DAΦNE TECHNICAL NOTE

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DAΦNE PROJECT REVIEW

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The Committee heard presentations for a full two days and was extremely impressed with the depth and quality of the work that had been done since the first Review. Clearly, the Project has made a lot of progress and appears to be proceeding smoothly.

Our comments are presented following the format of the talks and we have tried to make a critical analysis of what has been achieved so far as well as to provide suggestions for future priorities.

Project Overview

The Committee received a general overview of the status of the project. We were pleased to see that the project has advanced into an engineering phase. There is now a preliminary schedule and the project has been formulated into a WBS structure which should permit easy cost tracking.

The Committee felt 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. Vignola agreed to provide this at the next Review.

The Committee also recommended that a set of parameters with 30 or 60 bunches per ring be adopted as the goal of the initial implementation and that all of the design effort be directed at this set of parameters. The future upgrade to 120 bunches should not be precluded by the design but should be treated as a separate problem for later.

The lattice design has concentrated on the single ring problems up to now and will be moving on to the two-beam problems. We agreed with this prioritization. The recent formation of the KLOE collaboration, who have submitted a letter of intent to build a detector for DAΦNE, is welcomed. This means that the design of the Interaction Region can now begin in earnest. The Interaction Region Design should be the main topic of the next Review.

The Committee did not hear a presentation of the Civil Engineering but was informed of the decision to provide a detector building. This was considered an excellent idea. The Committee asked about the need to cut the concrete foundation of the building to provide a passage for the detector to the far side of the ring. We were assured that the civil engineers would ensure that the detector would be supported on an independent platform to isolate the ring components (and their sensitive alignment) from the detector mass. However, there exists the possibility for the two machine arcs to lose relative alignment and coplanarity which could change slowly with time. It is suggested that a correction procedure be worked out to maintain small vertical beam sizes in the presence of piecewise movement of the two ring arcs.

The Committee inquired as to whether the physics requirements would ever require the use of asymmetric energies in the two rings. Franzini stated that in the Φ meson system, unlike the B meson system, this would be detrimental to the detection process and would never be a requirement. The arguments defining the ultimate top energy of DAΦNE were less clear cut and the Committee strongly endorsed the decision to optimize all of the machine components for operation at 510 MeV, even if this meant a degradation in the performance at higher energy.

Main Rings Design

The lattice layout has remained basically the same but has been modified in many important details to dramatically improve the flexibility and dynamic aperture. The dynamic aperture now almost covers the whole physical aperture. The amplitude dependence is extremely good. The main remaining problem is the energy dependence of the tunes. The usual slight quadratic variation of the horizontal tune, combined with the usual slight cubic variation of the vertical tune, leads to a crossing of the tunes at an energy error of about -1 %. This is believed to be the reason for the limitations in dynamic aperture at large negative energy errors. The Committee believes that small adjustments in the tune can improve this last remaining problem. We noted that the simulations have been done at fixed energy errors, rather than using the synchrotron energy oscillations and the higher multi-pole studies have been done for single errors at a time. When the tunes have been optimized, we would recommend a simulation of the whole ring, including all the errors, synchrotron energy oscillations and typical misalignment of elements, as a final check on the validity of the correction scheme.

It has been demonstrated that the limiting effect on the Touschek lifetime is mainly due to scattering effects which lead to a loss of the particles at the physical aperture. There is only a small influence of scattering processes in which the particles are lost from the RF bucket. A reduction of the RF voltage to half of its nominal value would lead to a reduction in momentum acceptance, which in turn would reduce the Touschek lifetime from 3 to 2 hrs 40 min. This is the change in RF voltage which would be necessary to keep the bunch length at 3 cm, if the broad band impedance is only 1 Ohm instead of 2 Ohm. This is still acceptable, but a further reduction of the impedance would lead to a steep decay of the Touschek lifetime. Consequently, alternative methods would be necessary to lengthen the bunch (e.g. higher harmonic cavity). This option should be studied if the impedance estimates indicate that the ring impedance is much less than the present numbers.

The most critical positions in the lattice for the Touschek scattering are those with small horizontal beta functions combined with a large dispersion. A scaling from this position to the maximum beta value in the lattice reveals that, for the particles lost due to the scattering process, about 80% of the aperture is used for the betatron amplitude. This in turn makes it likely that the particles will be lost at the dynamic aperture rather than the physical aperture. In this context the computations of the dynamic aperture with a realistic magnet error scenario is very important.

