



# Development of the Electron string ion sources thermometry systems

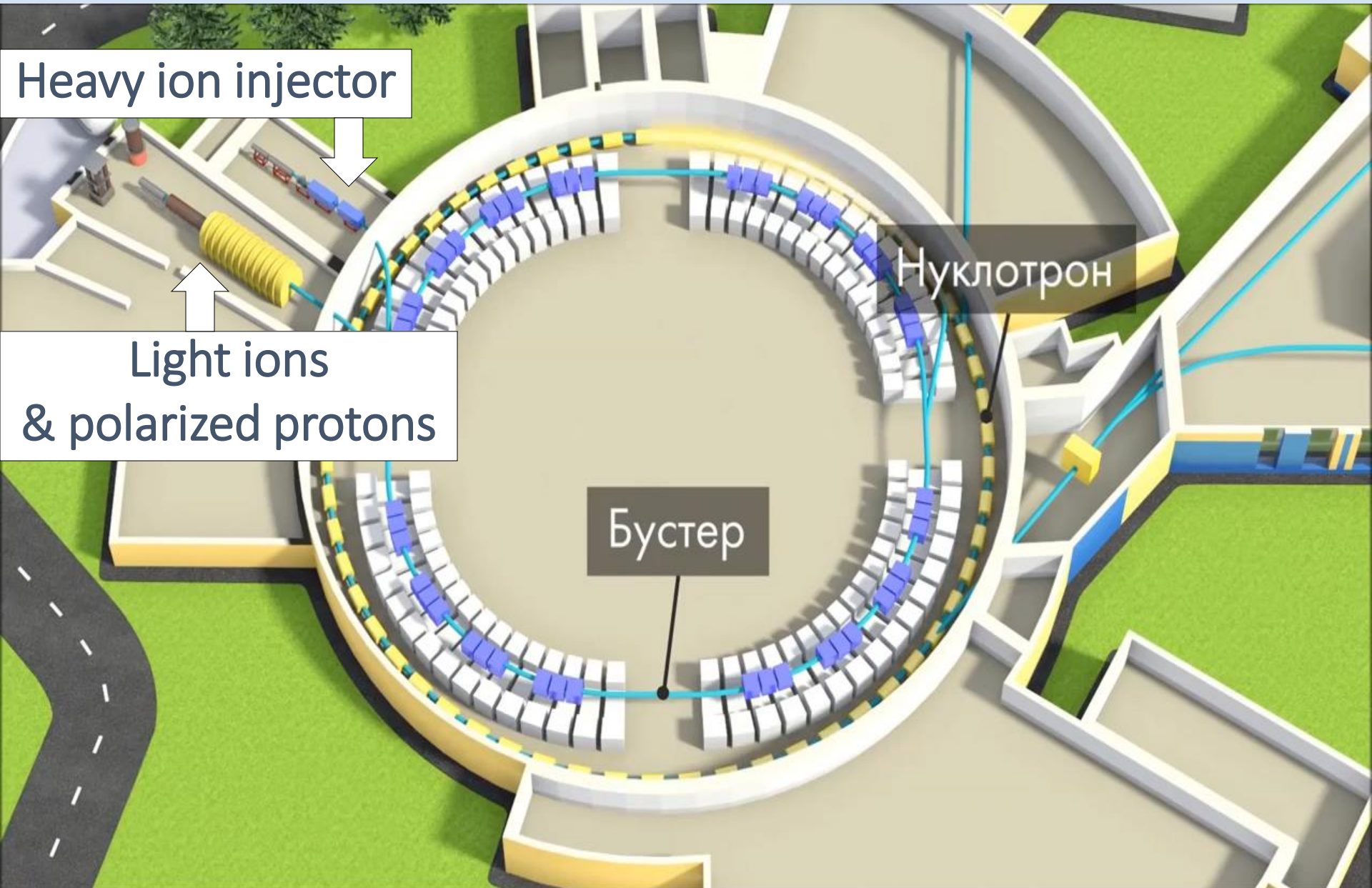
Ponkin Dmitry

LHEP JINR senior engineer

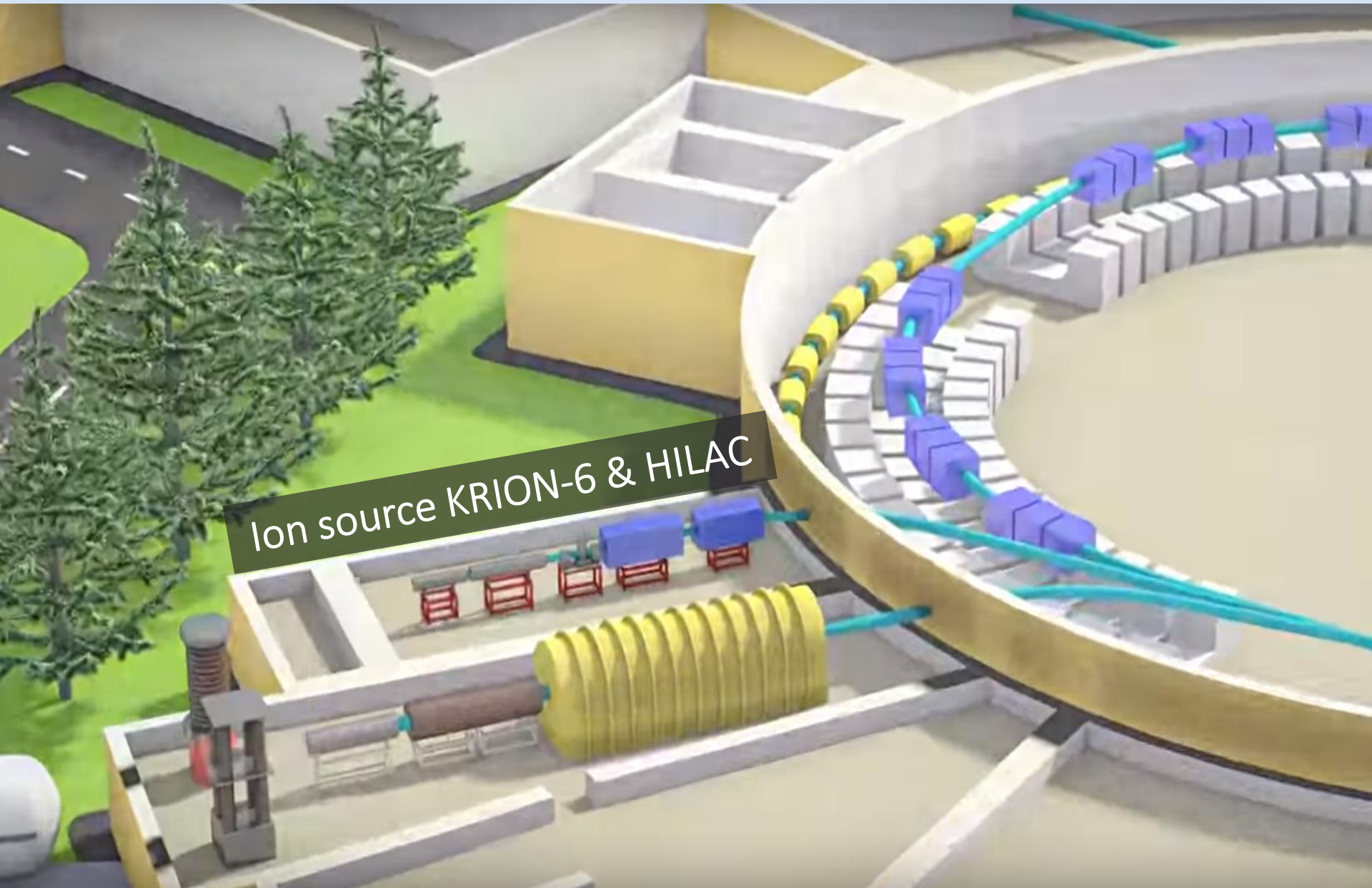
on behalf of the NICA acceleration division

