TRANSPORT BEAM LINES FOR NICA ACCELERATOR COMPLEX

O.Kozlov, A.Eliseev, I.Meshkov, V.Mikhaylov, A.Sidorin, N.Topilin, G.Trubnikov, A.Tuzikov, JINR, Dubna, 141980, Russia

Abstract

In the last years Nuclotron-based Ion Collider fAcility (NICA) project is developed by Joint Institute for Nuclear Research (JINR), Dubna, Russia. The goal of the project is to construct new accelerator complex that will be used for 1) colliding ion beams on first stage and 2) colliding polarized proton/deuteron beams on second stage of the project. NICA accelerator complex will consist of two linear accelerators, two synchrotrons, two storage rings of the collider and transport beam lines. Geometry and magnetic system of NICA beamlines are presented in this report. Results of beam dynamics simulations within the beam lines are considered.

INTRODUCTION

Project NICA/MPD [1] is JINR flagship project being fulfilled by world-wide international collaboration. This project represents a large long-term investment for JINR high energy physics and is designed with significant upgrade potential.

NICA project intends the development of new accelerator complex based on existing superconducting synchrotron Nuclotron [2]. In frame of NICA project the existing accelerators such as Nuclotron and linac LU-20 have to be modernized to match the project specifications. The following facilities are expected to be included: heavy ion source KRION of ESIS type, source of polarized protons and deutrons (2nd stage of the project), heavy ion linear RFQ accelerator (HILac), superconducting Booster synchrotron [3], Collider having two superconducting storage rings [4], transport beam lines connecting specified elements of NICA complex.

Physical projects of three beam lines are presented in this report. They include HILac-Booster, Booster-Nuclotron [5] and Nuclotron-Collider beam lines. Scheme of NICA accelerator complex with these beam lines are shown in Fig.1.

HILAC-BOOSTER BEAM LINE

General

HILac-Booster beam line is used for ion beam transportation from HILac to Booster. It provides a beam injection into Booster and the beam matching with its lattice functions. Beam energy is equal to 6.2 MeV/amu.

Geometry

The beam line is located in the median plane of Booster. HILac axis is parallel to axis of a straight line of Booster which a beam is injected into. For the injection into Booster a beam is horizontally deflected on 8.6 deg and placed onto the closed orbit by the injection septum with the same angle of a beam bending. The total length of the beam line, including focusing lens located in the injection straight line of Booster, is 42 m.

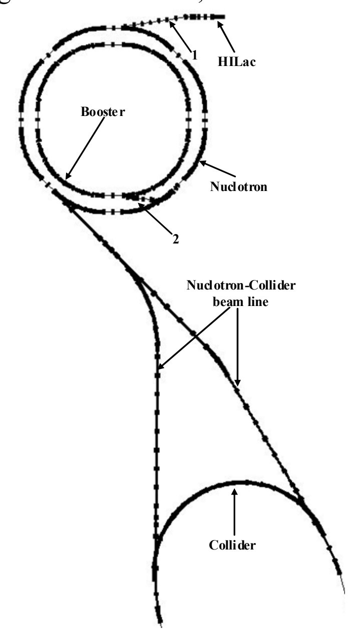

Figure 1: Scheme of NICA accelerator complex. 1 – HILac-Booster beam line, 2 – Booster-Nuclotron beam line.

Magnetic system of the beam line consists of a bending magnet M1, 14 quadrupole lenses and steerers. Parameters of dipole magnets and quadrupole lenses are given in Table 1.

Scheme of the beam line is presented in Fig. 2.

Lattice

Optical lattice of the beam line can be divided functionally on two parts: before and after the bending magnet M1. First part has zero-value dispersion and used for matching of alpha and beta functions of a beam. Second part is used for dispersion matching. The lattice enables matching of any possible beam with Booster lattice functions.

Table 1: Parameters of Dipoles and Quadrupoles of HILac-Booster Beamline

Magnet	Dipole	Quadrupole
Max. magnetic field (gradient), T (T/m)	1.21	13
Bending angle, deg	8.6	0
Aperture, mm	81	76
Pole width, mm	190	104
Yoke length, mm	590	250
Effective length, mm	647	290

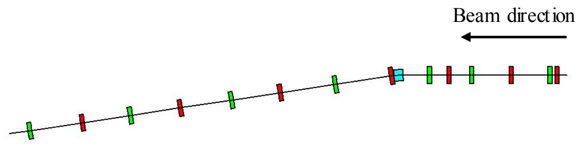

Figure 2: Scheme of HILac-Booster beam line. Red rectangles – focusing lenses, green ones – defocusing lenses, cyan one – bending magnet.

