THE DAΦNE MAIN RING MAGNET PROTOTYPES

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Abstract

The arcs of the DAΦNE Main Rings are equipped with bending magnets, quadrupoles, sextupoles and correctors of unconventional shape, in order to cope with the large size and peculiar design of the vacuum chamber, where the synchrotron radiation emitted by the high current electron beam is absorbed in a special antechamber isolated from the beam through a narrow slot. The magnets have been designed at LNF and the prototypes realized in Italy by Ansaldo Energia (dipoles, quadrupoles, sextupoles) and in France by Sigma-Phi (correctors). The paper describes the final adjustments on removable end caps and the results of magnetic measurements performed on the prototypes to check the field quality requirements.

1 INTRODUCTION

The two pseudo-elliptic, intersecting Main Rings [1] of DAΦNE are equipped, in the bending sections, with eight 9 m long aluminium vacuum chambers named "arcs". Two bending magnets, three large quadrupoles, two sextupoles and two corrector magnets are located around the vacuum chamber.

Two types of bending dipoles, each one having two different magnetic lengths, are under construction. Quadrupoles and sextupoles are expected to be delivered this summer. Corrector magnets have been delivered and are ready to be installed.

Eight out of sixteen dipoles have parallel ends (P.E. Dipoles) and the other eight are sector like shaped (S.L. Dipoles). Quadrupoles and sextupoles are fully symmetric. Large horizontal/vertical correctors are used for orbit correction. All magnets are laminated.

2 DIPOLE MAGNETS

Two dipole magnet prototypes, one for each type, have been built by ANSALDO Energia, Italy. The first one has been completely characterized. The second one, delivered at the end of May, is now under measurement. The series production of the P.E. Dipoles is in progress. Table I lists the main parameters of these magnets.

The construction of the first prototype was slower than schedule because the laminations were out of tolerance. After some attempts to recover the inconvenient, the decision was taken to machine with a suitable tool the pole surfaces, allowing for a gap increase of 0.6 mm. Accurate measurements were performed to verify the presence of short circuits among laminations on the machined surfaces and an extensive power up/down at the maximum ramp speed rate was accomplished to detect any possible degradation phenomena. The magnet was powered up to the maximum current, corresponding to a beam energy of about 715 MeV (@ 650 A, 1.8 T). Figure 1 shows a picture of the P.E. Dipole Prototype.

Table I - Design parameters of Main Ring dipoles

Dipole Type	Long		Short
Beam Energy (MeV)		510	
Nominal Field (T)		1.214	
Bending Radius (m)		1.4006	
Gap Height (mm)		75.6	
Magnetic Length (m)	1.21		0.99
Good Field Region (mm)		± 30	
ΔB/B @ 3 cm (%)		±0.015	
Turns per pole		144	
Nominal Current (A)		266	
P.E. Resistance (mΩ)	225.5		197.5
S.L. Resistance (mΩ)	197.3		175.5

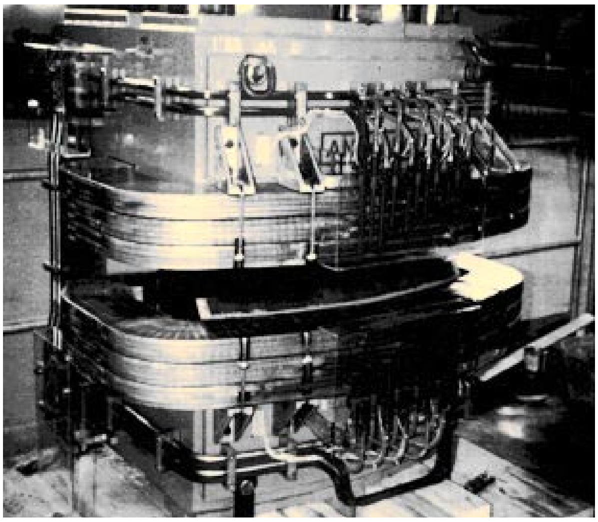

Figure 1 - The Parallel End Dipole Prototype.

