COMMISSIONING OF THE BOOSTER NICA ELECTRON COOLING SYSTEM

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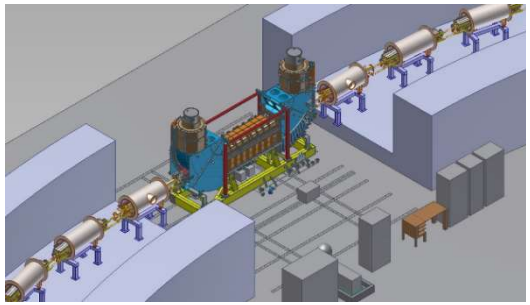
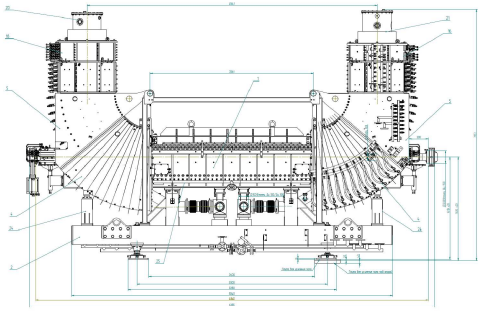
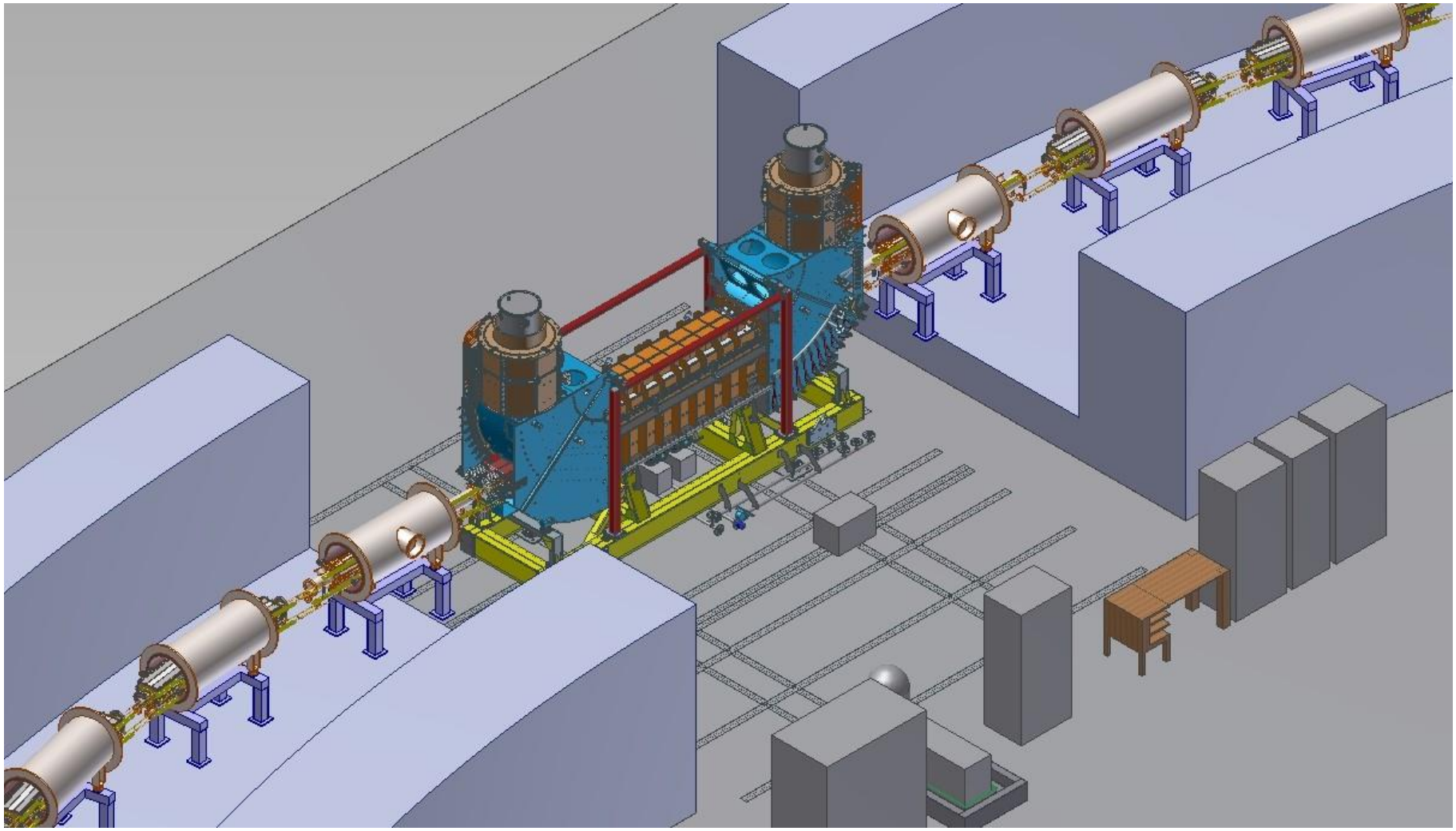
In order to achieve the required beam parameters in NICA booster, an electron cooling system (ECS) was designed, which was manufactured at INP (Institute of Nuclear Physics, Novosibirsk). In 2017 the system was shipped to JINR and its assembly and commissioning have been started. The distinctive feature of the present system is that for the first time ever an electronic cooling method with a magnetized E-beam will be applied to the superconducting synchrotron, which imposes some additional requirements for the construction and start of ECS, which itself is at room temperature.

