DAΦNE* Status Report

The DAΦNE Project Team**
presented by M.E. Biagini
INFN Laboratori Nazionali di Frascati - C.P. 13 - 00044 Frascati (Roma) - Italy

Abstract

The Frascati National Laboratories Φ-factory project consists of a two rings e^+e^- collider, an accumulator ring and a full energy linac injector. The lattice for the main ring and the accumulator is frozen, the vacuum system has been dimensioned, and the engineering design of the various components is in progress. An R&D program on the suppression of high order modes, leading to multibunch instabilities, is also in progress. In the following a general overview of the project is given.

1. INTRODUCTION

The DAΦNE project [1] has been approved and fully funded in June1990, commissioning is foreseen to start at the end of 1995. The accelerator complex will be housed in the existing LNF buildings, after the decommissioning of Adone (shutdown December 1992).

The major physics aim of a Φ-factory is to perform CP violation experiments with high accuracy. This sets very tough requirements on the peak and average luminosity and on the design of the interaction regions. Up to now, three experiments are foreseen: one, operating at the maximum luminosity, with the aim to improve the measurement of the decay ratios of K_L and K_S in two pions, the other two, with less demanding requests on the luminosity, will study multihadronic production and hypernuclei. The luminosity is optimized at 510 MeV, the short term luminosity goal is 10^{32} $cm^{-2}s^{-1}$, while the ultimate target is 10^{33} $cm^{-2}s^{-1}$.

2. DESIGN PARAMETERS

The main features of the design are:

- many bunches
- very flat beams
- relatively high emittance.

Four 1.8 T normal conducting wigglers are installed in each ring, to have full emittance tunability and increase the radiation damping.

At the space charge limit the luminosity, in the hypothesis of equal tune shift in both planes, can be written as:

$$L = hL_o = \pi \left(\frac{\gamma}{r_e}\right)^2 hf_o \frac{\xi^2 \varepsilon (1+\kappa)}{\beta_y^*}$$

where: L_o = single bunch luminosity, h = number of bunches, f_o = revolution frequency, γ = beam energy in units of the rest mass, r_e = classical electron radius, ξ = linear tune shift, ε = beam emittance, β_y^* = vertical beta function at the interaction point (IP), κ = coupling factor.

To get a high luminosity, we have chosen a reasonable value of the single bunch luminosity L_o, comparable to the one achieved in the VEPP-2M machine [2], and a very high number of bunches. To gain the factor h in the luminosity, without a reduction of the maximum tune shift, the bunches have to be kept separated out of the interaction point. Therefore the two beams circulate in two separate rings crossing at an horizontal angle 2θ in two interaction points.

For flat beams, the horizontal crossing should not excite synchro-betatron resonances, which limit the maximum achievable tune shift, due to the reasonably small value of the geometrical factor:

$$a = \theta \frac{\sigma_z}{\sigma_x^*} = .14$$

where σ_x^* is the r.m.s. horizontal size at the IP and σ_z is the bunch length.

In Table I the parameters relevant to the luminosity are given.

Table I - DAΦNE design parameters

E (MeV)	510.	θ (mrad)	10÷15
L_o ($cm^{-2}s^{-1}$)	4.5 10^{30}	σ_x^* (mm)	2.
κ	.01	σ_y^* (mm)	.02
ξ	.04	σ_z (m)	.03
ε^{max} (m-rad)	10^{-6}	h^{max}	120
β_x^* (m)	4.5	f_o (MHz)	3.17
β_y^* (m)	.045	N^{max} /bunch	8.9 10^{10}

A complete lattice overview is presented in [3]. The machine is based, as much as possible, on conventional technology. The challenge is the very high design current: RF and feedback systems have to be carefully studied in order to get rid of multibunch instabilities and the vacuum system has to cope with a very high synchrotron radiation power.

The commissioning strategy is, first of all, to maximize the single bunch luminosity: the design has enough flexibility to fine tune most of the parameters appearing in Table I. Then the total luminosity will be raised by gradually increasing the number of bunches.

The short term luminosity goal can be reached with 30 bunches. As explained in the following, the achievement of 10^{33} $cm^{-2}s^{-1}$ requires the improvement of the crossing region geometry to overcome the problems connected to parasitic crossings and the upgrade of the longitudinal multibunch feedback system.

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* Double Annular Φ-factory for Nice Experiments.

