FAST HORIZONTAL E+ INSTABILITY MEASUREMENTS IN DAFNE

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Abstract

In the more than decennial history of DAFNE, the Frascati e+/e- collider, the positron beam has always shown more difficulty to store high current than the electron one. Given that the two rings are identical, many types of measurement have been tried to figure out the problem and to solve it, but eventually only one technique has presented a crucial utility: the modal grow rate measurement. In principle this method could be implemented using a commercial spectrum analyzer with the right software procedure inside. Nevertheless it is much easier and faster to record data by means of the bunch by bunch feedback diagnostics and analyze them with the offline feedback programs. A large campaign of data taking has been carried out last fall. A comparison with grow rate records from previous years has pointed out clearly the difference with respect to the 2008 DAFNE performance showing the way to overcome the beam current limit. In particular, measurements have been done versus different machine conditions. A very fast horizontal instability, present only in the e+ ring, has been characterized showing linear behavior versus beam current. These data have been used to figure out the current limit problem.

INTRODUCTION

In the more than decennial history of DAFNE, the Frascati PHI-Factory, the positron beam has always shown more difficulty to store high current than the electron one. In the past years the impedances of the two rings were quite different due the presence of the ICE (Ion Clearing Electrodes) in the e- ring. After removal of these devices, the maximum storable beam current has continued to show a strong difference in spite of the fact that the two rings are identical, both from optics and impedance point of view. The beam current limit was apparently due to a strong horizontal instability producing loss of e+ current at the end of the bunch train during injection [1], [2]. This effect has never been observed in the e- beam and moreover during 2008 the positron current limit has become even lower.

To try to solve the problem, many measurements have been considered and carried out, but the only really useful technique was to measure the instability modal grow rates for the positron beam.

This technique could be implemented using a standard spectrum analyzer, but it is much faster to use the feedback system [3], [4] itself as diagnostic tool (see Fig.1), together with offline post-processing software programs developed during the longitudinal bunch-by-bunch feedback collaboration (between SLAC, ALS@LBNL and LNF) started in the nineties of the last century. They were developed in particular by Shyam Prabhakar [5] for his PhD thesis at SLAC.

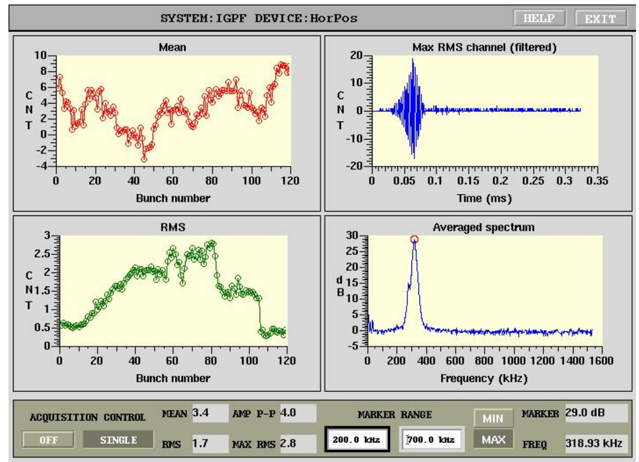

Figure 1: Positron grow-damp record made by switching off the horizontal feedback, I=575mA, 105/120 bunch [October 14, 2008].

MEASUREMENTS

Looking at Fig.2, the horizontal instability behavior versus total beam current is linear in a large range with the same unstable mode, the 119th (also indicated as -1). In the past years the instability grow rates, measured in the same conditions were 15ms^{-1} at 630 mA in 2004 and 25 ms^{-1} at 900 mA in 2005.

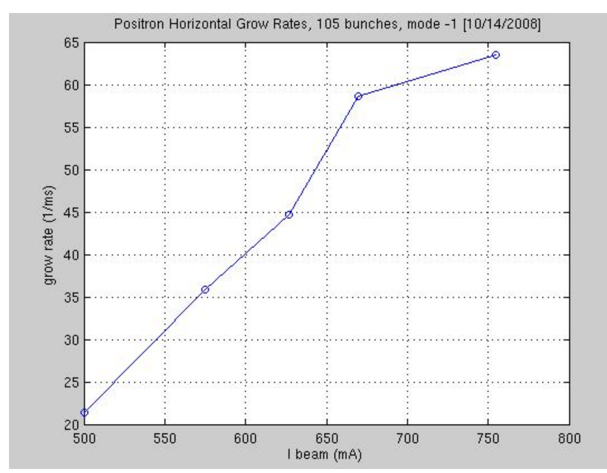

Figure 2: DAFNE e+ horizontal instability grow rate versus beam current [10/14/2009].