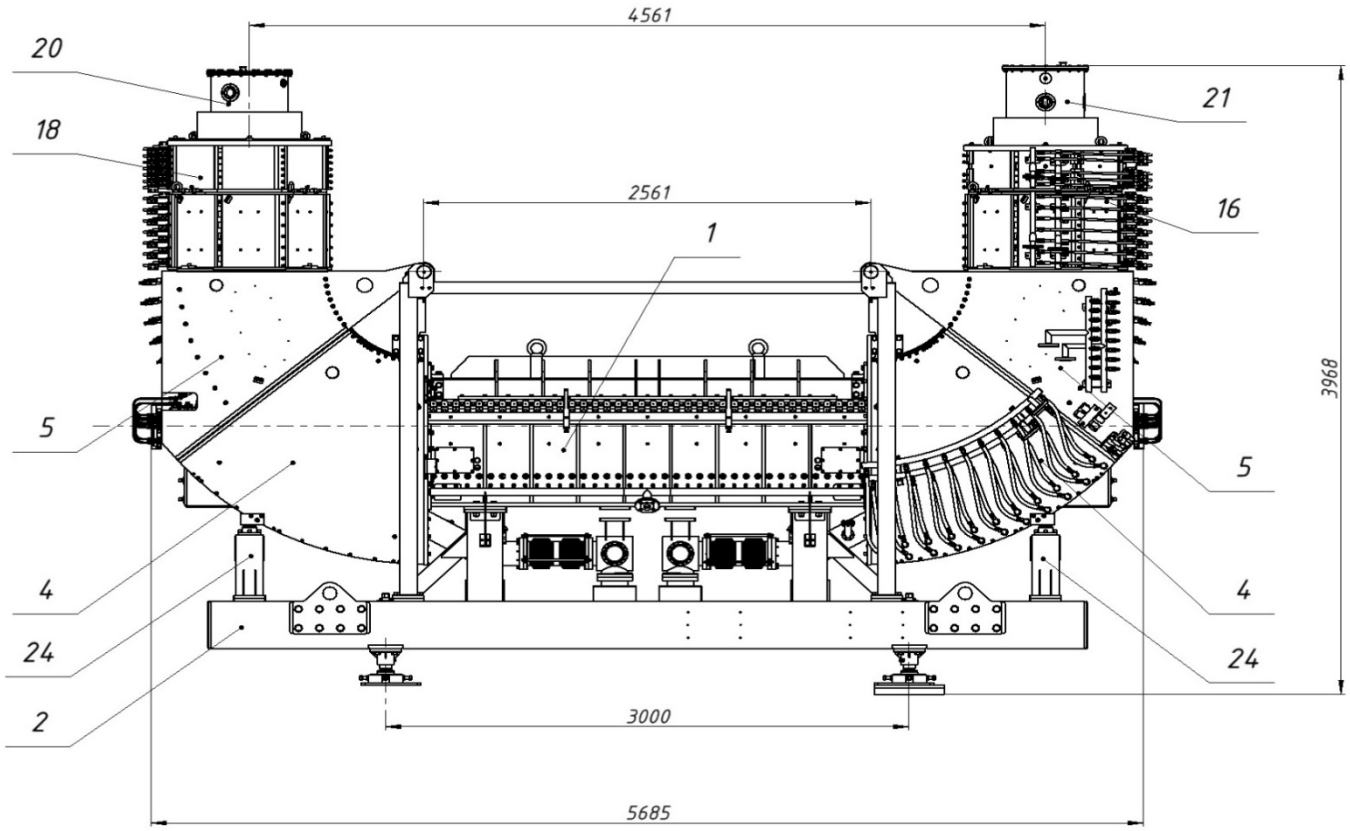
The report describes the main steps of assembly and start of ECS directly in a straight booster section, which include: MEP installation (water, electricity, air, oil system), geodetic works on putting the system on site. The measuring data of magnetic field uniformity of forward magnet unit (solenoid) are given.

The vacuum and magnet systems assembly takes several steps because of ECS structural features. At the final stage of vacuum system assembly the vacuum chamber is warmed up, bulk getters and cathode of electron gun are activated. On finishing the assembly and testing of the high voltage system, the E- beam is sent from the gun to the collector.



3-D model of ECS positioned in the booster of NICA collider



Booster Electron Cooling System (ECS)

1 – cooling section with forward solenoid in magnetic screen,2 – stand for ECS, 4 – toroidal magnetic circuit, 5 – toroidal section housing, 16 – gun solenoid section, 18 – collector solenoid section, 20 – electron collector, 21 – electron gun, 24 – stands for magnetic corrector.

