DAΦNE TECHNICAL NOTE
INFN - LNF, Accelerator Division

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THE INJECTION/EXTRACTION 2° SEPTUM MAGNETS OF THE DAΦNE ACCUMULATOR

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1. Introduction

The 2° injection/extraction septum is one of the most critical magnetic elements of both the DAΦNE Accumulator and Main Rings.

Two of them are placed at the end of the Transfer Lines from the Linac to the Accumulator. Positrons are injected counterclockwise in the Accumulator: they enter the ring through the septum on the right (looking towards the Accumulator from the Linac), are stored and damped inside the ring, and finally extracted through the other one. Electrons follow the opposite trajectory. The two septa are therefore specular with respect to the symmetry axis of the Accumulator passing through the RF cavity.

The peculiar characteristic of these magnets is a bending field confined around the beam in the Transfer Line, with stray field on the beam stored in the Accumulator kept as low as possible to avoid closed orbit deformation. It is realized as a C-shaped iron yoke closed by a thin copper conductor acting as a separator between the Transfer Line and Accumulator vacuum chambers. In order to minimise the amplitude of betatron oscillations of the injected beam around the stored one, the thickness of this septum must be kept as small as possible. The magnet is powered with continuous d.c. current, in order to avoid using a high power pulsed power supply at 50 Hz.

In order to test the feasibility of the magnet, a prototype has been built at LNF and measured successfully [1]. The final design has been included in the contract for the construction of the whole DAΦNE Accumulator, and two magnets have been built by TESLA Engineering and delivered to LNF in December 1994. Their main characteristics are listed in Table 1. Figure 1 shows a picture of the magnet, while Figure 2 is a copy of the magnet drawing.

Table 1 - 2° Septum parameters

Nominal field (T)	0.104
Bending angle (mrad)	38
Gap height (mm)	22.5
Magnetic length (mm)	623 ± 0.25
Septum conducting area (mm^2)	33.75
Septum thickness (mm)	1.5
Current (A)	1843
Current density (A/mm^2)	55
Resistance (mΩ)	0.62
Power (kW)	2.1
Voltage (V)	1.14
Water circuits per magnet	1
Total water flow rate (m^3/s)	1.0×10^{-4}
Pressure drop (atm)	3

