Status of the beam control renovation of the Proton Synchrotron at CERN

D. Barrientos*, H. Damerau, A. Lasheen, N. Pittet, B. Woolley
CERN, Geneva, Switzerland

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Motivation

The Proton Synchrotron (PS), CERN's first synchrotron, is in operation since 1959. Today, it accelerates protons delivered by the Proton Synchrotron Booster (PSB) or heavy ions from the Low Energy Ion Ring (LEIR). The ring, with a circumference of 628 m, is equipped with 25 RF cavities in a frequency range from 0.4 to 200 MHz [1]. The LLRF system in the PS includes local multi-harmonic feedback loops [2] to control amplitude and phase of the RF signal being sent to the cavities. In addition, global beam-based loops implement phase, radial or synchronization loops acting in several cavities simultaneously.

Due to the variety of beam characteristics that the PS need to deliver (from 10^8 to $3{\cdot}10^{13}$ charges) and the technology available, the current beam control is implemented in a mix of analog and digital hardware. As part of a larger renovation, the PS beam control will also be renovated, using a pulse-to-pulse digital system, allowing a high integration and largely reducing operation and maintenance costs.

The chosen architecture for the new PS beam control is based on the VMEbus Switched Serial (VXS) platform, currently in operation in several injectors at CERN: PSB, AD, ELENA, LEIR [3]. This choice allows reusing several components already validated and deployed as well as simplifying development and maintenance of the system.

The new beam control system will implement beam phase, radial and synchronization loops, acting on all RF systems or all cavities of one RF system simultaneously.

