Looking back over 10+ years experience with MTCA.4 LLRF systems at DESY

12th MTCA Workshop for Industry and Research

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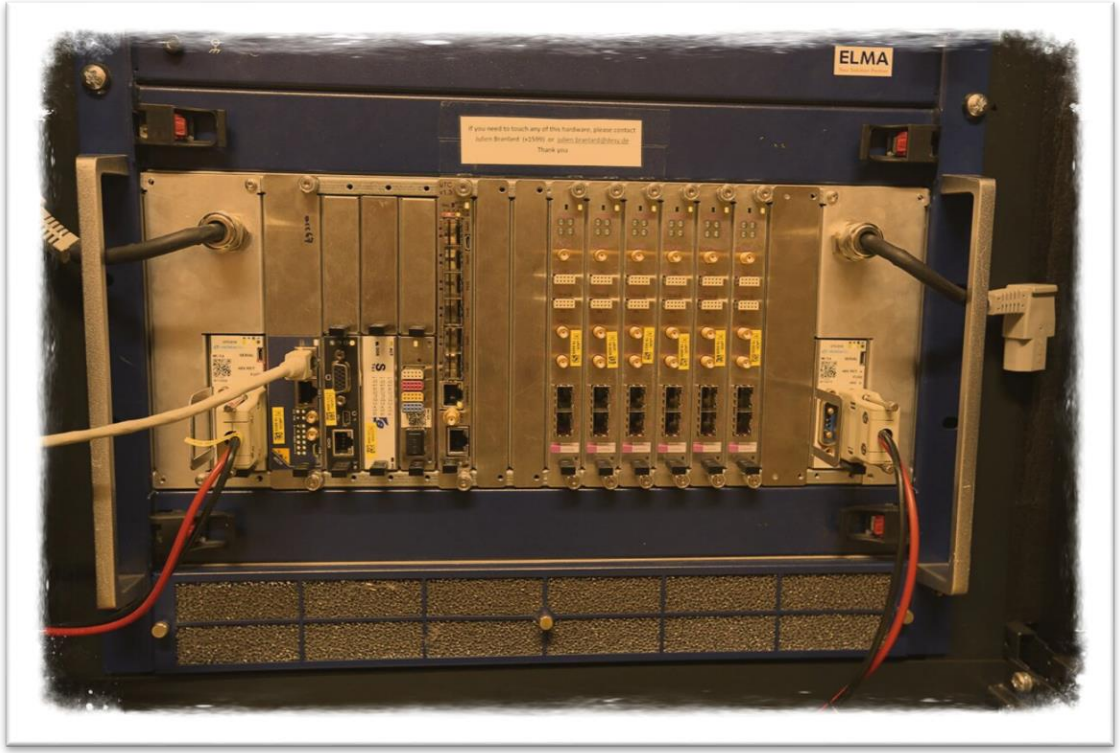
DESY Hamburg
05.12.2023



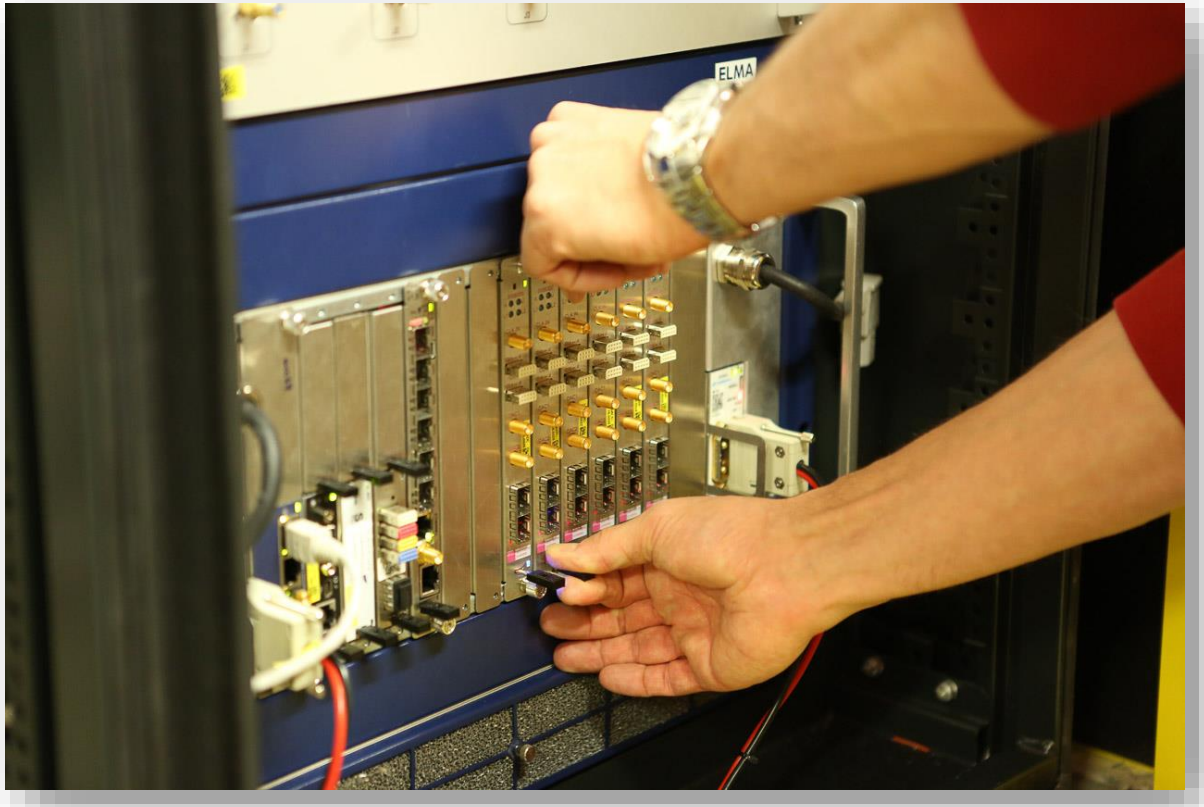
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

OVERVIEW

This presentation

- **Examples** of systems deployed **at DESY**
- **Examples** of systems deployed **outside DESY**
- **Operation experience** at EuXFEL
- Short term upgrade **roadmap**



REGAE

Time resolved diffraction with relativistic electrons

In operation since	Nov. 2011
Number of cavities	3
Cavity type and freq.	NRF, 3 GHz
Control type	SINCAV
RF duty cycle	0.02% (4us, 50Hz)
Remarks	

Crate occupation (2U)

slot			1	2	3	4	5	6
RTM	PM				DWC8VM1	DWC8VM1	DWC8VM1	
AMC		MCH	CPU	x2timer	SIS8300	SIS8300	SIS8300	

