DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

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DAΦNE PROJECT REVIEW

Frascati, July 5-6, 1994

Reviewers F. Bonaudi (CERN)
D. Boussard (CERN)
J.-P. Delahaye (CERN)
A. Hutton (CEBAF), Chairman
A. Wrülich (ST)

Overall Project Progress and Status

The Committee was pleased to note that the project has now received official authorization to install and commission DAΦNE. In addition many hardware prototypes have been delivered and tested since the last Review. The successful operation of the high current Linac which reached the design output current of 4 A at about 200 MeV during testing at Titan Beta was extremely welcome news. This result was obtained with only 5.9 A of injected beam (65% efficiency) compared to the specification of 40% which will result in lower activation of the gun region of the Linac.

More worrying is the accumulation of minor delays in almost all of the contracts. While it is difficult to know how the Project Leader could speed up these delays, it is already clear that all of the schedule contingency has been used up. Specific worries are the availability of the electricity and water utilities in the Linac building, which is already adversely affecting the Linac commissioning schedule, and the expected delays in the utilities for the other buildings.

The scheduling of the early operation of DAΦNE will be extremely complex. The Committee feels that the Laboratory Director should provide a global schedule for the start-up of DAΦNE, including the installation of the experiments. The Committee believes strongly that the experiments should be assembled outside of the accelerator hall and moved in only when certain pre-determined machine and detector milestones have been met. Clear definition of these milestones now will avoid conflict later. It will be the responsibility of the Project Leader to ensure that the machine components do not block the access path for the installation of the detectors in the accelerator hall.

Control System

The Controls Group has made major steps forward in every aspect of the design. Of particular note are:

- Operation of the kicker using the control system; resolving problems of operation in an electrically harsh environment.
- Definition of the system software environment.
- Definition of the application software environment including writing a large portion of the applications library.

Future work should now directed towards making the control system as robust as possible. Providing a back-up to CARON is only the first step. A study should be performed on the impact of broken or defective computer hardware to decide on whether other redundant elements are needed and in particular which control devices system should be on Uninterruptable Power Supplies (UPS).

The overall architecture of the Control System should be revisited to ensure that the operations environment is cleanly separated from the development environment by a "bridge". The development environment should also foresee the need for the software staff to access the system from their homes to speed up debugging of the inevitable problems that arise during commissioning.

The work on the database structure has begun. However the Project Leader should establish who is responsible for the accuracy of the numbers in the database. This is not usually the responsibility of the Controls Group, rather a person in each hardware group should take ownership of the database which affects that system. Even so, errors and inconsistencies will creep into the database and the Controls Group should carefully examine the robustness of the control system to database errors and should provide clear and helpful diagnostics to facilitate correction of these errors.

A similar separation of responsibility is necessary for the software. Requirements documents must be generated by the hardware groups, the accelerator physicists, and the Operations Group. The code will be produced by the Controls Group which is also required to put in place a code management system. Specific programs that are the responsibility of the Controls Group are the Save/Restore, Archive, and Alarms programs which need to be addressed soon.

The synchronization scheme was addressed but the solutions presented were not totally convincing. This is due to the lack of a clear set of requirements which should be produced by the accelerator physicists (the magnet ramp rate, the maximum permissible error, etc.). The Committee recommends adopting one standard solution rather than offering many options - flexibility is the enemy of operability.

The use of multiplexed digitizers to display wave forms from around the site is an excellent choice. The Committee would like to see a detailed list of digitizers and their locations, rather than general ideas. In particular, careful consideration must be given to which wave forms are required simultaneously to properly distribute channel assignments. For example, all of the kicker wave forms should be visible simultaneously.

The Committee is pleased to see that development has started on High Level Application Programs and that powerful software tools are being developed for a mode of operation based on accurate modeling of the ring optics. The verification of this model with measurements performed with beam will be one of the priority tasks during the commissioning phase. This is why full flexibility of the model should be implemented with the introduction of calibration ("fudge") factors for the main parameters to allow a precise matching of the theoretical model and the real machine. These factors are extremely useful as a figure of merit of the model to keep track of differences between theory and measurement and to help in localizing and eliminating possible errors. The on-model should be strictly confined to those functions used on-line to reduce the complexities of code management. Specifically, the lattice should be stored as single elements (not compressed) and features such as tracking are not needed on line.

