SIMULATIONS OF THE MULTITURN INJECTION INTO NUCLOTRON BOOSTER*

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Abstract

In order to increase the intensities of the ion beams in the JINR-Dubna superconducting Synchrotron NUCLOTRON, to raise their energies and to inprove their quality a booster synchrotron is under design. This booster synchrotron needs some kind of multiturn injection to store particles. The multiturn injection with betatron stacking is simulated in this paper. The simulations reveal the optimum values of the injection system parameters. The injection process can cover about fourteen revolution periods with an maximum efficiency of 45%.

1. INTRODUCTION

The accelerating complex of the JINR-Dubna High Energy Laboratory consists of Synchrophasotron and of the superconducting synchrotron NUCLOTRON. It provides heavy ion beams with record parameters and allows for important experiments in the field of nuclear physics to be carried out-[1].

In order to increase the beam intensities more than with an order, to raise the final energy of the ions in NUCLOTRON applying ion stripping and to improve the beam quality by electron cooling a booster synchrotron is under design-[2]. This will be a six period synchrotron with circumference of 50,52 m capable to accelerate protons up to 650 MeV and ions with z/A=0,5 up to 200 MeV/A. Some other important booster parameters are: beam rigidity at injection 0,647 Tm and maximum 4,9 Tm; betatron tunes $Q_x=Q_y= 2,25$; emittance of the injected beam 40π mm.mrad; acceptance 260π mm.mrad.

The now in operation linac LU-20 which accelerates protons up to 20 MeV and ions with Z/A=0,5 up to 5 MeV/A will be used as an injector into the booster. As the intensities of the linac beams are limited to 2.10^{11} for protons and to 1.10^{4} for heavy ions some kind of multiturn injection is required.

In this paper the results of a computer simulation of the betatron stacking in the NUCLOTRONS's booster is presented.

2. MULTITURN INJECTION WITH BETATRON STACKING

In the betatron stacking method-[3-5] the closed orbit is locally distorted by means of two, three or four bump magnets in a way to pass close to the injection septum. In the beginning the bump is as big as possible and then it is gradually reduced to zero.

In each time $t\in(0,T_s)$, T_s being the revolution period, a portion(slice) of the incoming beam is injected into the accelerator. In general the slice centre will have a linear x_i and an angular x'_i displacements with respect to the closed orbit and the slice will undergo betatron oscillations.

One turn later the slice will come again at the injection azimuth. However due to the betatron oscillations around the instantaneous closed orbit most of the particles will avoid the septum and will be accumulated into the accelerator.

Meanwhile a new portion(slice) of the incoming beam will be injected. The particles of this second slice will have larger amplitudes of the betatron oscillations as the orbit bump is reduced and the injection position is kept unchanged.

The process goes on until the bump height is reduced to zero.

3. COMPUTER SIMULATIONS

To simulate the multiturn injection into NUCLOTRON's booster with betatron (radial) stacking we have used the tracking code ACCSIM-[6]. Originally designed for simulating of the charge-exchange injection of protons into synchrotrons this program could be applied also for simulating of the betatron stacking process. The code uses the DIMAD's output files as input data for the ring magnet structure. The injection elements themselves are described by standard MAD input language. Statistics and scaterplots of the beam are provided at any time during the run.

We have studied three different laws of orbit bump fall-linear, exponential and cosine. As parameters

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describing the injection process we have used the full number of stored in the accelerator particles and the injection efficiency. The latter is defined as the ratio of the accumulated beam current to the product of the injector current by the number of injection periods.

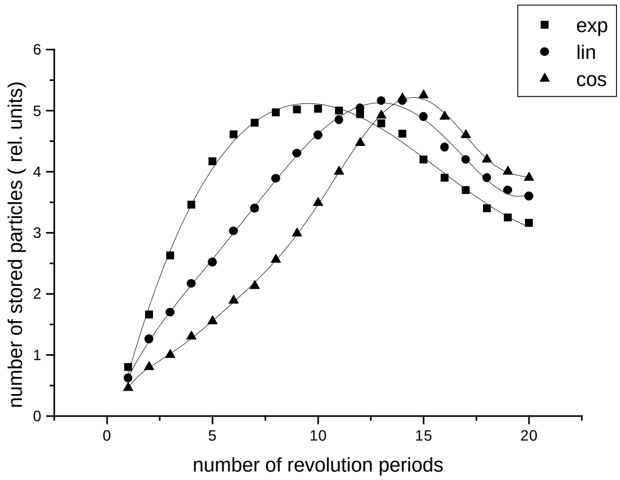

Figure 1. Accumulation of particles in the NUCLOTRON booster during the multiturn injection for different laws of orbit bump fall.

