TRAJECTORY MEASUREMENTS IN THE DAΦNE TRANSFER LINES

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Abstract

An improved beam position monitor system has been installed in the Transfer Lines (TL) connecting the DAΦNE Linac to the collider Main Rings through the Damping Ring, to monitor the beam trajectory and optimize the transmission efficiency.

Signals from stripline type beam position monitors are stretched, sampled through Track & Hold circuits and digitized to 12 bits. The sampling stage is triggered, according to the timing of the desired beam, to measure the amplitude of the signals induced on a BPM.

Hardware control, data collection and reconstruction of the beam position along the Transfer Lines are performed by the DAΦNE Control System on a VME standard local processor.

Design issues, implementation and performance of the system are presented.

1 INTRODUCTION

The injector chain of DAΦNE consists of a e+/e- Linac injecting into an intermediate storage ring (Accumulator), employed to accumulate the required single bunch current and to damp the longitudinal and transverse emittances before the injection in the DAΦNE main rings.

Linac, Accumulator and Main Rings are interconnected by ~140 m of Transfer Lines altogether.

Due to the requirement of using the pre-existing buildings, the TL are designed in such a way that different beams (electrons or positrons from the Linac into the Damping Ring and from the Damping Ring into either one of the Main Rings) traverse the same portion of the TL in opposite directions with different timing.

2 SYSTEM OVERVIEW

2.1 Pick-up Electrodes and Signal Processing

The low repetition rate (50 Hz from the Linac to the Damping Ring and 1 Hz for the injection in the Main Rings) requires a single shot detection system to measure the beam position.

To acquire the whole trajectory of the beam, 23 beam position monitors (BPMs) are installed along the lines.

The BPMs consist of 50Ω strip-line electrodes, with 0.15 m length and 30 degrees angular width, short circuited at one end inside the vacuum chamber of 37 mm radius.

The signal induced by the beam consists of two pulses of opposite polarities, according to the shape of the bunch. The different characteristics of the beam injected and extracted from the Damping Ring (Tab. 1) give a wide range of amplitudes and widths of the pulses (Fig. 1).

Table 1: DAΦNE Injector Beam Parameters

Parameter	Typical
LINAC bunch charge	1 nC
LINAC bunch length	10 ns FWHM
LINAC repetition rate	25-50 Hz
ACC bunch charge	3÷12 nC
ACC bunch length	300 ps FWHM
ACC repetition rate	1-2 Hz

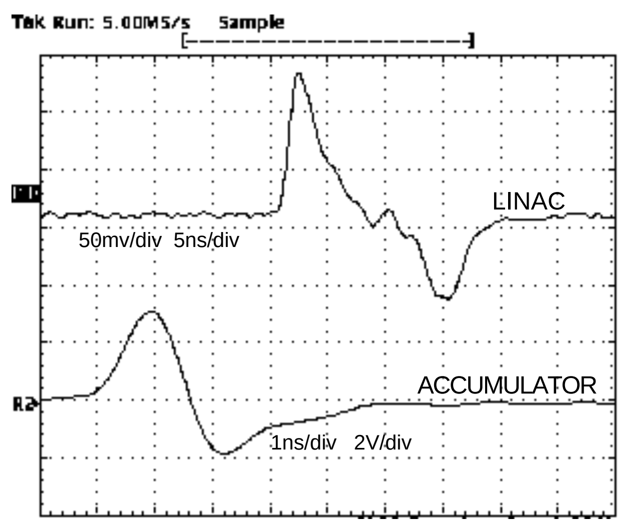

Figure 1: Typical pickup signals at the input of the BPM detection electronics, induced by the Linac beam and the Accumulator, measured at the end of ~50 m long coaxial cables.

In our case the Linac delivers bunches with a 10 ns FWHM length, while the damped beam extracted from the Accumulator has a 300 ps FWHM bunch length.

Each pickup signal is sent (through coaxial cables of typical length between 40m and 100m) to a wide band multiplexer system equipped with HP-E1366A boards and then to the detection electronics.

The beam position is determined by measuring the peak amplitude of the signals induced on each electrode, then calculated from a linear combination of the measured voltages through a non linear fitting function, in order to correct the non linear response of the BPMs.

The fitting function has been derived through a bench calibration with the wire method.

2.2 Detection Electronics

The block schematic of the detection electronic is reported in Fig. 2.

The peak amplitude of each pickup signal is sampled with different Track & Hold (T/H) Amplifiers (ANALOG DEVICES AD9101), which are triggered to hold the peak values for 5 µs.

Before arriving to the sampling stage each pulse is stretched through low pass filters in order to get a flat crest for accurate hold of the subsequent T/H stage.

