Accelerators Controls

KAI 2nd Workshop

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Kooperation für Anwendung und Innovation der HAW Hamburg und DESY

DESY.

Different accelerators … different challenges

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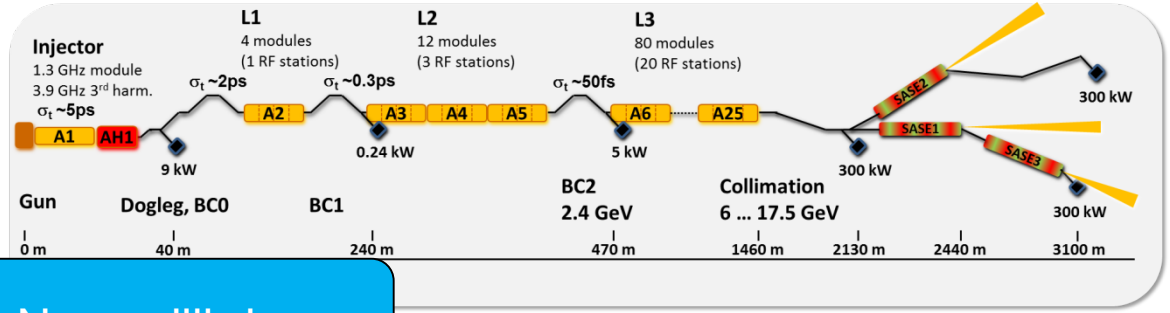
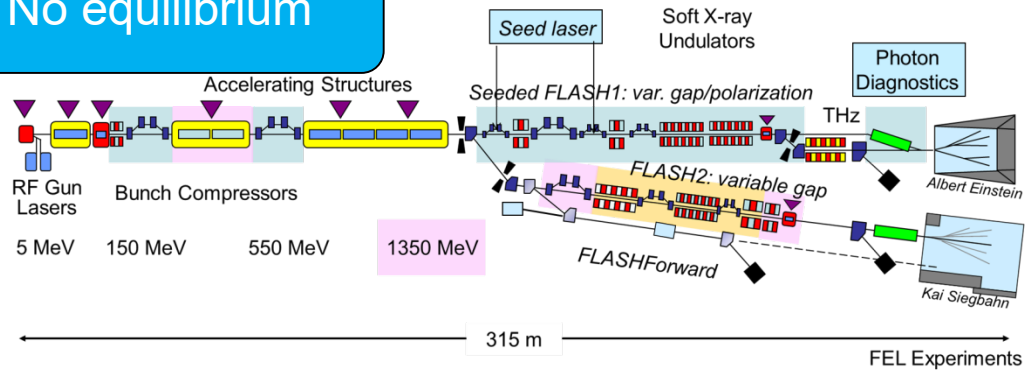
Accelerators at DESY …

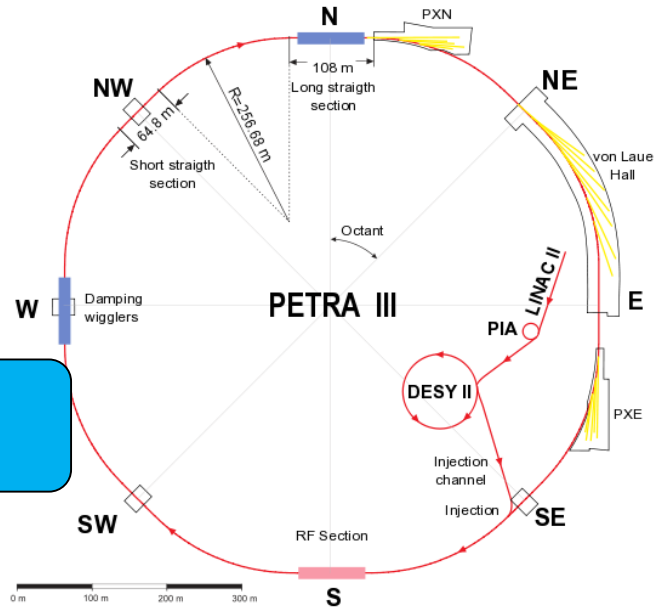
FELs…. (reproducibility / optimization / flexibility / …)



No equilibrium



Storage ring
(lattice / beamlines / optic &orbit / injection / availability/…)



Equilibrium but non-linear

Plasma accelerators (lasers control/ HPC /in-situ FB)

Highly non-linear

Challenges and degree of matureness very different, but

- → Increased complexity of controls
- → Higher demands on accelerator operations
- → Pushing the limits in terms of performance / reliability / availability
- → **Many real-time feedbacks used to ensure proper operation**

Challenges for controls to operation accelerators

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Facilities includes many, highly diverse and distributed components

Large number of sensors & components

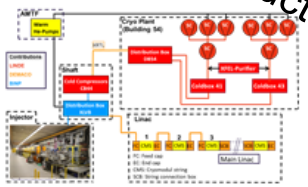
Large supply infrastructures: Cooling Systems/Power Distribution/Climatisation/Cryogenic System ...

