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THE IMPACT OF TRAJECTORY-SHAPED COIL ON THE BEAM DYNAMICS IN THE SC230 SUPERCONDUCTING CYCLOTRON

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Abstract

In this paper, we compared the effect of the cyclotron coil shape on the beam dynamics. Two models were created. The first has a conventional round coil, the second has a coil that follows the trajectory of the protons. Parameters of extracted beams are discussed.

INTRODUCTION

JINR plans to create a new center for biological research and medical applications. At Dzelepov Laboratory of Nuclear Problems was suggested [1] the conceptual design of a superconducting cyclotron SC230.

One of the main ideas in this design was the coil form. It was not round but followed the trajectories of protons which are squarish since the yoke has four sectors. This form allows for more efficient utilization of the generated magnetic induction flux.

We also reduce the yoke by "cutting off" the extra iron. The cyclotron becomes lighter and cheaper, and the transport width decreases.

Though the coil is combined from 8 sectors of circles to simplify the form, it is still a challenge to produce it.

In this article, we intend to determine the impact of a non-round coil by comparing two models: with a traditional round coil and with a squarish one. The geometry of both coils is presented in Fig 1.

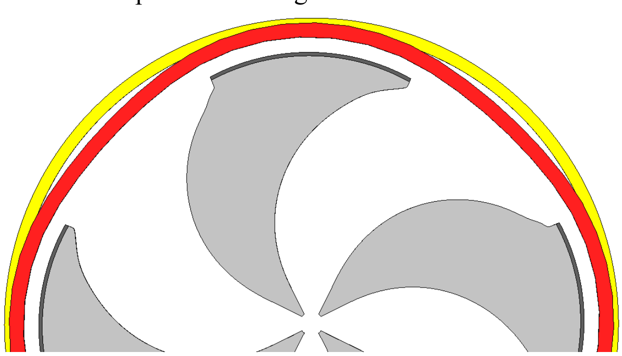

Figure 1: Geometry comparison of round and squarish coils beside sectors.

Sectors have a chamfer on the outer edge and in both cases, they are following the coil shape.

MAGNET SYSTEMS

The magnet systems in both cases were designed using the same principles:

1. To have an isochronous field on the same orbital frequency;
2. To prolong the stationary orbits to the maximum energy.

To do this, we had to adjust the spiral angle and azimuthal width of sectors. The geometry of sectors for both models is presented in Figs. 2 and 3.

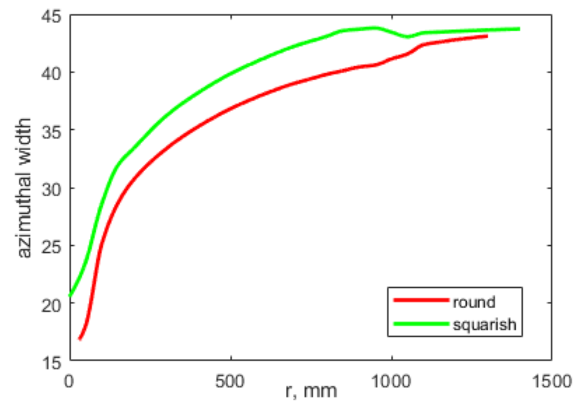

Figure 2: Azimuthal width of sectors.

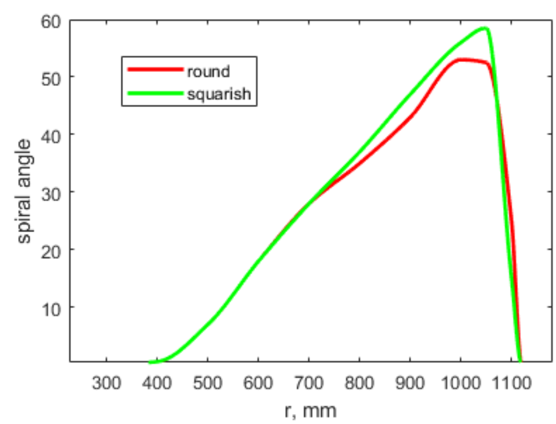

Figure 3: Spiral angle of sectors.

Orbital frequencies were analysed with a CORD code [2] and are almost coincident (see Fig. 4).