Bessel-Thomson low pass filters (Mini-Circuits BBLP-117), which provide a flat time delay design to preserve the pulse shape and avoid overshoot and ringing, have been employed.

The 3 dB frequency of the filters has been chosen as a compromise between the conflicting requirements of slowing down the fast risetime of the pulses from the accumulator beam and the requirement of performing measurements also at low currents.

The expected peak signal induced by a gaussian bunch with a σ rms length in a strip line through a gaussian filter can be deduced from (for σ_{eff}>(l/c)):

$$V_p = Q\left(\frac{\varphi}{2\pi}\right)Z_0 \frac{l}{c\sqrt{2\pi e}\sigma_{eff}^2} \qquad (1)$$

where Q is the bunch charge, $\sigma_{eff}^2 = \sigma^2 + \sigma_F^2$ with σ_F the width of the filter finite impulse response, φ is the opening angle of the electrode, Z_0=50 Ω the characteristic impedance of the transmission line, l the stripline length, and c the speed of light.

The analog to digital conversion is performed by a VME ADC Board (Green Spring IP-HiADC) based on Analog Devices AD684JQ sample and hold amplifiers and Analog Devices AD1671 analog to digital converter.

The ADC board, programmed through a VME CPU and externally triggered, allows the simultaneous acquisition of the four channels through its sampling input stage and the final A/D conversion within 800 ns for each channel.

The timing for the trigger of T/H amplifiers and the ADC board is provided by delaying of a proper amount of time, different for each BPM, the DAΦNE injection and extraction trigger provided by the timing system, with a Stanford DG535 Pulse Generator controlled through a GPIB interface, in order to hold the signal peak for the following ADC stage.

Since the pickup signals induced by the beam extracted from the Accumulator can exceed the T/H input range, voltage controlled attenuators (MiniCircuits ZAS-1) are placed before the T/H stage and controlled with a VME DAC board (Green Spring IP-DAC).

A calibration signal with a programmable amplitude has been introduced into the electronic system to measure the gain of each channel and subtract the corresponding offset from the measured beam position.

A VME local processor based on a Motorola 68000 CPU, which is an integral part of the DAΦNE Control System, controls the hardware, collects and reconstructs the beam position along the TL through a dedicated software developed in LabView. The VME processor also makes the measured trajectory available to the control system.

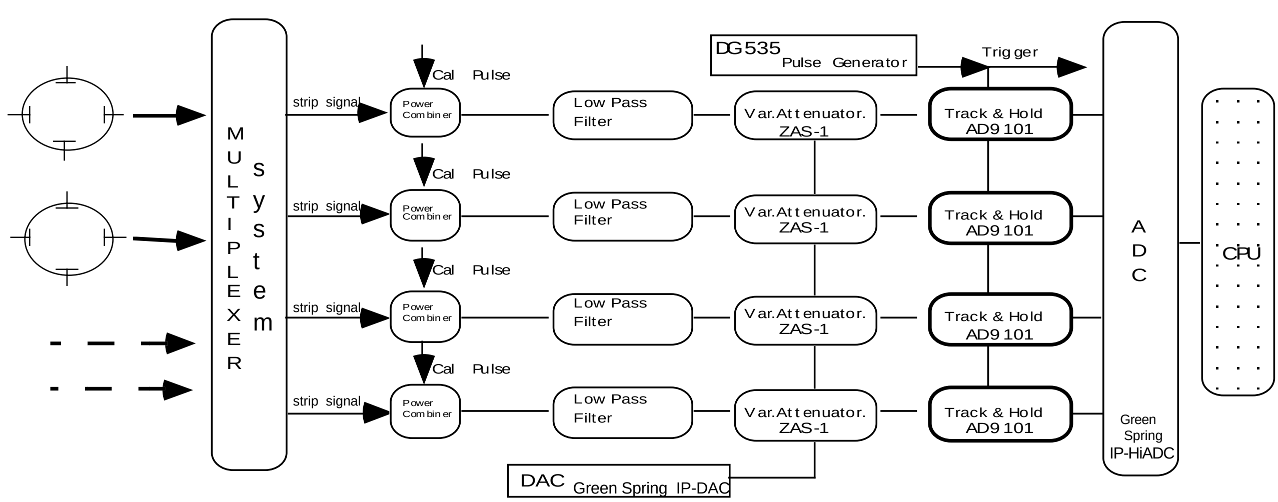

Figure 2: Block schematic of the detection electronics

3 MEASUREMENT RESULTS

3.1 Bench Tests

From bench calibration we can calculate the ratio between the peak amplitudes of the pickup signals as a function of the beam offset, and compare it to the dynamic range of the detection electronics. The input dynamic range of the T/H sampling amplifiers is compatible with a maximum beam offset of 20 mm from the center of the vacuum chamber.

