

# Control System of the European XFEL Accelerator

Kay Rehlich  
DESY

Real Time Conference 2016

June 9 2016



1993

2016

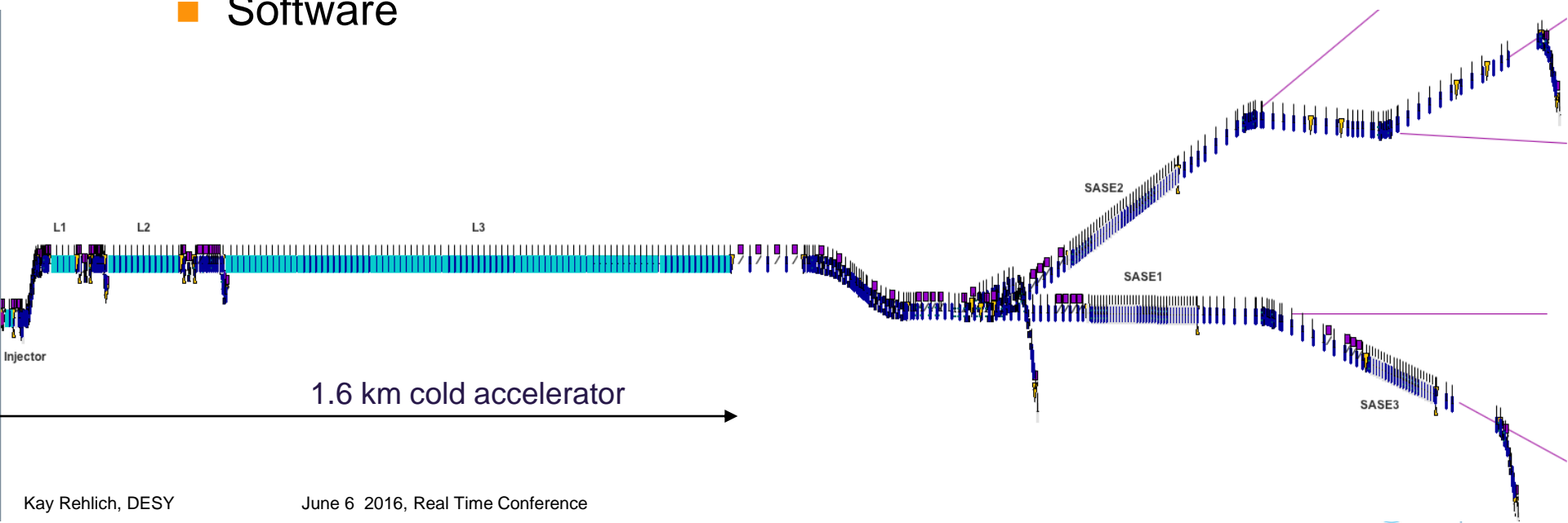
FLASH

+ FLASH 2

XFEL

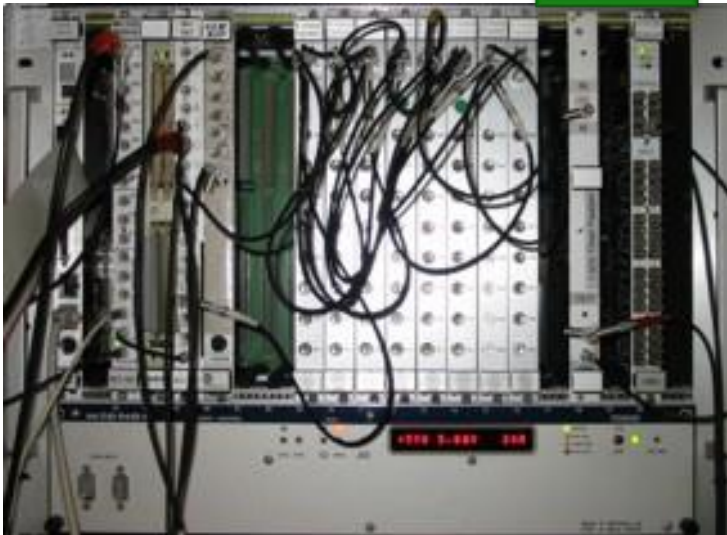
start

- The used standard
- Architecture
  - Hardware
  - Software





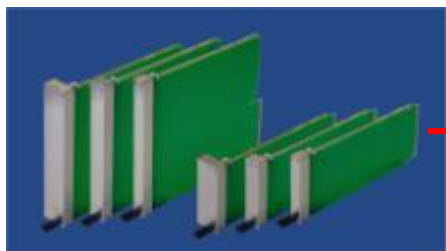
■ Since 1993 **VME**bus



- Most cables from rear
- Interne Clock & Trigger distribution
- Redundant fans
- Redundant power supply optional
- Modern, high-speed data transfer
- Excellent signal quality

