ФИЗИКА И ТЕХНИКА УСКОРИТЕЛЕЙ

MAGNET DESIGN AND BEAM DYNAMICS IN COMPUTED FIELDS FOR DC-350 CYCLOTRON

N. Yu. Kazarinov, M. N. Sazonov

Joint Institute for Nuclear Research, Dubna

The paper describes the results of 3D magnets simulation. The cyclotron magnet and analyzing bending magnet IM-90 of axial injection chanell are studied here. The influence of correction coils for cyclotron magnet is calculated. All magnetic fields have been calculated by MERMAID 3D code [1].

Представлены результаты 3D-моделирования магнита для циклотрона DC-350. Даны оценки влияния корректирующих катушек. Показаны результаты моделирования анализирующего магнита канала аксиальной инжекции с учетом динамики пучка в полученных полях. Все расчеты проведены с помощью пакета программ MERMAID.

PACS: 29.20.dg

DC-350 MAIN MAGNET

The cyclotron magnet has a classical H shape, the gaps between valley and sectors are 400 and 240 mm, correspondingly. The magnet parameters are shown in Table 1.

Due to symmetry of the magnet the $90°$ model has been used to simulate magnetic fields. The $90°$ model is 1/8 part of magnet. The magnet yoke has been optimized by using this model. The shape of final magnet is displayed in Fig. 1.

The influence of bended edges is about 50 Gs at high level of average magnetic field 1.5 T.

Table 1. **Magnet specifications**

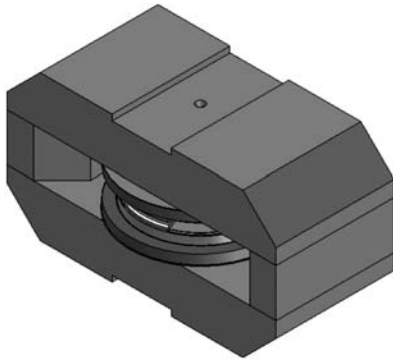| Pole radius, m	2
Extraction radius, m	1.76
Average magnetic fields, T	1.24 to 1.5
Number of sectors	4
Dimensions, m	$5 \times 4.7 \times 9.1$
Weight, t	about 1100

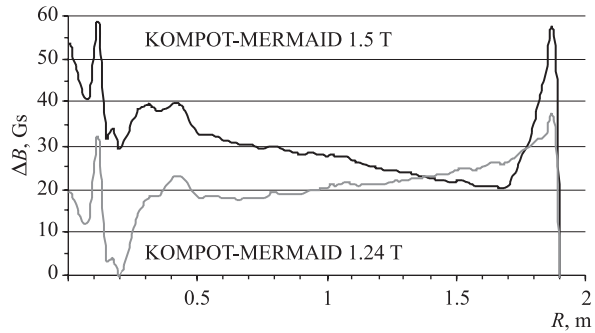Fig. 1. Main magnet of cyclotron DC-350

Fig. 2. Comparison of independent simulations with 90° magnet model

The result of calculated magnetic fields by 90° model has been compared with the results obtained by our colleagues from Efremov Institite by KOMPOT code [2]. The difference between independent simulations is presented in Fig. 2.

For both levels of average magnetic field 1.5 and 1.24 T the difference is less than 50 Gs.

CORRECTION COILS

There are nine radial correction coils C0–C8 for DC-350 cyclotron magnet (see Fig. 3). The correction coils are required for adjusting magnetic fields of constructed magnet.

The net effect of each correction coil has been calculated as difference between magnetic fields. One set is magnetic fields calculated with coil and another one is pure magnetic field of main magnet. Thus, a bunch of computations has been done to get influence of all correction coils at all levels of magnetic field.
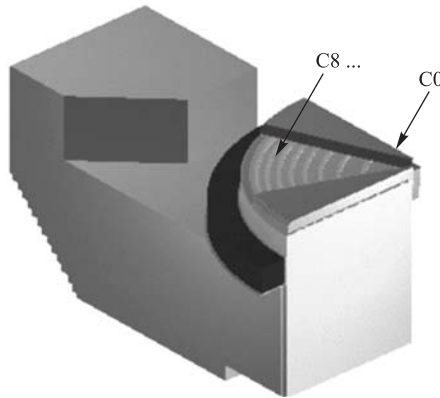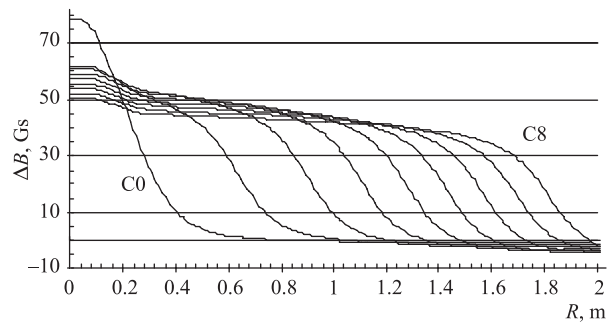

