THE RESULTS OF MAGNETIC FIELD FORMATION AND COMMISSIONING OF HEAVY-ION ISOCHRONOUS CYCLOTRON DC280

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INTRODUCTION

DC280 can accelerate heavy ions from Helium to Uranium with mass to charge ratio A/Z= 4 – 7. The extracted energy of the beams can be smoothly varied in the range W= 4 – 8 MeV/nucl. The main challenge of DC280 magnetic system formation is to cover all possible operational modes with minimal power consumption. Magnetic field level should be varied in the wide range from 0.64T till 1.32T. Parallel, the isochronous radial growth of average magnetic field should be varied from 30Gs to 100Gs. 11 radial and 4 pairs of harmonic correcting coils are employed and provide the needed operational correction.

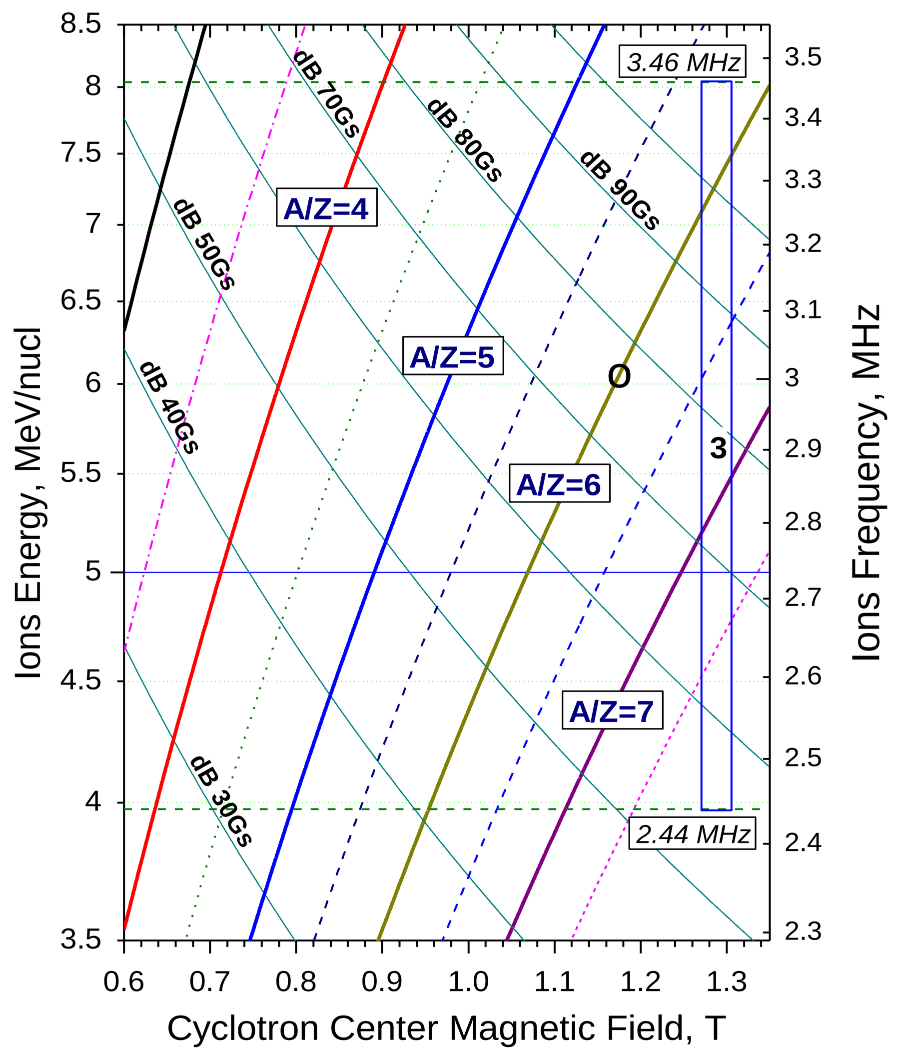

Figure1: operational modes diagram of DC280 cyclotron

DC280 is a compact type cyclotron. It has H-shape main magnet with 4 meter pole diameter, Table 1. Four pairs of straight, 45-degrees sectors form the variation of magnetic field, that keeps betatron frequencies on the ranges 1.005<Qr<1.02 and 0.2<Qz<0.3.