**AdvancedMC™**

AMC.0



**AdvancedTCA®**

**ATCA®**



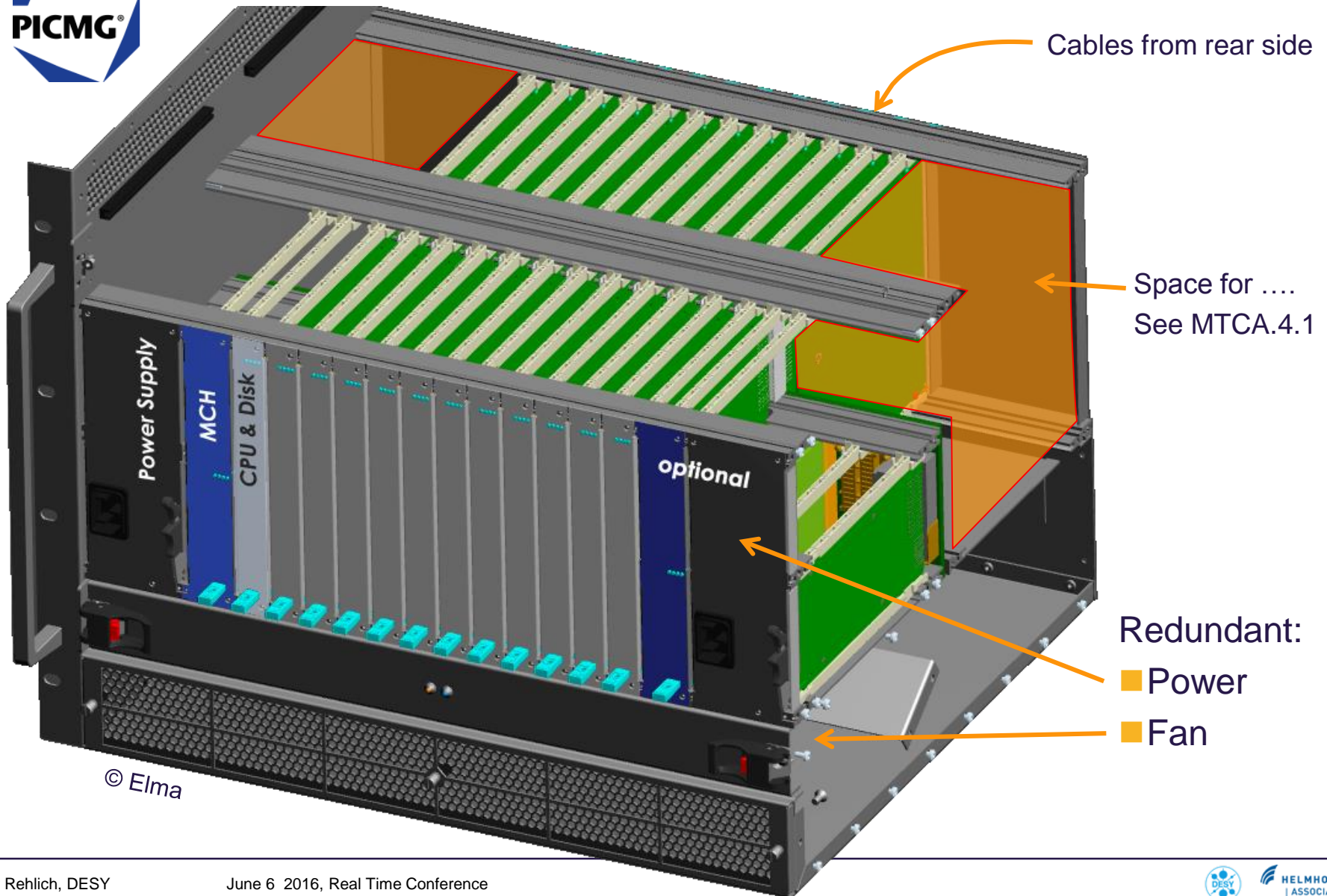
**μTCA®**

MTCA.0



**MTCA.4**

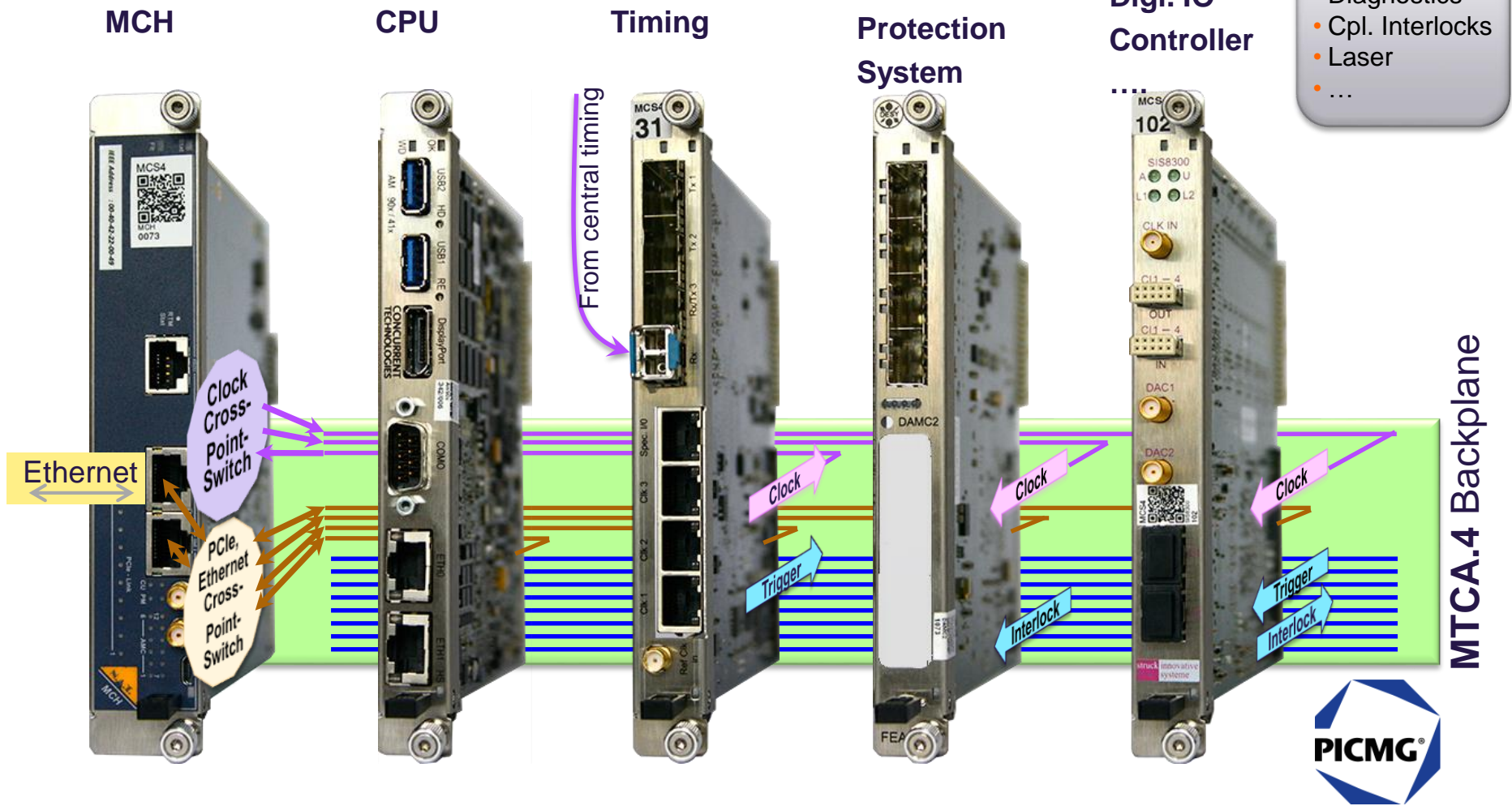
> 150 Mitglieder



# MTCA.4: Clocks, Triggers und Interlocks

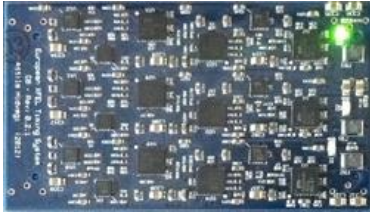
Common modules

Application modules



- LLRF
- Diagnostics
- Cpl. Interlocks
- Laser
- ...





