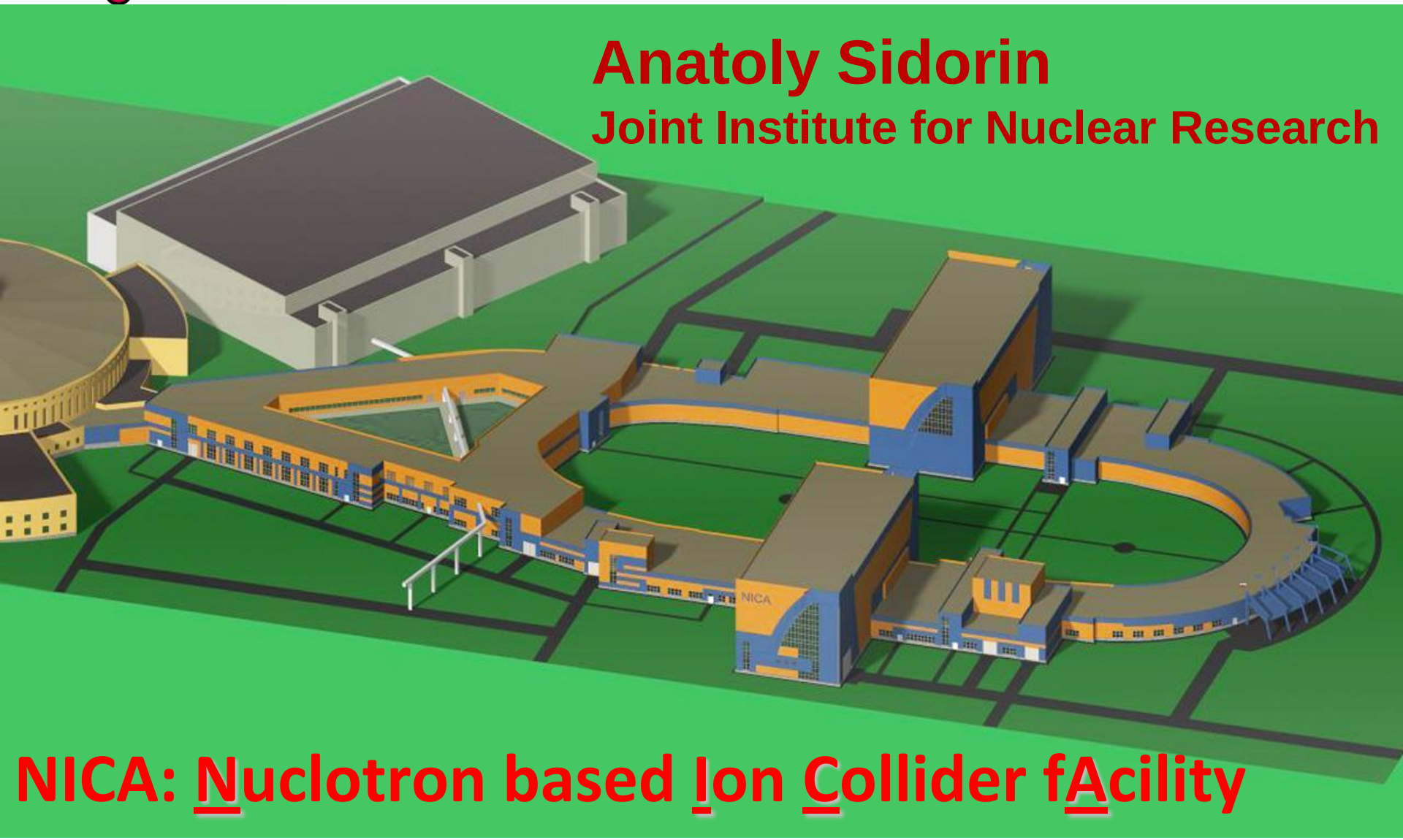
NICA accelerator complex

Anatoly Sidorin
Joint Institute for Nuclear Research



NICA: Nuclotron based Ion Collider fAcility

CREMLIN WP7 "Super c-tau factory workshop“ 26 May 2018

General information

NICA is an international project
realizing by international intergovernmental organization –
the Joint Institute for Nuclear Research
and brings the efforts of 18 member states and 6 associated countries.

Project NICA started as a part of the JINR Roadmap for 2009-2016
was described in the JINR 7-years Program.
It was approved by Scientific Council of JINR and
the Committee of Plenipotentiaries of JINR in 2009.
NICA is a flagship project of JINR presently.

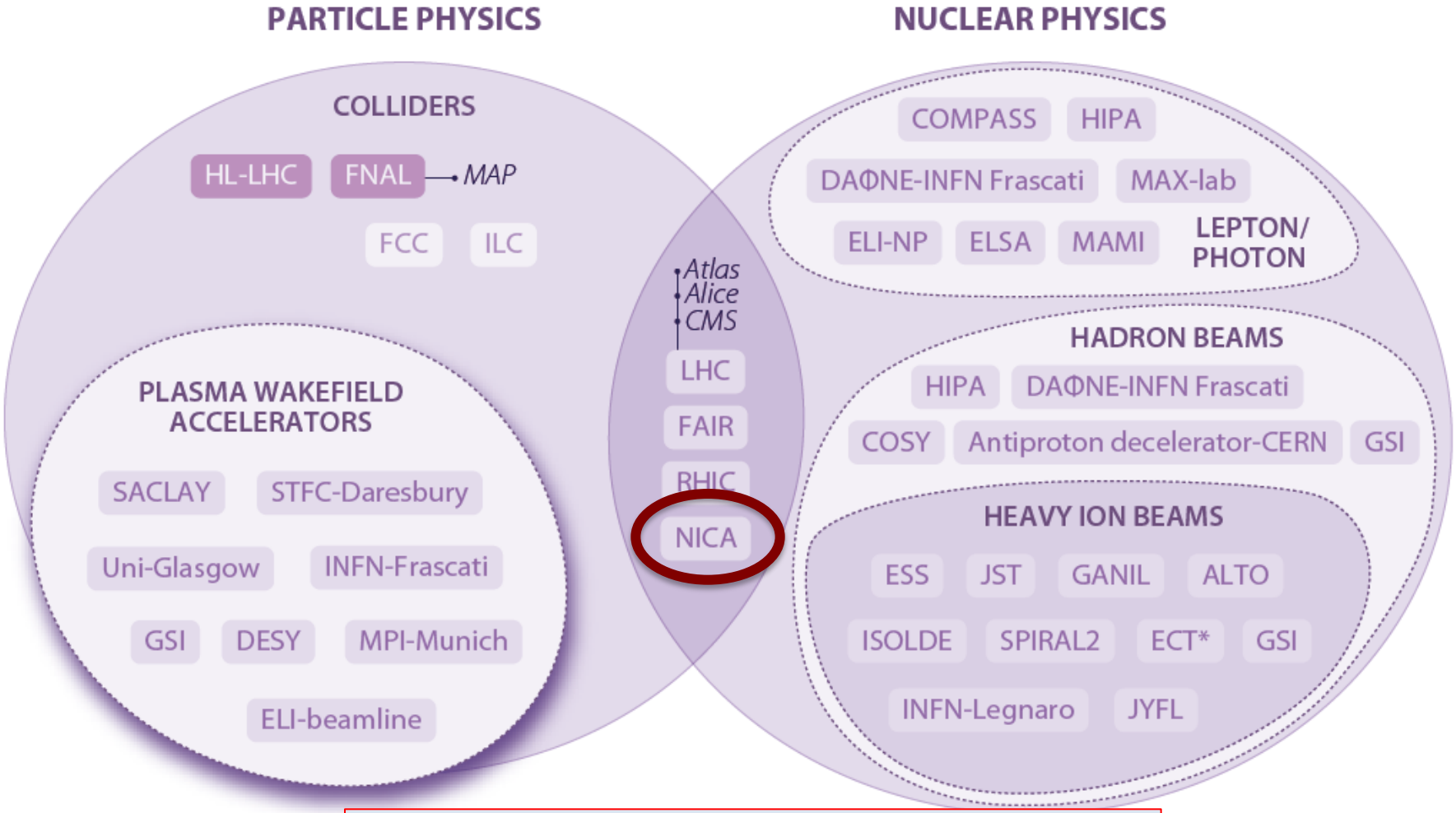
In 2016 between RF and JINR was signed a contract
presuming start of operation of basic configuration of the NICA complex in 2020.

In 2017 the project was included into ESFRI road map.

Project web-site: http://nica.jinr.ru/

New issue of the ESFRI Roadmap

Main Research Infrastructure in Particle and Nuclear Physics



NICA – Complementary Project

СОГЛАШЕНИЕ

между Правительством Российской Федерации и международной межправительственной научно-исследовательской организацией Объединенным институтом ядерных исследований о создании и эксплуатации комплекса сверхпроводящих колец на встречных пучках тяжелых ионов NICA

Правительство Российской Федерации и международная межправительственная научно-исследовательская организация Объединенный институт ядерных исследований (далее — Объединенный институт ядерных исследований), в дальнейшем именуемые Сторонами,

выражая общее желание содействовать укреплению потенциала Российской Федерации и Объединенного института ядерных исследований в области проводимых научно-технических и инновационных исследований в соответствии со статьей 30 Соглашения между Правительством Российской Федерации и Объединенным институтом ядерных исследований о местопребывании и об условиях деятельности Объединенного института ядерных исследований в Российской Федерации от 23 октября 1995 года,

стремясь создать комплекс сверхпроводящих колец на встречных пучках тяжелых ионов NICA (Nuclotron-based Ion Collider fAcility), обладающий беспрецедентными параметрами в области исследования физики частиц и ядер высоких энергий и обеспечивающий возможность его применения для инновационных разработок в приоритетных областях научных знаний, техники и технологий,

Agreement between RF Government and JINR (May 2016)

The primary purpose of the NICA construction

The project comprises experimental studies of **fundamental** character in the fields of the following directions:

- Relativistic nuclear physics;
- Spin physics in high and middle energy range of interacting particles;
- Radiobiology.

