Experience with MTCA.4 LLRF Systems at DESY

FEL and Synchrotrons

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Hamburg, 25.08.2021

TALK OVERVIEW

MTCA.4 LLRF systems

FLASH and XFEL

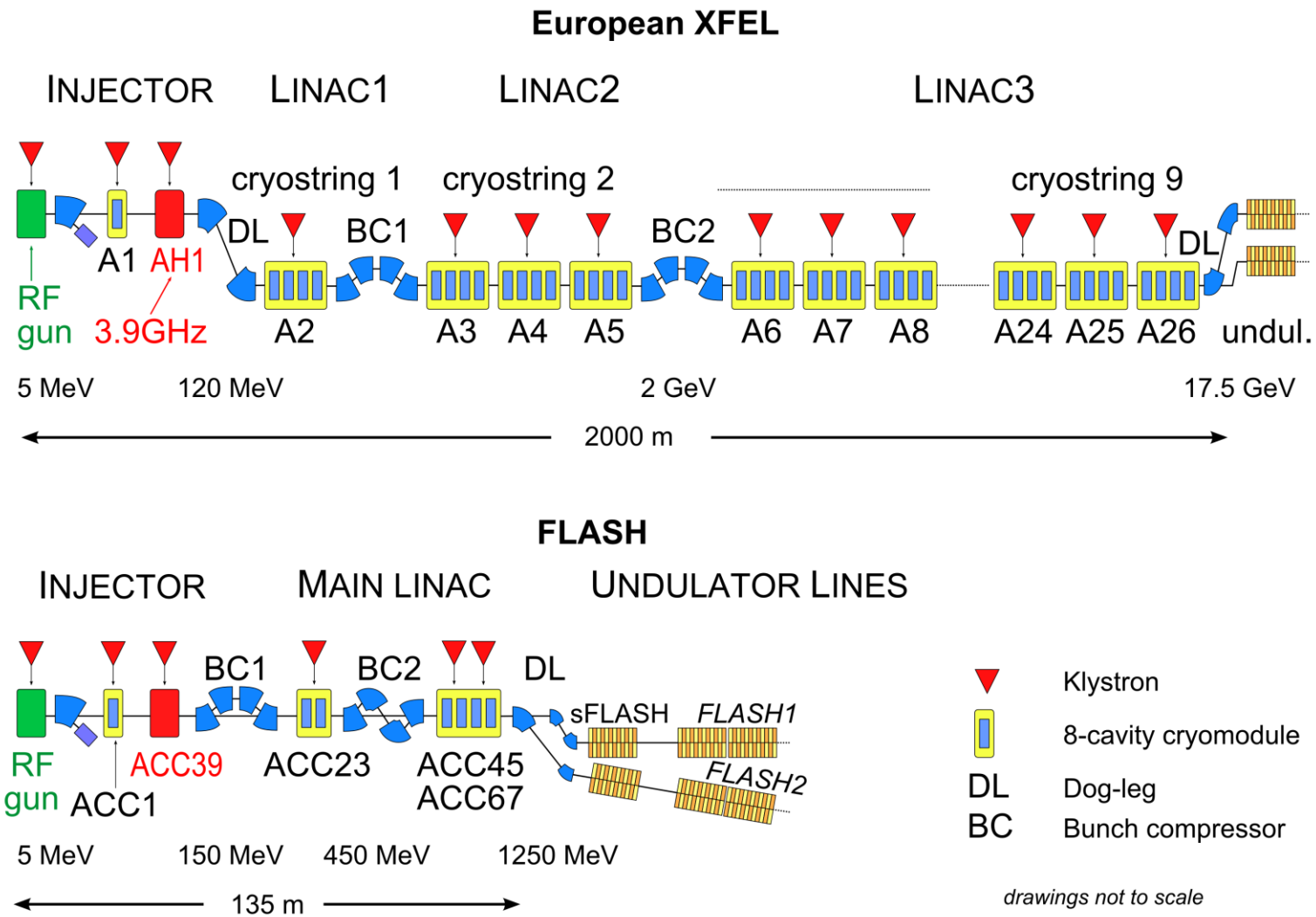
- Accelerator overview
- MTCA.4 for LLRF operation
- High-channel count + vector sum operation
- MTCA crate occupation
- RF availability statistics
- LLRF on-call statistics

PETRA IV upgrade

- Accelerator overview
- Single cavity regulation
- MTCA crate occupation
- Supervision concept
- Interlock Concept

FLASH and XFEL

High-channel count, vector-sum control



- **FLASH** operated with MTCA.4 **since 2013**
- **XFEL** operated with MTCA.4 **since 2017**

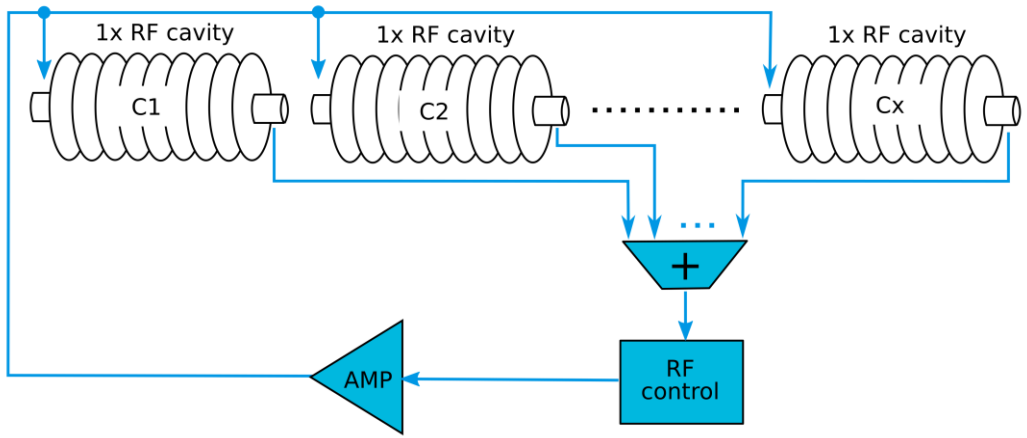
FLASH and XFEL

High-channel count, vector-sum control

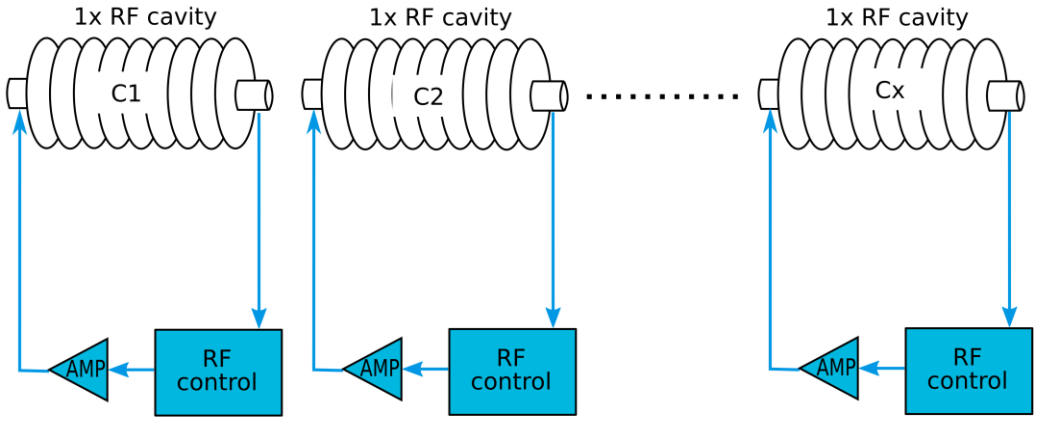
- **FLASH**
  - 7 RF stations
  - 8-16 cavities per RF control loop
  - Probe, forward, reflected + HPRF signals
  - **50+ signals per RF station**

