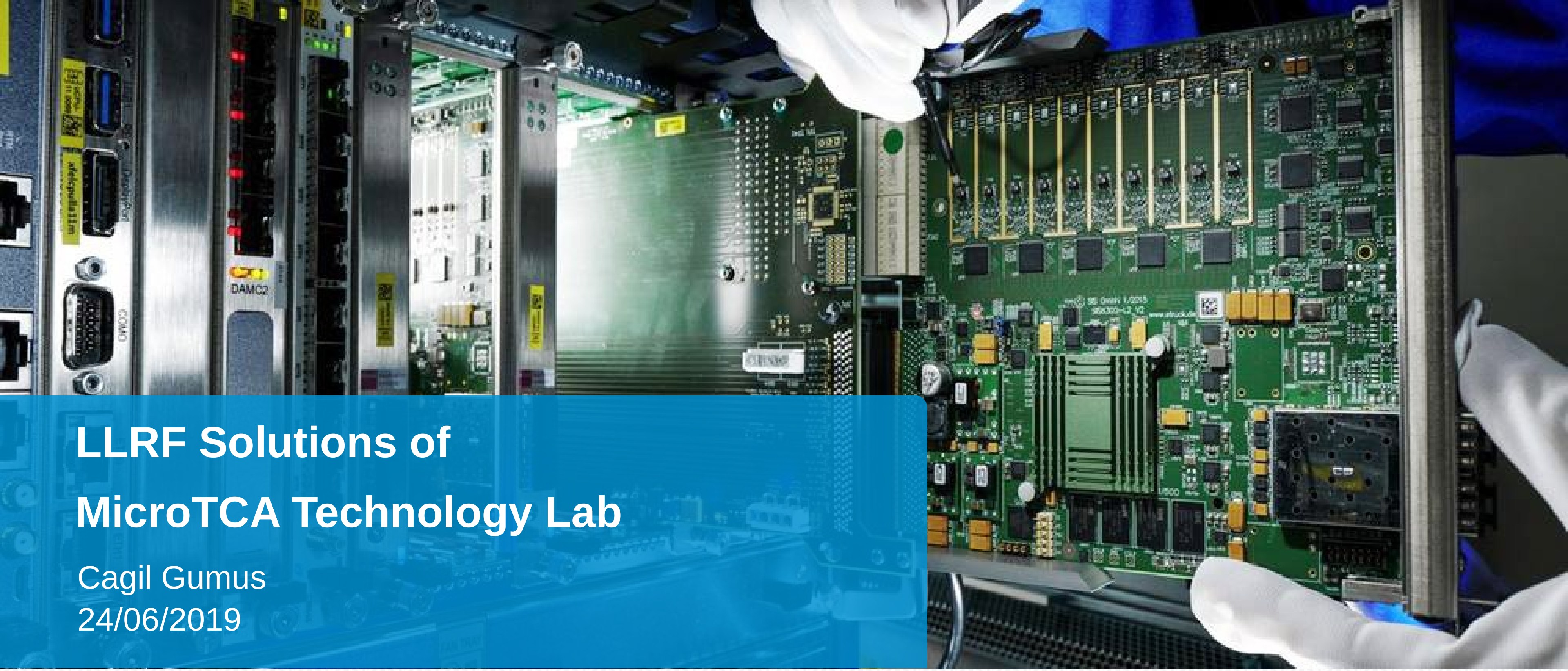


LLRF Solutions of MicroTCA Technology Lab

Cagil Gumus
24/06/2019

MicroTCA TECHNOLOGY LAB
A HELMHOLTZ INNOVATION LAB

DESY

Outlook

1. Our background in LLRF

2. Generic LLRF Control System Overview
   - Hardware
   - Firmware
   - Software + User Interfaces

3. Current LLRF Projects
   - Turkish Accelerator and Radiation Laboratory (TARLA)
   - Nuclotron-based Ion Collider Facility (NICA)

MicroTCA Technology Lab

- Close collabration with largest LLRF Control Group in the world
  - >60 FTE (~25 FTE for LLRF)
- MSK Responsibilities;
  - LLRF Control Systems for Accelerator Structures
  - Special Diagnostic Devices
  - Beam Stabilization Systems (transversal/longitudinal) in storage rings & linacs
  - Timing for pre-accelerator systems

