DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

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DAΦNE PROJECT REVIEW

Frascati, April 16-17, 1996

Reviewers

F. Bonaudi (INFN-Torino)
D. Boussard (CERN)
G. Brianti (CERN)
J.-P. Delahaye (CERN)
H. Hsieh (LBNL)
A. Hutton (CEBAF), Chairman
A. Wrülich (TS)

Introduction

The machine has made spectacular progress in the last six months as more and more equipment is arriving. The Linac has successfully accelerated electrons to 700 MeV, positron production is ready to be tested, the Accumulator Ring is fully installed and ready for hot checkout and commissioning. A large number of Main Ring components are here and one of the two Main Ring RF systems has operated successfully. There are still some machine worries, specifically the delivery of dipole magnets from Ansaldo, but even here the situation looks better than at the last Review.

Maintaining the machine installation schedule is still an issue but at present the primary worry is the interaction between the accelerator commissioning schedule and the installation of the experiments (particularly FINUDA). This will require close cooperation between the machine and the experiments, guided by clear priorities from the Laboratory Director.

Status of Experiments

DEAR (DAΦNE Exotic Atoms Research)

This experiment, approved by the Scientific Committee since our last Review, is suitable for early installation in one of the interaction regions. At present the group is also preparing a simpler version of the experiment (gas target at normal temperature and pressure), with which to verify background conditions. It would be extremely helpful if this could be augmented with some additional counters to properly quantify the background. This would be useful for the machine physicists as well as for the other two experiments. This simple version could be installed as soon as the quadrupole occupying the crossing point can be removed. It is recommended that the two versions of the experiment be mounted in a way that they can be rapidly installed, removed or interchanged to provide the maximum flexibility – for example, temporarily replacing one of the large detectors if it has to be removed from the machine for repair. It is recommended that preparations for the required supports be made already now (e.g. drilling in the pit floor for pillars etc.). It is worth noting that both versions of the experiment could run simultaneously on the machine in the two interaction regions as they share no common parts.

FINUDA

In spite of some unexpected difficulties and delays, much progress has been made: the superconducting coil has been wound and the steel is nearly ready for assembling the whole magnet. If all goes well, cold tests and magnetic measurements should take place at Ansaldo in the Autumn, with delivery to Frascati at the end of '96. The cooling of the coil in the DAΦNE hall cannot be before May '97 (expected delivery of the refrigerator by Linde). It is recommended that magnetic measurement probes be fitted to the magnet in order to check its reproducibility with time. All detectors are under fabrication (e.g. straw chambers at Frascati, drift chambers at Vancouver). The new geometry of the silicon micro-strip detector has made its production more difficult and caused some delay: it is foreseen that by Spring '97 only one half cylinder will exist, the other half being staged in the second half of the year. The installation time in the DAΦNE hall is estimated as 13 weeks, including 4 weeks for magnet installation and 3 weeks for coil cooling. This schedule means that a part of this installation must occur during the same period as the machine commissioning. This will have to be accommodated by interleaving the two activities. The way in which this is organized needs to be defined early to avoid problems with the radiation safety regulations (difficulty of employing external personnel in an area that has been irradiated).

KLOE

The fabrication of the magnet components made some progress, in spite of all the difficulties encountered. The coil winding at Oxford Instruments should now take place during the Summer, followed by assembling, cooling and tests at 1/2 current, before delivery to Frascati by July '97. The iron yoke should be pre-assembled at Milan by November '96, with re-assembly at Frascati in February '97. The construction of the calorimeters is half completed; the wiring of the drift chamber should take place from Summer '96 to Summer '97. A general system test will be carried out from next year on, with as many of the detector systems as possible; the rolling of KLOE into the beam position can now be foreseen for Spring '98. As KLOE can be completely mounted in the external Hall, the interference with the machine will be minimal.

Luminosity Monitors

The design and production of luminosity monitors for each interaction region should be initiated as this will be an early requirement. Since there is no guarantee that the luminosity will be the same in the two interaction points, both should be equipped with luminosity monitoring.

Machine Overview

The civil construction contracts have mostly been awarded and are either complete or appear to be in good condition. The provision of services (electricity, water) which were worrying the Committee at the last Review appear to have recovered a large part of the delay and (with the exception of the Main Ring electrical connections) are no longer a worry. The contract for the liquid helium plant has been let but will only arrive next spring. The installation of the helium distribution system could interfere with the installation and check-out of the accelerator and will need careful oversight.

