Overview of TUL-DMCS Projects and MicroTCA.4 Developments

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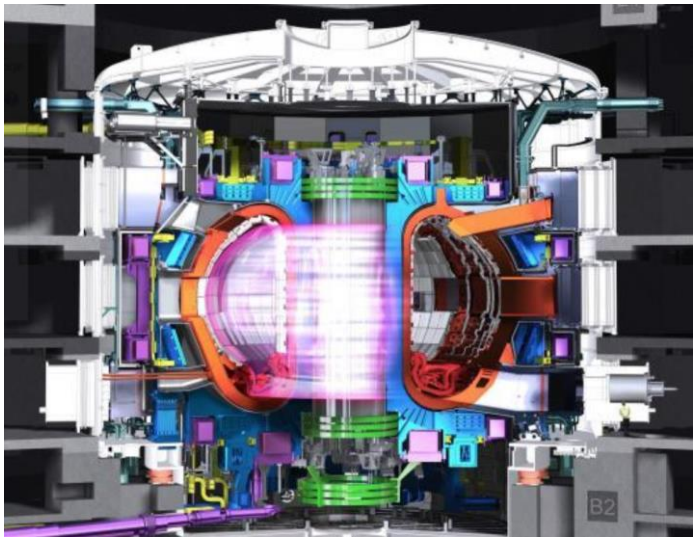
Agenda

- Image Acquisition and Processing with MicroTCA.4
  - Image Processing for Machine Protection and Control
- Smart MMC and RMC solution for xTCA systems
- Basic-AMC
- High-power piezo driver for European Spallation Source Accelerator

Fusion Projects - Plasma Diagnostics

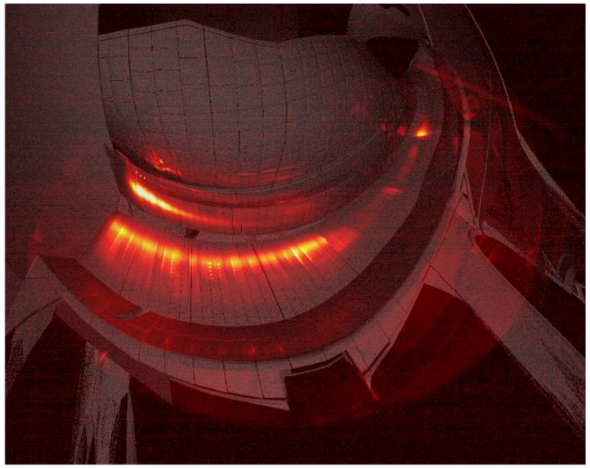
- **Works since 2010**
- **Applications:**
  - ITER
  - IPP/W7-X

➢ **A. Winter**
Thu 8/12, 9:45

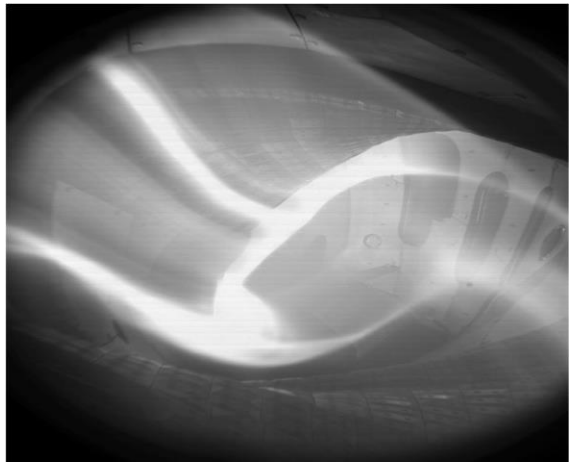


ITER Tokamak

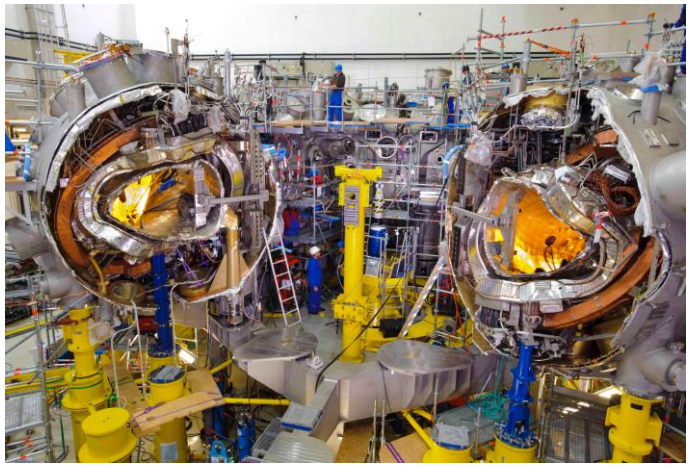
IR Diagnostics



VIS Diagnostics



W7-X Stellarator



Imaging Diagnostics – Image Acquisition and Processing

- Camera provides 1 or **more streams** of images
- **Frame grabber** configures camera, start and stop DAQ
- All devices are **synchronised** with machine (each frame includes timestamp)
- **All operations must work in real-time (hard real-time system)**
- Developed **hardware/software** should be compatible with **MicroTCA.4 subsystems**

