NICA: Nuclotron based Ion Collider Facility

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

PARTICLE PHYSICS

COLLIDERS

HL-LHC | FNAL

MAP

FCC | ILC

PLASMA WAKEFIELD ACCELERATORS

SACLAY | STFC-Daresbury

Uni-Glasgow | INFN-Frascati

GSI | DESY | MPI-Munich

ELI-beamline

NUCLEAR PHYSICS

LEPTON/PHOTON

COMPASS | HIPA

DAΦNE-INFN Frascati | MAX-lab

ELI-NP | ELSA | MAMI

HADRON BEAMS

HIPA | DAΦNE-INFN Frascati

COSY | Antiproton decelerator-CERN | GSI

HEAVY ION BEAMS

ESS | JST | GANIL | ALTO

ISOLDE | SPIRAL2 | ECT* | GSI

INFN-Legnaro | JYFL

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,
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.
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 $5 \times 10^5$ 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

Transmutation 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

Start of construction end of 2018
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

Dipole

Quad

HTSC current leads 17 kA

The Collider “twin” dipole and lens

И. Мешков, Г. Трубников  Сессия СЯФ ОФН РАН ОИЯИ 12.04.2016
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

Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)

Fixed target experiments area (b.205)
Extracted beams from Nuclotron

KRION-6T and HILac (3.5 MeV/u)

SPP and LU-20 (5 MeV/u)

Nuclotron 0.6-4.5 GeV/u

Spin Physics Detector (SPD)

NICA Collider (1-4.5 GeV/u, C~500 m)

Booste (3-660 MeV/u) inside Synchrophasotron yoke

Cryogenics

HV e-cooler

Multi-Purpose Detector (MPD)
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).
Polarized $p^\uparrow$ and $d^\uparrow$ 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)

3.2 MeV/u, Au$^{31+}$, 10 mA
Heavy Ion Linear Accelerator \textbf{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.


First (technological) run – end of 2018.
NICA accelerators
Injection chain for light ions
New fore-injector for LU-20 + SPI

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 $= 45 \text{T} \cdot \text{m}$;
- 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: $10^{-11} \text{Torr}$;
- zero beam crossing angle at IP;
- 9 m space for detector allocations at IP’s;

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

Start of the NICA collider commissioning 2020

Thank you for attention