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JOINT INSTITUTE FOR NUCLEAR RESEARCH

NICA

LHEP ЛФВЭ

имени Векслера и Балдина
ЛАБОРАТОРИЯ ФИЗИКИ ВЫСОКИХ ЭНЕРГИЙ

Construction of the ISCRA and SIMBO stations for applied research on high-energy ion beams. Radiation hardness testing of microchips by low energy pulsed ion beams at the SOCHI station

The implementation of the NICA (Nuclotron based Ion Collider fAcility) mega-science project at the VBLHEP JINR opens wide opportunities for development of applied research in such areas of science as: radiation hardness testing of semiconductor devices, the challenges for modern medicine and biology, radiation materials science. The ARIADNA (Applied Research Infrastructure for Advanced Developments at NICA fAcility) infrastructure, which is currently being created at VBLHEP, includes the following stations for applied research: the Irradiation Setup for Components of Radioelectronic Apparatus (**ISCRA**), the Setup for Investigation of Medical Biological Objects (**SIMBO**); the Station Of CHip Irradiation (**SOCHI**).

The description and current status of the ISCRA station, the prototype of the detector part of the ISCRA station (**DPS-NICA**), SIMBO and SOCHI stations are presented.

The poster includes the results of commissioning tests with ionizing radiation source at the ISCRA and SIMBO stations, the results of single event effects (SEE) testing of decapsulated microchips by pulsed heavy ion beams at low energy at the SOCHI station during five beam runs.

ISCRA & SIMBO stations at the VBLHEP JINR

The equipment of the **ISCRA** and **SIMBO** stations for high-energy ion beams extracted from the Nuclotron was mounted in December 2023. The commissioning of the diagnostics equipment of the ISCRA and SIMBO stations with ionizing radiation source & magnets tests were carried out in November-December 2024. **The equipment is ready for the first beam run in spring-summer 2025. The technology of radiation hardness testing of capsulated microchips with high-energy ion beams will be realized in Russia for the first time.**

Setup for Investigation of Medical Biological Objects (SIMBO)

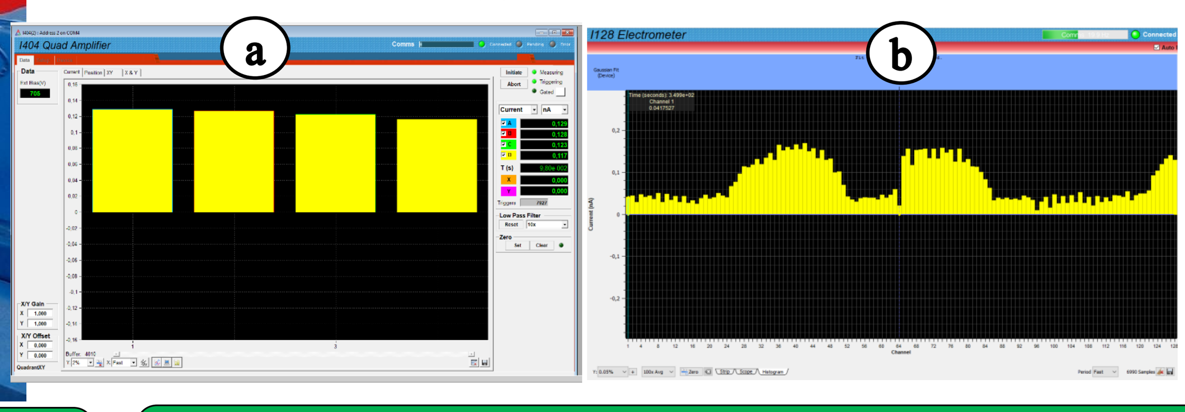
SIMBO — an applied research station for space radiobiological research and modelling of influence of heavy charged particles on cognitive functions of the brain of small laboratory animals and primates (energy range 400-1000 MeV/nucleon).

The equipment for the SIMBO station was manufactured as part of the ***JINR — «Vacuum systems and technologies» LLC (Belgorod)*** collaboration.

