THE DYNAMIC TRACKING ACQUISITION SYSTEM FOR DAΦNE E+ / E- COLLIDER

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Abstract

The goal of this paper is to describe the dynamic tracking acquisition system implemented for the DaΦne e+/e- collider at LNF/INFN. We have been using the system since last year and it has been possible to collect useful information to tune-up the machine.

A four-button BPM is used to obtain the sum and difference signals in both the transverse planes. The signals are acquired and recorded by a LeCroy LC574A oscilloscope with the capability to sample the input waveforms using a beam synchronous external clock generated by the DaΦne Timing System. The start of acquisition is synchronised to a horizontal kick given by an injection kicker. After capturing up to 5000 consecutive turns, data are sent through a GPIB interface to a PC, for processing, presentation and storage. A calibration routine permits to convert voltage data to millimetres values. The acquisition and control program first shows the decay time in number of turns. Then it draws a trajectory in the phase space (position and speed) in both the transverse planes. To do this the software builds a data vector relative to a second "virtual" monitor advanced by 90 degrees. This is done by two alternative ways: applying the Hilbert transform or using the transport matrix method. Examples of data acquired during the collider tune-up are shown.

1 INTRODUCTION

DaΦne is a Φ factory presently in operation at the Laboratori Nazionali di Frascati of I.N.F.N. In the last two years it alternated machine development and data taking shifts: during these periods it produces e+/e- collisions to give luminosity to one of the two installed experiments, KLOE in the Interaction Point 1 and DEAR in the Interaction Point 2. Recently DaΦne has reached in the IP1 a peak luminosity of 2.1×10^{31} cm^{-2} sec^{-1}, with an integrated luminosity up to 1.3 $pbarn^{-1}$ per day. The maximum stored current is more than 1 A for electrons and for positrons.

For the non-linear optics studies, a transverse monitor has been installed to record and analyze the dynamic characteristics of the beam by varying the machine parameters.

In this paper we describe the dynamic tracking monitor and acquisition system implemented for DaΦne and show some example of taken data. The system has been used since last year allowing collecting useful information to tune-up the machine.

2 DYNAMIC TRACKING

A coherent signal proportional to the transverse displacement of the bunch can be obtained by processing the signal 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 π/2 betatron phase difference, then the transverse beam position at the second monitor is proportional to the angle of the beam at the first monitor. Plotting the first monitor data versus the second ones (on turn by turn basis) is equivalent to a phase space plot at the azimuth of the first monitor. A dynamic tracking system makes possible to perform 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 (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.

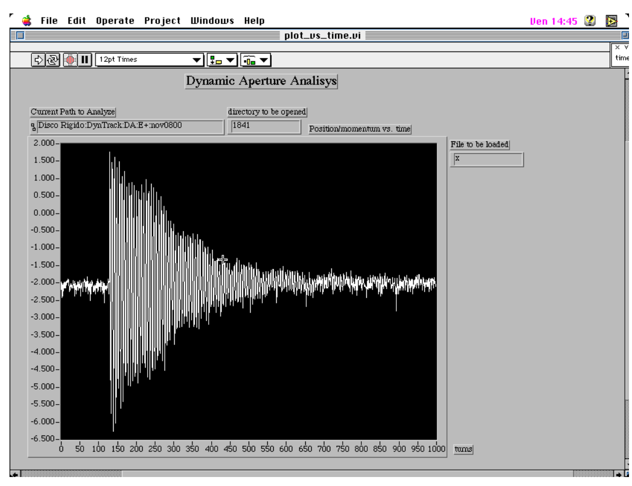

Figure 1: Horizontal displacement (in mm) after a kick versus number of turns.

3 SYSTEM DESCRIPTION

3.1 Signal acquisition

A four-button Beam Position Monitor is used to obtain transverse signals at the passage of a beam. 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 LC574A oscilloscope with the capability to sample the input waveforms using a beam synchronous external clock generated by the DaΦne Timing System [3]. The digitizer accepts frequencies in the 50:500 MHz range, and the DaΦne RF is 368 MHz. The lowest frequency fitting as clock is RF/6 and the harmonic number is 120, hence 19 values over 20 have to be discarded because for now we limit the analysis to the single bunch case. However, multibunch analysis is also possible [4]. A phase shifter with a range of 20 nsec is used to time correctly the acquisition of the signals generated by the selected bunch.

The start of acquisition is synchronised to a horizontal kick given by one of the injection kickers. Usually the kick has a peak voltage in the range from 2 to 6 kV corresponding to an angle from ~1 to ~3 mrad.

After capturing up to 5000 consecutive turns, data are sent through a GPIB interface to a personal computer, for processing, presentation and storage. In Fig. 2 a simplified scheme of the acquisition system is shown.

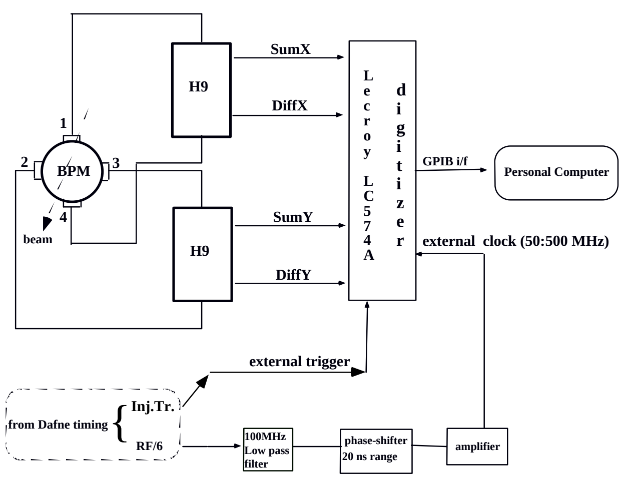

Figure 2: The acquisition system.

