COMMISSIONING OF NEW LIGHT ION RFQ LINAC AND FIRST NUCLOTRON RUN WITH NEW INJECTOR

A.M. Bazanov, A.V. Butenko, A.I. Govorov, B.V. Golovenskiy,D.E. Donets, V.V. Fimushkin, V.V. Kobets, A.D. Kovalenko, K.A. Levterov, D.A. Lyuosev, A.A. Martynov, V.V. Mialkovsky, V.A. Monchinskiy, D.O. Ponkin, R.G. Pushkar, V.V. Seleznev, K.V. Shevchenko, A.O. Sidorin, I.V. Shirikov, A.V. Smirnov, G.V. Trubnikov, Joint Institute for Nuclear Research, Dubna, Moscow Region, Russia
S.V. Barabin, A.V. Kozlov, G.N. Kropachev, V.G. Kuzmichev, T.V. Kulevoy, Institute of Theoretical and Experimental Physics NRC "Kurchatov Institute", Moscow, Russia
A.S. Belov, Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
S.M. Polozov, National Research Nuclear University – Moscow Engineering Physics Institute, Moscow, Russia

Abstract

The new accelerator complex Nuclotron-based Ion Collider fAcility (NICA) is under development and construction at JINR, Dubna now (Fig. 1). This complex is assumed to operate using two injectors: the Alvarez-type linac LU-20 as injector of light ions, polarized protons and deuterons and a new linac HILAc – injector of heavy ions beams. Old HV fore-injector of the LU-20, which operated from 1974, was replaced by the new RFQ accelerator, which was commissioned in spring 2016. The first Nuclotron technological run with new fore-injector was performed in June 2016 with beams of D^+ and H_2^+. The polarized deuterons beam were successfully injected and accelerated in the Nuclotron ring during the last run #53. Main results of the RFQ commissioning and the last Nuclotron run with new fore-injector are presented in this paper.

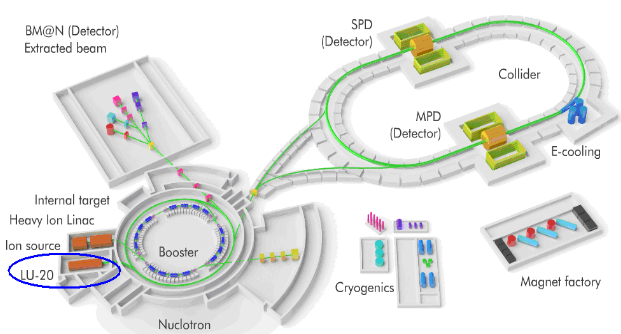

Figure 1: NICA complex. Proton, light and polarized ion linac LU-20 with new RFQ injector is marked.

INTRODUCTION

The injection system of the operating superconducting fast cycling synchrotron Nuclotron is under upgrade now.

Up to 2016 year, the charged particles for injecting into LU-20 linac were pre-accelerated with the electrostatic tube supplied by pulsed HV transformer with voltage up to 700 kV. The ion sources supply of up to 5 kW power placed at the HV "hot" platform was provided by feeding station consisting of motor and generator isolated one from the other with wood shaft. The new fore-injector of LU-20 based on the RFQ linac was constructed and put in to operation in 2016 (see Fig. 2). Pulsed HV supply up to 120 kV (based on HV pulsed transformer) was designed and assembled to provide necessary electric potential of the ion source terminal. The ion source systems supply is provided using isolation transformer on 160 kV, 35 kWA.

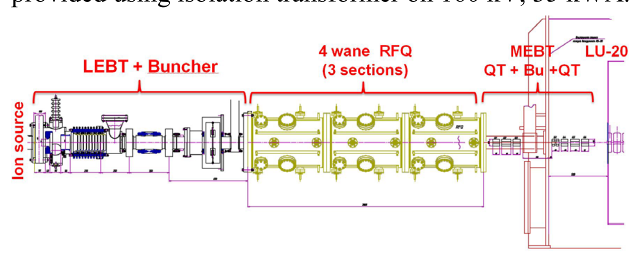

Figure 2: New fore-injector for LU-20 scheme.

New RFQ linac parameters are presented in Table 1, the project is performed in collaboration of JINR, MEPhI and ITEP. The beam dynamics simulation, the RFQ resonator simulation and design as well as RF system development were carried out in 2011-2013 [5]. The accelerator's resonator was manufactured in VNIITP (Snezhinsk).

