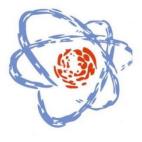
The XXIV International Scientific Conference of Young Scientists and Specialists (AYSS-2020)





Development of the Electron string ion sources thermometry systems

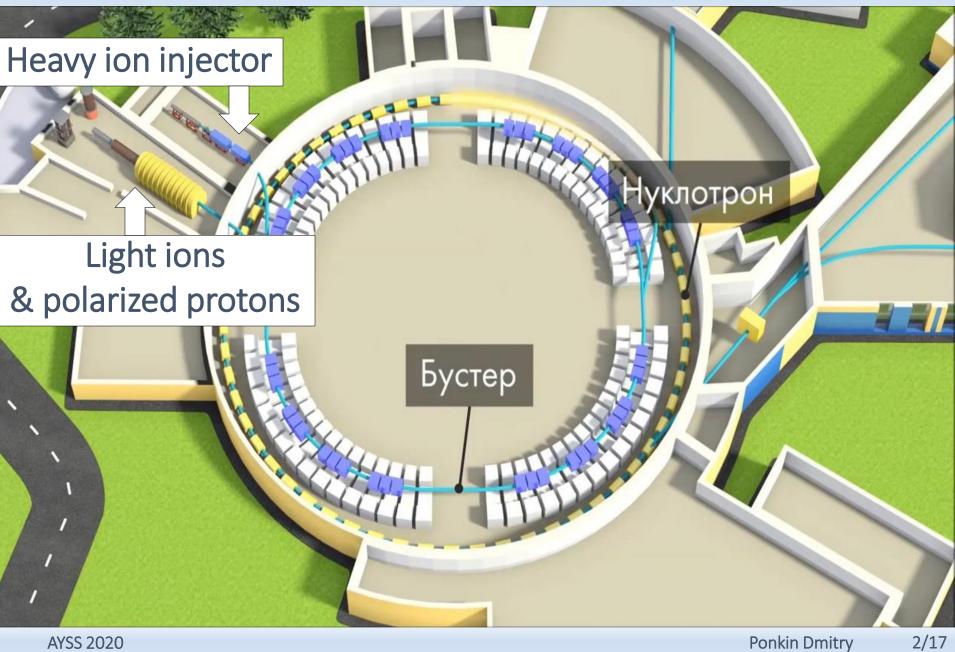
Ponkin Dmitry

LHEP JINR senior engineer

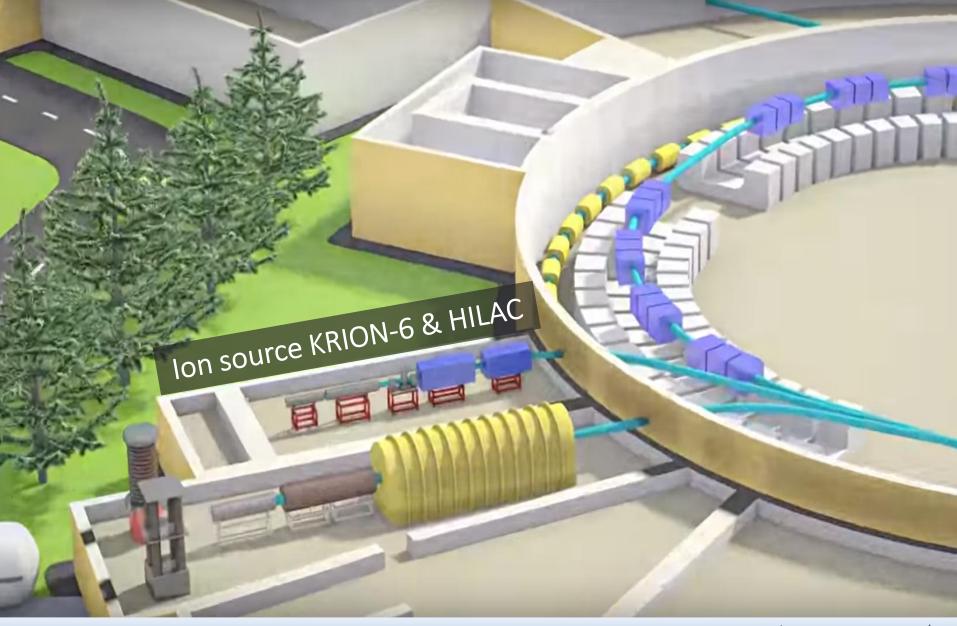
on behalf of the NICA acceleration division

