Status of the MicroTCA-based Accelerator Control Systems at the European XFEL and FLASH

… and some more projects

Tim Wilksen, DESY

8th MicroTCA Workshop

Hamburg, 04.12.2019

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Outline

MicroTCA-based Accelerator Control Systems at DESY

01 EuXFEL
- XFEL Accelerator

02 FLASH
- FLASH1 and FLASH2
- FLASHForward
- FLASH 2020+

03 Projects
- SINBAD-ARES
- REGAE
- LUX (ANGUS)
- KALDERA
- PETRA IV

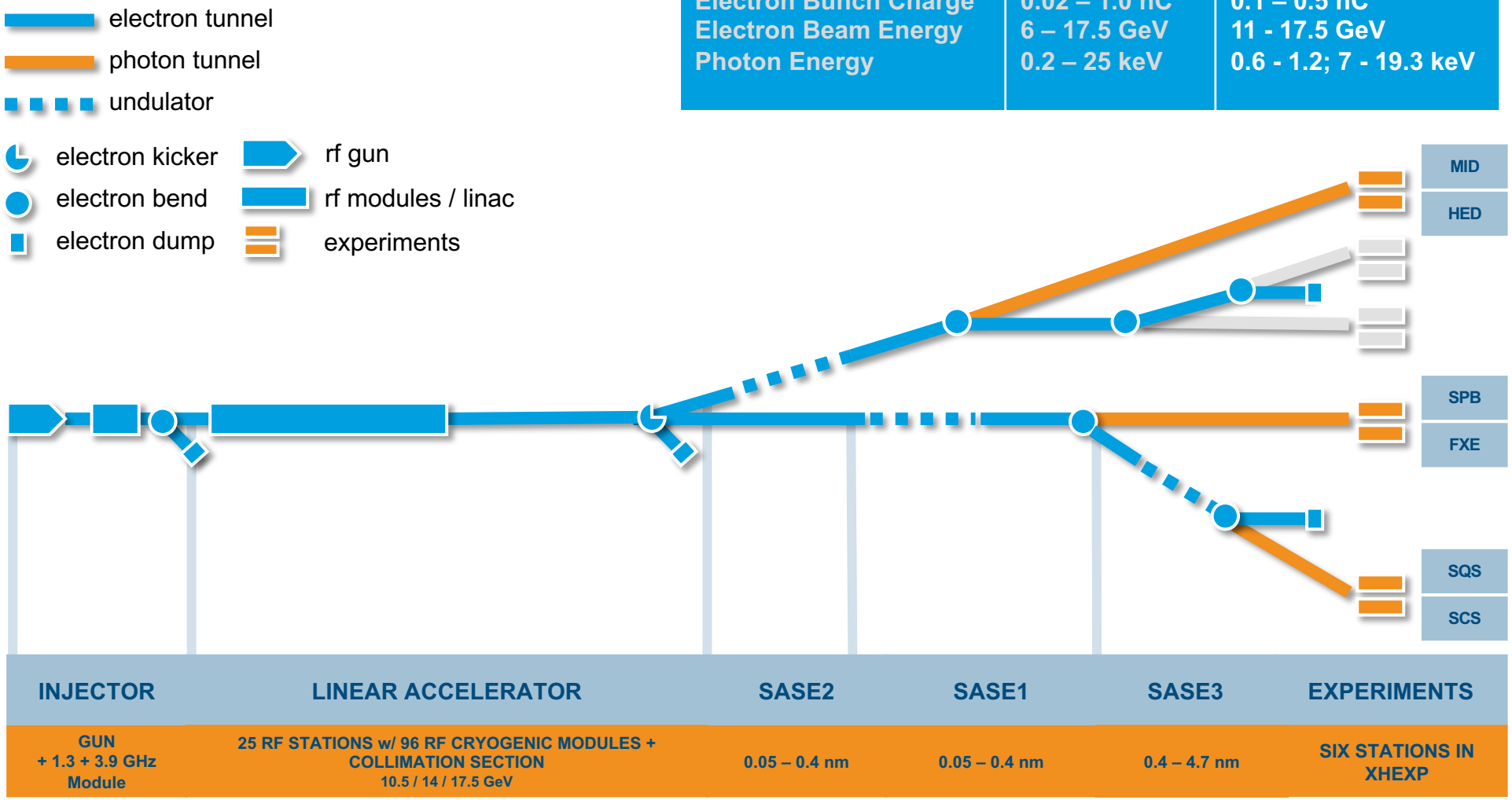
04 Summary

EuXFEL

The European XFEL

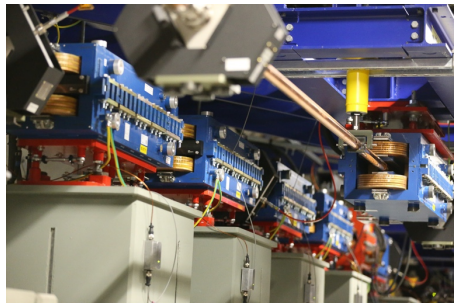
Accelerator Layout

Parameters	Design	Achieved
Pulse Repetition Rate	1 - 10 Hz	10 Hz
Bunch Repetition Rate	0.5 - 4.5 MHz	4.5 MHz
RF Pulse (Flat Top)	650 µs	650 µs
Electron Bunches	27000 / s	27000 / s @ XTL
Photon Pulses	27000 / s	5000 / s
Electron Bunch Charge	0.02 – 1.0 nC	0.1 – 0.5 nC
Electron Beam Energy	6 – 17.5 GeV	11 - 17.5 GeV
Photon Energy	0.2 – 25 keV	0.6 - 1.2; 7 - 19.3 keV

