RECENT DEVELOPMENT OF ECR ION SOURCES AT FLNR

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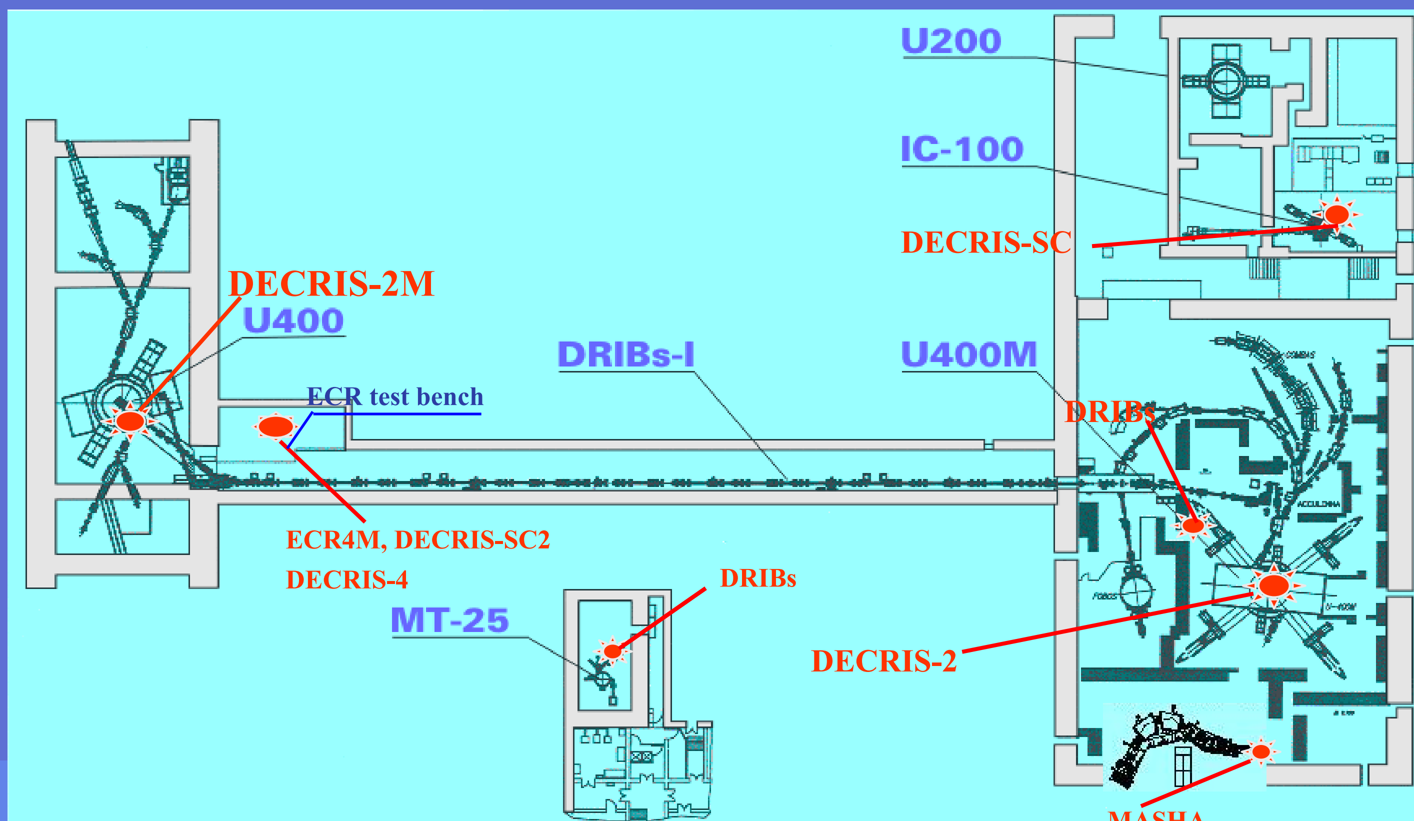
OVERVIEW OF THE FLNR (JINR) CYCLOTRONS WITH ECR ION SOURCES

U400 + DECRIS-2M

U400M + DECRIS-2

CI-100 + DECRIS-SC



DECRIS - Dubna ECR Ion Sources

DECRIS-2, DECRIS-2m, DECRIS-3, DECRIS-4, DECRIS-5 are “room temperature” ECR ion sources. The axial magnetic field is created by the coils with independent power supplies. The radial magnetic field is created by permanent magnet hexapole, made from NdFeB.

DECRIS-SC – axial magnetic field is created by superconducting solenoids

DECRIS-2 – U-400M cyclotron – 1995
ECR4M – U-400 cyclotron – 1996 (collaboration FLNR – GANIL (France))
(modernization 2011-2012)

DECRIS-3 – TESLA Accelerator Installation (Belgrade) -1997

DECRIS-2m – BIONT Inc. (Bratislava) – 2003

DECRIS-SC – CI-100 cyclotron - 2004

DECRIS-3 - DC-60 accelerator complex (Astana, Kazakhstan) – 2006

DECRIS-4 – in operation at the test bench - 2005

DECRIS-2m –DC-72 cyclotron (Bratislava) – tested – 2007

DECRIS-SC2 – new ion source for U-400M – tested – *2011*

DECRIS-5 – for DC-110 cyclotron – tested – 2012

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- ECR4M – modernization of the source for U-400R project
- DECRIS-SC2 – new ion source for U-400M
- DECRIS-5 – ion source for DC-110 cyclotron
- Summary

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ECR4M ion source

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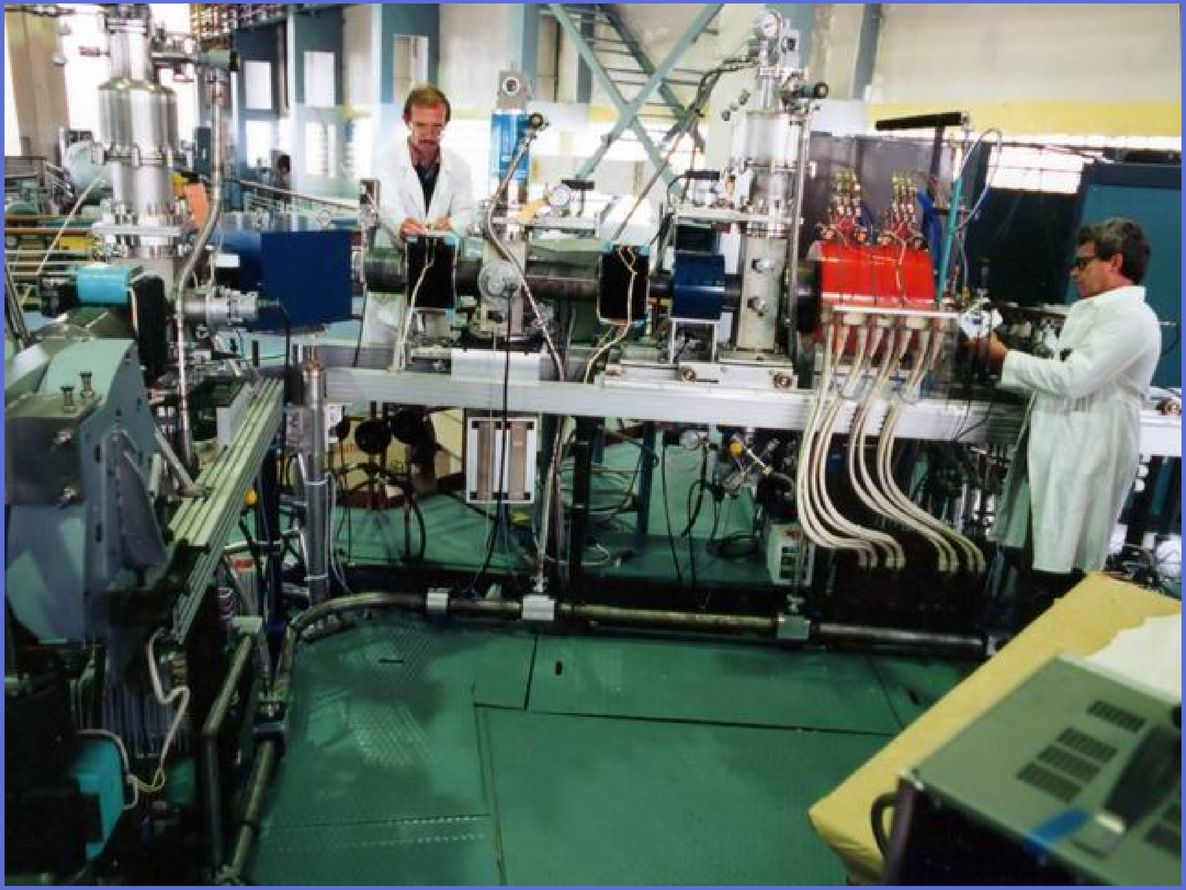
The ECR4M source and the axial injection system were commissioned in 1996.
First accelerated Ar beam – November 1996.
First accelerated ^{48}Ca beam – November 1997.



Since 1997 about 66% of the total beam time were used for acceleration $^{48}Ca^{5+}$ ions for synthesis of new superheavy elements.

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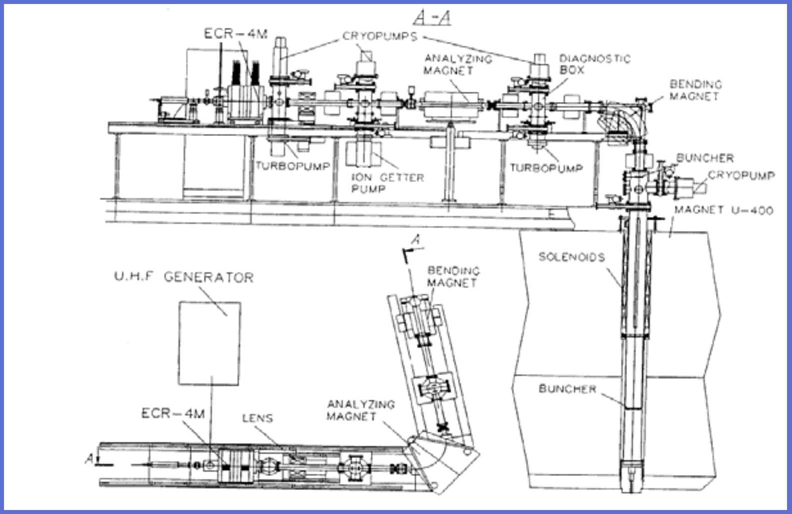
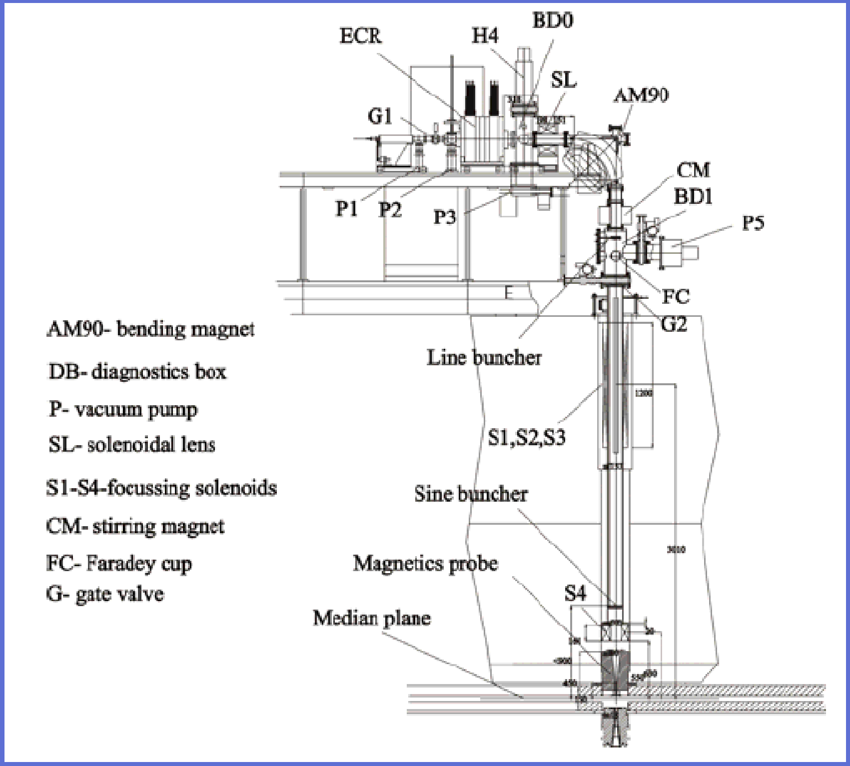
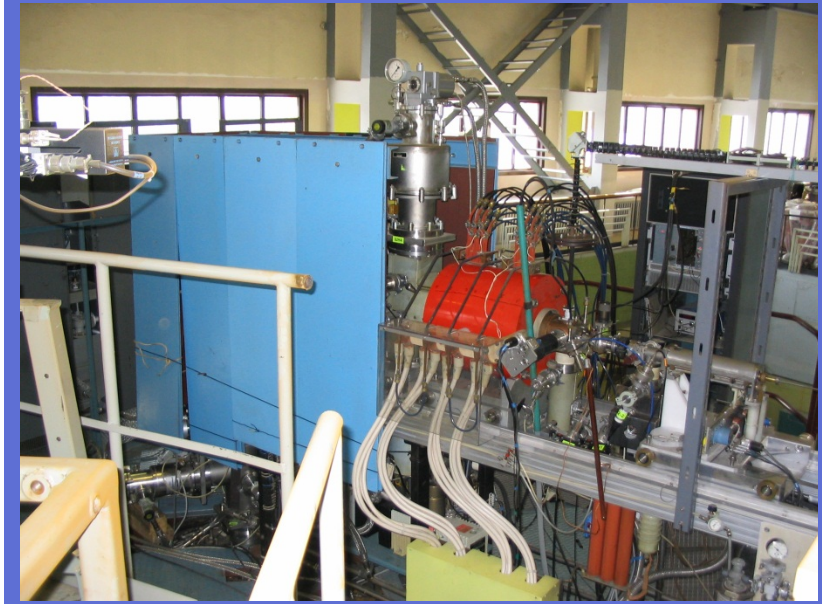
2002

Modernization of the U400 axial injection.

