# DAΦNE, The Frascati Φ-factory

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*Abstract*

The $e^+e^-$ Φ-factory DAΦNE is presently under construction in Frascati. It is designed as a double ring system with a maximum number of 120 bunches/beam. The short term luminosity goal is L=1.3 $10^{32}$ $cm^{-2}$ $sec^{-1}$ with 30 bunches. The strategy, adopted to achieve such a luminosity, is common to many factory designs : high current, many bunches and separate rings. The technical problems are complicated by the relatively low energy of the beams. A general overview of the project and the most significant technical solutions adopted for DAΦNE are presented.

## I. INTRODUCTION

The construction of DAΦNE in the Frascati National Laboratories (LNF), has been approved and fully funded by the National Institute of Nuclear Physics (INFN) in June 1990, while the engineering design phase has started in January 1991.

The layout of the new accelerator complex (housed in the buildings where ADONE and its injector Linac have been running until the last April) is shown in Fig. 1.

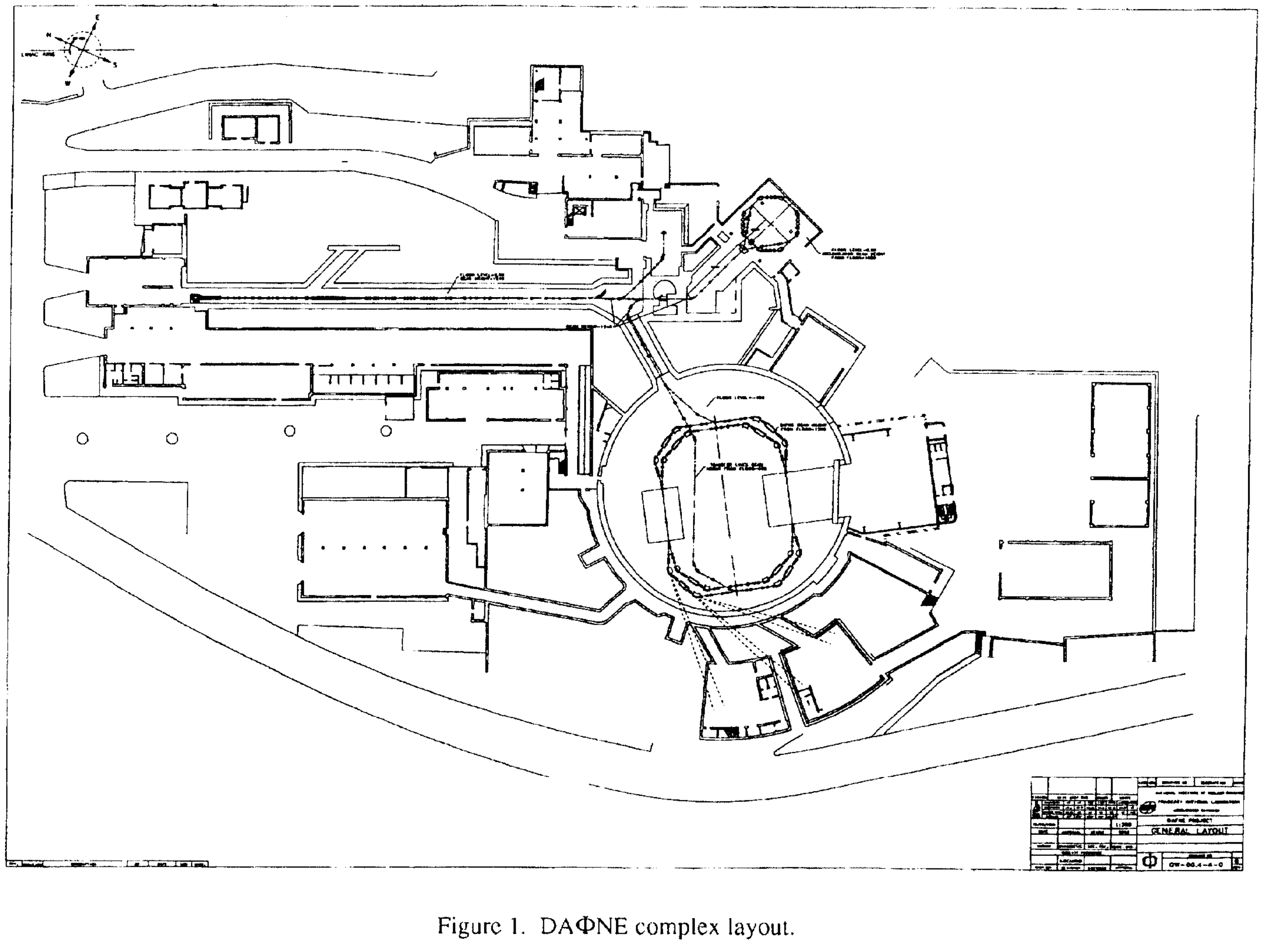


Figure 1. DAΦNE complex layout.