Transmitter Piggyback  
with 3 channels of  
link drift compensation

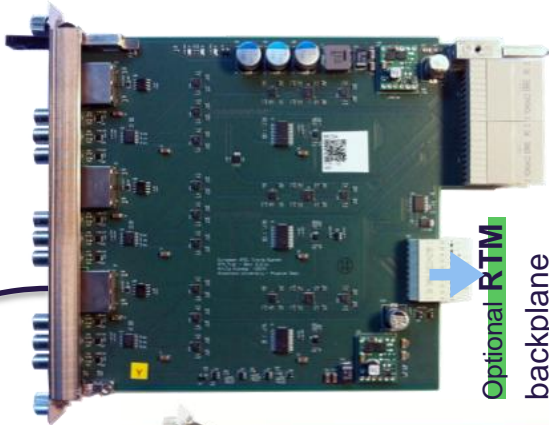


**x2timer /  
NAMC-psTimer  
receiver / transmitter / repeater**

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



> 100 m

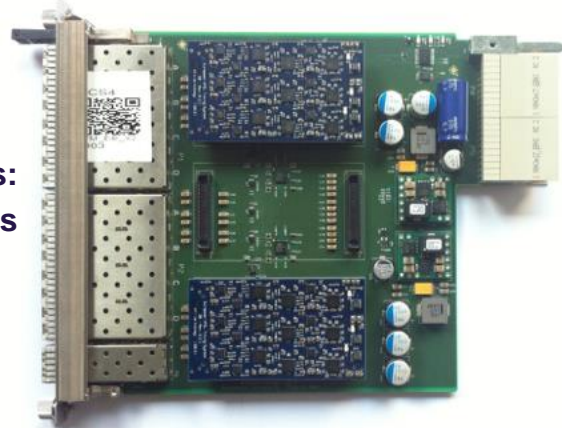


Optional RTM  
backplane  
AMC



x2timer /  
NAMC-psTimer  
receiver / transmitter

9 SFP outputs:  
with length compensated fiber links



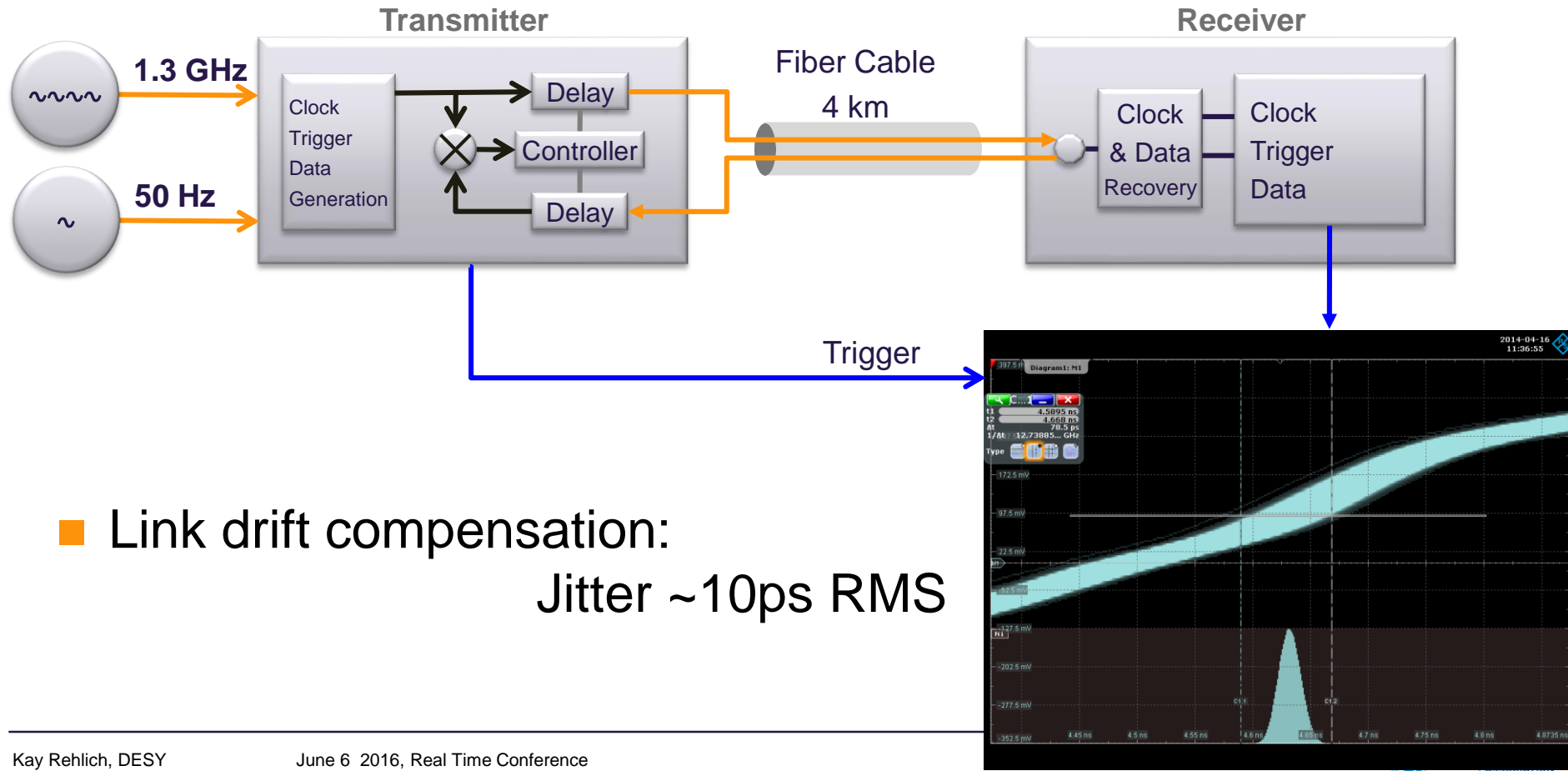
9 Fiber outputs (ST):  
Triggers, Clocks, Data  
used for modulators