There was only a brief presentation of the Interaction Region and the beam separation scheme, as little work had been done to this topic. Nevertheless, the Committee still feels that the separation of the beams at the parasitic crossings needs to be studied in detail.

The main effect is due to the beam lifetime. The kick given by a gaussian beam is a maximum at 1.6 σ and this is also the position of maximum non-linearity in the field (quadrupole, sextupole, octopole etc.). Particles in the tail of the other beam which pass through this non-linear field are strongly disturbed and can be lost, reducing the beam lifetime. A safe rule is to treat this position as a "dynamic scraper" and demand that the centre of the other beam be at least 6 σ away. This would give a minimum separation between beam centres of 7.6 σ. The separation with 60 bunch operation in DAΦNE is 7.7 σ, which just meets this criterion. With 120 bunches in the ring, the crossing angle would need to be increased or the interaction region parameters modified to maintain the required separation. To date no good simulations of this effect have been performed and the Committee would encourage the DAΦNE machine group to try and perform these simulations. The effect of the long range forces due to parasitic crossings should also take into consideration the fact that the horizontal tails of the distribution are not gaussian, but are extended due to Touschek scattering. This could have an adverse effect on the lifetime due to the parasitic crossings.

Another effect is at injection. In this case the injected bunch is oscillating around the stored bunch into which it will eventually coalesce at about 8 σ radius. It can therefore hit the opposing beam head-on and see an extremely large tune shift (roughly 100 times the nominal value at the interaction point at each parasitic crossing). This must be avoided, either by injecting vertically (not recommended for DAΦNE) or by separating the beams vertically during horizontal injection.

The crossing angle may need to be increased when more than 60 bunches are put in the ring. Simulations performed by Piwinski (DESY) show that the maximum crossing angle is given roughly by the horizontal rms beam size divided by the longitudinal rms bunch length - about 70 mrad for the parameters of DAΦNE. These problems of beam separation at the parasitic crossing for 120 bunches are therefore felt to be soluble and should be studied later in collaboration with the detector group.

It is the conviction of the Committee that the design of the Interaction Region will require the active collaboration of two or three experimental physicists familiar with background calculations. They should be intimately involved in the development of the optical and mechanical parameters, and should also ensure that the detector is adequately protected from accidental beam loss at injection.

Injector Complex

The Committee was extremely pleased that the Linac has been ordered at such an early stage of the project. The design by the US firm Titan Beta is based on conventional technology largely tested at SLAC. It has been optimized for positron production, which is certainly the most demanding performance specification. In order to spread out the system check-out and beam commissioning, it is strongly recommended that the Linac be installed in stages so that electron beams are available as early as possible.

The proposal to add a Linac test beam and dedicated test area is supported by the Committee. This will provide an extremely useful test facility, very much needed in the future for test and calibration of machine and detector elements.

The transfer lines from the Linac to the Accumulator and the Main Ring suffer strongly in complication and length from numerous constraints coming both from the location of existing buildings and the need, for economic reasons, to use the same lines for the transfer of both kinds of particle for both injection and extraction. Their design should be pursued to see if it is possible to simplify the optics, standardize the equipment and reduce the number of systems (magnetic elements, power supplies etc.).

They should provide transverse and longitudinal acceptances well above the beam emittances and, in particular, the momentum acceptance in the transfer line from Linac to the Accumulator should be maximized for operational efficiency of positron beam transfer.

The accumulator design is very well advanced, with the optics providing comfortable dynamic acceptance and ideal locations for injection and extraction elements. Nevertheless, the accumulated beam of 130 mA is at the limit of the transverse stability mainly due to the impedance of the 5 kickers foreseen. A reduction of the number of kickers and of their beam impedance is strongly recommended. In particular, the kicker K5, which is presently dedicated for extraction, could be avoided if a change of the sign of the kicker field between injection and extraction can be provided by the power supplies.

The Committee believes that the choice of the RF frequency in the Accumulator should be further studied. The lower limit of the frequency should be determined by the voltage needed to provide the necessary momentum acceptance. A lower frequency would allow a longer pulse to be accepted at injection, thus relaxing the presently rather high positron current of 36 mA required from the Linac. Moreover, the bunch after accumulation and damping would be more stable because the equilibrium bunch length after damping is longer (presently σ_s = 2.2 cm at low current, which is far from the Main Ring RF bucket acceptance of 81 cm).

Control System

The proposal for the Control System is based on Macintosh personal computers operating LABVIEW software. In this proposal, a central processor is substituted for the distributed computing more usually selected for accelerator control systems. This choice is probably justified for DAΦNE which is a relatively compact machine. The decision to distribute intelligence to all of the VME crates is a good one. The Committee is somewhat concerned at the effort that would be required to develop a Macintosh LC in a VME crate and would be happier to see the use of a commercial product.

