DAΦNE Storage Rings

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Abstract

The lattice for the double ring e^+e^- collider DAΦNE, the Frascati Φ-factory project is presented. Electrons and positrons circulate in two horizontally separated storage rings and collide at a horizontal half angle θ=10 mrad in one or two interaction points. This allows a very short bunch distance and therefore a very high collision frequency ($f \leq 380$ MHz). Due to the high number of bunches (120), the higher order modes (HOM's) in the RF cavities can excite multibunch instabilities. An R&D program on the suppression of the HOM's in the RF cavities is in progress.

I. INTRODUCTION

The general description of the machine is given elsewhere [1]. The two rings cross in the horizontal plane in two points and have a symmetry axis so that the two interaction regions have the same magnetic structure and the same optical functions. Each ring consists of two parts: an inner one, shorter, and an outer one, longer, which are symmetric and have a very similar structure. A crab-crossing [2] scheme is contemplated, if necessary.

A description of lattice and dynamic aperture is presented in Sections II and III. A summary of the preliminary results on cavity R&D is given in Section IV.

II. THE LATTICE

The lattice is a four-period modified Chasman-Green type. To increase the radiated energy per turn, a 2 m long, 1.9 T normal-conducting wiggler is incorporated into each achromat. The emittance value can be adjusted by tuning the dispersion function in the wiggler region.

Two different solutions have been designed, a higher emittance one with $\varepsilon = 10^{-6}$, and a lower emittance one with $\varepsilon = 5 \times 10^{-7}$. Moreover, a lattice with a high momentum compaction, useful to increase the threshold for the longitudinal microwave instability, is under study.

In the following the high emittance lattice [3] is described in detail. The optical functions of half ring are shown in Fig.1. A parameter list is given in Table I.

Table I - Single ring lattice parameters

Circumference (m)	94.56
Horizontal betatron tune Q_x	4.12
Vertical betatron tune Q_y	6.10
Horizontal natural chromaticity Q'_x	- 4.8
Vertical natural chromaticity Q'_y	- 17.8
Emittance ε (m-rad)	9.5×10^{-7}
Energy loss/turn with wigglers (keV)	13.75
Momentum compaction α_c	0.0068
Betatron damping time τ_x (msec)	24.0
Relative energy spread (rms)	4.3×10^{-4}

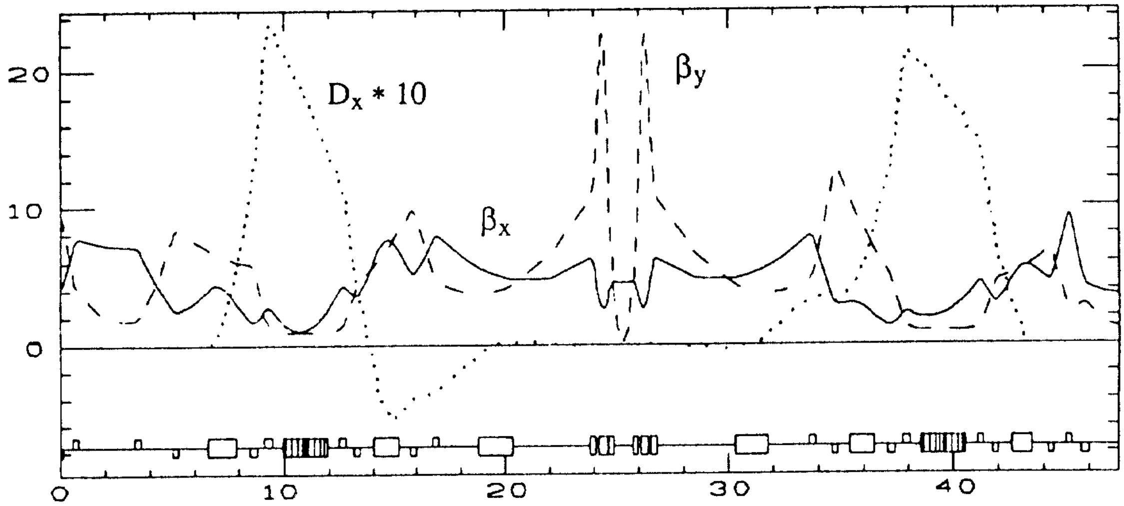

Figure 1. Optical functions of half ring.

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A. Low-β insertion

The low-β insertion is one of the most crucial parts of the Φ-Factory design because of the constraint imposed by the experimental apparatus, that is the requirement of a large unencumbered solid angle around the interaction point (IP). A tentative agreement has been reached with the users on a low-β insertion confined within a cone of half-aperture angle 8.5°, over a length of ± 5 m from the IP. The distance of the first quadrupole from the IP is 43.3 cm and the quadrupole maximum outer diameter $Ø_Q$ is 12.9 cm. Another constraint is the horizontal separation required at a short distance from the IP, to allow for a short bunch-to-bunch longitudinal distance L_b.