- **XFEL**
  - 25x RF stations
  - 32 cavities per RF control loop
  - Probe, forward, reflected + HPRF signals
  - **100+ signals per RF station**

Vector-sum control : used at **FLASH** and **XFEL**



Single-cavity regulation: to be used at **PETRA** (→ last slides)



FLASH and XFEL

MTCA.4 LLRF components* in the tunnels

	XFEL	FLASH
ADCs	~ 350	16
DWCs	~ 350	14
CPUs	~ 55	4
MCHs	~ 55	4
TIMER	~ 55	4
DAMC02	~ 30	2
TCK7	~ 55	3
PM	~ 100	4
others	~ 20	6
TOTAL	**~ 1070**	**57**

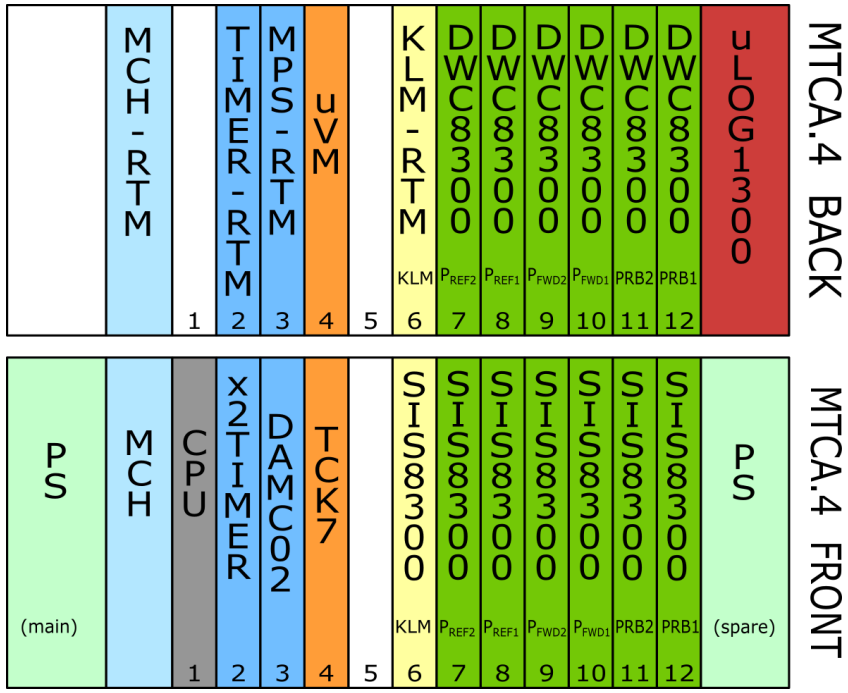
- Only components installed in tunnels are listed
- Other components are useful as witness outside of radiation prone environments

* more in other subsystems (technical interlock, special diagnostics, etc…)

FLASH and XFEL

MTCA.4 LLRF components* in the tunnels

Standard crate occupation

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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
=========================================
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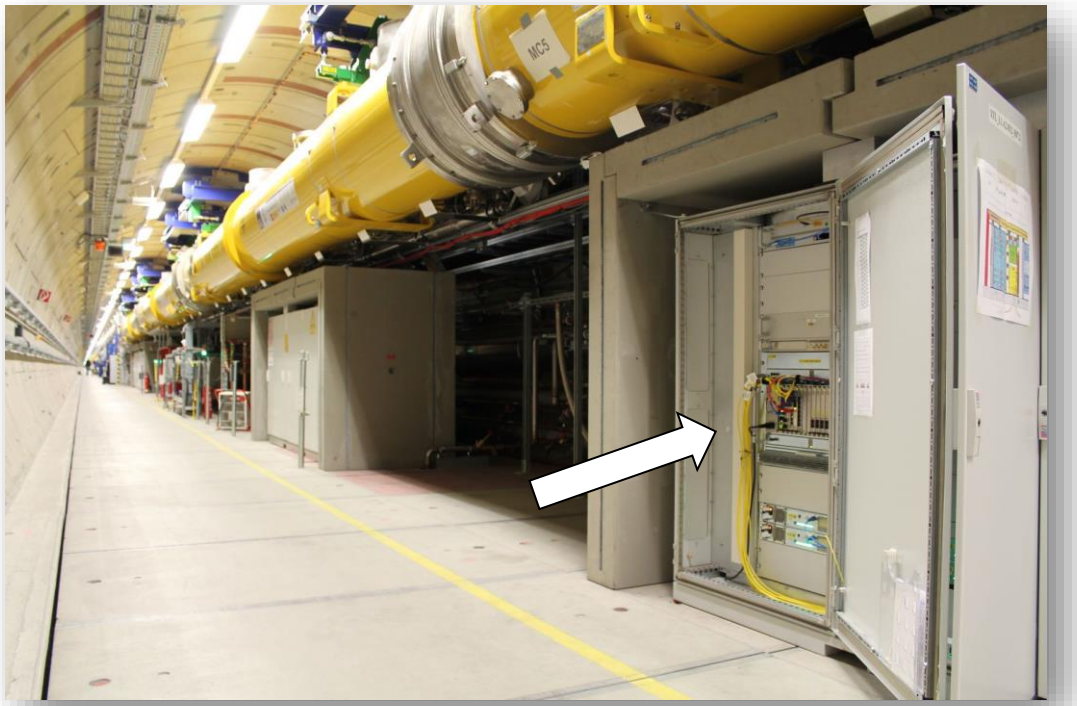