Table 1: The LU-20 Fore-Injector Design Parameters

Z/*A*	0.5	0.3
RFQ input		
Injection energy, keV	61.8	103.0
Maximum current,mA	20	10
Normalized trans. emittance, π·cm·mrad	0.2	0.15
Operating frequency, MHz	145.2	
Output		
Output energy, MeV/u	0.156	0.156
Transmission RFQ, %	≥85	≥90
$\Delta p/p$, %	≤ 4	≤ 4
Normalized trans. emittance, π·cm·mrad	≤0.5	≤ 0.5
Resonator length, m	≤ 3	≤ 3
Voltage at electrodes, kV	84	140

ISBN 978-3-95450-181-6

RESONATOR TUNING AND RF COMMISSIONING

The four-vane resonator with displaced magnetic coupling windows was chosen for the NICA RFQ design. It should operate at 145.2 MHz like the LU-20 main resonator operating frequency. The LU-20 is the Alvarez-type DTL which RF system operates in self-excitation mode. Correspondingly, the new LLRF provides appropriate frequency and phase of RF oscillations in the RFQ and buncher [4].

After manufacturing and preliminary vacuum and low-power RF tests at VNIITP the resonator was transferred to ITEP and placed in tuning hall in March 2015. Resonator was excited on operating frequency and RF required field distribution in four quarters was measured (Fig. 3) [6].

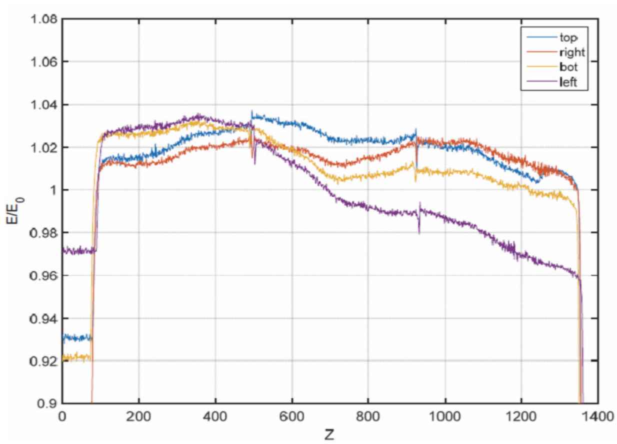

Figure 3: RF field amplitude deviation (< 2%) in four quarters of RFQ resonator.

RF power load was the next step in tuning. It was realized easily and about 380 kW was feed into RFQ resonator (~340 kW is necessary for carbon ions C^{4+} acceleration). Multiple RF sparks on the same place were not observed but training of multipactor was necessary and it was done. Vacuum of (8-9)·10^{-8} Torr was achieved after RF commissioning. The resonator was filled by dry nitrogen, transported to JINR and installed in test position in LU-20 injector hall (see Fig.4).

COMMISSIONING AT JINR

In injectors hall the RFQ resonator was equipped by all RF, tuning and vacuum components which were dismounted for the transportation. High power RF system was also assembled at projected place and the resonator was pumped and loaded RF power.

Further, the laser ion source, HV fore-injector (up to 120 kV) and LEBT (two focusing solenoids, two steerers and beam diagnostics box) were mounted to the linac support, tested and the deuterium beam was injected into RFQ. The magnetic separator with a special vacuum chamber for smooth angle changing was installed at the RFQ output to measure the beam spectrum for different *Z*/*A*. At the end of separator a special set of collectors and slits for the beam registration were installed.

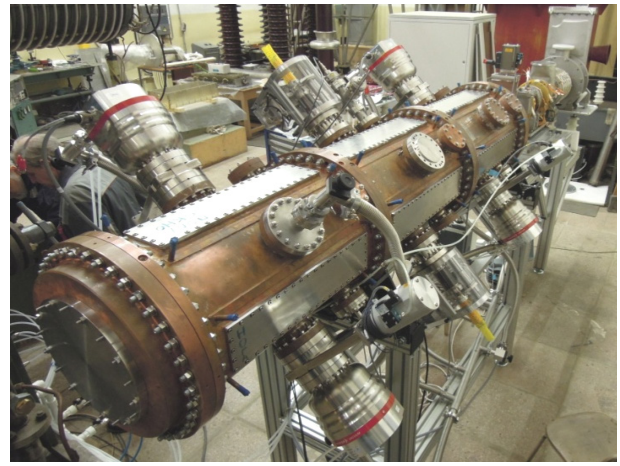

Figure 4: RFQ linac with RF and vacuum components installed on resonator on test area at JINR (Nov. 2015).

