MicroTCA @ European XFEL

Kay Rehlich

DESY

Outline

1.6 km cold accelerator

3.3 km
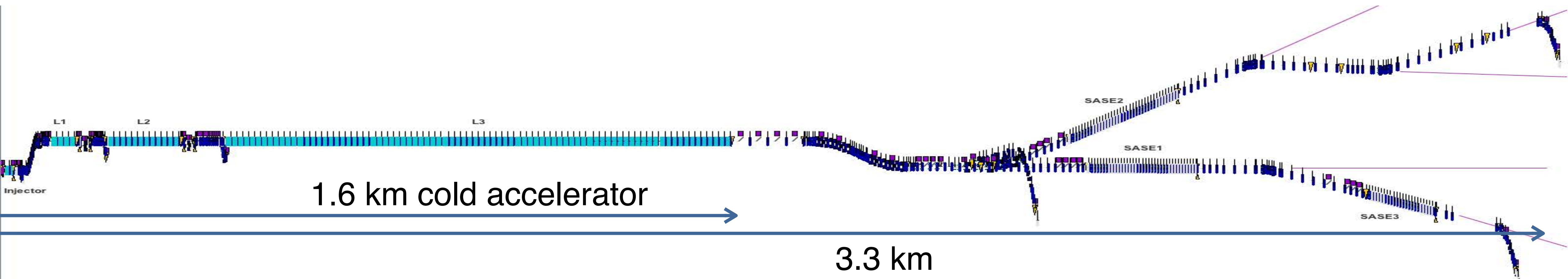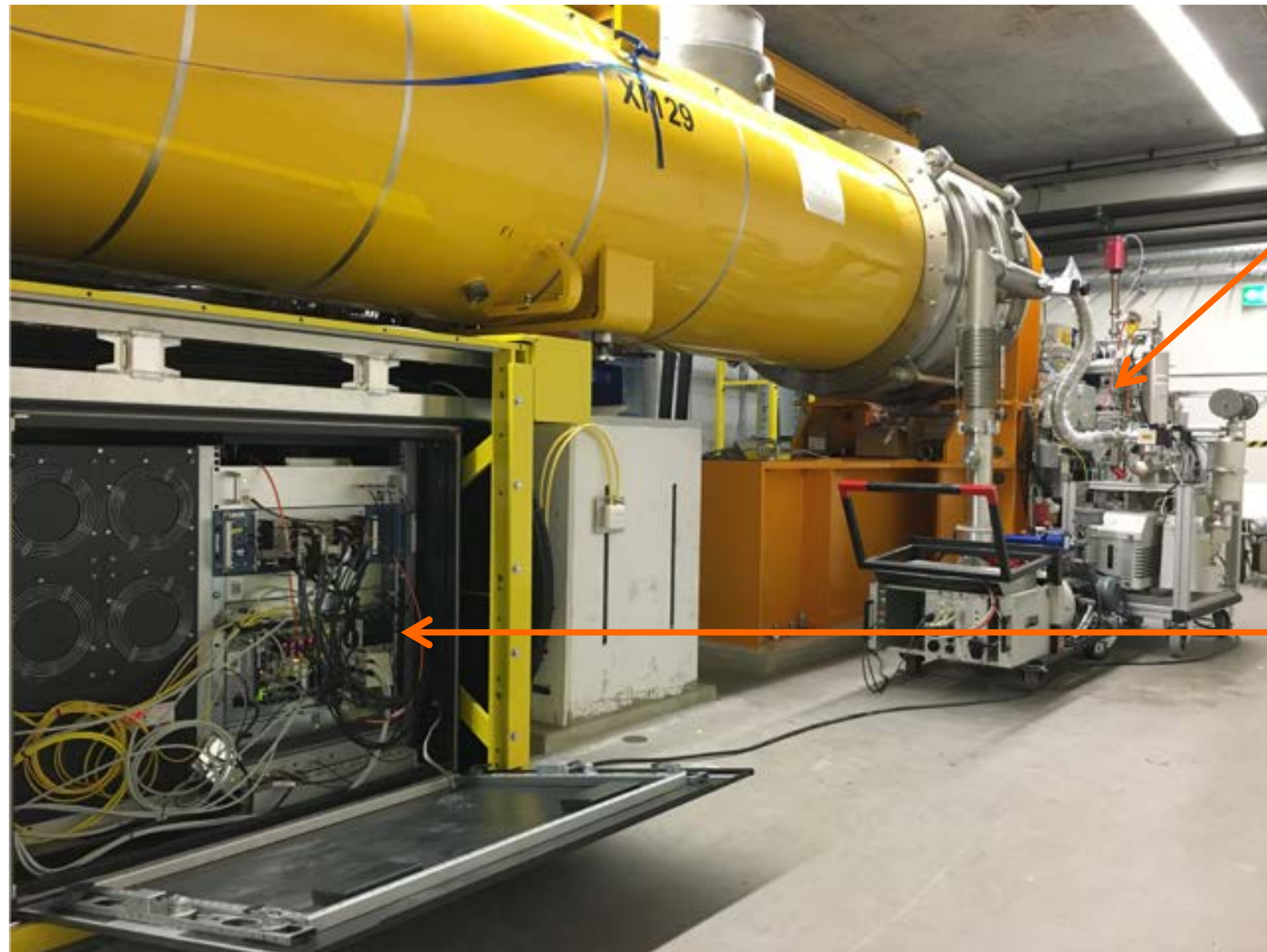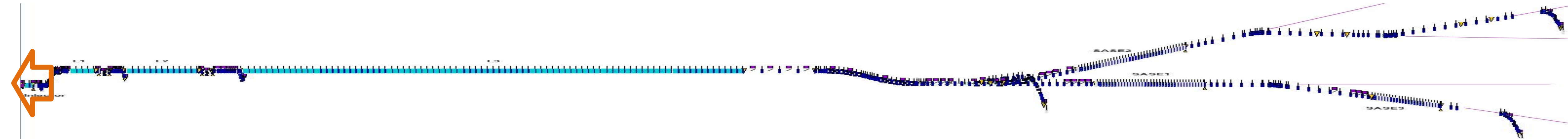
**European XFEL
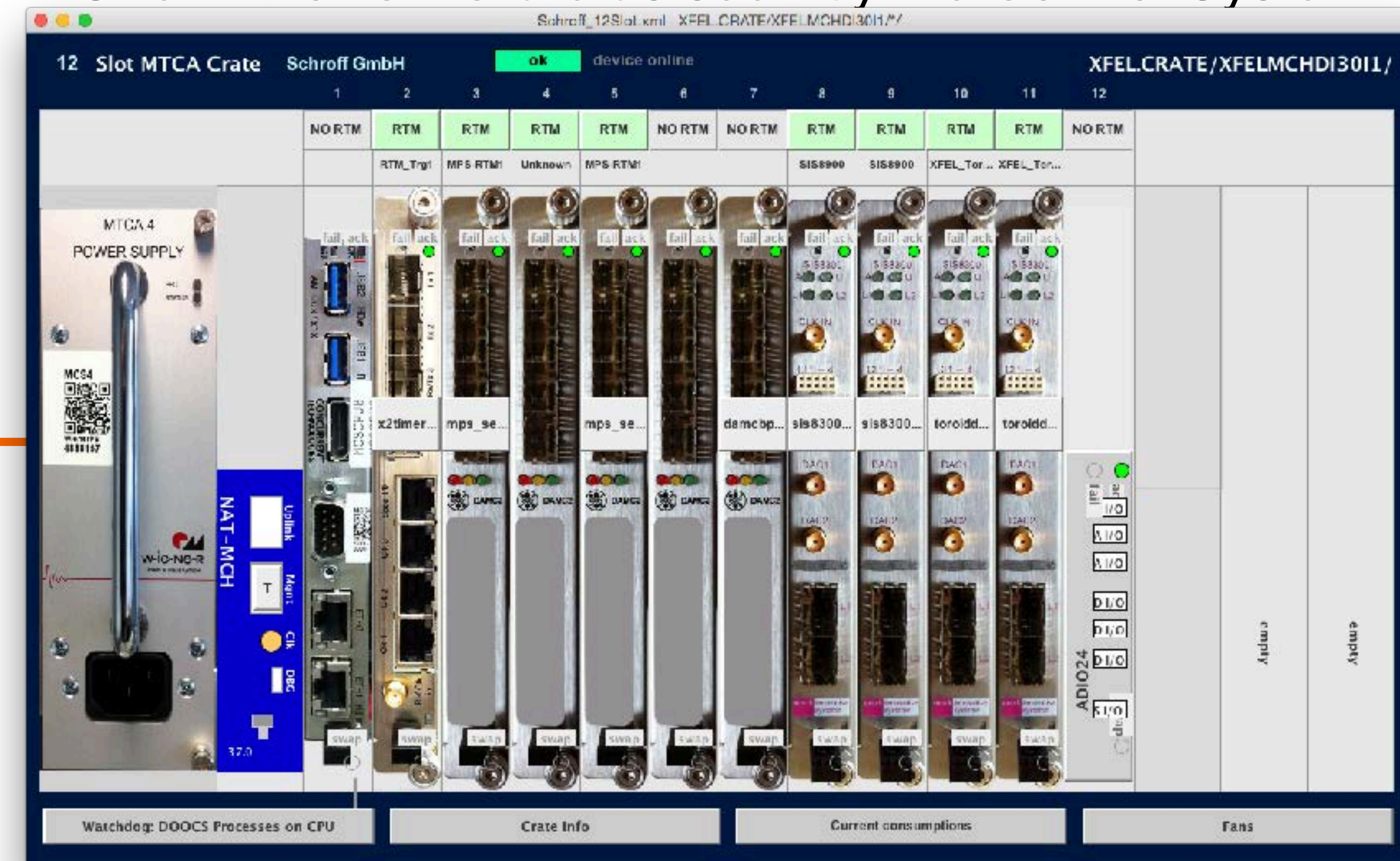MicroTCA Systems
Control System DOOCS**
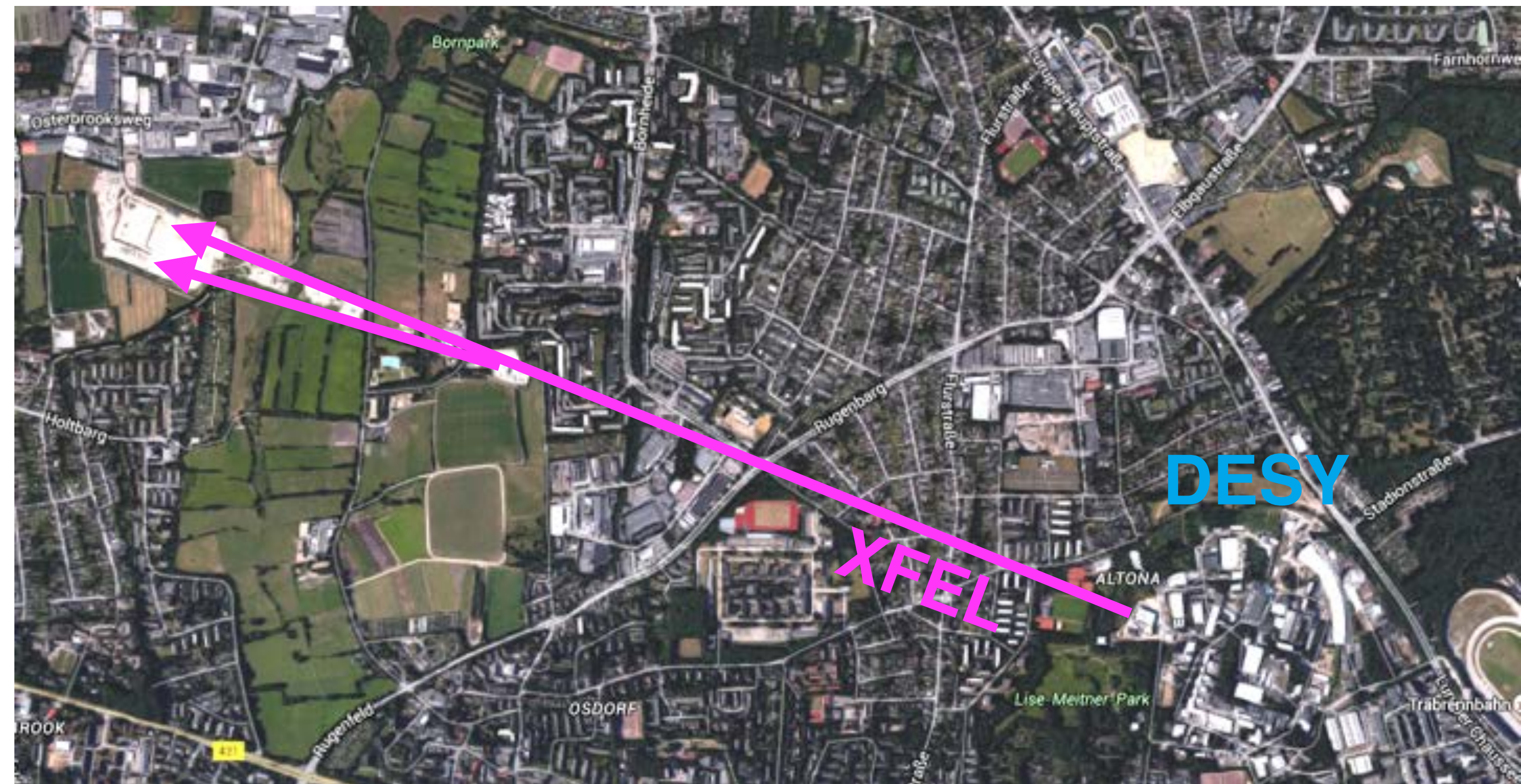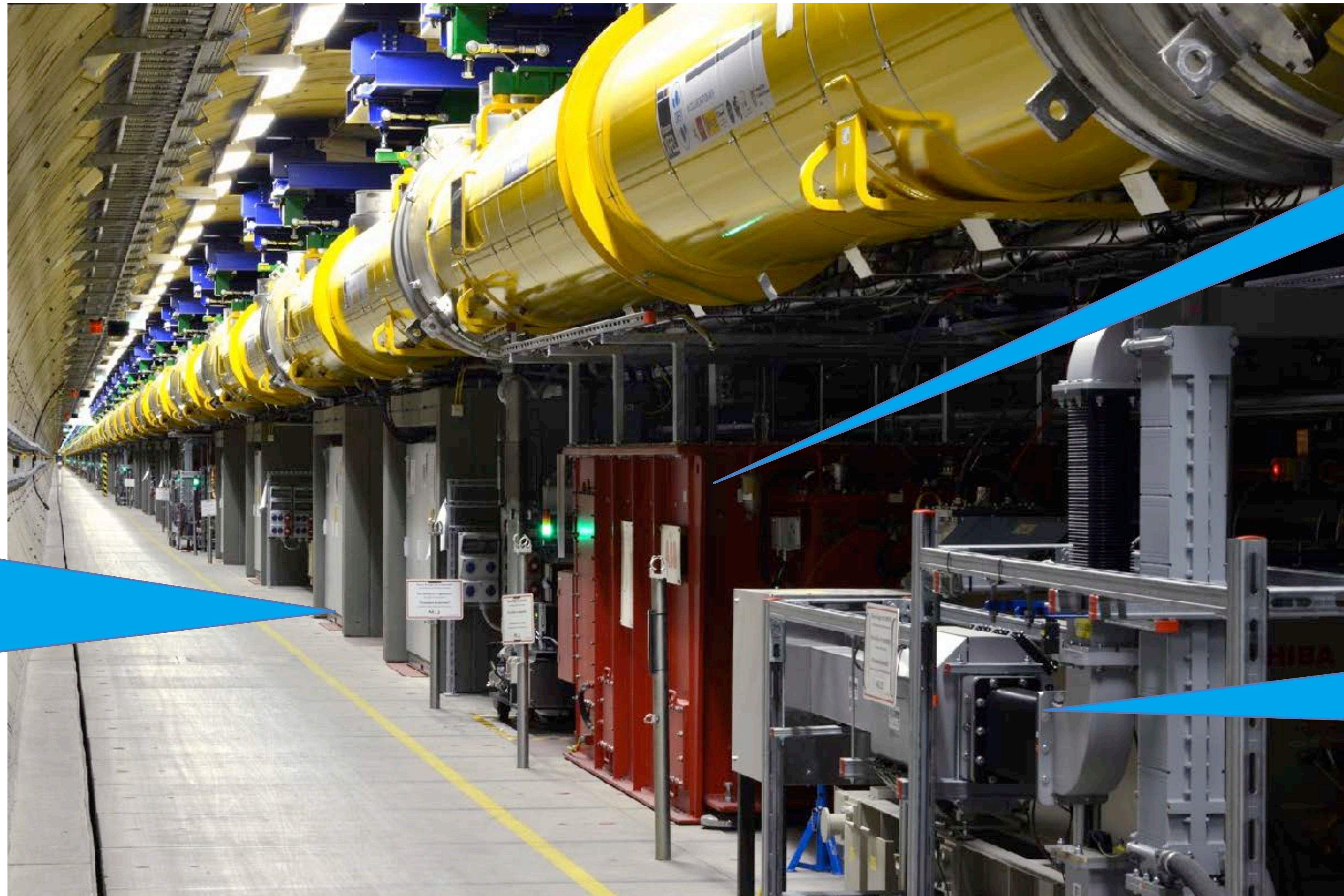
First MicroTCA Crate in the Injector