The optical parameters at the IP relevant to the luminosity are the following:

$$k_\beta = \frac{\beta_y^*}{\beta_x^*} = .01 \qquad \beta_y^* = .045\ \text{m} \qquad \beta_x^* = 4.5\ \text{m}$$

The low-β insertion consists of a quadrupole triplet followed by a long drift and a special designed split field magnet. The first quadrupole is rather weak and focussing in the horizontal plane. This provides better control over the β functions and keeps the horizontal beam size small inside the quadrupole triplet and along the rest of the insertion.

Let us point out that the low-β insertions give the largest contribution to the ring chromaticity; in particular the vertical chromaticity is $Q'_y = -10.32$ for the insertions compared with $Q'_y = -17.76$ for the whole ring.

The half separation Δ_x between the two beams along with the horizontal beam size in the low-β insertion are plotted in Fig.2. In the same figure the first parasitic crossing points for 30, 60, 120 bunches are indicated.

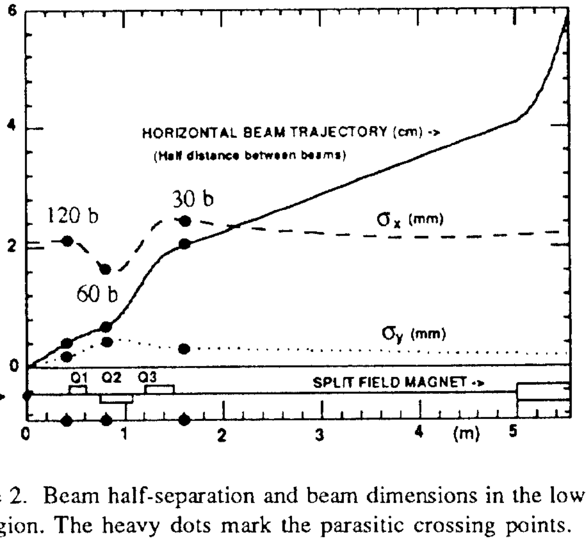

Figure 2. Beam half-separation and beam dimensions in the low-β region. The heavy dots mark the parasitic crossing points.

B. The achromats

The low-β insertion is connected to the main arcs by a matching section consisting of a long drift and two quadrupoles. The length of the drift is chosen in order to have a good separation between the first quadrupoles of the two rings. In this section, at π/2 horizontal betatron phase advance from the IP, there is room for the crab-cavity if necessary.

The dispersion and the horizontal β-function in the wiggler magnet are adjusted in order to tune the emittance, the contribution of the bending magnets to the emittance being negligible.

C. The zero dispersion insertions

Most flexibility in changing the betatron tunes is obtained in the zero dispersion insertions.

The short insertion has a 2.6 m long drift space with rather small β_x, suitable for the RF cavity. The long insertion provides space for injection septum and kickers, diagnostics and also free space for future developments.

III. DYNAMIC APERTURE

The study of the dynamic aperture has been performed with the computer code Patricia [4]. The strong sextupoles needed to correct the high vertical chromaticity are indeed the main limiting effects on the dynamic aperture.

To correct the tune-shift for particles with large oscillation amplitudes, a careful sextupole optimization in the dispersion-free regions has been performed.

The dynamic aperture is shown in Fig. 3, where the stable area for off-momentum particles, with a deviation $\Delta p/p = -.5\%$ (dashed line) and $\Delta p/p = +.5\%$ (dot-dashed line), are plotted for comparison on the unperturbed one (solid line).

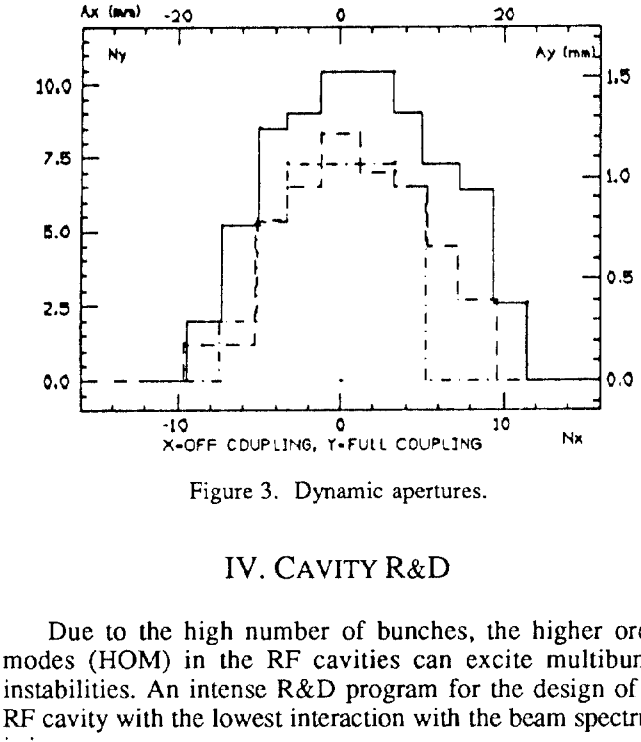

Figure 3. Dynamic apertures.

