# A DATA ACQUISITION SYSTEM FOR TRANSVERSE DYNAMICS MEASUREMENTS

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*Abstract*

A data acquisition system (DAS), developed to track dynamically the beams in the DAΦNE Φ-Factory is presented in this paper. From a hardware point of view, the DAS is composed of two oscilloscopes and a personal computer, connected together through an IEEE 488 interface. The software is written in LABVIEW 6.0 and it is portable on different platforms. It produces as output a database that can be read by any spreadsheet or text editor.

A LECROY LC584AM/LC574A oscilloscope, built around a PowerPC working at 96MHz, can digitize to 8-bit waveforms from four channels. Special feature of this oscilloscope is the capability of being synchronized with an external clock in the range 50 - 500 MHz. The clock signal RF/6 is generated by the DAΦNE Timing System. It allows to select anyone between the 120 bunches using a phase shifter.

The oscilloscope samples difference and sum signals in the horizontal and vertical plans from a Beam Position Monitor (BPM). A second oscilloscope can sample synchronously four signals from another BPM (this feature is under development). It is possible to store up to 500k contiguous fixed-point values for each channel; these data correspond to a record of 25k consecutive bunch turns in the Main Ring. The system is standalone, even though the operator can work remotely from the consoles of the DAΦNE control system. If the record is considered valid, data are downloaded to the computer; the transfer of up to 1 Mbyte for each channel is done as quickly as possible to perform many measurements without delaying the machine operations. Then the measurements are converted to millimetres by a suitable algorithm; besides other beam data are calculated using machine parameters or the Hilbert transform.

Finally, data are automatically inserted in a database tree that is built using time stamps and can be remotely accessed by the users. Off-line retrieval and presentation tools are also developed in LABVIEW.

## 1 INTRODUCTION

This paper describes a data acquisition system developed to track the electron or the positron beam dynamically in the transverse planes, on a turn-by-turn basis.

In the DAΦNE Φ-Factory, the high luminosity asks for a careful tune-up of many machine parameters. A coherent signal proportional to the transverse displacement of the bunch can be obtained by processing the pulses from the beam position monitor electrodes.

The method of dynamic tracking [1] consists in exciting a free transverse betatron oscillation by kicking the beam and recording the transverse displacements at two different azimuths in the storage ring. If the two monitors have $\pi/2$ betatron phase difference, then the transverse beam position at the second monitor is proportional to the angle of the beam at the first one. A dynamic tracking system allows performing studies on the non-linear beam dynamics [2]. In particular, the tune dependence on amplitude is found by fitting the decay of the coherent signal as a function of the number of turns [3] (an example of a recorded data sequence is shown in Fig.1). The dynamic aperture is defined as the maximum displacement amplitude (the stable acceptance) without intensity loss.

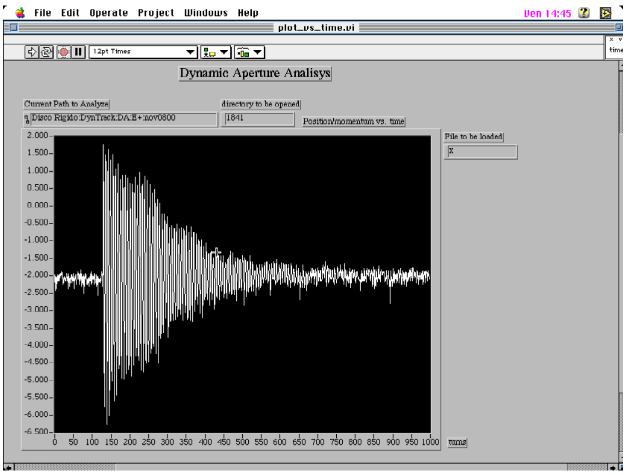


Fig.1: Horizontal displacement (in mm) after a kick versus turn number.

## 2 THE ACQUISITION SYSTEM

### 2.1 Signal acquisition

A four-button Beam Position Monitor is used to obtain transverse signals at the passage of a beam. By using hybrid junction components, it is possible to produce sum and difference signals in the two transverse planes at one azimuth of the storage ring. The signals are acquired and recorded by a four-channels LeCroy LC584AM/LC574A oscilloscope with the capability of sampling the input waveforms using a beam synchronous external clock generated by the DAΦNE Timing System [4].

