EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/PPE/92–25
7 February 1992

# DESIGN OF A MAGNET ENVISAGED FOR THE NA48 EXPERIMENT

G. Arduini

## Abstract

A possible configuration for the dipolar magnet of the spectrometer envisaged for the NA48 experiment at CERN is proposed.

3–D field calculations were carried out; their results show that the requested performances and the complete compatibility with the experiment environment are easily achieved with the presented solution.

## Introduction

The magnetic spectrometer for the NA48 experiment consists of a central dipole magnet that surrounds the cylindrical vacuum tank containing the $K^o$ decay fiducial region and of two sets of drift chambers on each side; the external diameter of the tank in the gap of the dipole is 236 cm ( see figg. 1 and 2 ) [1].

The magnet must meet the following requirements:

- Field integral $\int_{-6m}^{+6m} B_y dz \approx 0.8$ T·m ( equivalent to a transverse momentum change of $\approx 240$ MeV/c ) with a nonuniformity smaller than 10% in the active region ( a circular region of 110 cm radius centred on the beam axis )[2].
- Fringe field intensity less than 200 G 250 cm away from the center of the magnet, along the beam ( z–axis ), where the drift chambers will be located [2].
- Magnet aperture as needed in order to accomodate the vacuum tank.
- The overall width ( x–axis ) of the dipole limited to 400 cm in order to permit handling of the wire chambers of the adjacent NA38 experiment ( see fig. 2 ).
- The maximum overall consented length ( z–axis ) of approximately 300 cm in order to allow enough space for intervention on the drift chambers; this value doesn't include possible magnetic shields if they are designed in a way permitting their easy removal.
- Its half-height ( y–axis ) must be shorter than the height of the beam pipe to ground, i. e. 286 cm.
- The stray fields in the NA38 experimental area must be weak, expecially in the zone where the wire chambers are placed ( see fig. 2 ).
- The required excitation power should remain below 1.5 MW.
- Finally the design shall aim to low manufacturing cost.

## Description of the model

The proposed dipole is shown in figg. 3a and 3b; it comprises:

- the barrel shaped iron yoke 200 cm long ( z–axis );
- 2 main coils ( one on each side of the yoke ), each one divided in 24 identical flat pancakes with section $15 \times 10$ cm$^2$ and current density $J_m = 150 \text{ A} \cdot \text{cm}^{-2}$;
- 2 compensating coils mounted above and below the yoke with the purpose of reducing the stray field, each one consisting of 3 identical pancakes with section $40 \times 10$ cm$^2$ and current density $J_c = 225 \text{ A} \cdot \text{cm}^{-2}$;
- 2 removable iron shields centred at z = ±205 cm and 30 cm wide in the direction of the beam; they have the same transverse section as the yoke.

This shape minimizes the volume of iron and limits the dimensions of the gap just to what is demanded decreasing in this way the fringe field in the region of the wire chambers.

The two compensating coils reduce by a large extent the flux dispersed around the magnet and in particular cause a steep decrease of the field in the axial direction; their efficiency is enhanced if the coils sides are approaching the dipole horizontal symmetry plane; in our case, due to the particular shape of the yoke, this can be achieved without increasing the overall magnet width.

The compensating coils can be manufactured piling up flat pancakes which are afterwards bent on a large radius ( 524.5 cm ) cylindrical surface.

The simplicity of shape of both main and compensating coils is a peculiar advantage of this solution compared to the traditional window–frame type magnet ( proposed in ref. [1] ).

The intention to use equal pancakes to form the main coils has required the particular outline of the transverse section of the yoke whose width decreases approaching the poles; the magnetic flux carried through the yoke having the same behaviour, the induction in the iron is kept everywhere below saturation. The chosen iron shape is furthermore minimizing the yoke weight.

The iron shields ( each divided in two parts to permit its removal ) could be adapted in order to act as flanges in the connection between the vacuum tank and the drift chambers centred at z = ±250 cm.

The yoke as well as the shields can be manufactured by flame cut iron plates welded together; a minimum amount of machining is necessary for the mating surfaces the tolerances being not critical in our case.

## Specification of the magnet

3–D magnetic field calculations for the above–mentioned configuration have been performed with the program TOSCA$^{\mathrm{VF}}$ at CERN; fig. 4 shows the input geometry created by means of the TOSCA$^{\mathrm{VF}}$ pre–processor SCARPIA$^{\mathrm{VF}}$ [3].

