

MicroTCA developments and history at DESY

2026 MicroTCA/ATCA Workshop for Large Scientific Facility Control

Holger Schlarb, MSK/DESY
HEPS, Beijing, 17.09.2026

SLAC & DESY Reliability Workshop 2005

Challenges to operate huge facilities (e.g. ILC or Eu-XFEL) with thousands of devices

Example:

- Server PC has an MTBF ~50,000 h (~99.99%)
—> downtime per year: **53 minutes**
- With 1000 systems required to run it, it drops to 90%
—> downtime per year: **37 days**

Mean Time Between Failures

MTBF Estimates for R1304RPMSHOR

Copyright ©2013 Intel Corporation

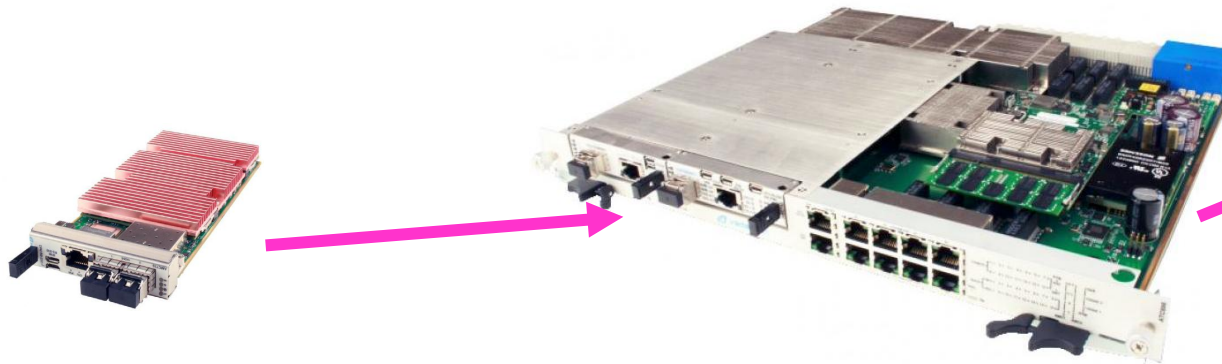
Subassembly (Server in 40C ambient air)	Server Model	
	R1304RPMSHOR	
	MTBF	FIT
	(hours)	(flrs/10 ⁹ hrs)
S1200V3RPM board	371,523	2,692
Power Supply - 450W MiniERPS	967,300	1,034
Cooling Fan (1-fixed fans)	490,000	2,041
Cooling Fan (2-fixed fans)	77,680	12,873
Front Panel board	8,272,282	121
HS Backplane(4x3.5")	935,180	1,069
Totals without motherboard =	58,300	17,138
Totals with motherboard =	50,400	19,830

MTBF is limited
by the fans

ATCA: a Standard developed by the Telecom Industry

ATCA = Advanced Telecom Computing Architecture

- Introduced in 2003
- Requirements
 - 99.999% reliability → downtime per year = 5.3 minutes
 - Very high system throughput (full mesh architecture)
 - Remote management (monitoring and control)



Advanced TCA®



MicroTCA: a Standard Developed by Telecom Industry

MicroTCA: 2006



ATCA: 2003

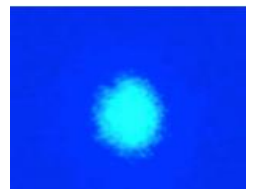
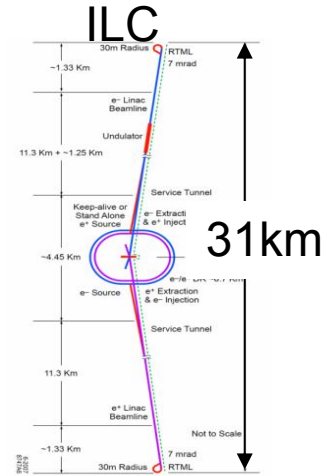


*A scalable family
with the same
system
architecture*



History of MicroTCA@DESY

- Nov. 2005: Reliability Workshop in Grömitz, Germany
 - Joint meeting with ILC (International Linear Collider, 33km, 500GeV)
- Dec. 2007: European XFEL Crate-Standard Workshop
 - MicroTCA and ATCA were defined to be used
- Mar. 2009: First PICMG Meeting “xTCA for Physics”
 - Hardware group: rear I/O and timing
 - Software group: standardization of interfaces for FPGAs...Opsys
- Oct. 2011: Official announcement of PICMG Specification
 - “MTCA.4 Enhancements for Rear I/O and Precision Timing“
- Jul. 2012: Start of Helmholtz Validation Funds till Dec. 2014
 - „MicroTCA.4 for Industry“
- Jan. 2014: Reestablish HW/SW PICMG working groups
 - „MicroTCA.4.1 release: 01. Nov 2016“
- Oct. 2016: MicroTCA TechLab
- Jan. 2017: Commissioning European XFEL ...
- Since 2022: Preparation for PETRA IV



MicroTCA: a Standard Developed by Telecom Industry

- 2007 decision to use xTCA for EuXFEL

- Since 1993 **VME** bus
... at FLASH
- > 40 years old



- Redundancy of fans
- Redundancy of power supplies is possible
- Modern, high-speed Data transfer
- Excellent signal quality for analogue IO
- Remote management
- *Cables from the rear*
- *Internal Clock & Trigger distribution*

Performance
+
Functions
+
Availability

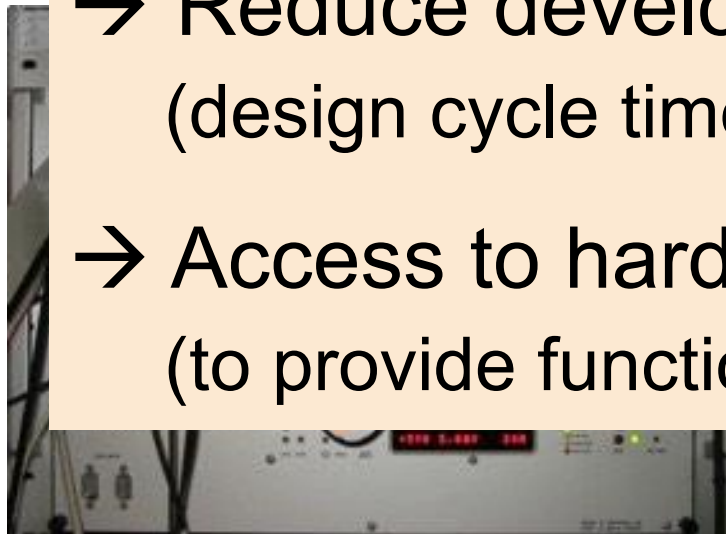
MicroTCA: a Standard Developed by Telecom Industry

- 2007 decision to use xTCA for EuXFEL



& MOSA = Modular Open System Approach

- Since ... at 1
 - > 40
- No **vendor lock-in!**
(Any company can step in)
 - Reduce development expense
(design cycle time, and manufacturing costs)
 - Access to hardware/firmware/software
(to provide functionalities we need)



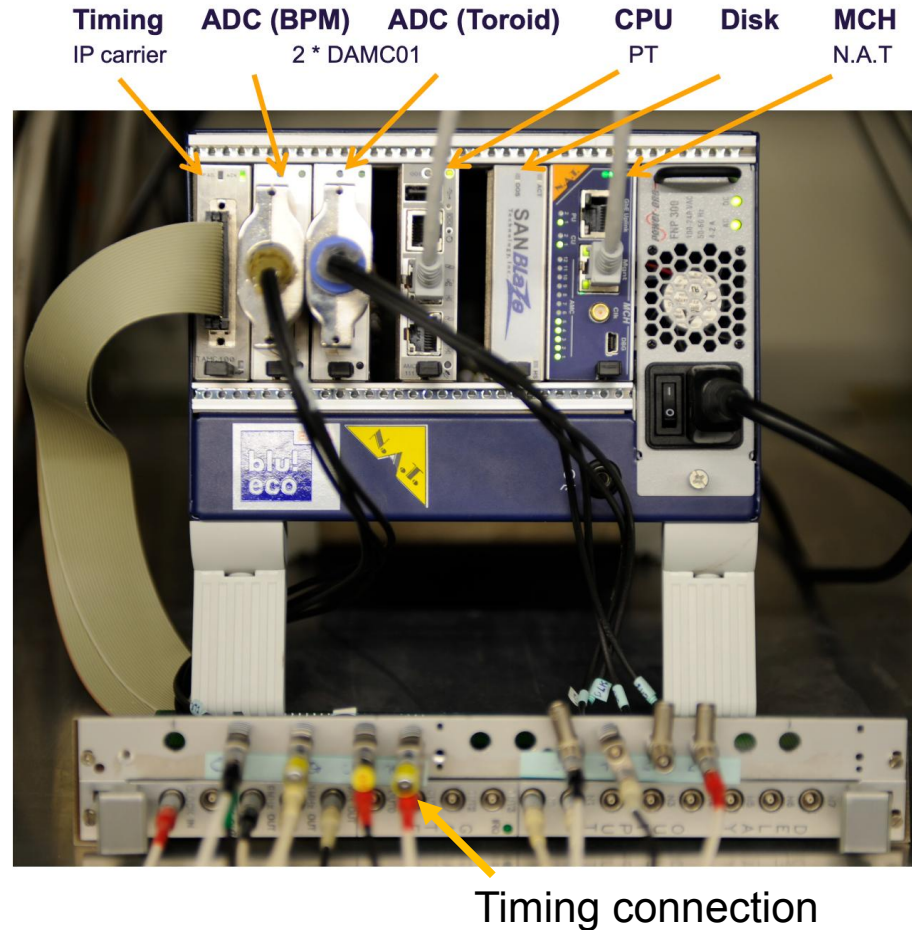
- Cables from the rear
- Internal Clock & Trigger distribution

