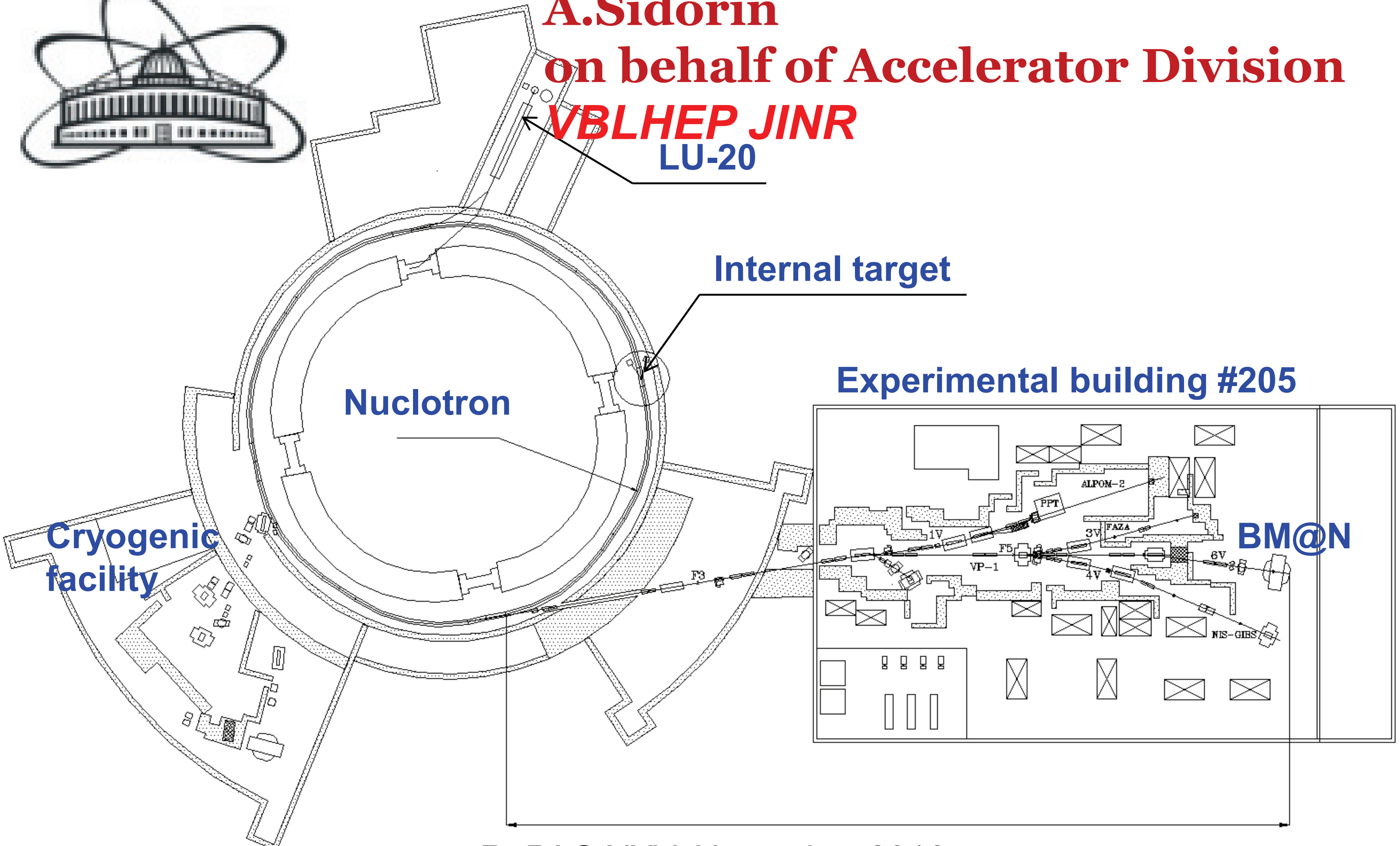
Status of the Nuclotron

A.Sidorin
on behalf of Accelerator Division
VBLHEP JINR



RuPAC XXV, November 2016

Contents

- Statistics of the operation in 2015 - 2016
- Machine development
- Ion source and new fore-injector
- Nearest plans
- Preparation for Booster assembly and

Baryonic Matter at Nuclotron (BM@N) experiment

Statistics of operation

Run #51   26.01-15.03.2015 (1150 h, 70% beam time)

Test of BM@N systems with deuteron and carbon beams

Machine development:

- Development of the beam diagnostics,
development of hardware and software for Q-meter
 - **Test operation of the system for precise measurements of the power supply currents**
- The works for improvement of the current stability
of the transport lines has been started
-**Put into operation new Nuclotron thermometry system**
-Development of the TANGO based control system (each run)
- Methodical experiments for beam bunching and re-bunching,
stochastic cooling has been prolonged

Cooling ~ 120 h, preparation of all systems ~ 50 – 100 h

Statistics of operation

Run #52 “technological” 02.06 - 30.06.2016 (650 h)

RFQ fore-injector commissioning (first stage)

Optimization of SPI regimes

Test of polarimeters:
after LU-20, at Internal target, at extracted beam

Test of the Booster power supply prototypes at SC load

Test of White Rabbit segment at BM@N

Improvement of beam line current stability

Routine operation with injection at magnetic field plateau
+ adiabatic capture

Statistics of operation

Run #53 26.10-25.12.2016 (plan duration 1400 h)

SPI optimization, polarimetry

Spin physics experiments

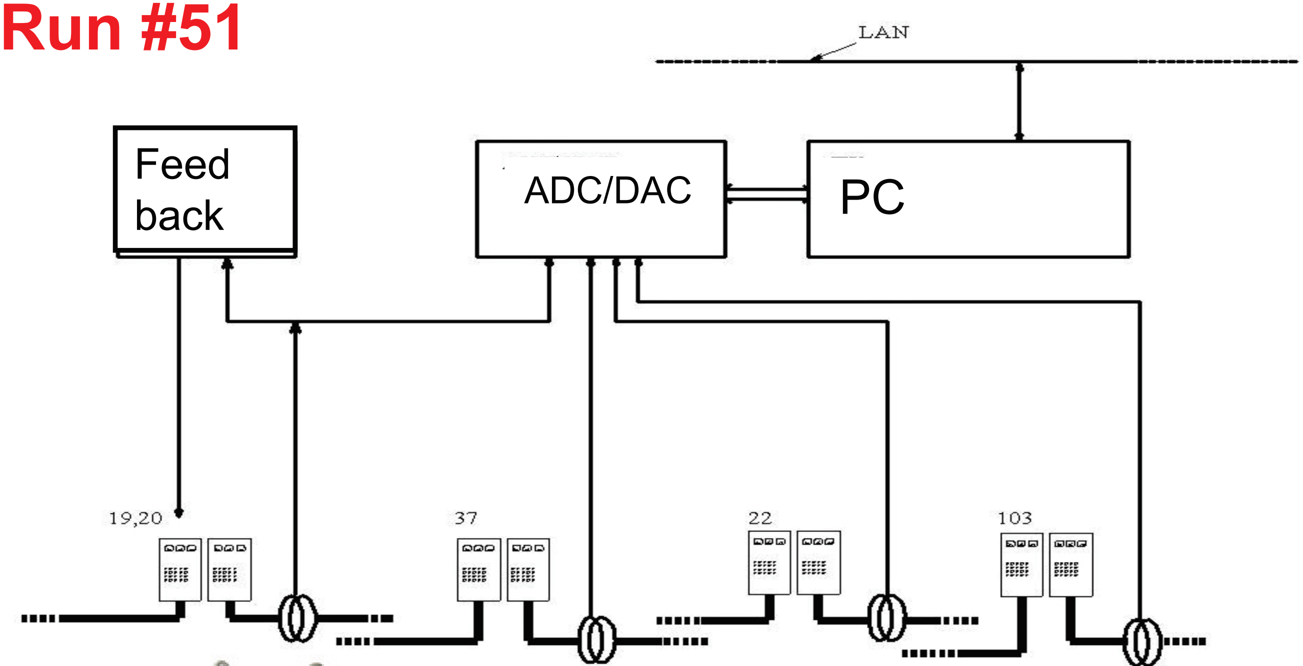
Test of BM@N and MPD elements

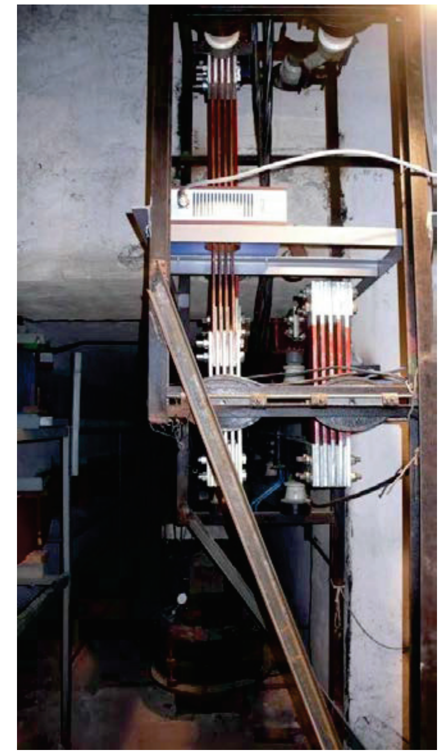
Test of the Booster power supply prototypes
with beam acceleration

Stochastic cooling

System for precise current measurements

Run #51





Current transformer ITZ Ultrastab.
The absolute relative mistake 6,5 10^{-5}.

System for precise current measurements

Run #51

Current control at slow extraction plateau

Working point control during acceleration

Current at the slow extraction plateau is 3741.8 A,
The ripple amplitude is 0.071 A,
Relative stability $1.9*10^{-5}$!!!

Thermometry

Run #51

10 measurement loops:

8 - octants of the Nuclotron

Measurement period + inflector magnet + electrostatic septum

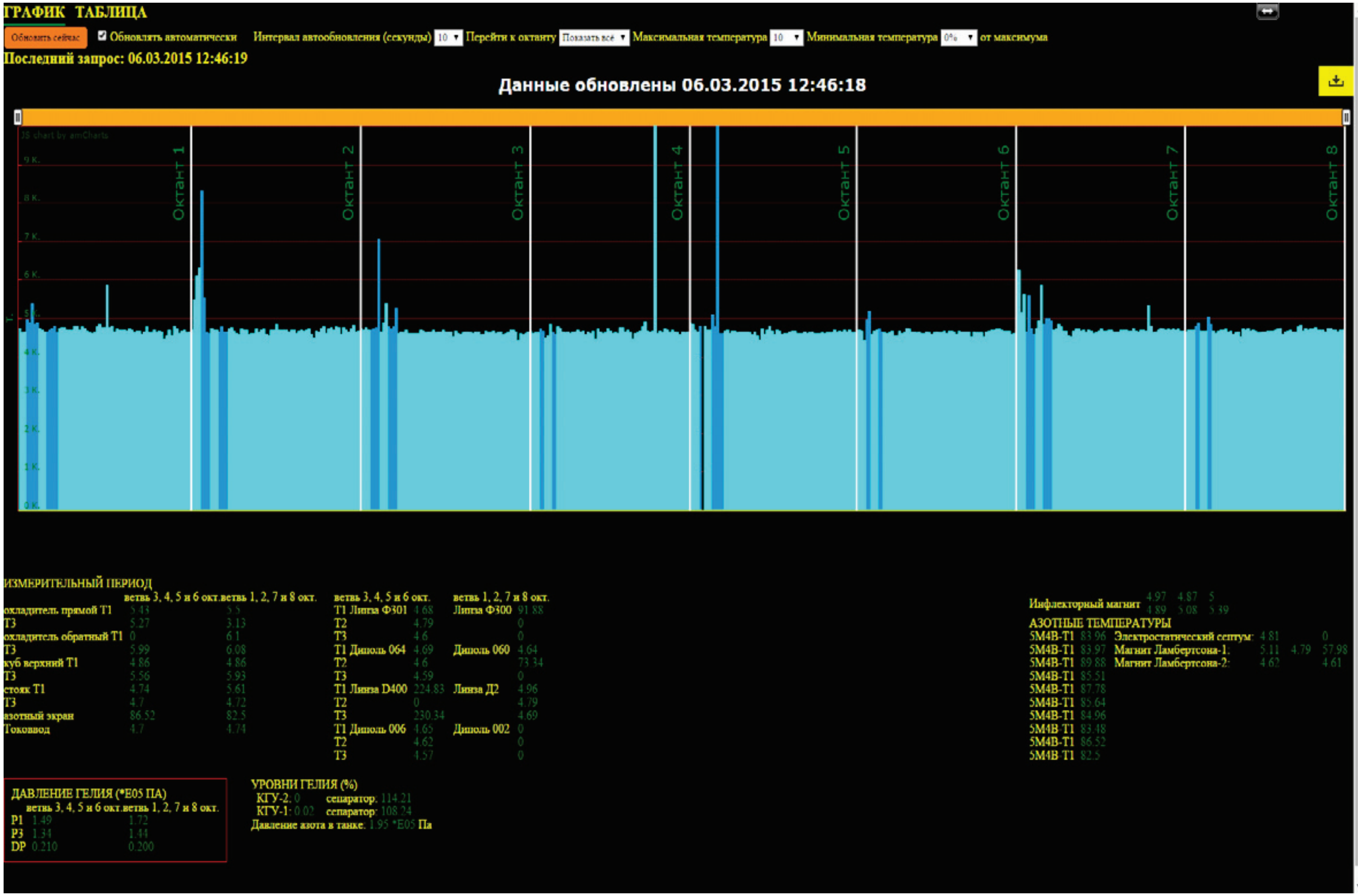
All insertions + nitrogen shield

Additionally the system registries
input and output pressure in the helium tracts,
helium level in liquefiers, nitrogen pressure in the tank