Comments

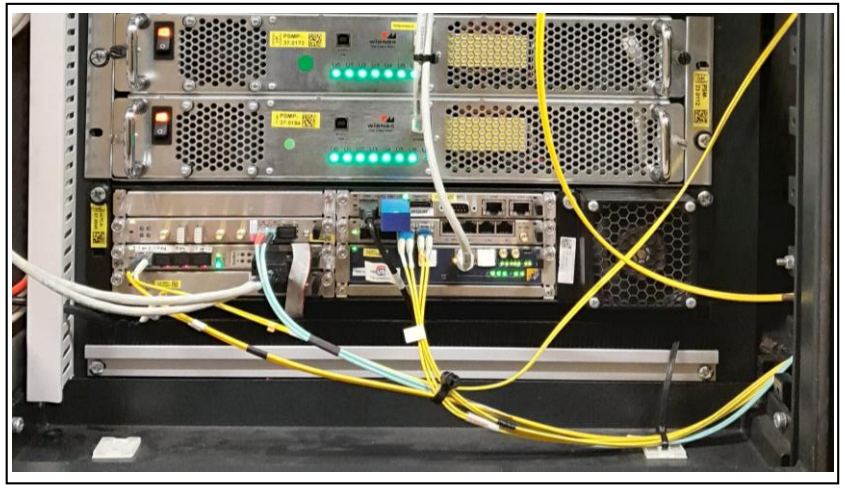
- *Facility with 3 RF systems in one crate: RF Gun, Buncher and TDS*
- *Short RF pulse 4us, repetition rate up to 100Hz, S-Band 3GHz*

FLASH

Soft X-Ray FEL

FLASH

Free-Electron Laser
in Hamburg



In operation since	2014 (inst. 2013)
Number of cavities	1
Cavity type and freq.	NRF 1.3 GHz
Control type	SINCAV
RF duty cycle	1%
Remarks	

Crate occupation (2U)

slot			1	2	3	4	5	6
RTM		PM			DWC8VM1	MPS		DWC10
AMC		MCH	CPU	x2timer	SIS8300-LS	DAMC2		SIS8300

Comments

- *Single cavity control 2U crate setup*
- *Fast pulse cut on higher reflection → Gun lifetime management*

FLASH

Soft X-Ray FEL

FLASH

Free-Electron Laser in Hamburg

In operation since	2014 (inst. 2013)
Number of cavities	12 INJ + 3rd harm.
Cavity type and freq.	SRF 1.3 / 3.9 GHz
Control type	VS
RF duty cycle	1%
Remarks	Mixed LLRF INJ system

Crate occupation (9U, LLRF)

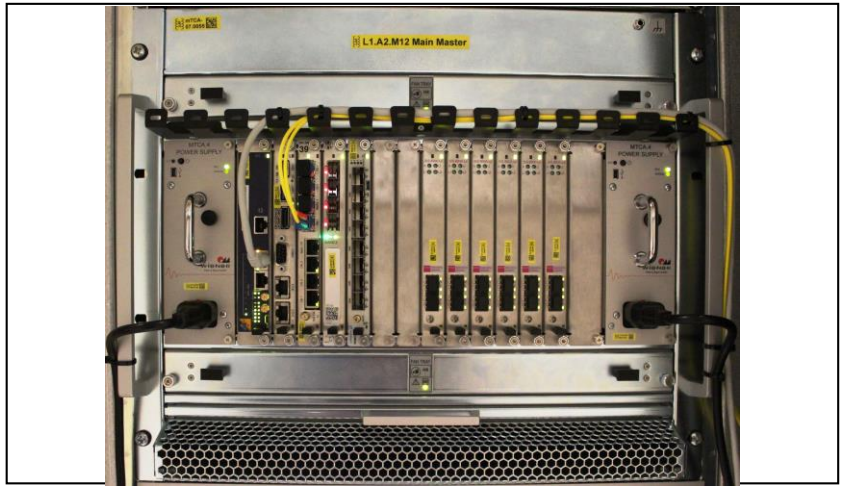
slot			1	2	3	4	5	6	7	8	9	10	11	12		e15
RTM					VM2LF	VM2HF	MPS	DWC10	DWC10	DWC10	DWC10	DWC10	DWC10	DWC10		
AMC	PM	MCH	CPU	x2timer	TCK7	TCK7	DAMC2	SIS8300L2	SIS8300L2	SIS8300L2	SIS8300L2	SIS8300L2	SIS8300L2	SIS8300L2		

Comments

- *External LO/CLK Generation for 1.3GHz an 3.9 GHz*
  - *Additional out of loop measurement using splitter signals*
- *Fast intra-train BBF integration via optical link*
- *1.3 GHz automated resonance control using PZT*

XFEL

Hard- and Soft X-Ray FEL



In operation since	2017 (gun 2015)
Number of cavities	16 / crate
Cavity type and freq.	SRF 1.3 / 3.9 GHz
Control type	VS / SINCAV
RF duty cycle	1%
Remarks	

Crate occupation (9U)

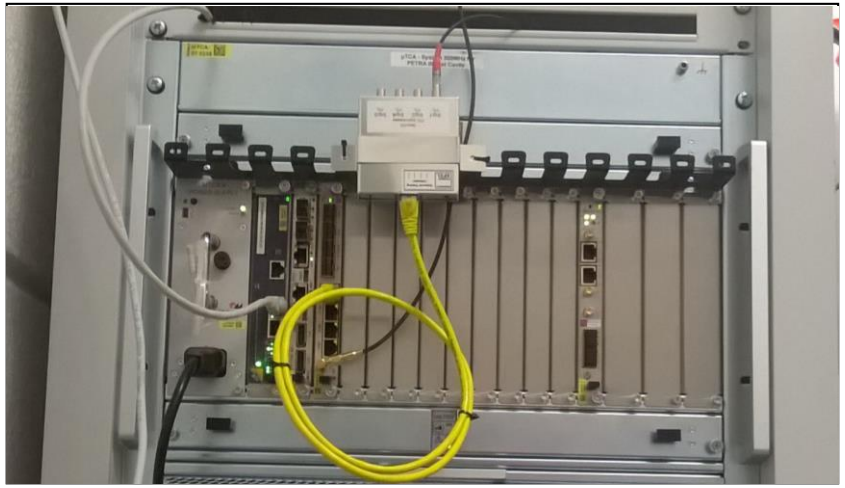
slot			1	2	3	4	5	6	7	8	9	10	11	12		e15
RTM		uBM		x2timer-RTM	MPS	VM		DWC10	DWC10	DWC10	DWC10	DWC10	DWC10	DWC10		uLOG
AMC	PM	MCH	CPU	x2timer	DAMC2	TCK7		SIS8300	SIS8300	SIS8300	SIS8300	SIS8300	SIS8300	SIS8300		PM

