DAΦNE, THE FIRST Φ-FACTORY

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Abstract

DAΦNE, a high luminosity e^+/e^- Φ-factory, is presently under construction in Frascati.

The beginning of the collider commissioning is scheduled by winter 1997, with a short term luminosity goal $L=1.3\ 10^{32}\ cm^{-2}\ sec^{-1}$.

DAΦNE shall be the first of the new generation of very high luminosity colliders, called factories, to come in operation.

Other factories under construction are PEP-II [1] and KEK-B [2]: first collision, for both machines, is planned for 1998.

1 INTRODUCTION

The construction of the Φ-factory DAΦNE (including a completely new injector) was approved by the INFN Board of Directors in June 1990, while the engineering design started in spring 1991. This new facility is housed in the existing building of the ADONE accelerator, which has been shut down in April 1993.

An artist's view of DAΦNE is shown in Fig. 1.

The collider design is optimized at the Φ energy (1.02 GeV c.m.). It consists of two high current separate rings, crossing at a total horizontal angle of 25 mrad in two interaction regions, equipped with superconducting solenoids for the experimental detectors. The components of the Main Rings are being installed into the DAΦNE hall. Start of commissioning is expected by winter 1997.

In the following we will present briefly the main features and the status of the injector complex, the collider and its principal subsystems: more detailed information can be found in a series of papers presented at this Conference [3].

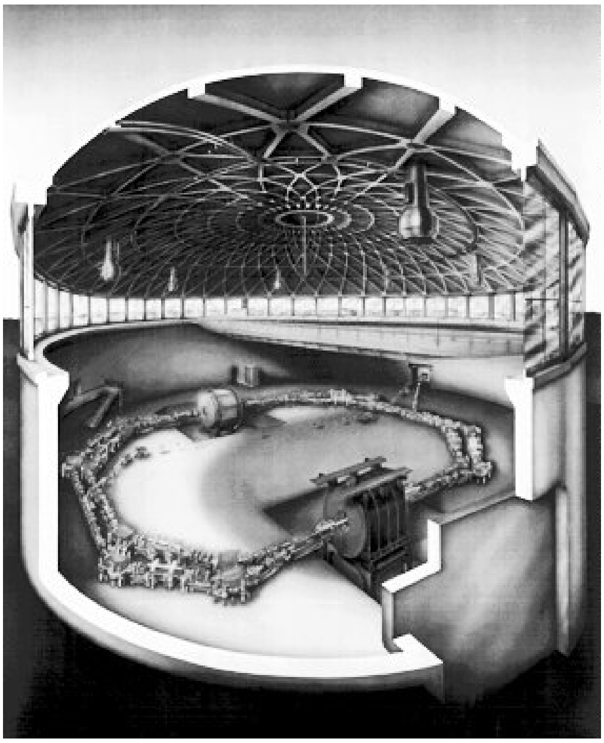

Figure 1 : An artist's view of DAΦNE showing the magnets layout and the two detectors, KLOE on the right and FINUDA on the left.

2 INJECTOR

The injector consists of an e^-/e^+ Linac and an Accumulator/damping ring, connected to DAΦNE through ~160 m long Transfer-lines.

The Linac, built by Titan Beta, has been already installed and commissioned with electrons. Positron commissioning is under way. The main design parameters for electrons and positrons are listed in Table I.

Table I - DAΦNE LINAC parameter list

	e^-	e^+
Max Energy (MeV)	800	550
Emittance (mm-mrad)	1.0	10.0
Relative energy spread	±.005	±.01
Pulse width(ns)	10.0	10.0
Peak current (mA)	150.0	40.0
Max repetition rate (Hz)	50.0	50.0

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The Accumulator is used to damp the transverse and longitudinal emittances of the Linac beam (e^- or e^+), thus relaxing the injection requirements in the design of DAΦNE.

The injection chain works as follows: LINAC beam is first injected at ~ 50 pps in one RF Accumulator bucket, damped, extracted at ≈1 Hz, and injected into a single DAΦNE bucket.

The Accumulator (whose main parameters are listed in Table II) has been built by Oxford Instruments and completely installed (see Fig. 2) together with the transfer lines.

Accumulator commissioning is under way and first beam has already circulated.