KEY PARAMETERSOF BOOSTER ELECTRON COOLING SYSTEM

Electron Energy, keV	1,5 ÷ 60
Adjustment accuracy of energy and its stability, ΔE/E	$\leq 1 \cdot 10^{-5}$
Collector potential with respect to the cathode, kV	0,5 ÷ 2,0
Electron beam current, A	0,2÷ 1,0
Beam current stability, ΔI/I	$\leq 1 \cdot 10^{-4}$
Electron beam loss current, δI/I	$\leq 3 \cdot 10^{-5}$
Power near cathode,W	100
Maximum power in collector, W	2 000
Forward solenoid length, mm	2522
Cooling system length, mm	5715
Full length with vacuum dampers, mm	**6355**
Electron gun cathode diameter, cm	3,0 ÷ 5,0
Longitudinal magnetic field, kG	1,0÷2,0
Uniformity of magnetic field near cathode, ΔB/B	$<10^{-3}$
Uniformity in forward solenoid, ΔB/B	$<10^{-4}$
Vacuum near cathode, torr	$<10^{-9}$
Vacuum in cooling section, torr	$<10^{-10}$
Total power at magnetic field 2 kG, kW	**500**

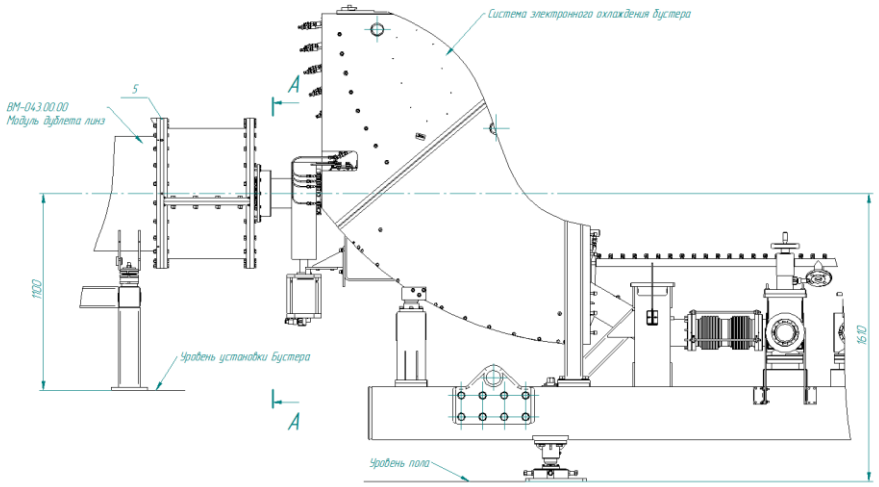
Shipping, assembly, installation

The electron cooling system was sent to Dubna in March 2017 by Institute of Nuclear Physics(Novosibirsk), and arrived at JINR on the 4th of April 2017.

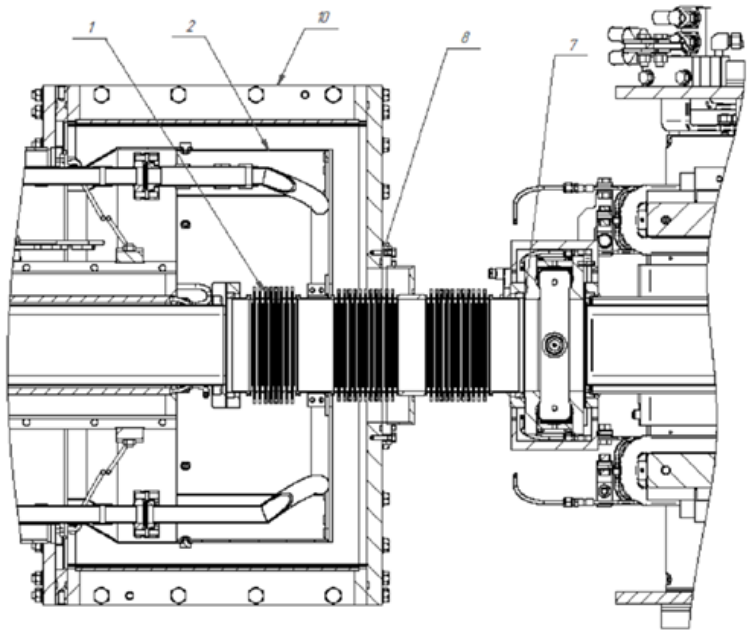
Arrival and dump at LHEP, JINR

Before arrival, the site was prepared for installation; the floor under ECS was strengthened by placing additional stabilizing jacks to hold up 15 tons weight. Also, before arrival to JINR, calculating of heat-cold pass in parts, connected to booster magnets, began.

ECS has become the first of the booster elements, installed in the proper location. Before its shipping to JINR, the development of “heat-cold” transition for connecting beam chambers at different temperatures was begun. ECS works at room temperature and is connected with the chamber of superconducting magnets which work at cryogenic temperatures.



