

# Overview of DMCS Projects and MicroTCA.4 Developments

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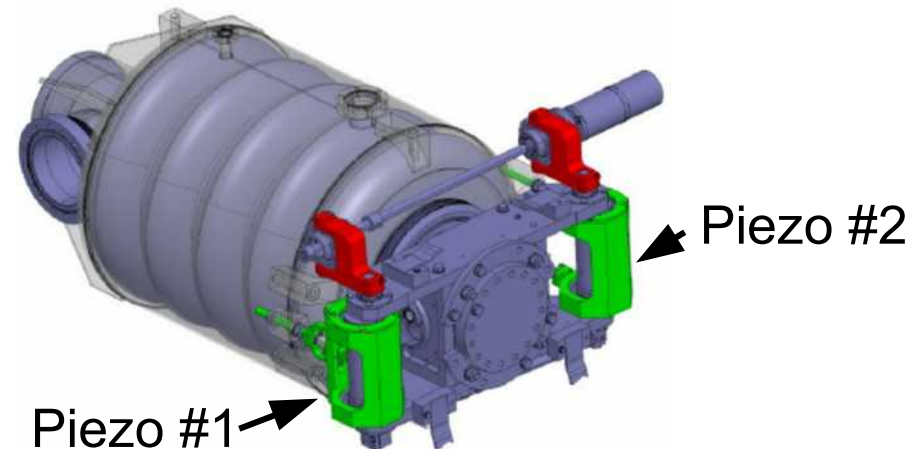
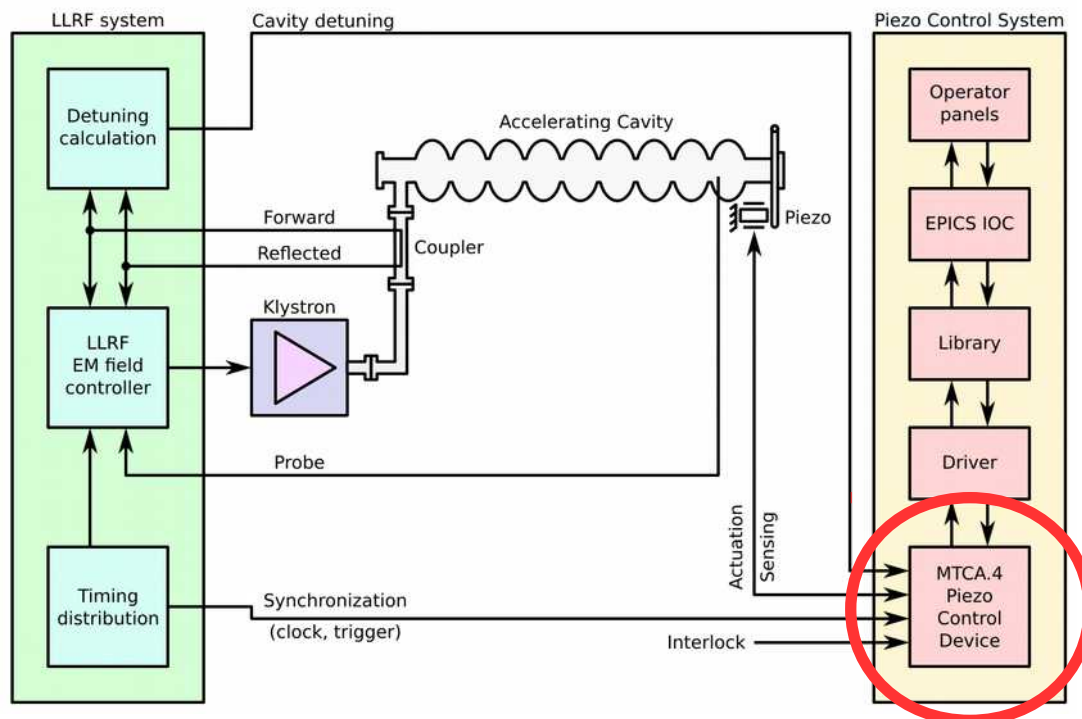
## Agenda

- Introduction
- High-Power Piezo Driver for Accelerator Applications
- Management Controller Developments for xTCA Systems
- Image Acquisition and Processing System in MicroTCA.4
- Conclusions

# High-Power Piezo Driver for Accelerator Applications

# High Power Piezo Driver - Motivation

- ▶ This work is being done in frame of the Polish in-kind delivered by the **Polish Electronic Group (PEG)** within in-kind agreement signed between PEG and ESS on 2016-11-08, (together with Schedule AIK 8.2, signed 09.2017, ESS-0060409)
- ▶ Department of Microelectronics and Computer Science, Lodz University of Technology as a member of PEG consortium is responsible for piezo driver system delivery for elliptical cavities of ESS linac.



ESS cavity with 2 piezo actuators

## Piezo Actuators Planned for ESS Accelerator

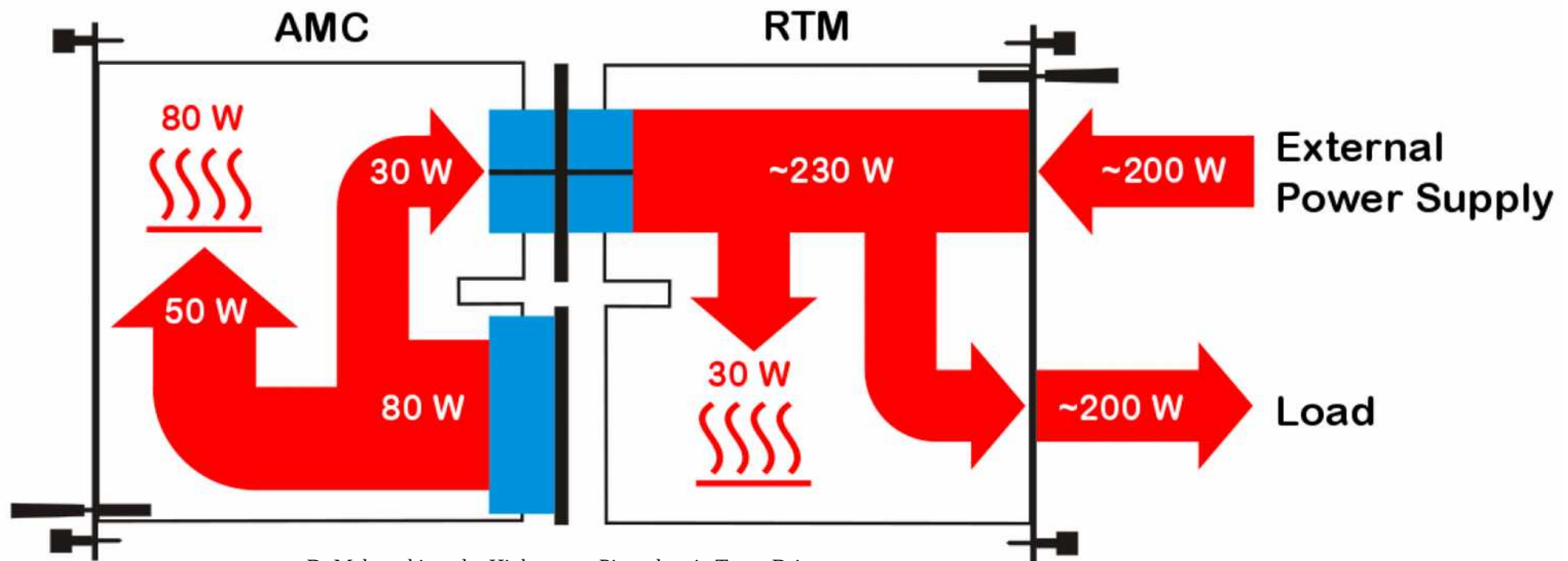
Cavity type	Piezo actuator type
Medium Beta cavities	Noliac NAC 2022 H30
High Beta cavities	Noliac NAC 2022 H30
Spoke cavities	Piezo #1: Noliac NAC2022-H90-A01 Piezo #2: PI PICMA P-888.91/51