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It consists of an $e^+e^-$ Linac, a damping ring used for both beams, rather long transfer lines to cope with the necessity of using existing buildings, and a twin rings collider with two interaction points. All the accelerators are designed for the same working energy of 510 MeV.

The first interaction region is dedicated to a large detector KLOE [1]. This detector has been approved and funded by INFN and it is in the construction phase. The major physics aim of KLOE is the observation of direct CP-violation in $K_L$ decays, i.e. the measurements of $\varepsilon'/\varepsilon$ with accuracy in the $10^{-4}$ range. In order to achieve such a result a luminosity L=5 $10^{32}$ $cm^{-2}s^{-1}$ integrated over an effective year of $10^7$ seconds is required.

The second interaction region is assigned to a smaller size detector, FINUDA [2], for hypernuclear physics.

The installation of three beam lines for soft X-rays [3] is planned.

The start of the commissioning, with 30 bunches, is scheduled for the beginning of 1996 with a short term luminosity goal of 1.3 $10^{32}$ $cm^{-2}$ $s^{-1}$. The target luminosity L ~ 5 $10^{32}$ $cm^{-2}$ $s^{-1}$ should be achieved in a period of ~ 2-3 years of operation by pushing up the current and, at same time, by fine-tuning all the machine parameters.

## II. INJECTOR COMPLEX

The injector complex of DAΦNE consists of an $e^+e^-$ Linac, a damping ring and transfer lines.

The Linac [4] is an S-band structure with a SLED type pulse compression system capable of accelerating electrons up to 800 MeV at 50 pps. In the positron mode of operation, a first section is used to accelerate electrons to 250 MeV.

The electron beam is focused by a quadrupole triplet onto a high Z converter, positron are collected by 5 T tapered flux concentrator and accelerated to the nominal operating energy of 510 MeV. The design positron current is larger than 30 mA in a 10 ns pulse within ±1% energy spread and $10^{-5}$ m·rad emittance. The Linac construction has been committed to industry and it is in progress in U.S. Installation at LNF will begin in early 94 and the Linac is expected to be operational for the end of the same year.

The design of the transfer lines has been completed, and the contract awarded to an Italian firm. Installation will begin in the first months of 1995.

The damping ring has been adopted to avoid injection saturation due to the large current to be stored in the collider, to improve the longitudinal acceptance for the Linac beam, and to deliver low emittance and low energy spread beams to the main rings. With this arrangement, injection requirements to the main ring lattice are strongly reduced. A compact 4 period structure, with a total length 1/3 of the main rings, and vanishing dispersion at the injection/extraction septa, allows injection of both electrons and positrons in the single bunch mode at 50 Hz repetition rate. Extraction will be performed at the optimum current level for injection into the main rings, typically at ~1 Hz. Detailed specifications have been sent out for bid, and the tenders from potential vendors are under evaluation. The contract for complete construction and installation will be awarded next June. Commissioning will be performed in the second half of 1995.