Comments

- *Manager – Subordinate configuration (optical link connection)*
- *Introduction of the RF backplane (RTM) with uLOG*
- *Fast klystron protection system based on SIS8300 – DWC10*
- *32 cavity vector sum control*

PETRA IV - 500 MHz (and 1500 MHz)

Test setup with HOM damped cavity for PETRA IV LLRF system



In operation since	2022
Number of cavities	1
Cavity type and freq.	NRF, 500 MHz
Control type	SINCAV
RF duty cycle	CW
Remarks	

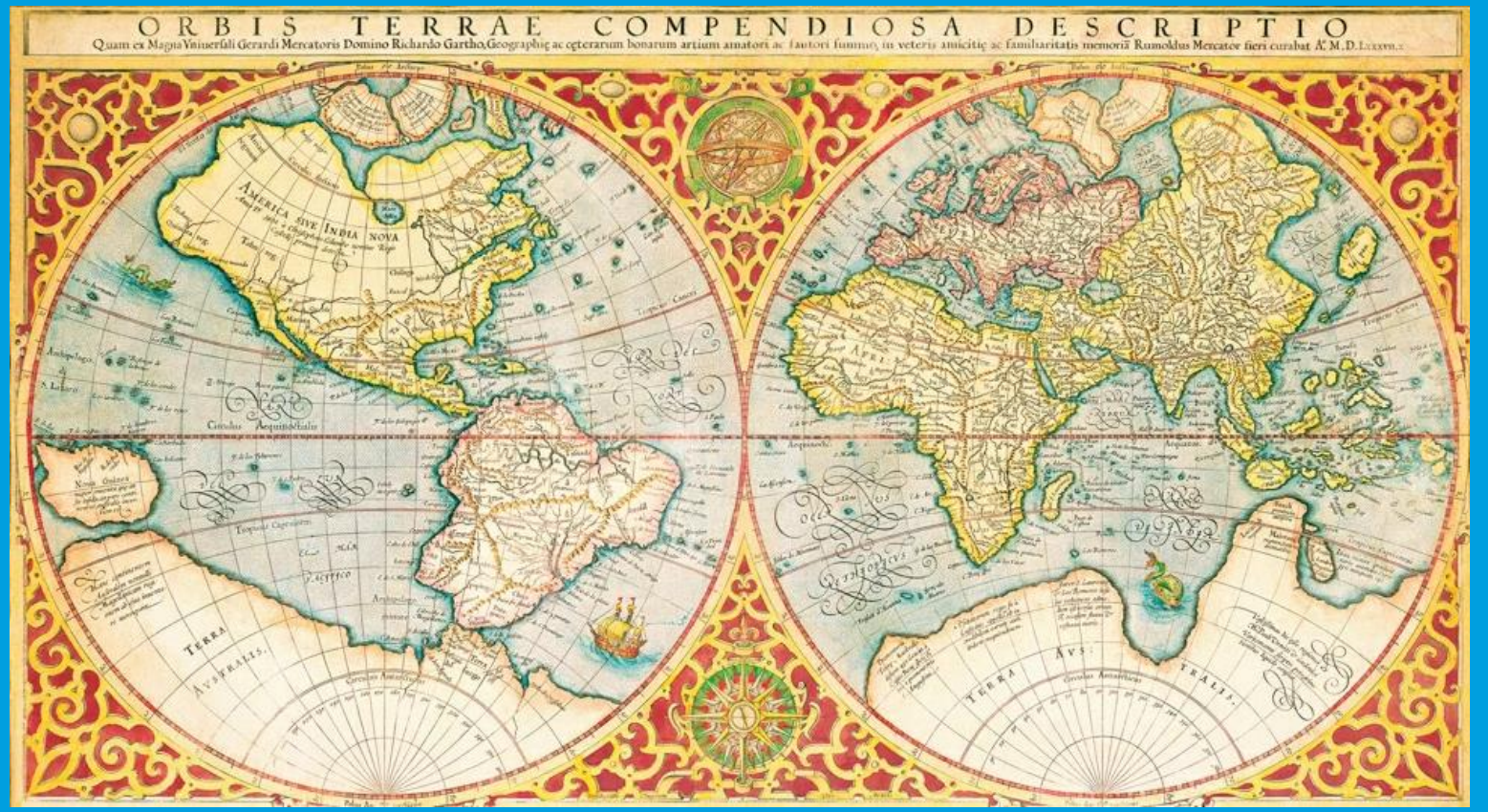
Crate occupation (9U)

slot			1	2	3	4	5	6	7	8	9	10	11	12		e15
RTM				x2timer-RTM										DWC8VM1		
AMC	PM	MCH	CPU	x2timer										SIS8300		

Comments

- *Test stand for new PETRA IV LLRF system*
- *Single cavity system, 500MHz*
- *In the future*
  - *up to 6 RF stations at 500 MHz, 6 RF stations at 1500 MHz*
  - *4 single cavities systems per RF station*

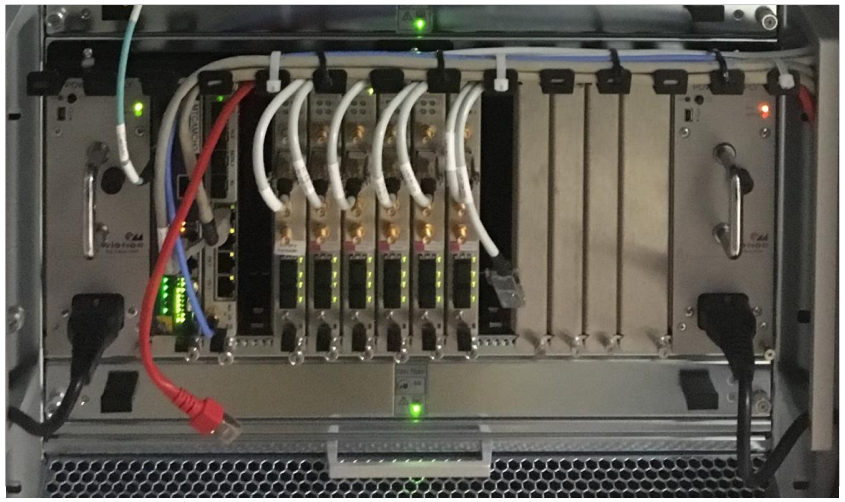
OUTSIDE DESY



ELBE at HZDR

Electron Linac for beams with high Brilliance and low Emittance

ELBE.
CENTER FOR HIGH-POWER RADIATION SOURCES



In operation since	2017
Number of cavities	4
Cavity type and freq.	SRF, 1.3 GHz
Control type	SINCAV
RF duty cycle	CW
Remarks	External CPU