Dubna, 9-13 November 2020

# NICA injection complex

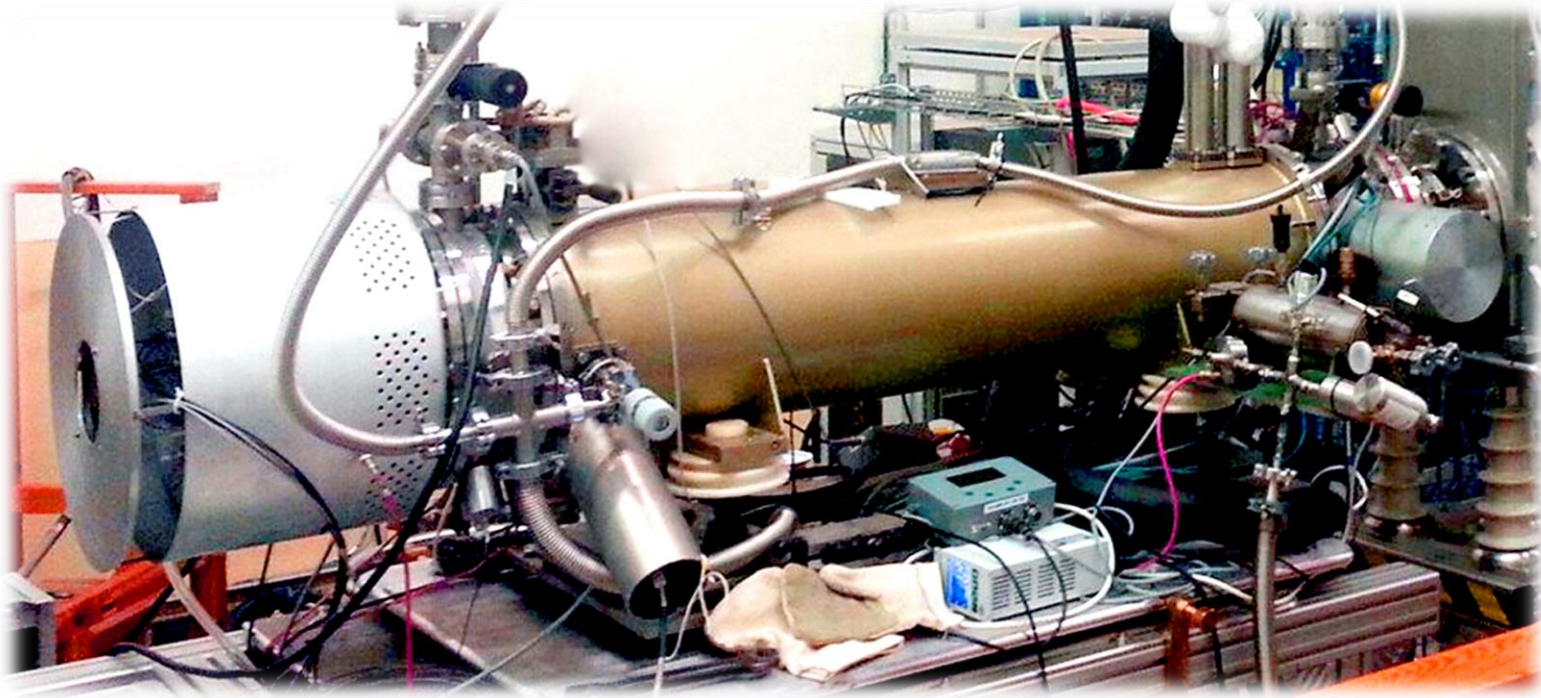


# Heavy ion injection





# Heavy ion source KRION 6T



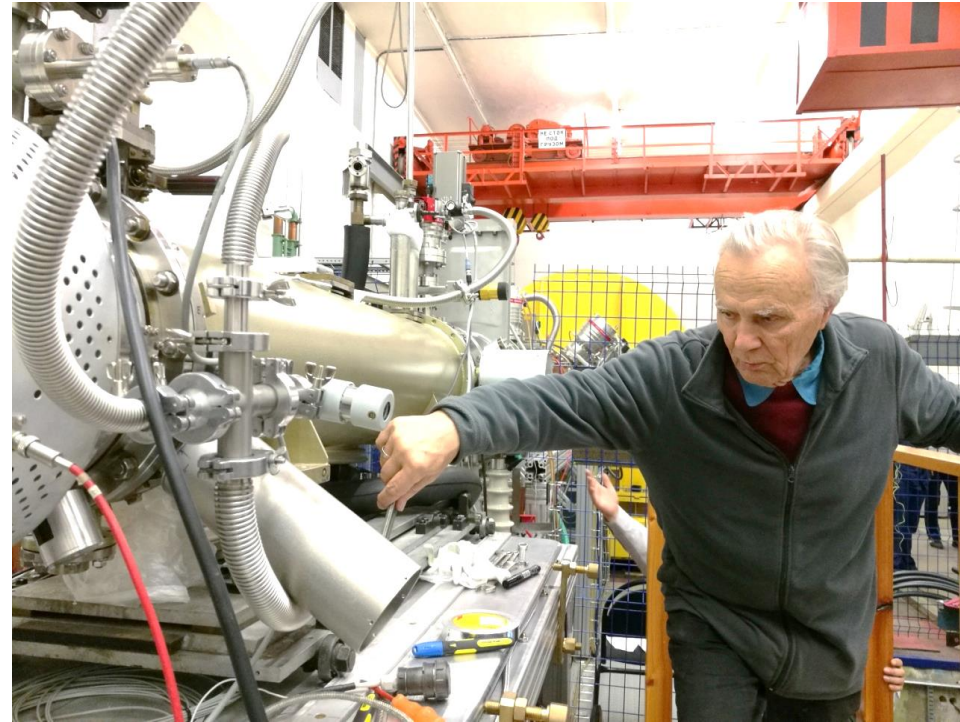
Ions produced and injected:  $^{78}\text{Kr}^{17+}$   $^{124}\text{Xe}^{41+}$   $^{40}\text{Ar}^{16+}$   $^{12}\text{C}^{6+}$

