SCHOTTKY SIGNAL FROM DISTRIBUTED ORBIT PICK-UPS

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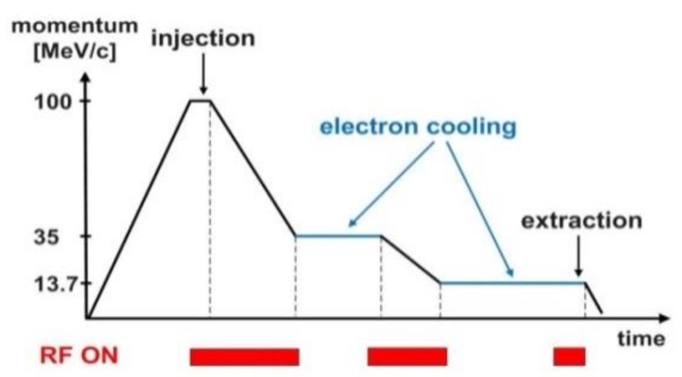
ABSTRACT

In the CERN Extra Low ENergy Anti-proton (ELENA) ring, intended for the deceleration of antiprotons, the longitudinal Schottky signal is obtained by summing the multiple electrostatic pick-up (PU) signals that are also used to measure the closed orbit. The signals from the individual PUs are phase-compensate to a single, common longitudinal location in the machine and added in the time domain. In this contribution, the related theoretical phase compensation is calculated and compared to measurements. We show how the cross correlation between the Schottky noise from the individual PUs can be used to find the correct phase-compensation for an optimal signal-to-noise ratio (SNR). This improvement in terms of SNR is, as expected, proportional to the square root of the number of PUs. The capability of the system to measure both, the bunched and the un-bunched low intensity (~3·107 H- @ 100keV / 144kHz) beams is confirmed by the experimental results presented. Furthermore, the inter-bunch phase correlation is briefly addressed and, for the case of bunched beams, the Schottky signal levels once down converted to different harmonics of the revolution frequency (f_{rev}) are presented. In applications where the coherent beam signal dominates the spectrum and limits the dynamic range of the signal processing system, a down-conversation to a non-integer multiple of the RF harmonic is proposed as a way to reduce the coherent signal level.