Technical requirements for the ion beams at the SIMBO station

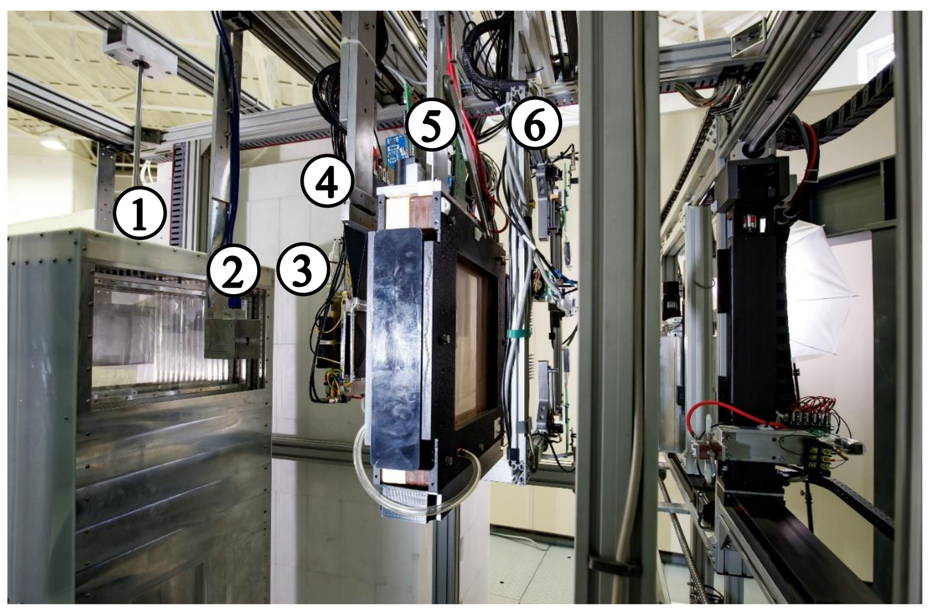
Type of ions	$^{12}C^{6+}$, $^{40}Ar^{18+}$, $^{56}Fe^{26+}$, $^{84}Kr^{36+}$
Ion energy at the exit from the Nuclotron, MeV/nucleon	400-1000
Ion flux density, particles/(cm²·s)	$10^3..10^6$
Irradiation time per run, min	1-5
Radiation dose, Gy	1-3
Maximum irradiation area in the scanning mode/nonscanning mode, mm	100×100/Ø10
Flux uniformity for the maximum irradiation area in the scanning mode/nonscanning mode, %	5/10
Beam FWHM at the target, mm	25-35

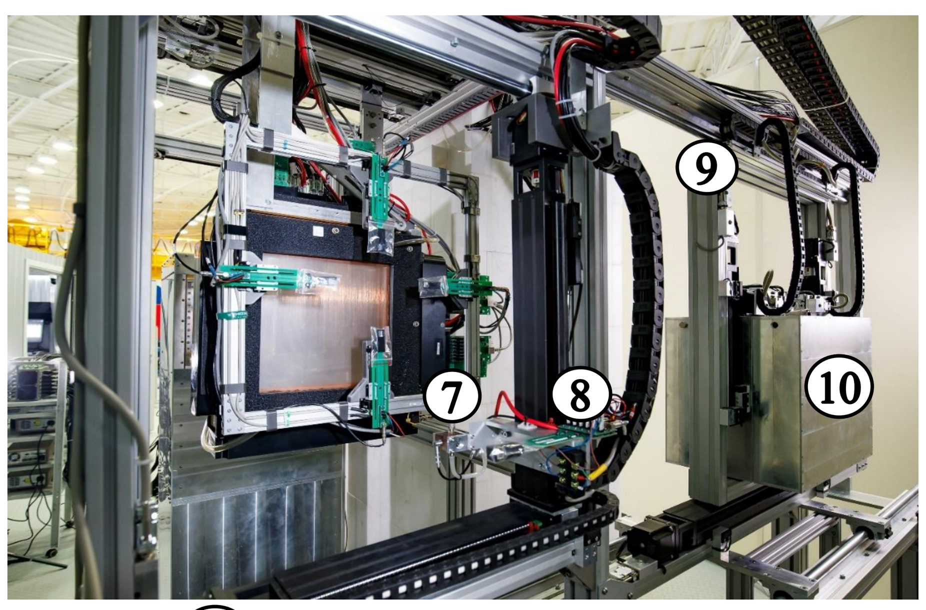
Ion beam diagnostics system tests: (a) Tissue-equivalent ionization chamber QIC-2S (b) Ionization chamber IC64-16



