	-	>300	~56	
BHMs	*100*	4	1	1

[&] Also other diagnostics, not installed in FLASH2: e.g. Wire Scanners, Dosimetry monitors
[%] Also other diagnostics, not XFEL-type: e.g. Ionization chambers, Cherenkov monitors
* With FLASH-electronics and with test-LCBPM-electronics
[#] Electronics: by PSI at XFEL, by DESY at FLASH2 (LCBPM)

Diagnostics Commissioning

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- "Cold" Commissioning
  - Check monitors (mostly vacuum parts):

    e.g.: screens: motors, light; BPMs: short, symmetry
  - Check cables
  - Technical checks of electronics

    Check individual components (mostly MTCA-based) and how the parts work together

    Check availability and quality of signals needed: timing, IT
  - Test servers
  - Panels (!)
  - Pre-calibration: either theoretical values or from lab measurements
- Commissioning with beam
  - Adjustment of trigger, clock
  - Adjustment of electronics settings
  - Calibration with beam

First beam in FLASH2: Preparation

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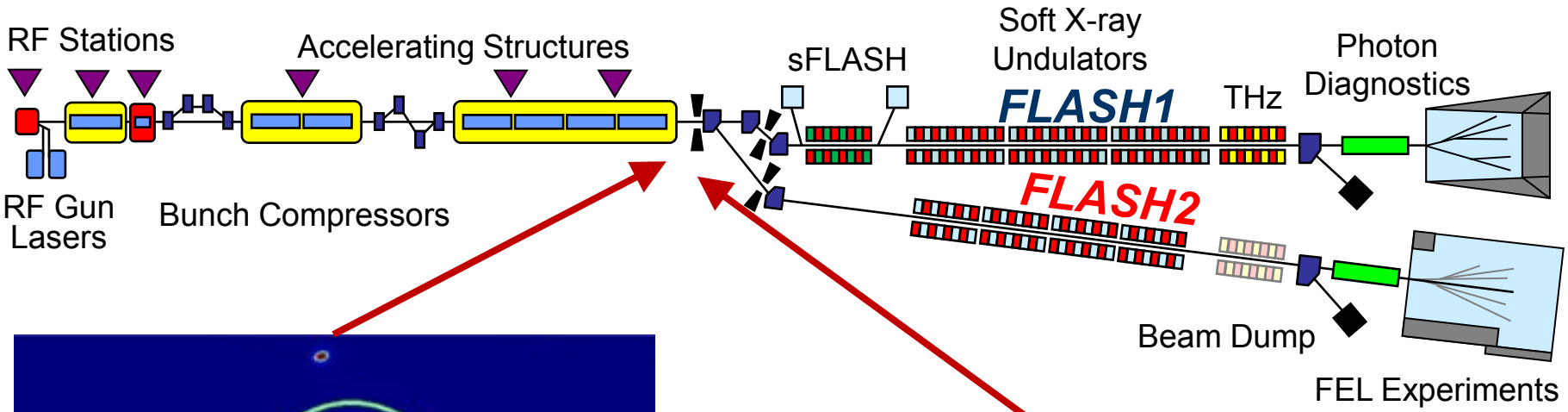
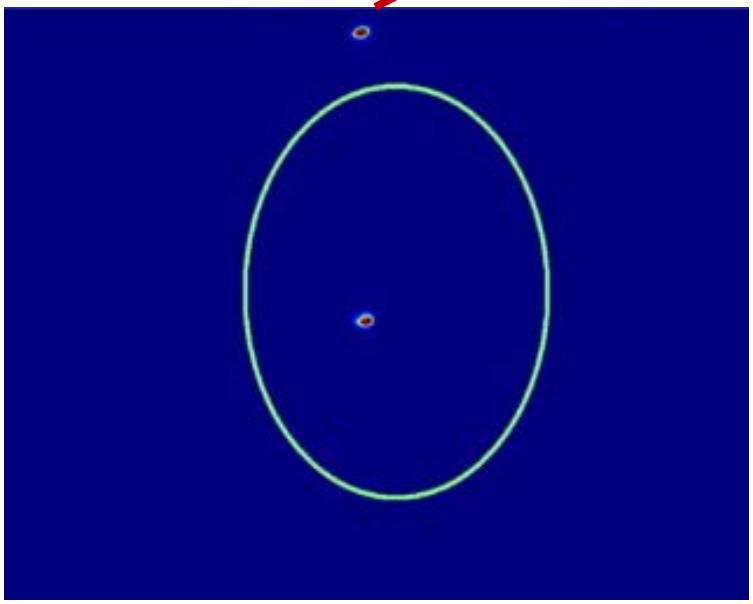
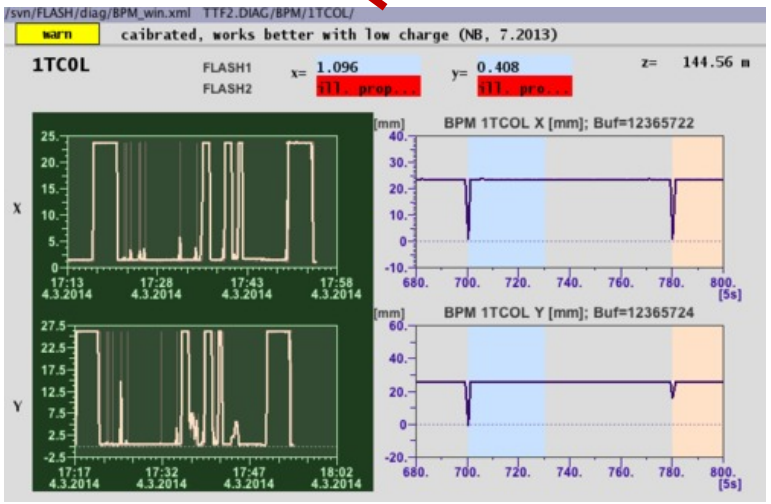
> Beam separation seen on BPM and screen before septum







First beam in FLASH2 Extraction

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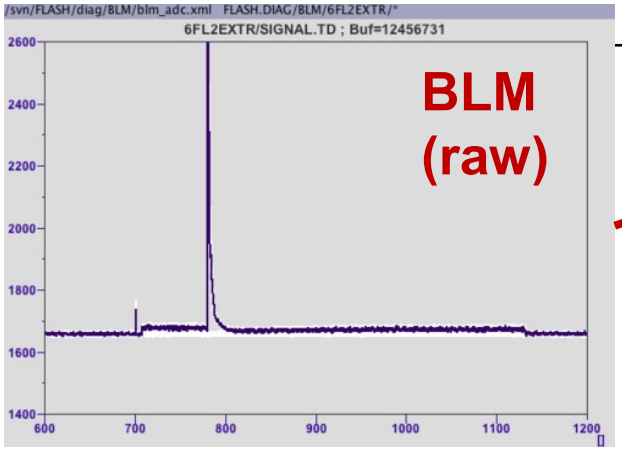
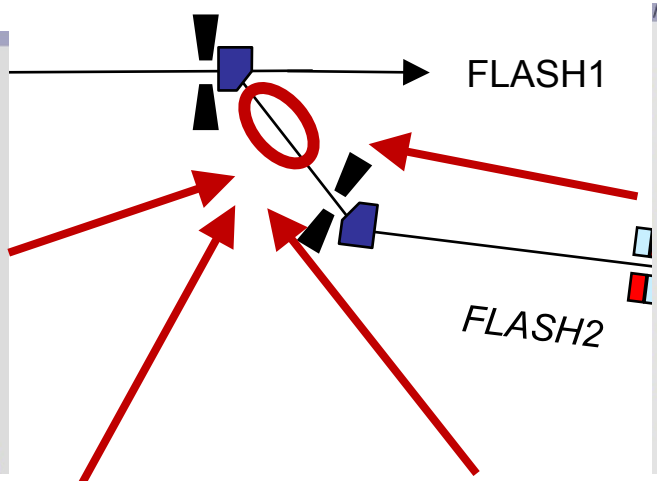
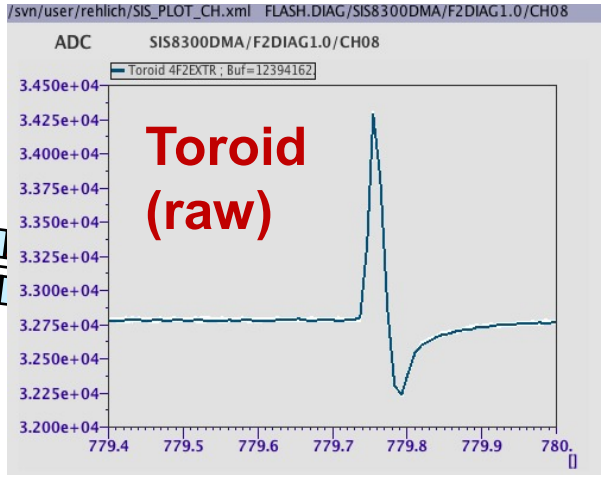
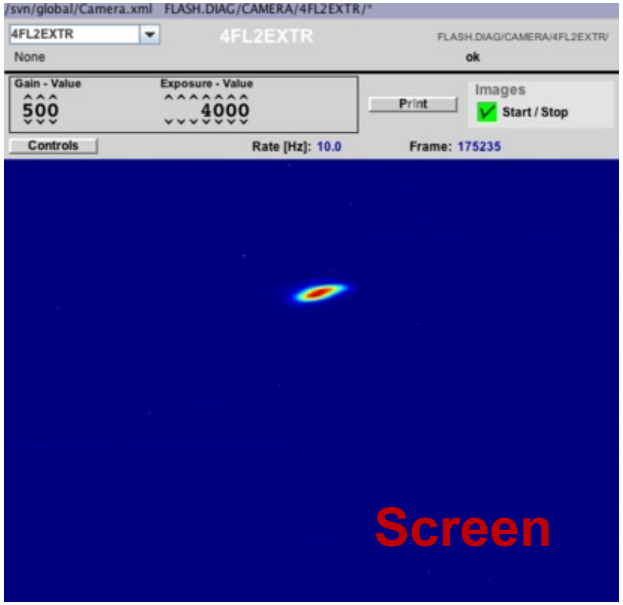






BPM (Scope)



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Diagnostics Monitors at FLASH2

FLASH.
Free-Electron Laser in Hamburg

- Charge monitors / toroids

  Toroid Protection System (TPS)

- Screens

- Beam Position Monitors:

  Cavity BPMs (CBPM)

  Button and Stripline BPMs (Low Charge BPMs)

- Beam Loss Monitors (BLM)

  Beam Halo Monitors

  Ionization Chambers

  Cherenkov Monitors

- Beam Arrival Monitors

- Bunch Compression Monitor

  etc.