RF Control

- Amplitude (rms) stability of **0.01%**
- Phase (rms) stability of **0.01°**
- Any arbitary pulse shape to CW RF operation
- Low latency (<2us) control loop on FPGAs
- MIMO + P controller for fast RF Feedback
- Realtime Q_l and detuning calculation
- Fast RF gating with external or internally generated interlock
- Single cavity or multicavity (vector sum) regulation options
- External timing synchronization available **(Whiterabbit & MRF possibilities)**

Resonance Control Specs

- Motor controller/driver FMC solutions available
- Piezo control/sensor on DRTM-PZT4
- Fast feedback on Piezo actuation using cavity information
- Advanced microphonic compensation techniques

Example LLRF Control using MicroTCA.4

[1]

[2]

[2]

Simple ———► Complex

Starter LLRF Setups are now available!

[1] Picture taken from: vadatech.com

[2] Picture taken from: schroff.nvent.com

Example LLRF Control using MicroTCA.4

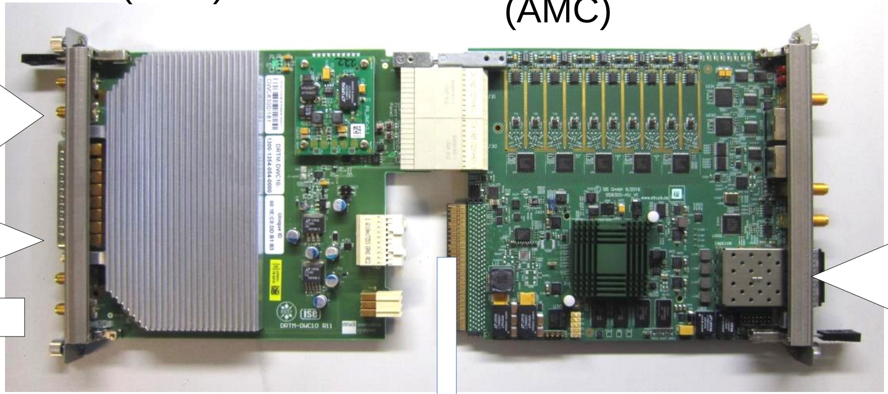
RF Front end
(RTM)

Digitizer/Controller
SIS8300 -xx w/
Virtex6 or Kintex
Ultrascale FPGA
(AMC)

Cavity signals

Reference

Drive



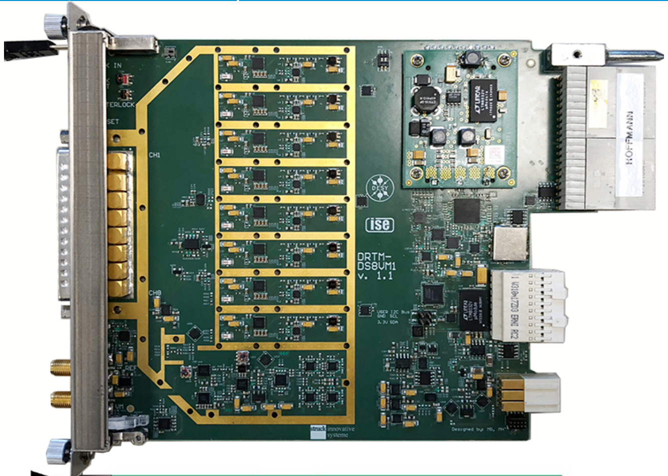
External Trigger

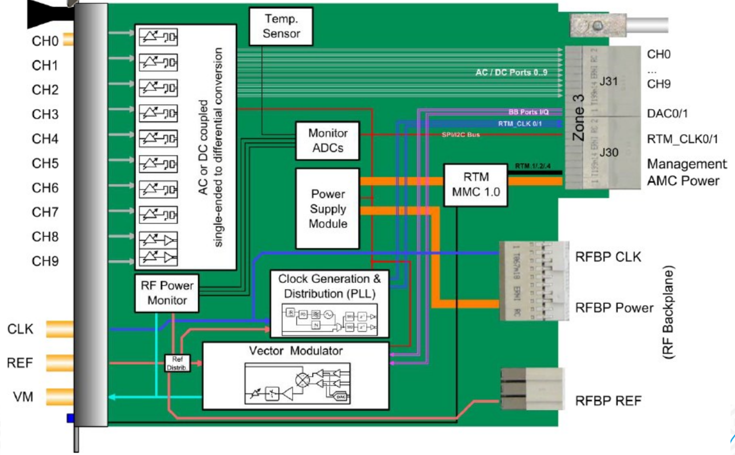
To CPU via PCIe

DRTM-DS8VM1

RF Front-end:

