# RF and phase reference signal distribution and processing in uTCA based LLRF system

## EuCard WP10.6 - LLRF at FLASH

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**On behalf of the LLRF Team**

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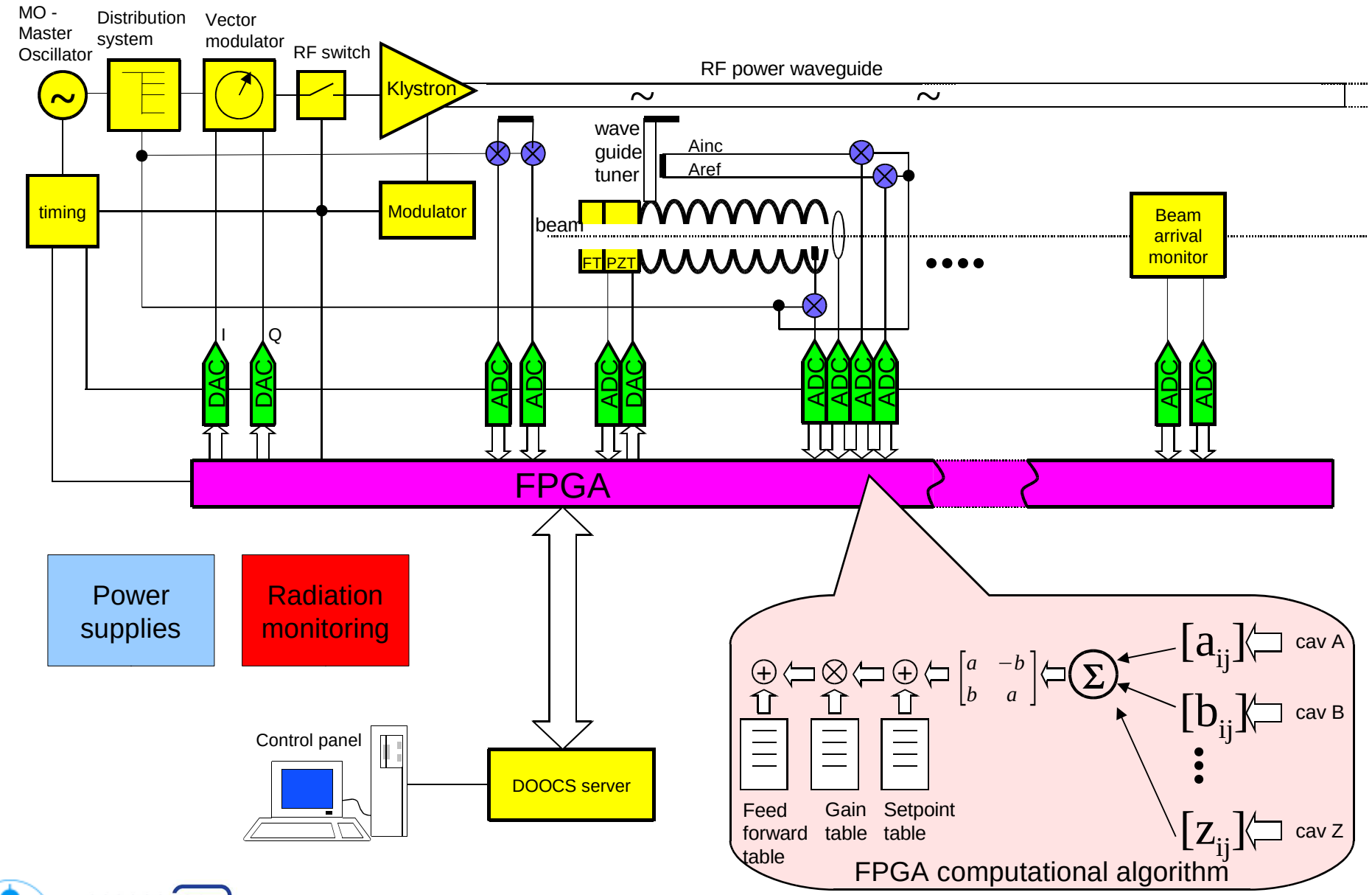
# Introduction: RF signals in LLRF



# RF and Analog Signals

For one cryomodule we need to process 24 RF signals + synchronization + klystron drive + diagnostics...

That means 24x:

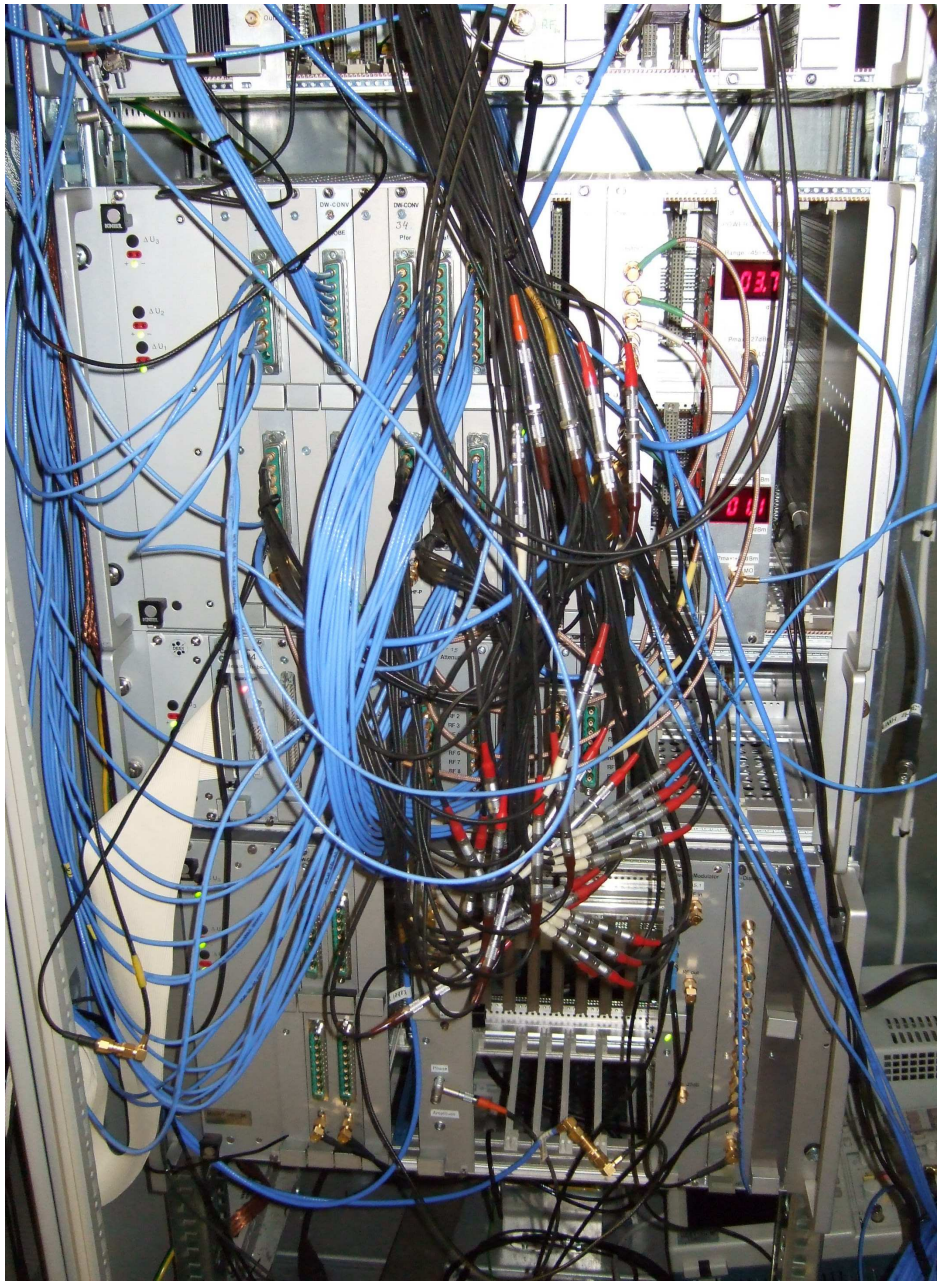
- downconverter channels
- LO distribution
- IF signals to digitizers

High performance of regulation required (0.01 % amplitude, 0.01$^{o}$ phase)

- low crosstalk
- high linearity
- 16-bit ADCs/~80 - 100 MSPS (x24)

Required also: high reliability (expensive FLASH down time), easy maintenance (hot swap) and 10 fs of RF synchronization

# This Worked in the Past … Really!



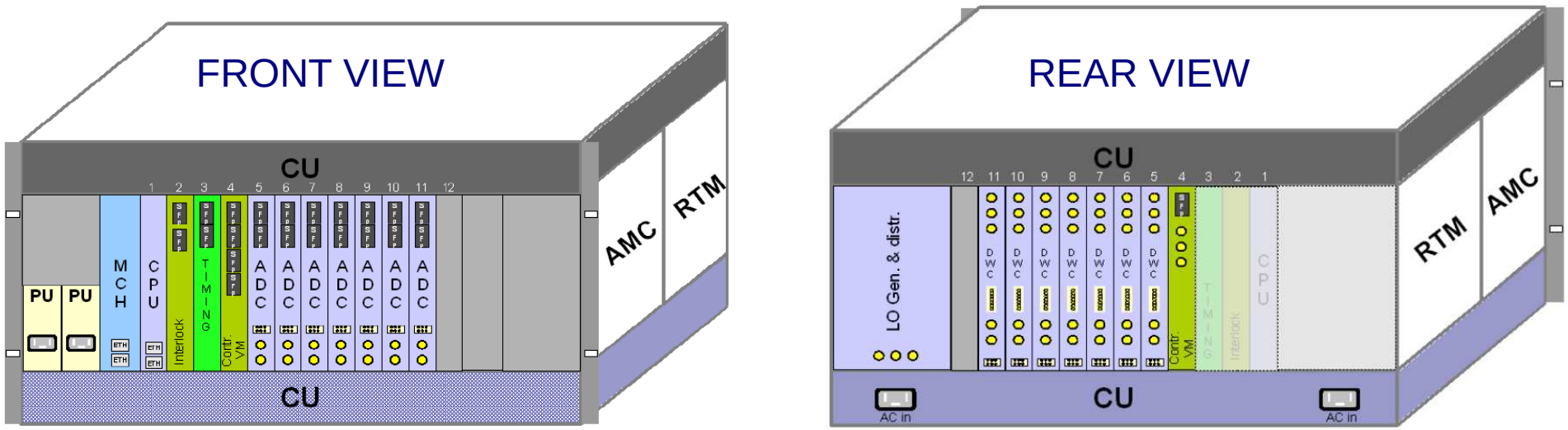
# EuCARD Objectives for LLRF at FLASH

- Update electronics and achieve:
  - High performance of RF and analog signal processing
  - High availability
  - Modern form factor (upgrade-ability)
  - Higher computing power

Idea of uTCA (previously ATCA) based system was developed

# LLRF in uTCA Crate

- The new LLRF system concept: compact design in uTCA crate
- Both AMC (front) and uRTM (rear) modules are used
- Many RF signals must be distributed inside of the crate (minimum external connections)
- RTM cards with downconverters, vector modulators were designed and integrated with support of the RF Backplane

