DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, July 22, 1993

Note: **G-20**

DAΦNE PROJECT REVIEW

Frascati, July 13-14, 1993

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Overall Project Progress and Status

The Committee noted the progress made since the last Review and is pleased to see that the major Project milestones set at that time have all been met.

A number of important events have taken place (decommissioning of the old Linac and of ADONE, detailed engineering studies of many DAΦNE components, tendering actions, placing of contracts). The Committee was very impressed with the quality of the specifications written for the accumulator and transfer lines. This style of working should ensure that there are no surprises when the hardware is delivered.

The overall completion date of DAΦNE has been postponed by 6 months ("Installation/System check out", now to be finished at the end of June 1996), reflecting in particular, the delays noted in the last Review with respect to the availability of buildings. The Committee stresses that all efforts must be made to avoid further delays. In particular, every effort should be made to complete the installation of the utilities (electrical power substation and cooling system) in the linac tunnel and klystron gallery before the linac is delivered by Titan Beta.

It was particularly pleasing to see the progress made in the following systems:

- Study of KLOE Intersection Region;
- RF cavity for the Main Rings;
- Feedback system;
- Vacuum system,

as discussed in the individual chapters of the present report.

The Committee heard with interest the new proposal for a low-beta insertion based on solenoidal focusing.

Main Ring Optics

The main ring optics with the interaction regions designed for various operating conditions has been discussed. Optimized solutions have been presented which respect all the necessary boundary conditions to reach a high luminosity, i.e. large emittance to store high currents, small vertical beta function at the interaction point and a small emittance coupling. Arc and interaction region have been decoupled by keeping the optics outside the interaction regions nearly constant and by applying for the design of the interaction regions the transparency criteria, i.e. to provide the same transfer matrix and the same beam separation for all solutions.

Optics of the interaction regions have been presented which take into account the large solenoid field of KLOE and FINUDA. Satisfactory solutions have been found for the compensation of the solenoid fields by applying the rotating frame method. The large solid angle required for KLOE makes the introduction of small permanent magnet quadrupoles for the low beta optics necessary. For FINUDA on the other hand, an extremely interesting compensation method with superconducting solenoids has been presented.

Beside the interaction region solutions for KLOE and FINUDA, also an optics for the straight section without experiments has been provided, all of them with similar optical parameters. In addition a relaxed optics of the interaction region has been developed, where the vertical beta function at the IP has been increased from 1 to 8 m. The Committee expressed some doubt, if the relaxed optics is really needed for starting the commissioning. It was not obvious what could be gained by such an approach and if it is really worthwhile to make this effort.

The combination of the various interaction region designs leads to different lattices with different characteristic parameters. The Committee pointed out, that for the optics where the KLOE interaction region is combined with the detuned version, a problem with the coupling could arise, since the integer parts of the tunes are equal in both planes.

Dynamic Aperture

Magnetic imperfections for the DAΦNE dipoles and quadrupoles have been deduced by extrapolation from similar magnets in other machines like ALS, AA, etc. Simulations have been performed for all the various lattices using PATRICIA and the DAΦNE tracking program, written specifically for DAΦNE, which includes the effects of solenoids and a finite crossing angle.

The estimated dynamic aperture has been calculated in the different situations studied including some, but not all errors. Since other sources of errors are not yet included, the stability limit. is likely to be reduced. However, the Committee felt that the requirements for the physical and the dynamic aperture had not been clearly defined and there was disagreement among the Committee members as to whether the present results are sufficiently good.

To clarify the situation, the Committee would like to see the following information presented in the next Review:

a) a definition of the proposed physical aperture and the required dynamic aperture with the motivation for the choices;

b) a discussion of the physical processes associated with these choices (Touschek effect, beam-beam blow-up, long range beam-beam effect of the parasitic crossings etc);

The effect of the following errors should be estimated to evaluate their importance in a machine the size of DAΦNE:

a) the fringing fields of the main magnets;
b) the synchrotron motion;
c) a finite closed orbit;
d) tilt of the magnets.

