DEVELOPMENT OF THE NICA INJECTION FACILITY

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Abstract

The new accelerator complex **N**uclotron-based **I**on **C**ollider f**A**cility (NICA) is assumed to operate using two injectors: the Alvarez-type linac LU-20 as injector for light ions, polarized protons and deuterons and a new linac HILac for heavy ions. The main features of ion sources and both linacs are presented. Upgrade for pre-accelerator of LU-20 is described.

INTRODUCTION

The general goals of the Nuclotron-based Ion Collider fAcility NICA project at JINR (Dubna) [1] are providing of colliding beams for experimental studies of both hot and dense strongly interacting baryonic matter and spin physics (in collisions of polarized protons and deuterons). The first direction of the program requires heavy ion collisions in the energy range of $\sqrt{s_{NN}} = 4\div11$ GeV at an average luminosity of $L = 1\cdot10^{27}$ $cm^{-2}\cdot s^{-1}$ for $^{197}Au^{79+}$ nuclei. The polarized beams mode is proposed to be used in the energy range of $\sqrt{s_{NN}} = 12\div27$ GeV (protons) at a luminosity up to $1\cdot10^{32}$ $cm^{-2}\cdot s^{-1}$. It is supposed that SPP (Source of Polarized Particles), LIS (Laser Ion Source) and Duoplasmatron (arc source) would be ion sources for LU-20 with the subsequent injection into the operational superconducting synchrotron Nuclotron.

The heavy ions from ESIS (Electron String Ion Source) will be injected into HILac followed by acceleration in Booster. The beam must then be stripped to get bare nuclei for injection into the Nuclotron. After the final acceleration in the Nuclotron the ions transfer into the collider rings. An upgrade of LU-20 based injector with a substantial improvement of the ion sources SPP and ESIS is needed. Update of LIS is also desirable to increase charge state of ions being injected into LU-20.

ION SOURCES

The Nd-YAG laser will be used in new LIS instead of CO_2-laser used so far. Higher power density on the target produces higher charge state. In case of carbon target fully stripped C^{6+} is the main product [2], whereas C^{6+} don't appear in CO_2-laser induced plasma. Thus there is no need for beam stripper at the exit of the linac which is needed now for Nuclotron injection and minimization of the beam losses on residual gas. In addition to this advantage a lower RF power level is necessary for acceleration in LU-20 which might result in longer power tube life time. The project assumes the design and construction of SPP - a universal high-intensity source of polarized deuterons (protons) using a charge-exchange plasma ionizer. The output $D^+\uparrow$ ($H\uparrow^+$) current of the source is expected to be at a level of 10mA. The polarization will be up to 90% of the maximal vector (±1) for $D^+\uparrow$ ($H^+\uparrow$) and tensor (+1, -2) for $D^+\uparrow$ polarization. Realization of the project is carried out in close cooperation with INR of the RAS (Moscow). The equipment available from the CIPIOS ion source (IUCF, Bloomington, USA) is partially used for the Dubna setup. The new source at the JINR Nuclotron accelerator facility will make it possible to increase the polarized deuteron beam intensity up to the level of 10^{10} d/pulse [3]. The Electron String Ion Source (ESIS) is a sophisticated modification of Electron Beam Ion Source (EBIS) working in a reflex mode of operation under very specific conditions [4]. The ion source of ESIS-type, named Krion-6T is currently under first full scale tests towards reaching its project parameters: 6T superconducting solenoid of 1.2 m length and electron injection energy range of up 25.0 keV. Expected peak pulse current is up to 10 mA of Au^{31} ions, planned for NICA injector [5].