IV. CAVITY R&D

Due to the high number of bunches, the higher order modes (HOM) in the RF cavities can excite multibunch instabilities. An intense R&D program for the design of an RF cavity with the lowest interaction with the beam spectrum is in progress.

Two different approaches have been followed:

a) coupling off and damping the higher order modes (HOM's) with absorbers;

b) shifting the HOM's frequencies while keeping that of the fundamental mode constant.

One method which has been recently proposed for coupling off the HOM's [5-6] consists in connecting one or more waveguides to the lateral surface of the resonator. The waveguide cut-off wavelength has to be higher than the fundamental mode wavelength in order to let it trapped in the cavity, whereas the HOM's are free to propagate out. A 380 MHz brass cavity prototype has been tested. Two waveguides are connected to the resonator and a dissipative load is placed at the other end of each guide.

In Fig. 4, the measured frequencies and the quality factors Q's of the unperturbed prototype, and the spectrum of the waveguide-loaded cavity are compared. The measured reduction is 12 % for the fundamental mode frequency and 25 % for Q_0. The few remaining modes have a residual Q of some hundreds.

Some technological problems remain open: due to the pill-box shape that ensures the best coupling with the guides, the cavity is, in principle, prone to multipacting. Anyway, with appropriate surface coatings, multipacting can be inhibited. Furthermore, each damping load will dissipate a fraction (some kW's) of the parasitic beam losses and therefore adequate cooling must be provided. In alternative to the present design, the use of ridged waveguides will be investigated in order to reduce the overall size of the cavity.

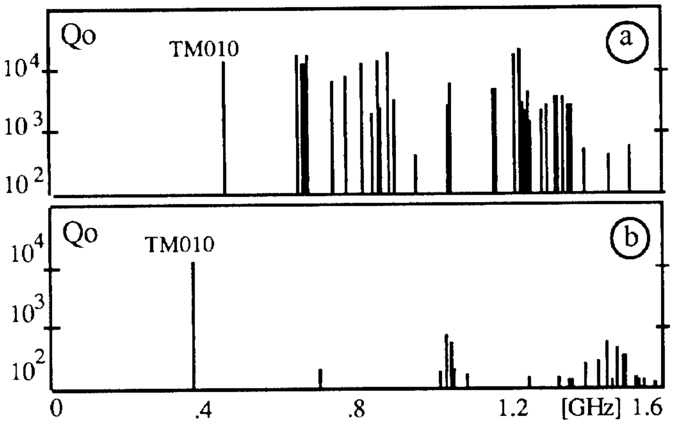

Figure 4. Spectrum of the uncoupled (a) and coupled (b) prototype cavity .

An other design for absorbing the cavity HOM's is being investigated. It consists of a resonator with relatively large beam holes, connected to the beam pipe with long tapered tubes which prevent trapping of parasitic modes in the resonator region [7]. In addition, the tapers reduce the cavity loss factor with beneficial effects on the broad-band impedance of the machine. However, the HOM's have to be damped by means of ferrites or other lossy materials located inside the tapered tubes and the heating produced by the parasitic beam losses has to be removed.

An optimization of the tapered profiles has been carried out on paper. Simulations with TBCI [8] give a loss factor of about 0.12 V/pC/cell. Two parasitic dipole modes, however, remain trapped in the resonator and, should they overlap the beam spectrum lines, detuning is required.

In Fig. 5 the long-tapered cavity profile is outlined along with the electric field lines of the fundamental mode.

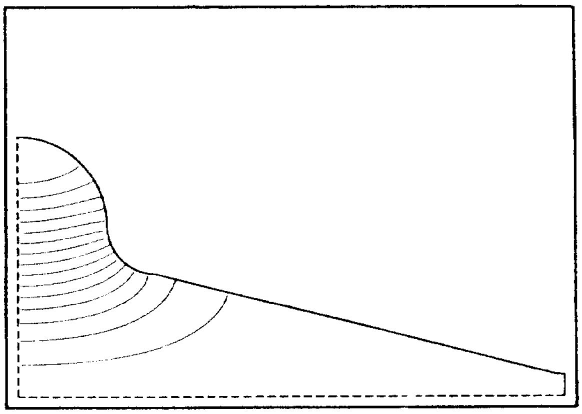

Figure 5. One quadrant of the long-tapered cavity.

An alternative way to fight collective coupled-bunch instabilities consists in shifting the HOM frequencies, without affecting the fundamental one, by means of perturbing metallic objects appropriately located [9]. Indeed, in small ring accelerators like DAΦNE, the spacing of beam spectrum lines is of the order of several MHz, so that the shift of a few offending HOM's can be a very powerful technique to decouple the beam oscillation modes from the cavity modes. The feasibility of this method is under study: one has to focus on the most dangerous cavity HOM's and to carefully consider the influence of the cavity tuning system at the injection.

V. REFERENCES

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