- 8 analog input channels (5 to 700 MHz) with phase resolution of 0.050°at 700MHz
- 2 analog input channels (DC to 400 MHz) with phase resolution of 0.05°at 400MHz
- One high frequency vector modulator channel (0.05 to 1.0 GHz) with modulation bandwidth from DC to 50 MHz
- Ultra-low jitter clock generation using on-board PLL
- Board was designed by DESY and is licensed to and produced by Struck





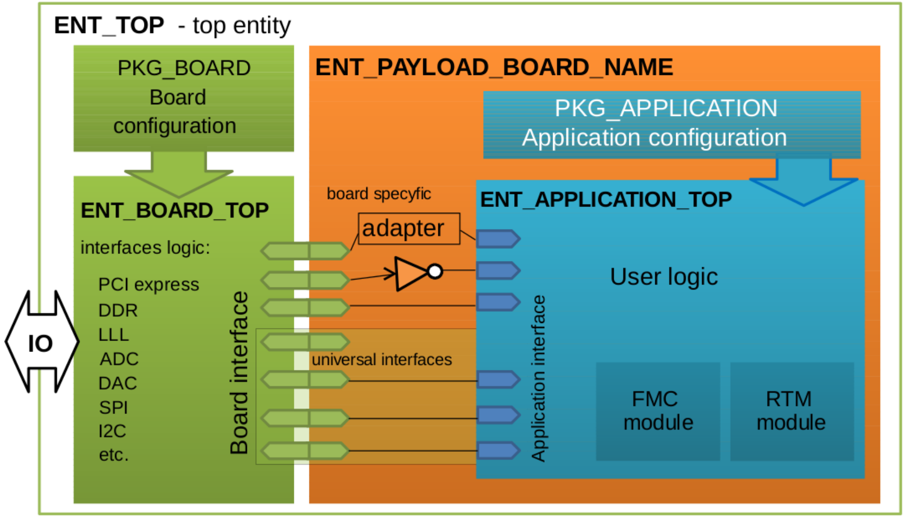
DRTM-DWC8VM1

RF Front-end:

- Input frequency range: L and S Band
- Output frequency range: L, S and C Band
- Short term amplitude stability 0.003% in the range 10 Hz – 10 MHz at 1.3 GHz
- Short term phase stability 4 fs in the range 10 Hz – 10 MHz at 1.3 GHz
- Board ws designed by DESY and is licensed to and produced by Struck

