HORIZONTAL INSTABILITY AND FEEDBACK PERFORMANCE IN DAΦNE E+ RING

Alessandro Drago, Istituto Nazionale di Fisica Nucleare,
Laboratori Nazionali di Frascati, Frascati, Italy

Abstract

In DAΦNE, after the 2003 shutdown for the installation of FINUDA, a strong horizontal multibunch instability was found to limit the positron beam for currents >450mA. The author has performed transverse grow-damp measurements in order to estimate the instability growth rates as well as the feedback damping rates for each bunch at different beam currents and to evaluate the tune shift along the bunch train. In particular, a strong dependence of oscillation amplitudes on the position of the bunch in the train has been observed. In this paper, the author describes the set-up for multibunch oscillation amplitude recording, summarizing some observations on the transverse instability and discussing the feedback performance. The feedback raises the threshold by about a factor of two, depending on the machine configuration.

INTRODUCTION

In DAΦNE, after the 2003 shutdown for the installation of FINUDA [1], a strong horizontal multibunch instability was found to limit the positron beam for currents >450mA. Measurements have been planned to understand the behaviour and characteristics of the instability.

ACQUISITION SYSTEM DESCRIPTION

To study the strong horizontal multibunch instability, the author has carried out measurements by recording the transverse displacements for each bunch on a turn-by-turn basis.

Switching off the horizontal feedback for short periods, data have recorded during transverse grow-damp to estimate the instability growth rates for each bunch at different beam currents and to evaluate the tune shift along the bunch train. In particular, a strong dependence of oscillation amplitudes on the bunch position along the train has been observed.

In this part of the paper, we describe the apparatus for tracking multibunch oscillation amplitude. A scheme of the system is in Fig. 1.

A pulse generator HP8116A is used to generate two synchronous output triggers in manual mode. The operator can easily modify the pulse widths by the instrument panel in a large range of values. One of the output signals, of variable duration, is used as a gate to switch off the horizontal (and/or the vertical) feedback for the duration of the pulse. The other pulse triggers the start of data acquisition.