The LABVIEW software environment was developed to control laboratory instruments and is extremely well adapted to the initial check-out of the storage ring components. The use of LABVIEW as a control system seemed to the Committee to be much less obvious. In this case the experience at ADONE and LISA is not very relevant, as these are extremely easy machines to control compared to DAΦNE. The Committee was not convinced that the extremely complex manoeuvres that will be required for commissioning and operating DAΦNE will be possible in this software environment. We felt that it would be useful if the Controls Group spends some time studying the operation of other modern storage rings of a similar size to get a better feel for the kind of data acquisition and correlated control that will be needed. It might also be an advantage to the project if an existing control system could be adopted, as this would reduce the cost, and more importantly, the technical and financial risk.

The Committee felt strongly that a sufficient subset of the control system must be in place for the check-out phase prior to installation. In particular, it is very important that the magnetic measurements be made using the power supplies and controls that will be used during the machine operation.

It is recommended that the Project Management organize a Special Review of the Control System in about three months. The Review Committee members should have experience of control systems in small, modern storage rings and preferably have some knowledge of control systems based on personal computers.

Project Engineering

The engineering staff has now increased to 16 engineers and designers but the Committee agrees with Hsieh that this will not be sufficient to build the project. We therefore support the conclusion that industry must be heavily involved in the construction of elements and even whole systems. The Linac contract is a good example of this philosophy.

It was very clear to the Committee that Hsieh has the organization of the Project Engineering well under control. In particular, the Committee was impressed with the scheduling and cost breakdown (WBS) work that had been done.

Vacuum System

The Committee was in agreement with all of the basic choices that have been taken for the vacuum chamber. It was agreed that an aluminium chamber with cooled copper absorbers in an antechamber offered the best compromise between performance and cost. The Committee was pleased to see that the slot size had been increased to 1 cm and that the detailed calculations of power densities and impedance supported this decision. We were also pleased to see that detailed thermal and structural analysis has begun.

The Committee still felt uncomfortable with the outgassing rates. We are in agreement with adopting a nominal outgassing rate of 2×10^{-6} molecules per photon for the copper absorber which receives a high photon flux to clean it. We felt that there may also be an additional contribution from the aluminium walls illuminated by low energy photons scattered from the copper absorber. We recommend that simulations of this effect be carried out. We were pleased to see that outgassing tests will be carried out.

We strongly support the outgassing test on a chamber with the primary copper absorber surrounded by an aluminium model of the standard BNL stainless steel chamber (which makes calibration easier). These data will be extremely valuable for confirming the required pumping speed. The possibility of doing some of these measurements at the EPA at CERN was mentioned by J.-P. Delahaye and this offer should be followed up.

The future work on the Interaction Region vacuum system should also look carefully into preventing the synchrotron radiation produced by the splitter magnet from outgassing in the region immediately upstream of the detector. The gas pressure in this region should be as low as possible to reduce the detector background from beam - gas interactions.

Ion trapping calculations have been performed by looking at the focusing effect of the bunches on the ions. It has been demonstrated that breaking the symmetry of the focussing structure, by introducing a gap in the bunch structure, creates half integer resonances which clear the ions. This process can be considerably reduced if the nonlinear space charge force is taken into account, which normally has a stabilizing effect for the ions. Simulations should be performed which take into account the nonlinear space charge force, before making a decision about clearing electrodes. In the wigglers, it is expected that there is an enhancement of the trapping efficiency which should be analyzed for DAΦNE.

Magnetic Components

The Committee was extremely impressed by the progress that has been made in the magnet design since the previous meeting. There was some discussion on whether or not the dipoles of the Accumulator Ring should be laminated. The decision is usually very dependent on the details of the particular magnet. An evaluation of the relative merits of solid and laminated dipole cores should be carried out for the next Review.

The Committee was unanimously against the use of trim windings on the magnets as this introduced a lot of operational difficulties and would require complicated power supplies. Wherever possible, separate correction magnets should be foreseen. In addition, a few portable active shunts could be provided for initial operation of the machine.

The Committee was pleased to see that prototypes of the splitter magnet and the septum magnet are in construction. The prototype Interaction Region quadrupole which has been built is extremely interesting and the Committee recommends that the optimization of the field quality continues and that the results be compared with the permanent magnet quadrupole which is being used at Cornell on the CESR storage ring.