## III. MAIN RINGS

The magnetic layout of DAΦNE is shown in Fig. 2. Its

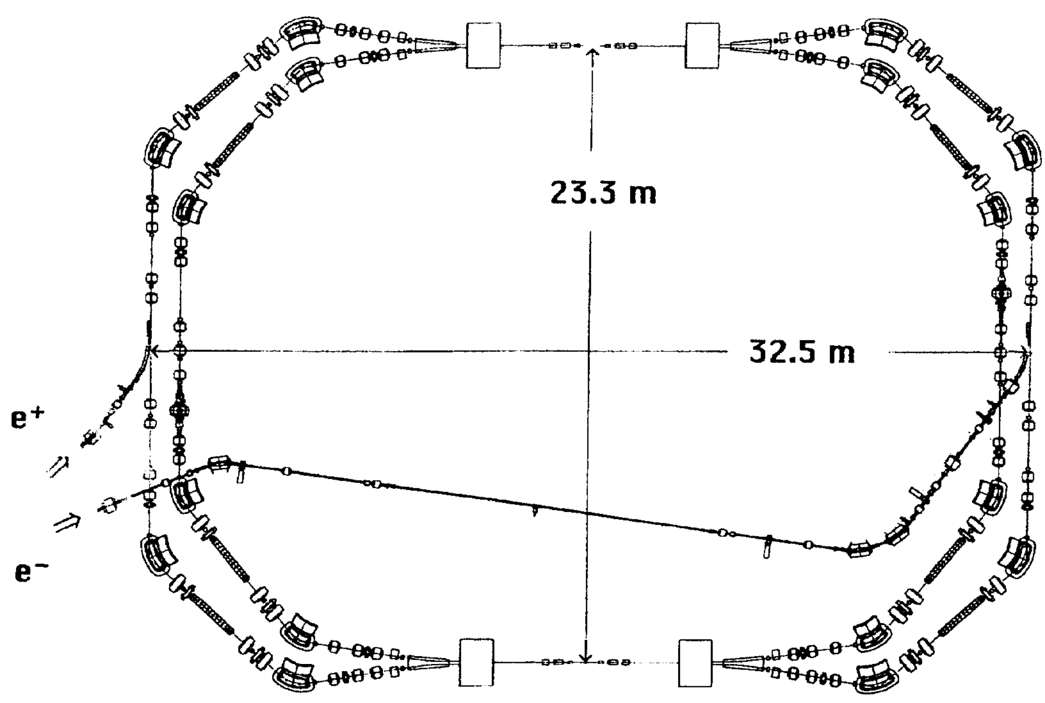


Figure 2. DAΦNE magnetic layout.

main features, in order to achieve the design luminosity, are based on well proven accelerator physics: the large luminosity improvement is reached with the same interaction conditions of already operating colliders, by increasing the number of colliding bunches up to the RF harmonic of the revolution frequency and by reducing the number of interaction points with the adoption of a double ring scheme.

The large stored current required by this scheme is the major technical challenge of DAΦNE: the vacuum system must hold a heavy gas load, due to the intense synchrotron radiation, and the beam stability can be destroyed by multibunch instabilities, so that careful design of the RF cavity and vacuum chamber are necessary to avoid high order oscillation modes, and, in any case a powerful feedback system is required. The main ring design is based on conventional technology and well established physics parameters (see Table 1).

Table 1. DAΦNE Parameter List

| | | |
|---|---|---|
| Beam Energy (MeV) | | 2 × 510 |
| Luminosity ($10^{32}$ cm$^{-2}$ sec$^{-1}$) | | 1.35 (→ 5.40) |
| Bunches per ring per species | | 30 (→ 120) |
| Particles/bunch | | 8.9 $10^{10}$ |
| Luminosity lifetime (hr's) | | 2 ÷ 3 |
| Single ring circumference | | 97.69 m |
| Filling time (min.) | | < 2 (topping up) |
| Time between collisions (ns) | | 10.9 (→ 2.7) |
| Crossing half-angle (mrad) | | 10 ÷ 15 |
| Interaction Point (IP) | | 1 or 2 |
| Interaction Region Length | | 2 × 10 m |
| Free space @ IP | | ± 46 cm |
| β-function @ IP : | H | 4.5 m |
| | V | 4.5 cm |
| Beam r.m.s. dimension @ IP : | H | 2.1 mm |
| | V | 21 μm |
| Beam-beam tune shift per crossing : | H | .04 |
| | V | .04 |
| β-tune : | H | 5.18 |
| | V | 6.15 |
| Natural Chromaticity : | H | - 9.2 |
| | V | - 20.6 |
| Momentum compaction | | .005 |
| Dipoles per ring | | 8 |
| Wigglers per ring | | 4 |
| Quadrupoles per ring | | 51 |
| Sextupoles per ring | | 16 |
| Peak magnetic field (T) : | Dipoles | 1.2 |
| | Wigglers | 1.8 |
| Energy loss/turn (keV) | | 9.3 |
| Relative natural r.m.s. energy spread | | 4 $10^{-4}$ |
| Natural emittance (mm×mrad) | | 1.0 |
| RF frequency (MHz) | | 368.25 |
| RF harmonic number | | 120 |
| Peak RF voltage (kV) | | 250 |
| Synchrotron frequency (kHz) | | 21.4 |
| Z/n (Ω) | | 1.0 |
| r.m.s. bunch length (cm) | | 3.0 |
| Damping time (msec) : | $\tau_s$ | 17.8 |
| | $\tau_x$ | 36.0 |
| | $\tau_y$ | 35.7 |

Flat beams (κ=.01) are foreseen at the IP, so that only one betatron function must be in the range of few centimeters, thus avoiding large contributions to the chromaticity and strong non linear correction fields.