608 thermo-resistors, 28 precise test resistors, 10 64-channel comutators,
10 24-bit USB-2416 (Measurement Computing Corporation)

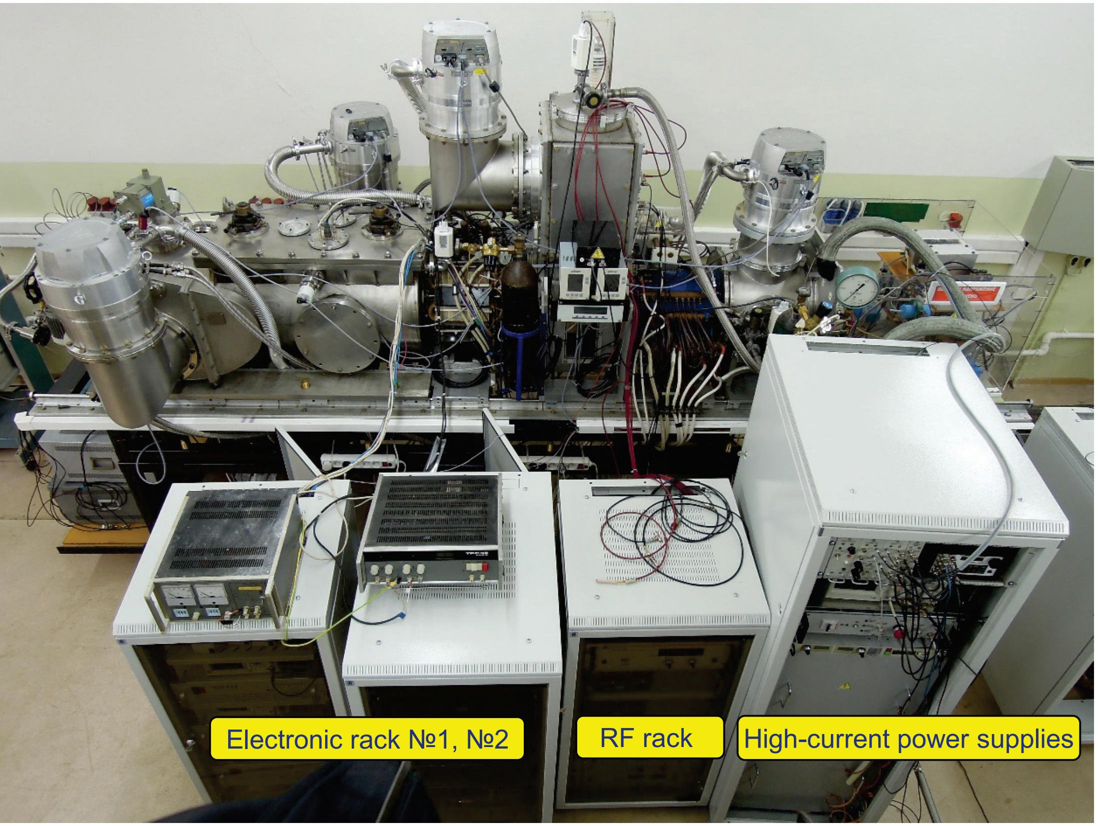
Thermometry

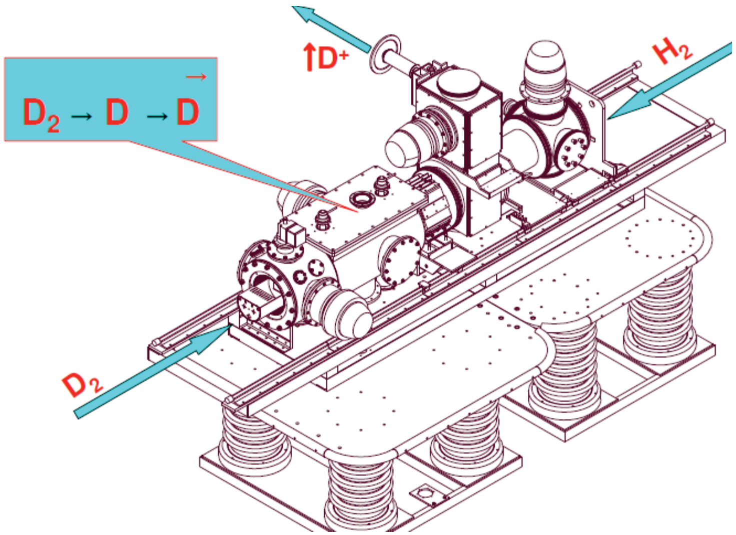
Run #51



TANGO window

Source of polarized ions (p, d, H)
JINR+INR RAS

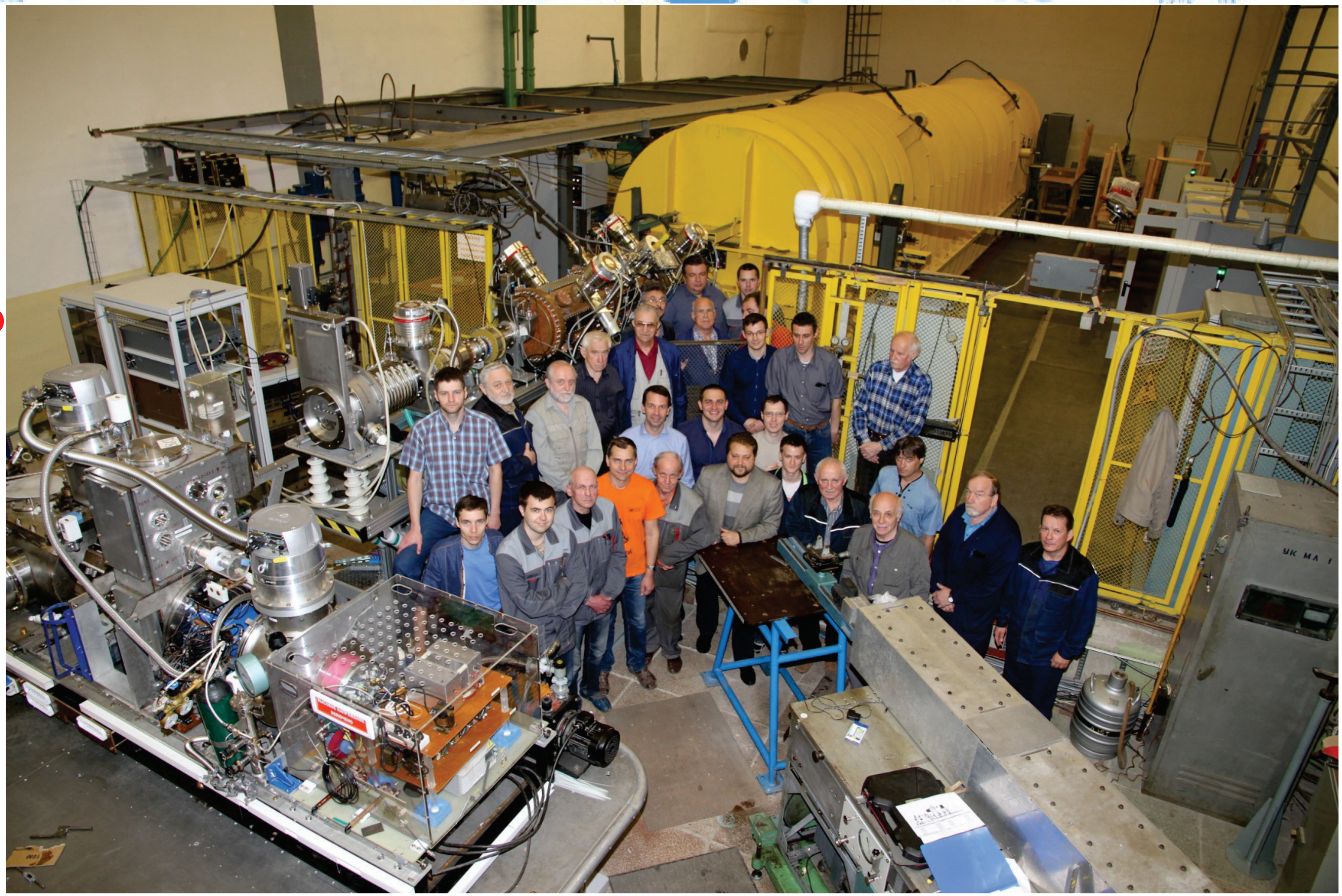




- In August 2012, the ABS was transported from the INR of RAS (Moscow) and assembled at JINR
- All-inclusive SPI-tests are carried out in 2014-2015 at JINR
- ~ 2 mA deuteron beam current was achieved in July 2015
- First operation at injection complex – may 2016

Commissioning of New Light Ion RFQ Linac and First Nuclotron Run with New Injector