Applied researches based on particle beams generated at NICA are dedicated to development of novel technologies in material science, environmental problems resolution, energy generation, particle beam therapy and others.

Education program is one of the first priority activities at JINR, as formulated in JINR Roadmap.
The proposed NICA facility offers various possibilities for teaching and qualification procedures including practice at experimental set ups, preparation of diploma works, PhD, and doctoral theses.

Stages of the experimental program realization

-Fixed target experiment with heavy ion

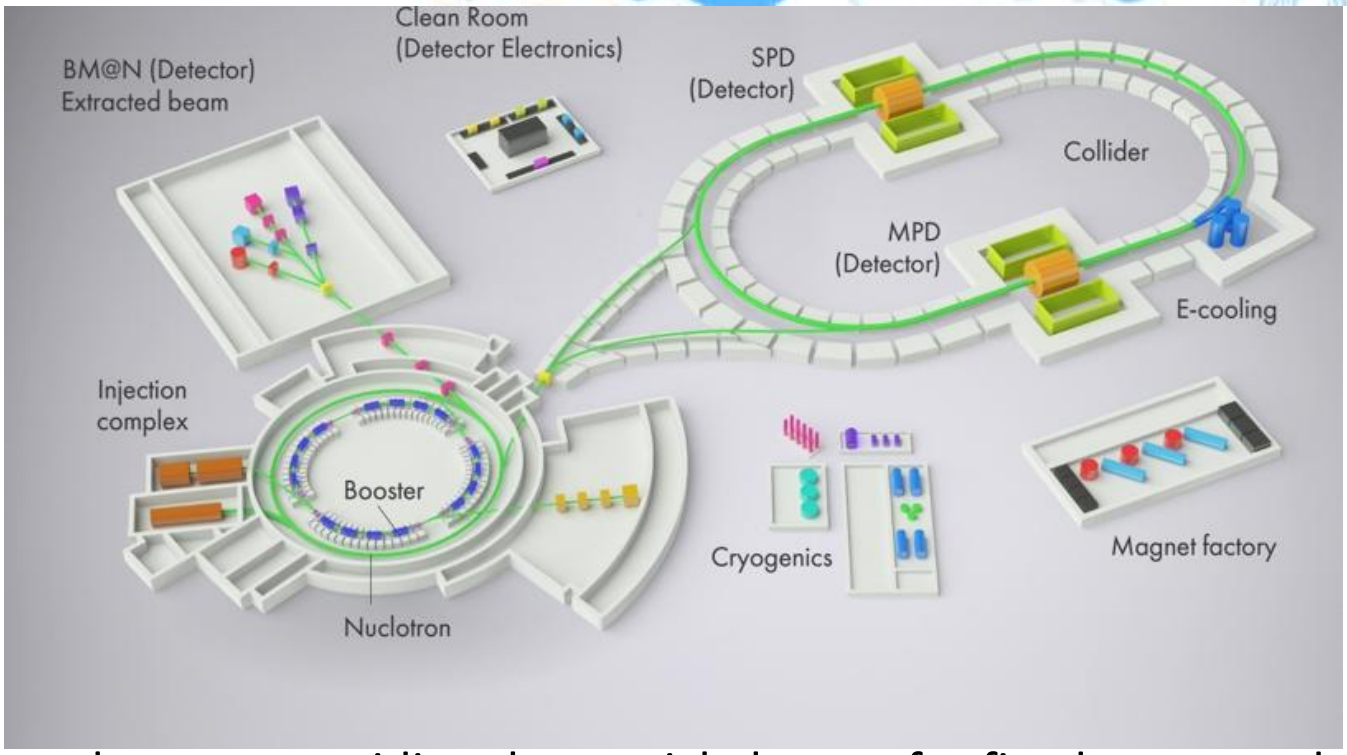
-Basic configuration of the collider and detector

-Project configuration, heavy ion collisions

-Collisions of heavy ions with light ions (protons)

-Spin physics program

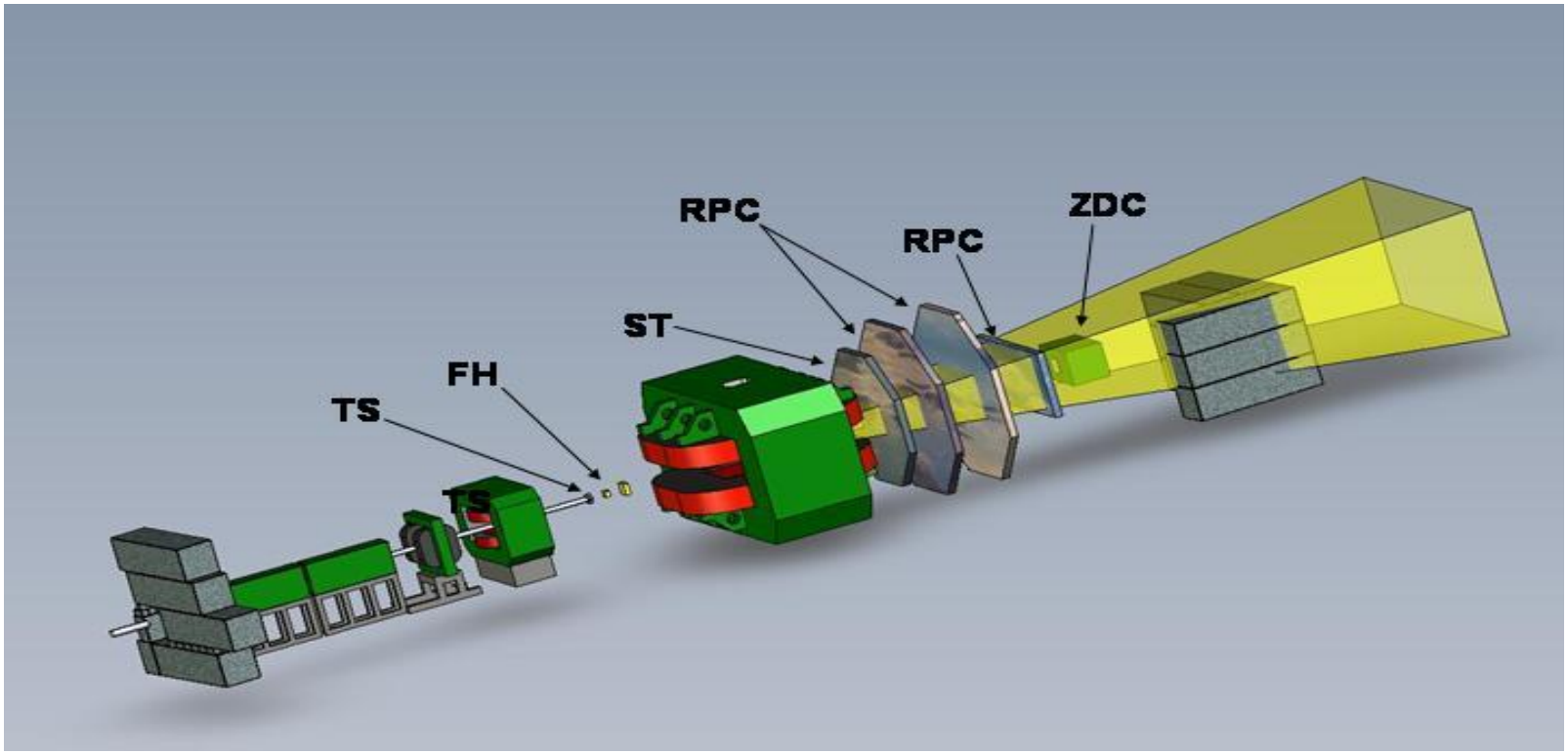
The NICA complex includes:



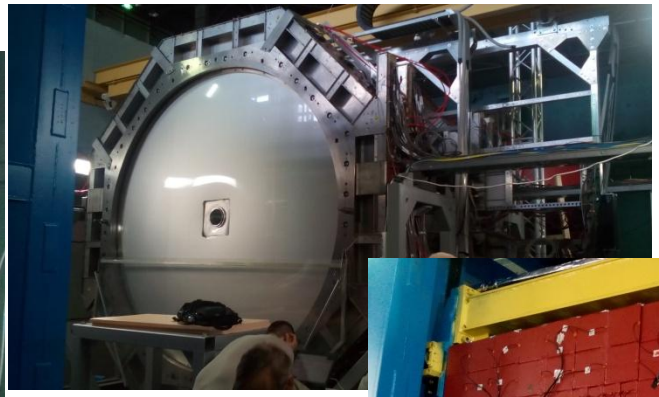
- Set of accelerators providing the particle beams for fixed target and collider experiments,
- Experimental facilities,
- Line for assembling and cryogenic testing of SC-magnets,
- Workshops for construction of the detector elements,
- NICA innovation center,
- Required infrastructure.

