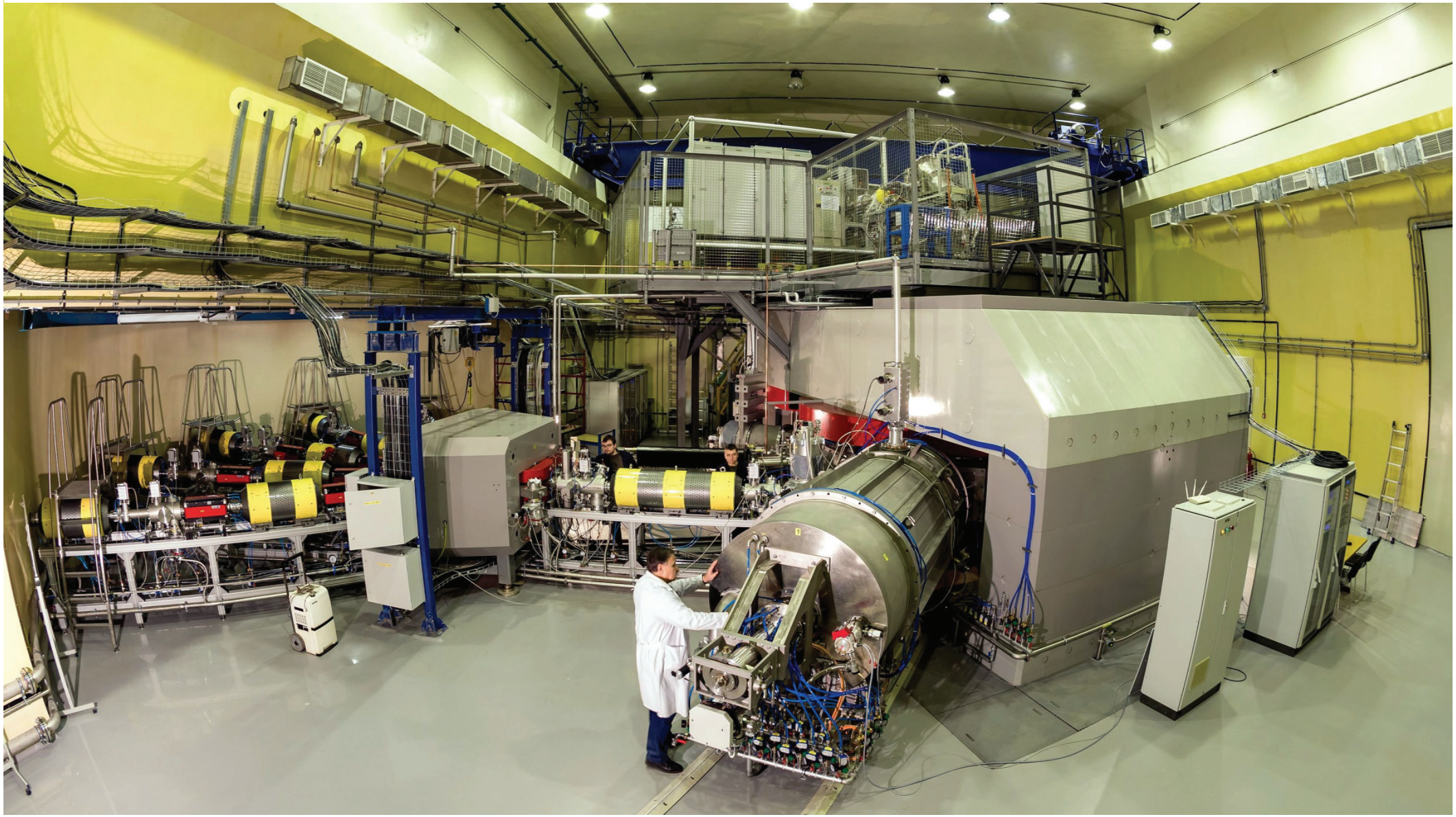
PECULIARITIES OF PRODUCING ^{48}CA, ^{48}TI, ^{52}CR BEAMS AT THE DC-280 CYCLOTRON



The first beam of 84Kr14 + ions in the DC-280 cyclotron was obtained on December 26, 2018. and on January 17, 2019, the 84Kr14 + ion beam was extracted from the accelerator

Superheavy Elements (SHE) Factory – the Goals .

