

# The MicroTCA-Based Accelerator Control System For The European XFEL

Experiences With A Production System

Tim Wilksen  
7<sup>th</sup> MicroTCA Workshop  
Hamburg, 05.12.2018

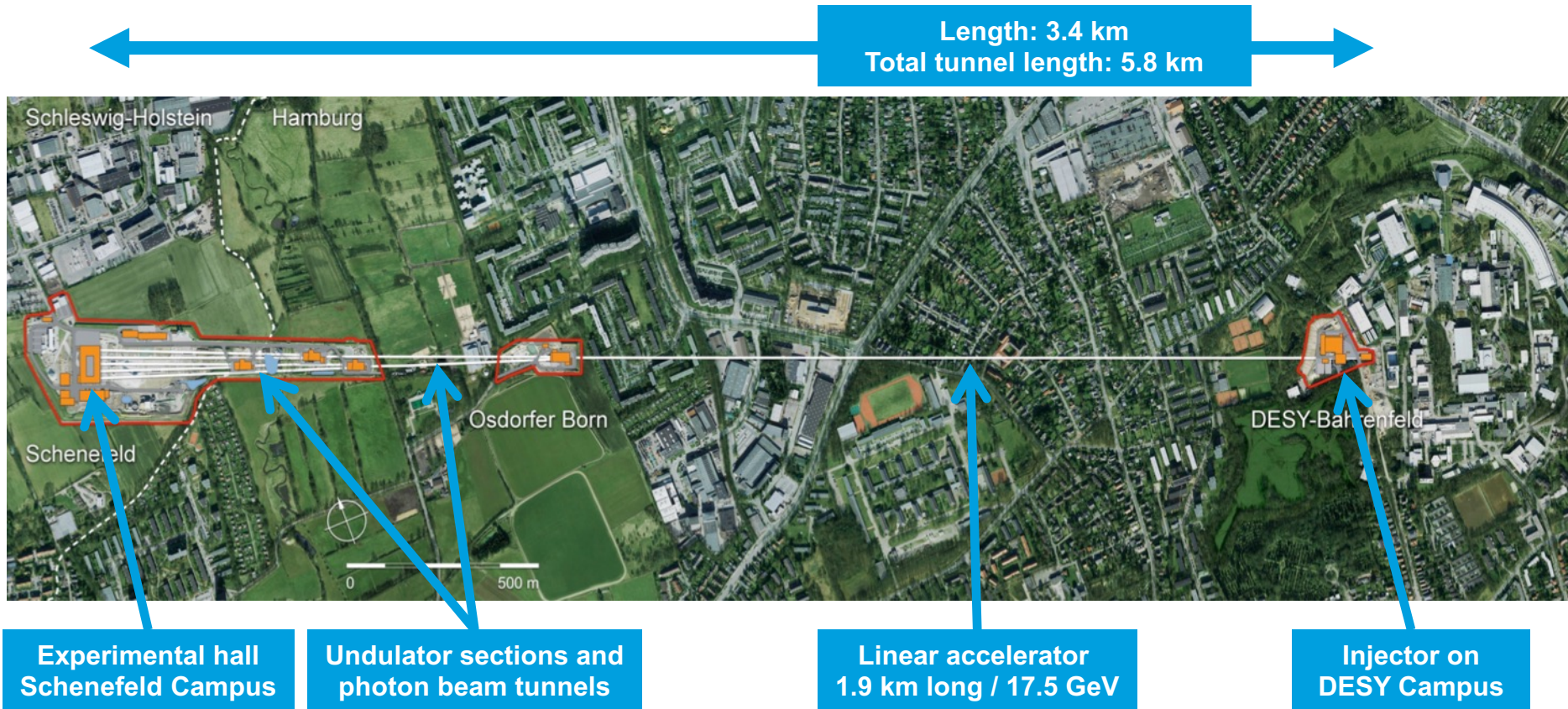
# Overview

- 1 Overview**
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- 3 The Accelerator Control System**
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# The European XFEL