Crate occupation (9U)

slot			1	2	3	4	5	6	7	8	9	10	11	12		e15
RTM					DS8VM1	DWC8VM1	DWC8VM1	DWC8VM1	DWC8VM1	DWC8VM1						
AMC	PM	MCH	x2timer		SIS8300	SIS8300	SIS8300	SIS8300	SIS8300	SIS8300						

Comments

- *Facility with 6 RF systems in one crate*
- *4 SRF cavities at 1.3 GHz*
- *NRF buncher at 1.3GHz and 260MHz*

HoBiCaT Testing Cryomodule at HZB

LLRF systems development and debugging

HZB Helmholtz Zentrum Berlin

In operation since	2023
Number of cavities	Up to 2
Cavity type and freq.	SRF 1.3 / 1.5GHz
Control type	SINCAV
RF duty cycle	CW
Remarks	Previously using a 2U crate

Crate occupation (9U)

slot			1	2	3	4	5	6	7	8	9	10	11	12		e15
RTM		uBM		x2timer-RTM		RPZT4	DWC8VM1							RPZT4	DWC8VM1	1500 uLOG
AMC	PM	MCH	CPU	x2timer		FMC25+MD22	SIS8300-KU							FMC2ZUP+MD22	SIS8300-KU	PM
						1.3 GHz								*1.5 GHz*		

Comments

- *Two sets for two different frequencies : 1.3 GHz (left) 1.5 GHz (right)*
- *CW - long pulse*
- *FMC25 for piezo feedback (upgrade to FMC2ZUP) + MD22 for motor control*
- *ChimeraTK system adapter for EPICS*

BESSY-II booster ring

Replace former analogue LLRF system

HZB Helmholtz Zentrum Berlin

In operation since	2022
Number of cavities	2
Cavity type and freq.	NC 500MHz
Control type	SINCAV
RF duty cycle	CW, ramp-up and down
Remarks	

Crate occupation (9U)

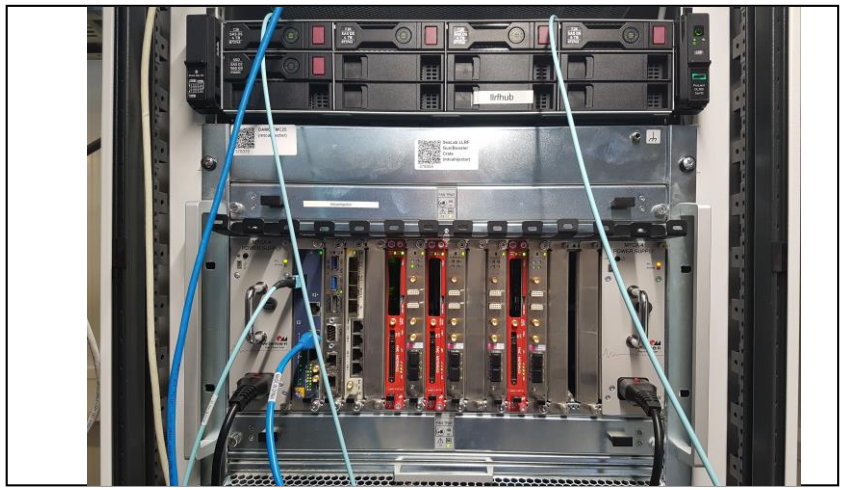
slot			1	2	3	4	5	6	7	8	9	10	11	12		e15
RTM		uBM		x2timer-RTM	DWC8VM1	DWC8VM1										
AMC	PM	MCH	CPU	x2timer	SIS8300-KU	SIS8300-KU										PM

Comments

- SIS8300-KU *RJ-45 front connectors for communication with interlock PLC*
- *Low Frequency DWC8VM1 version*
- *Long pulse firmware and server. We will test ramp-up and down operation*
- *ChimeraTK system adapter for EPICS*

SEALAB/bERLinPro

Energy Recovery Linac



In operation since	2024
Number of cavities	4
Cavity type and freq.	SRF 1.3 GHz
Control type	SINCAV
RF duty cycle	CW
Remarks	External CPU controls Gun and Booster

Crate occupation (9U)

slot			1	2	3	4	5	6	7	8	9	10	11	12		e15
RTM		RTM MCH		psTimer-RTM		DRTM-PZT4	DRTM-DWC8VM1	DRTM-PZT4	DRTM-DWC8VM1	DRTM-PZT4	DRTM-DWC8VM1	DRTM-PZT4	DRTM-DWC8VM1			uLOG
AMC	PM	MCH-PHYS80	MPS AMC-ADIO24	x2timer		FMC25 + MOTDRV.22	SIS8300	FMC25 + MOTDRV.22	SIS8300	FMC25 + MOTDRV.22	SIS8300	FMC25 + MOTDRV.22	SIS8300			PM

Comments

- *The whole MTCA control setup consists of two independent crates:*
  - *Injector (1,5-cell Gun and 3 two-cell Boosters) under external CPU control (Industrial high-performance PC)*
  - *Linac (temporally has transverse deflecting Cavity control, reserved for the Linac)*
- *A stepper motor for coarse tuning and piezo actuators for fine tuning are provided to compensate microphonics from all possible sources*

TARLA

Accelerator driven photon and electron source

In operation since	In commissioning
Number of cavities	6
Cavity type and freq.	NRF 260 MHz NRF 1.3GHz SRF 1.3 GHz
Control type	SINCAV
RF duty cycle	Various / CW
Remarks	1 crate / facility

Crate occupation (9U, LLRF)