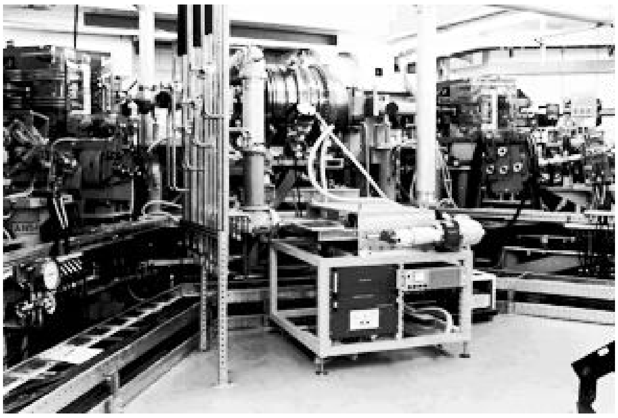

Figure 2 : View of the Accumulator with the RF cavity.

Table II - Accumulator Main parameters

Max Energy (MeV)	550
Circumference (m)	32.56
Emittance (mm-mrad)	0.26
RF frequency (MHz)	73.65
RF peak voltage (kV)	200
Single bunch av. current (mA)	150
Bunch length (cm)	3.0
Synchrotron loss (keV/turn)	5.2
Damping time, τ_ε/τ_x (ms)	10.7/21.4

3 DAΦNE

The major physics motivation for the construction of DAΦNE is the observation of direct CP-violation in K_L decays, i.e. the measurement of ε'/ε with accuracy in 10^{-4} range by the KLOE detector [4].

A second detector FINUDA [5] for nuclear physics is also approved and under construction.

In order to achieve a very high luminosity, mandatory target for any factory, the DAΦNE design is based on the high current, double ring approach, adopted also by PEP-II and KEK-B. This high current approach allows to use single bunch parameters quite conservative from an accelerator physics point of view, but it moves the difficulties to engineering challenges (vacuum, RF, multi-bunches). The correctness of such a statement can be easily deduced by inspection of the DAΦNE design parameters listed in Table III together with the PEP-II and KEK-B ones.

Table III - DAΦNE, KEK-B and PEP-II design parameters

	DAΦNE	**KEK-B**		**PEP-II**	
		L.E.R.	H.E.R.	L.E.R.	H.E.R.
Energy (GeV)	0.51	3.5	8.0	3.1	9.0
Maximum luminosity [$cm^{-2}s^{-1}$]	$5.3\text{x}10^{32}$	1010^{34}		$3\text{x}10^{33}$	
Trajectory length [m]	97.69	3016.26		2199.32	
Emittance, $\varepsilon_x/\varepsilon_v$ [mm·mrad]	1/0.01	0.018/0.00036		0.064/0.0026	0.048/0.0019
Beta function, $\beta^{*,x}/\beta^{*,y}$ [cm]	450/4.5	33.0/1.0		37.5/1.5	50.0/2.0
Tranverse size, $\sigma^{*,x}/\sigma^{*,y}$ [mm]	2/0.02	0.077/0.0019		0.16/.006	
Beam-beam tune shift, ξ_x/ξ_v	0.04/0.04	0.039/0.052		0.03/0.03	
Crossing angle, θ_x [mrad]	± 12.5	± 11		0	
Betatron tune, ν_x/ν_v	5.09/6.07	45.52/45.08	47.52/43.08	36.57/34.64	24.57/23.64
RF frequency, f_{RF} [MHz]	368.25	508.9		476	
Number of bunches	120	5120		1658	
Minimum bunch separation [cm]	81.4	58.9		126	
Particles/bunch [10^{10}]	8.9	3.3	1.4	5.9	2.7
RF voltage [MV]	0.250	5 ÷ 10	10 ÷ 20	5.5	14.0
Bunch length σ_z [cm]	3.0	0.4		1.0	1.1
Synchr. radiation loss [keV/turn]	9.3	1500*	3500	700*	3570
Damping time, τ_ε/τ_x [ms]	17.8/36.0	23/46		26.4/52.8	19.8/39.6
Single bunch lum. [$cm^{-2}s^{-1}$]	$4.4\text{x}10^{30}$	$1.95\text{x}10^{30}$		$1.8\text{x}10^{30}$	

* Wiggler on.

3.1 Main features and optics.

In DAΦNE electrons and positrons circulate in two separated storage rings (see Fig. 3) laying in the same horizontal plane with horizontal crossing in 2x10 m long interaction regions (IR1 and IR2), at an angle of ± 12.5 mrad.

