ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-TUPRO099

DEVELOPMENT OF A METHOD FOR MEASURING THE RADIAL COMPONENT OF THE MAGNETIC FIELD IN AVF CYCLOTRONS

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Abstract

In AVF cyclotrons the median plane of the magnetic field rather often does not coincide with the mid-plane of their magnetic system. To measure the radial component of the magnetic field, equipment based on search coils is developed and used to correct the median plane of the magnetic field. The equipment for Br mapping is described. The Br mapping and shimming results are presented for two proton therapy IBA C230 cyclotrons.

INTRODUCTION

A vertical deviation of the beam center from the median plane of the vacuum chamber was observed and corrected in some cyclotrons (AVF Cyclotron, Einhoven, the Netherlands [1], AGOR, Groningen, the Netherlands [2], U-120M, Rzez, Chech Republic [3], AIC-144, Krakow, Poland [4], JINR Phasotron, Dubna, Russia [5]). Thus it is very important for the cyclotron design to know the tolerances for horizontal components of the magnetic field [6], their relation to the manufacturing tolerances for magnetic and current elements and the method for measurement and correction of the magnetic field. At the IBA proton serial cyclotron C230 there is a high motivation to get the highest possible beam transmission efficiency. This efficiency considerably depends on the radial component (Br) of the magnetic field. The Br mapping equipment was designed and used for measurement and correction of the radial field component for two cyclotrons PAP116 and PAP125.

B_R MAPPING FOR THE PAP116 CYCLOTRON

The PAP116 C230 cyclotron was designed for the first Russian radiological center in Dimitrovgrad. The magnetic field mapping and correction and the commissioning and beam test of the cyclotron was performed at JINR, Dubna. The dedicated Br mapping equipment was designed and used at JINR. The equipment is based on using the search coils which shift in the vertical direction [6]. The Br mapping system in the cyclotron magnet is shown in Fig.1. The system consists of a measurement disk with 35 search coils, alignment system and pneumatic system of the disk vertical shift. The measurement disk diameter is the same as the cyclotron pole diameter. This system allows measurement over the whole working region of the cyclotron but has certain mechanical difficulties due to a very small cyclotron sector gap of ~9mm at the pole edge.

To test the mapping system, the response of some correction elements was measured. The responses of magnetic field elements were compared with the ones simulated by the 2D POISSON and 3D TOSCA codes. The trim coil response is shown in Fig.2, and the response for the 1.5 mm central iron plug shift is in Fig.3. The Br measurement error is about ±1 G.

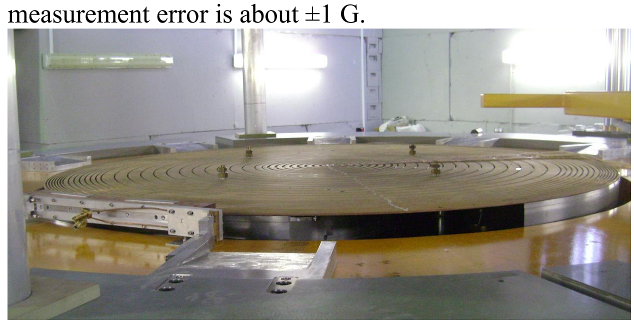

Figure 1: Br mapping system for the C230 PAP116 cyclotron.

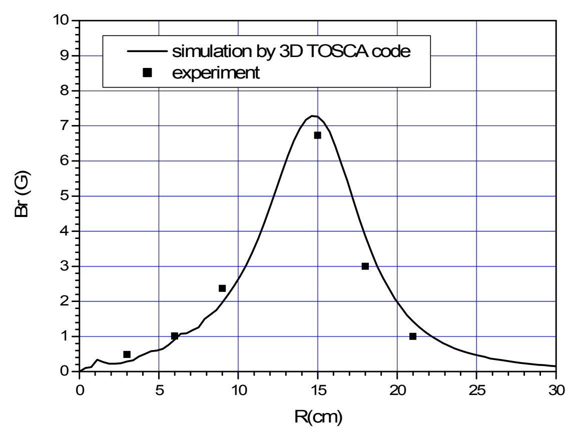

Figure 2: Br response for the central trim coil.

