Operational Statistics with MTCA LLRF Systems at FLASH and XFEL

9th MicroTCA.4 workshop

Julien Branlard,
for the LLRF team

DESY, Hamburg, 01.12.2020

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

1. INTRODUCTION

2020 - Covid-19

Covid-19 “light” shutdown

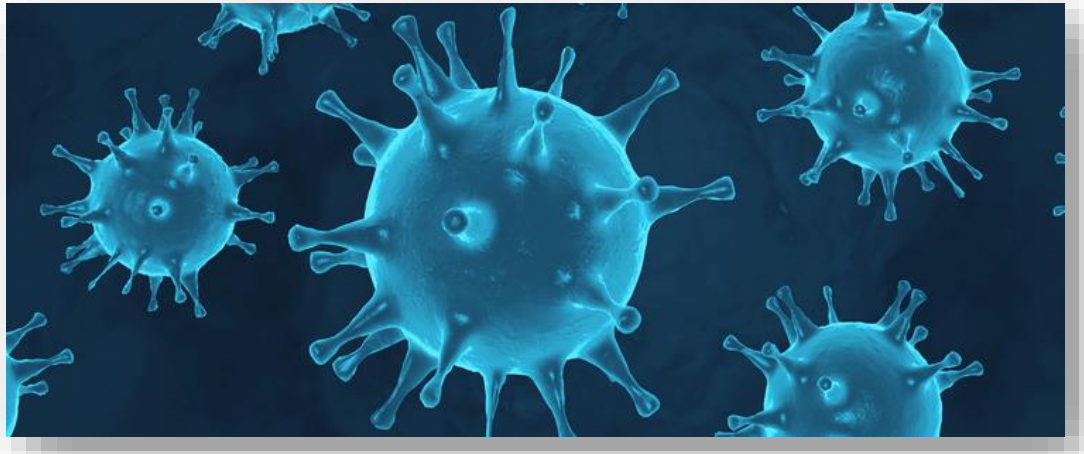
- Spring: de- (and re-)tuned all cavities for both machines
- Summer: operation resumed

FLASH

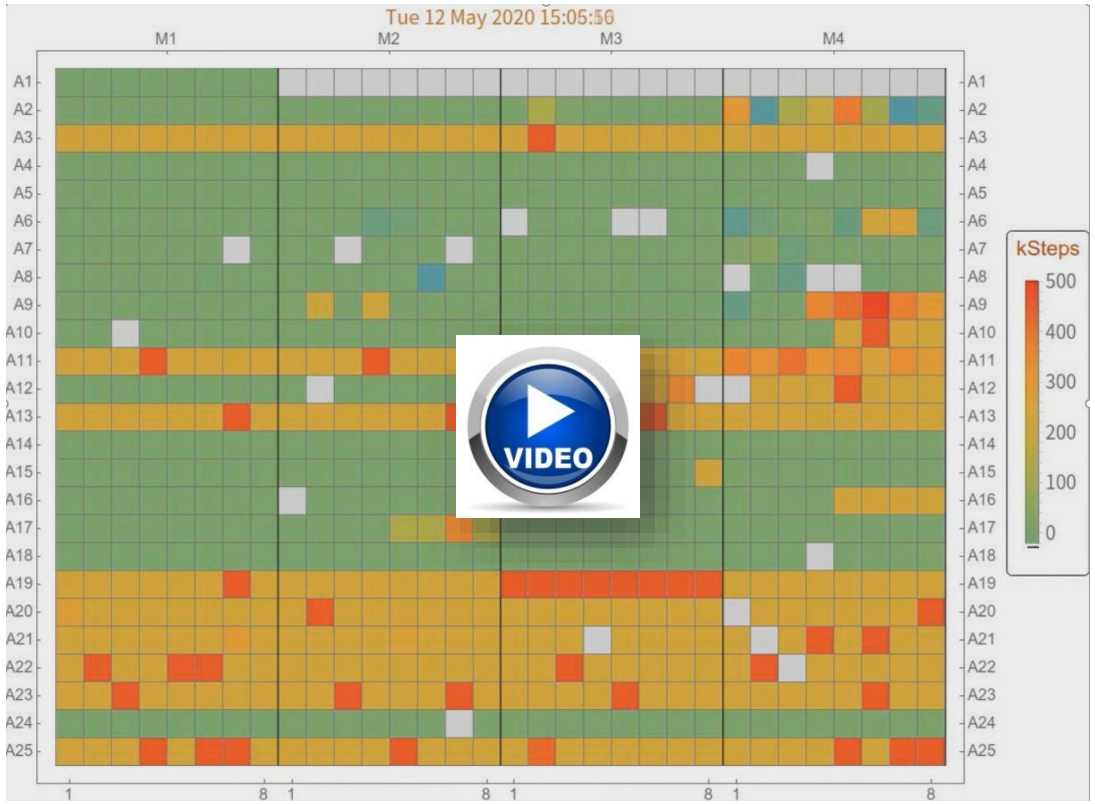
- Only 2 user blocks (9 wks total) cancelled in Spring
- Smooth beam operation, run downtime below 2% (due to technical failures)

XFEL

- 5640 operating hours (6888 hours planned)
- 1856 user hours (as planned) with 95% availability
- 30 keV (world record) and 17.8 keV (routine) photon energy