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

# EBIS = Electron Beam Ion Source

## History

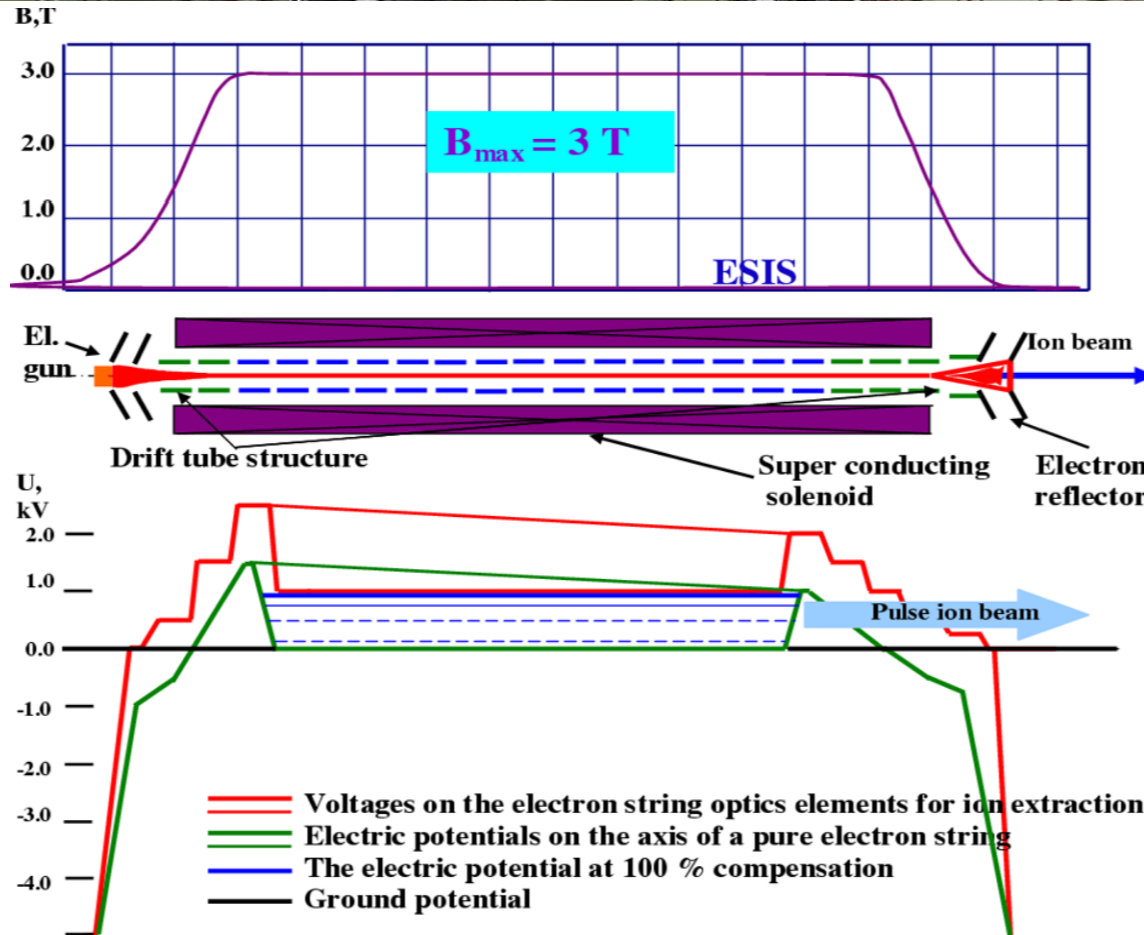
- Invented by E.D. Donets at JINR, Dubna in 1968. Au<sup>19+</sup> beam in 1969.
- 1970-1985, in Dubna, cryogenic version of EBIS KRION-I,2, bare ions C, N, O, Ne, Ar, Kr, Xe. HCI physics begins.
- 1970-1985, Europe, US, Japan, a lot of EBIS (*EBIS time*), U<sup>90+</sup> !
- 1982, at Bekerley, EBIT, from EBIS, 1990s, SuperEBIT, U<sup>92+</sup> !
- 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**

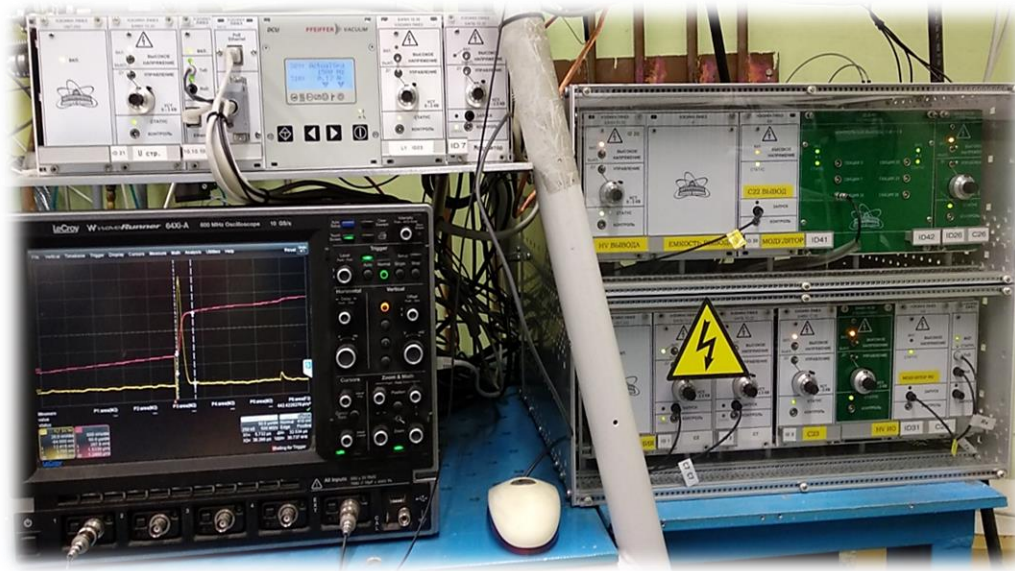
# ESIS = EBIS in electron reflex mode of operation





# ESIS KRION 6T electronics

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



## Ion motion control system

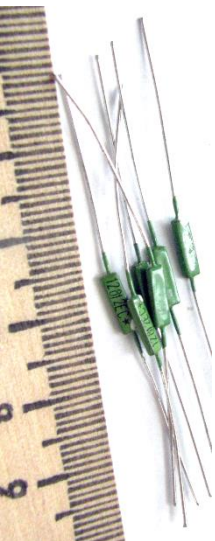
- DC barrier modules
- pulsed barriers modules
- extraction modules
- interface modules
- drift structure divider

## Beam diagnostics

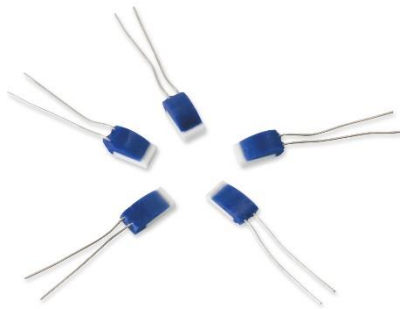
- beam profile monitor
- oscilloscopes
- ion collectors
- ToF system
- induced signals