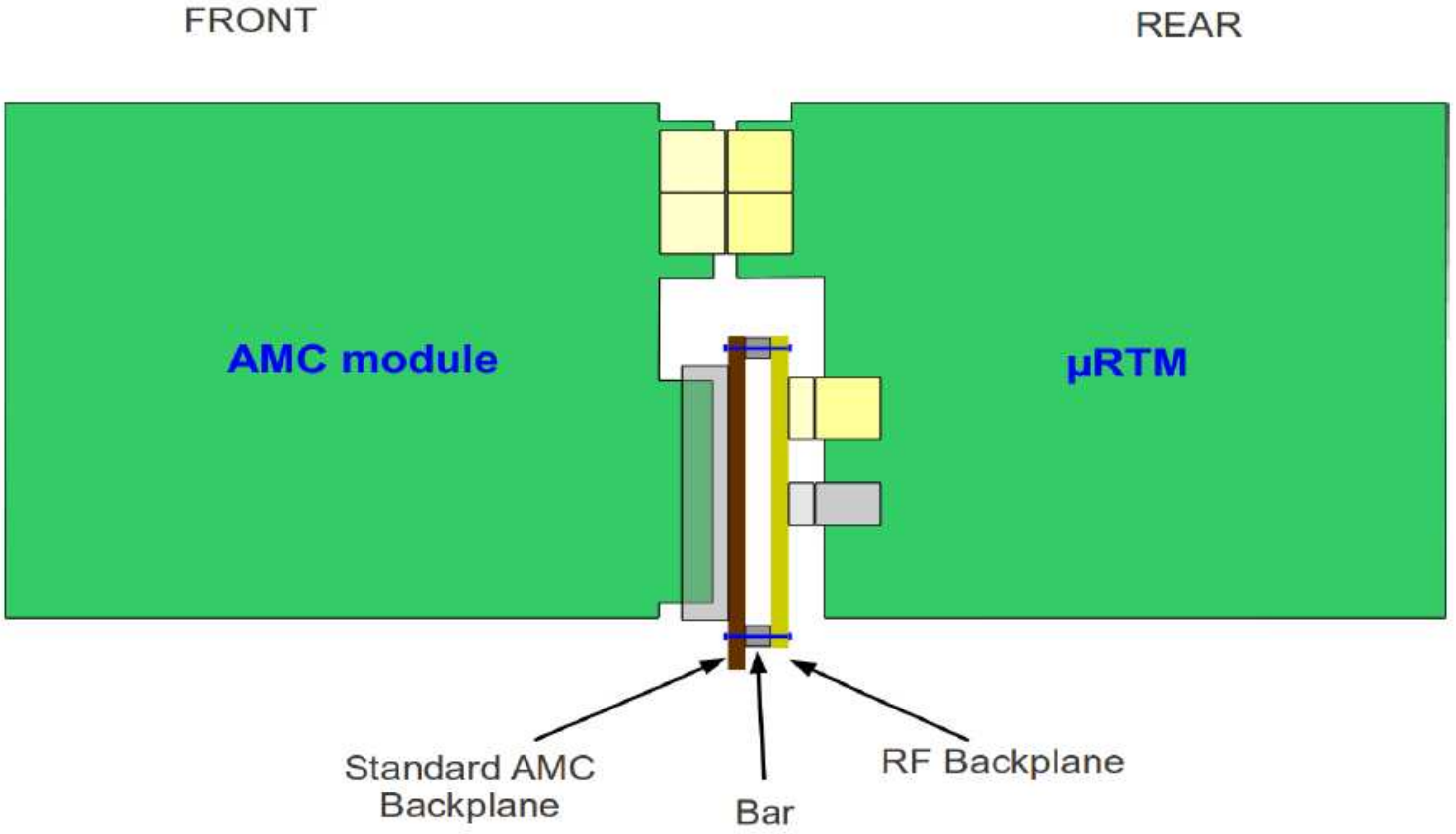



Courtesy of T. Jeżyński

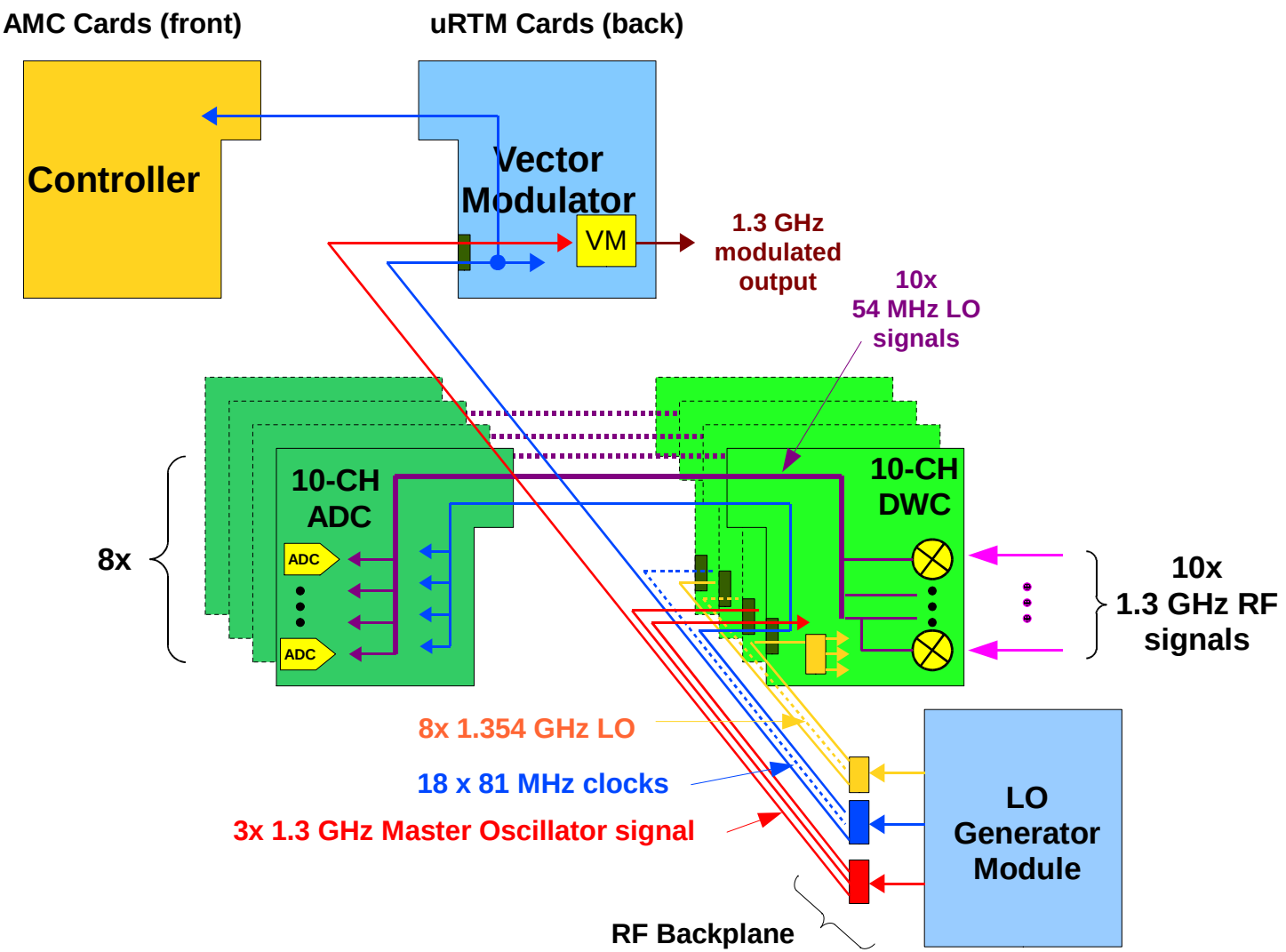
# AMC, RTMs and RF Backplane

AMC Modules:
- Controller
- ADC card

uRTM Modules:
- Mutichannel downconverter
- Vector Modulator



# LO, RF and Clock Signal Distribution Inside of the uTCA Crate

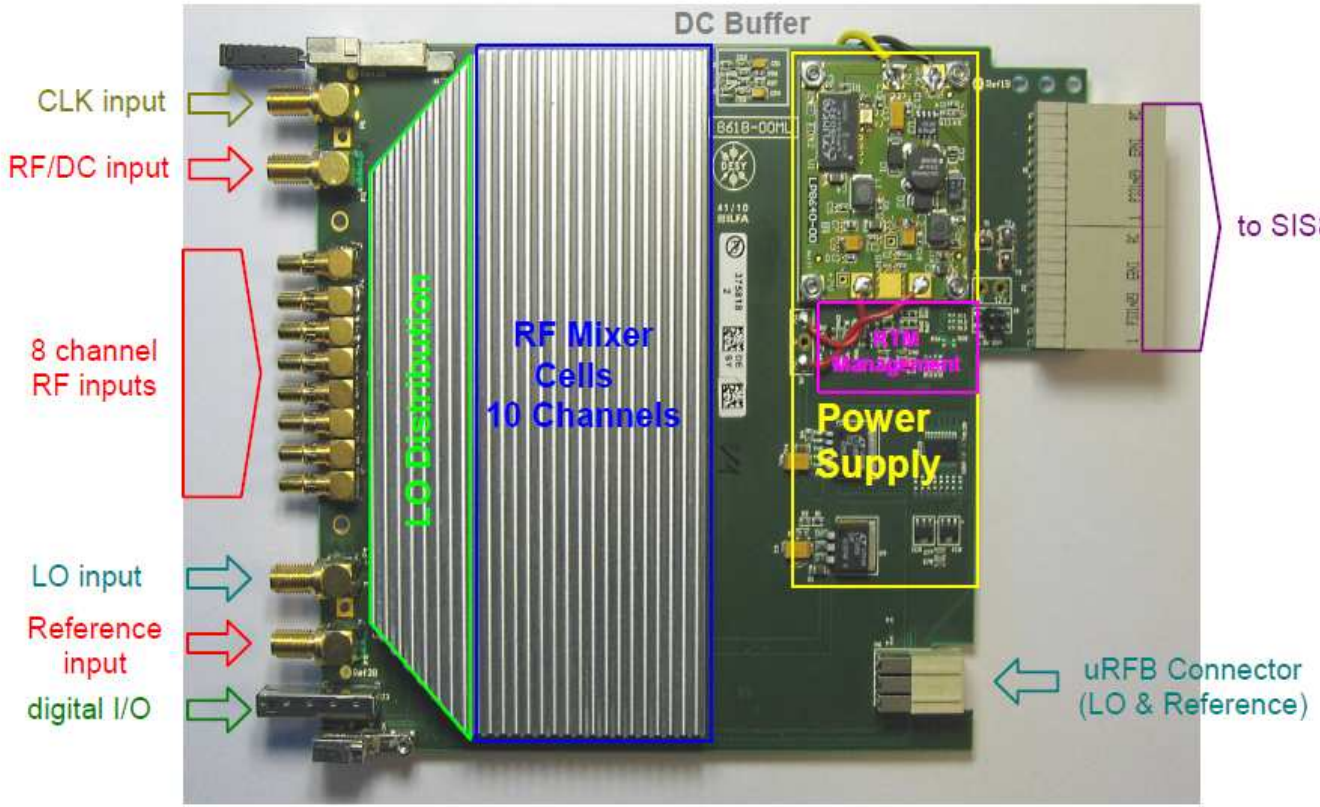


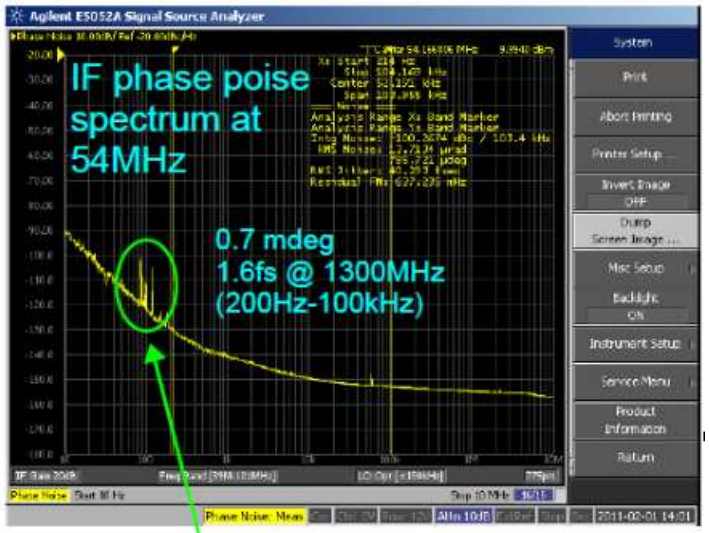
# RTM Downconverter (DWC)

- Collaborative effort: DESY, WUT
- 10-channel downconverter module
- Change the cavity frequency (1.3 GHz) down to 54 MHz IF signal
- Very high performance required (linearity, low crosstalk, low noise contribution)
- RF Backplane compatible
- Minimum cable connections (LO distribution on board)

# DWC RTM Version

- Prototype integrated on RTM form factor in 2011 (M10.6.8)
- Excellent performance