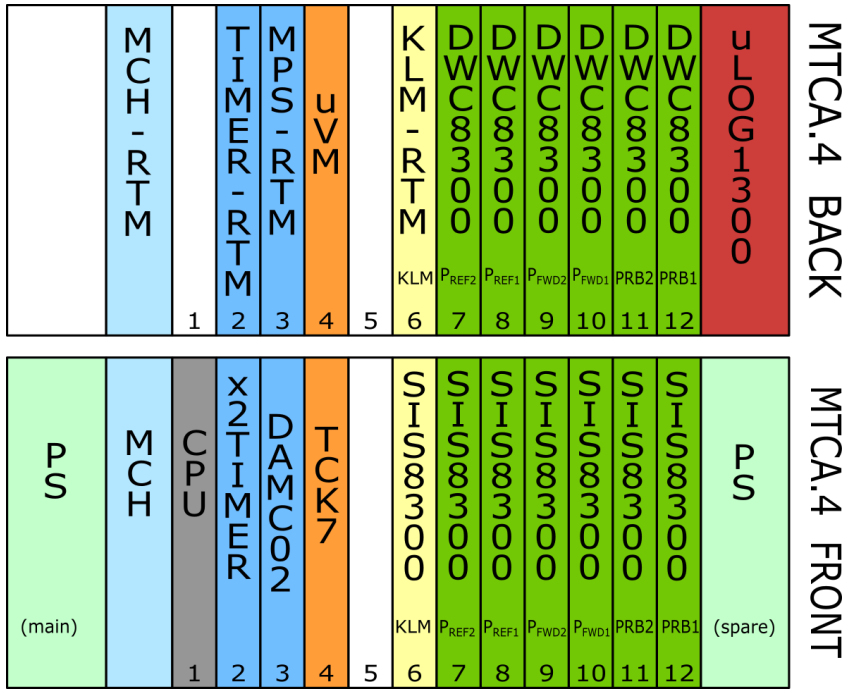
Movie credit N. Walker



1. INTRODUCTION

MTCA.4 LLRF Systems

Standard crate occupation




```
FRU Information:
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 FRU  Device    State  Name
=========================================
  0   MCH       M4     NMCH-CM
  3   mcmc1     M4     NAT-MCH-MCMC
  5   AMC1      M4     CCT AM 902/411
  6   AMC2      M4     X2TIMER
  7   AMC3      M4     DAMC2V3
  8   AMC4      M4     DAMC-TCK7
 10   AMC6      M4     SIS8300L
 11   AMC7      M4     SIS8300L2 AMC
 12   AMC8      M4     SIS8300L2 AMC
 13   AMC9      M4     SIS8300L2 AMC
 14   AMC10     M4     SIS8300L2 AMC
 15   AMC11     M4     SIS8300L2 AMC
 16   AMC12     M4     SIS8300L2 AMC
 40   CU1       M4     Schroff uTCA CU
 41   CU2       M4     Schroff uTCA CU
 51   PM2       M4     PM-AC1000
 53   PM4       M4     PM-AC1000
 60   Clock1    M4     MCH-Clock
 61   HubMod1   M4     MCH-PCIe
 64   MCH1-RTM  M4     MCH-RTM-ComEx
 91   AMC2-RTM  M4     X2TIMERRTM
 92   AMC3-RTM  M4     DAMC2RTM
 93   AMC4-RTM  M4     DAMC-TCK7 RTM
 95   AMC6-RTM  M4     SIS8300LRTM
 96   AMC7-RTM  M4     SIS8300L2 RTM
 97   AMC8-RTM  M4     SIS8300L2 RTM
 98   AMC9-RTM  M4     SIS8300L2 RTM
 99   AMC10-RTM M4     SIS8300L2 RTM
100   AMC11-RTM M4     SIS8300L2 RTM
101   AMC12-RTM M4     SIS8300L2 RTM
104   eRTM15    M4     DRTM-LOG1300
=========================================
```