# The European XFEL

## Aerial View Of The European XFEL



Schenefeld,  
Schleswig-Holstein

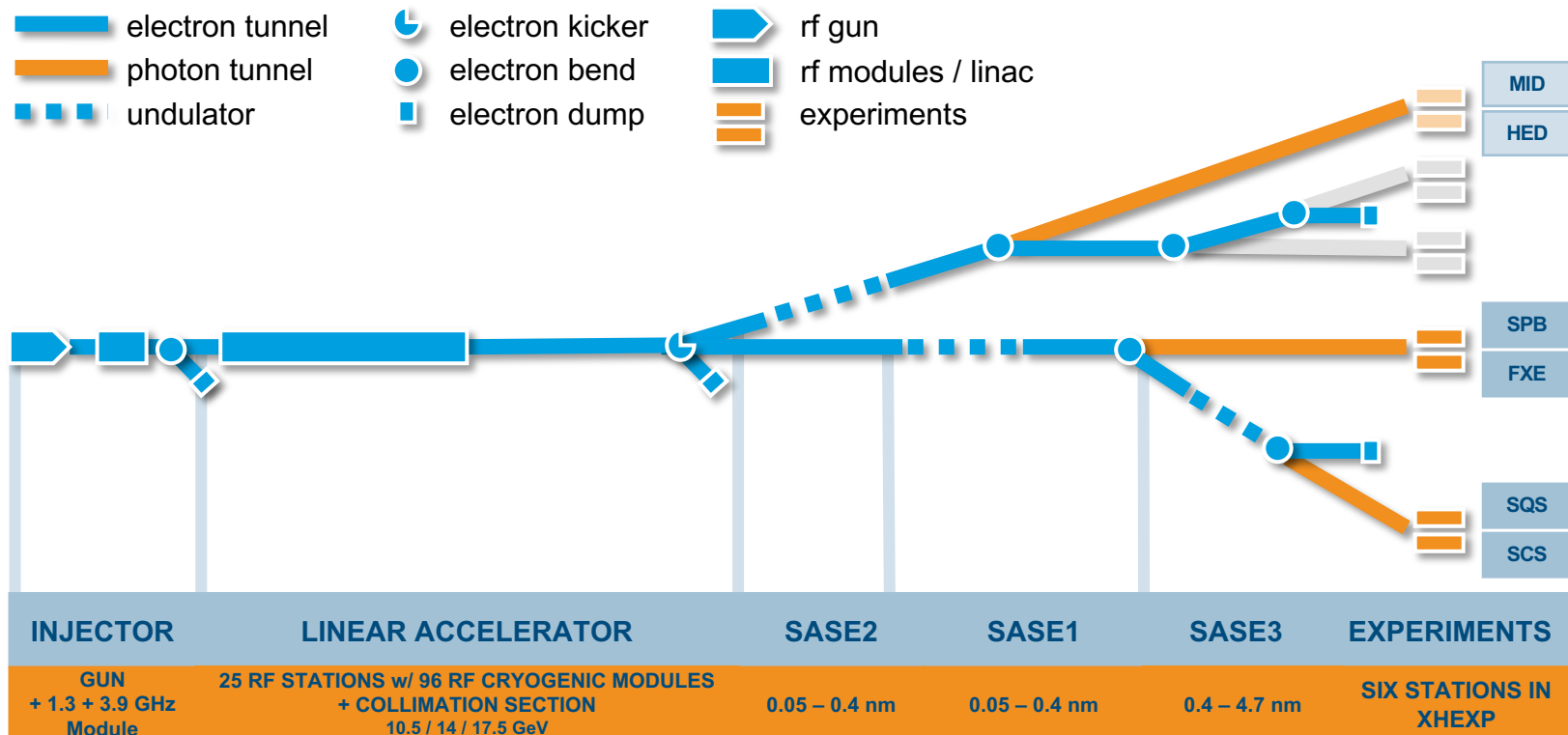
Hamburg



# The European XFEL

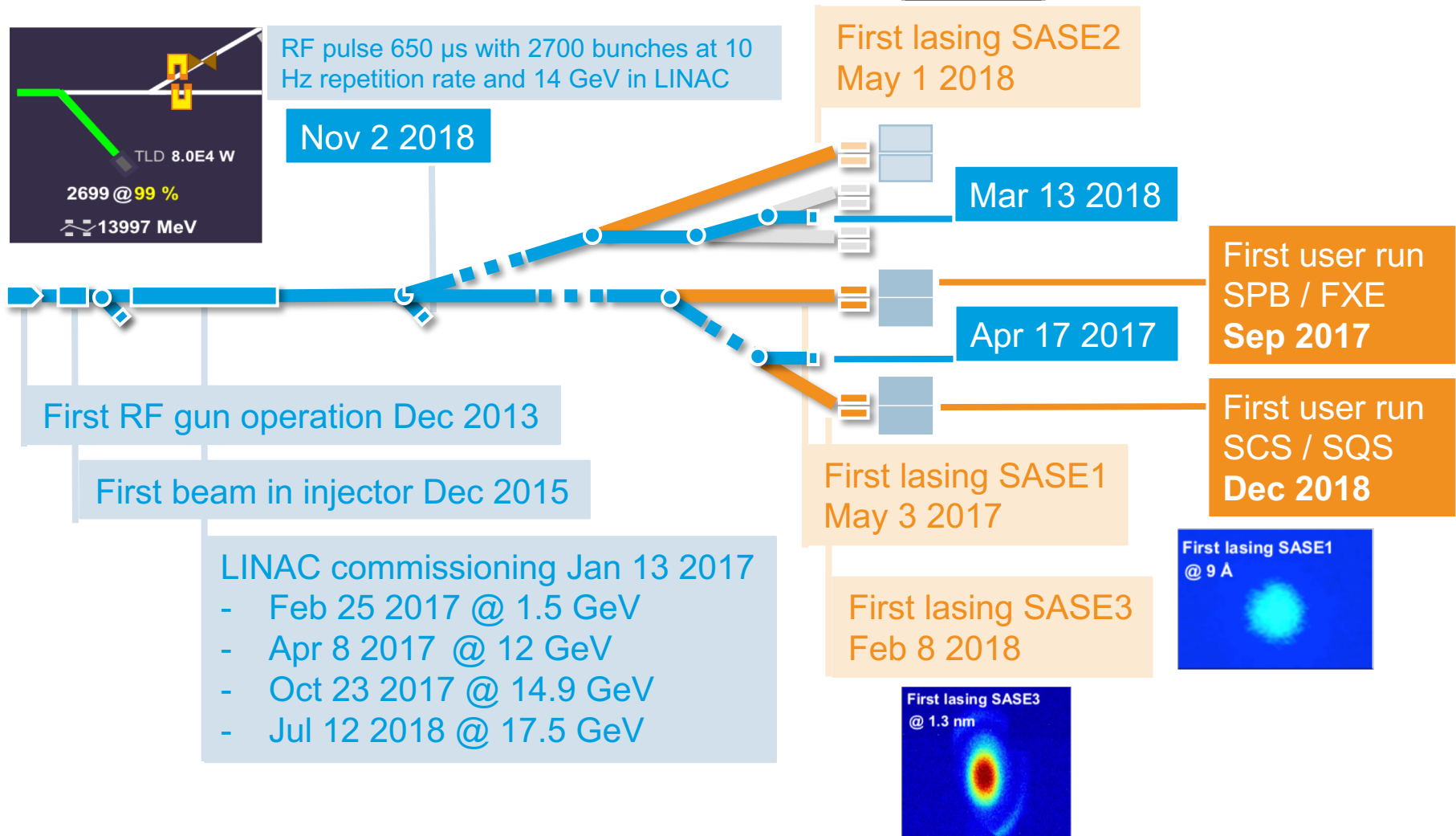
## Accelerator Layout

Parameters	Design	Achieved
Pulse Repetition Rate	1 - 10 Hz	10 Hz
Bunch Repetition Rate	0.5 - 4.5 MHz	4.5 MHz
RF Pulse (Flat Top)	650 $\mu$ s	650 $\mu$ s
Electron Bunches	27000 / s	27000 / s @ XTL
Photon Pulses	27000 / s	5000 / s
Electron Bunch Charge	0.02 – 1.0 nC	0.1 – 0.5 nC
Electron Beam Energy	6 – 17.5 GeV	17.5 GeV
Photon Energy	0.2 – 25 keV	0.6 - 1.2; 7 - 19.3 keV



# The European XFEL

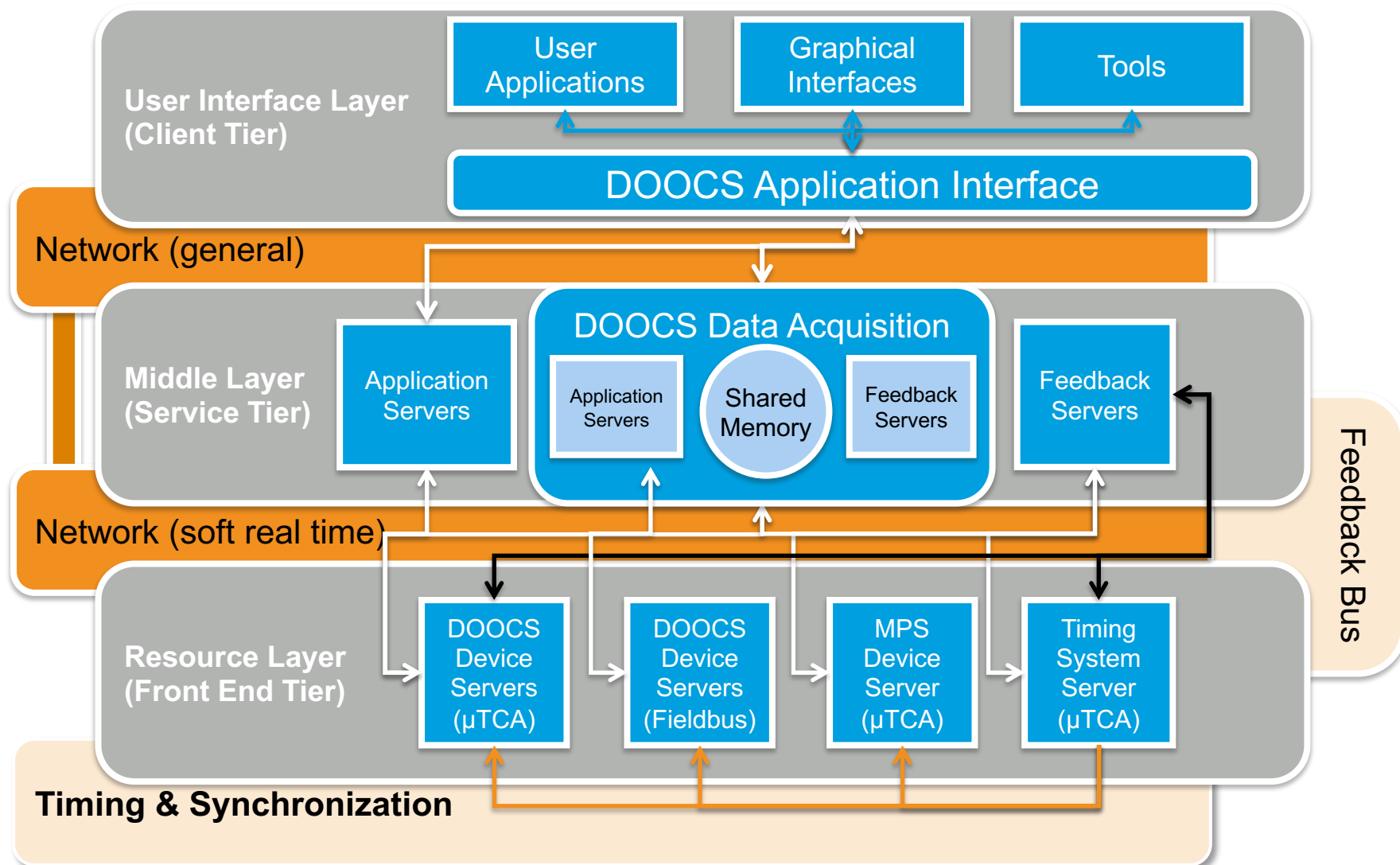
## Commissioning Timeline



# The Accelerator Control System

# The Accelerator Control System

## System Layout





# The Accelerator Control System

## Standards

DOOCS USB stick with a ready-to-run  
DOOCS installation, NAT psTimer and  
Struck SIS8300 support available