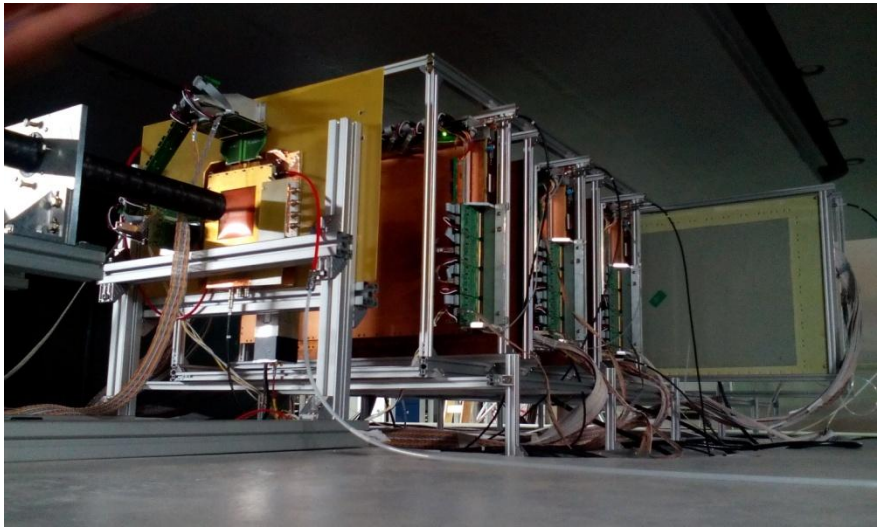
Main experimental facilities

Baryonic Matter at Nuclotron (BM@N) –
fixed target experiment at the Nuclotron extracted beams
which main goals are investigations of strange / multi-strange hyperon,
hypernuclei production and short range correlations.



BM@N: assembly and test with the Nuclotron beams



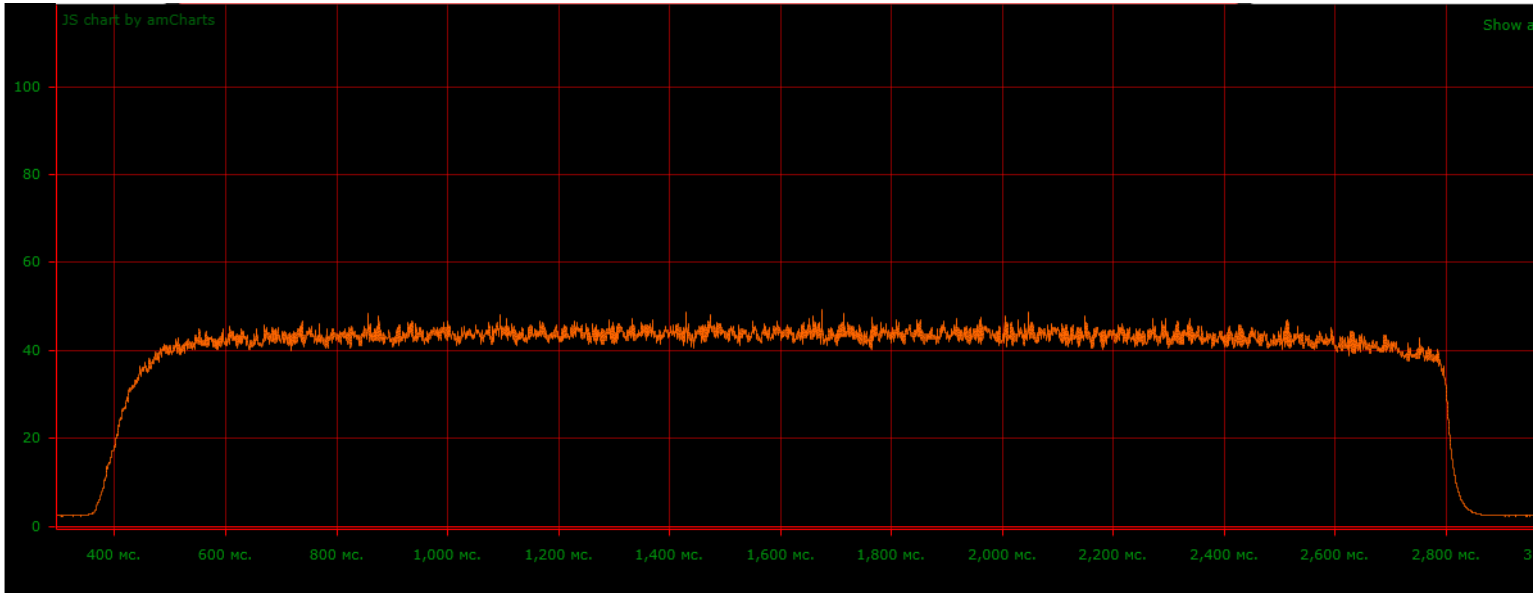


Main experimental facilities

Baryonic Matter at Nuclotron (BM@N):

-Three technological runs (2016 – 2017)

-**5.02 – 4.04.2018 experiments** with C, Ar, Kr beams (Short range correlations, strange production)

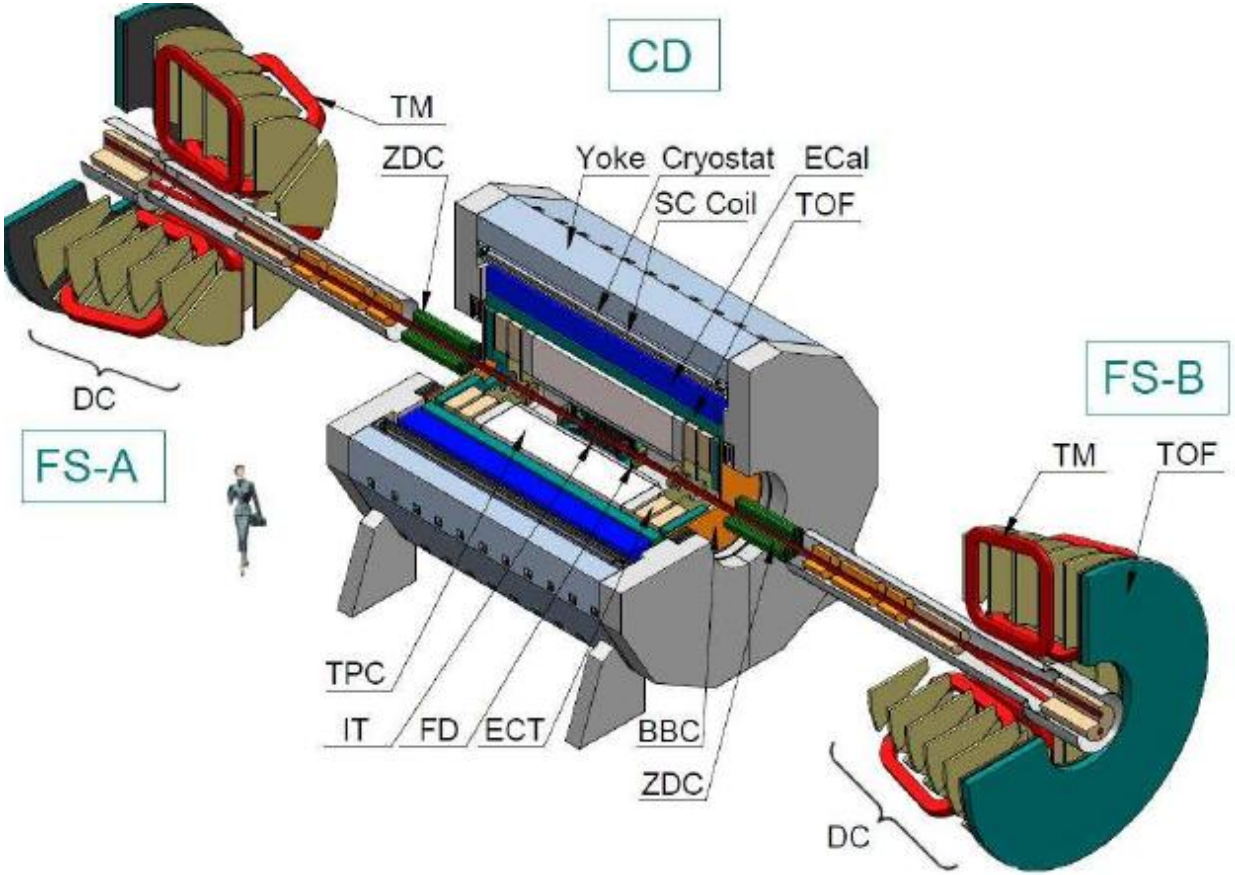


Intensity of extracted Kr beam. Spill duration 2.5 sec.
Up to $5 \cdot 10^5$ ions per cycle

Main experimental facilities

Multi Purpose Detector (MPD)

aiming to study of hot and dense strongly interacting matter in heavy ion (up to Au) collisions at the centre-of-mass energy range of max baryonic density (up to 11 GeV).



