DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, July 3, 1996
Note: **MM-18**

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

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1. Introduction

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

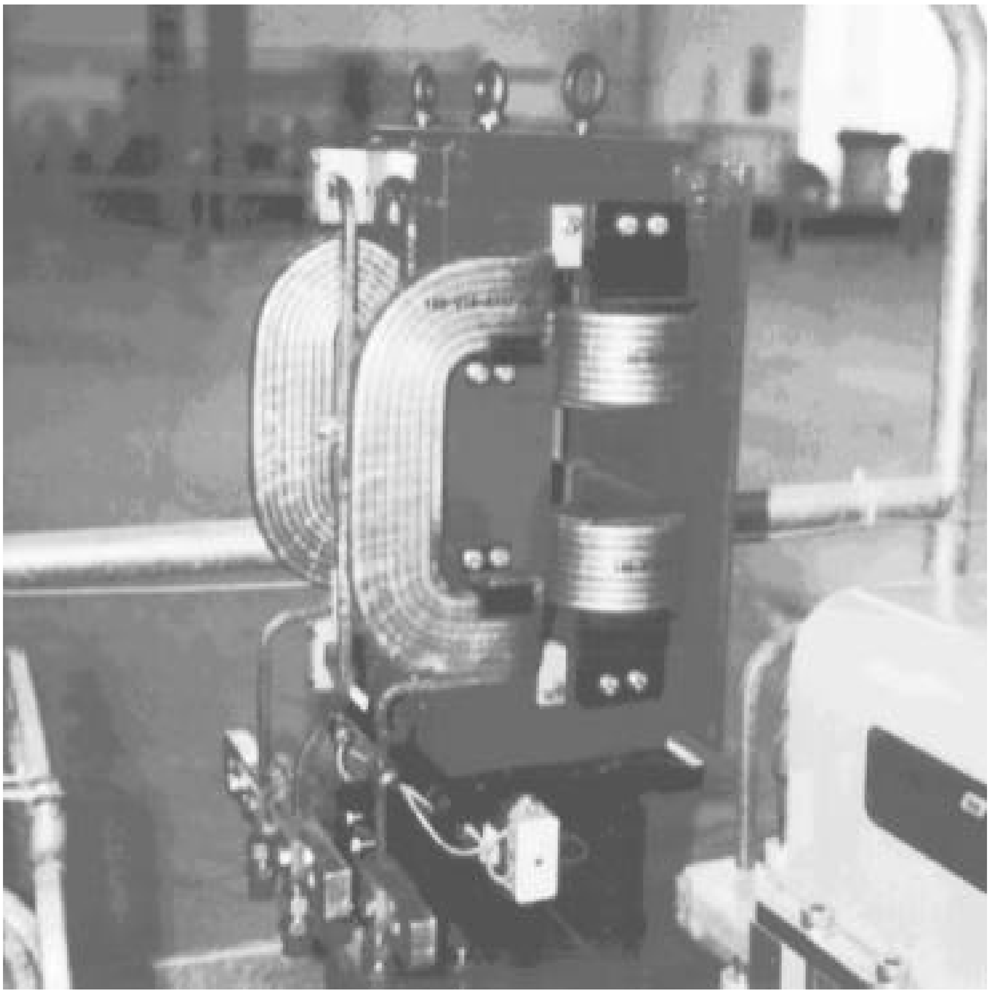

Figure 1 - The "Lambertson" Corrector Magnet

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

Table I - "Lambertson" Corrector Magnet prototype parameters.

"Lambertson" Corrector H/V	units	CH	CV
Energy	MeV	510	510
Nominal current	A	215	127
Nominal field (design)	G	259	259
Measured field	G	246	259
Deflection Angle	mrad	2.9	4.0
Magnetic Length (Design)	mm	197	197
Measured length (FWHM)	mm	196	239
Magnet gap	mm	≈170	97
Number of turns		32	16
Copper Wire Diameter	mm	6 * 6	6 * 6

2. Electrical measurements

The resistance of the "Lambertson" 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 12.11 mΩ @ 23 °C

Vertical coil 11.9 mΩ @ 23 °C

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

Horizontal coil 2.514 V @ 215 A, corresponding to 11.7 mΩ

Vertical coil 1.56 V @ 126.6 A, corresponding to 12.3 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 good.