Performance
+
Functions
+
Availability

First Test System Running @ DESY 2009

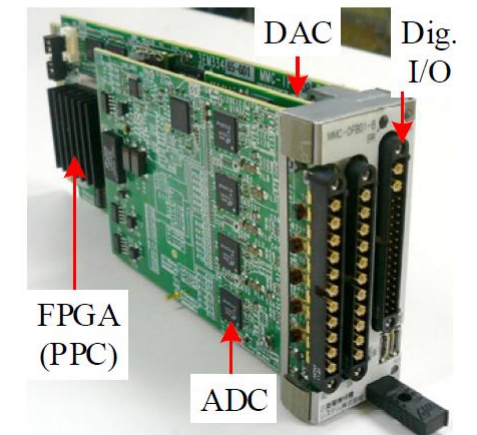
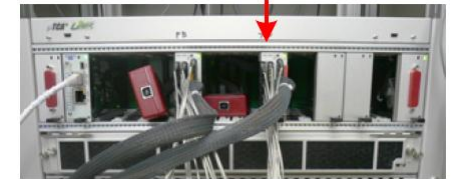
Used I/O modules:

- IP carrier to adapt the FLASH timing system
- Two channel ADC to read a Beam Position Monitor
- Two channel ADC to read the beam current



In parallel at KEK:
LLRF/BPM (2010)

μTCA board



@Shin Michizono

First one applying MicroTCA
to an accelerator

Lessons Learned

- It all worked well

But:

- Not enough space on panels for cables
 - Not enough space for analogue signal conditioning
 - Single-size AMC is too small
 - Clock and trigger distribution should be inside the crate
 - ...
-
- Conclusion: Start of MicroTCA.4 specification development **2009**

Specification of „xTCA family“

PICMG = PCI Industrial Computer Manufacturers Group



<https://www.picmg.org/>

- Non-profit organisation for standardization

MTCA.4 =
Micro
Telecommunications
Computing
Architecture
.4

Adopting Telcom standard to Research Needs

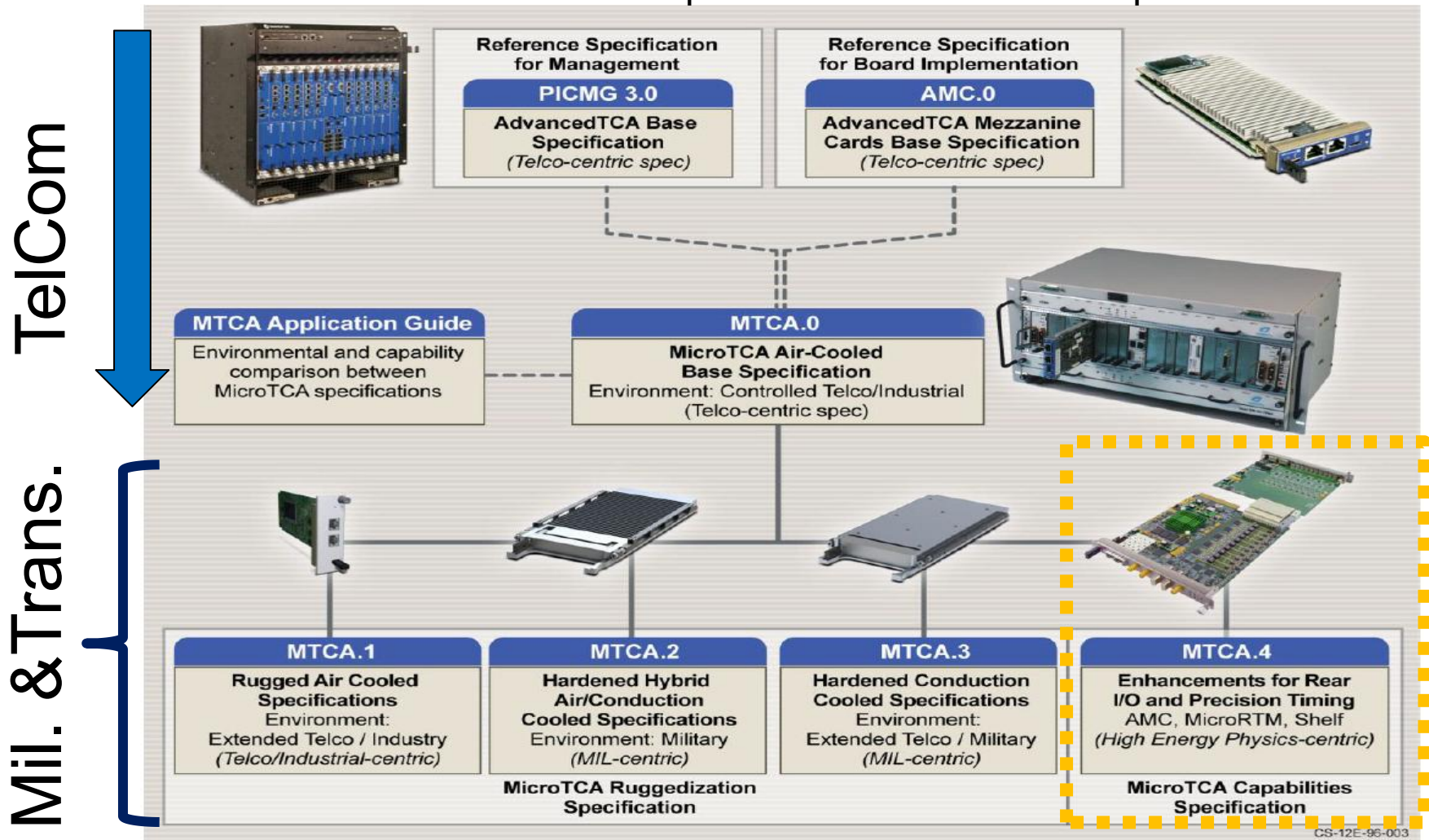


Figure 1. The MicroTCA family of specifications maximizes reuse from its ATCA and AMC parent specifications.

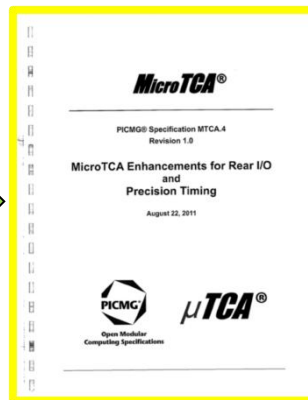
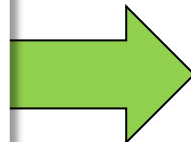
Ref:
MicroTCA
App. Guide



MicroTCA Specifications

xTCA for Physics“ interest group (38 partners): 03/2009

- **Research institutions:** SLAC, FNAL, IHEP, IPFN, ITER, DESY
- **Industry:** Connector-, Board-, Crate-, System vendors

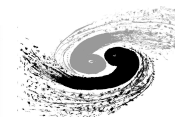


**MicroTCA.4
2011**

SLAC



Fermilab



Within 2 years!!!

MTCA.4 hardware platform : Crates

> „xTCA for Physics“ interest group (38 partners): 03/2009

- **Research institutions:** SLAC, FNAL, IHEP, IPFN, ITER, DESY
- **Industry:** Connector-, Board-, Crate-, System vendors

> Modular & Modern architecture

- Reusability + PCIe + Ethernet

> High reliability

- Redundant Power Supply / Fans
- Remote Maintenance through management

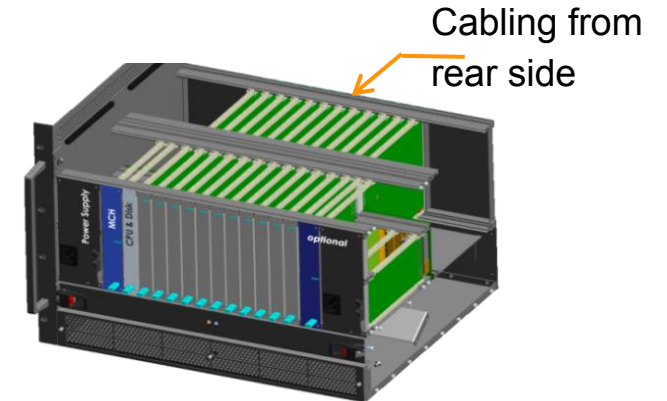
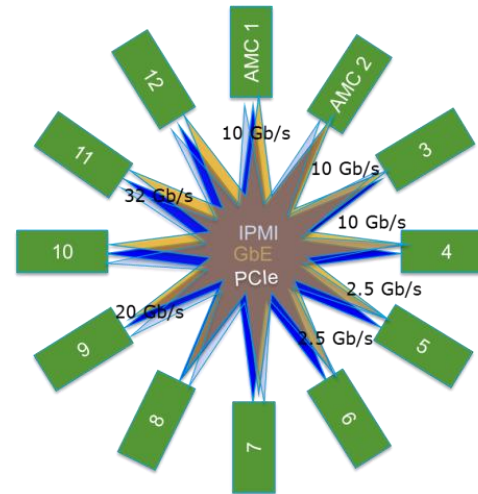
> High Performance

- 4x PCIe gen3 lane, 10GbE... 40 GBit/s
- Low analog noise ...