Table 1. : Main parameters of DC-280 cyclotron magnet

Main size of the magnet, mm	8760x4080x4840
Diameter of the pole, mm	4000
Pole to pole gap, mm	500, accuracy ±0.2
Sector to sector gap, mm	208, accuracy ±0.17
Poles axis centering, mm	accuracy 0.53
Sector angular extent (spirality)	45° (0°)
Main magnet power, kWt	280
Correcting coils power, kWt	18

MAPPING SYSTEM

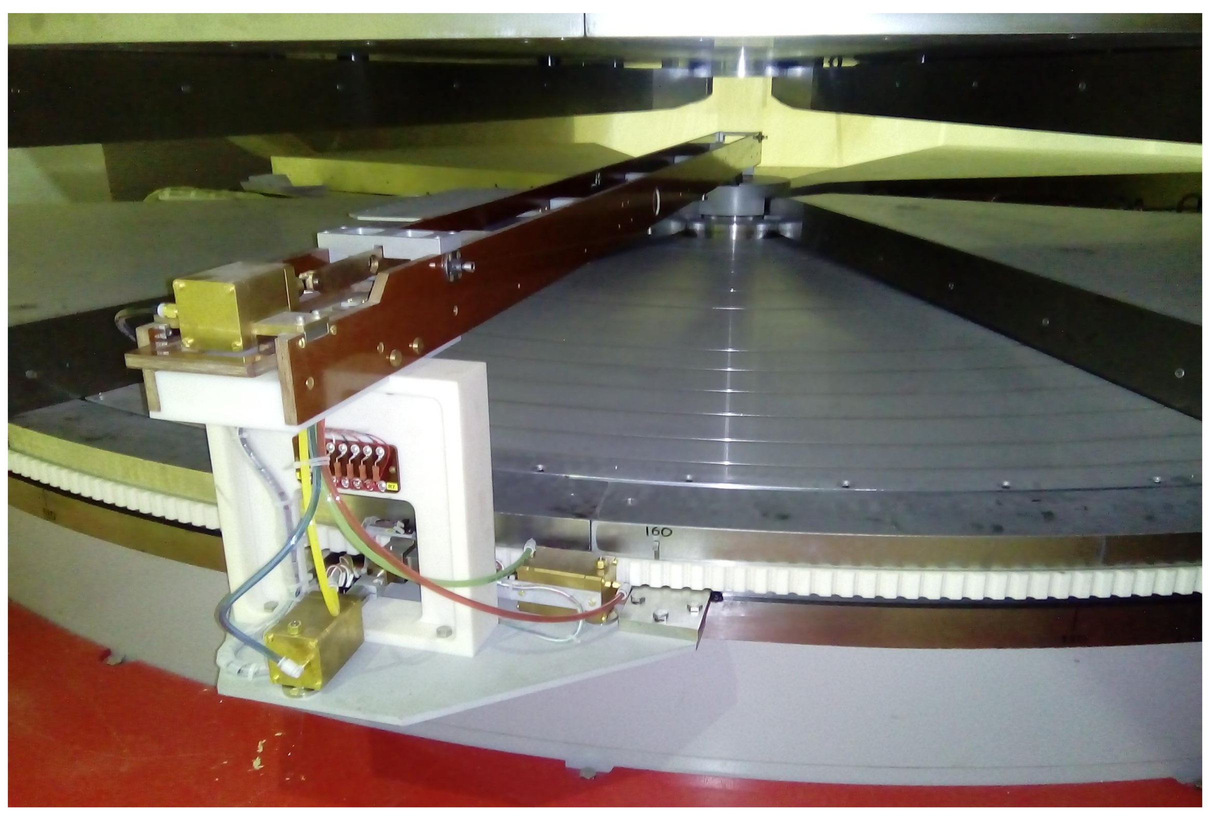

Figure 2: DC280 magnetometer with toothed belt

DC280 mapping system is based on 14 Hall probes, that are placed on the plank with radial distance of 160mm one to another. The plank is moved radially with a step of 10mm or 20mm in a range of 160mm. The maximal radius of mapping is 160mm*14 = 2240mm.