JINR
ITEP
MEPhI
VNIITP

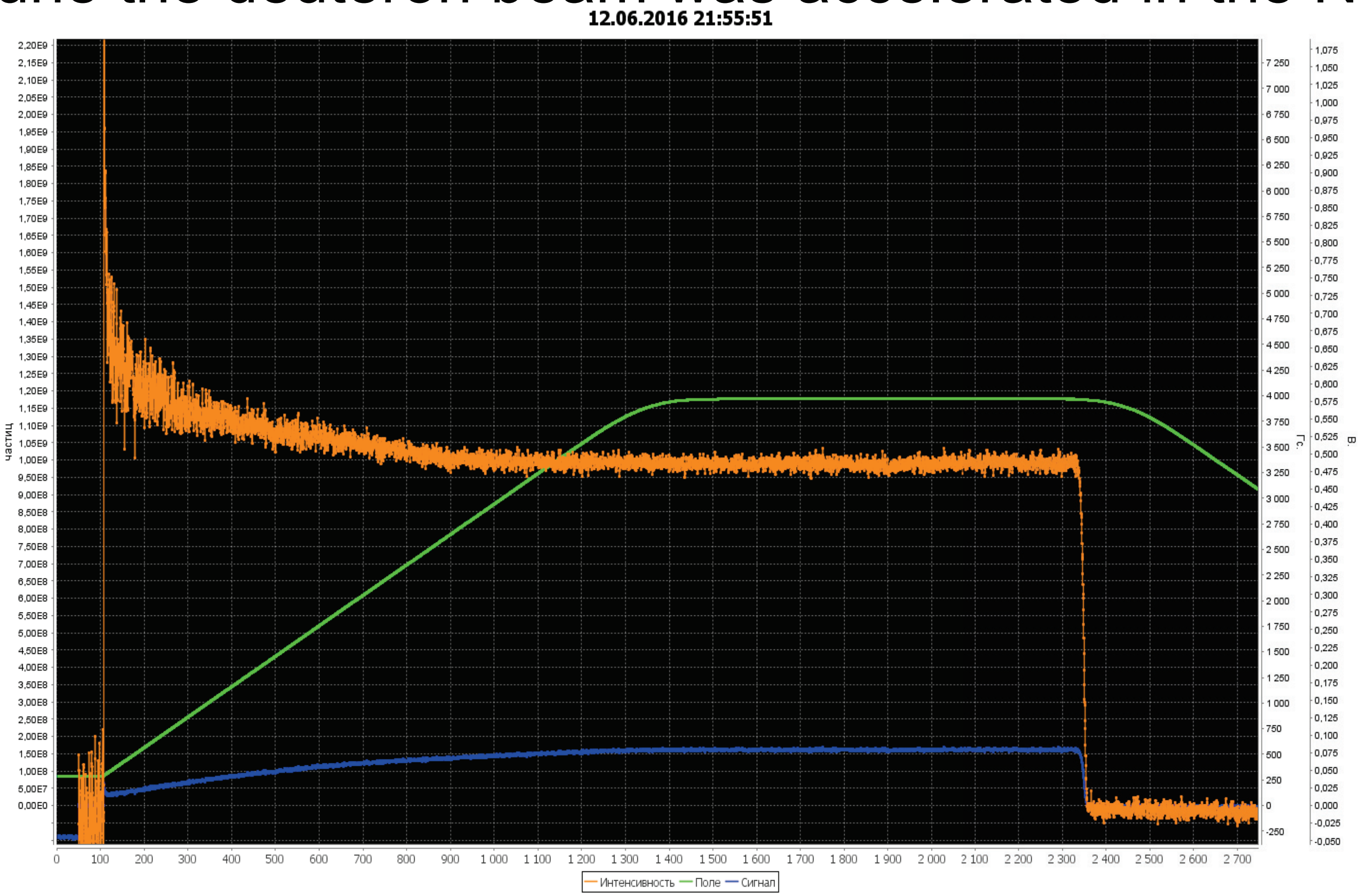


A.Sidorin, A. Butenko, next talk

New fore-injector for LU-20

12 of June the deuteron beam was accelerated in the Nuclotron

Run #52



Energy 750 MeV/u, intensity 10^9

Run #53 – experiments with polarized deuteron beam

Status of the Nuclotron

Parameter	Project	Status (November 2016)
Max. magn. field, T	2	2 (1.8 T routine)
B-field ramp, T/s	1	0.8 (0.3÷0.6 routine)
Accelerated particles	p–U, d↑	p-Xe, d↑
Max. energy, GeV/u	12 (p), 5.8 (d) 4.5($^{197}Au^{79+}$)	5.6 (d, ^{12}C), 1.5 ($^{124}Xe^{42+}$, $^{40}Ar^{16+}$)
Intensity, ions/cycle	$1*10^{11}$(p,d) $1*10^{10}$ (d↑) $2*10^{9}$ (A > 100)	d $5*10^{10}$ ($2*10^{10}$ routine) d↑ $5*10^{8}$ $^{124}Xe^{24+}$ $1*10^{4}$ ^{12}C $2*10^{9}$ $^{40}Ar^{18+}$ $2*10^{5}$ $^{7}Li^{3+}$ $3*10^{9}$

Plans

2017:

Preparation for the Booster construction
and BM@N experiment

Test of BM@N detector:

Two Nuclotron runs
-February – March 2017 (laser source d, Li, C)
-November – December 2017 (KRION source, Kr, Ar)

2018:

Booster assembly and commissioning

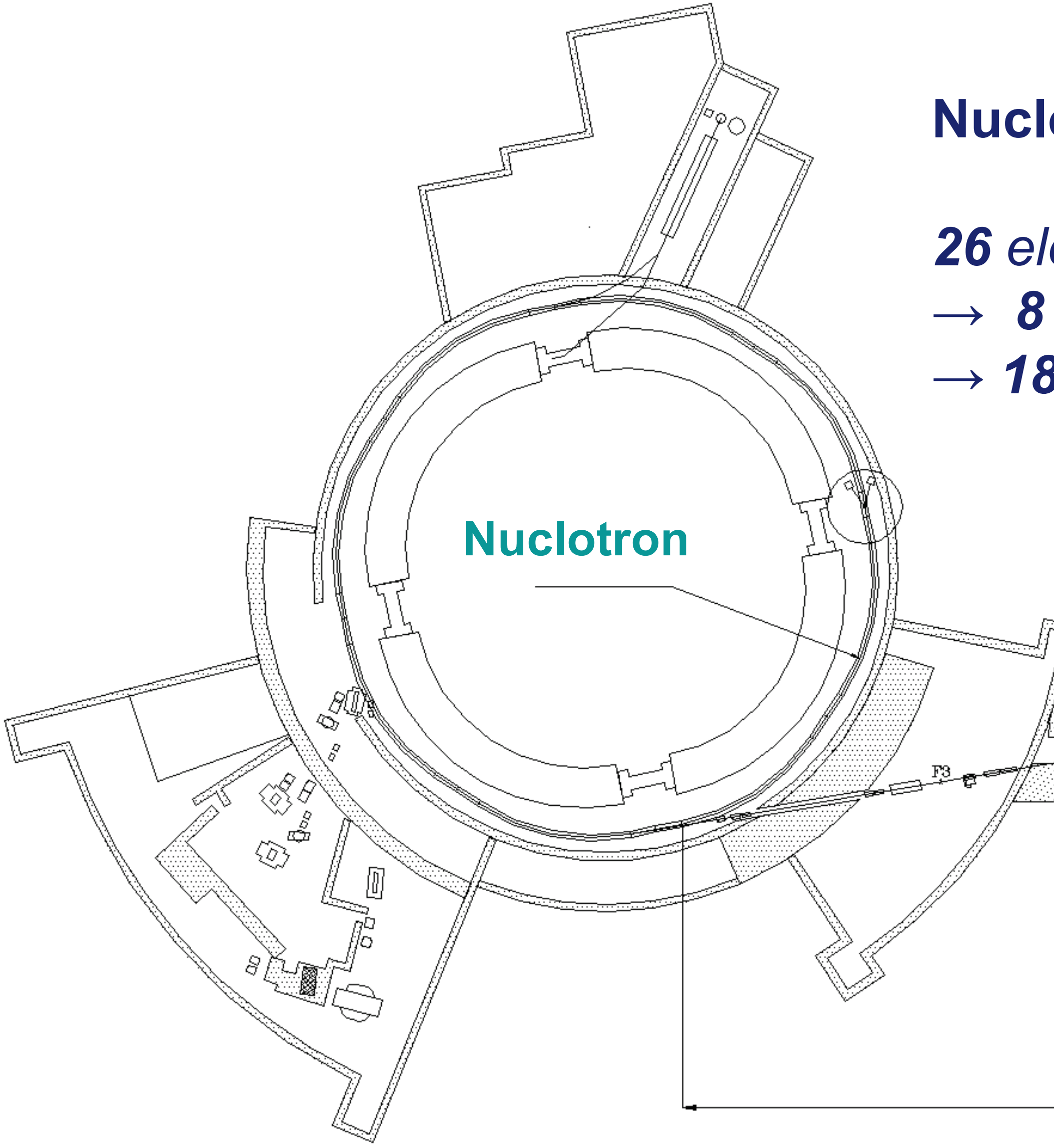
Preparation for BM@N

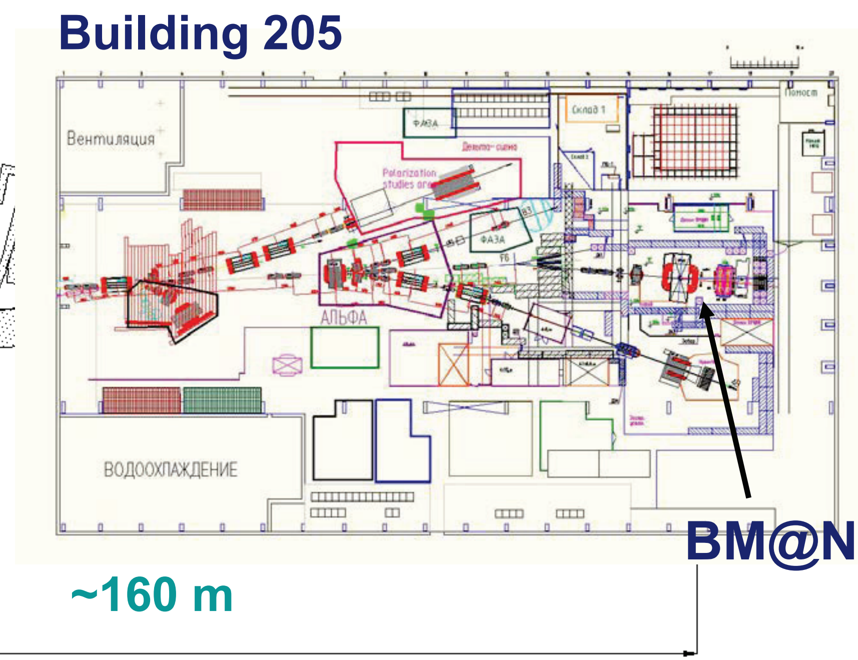
Nuclotron to BM@N beam line:

***26** elements of magnetic optics:*

→ ***8** dipole magnets*

→ ***18** quadruple lenses*





Improvement of the beam line current stability

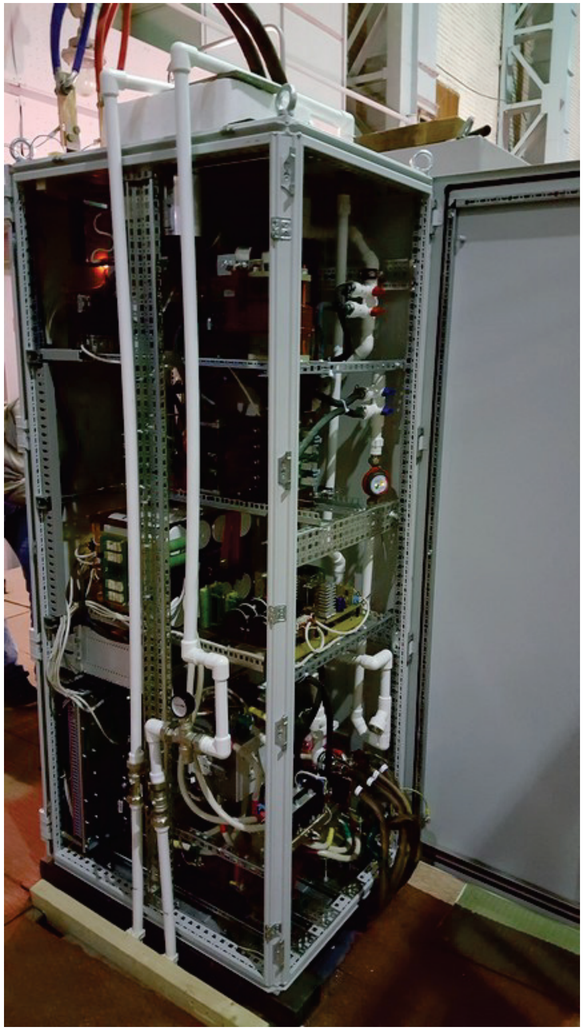
Run #52

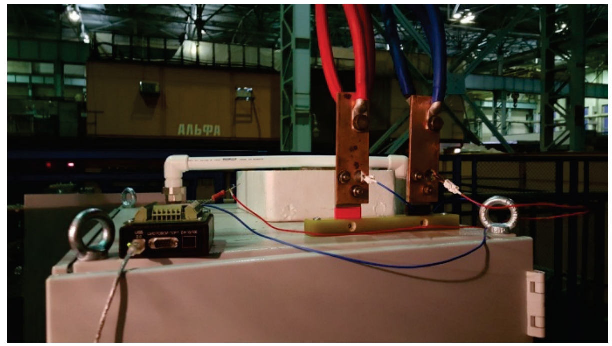
Prototype of the current control unit

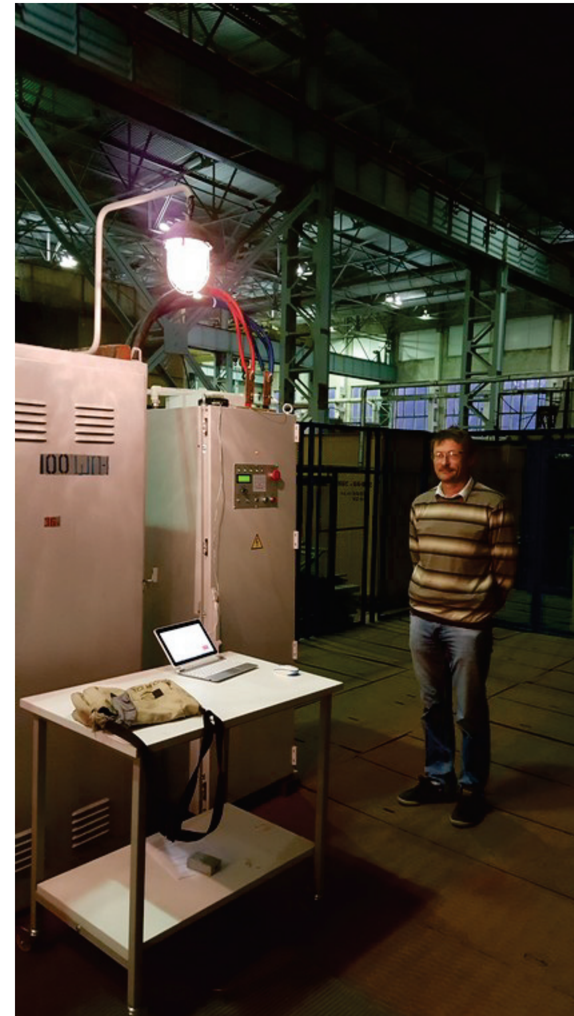
Long-range relative current stability of 50 КВ source **is better than 10^{-3}.**
Ripple at 300 Hz 0.5…1% (depending on output current). (Run #52)

