Development of a New Measurement System for Beam Position Pickups in the LINAC and Beam Energy Measurement (Time of Flight) in the MEBT for MedAustron

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The MedAustron Hadron Therapy Center

MedAustron is a synchrotron based hadron therapy center. The design based on the PIMMS (Proton Ion Medical Machine Study) uses proton and carbon ions. The facility features 4 irradiation rooms. Three rooms are dedicated to clinical operation and one room is dedicated to non-clinical research. A 7 MeV/u beam is sent to a 77 m circumference synchrotron which accelerates the beam to 800 Mev/u providing beams for treatment and research. Patients are treated with protons since December 2016. In 2022 the last treatment room Gantry was put in operation and 400+ patients can be treated yearly.
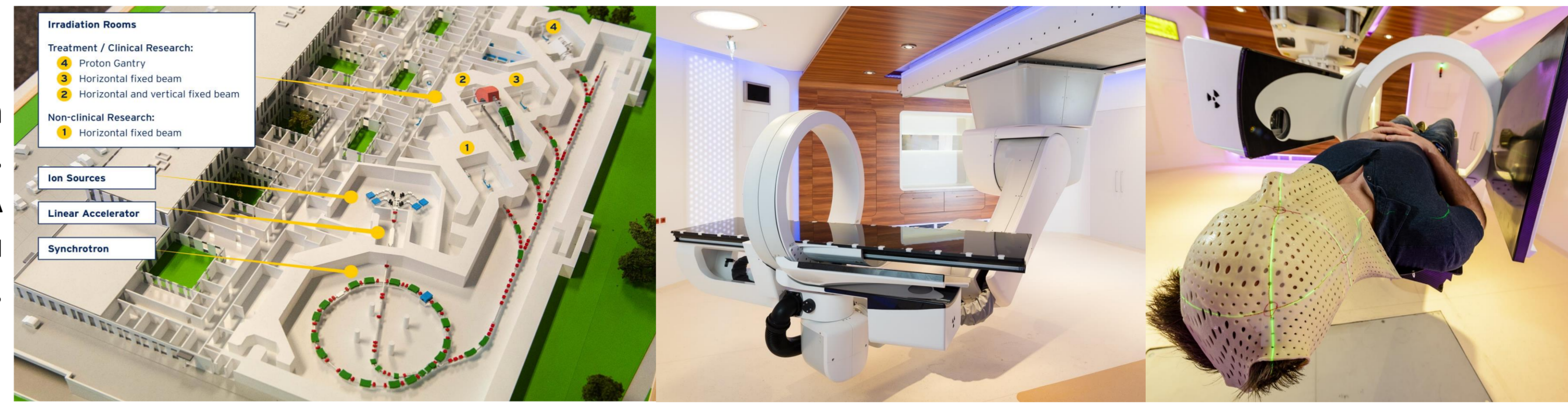
Beam Instrumentation

The MedAustron accelerator complex uses a set of non invasive beam instrumentation devices for online beam monitoring [1]. For some of these devices are foreseen to be used with the new system.

Within the injector part this includes phase probes distributed along the RFQ, Linac and MEBT line (4 probes in total) used for time of flight measurements,. At the entry of the IH tank a four-button probe used for beam position verification is placed.