# Cryogenic measurements:

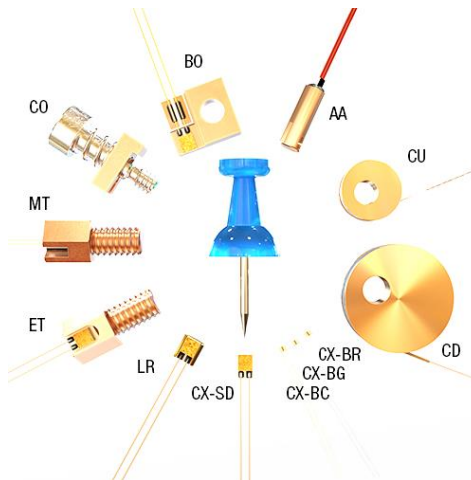
- cryogenic sensors (precision, stability)
- sensor wiring and connection
- meas. electronics
- current source
- signal shielding



TBO

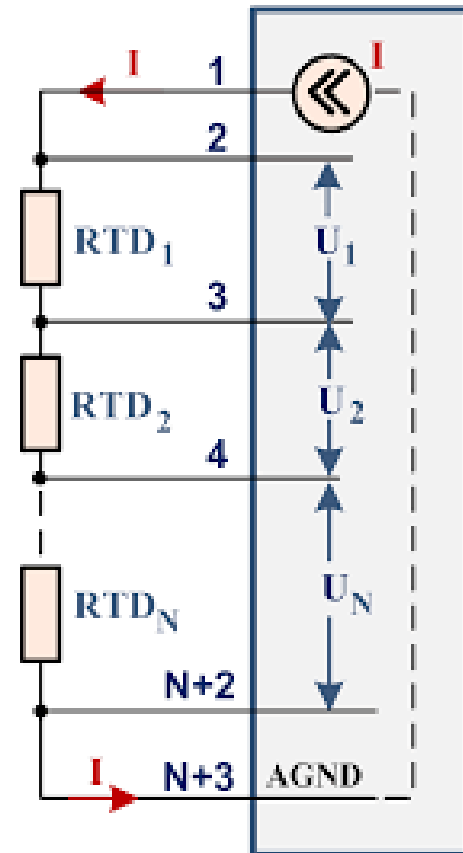


PT sensors



Cernox

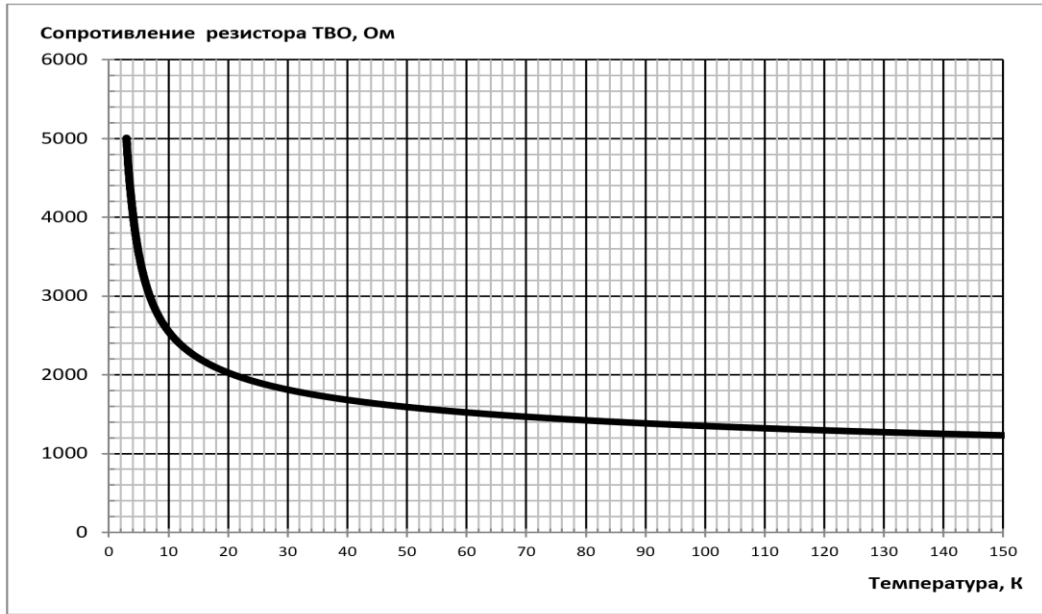
## 4-wire



$$U = IR, R = U/I$$



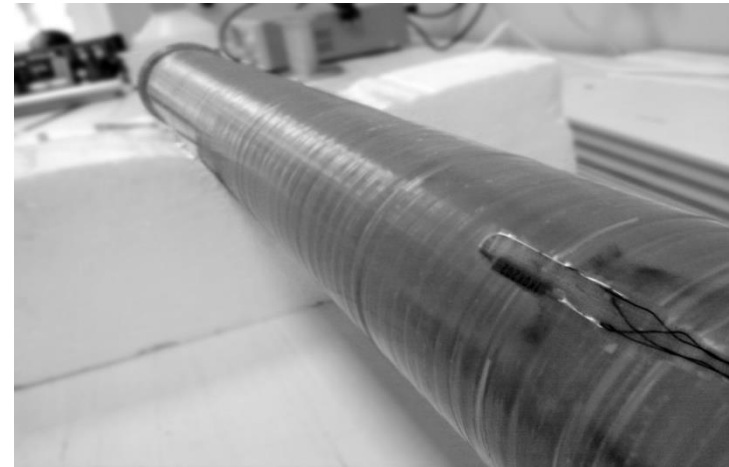
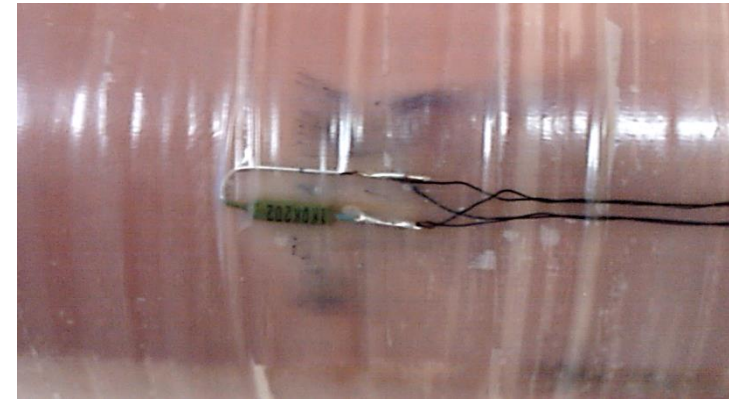
# Thermometry => superconducting solenoid



