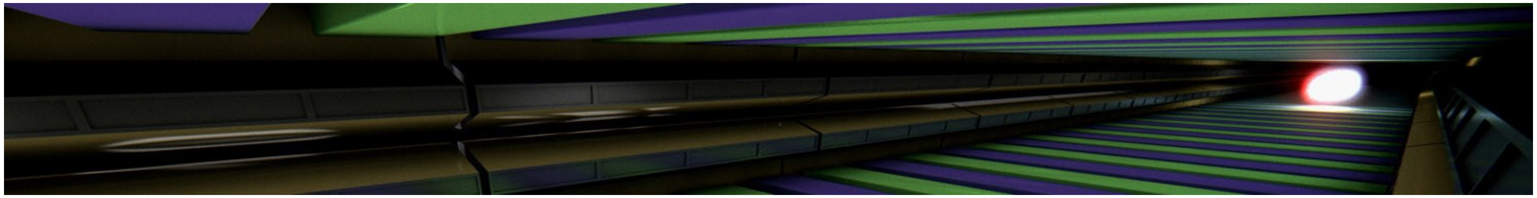


E-XFEL STANDARD ELECTRON BEAM DIAGNOSTICS

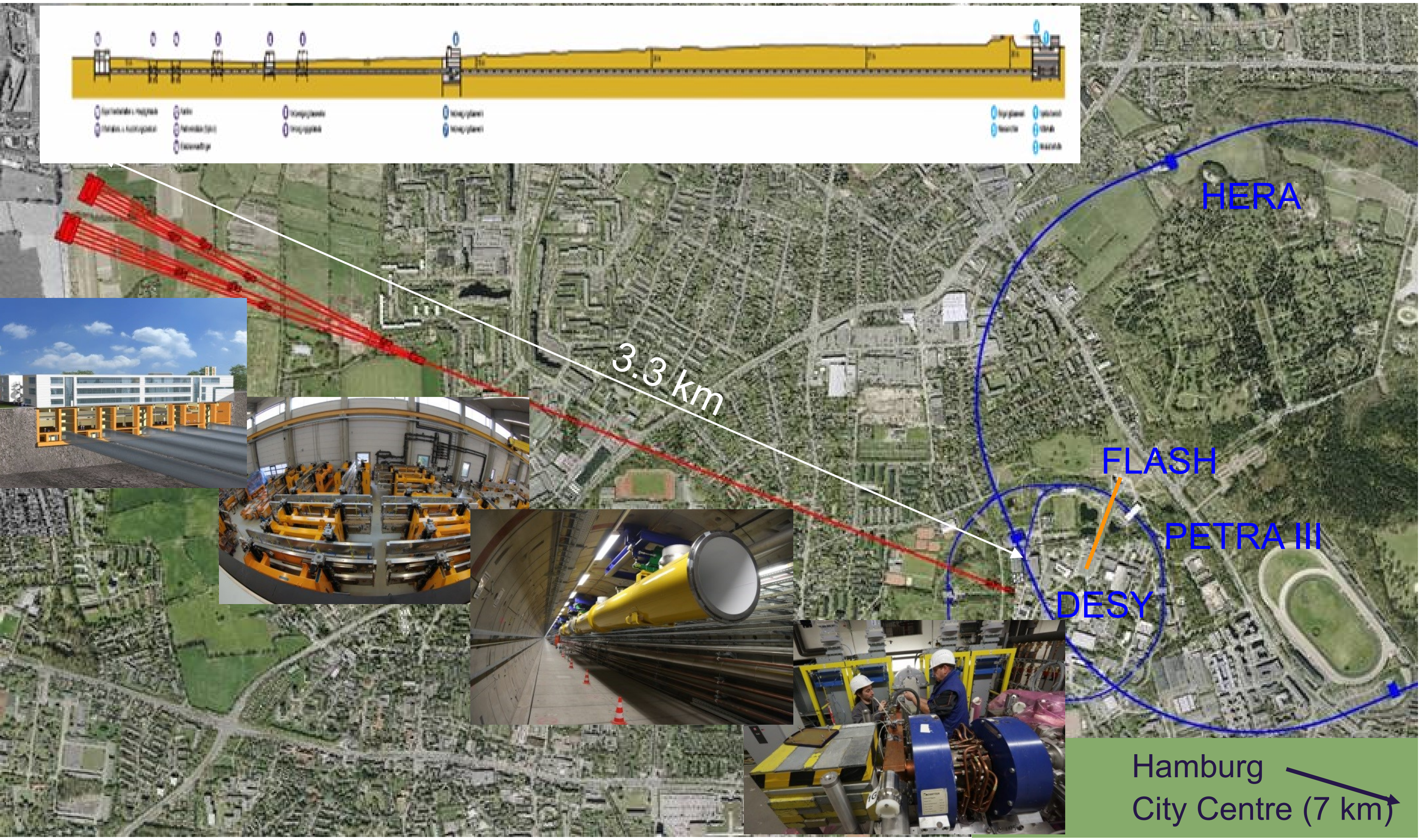
Dirk Nölle for the XFEL Diagnostics Team

DEELS Workshop, ESRF, 12.05.2014

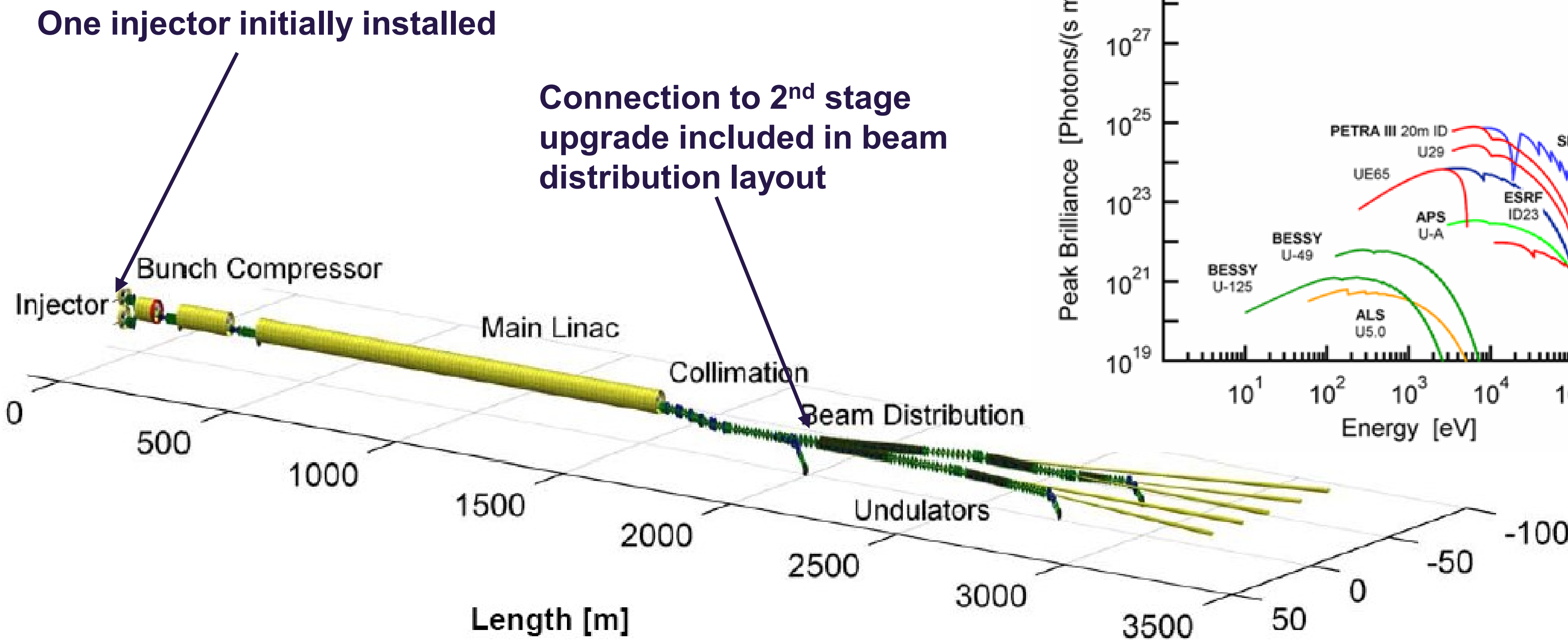
Outline

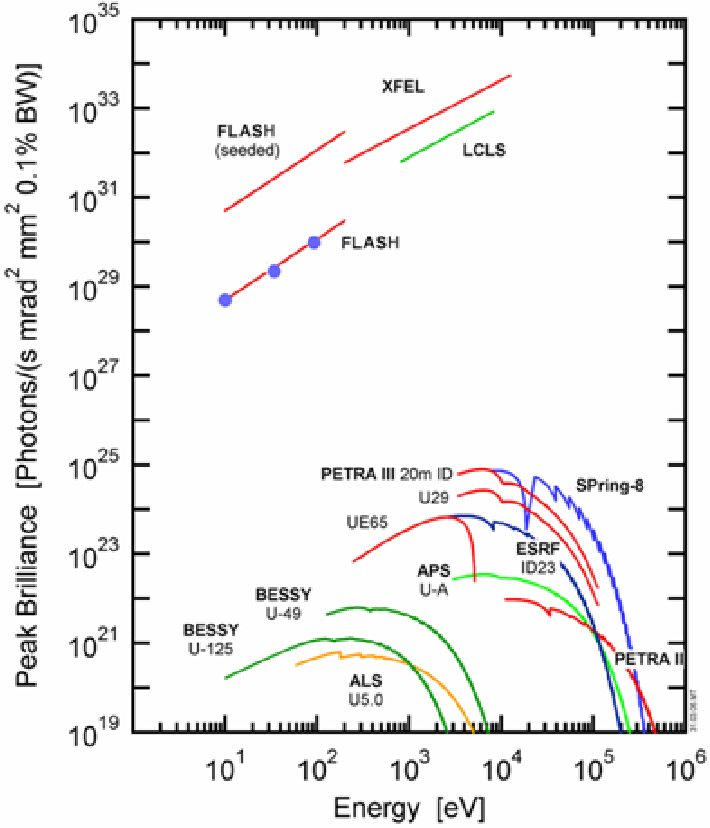
- Short Roundtrip of the XFEL Project
- What is the Standard Diagnostics?
- Beam Position Monitors (Collaboration with PSI/CEA)
  - → This talk will show the aspects of the mechanics
- Charge Monitors
  - → Toroids
  - → Dark Current Monitors
- Beam Size Measurements
  - → Screens
  - → Wire scanners
- Beam Loss Monitors
- Dosimetry System
- Other … Restriction of the Talk´s Scope to "Main Systems"