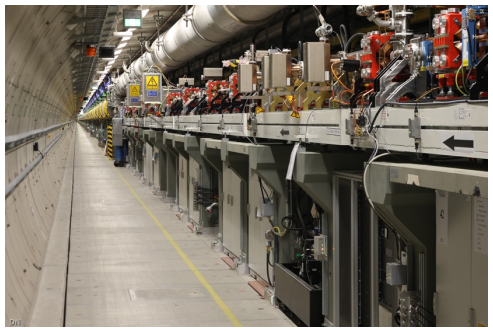


EuXFEL Accelerator Control System

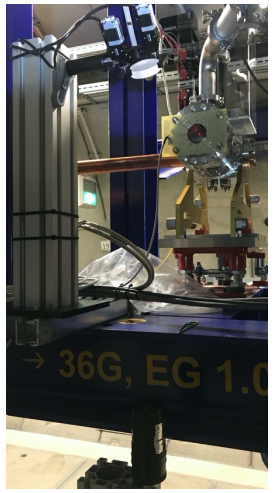
Huge number of diagnostics and diversity in components

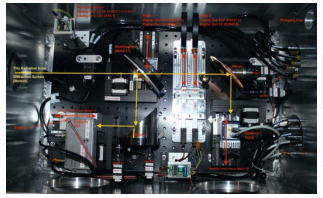


Environment Components	Count
Rack Status Monitor	244
Network Switches (XACC)	53



Beamline Components	Count
Magnets	1519
Vacuum (pumps, valves, shutter)	~1000
Cryogenic RF modules	96
Undulator	1 + 90



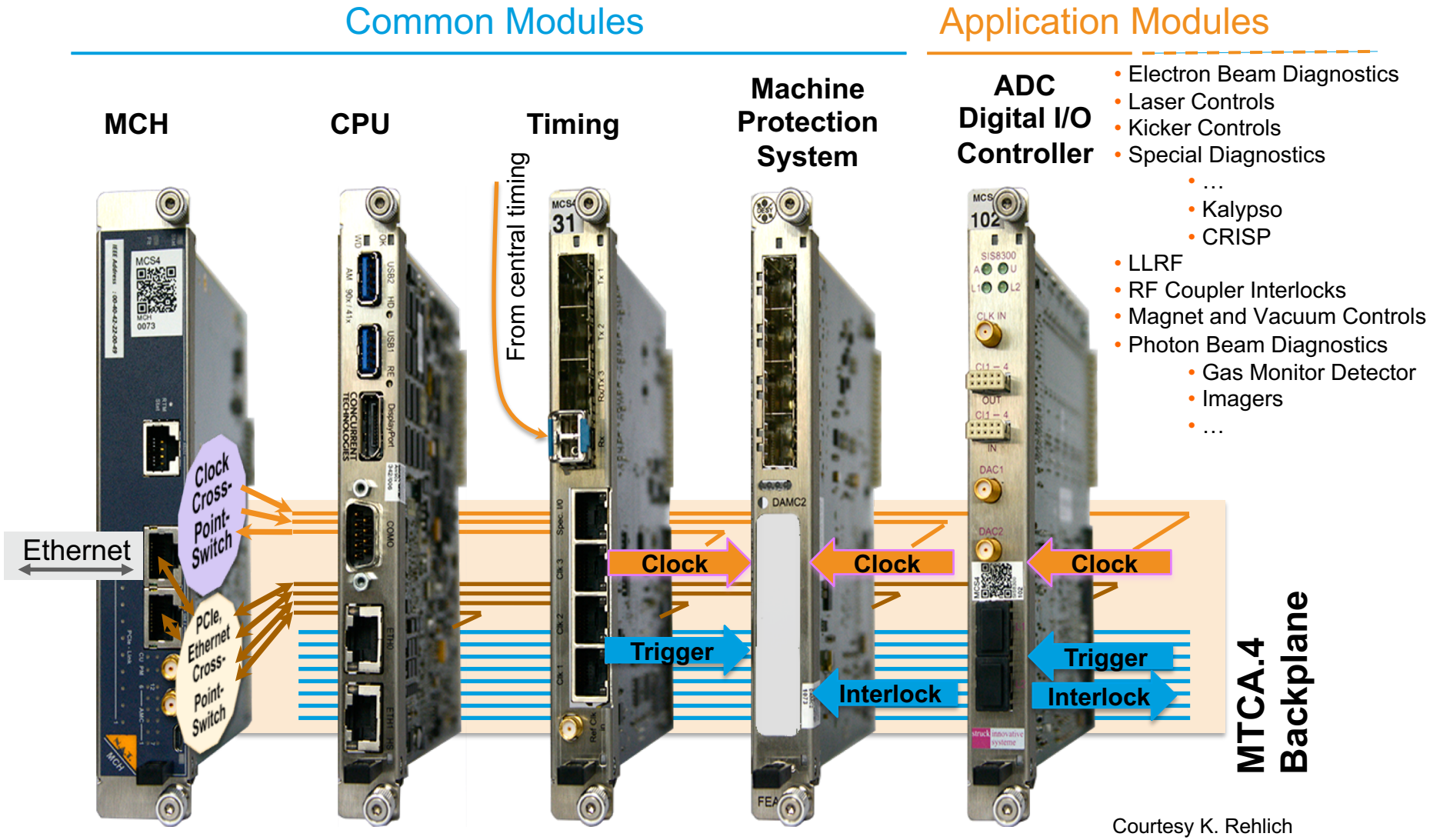


Diagnostic Components	Count
Charge Monitor	36
Beam Position Monitor	452
Beam Loss Monitor	472
Dark Current Monitor	8
Wire Scanner	14
Screens	80
Bunch Compression Monitor	4
Beam Halo Monitor	32
Collimator	7
Bunch Arrival Time Monitor	7

- More than 10 million addressable DOOCS control system parameters visible in accelerator namespace
- About 700.000 local DOOCS archives plus TINE central archive
- More than 20.000 DOOCS channels from MicroTCA front-ends are sent to the DAQ producing data of up to 30 TB/day

MicroTCA Common Module Set

Standard set of MicroTCA modules used in the European XFEL accelerator control system