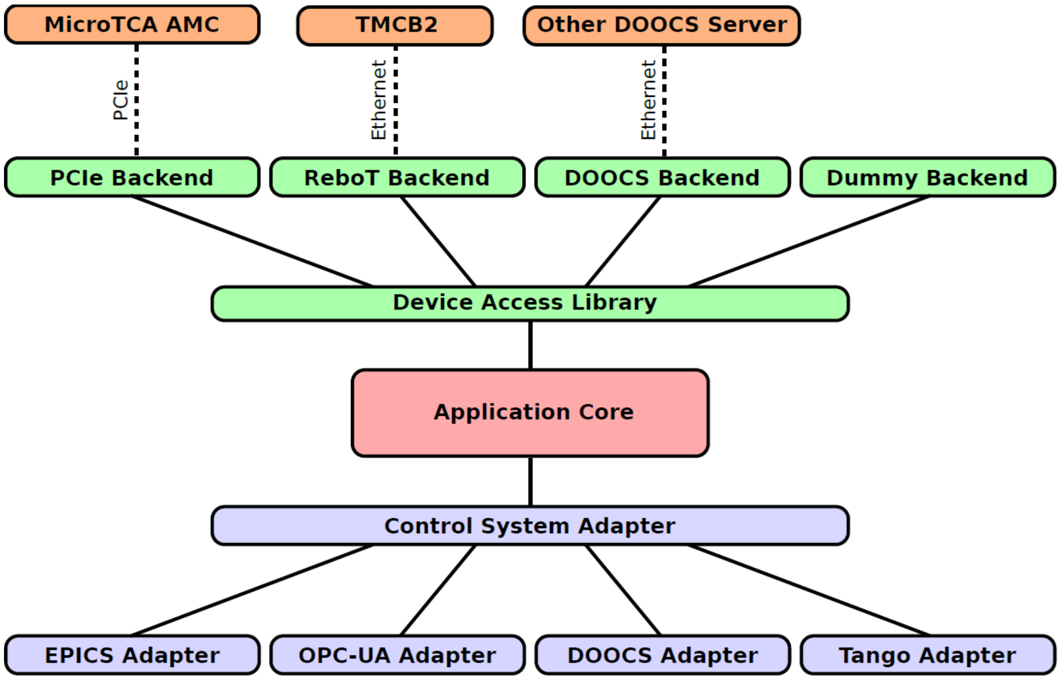
FPGA Firmware Framework

- **547,769** Lines of VHDL code accumulated over 15 years
- Maintained by DESY + other Helmholtz Labs
- Abstraction between board and application level + modular approach
  - >90% of similar code across different projects
- IP-core approach → Easy integration to your custom solution