XFEL-type

Charge Monitors / Toroids

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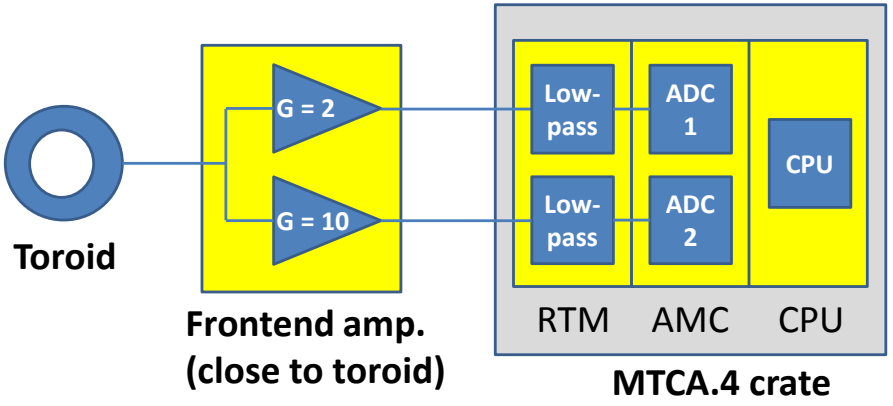
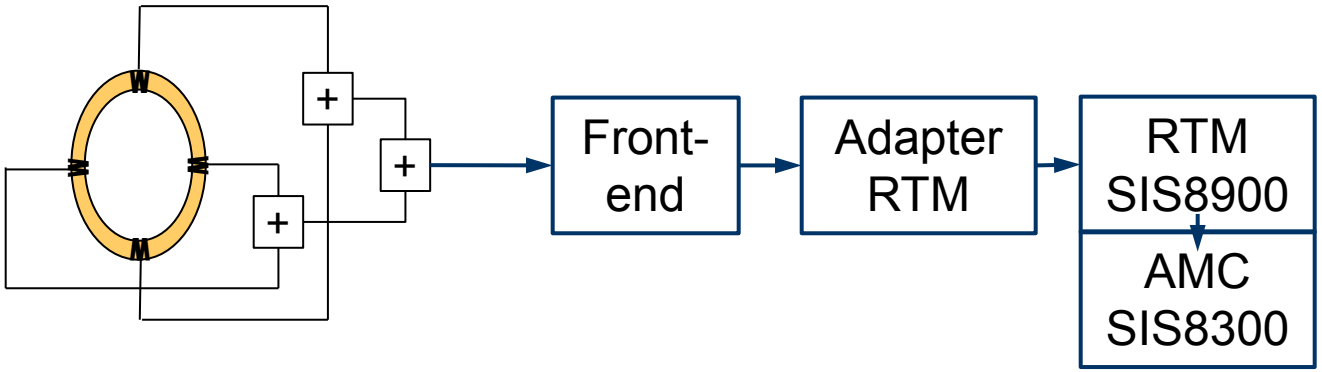
- System for the XFEL still under test
  - Network of monitors to interlock on transmission and bunch pattern failure
  - Noise < 1 pC
  - Electronics still in development

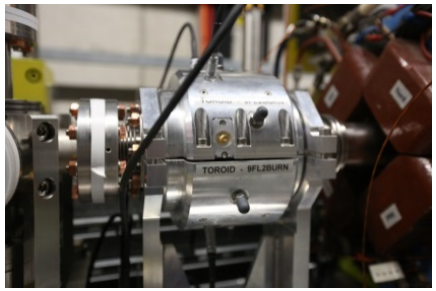
    Front-End design almost ready:
    low-gain and high gain amplifier

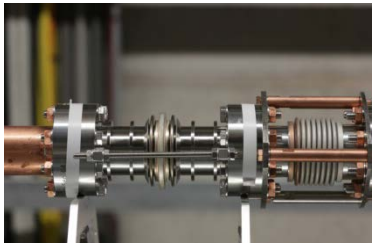


M. Werner, WEPF02

- Temporary solution for FLASH2
  - Put signal from front-end electronics (low-gain only) on MTCA-ADC
  - Differential signal sent over CAT cables







Charge Monitors / Toroids

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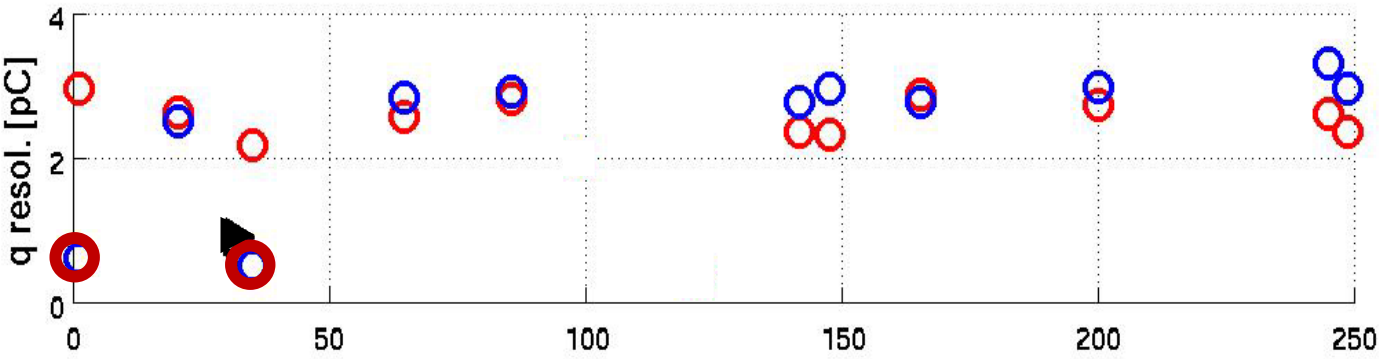
Resolution of charge monitors along FLASH(1) (~ 0.4 nC)

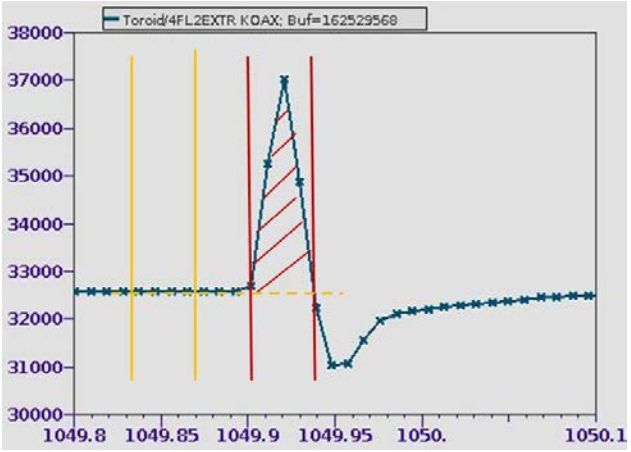


- *FLASH-type (VME)*
- *FLASH2-type (MTCA)*
- *FLASH2 with new amplifier*
- *Dark current monitor*