The intensity of ^{48}Ca ion beam was increased from 0.9 to 1.4 pμA.







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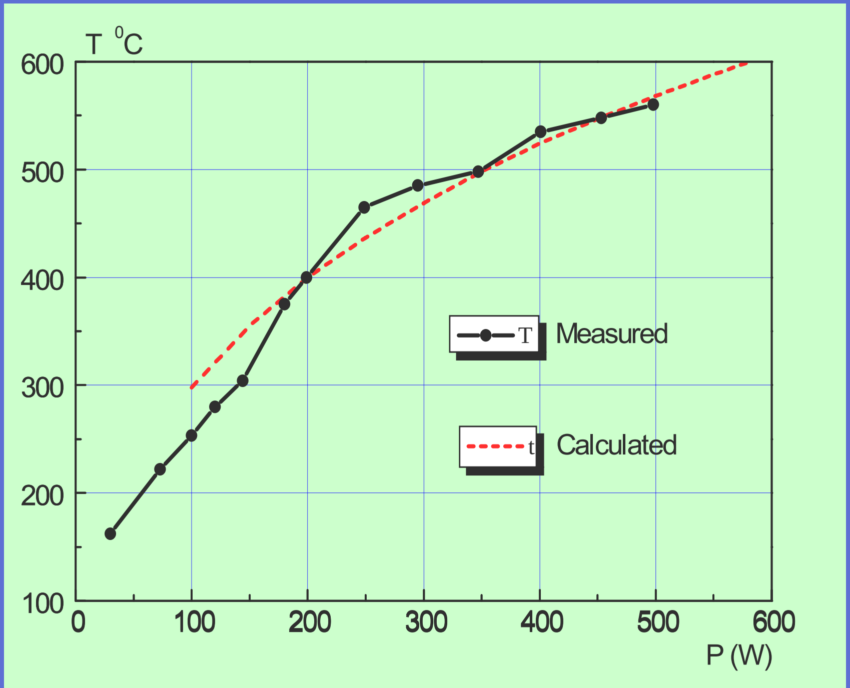
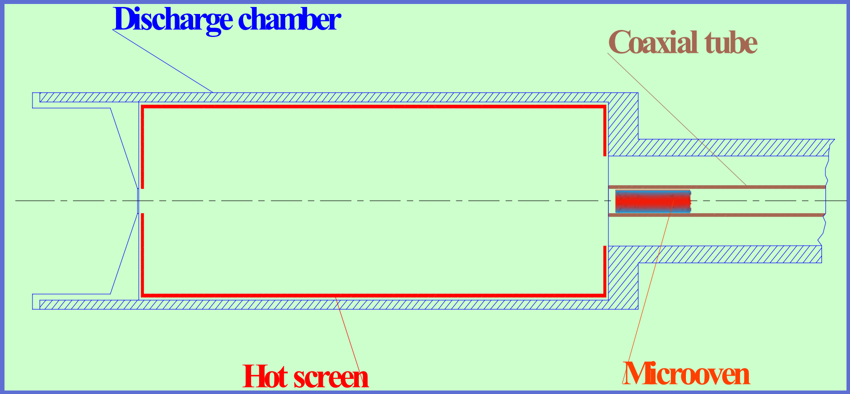
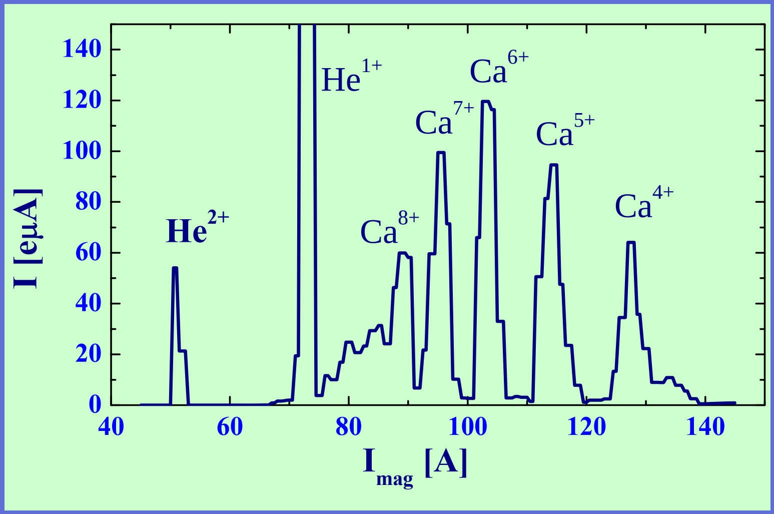
Production of the ^{48}Ca ion beam







The screen is heated by microwaves and plasma electrons.

Ca spectrum with hot screen

760 samples of metallic ^{48}Ca were used since November 1997 till September 2012

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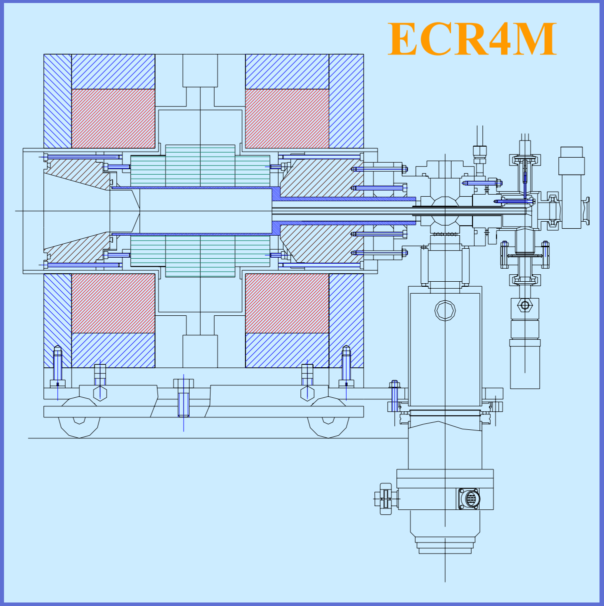
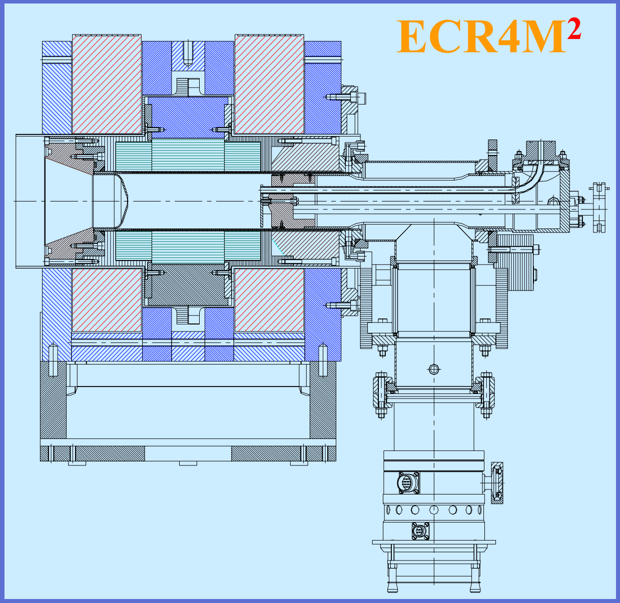
Efficiency of the beam transmission from the ion source to the target at U400.

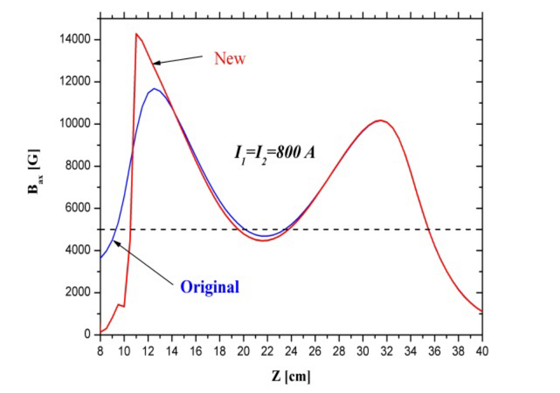
<table>
<tr><th>Measurement point</th><th colspan="2">Beam intensity</th><th>Ion</th><th colspan="5">Transmission</th></tr>
<tr><td>ECR source, after separation</td><td>$1\cdot10^{14}$ pps</td><td>84 μAe</td><td>$^{48}Ca^{5+}$</td><td rowspan="2">32%</td><td></td><td></td><td></td><td rowspan="5">8.5%</td></tr>
<tr><td>Cyclotron center</td><td>$3.5\cdot10^{13}$ pps</td><td>27 μAe</td><td>$^{48}Ca^{5+}$</td><td rowspan="2">81%</td><td></td><td></td></tr>
<tr><td>Radius of beam extraction</td><td>$2.8\cdot10^{13}$ pps</td><td>22 μAe</td><td>$^{48}Ca^{5+}$</td><td></td><td rowspan="2">40%</td><td></td></tr>
<tr><td>Extracted beam (charge exchange method)</td><td>$9.7\cdot10^{12}$ pps</td><td>28 μAe</td><td>$^{48}Ca^{18+}$</td><td></td><td></td><td rowspan="2">82%</td></tr>
<tr><td>Target</td><td>$8\cdot10^{12}$ pps</td><td>23 μAe</td><td>$^{48}Ca^{18+}$</td><td></td><td></td><td></td></tr>
<tr><td>Measurement point</td><td colspan="2">Beam intensity</td><td>Ion</td><td colspan="5">Transmission</td></tr>
</table>

Modernization of the ECR4M for U400R project

Higher magnetic field in the injection region. New hexapole.
The increase of the discharge chamber Ø from 64 to 74 mm
Possibility to install resistively heated thermal screen
Direct UHF injection







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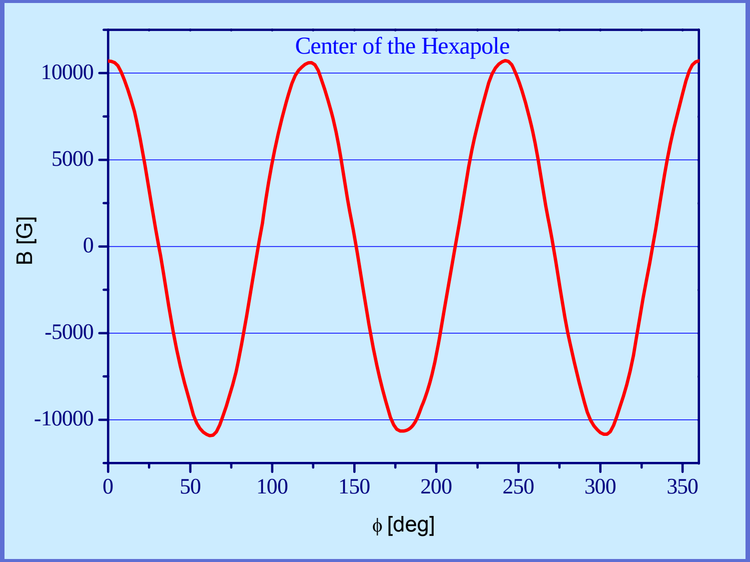
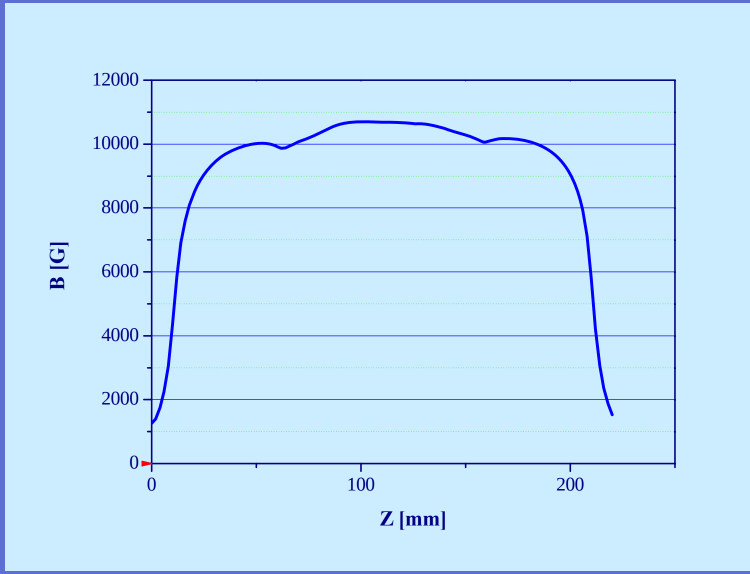
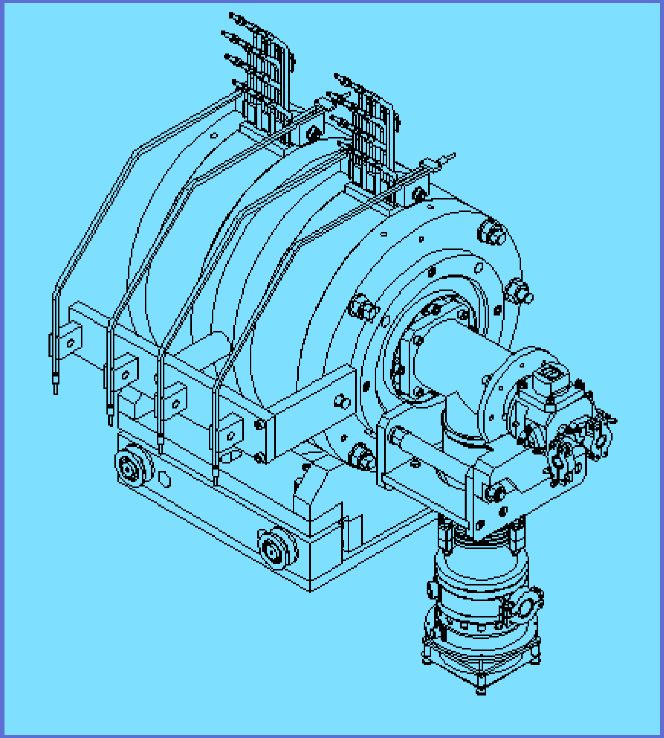
Radial magnetic field distribution