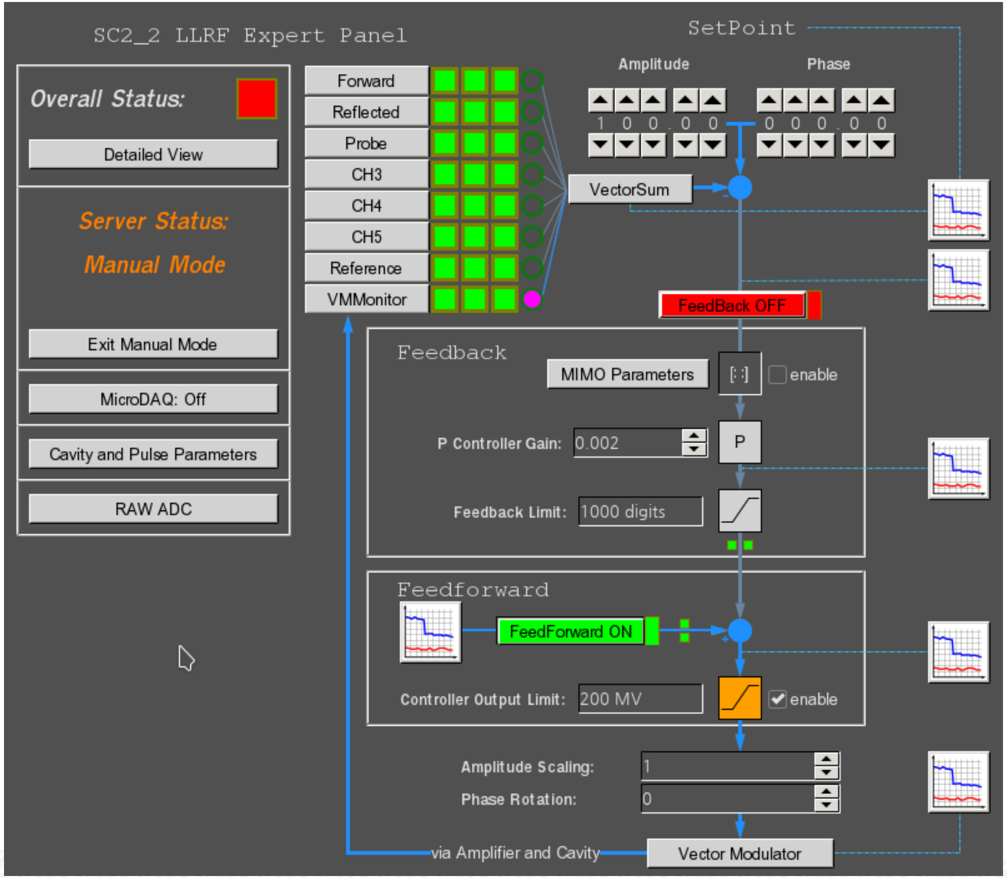
Software

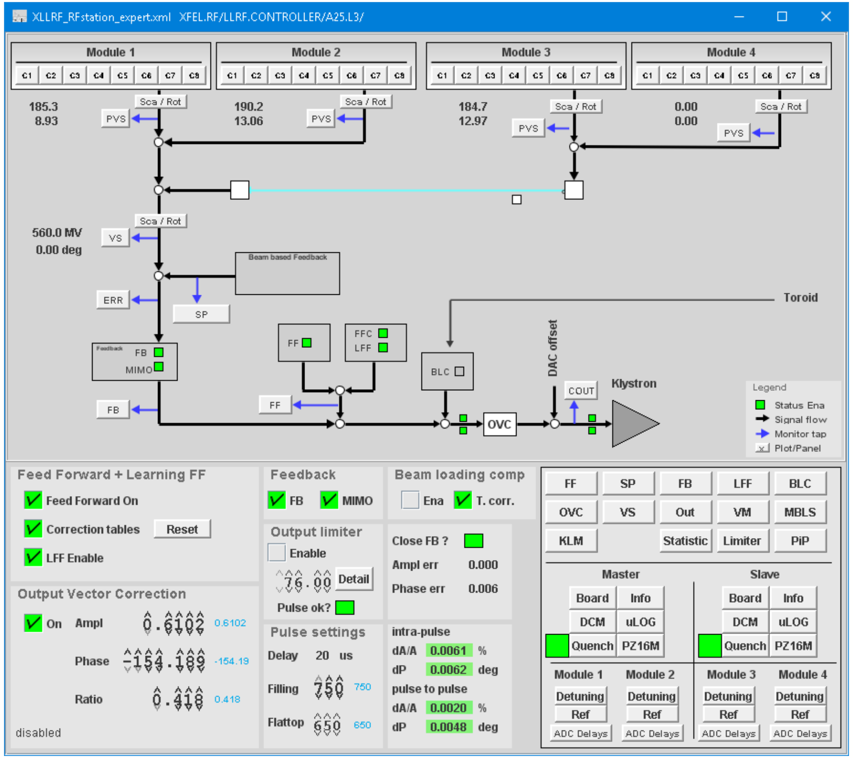
- Abstraction layer between specifics of underlying system
- Same code for all facilities
- Hooking the server to many different control systems
  - EPICS,
  - OPC-UA,
  - DOOCS,
  - TANGO
  - <insert_your_control_system>



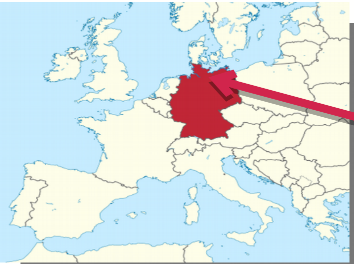
https://github.com/ChimeraTK

User Interface

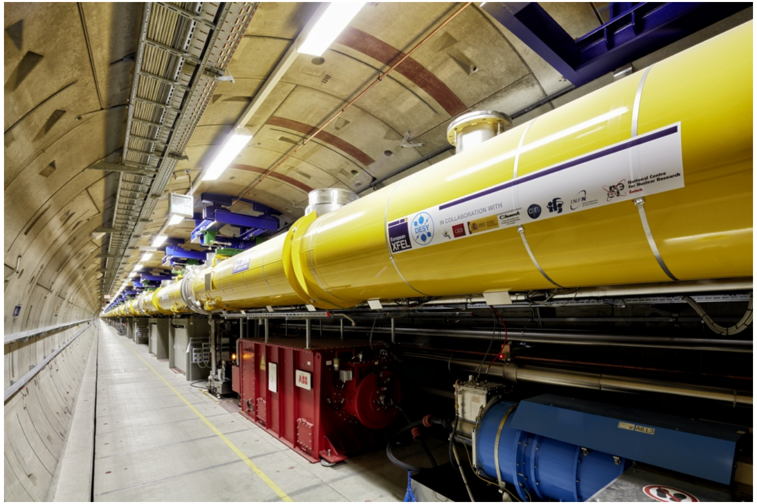




MicroTCA in European XFEL



- Biggest success story of MicroTCA
- 800 Superconducting Cavities
- Over 200 MicroTCA Crates (> 2000 components)
  - LLRF
  - Synchronization
  - Timing
  - Beam Diagnostics
  - ...

