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DAΦNE*: the Frascati Φ-Factory

The DAΦNE Project Team**
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Abstract

An overview of the Frascati Φ-factory and the salient project features are presented.

I. INTRODUCTION

The DAΦNE accelerator complex of the INFN Frascati National Laboratories consists of two rings colliding beam Φ-Factory and a 510 MeV e^+/e^- injector for topping-up. A general layout of the complex is shown in Fig. 1.

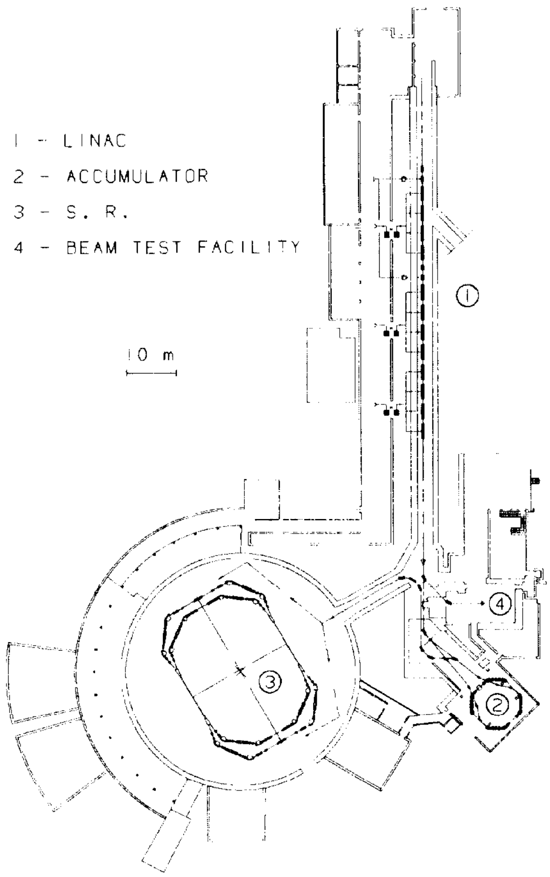

Figure 1. DAΦNE layout.

The project has been approved by INFN Board of Directors in June 1990 and the engineering design has started in January 1991. Construction and commissioning is scheduled for the end of 1995. The construction budget is 81 GLit (no salary and conventional constructions).

The short-term luminosity goal is 10^{32} cm^{-2} sec^{-1} while the final luminosity target is ~10^{33} cm^{-2} sec^{-1}.

II. THE Φ-FACTORY

Table I
DAΦNE single ring parameters list

Energy (MeV)			510
Circumference (m)			94.56
Dipole bending radius (m)			1.400
Wiggler bending radius(m)			0.9
Wiggler length (m)			2.0
Wiggler period (m)			0.5
Horizontal β-tune			4.12
Vertical β-tune			6.10
Natural chromaticities:	Horizontal		-4.8
	Vertical		-17.8
Momentum compaction			.0068
I_2 (m^{-1})			14.4
I_3 (m^{-2})			14.2
Energy loss/turn (KeV) :	Bend. magnets	4.27	
	Wigglers	9.41	
	Total		13.75
Damping times (msec):	τ_s		11.6
	τ_x		24.0
	τ_y		23.4
Natural emittance (m-rad)			.95 10^{-6}
Relative rms energy spread			4.31 10^{-4}
β_y @ IP (m)			.045
β_x @ IP (m)			4.5
σ_y @ IP (mm)			.021
σ_x @ IP (mm)			2.11
κ			.01
Bunch length σ_z (cm)			3.0
Crossing half angle (mrad)			10.0
f_{RF} (MHz)			380.44
Harmonic number			120
Number of bunches			1 ÷ 120
Maximum number of particle/bunch			9.10^{10}
Maximum bunch peak current (A)			57
Maximum average current/bunch (mA)			46
Maximum total average current (A)			5.5
Maximum synchrotron power/beam (KW)			75
V_{RF} (KV)	@ Z/n = 2 Ω		241
	@ Z/n = 1 Ω		122
Parasitic losses @ σ_z = 3 cm (KeV/Ω)			7

* Double Annular Φ-factory for Nice Experiments.
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The main features of the Φ-factory are :

- electrons and positrons circulate in two separate storage rings and collide at an horizontal half-angle θ_x = 10 mrad (in one or two interaction points) in order to have high collision frequency without parasitic crossings;
- the novel design of the magnetic lattice is a 4-period modified Chasman-Green type, with a 1.9 Tesla normal conducting wiggler magnet inside the achromat. This solution allows ample emittance tunability, without changing the wiggler magnetic field, and it gives, at the same time, strong radiation damping;
- a crab-crossing option is contemplated (if needed).

The single ring parameter list is given in Table I; the injection system and the storage rings design are described in more details elsewhere [1], [2].

III. DESIGN PHILOSOPHY

The design is based, as much as possible, on conventional technology and all the critical components (injector, vacuum system etc.) will be dimensioned to cope with the target luminosity of 10^{33} cm^{-2} sec^{-1}.

