INJECTION OF THE PROTON BEAM INTO THE COMPACT CYCLOTRON WITH SOLENOID

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Abstract

For the beam injection into compact cyclotron the spiral inflector is usually used [1]. Our investigation [2] shows the big growth of the beam emittances, especially of the vertical one due to spiral inflector.

That is why we are looking for some other device for the external injection. Solenoid looks as a possible alternative to the spiral inflector. In this paper we have studied the dynamics of the H^- beam injected by means of solenoid.

METHOD OF INJECTION

It is supposed that the solenoid axial magnetic field and the cyclotron magnetic field in the median plane have the same value. Solenoid placed in the vertical hole in the cyclotron yoke and the pole tip. Beam enters into the solenoid from the ion source with some angle respect to the solenoid axis. For this condition the beam trajectory is a spiral and for the proper chosen injection angle the spiral radius is almost equal to the solenoid inner radius.

SIMULATION OF BEAM DYNAMICS

Initial conditions for the 500 particles had the next parameters: beam cross section 5x5 mm^2; longitudinal (bunch length) beam size 5 mm; transversal emittances 30π mm·mrad; beam energy 30 keV; beam energy spread ±1%;

Firstly we have chosen the beam starting point and the angle between the beam velocity and the solenoid axe to provide the beam spiral trajectory with the 30 mm radius and the symmetrical one regard to the solenoid axe. Solenoid had the 0.6 T (Fig. 1) homogeneous axial magnetic field inside and the axial stray field outside the solenoid entrance going down to zero along the 50 mm distance. The radial component of the stray field was calculated on the base of Maxwell's equations.

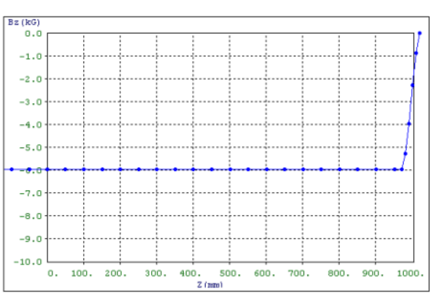

Figure 1:Solenoid axial magnetic field

The first computer simulation was done for the beam starting point lying outside the solenoid(case1). The beam passed the stray field before entering to the homogeneous solenoid field. The start angle between the beam velocity and the solenoid axe was equal 25°. Due to the stray field this angle increases up to 50° when the beam enters in the homogeneous field region. Results for the beam with zero intensity(case1) are shown in Figs. 2-4.

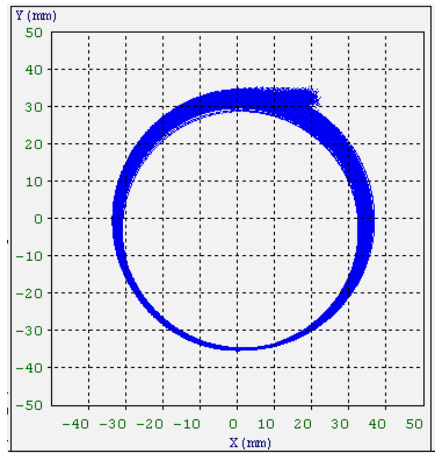

Figure 2:Beam trajectory view on horizontal plane(c1).

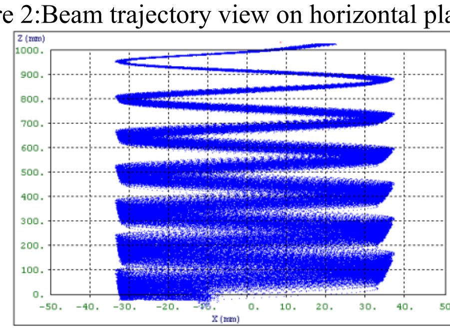

Figure 3: Beam trajectory view on "Z-X"plane(c1).

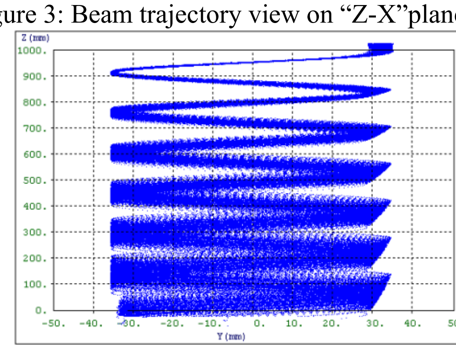

Figure 4: Beam trajectory view on "Z-Y"plane(c1).

It is evident the large growth of the vertical beam size (from 5 to 80 mm) due to the influence of the magnetic field radial component at entrance of the solenoid.

The next set of calculation was done for the beam starting point lying inside solenoid(case2) to exclude the negative influence of the magnetic field radial component. The starting angle between the beam velocity and the solenoid (cyclotron) axe was equal 45°.

Results for the beam with zero intensity(case2) are shown in Figs. 5-7. It is seen that with these conditions the transversal beam sizes do not increase.

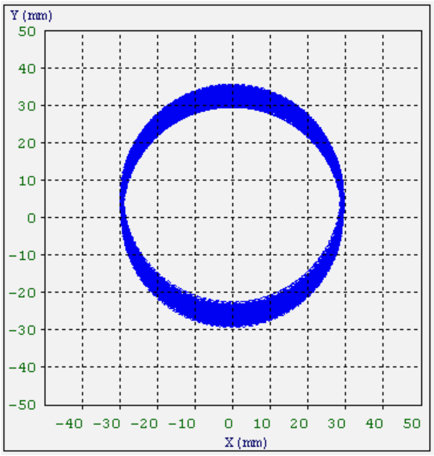

Figure 5: Beam trajectory view on horizontal plane(c2).

