Status and Experience with MicroTCA.4 LLRF systems at DESY.

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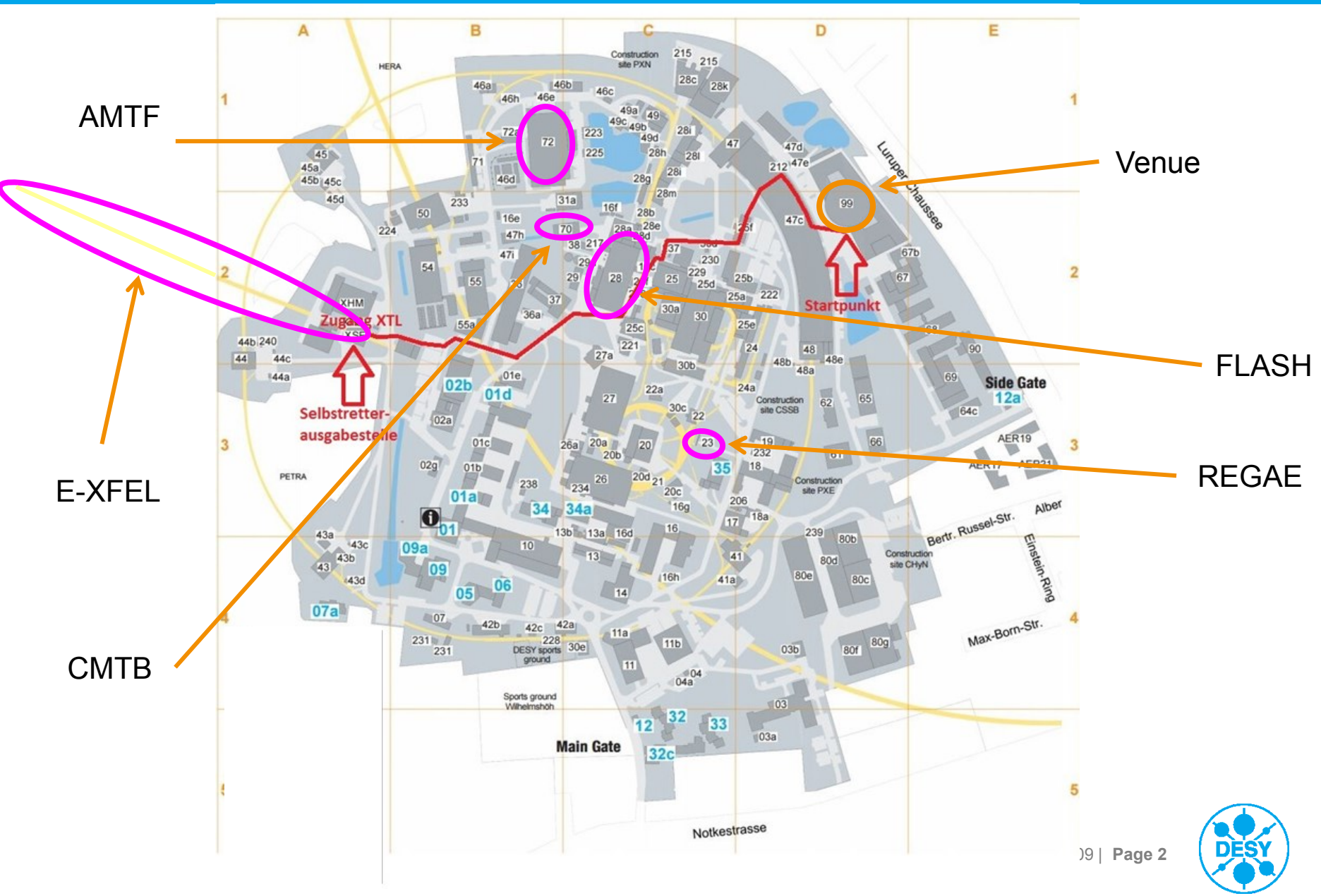
On behalf of the LLRF team
4th MicroTCA.4 Workshop
2015/12/09