Piezo type	Noliac NAC 2022 H30	Noliac NAC 2022 H90	PI Stack 2x P-888.90 + 1x P-888.50
Dimensions	10 x 10 x 30 mm	10 x 10 x 90 mm	10 x 10 x 90 mm
Cell material	NCE51F	NCE51F	PIC252
Number of cells	15	45	
Total capacitance (room temp.)	5.54 $\mu\text{F}$ $\pm 15\%$	17.4 $\mu\text{F}$ $\pm 15\%$	32 $\mu\text{F}$ $\pm 20\%$
Total capacitance (cryo, 20 K)	<b>~1.85 <math>\mu\text{F}</math></b>	<b>~5.8 <math>\mu\text{F}</math></b>	<b>~9.8 <math>\mu\text{F}</math></b>
Max. free stroke	46.2 $\mu\text{m}$	145.2 $\mu\text{m}$	94 $\mu\text{m}$
Blocking force	4200 N	4200 N	3600 N
Max. operating voltage	200 V ( $\pm 100$ V)	200 V ( $\pm 100$ V)	-20 to 120 V
Max. operating temperature	200°C	200°C	150°C

## Challenges of Piezo Driver Implementation in MicroTCA.4 Form Factor

**Decided to use solution III AMC + RTM card + External PSM**

1. 5-10 Watts for Payload (from AMC)
2. Untimed power for Piezo Driver from external power supply
3. **Limited piezo power by cooling capability to ~20-25 Watts**



D. Makowski et al. „High-power Piezoelectric Tuner Driver for Lorentz Force Compensation”, *TNS*, in print



## Piezo Driver RTM Module – Second Prototype

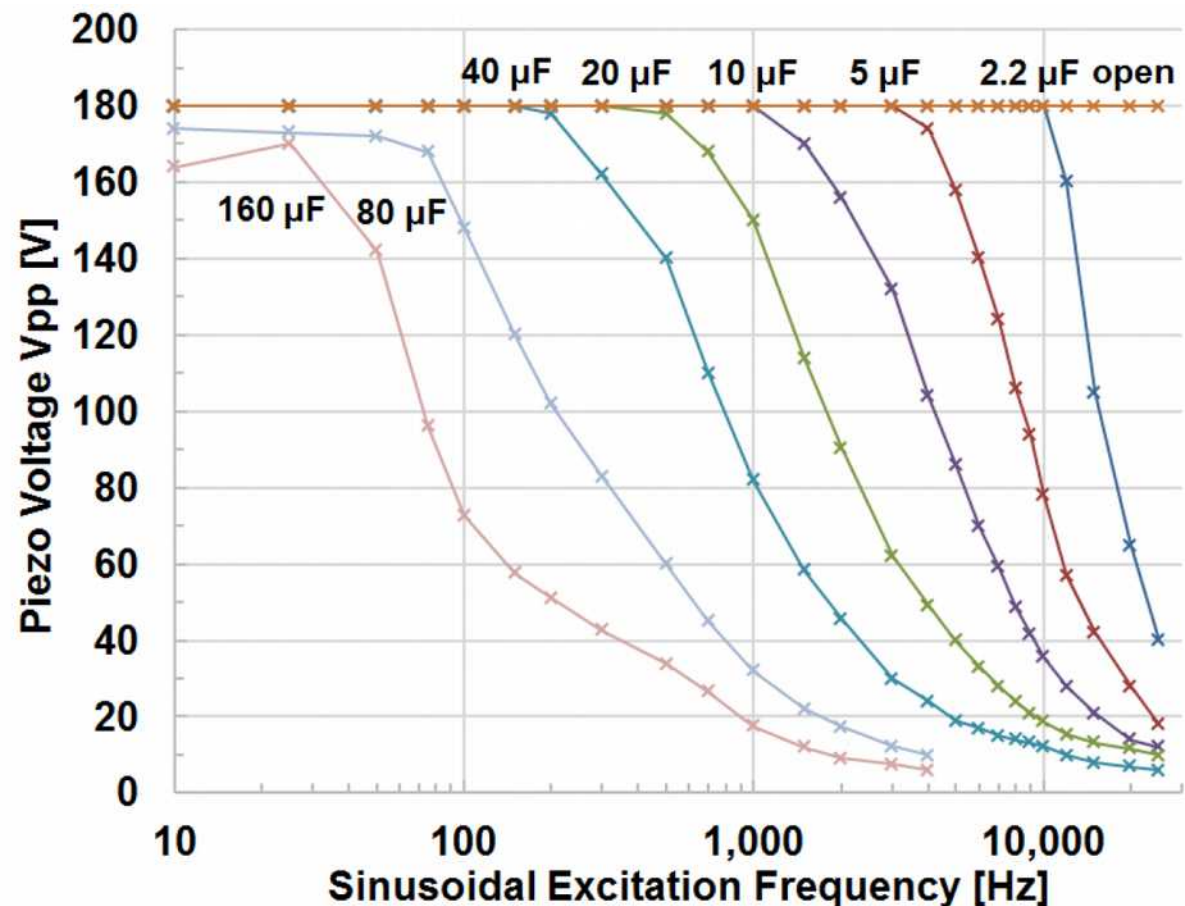
- ◆ Based on high efficiency Class-D amplifier (PWM)
- ◆ 2 channels available:
  - ◆ 2x 35 Watts (MTCA.4 power supply)
  - ◆ **2x 100 Watts (external power supply)**
- ◆ Piezo driver and piezo sensor mode
- ◆ Build-in diagnostics (advanced implementation of RMC)
- ◆ Various protection mechanisms for both Piezo channels to protect driver itself and piezo actuator



