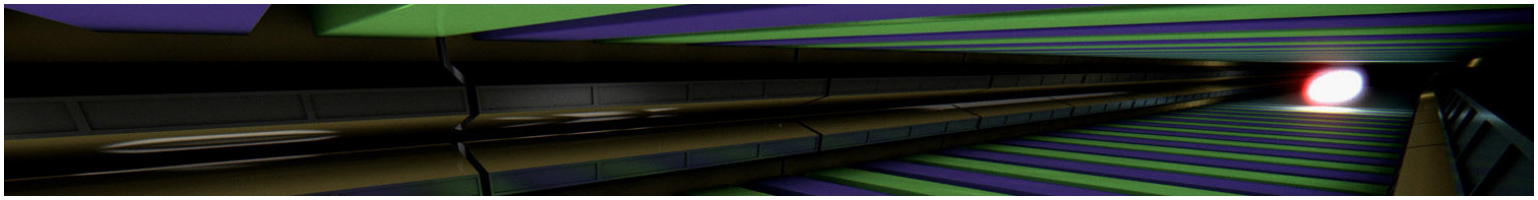


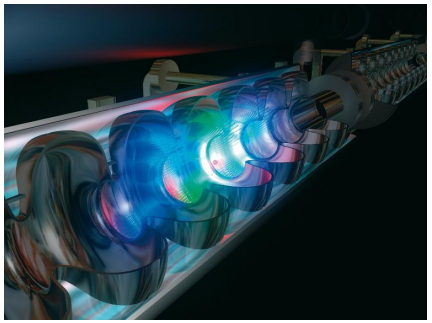
The European XFEL LLRF System

J. Branlard, G. Ayvazyan, V. Ayvazyan, M. Grecki, M. Hoffmann, T. Jeżyński, T. Lamb, F.Ludwig, U. Mavrič, S. Pfeiffer, C. Schmidt, H. Weddig, B. Yang,P. Barmuta, S. Bou Habib, Ł. Butkowski, K. Czuba, M. Grzegrźołka, E. Janas, J. Piekarski, I. Rutkowski, D. Sikora, Ł. Zembala, M. Żukociński, W. Cichalewski, K. Gnidzińska, W. Jałmużna, D. Makowski, A. Mielczarek, P. Perek, T. Poźniak, A. Piotrowski, K. Przygoda, A. Napieralski, M. Kudła, S. Korolczuk, J. Szewiński, W. Wierba, K. Oliwa, H. Schlarb

IPAC 2012, New Orleans LA - May 21st 2012

Overview

- XFEL
  - Main numbers
  - LLRF perspective
- LLRF architecture
  - Main components
  - microTCA crate
- System integration
  - RF station
  - Signal flow
  - Software and automation
- Summary



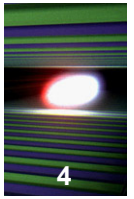
European XFEL

The European XFEL

- XFEL: European X-ray Free-Electron Laser
- Pulsed, superconducting LINAC (17.5 GeV)
- TESLA 1.3 GHz RF cavities
- First beam: Dec 2015

European XFEL

The European XFEL



Jan 20th 2012

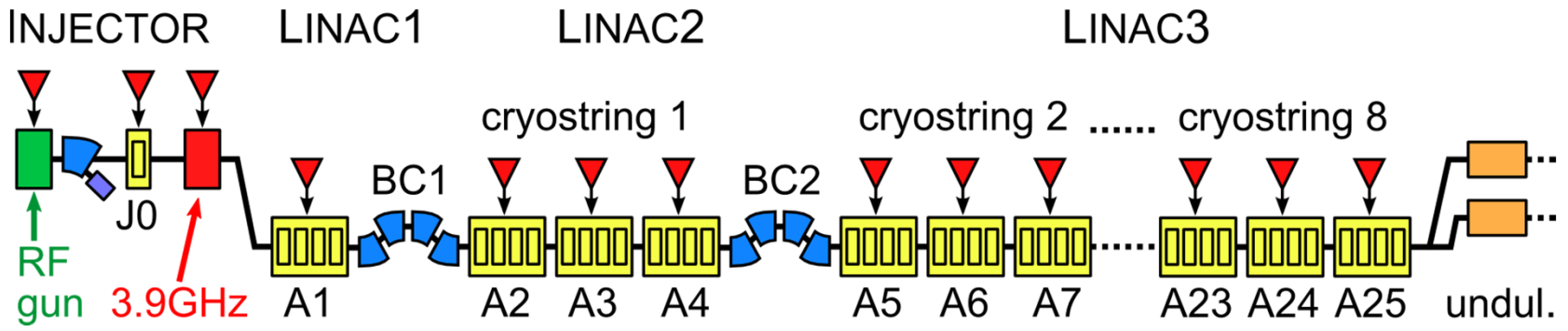
European XFEL

The European XFEL

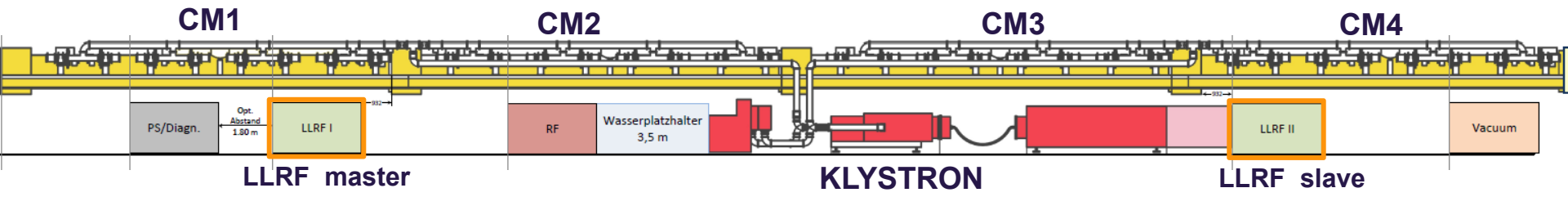
156 weeks before tunnel closes….

DESY HELMHOLTZ ASSOCIATION

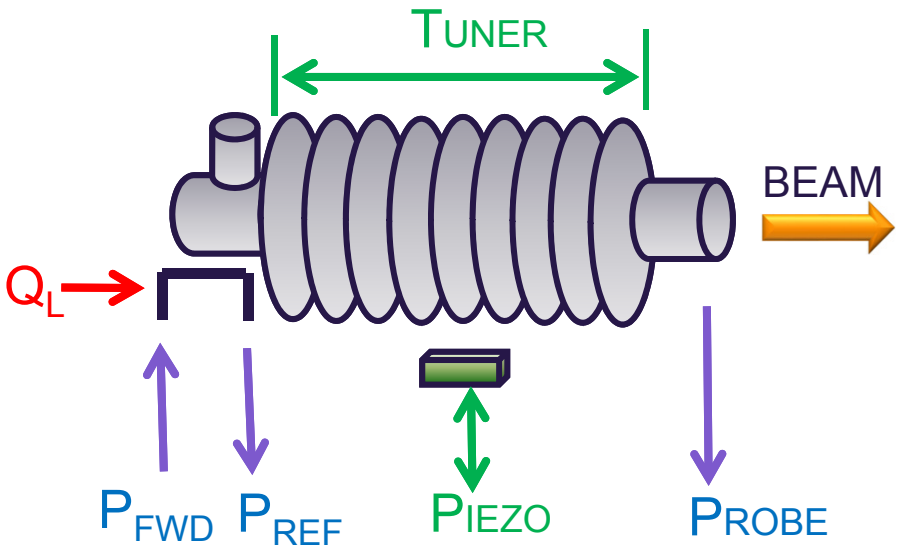
The European XFEL - Numbers

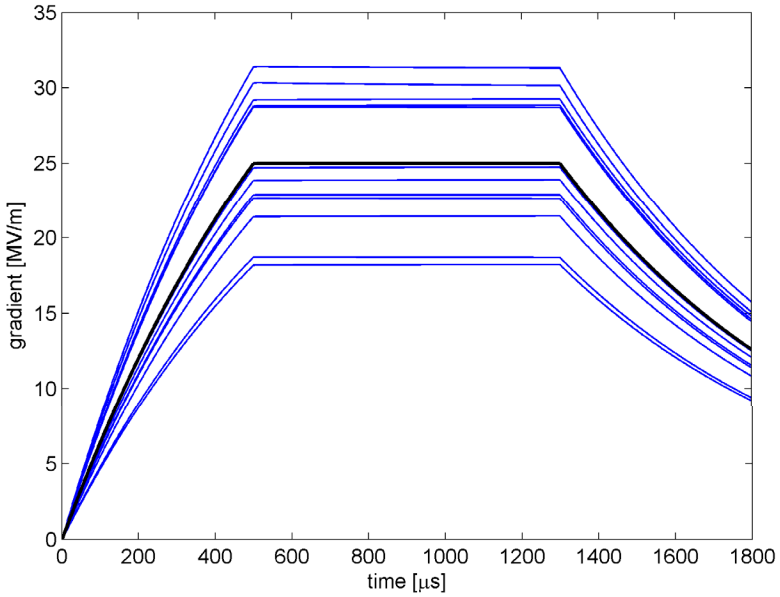


- 808 superconducting 1.3 GHz TESLA RF cavities
- 101 cryomodules (8 cavities)
- 25 RF stations (4 cryomodules)
- 1 LLRF system / RF station (i.e. per klystron)