> Resolution measured with intermediate solution: < 1 pC rms

> Planned improvement of signal processing

- Parabola fit
- Correct phase of ADC sampling



Charge Monitors: Beam Distribution to FLASH1 and FLASH2

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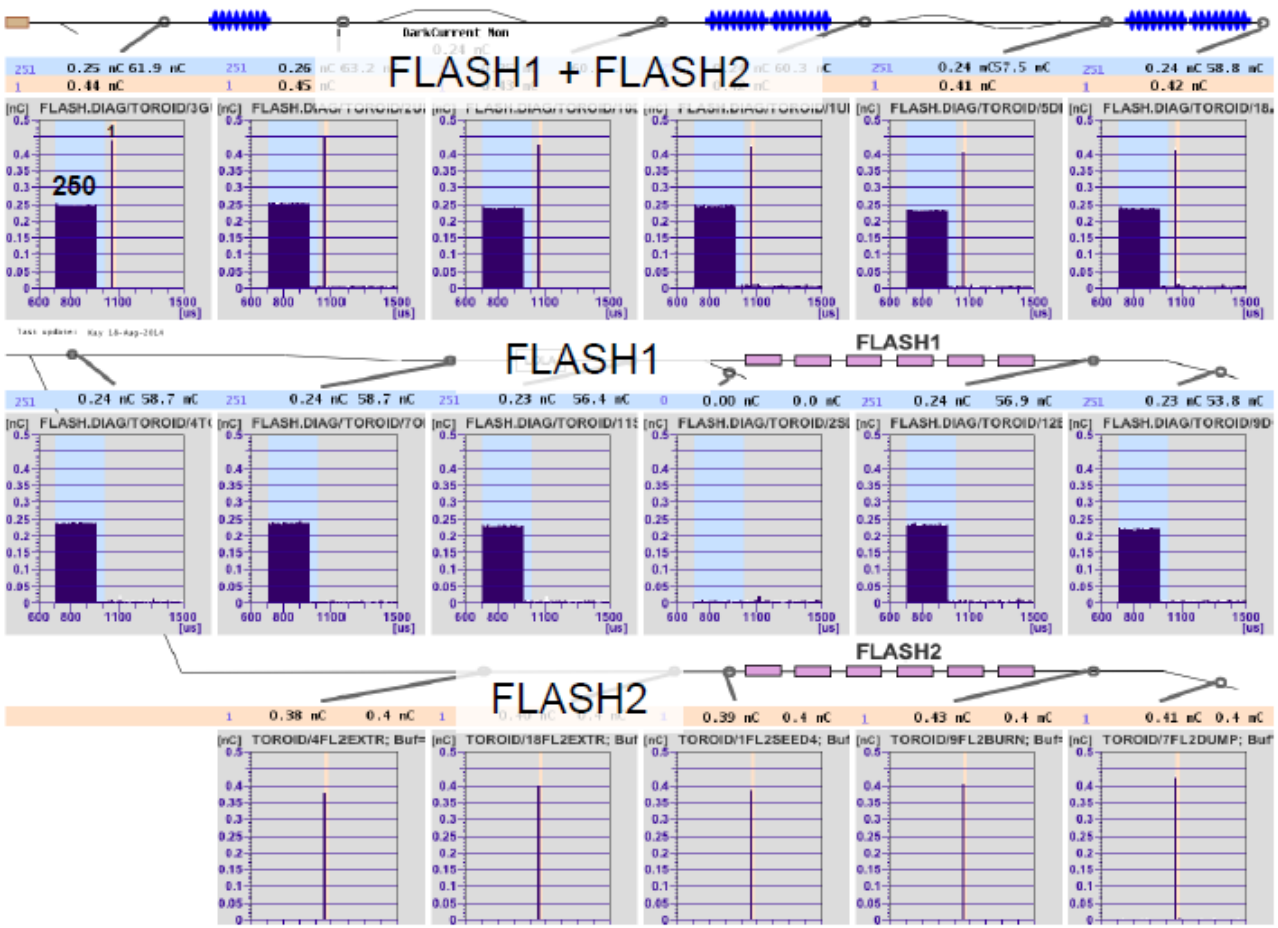

Combined beam in accelerating section

FLASH1 (250 bunches)

FLASH2 (1 bunch)

Both FLASH1 and FLASH2 receiving bunches at 10 Hz

Toroid Protection System (TPS)

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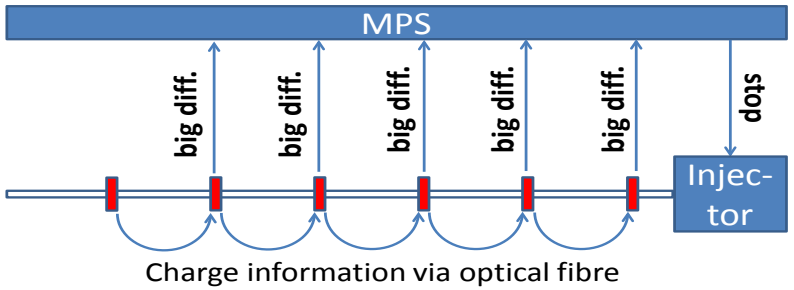
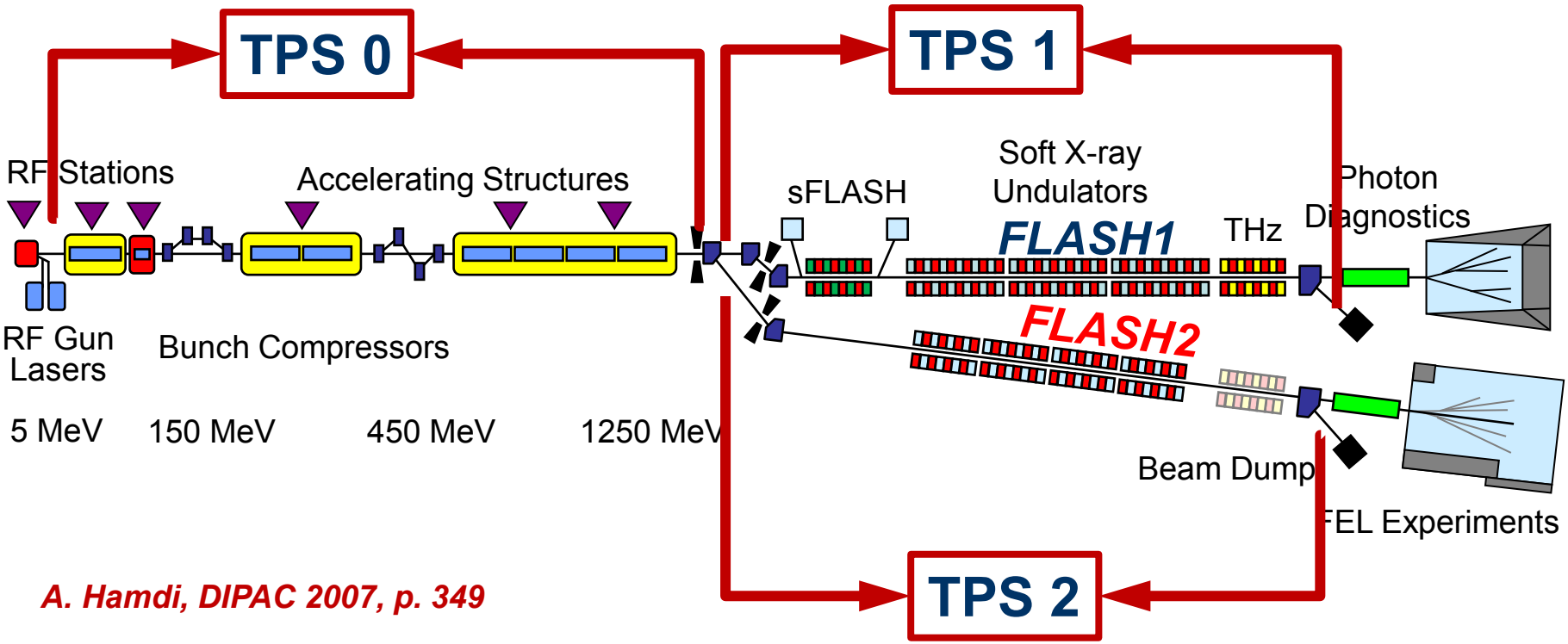
- Temporary solution using 3 TPS modules designed for FLASH

At XFEL:



M. Werner, WEPF02

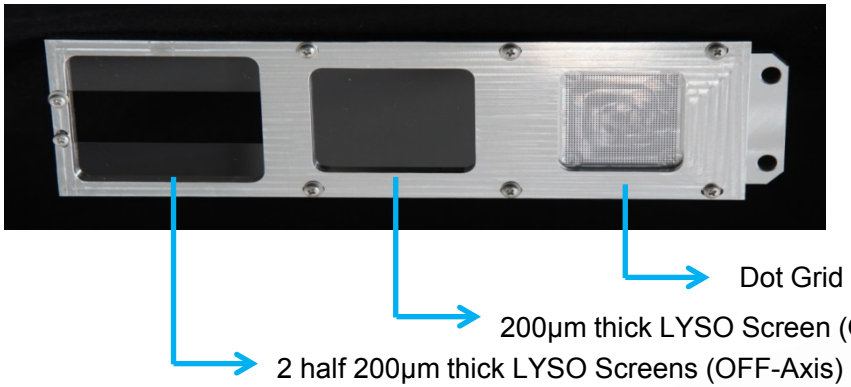


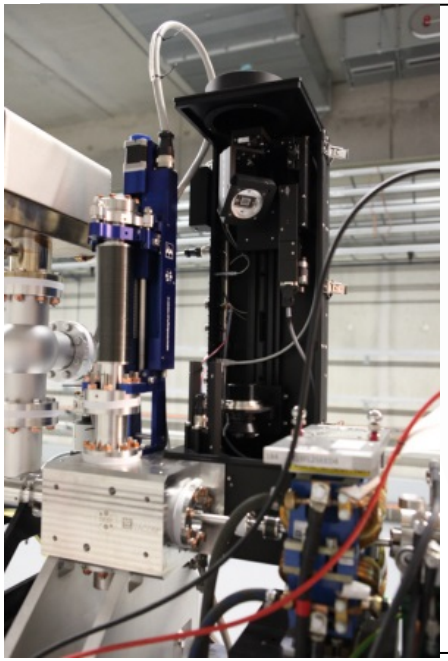
A. Hamdi, DIPAC 2007, p. 349

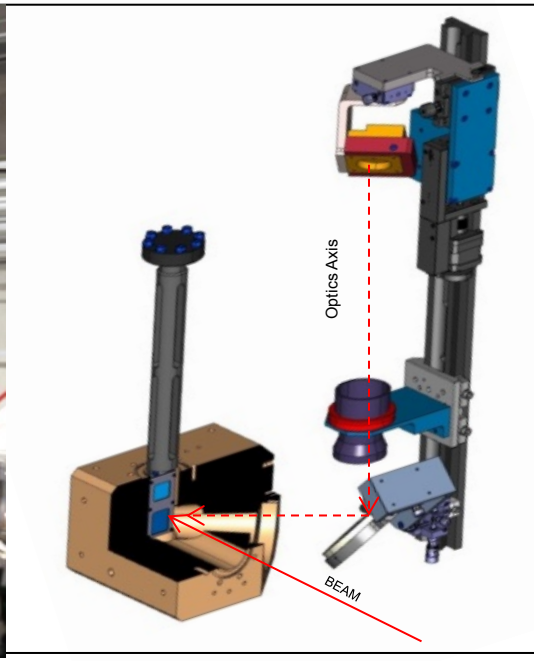
Screens

FLASH.
Free-Electron Laser in Hamburg

- Scintillator based (LYSO:Ce), spatial suppression of COTR
- Optics:
  - Look under 45 deg
  - Uses “Scheimpflug´s” principle to extend depth of field
- 10 µm resolution required
  - single bunch, streaked
- Demonstrated at FLASH1







