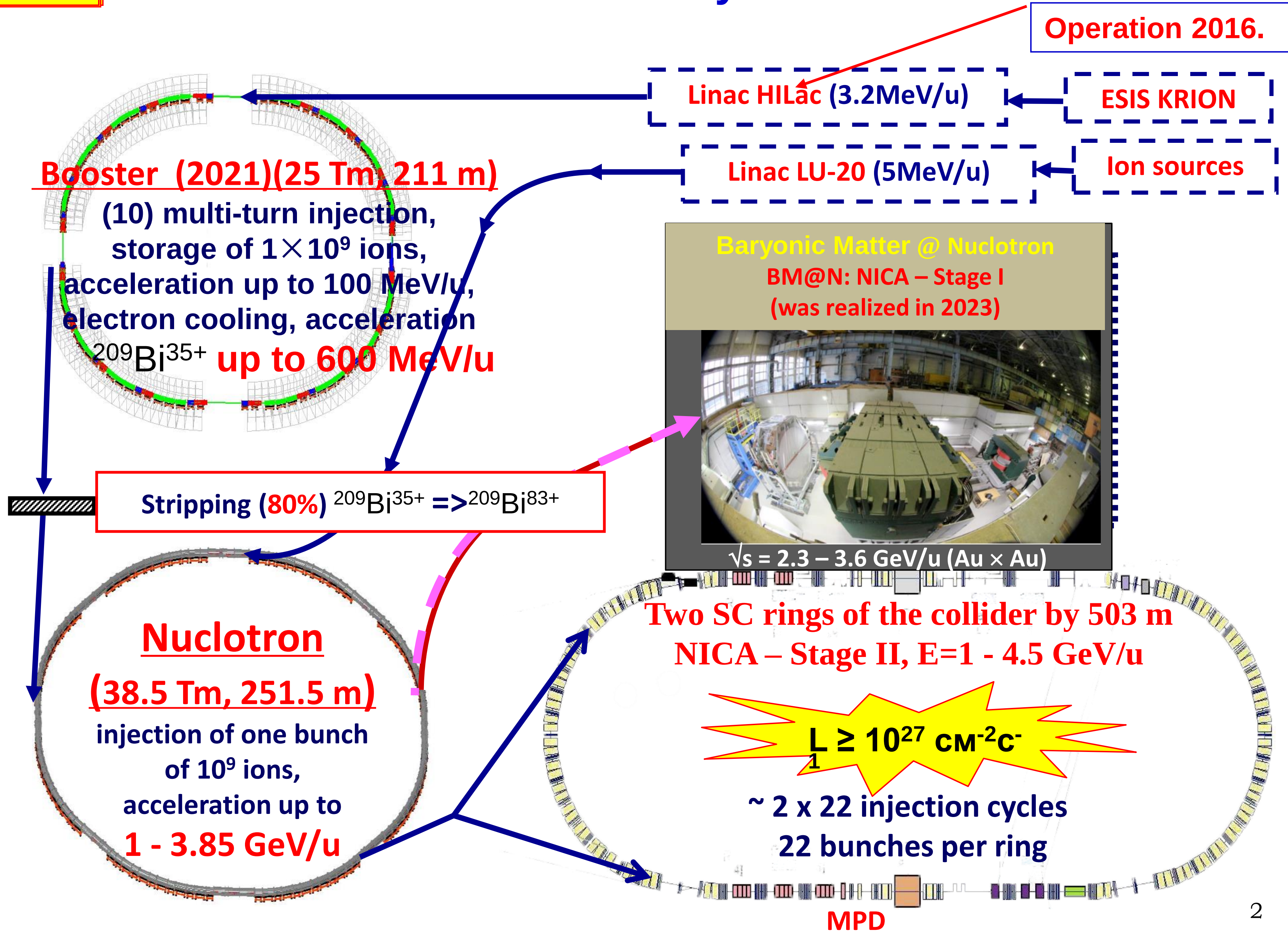
Construction and commissioning of NICA complex

Evgeny Syresin on behalf of Accelerator division

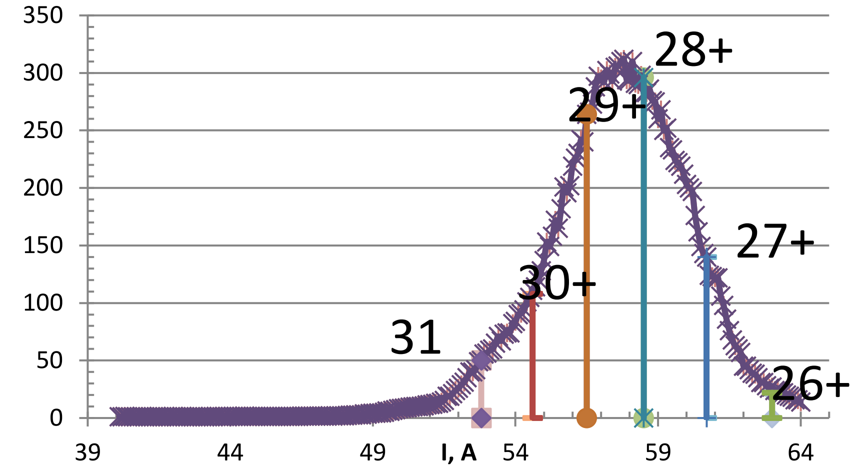


2025

NICA – collisions for Heavy ion mode



Ion source KRION-6T



Xe ion charge distribution at KRION exit

Project ion intensity $2 \cdot 10^9$ Bi^{35+} per pulse

Достигнутые величины

Ar^{16+} - $5 \cdot 10^8$ ions per pulse

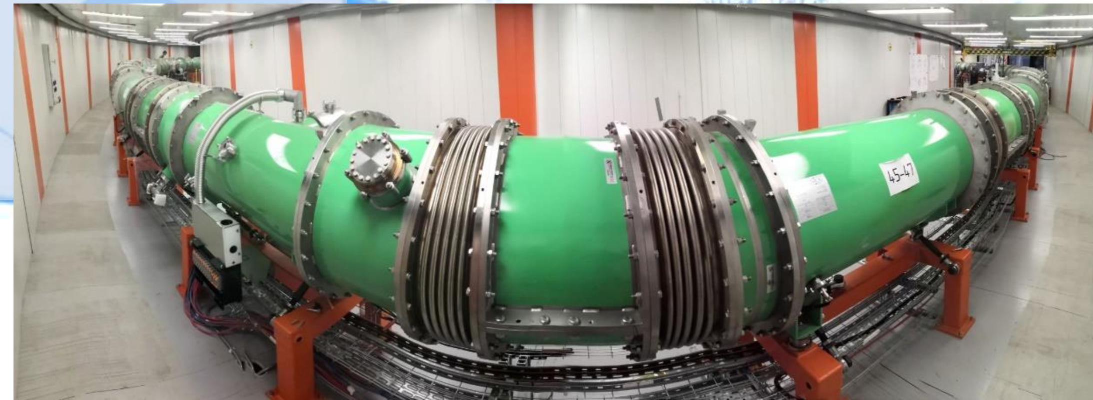
Xe^{28+} - $2 \cdot 10^8$ ions per pulse