HELMHOLTZ GEMEINSCHAFT

DESY

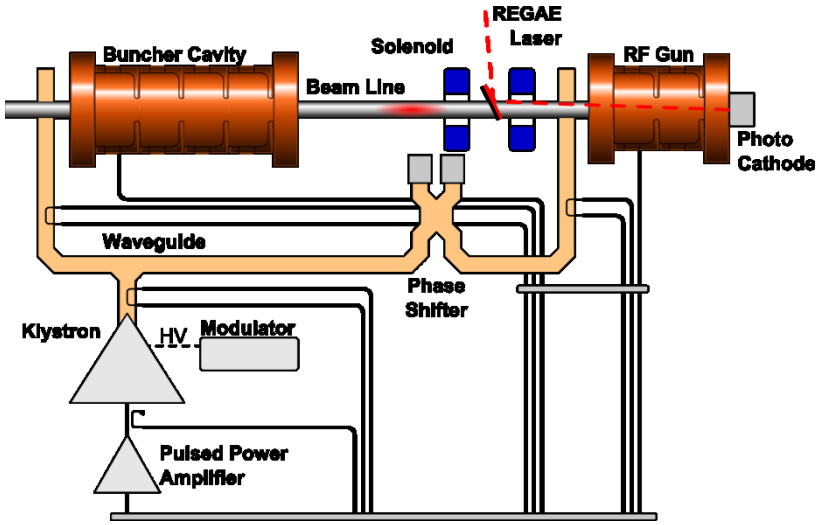
DESY LLRF installations overview

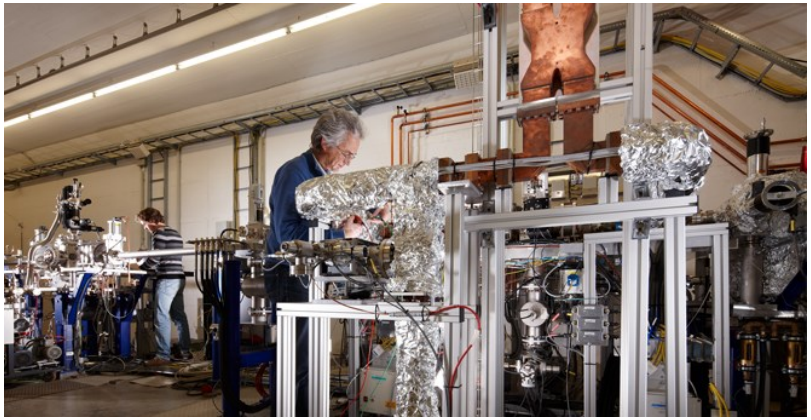


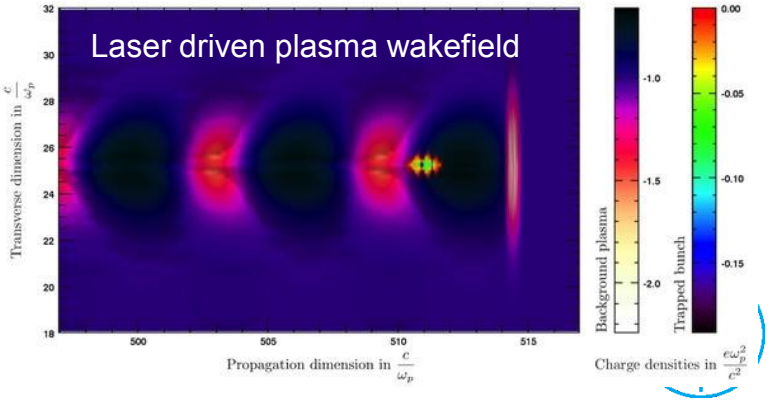
Relativistic Electron Gun for Atomic Exploration

Courtesy M. Hoffmann

- Time resolved electron diffraction experiments (MPI) and test facility for laser driven plasma-wakefield acceleration (LAOLA)
- Generation of sub-10 fs electron bunches
  - **Timing stability:** **<10 fs at the target**
  - **Very low charge:** **150..300 fC**
- RF parameter of the REGAE accelerator:
  - NRF gun (1.5-cell) and buncher cavity (4-cell)
  - 2.998 GHz S-band structures
  - 6 µs pulse length and up to 50 Hz repetition rate (up to now only 12.5 Hz)
  - Driven by one klystron, with motorized waveguide phase shifter





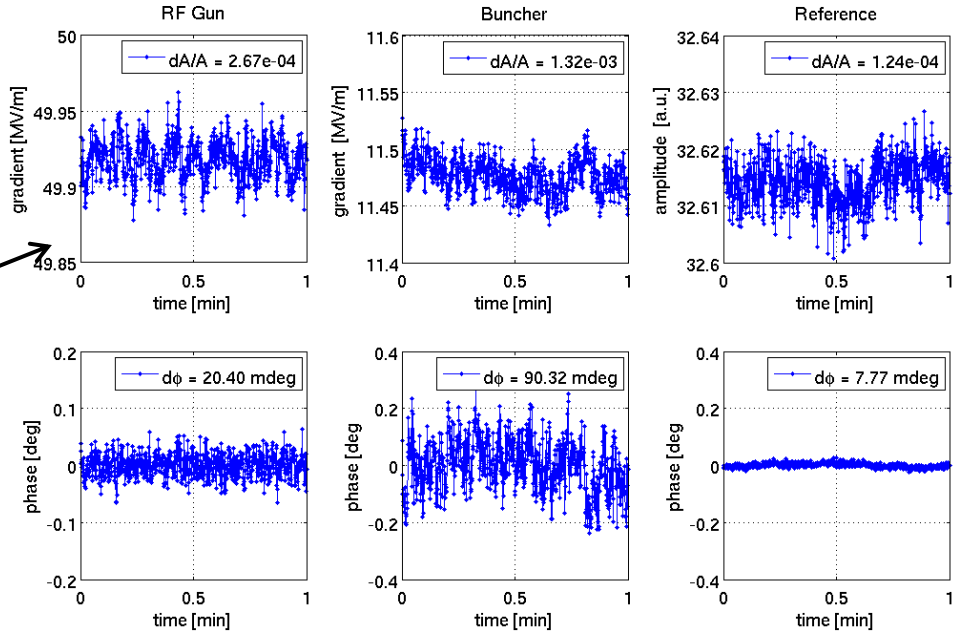


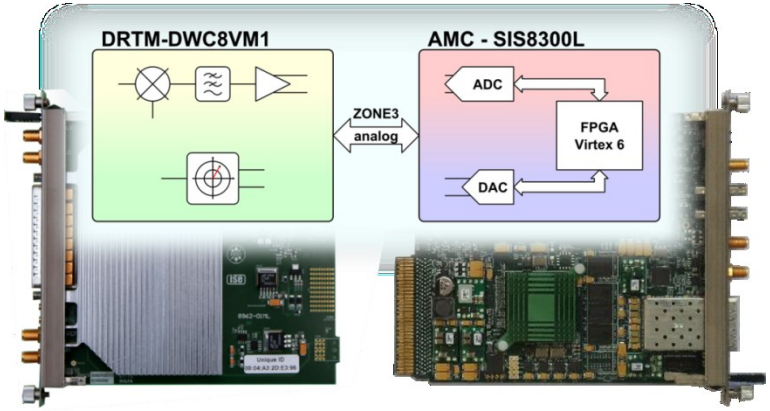
LLRF system at REGAE

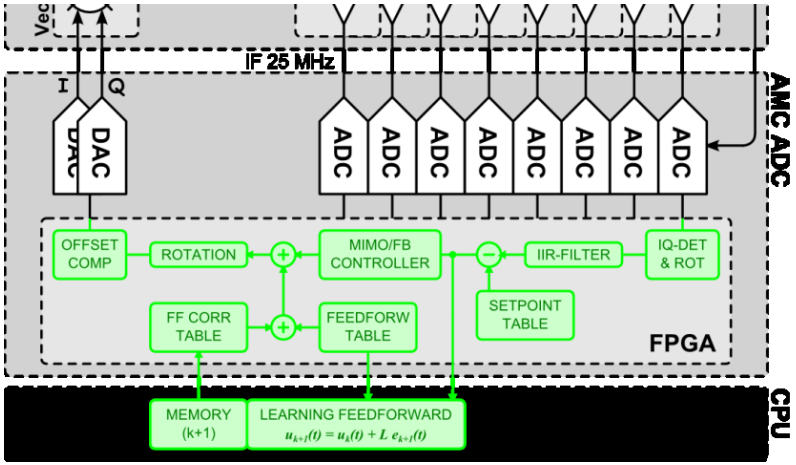
Courtesy M. Hoffmann

- MicroTCA.4 based LLRF system
  - Running since Nov. 2011
  - Single cavity controller since 2014
- Stability requirements:
  - **dA/A < 0.01%**
  - **dφ < 0.01° (9.3 fs @ 3.0 GHz)**
- One klystron for two cavities
  - Coupling of cavities
  - 2 input/4 output system
  - Buncher phase = RF gun phase + 90°

