DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, January 13, 1994

Note: **G-23**

DAΦNE PROJECT REVIEW

Frascati, January 11-13, 1994

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Overall Project Progress and Status

DAΦNE has now progressed definitely into the phase of hardware ordering and fabrication. The Committee heard with pleasure the status of the various components and noted the considerable understanding reached in many of the areas that were indicated in the July '93 Review as being critical.

The first day of the Review coincided with the delivery on site of the first Wiggler magnet, a most auspicious event.

Specifications and ordering of the building work and of the utilities (cooling and electrical distribution systems) is well advanced, with one possible critical component being the installation of utilities in the Linac wing which need to be completed prior to Linac commissioning. The construction work on the DAΦNE Hall and KLOE building is expected to start within a couple of weeks.

The construction and assembly of the Linac at the manufacturer's plant (Titan Beta) has progressed well, as documented by photographs taken there.

The recent decision to ask the manufacturer to completely test the Linac with beam at the factory is welcomed by the Committee as a significant improvement, giving the best possible guarantee that reassembly and tests at Frascati will be successful. The running in at the factory will also profit from the expertise of SLAC personnel.

The delivery of the Linac at DAΦNE is expected during the summer 1994, with injection into the Accumulator scheduled for September 1995.

The Transfer Line hardware, ordered from Ansaldo, is expected in April 1995. The power supplies have also been ordered.

The Accumulator hardware, ordered from Oxford Instruments, should be delivered in August 1995: this contract seems to proceed very well, judging from the Preliminary Design Review prepared by the manufacturer.

The Accumulator building is about 95% complete and will be ready in time for installation of the utilities, the critical path item.

The engineering designs of the Main Ring are about 90% complete and much of the procurement is under way.

The Main Ring dipoles have been ordered from Ansaldo, with delivery times of 10 to 11 months (prototype), 18 months (first ring), 23 months (second ring).

The Main Ring Vacuum Chambers (reported elsewhere), which are on the critical path, are progressing well. The Aluminum plates have been ordered and full scale prototypes either exist (dipole chamber, under test) or are nearing completion (wiggler chamber). The contract for the fabrication of the final chambers should be placed in August 1994, with delivery dates spanning the period January 1995 to March 1996.

Concerning the RF cavities for the Main Ring, a change of technique was forced on the project by the prospective manufacturer. The cavities are no longer produced by electroforming, but by conventional fabrication out of solid copper forging; the Committee is worried that the delivery time now envisaged may be optimistic (10 months for finalizing the contract, and production and delivery of the first cavity).

The main milestone dates for DAΦNE have not changed since the last Review (commissioning to start in July 1996); but, as was pointed out by the Project Leader, the present sustained rate has to be maintained by everybody if the Project is to stay on track.

The Committee feels confident that the Project will continue to proceed well and wishes to record its high appreciation of the enthusiasm and competence of the Project staff.

Main Ring Apertures and Lifetimes

The beam lifetime has been estimated and the main limitations clarified. The calculated ratio of average to peak luminosity of 0.75 would be acceptable, but relies on a minimum beam lifetime of 3 hours, runs for physics of less than 1 hour and injection times as short as 10 min. The Committee recommends to check if all the necessary operations for intensity topping-up or refilling are reasonably taken into account and to review the implication of an increase of injection time on the average luminosity.

Taking advantage of the LEDA code specially developed, the locations in the rings where the particle are lost could now be precisely identified. This would allow dedicated scrapers to be introduced to localize the beam losses and reduce the overall background of the Ring and, more particularly, the detectors.

Finally a beam lifetime of 4 hours, has been estimated, mainly limited by Touschek lifetime, which looks sufficient. The lifetime is based on the present estimates of the RF and dynamic acceptances but is very dependent on the bunch length. For this reason the proposal to provide an independent adjustment of bunch length (by a higher harmonic cavity) is supported by the Committee.

