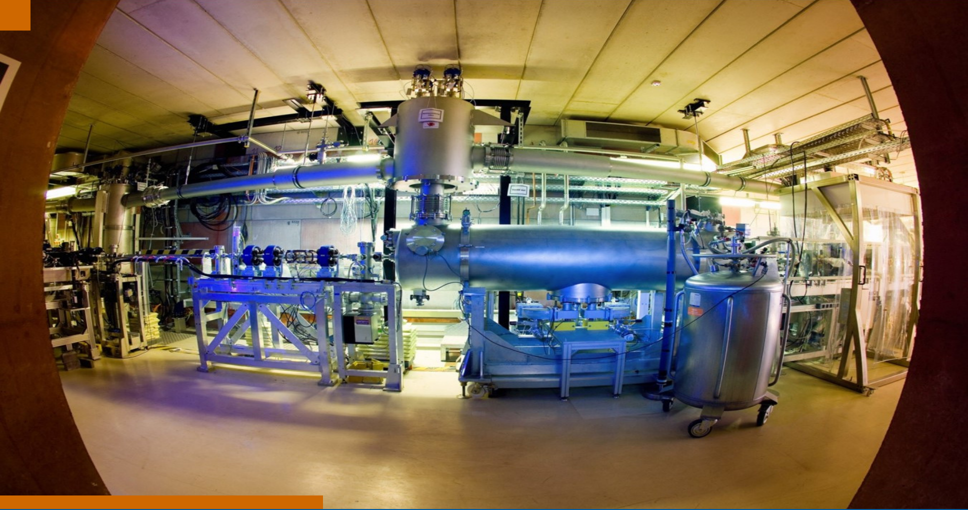


Digital LLRF Operation using MicroTCA at ELBE

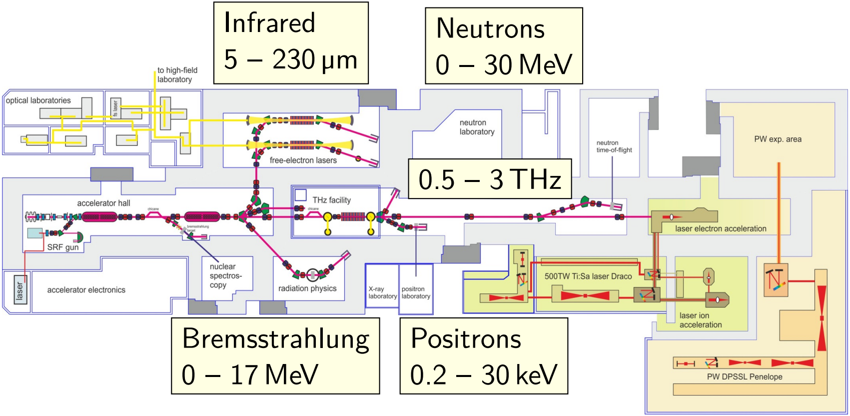
K. Zenker, R. Steinbrück, M. Kuntzsch

DESY: Ç. Gümüș, M. Hierholzer, S. Pfeiffer, C. Schmidt

HZDR

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

ELBE – Center for high power radiation sources



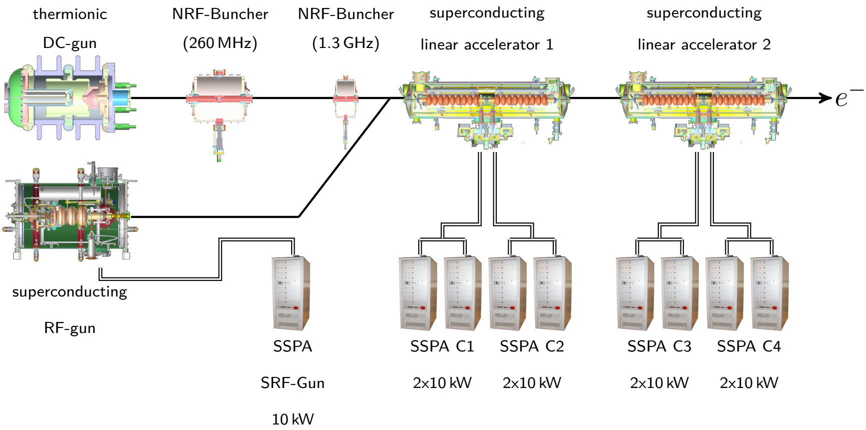
Characteristic:

- Multi-source facility
- Pulsed and CW mode operation

Example beam parameter:

- Beam energy: 8 MeV – 40 MeV
- Average beam current: 1600 µA

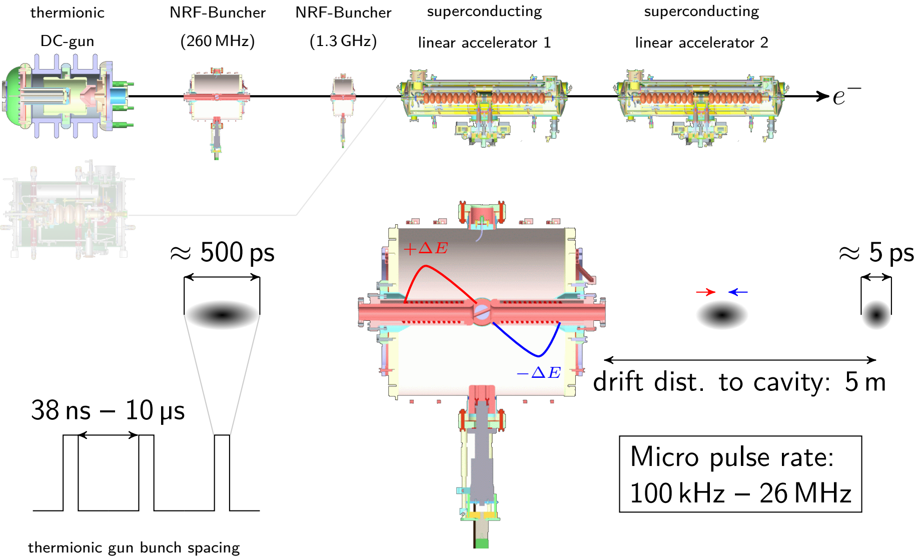
Accelerator



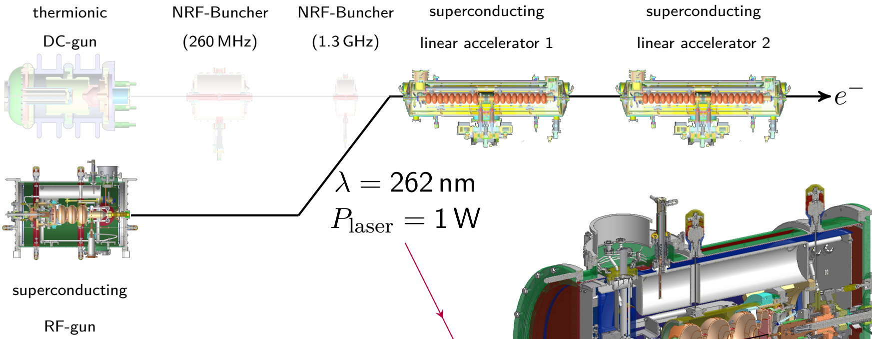
Cavity powering at ELBE

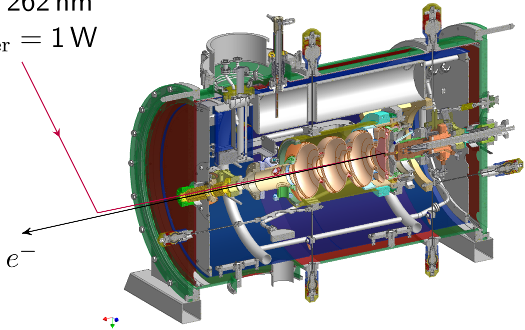
Individual SSPAs allow single cavity control in cw mode!

Accelerator



Accelerator





- RF power: 1 SSPA (10 kW)
- 3.5 TESLA cells
- Mg/Cs_2Te photo cathode
- Bunch charge up to 200 pC (potentially 1 nC)

⇒ See talk by J. Schaber (ARD Session IV)

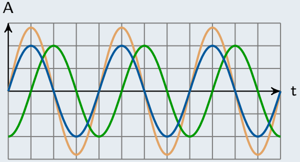
Digital Low Level RF (LLRF) at ELBE

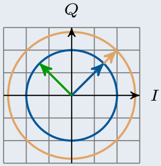
What is a LLRF?

Controller that stabilizes the RF field inside a cavity.