The value of the field integral is:

$$0.78\ \mathrm{T}\cdot\mathrm{m} \leq \int_{-6m}^{+6m} B_y dz \leq 0.83\ \mathrm{T}\cdot\mathrm{m}$$

with a nonuniformity of 6 %.

The fringe field modulus distribution in the active area of the drift chambers is shown in fig. 5:

$$|\mathbf{B}| \leq 185 \text{ G.}$$

Another important result is the low value of the field modulus in the NA38 experimental zone ( see figg. 2 and 6 ):

$$|\mathbf{B}| \leq 92 \text{ G.}$$

The main data of the magnet are listed hereafter:

| | | | |
|---|---|---|---|
| Overall dimensions: | | Length ( shields excluded ): | 310 cm |
| | | Width: | 400 cm |
| | | Height: | 300 cm |
| Yoke + shields: | Material: A37 or A35 steel | | |
| | | Yoke weight: | 42.5 t |
| | | Shields weight: | 6.4 t each |
| | | Total weight: | 55.3 t |
| Coils: | Material: aluminium | | |
| | Main coils: | Weight: | 3.8 t each |
| | | Power consumption: | 183 kW each |
| | Compensation coils: | Weight: | 4.1 t each |
| | | Power consumption: | 311 kW each |
| | Total weight: | | 15.8 t |
| | Total power consumption: | | 988 kW |

## Conclusions

This design respects all the conditions mentioned in the introduction; moreover it is certainly possible to further improve the characteristics of this dipole by:

- moving the compensating coils sides closer to the horizontal symmetry plane;
- diminishing the volume of iron in the regions where the magnetic flux density is well below saturation.

## Acknowledgments

I would like to thank Guido Petrucci ( CERN ) for the suggestion of this solution and for his constant advice throughout the development of this study, Wilfried Flegel ( CERN ) for support and hospitality in his group during my stay at CERN, Paola Dalpiaz ( University of Ferrara ), Jean Duclos ( University of Ferrara ) and Davide Tommasini ( Sincrotrone Trieste ) for interesting discussions.

## References

[1] G. D. Barr *et al.* , "Proposal for a precision measurement of $\epsilon'/\epsilon$ in CP violating $K^0 \longrightarrow 2\pi$ decays", CERN/SPSC/90-22/P253.

[2] G. Neuhofer, private communication.

[3] TOSCA$^{\mathrm{VF}}$, Vector Fields Limited, Oxford.