Irradiation Setup for Components of Radioelectronic Apparatus (ISCRA)

ISCRA — an applied research station for Single Event Effects (SEE) testing on **capsulated microchips** with **high energy ion beams (150-500 MeV/nucleon)**. The equipment for the ISCRA station was manufactured as part of the ***JINR — National Research Centre «Kurchatov Institute»-ITEP (Moscow)*** collaboration with ***JSC «Experimental Research and Production Association SPECIALIZED ELECTRONIC SYSTEMS»/National Research Nuclear University MEPhI (Moscow) — «GIRO-PROM» LLC (Dubna)*** participation.



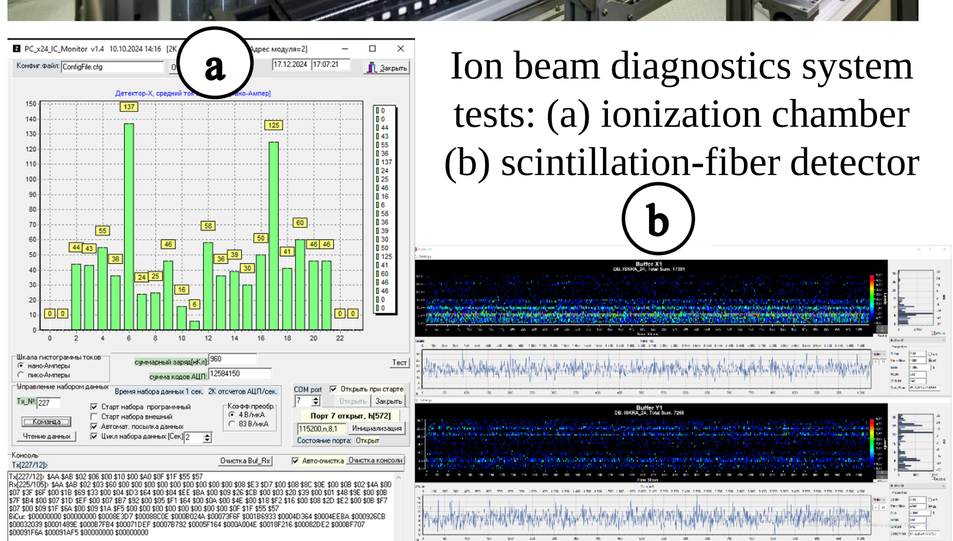


Technical requirements for the ion beams at the ISCRA

Type of ions, energy MeV/nucleon	$^{197}Au^{79+}$	150-350
	$^{131}Xe^{54+}$	150-367
	$^{84}Kr^{36+}$	150-392
	$^{56}Fe^{26+}$	150-449
	$^{40}Ar^{18+}$	150-426
	$^{12}C^{6+}$	150-507
Ion flux density, particles/(cm²·s)	$10^2..3\cdot10^5$	
Maximum irradiation area in the scanning mode/ nonscanning mode, mm	200×200/20×20(Ø29)	
Beam diameter in nonscanning mode, mm	Ø73	
Flux uniformity for the maximum irradiation area in the scanning mode/nonscanning mode, %	15/10	

