Splitter Magnets for DAΦNE Project

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Abstract

This paper describes the design of the splitter magnets which separate the circulating beams immediately after passing through the DAΦNE interaction point. The results of both 2-D and 3-D magnetic calculations will be presented, the electrical and mechanical design will be described. A 1/3 length prototype of this magnet is under construction.

1. INTRODUCTION

A 510 MeV electron positron colliding beam facility, known as DAFNE, is currently under design and construction at Laboratori Nazionali di Frascati dell'INFN. The project consists of two storage rings, accumulator, electron/positron linac and transfer lines. There are two splitter magnets, located on the either side of the interaction point, they deflect the circulating beams into IP with appropriate crossing angle and guide them into the appropriate storage ring afterward. The magnets are of iron core electromagnetic type, the design field is 0.17 Tesla at a magnetic gap of 50 mm. A full scale prototype of reduced length is presently under construction. A very careful magnetic calculations, both in two and three dimensions, have been carried out to assure that both the dipole field uniformity and the other harmonic contents of this magnet are within the limits required by machine lattice.

2. MAGNETIC CALCULATIONS

The design parameters of the Splitter Magnet for DAΦNE are:

Energy	510	MeV
Bending angle	0.15	rad
Bending radius	10	m
Magnetic field	0.17	Tesla
Full gap	50	mm
Magnetic length	1.5	m
Entrance beam-beam separation	10	cm
Exit beam-beam separation	32.46	cm
Field quality ($\Delta B/B$ at ± 25 mm)	$< \pm 5 * 10^{-4}$	

A simple minded way to generate an alternate and compact magnetic field is to place, side by side, two H-type magnets with opposite polarity (shown in Fig. 1a). This arrangement can be further simplified by observing the magnetic flux path (Fig. 1b) in the central return leg, the fluxes from the two magnets cancel each other, and so no iron is necessary (Fig. 1c).

Figure 1c shows the configuration which has been studied carefully in two dimension by means of POISSON computer code [1]. We have focussed our attention to the beam entrance end,where due to the small trajectory separation, is a more critical area.

Many different magnet geometries have been studied:

- Magnet with iron poles and correction shims
- Magnet with iron poles without correction shims but with pole face windings
- Window-frame type magnet with different type coil geometry.

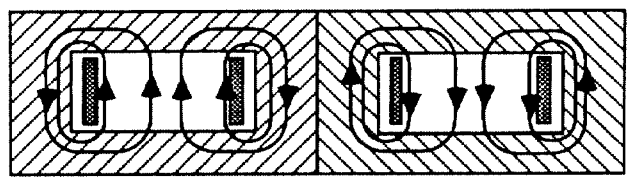

Fig. 1 a

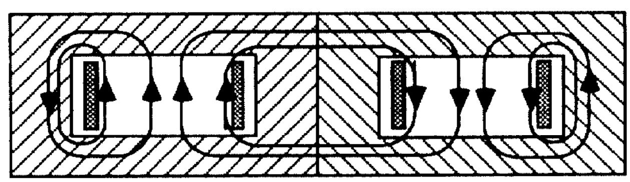

Fig. 1 b

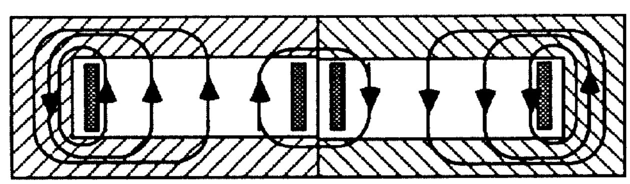

Fig. 1 c

Figure 1a,b,c - Split field magnets

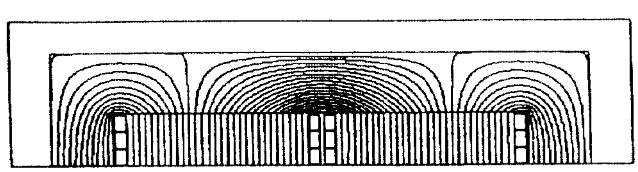

Figure 2 - Basic geometry and field lines plotted by Poisson

This paper will only discuss the configuration shown in Fig. 1c, since it is the more favourable one from the field quality point of view.

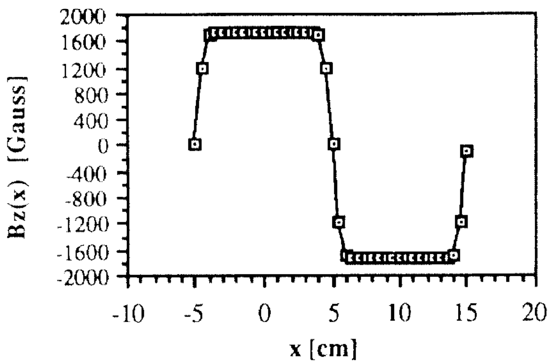

Figure 3 - Bz(x) Poisson code

A 2-D Poisson analysis was carried out on the magnet geometry shown in Fig. 2 which also shows the flux lines within the magnet boundary. The mesh size of this particular run is of 1 mm in order to obtain more precise results.