In conclusion, the Committee is favorable impressed with the quality and quantity of the work performed by the expanded Controls Group since the last Review, but the pressure should be maintained to ensure that the Control System is available in time for commissioning. The Committee recommends that a member (or members) of the Controls Group visit an operating accelerator for a couple of weeks to gain practical experience of the real life problems facing a control system in an operating environment.

Visit to the Kickers Laboratory

The Committee was pleased to visit the Kickers Laboratory for at least two good reasons: First, the experimental results obtained with the kicker prototype and power supply are excellent with a quasi-perfect shape of the kicker pulse. Secondly, it provides a realistic test stand for the Control System to provide local control of a specific system including the observation of pulsed analog signals in a particularly noisy environment.

Even though the Control System was configured without the (Purgatory) CARON data router, the test set-up will give non-controls experts useful operational experience of the computer control structure foreseen for the whole facility.

The Committee encourages the hardware experts to use this facility as much as possible not only to test the reliability of the equipment but also to get use to the Control System and to suggest any possible improvement and modification for a user-friendly, effective interface.

In other machines, the kicker system usually causes a large fraction of the machine downtime. Every effort should be made to increase the standardization and modularity of the equipment to reduce trouble-shooting and maintenance time as well as working on increasing the reliability of the hardware itself.

Transverse Beam Stability

The transverse behaviour of the beam has been carefully re-evaluated, taking advantage of the very complete knowledge of the various contributions from the different elements to the ring impedance which had been obtained previously.

The transverse stability of the single bunch operation in DAΦNE is particularly reassuring with resistive wall instabilities easily damped by chromaticity correction in the most favourable tunes just above the integer, and with a threshold of the mode coupling well above the designed current for a reasonable bunch length.

The multibunch transverse instabilities are more of a concern with expected rise time much shorter than the natural damping times by synchrotron radiation. Nevertheless, operation with 30 bunches is reasonably safe with rise times well within the capabilities of the transverse feedback system which has been designed. Naturally, this result requires that the most critical high order modes of the cavity are sufficiently damped. On the other hand, operation with 120 bunches is just at the limit of the feedback performance and will have to be carefully reviewed after beam commissioning once the overall impedance of the ring has been precisely measured.

RF System

The major elements of the Accumulator RF system: cavity and RF power generator are expected by the end of the year. There is an additional delay for the cavity fabrication related to some welding difficulties of the cavity vacuum port but, at present, none of these elements is on the critical path.

As the final installation and testing of the accumulator RF system is foreseen for the second half of 1995, a heavy testing period for the RF group can be anticipated for the end of 1994. The Committee was impressed with the excellent new facilities that are available to the RF Group for testing. This should facilitate the considerable amount of detailed acceptance testing that will be required for all of the RF components.

The Committee took note of the excellent results of the preliminary control board for the accumulator RF system and suggests that in the final design, enough flexibility should be provided to accommodate future changes.

The contract for the first main ring cavity is about to be awarded (although work has already started at the vendor), with delivery expected by the end of 1994. The fabrication technique chosen (machining out of a single solid copper forging) is in principle a low risk one and therefore no particular difficulties are expected. The auxiliary elements: main coupler, tuner, HOM waveguides either exist already or will be available by the end of the year for high power cavity testing in early 1995 using a tetrode amplifier.

The HOM waveguide and transitions have been tested under vacuum conditions and no multipacting could be detected up to 1 kW of transmitted power at 742 MHz. This is a very positive result which will have to be complemented by the full cavity test to investigate possible multipacting effects in the waveguide at the fundamental frequency. The prototype waveguide coupler for the cavity tapers has been measured and showed a satisfactory response.

The 150 kW klystrons are delivered and low power tests have already shown good performance, especially concerning the critical group delay parameter. Power tests should take place before the end of the year.

Further studies of the cavity resonances have been presented to the Committee which confirm the previous results. In particular the use of the new code HFSS to evaluate the loaded Q's of the various modes in both the main cavity and the 3rd harmonic cavity was quite impressive.

Similarly the simulations of beam instabilities taking into account the detailed cavity behaviour (including the RF feedback) have demonstrated directly the validity of the solutions already adopted.