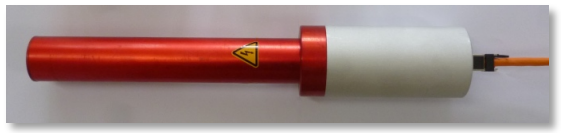
Courtesy K. Rehlich

MicroTCA Applications – Example 1

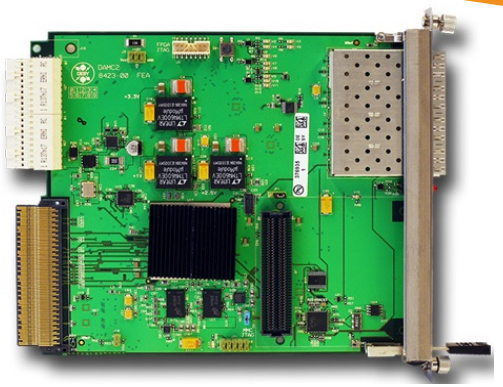
Beam Diagnostics – Beam Loss Monitor System

MTCA.4 based button and strip-line BPM electronics at DESY
Hans-Thomas Duhme (M, DESY)

Courtesy T. Wamsat, MDI

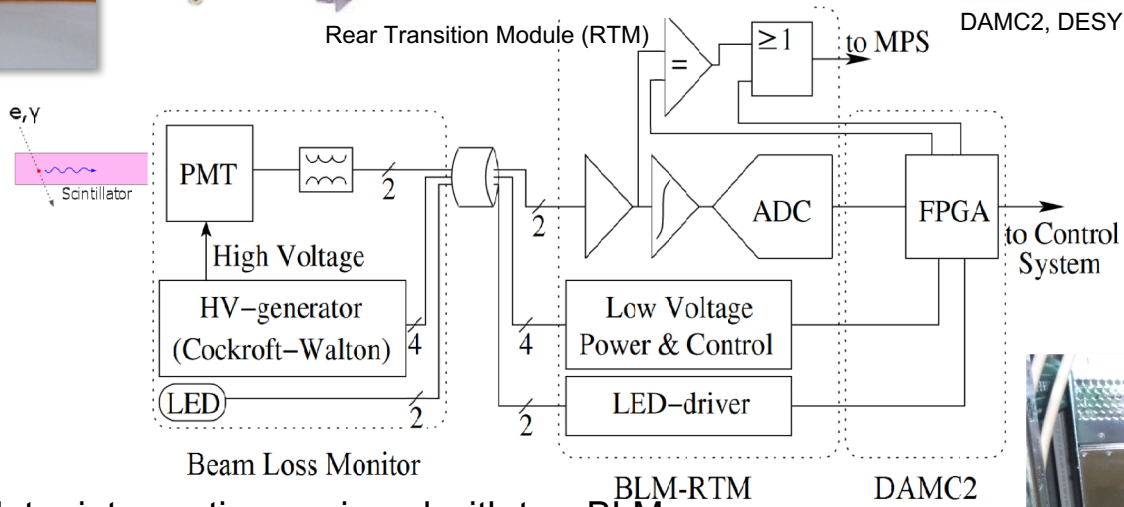


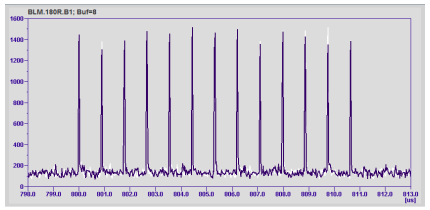
Rear Transition Module (RTM)



DAMC2, DESY Advanced Mezzanine Card

- Plastic scintillators
- HV: 0V – 900V
- 8 channels/RTM
- ADC: 14 bit @ 45MHz
- RJ-45 connectors
- Bunch by bunch resolution





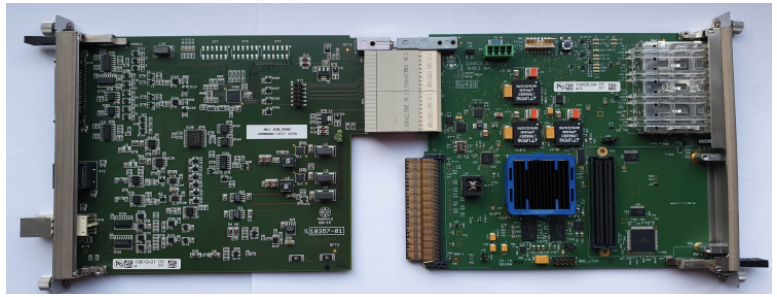
13 bunches @ 1.13MHz rep. rate

- Most BLMs in undulator area, each undulator intersection equipped with two BLMs
- A total of 472 BLMs are installed
- Cable-connected to 78 RTMs in 58 µTCA crates located in the tunnel
- All BLMs connected to the Machine Protection System (MPS)
  - Stops beam production at the photoinjector gun

µTCA crate

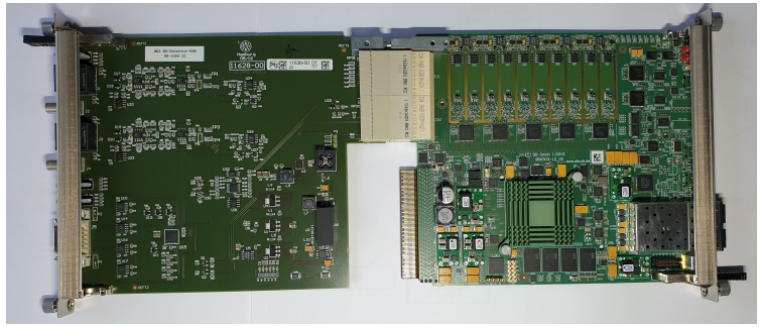
MicroTCA Applications – Example 2

Beam Diagnostics – Wire Scanner



Wire Scanner Motion Control RTM connected to DAMC2:

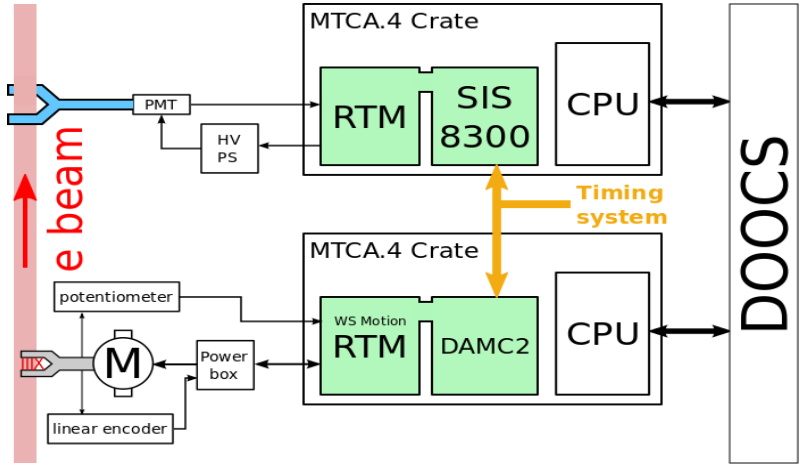
- Controls one WS unit (hor. + ver. plane)
- Read position from Heidenhain incremental encoder
- Control Linmot Motorcontroller
- Precise trigger from Timing System to start fast scan

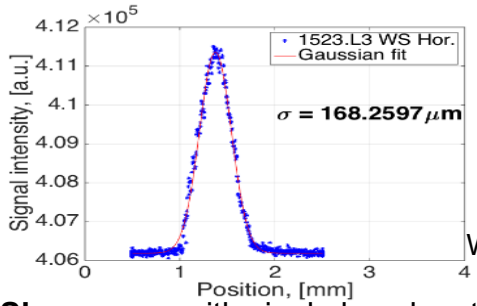


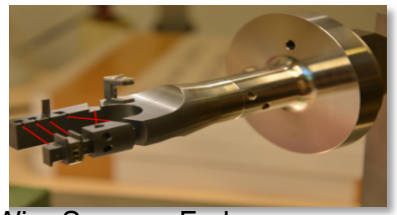
Wire Scanner Detector RTM connected to SIS8300-L2D:

- Readout of two Photomultipliers dedicated to WS
- Controls external high voltage power supply (iseg)

RTM developed at DESY/MDI

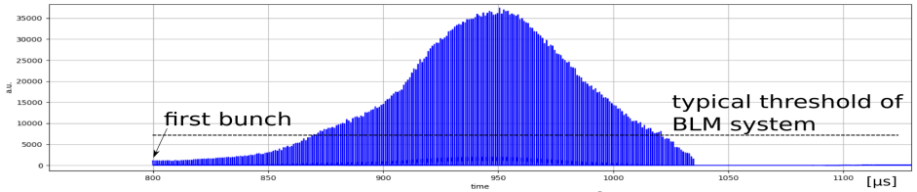






Wire Scanner Fork

Slow scans with single bunches to measure beam halo distribution or beam optics matching



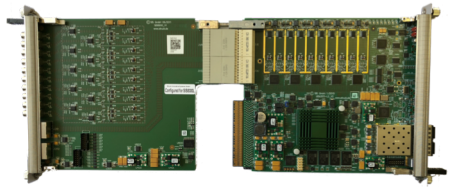
Fast scans allow to measure beam profiles in a non-destructive manner during user operation with long bunch trains; scan within one bunch train

Courtesy
T. Lensch, MDI

EuXFEL Status 2019

Statistics on MicroTCA components @ EuXFEL

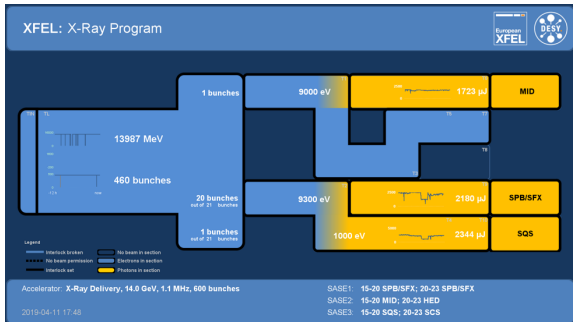
- More than **30 different kinds of MicroTCA-based software applications** are in use
- Redundant server infrastructure for essential services
  - Almost **300 MicroTCA systems** online as of November 2019
  - More than **4200 MicroTCA modules** (AMC, RTM, P/S, MCH,…) installed at XFEL e.g.
  - Timing System: ~ **420** modules
  - DAMC2 AMC: ~ **560** modules
  - DAMC-TCK,-FMC: ~ **110** modules
  - SIS ADC AMC and RTM: ~ **500** modules
  - AMC-CAN: ~ **45** modules
  - Many RTM solutions for diagnostics (BLM), MPS, TIL, …
- Still growing number of MicroTCA components to be installed but rate slows down
- Basic management done via DOOCS IPMI and watchdog server – almost 300 IPMI server and 300 watchdogs online



Experiences

Some experiences with MicroTCA components at the accelerator control system

Overview and experience related to MicroTCA applications at the European XFEL Experiments
Bruno Fernandes (European XFEL)



- Core systems are running since end of 2013 and injector since 2015
- **Successful machine operations in production mode since 2017**
- Issues w/ MTCA hardware are becoming less and less:
  - DAMC2 – overcurrent issue: bad batch of capacitors - replacement with fixed ones done for faulty ones
  - MCH – P/S communication issues – rare and various signatures – very hard to reproduce in lab test
  - MCH – P/S not starting up after power glitch – Analysis by MSK revealed firmware issue of P/S – Fixed and deployed
  - MCH firmware – some smaller issues resolved but not completely rolled out
- Various other issues likely related to beam operations are becoming more prominent now
  - Radiation-induced failures (SEU on SSD, possibly FPGA) mostly in LINAC areas
  - However redundant SSD – RAID – saves downtime
  - Some FPGA black outs and/or memory corruption
  - More investigations and analysis are ongoing – see also

Insight on failures of MTCA systems installed in FLASH and EuXFEL tunnels
Julien Branlard , Christian Schmidt (M, DESY)

