DAΦNE TECHNICAL NOTE

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Note: **MM-17**

MEASUREMENTS ON TESLA "C" CORRECTOR PROTOTYPE FOR THE DAΦNE MAIN RINGS

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1. Introduction

The prototype of the HV (Horizontal/Vertical) "C" Corrector Magnet, built by TESLA Engineering, Storrington (U.K.), was delivered to LNF on May 2, 1996, together with a second prototype, the "Lambertson" HV Corrector Magnet [1].

These Corrector Magnets were designed by LNF staff and Fig. 1 shows a picture of the "C" prototype. Table I gives its main parameters.

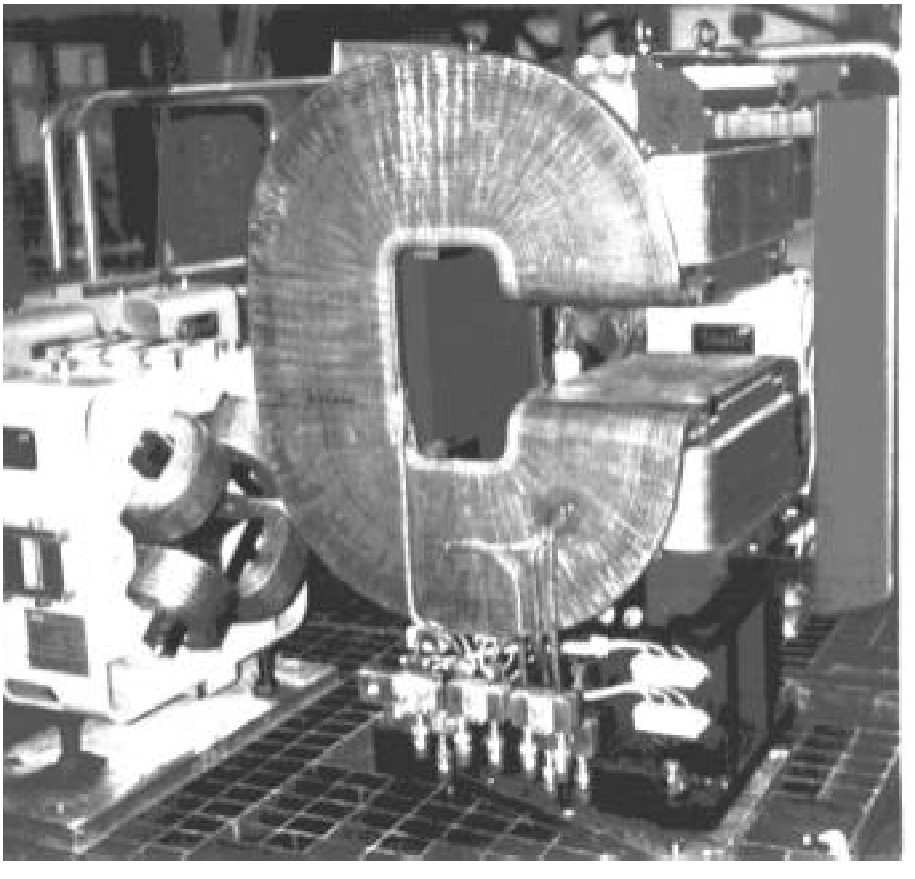

Figure 1 - The "C" Corrector Magnet in the magnetic measurement laboratory near a "small" Main Ring quadrupole.

Table I - "C" Corrector Magnet prototype parameters.

"C" Corrector H/V	units	CH	CV
Energy	MeV	510	510
Nominal current	A	171	109
Nominal field (design)	G	1040	363
Measured field	G	1040	365
Deflection Angle	mrad	22	9.5
Magnetic Length (Design)	mm	328	328
Measured length (FWHM)	mm	331	397
Magnet gap	mm	132	100
Number of turns		64	60
Copper Wire Diameter	mm	$6 * 6$	$6 * 6$

2. Electrical measurements

The resistance of the "C" HV Corrector Magnet coils was measured by means of a micro-ohm-meter (AOIP mod. OM 20) at room temperature.

The measured values were:

Horizontal coil 46.85 mΩ @ 23 °C

Vertical coil120 mΩ @ 23 °C

The same measurement were accomplished by using the Volt-Ampere method and the following data were measured:

Horizontal coil 8.22 V @ 171 A, corresponding to 48.1 mΩ

Vertical coil13.47 V @ 109.4 A, corresponding to 123 mΩ

These values were obtained at the same room temperature as in the preceding measurement. The agreement between the results obtained with the two different methods is very good.

The inductance and resistance of the magnet prototype was also measured by means of a LCR meter (LCR meter HP 4284 A) at different frequencies. The results are shown in Figure 2. The corresponding dc values can be extrapolated from these data. They are consistent with the measured and design data.

