DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, March 8, 1994

Note: **L-14**

DIPOLE FRINGING FIELD EFFECT ON REFERENCE ORBIT

C. Biscari

The main ring dipoles have been represented up to now with a rectangular model of the magnetic field on axis[1]: they are completely defined with only two of the three parameters: angle, arc length and bending radius.

The main rings have four types of dipoles, whose nominal characteristics are listed in table I:

Table I - Main ring dipoles

	Angle (°)	*Bending radius* (m)	*Arc length* (m)	*Gap height* (m)
Sector short	40.5	1.40056	0.9900	0.075
Parallel ends short	40.5	1.40056	0.9900	0.075
Sector long	49.5	1.40056	1.2100	0.075
Parallel ends long	49.5	1.40056	1.2100	0.075

The real field shape is of course not rectangular: the fringing field length depends on gap height and also on dipole shape (parallel ends or sector type). The real magnetic field behaviour will be available only when dipole prototypes will be measured. Anyway it is possible to use a field model more realistic than the rectangular one to compute the trajectory inside the dipoles.

Two models have been used for the fringing field behaviour: linear and cosine like (see Fig. 1). The extension of the fringing corresponds to two gap heights (2 g = 15 cm). Considering half a dipole with arc length L_{arc} and defining:

$z_1 = L_{arc} - g$;

$z_2 = L_{arc} + g$,

the magnetic field along the beam trajectory is:

$$B(z) = B_o \qquad z < z_1$$

$$B_L(z) = B_o \left(1 - \frac{z - z_1}{2g}\right) \qquad z_1 < z < z_2 \text{ (linear)}$$

$$B_S(z) = \frac{B_o}{2}\left(1 + \cos \frac{\pi (z-z_1)}{2g}\right) \qquad z_1 < z < z_2 \text{ (sinusoidal)}$$

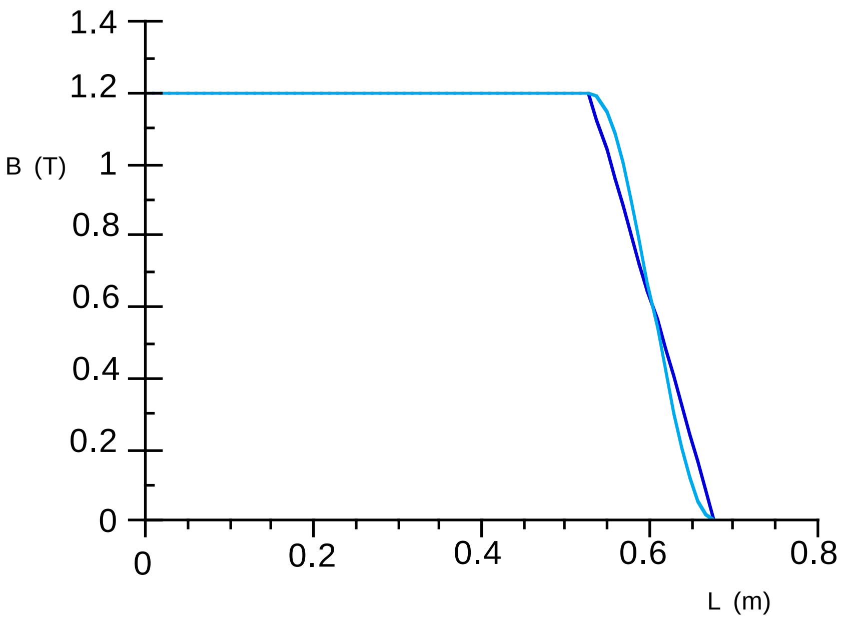

Fig. 1 - Magnetic field behaviour models in half dipole.

In the fringing region the curvature of the beam trajectory is not constant (see figure 2).

