Development of the Electron string ion sources thermometry systems

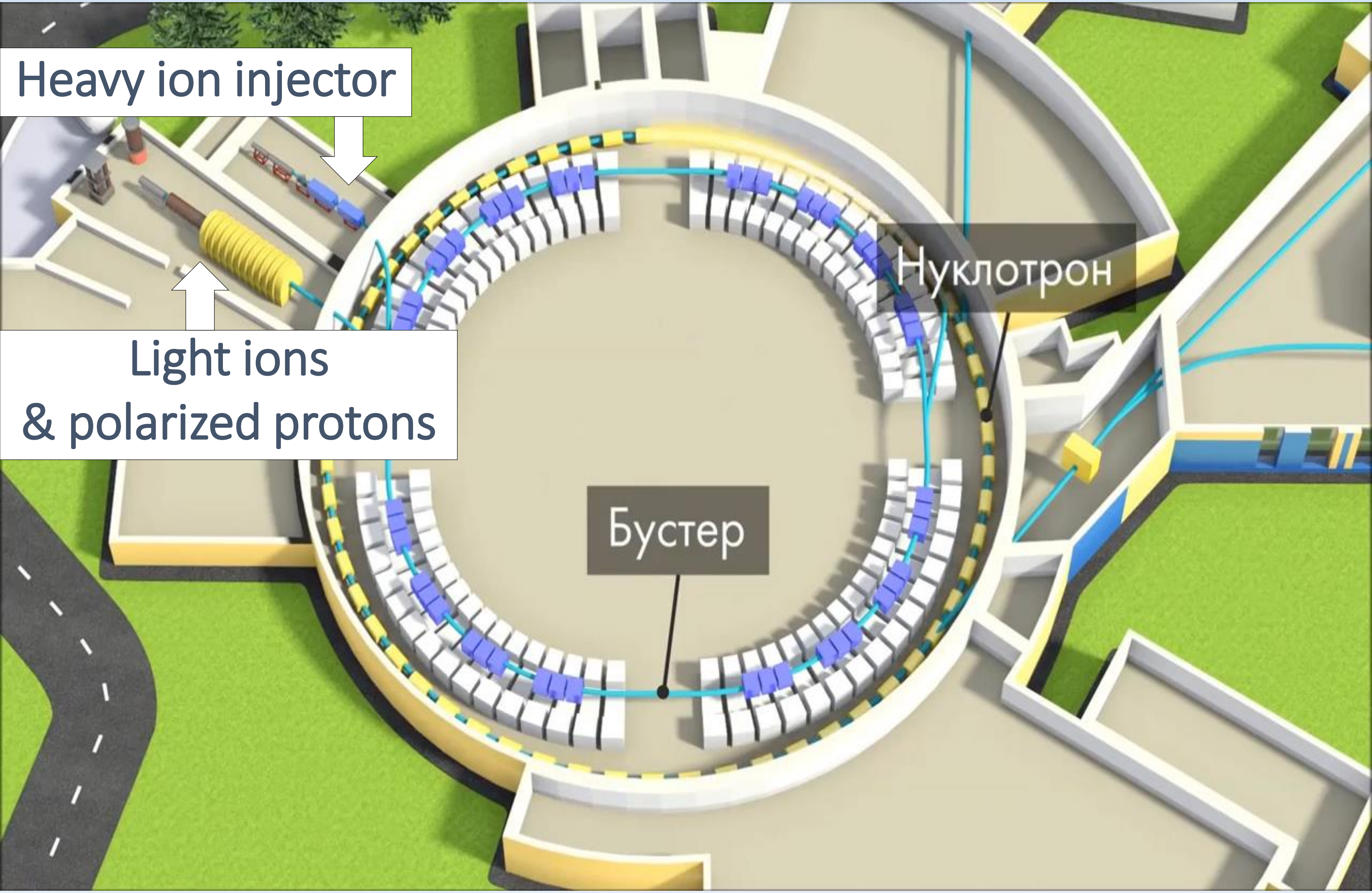
Ponkin Dmitry

LHEP JINR senior engineer

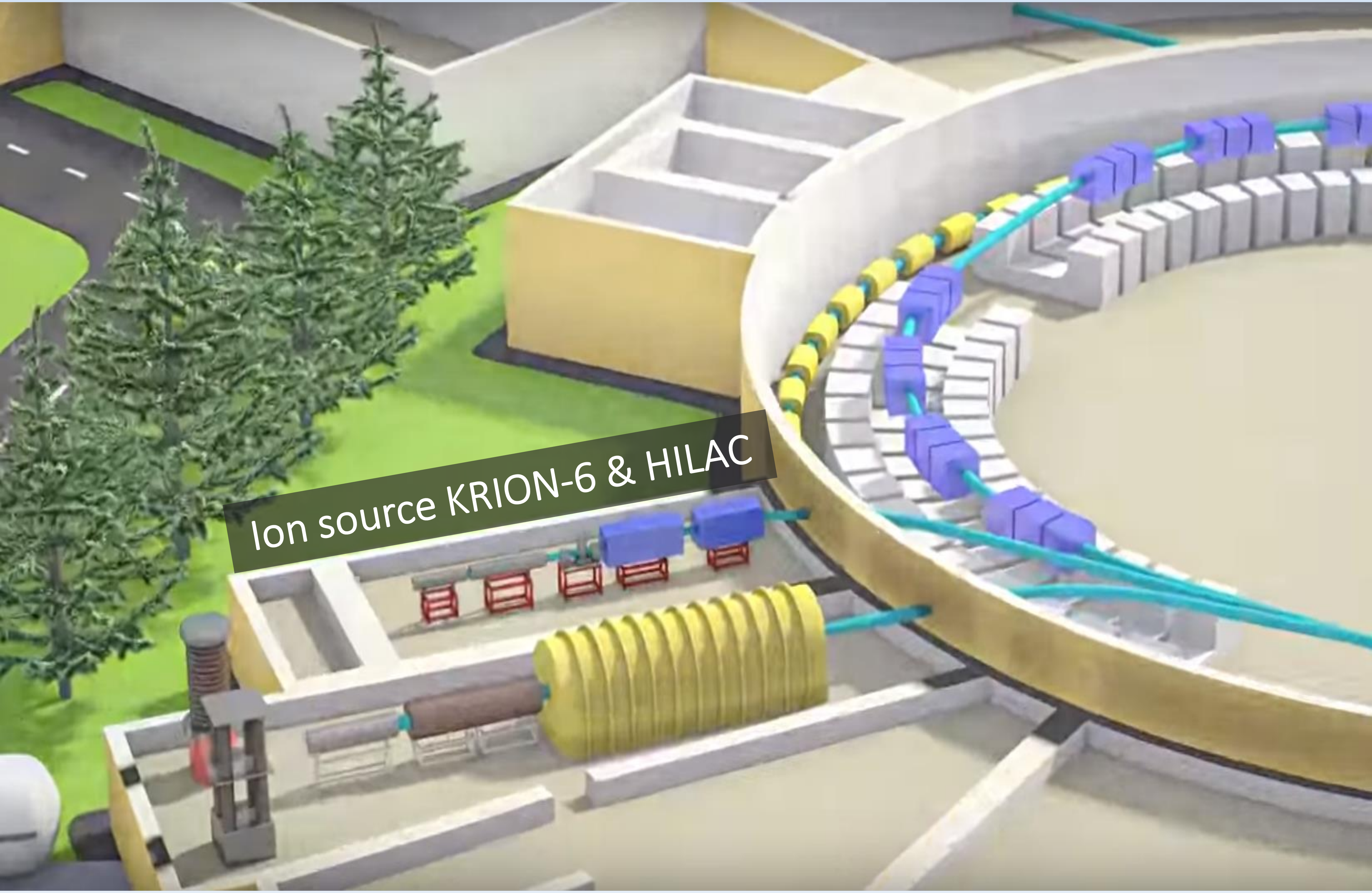
on behalf of the NICA acceleration division

