

Status of the accelerator facility U-400M

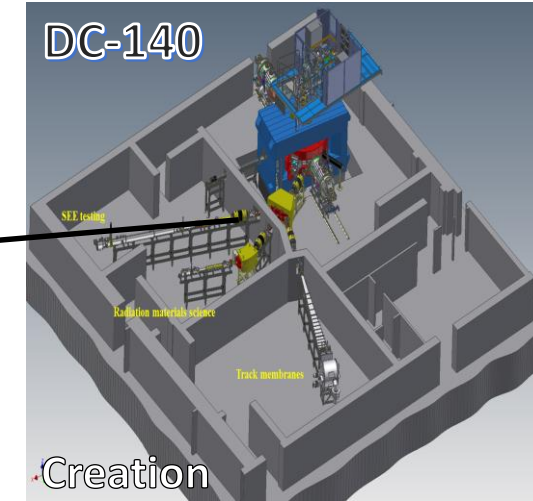
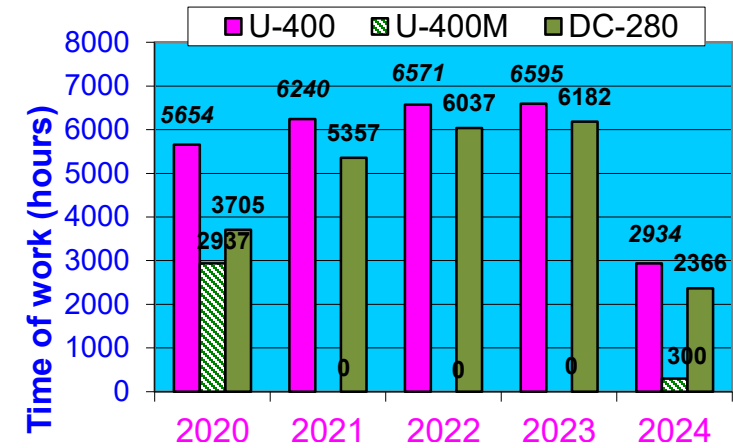
(03-5-1129-2017/2028)

Head of FLNR Accelerator department

Vasiliy Semin

Accelerated complex FLNR

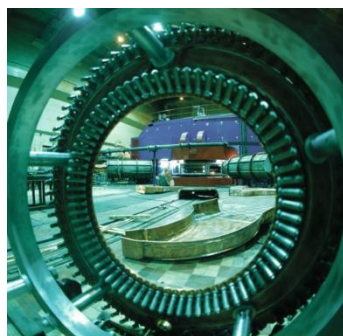
Sum time of work of accelerator facilities (hours)	2019	2020	2021	2022	2023	2024 (up 1st June)
	20110	15124	15065	16834	16583	5894



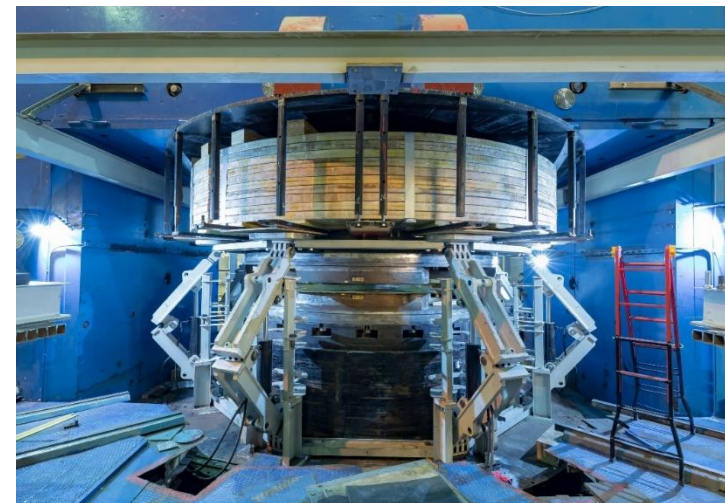
U-300 Cyclotron 1960 - 1989



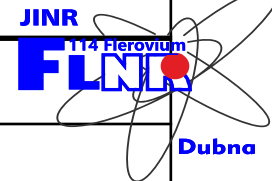
U-300→U-400M 1989 - 1991



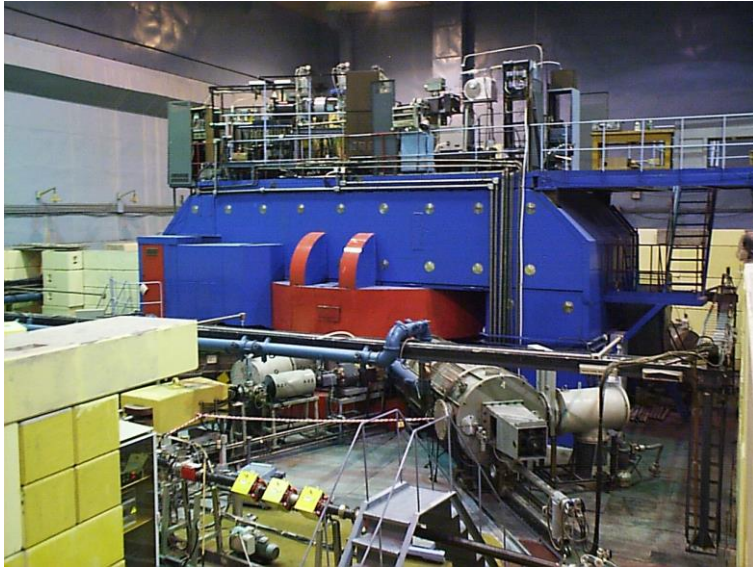
Modernization U-400M 2020 - 2024



Systems	List of work
Axial injection system	Change of Ion source DECRIS-2 → DECRIS-2M
Cyclotron magnet system	New main magnet coils
	Measuring of magnetic field: Correction of magnetic field by sector shims (compensation of first harmonic by sectors shims), Increasing of magnetic field level on extraction radius (valley shims)
	Repair of correction coils
Accelerator system	Modernization of resonator frequency tuning system (New short circuit plate actuator)
	New frequency autocorrection system (Based on change resonator capacity)
RF power supply system	New feeder line
	Generator matching system (matching the generator to the of the feeder line)
	Load matching system (matching the load to the of the feeder line)
Inner cyclotron equipment	New inner current probs
	Modernization of extraction system (new focusing magnet channel + the imitator of magnetic channel))
	Center of orbit position measure system
Vacuum system	New modern equipment: High vacuum cryopumps, turbomolecular pumps, new forvacuum line, new measure equipment
Transport channel system	Increasing the aperture of the first section of the high-energy channel
	New diagnostic elements
	New magnetic-optical elements on low energy channel
Water cooling system	Cooling line upgrade, additional controls, additional special modules
Control systems	New control system
Safety systems	Access control and locking system, Automatic radiation monitoring system



New main magnet coils (the prepare)



View to U-400M before start modernization



Dismantling of vacuum chamber



The dismantled equipment



View after dismantling of RF resonators



Dismantling of old main magnet coils



Descent of the coil by lift system

The prepare :

- Dismantling of transport channel equipment
- Dismantling accelerate system resonators
- Dismantling inner cyclotron elements
- Dismantling vacuum chamber
- Dismantling old main magnet coils

03.2021

New main magnet coils (the installation)

2 coils:

- 10 main section
- 1 additional section
- Sum mass 55 ton



The system for move in confined spaces

Gap size 84 mm
Section height 76 mm



Coil section installation system



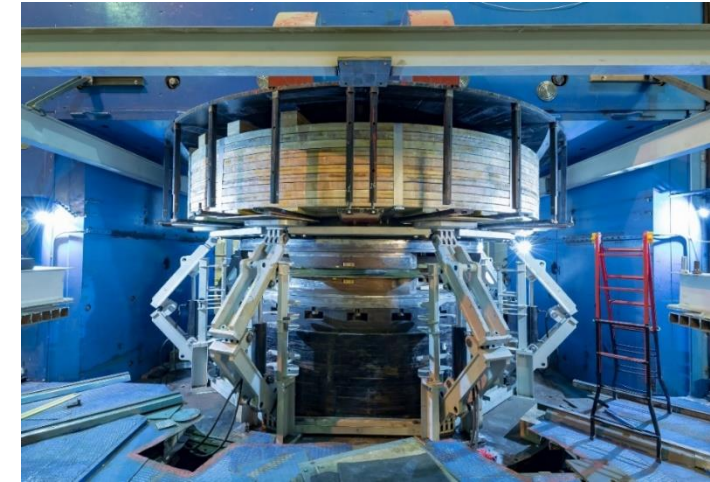
Upper coil lift process



The coil sections move in cyclotron hall



First section of Upper coil 14.08.2021

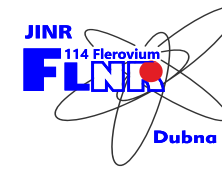


Upper coil installed 25.08.2021

New main magnet coils (the installation)

