G.G. Gulbekian, I.V. Kalagin, S.N. Dmitriev, Yu.Ts. Oganessian, B.N. Gikal, S.L. Bogomolov, I.A.Ivanenko, N.Yu.Kazarinov, V.A. Semin, G.N. Ivanov, N.F.Osipov

Heavy Ion Cyclotrons of FLNR JINR Status and Plans

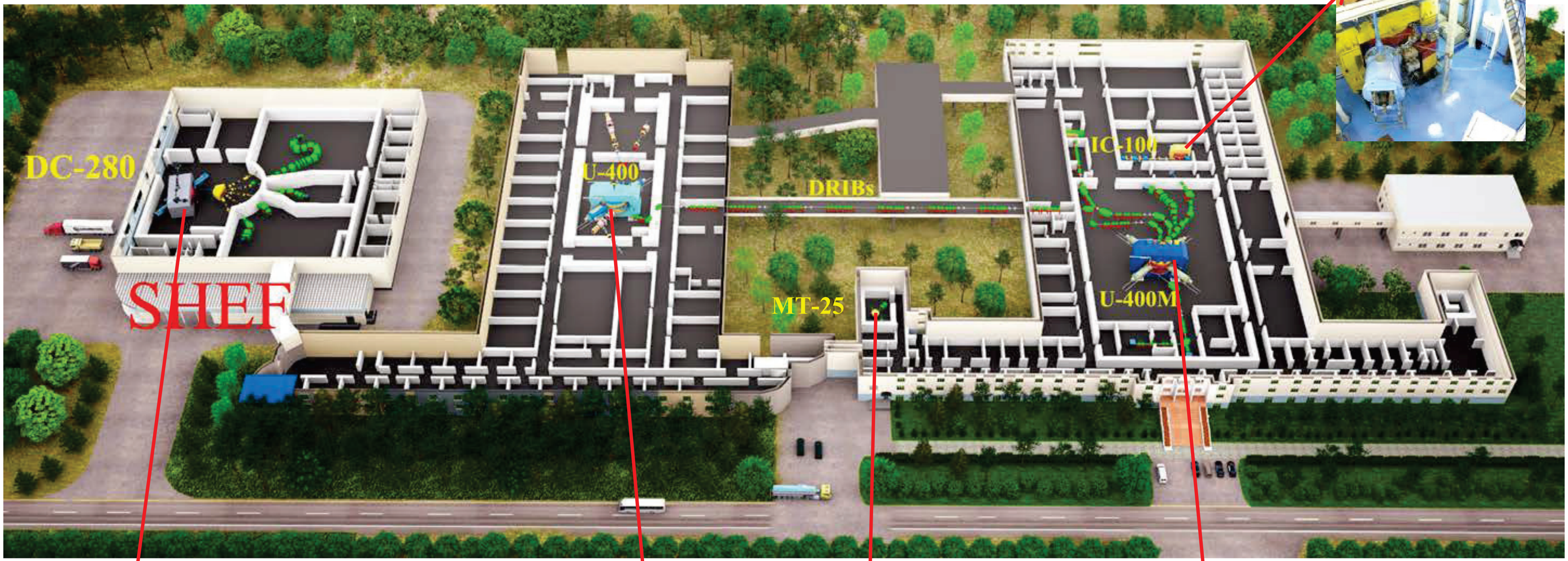
Igor Kalagin

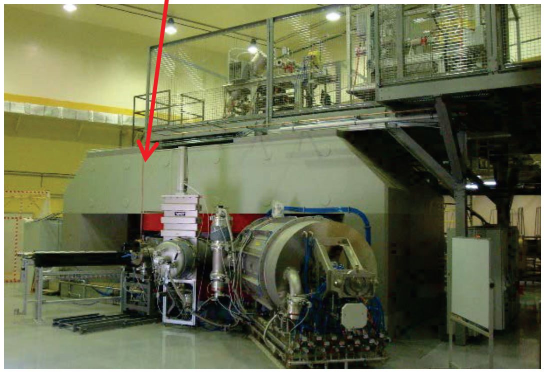
Flerov Laboratory of Nuclear Reactions
Joint Institute for Nuclear Research

RUPAC-2018, Protvino

FLNR JINR Accelerator Complex

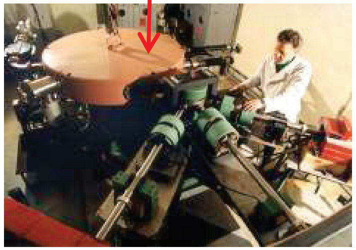
IC-100





DC-280

U-400



MT-25

U-400M

BASIC DIRECTIONS of RESEARCH at FLNR

U-400, U-400M & DC-280 cyclotrons (^{48}Ca, ^{50}Ti 5 ÷ 6 MeV/n)

- synthesis and study of properties of super heavy elements;
- chemistry of new elements;
- fusion-fission reactions;
- nuclear- , mass- spectrometry of SH nuclei.

U-400M cyclotron (ions 15 ÷ 60 MeV/n)

- properties and structure of light exotic nuclei;
- reactions with exotic nuclei.

IC-100 (C ÷ W 1.2 MeV/n), U-400 (Ar ÷ Bi 2.5 ÷ 3.5 MeV/n)

- Radiation effects and physical groundwork of nanotechnology.

