DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

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DAΦNE PROJECT REVIEW

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As a general comment let us state that the committee was impressed by the amount and quality of the work already done on the project and by the clarity of the presentations on a large variety of subjects.

Before entering into the detailed technical comments, let us discuss the most crucial point for the project : Are the projected luminosity values realistic ?

The highest luminosity reached so far in the world at any energy has been achieved in CESR at Cornell with L=2 10^{32} cm^{-2} sec^{-1} at an energy of 5.3 GeV. If the CESR luminosity is scaled with energy to 500 MeV assuming the luminosity is space charge limited ($L \propto \gamma^2$) this corresponds to a value of L=2 10^{30} cm^{-2} sec^{-1}. However, the best performing machine in the energy range of the Φ-factory (510 MeV) is presently VEPP-2M at Novosibirsk which has been able to achieve a luminosity of L=4.3 10^{30} cm^{-2} sec^{-1}. Therefore luminosities above 5 10^{30} cm^{-2} sec^{-1} for a Φ-factory exceed the present state of the art performance.

The basic parameters of the present design of DAΦNE should enable the machine to reach higher luminosities mainly by separating the beams into two storage rings and by using a horizontal crossing angle which makes possible the use of high bunch collision frequencies. Nevertheless it should be pointed out that no practical experience with electron machines is presently available for horizontal crossing as collisions with vertical crossing angles have only been realized till now (DORIS, DCI). The recent modification from vertical to horizontal crossing has certainly improved the performance of the machine with regard to the beam-beam interaction and has opened the possibility of installing a crab cavity with less demanding parameters in a later stage. Furthermore the goal of achieving a small emittance coupling can be reached easier. Special care must be taken for the vertical beam position to insure the beams collide properly which is more difficult for the horizontal crossing scheme.

The number of bunches in the ring will be limited by the total beam intensity per ring, the related multibunch instabilities and the possible bunch separation at the parasitic crossing points (which should be at least > 7 σ_x to avoid strong long range interaction, following a conclusion of a recent workshop on this subject held in Berkeley on March 1990).

The committee recommends the adoption as a design goal the very challenging luminosity of

$$L = 10^{32}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$$

with a single interaction, which corresponds already to an improvement by a factor of 20 above the best performance presently achieved in the world. It is recommended to approach this value by reducing the bunch collision frequency by a factor of 5 and keeping the other parameters as presented, i.e.

N_B	=	$9\ 10^{10}$	ξ_{max}	=	0.04
B	=	24	ε_x	=	10^{-6} πm-rad
f_B	=	76 MHz	$\kappa=\kappa_\beta$	=	0.01
θ_x	=	10 mrad	β_y	=	4.5 cm

The committee is pretty confident that such performances could be reached within a reasonable amount of time even considering the rather high current per beam (1.1 A) and the already high number of bunches (B=24). As a consequence of this approach the work on the multibunch feedback system should concentrate on these parameters in the first stage.

For the parameters stated above the separation of the orbits at the first parasitic crossing corresponds to a horizontal distance of 20 σ_x. Higher luminosities based on populating more bunches (B>24) could be envisaged in the future after a vigorous R&D program. The basic elements of the complex should be dimensioned from the outset to cope with a target luminosity of

$$L = 10^{33}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$$

The novel design of the magnetic lattice including the damping wigglers in the achromats has been well appreciated by the committee. Especially the flexibility of the lattice which will allow one to match the optics to the various requirements arising during the machine optimization.

The dynamic aperture has been optimized to high performance regarding the variation of the tune with amplitude and momentum respectively, over the full stable regime. The committee took note that the optimization of the dynamic aperture is still in progress. Although the dynamic aperture is more than sufficient for quantum lifetime, an increase, especially in the horizontal aperture, is needed in order to improve the Touschek lifetime. Further improvement is also needed for the off momentum aperture. Tracking for chromaticities in the range 0 to +1 and off energy tracking for deviations greater than 0.5% is suggested. Since the dynamic aperture as presented is quite tight, care should be taken to properly assess the chromatic effects of the non-standard elements such as solenoids and wigglers. The reduction in the vertical chromaticity suggested by the solenoid/skew quad insertion could possibly ease concerns on the dynamic aperture. The dynamic behaviour could be improved by detuning the unused low beta insertion. Moreover for the commissioning phase a simplified optics without wigglers should be explored.

