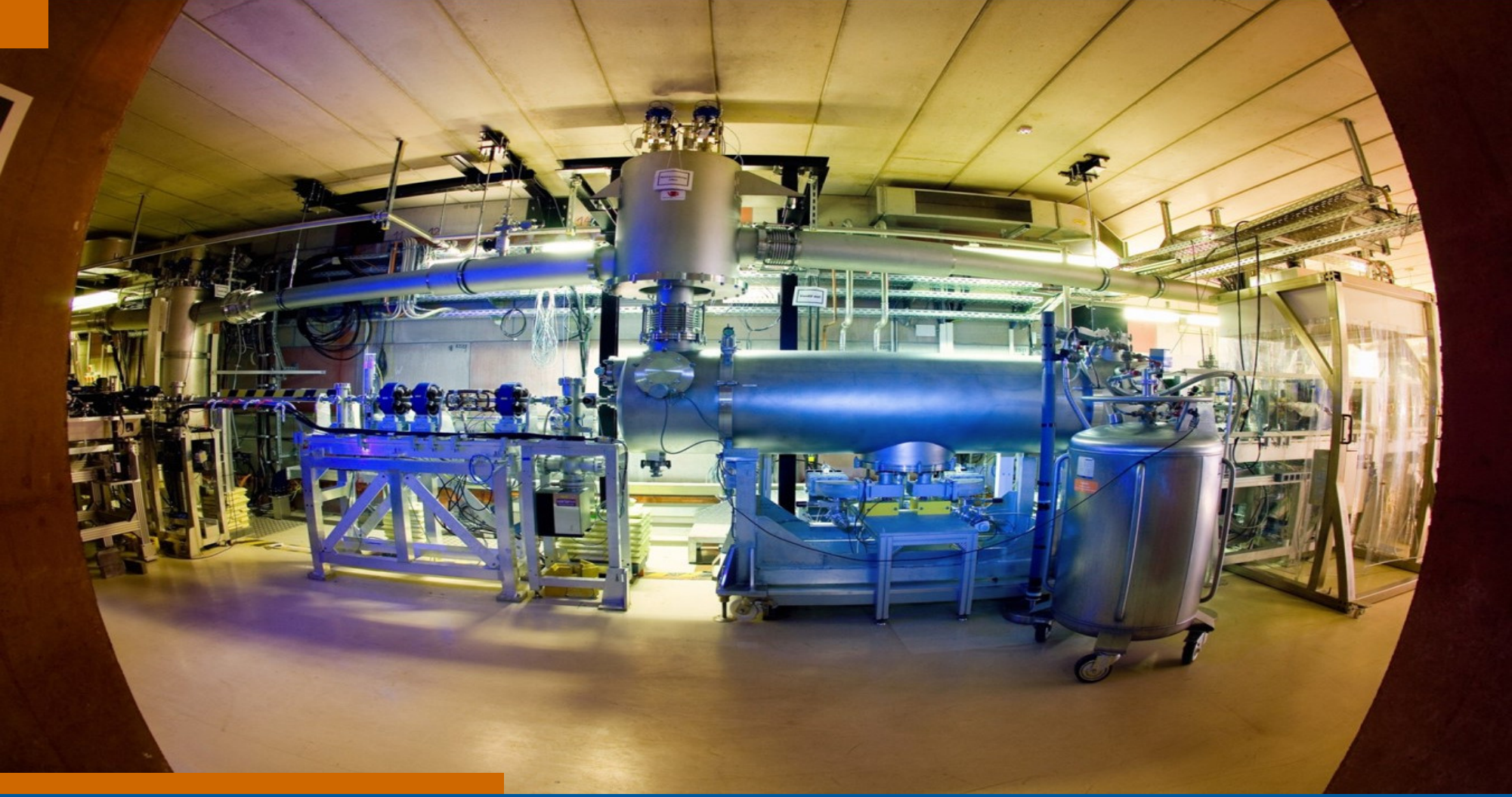


The MicroTCA.4 based LLRF system for CW operation at ELBE

Klaus Zenker, MicroTCA Workshop, 03.12.2020

