SCREENING OF OPTICAL ELEMENTS IN C400 AXIAL INJECTION BEAM LINE

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Abstract

C400 is compact superconducting cyclotron for hadron therapy. The permissible level of the transverse magnetic field at the horizontal part of axial injection beam line of a cyclotron is about 10 Gauss. At the same time the C400 magnetic field is about 500 Gauss at the places of the ion sources, vertical bending magnet and quadrupole lens location. Thereby the screening of these beam-line elements is needed. The 3D OPERA model of the cyclotron and channel elements is used for this purpose.

INTRODUCTION

The C400 cyclotron for carbon therapy is developing by IBA in collaboration with JINR. The axial injection channel of the cyclotron (Fig.1) includes three ECR ion sources, bending magnets BMR40 with bending radius of 40 cm, three solenoids S1 – S3 and quadrupole Q [1]. The length of the vertical part of injection channel is about 4m from the carbon and alphas ECR axis to the median plane of the cyclotron.

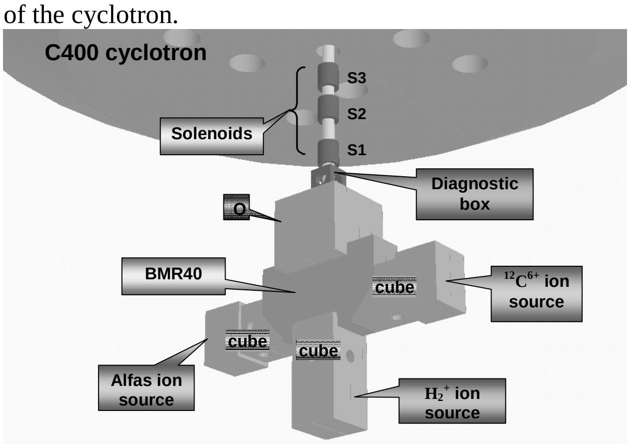

Figure 1: C400 axial injection beam line

The main particularity of the axial injection system is presence of the strong C400 cyclotron magnetic field in vertical part of channel (Fig.2a). Big values of the C400 magnetic field (Fig.2b) in the region of the horizontal part of the channel and inside the BMR40 magnet and the quadrupole lens affect significantly the particles trajectories and cause huge losses of particles. As it was shown in [2] the transverse magnetic field in the channel must be less than 10 – 15 Gauss to avoid the significant particle losses in the cyclotron inflector. This leads to necessity of an additional shielding.

For these purposes simulations of cyclotron magnetic field shielding by iron screens were performed by means of TOSCA code. Corresponding models of the C400 cyclotron and the injection channel were created.

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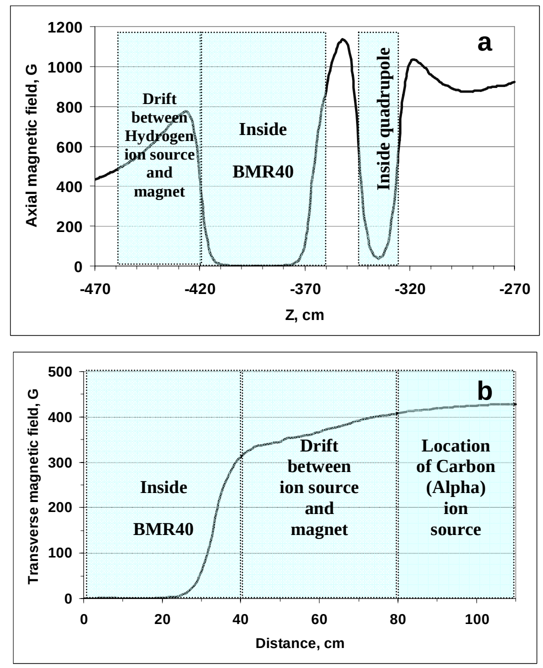

Figure 2: C400 magnetic field distributions in the region of the injection beam line elements

SHIELDING OF BENDING MAGNET AND ION SOURCES

Regions in which the magnetic field has to be reduced to the permissible level are presented in Fig.3.

