A new longitudinal diagnostic system for CERN's antiproton machines

ID 69

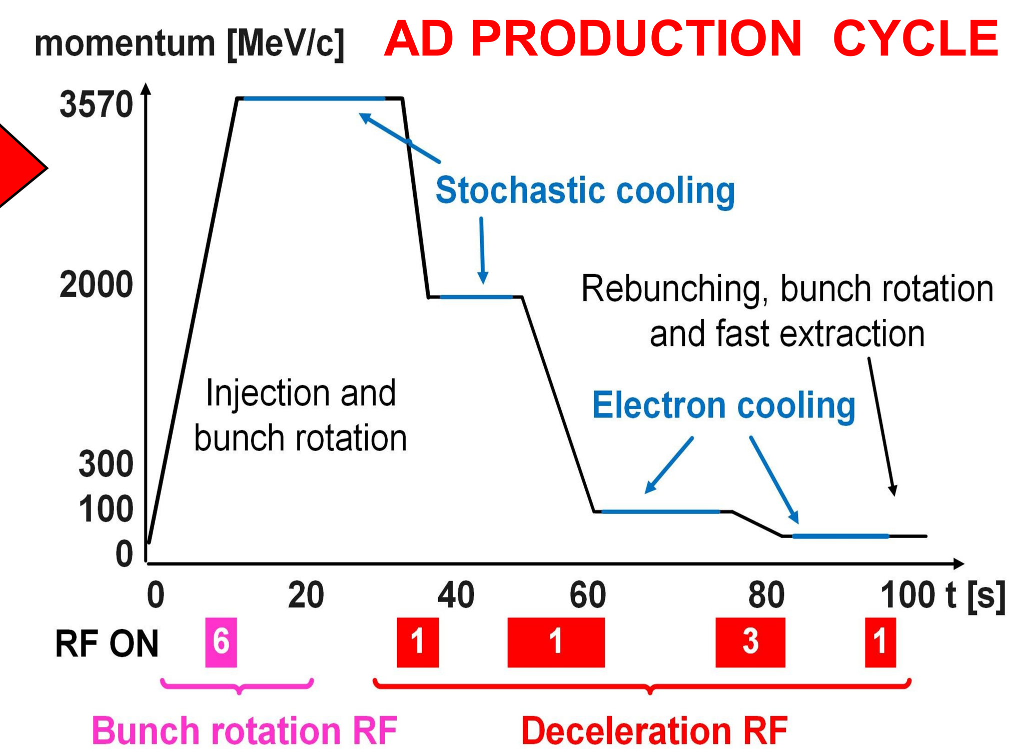
Low Level RF Workshop 2022
9-13 Oct 2022, Brugg-Windisch, Switzerland