C. Wiebers, IBIC2013, WEPF03

Screens

FLASH.
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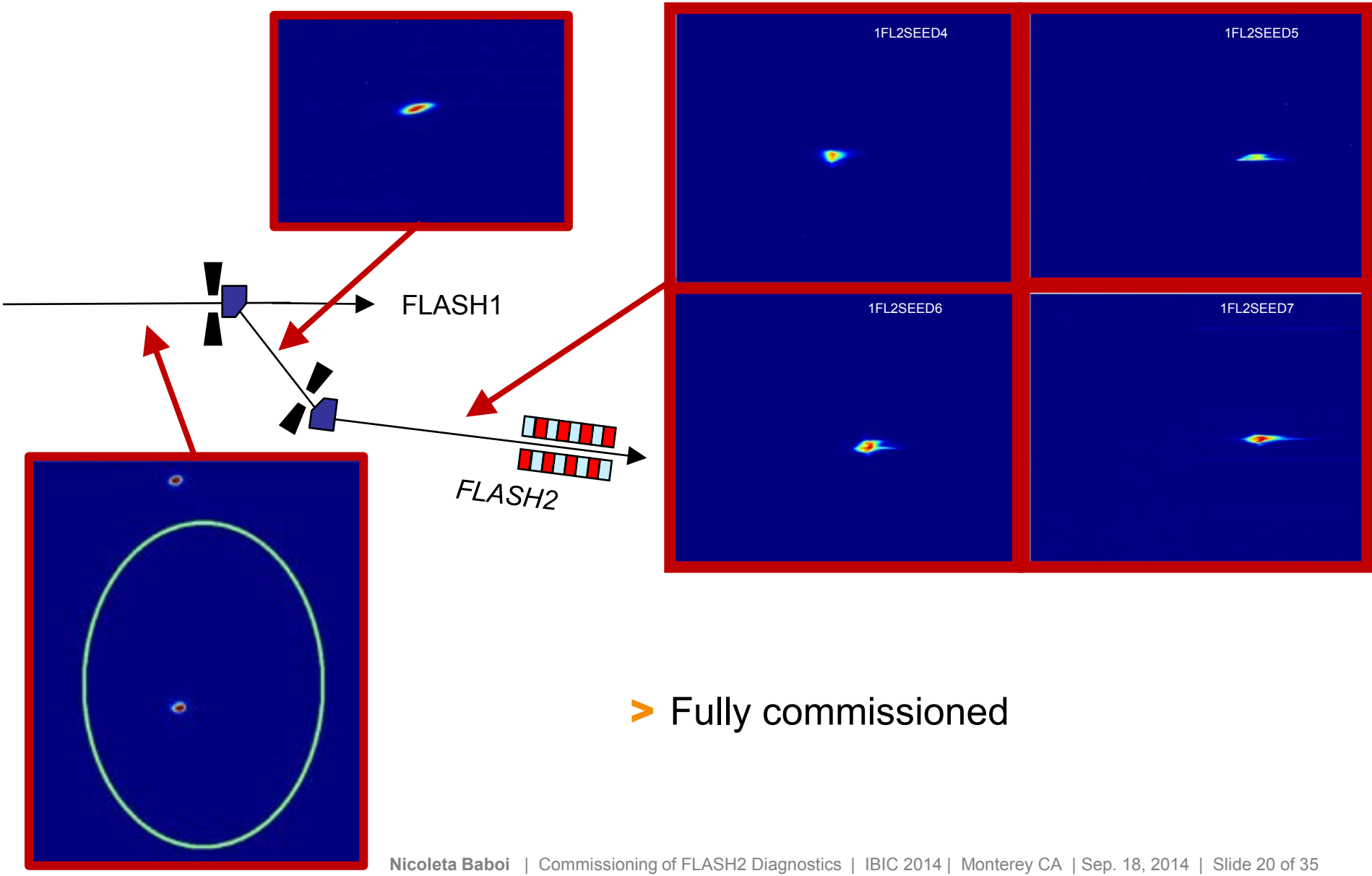

> Fully commissioned

Cavity BPMs

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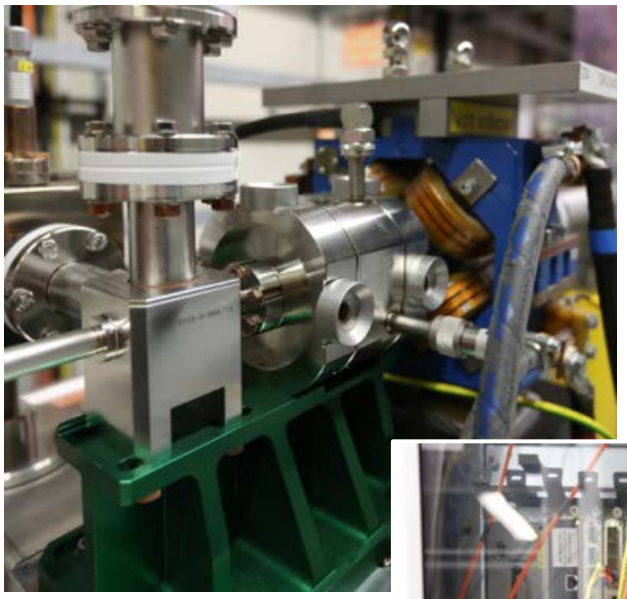
- Cavities
  - Dipole + reference resonator
  - 3.3 GHz, low Q (about 70)
  - 17 installed between undulators – 10 mm pipe
  - No individual tuning



- Readout (PSI)
  - MBU (Modular BPM Unit) with 2 RFFE for 2 cavity BPMs
  - Up to 4 MBUs connected to 1 DAMC2 interface board
  - Timing: decoding timing protocol via fiber in MBU

- Resolution requirement
  - 2 μm rms for 0.1-1 nC and within ± 0.5 mm (1 μm at XFEL, but longer cables at FLASH2)

M. Stadler, WEPD12

Cavity BPMs: Resolution Measured

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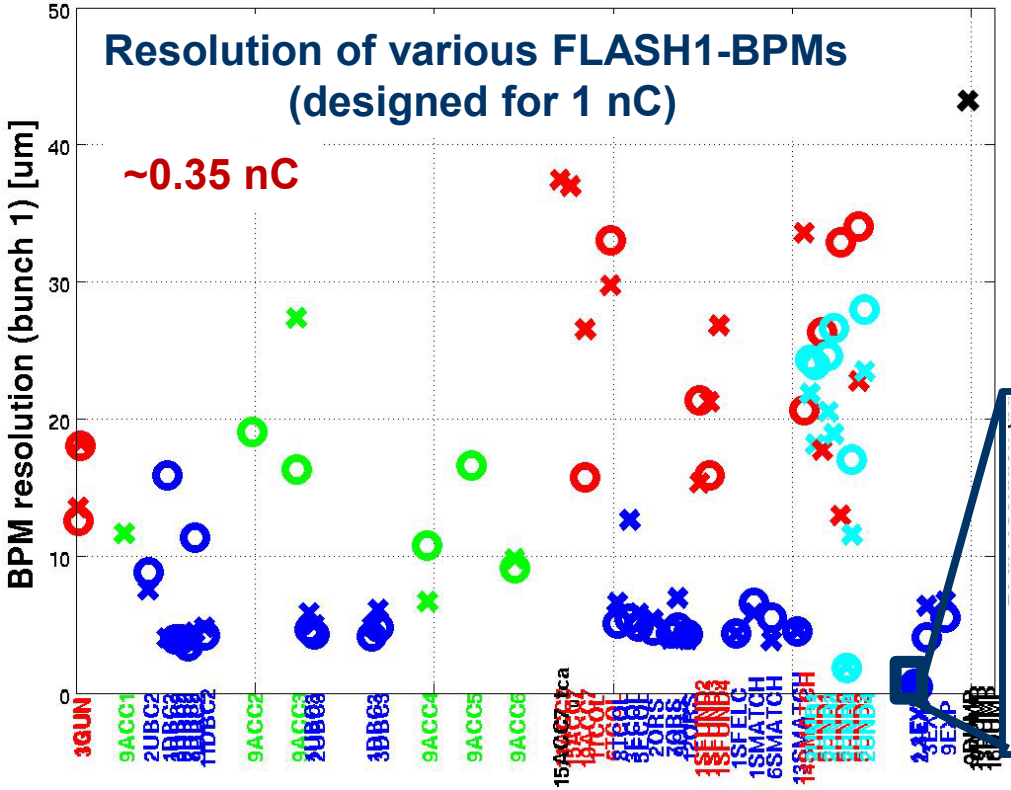
Test BPMs in FLASH1