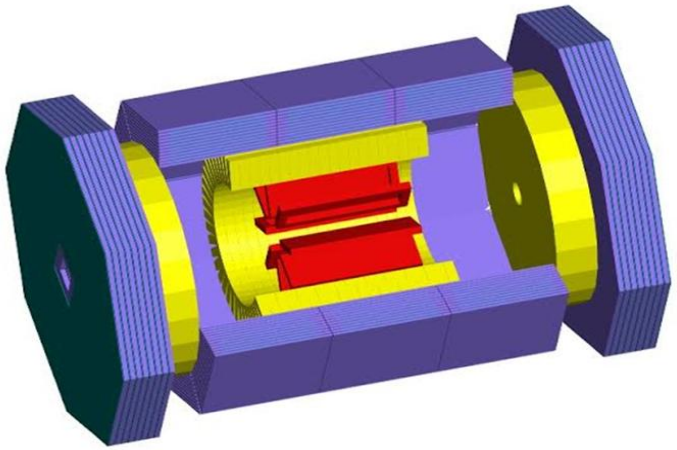
Main experimental facilities

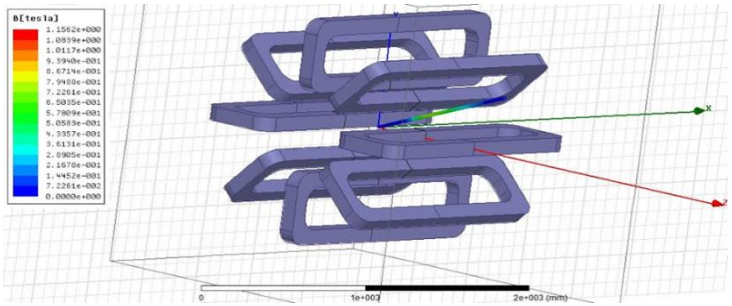
Multi Purpose Detector (MPD)

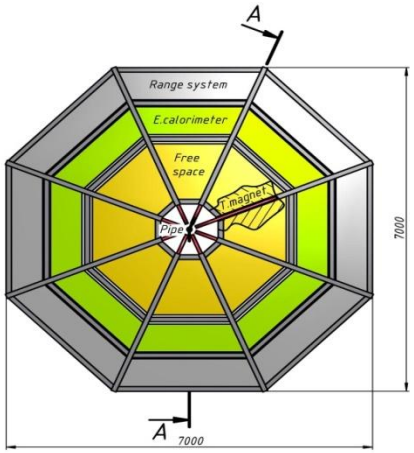
CREMLIN WP2 Working Meeting
„Exchange on Policy- and ESFRI-related Issues”, April 2016, Dubna

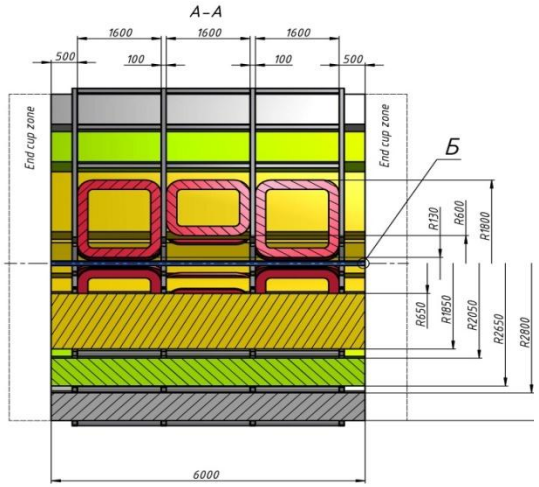
Main experimental facilities

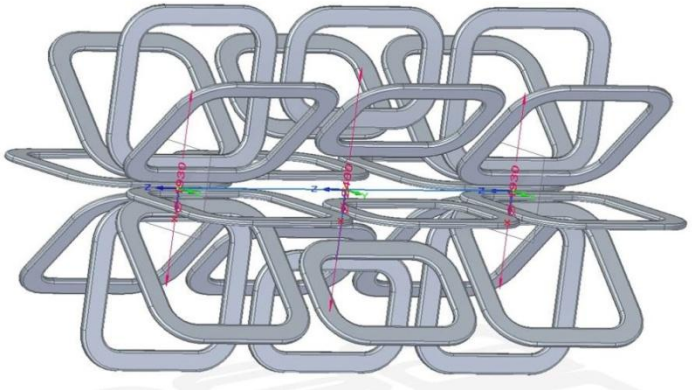
Spin Physics Detector (SPD) aiming to study of spin physics with colliding beams of polarized deuterons and protons at the energies up to 27 GeV (for protons).







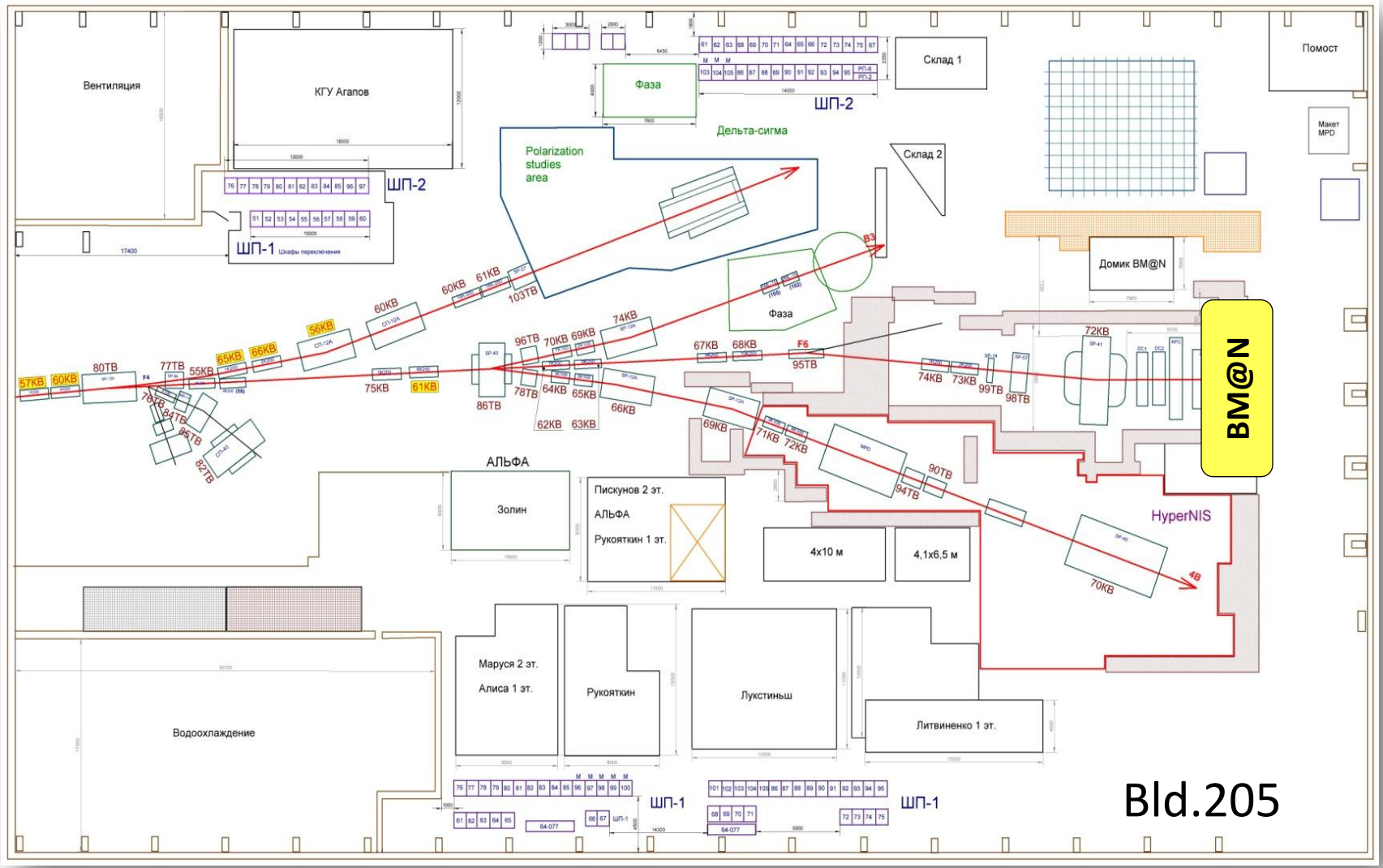




Main experimental facilities

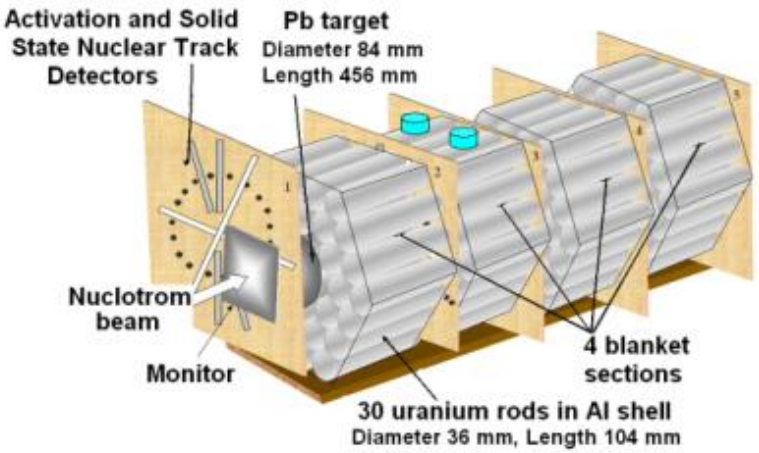
Area for radiobiology and applied research

is under development in the existing experimental building.