Beam Stability and Feedback

A very complete impedance budget for the Accumulator and Main Ring has already been calculated and clearly shows that both rings are dominated in the longitudinal plane by the kicker magnets. The study of a low impedance kicker (including the effect of its tank), possibly of the same type for the Accumulator and Main Ring, is therefore strongly recommended. The contribution of the instrumentation (Beam position monitors etc.) has still to be added.

In both machines, the single bunch current is at the limit of transverse stability, even taking into account the strong bunch lengthening which has been derived from the broad-band impedance model best fitting the estimates of the sum of the impedances of the single elements. The transverse impedance is therefore extremely important and it should be evaluated independently of the longitudinal impedance in the Accumulator as was already done in the Main Ring.

The resistive wall instability in the Main Ring has a very fast rise-time and will require the adoption of positive transverse chromaticities in operation. This increases the sextupole strength and the effect on the dynamic acceptance needs to be evaluated in this operating condition.

Multi-bunch instabilities are very severe especially in the longitudinal plane with such a large number of closely spaced bunches, each having a high current. The philosophy adopted is to damp the parasitic modes in the cavity as much as possible and in addition to develop a broad band feedback system. The Committee agrees with this philosophy.

The Committee has been extremely impressed by the very good progress already achieved in the development of longitudinal and transverse feedbacks, based on the very promising techniques of Digital filters. This work has been done in close collaboration with SLAC, LBL and CERN in the framework of the SLAC Beauty Factory study. It strongly encourages the construction of a kicker and feedback prototype adapted to DAΦNE and recommends continuation of the collaboration on tests with beam in the ALS next year.

RF System

The Committee was pleased to see the vigorous effort that is being made to optimize the RF cavity and believes that it has been extremely important to investigate many different possibilities. However, the Committee feels that a consensus should be reached by the time of the next Review. This deadline is necessary to allow time for prototype construction and testing.

The Committee is particularly concerned with the large number of higher order modes with a high quality factor in the cavity envisaged at present. We recommend that a comparison be made with RF cavity shapes which have already been adopted in similar rings rather than further optimization of the present cavity. We felt that the criteria to be used for this comparison should be the number and strength of the trapped modes, rather than the reduction of the total energy loss factor.

For the tapered cavity, the mechanical deformation is not applied on the neck of the cavity but further out on the taper. There is some concern about the mechanical stability of the device under vacuum. Stress analysis for the required tuning (i.e. deformation) range should be performed.

It may be necessary to use the klystron in a feedback system to stabilize the fields in the RF cavity. If this were the case, it would be extremely important to place the klystron physically close to the cavity to reduce the delay time of the feedback system. While the Committee was not sure that the DAΦNE parameters are such that a feedback system is needed, we recommend that all the various beam-cavity interactions be studied (including the effect of the gap in the bunch train required for ion clearing) before finalizing the position of the klystron.

The work on resonator absorbers is extremely interesting and should be actively pursued. Similarly, the work on HOM tuning is also interesting but the principle may be difficult to apply in practice.

Impedance Measurements

The set up of an impedance measurement bench based on the coaxial wire method and synthetic pulse technique will be extremely useful to check the calculations made with computer programs to estimate the impedance of more complicated elements and to help in reduction of their impedance. The technique has already demonstrated very interesting results on the loss factors of the kickers. It could also be used to deduce the real and the imaginary parts of the impedance as a function of the frequency. Moreover, the Committee strongly suggests extending the method for measurement of the transverse impedance if at all possible.

Summary

The Committee approved of the priorities that have been set by the Project Leader and congratulates the DAΦNE Machine Group for the quantity and quality of the work that has already been achieved, including placing the order for the Injector Linac.

We recommended that the Project Leader specifies a single set of parameters for the initial implementation (30 or 60 bunches) and defines a set of milestones to be met in order to achieve completion in a timely fashion.

We were pleased that the KLOE collaboration has submitted a letter of intent to build a detector for DAΦNE and recommend that the Detector Group works actively with the Machine Group to design the Interaction Region to ensure that background conditions will be acceptable.

We recommend that there be a specialized Review of the control system in about 3 months time (April).

We have decided that the next Machine Advisory Committee Meeting will be in 6 months time (July) with the following topics on the Agenda:

- Project Milestones
- Interaction Region
- RF System.

Finally, the members of the Committee would like to thank the DAΦNE Machine Group for their hospitality and especially for the open way in which they presented the results of what was quite clearly a considerable amount of work. It is the positive attitude of this group that will bring the Project to a successful conclusion.