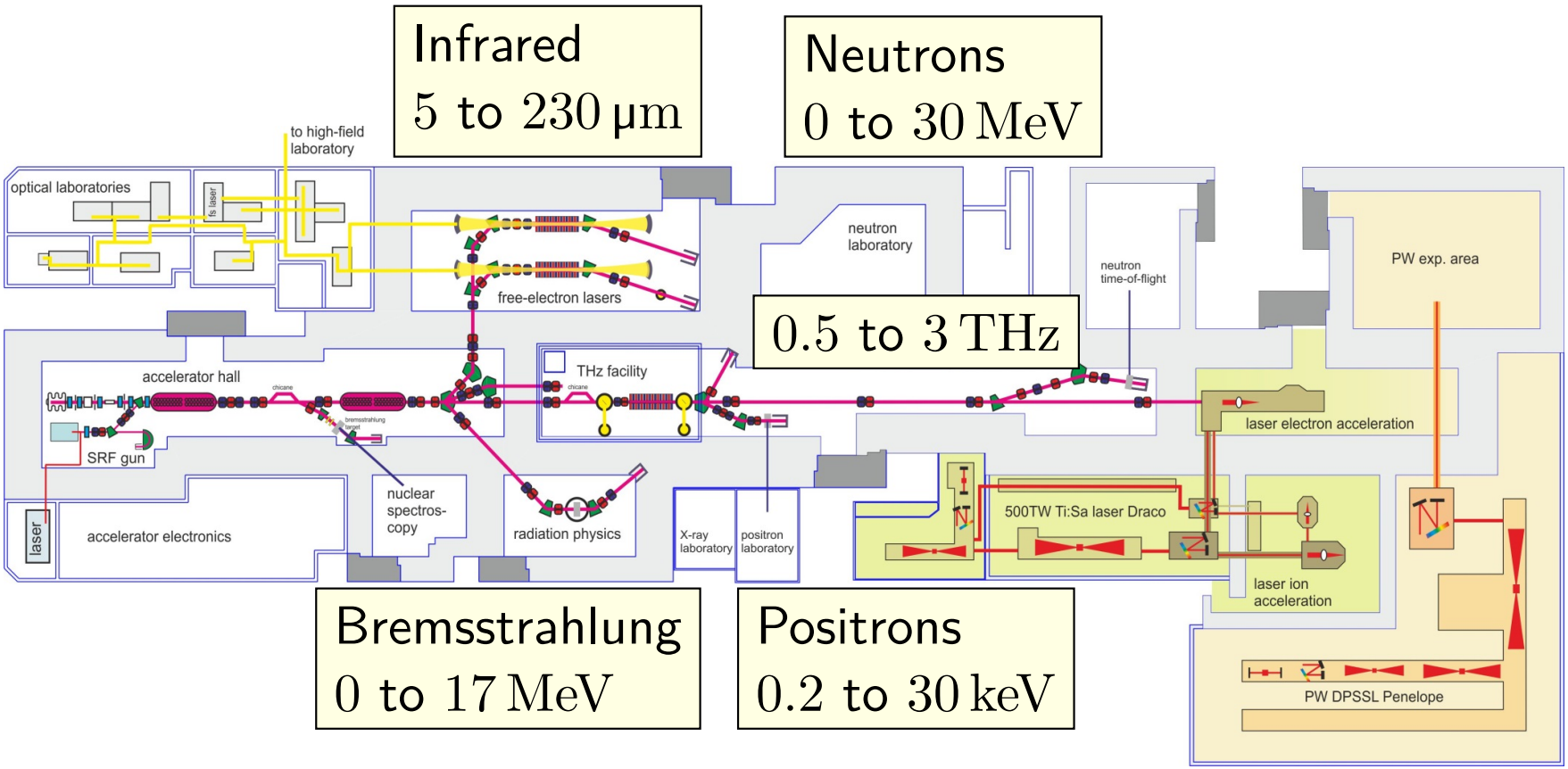
HZDR

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Member of the Helmholtz Association