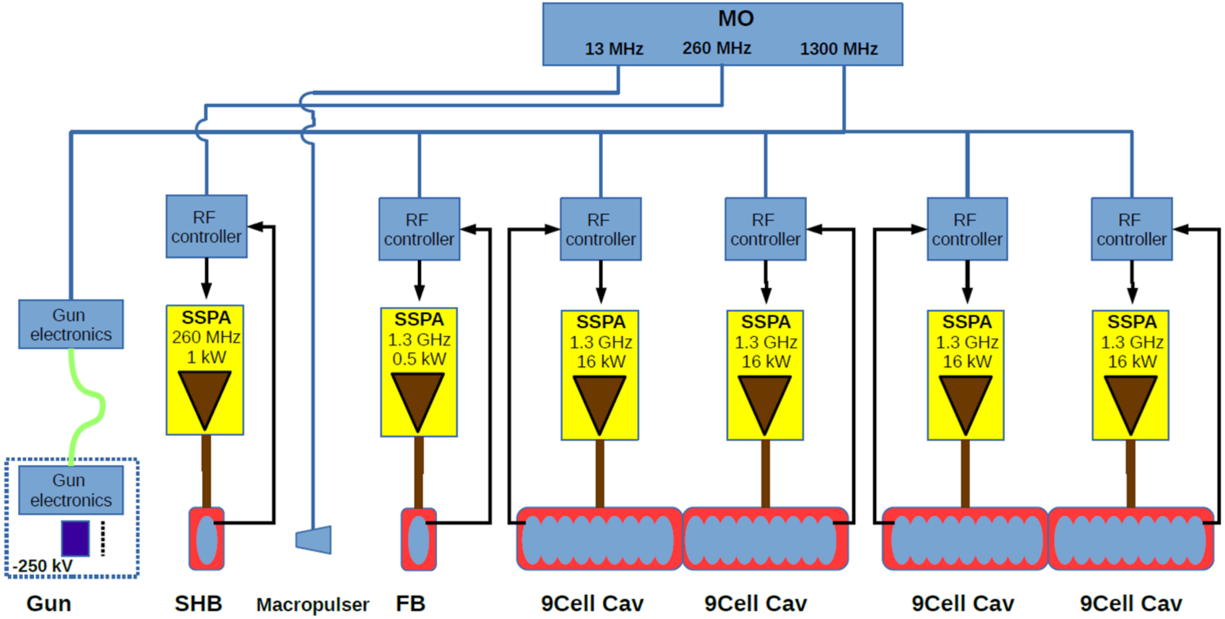


LLRF Project Examples

LLRF Project Examples

Turn-key LLRF System for the entire LINAC [1].

- Turkey's First Particle Accelerator
- 40MeV Free Electron Laser + Bremsstrahlung Radiation line
- Overall design is similar to ELBE accelerator in Dresden/Germany (HZDR)
- EPICS as Control System
- CW RF operation
- SSPA's for amplification

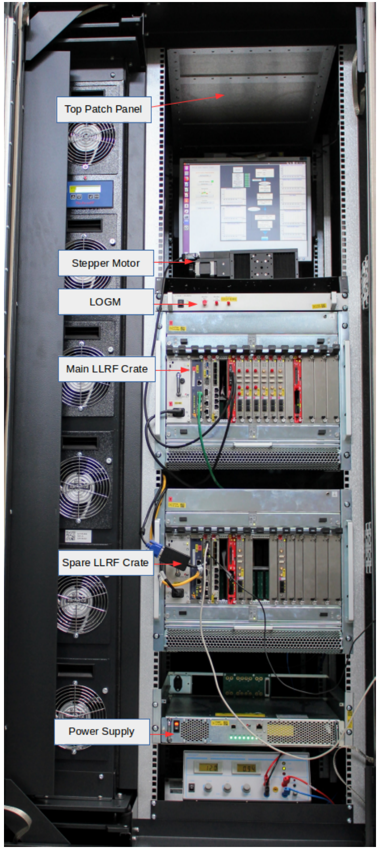


[1] C. Gumus et al., "Design and Status of the MicroTCA.4 Based LLRF System for TARLA" in IPAC'18, Vancouver, Canada