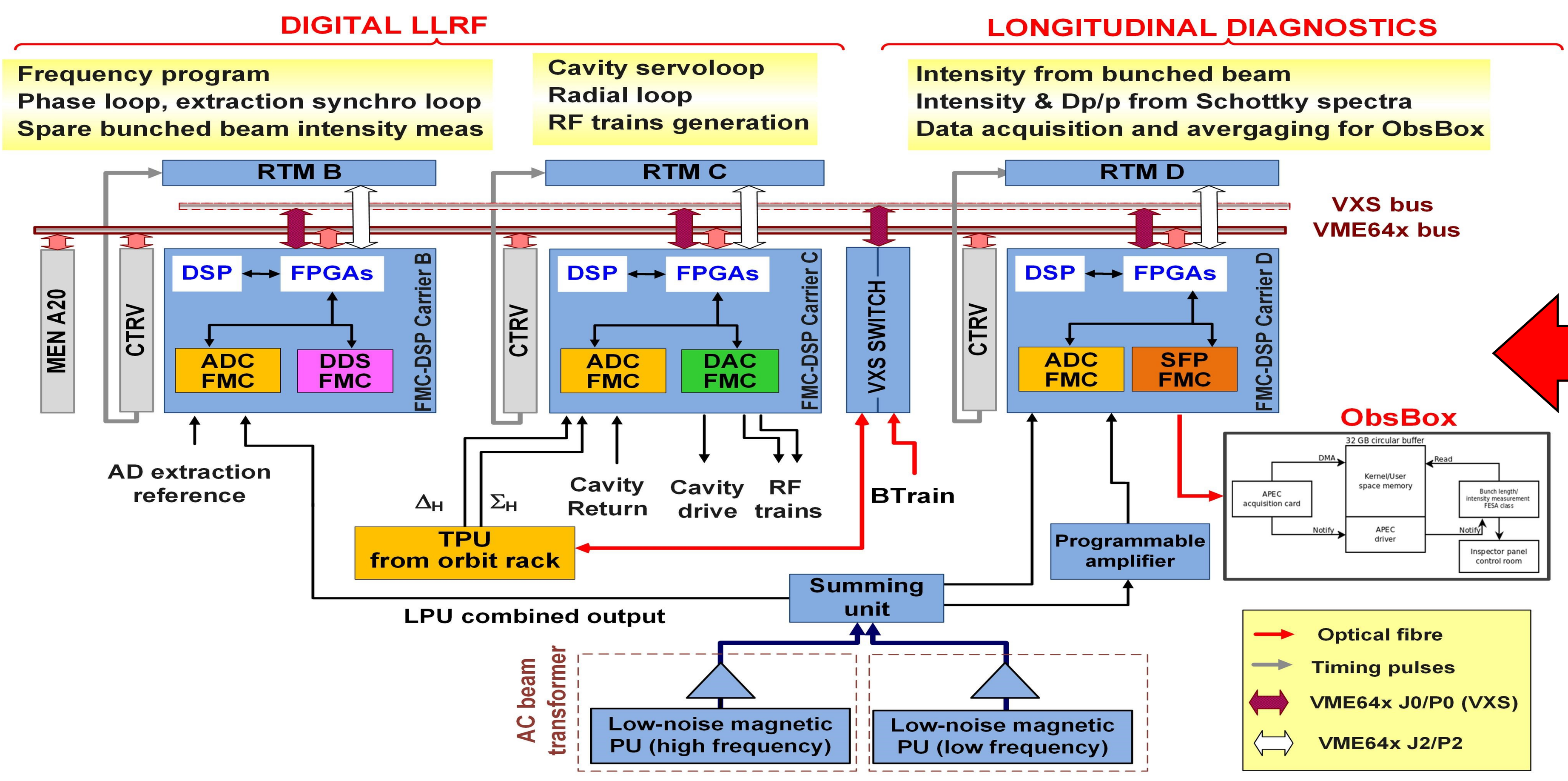
M. E. Angoletta, D. Barrientos, B. Bielawski, M. Jaussi, J. Molendijk, V. R. Myklebust, M. Niccolini, S. Novel Gonzales, A. Rey, M. Soderen, M. Suminski
CERN, Geneva, Switzerland

Introduction

Traditional beam transformers don't work at the low intensities (up to 4E7 antiprotons) of CERN's Antiproton Decelerator (AD) and Extra Low Energy Antiproton ring (ELENA) hence other ways of measuring the intensity are required. Processing data in the frequency domain is carried out in the LLRF systems and provides bunched beam intensity and bunch length,

Here we describe a new, powerful longitudinal diagnostic system under development that treats time-domain data. For bunched beams, intensity, bunch length, peak values and turn-by-turn beam profiles are available. Debunched beam signals will also be treated to measure intensity and Δp/p values. The system will help setting up and monitoring RF and cooling systems. It will also allow operators to monitor the performances of the two machines.
This poster focus on the AD implementation and shows preliminary beam results and plans.