The usage of 14 probes decreases a time of mapping: the mapping of full, 360° azimuth range with 1° azimuthal and 10mm radial steps takes about 7 hours. The 90° range mapping with 2° and 20mm steps takes about 1 hour.

The mechanisms of radial and azimuthal motions are equipped with pneumatic engines, Fig. 2. The azimuthal step motion is provided by standard polyurethane toothed belt that is placed around bottom pole.

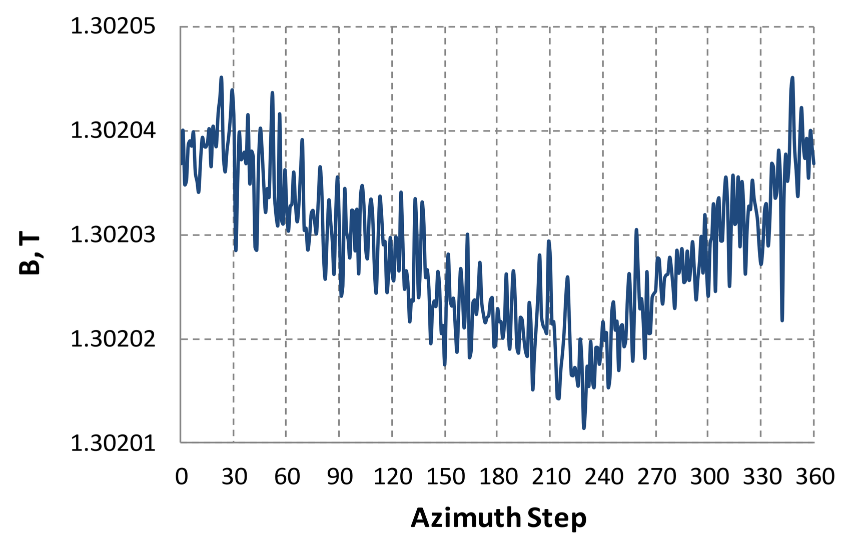

Figure 3: Signal from Hall probe, positioned at cyclotron centre during one azimuthal motion of magnetometer plank. It demonstrates a good centering of the magnetometer and the low level of probe noises, not more than 2*10-5.