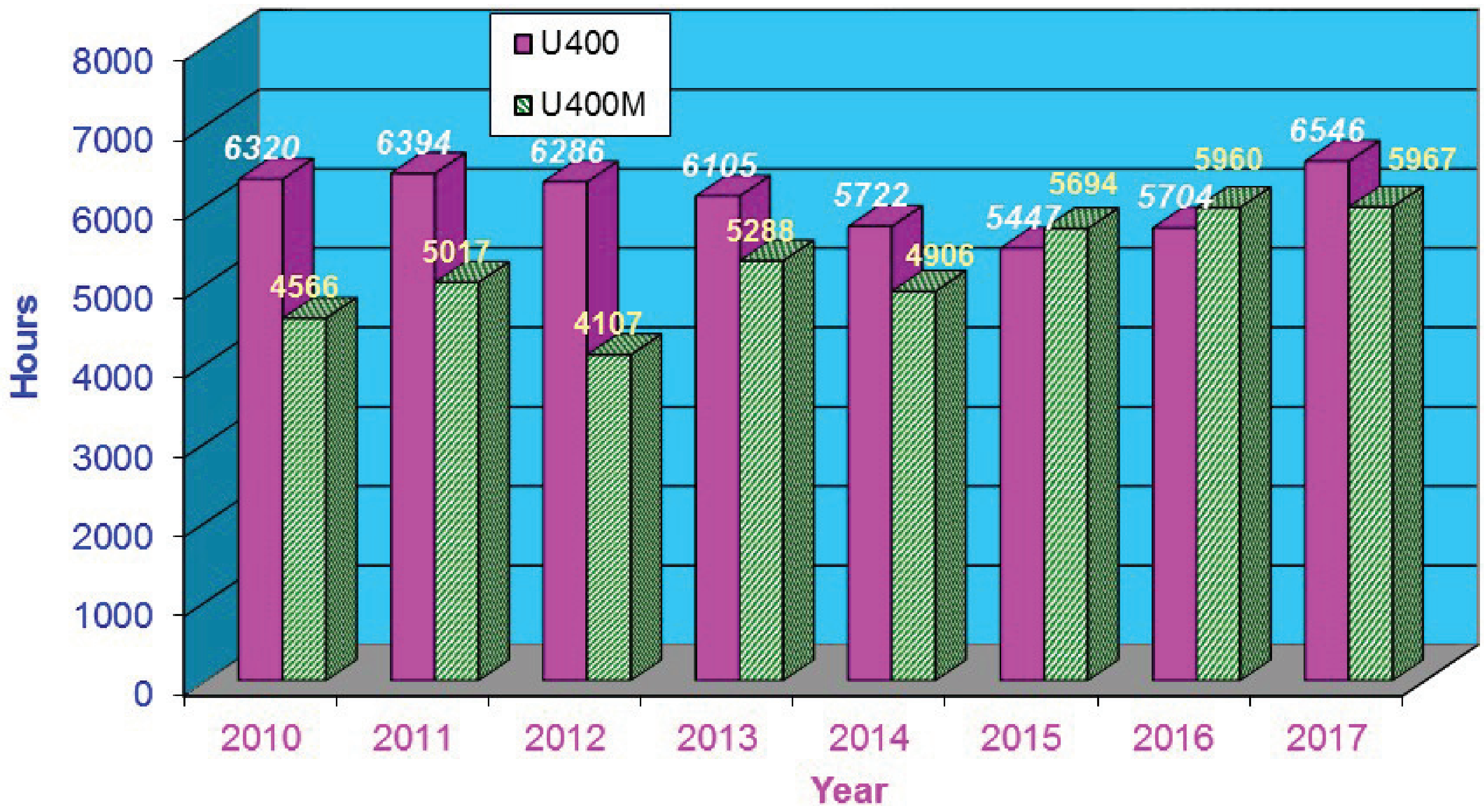
U-400 & U-400M (O ÷ Bi 3 ÷ 5 MeV/n) and
U-400M (O ÷ Bi 15 ÷ 60 MeV/n)

- SEE testing of electronic components

Flerov Laboratory of Nuclear Reactions

Total operation time of U-400, U-400M, IC-100 and MT-25 accelerators	2015	2016	2017
	14 034	15 724	16 657

OPERATION TIME OF U-400 AND U-400M ACCELERATORS



U400 CYCLOTRON (1978)
stand-alone & post-accelerator

Ion	Ion energy [MeV/A]	Output intensity
$^{6}He^{1+}$	11	$3\cdot10^{7}$ pps
$^{16}O^{2+}$	5.7; 7.9	5 pμA
$^{18}O^{3+}$	7.8; 10.5; 15.8	4.4 pμA
$^{40}Ar^{4+}$	3.8; 5.1 *	1.7 pμA
$^{48}Ca^{5+}$	3.7; 5.3 *	1.2 pμA
$^{48}Ca^{9+}$	8.9; 11; 17.7 *	1 pμA
$^{50}Ti^{5+}$	3.6; 5.1 *	0.5 pμA
$^{58}Fe^{6+}$	3.8; 5.4 *	0.7 pμA
$^{84}Kr^{8+}$	3.1; 4.4 *	0.3 pμA
$^{136}Xe^{14+}$	3.3; 4.6; 6.9 *	0.08 pμA
$^{160}Gd^{19+}$	5.5	0.01 pμA
$^{209}Bi^{19+}$	3.4	0.01 pμA

Main tasks:

- **New heavy isotopes**
- **Fusion-fission**
- **Nuclear spectroscopy**
- **SHE chemistry**
- **Multi nucleon transfer reactions;**

Experimental setups at U400 :

1. **GFRS** (**G**as-**F**illed **R**ecoil **S**eparator), **channel N1**
2. **Chemical setup, channel N2**
3. **SHELS** (**S**eparator for **H**eavy **EL**ement **S**pectroscopy), **channel N3**
4. **Corset** (Investigation of the fusion-fission reactions), **channel N6**
5. **SEE testing of electronic components, channel N8;**
6. **MAVR** (High-resolution magnetic analyser), **channel N9**
7. **Channel for applied research, channel N10**