### Common Software Framework

DOOCS as standard control system software for MicroTCA-based read-out and controls

Interfaces to Epics (Cryogenics Controls), Tine (Magnets and Vacuum Controls), Karabo (Photon diagnostics and experiments controls)

System Integration w/ Ubuntu-based Linux as operating system standard and DOOCS for management

### Common Hardware Platform

MicroTCA.4 PICMG Standard

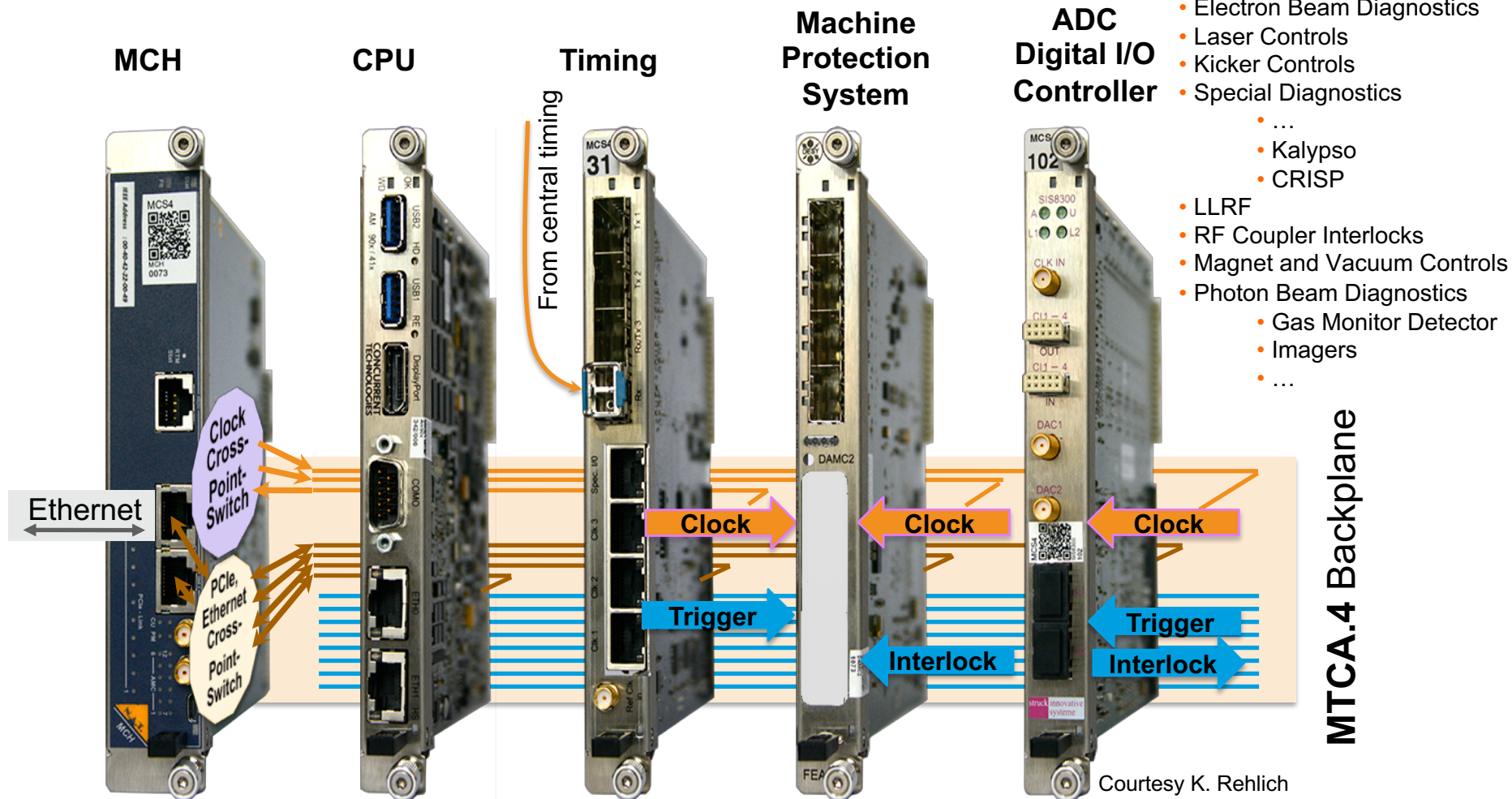
Basic set of MicroTCA modules common for all systems

# MicroTCA Common Module Set

Standard set of MicroTCA modules used in the European XFEL accelerator control system

## Common Modules

## Application Modules



# MicroTCA Applications

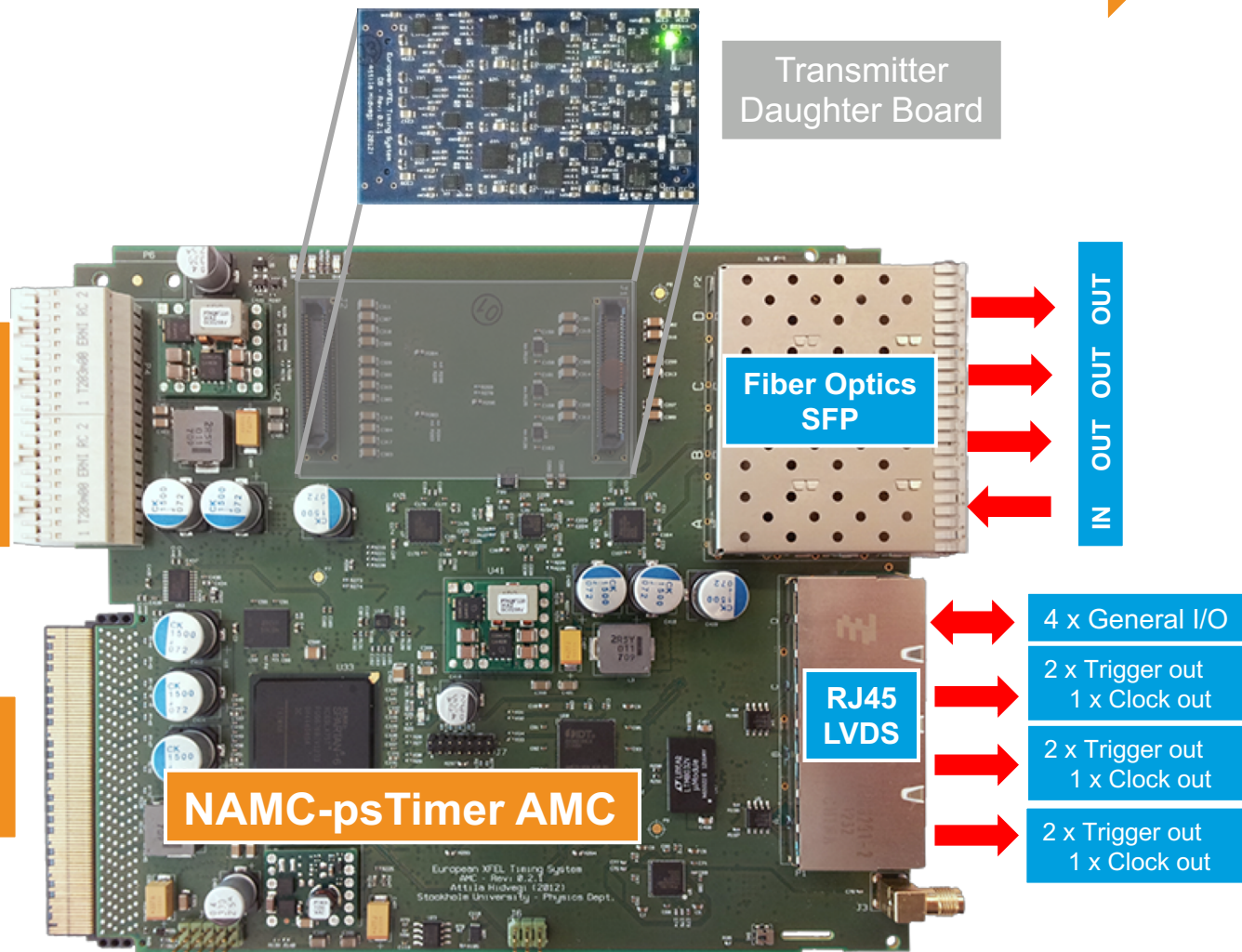
## Timing System Workhorse – NAMC-psTimer AMC

