THE COMPENSATION OF BEAM VERTICAL DEFOCUSING AFTER THE SPIRAL INSPECTOR BY USING THE PASSIVE MAGNETIC CHANNEL.

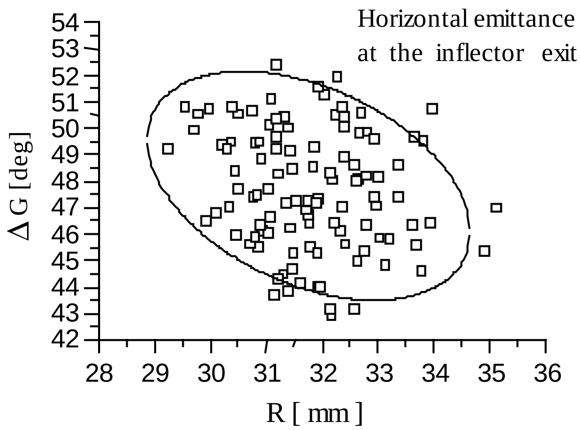
I. Ivanenko, G. Gulbekian, I. Kalagin, A. Morduev, FLNR, JINR, Dubna, 141980, Russia

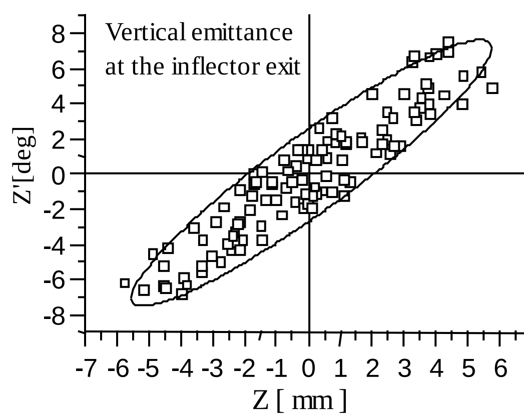
Abstract

For injection of the charged particles from axial injection system into median plane of the U400 cyclotron the spiral inflector is used. The calculations and experimental results have shown the presents of the strong vertical defocusing of the injected beam after inflector passing. The passive magnetic channel is used as the focusing element. The passive magnetic channel is stated between the inflector output and the first accelerating gap inside the inflector box.

1 SPIRAL INFLECTOR

The role of the spiral inflector is to bend the beam from axial direction onto cyclotron median plane. For design of the inflector of the U400 cyclotron the CASINO code was used[1]. The common parameters of the inflector: magnetic radius 25.6mm, electric radius 25mm, electrode gap 10mm, electrode width 20mm. The numerical simulation of the beam transportation through the inflector was carried out. Monoenergetic and continues beam has been considered. At the inflector input the 150π mm·mrad emittances in both transverse directions have been assumed. Fig. 2 and 3 show the radial and axial emittances at the inflector exit (Fig. 1, position P2). After the inflector exit the injected beam move through the drift space inside the inflector box. Fig. 4 and 5 show the radial and axial emittances at the inflector box output window (Fig. 1, position P3) in comparison with the cyclotron radial and axial acceptances before magnetic channel installation[2].





Figures 2, 3: Radial and vertical emittances at the inflector exit.

