MicroTCA Specification Development

Kay Rehlich, DESY

19. September 2024

The 2024 MicroTCA/ATCA for Large Scientific Facility Control International Workshop
University of Science and Technology of China (USTC), in Hefei, China

SLAC & DESY Reliability Workshop 2005

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

Example:

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

Availability = MTBF / (MTBF + MTTR)

0.9999 = 50000 / (50000 + 5)

Mean Time Between Failures

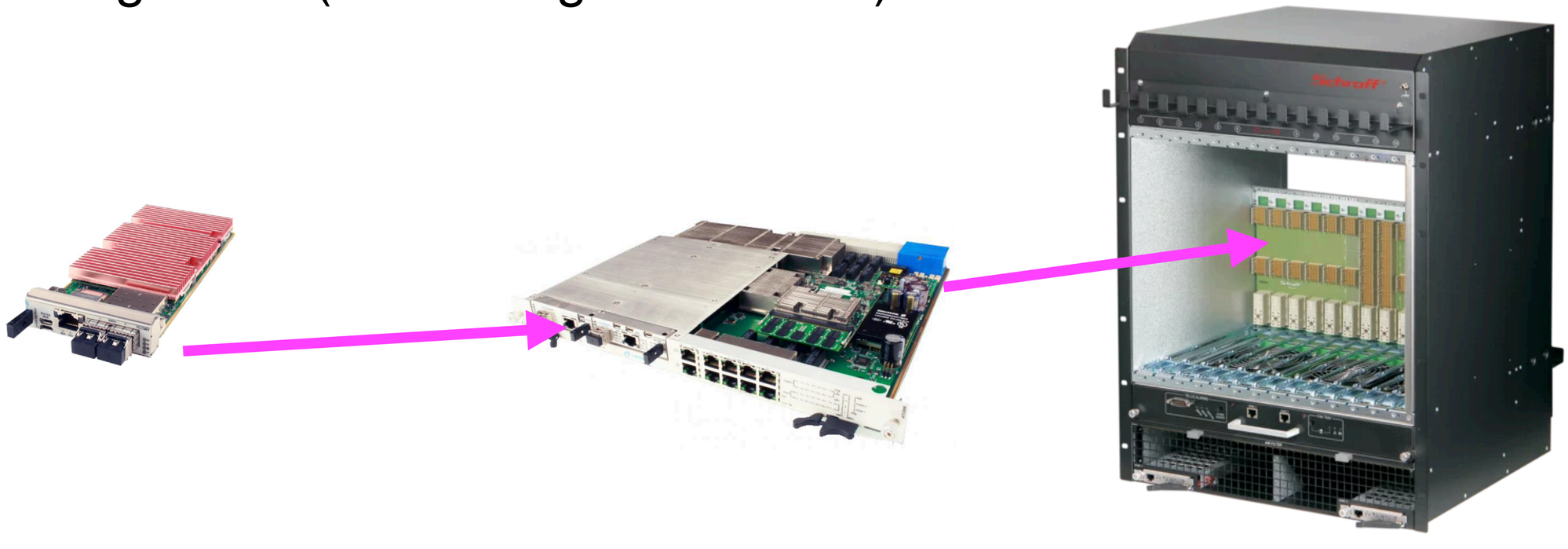
MTBF Estimates for R1304RPMSHOR

Subassembly (Server in 40C ambient air)	Server Model R1304RPMSHOR	
	MTBF (hours)	FIT (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 fan