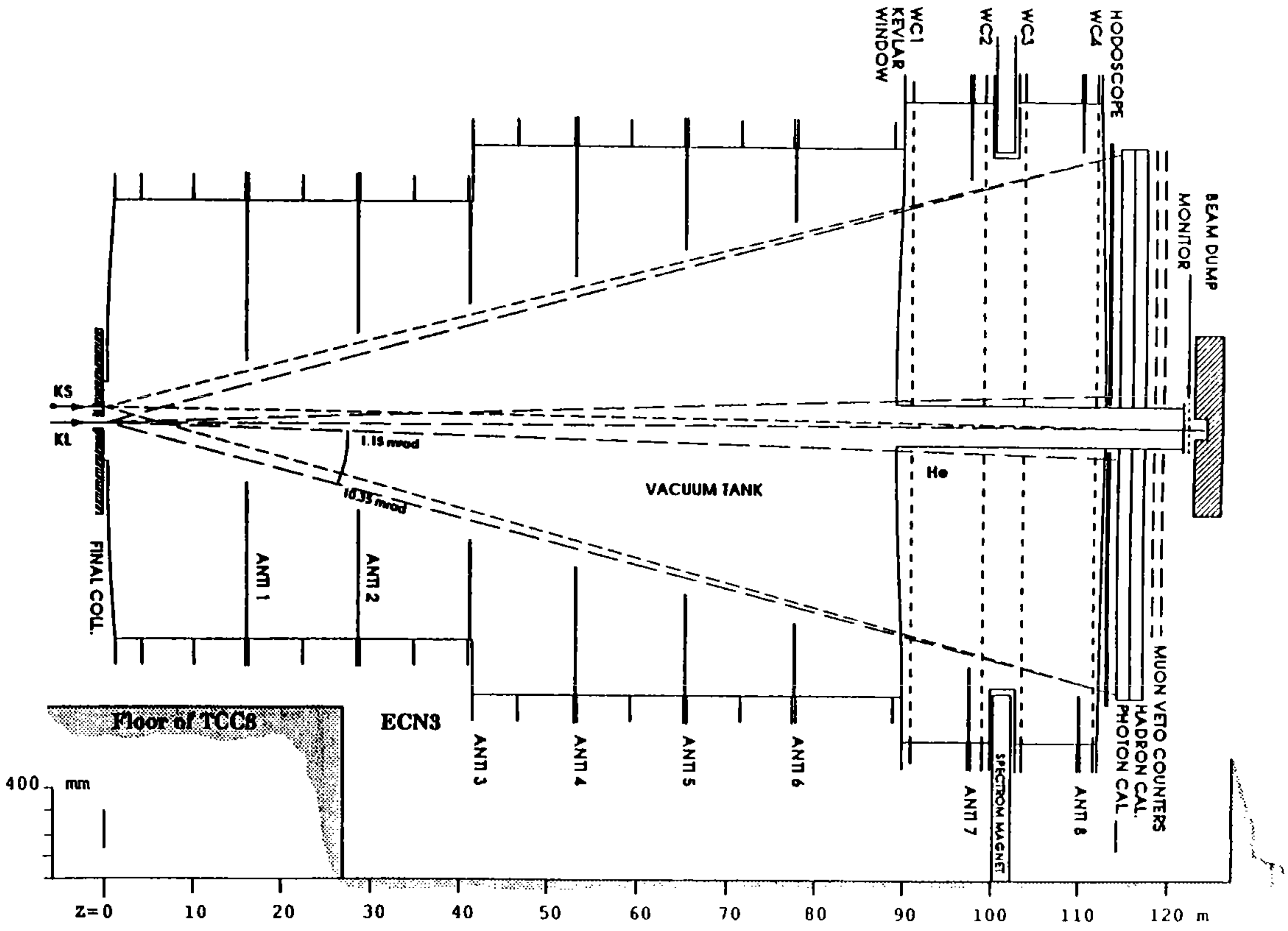

Fig. 1 Schematic layout of the NA48 experiment: the vacuum tank and the magnetic spectrometer are shown.