DUBNA Gas Filled Recoil Separator

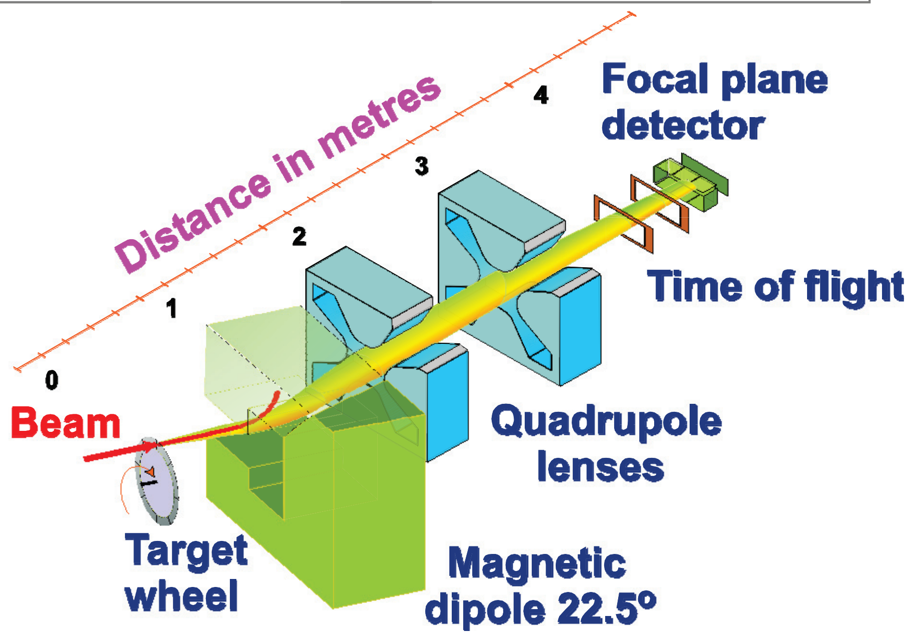
Target	+	Beam	→	Isotopes
^{238}U, $^{242,244}Pu$, ^{243}Am, $^{246,248}Cm$, ^{249}Cf	+	^{48}Ca	→	112 – 118