The European XFEL: Birds View



Accelerator Layout

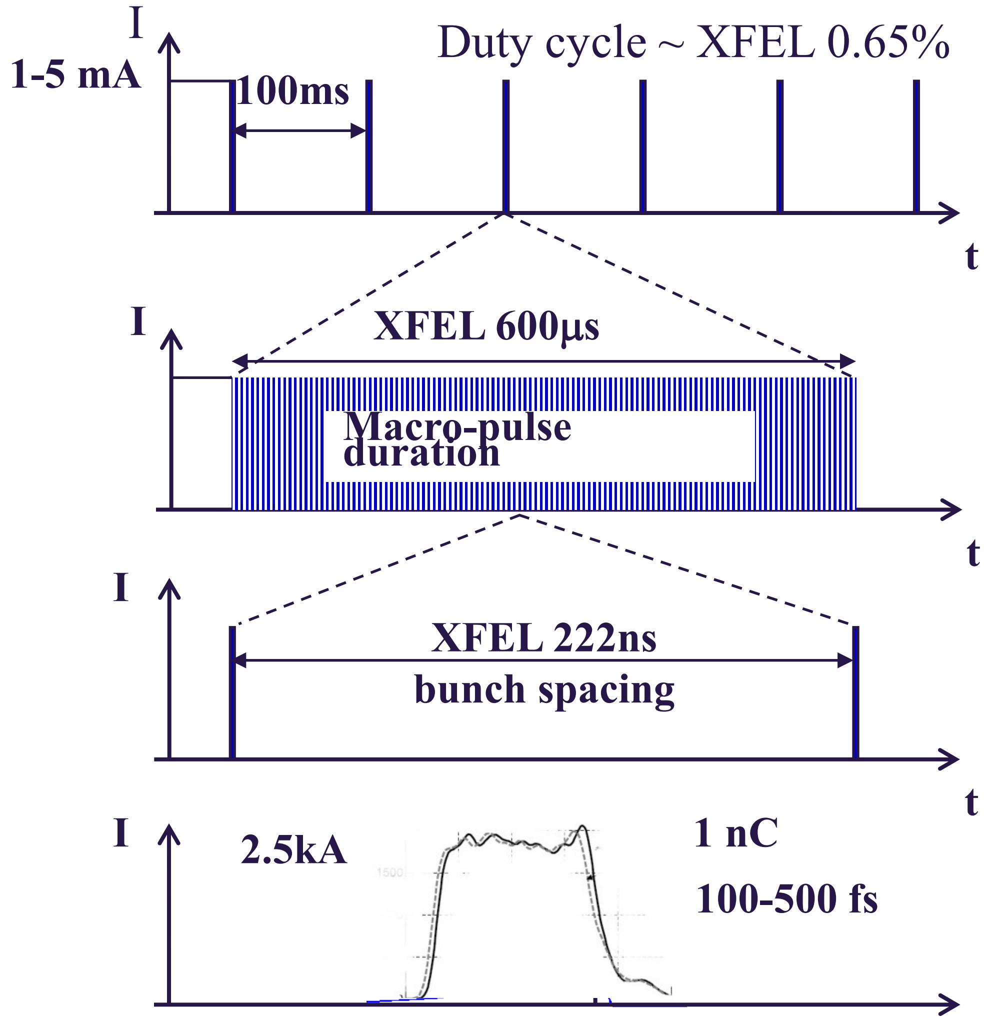




- 17.5 GeV superconducting LINAC
- RF photoinjector, two bunch compression stages
- 3 SASE undulators plus 1 spontaneous source, extension possible
- 5 experimental stations to be extended to 10
- potential extension with a second experimental hall

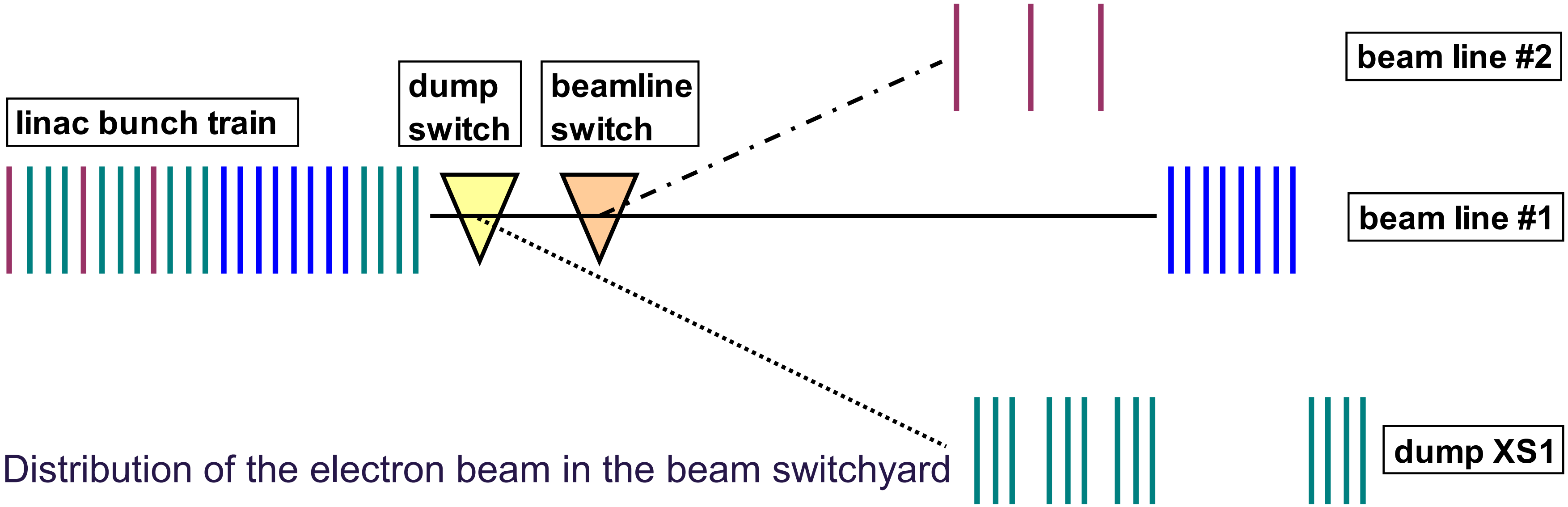
E-XFEL Time Structure: High Duty Cycle

- Repetition rate
- Macro-pulse
- Bunch
- Slice
- **Up to 27000 Bunches/s**



FLASH and E-XFEL have the same time structure

E-XFEL Time Structure: Beam Distribution



- Distribution of the electron beam in the beam switchyard
- Kicker septum scheme with precision kicker and septum + knock out kicker
  - Machine operated with fixed beam loading (only length of the train is varied)
  - 3 way switch
    - SASE 1
    - SASE 2
    - Dump
  - First bunches send to the dump (used for locking of feedbacks)
  - First half train is send to SASE 1
  - Second half train is send to SASE 2
  - Not needed bunches can be knocked out to the dump

XFEL Construction

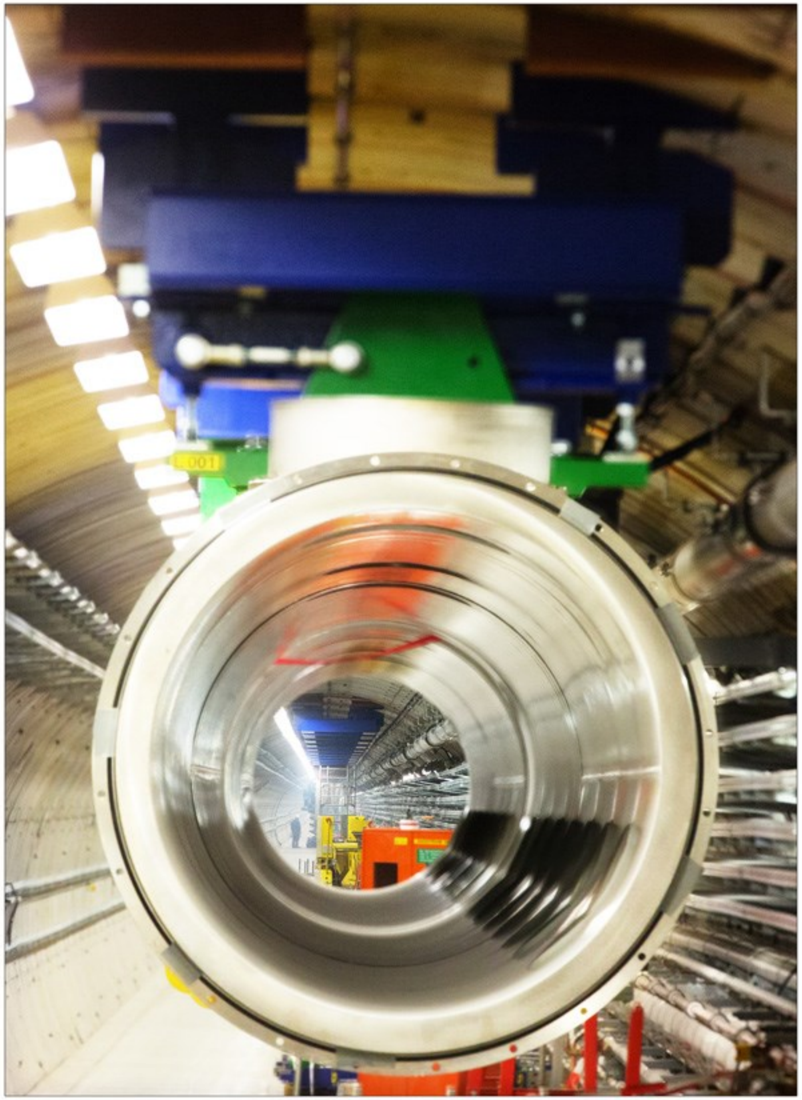
- Civil Construction started 2009
- Christmas 2009: XFEL Company founded
- Underground Construction finished: 6/2013
- Infrastructure of XTL ready: 9/2013
- RF Test of Gun in the Injector Tunnel: Dec 2013
- Start of Machine Installation: now
- Commissioning of the Gun: Summer 2014
- Commissioning of the Injector: Spring 2015
- Installation Ready; Tunnel Closed: 7/2016
- First Lasing Possible: Dec 2016

Open Day for DESY Staff, Feb. 2012

2/2012

What a Vision!!! (same Position 3/2014)

But ….

