INSTALLATION AND ALIGNMENT OF THE DAΦNE ACCELERATORS

C. Biscari, F. Sgamma, LNF-INFN, Frascati, Italy

Abstract

Installation, alignment and survey of the magnetic elements and vacuum chambers of DAΦNE are described. The networks of the Damping Ring and two Main Rings are described, focusing the techniques chosen to obtain the required precisions. A description of the mechanical measurements, coupled to the magnetic ones, to refer the magnetic axis of quadrupoles and sextupoles to their fiducials is underlined: emphasis is put on the strategy to couple precision with quickness. The results of first phase alignment job and its refinement are analyzed using the orbit measurement.

1 INTRODUCTION

DAΦNE (Double Annular Φ-factory for Nice Experiments)[1] is a high luminosity double ring e^+/e^- Φ-Factory with a short term luminosity goal L=1.3 10^{32}cm^{-2} sec^{-1}.

The injector consists of an e^+/e^- Linac and an Accumulator/Damping Ring, connected to DAΦNE through ~ 160 m long Transfer-lines. The machine general layout occupies three areas (see Fig. 1), which were previously occupied by ADONE and have been adapted to the new machine and experiments.

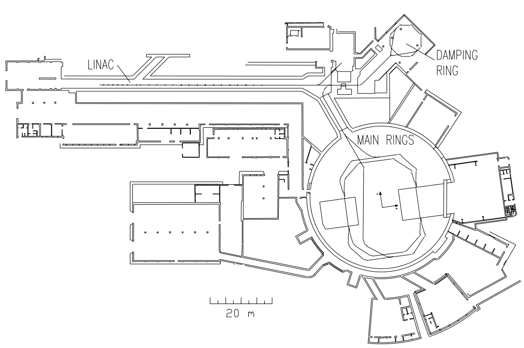

Figure 1: DAΦNE complex layout

The two Rings of the collider are co-planar (see Fig. 2) and each of them, comprised in a rectangle 31 m large and 26 m high, contains 8 bending magnets with a C structure, 4 wigglers, 39 quadrupoles and 16 sextupoles of two different families (“small” and “large”, depending on the internal bore), one rf cavity, 30 corrector magnets. In the Interaction Regions, shared by the two rings, 4 splitter magnets and 4 superconducting solenoids are placed. In the “Day One” configuration, i.e. without experiments, the Interaction Regions contain 14 quadrupoles.

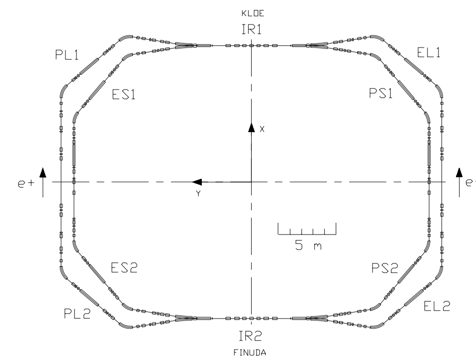

Figure 2: Main rings layout

2 GENERAL NETWORK

A general network, connecting the three separate installation areas, have been defined to allow an alignment with respect to a reference system based on the DAΦNE Main Rings symmetry axis (see Fig. 3). The number of nodes and their position has been defined using the criterion of having at least two nodes in each area and putting them, if possible, along significant lines.

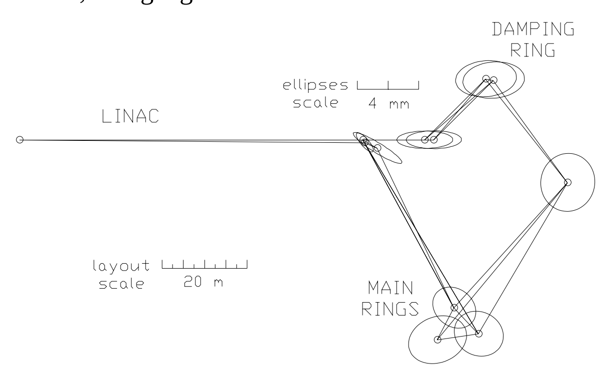

Figure 3: General network

This network has been realized with sockets, with a 30 mm diam. bore and a conical fit for Taylor-Hobson spheres, mounted on pillars or directly inserted in the floor.

A network pre-analysis, which takes into account the number and type of measures (distances and angles) and their precision, allowed to calculate for each node the dimensions of the 99% probability ellipse. This pre-analysis, made with STAR*NET, a Starplus Software Inc. program, showed a maximum ellipse semi-major axis of 1.9 mm.

The survey of the network has been realized measuring angles and distances with the Leica theodolite T3000 equipped with the D2000 Distomat.

