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STATUS OF DAΦNE*, THE FRASCATI Φ-FACTORY

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Abstract

An overview of DAΦNE, the Φ-factory under construction at the INFN Frascati National Laboratory and the salient project features are presented.

INTRODUCTION

The DAΦNE Φ-factory complex of the INFN Frascati National Laboratory consists of two 510 MeV storage rings and an injector for topping-up. The project has been approved by the INFN Board of Directors in June 1990 and the engineering design has started in January 1991. The construction budget is 92 GLit (no salary and conventional constructions) and the commissioning of the main rings is scheduled at the end of 1995. The general layout of the complex, which will be housed in the existing LNF buildings, is shown in Fig. 1.

In the storage rings, electrons and positrons circulate in opposite directions, intersecting at two interaction points. 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 nuclear physics experiments, with a smaller size detector.

The short term luminosity goal is 1.3 10^{32} $cm^{-2}s^{-1}$ while the ultimate target is ~10^{33} $cm^{-2}s^{-1}$.

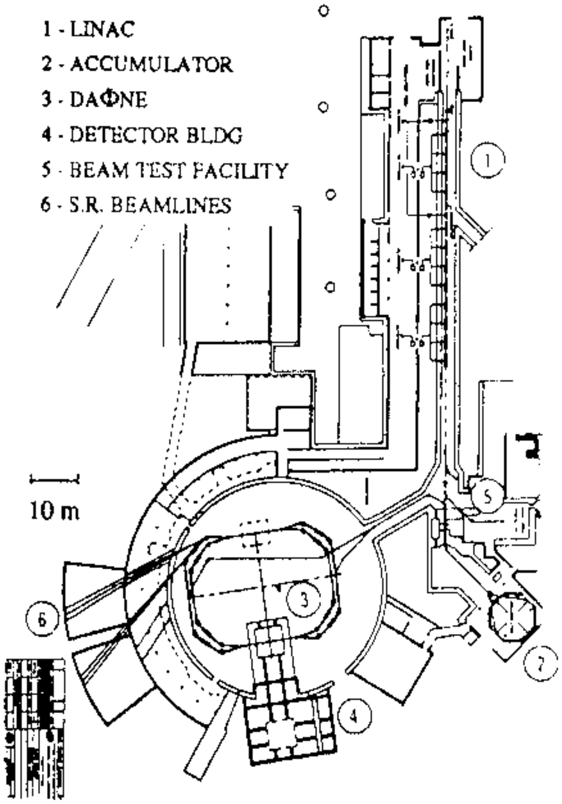

Figure 1. DAΦNE complex layout.

INJECTOR

The injector consists of an e^+/e^- Linac and an Accumulator.

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

A 32.56 meter long positron/electron Accumulator, E_{max} = 550 MeV, is used to damp the transverse and the longitudinal emittance of the linac beams, thus relaxing the injection requirements in the design of the main rings. The mag-

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* Double Annular Φ-factory for Nice Experiments.

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netic structure consists of four quasi-achromatic arc sections and four long straights to accommodate RF, injection and extraction elements. The extraction of the single damped bunch takes place at 1 Hz, filling one main ring bucket at a time. Accumulator and transfer lines design has been completed and the procurement procedures are in progress: the commissioning will be completed within 1995.

Table I. Linac parameter list.

	e^-	e^+
Max energy (MeV)	800	550
Emittance (m-rad)	10^{-6}	10^{-5}
Rel. energy spread	±.005	±.01
Pulse width (ns)	10.	10.
Peak current (mA)	150.	40.

DAΦNE

The main features of DAΦNE are:

- electrons and positrons circulate in two separate storage rings and collide at a horizontal half-angle $\theta_x = 10 \div 15$ 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 2 meters-1.8 Tesla normal conducting wiggler magnet inside the achromat. 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 allows the installation of 4 RF cavities for crab-crossing.

The lattice design is completed and the single ring parameter list is given in Table II.

