Report on the implementation of the Nuclotron-NICA project and proposal for its continuation

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During 2021-2024

I stage of the mega-science project NICA was realized:

injection complex of the collider was created including

-heavy ion source KRION-6T,

-HILAC,

-Booster,

-Nuclotron,

the program of fundamental and applied researches was started at fixed targets.

Three commissioning runs (second, third and fourth) at the collider injection facility were performed (total duration 5687 h)

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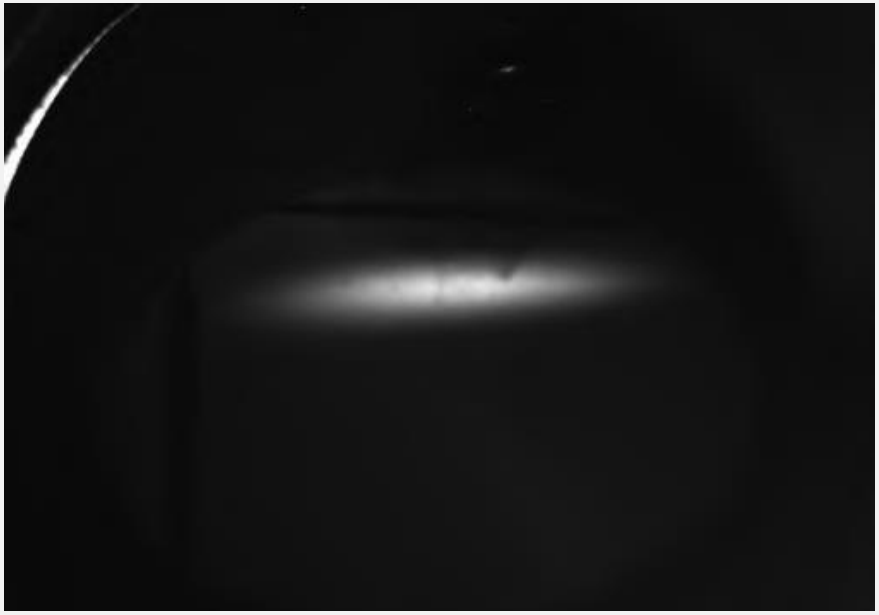
The second run - from 06.09 to 23.09.2021:
Test of the fast beam extraction from the Booster
and beam transport line from the Booster to Nuclotron.
He^{+} ions from the plasma source and Fe^{14+} from the laser source were accelerated.



Iron beam spot at the luminescent screen
at the exit of the Booster-Nuclotron beam transport line.

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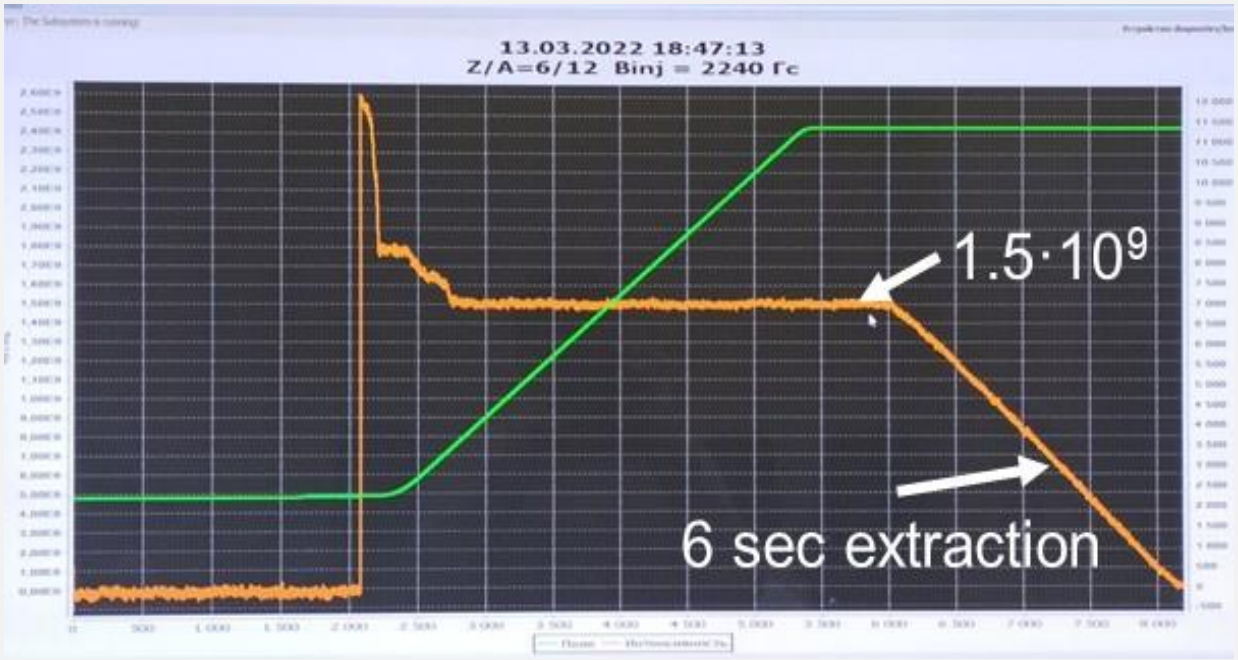
The third run – from 06.01 to 01.04.2022:
Carbon ions from the laser source were accelerated
to the energy of 3 GeV/u at the exit of the Nuclotron.