RESULTS OF MAPPING

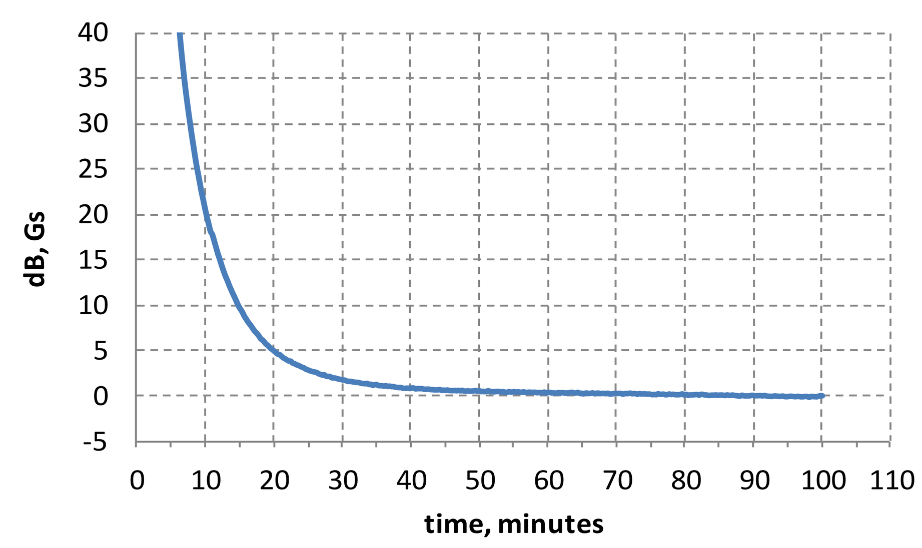

Figure 4: The time, required for magnetic field stabilization at first turning on. It takes about 40 minutes to reach the magnetic field stability of 10-4

During the mapping, the database of main magnetic fields and additional fields of correcting coils was collected at different levels in the range 0.6T – 1.32T.

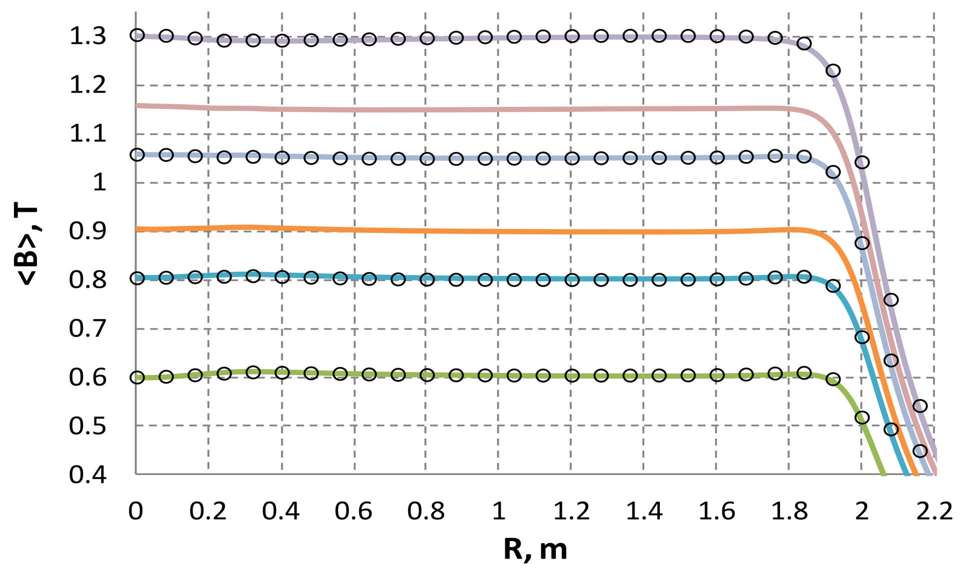

Figure 5: The calculation of the average magnetic field (circles) and the results of the measurements (line).