The Gun

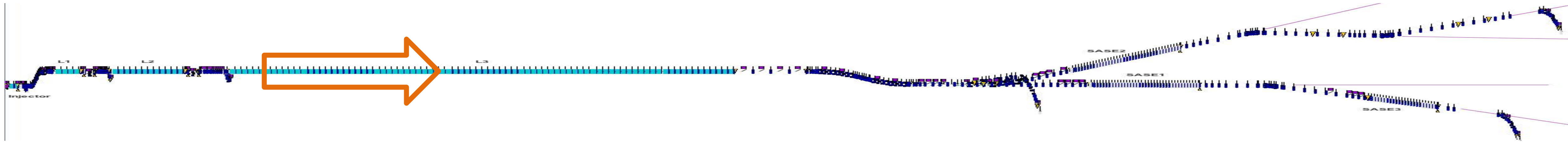### One MicroTCA Crate as seen by the Control System

The Cold Linac

Racks for:
• Vacuum
• Cryo
• Magnets
• RF
• LLRF
• Coupler
• Diagnostics

Pulse Transformer for Klystron

10 MW Klystron with 2 Wave Guides, 1.3 GHz

One RF Station = 4 Modules = 32 Cavities = 5 MicroTCA ≅ 50m

Coupler Interlock
Slave

LowLevel RF
Slave

Coupler Interlock
Master

Diagnostics
Vacuum, Magnets

LowLevel RF
Master

XFEL Key Dates

- FLASH First lasing at 109 nm :   2000

- Injector operation started: Dec. 2015
- Main tunnel closed: 13. 1. 2017
- First Beam in dump 2.5 GeV: 25. 2. 2017
- 12 GeV in main dump: 8. 4. 2017

6 weeks:

  2 km beam line,

  700 cavities

- Beam permission SASE 1:   26. 4. 2017
- Beam in SASE 1 dump (~1 km):   27. 4. 2017
- First Light: 2. 5. 2017
- User runs since: Sept. 2017

# From VME (FLASH) ➡ MicroTCA (XFEL)

VME is 35 years old!!!
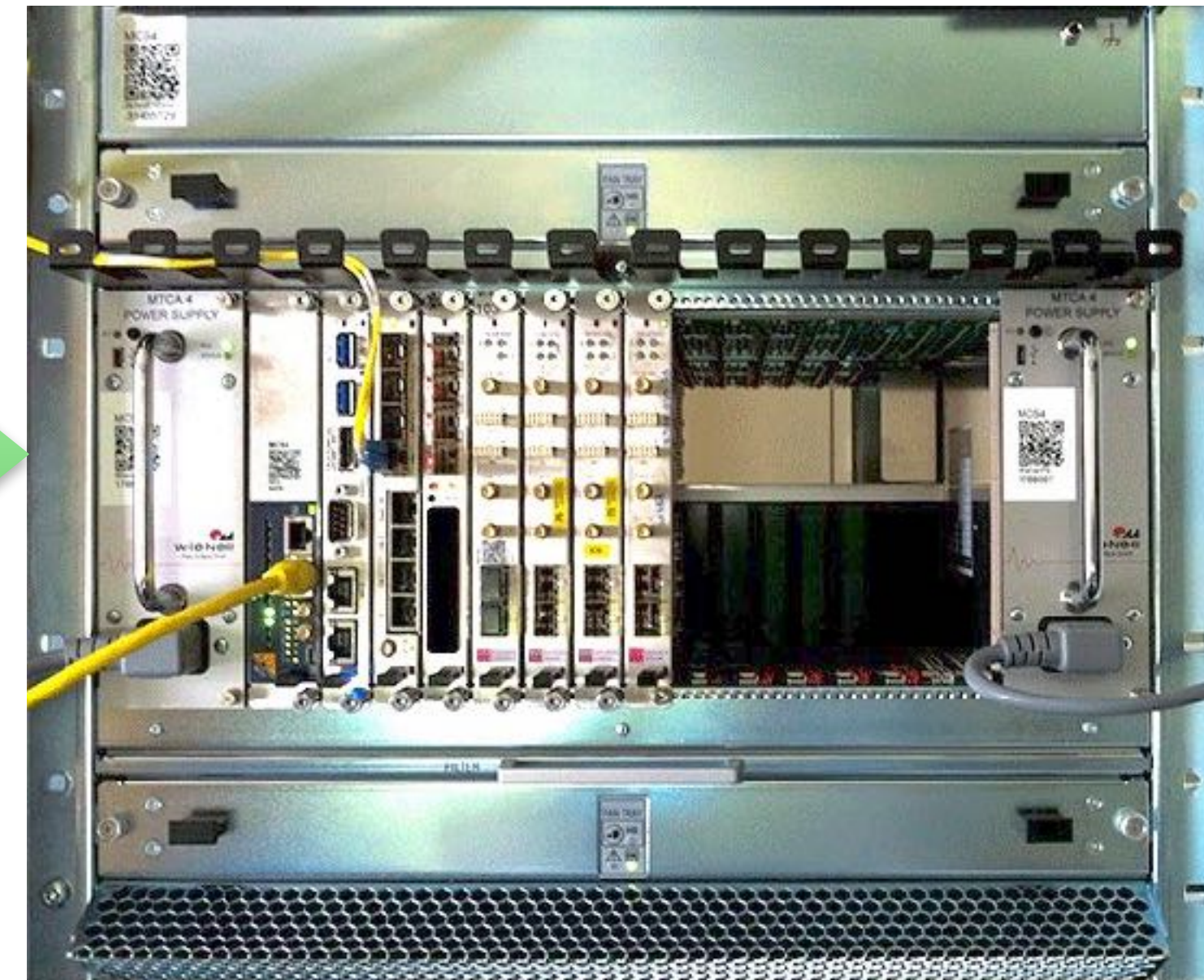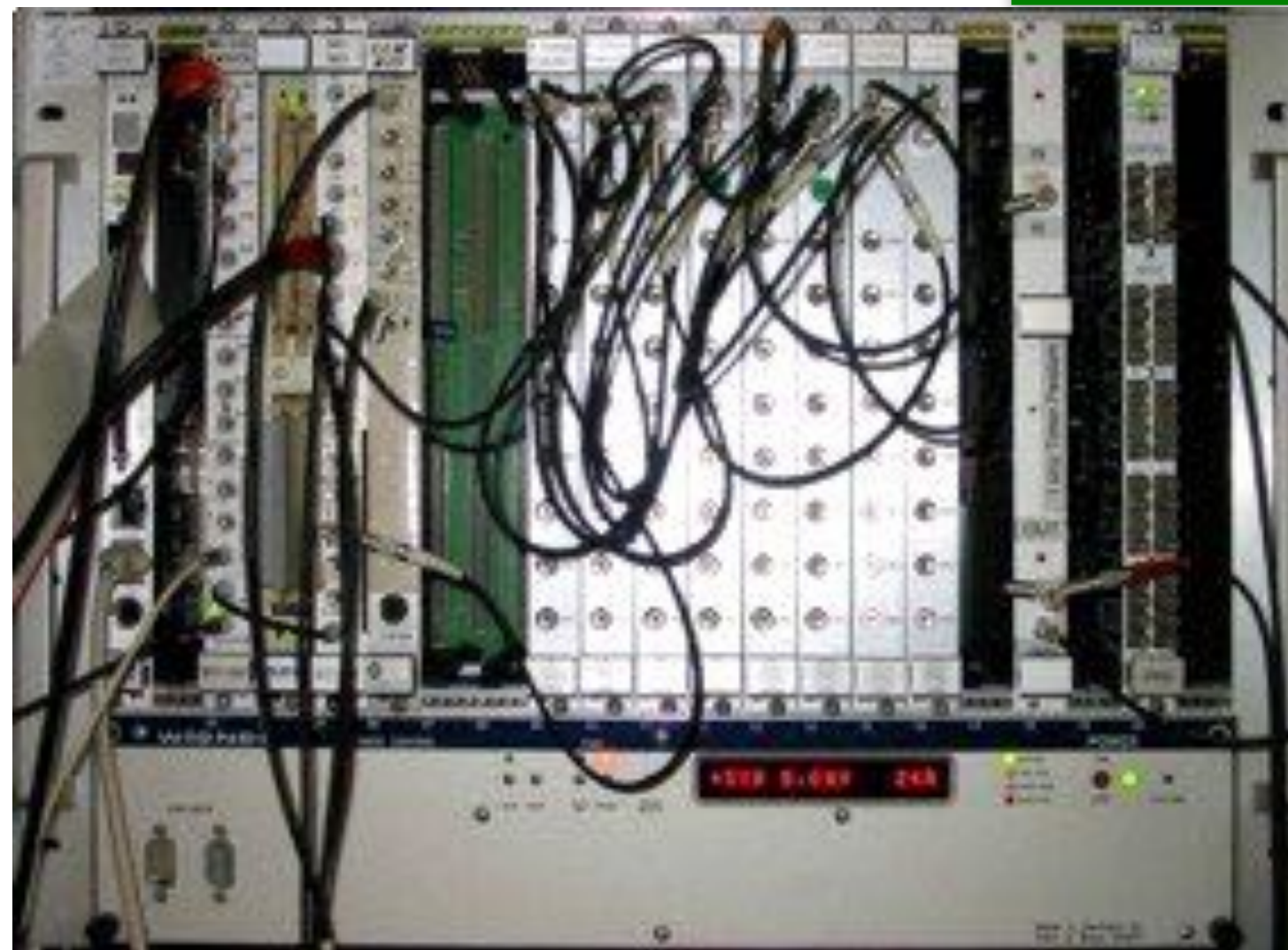
- Redundant fans & power supplies
- Internal clock & trigger distribution
- Modular: reusable components
- Complete remote management
- Modern high-speed data transfer
- Highest signal quality
- I/O cables from rear side

