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Twin Aperture Quadrupoles for the LHC Cleaning Insertions

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Twin-aperture quadrupoles are proposed for the FODO structure of the LHC cleaning insertions. These quadrupoles will be of the conventional type with laminated iron cores and normal conducting copper coils. Their somewhat unconventional design is described and the main characteristics are given.

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Twin Aperture Quadrupoles for the LHC Cleaning Insertions

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Abstract **- Twin-aperture quadrupoles are proposed for the FODO structure of the LHC cleaning insertions. These quadrupoles will be of the conventional type with laminated iron cores and normal conducting copper coils. Their somewhat unconventional design is described and the main characteristics are given.**

I. Introduction

The Large Hadron Collider (LHC) will provide proton-proton collisions with a centre of mass energy of 14 GeV. The schematic ring layout is given in Fig. 1. Two insertions are reserved for beam collimation. One in octant 3 for betatron cleaning and the second in octant 7 for momentum cleaning [1, 2]. A FODO structure consisting of warm twin-aperture quadrupoles is proposed. The two beams will be separated within the insertions from their normal 194 mm radial distance to 224 mm separation. This is done by two sets of dipoles. Since superconducting magnets are very sensitive to beam losses and because of the particular magnetic field configuration conventional magnets with normal conducting copper coils were chosen. The dipoles are classical H-type magnets with one aperture for both beams. The twin-aperture quadrupoles represent a new feature in magnet design with two apertures in a common structure. Basic parameters for these quadrupoles are proposed in [2] and [3].

II. Design of the Twin-Aperture Quadrupoles

The FODO structure proposed for the cleaning insertions requires two-in-one quadrupoles with identical magnetic properties in the two apertures (i.e. opposite optical polarities "FD" or "DF" seen by the two beams. The cross-section of this quadrupole is shown in Fig. 2. It has a somewhat unconventional appearance with two poles in each quadrant of the magnet.

With an aperture of 44 mm diameter and a beam-beam separation of 224 mm, a maximum gradient of 37 T/m can be obtained. This value is lower than can be expected for a single quadrupole since the iron section of the poles and the return yoke are reduced and saturation starts for lower values of fields in the aperture. It should be noted that this effect is further amplified if the beam-beam separation is reduced.

In the present design the field on the pole tips is about 0.8 T. The maximum field in the iron at the narrowest part of the poles goes up to 1.9 T.

The main parameters of the twin-aperture quadrupoles are given in Table I. A cross-section with flux lines is shown in Fig. 3.

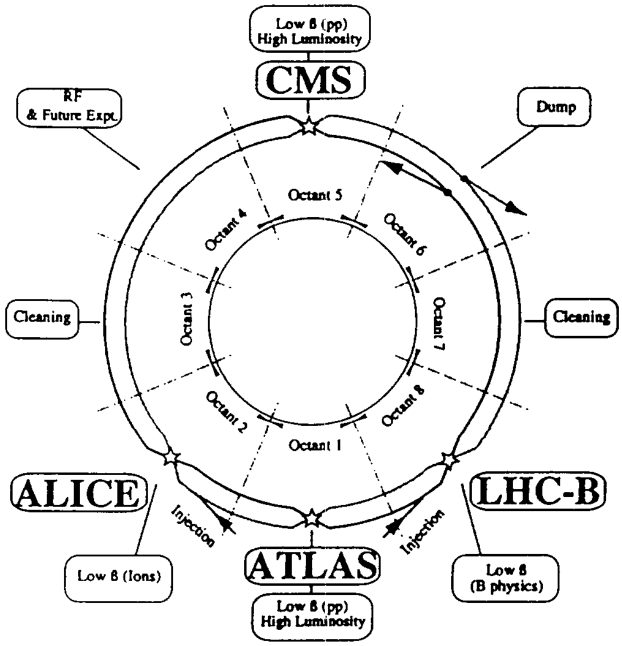

Fig. 1. LHC Layout.