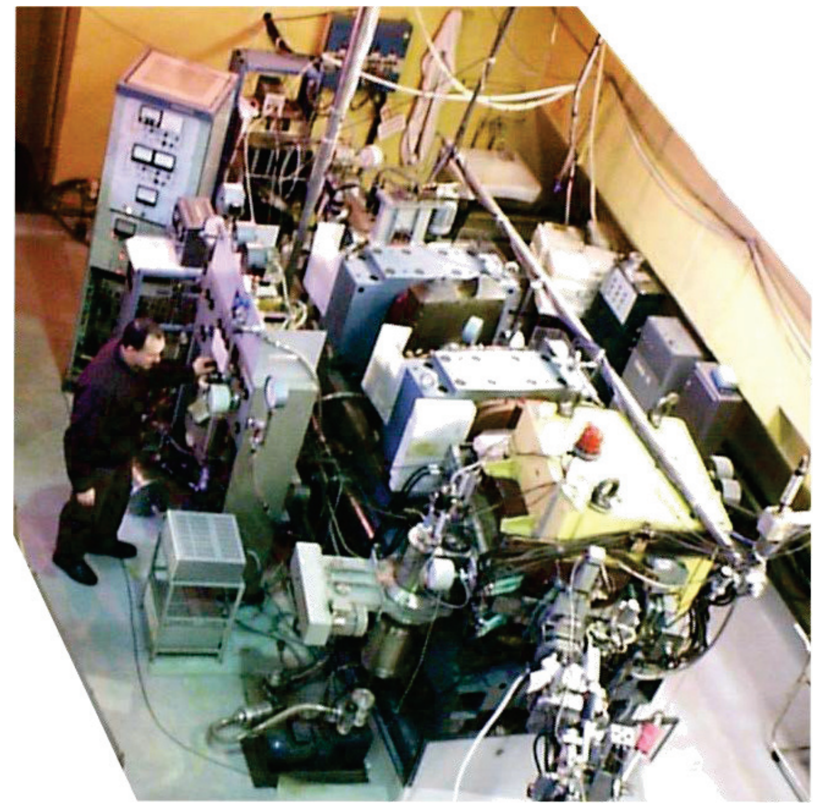
Ion beam energy: 5.00 – 5.75 MeV/A

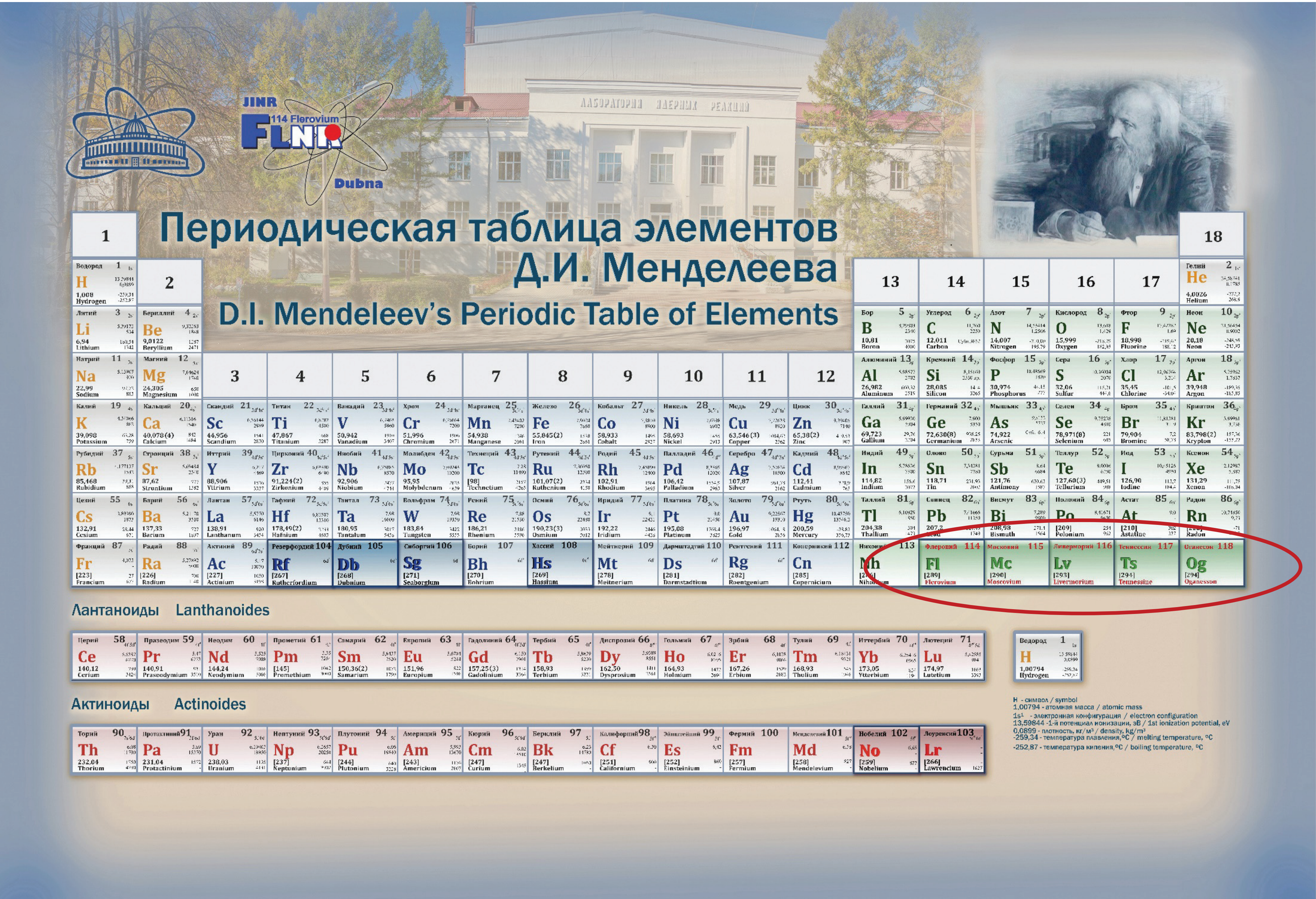
Beam intensity: 6 - 8·10^{12} pps

Consumption of ^{48}Ca = 0.5-0.7 mg/h

Beam time: 2000 – 4000 hours per year



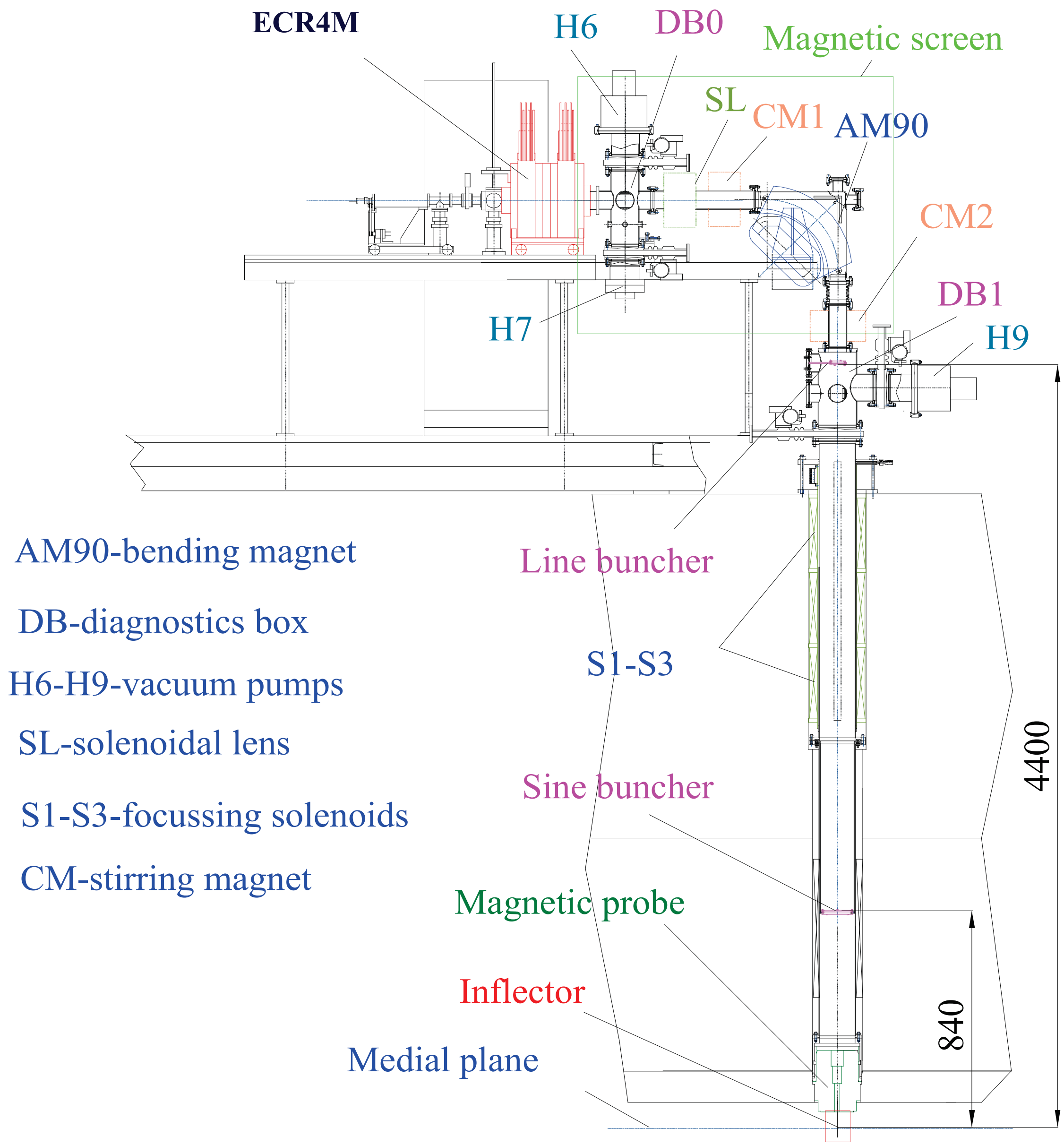



JINR
114 Flerovium
FLNR
Dubna
ЛАБОРАТОРИЯ ЯДЕРНЫХ РЕАКЦИЙ
Периодическая таблица элементов
Д.И. Менделеева
D.I. Mendeleev's Periodic Table of Elements
Лантаноиды Lanthanoides
Актиноиды Actinoides
H - символ / symbol
1,00794 - атомная масса / atomic mass
1s1 - электронная конфигурация / electron configuration
13,59844 -1-й потенциал ионизации, эВ / 1st ionization potential, eV
0,0899 - плотность, кг/м3 / density, kg/m3
-259,34 - температура плавления,°C / melting temperature, °C
-252,87 - температура кипения,°C / boiling temperature, °C
Нихоний 113 Nh Nihonium
Флеровий 114 Fl [289] Flerovium
Московий 115 Mc [290] Moscovium
Ливерморий 116 Lv [293] Livermorium
Теннессин 117 Ts [294] Tennessine
Оганесон 118 Og [294] Oganesson