Innovations based on NICA technologies

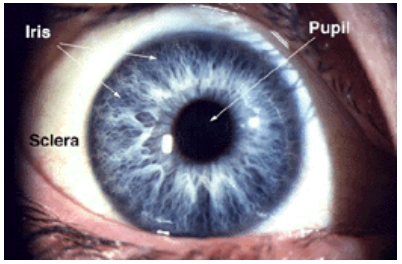
Transmutaion of nuclear fuel waste

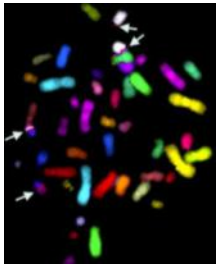


Testing of space craft elements and electronics

Design and Development of accelerator and detector technologies for medicine

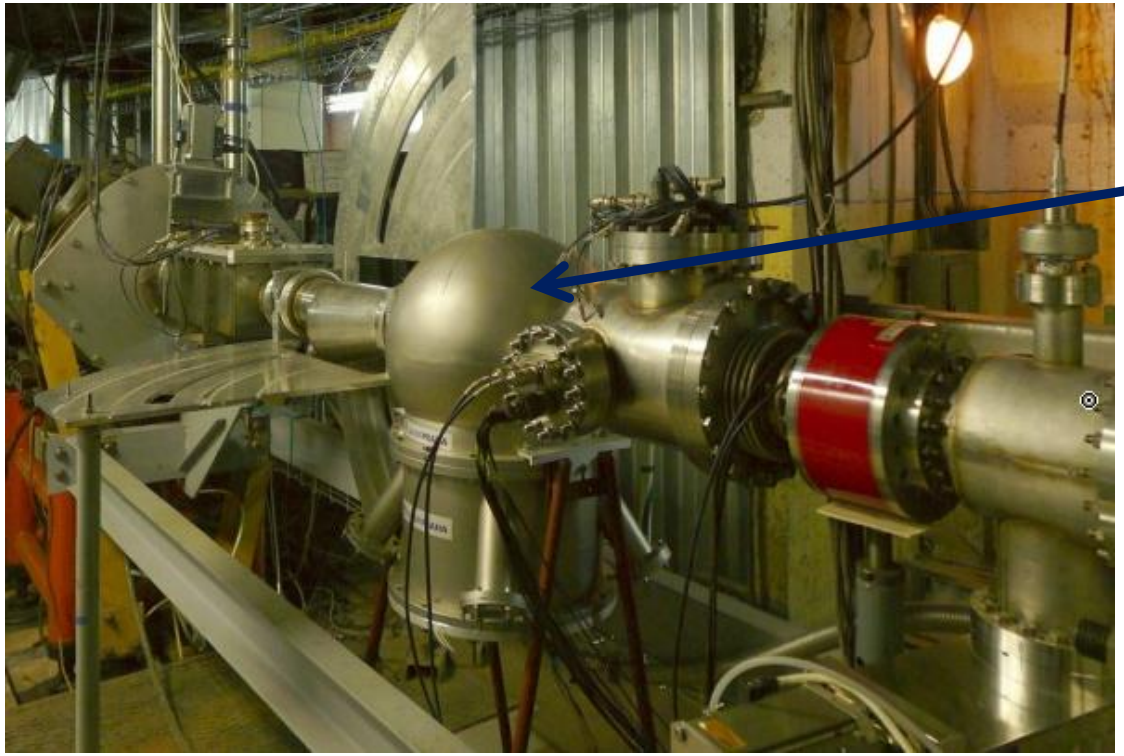
Radiobiology and medicine

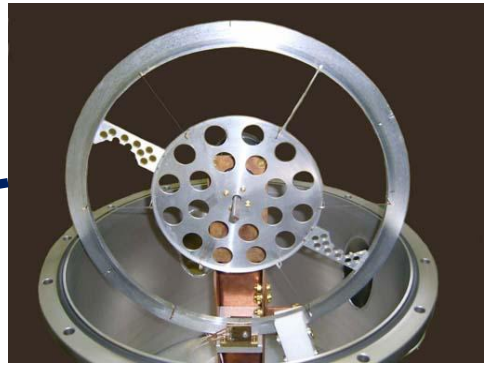




Main experimental facilities

The Nuclotron internal target station equipped with six different targets: wire, strip and film with material from hydrogen to tungsten dedicated for particle physics, spin physics, relativistic atomic physics experiments.





New buildings of the NICA complex

NICA innovation center

Collider building

New compressor hall building

New buildings of the NICA complex

Collider building

Official start of the construction 25 March 2016

New buildings of the NICA complex

Collider building

2017

New buildings of the NICA complex

Collider building

http://nucloweb.jinr.ru/nucloserv/205corp.htm

New buildings of the NICA complex

NICA innovation center

- cluster of JINR computer center dedicated to collect and process the data from NICA detectors,
- 500 offices for scientists,
- laboratory rooms for preparation of experimental equipment and fast analysis of results,
- conference hall

Line for assembling and cryogenic testing of SC-magnets

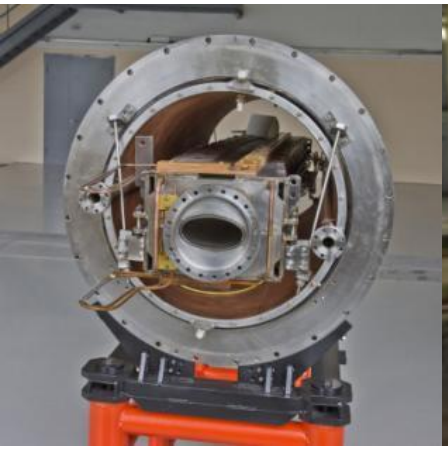
Main production areas:

- Incoming inspection zone
- SC cable production hall
- SC coils production hall
- Area for assembling the magnets
- Area for the magnetic measurements under the room temperature
- Leakage test area
- Area for mounting the SC-magnets inside cryostats
- Cryogenic tests bench

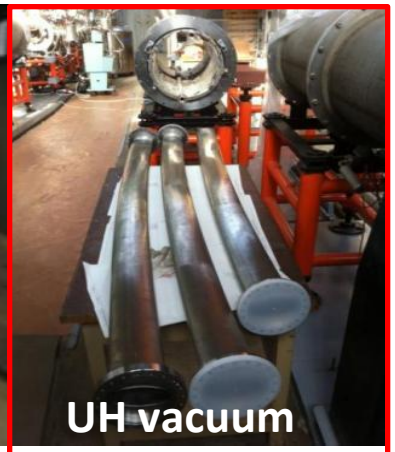
450 magnets for NICA and FAIR projects

5. СП магниты для Бустера, Нуклотрона и для SIS-100 (FAIR)

The Booster Elements

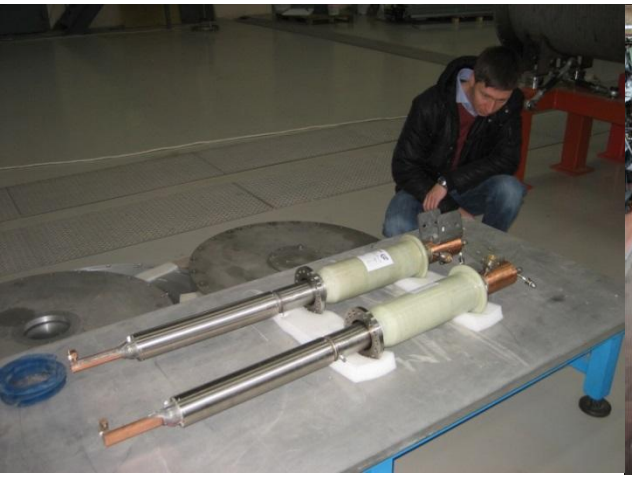


Booster dipole and quadrupole lens

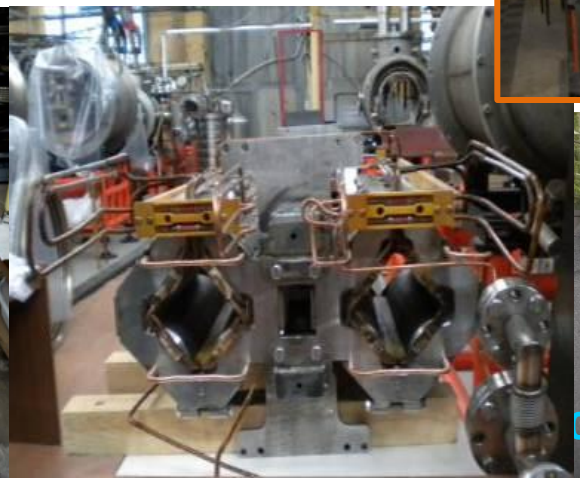


UH vacuum chambers (curved)