The station includes the following components

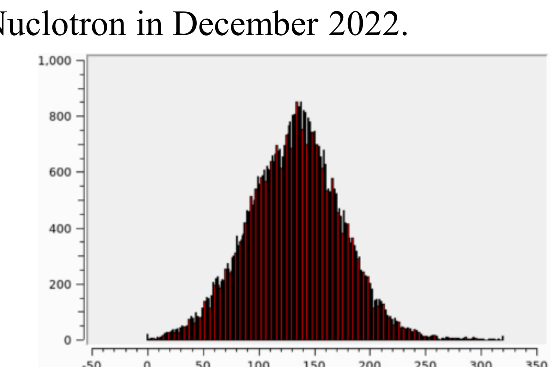
1. Energy degrader (polycarbonate);
2. System of ion beam profile projection and video control;
3. Ionization chamber №1;
4. Scintillation-fiber detector;
5. Proportional wire ionization chamber №2;
6. A particle flux density meter;
7. Miniature gas-filled ionization chamber №3;
8. Silicon detector;
9. Test object positioning system;
10. Chamber with drained atmosphere for testing at negative temperatures;
11. System of positive temperature setting for test objects (+25°C … +125°C, ±5°C, 10 min);
12. System of negative temperature setting of test objects (minus 60 ºC … 0 ºC, ±5ºC, 15 min);
13. Equipment for connection of test equipment to test objects
14. Workplace in the Measurement Hall of Building 1



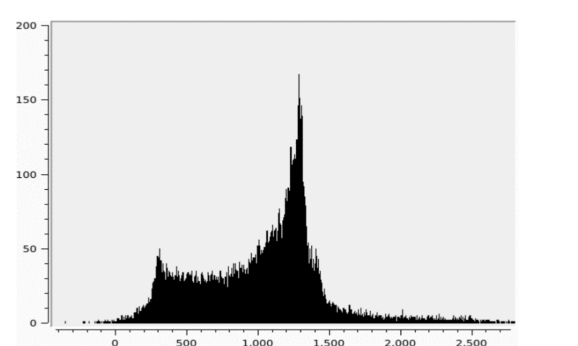
Ion beam diagnostics system tests: (a) ionization chamber (b) scintillation-fiber detector

The DPS-NICA project (as a part of ISCRA station)

The Detector Part of the Station (DPS) is manufactured as part of the ***JINR — Skobeltsyn Nuclear Physics Research Institute (Moscow State University, Moscow)*** collaboration. The DPS is an experimental facility that allows recovering trajectories (tracks) and energies (by energy release in the layers) of the particles entering it. The DPS is designed to mass testing of the microchips by precise localization of the most vulnerable regions in them. The DPS-NICA prototype was tested on ion beams (*Xe*) extracted from the Nuclotron in December 2022.