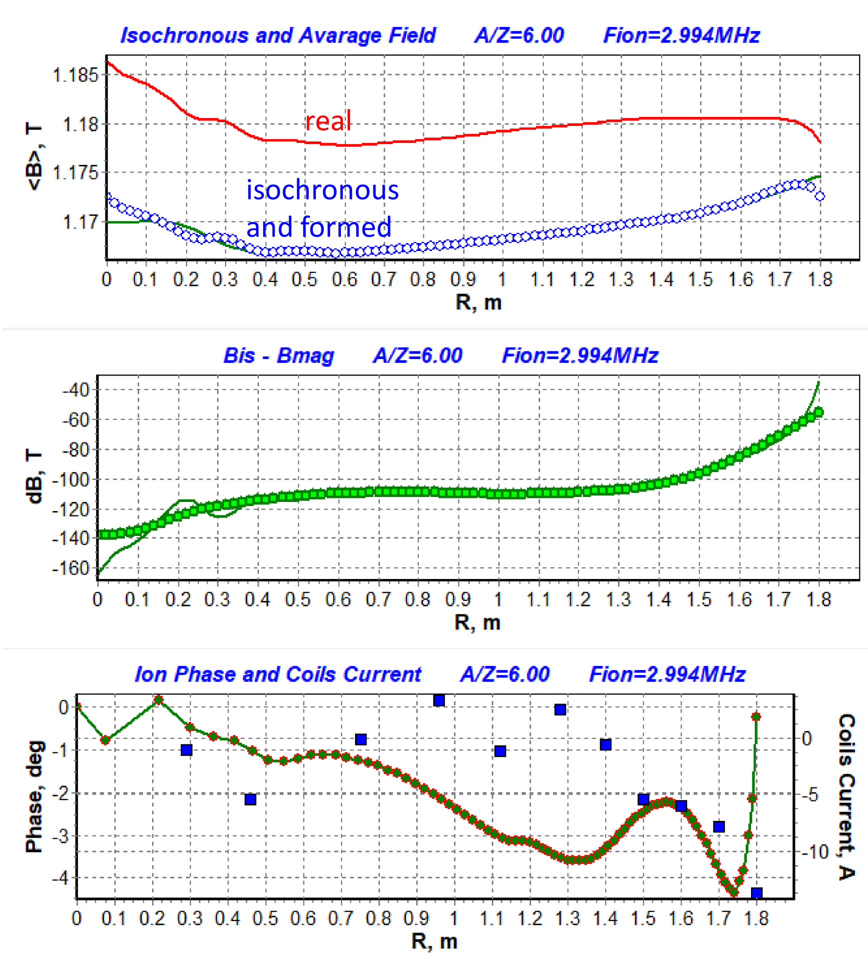

Figure 6: Calculation of A/Z=6 operational mode parameters, based on measurements of main and correcting coils magnetic fields .

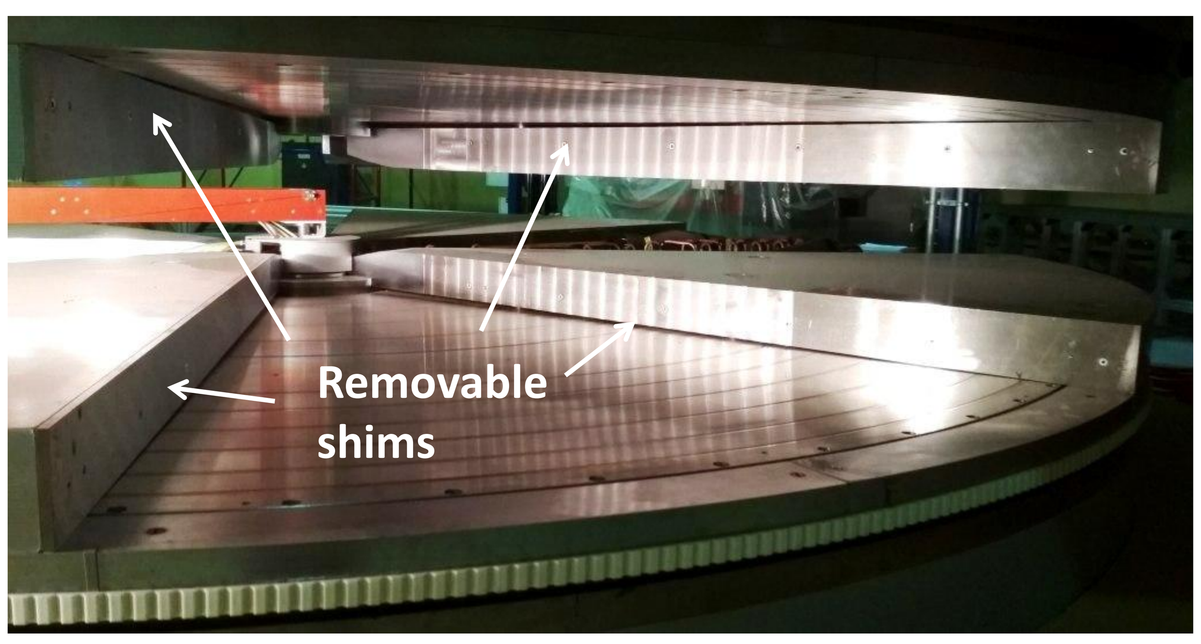

Figure 7: Removable shims have the shape of 10mm width plates and are placed at each edge of sectors

To correct magnetic field the sectors are equipped with removable shims. The shims have the shape of 10mm width plates and are placed at edges of sectors. The shims could be easily removed and machined.