ATCA: a Standard Developed by Telecom Industry

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

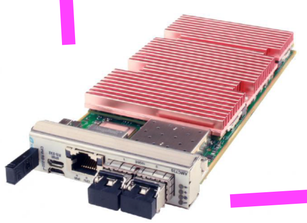


MicroTCA: a Standard Developed by Telecom Industry

MicroTCA: 2006

A scalable family with the same system architecture

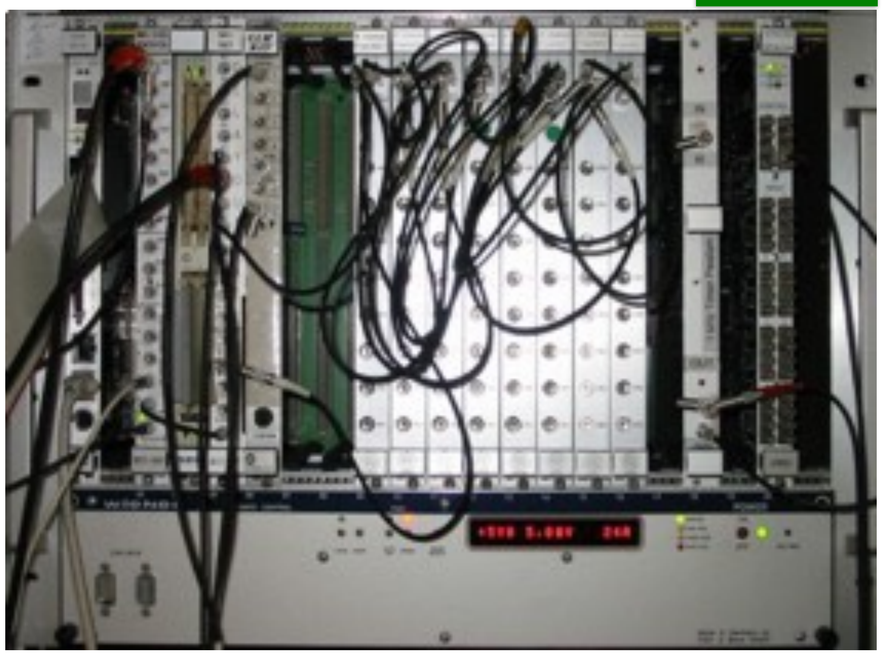
ATCA: 2003



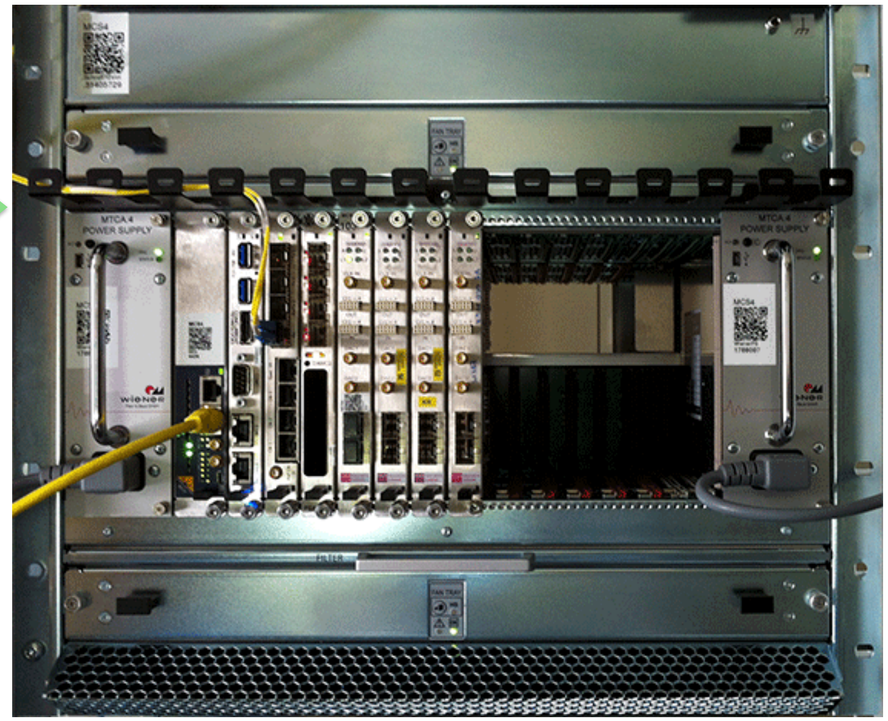
AMC

VME —> MicroTCA Migration @ DESY

- Since 1993 … *VME*bus at FLASH



µTCA®

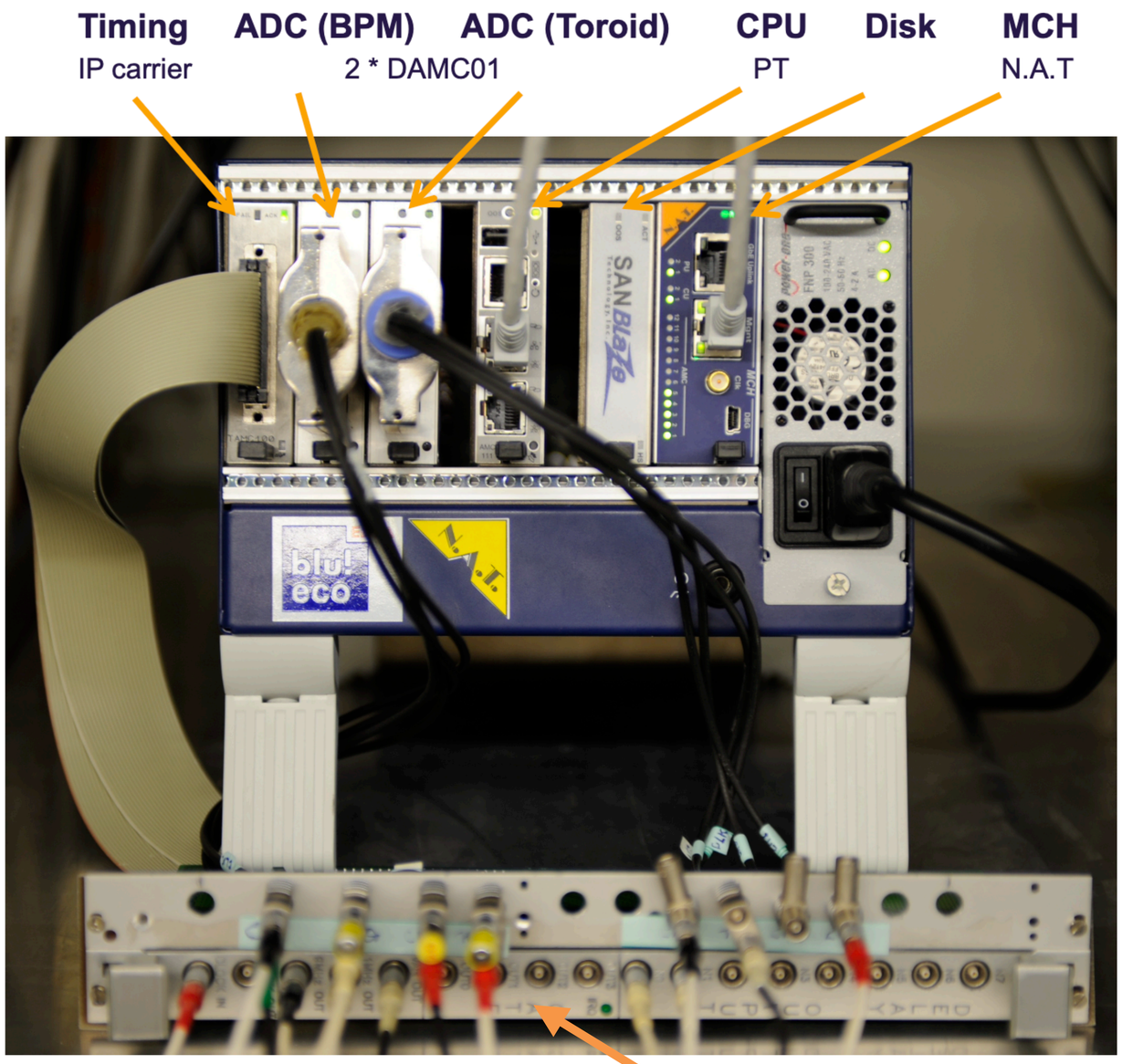


- Cables from rear
- Internal Clock & Trigger distribution
- Redundancy of fans
- Redundancy of power supplies possible
- Modern, high-speed Datentransfer
- Excellent signal quality for analog IO
- Remote management

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



Lessons Learned

- It all worked well
- But:
  - Not enough space on panels for cables
  - Not enough space for analog signal conditioning
  - Single size AMC is too small
  - Clock and trigger distribution should be inside crate
  - …