This means to control:

- Amplitude
- Phase





Motivation for the digital LLRF:

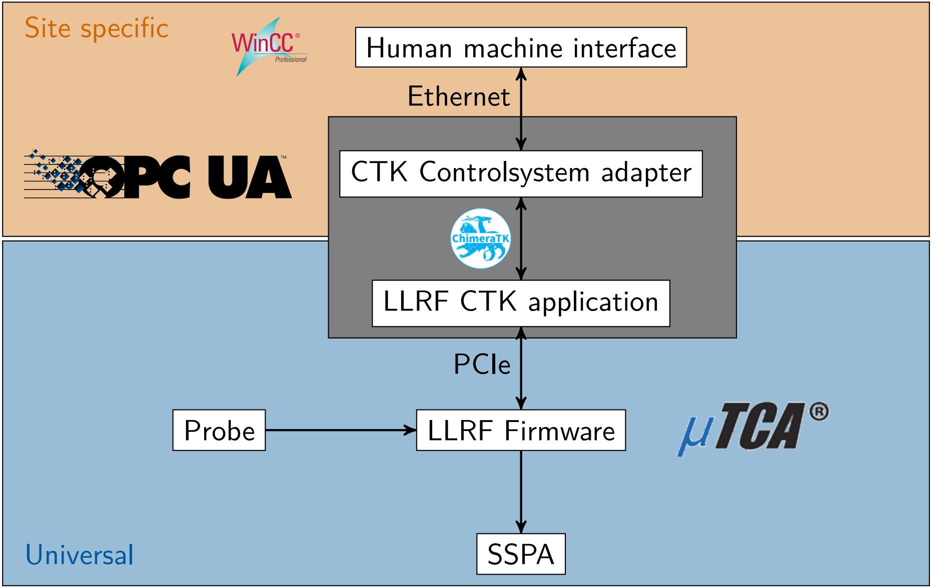
- Improve diagnostics
- Longitudinal beam based feedback
- Flexibility of the system
- Improve stability

Challenge:

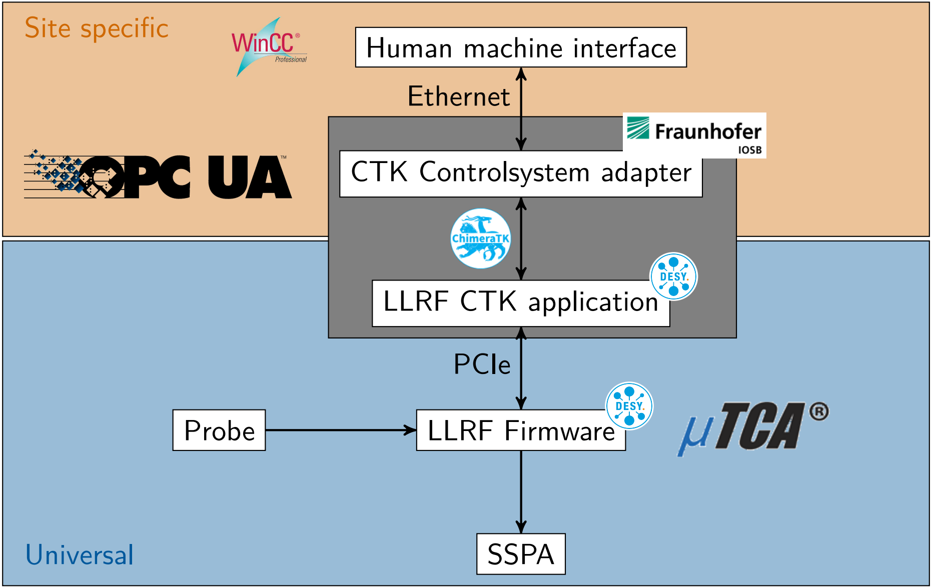
- Single cavity control
- CW and pulsed mode operation

$\Rightarrow$ We develop a **universal solution** applicable to other machines like MESA, TARLA,...