3 LOCAL NETWORKS

Two local reference networks were defined and realized: one for the LINAC, based on five nodes in the floor along a line parallel to the LINAC axis at a distance of 1 m, and another one for the Main Rings, made by 15 sockets on pillars. Figure 4 shows the MAIN RINGS local network, together with a schematic layout of the two RINGS, and the 99% probability ellipses.

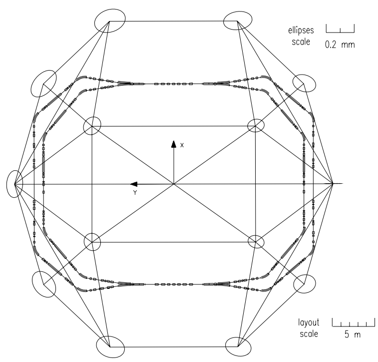

Figure 4: Main ring network

The Main Ring network was designed to have two nodes in each quarter of the machine for distance measurements between them and the bending magnets (8 nodes in total); the other 6 external nodes have been defined to connect the former 8 and to set references to align the experiments. The network pre-analysis showed a maximum ellipse semi-major axis of 0.1 mm. The survey of this network was realized measuring distances with invar wires and the Distinvar instrument, designed at CERN, with a precision of 0.05 mm; the wires were calibrated at CERN. Angle measurements, with a precision of 3”, were also performed to increase the redundancy of the network. The socket levels have been accurately measured with Leica N3 Precision Level (± 0.02 mm) with respect to the LINAC axis level (the Damping Ring is 600 mm higher and the Main Ring 500 lower). The levels of many other wall references, realized in LINAC, Damping Ring and Transfer Lines, were measured.

4 DAMPING RING ALIGNMENT

The Damping Ring network, connecting the bending magnets to the local references placed on pillars, is shown in Fig. 5. Only distance measurements, with the invar wires technique, were performed. The pre-analysis maximum ellipse semi-major axis resulted 0.2 mm long. A first rough positioning (± 1 mm) was previously performed, surveying the polar coordinates of bending magnet nodes with theodolite and distomat placed in the center of the machine; a good leveling action was also performed in this phase. Four network surveys, alternated with three adjusting operations between them, were then performed to lower for each node the maximum difference between the measured position and the nominal one to less or equal to 0.1 mm.

After any adjusting action in the horizontal plane a very accurate level adjustment was realized. The bending magnet nodes, when in the final position, were used to align multipoles, correctors, rf cavity, and to survey beam position monitors.

The measured closed orbit with no correction was:

$$x_{rms} = 1.6 \text{ mm}; \; y_{rms} = 3.7 \text{ mm}$$

From the vertical orbit analysis it was found that it could be corrected by displacing two quadrupoles by - .3, .1mm. After these displacements the residual rms closed orbit is within 1 mm.

The Accumulator runs with no correctors performing above design parameters[2].

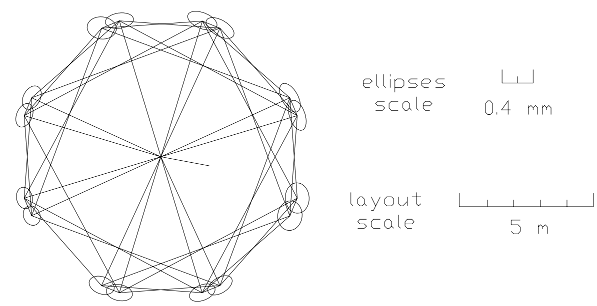

Figure 5: Damping ring network

5 MAIN RING QUADRUPOLES AND SEXTUPOLES MECHANICAL MEASUREMENTS

All the 92 quadrupoles and 32 sextupoles have been magnetically measured with a rotating coil machine, determining the position of the magnetic center with respect to three references on top of each magnet (three 10 mm bores). The orientation of the magnetic axis, passing through the magnetic center, was supposed to be the same of the mechanical axis: for this reason every magnet has been also mechanically measured (see Fig. 6).

To get the three reference bores easily manageable from the survey and alignment point of view, a removable plate was placed on top of each magnet, fitting on tooling balls inserted in the bores: the table bottom surface presents three different features to allow a free but unique, and therefore repeatable, positioning on the magnet. The table is equipped on the top with two micrometer slides on which two Taylor-Hobson sphere sockets are fixed.

The mechanical axis of each magnet has been materialized with a specific tool (a half cylinder, lying on the magnet lower poles, with two marks just along its axis). With the slides in a arbitrary but always equal position, just near the alignment position, seven points have been surveyed for each magnet: the two half cylinder marks, three points on the upper table surface, the two T.H. spheres.

The survey system consists of two theodolites connected to a PC and managed by a LEICA program (ECDS3), able to get 3D coordinates of any point with respect to a reference system based on the theodolites.