ELBE – Center for high power radiation sources

e^- flow since almost 20 years



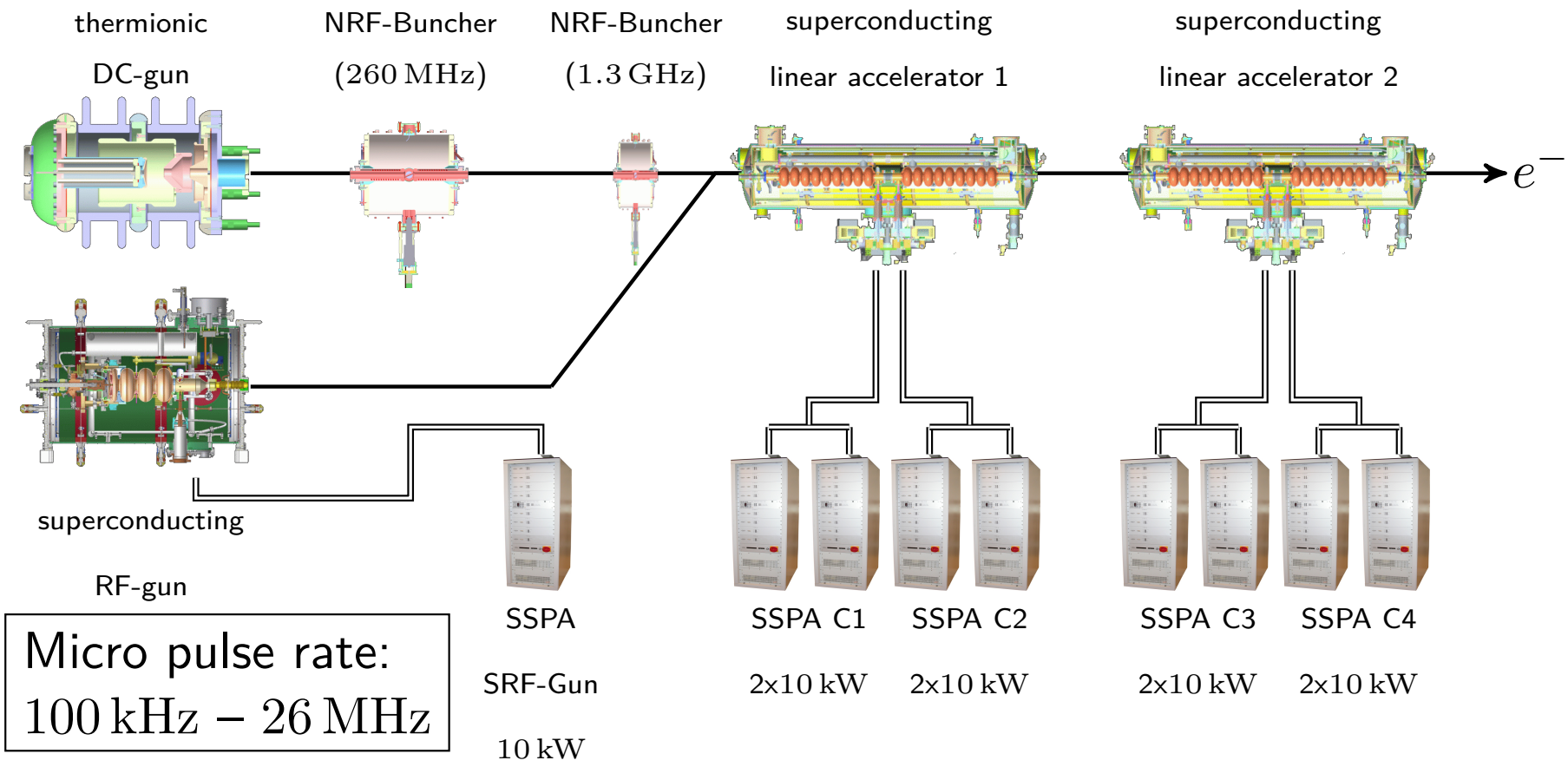
Characteristic:

- Multi-source facility
- Pulsed and CW mode operation

Example beam parameter:

- Beam energy: $8\,\mathrm{MeV}$ to $40\,\mathrm{MeV}$
- Max. average beam current: $1.6\,\mathrm{mA}$