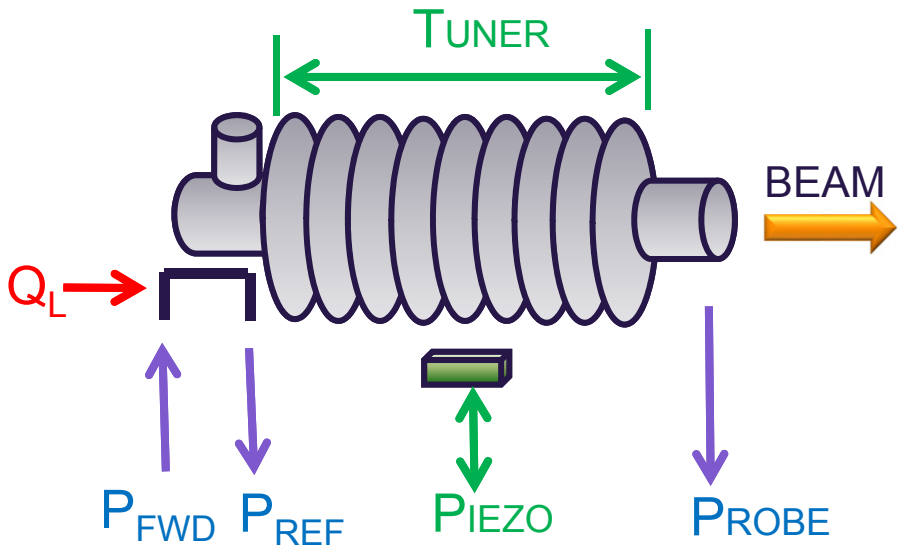
LLRF Requirements





- Control accelerating field for each RF station (vector sum) :
  - $\Delta A/A = 0.01\%$ (RMS)
  - $\Delta\phi = 0.01°$ (RMS)

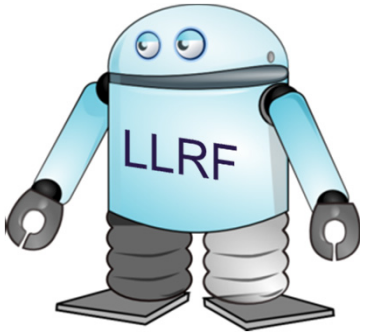
LLRF Requirements



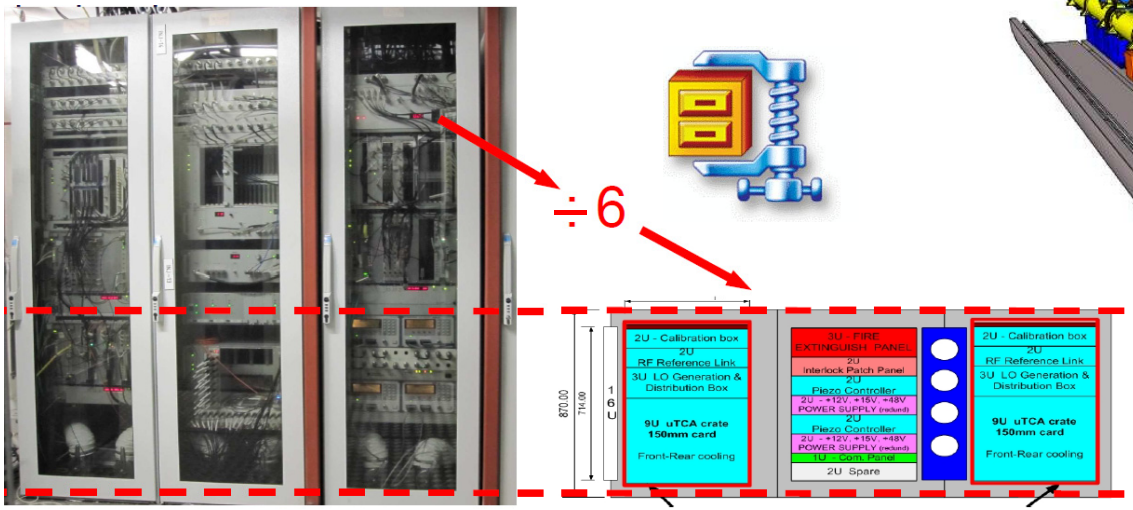
- Control accelerating field for each RF station (vector sum) :
  - $\Delta A/A = 0.01\%$ (RMS)
  - $\Delta\phi = 0.01°$ (RMS)

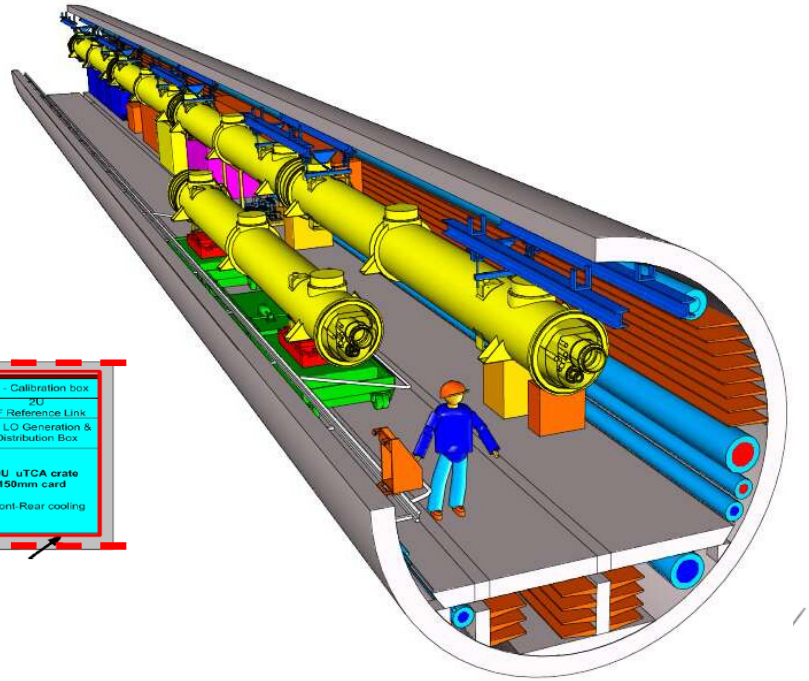
The LLRF should provide:

- Stable RF reference
- Interface to subsystems
  - RF support
  - Commissioning
- High degree of automation