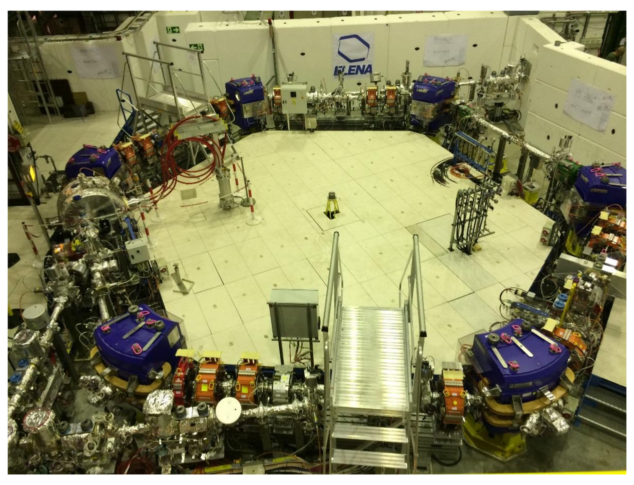
THE ELENA RING



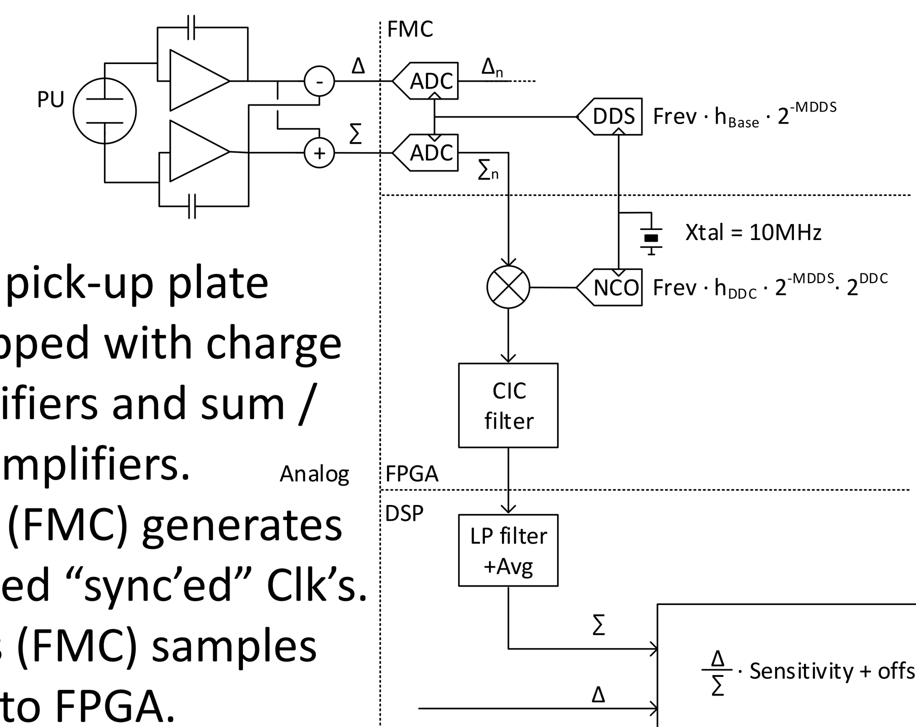
ELENA pbar cycle

Parameter	Injection	Extraction
Momentum, MeV/c	100	13.7
Kinetic Energy, MeV	5.3	0.1
Revolution frequency, MHz	1.06	0.145
Expected number of particles	$3\cdot10^7$	$1.0\cdot10^7$
Number of extracted bunches	4 (operationally)	
Extracted bunches length, m/ns	1.3/300	
Circumference, m	30.4	

The CERN ELENA, Extra Low Energy Anti-proton ring is designed to decelerate anti protons from the CERN AD from 5.3MeV to 100keV (β = 0.015). It handles $3\cdot10^7$ anti protons or, alternatively during commissioning, the same number of H^- coming from a local source. The deceleration calls for beam cooling and Schottky signals are used to evaluate this.



THE ORBIT SYSTEM + SCHOTTKY



VXS-DSP-FMC Carrier, mounted with DDS and ADCs

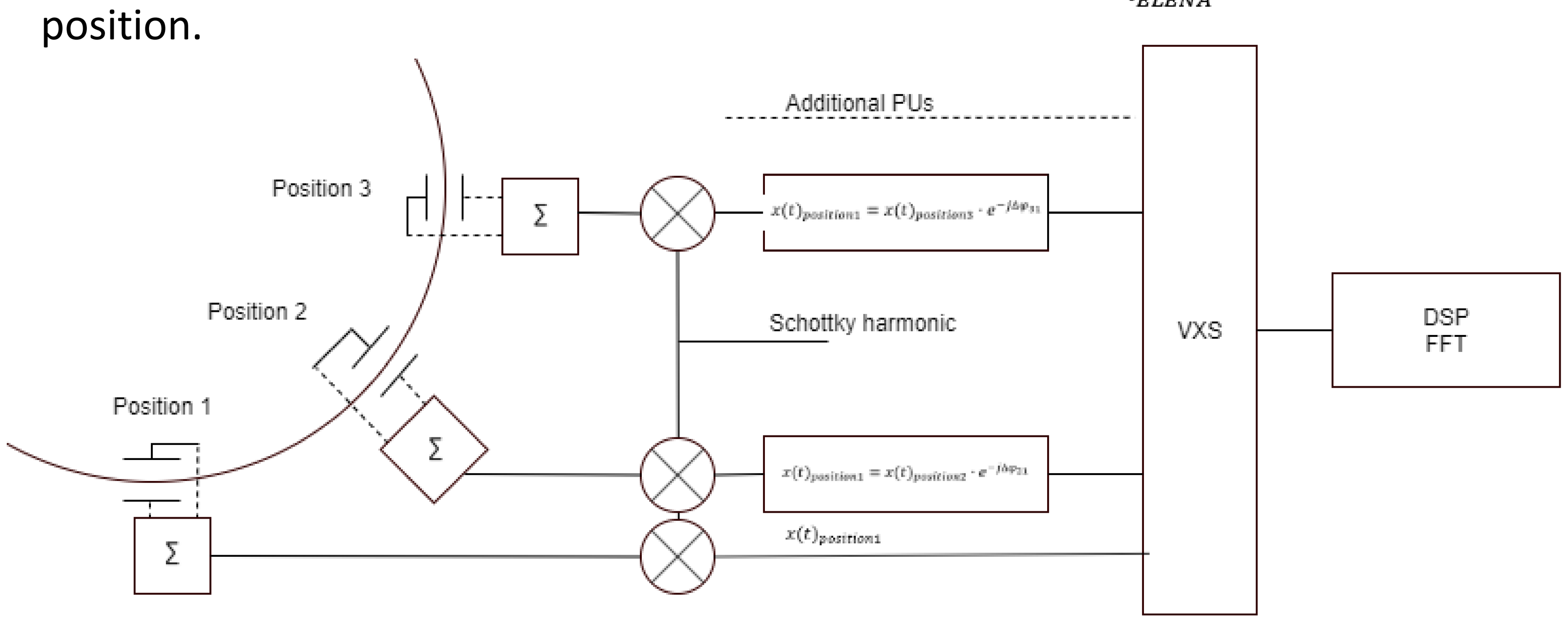
- Each pick-up plate equipped with charge amplifiers and sum / diff amplifiers.
- DDS' (FMC) generates needed "sync'ed" Clk's.
- ADCs (FMC) samples data to FPGA.
- Down conversion and CIC decimation and filtering in FPGA.
- Position calculation in DSP.
- Data share over VXS bus, allowing calculation of eg. mean radial position.