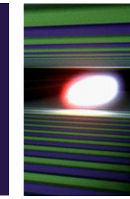


More Pictures from the XFEL Project:

http://xfel.desy.de/pictures/

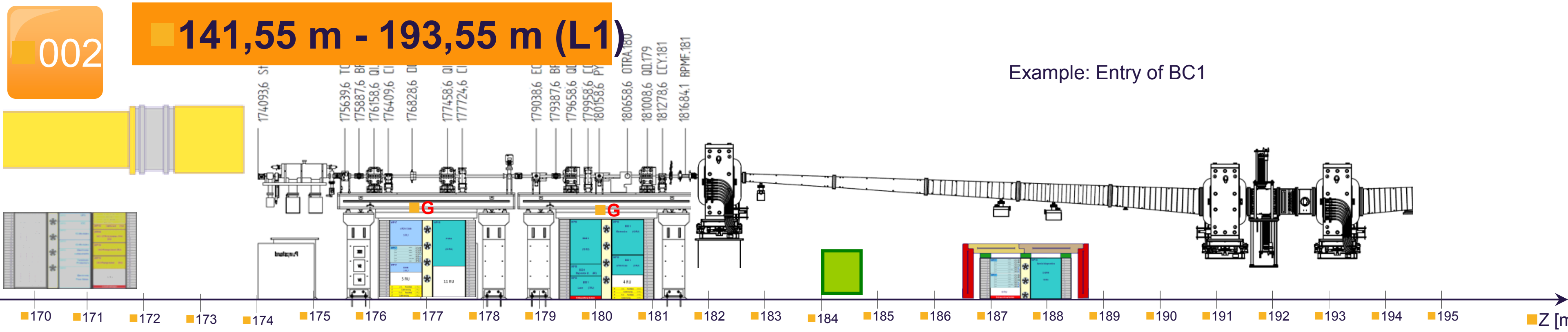
http://adweb.desy.de/home/dnoelle/WWW/XFEL_meets_Photoshop/index.html

What is Standard Diagnostics at XFEL?



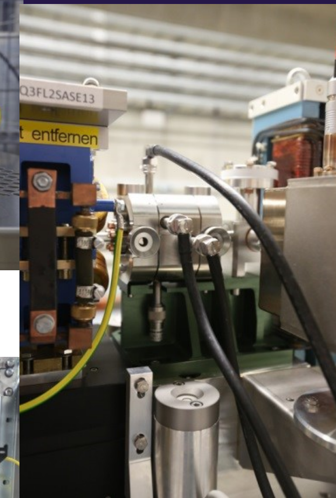
System	Subsystem	Gun	Injektor [XTIN]	XTL	XTDs
BPM System	Button	1	16	180	111
~ 480	BPME				101
	BPMF/I		3	19	5
	BPMR		1	30	
	Button Array			3	
	HOM		2		
Charge	FCUP	3			
~ 50	DCM	1	1	8	
	Toroid	1	3	16	15
Screens	Simple	3			
~ 75	OTR_ABCL		7	26	16
	OTR_DE		1	4	5
	OTRS			3	
	Beam Size Dump			1	2
Wire Scanners				6	6
12					
Loss Monitors	BLM	1	18	100	192
~ 320	BHM		1	1	2

Electronics in XFEL

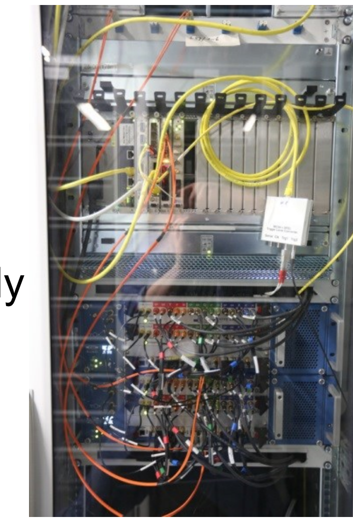


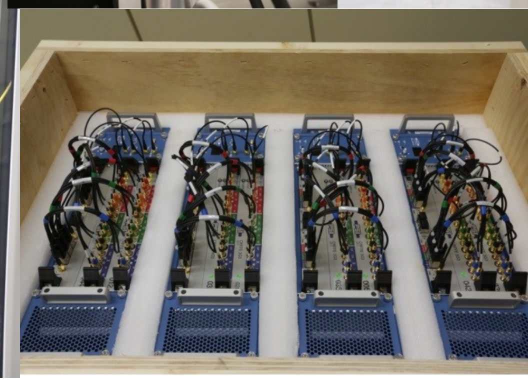
- Long Tunnel
  - All electronics inside
  - Limited space
  - Mixture of Trades
- Using KDS as a planning tool
  - All cables have to be specified
  - Orders are generated
  - Documentation is ready when cables are installed.

3Lab InKind Contribution: BPM System

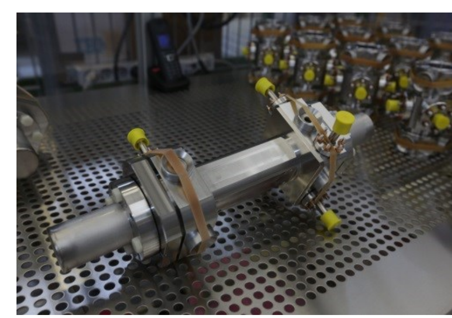


- 3 types of BPMs
  - Button BPM for different beam pipes
  - Cavity BPM for 2 beam pipe diameters
  - Reentrant Cavity BPM 30% of cold LINAC
- Build by 3 Lab Collaboration
  - CEA: Reentrant Cavity BPM + RFFE
  - PSI: Entire Electronics, except Reentrant RFFE
  - DESY: Entire Mechanics, except Reentrant Body

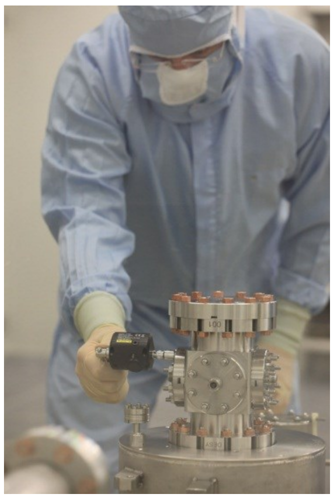




- Readout
  - MBU (Modular BPM Unit)
    - → 4 Button BPMs
    - → 2 (Reentrant) Cavity BPMs,
    - → 1 Cavity + 2 Buttons
  - Connection to DOOCS via a FPGA-FPGA Bridge with optical fibers. Up to 4 MBU connect to 1 DAMC02 interface board.
  - Timing: Decoding XFEL timing protocol (via fiber) in the MBU
  - Ref. Frequency (Cavity only) 216 MHz
- More Details, Specs and Performance: to be presented by Boris

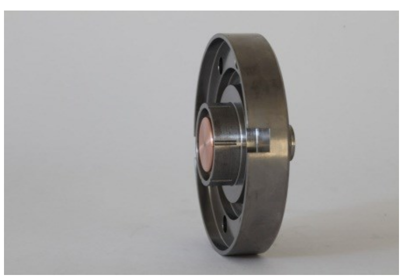


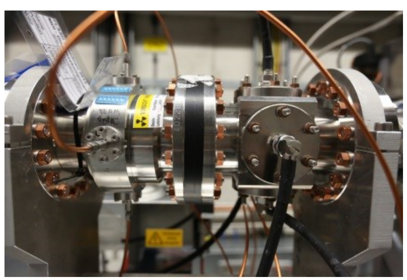
WP-17: Cold BPMs

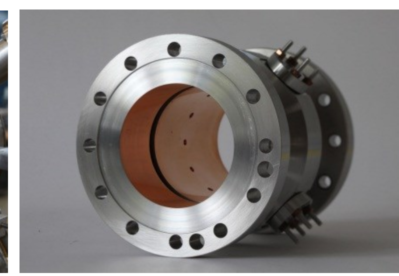


Delivery of cold BPMs for module assembly established:

- Production of BPMs finished
- First assemblies with both types successful
- Stock building of BQU for module production done
- Assembly of BQU for modules possible any time on request.







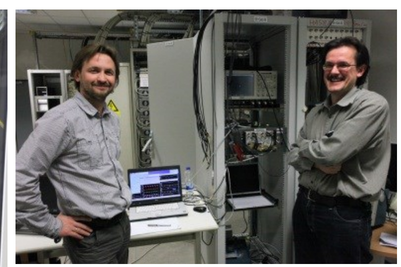
Warm BPMs

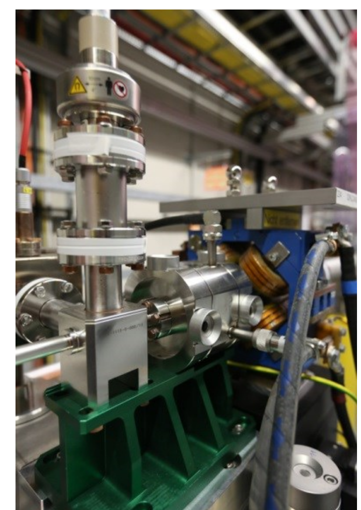






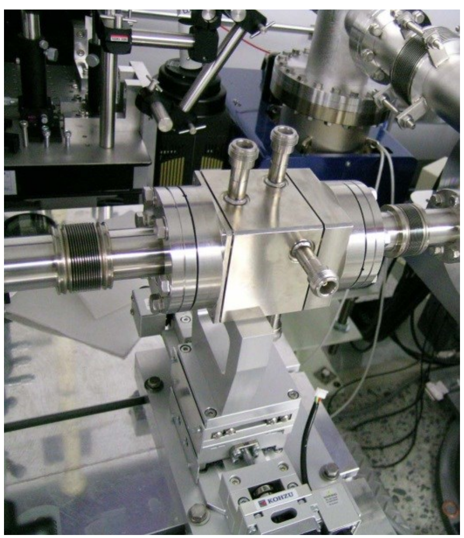
- BPM System on Schedule
  - Prototype tests @ FLASH all types successful
  - All BPMs in house. Series production finished
  - Electronics development has reached and even exceeded specifications.
  - Pre-series of Cavity BPM system (Pickup by DESY and electronics by PSI) and is installed at FLASH II. Operation starts in KW17.