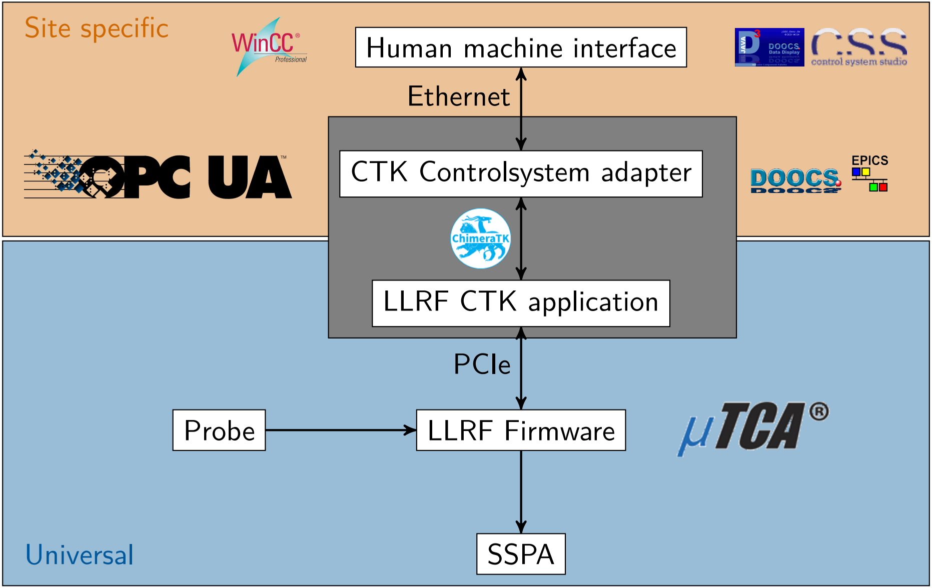
Universal implementation of the dLLRF



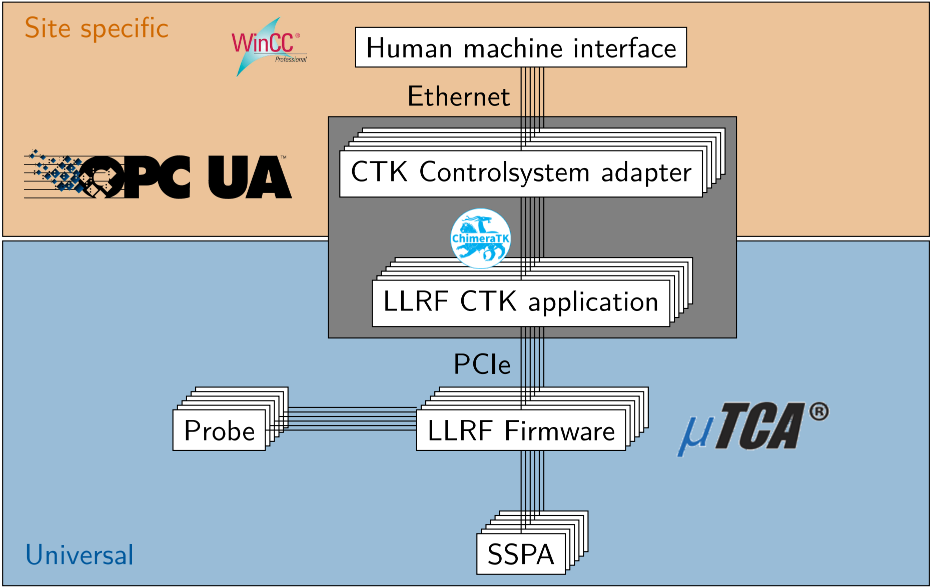
Universal implementation of the dLLRF



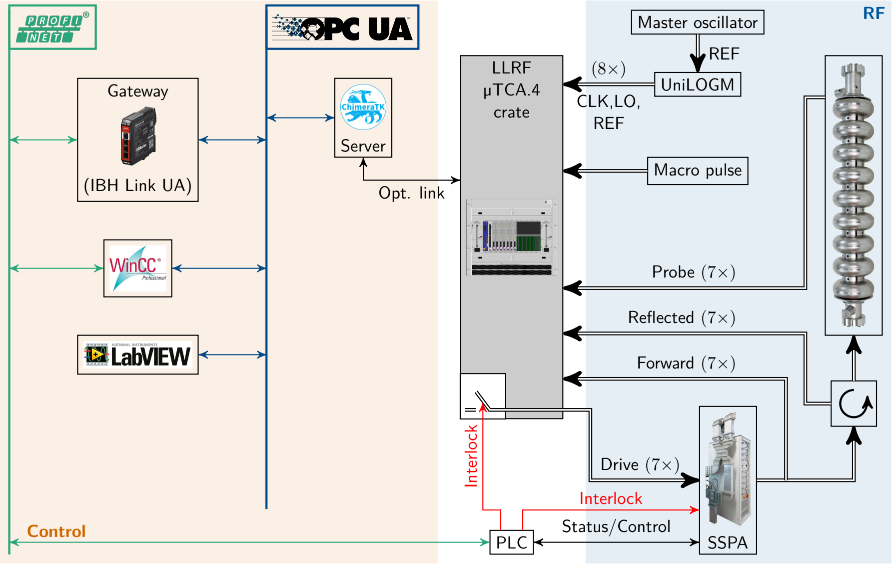
Universal implementation of the dLLRF



Universal implementation of the dLLRF



Integration into ELBE infrastructure



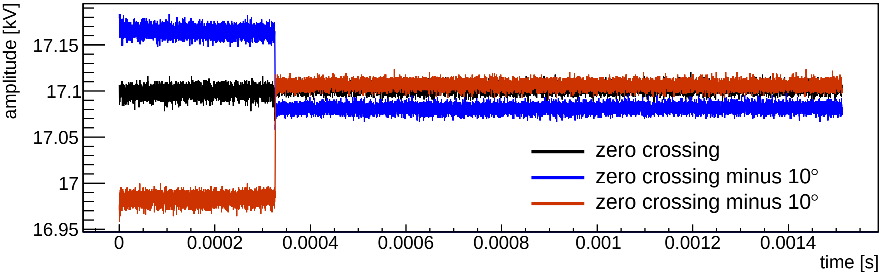
ELBE operation with dLLRF

What changed with the dLLRF in operation at ELBE?

- Look and feel did not change for operators
- More diagnostics improve beam tuning

Example:

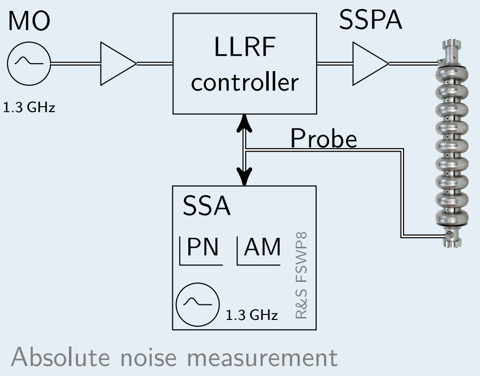
- Phase tuning of the buncher



Klaus Zenker | Institute of Radiation Physics | http://www.hzdr.de

Out of loop measurement of Amplitude Modulation and Phase Noise