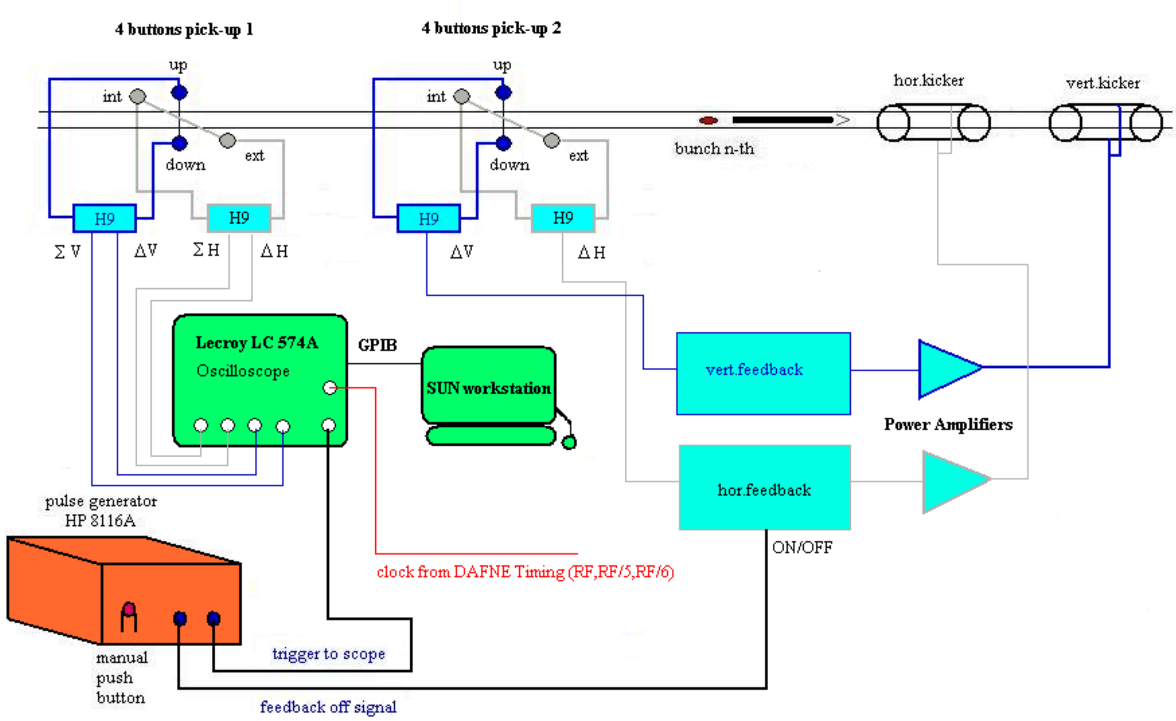

Figure 1: Scheme of the apparatus used to make the measurements: the off signal can be applied to one or both the transverse feedbacks.

The Lecroy LC574A oscilloscope has the feature to accept an external signal as sampling clock for frequencies included in the range 50-500MHz. The DAΦNE timing system [2] can provide triggers at RF (~368 MHz), RF/5 or RF/6 to the acquisition system. The signals to be recorded come from a four buttons pick up. Two H9 hybrid junctions provide the horizontal and vertical sum and difference. The oscilloscope acquires these four signals during a grow-damp recording. Several programs on a SUN workstation allow data storage and off-line analysis [3]. The transverse feedbacks use the same type of pickup and hybrid junctions as input to the low power electronics. The system generates the correction signal by a partially digital approach [4]. Each feedback makes use of two 250W power amplifiers.

OBSERVATIONS ON THE INSTABILITY

Measurements on the e+ horizontal instability have been done in two days of December 2003. The author has turned off the horizontal feedback for periods in the range 100-500 μs, recording the x and y bunch-by-bunch displacements [5], [6]. The injected patterns have been 60 or 90 or 120 bunches with just one gap or no gap at all (the harmonic number is 120). The analysis programs have highlighted a first characteristic of the instability: it becomes progressively stronger toward the end of the bunch train. Figure 2 shows a grow-damp record of the horizontal instability for bunch 75, 80, 85 and 90 versus revolution turns. The bunch #90 is the last of the train and it has the largest horizontal displacement.

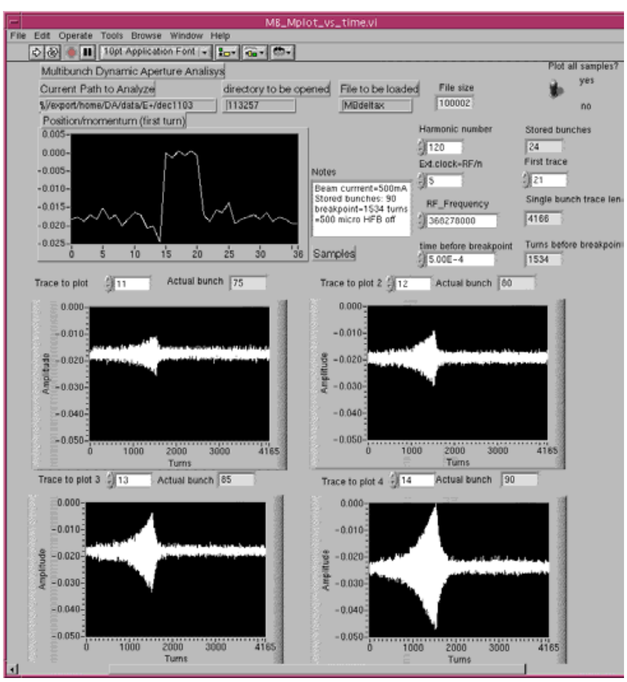

Figure 2 – Hor.instability grow/damp for the bunches 75, 80, 85, 90 versus revolution turns (1 turn = 324 nsec)

In Fig. 3, the maxima horizontal displacements provided by a data record are plotted for all bunches, and it is remarkable to observe that bunches in the first part of the train are not oscillating at all.