The starting point of our design philosophy is the consideration that the highest luminosity reached so far in the world, at the Φ-factory energy (510 MeV) is L = 4.3 10^{30} cm^{-2} sec^{-1} with VEPP-2M in Novosibirsk. Therefore, also our initial luminosity goal is very challenging and one has to be very careful in the fundamental choices.

The nature of a 'factory' in itself dictates an optimization of the luminosity at the operating energy. This process leads, no matter what, to adopt a design in which all the parameters are chosen in such a way that the storage ring works near to the space charge limit in both planes. Under this assumption, the luminosity per interaction point (given by the number of bunches h multiplied the single bunch luminosity L_o), can be written as :

$$L = h\,L_o = \pi \left(\frac{\gamma}{r_e}\right)^2 h\, f_o\, \frac{\xi^2\, \varepsilon\, (1+\kappa)}{\beta_y}$$

where γ is the electron energy in units of its rest mass, r_e the classical electron radius, h the number of bunches, f_o the revolution frequency, β_y the value of the vertical β-function at the IP, ξ the linear tune-shift, ε the emittance and κ the coupling coefficient.

By the inspection of the above formula, it is evident that, for a given luminosity, one has two basic alternatives :

- small ring footprint and few bunches;
- larger ring footprint and many bunches.

The first alternative, that is pursued with different approaches in many Φ-factory designs, is surely attractive from the accelerator physics and from the cost point of view, but it is also the most uncertain, since it requires single bunch luminosity L_o, which has never been achieved in the existing machines.

We have decided to adopt the second solution, with two separate storage rings, because it allows to reach the same luminosity without pushing L_o to very high values.

Table II
DAΦNE design parameters

L_o(cm^{-2}sec^{-1})	4.5 10^{30}	ε^{max} (m-rad)	10^{-6}
h^{max} (N^{er} of bunches)	120	κ	.01
f_o(MHz)	3.17	β_x @ IP (m)	4.5
ξ	.04	β_y @IP (m)	.045
θ_x (m-rad)	10	σ_z (m)	.03

The DAΦNE design parameters, relevant to the luminosity, are listed in Table II. These values indicate clearly other distinctive features of the design, like flat beam, large emittance and horizontal crossing angle. The horizontal crossing, due to the values of the beam sizes at the interaction point, and to the reasonable value of the geometrical factor

$$a = \theta_x \frac{\sigma_z}{\sigma_x} = 0.14\ ,$$

should not excite synchrobetatron resonances [3].

It is also evident, from the value assumed for L_o, that our choice is quite conservative from the single bunch luminosity point of view (VEPP-2M has already achieved such luminosity and the single bunch parameters of DAΦNE are very similar to the Novosibirsk machine), but it is very demanding under other aspects, particularly for the very high current which is needed to fill all the bunches and the problems connected to.

The parameters shown in Table II are the reference ones, and our commissioning strategy will be to fully use the flexibility built in the storage rings design to fine tune all of them in order to maximize L_o and to try to go over the design value. In parallel, with the optimization of L_o, we will gradually increase the number of bunches. This will require a certain amount of R&D, that is already started, in order to properly cure the multibunch instabilities.

Finally, it is worth to mention that our design, at this stage, foresees the use of flat beam: nevertheless, a round beam option can be adopted, should its effectiveness be demonstrated.

IV. STATUS OF THE PROJECT

The engineering design of vacuum and magnetic components, diagnostics, power supplies of the accumulator ring and of the main rings is in progress, and the first prototypes will be built in the next few months.

Our main concern, at this time, is how to handle the multibunch instability that is the most harmful problem in the design of high current storage rings and the most serious limitation for the luminosity. The parasitic high order modes of the RF cavities are responsible of such instability. The instability growth rate must be kept below the damping rate induced by the radiation. This can be obtained trough feedback system and proper RF cavity design.

We are designing a broadband (~50 MHz) feedback system with a damping time in the range of hundreds of μsec. Such system should allow, at the machine start-up, to store 30 bunches if we have been able to design a good RF cavity. For this reason we have started a robust R&D program on the resonators and the first results are reported in reference [2].

We are also defining the engineering details of the interaction region. The aperture of the first three quadrupoles has to allow for good beam lifetime, moreover the beam separation and, at the same time, the outer dimensions are restricted by the experimental apparatus. Figure 2 shows a section of a permanent magnet hybrid-type quadrupole that we are building in collaboration with Ansaldo-Ricerca: this kind of magnet seems a good candidate for the IR quadrupoles and we will perform magnetic measurements next summer.