LU-20 FOREINJECTOR UPGRADE

At present time, the injector of the Nuclotron is the Alvarez-type linac LU-20, which was built in 1974 as a proton injector. It accelerates protons from 600 keV to 20 MeV. Originally designed as so-called $L = \beta\lambda$ Alvarez drift-tube linac (DTL), it was adopted for operation as $2\beta\lambda$ - DTL that made it possible to accelerate also ions with q/A≥1/3 [6]. Presently the charged particles to be injected into LU-20 are pre-accelerated with the electrostatic tube supplied by pulse transformer voltage up to 700 kV. The ion source supply of up to 5 kW power placed at the HV "hot" platform are provided by feeding station consisting of motor and generator isolated one from the other with wood shaft. Power consumption of new ion sources is ~15 kW for ESIS and ~25 kW for SPP. Thus, the upgrade is needed [7]. The new fore-injector will be based on RFQ and electrostatic tube as pre-accelerator between RFQ and ion sources. Replacement electrostatic tube with RFQ will allow to decrease potential of the "hot" platform and to use the isolation transformer to feed sources. Constant voltage source up to 150 kV will be used to provide necessary electric potential. Installation of two separate RFQ (for q/A=1 and q/A=0.3-0.5) are planned to cover the necessary range of particles charge-to-mass ratio [7]. RF amplifier for RFQ was already built and tested and

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production of the barrels and electrodes are being made. These works are performed in collaboration with ITEP (Moscow, Russia). Two isolation transformers 35 kWA-160kV of STL Stewart Transformers Ltd have been supplied.

Table 1: Fore-Injector RFQ Parameters

RFQ Input			
q/A	1.0	0.5	≥ 0.3
Injection energy, [keV]	≤ 150	61.8	103
Maximum current,[mA]	40	20	10
Normalized emittance, [π·cm·mrad]	0.4	0.2	0.15
Operating frequency	145.2 MHz		
RFQ Exit			
Output energy [MeV/u]	0.631	0.156	0.156
Transmission RFQ, [%]	≥ 80	≥ 85	≥ 90
Δp/p, [%]	≤ 6	≤ 4	≤ 4
Normalized emittance [π·cm·mrad]	≤ 1.0	≤ 0.5	≤ 0.5
Lengh, [m]	≤ 3	≤ 3	≤ 3
Voltage at electrodes, kV	126	84	140

HILAC STATUS

As an injector for heavy ions into the synchrotron Booster of the NICA accelerator facility the new Heavy Ion Linac (HILac) with Krion-6T source is under construction.

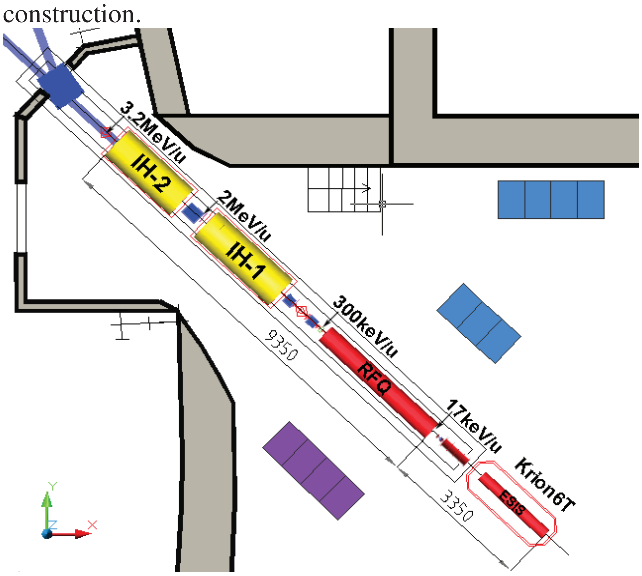

Figure 1: Layout of the heavy ion injector for NICA.