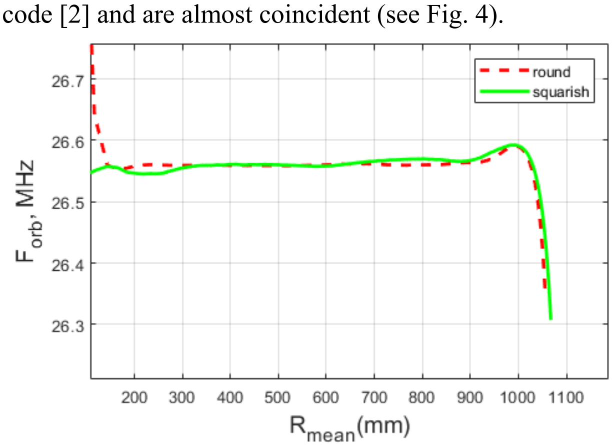

Figure 4: Orbital frequency against mean radius.

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In the round model, we managed to prolong the stationary orbits only up to 219 MeV, though in the squarish model we had 226 MeV.

Dangerous resonances were avoided in both cases. The betatron tunes for both models are provided in Figs. 5 and 6.

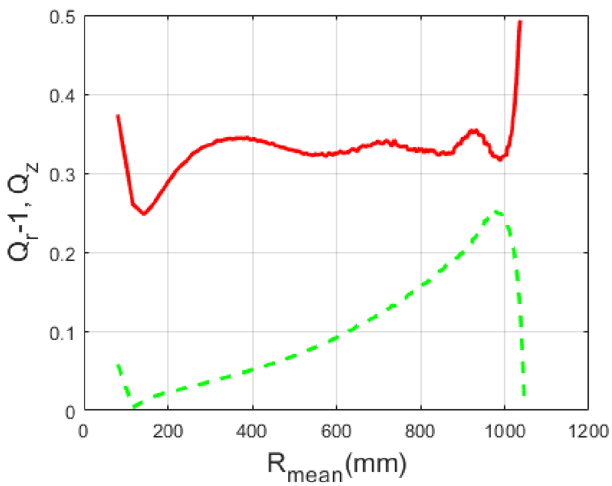

Figure 5: Vertical and radial betatron tunes in the round model.

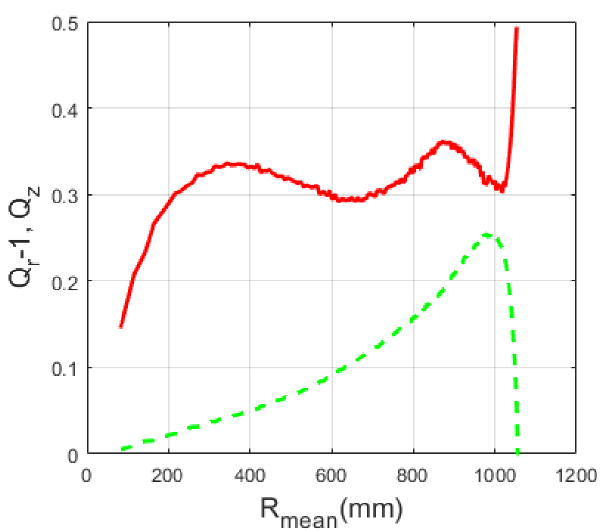

Figure 6: Vertical and radial betatron tunes in the squarish model.

Mean magnetic fields against radius (see Fig. 7) are not quite indicative in this case since trajectories are not round. More interesting is to look at the field in the middle of a sector/valley presented in Fig. 8.

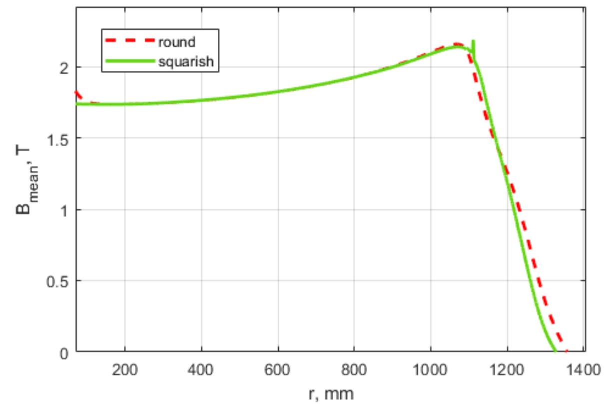

Figure 7: Mean magnetic fields against radius.