ECR-4M [2]



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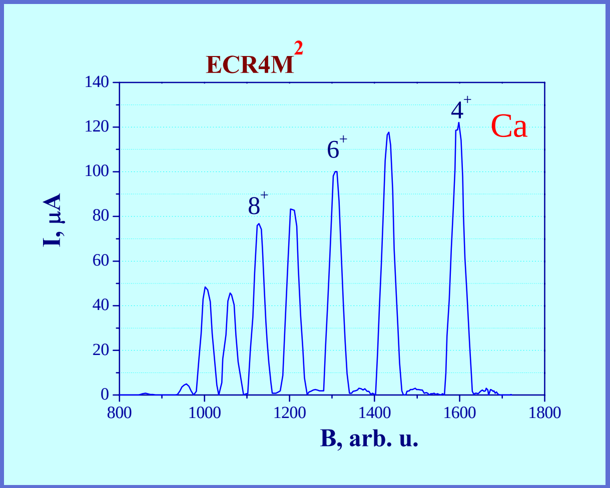
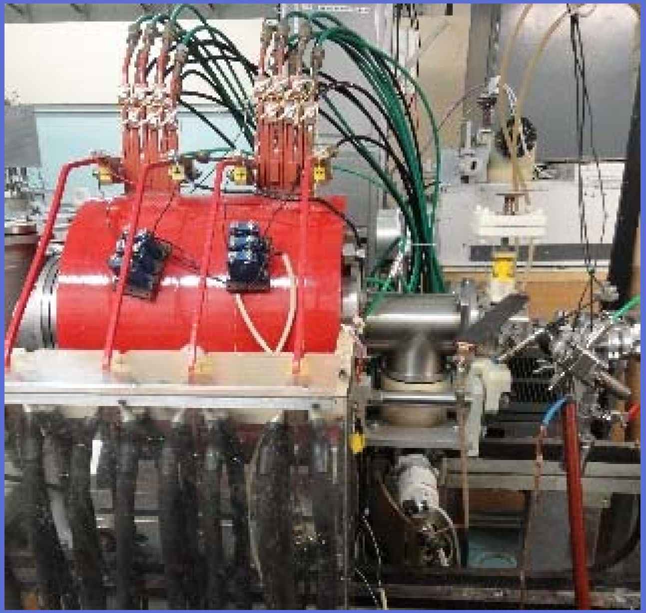
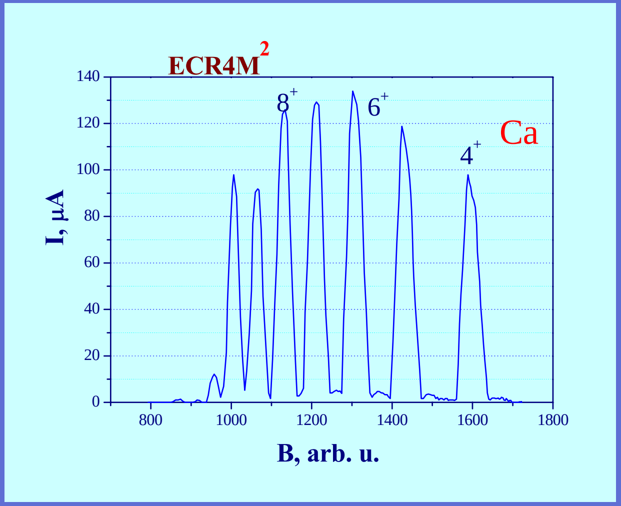
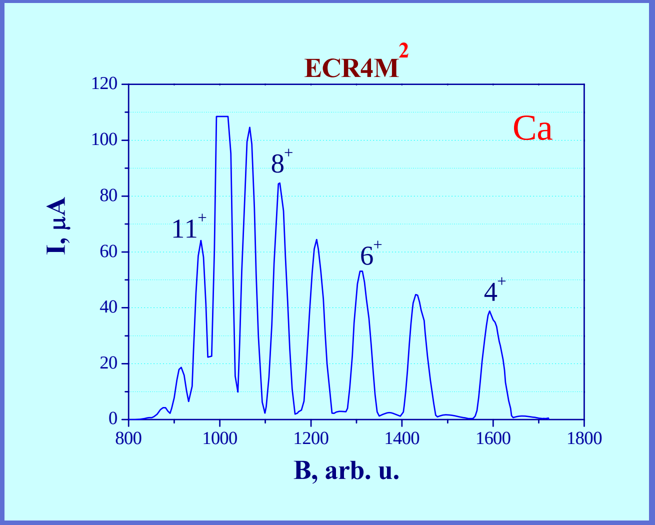
Production of Ca beam from ECR4M^2 at the test bench









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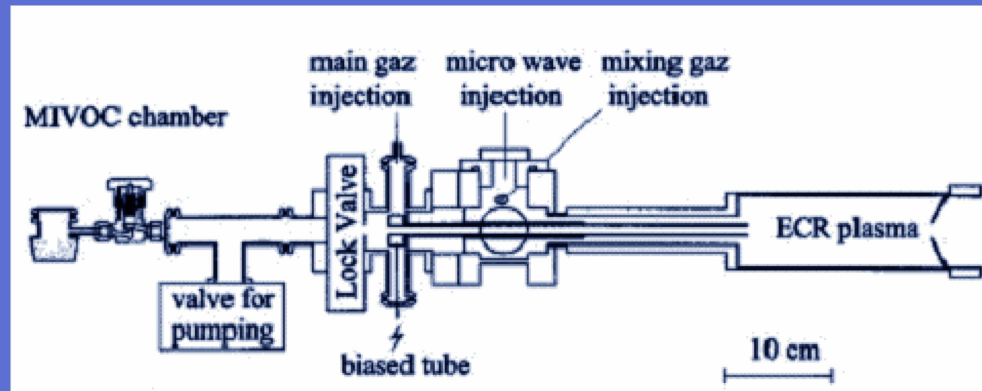
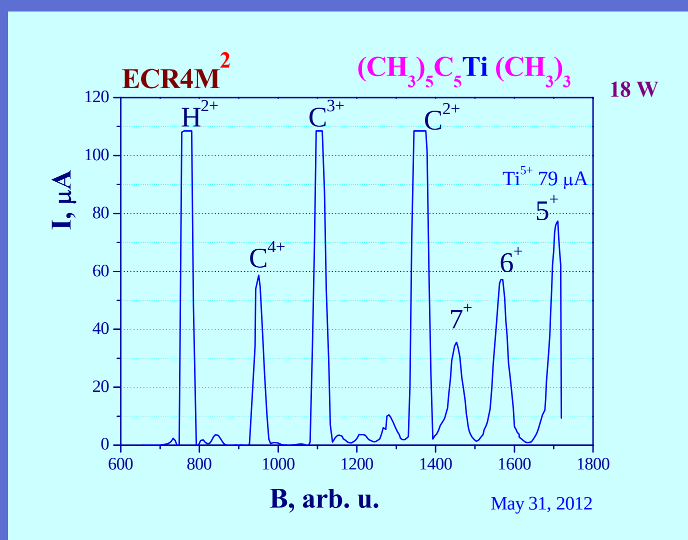
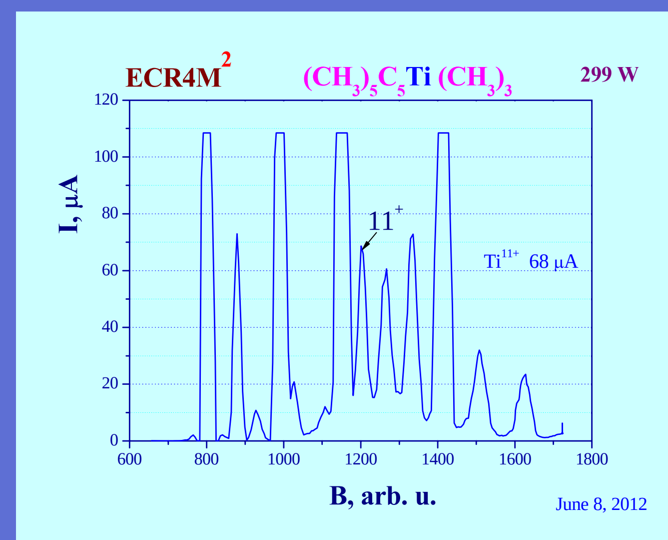
Development of Ti beam using MIVOC method with ECR4M^2

(Metal Ions from VOlatile Compounds)



The goal of experiments: production of intense ^{50}Ti ion beam for research on synthesis of superheavy elements.





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DECRIS –SC2 ion source for U - 400M

Motivation for development of DECRIS-SC2

The U-400M was equipped with DECRIS-2 source in 1995.

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TYPICAL ION CURENTS (eμA) of DECRIS-2

Ion	Li	B	O	Ar	Kr	Xe
2+	300					
3+	70	200				
4+		80				
5+			660			
6+			450			
7+			40			
8+				600		
9+				340	100	
18+						45
20+						40

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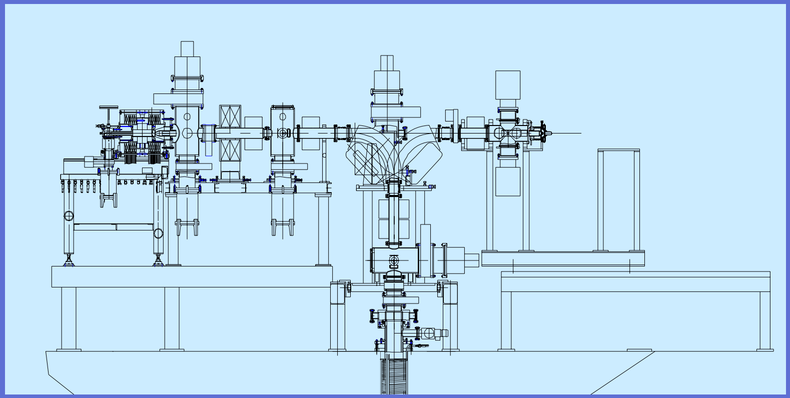
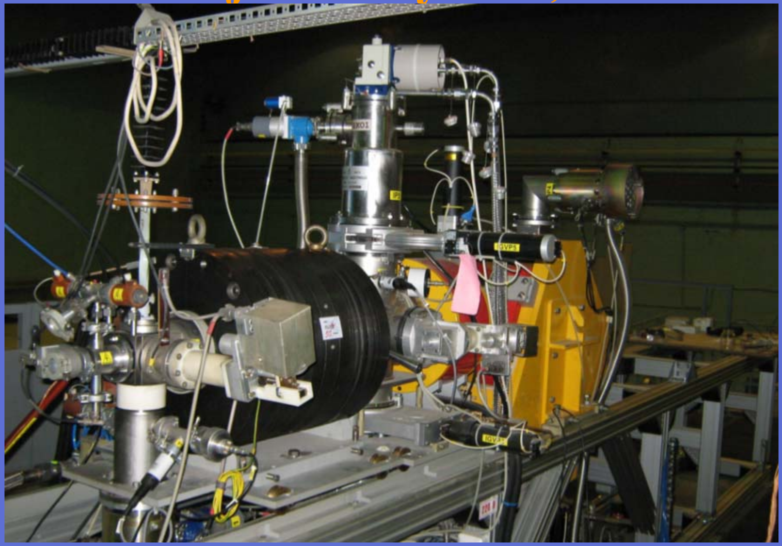
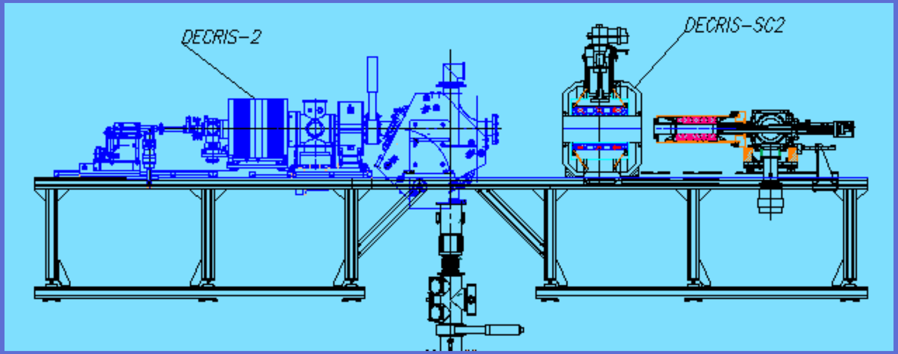
Modernization of the U-400M axial injection system, 2007







Since 2008 the cyclotron operates in two modes:

high-energy ion beams (A/Z = 3 – 5)

Li, B, C, N, O, Ne, S ions with energies of 35 -55 MeV/n for generation secondary beams

low-energy ion beams (A/Z = 8 – 10)

Ne, Fe, Kr, Xe, Bi ions with the energies of 5 – 9 Mev/n for experiments in nuclear physics (SHE) and material physics

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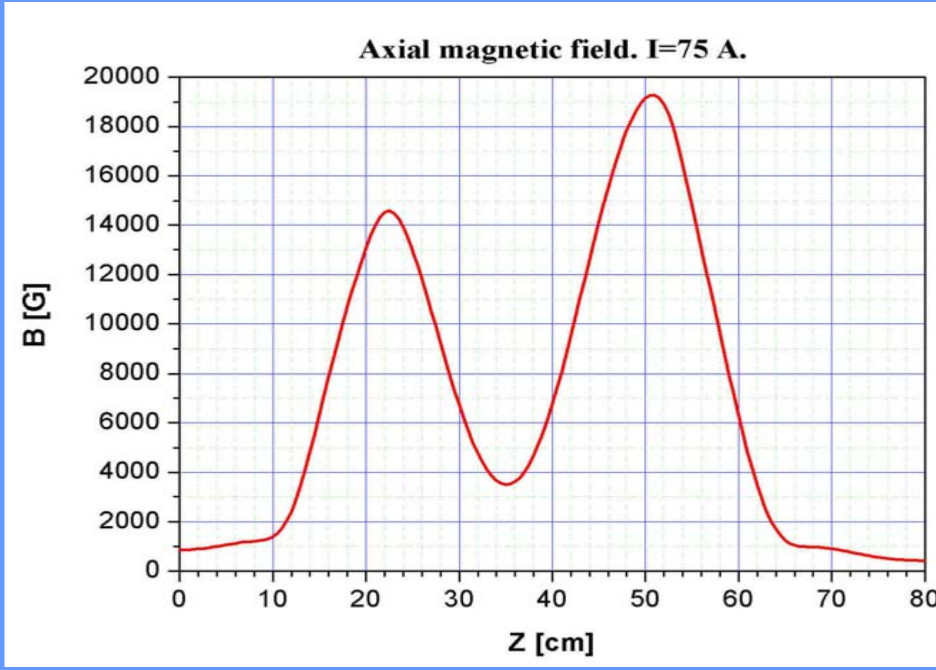
The main goal of the DECRIS-SC2 source is the production of more intense beams of ions in the mass range heavier than Ar.