A complete set of point by point magnetic measurements was performed using a Hall Probe mounted on a x-y-z computer controlled positioning system. The required transverse homogeneity was obtained without any shimming. The magnetic length, estimated on the beam trajectory calculated from the measured field, was obtained by adjusting the thickness of the end pole caps which were also iteratively shaped to minimize the natural integrated sextupole term of the magnet.

Figure 2 shows the integrated gradient due to the parallel ends and the sextupole term as a function of beam energy. Higher order terms are negligible. Figure 3 plots the field B on the ideal trajectory and the distance D between the real beam trajectory calculated from the measured field and the ideal one.

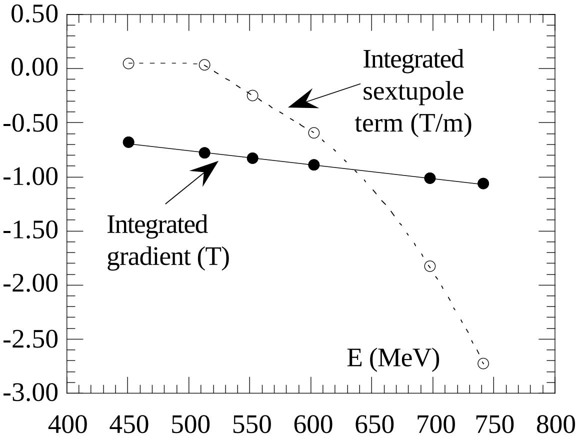

Figure 2 - P.E. Dipole integrated gradient and sextupole term as a function of beam energy.

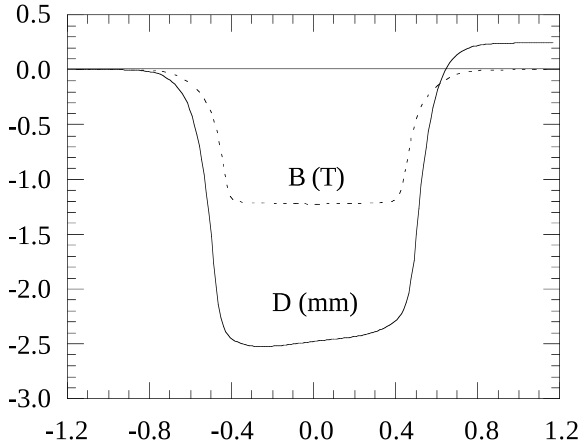

Figure 3 - Magnetic field on ideal trajectory (B) and distance (D) between calculated and ideal trajectories.

3 QUADRUPOLE PROTOTYPE

A first large quadrupole prototype was delivered by Ansaldo in May 1995 and a second one in February 1996. The main parameters are listed in Table 2 and a picture of the quadrupole is shown in Figure 4.

Table 2 - Large Quadrupole prototype parameters

	Nominal	Maximum
Energy (MeV)	510	750
Nominal Gradient (T/m)	3.6	8
Bore Diameter (mm)	108	108
Good Field Region (mm)	± 30	± 30
ΔB/B @ 3 cm (%)	≤0.05	≤0.05
Magnetic Length (m)	0.3027	0.3005
Nominal Current (A)	64.6	146
Resistance (mΩ)	115	118

The magnetic length (296 mm) was measured by means of the Hall Probe positioning system and the integrated field components with a Rotating Coil equipment built by Danfysik (Denmark). The 12-pole term was reduced by an order of magnitude by chamfering the removable end caps and Fig. 5 shows the resulting fractional deviation of the integrated field from the ideal quadrupole at 30 mm from the axis: the most relevant high order components are the sextupole (0.017%), the octupole (0.024%), the 12-pole (0.005%) and the 20-pole (0.003%).