## ■ Distributes:

- Triggers, gates, clocks (10ns ... 5ps resolution)
- Bunch information (charge, destination,...), unique ID



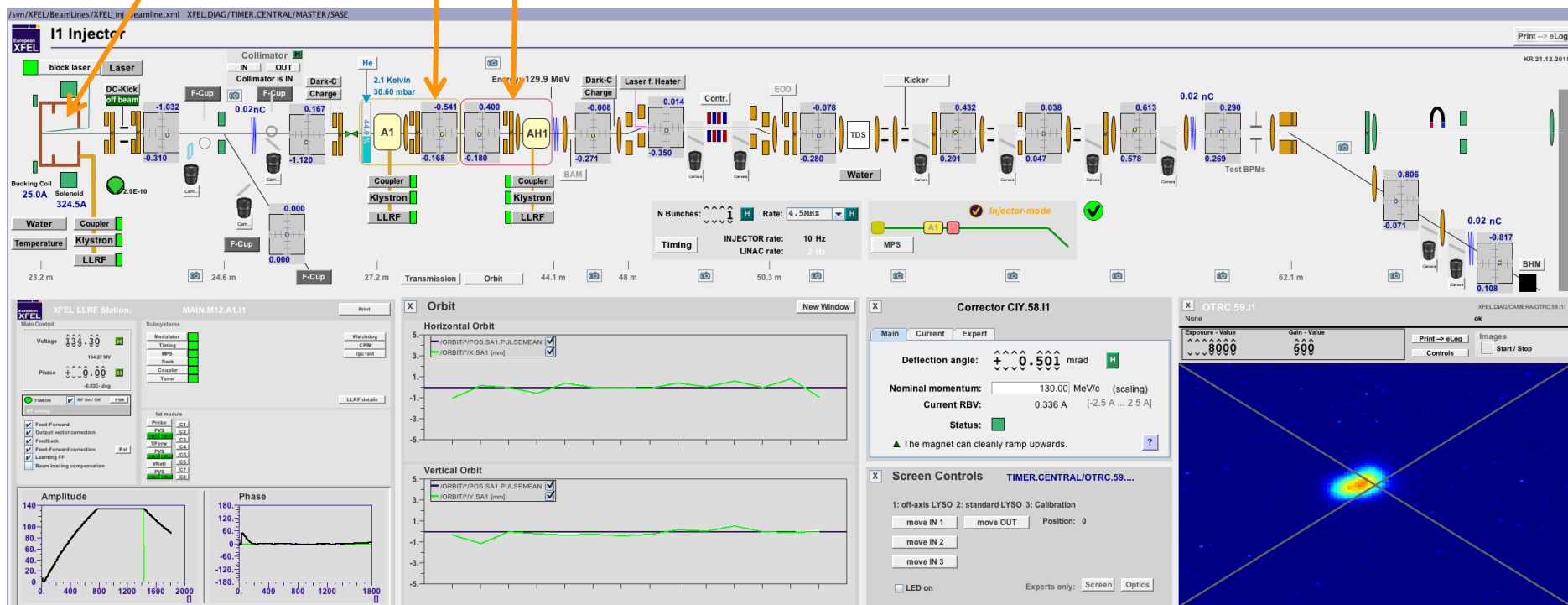
## ■ Link drift compensation:

Jitter  $\sim 10$ ps RMS

Photo Gun

2 superconducting acceleration modules (1.3 and 3.9 GHz)

length: 45m



■ In operation since Dec. 2015

■ Implements most of the XFEL subsystems:

- Klystron, Modulator, LLRF, BPM, Toroid, Magnet, Laser, Undulator, Vacuum, Water, Camera, Motor, Cryo, Timing, Protection, Dump, ...
- DAQ system, middle layer servers, GUI programs and tools, ...

■  $> 3.3 \cdot 10^6$  control system properties online now (270 000 channels with history)

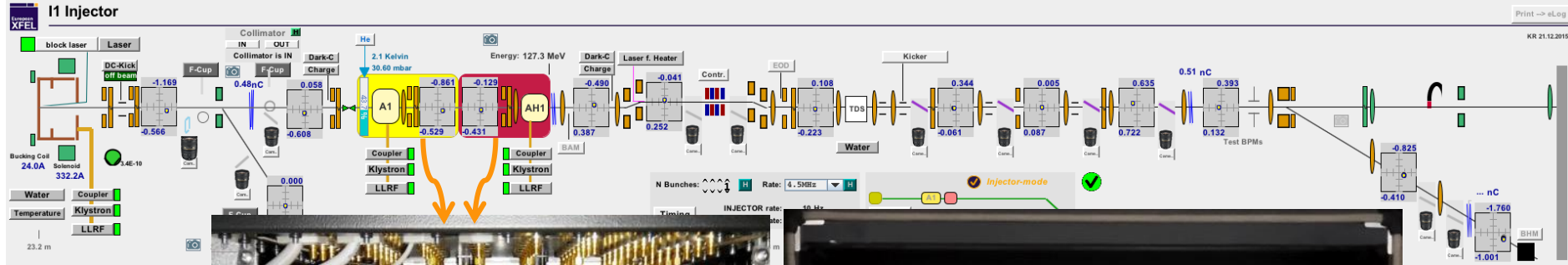
# XFEL Injector: 1. Diagnostics Crate



Gun

Rack Cooling





1 von 100  
Superconducting  
Accelerator Modules

1 **Klystron**  
drives 4 Modules  
MicroTCA Crates:  
2 LLRF  
2 Coupler Interlocks  
1 Diagnostics

LLRF MicroTCA Crate

# MicroTCA Remote Management

AMC Module AM 900/412 FRU info

DOCS Adr: XFELCRATE/XFELMCHDI3011/AMC1/  
Slot: 1  
IPMB Adr: 114  
FRU ID: 5  
Manufacturer: Concurrent Technologies  
Production Date: Fri Feb 14 15:45:00 2014  
Serial Number: M23485/016  
Version: unavailable  
MMC version: 3.1

Temperatures (degrees C) graph showing values between 36 and 52 over time.