Table of the main parameters.

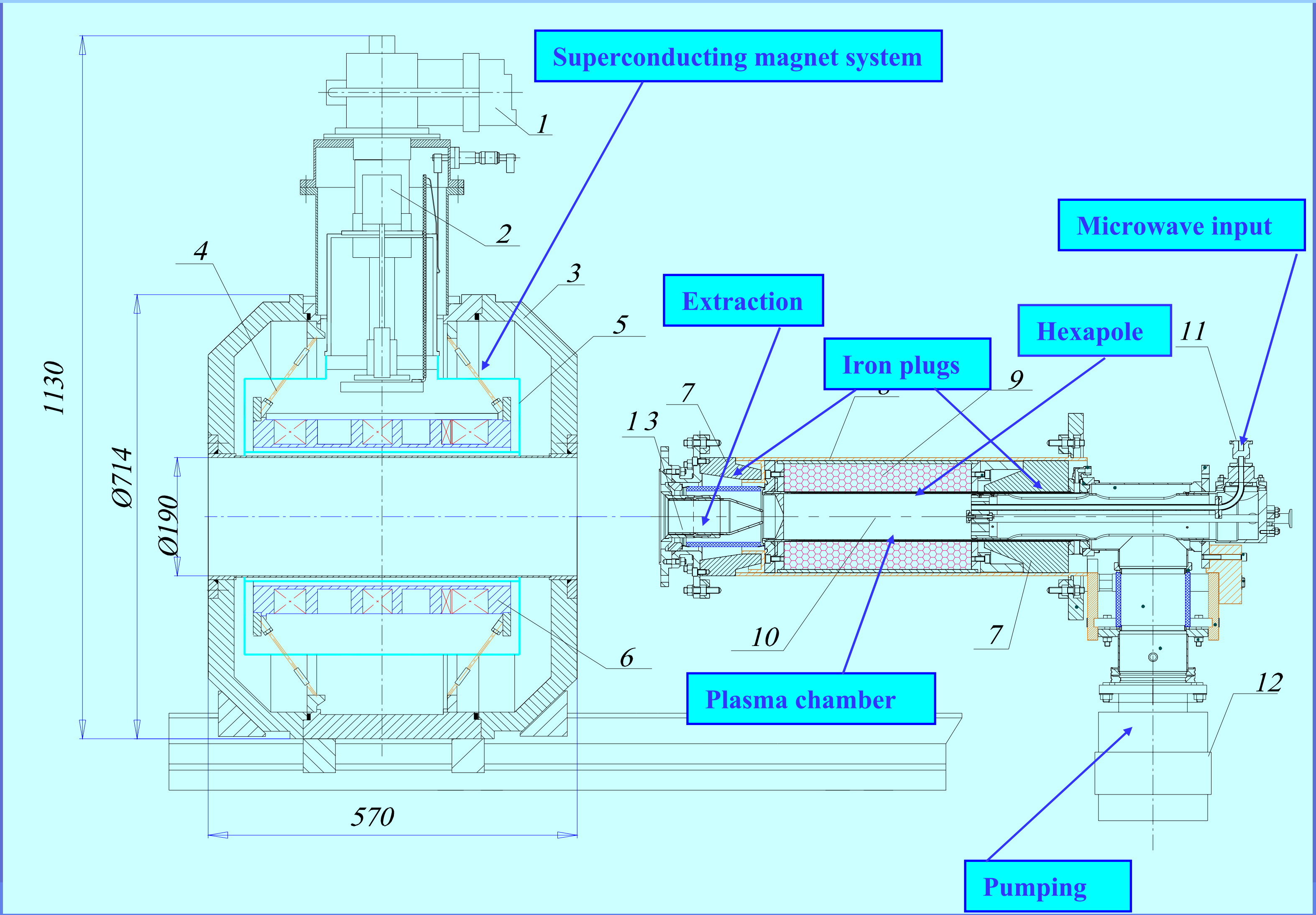
Operating frequency	14 GHz
Axial magnetic field (injection/extraction)	1.9 / 1.4 T
Radial magnetic field	1,1 T
Hexapole material and structure	NdFeB, 24 pieces
Plasma chamber inner diameter	74 mm
Plasma chamber diameter	300 mm
Extraction voltage	up to 30 kV



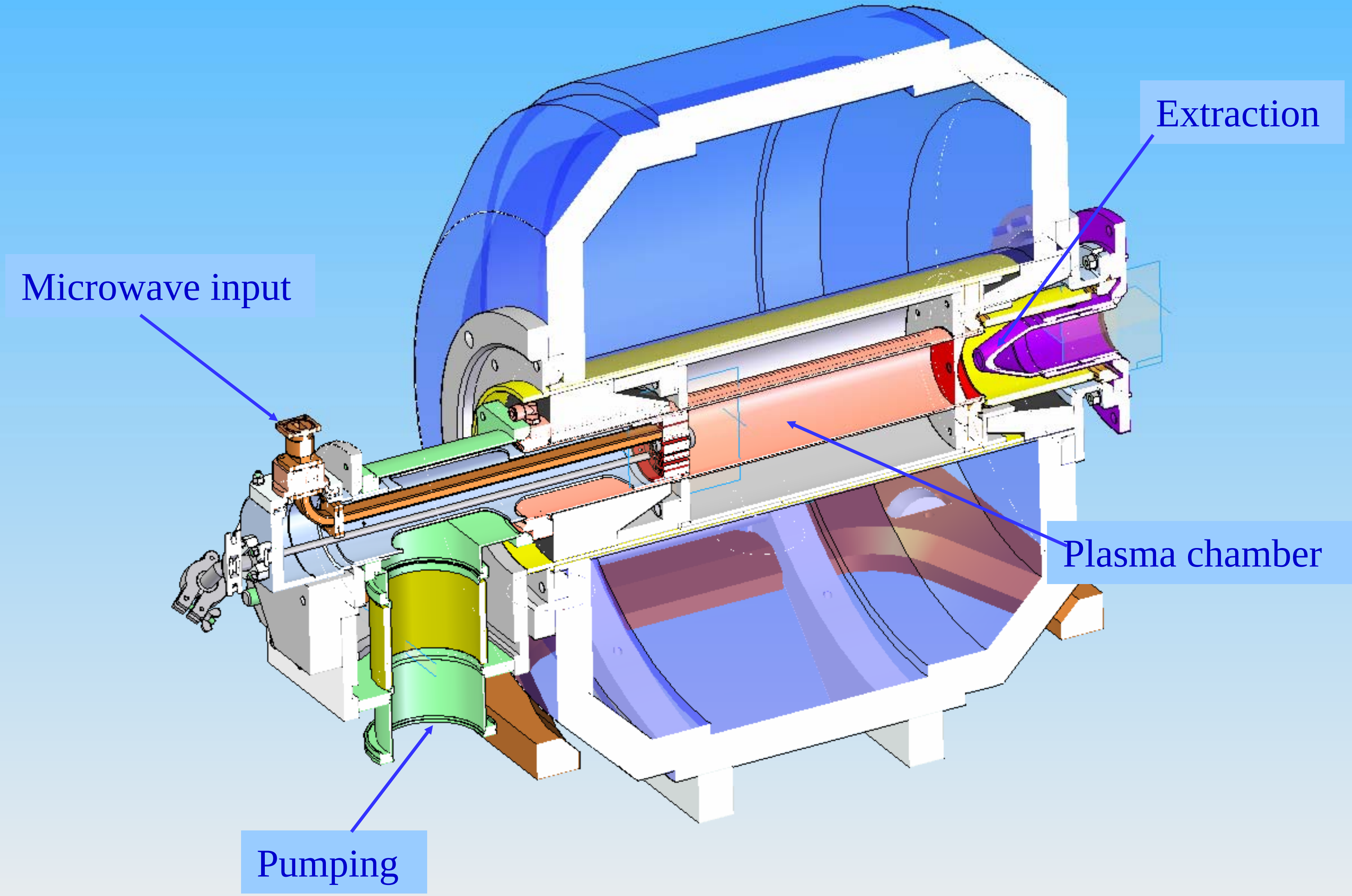
The design of DECRIS-SC2 is based on the experience of creation and exploitation of DECRIS-SC source for CI-100 cyclotron.

DECRIS-SC2

DECRIS-SC2 is the compact version of the "liquid He free" superconducting ion source. The axial magnetic field is created by superconducting coils and iron plugs. The radial magnetic field is formed by permanent magnet hexapole.



DECRIS-SC2



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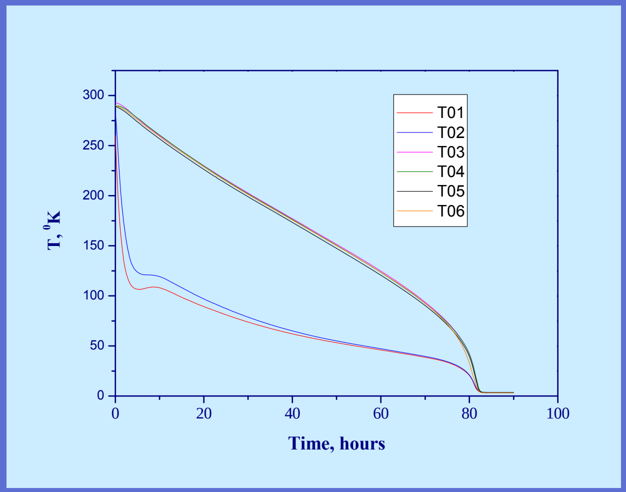
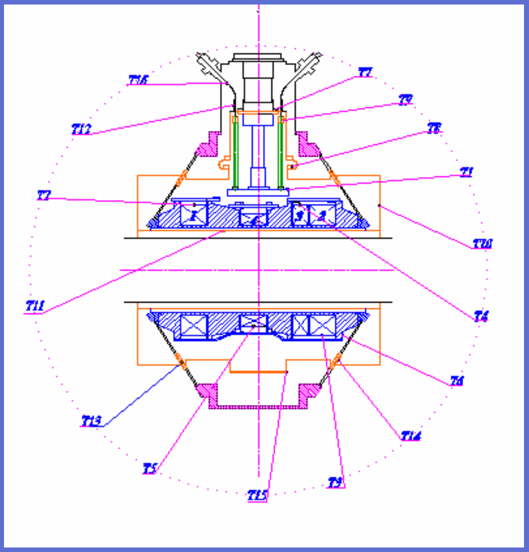
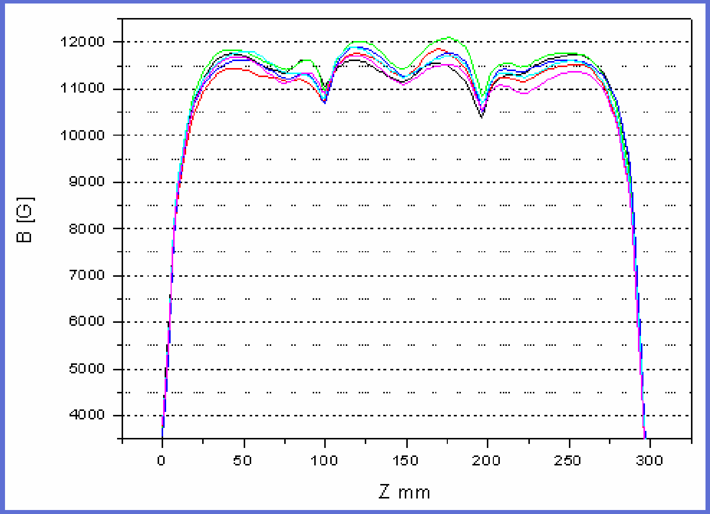
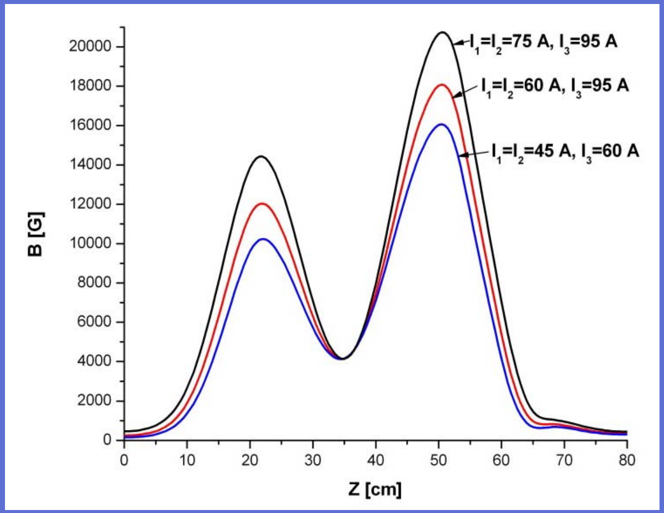
Tests of the superconducting magnet system

