BOOSTER SYNCHROTRON AT NICA ACCELERATOR COMPLEX

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Abstract

NICA is the new complex being constructed on the JINR aimed to provide collider experiments with ions up to Au at energy of 4.5x4.5 GeV/u. The NICA layout includes 600 MeV/u Booster synchrotron as a part of the heavy ion injection chain of the NICA Collider. The main goals of the Booster are the following: accumulation of $2{\cdot}10^9$ Au^{31+} ions; acceleration of the heavy ions up to energy required for effective stripping; forming of the required beam emittance with electron cooling system. The layout makes it possible to place the Booster having 210.96 m circumference and four fold symmetry lattice inside the yoke of the former Synchrophasotron. The features of the Booster, its main systems, their parameters and current status are presented in this paper.

INTRODUCTION

The Booster of the NICA accelerator complex [1] is a superconducting synchrotron which will be placed inside the yoke of the former Synchrophasotron (see Figure 1). Main goals of the Booster are accumulation of $2{\cdot}10^9$ Au^{31+} ions; acceleration of the heavy ions up to energy required for effective stripping; forming of the required beam emittance with electron cooling system. The Booster has four fold symmetry lattice with DFO periodic cells (see Figure 2). Each quadrant of the Booster has 10 dipole magnets, 6 focusing, 6 defocusing quadrupole lenses and multipole corrector magnets. Missing dipole cells of the lattice are used for installation of injection, extraction, RF and electron cooling systems.

Accumulation of ions is provided by means of multivariant injection of ion beams into the Booster [2]. 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.

Fast (single-turn) extraction provides ion stripping and transfer from the Booster into the Nuclotron. Slow extraction is not designed for the current version of the Booster and is considered to be implemented during later modernizations of the accelerator.

The Booster has working cycle of 4.02 s duration (see Figure 3). In case of necessity a technological pause between the Booster cycles of 1 s duration is presumed. Beam injection energy is equal to 3.2 MeV/amu. Electron cooling of a beam is fulfilled in the energy range from 65 to 100 MeV/amu. Maximal magnetic field in the dipole magnets is 1.8 T that corresponds to energy of Au^{31+} ions equal to 578 MeV/amu.

The design working point of the Booster is $Q_x = 4.8$, $Q_y = 4.85$. Lattice functions of the Booster are presented on Figure 4.

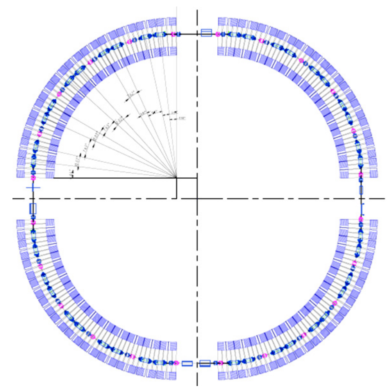

Figure 1: Layout of the Booster inside the former Synchrophasotron yoke.

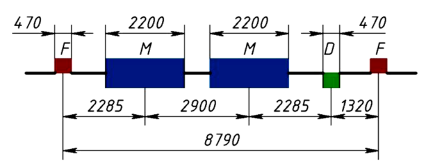

Figure 2: Regular DFO-cell of the Booster.

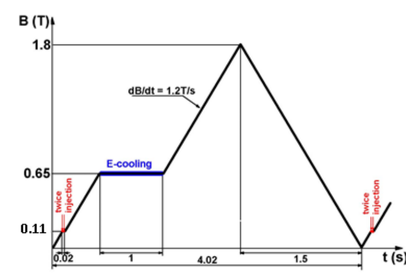

Figure 3: Working cycle of the Booster.

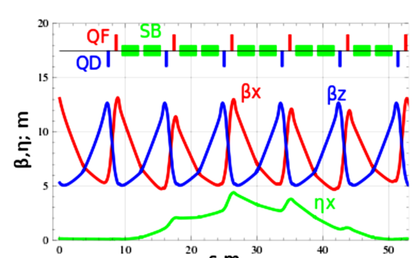

Figure 4: Lattice functions of the Booster synchrotron.

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SUPERCONDUCTING MAGNETS

The magnetic system of the Booster is based on superferric Nuclotron-type magnets [3]. The Nuclotron-type magnets include a cold (4.5K) window frame iron yoke and a superconducting winding made of a hollow NbTi composite superconducting cable cooled with a two-phase helium flow.

The iron yoke of the dipole magnet consists of two symmetric parts that are bolted together. The half-yokes of the dipole are fabricated of laminated isotropic electrical steel. The sector magnet is 2.2 m long and has a radius of the curvature of about 14 m. The magnet is fixed in a cryostat with 8 suspension rods and is adjusted in relation to the adjacent magnets (see Figure 5).

Figure 5: The dipole magnet inside the Booster cryostat.

The Booster quadrupole is 0.47 m long. The quadrupoles are installed by pairs. Doublet of the quadrupoles is a single rigid mechanical construction of about 1.8 m length. A doublet consists of a focusing quadrupole lens, a defocusing lens, a cylinder for rigid mounting of lenses with each other, as well as two beam position monitors. The doublet is fixed in a cryostat with 8 suspension rods and is adjusted as a unit.

Facility for the assembly and tests of Nuclotron-type magnets is under commissioning at the Laboratory of High Energy Physics now [4]. Equipment of the facility is allocated in separate building of 2600 m^2 and provides: SC cable production; windings production; assembling yokes of magnets and winding, welding and brazing cooling channels of magnets; room temperature magnetic measurements; check of vacuum tightness of cooling channels, beam pipes and cryostats; assembling magnets in cryostats; cryogenic tests of magnets at 6 benches. At present manufacturing, testing and magnetic measurements of the Booster magnets are started in the facility.

