DAΦNE TECHNICAL NOTE

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DAΦNE PROJECT REVIEW

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Introduction

The project has moved into a new phase with the extremely successful first operation of the Injector complex – Linac and accumulator. While the Linac commissioning was the responsibility of Titan Beta, the INFN personnel, coordinated by Fernando Sannibale and Mario Vescovi, not only provided active support during the first commissioning but now are operating and improving the machine. The accumulator commissioning was the responsibility of INFN, coordinated by Andrea Ghigo, and the successful integration of all the systems and the rapid first operation (in time for presentation at EPAC) is an extremely positive indication of a successful outcome of the whole project.

Most of the other parts of the construction have made significant progress, with the major exception of the main ring magnets from Ansaldo which are now the last items for completion of the Main Rings. The Committee was extremely distressed to discover that late delivery of these magnets will lead to a delay of about six months in the project and urge the Project Leader, the Director of the Frascati Laboratory and the President of INFN to do everything in their power to speed up the delivery of these magnets*.

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* Immediately following the Review, a new magnet delivery schedule was delivered during a meeting with a senior representative of Ansaldo. This schedule shows the magnets arriving two months earlier than the previous schedule. The Committee was pleased by this response from the vendor but, nevertheless, encourages the Project Leader to follow the production closely.

The experiments have also made significant progress, but the expected order of completion of the three experiments is now not well separated, either from each other or from the accelerator completion. It is difficult to foresee how to best to optimize the machine commissioning and to provide the best physics within the constraints. This is an area that will require careful attention in the coming months. The most important thing for the Project is to maintain the most aggressive installation schedule possible.

Status of Experiments

As a general remark, all three experiments should define the minimum initial beam and background conditions which are acceptable to their apparatus to aid in evaluating different commissioning strategies. The three approved experiments have now reached such an advanced state of development and construction that detailed preparations for their installation around the machine are possible.

DEAR

The experiment is conceived for occupying either of the two intersections as soon as the central insertion quadrupole can be removed. The thin wall vacuum chamber (90 mm internal diameter, 0.25 mm Al plus 0.67 mm Carbon fiber composite) will be provided by DEAR: two prototypes for vacuum tests by the DAΦNE machine group and two final ones have been ordered.

Since the experimental apparatus sits completely outside (above) the beam tube, rapid installation and removal are possible. For this purpose, all of the experimental equipment is mounted on a platform. A simple version for background measurements will be installed initially, to be replaced later by the final version.

By May 1997 the entire apparatus is expected to be tested and available.

Easy exchange of information on machine conditions and on background between experiment and machine should be foreseen right from the start to enable the measured background to be correlated with machine conditions.

FINUDA

The construction of most of the detectors is very advanced or even complete (scintillators, drift chambers, straw tubes). The Silicon micro-strip production has started and the robot for their installation is being manufactured.

The spider-shaped "clepsydra" support has arrived; the signal-cable transporter system (portal structure and drum) are on site and the rails have been installed in the pit.

The main uncertainty concerns the magnet (both quality and planning-wise): it is now suspected that the superconductor cable used in the already wound and impregnated coil is sufficiently lousy to limit the operating magnetic field well below the planned 1.1 T. The real value will however only be known when the coil will be cooled and tested at the factory (early in 1997). Barring new bad surprises, the complete magnet (tested and with field map measured) could be delivered to Frascati at the earliest in April 1997.

Since the operating value of the magnetic field will affect the specifications of the permanent magnet quadrupoles, and possibly the aperture of the thin vacuum chamber, the order for these items will be kept in abeyance.

The delivery of the Helium refrigerator/liquifier from Linde is expected in May '97, i.e. in time for the operation of the large solenoids and of their compensators. In order not to interfere with the installation of FINUDA into its pit, a section of the helium transfer line can be left out, while still allowing the thermodynamic tests and acceptance of the main Linde supply.

The FINUDA installation schedule requires 3 months (at 3 shifts/day) of work inside the DAΦNE hall. This needs careful scheduling in order to take advantage of machine-off periods.

KLOE

Close to 100% of the electro-magnetic calorimeter modules have been built. All of the components for the wire chamber are on site and tested: the stringing will start at the beginning of November '97 and continue for about 8 months. A system test will be run early in '97 with some calorimeter, final electronics and DAQ.