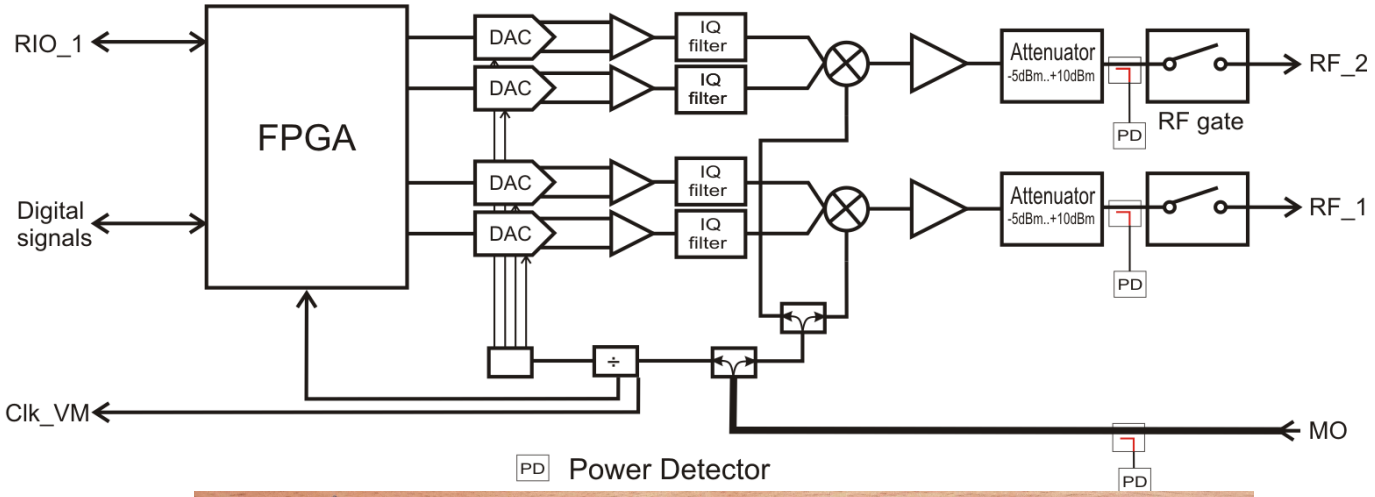



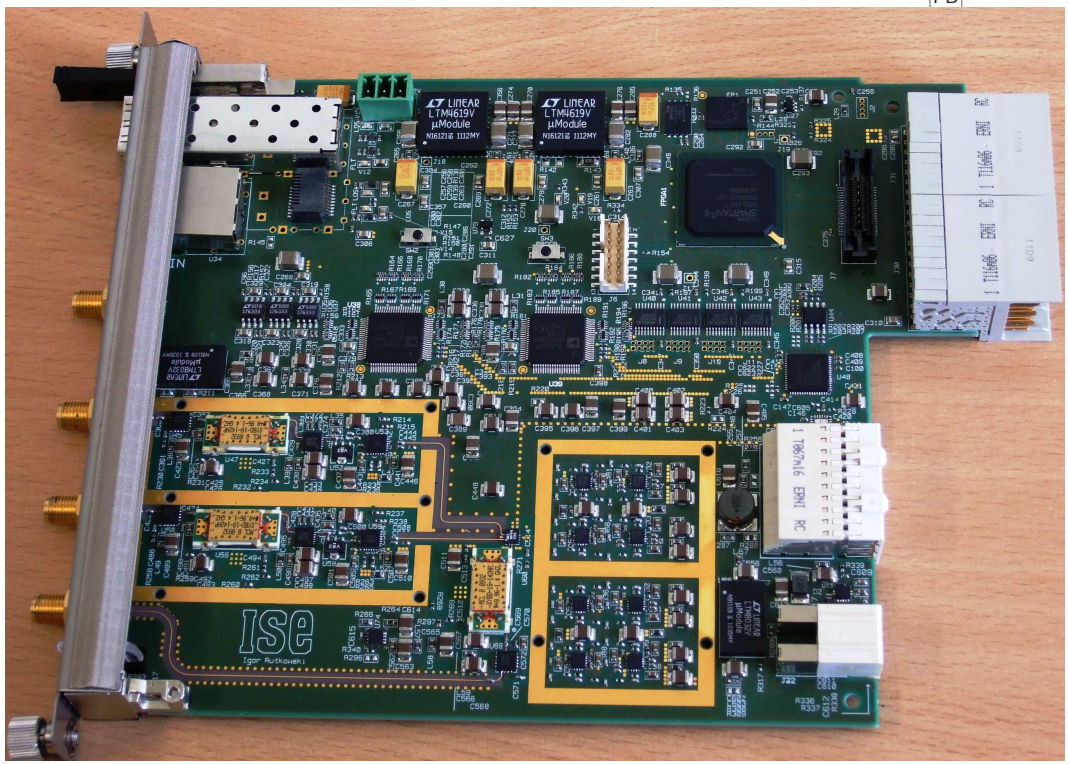

Courtesy of Jan Piekarski and Matthias Hoffmann

# RTM Vector Modulator (uVM)

- Collaborative effort: DESY, TUL, WUT
- Designed for modulation of the klystron input signal
- Driven directly from AMC digital controller card (uTC)
- Assumed minimum front panel connections
- Two-channel device
- Operation frequency range of 216 MHz to 3.9 GHz (for various applications in the machine)
- Objective: low noise floor (below -160 dBc)
- Prototype was successfully tested in 2011 (EuCARD Deliverable 10.6.8)