SIS-100



HTSC current leads 17 kA



The Collider “twin” dipole and lens

Line for assembling and cryogenic testing of SC-magnets

April 2016

Official start up

28 November 2016

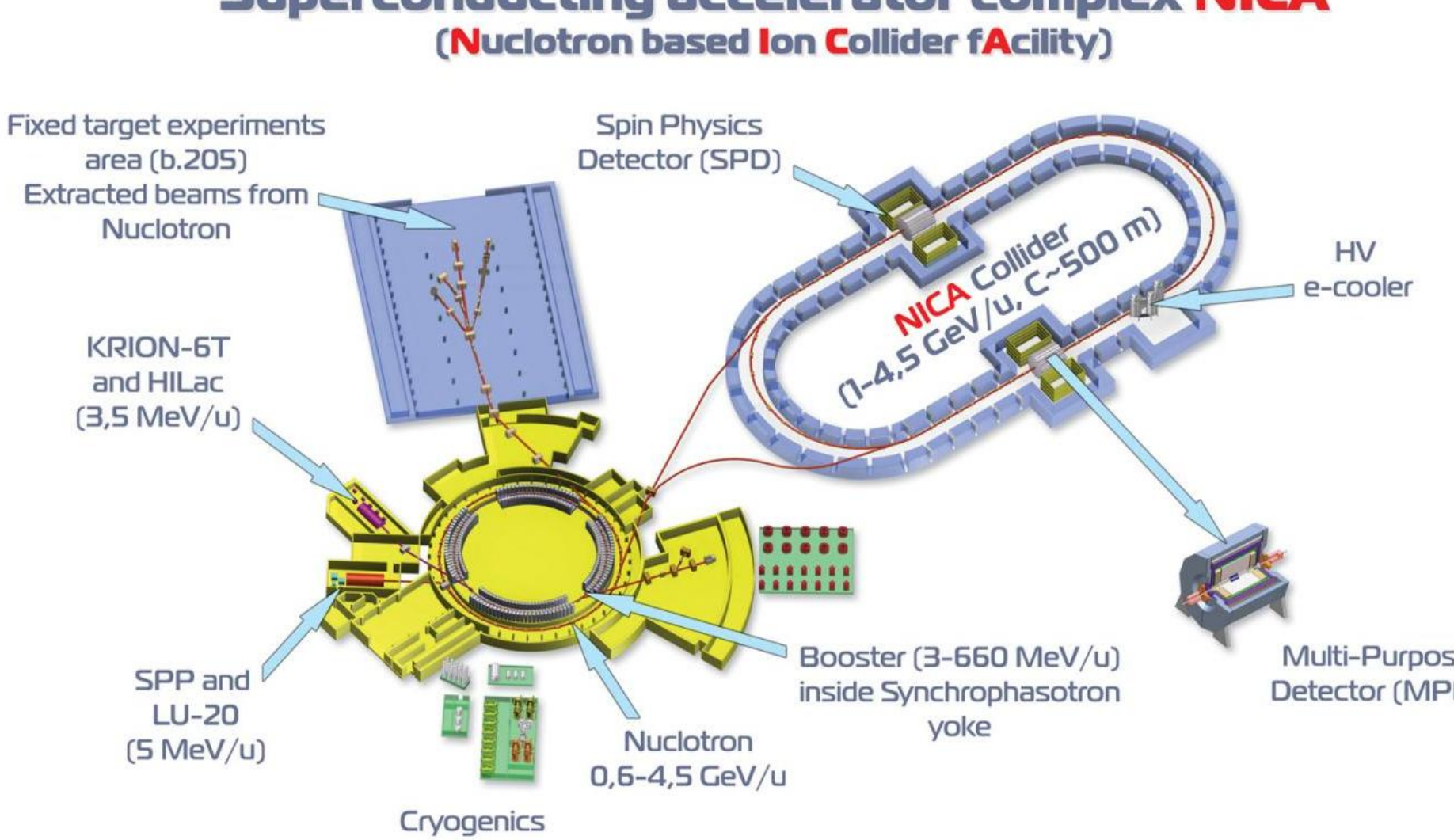
Cryogenic facility

New helium liquefier (1000 l/h)

Finally the cooling power should be doubled from 4 kW to 8 kW @ 4.5K

Largest in Russia
Commissioned in may 2016

NICA accelerators



NICA accelerators

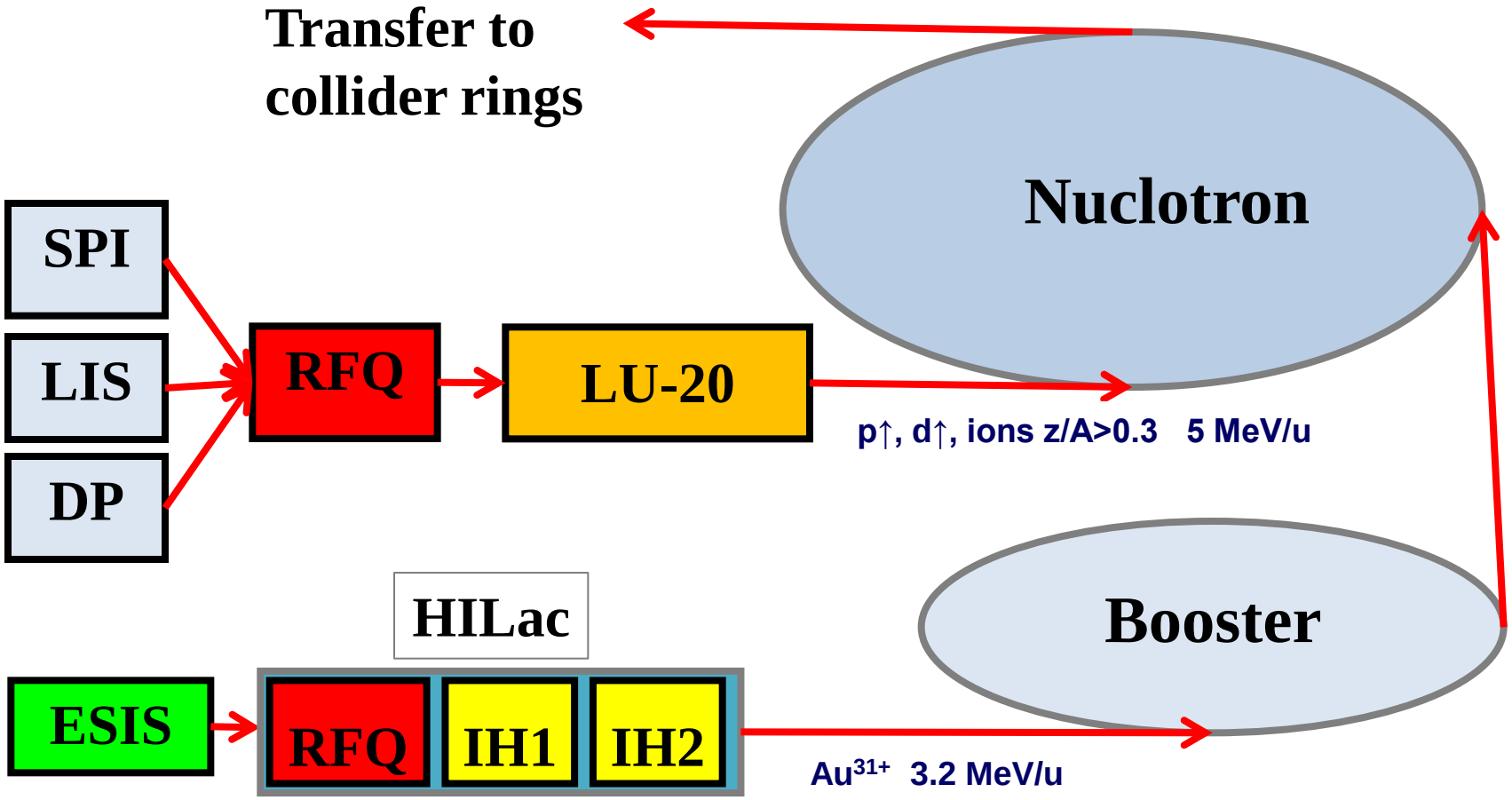
Main accelerator of the NICA complex is **the Nuclotron** –
superconducting ion synchrotron at magnetic rigidity of about 42 T·m
equipped with two injection chains: for heavy and for light ions.

Injection chain for heavy ions consists of:
the ion source (KRION-6N), heavy ion linear accelerator (HILac),
superconducting booster synchrotron (Booster) and required beam transport lines.

Injection chain for light ions includes:
Laser ion source (LIS), Source of polarized ions (SPI), Duoplasmatron,
RFQ accelerator as a foreinjector, Drift tube linac of Alvarec type (LU-20)
and required beam transport lines.

The collider experiments will be provided at two storage rings
with two interaction points (IP).