The Committee fully endorsed the decision taken by the Project management to delay the Linac commissioning with positrons in order not to interfere with the access of external personnel for the installation of the Accumulator. The present situation of the Injector complex is that the commissioning is totally de-coupled from the installation of the Main Ring – an improvement on the previous plan.

The Project Leader presented a schedule showing commissioning of the Injector Complex starting in May 96 and the Committee was convinced that this is on track. The schedule also showed the end of the installation of the Main Ring by December 96. This will require aggressive optimization of the manpower to achieve this goal but the Committee felt that the mechanical installation could be achieved by this date.

The detailed electrical checkout and pre-commissioning is liable to take another couple of months but no major problems are foreseen.

Linac + Accumulator Status and Commissioning Plans

The installation of the whole injector complex constituted by the Linac, the Transfer Lines and the Accumulator is now complete. During a visit to the Facility, the Committee was impressed by the high quality of the equipment provided by Titan Beta for the Linac and by Oxford for the Accumulator and by the great care of the installation made in close collaboration with INFN staff.

The commissioning of the Injector Facility will start in May in interleaved mode between the Accumulator and positron operation in the Linac. The Committee recommends that a well-defined pre-commissioning plan of the Accumulator be prepared, assigning clear responsibilities, and should include precise cold and hot checks of every piece of equipment. Priority should be given to the commissioning of the Accumulator with electrons in order to identify any possible hardware or software problems as soon as possible. In particular high level software debugging and tests in the Accumulator will be extremely useful in preparation for the Main Ring commissioning next year.

The nominal performance with electrons in the Linac has already been demonstrated at the end of last year up to a maximum energy of 700 MeV (specification is 800 MeV). The Committee is confident that the INFN Linac team, in close cooperation with the Titan Beta expert, is fully able to commission the Linac with positrons. But the Committee is concerned with the failure of the Thomson klystrons to run reliably at their nominal rating, particularly since they have to work close to top performance to obtain the nominal positron energy of 510 MeV. The Committee supports the search for an alternative source of klystrons, preferably with higher RF power, in order to provide some margin. In parallel, the Committee recommends preparing a back-up plan for positron commissioning of the Accumulator at a somewhat reduced energy to ensure that the positron-specific hardware and software is operating correctly.

Global Installation Plans

The global installation plans are in an early stage. An impressive preliminary list of tasks and resources has been established by Francesco Sgamma who has been assigned by the Project as the person responsible for installation. It is recommended that a commercially available scheduling tool, such as MacProject or Microsoft Project, be used to convert the list into a schedule chart with estimated manpower requirement. With such a management tool, it is possible to manage such a complicate inter-related set of tasks. With the information available today, it is difficult for the Committee to evaluate whether there are sufficient resources available to maintain the aggressive installation schedule but it was felt that a fair amount of external personnel would be needed.

The DAΦNE group has taken official occupancy of the storage ring hall, a rough machine alignment net has been established, and the alignment primary pillars have been placed to an accuracy of 2 mm with respect to the ideal location. The pillars would be more useful if they can be adjusted to a better accuracy of 0.5 mm.

There is a substantial quantity of multipoles available. It would be prudent to proceed to place these components on their respective girders and to align them to the required accuracy. These girders can then be placed in the lattice with respect to the primary pillars whenever there is manpower available. The multipoles should be parted ready to accept the vacuum chambers. All the wigglers have been delivered and magnetic measurement of these magnets should take place as quickly as possible so that they can be positioned in the DAΦNE hall to some reasonable accuracy. Parting the wiggler to accept the vacuum chamber is not a quick operation, so it should be done whenever the manpower is available rather than waiting for the last minute.

The positron arc vacuum chambers are also ready for installation. The alignment group should try to utilize one of the chambers for installation and alignment practice.

The alignment group has very limited manpower and equipment at the present time. They will be hard pressed to carry out all the alignment demands such as magnetic measurement; improvement of the storage ring alignment net; placing girder supports in the storage ring; and alignment of components on the girders. The project should proceed to negotiate with other organizations, such as the Trieste Synchrotron Radiation Facility, to carry out some of the tasks. The in-house alignment group should maintain responsibility for the network and ring component placement as these tasks will be repeated rather often in the life of the project.

