DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

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DAΦNE PROJECT REVIEW

Frascati, July 7-8, 1992

Reviewers

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The Committee heard presentations for a day and a half and was again impressed with the progress that has been made since the last Review. The Committee was particularly pleased to see that many of the questions raised in the last Review have already been addressed, and in many cases, resolved. We were also pleased to see that the Project Milestones that were due in the last six months (freezing of the optics of the Transport line and the Accumulator Ring, decommissioning of the Accumulator Building) have all been met on schedule.

Project Overview

The Committee received a general overview of the status of the project. The Committee had requested that the Project Leader should provide a formal set of Project Milestones (one, or at most two, per year) which could be used to ensure that the project proceeds smoothly. This was provided and the Committee will use these milestones to help track progress as the Project proceeds (see attached list).

The experimental program is now more clearly defined. Two synchrotron light beam lines have been added and it has been decided that the second Interaction Region will only have a small detector. A decision on this detector is expected by the end of this year. This will help the DAΦNE Machine design group to finalize the layout of the Interaction Regions.

Concerning the general layout of the facility, the guiding principle of minimizing the modifications to the existing buildings has been maintained. The work required on the DAFNE hall has been defined, resulting in a very satisfactory solution for the experimental pits and for the independent support for the main, heavy (1000 ton) experiment. The Committee was pleased to see that the existing machine foundations will remain intact. The authorization to bid for the conventional construction is due very soon (July 17, 1992).

The Linac has already had a design review with the supplier (Titan Beta) and procurement of the klystrons has begun. There will be a detailed Design Review in October 1992. This important part of the Project appears to be proceeding well.

The DAΦNE lattice study has continued with single ring problems up to now, specifically the strong optical effects of the experimental solenoid, and the design of the Interaction Region has not progressed. The Committee feels strongly that the detailed design of the Interaction Region should be presented at the next Review.

The design of the feedback system is continuing in collaboration with SLAC and LBL and appears to be making steady progress.

Control System

The Committee had asked for a review of the Control System by a group of control experts. This review was held and endorsed the DAΦNE proposal based on the Macintosh LC. The Committee was informed of the decision of the Project Leader to accept this expert recommendation.

The Committee had expressed doubts about the development effort required to put the Macintosh LC in a VME crate. The Committee was pleased that a prototype board has been developed since the last Review and successfully tested and that a commercial prototype is under construction.

The Committee is still worried about the lack of a complete analysis of the system needs and recommends that a small group of experts from the accelerator physics, operation and control groups study in detail all of the activities that will be needed to commission and operate DAΦNE The work on the operational procedure carried out in defining the timing system is a good example of this. The Committee feels that a complete budget of the network traffic and the software effort needed should be available for the next Review.

Injector complex

The Committee was very pleased to see the tremendous progress accomplished since the last Review on the design of the transfer lines: the total number and maximum gradients of the quadrupoles and the electron and positron beam envelopes have been significantly reduced with a better standardization of the magnetic elements. The acceptances of all transfer lines now fit the maximum transverse and longitudinal emittances expected from the accumulator and the linac, even with the more demanding positron beam parameters. In order to give some margin, especially for the beam momentum spread, the Committee recommends to study the possibility of local horizontal enlargement of the vacuum chamber at the few places presently limiting the acceptance.

The Committee noted the decision to limit the capability of the transfer lines to a maximum energy of 510 MeV plus some margin which corresponds to the maximum energy available for the positron beam. This implies that energy ramping would be required in the main ring if an operation at higher energy is ever required.

The beam diagnostics foreseen seem rather complete. Nevertheless, the addition of transparent profile monitors based on thin grids (harp systems) is recommended in the part of the lines working in both directions. It would provide non destructive monitors for the beam and allow tuning while monitoring the beam in both directions.

The use of the spectrometer line will be extremely useful to continuously monitor the beam energy at the end of the linac. It could be used in a closed loop with the RF linac phasing to stabilize possible drift. This option should be studied at a later date.

Finally the design of the transfer lines is felt by the Committee to be sufficiently well advanced that the specification of the elements can be prepared for tendering.

The Accumulator design is also very close to its final version. The new working point is welcomed as it provides better beam stability. At the last Review, the Committee recommended a reduction in the number of kickers in the ring to reduce the complexity and the ring impedance. The new arrangement that has been found is an improvement in all respects.

Nevertheless, the overall layout of the Accumulator should be reviewed to reduce as much as possible the changes of vacuum chamber dimensions and provide room for more efficient kicker tank tapers, as the kickers have been shown to be the major contribution to the impedance budget.