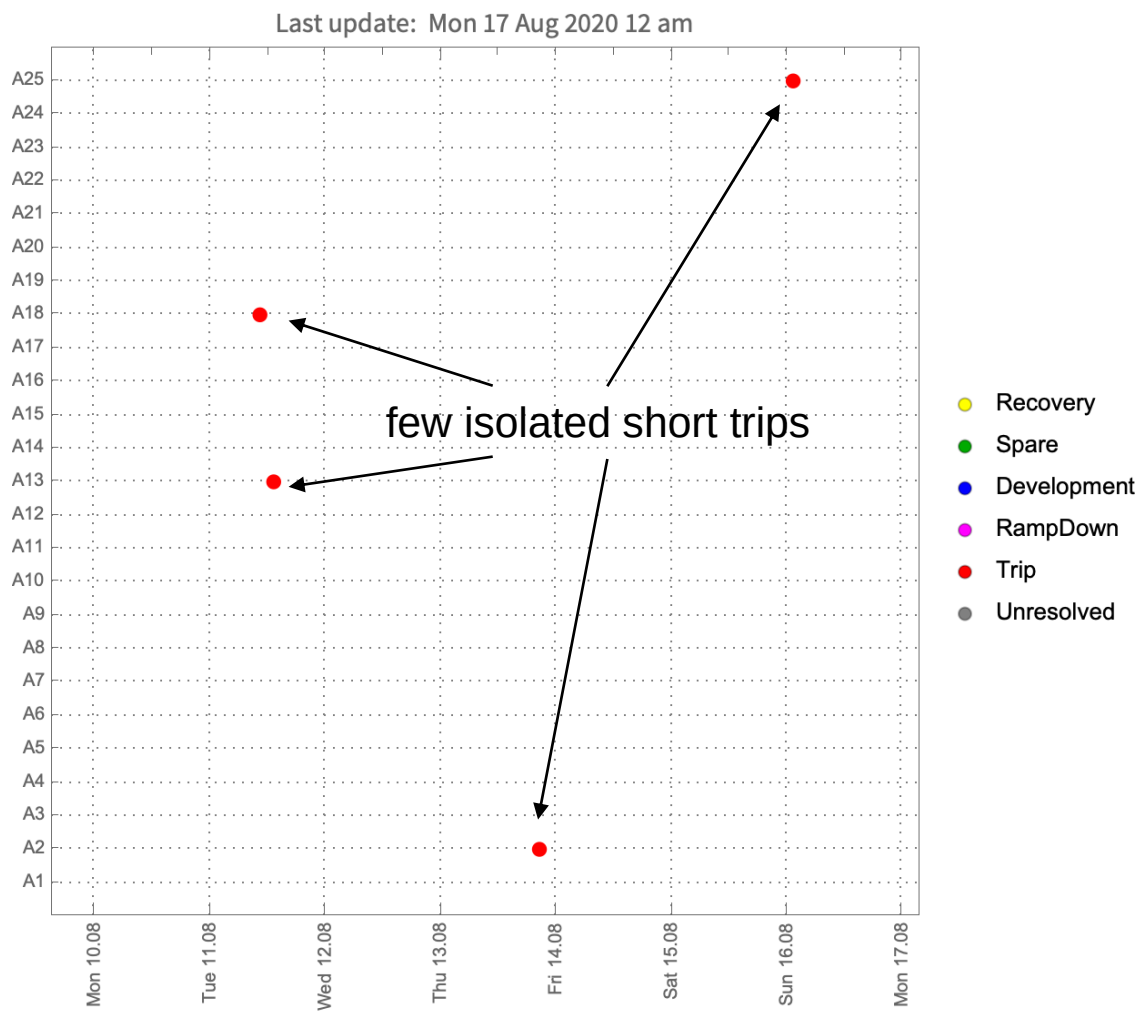
~10x @ FLASH

~60x @ XFEL

2. Monitoring the RF availability at XFEL

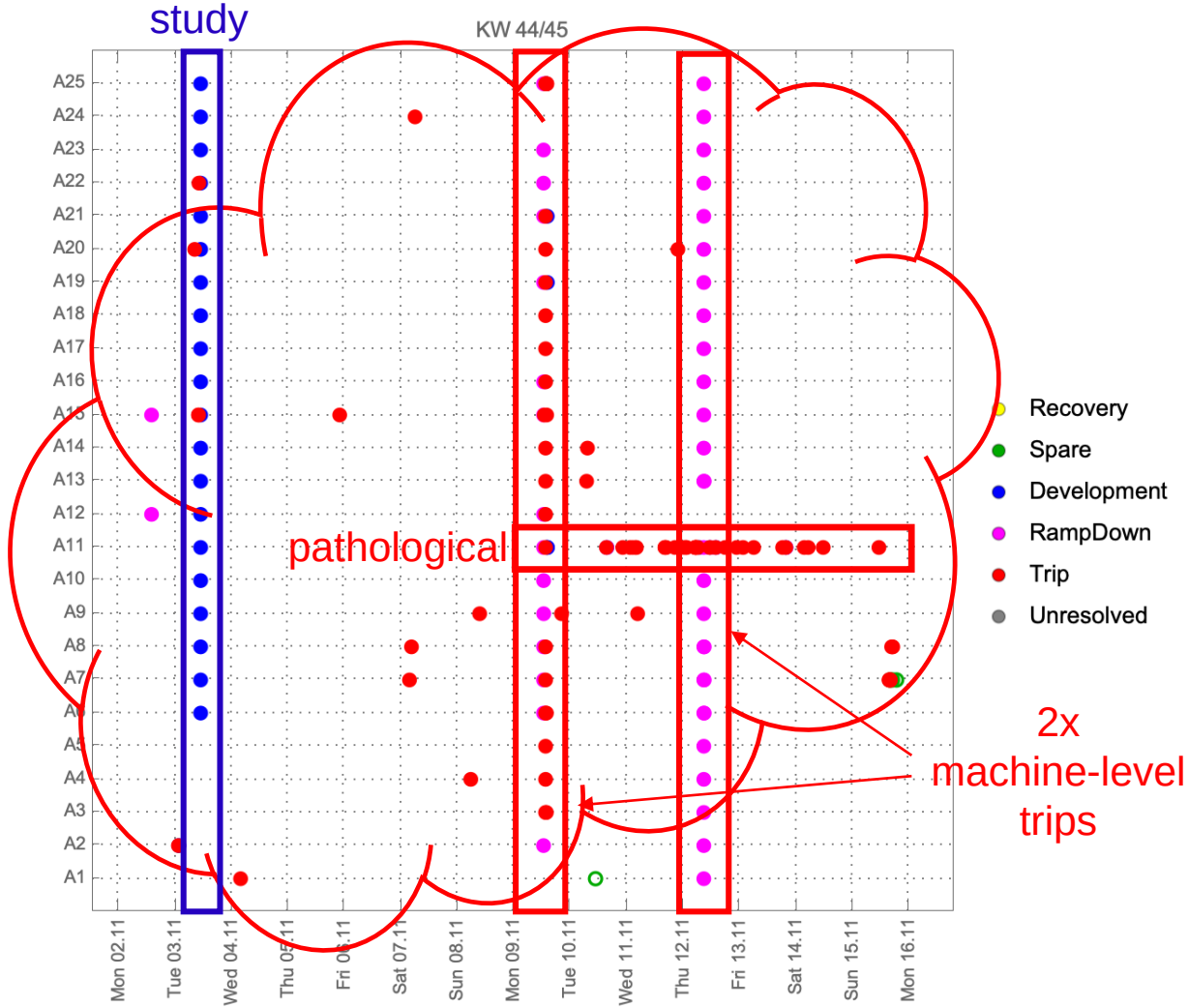
Live XTL report

GOOD week



machine study

BAD week



2. Monitoring the RF availability at XFEL

Finding the trip root cause

Development of automatic tool

- Tracks interlock history
- Identifies known patterns
- Checks for coincidental trips
- Saves a DAQ snapshot