In the electron ring, the measurement system has evidenced a different and much slower unstable mode, as compared with the positron one. The Fig.3 shows the behavior of the instability. The grow rates are much slower and again linear versus beam current. At 1500mA the instability grow rate is less than 7 ms^{-1}, whereas the feedback system is identical in power and components, as well as in measured damping rate, to the positron one. In the e- ring the unstable horizontal mode is the number 1. The vertical data (in the same plot, presented by the asterisk) are even slower than the horizontal grow rates.

Since impedances and hardware of the two rings are equivalent, the source of such strong instability should be found in the nature of the positron beam itself that, from models and theory, is foreseen to be sensitive to the parasitic e- cloud generated in the vacuum chamber.

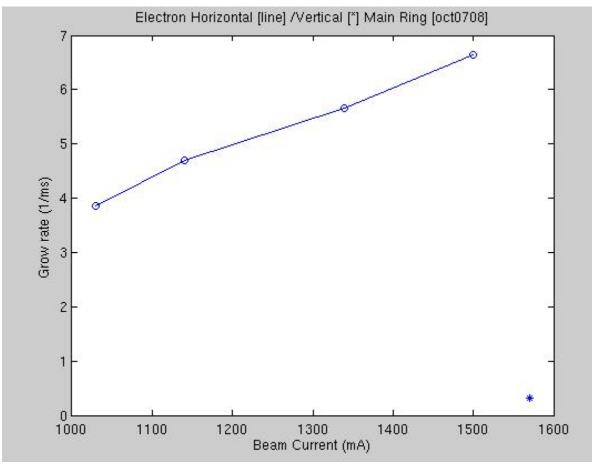

Figure 3: DAFNE e- horizontal instability grow rates versus beam current [October 7, 2008].

Positron Grow Rate Measurements versus Machine Parameters

To characterize better the e+ instability, understanding not only the anomalous behavior but also its reasons, studies to restrict the possible sources of instability have been carried out, in particular grow-rate measurements in the following conditions:

• on/off setting of e-cloud compensating solenoids [Oct 03, 2008]

• Variation of β_x in the RF cavity [Oct 23, 2008]

• Increase by +0.5 of $\Delta\nu_x$ in PS1-PS2 zones [Nov 04, 2008]

• Further increase by +0.5 of $\Delta\nu_x$ in RCR zone [Nov 05, 2008]

• Variation of beam orbit in the dipoles [Nov 10, 2008]

First of all, switching off the solenoids installed in the positron ring, the grow rate of the e+ instability does not change. This can be due to the fact that in the DAFNE e+ ring the solenoids have been installed only in a limited number of straight sections and not in the wigglers and the dipoles, so they seem ineffective, at least in the horizontal plane. Vertical measurements in this condition have not been done. However positive effects have been observed in the vertical positron beam size.

As a second test, the β_x in the RF cavity was halved, passing from 4 m to 2 m, to test the hypothesis of a high order mode possibly driven by the radiofrequency system. Also in this case, no variations were measured for the instability grow rates.

The following tests have been done concerning variations of the horizontal tune. In particular the e+ instability grow rates have been measured versus $\Delta\nu_x$ in PS1-PS2 and RCR ring zones with the following optics condition (see fig.4):

• Collision (regular) optics
mode m = -1 (blue)

• $\Delta\nu_x$ = + 0.5 (PS1÷PS2) , $\nu_x = \nu_y$
mode m = 0 (red)

• $\Delta\nu_x$ = + 1.0 (0.5 in PS1÷PS2 0.5 in RCR), $\nu_x = \nu_y$
mode m = -1 (cyan)

This is to study the e+ instability as a function of the relative betatron phase advance between the wigglers. As shown in Fig. 4, no evident variations have been found.