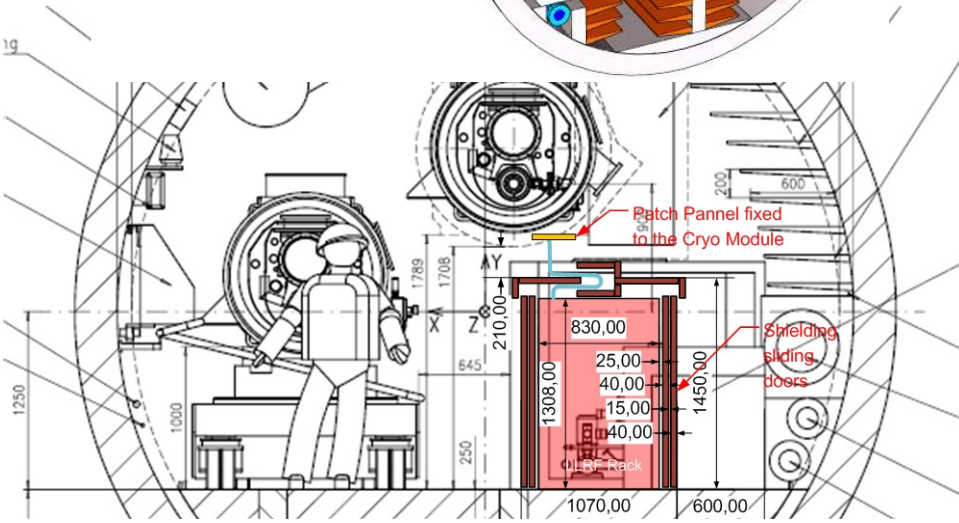


LLRF Requirements





Section	Rack space
Injector	**16U**
Linac 1	28U
Linac 2	28U
Linac 3	28U

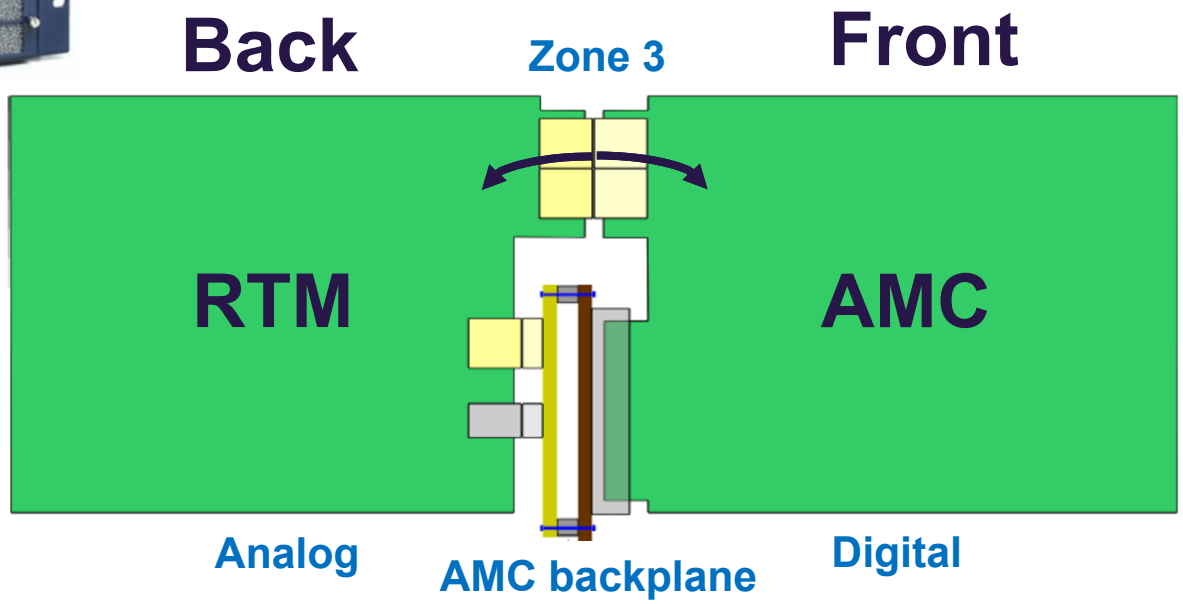


European XFEL

The micro TCA crate (MTCA.4)

µTCA®

- AMC: Advanced Mezzanine Card
- RTM: Rear Transition Module
- 12 slots, hot swap
- Redundant power supply

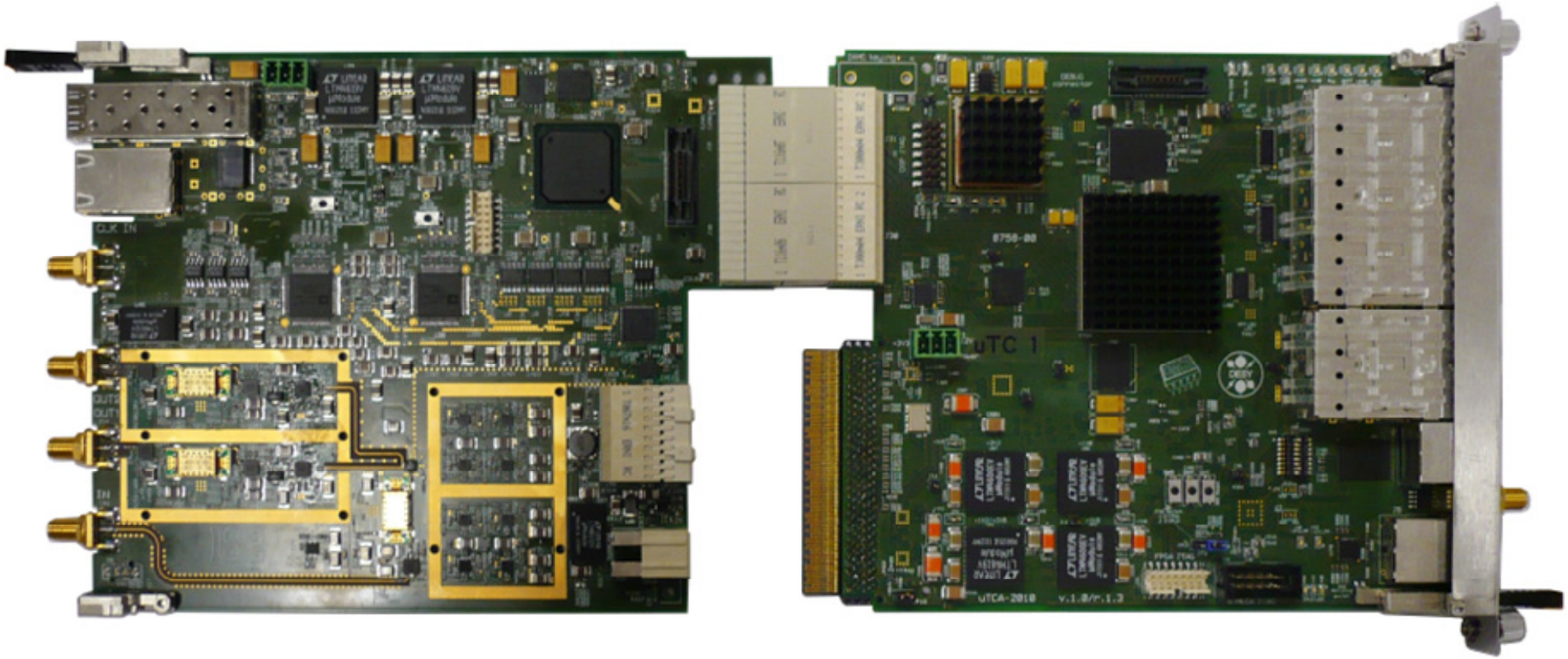


European XFEL

The micro TCA crate (MTCA.4)