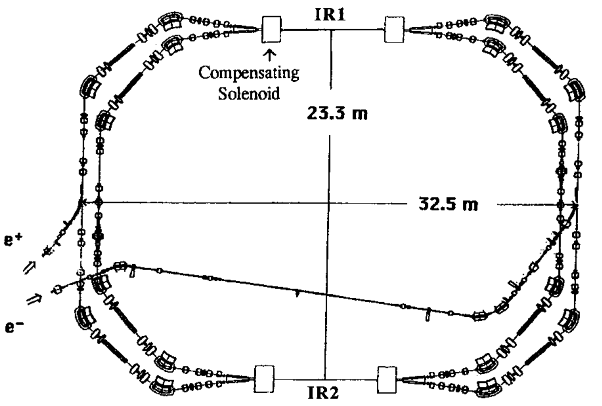

Figure 3 : DAΦNE magnetic layout.

The regular lattice is a modified Chasman-Green type: it consists of 4 achromats, each housing a 2 m long, 1.8 T normal conducting wiggler to increase beam emittance and radiation damping.

The straight sections orthogonal to the IR are used for injection, RF and feedback systems.

Such a magnetic structure, with all the quadrupoles and sextupoles powered independently, has built in enough flexibility to cover a wide range of betatron tunes keeping good dynamic aperture for single beam.

Figure 4 : Compensating s.c. solenoid.

The IRs are equipped with a compensating s.c. solenoid (see Fig. 4) at each end.

Three different low-β optics designs have been developed [6], one without longitudinal field for commissioning purposes, the other two with permanent magnet quadrupoles, for KLOE and FINUDA experiments. The three IR designs are completely equivalent and interchangeable from an optic point of view.

At the IR the experiments have a 500 μm thick Be vacuum pipe.

The KLOE's Be pipe (see Fig. 5) has a very complicate bulb-like shape, with a very thin (50 μm Be) inner shield to prevent RF losses. This shape is needed to avoid K_S regeneration effects. The chamber is now being built by K-TEK.

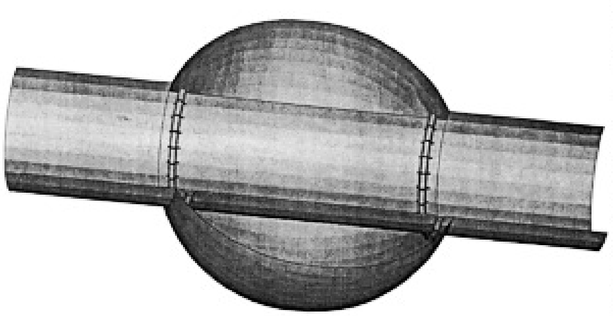

Figure 5 : View of KLOE vacuum chamber.

As far as the two beam operation is concerned (let us remind that DAΦNE can operate with one or two interactions points) a careful study of the betatron tune working point with a beam-beam simulation code (10^6 turns) is in progress.

At present there are two working point candidates with different β-tunes, depending if one assumes 1 or 2 crossing per turn.

The results are summarized in Table IV where L/L_o is the calculated single bunch luminosity reduction with respect to the nominal one.

Table IV : Beam-beam simulation results

Crossing	ν_x	ν_y	L/L_o (%)
1	4.53	6.06	98
2	5.09	6.07	86

3.2 Vacuum system

The DAΦNE vacuum system is dimensioned for an operating pressure of 1 nTorr with 5 A circulating current.

A design of the arc vacuum vessel, similar to ALS, has been adopted, consisting of 2 chambers connected through a narrow slot.

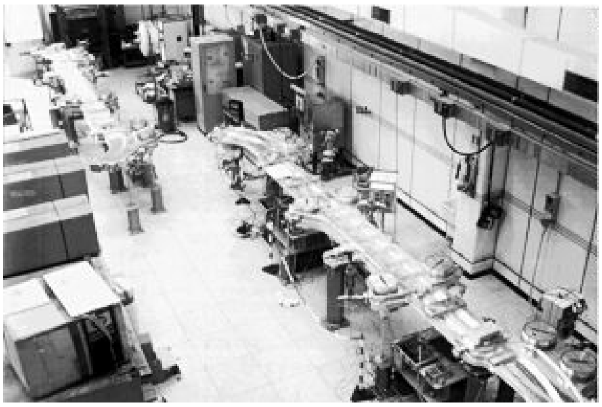

Figure 6 : The first 2 arc vacuum chambers during acceptance tests.