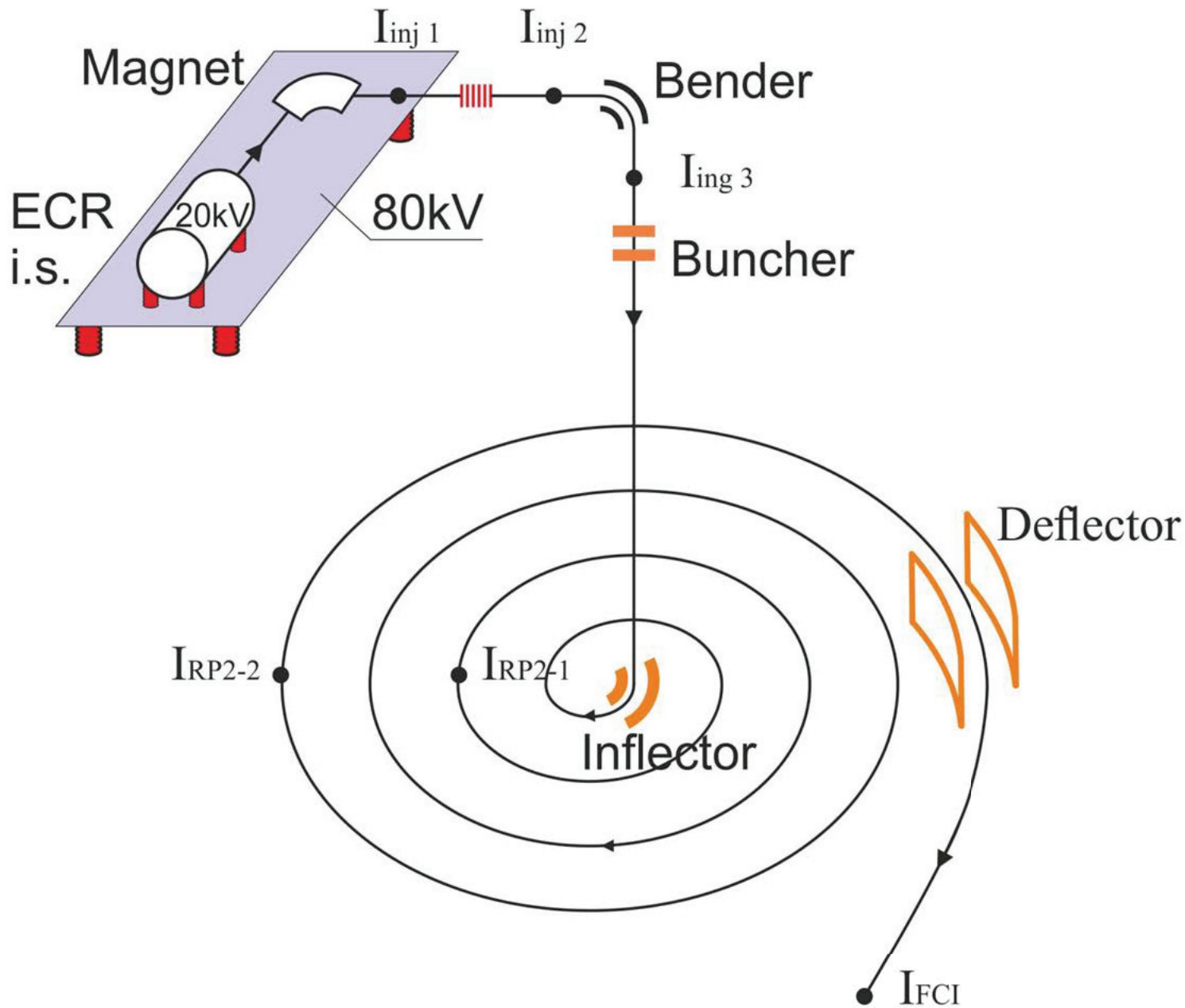
- **Experiments at the extremely low (σ<100 fb) cross sections:**
  - **Synthesis of new SHE in reactions with ^{50}Ti, ^{54}Cr ...;**
  - **Synthesis of new isotopes of SHE;**
  - **Study of decay properties of SHE;**

- **Experiments requiring high statistics:**
  - **Nuclear spectroscopy of SHE;**
  - **Study of chemical properties of SHE.**

To carry out the scientific program, the DC-280 has to provide the following parameters of ion beams:

	DC-280	U-400
Ion energies (smooth variation)	**4 - 8 MeV/n**	4 – 20 MeV/n
Ion masses	**10 - 238**	7 - 209
Intensities (A~50)	**>10 pμA**	1 pμA
Efficiency of beam transfer from ion source to physical facility	**>50%**	~10%

DC280 Cyclotron



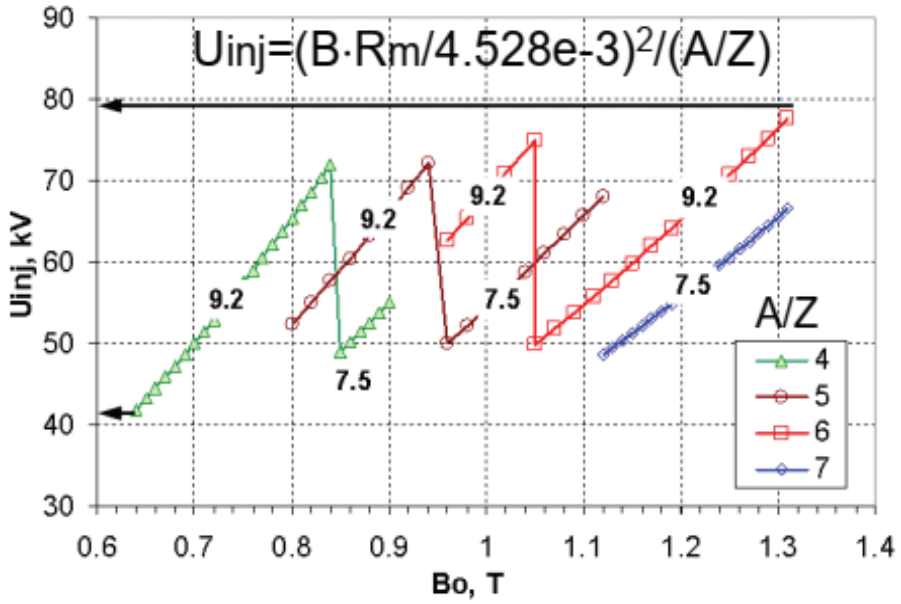
DC-280
Main Parameters

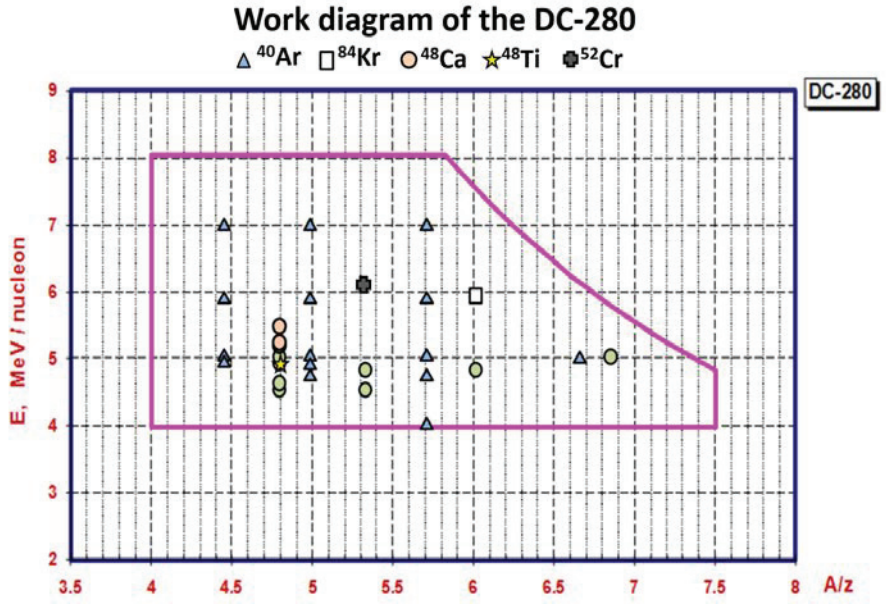
parameters	design	achieved
Injecting beam energy	Up to 80 keV/Z	38,04 – 72,89 keV/Z
A/Z	4÷7.5	4,4($^{40}Ar^{+7}$) ÷6,9($^{48}Ca^{+7}$)
Energy	4÷8 MeV/n	4,01 – 7 MeV/n
Ion (for DECRIS-PM)	4-136	12 ($^{12}C^{+2}$) – 84 ($^{84}Kr^{+14}$)
Intensity (A~50)	>10 pμA	10,4 pμA ($^{40}Ar^{+7}$);
Magnetic field level	0.6÷1.3 T	0.8÷1.23 T
K factor	280	
Dee voltage	2x130 kV	130 kV
Power of RF generator	2x30 kW	
Accelerator efficiency	>50%	51,9 % ($^{48}Ca^{+10}$ 5 pμA)