Axial injection system of U-400 Cyclotron

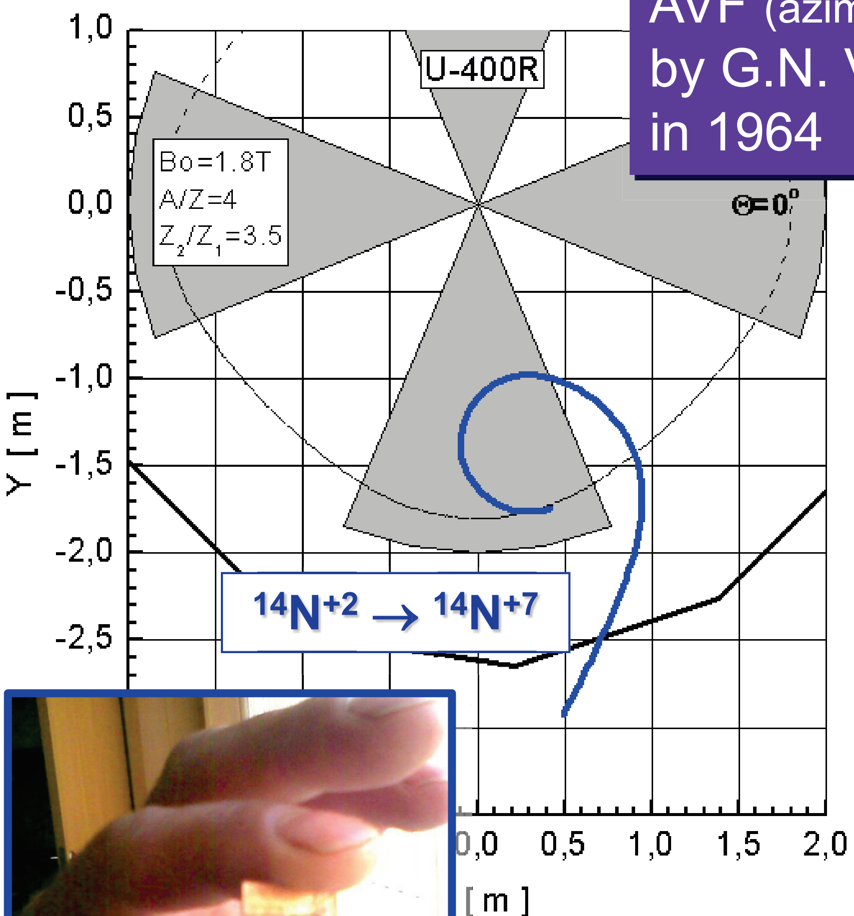
ECR4M ion source
made by GANIL 1995,
upgraded by FLNR 2013

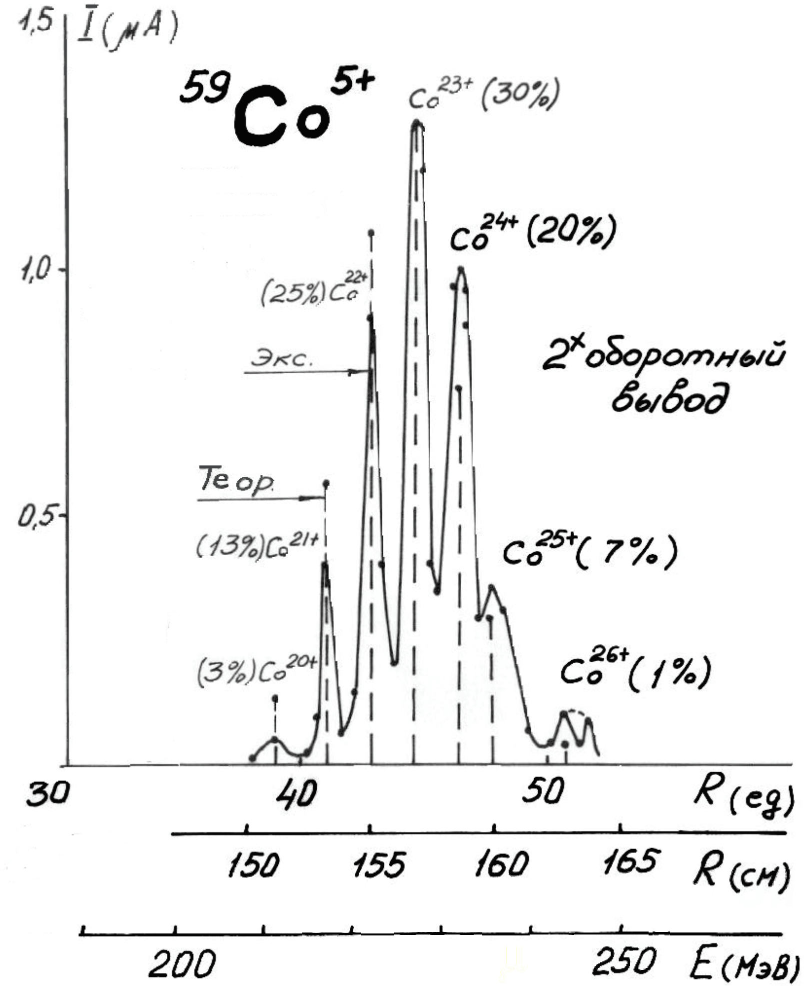
$^{48}Ca^{5+}$ - 100 eμA
$^{132}Xe^{12+}$ - 50 eμA
$^{209}Bi^{19+}$ - 20 eμA