** A. Aragona, S. Bartalucci, M. Bassetti, M.E. Biagini, C. Biscari, R. Boni, A. Cattoni, V. Chimenti, A. Clozza, S. De Simone, D. Di Gioacchino, G. Di Pirro, A. Esposito, S. Faini, R. Fedele, G. Felici, A. Gallo, A. Ghigo, S. Guiducci, H. Hsieh, S. Kulinski, M.R. Masullo, C. Milardi, M. Modena, L. Palumbo, M. Pelliccioni, M. Preger, G. Qiao, G. Raffone, C. Sanelli, F. Sannibale, M. Serio, F. Sgamma, B. Spataro, A. Stecchi, T. Tanabe, L. Trasatti, C. Vaccarezza, V. G. Vaccaro, L. Verolino, M. Vescovi, S. Vescovi, G. Vignola, J. Wang, M. Zobov.

3. Interaction Region

The machine has two 10 m long interaction regions. The low-β quadrupoles are .45m far from the IP and are confined in a cone of 8.5° half aperture, leaving a free solid angle for the apparatus of 99%. The only solution to fit them in such a narrow space is to use permanent magnet quadrupoles.

On one interaction region there is an experimental detector with a .6T, 5m long solenoidal field. A correction scheme to compensate the coupling due to the solenoid is presented below.

3.1 Parasitic crossing points

One of the main problems in going to very high collision frequency is that of the unwanted parasitic crossing points. We have adopted a scheme whereby the separation at the interaction regions is given only by the horizontal crossing angle at the IP.

The crossing angle has to be kept small in order to avoid synchro-betatron resonances. Anyway, an interaction region design suitable to work with all the 120 bunches, i.e. a maximum collision frequency of 368 MHz, is necessary. Two different configurations are presented here, both with $\beta_y{}^* = .045$ m:

- $\beta_x{}^* = 4.5$ m and $\theta = 10$ mrad
- $\beta_x{}^* = 3.0$ m and $\theta = 15$ mrad.

From beam-beam simulations [4], it seems that the minimum required separation between the two beams at the parasitic crossings should be at least 7 σ_x, since particles in the tails must not see the non-linear field in the core of the other beam. Table II shows the ratio $2\Delta x/\sigma_x$ for the two crossing angles: the above criterion is satisfied with 60 bunches for 10 mrad and with 120 bunches for 15 mrad.

An estimate of the influence of the parasitic crossings on the luminosity is the corresponding value of the tune shift parameter ξ^p in both planes. This is also shown in Table II, for the two cases, as a function of the number of bunches N_b and the bunch spacing s. In the worst case (N_b = 120 and 60) the parasitic tune shifts are less than 10% of that at the IP, for N_b = 30 this is much smaller, so that a 10 mrad crossing angle is still acceptable.

Table II
First parasitic crossing

θ(mrad)	N_b	s(m)	Δx(mm)	ξ^p_x	ξ^p_y	$2\Delta x/\sigma_x$
10.	120	.4	4.0	.0028	.0022	3.8
10.	60	.8	7.0	.0006	.0037	8.1
10.	40	1.2	14.5	.0002	.0008	13.
10.	30	1.6	20.7	.0002	.0003	15.
15.	120	.4	6.0	.0008	.0010	6.9
15.	60	.8	10.5	.0002	.0016	14.
15.	40	1.2	21.8	.0001	.0003	22.
15.	30	1.6	31.0	.0001	.0001	26.

3.2 Solenoid compensation scheme

Due to the relatively high magnetic field (.6 T), the dimensions (5 m) and the position (the low-β triplet is not shielded) of the detector solenoid, a new approach has been studied to compensate the field integral on the beam trajectory. This method [5], giving to each quadrupole of the triplet a rotation angle around its axis proportional to the field integral at its location, and adding at both ends two shorter (1 m) compensating solenoids (1.5 T), allows to decouple the machine at the IP and at the end of the interaction region, with a small perturbation of the optical functions, easily matched with the following quadrupoles. Since the quadrupoles are fully immersed in the solenoidal field, an ideal compensation scheme would require to continuously rotate the quadrupoles in order to track the rotation generated by the solenoid. This is technically too complicate, therefore four skew quadrupoles, located in the arcs, will be used to compensate the residual coupling.

4. Status of the Project

The lattice design is completed and exhibits a good dynamic aperture. The sensitivity to alignment and field errors and the vacuum chamber aperture required to get a good beam lifetime have been estimated [3]. A complete single ring parameter list is given in Table III.

Table III
DAΦNE single ring parameter list

Energy (MeV)		510.
Circumference (m)		97.69
Dipole bending radius (m)		1.4
Wiggler bending radius (m)		0.94
Wiggler length (m)		2.0
Wiggler period (m)		.64
Horizontal β-tune		4.87
Vertical β-tune		4.85
Natural chromaticities	Horizontal	-6.9
	Vertical	-16.9
Momentum compaction		.017
Energy loss/turn (KeV):	Bend.magnets	4.27
	Wigglers	4.96
	Total	9.3
Damping times (msec):	τ_z	17.8
	τ_x	36.0
	τ_y	35.7
Natural emittance (m-rad)		10^{-6}
Natural relative rms energy spread		$3.97\ 10^{-4}$
Natural bunch length σ_z (cm)		.81
Anom. bunch length σ_z (cm) @ Z/n = 2 Ω		3.0
RF frequency (MHz)		368.25
Number of bunches		1 ÷ 120
Max. bunch peak current (A)		57.
Max. total average current (A)		5.3
Max. synchrotron power/beam (KW)		49.
V_{RF} (KV) @ Z/n = 2 Ω		254.
Parasitic losses (KeV/Ω) @ σ_z = 3 cm		7.