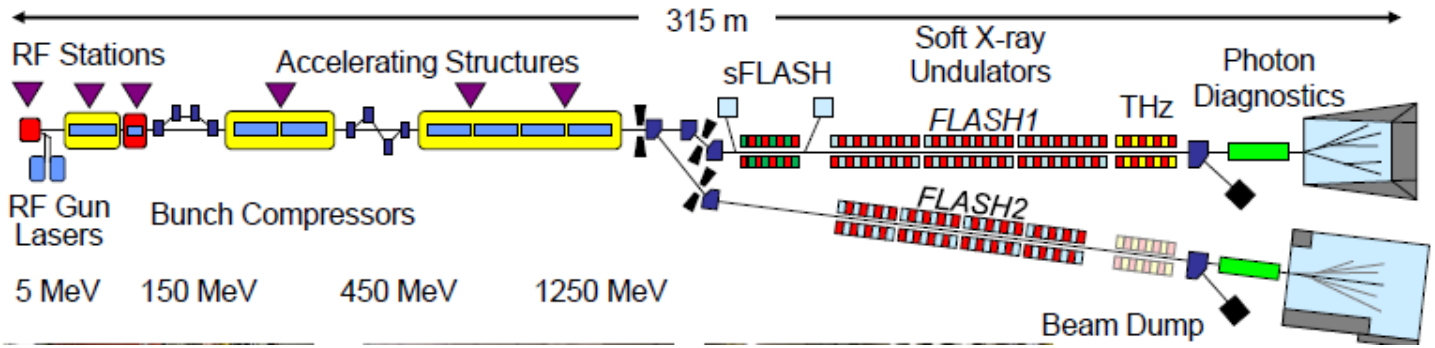
~ 2x improvement required



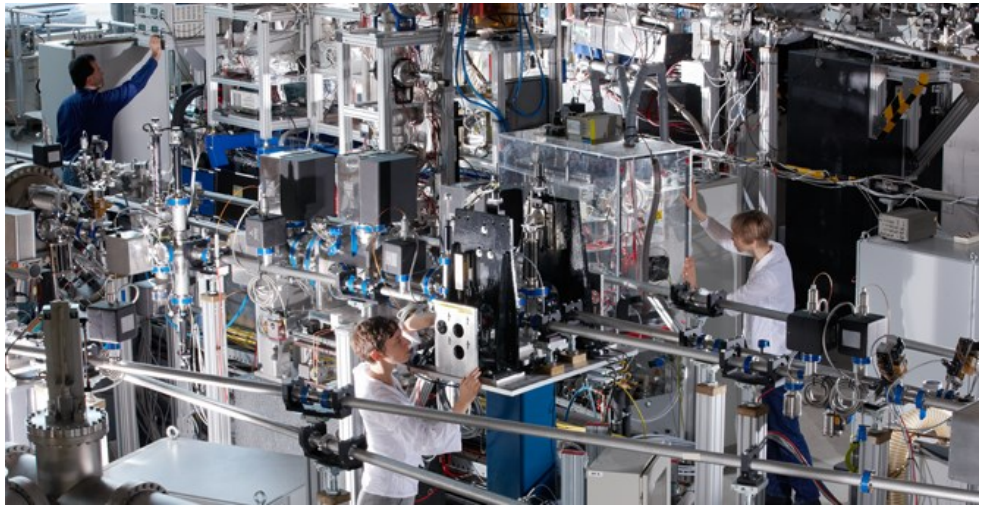




Free Electron LASer Hamburg



Flash | and FLASH II location site view



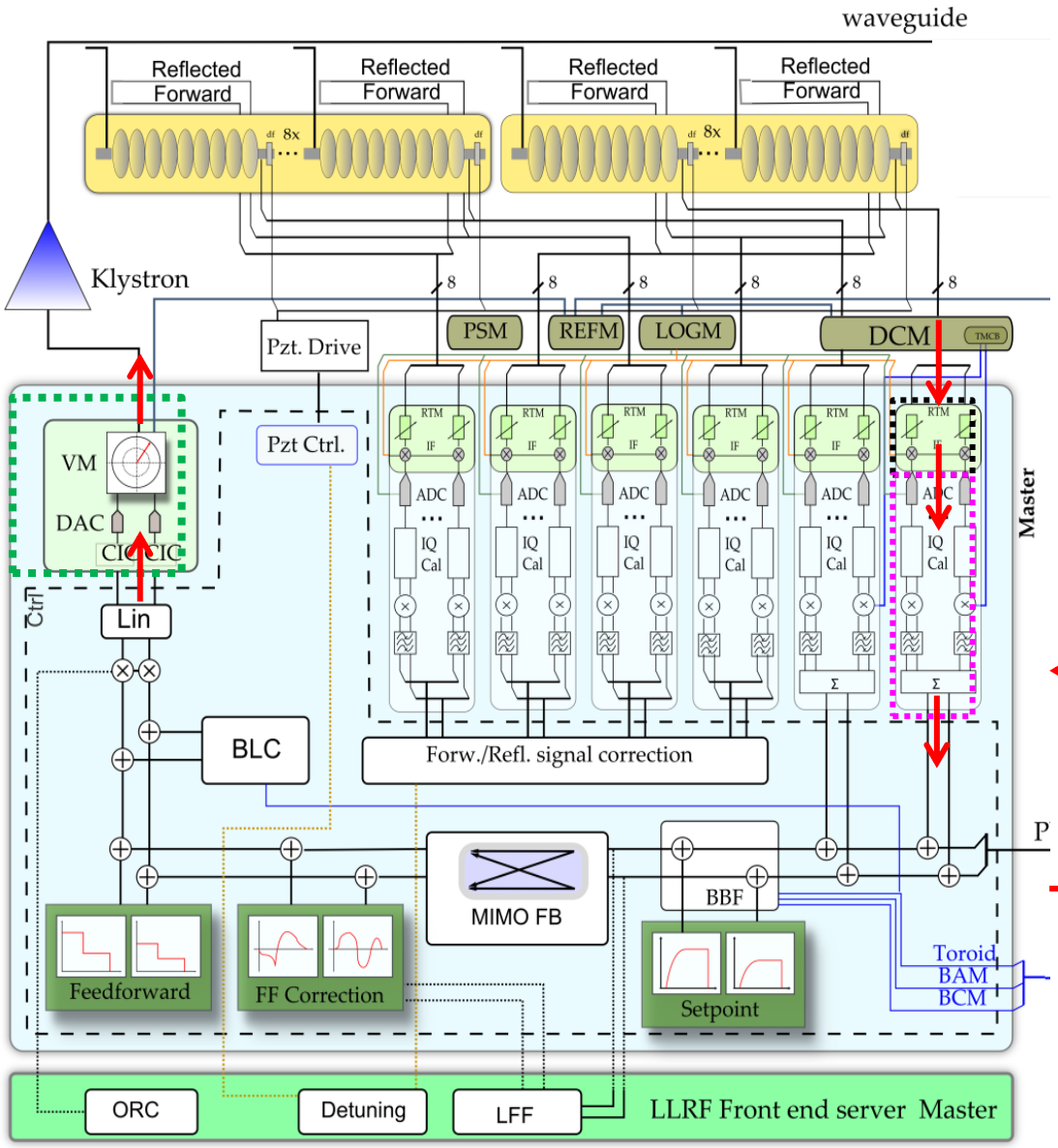
User experimental hall

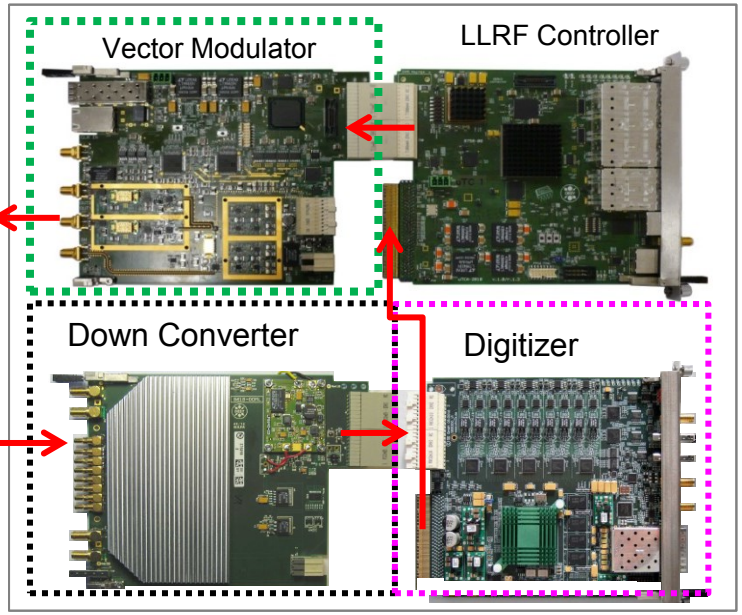
Regular FLASH operation

- System for all SC modules in operation since >2years
  - Startup issues mainly due to software migration
  - Hardware mostly prototype versions (no major issues found)