Evaluation of MicroTCA: 2008 ....
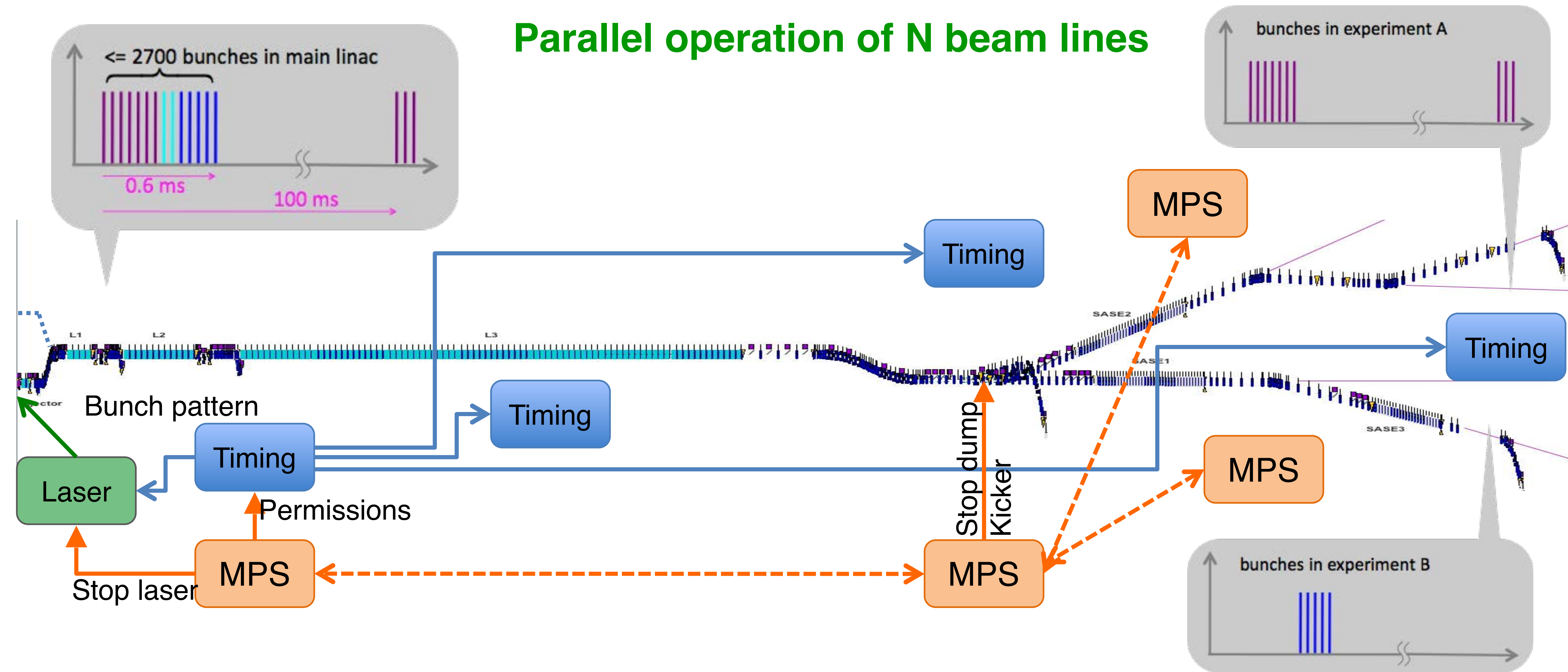
We started with MTCA.0 single modules:

• TAMC100 as carrier for IP Timing

• DESY development DMAC01 to understand the standard:

  • AMC with Virtex 5 and PCIe

  • MMC code on Atmega128

  • 2* ADC 100MSPS
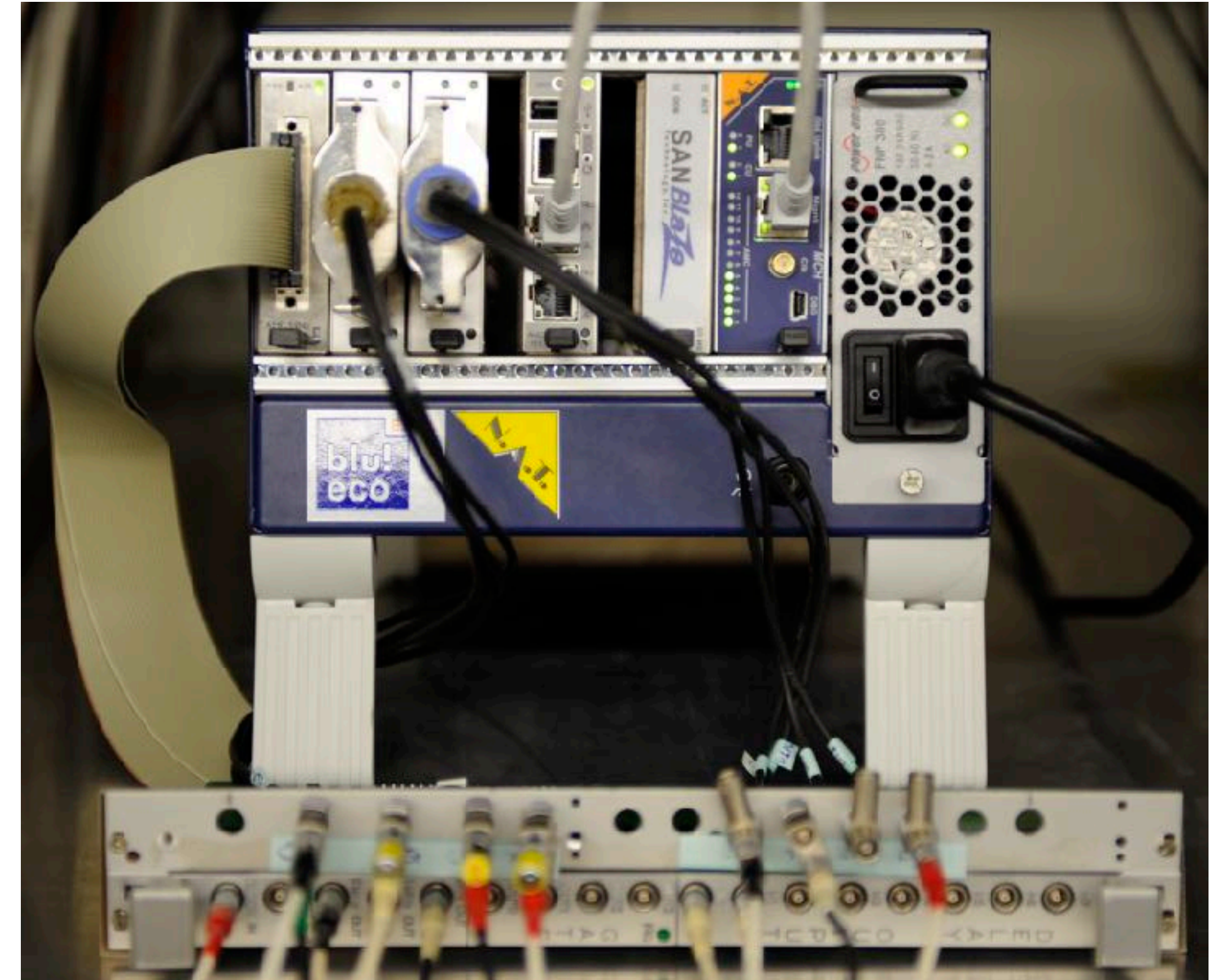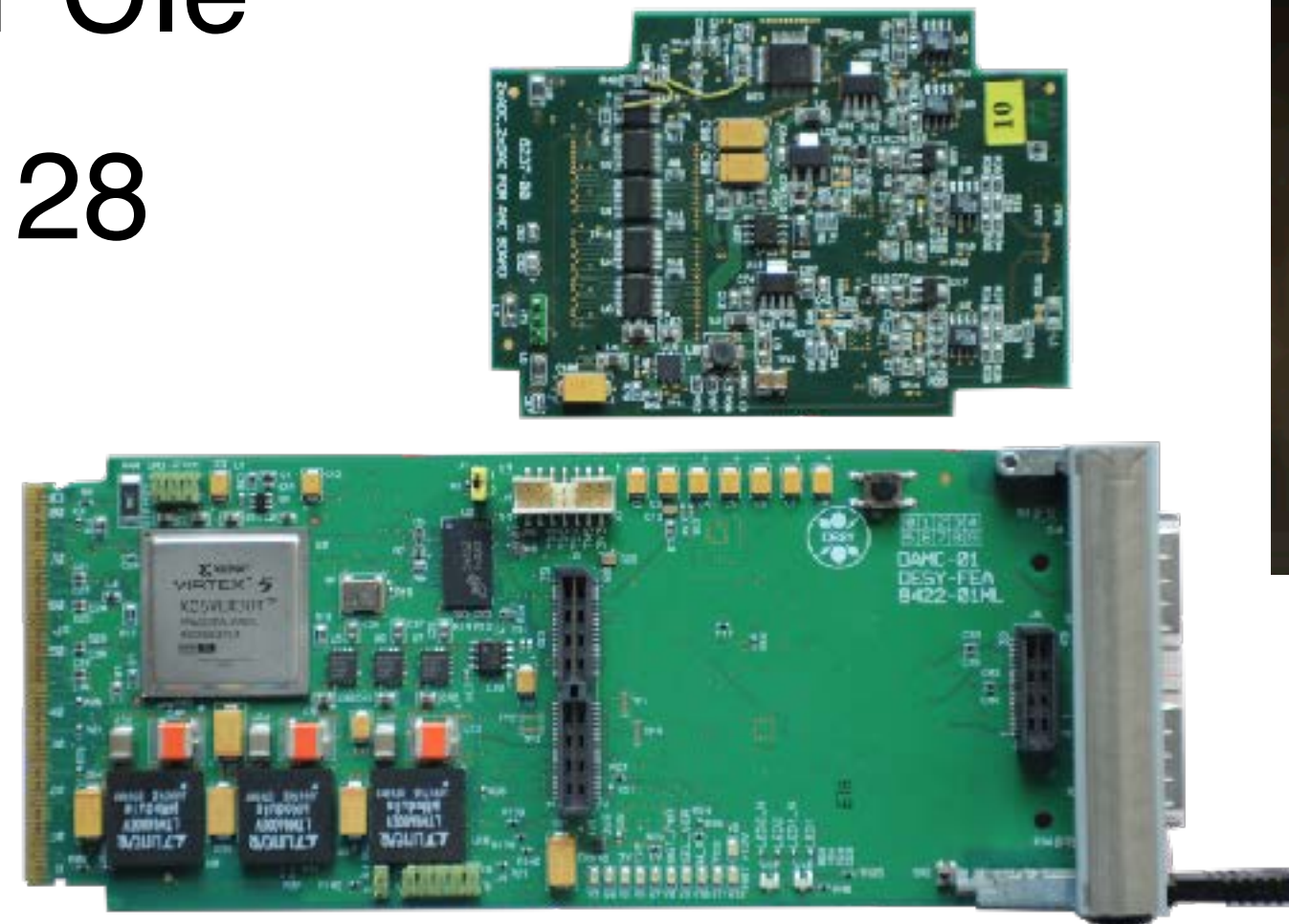
➡ Single modules are too small & cables from front are not optimal