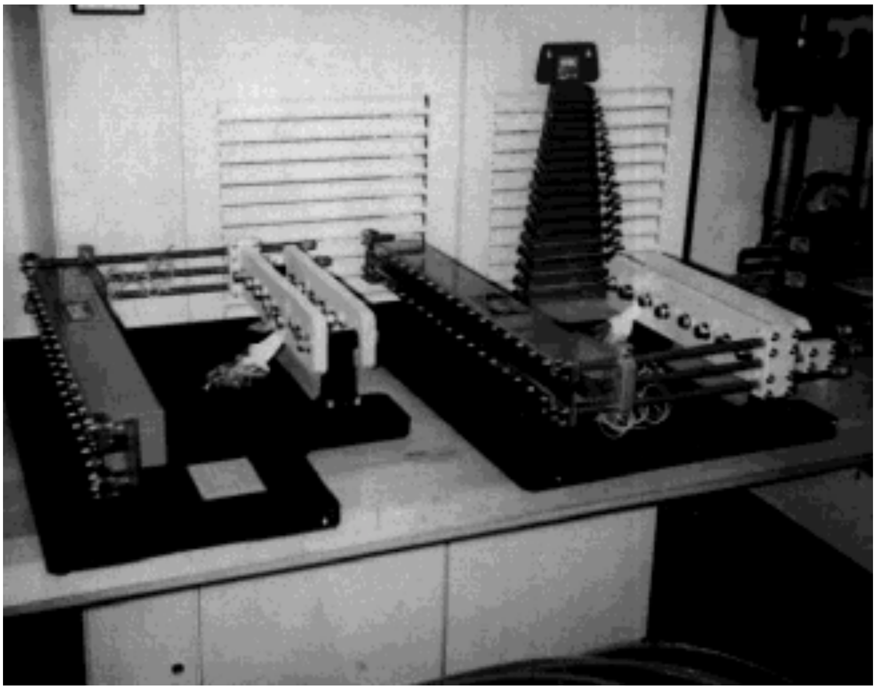

Figure 1

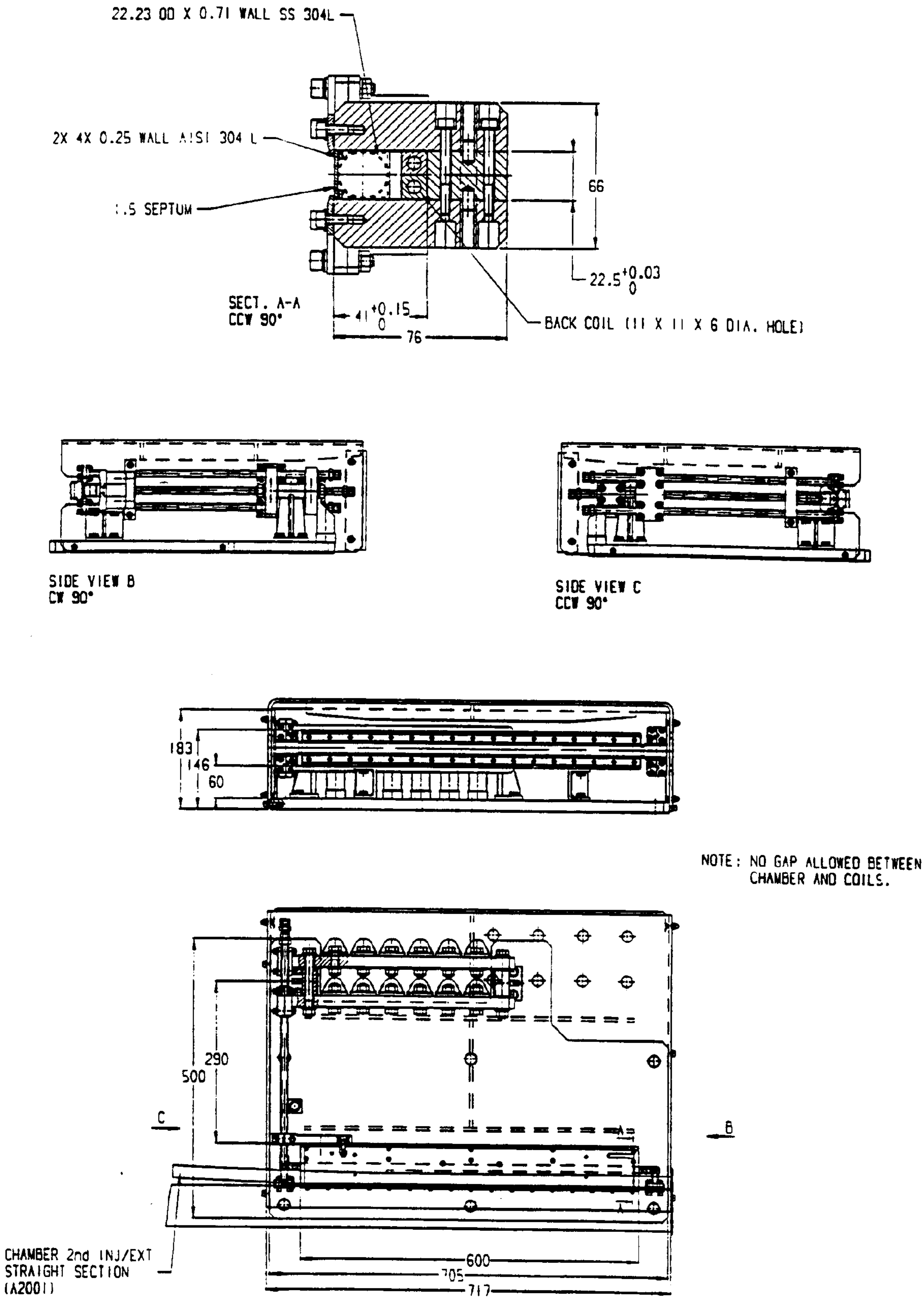
22.23 OD X 0.71 WALL SS 304L
2X 4X 0.25 WALL AISI 304 L
.5 SEPTUM
66
22.5 +0.03 0
SECT. A-A
CCW 90°
41 +0.15 0
76
BACK COIL (11 X 11 X 6 DIA. HOLE)
SIDE VIEW B
CW 90°
SIDE VIEW C
CCW 90°
183
146
60
NOTE: NO GAP ALLOWED BETWEEN
CHAMBER AND COILS.
290
500
C
B
600
705
717
CHAMBER 2nd INJ/EXT
STRAIGHT SECTION
(A2001)

