HEAVY ION INJECTION CHAIN OF NICA COLLIDER

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Abstract

New accelerator complex is constructed by Joint Institute for Nuclear Research (Dubna, Russia) in frame of Nuclotron-based Ion Collider fAcility (NICA) project. The NICA layout includes new 600 MeV/u Booster and existing Nuclotron synchrotrons as parts of the heavy ion injection chain of the NICA Collider as well as transport beam lines which are the important link for the whole accelerator facility. Designs and current status of beam transfer systems of the NICA complex are presented in this paper.

INTRODUCTION

The NICA project [1] intends the construction of new accelerator complex based on existing superconducting synchrotron Nuclotron. In frame of NICA project the existing accelerators such as Nuclotron and linac LU-20 were modernized to match the project specifications. The following facilities are being included: the heavy ion source KRION of ESIS type, the source of polarized protons and deutrons, the heavy ion linear accelerator (HILAC), the superconducting Booster synchrotron [2], the Collider having two superconducting storage rings, and transport beam lines.

In the paper, designs and current status of three beam transport channels connecting the primary elements of the heavy ion injection chain of the NICA Collider are detailed:

1) beam line from the HILAC to the Booster;
2) beam line from the Booster to the Nuclotron;
3) beam line from the Nuclotron to the Collider.

Main parameters of ion beams along the Collider injection chain and working modes of the beam transfer systems are given in Table 1.

Table 1: Main Parameters of Beam Transfers

Ions	Au^{30+}, Au^{31+}, Au^{32+} (from HILAC); Au^{31+} (inside Booster); Au^{78+}, Au^{79+} (at the exit of Booster); Au^{79+} (at the entry of Nuclotron and further)
Intensity:	
HILAC-Booster	up to $2.5\cdot10^9$ (Au^{31+}); up to $6\cdot10^9$ (total);
Booster-Nuclotron	up to $1.3\cdot10^9$ (Au^{79+}); up to $1.5\cdot10^9$ (total);
Nuclotron-Collider	up to $1\cdot10^9$ (Au^{79+}).
Energy, MeV/amu:	
HILAC-Booster	3.2
Booster-Nuclotron	572
Nuclotron-Collider	1000 ÷ 4000
Repetition rate of beam transfer, Hz	up to 0.25
Transverse 95% emittance, $\pi\cdot$mm$\cdot$mrad:	
at the exit of HILAC	10
at the entry of Booster	15
Booster-Nuclotron	0.2 ÷ 3 (hor.) / 0.2 ÷ 1.5 (vert.)
Nuclotron-Collider	up to 3 (hor.) / up to 1.5 (vert.)
Transverse acceptances, $\pi\cdot$mm$\cdot$mrad:	
HILAC-Booster	38
Booster-Nuclotron	8 (hor.) / 6 (vert.)
Nuclotron-Collider	13 (hor.) / 10 (vert.)
R.m.s. longitudinal momentum spread:	
at the exit of HILAC	$2.5\cdot10^{-3}$
at the entry of Booster	$5\cdot10^{-4}$
Booster-Nuclotron	$1.1\cdot10^{-4}$ ÷ $2.1\cdot10^{-4}$
Nuclotron-Collider	up to $2\cdot10^{-4}$

BEAM TRANSFER FROM HILAC TO BOOSTER

The beam transfer in the HILAC-Booster transport channel [3] involves beam debunching, betatron matching of ion beam of the target charge state with the Booster, separation and collimation of neighbor parasitic charge states of ions. The ion-optical system of the transport channel and the beam injection system of the Booster provide multi-variant injection for accumulation of beams in the Booster with required intensity [4]. Main methods of beam injection into the Booster are single-turn, multi-turn and multiple injections. Ions are accumulated on the horizontal phase plane of the Booster.

Layout of the channel is shown in Figure 1. The beam transport channel provides the beam transfer only in the horizontal plane as the HILAC axis is located on the median plane of the Booster.

The beam transport channel contains 2 dipole magnets, 7 quadrupole lenses, a debuncher (produced by Bevatech company) and a set of steerers. At present all the transport

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channel elements are available at JINR and ready to be mounted (see Figure 2). Pulsed power supplies of the channel magnets will be assembled until the end of 2018.