A complete treatment of this topic should also include the intrinsic nonlinear effects of the damping wigglers, including their distortions coming from the pole width (which has a very deteriorating effect on the dynamic aperture even for comparable small values). A close interaction with the magnet design group is needed in the near future in order to define the tolerable magnet multipole errors. Possible nonlinear effects coming from parasitic crossings should also be investigated.

The scheme presented for closed orbit correction meets the requirements for DAΦNE. The committee recommends providing a large margin (factor of 3) on the corrector strengths compared to the results derived from the simulations. Beside the bump method presented, alternative correction methods (most effective corrector, harmonic correction) should be available in the final control system. For phase I of the machine commissioning with the sextupoles off, it has to be verified that the off momentum behavior of the optics permits this approach.

The committee was impressed by the new ideas developed for the solenoid compensation. Especially the possibility of combining the solenoid compensation with a vertical orbit movement to adjust the collision is very interesting. The work on a solenoid based insertion geometry should go on, but for the time being the conventional quadrupole insertion should be taken as a basis for the future work.

One of the most challenging tasks will be the cure of multibunch instabilities. The two level approach adopted for DAΦNE (damping the modes in the cavity and providing a feedback for the beam) has been well appreciated by the committee. A lot of progress has already been achieved in developing cavities with a lower parasitic mode content. The shift of the remaining modes from overlapping with a multibunch mode, as envisaged for DAΦNE has been considered as a very good idea. The shift of the higher order modes that occurs due to the cavity tuner motion should also be taken into consideration. For the implementation of the feedback system the adopted philosophy of starting with a less complicated system for a larger bunch spacing has been positively recognized. From the experience with DORIS I with multibunch operation and crossing angle, the use of decoupling transmitters and RF-quadrupoles to split the tunes is not recommended. It would be mutually beneficial to have an INFN staff member participate in the ECFA Beauty Factory working group on multibunch feedback.

The problem of ion trapping has not been addressed. Although a gap in the bunch structure should alleviate the ion trapping, it is not without problems following the experience with DORIS. Since the ions are cleared by the gap in a resonant way, a decay in current during one filling will move ion species in or out from stable bands and therefore affect the lifetime (background in the experiment) in an unpredictable way. Since it is envisaged that all bunches could be filled to achieve the highest luminosities, one should explore the possibility of installing clearing electrodes in the ring for the use of either constant field clearing or resonant clearing.

A study of the variation of the integrated luminosity as a function of the beam collision time and dead time for injection for various beam lifetimes taking into account the dynamical pressure rise would be useful to better estimate the available time left for injection. The topping-up injection scheme is certainly attractive as it reduces the injector complex requirement. The present design based on a linac and simple accumulator fits the requirements with conventional technology. In a first stage based on a luminosity of 10^{32} the positron production can be relaxed by a factor of ten.

The single bunch injection scheme provides the maximum flexibility in arranging various bunch patterns in the storage rings. Until the transient effects of large single bunch currents injected in one shot (20-50 ma) are completely explored, the alternative solution of injecting a few bunches with correspondingly less single bunch current from the collector ring should not be excluded. Since a short injection time is of paramount importance for an efficient machine operation, the inclusion of a collector ring at the end of the linac has been strongly appreciated.

The committee appreciated the large amount of work which has been done for the vacuum system in a relatively short time. The solution with an antechamber should be explored further to determine if it is the only approach to handle the gas load generated by the high beam currents. The choice of the material should be done as soon as possible since it is affecting greatly the design of other components (magnet aperture, wiggler gap). The height of the connection slot to the antechamber seems to be very conservative in comparing the frequencies of the bunch spectrum and the cutoff frequency of the slot. By increasing the slot to 1 cm (as adopted by the ALS and ELETTRA) the problems on beam steering and closed orbit control could be alleviated. The usefulness of NEG pumps could also be investigated.