The inductance and resistance of the magnet prototype were also measured by means of a LCR meter (LCR meter HP 4284 A) at different frequencies. The results are shown in Fig. 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 "Lambertson" Corrector Magnet is listed in Table II.

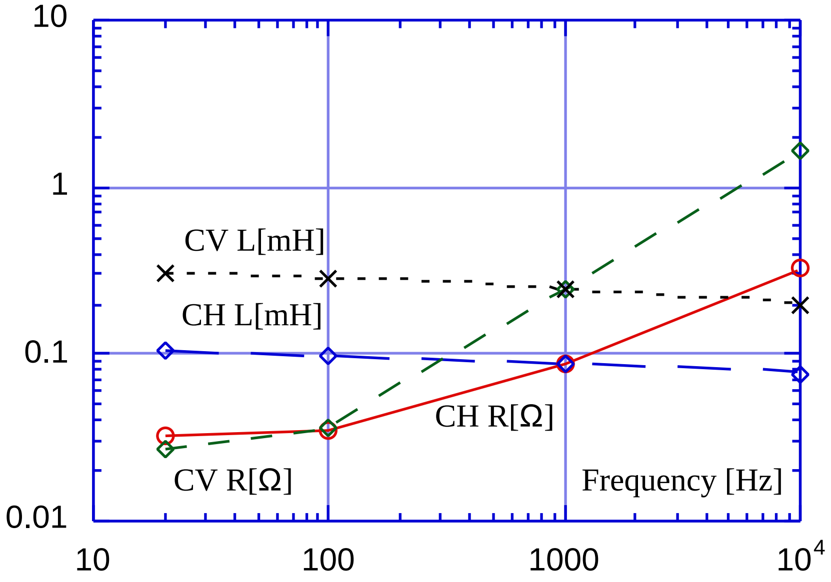

Figure 2 - Resistance and inductance versus frequency
for the "Lambertson" Corrector Magnet

Table II - Temperature rise of magnet coils.

Time (min)	0	1	2	4	8
Temperature (°C)	16.2	18.3	18.9	19.2	19.5

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 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. The difference, taking into account the different cycling procedures, is negligible.

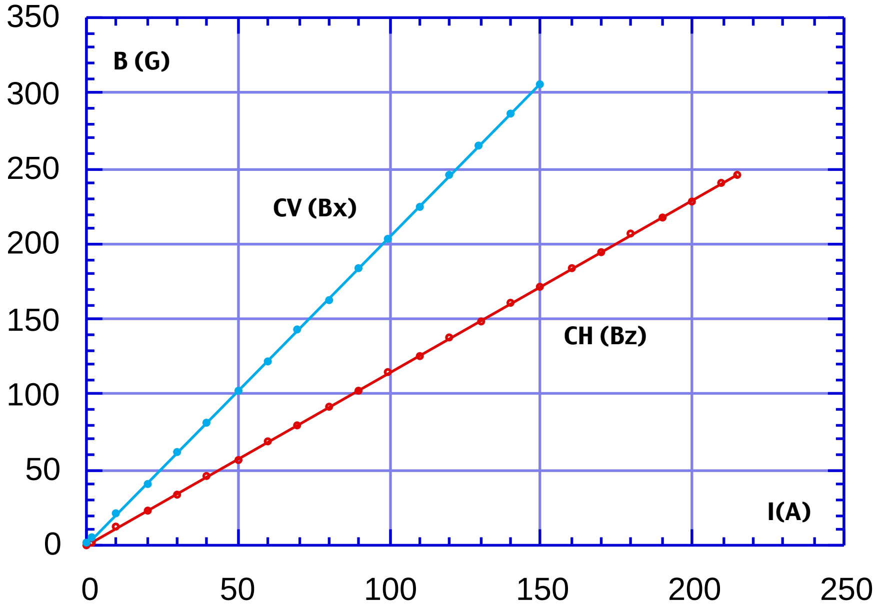

Figure 3 - Field components at magnet center versus current.

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 the horizontal and 15 mm in the vertical one (due to the small gap) with CH set at the nominal working point (215 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 measured region is quite large, due to the small size of the corrector (58%).