TARLA – LLRF System Overview

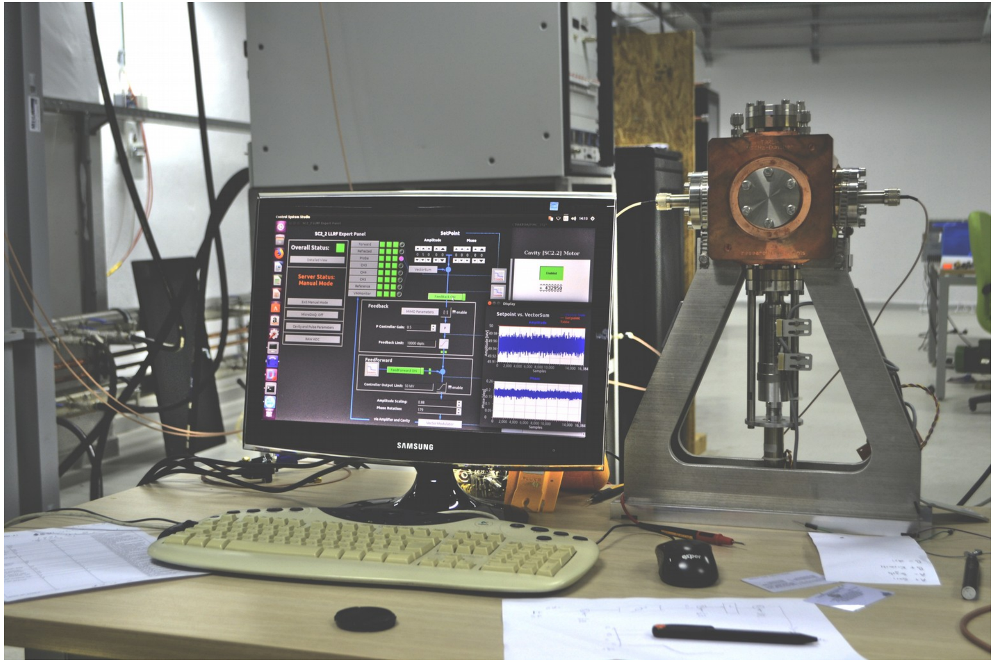
Turn-key LLRF System for the entire LINAC.

- 6 Cavity RF Regulation
  - 4x Superconducting 1.3 GHz Tesla type cavities
  - 1x Normalconducting 1.3 GHz Buncher cavity
  - 1x Normalconducting 260 Mhz Subharmonic Buncher Cavity
- Resonance Control
  - Stepper Motor control on all cavities
  - Piezo Actuator/Sensor control on SC cavities
- Drift Compansation Module for CW RF Operation



TARLA – Latest Status

- Main construction finished including clean room
- Cryogenic system commissioning done
- First ever high power RF operation on close loop of 1.3 GHz Buncher Cavity (September 2018)
- Next months → Cryomodule acceptance tests
- Q3 2019 → Main LLRF Rack will be shipped to Ankara after inner rack cabling
- First accelerated beam in end of 2020