The oscilloscope is built around a PowerPC working at 96MHz and can digitize to 8-bit waveforms from four channels. A second oscilloscope allows acquiring other four sum and difference signals coming from a second BPM with a suitable betatron phase advance with respect of the first one. The digitizer accepts clock frequencies in the 50÷500 MHz range, and the DAΦNE RF is 368 MHz. The lowest synchronous frequency fitting as clock is RF/6 and the harmonic number is 120, hence 19 values over 20 must discarded because we limit the analysis to the single bunch case. However, multibunch analysis is possible [5] and it is in progress. A phase shifter with a range of 20 nsec is used for a correct timing of the acquisition of the signals generated by a selected bunch. The start of acquisition is synchronized to a horizontal kick given by one of the injection kickers, as shown in the following Fig. 2 obtained by the oscilloscope.

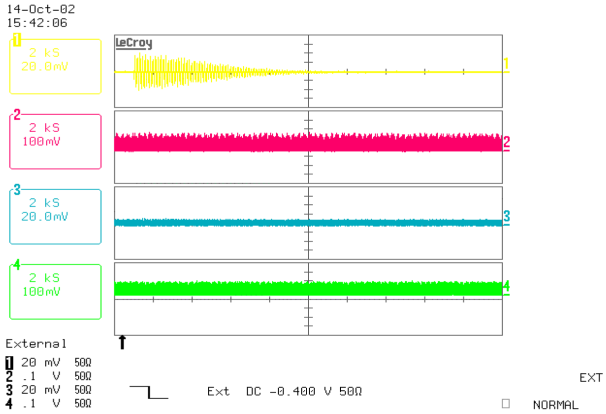


Fig. 2: The four signals acquired by the oscilloscope: from the top ΔH, ΣH, ΔV, ΣV.

After capturing up to 25k consecutive turns, data are sent through a GPIB interface to a personal computer, for processing, presentation and storage. A simplified scheme of the acquisition system is shown in Fig. 3.

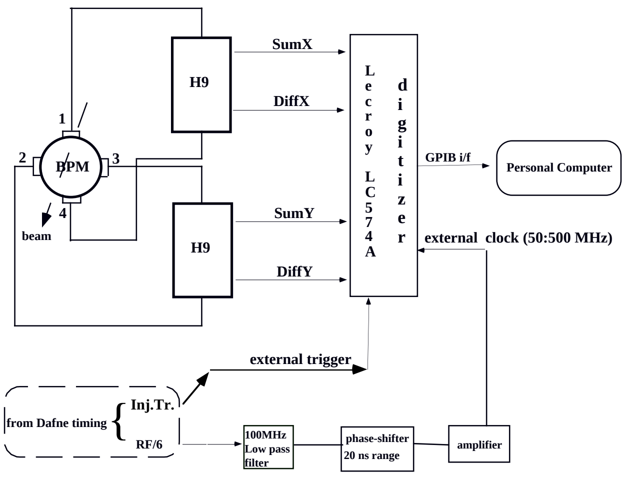


Fig. 3: The acquisition system.

## 2.2 Performances

All the programs are written using LABVIEW 6.0 and can run on different platforms. In a first version, the system was implemented using a MacIntosh Quadra with a National Instruments board for NUBUS – IEEE 488 interface; the plot in Fig.1 is obtained using this acquisition system. The following version has been implemented using a SUN Ultra 5 equipped with a National Instruments board for PCI – IEEE 488 interface. The user interface of the acquisition program obtained using the SUN workstation is shown in Fig.4.

Acquisition, conversion and storage of 100k points x 4 channels (.8 Mbytes through IEEE488) takes more than 1 minute using a Macintosh Quadra and only 12 sec with Sun Ultra 5. Acquisition, conversion and storage of 500k points x 4 channels (4M bytes through IEEE488) takes half minute on Sun Ultra 5, and would be not possible on the Macintosh Quadra.

Remote operations are performed using the VGA out port of the oscilloscope to see the LeCroy monitor in the control room and using the Unix remote login from the control system consoles.

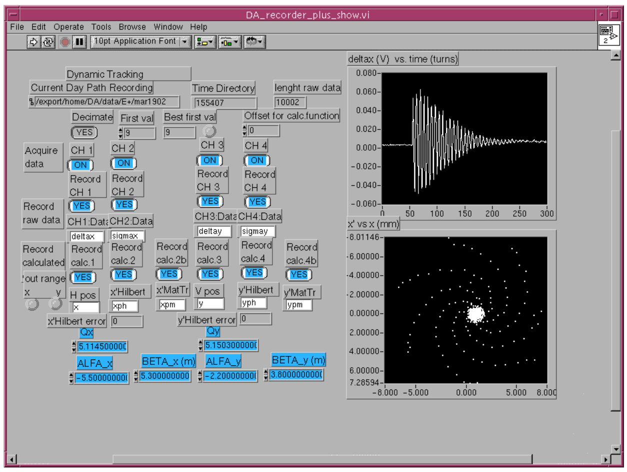


Fig. 4: The acquisition program user interface.

