LLRF AND LONGITUDINAL DIAGNOSTICS IMPLEMENTATION FOR CERN'S ELENA RING

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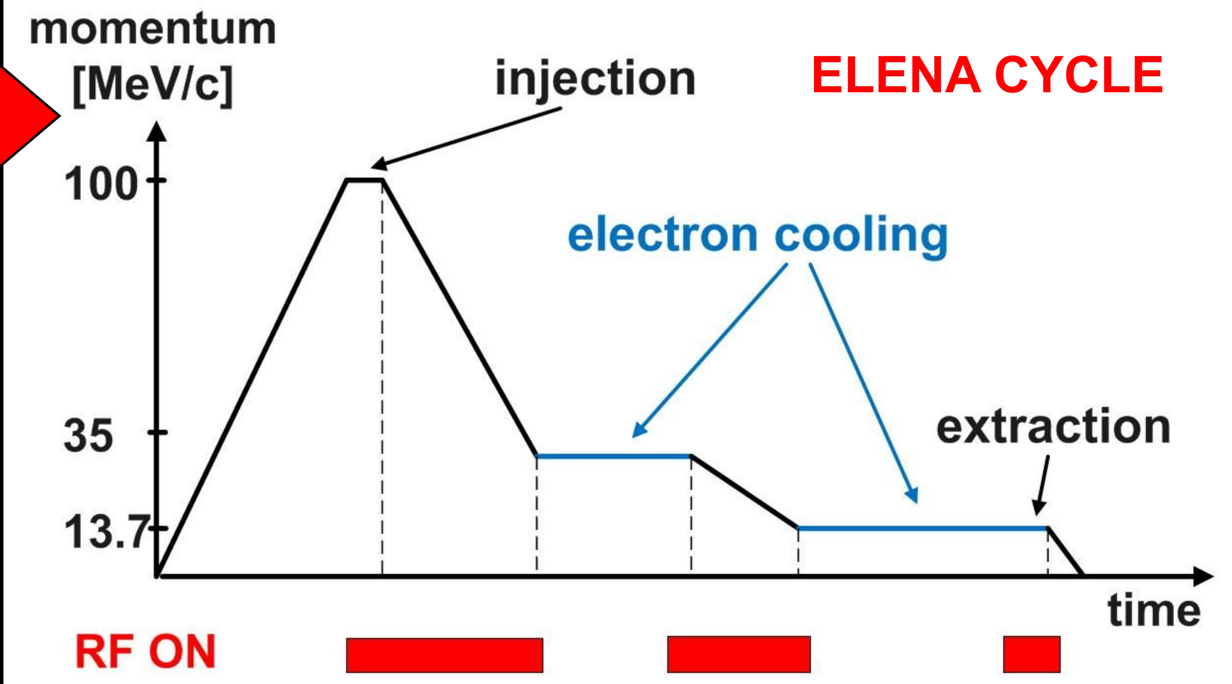
ABSTRACT

CERN's Extra Low ENergy Antiproton (ELENA) ring [1] is a new synchrotron to be commissioned in 2016 to further decelerate the antiprotons coming from CERN's Antiproton Decelerator (AD).

ELENA's LLRF will implement beam phase, radial, extraction synchronisation and cavity loops.

Essential longitudinal diagnostics are **a)** the intensity measurement for bunched and debunched beams and **b)** the measurement of *Δp/p* for debunched beams to assess the electron cooling performance. Two approaches are planned to satisfy the longitudinal diagnostics needs. The baseline system is based upon ultra-low-noise AC beam transformers [2]. A novel method [3] is also envisaged and includes combining signals from the twenty electrostatic pick-ups (PUs) used for orbit measurements to improve the SNR.

For both approaches the digital signal processing will be carried out with the leading-edge hardware family [4] used for ELENA's low-level RF system (see poster #45).