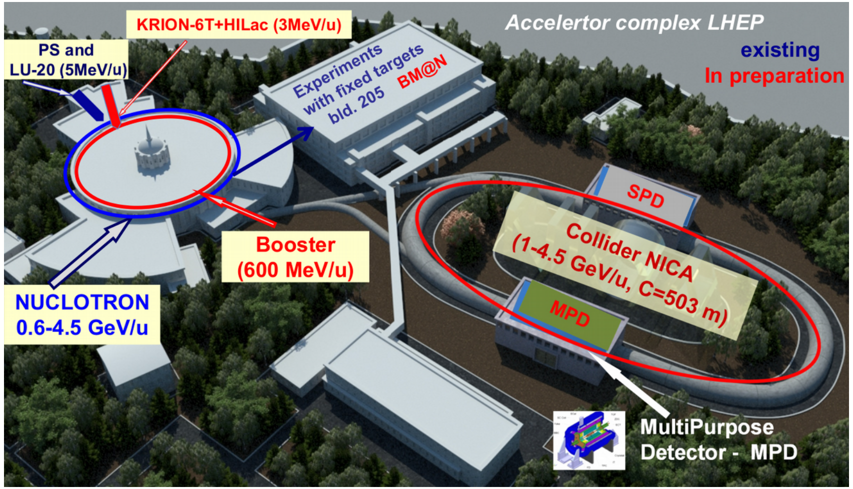


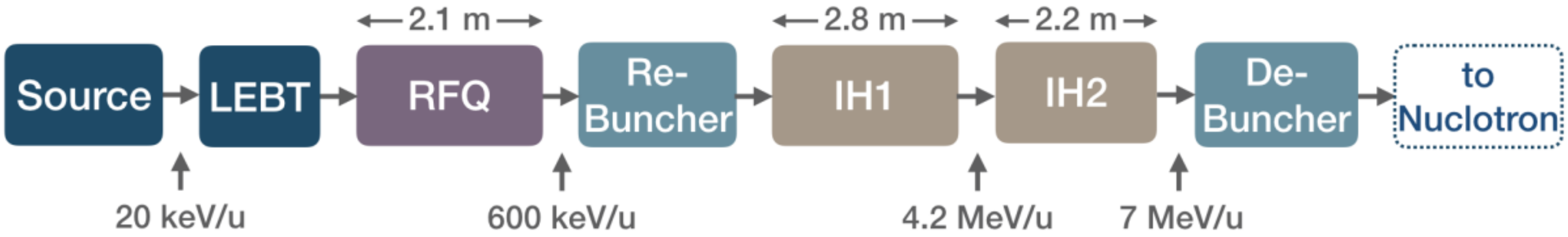
LLRF Project Examples

NICA

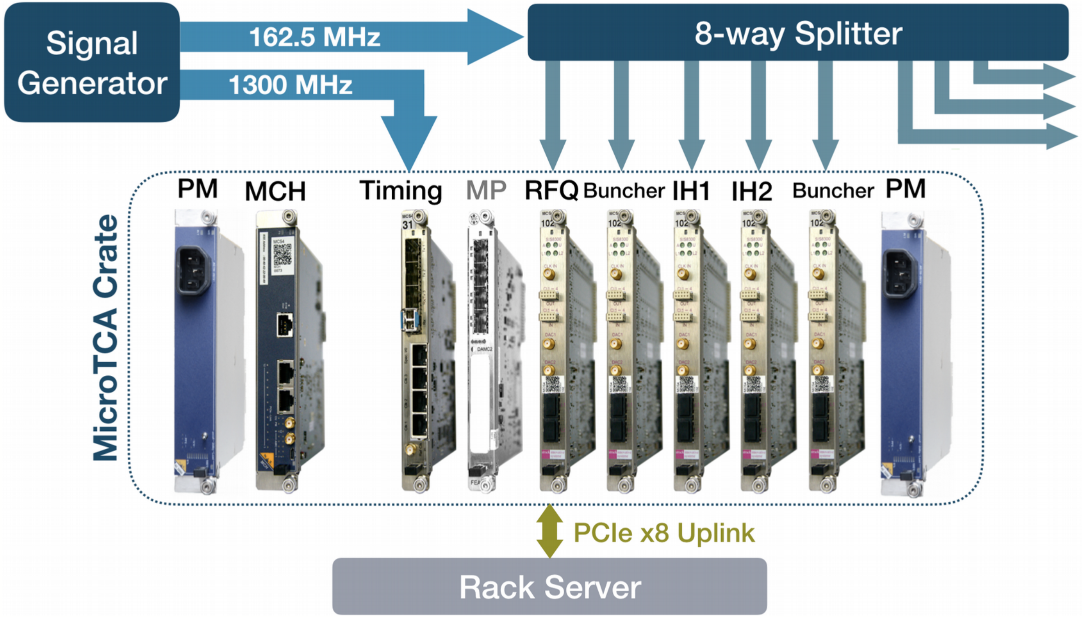
Nuclotron-based Ion Collider Facility at JINR
Dubna/ Russia

- For ion collider upgrade: Light ion frontend Linac (LILac) for polarised particles
- LLRF Control of 6 cavities
- DOOCS as Control System
- 5 Hz rep. Rate with 1 – 300 us pulse length
- 5 mA beam current





NICA LiLAC LLRF Overview



Cooperation with BEVATECH

NICA LiLAC LLRF Status

- Currently ongoing system integration:
- Board tests are finished
- Firmware + Software ready.
- Q3 2019 → Crate will be shipped to Bevatech – Frankfurt Germany

LLRF Crate

External Server

Signal Generator as MO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