DC280. Parameters and Goals

	DC280 Parameter	Goals
1.	High injecting beam energy (up to 80 kV)	Shift of space charge limits for factor 30
2.	High gap in the center	Space for long spiral inflector
3.	Low magnetic field	Large starting radius. High turns separation. Low deflector voltage
4.	High acceleration rate	High turns separation.
5.	Flat-top system	High capture. Single orbit extraction. Beam quality.

DC-280 DESCRIPTION

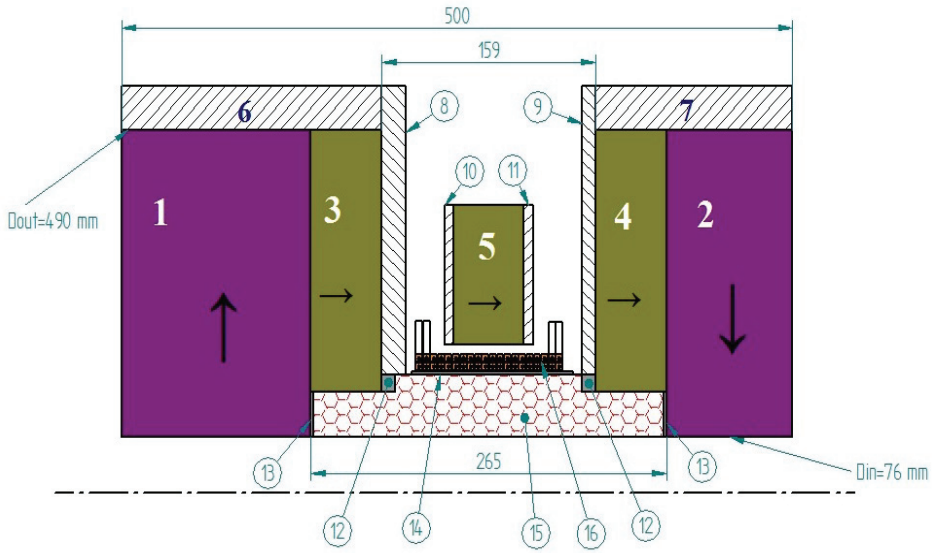


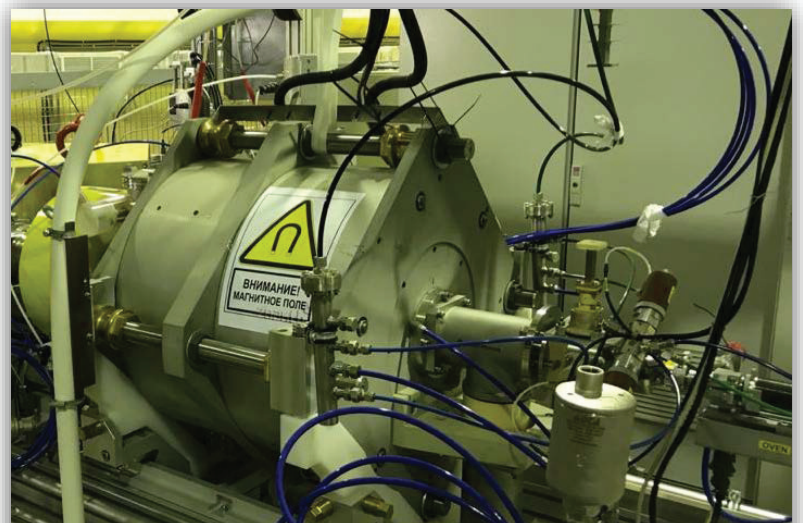


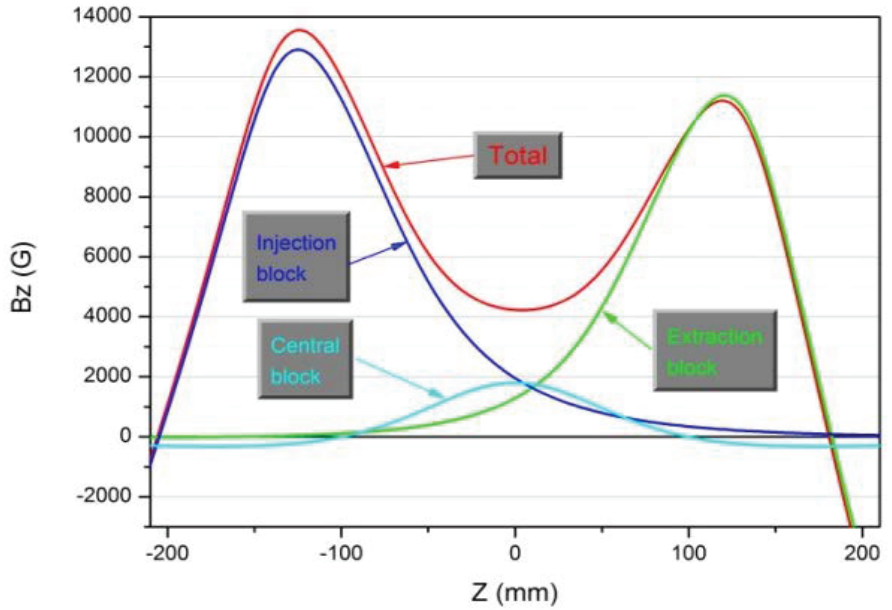
To ensure optimal injection conditions for all range of accelerated ions, two versions of the inflector type A and type B with two magnetic radii of 7.5 and 9.2 cm are used. Magnetic field Dependence of injection voltage.

The work diagram of DC-280 cyclotron with marks of tested regimes is presented on Fig.2. The cyclotron has shown reliable and highly effective work.