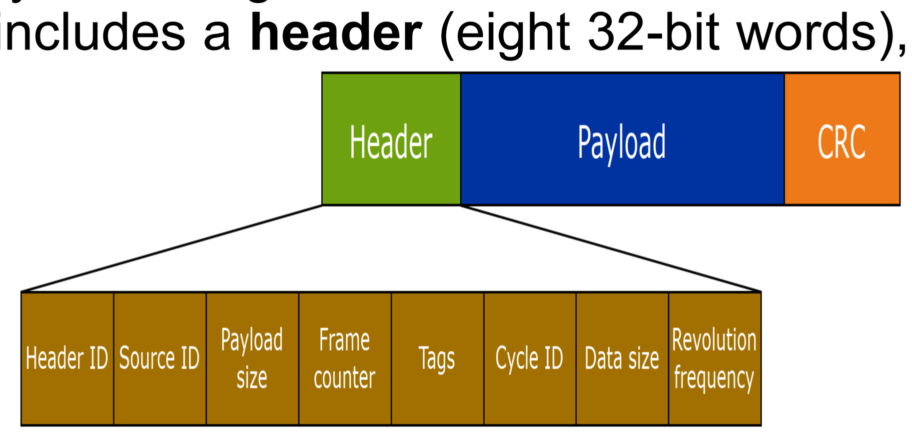


Longitudinal diagnostics and AD LLRF. Keys: FMC—FPGA Mezzanine Card, ADC – Analogue-to-Digital Converter, SFP – Small Form-factor Pluggable Transceiver, LPU – Longitudinal Pick-Up, CTRV – Timing Receiver Module, MEN A20 – Master VME board, RTM – Rear Transition Module, ObsBox – processing module.

Hardware

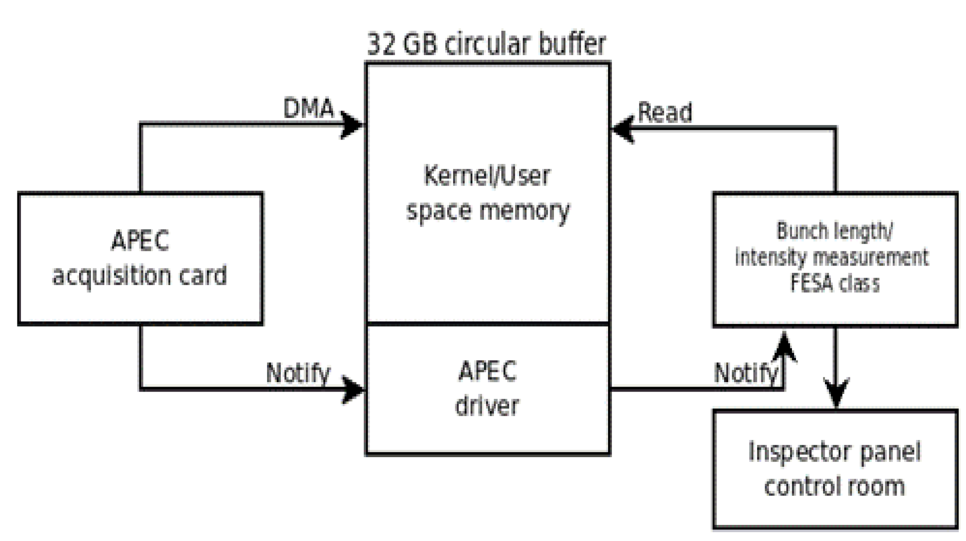
Data acquisition in LLRF crate

Analogue signals from a low-noise magnetic pick-up are sent to the FMC-DSP Carrier board D, hosted by the LLRF system. This board provides digitized data to the Obsbox system and is clocked at a fixed frequency of 122.7 MHz. Digitized data are low-pass filtered to a sampling rate of 61.4 MSPS. A new data frame is created every 12.5 μs, as a new the revolution frequency value is generated.
The frames structure includes a **header** (eight 32-bit words), a **payload** (variable size) and a **Cyclic Redundancy Check value** (32 bits) for the frame.



ObsBox

The system is based on COTS hardware and custom firmware/driver allowing fast transfers from serial link to the host. It can receive data at a rate of up to 10 Gbps, although in AD/ELENA is configured for two channels and 2 Gbps rate. Data are transferred to a circular buffer in the host sequential RAM, where applications can access it to obtain intensity and bunch profiles.