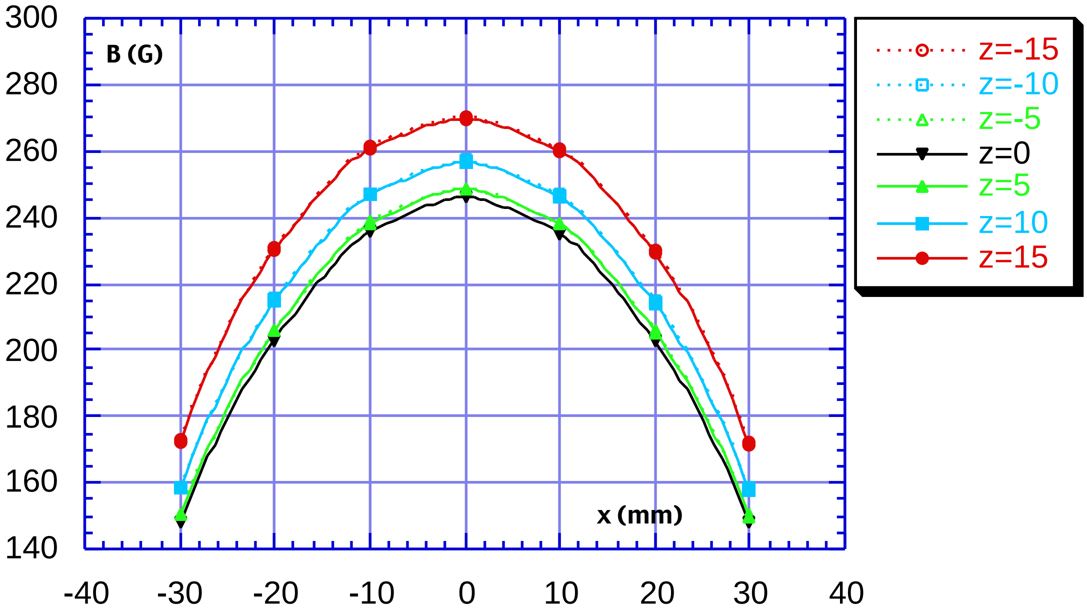

Figure 4 - Vertical field component at magnet center with
CH @ 215 A, CV off (expanded scale).

The field in this case does not change much when also the vertical corrector CV is switched on: Figure 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 measured region (±30 mm in the horizontal direction and ± 15 in the vertical one) becomes now 63%.

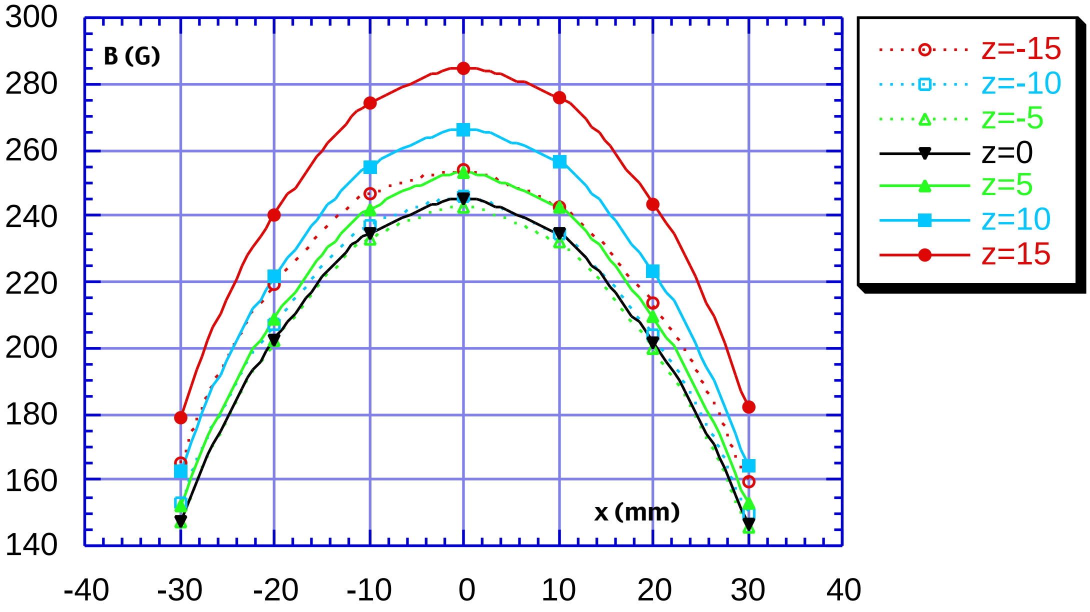

Figure 5 - Vertical field component at magnet center with CH @ 215 A and CV @ 126.6 A (expanded scale).