BACK

FRONT



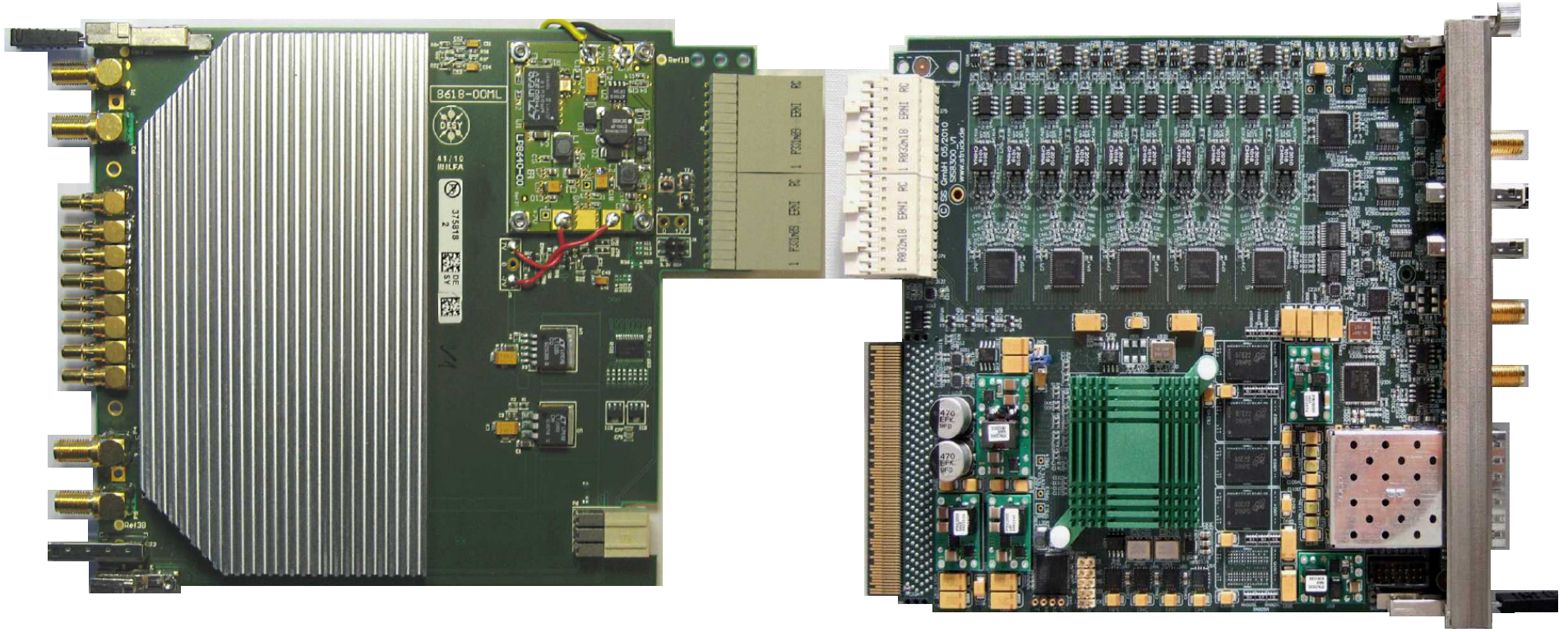
Vector Modulator (VM)

LLRF Controller (uTC)

The micro TCA crate (MTCA.4)

BACK

FRONT

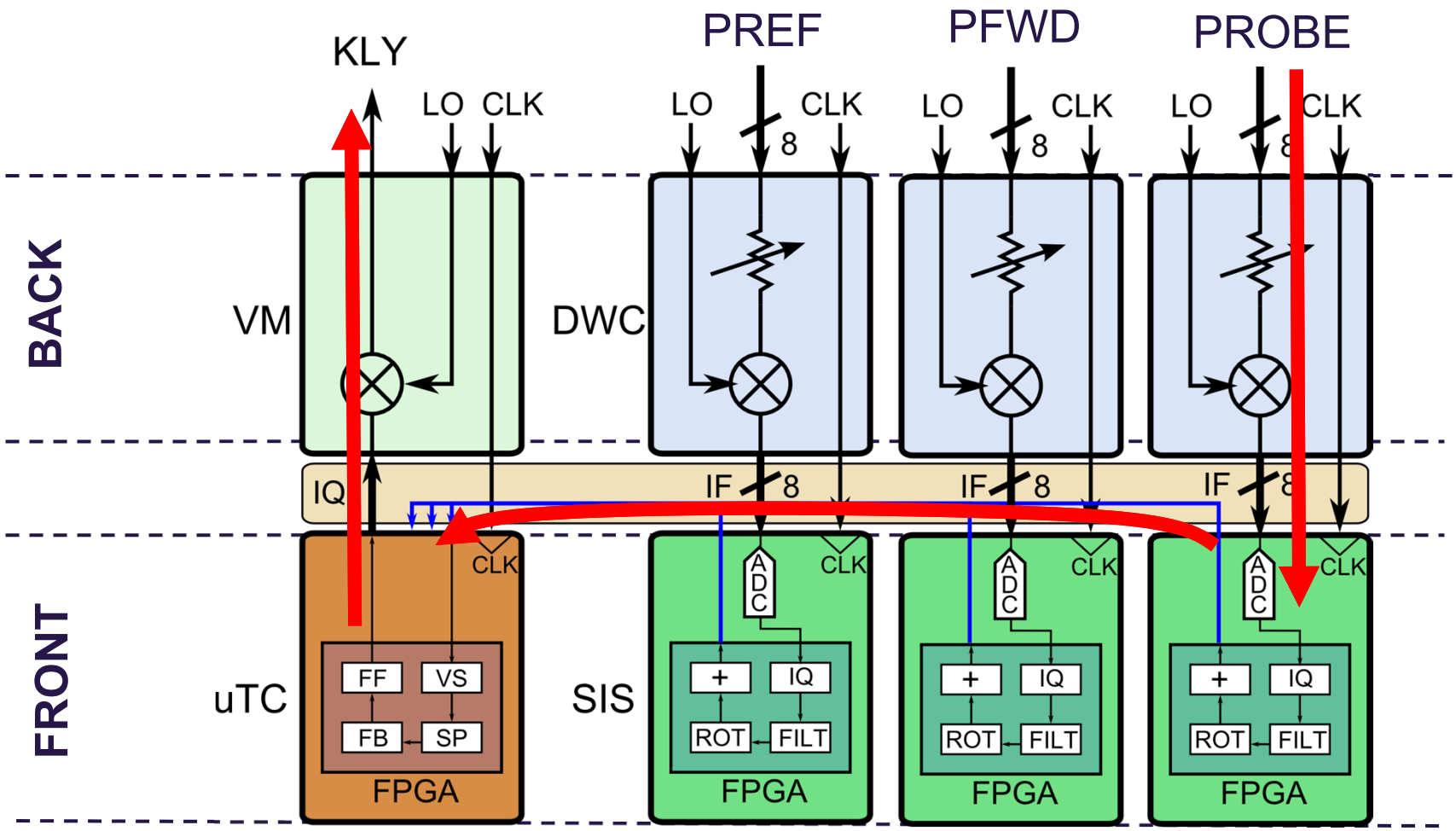


Down Converter (DWC)

Digitizer (SIS)

European XFEL

The micro TCA crate (MTCA.4)



European XFEL

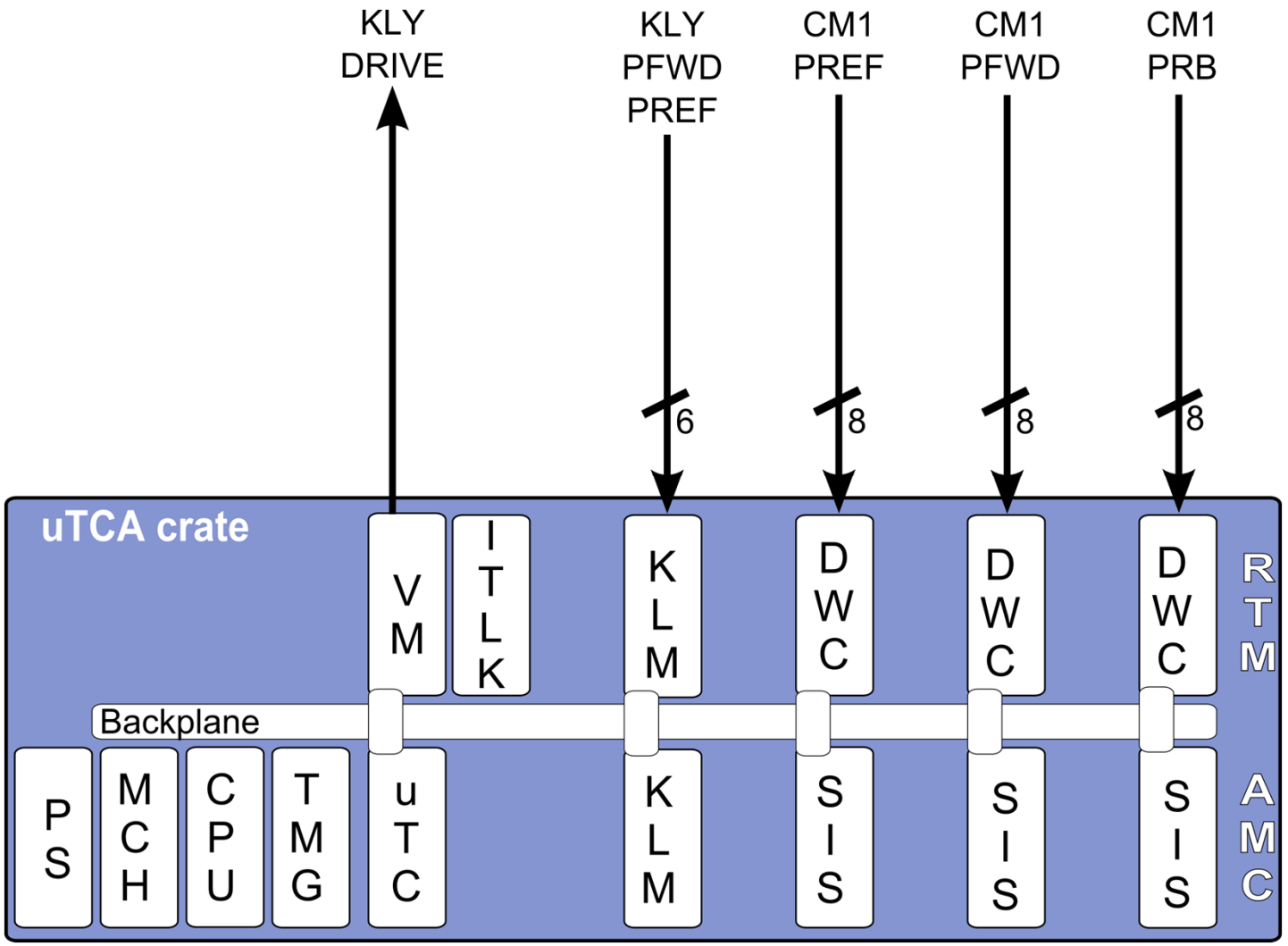
The micro TCA crate (MTCA.4)