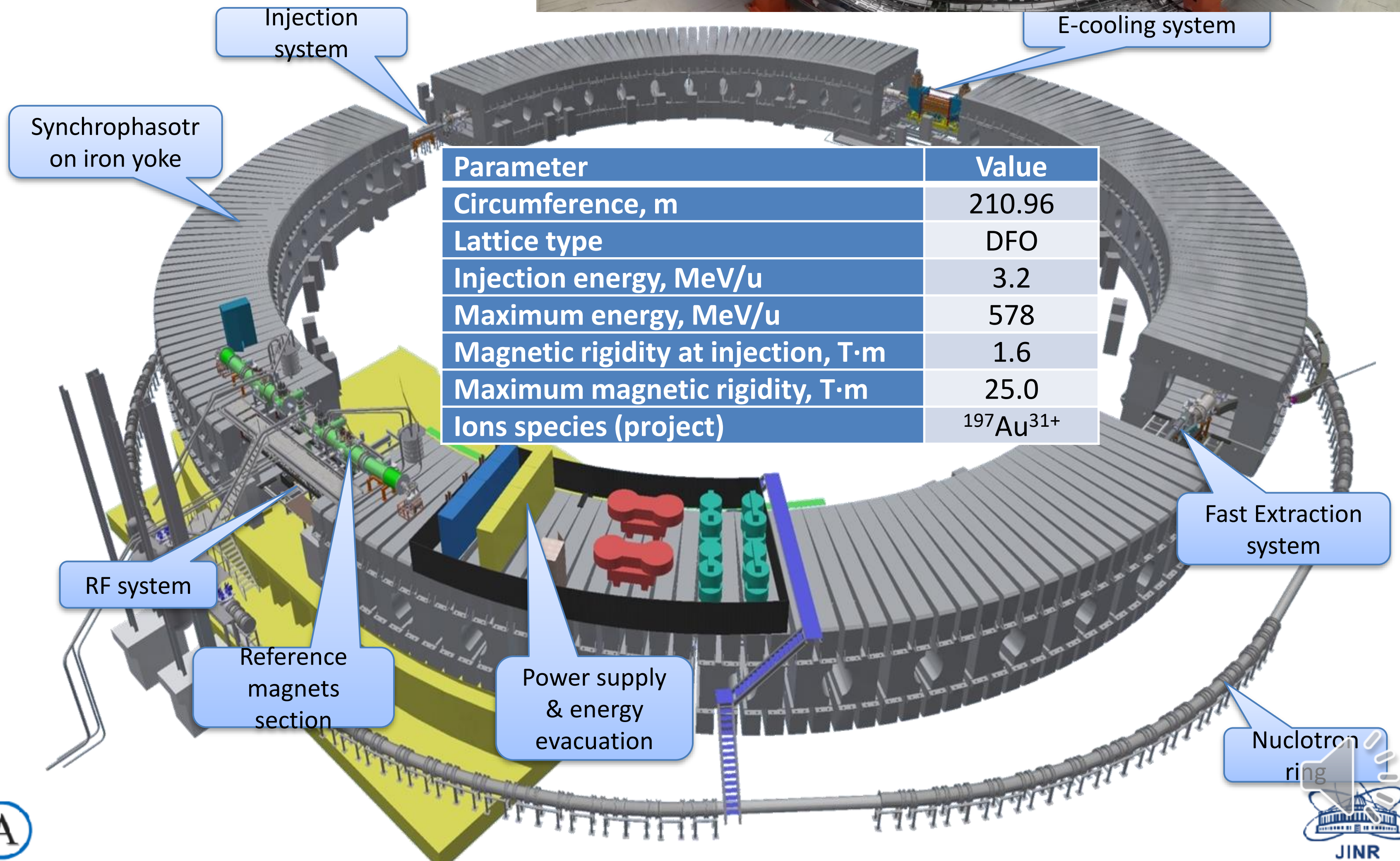
Bi^{35+} - $2 \cdot 10^8$ ions per pulse

First Collider beam run is planed with Xe^{28+} и Bi^{35+} ions

Further development and upgrade of KRION-6T during April-May and September-October 2024 beam runs with N, Kr, Xe ions at injection rate 10 Hz and injection pulse duration 410^{-6} s.

Booster ring run – January 2025





Parameter	Value
Circumference, m	210.96
Lattice type	DFO
Injection energy, MeV/u	3.2
Maximum energy, MeV/u	578
Magnetic rigidity at injection, T·m	1.6
Maximum magnetic rigidity, T·m	25.0
Ions species (project)	$^{197}Au^{31+}$