A lot of progress with a relatively small staff has been reached on the field of magnet design. An immediate strong interaction of the magnet group with the beam dynamics group is recommended. The various design steps of the elements have to be accompanied by tracking calculations in order to define the tolerable field errors. The effects of coil placement tolerances on the split field magnets should be investigated. If permanent magnet quadrupoles are adopted for the insertion quads this could limit the tunability of the insertion. If superconducting quadrupoles are used in the insertion they must be shielded from any synchrotron radiation.

The committee expresses concern about the high power required for the damping wiggler. A reduction of the gap size could partly resolve the problem. The gap size envisaged seems to be large compared to the vertical beta function in the wiggler, if a scaling is performed from the maximum beta and the aperture of the insertion triplet. The tolerable parameters for the wigglers from the beam dynamics point of view (as period length and pole width) have to be explored by the beam dynamics group. The possibility of using hybrid wigglers with permanent magnets (for a reduced gap) should be explored. The damping wigglers could benefit from further optimization of the parameters. The large wiggler parameter of K = 90 will result in a large amount of radiation on the walls of the vacuum chamber. When the details of the wiggler are worked out a proper assessment of the total power radiated is recommended.

The committee took note of the ideas presented for the computer control system. The use of distributed computing power and the use of commercial products with well established standards has been appreciated. It is suggested that a more detailed presentation on the control system be made at the next review.

Since the beam diagnostics for the machine have not been covered in this review we recommend that it be presented in the next review. It is very important to be able to measure the luminosity and to insure that the beams collide properly considering the small vertical beam size of 20 μm.

Some additional work to clarify exact which type of acceptance (RF, physical or dynamic) is limiting the Touschek lifetime is needed. A more detailed presentation of all the lifetime aspects should be included in the next review.

Moreover the committee would appreciate the presentation of an overall project schedule to be presented for the next meeting which should take place approximately half a year from now.

Engineering Comments (H. Hsieh)

Additional technical and engineering considerations on the main components are presented in the following section.

<u>VACUUM SYSTEM</u>

The Vacuum group has just begun to work on the DAΦNE, the presentation shows this group has recognized the degree of difficulty to achieve the required vacuum quality for this machine. The chamber material selection has not been systematically examined at this point in time, the proper material is vitally important to the final outcome of DAΦNE vacuum quality. There are numerous factors which should be examined simultaneously, such as desorption rate, RF heating, cooling associated problem, combined stress due to the vacuum load and local heating, in-situ bake out needs, surface treatment, extrusion vs wrought material, fabrication methods, magnetic properties of virgin metal and weldment, residual radiation after some period of operation.

The ante-chamber seems to be the favourite choice of the vacuum chamber cross section for the new machines in the world. This type of design should not automatically become the choice of DAΦNE without detailed studies on the suitability to this machine.

The high temperature photon absorber concept appears very interesting and indeed is very novel, but there are many issues which should be carefully examined on paper before embarking on a testing program. Some considerations that come to mind immediately are:

- material, fatigue and thermal stress,
- mechanical stability of the absorber at high temperature,
- what is the proper temperature and what is the range of the temperature permissible,
- the sublimation related problem, incident angle and its criticality,
- producibility study,
- maintenance problems,
- safety considerations,
- second line of defense if the absorber fails,
- what is the implication on the vacuum chamber integrity.

There exists vast amount of information in the literature concerning UHV problems, The vacuum group should immediately start a literature search to benefit from the previous efforts. It is indeed very important to embark on a systematic verification testing program for new concepts never done before. The DAΦNE group should try to collaborate with other laboratories in using their existing facilities rather than doing them on site in Frascati, this will not only shorten the time to gain the information but also INFN can benefit from the collaborator's experiences.

There are experiments be conducted by the NSLS/BNL vacuum group to evaluate the desorption rate of a combination of surface coatings and base metals. The same group is also studying the desorption rate as a function of photon incident angles. The experiments are being carried out in their 750 MEV storage ring. DAΦNE vacuum group should contact them and determine if BNL's results can benefit DAΦNE.

