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The DC130 project:
new multipurpose applied science facility for FLNR.

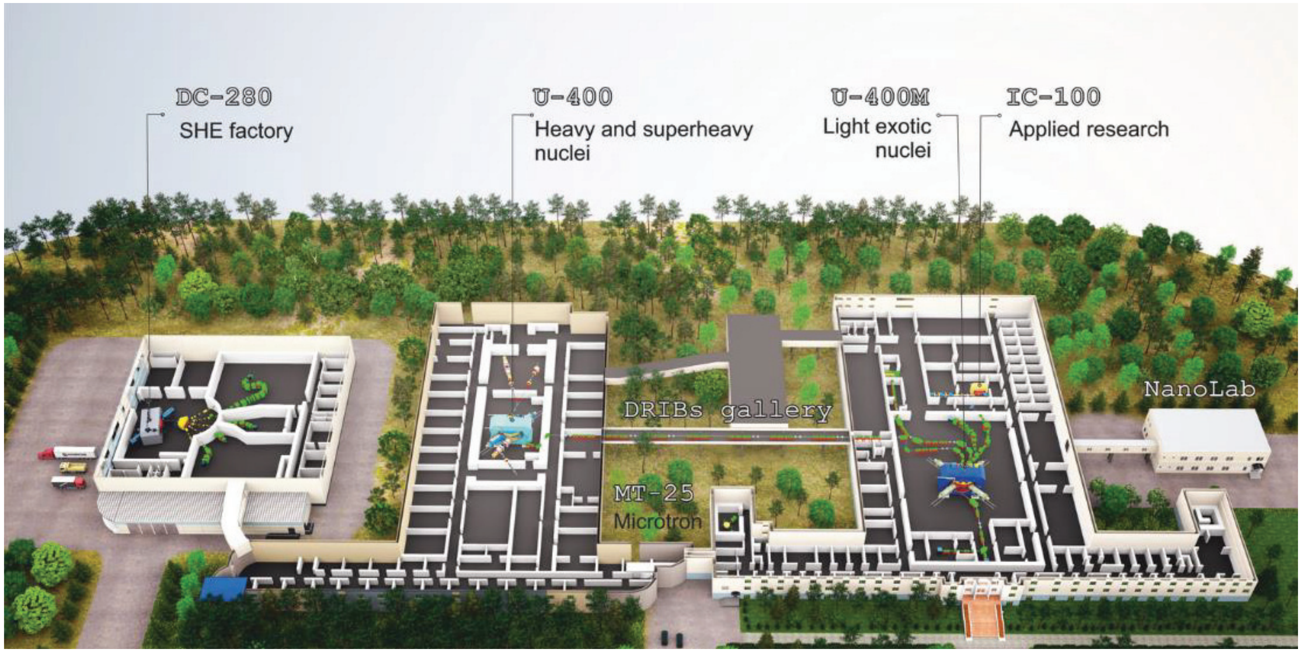
Outline

1. FLNR accelerating complex in 2018.
2. Main applied activities in FLNR connected with HIB
3. Preliminary conclusions: beam requirements.
4. The DC130 cyclotron parameters.
5. DC130 project road map.

FLNR accelerating complex in 2018.

4 cyclotrons and Microtron (e-beams)….

Beam operation time – 7 years review: ~ 16 000 hours/year of the ion beams **ON** physical targets

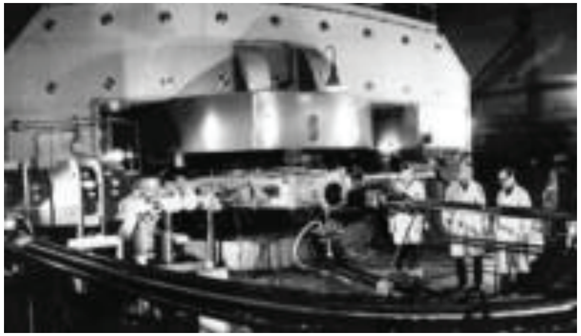


FLNR carries out research in the field of **heavy ion physics** in three main directions:

- Synthesis and properties of nuclei at the stability limits
- Accelerator complex of ion beams of stable and radioactive nuclides (DRIBs-III)
- Radiation effects and physical bases of nanotechnology, radioanalytical and radioisotope investigations at the FLNR accelerators

Science for life - applied physics researches

Since middle of 1970's track membrane technology based on HIB were realized at U300 in FLNR.



