LIBERA

MedAustron

Development of a MTCA.4 LINAC LLRF system for the MedAustron LINAC upgrade

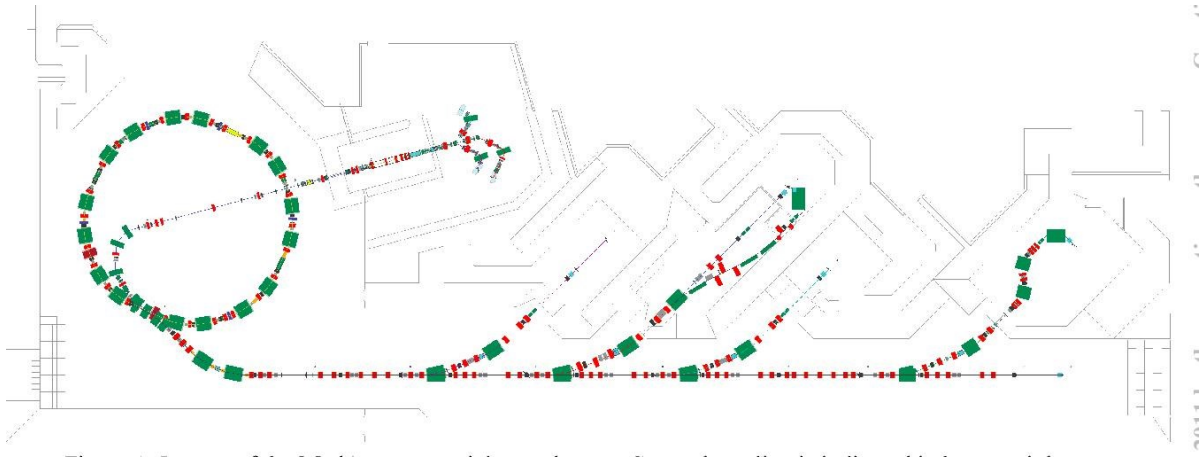
B. Baričević, A. Bardorfer, P. Paglovec, M. Oblak, M. Škabar, M. Cargnelutti - Instrumentation Technologies, Slovenia
C. Schmitzer, M. Repovz, M. Wolf, M. Cerv, S. Myalski - EBG MedAustron, Austria

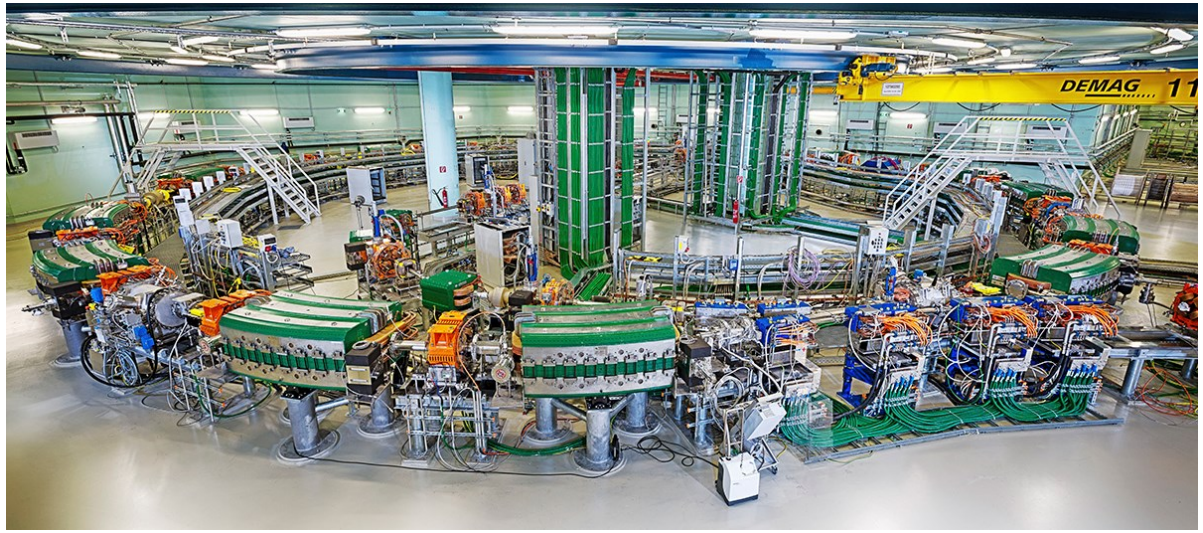
MicroTCA Workshop
December 2021

Outline

- MedAustron introduction
- LINAC LLRF requirements
- LINAC LLRF upgrade project
- MTCA.4 technologies and architecture
- Results and current status