Thermal measurements were also accomplished and the worst figure for the "C" Corrector Magnet is listed in Table II.

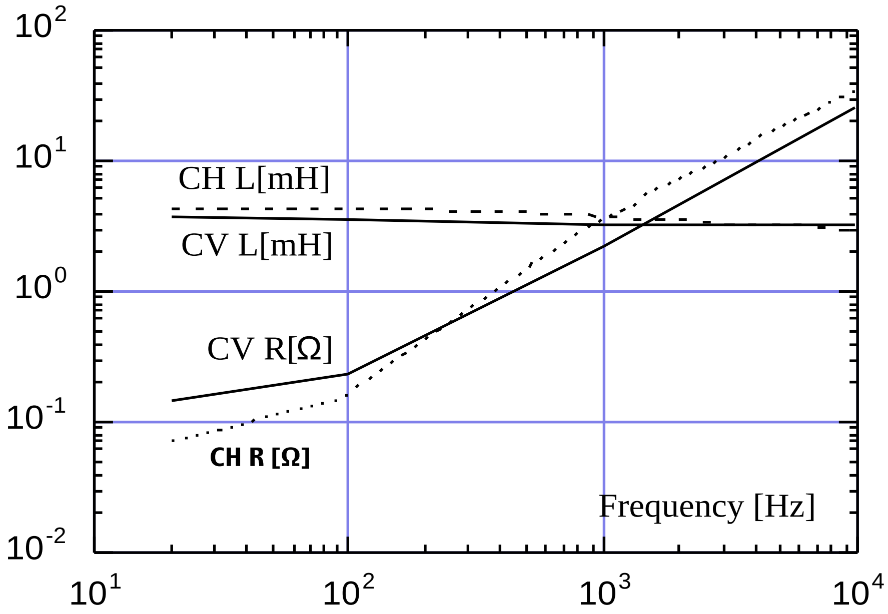

Figure 2 - Resistance and inductance versus frequency
for the "C" Corrector Magnet

Table II - Temperature rise of magnet coils.

Time (min)	0	3	6	9	12
Temperature (°C)	28.4	34.2	34.6	34.6	34.6

3. Magnetic measurements

The horizontal and vertical components of the field at the magnet center have been separately measured as a function of the current in the corresponding coil (in the following we indicate with CH the horizontal corrector coil, which generates the vertical field component, and with CV the other one). Both field components are linear over the operating range, as shown in Fig. 3.

Since the coils were powered by unipolar power supplies, it was not possible to check carefully the behaviour of remanent fields when inverting the corrector polarity, which, of course, will be done in the normal operation of the ring with the final bipolar power supplies. However, the remanent fields observed during the cycling operation with the available equipment are of within few Gauss.

We have also measured the dependence of each component on the current in the corresponding coil with the other coil set at the maximum current. Taking into account the remanent field coming from the cycling procedure with both coils excited, the difference with respect to the previous measurement with the other coil switched off is negligible.

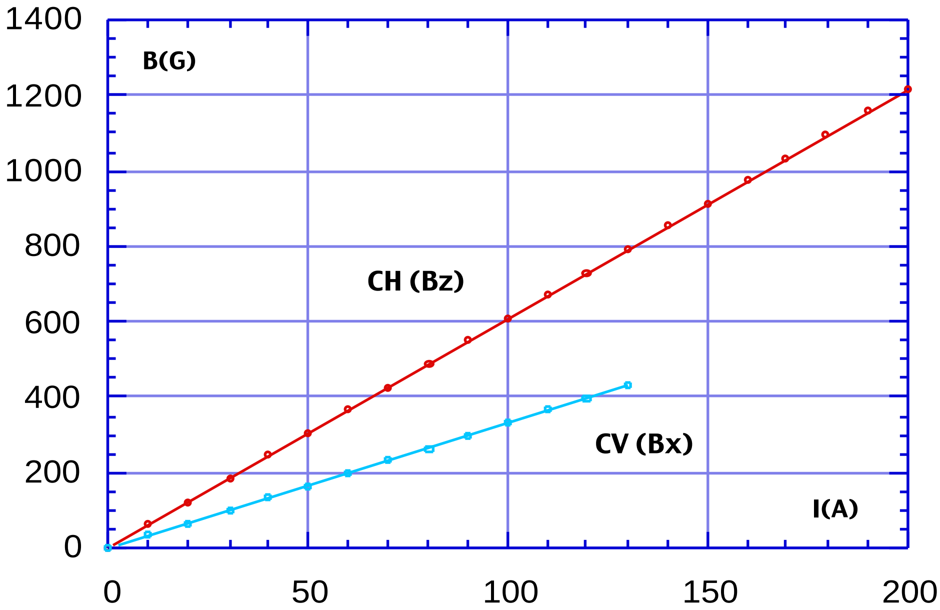

Figure 3 - Field components at magnet center versus current.