In the synchrotron ring 20 shoe-box pick ups provide horizontal and vertical beam position measurements, as well as base-line tune via a coupled BBQ system and two dedicated Schottky monitors for each transverse plane.
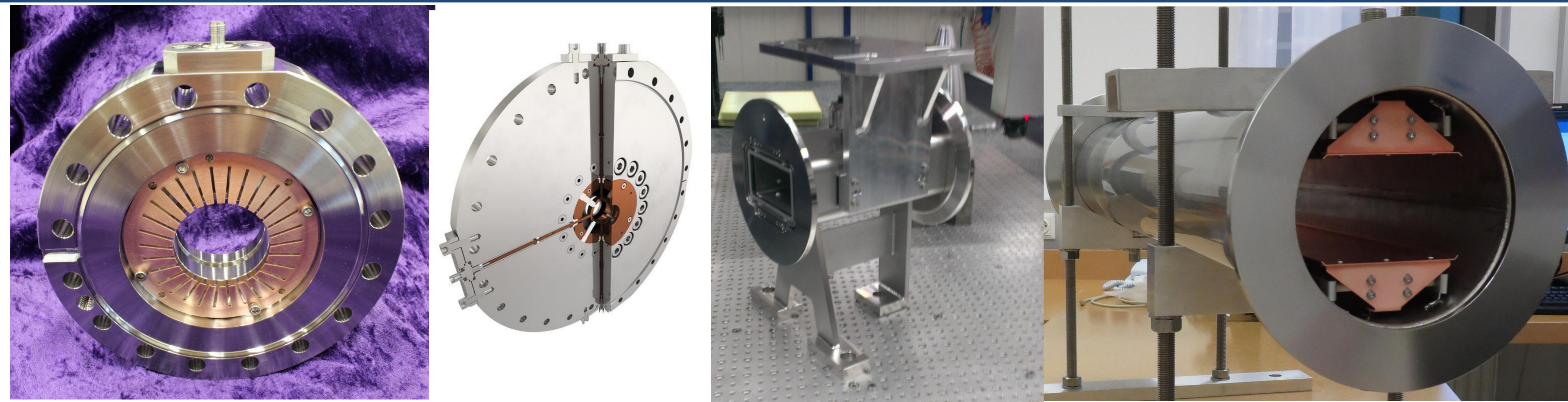

Fig.1: From left to right – A commercially available phase probe from NTG [2] as installed in the MedAustron Linac for time-of-flight measurements, four-button probe for beam position at the entry of IH-tank, Synchrotron shoe-box pick up as used for beam position measurement and by the synchrotron LLRF for radial position and phase regulation.

Platform used

The system is developed together with Instrumentation Technologies and is based on MicroTCA.4 COTS from Vadatech. This platform is currently in use for beam position measurement at the entry of the IH-tank and Time Of Flight measurement along the Injector part. The same MicroTCA crate is also prepared to be used for Injector low-lever RF [3].
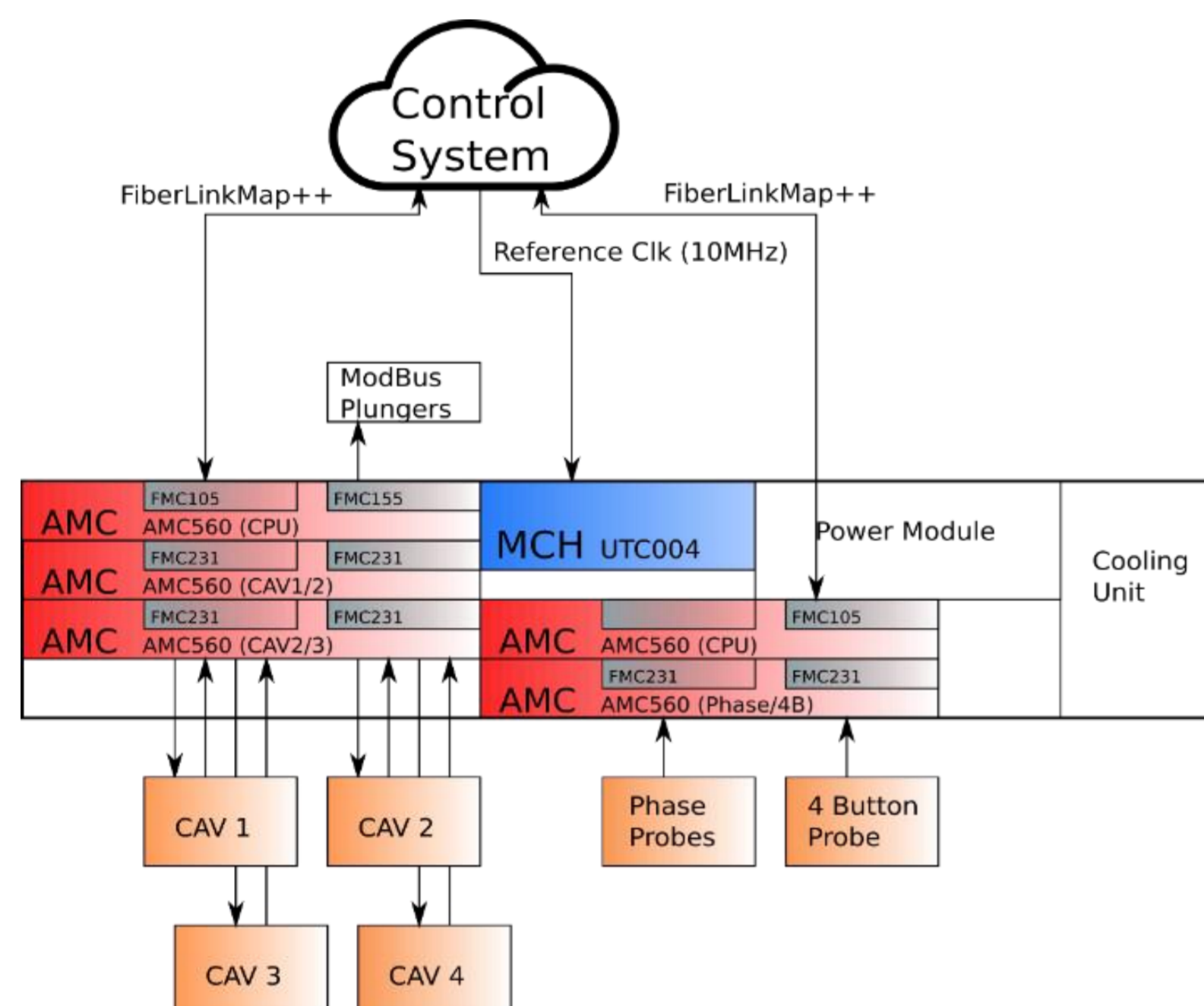