- Conclusion: Start of MicroTCA.4 specification development **2009**

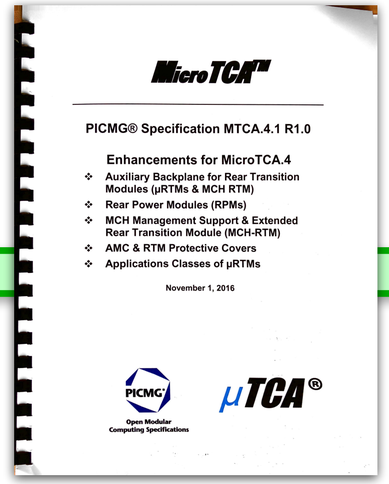
MicroTCA Specifications

MicroTCA.0

2006

MicroTCA.4

2011



MicroTCA.4.1

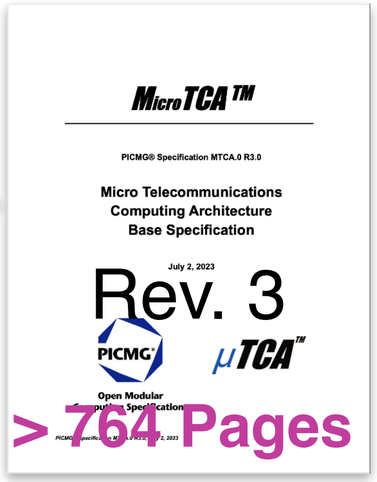
2016

Next Gen

2024

MicroTCA.0 r2

2020

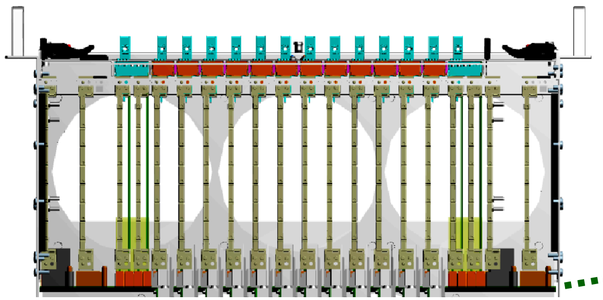


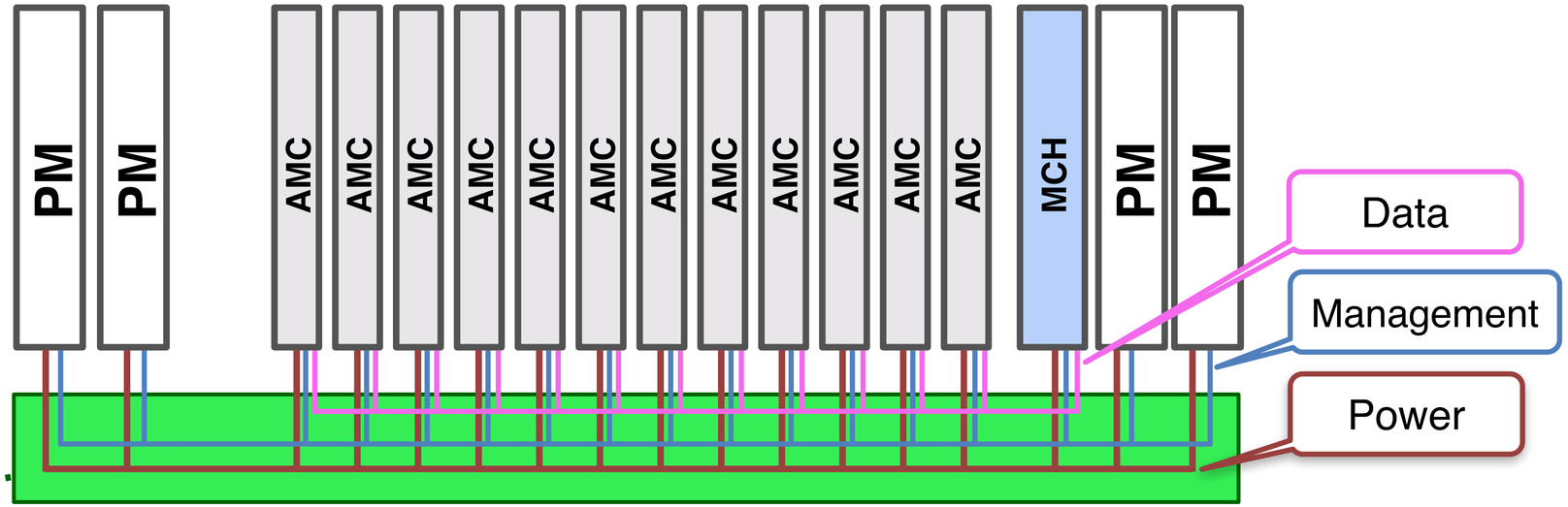
MicroTCA.0 r3

2023

MicroTCA Generations: **MTCA.0** MTCA.4 MTCA.4.1