**HDP-200 – Piezo Control Device**

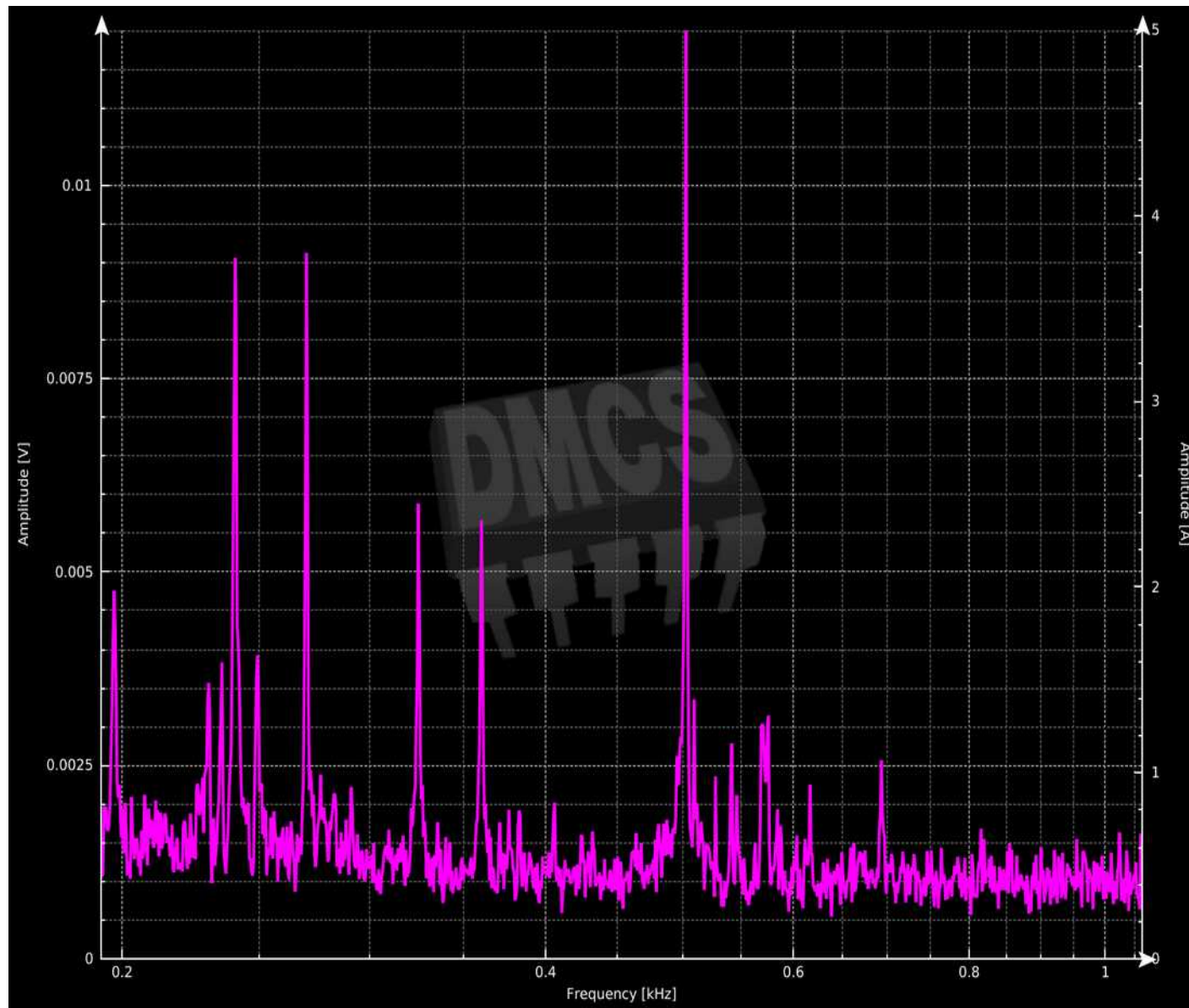
## Piezo Control Device – SOA Characteristics

- ◆ Tested at laboratory conditions
- ◆ Single channel
  - ◆ Channel A as driver
  - ◆ Channel B as sensor
- ◆ 2.2  $\mu\text{F}$  to 160  $\mu\text{F}$  load
- ◆ Sinusoidal test signal
  - ◆ 10 pulses
  - ◆ 14 Hz repetition rate
- ◆ Various protections limit the maximum frequency of operation