The Committee also recommends avoiding two different kinds of beam position monitors for the observation of injection trajectories and the closed orbit as is presently foreseen. The Committee would prefer a single system, optimized for the closed orbit, but which can observe the injected beam, albeit with a lower resolution.

Main Ring Optics

The Committee notes with satisfaction the improvements that have been made to the linear optics since the last Review; namely a new working point above the integer for better beam stability, a higher and adjustable crossing angle for larger beam separation at the parasitic crossing points, and a triplet close to the interaction point compatible with operation of the main rings with and without solenoidal field in the detector.

The Committee is pleased to see that the study of the perturbations produced by reasonable errors of the magnetic fields and the adaptation of the lattice to the solenoidal field of the detectors has started. The Committee is particularly concerned by the significant reduction of the dynamic acceptance with random errors and the change of working point induced by the detector solenoid and recommends reviewing the basic lattice with top priority.

It is necessary to ensure that enough flexibility is available to fulfill the numerous constraints, including the tuning of the working points over a large range, and the relative phase between sextupoles. The reason for the deterioration of the dynamic acceptance for negative off-momentum particles in the absence of errors should be identified first to develop a criteria for correction.

Beam-beam Interaction

The Committee had brought up the problems associated with the parasitic crossings at the last Review and were pleased to see that the Project team has already made considerable progress in studying the effects.

The simulations indicate that the effects are manageable, even with 120 bunches, if the crossing angle can be increased to ±15 mrad. The Committee endorses the decision to specify the hardware to provide the flexibility needed to change the crossing angle over a range of ±10÷15 mrad with a nominal value of ±12.5 mrad.

The theoretical studies of the maximum beam-beam limits are interesting and should be pursued. The Committee agrees with the Project Leader that the engineering design of the Project should be based on a nominal value of the tune shift of $\Delta Q = .04$.

In general, the Committee encourages the Project Team to maximize the flexibility of the machine parameters to enable the luminosity to be optimized during operation.

Vacuum System (Main Ring, Experimental insertion)

The general study of the vacuum system has progressed, and the Committee was pleased to see that some of the design assumptions have in the meantime been verified by measurements.

The subject of outgassing rates (which was raised at the previous Review) has now been studied by means of experiments made at Brookhaven on the National Synchrotron Light Source in an aluminum chamber with a copper absorber. These measurements confirm that the design value (desorption coefficient = 2 to 3 10^{-6} molecules per photon) can be reached. The Committee was impressed by the care taken in designing and carrying out these experiments. It is now necessary to evaluate the expected clean-up rate using a realistic model of the vacuum chamber geometry.

The mechanical design of the vacuum chamber of the main ring arcs (the upgraded version) now gives a conductance-limited pumping speed of 50.000 l s^{-1} using 18 ports. The thickness of the chamber walls and the mechanical details have still to be finalized by proper calculation. It is now necessary to carefully evaluate the pumping requirements (speed and capacity) and the resulting pressure profile.

The position of the copper absorbers, as now presented, appears straightforward and efficient. However, the concept of cooling them in-directly, via thermal contact with the aluminum chamber does not look appealing to the Committee. It is felt that too many points remain to be verified before such a choice could be adopted (in particular, the compatibility of materials under conditions of high vacuum, differential expansion, trapped gases, fatigue, etc.). More conventional, water cooled absorbers independent from the mechanical structure are recommended.

The choice of the main vacuum pumps is still open and no convincing candidate was proposed to us; all solutions considered were said to have serious drawbacks or uncertainties (NEGs, sublimators, cryopumps). This point should receive urgent consideration after the system requirements have been defined.

The Committee feels that a full scale prototype of a part of the main arc vacuum chamber should be built, using the final material proposed and incorporating all required accessories (absorbers, bake-out jackets, pumps, gauges, etc.); this appears necessary in order to meet the overall time schedule.

The Committee was happy to see that the subject of Ion Clearing has been studied analytically and by simulation; the study indicates that clearing electrodes will be needed, operating at rather modest voltages, to be used in connection with gaps in bunch filling. This study should continue with tracking of the ions.

The experimental chamber design has a number of particular requirements:

- large diameter at the crossing point (10 cm are asked by the KLOE collaboration, in order to minimize $K_L \rightarrow K_S$ regeneration);
- presence of permanent magnet triplets upstream and downstream, to be rotated relative to one another and surrounded by a photon calorimeter;
- impossibility to install conventional sputter ion pumps in the straight between the splitter magnets;
- expected slow degassing of the central part, where the photon bombardment will be low.