European XFEL

The micro TCA crate (MTCA.4)

BACK

System integration

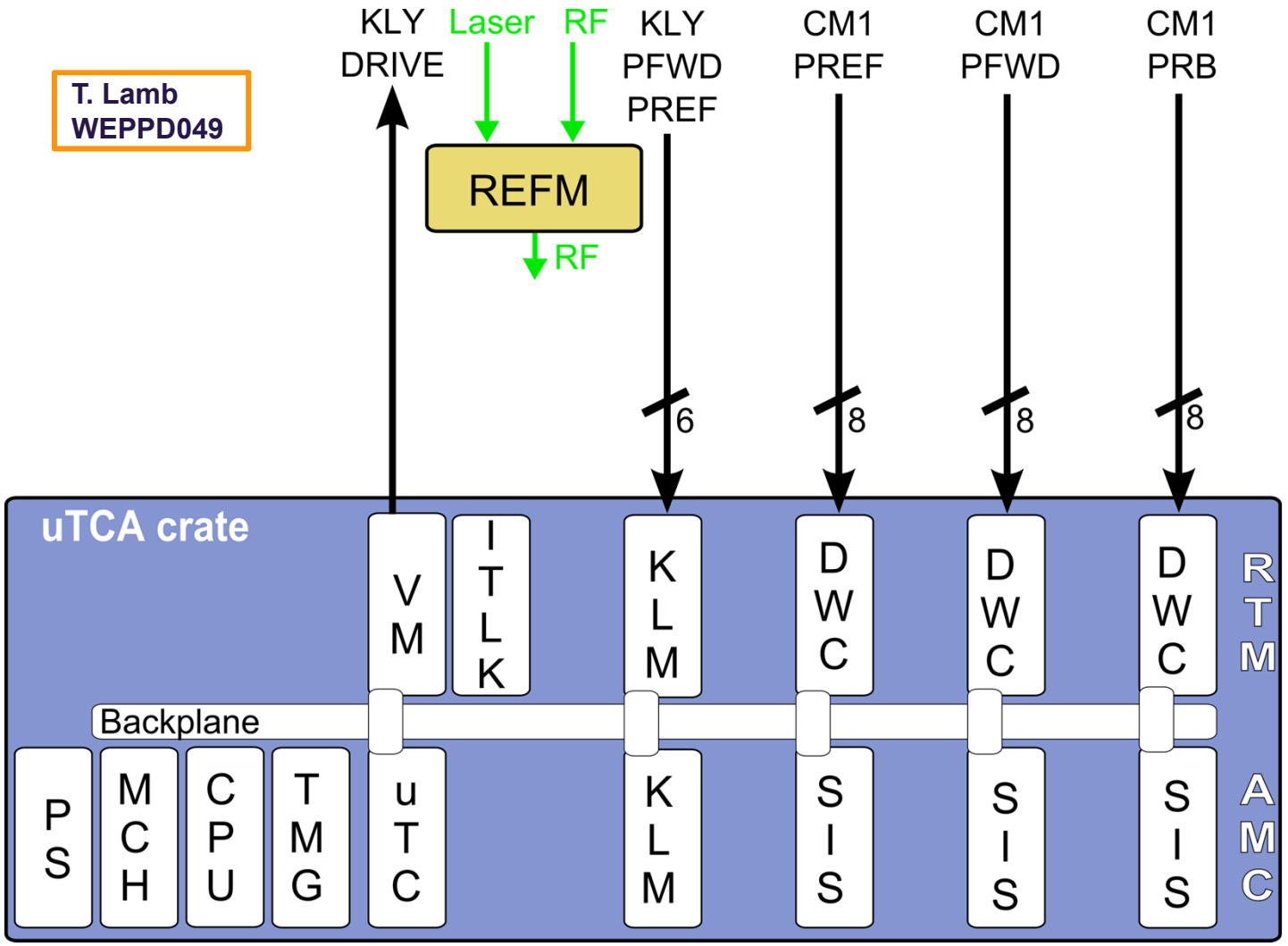


System integration

REFM

RF Reference Module

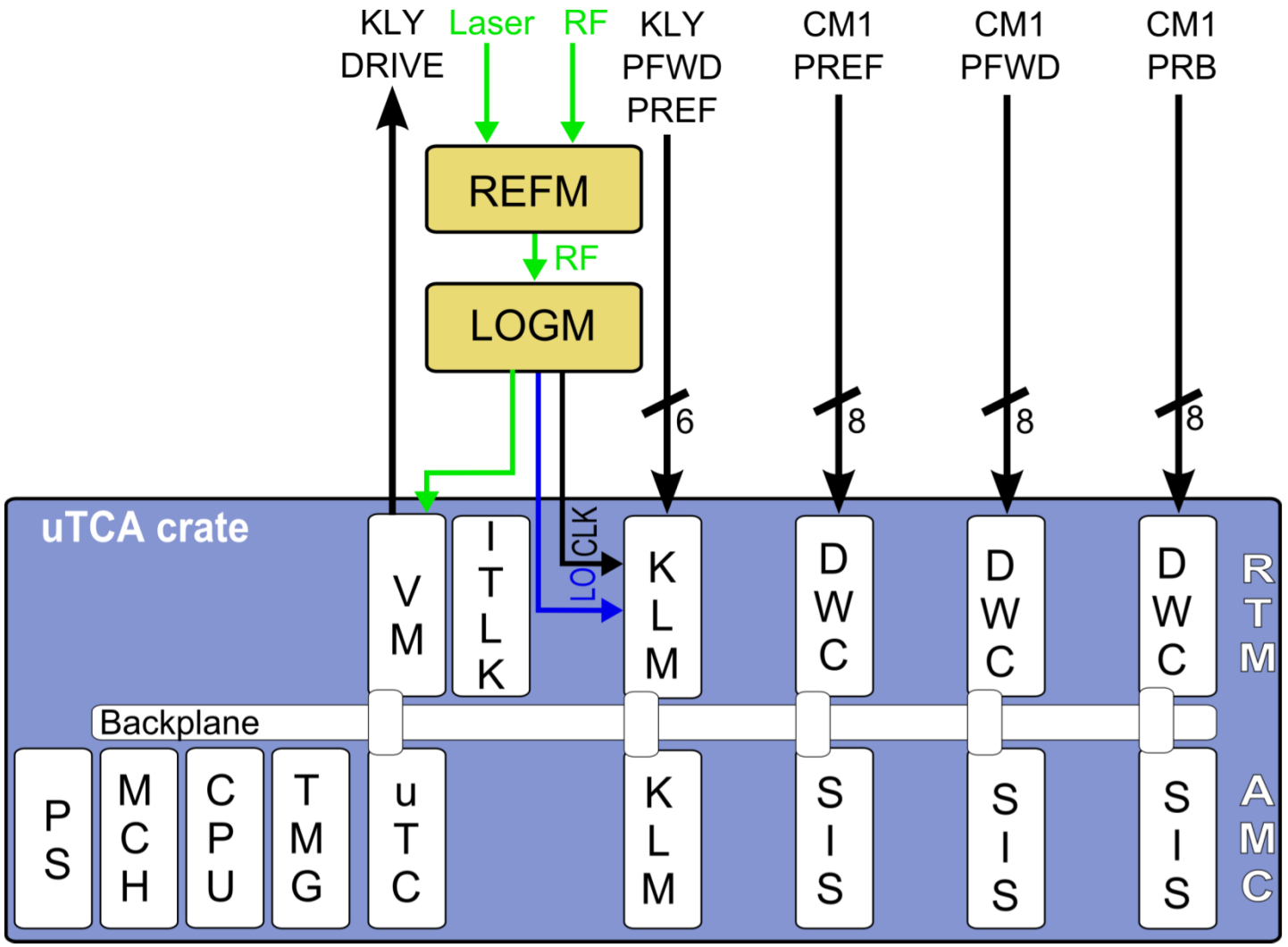
T. Lamb
WEPPD049



System integration

REFM
RF Reference Module

LOGM
Local Oscillator
Generation Module

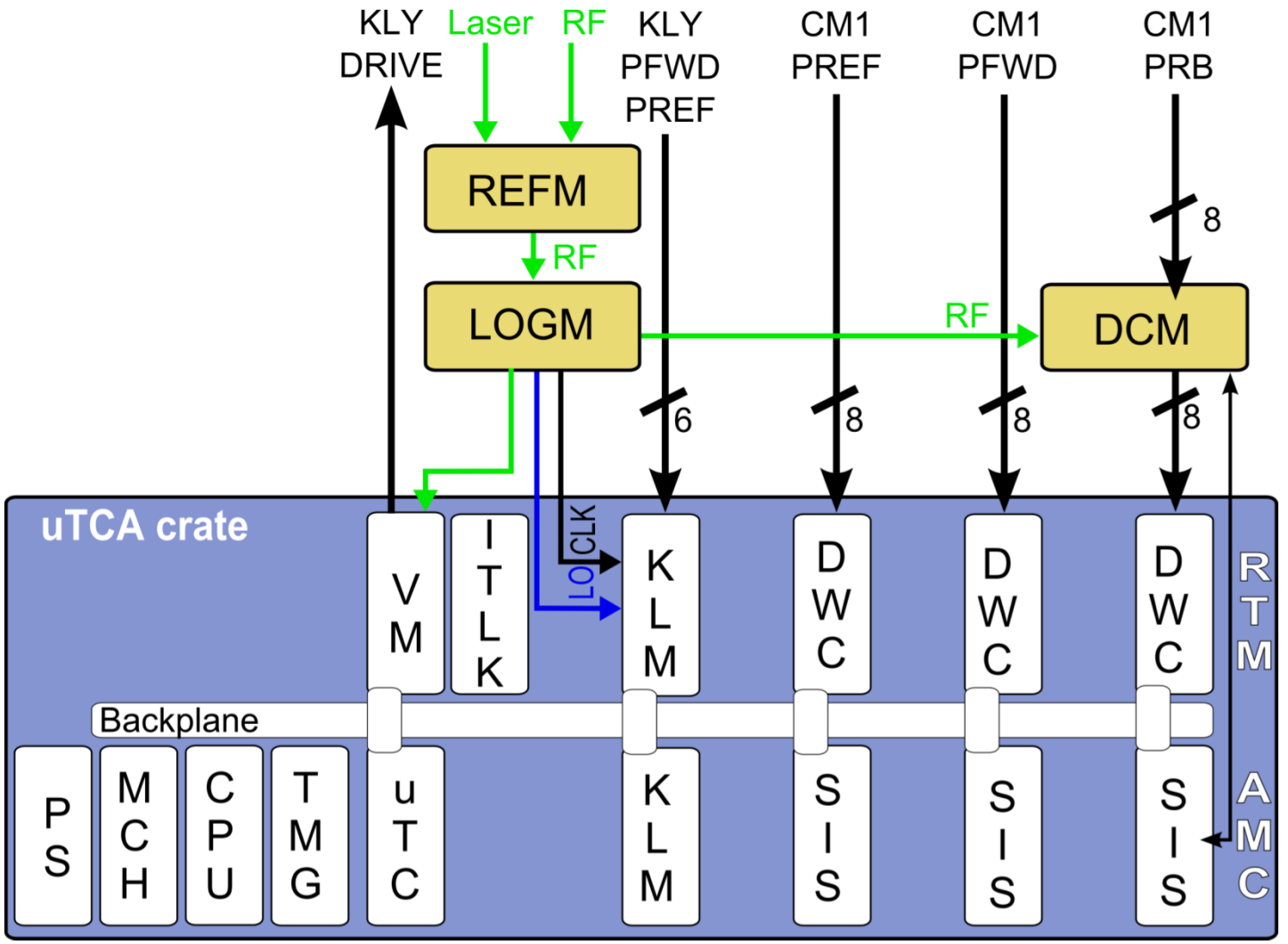


System integration

REFM
RF Reference Module

LOGM
Local Oscillator Generation Module

DCM
Drift Compensation Module



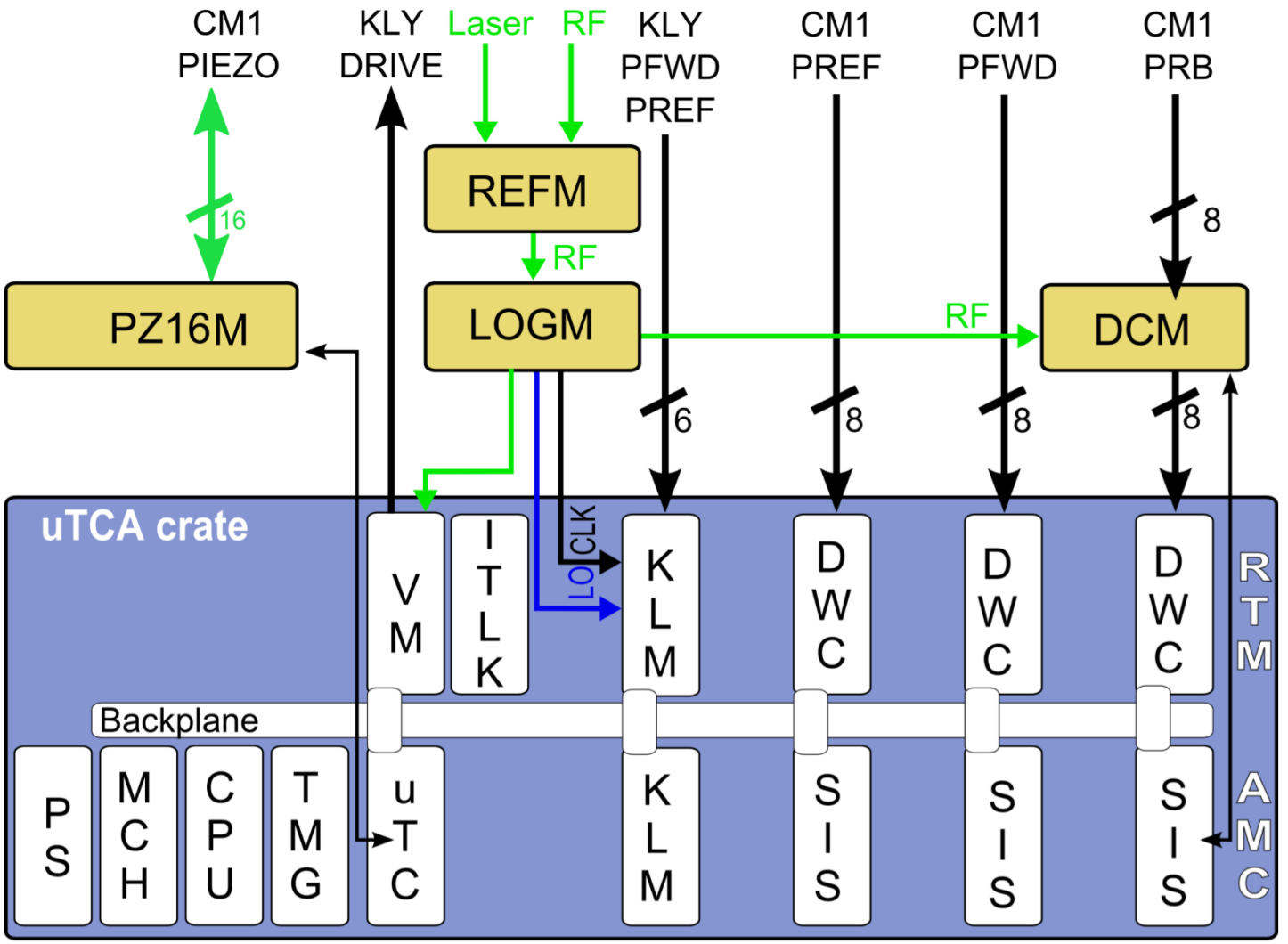
System integration

REFM
RF Reference Module

LOGM
Local Oscillator Generation Module

DCM
Drift Compensation Module

PZ16M
Piezo Driver Module



System integration

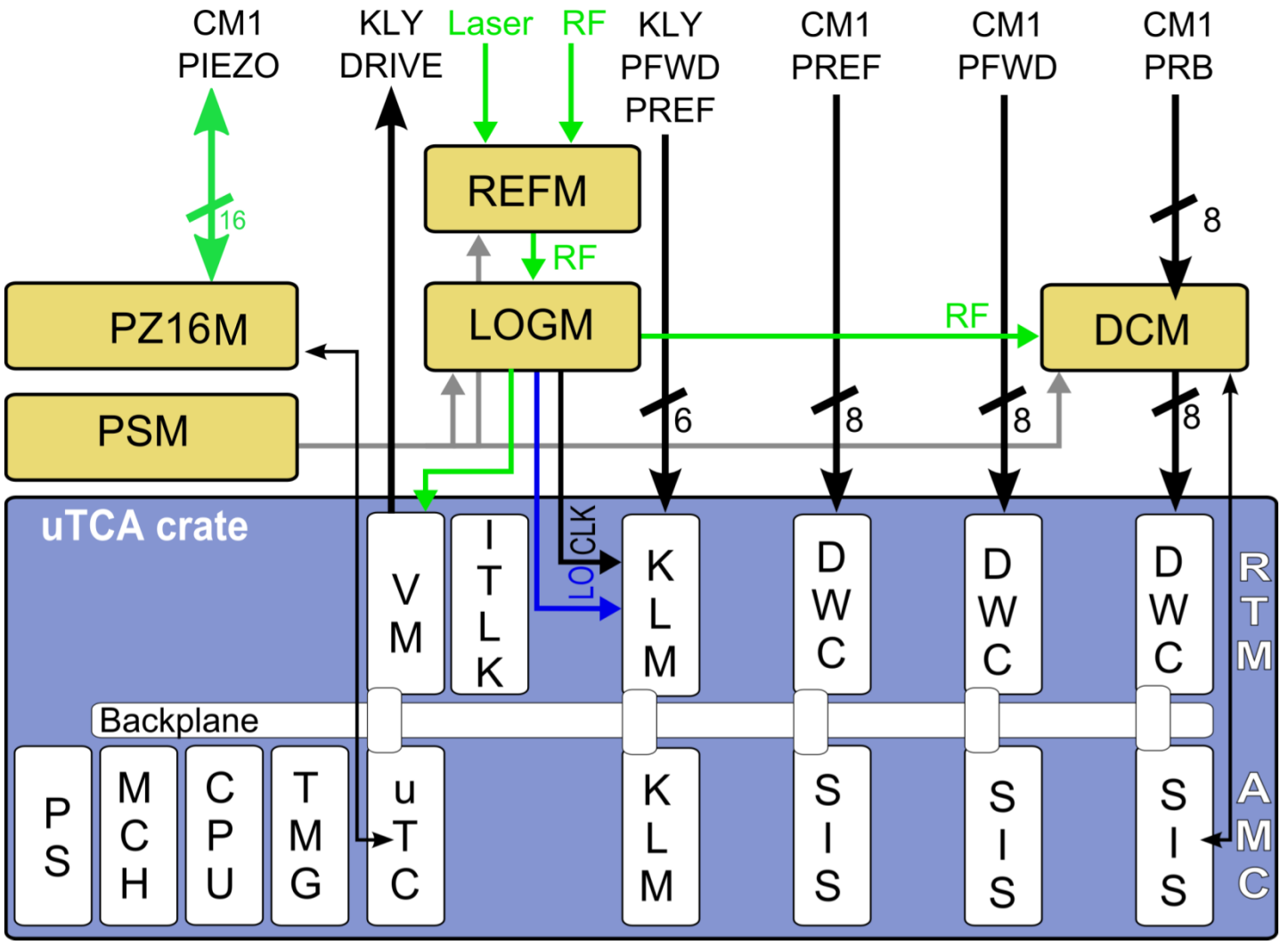
REFM
RF Reference Module

LOGM
Local Oscillator Generation Module

DCM
Drift Compensation Module

PZ16M
Piezo Driver Module

PSM
Power Supply Module



System integration