$$\Delta\varphi = 2\pi f_{Schottky}\cdot\Delta t = 2\pi\cdot h_{Schottky}\cdot f_{revolution}\cdot\Delta t$$

where

$$f_{revolution} = \frac{\beta c}{l_{ELENA}} \text{ and } \Delta t = \frac{l_{distance\_between\_PUs}}{\beta c}$$

$$\Delta\varphi = 2\pi h_{Schottky}\frac{l_{distance\_between\_PUs}}{l_{ELENA}}$$



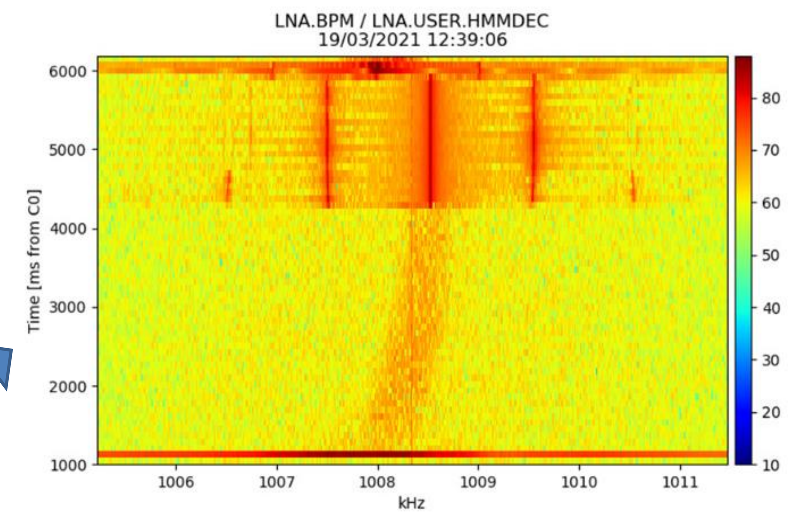
- Same sum signals and LOs for orbit and Schottky. Same harmonic used, else time multiplexed usage e.g. orbit for bunched beam on ramps and Schottky on plateau.
- One reference position, all other PU signals are phase compensated to this point before added and FFT. Phase compensation either from cross correlation or relative mechanical position of PUs.
- LO shall be the same for all down mixers or in fixed phase relationship.