Parameter	Inj.	Extr.
Momentum [MeV/c]	100	13.7
f_{REV} [MHz]	1.06	0.145
Expected particles nb	$3\cdot10^7$	$1.8\cdot10^7$
Circumference [m]	30.4	
Extracted bunches nb	4	
Extracted bunches length [m/ns]	1.3 / 300	

Table 1: ELENA ring parameters

1. LLRF

The LLRF will implement beam phase, radial and extraction synchronisation loops. Bunched-beam cooling is planned at extraction and a double harmonic extraction scheme might be required later on. The HLRF will be a wide-band Finemet-based cavity, with voltage/phase loop implemented in the LLRF system. A dynamic range of 72 dB (25 mV to 100 V) is required in the cavity control path. A real-time controlled gap relay will short-circuit the cavity when no voltage is applied to it. All data processing will be done in [I,Q] coordinates.

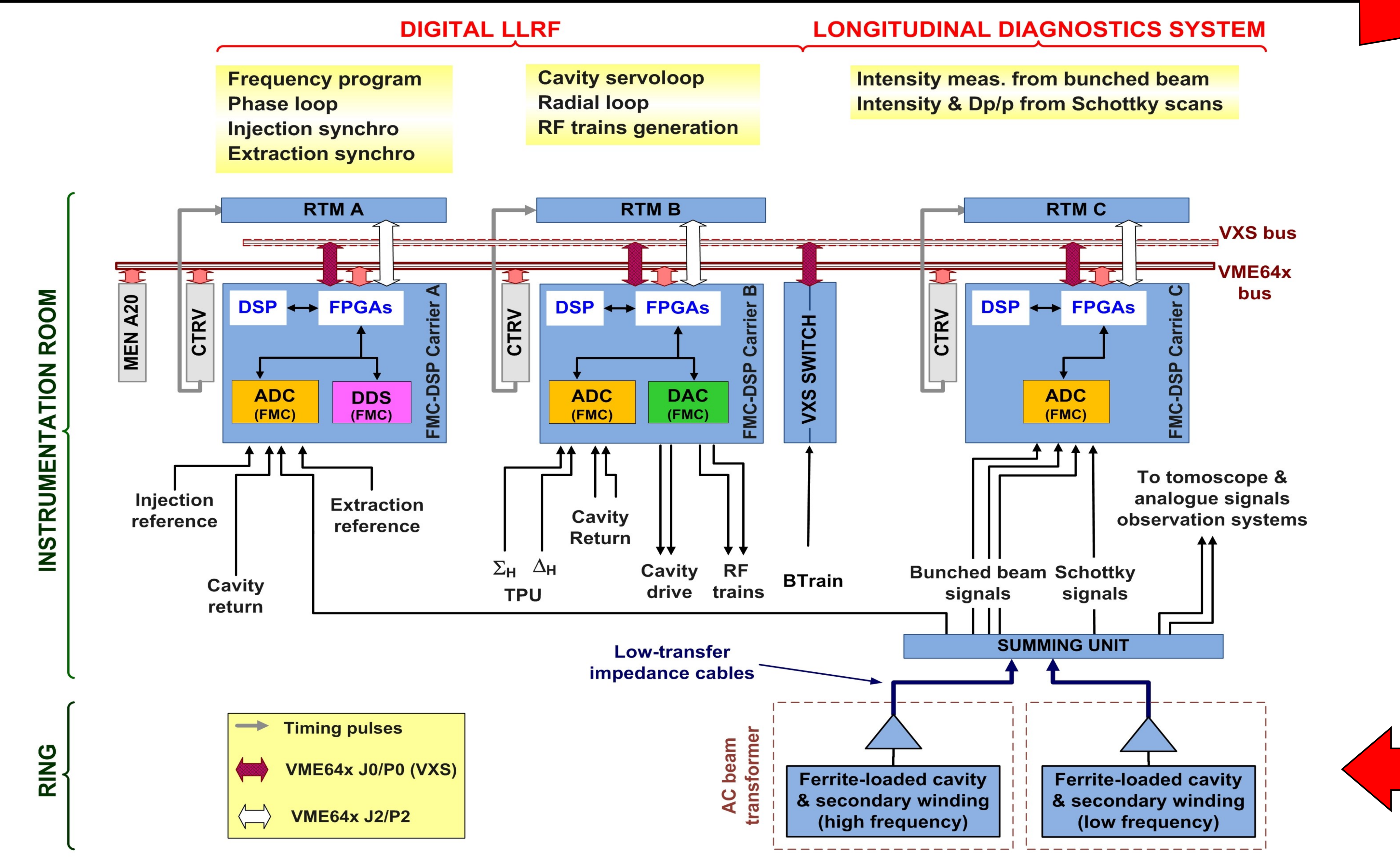


Fig. 1: LLRF and Longitudinal diagnostics systems. Keys: **DDS** - Direct Digital Synthesiser; **ADC** - Analogue-to-Digital FMC board; **DAC** - Digital-to-Analogue FMC board; **RTM** - Rear Transition Module; **TPU** - Transverse Pick-Up; **CTRV** - Timing Receiver Module; **Men A20 –** master VME board; **BTrain** - measured magnetic field.
The blue & the FMC blocks are custom hardware designed by CERN's BE/RF group [4].