... In 2018

- Creation and development of track membranes (nuclear filters) and the heavy ion induced modification of materials.

- Activation analysis, applied radiochemistry and production of high purity isotopes.

- Ion-implantation nanotechnology and radiation materials science.

- Testing of electronic components (avionics and space electronics) for radiation hardness.

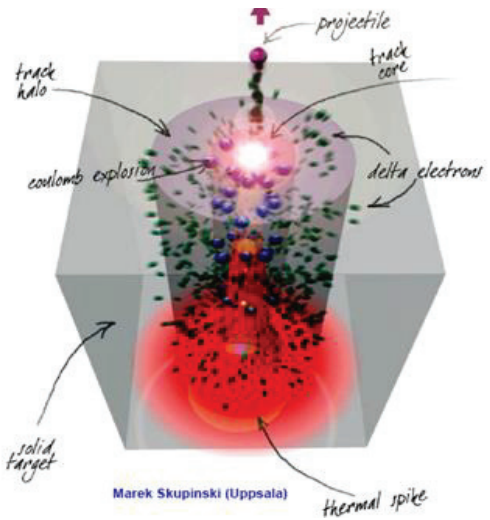
Ion track technology

Heavy ion track etching method allows

- to vary the pore diameter and pore density independently
- control over the pore orientation (parallel, normal to surface, tilted, non-parallel…)
- to produce either through or non-through pores
- control over the pore shape and thus control over the hydraulic resistance and retention properties of membranes
- production of both symmetric and asymmetric membranes