Infrastructure

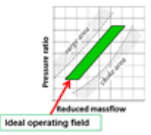
Here at the example of the Cryogenic-System:

XFEL cryogenic system:

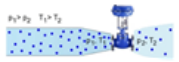
- 671 control valves
- 2647 temperature sensors
- 800 pressure sensors
- 212 flow sensors
- >100 level sensors
- 433 regulation loops
- > 22000 records
- > 220000 properties



4-stage cold compressors:



Joule Thomson Ventil



Cooling loop	unit	Test results CB 41 + CB 43
2K	kW	> 1.9
5K – 8K	kW	4.0
40K – 80K	kW	25.9

Similar complexity for water cooling & power distribution…

Large number of sensors & components

Beam line devices ...

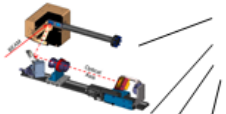
Magnets & RF

Magnets	103 Dipoles, 495 Quads, 59 Multipoles, 403 Correctors, 103 Quad-Movers, 2 Solenoids
Modules	101 x 1.3 GHz, 1 x 3.9 GHz, 27 RF Stations 808 SRF cavities & HP Coupler & HOMs …
Fast Devices	34 kicker magnets, 3 transverse deflecting structure
Undulator	1 Laser Heater Undulator, 91 SASE Undulator Segments
Vacuum	Total 4400 m of cold & warm vacuum in various sections: beam (1), coupler (99), laser (2), dump (3), iso (21) adds to 760 sputter ion pumps /140 titan sublimation pumps/ 40 pump carts/ 54 valves / 8 fast shutter / + vacuum gauges
	And many more .....

Large number of sensors & components

For beam diagnostics ... mostly bunch-to-bunch resolution required

Diagnostics

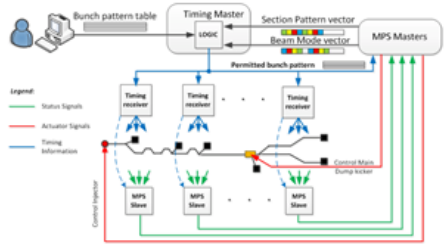


Installed Diagnostics Items	Number
Beam Position Monitors	453
Charge Monitors	51
Imaging stations	67
Dark current monitors	9
Wire Scanners	12
Loss Monitors	474
Dosimetry Systems	630
Transverse Deflecting Structures	2
Bunch Compression Monitors	4
Beam Arrival Time Monitors	7
Electro-Optical Systems	3
THz spectrometer	1

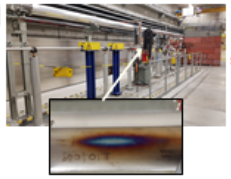
High power beam & beam density

Machine protect to prevent acc. & photon sub-system damages

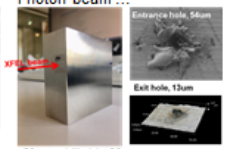
Machine Protection



e⁻ beam beam ...



Photon beam ...



50 mm drilled in 26sec

~ 8% of max beam

- 160 collectors boards
- ~ 4000 different signals (magnets/BLMs/toroids/vacuum/ diagnostic/couplers/waveguides/..

→ up 500kW electron beam power

→ Damages within ~ few us possible

Challenge:

- Large number of different inputs
- Fast reaction time ~ us
- Re-configurable
- Not too restrictive …but still save

Challenges for controls to operation accelerators

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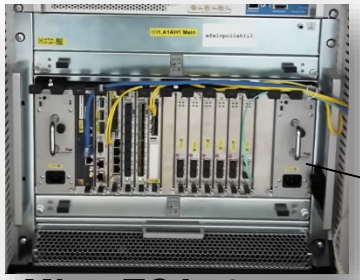
Digitalization changes …