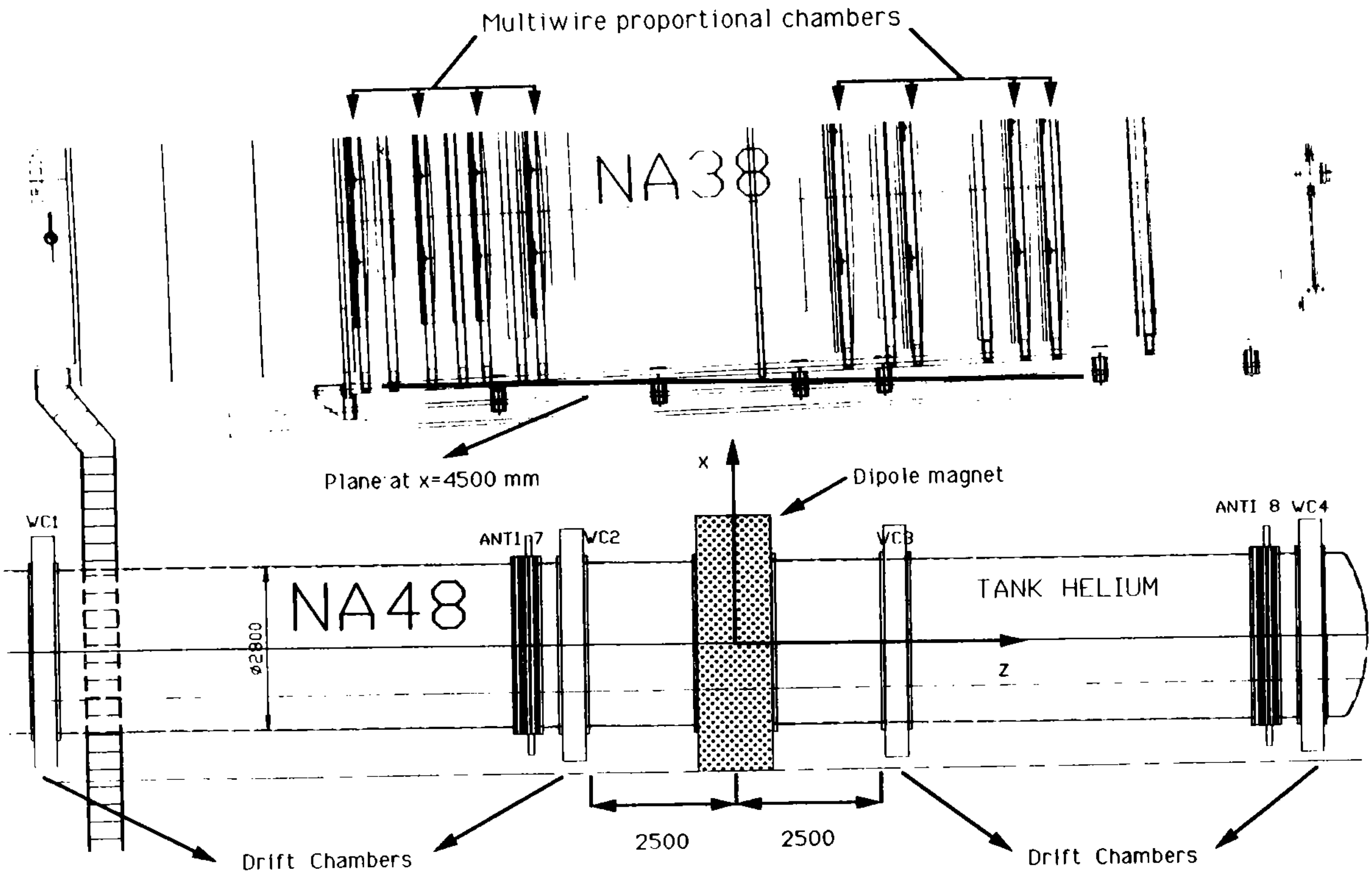

**Fig. 2** Layout of the NA48 magnetic spectrometer in the North Area ( dimensions in mm – scale 1:100 ).