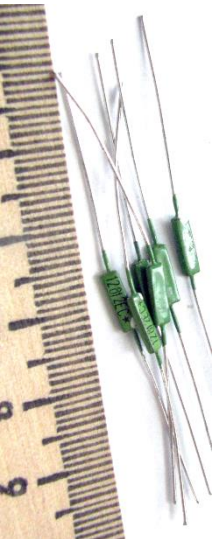
TBO\* resistor:

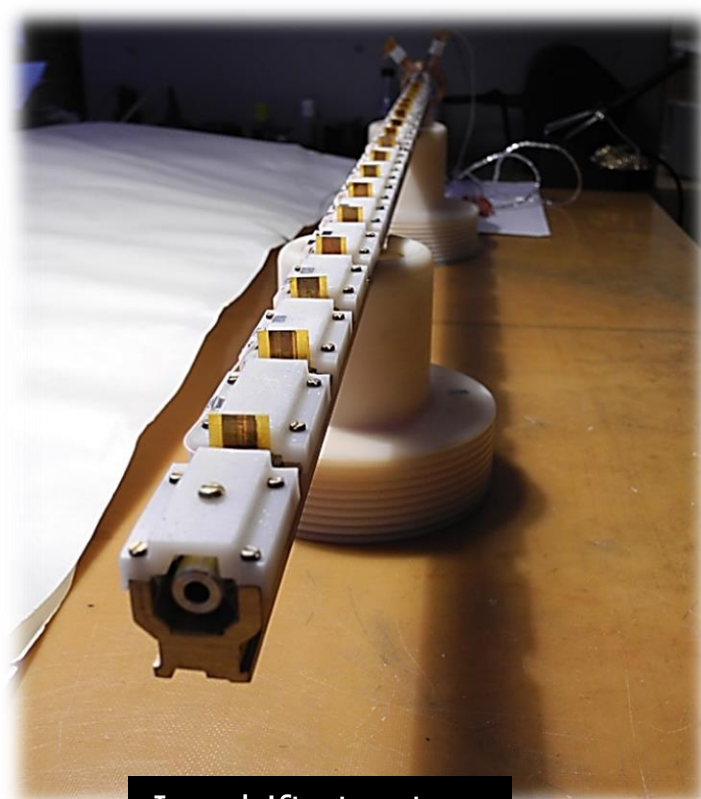
- heat resistant
- moisture resistant
- volume

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

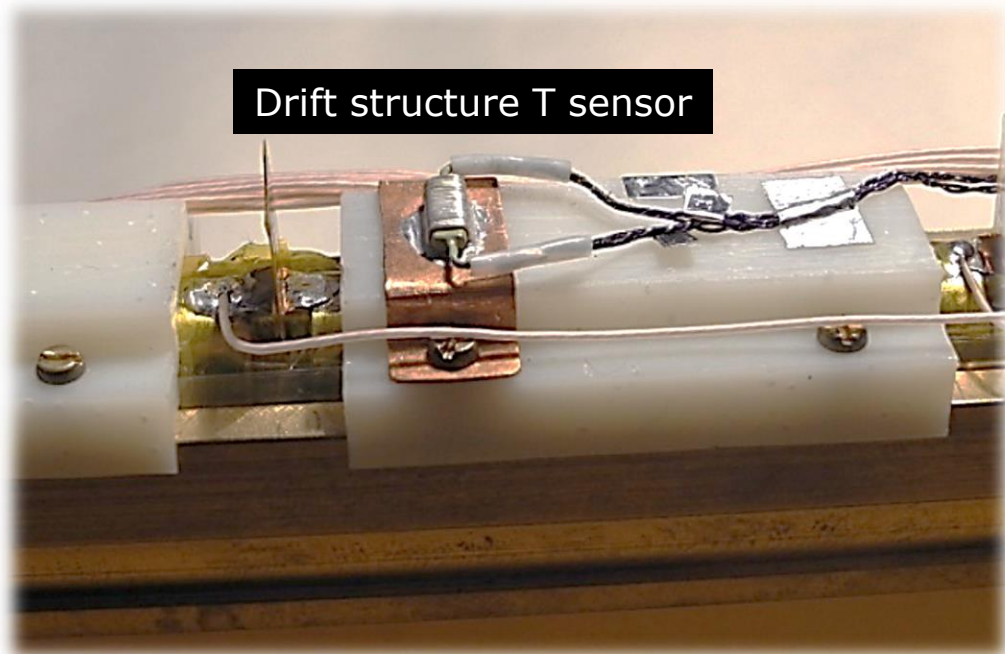
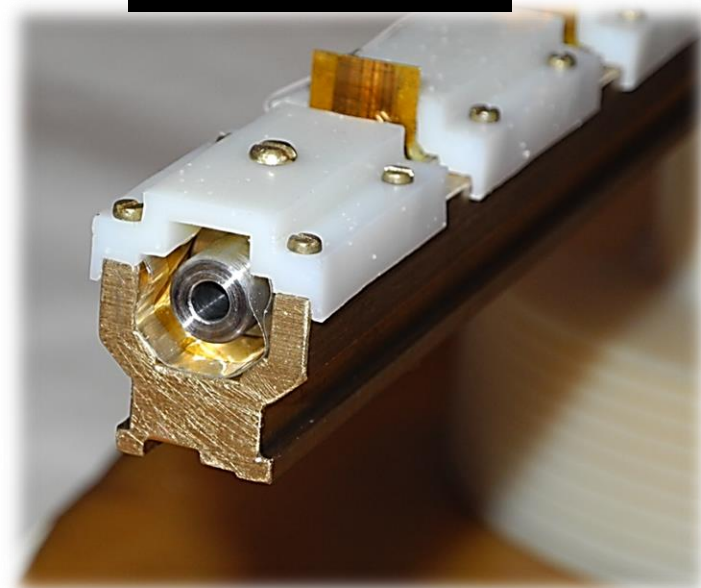


KRION 6T  
superconducting solenoid  
T sensor





Ion drift structure

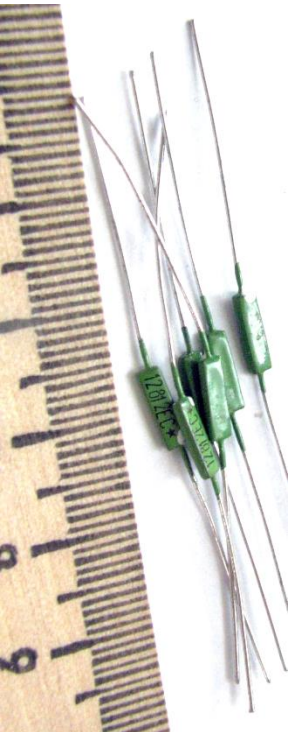


Drift structure T sensor

# Slow control => thermometry

TBO\* resistor:

- heat resistant
- moisture resistant
- volume



Measurement scale	4 - 300 K
Accuracy	$\pm 0,3^* \%$ in 30 K range
Channels	$N * 8$
ADC resolution	24 bit
Current source	10/100/1000 $\mu$ A