Heat-cold pass, side view



Heat-cold pass top vie

In April-May 2017 assembly of ECS without the vacuum system began, as well as connection of all systems for testing and functioning of ECS. Geodetic works were performed (adjustment) to place ECS relatively to booster beam. The adjustment was made using trackerLeicaAT4101. High-voltage system was hooked up, water-supply for ECS cooling was conducted.

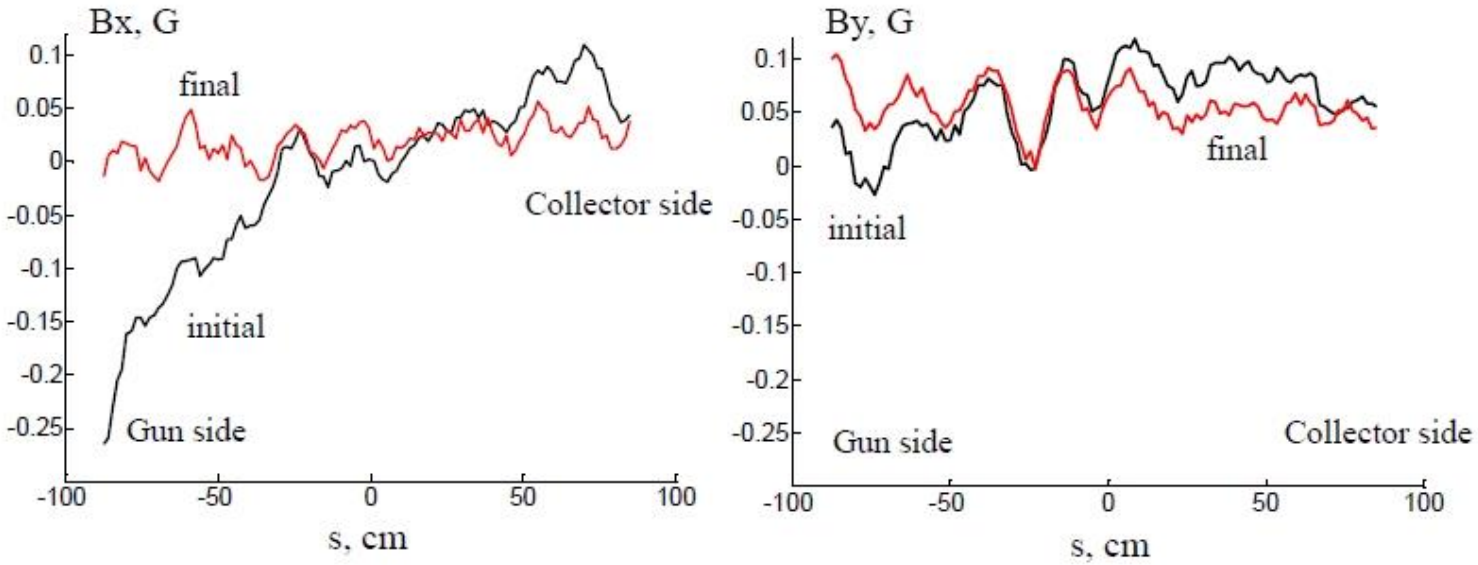
Magnetic fields measurements, high-voltage system testing.

ECS's full power at magnetic field of 2 kGis500kW, and to provide such power supply an additional electric substation is being built specifically for ECS. While it has not been finished yet, the high-voltage system testing was performed using the temporary scheme, of only 120 kW, corresponding to 1 kG.

Magnitude measurements were made of compass method.

Works in order:

Mechanical installation of stands, optics, moving system, etc.;
Final adjustment of cooler (laser tracker);
Magnitude measurements;
Placing of coils (circuits)



Magnitude measurements data. Black line is before correction, the Red line is after correction

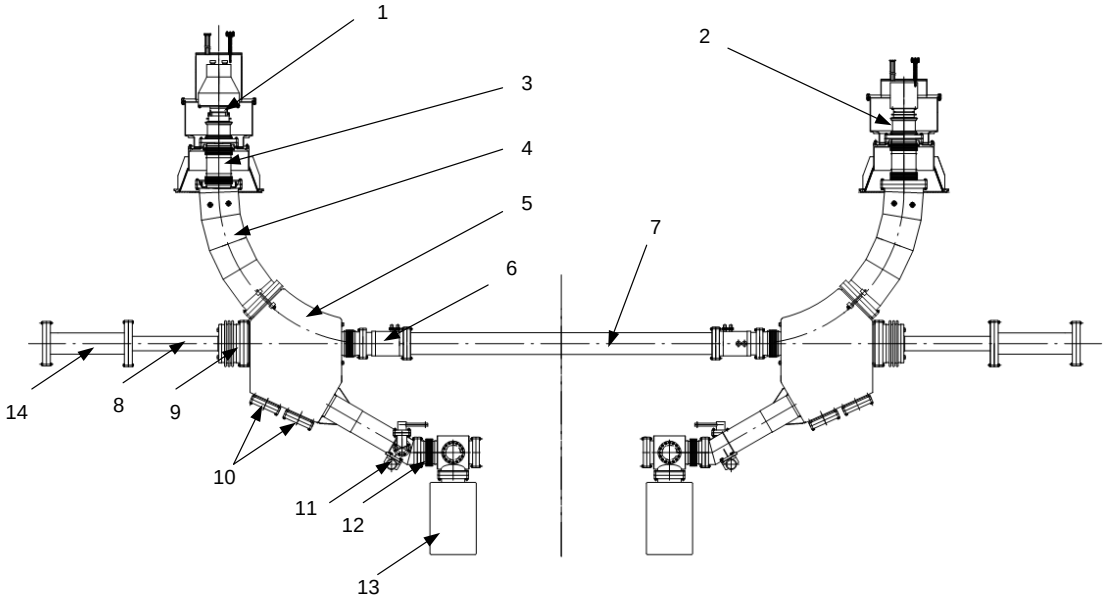
While adjusting the cooling section of booster ECS, mean-square magnetic field nonuniformity was achieved B /Bs=$2 \cdot 10^{-5}$in a wide range of magnetic field values at proportional adjustment (tune) of magnetic fields.