Timing Synchronises, MPS Permits

Parallel operation of N beam lines

<= 2700 bunches in main linac

0.6 ms

100 ms

bunches in experiment A

bunches in experiment B

Timing

MPS

Timing

Bunch pattern

Timing

Timing

Laser

Permissions

Stop dump Kicker

MPS

Stop laser

MPS

MPS

L1 L2 L3

SASE2

SASE1

SASE3

The Timing System

- ## Distributes:
  - Triggers, gates, clocks (10ns … 5ps resolution)
  - Bunch information (charge, destination,…), unique ID
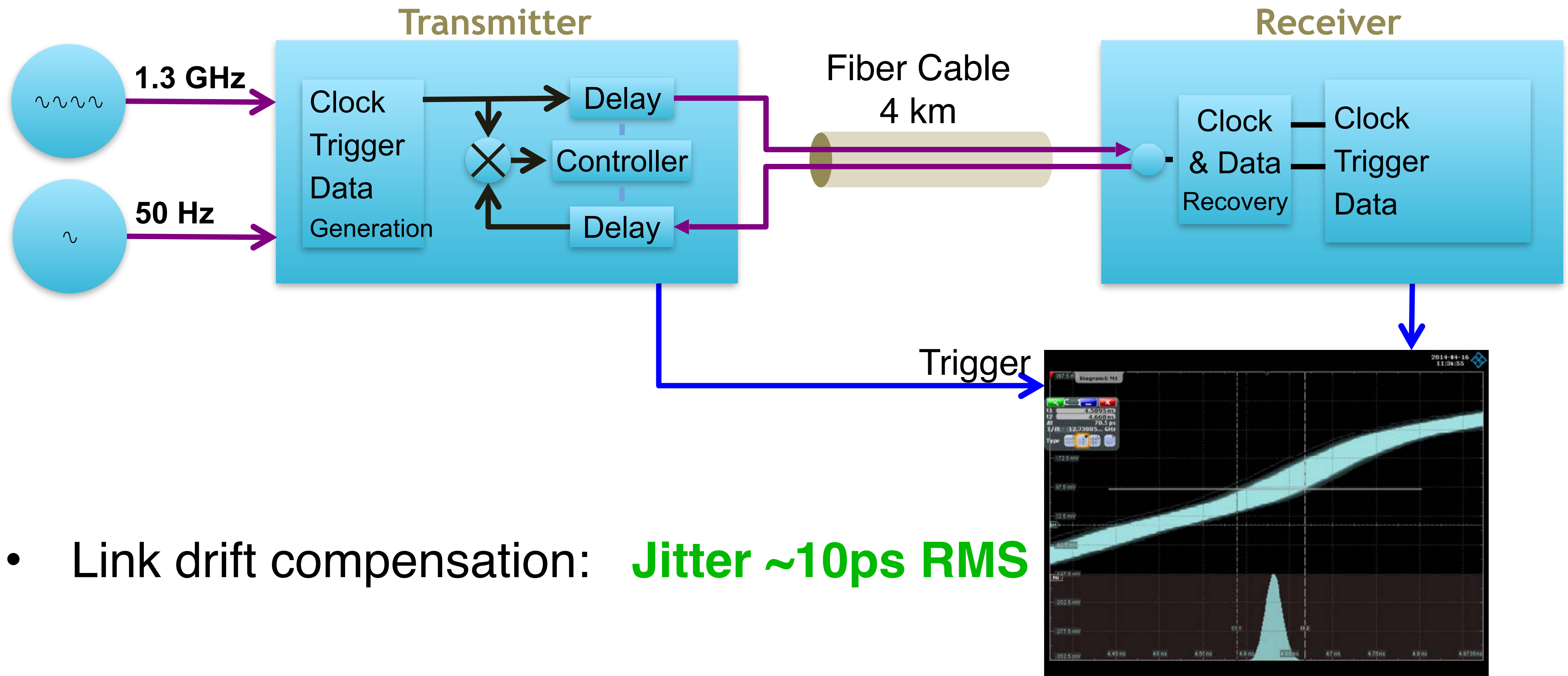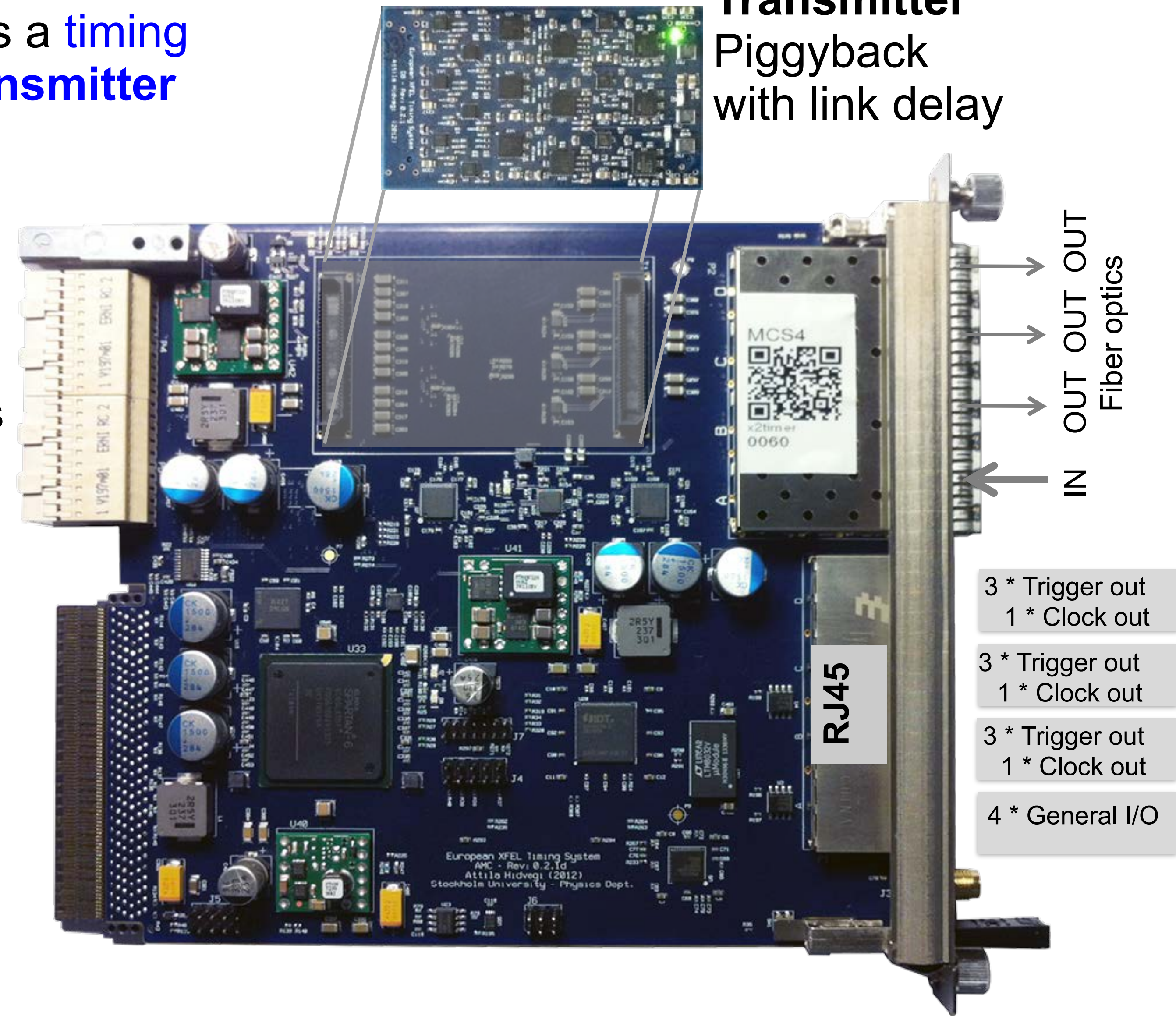