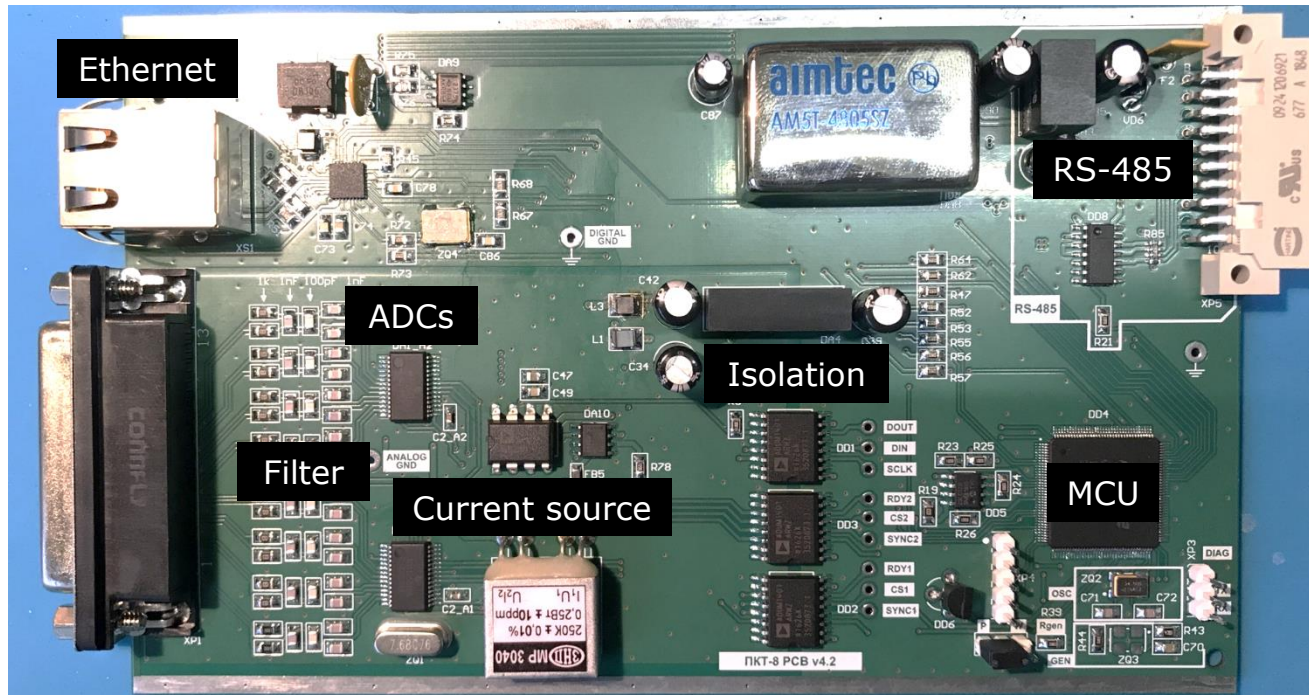
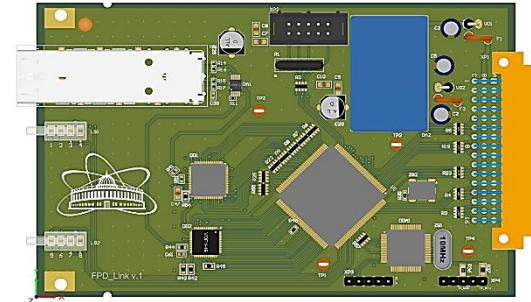
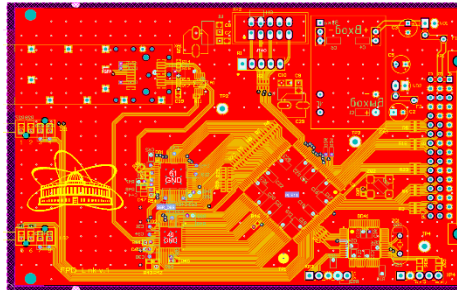
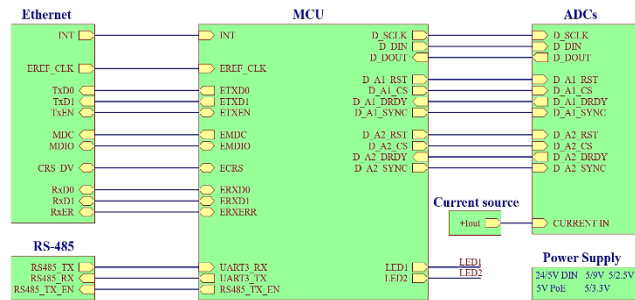
## Advantages

- 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

ПКТ-8 Измерения

Не защищено | 192.168.100.15/index.html

PKT-8 CRYOGENIC TEMPERATURE MEASUREMENT MODULE WEB INTERFACE

Measurements

Device settings

Coefficients

Network settings

ДИАЛТЕК

ЛФВЭ

channel	R, Ohm	T, K
1	112.25	0.00
2	254.43	0.00
3	349.29	0.00
4	403.82	0.00
5	550.51	0.00
6	677.76	0.00
7	942.45	0.00
8	1229.42	0.00

Last Update: 11:50:50

11:50 10.11.2020



# PKT-8 CRYOGENIC TEMPERATURE MEASUREMENT MODULE

Measurements

Device settings

Coefficients

Network settings

WEB

Modbus Poll - [web\_rev02.mbp]

Tx = 8352706: Err = 0: ID = 100: F = 03: SR = 0ms

Alias	01000
1000	11218
1001	--
1002	25434
1003	--
1004	34924
1005	--
1006	40373
1007	--
1008	55066
1009	--
1010	67792
1011	--
1012	94236
1013	--
1014	122931
1015	--
1016	0
1017	channel 2
1018	pga 4
1019	sps 1
1020	10
1021	0
1022	0
1023	0

Modbus TCP

# WEB INTERFACE

Modbus Poll - [web\_rev02.mbp]

Tx = 821800: Err = 0: ID = 100: F = 03: SR = 0ms

Alias	01000
1000	11218
1001	--
1002	25434
1003	--
1004	34924
1005	--
1006	40373
1007	--
1008	55066
1009	--
1010	67792
1011	--
1012	94236
1013	--
1014	122931
1015	--
1016	0
1017	channel 2
1018	pga 4
1019	sps 1
1020	10
1021	0
1022	0
1023	0