Initial rms(Bx)=8·10-5, rms(By)=3.5·10-5; Final rms(Bx)=1.6·10-5, rms(By)=2.0·10-5

Disassembly of magnetic system for further assembly with the vacuum system

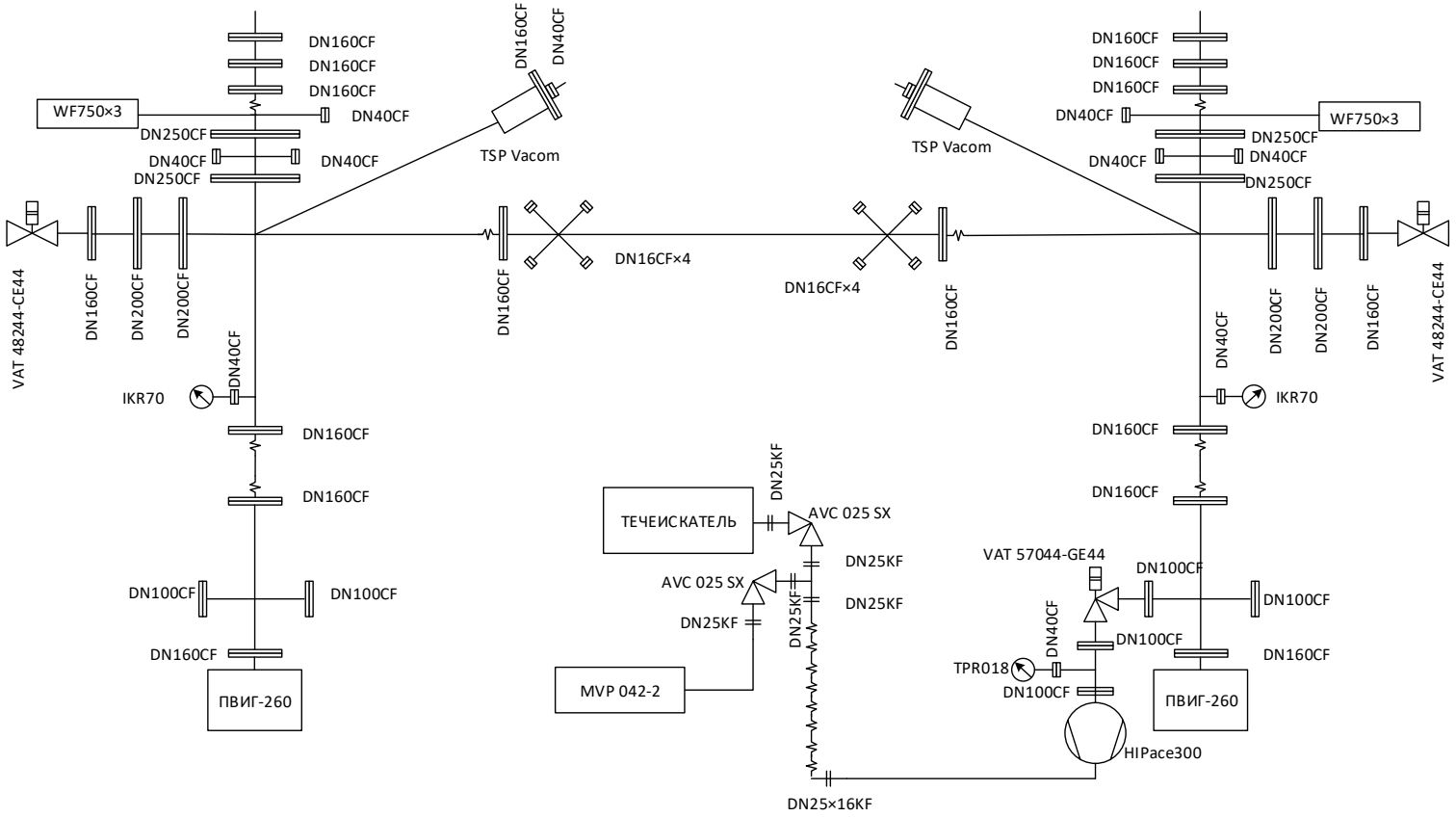
Performed works:
Cut of water, power supply;
Taking-out of toroidal rings and solenoids;
Preparation of heaters and insulation, where possible in advance;
Assembly of derivation plates and bent chambers;
Assembly of vacuum system with further leak hunting;
Assembly of magnetic system.