The horizontal coil size has been chosen as small as possible, in order to improve the magnetic field homogeneity. The copper conductor size used in these calculations are: 7.5 * 5.5 mm^2.

Fig. 3 shows the magnetic field, as calculated by Poisson, in the section under examination.

The maximum deviation with respect to the median plane central magnetic field is in the order of $-7*10^{-4}$ at x=-25 mm, where "x" axis represents the radial coordinate, perpendicular to the beam direction. The "beam centers" are located at x=0.0 cm and x=10.0 cm respectively.

Being a picture frame window magnet, It is therefore very important to understand the influence of the coil location accuracy to the field quality. Two cases, where the coil has been considered as a single turn having the same external dimensions as that of the three turns, have been investigated due to the effect of a 2 mm upward and downward shift on the field homogeneity. The figure 4 depicts this effect. It is clear that during the magnet engineering design and manufacturing, a great care must be excised to assure that the proper coil location accuracy can be achieved.

A 3-dimensional calculation of a 40 cm long magnet has been performed with the Magnus code [2]. The coil ends have been assumed to be saddle-type to provide more space for the machine vacuum chamber and to improve the fringing field quality.

At the present time, a pseudo elliptical shape vacuum chambers, one for each beam, have been considered. Fig. 5 shows the upper half of the iron with the four coils.

The resolution of the results was not satisfactory, even if we had used nearly the maximum number of mesh points (≈14,000) of the present version of Magnus, because the variations of the magnetic field take place within the distance comparable to that of mesh dimension, about 1 cm in the input section. Consequently, the magnetic potential best fit done by the code cannot be very accurate giving an overshoot phenomenon with damped oscillations that can be clearly observed in the table of the magnetic field values.

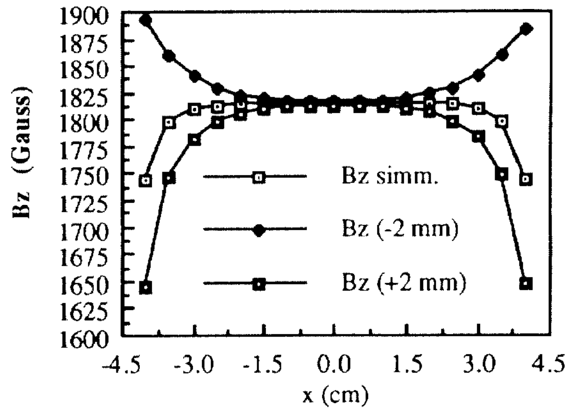

Figure 4 -Bz(x) as function of the coil position

Point by point results must be analyzed very carefully, although the general field slopes confirm qualitatively the Poisson results, taking into account the coil end fringe field effects that Poisson cannot evaluate.

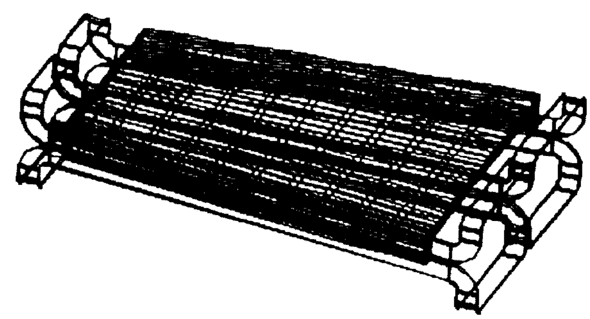

Figure 5 - Upper half magnet with the coils

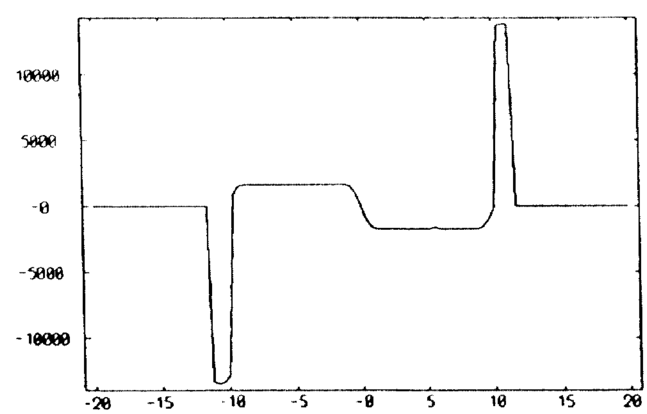

Figure 6 - Bz(x) at the center of the magnet (Magnus code)

The figure 6 shows the magnetic field as a function of the radial coordinate, Bz(x), on the median plane of the magnet. The high and narrow peaks correspond to the magnetic induction inside the iron return legs (≈ 1.3 Tesla). The flat-tops are the good field regions. The useful zone, going from the entrance to the end of the magnet increases moving away from the interaction point.

