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EXPANSION OF THE MTCA BASED DIRECT SAMPLING LLRF AT MEDAUSTRON FOR HADRON SYNCHROTRON APPLICATIONS

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Abstract

The MedAustron Ion Therapy Centre is a synchrotron-based particle therapy facility located in Lower Austria, which delivers proton and carbon ion beams for cancer treatments. Currently the facility treats over 400 patients per year and is expected to double this number in the future. Six years since the start of clinical operation, MedAustron is experiencing end-of-life issues concerning the digital Low Level RF components in the injector and the synchrotron. Replacements for these applications are under development and the chosen hardware is suitable to also update multiple beam diagnostic devices in the facility. Main targets for updates are the Schottky monitors, which were never properly integrated into the MedAustron Control system and the position pickup measurement system, which currently does not support turn by turn measurements. Comparison measurements with other state of the art diagnostic devices are ongoing to demonstrate the capabilities of the generic hardware. Furthermore, these measurements should show the increased usability and diagnostic potential compared to the legacy devices.

INTRODUCTION

MedAustron and Instrumentation Technologies continued to work on a LLRF and beam diagnostic solution to replace all RF applications used at MedAustron and already presented in the last years [1–3]. In the current paper new beam diagnostic usecases in the MedAustron Synchrotron will be shown and measurement results of Schottky detectors and classical Shoebox Pickups will be compared to other off the shelf equipment.

MEASUREMENT SETUP

Position Measurement System

The MedAustron Synchrotron contains multiple beam position monitors in form of Shoebox Pickups. These Pickups are located in different dispersion regions of the Synchrotron and can be used to measure the orbit of the beam circulating in the synchrotron. Head amplifiers are connected to these pickups with short cables to keep the interference and cable influences at a minimum. These head amplifiers generate sum and delta signals out of the pickup plate signals. Afterwards these sum and delta signals are forwarded out of the synchrotron hall and further amplified in distribution amplifiers. The distribution amplifiers generate multiple copies of the pickups signals. Spare outputs of the distribution amplifiers are used to parasitically measure the two horizontal pickups in high and low dispersion regions.

Digital Data Processing of the Position Measurement

The output of the position measurement system is digitized with off the shelf hardware from Vadatech which was presented in Ref. [1]. For the beam position measurement one AMC560 Carrier card and one FMC231 AD/DA converter card is used. The signals produced by the distribution amplifiers are directly sampled and then demodulated to baseband signals using the revolution frequency of the synchrotron. The resulting amplitude of the delta signal is divided by the amplitude of the sum signal, to calculate position information independent of the beam current. The results of this calculation can then be calibrated to represent absolute position data. This calibration will be finalized in the future.

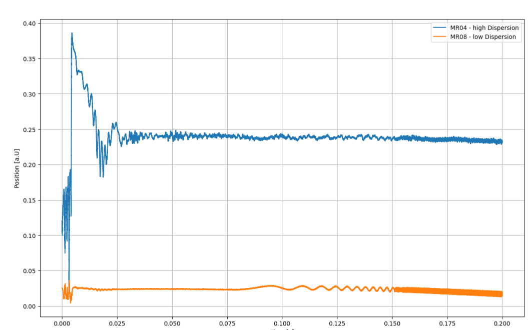

Figure 1: Qualitative position measurement in high and low dispersion regions of the synchrotron.

Schottky Monitors

The Schottky monitors are directly connected to standard low noise amplifiers (FEMTO- HVA-200M-40-F) and afterwards connected to the digitizer hardware outside of the synchrotron hall. In this setup sum and delta signals are calculated after digitizing the signals.

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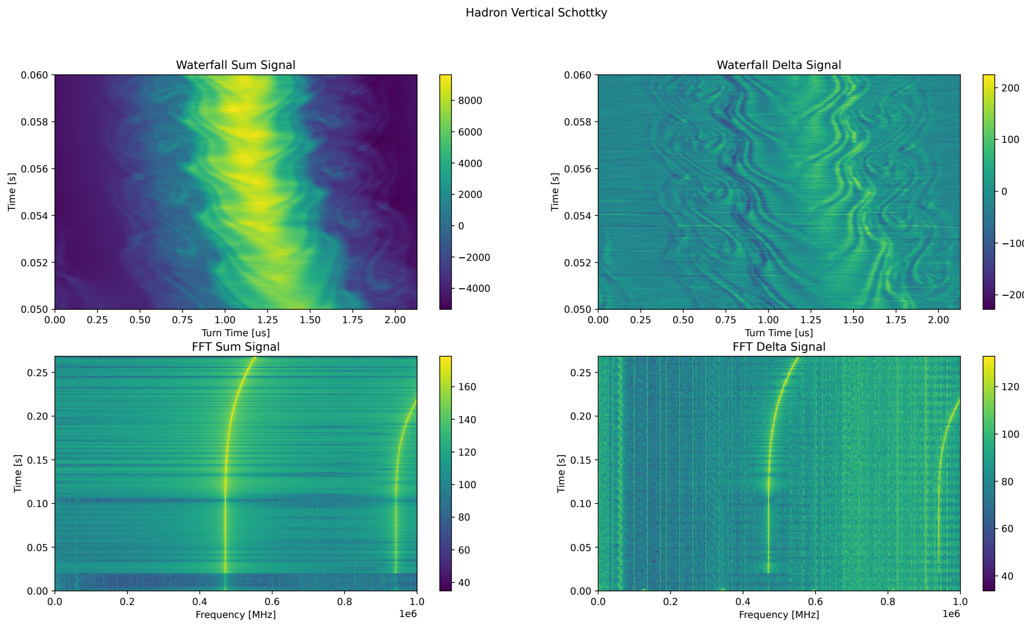

Figure 2: Waterfall diagram and frequency analysis of beam injection with the Libera Hadron.