Vacuum chamber of electron cooling system (assembling)



1. Gun, 2. Collector, 3. Sublimation pump TSP-IKG «VACOM», 4. Bent chamber,
5. Toroid section, 6. Pick-up station, 7. Cooling section, 8. Dipole section, 9. Bellows,
10. NEG position, 11. Vacuum valve, 12. Bellows, 13. Ion pump, 14. Connector.

Vacuum scheme of electron cooling system

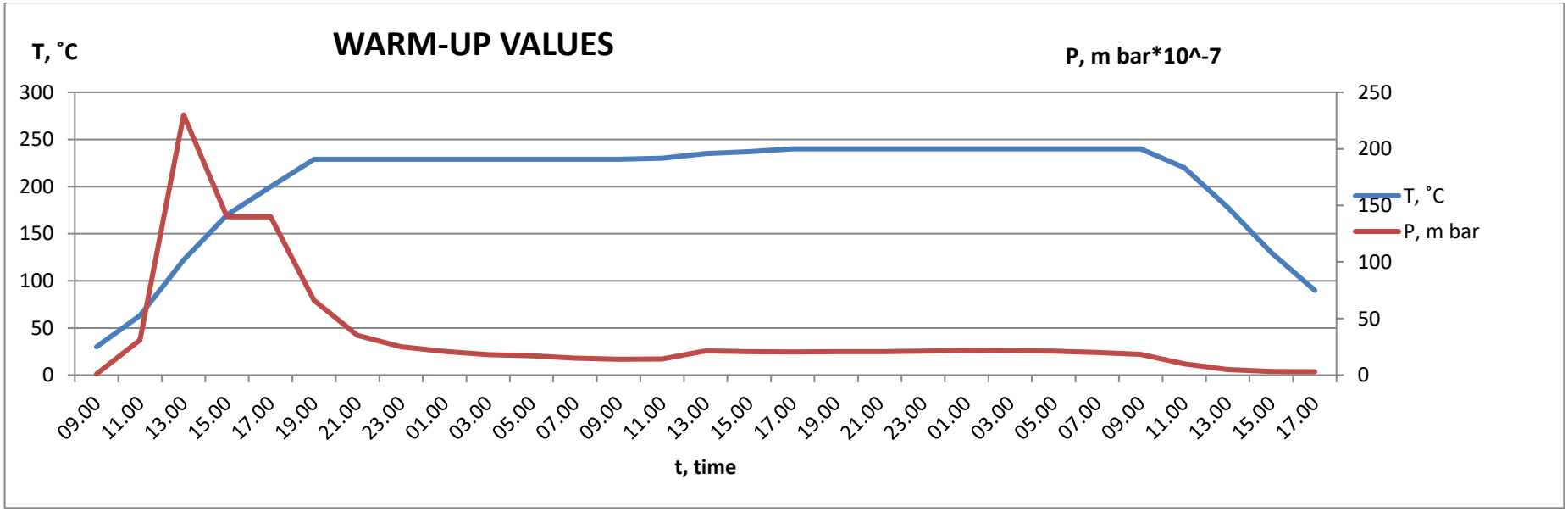


Warm-up

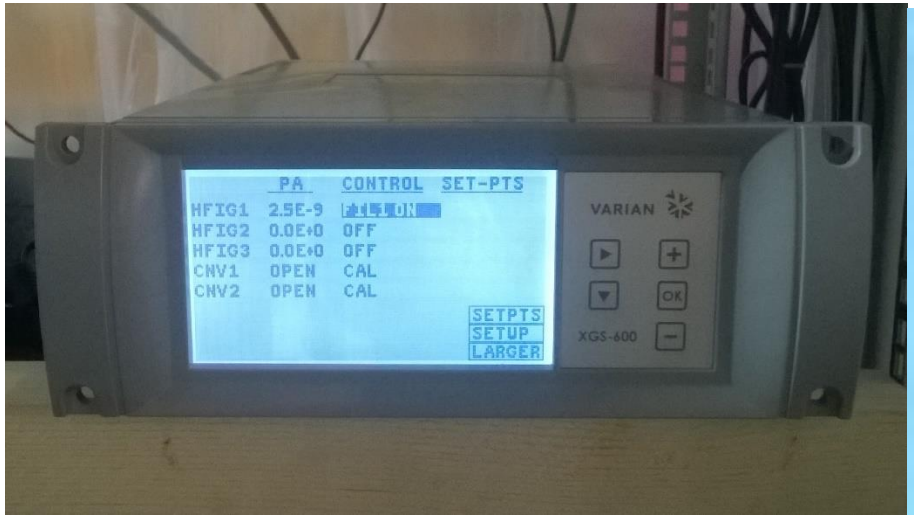
To achieve the required vacuum, warm-up was performed within 3 days at t=250ºC, and by the end of August 2017, the value was