~10x @ FLASH

~60x @ XFEL

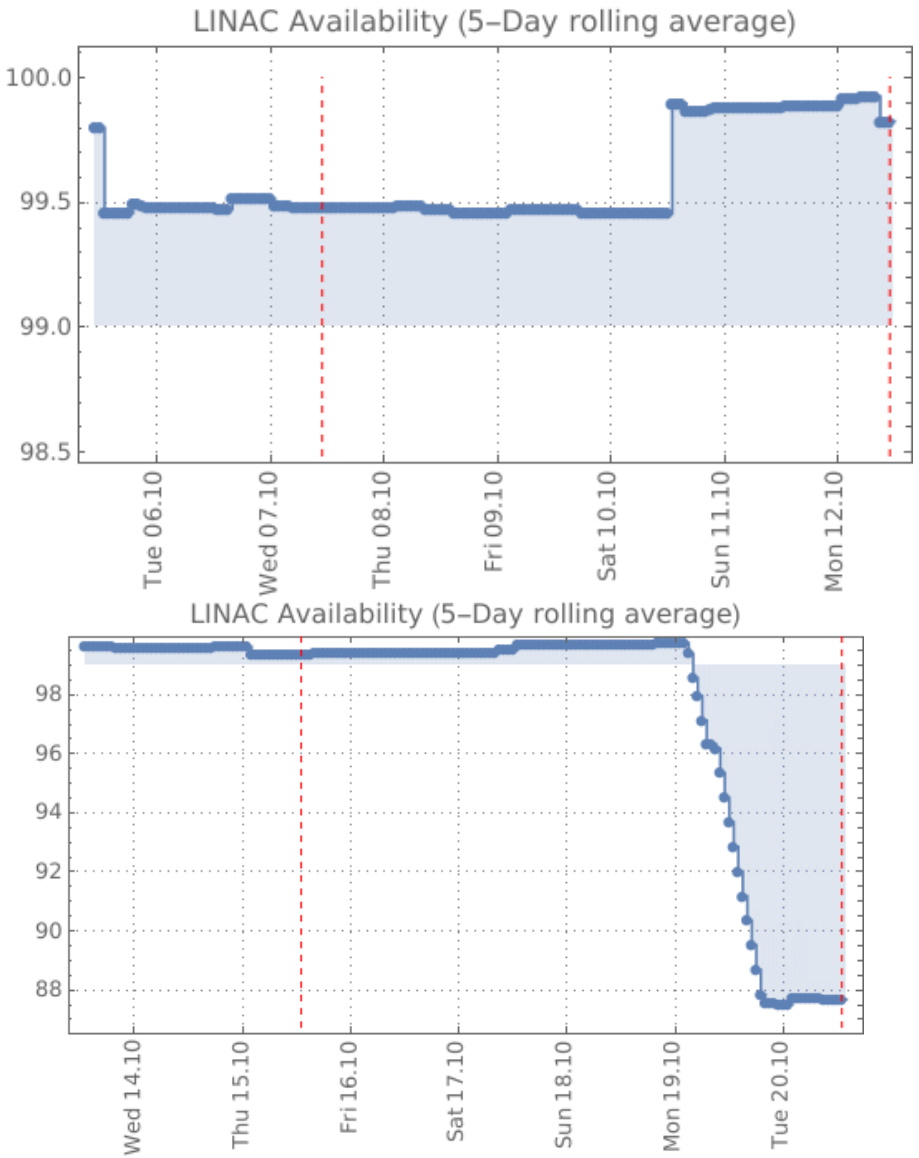
Monitoring the RF availability at XFEL

RF availability

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

Dominant root causes

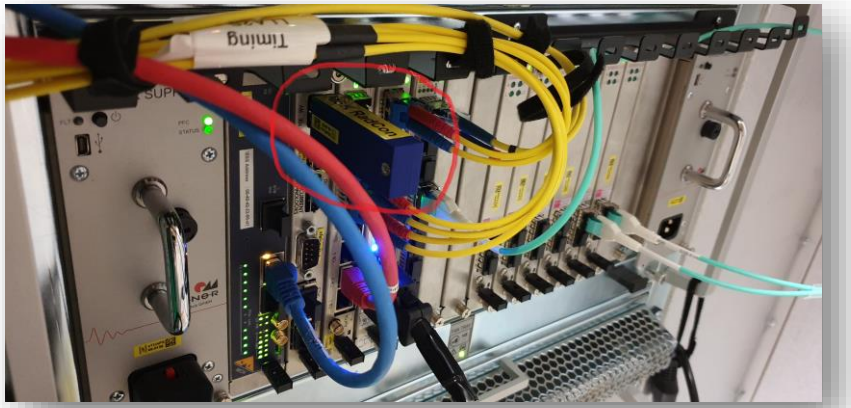
- RF (high/low power)
  - Many short trips (~minutes)
- Cryogenics
  - 1 major event (1.5 days)
- Operations
  - Not enough exception handling, conceptual automation mistakes, …



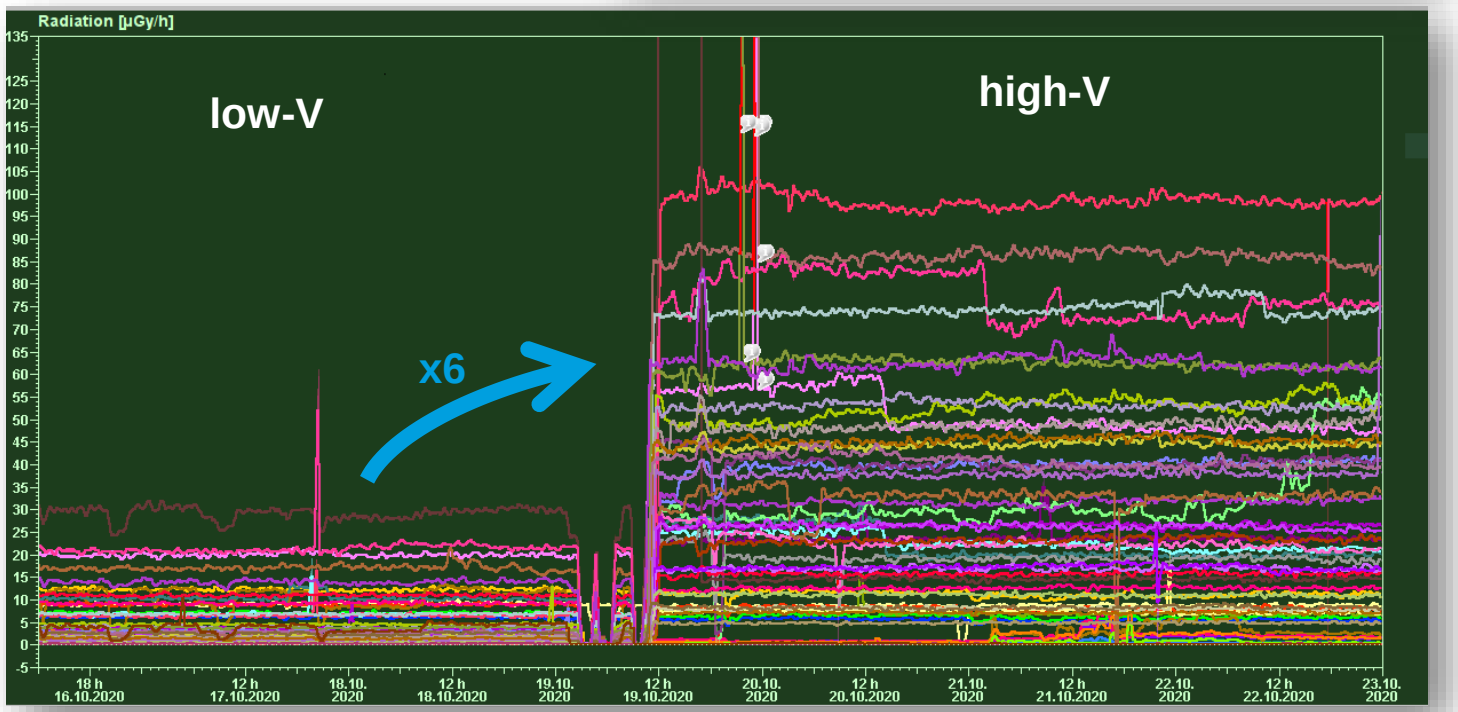
High-Voltage (high-V) experiment at XFEL

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

USB RadCons
(inside racks)