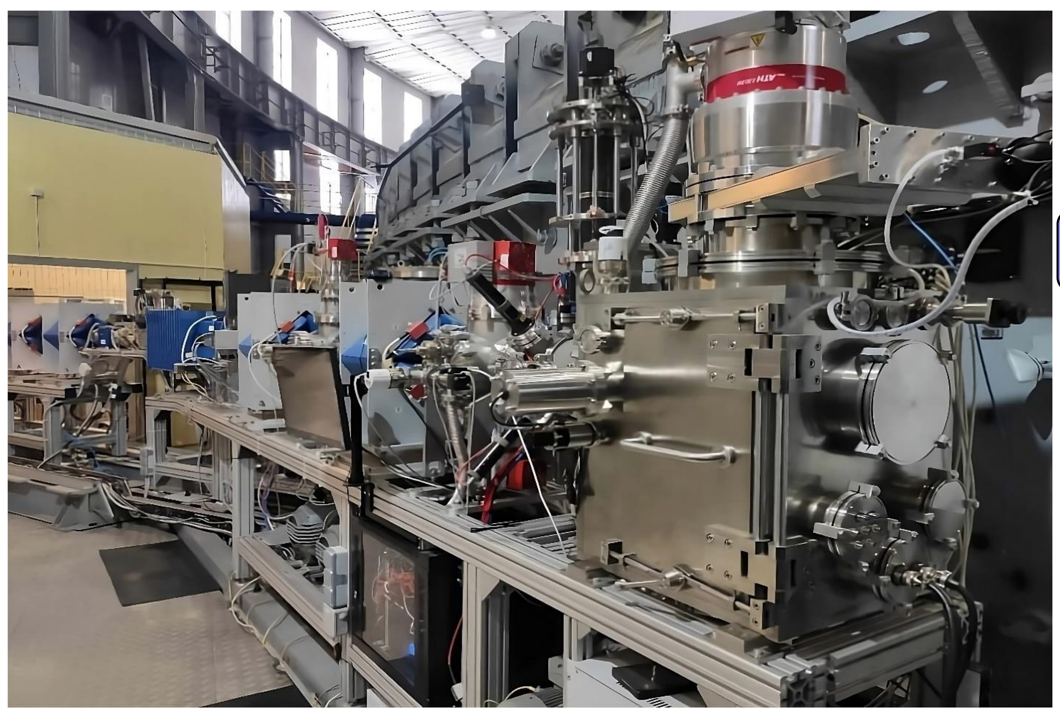


Ion beam profile in horizontal direction



Energy release from *Xe* in ADC counts

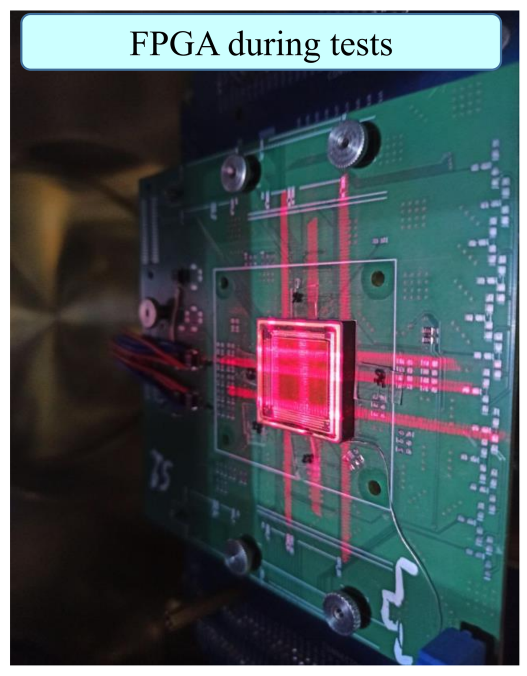
Station of CHip Irradiation (SOCHI)



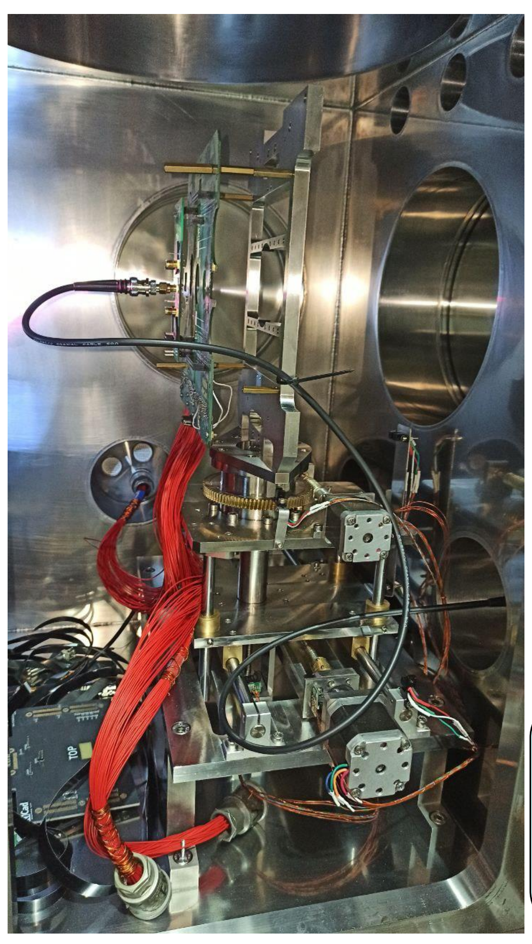
SOCHI — an applied research station for Single Event Effects (SEE) testing on **decapsulated** microchips (ion energy up to 3.2 MeV/n).