Dubna, 9-13 November 2020

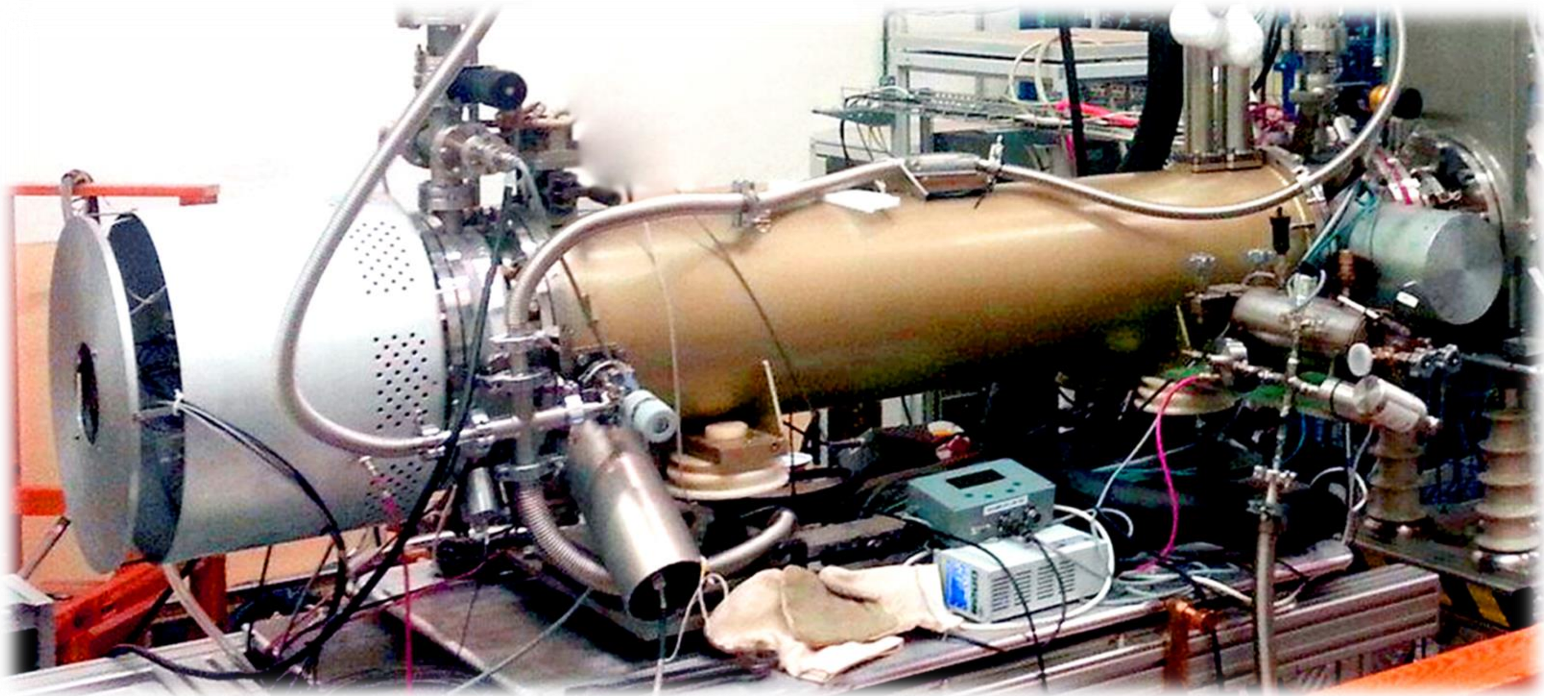
NICA injection complex



Heavy ion injection



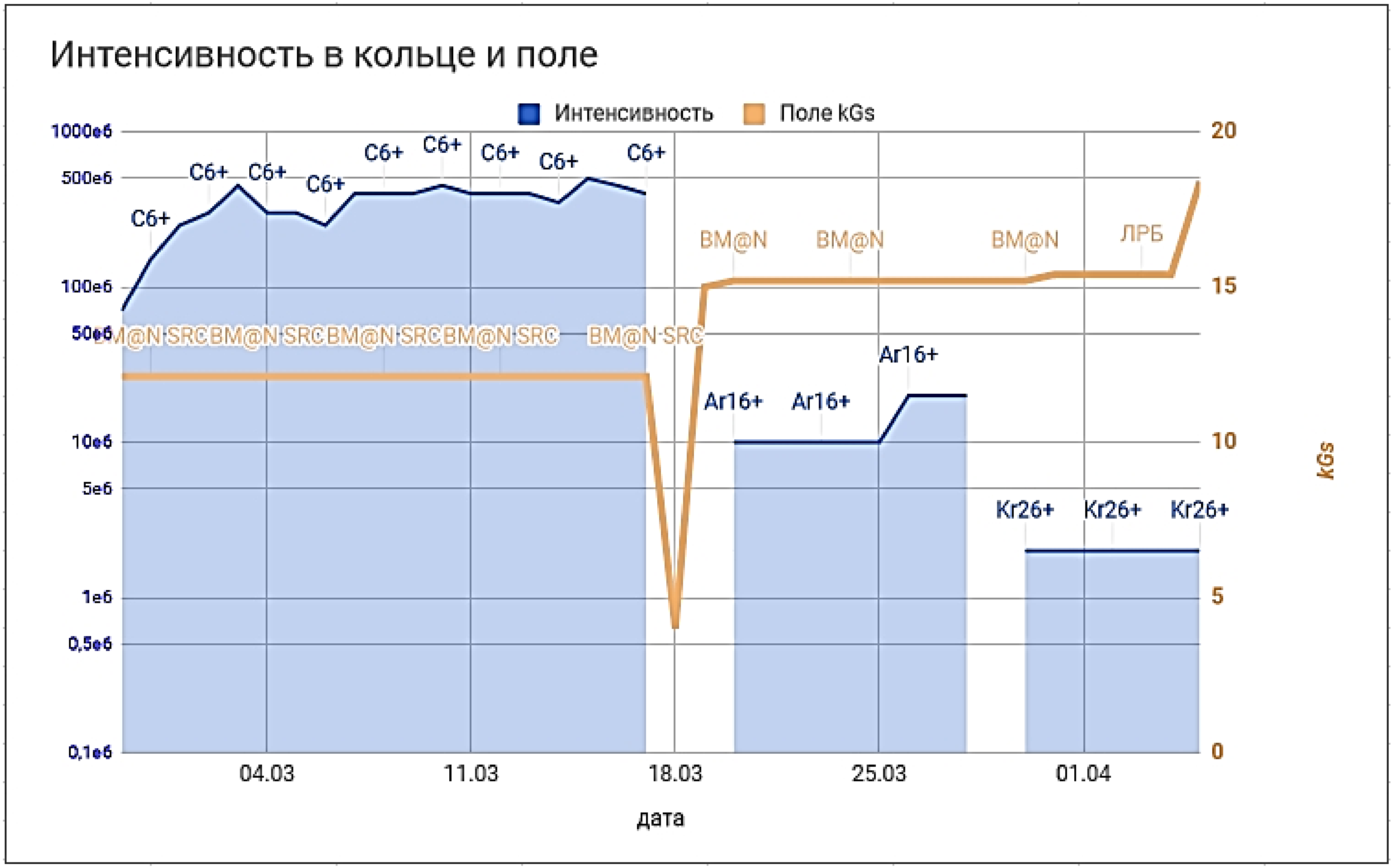
Heavy ion source KRION 6T



Ions produced and injected: $^{78}Kr^{17+}$ $^{124}Xe^{41+}$ $^{40}Ar^{16+}$ $^{12}C^{6+}$

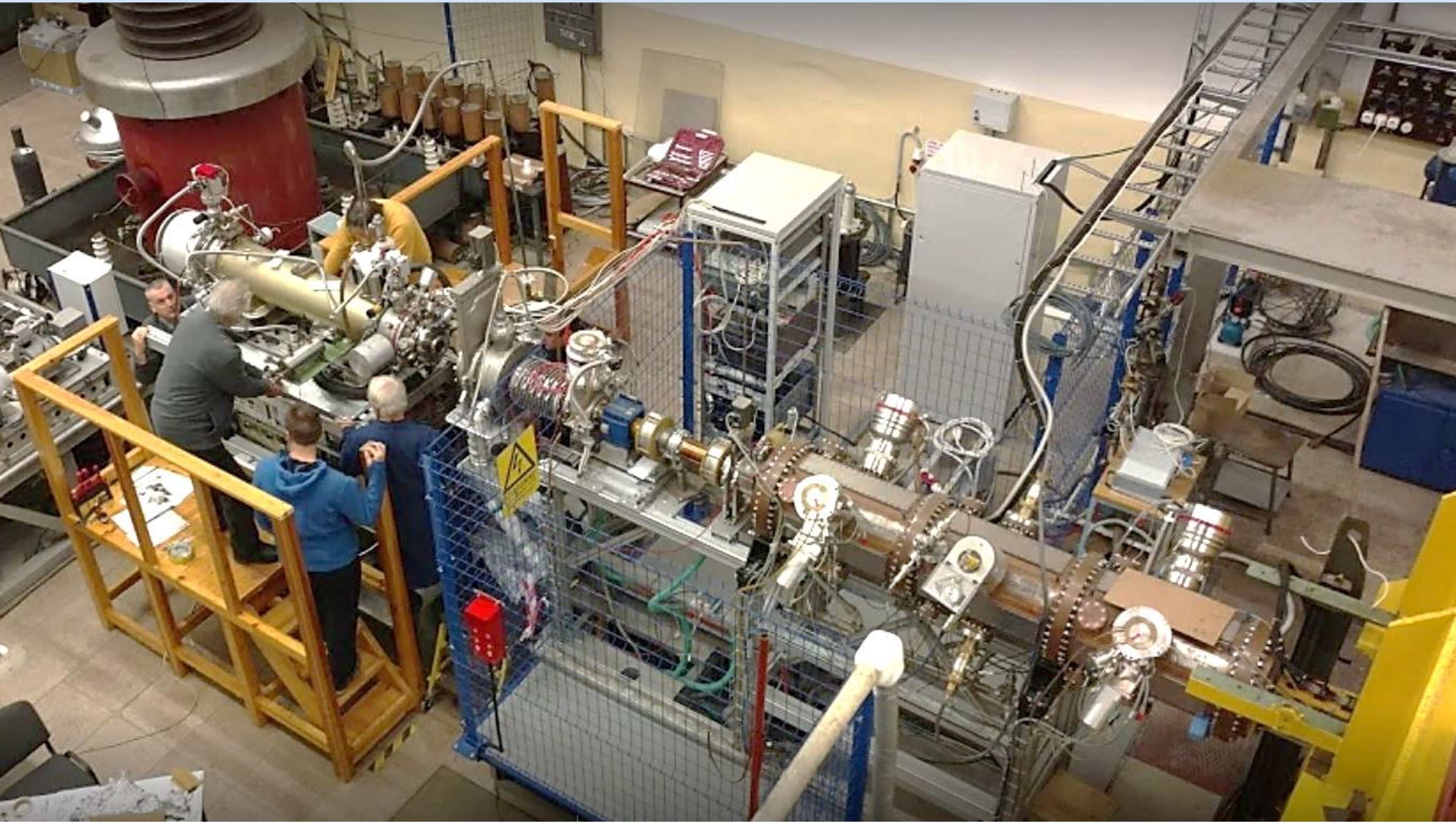
- 5.4 T SC solenoid
- E inj. up to 25 kV
- electron string
- cryogenic
- highly charged ions
- unique technology

55^{th} Nuclotron run, 2018



NICA injector

55th Nuclotron run (2018)



EBIS = Electron Beam Ion Source

History

•Invented by E.D. Donets at JINR,Dubna in 1968. Au^{19+} beam in 1969.