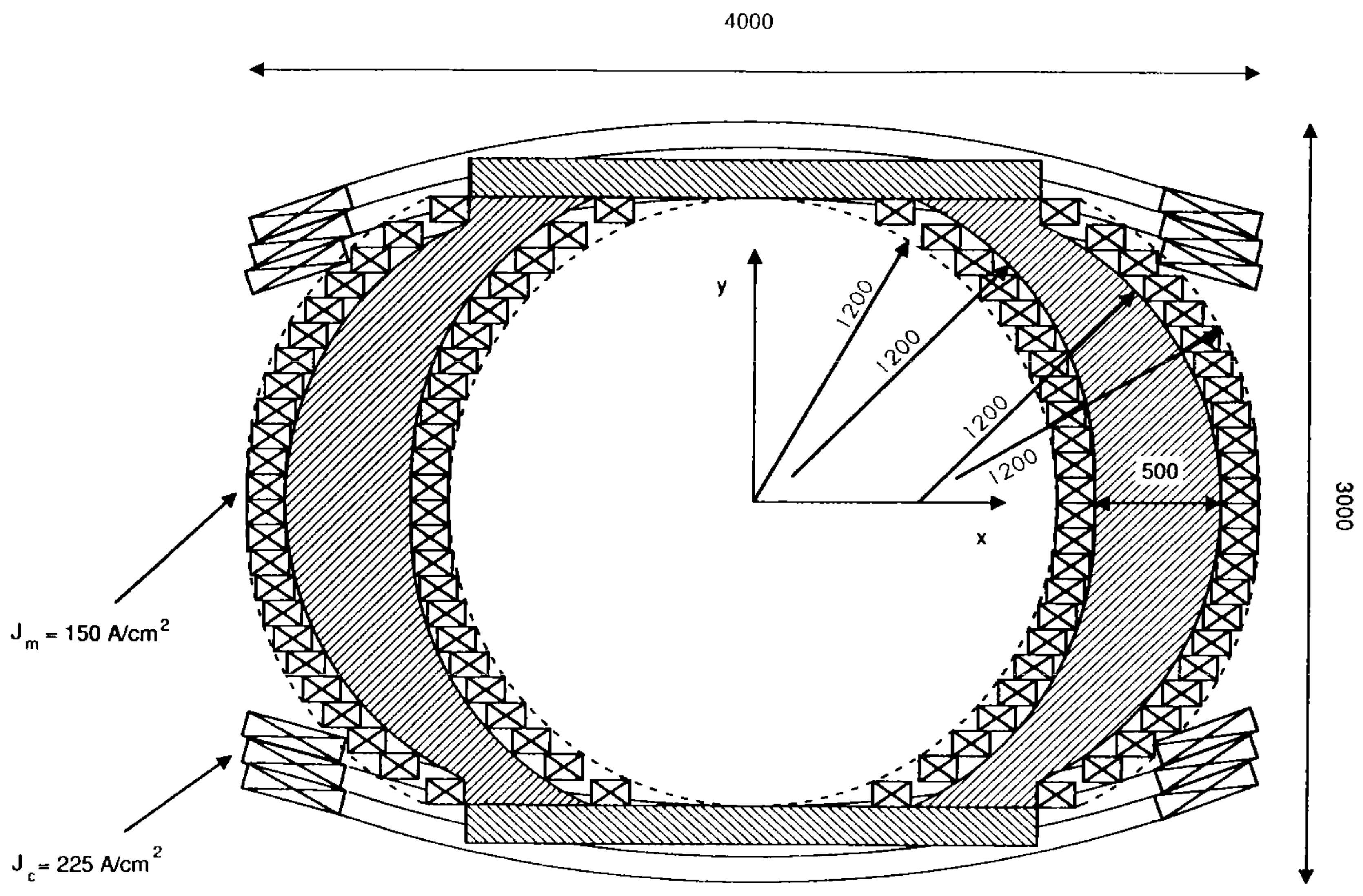

**Fig. 3a** Magnet section in the symmetry plane z = 0 perpendicular to the beam direction ( dimensions in mm – scale 1:25 ).