New source at the beam line

Run #53



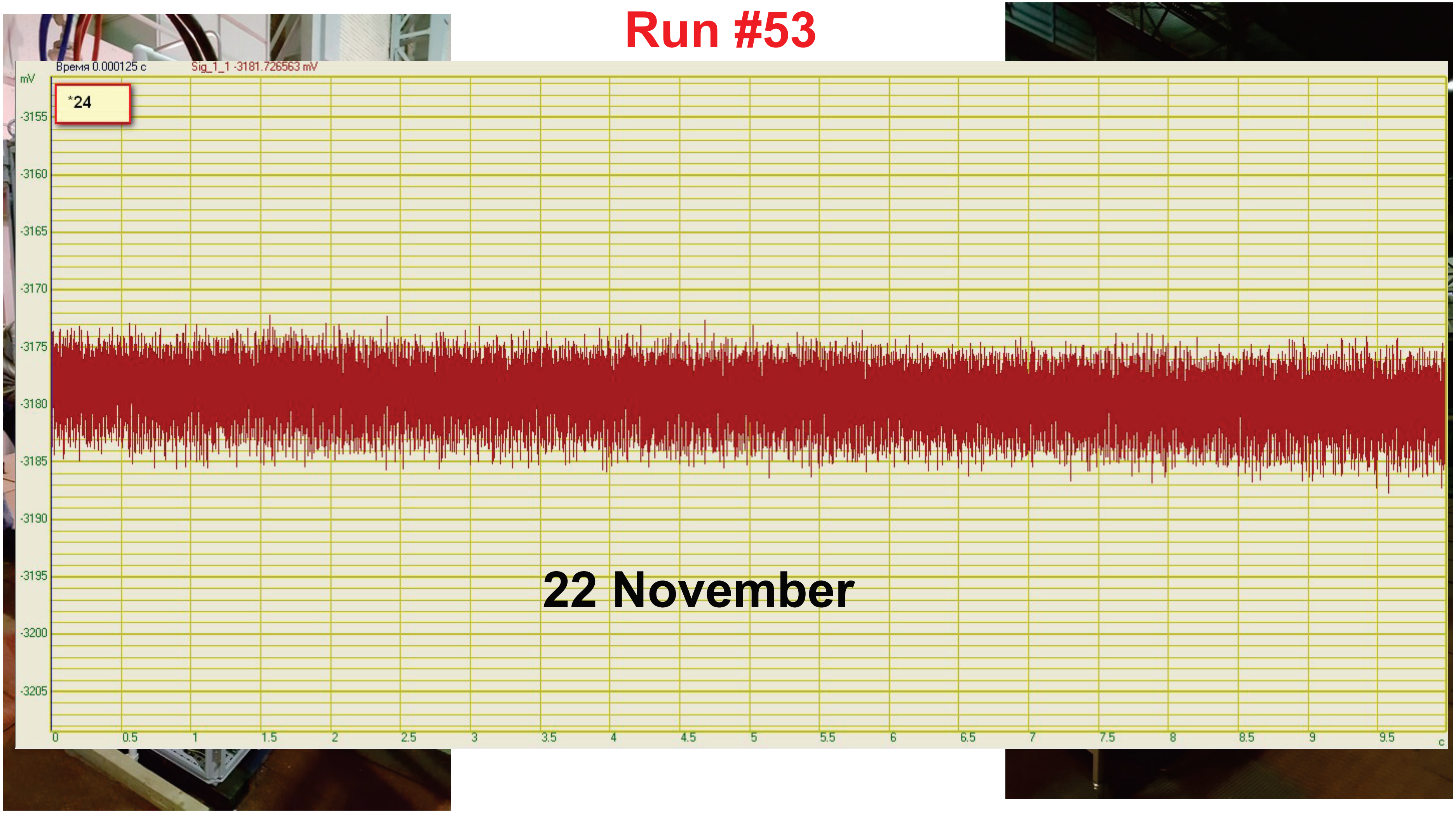




ИП-600-180 **LM Invertor (Moscow)**
600 A, 180 V, ripple 10^{-4}

New source at the beam line

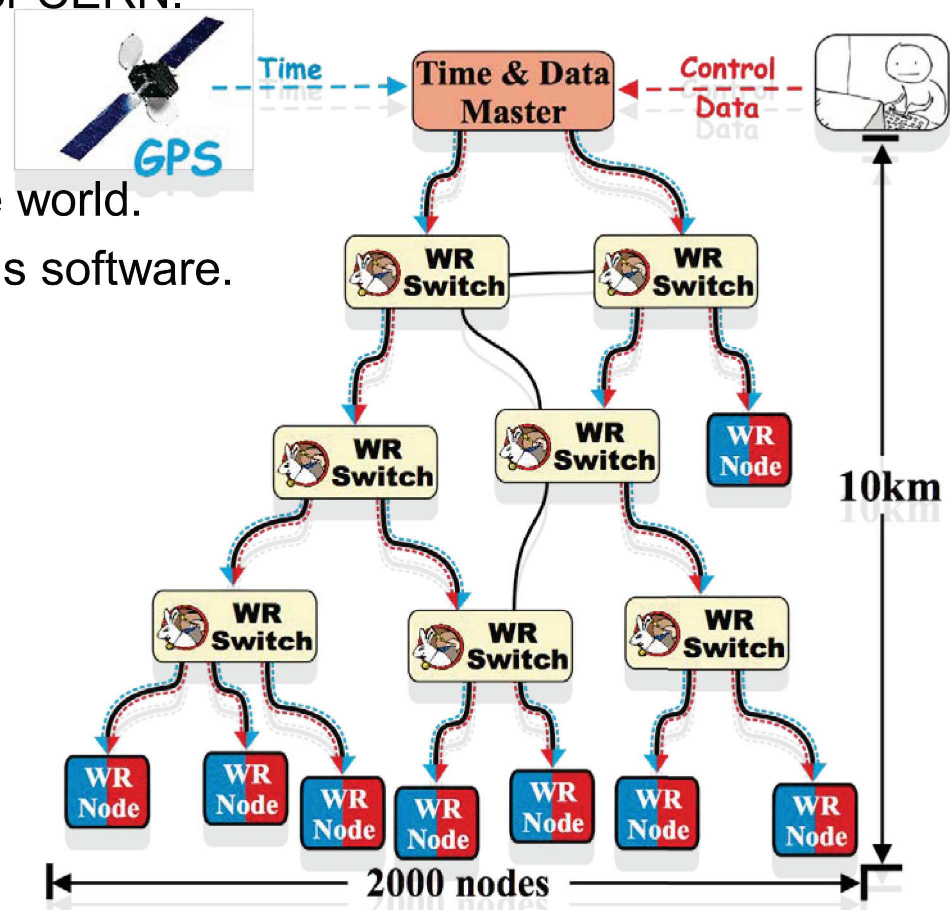
Run #53



ИП-600-180 **LM Invertor (Moscow)**
600 A, 180 V, ripple 10^{-4}

NICA synchronization system

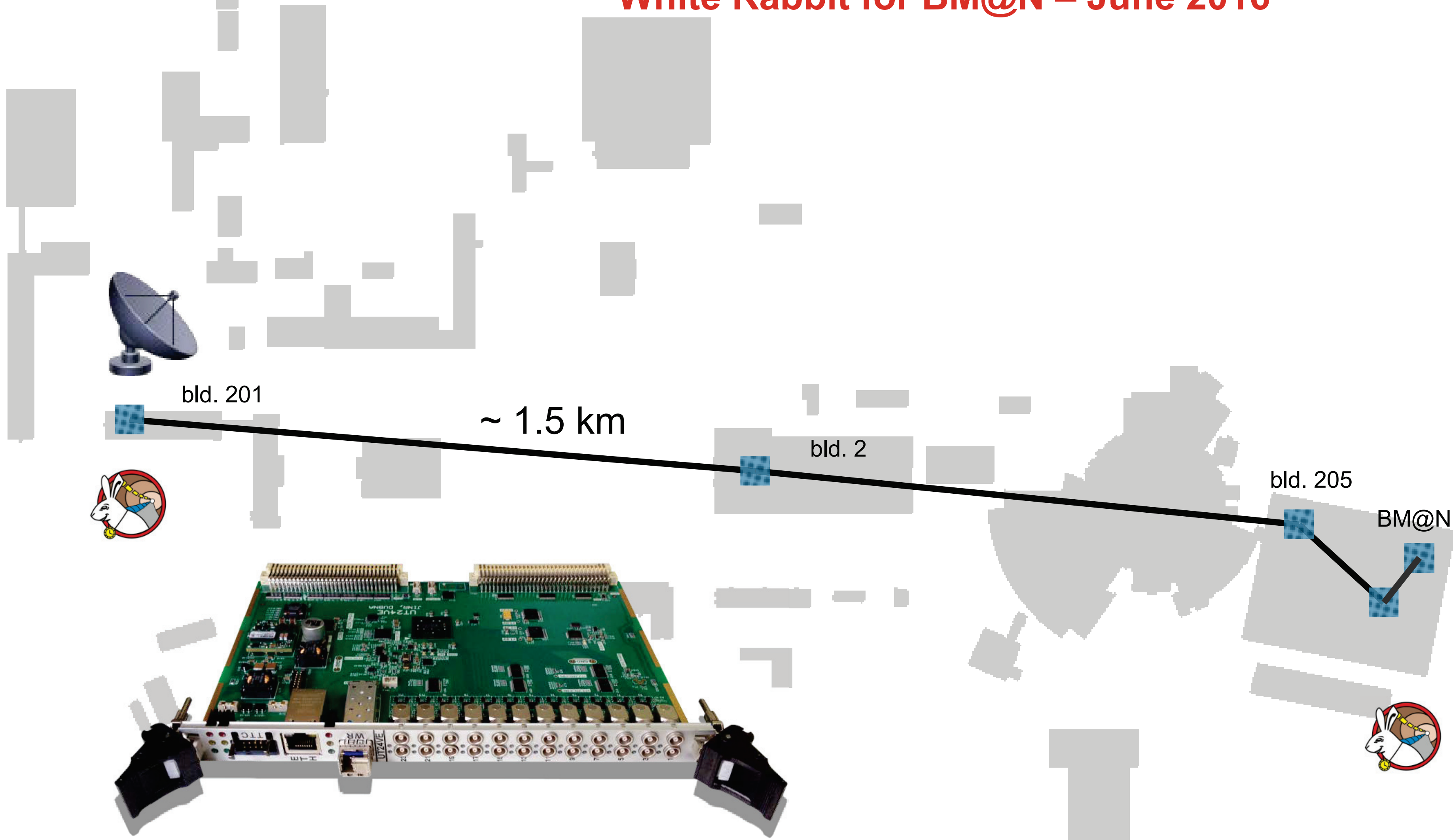
White Rabbit project was started to develop next generation control and timing network for CERN.
Later FAIR facility joined the project.
Currently, the project is a collaboration of many institutes and companies around the world.
The project is both, open hardware and opens software.
The projects aims at creating an Ethernet-based network with:
low-latency,
deterministic data delivery and network-wide,
transparent,
high-accuracy timing distribution.
The White Rabbit Network (WRN) is based on existing standards, namely Ethernet, Synchronous Ethernet and PTP.