Structure of the injector complex



Polarized p↑ and d↑ beams, protons and light ions
are planned to be accelerated with existing Linac LU-20,
Heavy ions: HILac + Booster

NICA accelerators

Injection chain for heavy ions

Cryogenic heavy ion source KRION

of Electron String Ion Source (ESIS) type

provides up to $2.5 \cdot 10^9$ Au^{31+} particles per cycle

at repetition frequency up to 10 Hz

Two runs at Nuclotron (2014, 2018)

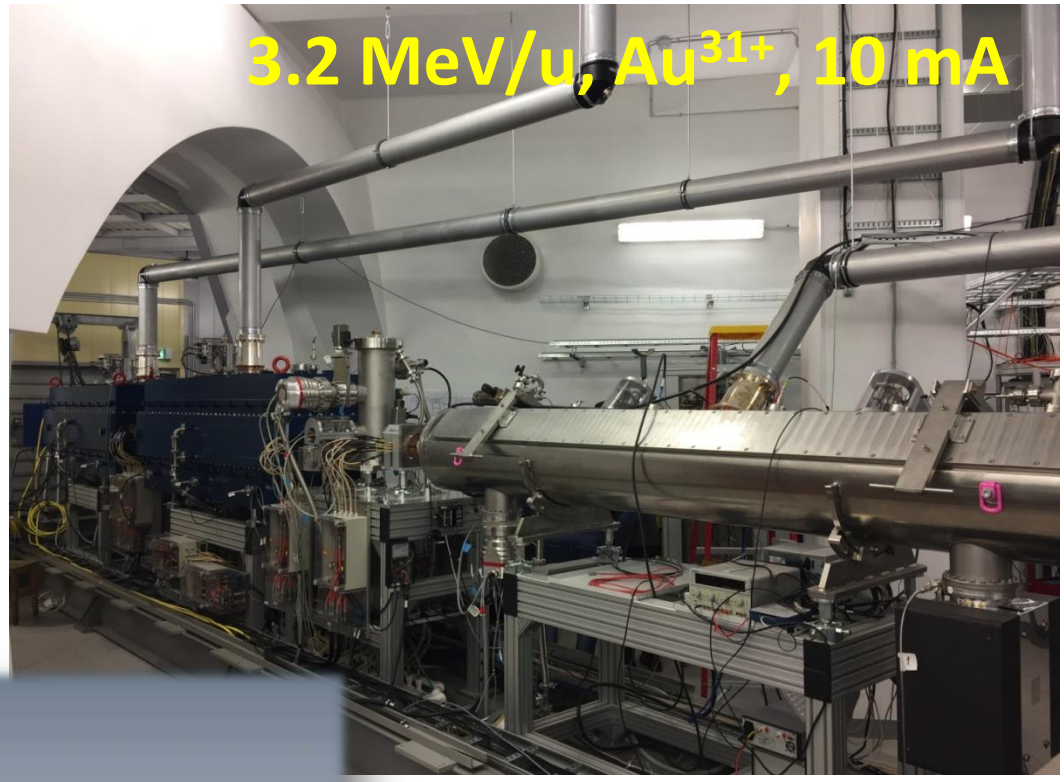
NICA accelerators

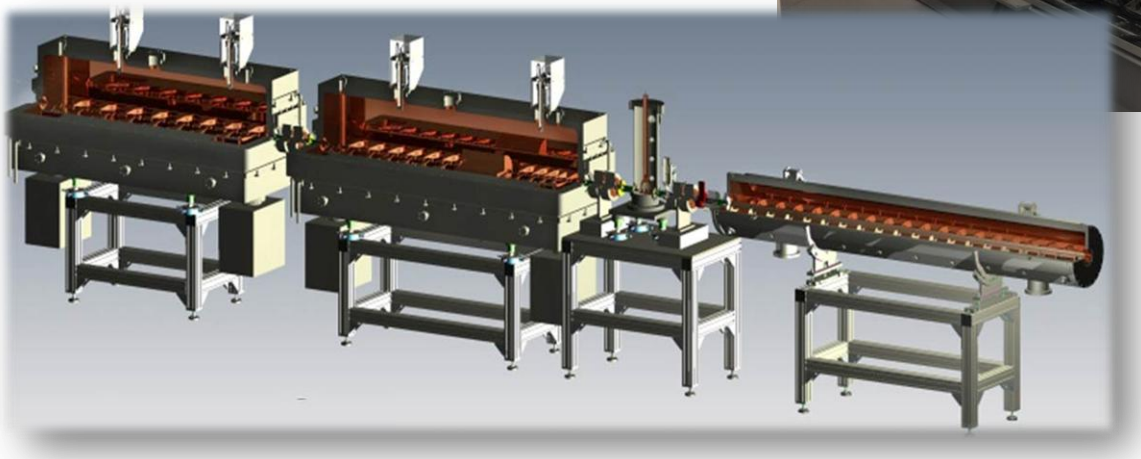
Injection chain for heavy ions

Heavy ion linear accelerator (HILac)

First in Russia
high current (10 mA) heavy ion Linac
(designed and constructed in Germany)

First Linac with transistor RF amplifier
(fabricated in Australia)

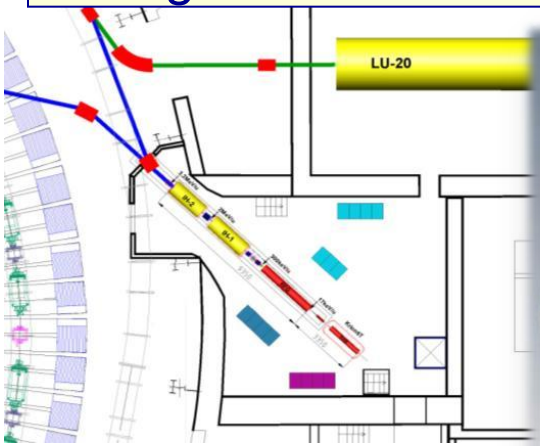


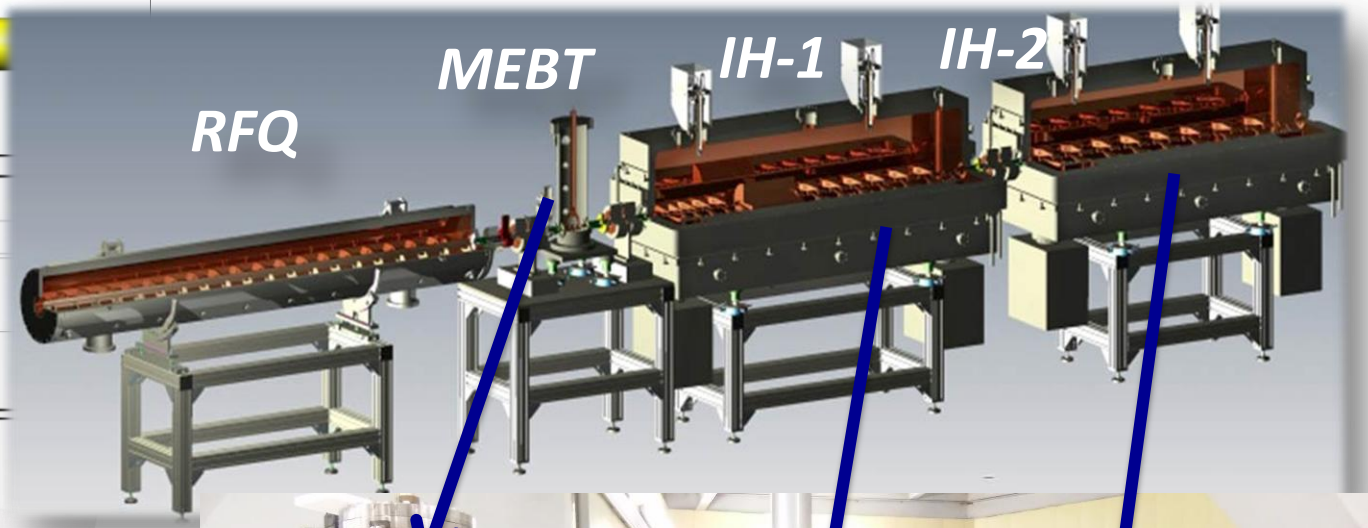


Heavy Ion Linear Accelerator HILAc

high current (10 mA), the first Linac with transistor RF amplifier

Design and fabrication by “BEVATECH OHG” Germany, Offenbach/Mainz





overall commissioning: Oct. 16

NICA accelerators

Injection chain for heavy ions

The Booster should accelerate ions up to 600 MeV/u (for ions with $Z/A = 1/3$).
The magnetic ring of 211 m long is placed inside the window of the Synchrophasotron yoke.

Fabrication of the magnetic system is completed.

Start of assembly – September 2018.

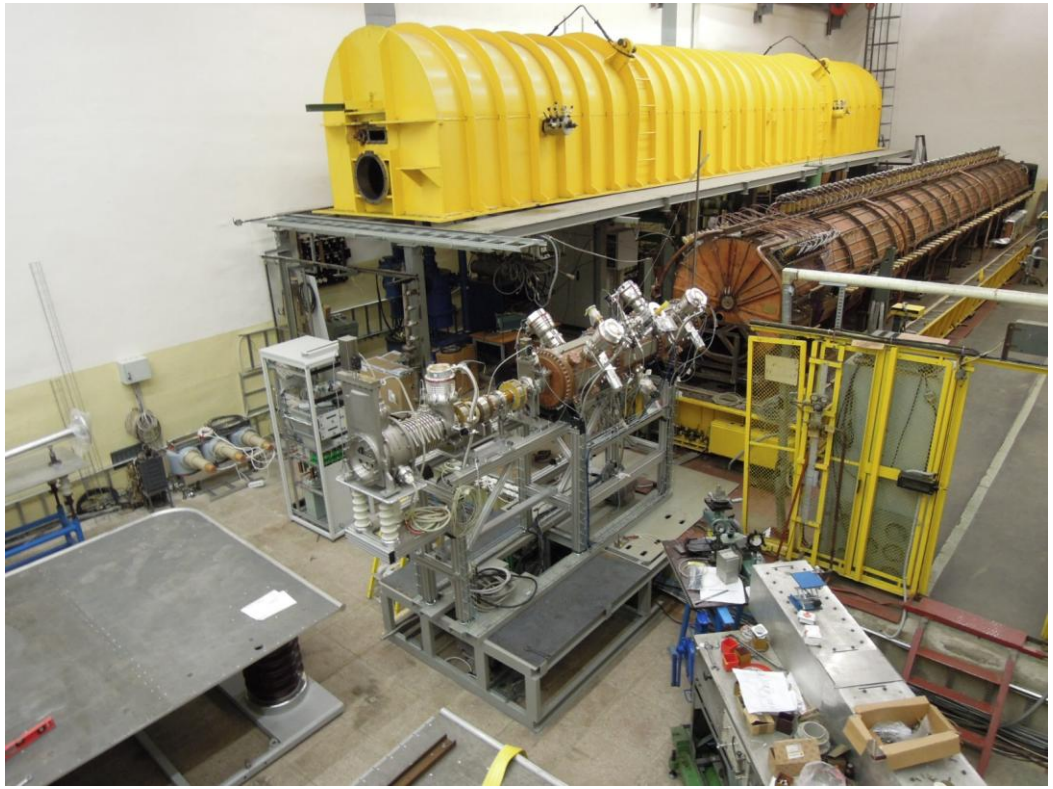
First (technological) run – end of 2018.