Figure 6 shows the vertical field component with only CV (the "other" coil) set to its nominal current (CV @ 126.6 A, CH off). Its contribution is small with respect to the other one (≈±5%).

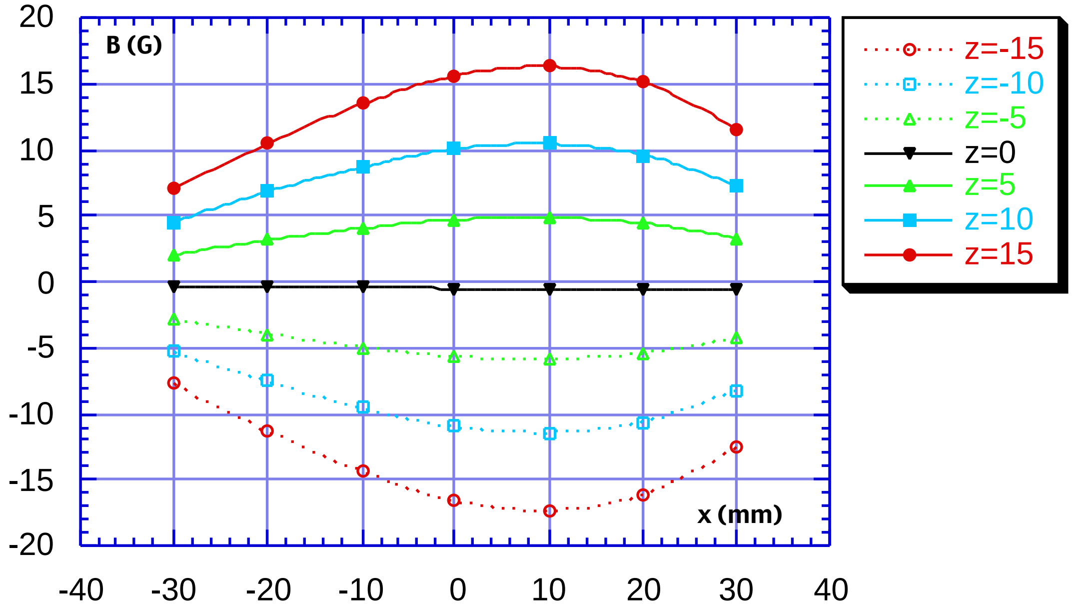

Figure 6 - Vertical field component at magnet center with CV @ 126.6 A, CH off.

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 0.35 G at the corrector center and within 0.2 G and 0.5 G in all the other points. The agreement is very good and 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 is almost independent from the vertical position, exhibits a small gradient (0.144 T/m) and its variation within ±30 mm in the horizontal direction is 31%. When also CH is switched on, the field changes significantly, depending both on the horizontal and vertical positions. The overall variation over the measured range is 105%. The perturbation introduced by the "other" coil is antisymmetric with respect to the magnet center and almost 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 0.45 G at the magnet center, and between 0.25 and 0.80 G within the measured range of positions.

The behaviour of the field has been measured in steps of 20 mm along straight lines parallel to the magnet axis. The longitudinal scans have been taken also varying the horizontal distance from the central axis in steps of 10 mm between ± 30 mm and the vertical one in steps of 5 mm between ± 15 mm. Both field components on the central axis (x = z = 0) are shown in Fig. 10, normalized at the nominal excitation current of CV (126.6 A).

The full width at half maximum is 196 mm for the vertical component and 239 mm for the horizontal one. The tails extend to ≈±30 mm for the horizontal component and ≈±15 mm for the vertical one. The "Lambertson" corrector is therefore less critical than the other Main Ring ones [2,3,4] from the point of view of the interference with the yokes of neighbouring magnets.