Weekly review

- Discussion with experts
- Looking at the DAQ data
- Defining root cause
- Update database

Stations	Type	Time	Duration	OnBeam	LinacDownTime	RootCause
A2–A21,A23–A25	LinacOff	Wed 18 Nov 2020 17:08:05	1.4 hours	On	1.4 hours	INFRASTRUCTURE : NETWORK_HARDWARE : NETWORK SWITCH
A22	Trip	Wed 18 Nov 2020 17:01:57	4.9 hours	On	43 seconds	LLRF : QUENCH_DETECT : {M3.C7}
A22	Trip	Wed 18 Nov 2020 16:25:38	4.9 hours	On	60 seconds	LLRF : QUENCH_DETECT : {M3.C7}
A22	Trip	Wed 18 Nov 2020 14:05:41	4.9 hours	On	22.1 minutes	LLRF : HARDWARE_FAULT : DCM / RADIATION
A11	RampDown	Wed 18 Nov 2020 13:36:20	15.5 minutes	On	62 seconds	KLYSTRON : MAINTENANCE
A18	Trip	Wed 18 Nov 2020 10:27:42	1.5 hours	On	1.5 hours	TIMING : COMMS_ERROR : REBOOT / RADIATION
A11	Trip	Tue 17 Nov 2020 16:20:09	2.3 minutes	On	2.3 minutes	KLYSTRON : GUN_ARC
A11	Trip	Tue 17 Nov 2020 14:57:27	2.2 minutes	On	2.2 minutes	KLYSTRON : GUN_ARC
A8	Trip	Tue 17 Nov 2020 13:05:10	1.8 minutes	On	1.8 minutes	LLRF : QUENCH_DETECT : {M2.C7}
A11	Trip	Tue 17 Nov 2020 12:15:17	44.4 minutes	On	38.1 minutes	KLYSTRON : MPS_HF_INHIBIT :
A11	Trip	Tue 17 Nov 2020 11:33:25	2.3 minutes	On	2.3 minutes	KLYSTRON : GUN_ARC
A11	Trip	Tue 17 Nov 2020 10:55:00	1.5 minutes	On	92 seconds	KLYSTRON : GUN_ARC
A23	Development	Tue 17 Nov 2020 01:28:49	7.8 minutes	On	6.5 minutes	LLRF : COMMS_ERROR : REBOOT / RADIATION
A8	Development	Tue 17 Nov 2020 00:33:20	10. minutes	On	58 seconds	LLRF : COMMS_ERROR : REBOOT / RADIATION
A12	Development	Tue 17 Nov 2020 00:06:11	17.8 minutes	On	15. minutes	LLRF : COMMS_ERROR : REBOOT / RADIATION
A11	Trip	Mon 16 Nov 2020 23:13:21	7. minutes	On	5.3 minutes	KLYSTRON : GUN_ARC
A10	Trip	Mon 16 Nov 2020 19:58:07	50. seconds	On	50 seconds	KLYSTRON : KLM : unstable
A6–A25	Development	Mon 16 Nov 2020 13:02:13	11.9 minutes	On	30 seconds	

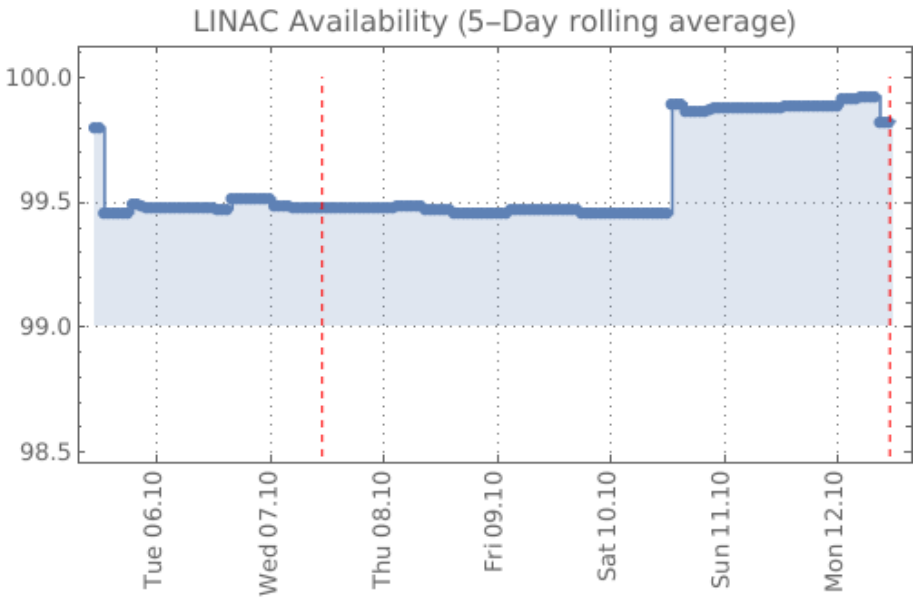
2. Monitoring the RF availability at XFEL

