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OVERVIEW OF DAΦNE*, THE FRASCATI Φ-FACTORY

The DAΦNE Project Team**

presented by M. Serio

INFN, Laboratori Nazionali di Frascati - C. P. 13 - 00044 FRASCATI (Roma) - Italy

Abstract

An overview of DAΦNE, the Frascati Φ-Factory project is presented. The DAΦNE project has been approved and fully funded by the INFN Board of Directors in June 1990. The end of construction is scheduled for December 1995. The short-term luminosity goal is 1.3 10^{32} cm^{-2} sec^{-1}, while the ultimate luminosity target is ~10^{33} cm^{-2} sec^{-1}. All critical components of the project, injector, vacuum system, RF and feedback are dimensioned to cope with the target luminosity.

1. INTRODUCTION

The DAΦNE accelerator complex consists of two storage rings and an injector for topping-up at 510 MeV. In the storage rings electrons and positrons circulate in opposite directions, intersecting in two interaction points. The complex will be housed in the existing LNF buildings.

The first interaction region is dedicated to a large detector, KLOE [1], for CP violation experiments. A letter of intent has been submitted to use the second interaction region for experiments on hypernuclei, with a smaller size detector.

The short-term luminosity goal of 1.3 10^{32} $cm^{-2}s^{-1}$ can be reached with 30+30 bunches.

2. INJECTOR

The relevance of a powerful and reliable injection system to the average luminosity has been recognized as a key feature of the whole project. The injector consists of an e^+/e^- Linac and an Accumulator ring.

The Linac, operating at 50 Hz, has been ordered turn-key to TITAN-BETA and it will be in operation by the end of 1994. The main parameters for electrons and positrons are listed in Table I.

Table I
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.

The 32.56 meter long Accumulator ring, E_{max} = 510 MeV, is used to accumulate the required number of electrons (positrons) and to damp the transverse and the longitudinal emittance of the linac beam, thus relaxing the injection requirements in the design of the main rings.

Two magnetic channels transfer the beams from the Linac to the Accumulator. Electrons are injected into a single Accumulator RF bucket from one channel and extracted from the other one; positrons follow the opposite path. Extraction takes place at 1 Hz, filling one main ring bucket at a time. The Accumulator and transfer lines design have been completed and the procurement procedures are in progress: commissioning will be completed within 1995.

3. MAIN RINGS

The main rings magnetic layout is shown in Fig. 1.

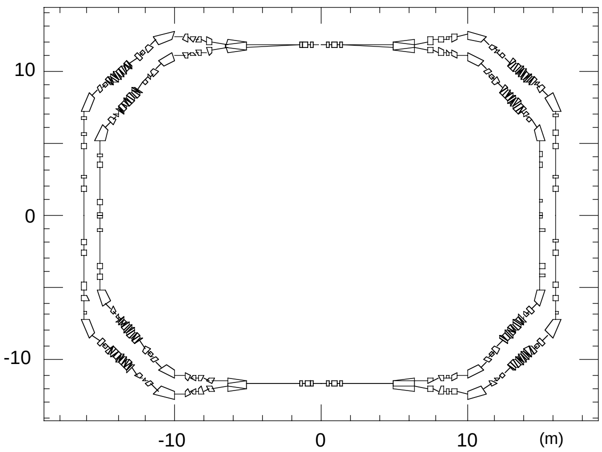

Figure 1 - Magnetic layout of the main ring.

The salient features are:

- electrons and positrons circulate in two separate storage rings and collide at a horizontal half-angle θ_X = 10 ÷ 15 mrad, depending on the number of bunches, in order to minimize the effect of parasitic crossings. The crossing angle can be changed by powering a small (±20 mrad) dipole, located after the splitter magnet that separates the trajectories of the two beams;
- the novel design of the magnetic lattice is a 4-period modified Chasman-Green type, with a 2 meters-1.8 Tesla normal conducting wiggler magnet inside each achromat.

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* Double Annular Φ-factory for Nice Experiments.

** M. Serio, 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 Massa, G. Di Pirro, A. Esposito, S. Faini, R. Fedele, G. Felici, A. Gallo, A. Ghigo, S. Guiducci, H. Hsieh, S. Kulinski, C. Marchetti, M.R. Masullo, M. Migliorati, C. Milardi, M. Modena, L. Palumbo, R. Parodi, M. Pelliccioni, M. Preger, G. Qiao, G. Raffone, C. Sanelli, F. Sannibale, F. Sgamma, B. Spataro, A. Stecchi, L. Trasatti, C. Vaccarezza, V.G. Vaccaro, L. Verolino, M. Vescovi, S. Vescovi, G. Vignola, J. Wang, M. Zobov.