The survey process can be separated from the elaboration one: the coordinates of the two T.H. spheres are successively calculated with respect to a reference system with an axis coincident with the magnet mechanical one and another parallel to the table plane. The acquisition process is very accurate (± 0.02 mm) and safe because any discrepancy in collimation between the two operators, one for each theodolite, may be easily detected by the program and verified also later. On the contrary the measuring time has been very short, not more than 20 min/magnet, due in large part to the magnet moving operations and table positioning: the large number of magnets pushed this result.

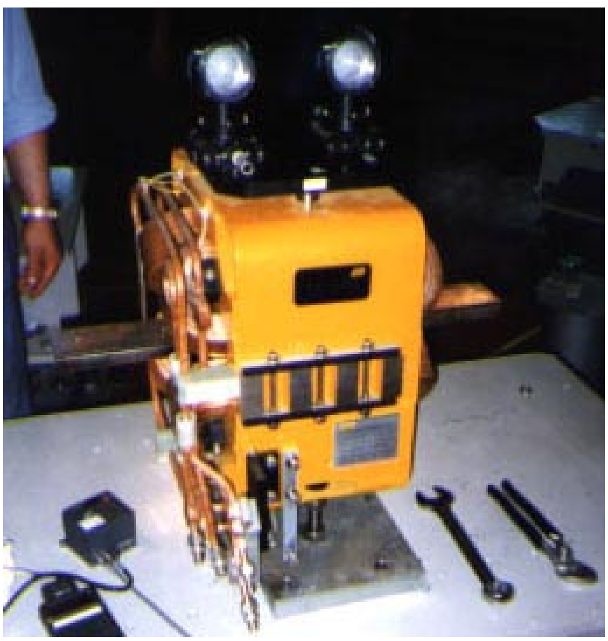

Figure 6: Quadrupole mechanical measurements

As a result of magnetic and mechanical measures we got for any magnet the position of the two slides so that, after the eventual axial rotation, defined as rotation of the table with respect to the horizontal plane, the two T.H. sphere could lie just in the vertical plane passing through the magnetic center and oriented longitudinally as the mechanical axis; with the slides in the specific positions the distances between the T.H. spheres and the plane passing through the magnetic center, oriented as the mechanical axis and perpendicular to the vertical one, were also calculated to complete the information necessary to align the magnet.

6 MAIN RING INSTALLATION AND ALIGNMENT

The Main Ring network, connecting the bending magnets to the 8 local references placed on pillars and between them, is shown in Fig. 7.

Only distance measurements, with the invar wires technique, were performed.

The pre-analysis max ellipse semi-major axis resulted 0.2 mm. Five network surveys and four adjusting operations between them were performed to obtain that for each node the maximum difference between the measured position and the nominal one could be less or equal to 0.1 mm. The bending magnet nodes were used to align and/or survey the other machine components.

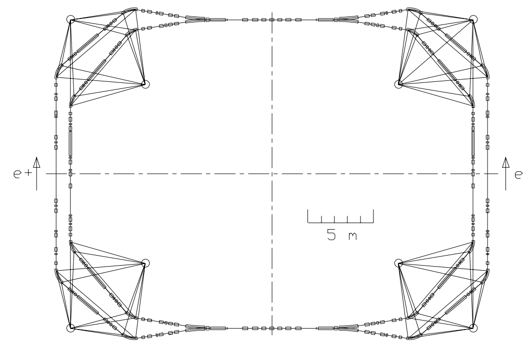

Figure 7: Main Ring Network.

The installation of the bending magnets (C magnets) resulted very critical due to the little clearance (1 mm) between the magnet poles and the arc vacuum chambers, a 10 m long single piece. The arc chambers were installed just after the positioning and rough alignment of magnetic elements involved (with their upper part removed) and then well leveled; at this point the bending magnets, suspended to the crane in a very horizontal way with adjustable cables at the proper height, were slowly horizontally moved to fit the vacuum chamber till around their final position: only then the three legs were lowered to support the magnet weight. Some difficulties for the installation of external bending magnets arose from the little space between the positron and electron machines.

In the first operation of the machine it has been measured that the closed orbit is mainly determined by the "cross-talk" of one ring on the other and by the transfer lines fringing fields on the rings, while the alignment error effect is much smaller. In particular on the e^+ ring displacing three quadrupoles from their nominal positions has been used to correct the vertical bare closed orbit to less than 5 mm. Both rings are stable with no correctors.

7 CONCLUSIONS

All the survey and aligning job has been performed with only two specialized operators, helped by two other not specialized. It must be underlined that the 92 quadrupoles and the 32 sextupoles have been aligned in 25 working days. During the two last years the aligning job has never been a bottle neck for the machine installation and has assured a very good start for the machine commissioning.

REFERENCES

[1] C. Biscari et al.: "Performances of DAΦNE", these Proceedings.

[2] M.E. Biagini et al.: "Performance and Operation of the DAΦNE Accumulator", these Proceedings.

[3] M. Bassetti et al.: DAΦNE Main Ring Optics", these Proceedings.