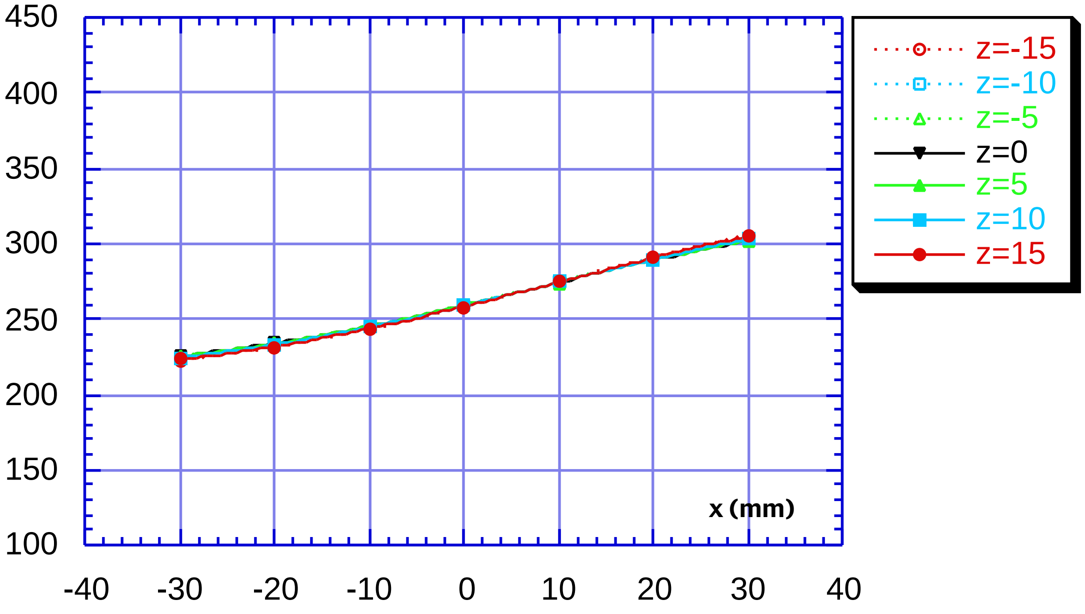

Figure 7 - Horizontal field component at magnet center with CV @ 126.6 A, CH off (expanded scale).

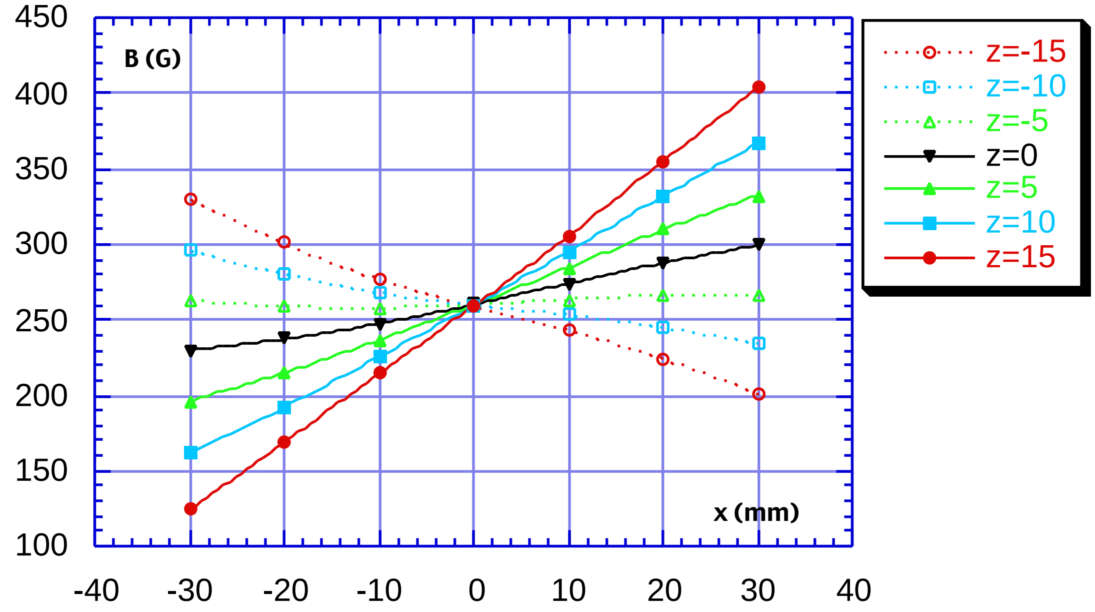

Figure 8 - Horizontal field component at magnet center with
CV @ 126.6 A and CH @ 215 A (expanded scale)