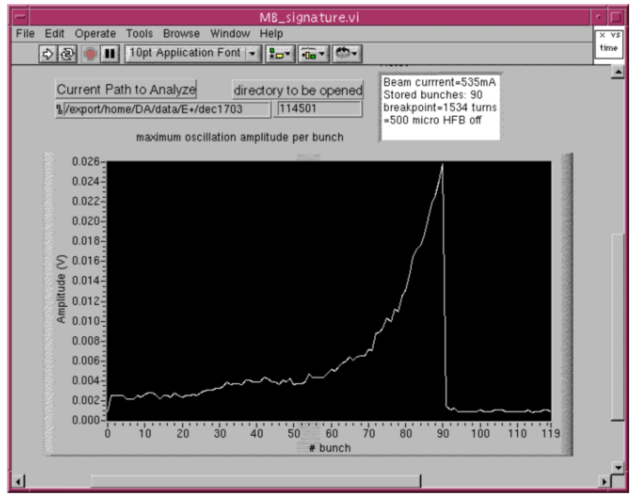

Figure 3 – Maxima horizontal displacements (during a grow/damp record) versus bunch number.

Another characteristic that is possible to evaluate by the acquisition system is the bunch-by-bunch tune shift. The algorithm makes use of an fft routine working with selectable number of points. In Fig. 4 (on the left), the horizontal x tune is plotted versus the corresponding bunch number over a grow-damp record. The tune does not seem to change meaningfully over the train (it is .1211), still if the signal magnitude changes very much as plotted in Fig. 4 on the right. In this example, the fft routine provides a ~1/500 resolution.

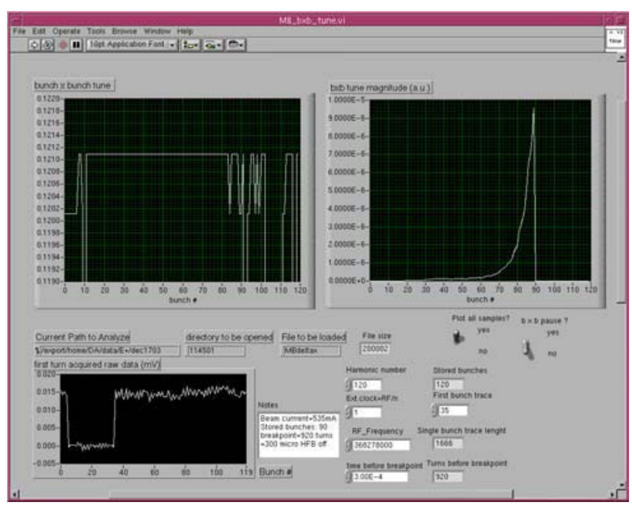

Figure 4 – Bunch-by-bunch horizontal tune (value and magnitude) during a grow/damp record for all 90 bunches

The horizontal tune evolution of a bunch during subsequent time slots has been evaluated too. In fact, in fig. 5, another analysis program shows the behaviour of bunch #90. In this case, the horizontal tune changes slightly during the grow-damp moving from .1202 to .1211, up to .1216.