The magnet has made good progress: the coil has been wound at Oxford and installed in its cryostat; cooling and tests at 1/2 current will start in November '96. Coil delivery to Frascati is expected in April '97. The steel (now about 3/4 complete) is being pre-assembled at INNSE Milano; by end February '97 the steel should have been transported to Frascati and re-assembled, ready to receive the coil. Cooling and tests (using the Linde liquefier) should start in late Spring, with field mapping in June/July.

The KLOE assembly hall is still not available (draining, final flooring, rails, door, general cleaning, etc.).

The thin wall Be chamber with its spherical central part and screen is being fabricated.

The design of the permanent-magnet quadrupole assemblies, with their 5 degrees of freedom adjustments on each side, is now in the final stage (selection of components and materials, etc.). A recent complication was the addition of a heavy (450 Kg) sleeve-like calorimeter surrounding the quadrupoles which must be supported from the outside.

Machine Overview

The big news is obviously the successful results from the Linac and the Accumulator which are addressed below. As part of this, the Control System had its first real test which went extremely well. The control of the transfer line and the Accumulator implied that all three levels of the control system be operational and software drivers for examples of all classes of machine component be functional. The only hardware problems found was that the use of coaxial cable for communication links seems to be excluded, even for short distances. The use of optical fibers, foreseen for the long distance connections was successful and this will now be the standard for all the project. The high level software has been run off-line but now needs to fully tested in real-time use. The Committee strongly recommends continuing commissioning of the Accumulator until all aspects of the Control System have been fully tested.

Civil construction has made progress with the Finuda pit virtually complete and the KLOE pit close to completion, although this part is somewhat late. This means that the DAΦNE Hall can be closed completely within the next month to permit installation of clean components. The cooling systems are within a month of completion while the electrical power distribution is delayed due the bankruptcy of the original contractor. Fortunately, the Project has been able to re-award the contract and work has already begun. This will lead to some delays in the checkout of components (this does not affect the cabling from the power supplies to the machine components and so should have minimal impact on component installation).

The refrigeration contract was let in January and is expected to be completed in May, just ahead of the time when the experiments need them. The only superconducting machine components are the compensating solenoids and these have already been delivered by Oxford Instruments and are in place in the Hall.

Of the eight Arc vacuum chambers, six are already complete and delivered, the last two are expected in November. The first RF cavity has now completed all acceptance tests with the final RF system and the second cavity is under construction.

The first version of the feedback system is operating routinely at the ALS, Berkeley where it is successfully controlling the coupled bunch instabilities. The production electronics for DAΦNE is now being built at SLAC and many of the boards are already complete and checked out. There has also been good progress on the power electronics and all of these components are due at LNF by December.

The Committee visited the DAΦNE Hall and was impressed by the quantity of equipment already installed and the high quality of the installation work that had already been carried out. The cooling water distribution was particularly well done. The cable trays were complete and ready for cable installation, which had not yet started. All of the stands were already in place and those magnets that had been delivered were installed. The vacuum components are on site but installation in the Hall awaits completion of the "dirty" installation work.

The principal worry of the Project Leader (and the Committee) is the scheduled late delivery of the large quadrupoles and, particularly, the main ring dipole magnets. Apart from minor delays that are to be expected in any large project, these two items (both from Ansaldo) can really delay project completion significantly. While waiting for these magnets, the Committee strongly recommends that the Project make maximum use of the time to finish whatever can be done – even when this means going out of the preferred order, and even when this means additional work.

Linac Status and Commissioning

A complete overview of the commissioning and performance achievements of the Linac was presented. Remarkable progress was achieved in the rather short periods dedicated to Linac operation. The functionality of all the subsystems was convincingly demonstrated.

In a four weeks period dedicated to electron commissioning, the specified beam parameters were reached and partly also exceeded. Positron commissioning was started in July and already at this first attempt parameters were reached which are very close to those required for injection into DAΦNE. An impressive improvement was achieved during the second commissioning period in October, when the gun current was increased from 4.5 to 7.7 A (nominal 8 A) and the conversion energy was brought from 80 MeV to the nominal value of 250 MeV. The excellent agreement between the theoretical prediction of the beam energy with the actual measured value, also indicates the perfect phasing of the system and the reliable power measurement.

It was demonstrated that operation in the decelerating mode for particle conversion increases the capture efficiency significantly. This enhancement provides a large margin for the klystron power requirements, since only 38 MW from each klystron (specification 45 MW) are required to accelerate positrons up to an energy of 515 MeV. Moreover, it is an effective method to reduce the momentum spread of the beam and consequently to enhance the beam acceptance in the accumulator.