The electron and positron beams are stored in two separated rings laying in the same horizontal plane with horizontal crossing in two interaction regions at an angle of ± 12.5 mrad. The lattice of each ring consists of 4 achromats, each housing a 2 m long, 1.8 T normal conducting wiggler to increase and finely tune the beam emittance, and to increase radiation damping, which compensates for the low operating energy, as suggested by beam-beam interaction models and simulations. The straight sections at 90° with respect to the interaction regions are used for injection, RF and feedbacks.

The main rings optics (frozen) shows satisfactory dynamic aperture (see Fig. 3).

The engineering design has been completed for all the major components and the procurement phase is in progress. The installation of the main rings is scheduled for the end of 1995.

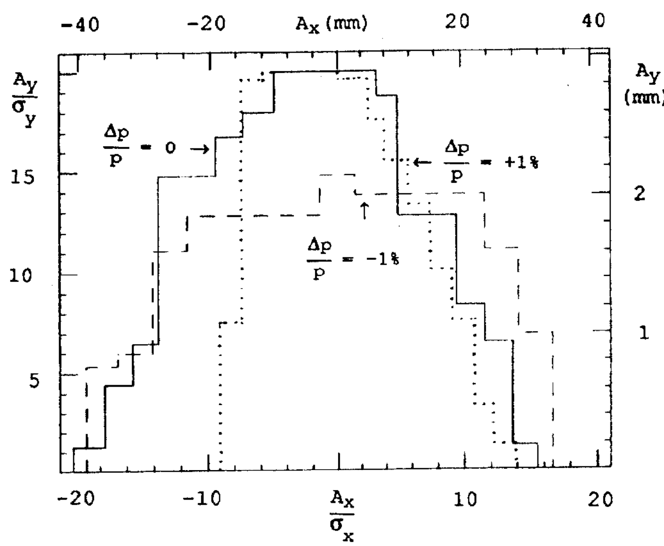


Figure 3. Dynamic Aperture @ IP with 8 families of sextupoles

## IV. INTERACTION REGIONS

Careful study has been dedicated to the interaction regions (IR), where a solenoidal field of 0.6 T is required by KLOE and 1.5 T by FINUDA. A new compensation scheme, including compensating superconducting solenoids and rotation of the low-b permanent magnet quadrupoles has been developed to accurately decouple the betatron normal modes at the IP.

Three different IR's have been designed [5], one without longitudinal fields for commissioning purposes, the others to accommodate KLOE and FINUDA experiments, under the conditions of complete transparency with respect to the rest of the ring (i.e. with the same transfer matrix). In Fig. 4 a detail of the KLOE IR is shown.