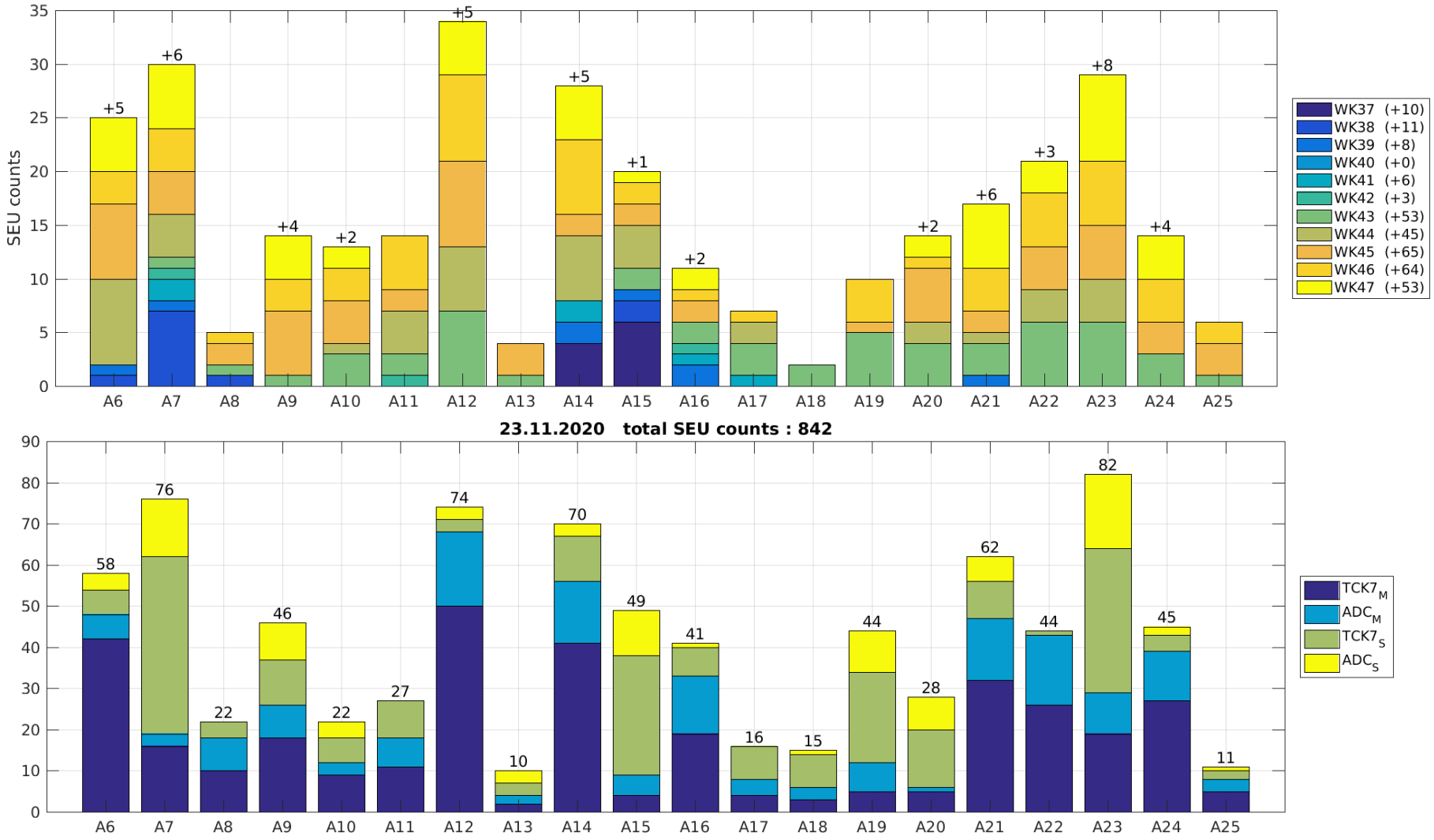


- **Monitor**
  - SEU
  - LLRF system failures
  - Cavity quenches
  - Gradient limiters
  - Radiation



High-Voltage (high-V) experiment at XFEL

Single Event Upsets

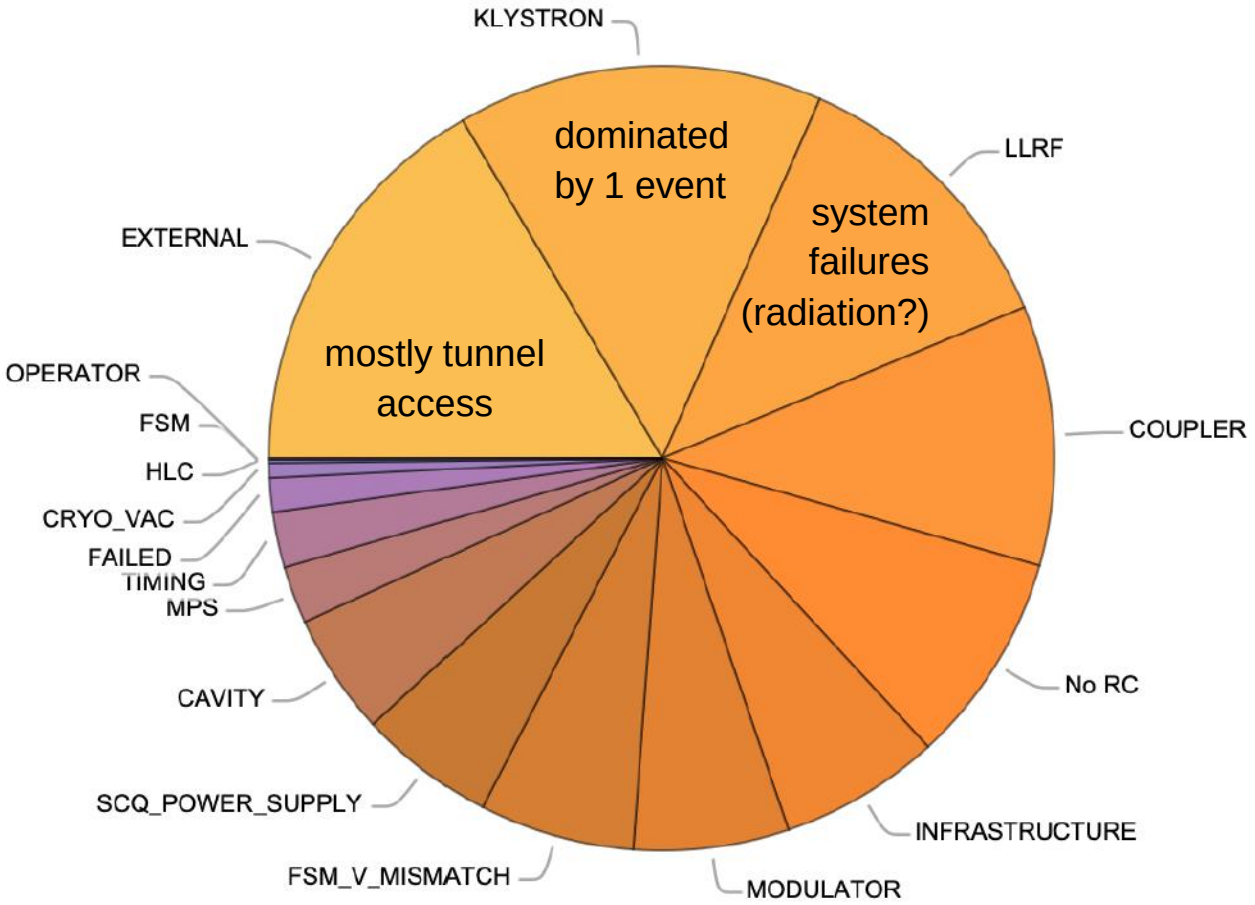


High-Voltage (high-V) experiment at XFEL

High-Voltage (high-V) Experiment

		Total	Low-V	High-V
Availability	%	97.9	**98.7**	**95.6**
Total operation time	days	125.2	90.4	34.8
Number of events	hrs	300	124	176
Total down time	hrs	64.7	**27.9**	**36.9**