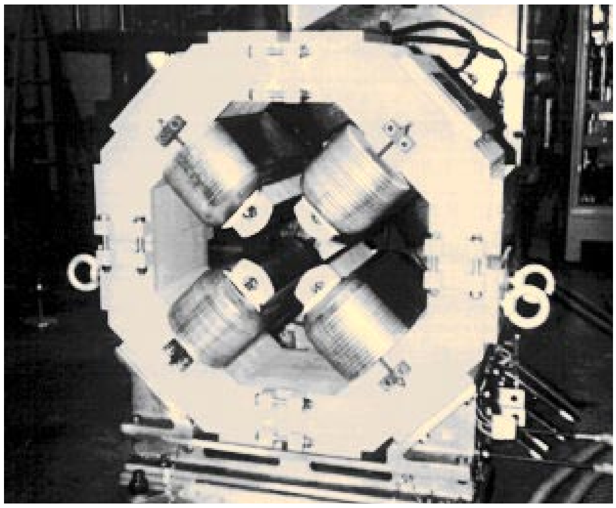
Figure 4 - Large Quadrupole Prototype.

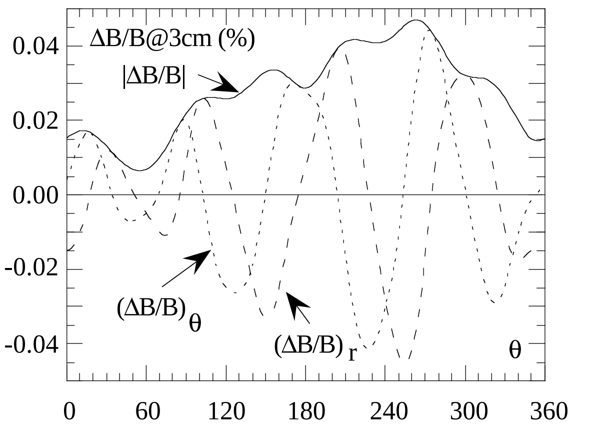

Figure 5 - Integrated field deviation from ideal quadrupole on a 30 mm radius circle around the magnet axis.

4 SEXTUPOLE PROTOTYPE

This prototype was delivered in December 1995. The main parameters are listed in Table 3 and a picture of the sextupole, assembled on the arc vacuum chamber, is shown in Fig. 7.

Table 3 - Sextupole prototype parameters

	Nominal	Maximum
Nominal Gradient (T/m^2)	90	234
Bore Diameter (mm)	108	108
Good Field Region (mm)	± 30	± 30
<ΔB/B> @ 3 cm (%)	0.11	0.11
Magnetic Length (m)	0.153	0.151
Nominal Current (A)	78.3	209.3
Resistance (mΩ)	41.6	41.6

The integrated field deviation from the ideal sextupole at 30 mm from the magnet axis is plotted in Fig. 8.

The dominant high order harmonic is the 18-pole (0.08% @ 3 cm, independent of the excitation current). There are also contributions from the 8-pole, 10-pole and 12-pole (≈0.015% @ 3 cm, independent of excitation current).

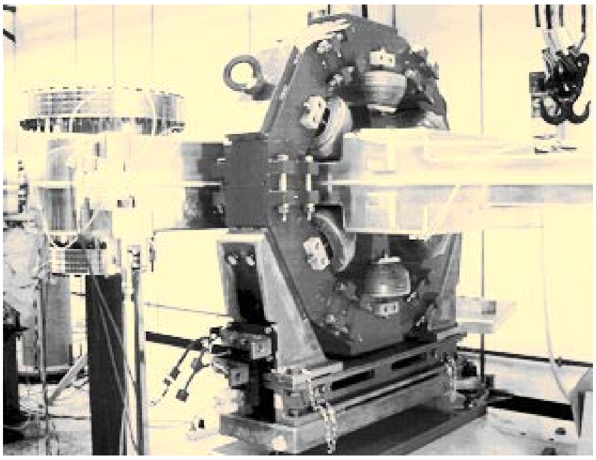

Figure 7 - The sextupole prototype assembled on the arc vacuum chamber.