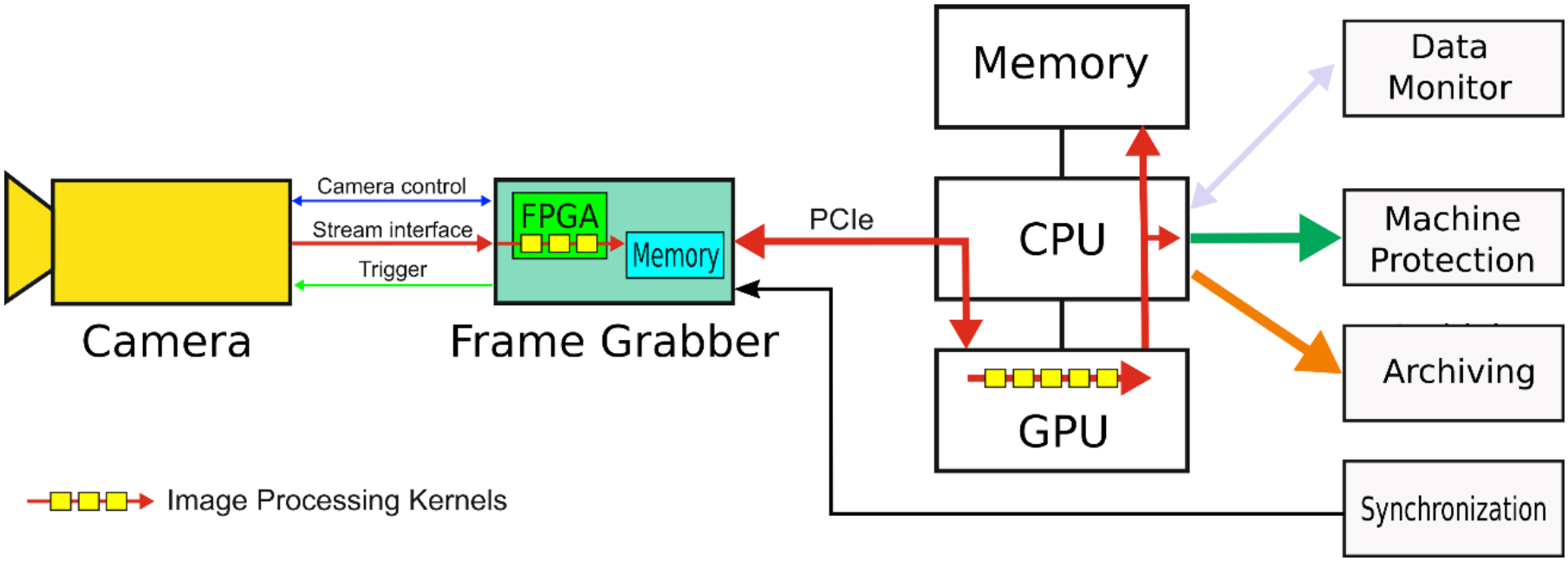
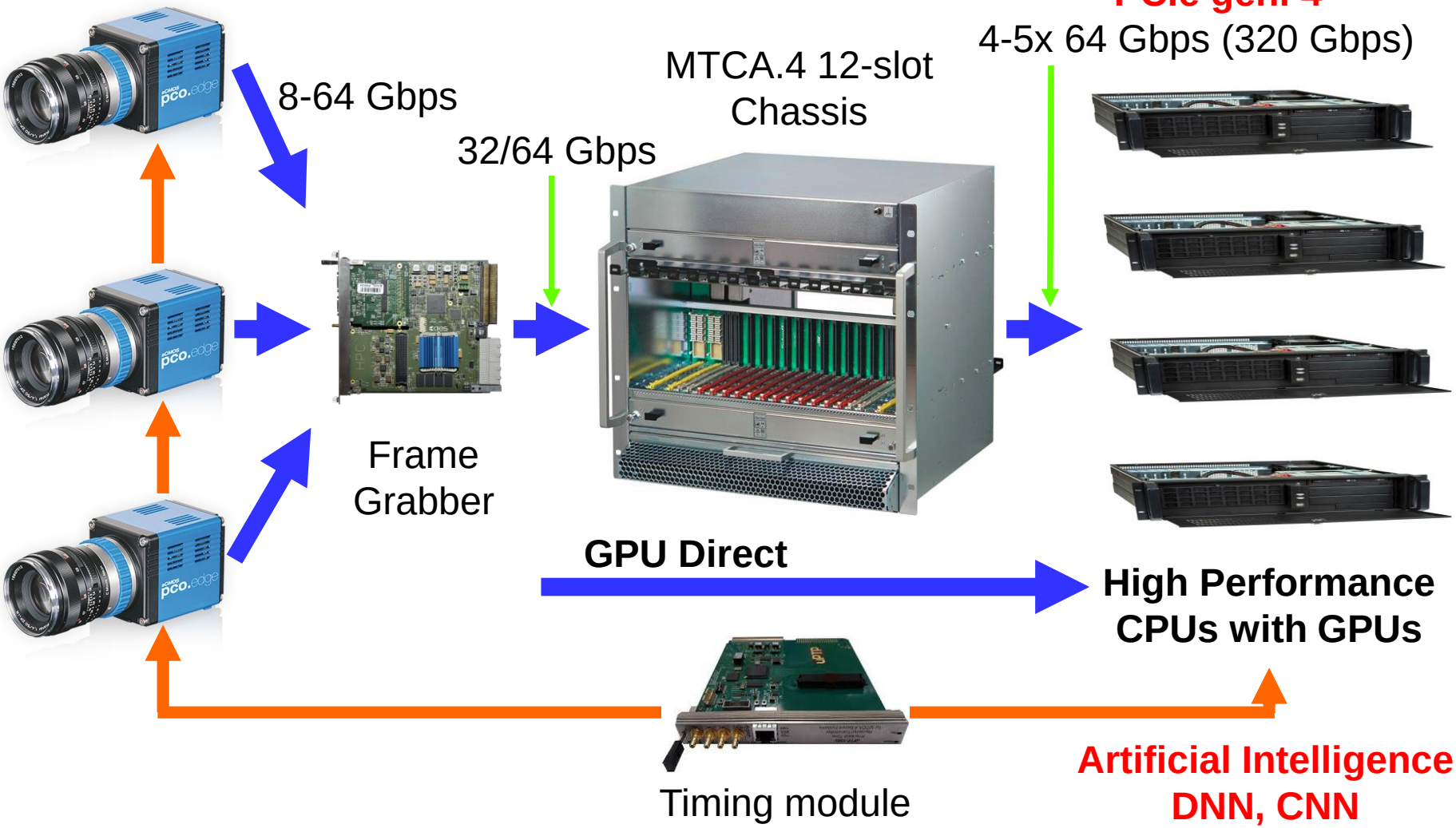


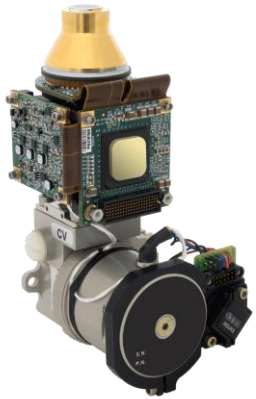
Image Acquisition and Processing with MicroTCA.4



Hardware is Available

✓	Camera Link	2.04 Gb/s, 5.44 Gb/s, 6.8 Gb/s
✓	Camera Link-HS	2.4 Gbps / 128 Gbps
✓	CoaXPress 2.0	n x 6.25/12.5 Gb/s (n=4 → 25/50 Gb/s)
✓	1 GigE Vision	800 Mb/s
✓	10/25 GigE Vision	10/25 Gbps
✓	IEEE1394/Fire Wire	0.4 Gb/s (1394a) or 0.8 Gb/s (1394b)
✓	HD-SDI	1.45 Gb/s (max. 2.9 Gbps)

SCD Hercules (CL)



Emergent HR-12000M camera with 10 GigE Vision interface

FMC Carrier Modules

Frame grabber is composed of:

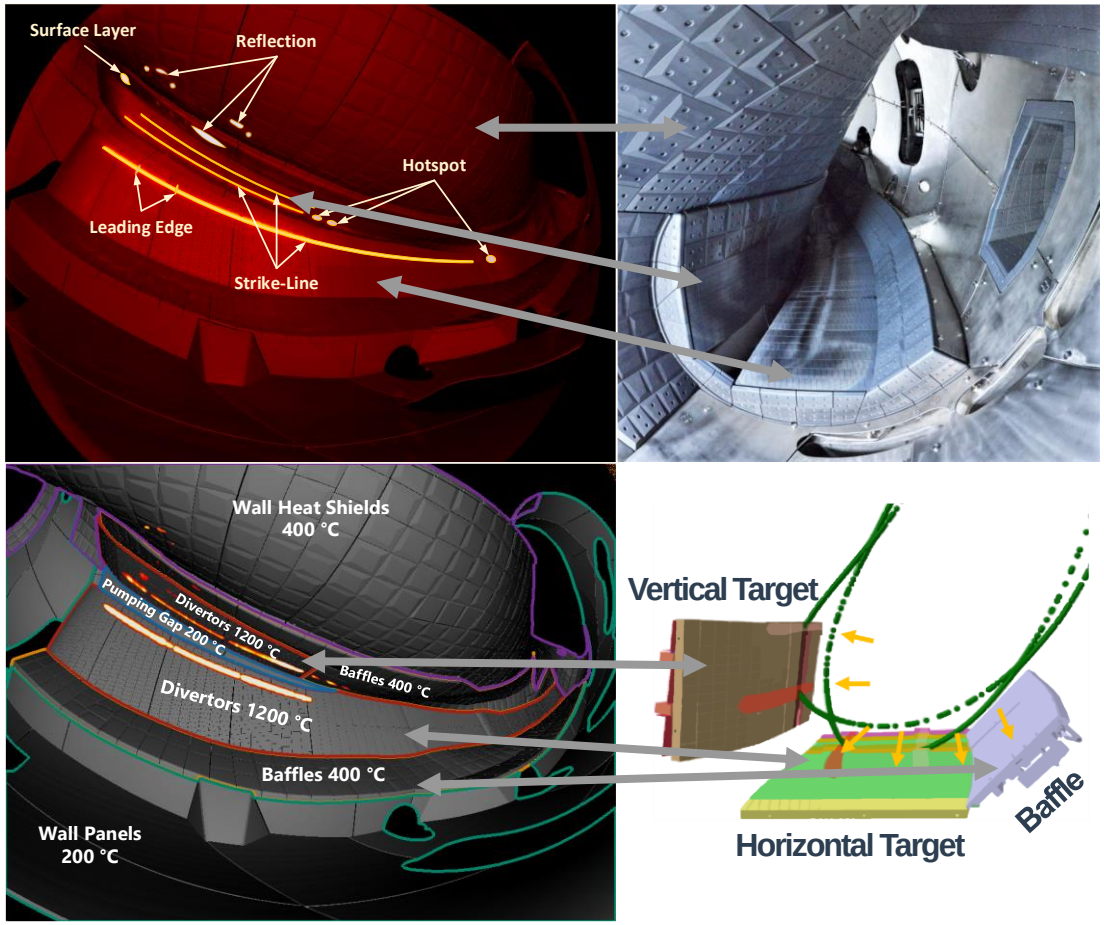
- Hardware we have
- FMC carrier
  - Artix 7 FPGA (<6.5 Gb/s)
  - Zynq US+ (<16 Gbps)
  - **Kintex US+ (<32 Gb/s)**
- FMC modules supporting various camera interfaces (8 standards)

Software support:

- **IP cores** for selected **camera interfaces**
- Common Linux driver (**dmtcauni**)
- **Dedicated camera library** (GenICam)
- Real-time processing software
- Algorithms (FPGA, CPU, GPU)
- **We move from development phase to maintenance**

Machine Protection with Imaging Systems

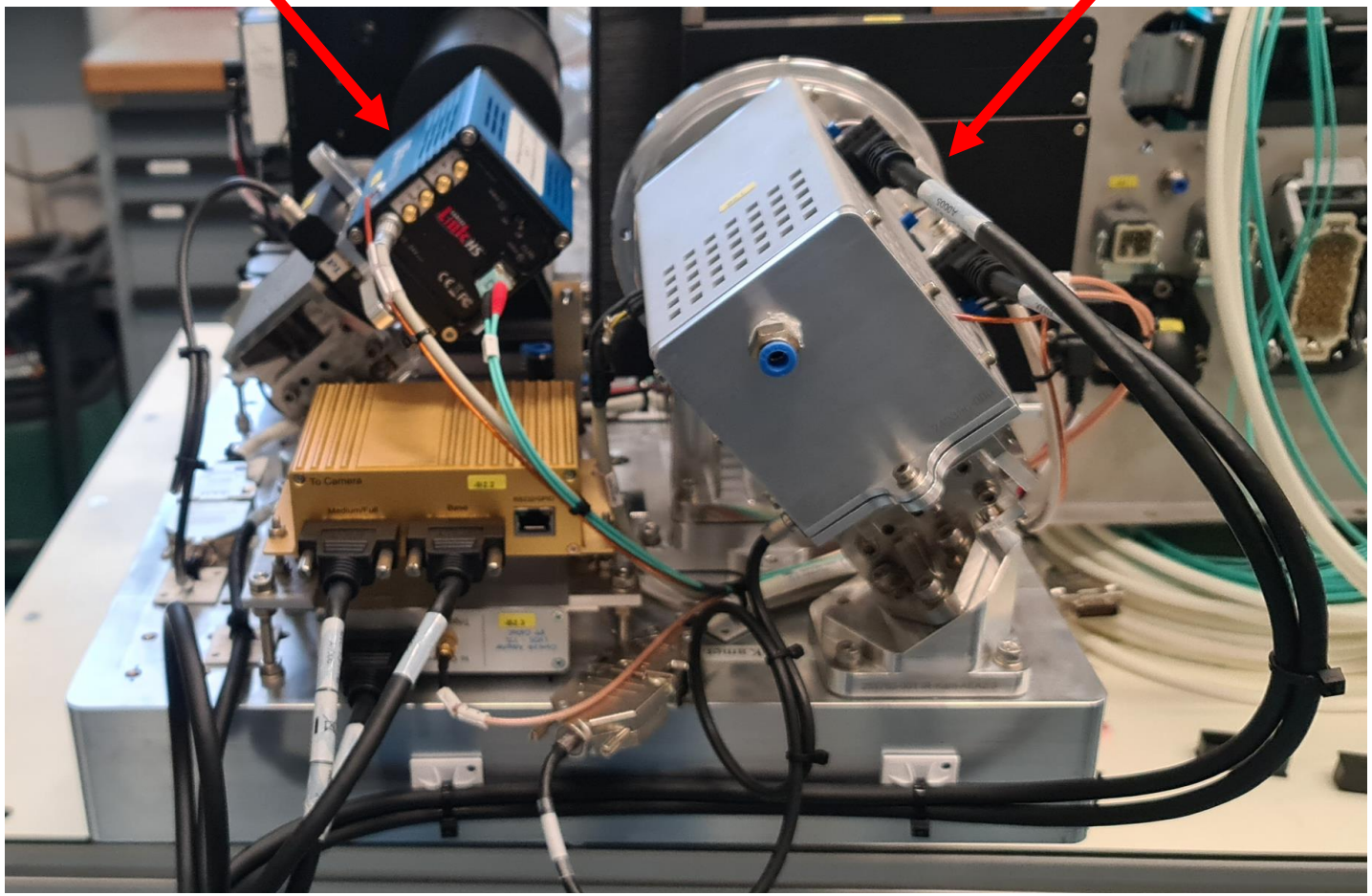
- **Thermal Overload Detection** system is being prepared for the OP2.1 campaign in Wendelstein 7-X
- **Protect Plasma Facing Components** (PFCs) from thermal overloads with infrared (IR) cameras
- **Trigger the Fast Interlock System** (FIS) to terminate a discharge when a thermal overload is anticipated
- **W7-X has 12 IR cameras**, and **10 divertor units** are monitored