Tutorial on MTCA.4  
based Timing System  
*Kay Rehlich*



Three optional **RTM**  
**variants:**  
9 lemo outputs, SFP  
outputs, optical outputs with  
more trigger or clock signals

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

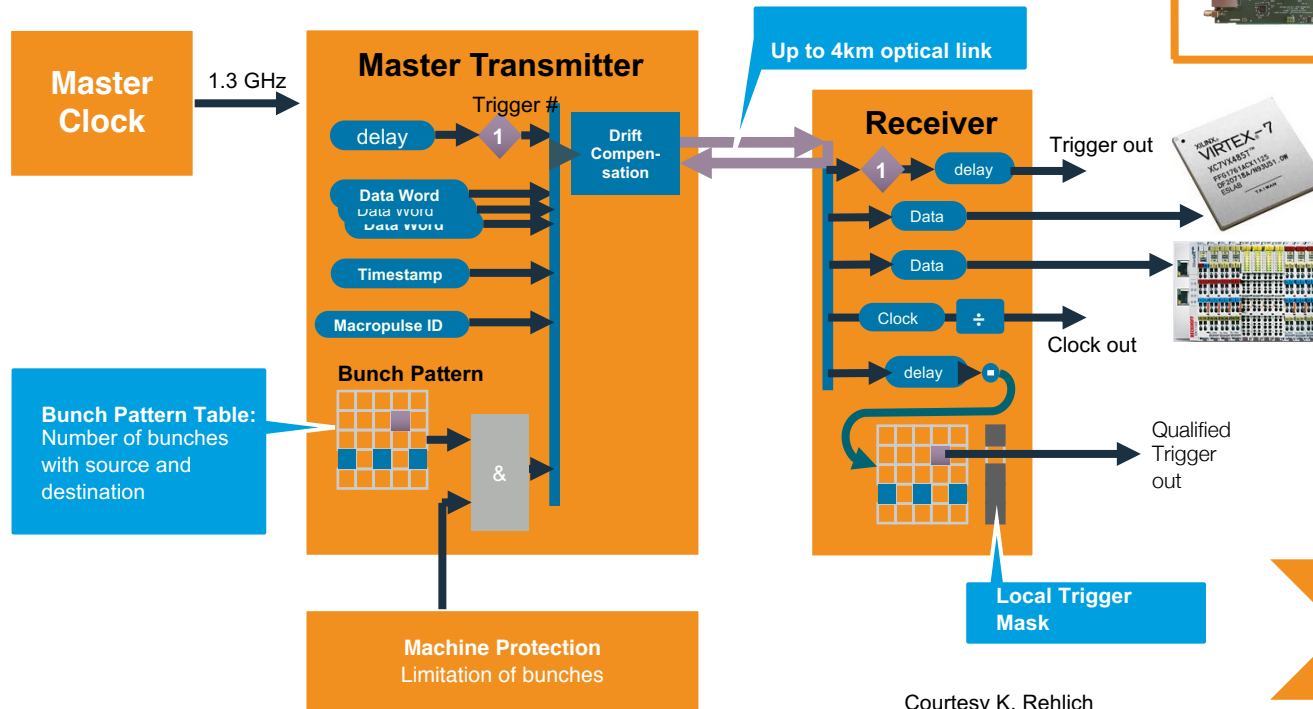


Courtesy K. Rehlich

# MicroTCA Applications

## Timing System @ EuXFEL

- Star topology with master timing system synchronized to 1.3 GHz reference from master oscillator
- Timing Master distributes encoded data with events for trigger, bunch pattern table, clocks to all receivers across the accelerator subsystems as well as shot or train ID for tagging data



Courtesy K. Rehlich

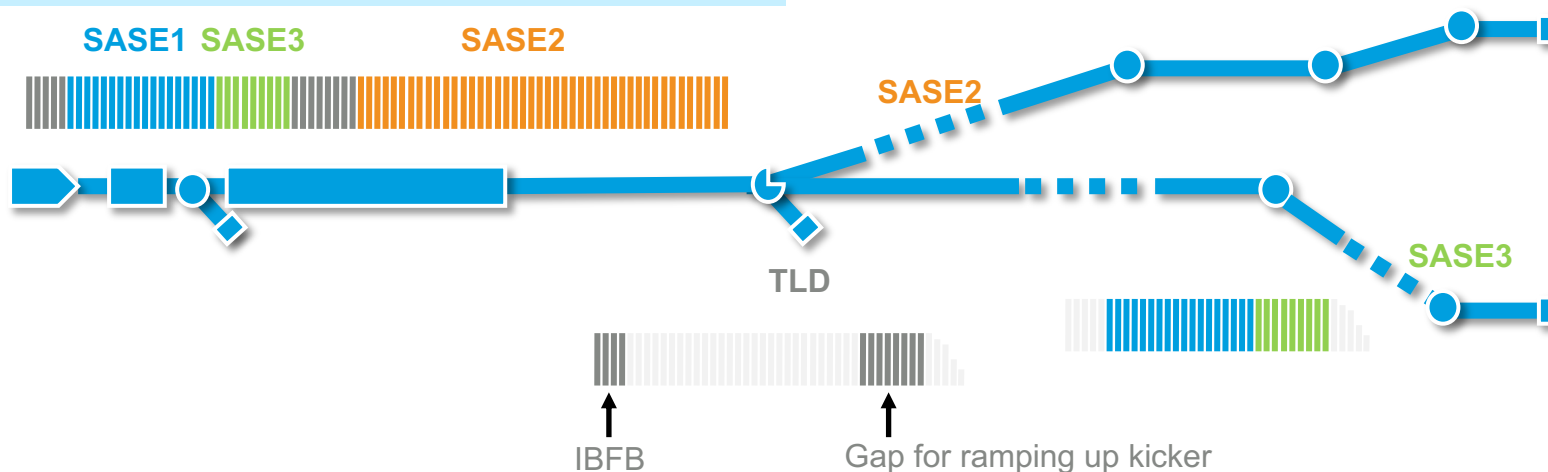
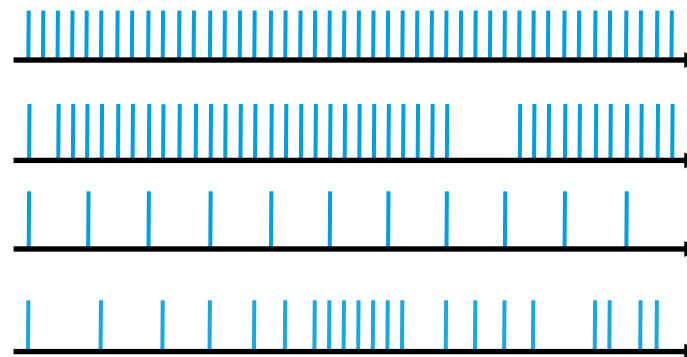