Precise control over structure and transport characteristics

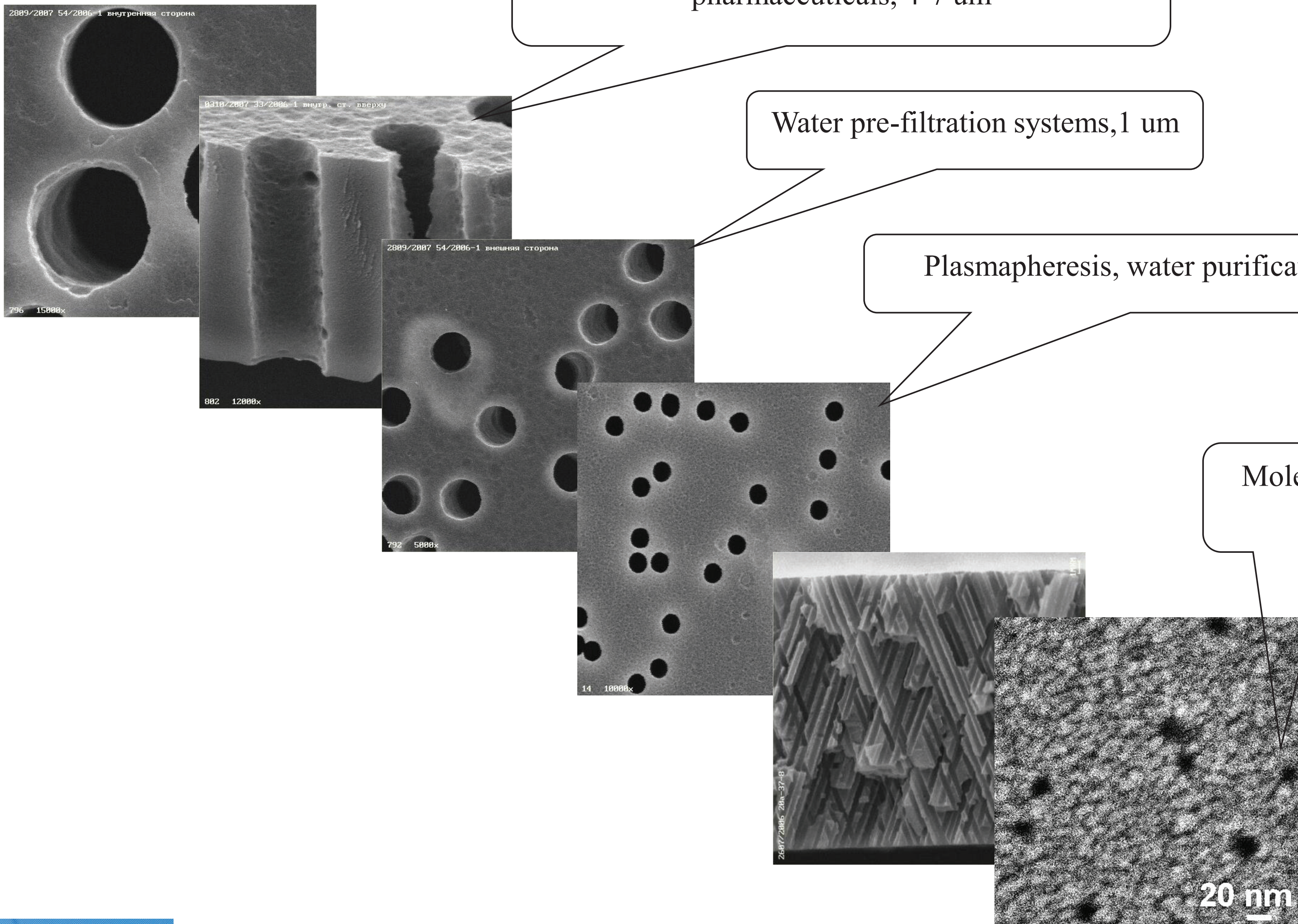
Heavy ion



IC-100 dedicated beamline for ion track technology

Ion track technology

Micrometers



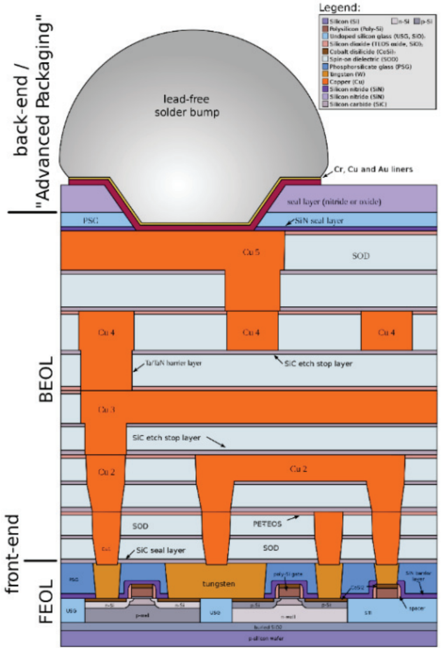
Ion-implantation nanotechnology and radiation materials science.

- Examination of the dense ionization effect in ceramics and oxides with heavy ions of fission fragments energy ($MgAl_2O_4$, MgO, Al_2O_3, ZrO_2, SiC, ZrC, ZrN, AlN, Si_3N_4)
- Accumulation of mechanical stresses under swift heavy ion irradiation

B^{+2}, Ne^{+4}, Ar^{+7}, Kr^{+17}, Xe^{+26} ions with energy $\approx$ 1.2 MeV/amu

Testing of electronic components (avionics and space electronics) for radiation hardness.* (THOEA01 P. Chubunov)

Question to be answered – what will be if…you have TOO much species in your "sandwich"…. or ONE is already enough ???



*Courtesy to Wiki

- What does it mean for FLNR ??

Using the accelerator complex to irradiate the DUT (Device Under Test) with the heavy ion beams (with well-known characteristics).

- What does it mean for Users ??

To observe response and operate the DUT under exposure online.

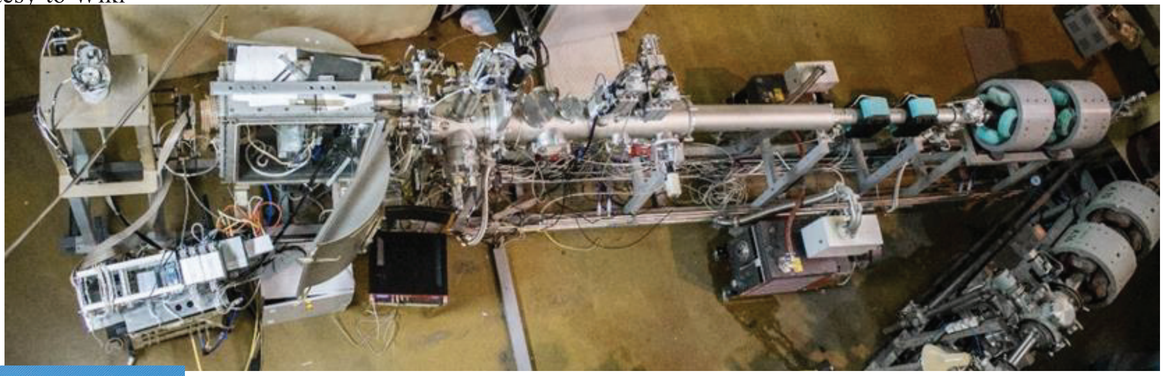
Goal:

Obtaining experimental data within Earth limits to predict SEE rate in space.