Dubna, 9-13 November 2020

NICA injection complex



Heavy ion injection



Heavy ion source KRION 6T



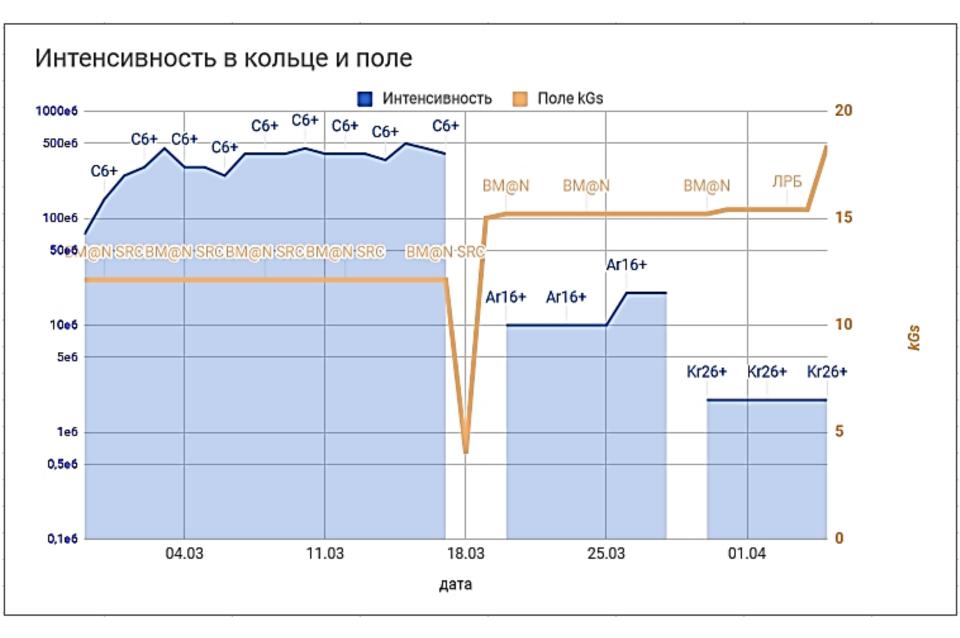
lons produced and injected: ⁷⁸Kr¹⁷⁺ ¹²⁴Xe⁴¹⁺ ⁴⁰Ar¹⁶⁺ ¹²C⁶⁺

- 5.4 T SC solenoid
- E inj. up to 25 kV

- electron string
- <u>cryogenic</u>

- highly charged ions
- unique technology

55th 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. Au¹⁹⁺ beam in 1969.

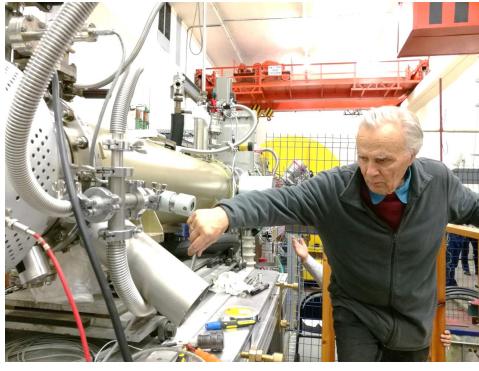
•1970-1985, in Dubna, cryogenic version of EBIS KRION-I,2, bare ions C, N, O, Ne, Ar, Kr, Xe. HCI physics begins.

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

•1982, at Bekerley, EBIT, from EBIS, 1990s, SuperEBIT, U⁹²⁺!

•Since 1985, in accelerator fields, ECRIS time

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

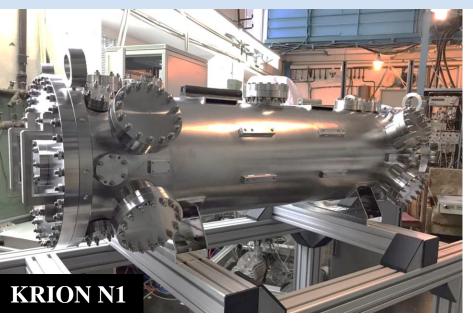


Prof. E.D. Donets near Krion-6T ESIS during Nuclotron run #55, JINR, Dubna, February 2018