Fig. 3. The 90° magnet model with correction coils

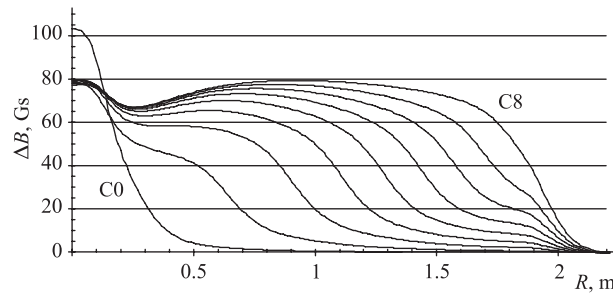Fig. 4. Net effect of correction coils at average magnetic field 1.5 T

Fig. 5. Net effect of correction coils at average magnetic field 1.24 T

The coils C1–C7 have been designed to have maximal total current 960 A/turns, while the coil C0 of central region has 1500 A/turns. The results of net influence of the correction coils are shown in Figs. 4 and 5.

The symmetric results have been calculated for reverse current of correction coils. The net effects to average magnetic field are more than 40 Gs (1.5 T) and more than 60 Gs (1.24 T) for each coil.

IM-90 MAGNET

The ion beams after superconducting ESR ion source come into analyzing bending magnet IM-90. It is a start of axial injection channel of DC-350 cyclotron. The geometry of simulated magnet is shown in Fig. 6.
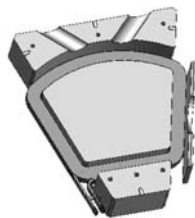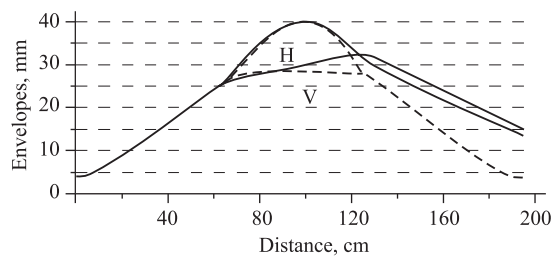

Fig. 6. Geometry of bending magnet IM-90

Fig. 7. Beam envelopes for angle $\xi = 29.5°$

Table 2. **IM-90 magnet parameters**

Ion mass-to-charge ratio A/Z	5–10
Accelerating voltage, kV	25
Beam bending angle, °	90
Radius of beam trajectory, mm	350
Gap between magnet pole, mm	120
Magnetic field, T	0.184 ($\pm 1\%$)
Distortion of magnetic field at beam area, mm	$\Delta R = \pm 60$ ($\Delta B/B < 10^{-3}$)

The magnet has shield screens at beam entrance and at beam exit. Due to magnet symmetry the 1/4 part of magnet has been simulated. The parameters of IM-90 magnet are shown in Table 2.

The design of magnet includes bunch dynamics in calculated fields. The beam dynamics has been estimated with linear approximation.

The geometry of magnet has been chosen by changing the angle between beam trajectory normal and magnet pole boundary ξ at entrance and exit.

The horizontal and vertical beam envelopes for angle $\xi = 29.5°$ are shown in Fig. 7. Ideal beam envelopes are depicted as dashed lines and simulated beam is shown as solid lines.

REFERENCES

1. *Dubrovin A. N.* User's Guide MERMAID: Magnet Design in Two and Three Dimensions. SIM Limited, Novosibirsk Department. 1994. P. 3–60.

2. *Kukhtin V., Lamzin E., Sytchevsky S.* Magnet Field Formation in Cyclotrons on the Basis of 3D Numerical Simulations // XXXIV Eur. Cyclotron Progress Meeting (ECPM 2006), Oct. 6–8, 2005.