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)		.64
Horizontal β-tune		5.15
Vertical β-tune		5.13
Natural chromaticities:	Horizontal	-7.2
	Vertical	-18.8
Momentum compaction		.016
Energy loss/turn (KeV)		9.3
Damping times (msec):	τ_s	17.8
	τ_x	36.0
	τ_y	35.7
Natural emittance (m-rad)		10^{-6}
Natural relative rms energy spread		$3.97\ 10^{-4}$
RF frequency (MHz)		368.25
RF harmonic number		120
Current/bunch (mA)		43.7
V_{RF} (KV) @ Z/n = 2 Ω		254.
Natural bunch length σ_z (cm)		.81
Turbulent bunch length σ_z (cm)		3.0

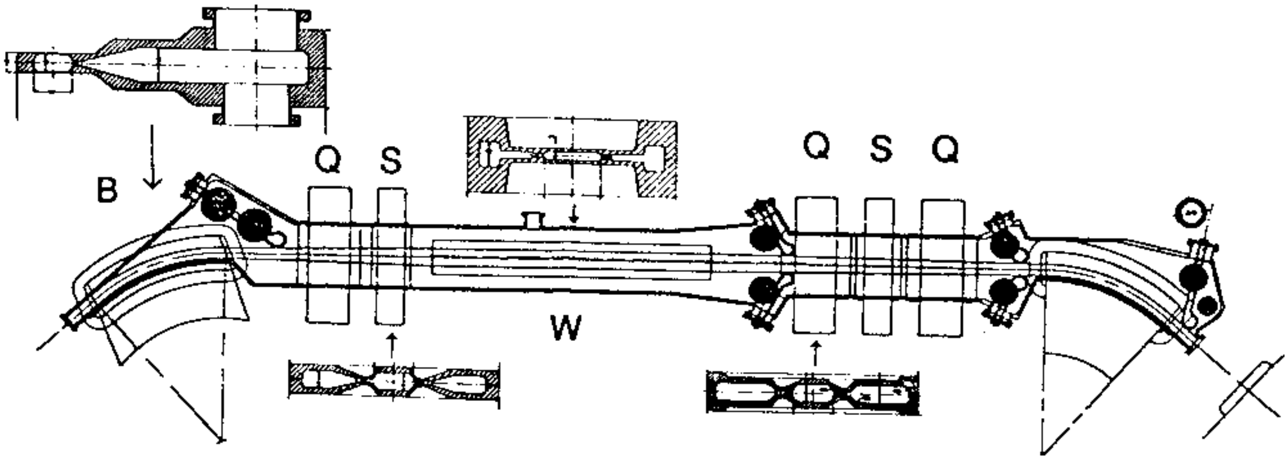

Figure 2. Main rings arc vacuum chamber and cross sections.

LUMINOSITY DESIGN STRATEGY

The main features of the design in order to achieve high luminosity are:
- many bunches
- high currents
- flat beams
- high emittance.

Let us remind that at the space charge limit the luminosity, in the hypothesis of equal tune shift in both planes, can be written as:

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

where: γ = electron energy in units of its rest mass, r_e = classical electron radius, h = number of bunches, f_o = revolution frequency, ξ = linear tune shift, ε = beam emittance, κ = vert./horiz. emittance ratio, $\beta_y{}^*$ = vertical β-function at the interaction point, L_o = single bunch luminosity.

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 outside the interaction point. Therefore the two beams circulate in two separate rings crossing at a horizontal angle 2 θ_x in two interaction points.

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

Table III. Luminosity parameters @ 510 MeV.

L_o ($cm^{-2}s^{-1}$)	4.36 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 ≥ $7\sigma_x$ at the parasitic crossings. The challenge with 120 bunches is the very high current that dictates severe requirements on vacuum, RF and feedback systems.

The project effort, at this moment, is concentrated to guarantee the accumulation of at least 30 bunches for a short term luminosity of 1.3 10^{32} $cm^{-2}s^{-1}$.