• ESIS Krion 6T and Krion N1 for NICA JINR

•In China, Shanghai EBIT

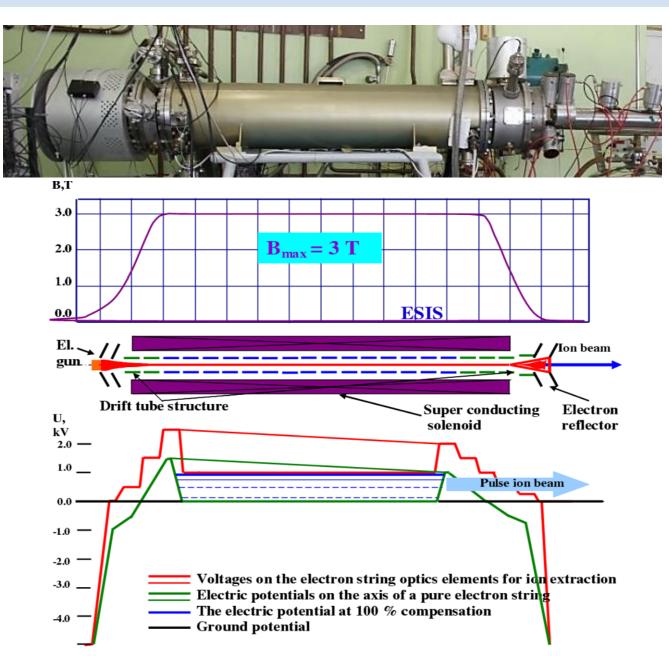
EBIS = Electron Beam Ion Source







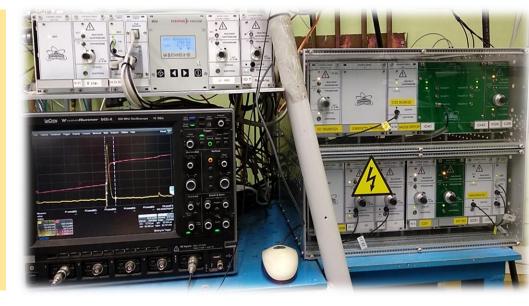
ESIS = EBIS in electron reflex mode of operation



ESIS KRION 6T electronics

Slow

- vacuum
- ion optics supply control
- HV electrodes
- electron gun supply
- Synchronization
- <u>thermometry</u>



Ion motion control system

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

Beam diagnostics

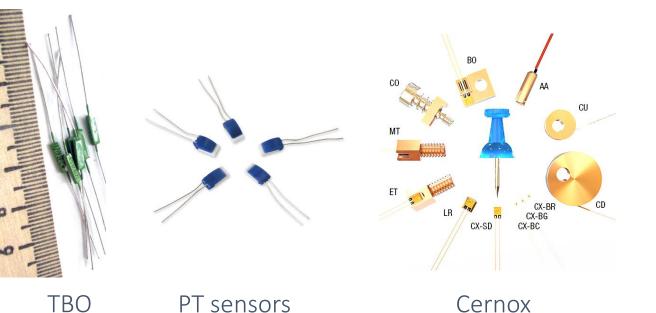
- beam profile monitor
- oscilloscopes
- ion collectors
- ToF system
- indused signals

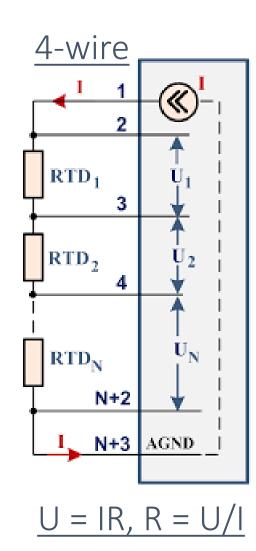
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Cryogenic measurements:

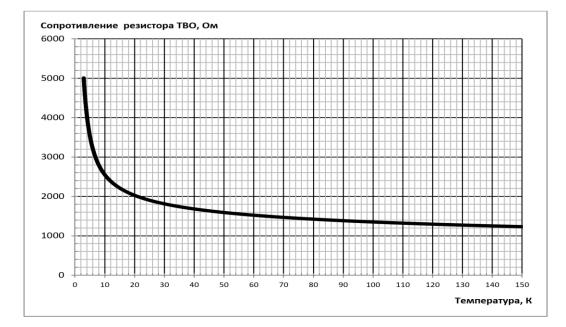
- cryogenic sensors (precision, stability)
- sensor wiring and connection
- meas. electronics
- current source
- signal shielding

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Thermometry => superconducting solenoid