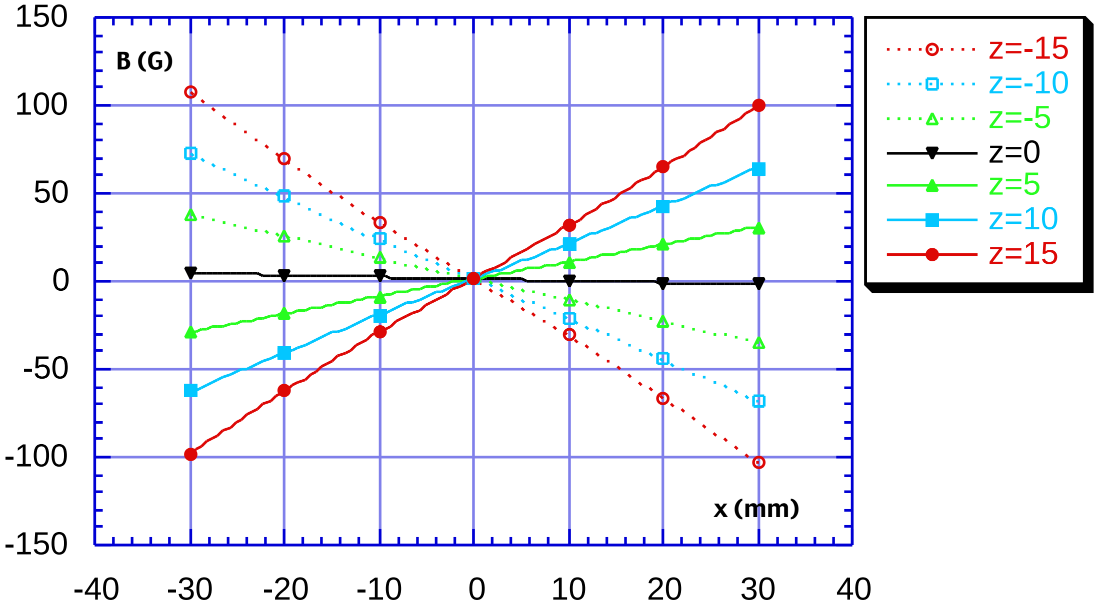

Figure 9 - Horizontal field component at magnet center with
CH @ 215 A and CV off.

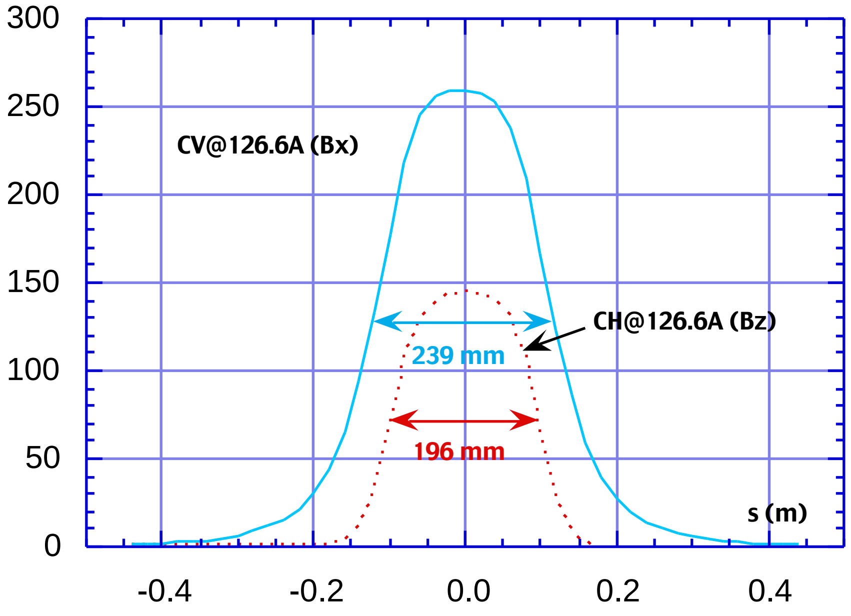

Figure 10 - Horizontal and vertical field component along the magnet axis.
CH = CV @ 126.6 A

The values of the field integrals 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.

