PROGRESS IN NICA BOOSTER DESIGN

A.Butenko, H.Khodzhibagiyan, V.Mikhaylov, I.Meshkov, G.Trubnikov, A.Tuzikov, A.Valkovich, A.Sidorin, JINR, Dubna, Russia

Abstract

NICA is a new accelerator complex being under design and construction at Joint Institute for Nuclear Research in Dubna. A few changes in NICA booster ring design took place over the last half a year.The most significant one is making use of DFO doublet optical structure instead FODO lattice studied previously. Based upon this new optics the injection and extraction systems were proposed. Both "One time, many turn" and "Many times, one turn" schemes of injection are presented here. Fast extraction system (to inject beam to Nuclotron) is mentioned too. Optimal arrangement of the closed orbit correction system (correctors,BPMs) was found. Chromaticity correction system with relatively small reduction in dynamical acceptance is paid attention to.

INTRODUCTION

The NICA/MPD project [1] started at the Joint Institute for Nuclear Research (JINR) in Dubna in 2007. The goal of the project is to carry out experimental studies of the hot and dense strongly interacting quantum chromodynamics matter and light polarized ions. The NICA accelerator complex will consist of two injector chains, a new 600MeV/u superconducting booster synchrotron, the existing superconducting synchrotron – Nuclotron [2], and the new superconducting collider consisting of two rings each of about 503 m in circumference. The report presented is to describe the latest results of the R&D efforts in NICA booster ring design.

OPTICAL STRUCTURE OF THE BOOSTER RING

One of the most significant developments in the overall design of the booster ring is the choice of DFO-doublet-based lattice. In previous reports FODO lattice was considered as the most possible solution for the ring.

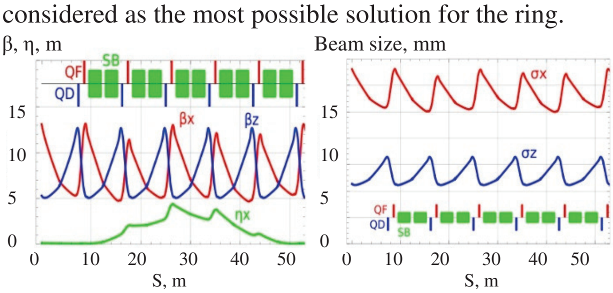

Figure 1: Optical functions and envelopes in the ring.

Optical structure of the booster ring has periodicity and has four super periods. Each of them has 5 regular DFO periods and one period having no bended magnets in it. Regular period includes couple of lenses (defocusing and focusing ones) and couple of bended dipole magnets. Schemes of both regular DFO period and straight section are presented at the Fig.1.

Table 1: Main parameters of the Booster ring

1. Main Parameters		
Energy of injection, MeV		6.2
Maximum energy of the Au+32 ions,MeV/amu		600
Magnetic rigidity,	at injection	2.2
T·m	maximum	600
Circumference, m		211.2
Coulomb intensity limit, part/cycle		5×10e9
Transition energy, GeV/amu		4.5
2. Lattice and Magnetic Elements		
Number of superperiods		4
DFO-type periods		24
Dipole magnets		40
Quadrupole lenses		48
Magnetic field in dipole magnets, T		1.8
Gradient in F/D-lenses, T/m		24.7/-24.2

Lattice functions in one super period are presented at Fig.1 Envelope functions of the beam corresponding to the physical acceptance of the vacuum chamber (Ex=123π mm mrad, Ey=66 π mm mrad) and energy spread (estimated to be ~5×10e-3) are shown at the Fig.1. Main parameters of the optical structure of the booster ring are given at the Table 1.

INJECTION AND EXTRACTION SCHEMES

njection system for the booster ring with new DFO optics was developed. By now, three major injection schemes are at the table: “one time, many turns”, “many times, one turn” and “one time, one turn”.

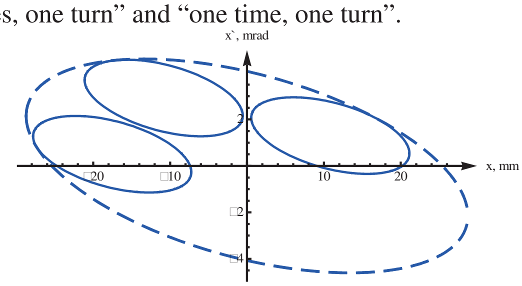

Figure 2: “One time, many turns” injection scheme in phase space.

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Fig.2 gives an appearance of the “three turns” injection in phase space. The phase advance corresponding to the circumference of the ring separates small ellipses.Phase space shown at the Fig.2 is depicted for the betatron motion around closed orbit with the local bump introduced.

Local bump necessary for the proper “one time, many turns” scheme operation is presented at Fig.3. For the comparison, the local bump in “one time, one turn” approach is depicted at the Fig.4. The overall layout of the injection system is given at Fig.4.