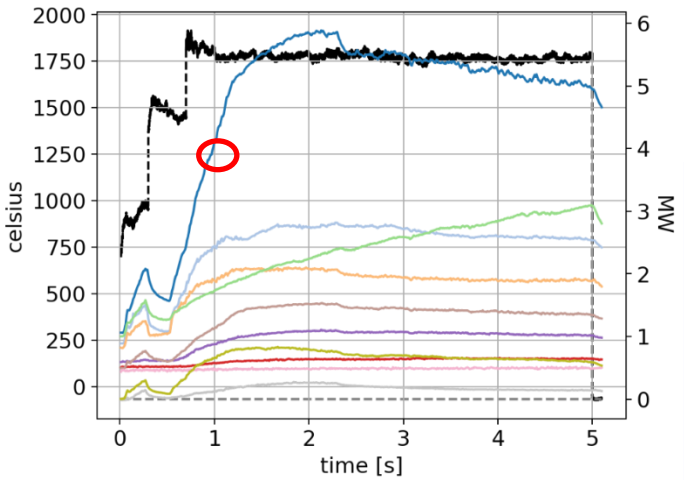
Cameras Assembled in Endoscope

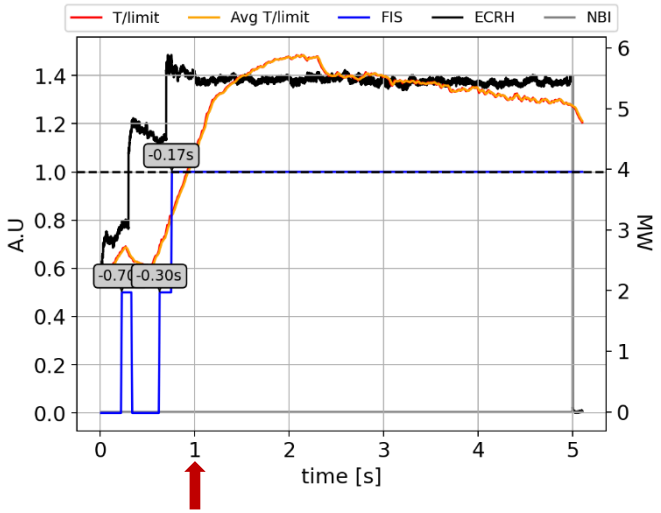
PCO Edge 5.5, CLHS

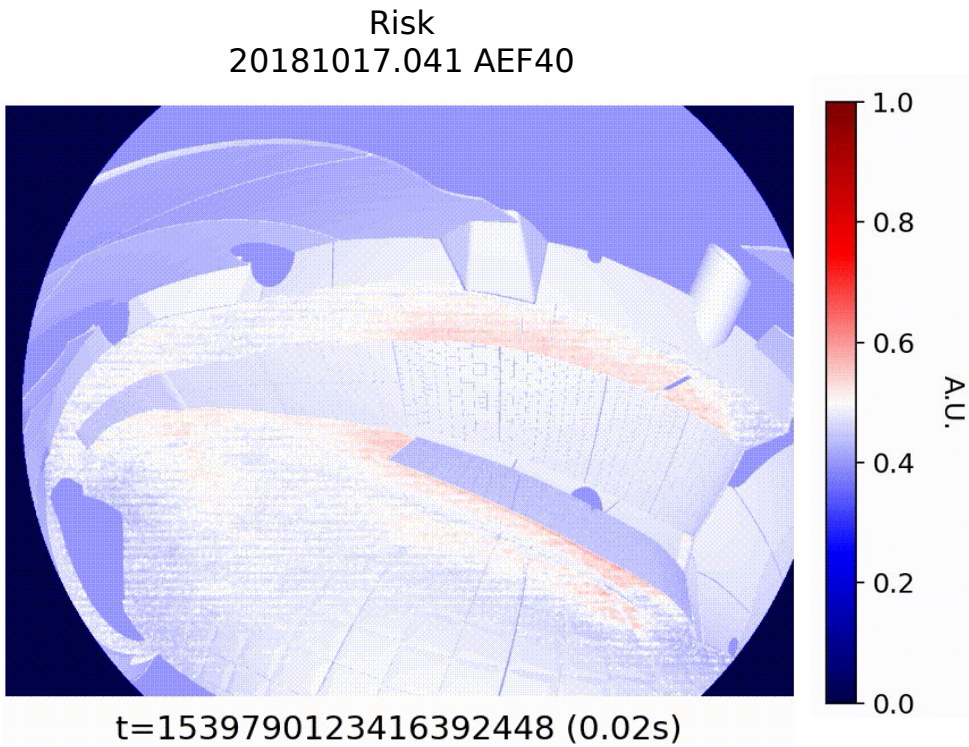
SCD Hercules, CL



Thermal Overload Detection (TOD)