Sub-nanosecond accuracy

Synchronization: test at BM@N

White Rabbit for BM@N – June 2016



UT24VE — Universal Board with White Rabbit support and Power-over-Ethernet

The Booster power supply

Three companies participate in the tender:

-LM Invertor (Moscow)

-EVPUas (Slovak Republic)

-Frako-Term (Poland)

Prototypes were tested during the Run #52
Operation on SC load for Quadrupole supply

The Booster power supply

Run #52

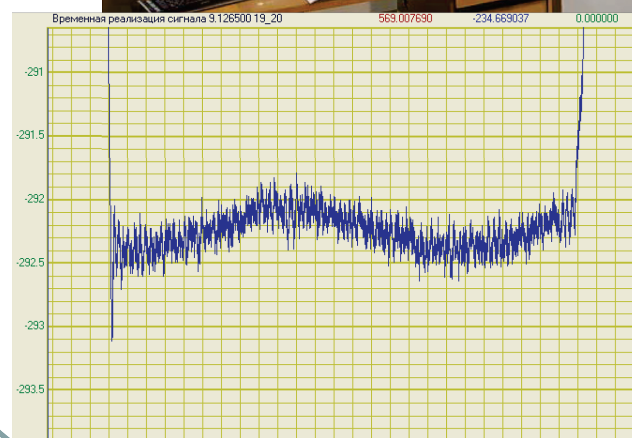
Three compani

-LM Invertor (Mos

-EVPUas (Slovak

-Frako-Term

PS-1000 (1kA)



Prototypes were t

Operation on SC load for Quadrupoles supply

The Booster power supply

Run #52

Three companie

-LM Invertor (

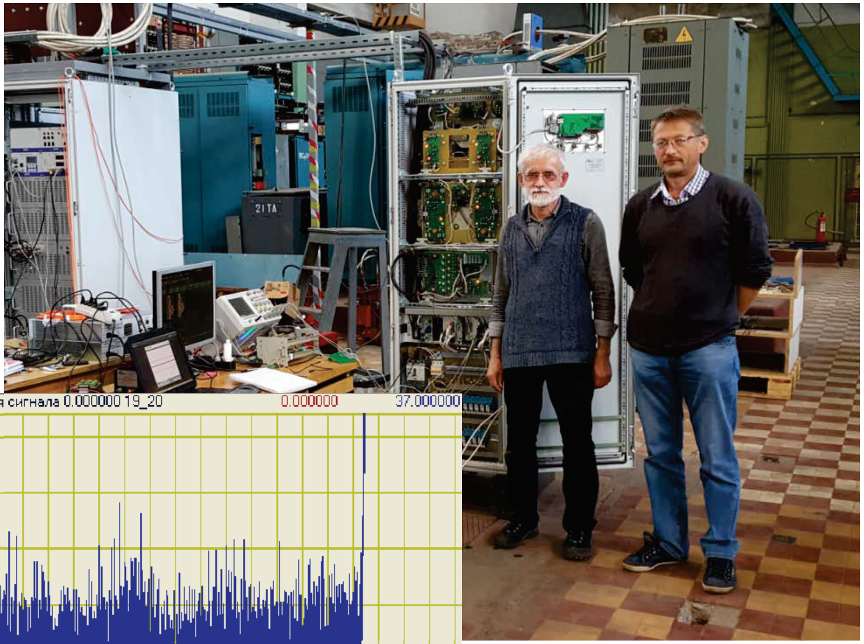
-EVPUas (Slovak

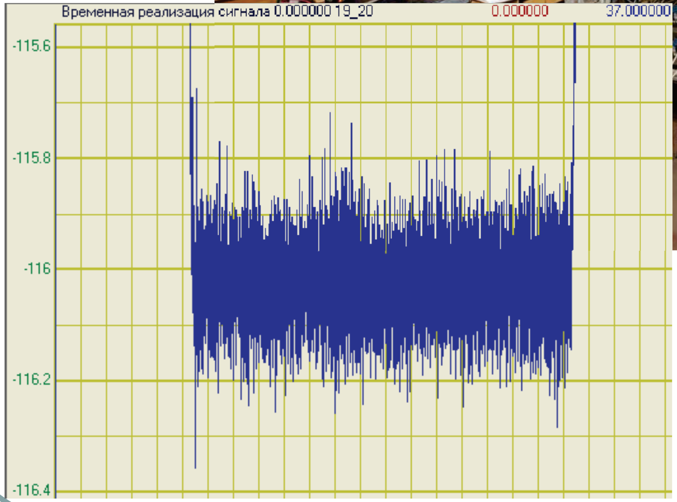
-Frako-Term (Pola

Prototypes were test

Operation on SC load for Quadrupole supply

IP600-80D (600 A)





The Booster power supply

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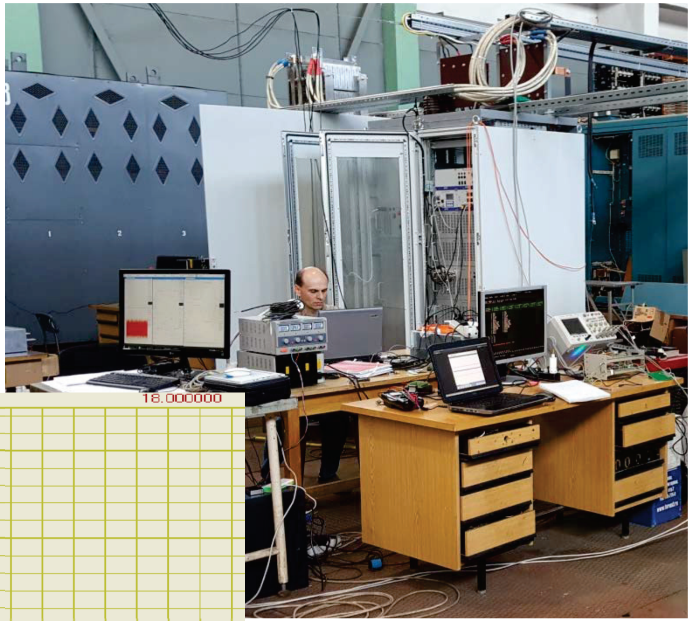
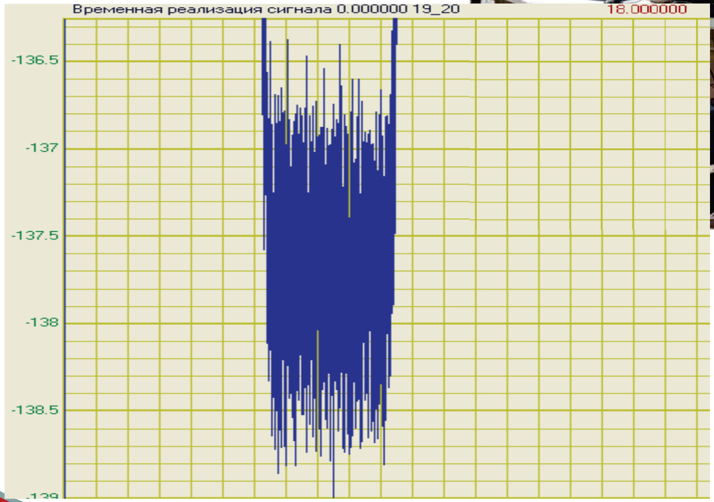
Prototypes ar

Operation on SC load for Quadrupoles supply

PS600 (600 A)





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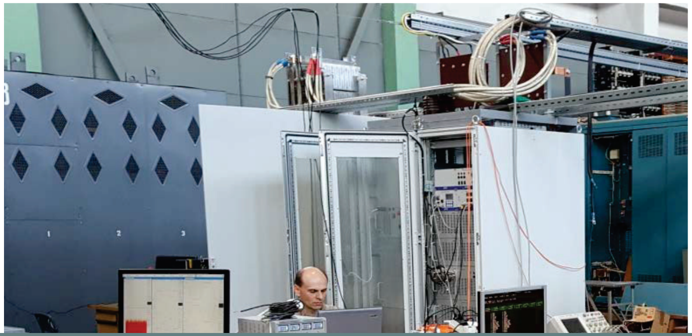
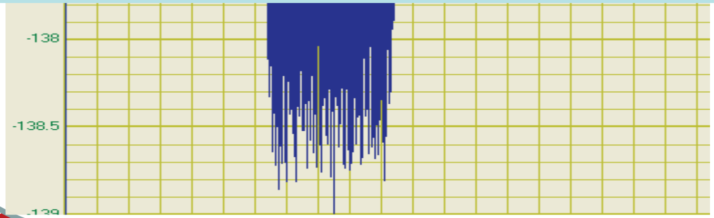
PS600 (600 A)



This Run:

-Test of dynamic behavior during the beam acceleration



Prototypes ar

Operation on SC load for Quadrupoles supply

Development of cryogenic system

Cryogenic System of Nuclotron

Operating temperature, K	4.5
Refrigerating capacity at 4.5 K, W	**4000**
Total capacity of the compressors, nm^3/h	17220
Total power of electric motors, kW	4180
Flow rate of cooling water, m^3/h	200
Total «cold» mass, t	80

Consumption of liquid N2, kg/h 850

Cryogenic System of NICA complex

Operating temperature, K	4.5
Refrigerating capacity at 4.5 K, W	**8000**
Total capacity of the compressors, nm^3/h	30420
Total power of electric motors, kW	7400
Flow rate of cooling water, m^3/h	356
Total «cold» mass, t	290

Consumption of liquid N2, kg/h 2300

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Consumption of liquid N2, kg/h 850

capacity will be doubled

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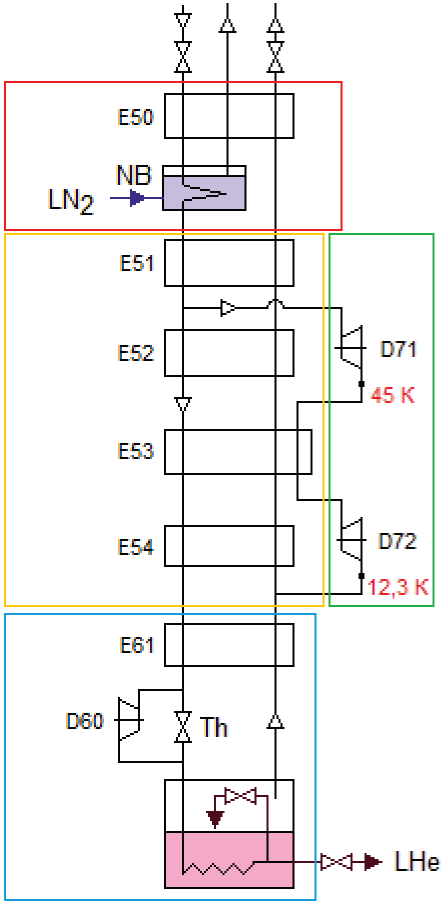
HELIUM LIQUIFIER OG1000



Operating gas	helium
Capacity, l/h	1100±100
Liquid nitrogen consumption, kg/h	≤560
Energy consumption, kW	1760
Compressed helium pressure, MPa	2,5
Compressed helium flow rate, Nm^3/h	6600
Total mass, kg	14000
External dimensions, m×m×m	5×5×10

The principal scheme of the liquefier OG – 1000:

E50, E51, E52, E53, E54, E61 – heat exchangers;

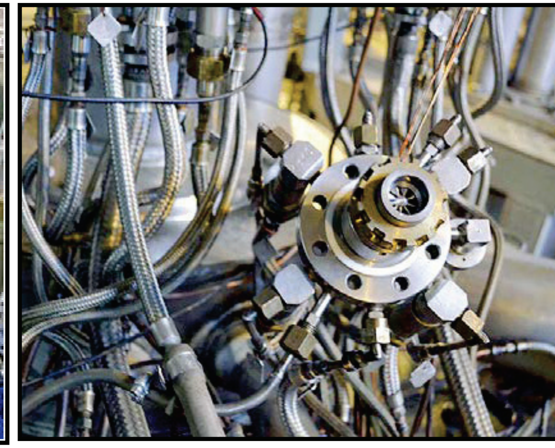
D71, D72, D60 – turbo expanders;

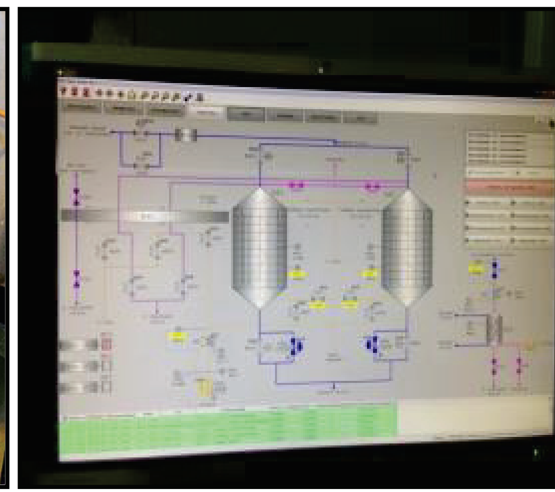
Th – throttle;

NB – bath of liquid nitrogen.