  - Partly installed inside the accelerator tunnel
- RF-Gun in regular operation since Jan 2015
- Currently concentrating on stepwise upgrades
  - Software/Firmware + specific HW components

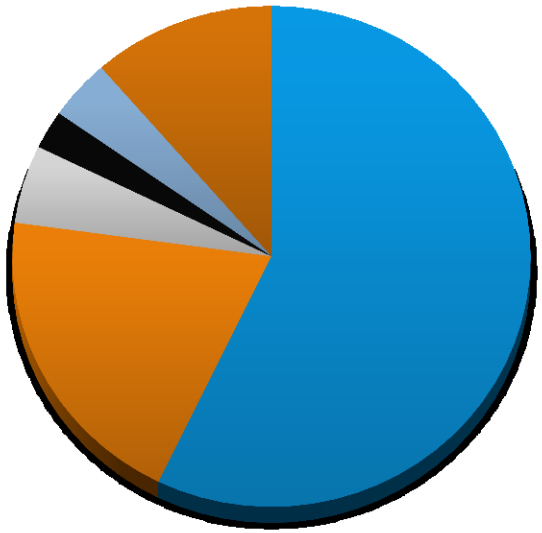
System fulfills expectations regarding quality and reliability.
Gained a huge amount of experience for the XFEL commissioning and operation!

MicroTCA.4 LLRF System – signal flow



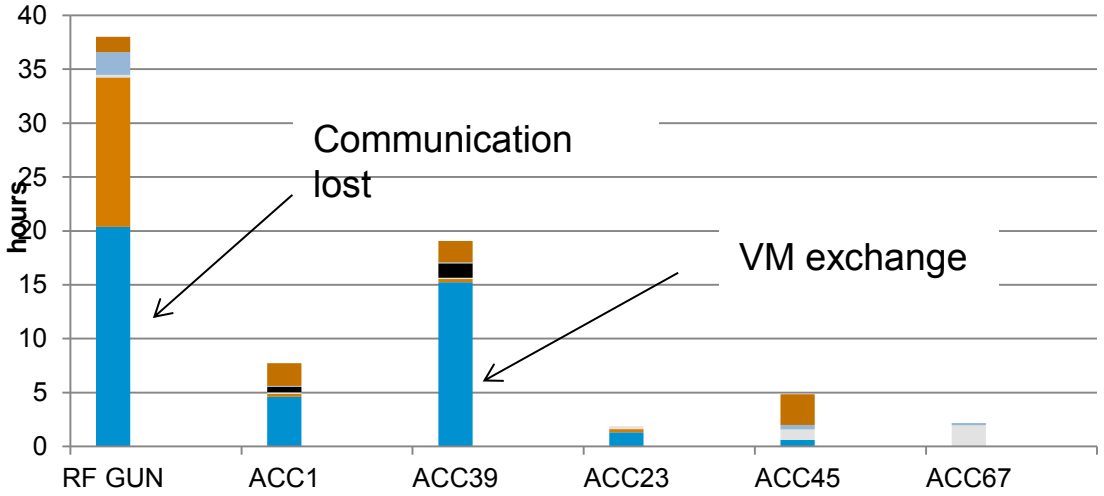


LLRF@FLASH counted downtime in categories (2015)