		Total	Low-V	High-V
Trips	hrs	40.1	**13.5**	**26.6**
Linac off (access)	hrs	18.3	10.7	7.6
Ramp down	hrs	3.5	1.8	1.7
Development	hrs	1.9	0.8	0.8



LLRF on-call statistics

Extracted from on-call ticket tracker (Redmine)

2020 stats not fully representative

- Covid-19

“Setup” is often the root cause

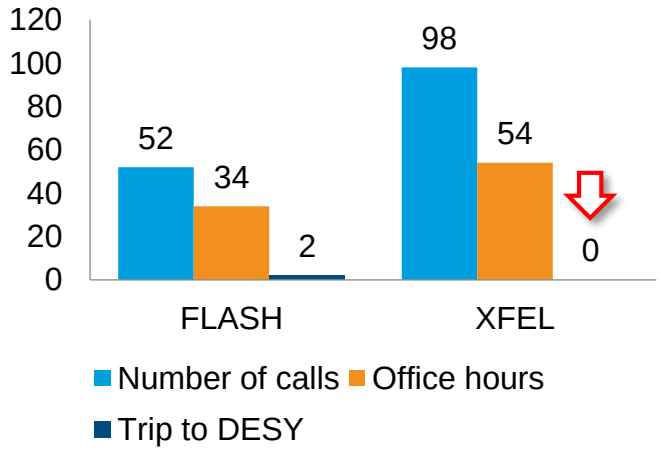
- more automation
- more exception handling

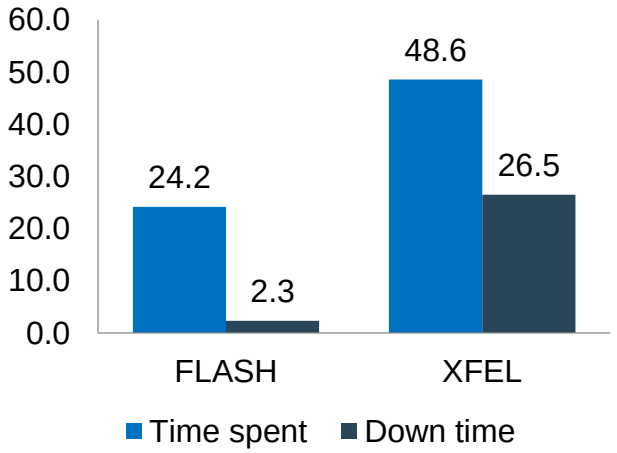
MTCA is more dominant at XFEL

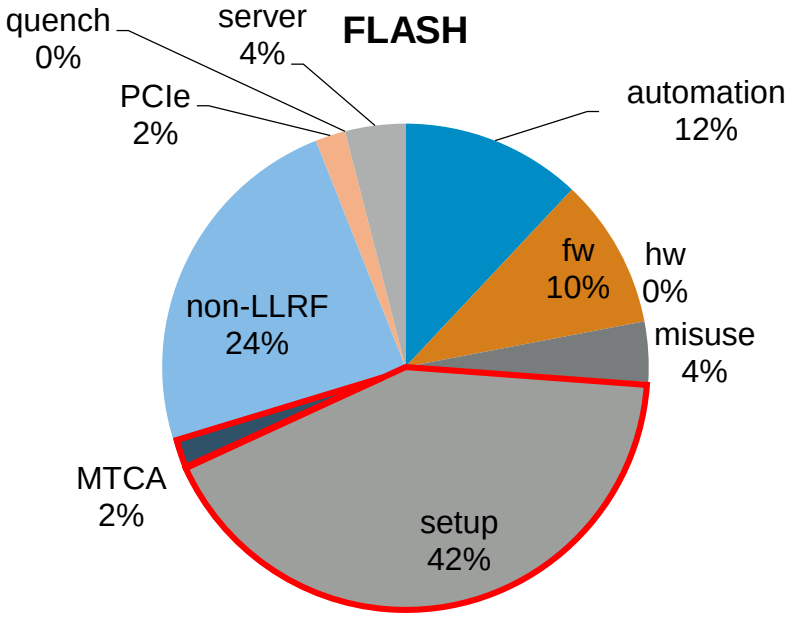
- due to installation in tunnel ?

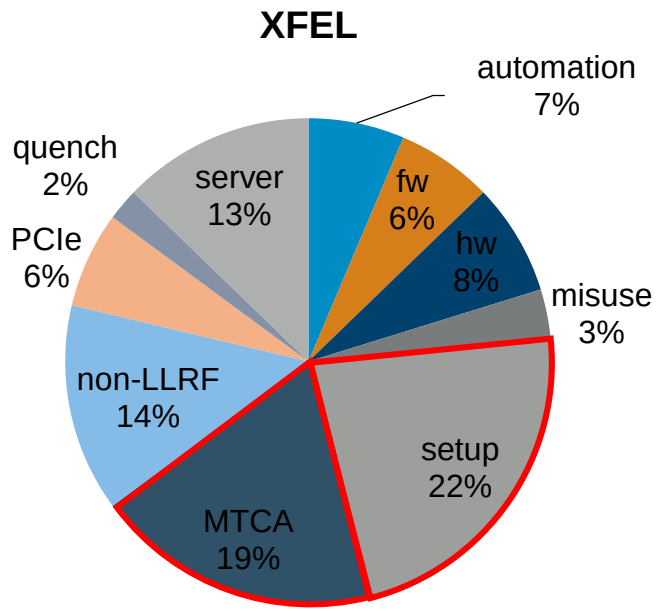
0 trip to DESY for XFEL

- remote troubleshooting!