The system was calibrated using of H^+, D^+ and carbon beams, which were generated by laser ion source using different targets and accelerated by 63 kV in accelerating tube. The first beam was successfully accelerated in RFQ linac 10-12 Dec. 2015.

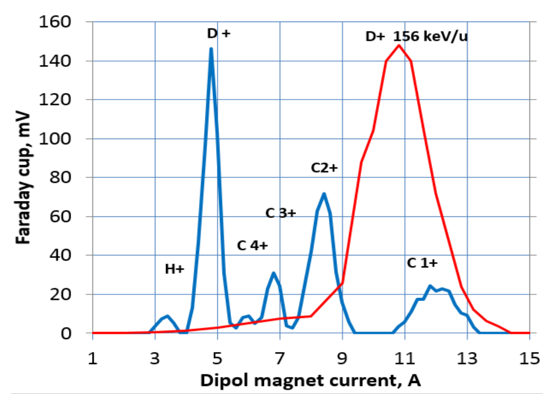

Figure 5: Measured spectrums for ions from the LIS with deuterated polyethylene target, HV = 63 kV (blue) and accelerated up to 156keV/u in RFQ deuterium beam (red).

Measured spectrums for both deuterium and carbon ion beams are presented in Figure 5, the beam current is about ~10 mA for the deuterium beam and ~5 mA for the carbon one. Good agreement of simulation and experimental results was observed for accelerated/non-accelerated carbon and deuterium beams. The current transmission coefficient through the RFQ is close to 80 % that agreed with projected value.

In February 2016, the old HV fore-injector accelerator tube was dismounted and the new RFQ fore-injector was installed on the LU-20 axis. All the systems of the accelerator were assembled, aligned and commissioned again. The new HV platform 15 m^2 for the Source of Polarized Ions (SPI) was constructed [1,2].

Two triplets of quadrupoles for the MEBT line were designed, manufactured and assembled with vacuum system between the RFQ and LU-20 resonator. All magnets of LEBT and MEBT lines are powered by pulsed power supplies with a special control system, which were designed and assembled in LHEP JINR.

ISBN 978-3-95450-181-6

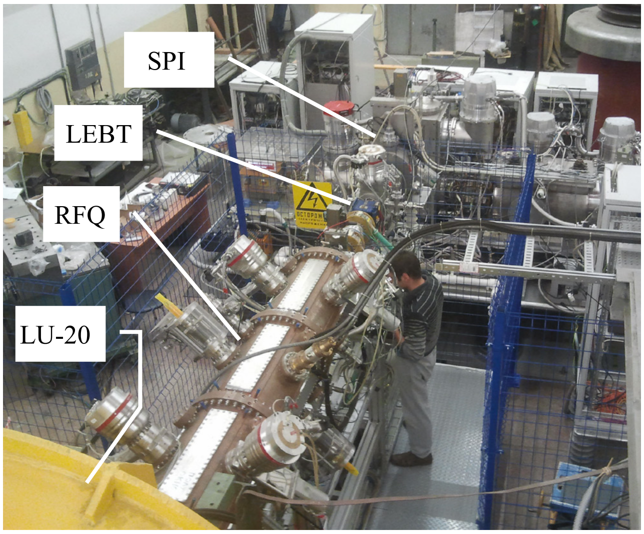

Figure 6: Source of Polarized Ions mounted on the HV terminal and RFQ connected to the LU-20

The first deuteron beam was accelerated in LU-20 with new fore-injector in March 2016 with transmission factor up to 20% thru the whole injector. To increase capture efficiency of the beam in LU-20 the new buncher in MEBT line is needed. Such cavity was designed and under manufacturing now.

NUCLOTRON RUN

During May 2016, the new SPI was disassembled, transferred and mounted on the HV terminal platform of the new fore-injector (see Fig. 6). In June 2016, the first technological Nuclotron run #52 with the deuteron beam from the new fore-injector and SPI was provided. During that run all the main systems of the ion source and injector were commissioned and put in to operation.