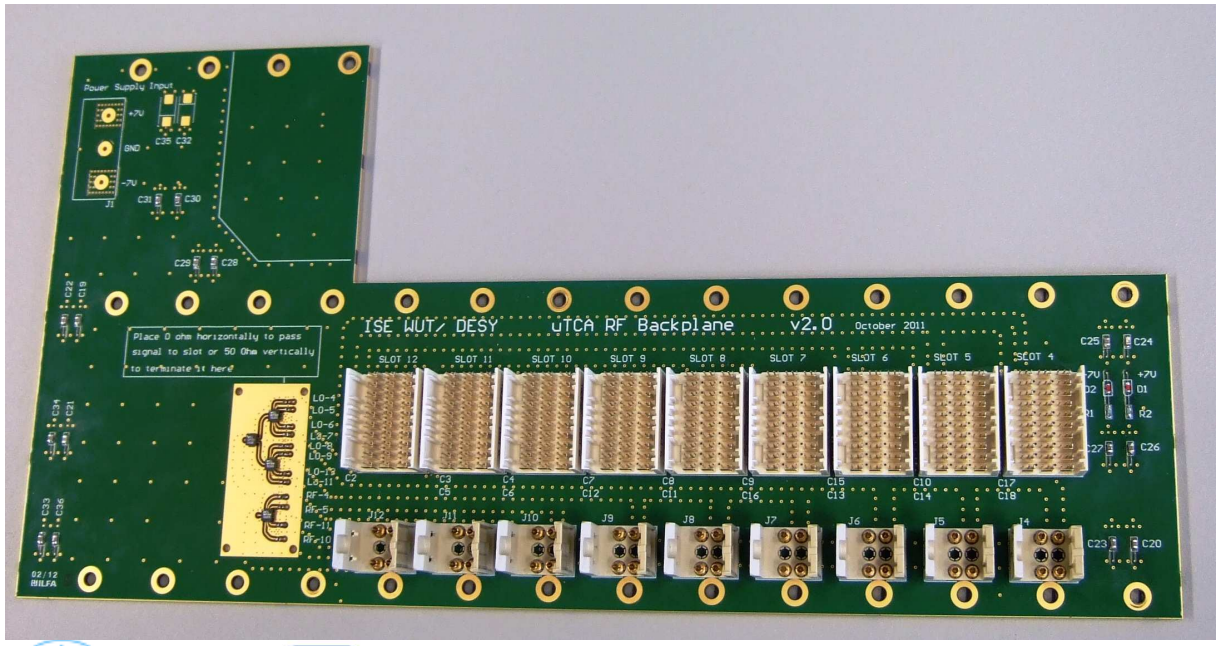
# uVM Device

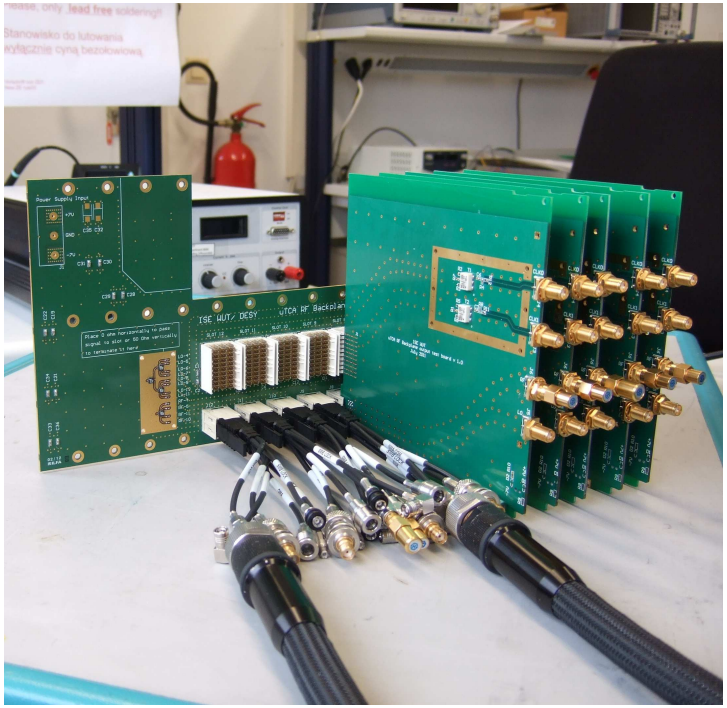

RIO_1
Digital signals
Clk_VM
FPGA
DAC
DAC
DAC
DAC
IQ filter
IQ filter
IQ filter
IQ filter
÷
Attenuator
-5dBm..+10dBm
Attenuator
-5dBm..+10dBm
PD
PD
PD
RF gate
RF_2
RF_1
MO
PD Power Detector



# RF Backplane

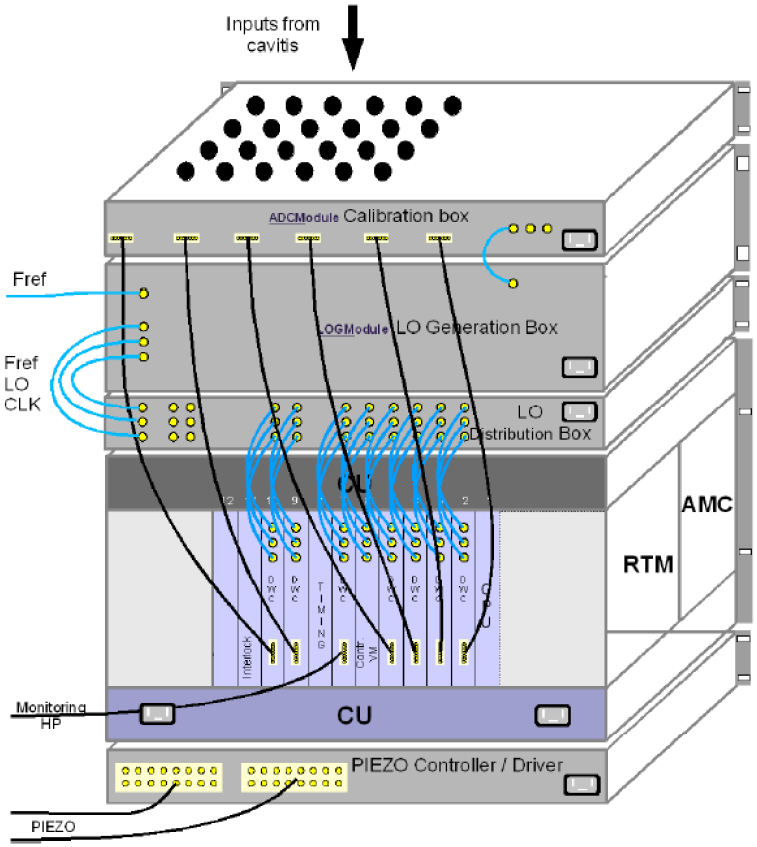