As pointed out by Fernando Sannibale, it still has to be verified that the degradation of the klystrons occurring during the first two commissioning periods is limited to the first generation klystrons. The regular operations mode foresees equal powering of all klystrons at the minimum level necessary to accelerate the nominal positron current to 510 MeV and this should significantly increase the klystron lifetime. It is also foreseen to operate with four spare klystrons in house, starting with the storage ring commissioning. This gives a large safety margin, even if the next generation of klystrons has problems. Although the situation is not dramatic, it is recommended to order one Toshiba klystron and to perform the necessary modifications for implementation of it in the existing system.

The Committee agrees that a Linac commissioning period should be scheduled in January, when the spare klystrons are delivered, to demonstrate nominal positron and electron performance parameters. These tests should be planned with a clear list of objectives to be attained, so that, subsequently, the Linac can be operated as a "turn-key" operation and all attention can be devoted to the downstream systems.

Accumulator Status

The Committee congratulates the team in charge of the Accumulator for the excellent performances already achieved in a very short first phase of the commissioning.

After a completion of the ring installation within schedule in December '95 and systematic tests of the various elements during the first five months of '96, up to 75 mA of electron beam could be stored end of June '96, after one month only of commissioning with beam. The beam performance is mainly limited by the reduced beam lifetime induced by vacuum outgassing from synchrotron radiation desorbing the vacuum chamber. The degassing rate rapidly improves with beam clearing, which augurs well that the nominal stored beam of 120 mA will be reached after a reasonable amount of accumulated beam dose.

The basic optics parameters, like tunes and chromatics were in excellent agreement with the theoretical model deduced from magnetic measurements. A precise resolution frequency and a closed orbit with 8 mm peak to peak in the horizontal plane and 5 mm in the vertical plane demonstrates the quality of the alignment. A momentum acceptance of +3.7%, -2.7% limited by the vacuum chamber dimensions, has been measured, in good agreement with the dynamic aperture calculation, which will be extremely useful for the accumulation and storage of positrons with large emittances and momentum spread.

The Committee recommends defining the parameters still to be achieved for a good characterization of the Accumulator, first with electrons, then with positrons once the Linac will have achieved an acceptable performance with positrons at the nominal energy of 510 MeV (presumably beginning of '97):

- injection and accumulation efficiency
- initial outgassing rate with synchrotron radiation and improved with beam cleaning
- beam lifetime versus vacuum performance
- equilibrium beam emittances and bunch lengths as a function of the bunch charge
- transverse and longitudinal beam stability.

An analysis of the measured natural closed orbit is under progress. A pre-correction of the closed orbit by physical displacement of the lattice quadrupole rather than by powering the correctors is recommended in order to minimize the errors at the source and reduce the necessary correction strengths.

Tests of the extraction system with electron beam and commissioning with beam of the transfer line downstream the Accumulator as close as possible to DAΦNE are encouraged as the best preparation for the transport and injection of the positron beam from the Linac to the Accumulator.

More generally, the early operation of the Accumulator is an excellent opportunity to get experience and test the control system as well as the high level application software and suggest possible modifications or improvements before the DAΦNE commissioning.

Non Sliding Contact Bellows

Two original designs of shielded bellows without any sliding contact were presented:

- a "bellows shielded bellows"(b.s.b.) where the shielding is provided by standard mini-bellows one close to the other, to equip the 20 bellows of the straight sections;
- an improved version of the "strip shielded bellows" presented at the last Review to equip the 16 bellows in the arcs.

The very good (and new) idea of the "b.s.b." design is well received by the Committee as a simple, compact and flexible solution. Nevertheless, the Committee recommends an evaluation of the capability of the heat transfer of this bellows taking into account all possible sources of power including synchrotron radiation from the nearby bending magnets and heat being conducted along the chamber.

The "strip shielded bellows" have been improved with respect to their thermal exchange efficiency between strips and spacers. The engineered mechanical design of this bellows can be improved, as the Committee found the prototype conceptually good but not totally convincing in its execution. The spacers between the strips should allow better electrical and thermal contact.