Example Production Process: BPME Cavity BPM for the Undulator Sections

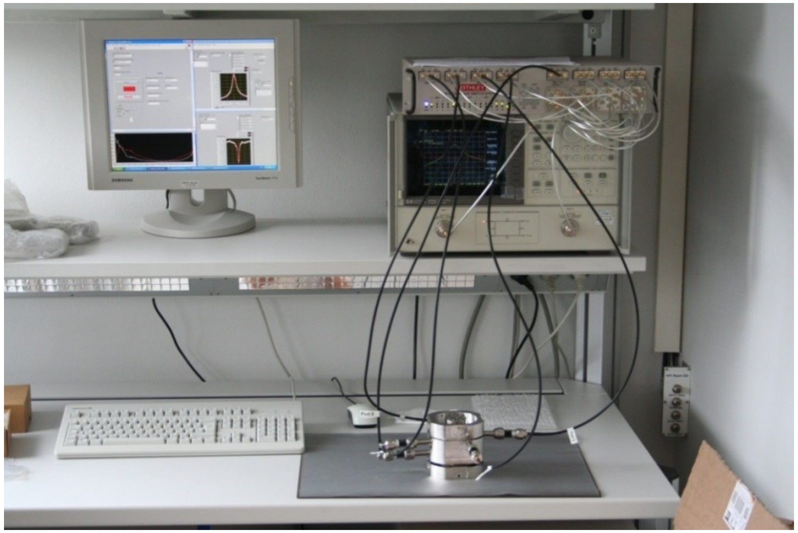
- Goal: robust high performance BPM, suited for mass production.
- No individual tuning foreseen
- Starting point: SACLA design by T. Shintake
- First prototype @ 4.4 GHz
- Design adapted to XFEL frequency 3.3 GHz
  (in Agreement with Electronics Development)
- RF simulation and mechanical design at DESY
- Prototypes in DESY workshop
- Beam tests at FLASH and PSI injector
- Industrialization; Qualify companies (painfull)
- Tender process (European)
- Pre-series 2 x 9 BPMs (perfect quality from two vendors)
- Series production with extensive QA support from DESY
- Finally 140 BPMs in spec.



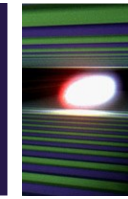
- Similar Procedure for Beamline Cavity BPM
  Series of 30 BPMs finished successfully

Series production of Undulator Cavity BPMs

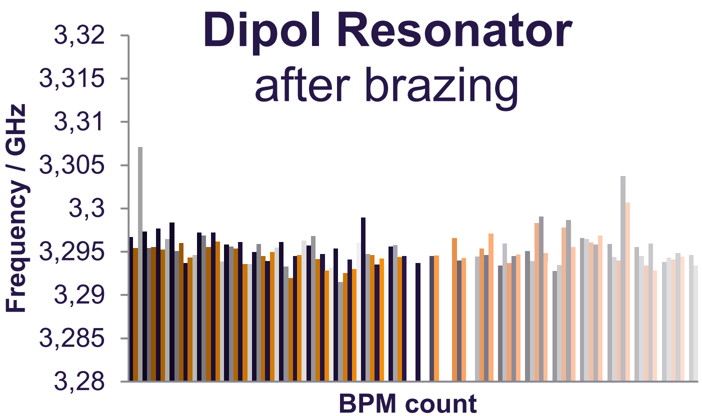
- DESY provided a system to measure RF properties at FMB Berlin observe status of BPM fabrication at each step:
  - before brazing,
  - after brazing and
  - after welding of feedthroughs
- A measurement takes few minutes with additional analysis
- Measurement results send to DESY for revision and to get permission for next step.
- Delivery of BPMs in small lots after final production each, final measurement at DESY for acceptance.
- Additional acceptance Tests; Leak Check, RGA and Particle Cleanliness

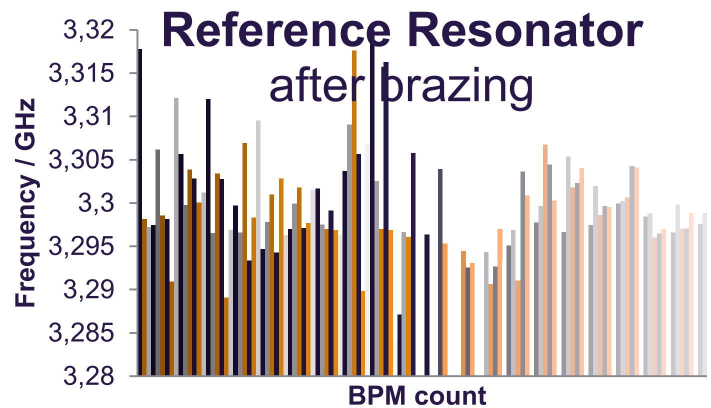


Series production of Undulator Cavity BPMs



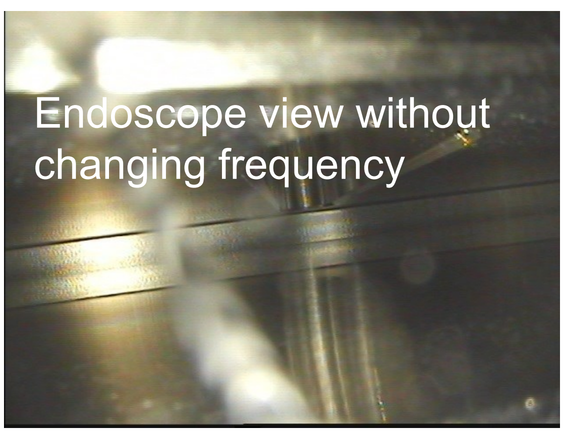
- After some pieces we observed a larger frequency variation at the reference resonator after brazing (still in spec)
- Production stopped, Investigation, Counteraction fixed, Production continued.

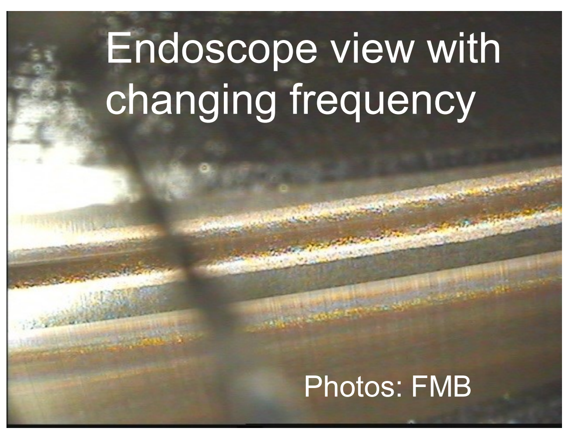




Larger resonance frequency difference before and after brazing is correlated with brazing material getting into the resonator;

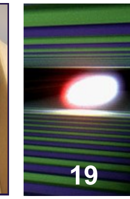
counteraction increase brazing foil inner diameter





Dipole resonator	3295.4 ± 1.6 MHz 69.3 ± 1.1
Reference resonator	3301.3 ± 5.4 MHz 75.5 ± 1.2
Difference of Resonance frequencies	6.4 ± 4.7 MHz

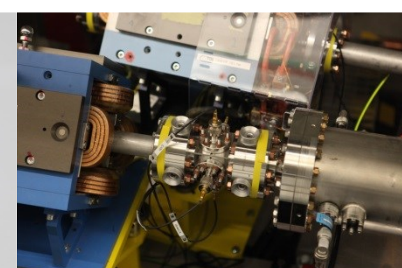
Button BPMs

Except of the Cold BPMs produced by industry, 3 further types are produced in house, using a High Precision Machine (OKUMA)

- BPMA: working horse 40,5 mm beam pipe (220 on stock)
- BPMD: 96 mm beam pipe for Dumps, Switchyards
  25 have been produced
- BPMW: BPM before the dump window (200 mm); all 3 items are available
- All feed-throughs delivered;
  Custom Development together with Industry (VACOM).
- Cleaning and final Assembly in House (ISO5 Cleanroom)



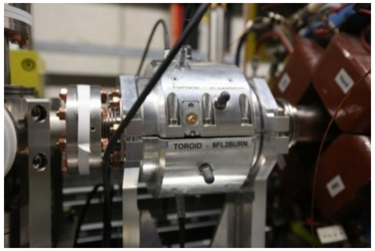
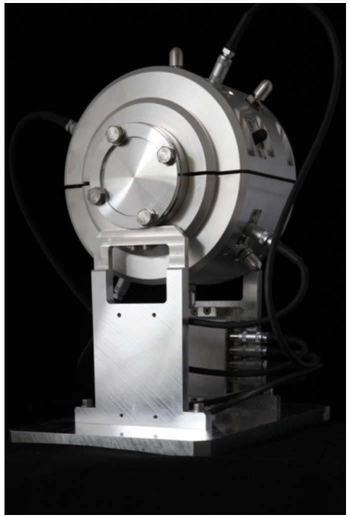
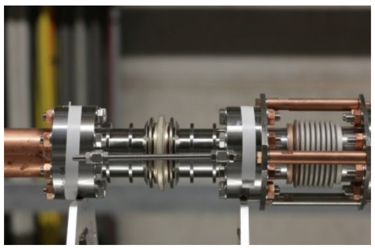


E-XFEL Diagnostics

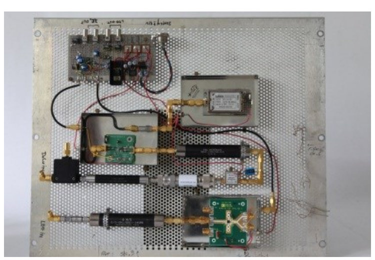
BPM Production at the DESY Workshop

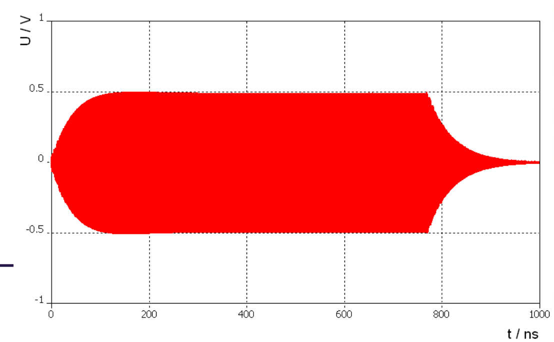
2 h/ BPM in 1.4429

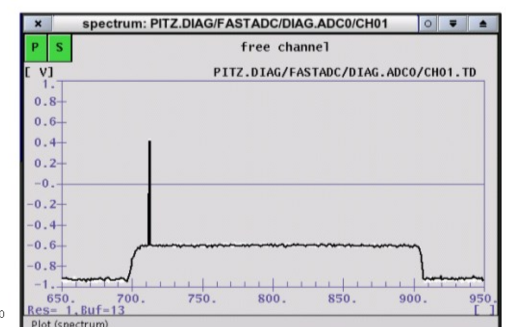
WP-17:Charge Measurements

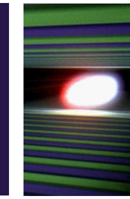
- Current Transformers or Toroids
  - Network of monitors to interlock on transmission and bunch pattern failure
  - Noise < 1 pC
  - Electronics still in development
  - Vacuum hardware and most of the Front-End Electronics ready
  - 4 pickups and prototype front ends installed in FLASH II
- Dark Current Monitor
  - Cavity based
  - Measure dark current and bunches
  - Sensitivity about 10 nC (DC), 100 fC (bunched)