DECRIS-PM
(14 GHz)







Magnetic structure of DERIS-PM.

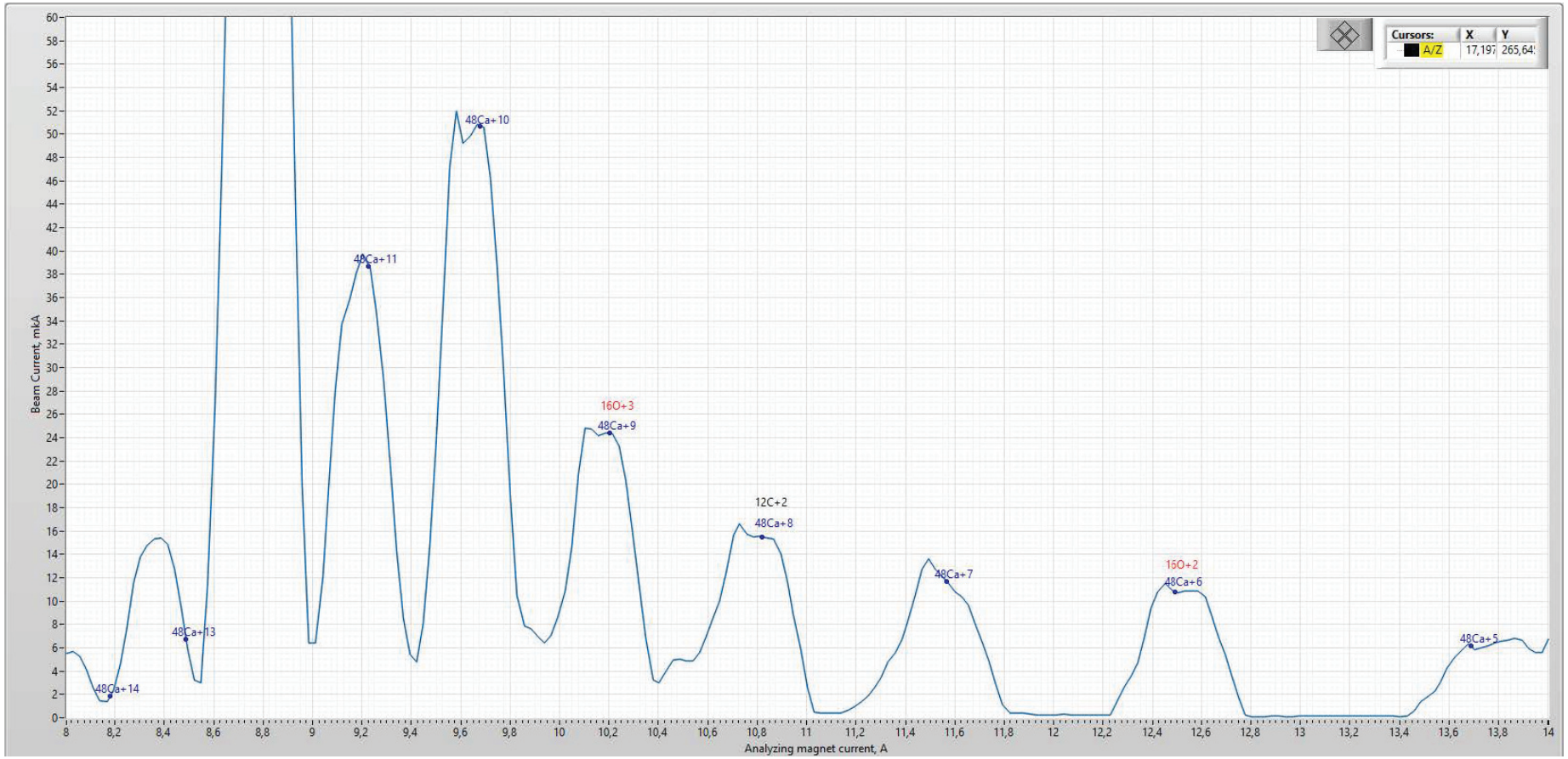
1÷5 – PM rings; 6. 7 – soft iron rings;

8÷11 – soft iron plates;

12÷14 - auxiliary elements;

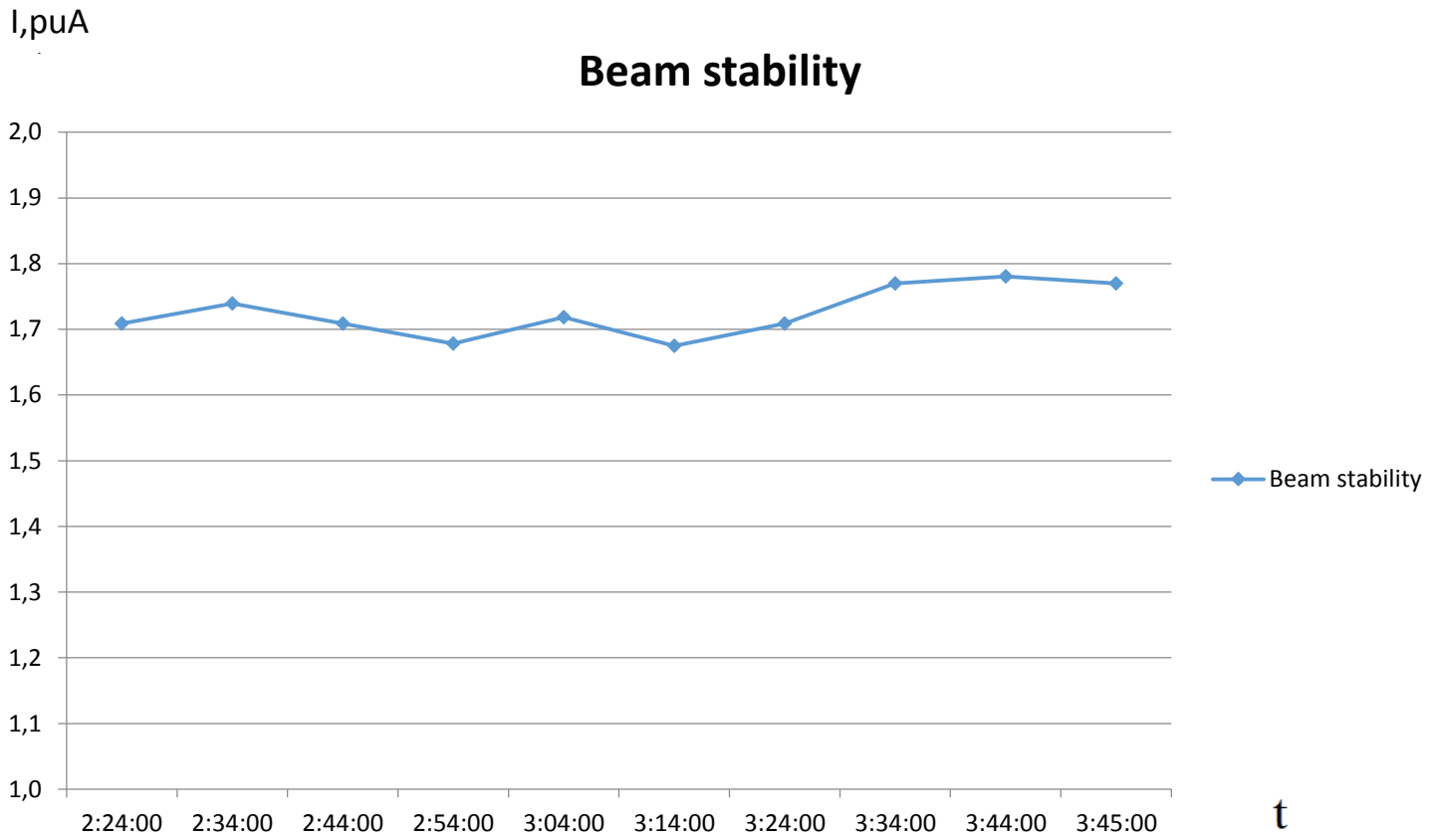
15 – hexapole; 16 – coil.