Vacuum System

The Vacuum System in general has made good progress. Specifications and constructional drawings have been finalized and issued for the first major components of the main rings. In particular, the arcs and straight section chambers are being ordered from the same manufacturer who made the prototypes.

- The thick aluminium alloy plates have been ordered, and some are on hand.
- The wiggler prototype chamber has been shipped to the manufacturer of the wiggler to ensure the proper fitting of the two elements together.
- The positron ring chambers will be made first: the present schedule foresees that both rings should be under vacuum just in time for the DAΦNE commissioning (June 1996).

We recommend that the necessary drawings and specifications for all the remaining vacuum components (chambers, pumps, gauges, absorbers, etc.) be completed in Autumn 1994. In particular, the final details of the arc chambers should be finished up as soon as possible to free the designers to work on the detailed vacuum layout of the straight sections upstream of the detectors.

The surface finish and cleaning of the aluminium chambers is still subject to some studies and confirmation; an apparently satisfactory treatment is based on a chemical detergent dissolved in water. The Committee feels somewhat uneasy about the "black magic" aspect of vacuum surface technologies in general (i.e. not limited to the DAΦNE project alone).

The titanium sublimation pumps are under study for final optimization (filament operating conditions, lifetime, titanium adhesion and flaking off). The NEG pumps for the intersections are under final design and look satisfactory.

It is recommended that "official" residual pressure profiles be issued (for different machine conditions), so that everybody uses the same assumptions for calculating backgrounds and lifetimes.

Visit to the DAΦNE facility

The Committee visited with great interest the building site (Linac wings, accumulator and main DAΦNE halls, auxiliary buildings) and was pleased to see the progress already made. However, it was noted that the installation of the services (electric power and cooling) for the Linac will be late relative to previous schedules (now foreseen to be ready in November '94) and this will affect the installation and commissioning of the Linac. It is very important to expedite this phase as much as possible.

Some of the DAΦNE prototype work was also visited (magnetic measurements, permanent magnet quadrupoles, klystrons for main rings, cavities, kickers, etc.) and, whenever appropriate, comments are given in the relevant sections.

Since the visit occurred during an extremely hot day, the Committee was made aware of the large temperature differences that exist on the site. The Committee recommends that the Project Leader carefully evaluates the thermal stability of the various machine elements, including the control elements and power supplies, to establish the requirements for additional heating, cooling, forced ventilation or air conditioning where appropriate. The latest generation of accelerators tend to have tight tolerances which can only be met by aggressively attacking the diurnal thermal cycles.

Main Ring Optics for Day 1 and with KLOE and FINUDA

The Committee heard with pleasure that the solenoid characteristics of KLOE and FINUDA are defined now, which allowed the interaction region optics to be finalized and the corresponding optical functions to be matched to the arcs. The same concept of solenoid compensation has been adopted for both experiments, with identical solenoid compensators, placed at the same distance from the interaction point. They have been moved outwards toward the splitter magnets in order to give more space to the experiments. Since the compensators are frozen now, the call for tenders can be initiated.

The new iron geometry of the KLOE magnet improved the end field characteristics so that all three quadrupoles are now in the flat top region of the field. The apertures of the QF2 quadrupoles have been increased in order to improve the background. Magnetic measurements at the company have been performed for the two prototypes of the QF1 permanent magnet quadrupoles. After shimming and tuning, the elements are now better than the specifications (by about a factor 2) and can be considered as final. New specifications for QD1 and QF2 will be given to the vendor.

The FINUDA optics could be improved by reducing the vertical beta function in the second quadrupole which considerably reduced the vertical chromaticity.

For the finalized optics, the tracking calculations have been repeated and have been found to be not very different from the previous calculations. Also, the inclusion of the measured multipole errors of the two QF1 quadrupoles did not alter the results very much. The same errors applied for the QD1 generated a considerable reduction in the dynamic aperture, which demonstrates that more care has to be taken for these magnets.

The lattice configuration without experiments and the DAY-1 optics have been presented. Tracking calculations have been presented which demonstrated a good non-linear behaviour and a sufficiently large dynamic aperture. The tracking should be repeated to include the non-linearities in the fringe field of the permanent magnet quadrupoles since the beams pass off-axis in these magnets.