MEASUREMENT

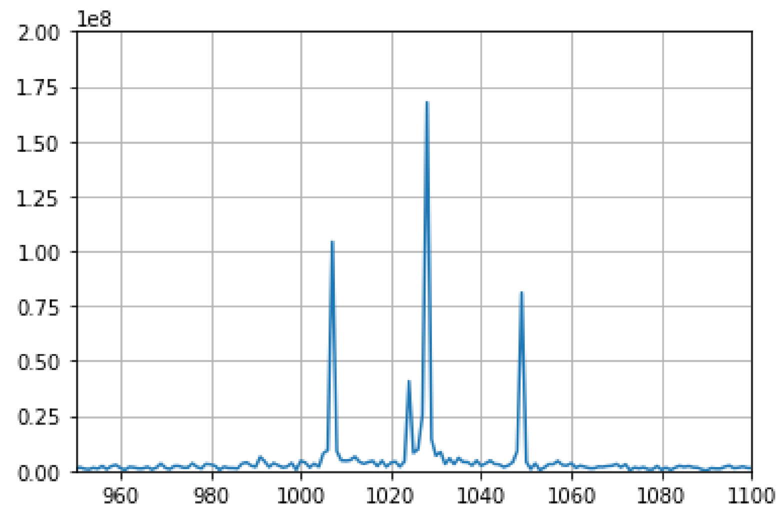
Beam @ extraction:

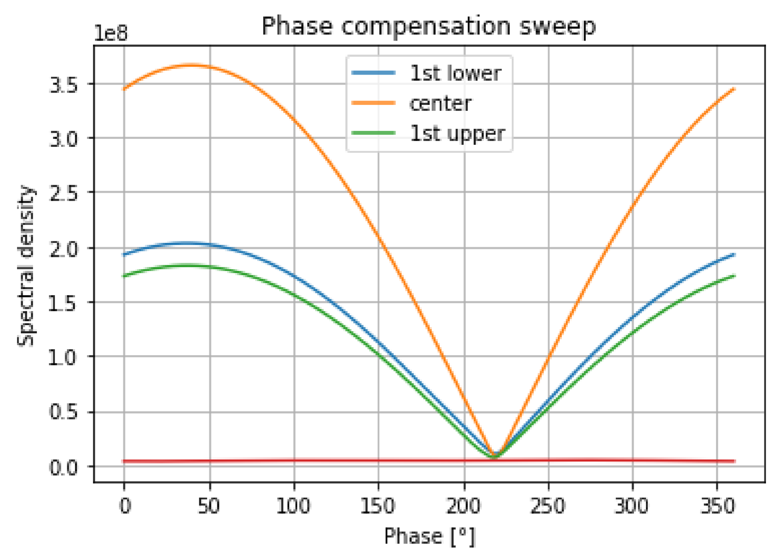
~ $1\cdot10^7$ H^- at 100keV =

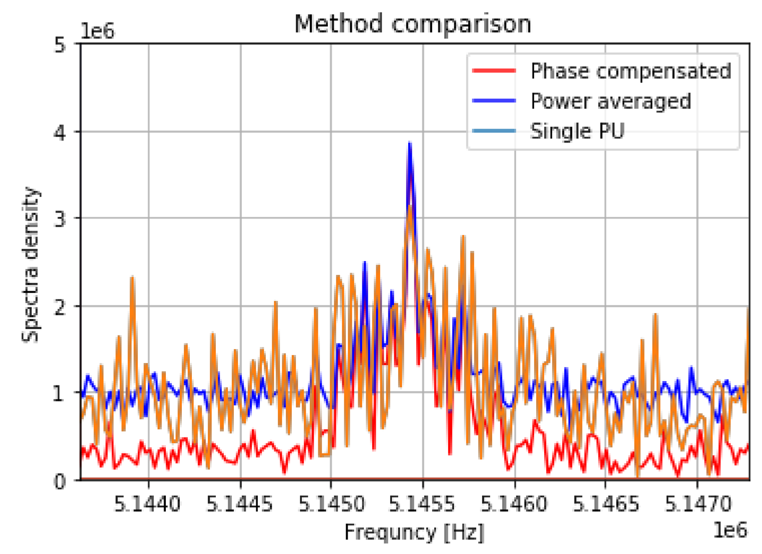
$$i_{RMS} = 2ef_{rev}\sqrt{\frac{N}{2}} \sim 100pA$$