POWER SUPPLY SYSTEM

At design of the Booster power supply system [5] the requirement of consecutive connection of lattice dipole magnets (total inductance 16.4 mH), quadrupole focusing (total inductance 0.6 mH) and defocusing (total inductance 0.6 mH) lenses is accepted for a basis. The main powerful source of the power supply system forms a demanded current (up to 12.1 kA) with the required magnetic field ramp of 1 T/s in the general chain according to a demanded cycle. Two additional power supply sources of essentially smaller power are intended for flexible adjustment of the Booster working point. One of them allows varying simultaneously the magnetic field gradient in focusing and defocusing lenses, another only in defocusing ones.

Currently power supplies from different manufacturers are tested at the Laboratory of High Energy Physics during the Nuclotron runs.

BEAM INJECTION SYSTEM

The beam injection system of the Booster [6] consists of an electrostatic septum and three electric kickers. The system's elements are located in the vicinity of the 1st straight section of the Booster (see Figure 6). The section has a bypass of cryogenic and superconducting communications and the largest part of the section including the septum and the kicker IK2 is room-temperature while the kickers IK1 and IK3 are placed inside the Booster cryostat.

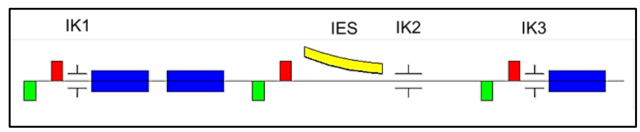

Figure 6: Layout of the beam injection system. Notation: blue – lattice dipole magnets, red – focusing quadrupole lenses, green - defocusing quadrupole lenses.

The electrostatic septum represents a pair of curved electrodes. High voltage (up to 125 kV) is applied to the cathode. Length of the IES is 1.9 m. Gap between the electrodes is 35 mm, thickness of the anode (which serves as a knife) is 1 mm. Currently the technical design of the septum is finished and its manufacturing will be started in the nearest future.

The electric kickers represent pairs of conducting plates. Lengths of the kickers IK1 and IK3 are 0.45 m, length of the IK2 is 0.8 m. Five power supplies of the kickers [7] provide independent unipolar charging/discharging of each of the plates (excluding one of the plates of the kicker IK1). Maximal voltage between the plates: IK1 – 40 kV, IK2 – 45 kV, IK3 – 60 kV. Currently the kicker prototype and the power supply (with voltage up to 60 kV) are manufactured and will be tested in the nearest months.

BEAM EXTRACTION SYSTEM

The beam extraction system of the Booster consists of a magnetic kicker, two magnetic septa, a stripping station and a closed orbit bump subsystem including four lattice dipoles with five additional HTS current leads. The system's elements are located in the vicinity of the 3rd straight section of the Booster (see Figure 7). The section has a bypass of cryogenic/superconducting communications and all the elements inside it are room-temperature.

Designs of the kicker and the septa as well as the whole system are being developed by Budker Institute of Nucle-

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ar Physics (BINP, Novosibirsk) now. The kicker magnet is made of couple of conductors and the passive copper screen with opposite induced current [8]. Length of the kicker is 1.5 m. The maximum magnetic field is 0.17 T; the corresponding current in the kicker magnet conductors is 32 kA.

Two eddy-current septa have lengths of 0.4 and 1.4 m. The maximum magnetic fields of the septa are 0.5 and 1.3 T; the corresponding currents are 3 and 5.4 kA.

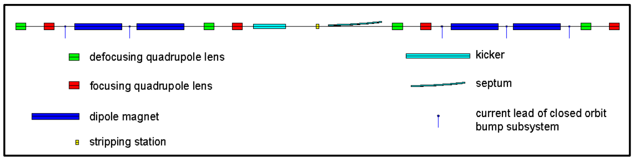

Figure 7: Layout of the beam extraction system.

RF SYSTEM

The RF system of the Booster [9] is based on amorphous iron loaded cavities. Two RF stations are to provide 10 kV of acceleration voltage. Frequency range of operation of the stations in the NICA Collider injector chain is from 587 to 2526 kHz. The provisions are made for autonomous mode of operation in the frequency range of 0.5 – 5.5 MHz at the same accelerating voltage.

The accelerating cavity consists of two coaxial quarter-wave resonators, working in push-pull mode onto a common accelerating gap (see Figure 8).

The RF stations have been designed and created at BINP (Novosibirsk). At present they have been delivered to JINR and are tested in Dubna.

Figure 8: RF station.

ELECTRON COOLING SYSTEM

The electron cooling system of the Booster [10] (see Figure 9) provides the ion beam cooling in the energy range from 65 up to 100 MeV/amu. The maximum electron energy is 60 keV.

The e-cooler have been designed and created at BINP (Novosibirsk). At present it is ready to be delivered to JINR in the nearest months.

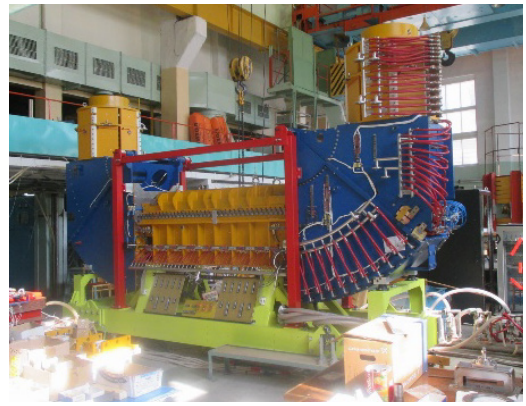

Figure 9: Electron cooling system.

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