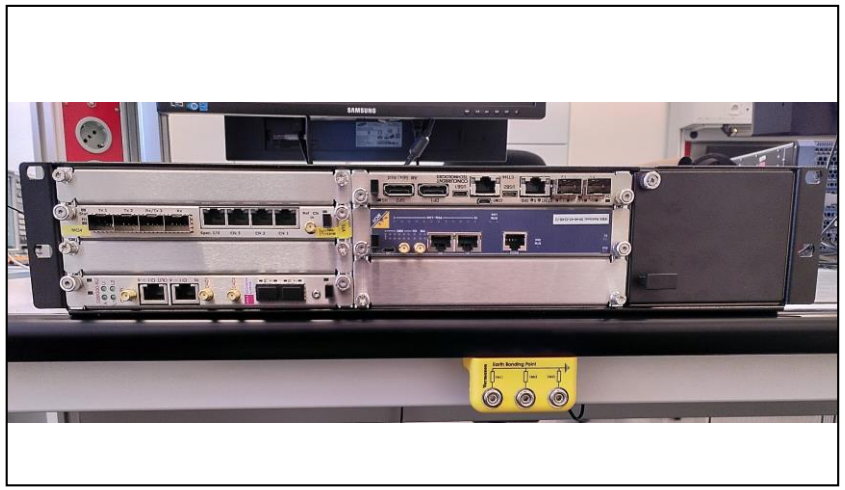
slot			1	2	3	4	5	6	7	8	9	10	11	12		e15
RTM					DRTM-PZT4	DRTM-PZT4	DWC8VM1	DWC8VM1	DWC8VM1	DWC8VM1	DWC8VM1	DS8VM1				
AMC	PM	MCH	CPU	x2timer	FMC25 MD22	FMC25 MD22	SIS8300L2	SIS8300L2	SIS8300L2	SIS8300L2	SIS8300L2	SIS8300L2				

Comments

- *External CPU using MCH with PCIe uplink*
- *Combined RF and frequency control (motor tuner and piezo tuner)*

STF vertical test stand (KEK)

Cavity Vertical Test Stand



In operation since	2022
Number of cavities	1
Cavity type and freq.	SRF 1.3 GHz
Control type	SINCAV
RF duty cycle	Pulsed / CW
Remarks	

Crate occupation (2U)

slot			1	2	3	4	5	6
RTM		PM			DWC8VM1			
AMC		MCH	CPU		SIS8300-LS		x2timer	

Comments

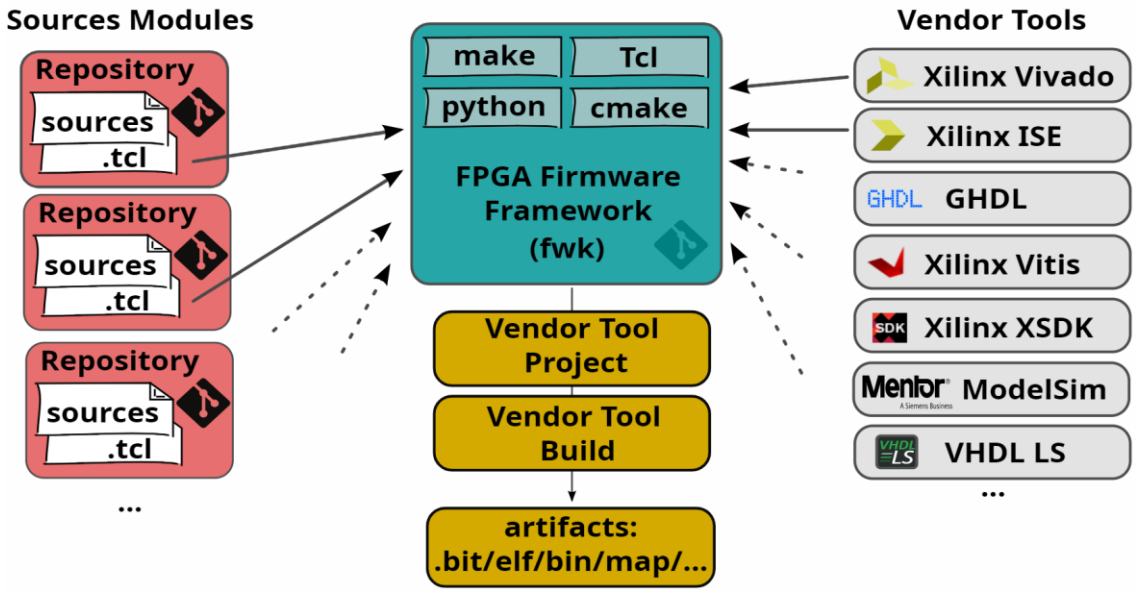
- *Self excited loop (SEL) controller*
- *EPICS control*
- *System developed and also used at DESY (VTS)*