Additional simulations should be devoted to include those errors that appear to be significant. Discussions with the engineering group should occur to clarify the feasibility of the main magnet specifications.

Alternate Interaction Region Design

An alternate design of the Interaction Region has been presented based on the use of a compact solenoid located near the crossing point, within the large experimental solenoid.

This scenario provides optical functions as good as with a classical scheme with quadrupole triplets. The advantage is the simpler mechanical design and, as a consequence, a lower sensitivity to alignment imperfections.

The Committee is positively impressed by this proposal and recommends that the studies be continued to investigate its practical feasibility. This will require some discussion and preliminary estimates of space occupancy both with experimental physicists and engineering groups.

Bunch Lengthening

Because of the high peak current in each individual bunch at the nominal charge per bunch, bunch lengthening due to both potential well distortion and longitudinal turbulence is anticipated to be extremely important in DAΦNE. In this respect, the impressive effort invested to predict the longitudinal bunch behaviour as well as possible is strongly supported by the Committee. The model based on the determination of the stationary particle amplitude distribution from the Haissinski equation, as tested and checked on the SLC Damping Ring (although for a smaller bunch lengthening), certainly constitutes the state of the art of the present knowledge in this field. Beam measurements in DAΦNE will eventually be very useful to check the validity of this model in the strong bunch lengthening regime. In the meantime the Committee is not aware of any better way of predicting the effect. Effort should now be directed to understanding how to cope with any eventual differences in the bunch behaviour (either shorter or longer).

A very large synchrotron frequency spread along the bunch is deduced from the best fit of the line distribution. This will be very helpful for Landau damping of most of the quadrupole modes.

As recommended during the last review, the dependence of the effective impedance with the bunch length has now been calculated, and demonstrates a reduction of the total impedance for short bunches but with a higher real part of the impedance. This very interesting result is consistent with the single broad band impedance model scanned by the bunch spectrum where the inductive part of the impedance at low frequency is partly compensated by the capacitive part at high frequency.

Transverse Impedance Measurements

The Committee is pleased to see the progress realized on the transverse coupling impedance measurements, for which an improved method is now proposed.

Based on a very general analysis of the wire method, it has been shown that one of the main source of errors due to the perturbation by the imperfectly matched adaptation cones can be removed by an additional measurement of the system using the cones alone. This has the advantage of avoiding the loss of information by elimination of the signal reflections in the tube domain and should considerably improve the accuracy of the measurement. This has been partly demonstrated, at least in the low frequency range, by comparison of the measured kicker magnet impedance and the loss factor calculated using MAFIA for several values of the bunch length.

In order to better quantify the precision, resolution and sensitivity of this improved method, we strongly recommended using a simple element such as a pill box cavity which is easy to calculate. Comparison of the measurements with the present system up to 2 GHz with calculations of the same shape over the same frequency range would provide a more convincing test of the system. An extension of the measurement at higher frequencies could then be envisaged.

The Experiments for DAΦNE (FINUDA)

A second experiment for DAΦNE has now been approved (FINUDA: Fisica Nucleare a DAΦNE), and this was presented by its spokesman, Tullio Bressani. At present the collaboration includes 50 physicists.

The main purpose of the experiment is to study the production of Λ-hypernuclei produced by tagged K^- in nuclear targets surrounding the intersection vacuum chamber.

The superconducting magnet (1.1 T field) is under tendering at present, and should be ordered in September/October for delivery at the end 1995. The overall mechanical design of the detector has started and should be defined by the end of 1993.

The necessity to carry out experiments with many different targets nuclei will require some kind of access mechanism, yet to be studied. Certain beam tests will be done at Triumph.

It was stated that, while the experiment can be rolled sideways to remove it from the DAΦNE beam, it will always remain inside the machine hall and access to it will be restricted to periods of beam-off. The design of the detector should take into account the impact of detector repairs on the global experimental program.

The progress of FINUDA will be reported regularly to the Review Committee.