NICA

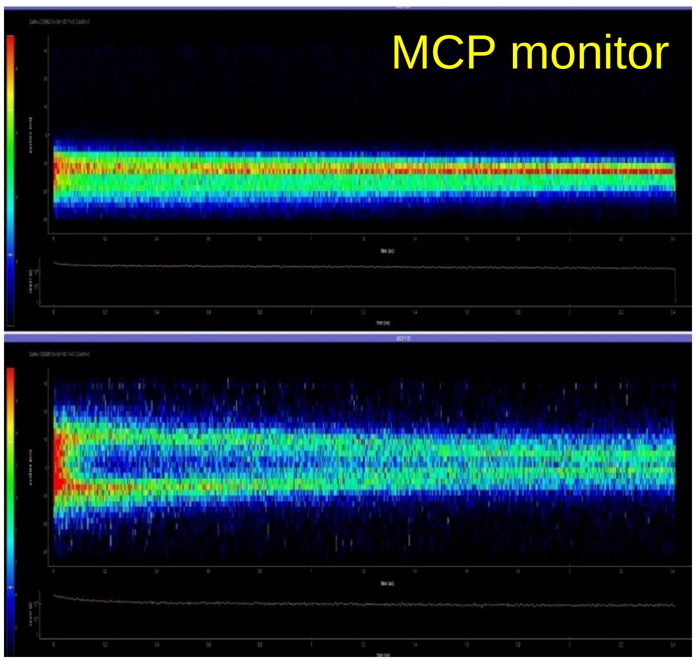
JINR

Electron cooling of Xe beam

$^{124}Xe^{28+}$ at injection energy

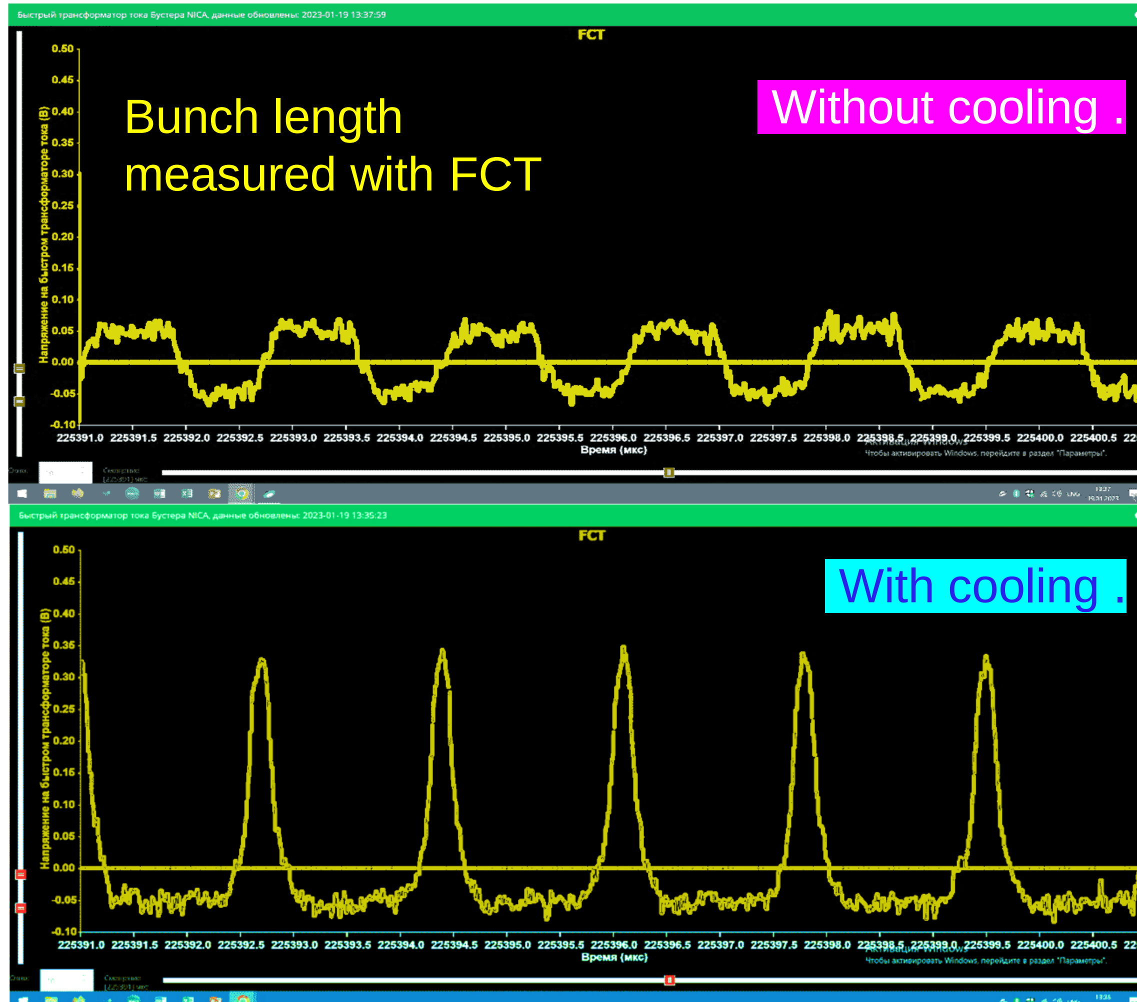
Transverse cooling

Electron energy 1,93 keV
Electron current 150 mA



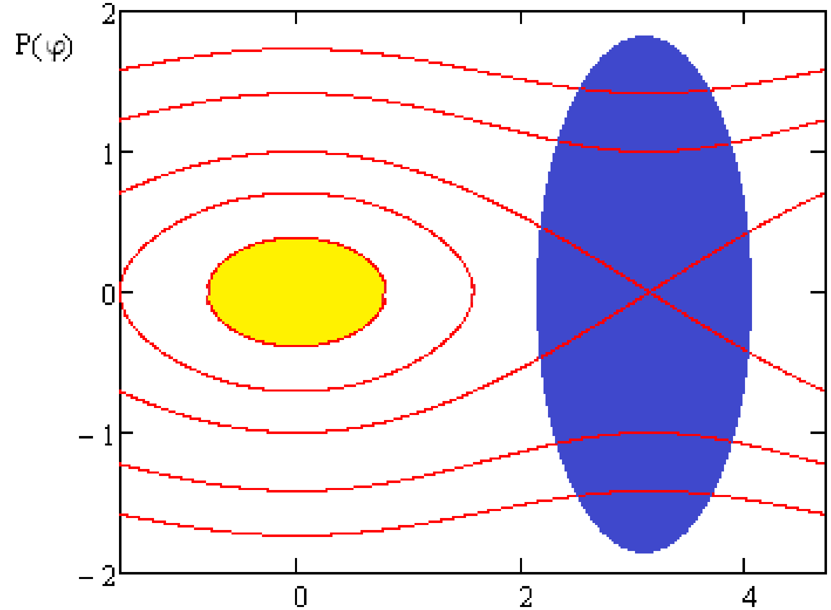
Signals from Ionization profile monitors during beam circulation

Longitudinal electron cooling



Beam Accumulation at electron cooling

- Beam accumulation happens in the longitudinal plane at Booster injection
  - 4 μs bunch – 8 μs revolution time
- Each new injection happens after the previous one is cooled to the core
  - Expected injection rate – 10 Hz
  - 10 – 15 injections will require
  - Total cycle duration ~5 s
- The permanently present 1st RF harmonic weakly affects large amplitude particles
- For small amplitude particles the cooling force will be intentionally reduced to avoid overcooling



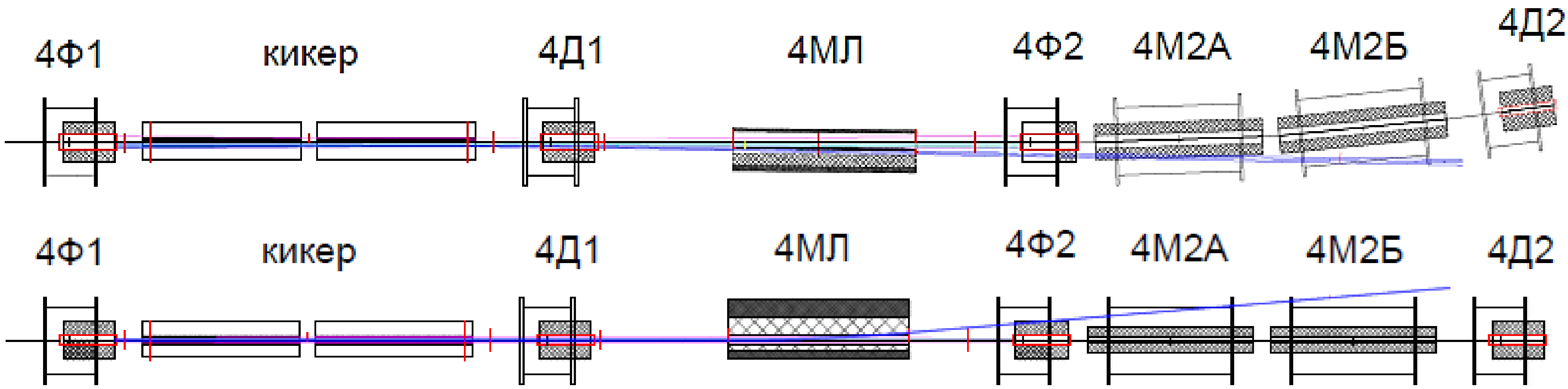
- To avoid anticoolig we need to match well the injection magnetic field and e-beam energy
  - It happens since for large $\Delta p/p$, dF/dt changes sign after reaching the peak