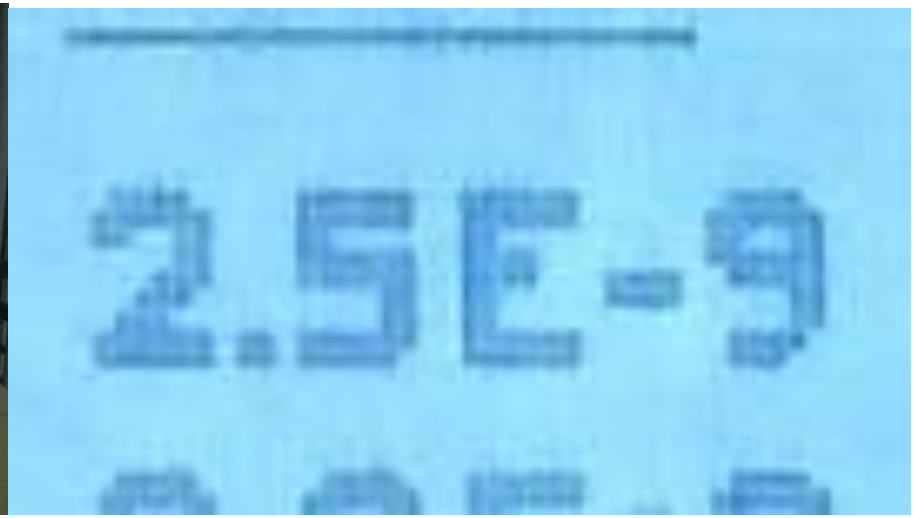
Performed works:

Installation of warm-up system;
Warm-up;
Degasification of TSP;
NEG activation;
Cathode activation;
Pumps switching-on;
UHVvacuum gages connection;
Titanium diffusion.