Problems: Water cooling channel leak

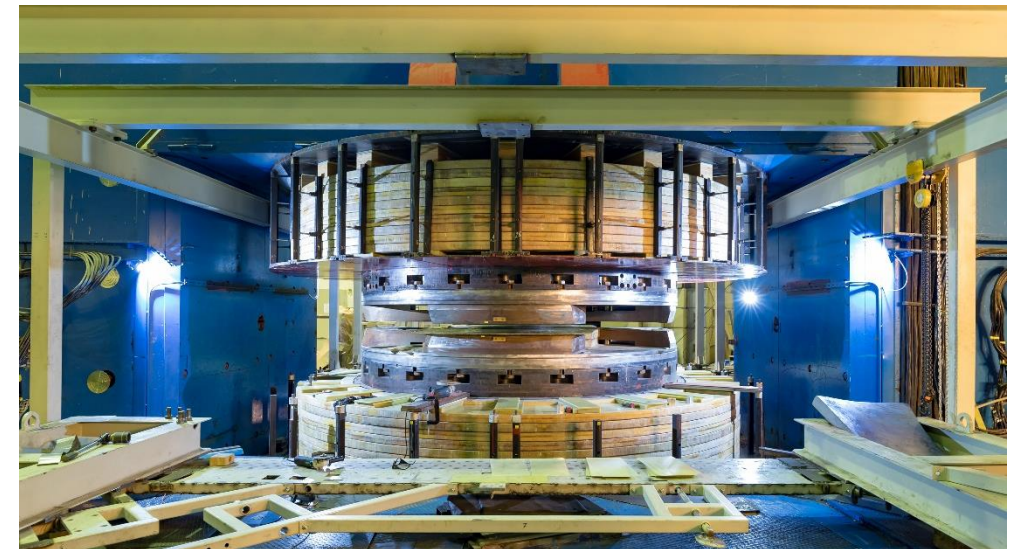
Lost time 2 months



GKMP
RESEARCH & PRODUCTION
COMPANY



Organization of repair work at FLNR Assembly Hall



Completion of installation of new coils 03.11.2021

Started after connecting the magnet to:

- Power supply
- Water cooling



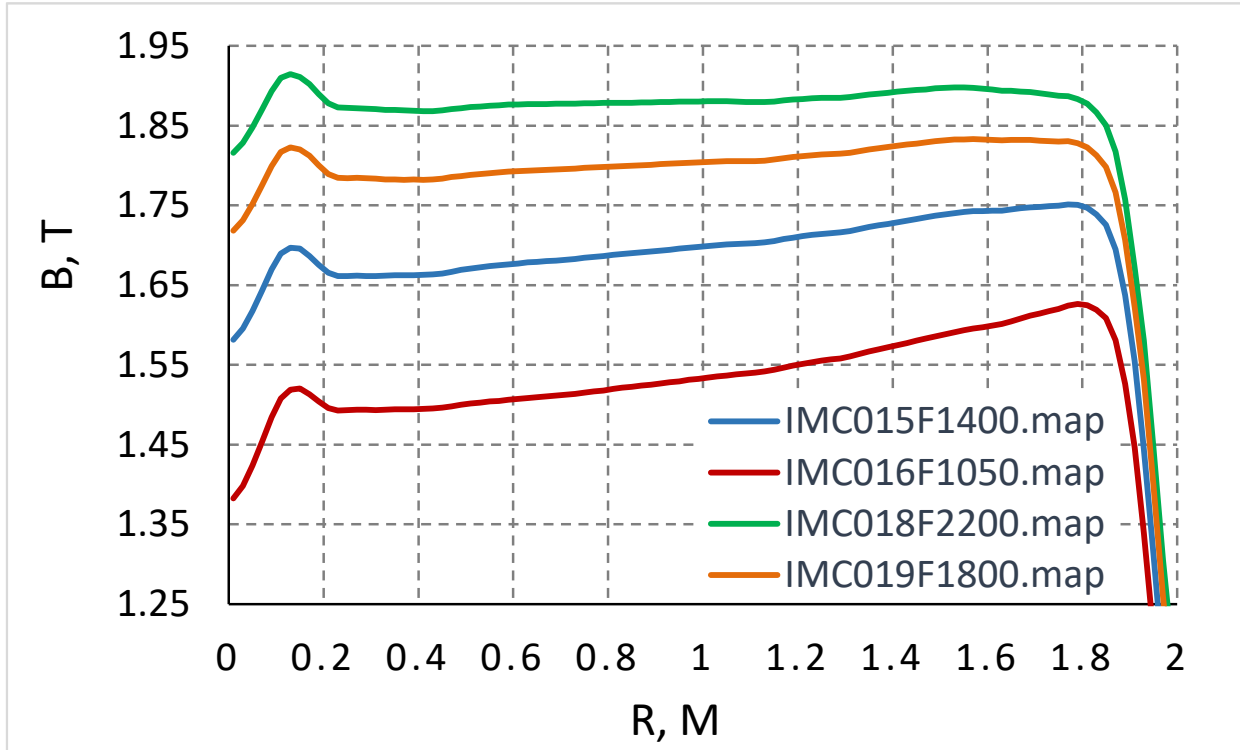
Magnetic measurement system.

Automatic mapping system:

- 14 Hall probes
- Hall probe step 160 mm
- Total radius of mapping 2240 mm
- Azimuthal range of mapping 360°
- Azimuthal step 1° or 2°

Total time of mapping 8 hours

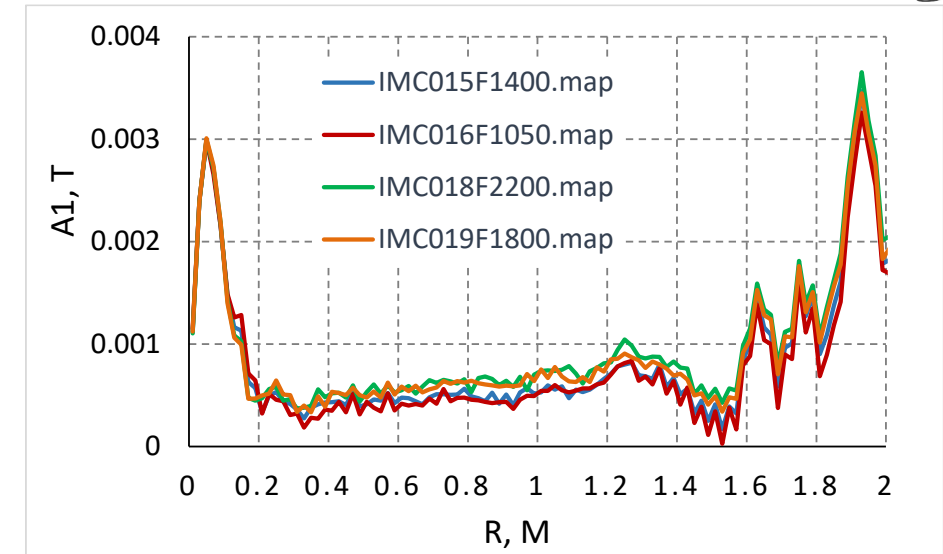
Magnetic field measurement and correction



Level of magnetic field with current in coils
1050A, 1400A, 1800A, 2200A.

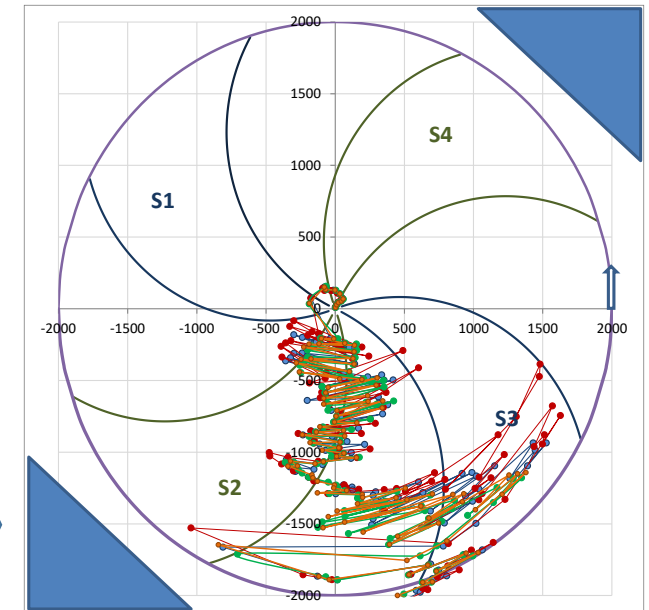
4 level of magnetic field correspond
to current in main coils:
1050 A, 1400 A, 1800 A and 2200 A

First harmonic:

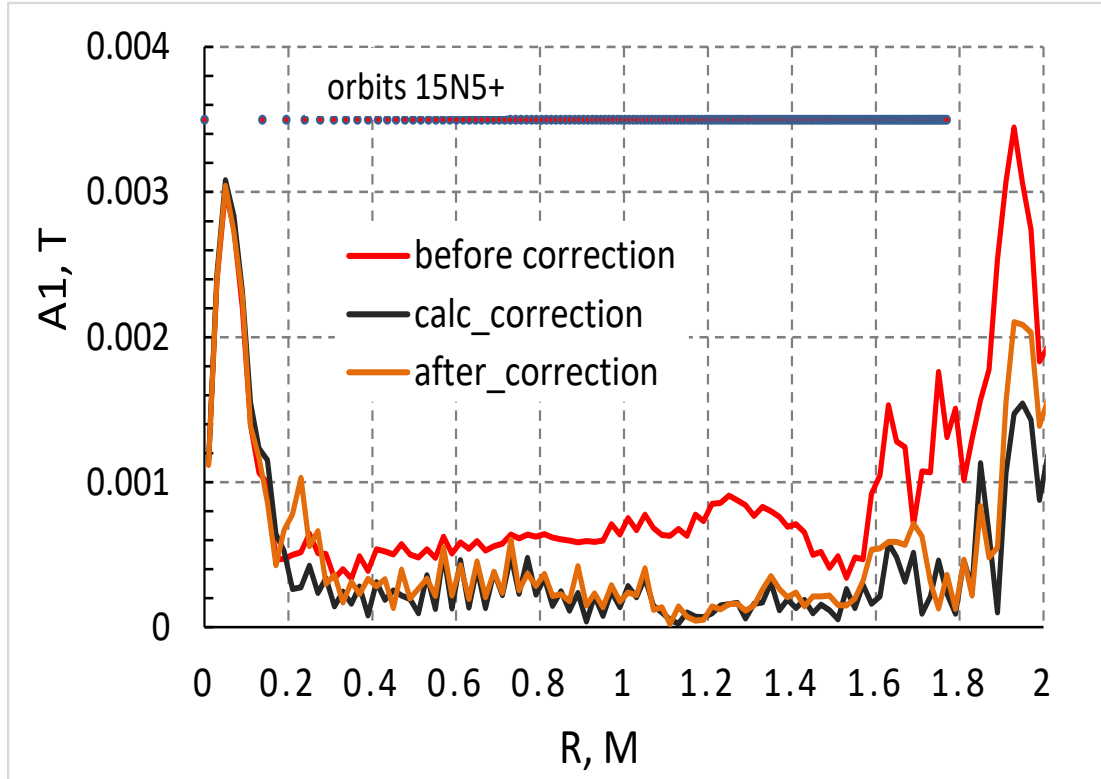


First harmonic level with
current in coils 1050A,
1400A, 1800A, 2200A.

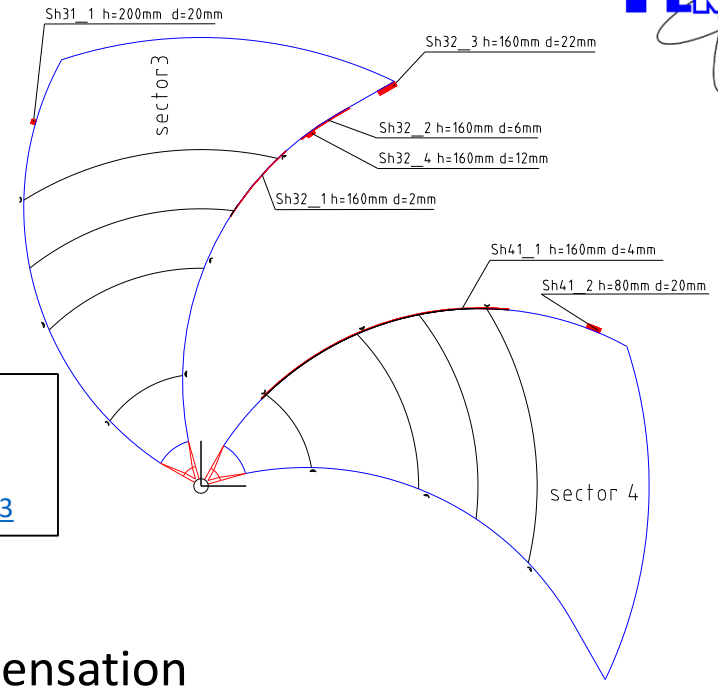
First harmonic phase with
current in coils 1050A,
1400A, 1800A и 2200A.



First harmonic of magnet field compensation by sectors shims



Results of Reconstruction of U400M
Cyclotron Magnetic Structure April 2024
[Siberian Journal of Physics](#) 18(4):36-43
DOI: [10.25205/2541-9447-2023-18-4-36-43](#)



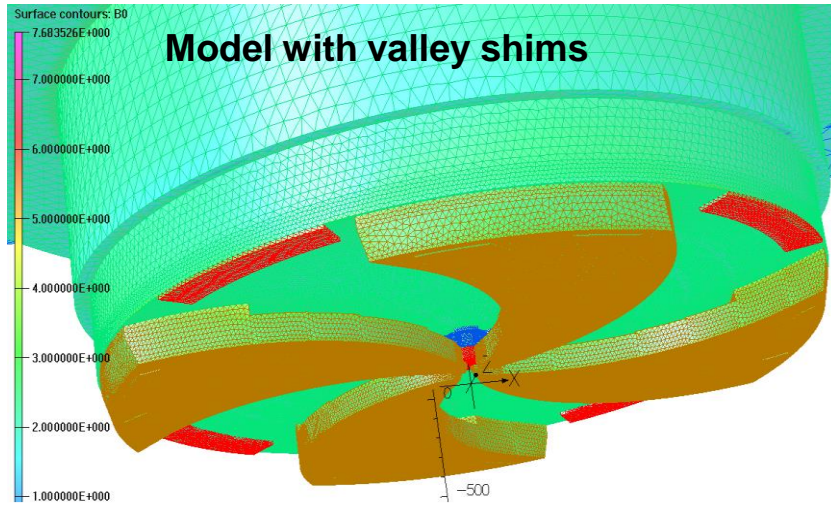
Shim placement for first harmonic compensation



Comparison of first harmonic amplitudes:

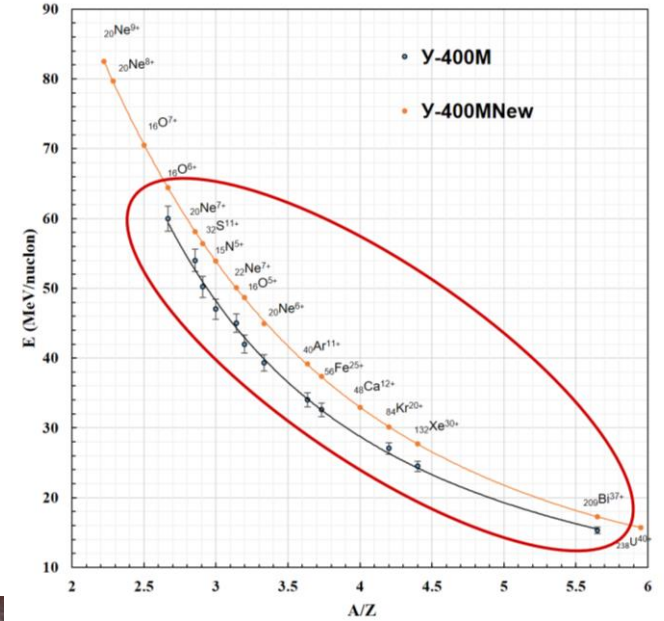
- Before shimming
- Calculation after shimming
- Measurement results after shimming

Magnetic field measurement and correction

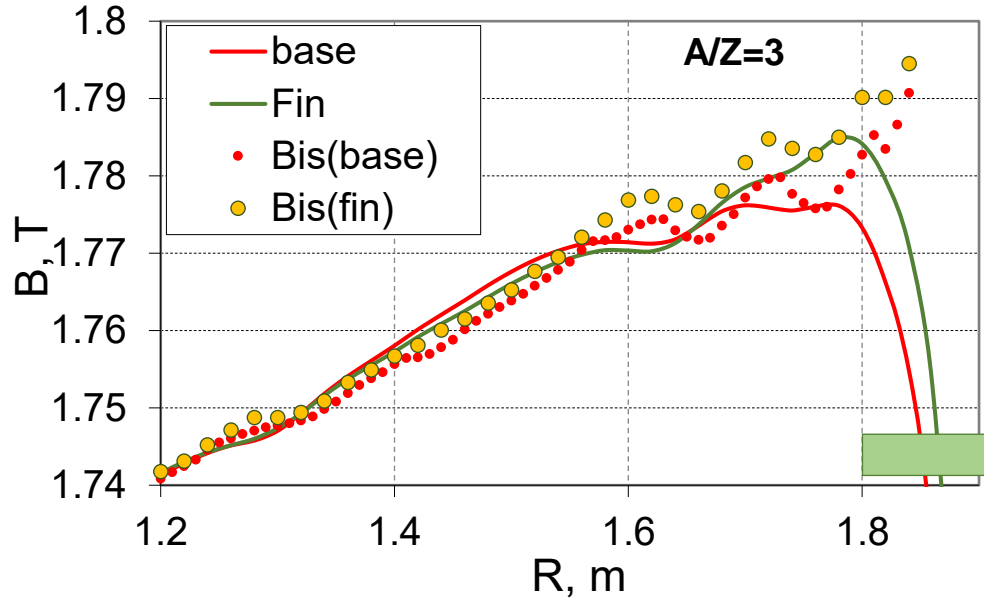


Valley shims:

- Increase of magnetic level on extract radius
- Increase of extraction radius 10 – 15 mm
- Increase of extraction energy
- Increase of extraction efficiency



