NON LINEAR BEAM DYNAMICS AT DAΦNE

C. Vaccarezza, D. Alesini, G. Benedetti, S. Bertolucci, C. Biscari, M. Boscolo, S. Di Mitri, G. Di Pirro, A. Drago, A. Ghigo, S. Guiducci, F. Marcellini, G. Mazzitelli, C. Milardi, M. Preger, F. Sannibale, M. Serio, A. Stecchi, M. Zobov, INFN LNF Frascati Italy
P. Raimondi, SLAC, California, USA; E. A. Peredeventsev, BINP, Russia

Abstract

Studies and measurements have been performed at DAΦNE to improve dynamic aperture, beam lifetime and beam-beam performance. Measured tune scans for different working points are presented. After the measurement of an octupole-like term in the wiggler field, decoherence measurements with wigglers on and off have been performed. The effect of this cubic term on the chromaticity and dynamic aperture is presented.

1 INTRODUCTION

In the past year of DAΦNE running [1-3] machine-studies have been interspersed with experiment data-taking. Mainly the machine development has been devoted to beam-beam studies [4], characterisation of the machine non-linear behaviour, and background reduction for both the installed experiments [5]. At present the peak luminosity has reached $L \approx 2.9 \times 10^{31} cm^{-2} s^{-1}$ with about 600 mA per beam, with an average integrated luminosity of $L_i \approx 1.4\, pb^{-1}/day$. The Kloe experiment is routinely collecting data. The non-linearities present in the machine play a major role affecting the dynamic aperture, the beam lifetime, (with relation to the background and the integrated luminosity), and the beam-beam behaviour (single bunch luminosity). The study moved from extensive beam lifetime measurements vs. betatron tunes in both rings resulting in a high sensitivity of the machine to high order resonances (section 2). The decoherence measurements, (dynamic tracking), with the wigglers powered on and off show the effect of a strong dependence of the tune on the betatron amplitude oscillation, (section 3). The presence of a cubic term in the wiggler is accounted for the residual non-linear chromaticity of the machine even with sextupoles off. The strength of the octupole thin lens to be taken into account in each pole, found from the chromaticity measurements, agrees with the value obtained from the measurements of the betatron tunes vs. the localised orbit bumps inside the wiggler [6]. The effect on the dynamic aperture is described in section 5.

2 TUNE SCANS

Tune scan measurements have been performed on both electron and positron rings to find the best working point for the DAΦNE machine. The beam lifetime, normalised to the beam current and coupling, is an indication of the strength and width of resonances.

The obtained results for the lifetime show a high sensitivity of the machine even to high order resonances, (sixth order). Figure1 shows the scan around the standard working point (WP), $Q_x = 5.15$, $Q_x = 5.21$, adopted for the positron ring of the collider, the sixth order resonance is clearly seen.

In Figure 2 the beam roundness, $R = \sigma_y/\sigma_x$, measured at the Synchrotron Light Monitor, is reported in the tune footprint. It is clearly affected by the presence of two difference resonances, ($2Q_x - Q_y$, $Q_x - Q_y$).

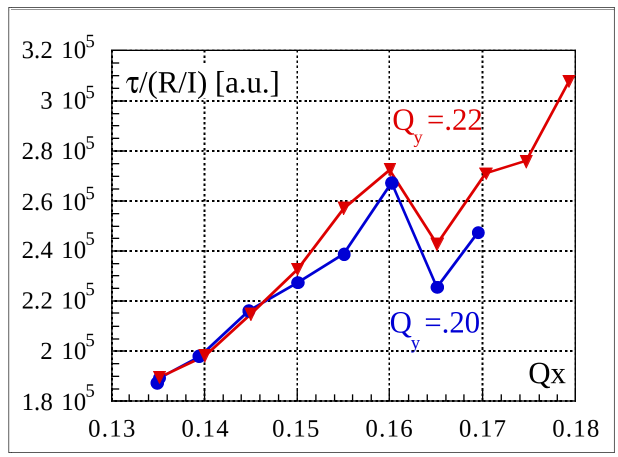

Figure 1: The normalised lifetime of the positron beam, vs. the horizontal betatron tune.

