# THE MCP-BASED SYSTEM FOR MONITORING SPACE-TIME CHARACTERISTICS OF CIRCULATING BEAM OF NUCLOTRON

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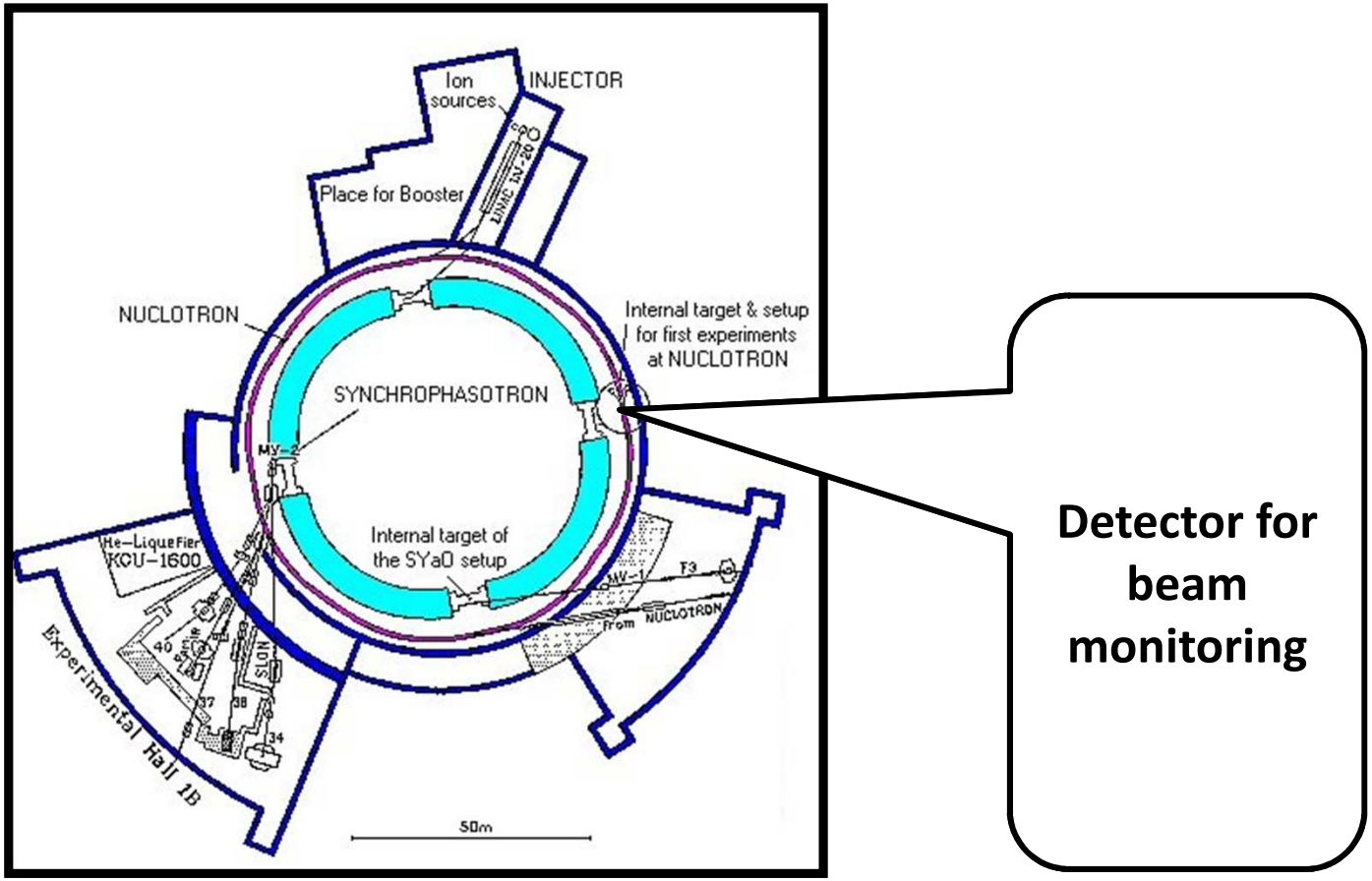
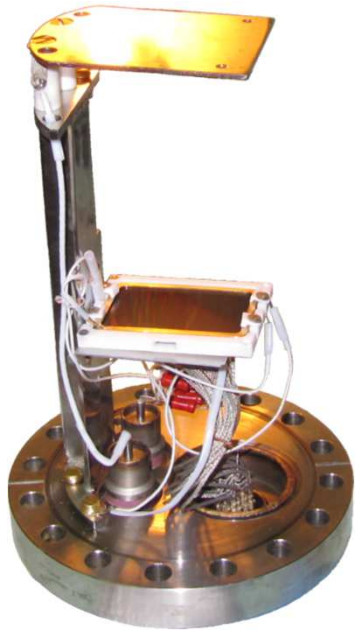
# Diagnostics of circulating beam

Creation of modern nondestructive control systems of space-time characteristics of the beam during acceleration and extraction is the one of the most important tasks for exploitation of the Nuclotron accelerator complex (JINR LHEP).