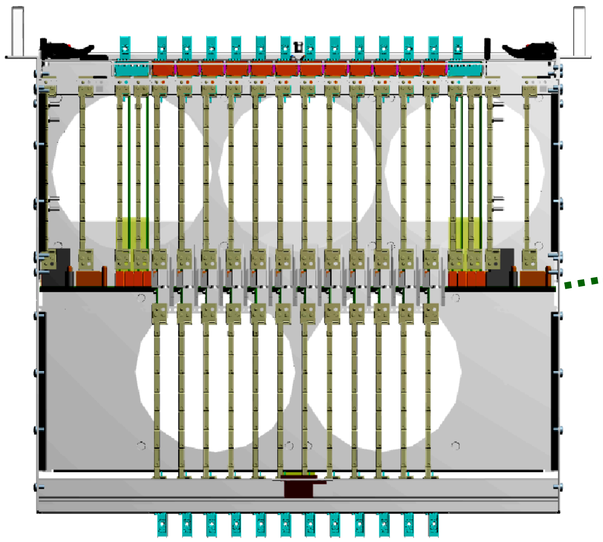
Front Side



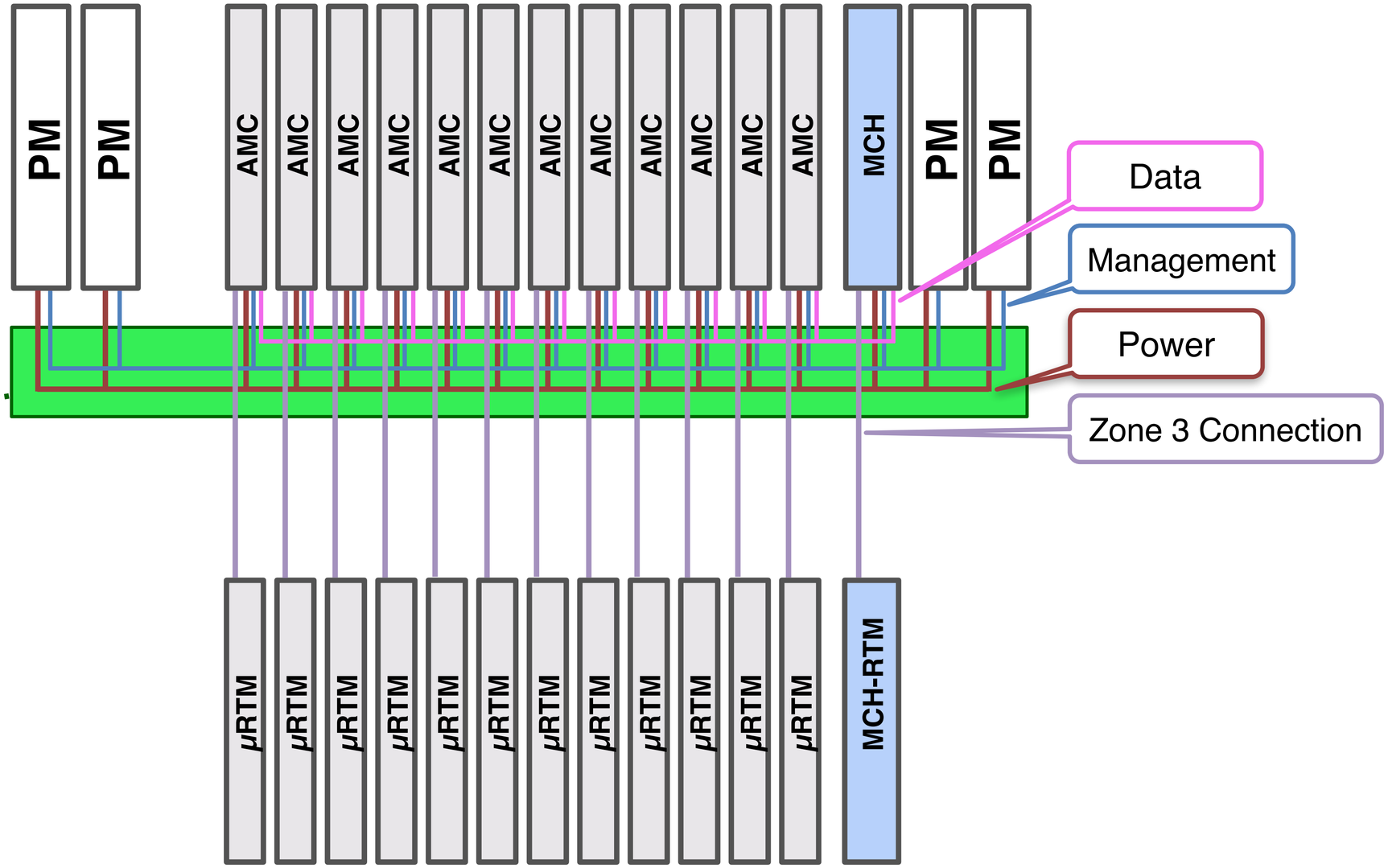


MicroTCA Generations: MTCA.0 **MTCA.4** MTCA.4.1

Front Side

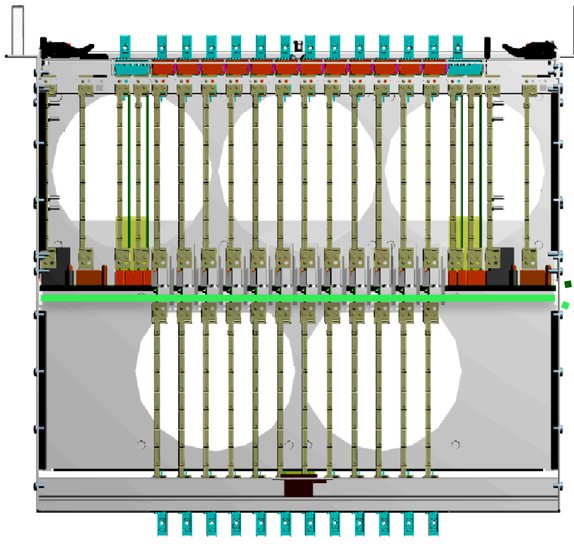


Rear Side

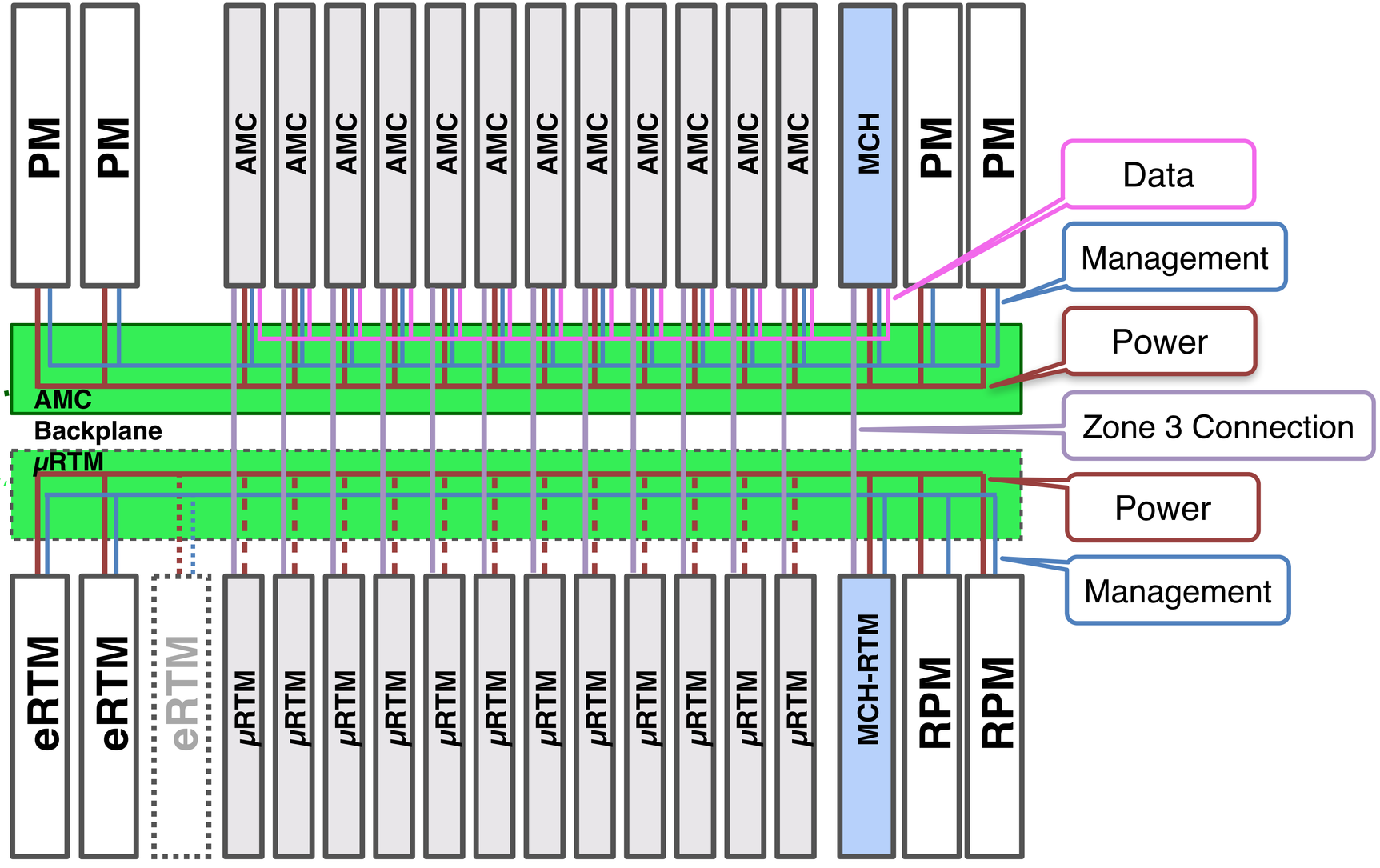


MicroTCA Generations: MTCA.0 MTCA.4 **MTCA.4.1**

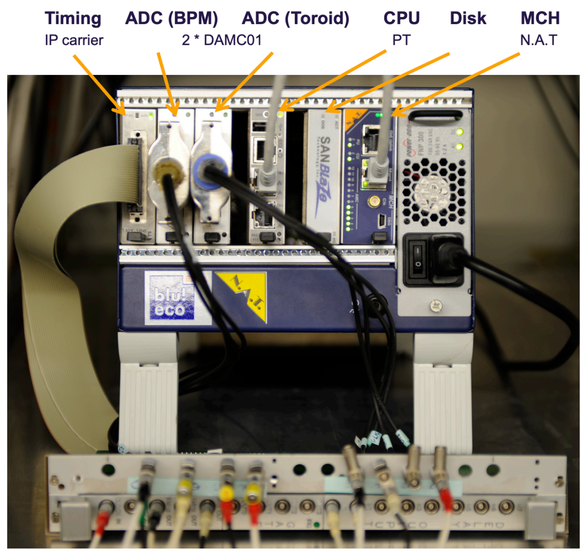
Front Side



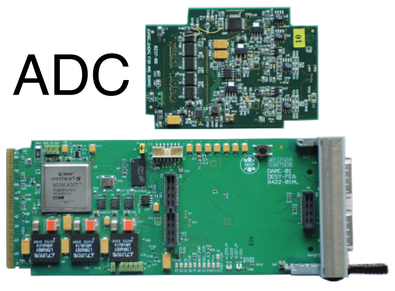
Rear Side



MTCA.0 First Test 2009 —> 2011 First LLRF MTCA.4

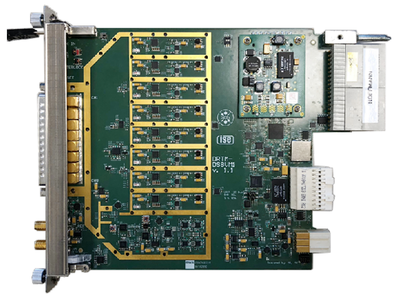


2009

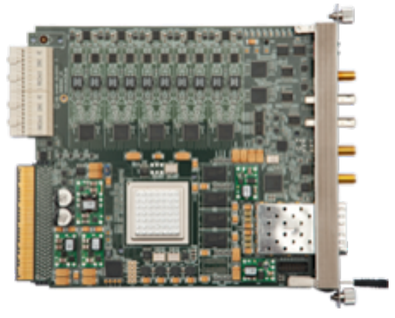


DESY DAMC1

2011



Downconverter



SIS8300

Requirements for the Next Generation of MicroTCA

- **Keep the standard alive for a long time**
  - Adapt state-of-the-art technology

- **Backward compatibility**
  - All existing AMC modules MUST be usable

- **Protect your Investment**
  - Modularity: Just upgrade parts that limit your system