2. AC BEAM TRANSFORMER [2]

The DC beam currents in ELENA are very low, between **a few µA and down to 0.2 µA**, which rules out to measure the intensity with a conventional DC beam current transformer. The baseline solution is based on an ultra-low-noise AC beam transformer as an adaptation of that successfully operational in CERN's AD [5], see Fig. 2.

The low-frequency cut-off of the combined AC beam transformer will be of 3 kHz to measure the bunch length at the lowest f_{REV} value; the bandwidth will go to 30 MHz or higher to measure the shortest bunch length and high Schottky harmonics.

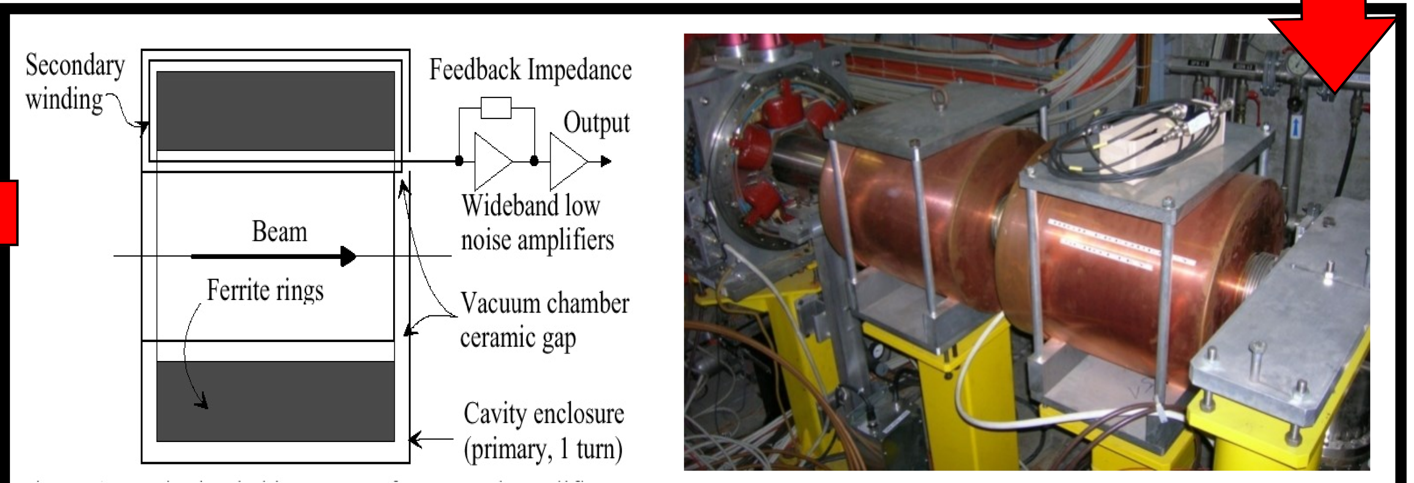


Fig. 2: AC beam transformer overview (left) and AD ring system (right).

3. DIGITAL SIGNAL PROCESSING

The FPGAs and the DSP in the DSP-FMC-Carrier board will share the digital processing implementation.

Debunched-beam processing: spectral analysis of Schottky signals, the same as that deployed in the AD [6].

Bunched-beam processing: A new bunched beam measurement, bunch length independent, will be implemented by integrating the bunch shape, once the baseline is identified, and subtracting the baseline value itself. The intensity value will be obtained by averaging a user-selectable number of bunches. See Fig. 3.