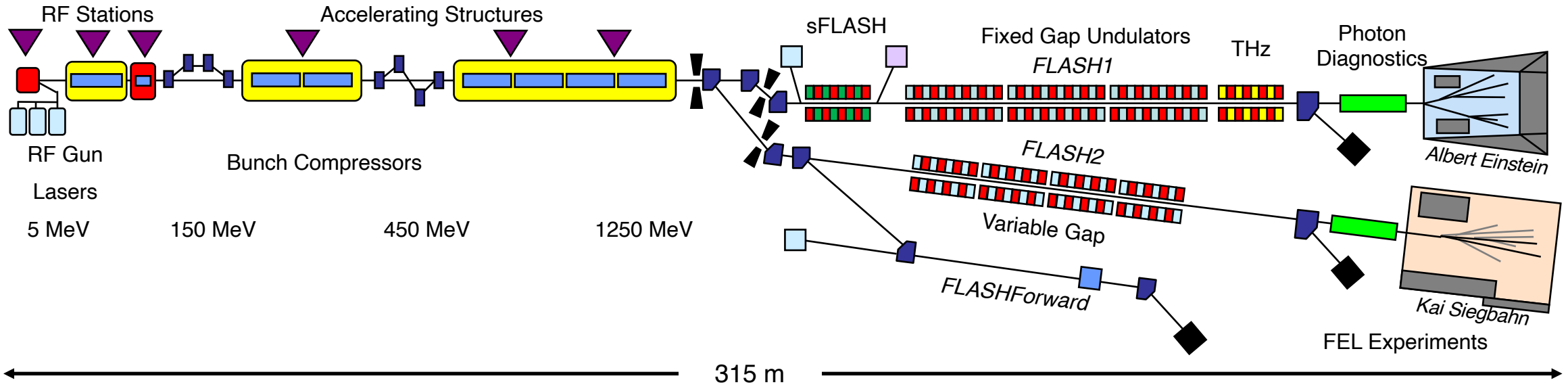
- **Remote management** of crates and modules through IPMI pays off now during standard operations – enables fault resolution and saves downtime of machine operations

FLASH

FLASH MicroTCA-based Accelerator Controls

Accelerator Layout

The FLASH accelerator control system was the first production system at DESY using MicroTCA technology at DESY after serving as "test-bed"!



Parameters	
Pulse Repetition Rate	10 Hz
Bunch Repetition Rate	1 MHz (3 MHz@5 Hz)
RF Pulse (Flat Top)	500 - 800 µs
Electron Bunches	10 - 5000 / s
Electron Bunch Charge	0.2 – 1 nC
Electron Beam Energy	0.35 – 1250 MeV
Photon Wavelength	4.2 - 51; 4 – 90 nm

FLASHForward:

Future-**OR**iented **W**akefield **A**ccelerator **R**esearch and **D**evelopment

- Electron beam-driven plasma-wakefield experiment
- Accelerate external injected bunches in a PWFA up to > 1.5 GeV
- Parallel operation with FLASH1 + 2 hence shared control system and technology! Uses MicroTCA-based solutions, too.

FLASH Status 2019

Statistics on MicroTCA components @ FLASH

- More than **30 different kinds of MicroTCA-based software applications** are in use – FLASHForward with specialized ones
- Redundant server infrastructure for essential services
  - Almost **65** MicroTCA systems online as of November 2019
  - About **1000** MicroTCA modules (AMC, RTM, P/S, MCH,…) installed at FLASH
  - Timing System: ~ **72** modules
  - DAMC2 AMC: ~ **53** modules
  - DAMC-TCK,-FMC: ~ **41** modules
  - SIS ADC AMC and RTM: ~ **183** modules
  - RTM solutions for diagnostics (BLM), MPS, TIL, …
- Migration from VME technology and FLASH 2020+ upgrade proposal (see next slide)
- Basic management done via DOOCS IPMI and watchdog server – almost 70 IPMI server and 100 watchdogs online

FLASHForward

flashfwdcpudiag1 (28m.OG1.001 Rack 1):
- timing (FFWD)
- **Laserlock** (synchronisation)
- ADC (Laserlock monitoring)
- constant server
- **Pico server** (Server für Pico/Piezo Motore innerhalb FFWD)
- IOTA server (Auslesen des Gas-Pulvers im Bond Lab)
- Hexapod Monitor
- State machine (laser amplitude automation controls)
- **Allnet 4064** (remote 230V power outlets)
- **Camera server** with DAQ sender
- **Beamposition**
- **SNMP** (Control of Netgear PoE Switche)
- **Fred** (Fuse Relais Temperature monitoring)

flashfwdcpudiag2 (28m.OG1.001 Rack 1):
- timing (FFWD cameras und HV Pulser von MIN)
- ADC (Laser diode signals, stretcher, HV pulser current)
- SNMP (Control of Netgear PoE Switche)
- Camera Server (für viele Kameras) with DAQ sender
- Pico server (for Pico/Piezo motor controls)
- **Kicker monitoring and controls**
- **Shutter** (Controls for laser shutter in Laser-Lab)
- **Beckhoff server** (Bondlab vents and pressure)
- **Edwards** (Turbo Vakuum Pumpen Auslese)
- **Tescom ER 5000** (Dry Turbo Pump in Bondlab)
- **Dazzler Crystal** r/o (Dazzler Laser Systems)
- **RVC 300** (turbo pump controls)
- Delta magnet controls and read out in Bondlab

flashfwdcpudiag3 (Tunnel Rack 20):
- timing (FFWD cameras)
- ADC (Laser diode signals)
- SNMP (Steuern der Netgear PoE Switche)
- Pico server (for Pico/Piezo motor controls)
- Camera server with DAQ sender
- Beamposition
- **Agilent turbo pump controls**
- Hexapod monitoring
- Beam stabilisation