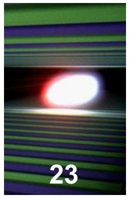
European XFEL

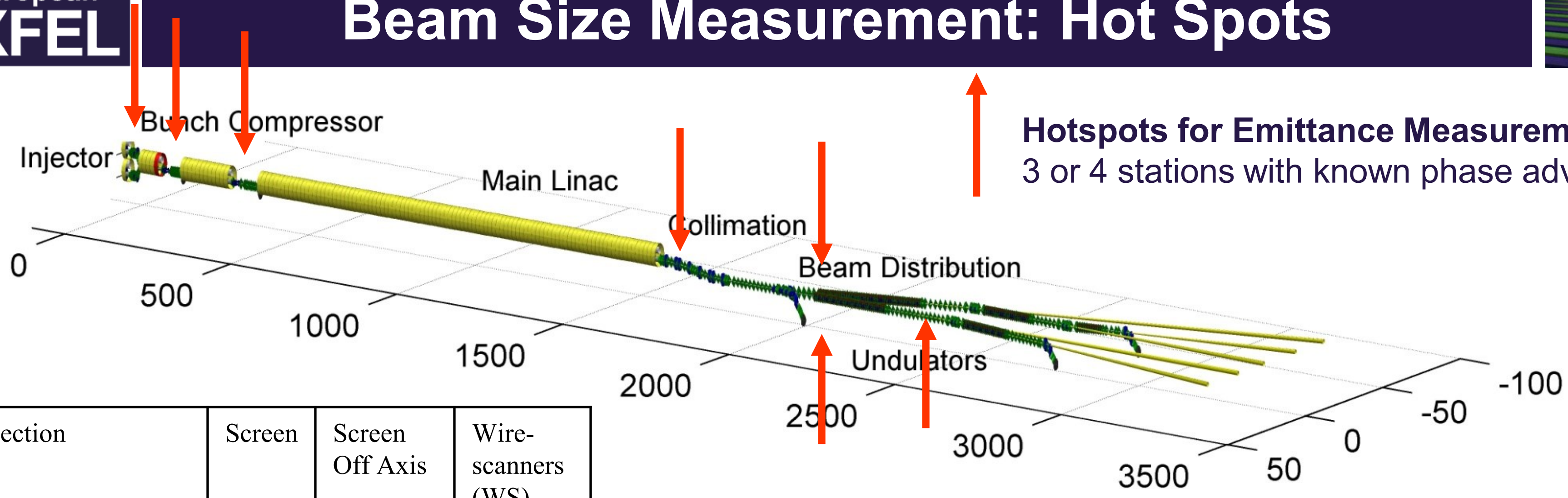


WP-17: Beam Size Measurements

- Screen Stations
  - Scintillator based, Spatial suppression of COTR
  - On Axis, Off axis screen plus calibration target
  - Uses “Scheimpflug´s” Principle to extend depth of field
  - Big chip 4 MP CCD with GigE interface
  - 10 µm resolution, sensitivity sufficient for about 50 pC (single bunch, streaked, shown at FLASH)
  - About 60 stations, 12 with off axis screens
  - Vacuum hardware in house, final assembly started
  - 4 XFEL type stations installed at FLASH II
- Wire Scanners
  - Triggered fast scanner with 1 m/s speed, slow scans also available
  - Separated horizontal and vertical units
  - Full profile within a macro-pulse
  - Vacuum hardware to be delivered house, remaining components ordered
  - Detector development going on

Beam Size Measurement: Hot Spots



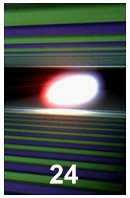


Hotspots for Emittance Measurements
3 or 4 stations with known phase advance

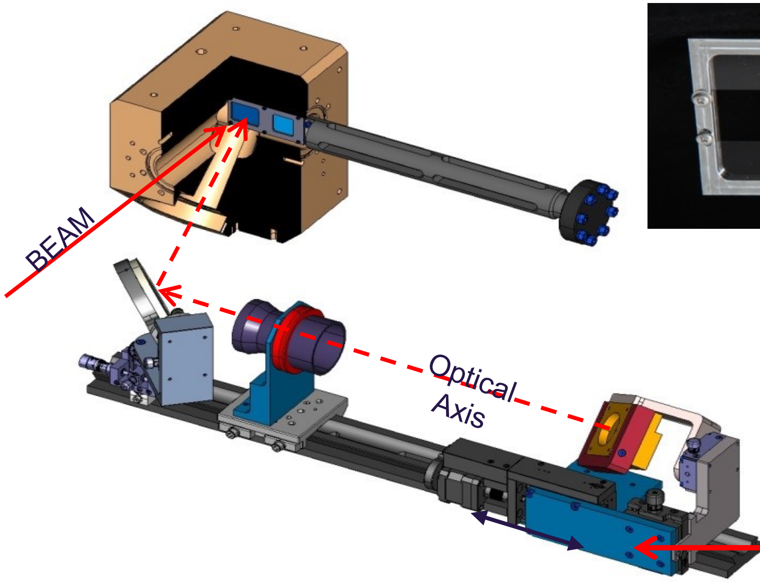
Section	Screen	Screen Off Axis	Wire-scanners (WS)
Injector	5	4	0
BC1	3	4	0
BC2	6	4	0
Collimator	7		3
Beam Distribution	5		
Undulator Lines	11		3 x 3
Chicanes	3		
Dump	6		
Photon	3		
Total	**49**	**12**	**12**

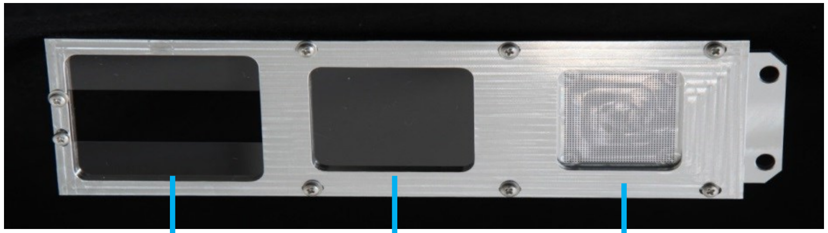
XFEL uses Screens and fast Wire Scanners

- to check and detect beam at critical places
- to match the optics and to measure emittance at
  - Injector (Screen)
  - Bunch Compressor B1 and B2 (Screen)
  - after the LINAC (Screen/WS)
  - before the undulators (Screen/WS)
- to measure slice parameters in combination with a transverse mode structure in
  - Injector
  - Bunch Compressors B1 and B2



XFEL Screens: Optics Design
Record On-Axis **and** Off-Axis Profiles



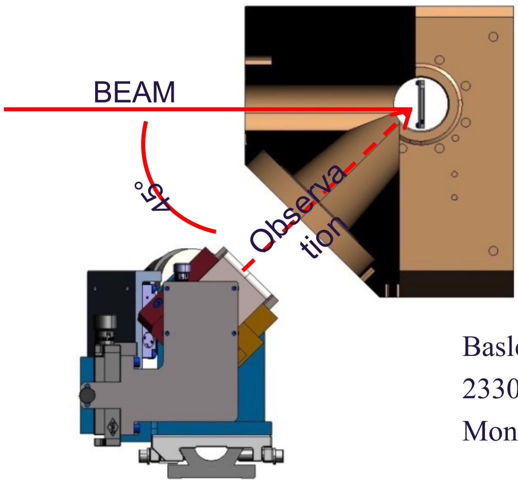


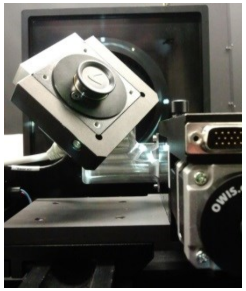
Dot Grid Target(spot Ø .50mm)

200µm thick LYSO Screen (ON-Axis)

2 half 200µm thick LYSO Screens (OFF-Axis)

Camera on a moving stage for focussing.