DECRIS PM Producing of ^{48}Ca



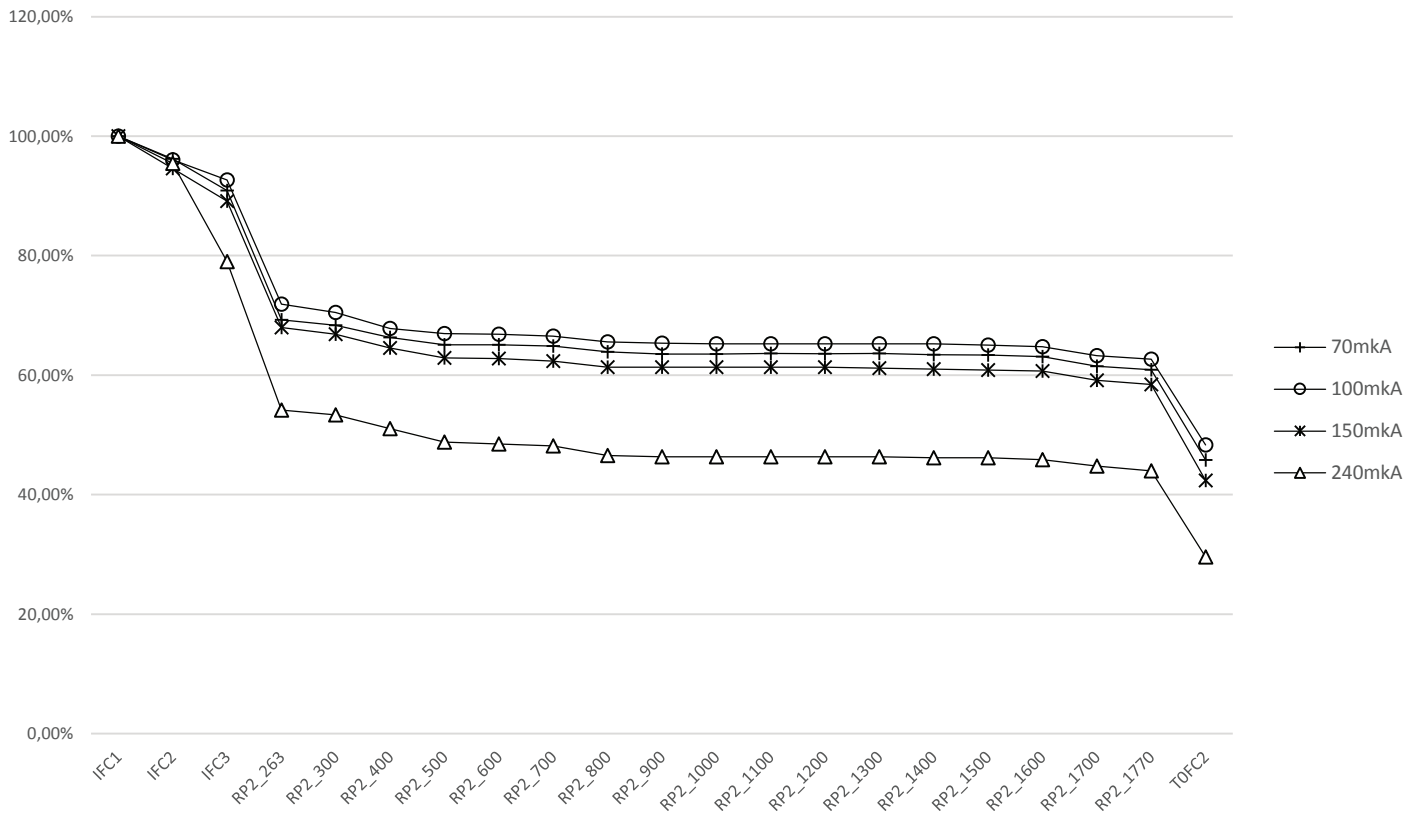
How we can see from the spectrum obtained from the ECR source, ions with charge +7, +10 don't have impurities. Due to the lower consumption, $^{48}Ca^{+10}$ was chosen for experiments on the synthesis of superheavy elements.

Producing of ^{48}Ca



Beam stability is about 1-3%.
Calcium consumption ~0,2-1,5 mg/h

Producing of ^{48}Ca



The total efficiency of transporting the ion beam of $^{48}Ca^{10+}$ from the vertical part of the injection to the transport channel is about 50%.