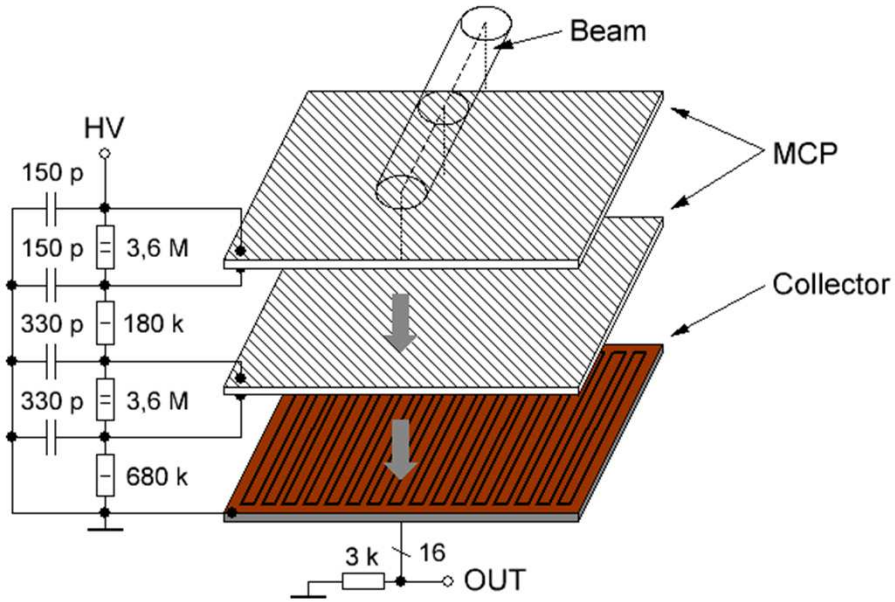


# The detector based on MCP

The detector consists of two MCPs (chevron assembly). The contact areas (pads) electrically isolated from each other were used as the collector of electron avalanches.



**Detector prototype.**

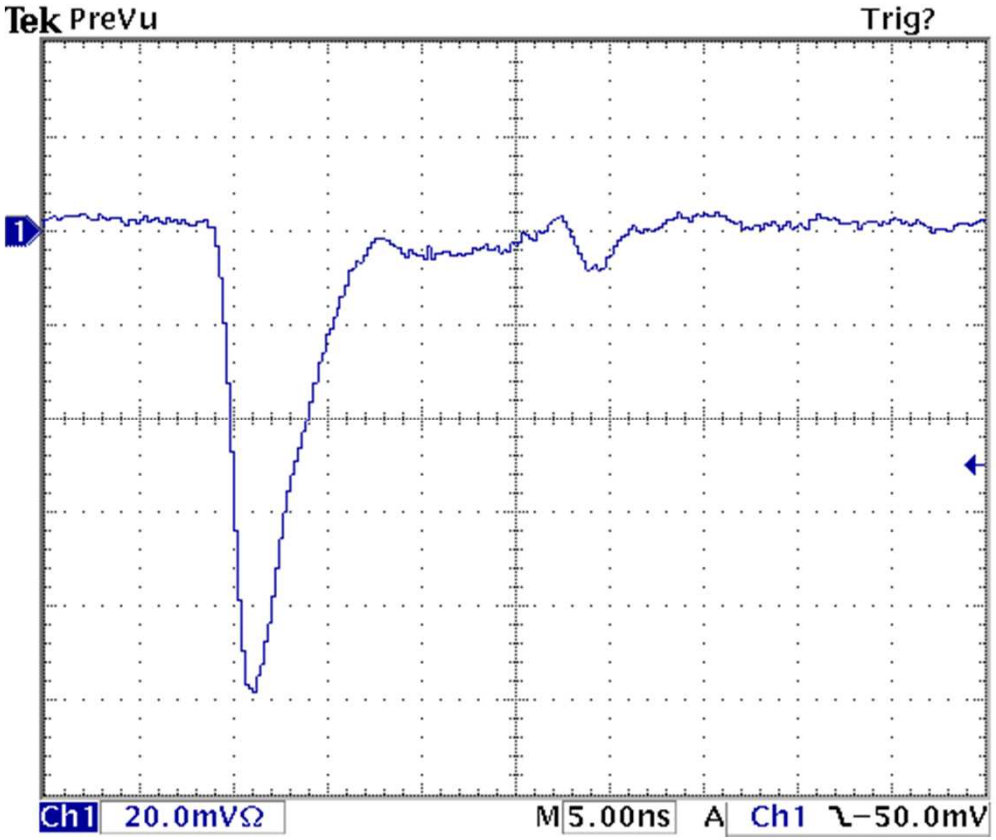



**Schematic view of the prototype of coordinate-sensitive detector based on MCP.**

The voltage was supplied via a passive splitter to each side of the MCP along its perimeter. An amplified signal was recorded from 16 pads of a printed circuit board situated under the MCP chevron assembly.