The mapping results for the Br component of the magnetic field are presented in Fig.4. The vertical offset of the beam center from the median plane of the cyclotron due to the measured Br component of the field is shown in Fig.5. This result is compared with the one measured at the cyclotron during the test with an accelerated beam.

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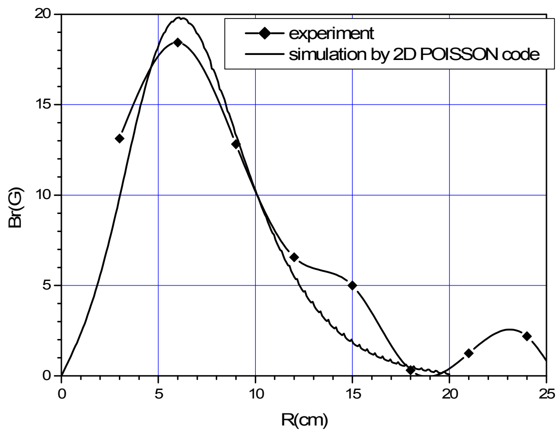

Figure 3: Br response due to the 1.5 mm vertical shift of the central plug.

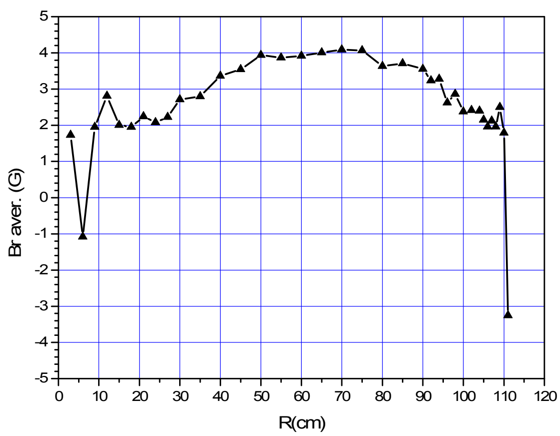

Figure 4: Br component of the magnetic field for the PAP116 cyclotron.

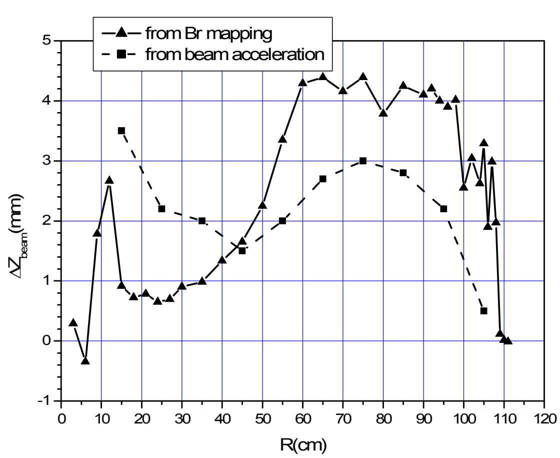

Figure 5: Vertical offset of the beam.

THE B_R MAPPING AND CORRECTION FOR THE PAP125 CYCLOTRON

For the C230-PAP125 cyclotron it was proposed to use the next-generation Br mapping system. As the main problem of the PAP116 system was manufacturing and use of a measurement wheel of a large diameter (225 cm), a system with the wheel diameter 72 cm was developed. The main preference of this wheel is not only the low weight but also a possibility of varying the median mapping plane in a wide vertical range, which allowed checking the position of the magnetic median plane. The view of the mapping system at the cyclotron PAP125 is shown in Fig.6.

Figure 6: Br mapping system for the C230 PAP125 cyclotron.

To check the Br mapping system usability the mapping in four planes at the distances -10, -5, 5, and 10 mm from the median one was performed. Physically, this experiment means measurement the Bz magnetic field gradient as $\Delta Br = dBz/dr * \Delta z$, using the Br mapping system.

The mapping results are shown in Fig.7. The results of calculating the Bz gradient from the Br map and from the Bz map are presented in Fig.8. Also, the sign of the Br component was definitely determined in this experiment.