The Committee expressed some doubt if the interaction point in the DAY-1 optics should be blocked by a quadrupole. It underlined once more the importance of having as many diagnostics as possible right at the interaction point to enable tuning algorithms to be developed. On the other hand, the Committee understands the importance of having a DAY-1 optics which is at least as simple as the operations optics, which was a feature of the solution presented. Conclusions on this topic should be presented at the next meeting, together with some initial thoughts on the commissioning strategy which would clarify the relative importance of the instrumentation at the Interaction Point.

Background for experiments

A very important contribution to background due to the Toushek effect, which is not present in other factories, has been identified and analyzed in detail. As a first remedy, a larger aperture for QF2 has been adopted, and adjustable horizontal scrapers have been proposed on the incoming beams just upstream of the splitter magnets.

A careful study of the effect of these scrapers on the beam lifetime (mainly because of the Touschek scattering) shows that acceptable conditions should be obtainable for the physics runs.

A simulation study has been started of the expected background (off-momentum and Coulomb-scattered electrons; beam-gas bremsstrahlung photons) reaching the KLOE detector. The real machine and experiment geometry (magnetic fields, obstacles etc.) have been used in the Monte Carlo program. The most important source regions and particle pathways have been identified.

The Review Committee supports the decisions already taken and recommends that this work should be continued (and later extended to FINUDA), including the simulation of the showers induced in the various materials located inside the detector. The goal of this work is to determine if the calculated background rates in the detector are acceptable. In this regard, it is important that all of these calculations use the same "official" vacuum pressure profile for standardization and cross-comparison.

Interaction Region Design Updating

The mechanical design of the Interaction Region is particularly critical because of the fragility of the 500 μm thick beryllium vacuum chamber in the center of the detector and the necessary flexibility for the precise orientation of heavy permanent quadrupoles close to the Interaction Point. There are also strict requirements for minimum shielding of the detector in this region, particularly at low deflection angles so no reinforcing structures can be permitted (other than removable installation supports).

There has been good progress in finalizing the position and support structure of the compensating solenoids which are now identical for the two detectors. The Committee was pleased to note that both experimental collaborations have finalized the magnetic field profile. The Committee heard that the FINUDA experiment expected to run at the full detector field (1.1 Tesla) for at least two years after which a single change of current to 80% of this value is foreseen. The Committee found this a reasonable scenario and foresaw no difficulties in re-engineering the Interaction Region for the new parameter set at that time.

The Committee is especially concerned with the progress of the interaction region mechanical layout for both detectors, taking into account the $1^1/2$ to 2 years time that has usually been necessary for the design and construction of such complicated areas in similar detectors elsewhere. The Committee strongly recommends that a dedicated meeting with all the parties concerned be organized for each detector on the detailed interaction region requirements as soon as possible in order to precisely define the technical ground before the next LNF Scientific Committee on 3-4 October 1994. At least one independent physicist with practical experience on an existing detector with a similar interaction region should be invited to participate.

Conclusion

The Committee would like to congratulate the Project Team on the considerable progress that has been made. The major worry of the Committee continues to be the detailed design of the two Interaction Regions. In addition, the Committee is worried about the lack of contingency in the schedule.

The next Review will take place as follows:

8th Review will be held on 21-22 February 1995

The Agenda of the 8th Review should include presentations on:

- **FINUDA and KLOE Interaction Region**:
  Mechanical and Installation
  Background
  Alignment
- **Control System**
  Software Requirements
- **Instrumentation Schedule**
- **Linac**
  First Commissioning Results and Future Plans
- **Accumulator**
  Commissioning Plans
- **Main Rings**
  Commissioning Goals

DAΦNE PROJECT

PRINCIPAL MILESTONES

DEC 94	LINAC OPERATIONAL
SEP 95	BEGIN ACCUMULATOR COMMISSIONING
JUN 96	BEGIN MAIN RINGS COMMISSIONING

CONCLUSIONS

WE ARE AWARE THAT THERE IS ALMOST ZERO CONTINGENCY (SPECIALLY FOR THE LAST MILESTONE) BUILT IN OUR SCHEDULE, NEVERTHELESS WE ARE CONFIDENT TO MAINTAIN IT.