# Signal characteristics

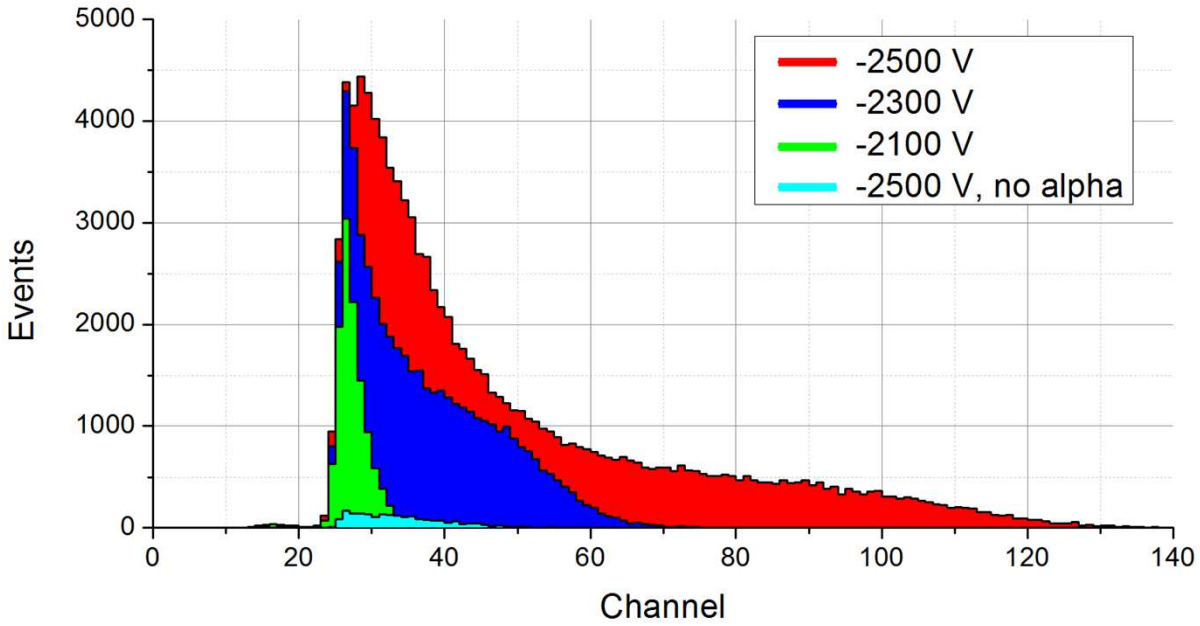
The following signal characteristics were studied: the amplitude increases 10 times if the voltage changes from -2000 to -2550 V; the signal width at the base is from 5 to 7 ns and practically doesn't depend on the plate voltage. For all measured voltages the signal front is less than 1 ns providing a time resolution of the detector of 100 ps.




**The detector signal recorded using an oscilloscope. The detector power supply voltage is -2400 V.**

# Testing in the vacuum test bench

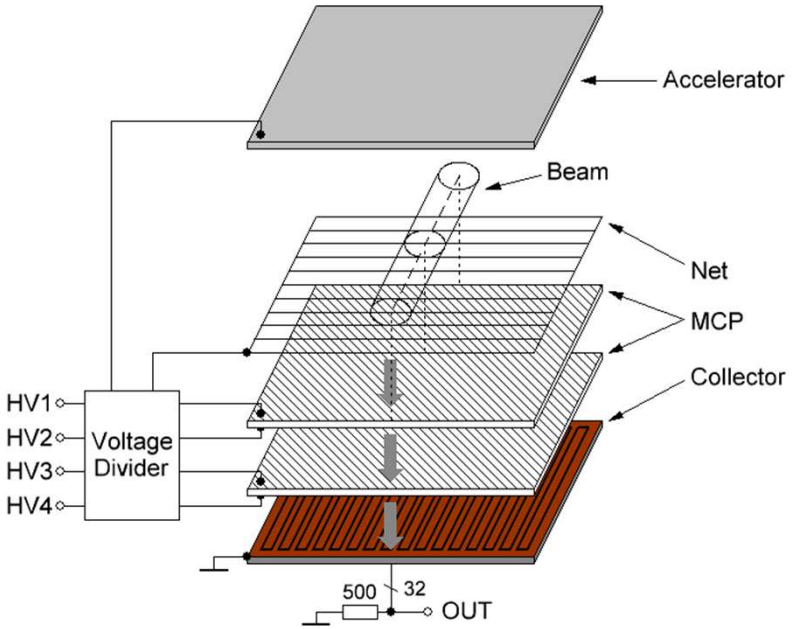
The specialized vacuum test bench was designed and developed. An α source with an ion energy of 4 MeV situated above the assembly at a distance of 4 cm inside a vacuum chamber was used for testing.