Volts graph showing values between 0 and 6 over time.

Control functions: Cold Reset, Reboot

12V payload power: Activate, Deactivate

Management View

12 Slot MTCA Crate Schroff GmbH ok device online XFELCRATE/XFELMCHDI3011/

Hardware components visible: MTC4 POWER SUPPLY, x2timer, mps\_se, damcbp, sis300, toroid, ADIO34.

Watchdog: DOCS Processes on CPU

Crate Info, Current consumptions, Fans

Display by standard controls tool jddd

0.82 load 27.48 %

22 online 3 errors offline 1

FLASH, PETRA, LINAC2, DESY, XFEL, Lab, REGAE, SALDME

sorted unsorted Filter: "udevtmp"

sysinfo: ok Online Sys Info

WD properties: ok Online properties

DISK: ok Online properties

NET: ok Online properties

FS.ROOT: ok Online properties

FS.EXPORT: ok Online properties

CAREPEATER: ok Online 0.00 properties

SVR.WATCHDOG: ok Online 6.10E8 locations

SVR.BLM: ok Online 6.10E8 locations

SVR.TOROID: ok Online 6.10E8 locations

SVR.BLMDMA: remote\_errors: error\_count = 1 Online 6.10E8 locations

system status reihch@mcarehlich.desy.de

DOCS Control System View

XFELDIAG/TIMER/DI3011/

CPU Interface: Macro Pulse Number: N22272173

Dividers: Delay, Rate, Div

RTM Triggers: VCC W/ out Ena., VCC W/ out Ena., VCC W/ out Ena., VCC W/ out Ena.

Front Triggers: VCC W/ out Ena., VCC W/ out Ena., VCC W/ out Ena., VCC W/ out Ena.

Backplane Clocks & Triggers: PLL, CrossPointSwitch, FPGA MUX

# MicroTCA Crate Management View

SystemStatus.xml ///

## DOOCS System Status

Applications Server Status Network Status FLASH Timing FLASH VME FLASH μTCA MicroTCA FLASH,Lab MicroTCA XFEL AMTF

### XFEL MicroTCA Crates

XFELMCHXH1 :	show	Schroff GmbH	12	●
XFELMCHTIME1 :	show	Schroff GmbH	12	●
XFELMCHLLGUN1 :	show	Schroff GmbH	6	●
XFELMCHLASER1 :	show	Schroff GmbH	12	●
XFELMCHDI3011 :	show	Schroff GmbH	12	●
XFELMCHVAC1 :	show	Schroff GmbH	6	●
XFELMCHMAG1 :	show	Schroff GmbH	12	●
XFELMCHLLA2M :	show	Schroff GmbH	12	●
XFELMCHLLA2S :	show	Schroff GmbH	12	●
XFELMCHDI131L1 :	show	Schroff GmbH	12	●
XFELMCHLASER2 :	show	Schroff GmbH	12	●
XFELMCHLLA6M :	show	Schroff GmbH	12	●
XFELMCHILA2M :	show	Schroff GmbH	12	●
XFELMCHILA2S :	show	Schroff GmbH	12	●
XFELMCHDI533L3 :	show	Schroff GmbH	12	●

### AMTF MicroTCA Crates

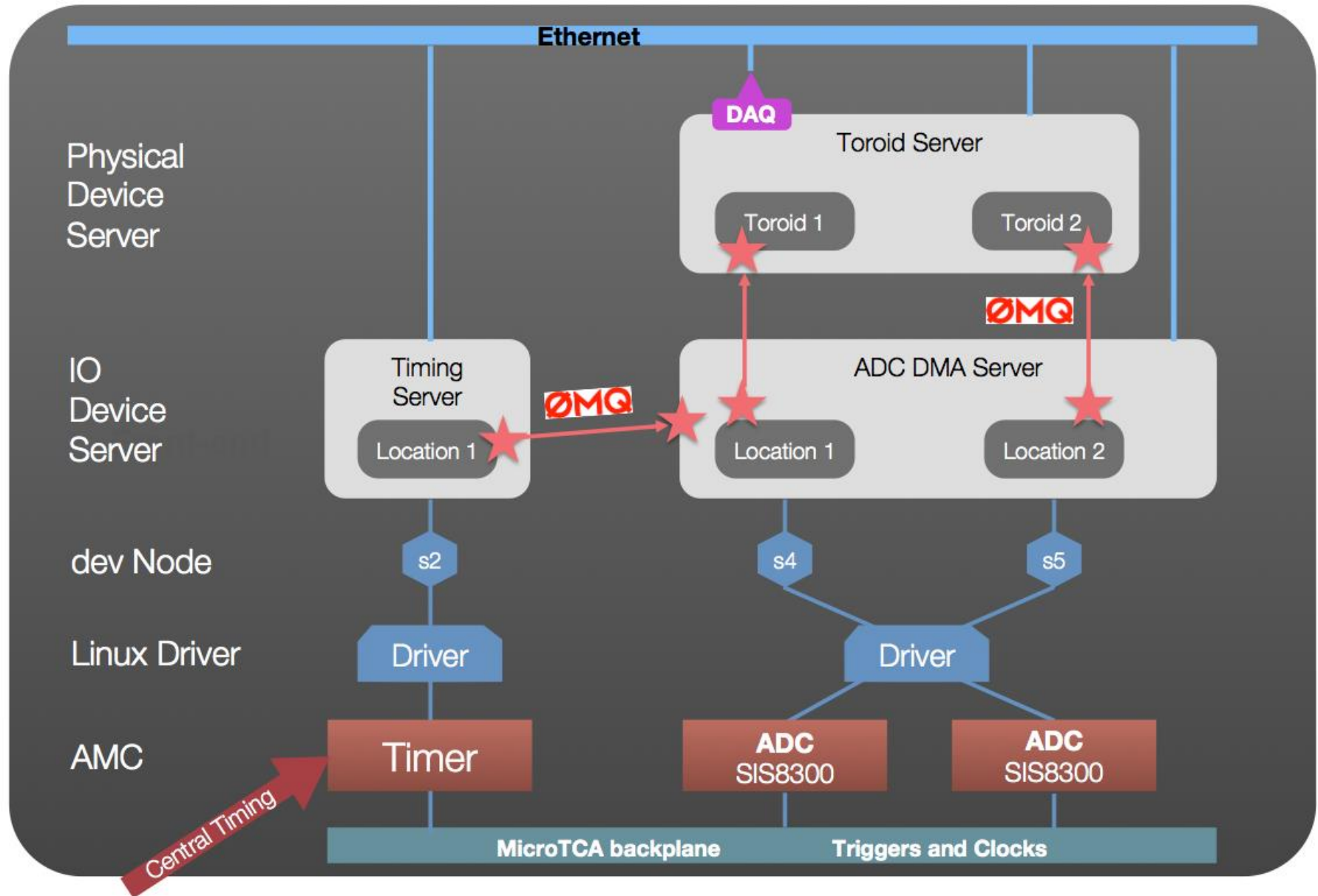
MSKMCHAMTF1 :	show	Schroff GmbH		
MSKMCHAMTF2 :	show	ELMA Electronic Gm		
MSKMCHAMTF3 :	show	Schroff GmbH		
AMTFM33MCH :	show	ELMA Electronic Gm		
AMTFM31MCH :	show	ELMA Electronic Gm		
MSKMCHAMTF39 :	show	Schroff GmbH	12	●
AMTFM339-MCH :	off			