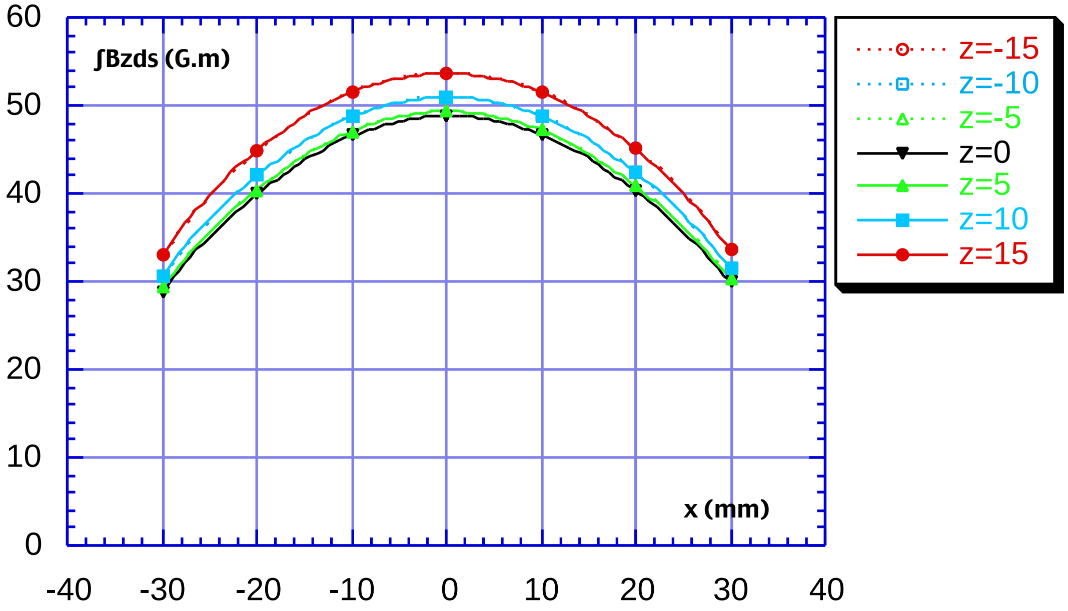

Figure 11 - Integrated vertical component with CH @ 215 A, CV off.