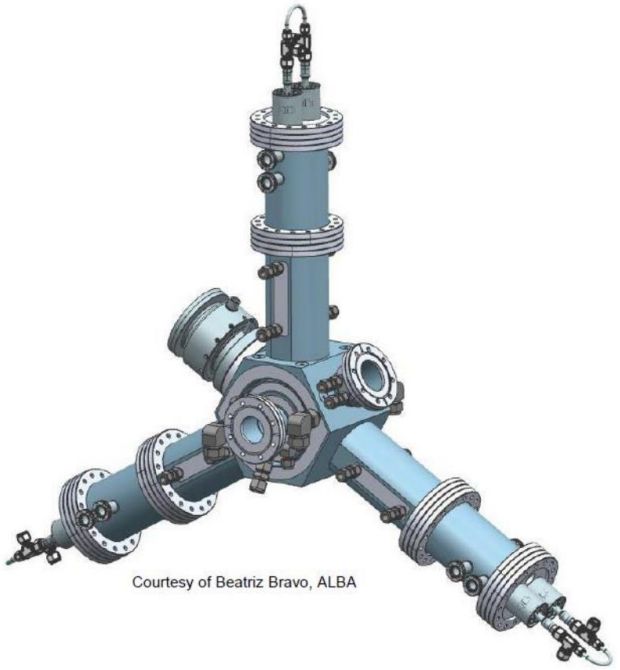


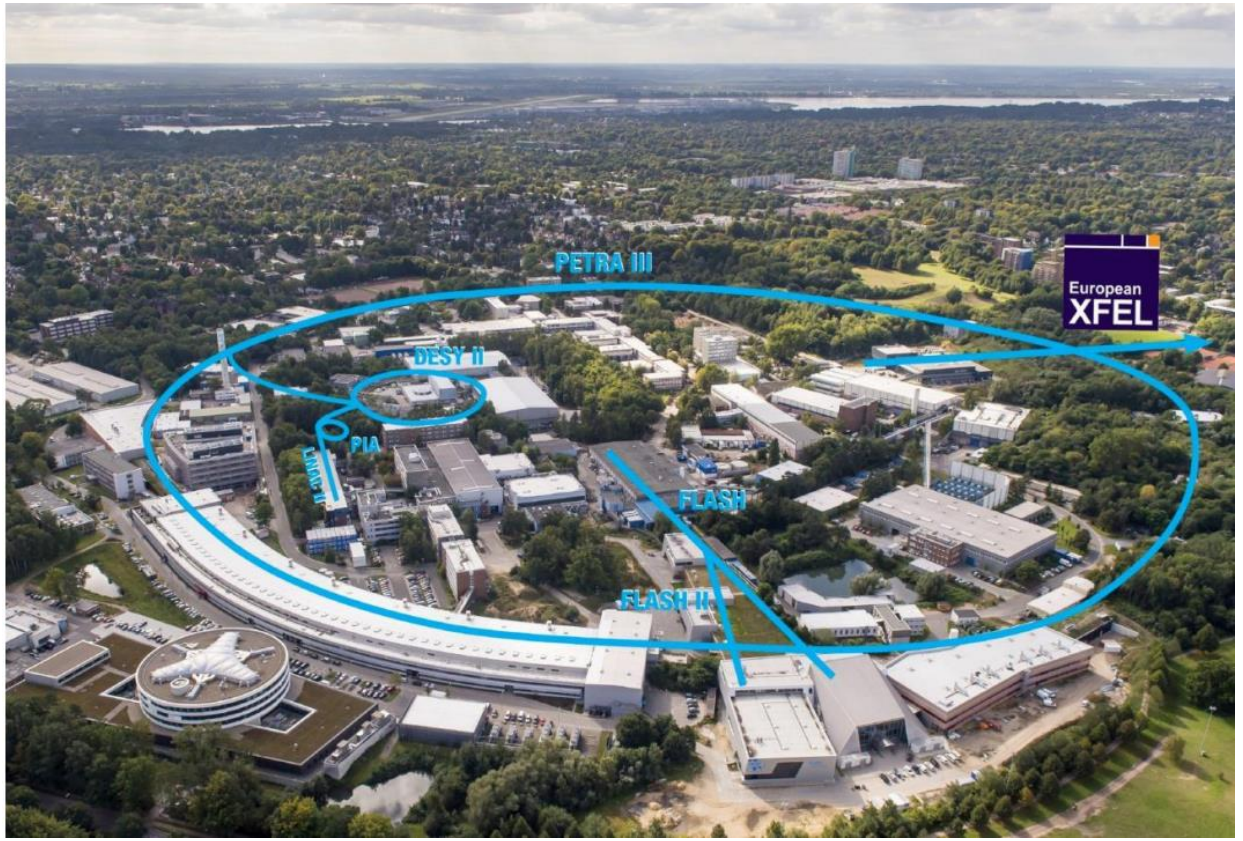


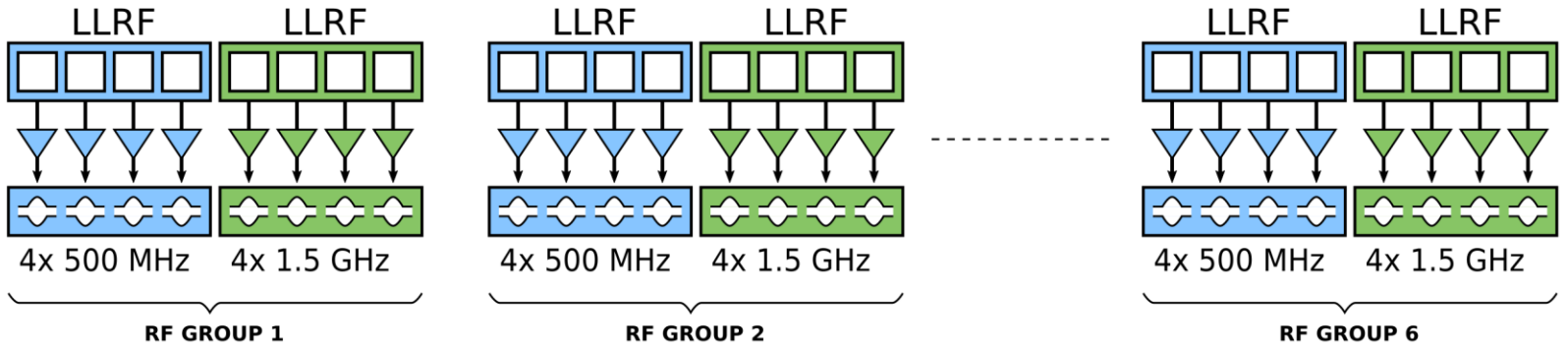
PETRA IV

MTCA.4 LLRF crate

- **PETRA III → PETRA IV upgrade**
  - 24 new cavities optimized for HOM damping
  - Develop a concept to react to a system failure
  - Upgrade LLRF system