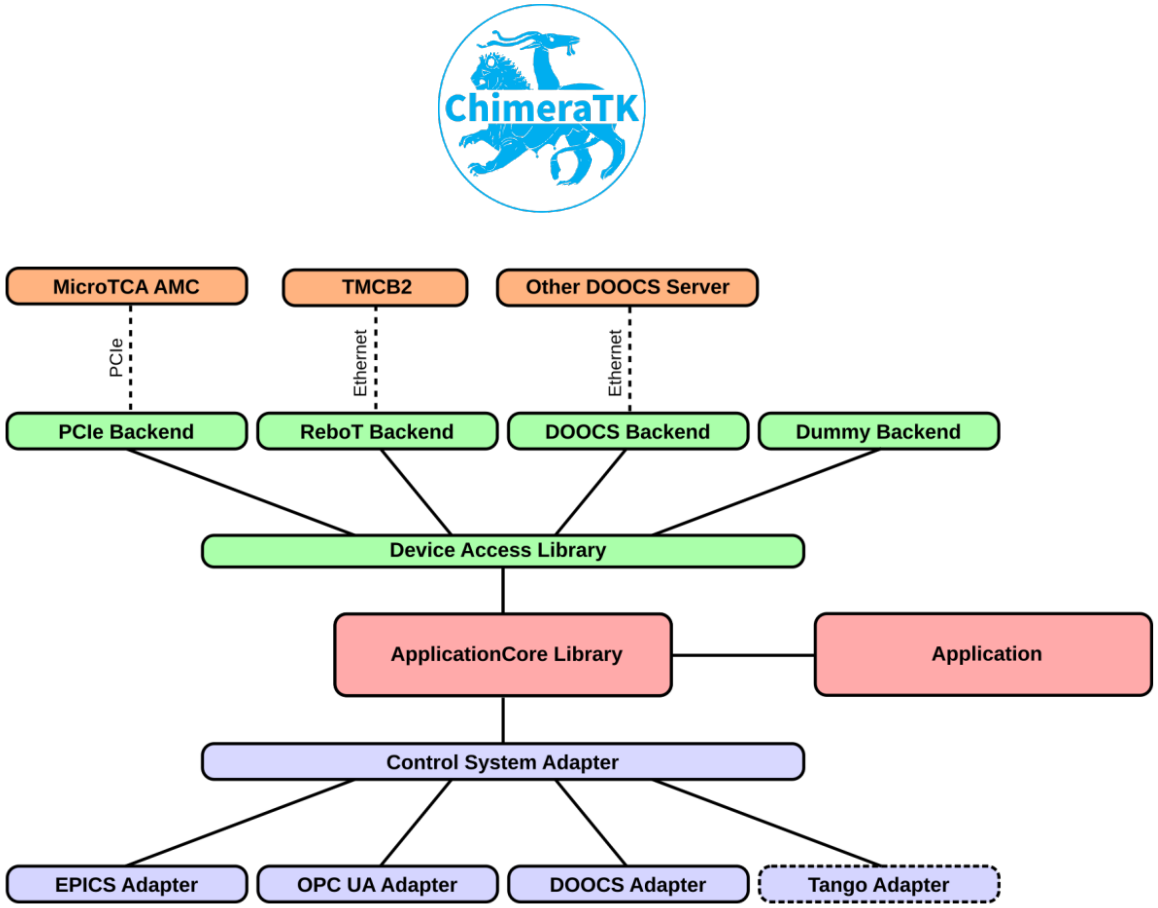
Operation experience

Source: gifsec.com

Firmware / Software

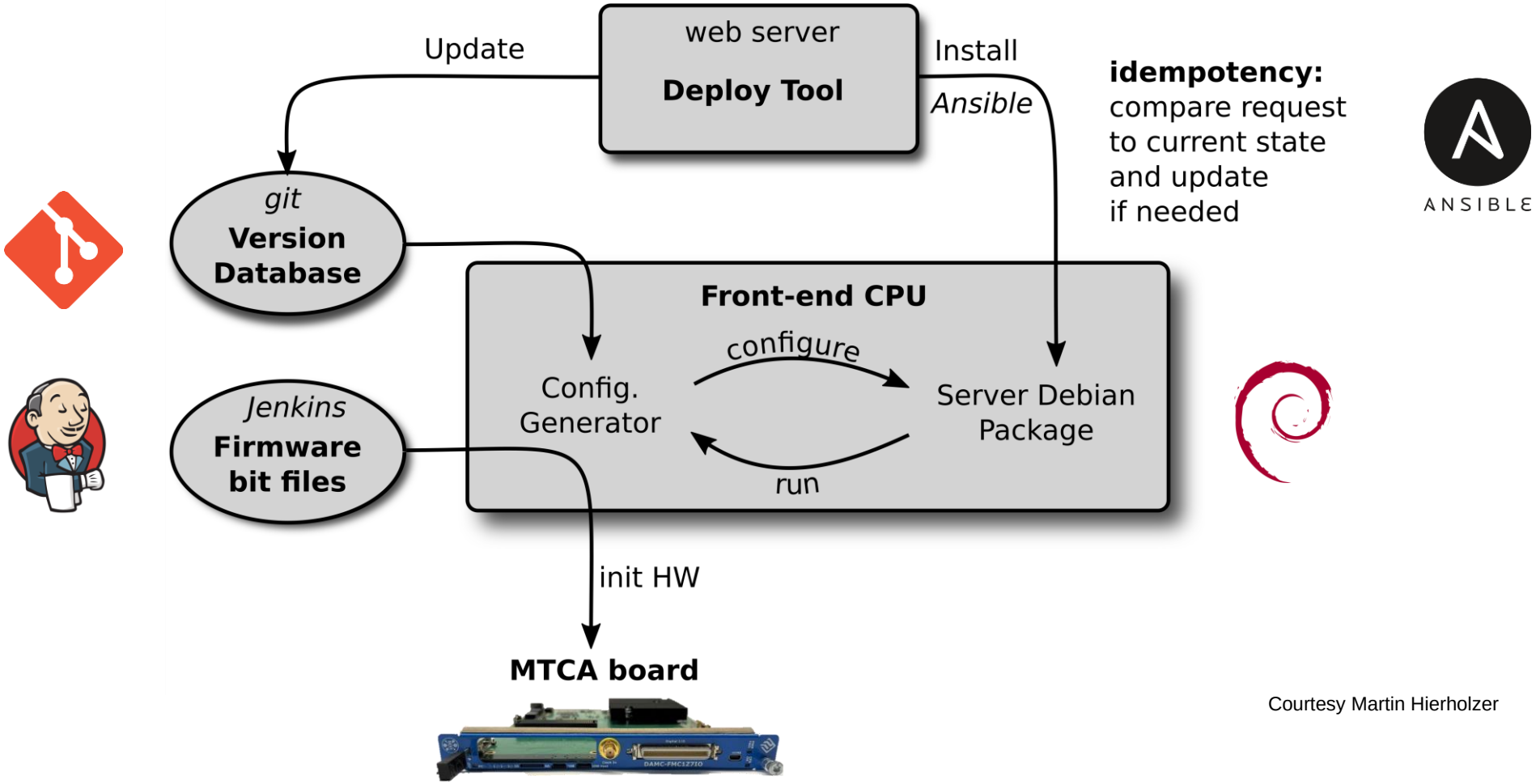
Framework development





Deployment tool

General mechanism



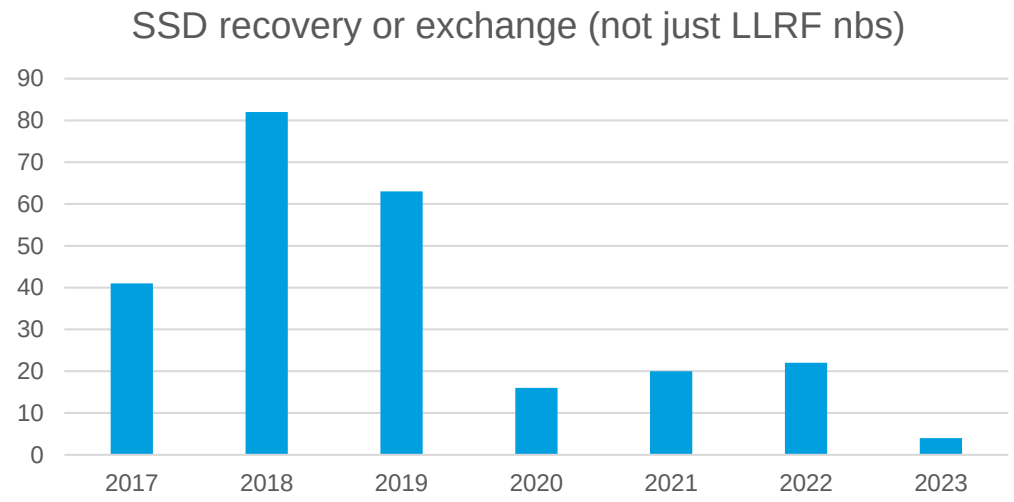
Courtesy Martin Hierholzer

Operation experience at XFEL

Overall

- **Very few hardware failures**
  - Dominant problem is loss of PCIe communication (probably related to radiation)
  - Recovery through power cycle / FPGA restart
- **Statistics at XFEL (since 2017)**
  - SSD RAID failure → recovery / exchange