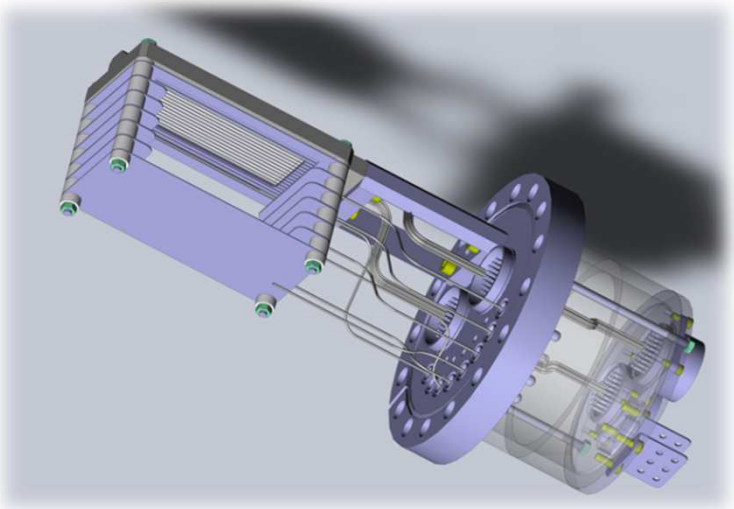

**The histogram of the signal area (QDC spectra) for different powering voltages of the MCP assembly. The time of collecting each spectrum is 15 min.**

# A new detector for beam diagnostics

The detector overloading was the main problem during its testing with the beam. The detector operated at low beam intensities (less than $1 \cdot 10^8$) only. For this reason a new detector was developed for registration of the space-time characteristics of the radial beam component.




**The MCP-based system for measuring the radial coordinate of the Nuclotron beam.**

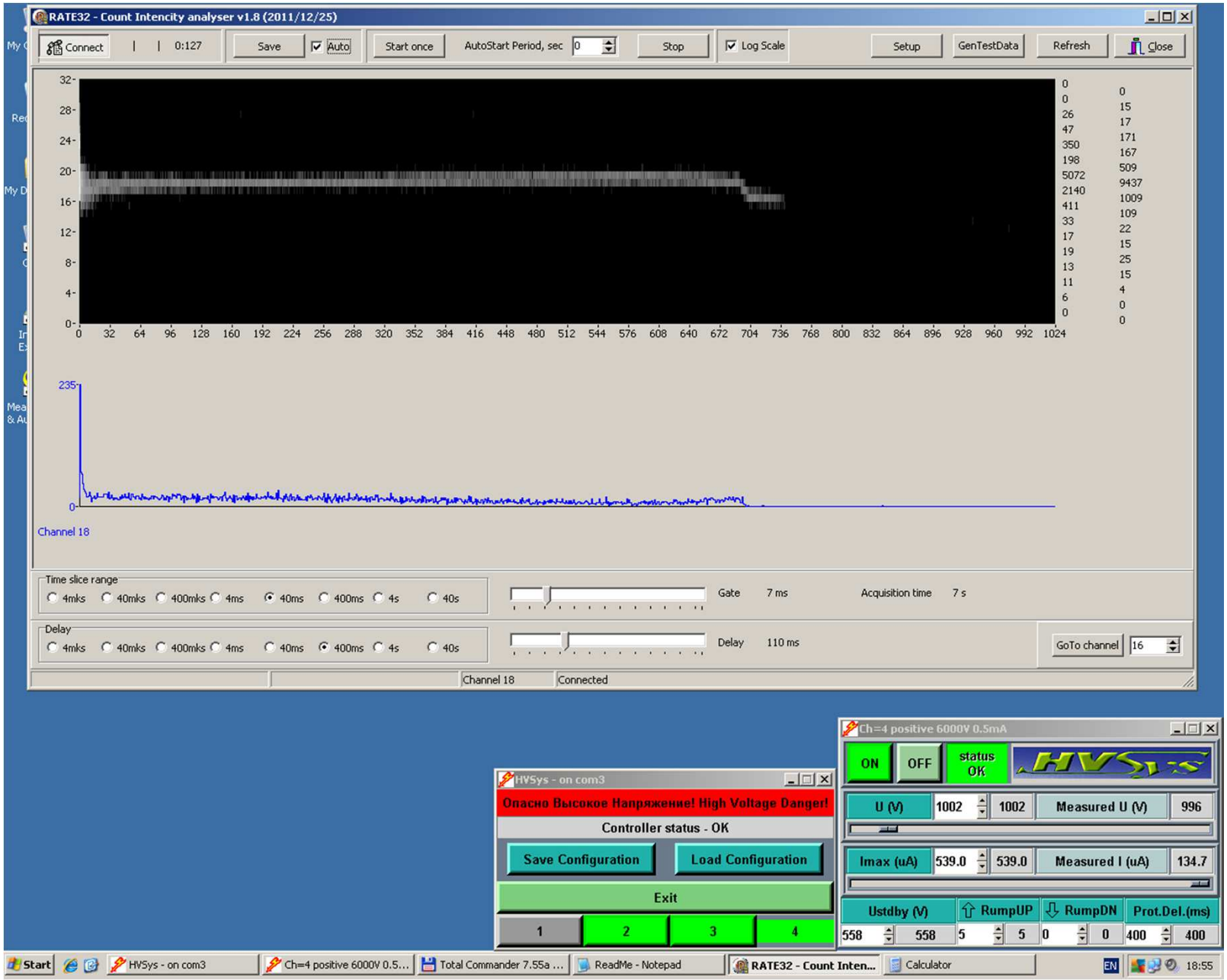


**The design of the new detector for diagnostic of the radial beam coordinate.**

The system of separate high voltage supply of each MCP is used to eliminate overloading. An additional cutoff mesh electrode was installed to control the ion flow. The new system can operate with intensities up to $10^9$ particles per acceleration cycle.