Interaction for KLOE (Mechanical and Vacuum Design)

The study of the KLOE Interaction Region has made much progress in the last six months. An overall concept is now available which, while needing further verifications and optimization, appears to be a valid basis for the design.

The triplets and the vacuum chamber are supported separately: the 3 permanent-magnet quadrupoles of each triplet are assembled and pre-aligned together in a tubular girder, which can be remotely aligned *in situ* by means of stepping motors and mechanical cams (5 degrees of freedom). This will allow transverse alignment (2 coordinates) and 3 angular adjustments. The tubular girder will be supported by the end plate of the track chamber and by an outer support. The supports of the vacuum chamber will be adjustable locally only.

The design of the vacuum chamber is based on a central bulb-shaped part (0.5 mm Be) of 100 mm radius brazed to two cylindrical sections (also of 0.5 mm Be) of 90 mm diameter. The Be section would be 606 mm long overall, and would be brazed to conically-shaped Cu sleeves that would continue into the more conventional Cu branches.

The central, thin RF screen (50 μ Be, as now considered) presents many problems (method of connection to the Be chamber, possible subdivision into strips, heat flow, stability under thermal deformation etc.) The buckling behaviour of the vacuum chamber has been studied in order to assess safety margins etc. We are concerned that the mechanical problems with the RF screen are extremely difficult to solve.

The Committee recommends that a detailed evaluation of all the different heat sources in the Interaction Region should be made and the RF losses without the screen should be carefully evaluated. This may well lead to the conclusion that the RF heat losses are acceptable and the screen is unnecessary.

The installation and alignment methods of the full vacuum chamber assembly must now be studied in detail together with the KLOE experimenters.

The distribution of vacuum pumps on each side (2 ion pump units upstream of the splitter magnet, one special ion pump inside the compensating solenoid, one non-evaporable getter pump (NEG) just upstream of the experiment, one special ion pump between Q3 and Q2) is now very convincing. The situation of synchrotron radiation hitting the chamber, the outgassing coefficients, the pressure distribution and evolution have been studied. The effect of photons scattered onto surfaces that are not scrubbed by the primary synchrotron radiation beam should be evaluated.

Project Engineering

The list of activities of the last 12 months was presented and discussed. A lot of detailed design work was done, specifications issued and several important contracts were placed (Transfer Lines, Accumulator Ring, Wigglers, etc.).

The activity planned for the next 6 months will shift more and more to design and specifications for the Main Rings and will include also technical assistance to those manufacturers already under contract.

The sequence of installation and alignment activities in the Linac wing, in the Accumulator hall and along the Transfer Lines up to the Main Rings has been carefully analyzed.

Magnetic measurements made on the splitter magnet prototype have led to a better understanding of coil and steel tolerances.

The detailed manufacturing aspects of several critical components have been studied (e.g. electroforming for the Main Ring cavities).

Detailed constructional drawings of many important components of the Main Ring (dipoles, quadrupoles, sextupoles) have been made, together with their supporting fixtures.

The Committee was impressed by the quality and quantity of the design work done and by the fact that the necessary, sustained pace has been maintained.

Control System

The Control System architecture was already defined at the time of the last Review. The Committee had then recommended that the Controls Group should concentrate on defining the detailed configuration of the actual system to be built. The Committee is extremely concerned about the time that it will take to implement the hardware and software and considers that the definition of the Control System as a whole, rather than isolated hardware issues, is one of the most pressing problems in the entire Project.

The Committee was informed that the first commercial prototypes of the DEVIL cards have arrived and are now performing well after some initial problems. Since the OPLA card was already working at the time of the last Review the main hardware components are now in good shape.

A detailed breakdown of the number of devices to be controlled and the number of control points per device was presented. It is the opinion of the Committee that the number of control points (2369), corresponding to about 7000 variables, is too small. It is the experience in every accelerator that this number grows rapidly during the design phase as the need for additional troubleshooting capability is recognized. In a "factory" this need will be extremely important to provide a high availability of the machine for experimentation. It is recommended to evaluate the Control System performance (specifically the network performance) for at least three times the present number, say 20,000 variables.