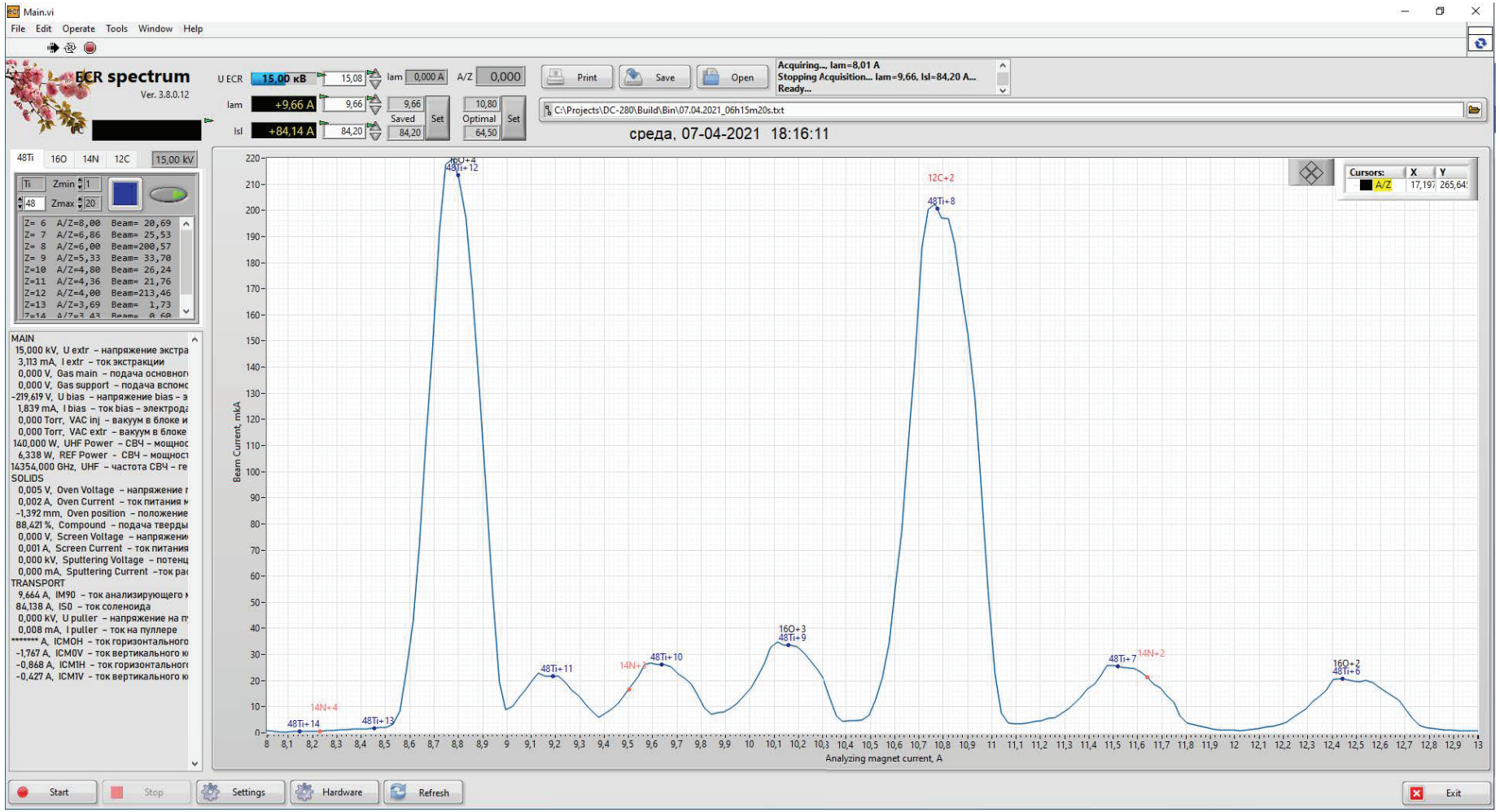
Producing of ^{48}Ca

Ion	Energy (MeV)	Intensity (pμA)				
		Axial injection		cyclotron		Transport channel
		after separation	vertical part	R=400	R=1770	
$^{48}Ca^{+7}$	240	10,9	9,8	6,9	6,1	5,2
$^{48}Ca^{+10}$	240	9	8,1	5,58	5,1	4,7
$^{48}Ca^{+10}$	240	23	19	12,8	10,6	7,1

Ion	Energy (MeV)	Efficiency				
		axial injection	capture	cyclotron	extraction	Total
$^{48}Ca^{+7}$	240	90%	71%	88%	85%	48%
$^{48}Ca^{+10}$	240	90%	69%	91%	91%	51%
$^{48}Ca^{+10}$	240	82%	67%	83%	67%	31%

On the vertical, with an increase in the intensity from the ion source to 240 μA, we observed a deterioration of the beam transmission through the spherical deflector (Bender) from 94.22% at 150 μA to 79% at 240 μA, and the capture in acceleration decreased from 69% to 67%, respectively. This may be due to an increase in the space charge of the beam or the tuning of the accelerator as a whole.