BOOSTER-NUCLOTRON BEAM LINE

General

Booster-Nuclotron beam line connects two key elements of NICA accelerator complex. The beam line is designed for transmitting ion beams and matching their parameters with lattice functions of Nuclotron, ion stripping to a maximum charge state (hereinafter, the central beam charge) and the separation of parasitic charge states. Beam energy is equal to 600 MeV/amu (and less a bit after ion stripping due to ionization losses).

Geometry

Due to the specific features of the mutual position of Booster and Nuclotron, a beam in the beam line is transported in the horizontal and vertical planes simultaneously. A beam is extracted from Booster in the horizontal plane. The extraction angle is 100 mrad. A beam is injected into Nuclotron in the vertical plane. The inclination angle of the injection line to Nuclotron plane is 105 mrad. The distance between Booster and Nuclotron planes is 3.76 m.

The project of the beam line assumes that Booster will be rotated by 7.5° counter to the beam circulation direction.

The total length of the beam line is 30.5 m. Its azimuthal size is 45°, which corresponds to the beam injection through one Nuclotron octant from the point of extraction from Booster.

The angular characteristics of the beam line are as follows: the bending angle of a beam in the VBM magnet is 8 deg and it is 58 deg in the TBS section.

Magnetic system of the beam line consists of four bending magnets, Lambertson magnet, 8 quadrupoles and steerers. Magnetic elements of the beam line are supposed to be superconductive. Parameters of the magnetic system elements are given in Table 2.

The stripping station is placed inside Booster yoke. After stripping an ion beam has at least two charge states. Ions with a central charge state are injected into Nuclotron. Parasitic charge states are separated in the vertical direction via dipole magnets and then Lambertson magnet.

The magnetic system of the beam line limits the ion magnetic rigidity. The maximum magnetic rigidity of ions transported from Booster to the stripping station is 25 T m, which corresponds to the maximum magnetic rigidity of Booster itself. After the stripping station the maximum magnetic rigidity of ions with the central charge state is 11 T m.

General view and the scheme of Booster–Nuclotron beam line is given in Fig. 3 - 4.

Table 2: Parameters of Dipoles and Quadrupoles of Booster-Nuclotron Beam Line

Magnet	Type	Effective length, m	Max. magnetic field (gradient), T (T/m)
VBM	rectangular dipole	2.2	1.6
TBM1–TBM3	sector dipole	2.06	1.8
LM	Lambertson magnet	1	1.5
Q1–Q2	quadrupole	0.4	25
Q3–Q6	quadrupole	0.4	15

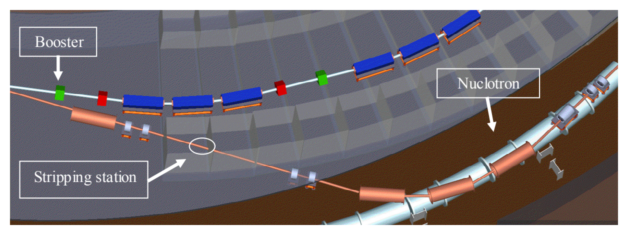

Figure 3: General view of Booster-Nuclotron beam line

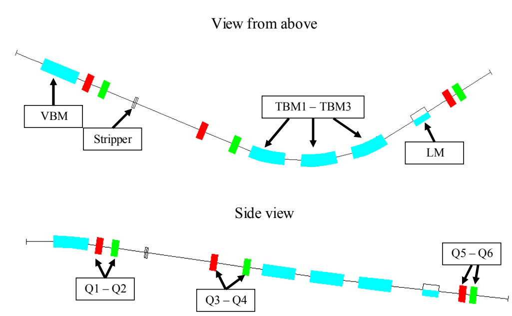

Figure 4: Scheme of Booster-Nuclotron beam line

Lattice

A beam is focused in the beam line using 6 quadrupoles and field gradients in dipole magnets. Optical lattice of the beam line provides 100% transmission of ions of the central charge state but it can not match beam parameters with lattice functions of Nuclotron in full and some dispersion functions stay mismatched.

The beam is transported in the beam line with increasing emittance. The reasons for the growth of beam emittance are multiple scattering on atoms of the stripping target, the coupling in the TBS bending section, and the mismatch of dispersion functions of a beam injected into Nuclotron. The estimates of the total growth of effective beam emittance in the beam line give about 45% for horizontal emittance and less than 40% for vertical emittance.