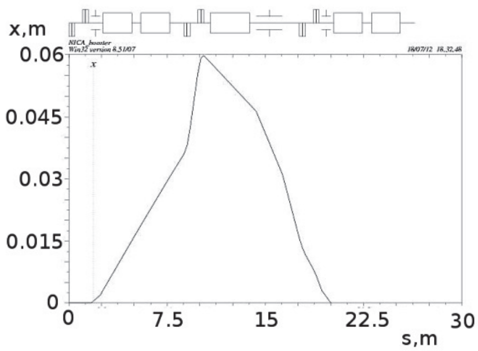

Figure 3: Local bump for the beam injection over three turns.

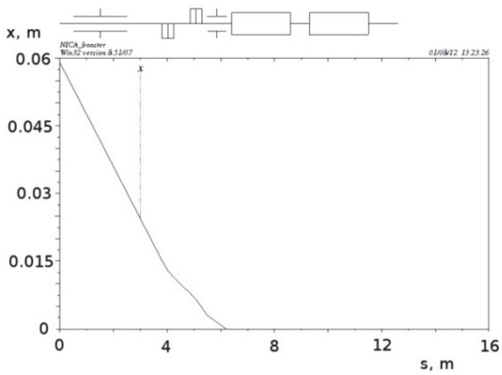

Figure 4: Local bump for the single beam injection over one turn.

Position of the injection plates to be used for the creation of the local bump was chosen in such a way as to have no significant reduction of dynamical acceptance at the new orbit. The behaviour of the envelope function for the injected beam during the first three turns is depicted at the Fig.5.

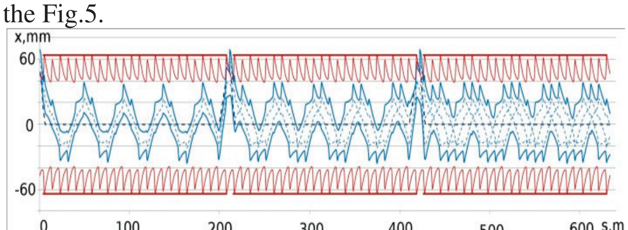

Figure 5: Envelope function of the stored beam during the injection (three turns)

The behaviour of the injected and stored beam near the first straight section is given at the Fig.6.

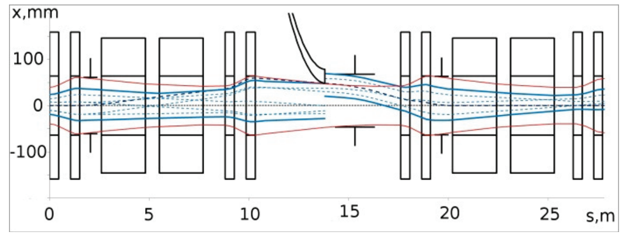

Figure 6: Envelope functions of the stored and injected beam during the injection (first straight section of the ring).

Main parameters of the deflection plates are given in the Table 2.

Table 2: Main parameters of the deflection plates.

	Voltage, kV	E-field, kV/cm	Deflection angle, mrad
IK1	35.4	2.9	5.5
IK2	18.2	-1.6	-8.5
IK3	58	4.6	8.8

The emittance of the beam coming from the linac is anticipated to be 10 π mm mrad. With the system described here the emittance of the beam immediately after the injection is estimated to be 117 π mm mrad.

As for the fast extraction system there are three options to proceed: with horizontal kicker, vertical kicker and “skew” kicker. The one with vertical kicker is considered as the most possible for the actual realisation. In this configuration the extraction system consists of vertical kicker and three lambertson magnets. Length of the kicker is 2.5 m, magnetic field is 0.1T.

Envelope functions in x,y-directions for the last scenarioare given at the Fig.7,8.

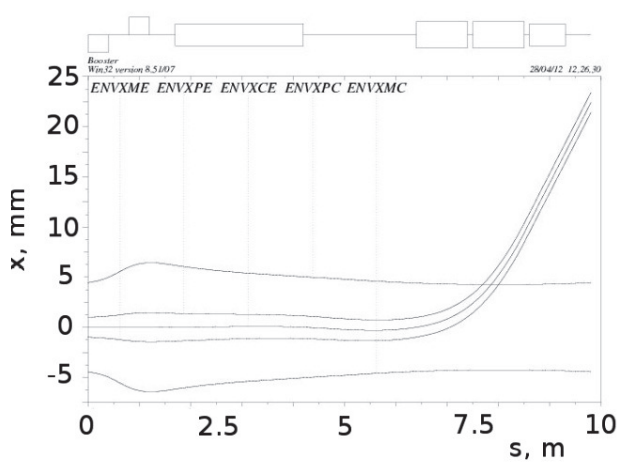

Figure 7: Fast extraction of the beam in x-direction.