An increase of ion accumulation intensity by a factor of 5 is planned. However application of electron cooling is restricted by ion bunch space charge effects at a level of $\cdot 10^9$ ions of Bi^{35+}

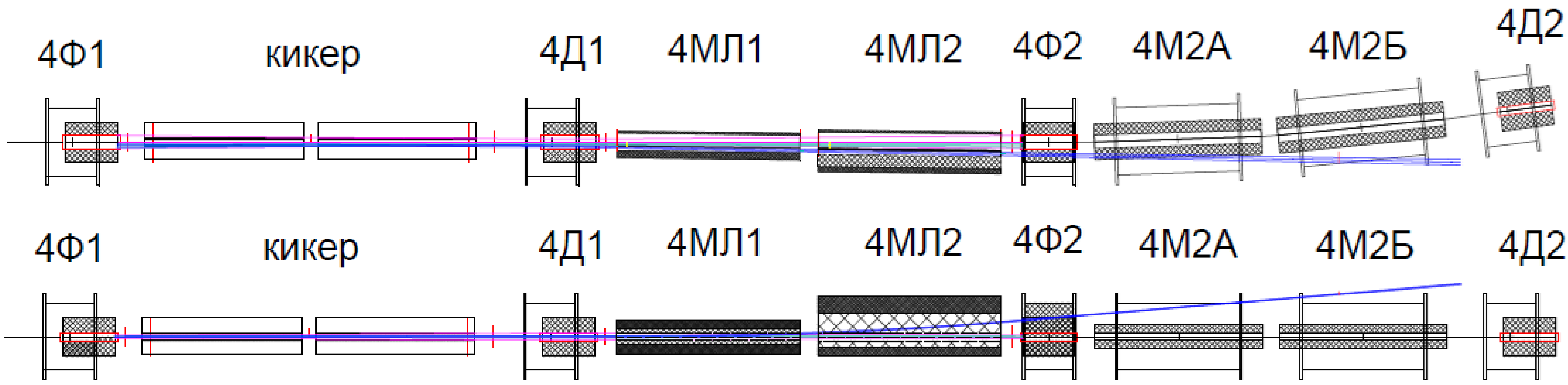
KRION-6T- HILAC -Booster beam run with Xe ions at realization of multi cycle injection, accumulation and electron cooling is planned in January 2025

Nuclotron extraction system

Start configuration (magnetic rigidity up to 29 T·m)



Full configuration (magnetic rigidity up to 38.5 T·m)

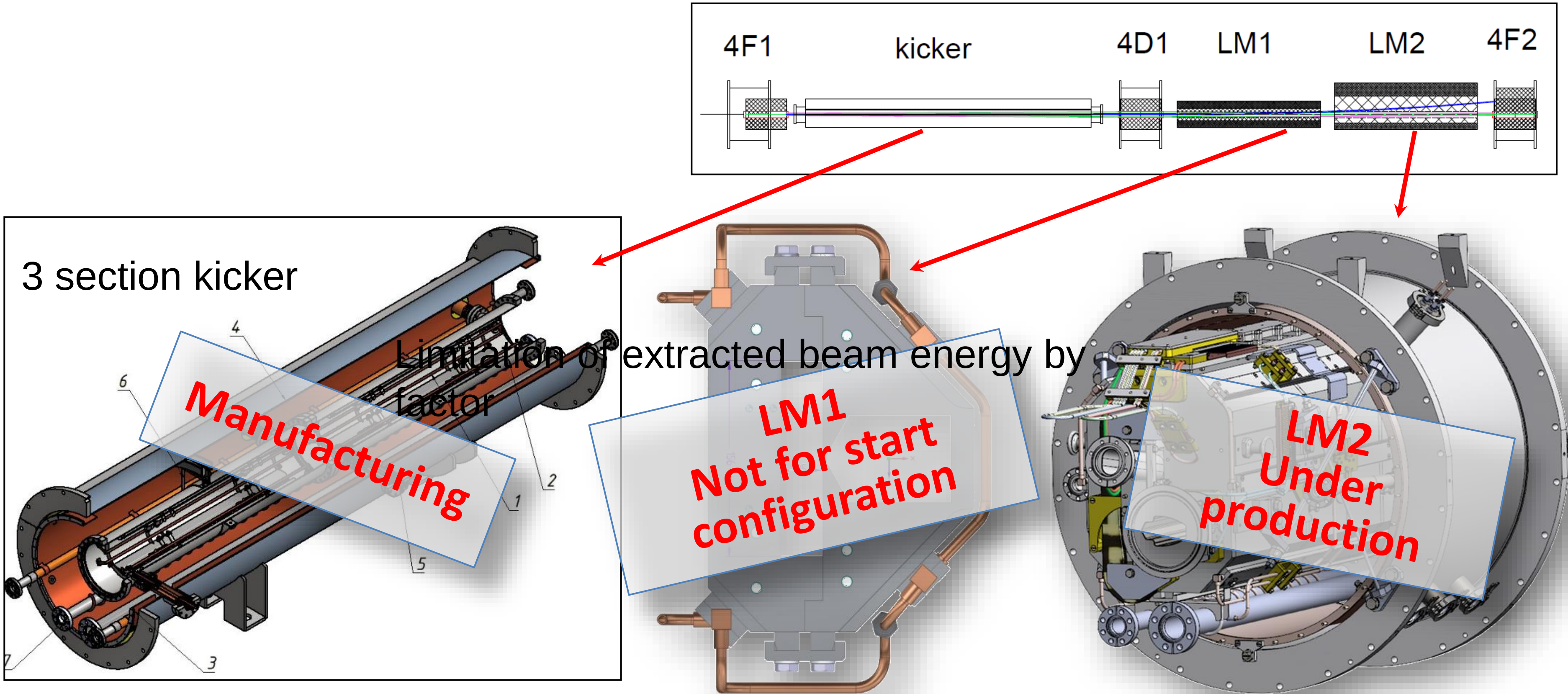


Application of one extraction Lambertson magnet permits to reach the maximal kinetic ion energy 2.5 GeV/n in first Collider beam runs

Nuclotron operation at fast beam extraction system

March 2025

Design was finished, equipment is under construction



- ✓ Limitation of extracted beam energy by factor 1,6 (~2.5 GeV/u for Bi)
- ✓ Doubling of injection LM with the same design and tooling for higher current;
- ✓ **Commissioning of fast beam extraction system – February 2025**

NICA Stage II-a (basic configuration):