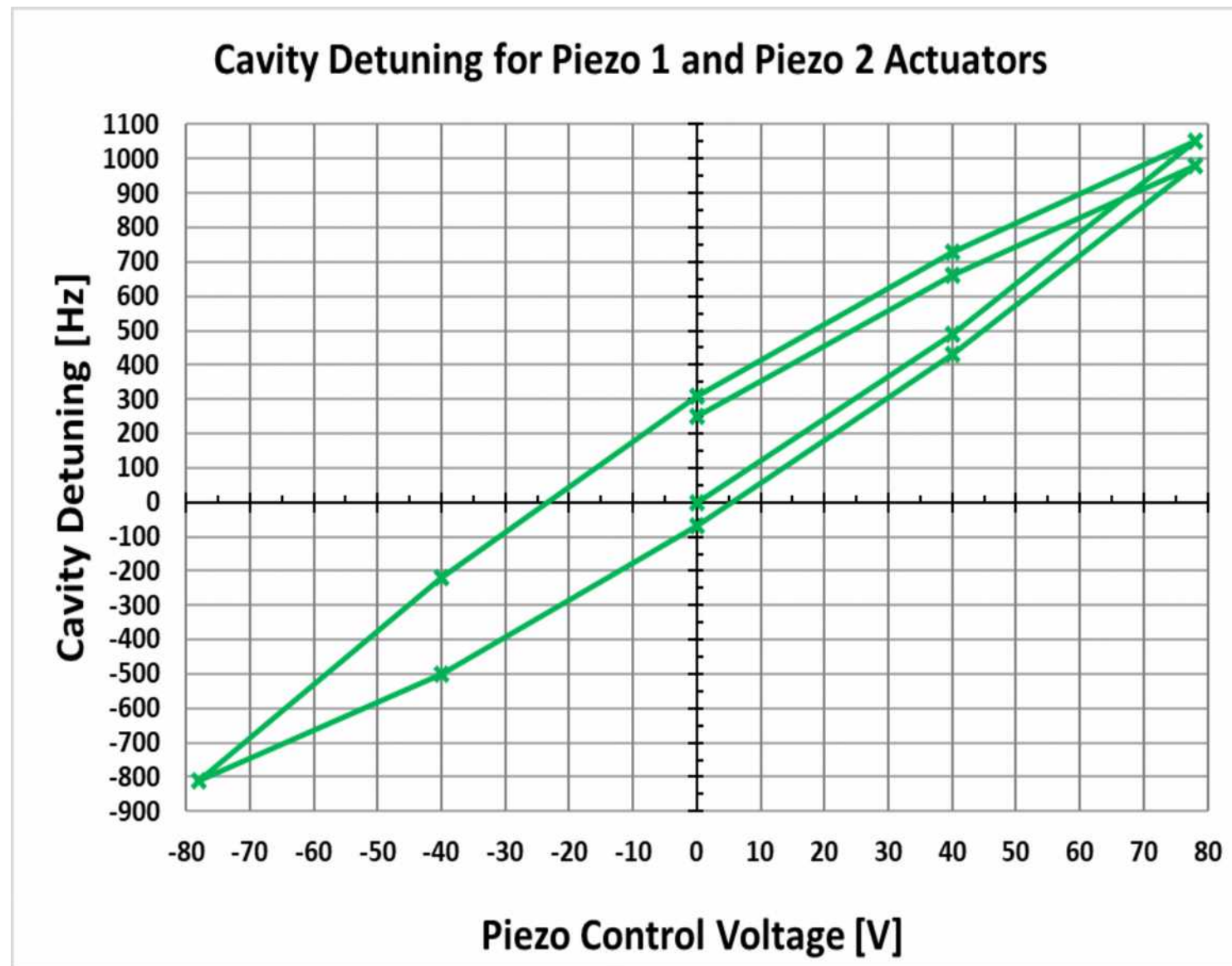




## Cavity Resonances [200 Hz – 1 kHz]



## Cavity Detuning for Piezo 1 and Piezo 2 actuators



## Interested – Visit our Poster

- ◆ Designed a two channel 2x 100 Watts PWM piezo driver prototype (HPD-200)
- ◆ Two solutions available:
  - ◆ Internal MicroTCA.4 and,
  - ◆ External power supply
- ◆ Suitable for driving large piezo actuators (room temperature capacitance  $<160 \mu\text{F}$ )
- ◆ Prototype successfully tested in laboratory and cryo-conditions
- ◆ Initial compensation of LFD for elliptical cavity of ESS accelerator
- ◆ Starting pre-production and mass production next year



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### High-Power Piezo Driver for Accelerator Applications

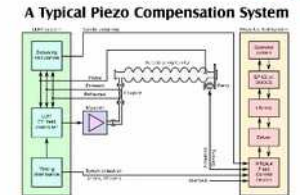
Dariusz Makowski, Aleksander Mielczarek, Piotr Perek, Grzegorz Jablonski, Aleksander Szubert, Pawel Plewinski, Wojciech Cichalewski, Andrzej Napieralski

#### Accelerating Cavity Detuning Compensation

- The cavity detuning can be easily calculated by an LLRF system
- Detuning compensation reduces power loss and helps maintaining the flat-top
- Main causes for the detuning are the Lorentz force and microphonics
- Compensation requires application of mechanical impulse to the cavity
- The actuation is done with piezoelectric elements

#### Piezo Compensation System Developed by DMCS

- System implemented almost completely in the MicroTCA.4 architecture
- Two channels, configurable in actuator or sensor mode
- Safe discharge of the piezo-element
- Up to 100 W per output channel, simultaneous operation possible
- Live monitoring of power delivered to the actuator
- Extensive health monitoring through IPMI



HPD-200 – Piezo Control Device (RTM)



19" 200 W Power Supply Module

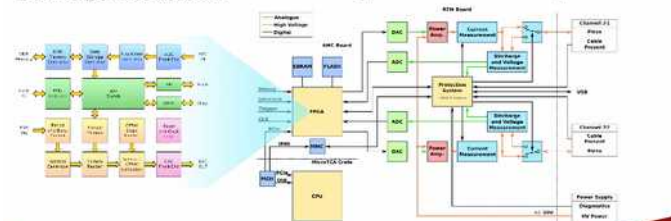


HVC-80 with HPD-200

#### Advanced Health Management

- IPMB extended to external devices
- Dynamically allocated sensors
- Used for power supply module monitoring

#### Block Diagram of Piezo Driver



Cavity with Piezo Tuners



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www: <https://dmcs.pl>, e-mail: [cadaq@dmcs.pl](mailto:cadaq@dmcs.pl)

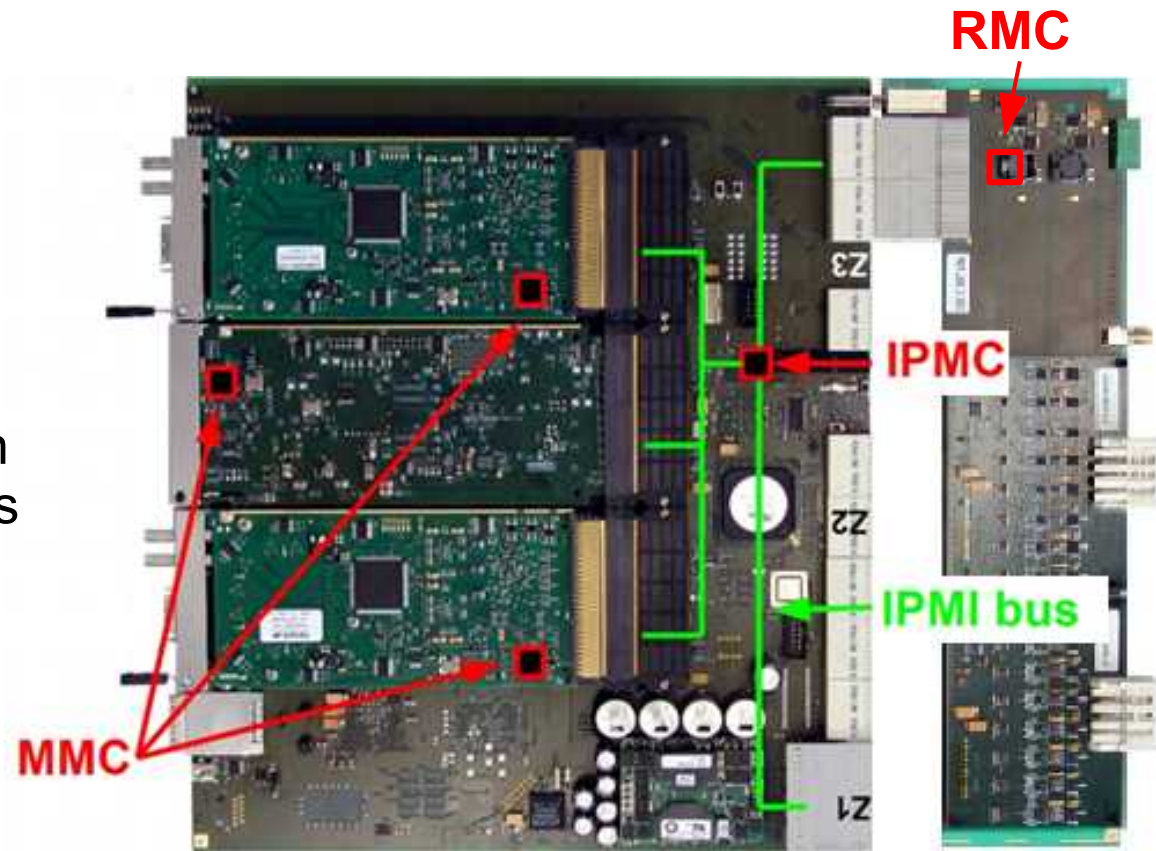
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# Management Controller Developments for xTCA Systems