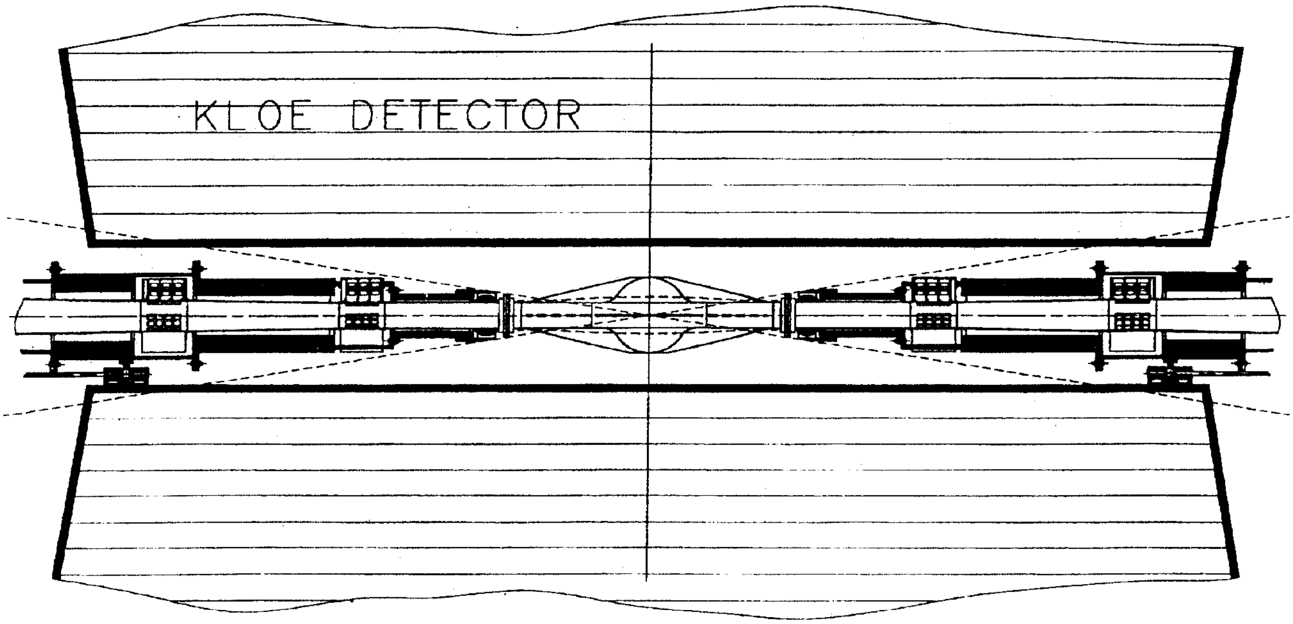


Figure 4. KLOE Interaction Region.

## V. VACUUM SYSTEM

The DAΦNE vacuum system[6] is dimensioned to keep the average operating pressure ~1 nTorr with 5 A of circulating current.

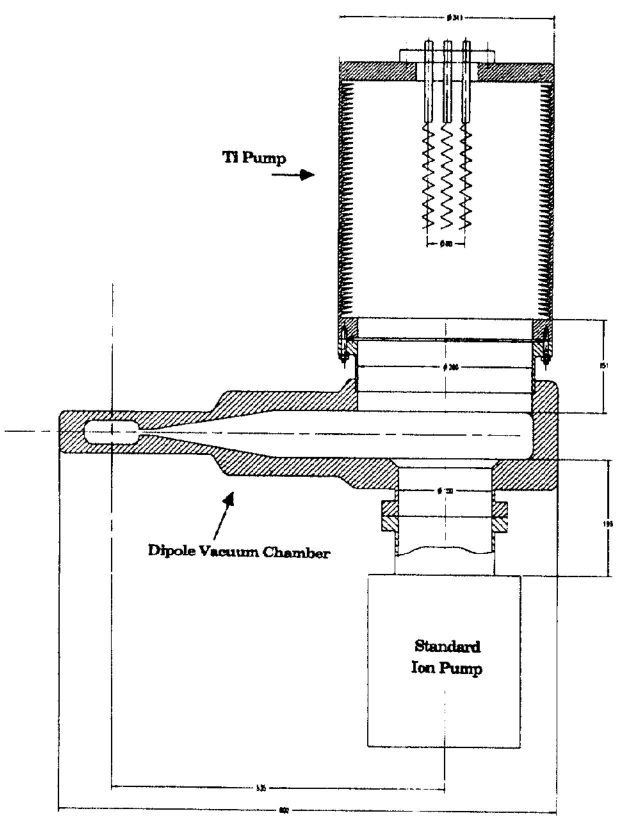


Figure 5. Dipole vacuum chamber cross section.

A design, similar to ALS, has been adopted for the vacuum vessel, consisting of two chambers connected through a narrow slot. The beam is stored in the first one, while the synchrotron radiation photons hit the wall of the second (the antechamber), after traveling through the slot. The chamber has been designed in such a way that ≈ 95% of the photon flux is concentrated on a limited number of copper absorbers in the antechamber. More than 90% of the gas load is removed by titanium sublimation pumps, while sputter ion pumps are used to get rid of those gases which cannot be pumped by the sublimators. Figure 5 shows a cross section of the vacuum chamber in the bending magnet. Measurements performed on a full scale prototype indicate that, at full current operation, a new layer of Ti must be deposited on the wall of the sublimator vessel once a week.