Courtesy Tim Wilksen



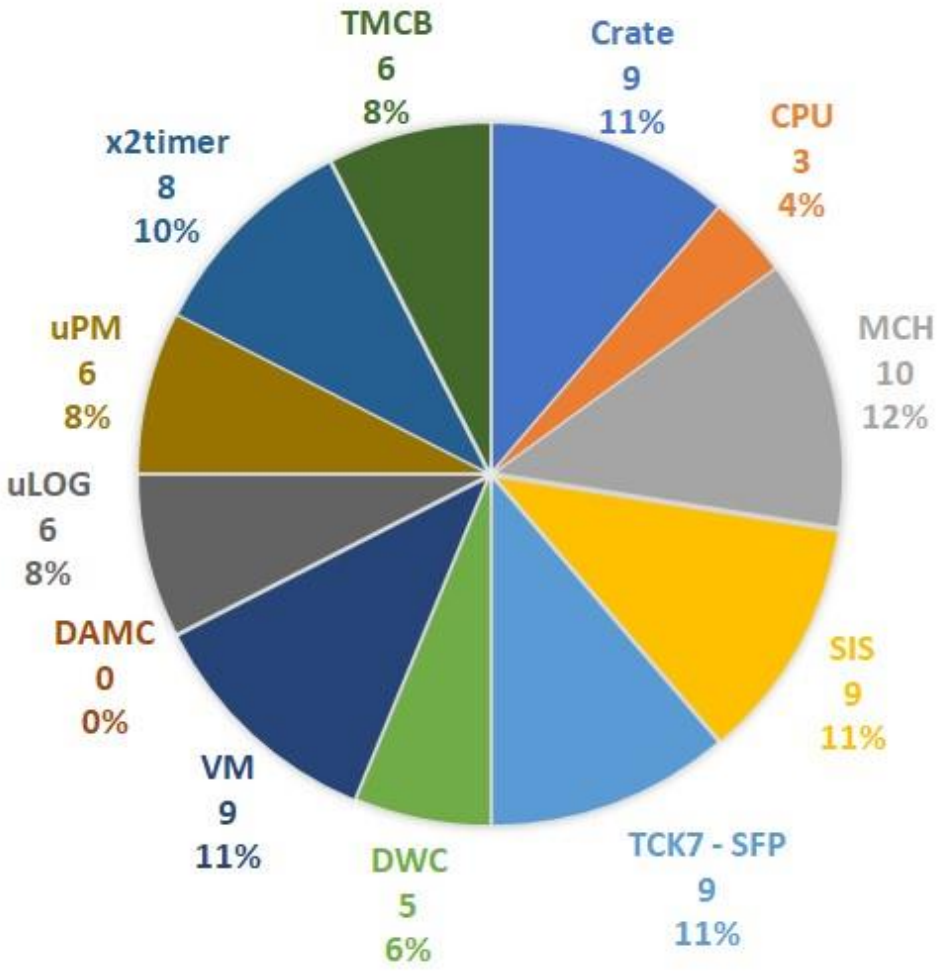
Operation experience at XFEL

Overall

- **Very few hardware failures**
  - Dominant problem is loss of PCIe communication (probably related to radiation)
  - Recovery through power cycle / FPGA restart

- **Statistics at XFEL (since 2017)**
  - SSD RAID failure → recovery / exchange
  - Board exchange (DWC, uLOG, uPM, etc…)
  - FW reprogramming (MCH, uPM)
  - SFP module degradation
  - Firmware incompatibility (MCH, uBM)
  - Crate exchange (CU, AMC backplane pins)

Total	125
Total w/o SSD	80



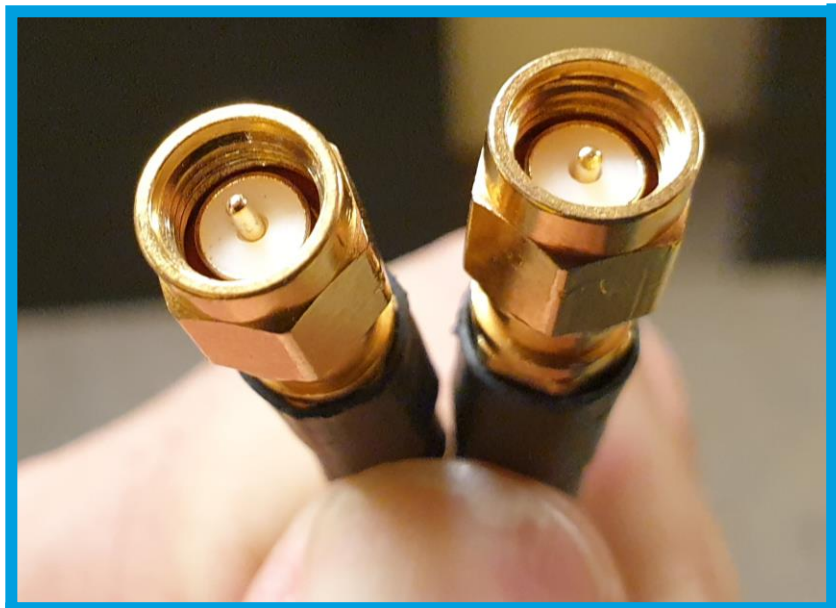
Operation experience at XFEL (FLASH)

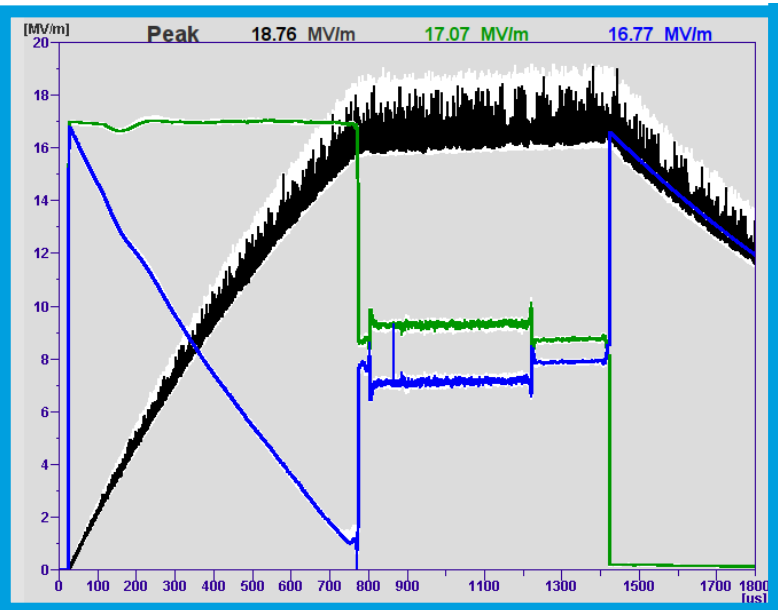
More specifically

- Some issues
  - with **module insertion** (broken pins, extraction force, new connectors etc…)
  - with **startup currents** for new designs (typically in-rush over current)
  - with crate **fan management** or **redundant** power supply
  - with **boot sequence** for specific crate configurations