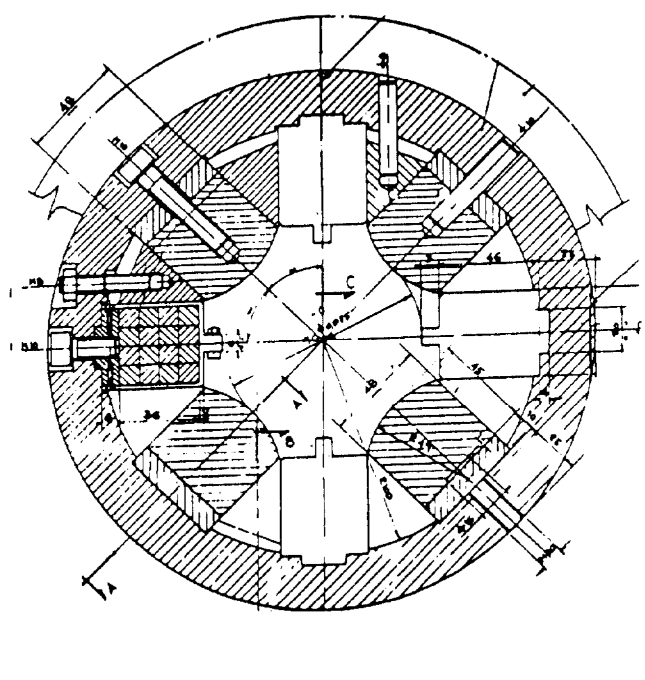

Figure 2. Permanent magnet hybrid-type quadrupole (section).

Figure 3 shows the magnetic field at the Centre of the split field magnet as predicted by the 3D Magnus code calculations. The field quality of this magnet is very sensitive to the coil positioning and we are building a prototype whose engineering design is shown in Fig. 4.

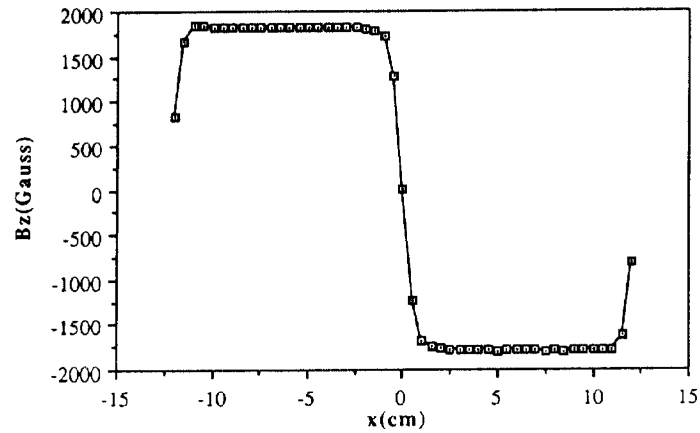

Figure 3. Computed magnetic field at the centre of the split field magnet.

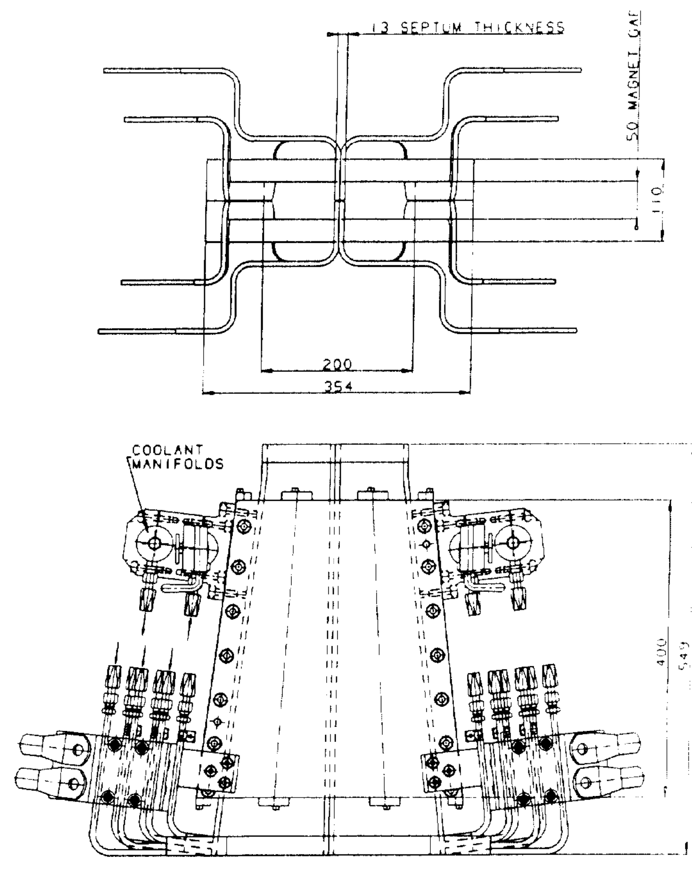

Figure 4. Engineering design of the split field magnet.

V. REFERENCES

[1] R. Boni et al., "The Frascati Φ-Factory Injection System", these Proceedings.

[2] S. Bartalucci et al., "DAΦNE Storage Rings", these Proceedings.

[3] S. Bartalucci et al., DAΦNE Technical Note G-1, (1990).