Figure 2

2. Electrical Measurements

The measurement of the electrical resistance of the 2° septa has been performed by means of the Volt-Ampere method, due to its very low value. To measure the d.c. current we used a very precise DCCT (a HOLEC device) for a maximum current of 2250 A. The voltage at the magnet connections was measured by means of a Fluke 77 volt-meter, rated 0.3% absolute precision.

The following readings were recorded:

Voltage = 1.14 V   Current = 1843 A

These values give a resistance of 0.62 mΩ, in good agreement with the TESLA design value of 0.6 mΩ (@ 20° C).

We tried also to perform a measurement of the magnet resistance and inductance versus frequency using an L-R-C meter HP 4284A. However, the extreme low values of the resistance and inductance made the measurements very difficult and their results not reliable enough.

3. Hydraulic and Thermal Measurements

The hydraulic and thermal measurements were made at the nominal excitation current (1843 A), and, starting from a room temperature of 23±1 °C, after 3 hours of continuous operation the temperature of the magnet iron mass was practically unchanged. The copper conductor temperature slightly increased to about 25°C. This very small temperature increase was justified by an operating current lower than the specified one (1843 A instead of 2125 A), being the total water flow rate $9.7 * 10^{-5}$ m^3/s very near the specified one.

4. Magnetic Measurements

All magnetic measurements described in the following have been performed on both magnets. The results are the same within the experimental errors. We therefore present in this note the results obtained for Septum #1. The measurements have been done with a Hall probe system driven by a computer controlled 5 axis positioning system [2].

Figure 3 shows the field at the magnet center as a function of the excitation current. The behaviour is linear up to 2300 A, the nominal field of 0.104 T being achieved with 1843 A.

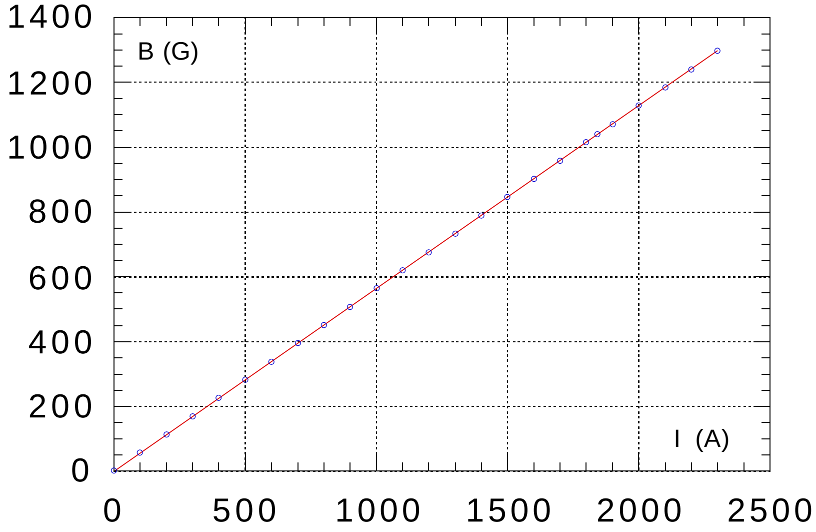

Figure 3 - Excitation curve of Septum #1

The space available for the vacuum vessel is 28 mm in the horizontal direction between the thin septum and the coil, and 22.5 mm in the vertical one between the upper and lower parts of the yoke. The stainless steel vacuum vessel has a circular cross section of 22.23 mm outer diameter, and a thickness of 0.71 mm. It is adjacent to the inner coil on the transfer line side, and to the thin septum on the Accumulator one.

Due to the large value of the nominal bending radius (16.35 m), we have estimated the magnetic length along a straight line parallel to the thin septum, approximately at the centre of the magnet gap. Taking a reference system with the longitudinal axis (y) on the intersection between the horizontal symmetry plane of the magnet and the thin septum surface on the storage ring side, and a horizontal axis (x) perpendicular to the first one at the magnet centre and lying on the symmetry plane with the positive direction towards the Accumulator ideal trajectory, the field has been measured at a horizontal position equal to -15 mm.

