DEVELOPMENT OF HARDWARE AND SOFTWARE TO BEAM LOSS RF CAPTURE AND ACCELERATION IN BOOSTER AND NUCLOTRON

Oleg Brovko, Anton Volodin*, Fyodor Ganyushkin, Valery Lebedev,
Evgeny Syresin, Andrey Troitsky

Joint Institute for Nuclear Research, Joliot-Curie 6, Dubna, 141980 Russia

Email: Volodin@jinr.ru

INTRODUCTION

The NICA collider complex is being constructed at the Joint Institute for Nuclear Research and is designed to study the properties of dense baryonic matter. Four commissioning runs of the collider injection complex were conducted, a considerable beam loss was observed at the beginning of acceleration in both Booster and Nuclotron. Significant fraction of this loss has been attributed to inaccuracies in setting up the acceleration process. (Fig.1a and Fig.1b). An operation of the injection complex for collider requires an increase in the intensity of Nuclotron output by about 2 orders of magnitude. To achieve this goal, it is necessary to optimize the operation of all systems of the complex, including the operation of the RF system.

The main goals for improvement RF systems are: (1) prevention of the longitudinal emittance growth during beam accumulation and acceleration, (2) optimization of the beam bunch-to-bunch Booster to Nuclotron beam transfers to prevent the longitudinal emittance growth, (3) minimization of beam losses during acceleration. The latter requires matching the acceleration rate to the capabilities of existing RF systems.

By the present time (11.24.2023), the following items were complete: (1) a new device programmable generator determining the profile of the accelerating voltage amplitude which has better accuracy and flexibility. (2) Beam position monitor. This will make it easier to set up beam capture by RF systems. (3) the "Phase detector" which will allow us to monitor the beam phase relative to accelerating voltage.(4) Also the software generating optimal dependence of accelerating voltage and magnetic field in the ring dipoles so that to avoid the beam loss related to insufficient size of RF bucket (5) An operation of Booster and Nuclotron RF stations at the different revolution frequency harmonics has been confirmed. An operation of Booster RF at the first harmonic is required for beam accumulation. This harmonic is also planned to be used for the entire acceleration of the beam.

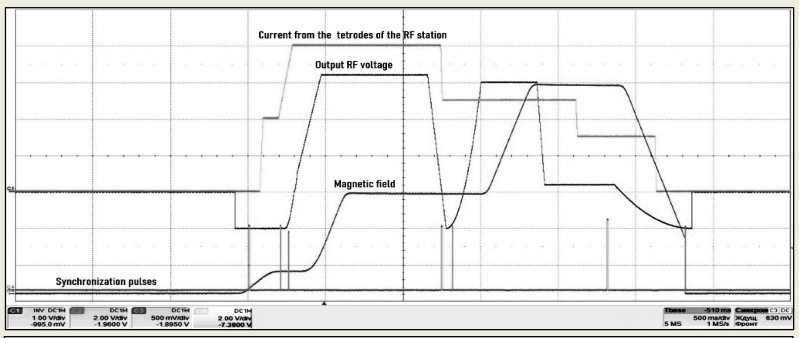

Fig.1a. Dependence of accelerating voltage and magnetic field on time in milliseconds, synchronization pulses (Booster)

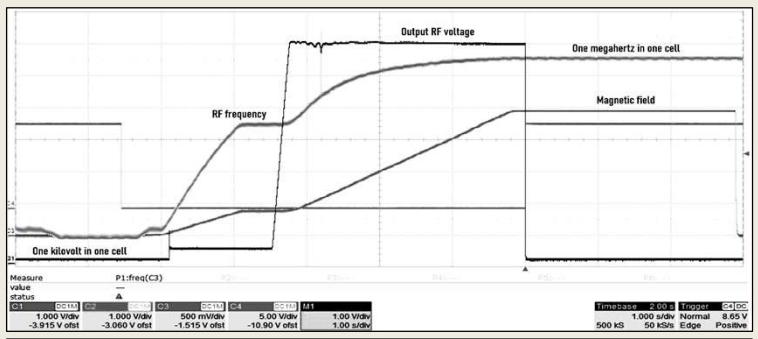

Fig.1b. Dependence of accelerating voltage, magnetic field and accelerating frequency on time in milliseconds (Nuclotron)