Shows all Crates in XFEL

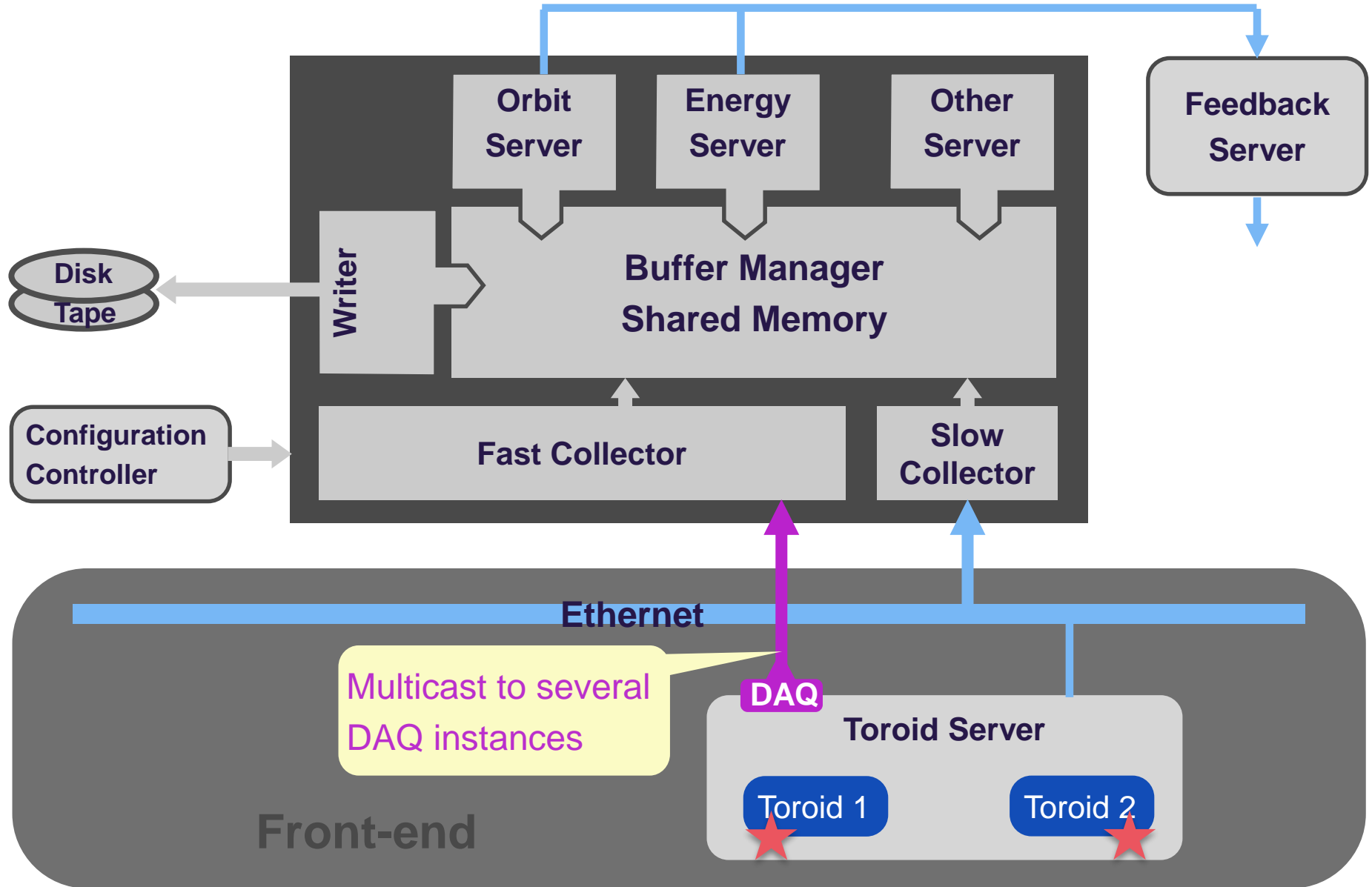
Shows all Modules in selected Crate

### Modules in selected crate: XFEL.CRATE/XFELMCHDI3011/

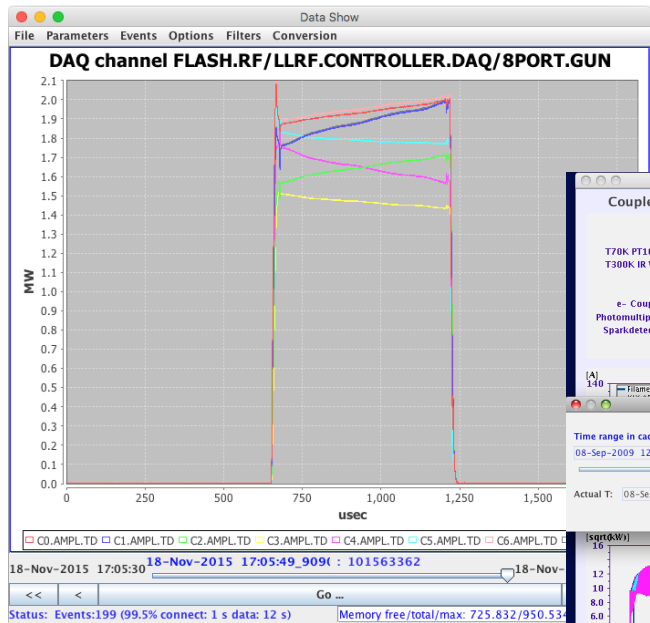
	Crate	Fans	Power Modules	Serial:	MMC version
RTM4 :	Unknown unavaiable	info	● ● ● ●	unavailable	0.00
RTM3 :	MPS-RTM1 ATP	info	● ● ● ●	01-012	0.00
RTM2 :	RTM_Trg1 Stokholm University	info	● ● ● ●	030	0.00
AMC6 :	DAMC2 Deutsches Elektronen-Synchrotron	U= 3.3 Temp= 33.0	info	● ● ● ●	1025 1.01
AMC2 :	X2TIMER Stockholm University	U= 3.3 Temp= 37.0	info	● ● ● ●	0067 2.00
AMC4 :	DAMC2 Deutsches Elektronen-Synchrotron	U= 3.5 Temp= 35.0	info	● ● ● ●	4125 2.03
AMC3 :	DAMC2 Deutsches Elektronen-Synchrotron	U= 3.3 Temp= 36.0	info	● ● ● ●	4063 2.03
COOL_UNIT2 :	Fan speed= 2580 2640 3060 3060 Temp= 32.0 29.0	info	● ● ● ●	1051405710AB	1.18