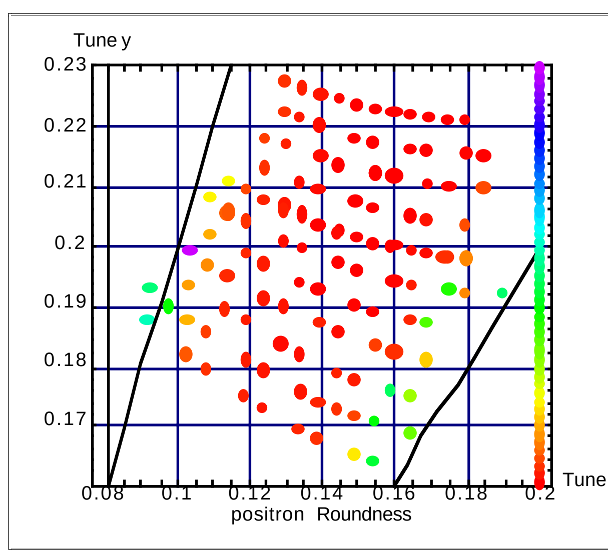

Figure 2: The positron beam roundness in the betatron tune plane. From red (lowest value) to violet (highest).

An extensive exploration around the half-integer has also been carried on, namely close to $Q_x = 4.73$, $Q_x = 5.08$, where no significant improvements on the lifetime come out, confirming the good choice for the adopted WP.

3 DYNAMIC TRACKING MEASUREMENTS

With the DAΦNE dynamic tracking acquisition system [7], it is possible to restore the beam trajectory in the transverse phase space; in particular the betatron tune dependence on amplitude is found fitting the decay of the coherent signal, which is proportional to the beam transverse displacement, vs the number of turns.

Figure 3 shows the measurements performed for two different lattices with wigglers on and off respectively. They have a different decay time of the signal and also different reconstructed phase space deformation. The non-linear coefficient C_{11} [8] defined as:

$$\Delta Q_x = 2c_{11} J_x$$

where J_x is the betatron action variable, depends on the non-linear element strengths, optic functions at their position and relative phase advance.

Lattices with wigglers on have negative values of C_{11} (values ranging from –200 to –1000 have been measured) depending on the value of the horizontal betatron function at the wiggler position). Lattices with wigglers off have positive values of C_{11}, which means that there are other non-linearities in the machine, whose overall contribution is compensated by the wiggler non-linearity. One of these is a sextupolar term in the "C" corrector magnets [6].

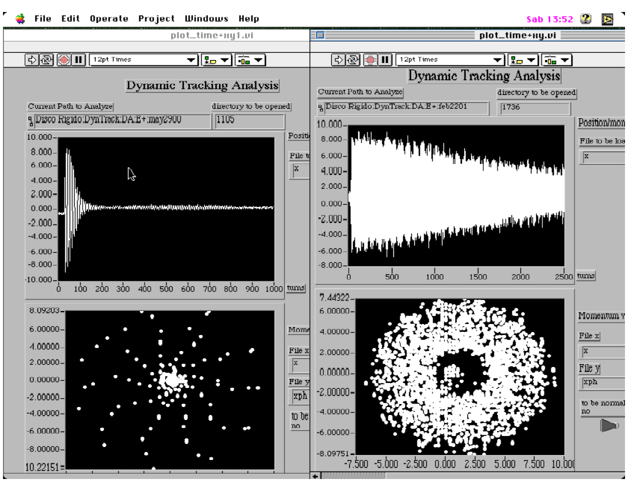

Figure 3: Dynamic tracking measurements of the beam transverse displacement vs number of turns (above), and phase space trajectory (below). The case with wiggler on is shown on the left, wiggler off on the right.