This choice allows ample emittance tunability, without changing the wiggler magnetic field, and it gives, at the same time, strong radiation damping which is one of the fundamental properties that lead to high luminosity;

- the magnetic structure design has built-in enough flexibility to tune other lattice parameters such as momentum compaction, beta at the interaction point, etc; it allows also the installation of 4 RF cavities for *crabbing*;
- the correction scheme for the coupling introduced by the KLOE detector solenoidal field is performed by two 1.5 T, 1 m, compensating solenoids, plus a tilt of the low-β quadrupoles, increasing outward from the interaction point. The small residual coupling is corrected by means of 4 weak skew quadrupoles located in the arcs [3].

The single ring parameters are listed in Table II below.

Table II
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)		0.64
Horizontal β-tune		5.15
Vertical β-tune		5.13
Natural chromaticities		
	Horizontal	-7.2
	Vertical	-18.8
Momentum compaction		0.016
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)		0.81
Turbulent bunch length σ_z (cm) @ Z/n = 2 Ω		3.0
RF frequency (MHz)		368.25
RF harmonic number		120
Max. bunch average current (mA)		43.7
V_{RF} (KV) @ Z/n = 2 Ω		254.

The optical functions behaviour is presented in Fig. 2.

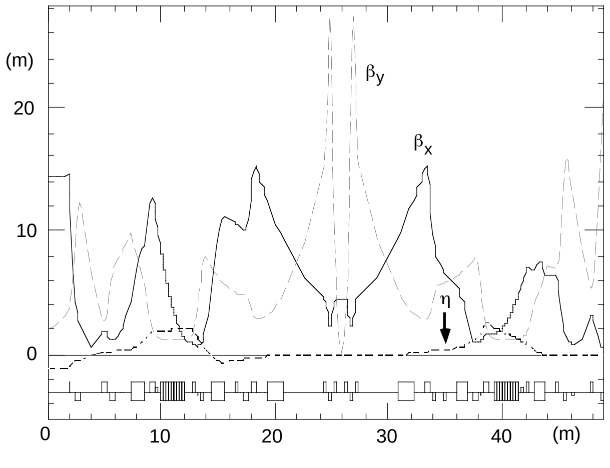

Figure 2 - Optical functions (half ring).

4. LUMINOSITY STRATEGY

The main choices (and related problems) to achieve high luminosity are very similar to those adopted for other higher energy factories, namely:

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

Let us just remind that, 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, $\beta_y{}^*$ = vertical beta function at the interaction point, 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.

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

Table III - DAΦNE luminosity parameters @ 510 MeV

L_o ($cm^{-2}s^{-1}$)	$4.5\ 10^{30}$	θ_x (mrad)	10÷15
κ	.01	$\sigma_x{}^*$ (mm)	2.
ξ	.04	$\sigma_y{}^*$ (mm)	.02
ε^{max} (m-rad)	10^{-6}	σ_z (m)	.03
$\beta_x{}^*$ (m)	4.5	h_{RF}	120
$\beta_y{}^*$ (m)	.045	f_o (MHz)	3.17

These parameters allow to fill a maximum of 120 bunches with a beam-beam separation $\geq 7\sigma_x$ at the parasitic crossings. The challenge with 120 bunches is the very high current, that poses severe requirements on vacuum, RF and feedback systems.

The project effort, at this moment, is concentrated to guarantee the accumulation of at least 30 + 30 bunches for an initial routine luminosity $L = 1.3\ 10^{32}\ cm^{-2}s^{-1}$.

5. VACUUM SYSTEM

The main ring vacuum system is dimensioned for an operating pressure of 1 nTorr with ~ 5 Amp of circulating current. The arc vacuum chamber is made of Al 6063. Water cooled copper absorbers of the synchrotron radiation produced in the wigglers and dipoles are used. The value of the desorption coefficient adopted in the calculations is $\eta_e \leq 3\ 10^{-6}$ (molec/photon), as measured at NSLS-BNL, in an experimental set-up similar to the DAΦNE vacuum chamber. In addition to sputter ion pumps, used all along the ring, Ti sublimators are located in the vacuum antechamber of the arc sections, right close to the copper absorbers and above the ion pumps, to achieve the required pumping speed.