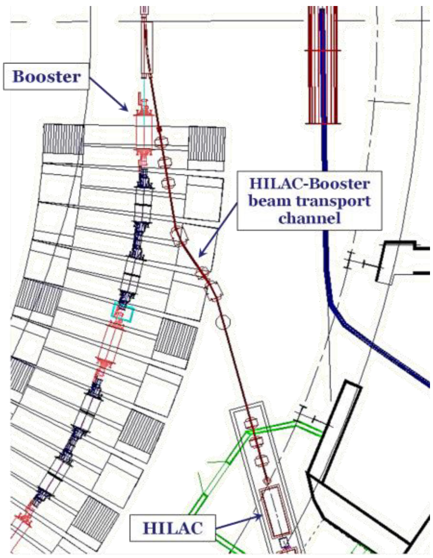

Figure 1: Layout of the HILAC linear accelerator, the Booster synchrotron and the HILAC-Booster beam transport channel.

Figure 2: Dipole and quadrupole of the HILAC-Booster beam transport channel.

Beam diagnostics devices of the channel have been partially purchased and manufactured. Start-up configuration will contain 3 fast current transformers and 4 multi-wire beam profile monitors. Full set of diagnostics devices will not be ready until the channel commissioning so the final configuration of the beam diagnostics system is planned to be installed on autumn of 2019.

Vacuum system of the channel will provide to achieve vacuum of order of 10^{-9} Torr along the whole channel except the final section where differential pumping will reduce residual gas pressure down to level of 10^{-11} Torr. Vacuum equipment is purchased and will be delivered until March of 2019.

Commissioning of start-up configuration of the HILAC-Booster beam transport channel is planned on April of 2019.

BEAM TRANSFER FROM BOOSTER TO NUCLOTRON

The beam transfer from the Booster to the Nuclotron involves betatron matching of ion beam with the Nuclotron, ion stripping to bare nuclei, separation and collimation of neighbor parasitic (hydrogen-like) charge state of ions. Ion stripping is fulfilled in a stripping station located in the fast extraction straight section of the Booster [2]. Stripping efficiency is estimated by values of 80-85% that lead to necessity of separation of hydrogen-like ions in the transport channel and their collimation in a foundation of the Nuclotron building.

The transport channel has a complicated 3D geometry with bends in both horizontal and vertical directions (see Figures 3 and 4). Due to mutual locations of the Booster and the Nuclotron, the channel passes through a concrete floor above the Nuclotron tunnel. At present creation of an embrasure in the floor for the channel installation is near completion (see Figure 5).

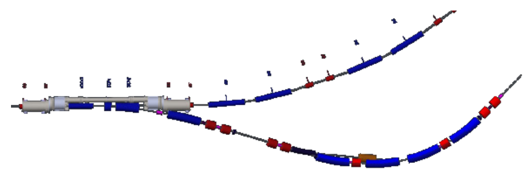

Figure 3: 3D model of the Booster-Nuclotron beam transport channel, view from above.

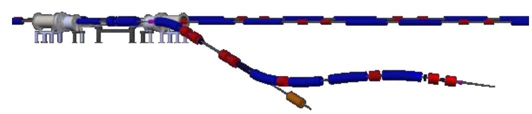

Figure 4: 3D model of the Booster-Nuclotron beam transport channel, side view.

Figure 5: The embrasure for the Booster-Nuclotron channel.

The channel lattice contains five dipoles, eight quadrupoles, a septum for separation of a parasitic charge state of ions, three steerers and set of beam diagnostics devices. All the magnetic elements are tilt. Concept of the optical system tuning is that betatron coupling arising from 2D bends is compensated by tilt quadrupoles so a beam at the entry of the Nuclotron is fully decoupled and matched. Beam parameters at the entry of the channel can be altered in wide ranges due to use of different schemes of beam injection and accumulation in the Booster and use of an electron cooling system of the Booster (see Table 1).

The channel equipment as well as the fast extraction system of the Booster is room-temperature, it is under development and fabrication by Budker Institute of Nuclear Physics (BINP, Novosibirsk) now. At present designs of the magnets as well as beam diagnostics devices

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are near completion (3D models of a dipole and a quadrupole are shown in Figure 6). Commissioning of the Booster-Nuclotron beam transport channel is planned on December of 2019.

Figure 6: 3D models of a dipole and a quadrupole of the Booster-Nuclotron beam transport channel.

BEAM TRANSFER FROM NUCLOTRON TO COLLIDER

The Nuclotron-Collider transport channel provides alternate filling of the Collider rings by ions. The beam transfer in the transport channel involves betatron matching of ion beam with the Collider rings except vertical dispersion and its derivative.

The channel will be located as in existing buildings of the LHEP site as in new ones being under construction now. The channel starts from the Nuclotron tunnel (the basement of the Bldg #1), passes through the extension of the Bldg #1, goes along the channel tunnels and enters the Collider area (the semi-ring E of the Bldg #17).