To counteract the effect of the octupole-like a new "detuned" optics (Mar 2001) has been applied on both thepositron and electron ring [9]; lowering the β-functions in the wiggler reduces the effectiveness of the octupole-like term.

4 CHROMATICITY

The measured non-linear terms have been included in the model, which now fits satisfactory the chromaticity behaviour. As an example the natural chromaticity of the positron ring with wiggler on and wiggler off are shown in Figs.4-5.

Figure 4 shows the measured chromaticity together with the model predictions with the cubic term. For the lattice with wigglers off the chromaticity is linear (Fig. 5).

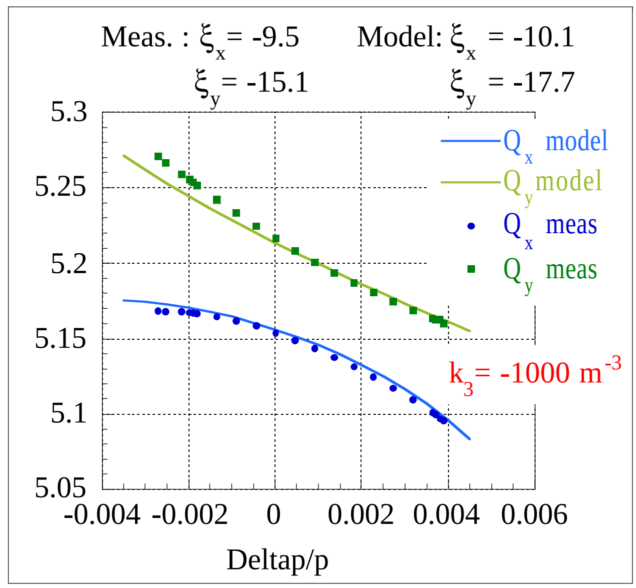

Figure 4: Measured (dots) and (simulated (full line) natural chromaticity with wiggler on for the positron ring.

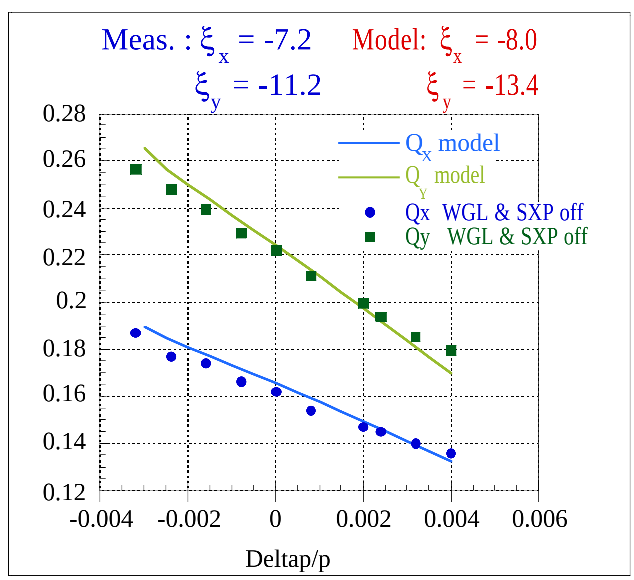

Figure 5:Measured (dots) and simulated (full line) natural chromaticity with wiggler off for the positron ring.

5 DYNAMIC APERTURE

The dynamic aperture has been calculated with the MAD code for the old optics for the Kloe experiment. The on energy dynamic aperture reduction, for the error free machine, is about 30%, see Fig. 6.