Modbus RTU

R, Ohm

112.18

254.41

349.28

403.73

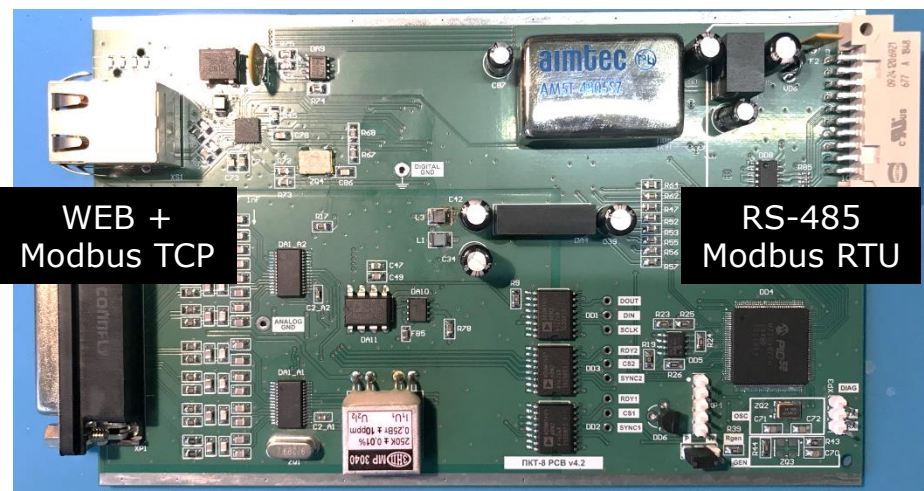
550.65

677.99

942.37

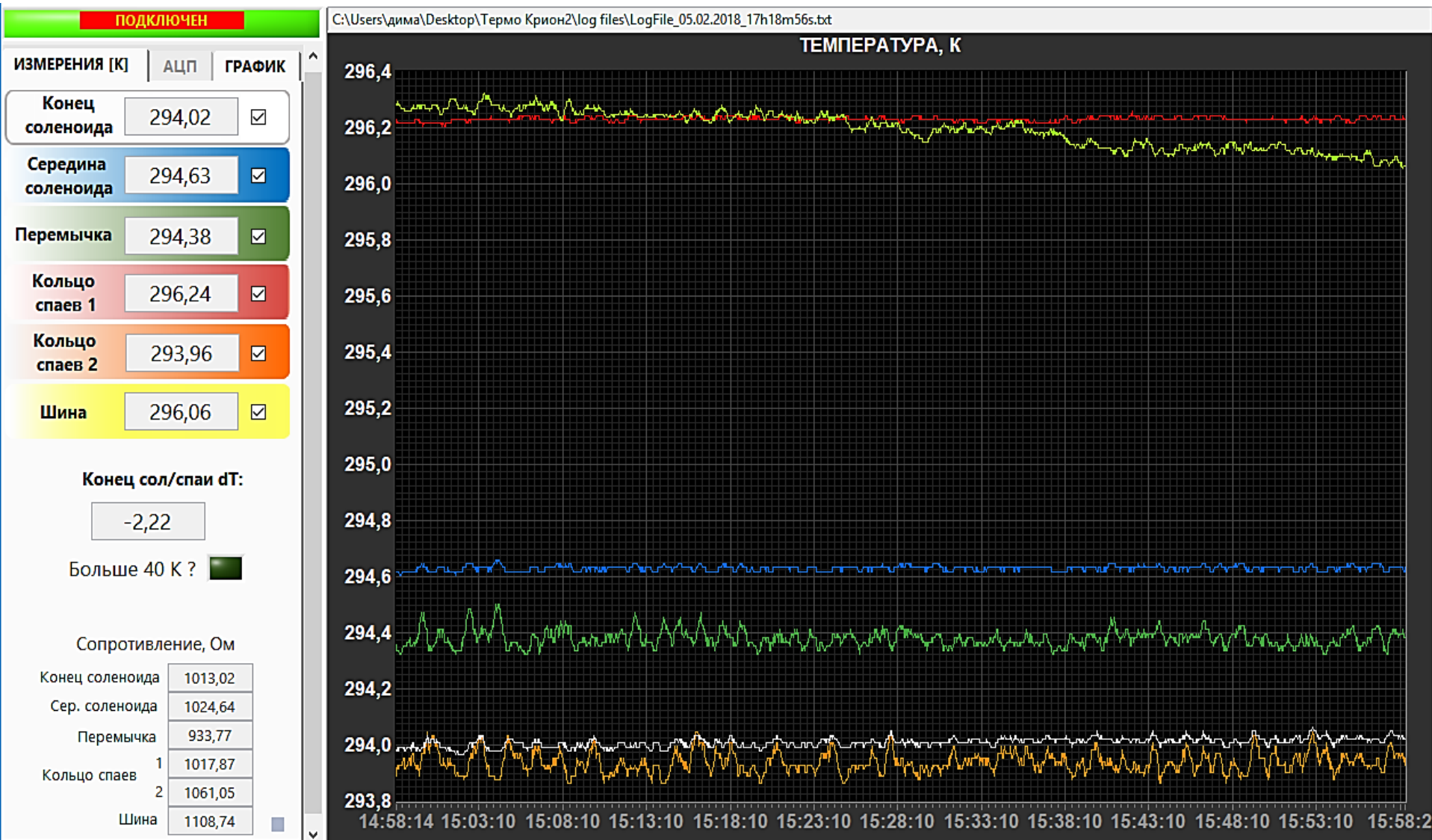


Web interface  
+ Modbus

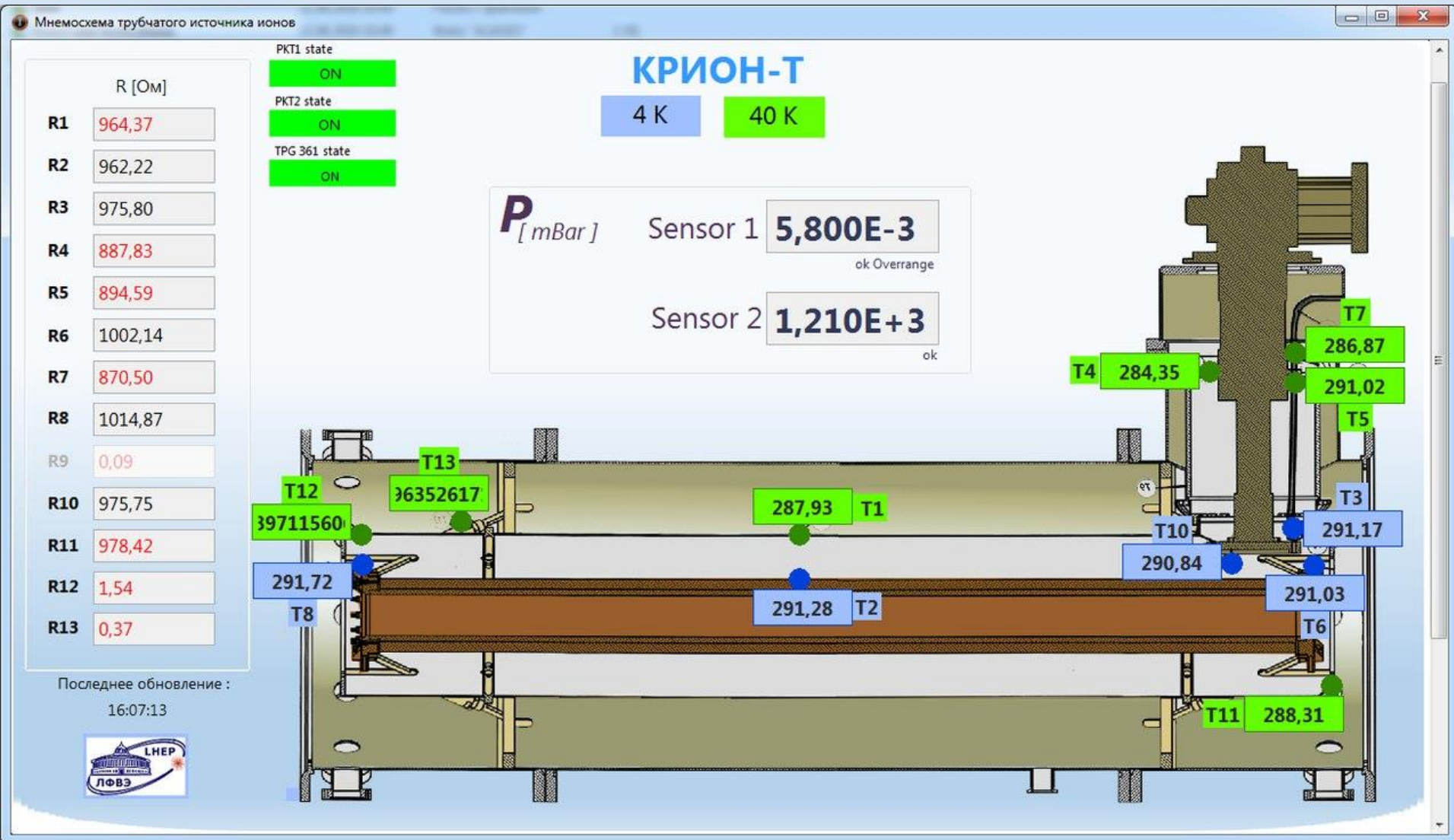




# Slow control => thermometry

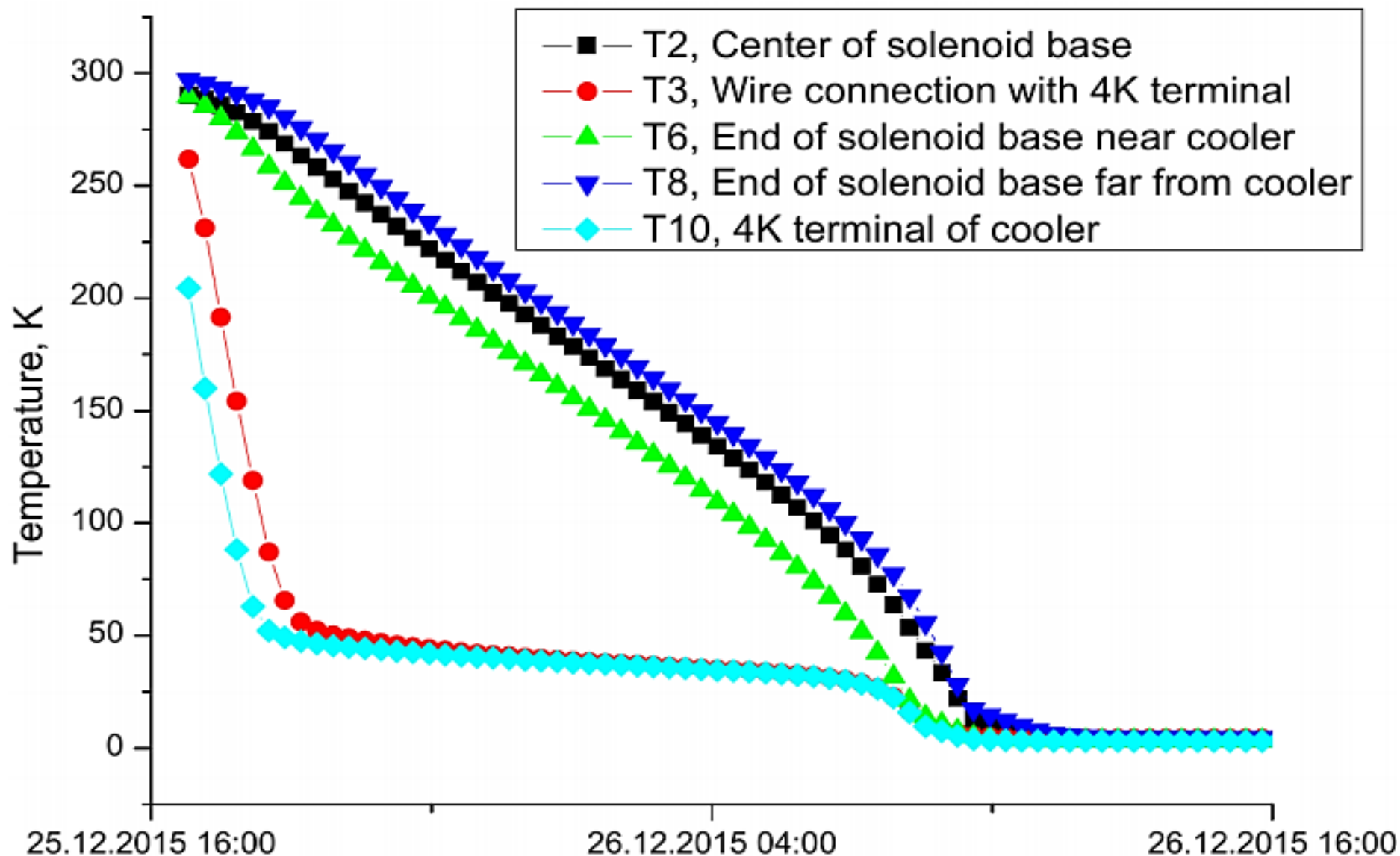


# Slow control => thermometry



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