Motivation: Technology Trends

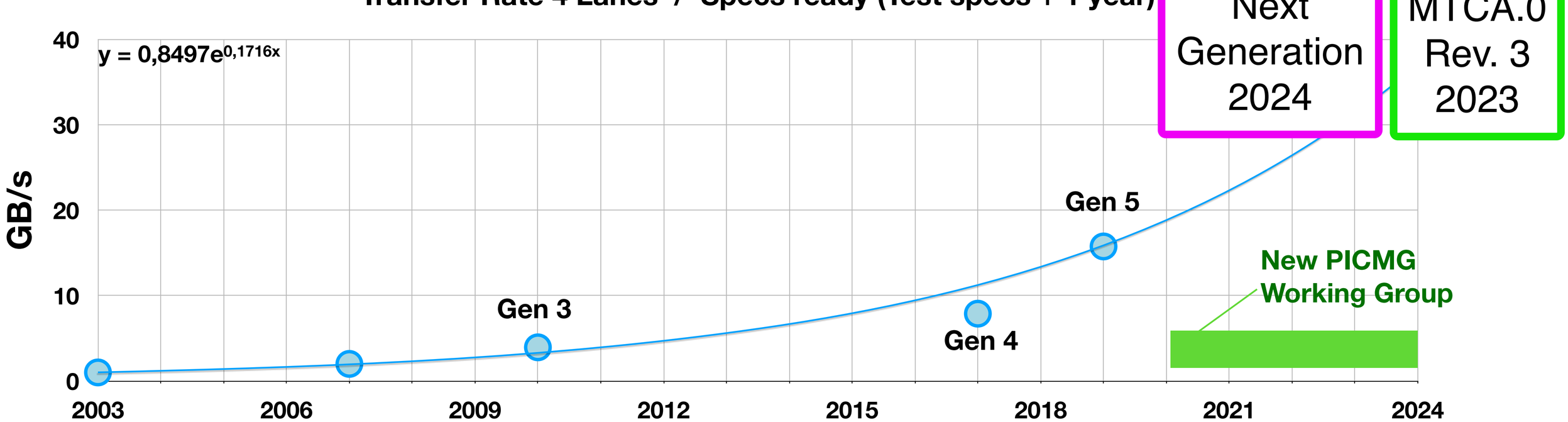
PCI Express version	Introduced	Line code	Transfer rate	Throughput (simplex)				
				×1	×2	×4	×8	×16
1.0	2003		2.5 GT/s	250 MB/s	0.50 GB/s	1.0 GB/s	2.0 GB/s	4.0 GB/s
2.0	2007	8b/10b	5.0 GT/s	500 MB/s	1.0 GB/s	2.0 GB/s	4.0 GB/s	8.0 GB/s
3.0	2010		**8.0 GT/s**	985 MB/s	1.97 GB/s	**3.9 GB/s**	7.88 GB/s	15.8 GB/s
4.0	2017	128b/130b	16.0 GT/s	1969 MB/s	3.94 GB/s	7.9 GB/s	15.75 GB/s	31.5 GB/s
5.0	*2019*	128b/130b	**32.0 GT/s**	3938 MB/s	7.88 GB/s	**15.8 GB/s**	**31.51 GB/s**	**63.0 GB/s**
6.0	*In preparation*	PAM4	64.0 GT/s	~7800 MB/s	~15.7 MB/s	~31.4.8 GB/s	~62 GB/s	~124 GB/s

Old

New

* 4

Transfer Rate 4 Lanes / Specs ready (Test specs + 1 year)



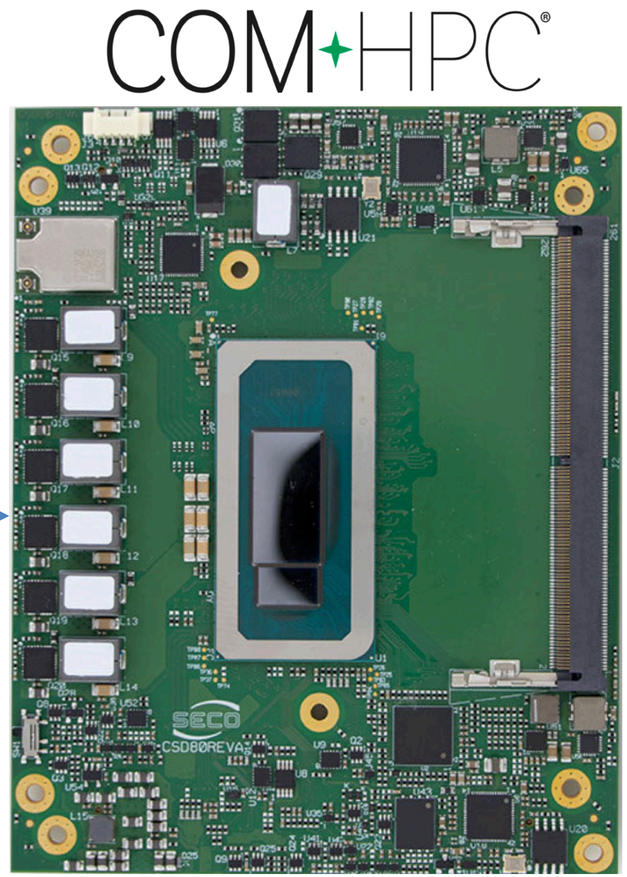
Technology Trends: CPU & FPGA

COM-HPC defines the direction of technology

- Client type modules up to **200 Watt**
- Up to **49 PCIe gen 5 lanes**
- **PICMG** published 2021

Actual design:

- Intel 13th Gen: PCIe gen 4/5



© SECO

FPGA

- PCIe gen 4/5
- **75 … 220 W**

© Xilinx® Alveo™

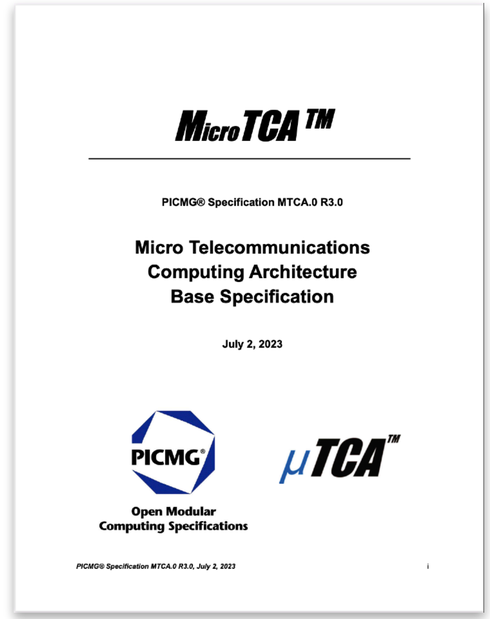
PICMG MicroTCA Next Generation Working Group