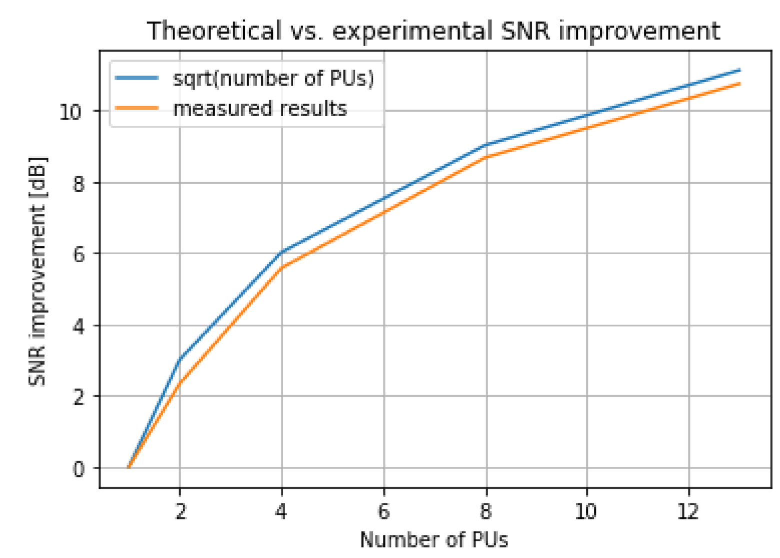


- A measurement of un-bunched and bunched beam using 13 PUs amplifier: $1\cdot10^7$ H^-
- A bunched beam spectrum from one PU.
- Adding in time domain the signal from two PUs, with one PU phase compensated before performing the FFT. The phase is here swept through 0 to 360° to show the resulting amplitude of the low, high and centre bin. This shows both constructive and destructive interference (180° apart) i.e. respectively a "max" and a "dip". This at the same angle for all frequencies in the spectrum.
- The constructive phase corresponds to the calculated phase needed for location compensation, found either from the PU location of cross-correlation between the two PU signals.
- A small "spur" is here seen just next to the centre bin. Spur's and other interference that are not correlated in the different down converters will be averaged out (lowered) using the technic presented. In the same time the Schottky will be added constructively
- Comparing power averaging of Schottky spectra with the presented complex phase compensated adding: The plot shows a spectrum calculated from a single PU, 13 spectra calculated by "normal" FFT and following averaging of spectra vs. the presented technic of same 13PUs (resp. orange, blue and red). The "normal" gain in from the decreased spread of the noise is seen for the blue where-as the increased sensitivity (decrease of noise level) is observed for the red (same spread, but at a lower level).
- Taking 2, 4, 8 or 13 PU and evaluating the SNR gain between "normal" averaging and the phase com. Technic is shown to follow an expected sqrt(number of PU used) relation









CONCLUSIONS

A substantial SNR improvement of the longitudinal Schottky signal can be achieved using the presented phase compensating technic, where signal from several distributed PUs in a ring is phase compensated before being summed and presented as frequency domain Schottky spectrum. The method validated the expected $\sqrt{number\ of\ PUs}$ SNR improvement, superior to the power-spectral density (PSD) averaging of a single beam pickup. The values required for the phase compensation were calculated from the knowledge of the relative physical location of the PUs in the ring, and validated by cross correlation between sampled data from individual PUs. Cable lengths between PUs and the acquisition system were included as necessary and cable length differences minimized. Unwanted interference/spur if uncorrelated will be reduced. The presented method is implemented as an extension to the existing CERN ELENA orbit measurement system i.e. using the same PUs and acquisition system, operating either time multiplexed: Measuring the orbit when the beam is bunched and performing the longitudinal Schottky analysis when the beam is un-bunched for cooling at fixed energy or operating on the same harmonic of f_{rev} for orbit and Schottky monitoring. The ELENA Schottky system i.e. this technique has been used during the commissioning of the ELENA electron-cooler.