MedAustron introduction





MedAustron

- Synchrotron particle therapy center
- Location: Wiener Neustadt, Austria
- Particles: protons / heavy ions
- Machine:
  - LINAC (216.816 MHz)
  - Synchrotron (400 kHz - 10MHz)
  - 3 treatment rooms (+1 research)

- Installation: 2012
- First treatment: 2016

Motivations for the upgrade

- Very limited support for the current LLRF
- System based on obsolete technology (HW and SW - Win XP)
- Limitations (e.g. max 500us pulse length)
- Limited data access and no logging
- Different systems for injector and Synchrotron
- Spare parts and maintenance

Requirements for the LINAC LLRF upgrade

- State of the art MTCA.4 solution, based on commercially available subsystems (COTS)
- Applications to be addressed through the same platform:
  - LINAC and Synchrotron
  - LLRF and Beam Instrumentation
  - RF knockout extraction
- Unified design, common building blocks (simpler spare part management)
- Frequency flexibility (direct sampling)
- Technical requirements:
  - RF frequencies: 400 kHz – 10 MHz, 216 MHz (universal solution)
  - Phase reference at 10 MHz
  - Stability: Amplitude 0.02 % RMS, phase 0.02 ° RMS (0.05 % RMS, 0.05 ° RMS for the LINAC)
  - Isolation: 70 dB
  - Real time Control System interface
  - Cavity tuning system
- Other requirements: (Synchrotron LLRF)
  - RF Frequency ramping sequencing
  - Multi-harmonic feed-back
  - Integration of beam diagnostic signals within the LLRF feedback