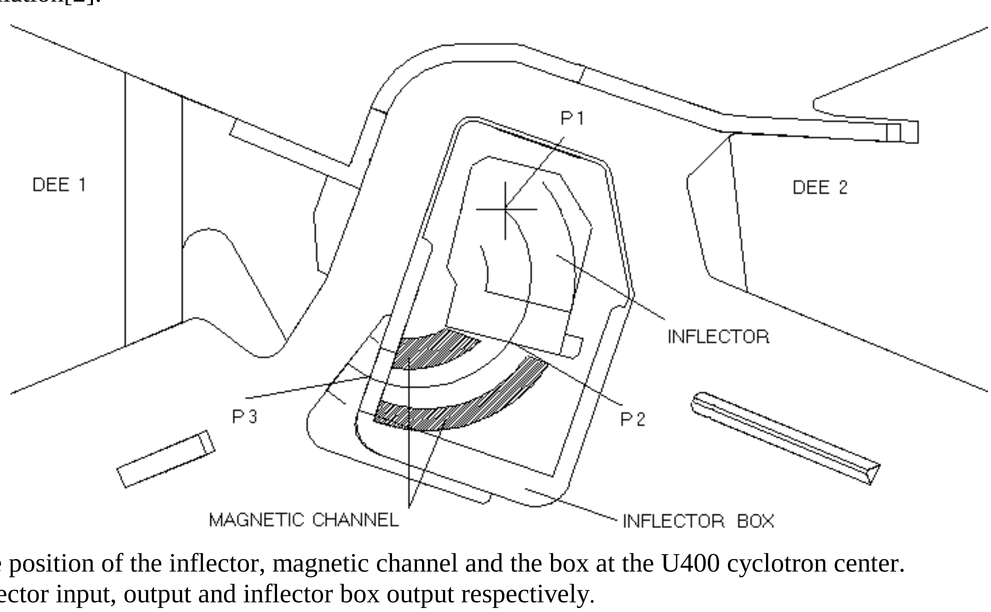


Figure 1: The position of the inflector, magnetic channel and the box at the U400 cyclotron center. P1, 2,3 – inflector input, output and inflector box output respectively.

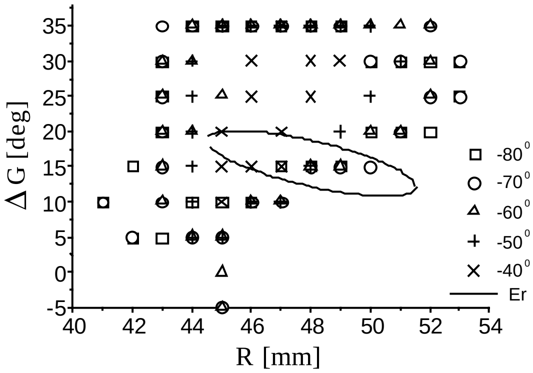


Figure 4: Radial emittance at the box output window (without magnetic channel) in comparison with the cyclotron radial acceptance.

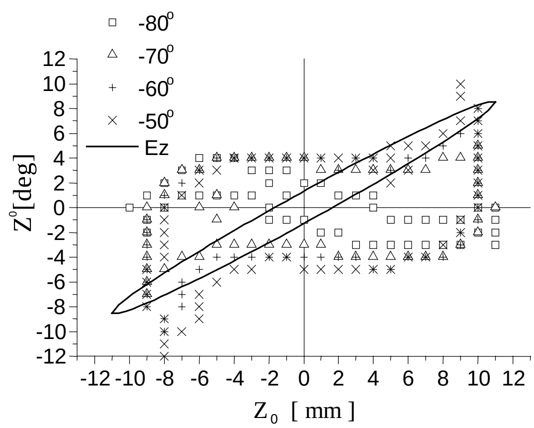


Figure 5: Vertical emittance at the box output window (without magnetic channel) in comparison with the cyclotron vertical acceptance.

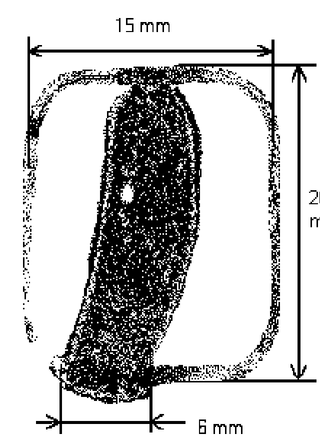


Figure 6: Beam trace at the thermos-sensitive film without magnetic channel, position P3 in the Figure 1.