Commissioning and successful test of the 1000 l/h helium liquefier







The largest helium liquefier in Russia was installed and successfully launched at JINR in June 2016

Beginning of the Booster magnet serial production

2015

H. Khodzhibagiyan,
The Progress on Manufacturing and Testing of the SC Magnets
for the NICA Booster Synchrotron

Beginning of the Booster magnet serial production

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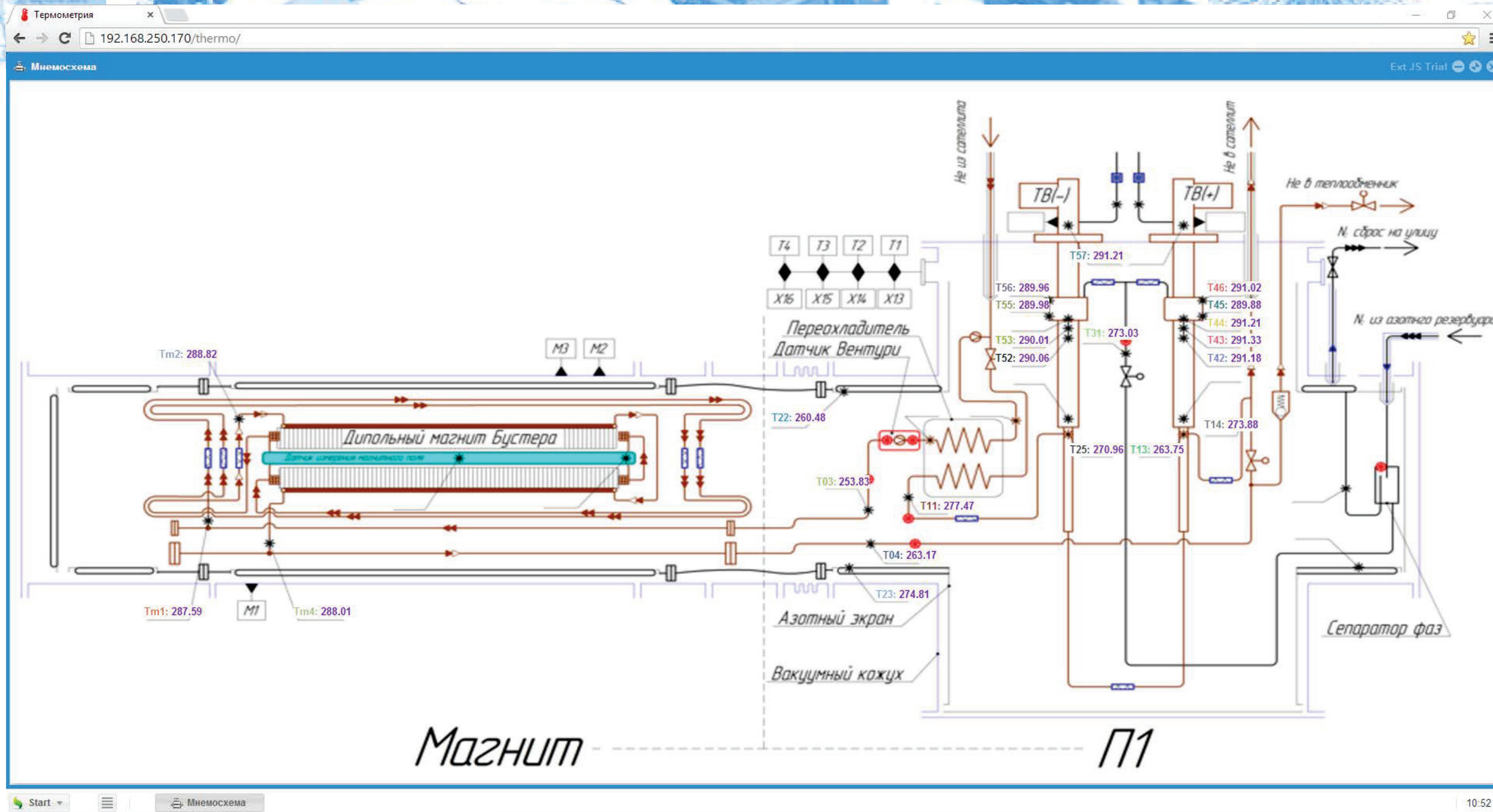
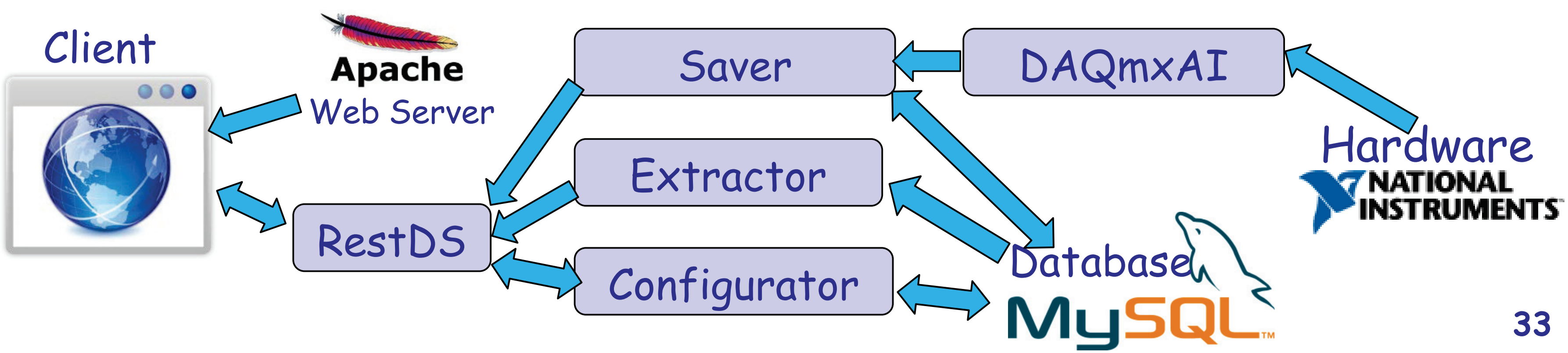
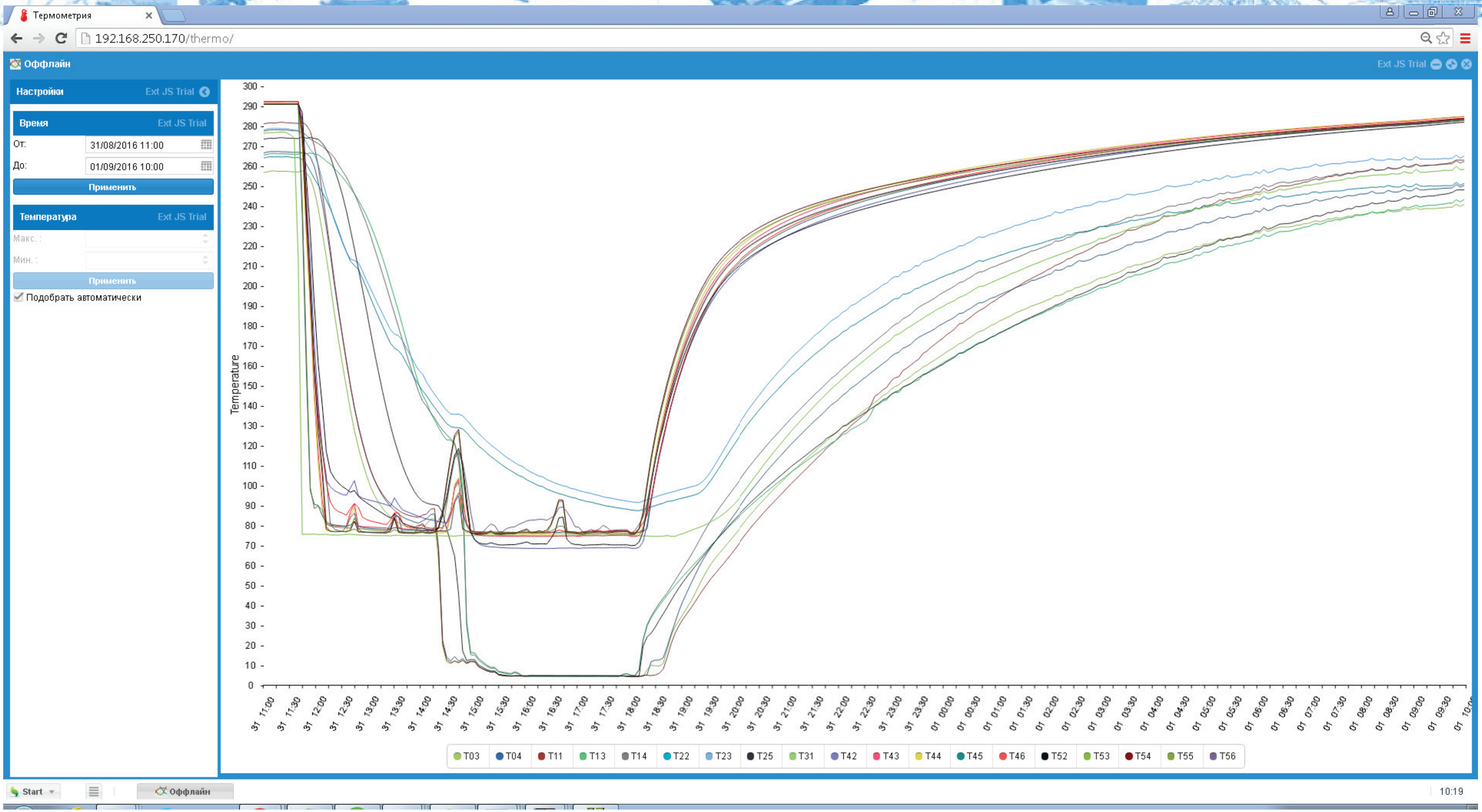
H. Khodzhibagiyan,
The Progress on Manufacturing and Testing of the SC Magnets
for the NICA Booster Synchrotron

TANGO: Thermometry at test-bench



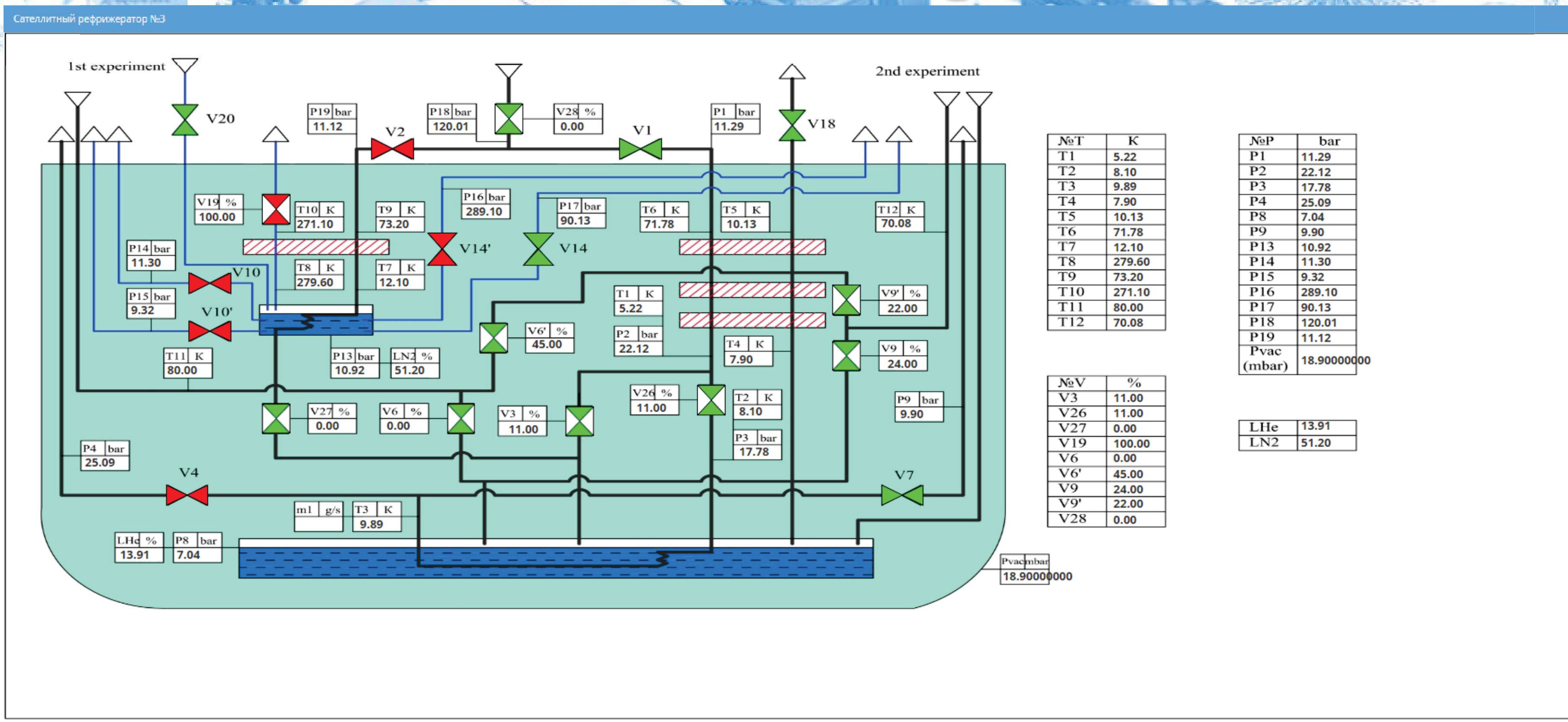


Thermometry: result representation



Temperature data, collected during the experimental session.