# MicroTCA Applications

## Bunch Pattern Application On MicroTCA Timing System Master

Bunch pattern define structure of electron and photon beam – Number, spacing, distribution

- Bunches up to 27000/s w/ 650  $\mu$ s RF pulse
- Spacing up to 4.5 MHz at 10 Hz repetition
- Pre-bunches, intermediate gaps
- Lower bunch repetition frequencies 1 MHz
- Any user-defined bunch patterns
- Beamline-specific bunch patterns
- Bunch patterns for pump-probe lasers

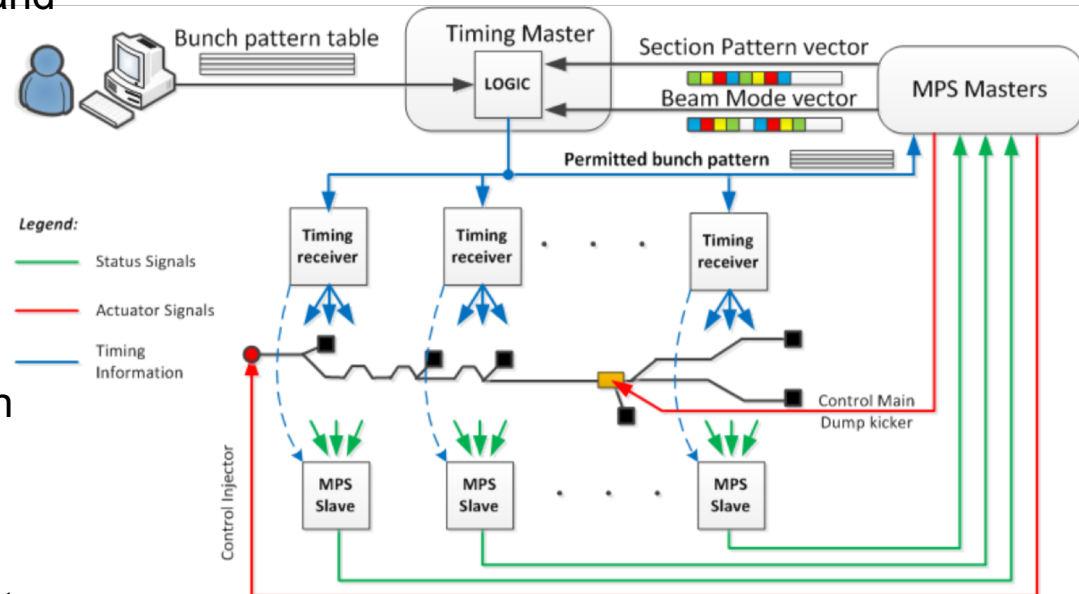


# MicroTCA Applications

## Machine Protection System

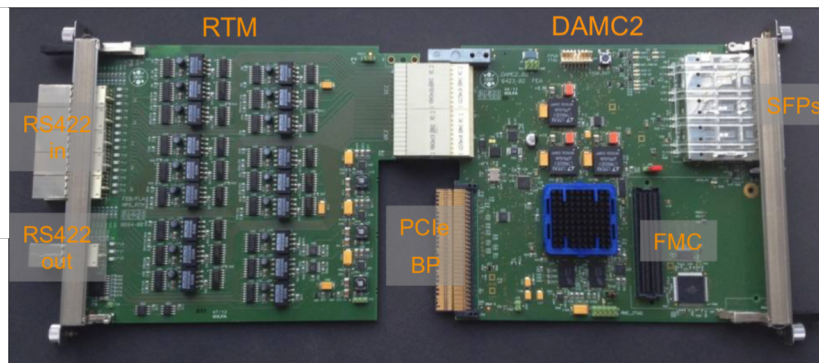
Protection from accelerator damage and activation through beam operations:  
**stop or limit electron beam**

- Decentralized system with master
- Collects various inputs from subsystems via RS422 inputs
- FPGA-based processing of input signals
- Provides beam and section pattern to timing system
- Autonomous slave MicroTCA modules (DAMC2 + MPS RTM)
- RTM with RS422 inputs and outputs



- XILINX Virtex-5 FPGA
- MMC support
- onboard flash-memory
- 1 Gbit SDRAM
- optional dosimetry FMC-card

**XFEL & FLASH**

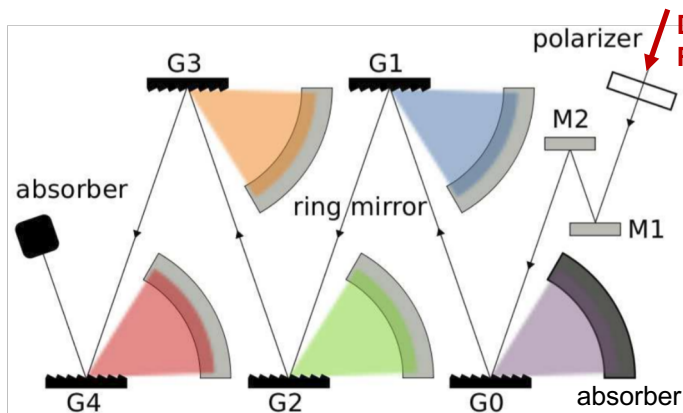


- 45 digital inputs (RS422)
- 7 digital outputs (RS422)
- 2 input lines from backplane
- 2 output lines to backplane
- 3 digital inputs from FMC-card
- I<sup>2</sup>C-bus to FMC-card
- PCIe-bus to all FPGA-registers
- 4 double-fibred bi-directional optical links (SFPs)
- IPMI and JTAG for firmware updates

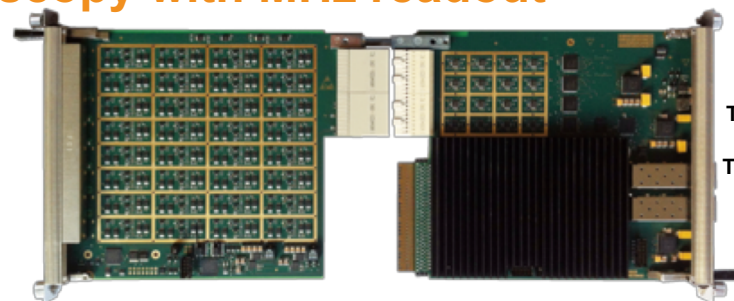
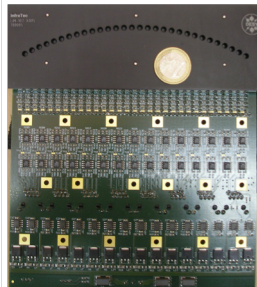


# MicroTCA Applications

## Special Diagnostics – CRISP THz Spectroscopy with MHz readout



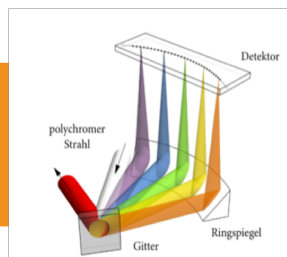
Detector Board



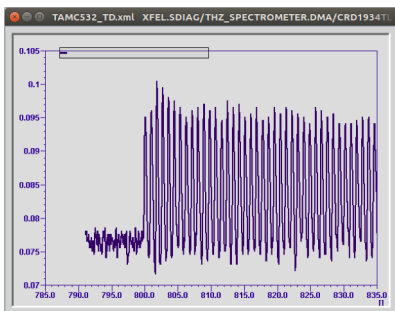
TEWS  
TAMC532  
AMC  
TAMC532-  
TM  
RTM