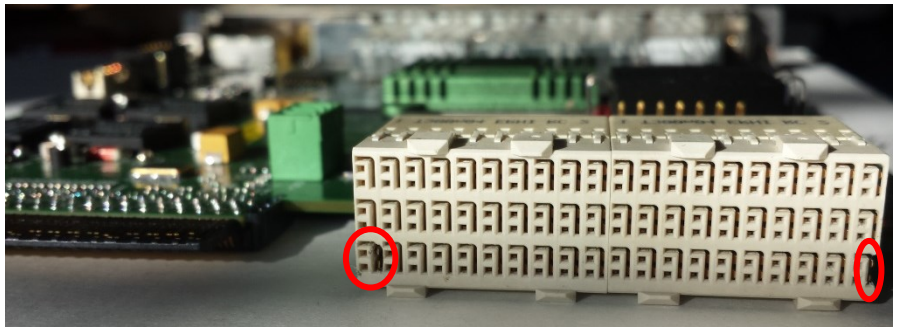
- Infrastructure (Timing, power, cooling water, crate)
- Server (crashes, malfunction, restarts)
- Automation (diverging routines, not working functions,...)
- Firmware (malfunctions, required reboots, crashing)
- Operation (misusage, exceeding tresholds, ...)
- Performance (no machine operation, because of not working regulation)

- Tunnel installation requires access (machine recovery counted)
  - Exchanging parts, hardware failures
- RF-Gun system was installed in this year
- ACC45 tuning time for variable gradients



Examples of most recent hardware failures

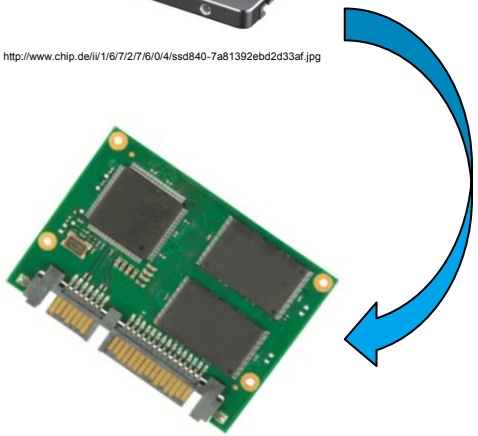
- Broken Zone3 connection
  - VM ACC39 exchange for upgrade
  - FLASH installation space very limited



Picture: uTC1.3 broken Zone3 connector due to missing mechanical rails in prototype stage.

- Failures of SSD's / Raid array
  - Mainly visible on the RF GUN
  - Often not the SSD's are broken but the RAID (sw) was loosing a disk
  - Installed new special single cell type SSDs
  - Installation of radiation monitors to study what is the correlation

Ref: http://www.chip.de/ii/1/6/7/2/7/6/0/4/ssd840-7a81392ebd2d33af.jpg



- In the past we have seen:
  - Broken cables (optical and copper)
  - Power cuts of the whole rack system
- We have not seen:
  - Individual modules dying or degrading in performance or availability

Currently installed LLRF MicroTCA.4 hardware at FLASH

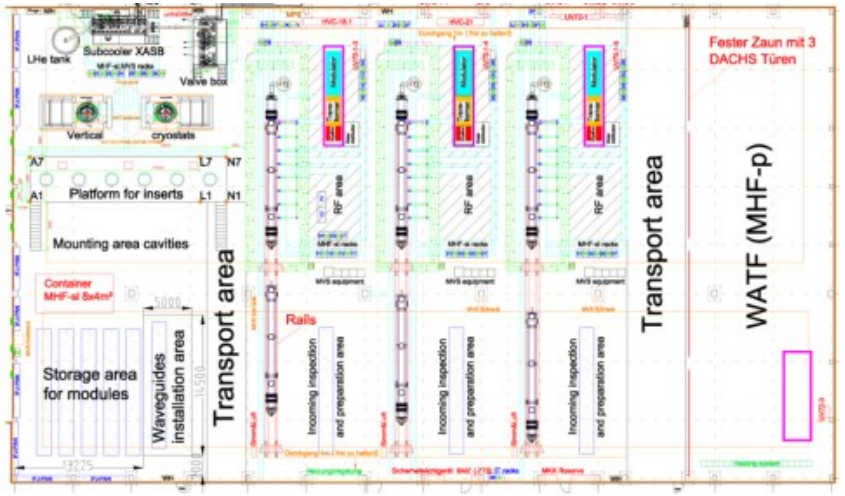
Hardware	RF GUN	ACC1	ACC39	ACC23	ACC45	ACC67	Test-stand
MTCA Crate	Schroff 2U	Schroff 12S LLRF AMC BP	Schroff 12S LLRF AMC BP	Schroff12S LLRF AMC BP	ELMA 12S AMC BP, LLRF RTM BP Prep	ELMA 12S AMC BP LLRF RTM BP Prep	ELMA 12S AMC BP,RTM backplane compatible
MCH	NAT MCH-PHYS	NAT MCH-PHYS	NAT MCH-PHYS	NAT MCH-PHYS	NAT MCH-PHYS	NAT MCH-PHYS	NAT MCH-PHYS
Timer	X2	X2	X2	X2	X2	X2	X2
Power supply	1x Vadatech PEM	1x Wiener PS 1KW	1x Wiener PS 1kW	1x Wiener PS 1kW	Vadatech PEM	Vadatech PEM	Vadatech PEM
Controller	Struck SIS8300LS	Vadatech TCK7	uTC	Vadatech TCK7	uTC	uTC	Vadatech TCK7 + uTC
VM	Struck DWCVM rev 1.1	1xVM 2.3LF	VM 1.2HF	VM 2.2LF	VM.1.2	VM 1.2	VM 2.2 + 1.2
Digitizer (STRUCK)	SIS8300LS+KLM	2xSIS8300LS 1xSIS8300LS2	SIS8300LS	SIS8300LS	SIS8300LS	SIS8300LS SIS8300LS2	SIS8300LS
DWC	1x DWCVM rev 1.1	3x Vers 2.2	3x Partly broken (re-soldered)	6x Vers 2.2	6x Vers 2.2	6x Vers 2.2	6x Vers 2.2

→ final →exchange →upgrade

- FLASH ➔ 56 SRF 1.3GHz / 4 SRF 3.9GHz/ 1 NRF gun
- Upgrade goal: consistent setup for FLASH and XFEL => maintenance