3 dedicated beamlines with E=3÷60 MeV/n.

Since 2010, more then 4000 devices has been tested.

~ 3000 hours per year



What heavy ion beams parameter do these all-sort practical applications need?

“Shaken, not stirred”

Ion track technology needs:
- energy **2** and 4,5 MeV per nucleon
- Ions from Ne up to Bi
- Intensity with Xe (as example) $1x10^{12}$ c^{-1}
- Irradiation zone 650*250 mm (2 AMeV) and 325*190mm (4,5 AMeV)
- Beam uniformity 5 %
- Casemate - “green area” - people around irradiation chamber
- Oversize irradiation chamber => dedicated beam line

Radiation materials science:
- energy up to 2 and **4,5** MeV per nucleon
- Ions from Ne up to Bi or U
- Intensity with Xe (as example) $1x10^{12}$ c^{-1}
- Irradiation zone Ø30 mm (2 AMeV) and Ø20 mm (4,5 AMeV)
- Dedicated beam line due to specific T° requirements and sample preparation procedure.
- Casemate - “green area” - people around irradiation chamber

Testing of electronic component (SEE testing):
- Energy, which could provide the ion range in Si around 50 mkm - **4,5** MeV per nucleon
- Ions from Ne up to Bi
- LET up to 100 MeV/(mg×cm^2)
- Intensity $1x10^5$ c^{-1}×cm^{-2}
- Irradiation zone 200*200 mm at least - *usual user' question is “when we can irradiate the whole device?”*
- Dedicated beam line due to specific requirements and sample preparation procedure.
- Casemate - “green area” - people around irradiation chamber
- Cocktail – quick switching between ion types.

What we need from cyclotron to fit applied science requirements?

- 24*7*365 ~ 7000 of beam time
- Simplicity of operation
- Time stability
- **Beam cocktail**
- Relatively cheap in use – beam time costs
- Factory approach/routinely use - "turning lathe“
- Economy factor: to use the existing stuff from the FLNR stock

What we are looking for:

The idea is to modernize/totally upgrade the old U200 machine

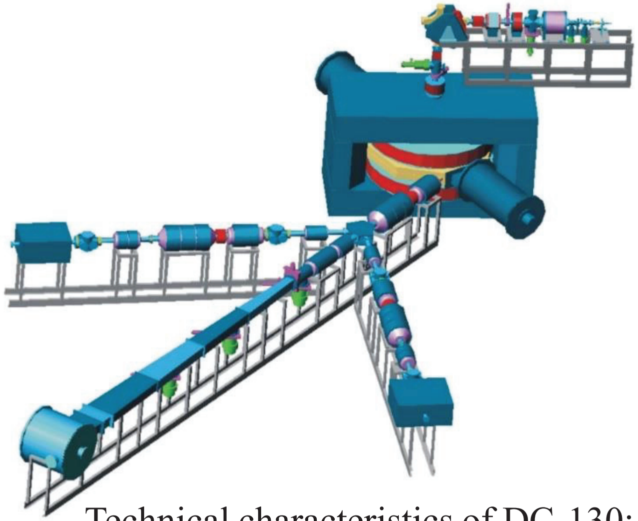
U-200 Cyclotron

In 1968 the U-200 was put into operation in the FLNR. In 2013 it was decommissioned, because of being outdated physically and technologically.

Parameters of U-200:

- Diameter of the magnet pole – 2 m
- Internal ion source of PIG type
- Accelerated ions – He – Ar
- The ion energy 3 -18 MeV/nucleon

The project of DC-130 cyclotron



Technical characteristics of DC-130:

- range of ions from O to Bi,
- external beam injection from ECR ion source,
- ion energies:

2 MeV/nucleon (A/Z=7.818 – 8.25)

4.5 MeV/nucleon (A/Z=5.212 - 5.5).

Physical installations:

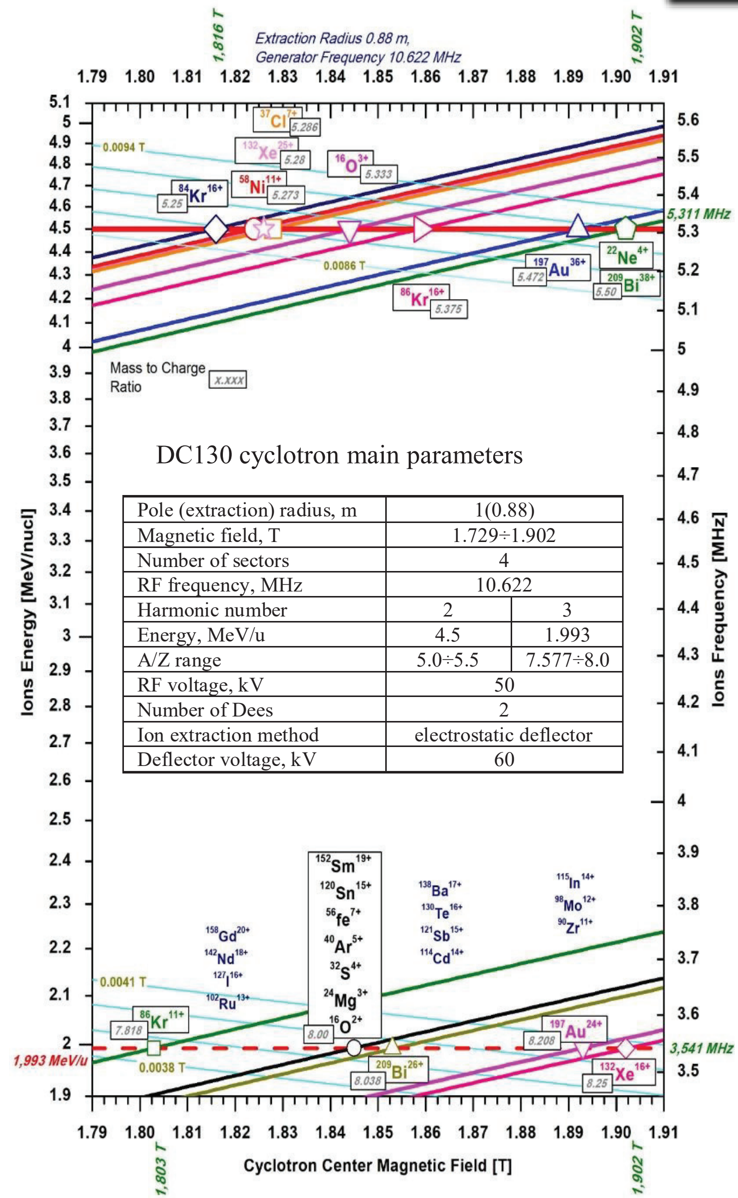
- installation for scientific and applied research,
- facility for irradiation of polymer films,
- installation for testing of electronic components.

If we will base the main magnet and acceleration system of DC130 on the U200 cyclotron, that now is out of operation, then…

The design should based on **existing** systems of IC100 and U200 cyclotrons and use only proven technical solutions of DC110.

DC130 cyclotron magnet main parameters

Size of the magnet, mm	5000×2100×3600
Diameter of the pole, mm	2000
Distance between the poles, mm	160
Number of the sectors pairs	4
Sector angular extent (spirality)	43° (0°)
Sector height, mm	45
Distance between the sectors (magnet aperture), mm	30
Distance between the sector and pole (for correcting coils), mm	20
Number of radial coils	6
Maximal power, kW	≈ 300