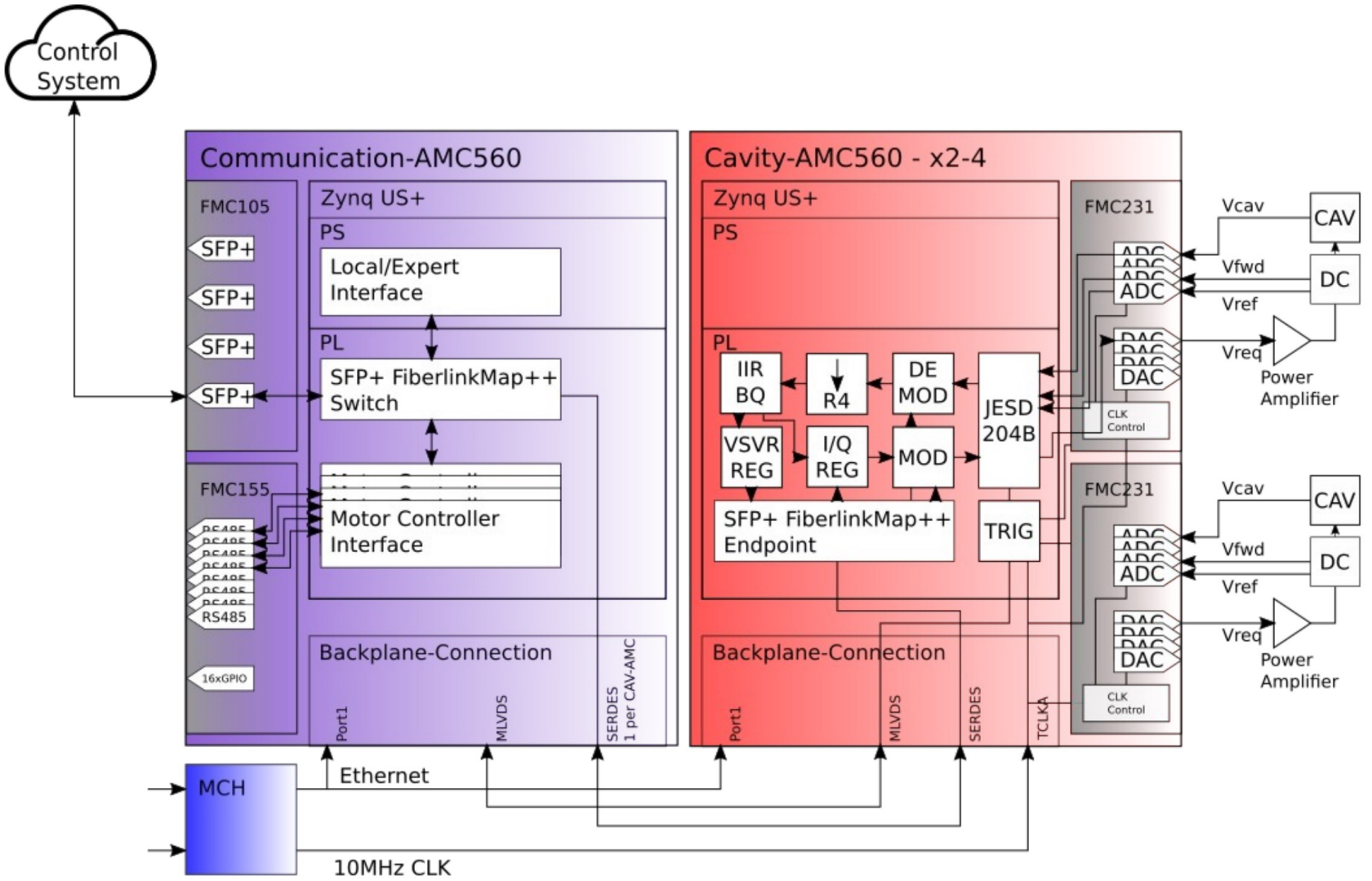
Development project

- Collaboration project between MedAustron and Instrumentation Technologies teams
- Both teams actively involved in the project with their expertise and resources
- First project phase: concept evaluation, system architecture definition, development activities planning
- Project tasks split among the teams
- Common project management and issue tracking tools (Redmine)
- Common code repository (Gitlab)
- Weekly progress meetings involving both the teams
- Integration testing sessions