- ## Link drift compensation: **Jitter ~10ps RMS**

MicroTCA.4 Timing Receiver / Transmitter

Can be used as a timing **receiver** or **transmitter**

Transmitter
Piggyback
with link delay

Optional **RTM**:
9 transmitters,
Further triggers or clocks

OUT OUT OUT
Fiber optics

IN

MicroTCA **backplane**:
TCLKA and TCLKB,
8 * M-LVDS

RJ45

3 * Trigger out
1 * Clock out

3 * Trigger out
1 * Clock out

3 * Trigger out
1 * Clock out

4 * General I/O

RTM Timing Extension Modules

9 Lemo outputs (50 Ohm):
- Triggers, Clocks, Data
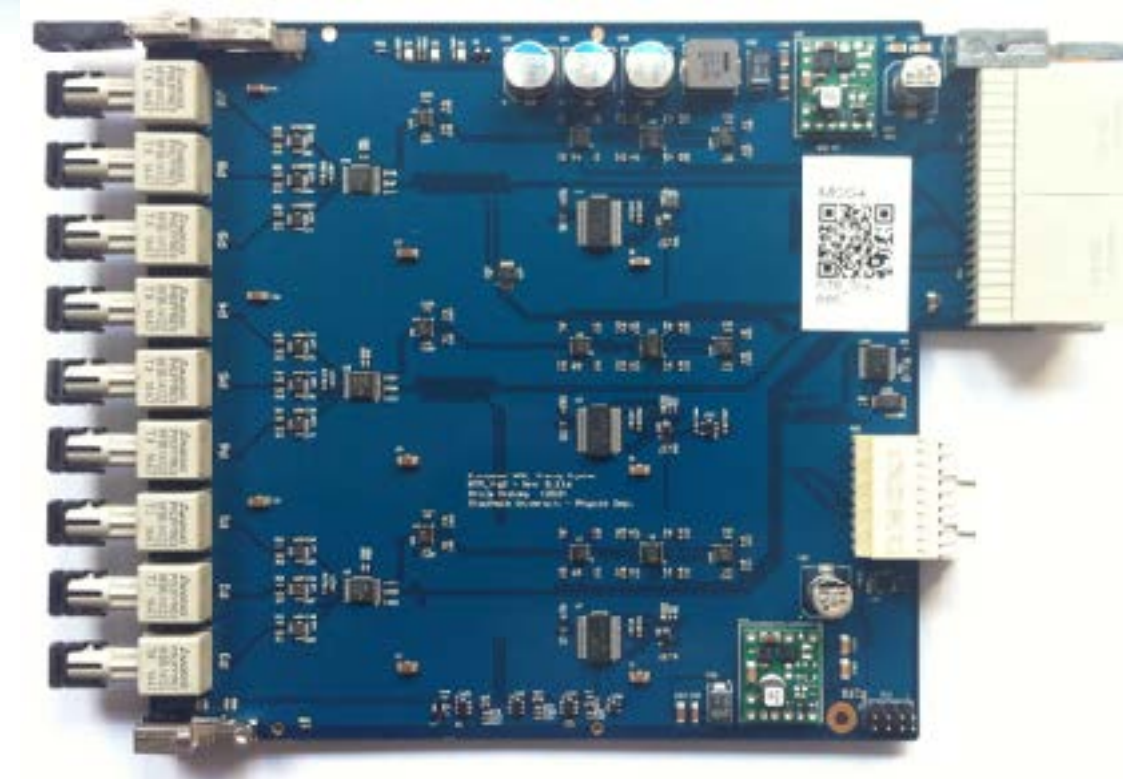- 3 channels with 5ps resolution

> 100 m

RTM backplane AMC
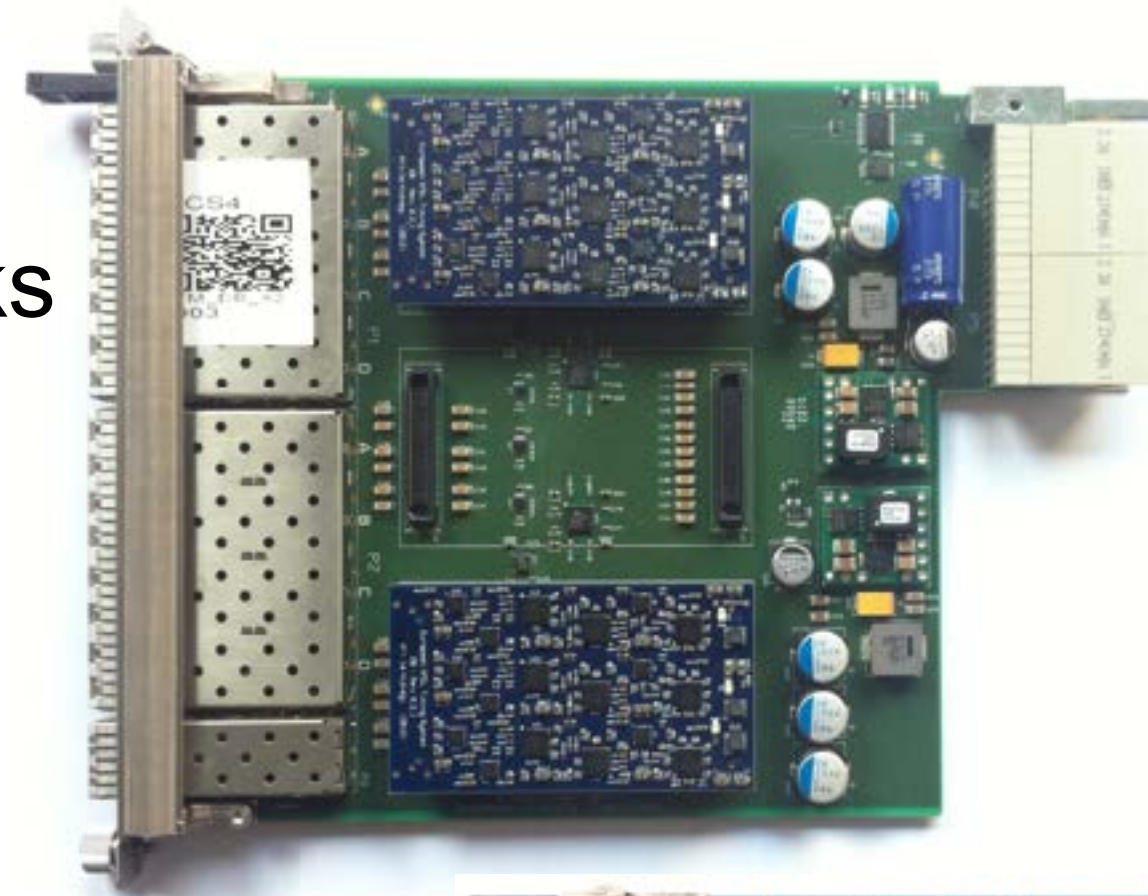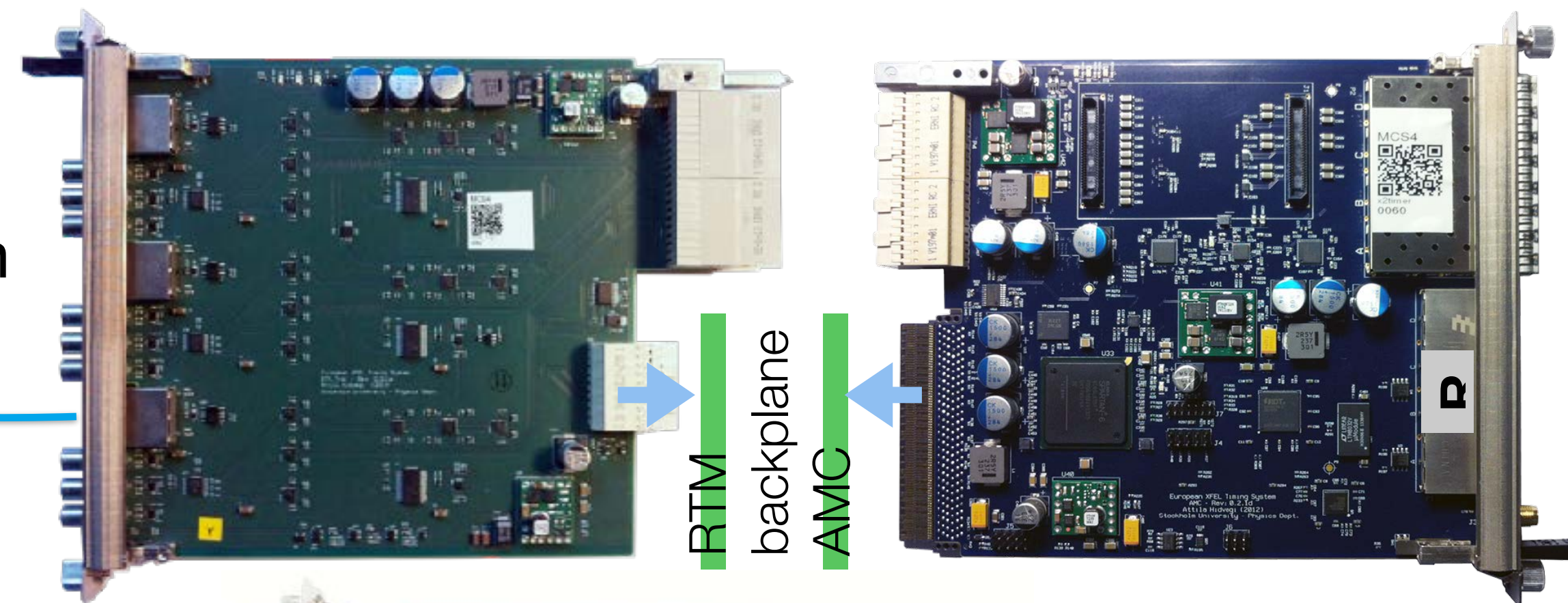
9 SFP outputs:
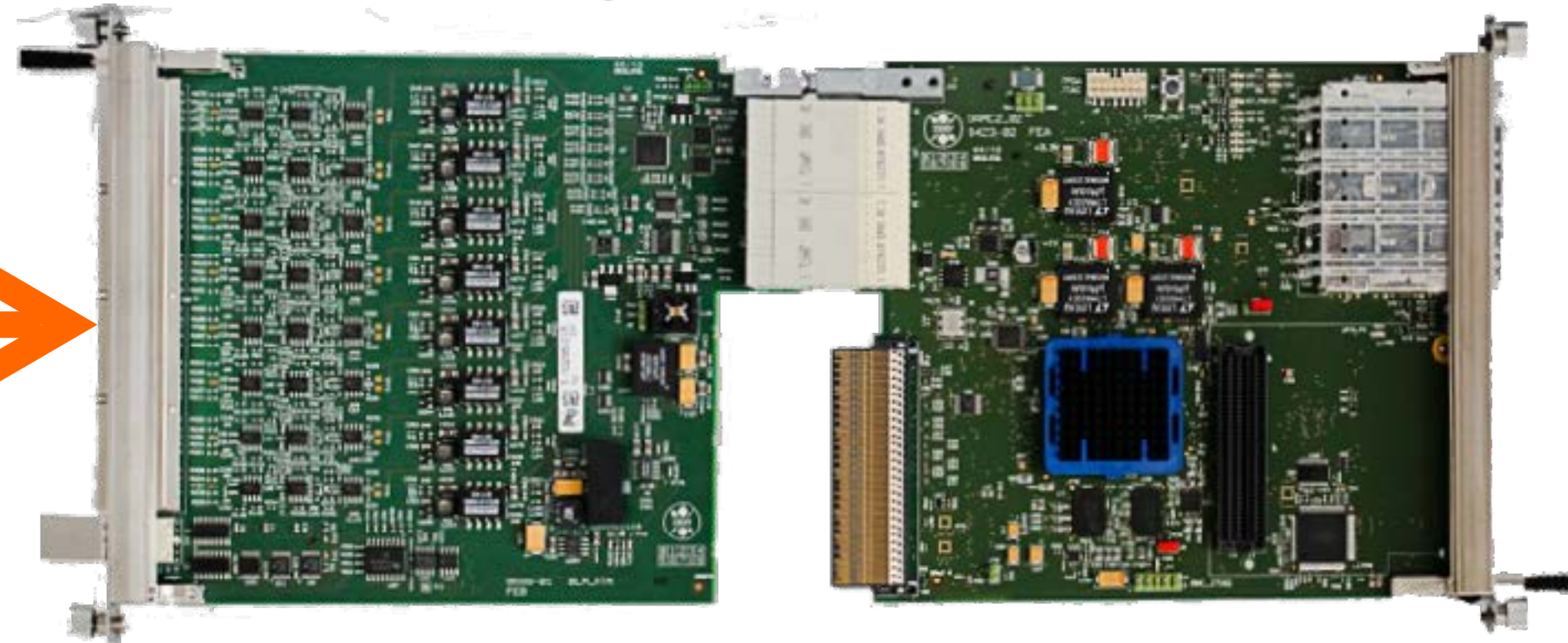- length compensated fiber links