Visit to the Facility

The visit of the Committee to all buildings and installation showed marked progress with respect to the 9th Review of October '95. The Accumulator is particularly impressive as it is now completely installed and is undergoing final electrical and hydraulic tests prior to commissioning with beam. The Project obtained beneficial occupancy of the Main Hall in January '96 and in the succeeding three months a sizable amount of installation work has been carried out, including floor preparation, cable trays, pipework, magnet and vacuum chamber supports and alignment monuments. Also the installation of the various utility buildings has made considerable progress, in the case of the hydraulic pump room recuperating most of the delay which had been incurred in placing the contract. Altogether, the present status makes it credible that the entire machine complex can be installed by the end of '96. This requires establishing a detailed schedule, based on available resources, and continually up-dating it on the basis of actual achievements.

Interaction Regions

The mechanical design of the Day-one interaction region has been simplified by eliminating the quadrupole rotation option. The design work appears to be in hand. It is recommended that the two girders be supported on an appropriately designed support structure so they can be used to keep the machine in operation in the event that a detector needs to be rolled out of the ring.

Much progress has been made in the mechanical design of the FINUDA interaction region. The low-beta quadrupoles will be supported by a cylinder which is suspended by aluminum spokes anchored to the outer shell of the detector. The alignment accuracy of these quadrupoles is about 150 μm. The temperature variation of the aluminum spokes should be carefully restricted in order to keep the position of the low-beta quadrupoles stabilized. The relative position adjustment of the low-beta quadrupoles is done by cams and universal joints. Caution should be exercised to assure non-slipping action between the cams and the barrel containing the low-beta quadrupoles. The backlash in the universal drive chain has to be eliminated to ensure the repeatability of the adjustment.

Not much progress has been made towards completing the mechanical design of the KLOE interaction region in the last six months. The rigidity problem of the RF shield has been solved by making it a complete cylinder with slits in the mid-plane to avoid synchrotron radiation heating. Axial flexibility has been achieved by introducing spring-finger like configuration at each end of the cylinder. The staff should be commended for coming up with such a novel idea to make this critical part more predictable and reliable. It appears that some parameters still have to be ironed out between the DAΦNE and KLOE groups. We would like to recommend more frequent meetings between these two groups to facilitate the design process.

Bellows Shield

The geometric constraints on the bellows between the DAΦNE arcs and straight sections has led to the development of RF connections without sliding contacts, using an array of undulating copper strips. It is gratifying to see that the design of this RF shield has made great strides. The electrical performance has been improved to such an extent that it is now a viable option for DAΦNE, which has a large angular offset between the arc chamber and the straight section vacuum chamber during the bake-out procedure.

The Committee has been presented with detailed impedance measurements of this object, as well as with MAFIA simulations. The most dangerous modes can be considerably reduced with modifications to the original structure (combs and strips). The results are convincing from an electrical point of view, but a through mechanical design remains to be done. In particular the question was raised of the long term integrity of the electrical contacts between strips and combs.

The ANSYS result shows that the maximum temperature in the BeCu strip is in the order of 70 °C with the anticipated total heat load of 650 mW. The low temperature is due to an assumption that there is heat transfer between the combs and the strips. The higher thermal load deposited in the middle strips is assumed to be transferred by conduction, both axially and transversely. However, heat transfer through a contact is critically dependent on the contact pressure, but the present mechanical set up will not provide a high contact pressure. Therefore, the temperature of the middle strips will be much higher than that of the ANSYS calculation and it could reach a maximum of 140 C, which would have an annealing effect on the material. It is recommended that the current cylindrical combs should be replaced by a strap similar to that of undulating strips and that it should be welded to the undulating strips.

It is further recommended that a different BeCu alloy or Glidcop material be examined to improve the reliability of this component which is a well known "trouble maker" in all the high current accelerators of to-day. Glidcop material is an aluminum-dispersed copper alloy, it possesses both high thermal conductivity and very high yield strength, even at high temperature operation. A worst-case scenario heat load should be used for computational purposes. The mechanical design should be carried out as quickly as possible so extensive electrical and mechanical tests can be carried out prior to series production.

RF Measurements and RF Systems

Shunt impedance measurements of the final version of the longitudinal kicker prototype have shown some discrepancy with calculations. There is no really convincing explanation for the difference, but on the other hand the consequences (a slight increase of amplifier power) can be easily tolerated. The power amplifier itself has been shown to be within specifications.