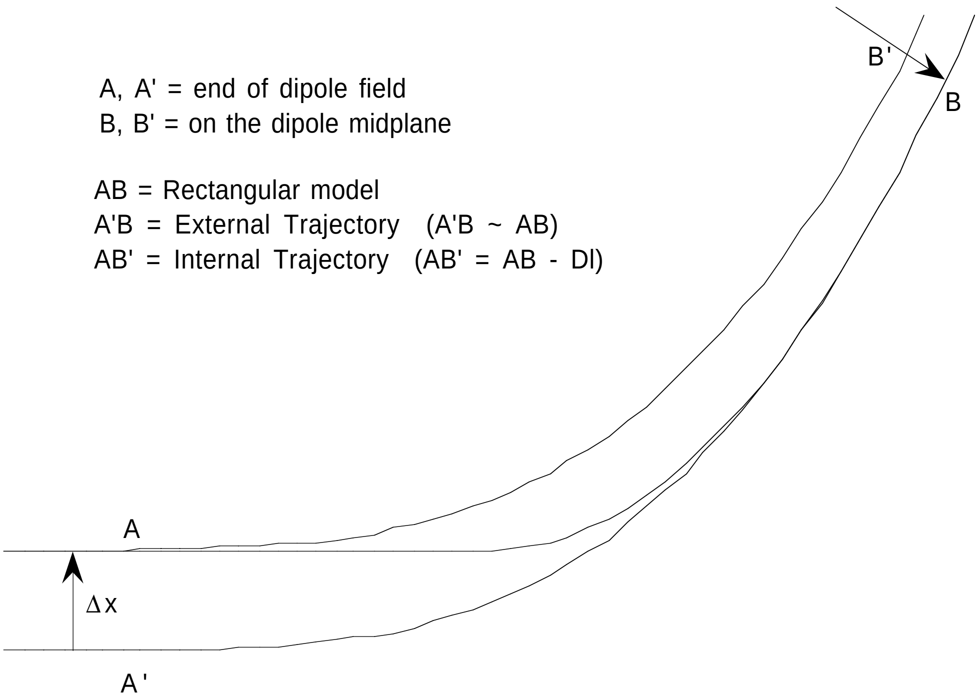

Fig. 2 - Beam reference trajectory with rectangular model and with fringing.

Starting from the magnet center, the trajectory of a particle in the real field with fringing (path BA' in Fig. 2) comes out of the magnet parallel to the "ideal" trajectory (defined as the solution for the rectangular model; path BA in Fig. 2): this because the integral of the magnetic field along the trajectory and therefore the angle are the same as in the ideal case. The trajectory is displaced by a distance Δx towards the outside of the ring. The lengths of the two paths are almost the same: they differ by ~ 10^{-6} m. If we keep the center of the magnet (point B) in the same position as in the present layout, the layout of all the ring elements (but dipoles) must be displaced outward with respect to the present position; the total circumference length remains unchanged within ~10^{-5} m.

Another possibility is to maintain the present layout of the ring unchanged, forcing the beam trajectory to do the nominal angle in the dipoles by increasing slightly the value of B_o (path B'A in Fig. 2). The integral of the magnetic field along the trajectory is kept; the path length is shorter than that calculated with the rectangular model of the bendings by a quantity Δl_i, which comes out to be of the same order than Δx. The ring circumference will be shortened by $\Sigma \Delta l_i$, taking the sum over all the ring dipoles.

Δl has been computed by imposing that the trajectory reaches the midplane of the dipole with the right angle, using B_o as free parameter. Table II gives the results for the two considered fringing models and for the long and short dipoles; with these models there is of course no difference between the sector and the rectangular dipoles. $\Delta\rho$ is the relative change of the bending radius at the center of the dipole; the value is negative because the nominal magnetic field must be slightly increased.

Table II - Change in trajectory length and bending radius

	SHORT	LONG
Triangular model		
Δl (mm)	0.46	0.59
$\Delta\rho$ (%)	- 0.05	- 0.05
Sinusoidal model		
Δl (mm)	0.26	0.32
$\Delta\rho$ (%)	- 0.03	- 0.03

The differences between the results corresponding to the two models (which in principle seem very similar) show that the magnetic field shape is really an important parameter.