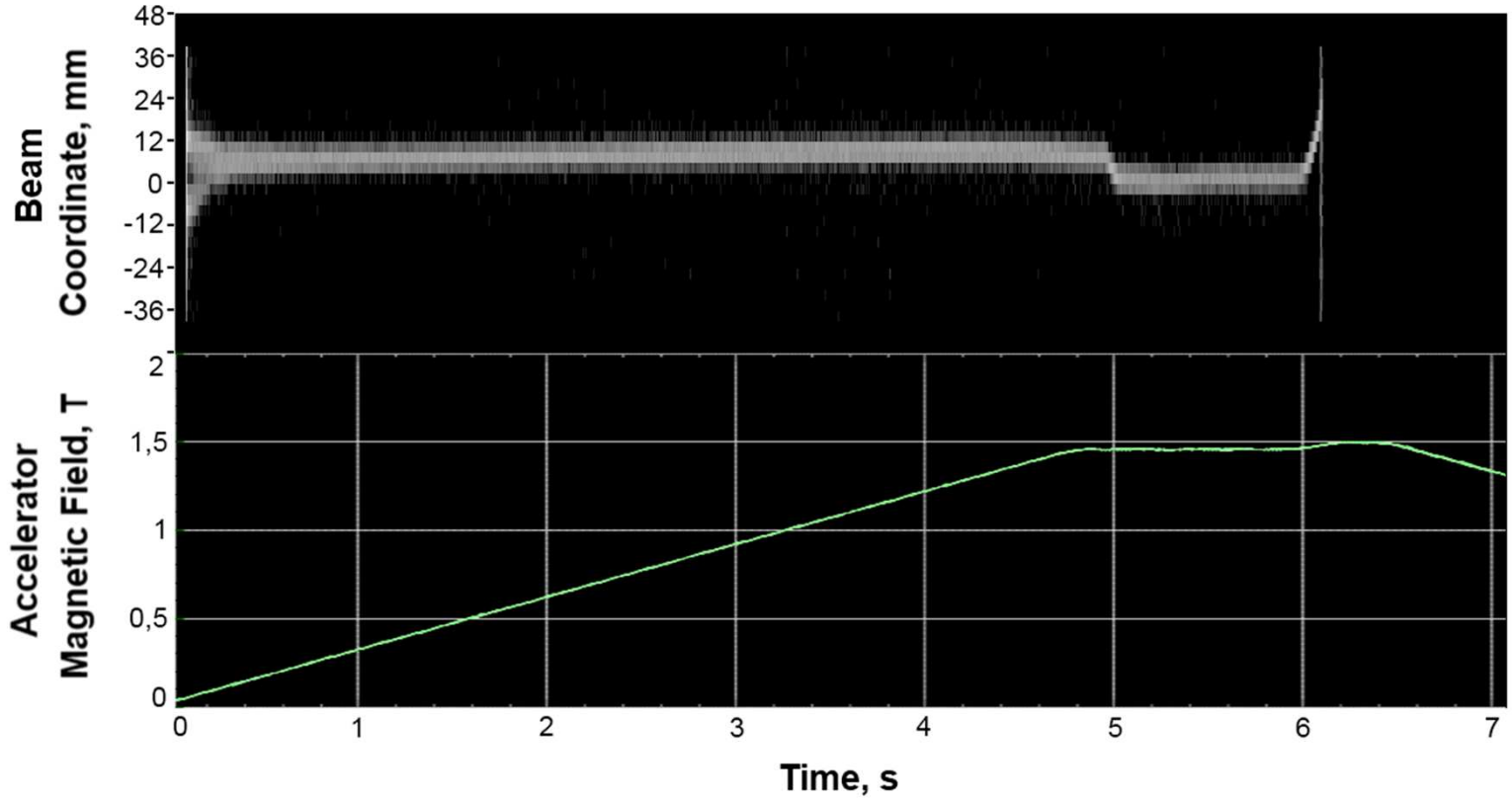
# Electronics for data acquisition

The specialized electronic module and software for remote control, visualization and data recording were developed to provide the detector operation in the accelerator ring.