Cooling









Radial magnetic field distribution

Axial magnetic field distribution

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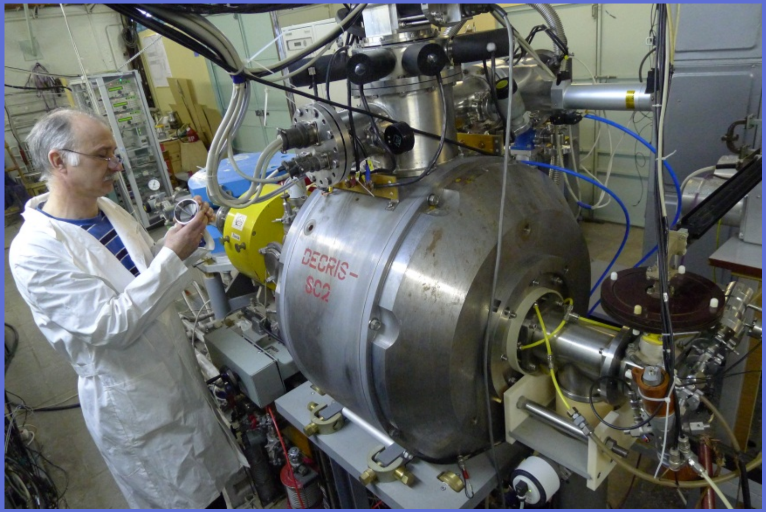
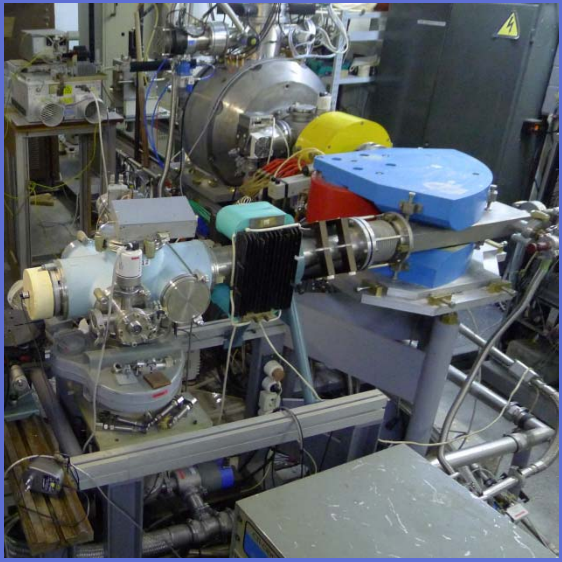
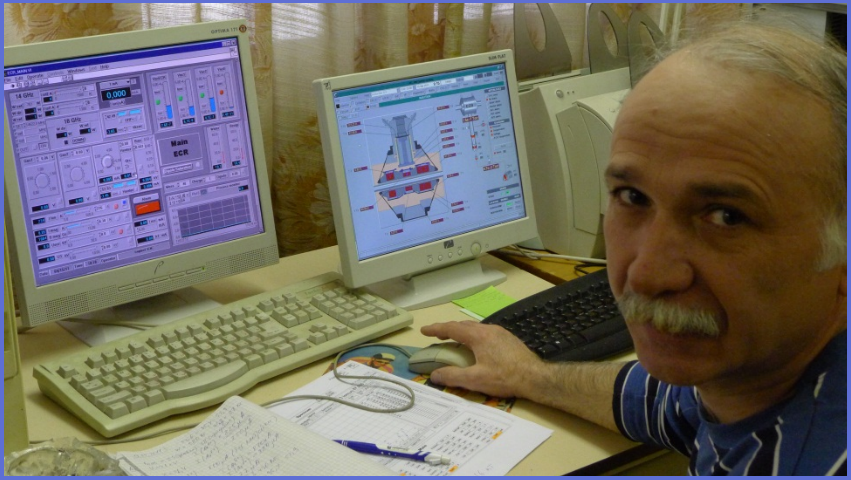
DECRIS-SC2 at the ECR test bench





Power supply and control system of SC magnet

Operator console



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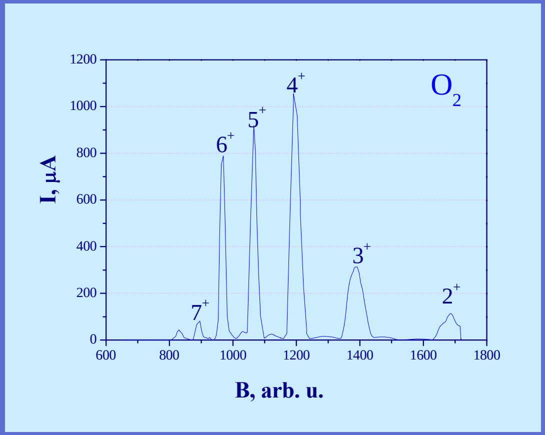
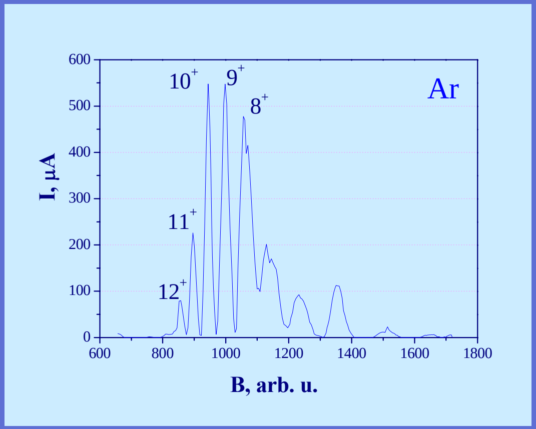
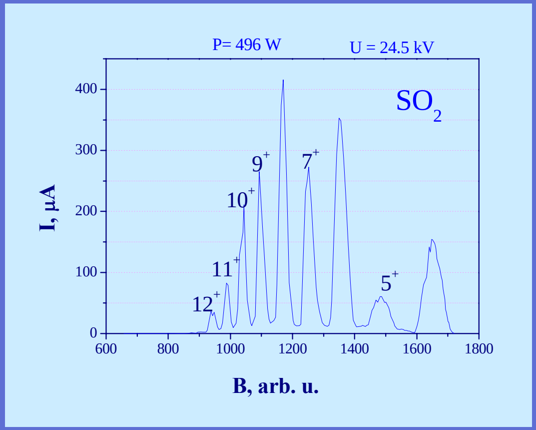
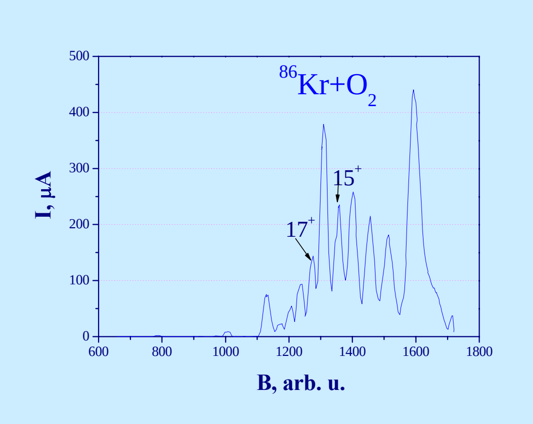
DECRIS-SC2: results of the test









Ion	Current, (eμA)
O^{5+}	920
O^{6+}	820
S^{9+}	265
S^{11+}	90
Ar^{8+}	880
Ar^{9+}	680
Ar^{11+}	250
Ar^{12+}	120
Kr^{15+}	250
Kr^{17+}	150
Xe^{30+}	~ 1

Future plans: to test the source with 18 GHz frequency

DECRIS-5 source

for DC-110 cyclotron complex

The complex is intended for industrial production of track membrane ("nuclear filters").

Fixed energy 2.5 Mev/n

Ions	$^{40}Ar^{6+}$	$^{86}Kr^{13+}$	$^{132}Xe^{20+}$
A/Z	6.667	6.615	6.6
Energy	2.52	2.52	2.52
I (from ECR) eμA	190	210	150
I (accelerated) eμA	12	13	10

The source parameters are determined by

required intensity of $^{132}Xe^{20+}$ ion beam (≥ 150 μA)

Table of the main parameters of DECRIS-5.

Operating frequency	18 GHz
Axial magnetic field	2.2/1.35 T
Radial magnetic field	1.15 T
Hexapol structure	NdFeB, 36 pieces
Plasma chamber inner diameter	80 mm
Pllasma chamber length	300 mm
Extraction voltage	20 kV

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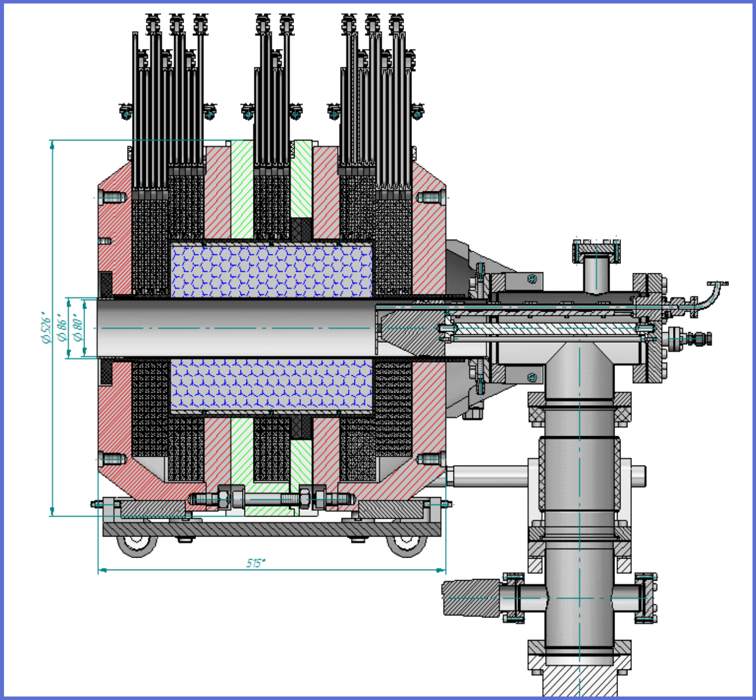
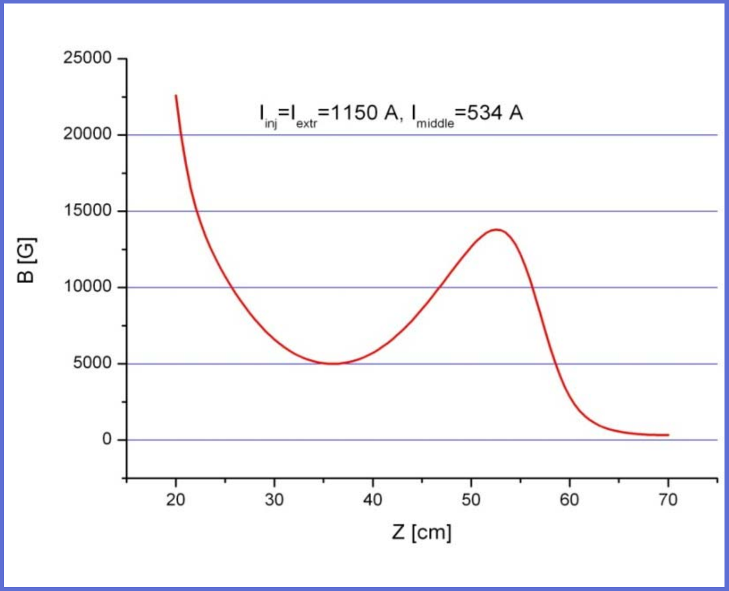
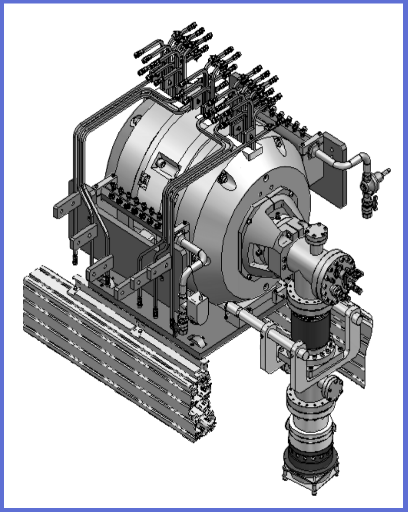
DECRIS-5