The Committee was pleased to see that the DAΦNE cavity has already been tested up to 300 kV (nominal 250 kV) with only a limited amount of conditioning. The vacuum limitation is probably accidental and hopefully will be removed after the new cycle of cleaning of baking which is planned. In this respect if would have been useful to make a residual gas analysis on the cavity as it is now, to help understand the vacuum limitation. The problem should be easier on the second cavity which is expected to need fewer machining cycles to reach the correct frequency.

The cavity tuner and HOM dampers (including the two additional ones mounted on the cavity cones) behaved as expected. The RF coupler was set to $\beta = 1.4$ to allow cavity testing at full field with a tetrode amplifier, rather than the nominal $\beta = 2.5$ corresponding to 30 bunches. The cavity was tested with the klystron, but the coupler has only been tested up to 30 kW CW (80 kW nominal). Even after cavity re-assembly with $\beta = 2.5$, it will not be possible to test the couplers at full power without beam. The Committee recommends building a test set-up for couplers (two couplers connected back-to-back in a matched transmission line configuration). This would guarantee a defect-free coupler in case of replacement. It would also require building two spare couplers which would be available at anytime, which the Committee strongly believes should be available given the well known lack of robustness of these components.

The Accumulator RF system is ready for commissioning after having already been tested in June '95. No problems are expected except in case of a window failure. Having no spare coupler available might delay the commissioning of the Accumulator by several months and again, the Committee recommends procuring a spare.

Control System Status

The installation of the control system hardware has made steady progress and is keeping up with the installation of the equipment that it controls. Similarly, generation of the low-level software drivers is also keeping place with the arrival of new equipment. It would appear that, if this level of activity can be maintained, all of the machine components can be tested initially using the final control system connections – a great advantage.

The production of the software for the middle-level software is not quite keeping pace so that no automated routines (such as hysteresis, automated RF switch-on etc.) are currently available. This has not limited the ability of the control system to support the commissioning of the transfer lines but is likely to be a serious limitation in commissioning the Accumulator Ring. Hopefully, this situation will have been rectified by the time the Main Rings are ready to be commissioned.

The high-level software is composed of two parts. The first, the creation of the environment and libraries is well advanced, seems to be rational and is well documented. This environment was specifically designed to accept Fortran code to facilitate the use of code used for simulation and to help non-controls experts write code. It was also designed to enable the accelerator physicists to participate in creating the high-level controls. It is rather evident that, for a variety of valid reasons, this has not yet occurred. The Committee believes that this is about to become a crisis situation with the commissioning of the Accumulator.

The Controls Group is to be commended on the amount of work that they have been able to achieve, especially since two members of the Group have left over the last year, but it is not reasonable to expect that they can continue to keep up without additional help. It is already late to be trying to augment the Group, as any new person will initially be a drain on the Group until they are trained. The Committee strongly urges the Project Leader and the Laboratory Director to examine all possible means for rapidly adding additional personnel (at least three) to the Controls Group and, in addition, the accelerator physicists need to be freed up to participate in producing the high-level application programs.

Vacuum System and Diagnostic

It is a pleasure to see the fruits of many years of effort by both the Vacuum and Mechanical Groups. The positron arc chambers are now all built. The test results showing both an extremely low outgassing rate and low base pressure are indications that the vacuum processing technique is correct, and that there is an extremely smooth surface finish (0.2 μm). It is suggested that one of these chambers be moved into the DAΦNE Hall for installation and alignment practice. The clearing electrode design has been selected after careful evaluation. The Vacuum Group should proceed to complete the electron arc chamber fabrication.

There are numerous other type of chambers that need to be fabricated, especially the injection straight and RF straight sections. These chambers should be made available to the installation and alignment team as early as possible. With the very late delivery of some dipole magnets, the pre-installation of all the straight sections will substantially reduce the duration of installation after the delivery of the final dipole.

Magnetic Measurements

The magnetic measurements carried out so far show that all the measured components comply with the specifications. The field quality is satisfactory. From the point of view of the schedule, the most stringent requirements are set by the delivery of the main dipoles, which will be completed only by December '96.

Priority should be given to the outer arc dipoles, which are necessary to install the vacuum chambers, over the ones of the inner arcs which can be installed at the last moment.