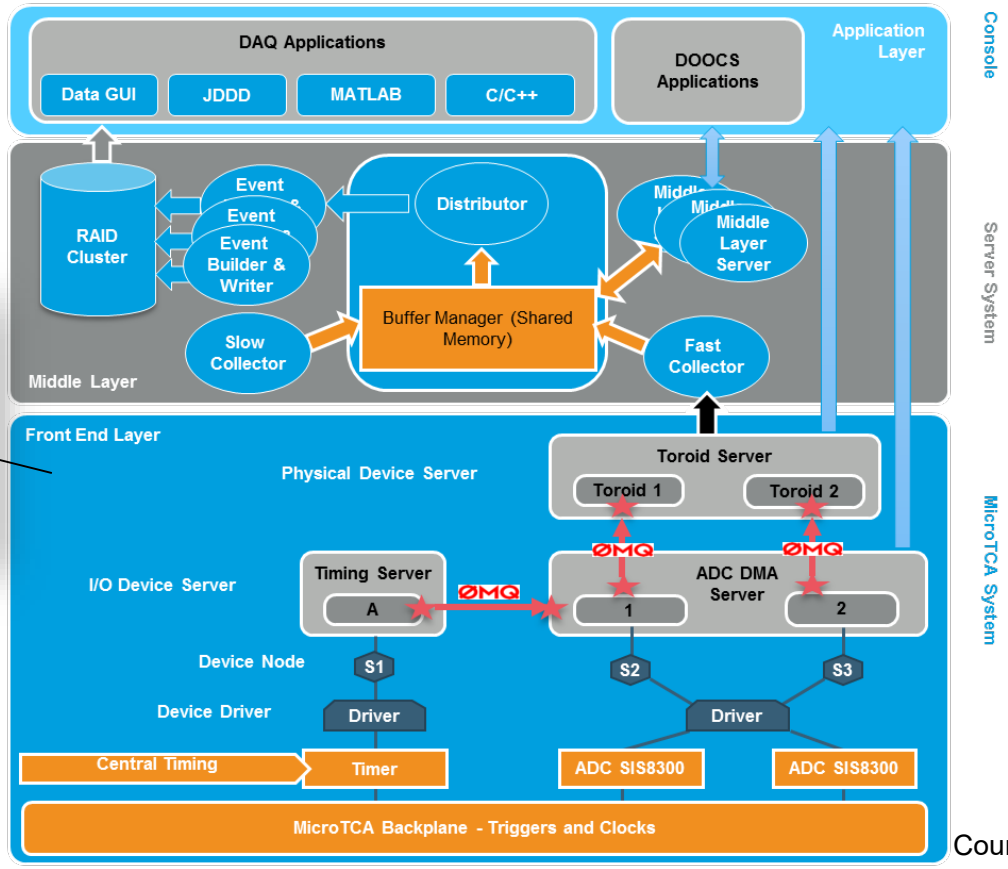
- **Classical 3 tier structure**

DOOCS

Standardize hardware & software



MicroTCA .4



Courtesy: T. Wilksen

Example EuXFEL:

- **> 10 million control parameters**
- **> 700.000 local archives**
- **> 20.000 high data rate channels**
- **> 40 TB/day DAQ** (compressed)

➔ **Configuration management** already challenging

➔ **Large amount of data available**

- data mining
- information extraction
- machine / system optimization
- failure detection
- predictive maintenance
- …

➔ **< 1% sent from front-ends**

- Requires new techniques & technologies → Smart AI/ML based automation

Challenges for controls to operation accelerators

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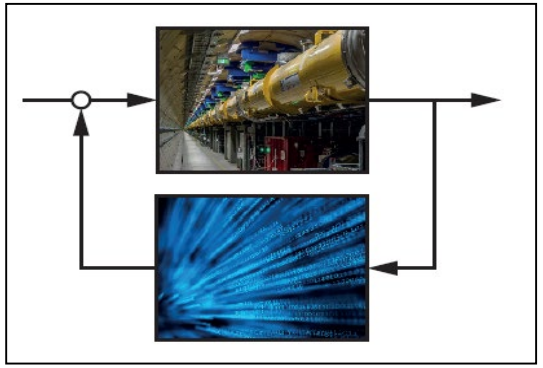
Cooperation options HAW-DESY

- **Data mining & data analytics**
- **Fault diagnosis & smart supervisory control**
- **Many & complex real-time feedbacks involved**
- **Software engineering & architecture**
- **Embedded Electronics Development / Firmware**



Courtesy: A. Eichler