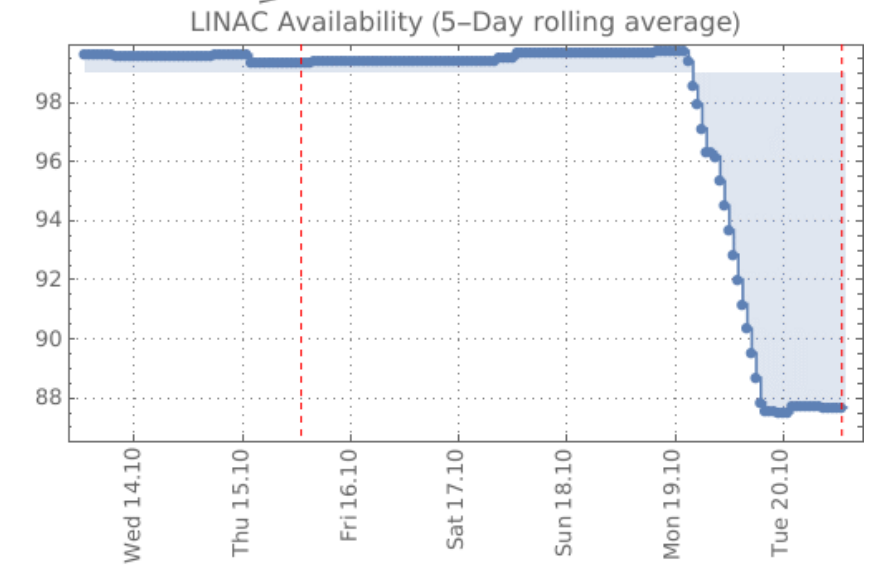
RF availability

- Typical > 95%
- Good week > 99%
- Bad week > 90%

Dominant root causes

- RF (high/low power)
  - Many short trips (~minutes)
- Cryogenics
  - 1 major event (1.5 days)
- Operations
  - Not enough exception handling, conceptual automation mistakes, …





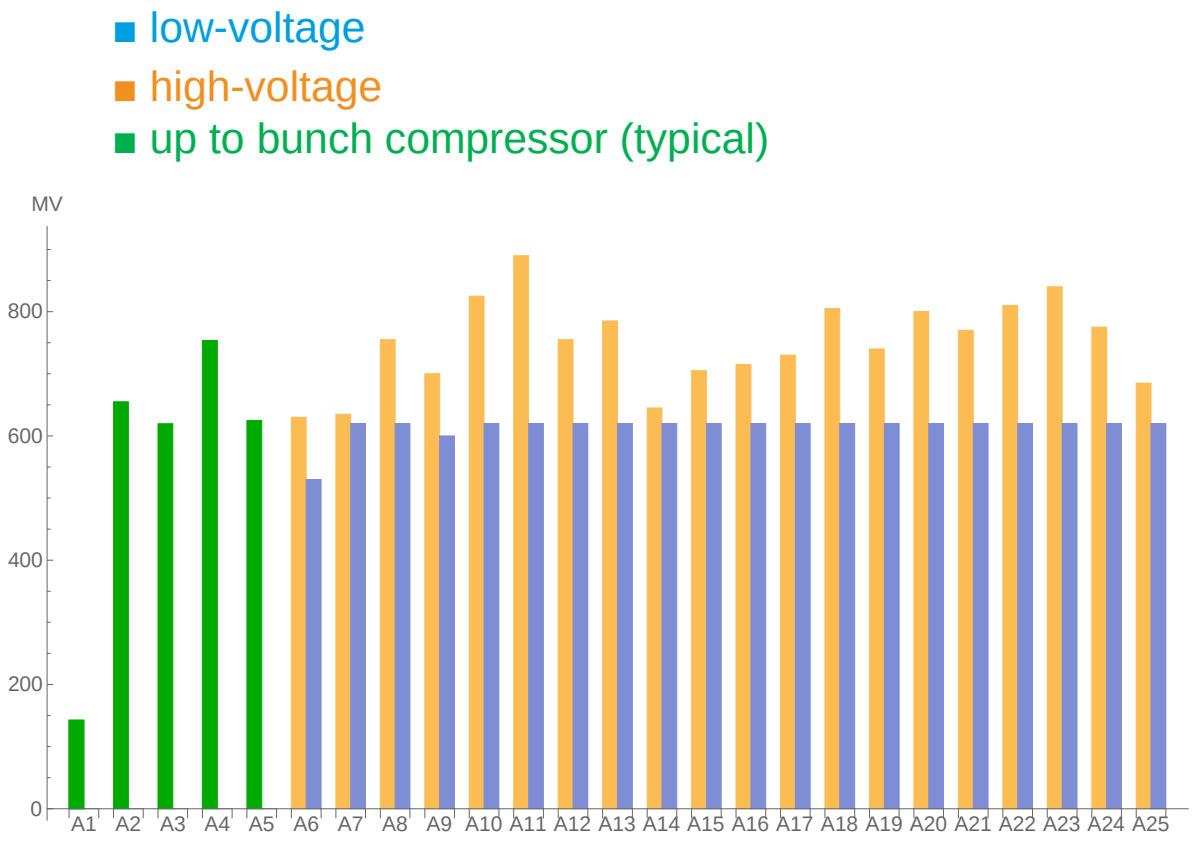
3. High-Voltage (high-V) experiment at XFEL

Two modes of operation:

- low-V : for beam energies 11.0 – 14.0 GeV
- high-V : for beam energies 14.5 – 16.5 GeV