Following the procedure adopted for the other correctors in the DAΦNE Main Rings [2,3,4], we have measured the vertical component of the field on a vertical plane perpendicular to the magnet axis at its midpoint up to a distance of 30 mm from the longitudinal axis in both the horizontal and vertical directions with CH set at the nominal working point (171 A). The result is shown on an expanded scale in Fig. 4 as a function of the horizontal position, each curve corresponding to a different vertical position. The field depends slightly on both the horizontal and vertical positions. The overall variation within the good field region (± 30 mm) is 1.4%.

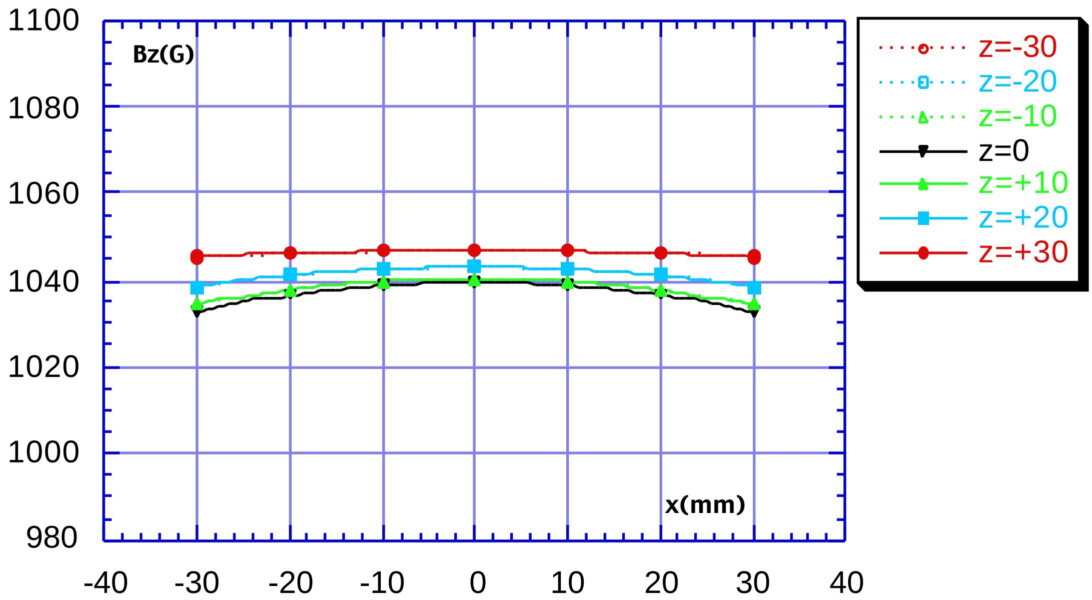

Figure 4 - Vertical field component at magnet center with.
CH @ 171A, CV off (expanded scale).

The field changes significantly when also the vertical corrector CV is switched on: Fig. 5 shows the vertical field component, on the same scale as in Fig.4, with both corrector coils set at their nominal currents. The overall variation of the field in the good field region (±30 mm in both directions) is now 8% and depends both on the horizontal and vertical positions. This implies that the orbit corrections in the two planes are influenced by each other. It can also be observed that the contribution to the vertical field tends to vanish on the horizontal plane at a distance of ≈8 mm from the center (negative values of the horizontal coordinate are towards the external iron shield, see Fig.1).