## Intelligent Platform Management Controller for AdvancedTCA

- ◆ AdvancedTCA board requires:
  - ◆ IPMC – IPMI controller implemented on ATCA carrier
  - ◆ MMC – controller needed on each AMC card
  - ◆ RTC – controller on RTM card
- ◆ Various microcontrollers tests:
  - ◆ Atmel, NXP, Renesas
- ◆ IPMC - final solution available with Renesas that offer 6 I2C controllers
  - ◆ Complex solution that requires a lot of work
- ◆ MMC – mainly based on Atmel ATxmega
  - ◆ Much simpler than IPMC
- ◆ Time consuming and challenging task, but we learned a lot during this exercise



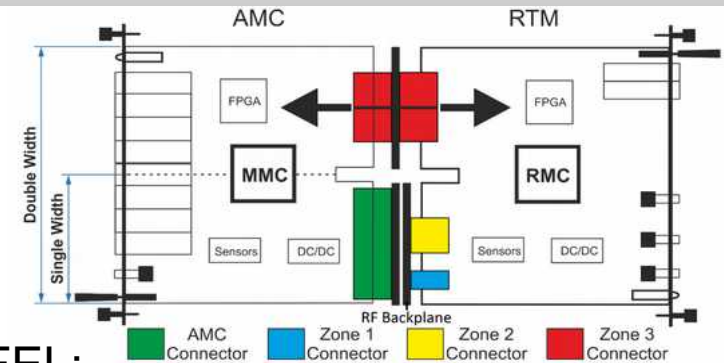
ATCA carrier with 3 AMC slots and RTM  
(before MTCA.4, <2007)



## Development of MMC 1.0 solution for DESY

### ◆ Unified solution for AMC and RTM cards

- ◆ Basic and Advanced versions available
- ◆ Includes hardware (schematics) and firmware
  - Microcontroller and CPLD
- ◆ Implemented on various AMC-RTM modules of E-XFEL:
  - TCK7, DAMC2, SIS8325, DS-800,...
  - VM2LF, DWC10, CLKFT, uLOG,...
- ◆ Available evaluation kits
- ◆ Based on previous work (AdvancedTCA)
- ◆ **Many new ideas implemented**
  - ◆ New RTM solution – part of MicroTCA.4.1
  - ◆ Monitoring and diagnostics
  - ◆ RTM currents and voltages monitoring
  - ◆ Support of PMBus DC/DC converters
  - ◆ Payload management and monitoring



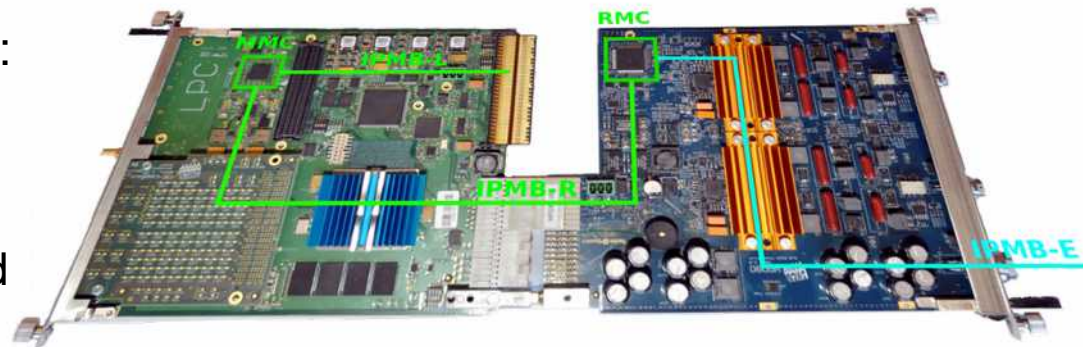
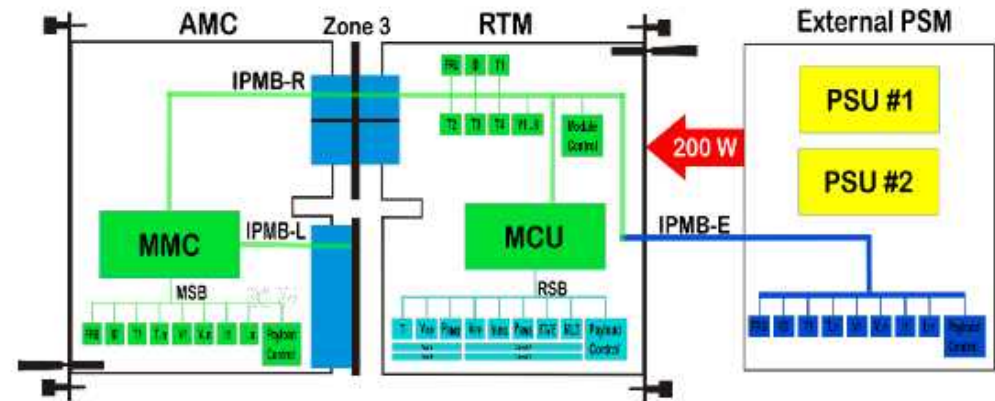
**TCK7 and VM2 Devices**



**AMC and RTM Evaluation kits**

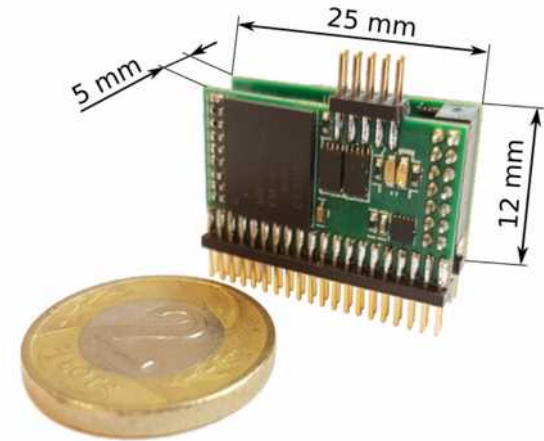
## Extension of IPMI Management for MicroTCA.4

- ◆ Developing and testing new solutions
- ◆ Dynamic IPMI sensors for RTM
  - ◆ Available via IPMB-R
  - ◆ Requires RTM Management Controller
  - ◆ Implemented on Piezo Driver Module
- ◆ Management and control of External Piezo Power Supply
  - ◆ Diagnostics of external PPSM
    - Monitor temperatures
    - Monitor voltages
    - Monitor fans
  - ◆ Disable  $\pm 50$  V voltage during hotplug:
    - AMC or RTM deactivated
    - AMC or RTM removed
    - Power supply cable removed
- ◆ FMC FRU support with unique ID