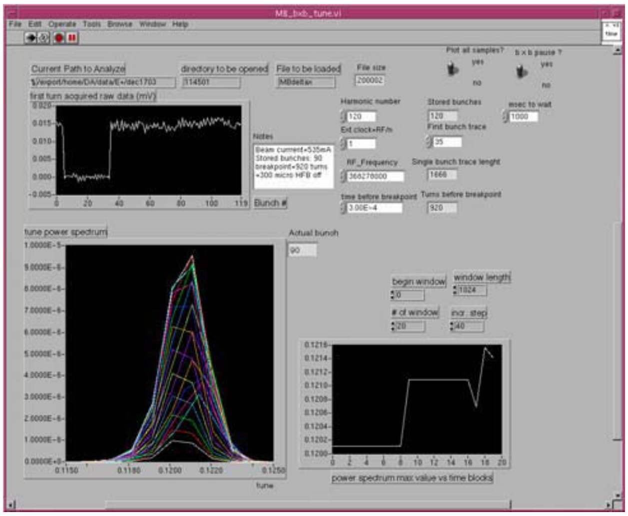

Figure 5 – Bunch #90 horizontal tune during a grow/damp record (magnitude versus value on the left plot, value versus time slot on the right plot)

The recorded data make possible to evaluate the instability grow rate at different beam current for all the bunches and for each bunch of the train: no meaningful differences have been found between the two cases. In the table 1 the instability grow rates and the horizontal feedback damping rates are summarized.

Table 1: horizontal instability inverse grow rates and horizontal feedback inverse damping rates

Injected bunches	**Beam current [mA]**	**1/ inst. grow rate [μs]**	**1/ fb damping rate [μs]**
90	535	35	16.8
90	500	70	18.9
90	484	no instability	no measure
60	525	52	28.3
60	500	68	34.2

FEEDBACK PERFORMANCE

From the table 1, the transverse feedback performance is very good, even if the horizontal instability grows very fast with the beam current. The best damping time measured is 16.8 μs. To summarize, the feedback system raises the instability threshold by a factor of two depending on the machine configuration.

CONCLUSIONS

Feedback damping rates and some characteristics of the horizontal instability have been measured, even if the source of the instability has to be identified yet.

The horizontal instability behaviour can be summarized in the following points:

a) progressively larger oscillations at the end of the bunch train;

b) inverse grow rates ≤35μs, still decreasing with the beam current;

c) weak influence of the bunch pattern on the instability threshold due to the small harmonic number (see table 1); the gap is useful;

d) very small tune shift both versus bunch position in the train and versus beam current.

It is remarkable to note besides these points, that the injection kickers, if not perfectly timed, can interact with the instability because they work in the horizontal plane. This can produce beam current saturation or, in the worst cases, loss of bunches during injection. Given that feedback performance is very good, a smaller impact of the instability can be found in different machine working point. This means, in particular, evaluating accurately betatron tunes, RF frequency and taking the best advantage of the Landau damping given in collision by the other beam.

ACKNOLEDGEMENTS

Thanks to D.Pellegrini and O.Coiro for the accurate installation and cabling, to F.Ronci and U.Frasacco for the board assembly. A.Stella has designed the calibration routines.

REFERENCES

[1] C.Milardi et al., "DAΦNE performance for the FINUDA experiment", this conference.

[2] A.Drago et al., "Implementation and Performance of the DAΦNE Timing System", 6th European Particle Accelerator Conference (EPAC 98), Stockholm, Sweden, 22-26 June 1998, p.1661, LNF-98/023 (P).

[3] A.Drago, A.Stella, "The Dynamic Tracking Acquisition System for DAΦNE e+/e- Collider", DIPAC2001 Proceedings, 5th European Workshop on Diagnostics and Beam Instrumentation, may 13-15, 2001, Grenoble, France.

[4] A.Drago et al., "Fast Electronics for the DAΦNE Transverse Feedback Systems", ICALEPCS-2001-WEAP048, Nov 2001. 3pp. Contributed to 8th International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS 2001), San Jose, California, 27-30 Nov 2001. Published in eConf C011127: WEAP048,2001. e-Print Archive: physics/0111209.

[5] S.Prabhakar, "New diagnostic and Cure for Coupled Bunch Instabilities", PHD Thesis, Stanford Un., SLAC-Report-554, February 2000.

[6] J.D. Fox et al., "Programmable DSP Based Multibunch Feedback: Operational Experience from Six Installations". BIW 2000, Cambridge, Mass., May 2000. SLAC-PUB-8410.