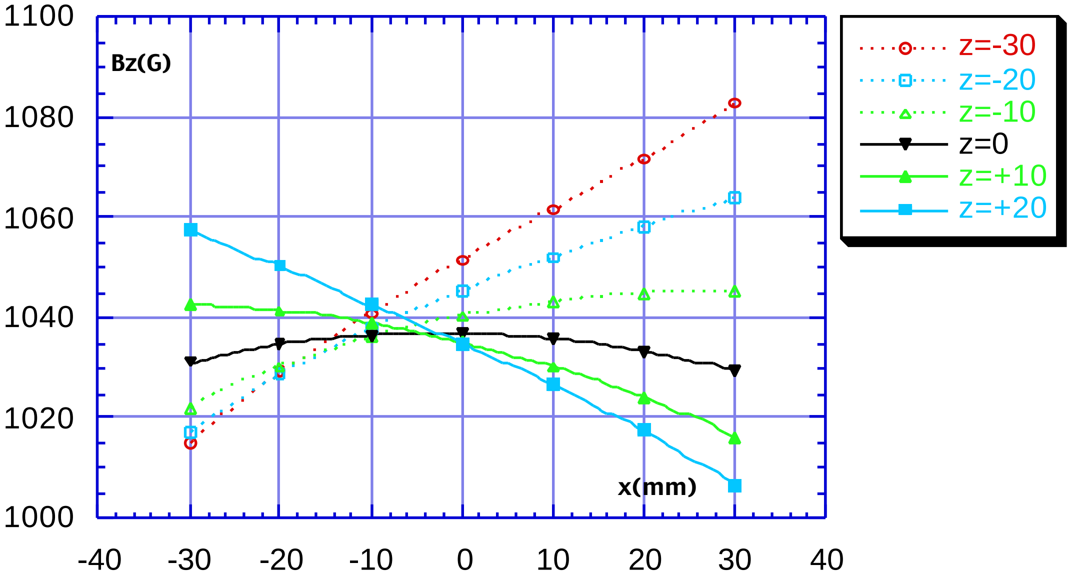

Figure 5 - Vertical field component at magnet center with
CH @ 171 A and CV @ 109 A (expanded scale).

This offset can be better observed by inspecting Fig.6, where we plot the vertical field component with only CV (the "other" coil) set to its nominal current (CV @ 109 A, CH off). The behaviour is almost linear in both directions.

We have then compared the field measured with both coils excited with the sum of the fields measured with each coil excited separately, namely the field given in Fig. 5 with the sum of those given in Fig. 4 and Fig. 6. The difference between the corresponding points is 2.65 G at the corrector center and within 2.50 G and 2.80 G in all the other points. There is therefore a small offset, coming from the different cycling procedures in the three separate measurements, but, apart from this effect, the fields created by the two coils add linearly in the good field region.

Due to the difference in the geometry of the two coils, we show in Figs. 7÷9 the corresponding measurements for the horizontal field component. With CV set at the nominal current the field variation within the good field region is now 9.5%, increased to 10.3% when also CH is switched on. In this case the perturbation introduced by the "other" coil is antisymmetric with respect to the magnet center but not linear in the displacement from it. As for the other component, the fields due to the two coils add linearly: the difference between the field measured with the two coils excited at the same time and the value obtained by summing up the fields measured with each coil excited separately is 0.35 G at the magnet center, and between 0.3 and 0.5 G inside the good field region.

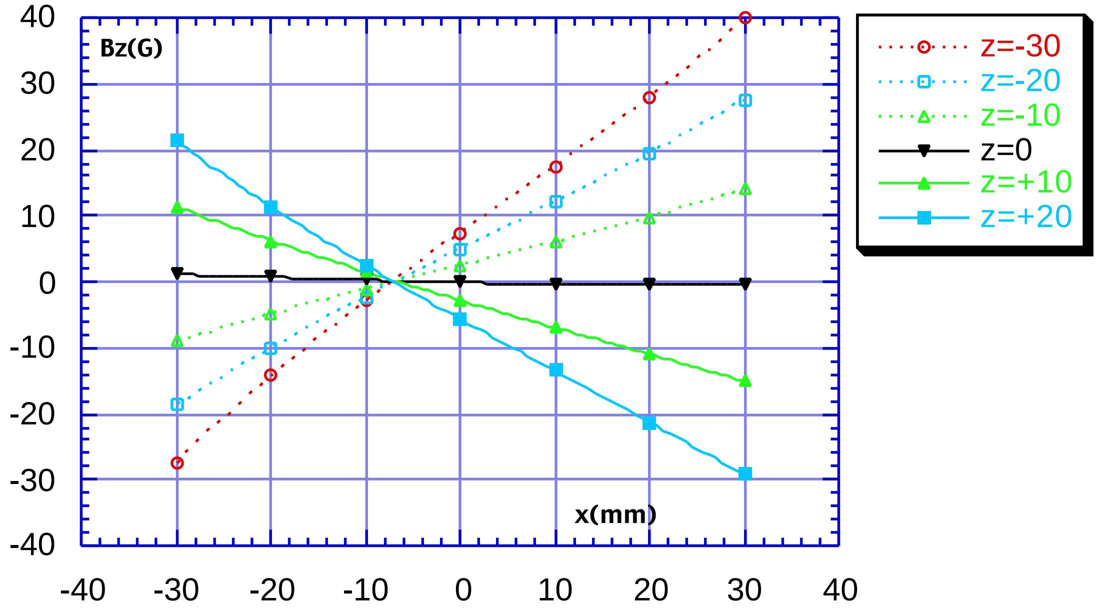

Figure 6 - Vertical field component at magnet center with CV @ 109 A, CH off.