Heavy Ion Beam Extraction by Stripping Foil

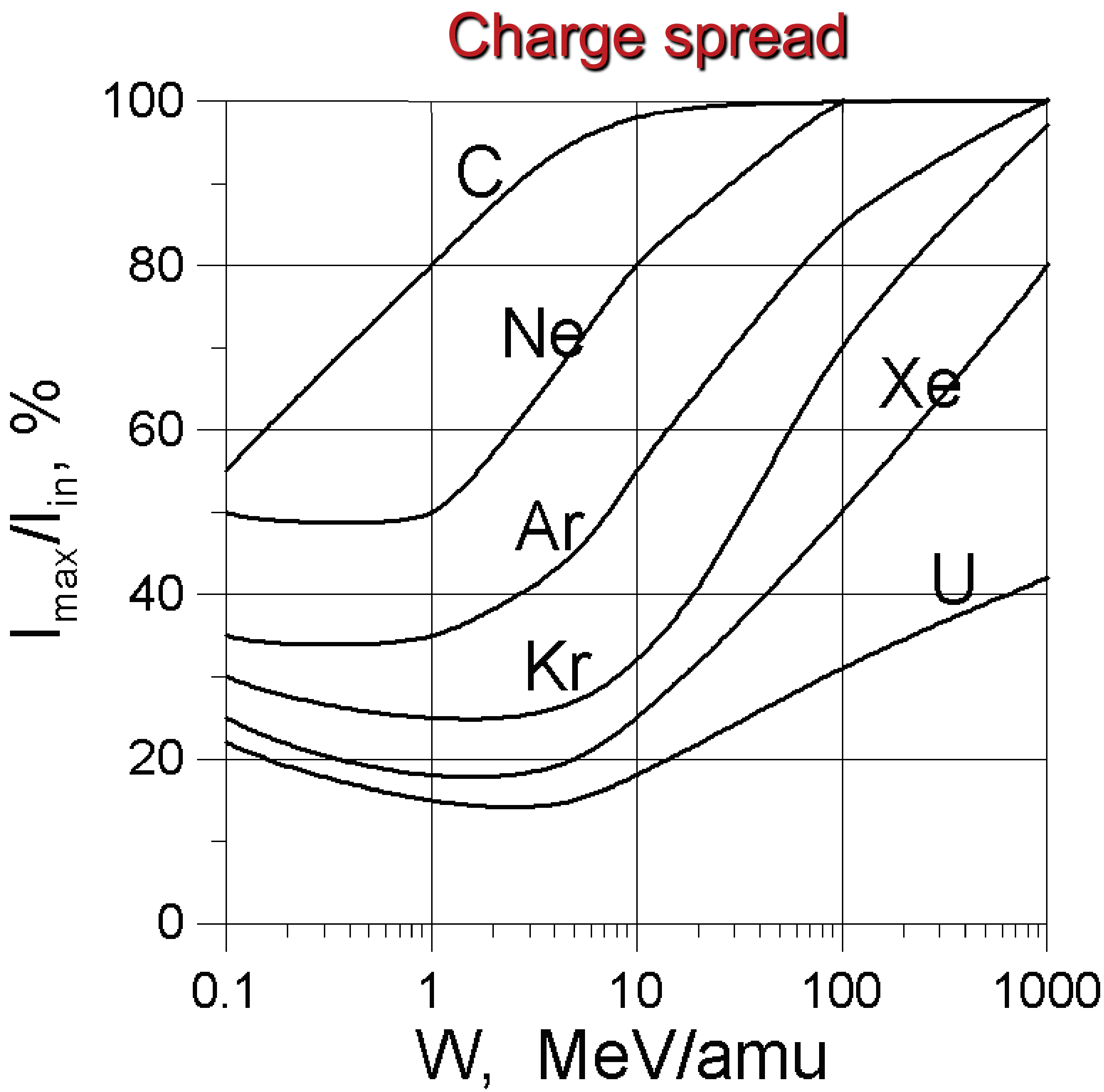
The method of heavy ion beam extraction from AVF (azimuthally-varying-field) cyclotrons suggested by G.N. Vialov, G.N. Flerov and Yu. Oganesyan in 1964





Thickness of stripping foils
20 ÷ 200 μg/cm²

Heavy Ion Beam Extraction by Stripping Foil



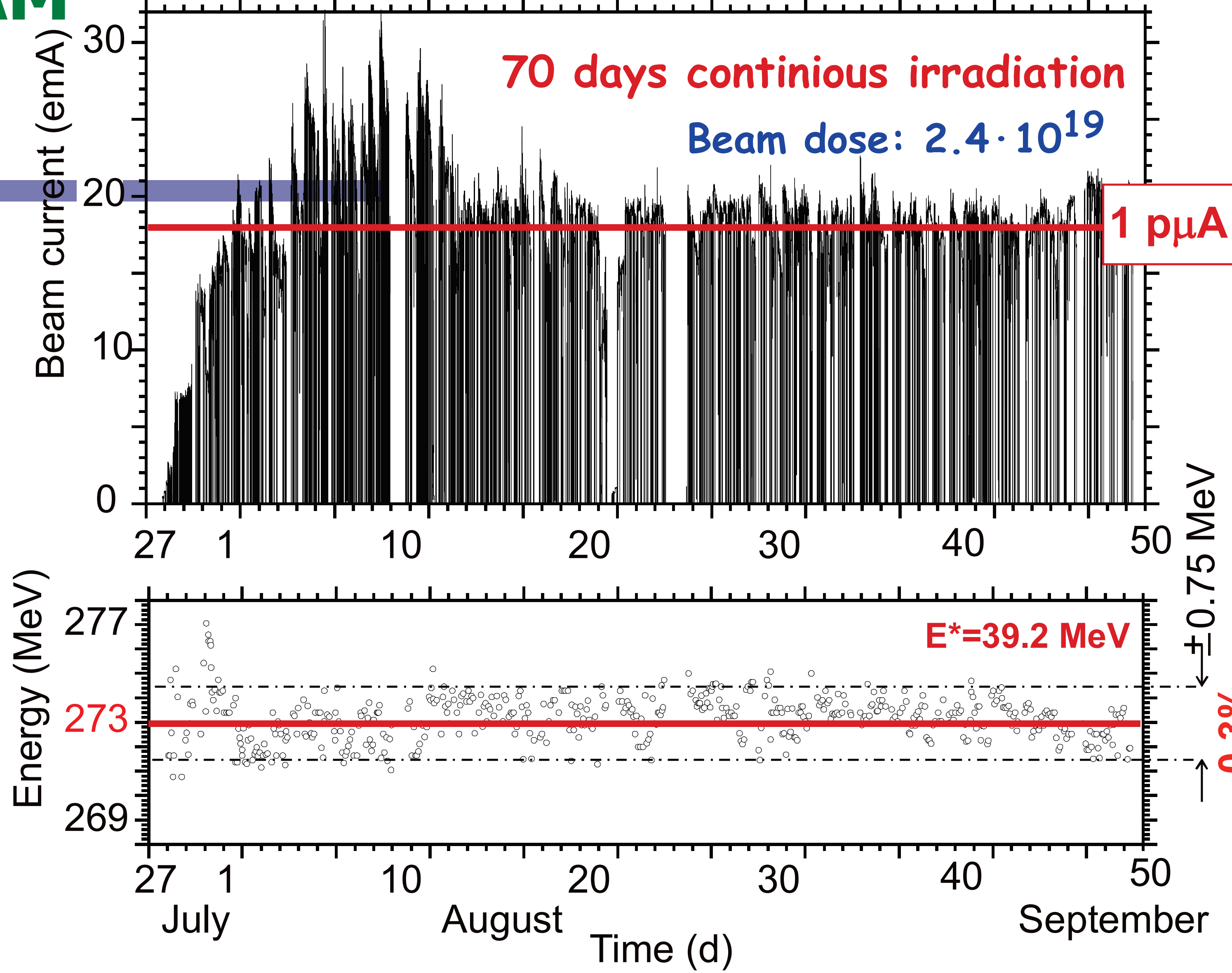
Dependence of the maximal efficiency of a single charge extraction by stripping on ion energy