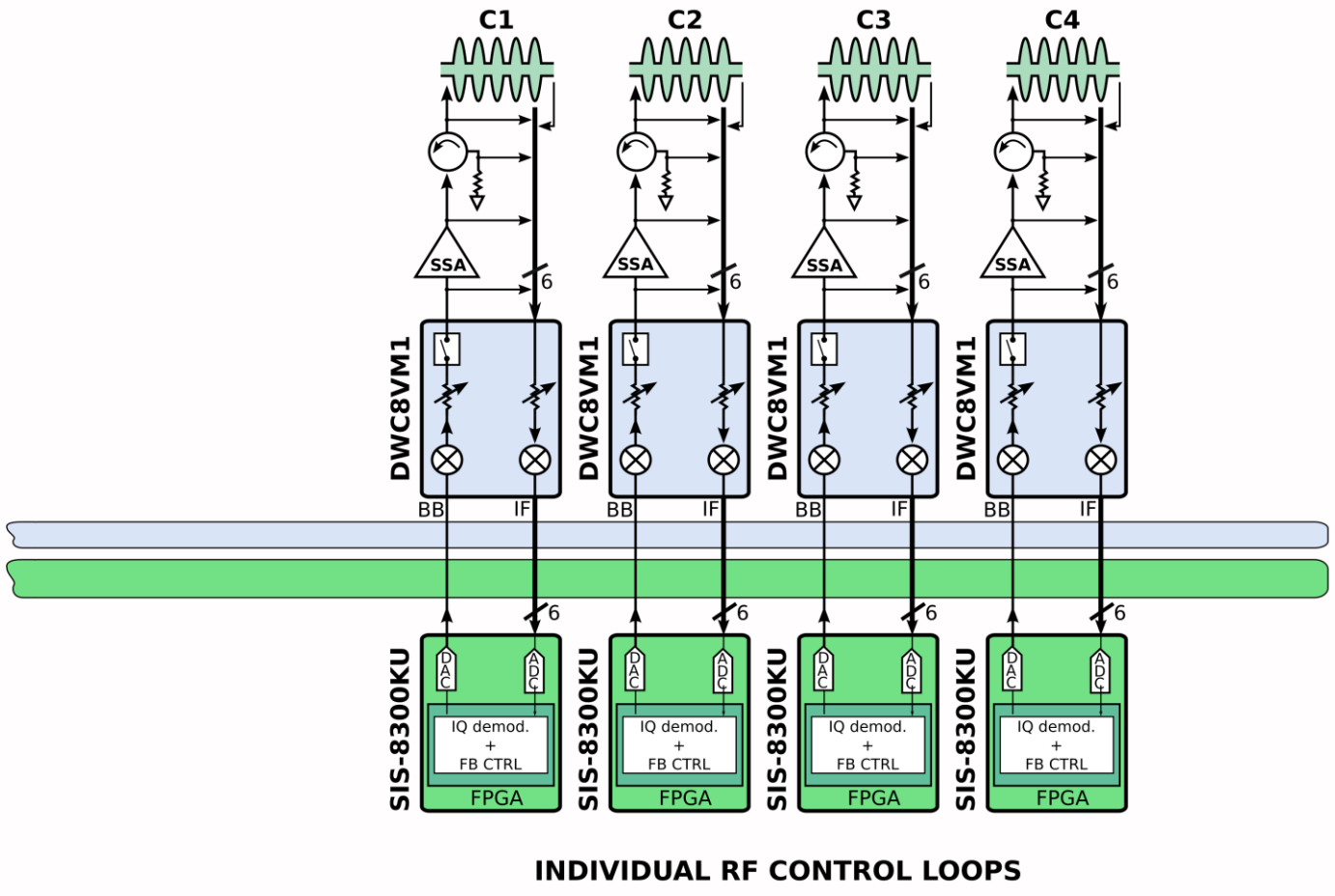




PETRA IV

MTCA.4 LLRF crate

- **4x individual RF control loops**
  - Single cavity regulation
  - Up- and down-conversion at analog front-end
  - High processing power on digitizer boards
- **1x supervisor module**
  - Fast exception handling
  - Common cryomodule control
- **1x uLOG** to provide
  - **LO** for down conversion
  - **RF** for reference and up-conversion
  - **CLK** for digital boards
- **1x interlock** aggregator
  - Common (RF station-wise) interlock
  - Individual (cavity-wise) interlocks



INDIVIDUAL RF CONTROL LOOPS

PETRA IV

MTCA.4 LLRF crate

- **4x individual RF control loops**
  - Single cavity regulation
  - Up- and down-conversion at analog front-end
  - High processing power on digitizer boards
- **1x supervisor module**
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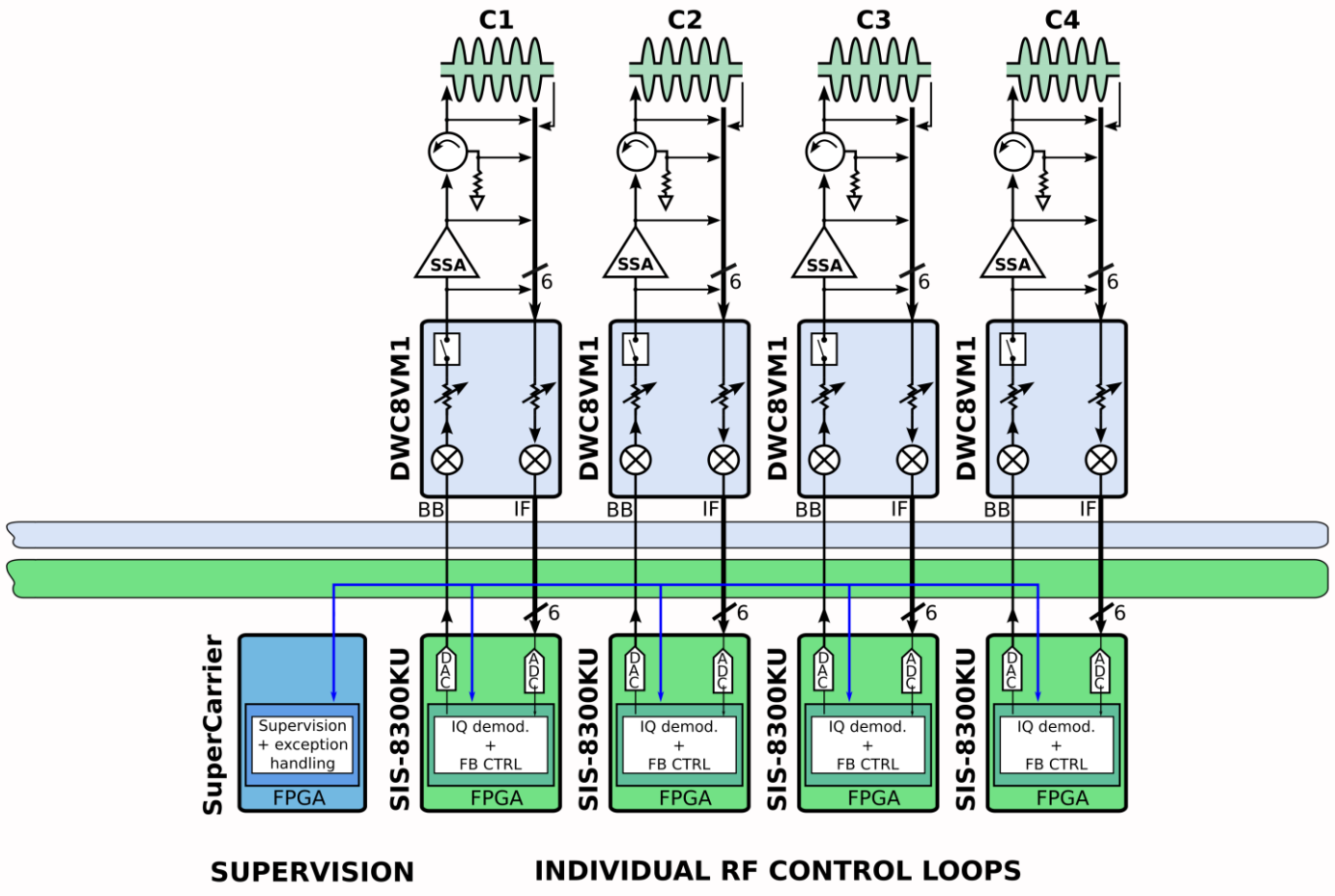