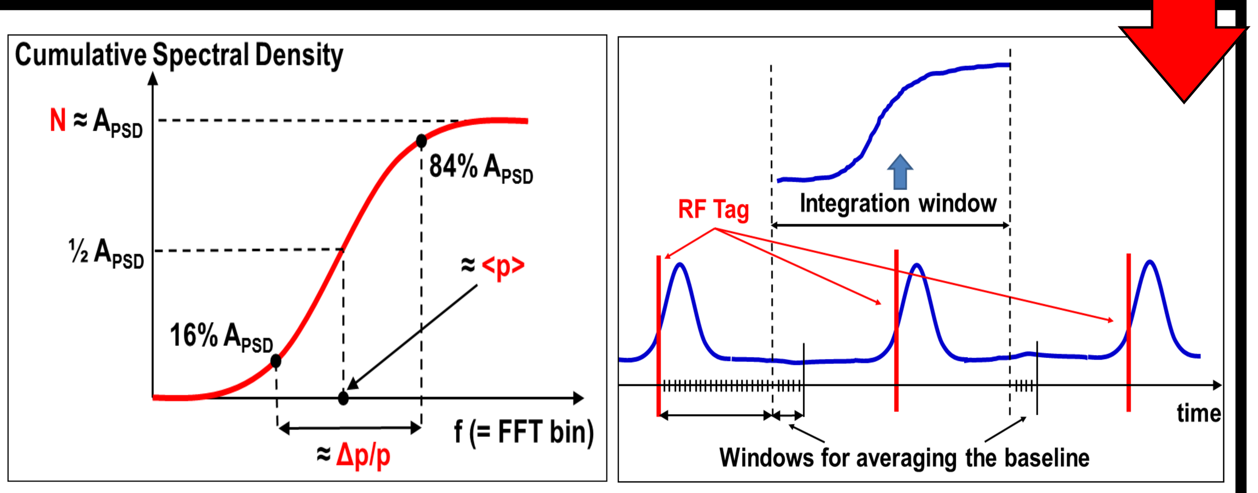


Fig 3: De-bunched (left) & bunched (right) signal processing.

4. DISTRIBUTED ELECTROSTATIC PU [3]

The design, optimized for high bandwidth and sensitivity, is based upon a stainless steel body containing two diagonal cut PUs, located inside quadrupoles and corrector dipoles to gain longitudinal space in the ring.

The digital signal processing for the longitudinal diagnostics task is identical to that implemented in the baseline solution [see section 3] once the PUs sum signals have been combined to increase the SNR. The many electrostatic PUs will then look as a single, distributed PU from to the processing system. The location of the revolution tag associated with the RF clock received from the LLRF varies with respect to the acquired Σ signals (for bunched beams) or phase of single turn Schottky signal (for debunched beam) due to the beam **time-of-flight** (ring azimuthal position of the nth PU) and **total cable delay**. This will be recalculated during the cycle as f_{REV} changes.

This approach provides the **sensitivity obtainable by a long electrostatic PU** and the **high bandwidth that can be obtained with short electrodes**. However, electrostatic PUs with slow time constants are sensitive to charging from secondary emission of lost particles; recovery is slow due to a very large bias resistor. This drawback as well as the need for significant efforts for study and development prevents using the distributed PU system as the baseline solution for ELENA commissioning and initial operation.