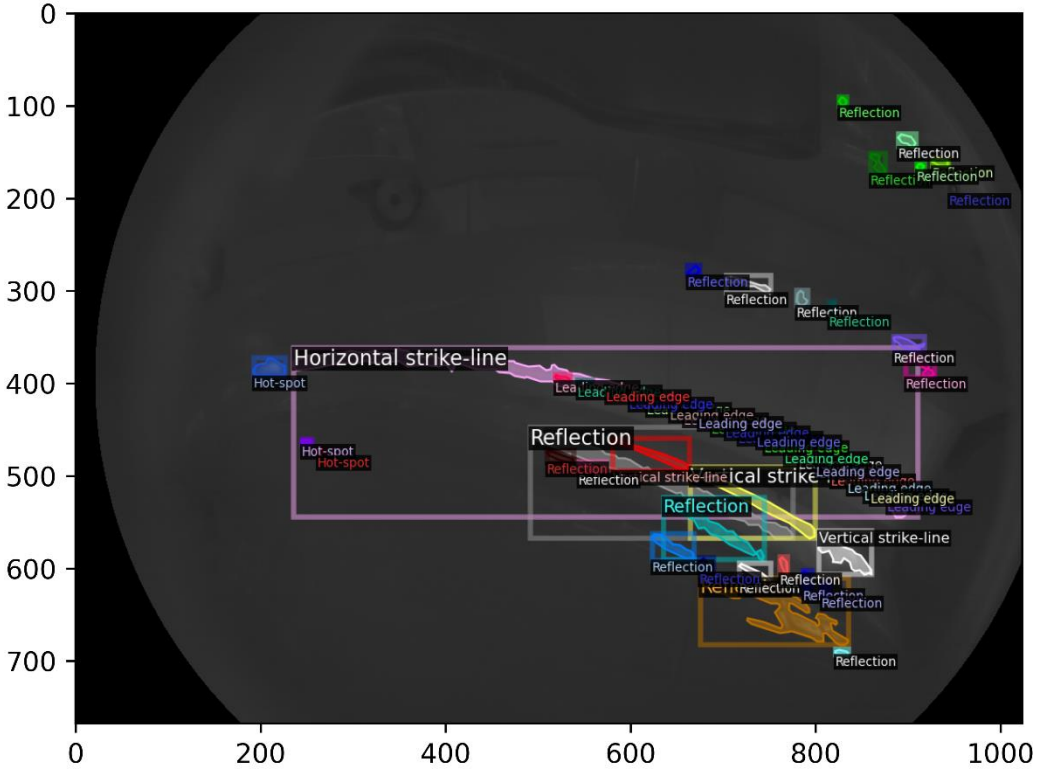


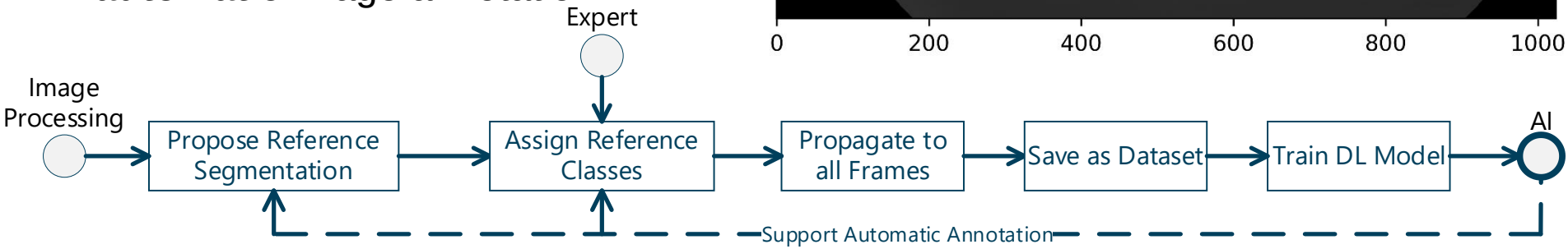


Low iota target overload at **~1 s**, anticipated **170 ms** before

Thermal Event Detection and Classification

- **Deep Learning** for instance segmentation (detection and classification) of **thermal events** in IR images
- Requires a substantial amount of **annotated data**
- Images are **complex** to annotate **manually** (100 frames per discharge second to annotate)
- Develop a method for **semi-automatic** image annotation





Discharge Sequence Annotation

Annotated Image

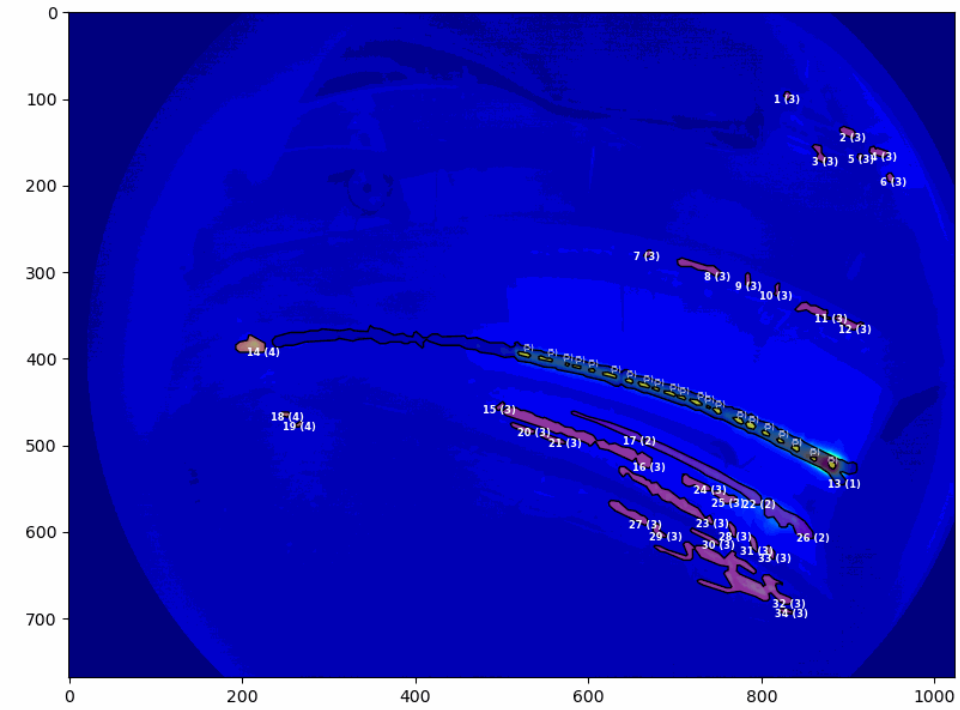
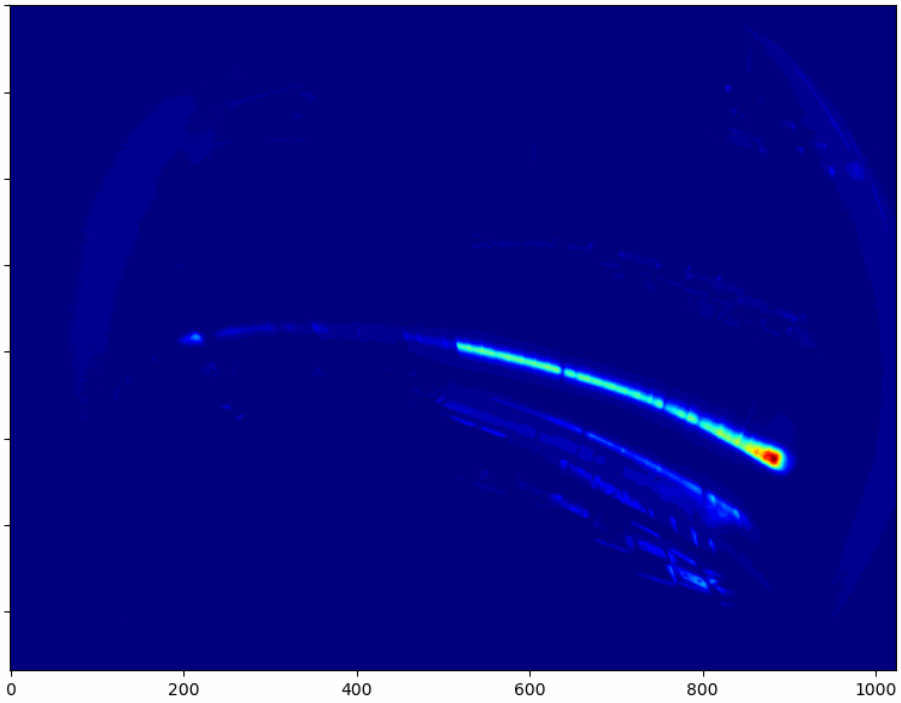


Image without Background

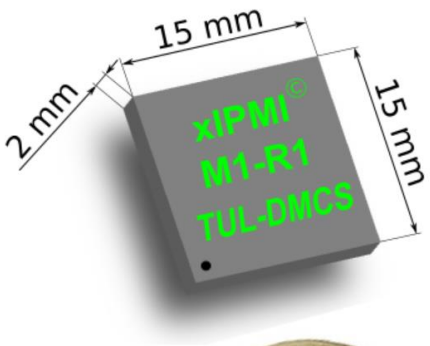


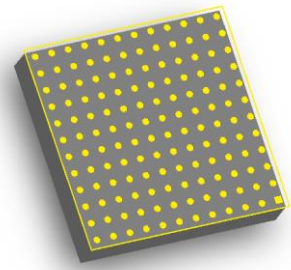
1: Horizontal strike-line
2: Vertical strike-line
3: Reflection
4: Hot-spot
5: Leading edge
6: UFO