The section from the RFQ entrance down to the end of the IH – DTL is under construction at Bevatech OHG [8]. The array is shown in Figure 1 and main parameters are listed in Table 2. The design of RFQ - and IH - tank1 follow closely to the BNL EBIS – linac [9]. IH – tank2 is added to reach a final kinetic energy of 3.2 MeV/u. The transport section MEBT between RFQ and IH-DTL is shown in Figure 2. A view on the IH1 drift tube structure is shown by Figure 3.The length from the IH1 - entrance to the linac exit, providing an effective voltage gain of up to 18.1 MV for beams with A/q – values up to 6.25, is 6.2 m. The gap voltage distribution along both cavities is shown in Figure 4. The charge state distribution as produced by the ion sources (EBIS and LIS) will be transported along the LEBT resulting in some reduction of "wrong" charge states focused into the RFQ acceptance. The end to end beam simulations by PARMTEQ and by LORASR started at the RFQ entrance with a waterbag input distribution and ended after the 3.2 MeV/u debuncher cavity.

Table 2: Main NICA – HILac Simulation Results

Parameter	unit	value
Operation frequency	MHz	100.625
Beam current at A/q = 6.2	mA	10
Injected beam:		
Energy	keV/u	17
$(A/q)_{max}$		6.25
RFQ:		
Outer tank length	mm	3160
Max vane-vane voltage	kV	80
Exit energy	keV/u	300
$\varepsilon_{norm,trans}$, 90%	π mm mrad	0.36
$\varepsilon_{norm,long}$, 90%	π keV/u · ns	2.6
Maximum rf power loss	kW	150
MEBT:		
Doublet/rebuncher/doublet		
Total length	m	1.4
IH – DTL (two cavities):		
Total outer length	m	4.8
Gap no. IH1/IH2		27 / 18
Max power loss IH1 / IH2	kW	198 / 187
Max beam load IH1 / IH2	kW	94.5 / 84
Exit energy	MeV/u	3.2
Debuncher section:		
Drift length	m	6.0
Final energy spread ΔW/W	%	± 0.15
$\varepsilon_{norm,trans,\ long}$, 90%	π mm mrad	0.7 / 3.5
Overall transmission	%	> 90

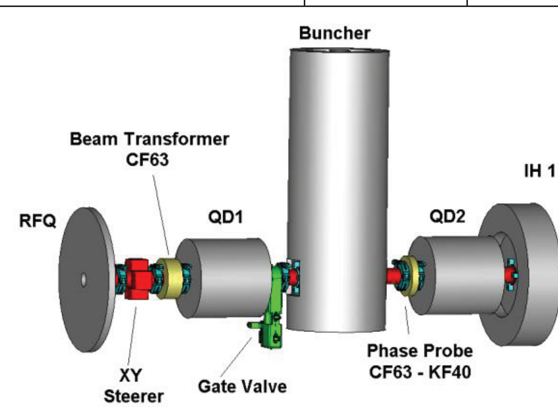

Figure 2: MEBT of NICA-HILac.

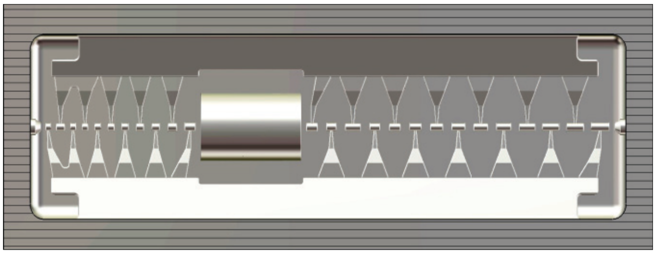

Figure 3: Cross section of IH-DTL 1.