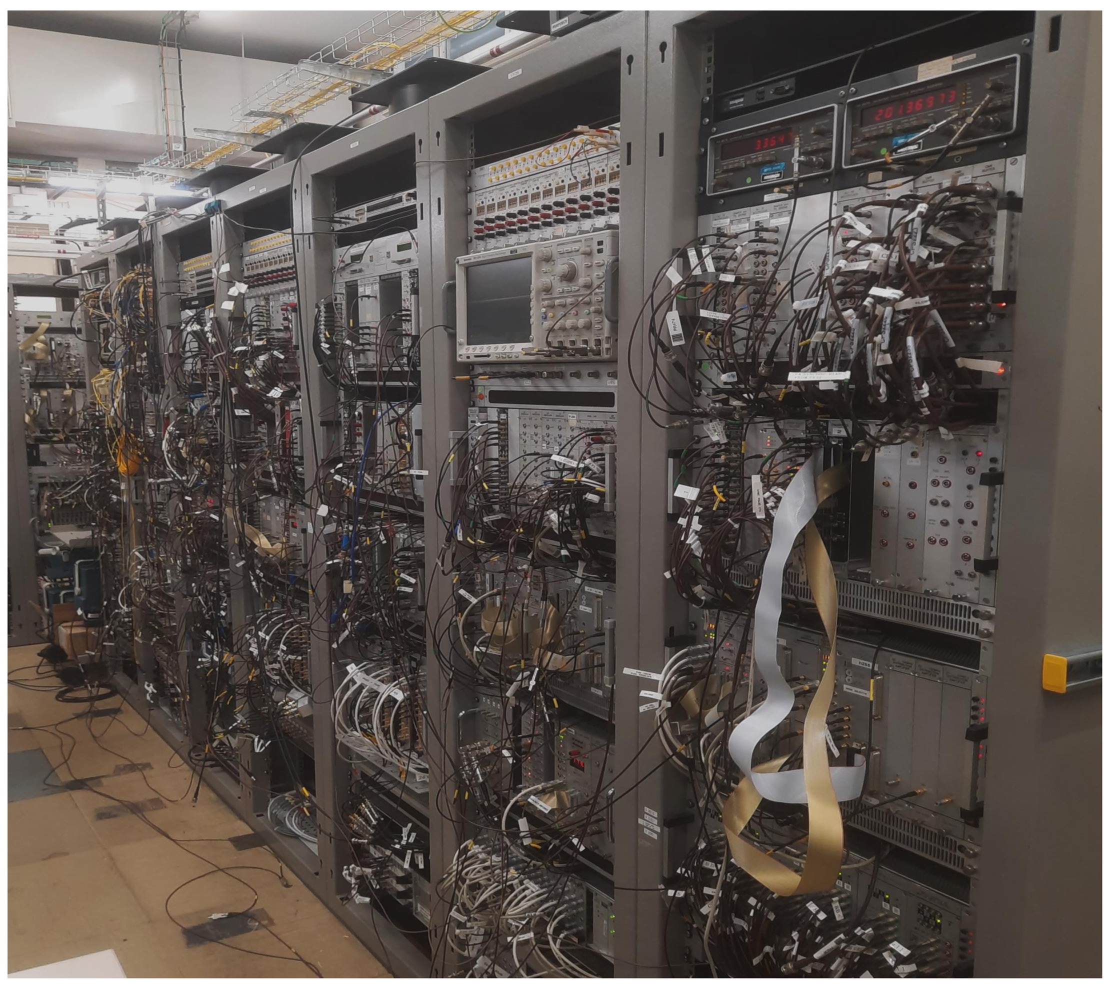

Figure 1 – Current implementation of the beam control system in the PS

VXS architecture

The VXS platform is well consolidated over several systems in the CERN accelerator complex [3]. Custom carrier boards allow using commercial or custom FMC mezzanines to make the system fully configurable. Point-to-point Gigabit links are used to exchange information over the backplane, with custom switches to select the routing of the links.

Some of the features of this platform are [4]:

- Built-in clock and synchronization signals routed over low-noise links in the backplane and distributed to all modules.
- Low-latency point-to-point high-speed links through the backplane with a flexible configuration.
- High pin count FMC connectors in the carrier boards.
- Fully remote configurable.
- Firmware and software management blocks already in operation.
- Acquisition, functions, internal timings also available and operational.

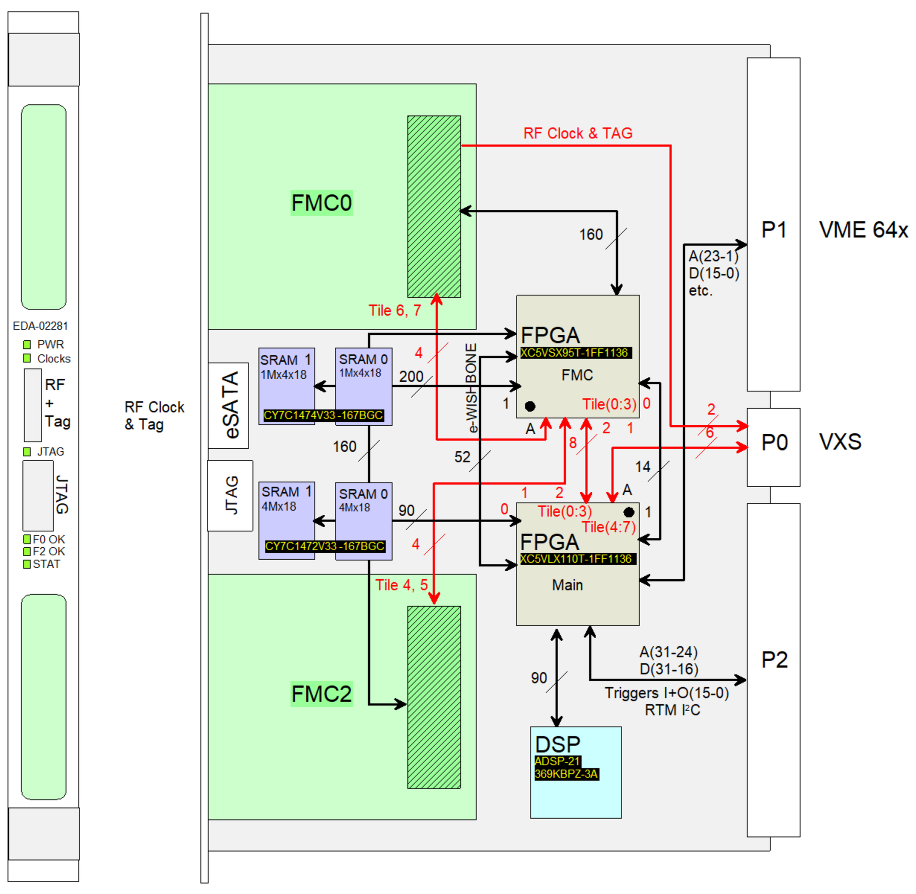

Figure 2 – VXS carrier design

VXS carrier:

- 2 FPGAs + 1 DSP processor.
- 2 FMC HPC connectors.
- VME 64x compatible interface.
- Internal clock and tag distribution. Available also from the front-panel.
- SRAM memories attached for acquisition (clocked with 100 MHz or RF clock).
- Available FMCs: 125 MSPS ADCs, 250 MSPS DACs, QSFPs, DDS, serial converters, etc.