## VI. RF CAVITY

The DAΦNE RF cavity [7] has been designed with the aim to reduce significantly the shunt impedance of the longitudinal high order modes (HOM) which are responsible of multibunch instabilities. The main features of the resonator are large and tapered beam tubes, which allow the HOM's to propagate out of the cavity, and an elliptical profile, to avoid multipacting.

An intense R&D program has been carried out to couple off and damp the HOM impedance by applying to the cavity walls three ferrite-loaded waveguides (WG) at 120°. In alternative to the ferrite loads under vacuum, we are studying a broadband transition from WG to coaxial. This design would allow to dissipate the HOM power on external 50 Ω loads, with enormous advantages from all points of view.

The measurements, performed on a cold prototype, have been very encouraging, so we have frozen the cavity shape.

Figure 6 shows the engineering design. In addition to the rectangular waveguide ports, there is provision for round ones, which will be used for the main coupler, tuner, vacuum pumps and diagnostics. Conventional loops or antennas tuned to most harmful HOM's can also be installed.

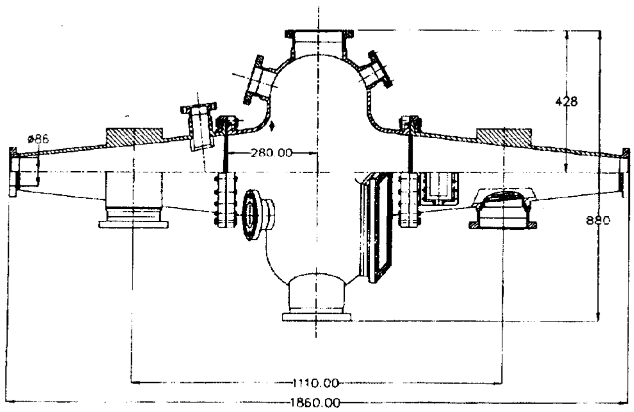


Figure 6. RF cavity engineering design.

The final prototype, electro-formed copper, will be available next fall. The only open problem is the choice between ferrites and broadband transition: at this moment the solution with transitions is preferred, and a major effort is being devoted to carry out the complete engineering design.

## VII. LONGITUDINAL FEEDBACK SYSTEM

We recognize that longitudinal multibunch instabilities can put a severe limit on the current intensity and luminosity achievable in DAΦNE.

Even if the HOM's in the accelerating cavities are heavily damped, the probability for a damped HOM to cross a coupled bunch mode frequency is large and, because of the relatively large current, the rise-time of the unstable modes can be faster than the natural damping time. Therefore, a powerful active feedback system capable of damping all the coupled modes and the injection transients [8] is necessary.

In the framework of a collaboration on feedback systems for the next generation of factories with intense beams and a large number of bunches with the SLAC/LBL B-Factory group, a bunch by bunch, time-domain feedback largely based on Digital Signal Processors (DSP) is under development. In fact, the design specifications are such to fulfill the ultimate performance specifications of ALS, PEP-II and DAΦNE [9, 10]. The first complete DSP feedback system is being realized for the ALS (2.2 ns bunch spacing).

Each bunch is treated as a separate oscillator: a bank of DSP filters operating in parallel compute the correction kick signals to be applied to each bunch by means of a power amplifier and a kicker, according to the measured phase errors, which are uniquely detected and digitized.

The main advantage of such a system is that the same DSP can process several bunches, thus reducing the hardware complexity. Moreover, it is possible to take advantage of the relatively low synchrotron frequency (~ 1/140 of the revolution frequency) and reduce substantially the sampling rate at which the synchrotron phase is detected. This results in less complex filters and reduces the overall data rate and computational load in the DSP section [10].

A proof-of-principle experiment with a down-sampled DSP feedback has been carried out at SPEAR with a single bunch, to measure the system performance and to get some operational experience [11]. A small scale (few bunches), full-functional prototype board to be used for tests at ALS is being developed at SLAC [12].

According to simulations, ~ 500 W of large band-width power are enough to damp out a 100 ps offset of the injected bunch with the other 29 at the full design current [8].

## VIII. ACKNOWLEDGMENTS


The DAΦNE machine project periodically undergoes a review by an international Committee of experts. I like to thank warmly A. Hutton (Chairman), F. Bonaudi, D. Boussard, J.P. Delahaye, A. Wrülich for their collaboration and advice throughout all the steps of this ambitious project.

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