Stable operation of the complex during 24 days was provided.
The beam was delivered for SRC experiment.



Magnetic field cycle and carbon beam intensity in the Nuclotron

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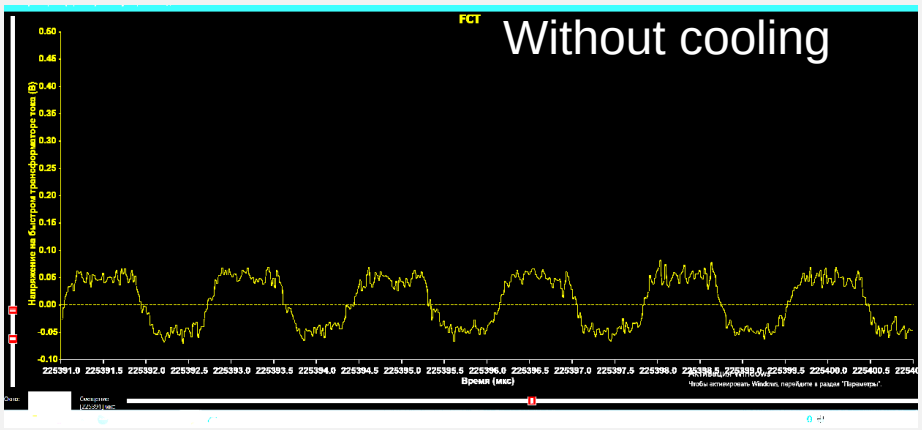
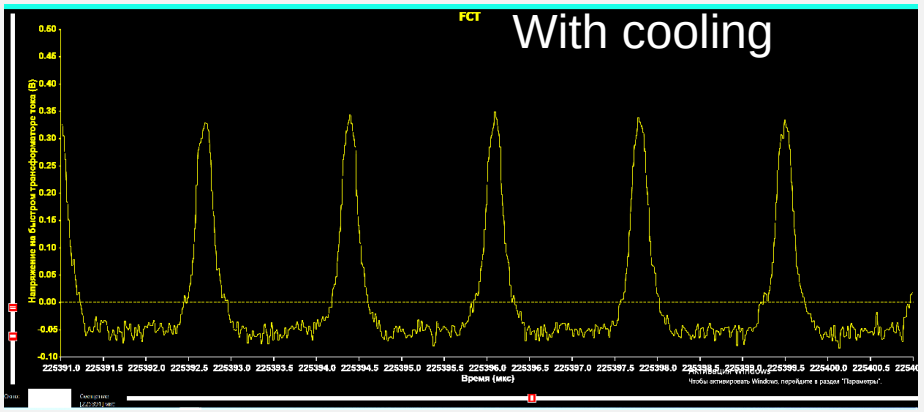
The fourth run - from 20.09.22 to 03.02.2023:
the collider injection complex was operated in the total configuration:
heavy ion source KRION-6T, HILAC, Booster and Nuclotron.

Modernization of the power supply and vacuum systems
at the extracted beam lines was completed.
The xenon beam at energy of 3.9 GeV/u was used for BM@N experiment
and for works in accordance with ARIADNA collaboration program.

Strategy for increase the heavy ion beam intensity was proposed
on the basis of the beam storage at injection with electron cooling application





Bunch length of the xenon beam measured by the fast current transformer

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Although the Run IV was quite successful

its major achievement was detailed characterization

of multiple beam loss sources

and formulating the path to an increase

of injection complex beam intensity

required for the collider operation in heavy ion mode.

With cooling

Electron cooling doubled intensity

of the beam extracted from the Nuclotron.

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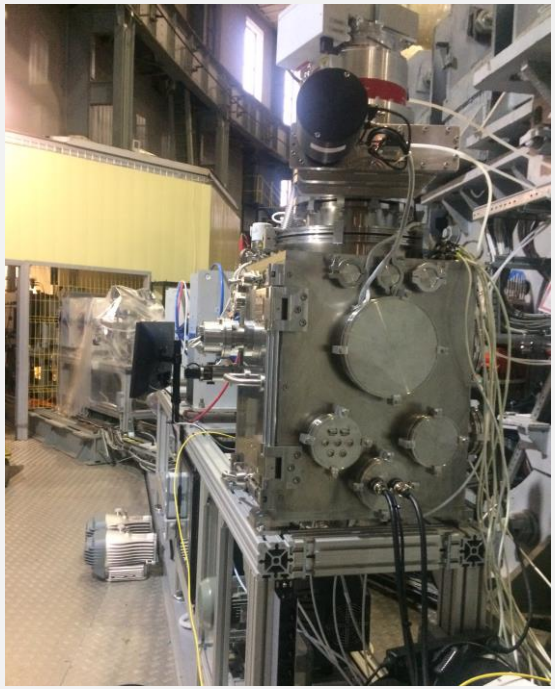
Assembly of the equipment of the SOCHI, SIMBO and ISKRA stations dedicated to applied researches was completed.
At the SOCHI station the program of experimental investigations has been started



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Preparation of the NICA collider systems for technological run scheduled for the end of 2024 is in the final stage.