The channel is divided in the following parts: the Head Section (HS); the Common Section (CS); the Northern Section (NS); the Southern Section (SS). The Head Section is situated in the Bldg #1 and transfers the beam from the Nuclotron tunnel to horizontal planes of the Collider rings. The HS ends by the fork section containing two vertical dipole magnets one of which is a switch magnet for alternate beam transfer into the channel branches. The Common Section follows the HS and transports the beam through the extension of the Bldg #1 along the horizontal planes of the Collider rings (at levels of +1340 mm and +1660 mm above the floor level in the Collider tunnel). The CS represents two parallel vacuum chambers with magnetic elements. Both the Northern and the Southern Sections have the horizontal arcs, the straight sections and the injection sections which are the short straight sections at the ends of the NS and SS just before the entrances of the beam into magnet cryostats of the Collider. The lengths of the channel sections are the following: the HS + the CS – 33 m, the NS – 143 m, the SS – 153 m. Horizontal projection of the channel is presented on Figure 7. Vertical profile of the Head Section is given on Figure 8.

The channel equipment is room-temperature, it is under development and fabrication by French company SigmaPhi now. The equipment deliveries will be started on summer of 2019. The channel commissioning depends on the civil construction and is planned on December of 2020.

The channel lattice contains 27 dipoles, 28 quadrupoles, 33 steerers and set of beam diagnostics devices. There are two types of the dipoles and quadrupoles which differ by lengths. The channel magnets are powered in pulsed mode.

At present designs of the magnets as well as beam diagnostics devices are near completion. 3D models of a dipole and a quadrupole are shown in Figure 9.

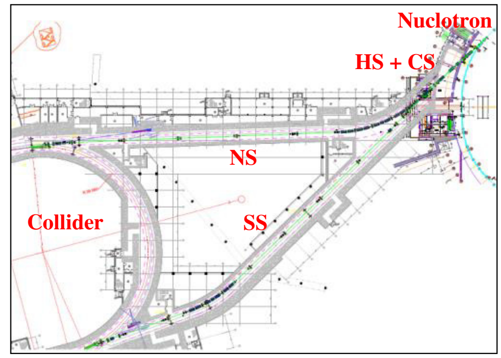

Figure 7: Horizontal projection of the Nuclotron-Collider beam transport channel.

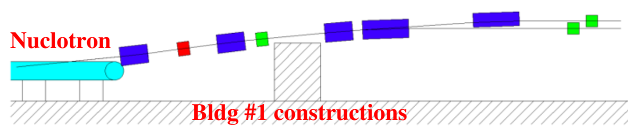

Figure 8: Vertical profile of the Head Section of the Nuclotron-Collider beam transport channel. Color markings: dark blue – vertical dipole magnets; red and green – quadrupoles (focusing and defocusing accordingly).

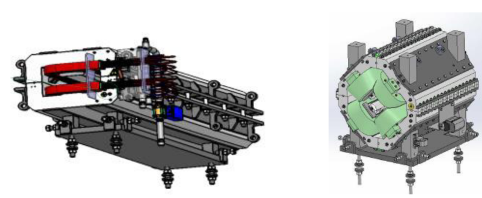

Figure 9: 3D models of a dipole and a quadrupole of the Nuclotron-Collider beam transport channel.

REFERENCES

[1] Technical Project of NICA Acceleration Complex (Dubna, 2015)

[2] A. Tuzikov, O. Brovko, A. Butenko, A. Eliseev, A. Fateev, V. Karpinsky, H. Khodzhibagiyan, S. Kostromin, I. Meshkov, V. Mikhaylov, A. Sidorin, A. Sidorov, A. Smirnov, E. Syresin, G. Trubnikov, V. Volkov, O. Anchugov, V. Kiselev, D. Shvedov, and A. Zhuravlev, "Booster synchrotron at NICA accelerator complex", Proceedings of RuPAC 2016, 160 (2016).

[3] A. Tuzikov, A. Butenko, A. Fateev, S. Kolesnikov, I. Meshkov, V. Mikhaylov, V. Shvetsov, A. Sidorin, A. Sidorov, G. Trubnikov, and V. Volkov, "Beam transfer from heavy-ion linear accelerator HILAC into Booster of NICA accelerator complex", Proceedings of RuPAC 2016, 443 (2016).

[4] V. Volkov, I. Meshkov, V. Mikhailov, G. Trubnikov, A. Tuzikov, and A. Fateev, "Conceptual design of the system of heavy-ion beam injection into the booster of the NICA accelerator complex", Phys. Part. Nucl. Lett. 11, 675 (2014).

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