## 2.3 Phase Space

Two monitors at $\pi/2$ of betatron phase can be used to produce a plot in the phase space in x or y. If our system acquires data from only one BPM, the second monitor will be "virtual" and has to be calculated. To do this the software builds a data vector relative to a second monitor advanced by 90 degrees. This is done by two alternative ways: by applying the Hilbert transform or using the transport matrix method.

The Hilbert Transform [6] applied to a data sequence produces a second data sequence with a 90 degrees phase shift with the same frequency and amplitude content. This gives the interesting advantage to have already homogenous phase space plots. The transport matrix method uses the Twiss parameters $\alpha$, $\beta$ at the monitor position as computed with the machine model. The transport matrix formula is

$$x'(i) = \frac{x(i+1) - (\cos(2\pi\ Q) + \alpha \sin(2\pi\ Q))\ x(i)}{\beta \sin(2\pi\ Q)}$$

where α, β are the horizontal or vertical Twiss parameters, and Q is the tune. This method is only an approssimation in presence of non-linear terms in the ring. A preliminary comparison has shown a good agreement between the results of the two methods.

### *2.4 Signal processing*

After the oscilloscope has captured the transient, data are downloaded to the personal computer following an operator request. A calibration routine using a linearizing algorithm allows converting data from voltage to millimetres. The acquisition and control program first shows the decay time in number of turns. It is important to have this plot in real time to understand if the captured data are correct. Then the program draws a trajectory representation in the phase space (position and angle) in both the transverse planes.

### *2.5 Database*

A database tree is automatically generated by the acquisition program. In the first level directories, the user chooses the type of particle electrons (E-) or positrons (E+). The second level directories are defined by the date of the day and have the format mmmddyy (for example apr1902). Inside these directories, readme files contain comments and machine parameters. The third level directories are defined by the time of the acquisition and have the format hhmmss (for example 143207).

Data files for spreadsheet application are: rough data in voltage (deltax, sigmax, deltay, sigmay) and calculated data in mm (x, xph, xpm, y, yph, ypm). All the data files have the same format: only one column and a numeric value in ASCII characters for each row. In this way, the data can be easily loaded in any spreadsheet.

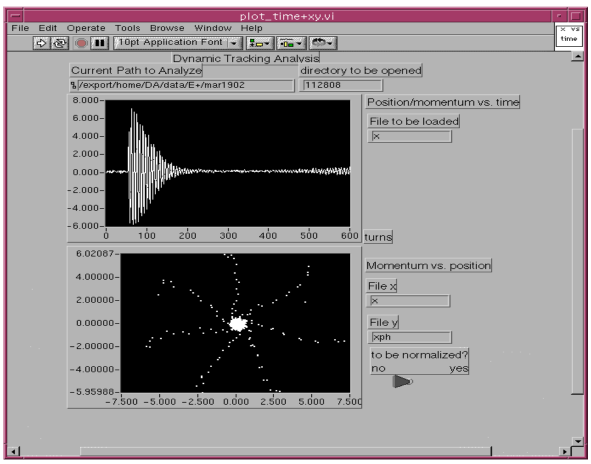


Fig. 5: Plot x in time and x’ versus x with 6kV kick.

## 3 BROWSING TOOLS

There are several tools to browse and retrieve data:

- plot_vs_time, that shows the horizontal displacement (in mm) versus number of turns;
- plot_xy, that shows the horizontal phase space plot obtained from the Hilbert transform;
- plot_time+xy, that shows the previous two plots together;
- fftplot_vs_freq, that shows a betatron tune analysis versus time & amplitude;
- 2plot_xy, that shows the angle versus position using Hilbert or formula methods in horizontal and vertical planes;
- MB_grow_damp, that performs grow-damp analysis for the multibunch cases.

## 4 CONCLUSIONS

The dynamic tracking acquisition system has shown to be a very useful tool to investigate the non-linear behaviour of the DAΦNE rings and to improve their performances. The first version of the system has been upgraded to download faster more data from the oscilloscope and to share easily the database with the UNIX based control system. A second oscilloscope has been added with the goal to have eight channels and to acquire signals from two BPM's. It is possible to continue to develop multibunch software tools to extend the use of the system to the transverse modal analysis.

## 5 ACKNOWLEDGEMENTS


The authors wish to thank Oscar Coiro and Donato Pellegrini for the realization of the set-up, very critical on the equalization of the cables. Thanks also to Mario Serio for many ideas and suggestions during the system implementation and to Mikhail Zobov for the interesting and useful discussions during the set-up of the system.


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