Fig.2: Block diagram of hardware and it's connections

Operation

The same architecture is used for four-button probe as is for phase probes. The Linac has a frequency of 216.816 MHz so direct sampling approach can be used. The signals from the detectors are amplified (in close proximity of the probes) and then fed to the MicroTCA crate for digitization (no additional front end is added). It is ensured that the cables have the same length.

After the ADC the signals are converted to the baseband (downmodulated with NCO). Outcome signals (in-phase and -quadrature) are filtered and converted to amplitude and phase.

With known distance between individual phase probes and the phase information the energy of the particles is calculated (Time Of Flight).

The beam position can be calculated from the amplitude measured of the four-button probe assuming that opposite buttons generate the same amplitude if beam passes in the middle.
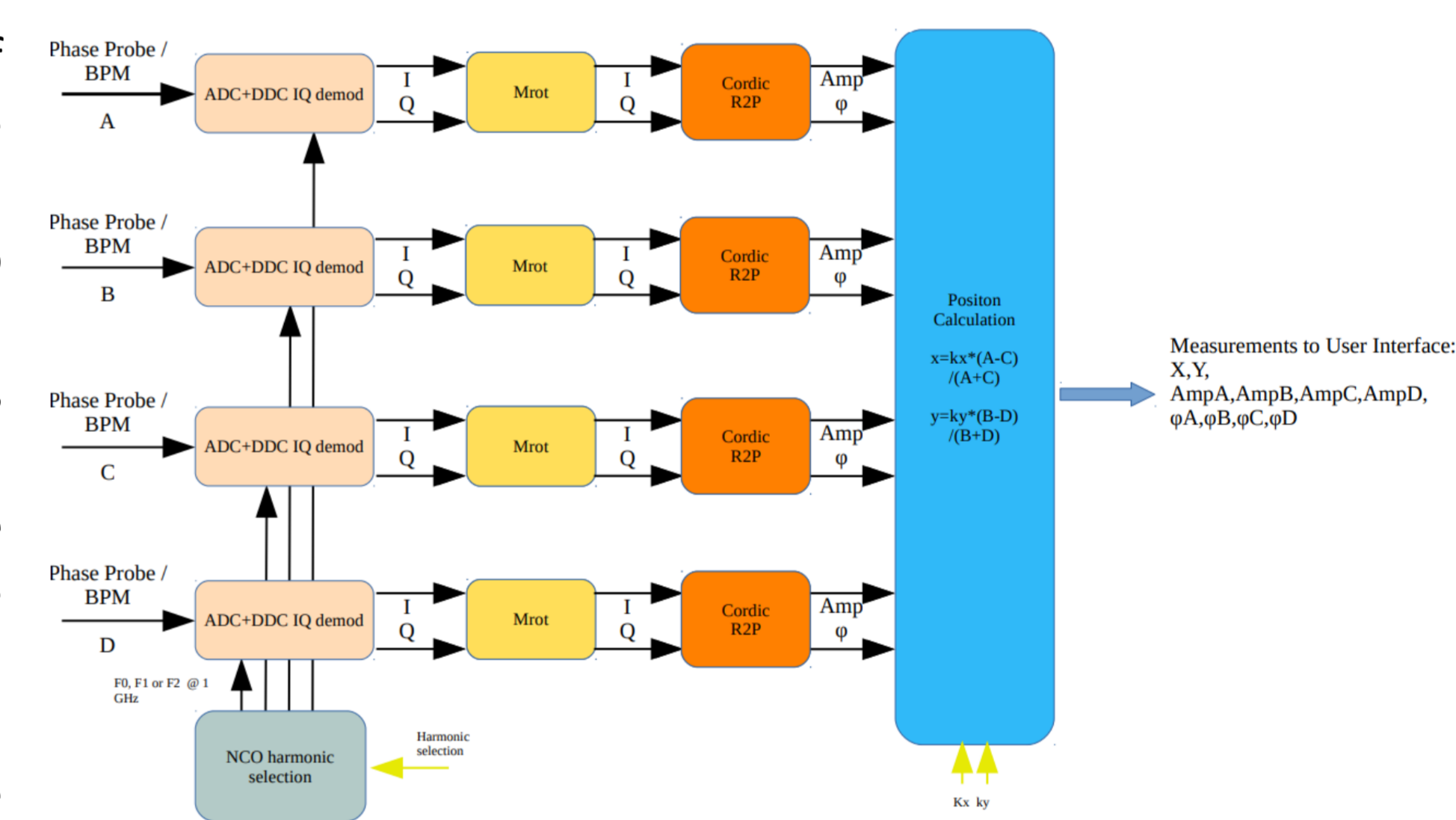

Fig.3: Block diagram for the beam position or Time of Flight measurement