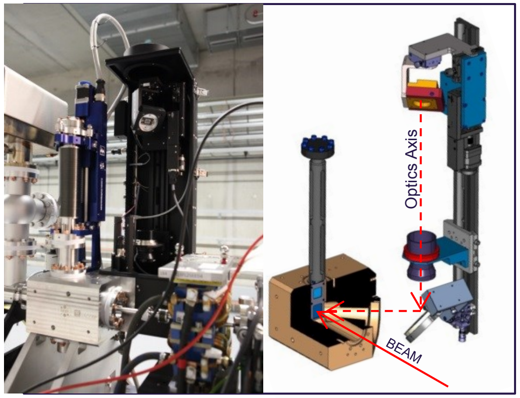


Basler Aviator avA2300-25gm
2330 x 1750 pix, 5.5 µm
Monochrome, GigE

f = 180mm for 1:1

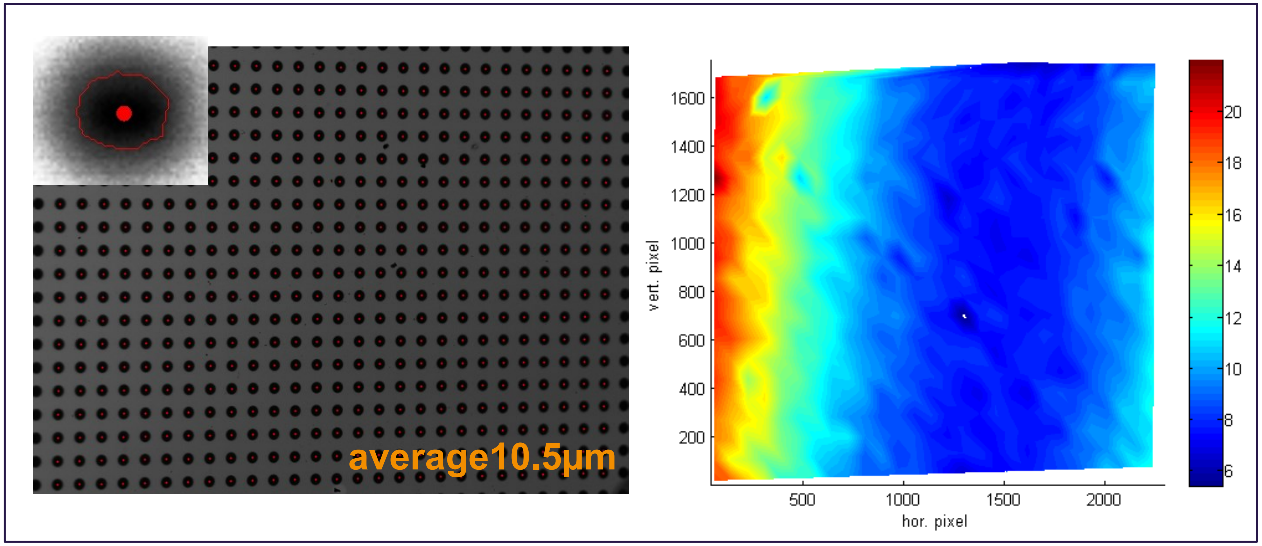
f = 120mm for 1:2

Large Area Photo Macro Lenses
from Schneider Kreuznach

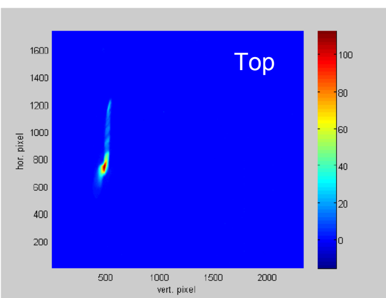


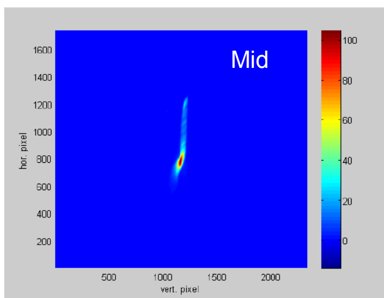
FLASH II Installation

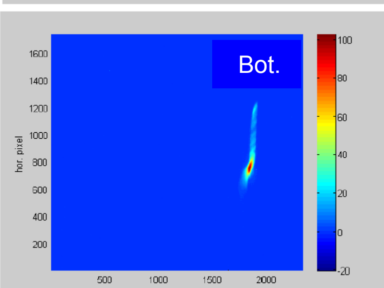
XFEL Screens: Resolution Measurement and System Performance

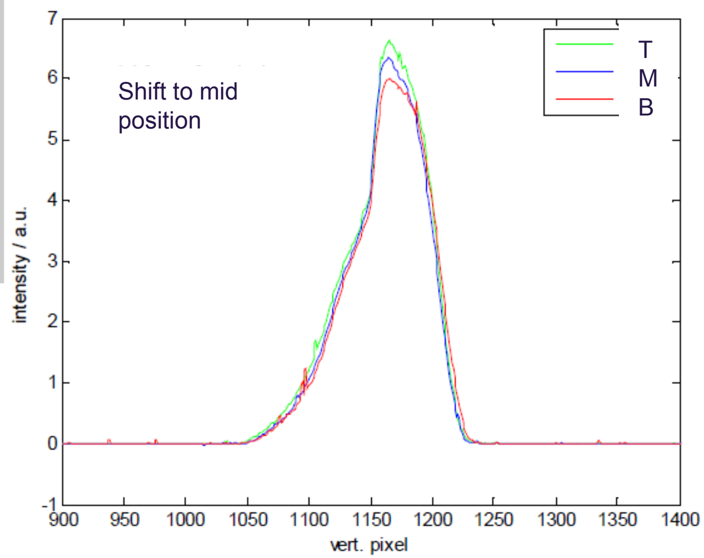


Resolution map of the Optics using the build in calibration target. The “tilt axis” goes from left to right.









Beam spots moved by a dipole along the “tilt axis” to different positions on the screen

Picture on the right shows the overlay of the single pictures.