3. Collider equipped with

- RF-1 (barrier voltage system) for ion storage
- RF-2 : 4 cavities per ring instead (100 kV RF amplitude)
- 1 channel of S-cooling per ring (cooling of longitudinal deg. of freedom)

Commissioning – Autumn 2024-Winter 2025

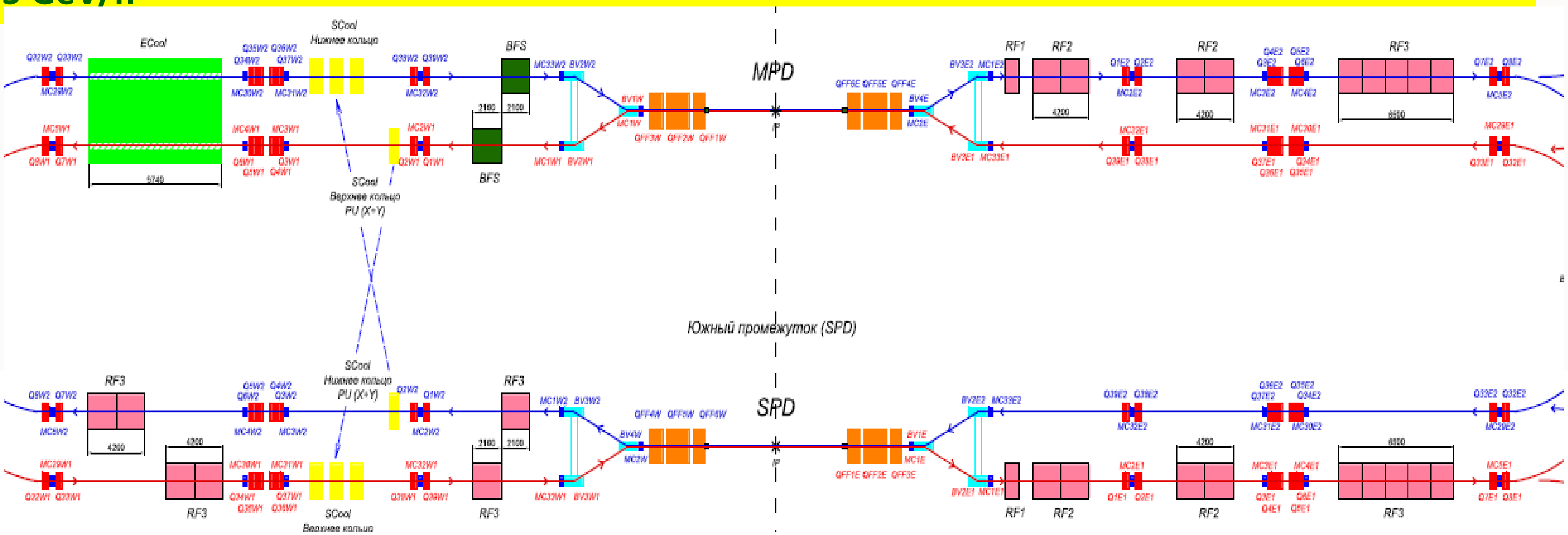
Technological run at cryomagnetic system testing

West arc W– January 2025

East arc E- March 2025

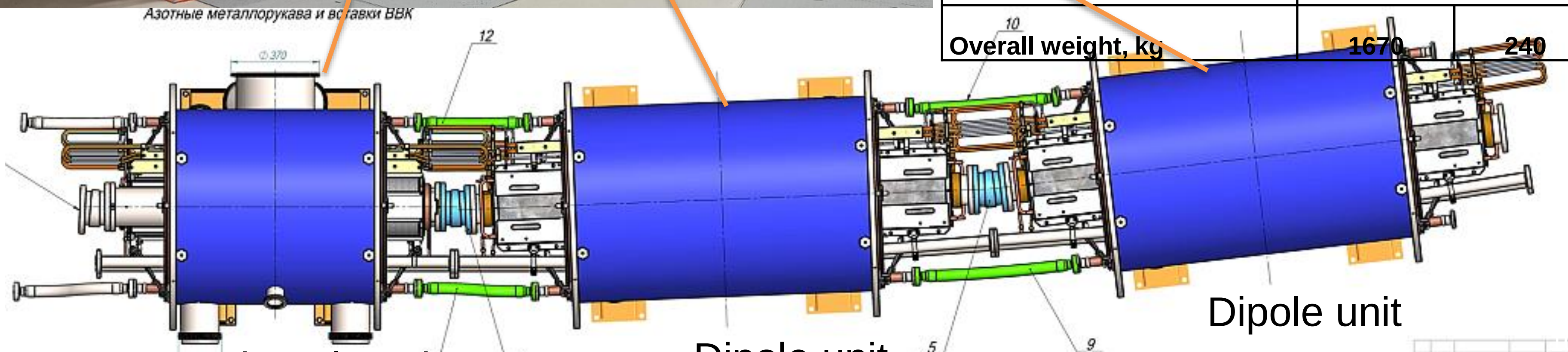
First beam run – Summer of 2025

Result: 22 bunches of the length σ ~ 2 m per collider ring that 2e25 $cm^{-2}\cdot s^{-1}$, ion kinetic energy E=2.5 GeV/n



Commissioning of the magnetic system: regular period

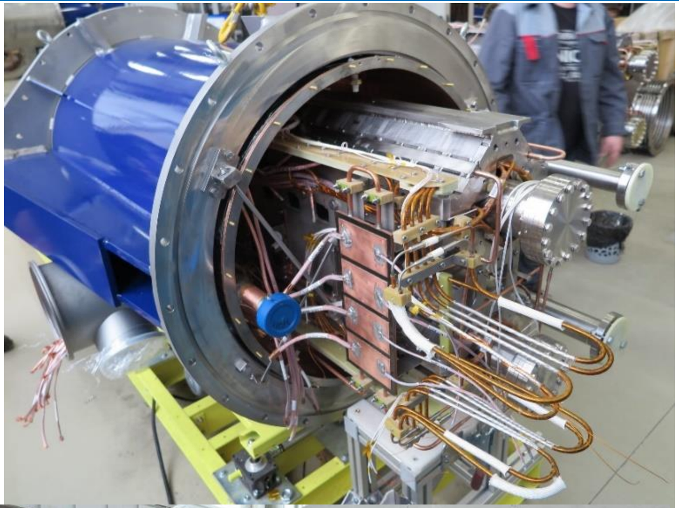
Parameter	Dipole	Lens
Number of magnets (units), pcs	80	46
Max. magnetic field (gradient)	1.8 T	23.1 T/m
Effective magnetic length, m	1.94	0.47
Beam pipe aperture (h/v), mm	120 / 70	
Distance between beams, mm	320	
Overall weight, kg	1670	240