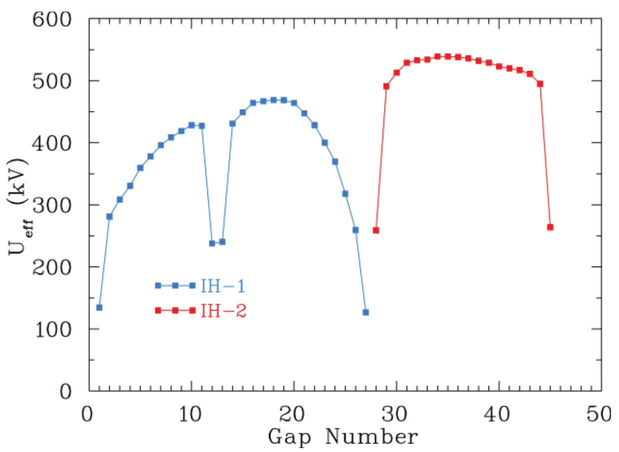

Figure 4: Effective gap voltage distribution along the IH – DTL.

The beam dynamics along the MEBT and IH – DTL was optimized for beam currents up 10 mA at A/q=6.25. Figures 5, 6 show the transverse and longitudinal output distributions. The small energy spread as needed for synchrotron injection was achieved by 6 m drift after the IH-DTL with a 4 gap coaxial debuncher at an effective gap voltage amplitude of 85 kV.

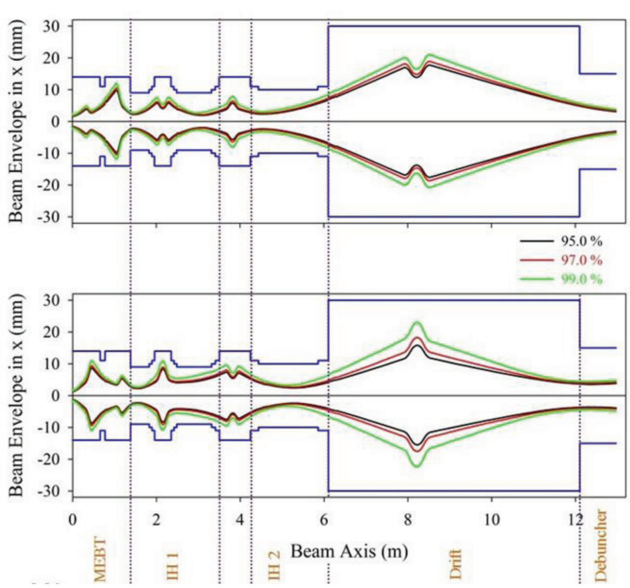

Figure 5: Transverse beam envelopes along the HILac.

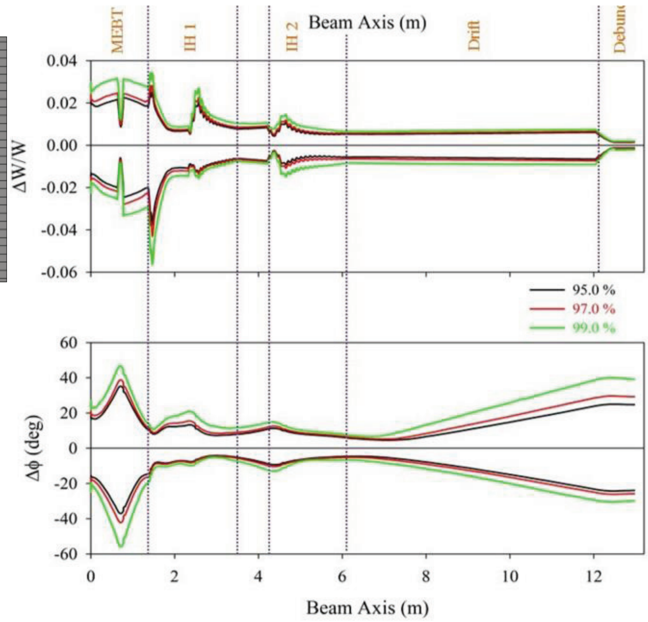

Figure 6: Longitudinal beam envelopes along the HILac.

CONCLUSION

The Injection complex for NICA project as a whole has passed the phase of concept formulation and is presently under development of the work project, manufacturing and construction of the main elements. The project realization plan foresees a staged construction and commissioning of the accelerator systems that form the main chains.

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