Main Ring Optics and Dynamic Acceptance

Previous estimates of the dynamic aperture included the effects of magnetic field errors. The Committee is pleased to see that the detrimental effect of other sources of errors has now been included, especially a finite closed orbit and realistic quadrupole tilts. In all cases, the dynamic acceptance looks acceptable although there is little margin.

The low sensitivity of the dynamic acceptance to closed orbit deformations is especially reassuring. Nevertheless the Committee supports the effort to correct the closed orbit as much as possible. The effect on the dynamic acceptance of the synchrotron motion has still to be introduced.

A list of the acceptable fields errors and magnet misalignments can now be elaborated and discussed with the engineering group to check their feasibility.

The improved fringe field of the KLOE magnet is certainly more favorable for the machine characteristics as the Interaction Region Quadrupoles are now in the flat region of the magnet field. Because of the strong interaction with the main Ring Optics, the magnetic field calculations of the magnets from both KLOE and FINUDA detectors should now be rapidly finalized in order that the position of the magnetic elements in the Rings can be frozen. The machine optics, including the detector fringing field, should be presented at the next meeting of the Review Committee. This is necessary to begin the detailed design of the mechanical installation, which is one of the most critical items on the schedule.

The betatron coupling was evaluated including a variety of error sources. The results demonstrated that the nominal coupling can be obtained at the nominal tune. A necessary flexibility of the choice of working point within a reasonable range has to be demonstrated both from the optics and from the dynamic aperture point of view.

Finally, in the event that clearing electrodes with constant voltage cannot be introduced, the effect of RF shaking at the ion resonating frequency on possible beam displacement at the Interaction Point should be investigated.

Control System

The progress in defining the Control System has been most impressive in the last six months. The talks on the different aspects of the system were convincing and the system now seems to be launched in a good direction. A Mini-Review of the Control System was held in October (report attached) and some recommendations were made at that time on the future directions, including work that should be presented at this Committee meeting. The numbers of the comments below refer to this document:

1) A clear description of the Control System philosophy was presented and was extremely useful to the Committee, as it will be to the Project, in helping everyone to understand how the System functions.

2) Some estimates of the execution times were presented, but only for a restricted part of the information cycle (CARON). Over the last few months there has been a lot of improvement in the time taken to handle messages in CARON which is an identified bottleneck. However, a complete estimate of the time taken to execute some standard operations is still needed. This will help to identify other areas where speed is essential and will help to focus further work.

3) The WBS should be completed and made definitive. The Committee was pleased to see that some of the critical hardware items had already been ordered.

4) The layout of hardware has progressed satisfactorily. The Committee approved the decision to adopt a commercially available LEXTEL board instead of the custom OPLA board. This reduces the amount of development and should increase reliability.

5) A list of the application programs needed for the machine has been published and seems to be a good basis for starting the process of doing detailed design of these programs.

Following the presentations, the Committee had some specific recommendations:

a) Provide an on-line back-up or fast replacement for CARON (a single point failure in this one computer could incapacitate the entire accelerator).

b) Arrange to write error logs off-line onto tape at frequent intervals to ensure that trouble-shooting of machine problems is not impeded by a computer problem in CARON.

c) To speed up response time it will be helpful if the Control System permitted grouped commands (for example, simultaneous instructions to all quadrupoles to execute a change in the machine tune) and the message structure should support this. This will also remove one of the bottlenecks in the information flow.

d) A way of synchronizing events in the machine should be found. For example, how will BPM readings of successive turns be time-stamped so that an orbit can be measured on a specific turn. Correlation plots of events in different parts of the accelerator are one of the most important tools available in the Control Room and the Control System needs to provide this capability.

The Committee would like to congratulate the Control Group on bringing the system to a state where everyone felt confident that control of the machine would be satisfactory. Nevertheless, much work remains still to be done to finish the detailed definition of the hardware layout and to provide the system and application programs needed. The Committee would like to see these items addressed in the next Review.