Ion beam parameters at the SOCHI station during tests

Type of ions	$^{12}C^{4+}$, $^{40}Ar^{8+}$, $^{131}Xe^{22+}$, $^{84}Kr^{14+}$
Ion energy at the exit from the HILac, MeV/nucleon	3.2
Ion flux density, particles/(cm²·s)	$10^3..10^5$
Maximum fluence per run, ion/(cm²)	$2\cdot10^7$
Maximum irradiation area, mm	Ø29
Uniformity in the beam center at the 20x20 mm area, %	10
Beam diameter, mm	Ø73
System of positive temperature setting for test objects	+25°C … +125°C, ±5°C; 10 min



FPGA during tests



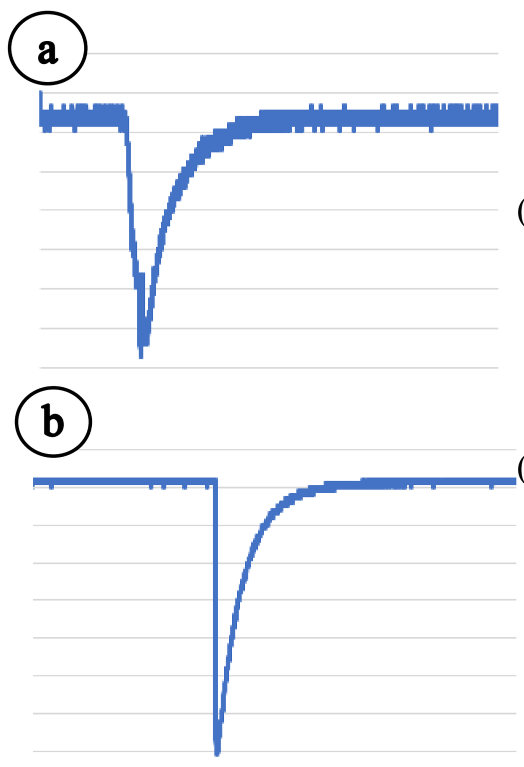
The SOCHI ion beam diagnostics system includes:

1. The ionization detector based on microchannel plates (MCP);
2. The system for online diagnostics and control of peripheral ion flux density and fluence;
3. A detector based on Faraday cup;
4. The fast total-absorption scintillation detector with optical readout;
5. The fast total-absorption phosphor detector with optical readout.

The technology of single event effects (SEE) testing on decapsulated microchips with pulsed heavy ion beams extracted from linear accelerators is being realized for the first time in Russia at the SOCHI applied station.

Five sessions with an ion beam were performed at the SOCHI station:

- Six types of microchips were irradiated;
- The diagnostics equipment was modernized;
- 42 pcs. of solid track detectors (Columbia Resin №39) with an area of 10×10 mm/7.5×7.5 mm were irradiated;
- The effect of pulsed heavy ion beam irradiation on the magnetic properties of a metastable compound $La_{0.5}Ba_{0.5}CoO_{2.87}$ for spintronics is being studied currently.

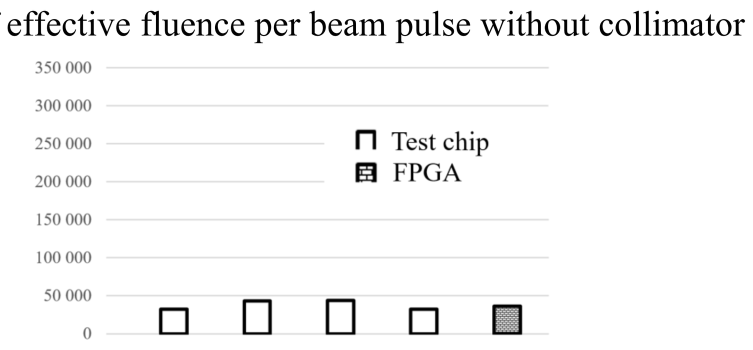


Oscillograms of the output response of the operating amplifier:

(a) typical oscillogram under tests with a «wide-slit» at the SOCHI;

(b) typical oscillogram under tests at the cyclotron in the FLNR JINR.

Estimates of effective fluence per beam pulse without collimator



Ion beam profile (horizontal) by MCP-detector during beam run