High-V

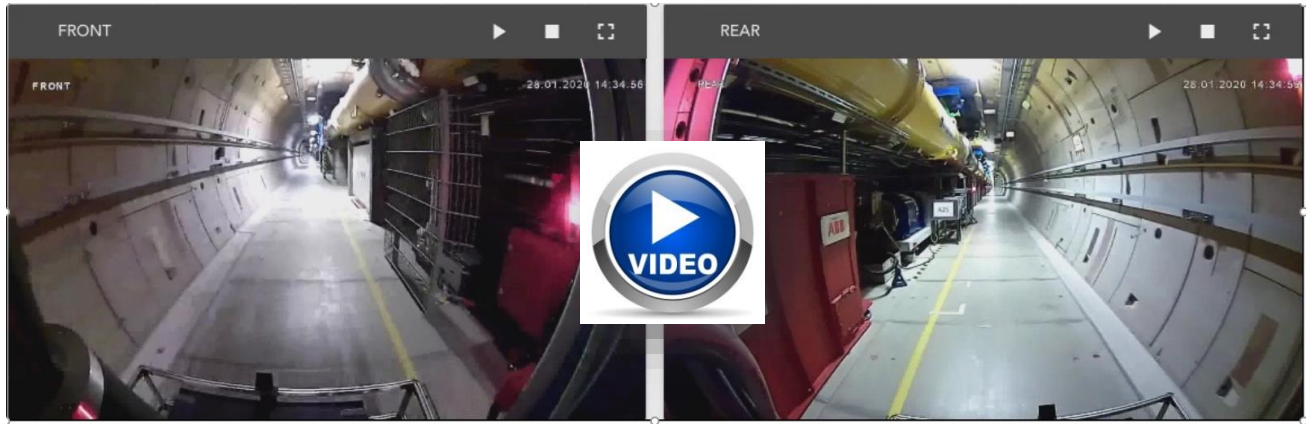
- Cavities operating at max gradient
  ➔ **more radiation coming from RF**
- Cavities operating with almost no RF overhead
  ➔ **almost at quench limit**
- Couplers, klystrons running with more power
  ➔ **more arcs, sparks, etc**..
- Overall, operating on the edge
  ➔ **more trips**

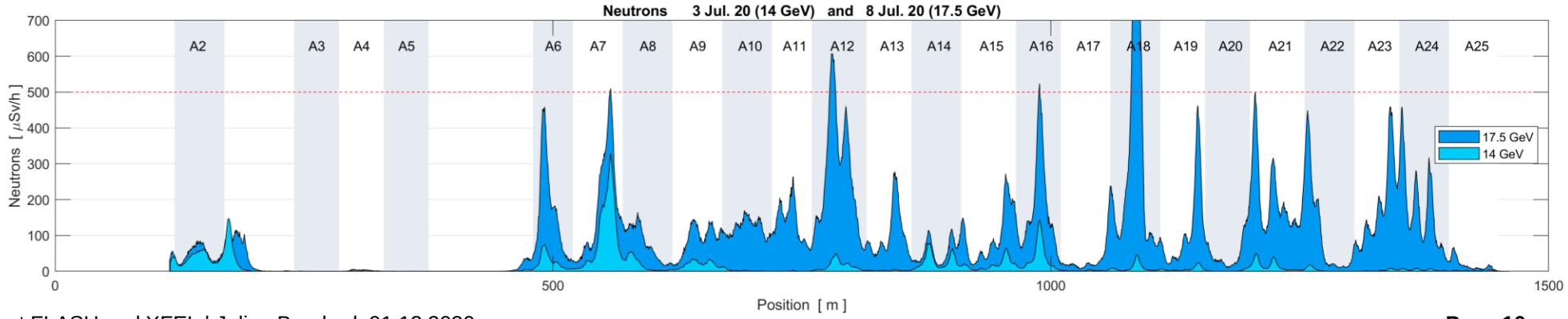


3. High-Voltage (high-V) experiment at XFEL

- 31.08 – 18.10.2020 → 7 weeks at low-V
- 19.10 – 22.11.2020 → 5 weeks at high-V

- **Monitor**
  - SEU
  - LLRF system failures
  - Cavity quenches
  - Gradient limiters
  - Radiation





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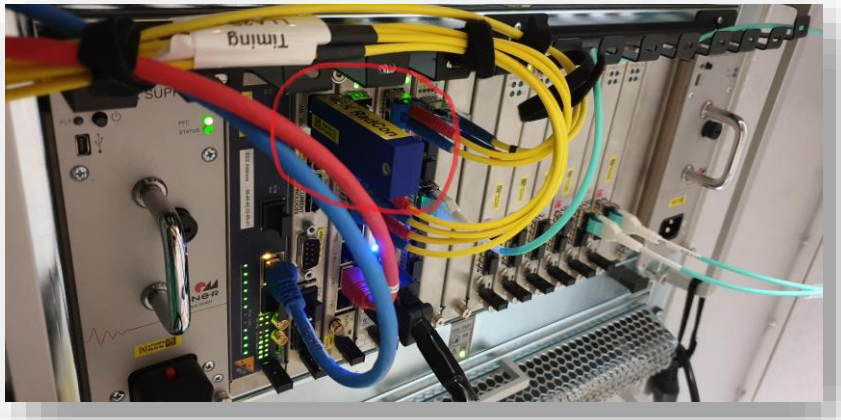
USB RadCons
(inside racks)