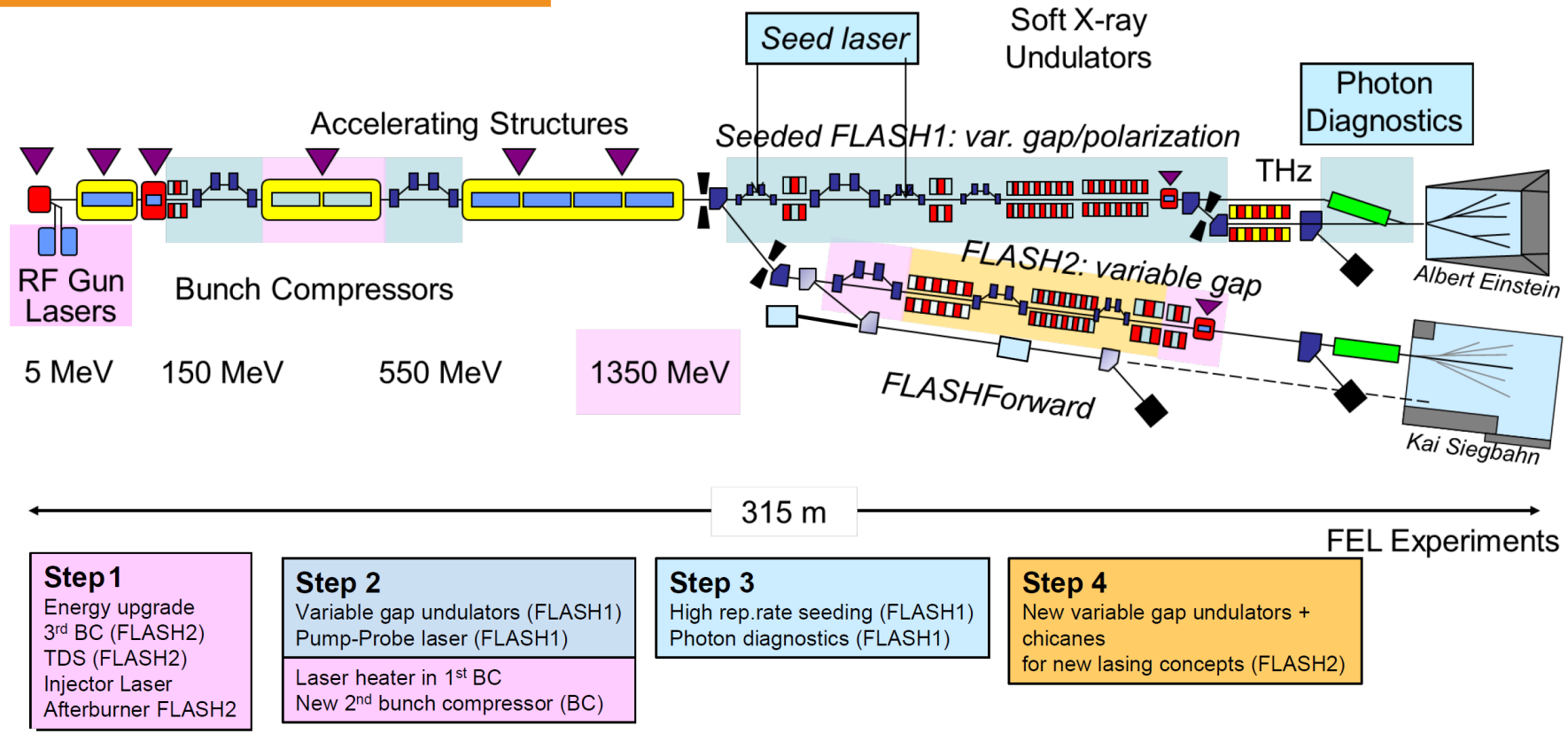
FLASH 2020+

Upgrade Proposal for FLASH

Plan for 2020+ incorporates using MicroTCA technology for controls and monitoring similar to EuXFEL and existing FLASH solutions

Ongoing migrations from VME to MicroTCA:

- Coupler Technical Interlocks
- RF Klystron Monitoring (7 + 1 system)
- FLASH1 Gas Monitor Detector and Multi-Channel-Plate Detector
- New photocathode laser
- FLASH experiment beamline support systems



New magnet controls: Replace SEDAC (COPCS) with low-cost MicroTCA solution:

- Fan-less Schroff MicroTCA crate
- Zync-based CPU AMC (FE/MCS development)
- I/O AMC for magnet P/S control (FE/MCS development)

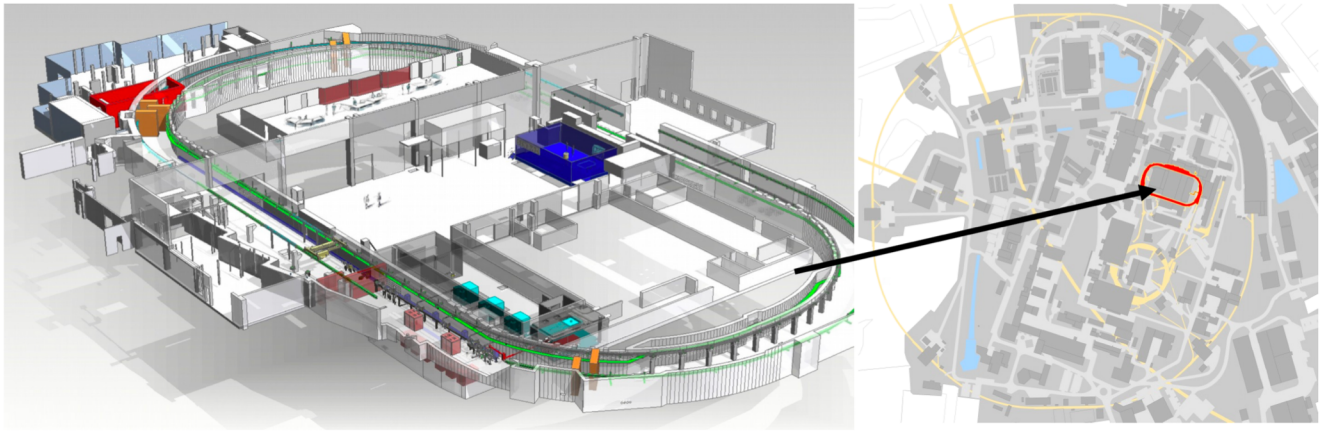
First system will be deployed in 2019/2020

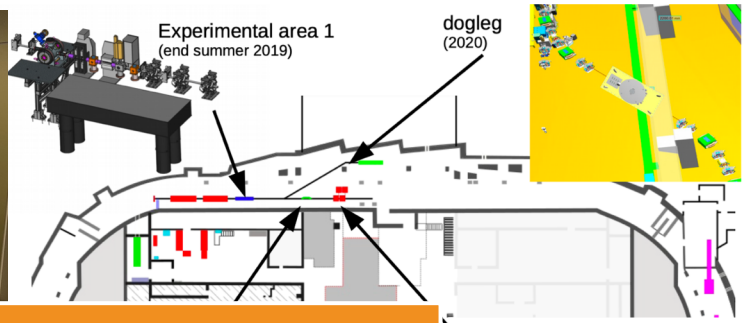
Projects - ARD et al.