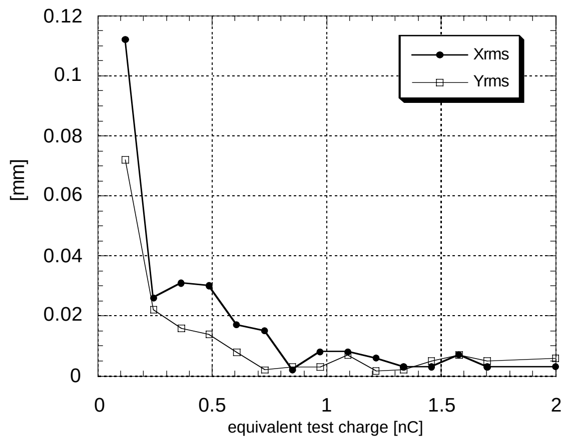

Figure 3: rms values of the measured beam position over 50 readings as a function of a test charge.

The resolution of the detection system has been measured by reading the position data as a function of the level of a test pulse. A typical diagram of the rms measured position is reported in Fig. 3, the pulse height of the calibration pulse, which spans the whole input range, has been converted into an equivalent test charge by using the eq. (1) to correlate the measurements directly to the beam intensity. The nonlinearity of the BPM detector produces a position offset which depends from the input level. The gain of each channel has been measured and is reported in Fig. 4 as a function of the equivalent test charge.

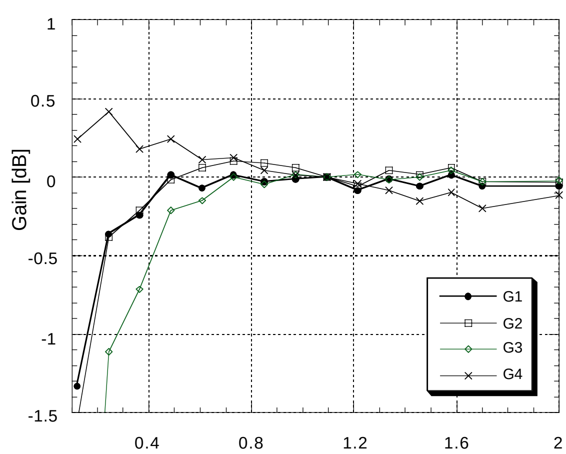

Figure 4: Normalized gain of the four channels as a function of a test charge.

A large difference between the four channels gain occurs in the low input level region. One source of this nonlinearity may be due to the droop rate of the T/H amplifiers.

3.2 Beam Tests

The BPM system has been installed, tested and will be fully integrated in the DAΦNE control system soon.

Examples of measured beam positions at different BPMs for several consecutive bunch passages are shown in Fig. 5a-b. Data refer to the beam extracted from the damping ring with a bunch charge of ~2 nC, they have been acquired using a temporary interface.

The actual resolution appears worse than expected, a possible reason may be a jitter of the trigger signal used to detect the bunch passage, which results in an inaccurate holding of the peak pulses.

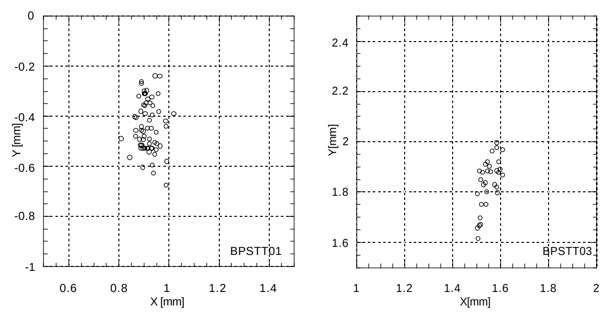

Figure 5a-b: measured beam positions over several bunch passages at different BPMs.

In the past the transfer line trajectory acquisition system relied on an oscilloscope and has been operated through a user interface available within the DAΦNE control system [1]. The interface allows to select the devices involved in the measurement and provides data access to the control system general database for saving and recovering purpose. The peak amplitude over the pickup signals is summed up for each BPM and presented as an histogram providing a rough measurement of the beam current, that gives an immediate and useful feeling of the beam transport efficiency along the TL.

The integration of the new BPM system in the existing user interface is straightforward. It will provide a fast and versatile tool for trajectory measurements. Automatic tasks to optimize the transport along the DAΦNE injection system are under study.

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REFERENCES

[1] G. Di Pirro et al.: "Integration of Diagnostic in the DAΦNE Control System", Proc. DIPAC97, pp. 67 (Frascati 1997).