Sustainability & Maintainability

A particle treatment center with a projected time of operation of +30 years has to put special effort into maintenance and development strategy to ensure smooth operation. A key aspect is to minimize technological diversity, the number of necessary spare parts and required training for personnel by limiting the number of specialized devices.

The presented platform follows a **modular approach** in the hardware selection and the firmware implementation. As designed it will be used (in addition to the presented beam instrumentation measurements) also for both low-lever RF systems (Linac and Synchrotron), RF knock-out extraction, Synchrotron shoe-box pickups. Most of the components can also be reused for **other applications** (Schottky pickup measurements, Tune,…) thus the maintainability is high and diverse training efforts reduced. In the case of MedAustron the new platform will potentially **harmonize 8 different systems** into one hardware setup.
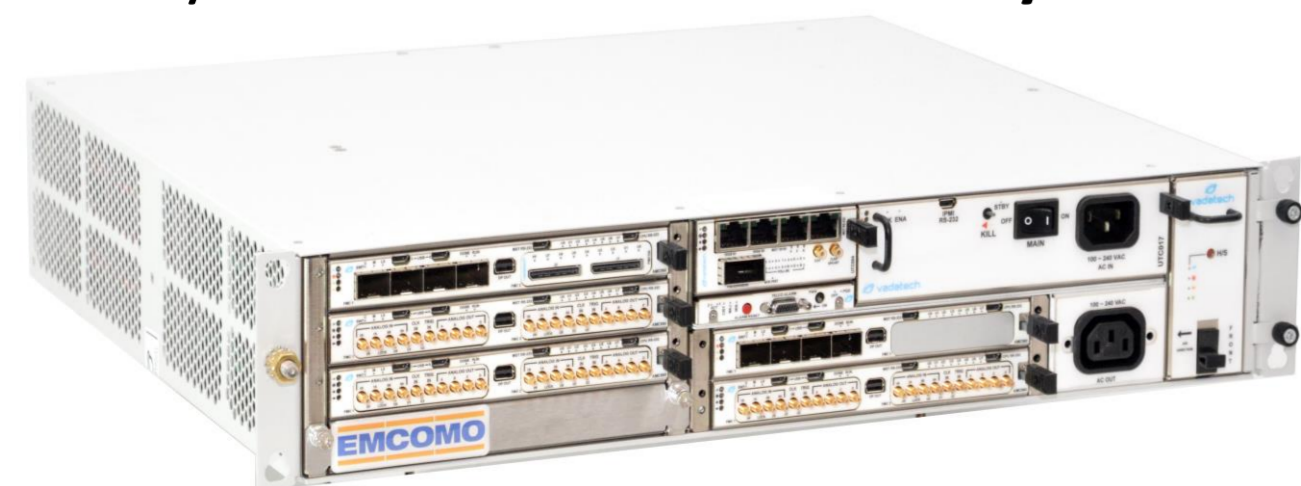