•1970-1985, in Dubna, cryogenic version of EBIS KRION-I,2, bare ions C, N, O, Ne, Ar, Kr, Xe. HCI physics begins.

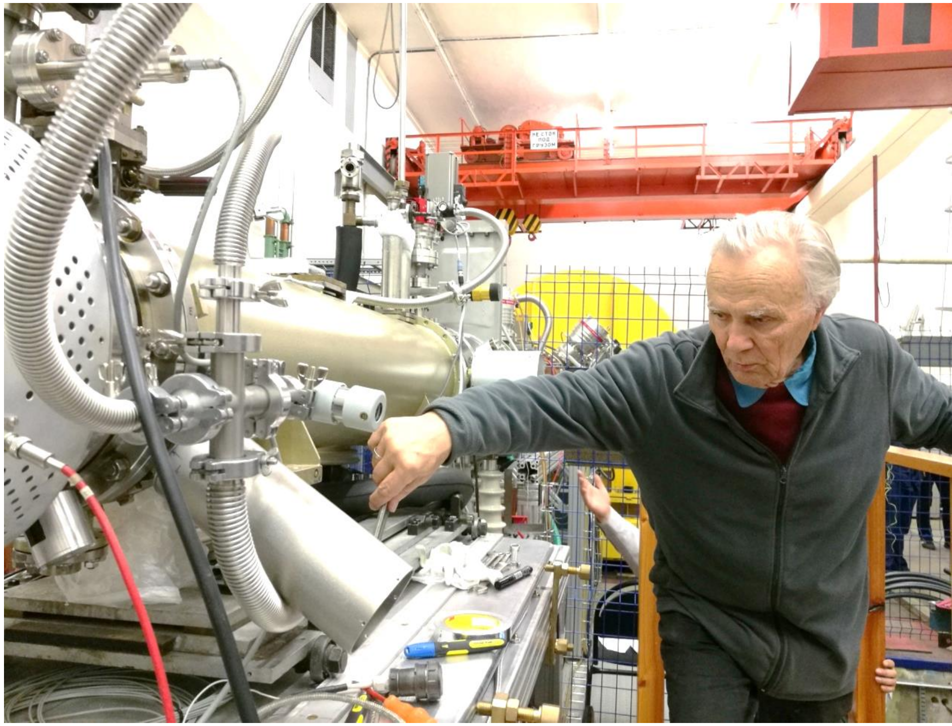
•1970-1985, Europe, US, Japan, a lot of EBIS (*EBIS time*), **U^{90+} !**

•1982, at Bekerley, EBIT, from EBIS, 1990s, SuperEBIT, U^{92+} !

•Since 1985, in accelerator fields, ECRIS time

•2001-2005, breakthrough of EBIS at JINR, new idea of ESIS, and high current EBIS at BNL.

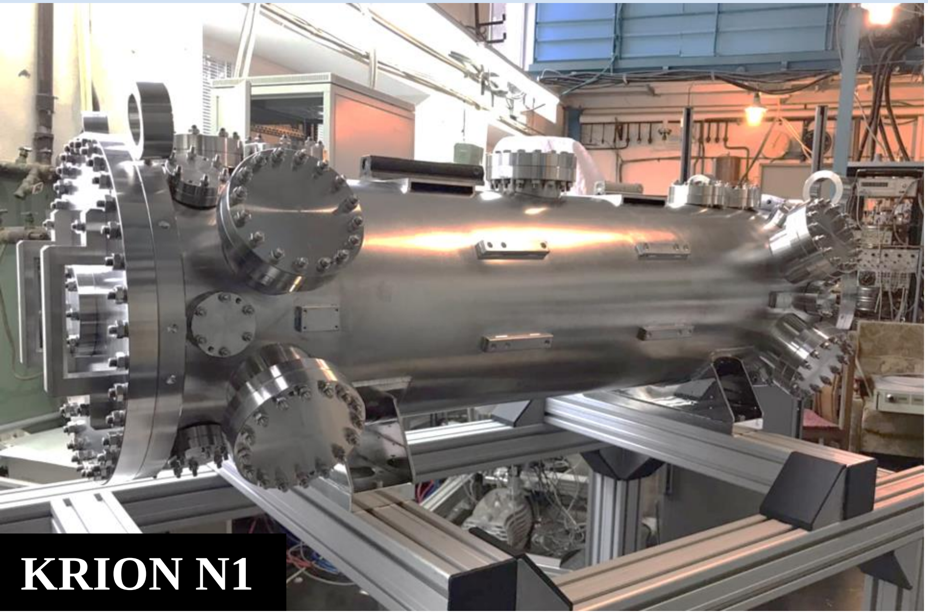
•In China, Shanghai EBIT



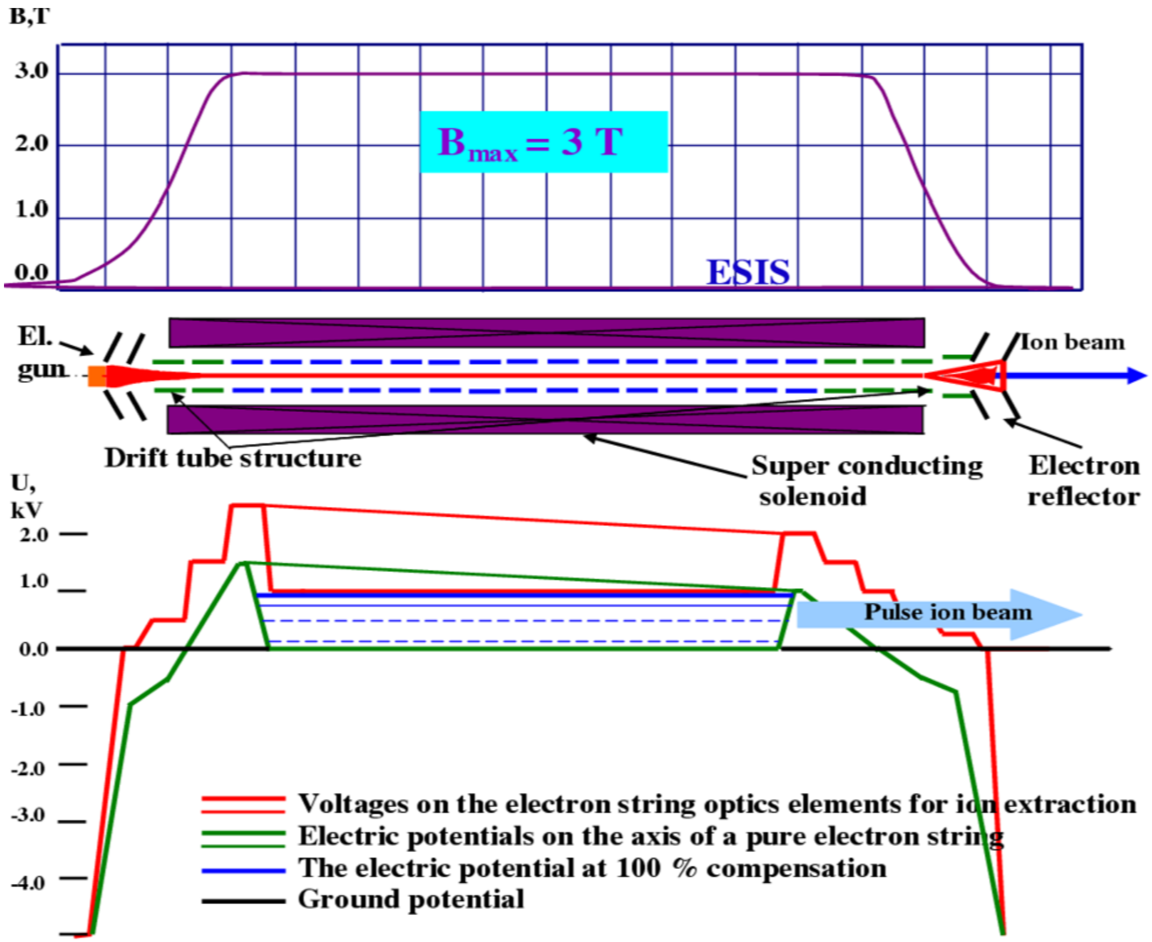
Prof. E.D. Donets near Krion-6T ESIS during Nuclotron run #55,
JINR, Dubna,
February 2018