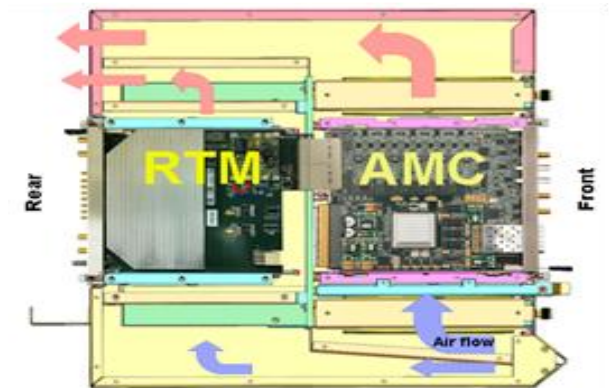
> Highly configurable / scalable

- Small to large system
- Different communication protocols / speed

$$V = \frac{E[Uptime]}{E[Uptime] + E[Downtime]}$$

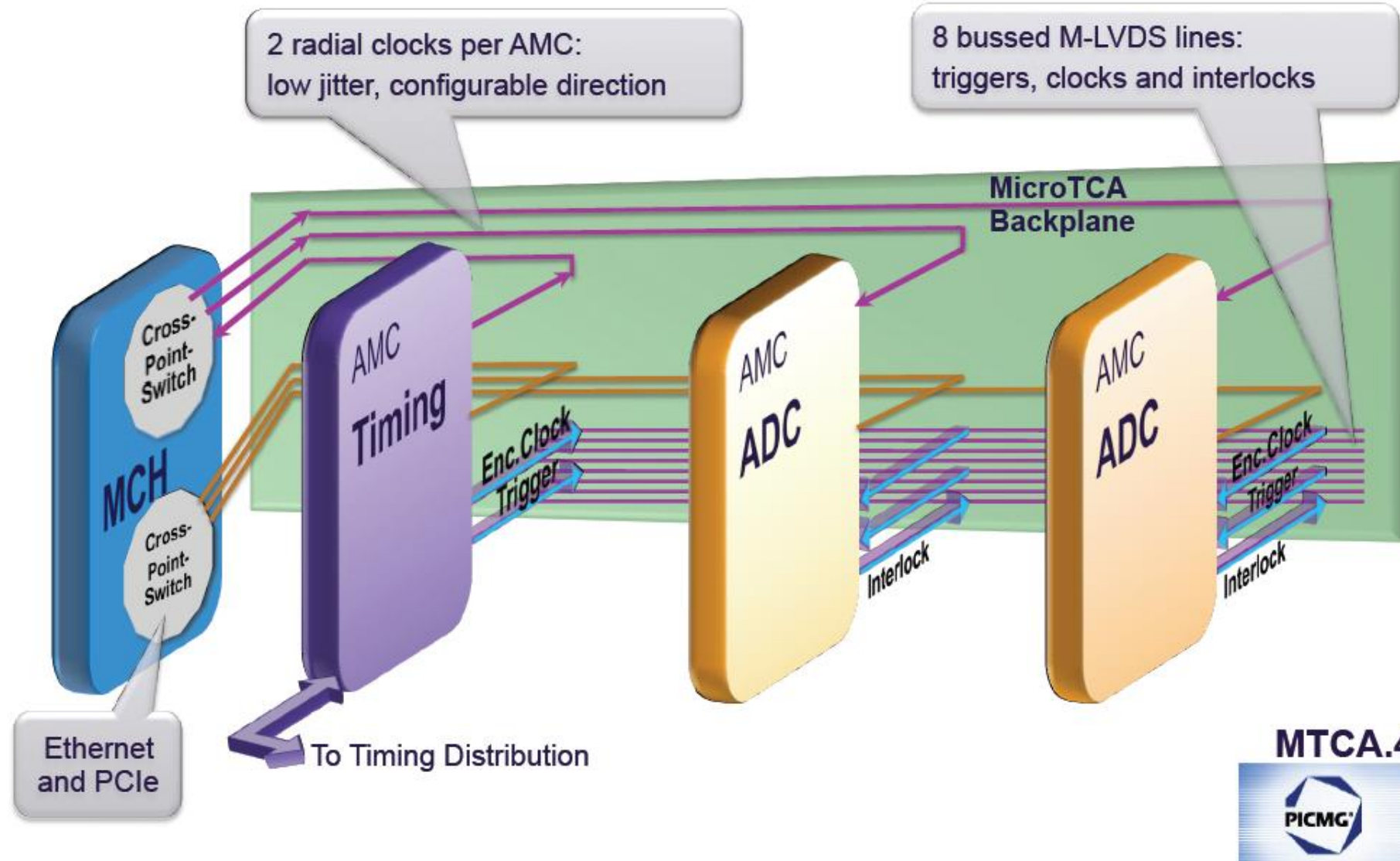


AMC – RTM concept



MTCA.4 hardware platform – precision timing/interlock

MCH =
MicroTCA
Carrier
Hub



MTCA.4



MicroTCA.4 hardware platform – Rear IO –

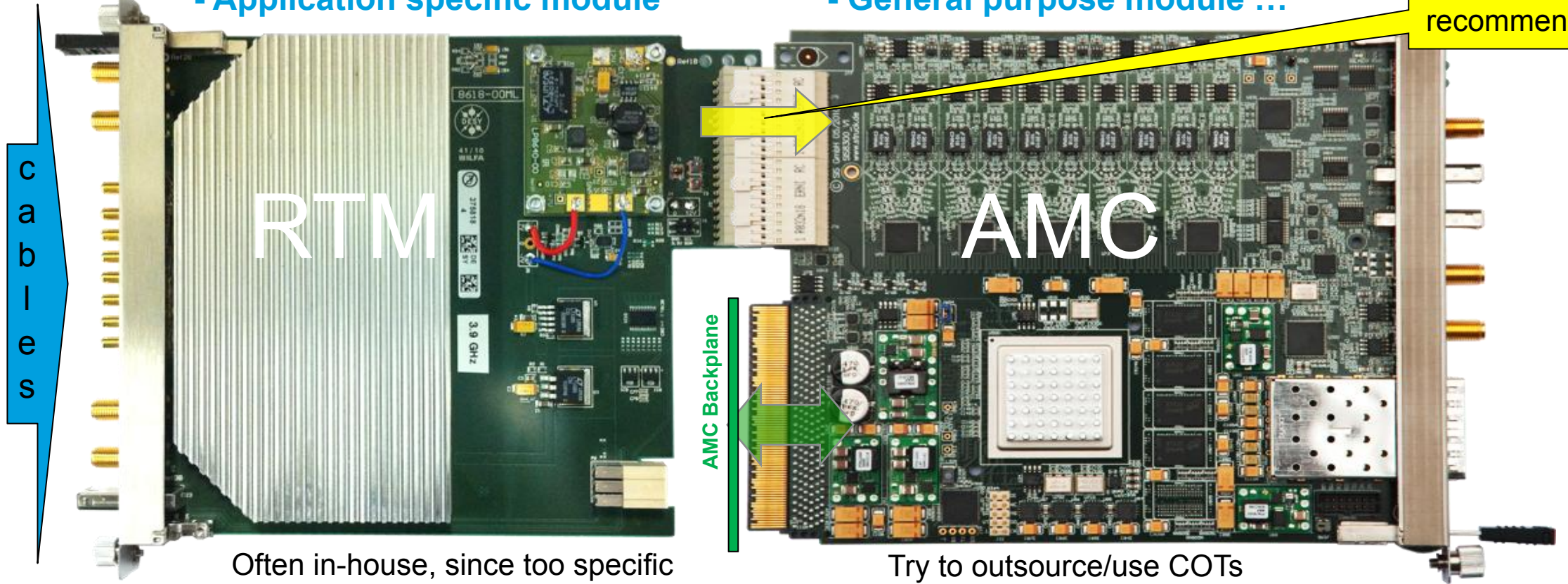
➤ **IO or Analogue Signal Conditioning**
(Rear-Transition Module)

➤ **Digital Signal Processing**
(Advanced-Mezzanine Card)

- Application specific module

- General purpose module ...

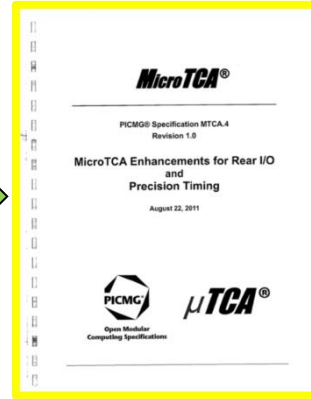
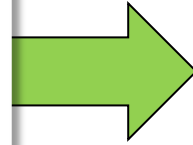
Zone 3 DESY
recommendation



- ➔ AMC-RTM split is an enormous benefit for obsolescence management
- ➔ And to tailor the hardware project to a smaller developer group



MicroTCA Specifications



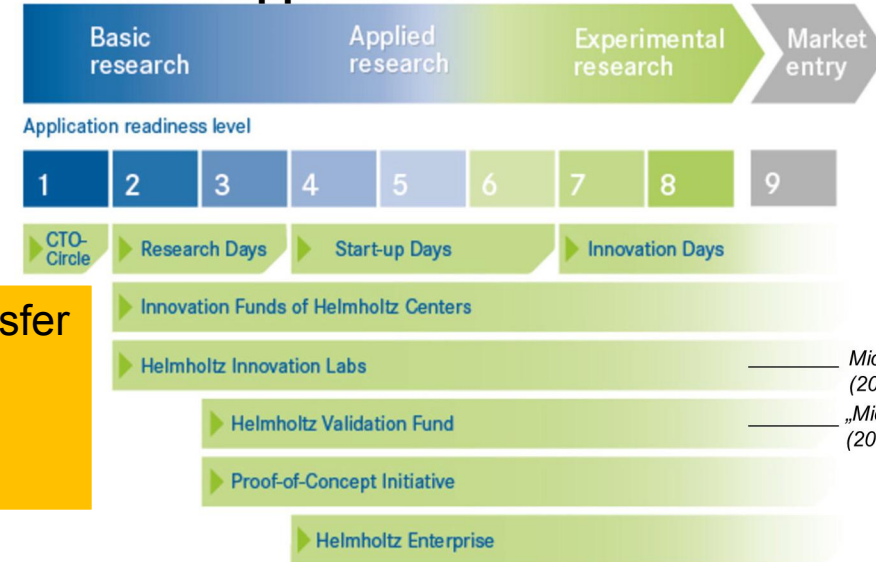
**MicroTCA.4
2011**

But it was a brand-new standard!!!