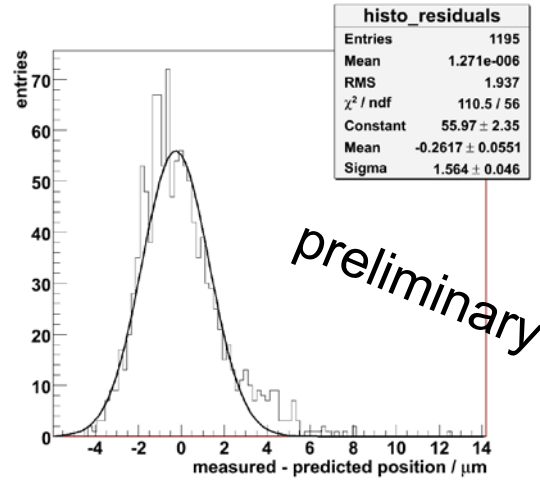
- 0.5 μm rms for 0.24 nC bunch charge and 0.5 mm bunch offset



BPMs in FLASH2

- Difference between expected and measured position with Gaussian fit

D. Lipka, TUPF07



Cavity BPMs: Charge Measurement

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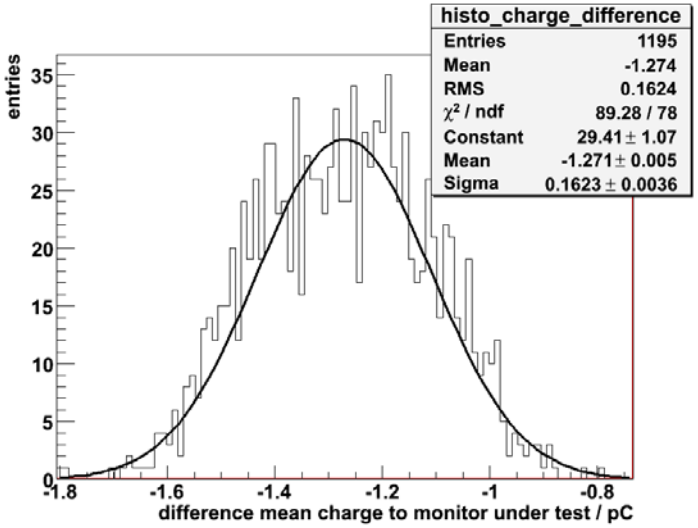
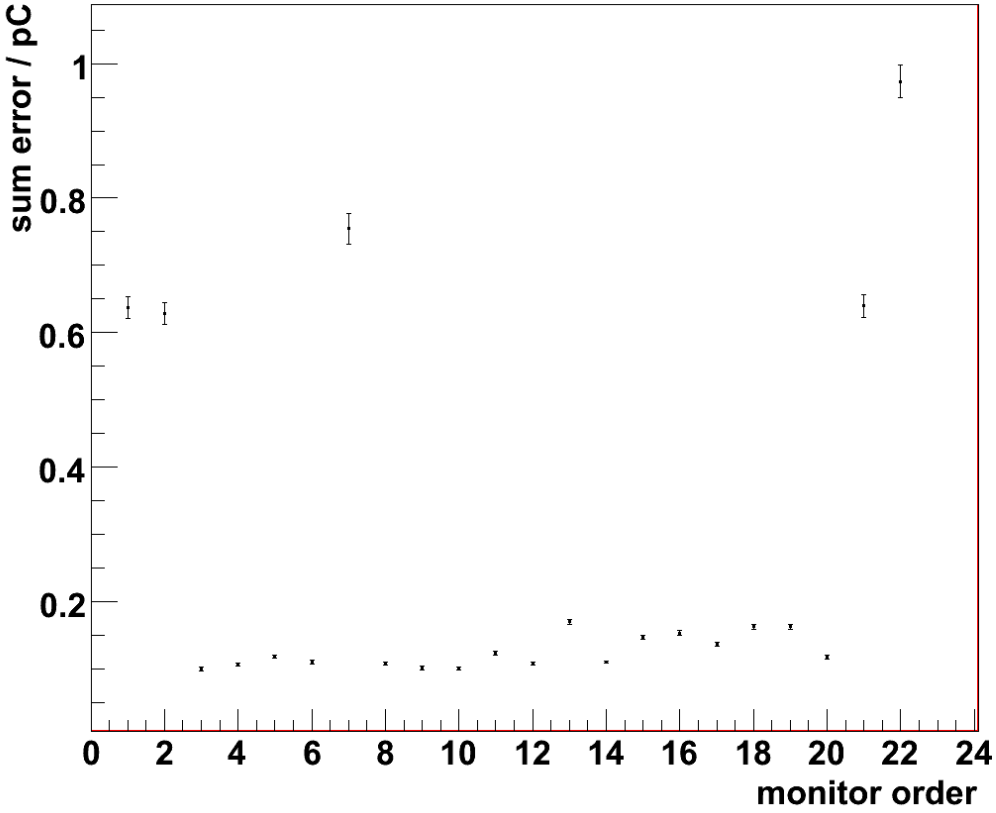
- Charge resolution for 100 pC bunch charge
  < 0.2 pC rms



D. Lipka, TUPF07



Button and Stripline BPMs: Overview

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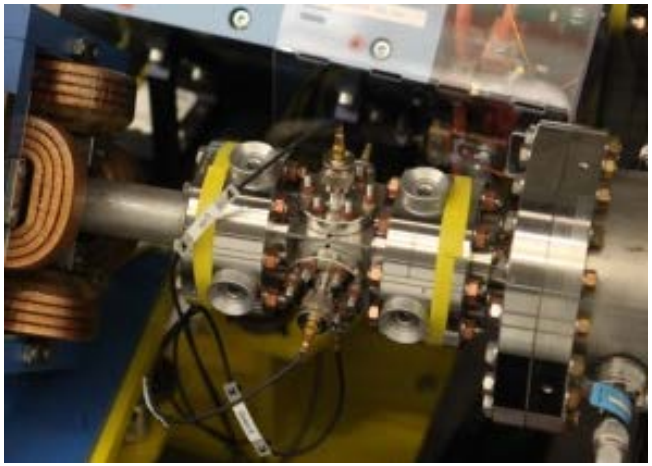
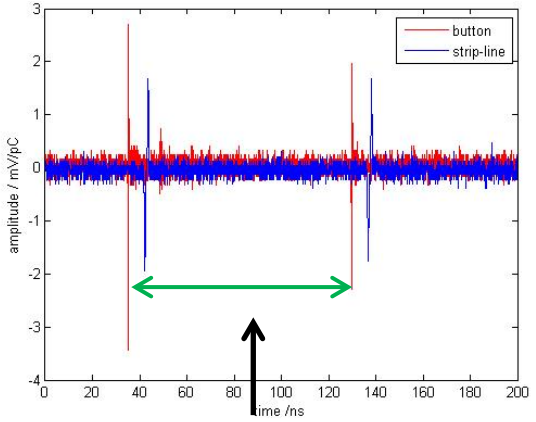
- Low Charge BPMs (LCBPM) electronics
  - Name chosen in contrast to system designed for FLASH for charges of 1nC and higher
  - Designed for FLASH2 (and to be installed in all FLASH)

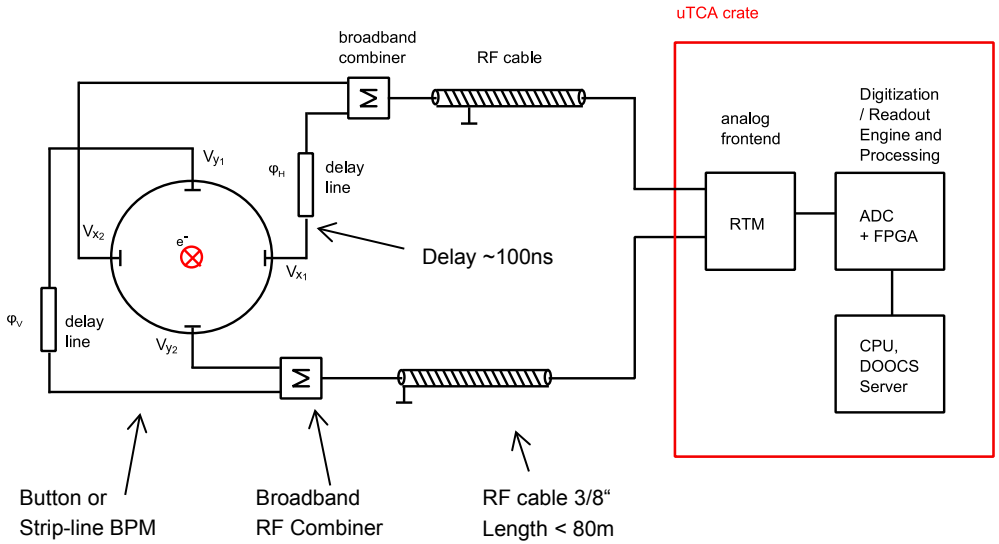


S. Vilcins, TUPF11

TYPICAL SIGNALS FROM BUTTON/STRIP-LINE BPM



Signal of horizontal plane, delay line: ~100ns



B. Lorbeer, TUPF08

Button and Stripline BPMs: LCBPM

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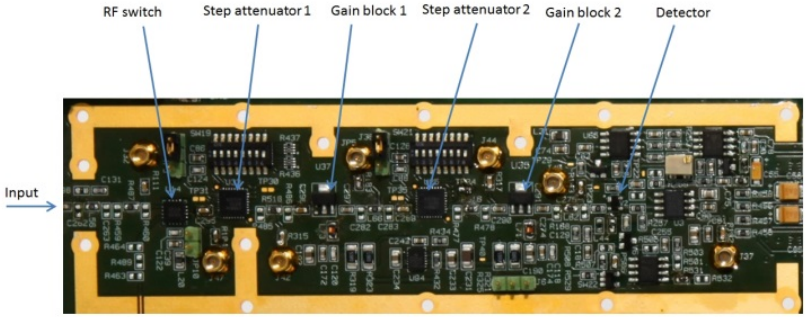
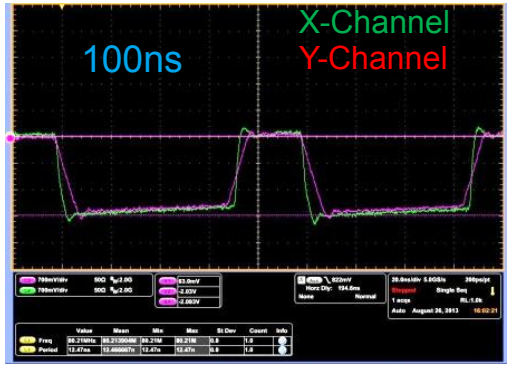
RF Front-End