- Some issues have been addressed over the years.
- Discussion with vendors on-going for the ones still open

Memories ☺




[MV/m]
Peak 18.76 MV/m 17.07 MV/m 16.77 MV/m
20
18
16
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12
10
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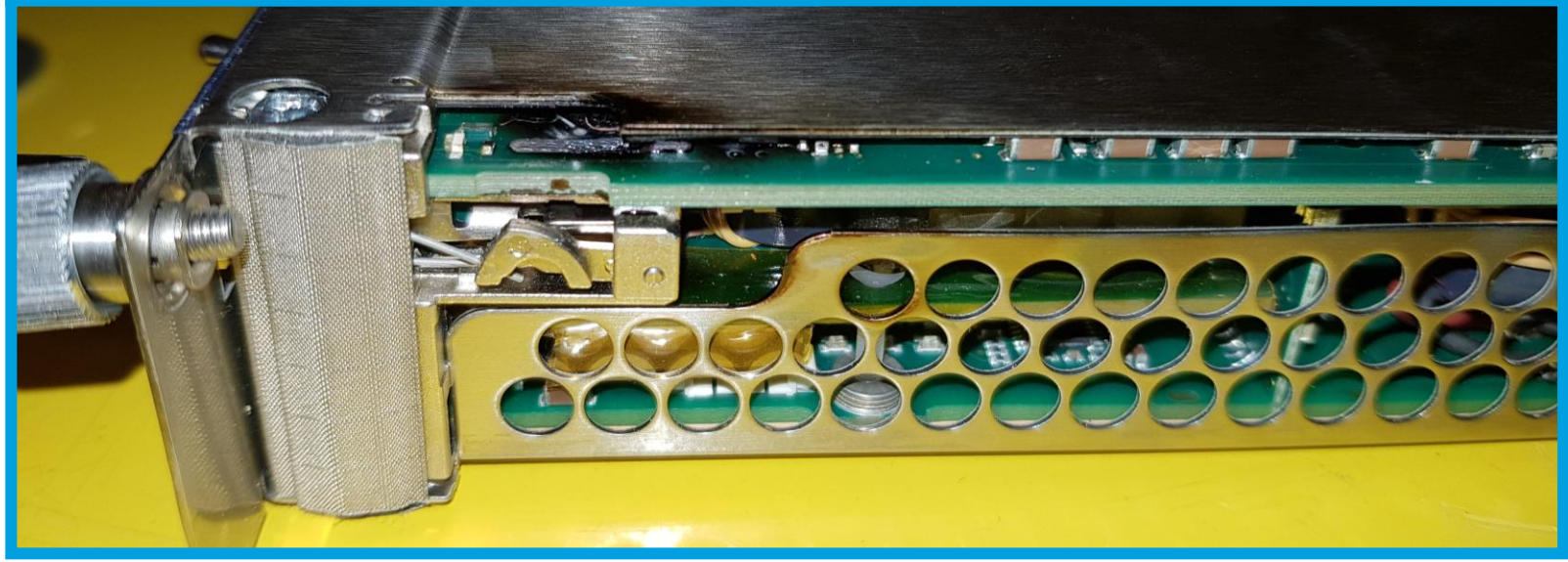
0
0 100 200 300 400 500 600 700 800 900 1100 1300 1500 1700 1800
[us]




470
EFK.
J04
PTH08T240
WAH
531690V
PTH12000
WAH
511979V
C828

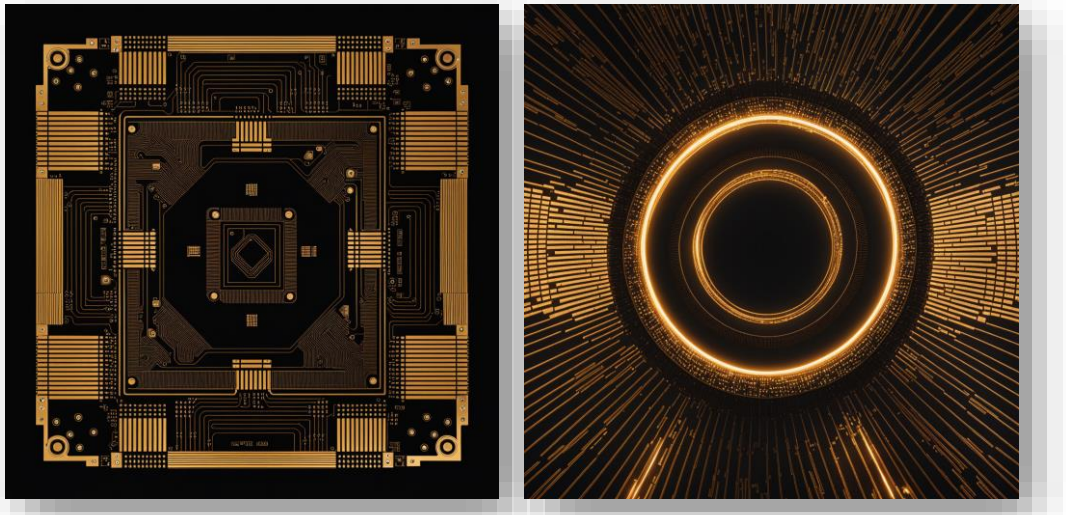
Upgrade roadmap

Short term

- 2023-2025 **CPU** upgrade
- 2024 **uLOG** new production with KVG
- 2024 FMC25 → (DAMC-FMC1)**Z7IO** (resonance control)
- 2025 Replacement of TCK7 → (DAMC-FMC2)**ZUP**
- 2025 Next generation **ADC** boards with Struck (improved SNR)
- 2025 ? x2timer → **x3timer** (gain experience)

- 2025 LLRF operation with DAMC-DS5014DR (**RFSoC**)

Thank you !



Generated by Playground AI keyword “*Next generation MicroTCA board*”

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