SINBAD-ARES

ARD Project

- **Framework for accelerator R&D related activities** in the former DORIS tunnel and associated areas at DESY
- Ultra-fast science R&D (fs to as-regime electron pulses) and high gradient accelerator development (laser-driven approaches)
  - Photocathode-Laser RF Gun
  - Normal-conducting S-band electron linac @ 2.99 GHz for production of ultra-short bunches with two RF structures
  - 100 MeV, 0.5-200 pC, single pulse @ 50Hz, few fs / sub-fs, norm. emittance < 0.5 mm*mrad
  - **Commissioning has started this fall, first electron seen!**
  - Upgrade plans for many years to come (ATHENA)
- Experiments:
  - PolariX – X-Band TDS with fs resolutin
  - Dielectric laser acceleration (DLA) – ACHIP program





MicroTCA-based control system using XFEL/FLASH solutions and its continued developments:

- Standard MicroTCA components (Crate, MCH, CPU, Timer)
- Photocathode Laser system
- Synchronization
- LLRF
- Beam diagnostics

Seven MicroTCA Systems so far, more to come …

PolariX Collaboration, Photo: PSI

REGAE - LUX - KALDERA

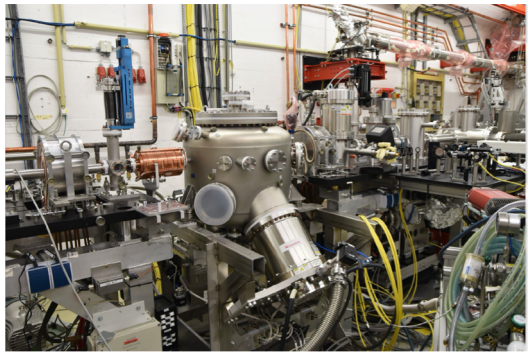
ARD Projects

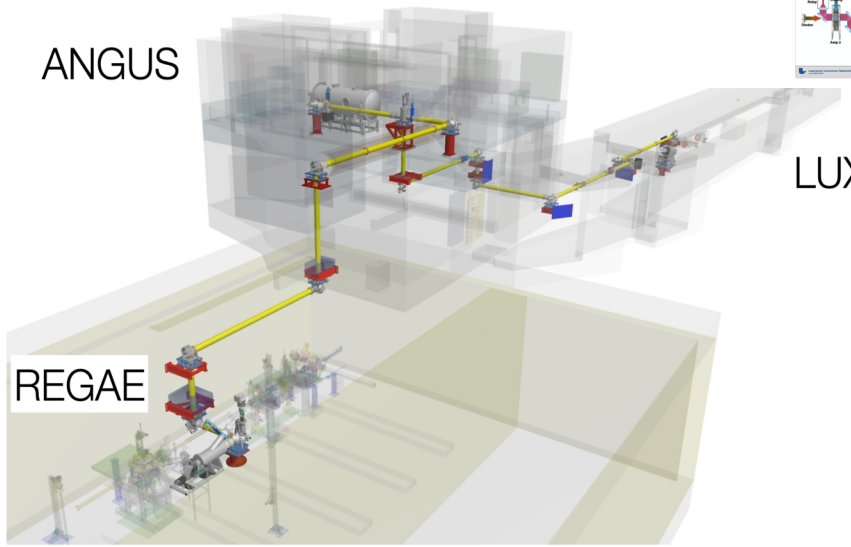
REGAE - Relativistic Electron Gun for Atomic Exploration

- external injection of electron bunches into laser-driven plasma wakefields
- time-resolved electron diffraction

MicroTCA-based controls
- for LLRF and laser synchronization
- experiment controls

- REGAE Beamline
- interaction chamber
- transverse deflecting structure / beam arrival cavity
- klystron & modulator
- laser transport beamline
- connection to ANGUS vacuum system
- in-coupling chamber
- ANGUS beam in the tunnel
- synchronization with ANGUS laser





LUX

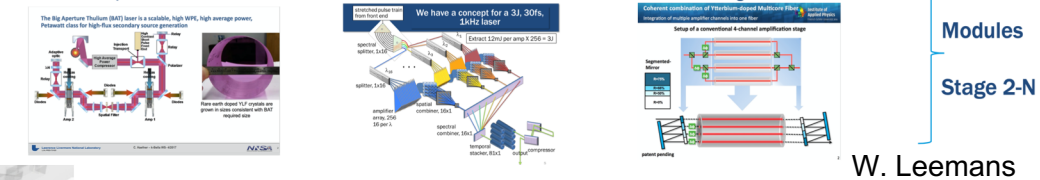
KALDERA - KilowAtt Laser at DEsy for Revolutionary Accelerators

ARD Project on Plasma Acceleration

- Laser for high average power technology demonstration
- High rep rate and stable beam has to be shown -> requires elaborated controls and feedbacks

Parameter	KALDERA	Hi-rep driver	Collider driver
Energy	>3J	3J	6.5J
Pulse duration	30 fs	30-130fs	130fs
Intensity	10^{19} W/cm^2	10^{19} W/cm^2	10^{18} W/cm^2
Reprate	1kHz	10kHz	50kHz
Average power	>3kW	30kW	~300kW

First MicroTCA System is already in deployment for tests!