Market entry barriers

- Awareness
- missing technology know-how
- limited number of available products
- expensive (initial development costs)
- legacy systems in facilities
- liability of „newness“

Received support from the Helmholtz Association



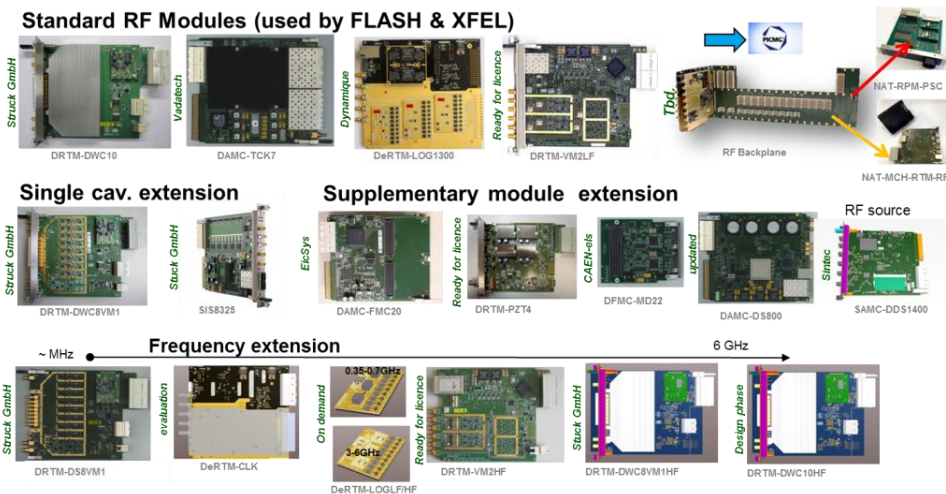
MicroTCA Technology Lab
(2017-2021)

„MicroTCA.4 for Industry“
(2012 -2015)

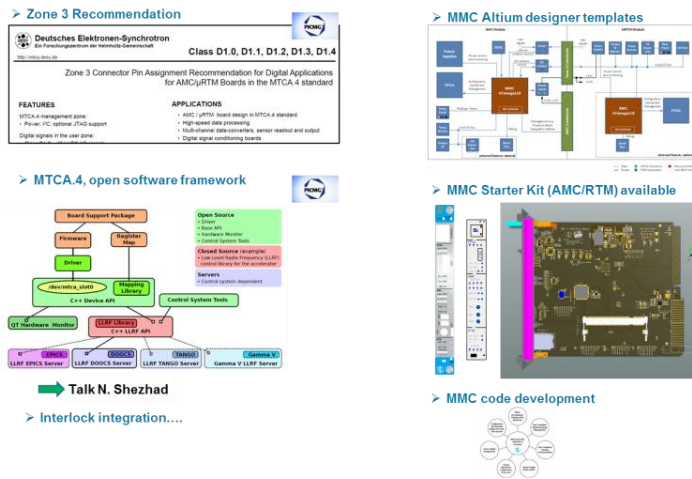
Technology Transfer
funds to support
dissemination of
MicroTCA

Helmholtz Validation Fund (2012-2015)

➤ Boards for RF controls & other appl.

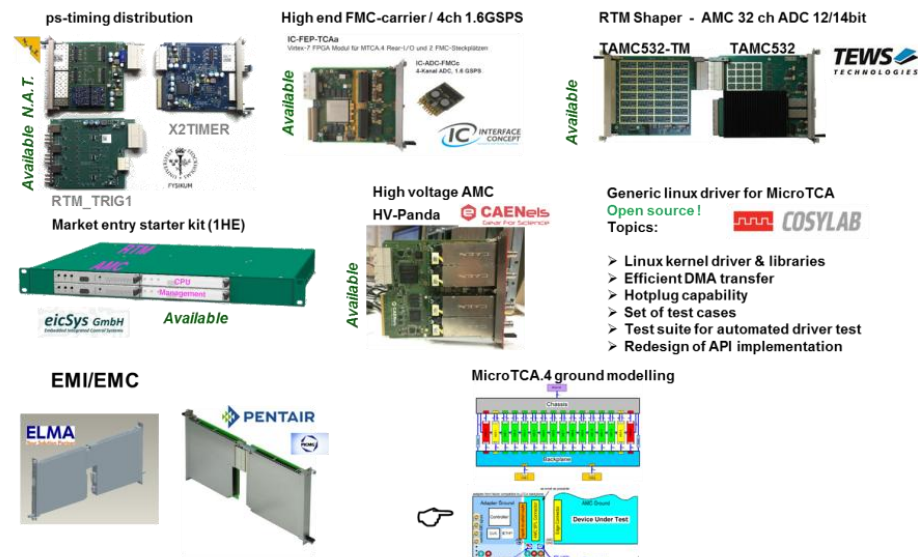


➤ Developments on standard & solutions

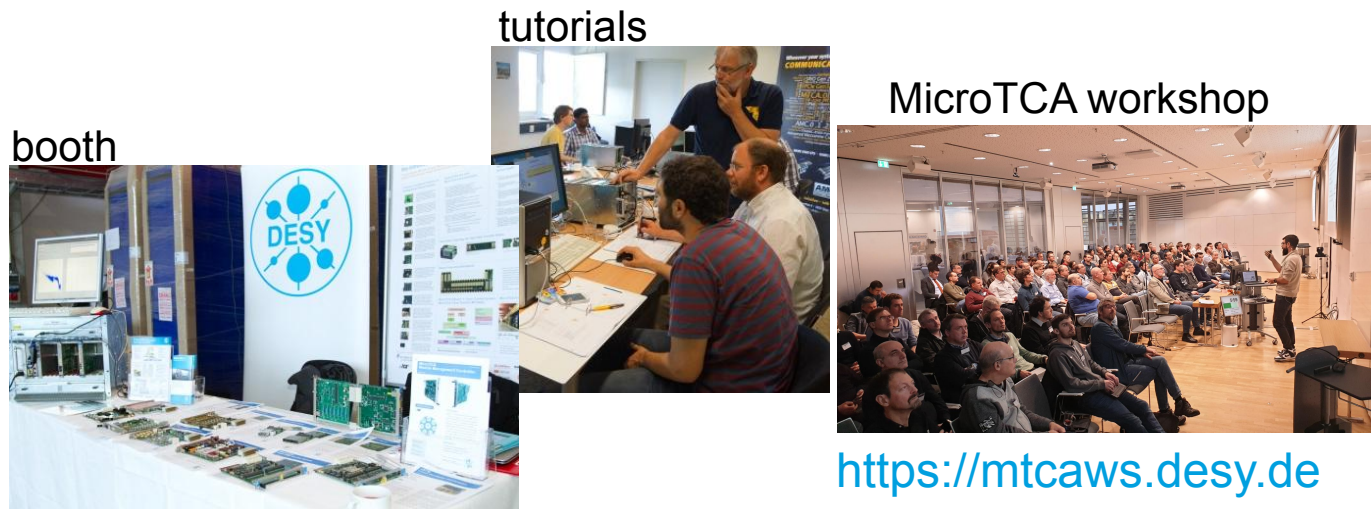


- 50 sub-projects were carried out and completed
- 25 new products on the market

➤ Extending product portfolio on market & EMI



➤ Support & Distribution & Marketing



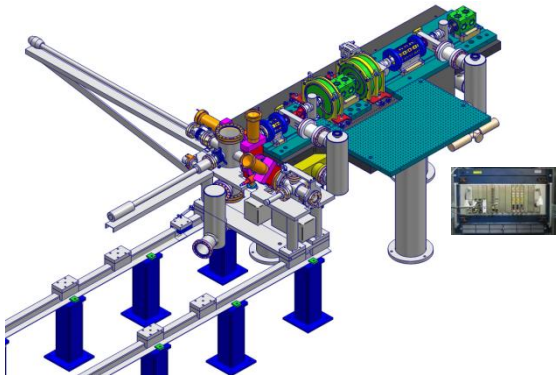
<https://mtcaws.desy.de>

Start small ...

- Equipping of facilities ...

3

2012 REGAE ~ 1 crate



OLD slide from 2015

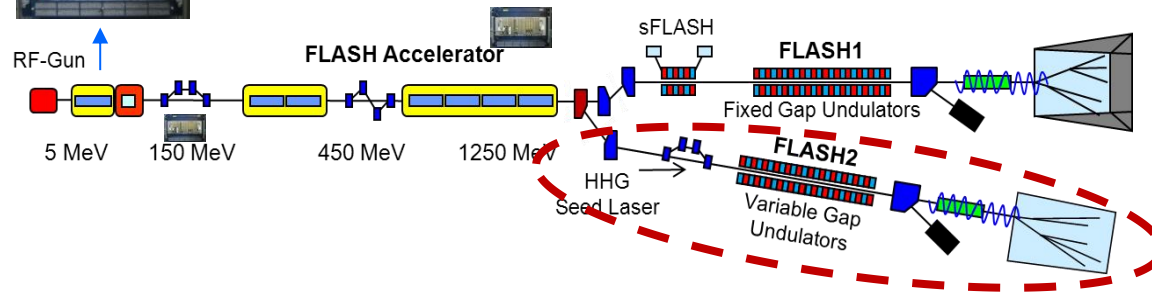
Labs for development ~ 15 crates
Operation at accelerators ~ 30 crates