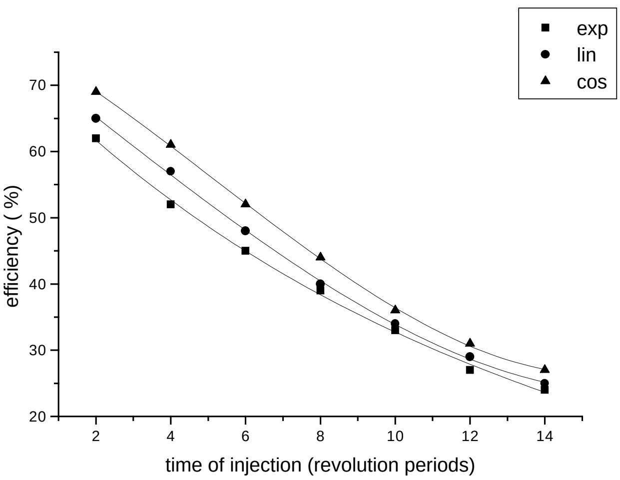

Figure 2. Efficiency of the NUCLOTRON booster multiturn injection versus the number of injected turns.

Fig.1 depicts the process of accumulation of particles into accelerator during the time (in revolution periods). The particles have been injected during fifteen revolution periods. According to fig.1 if the bump fall is exponential the number of stored particles increases faster while the losses during the last periods are quite big due to the small orbit step. On the contrary the cosine bump fall has bigger losses during the first periods.

Fig.2 shows the dependence of the injection efficiency on the duration of the injection process (in revolution periods). According to it the stacking efficiency slightly depends on the bump fall laws.

The stacking efficiency depends on large number of parameters- the distance beam centre- septum, the slope of the injection beam, the number of the injection periods(injection time), the number of betatron oscillation per turn Q, the emittance of the injected beam, the momentum spread of the injected beam etc.

The efficiency versus the initial radial position of the injected beam x_0 and the efficiency versus the injected beam slope x'_0 curves have resonant character-Fig.3 and Fig.4. The septum edge is deployed at x=30.0 mm. The dependence of the efficiency on the betatron number Q has a typical symmetrical shape-Fig.5.

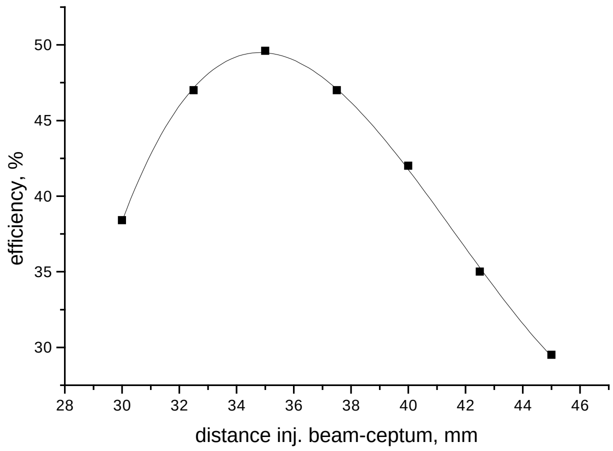

Figure 3. Efficiency of the NUCLOTRON booster multiturn injection versus the distance beam center-septum edge.

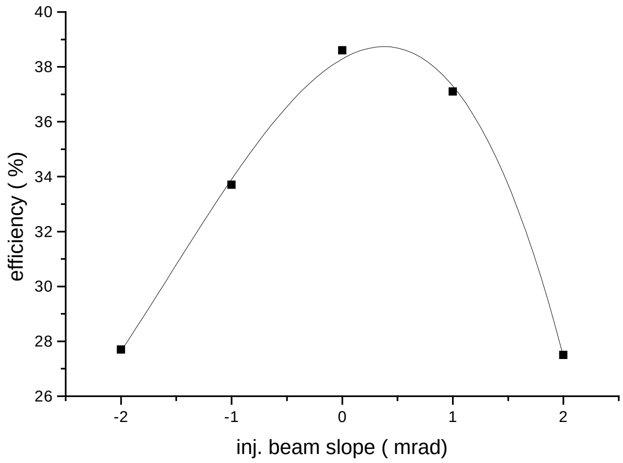

Figure 4. Efficiency of the NUCLOTRON booster multiturn injection versus the injected beam slope.

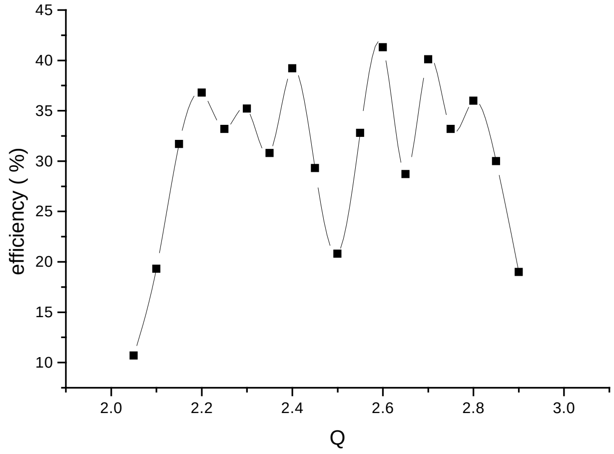

Figure 5. Efficiency of the NUCLOTRON booster multiturn injection versus the number of betatron oscillations per turn Q.

4. CONCLUSIONS

According to the computer simulations of the multiturn injection with betatron stacking into NUCLOTRON booster one can inject about fourteen revolution periods with an maximum efficiency of 45%. The centre of the injected beam should be slightly (~6 mm) dismissed outwards the septum edge while the beam slope should be close to zero. The number of betatron oscillations per turn Q should be chosen close to either 2.4 or 2.6.

5. ACKNOWLEDGEMENT

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