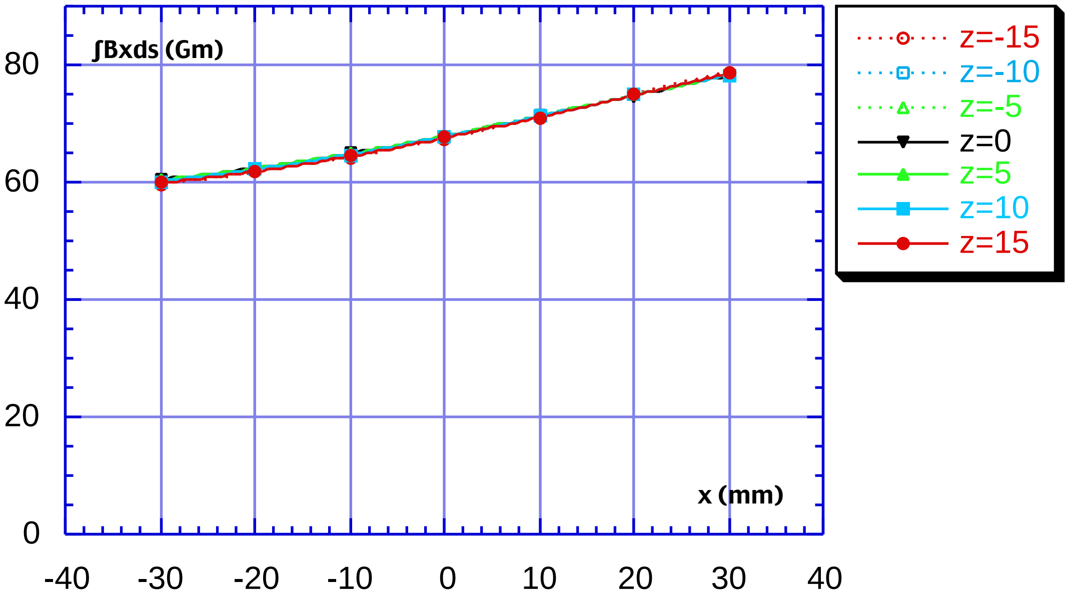

Figure 12 - Integrated horizontal component with CV @ 126.6 A

In the case of the horizontal corrector the overall variation of the field integral within the measured region is (-40%;+10%), the larger spread being related to the horizontal position, the smaller to the vertical one. The horizontal component does not depend on the vertical position, while it exhibits a linear behaviour with respect to the horizontal one. The variation within ±30 mm is (-12%,+16%).

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

$$\alpha_x \text{ (mrad)} = 6.81\text{x}10^{-3} \text{ I(A) / E(GeV)}$$

$$\alpha_z \text{ (mrad)} = 1.61\text{x}10^{-2} \text{ I(A) / E(GeV)}$$

By fitting the curve in Fig. 11 with a polynomial, we find also a small integrated second order term for the horizontal corrector:

$$\text{CH} \;\text{-->}\; S_z \text{ (T/m)} = \int(\partial^2 B_z/\partial x,z^2)\, dy = 2.0\text{x}10^{-2} \text{ I (A)}$$

while for the vertical one there is a small integrated linear term in the horizontal component:

$$\text{CV} \;\text{-->}\; K_x \text{ (T)} = \int(\partial B_x/\partial x)\, dy = 2.5\text{x}10^{-4} \text{ I (A)}$$

Due to the close proximity of the two rings this corrector and the "C" 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 1.5 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 126.6 A: the origin of the horizontal coordinate is at the magnet center, and the measurements are taken starting from the large coil on the yoke side (right) and from the iron shield on the left one.

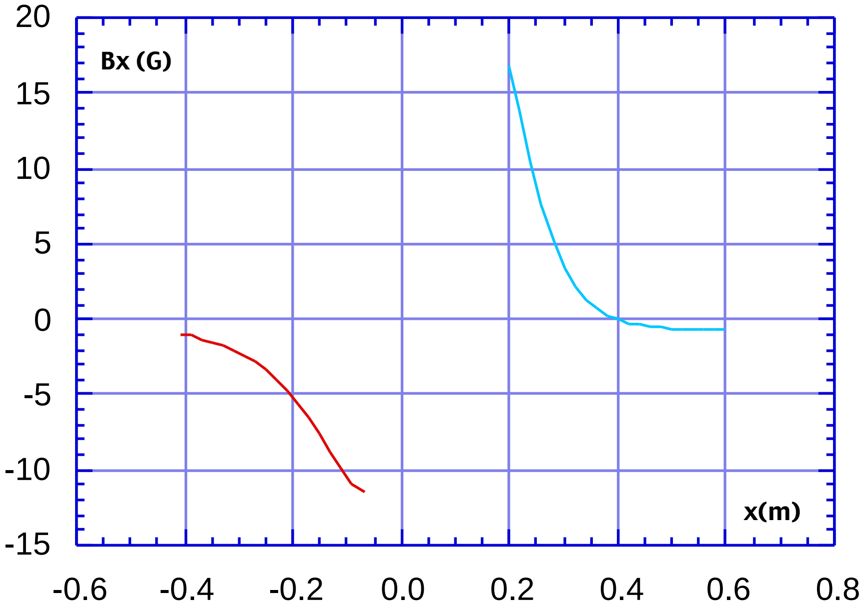

Figure 13 - Horizontal component of the stray field on the horizontal symmetry plane with CV @ 126.6 A and CH off.

4. Conclusions

The "Lambertson" 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.

Due to the small size of the magnet, the bending field depends on the position much more than the other Main Ring correctors [1,2,3,4]. There is also a small gradient in the horizontal component, leading to a small tune shift when the corrector is excited. These dependencies should be taken into account in the orbit corrections algorithms. 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 "C" Corrector Prototype for the DAΦNE Main Rings" - DAΦNE Technical Note MM-17.

[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.