> 30
> 400

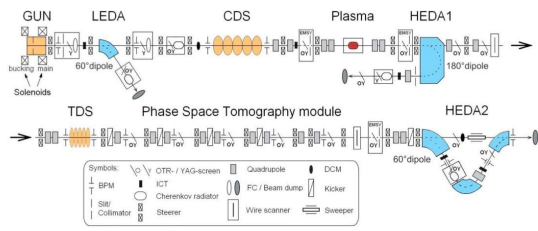
RF controls



2014 FLASH II ~ 20 crates



PITZ >13

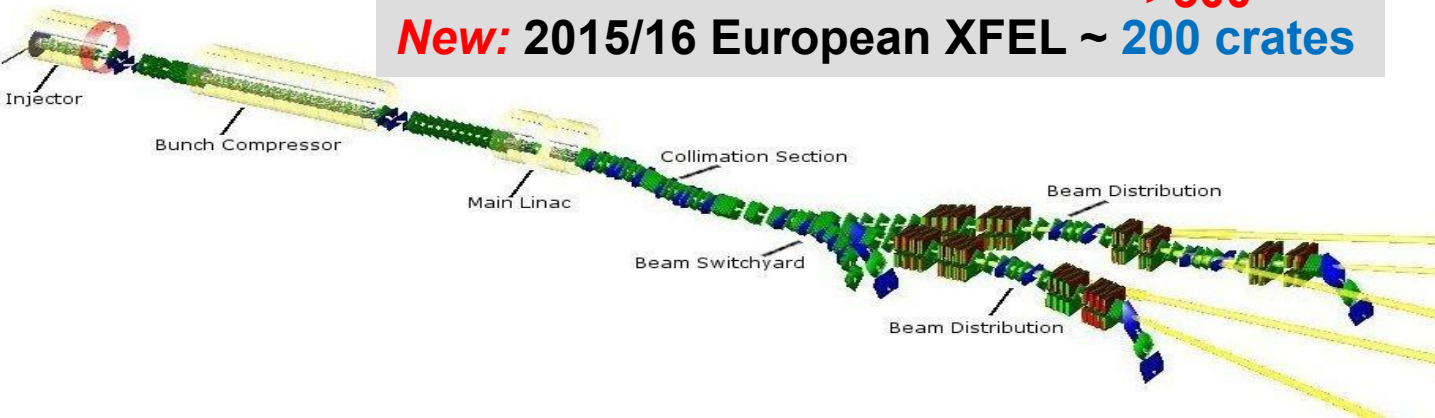


AMTF & CMTB >20

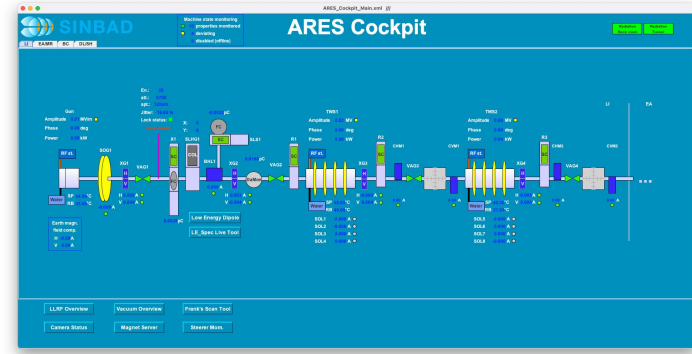


New: 2015/16 European XFEL ~ 200 crates

>300



ARES test accelerator >10



+ many more FALCO, KALDERA, Ts4i,...

Baseline configuration

MTCA.4 Platform as Integral Part of DESY Control System Standard

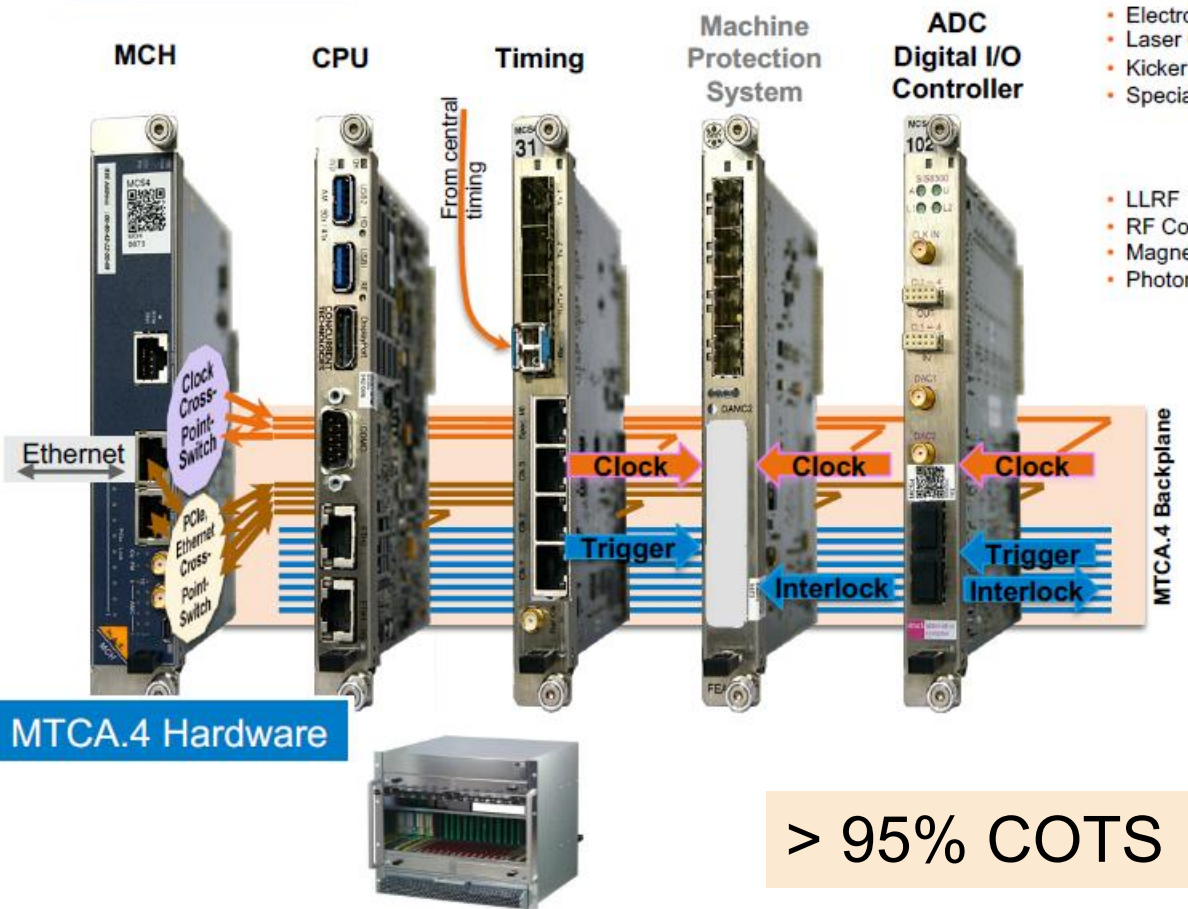
MTCA.4 platform connects and integrates well into the accelerator controls landscape!

Common Hardware Platform	MTCA.4 Platform (PICMG Standard)
	Industry Standards (PLC/OPC-UA)
	Computer center grade server nodes
Common Software Framework	Linux as operating system
	Open Source solutions
	DOOCS as base control system software framework
	Interfaces TINE, Karabo, EPICS v3 + v7, (Tango)

MTCA Common Modules

Application Modules (AMC + RTM)

Control System Applications



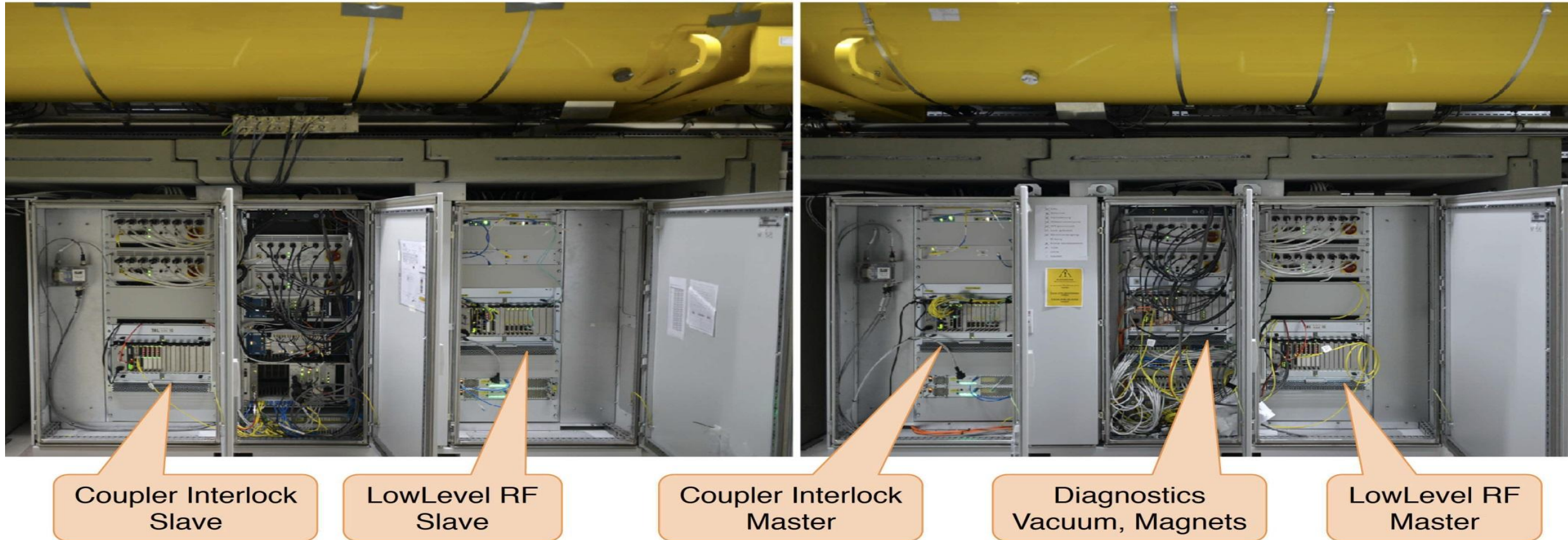
- Electron Beam Diagnostics
- Laser Controls
- Kicker Controls
- Special Diagnostics
 - Kalypso
 - CRISP
- LLRF
- RF Coupler Interlocks
- Magnet and Vacuum Controls
- Photon Beam Diagnostics
 - Gas Monitor Detector
 - Imagers
- ...