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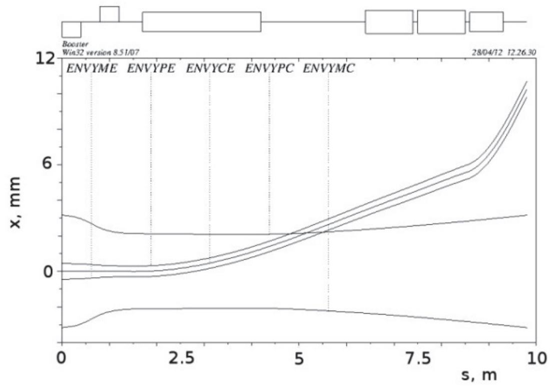

Figure 8: Fast extraction of the beam in y-direction.

ORBIT CORRECTION SYSTEM

Orbit correction system of the Booster ring was developed with rather standard means provided by MAD-X program [1].Typical orbit distortion with lenses shifted in the transverse direction with Gaussian law of the distribution (in average at 2mm) is shown at the Fig.9.

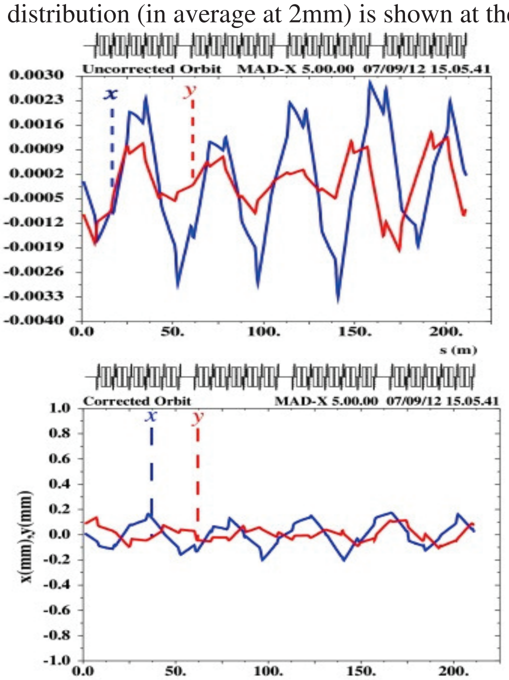

Figure 9: Closed orbit before and after correction.

CORRECTION OF THE NATURAL CHROMATICITY

Fig. 12 shows the variant of sextupoles arrangement to be implemented in the ring. The phase advance between focusing and defocusing sextupoles is approximately equal to an even number of π ($0\times\pi$). In the case of booster ring it is zero. The phase advance between two sextupoles of the same sign is odd multiple of π ($1\times\pi$). Fig.13 gives one an impression of how a dynamical acceptance got reduced due to the nonlinearity introduced.

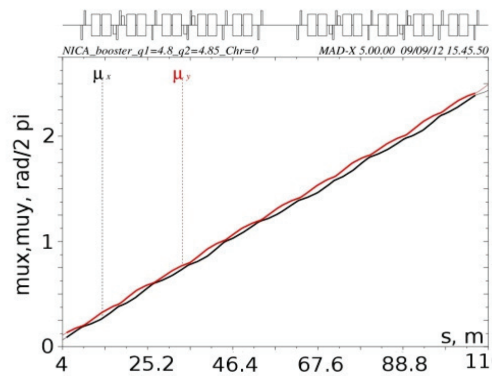

Figure 12: Betatronphase advance in the booster ring with sextupoles implemented.

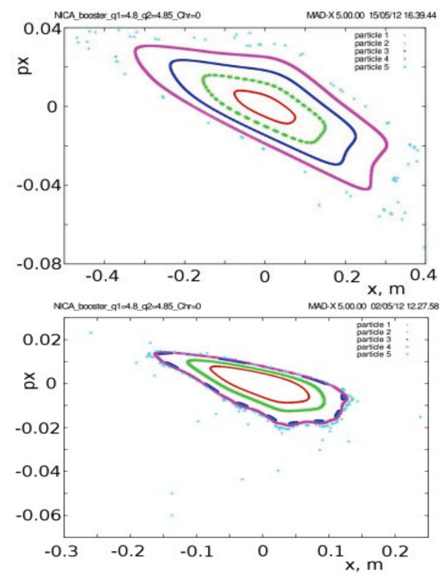

Figure 13: Dynamical acceptance with correct and wrong sextupoles arrangement (in terms of phase advance).

CONCLUSIONS

A few changes and developments in the NICA Booster ring design are described. The most significant ones are related to the development of the injection/extraction systems for the new DFO doublet lattice model of the ring. Other points of progress are the first steps towards the development of the closed orbit correction system and therefore deciding upon where dipole correctors and beam position monitors are to be located in the ring. Along with the closed orbit correction system chromaticity correction system is proposed. The system is designed in such a way as to minimize the reduction of the dynamical acceptance due to the nonlinearity introduced.

REFERENCES

[1] MAD-X computer code. Available:http://mad.web.cern.ch/mad/

[2] Nuclotron - based ion collider facility. Available:http://nica.jinr.ru/

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