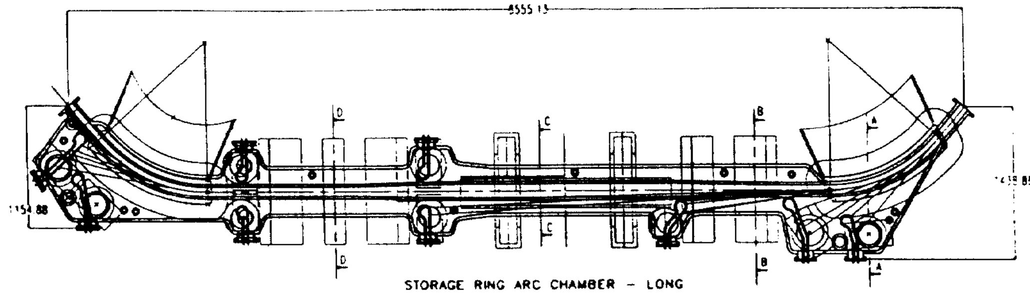

Figure 1. Storage Ring Arc Vacuum Chamber.

4.1 Vacuum system

The vacuum system for the Linac, accumulator and transfer lines will make use of standard technologies, like stainless steel for the vacuum chamber and sputter ion pumps for the pumping system; no *in situ* bake-out is foreseen. The working pressure will be in the range of low 10^{-8} Torr. The storage rings vacuum system [6] must reach a pressure of 10^{-9} Torr with 5 A of stored beam current. Such a requirement will be satisfied only by using advanced technologies, like aluminum vacuum chambers, synchrotron light absorbers and a combination of titanium sublimators and sputter ion pumps for the main pumping system. The project of the chamber for the whole complex has been completed. In Fig.1 the storage ring arc chamber design is shown.

4.2 RF cavity

The multibunch instability is one of the most serious concerns for the high luminosity, high current operation of DAΦNE. Much effort is presently put in the development of a 'single-mode' cavity [7], with the lowest contents of HOMs. Various damping techniques are investigated, in order to optimize the cavity final design. A prototype of a Single Trapped Mode Resonator [8] consisting of a pill-box with 3 waveguides and dissipative loads is presently being measured. The effect of various absorbing materials is also thoroughly investigated. A prototype of the 'day-one' accelerating cavity has been designed and its construction will be committed to industry soon. Its main feature is the presence of very long tapers, to reduce both the total loss factor and the effect of transverse deflecting modes.

4.3 Feedback system

A preliminary study of the growth rate of the longitudinal multibunch instabilities has evidenced the need for a powerful active feedback system. The proposed system [9] is a bunch by bunch, time-domain feedback. The preliminary design is a mixed analog/digital feedback system employing Digital Signal Processor techniques, which can be used with 30 and is upgradable to 120 bunches, capable of a damping time of 0.1-0.2 ms.

4.4 Injector complex

The Linac, operating at full energy with a repetition rate of 50 Hz, has been committed turn-key to industry. The delivery time, with a 10 mA e^+ beam as acceptance test, is two years from now. In Table IV the main parameters for electrons and positrons are shown.

Table IV
Linac parameter list

	e^-	e^+
Max energy (MeV)	800	590
Emittance (m-rad)	10^{-6}	10^{-5}
Rel. energy spread	±.005	±.01
Pulse width (ns)	10.	10.
Peak current (mA)	150.	40.

A compact positron/electron accumulator, at 510 MeV, is used to damp the longitudinal acceptance and the transverse emittance of the linac beam, thus relaxing the injection requirements in the design of the main rings. All the details can be found in [10]. The magnetic structure is made of four quasi-achromatic bending sections and four long straights to accommodate RF, injection and extraction pulsed elements. Two channels will transport the beams from the Linac to the accumulator. Positrons will be injected from one channel and extracted from the other one, while electrons will follow the opposite path. The extraction of the single damped bunch will take place at 1 Hz, filling one main ring bucket at a time. The design of the transfer lines to the DAΦNE ring has been completed too.

4.5 Magnetic components

The magnetic components design is well advanced. Details can be found in [11]. Their procurement will begin within few months.

5. REFERENCES

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