VXS Switch:

- Selectable clock and tag sources.
- Output clock and tag in the front panel.
- 72 by 72 configurable crossbar allowing multicast.
- White Rabbit compatible.
- Controllable via I²C from carrier via backplane.

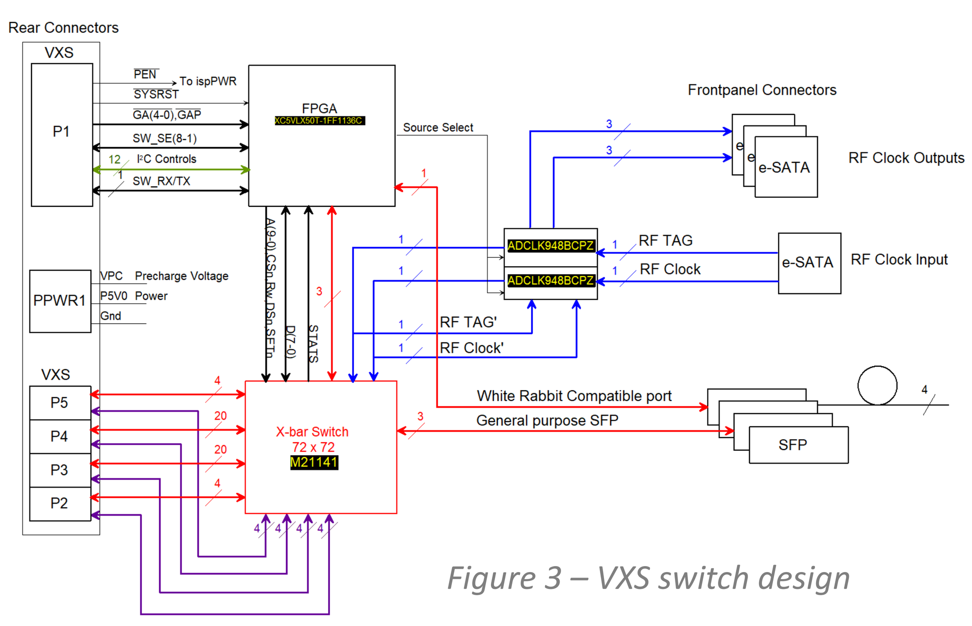

Figure 3 – VXS switch design

New PS beam control

New firmware is being developed to fulfill the specific features of the PS beam control implementation. Cavity phase, beam phase and coarse and fine synchronization signals are demodulated for all types of beams. The demodulated signals are fed to the beam loops module, where a digital switch allows changing loop inputs along the cycle.