- 10-layer RF board design
- Hybrid construction – main board + uRFB shield
- Edge plating for further shielding
- ERNI (3x10 diff pair) for CLK signals
- Radiall Coaxipack 2 for LO and MO signals



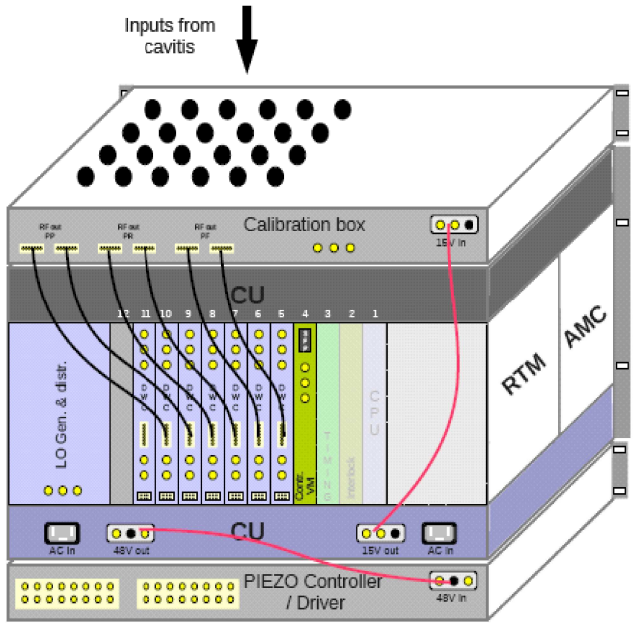



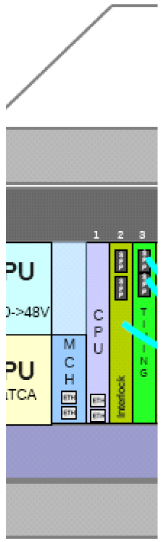
# LLRF System with vs without RF Backplane