Initial Executive Members … 14.11.2019	**ESS** **DESY** **Lodz University of Technology** **N.A.T.** **nVent**
+ Members of working group	**Amphenol** **Atom Computing** **BAE Systems** **Comtel** **Concurrent Technologies** **Embeck** **IOxOS** **ORNL** **Pixus Technologies** **Positronic** **powerBridge** **Samtec** **VadaTech** **Yamaichi**

Chair	**Kay Rehlich, DESY**
Editor	**Heiko Körte, N.A.T**
Secretary	**Thomas Holzapfel, powerBridge**

MicroTCA Supports 32Gb/s Now

- **PCIe gen 5**
- **25GBASE-KR, 4 lanes: 100 G Ethernet**
- **110 W for MCH and cooling**


MicroTCA™

PICMG® Specification MTCA.0 R3.0

Micro Telecommunications Computing Architecture Base Specification

July 2, 2023

PICMG®
Open Modular Computing Specifications

µTCA™

PICMG® Specification MTCA.0 R3.0, July 2, 2023 i

Rev. 3: July 2023

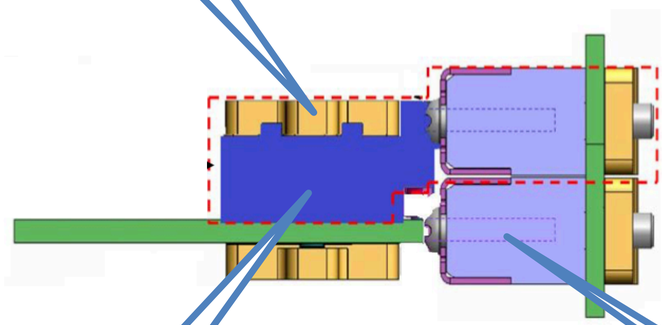
- **Next Step we are working on:**
  - Provide more PCIe lanes with **two connectors**
  - Allow up to 220 W per AMC (and MCH, cooling)

AMC Connector for: PCIe Gen 5 and More Power

✅ 32 Gb/s

Old connector

Possible new Connector OPTIONAL!



More Fat Pipe lanes e.g. PCIe x8, x16

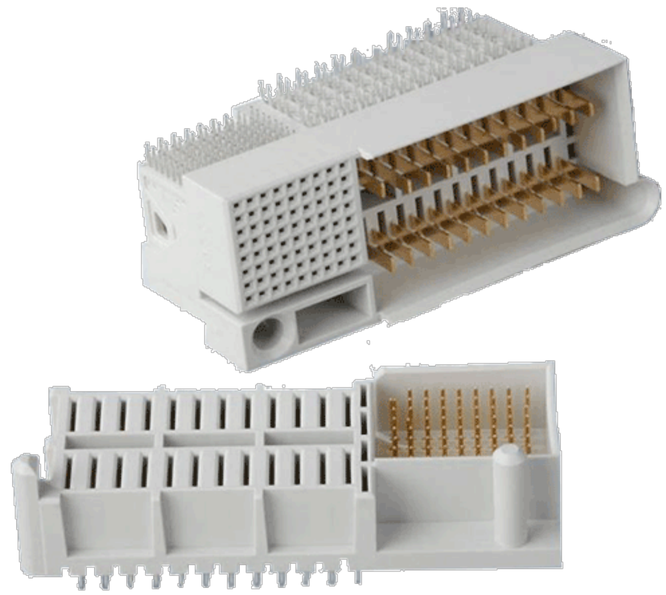
220 W: 2 * 9 power Pins

Card-edge Connector

100% backward compatible

Challenges: Power

- **Increase power from 80 W —> 220 W per slot**
  - Limitation of AMC connector: 8 pins @ 10.8 V = 98 W
  - Limitation of Power Module connector: 110 W
- **Solution:**
  - Use 9 pins on AMC + 2nd connector
  - Use 2 Power Module connectors



- **2 kW crate cooling**
  - Two times more airflow
  - Fans need more power
  - Simulations by nVent demonstrated the feasibility

Summary

ATCA started 2003:
Telecom system: high throughput, high reliability, remote management

Reliability Workshop 2005

MicroTCA 2006:
Smaller, IO oriented systems with the same features as ATCA

XFEL Decision to use ATCA or MicroTCA 2007

MicroTCA.4 2011:
Clock & Trigger integration
RTM space for signal conditioning

MicroTCA.4.1 2016:
2nd backplane for RTMs (e.g. for LLRF frequency distribution)

XFEL Injector Dec. 2015, Main Linac 2017

MicroTCA 2023:
100 Gb Ethernet (~12 GB/s) and 15.8 GB/s PCIe gen 5

MicroTCA Next Generation in preparation:
2 kW per crate, 220 W max. per AMC slot, 63 GB/s with 16 lanes