TANGO:Satellite refrigerator control

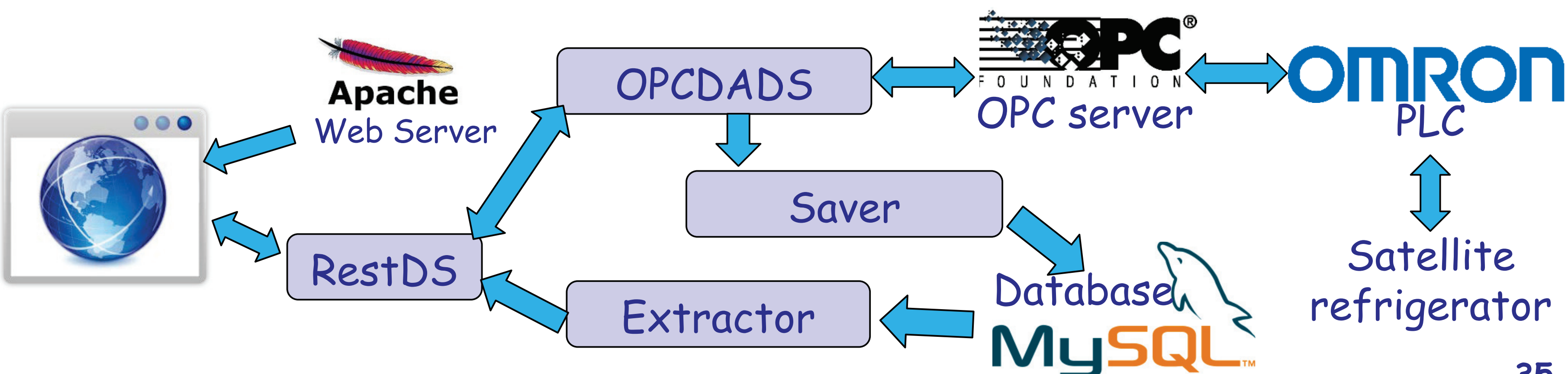


№T	K
T1	5.22
T2	8.10
T3	9.89
T4	7.90
T5	10.13
T6	71.78
T7	12.10
T8	279.60
T9	73.20
T10	271.10
T11	80.00
T12	70.08

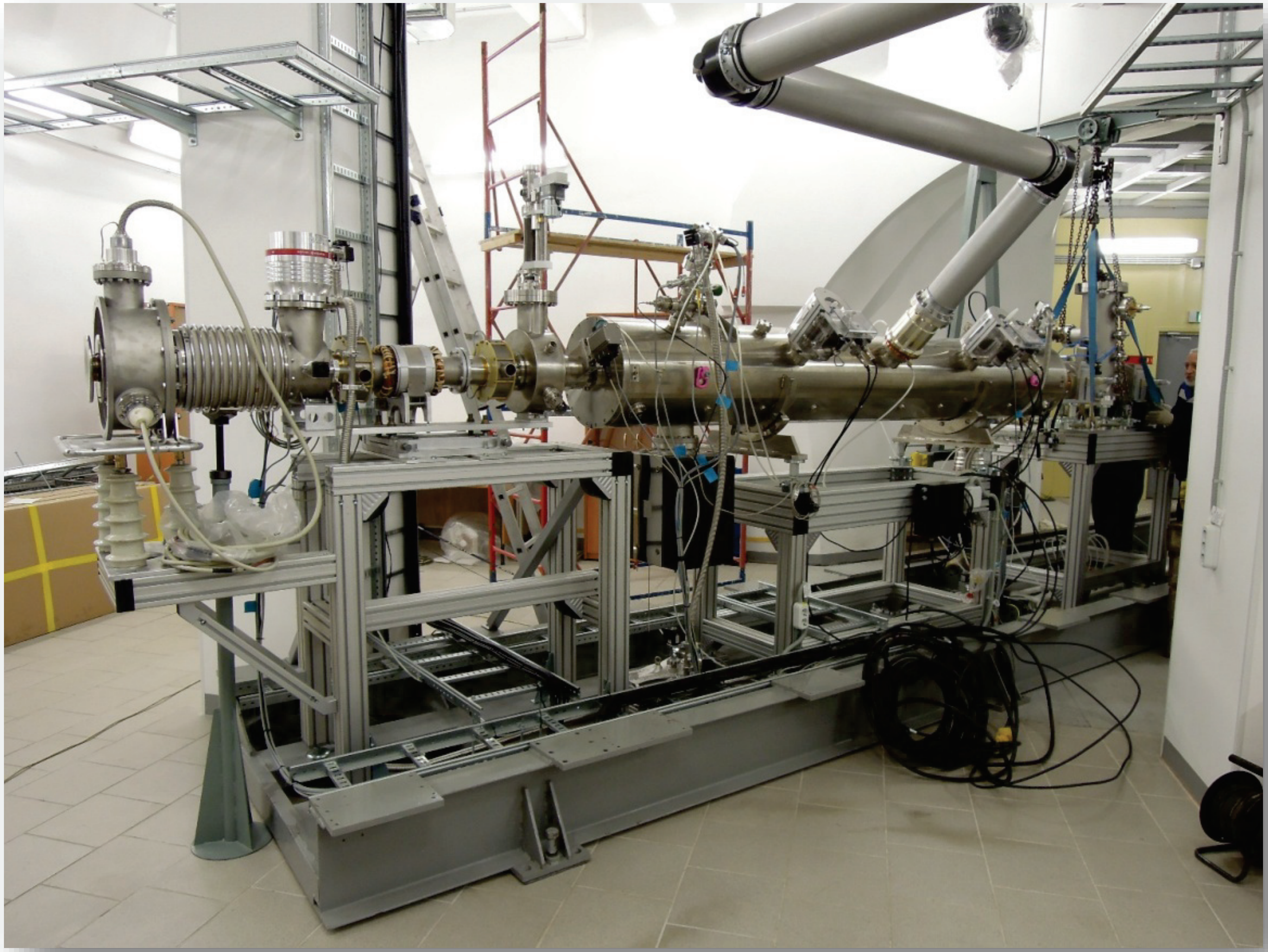
№P	bar
P1	11.29
P2	22.12
P3	17.78
P4	25.09
P8	7.04
P9	9.90
P13	10.92
P14	11.30
P15	9.32
P16	289.10
P17	90.13
P18	120.01
P19	11.12
Pvac (mbar)	18.90000000