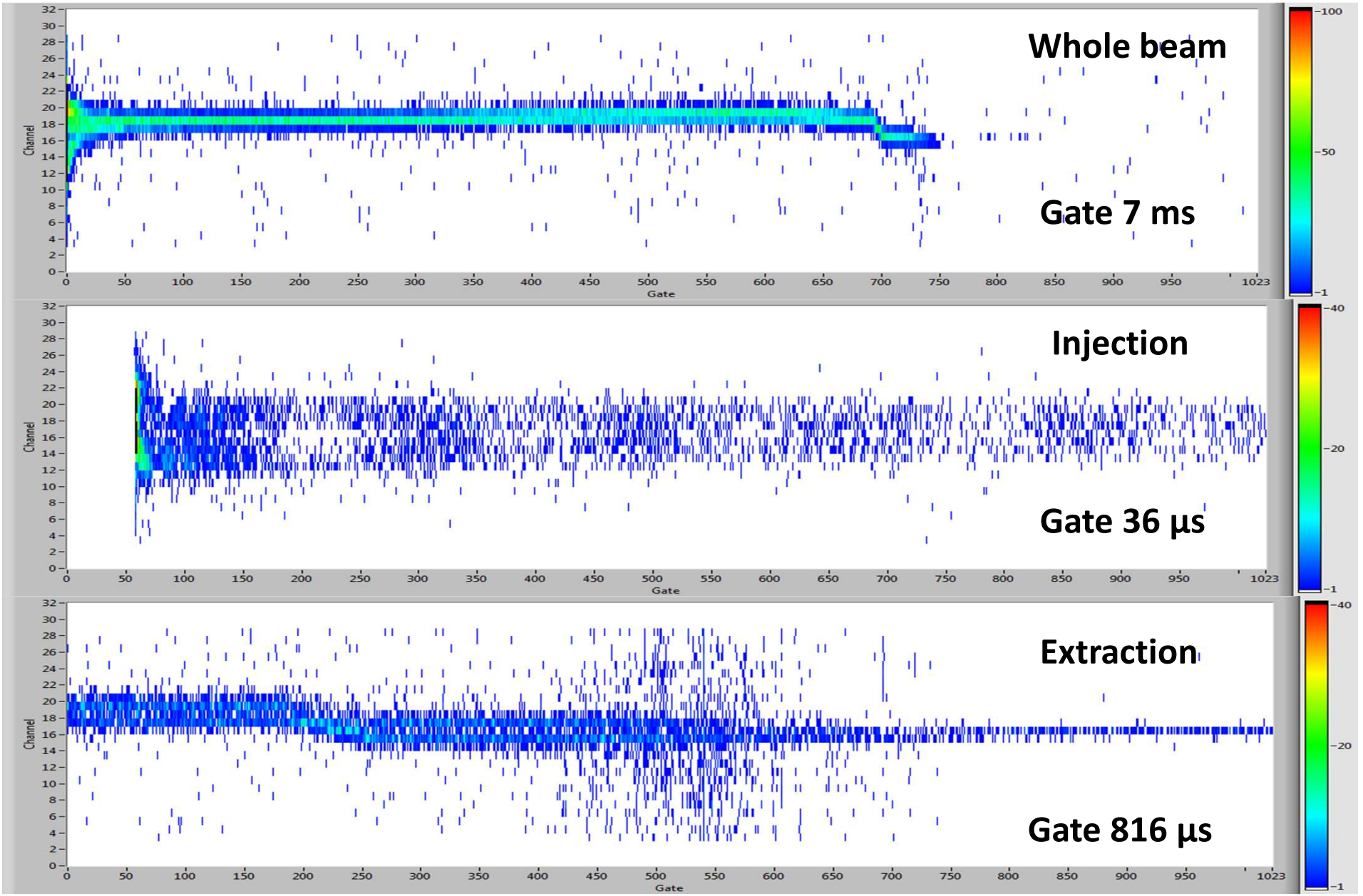
# Diagnostics of the beam

The results of the four last runs (2010 – 2012) of Nuclotron demonstrated that the MCP-based detector makes it possible to measure the beam orbit, space-time characteristics, and the beam transport quality (beam losses during circulation).