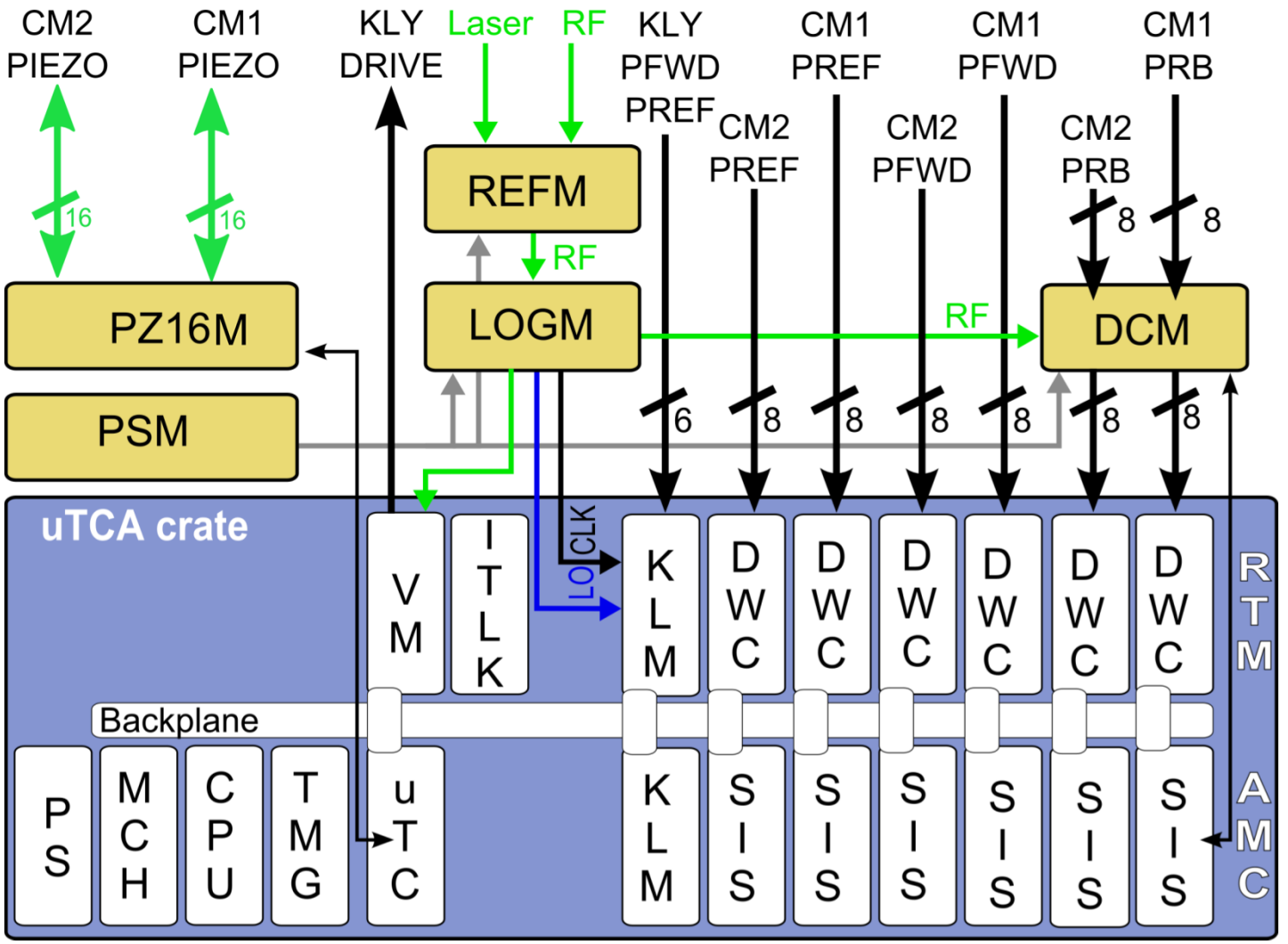
REFM
RF Reference Module

LOGM
Local Oscillator Generation Module

DCM
Drift Compensation Module

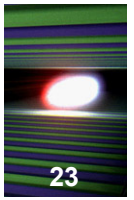
PZ16M
Piezo Driver Module

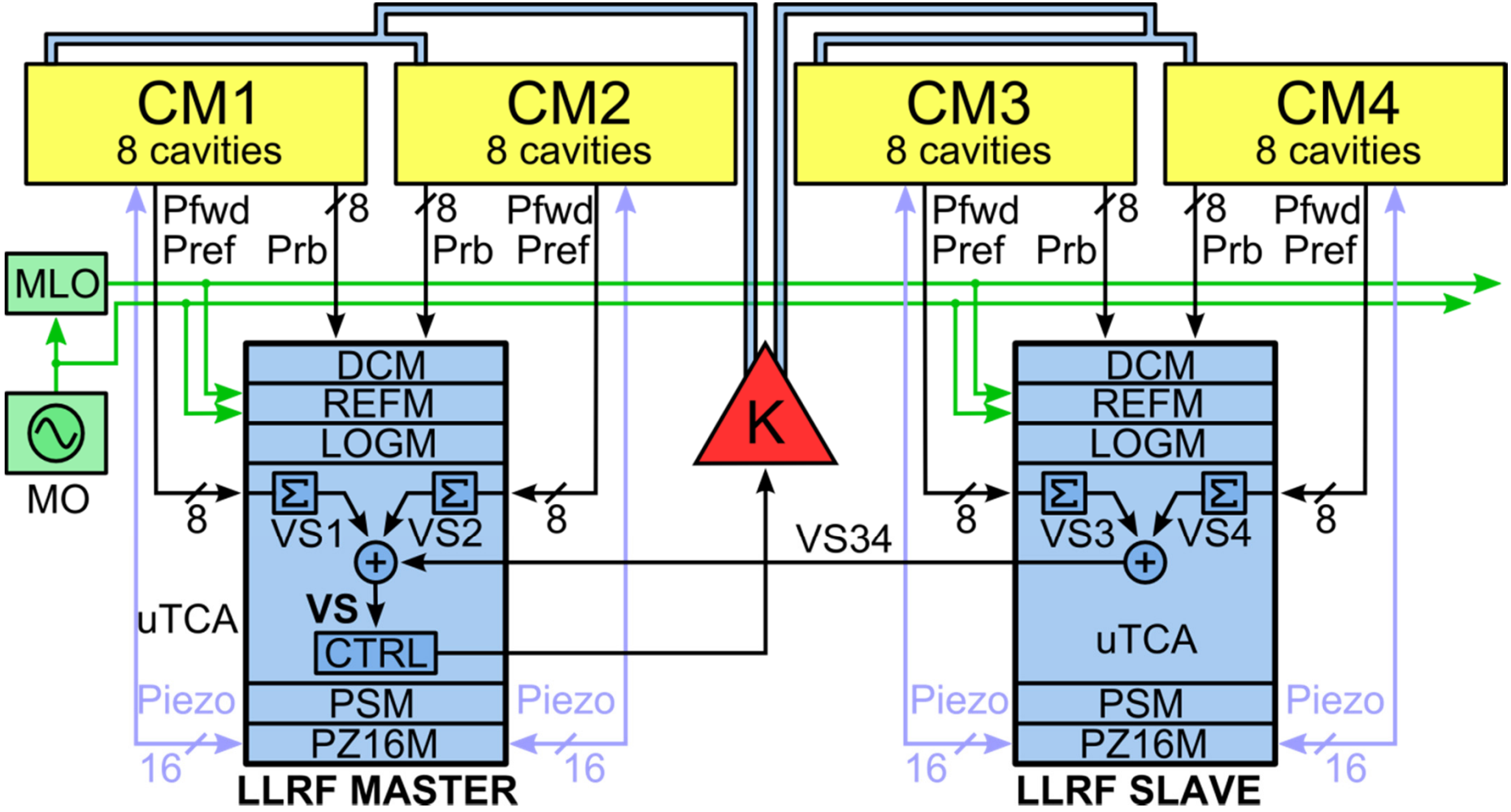
PSM
Power Supply Module



European XFEL

LLRF semi-distributed system





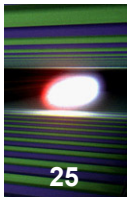
LLRF control and automation

- MIMO : second order → S.Pfeiffer talk **MOOAA03**
- LFF : modifies FF to minimize repetitive controller error
- BLC : modifies FF to compensate beam loading
- BBF : modifies SP to minimize beam energy error

- Gradient limiter: truncate RF/acts on SP to lower cav. grad.
- Quench detect: RF off at next pulse
- Auto Q_L: set and monitor cav. Q_L
- Auto piezo: Lorentz force detuning compensation

- Virtual probes: compute V_{CAV} from P_{FWD} and P_{REF}