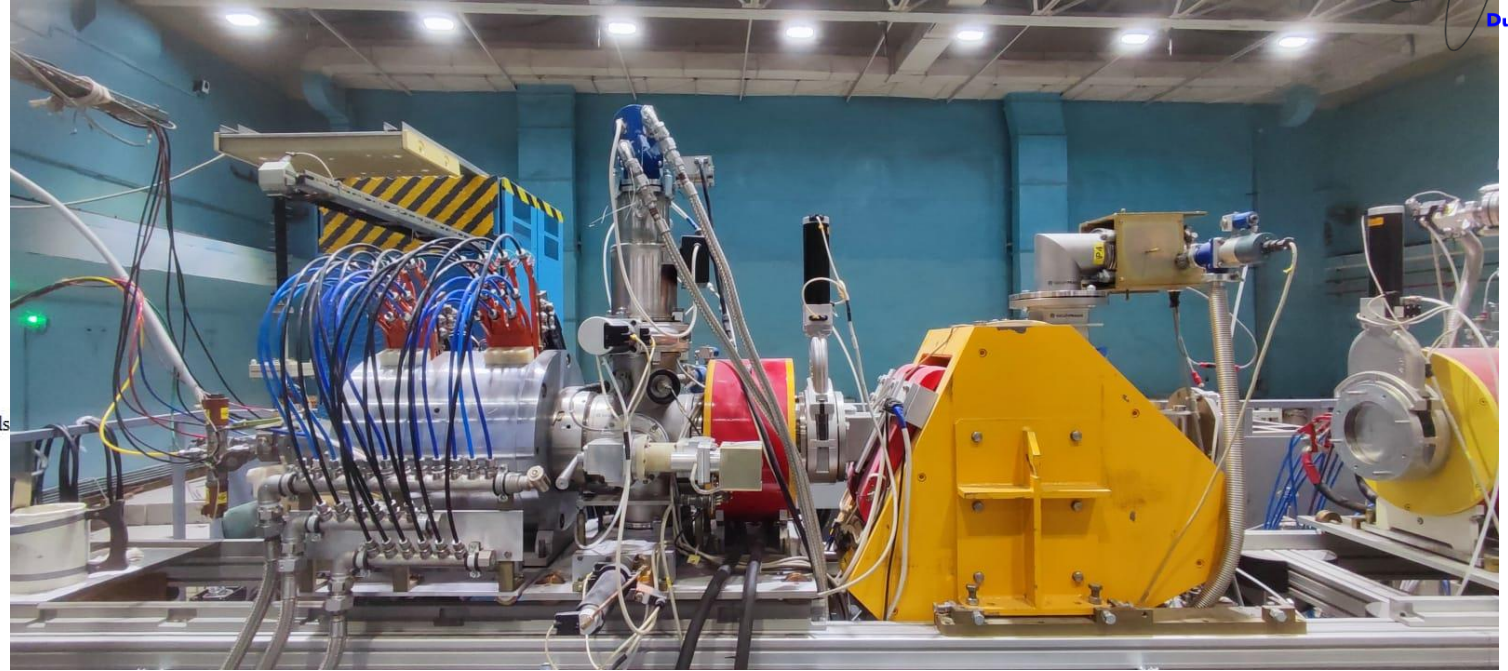
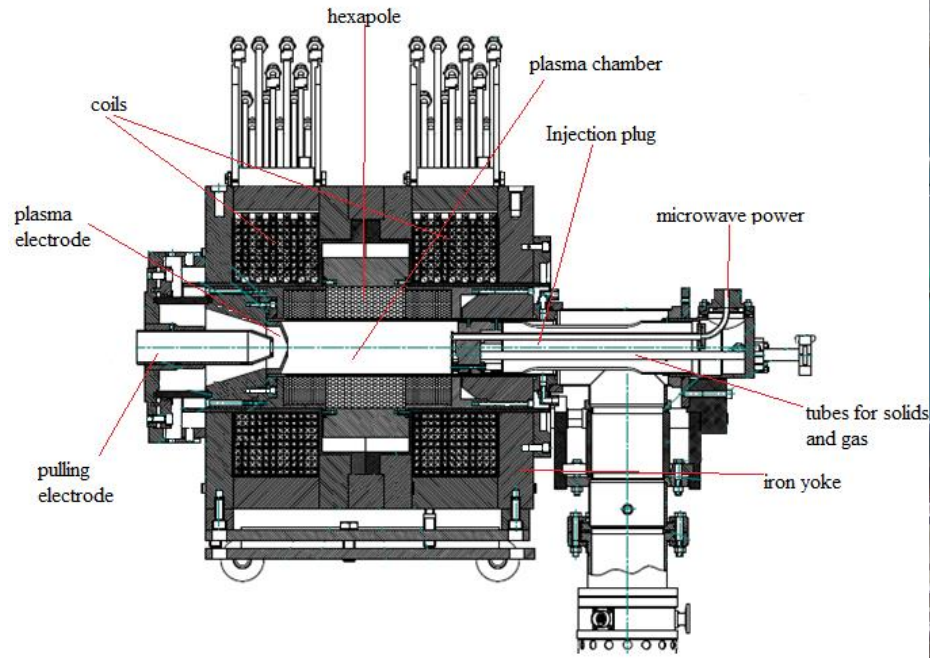
**Marked area:
output by existing system
recharge method**



Comparison of magnetic fields without (base) and with valley shims (Fin):
Magnetic field (lines), and isochronous fields (points)



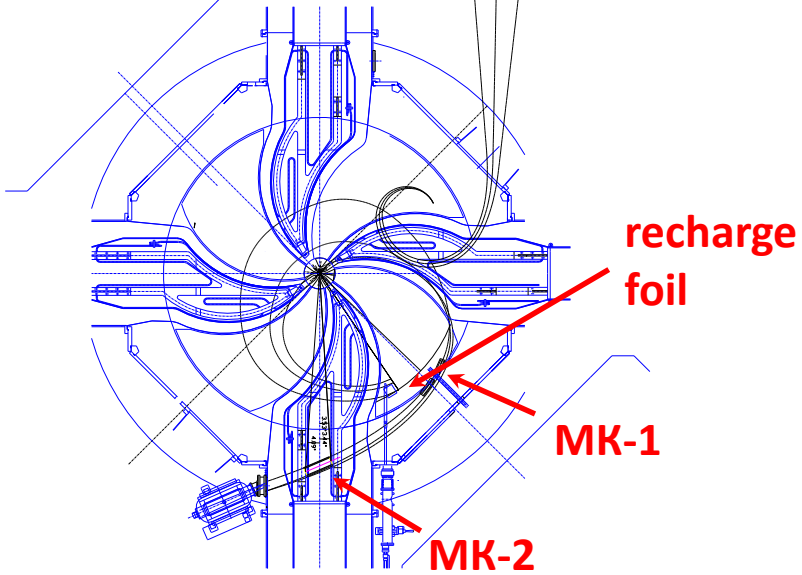
$R = 1800 - 1995 \text{ mm}$
height = 16 mm.



Comparison of source intensities

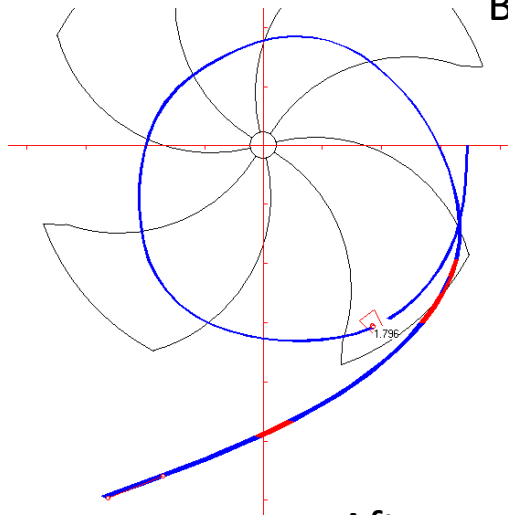
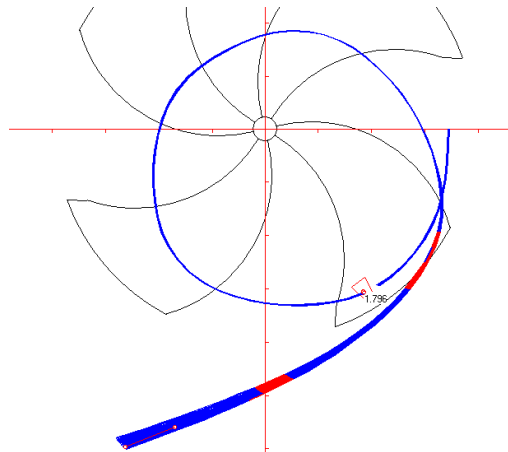
Ion	Ion current, μA	
	DECRIS-2	DECRIS-2M
$^{40}\text{Ar}^{8+}$	480	750
$^{132}\text{Xe}^{18+}$	30	114
$^{132}\text{Xe}^{20+}$	23	118
$^{132}\text{Xe}^{27+}$	-	32
$^{209}\text{Bi}^{27+}$	-	40
$^{209}\text{Bi}^{32+}$	-	11

extraction system diagram

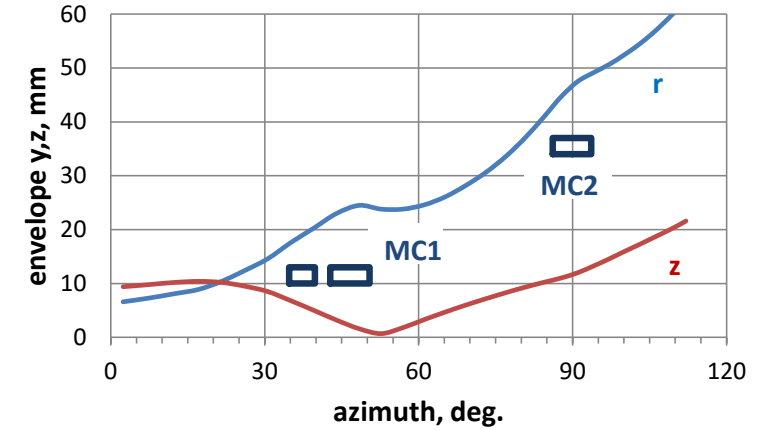


Traces from the beam on the magnetic channel MK2 (before modernization)