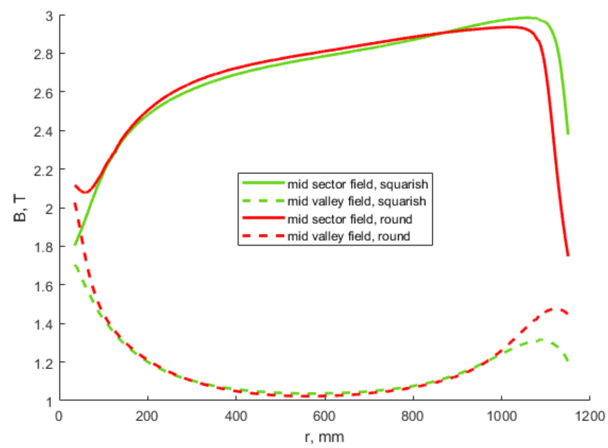

Figure 8: Magnetic field in the middle of sectors (blue) and valleys.

We can see that the squarish coil allows the extension of the raising magnetic field further along the radius for about 5 cm.

EXTRACTION SYSTEMS

In a round model, we put an electrostatic deflector in a sector on 105,9 cm from the center of the cyclotron. The beam profile that we have got just before the deflector is provided in Figs. 9 and 10.

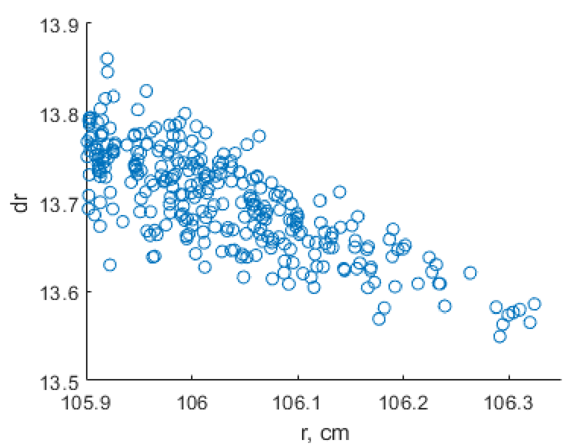

Figure 9: Horizontal beam profile before the deflector.

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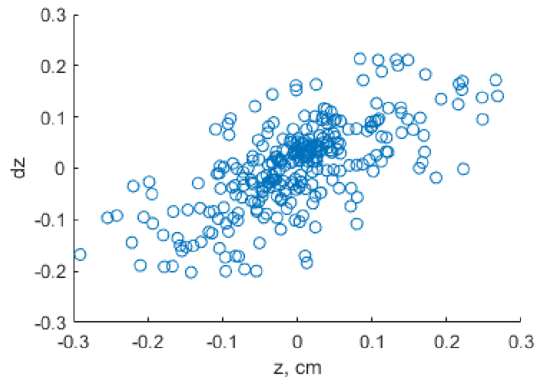

Figure 10: Vertical beam profile before the deflector.

In the round coil model, we still can extract the beam. We used one electrostatic deflector and 3 magnetic channels. Figure 11 shows the magnetic field map in the middle plane and the beam extracted trajectory.

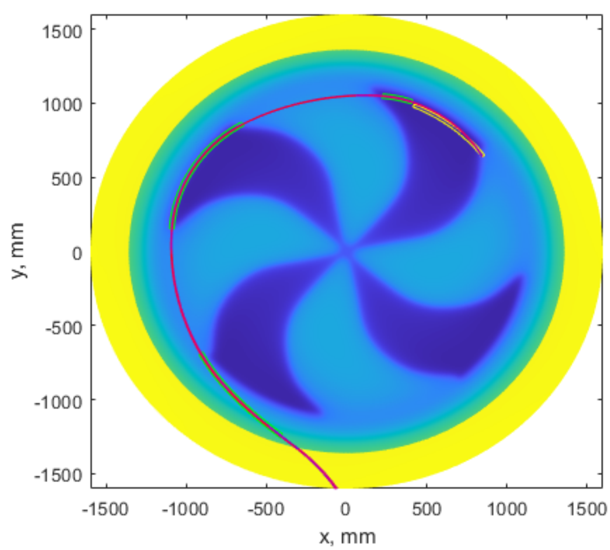

Figure 11: The trajectory of the extracted beam on the magnetic field map. Green regions – magnetic channels, yellow – the deflector.

CONCLUSIONS

We've built these two models on the same principles starting from only one key difference – the coil form. They have the same yoke size, similar field level, both have fourth harmonic of acceleration, same RF system. From both these cyclotrons, we can extract a beam with acceptable parameters. The main difference is that the squarish coil form cyclotron can achieve 226 MeV beam energy against 219 MeV for round one.

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[2] O. Karamyshev *et al.*, "CORD (Closed orbit dynamics): A new field map evaluation tool for cyclotron particle dynamics", *PEPAN Letters*, to be published.

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