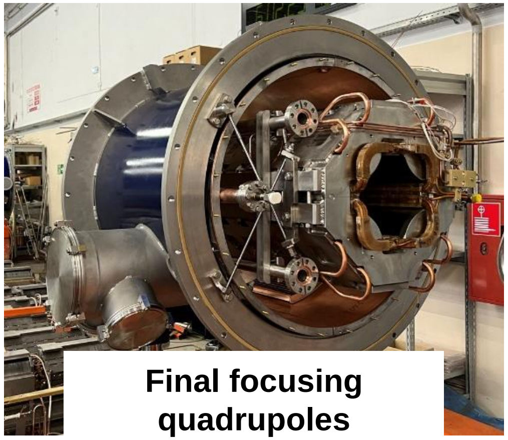


Comissioning W arc-December 2024, commisiong of E arc –February 2025

NICA Commissioning. The magnetic system: magnets

Quadrupole units

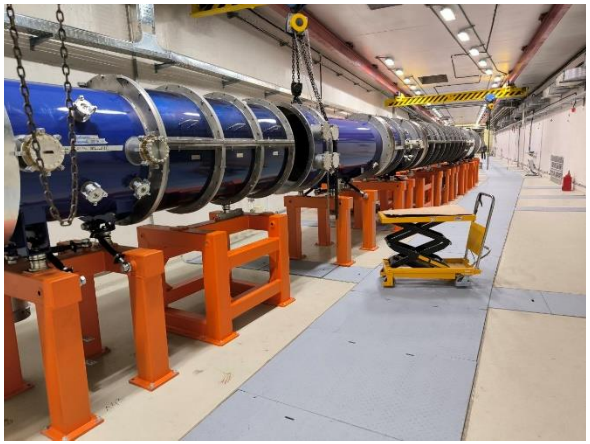




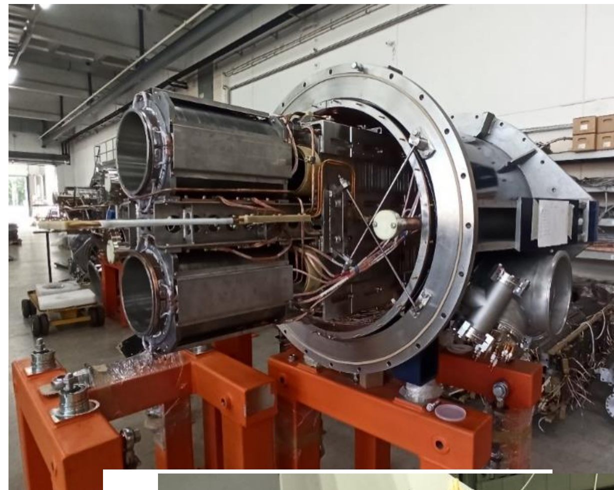
Final focusing quadrupoles

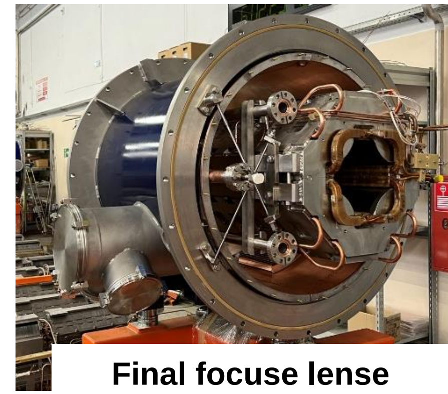
BI vertical 1x dipole units

Straight sections: magnets

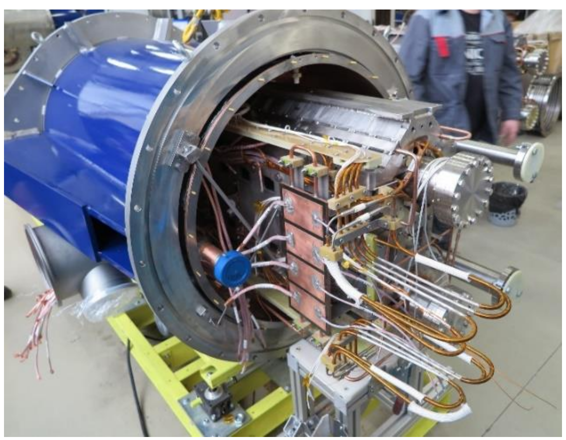


Straight section





Final focuse lense

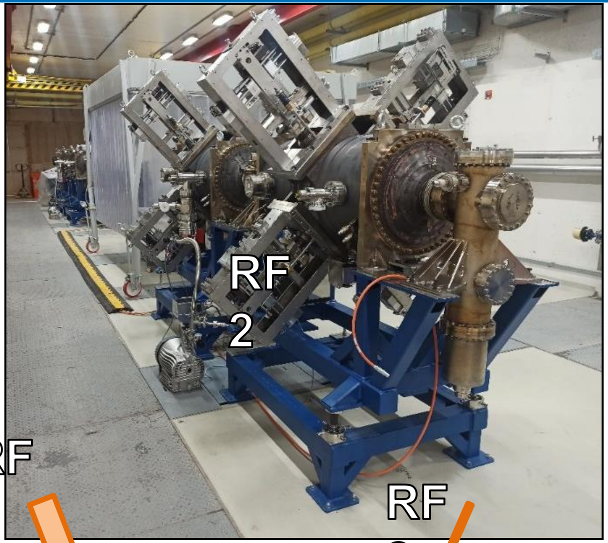


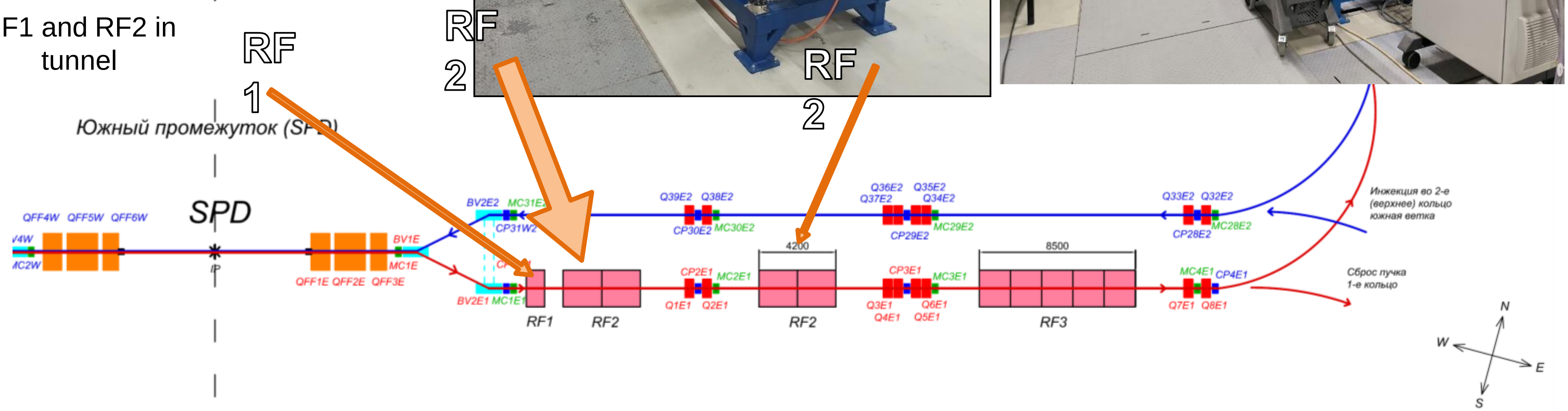
Straight section lenses

straight sections and MPD final focus

RF system: status RF1 and RF2

RF1 and RF2 in tunnel

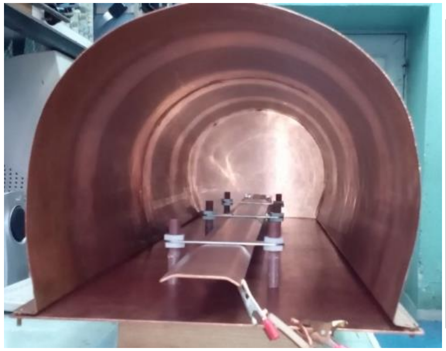


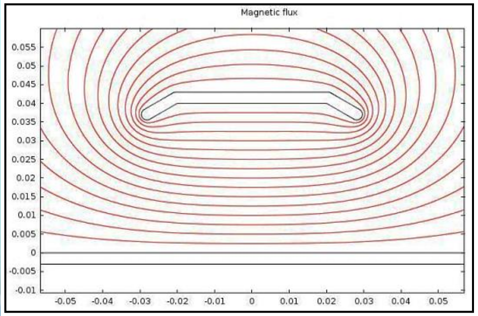


- **All RF1 and RF2 cavity in JINR.**