<u>CCD-Camera:</u>

Gain: 330

t_{exp} = 94556µsec

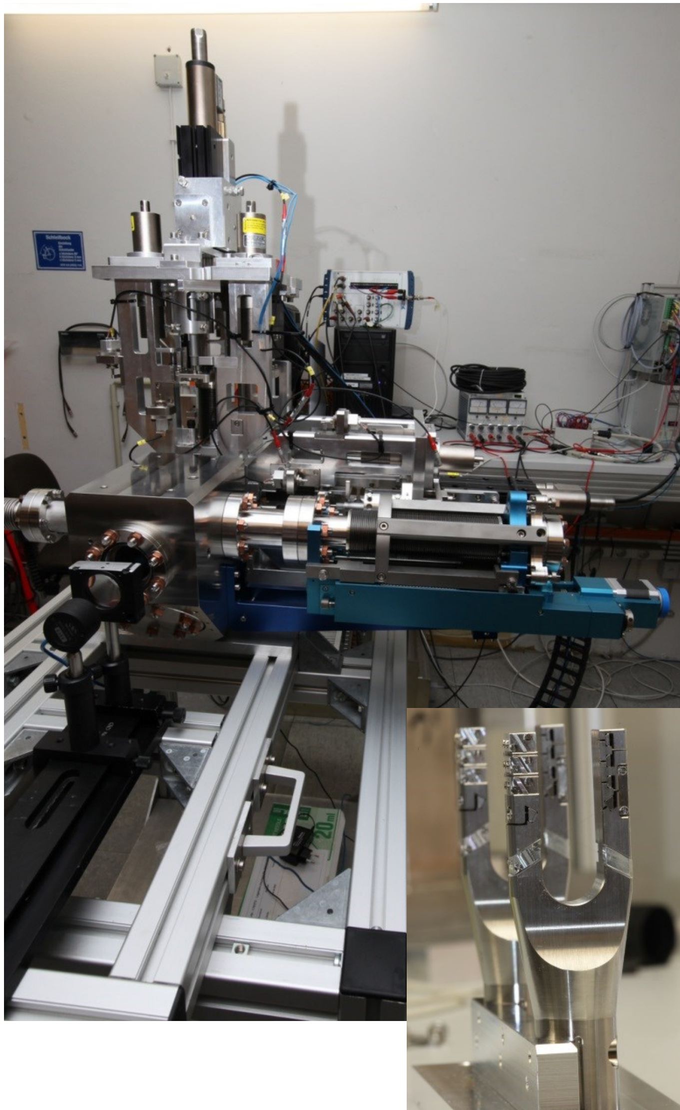
<u>Beam:</u>

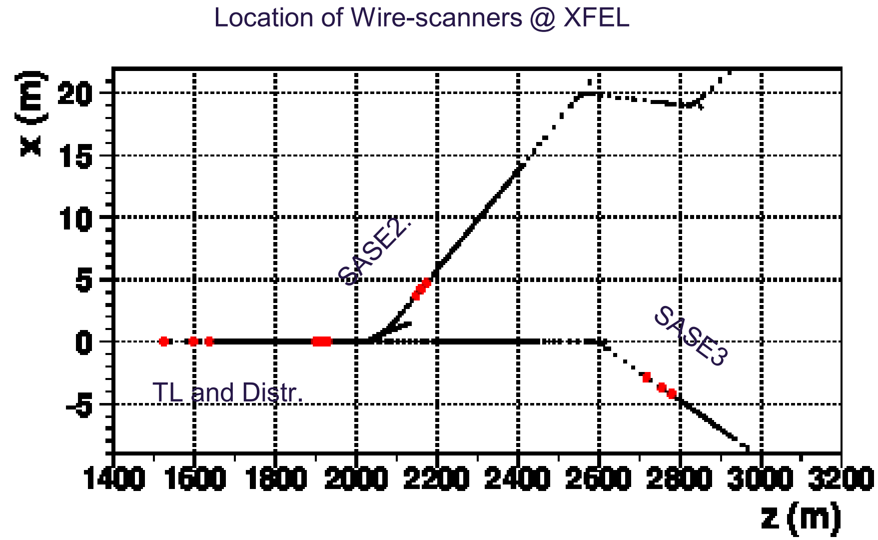
Single-Bunch

Q_b = 500pC

f_{rep} 10Hz

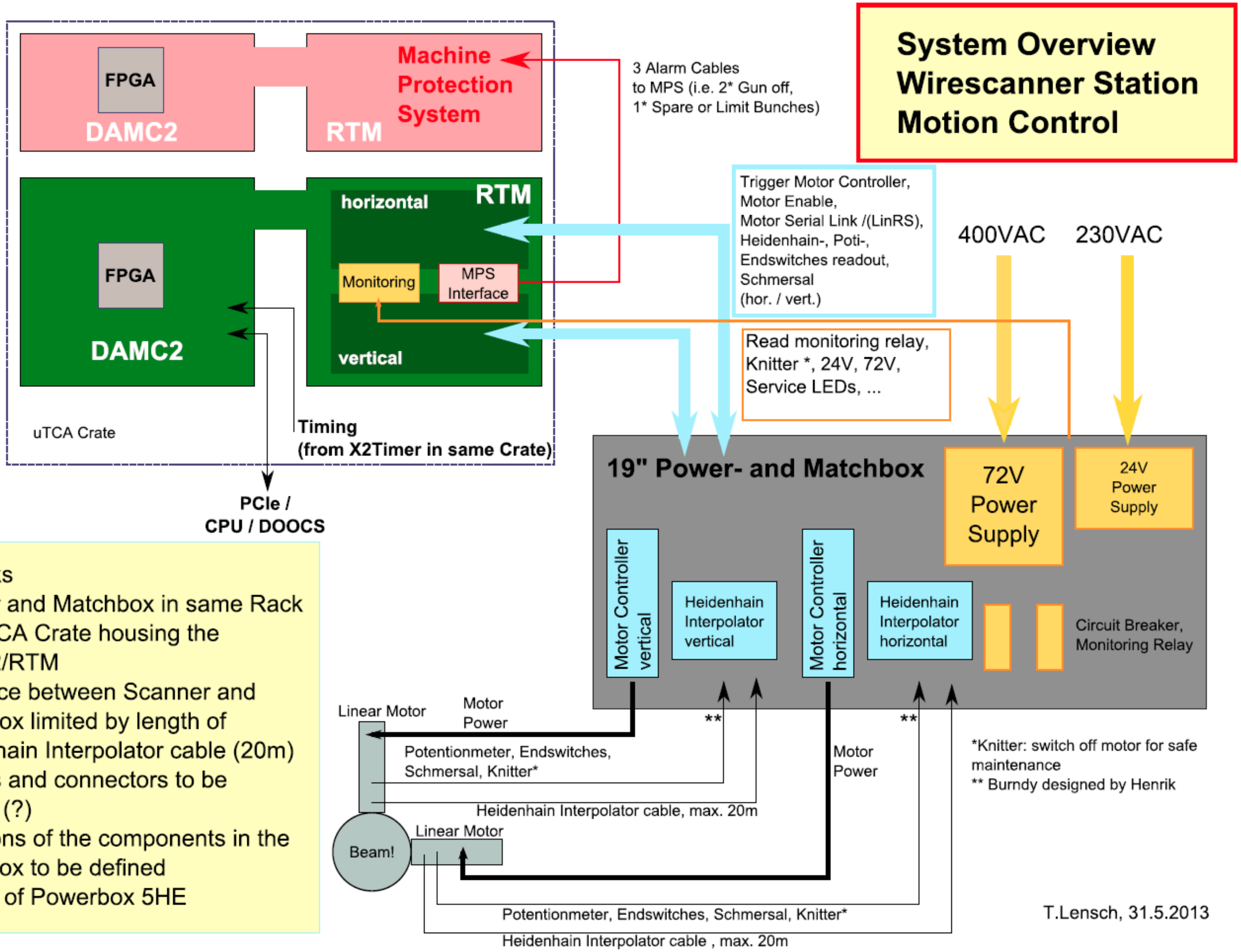
XFEL Wirescanner





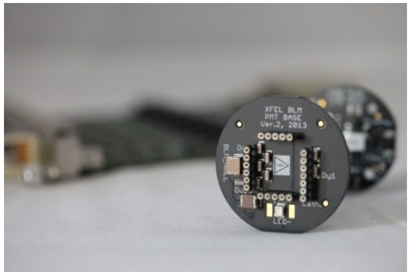
- Slow and fast scans (1 m/s) possible
- Fast Scan on trigger (Jitter < 10 µs) within one bunch train
- Max. 100 bunches/train should hit the wire
- Detector and Scanner weakly coupled (by DAQ)
- BLM suited as additional detectors
- WS planned before collimator and before each undulator
- Vacuum ports foreseen also in the BC´s (COTR)
- Mechanics ordered; ready Q1/2014

Wirescanner: Block Circuit

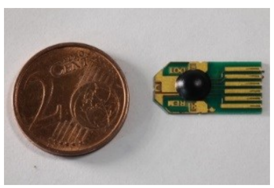


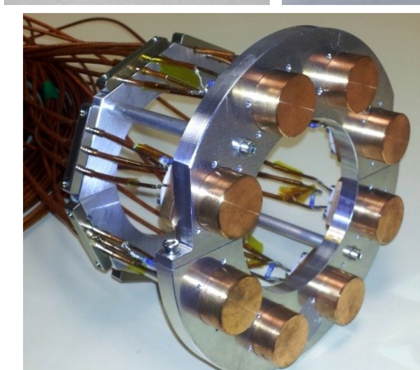
Remarks
- Power and Matchbox in same Rack with uTCA Crate housing the DAMC2/RTM
- distance between Scanner and Powerbox limited by length of Heidenhain Interpolator cable (20m)
- cables and connectors to be defined (?)
- positions of the components in the Powerbox to be defined
- height of Powerbox 5HE

WP-17: Loss and Dose Measurements



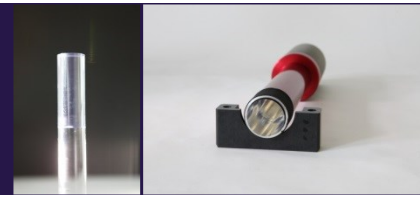


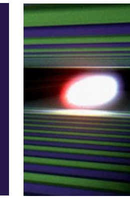



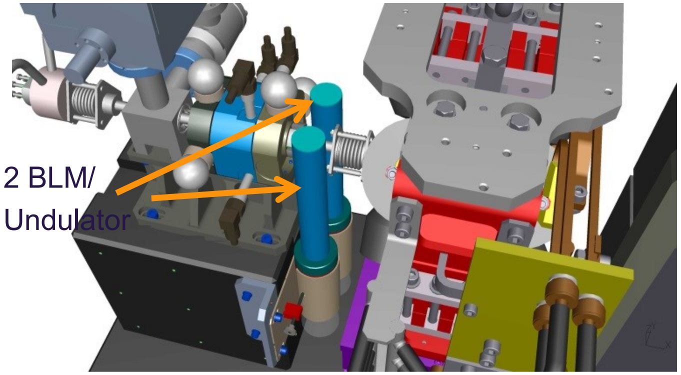
- BLM: Beam Loss Monitors
  - Based on Scintillators and Photomultipliers
  - µTCA based with low latency MPS interface
  - Scintillators & Mechanics: Production finished at IHEP
  - Pre-series being installed at FLASH II
- BHM: Beam Halo Monitors
  - Diamond and Sapphire crystals used as „ionization chambers“
  - µTCA readout similar to BLMs
  - Serious problem to get good diamond detectors.
  - System for the injector ready for installation
- Dosimetry:
  - Gamma and Neutron sensors
  - FMC board integrated on MPS board
  - Distributed system in electronics racks
  - Bus system with external sensors for undulators
  - Final prototyping phase

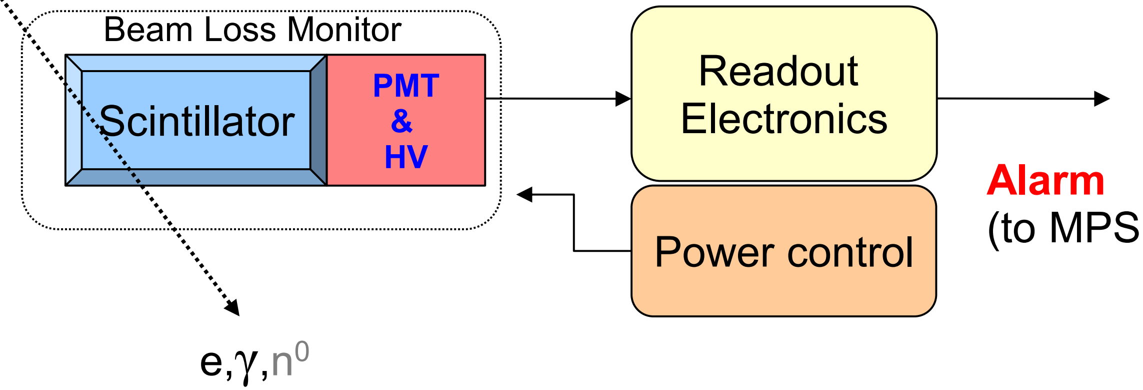
E-XFEL Diagnostics

Beam Loss Monitor System for XFEL

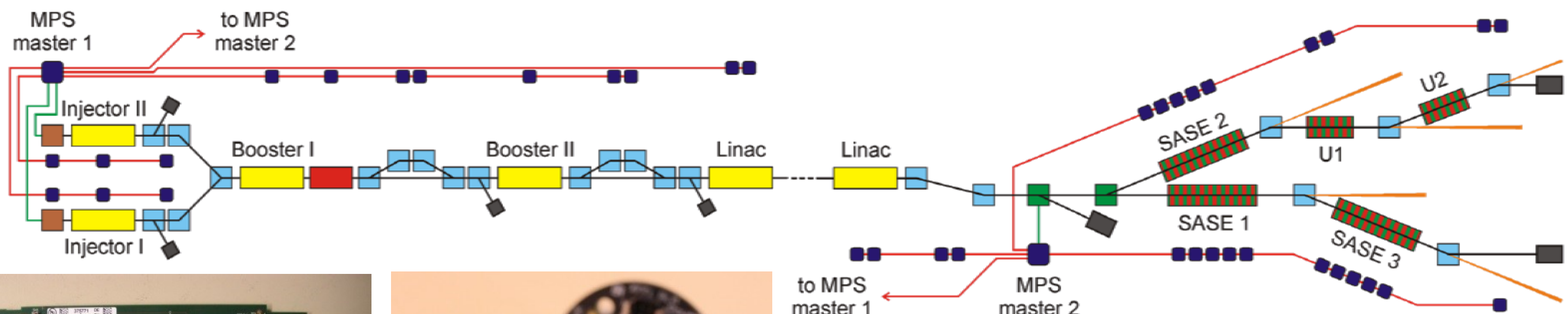


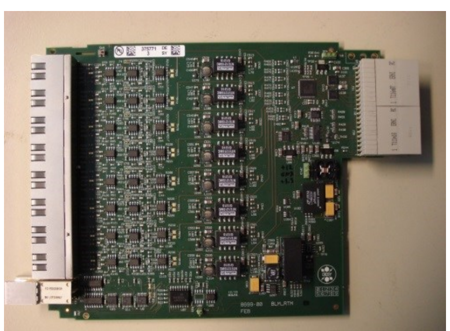


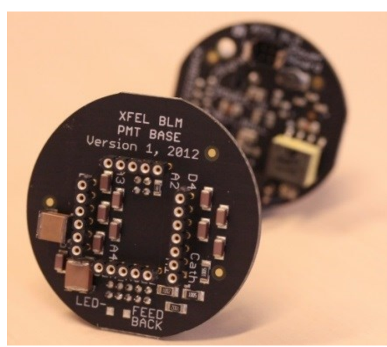




~300 Beam Loss Monitors
(More than half – in undulator area)



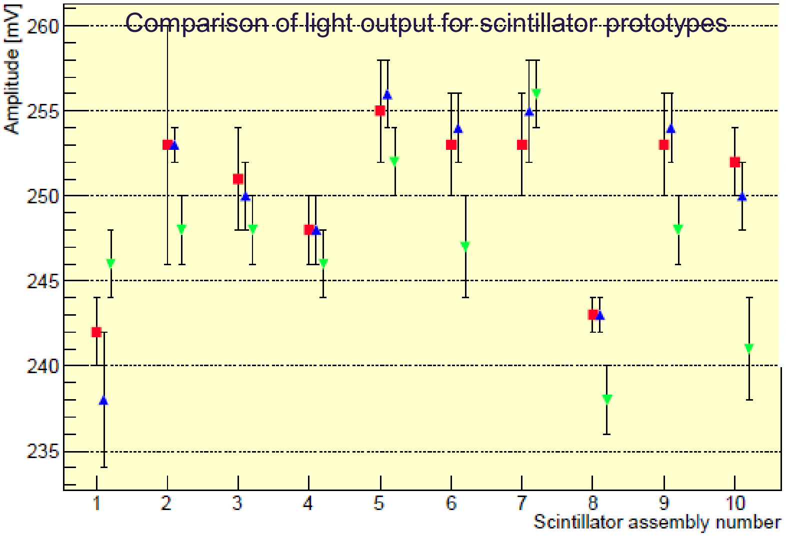




DAMC02 with custom RTM

- **Comparator, ADC, Alarm Generator**
- **Test Pulse Driver**
- **Supply for Cockcroft Walton Generator**
- **Prototypes in test**
- **Pre-series for FLASH II in Production**