MTCA.4 hardware selection

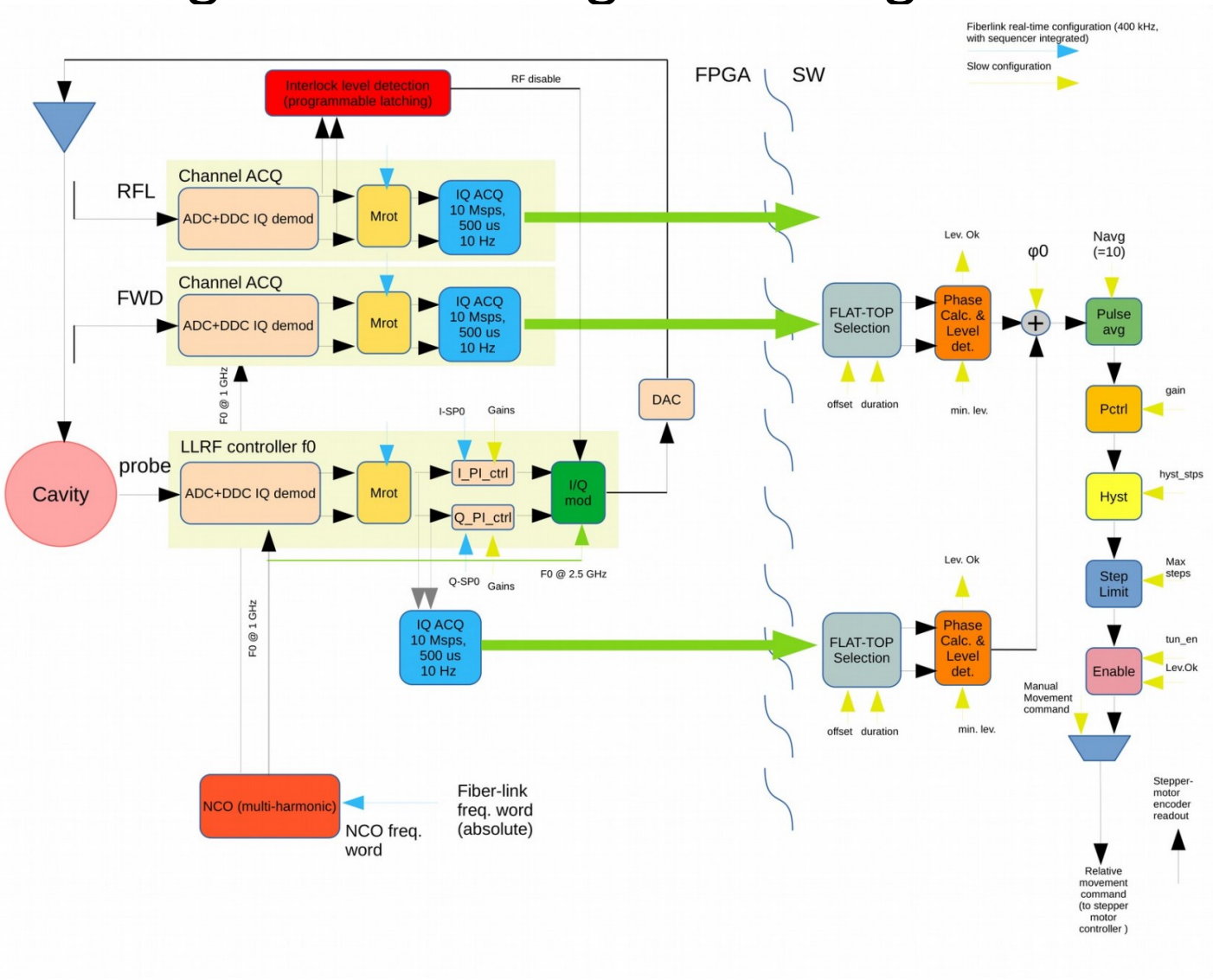
- AMC560 (AMC FPGA Carrier, dual FMC+, Xilinx Zynq Ultrascale+)
  - FMC231
    - 4x 16 bit ADC @ 1GSps
    - 4x 16 bit DAC @2.5GSps
  - FMC105
    - 4x SPF+
  - FMC155
    - 8x RS-485
- DAMC-FMC2ZUP (used in the initial phase)

MTCA.4 architecture



- Control System directly accessing FPGA (FiberlinkMap++ over SFP+) Real-time control capability.
- Possibility to apply sequences of IQ and NCO frequency settings at 10 MHz. (Synchrotron ramping)
- Local Expert interface
- Direct sampling and generation (no RF front-end and back-end)
- 10 MHz as phase reference (no MO reference at RF frequency)

Signal Processing block diagram



Main project activities

- Signal generation (drive)
- FE demodulation
- NCO
- Signal acquisition
- Trigger interface
- Fiberlink interfaces
- Interlock system
- Tuning system controller
- Pulse control sequencer
- OS setup (PetaLinux)
- Setting up the application
- Local GUI interface

Preliminary local expert GUI (Web GUI based work in progress version)

Results

- Concept evaluation phase
  - Platform setup and evaluation (functional and performance)
    - 0.012 % RMS, 0.043 – 0.053 ° RMS (@216 MHz)
    - 0.010 % RMS, 0.004 ° RMS (@ 10 MHz)
  - Power cycle repeatability
- Implementation phase
  - Most features have been implemented and confirmed
  - Confirmed closed loop functionality
  - Some features were implemented for the next applications (Synchrotron LLRF, Beam diagnostics)

Closed loop operation

Conclusions

- The LINAC LLRF system development is in the finalization phase
- Teams with different background have been effective in working together
- The selected MTCA.4 COTS components have been confirmed to fit the application requirements
- The developed architecture will be available for other LLRF applications
- Next steps:
  - Finalization of the LINAC LLRF application and verification
  - Extending the developed features to the needs of the other applications
    - LINAC Beam Diagnostics (Beam Position and TOF monitors)
    - Synchrotron LLRF
    - RF Knockout and extraction system

Thank you

For your attention

Contact information:
borut.baricevic@i-tech.si
matjaz.repovz@medaustron.at