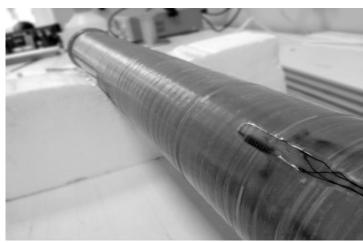


TBO* resistor:

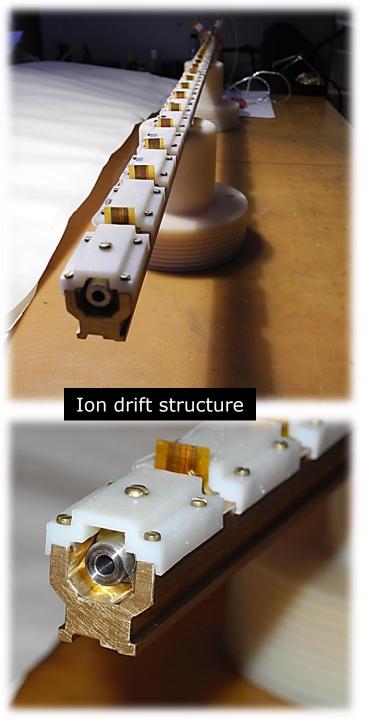
- heat resistant
- moisture resistant
- volume

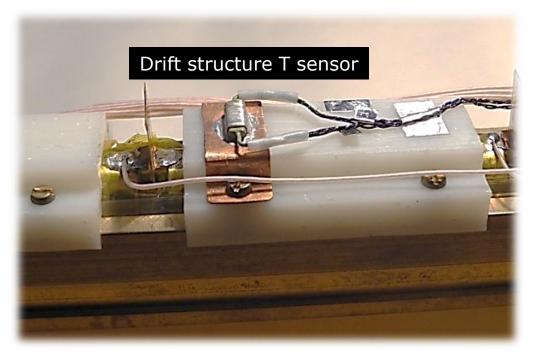
$$T = \sum_{n=1}^{m} K_n \cdot \left(\frac{R_0}{R_t}\right)^{n-1}$$





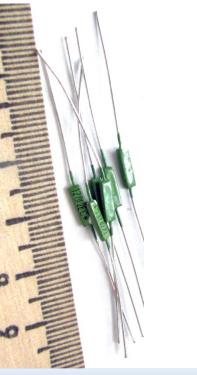
KRION 6T superconducting solenoid T sensor





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

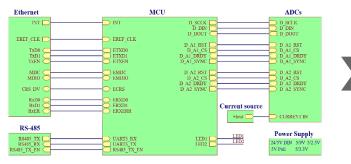
- PoE: less wires needed
- precision
- Modbus RTU/over TCP
- modular (3U case)
- robust & cost-effective
- on-board current source

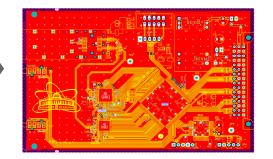


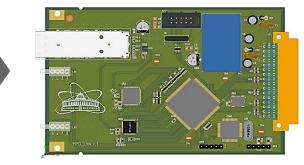
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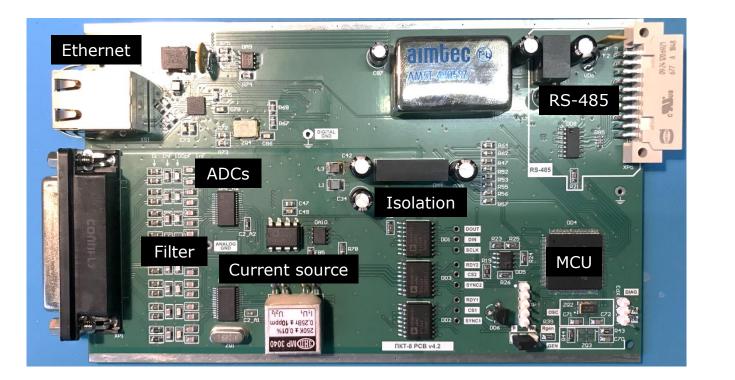
10/17

The design process









«Cool» resistor



The embedded system web interface

ПКТ-8 Измерения	× +				_
	ацищено 192.168.100.15/index.html				
	РКТ-8	CRYOGENIC TEMPERATURE MEASU	REMENT MODULE	WEB INTERFACE	
	Measurements	channel	R, Ohm	Т, К	
	Device settings	1	112.25	0.00	
		2	254.43	0.00	
	Coefficients	3	349.29	0.00	
	Network settings	4	403.82	0.00	
	LHEP	5	550.51	0.00	
	ЛФВЭ	6	677.76	0.00	
		7	942.45	0.00	
	Last Update: 11:50:50	8	1229.42	0.00	•