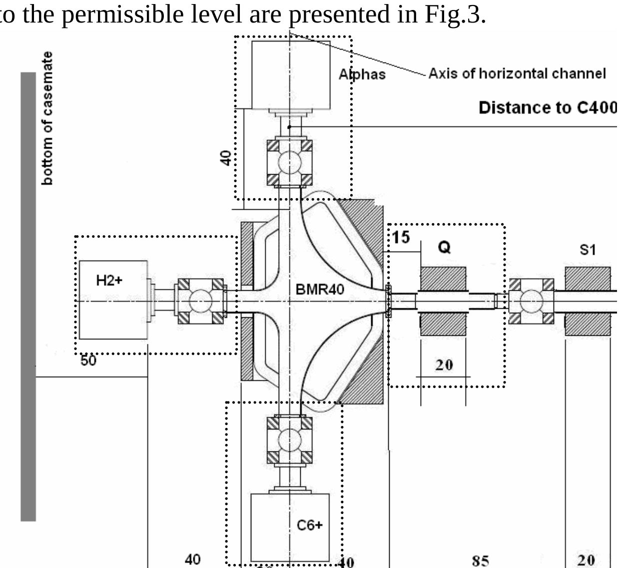

Figure 3: The scheme of the axial injection beam line and regions of an additional shielding (dashed lines).

The following shielding elements are proposed to reduce the magnetic field in the regions of quadrupole and ion sources to acceptable values (see Fig.4).

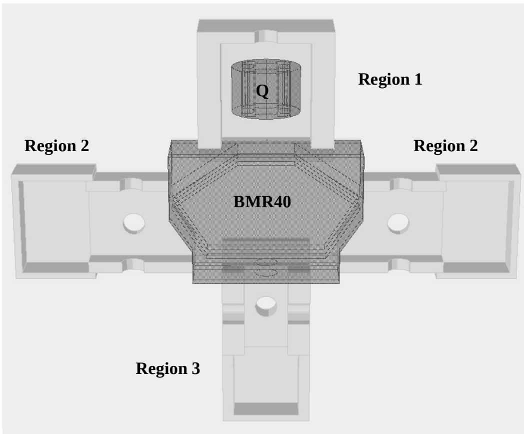

Figure 4: View of shielding elements

Shielding box in Region 1: length – 55 cm; lateral size – 60×60 cm; thickness of lateral walls and bottom wall connected to lateral walls of BMR40 – 10 cm; thickness of top wall – 5 cm; radius of a hole in top wall – 5 cm.

Horizontal shields in Region 2: connected to lateral walls of BMR40; lateral size - 40×30 cm; thickness of walls – 5 cm; radius of holes for diagnostic purposes – 5 cm. Shields of Carbon and Alpha ion sources in Region 2: sizes – 46×36×36 cm; wall thickness – 3 cm. Shielding insertion between BMR40 and Hydrogen ion source in Region 3: length including a part covering lateral walls of BMR40 – 50 cm; lateral size – 40×40 cm; thickness of walls – 10 cm; radius of holes for diagnostic purposes – 5 cm. Shield of Hydrogen ion source in Region 3: length – 33 cm; lateral size – 40×40 cm; thickness of lateral walls – 5 cm; thickness of bottom wall – 3 cm.

Proposed shielding permits to reach the permissible values of the C400 cyclotron magnetic field everywhere it is required. The axial magnetic field distributions on the vertical axis of the C400 are shown in Fig.5 – 6. The magnetic field distribution along the horizontal beam line is presented in Fig.7.

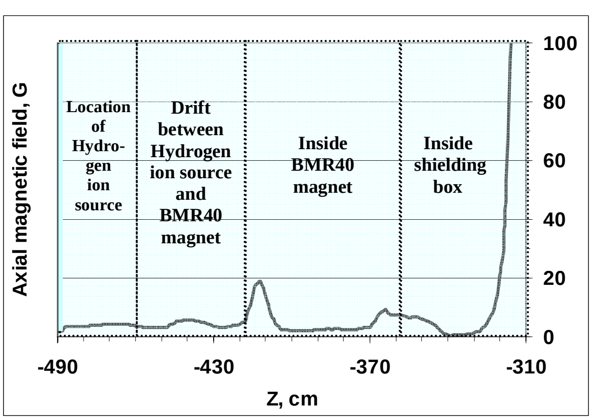

Figure 5: Axial magnetic field distribution on vertical axis of C400.

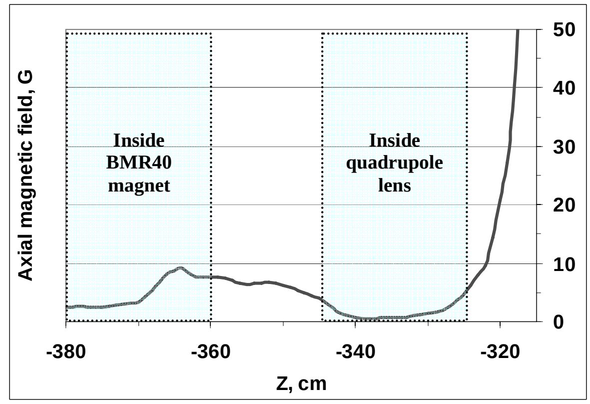

Figure 6: Axial magnetic field distribution on vertical axis of C400. Fragment.