## MMC Integrated Module – TUL-DMCS Solution

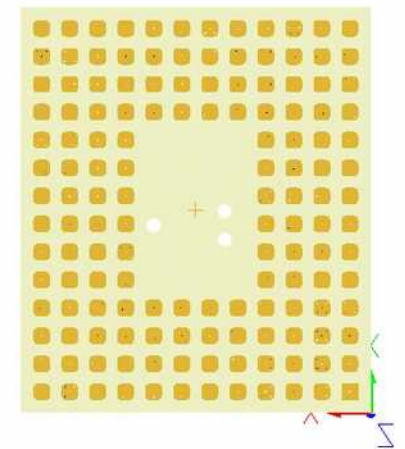
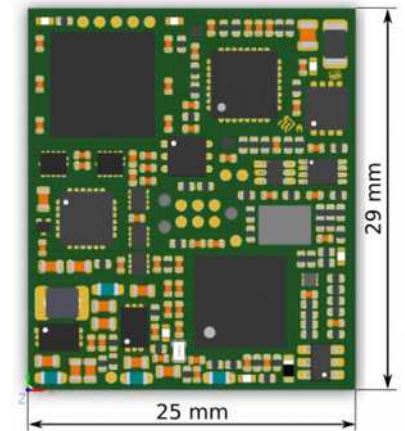
- ◆ Easy solution for MTCA.4 beginners
- ◆ Ready to use module with universal and customisable firmware
- ◆ Available two versions:
  - ◆ Basic – only AMC support
  - ◆ Advanced – extended RTM manager with diagnostics
- ◆ Based on ARM microcontroller and real-time OS
- ◆ Programmable unit for more advanced customisation
- ◆ Under testing on HVC-50 AMC module





## MMC-Stamp Module – DESY Solution

- ◆ Project developed by TUL-DMCS for DESY
  - ◆ See M. Fenner presentation:  
“DESY MMC System on a Module and its Applications”  
for more details
- ◆ Smart solution:
  - ◆ Module Management Controller dedicated for AMC modules
  - ◆ Extended solution supporting RTM
  - ◆ Atmel ARM microcontroller
  - ◆ Programmable FPGA logic
  - ◆ Available 4x I2C controllers
  - ◆ Small size




## Interested – Visit our Poster

- ◆ We developed solutions for:
  - ◆ AdvancedTCA
  - ◆ MicroTCA
- ◆ A few versions available
- ◆ Working on small-size but still powerful solution for xTCA applications



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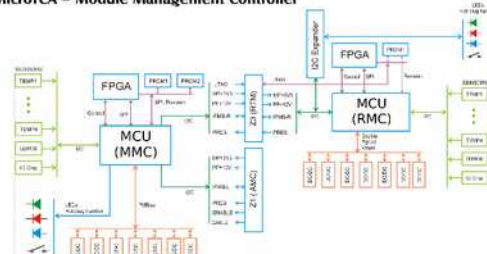
### Management Controller Developments for xTCA Systems at DMCS

Dariusz Makowski, Piotr Perek, Aleksander Mielczarek, Aleksander Szubert, Andrzej Napieralski

**Universal Solution for xTCA Management Controllers**

- Unified solution supporting AdvancedTCA and MicroTCA Management Controllers
- Small-size design easily applicable for custom modules
- Flexible, modular, easily customizable design
- Advanced RTM Management Controller with voltage and current monitoring
- Ready-to-use firmware with additional configuration tools

**MicroTCA – Module Management Controller**



**MMC Functionality:**

- Module Management
- IPMB-I communication
- Activation/Deactivation
- FRU Information
- Health Monitoring
- Temperature, Voltage, Current
- I2C/SPI sensors, ADC, PMBus
- Power Supply Management
- Payload Management (FPGA, DSP, MCU)
- RTM Controller
- HPML1 Firmware Upgrade
- Debugging

**RMC Functionality:**

- Basic Management
- I/O Expander
- EEPROM Memory
- Temperature sensors
- Advanced Management
- Additional health monitoring (I2C/SPI sensors, ADC, PMBus)
- Power Supply Management
- Payload Management
- HPML1 Firmware Upgrade
- Debugging

**AdvancedTCA – Intelligent Platform Management Controller**

- Compliance with basic IPMI commands required by the ATCA standard
- Compliance with PICMG 3.0 extension commands
- Carrier board management including hot-plug and E-keying
- Management of three AMC modules including hot-plug, E-keying and power supply control
- Sensor monitoring e.g. voltage, temperature, current
- Firmware upgrade over HPML1 protocol
- Debugging and diagnostic functionality
- Economical, easy to implement and small footprint solution




2018  
HVC-80 and HPD-200

2017  
DMC-TCK7 and DRTM-VM2

2013  
ATCA Carrier Board with RTM for ITRF applications

2006

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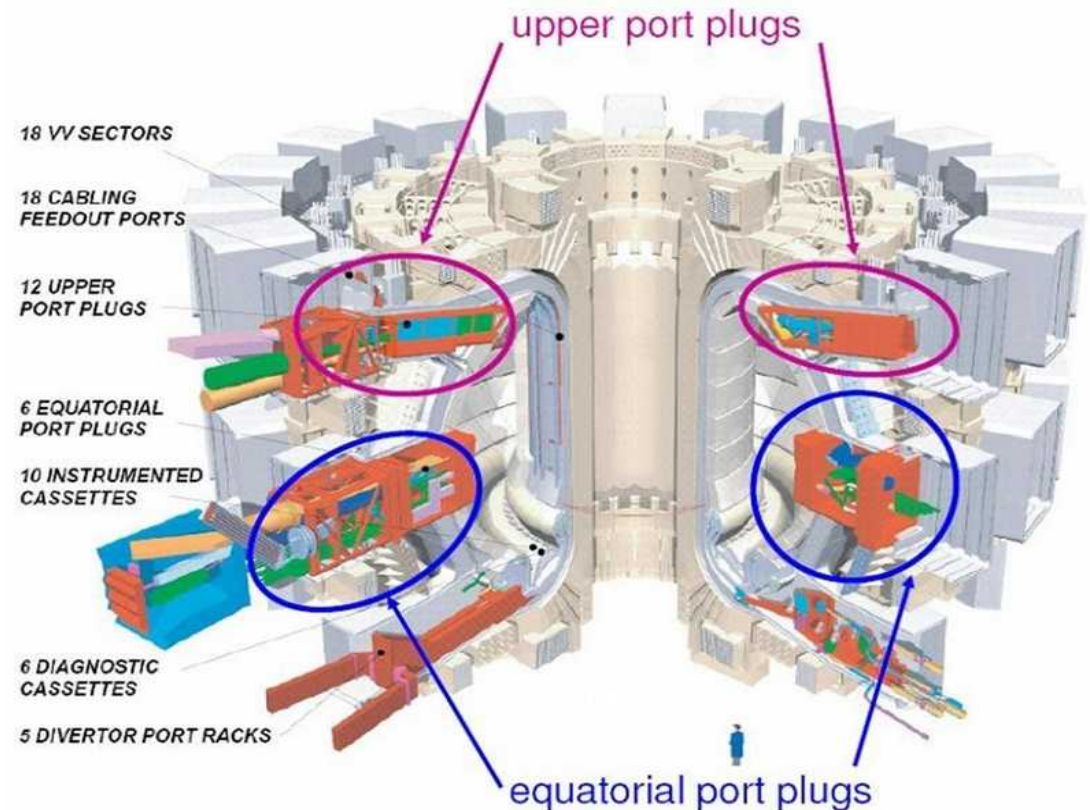