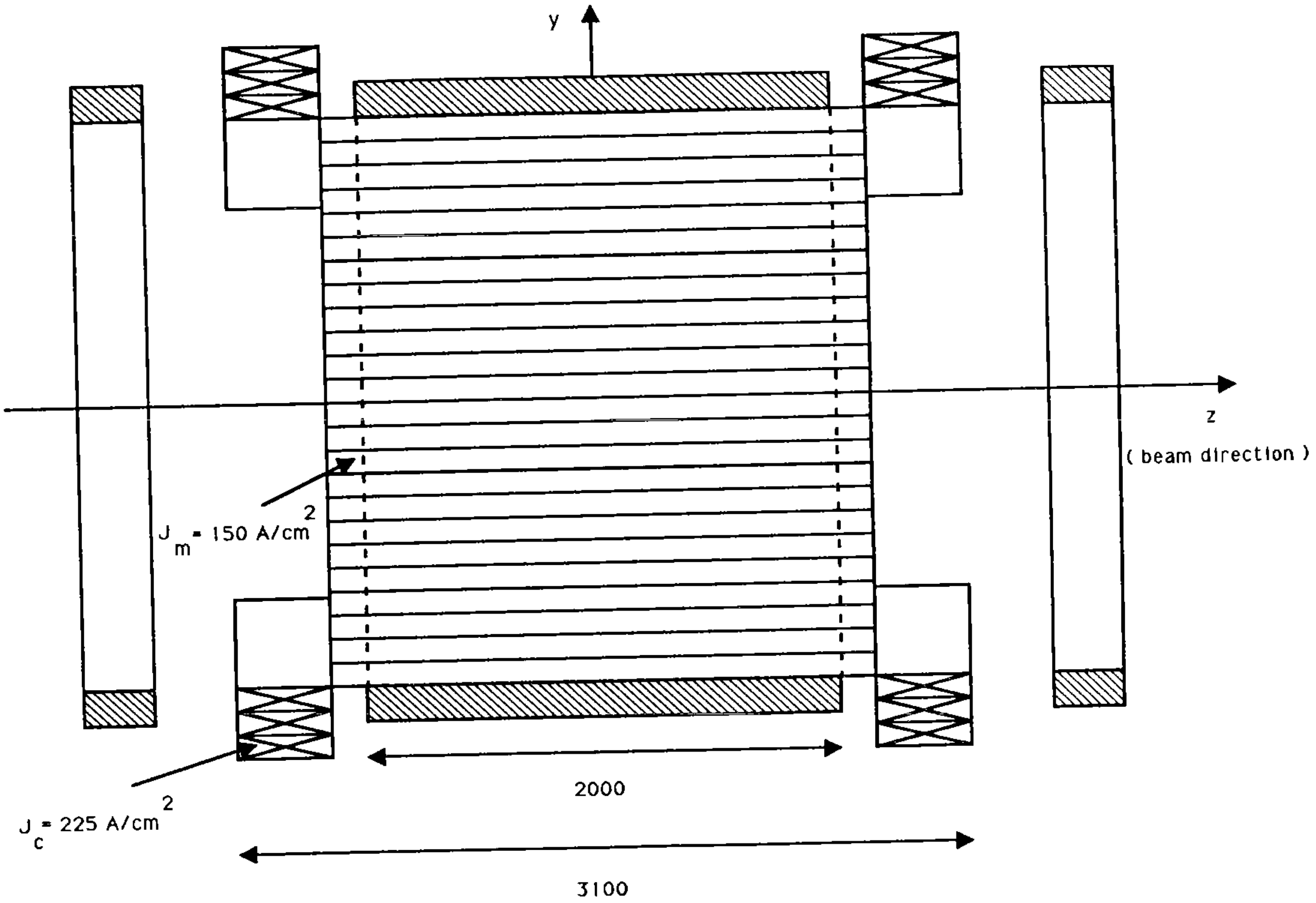

**Fig. 3b** Magnet section in the symmetry plane x = 0 containing the beam direction ( dimensions in mm – scale 1:25 ).

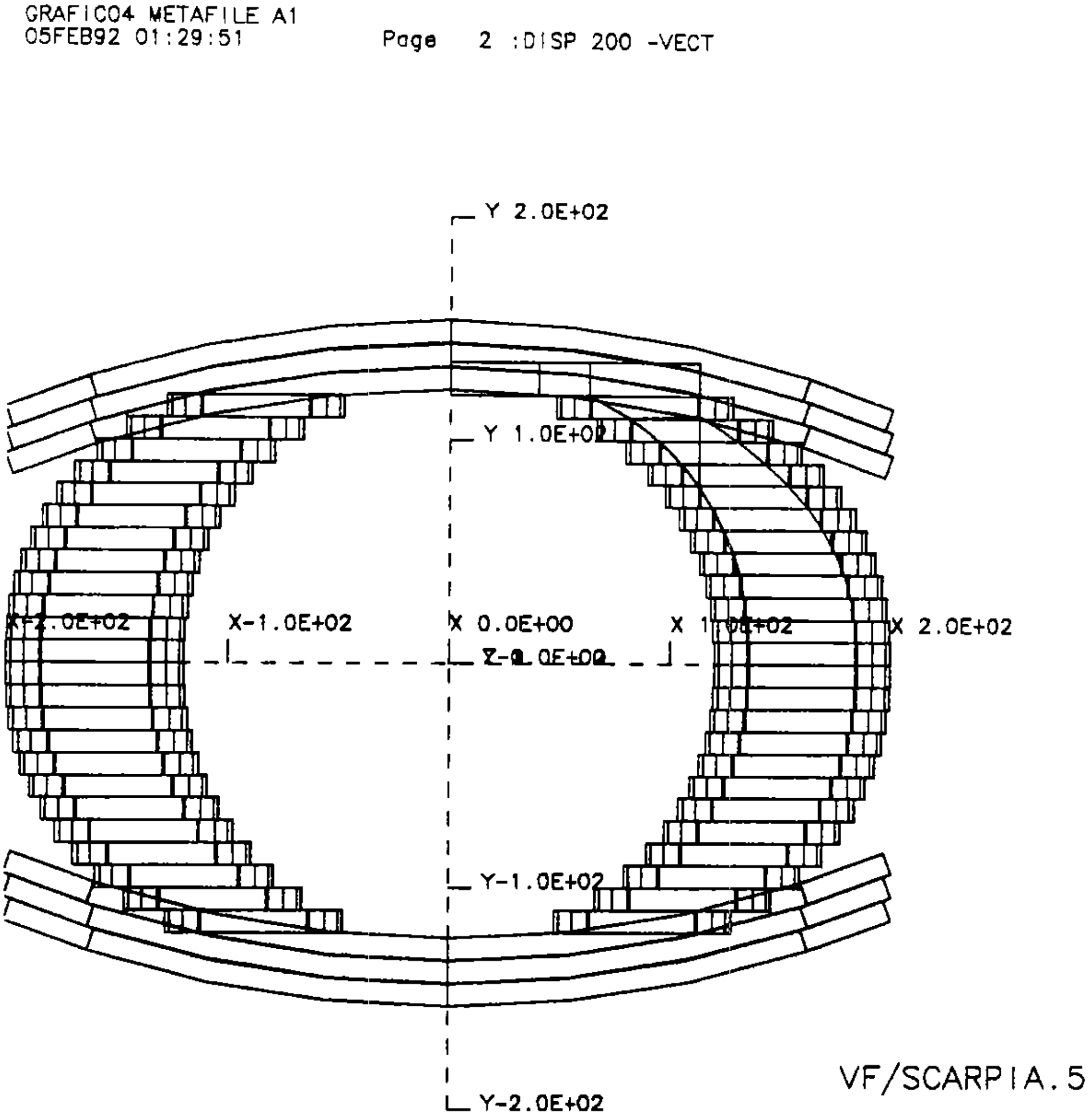

**Fig. 4** Input geometry for the program TOSCA$^{\mathrm{VF}}$; the magnet has eightfold symmetry and hence only one eighth of