According to the calculation results, the beam vertical dimension at the box output window is about 22÷23mm and the beam radial dimension is about 6.5mm. The box output window of 20mm-height and puller aperture are smaller then the beam vertical dimension. The experimental results of the beam acceleration have shown that the transmission factor at the cyclotron output radius was about 7÷9%. These results have been received without using of the bunchers system. To estimation the beam dimension at the box output window, the thermos-sensitive film was placed at the beam trajectory (Fig. 1, position P3). Fig. 6 shows the beam trace at this film after 5-minutes exposition. In the Fig. 6 the vertical dimension of the real beam is bigger then the height of the box output window. In order to avoid beam losses at the box window the passive magnetic channel was installed inside the box (Fig. 1).

2 PASSIVE MAGNETIC CHANNEL

The free space inside the inflector box is rather small (25mm along the beam trajectory) that is why the passive magnetic channel was chosen as the vertical-focusing element. After the inflector exit, the injected beam moves through the magnetic field gradient created by the channel. This gradient provides the focusing action on the beam vertical direction and the defocusing action on the beam radial direction.

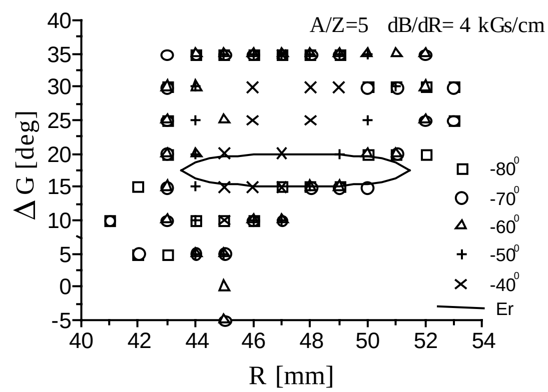


Figure 7: Radial emittance at the box output window (at 4kGs/cm gradient in the magnetic channel) in comparison with the cyclotron radial acceptance.

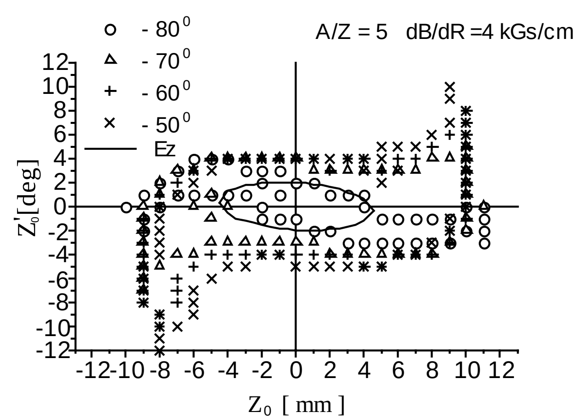


Figure 8: Vertical emittance at the box output window (at 4kGs/cm gradient in the magnetic channel) in comparison with the cyclotron vertical acceptance.

According to the calculation results, for 25mm part of the beam trajectory the best value of the magnetic field gradient is 4kGs/cm. Fig. 7 and 8 show the radial and axial output emittances at the box output window (after passing the magnetic channel) in comparison with the cyclotron radial and axial acceptances (Fig. 1, position P3). The calculation shows that the vertical dimension of the injected beam at the box output window is about 9mm and the radial dimension is about 8mm. In this case, the beam passes the window without losses. Fig. 9 shows the position and sizes of the magnetic channel elements[3].

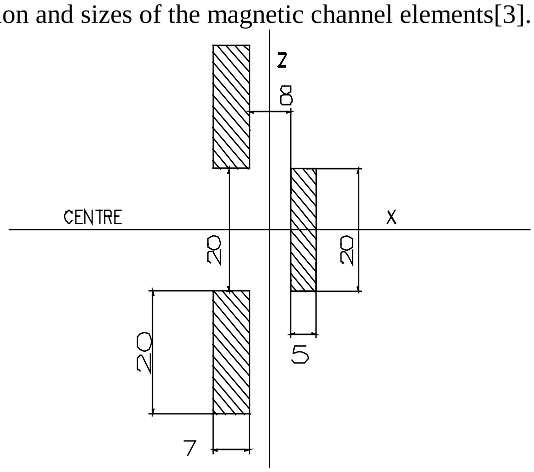


Figure 9: Position and sizes of the magnetic channel elements.