Figure 4 shows the behaviour of the field along this line.

The magnetic length, defined as the field integral divided by the field at the centre of the magnet is 632.1 mm, ≈9 mm longer than the specified value. We have verified that this difference does not affect the beam trajectory to an appreciable level, and therefore decided not to correct the steel length to achieve the nominal one.

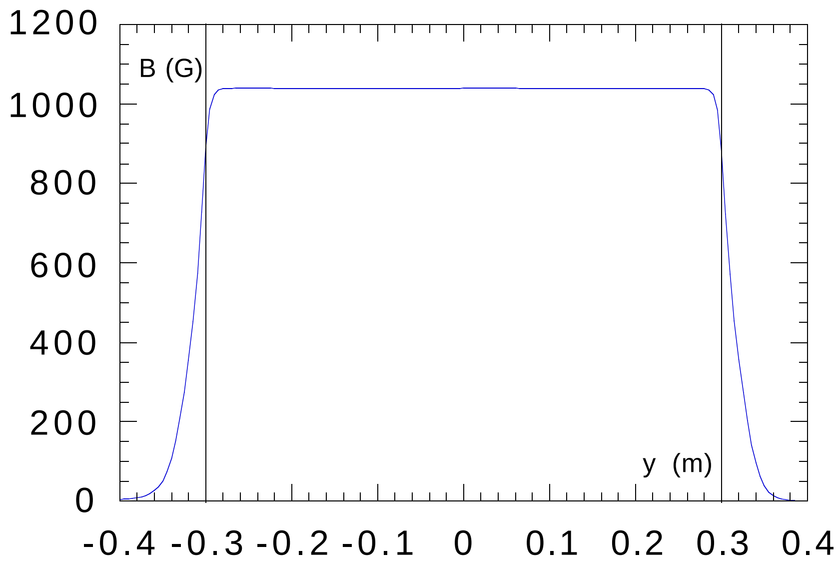

Figure 4 - Magnetic field at the centre of the magnet gap.
The vertical solid lines represent the boundaries of the yoke.

The magnet is slightly asymmetric in the longitudinal direction due to the different shapes of the coil on the two sides. The electrical connections are on the transfer line side, while on the other one, the Accumulator side, there is the return path of the coil. We have measured the field as a function of the horizontal position at the magnet centre and, on both sides, at 150 mm from the centre, at the yoke boundary (±300 mm) and at 25 mm outside the yoke (±325 mm).

Figures 5, 6, 7 and 8 show the results of these measurements. The limited horizontal range of the measurement is due to the size of the Hall probe support.