magnetic structure

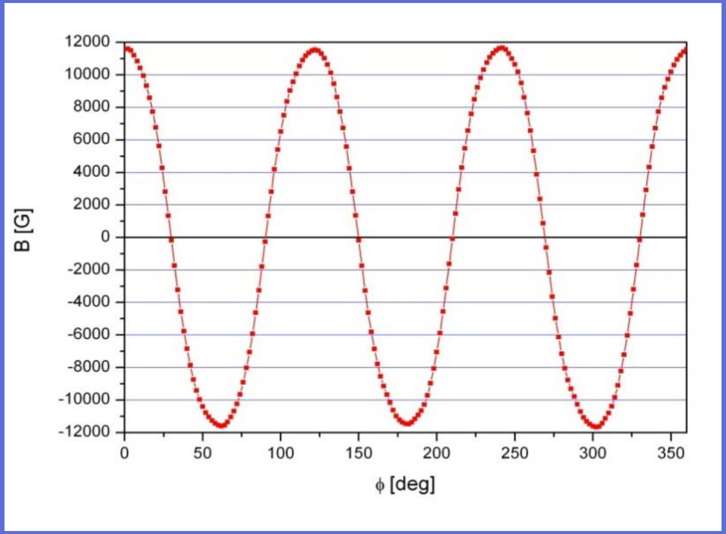


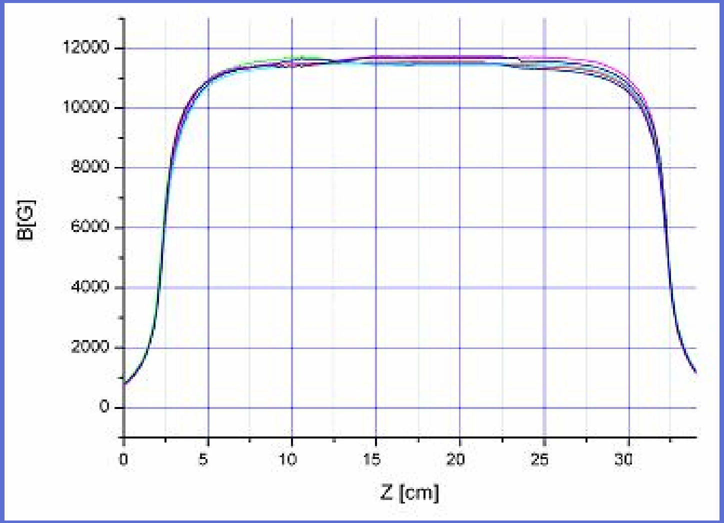




DECRIS-5

Radial magnetic field distribution

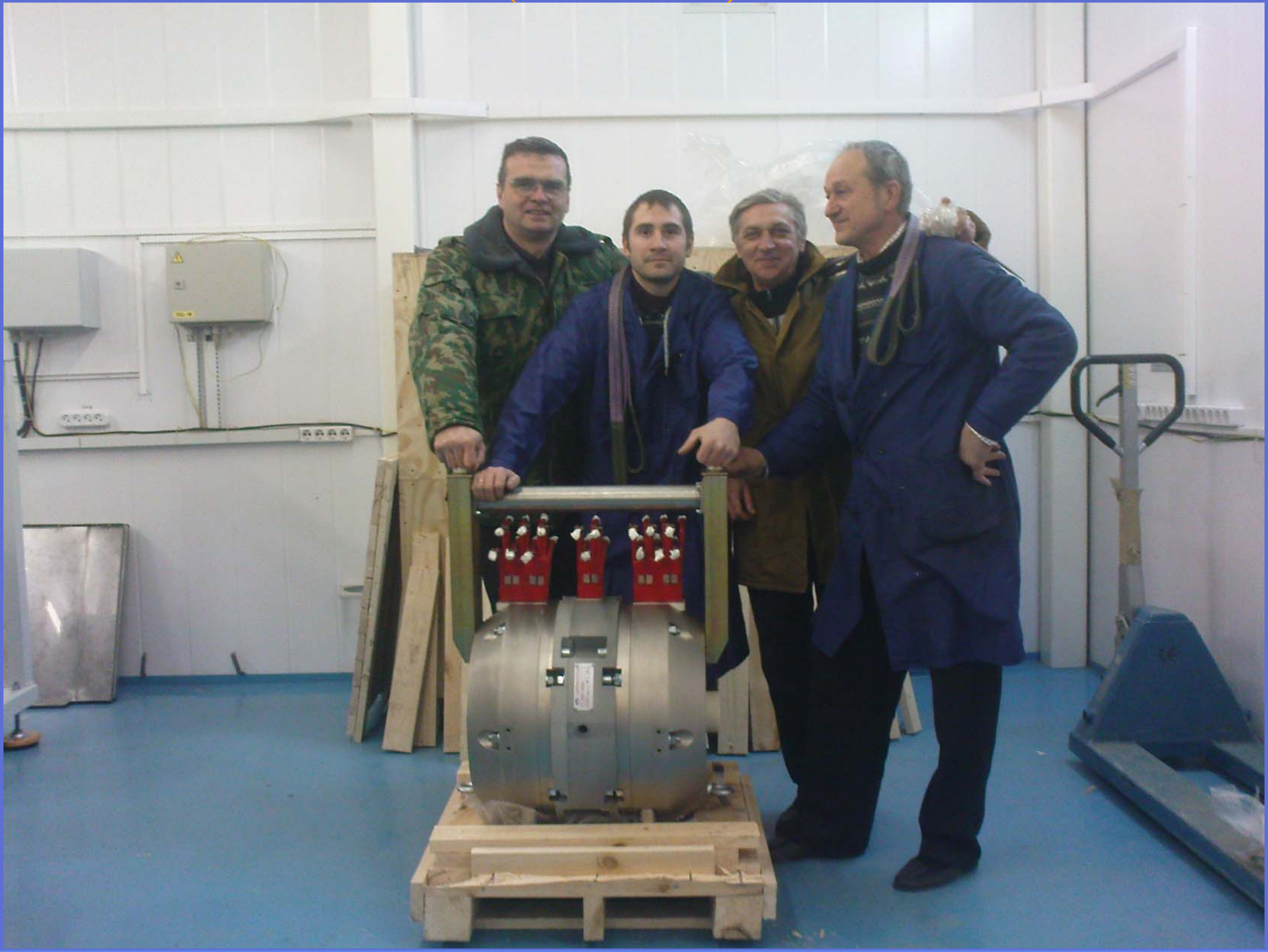




Hexapole design

DECRIS-5

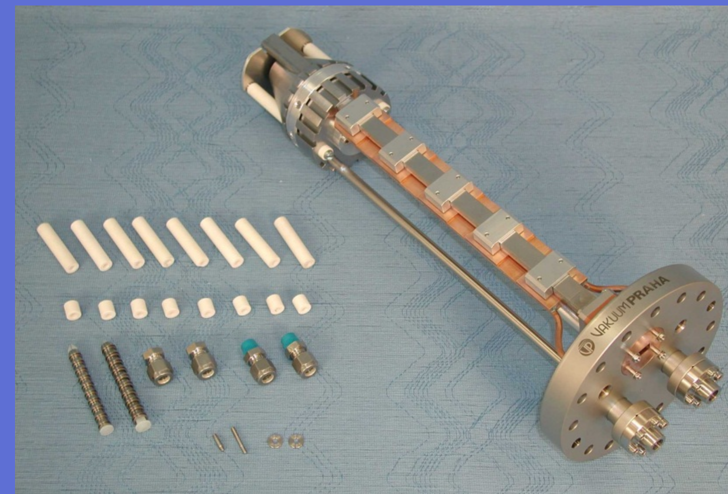
Magnetic structure just arrived from NIIEFA (18.02.2011)



Components

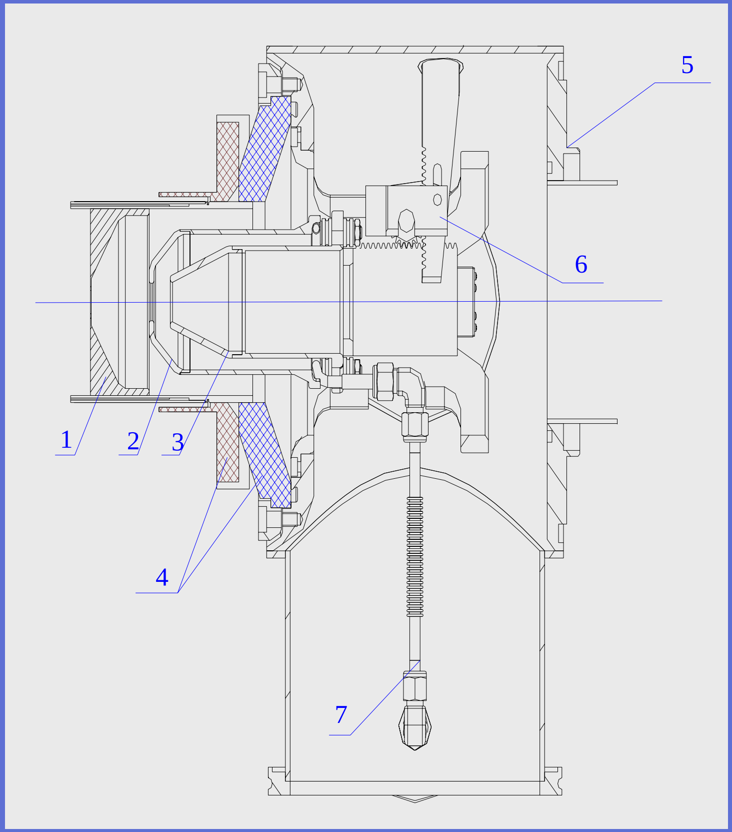
Plasma chamber

Shorting plug



Injection box

Plasma electrode



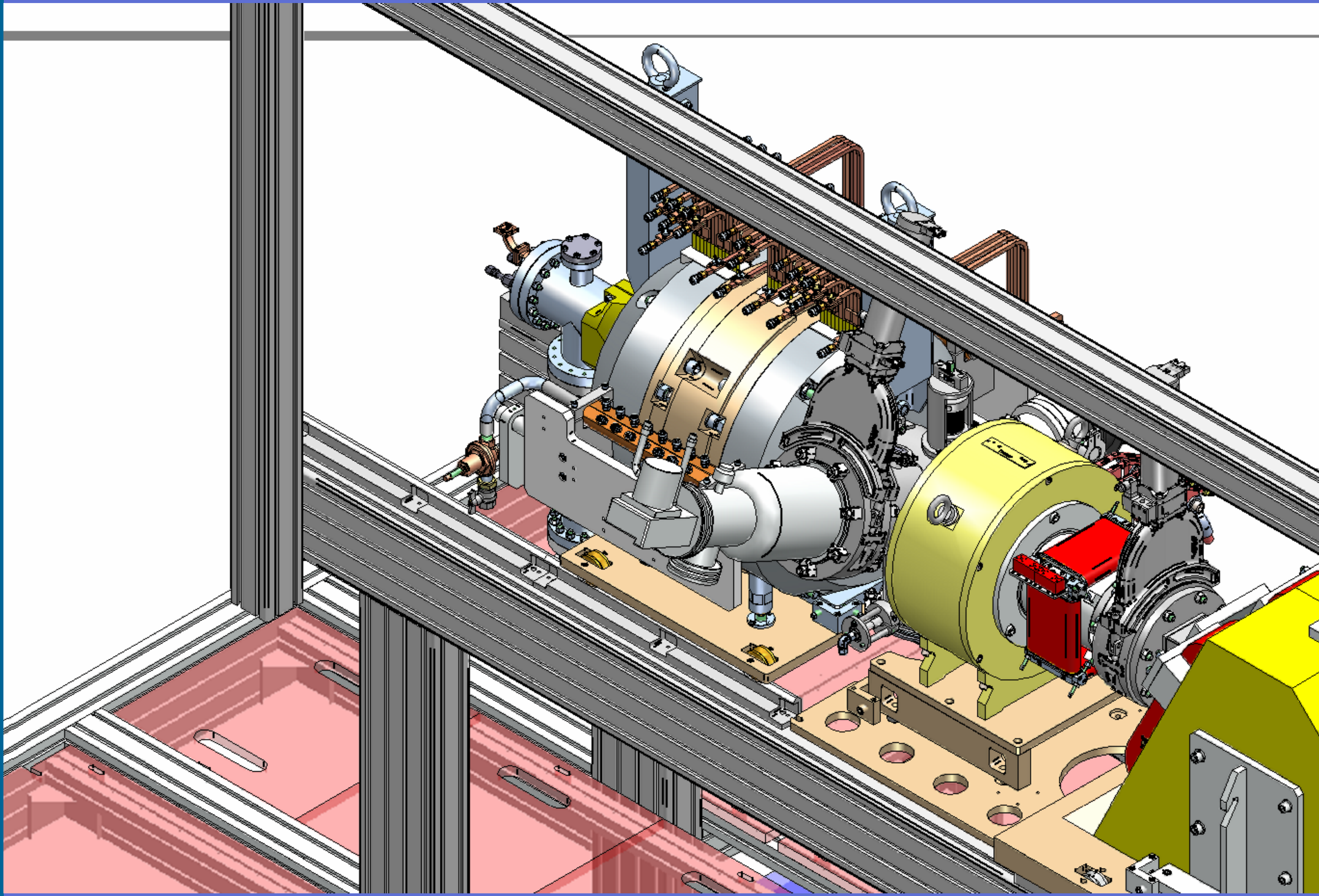
DECRIS-5

Extraction system

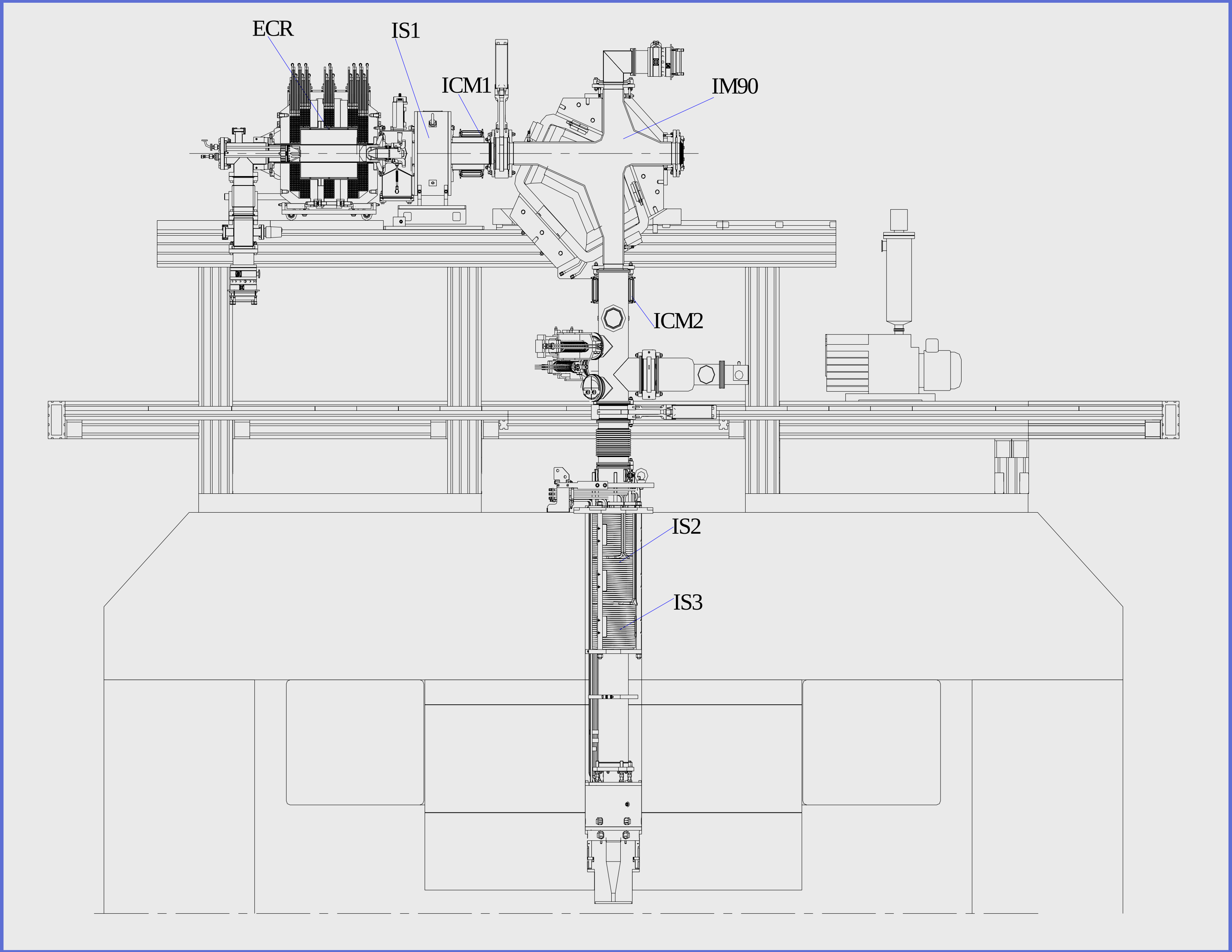
1- plasma electrode; 2 – puller;
3 – grounded electrode;
4 – insulators;
5 – extraction box;
6 – motion drive;
7 – cooling.