VACUUM SYSTEM

The main ring vacuum system is dimensioned for an operating pressure of 10^{-9} Torr with 5 Amp of circulating current. The arc vacuum chamber, made of Al 6063, is shown in Fig. 2. 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 $\eta_e \approx 3 \ 10^{-6}$ (molec. $photon^{-1}$), as measured at NSLS-BNL, in an experimental set-up similar to the DAΦNE vacuum chamber. In addition to sputter ion pumps, which are 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.

RF CAVITY

The RF cavity has been designed with the aim to reduce significantly the impedance of the longitudinal high order modes (HOM). The principal features of the resonator are large and tapered beam tubes, which allow the HOM's to propagate out of the cavity main body, and the gap nose cones, which greatly contribute to lower the TM011 (r/Q) value. An elliptical cavity profile has been chosen to avoid multipacting. This cavity is intended to operate as a day-one resonator.

An intense R&D program is in progress to couple off and further damp the HOM impedances by applying to the cavity walls a number of wave guides loaded with dissipative materials. Previous measurements, carried out on a wave guide loaded pill-box were encouraging. However the alternative standard solution, based upon damping antennas, cannot be excluded.

LONGITUDINAL FEEDBACK SYSTEM

The system is a bunch by bunch, time-domain feedback capable of a damping time of ~ 0.1 ms.

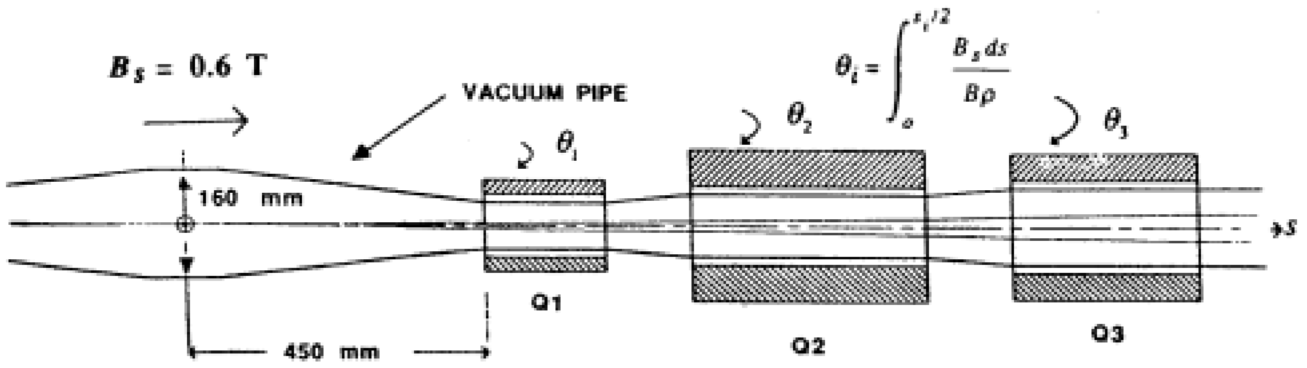

Figure 3. KLOE interaction region layout.

It is sized for 30 bunches and is upgradable to a full complement of 120 bunches, thanks to the modular architecture [3]. It is largely based on DSP (Digital Signal Processors). This 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 [4] is being carried out. In order to damp injection transients of 100 ps with 30 bunches at the full design current, it is necessary a wide bandwidth power amplifier of ~ 500 W.

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 they are confined in a cone of 9° half aperture, leaving a free solid angle for the apparatus of ~ 99%. The layout of the interaction region is shown in Fig. 3.

Due to the relatively high magnetic field (.6 T) and the large dimensions (5 m) of the KLOE detector, a new approach has been worked out to compensate the solenoidal field. This scheme [5] requires two 1 m - 1.5 T compensating solenoids plus a different rotation angle of the low-β quadrupoles, proportional to the field integral at their location. Since the quadrupoles are fully immersed in the solenoidal field, an ideal compensation scheme would require to continuously rotate the quadrupoles in order to follow 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 small residual coupling.

The main problems for the interaction region, which are not yet completely solved, are:

- mechanical support of the vacuum chamber and low-β triplet;
- trapped RF losses and relative cooling;
- pumping system.

ACKNOWLEDGMENTS

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