Bunched beam results

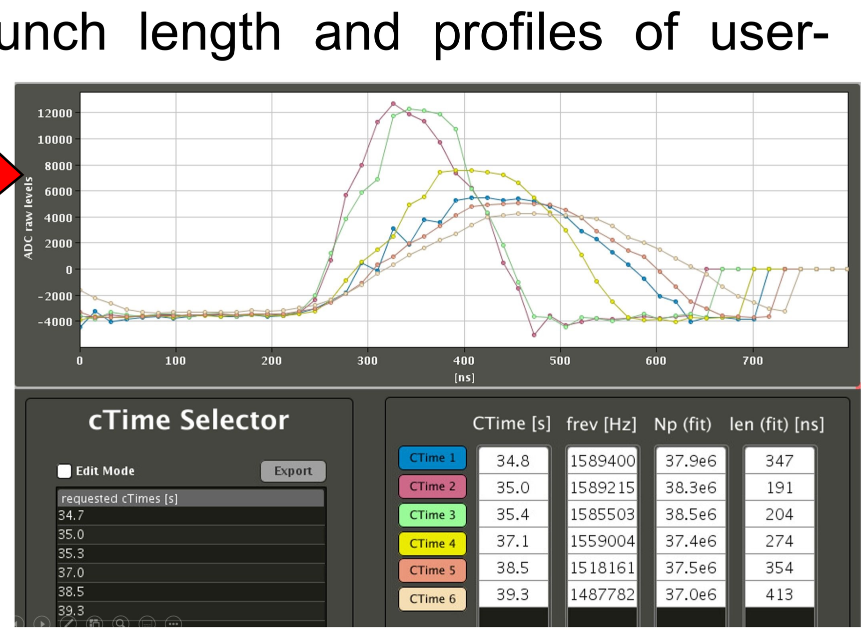
Here we show the preliminary versions of panels to select/visualise bunched beam data

OP monitoring display

The panel displays beam intensity, bunch length and revolution frequency as a function of the time in the cycle, CTime.
The use can select on-the-fly the subset of data by selecting the time interval between processed bunch data (25 μs – 10 ms) and averaging the characteristics over a selectable number of consecutive bunches (1-500). A resolution of about 80 ms is currently possible .

Waterfall plot

This panel shows the intensity, bunch length and profiles of user-selectable bunches. This is typically used to monitor the bunching or debunching process.
Bunches are shown as left-aligned owing to the detection process, which chops the raw sample stream at a fixed length before the rising edge. Each bunch profile is then zero-padded to obtain same-size data units. In the shownwater- fall plot, *CTime1* and *CTime 2* are at the beginning of the bunching process. *Ctime3* to *6* show the bunch lengthening due to deceleration.



Conclusions and future work

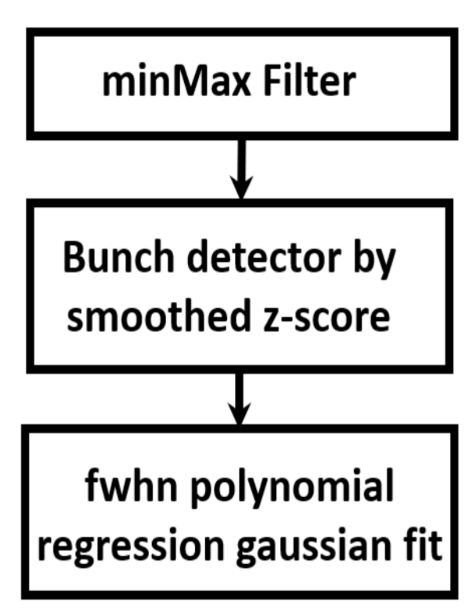
The AD/ELENA ObsBox systems will soon be completed with debunched beam treatment to measure intensity and Δp/p data from Schottky analysis. Additionally, the display settings will be controlled by a dedicated software to automatically follow changes in the cycle.

Finally, customised versions of these systems will be exported to CERN's LEIR and PSB, equipped with the same LLRF system, to provide bunch length, peak values and turn-by-turn beam profiles.

Bunched beam data processing

Overview

Samples are filtered to remove batches containing only noise. This is done by buffering a set of samples then looking at the min vs. max values difference. Data is send to the next stage is the difference is greater than a threshold.
A running z-score is then applied to the samples to detect roughly the bunch position.
The baseline is removed and the fine detection of bunches is done by measuring the full width at half maximum with criteria of baseline-to-peak height and minimum bunch length. The bunch length is calculated.
When a bunch is detected, the natural logarithm of the set of samples are fitted to a quadratic polynomial $y=ax^2 + bx + c$. The intensity is obtained from the integral of this expression.



Current throughput issues

AD/ELENA ObsBox systems have a higher sampling throughput than other CERN systems. As a consequence, these systems cannot currently fully process the available raw data stream. As an example. only 50.000 frames, out of the 2.5 million for bunched-beam data in the AD can now be processed. This corresponds to about 600.000 bunches, sufficient anyhow to characterize the beam in the deceleration phases.

Dynamic memory management in the bunch processing software and the driver interface to the APEC hardware are currently being optimized to solve this problem.