This section displays three key control system applications. The top screenshot shows 'MTCA.4 Remote Crate Management' with a rack of modules and a status window. The middle screenshot shows 'Node Management and Supervision' with a large green matrix display. The bottom screenshot shows 'DOOCS Data Acquisition for tagged, synchronized data recording' with multiple data plots and graphs.

European XFEL Linac

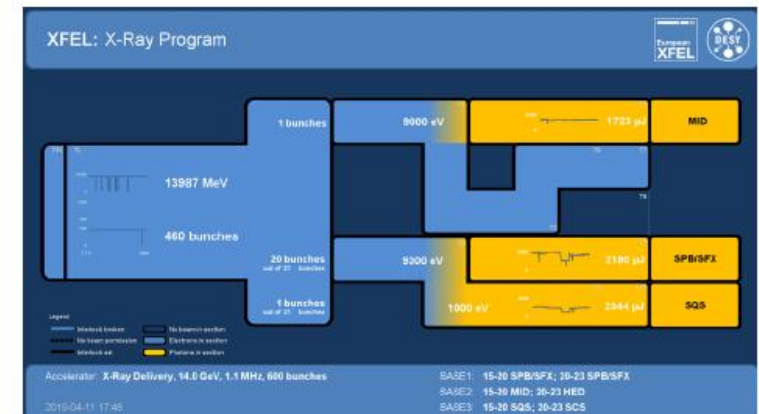
One RF Station = 4 Modules = 32 Cavities = 5 MicroTCA $\approx$ 50m



EuXFEL Status 2024

Statistics on MTCA components @ EuXFEL

- More than **30 different kinds of MTCA-based software applications** are in use
➔ Essential to have a portfolio of standard solutions for modular and efficient system integration!
- About **300 MTCA systems** @ EuXFEL as of 2024:
 - About **4800 MTCA modules** (AMC, RTM, P/S, MCH,...) installed e.g.
 - Timing System: 328 modules
 - DAMC2 AMC: 577 modules
 - DAMC-TCK + DAMC-FMC: 51 + 57 modules
 - SIS ADC AMC and RTM: 558 modules
 - Teledyne ADQ AMC / TEWS: 48 / 20 modules
 - Many RTM solutions for diagnostics BLM, Toroid, MPS, TIL, wire scanner, ...
- About 300 IPMI management server and watchdogs online – more than 2000 processes being monitored
- Core systems are running since end of 2013 and injector since 2015.
- Successful machine operations in production mode since 2017.**



Digital developments of the last years @ DESY

Strategy:

- Develop boards generically & cost efficient & for high yield product
- Non-exclusive production license to a company for dissemination

DAMC-FMC2ZUP
(Supercarrier)



(DMMC-STAMP)



DAMC-FMC1Z7IO



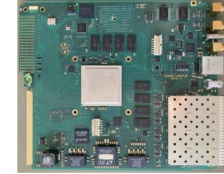
DAMC-DS812ZUP



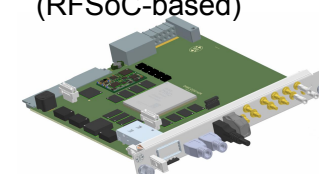
DAMC-MOTCTRL



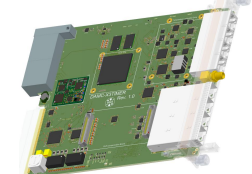
DAMC-UNIZUP



DAMC-DS5014DR
(RFSoc-based)



DAMC-X3Timer



2019

2020

2021

2022

2023

2024

2025



...

10-year list of license contracts: Struck, CAENels, AIES, Interface Concept, Sintec, MSU, MRF, Embeck, PAL, Piezotechnics, N.A.T, PWI, Durotronic, BEJING DAQ Technology, ESS, Zeiss, KVG, Atom Computing, AWS, D-TACQ, Soleil, ESO, Universal Quantum,...

Licensing Strategy

- We promote an ecosystem – this is part of the “DNA” of the group
- MSK has licensed almost all developments: components are available for us **and** for third parties
- Strategy: Concentrate on the application; purchase all standard infrastructure “off-the-shelf”.

AMC

DAMC-FMC2ZUP
Zynq Ultrascale+ MPSoC based Dual FMC/FMC+ Carrier Board with D1.1 RTM support



DAMC-FMC1Z7I0
Cost-Optimized IO Controller Board with one FMC socket



DAMC-FMC25
AMC Dual HPC-FMC Carrier



DAMC-FMC20
AMC Dual FMC Carrier Board



DAMC-TCK7
AMC Data Processing and Telecommunication Module



X2TIMER
AMC Fast Timing System



DAMC-UNIZUP



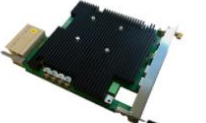
ADVANCED MEZZANINE CARDS
AMC boards (Advanced Mezzanine Card) are the key components of a MicroTCA system. Within the MicroTCA-4 crate, AMCs are placed in the front of the crate. They are connected by a high-speed backplane that carries serial links, power and management data. Every AMC card is monitored and managed. This allows hot-plug, hot-swap, health monitoring and thermal management of the modules.

There are six standard sizes of AMCs: single and double width as well as compact, mid-size and full-size height. Every combination of width and height is valid. The power consumption of an AMC is divided into 3.3V management power plus 12V payload power.
AMC boards are used for digital processing. On every AMC board there is a controlling unit called MMC (Module Management Controller).
Plugging in the AMC board to the MTCA crate connects the board to the backplane of the crate. The backplane ensures the connection of the AMC boards with every other AMC board in the crate. Plus, every AMC board is connected to the MCH (MicroTCA Carrier Hub), which is the overall management card of the MTCA system. The MCH gives management power to the AMCs first. This power is used to check if everything is ok with the AMC. If the MMC, the managing unit on the AMC detects no problems on the board, the MCH gives payload power to the AMC.

Clustering of AMCs in the system is possible.

RTM

DRTM-MXC
Mobile GPU Carrier



DRTM-AD84
RTM 8Ch ADC, 4Ch DAC



DRTM-PZT4
RTM 4 Channel Piezo Driver



REAR-TRANSITION-MODULES
RTMs, the rear-transition-modules, are extension boards that are placed in the back of the MTCA-4 crate. They directly connect to the front AMCs via the Zone 3 connector. The possibility to separate analogue and digital functions by moving sensitive analogue electronics to the RTM is one of the key strengths of MicroTCA-4.

DRTM-DWC8VM1
RTM 8 Channel Down-Converter 1 Channel Up-Converter



DRTM-LOG1300
eRTM Local Oscillator Generation



DRTM-VM2LF
RTM 2 Channel Vector Modulator Low Frequency



DRTM-DWC10
RTM 10 Channel Down-Converter



DRTM-DS8VM1
RTM 8-Channel Direct Sampling 1-Channel Vector Modulator



DRTM-VM2HF
RTM 2 Channel Vector Modulator High Frequency





DES Y MMC Stamp

FMC

DFMC-DS800
FMC Direct-Sampling A-D Converter



DFMC-AD16
FMC 16-channel A-D Converter



DFMC-TESTADP
FMC Loopback Adapter



FPGA MEZZANINE CARDS
FPGA Mezzanine Card (FMC) is a standard defining I/O mezzanine cards and corresponding carrier boards. Huge ecosystem of carrier boards, both in MicroTCA format and standalone boards, provides a good prototyping platform, suitable for experimental physics and industrial applications. The FMC mezzanine format provides additional degree of modularity for a lot of I/O applications, such as ADC and DAC boards, or communications boards.