Accelerator

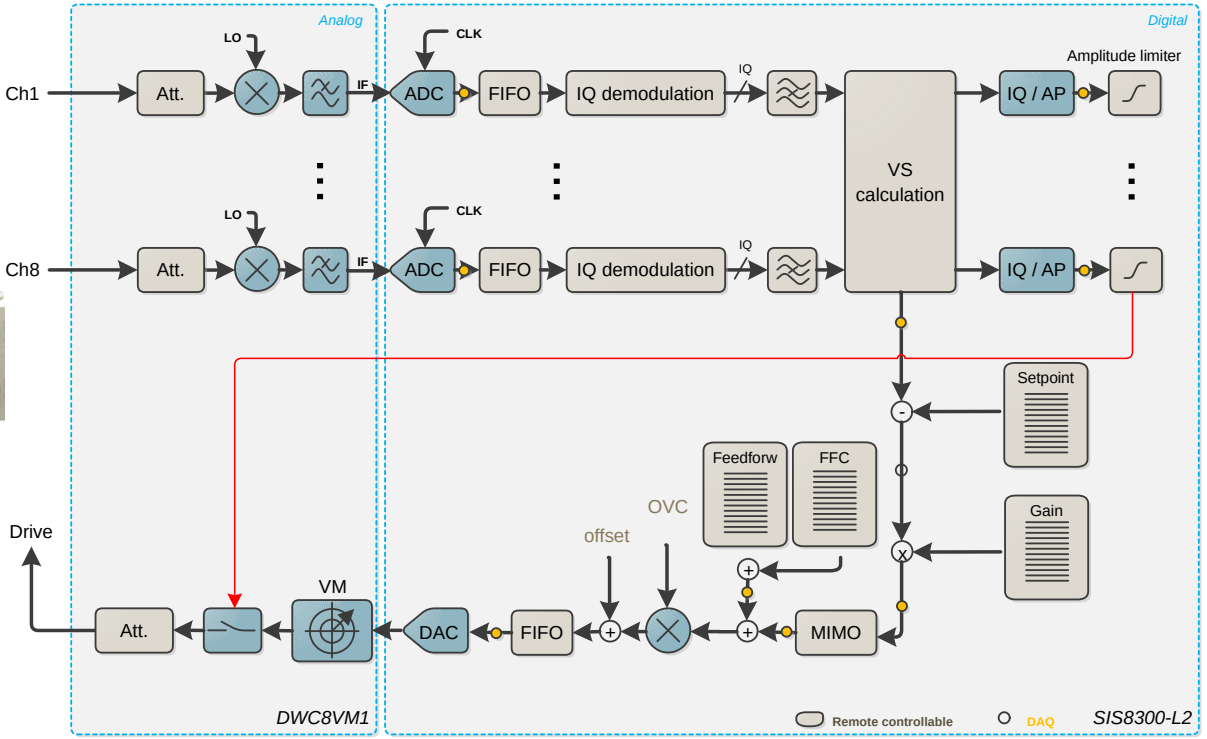


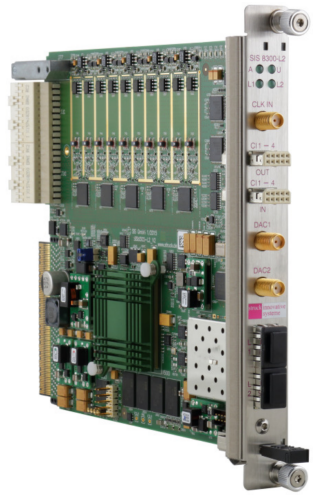
Micro pulse rate:
100 kHz – 26 MHz

Cavity powering at ELBE

Individual SSPAs allow single cavity control in cw mode!