NUCLOTRON-COLLIDER BEAM LINE

General

Nuclotron-Collider beam line is intended for beam transportation from Nuclotron to Collider rings. It provides a beam transmission to both rings of Collider and matching of beam parameters with lattice functions of Collider. Beam energy is varying from 1 GeV/amu to 4.5 GeV/amu.

Geometry

The beam line lifts a beam from Nuclotron tunnel up to a level of Collider rings and provides the beam injection into both rings of Collider whose median planes are separated vertically on a distance of 320 mm. The beam line consists of a common part and two branches ("left" and "right" ones). Scheme of the beam line is presented in Fig. 5.

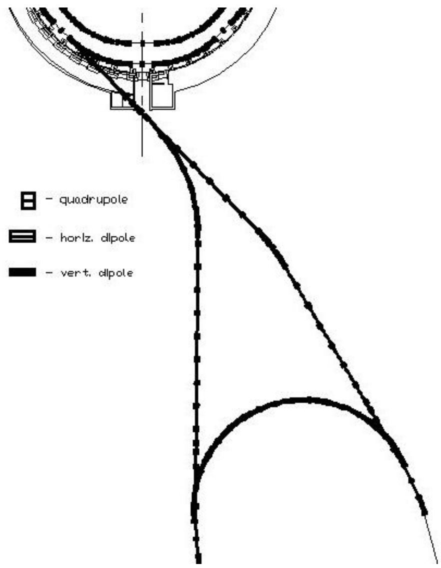

Figure 5: Scheme of Nuclotron-Collider beam line.

A beam is extracted vertically from Nuclotron. The extraction angle is 100 mrad. In the common part of the beam line a beam is transferred into the horizontal plane at the height of 1 m above the ground which is coincide with the median plane of Collider. Then the beam is switched for the injection into either top or bottom ring of Collider. After the switching magnet the beam is transported in the appropriate branch of the beam line to Collider, cross Collider in its median plane and lifts or lowers to the injection septum magnet of the corresponding ring. The beam injection into Collider rings is performed in the horizontal direction at an angle of 110 mrad.

Both branches of the beam line contain horizontal arcs those bend a beam by angles of 45 deg and 13.6 deg for left and right branches correspondingly.

The length of the common part is 39 m. The length of the left branch is 144 m. The length of the right branch is 149m. The total length of the beam line is equal to 332 m.

Magnetic system of the beam line consists of 22 dipole magnets, 40 quadrupole lenses and steerers. Magnets are supposed to be conventional room-temperature magnets except 4 dipoles and 2 quadrupoles that are located near Collider and are assumed to be superconductive. Parameters of the beam line magnets are given in Table 3.

Lattice

A beam in the beam line is focused by means of quadrupoles. At the exit of each branch the beam is matched with lattice functions of Collider ring. The lattice enables the beam matching with any possible lattice functions of Collider.

Table 3: Parameters of Magnets of Nuclotron-Collider Beamline

Magnet	Type	Effective length, m	Max. magnetic field (gradient), T (T/m)
Dipole	room-temperature	2	1.5
Dipole	room-temperature, wide-aperture	2	1.5
Dipole	superconductive	1	1.8
Quadrupole	room-temperature	0.5	20
Quadrupole	superconductive	0.4	20

CONCLUSION

Physical projects of three beam lines considered in this report are on stage of finishing their development. In the near future the development of technical designs of these beam lines and their magnetic elements will start.

The proposed beam lines fit all the specified requirements except the beam matching in Booster-Nuclotron beam line. But the beam line optics can be tuned so that the beam emittance growth at the end of the beam line (and in Nuclotron after the beam filamentation) will be minimized.

REFERENCES

[1] A.Sidorin, A.Kovalenko, I.Meshkov, G.Trubnikov, Project of the Nuclotron-Based Ion Collider Facility (NICA) at JINR. Proceedings of IPAC'10, Kyoto, Japan, 2010, pp.693-695.

[2] A.Sidorin et al., Status of the Nuclotron. 'Nuclotron-M' project. Proceedings of IPAC'10, Kyoto, Japan, 2010, pp.684-686.

[3] A.Sidorin et al., Design of the Nuclotron Booster in the NICA Project. Proceedings of IPAC'10, Kyoto, Japan, 2010, pp.681-683.

[4] O.Kozlov et al., Design of the NICA Collider Rings. These Proceedings.

[5] A.Tuzikov, V.Mikhaylov, Booster-Nuclotron Beam Line for NICA Project. ISSN 1547-4771, Physics of Particles and Nuclei Letters, 2010, Vol. 7, No. 7, pp.478-482.