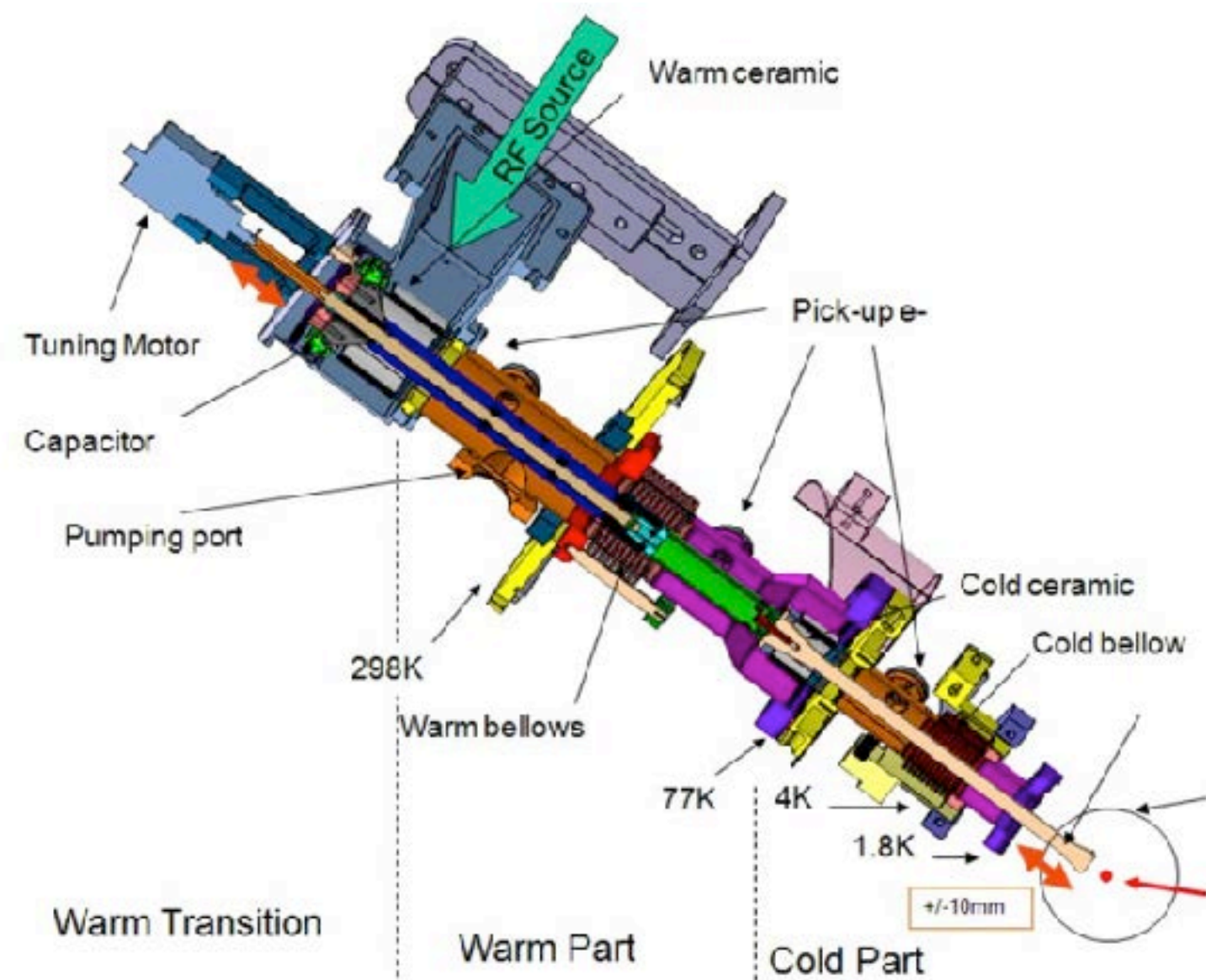9 Fiber outputs (ST):
- Triggers, Clocks, Data
- used for modulators

Beam-Loss and Coupler Interlock

~350 Multipliers

Beam Loss Monitors:
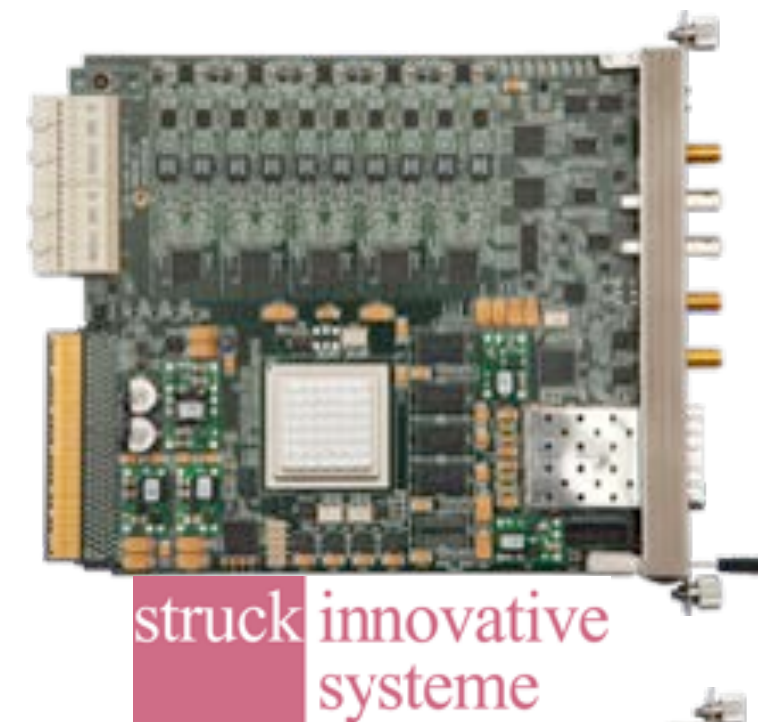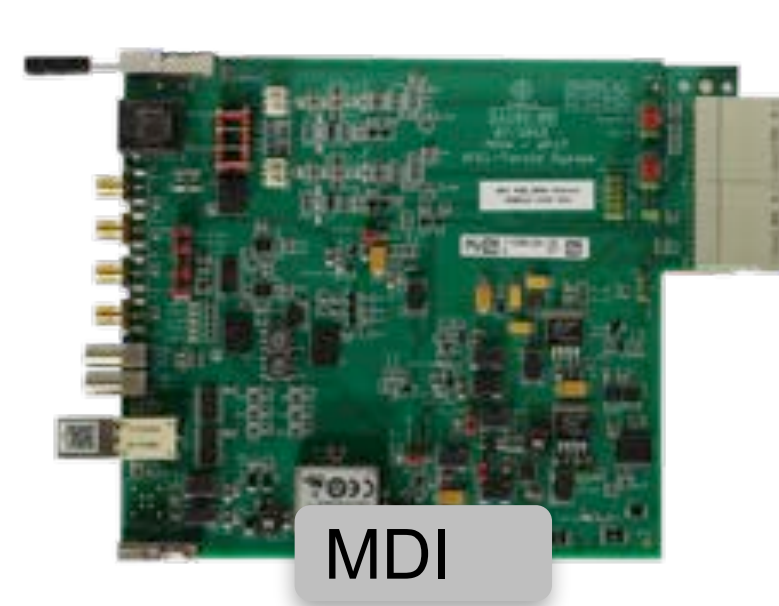- PhotoMultiplier readout RTM
- DAMC2 with interlock logic

Coupler Interlocks:
- Analog readout RTM
- DAMC2 with interlock logic

784 Power Couplers

Diagnostics: Based on Modular MicroTCA

MDI

Toroid Protection:
- Analog readout RTM
- SIS8300 ADC @ 108 MSPS
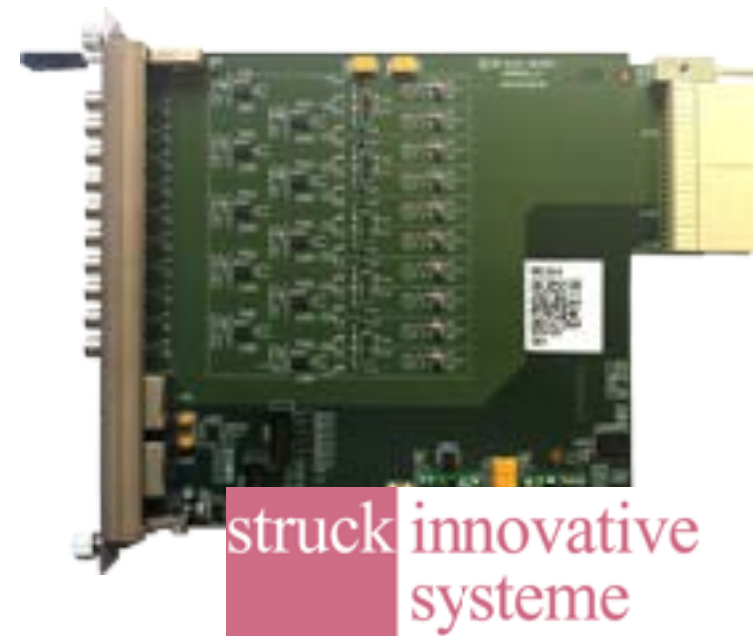
Kicker, FC, etc. readout:
- Amplifier RTM
- SIS8300 ADC @ 108 MSPS

Photon Gas Monitor Detector:
- ADC @ ≦ 7 GSPS
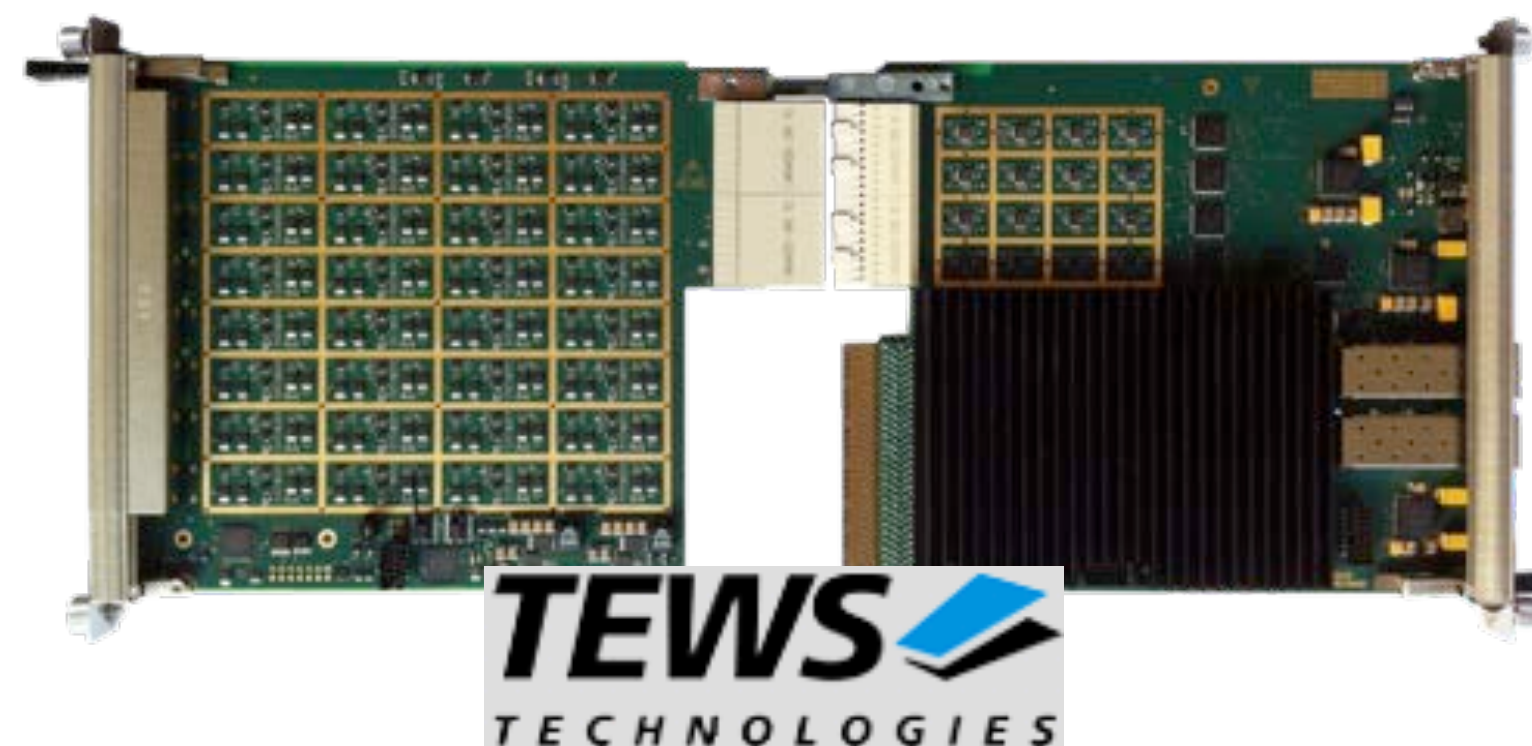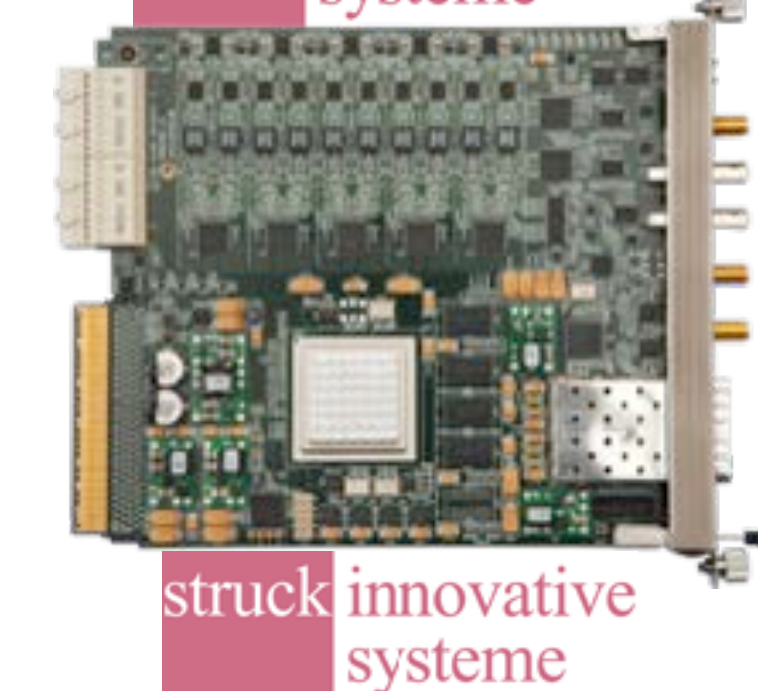
128 channel Spectrometer:
- Shaper/Amplifier RTM
- 32 ch. ADC @ 54 MSPS