### Electron bunch length characterization

- 4 pyroelectric detector board with 30 channels
- Parallel readout of all 120 channels by 4 TAMC532 each with 32 ADCS and TAMC532-TM shaper RTM

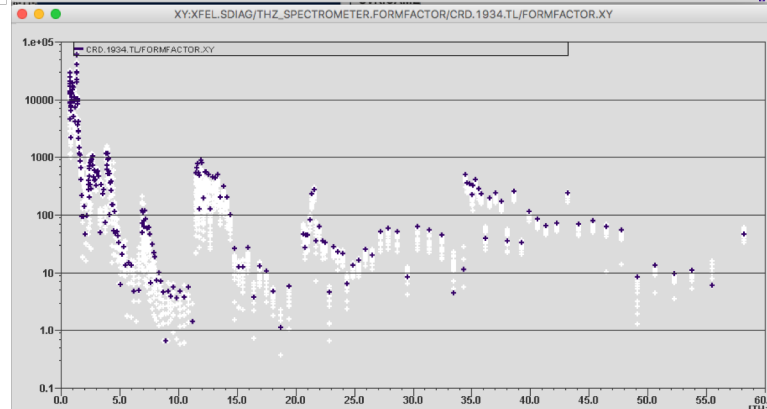
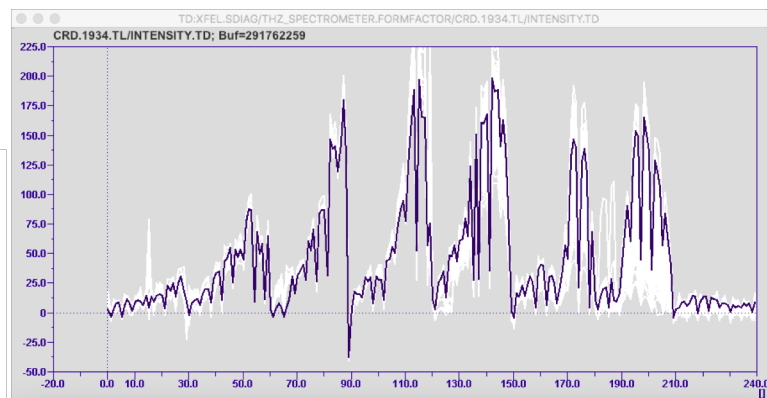
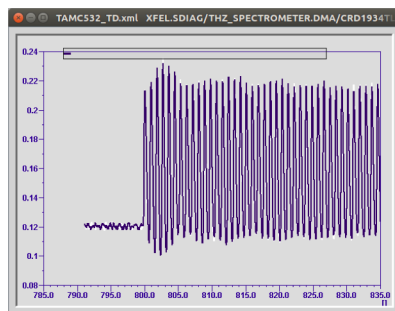


### Channel 1



...

### Channel 120



Courtesy C. Gerth

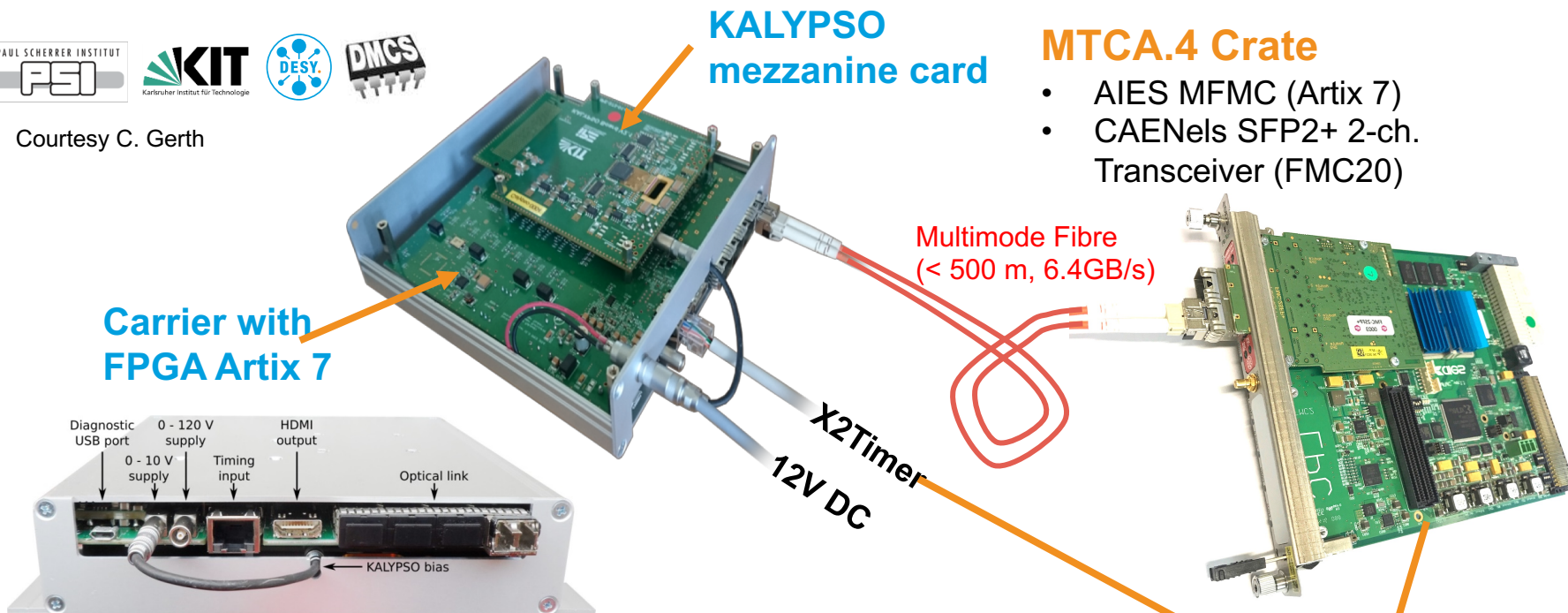
Courtesy O. Hensler

# MicroTCA Applications

## Special Diagnostics – KALYPSO Line Detector with MHz readout



Courtesy C. Gerth



A. Mielczarek *et al.*, *IEEE Transactions on Nuclear Science*, in print, 2018.

### KALYPSO mezzanine card + FPGA Carrier

- Parameters for current version 2.1
  - 256 pixels, 50  $\mu\text{m}$  pitch
  - 14 bit ADC, 2.7 Mfps
- Synchronisation to clock of timing system
- Continuous, low-latency data stream out





# MicroTCA Applications

## “Slow” MTCA.4 Applications

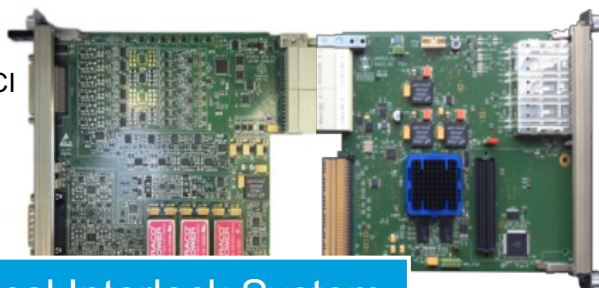
- Magnet Controls connected to P/S controls via CANbus
- Vacuum Controls connected via CANbus to vacuum electronics
- Large, distributed Dosimetry System
  - Using FMC on MPS DAMC2 w/ external DOSIMON Boxes connected via ring line (RS488 telegrams)

## Vacuum And Magnet Controls



ESD 4-Fold CANbus AMC

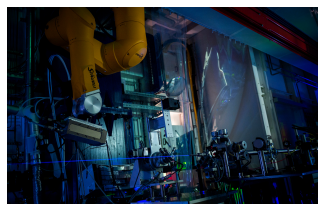
RTM w/ VHDCI  
inputs for  
coupler  
interlock  
signals