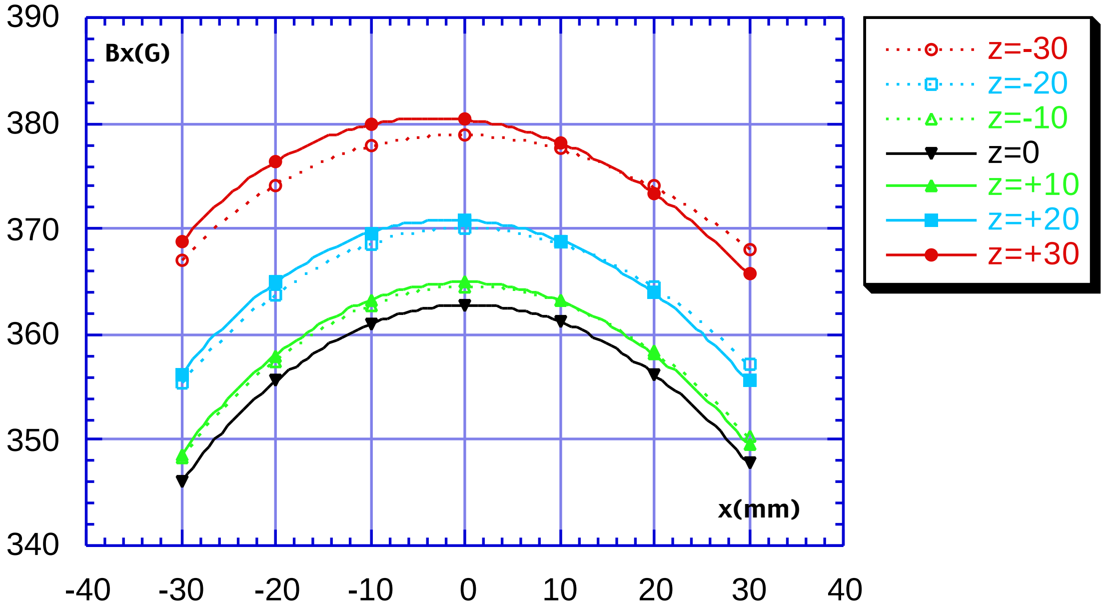

Figure 7 - Horizontal field component at magnet center
with CV @ 109 A, CH off (expanded scale).

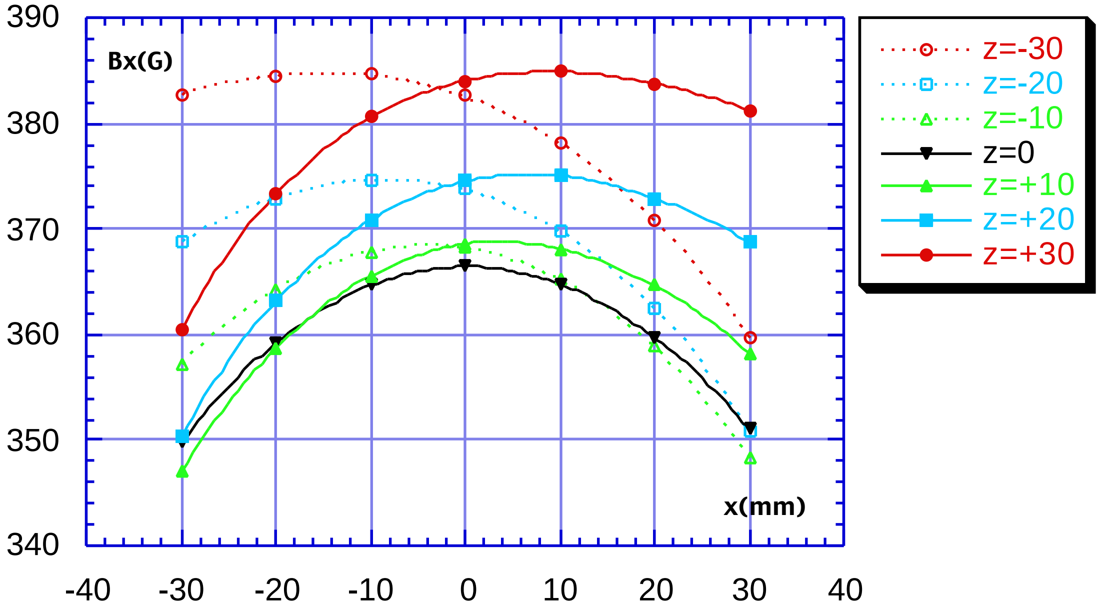

Figure 8 - Horizontal field component at magnet center with CV @ 109 A and CH @ 171 A (expanded scale)