W. Leemans

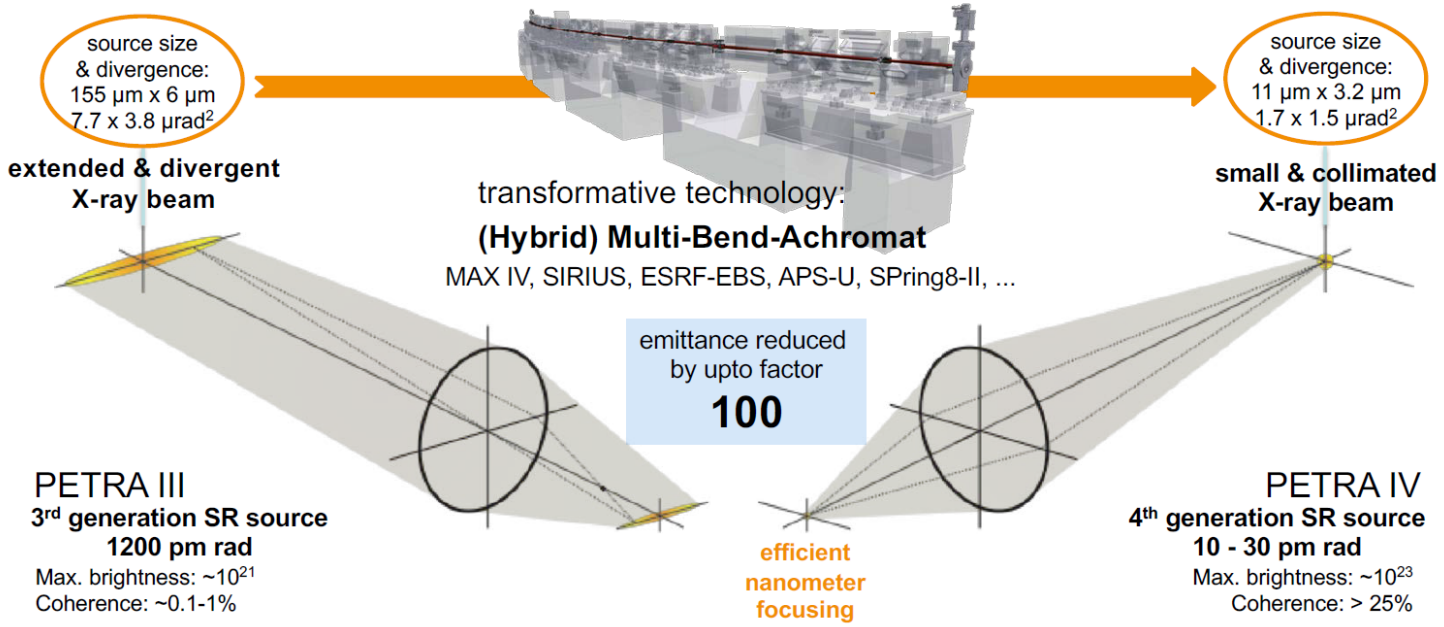
LUX – Laser-plasma driven light sources

- 200 TW, 25 fs laser system **ANGUS** at 5 Hz
- LUX beamline 60 m long with plasma target
- Laser-plasma driven undulator

LUX/ANGUS: MicroTCA-based controls
- Synchronization with RF / REGAE
- To be extended to use more diagnostics and controls (magnets, BPM, kicker,…): LUX -> demoFEL

PETRA IV

The ultimate 3D X-ray microscope - Outlook



MicroTCA-based accelerator control system

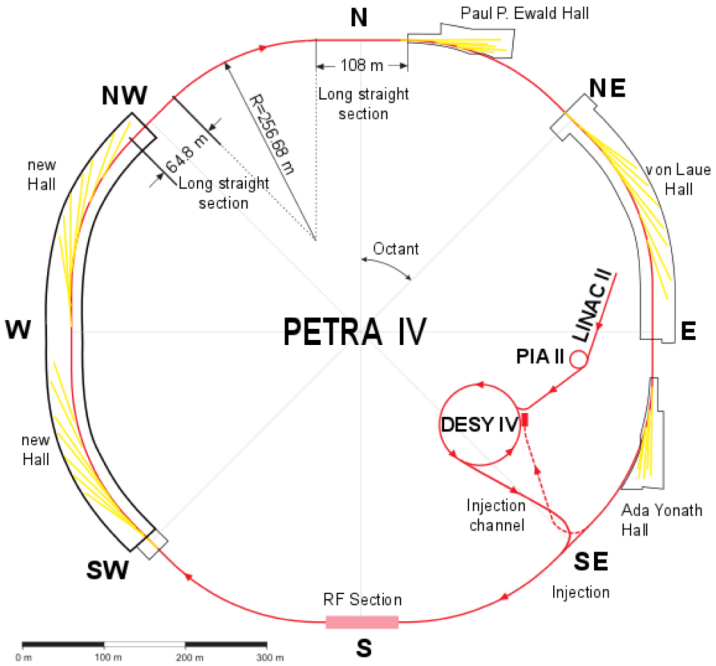
- Use XFEL technology and approaches as fits
- Adapt, modify and enhance where PETRA IV requires new implementations
- More than 4000 magnets
- New booster synchrotron DESY IV
- Refurbished pre-accelerator LINAC II
- PETRA IV RF 500 MHz and 1.5 GHz 3rd harmonic system with new solid state amps
- New beam diagnostics – turn-by-turn BPM data, advanced feedbacks, single bunch data capabilities

Systems to use MicroTCA technology:

- Timing
- Beam diagnostics: charge and beam loss monitor
- RF controls
- Machine protection system
- …

Timeline:

- Technical Design Report 2020-2022
- Construction 2025 – 2027



Summary

- Successful operation of MicroTCA-based accelerator controls at EuXFEL since 2017 (2015)
- FLASH facility will migrate entirely to MicroTCA-based system with the 2020+ upgrade
- MicroTCA has arrived at many accelerator research and development projects now – i.e. SINBAD-ARES
- Standard – almost COTS-like – solutions are available and can be readily deployed for DESY projects
- ARD projects will become challenging with respect to complexity and demands to MicroTCA controls
  – needs continuous evolution and advancement
- Next large project: PETRA IV