MAGNETIC COMPONENTS

Although most parts of the accumulator ring and the storage ring's magnets have been looked at in a preliminary way, the selection of the dipole gap height and the bore radius of the multipole magnets can not be finalized until after the vacuum chamber shape has been determined. It is rather urgent to have the project management decide the proper beam stay clear aperture in the various magnetic components so that the vacuum chamber can be properly designed and a finite element analysis can be done on both the heat transfer and thermal stress. The forced cooling and associated hydraulic considerations can be proceeded.

Accumulator Ring Magnets

The accumulator ring dipole is a relatively high field combined function magnet and the magnetic pressure is on the order of ten atmospheres. An 'H' type magnet is more suitable than a 'C' type for such a heavy load. An additional bonus of 'H' magnet is not to have high stray field spilling over to the transfer lines which are rather close to the AR dipoles. Since current density appears high for this dipole, it perhaps is better to re-examine the choice.

The accumulator ring sextupole is made of six current filaments located inside of the ring quadrupole. The perturbation of the quadru-pole field and the residual dipole field due to this type of arrangement suggests to reconsider the conventional way, namely having sextupoles outside the quadrupole. Alternatively a permanent magnet type sextupole such as that of SLAC's Damping ring could be considered.

The accumulator ring injection and extraction elements are conventional. There should not be any surprises, however, one should try to build internal kicker elements rather than the external ferrite type with ceramic chambers since the reliability of the injector is very important.

Storage Ring Dipole

This is a pure dipole with a reasonable field strength requirement of 1.2 Tesla. The pole width to gap ratio appears too large if 1.2 Tesla is the maximum field. We are sure this problem will be looked at during the optimization. The power dissipation is in the order of 11 kw per magnet, this also seems high. The current density of 3.5 Amp/mm*2 is a optimized number done by in-house staff; without knowing the optimization process, it is hard to make any comments. The energy cost is high here, it may be prudent to re-examine the current density for a machine life of 20 years and all the other ancillary costs, such as power station upgrade, process water system, power supplies and control, support stands, power consumption, materials, manufacturing, handling, transportation, and Adone existing floor loading capability, etc. The gap height of 5 cm to compare with beam stay clear requirement of 4 cm seems unreasonably small, especially for an aluminium chamber and allowing for an in-situ bake. This point should not be overlooked during the finalization of the parameters.

Storage Ring Multipoles

The storage ring multipoles are conventional. The only point one should pay attention to is to provide enough clearance between the poles and the vacuum chamber so that there will be no displacement of multipoles due to either the bake-out or asymmetric heating of the chambers during operation.

Storage Ring Injection Elements

They are conventional equipment, there should not be any surprises. Ceramic chambers for the kickers are again potential sources for reliability problems. The effects of heating at high beam current should be examined carefully.

SPECIAL MAGNETS

Wiggler Magnets

There are eight 1.9 Tesla resistive type wiggler magnets in DAΦNE for radiation damping purpose. The power dissipation of these magnets is very high. During the conceptual design period, it is proper to reduce the complexity of the machine components so that the fabrication of such a machine is assured. DAΦNE is now in the period of optimizing the machine parameters. These wigglers should be re-visited and the parameters should be reviewed, since 2/3 of the synchrotron radiation in this machine is due to these wigglers and 80% of the wiggler radiation is deposited on the chamber wall between the wiggler and the downstream dipole magnet. It is suggested to consider an alternate solution in which such a situation can be eliminated.

Splitter Magnet

This is essentially a two septum magnet. Since it is a picture frame window magnet, the sensitivity of the individual conductor location should be examined carefully, the stray field at the ends should also be carefully measured. It is a good approach to build a prototype to measure the field characteristics, especially the three dimensional properties.

IP Tunable Permanent Quadrupole

It is a very novel approach, it is certainly worth a while to make a prototype for further investigation.

IP Superconducting Quadrupole

It is a cold bore magnet, it is an interesting concept, however, some questions have to be answered and much more detailed works have to be done prior to any decision can be made about its viability. Some of the problems which come to mind are:

- what to do with the upstream bending magnet radiation,
- non bakable beam tube,
- what to do to recover from vacuum incidents,
- end effects,
- how to transport the current to three magnets in three different cryostats,
- the outer diameter shown will be larger in reality,
- repairability, etc.