The decreasing of pole to pole gap under magnetic field forces was investigated. For 1T magnetic field the converging of poles was not uniform azimuthally and varied from 0 to 0.2 mm.

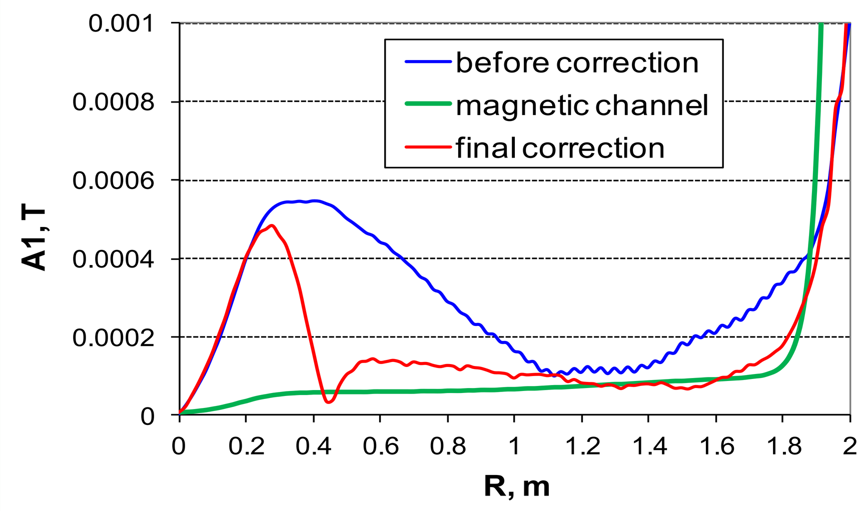

Figure 8. The amplitudes of first harmonic before and after correction and caused by magnetic channel installation.

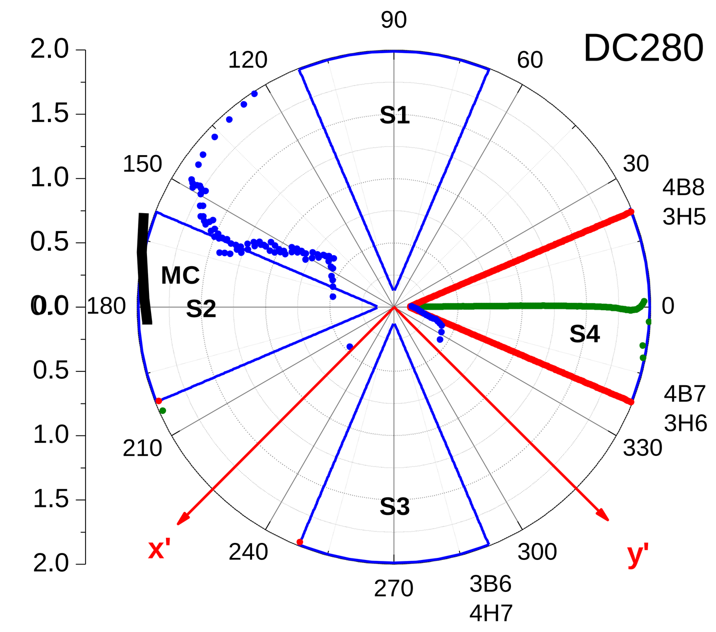

Figure 9. The phases of first harmonic before correction and caused by magnetic channel installation.