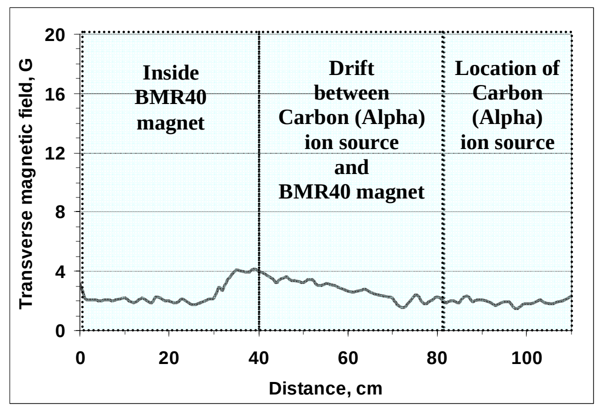

Figure 7: Magnetic fields along horizontal beam line.

Material of the shielding elements is Steel 1010. Total mass of the screens is about 2.5 tons. The magnetic field level with switched-on BMR40 bending magnet does not exceed 1.7 T inside the shielding elements and lateral walls of BMR40.

INFLUENCE OF SHIELDING

Presence of the shielding elements leads to a small changing of distributions of magnetic fields of BMR40 magnet and C400 cyclotron.

Influence of the shielding on magnetic field of BMR40 is not significant. The difference between magnetic field of shielded bend and one without the screens is about 1-2 Gauss and may be compensate by the small changing of the winding current.

The shielding also results in a small weakening of focusing properties of the magnet. This fact is taken into account in simulations of beam dynamics as well.

Influence of the shielding on magnetic field distribution inside C400 cyclotron is considerable. Presence of the screens results in some deformation of effective median plane of the cyclotron. The average magnetic field in the median plane of the cyclotron changes on about 5 G in presence of the beam line screens. Change of even harmonics of the axial magnetic field in MP is not considerable and does not exceed 1 G. Radial component of the magnetic field has values less than 2 G.

Changing of the average magnetic field in the median plane of C400 cyclotron is shown in Fig.8.

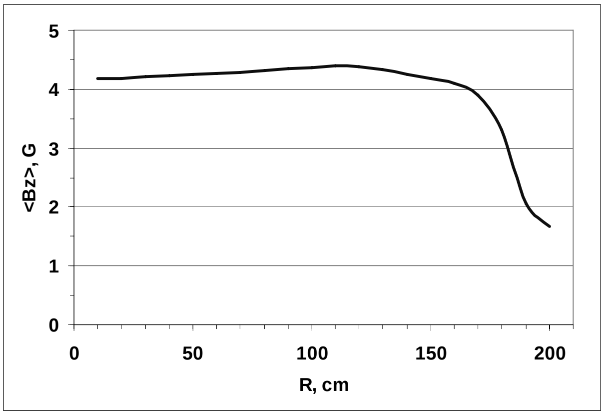

Figure 8: Dependence of the average magnetic field in MP on radii.

Thereby the cyclotron magnetic field shimming should be carried out with installed shield.

CONCLUSION

The screening of the axial injection channel is proposed.

The permissible values of the C400 cyclotron magnetic field are obtained everywhere it is required

Influence of the shielding on magnetic field of BMR40 bending magnet in general is not significant.

Change of the magnetic field of screened bend may be compensated by the small changing of the winding current.

The shielding results in a small weakening of focusing properties of the magnet.

Presence of the screens results in some deformation of effective median plane of the cyclotron. Thus the cyclotron magnetic field shimming should be carried out with installed shielding elements.

REFERENCES

[1] N.Kazarinov, V.Aleksandrov, Y.Jongen, V.Shevtsov, A.Tuzikov. Axial injection beam-line of C400 superconducting cyclotron for carbon therapy. These Proceedings, FR5REP102.

[2] V.Alexandrov, G.Gulbekian, N.Kazarinov, V.Shevtsov, A.Tikhomirov. Numerical simulation of the $^{48}Ca^{5+}$ ions transport along the U-400 cyclotron's injection line. In: Proc of the 16-th Int. Conf. on Cyclotron and their Applications, May 13-17, 2001, East Lansing, Michigan, USA, p. 390.