Alignment

The method proposed for setting reference pillars and surveying the various machines and transfer lines was described.

The instruments to be used will be conventional, high quality ones (invar wires, theodolites and levels).

Expected error ellipses have been calculated and appear quite satisfactory. It was stressed that all the measurements can be done or repeated with all the DAΦNE components in place. However, as for other storage rings, this is not true when the KLOE and/or FINUDA detectors are installed and the movement of these heavy components can also affect the alignment of the nearby machine elements. Alternative survey paths have to be studied for these situations which are most critical in the region of the low-β quadrupoles.

Instrumentation

This was the first time that the general beam instrumentation has been presented to the Committee and we were all extremely impressed by the completeness of the proposal. The Committee fully endorsed the proposal with only a few minor comments.

It is suggested that Optical Transition Radiation monitors be examined as an addition (or alternative) to the fluorescent screens proposed. They could provide permanent monitoring of several points in the transfer lines as the detector (5 μ aluminum) does not significantly scatter the beam and might be able to be left permanently inserted.

It is recommended that a diagnostic station be provided at the end of the injection lines just before the DAΦNE rings to enable the injector chain to be tuned up prior to dumping or topping up the previous fill. This will help to minimize the time lost to the injection process and maximize the time for Physics.

In designing the electronics for the DAΦNE ring BPMs, the possible need for beam shaking should be borne in mind.

The possibilities of using synchrotron radiation to provide detailed information of the beam properties was presented. The Committee was worried that the vertical resolution (only 25% of the vertical beam size) was too coarse. In addition, vibration of the mirror mounts could degrade this resolution even further.

There were many options for highly sophisticated diagnostic devices presented, all of which provide useful information. A prioritized list of these instruments should be elaborated to ensure that the most important devices are operational on Day 1.

The discussion of the instrumentation for the interaction region addressed the hardware in a convincing manner. Several techniques for tuning up the luminosity were also presented based on work done at SLC and LEP. These techniques are not trivial and will require some time to be made operational. For example, the luminosity can be low for many reasons (transverse displacement of one or both beams, increased coupling, tilted beams, vertical crossing angle, vertical dispersion, minimum beta value displaced from interaction point, etc.) and the techniques need to be able to give some information on which effect is causing a reduction in luminosity. The Committee recommends that the Day 1 interaction region contain as complete a set of diagnostics as possible, including additional diagnostics exactly at the Interaction Point (wire scanner?), to be used in debugging these techniques. This also means that the software for these techniques should be available on Day 1.

Vacuum

Vacuum work progresses very well and is on schedule. The first prototype chamber looks impressive and the following features are noted:

a) The surface finish using ethanol as coolant is excellent, which results in very low outgassing ~ 5×10^{-13} Torr l/s cm^2.

b) The weld is of good quality and leak tightness. However, the weld prep should be changed to move the weld closer to the wall.

Good results have also been obtained with the Titanium Sublimation Pumps (TSP) and one can consider its associated problems solved.

The choice of 10 mm diameter for the Distributed Ion Pumps (DIP) is good and the measured pumping speed is in good agreement with the value predicted by the empirical formulae. The measurements should be repeated with a "plate type" DIP for comparison to see if this would be a more suitable pump.

Some suggested topics for further investigation are listed below:

a) the methods for mounting and cleaning of arc absorbers;

b) glow discharge cleaning;

c) a comparison of the desorption rates of ethanol and oil machined chambers using a simple electron gun.

Ion Clearing

The necessity for ion clearing is well documented and the Vacuum Group has an extremely good understanding of the problems as demonstrated by the simulations presented.

The implementation of clearing electrodes has to be studied further to satisfactorily resolve the following problems:

1) Good mechanical mounting;

2 RF heating of the long plates;

3) Sizes and locations of "button" clearing electrodes.