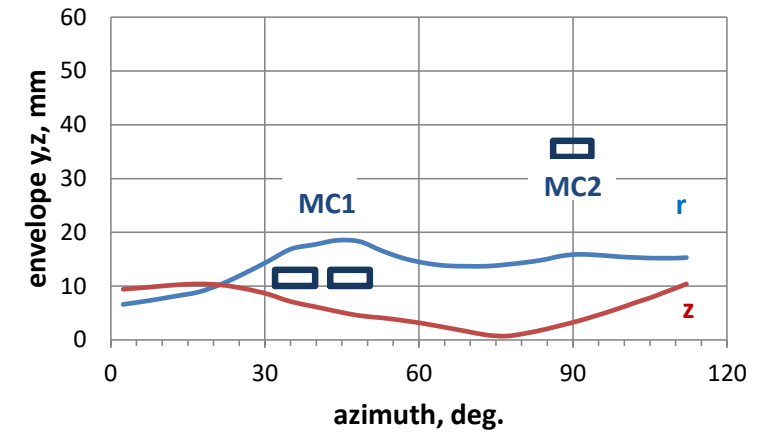
Calculation of output from a cyclotron trajectory beam envelope



beam envelope

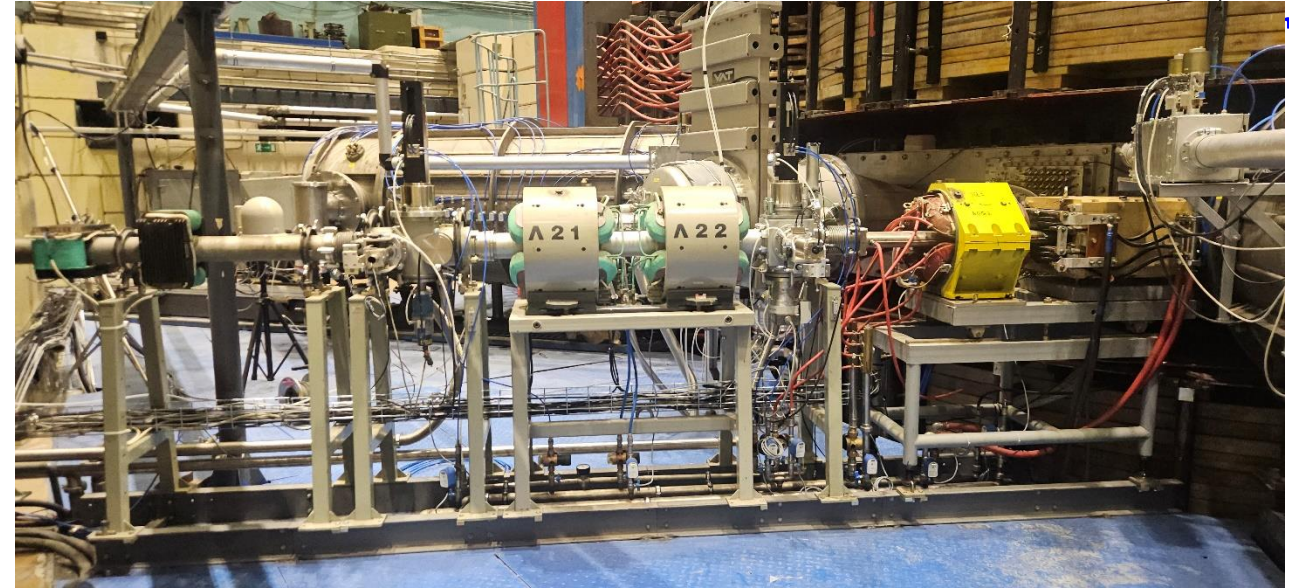
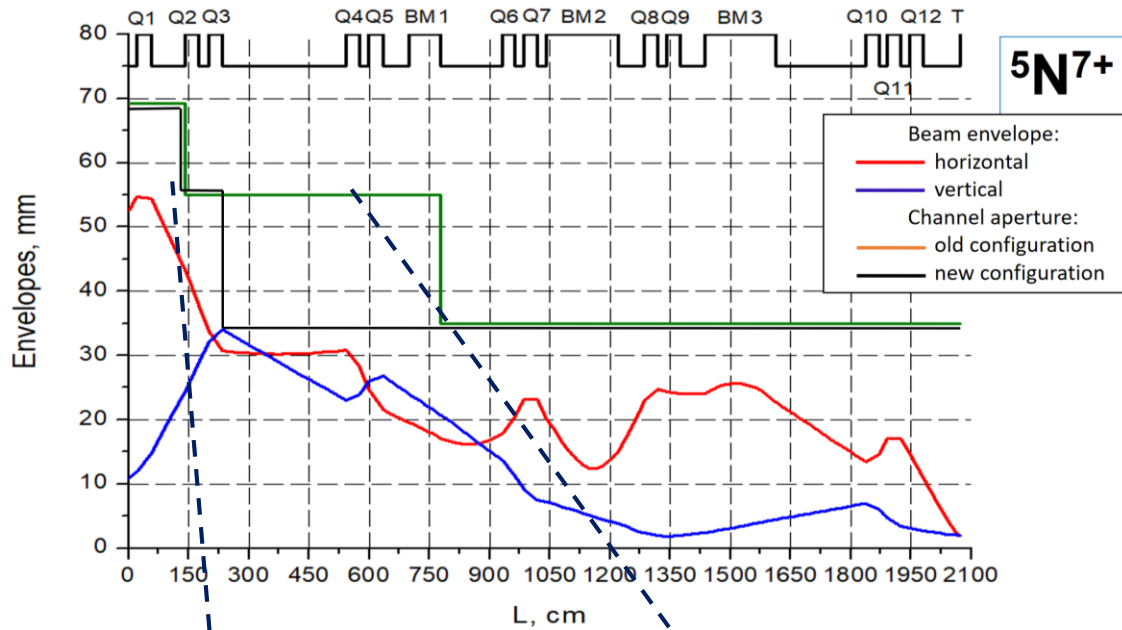


Before modernization

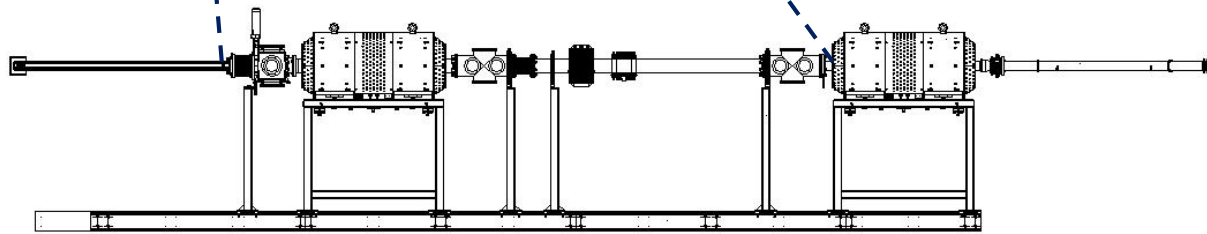


After modernization with New magnetic channel MK-1 (extended by 96 mm)

Increasing the aperture of the first section of the high-energy channel



Calculation of ${}^5\text{N}^{7+}$ beam transportation through the Acculina II channel



Scheme of the new initial section of the transport channel

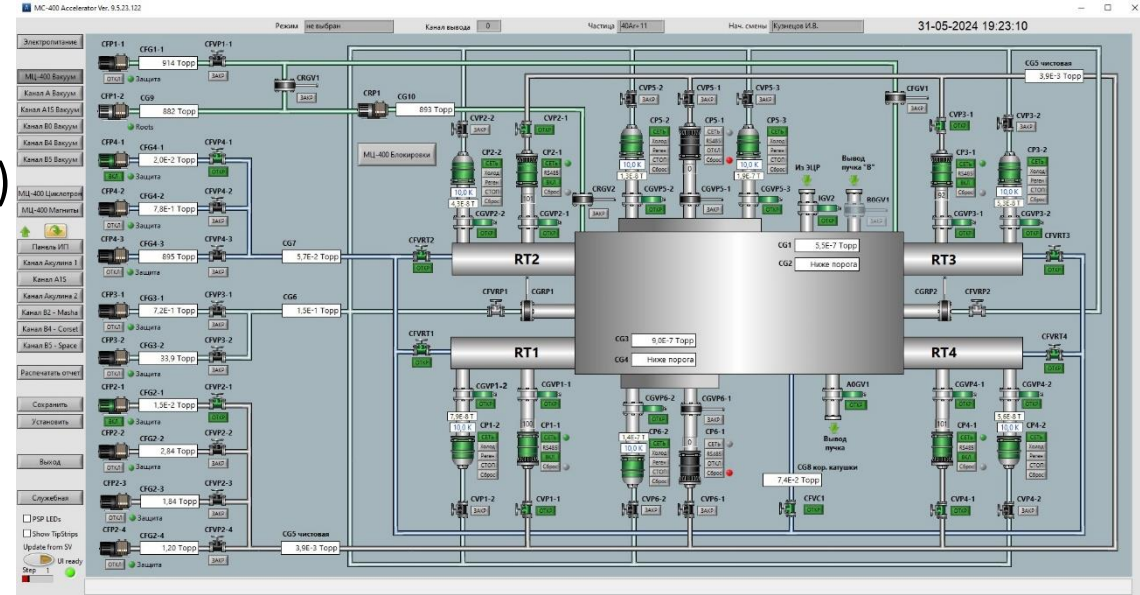
Modernization of transport channel:

- Increasing aperture
- Additional ion-optical elements
- Additional diagnostic items
- Adjusting the arrangement of elements
- Replacement of vacuum equipment
- Updated water cooling system
- Update of power supply and control lines
- New control systems

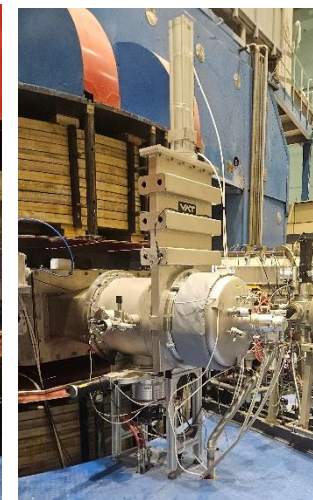
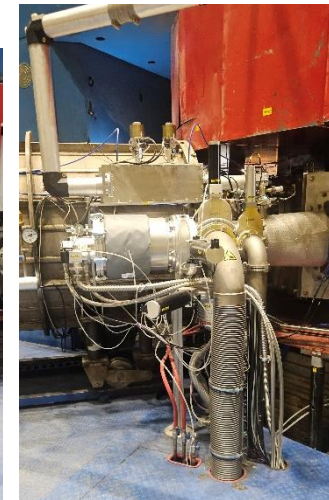
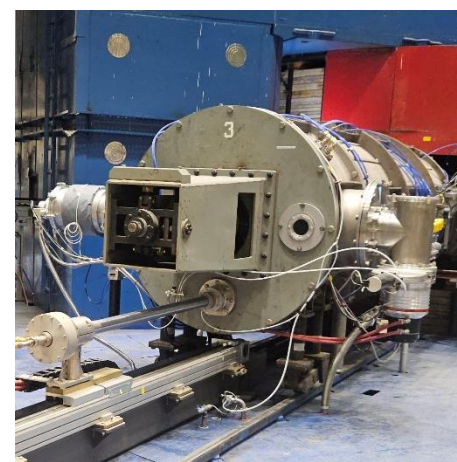
Vacuum system upgrade:

- New cyclotron chamber pumping system (cryopump, TMP)
- New forevacuum lines (cyclotron, channels)
- New Roots pump
- New measuring elements
- New control system

Obtaining a working vacuum level within 1 day



View of the control panel of the cyclotron vacuum system



Forevacuum pumps

Cryopump compressors

Roots pump

High vacuum pumping systems

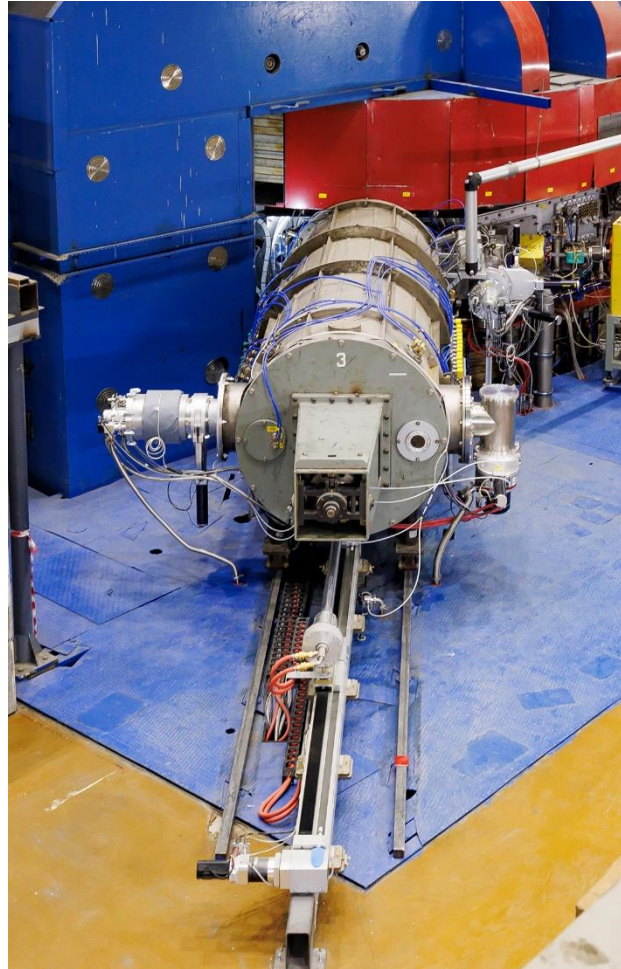
Frequency range 11.5÷ 24 [MHz]

Cold measurements of the frequency range of the accelerating system

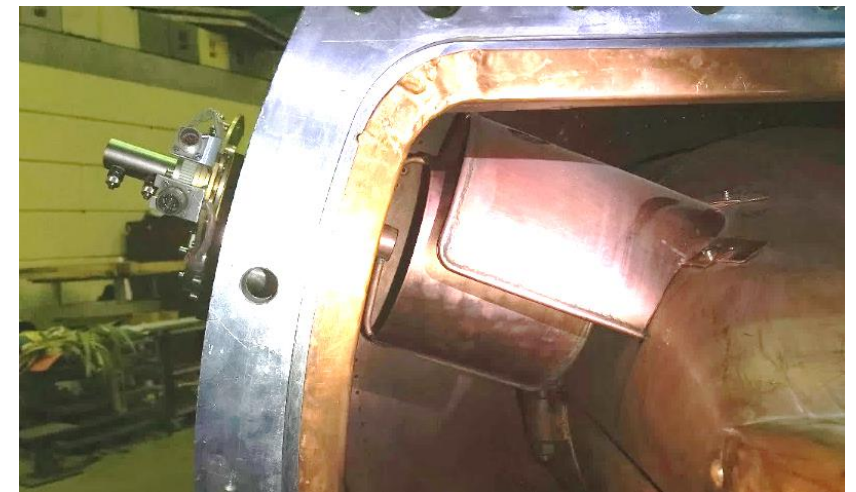
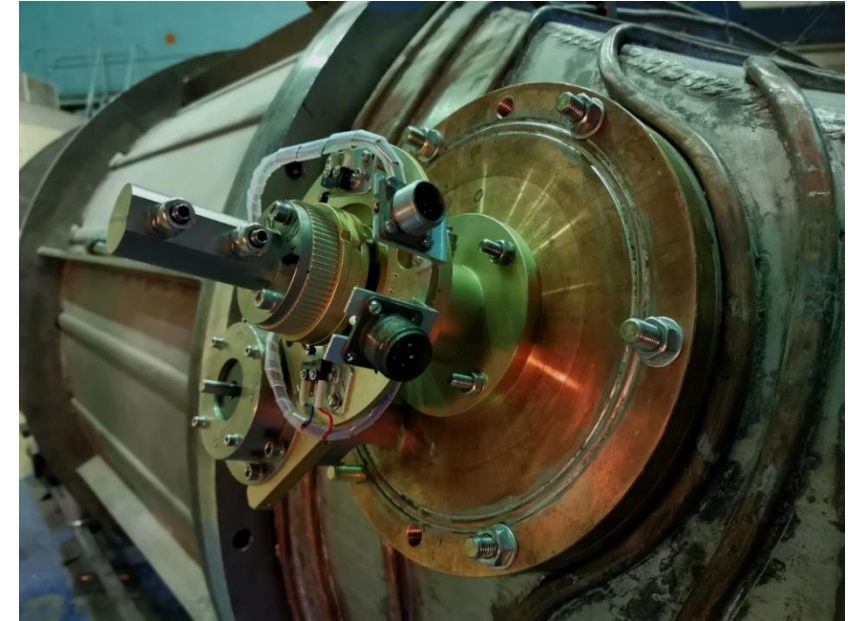


Accelerate system

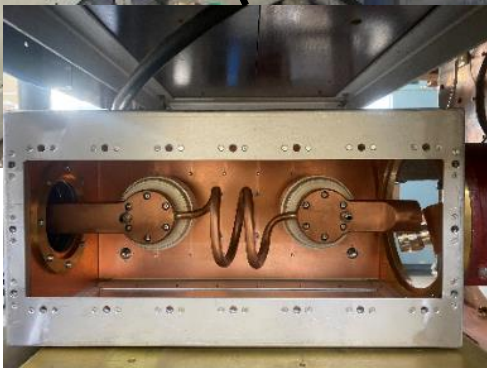
Modernization of resonator frequency tuning system
(New short circuit plate actuator)