• **ESIS Krion 6T and Krion N1 for NICA JINR**

EBIS = Electron Beam Ion Source



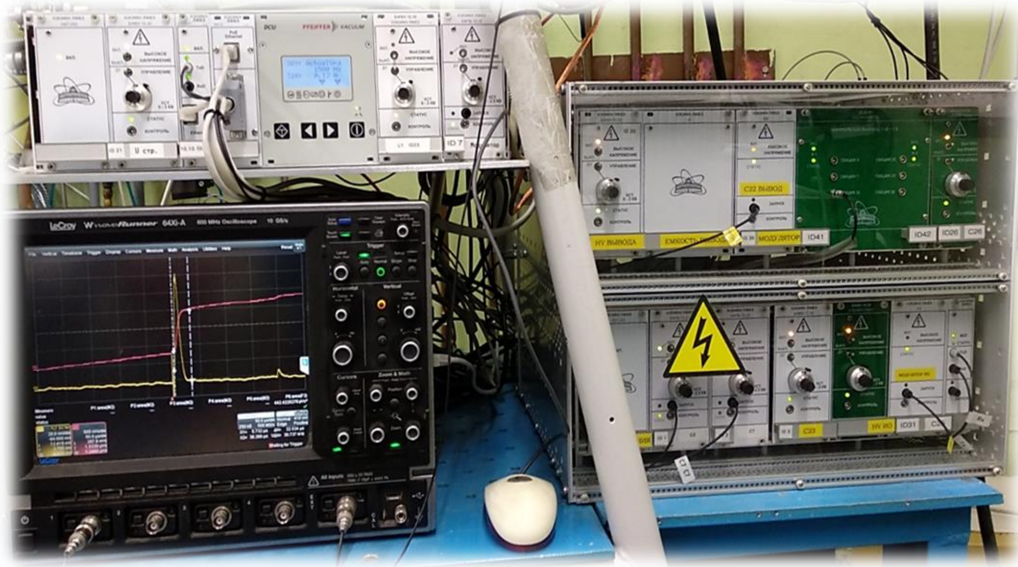
ESIS = EBIS in electron reflex mode of operation



ESIS KRION 6T electronics

Slow control

- vacuum
- ion optics supply
- HV electrodes
- electron gun supply
- Synchronization
- thermometry



Ion motion control system

- DC barrier modules
- pulsed barriers modules
- extraction modules
- interface modules
- drift structure divider

Beam diagnostics

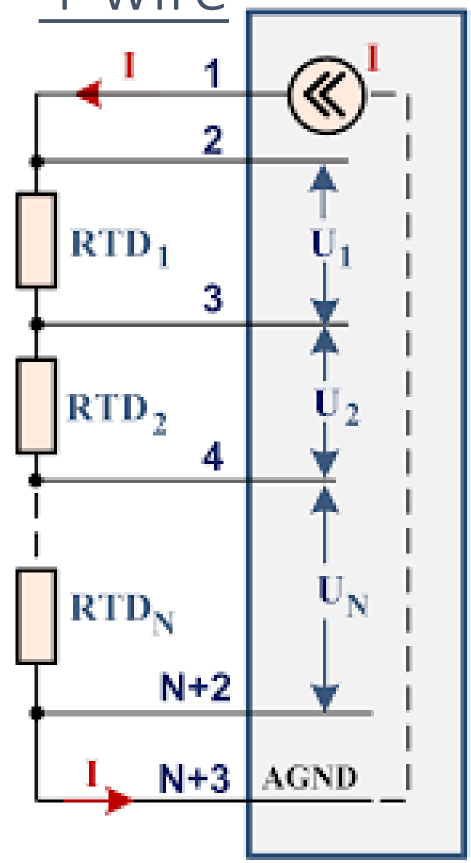
- beam profile monitor
- oscilloscopes
- ion collectors
- ToF system
- indused signals

Cryogenic measurements:

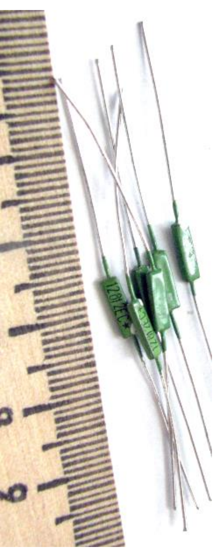
- cryogenic sensors (precision, stability)
- sensor wiring and connection