A number of impedance measurements, using the wire method, were presented to the Committee. The new version of the non-sliding contact bellows for the straight sections, using electro-formed "mini-bellows" showed a negligible (non measurable) impedance up to 3.5 GHz. This is in contrast with the case of an assembly of longitudinal strings which exhibited many resonances. The impedance of the undulator strip version has been shown to be negligible in the case of no lateral slot (version upstream of the bending magnets) and acceptably low in the case of a single lateral slot (version downstream of the bending magnet).

Six-Button Position Monitors

The committee appreciates the complete theoretical analysis which was performed on the six-Button electrodes. The precision is considered as sufficient for beam position monitoring for at least those electrodes which are at positions with nominal beam distances of 5 and 7 cm. The validity of their use at the interaction point for beam collision finding has still to be proved.

Ion Clearing Electrodes

The ion clearing electrodes and their electrical connections will become inaccessible after completion of the vacuum chambers. This has raised a number of questions concerning their long term integrity (especially after the baking cycles). The continuity of the electrical connections could possibly be checked using time domain reflectometry, or a similar method, although it is realized that the high electrical losses of the electrodes may render the method ineffective. However, some useful indication of a lack of change before and after bakeout would be extremely valuable as well as being able to go back and compare after a period of beam operation.

Radio-frequency

As expected the wire method measurement gave poor results for the impedance of the fundamental mode of the cavity but confirmed the damping of its higher order modes. With all wave guide dampers attached to the cavity the worst case higher order mode shunt resistance is below 350 Ω, up to 3 GHz.

A full size test of the RF system, including the RF feedback loops and the prototype remote control circuitry was presented. The klystron delay is stable and better than specifications. No problems have been noticed up to full cavity field, even with some amount of cavity de-tuning.

In the 120 bunches case, Robinson anti-damping takes place, due to the unusual shape of the dynamic impedance of the RF system.

This effect may be difficult to cure with a classical longitudinal feedback system as the coherent synchrotron frequency will rapidly decrease. A better solution, for the 120 bunch case, would be to use RF feed-forward (with one turn delay) to relax the requirements on RF feedback.

The second cavity should be delivered towards the end of '96, but at the moment, there is no RF window available (except that of cavity one) for cavity testing. The too recently delivered windows seem to have been badly titanium coated and must be returned to the manufacturer for disassembly and urgent repair.

The Committee recommends that installation of the RF system start as soon as possible and that, once installed, the RF Group make themselves available to assist elsewhere in the Project.

Magnetic Measurements

Measurements were presented on the main dipoles "Parallel Ends Short" (PES) and "Sector-like Short" (SLS), on the "Lambertson" H/V Corrector, on the "C" H/V Corrector and on the splitter magnet.

The Committee was impressed by the high level of professionality of work and by the care taken in setting the final magnetic length of main dipoles by machining of removable end caps. They was done taking into account real and nominal particle trajectories through the magnets. From these measurements it is anticipated that maximum beam energy reachable by the magnetic system will be 700 MeV.

Magnetic measurements have revealed a reduction of the path length in the bending magnet. It is recommended that the machine alignment be performed such that the nominal circumference compensates this effect to first order. Any resulting error in the circumference can be accommodated by adjusting the RF frequency of the Main Rings and the Accumulator. No deterioration of the injection efficiency is expected from a small error in the accumulator path length, but if necessary, the accumulator can be adjusted to its nominal circumference at some convenient later stage.

The measurements on the "Lambertson", "C" and Splitter Magnets are quite satisfactory. In particular the difficult splitter magnet appears to be of excellent quality, which is important given its sensitive position in the machine.

Installation Planning

Francesco Sgamma has done a thorough and creditable job in planning the storage ring mechanical and vacuum installation and alignment. In view of Ansaldo's schedule delay in delivering storage ring dipoles, large quadrupoles and sextupoles, the plan is to install the inner arc chambers and connecting straight section components first, followed by an approximate alignment after installation. The Vacuum Group will then proceed to install the ancillary equipment onto the arc vacuum chambers and make vacuum connections so that leak checking can be performed.

The Mechanical Group, in the mean time, can proceed to install and rough align the outer arc chamber and the connecting straight section components. It is useful to install and to align the outer arc chambers, even if they have to be removed when the long dipoles become available since this will shorten the duration of the final installation of the outer arcs.

The present alignment pillars are located within 0.2 mm of their intended locations. A repeatability check of the removable alignment pillars should be carried out to assure the soundness of the design.

Mechanical placement of the straight section components on their respective girders is complete. It is not a moment too early that the Alignment Group should proceed with the task of aligning the components on the girders. If manpower is the limiting factor preventing this work, the DAΦNE project should plan to obtain help from other organizations in Italy.