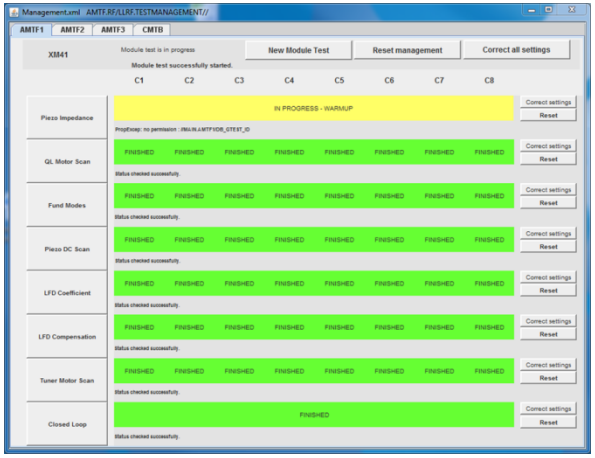
Accelerator Module Test Facility

Picture with courtesy of Jacek Swierblewski



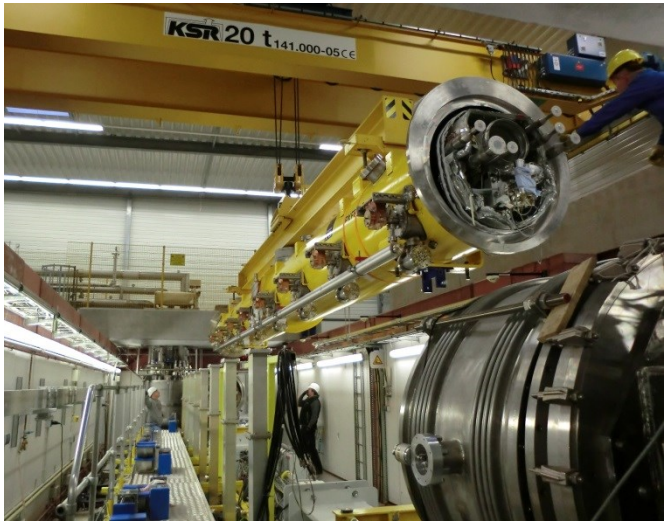
(3 x RF stations 1.3GHz + 1 x 3.9GHz)

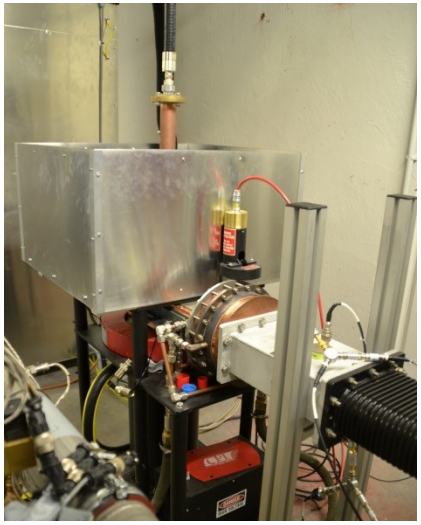
- AMTF (Accelerator Module Test Facility)
  - Development of automatic test and qualification of modules
  - System parameter characterization and database storage
  - Automated test routines essential => 7 days/module
- All modules have to be tested prior tunnel installation!
- Retrieved characterization data is being used in XFEL system setup
  - Tuner, fundamental modes, piezo, maximum gradients

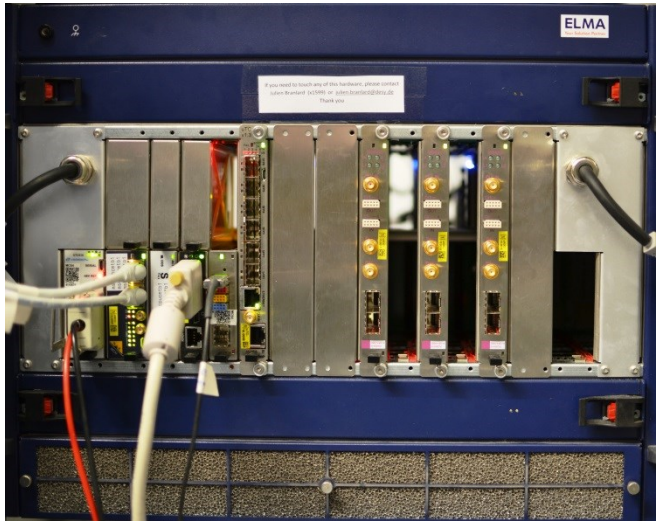


Courtesy: M. Omet

CryoModule Test Bench

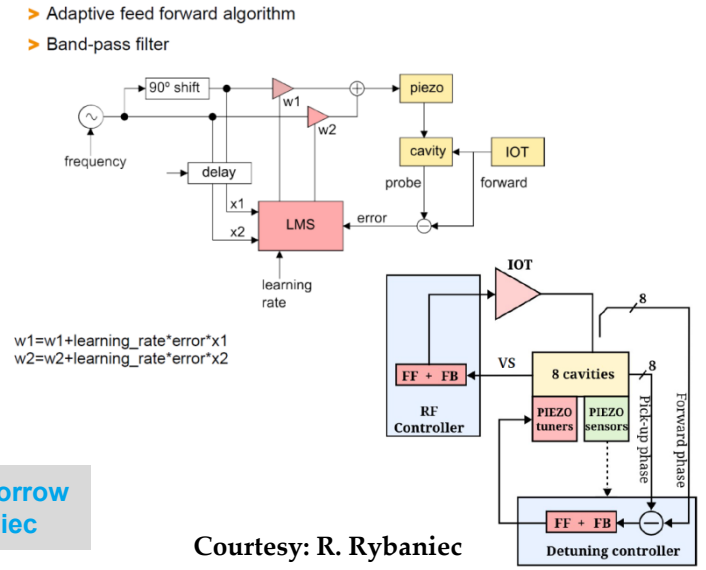






Test facility with cryomodule installation (left), amplifier IOT (mid) and MicroTCA test setup (right)