- meas. electronics
- current source
- signal shielding

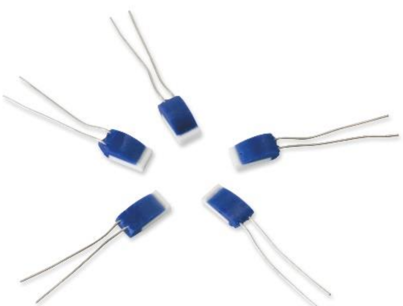
4-wire



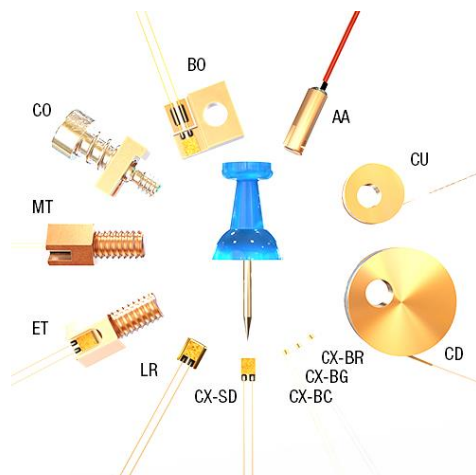
$U = IR, R = U/I$



TBO

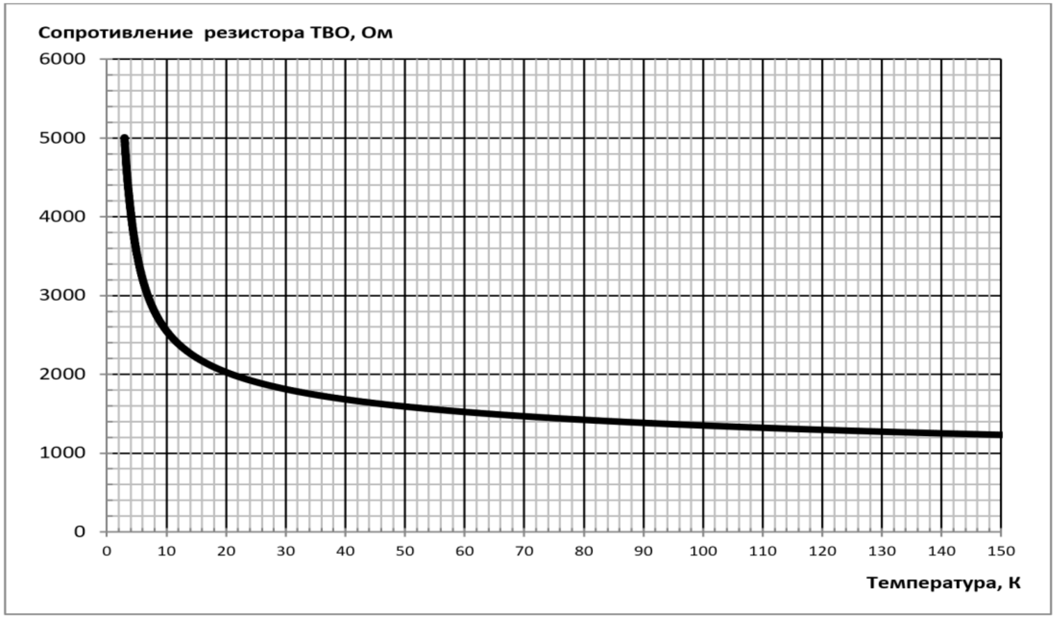


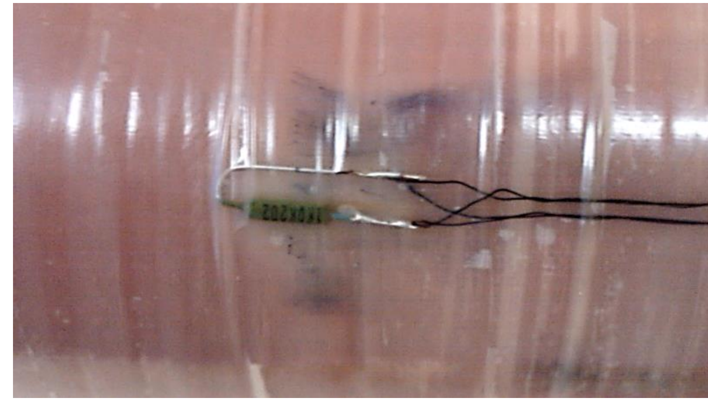
PT sensors

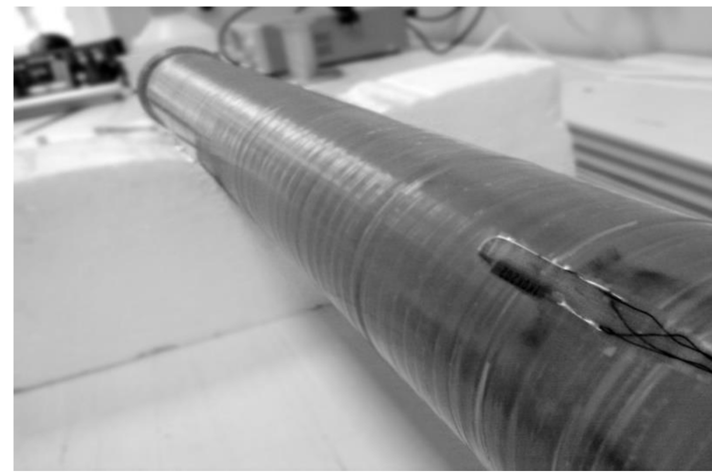


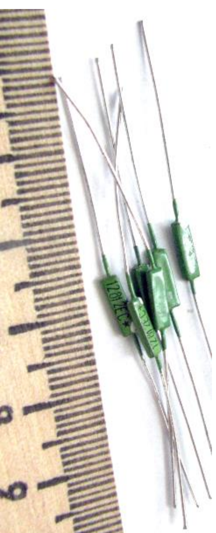
Cernox

Thermometry => superconducting solenoid







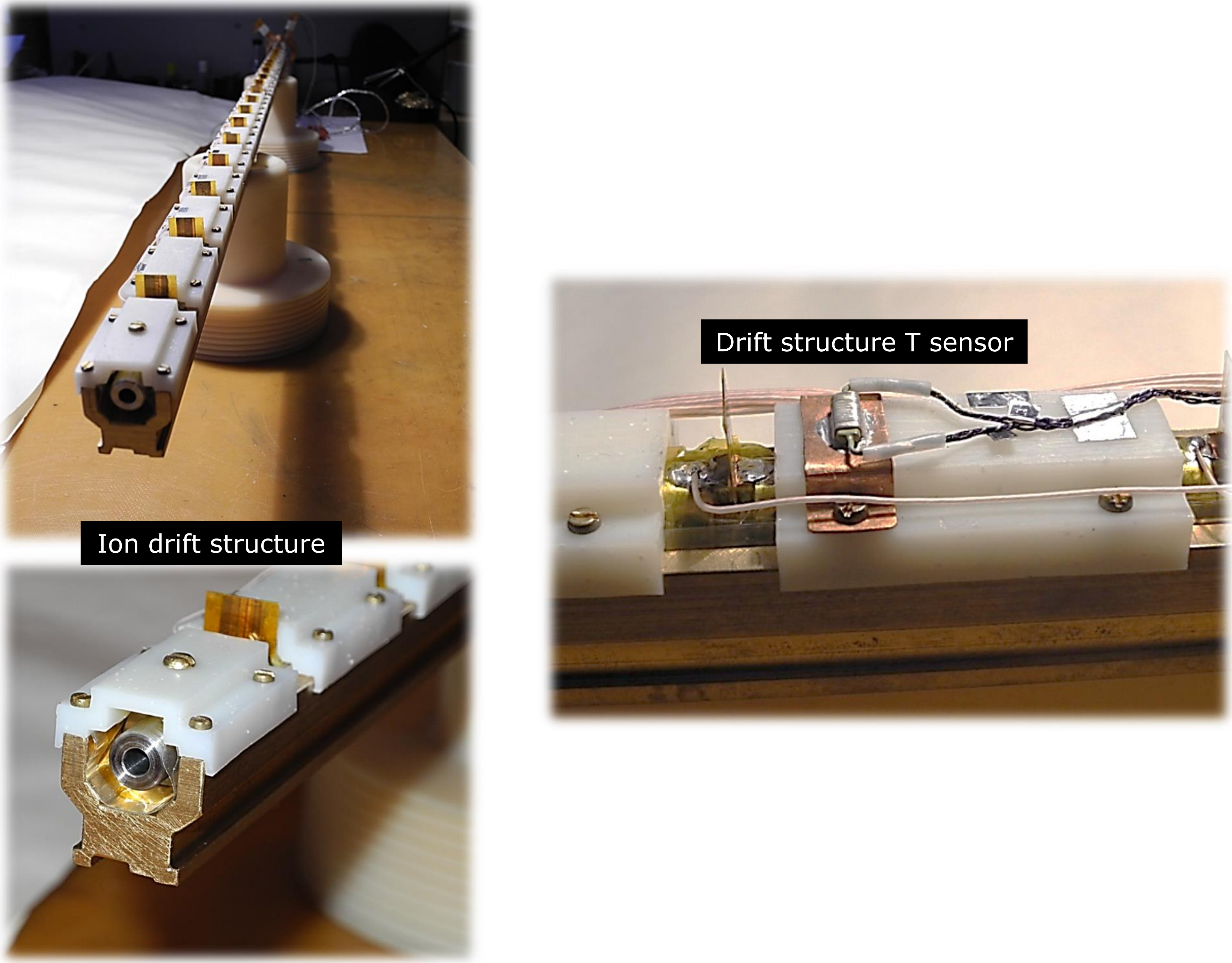


TBO* resistor:

- heat resistant
- moisture resistant
- volume

$$T = \sum_{n=1}^{m} K_n \cdot \left(\frac{R_0}{R_t} \right)^{n-1}$$

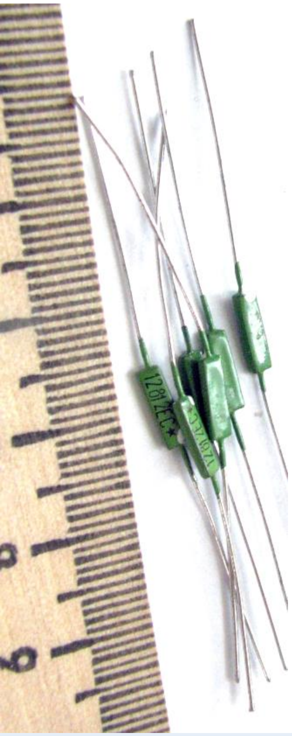
KRION 6T
superconducting solenoid
T sensor


Ion drift structure
Drift structure T sensor

Slow control => thermometry

TBO* resistor:

- heat resistant
- moisture resistant
- volume

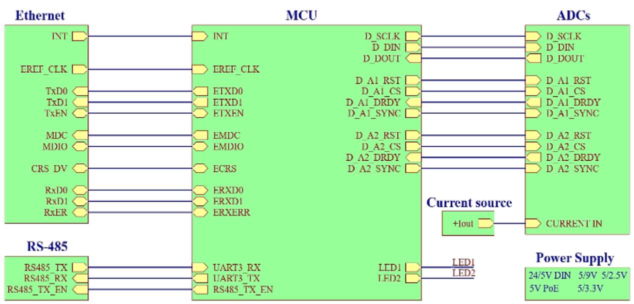


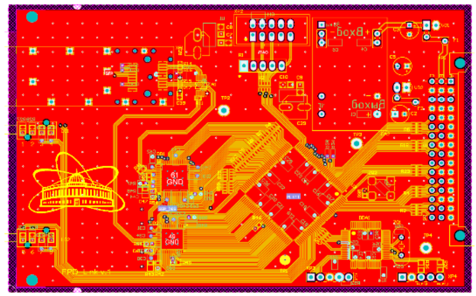
Measurement scale	4 - 300 K
Accuracy	± 0,3* % in 30 K range
Channels	N * 8
ADC resolution	24 bit
Current source	10/100/1000 uA

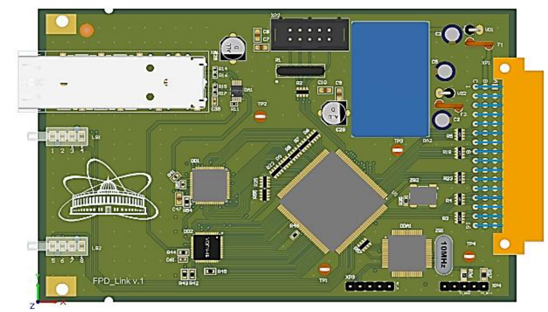
Advantages

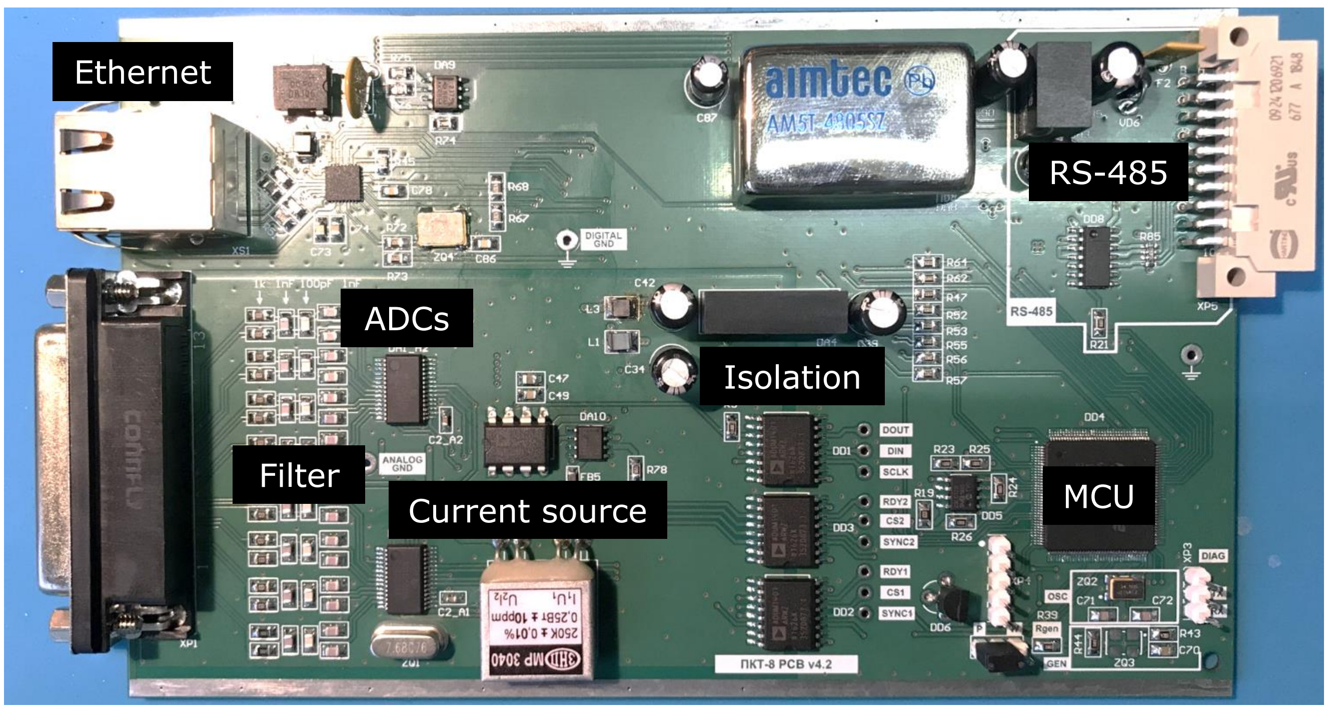
- PoE: less wires needed
- precision
- Modbus RTU/over TCP
- modular (3U case)
- robust & cost-effective
- on-board current source

