MATERIAL CONSIDERATION FOR MAGNETIC CHANNELS

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1. INTRODUCTION

In the attempt to optimize the extraction system of the LNS CS cyclotron we were looking for a two-bar passive magnetic channel which could fit the CS requirements for the beam extraction system.

Three sets of two-bar channels were tried: two sets - same geometry but different materials, one - different geometry. The results of theoretical estimates and measurements are discussed.

2. THEORETICAL ESTIMATES

For the theoretical estimates we used the simple model given in the paper by B.Carbonel et. al..[1] We adopted their formulae with notations shown in Fig. 1.

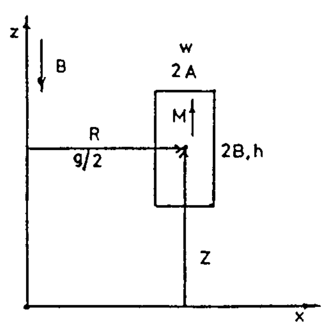

Fig. 1. Schematic explaining the used notations for a single bar. Capital letters - used in formulae, lower case letters - in the text.

For a single bar we have the axial field component $B = B_z(x,0)$

$$B = M[\arctan\frac{x_1}{c_1} - \arctan\frac{x_2}{c_1} - \arctan\frac{x_1}{c_2} + \arctan\frac{x_2}{c_2}] \quad (1)$$

and for the gradient $G = \frac{\partial B}{\partial x}$

$$G = M\{\frac{1}{c_1[1+(\frac{x_1}{c_1})^2]} - \frac{1}{c_1[1+(\frac{x_2}{c_1})^2]} - \frac{1}{c_2[1+(\frac{x_1}{c_2})^2]} + \frac{1}{c_2[1+(\frac{x_2}{c_2})^2]}\}$$

where

$$x_1 = x - R - A$$
$$x_2 = x - R + A$$
$$c_1 = Z + B$$
$$c_2 = Z - B$$

For the magnetization M at full saturation we adopted the experimental value M=0.2770 Tesla from MSU data.

The two-bar field in this model is a simple superposition of the single bar fields .

The obtained estimates are discussed below in comparison with measured results.

3. EXPERIMENTAL SETUP

We are looking for a field distribution in a narrow aperture g=8mm. The bulk size of the probe is of the same order of magnitude. The only possibility to get nearly point readings was to cut a groove in the bars which let the probe pass through the bar set. A precise

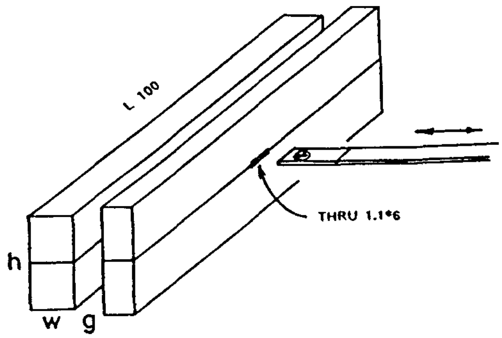

Fig. 2. A two- bar channel. The groove is to let pass thru the Hall probe.

machining of this groove meeting the probe sizes is rather difficult. That is why we decided to design each bar in two pieces. Figure 2 shows the schematic design. The bars are being held in a frame made up of brass. The cross-section of the frame at the groove position is shown in Fig. 3. A set of alignment plates and fixing screws is holding the bars in the test position. The whole setup is put in a test magnet equipped with a precise probe moving mechanism (precision within 0.1 mm).

4. RESULTS

First we measured the magnetic field of bars made up of soft iron with dimensions shown in the upper part of Fig. 4.

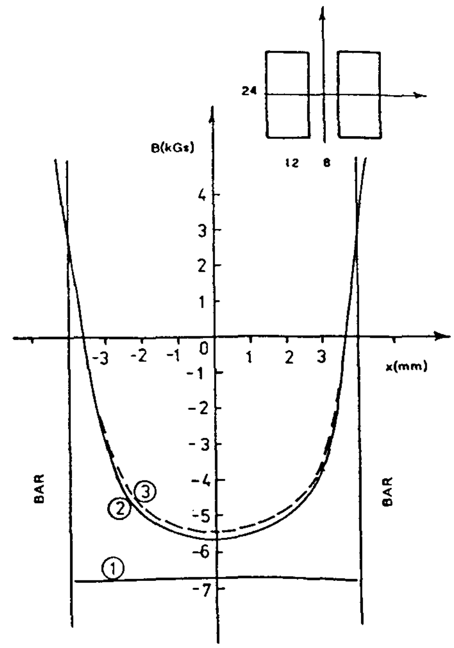

Fig. 4. Results for a symetric two- bar channel. The bar dimensions in milimeters are shown in the upper part. 1- theoretical field, 2- Armco iron, 3- soft- iron.