Fig. 7 shows the results of Poisson and Magnus (200 against 20 mesh points are compared) at the end section. It is evident that the field decreases due to the fringe field induced by the coil saddle ends..

One can notice that the field predictions between Magnus and Poisson are inconsistent, with finer mesh, Poisson seems to do better than that of Magnus. One can also notice that the field directives appears to compare well between these two codes.

Fig. 8 shows the vertical component of the magnetic field Bz(x) along the beam trajectory, 5 cm apart, starting from the I.P.end, moving towards the magnet center.

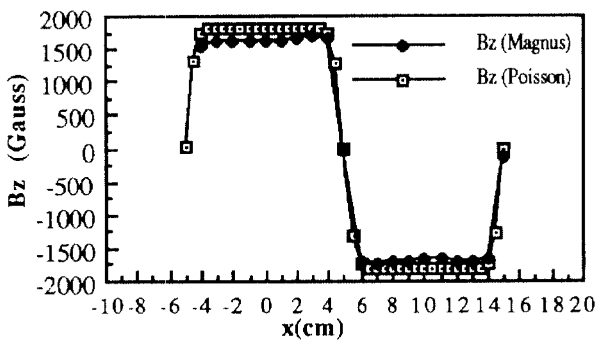

Figure 7 - Magnetic field at the magnet entrance as evaluated by POISSON and MAGNUS

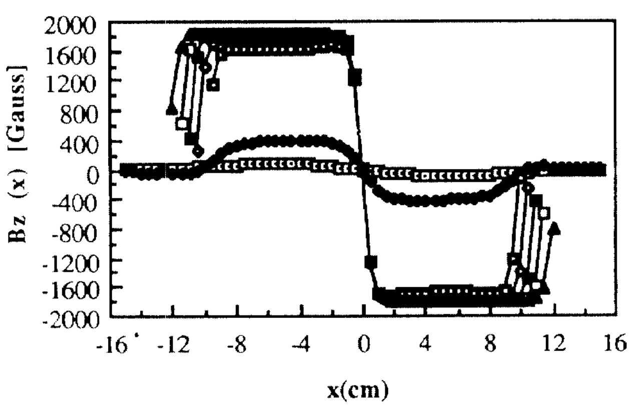

Figure 8 - 3-D magnetic field vs. radial coordinate at different longitudinal position.

A 40 cm long, full cross section prototype magnet is presently being built. Detailed magnetic measurements will be carried out to verify the validity of the field calculation and proper shaping of the magnet ends

3. Electrical and Hydraulic Parameters

Each coil has 3 turns that are in series for electrical connections and in parallel for hydraulic connections. The two right side coils, as the two on the left, will be electrically in series. It is not sure, at the moment if it will be used only one or two power supplies to compensate minor differences of the magnetic field flat-tops.

The following list shows some of the more important parameters of the splitter magnet:

		Prototype	Final
Mag.length	(m)	0.4	1.5
Cu. conductor	(mm)	7.5 * 5.5	Ditto
Conductor hole	(mm)	5.5 * 3.5	Ditto
Ave. turn length	(m)	1.8	4.1
Cond. length/coil	(m)	5.4	12.3
R/ Coil (60 ° C)	(mΩ)	5	11.2
Total resistance	(mΩ)	20	44.8
Nom. current	(A)	1128	1128
Max.current	(A)	1660	1660
Nom. Amp/mm^2	51.3	51.3	
Max Amp/mm^2		75.5	75.5
Nom Voltage	(V)	22.6	50.5
Max Voltage	(V)	33.2	74.4
Total power	(kW)	25.5	57
Max power	(kW)	55.1	23.5
Water flow m^3/secx10^{-4}		4.4	9.8
Water ΔT	°C	30	30
Water ΔP	ATM	0.35	3.3

4. Mechanical Design

The splitter magnet is a picture frame window solid iron yoke type. It essentially is made of two conventional septa. The location of the multi-turn coils have to be located and aligned properly in order to achieve good field quality. The electrical insulation will be accomplished by applying multi-layer of Kapton tapes with pressure sensitive backing, the insulated coils will be confined in a well made mechanical mold and cured at temperature consistent with the adhesive of the Kapton tape. The coil packs will be located and confined accurately at appropriate locations inside the magnet yoke by mechanical means. Two fiducial marks capable of accepting Taylor Hobson spherical targets will be provided for alignment purpose. The roll and pitch will be determined by placing an electronic inclinator on the surfaces precisely machined on the magnet top with respect to the median plane of the magnet.

5. References

[1] Poisson/Superfish Reference Manual - Los Alamos Accelerator Code Group MS H829, Los Alamos National Laboratory, Los Alamos, NM 87545 USA.

[2] The MAGNUS Package - Ferrari Associates, Inc. - P.O. Box 1866, Orange Park, FL 32067 USA.