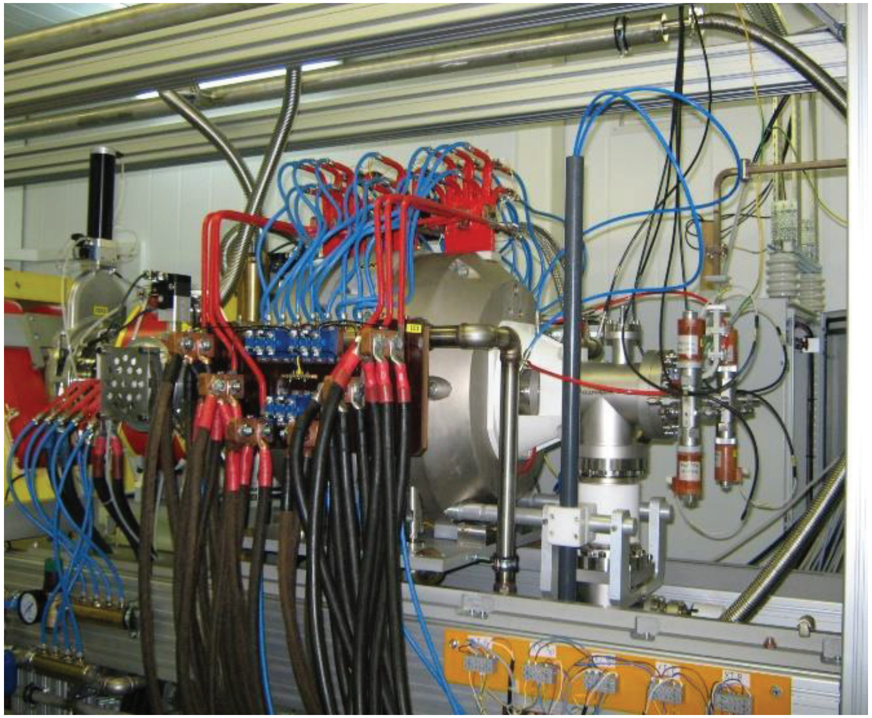


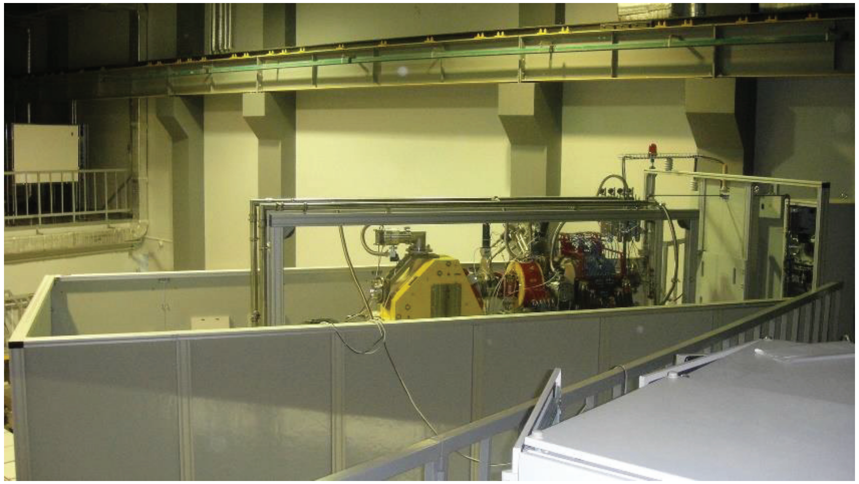
DC130 cyclotron main parameters

Pole (extraction) radius, m	1(0.88)	
Magnetic field, T	1.729÷1.902	
Number of sectors	4	
RF frequency, MHz	10.622	
Harmonic number	2	3
Energy, MeV/u	4.5	1.993
A/Z range	5.0÷5.5	7.577÷8.0
RF voltage, kV	50	
Number of Dees	2	
Ion extraction method	electrostatic deflector	
Deflector voltage, kV	60	

Ion source for DC130 project

The 18 GHz DECRIS-5 ion source was developed on the basis of sources of the DECRIS-4 (14 GHz) series with copper windings created at FLNR (JINR, Dubna) by intensifying the magnetic structure and changing to a new type of microwave oscillator.

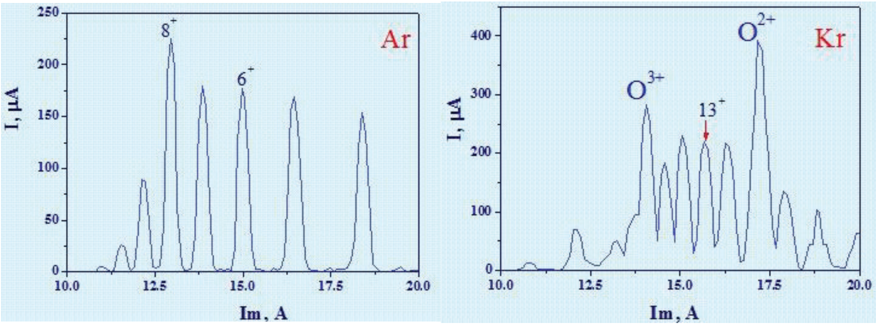




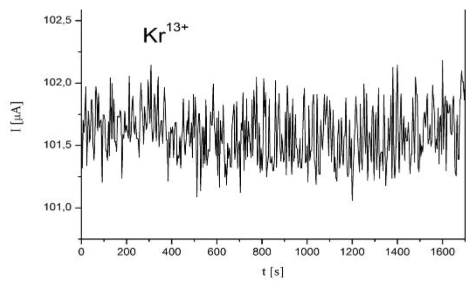
Assembled DECRIS-5 and axial injection system at the DC-110 cyclotron