It is important to complete the test of the sector dipole magnet prototype as soon as it is delivered to LNF, in order to use the dipole measuring bench solely for the measurement of the wigglers and production dipoles in the second half of '96.

This is a critical area for maintaining the overall schedule and which requires additional staff, as it is not possible to find external personnel who can do the job.

The required magnet operating range should be carefully evaluated so that the de-gaussing cycle can be as small as possible. This will minimize the hysteresis effects and improve the reproducibility of the machine settings. Similarly, the machine will be more reproducible if the magnets are always brought to the set point from above. This avoids creating a smaller cycle when the magnet is switched off which can produce small residual effects.

Diagnostics

The Committee expressed some concern on the functionality of the 6-button BPM for the detection of orbit displacements for two simultaneous beams. The Committee recommends continuing the studies to demonstrate the theoretical feasibility of the technique, assuming that the beam intensities and the sensitivity patterns are known for all the buttons. The calculations should attempt to quantify the accuracy that can be obtained in real-life operation when errors are included.

Nevertheless, the 6-button BPMs are considered to be useful diagnostic elements for obtaining an approximate beam position measurement during the Day-one phase, especially since directional couplers at positions nearby are extending the information about the orbit positions. The installation should therefore proceed in parallel with the theoretical evaluation.

Electronics

The Committee appreciated the considerable progress which has been made in this area and the high level of experience which has been accumulated by the Electronics Group. It took note with satisfaction that the timing system is completed, tested and ready for installation in the field. Also the control of the major diagnostics, such as current measurement, stripline reading and synchrotron light monitoring is ready to be operated from a medium level control panel for the commissioning of the accumulator.

The integration of these systems into the higher level of the control system is less advanced, and consequently the use of high level software routines for the initial commissioning and tuning of the accumulator will be delayed. Since the overall commissioning time has to be shared between the accumulator and positron production, the scheduling of the commissioning sequences should take into consideration the likely late arrival of the high level control of the accumulator, since a lot of time could be wasted in performing the operations from lower levels of the control system.

The Committee strongly supports the approach of using the accumulator to test equipment and software required for the main ring, as this will certainly speed up the final commissioning. This should be done, not only for systems which are identical for both rings, but also for any system from the main ring which can be integrated into the accumulator for test purposes with some reasonable effort.

Conclusion

The Committee expressed its concern about the interference between the installation of the detectors and the machine commissioning. The LNF Director needs to establish prioritized laboratory goals for DAΦNE from which a global commissioning strategy and plan can be derived for both the machine and the experiments, designed to meet these laboratory goals. The plans should include the conditions that must be met prior to installation of an experiment in DAΦNE – both the machine conditions that must be achieved, as well as the state of readiness of the experiment that should be demonstrated.

Similarly, there needs to be a top-level commissioning strategy for commissioning the machine with a good estimate of the order of the activities and a rough idea of the schedule so that the appropriate software can be prepared logically. Given the small number of people at Frascati who have commissioning experience, the Laboratory Management should make every effort to attract visitors with the appropriate experience to participate in the delicate phases of the commissioning.

There also needs to be a clearer definition of who does what in the coming year. This will be a tough year, with installation proceeding in parallel with commissioning and it is extremely important that every member of the Project Team knows what is expected of him or her, and what are the relative priorities when several tasks are assigned to be worked on simultaneously. Finishing one task perfectly while another task lies untouched is not acceptable, when all of the tasks are intermingled and non-completion of a task can strongly impact the work of a colleague.

The Committee has been extremely impressed by the professional work that has been carried out and is certain that everyone working on the Project can see the results that have already been obtained. Continuing in the same way will ensure that DAΦNE will be a machine that everyone can be proud of.

The next Review will take place as follows:

11th Review will be held on October 8-9, 1996

The Agenda of the 11th Review should include presentations on:

- Global installation strategy and schedule
- Global commissioning strategy and plan
- Detailed Accumulator commissioning results including first operational experience with the Control System
- Main Ring pre-commissioning and commissioning strategy
- Interaction Region layout.

DAΦNE PROJECT
PRINCIPAL MILESTONES

MAY 96 **BEGIN LINAC (e^+) and ACCUMULATOR COMMISSIONING**

DEC 96 **MAIN RINGS INSTALLATION COMPLETE**

For the last milestone there is no contingency.

The new INFN labor contract, which contemplates overtime's reduction, can have some impact on the last milestone.