There are many types of equipment generating vibration inside the Main Ring area. It is important to isolate them from the storage ring floor. There are water mains located in the vicinity of magnetic components and it would be better if they are also isolated from the concrete floor.

There will be numerous activities going on simultaneously in the DAΦNE Hall. Therefore, a clean and quiet environment is very difficult to maintain during the vacuum-related installation tasks; such as installing photon absorbers, TSPs, SIPs, etc. It would be better if light-weight components can be installed in the vacuum laboratory prior to moving the chambers into the DAΦNE Hall. It is true that transportation will be much more risky with many components attached to the chamber, nevertheless, a careful planning and suitable transportation fixture will eliminate this possibility.

Following the Review, there was a meeting with G. Dalmut of Ansaldo which was very positive. He gave a credible reasons (both availability of machinery and manpower as well as the priority given to DAΦNE over other Ansaldo's contractual obligations) for shortening the delivery schedule. It looks feasible that the original 4/15/97 date can be moved up to 2/15/97. The sequence of delivery, unfortunately, cannot be altered without impacting the new schedule, but this should not be detrimental to the final outcome of the installation.

With this information on hand and believable, the DAΦNE internal schedule is on the critical path at the present time. The staff here should not confuse the enormous amount of components crowding the DAΦNE Hall with completion of all the real installation tasks. Most of this equipment is either not mounted or not aligned. The cooling system is far from complete; cabling has not yet started; transfer line components are not placed; the wiggler magnetic measurements have not been done and need another 40 days for completion; the serial production splitters and some of the correctors are still in the vendor's plants; the vacuum-related installation plan has not been thought out carefully; RF power supplies are not in place; control/diagnostic wiring harnesses are not pulled; many vacuum components are still being made (the last elements may come as late as January next year); the control room is still vacant; etc., etc. There is an enormous amount of work still to be done and yet there is not much time left.

The final completion date for DAΦNE is not in the hands of a few vendors (every project has problems with a few vendors) but is firmly in the hands of the Project staff. It is vital that the entire staff push ahead aggressively with completing the installation and checkout, even if this means crossing Group boundaries.

Conclusions and Recommendations

- Ensure that delivery of the remaining magnets stays on schedule by all means necessary. In particular, the Committee recommends sending someone to Ansaldo at least three days a week, if not full time, until the last magnet is delivered. The mere presence of this person will maintain pressure on the manufacturer.

- Assign a person to coordinate all of the system integration for DAΦNE main rings, as was done by Sannibale for the Linac and Ghigo for the Accumulator. This is in addition to the excellent job being done by Sgamma for component installation, but needs to be integrated with his schedule.

- Assign one person from the Machine Group to be the interface with each experiment to facilitate communication. The person should be able to make decisions and fix all of the multiple small problems that are guaranteed to come up and which should not need the intervention of the Project Leader to resolve.

- Put maximum pressure on the civil construction firm to complete the KLOE Hall so that it can be sealed off with the shielding wall. This will permit installation of "clean" equipment to start in DAΦNE and will also allow the KLOE group to start transport tests of their wire chamber.

- Complete the Linac and Accumulator commissioning with the goal of producing electron and positron beams of nominal specification at the temporary wall between the Injector and the DAΦNE Hall. This should be done entirely under computer control and will test the extraction and all of the pulsed magnets that have not yet been exercised. The Committee would like to see this work completed ready for the next Review, in time to be presented at PAC in May '97.

- Given the likely collision between the construction of the experiments and the DAΦNE commissioning, the Project Leader should re-examine the commissioning strategy to start without the quadrupole at the interaction region. This would simplify the strategy by eliminating one step, and would also reduce the amount of modifications needed to install the simple version of DEAR. The Committee is strongly in favor of having information on backgrounds as early as possible in the commissioning.

- The Committee would like to see a parameter list set up with the theoretical parameters and a regularly updated list of experimentally obtained numbers. This is the best way of keeping track of progress and to ensure that nothing falls through the cracks.

The next Review will take place as follows:

12th Review will be held on April 22-23, 1997

The Agenda of the 12th Review should include presentations on:

- Installation Status
- System Integration Status
- Complete Commissioning Results from the Linac and Accumulator
- Global Commissioning Strategy including Integration of the Detectors
- Main Ring Commissioning Goals and Plans.