the problem has been meshed; on the other hand all the conductors must be specified [3].

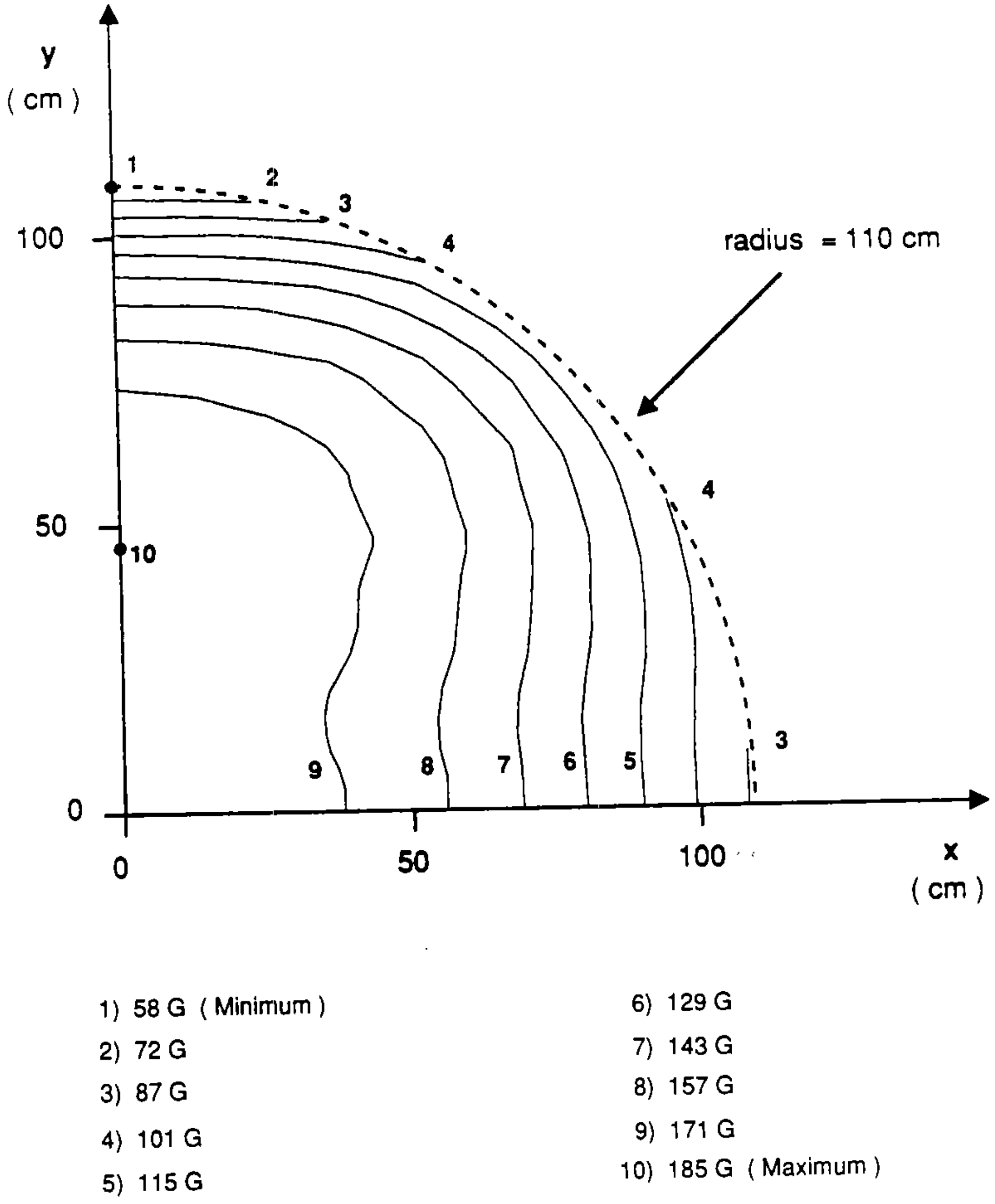

Fig. 5 Line contours map of the fringe field modulus distribution in the active area of the drift chambers placed at $z = \pm 250$ cm ( see fig. 2 ); field values corresponding to each line are listed.