Out of loop: Measurement of the probe signal with respect to the internal reference of the signal source analyser.



- Includes all noise sources in the control loop

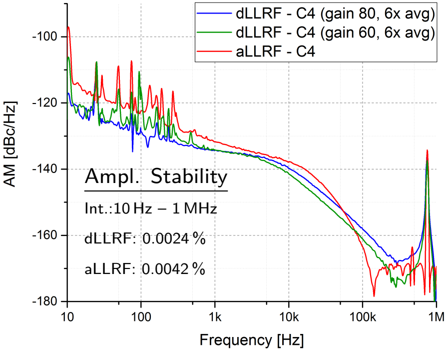
$\Rightarrow$ MO is the dominant noise source below 10 Hz

Member of the Helmholtz Association
Klaus Zenker | Institute of Radiation Physics | http://www.hzdr.de

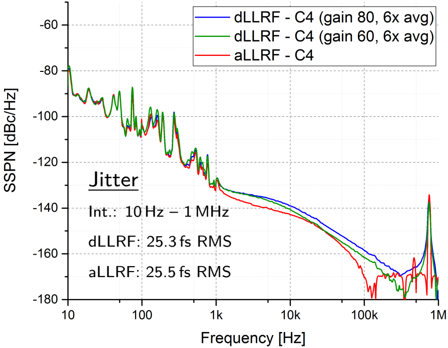
Noise measurements for a 1.3 GHz SRF cavity

Absolute noise measurement with p-controller and Notch filter

Amplitude:



Phase:



Controller performance:

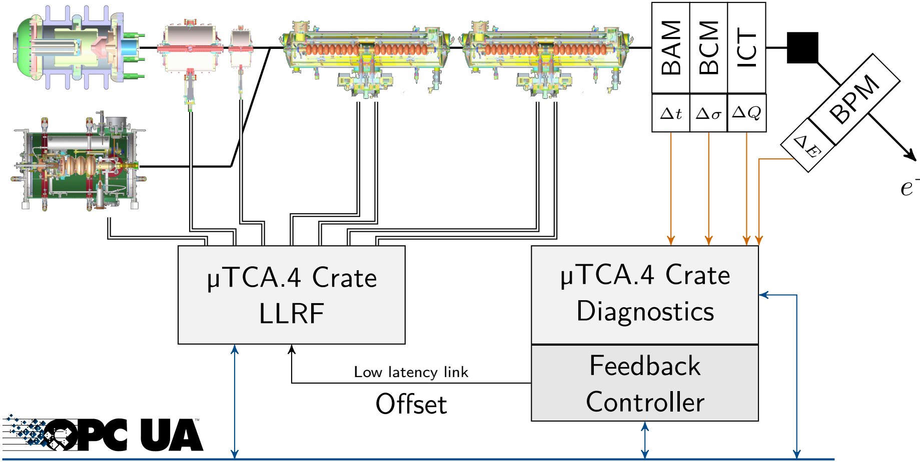
- Phase noise of dLLRF is similar to aLLRF phase noise
- Amplitude modulation of dLLRF is reduced by about 10 dB