Smart MMC and RMC solution for xTCA systems including FMC support

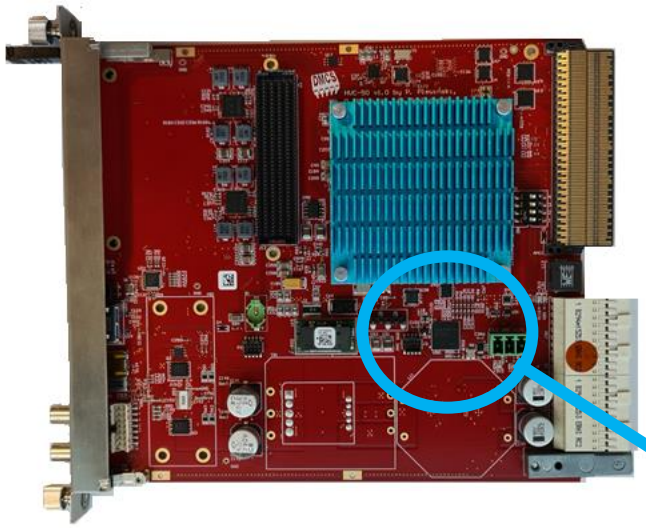
Smart MMC and RMC solution for xTCA

- TUL-DMCS works on **MMC/IPMC solutions since 2006**
- ASIC-like solution:
  - **Miniature size 15 mm x 15 mm x 2 mm**
  - **Cost-effective solution**
- Looking for solution for both:
  - **AdvancedTCA (Carrier and RTM)**
  - **MicroTCA (AMC, RTM)**
  - **Basic and Advanced versions**
- ARM microcontroller
  - 1 or 2 ARM cores
  - Low consumption power
  - Ready to be integrated with RTM
- **Programmable logic with up to 12 I2C interfaces**
- **Working of firmware and software**
  - Full HPM.1 support including **HPM.1 roll-back** (first time in MTCA.4 world)