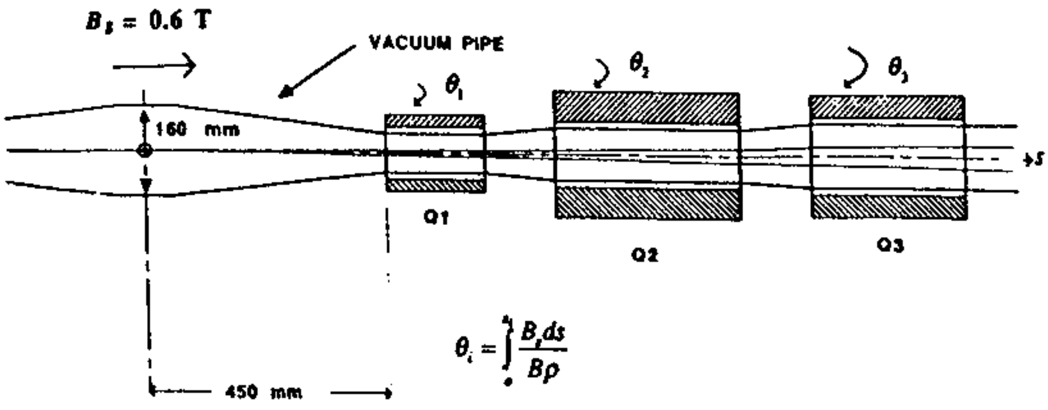

Figure 3 - KLOE interaction region layout.

6. RF SYSTEM

The reduction of the beam-cavity spectra interaction is the most demanding feature of the DAΦNE RF system. The RF cavity design is well in progress with the aim to significantly reduce the impedance of the high order cavity modes (HOM). This can be accomplished both by properly shaping the resonator and, more effectively, by coupling off the HOM electromagnetic fields through the connection to the cavity surface of waveguides with a cutoff higher than the accelerating mode. HOM fields may dissipate in lossy materials (i.e. ceramics, ferrites, etc) applied to the far end of the waveguides.

Previous measurements, carried out on a waveguide loaded pill-box were encouraging. Tests of various waveguide loaded full scale prototypes are foreseen very soon. An R&D program is in progress to evaluate the capability of various dissipative materials to operate in ultra high vacuum conditions. However the alternative standard solution, based upon damping antennas cannot be excluded.

7. LONGITUDINAL FEEDBACK SYSTEM

Longitudinal multibunch instabilities may limit severely the current intensity achievable in DAΦNE [4], even though the HOM's in the accelerating cavities are heavily damped. We are working on a powerful active feedback system, capable of damping all the coupled modes and injection transients with a damping rate at least two orders of magnitude larger than the natural damping.

From the results of a preliminary study we are convinced that a longitudinal feedback system largely based on analog/digital techniques is feasible and works well [5]. The approach with DSP (Digital Signal Processors) technique is common to other factories with intense beams and a large number of bunches. In fact, a collaboration has been set up with the B-Factory group at SLAC, where considerable R&D on feedback systems for the next generation of electron-positron colliders [6] is being carried out.

The system under development at DAΦNE is a bunch by bunch, time-domain feedback capable of a damping time of ~ 0.1 ms. It is sized for 30 bunches and upgradable to a full complement of 120 bunches, thanks to its modular architecture. A wide bandwidth power amplifier of ~ 500 W is enough to damp an initial offset of 100 ps of one bunch at injection, with the other 29 bunches at the full design current.

8. KLOE INTERACTION REGION

The interaction region is 10 m long. The low-β quadrupole triplets, of permanent type, are 45 cm far from the IP and are confined in a cone of 9° half aperture, leaving a material-free solid angle for the apparatus of ~ 99%. It is a requirement of the experimenters to have a large (radius ≥ 8 cm) aperture vacuum chamber at the IP. The layout of the interaction region is shown in Fig. 3.

The main problems for the interaction region, which we are presently working on, are:

- mechanical support of the vacuum chamber and low-β triplet;
- trapped RF losses, due to the cavity-like shape of the vacuum chamber, and relative cooling;
- pumping system.

9. ACKNOWLEDGMENTS

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10. REFERENCES

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