DFMC-MD22
FMC 2 channel stepper motor driver



DFMC-SFP4
FMC 4-Channel SFP+ Adapter



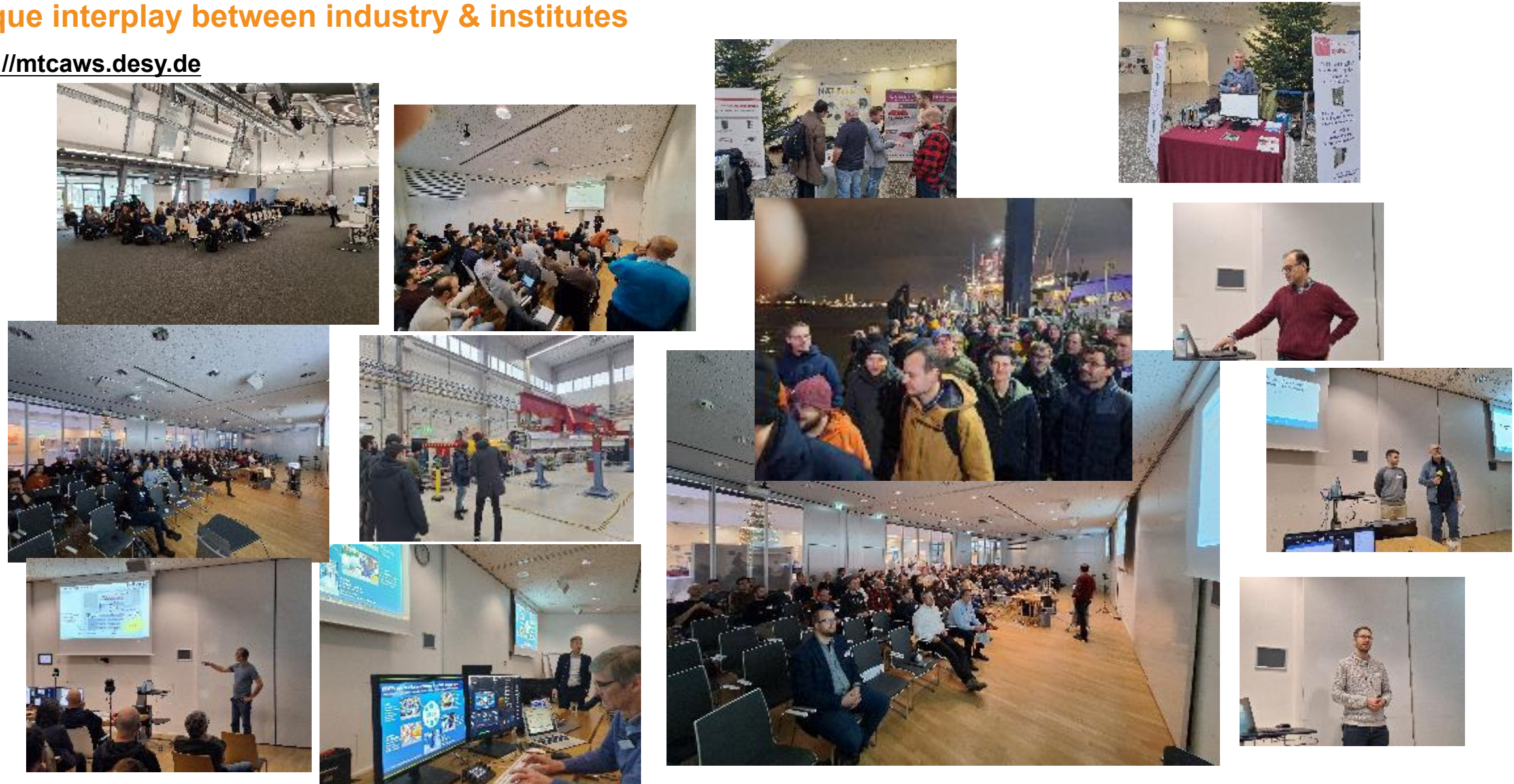
DFMC-UNI-I0
FMC Multi-Purpose I/O Board



14th MicroTCA Workshop (2025)

Unique interplay between industry & institutes

<https://mtcaws.desy.de>



13th MicroTCA Workshop: participating entities...

Institutes:



Exhibitors:



Industry:



Universities:



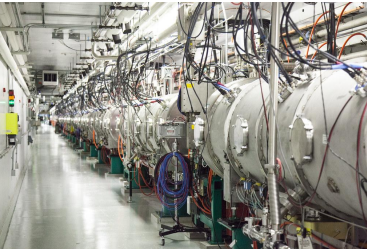
Further dissemination of MicroTCA...

Large-scale accelerators:

→ Very international

America

SNS

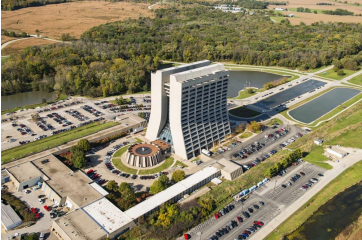


Thomas Justice (ORNL)

APS-U



Fermilab



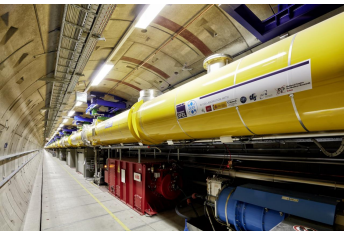
Andrew Withbeck (FNAL)

Sirius



Europe

EuXFEL



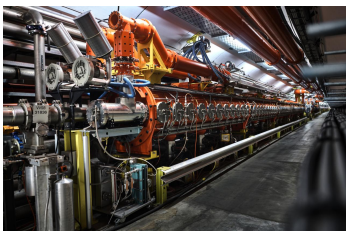
Tim Wilksen (DESY)

ESS



Faye Chicken (ESS)

CERN



F. Ferreira (CERN)

FAIR - GSI



Diamond



Alba



MYRRHA *new*



K. Meeus(SCK-CEN)

Soleil



Bessy



PETRA IV



Asia

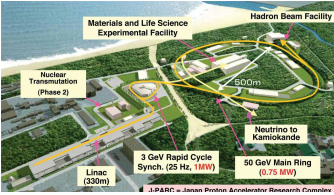
PAL-FEL



Spring 8



J-PARC



Fumihiko Tamura (J-Parc)
Yasuyuki Sugiyama (KEK)

CSNS



SXFEL



HEPS



Fang Liu (IHEP)
BEPC *new*



HALF/HLS-II



S3FEL... *new*



LUTF *new*



Ansto



Community is steadily growing...

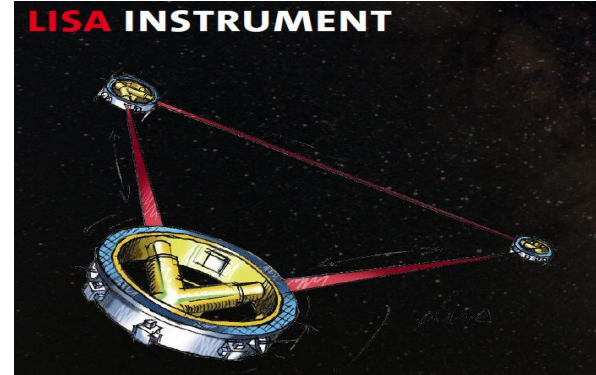
Other research communities ...

→ Cross discipline synergies

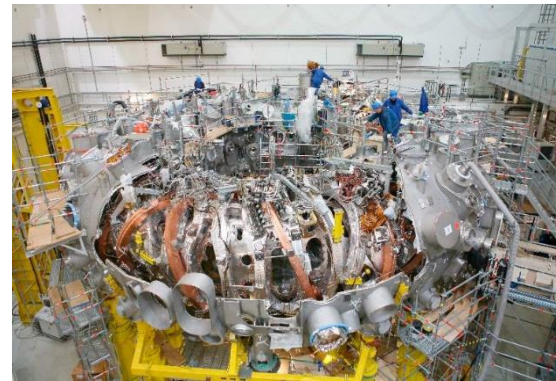
Astrophysics Observatories



Gravitational Wave Detection



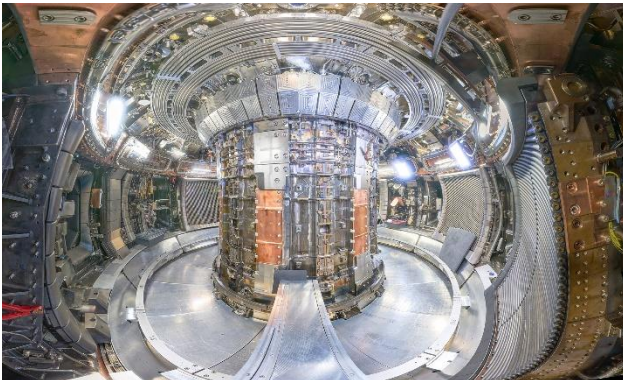
Fusion: W7-X Stellerator



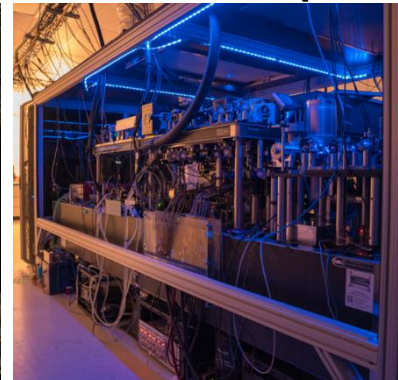
Fusion: ITER



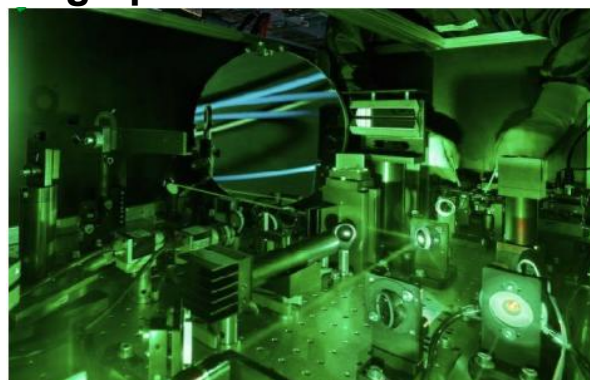
Fusion: ASDEX



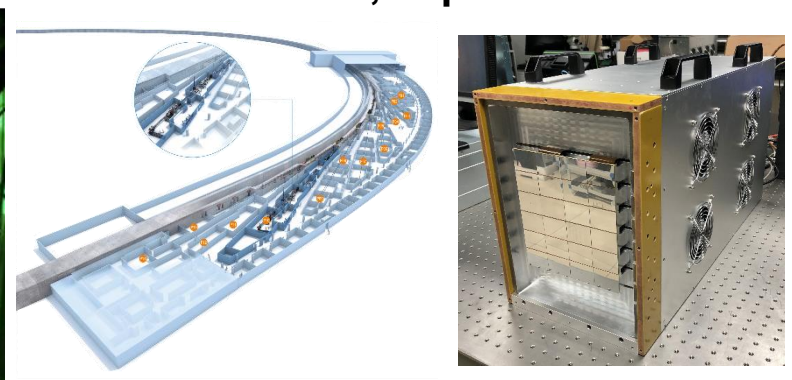
Quantum Comp.