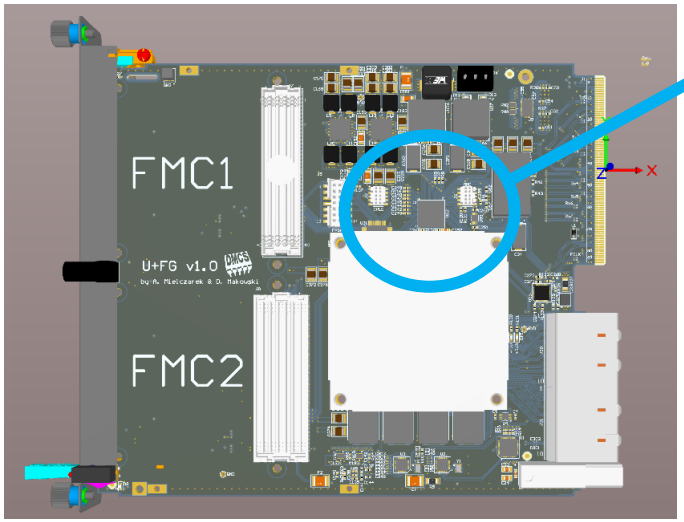


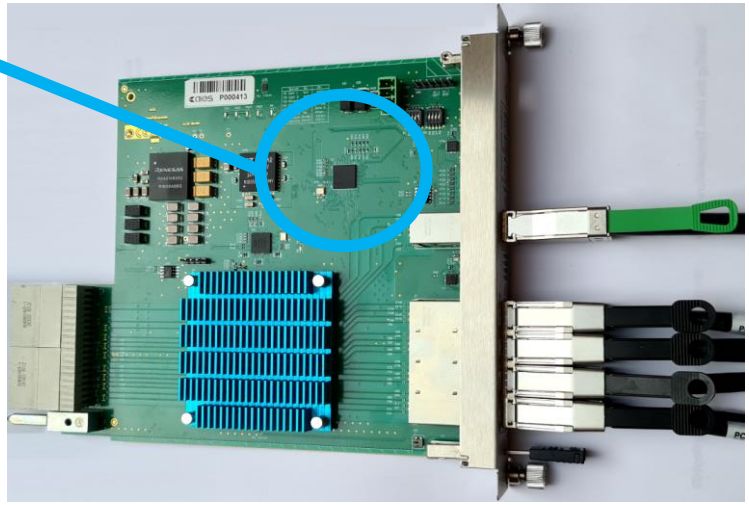


MicroTCA – MMC Implementations



MMC

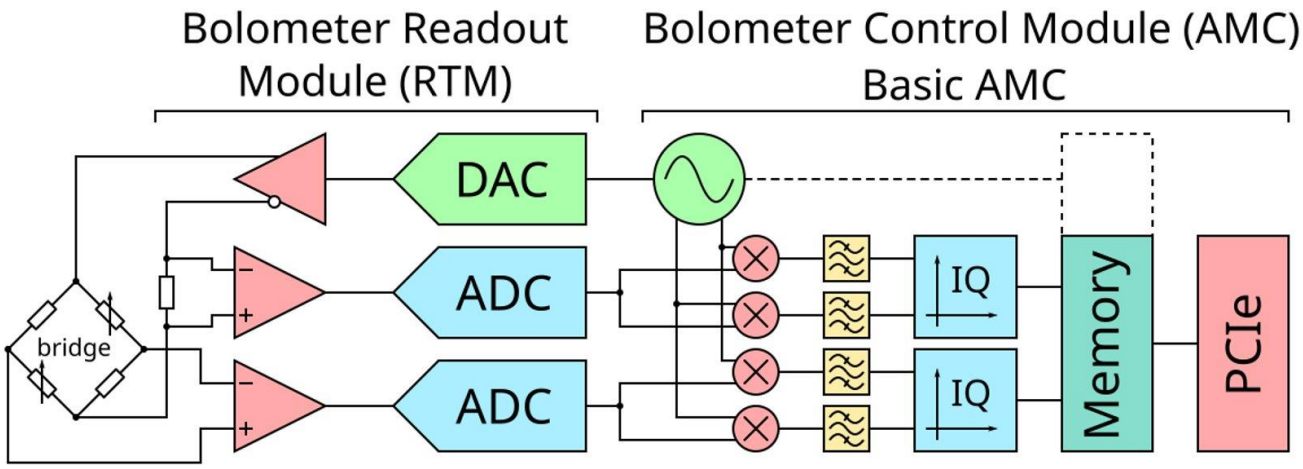




Basic-AMC – the low-cost MicroTCA.4 Compliant Carrier Module

- See presentation on Wed 7/12, 16:45
- See presentation on Thu 8/12, 9:45

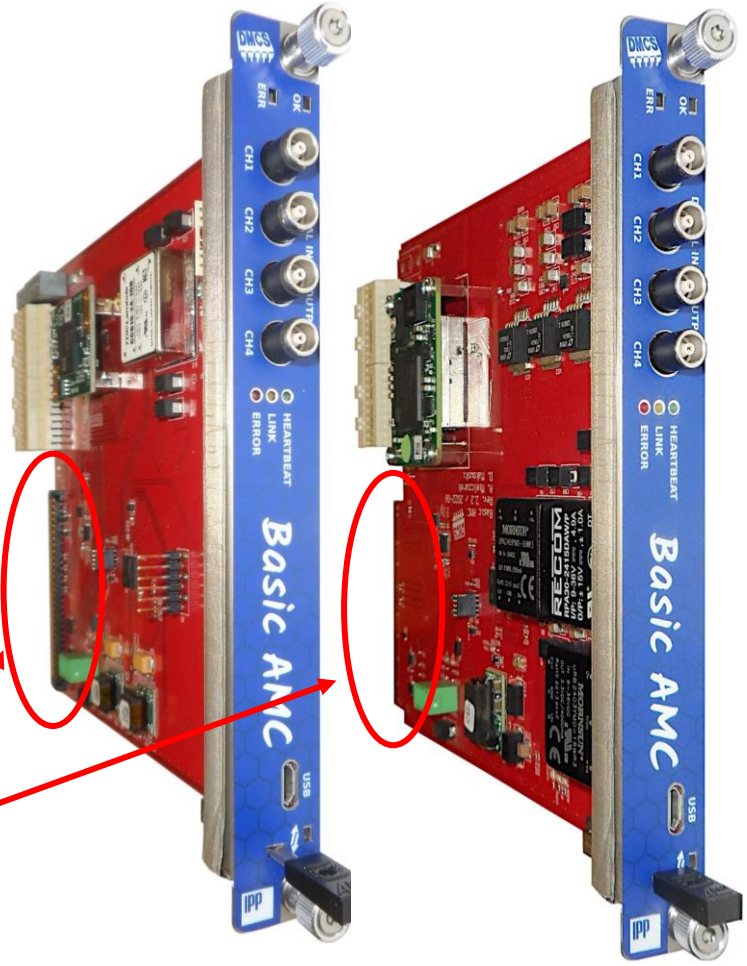
Bolometer System for W7X



- Use MicroTCA.4 standard to build the system, cost-effective design
- Provides excitation signal for bolometer Wheatstone bridge
- Measure and digitally process signal from the Wheatstone bridge
- **Measurements used for real-time plasma control**
- Data acquisition and processing part **implemented as D-AMC**
- Analogue low-noise front end and **digitalisation part implemented as D-RTM**

Basic-AMC Features

- Based on commercial Trenz FPGA module
- Offers multi-gigabit connectivity
- FPGA I/O signals on Zone 3 and three LVDS clocks
- Provide **voltages for analogue components** on RTM
- The PCB has only 6 metal layers, including two full ground planes
- **Pre-production succeeded (no problems detected)**
- **Production finished (ca. 55 modules)**
- **Problems with components (Harting/ITB connectors) – need to redesign PCB**
- **Final test next month…**

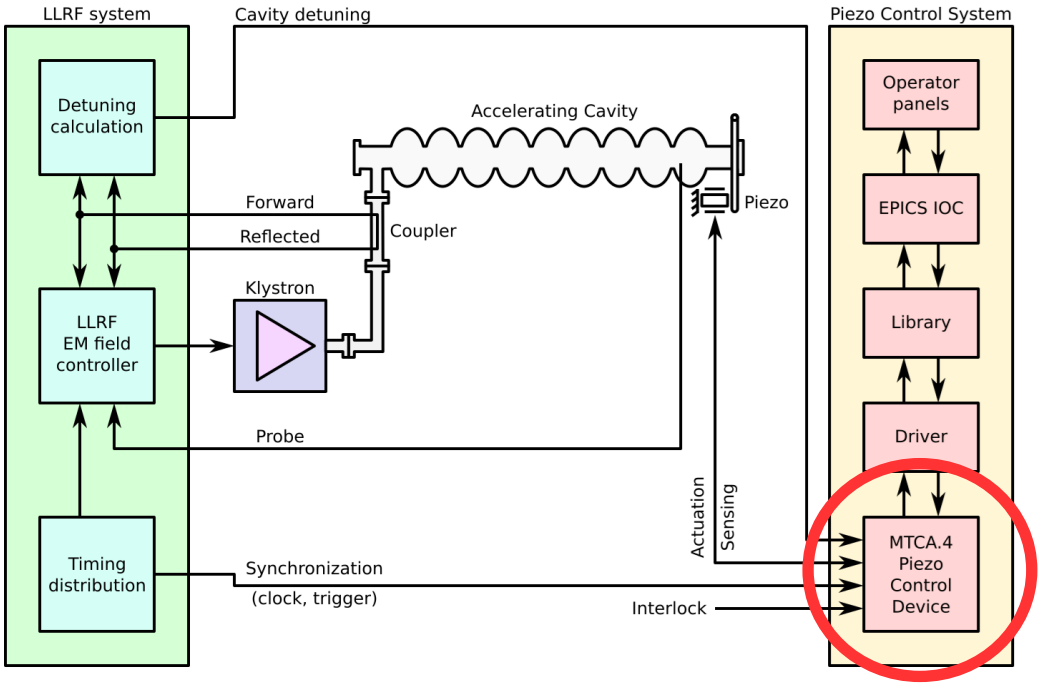


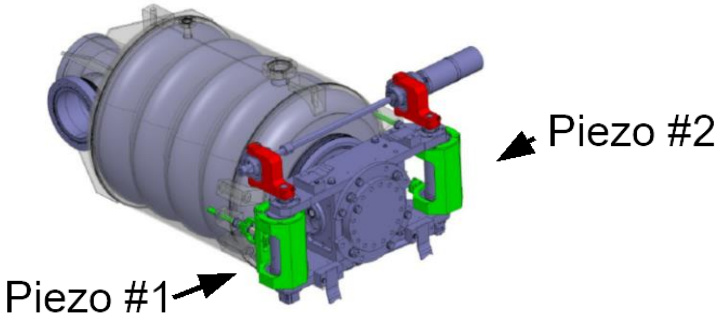
Version 1 **Version 2**

High-power piezo driver for European Spallation Source Accelerator

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.