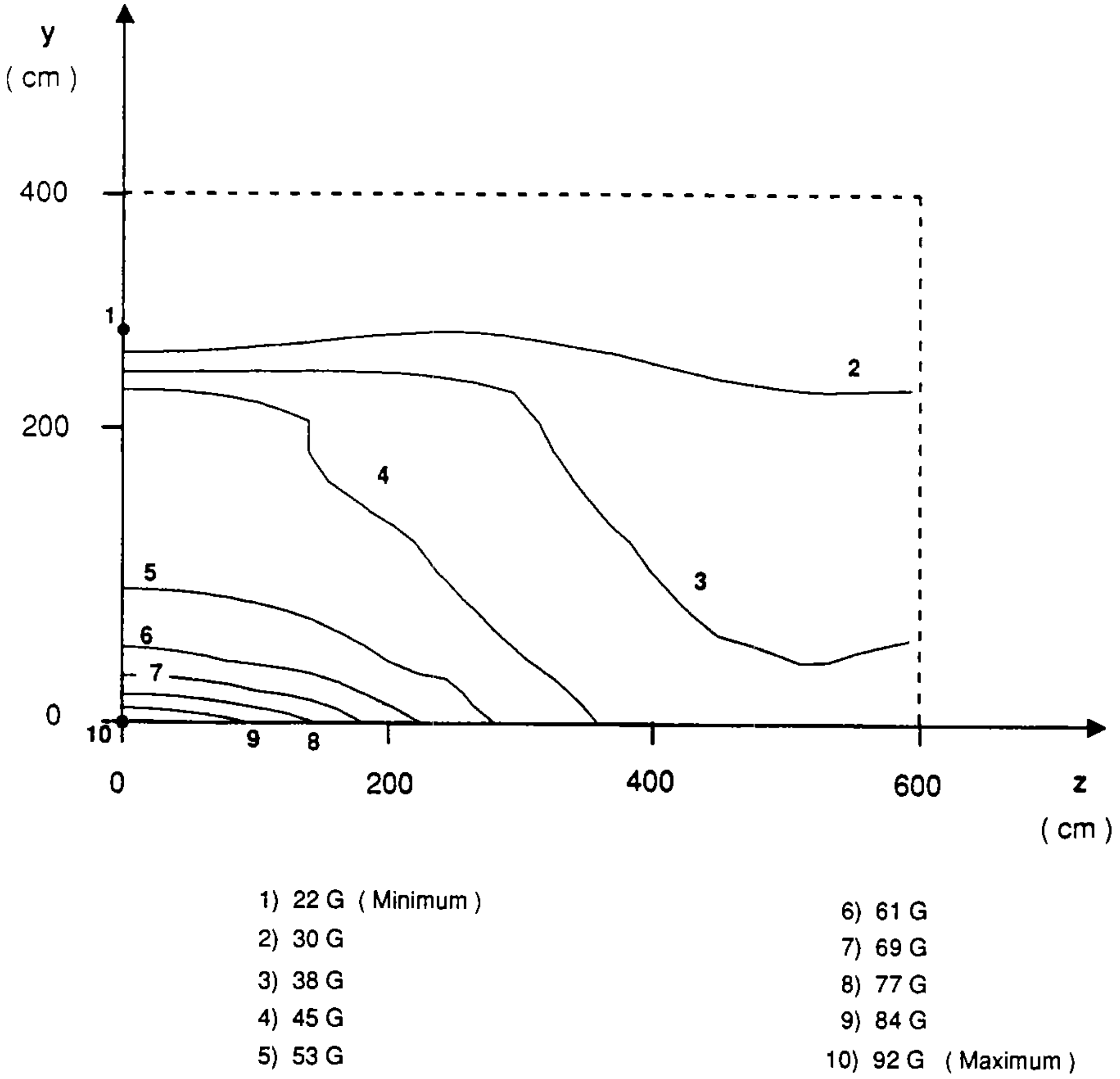

**Fig. 6** Line contours map of the stray field modulus in the NA38 area ( plane x = 450 cm – see fig. 2 ); field values corresponding to each line are listed.