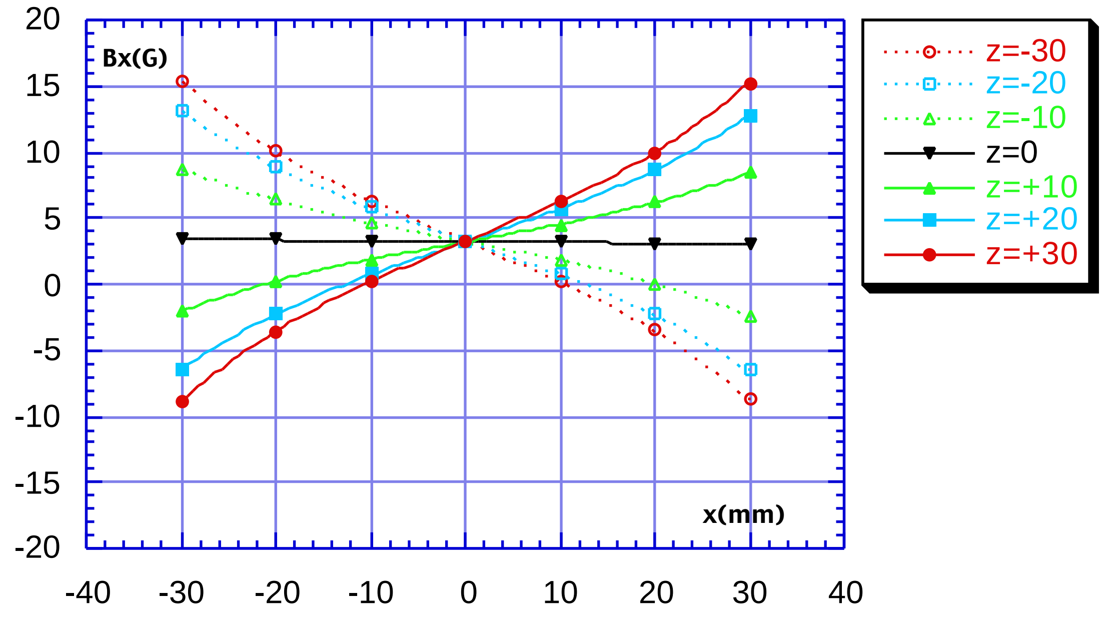

Figure 9 - Horizontal field component at magnet center with CH @ 171 A and CV off.

The behaviour of the field has been measured in steps of 20 mm along straight lines parallel to the magnet axis at different horizontal and vertical distances from it in steps of 10 mm inside the good field region. Both field components on the central axis (x = z = 0) are shown in Fig. 10, normalized at the nominal excitation current of CV (109 A).

The full width at half maximum is 331 mm for the vertical component and 397 mm for the horizontal one. As in the case of the Square, Rectangular and HVSQ Correctors [2,3,4] there are long tails, not negligible even at half a meter from the magnet center. This should be kept in mind for those correctors located into the ring near other magnetic elements, since the calibration could change significantly due to the absorption of the field lines by the yokes of the neighbouring magnets.

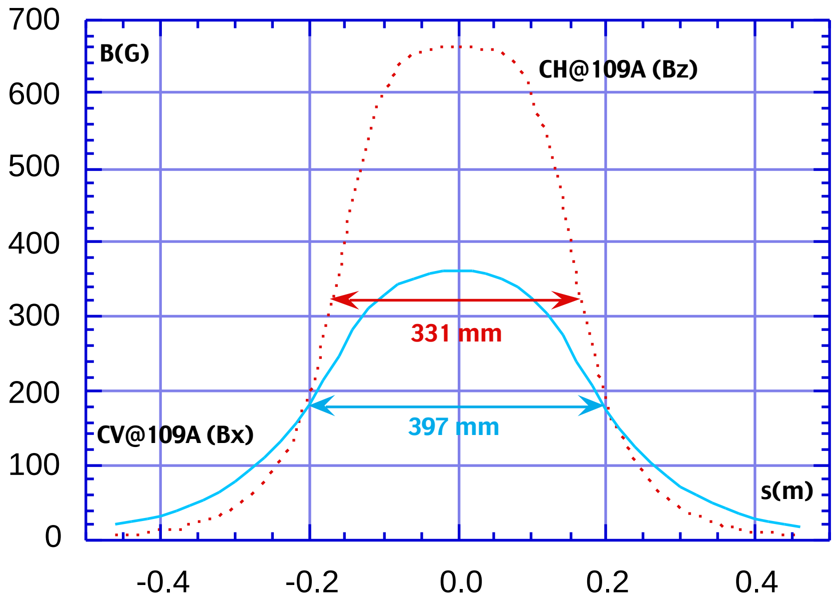

Figure 10. Horizontal and vertical field component along the magnet axis.
CH = CV @ 109 A

The value of the field integral taken along lines parallel to the magnet axis at different horizontal and vertical positions are given in Fig. 11 and Fig. 12 for the vertical and horizontal component respectively (the scale is expanded).