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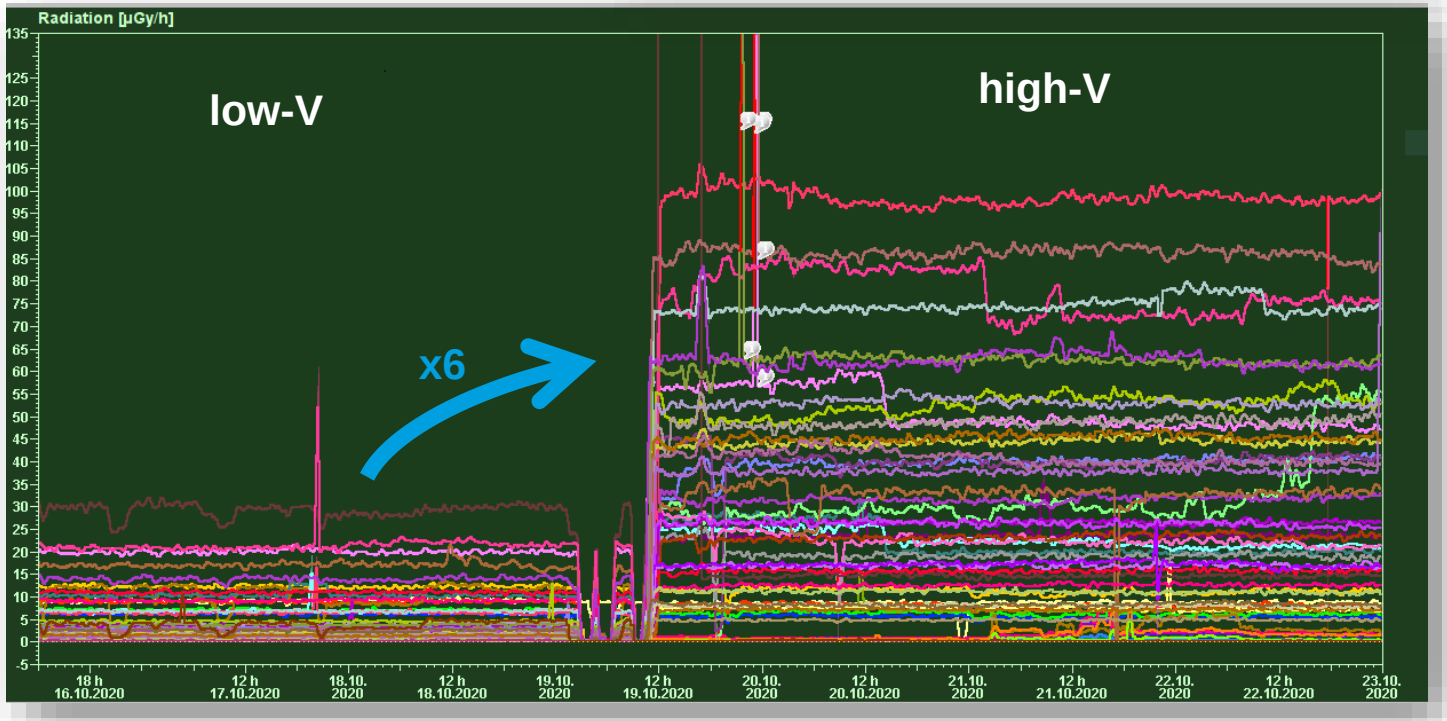


4. MicroTCA-related failures (1/2)

Re-occurring events

Loss of PCIe for one or more boards

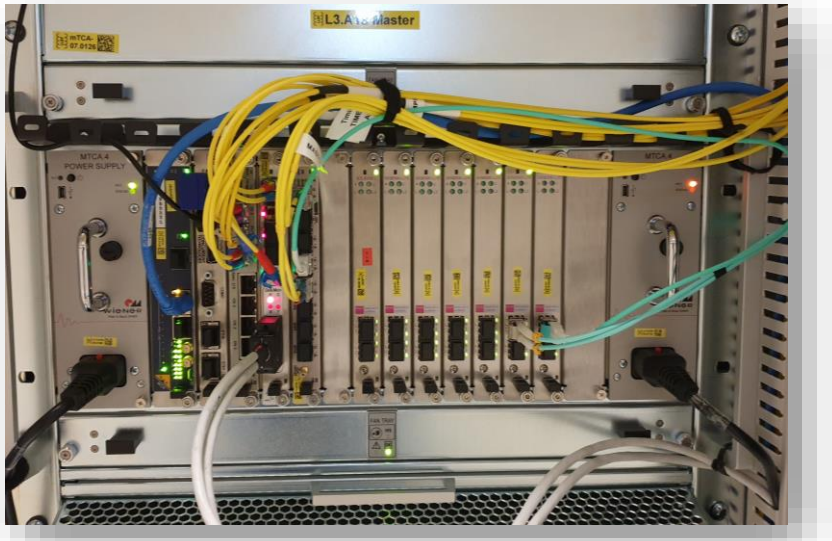
- Dominant LLRF failure, is it firmware related ?
- Happens on TCK7 / SIS8300, **not** DAMC02, **not** x2timer
- Can continue to operate if affecting “non-crucial” boards.
- Otherwise, immediate intervention required
- Happens more (x10) for systems in tunnel
- Master student working on alternate communication channel (diagnostics, recovery)

Backplane manager and over-current on the uLOG

- Not real OC
- Corruption in I2C bus talking to hot plug controller (HP controller issues an “fake” OC)
- Fixed with a new MCH-RTM FW, more robust I2C communication protocol

4. MicroTCA-related failures (2/2)

Isolated events



Secondary power supply failure (1x)

- Seems not a HW failure, power supply is actually OK
- No communication with MCH, no message on management server
- Redundant power supply took over

Overcurrent flag not recoverable via `shutdown <fru>` (1x)

- Observed on DAMC02, (but could be affecting other boards)
- Script work around to clear work around flag in MCH (temporary solution)

Problem with MCH command (1x)