Rear Transition Module (RTM)
180mmx162mm
Compatible with the MTCA.4 for physics standard

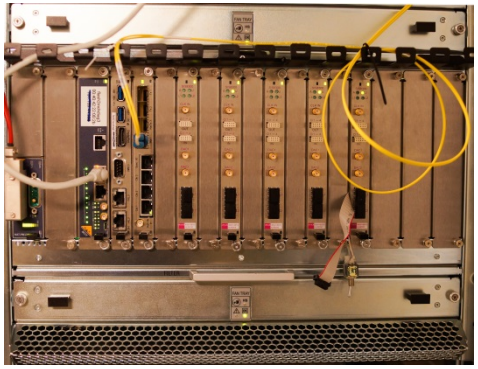


G=38dB
Att.>60dB
Peak Detector

RTM Analog Output Signals

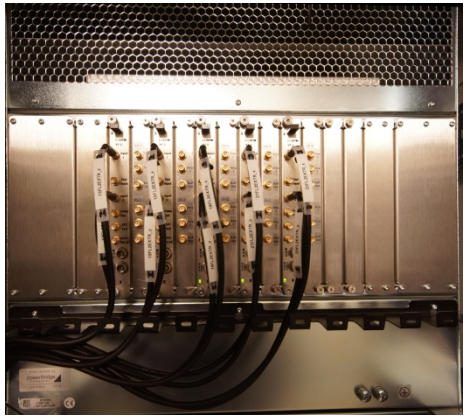


MicroTCA crate



Front Side

5 BPMs/crate



Back Side

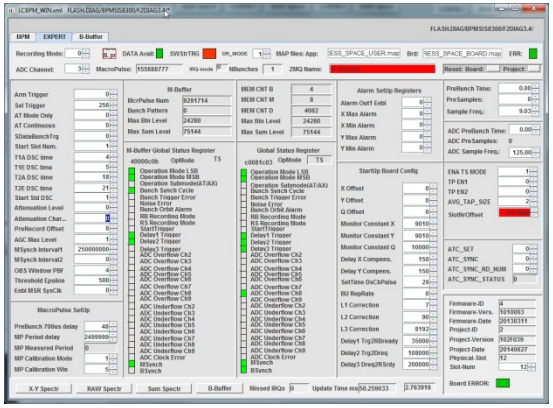
Crate used for the tests includes:

- management carrier hub (MCH)
- hard disk (HD), processor (CPU)
- Digitizer SIS8300
- timing module x2timer

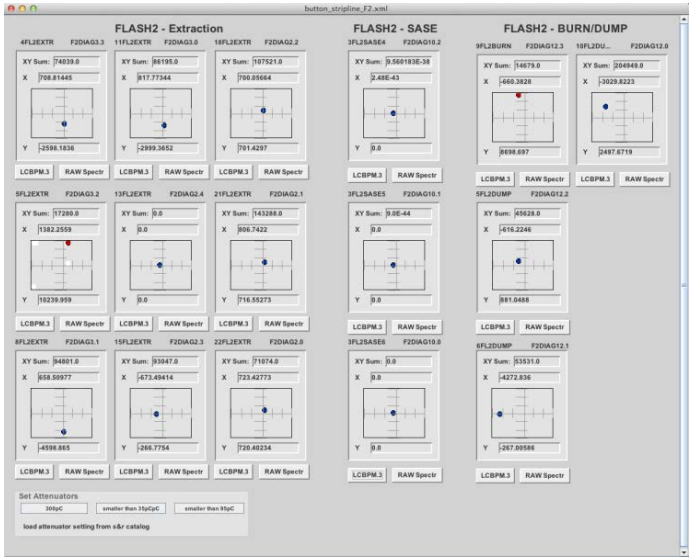
Button and Stripline BPMs: Operation

FLASH.
Free-Electron Laser in Hamburg

Server Panel for Firmware Adjustment



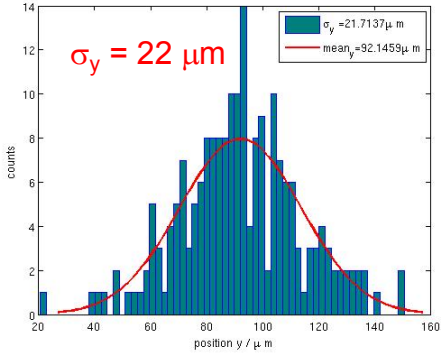
BPM Expert Panel



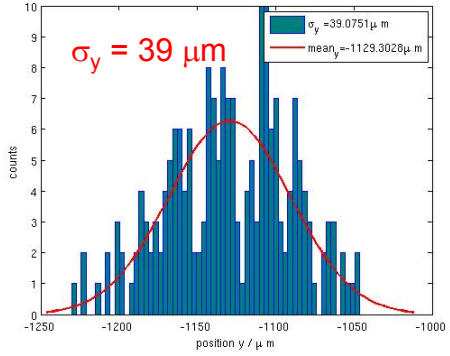
Requirements (from XFEL requirements)

bunch charge	0.1-1	nC
bunch spacing	≥222	ns
maximum macro-pulse repetition rate	25	Hz
beam pipe diameter	40.5	mm
single bunch resolution	50	µm
Averaged RMS resolution over 1000 bunches of identical train	10	µm
Range for max. resolution	+/- 3	mm
Operation range with reasonable signal	+/-10	mm

RMS at q=36 pC, 200 pulses (incl. beam jitter)



Strip-Line BPM



Button BPM

Beam Loss Monitors

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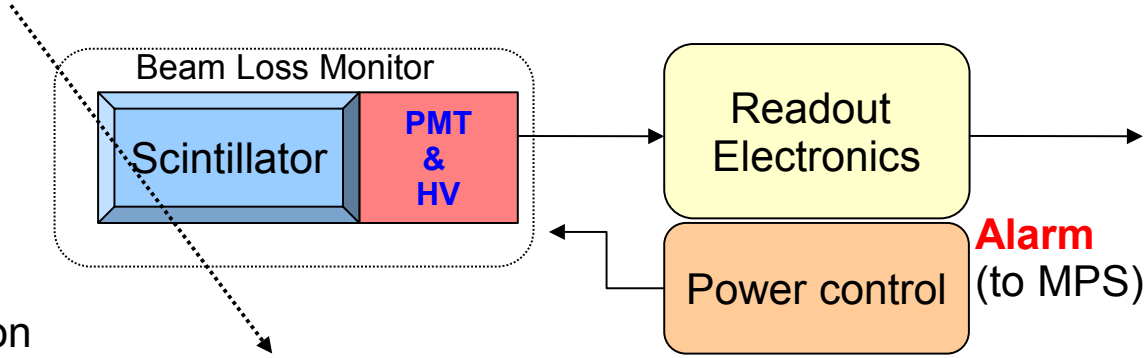
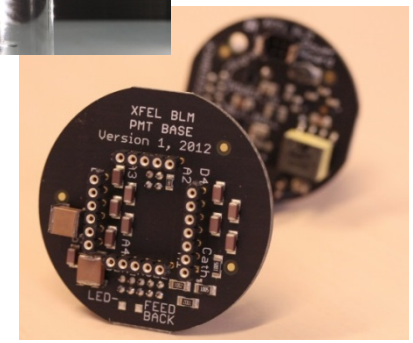
- Detector
  - Scintillator or fused silica (rod or fiber)
  - PMT: HV voltage (~500 V) generated by Cockcroft-Walton multiplier on board mounted at PMT
  - Scintillators and mechanics built by IHEP, Protvino (60 for FLASH2)
- Electronics MTCA-based with low latency interface with MPS
- Alarms algorithms
  - Single bunch
  - Multi-bunch
  - Integration
  - OR of comparator and FPGA alarms



A. Kaukher, BIW 2012, p. 35



Beam Loss Monitors: Status

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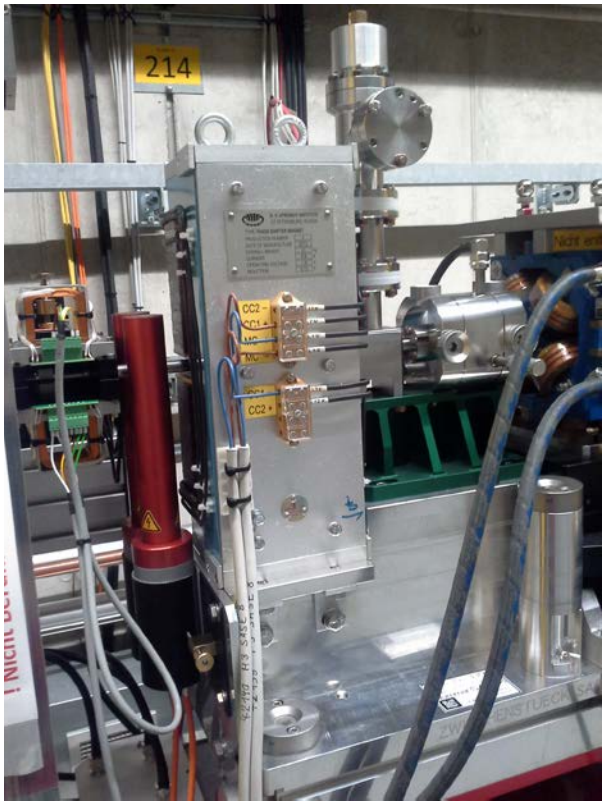