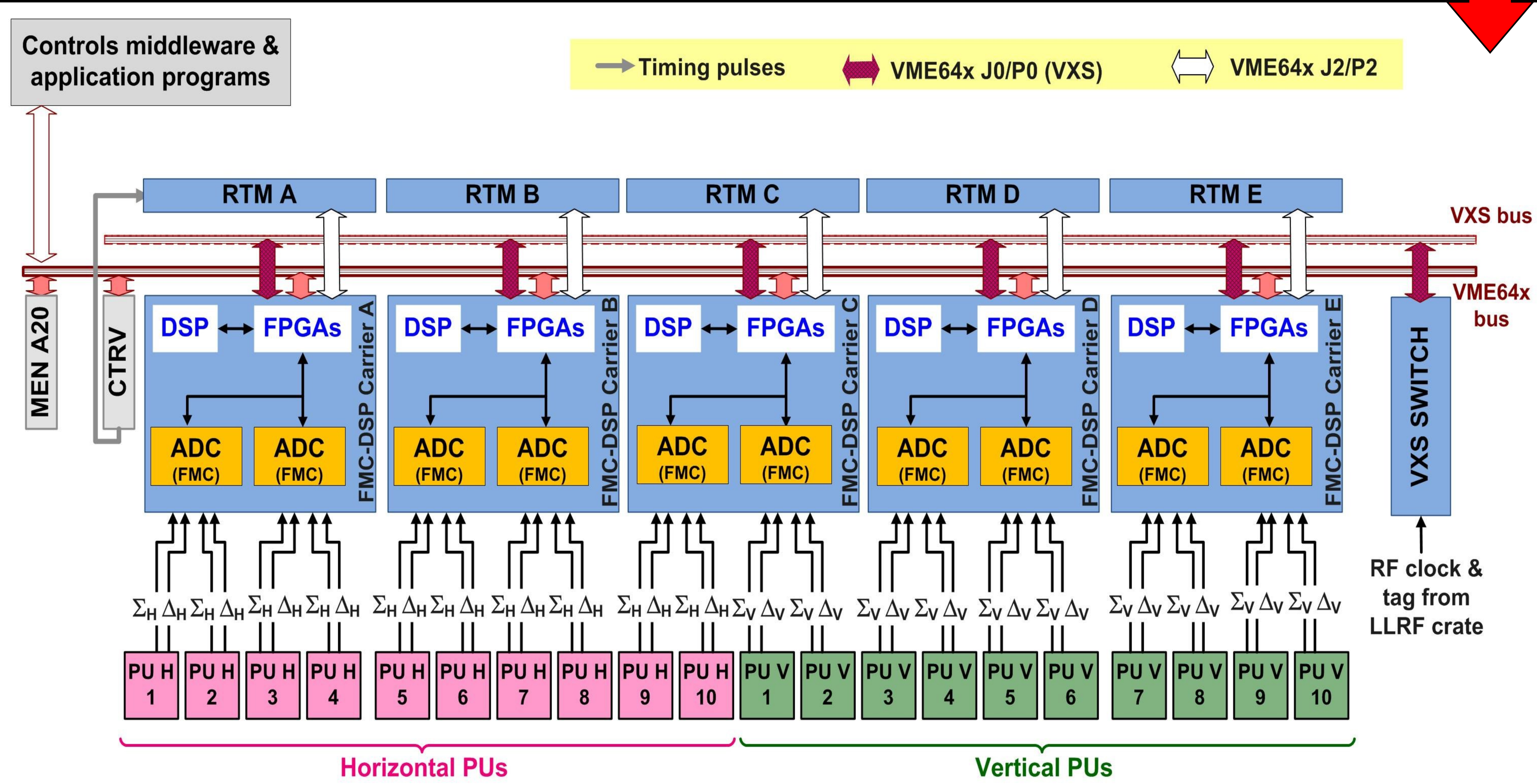


Fig. 4: Beam orbit and longitudinal parameters measurement system. Keys: **PU H , PU V** – Horizontal, Vertical transverse Pick-Up. See also Fig. 1 for keys to the other blocks.

REFERENCES

[1] T. Eriksson (editor) et al., "***ELENA, an Updated Cost and Feasibility Study***", CERN-BE-2010-029.

[2] M. E. Angoletta et al., "***An Ultra-Low Noise AC Beam Transformer and Digital Signal Processing System for CERN's ELENA Ring***", IBIC'13, Oxford, September 2013, TUPF27.

[3] M. E. Angoletta et al., "***Longitudinal Beam Diagnostics from a Distributed Electrostatic Pick-Up in CERN's ELENA Ring***", IBIC'13, Oxford, September 2013, WEPF28.

[4] M. E. Angoletta et al., "***A Leading-Edge Hardware Family for Diagnostics Applications and Low-Level RF in CERN's ELENA Ring***", IBIC'13, Oxford, September 2013, TUPF28.

[5] C. Gonzalez, F. Pedersen, "***An Ultra Low Noise AC Beam Transformer for Deceleration and Diagnostics of Low Intensity Beams***", PAC'99, p 474.

[6] M.E. Angoletta et al., "***The New Digital-Receiver-Based System for Antiproton Beam Diagnostics***" PAC'01, p. 2371.