26 of October 2016 the next run #53 was started with the scheduled duration of about 1400 hours. Main task of the run is experimental investigations in spin physics in few body nuclear systems (with polarized deuterons). The polarized beam was successfully injected and accelerated in Nuclotron ring. Average intensity of the beam is about $5\text{-}7\cdot10^{8}$ particles per cycle (up to 10^{9} ppc, Figure 7).

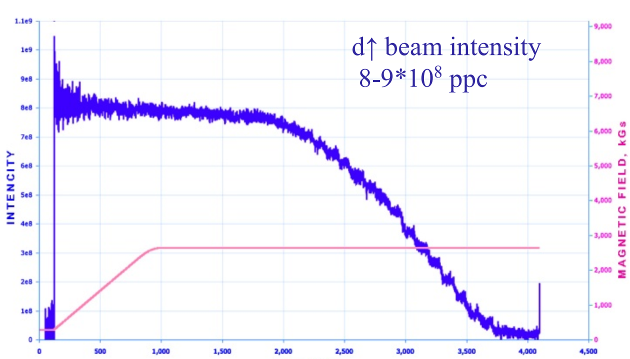

Figure 7: Polarized deuterons beam accelerated in Nuclotron ring – blue line, main magnetic field – red line.

CONCLUSION

After four years of intensive discussions, simulations, construction and manufacturing the new RFQ linac for LU-20 injection complex upgrade was installed in the Nuclotron injector's hall at LHEP JINR and put in operation (Fig. 8). Deuterium and carbon beams were successfully accelerated in new fore-injector. Stable and safety operation of the LU-20 with new RFQ and SPI during the Nuclotron superconducting synchrotron run was demonstrated. The polarized deuteron beam successfully injected and accelerated in Nuclotron for physical experiments. To increase the intensity to reach the project level of the beam the new buncher and a lot of work on optimization for all systems of accelerator is needed.

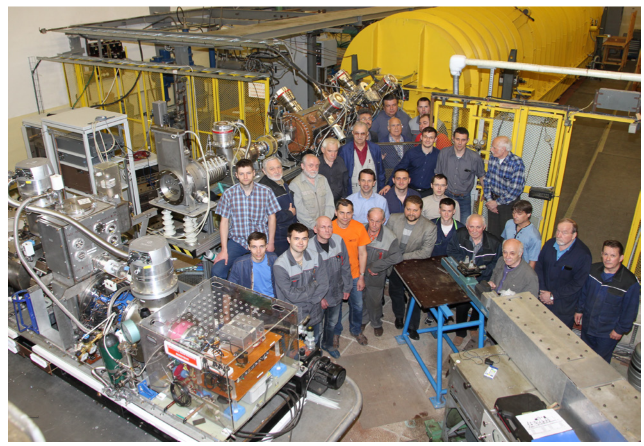

Figure 8: LINAC team during commissioning of the RFQ and the SPI.

ACKNOWLEDGEMENTS

We would like to thank all Institute of Technical Physics (Snezhinsk) specialists which are take part in resonator manufacturing and personally I.V. Mamaev, K.A. Klykov, M.Yu. Naumenko and G.N. Ostashkov.

We also would like to thank MEPhI TechnoPark and personally A.N. Petrovsky, A.P. Korotkova and S.S. Korotkov for the organization support.

REFERENCES

[1] G. Trubnikov, N. Agapov, V. Alexandrov et al., Proc. of IPAC'10, 693-695 (2010).
[2] V.Fimushkin, A. Kovalenko, A. Belov et al., Proc. of PSTP'15, PoS (PSTP2015) 041.
[3] A.V. Butenko, E.E. Donets, E.D. Donets et al., Proc. of IPAC'13, 3915-3917 (2013).
[4] A.V.Butenko, E.E.Donets, E.D.Donets et al., Proc. of IPAC'14, 2103-2105 (2014).
[5] V.A. Andreev, A.I. Balabin, A.V. Butenko et al., Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations, 6 (88), 8-12 (2013).
[6] V.S. Aleksandrov, A.V. Butenko, et al., Proc. of IPAC'16, 940 - 943 (2016).

ISBN 978-3-95450-181-6