Reasons of first harmonic of the magnetic field:
- finite accuracy of manufacturing and assemblage
- not uniform converging of the poles under magnetic field
- magnetic channel installation

Without magnetic channel installation the first harmonic has amplitude up to 10Gs, Fig. 8.

Analysis of combination of measured first harmonic without magnetic channel and calculated first harmonic, produced by magnetic channel, gave the final shapes of sectors shims to compensate the total first harmonic, Fig. 7. Final measurements shown that first harmonic was decreased to 1 – 2 Gs, Fig 8.

RESULTS OF COMMISSIONING

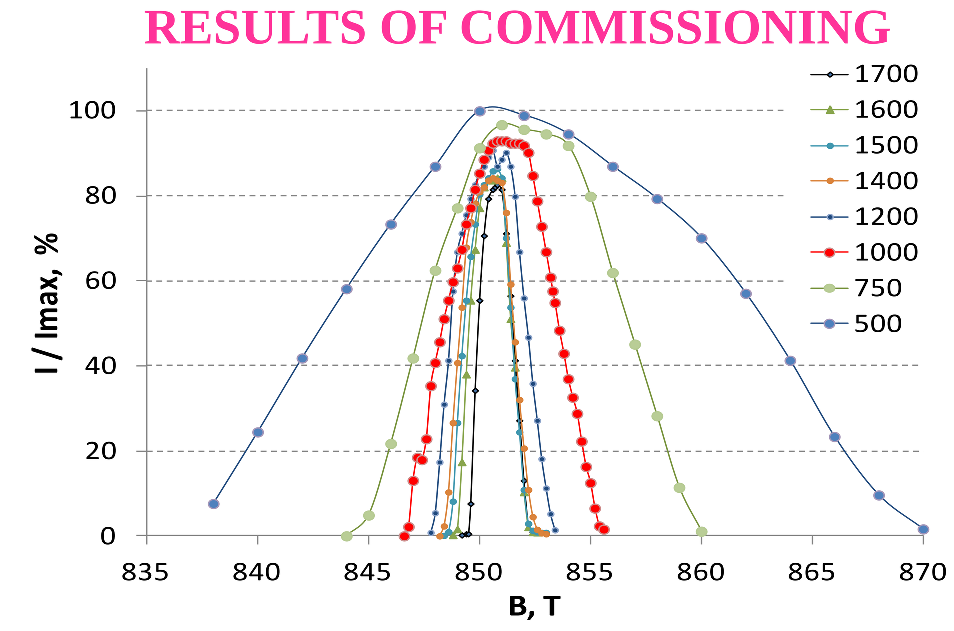

Figure 10. The dependence of relative current of 84Kr14+ beam on magnetic field level at different radiuses

In the first half-part of 2019 the beams of 84Kr14+, 12C2+ and 40Ar7+ were accelerated to energy 5.9 MeV/nucl. The intensities of extracted beams from cyclotron were 1.35, 6 and 10 pmkA respectively.

For 84Kr14+ beam the efficiency of injection into cyclotron was 14% without bancher, and 55% with bancher. Efficiency of acceleration to the extraction radius was 85%. Efficiency of beam extraction to the ion transport channel was 89%.

For 12C2+ beam the efficiency of injection into cyclotron was 11.5% without bancher, and 54% with bancher. Efficiency of acceleration to the extraction radius was 83% and efficiency of extraction was 64%.

SUMMARY

DC280 cyclotron was commissioned in the beginning of 2019. Despite the cyclotron is still in the progress of adjusting, the first experiments have shown a good efficiency of beam acceleration. In particular, it demonstrates that cyclotron magnetic system forms the operational magnetic field in a good coincidence to isochronous. To reach planned intensities of ion beams with middle atomic masses (A~50) up to 10 pμA, the more operational time, improvement of vacuum conditions in the cyclotron chamber, adjustment of flat-top and usage of magnetic field database for programmer optimization of the operational modes parameters are needed.

REFERENCES

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