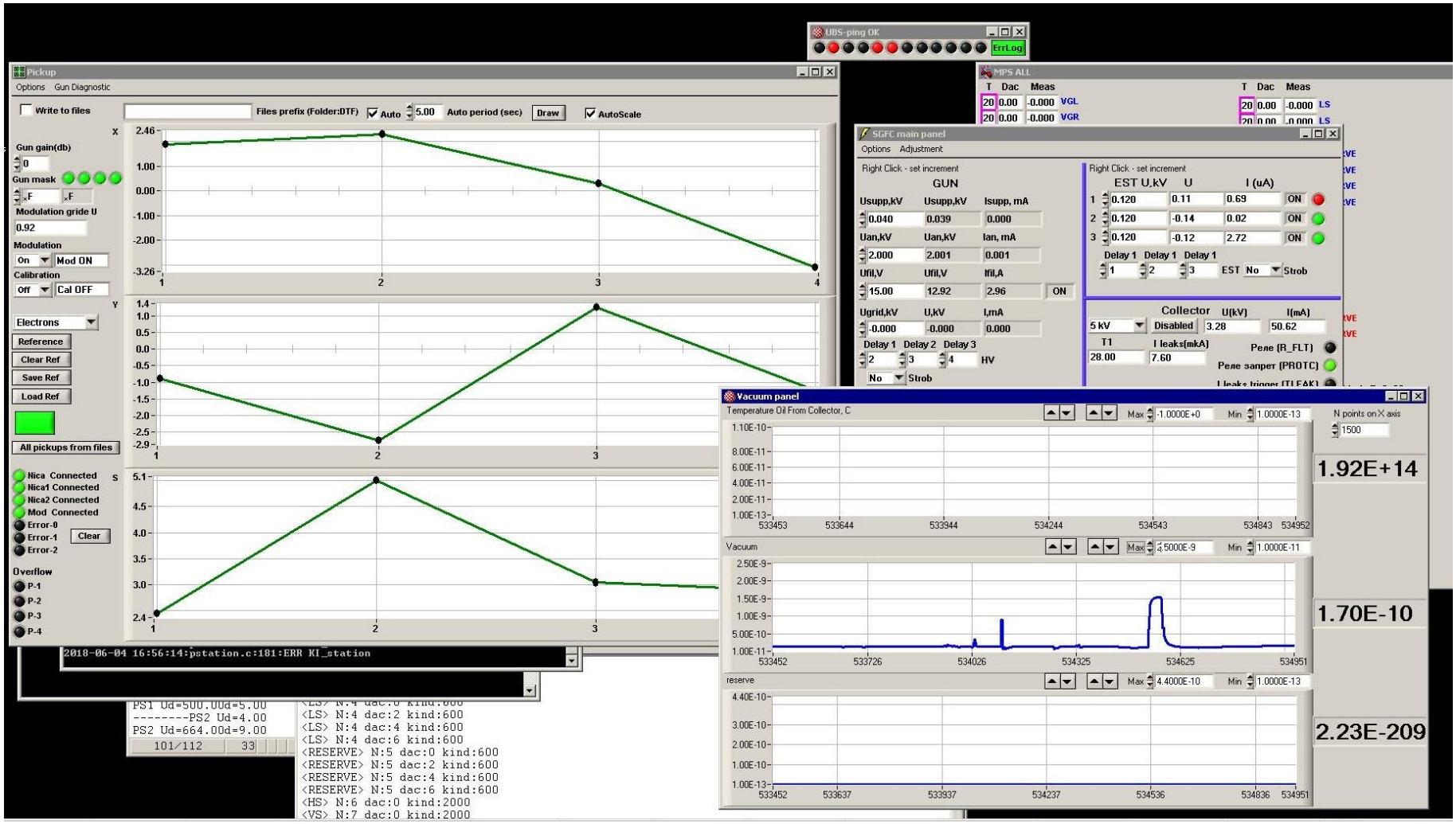
Vacuum data within3-days warm-up



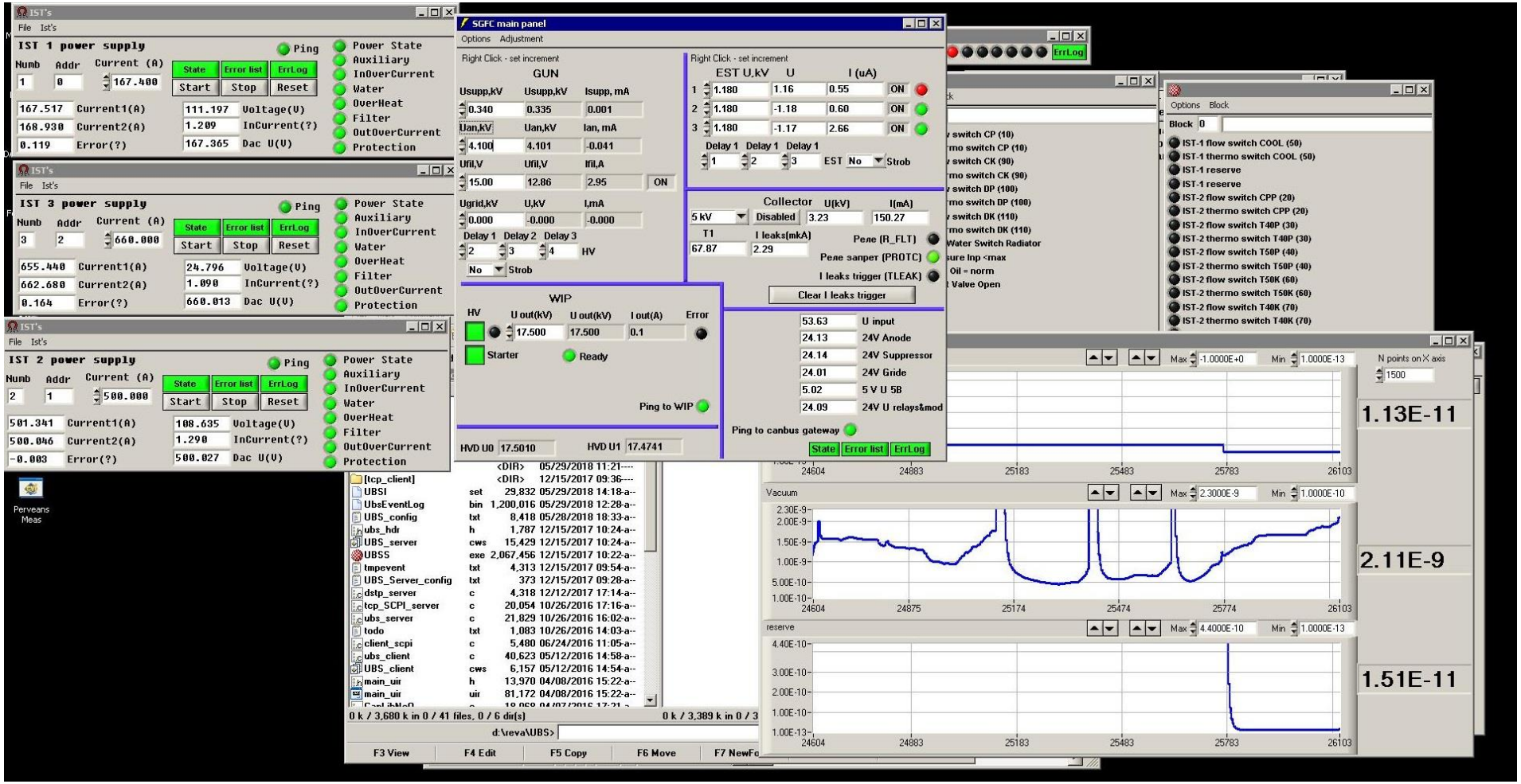


In August 2017 vacuum = 2.5 E-9 Pa was achieved

The present state in summer 2018 and beam experiments.



Horizontal and vertical beam signals from 4 pick-up stations:
gun, entry and exit of straight-lined solenoid, collector.



vacuum range during beam adjustment at 17 kV, 150 мА.

Summary

There is enough new decision for future hard works. At the end of work the NICA collider will obtain a powerful system of the electron cooling.

Thank you for attention! Спасибо за внимание! Благодаря за вниманието!