Magnets, Vacuum, Cameras, slow IO, ...

Kontron: 4* Ethernet IO

Tews: 16 * RS-232 IO

Concurrent
CPU: i7 Quad-Core
PCIe Gen3
Redundant SSD
Remote console

ESD: 4* CAN IO

ESD: Digi/analog IO

$$\sigma(d\text{A/A}) = 0.0057\ \%$$

Integration of Controls, Management and Development

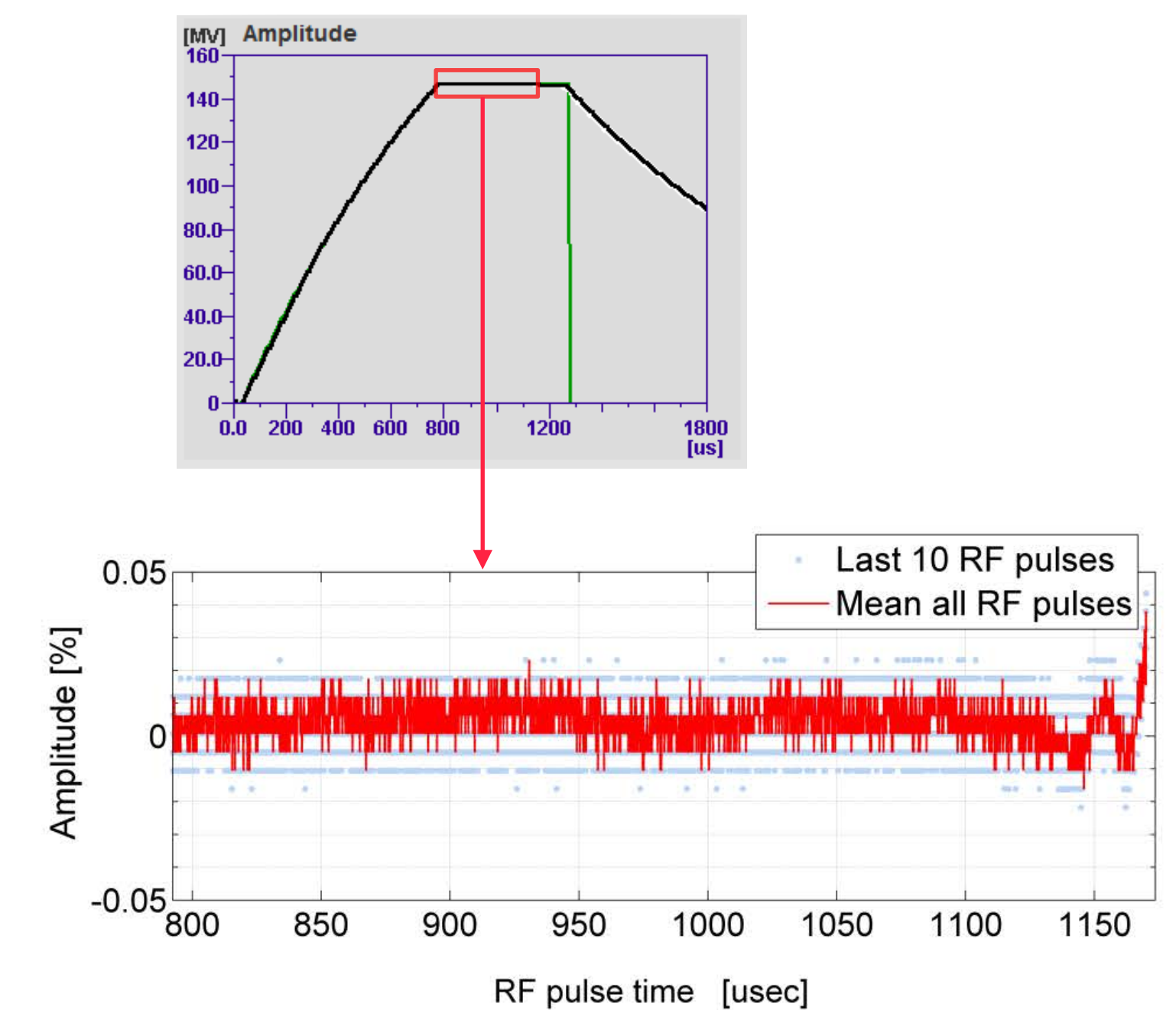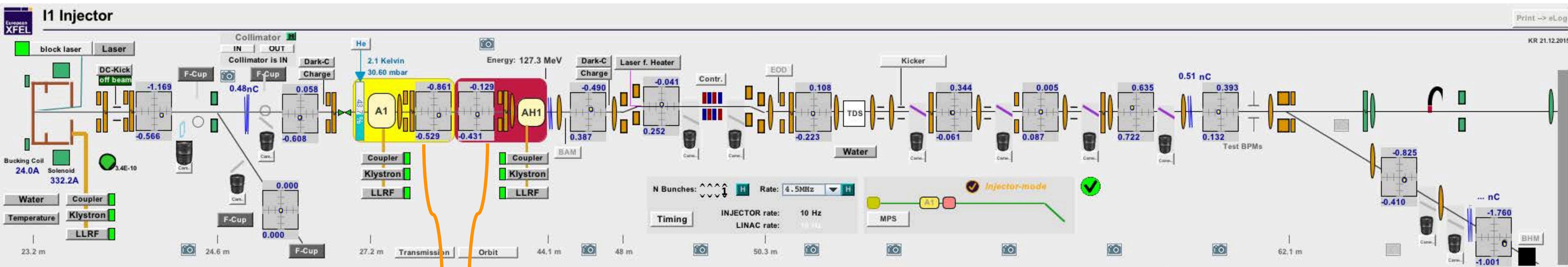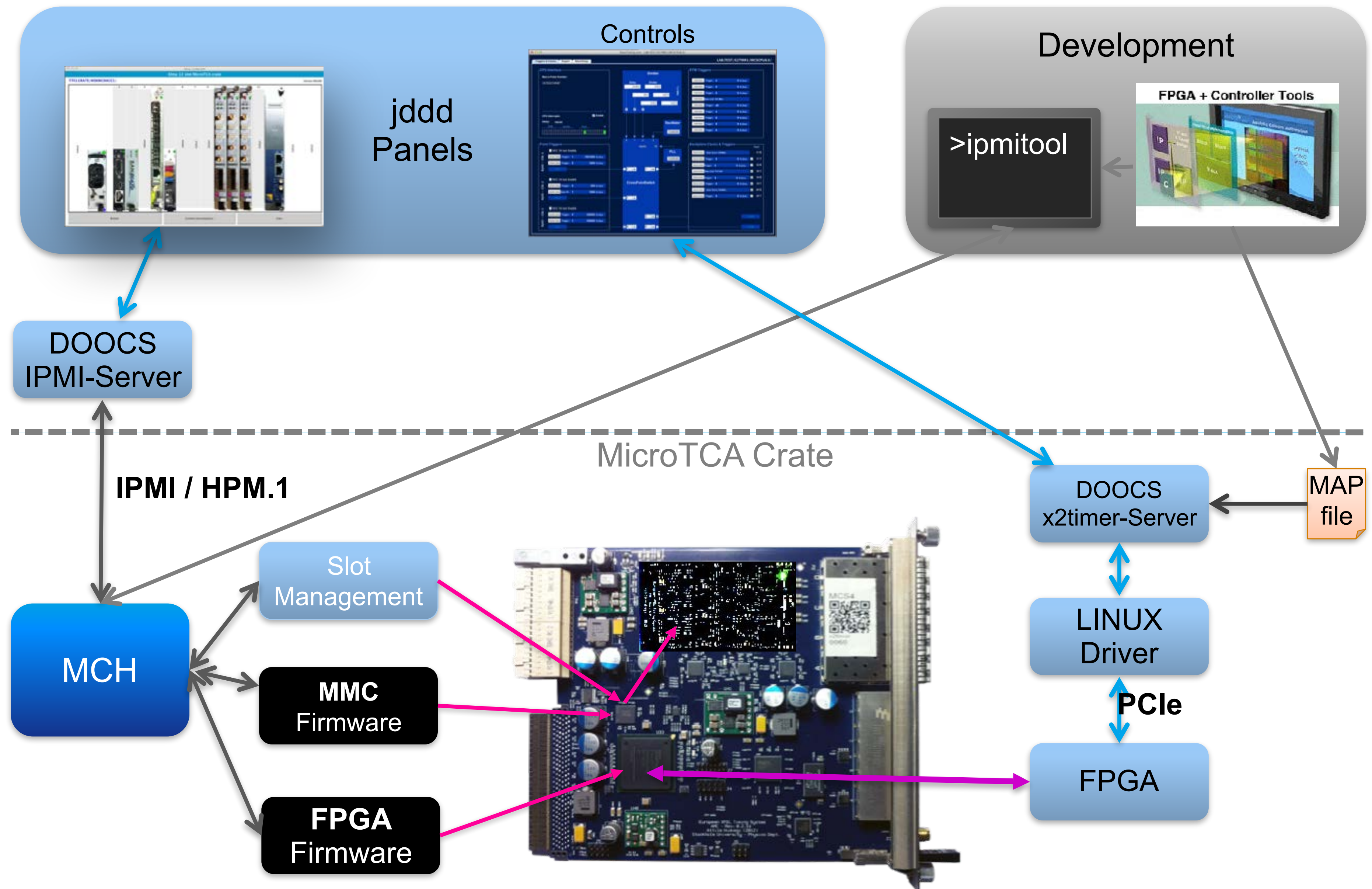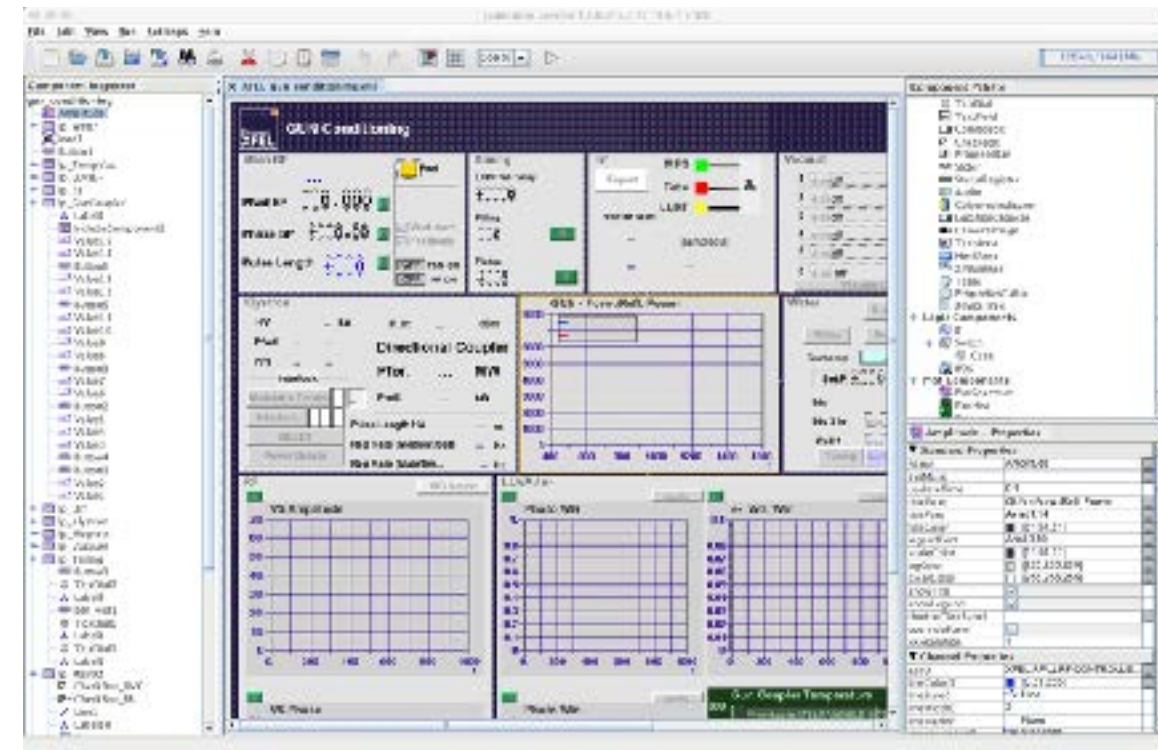**Panel Editor**