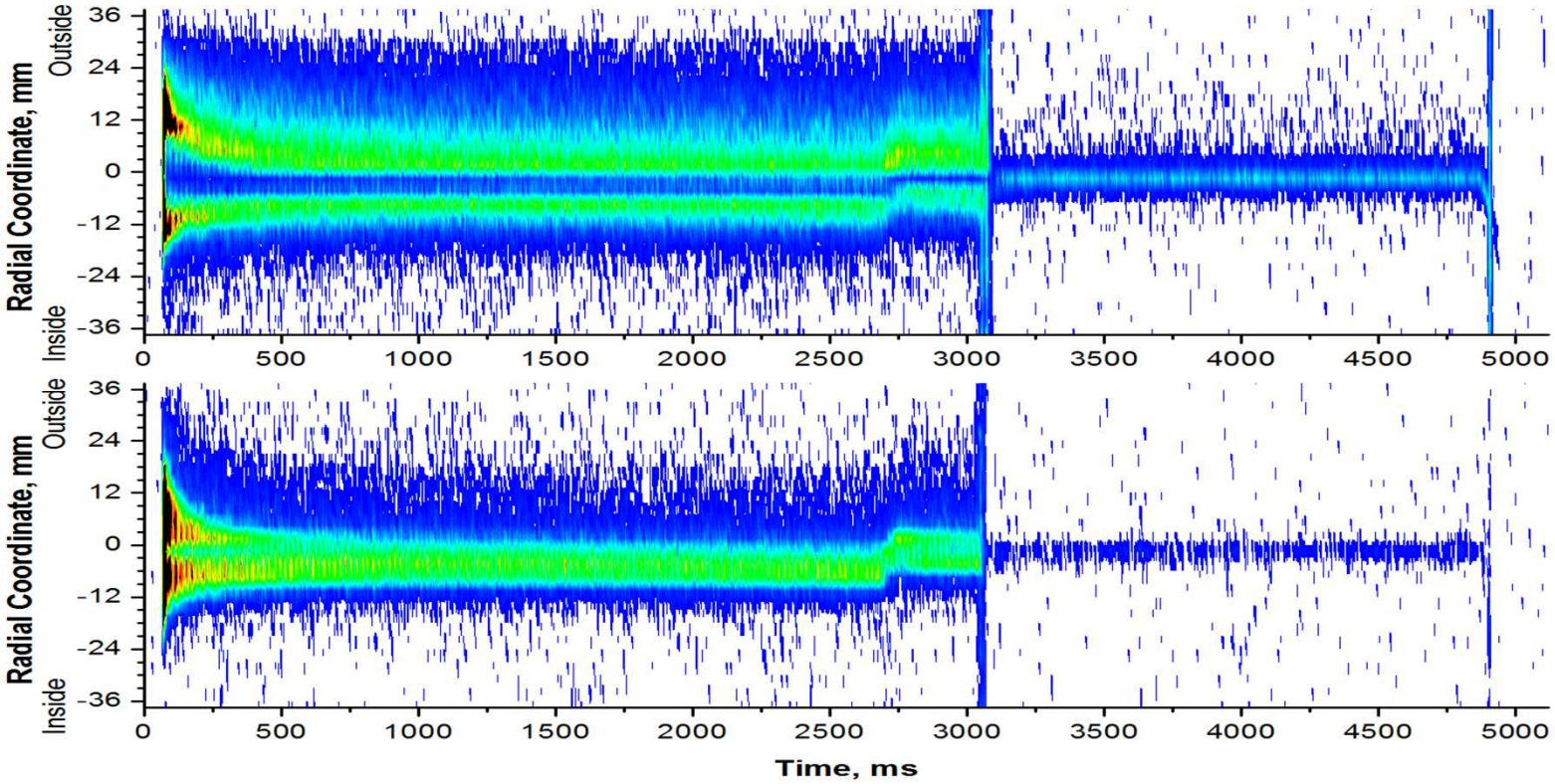

**The data from the MCP detector (upper plot) and the magnetic field of the accelerator (lower plot).**

# The beam distributions at specific time intervals



# Registration of the beam losses. Detector overloading.

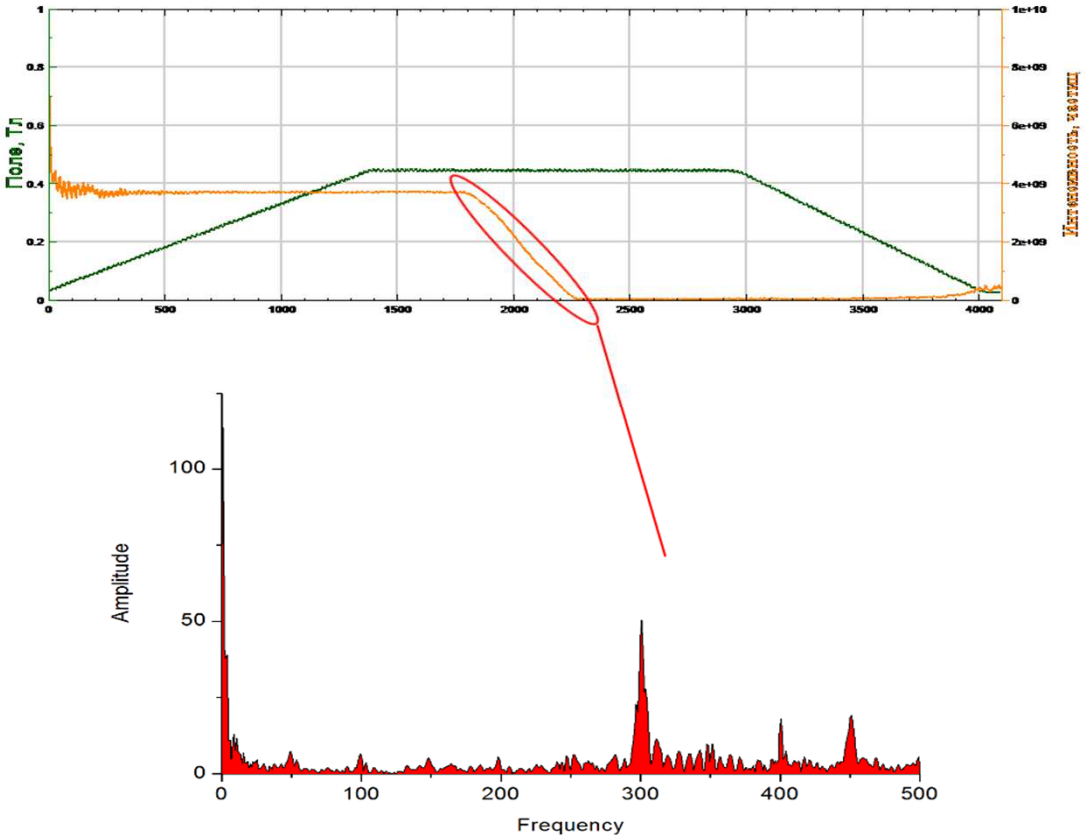
The MCP-based monitoring system is capable of registering the time instant of the beam interaction with the accelerator chamber using typical “actuation” lines of all detector channels.