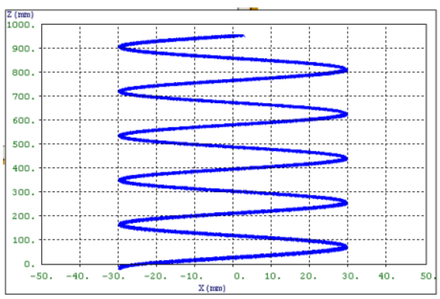

Figure 6: Beam trajectory view on “Z-X”plane(c2).

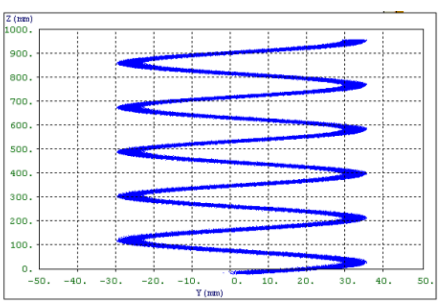

Figure 7: Beam trajectory view on “Z-Y”plane(c2).

Then the simulations were done taking into account the beam space charge for the 2 values of the beam intensities 0.1(case3) and 0.5 mA(case4). The results for the 0.1 mA intensity are shown in Figs. 8-10 and for 0.5 mA in Figs. 11-13.

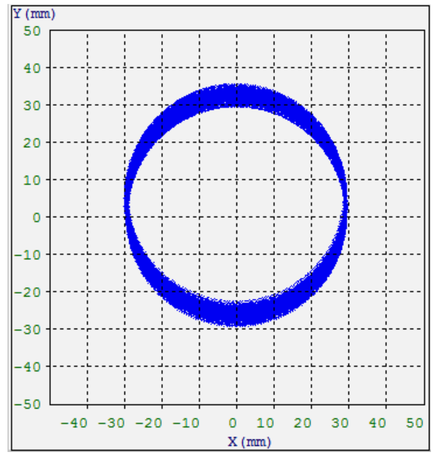

Figure 8: Beam trajectory view on horizontal plane(c3).

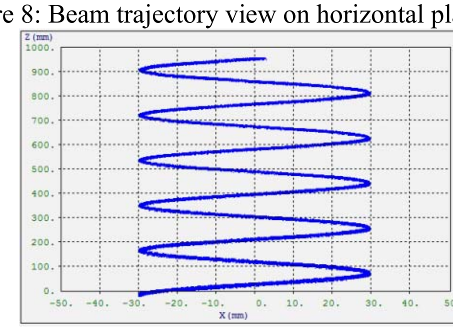

Figure 9: Beam trajectory view on “Z-X”plane(c3).

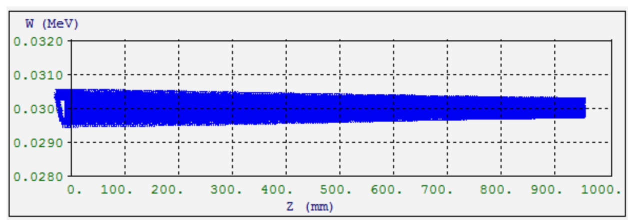

Figure 10:Beam energy spread vs.Z(c3).

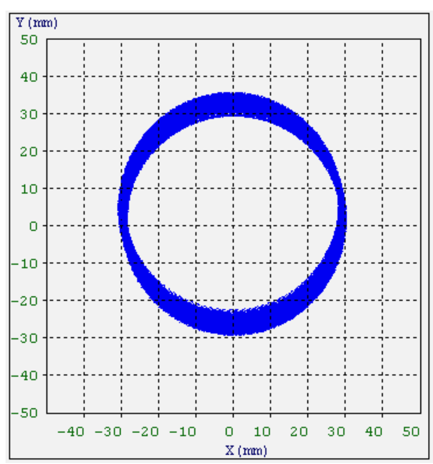

Figure 11: Beam trajectory view on horizontal plane(c4).

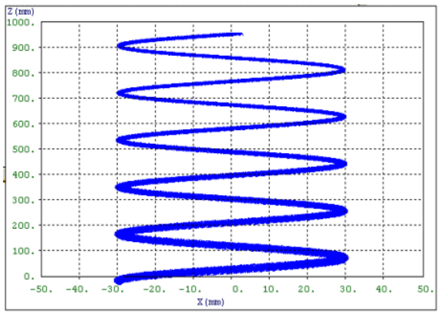

Figure 12: : Beam trajectory view on “Z-X”plane(c4).

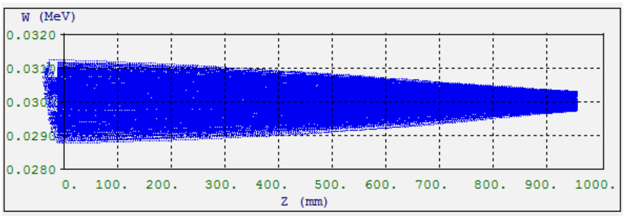

Figure 13: Beam energy spread vs.Z(c4).

It is seen the growth of the beam energy spread (up to 2% for 0.1mAand up to ±4% for 0.5 mA) and as a consequence – the growth of the vertical beam size (up to 8 mm for 0.1 mA and up to 12 mm for 0.5 mA).

CONCLUSIONS

The above described investigation has shown good perspectives (prospects) of the “solenoid injection” for the low intensity beam.

REFERENCES

[1]P.Heikkinen,M.Rinta-Nikkola,Ion Optics in the Juvaskyla K130 Cyclotron,Proc. of 13th International Cyclotron Conference,Vancouver,1992,p392.

[2] E.V.Samsonov,L.M.Onischenko,Beam Dynamics with Space Charge in compact Cyclotron on Energy 1.8MeV,Proc. of 19 RUPAC,Dubna 2004,p153.