TABLE I
PARAMETERS FOR THE TWIN-APERTURE QUADRUPOLES

Basic:		
Aperture ø	44.0 mm	
Gradient	37 T/m	
Magnetic length	2.94 m	
Dimensions:		
Core length	2.9 m	
Overall length	3.2 m	
Coil:		
Conductor H x W	Coil 1	18.0 x 20.5 mm
	Coil 2	17.0 x 17.0 mm
Cooling hole	7.0 mm	
No. of turns	11	
Electrics:		
Current	685 A	
Resistance	37 mΩ	
Dissipated power	17 kW	
Cooling:		
Pressure	4 bar	
Water flow	10 l/min	
Temperature rise	26° C	
Weight		
Copper	1.5 t	
Core	8.5 t	
No. of units	48	

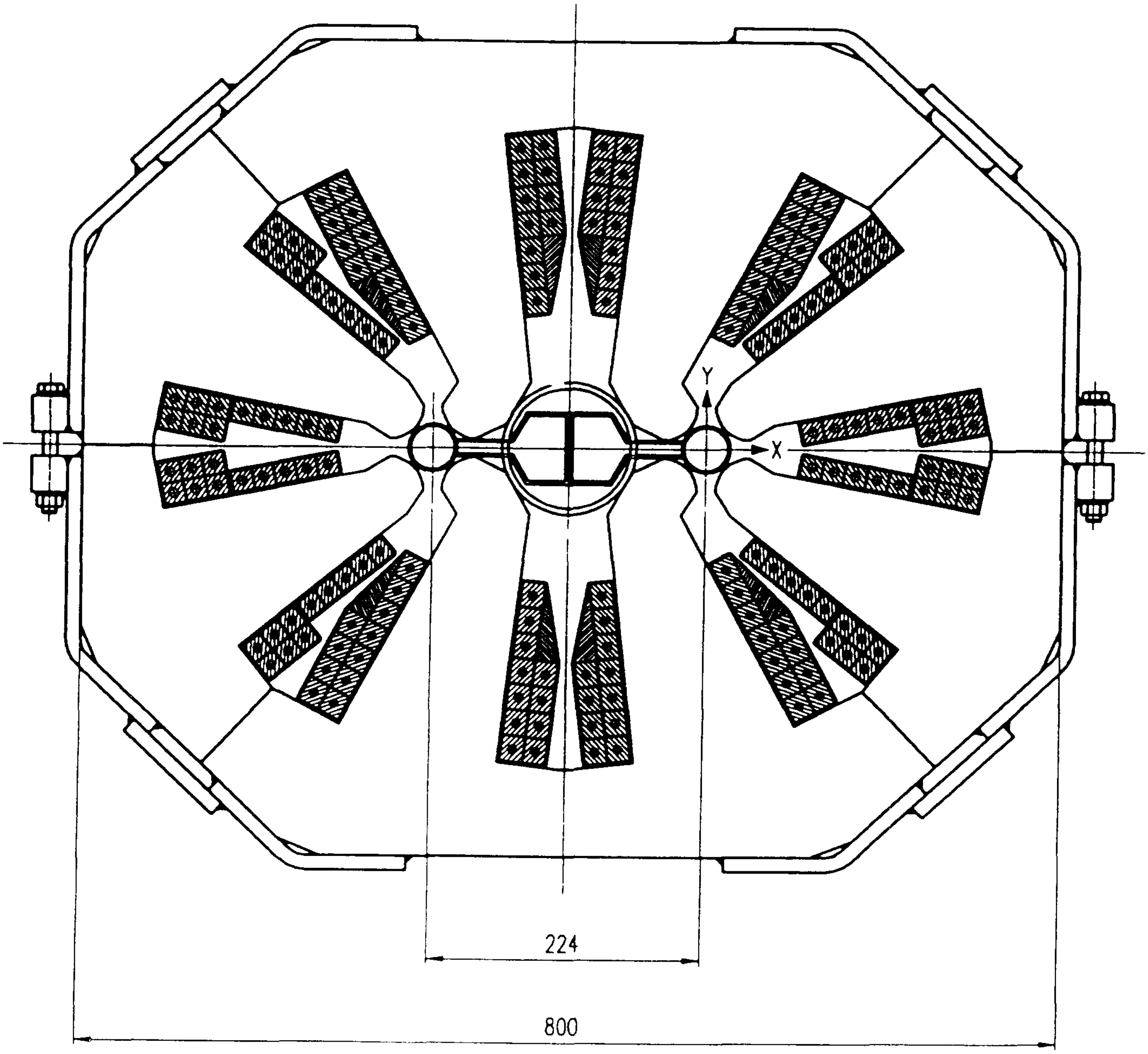

Fig. 2. Quadrupole for cleaning insertion.