Ion source for DC130 project

Ar and Kr spectra at the DC-110 cyclotron

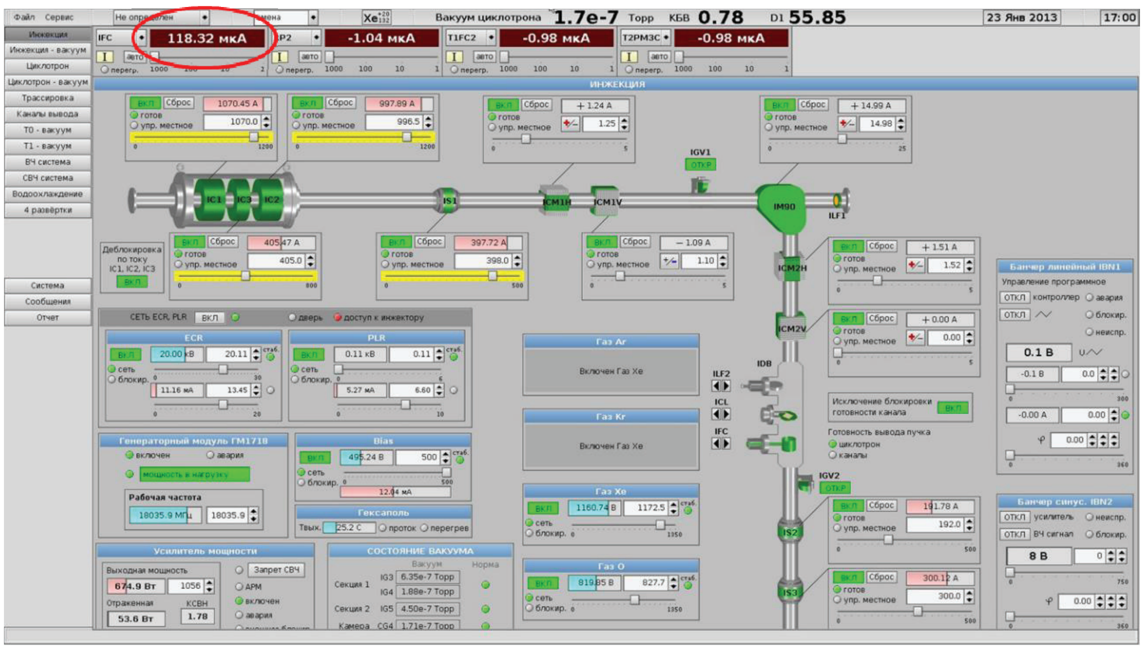


Kr beam stability



Beams of Ar, Kr, and Xe ions were produced from the source.