DECRIS-5

General view of the source



DECRIS-5 and axial injection system of the DC-110 cyclotron



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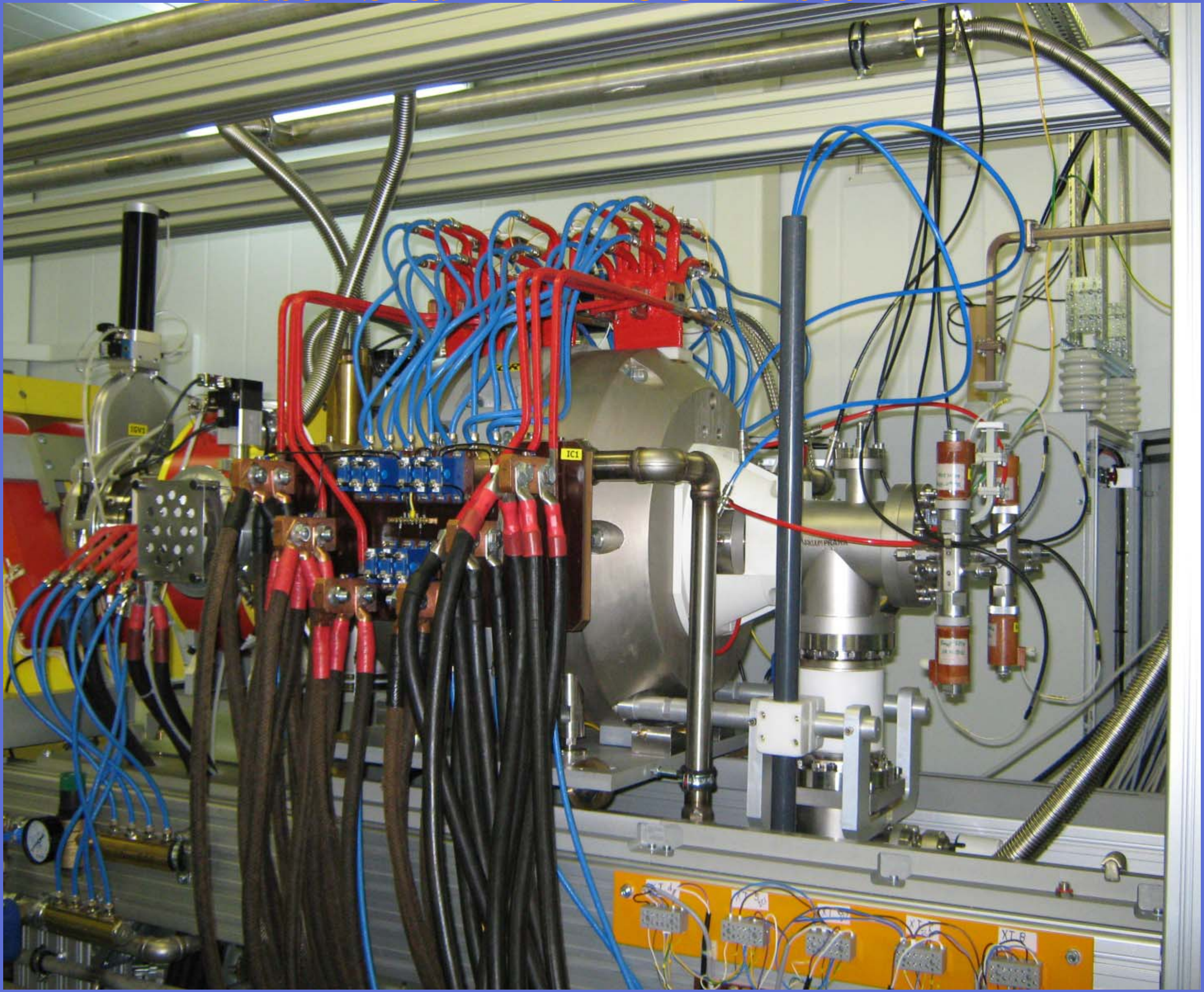
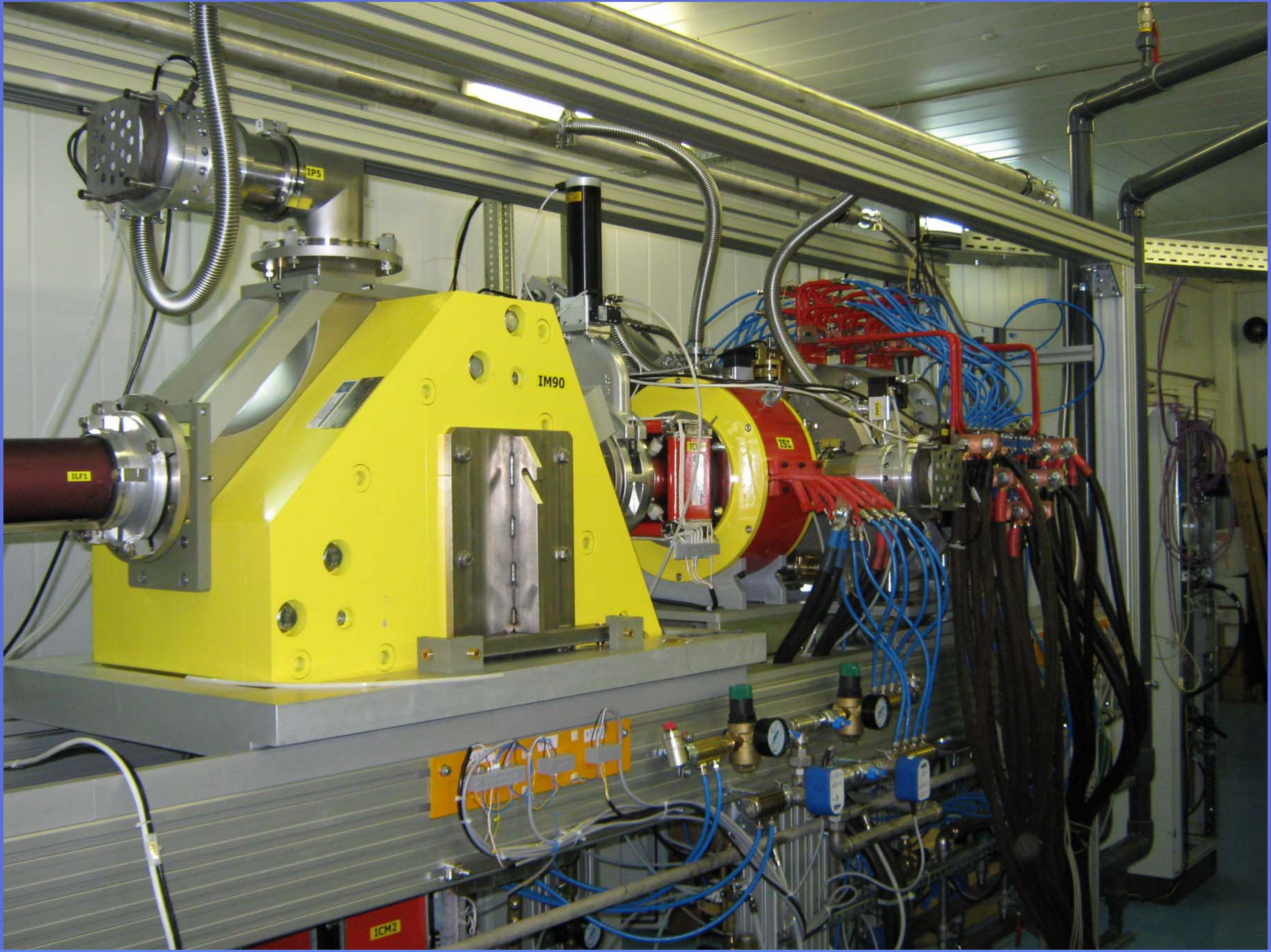
The assembled DECRIS-5 ion source



Part of the axial injection system



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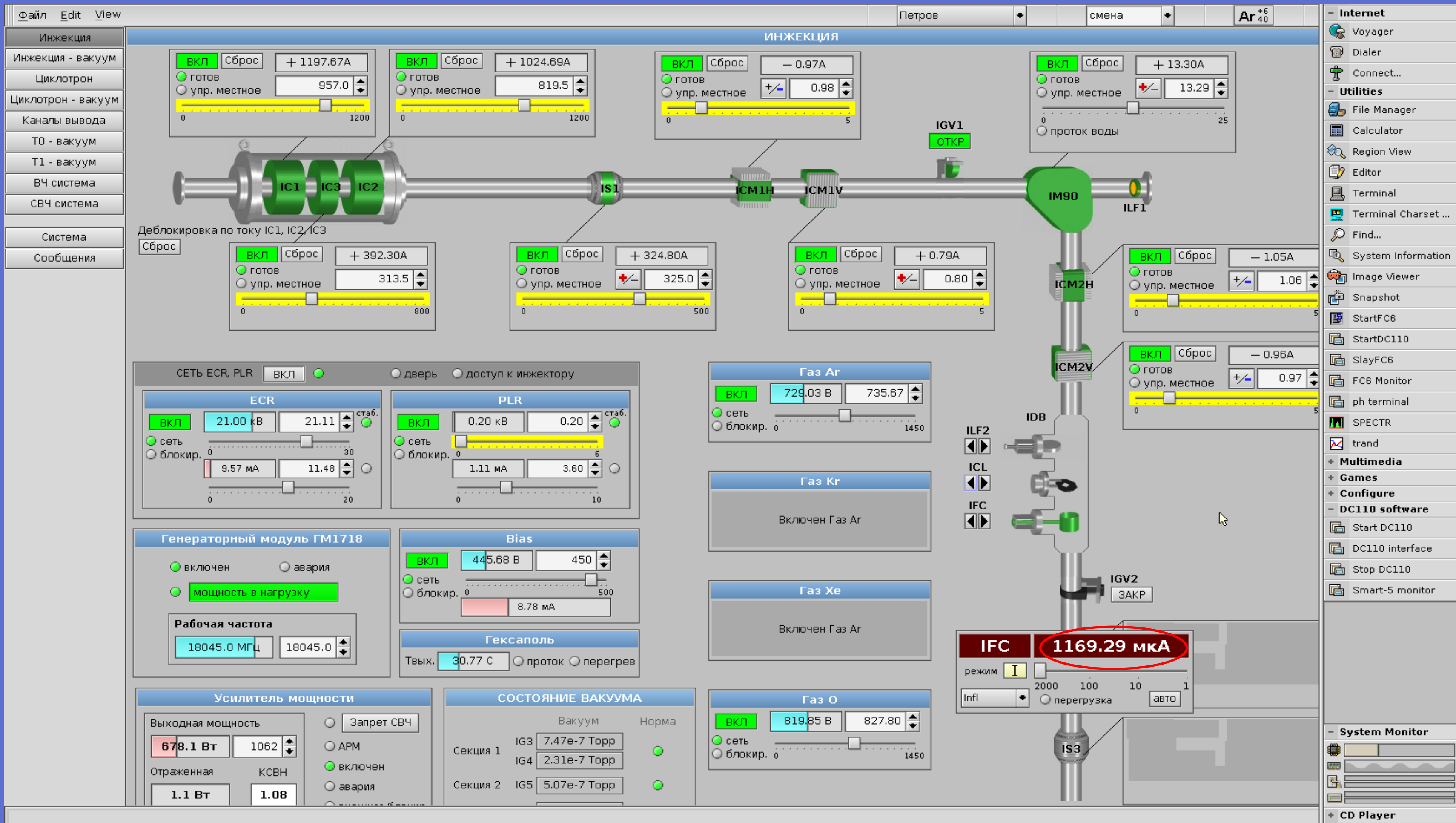
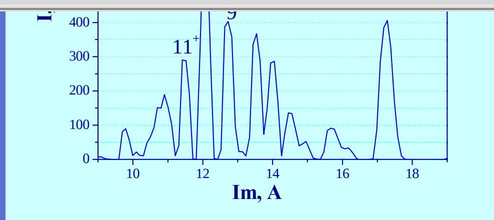
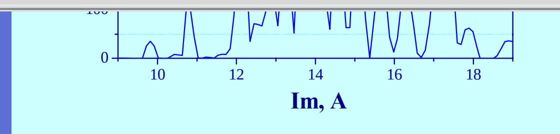
DECRIS-5