The development of special ion pumps with rotational symmetry was presented (a model was shown): these could fit inside the compensating solenoids and between the quadrupoles of each triplet. The solenoidal magnetic field would drive these pumps: if ever the detector needed to operate with the field off (e.g. for geometrical checks), the experimenters could run at lower luminosity.

The Committee proposes that a complete review of the Vacuum System be held at the time of the next Machine Advisory Committee Review, inviting two or three vacuum experts to participate.

RF System

The design of the RF system of the Accumulator seems to be completed, with the exception of some details of the cavity design, for instance the tuner (hopefully without sliding contacts) and HOM dampers. The Committee is pleased to see that the contract for the RF power amplifier has already been awarded.

Progress in the design of the main ring RF system has been substantial. In particular, the detailed theoretical studies of RF feedback performance show very encouraging results. The Committee strongly recommends an RF feedback experiment with an existing 500 MHz klystron. This will allow a reasonable assessment of the proposed technique, in particular the feasibility of a compensated RF feedback using the notch filter technique. One should also make sure that the klystron specifications (phase stability versus high voltage and output power) are discussed in due time with the klystron manufacturer.

The prototype cavity of the main ring will be an extremely useful tool to evaluate the performance of the RF system. A vigorous effort should be put into the measurement of R/Q's of the various modes, as well as their damping factors with different HOM devices. At present, these damping factors are only known from pill box measurements.

In view of the dead line for ordering the main ring cavities (Spring 1993), the Committee strongly recommends tests in parallel on several prototypes with different cavity shapes (for instance a cavity without nose cones or a cavity copied from another machine). This would make a comparison possible on the basis of achievable HOM resistances for various cavity shapes.

The Committee believes that the day-one cavity should not be too different from the top performance design, and therefore supports the idea that R&D on cavities and HOM damping should be made as early as possible.

The choice of HOM technology (inside or outside vacuum) depends critically on the powers involved. This is difficult to evaluate without a precise knowledge of the cavity parameters that only the model measurements can provide. This points again in the same direction, i.e. full use of the model measurements, possibly on various cavity shapes. If dampers in vacuum turn out to be acceptable, it seems desirable to equip the cavity with a dedicated vacuum pump.

The Committee is worried about the short time remaining before it will be necessary to place the order for the cavity. The RF Group is encouraged to make every effort to obtain sufficient data to be able to freeze the cavity shape by the next Review. Accordingly, the Committee would like the RF system to present this final design at the next Review.

Impedance Budget

The Committee was impressed by the quality of the work made in evaluating in detail the impedance budget of the accumulator and the main ring. The elimination of the fifth kicker in the Accumulator and the inclusion of tapers, where possible in both system has greatly improved the situation. We expect the next step to be a fruitful collaboration with hardware designers (in particular for the injection and longitudinal feedback kickers in order to further reduce the most harmful contributions. Despite the nice agreement between computer evaluations and the more refined broad band model, one should not be overconfident in the final numbers produced.

It is recommended that efforts in this area be continued. In both the Accumulator and Main Rings, the longitudinal impedance continues to be dominated by kickers. In the Accumulator, elimination of the transitions between kickers K1 and K2 should be considered. Also the use of elliptical tanks for the kickers, which decrease the variation of the vertical dimension of the vacuum chamber, is recommended. Additionally, the contribution due to the RF cavity should be isolated so as to expose the effects of the surrounding kickers, K3 and K4.

In the Main Rings, the stripline kickers are superior to the previous ferrite kickers. As the kicker tanks have the same cross-section as the connecting vacuum chamber, the deviation of both the longitudinal and transverse impedance from resistive-wall values must be due to the electrodes. Two of the four "clover leaves" should be eliminated and the cross-sections of the supports and interconnect loops should be minimized. This should reduce the longitudinal impedance.

The transverse impedance of the Accumulator is distributed uniformly throughout the machine. It is interesting that the RF straight contributes less than the other straight section containing kickers. In the Main Rings, the transverse impedance is dominated by the small vertical height of the wiggler chambers and the electrodes of the kickers.

The current capability of DAΦNE is likely to be limited by impedance associated effects. A continued effort in the area of impedance reduction is recommended. Once the above components have been reconsidered, the contribution of the injection chambers may become more significant. The impedance of the Accumulator injection chambers may be improved by, for example, continuing the elliptical pipe through the cylindrical tank having removed only just enough material from the elliptical pipe to allow the incoming beam to enter.