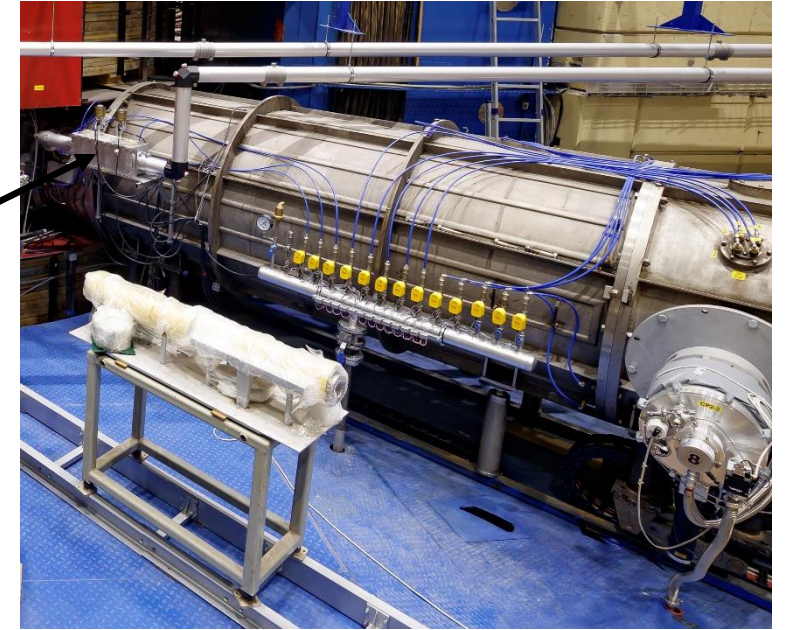
New frequency autocorrection system
(Based on change resonator capacity)



RF power supply system



Load matching system (matching the load to the of the feeder line)



Independent water cooling module for RF generators

- Power output from the generator after modernization:
1. Generator matching system
 2. Measuring line
 3. Power switch

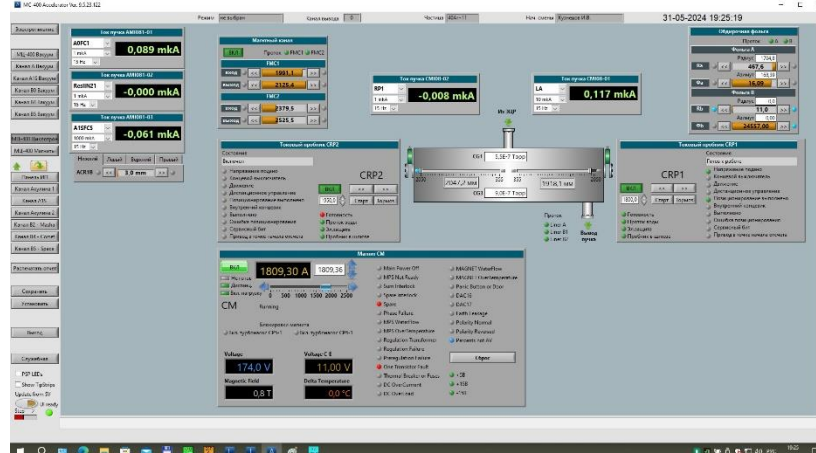
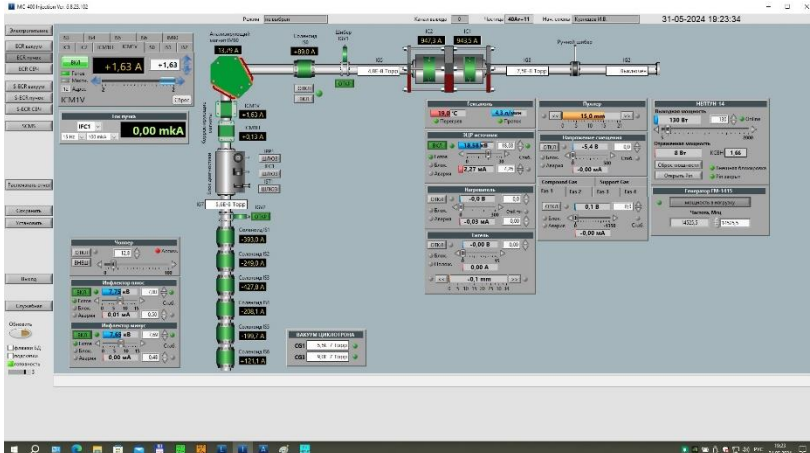


Axial injection

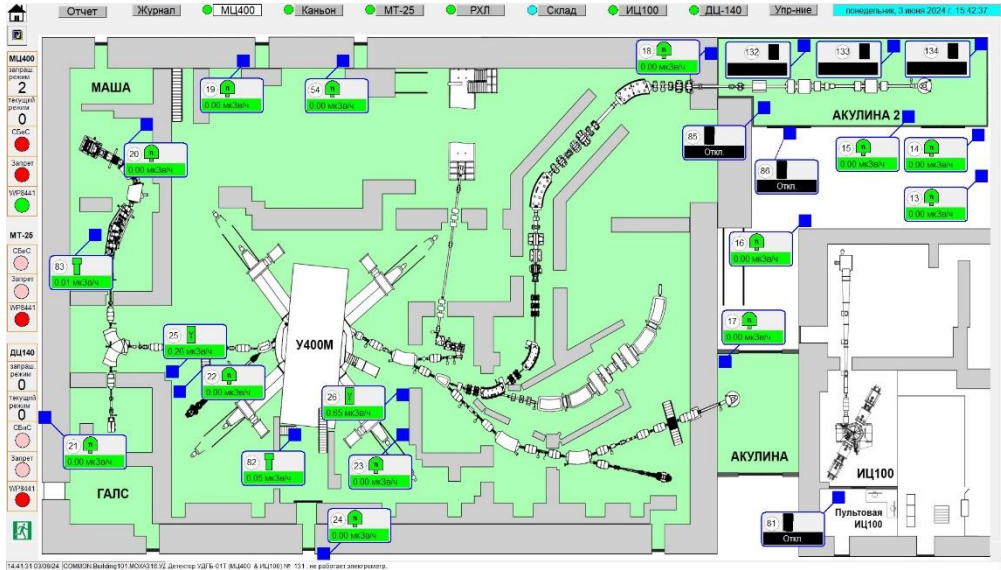
- Additional power supplies
- Replacing cable lines for powering elements
- New control system layout
- Design and completion of control racks
- Control system drivers for new elements
- Control system software
- Commissioning

Cyclotron

RF



View of the control panels



Part of the 101 building system provides:

- neutron radiation control
- gamma radiation control
- data collection and storage
- control signals to the access control system

View of the control panels



server



detector group



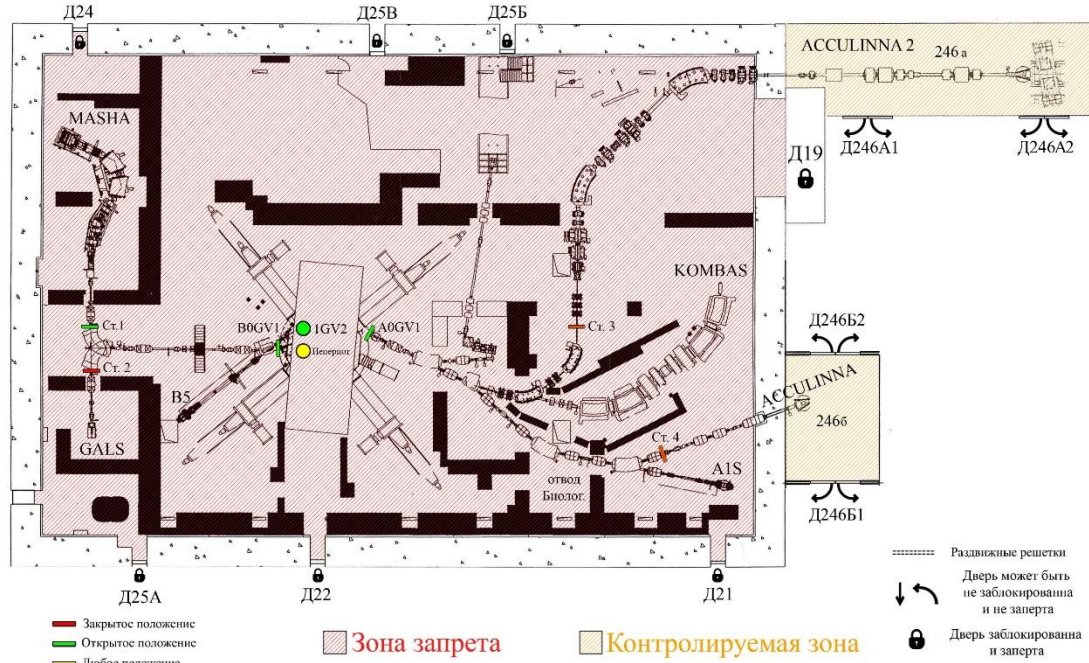
UDBN-01

n – radiation
E = 0,001 – 14 MeV



UDBG-01

γ – radiation
E = 0,06 – 3 MeV



- Controls access to the cyclotron hall and experimental rooms
- Control of accelerator installation protective stoppers
- Sound and light information signals