- Energy optimizer: distr. grad. losses to neighboring stations
- …

Test results at FLASH



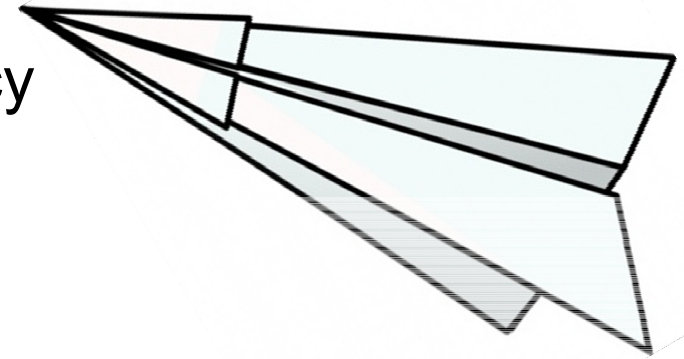
- uTCA system used in several test setup in DESY
  - FLASH, CMTB, REGAE **WEPPD048**, eBPM **MOPPR017**
  - Functionality demonstrated
- Regulation performance meets XFEL requirements
  - $\Delta A/A$ ~ 9e-5 rms (intra pulse)
    ~ 7e-5 rms (pulse to pulse)
  - $\Delta\phi$ ~ 0.01 deg (both)

  } Results from FLASH ACC1
- Full system integration remains to be demonstrated at FLASH
  - All 7 cryomodules equiped with XFEL LLRF system
  - Scheduled for this fall

Summary

- Overview of XFEL LLRF
  - signal flow
  - architecture design

- MTCA.4 based LLRF system
  - meet XFEL requirements
  - regulation, modularity, redundancy



- Full test at FLASH this year
  - Mass production starts next year

European XFEL

MSK - LLRF group at DESY

- **Schlarb Holger**
- Ayvazyan Gohar