COOL_UNIT1 :	Fan speed= 2640 2520 2940 2940 Temp= 29.0 28.0	info	● ● ● ●	1051405711AB	1.18
AMC5 :	DAMC2 Deutsches Elektronen-Synchrotron	U= 3.6 Temp= 33.0	info	● ● ● ●	4154 2.03
AMC11 :	SIS8300L2 Struck Innovative Systeme GmbH	U= 1.5 Temp= 56.0	info	● ● ● ●	219 1.33
AMC1 :	AM 900/412 Concurrent Technologies	U= 0.8 Temp= 41.0	info	● ● ● ●	M23485/016 3.10
AMC10 :	SIS8300L2 Struck Innovative Systeme GmbH	U= 1.5 Temp= 59.0	info	● ● ● ●	218 1.33
AMC9 :	SIS8300 Struck Innovative Systeme GmbH	U= 1.8 Temp= 45.0	info	● ● ● ●	031 1.00
AMC7 :	DAMC2 Deutsches Elektronen-Synchrotron	U= 3.5 Temp= 34.0	info	● ● ● ●	1087 2.02
AMC8 :	SIS8300 Struck Innovative Systeme GmbH	U= 1.8 Temp= 45.0	info	● ● ● ●	029 1.00
MCH :	NAT-MCH V1.5.R150127	Current= 2.4 Temp= 34.0 39.0 30.0 33.0	info	● ● ● ●	395 2.23



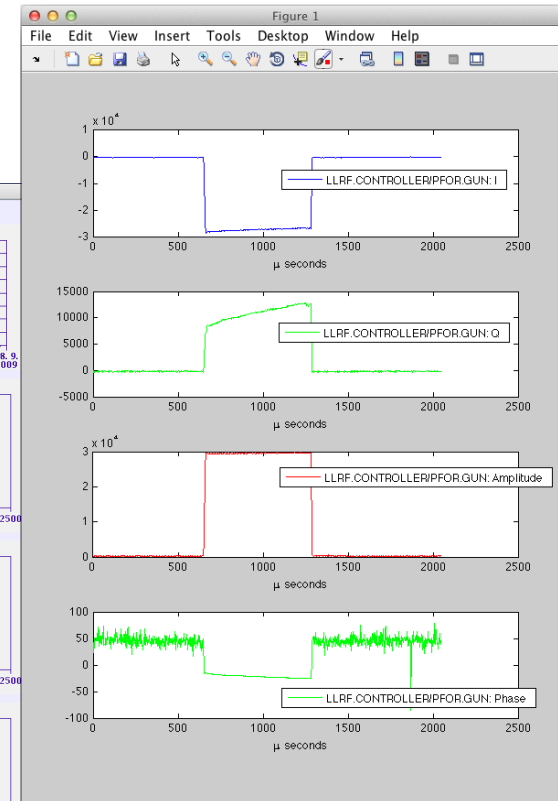
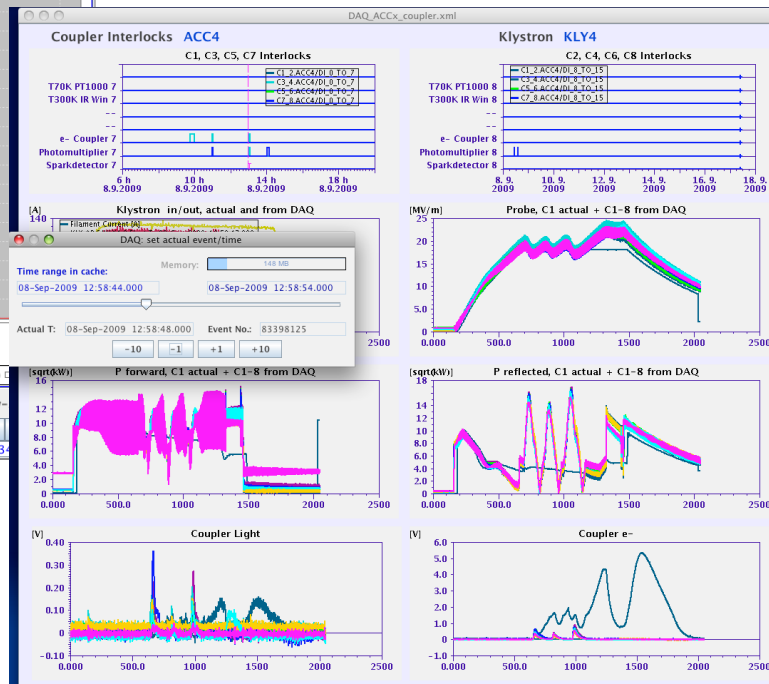