The value of Δl has been estimated also with the present design of the magnetic field for the main ring dipoles[2]. The field shape on axis for the parallel ends and the sector dipoles are plotted in Fig. 3, together with the sinusoidal model. There is quite a big difference between the two cases: the parallel end fringing is so long that goes inside the first quadrupole!

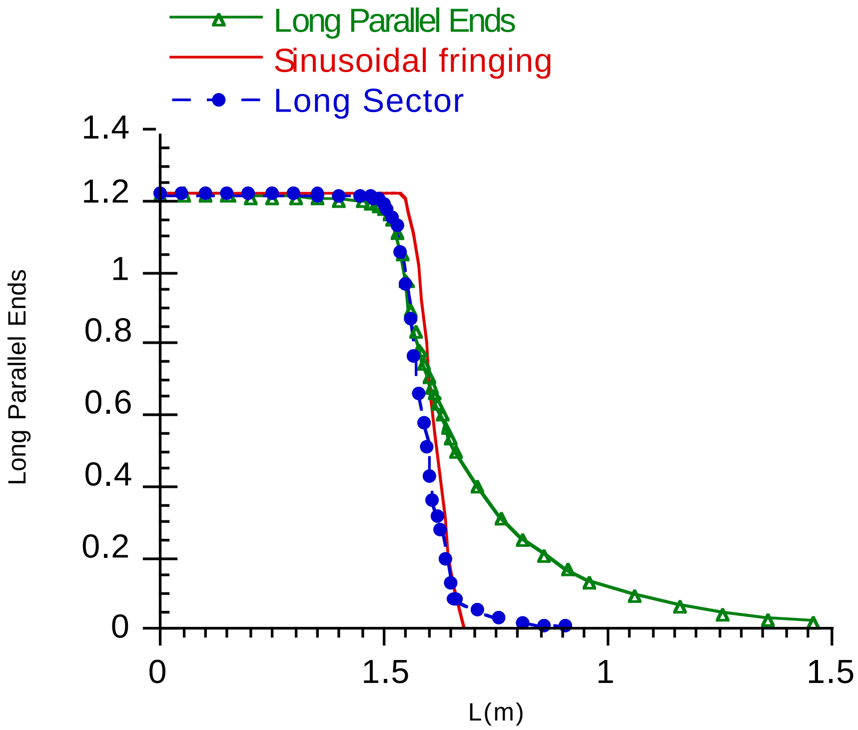

Fig. 3 - Magnetic field computation for long dipoles.

With these field shapes Δl is 2 mm for the long sector dipole and even 15 mm for the long parallel ends, which is really too much. Probably a field clamp will be necessary to shorten the fringing length.

We conclude that the modifications to the present layout can be the following:

i) Maintaining the present machine alignment, the total change in the ring circumference is of few millimeters (- 4.2 mm - triangular model; - 2.3 mm - sinusoidal model, corresponding to a central radiofrequency change of 19 or 10 kHz). If the ring circumference must be kept the same (because of the synchronization constraint with the accumulator) the difference in total length can be corrected by lengthening the drifts of the short and long straight sections by the corresponding amount, thus keeping the long axis of the present layout unchanged without modifying the transfer lines layout.

ii) Changing the magnetic center position both the short and the long axis of the ring will be longer; the arc chamber must be modified, and since the fringing of sector and rectangular dipoles will be different the change in the arc will not be symmetric. The total ring circumference is kept.

It seems more convenient to adopt the first choice. Anyway the final layout can be defined only after the measurements of dipole prototypes.

REFERENCES

[1] M.E. Biagini et al - 'Review of DAΦNE Lattices' - DAΦNE Technical Note L-9.

[2] C. Sanelli - private communication.