- Bock Marie Kristin
- Bou Habib Samer
- Bousonville Michael
- Branlard Julien
- Butkowski Lukasz
- Cichalewski Wojciech
- Czuba Krzysztof
- Felber Matthias
- Gerth Christopher
- Grecki Mariusz
- Hacker Kirsten
- Hoffmann Markus
- Hoffmann Matthias
- Jablonski Szymon
- Jalmuzna Wojciech
- Janas Ewa
- Jezynski Tomasz
- Kay Holger
- Kudla Ignacy Maciej
- Kuehn Daniel
- Lamb Thorsten
- Ludwig Frank
- Makowski Dariusz
- Malka Izabela
- Mavric Uros
- Moeller Guenter
- Pfeiffer Sven
- Piekarski Jan
- Piotrowski Adam
- Predki Pawel
- Przygoda Konrad
- Rutkowski Igor
- Schmidt Christian
- Sydlo Cezary
- Szczepanski Bartlomiej
- Szewinski Jaroslaw
- Tarnowski Szymon
- Weddig Henning-Christof
- Wendland Bibiane
- Wierba Woyciech
- Yang Bin
- Zembala Lukasz
- Zukocinski Mateusz

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The XFEL – a LLRF perspective

DESY HELMHOLTZ ASSOCIATION