4) A stripline should be available for RF shaking in case it is needed for efficient clearing.

RF System

The RF cavity for the Accumulator is now in fabrication and should be delivered in May 1994, so that RF power tests on this cavity can start before the end of the year. No major difficulties are expected from the Accumulator RF system since the cavity design ($\lambda/4$ resonator) is classical, and the dissipated power fairly small.

For the Main Ring RF cavity, the technology (electroforming) that was initially proposed has been abandoned because of the unwillingness of the potential manufacturer to guarantee the specified mechanical tolerances in some critical areas. Instead, the cavity will be machined out of oxygen-free copper forgings, which are in the process of being ordered by LNF and should be delivered to the manufacturer next April. The tendering process of the cavity is now completed and the selection of the firm almost decided. However, even if the contract is signed next March, the foreseen delivery by 15th November 94 looks optimistic, compared to the fabrication times for cavities at other laboratories and considering that not all final construction drawings are available now. Full field cavity tests can only be done early in 1995, which in the opinion of the Committee means that there is insufficient time to correct any design problems and fabricate new cavities. The Main Ring RF system is therefore still on the critical path.

The uncertainty of the cavity behavior essentially depends on high power problems (the low power studies carried out by the RF Group are rather complete) and, in particular, the possibility of multipactor effects, especially in the vicinity of the waveguide openings. Plans are being made to coat this region with titanium nitride to reduce the electron emission. Similar problems may be encountered by the SLAC B-factory cavity which has a similar shape. The Committee recommends that progress on the SLAC cavity be closely followed, especially during the high power tests.

A detailed evaluation of the thermal behavior of the Main Ring cavity was presented to the Committee, and showed that the cooling circuit is adequate to guarantee an even temperature distribution and to permit some tuning of the cavity through the cooling water temperature.

Damping of cavity HOM's through a broadband waveguide coaxial transition in vacuum appears a very promising technology, confirmed by low level measurements. The test foreseen with two transitions in series under vacuum conditions should give very useful results as far as multipacting phenomena are concerned if sufficiently high power is used. Results are expected before the next Committee meeting. Special care in the design of the waveguides has been taken to permit titanium nitride coating, which the Committee believes will be necessary.

Progress on the Main Ring klystron looks very satisfactory: specifications are exceeded on most of the parameters, especially on the group delay, which is critical for the stability of the RF system under high beam current. The low level analog controls for the Accumulator and the Main Ring are well defined and all critical elements tested satisfactorily.

A higher harmonic cavity in the Main Ring would give an additional degree of freedom to adjust the bunch length. Beam dynamics effects of this cavity have been presented to the Committee, from the point of view of both bunch lengthening and Landau damping. In view of experience elsewhere, the Committee recommends against using such a cavity in the passive mode. In view of the additional flexibility offered by an active cavity, the Committee recommends that space should be reserved in each Main Ring for a higher harmonic cavity and its associated power source. Several geometries for a harmonic cavity have been considered and preliminary estimates were presented which showed that a suitable design is possible. More work will be needed to permit selection of the cavity shape and address the problem of the stability of the two RF systems (normal and harmonic) which are strongly coupled together through the high intensity beam.

Radiation Safety System

The Committee heard a presentation based on the document used for obtaining the required clearance from the competent Ministry. This particular procedure is in progress and proceeding with due speed.

The Committee considers that the basic principles adopted are sound, i.e. making the four areas (Linac, Test Beam, Accumulator and Main Ring) as independent as possible.

However, at the next Review, the functional aspects of the system should be presented, pointing out the actions resulting from the most obvious events that will occur (forcing a door, losing the vacuum, unintentional closing of valves, etc.). Various commissioning situations should also be considered. A list of the equipment that would receive the enable signals from the safety system should also be presented, together with the corresponding veto signals. The Committee is primarily interested in ensuring that the various commissioning operations (e.g. RF conditioning) can be carried out safely in one area while installation is proceeding in another area.