- **Two RF1 and eight RF2 cavities were mounted.**
- **Commissioning of E-arc- February 2025**

Collider beam injection septa

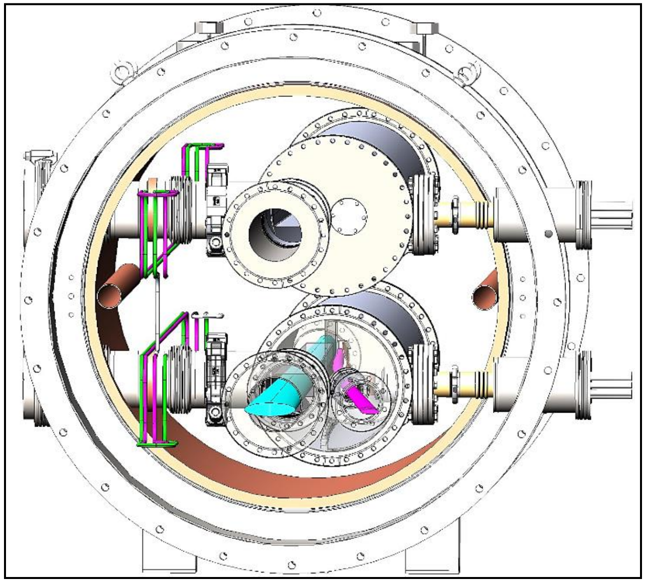
Effective length, m	2.5
Max. magnetic field, T	0.42
Bending angle, mrad	24
Gap, mm	30
Septum thickness, mm	3
Current, кA	50
Pulse duration, µs	10

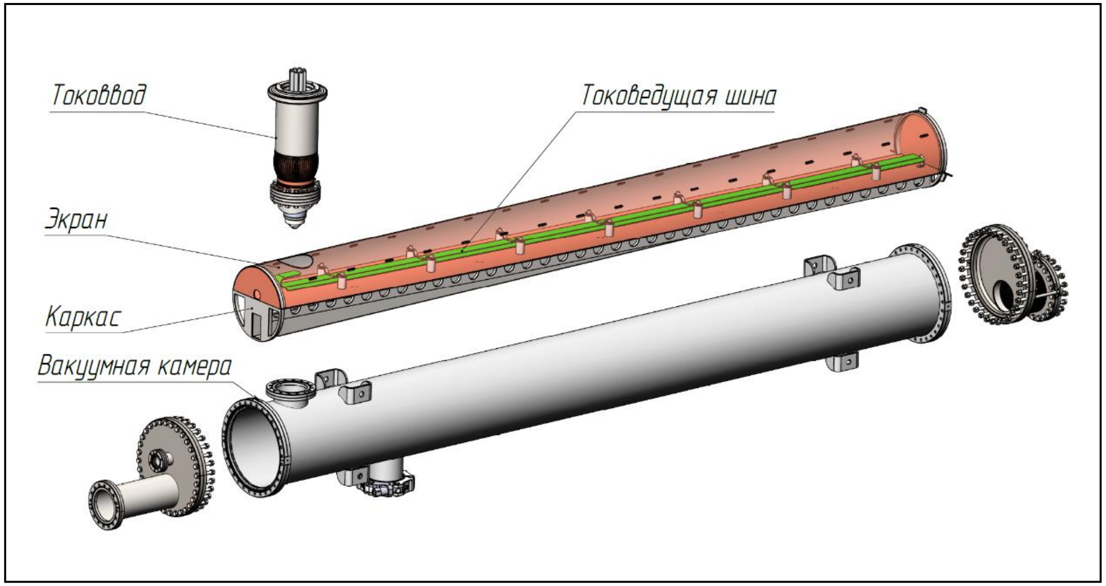




Septum's internal chamber with feedthrough
Construction in BINP- October 2024

Septum cryostat module





Commissioning of Collider injection system –February 2025

Collider power supply system

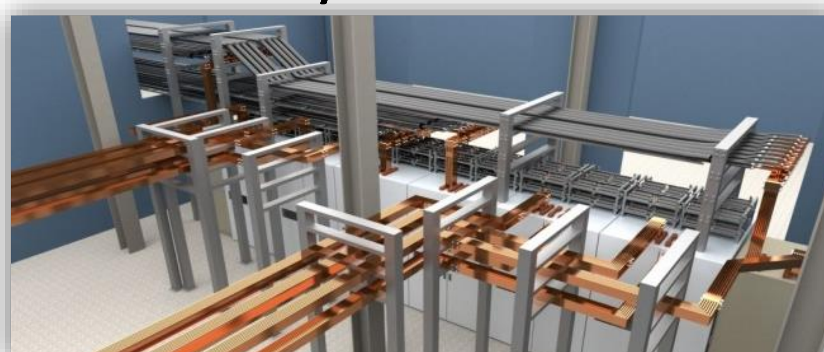
Each collider ring has its own power supply system based on 3 main current sources

2 sets of main PS for both collider rings are manufactured by NPP "LM Inverter" and delivered to JINR.