High power lasers

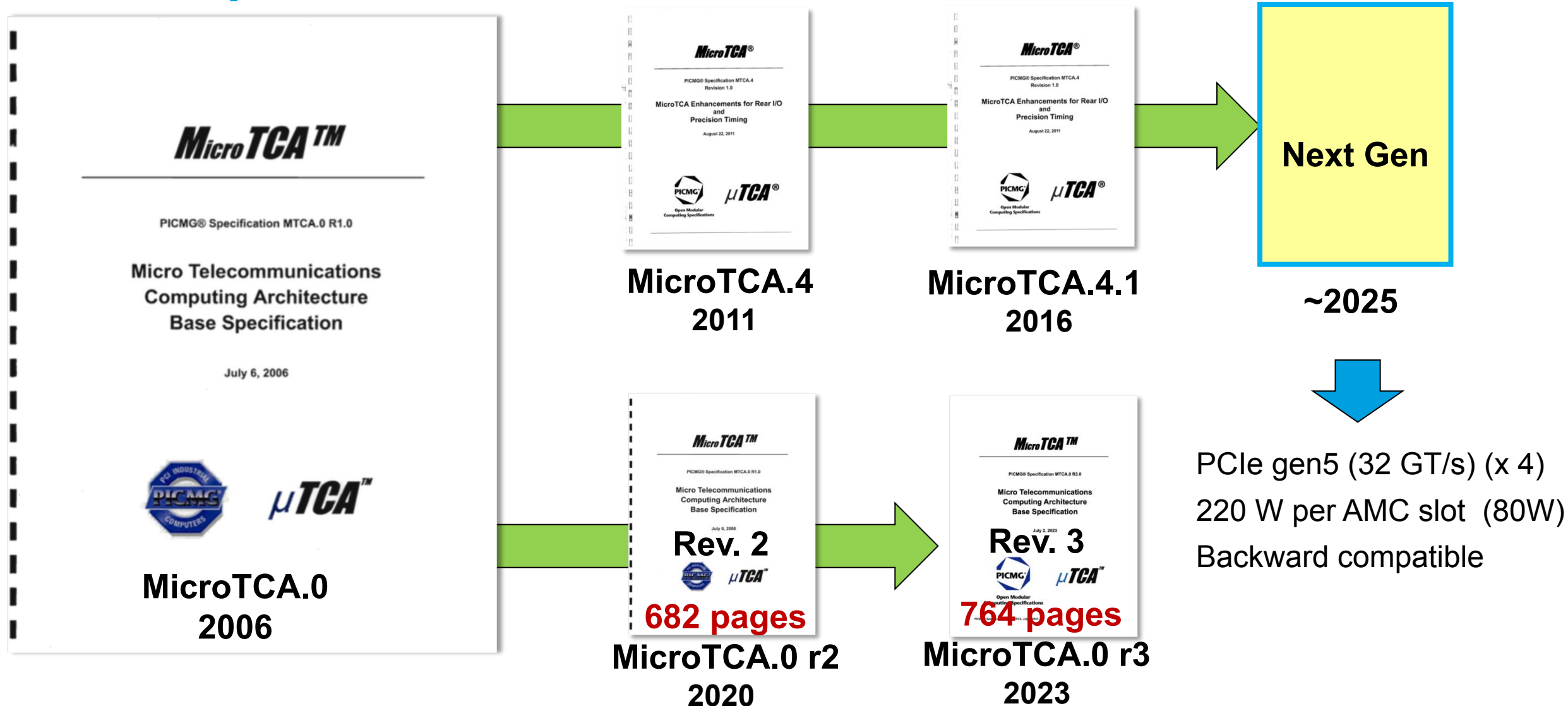


Photon beamline, exp. and detectors





MicroTCA Specifications

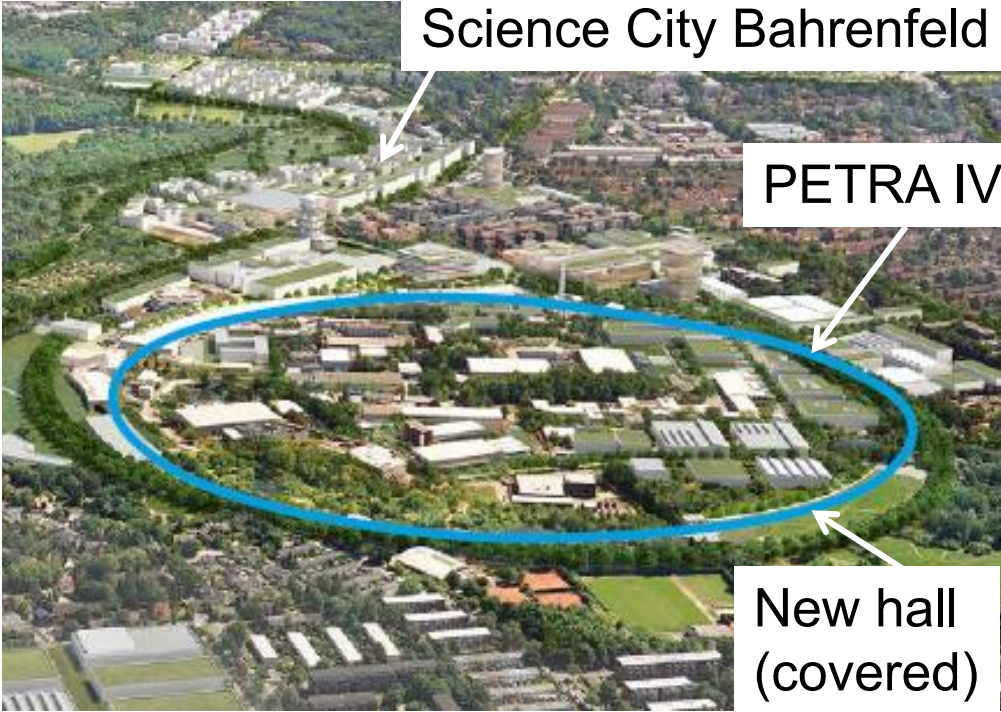
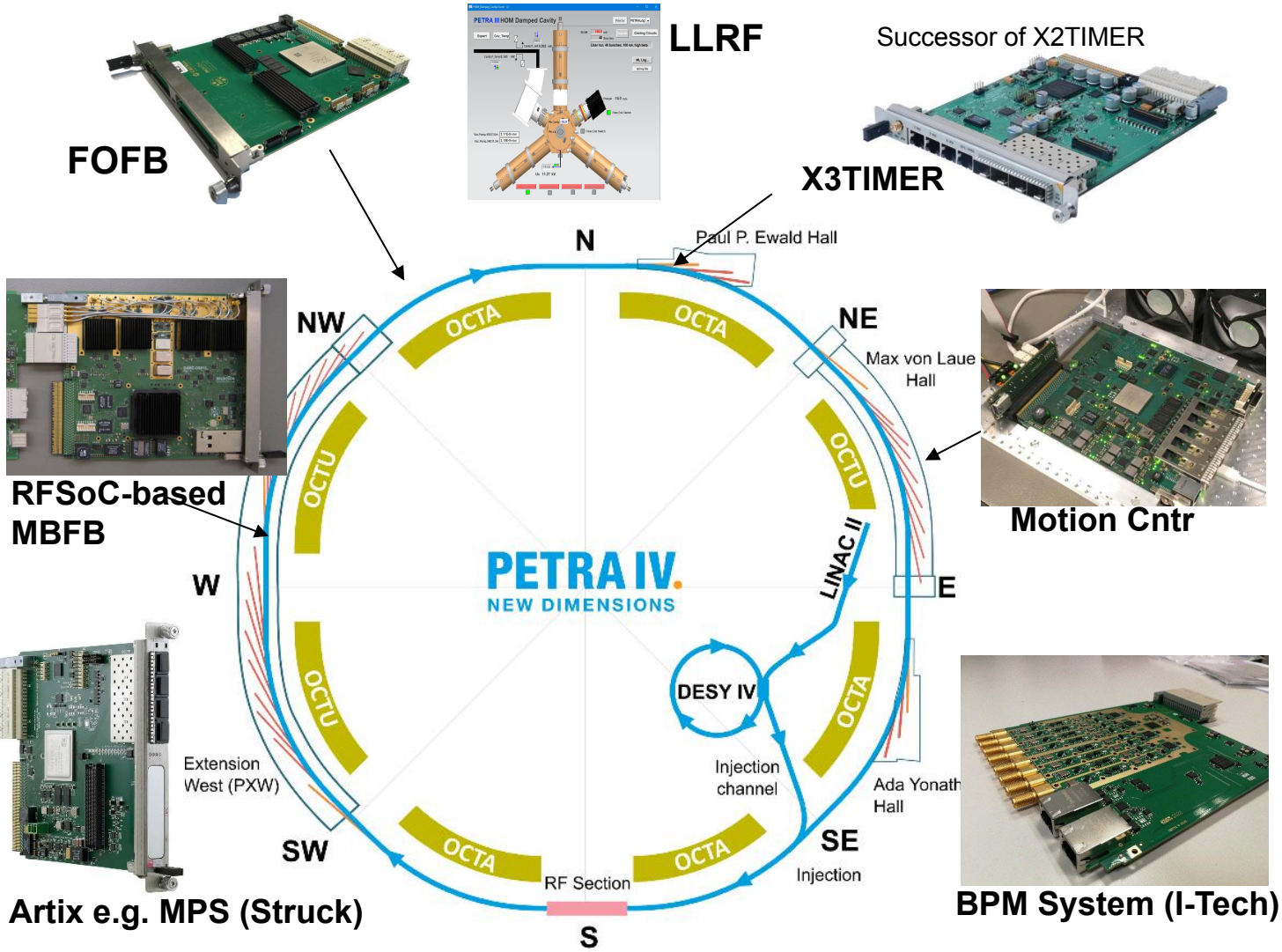


Summary: It's a worldwide growing ecosystem



MicroTCA Modules for PETRA IV Project

Hardware portfolio PETRA IV (incomplete)



+ beamline control
&
detector readout

Expanding portfolio towards SR

Thanks for the attention

Key takeaways

- Remote management
- AMC – RTM split
- Modern & high-performing
- Modularity & configurable
- Mostly COTS
- License to partners
- Open standard
- Ecosystem grows
- Price...
 - ➔ serviceability, fault prediction, and reduced MTTR
 - ➔ easy obsolescence management
 - ➔ became enabling technology
 - ➔ easy-to-extend facilities
 - ➔ reduces production & development resources
 - ➔ for the complex board, good strategy (product owner)
 - ➔ fundamental!
 - ➔ more and more community support is given
 - ➔ depends mostly on functions & QC in the company
 - ➔ availability of the product for 10+ years + service
 - ➔ pays off due to reduced cost for maintainability