In general, every effort should be made to reduce the longitudinal and transverse impedances; the engineering effort that this will require will undoubtedly pay off in the long run.

Beam Stability

Thanks to the reduction by a factor two of the longitudinal impedance of the Accumulator and the independent estimation of the transverse impedance in both rings, the thresholds for single beam transverse mode coupling instabilities are now safely above the maximum beam intensities foreseen in operation.

However, the rise-time of the coupled-bunch resistive wall instability driven by the transverse impedance is still much shorter than the natural damping time due to synchrotron radiation. A transverse feedback system seems just feasible in the case of 30 bunches, but becomes extremely critical with 120 bunches.

The Committee supports the continuation of the development of a transverse feedback system based on the promising technique of digital filters. In addition, it is extremely important to push as hard as possible to reduce the transverse impedance of the main ring wherever possible - any gain in the impedance will make the feedback system less difficult. The possible positive effect of octupoles should also be studied at a later date.

The Committee believes that it is extremely important to define a coherent set of machine conditions for the "Day 1" operation (beam parameters, RF cavity impedance, feedback power etc.) for which the ring is stable. The design of the RF and feedback systems should be consistent with these parameters.

Kicker Magnets (see "Impedance Budget" above)

Further development of the kicker magnets in both the Accumulator and Main Rings should take into careful account the contributions that these devices make to the longitudinal and transverse impedances. As a third injection kicker is planned for each Main Ring, the Committee recommends that an effort be made to find a location in the lattice that would accommodate a standard kicker.

Timing System

The timing system has reached a very mature level in a short time. The system is very flexible and measurement of jitter in the prototype system is pushing the capabilities of the available test equipment.

The Committee recommends that two higher order capabilities soon be addressed as part of the study of the Control System requirements.

- First, the attainment of equal charge in each of the filled bunches of a given main ring will probably be a requirement of the experiments.

- Second, integration of this timing system into an encompassing control program that selects e^+ or e^- from the linac, the appropriate configuration of the transport line, and the destination main ring would greatly enhance the automation of operation.

Impedance Measurement

The Committee was pleased to see that a set-up for a transverse impedance measurement bench has just started and produced preliminary results. But, before trying to measure complicated elements like a kicker, different methods and set-ups should be systematically compared. The source for errors and the lack of reproducibility should be carefully analyzed and reduced as much as possible. Then, the accuracy of the measurement (resolution, precision, reproducibility) should be demonstrated by comparison with theoretical estimation on a simple element like a step in a vacuum chamber which is easy to calculate.

Summary

The next months are critical to the Project as the design must soon be frozen to allow engineering and construction to proceed. The ultimate performance will be determined by the quality of the design being carried out now. Accordingly, for the next Review, the Committee would like the Project team to put special emphasis on the following areas:

- Main ring optics
  Demonstration of acceptable flexibility including chromatic corrections
- Interaction Region layout
- Definition of the Control System
  network budget and software estimate
- Definition of the Vacuum System
  pumping requirements, pump choice and mechanical design
- Definition of the RF cavity
  comparison of several cavity shapes, selection of final design, estimate of HOM power, proposal for HOM damping

The Committee continues to be impressed with the competence and enthusiasm of the Project Team and is working hard. The Committee remains confident that the Project goals can be met by the scheduled date.

The 4th Review will be held during the week of January 17-21, 1993.

The 5th Review will be held during the week of July 12-16, 1993.

PRINCIPAL DAΦNE PROJECT

MILESTONES

Sep 92	**SPECIFICATIONS OF TRANSFER LINE OUT FOR BID**
Nov 92	**SPECIFICATIONS OF ACCUMULATOR OUT FOR BID**
May 93	**START CONVENTIONAL CONSTRUCTION FOR MAIN RING** requires Adone shut-down + 4 months decommissioning + contract awarded and ready to go
Oct 93	**BEGIN INSTALLATION OF LINAC** requires beneficial occupancy of Linac building
Aug 94	**BEGIN INSTALLATION OF MAIN RINGS** requires beneficial occupancy of DAΦNE hall
Dec 94	**LINAC OPERATIONAL**
Apr 95	**BEGIN ACCUMULATOR COMMISSIONING**
Dec 95	**PROJECT CONSTRUCTION COMPLETE** **BEGIN MAIN RINGS COMMISSIONING**