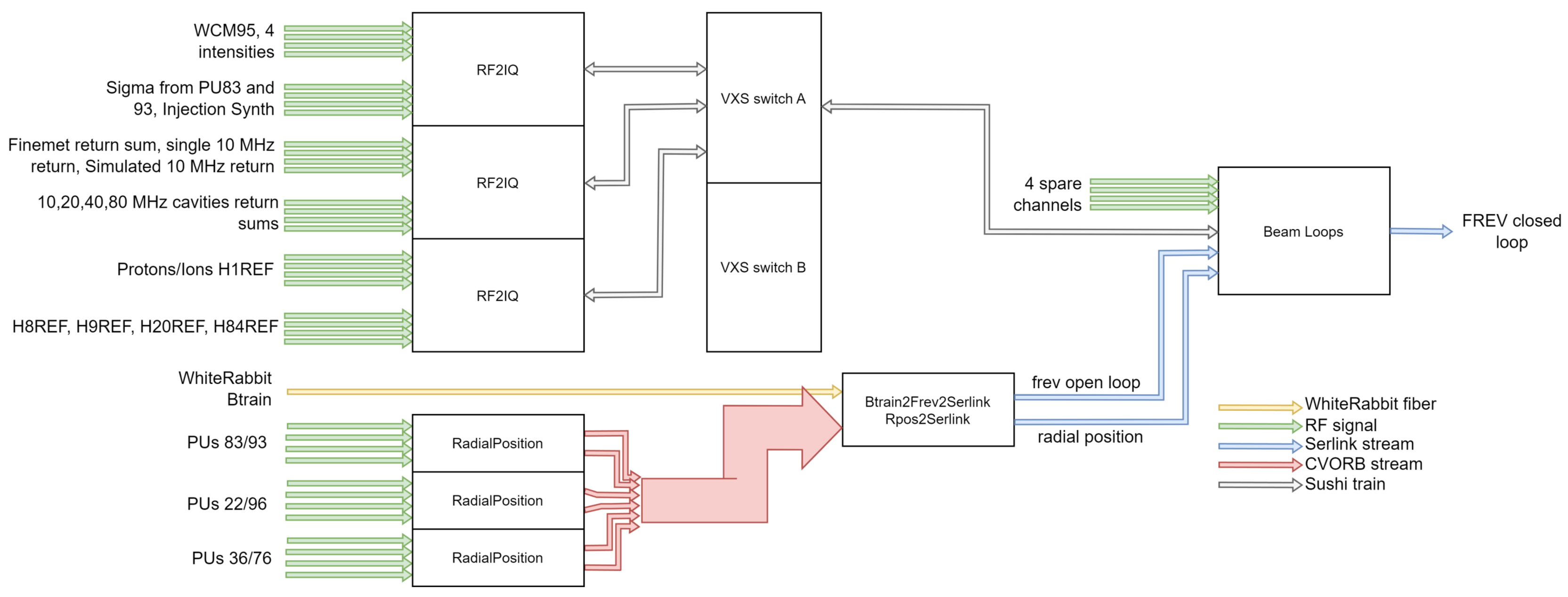

Figure 4 – New PS beam control implementation

The compact implementation of the new beam control is based on the demodulation of each channel using two harmonics simultaneously. The selected harmonics change using functions during the cycle. In the beam loops module, inputs and harmonics can be dynamically selected using smooth multiplexers. Acquisition, data transfer, functions and timings are provided by the VXS platform.

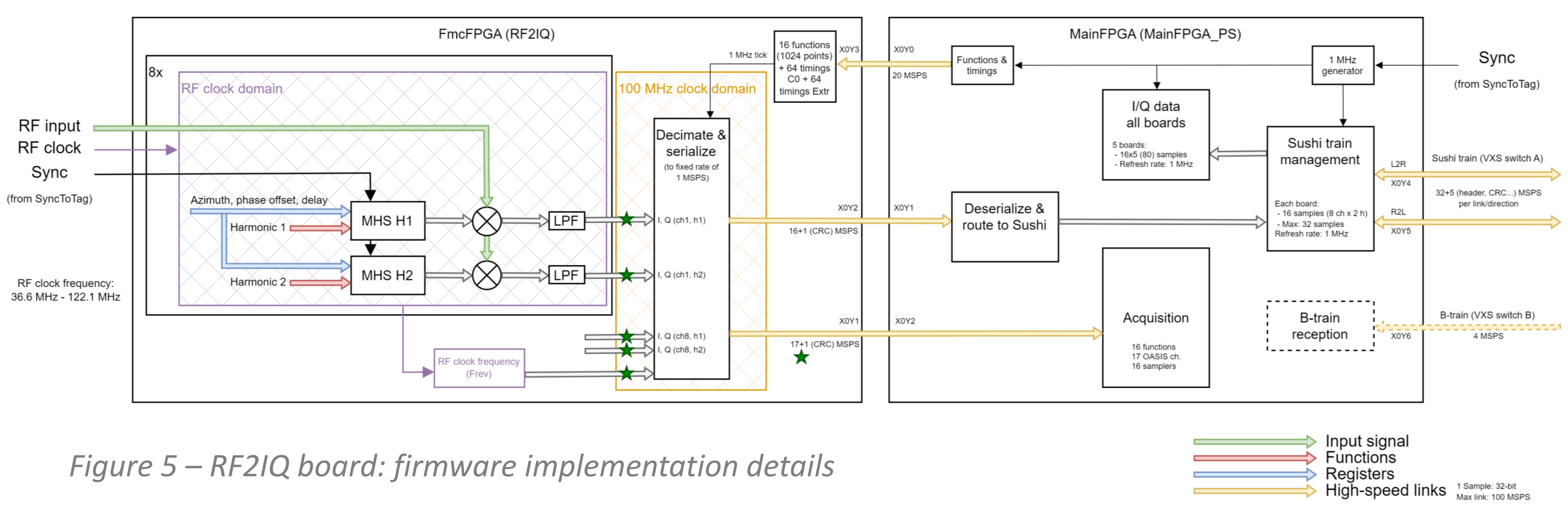

Figure 5 – RF2IQ board: firmware implementation details

The new design profits from previous hardware, firmware and software developments. As an example, MainFPGA software will be kept compatible to other VXS systems. Firmware with further capabilities will be adapted to the PS beam control needs.

The radial position detection chain has been already deployed whereas other components are being tested. A deployment campaign will cover non-destructive tests using Machine Development (MD) cycles, where an RF switch will be used to toggle between the generated revolution frequency signal of the current and new systems.

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*diego.barrientos@cern.ch

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