The design process



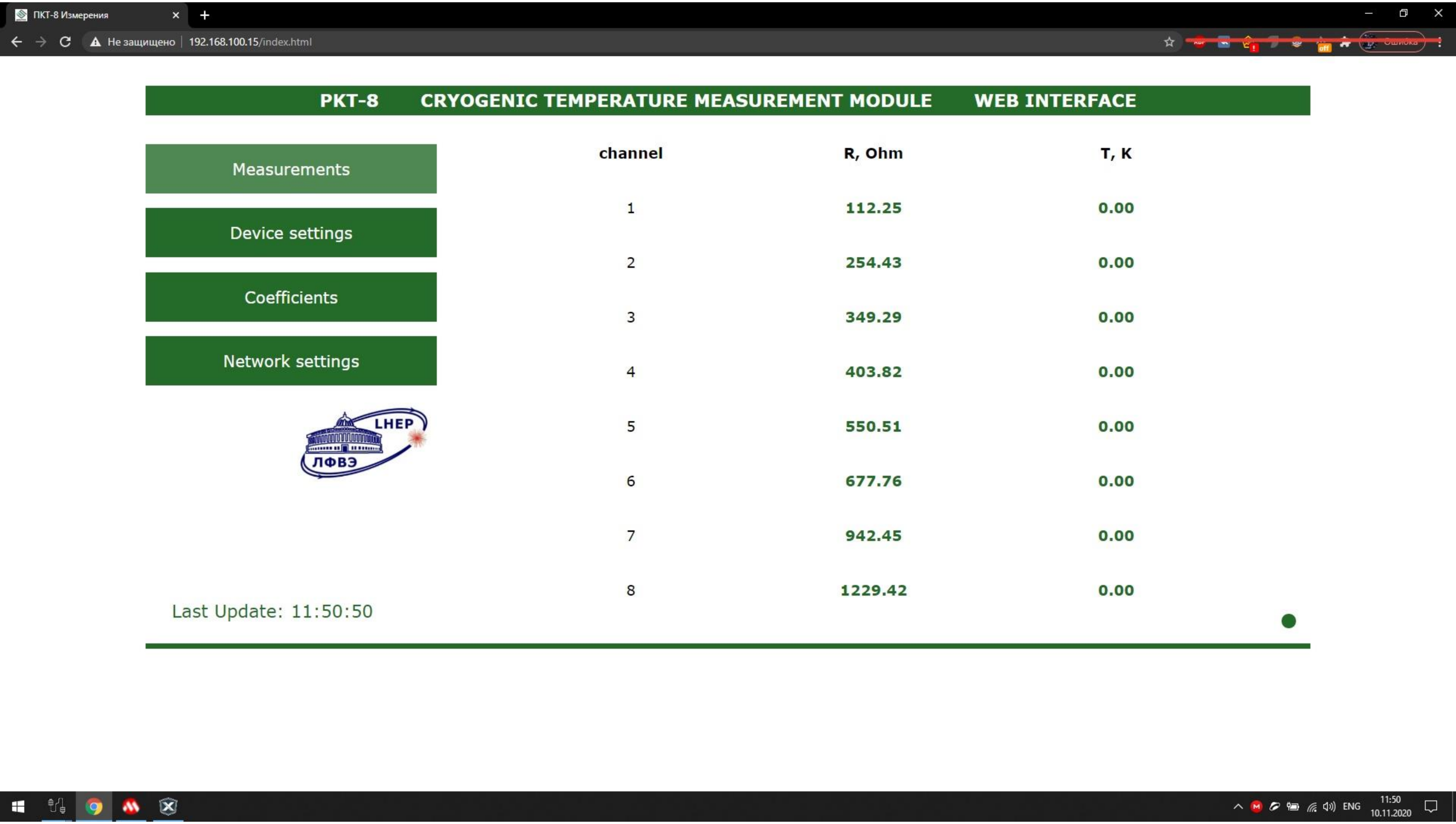


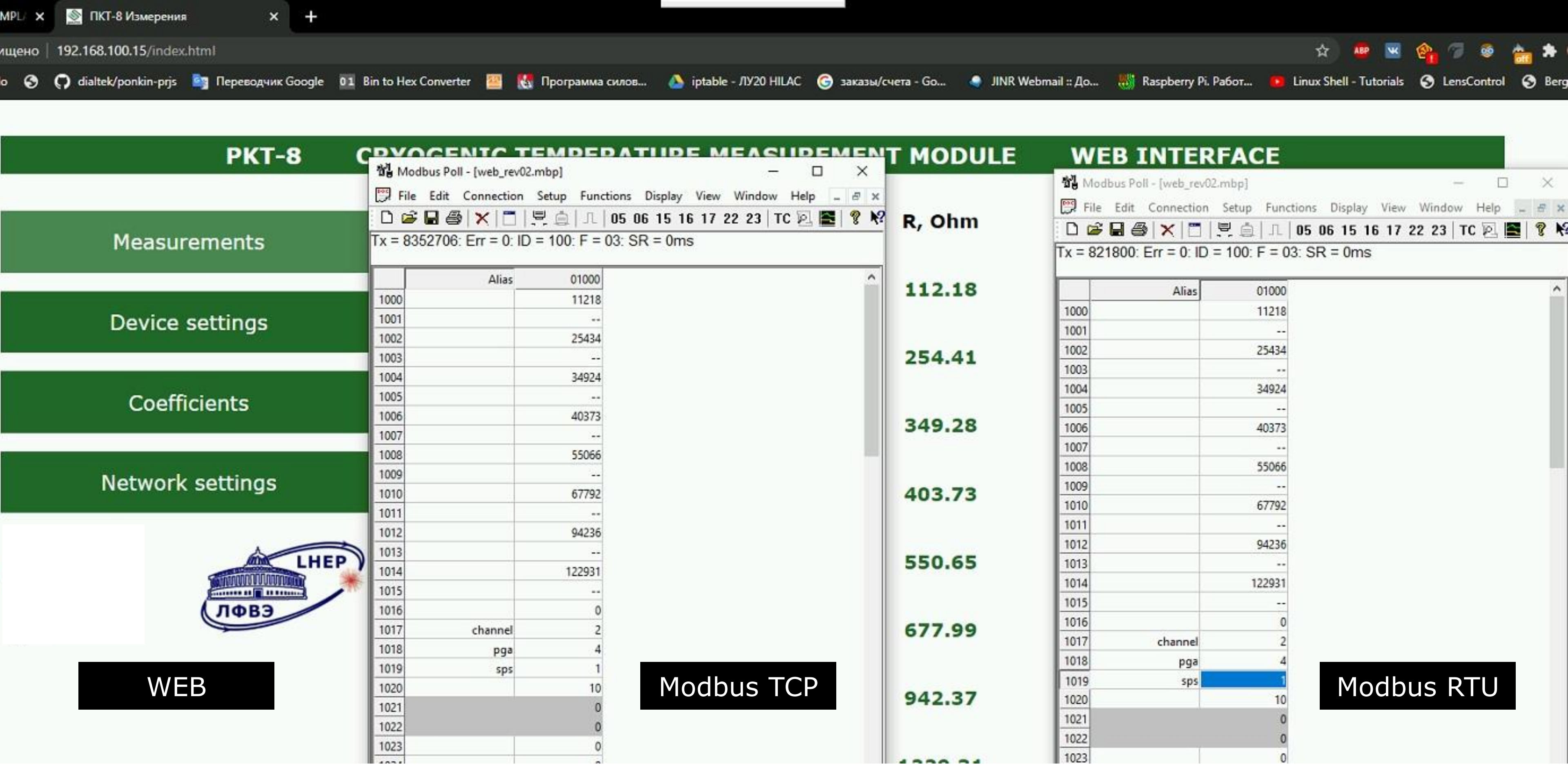




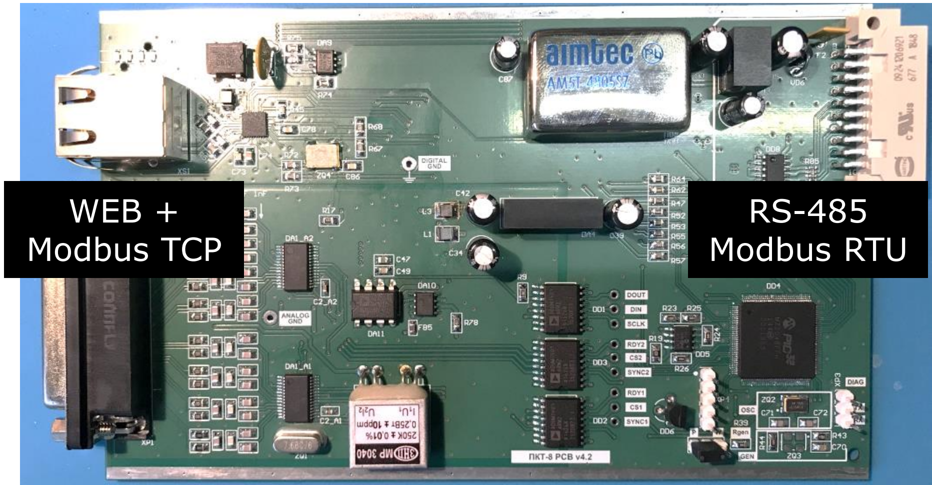
«Cool» resistor

The embedded system **web interface**

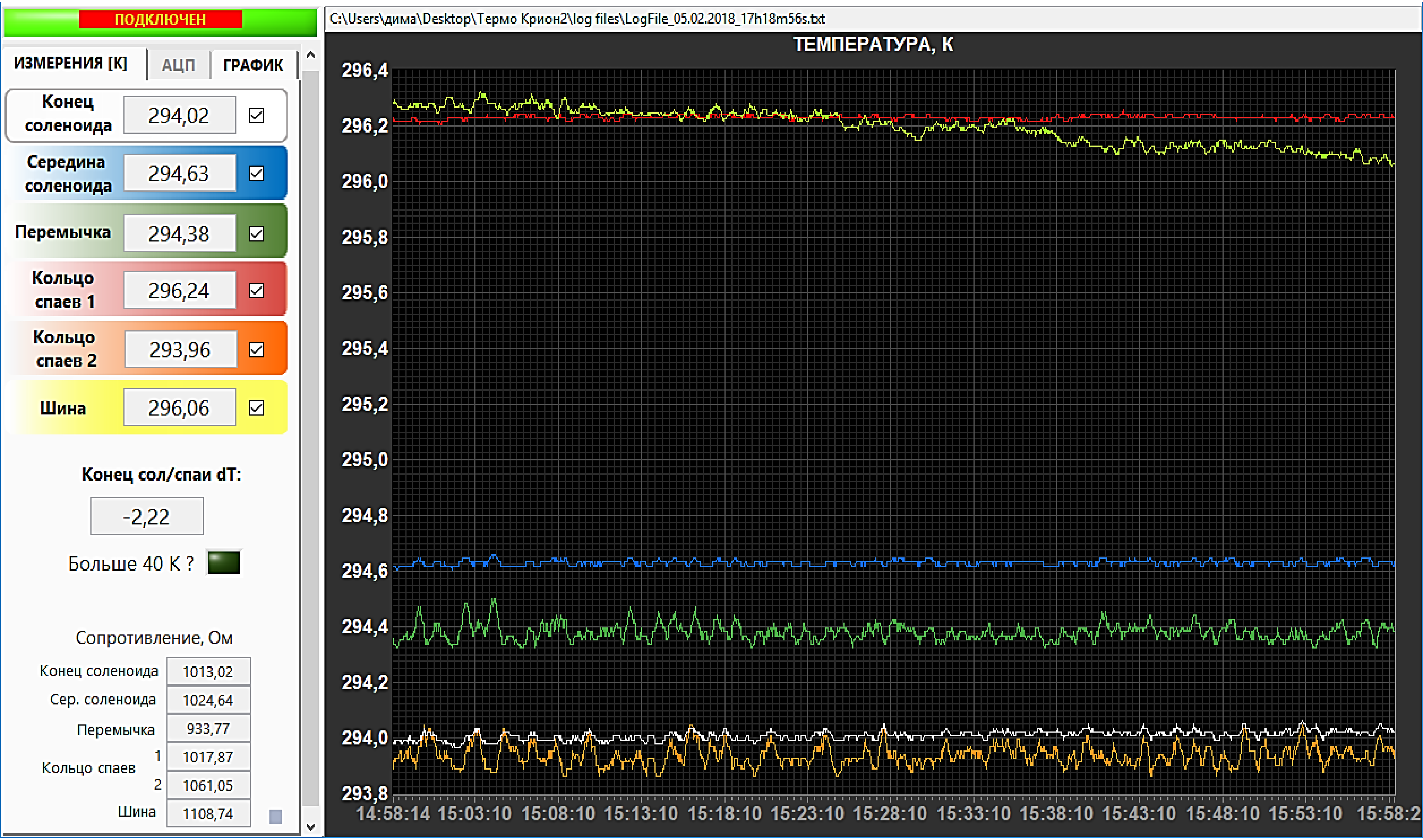




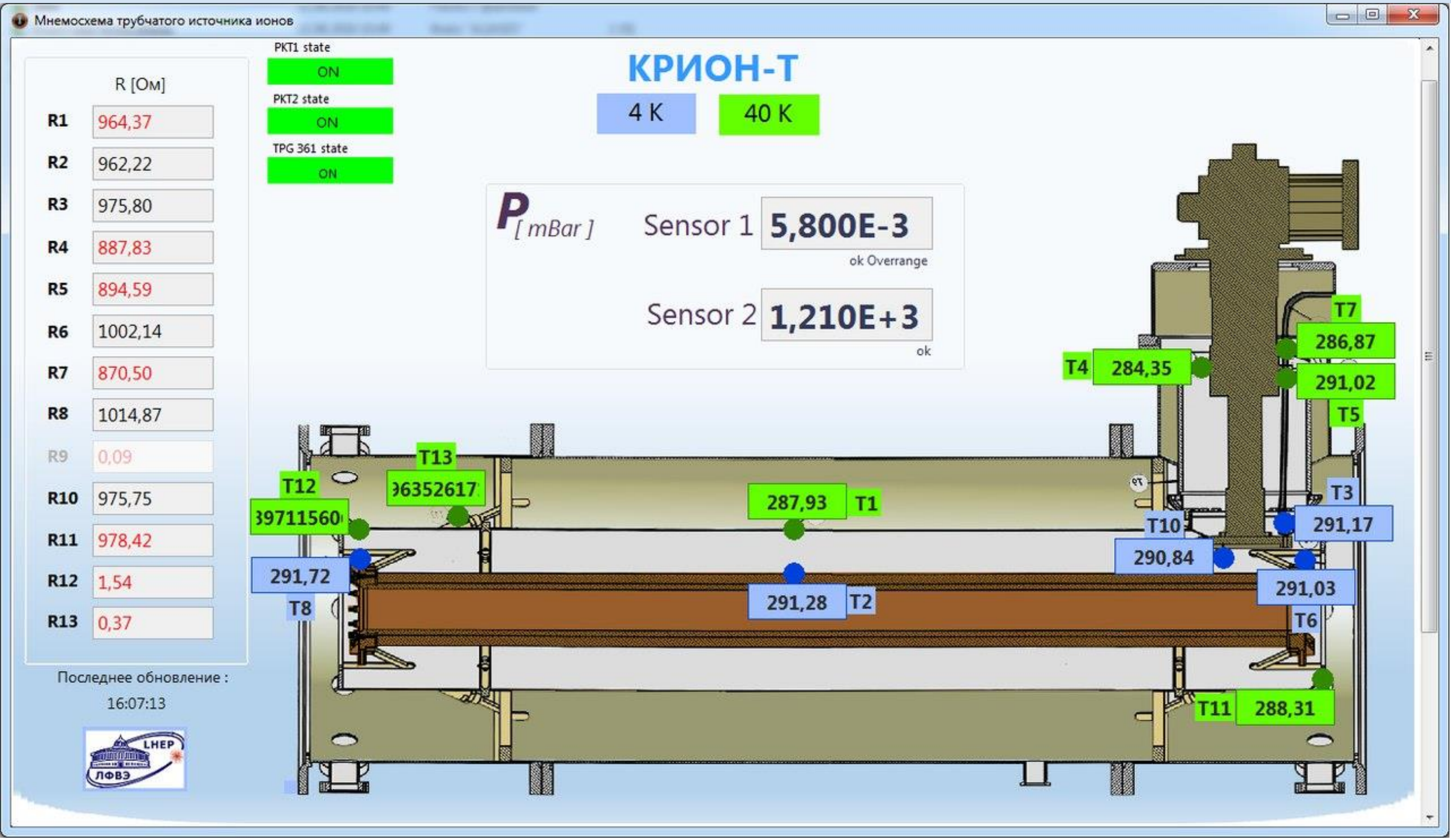
Web interface + Modbus



Slow control => thermometry

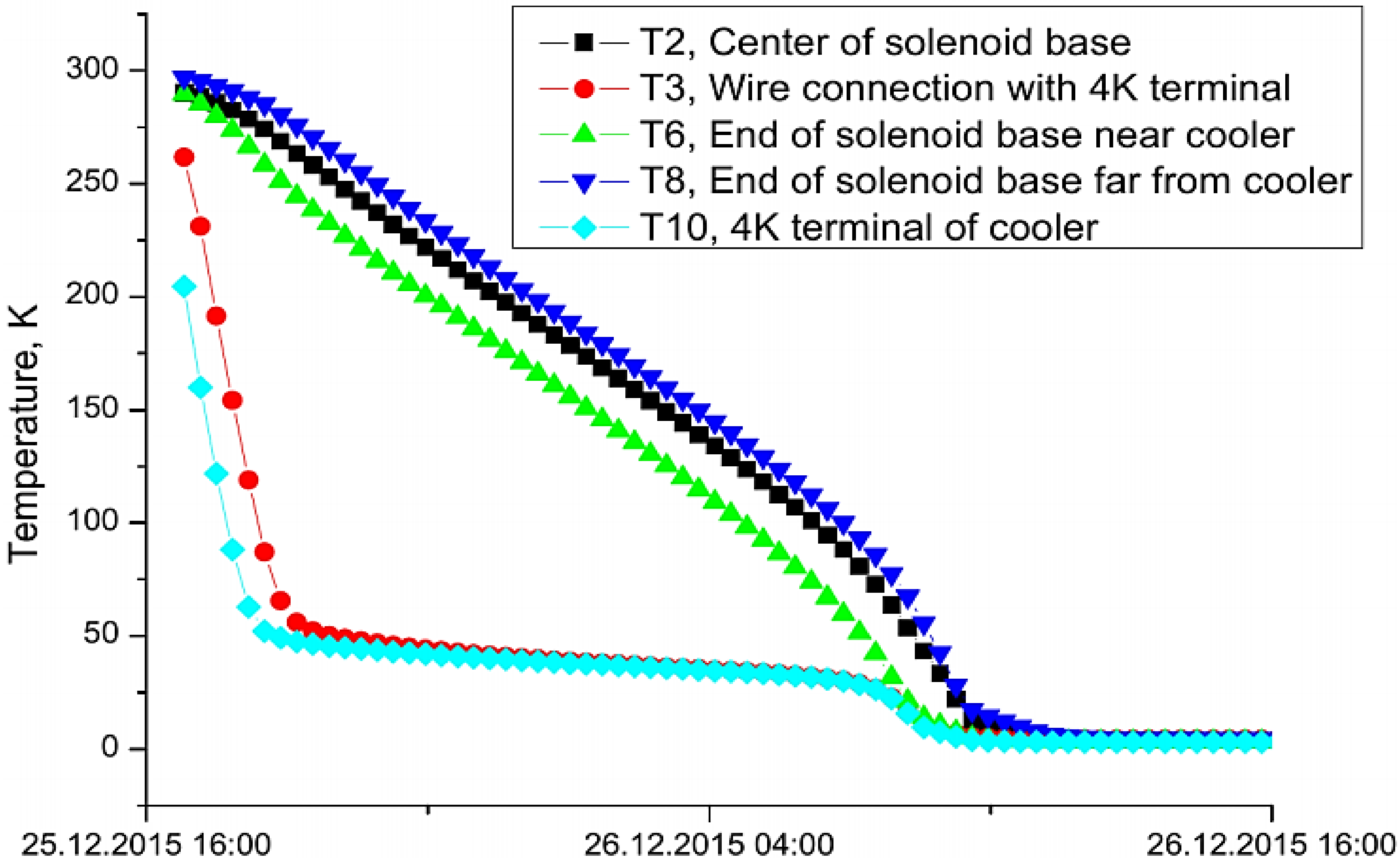


Slow control => thermometry



https://www.tango-controls.org/

Slow control => thermometry

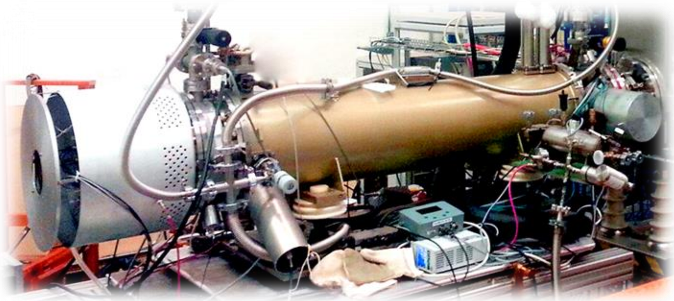


Summary

- ESIS Krion 6T successfully produced beams for the Nuclotron runs in 2014 and 2018, all the electronic systems were developed and works fine
- The thermometry system including electronics, sensors, wiring etc is a complicated system. It is complex and interesting
- The designed electronics is a powerful device with, can be used in other parts of the accelerator complex
- The design is done by a young engineers group, it has 2 diploma work and several study practices