DAMC2 AMC w/  
CPL IL Firmware

## Coupler Technical Interlock System

MTCA.4 based Cavity and Coupler  
Interlock at the European XFEL  
*Dimitri Tischhauser*



SPB/SFX  
Single Particles, Clusters, and Biomolecules  
Serial Femtosecond Crystallography

FXE  
Femtosecond X-Ray Experiments

## MTCA.4 @ Experiments

Overview, experience and first results  
of MTCA applications at European  
XFEL Experiments  
*Bruno Fernandes*

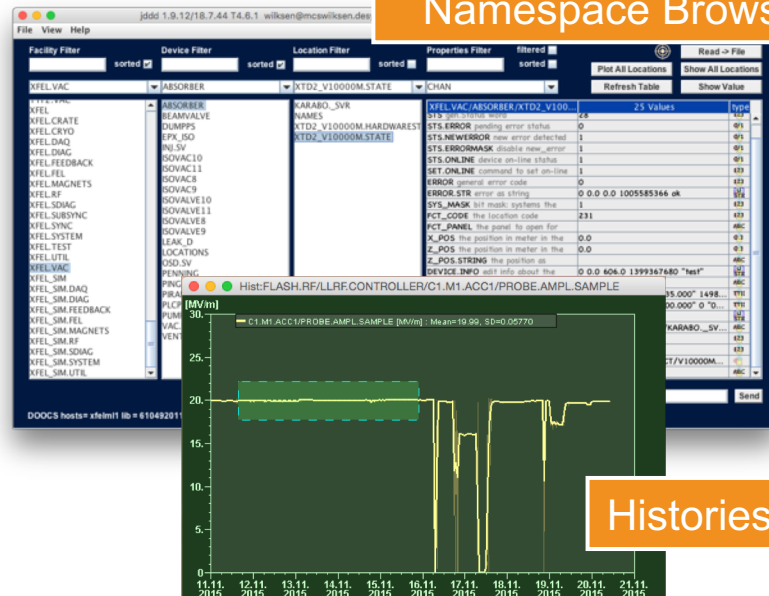
# Status and Experiences

# Status

## Some Stats On The Accelerator Control System

- More than 10 million addressable DOOCS control system parameters visible in accelerator namespace
- About 700.000 local DOOCS archives plus TINE central archive
- More than 20.000 DOOCS channels from MicroTCA front-ends are sent to the DAQ producing data of up to 30 TB/day
- About **30 different kinds of MicroTCA-based software applications** are in use
- Redundant server infrastructure for essential services

## Namespace Browser



## Histories

- About **250** MicroTCA systems online as of November 2018
- More than **3100** MicroTCA modules (AMC, RTM, P/S, MCH) installed at the XFEL accelerator control system e.g.
- Timing System: ~ **400** modules
- ADC AMC variants: > **400** modules
- DAMC2 AMC: ~ **600** modules

## MicroTCA Module List

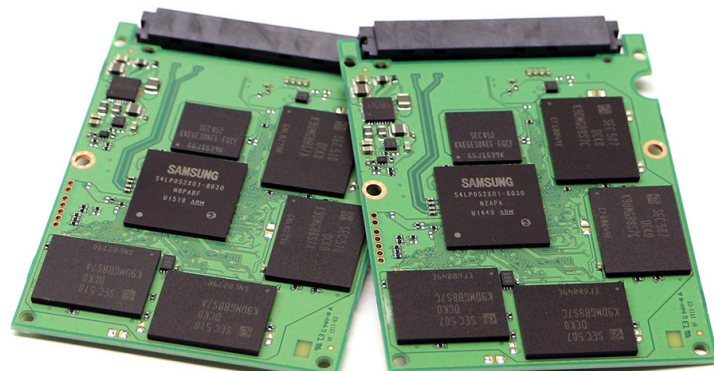
The screenshot shows the 'MicroTCA Module List' window. It displays a table with columns for Module Name, Vendor, and Status. The table lists various modules installed at the XFEL accelerator control system, including timing, ADC, and DAMC2 modules.

Module Name	Vendor	Status
RTM11	Schaff Gmbh	OK
RTM10	Schaff Gmbh	OK
RTM12	Schaff Gmbh	OK
RTM8	Schaff Gmbh	OK
RTM9	Schaff Gmbh	OK
RTM3	Schaff Gmbh	OK
RTM2	Schaff Gmbh	OK
AMC1	Schaff Gmbh	OK
AMC2	Schaff Gmbh	OK
AMC3	Schaff Gmbh	OK
AMC4	Schaff Gmbh	OK
AMC5	Schaff Gmbh	OK

# Experiences

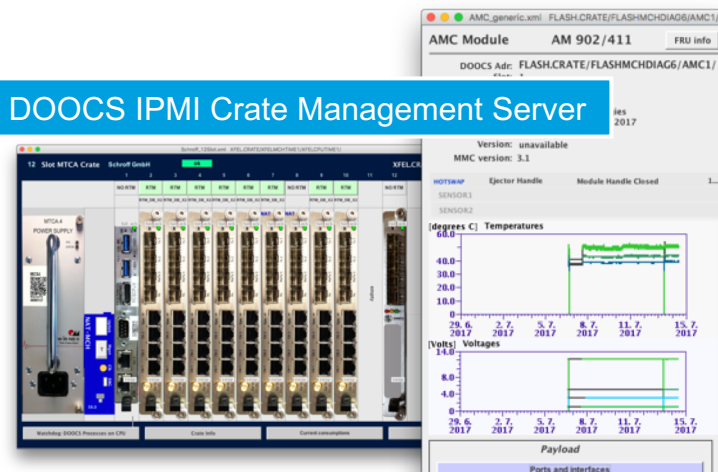
## Experiences With MicroTCA Components In The Accelerator Control System

- More than 1 ½ year of quite successful machine operations
- Teething trouble with MicroTCA components and system integration resolved
- Some leftovers turn into systematic ones:
  - DAMC2 – overcurrent issue: likely bad batch of capacitors affecting many installed AMC – replacement with fixed ones ongoing
  - MCH – P/S communication issues – rare and various signatures – very hard to reproduce in lab test stand if at all – not understood by now
  - MCH firmware – many smaller issues resolved by now
  - PCIe driver – CPU interrupt issues – mostly resolved but some interference with same of the kind ...
- Various smaller issues likely related to beam operations
  - Radiation-induced failures (SSD, possibly FPGA) mostly in LINAC areas however redundant SSD – RAID – saves downtime
  - Very rare FPGA black outs and/or memory corruption
- **Remote management** of crates and modules through IPMI pays off now during standard operations – enables fault resolution and saves downtime of machine operations