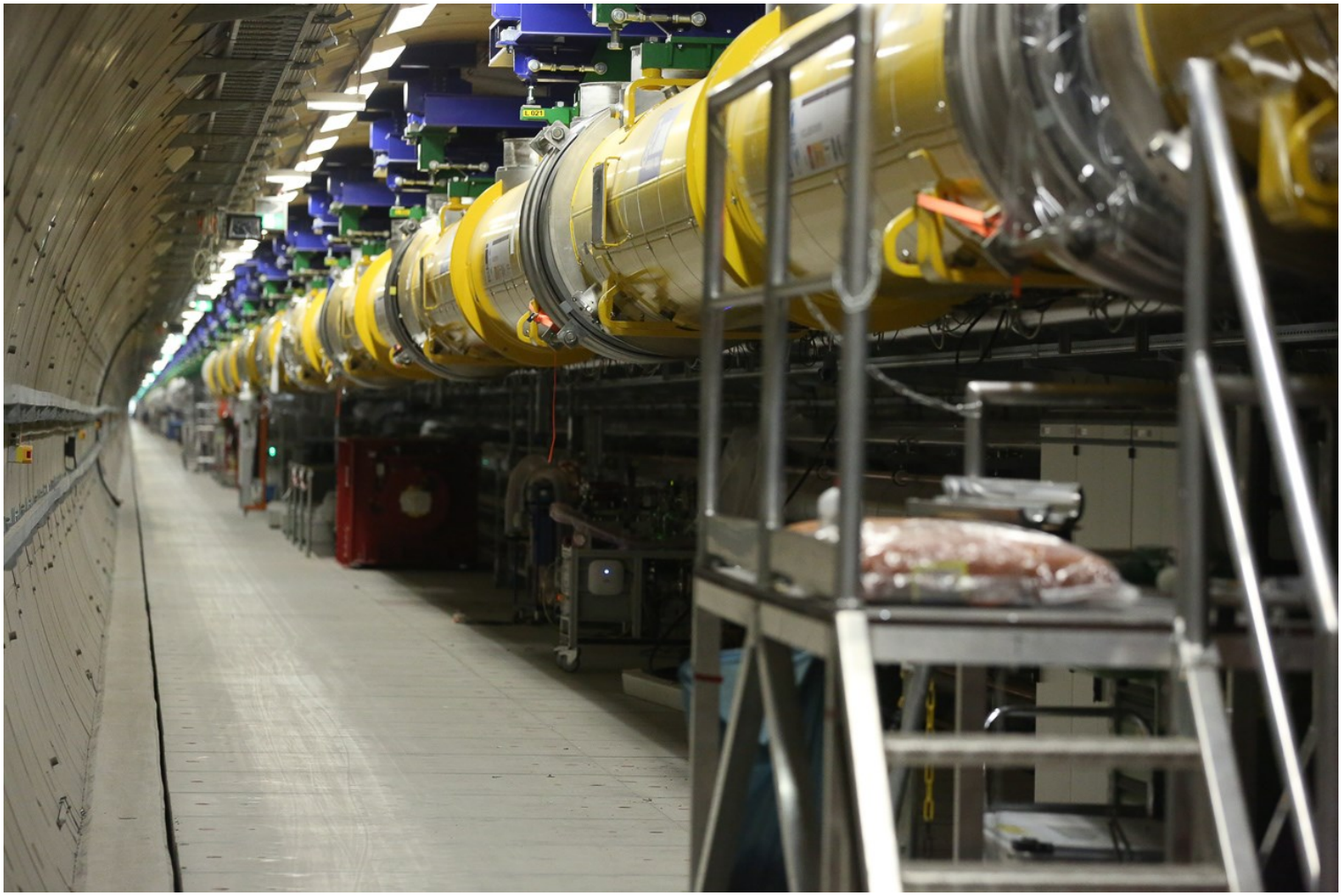
- Same LLRF system as used for AMTF/FLASH
- R&D basic principles for continuous wave and long pulse operation
  - Challenging: microphonic suppression
  - No pulse to pulse adaptations
  - Higher Ql > lower bandwidth
- Coupling of frequency and RF control much stronger
  - New control schemes / strategies required



Courtesy: R. Rybaniec

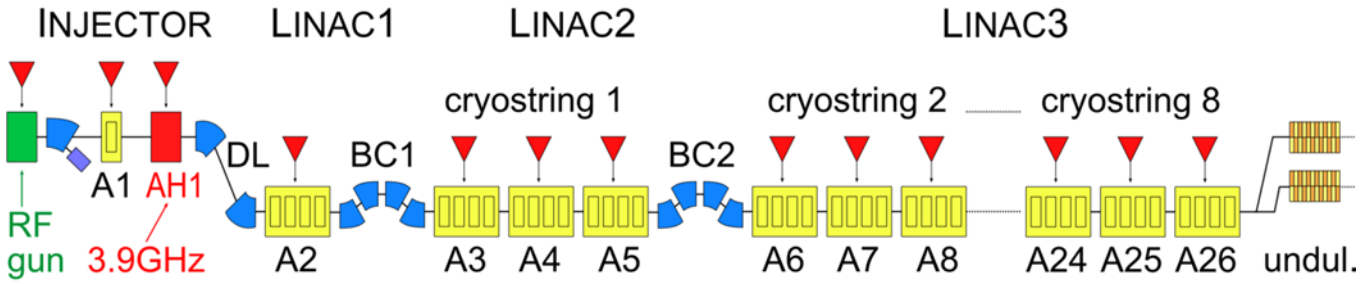
Talk tomorrow
R. Rybaniec

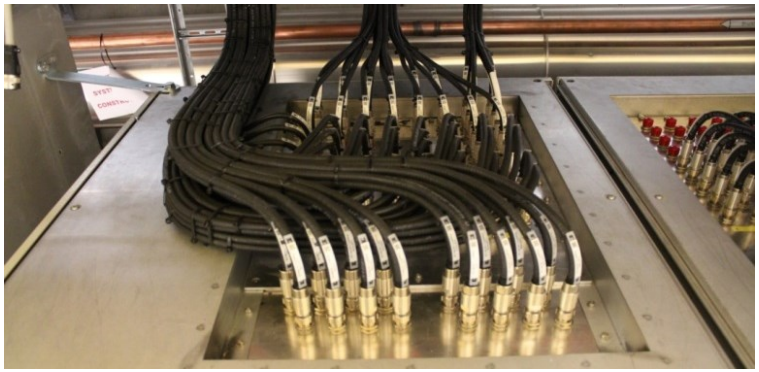
European *X*ray-*F*ree *E*lectron *L*aser



E-XFEL 808 SRF 1.3GHz / 8 SRF 3.9GHz / 1 NRF gun

- **European XFEL (808 SRF 1.3GHz / 8 SRF 3.9GHz / 1 NRF gun)**





- Currently injector commissioning, in parallel installation and pre-comissioning of the main linac components
- Complete in-tunnel installation for all LLRF components (except injector and MO)