Digital Data Processing of the Schottky Measurements

The schottky plate data is directly sampled by the µTCA based Vadatech solution and for comparison also by a Libera Hadron. Sum and delta signals are calculated in the digital domain and the results are then plotted in form of waterfall diagrams showing how the particle bunch changes its shape inside the synchrotron. Additionally the data is fed into a FFT algorithm, which should provide information about the revolution frequency, the synchrotron frequency and the beam tune.

MEASUREMENTS

Position Measurement

The position measurement (Fig. 1) shows the injection, adiabatic capture and the start of the acceleration inside the synchrotron. Due to a small mismatch of the Dipole field and the injection energy the beam position drifts a little bit at the beginning. Only after the radial loop is turned on the position stabilizes till the end of the measurement. At the beginning of the acceleration (at 100 ms) field ramping of the magnets is not exactly synchronous to the beam acceleration resulting in a small oscillation seen in the low Dispersion area.

Schottky Measurements

The schottky measurements are done with two different measurement devices and show the beam bunch in a waterfall diagram after capture (MedAustron uses a coasting injection) and before the acceleration starts. Dipole and quadrupole oscillations are clearly visible with both measurement devices. Both of the devices show a good resolution of the beam, which should make a tomography of the beam possible.

The FFT plots show the whole range from the beam injection, the capture and the start of the acceleration. Compared to each other both devices show a good resolution for the sum signals. Differences can only be seen at the Delta plots. There it looks like the Hadron (Fig. 2) exhibits a bit more noise compared to the Vadatech solution (Fig. 3) over almost the whole frequency range shown. Unfortunately none of the two devices can clearly show the beam tune while the beam is captured and without an excitation kick (either by a kicker or transversal RF excitation). Only at the very beginning of the measurement (first 10 ms) a small peak could be seen, which might be the beam tune. Further measurements will be needed to verify if these peaks are really the beam tune and to identify system improvements, which might show the beam tune more clearly.

RESULTS AND OUTLOOK

The chosen new hardware for the MedAustron RF applications continues to improve beam diagnostic capabilities available at the facility. The results show the suitability for the low frequency range needed at MedAustron and the beam resolution and turn by turn measurement bring new diagnostics like a beam tomography within reach. Nonetheless already the shown measurements increase the knowledge about the machine behavior compared to the legacy beam diagnostic devices.

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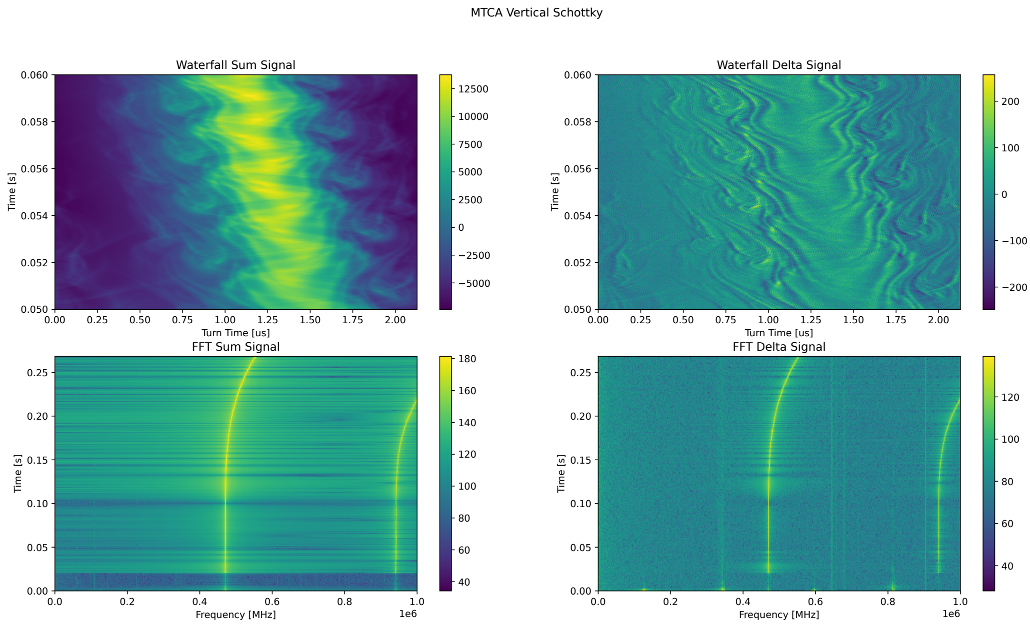

Figure 3: Waterfall diagram and frequency analysis of beam injection with the Vadatech µTCA solution.

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