- We are ready for the new designs
- We can offer the device for your cryogenic or precision meas.

problem:

unique facilities => unique electronics*



JINR

We are ready for collaboration in any technical questions

email: **ponkin@jinr.ru**

Thank you!

7. KRION-6T on the test bench

Specifications of KRION-6T

Length of the superconducting solenoid	1,2 m
Number of layers	24 layers
Induction	~10 H
Current in the solenoid	90 A (105 A planned)
Field on the axis in the middle (Bmax)	5,4 T (6T planned)
Length of the main ion trap	1 m
Maximum energy of the electrons	10 keV (11,5 keV with trap potential lift)
Emitter material	IrCe
Electron current from the gun	up to 30 mA
Capacity of the ion trap	up to 22 nC

8. Results achieved on the test bench

- the **jτ** ionization factor is the most important value giving information about the performance of the ESIS
- impossible to measure directly the electron string current, but possible to measure **effective jτ,** using the extracted ions spectrum.

Ion specious	Effective electron string current density **j**, A/cm^2
Kr^{15+}	665
Kr^{18+}	591
$Kr^{24,6+}$	847
$Xe^{23,2+}$	1090
$Xe^{24,9+}$	1579
$Xe^{25,4+}$	1587
$Tm^{40,8+}$	1092

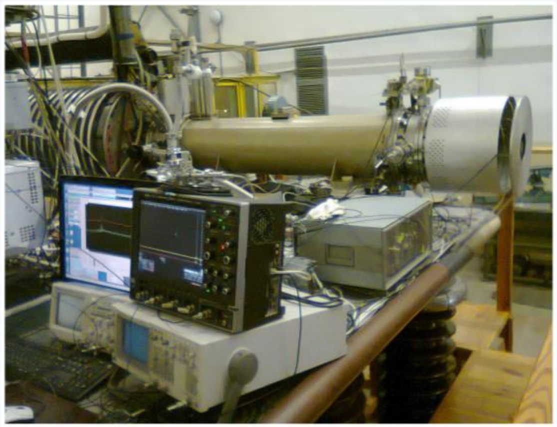
Examples of number of particles per pulse and times of ionization for different ions

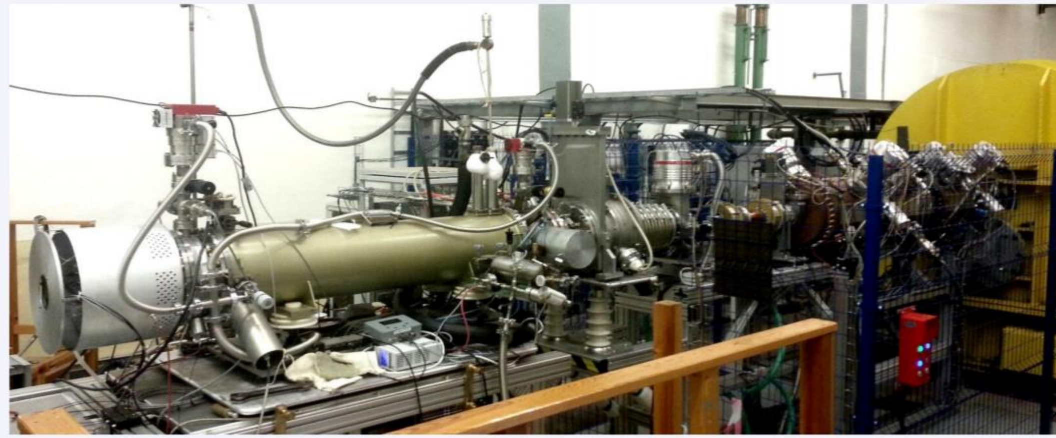
C^{4+}	$7x10^9$	-
Xe^{42+}	$5x10^9$	350 ms
Xe^{32+}	-	40 ms
Tm^{50+}	$3x10^7$	-
Au^{33+}	-	30 ms

The new KRION-6T ion source has much higher effective **j** (up to 1600 A/cm^2) in comparison with the KRION-2 which had only 200 A/cm^2. Another typical EBIS devices have only 100 - 300 A/cm^2.

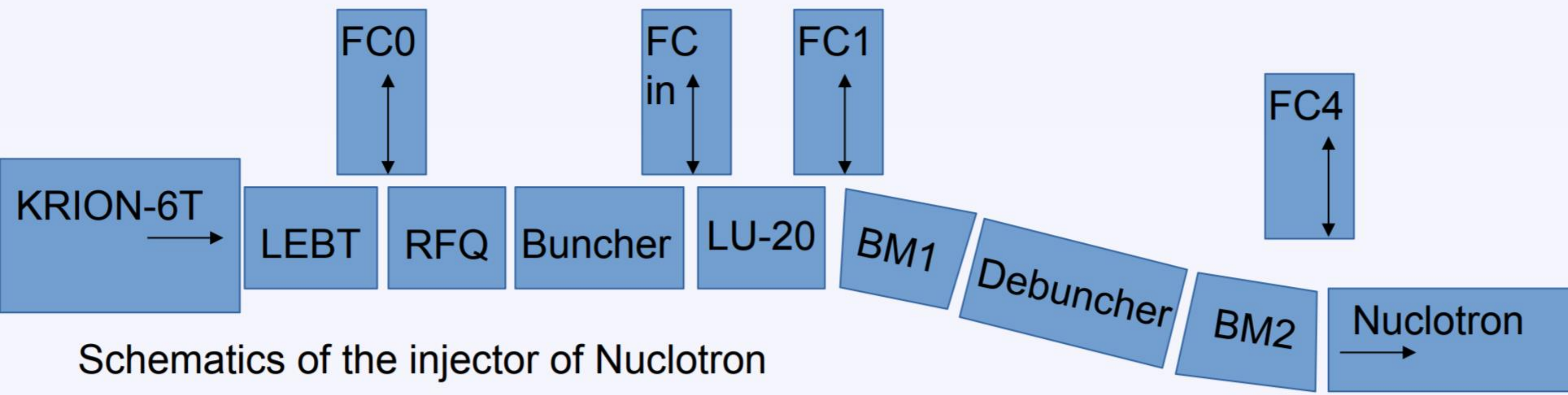
9. KRION-6T connected to the accelerator

- First time KRION-6T was in operation at Nuclotron at 50th run in May-June 2014
  The intensity of the Ar^{16+} beam was $3{,}9x10^7$ ppp.





KRION-6T on the high voltage platform of the LU-20



Schematics of the injector of Nuclotron