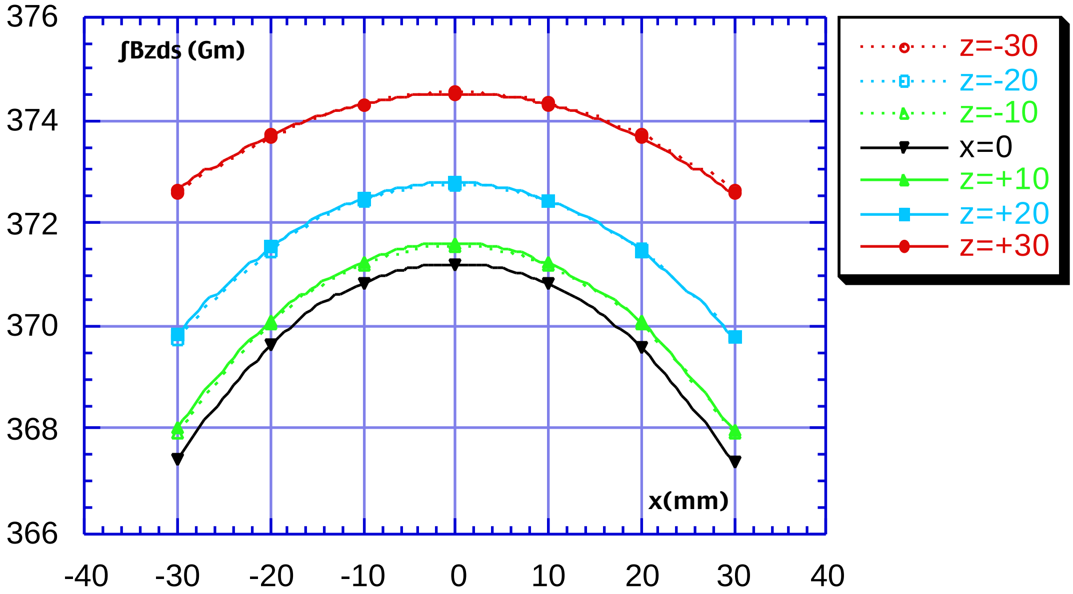

Figure 11 - Integrated vertical component with
CH @ 171 A, CV off (expanded scale).

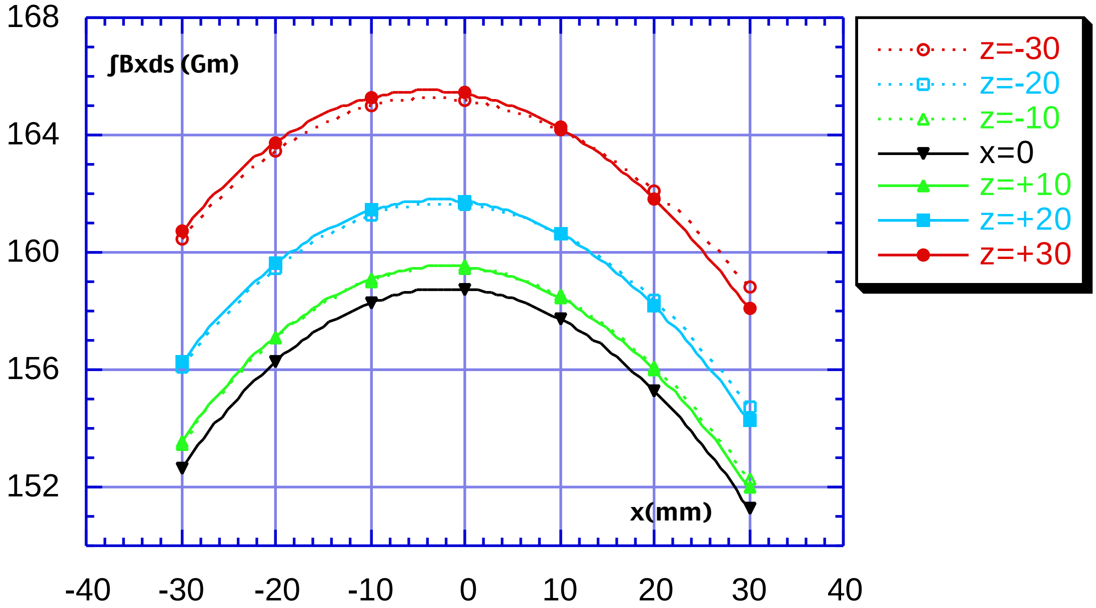

Figure 12 - Integrated horizontal component with
CV @ 109 A, CH off (expanded scale)

In the case of the horizontal correction the variation of the field integral within the good field region is ±≈1%, while it reaches ±≈4.5% for the vertical one, with negligible left-right and up-down asymmetries.