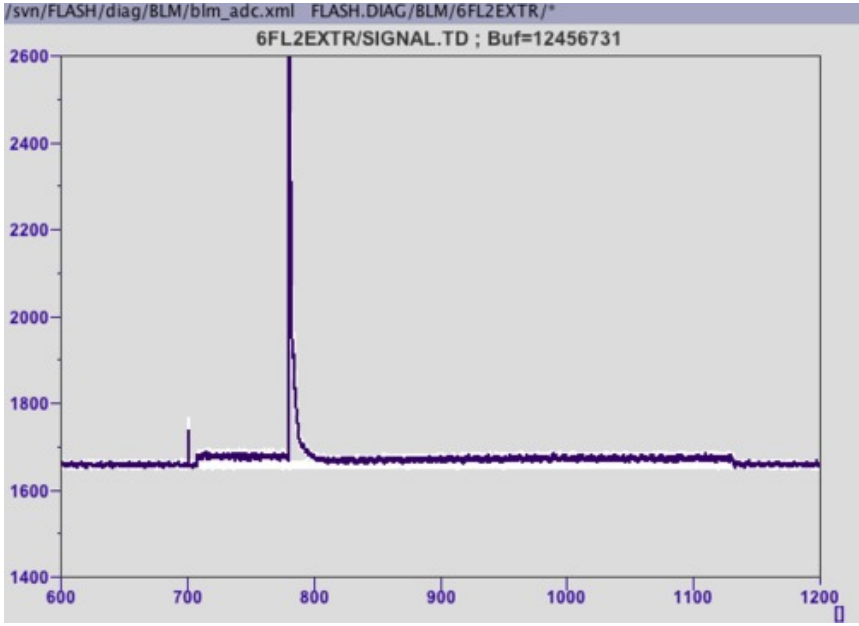

- Calibrated single and multi-bunch alarm
- Integration alarms to be calibrated

Dump Loss Monitors: BLMs and Ionization Chambers

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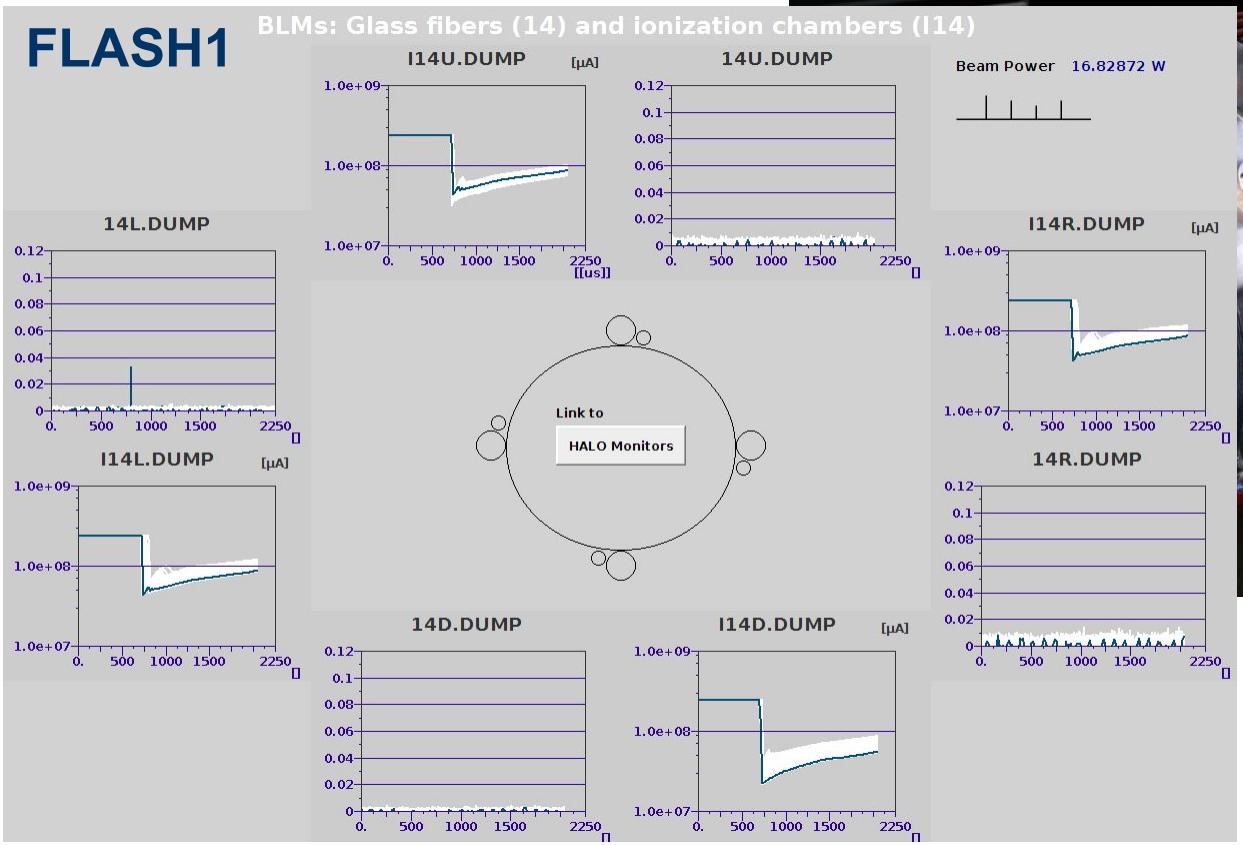
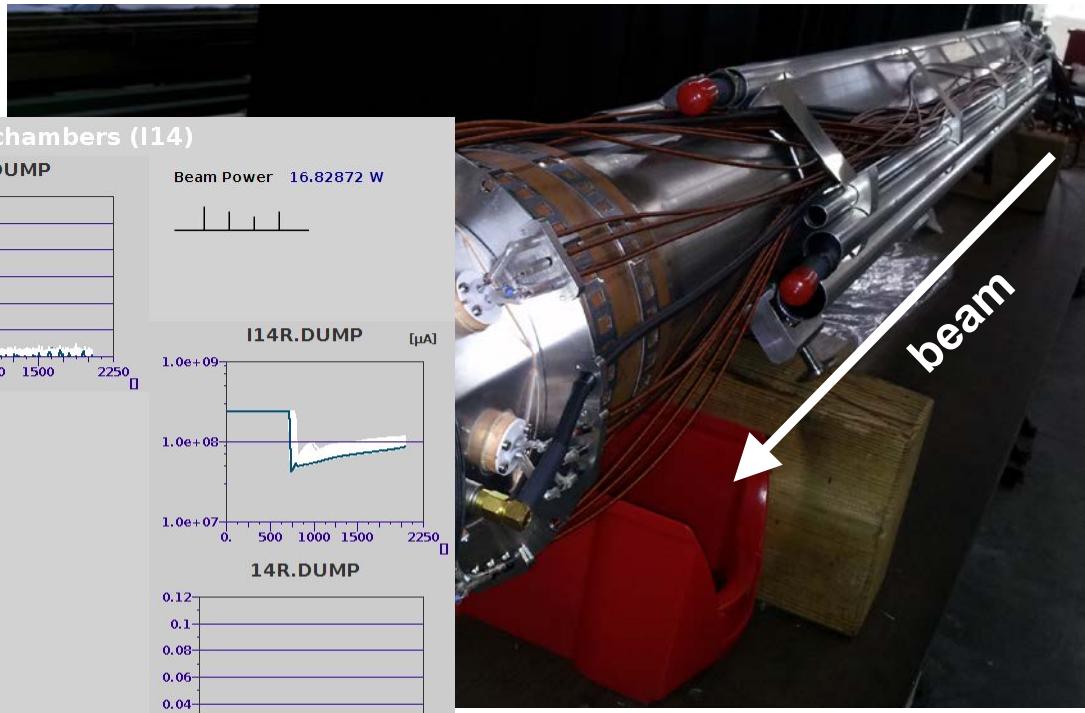
Free-Electron Laser in Hamburg

- Similar to FLASH1: BLMs based on quarz-fiber + Ionization Chambers (air filled cables) along last 2m of beam line