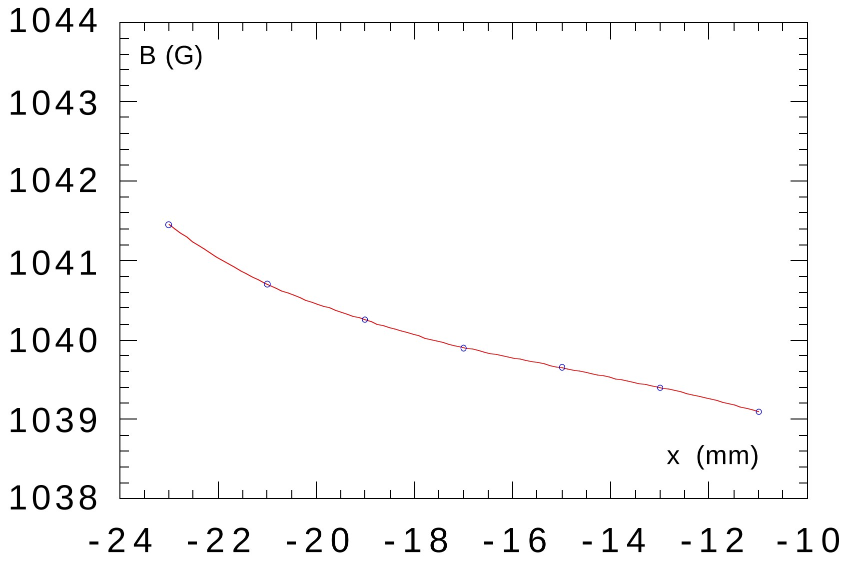

Figure 5 - Horizontal dependence of the vertical field at magnet centre

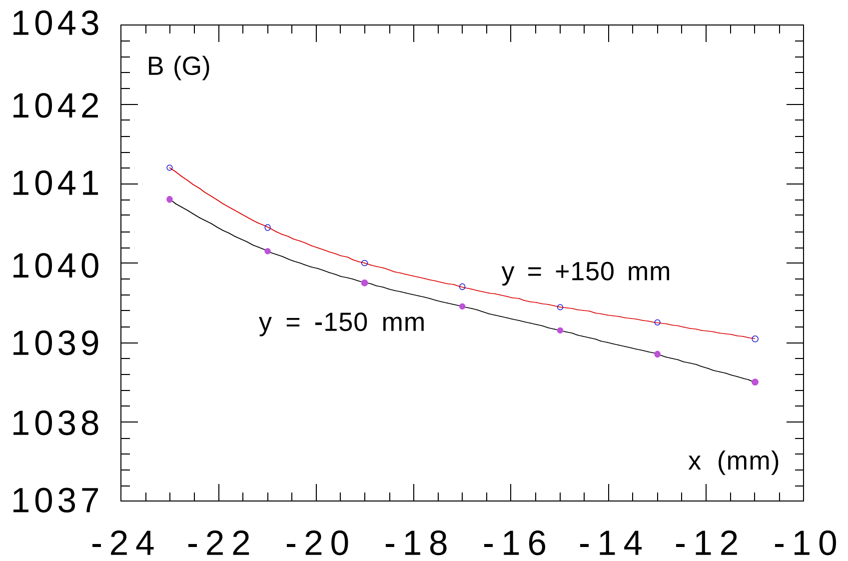

Figure 6 - Horizontal dependence of the vertical field at ± 150 mm from magnet centre

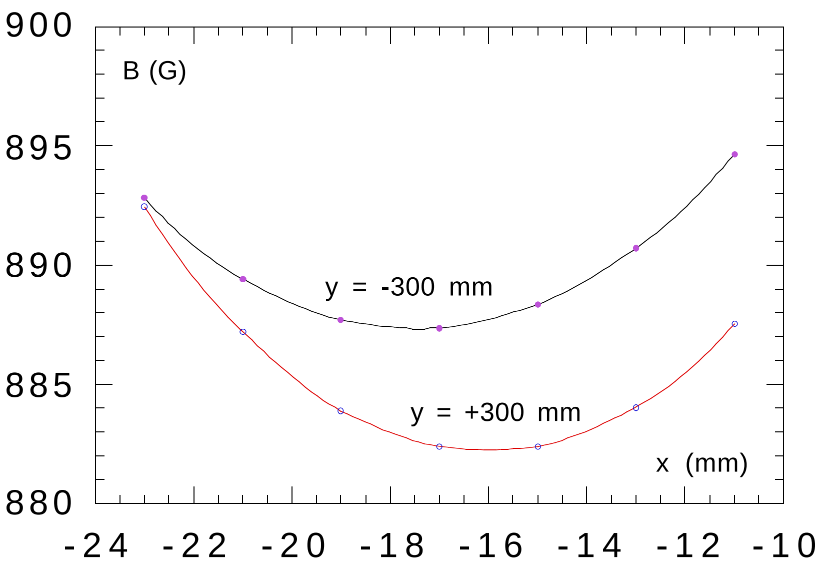

Figure 7 - Horizontal dependence of the vertical field at ± 300 mm from magnet centre (yoke boundary)