View of the control panels



Control buttons



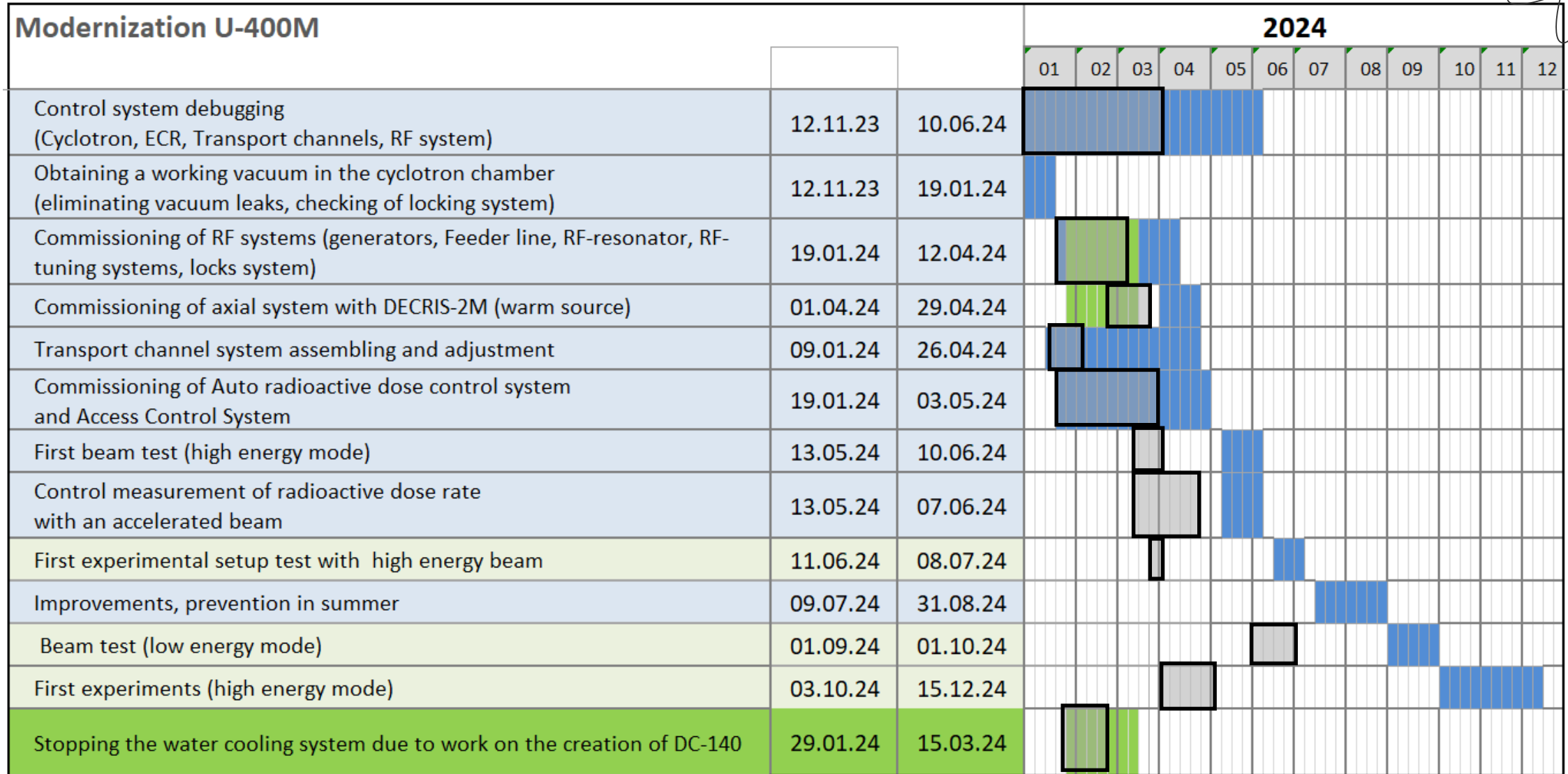
Elements of the information system



Access Control Elements



Modernization of U-400M (MC-400)



█ Plans presented at the 58th meeting of the PAC for Nuclear Physics in January 2024

Modernization of U-400M

Modernization U-400M			2020												2021												2022												2023												2024											
			7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12						
Task	Start	Finish																																																												
Disassembling cyclotron equipment	01.07.20	01.02.21	[Gantt bar: 2020-07-01 to 2021-02-01]																																																											
Dismantling old windings "GKMP"	01.02.21	01.06.21	[Gantt bar: 2021-02-01 to 2021-06-01]																																																											
Installation of new windings "GKMP"	01.06.21	01.02.22	[Gantt bar: 2021-06-01 to 2022-02-01]																																																											
Connection to power supply and water cooling system	01.02.22	01.03.22	[Gantt bar: 2022-02-01 to 2022-03-01]																																																											
Magnetic measurement and shimming	01.03.22	16.09.22	[Gantt bar: 2022-03-01 to 2022-09-16]																																																											
Installation of correction coils and internal elements of the cyclotron	16.09.22	01.11.22	[Gantt bar: 2022-09-16 to 2022-11-01]																																																											
Repair of correction coil (FLNR, LHEP)	01.07.22	01.12.22	[Gantt bar: 2022-07-01 to 2022-12-01]																																																											
Vacuum chamber installation and vacuum testing	01.11.22	09.12.22	[Gantt bar: 2022-11-01 to 2022-12-09]																																																											
Installation of RF resonators of the accelerating system	10.12.22	01.11.23	[Gantt bar: 2022-12-10 to 2023-11-01]																																																											
Installation of equipment on the cyclotron vacuum chamber	10.12.22	09.12.22	[Gantt bar: 2022-12-10 to 2022-12-09]																																																											
Installation of axial injection equipment (DECRIS-2M)	01.06.21	15.03.24	[Gantt bar: 2021-06-01 to 2024-03-15]																																																											
Manufacturing of additional elements	09.12.22	23.09.23	[Gantt bar: 2022-12-09 to 2023-09-23]																																																											
Obtaining the working vacuum level	01.11.23	19.01.24	[Gantt bar: 2023-11-01 to 2024-01-19]																																																											
Vacuum pumping of axial injection	15.03.24	30.03.24	[Gantt bar: 2024-03-15 to 2024-03-30]																																																											
Commissioning the RF system	19.01.24	12.04.24	[Gantt bar: 2024-01-19 to 2024-04-12]																																																											
Commissioning the axial injection system	01.04.24	29.04.24	[Gantt bar: 2024-04-01 to 2024-04-29]																																																											
Assembly and adjustment of the transport channel system	09.06.23	06.07.23	[Gantt bar: 2023-06-09 to 2023-07-06]																																																											
Installation of Access control and Auto radiation monitoring systems	01.02.22	25.12.23	[Gantt bar: 2022-02-01 to 2023-12-25]																																																											
Commissioning of Access control and Auto radiation monitoring systems	19.01.24	07.05.24	[Gantt bar: 2024-01-19 to 2024-05-07]																																																											
Commissioning with accelerated beam (High energies)	13.05.24	10.06.24	[Gantt bar: 2024-05-13 to 2024-06-10]																																																											
Monitoring dosimetry measurements with accelerated beam	13.05.24	07.06.24	[Gantt bar: 2024-05-13 to 2024-06-07]																																																											
Tests of experimental installations with accelerated beam (High energies)	11.06.24	11.07.24	[Gantt bar: 2024-06-11 to 2024-07-11]																																																											
First experiments (High energies)	06.09.24	15.12.24	[Gantt bar: 2024-09-06 to 2024-12-15]																																																											
Stopping the water cooling system for work on the creation of DC-140	02.02.24	15.03.24	[Gantt bar: 2024-02-02 to 2024-03-15]																																																											

Intensity and energy of type ions after modernization U-400M (MC-400)

Ion	2019		Expected	
	E (MeV/u)	I(pμA)	E (MeV/u)	I(pμA)
⁷ Li	35	5	39	10
¹¹ B	30	3	33	6
¹⁵ N	47	0.5	51	2
¹⁸ O	36	0.5	40	1.5
²² Ne	45	0.3	50	1
³⁶ S	40	0.12	44	0.2
⁴⁸ Ca	34	-	38	0.1
⁵⁶ Fe ¹⁵⁺	36	0.01	40	0.1



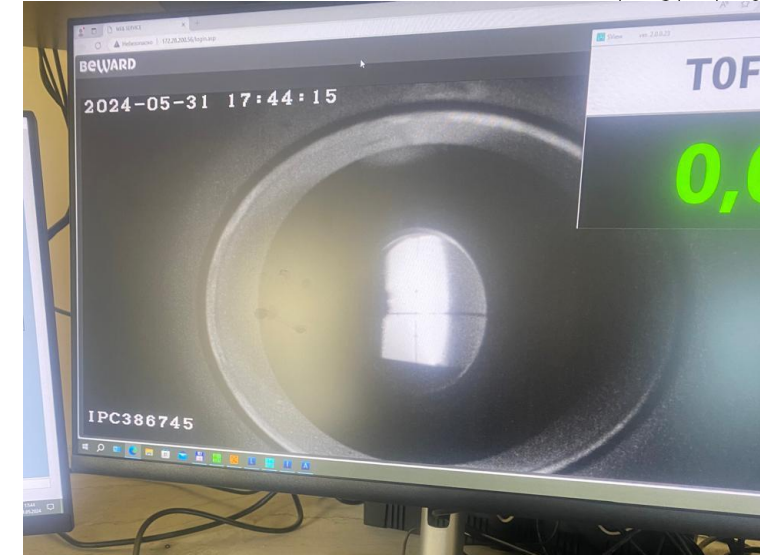
Start 13.05.2024

First beam:

$^{40}\text{Ar}^{11+}$ (E=39.2 MeV/n)

First extracted beam:

31.05.2024



MC-400 Accelerator Ver. 9.5.23.122

31-05-2024 19:25:19

Ток пучка AMI081-01	Ток пучка AMI081-02	Ток пучка AMI081-03	Ток пучка CM108-02	Ток пучка CM108-01
0,089 mKA	-0,000 mKA	-0,061 mKA	-0,008 mKA	0,117 mKA

Ток пучка CRP2: 1809,30 A

Ток пучка CRP1: 0,096

Вольтаж: 174,0 V

Магнитное поле: 0,8 T

Температура: 11,00 V

Дельта температура: 0,0 °C

Thanks
for attention