NICA accelerators

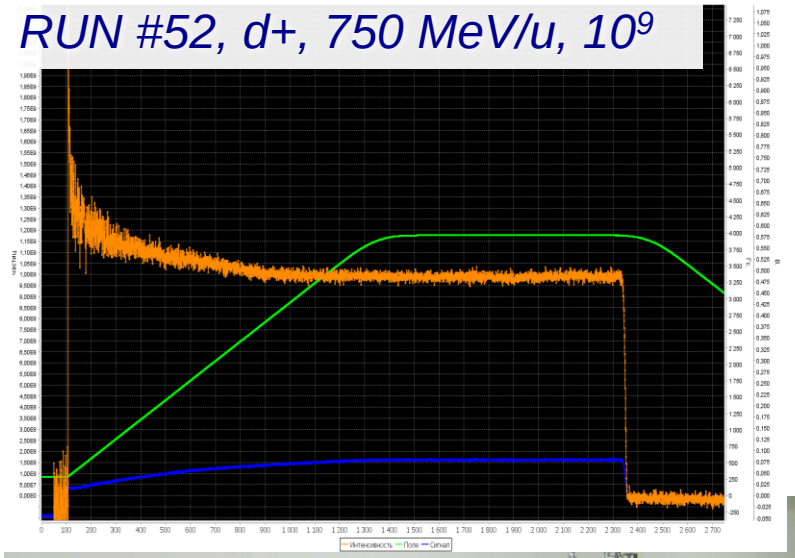
Injection chain for light ions

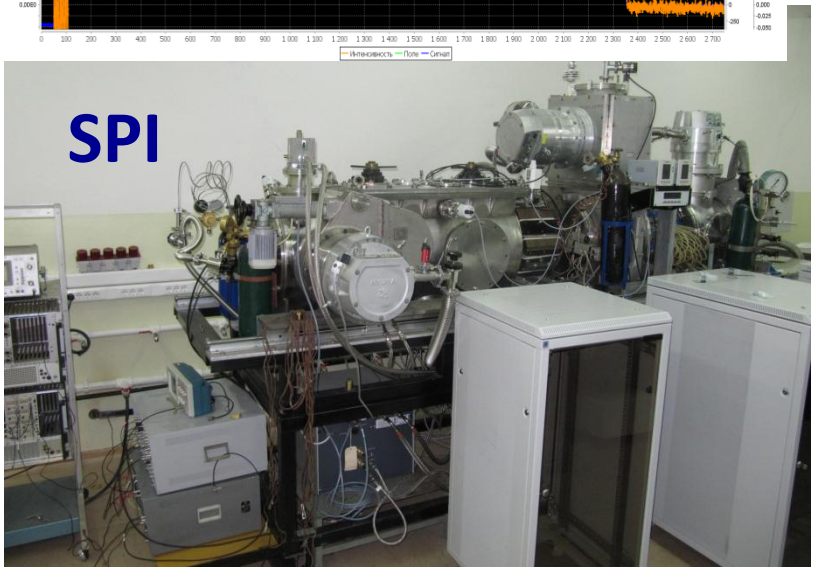
New fore-injector for LU-20 + SPI

JINR, INR, ITEP, MEPHI



RUN #52, d+, 750 MeV/u, 10^9





- **May ‘16 – beam is accelerated in LU-20**
- **June ’16 – the deuteron beam from SPI is accelerated in the Nuclotron ring**

2016 -2017:
two runs – acceleration of polarized deuteron and proton beams

NICA accelerators

Collider

The Collider ring 503.04 m long has a racetrack shape and is based on double-aperture (top-to-bottom) superconducting magnets at maximum dipole field 1.8 T;

The major parameters of the NICA Collider are the following:
- magnetic rigidity = 45 T·m;
-ion kinetic energy range from 1 GeV/u to 4.5 GeV/u for Au^{79+};
-energy of polarized deuterons is 6 GeV/u, protons – 12 GeV,

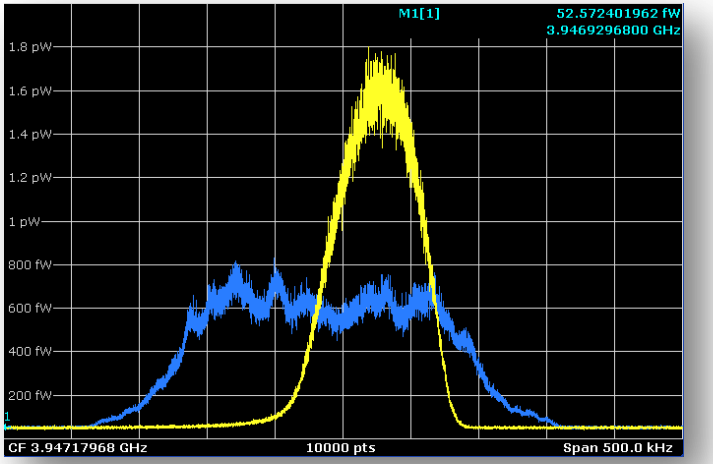
- vacuum in a beam chamber: 10^{-11} Torr;
- zero beam crossing angle at IP;
- 9 m space for detector allocations at IP's;

Average luminosity 10^{27} $cm^{-2}\cdot s^{-1}$ for gold ion collisions at $\sqrt{s_{NN}}$ = 9 GeV.
The luminosity in the polarized mode is up to 10^{32} $cm^{-2}\cdot s^{-1}$.

NICA accelerators

Collider

Stochastic cooling system



Successive test at the Nuclotron 2013

Cooperation with BINP

-The Booster acceleration system

(Tested at JINR – October 2014)

-The Booster electron cooling system

(commissioned at JINR - December 2017)

-Beam transfer line

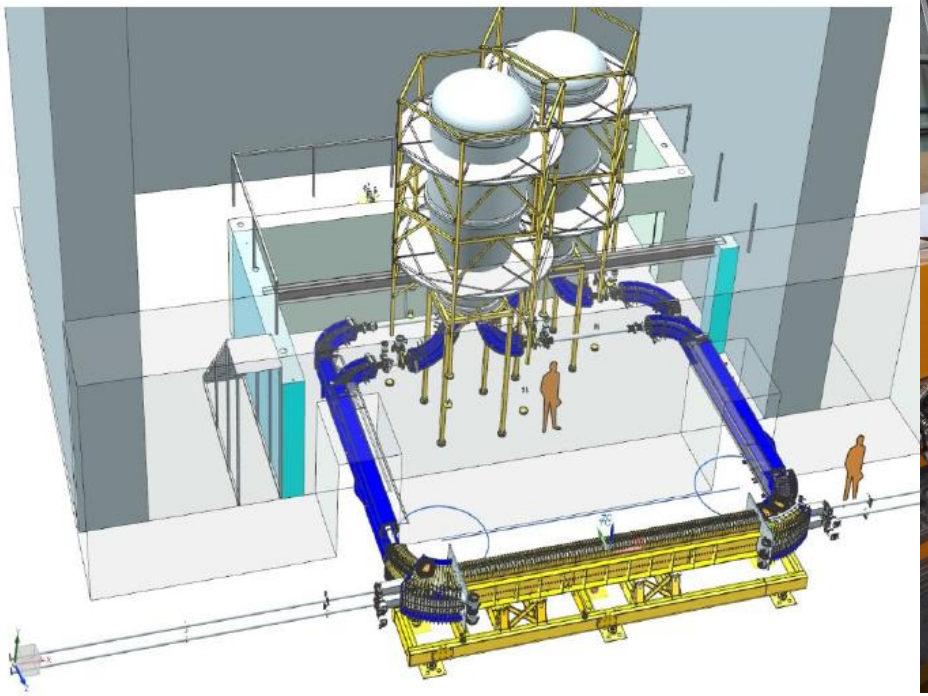
from the Booster to Nuclotron

-RF system of the collider

-Electron cooling system of the collider

Cooperation with BINP

Electron cooling system of the collider



Construction was started in 2016

Cooperation with BINP

Joint (JINR, BINP, ITEP) working group for dynamics study was organized in 2016

Last meeting
From 21 May to 22 May 2018

Cooperation with BINP

JINR and BINP are strategy partners in accelerator physics:

- BINP participated in development of JINR C-tau factory project

- JINR resonant neutron source (IREN) was constructed in co-operation with BINP

We hope for fruitful cooperation in Super C-tau project

NICA accelerator complex