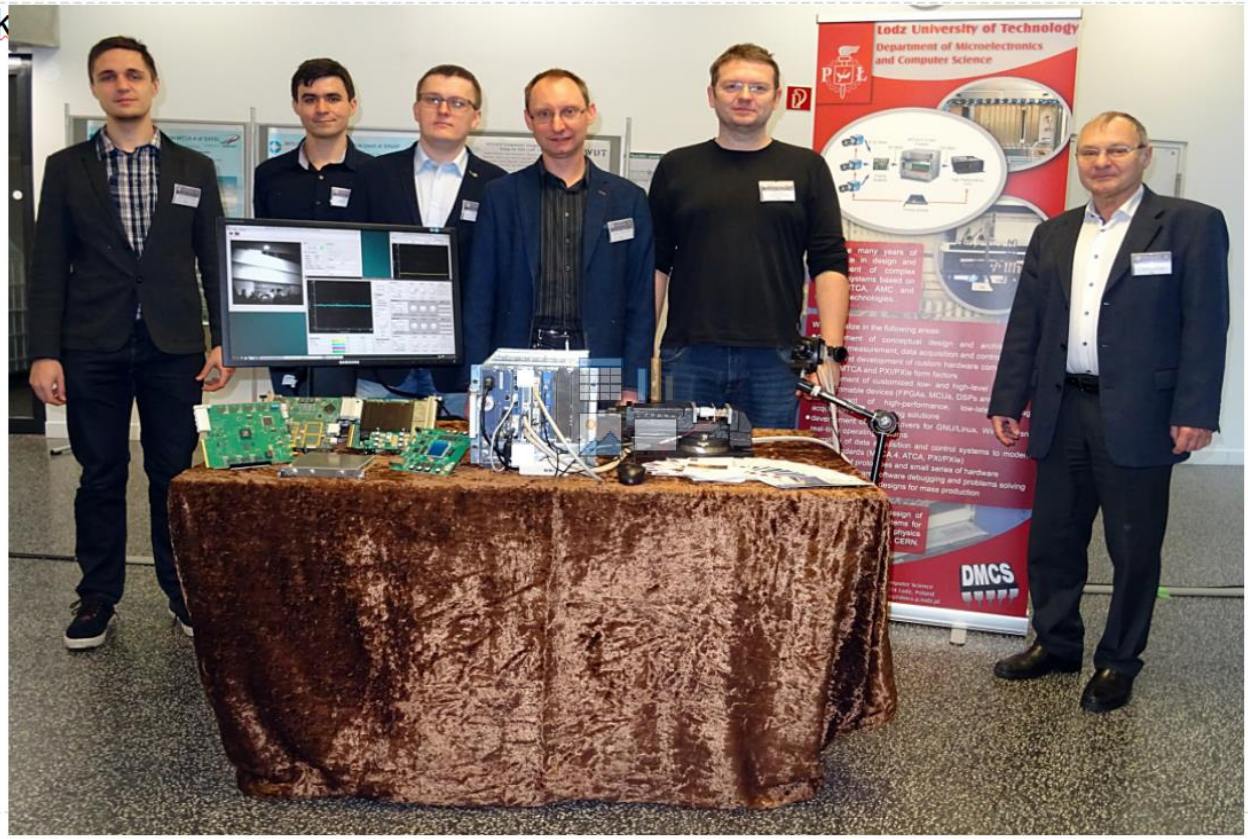


ESS cavity with 2 piezo actuators

MicroTCA.4 Workshop in 2017

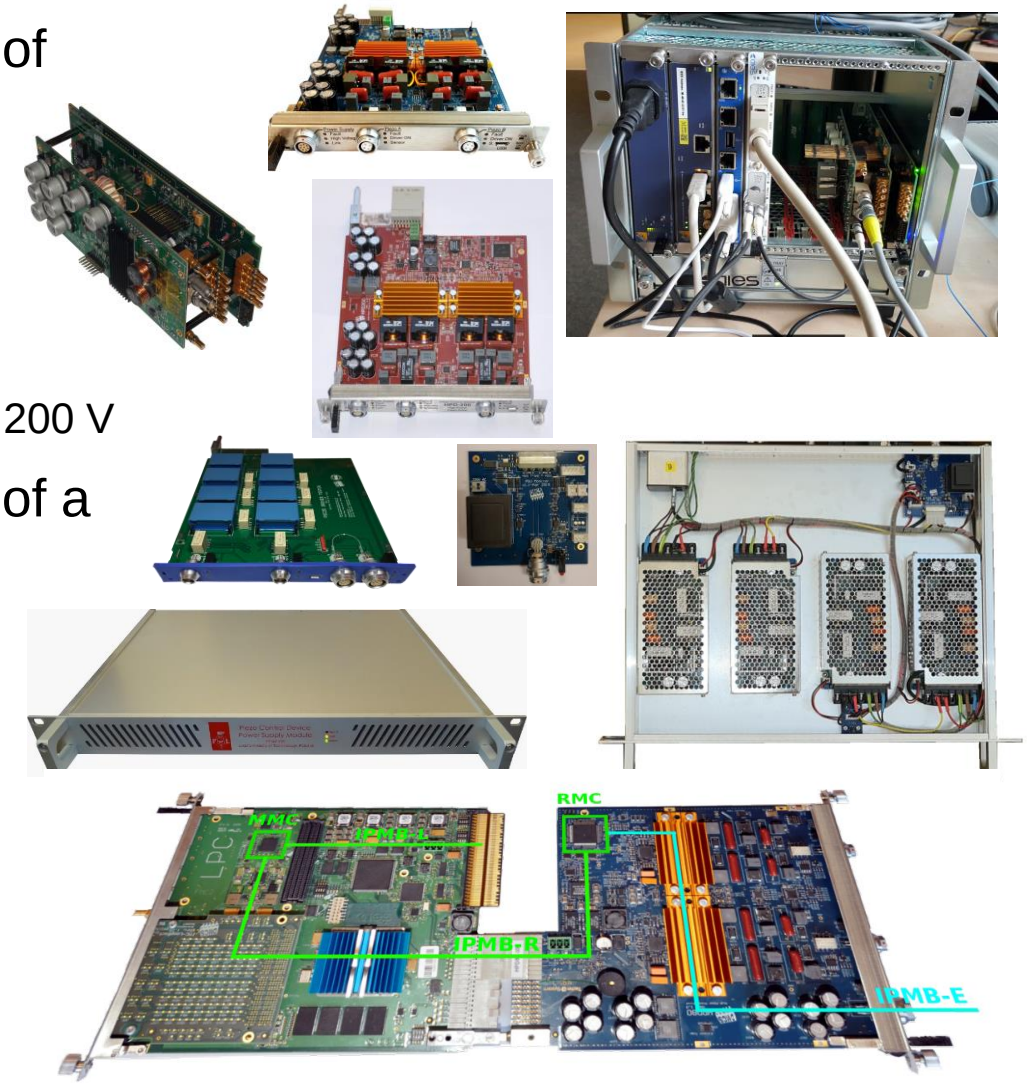
Live Demo at TUL-DMCS Booth

- Klik



History…

- Developed and tested 3 versions of piezo driver (HPD)
  - Linear amplifier
  - PWM amplifier
  - Bipolar and unipolar variants
  - Various voltage ranges: +/-100 V, +/- 200 V
- Developed and tested 2 versions of a dedicated Power Supply Module (PPSM)
- **Finally agreed for:**
  - HPD-200 (~+/- 190 V, ~380 Vpp)
  - PPSM-200 (+/- 100 V)
- **Class-D amplifiers**



Current Status

- Started mass production on beginning of 2022
  - HPD-200 (130 pieces)
  - PPSM-200 (130 pieces)
- Big problems with components availability
  - Components changed and PCBs redesigned
- Final production ongoing
  - **PPSM-200 (40 pieces manufacture), +90 under production**
  - **HPD-200 pre-production started, mass production in January'2023**
- Final tests and delivery to ESS

Thank you for your attention