3.2 The virtual monitor

Two monitors at $\pi/2$ of betatron phase can be used to produce a plot in the phase space. Since our system acquires data from the only BPM, our second monitor is "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 [5] 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 phase space plots already normalized.

The transport matrix method uses the Twiss parameters α, β 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. A preliminary comparison has shown a good agreement between the results of the two methods.

2.3 Signal processing

After the oscilloscope has captured the transient, data are downloaded to a personal computer following an operator request. A calibration routine 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. In the Fig. 3 it is shown a typical pattern with seven arms.

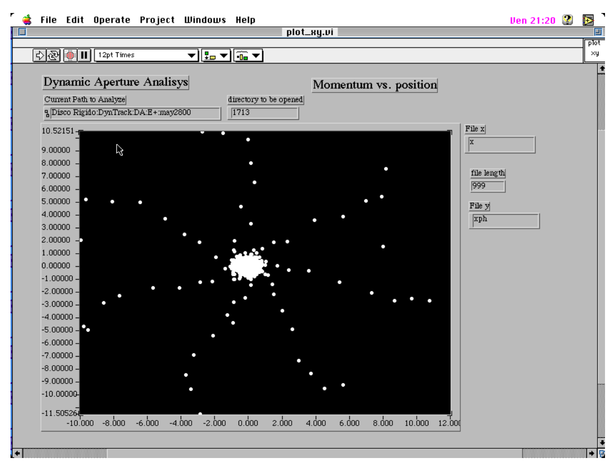

Figure 3: Horizontal phase space plot drawn using the Hilbert transform.

All the recorded data are stored in a database ordered according to the record time. It is possible, of course, to analyze the collected data with different machine parameters from the local workstation or from a remote computer.

4 RESULTS

The dynamic tracking system has made possible to perform studies on the non-linear beam dynamics in DaΦne.

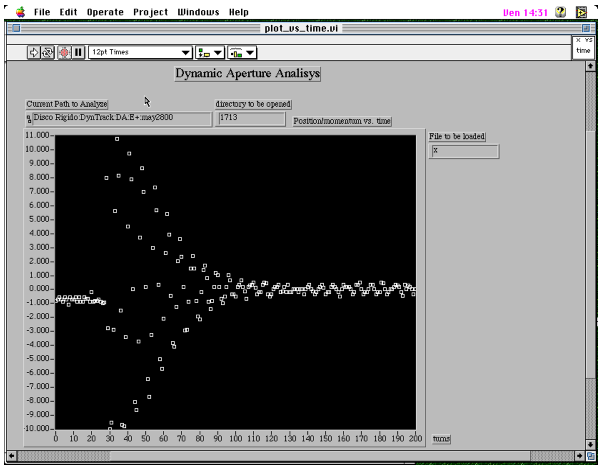

Figure 4: A coherent signal decay due to non-linear filamentation (displacements versus turns), data are from the same record of Fig. 3 .

Optics measurements on new configurations of the main rings are usually started with this tool [6], [7] to understand better the behaviour of the machine. The coherent oscillation amplitude decay through non-linear filamentation (see Fig. 4) helps to estimate directly nonlinearity strength and tune spread [8], and provides a quick tool to modify the dynamic aperture by varying sextupole settings.

The decoherence time is an indirect measurement of the tune on oscillation amplitude dependence, related to the nonlinearity of the ring. A study of the wiggler field nonlinearity and optimization of the sextupoles settings are among the most relevant results providing by the dynamic tracking system. Fig. 5 shows two distinct cases, corresponding to two different configurations of the rings.

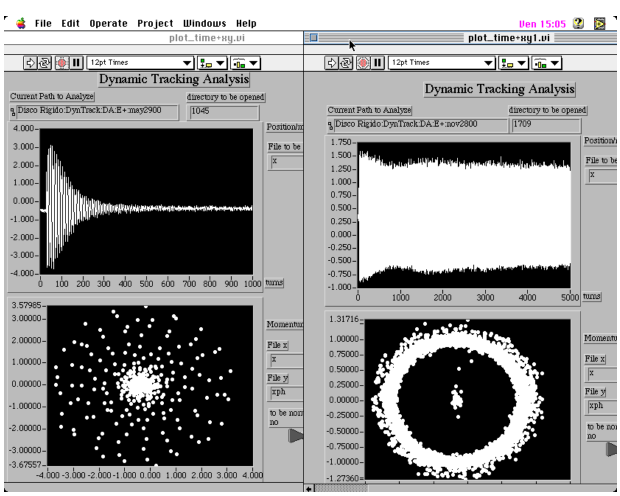

Figure 5: A comparison between optics with wigglers turned on and wigglers turned off.

5 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. Upgrade of the system will be provided in the next future. First of all, a more powerful workstation will be installed, to download data more quickly from the oscilloscope and to exchange data with the machine real time database in the control system. Then, a second oscilloscope will be used with the goal to have up to eight channels to acquire signals from two BPM's. We also plan to start multibunch software development to extend the use of the system to the transverse modal analysis.

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