The results of mapping of the Br component of the magnetic field in the PAP125 cyclotron are presented in Fig.9. The Br value achieves 20 G. This Br field leads to the large vertical beam offset in the central region of the cyclotron (Fig.10). The Br field was corrected using small correction shims on the central plug and sectors of the magnetic system (Fig.9). The vertical beam offset was considerably corrected too (Fig.10). The dedicated study of the compensated Br field distribution for this cyclotron using beam dynamics simulation is presented in the report of this conference [7].

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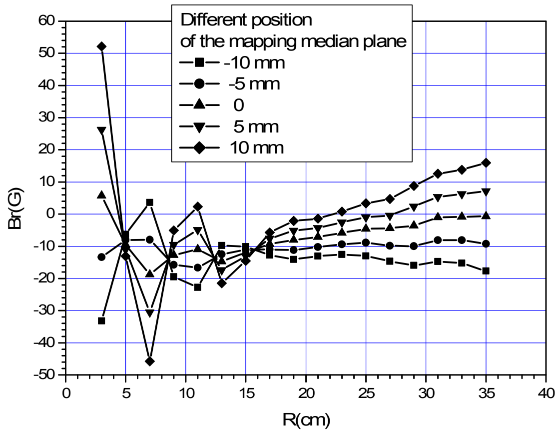

Figure 7: Br magnetic field at five planes of mapping.

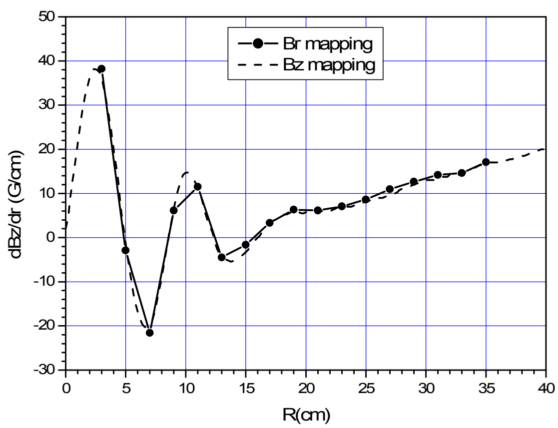

Figure 8: Bz magnetic field gradient from the Br and Bz mapping.

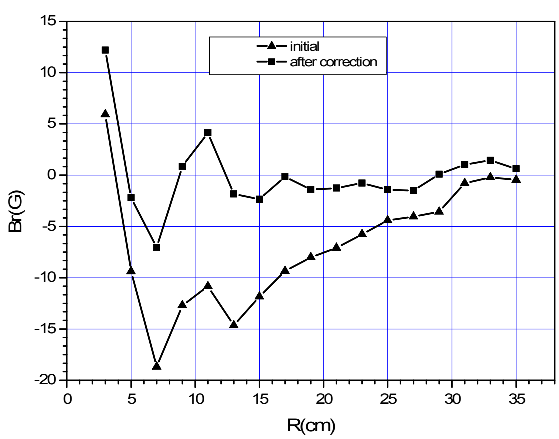

Figure 9: Br correction.

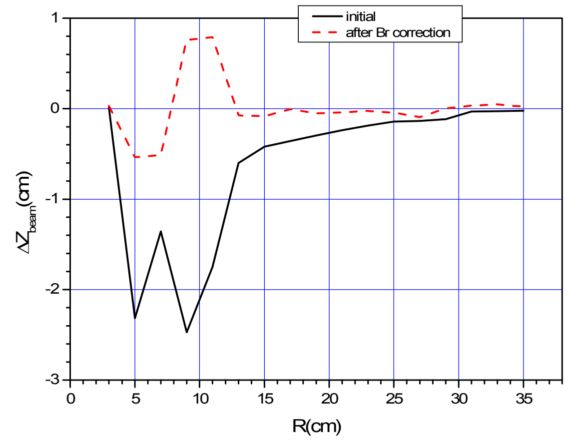

Figure 10: Vertical offset of the beam center for the measured Br component of the magnetic field.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance, interest and scientific support of the IBA company staff. We are especially grateful to Y.Jongen, Y.Paradise, E.Forton, C.L'Abbate, J.Brison.

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