# Slow control => thermometry



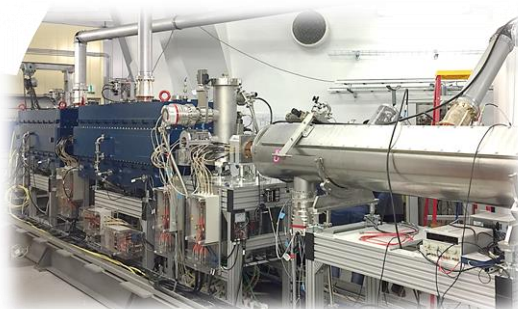
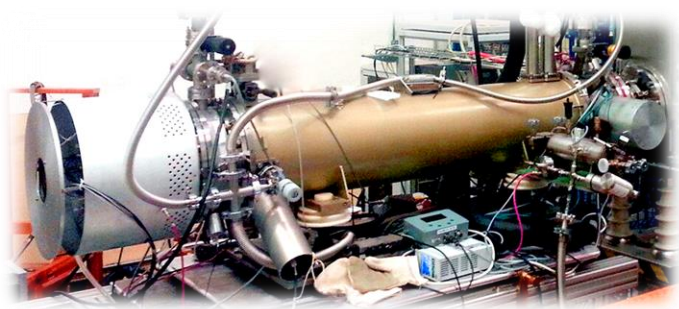


# Summary

- 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\*





**We are ready for collaboration in any technical questions**  
email: [ponkin@jinr.ru](mailto:ponkin@jinr.ru)

**Thank you!**