# Analyze all Shots with Bunch Resolution

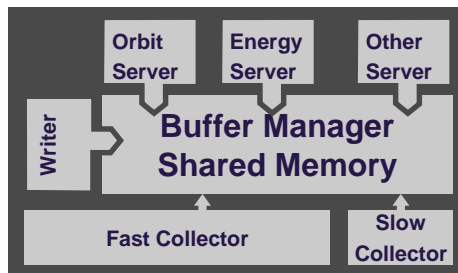


Jddd: GUI editor



DAQ GUI

MATLAB



daq\_status.xml
TTF2.DAQ//

### FLASH MAIN DAQ

**State:** linac GMD\_DATA... IMAGE\_DATA EOS\_THz BAMDIAG linac\_slow **Off**

Eventbuilder Writer Status

---

**Procedures**

(Re)-Start DAQ

ALL to INIT

---

**Run Control**

State: **RUN**

Run: 12196

Run Mode: Real

Processes: 1

Sample Rate: 1000

Experiment Run Control

EOS & THz Images

BAM GMD Backup

---

**DAQ FSM**

State: **RUN**

Processes: 40

---

**Slow Collector**

State: **RUN**

Events: 42843

**Eventbuilder**

State: **RUN RUN RUN RUN RUN RUN RUN**

Stream: main gmd\_data stream\_3 stream\_4 stream\_5 stream\_6 snapshot

Experiment: linac GMD\_DATA... IMAGE\_DATA EOS\_THz BAMDIAG linac\_slow snapshot

Events: 6998478 2936200 4983 4983 4983 52808 0

---

**DAQ ML Server**

BLM ML Server	862139	3464	<b>RUN</b>	Photonflux Server	864899	55	<b>RUN</b>
Toroid ML Server	865683	26	<b>RUN</b>	GMD Provider Server	864903	0	<b>RUN</b>
Orbit ML Server	831509	0	<b>RUN</b>	Photonenergy Server	768333	5	<b>RUN</b>
Charge ML Server	141924	0	<b>RUN</b>	Photonwavelength Server	547351	85	<b>RUN</b>
Beam Power Server	865730	1	<b>RUN</b>	THZ ML Server	865340	10	<b>RUN</b>
Energy ML Server	861644	1261	<b>RUN</b>	Pass Server	865645	8	<b>RUN</b>
FL1 Long. Feedback	786229	382	<b>RUN</b>	Beam Profile Measuremen	769877	2268	<b>RUN</b>
FL2 Long. Feedback	140152	100	<b>RUN</b>	BCM MLServer	865695	36	<b>RUN</b>
Slow LOLA Feedback	0	0	<b>RUN</b>	BLM HLC Server	865182	511	<b>RUN</b>
LLRF_ML_EnergyGain	142508	2	<b>RUN</b>	SASE Statistics Server	864643	315	<b>RUN</b>
Energy from Dipole	865729	2	<b>RUN</b>				

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**Distributor**

Stream: DAQ.LINAC DAQ.STREAM.2 DAQ.STREAM.3 DAQ.STREAM.4 DAQ.STREAM.5 DAQ.STREAM.6 DAQ.LINAC

State: **RUN RUN RUN RUN RUN RUN INITIALIZED**

Events: 1102650 2936203 4983 4983 4983 52808 1

---

**Snapshot ML**

State: **INITIALIZED**

Events: 1

---

**Fast Collector**

Stream: Normal BAM (BL1) BAM ML (BL3) WS Image

State: **RUN RUN RUN RUN RUN**

Events: 865723 865349 850384 0 1069268

Connections Connections Connections Connections Connections

Toroid Loss Rate @ FLASH.DIAG/TOROID/7ORS **0.00 %**

Toroid Loss Rate @ FLASH.DIAG/TOROID/12EXP **0.00 %**

---

**Front-End Server**

VMEDIA1	VMEDIA2	VMEDIA3	VMEDIA4	VMEDIA5	VMEDIA6	VMEDIA7	VMEDIA8	FLASHCPUDIAG8	FLASHCPUTIME1	FLASHPLCSVR1	VMEMID	
864889	863477	865668	864899	862991	865273	288465	863970	865663	865666	865534	865028	
FLASHCPUDIAG1	FLASHCPUDIAG4	FLASHCPUDIAG8			VMSYNCH1	VMSYNCH4	VMSYNCH6		VMSFLASH1	VMEGUN	VMEICP1	
865663	865665	865664			784580	723180	804146		865695	865666	859497	
VMEPM1	VMEPM2	VMEPM3	VMEDIA8	VMEDIA2	FLASHCPUDIAG1	FLASHCPUDIAG4	VMEDIA4	HALO	VMEDIA8	FLASH2CPUDIAG		
865648	865645	865667	864831	861697	865665	198395	864442	864614	860944			
VMEKLY2	VMEKLY3	VMEKLY4	VMEKLY5	VMEKLY6								
865642	865473	865650	120041	131126								
MSKCPUACC139	MSKCPUACC23	MSKCPUACC45	MSKCPUACC87	MSKCPURFGUN	VMEGUN1	VMEGUN2	VMEGUN2	VMEACC7				
865664	865663	865664	865663	865664	865504	865227	864837	865568				
VMEGUN2	VMEACC12	VMEACC3	VMEACC6	VMEACC7								
864790	864800	864893	864492	865069								
FLASH2CPUDIAG	FLASH2CPUDIAG	FLASH2CPUDIAG	FLASH2CPUDIAG	FLASH2CPUDIAG	FLASH2CPUDIAG	FLASH2CPUDIAG	FLASH2CPUDIAG	FLASH2CPUDIAG	FLASH2CPUDIAG	FLASH2CPUDIAG	DUMP2CPUDIAG	
860944	141798	860943	287968	860944	860944	860944	860944	860944	860945	860945	860945	

Storage Streams

Attached Processes

Data Collectors

Distributed Front-ends

Kay Rehlich, DESY

June 6 2016, Real Time Conference

## ■ PICMG Standard

- Started 2009 → MTCA.4 published 2011

- Q2 2016: MTCA.4.1 extensions

- Other projects can benefit from the standard

## ■ XFEL fast Diagnostics and Controls platform is *μTCA*<sup>™</sup>

- Final installation > **200 MicroTCA.4 Crates**

- Injector is fully operational since Dec. 2015

- Linac cool-down will start Oct. 2016

## ■ Critical Hardware and Software is successful in operation

# Thank you!

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More info: [doocs.desy.de](http://doocs.desy.de)