Interaction Region RF Losses

The evaluation of the interaction of the beam with the small cavity constituted by the 20 cm diameter spherical enlargement of the vacuum chamber in the Interaction Region of the KLOE detector was very convincing. The amount of RF power lost in the cavity as well as the unacceptably short rise time of the generated multibunch instabilities make it obligatory to shield the cavity from the circulating beam. This shield requires particular attention in this especially critical area in the middle of the Interaction Region, inside the detector, as it has to be thin enough to be transparent to the detector but thick enough for the 5 Amp of beam image current, and be equiped with slots large enough for adequate pumping.

Given the extreme sensitivity of the beam to such a small cavity, the Committee recommends carrying out a careful search for similar cavities all around the Rings and their systematic elimination or shielding from the circulating beam.

Interaction Region Mechanical Design

The proposed construction of the KLOE chamber and the layout of vacuum pumps was presented and discussed.

The Beryllium chamber design looks rather convincing, with the exception of the inner RF screen (50 μm of Beryllium), for which the Committee feels that brazing at each end is essential. This will ensure good contact for thermal conduction and prevent sparking. Several longitudinal slits in the shield would reduce buckling under thermal stress. It is recommended that the prototype chamber be thermally cycled during acceptance tests to see if there is any distortion by using a heat source (resistive wire) inside the sleeve. The final unit should be glow discharged before installation. The heat input into the screen (5 W) will raise the temperature by about 50 °C which is reasonable.

At the next Review the Committee wishes to hear a presentation of the proposed assembly and installation procedures, including temporary and final supports within KLOE, and surveying methods specific to the low-β inserction.

IR Vacuum Design

The vacuum system satisfies the pressure requirements of the experiment. However, as a general design rule, whenever any pump (NEG, SIP, DIP or TSP) is mounted directly above the beam, the beam should be protected by a solid surface to avoid dust particles falling through the beam and getting trapped.

The experience in the NSLS shows that there are a lot of "dust particles" observable after long shut-downs but only during the first month of operation. These events decrease from ~10 per day to 0 in about a month. It is worth mentioning that there are no pumps mounted above the beam in the NSLS.

The pump layout (already presented at the last Review) has not changed, but progress was made in the understanding of the distributed ion pumps and of the NEG pumps allowing the detailed design to proceed.

Conclusion

The Committee would like to congratulate the Project Team on the way that they have continued to make difficult design decisions on a tight schedule. The major worries of the Committee continue to be the detailed design of the two Interaction Regions and, to a lesser extent, the Control System.

The next Review will take place as follows:

7th Review will be held on July 5-6, 1994

The Agenda of the 7th Review should include presentations on:

- FINUDA and KLOE Interaction Region:
  - Mechanical
  - Vacuum
  - Background
  - Alignment
- Control System:
  - Software Requirements
  - Detailed Hardware Implementation
- Instrumentation schedule
- Engineering Status
- Linac Commissioning Plans
- The Personnel and Machine Safety System (not including radiation shielding).

PRINCIPAL DAΦNE PROJECT MILESTONES

Aug 93 ADONE DECOMMISSIONING COMPLETE √

BEGIN CONVENTIONAL CONSTRUCTION √

- *requires contracts awarded and ready to go (May 1 and Sep 1)*

OK (just now)

Dec 93 MAIN RING ENGINEERING COMPLETE

~ OK (>90%)

May 94 BEGIN INSTALLATION OF LINAC

- *requires beneficial occupancy of Linac building + utilities*

Dec 94 LINAC OPERATIONAL

Feb 94 BEGIN INSTALLATION OF MAIN RINGS

- *requires beneficial occupancy of DAΦNE hall + utilities*

Sep 95 BEGIN ACCUMULATOR COMMISSIONING

Dec 95 PROJECT CONSTRUCTION COMPLETE (ALL COMPONENTS ACCEPTED)