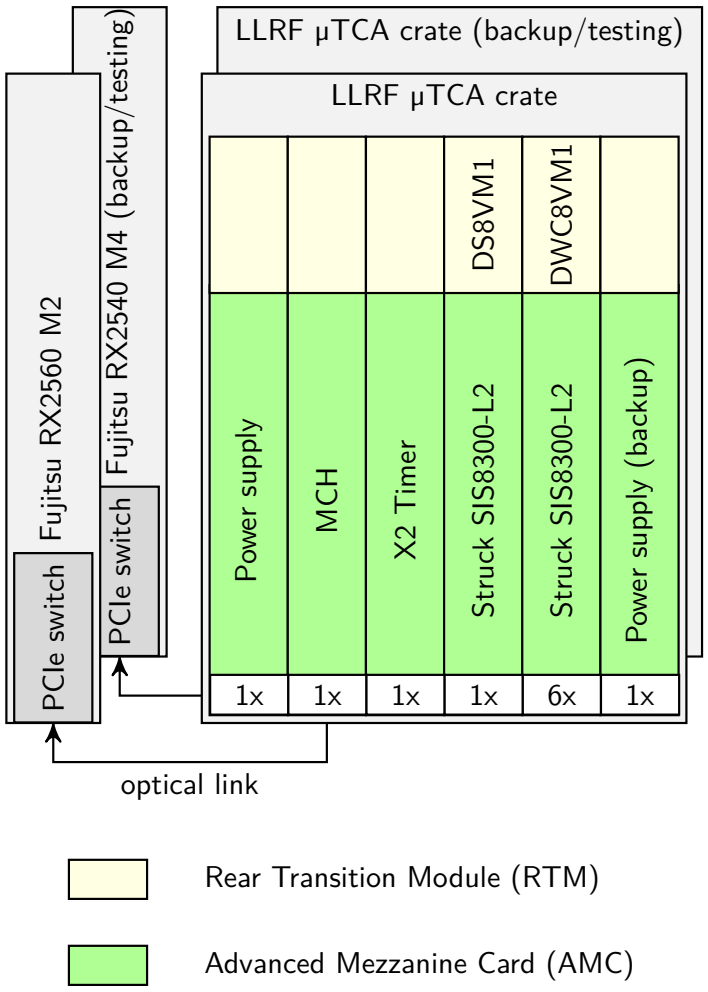
LLRF controller





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

Components of the digital LLRF at ELBE



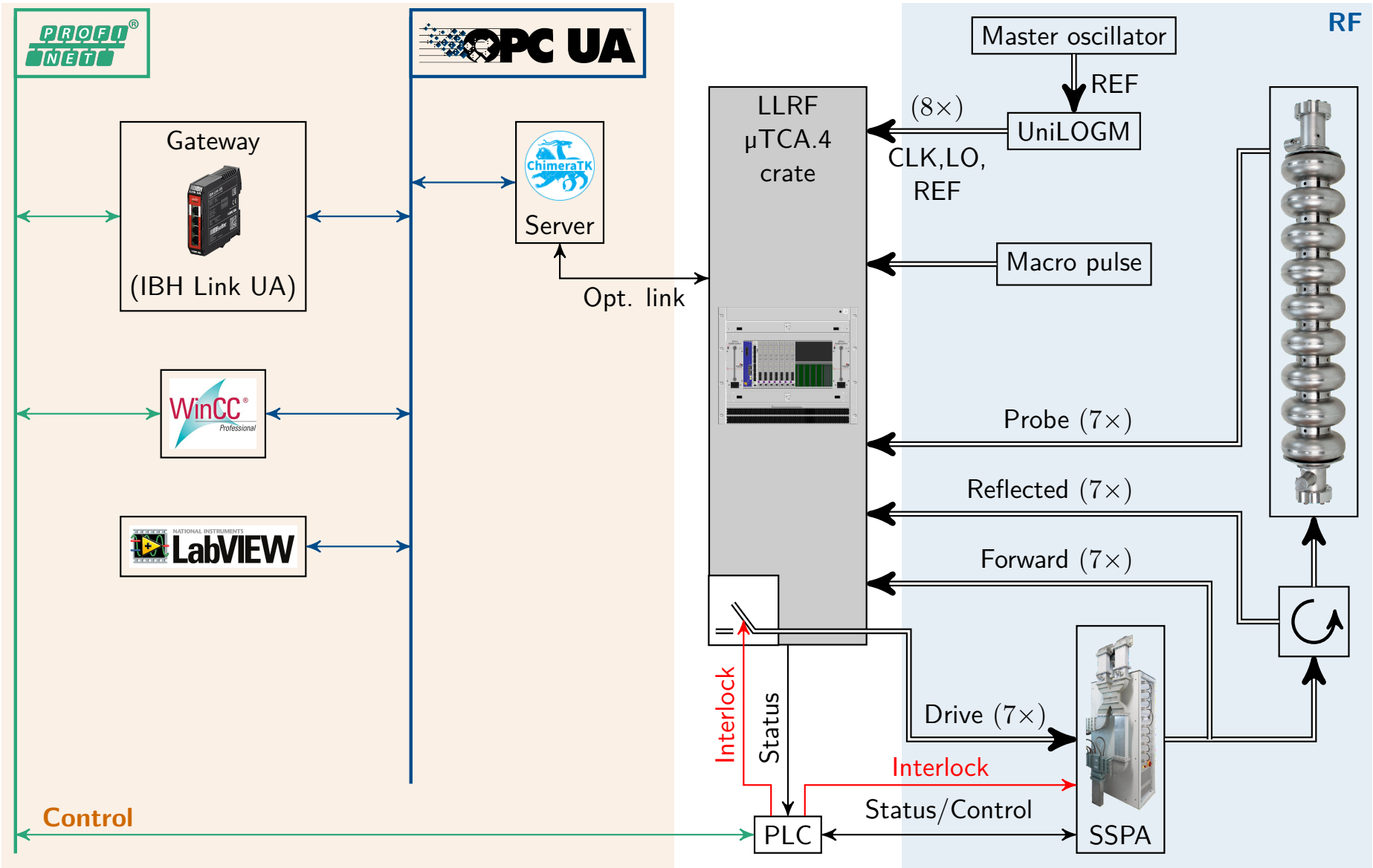
Hardware:

- Master oscillator: $1.3\,\mathrm{GHz}$ (REF), $260\,\mathrm{MHz}$ (REF), $78\,\mathrm{MHz}$ (CLK)
- UniLOGM: $8\times$LO ($1.3\,\mathrm{GHz}+54^{1}/_{6}\,\mathrm{MHz}$), $8\times$CLK ($65\,\mathrm{MHz}$), $8\times$REF ($1.3\,\mathrm{GHz}$))

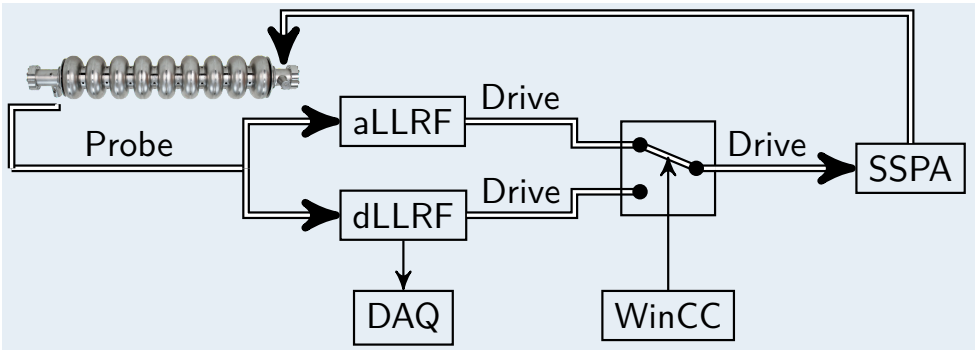
Software:

- Firmware for struck boards $\Rightarrow$ LLRF controller (adapted for cw operation in collaboration with DESY)
- Control software for the LLRF $\Rightarrow$ ChimeraTK (together with DESY)
- Adapter for ChimeraTK that is compatible with WinCC $\Rightarrow$ OPC-UA Adapter (TU Dresden and IOSB Karlsruhe)

Integration into ELBE infrastructure



User operation



Overview:

- Since August 2020 all ELBE beam paths/experiments are operated using the dLLRF
- Switching to the old aLLRF system is possible at any time

Performance:

- Phase stability of about $0.01°$ RMS ($23\,\mathrm{fs}$) (additive noise)
- Amplitude stability of $0.004\,\%$ RMS (additive noise)
- Long term beam energy variations of $0.05\,\%$ peak-peak (caused by temperature variations)

Future features

1. Measure the cavity detuning and bandwidth in CW mode
   - Andrea Bellandi (DESY) implemented a dedicated algorithm in the LLRF firmware
   - Algorithm was successfully tested at ELBE
2. Advanced Beam Based Feedback
   - Control the beam arrival time measured with a beam arrival monitor
   - Feedback via the LLRF controller
3. Improve long term stability
   - Improve temperature stability
   - Possibly use second tone based drift compensation
4. Improve ramp up procedure
   - Use firmware table rather than changing the set point in software
   - Possibly compensate detuning during ramp up via phase rotation $A\sin(\omega t) \rightarrow A\sin(\omega t + \phi(t))$

Summary

Digital LLRF at ELBE:

- In user operation since August without major problems
- First CW machine using the MicroTCA based digital LLRF system in user operation
- Huge improvement in terms of system flexible compared to the previous analogue system
- Performance of the dLLRF is good and meets requirements of future cw machines like MESA and TARLA

Acknowledgements:

- We thank DESY for the close collaboration in firmware and software development and general support.