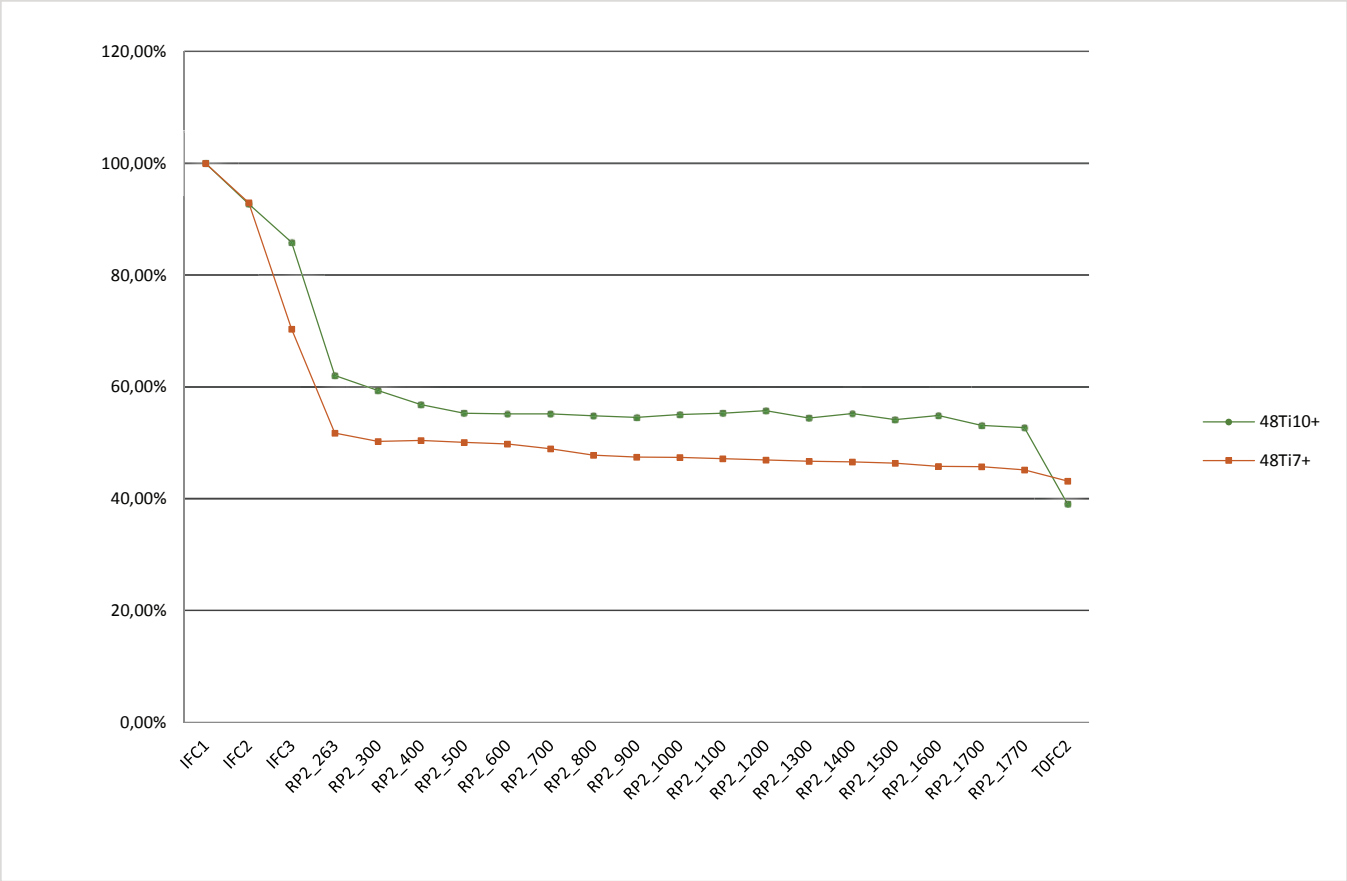
Producing of ^{48}Ti



The ions of ^{48}Ti with a charge of +7, +10 do not have impurities and we can use them in experiments on the synthesis of SHE.

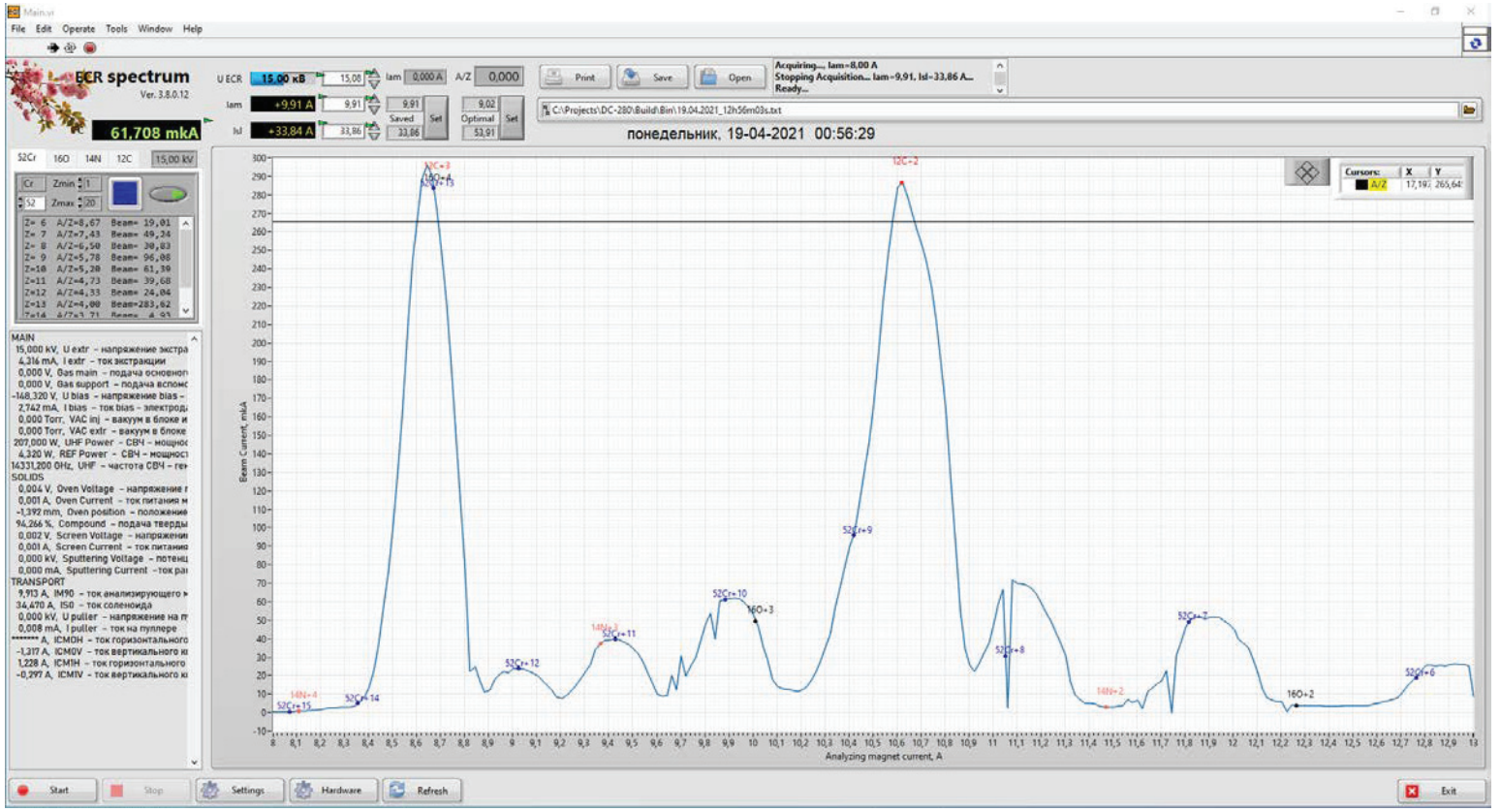
Compound $(CH_3)_5Ti(CH_3)_3$.