# Image Acquisition and Processing System in MicroTCA.4

## ITER Project

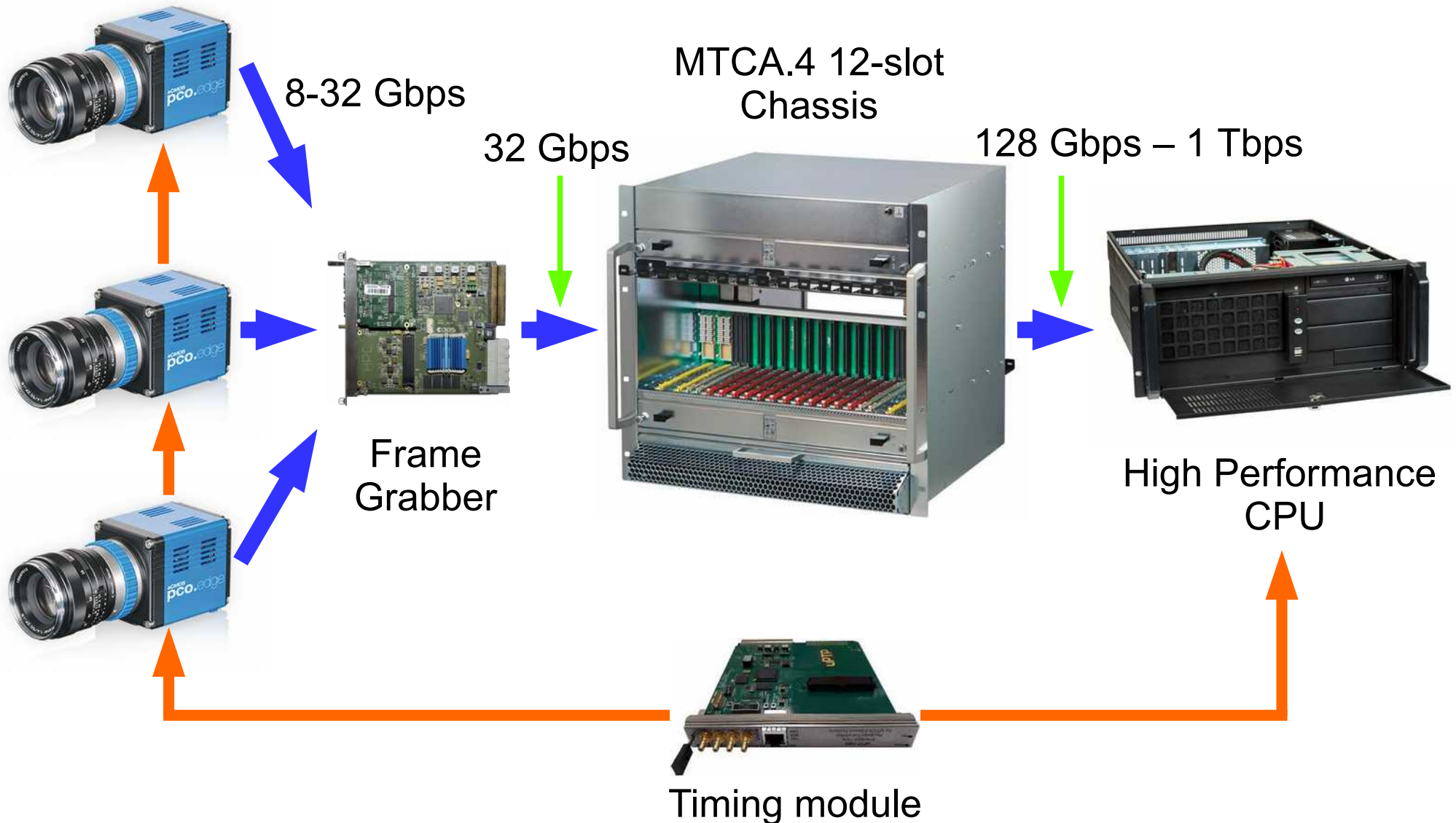
### Challenges in design of imaging systems for plasma diagnostics:

- Plasma diagnostics - monitor plasma temperature, density, radiative properties, first-wall resilience
- 200 cameras:
  - 1-8 Mpx @ 50-50000 FPS
- Throughput can easily exceed 8 Gb/s per camera
- Scalability and high reliability
- 50 ns synchronization accuracy



### ITER Diagnostic Port Plugs

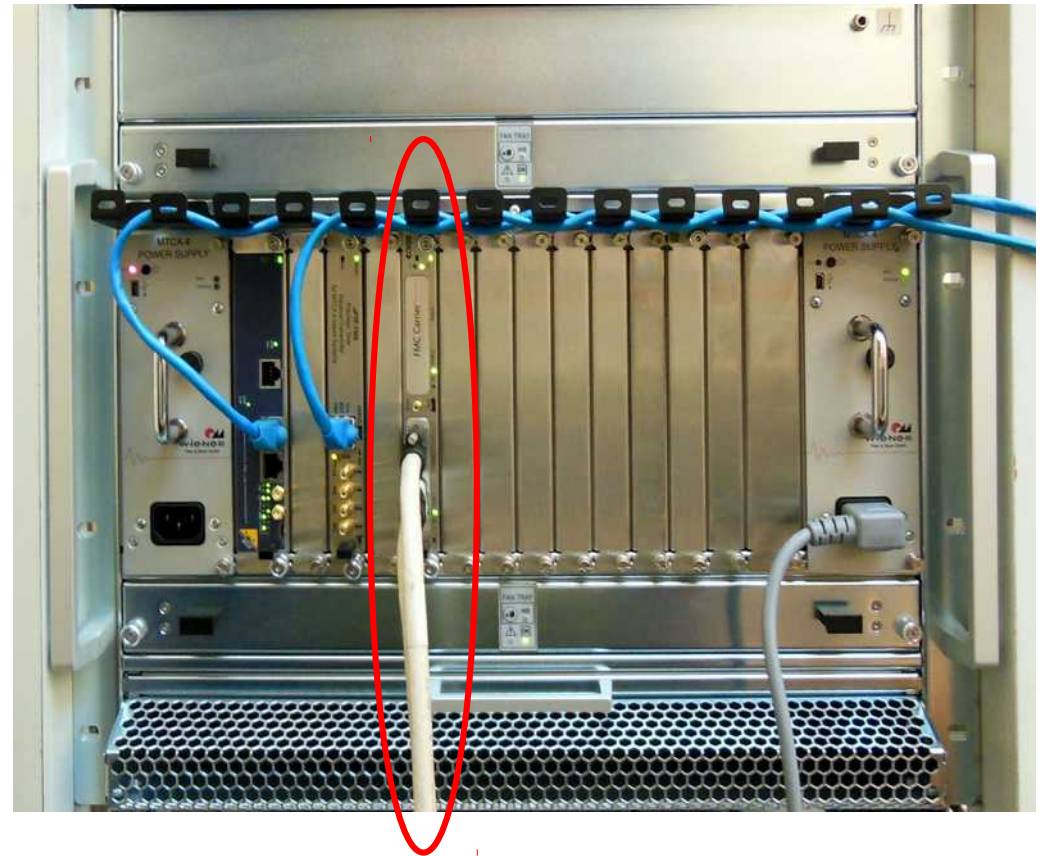
# Image Acquisition and Processing with MTCA.4 – Our Solution