Efficiency of transporting a $^{48}Ca^{5+}$ beam from the ECR source to a physical target

<table>
<tr><th>Measuring point</th><th colspan="2">Beam intensity</th><th>Ion</th><th colspan="5">Transmission factor</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 centre</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>Extraction radius</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 (by charge exchange)</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>
</table>

- Ionization efficiency of ^{48}Ca (neutral) to $^{48}Ca^{5+}$ - about **10%**
- Transformation of ^{48}Ca as working substance into the ^{48}Ca beam on target is about 1% in routine operation.

BEAM



70 days continious irradiation
Beam dose: 2.4·10^19
1 pμA
Beam current (emA)
30
20
10
0
27
1
10
20
30
40
50
E*=39.2 MeV
±0.75 MeV
0.3%
Energy (MeV)
277
273
269
July
August
September
Time (d)

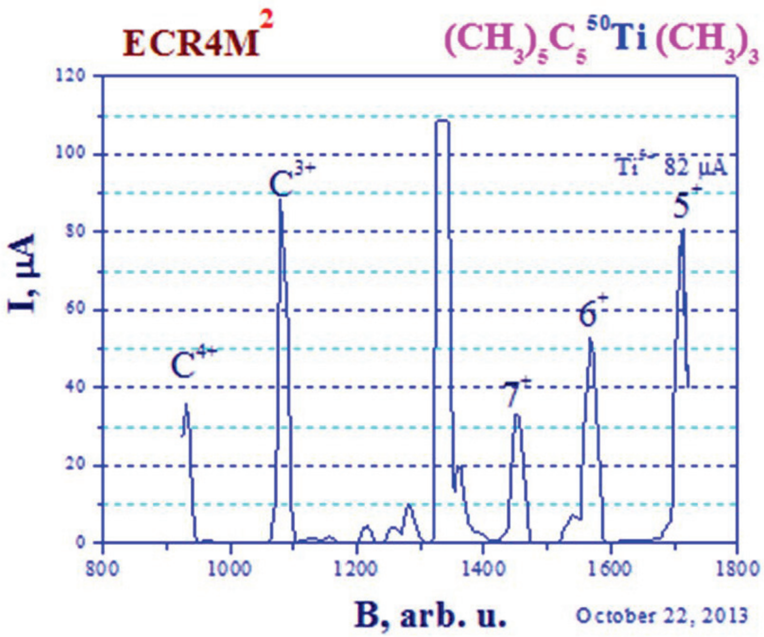
Development of ^{50}Ti beam using MIVOC method

(Collaboration between IPHC (Strasbourg, France) and FLNR JINR.)

Synthesis of compound (two steps)

$$^{50}TiCl_4 + (CH_3)_5C_5Si(CH_3)_3 \rightarrow Cp^*TiCl_3 + 3CH_3Li \rightarrow Cp^*Ti(CH_3)_3$$

where Cp^* - $(CH_3)_5C_5$



The spectrum of Ti ions, the source settings are optimized for $^{50}Ti^{5+}$ (82 mkA).