PROGRAMMER OF THE ACCELERATING VOLTAGE FORM

The accelerating voltage wave form generator will be programmed to match the accelerating voltage of existing RF Nuclotron systems with the growth rate of the magnetic field. The new device has a higher sampling rate and more bits (50 kHz, 12 bits) and can support longer cycles (up to 15 seconds). Faster sampling and better resolution will exclude an excitation of synchrotron oscillations. Its schematic is shown in Figure 2. The device is made in the Euromechanic standard, size 3U. The functional diagram of the device is shown in Figure 3.

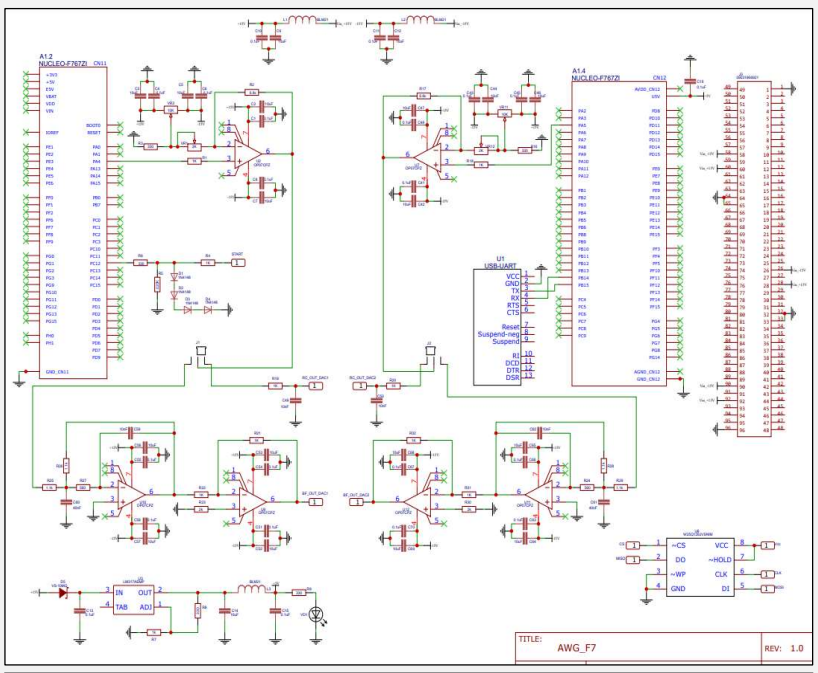

Fig.2. Schematic diagram of the accelerating voltage programmer

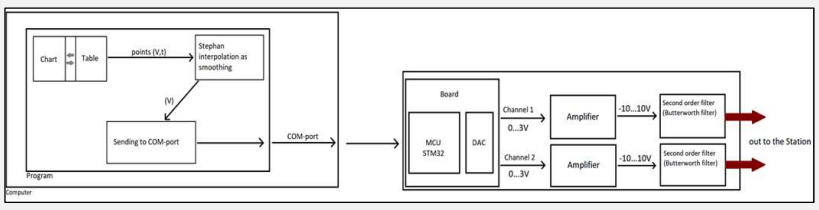

Fig.3. The functional diagram of the accelerating voltage programmer

BEAM POSITION MONITOR

Beam position monitor is a device that measures the position of a beam relative to an equilibrium orbit. The device is used to facilitate the adjustment of beam capture by RF Booster systems, as well as to control the growth of the longitudinal emittance. The beam position monitor worked out the 4th commissioning run and with its help, the growth of the longitudinal emittance was confirmed when the beam was withdrawn from the Booster into the Nuclotron (Fig. 4). The schematic and the device picture are shown in Figures 6 and 5, respectively.