PETRA IV

MTCA.4 LLRF crate

- **4x individual RF control loops**
  - Single cavity regulation
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  - Fast exception handling
  - Common cryomodule control
- **1x uLOG** to provide
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  - **RF** for reference and up-conversion
  - **CLK** for digital boards
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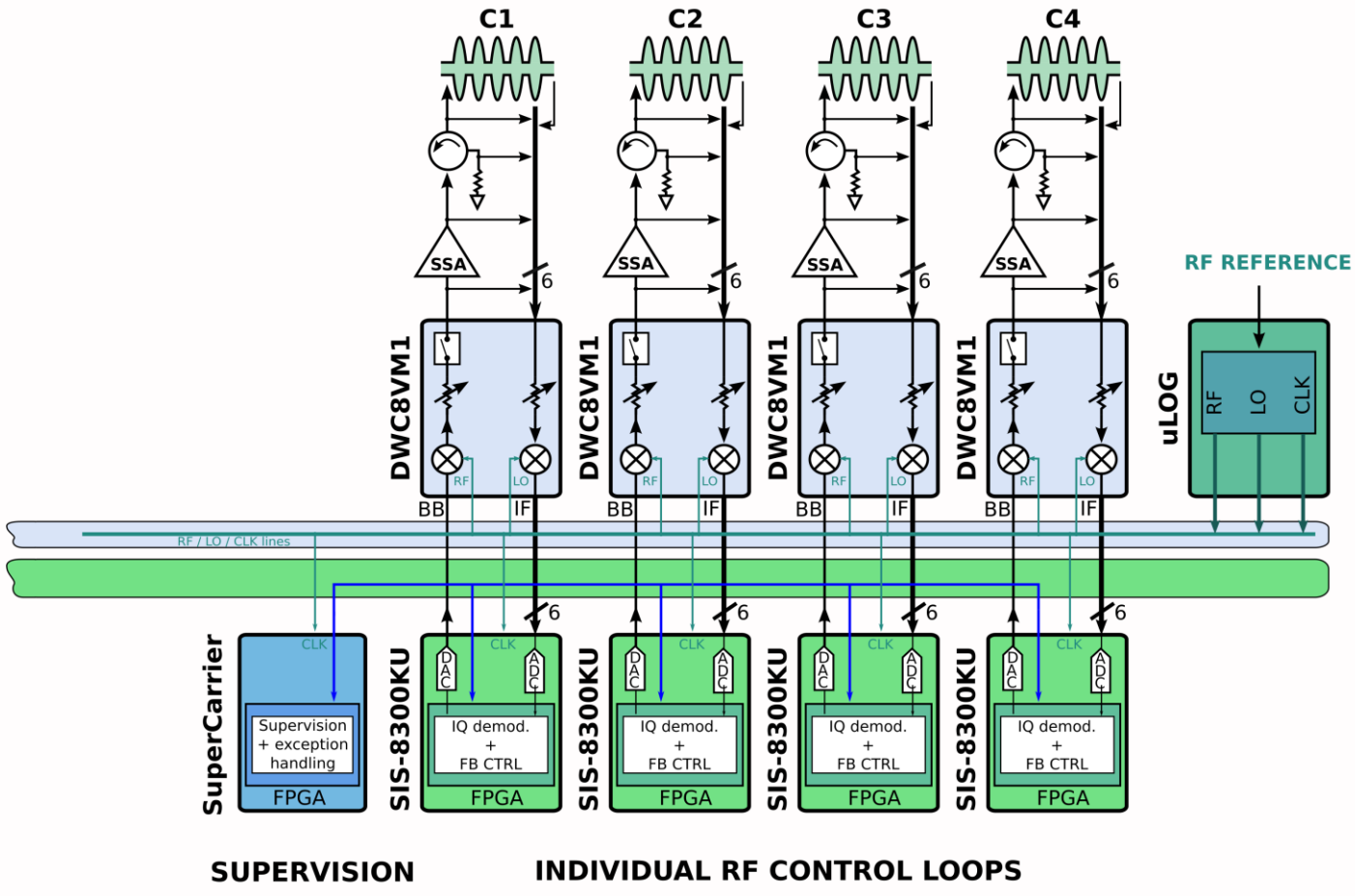
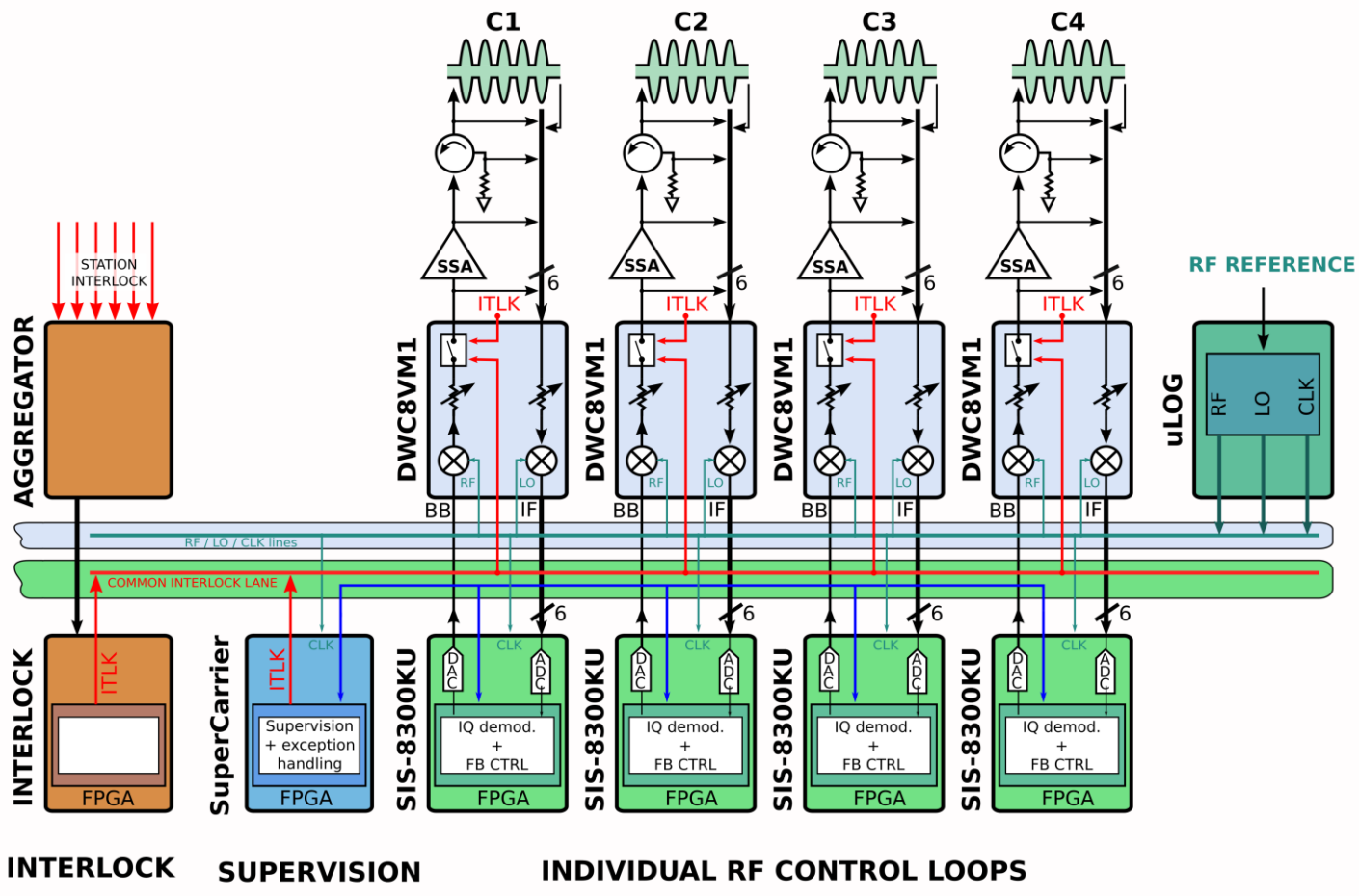


PETRA IV

MTCA.4 LLRF crate

- **4x individual RF control loops**
  - Single cavity regulation
  - Up- and down-conversion at analog front-end
  - High processing power on digitizer boards
- **1x supervisor module**
  - Fast exception handling
  - Common cryomodule control
- **1x uLOG** to provide
  - **LO** for down conversion
  - **RF** for reference and up-conversion
  - **CLK** for digital boards
- **1x interlock** aggregator
  - Common (RF station-wise) interlock
  - Individual (cavity-wise) interlocks



SUMMARY

- MTCA.4 for LLRF systems deployed at large facilities since **2017**
- Benefits include **remote management** and **reliability**
- FLASH / XFEL configuration : emphasis is on **large channel count** and **vector sum** operation
- PETRA IV configuration : emphasis is on **single cavity regulation** with **supervisory control**
- MTCA.4 development outlook for LLRF includes
  - next generation **Controller Boards**
  - next generation **uLOG**
  - next generation **ADCs**

Thank you for your attention!

Contact

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