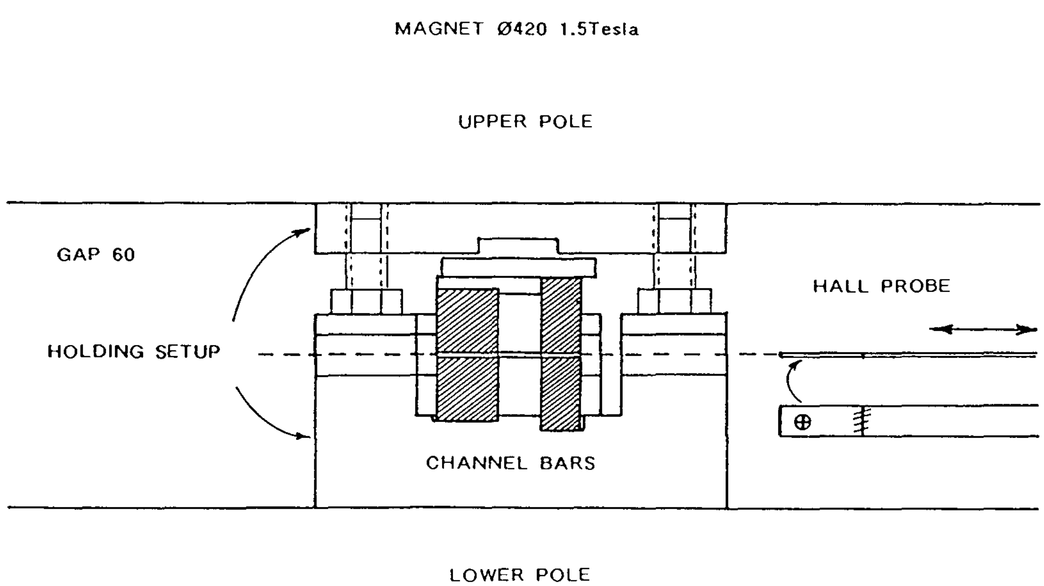

Fig. 3. The two- bar channel fixed by a holding setup in the gap of the test- magnet.

The measured magnetic field represents the dashed curve 3. The minimum field is by -5.54 kGs lower than the unperturbed magnet field (which is 15.336 kGs). The solid line 2 gives the field obtained with Armco iron bars. This gives a slightly lower field i.e. -5.69 kGs. The curve 1 shows the calculated field. Its value in the middle of the gap is -6.71 kGs.

We see that the real field is "smeared" against the theoretical distribution. It might be considered homogenous within an aperture of 3 to 4 mm . The second channel was made up of Armco iron and the bars have different dimensions. It was expected to get both diminished field and a given gradient. The sizes of the bars are shown in the left part of Fig. 5 as well as the calculated field gradient. The resulting measured field is given in the right part of this figure. The "smearing" effect is also well pronounced. For comparison the minimum field is -4.14 kGs and slightly shifted to the left of the middle point of the gap.

5. CONCLUSIONS

Theoretical estimates fail using the model[1] and bidimensional computer simulation by Poisson program is probably needed.

The chosen materials do not differ substantially.

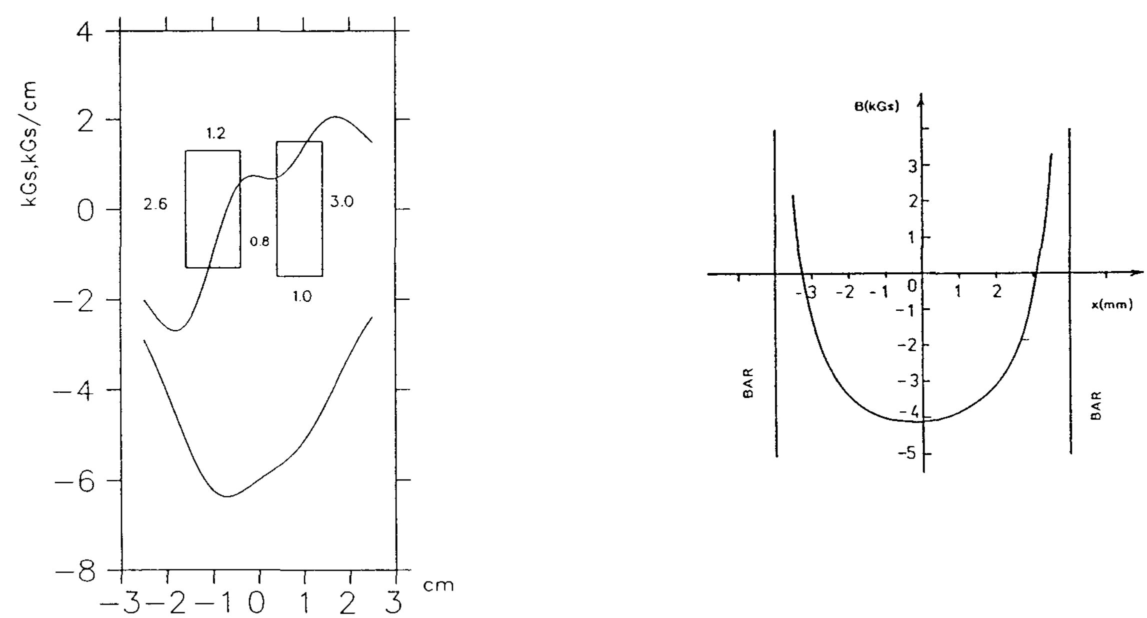

Fig. 5. Results for an asymetric two- bar channel. The bars are made up of Armco- iron. Left side - the theoretical estimates, right part - measured magnetic field.

REFERENCES

1) B. Carbonel et al., "Calculation of the geometry of magnetic channels for synchrocyclotrons and cyclotrons," Nucl. Instr. Meth. 84, 144-146 (1970).