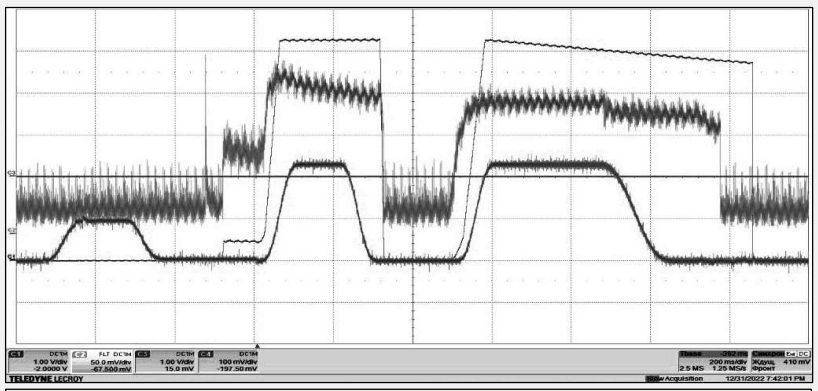

Fig.4. Beam position sensor

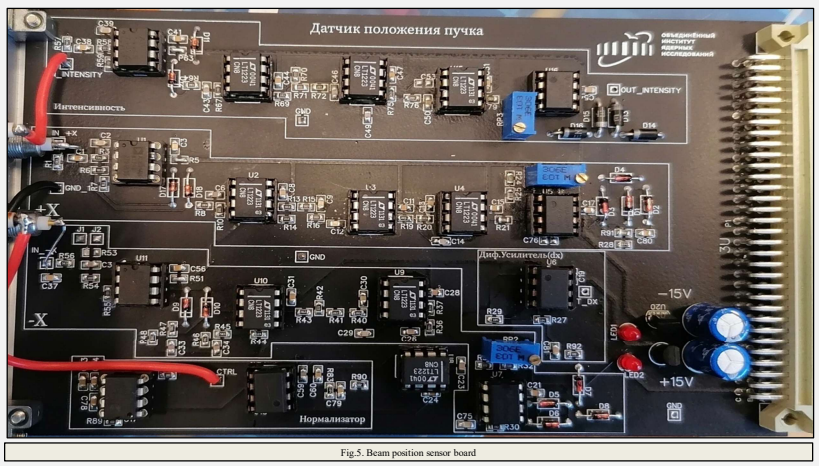

Fig.5. Beam position sensor board

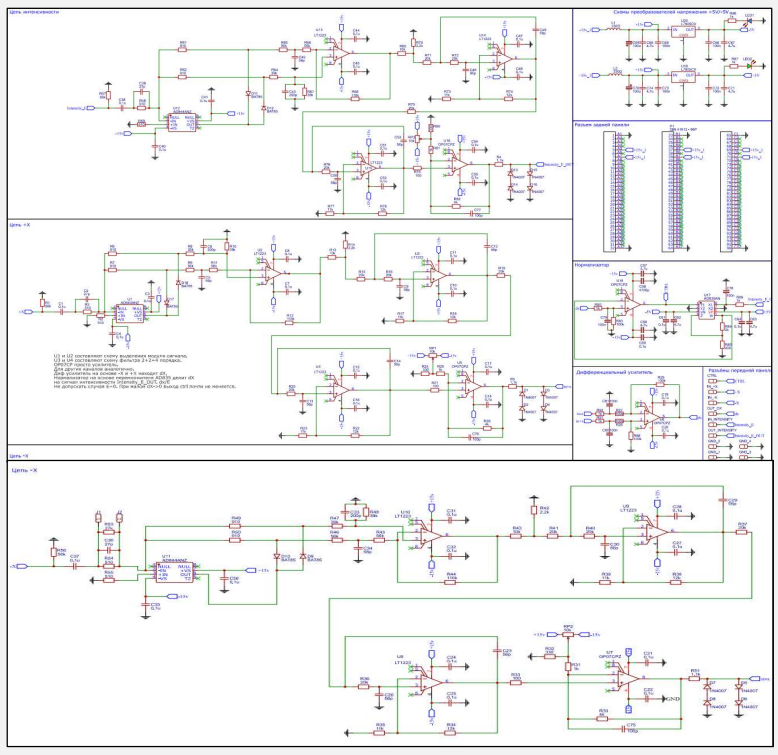

Fig.6. Schematic diagram of the beam position sensor

PHASE DETECTOR

Phase detector is a device for monitoring phases of accelerating voltage between Nuclotron stations. The location and design feature of the accelerating stations of the Nuclotron requires control of the phases of accelerating voltage. The schematic diagram is shown in Figure 7.