- `shutdown system_hard` inactive
- Happened together with previous 2 events, but probably no causality
- Problem still under investigation
- Board by board power cycle work around

5. LLRF on-call statistics

Extracted from on-call ticket tracker (Redmine)

2020 stats not fully representative

- Covid-19

“Setup” is often the root cause

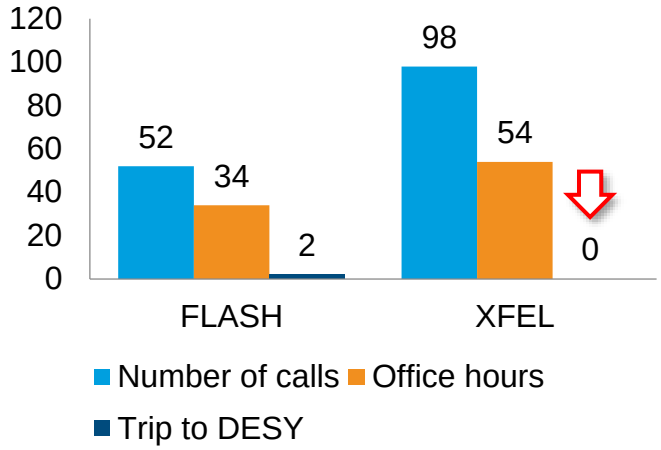
- more automation
- more exception handling

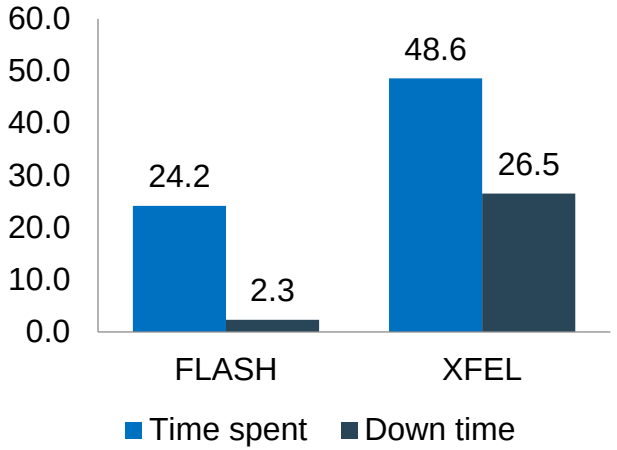
MTCA is more dominant at XFEL

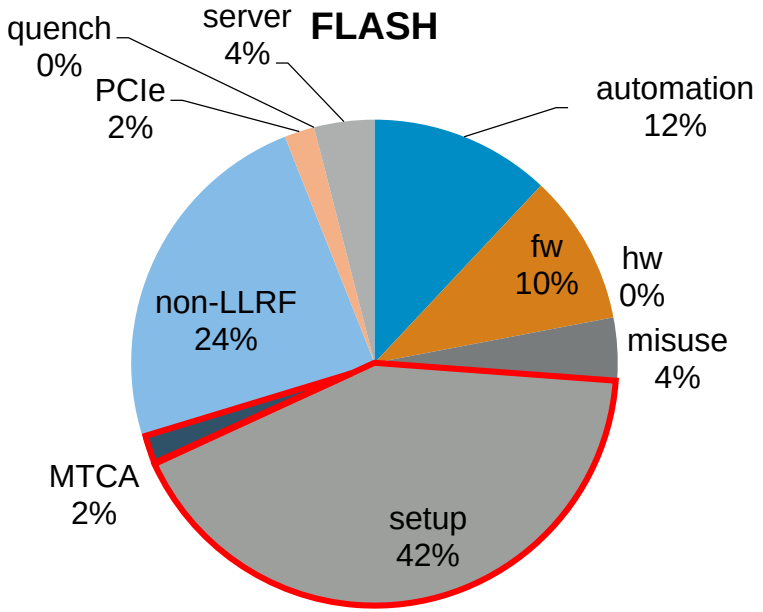
- due to installation in tunnel ?

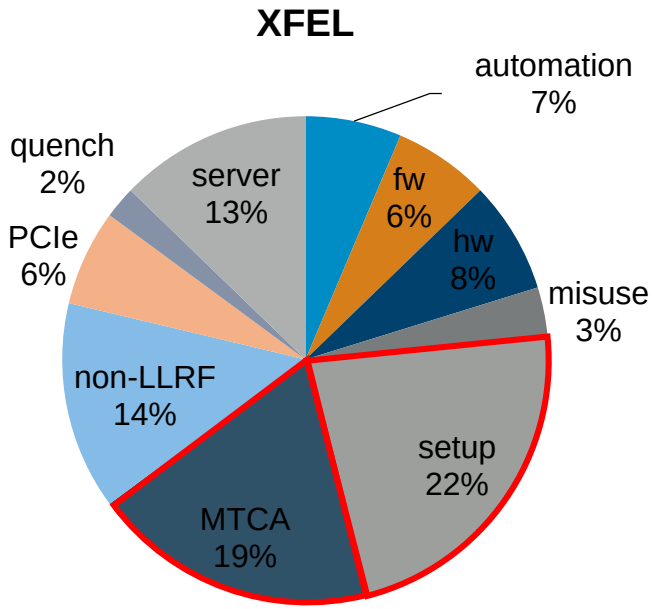
0 trip to DESY for XFEL

- remote troubleshooting!









Thank you for your attention!

Contact

DESY. Deutsches Elektronen-Synchrotron

www.desy.de

Julien Branlard
MSK
julien.branlard@desy.de
+49 (0) 40 8998 15199

Back up slides

High-Voltage (high-V) experiment at XFEL

Single Event Upsets