The beam circulates in the first chamber while the synchrotron radiation photons hit a system of water cooled copper absorbers located in the second one (antechamber). In this way more than 95% of the photon flux is collected in the antechamber. The achromat vessel (~10 m long) is made by two halves of Al alloy 5083-H321 plates which, after machining, are welded along the middle plane. The inner surface is mirror finished. The 8 arc chambers (see Fig. 7) are under construction and half of them have been completely tested. The main inconvenient with this long vacuum chamber is the large expansion during bakeout (~35 mm in the longitudinal direction and ~10 mm in the transverse one). To cope with these large displacements a special shielded bellow (see Fig. 7) with no sliding contacts has been designed and a prototype tested both from mechanical and the HOM induced modes points of view.

Figure 7 : DAΦNE bellow prototype (one half).

3.3 RF System

The RF System of each ring consists of a normal conducting single cell cavity fed by a 150 kW/cw klystron.

The RF cavity (see Fig. 8) is equipped with three waveguides to damp the parasitic modes that are dissipated into external 50 Ω loads.

The first cavity has been successfully power tested up to 30 kW, corresponding to ~350 kV, and the HOM behavior (see Fig. 9) found in agreement with expectation.

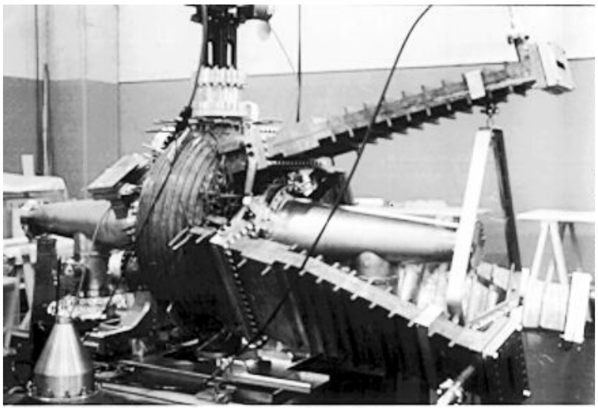

Figure 8 : The DAΦNE Cavity.

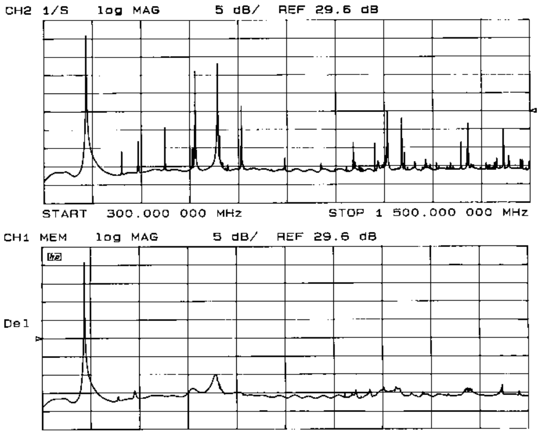

Figure 9 : Undamped (top) and damped (bottom) longitudinal spectra.

3.4 Longitudinal feedback

Even though the HOMs in the RF cavity are heavily damped the probability for a damped HOM to cross a coupled bunch mode frequency is not negligible and, due to the large total current, the growth rate of unstable modes can be stronger than the radiation damping rate even by two orders of magnitude. For this reason the required additional damping is provided by a time domain, bunch to bunch feedback system [7] largely based on Digital Signal Processors (DSP). It has been developed and tested [8] in the framework of a collaboration with SLAC/LBL PEP-II Group on feedback systems for the next generation of factories with intense beams and a large number of bunches.

The digital part is now under construction at SLAC, while the Kicker cavity for DAΦNE has been designed and built at Frascati.

3.5 Status of the collider construction

The procurement phase of all the major components has been completed. The installation inside the DAΦNE Hall has started in January 1996 (see Fig. 10). The completion of the installation phase is scheduled by the end of 1996 followed by the beginning of commissioning.

Figure 10 : DAΦNE installation progress. Status of the DAΦNE Hall in January 96 (left) and May 96 (right).

4 ACKNOWLEDGMENTS

I like to thank the DAΦNE Machine Review Committee (A.Hutton, Chairman, F.Bonaudi, D.Boussard, G.Brianti, J.P. Delahaye, H. Hsieh, A. Wrülich) for their constant advice; E. Iarocci and P. Laurelli, former and present LNF Directors, and the LNF Administration for their continuous support to this Project.

I am also pleased to acknowledge all the personnel of LNF Accelerator Division for their enthusiastic and professional commitment.

Special thanks to Pina Possanza not only for editing this article, but mainly for her outstanding and invaluable secretarial skills which constitute a reference point for everybody working in this Project.

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