The calibration factors, taken at the magnet center, give for the angular kick α to the beam:

$$\alpha_x \text{ (mrad)} = 0.0649 \text{ I(A) / E(GeV)}$$

$$\alpha_z \text{ (mrad)} = 0.0435 \text{ I(A) / E(GeV)}$$

By fitting the curves in Figs. 11,12 with a polynomial, we find also small integrated sextupole terms:

$$\text{CH} \dashrightarrow S_z \text{ (T/m)} = \int(\partial^2 B_z/\partial x,z^2)\, dy = 4.63\text{x}10^{-3} \text{ I (A)}$$

$$\text{CV} \dashrightarrow S_x \text{ (T/m)} = \int(\partial^2 B_x/\partial x,z^2)\, dy = 1.35\text{x}10^{-2} \text{ I (A)}$$

Due to the close proximity of the two rings this corrector and the "Lambertson" one [1] have been designed with iron shields to screen the other ring from the stray field of the correctors. We have checked both the horizontal and vertical field components on the horizontal symmetry plane along a straight line perpendicular to the magnet axis at its center. The vertical field component was found to be negligible (less than 3 G) outside the screen and the yoke on the other side, with both coils excited at their nominal currents. The horizontal component is negligible as well when CH is excited, while Fig. 13 shows its behaviour with CV set at 109 A: the origin of the horizontal coordinate is at the magnet center, and the measurements are taken starting from the "C" coil on the yoke side (right) and from the iron shield on the left one.

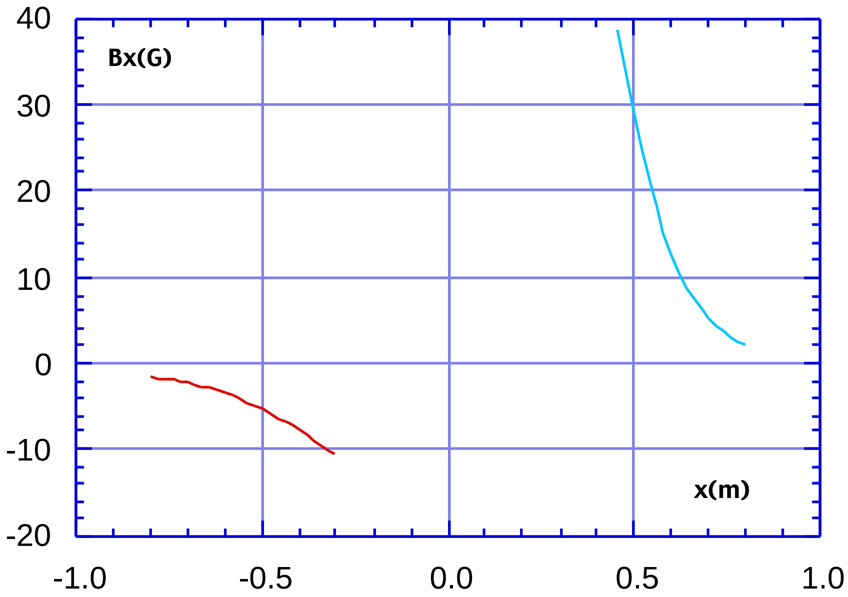

Figure 13 - Horizontal component of the stray field on the horizontal symmetry plane with CV @ 109 A and CH off.

4. Conclusions

The "C" Corrector Magnet prototype has been fully characterized at LNF. The measurements confirmed the reliability of its magnetic design. As in the case of the other DAΦNE correctors, the fields generated by the two coils add linearly within the good field region.

The interference of the field tails with the yoke of other magnetic components in the ring should be carefully checked during commissioning by calibrating each corrector with the beam and the closed orbit detection system. The measured stray fields on the horizontal plane are not harmful to the magnetic components of the other ring.

As a consequence of all the above described measurements, the prototype has been accepted and series production authorized.

References

[1] B. Bolli, F. Iungo, N. Ganlin, F. Losciale, M. Modena, M. Paris, M. Preger, C. Sanelli, F. Sardone, F. Sgamma, M. Troiani - "Measurements on TESLA Lambertson Corrector Prototype for the DAΦNE Main Rings" - DAΦNE Technical Note MM-18.

[2] B. Bolli, F. Iungo, N. Ganlin, F. Losciale, M. Paris, M. Preger, C. Sanelli, F. Sardone, F. Sgamma, M. Troiani - "Measurements on SIGMA-PHI Square Corrector Prototype for the DAΦNE Main Rings" - DAΦNE Technical Note MM-14.

[3] B. Bolli, F. Iungo, N. Ganlin, F. Losciale, M. Paris, M. Preger, C. Sanelli, F. Sardone, F. Sgamma, M. Troiani - "Measurements on SIGMA-PHI Rectangular Corrector Prototype for the DAΦNE Main Rings" - DAΦNE Technical Note MM-14.

[4] B. Bolli, F. Iungo, N. Ganlin, F. Losciale, M. Paris, M. Preger, C. Sanelli, F. Sardone, F. Sgamma, M. Troiani - "Measurements on SIGMA-PHI CHV+SkewQuad Corrector Prototype for the DAΦNE Main Rings" - DAΦNE Technical Note MM-16.