DC-110 control panel: Xe is online

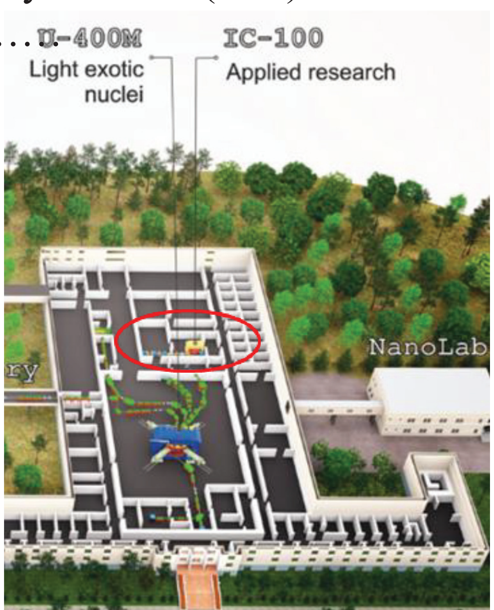


Results of the test

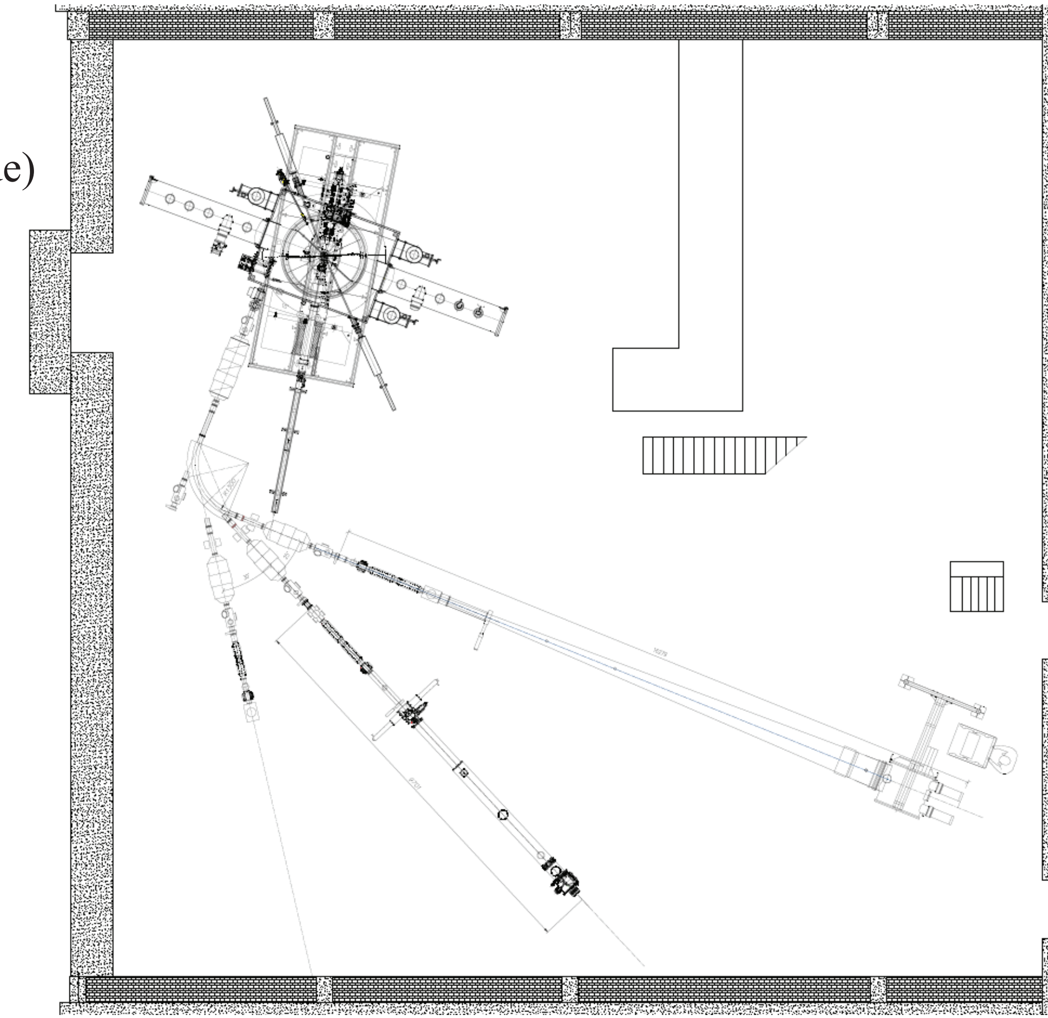
Ion	Current, (eμA)
Ar^{8+}	1200
Ar^{9+}	750
Ar^{11+}	300
Kr^{15+}	325
Kr^{17+}	230
Kr^{18+}	182
Kr^{19+}	120
Kr^{20+}	70
Xe^{20+}	220

DC130 prelaminar roadmap

What to do:
- Vacuum system + main chamber (new)
- Colling system (new)
- Control system (new)
- Axial injection (partly new)
- Beam extraction (new)
- Cyclotron magnetic structure (upgrade)
- RF system (upgrade)
- Magnet main coils (new)
- Beamlines (upgrade)
- Safety features (new)
- ....



The Design Study should be finished before the end of 2018.



DC130 prelaminar roadmap

2018 – Old stuff removing

2018 – Design Study

2018 – Building renovation

2019 – Equipment accumulation (purchasing)

2020 – Assembling

2020 – Start-and-adjustment works*

** We are optimists!* *(DC280 commissioning, U400M upgrade, U400 modernization)*

Conclusions

1. Flerov Laboratory of Nuclear Reaction begins the works under the conceptual design of the dedicated applied science facility based on the new DC130 cyclotron.
2. The main characteristics of the new DC 130 cyclotron are defined and fit main user requirements well.
3. The detailed project will be ready in December’2018.
4. If everything will go smoothly…… at end of 2020 the facility will be available for users.
5. We are still optimists! (DC280 commissioning, U400M upgrade, U400 modernization)

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Thank you !

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I'm just a soul whose intentions are good
Oh Lord, please don't let me be misunderstood