LLRF system for XFEL

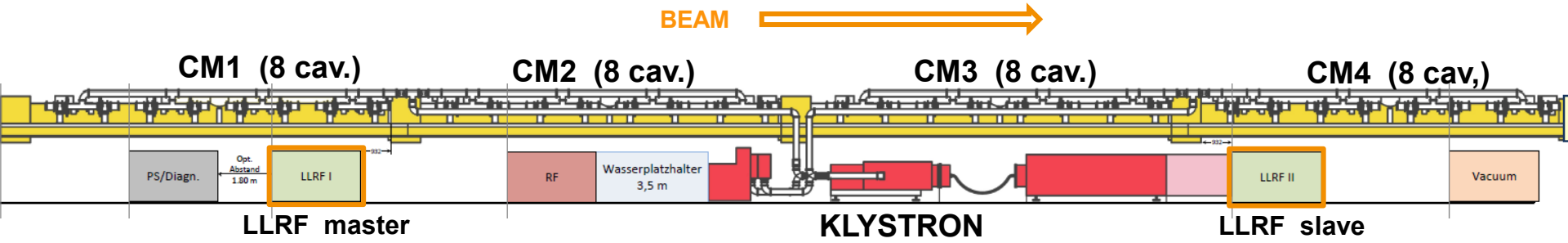
Courtesy: J. Branlard

- LLRF: DESY in-kind
  - 26 RF stations (808 cavities, 101 cryomodules)
  - MicroTCA.4 LLRF system, master / slave
  - Vector sum (32 cavities) RF control
  - 2 piezo per cavities (1kHz tuning)
  - Motorized cavity tuners
  - Motorized Q_L, one-time fixed power ratios

RF parameters:
- Pulse length 1.4msec (750 + 650 usec)
- Q_L = 4.6e6 (½ bw = 140 Hz)
- 10 Hz rep. rate
- ΔA/A = 0.01% ΔΦ = 0.01 deg.

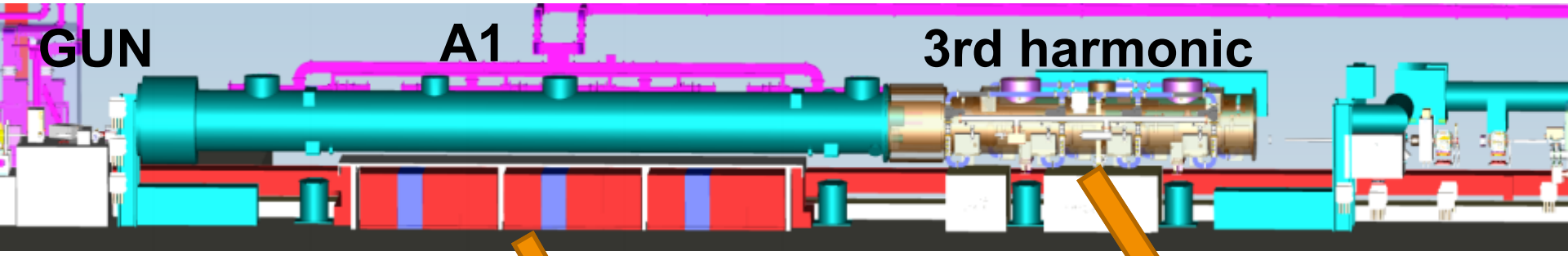
supporting modules

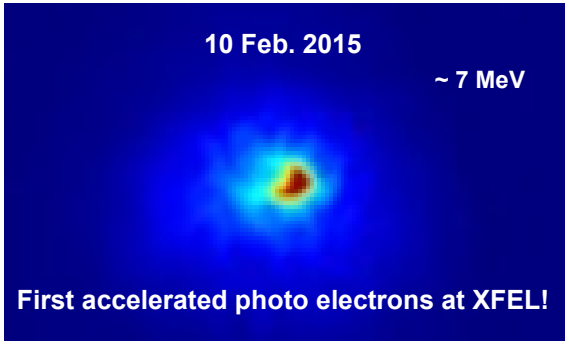
MicroTCA.4

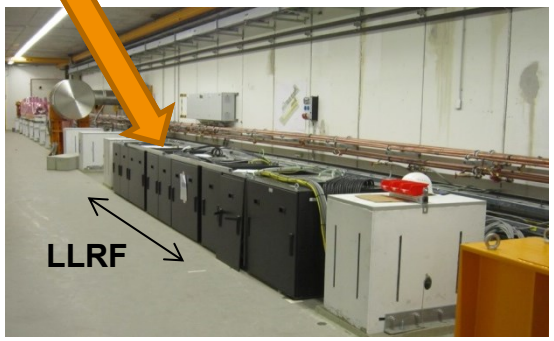


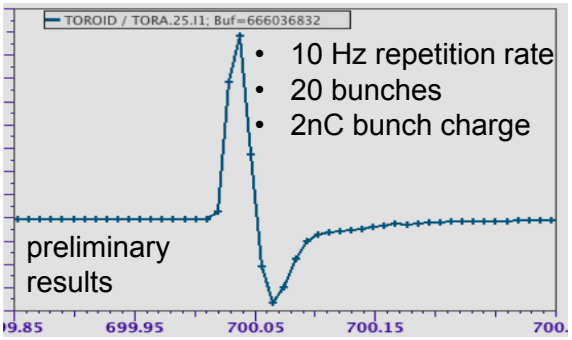
Injector setup and comissioning

Courtesy: J. Branlard









GUN:	commissioning since	Dec 2013	✓
A1:	installation	May 2015	✓
AH1:	installation	Sep 2015	✓
Injector:	cool down	Nov 2015	

Summary

- Several facilities in DESY which require LLRF support
  - Moved from prototype stage to mass production
  - Commissioning and maintenance work will increase dramatically in 2016
- FLASH and REGAE are running user facilities
  - Have a permanent monitor of system behavior and fault
  - Amount of lessons learned and bug fixes here are extremely important
- CMTB as test facility brings us to the next R&D project directions
  - New setups, cards can be tested here in a real system environment
- AMTF and XFEL
  - Permanent module test and system characterization
  - XFEL injector commissioning starts now => beam until the end of this year
  - Next year commissioning of the main linac (~ 50 MicroTCA crates fully equipped !)

Thanks for your attention