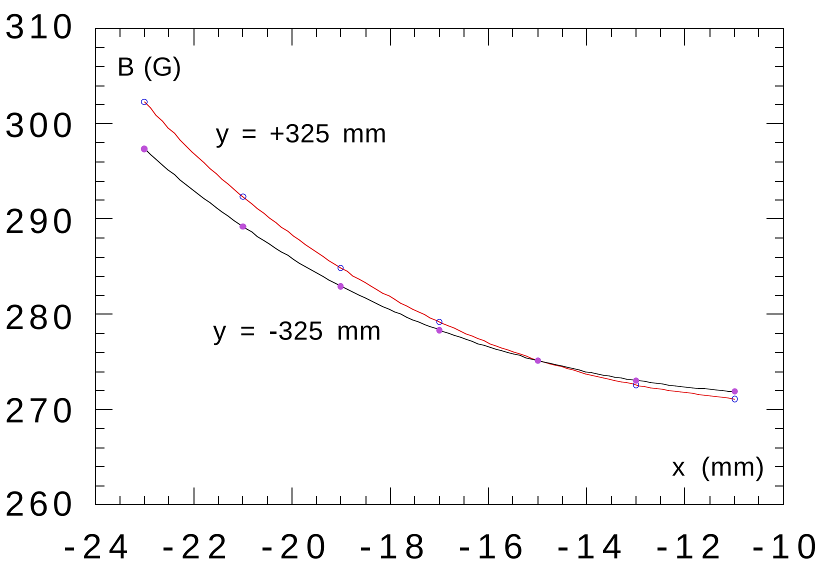

Figure 8 - Horizontal dependence of the vertical field at ± 25 mm outside the magnet yoke boundary

As already mentioned in the introduction, it is very important that the stray field outside the septum be kept as small as possible. Figure 9 shows the result of the measurements performed on the horizontal symmetry plane of the magnet at three horizontal distances from the outer face of the septum. The ideal trajectory of the stored beam lies at x = +21.4 mm, while the single turn orbit perturbation created by the kickers drives the stored beam at +5.2 mm from the septum.

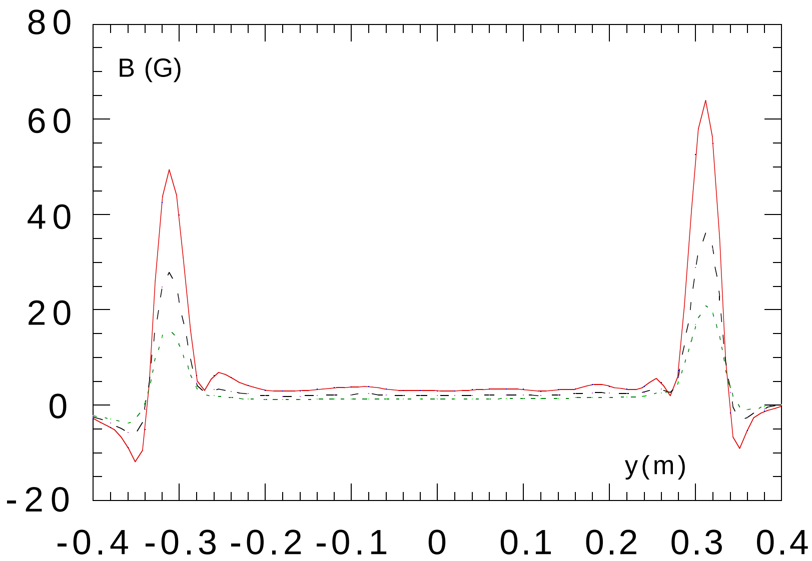

Figure 9 - Stray field outside the septum magnet.
Solid line x = +6 mm,
dashed line x = +12 mm dotted line x = +18 mm

Along the magnet the field is in the order of few Gauss; only at the two sides of the magnet, where the copper conductor is not shielded by the iron yoke, there are two peaks. However the overall field integral at +6 mm from the septum is only 5.5 Gm which drops to 2.2 Gm at +18 mm, near to the stored beam trajectory. This integral is of the same order of the integrated earth field along the injection straight section.

References

[1] M. Modena, H. Hsieh, C. Sanelli - "High Current Density Septum Prototype for Accumulator and Storage Rings of DAΦNE, the Frascati F-Factory" - 4th EPAC, London, 1994, p. 2304.

[2] B. Bolli, F. Iungo, M. Modena, M. Preger, C. Sanelli, F. Sgamma, M. Troiani, S. Vescovi - "Measurements on TESLA Quadrupole Prototype for the DAΦNE Accumulator and Main Rings" - DAΦNE Technical Note MM-4 (2/12/94).