Summary

Digital low level RF at ELBE:

- ✓ Integration into machine protection system
- ✓ Integration into HMI (WinCC)
- ✓ Controller design for all super conducting RF cavities and the normal conducting buncher cavities
- ✓ Digital LLRF in user operation
- Performance of the digital LLRF is comparable to the analogue LLRF
- Short development cycles thanks to our collaborators at DESY (LLRF Server+Firmware) and TUD/IOSB (OPC-UA)

Outlook

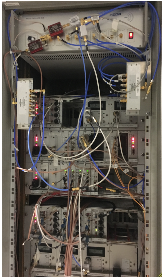


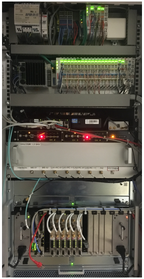
Beam based feedback:

- Diagnostic crate design and firmware
- ChimeraTK diagnostics application
- Feedback controller

Backup

Why replacing the analogue with a digital LLRF?





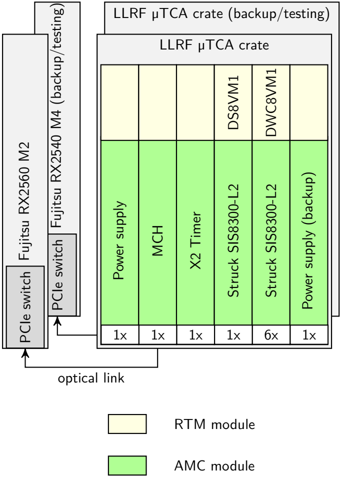
Analogue LLRF:

- Components are partly not available anymore / will not be available in future
- The system can not cover 360° for phase shift

Digital LLRF:

- Improves diagnostics
- Improves phase and amplitude stability (at least long term)
- Allows implementation of a longitudinal beam based feedback system

Components of the digital LLRF at ELBE



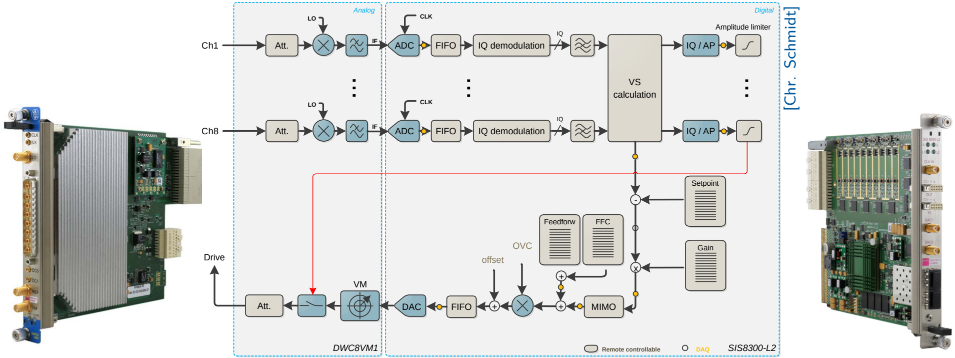
Hardware:

- Master oscillator: 1.3 GHz (REF), 260 MHz (REF), 78 MHz (CLK)
- UniLOGM: $8\times$LO (1.3 GHz$+54^1/_6$ MHz), $8\times$CLK (65 MHz), $8\times$REF (1.3 GHz))

Software:

- Firmware for struck boards ⇒ LLRF controller (adopted for cw operation in collaboration with DESY)
- Control software for the LLRF ⇒ ChimeraTK (together with DESY)
- Adapter for ChimeraTK that is compatible with WinCC ⇒ OPC-UA Adapter (TU Dresden, now IOSB Karlsruhe)

LLRF controller



- Per cavity/buncher: forward, reflected, probe, reference are sampled
- Control loop is based on vector sum signal ≡ probe signal
- Remote control and DAQ via ChimeraTK LLRF server (developed at DESY)