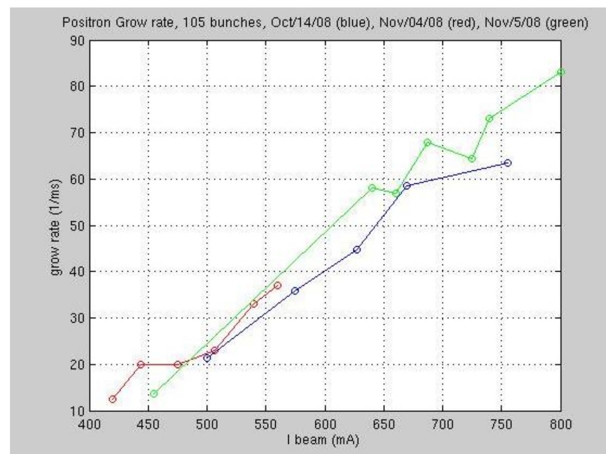

Figure 4: e+ instability grow rates versus Δvx in PS1-PS2 and RCR.

At Last Found a Difference

Then the e+ instability grow rates versus beam orbit in the main ring dipoles have been evaluated. The orbit variation is performed by applying a closed orbit bump in the dipoles and recovering the beam energy variation by changing the RF frequency (see Fig.5).

In this case, the e+ instability grow rates show meaningful differences versus orbit in the main ring dipoles that in fact have been slightly rotated in the last year to allow the Crab waist upgrade of the collider.

The e-cloud hypothesis seems to be confirmed and the source of the troubles is just inside the dipole zones.

A complete explanation can be found comparing the experimental data presented in this paper with the e-cloud simulations described in another paper of this conference [6] by Theo Demma.

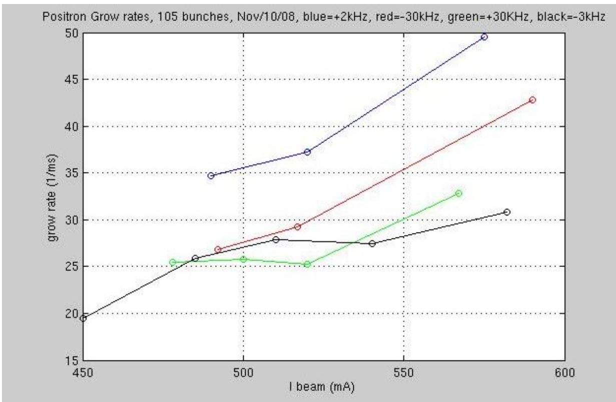

Figure 5: DAFNE e+ instability grow rates versus orbit in the main ring dipoles.

Further Investigations

Further investigations at even higher beam currents have improved the knowledge of the instability behavior. The beam current does not seem limited by the horizontal instability anymore [7]. Grow rates at higher e+ current have shown that the unstable mode changes, passing from -1 to -2 and then to -3, and becomes slower, as plotted in the Fig. 6. The horizontal positron instability behavior is definitely different from the other ring in mode number, grow rate and general characteristics.

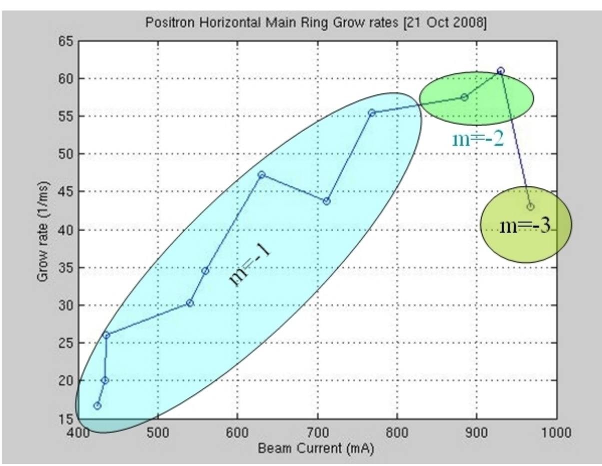

Figure 6: DAFNE e+ horizontal modes and grow rates.

CONCLUSIONS

A large amount of measurements has been done on the DAFNE main rings during last fall to understand why the maximum beam current storable in the positron ring was much lower than in the electron one. Apparently the limit was due to a very strong horizontal instability not present for the other beam.

A comparison of the new (fall 2008) data versus grow rate records from previous years has pointed out clearly what and where was the difference of the DAFNE performances. These data have shown how to overcome the current limit.

In particular, measurements have been done under different machine conditions. The very fast horizontal instability present only in the e+ ring has been characterized showing linear behavior of the grow rate versus beam current.

A complete explanation of the trouble has been found comparing the experimental data presented in this paper with the e-cloud simulations implemented for DAFNE and described in [6]. The solution found to control the instability is discussed in another paper of this conference [8] and is based on the acquired data.

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