## Frame Grabber Card for MTCA.4

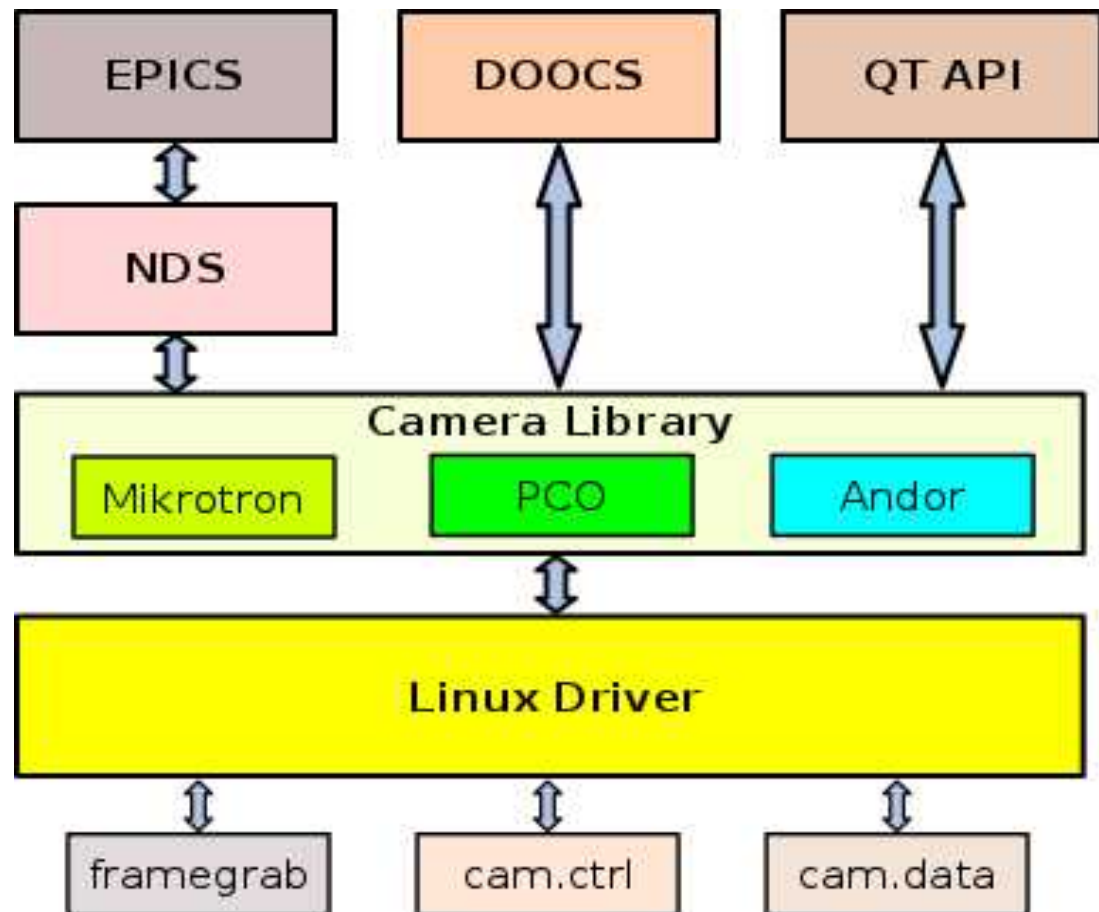
- ◆ Cost-effective solution for high-performance image acquisition systems
- ◆ Designed as FMC carrier module (HPC and LPC) with FMC extension modules:
  - ◆ Camera Link (Base, Full, Ext-Full)
  - ◆ Camera Link HS
  - ◆ CoaXPress
  - ◆ Universal IO module
  - ◆ Firmware support for selected protocols
- ◆ Provides all resources for data acquisition and control systems (FPGA processing power, SDRAM, clocks distribution, trigger and interlock signals)
- ◆ Based on Xilinx Artix 7 (XC7A200T) FPGA
- ◆ RTM Zone 3 connector (D1.2 Digital Class)



**Image Acquisition System with Full-Extended Camera Link**

## Image Acquisition System – Software Framework


- API for EPICS, DOOCS and QT
- Library for 3 cameras:
  - Microtron
  - PCO
  - Andor
- Available nodes:
  - Frame Grabber
  - Camera control
  - Camera image
- Linux driver and NDS library
- HMI panels






## Interested – Visit our Poster

- ◆ Developed a complete Image Acquisition System for MicroTCA.4
- ◆ Various cameras supported
- ◆ Scalable and configurable software framework
- ◆ Support for new cameras could be easily added
- ◆ We are open for collaboration



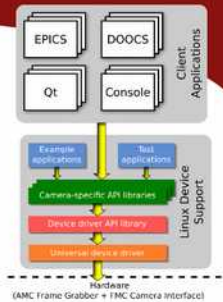
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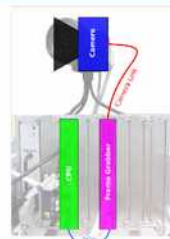
### High-Performance Imaging Systems based on MicroTCA.4 Standard

Dariusz Makowski, Piotr Perek, Aleksander Mielczarek, Andrzej Napieralski

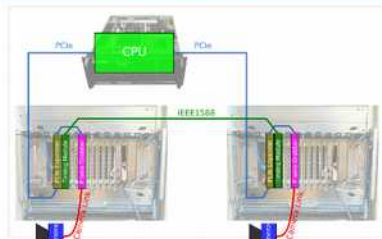
- MTCA.4-based modular, flexible systems dedicated for high-performance image acquisition, processing and visualization
- Frame grabber composed of:
  - Dual slot FMC carrier board with Xilinx 7-Series Artix FPGA
  - Up to 2 FMC modules with Camera Link Interface
- Universal FPGA firmware ensuring:
  - Low-latency image acquisition using dedicated DMA engine
  - UART interface for camera control and monitoring
  - Precise synchronization and triggering compliant with MTCA.4
- Full software support including:
  - Universal Linux device driver with low-level supporting API library
  - Dedicated libraries for specific cameras
  - Command-line example and test applications
  - High-level applications developed with Qt, DOOCS and EPICS

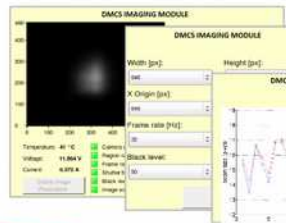
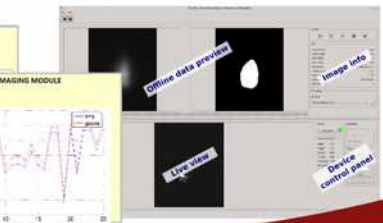


**Standalone System  
with Internal CPU**




**Distributed System  
with External CPU**



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## Live Demo at TUL-DMCS Booth



# Thank you for your attention