N. Baboi, BIW 2010, p. 420

Dump Loss Monitors: Beam Halo Monitors

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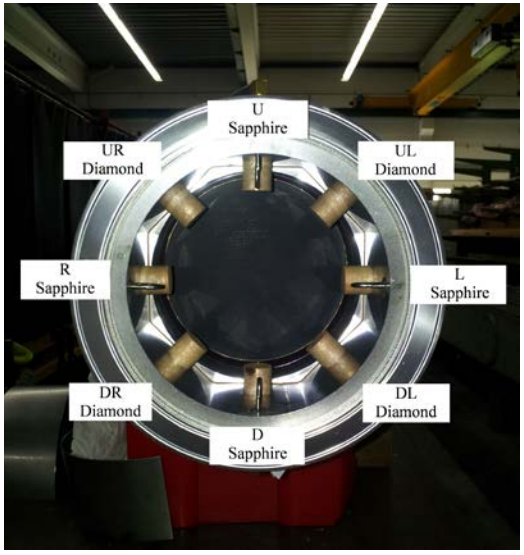
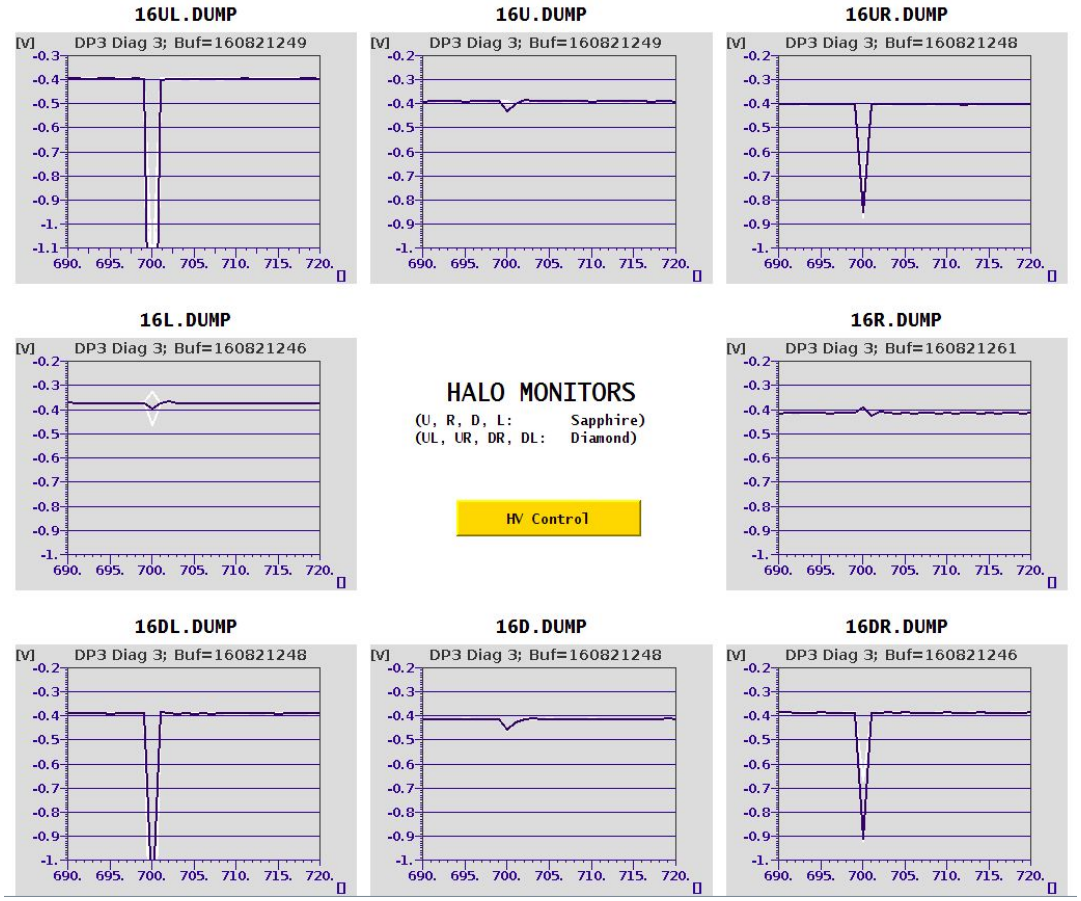
- Similar to FLASH1
- 8 sensors:
  4 Diamond + 4 Sapphire mounted behind the dump vacuum chambers
  - At XFEL mounted outside chamber



FLASH1



A. Ignatenko, IPAC 2012, p. 816

Other Electron Beam Monitors in FLASH2

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- Loss monitors
  - Cherenkov fibers along undulators (not for XFEL)
- Beam Compression Monitors

C. Behrens, IPAC'10, p.912

- Beam Arrival Monitors

A. Angelowski, MOPD25

- Coherent Transition Radiation monitors

S. Wesch, BIW 2012, THAP01

1st Lasing at FLASH2

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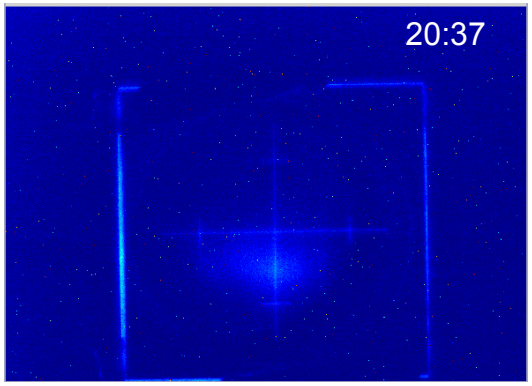
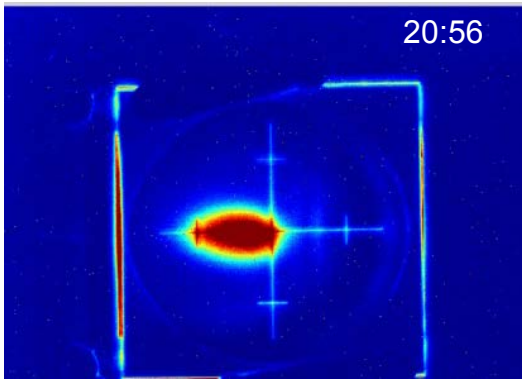
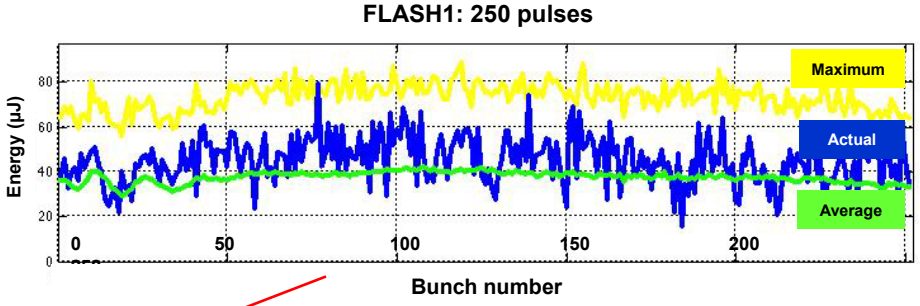
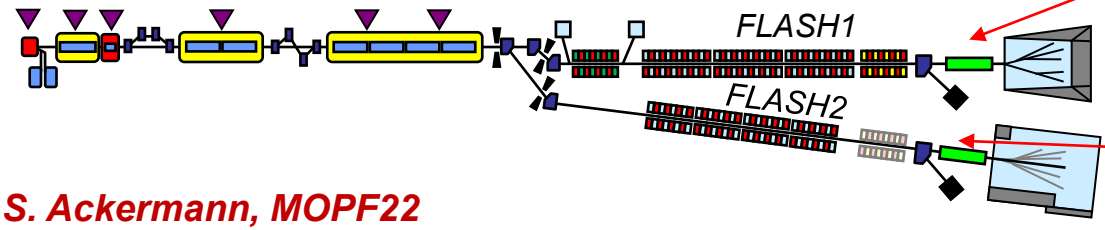
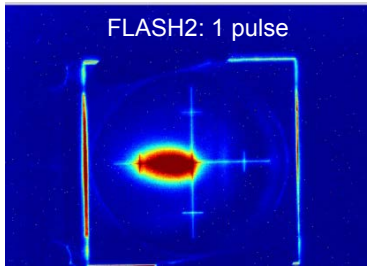




- FLASH1 lasing in parallel with 250 pulses







S. Ackermann, MOPF22
K. Honkavaara, FEL2014, WEB05
S. Schreiber, FEL2014

Concluding Remarks

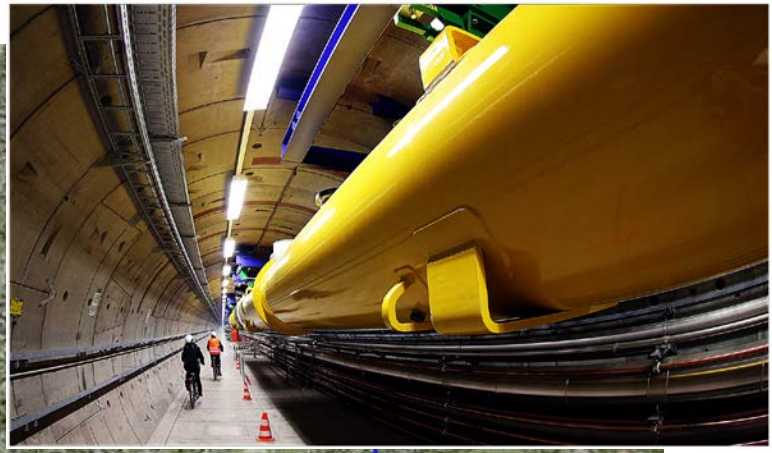
FLASH.
Free-Electron Laser in Hamburg

- XFEL and FLASH-type of diagnostics
- Some fully commissioned:
  - Screens
- Some in advanced commissioning state; still to do (e.g.):
  - Integration alarm of BLMs
  - Implement timing coupled mode and automatic gain control for LCBPMs
  - BPM calibration
- Some have temporary solution
  - Toroid electronics and Toroid Protection System
  - MTCA power supplies
  - How components work together
- Some to be commissioned
  - Dump instrumentation

Many Lessons Learned for the European XFEL

FLASH.
Free-Electron Laser in Hamburg

- The commissioning of FLASH2 paves the way for an easy(ier) commissioning of the XFEL diagnostics



D. Nölle, WEPF15

M. Hüning, IPAC2013, WEZB101

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FLASH.
Free-Electron Laser in Hamburg

- Many people contributed to the work and this talk
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  - and many others

- Other Labs involved
  - PSI: Cavity BPM electronics
  - IHEP, Protvino: BLM Detectors

- Most photos by Dirk Nölle