System with signals distributed outside the crate

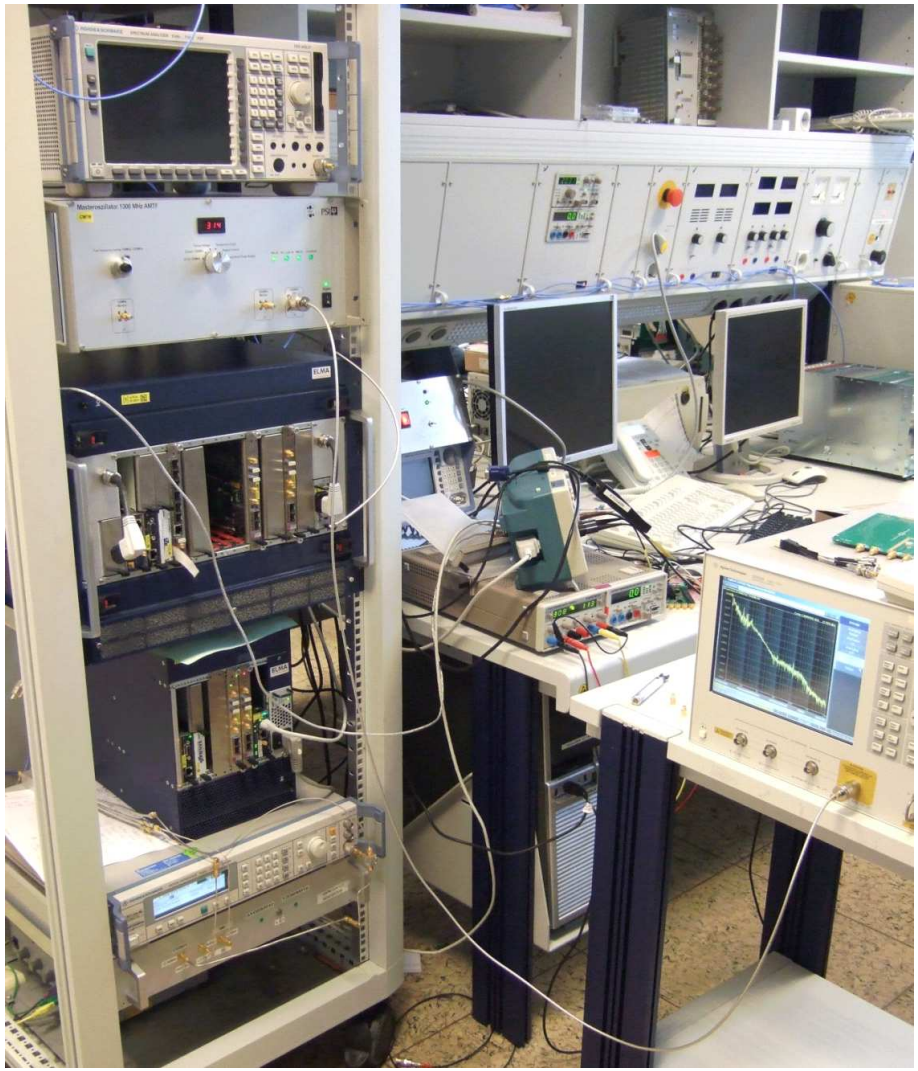



System with RF Backplane



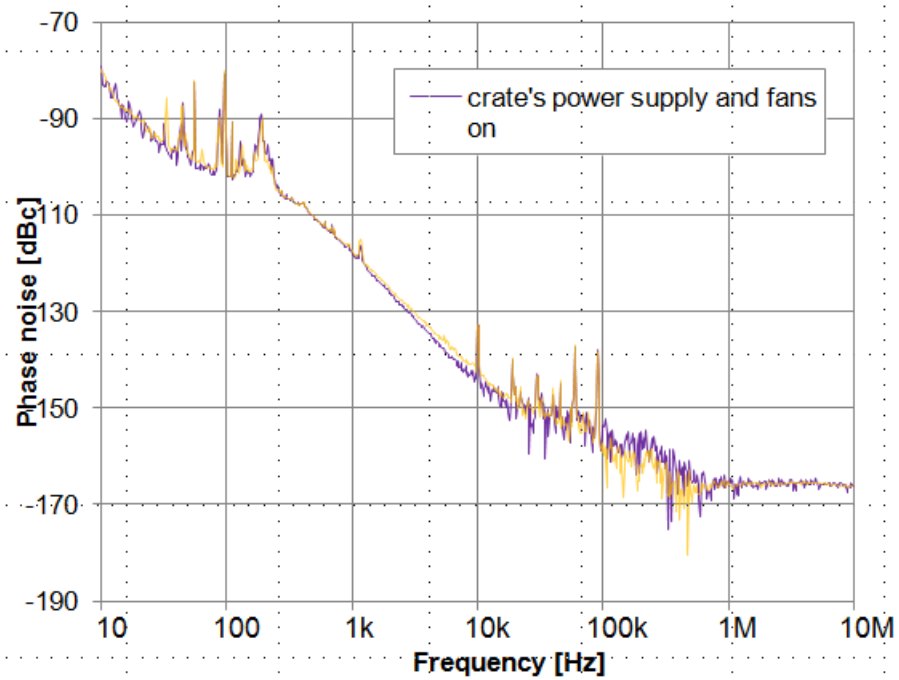



# uTCA Crate Tests with the RF Backplane



System tested with presence of digital subsystems

No degradation of field detection performance was observed



# uFMC

- uFMC board developed by NCBJ
- Supports fast ADCS (up to 500 MSPS) on FMC cards
- Can be used for direct sampling of GHz signals
- Foreseen for applications like Beam Arrival Monitor and Klystron Life Management

# Summary

- The LLRF collaboration supported by EuCARD developed compact and high performance LLRF system
- Highly sophisticated electronics with unique performance developed
- Universal solution with world's first RF Backplane supporting hot-swap on sub 100 fs level of accuracy!
- There is strong interest from other laboratories and companies - possible commercial production and use for other applications (radars, instrumentation for other control systems)
- Full system installation at FLASH planned in summer 2012
- No continuation in EuCARD 2 ...

Thank you for attention!