The network should be studied to identify the limitations and to ensure that these limits do not detract from the needed system performance. A start has been made in this direction, but a more detailed examination is needed. For example, the speed of the VME bus used to interconnect the crates in the second level was identified as a possible bottleneck if there are many processes running which require information to be shared between different crates on the third level (e.g. feedback loops).

The management of files to ensure that the database is up to date and consistent across the three levels of the control system is also a worry. File corruption is a major problem with large control systems with distributed processing and tools must be provided for network diagnosis during machine operation. It will also be necessary to implement some form of database history and operations logging. These aspects were addressed verbally in the presentation but a more complete written description will be needed before the system can be designed.

The most pressing priority for the Control System is still a detailed analysis of the operational requirements of DAΦNE. For the next Review, the Committee feels that a presentation of the following topics is vital:

1. A detailed description of the control system configuration (rather than the general architecture) including the number and location of the different elements and the expected traffic on the network.

2. An estimate of the time needed to execute some standard operations, breaking down the operation into time spent at the different levels and the various communication delays. This should be carried out for the proposed Control System configuration rather than general approximations. Suggested operations are:

   a) Change the setting of a magnet.

   b) A feedback system which measures and corrects an orbit.

   c) Measurement and correction of the machine tune.

3. A list of controls programs relevant to DAΦNE and an estimate of the manpower necessary to produce it. This should include system programs such as alarms, network checks, database entry and recovery, event synchronization, sequencing etc., as well as accelerator applications programs such as closed orbit correction, optics modification, tune measurement etc. The Committee considers this task to be of vital importance to the Project.

The present Controls Group is primarily a computer group and needs to be reinforced with people who have operational experience on ADONE who will also be involved with the definition and writing of the applications software.

If all of these steps can be carried out by the next Review, the Committee believes there would be a better understanding of the Control System as a complete system and the Project Leader must then ensure that appropriate resources are devoted to solving the problems if the commissioning timetable is to be met.

The Feedback System

The electronic part of the Feedback System now has an extremely detailed system layout, with all of the pieces specified, bus traffic evaluated and the Committee can only applaud the progress that has been made in such a short time. We strongly encourage the continued active participation of the Frascati group in the international collaboration and particularly to participate in the prototype testing at the ALS.

The kicker required for the feedback system still needs dedicated study. The Group should learn as much as possible from the ALS prototype, which has had some problems with trapped modes, and modify the present design accordingly.

Since the feedback no longer seems to be on the critical path, the Committee recommends that the Instrumentation Group now spends more time on the other instrumentation required for DAΦNE which has lagged behind.

Crab Cavity

The initial studies of a possible Crab cavity as an upgrade for DAΦNE is following the right direction. A shape has now been found which significantly increases the shunt impedance of the wanted TM_{110} mode. The TM_{010} mode of the cavities is now almost exactly half of the frequency of the TM_{110} mode which could conceivable load to problems. Attention should be payed to make sure that the frequency of this mode is not moved by the tuner into a dangerous frequency range.

Further effort should be primarily devoted to the extraction of the other unwanted modes. It would also be useful to have defined a rough physical size and location to the cavity so that space can be reserved in the ring for a future upgrade.

RF System

The progress in the RF system has been extremely impressive in the last six months. The klystrons and the RF cavities for the accumulator and the Main Ring have been defined, specified and orders have either been placed or are ready to order. The Committee would like to congratulate the entire RF group on their performance.

The remaining theoretical problems are with the feedback on the main RF cavity. The Committee recommends that someone be dedicated full time to studying the problem and ensuring that the beam-cavity-klystron system is treated as a whole.

RF Cavity

The Committee endorses the decision of a main ring RF cavity based on the rounded cell rather than the nosecone design for an easier fabrication as well as the adoption of a main coupler derived from the LEP design after adaptation to the slight change of frequency.

The Committee is pleased to see the first RF measurements made on the prototype of the RF cavity equipped with long tapers and broad-band waveguides optimized for coupling to the high order modes. This allowed a precise measurement of the frequencies and quality factors of the fundamental and higher order modes.