№V	%
V3	11.00
V26	11.00
V27	0.00
V19	100.00
V6	0.00
V6'	45.00
V9	24.00
V9'	22.00
V28	0.00

LHe	13.91
LN2	51.20



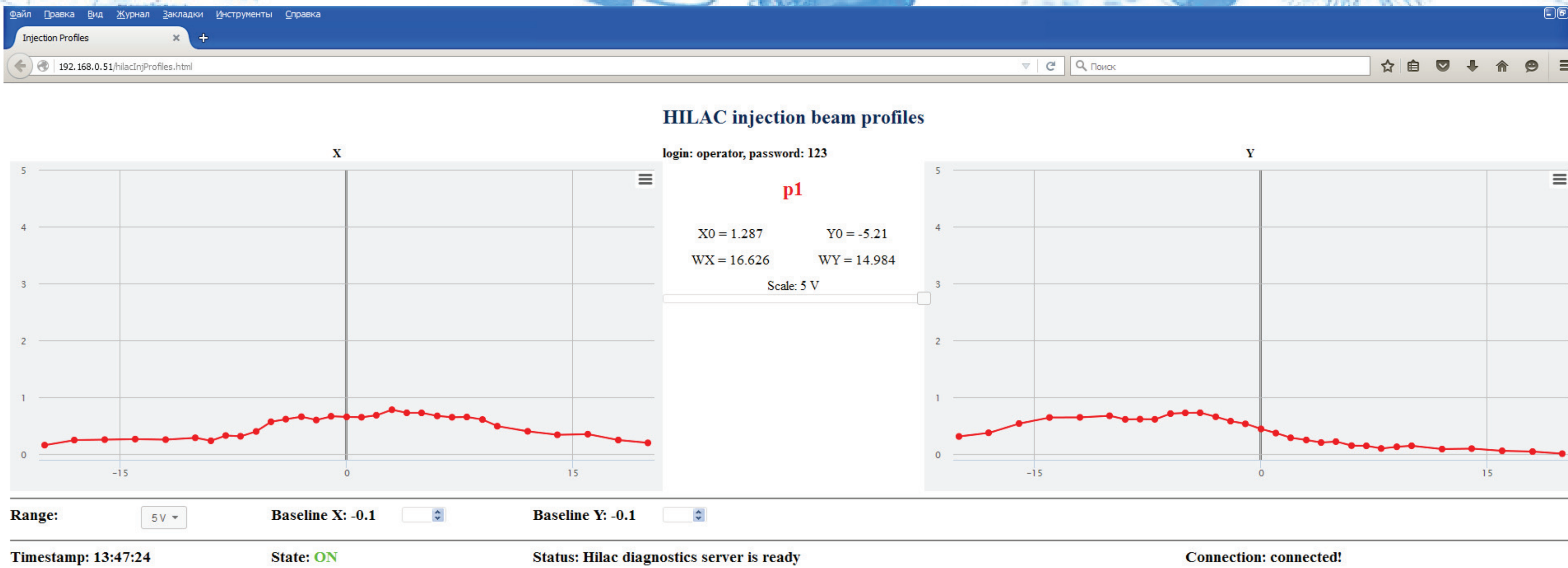
HILac commissioning

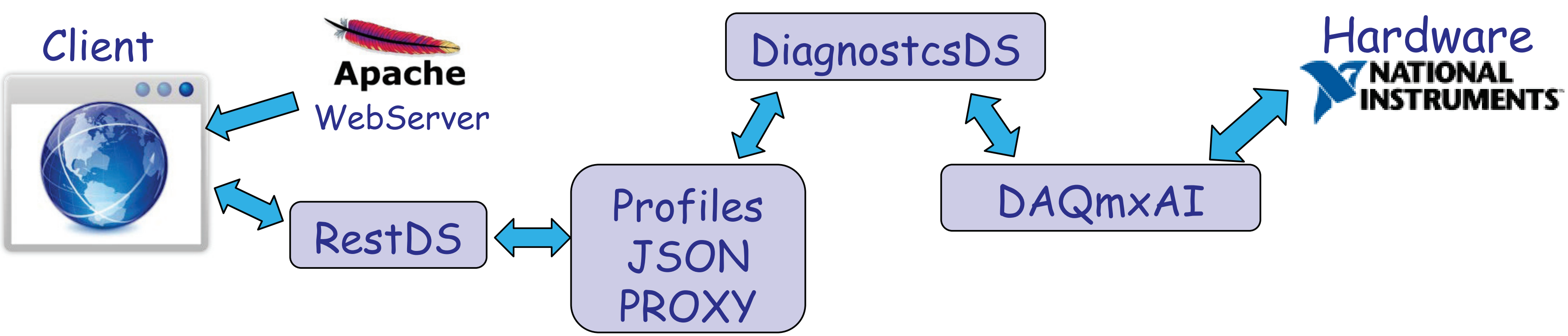


2016

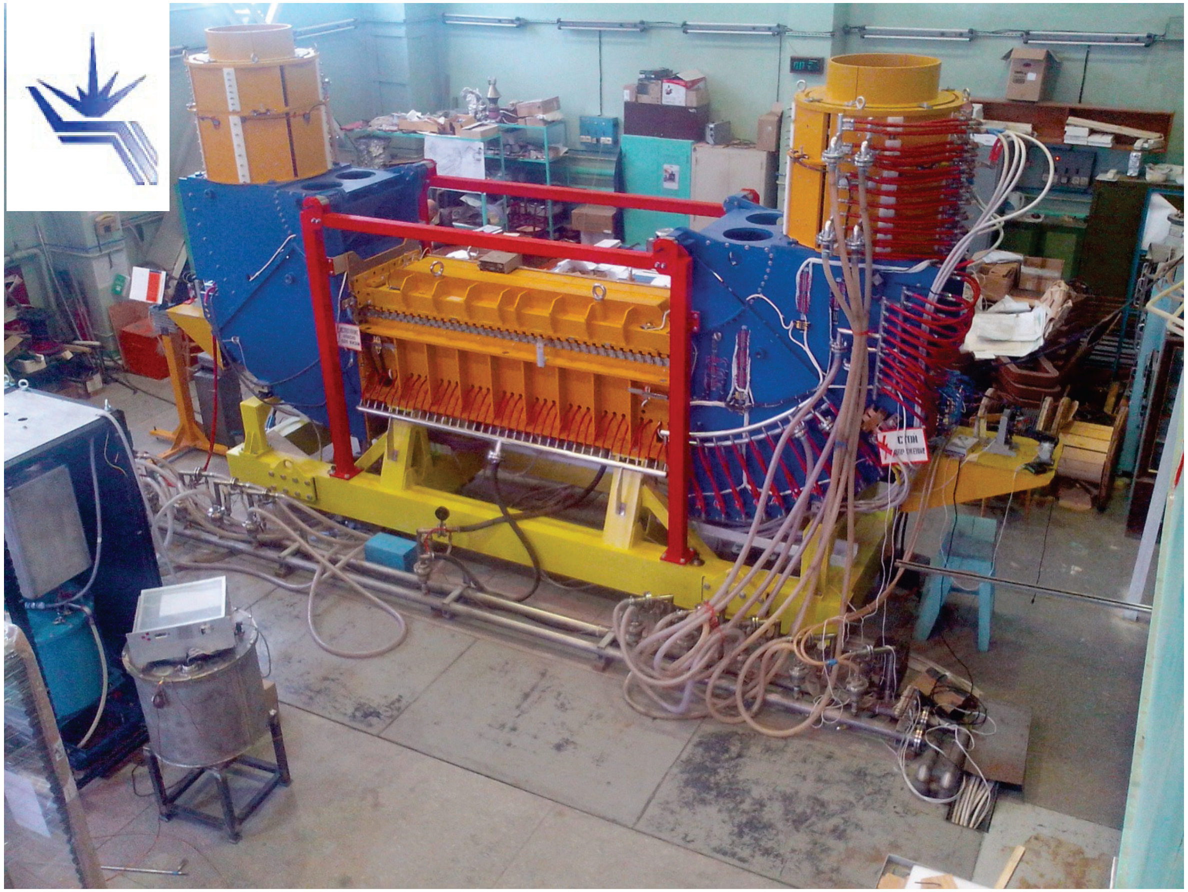
H. Hoeltermann (BEVATECH, Frankfurt, Germany)
Commissioning of the New Heavy Ion Linac at the NICA Project
this session

TANGO: HILAC beam profiles





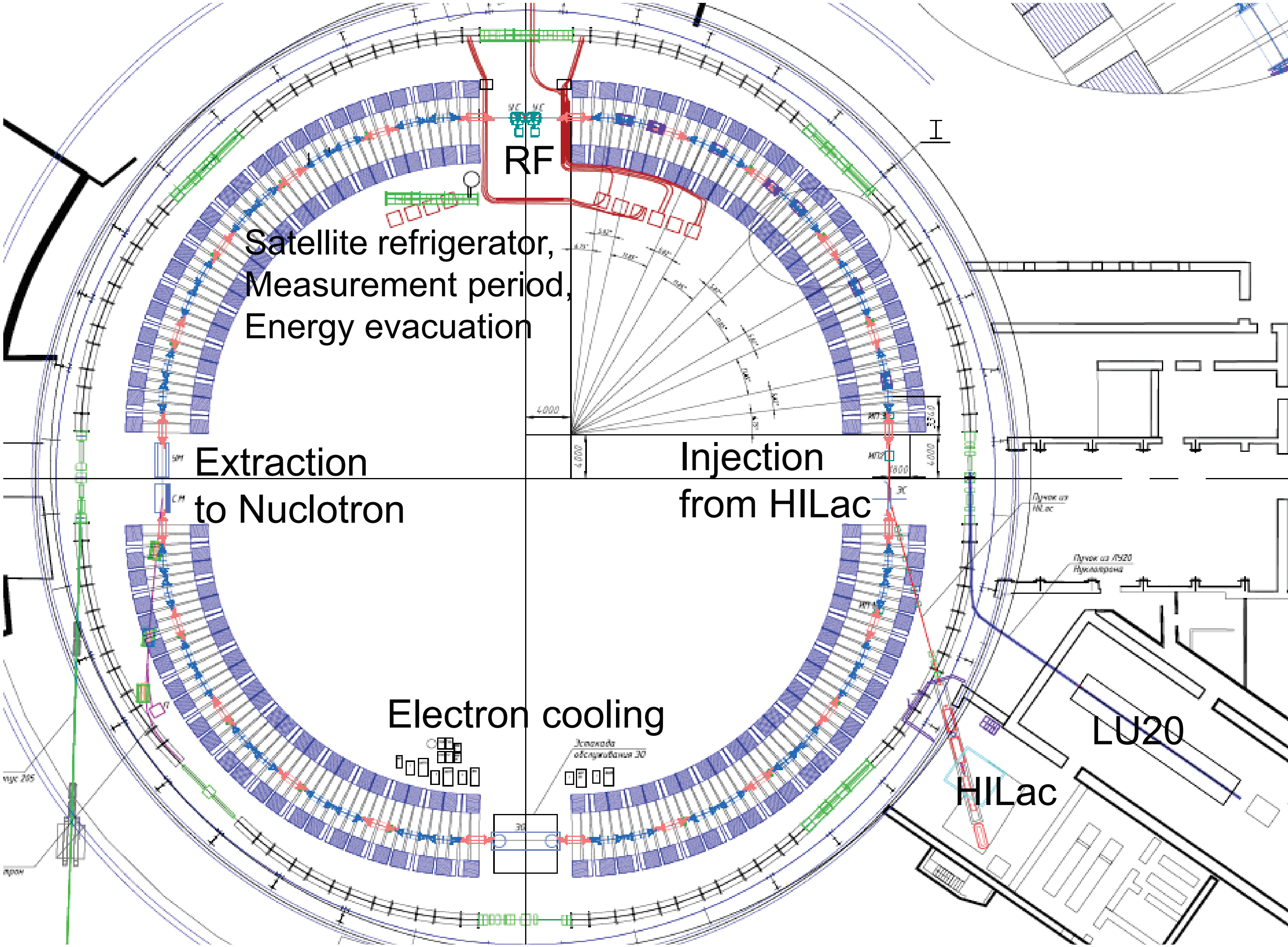
Commissioning of the Booster electron cooler



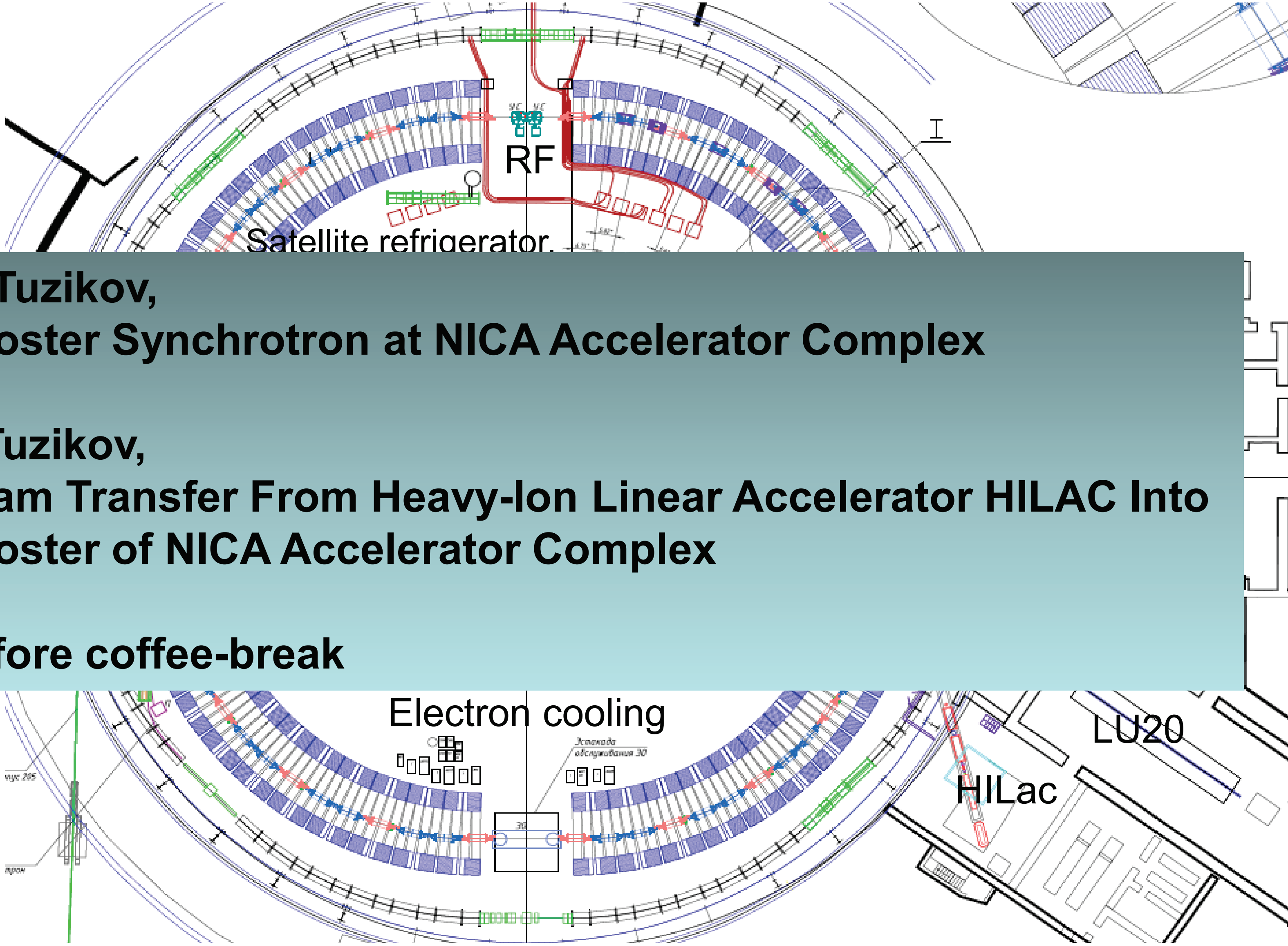
May 2016

A. Bubley (BINP),
Commissioning of the 60 keV Electron Cooler for the NICA Booster
Poster presentation

Booster


RF
Satellite refrigerator,
Measurement period,
Energy evacuation
Extraction
to Nuclotron
Injection
from HILac
Electron cooling
LU20
HILac

Booster



A. Tuzikov,
Booster Synchrotron at NICA Accelerator Complex

A.Tuzikov,
Beam Transfer From Heavy-Ion Linear Accelerator HILAC Into Booster of NICA Accelerator Complex

Before coffee-break

Toward Booster and BM@N

Thank you for attention