AYSS 2020

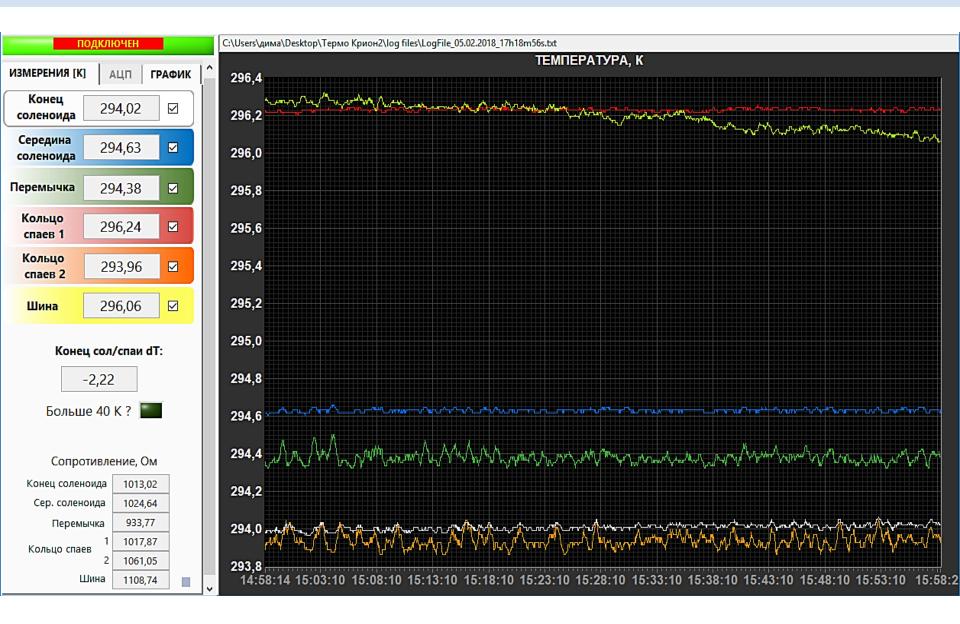
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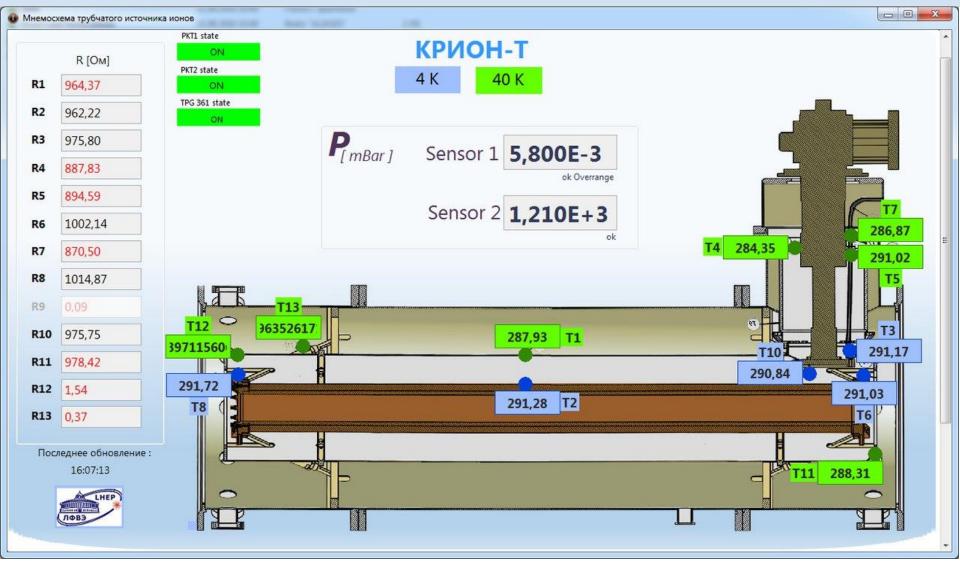
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measurements	TX - 0552700. E	EIT = 0. ID = 100. P = 03.	SR - 0115		Tx = 82180	0: Err = 0: ID = 100: F =	= 03: SR = 0ms	
		Alias 01000	0	112.18		Alias 010		-
	1000	11218		112.10	1000	Allas 010 112		
Device settings	1001				1000	112	18	
	1002	25434		100000	1002	254		
	1003			254.41	1002	2.14	34	
	1004	34924			1003	349	24	
Coefficients	1005				1004	- 343	24	
	1006	40373		349.28	1005	403	73	
	1007			040120	1007	405		
	1008	55066			1007	550	66	
Network settings	1009				1009			102
	1010	67792		403.73	1010	677	92	
	1011				1011			
	1012	94236			1012	942	36	
LHEP	1013			550,65	1013			
	1014	122931			1014	1229	31	
	1015				1015			
ЛФВЭ	1016	0			1016		0	
-	and the second s	channel 2		677.99	1017	channel	2	
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Web interface + Modbus