The broad-band waveguides on the cell and the tapers are shown to effectively damp below specifications, the most dangerous modes with an acceptable perturbation of the fundamental, mainly a 7 MHz reduction of its frequency which has to be compensated by the cell dimensions.

The absorption of the higher order mode (HOM) RF power with ferrites under vacuum has been extensively studied but relies on a brazing procedure still under development.

The Committee fully supports the decision to study as a first priority, the promising technique of HOM power damping on a load outside vacuum after transition from waveguide to coaxial line as it decouples the RF power absorption from the vacuum technology and opens the possibility of HOM damping optimization by direct measurement on the external load.

The first measurements at low power on a prototype are very encouraging with acceptable standing wave ratio up to at least 2.2 GHz.

An optimization of the dimensions, supports and mechanical design of the heavy broad-band waveguides including the study and minimization of the corresponding cavity deformations is now recommended.

Vacuum

Considerable progress has been made in the development of the vacuum system. Following the advice of the Committee, the vacuum chambers of DAΦNE have been made as similar as possible. There are now only two main types of chamber for the rings, one for the external bends and one for the internal bends. These chambers have also been made equal for about two thirds of the length. The only minor differences in the chambers are due to the pump ports and eventual synchrotron light ports. The Committee recommends that the option of including a synchrotron port for vacuum studies be examined.

A new arrangement of absorbers has been presented, where the absorbers are now made out of copper, as recommended by the Committee in the last MAC. Tests have been made on an aluminium absorber in order to study the arrangement of the cooling channels. The Committee supports the choice of the vacuum group, to use parallel channels with a connection at the end for the return flow, instead of inclined channels which are approaching each other at the ends.

The Committee is looking forward to seeing the two vacuum chamber prototypes which are now in preparation for the bending magnet and the wiggler. The possibility of constructing a small scale (e.g. 1/5) model of a complete half chamber should also be considered.

A novel technique has been presented for the cleaning procedure of the aluminium which seems to be very promising. The aluminium is machined in the presence of ethanol, in order to generate a protective Al_2O_3 layer (to reduce the absorption capabilities) and given a very smooth finish. This provides an efficient reduction in the desorption rates.

More pumping speed measurements of the Titanium sublimation pumps have been presented which showed satisfactory results. The Committee expressed some concern about the positioning of the titanium sublimation pump on top of the antechamber, opposite to the sputter ion pump below. To avoid problems with broken filaments falling into ion pump, a net or basket should be introduced there.

The Committee appreciates the extensive studies which have been performed to understand the ion trapping problem. It supports strongly the decision of introducing clearing electrodes in the electron ring in order to improve the ion clearing and avoid the necessity of having a gap in the ring filling which would reduce the luminosity.

Conclusion

The Committee believes that most aspects of the Project are well under control and would like to congratulate the Project Team on the way that they have managed to make difficult design decisions on a tight schedule. The major worries of the Committee are the detailed design of the two Interaction Regions and the Control System.

The next Reviews will take place as follows:

6th Review will be held on January 11-12, 1994

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

The Agenda of the 6th Review should include presentations on:

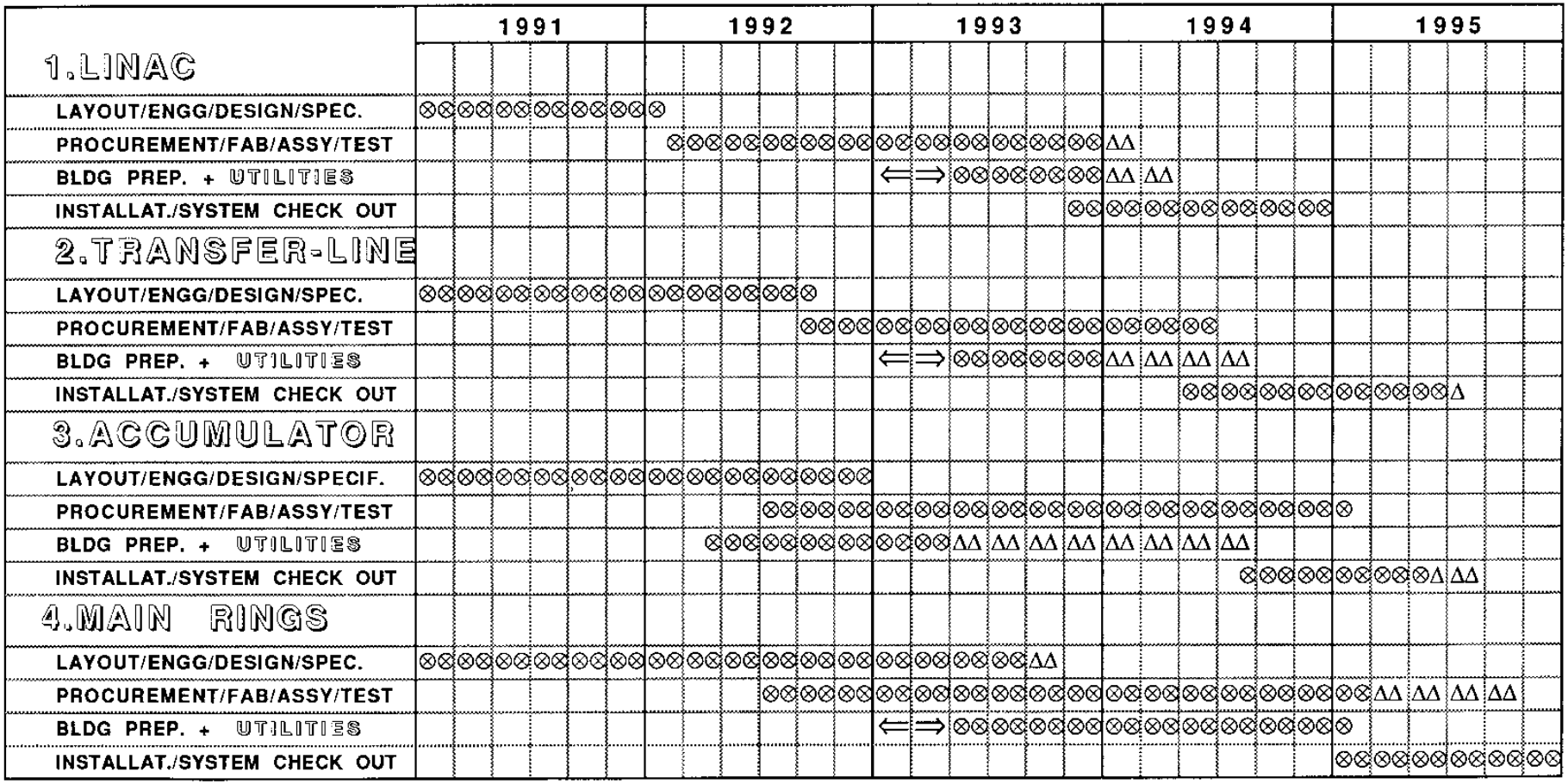
- FINUDA and KLOE Interaction Region:
  - Mechanical
  - Vacuum
  - Background
  - Alignment
- Control System:
  - Software Requirements
  - Detailed Hardware Implementation
- Instrumentation
- Engineering Status
- Linac Commissioning Plans
- The Personnel and Machine Safety System (not including radiation 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)
Dec 93	**ENGINEERING COMPLETE (TENDERS OUT)**
May 94	**BEGIN INSTALLATION OF LINAC** - requires beneficial occupancy of Linac building + utilities
Dec 94	**LINAC OPERATIONAL**
Feb 95	**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)**
Jun 96	**BEGIN MAIN RINGS COMMISSIONING**

DAΦNE PROJECT SYSTEM MILESTONES

(5th MACHINE REVIEW - July 13-14,1993)



⟸⟹ : ADONE SHUTDOWN

⊗ : JANUARY 19, 1993

Δ : JULY 93 UPDATE