All elements of regular part of cryo-magnetic system, their power supply, two RF1, eight RF2 cavities, vacuum beam pipe were installed.

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Expected results of the project in 2024:

1. The development and carryout works on the HILAC, Booster and Nuclotron, as well as the existing beam transport channels of accelerator facility, assembly of the start configuration and commissioning of the Nuclotron-Collider beam transport line in bldg. 1 and new building 17,
assembly and commissioning of the fast extraction section from Nuclotron,
assembly and commissioning sections for beam injection and beam dump in the Collider. Preparation for the beam run in 2025.

2. Commissioning of the cryogenic compressor station.
Start-up and commissioning of two Collider refrigerators in new building 17.
Start-up and adjustment work on the equipment of the nitrogen system.

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Delay from the schedule of the project during 2021 – 2024
is caused mainly by delay with delivery
of the engineering equipment of the collider building
and equipment of the collider itself.

Until December 2023, General Contractor of the collider building construction
was the Strabag company from Republic of Austria.
A triliteral agreement between JINR and two companies
- Strabag and Tavrida Energostroy –

on assignment of rights and transfer of obligations is being concluded.
Tavrida Energostroy will be the new General Contractor.
That agreement must be completed in December 2024.

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The undelivered equipment of the collider

is under construction at Russian companies.

The problem with transportation of the LILAC equipment from Germany

is not resolved yet.

To provide the experimental program with polarized beams

the works for performance improvement

of the existing accelerator LU-20 are carrying out.

The collider commissioning at the project configuration

depends on delivery of a few systems.

However these systems are not critical for the collider operation

at the basic configuration with colliding heavy ion beams up to Bi^{+83}

at the luminosity not less than $L = 10^{24}\ cm^{-2}\ s^{-1}$

and energy from $\sqrt{s_{NN}} = 4$ GeV/u.

Proposal for the project continuation

The aims of the Nuclotron-NICA project for **2025 – 2027** are:

- commissioning of the NICA complex objects

at basic configuration of the collider equipment,

- prolongation of the experiments at fixed targets

with heavy ion and light nuclei polarized beams,

- start the experiments at colliding beams,

- R&D, prototyping, testing,

pre-serial magnet production for the “new” Nuclotron ring.

Before the project completion,

the commissioning of the following elements is scheduled:

- beam transport line from the Nuclotron to collider,

- the collider at basic configuration of the equipment.

The creation of LILAC accelerator will be prolonged.

Proposal for the project continuation

Commissioning of the collider will be provided in the following stages:

- experiments with circulating heavy ion beams

at the kinetic energy up to 2 GeV/n

with internal target and colliding beams – 2025,

- commissioning of the beam cooling systems,

increase of the stored beam intensity - 2026,

- gradual increase of the colliding beam energy and luminosity – 2027.

Proposal for the project continuation

Manpower needs in the first year of implementation

397 FTE of the JINR personnel

The total cost estimate of the project (for the whole period, excluding salary):

35 900 k$

Nearest plans

December 2024 start of the Collider commissionning.

January 2025 storage of Xe ions in the Booster,

increase of the beam intensity.

March 2025 – beam run at Nuclotron and then at Collider.

June 2025 – injection of the Xe ions into Collider.

Beam experiments at Collider:

First stage – interaction with internal target,

test of the MPD subsystems

Second stage – colliding beam experiments

Preparation for the beam run in 2025

Major actions are:

1. Commissioning of KRION ion source and HILAC
operating with multiple injection pulses
(10 pulses at 10 Hz with 5 s repetition time, ~108 Xe28+ extracted from KRION)
2. Testing of synchronization upgrade required for beam accumulation
3. New software for ramp generation with corresponding generation of RF ramps
4. Upgrades of beam current measurements, orbit correction,
repairs of Nuclotron correctors and power supplies
5. Installation of new LLRF systems for Booster and Nuclotron
6. Vacuuming transport channel from Nuclotron to Bldg. 205
7. Installation and hardware commissioning of the fast extraction from Nuclotron
8. Installation and hardware commissioning of beam injection to the Collider.
9. Commissioning of the cryogenic compressor station.
    a. Start-up and commissioning of two Collider refrigerators in building 17.
    b. Start-up and tuning for the equipment of the new nitrogen system.

Thank you for attention