SSD on CPU AMC

### DOOCS IPMI Crate Management Server



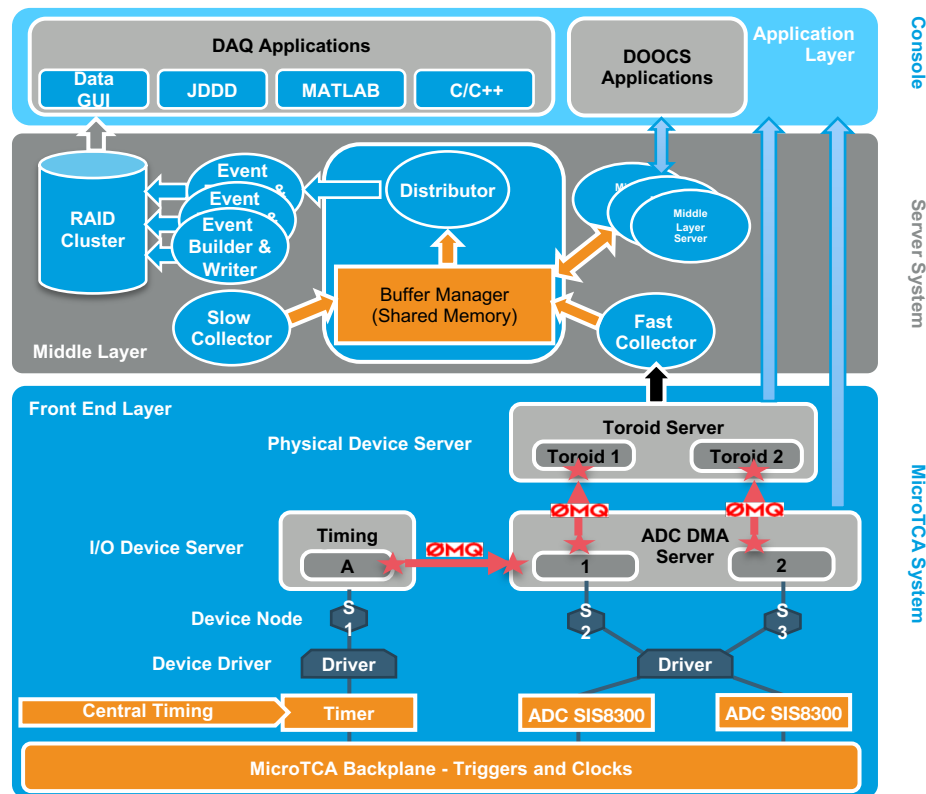
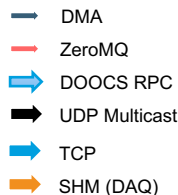
### MicroTCA Crate And Module Management



# Experiences

## MicroTCA Systems For DAQ

- EuXFEL: DAQ is integral part of accelerator control system
- Utilizes event-like structure allowing for synchronized data  
(big data trend in 2018 according to Gartner)
- Continuous data acquisition with multiple streams 24/7
- Input rate from MicroTCA systems about 1.5 Gbyte/s for standard data
- Would result in 130 TB/day without compression – compressed 30 TB/day



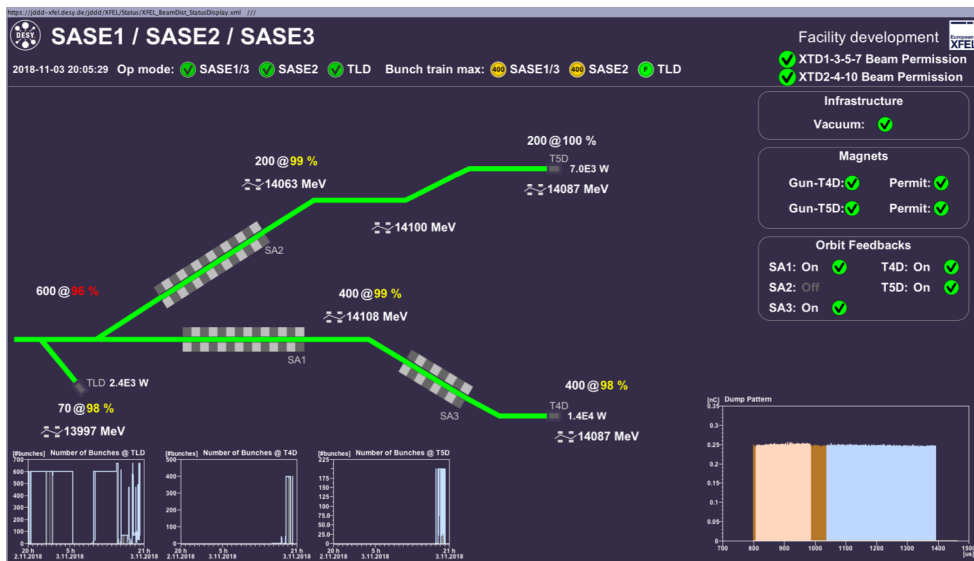
## Challenges:

- Expect more data to come from diagnostics AMC modules (see CRISP and KALYPSO)
- More data for monitoring with respect to fault detection, predictive analysis, post-mortem analysis and reliability and availability aspects in general
- Continuous wave (cw) operation
  - Requires capable CPU AMC (memory, processing power, throughput) -> MCH bandwidth
  - Requires faster Ethernet - CPU/MCH connection via 10G+ Ethernet
  - More CPU power per system - distribute AMC readout among several CPU modules
  - More powerful FPGA and shift applications from CPU to FPGA for data handling and processing

# Summary

# Summary

- The European XFEL accelerator is operating in **production mode** serving photon science users now using both electron beam lines
- **Standardization of hardware and software** simplified implementation and deployment
- **Stable operation** of the control system for the European XFEL linear accelerator since one and half a year
- Parallel operations of multiple electron and photon beam lines successful
- **MicroTCA.4 hardware platform well established** at the European XFEL

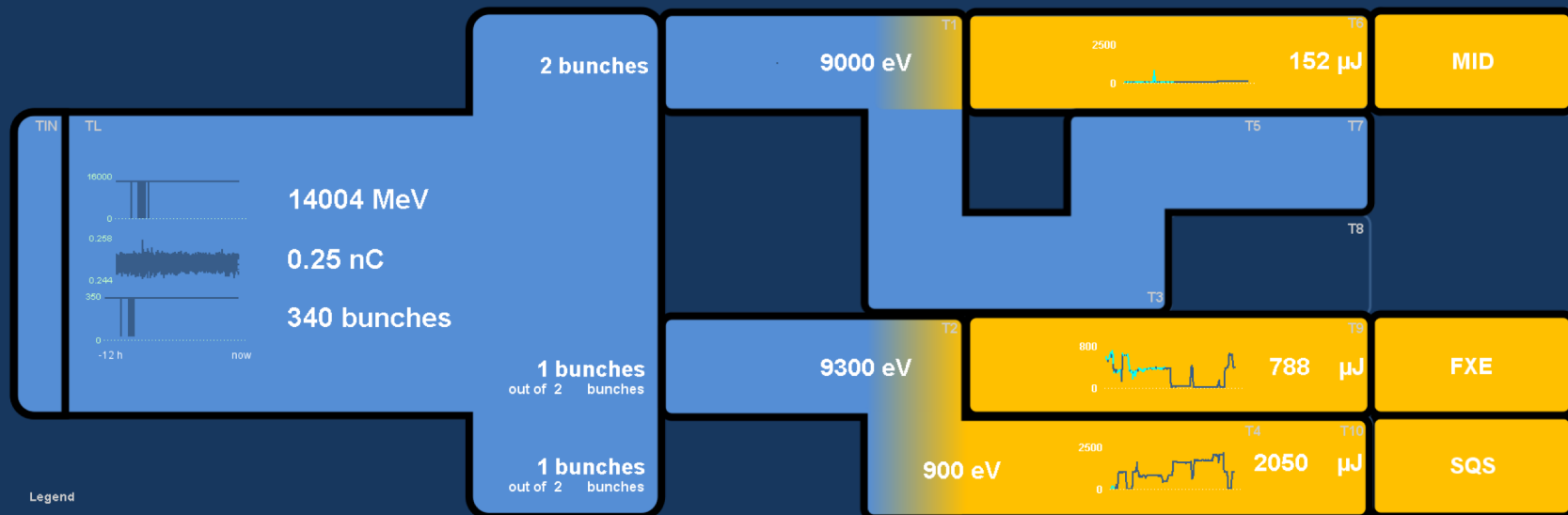


## Outlook

- Finish commissioning of four more experiments
- More demanding features requested by experiments (Timing System / MPS)
- Long-term experience with respect to reliability and availability

# Thank You

XFEL: User program



Accelerator: **User program**

2018-12-01 17:06

SASE1: -

SASE2: -

SASE3: -