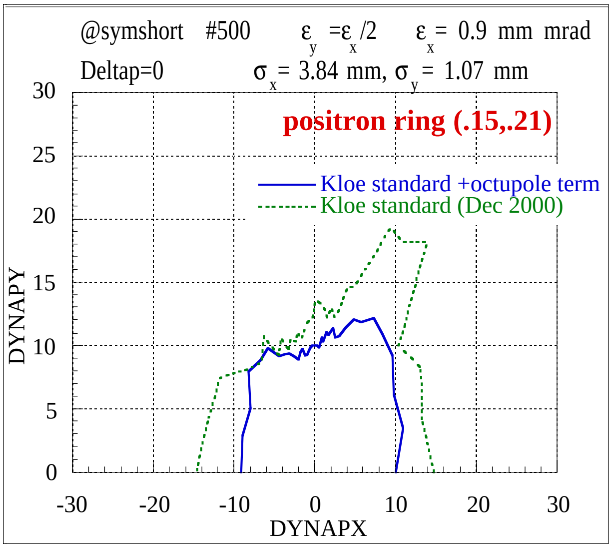

Figure 6: Dynamic aperture calculation for old (Dec 2000), expressed in number of beam σ's, with and without considering the octupole-like term in the wiggler.

The effect of the octupole-like term on the dynamic aperture is less severe in the case of the present optics, see Fig. 7.

The tune shift on amplitude is reduced, in agreement with the model prediction shown in Fig. 8. Further the beam-beam performance is positively affected as confirmed by the results obtained so far.

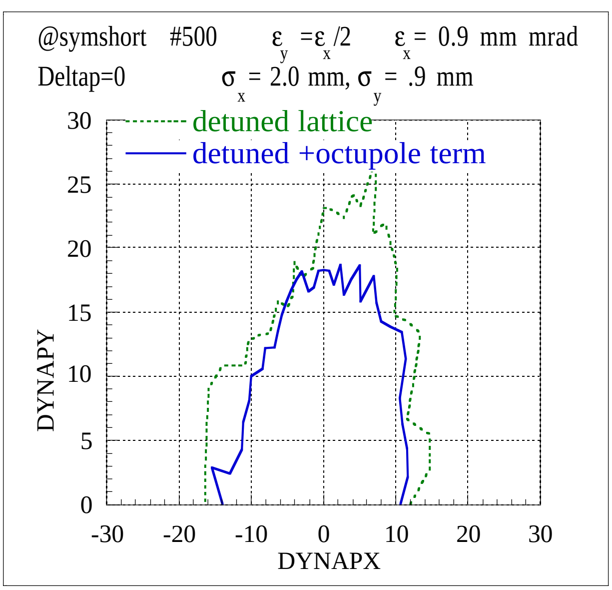

Figure 7: Dynamic aperture calculation for the DAΦNE actual optics (Mar 2001) expressed in number of σ's, with and without the wiggler octupole-like term.

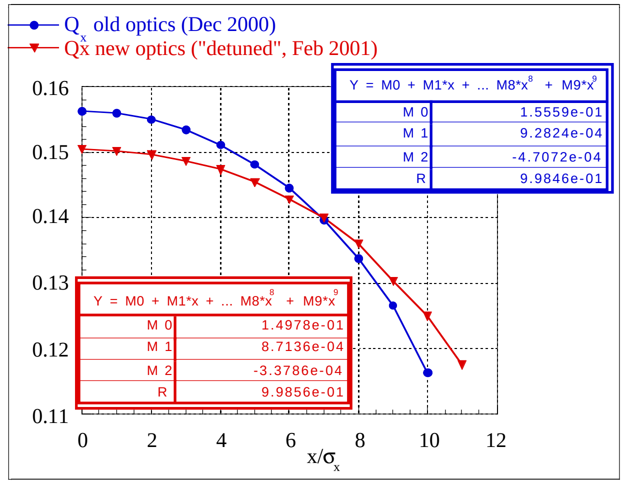

Figure.8: Tune shift on amplitude as predicted by the model for the old and present optics.

6 CONCLUSIONS

The installation of octupole magnets in the DAΦNE rings is underway [10] to optimise the octupole term benefits (Landau damping) and drawbacks.

Dynamic aperture improvements on the new optics are in progress with a six-dimensional phase space study by tracking a high number of particles, on and off energy, together with a betatron tune plane analysis. At the same time an empirical, way to optimise sextupole sets, with the trial and error method, is used. The sextupole strength distributions, calculated for constant chromaticity, are applied looking for beam lifetime and the background improvements.

7 REFERENCES

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