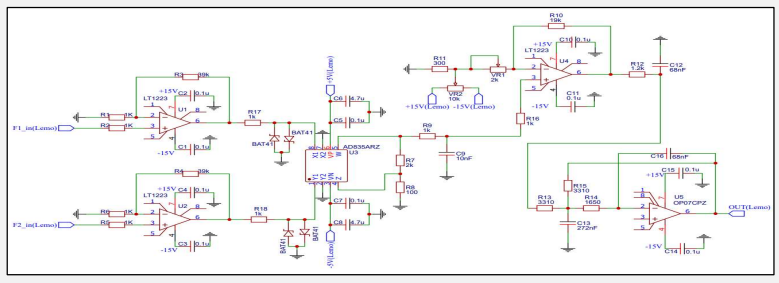

Fig.7. Schematic diagram of the phase detector

LONGITUDINAL ACCEPTANCE ASSESSMENT PROGRAM

The program will allow us to calculate a dependence of the longitudinal acceptance depending on the rate of growth of the magnetic field and accelerating voltage, as well as on other parameters. Figure 8 shows the program interface. Figure 9 shows the dependence of the beam intensity during the acceleration cycle in the Nuclotron

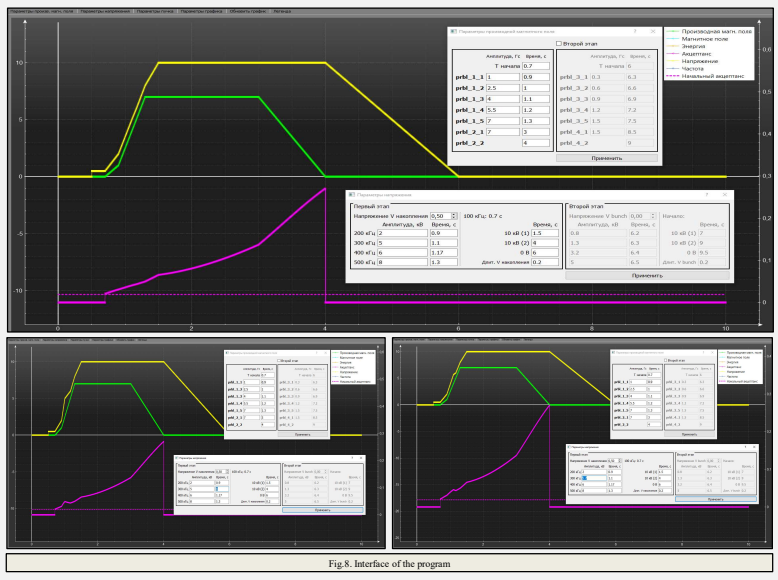

Fig.8. Interface of the program

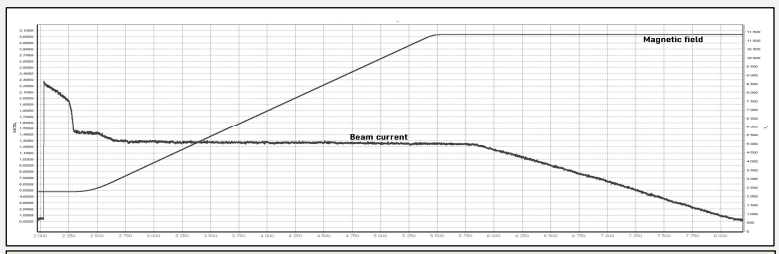

Fig.9. Beam current and magnetic field as a function of time in milliseconds