Fig.4: MicroTCA.4 hardware used

Measurement

System is already in use and measurements are possible via local web interface. Figure 5 shows the uncalibrated position measurement at the left. At the top the 4 Button signals can be seen for different particle types (proton, carbon) and some stray beam was measured in between (150-200μs). Without calibration data available, only reproducibility of the beam parameters can be evaluated right now. The two plots to the right show the energy measurement (TOF) in different machine configurations. The picture in middle shows an IH-DTL amplitude scan, resulting in different transmission efficiencies and energies, while the picture at the right shows the reproducibility, using a static machine configuration and the web interface. In the web interface multiple parameters are available to configure the measurement to specific machine properties.
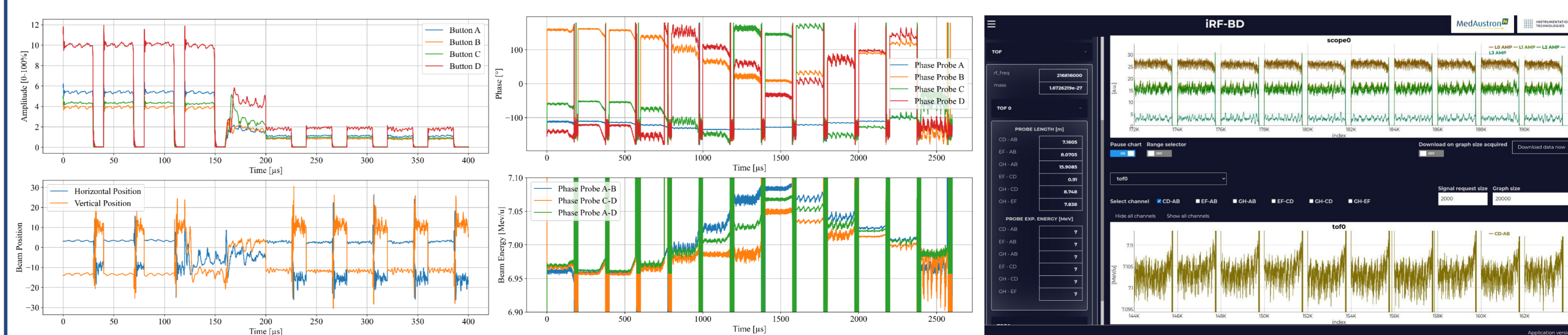

Fig.5: Beam position measurement (left), beam energy measurement (middle), beam energy measurement via local web interface (right)

References

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[2] NTG Neue Technologien GmbH & Co. KG - https://www.ntg.de/produkte/teilchen-beschleuniger/strahldiagnose/kapazitive-sonden/phasen-sonden/
[3] Development and Integration of a New Low-Level RF System for MedAustron, M.Wolf et al., LINAC 2022

Acknowlegements