12 energy evacuation keys was constructed and tested

68 Additional power supplies (10B x 300A)

Busbars system model in b.17



First operation of PS and magnets- January-February 2025

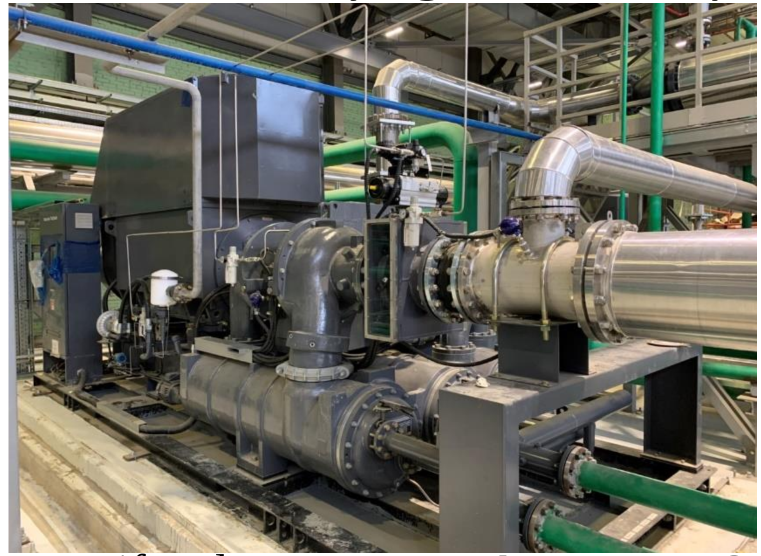
Technological run at cryomagnetic system testing
West arc W– January 2025
East arc E- March 2025

- I. Collider cryomagnetic tests:
- Tests of Power supplies on an equivalent load
- Tests of energy evacuation switchers
- Vacuum of isolation volume
- High vacuum of beam chamber
- Operation of control system
- Magnet system cryogenic cooling
- Thermometry tests
- Operation of quench protection and evacuation system
- Formation of magnetic cycle, power supplies tuning
- Corrector system tuning

Critical points creation of engineering infrastructure in Bl.17- distributed panels of power consumption system, water cooling system, ventilation system

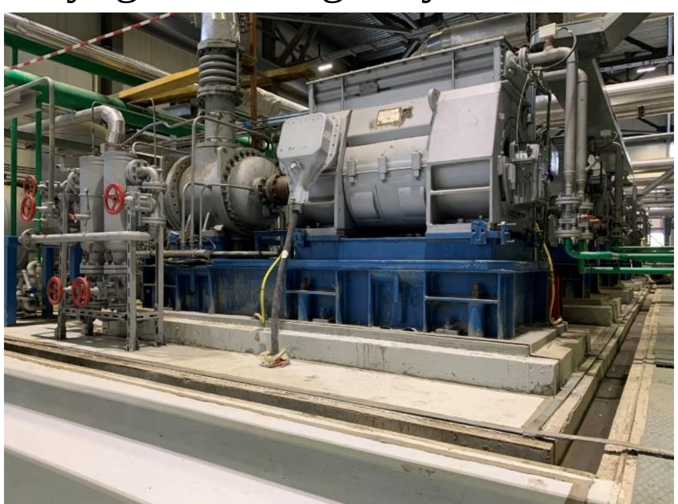
Status of cryogenic compressor station

Aerocom - 2 179/18



Hanwha Techwin SM5000

Commissioning and tests of nitrogen centrifugal compressor **Aerocom - 2 179/18 and two nitrogen centrifugal compressors Hanwha Techwin SM5000** was done. Compressors pass through tests in air medium and they are ready for testing in NICA cryogenic nitrogen system.



Spiral helium compressor

Commissioning and tests of two spiral helium compressors **«Kaskad- 110/30»** was performed Firm Helijmash.

Nuclotron-Collider beam transport channel

Parameters of pulsed magnet elements

Magnetic element	Number	Effective length, m	Max. magnetic field (gradient), T (T/m)
Long dipole	21	2	1.5
Short dipole	6	1.2	1.5
Quadrupole Q10	22	0.353	31
Quadrupole Q15	6	0.519	31
Steerers (BINP)	33	0.466	0.114

Magnets delivery in JINR in February 2021

Nuclotron-Collider transfer line was contracted by France firm Sigma Phi

JINR can not obtain part of ready equipment: power supplies, beam diagnostics, vacuum chambers and support stands.

JINR restarts construction and production of this equipment in Summer 2023. We plan to produce and install this equipment before Summer 2025.

Commissioning and tests November 2023-May 2025

Beam transportation –July 2025

Critical point is construction of magnet power supplies.

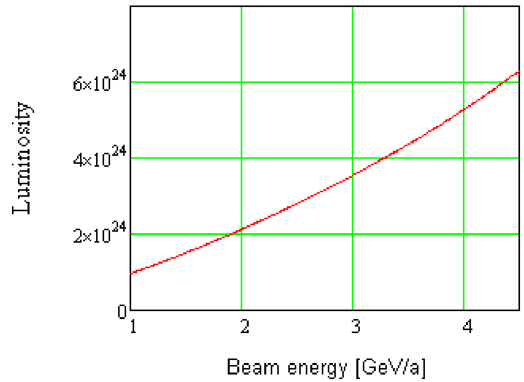
The first Collider run with beam

NICA Stage II-a (basic configuration): Summer 2025

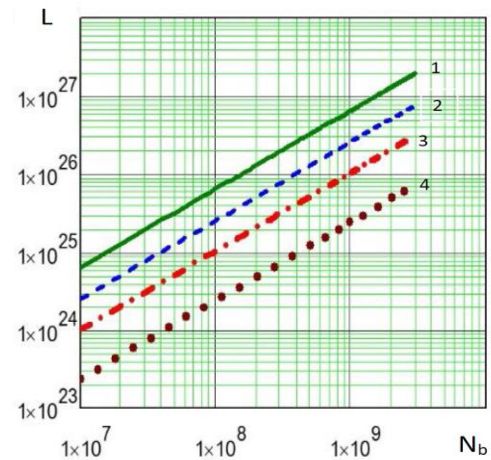
1. Injector chain KRION => Booster => BTL BN => Nuclotron
2. BTL Nuclotron => Collider
3. Collider equipped with
- RF-1 - (barrier voltage system) for ion storage
- RF-2 - 4 cavities per ring (100 kV RF amplitude)

Result: 22 bunches of the length σ ~ 2 m per collider ring that 2e25 $cm^{-2} \cdot s^{-1}$. Maximum kinetic ion energy 2.5 GeV/n

	Booster		Nuclotron		Collider
	Injection	Extraction	Injection	Extraction	
E	3,2 MeV/u	530 MeV/u	523 MeV/u	1,5-2,5 GeV/u	1,5-2,5 GeV/u
N	$5 \cdot 10^8$	$3.5*10^8$	$2.5*10^8$	$2*10^8$	$2*10^8$ (at injection) $4*10^9$ (at RF1 accumulation and formation of 22 bunches by RF2)
B_d, Тл	0,1	1,6	0,4	<1,2	<1.2



Collision of bunch to bunch N=2E8**



Dependence of luminosity on number ions per buch at different energies (1) 4.5 GeV/u (2) 3GeV/u, (3) 2 GeV/u, (4) 1 GeV/u.

Thank you for attention