Producing of ^{48}Ti



The beam of $^{48}Ti^{+10}$ from ECR source with intensity is about 2.5 pμA and $^{48}Ti^{+7}$ with intensity is about 3.14 pμA were obtained and accelerated with intensity 1,0 pμA and 0,93 pμA respectively. The total efficiency of transporting the ion beam of $^{48}Ti^{10+,7+}$ from the vertical part of the injection to the transport channel is about 40-45%.

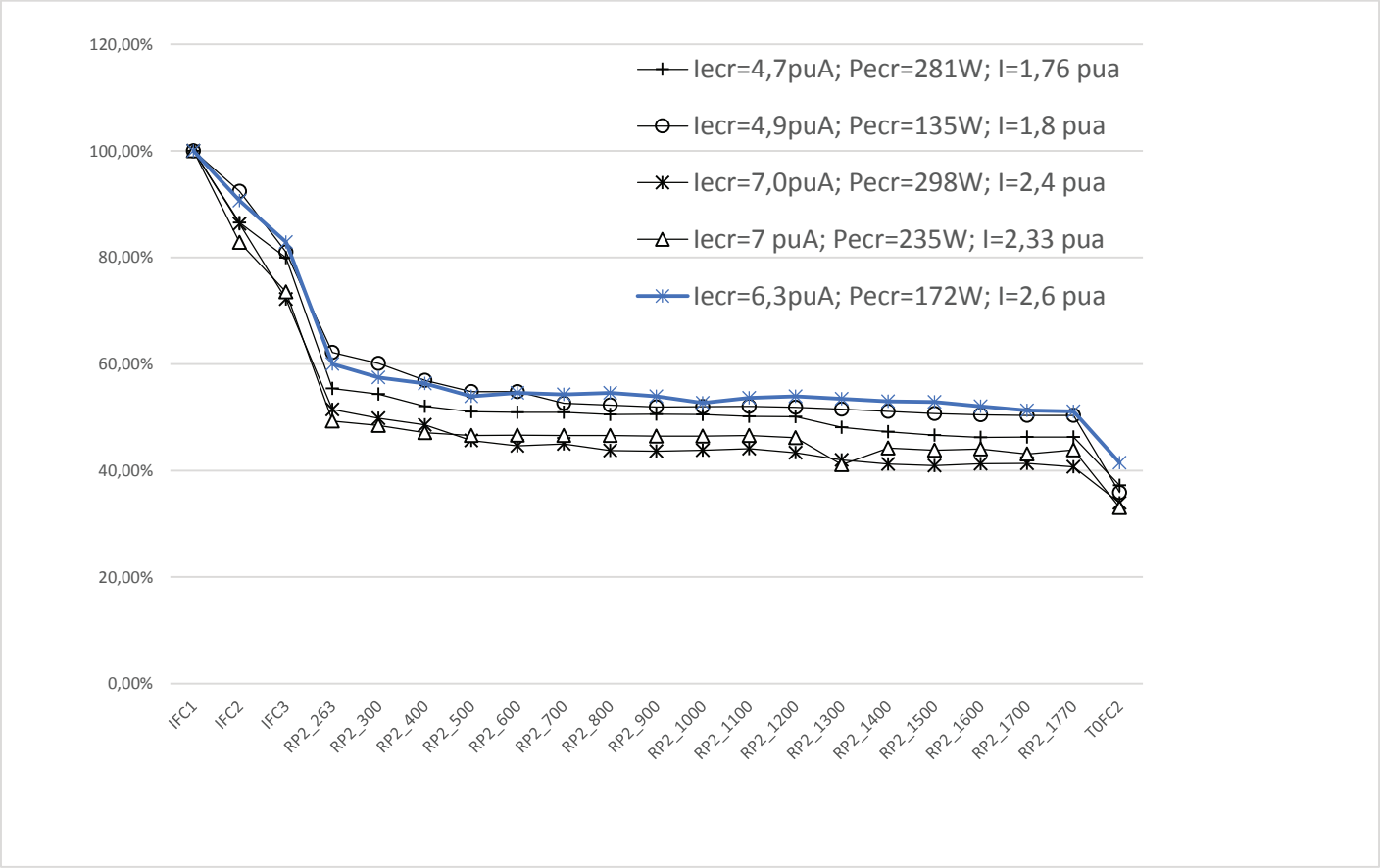
Producing of ^{52}Cr



The ions of ^{52}Cr with a charge of +7, +8, +10 do not contain impurities, but we cannot accelerate ions with a charge of +7 and +8 to the energy required for the experiment.

$C_{10}H_{10}Cr$

Producing of ^{52}Cr



The beam of $^{52}Cr^{+10}$ from ECR source with intensity is about 6,3 pμA and accelerated with intensity 2,6 pμA. We can see, that efficiency of acceleration worsen then we increase power input to ECR source.

The total efficiency of transporting the ion beam of $^{52}Cr^{10+}$ from the vertical part of the injection to the transport channel is about 50%.

CONCLUSION

- The beams of $^{48}Ca^{7+,10+}$, $^{48}Ti^{+7,+10}$ and $^{52}Cr^{10+}$ were accelerated and extracted from the DC-280 to the beam transport channel.
- Maximum intensity of accelerated ^{48}Ca ion beam is 10,6 pμA and 7,1 pμA were extracted.
- The efficiency of acceleration for ^{48}Ca is about 50 %. The beam is given to the GNS-2 experimental setup for a series of test experiments.
- The beams of accelerated $^{52}Cr^{10+}$ and $^{48}Ti^{7+,10+}$ ions with intensity 2,6 pμA and 1 pμA respectively were extracted from the DC-280 to the beam transport channel.
- The efficiency of acceleration for $^{52}Cr^{10+}$ and $^{48}Ti^{7+,10+}$ is about 40-50 %.
- For the the ion beam of ^{48}Ti and ^{52}Cr the intensity is limited by ion current from ECR source. We work to improve of the method of ion production and optimize the ECR source work mode.


THANKS
FOR YOUR
ATTENTION !
Flerov Laboratory of Nuclear Reactions , JINR