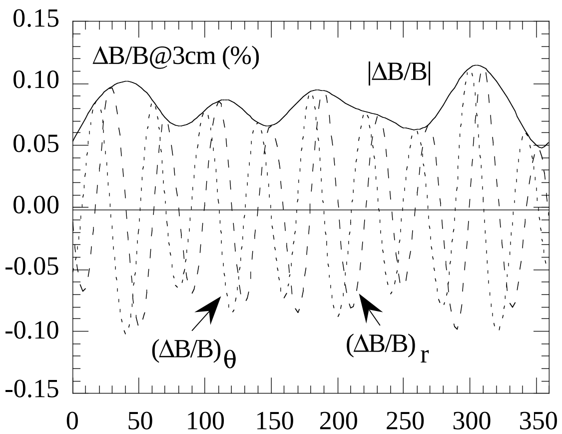

Figure 8 - Integrated field deviation from ideal sextupole on a 30 mm radius circle around the magnet axis.

5 RECTANGULAR CORRECTOR PROTOTYPE

Rectangular Corrector Magnets of large internal aperture (501 mm horizontal by 213 mm vertical) surround the arc vacuum chamber. The first prototype was delivered by Sigma-Phi (France) in March 1996, together with other 2 prototypes (the Square Corrector and the Horizontal/Vertical/SkewQuad Corrector) to be installed in the straight part of the rings. All remaining correctors (15 magnets) were delivered in May.

Figure 9 shows a picture of the Rectangular Corrector Magnet and Table 4 lists its main characteristics. In this magnet, a first coil (CH) creates a vertical field at the magnet center, which deflects the beam in the horizontal direction; the second coil (CV) acts as a vertical corrector.

Table 4 - Rectangular Corrector parameters

	CH	CV
Deflection Angle (mrad)	3	3
Nominal Field (G)	150	80
Magnet Gap (mm)	240	540
Magnetic length (mm)	362	456
Nominal Current (A)	8.78	6.36
Conductor Diameter (mm)	2.65	2.65

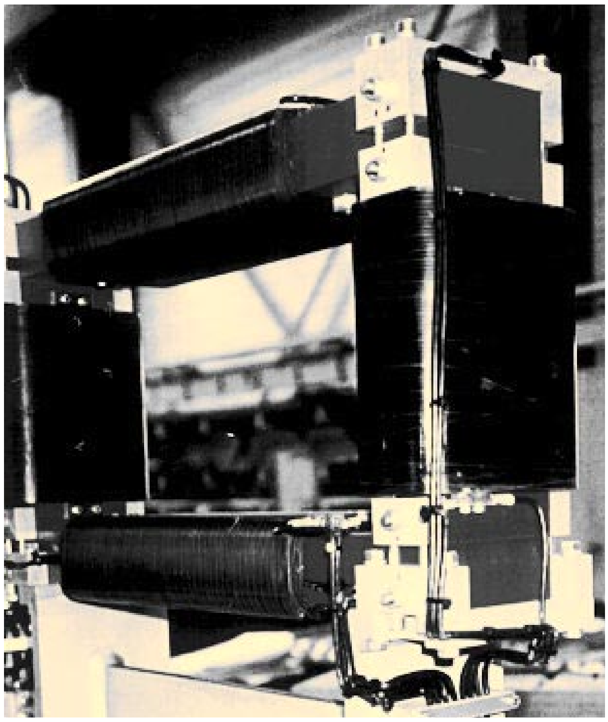

Figure 9 - The HV Rectangular Corrector Magnet

Due to the symmetry of the magnet, the vertical (horizontal) field component on the magnet axis does not change when CV (CH) is switched on. However, there is some interference between the two corrections when the beam does not pass in the center of the magnet. Being the magnet much larger in the horizontal direction, there is no influence of CH on the horizontal field component in the required operating range (±30 mm from the magnet axis). The vertical component instead changes up to ± 2% when CV is set to its nominal current, depending on the horizontal position of the beam. However the field at any point in the operating range is a linear combination of the separate effect of CH and CV, and this allows independent closed orbit corrections in the horizontal and vertical planes by means of a suitable correction algorithm.

REFERENCES

[1] G. Vignola, "DAΦNE, the First Φ-Factory", These Proceedings.