The magnetic field calculations were made with the program "FLUX2D". The relative gradient error across the x-axis is shown in Fig. 4. Table II shows the harmonics up to 10th order. It can be seen that only the sextupole component has an influence on the field quality in the useful volume. A further improvement in field quality will probably be possible by using a mathematical optimization program such as "POISOPT" for example.

The quadrupoles are assembled from 8 half quadrants, each with its pre-assembled excitation coil. The yoke are laminated and made from 1.5 mm thick low carbon steel laminations. The steel quality is the same as used for most accelerator magnets at CERN. The coils are made from copper conductor. Such assemblies have successfully been made before as octupoles with length of about 1 m. In order to avoid serious manufacturing difficulties, it is suggested to limit the length of the twin-aperture quadrupoles to about 3.0 m.

REFERENCES

[1] T. Risselada, "Regular FODO Structures in the LHC Insertions without Ring Crossing," CERN SL/Note 93-83(AP), September 1993.

[2] J.P. Koutchouk, R. Ostojic, T. Risselada, C. Rufer, W.S. Scandale, S. Weisz, "The Lattice Layout and Optics of LHC Version 4.1," CERN LHC Note 318, April 1995.

[3] J.B. Jeanneret, T. Trenkler, "LHC Cleaning Insertion: Some Parameters for the Dog-leg and the Warm Quadrupoles," CERN LHC Note 304, November 1994.

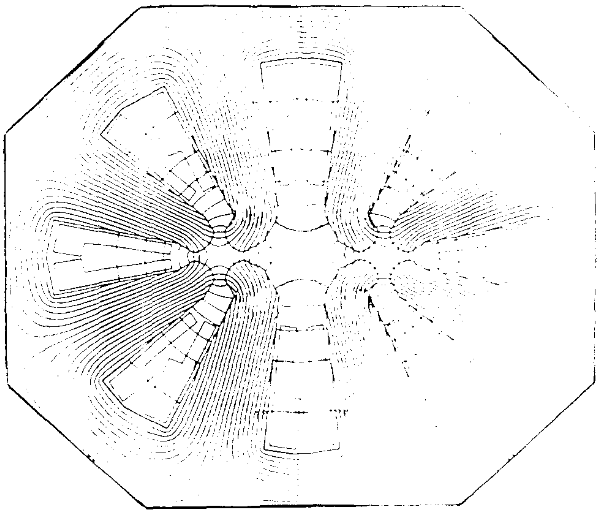

Fig. 3. Cross-section with flux lines.

TABLE II
SPECTRUM X = 0; Y=0 R = 10 mm

Harmonic Number	Flux density tesla	% fundamental
1	1.88 E-04	
2	0.371	
3	0.273 E-03	0.034
4	0.273 E-04	0.007
5	0.285 E-04	0.008
6	0.703 E-05	0.002
7	0.283 E-04	0.008
8	0.173 E-04	0.005
9	0.114 E-04	0.003
10	0.160 E-05	0.001

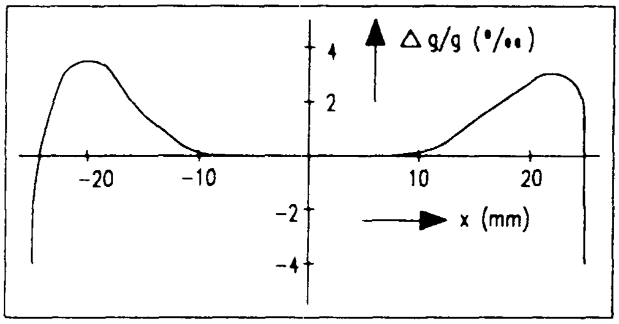

Fig. 4. Relative gradient error.