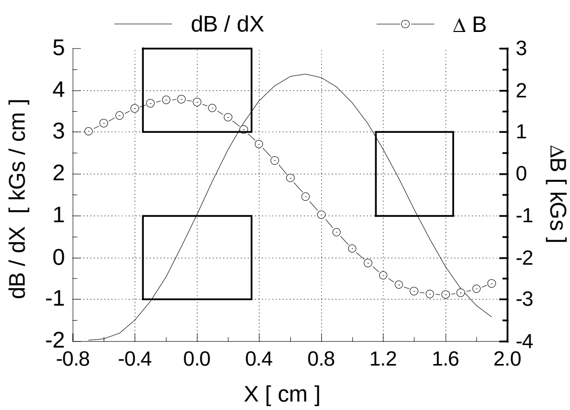


Figure 10: Distribution of the magnetic field gradient and ΔB along the cross-section of the channel.

This configuration of the channel provides the gradient, presented in the Fig. 10. Because of the restricted free space inside the inflector box the channel elements were produced at the arc form over the beam (Fig. 1). After the magnetic channel installation, the experimental results on the beam acceleration has shown that the transmission factor at the cyclotron output radius increased up to 10÷12%. Fig. 11 shows the distribution of the beam current value along the axial injection line and cyclotron radius. Fig. 12 shows the beam trace at the thermos-sensitive film (Fig. 1, position P3). At the Fig. 12 the vertical dimension of the real beam is about 7mm, radial dimension – about 6mm.

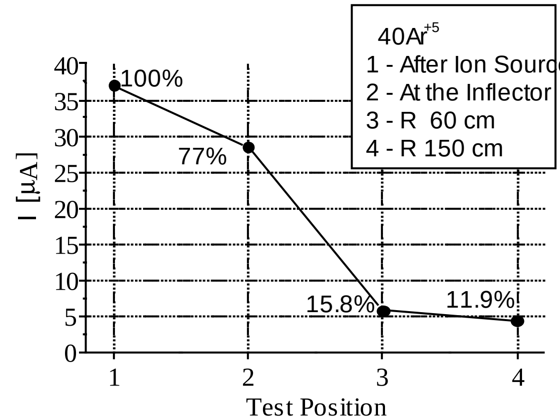


Figure 11: Distribution of the beam current value along the axial injection line and cyclotron radius.

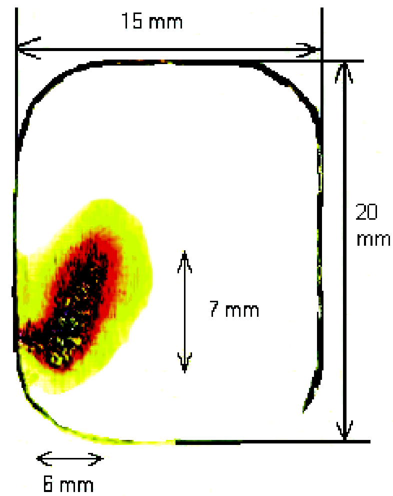


Figure 12: Beam trace at the thermos-sensitive film with magnetic channel, position P3 in the Figure 1.

3 CONCLUSION

In order to avoid beam losses at the window of the inflector box, the passive magnetic channel was installed inside the box. This channel provides the focusing action in the vertical direction of the injected beam after the inflector. The experiment results have shown the transmission factor at the cyclotron output radius increased from 7÷9% to 10÷12%.

REFERENCES

[1] CASINO Users Guide and Reference Manuel, B.F. Milton and J.B. Pearson, TRI-DN-89-19
[2] I.A. Ivanenko, “The Central Region Of The U400 Cyclotron”, Cyclotrons and their applications, 1998, 15 Conference, Caen, France.
[3] E.A. Ayrjan et al. “Design of Passive Magnetic Channels in Wide Range of External Magnetic Fields”, JINR, P9-98-210, Dubna, 1999.