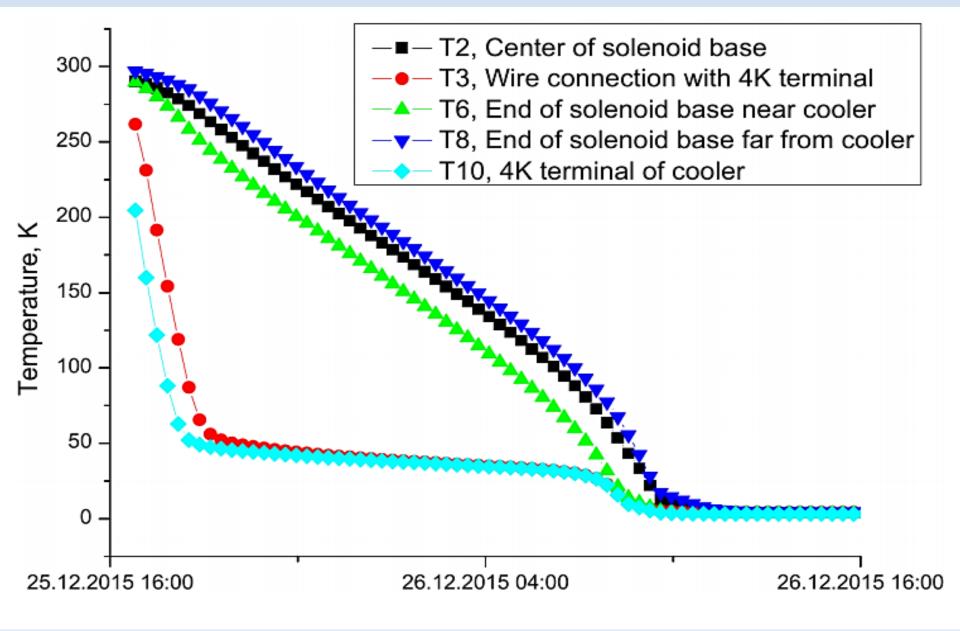








https://www.tango-controls.org/



AYSS 2020

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

Thank you!

7. KRION-6T on the test bench



Specifications of KRION-6T

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

8. Results achieved on the test bench

- the $\mathbf{j}\mathbf{\tau}$ 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

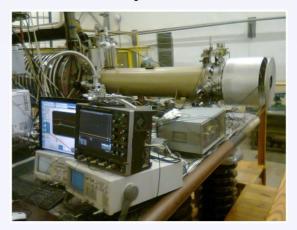
Examples of number of particles per pulse and times of ionization for different ions

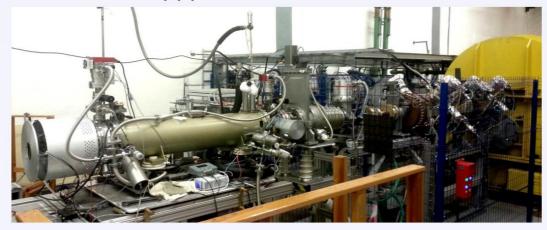
C ⁴⁺	7x10 ⁹	-
Xe ⁴²⁺	5x10 ⁹	350 ms
Xe ³²⁺	-	40 ms
Tm ⁵⁰⁺	3x10 ⁷	-
Au ³³⁺	-	30 ms

The new KRION-6T ion source has much higher effective **j** (up to 1600 A/cm²) in comparison with the KRION-2 which had only 200 A/cm². Another typical EBIS devices have only 100 - 300 A/cm².

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 Ar¹⁶⁺ beam was 3,9x10⁷ ppp.





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