Results of the test

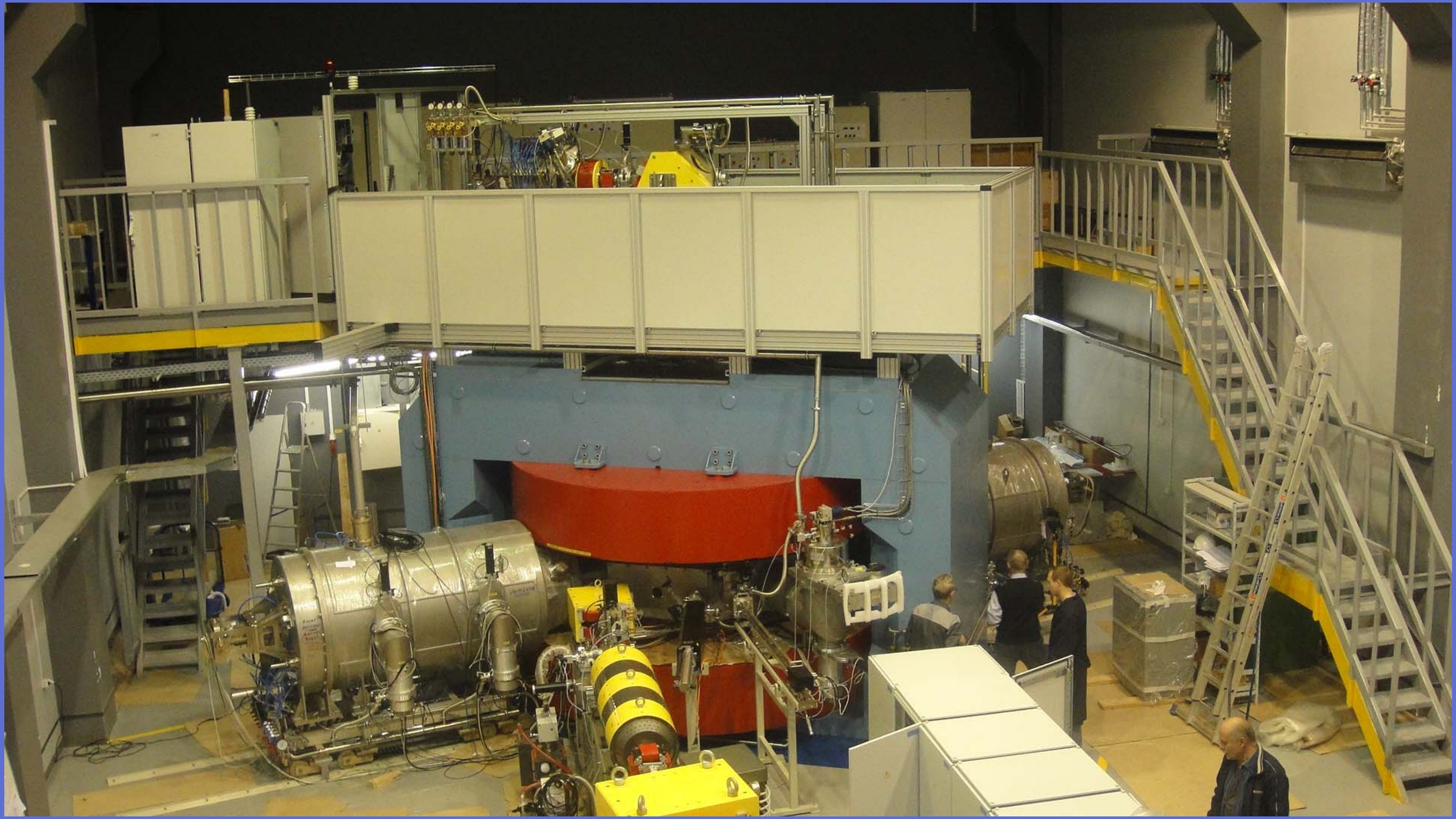






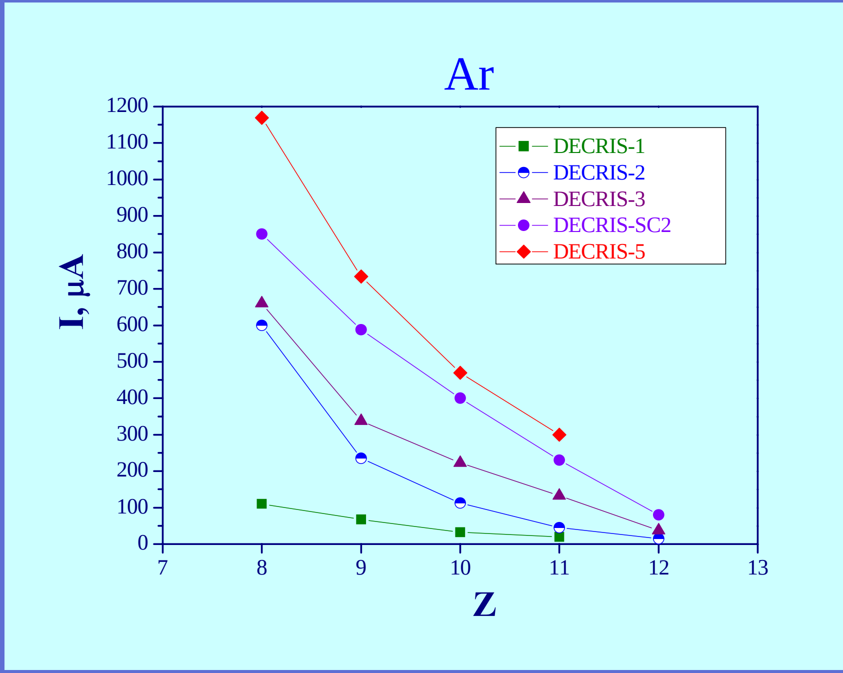
DECRIS-5 and axial injection system assembled with DC-110 cyclotron

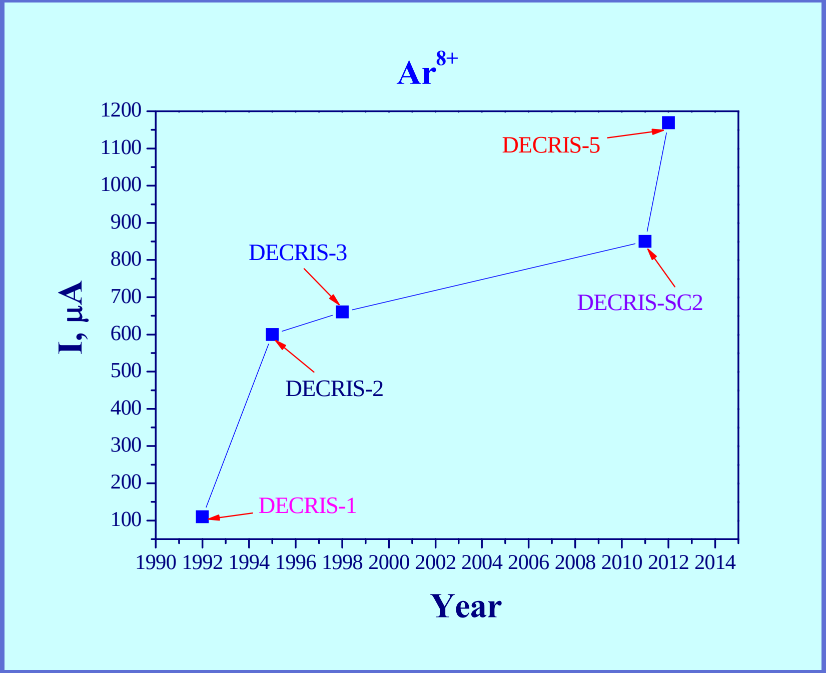
(Data are as of September 13, 2012)



The commissioning is in progress…

DECRIS sources development





Next project:

DECRIS-PM (14 GHz) & DECRIS-SC3 (18 GHz) ion sources

for DC-280 cyclotron

The cyclotron will be equipped with two high voltage (up to 100 kV) platforms with permanent magnet and superconducting ECR ion sources.

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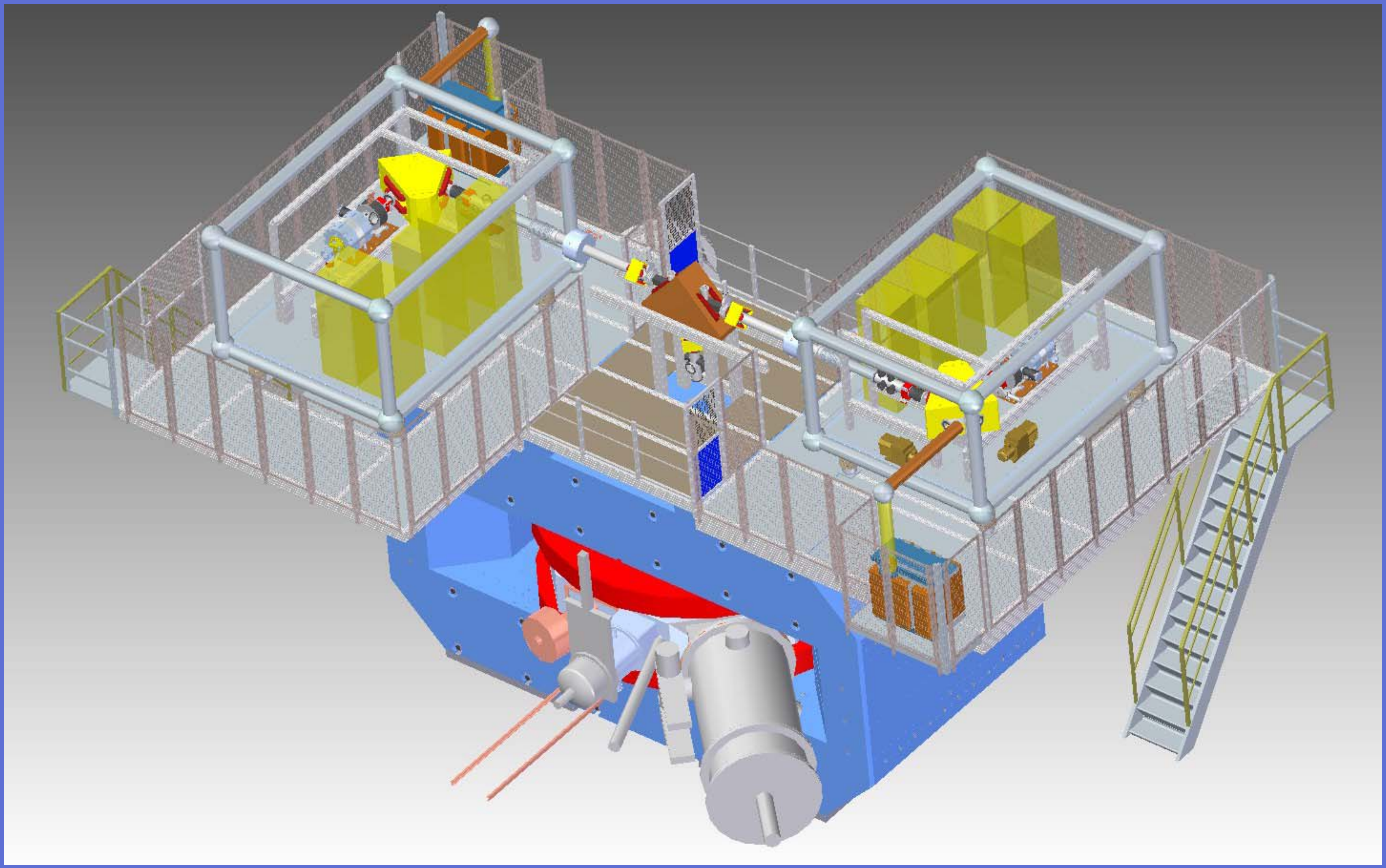
General view of DC-280 cyclotron and two high voltage platforms with ECR ion sources



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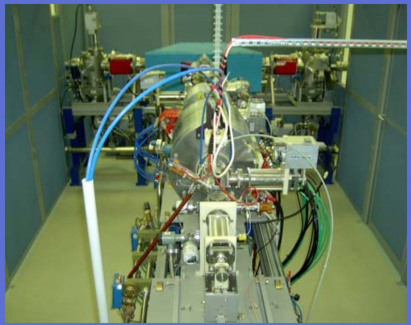
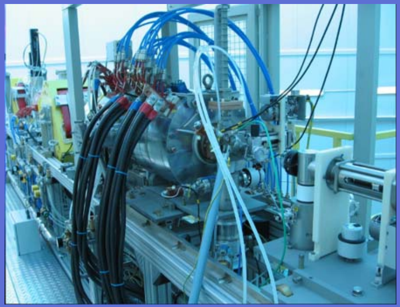
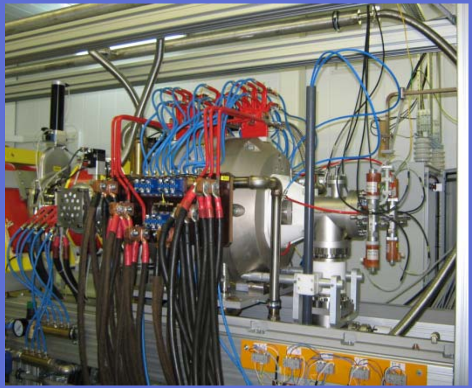
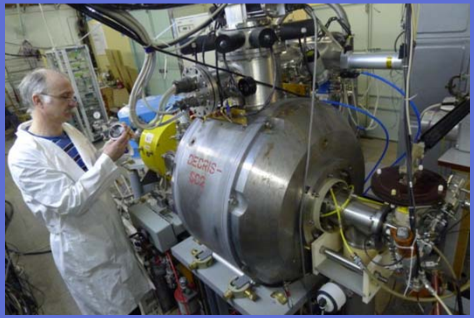
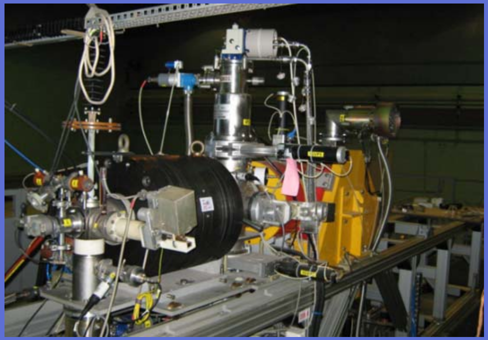
DECRIS ion sources

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