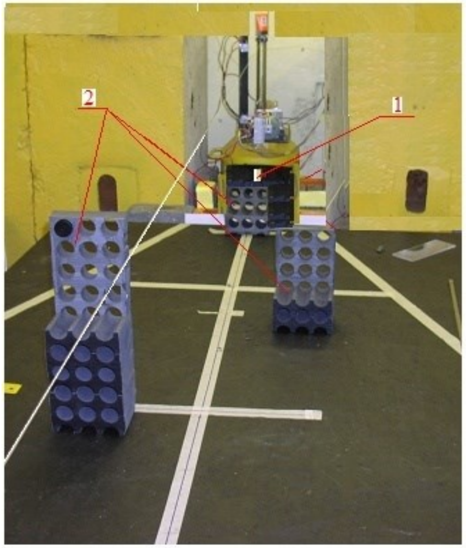
BLMS: Production of Housings and Scintillators @ IHEP Protvino

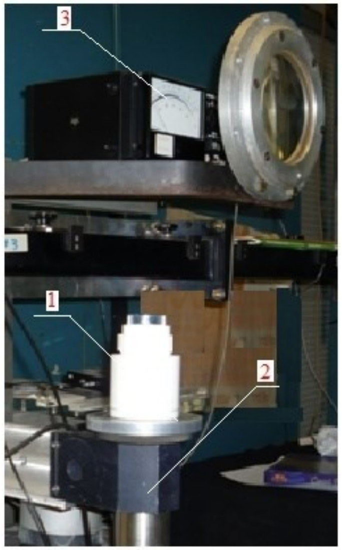


Test unit for scintillator test. The black cap houses beta source (Sr^{90})

scintillator

QA of mechanics after delivery





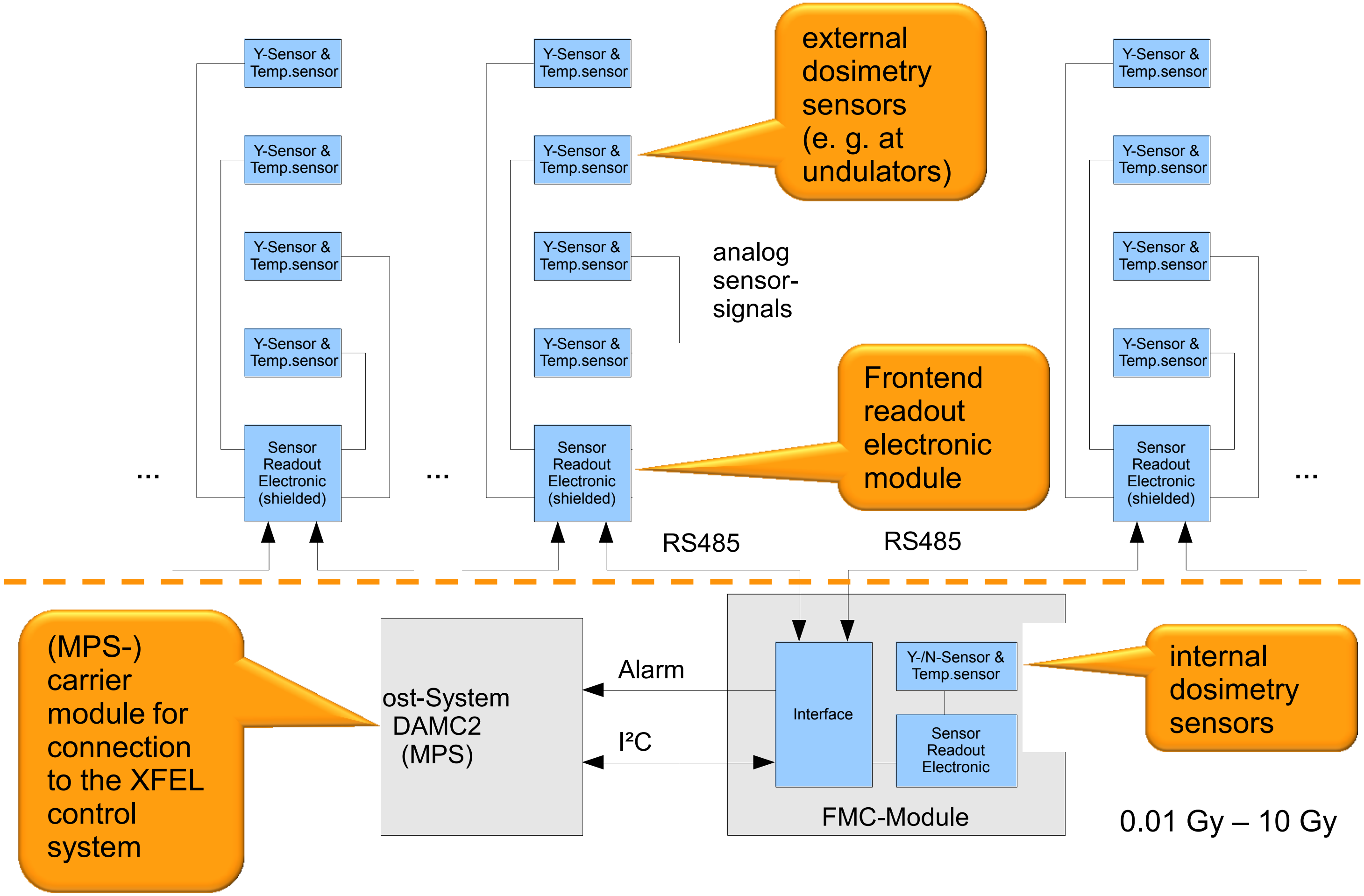
Picture from the irradiation facility at IHEP; Radiation Damage Tests

European XFEL

The radiation monitoring system

External Sensors 0.1 Gy – 2 kGy; up to 10 kGy => reduced resolution

Scalable frontend :
- # of channels
- # of readout modules
- cabling



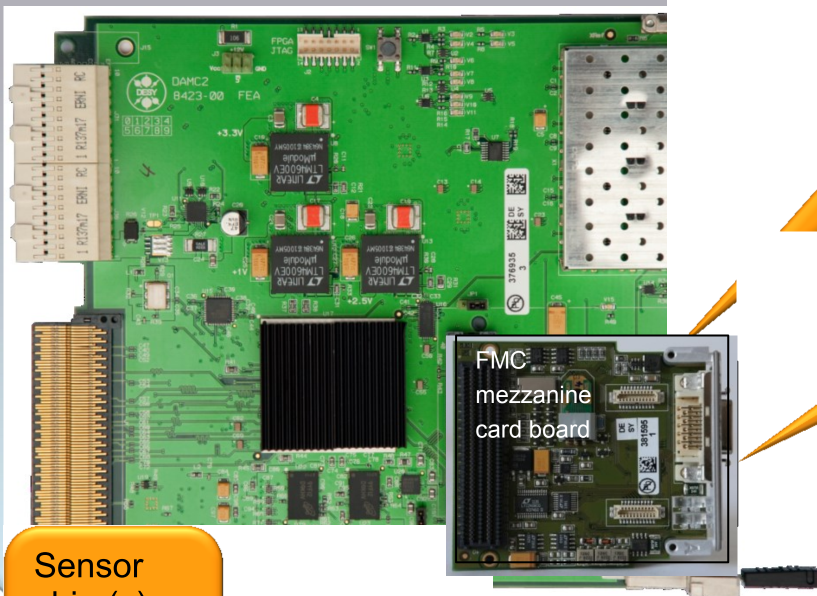
External (outside of electronic rack)

Internal (inside electronic rack)

Total: 540 external sensors + 330 internal sensors

Realization – system components & setup

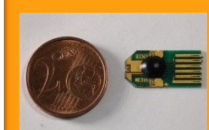
DESY AMC2 (µTCA) FMC Carrier in BPM MBU

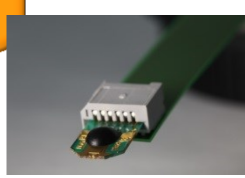


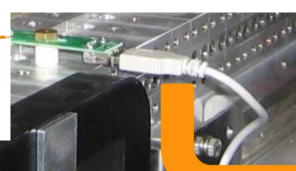
Dosimetry mezzanine card (FMC) on AMC motherboard for the Machine-Protection-System (MPS) carries dosimetry for measurements inside shielded electronic racks

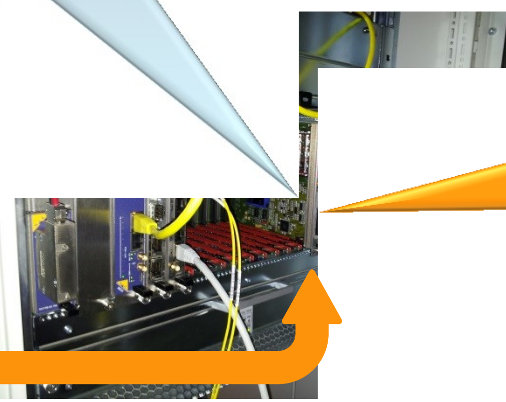
Frontpanel interface allows connection of external dosimetry sensors (DAMC02 only)

Sensor chip (γ)









Frontpanel interface of AMC board conducts undulator dosimetry signals

Undulators get milled notches to House RadFet sensors.

Other small Systems and special Items

- Focus of the talk was on items produced in bigger numbers
- Nothing reported on
  - Special OTR stations for the BC and dumps
    - → (start production of vacuum vessels soon)
  - Mechanics Contributions for WP-18
    - → E-BPM (start production of vacuum vessels soon)
    - → and BAM mechanics (ready)
  - Beam Halo Monitors
    - → Diamond Detectors used as ionization chambers using adapted BLM electronics
      - Serious problems to get the diamonds with required quality (electric strength worse than previously delivered sensors)
  - Gun diagnostics (clone of recent PITZ/FLASH design)
  - HOM based BPM Phase Monitor development for 1.3 GHz and 3.9 GHz systems

The End

Thanks to all colleagues contributing to the work presented here:

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