Address Browser

DAQ Data Browser
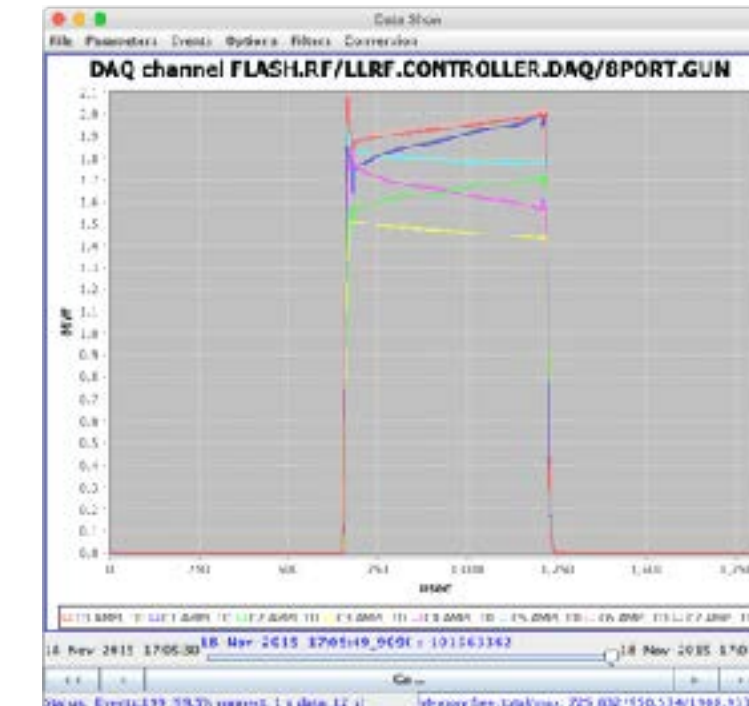
MATLAB & Special Apps
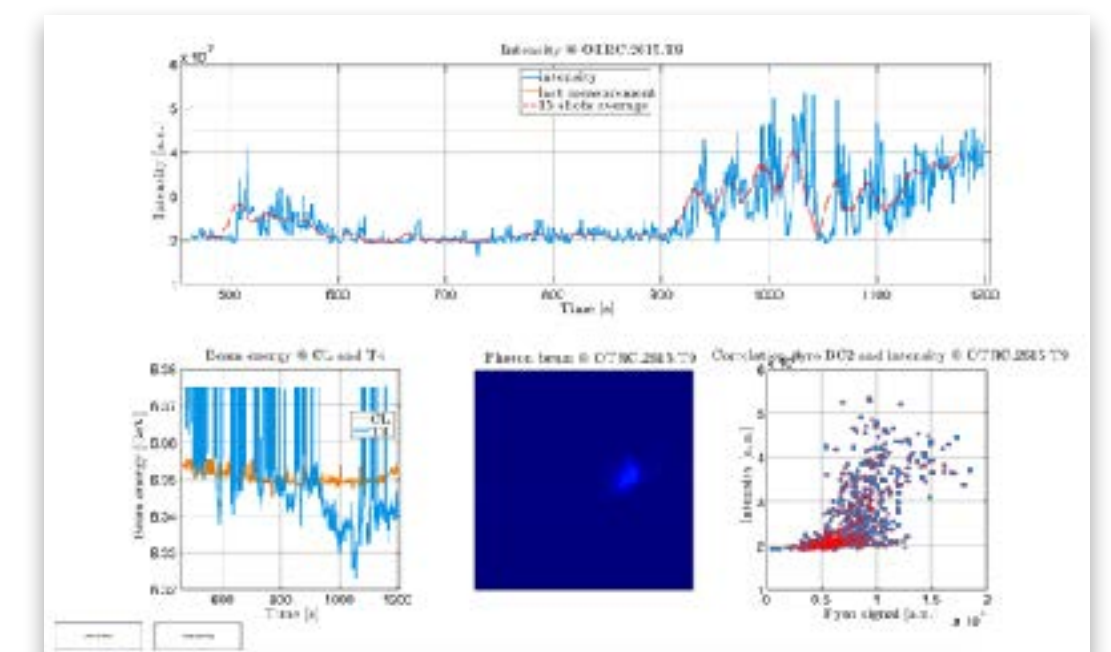
DOOCS
Architecture

XFEL:
> 600 000 Channels
Archived

DAQ

Orbit Server

FeedBack Server

Other Server

Writer

Disk Tape

Buffer Manager Shared Memory

Configuration Controller

Fast Collector

Slow Collector

Middle Layer Servers

Network Interfaces
- Get data
- Set Data
- Get Names

Front-end MicroTCA

IO Lib
- PCIe
- SNMP
- CAN ....

Device
- Status Register
- Float Value
- Float with History
- Waveform
- Polonominal
- Transformation

Archive
- Read
- Write
- Configure

Configuratio
- Restore
- Save

Front-end Servers in MicroTCA

DOOCS.

Ethernet

CPU

Physical Device Server

DAQ

Toroid Server

Toroid 1 . . . Toroid N

IO Device Server

ADC DMA Server

Location 1 . . . Location N

ØMQ

Timing Server

Location 1

dev Node

s4

s2

Linux Driver

Driver

Driver

Central Timing

MicroTCA backplane

Triggers, Clocks, Interlocks, Data

LLRF System: Complex Systems Require Lots of Diagnostics
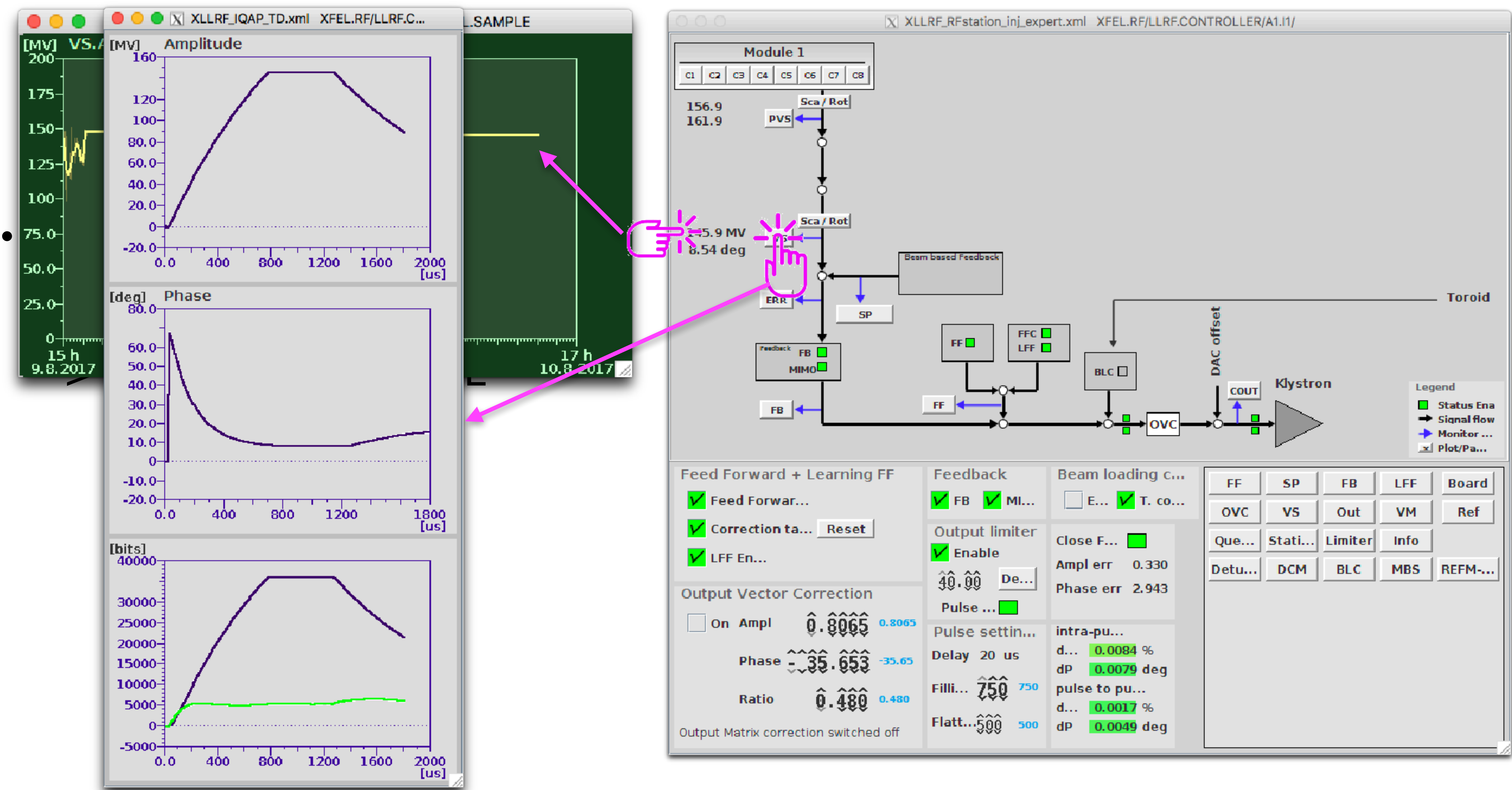
Summary

- **XFEL** is in operation and delivers beam to experiments

    - Very fast startup since HW & SW was debugged in FLASH & XFEL Injector

- ~ **250 MicroTCA** crates are installed and operational

- Parallel operation of $\geqq$ 3 beam lines:

    - Full HW/SW integration in MPS, Timing, Subsystems

- XFEL is controlled by **DOOCS**, has > 8 M properties (addressable items)

    - All fast data is controlled by MicroTCA, including photon experiments

- MicroTCA provides:
    - High speed data transfer
    - excellent analog performance
    - Complete local & remote management
    - Redundancy —> high availability