**One acceleration cycle at two different voltages of the locking electrode of the detector.**

# Application for extracted beam

Synchronous analysis of the data for circulating (MCP detector) and extracted beams (ionization chamber) was performed for adjustment of the regime of beam extraction to the target.

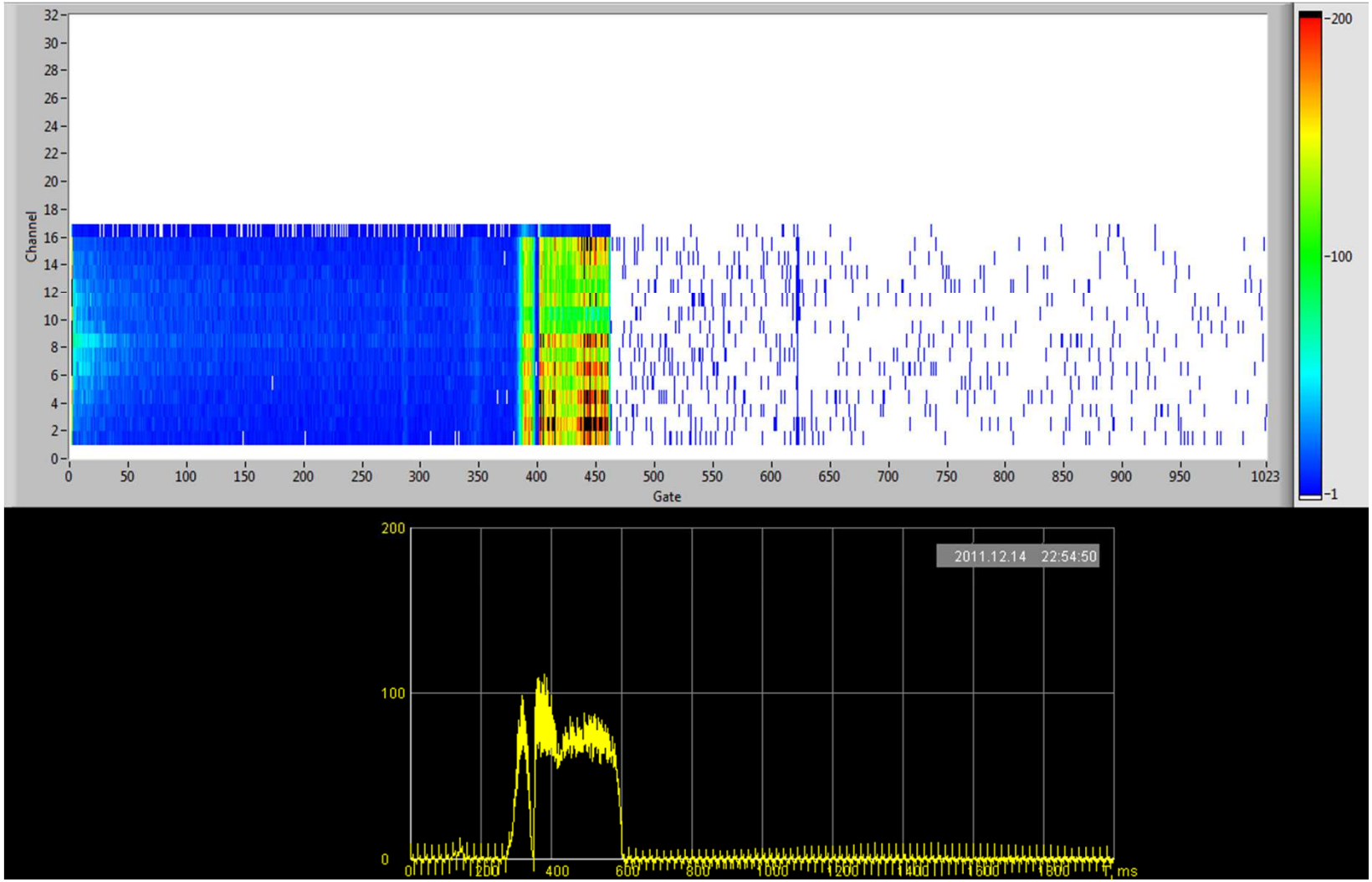



**Fourier analysis of the time interval of beam extraction.**

# Conclusions

- The new diagnostic system of circulating beam of Nuclotron based on MCP allows one to study the spatial and temporal beam structure in an intensity range from $10^5$ to $10^9$ singly charged ions.
- The electrostatic system of the detector provides the optimal regime of the detector operation depending on the vacuum, the beam type and intensity, thus extending the working range of the detector with respect to intensities and types of accelerated ions.
- The detector design makes it possible to change the width of the sensitive pads to 0.5 mm which determines the spatial resolution of the detector. At present, the sensitive area of the detector is 90 mm and the spatial resolution is 3 mm.
- The software for remote control of the detector parameters was developed and tested; this software provides digital and graphical information to the control panel of the accelerator in the operator-friendly form.
- This detector is useful for adjustment of the time structure of slow extraction of accelerated ion beams from Nuclotron.

# Thank you for your attention.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