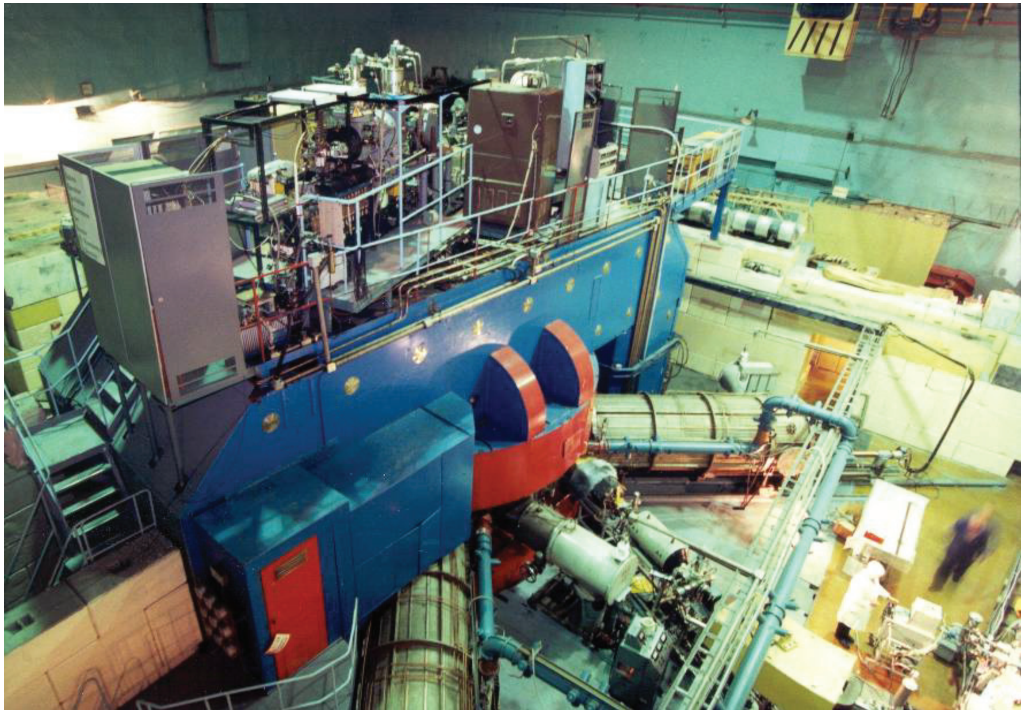
Acceleration at the U-400 cyclotron

The intensity of the injected beam of $^{50}Ti^{5+} \geq 50$ eμA

The intensity on the target ~ 10 eμA (~ 0.5 pμA)

The compound consumption rate of 2.4 mg/h (^{50}Ti consumption of 0.52 mg/h)

U400M CYCLOTRON (1991)
stand-alone & driving accelerator

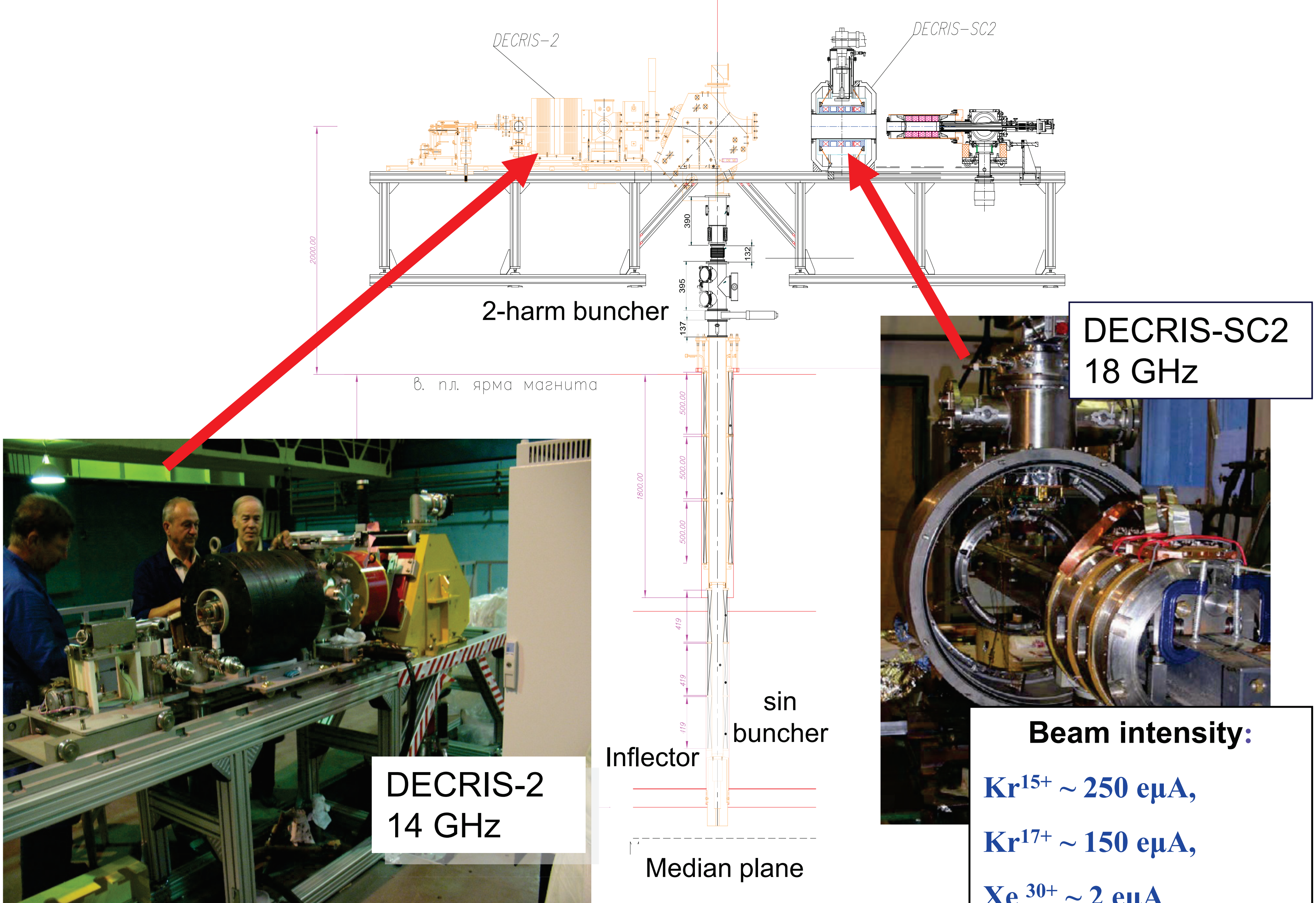


U400M E=15 ÷ 60 MeV/A E=4.5 ÷ 9 MeV/A		
Ion	**Ion energy [MeV/A]**	**Output intensity [pps]**
^{7}Li	35	6×10^{13}
^{18}O	33	1×10^{13}
^{40}Ar	40	1×10^{12}
^{48}Ca	5	3×10^{12}
^{58}Fe	5	1×10^{12}
^{124}Sn	5	2×10^{11}
^{136}Xe	5	4×10^{11}
^{132}Xe	25	3×10^{5}
^{238}Bi	5	3×10^{8}
^{238}Bi	15	1×10^{5}

Main tasks:

- *Producing of RIBs.*
- *Reactions with exotic nuclei;*
- *Properties and structure of light exotic nuclei.*

U-400M. Ion sources and axial injection system



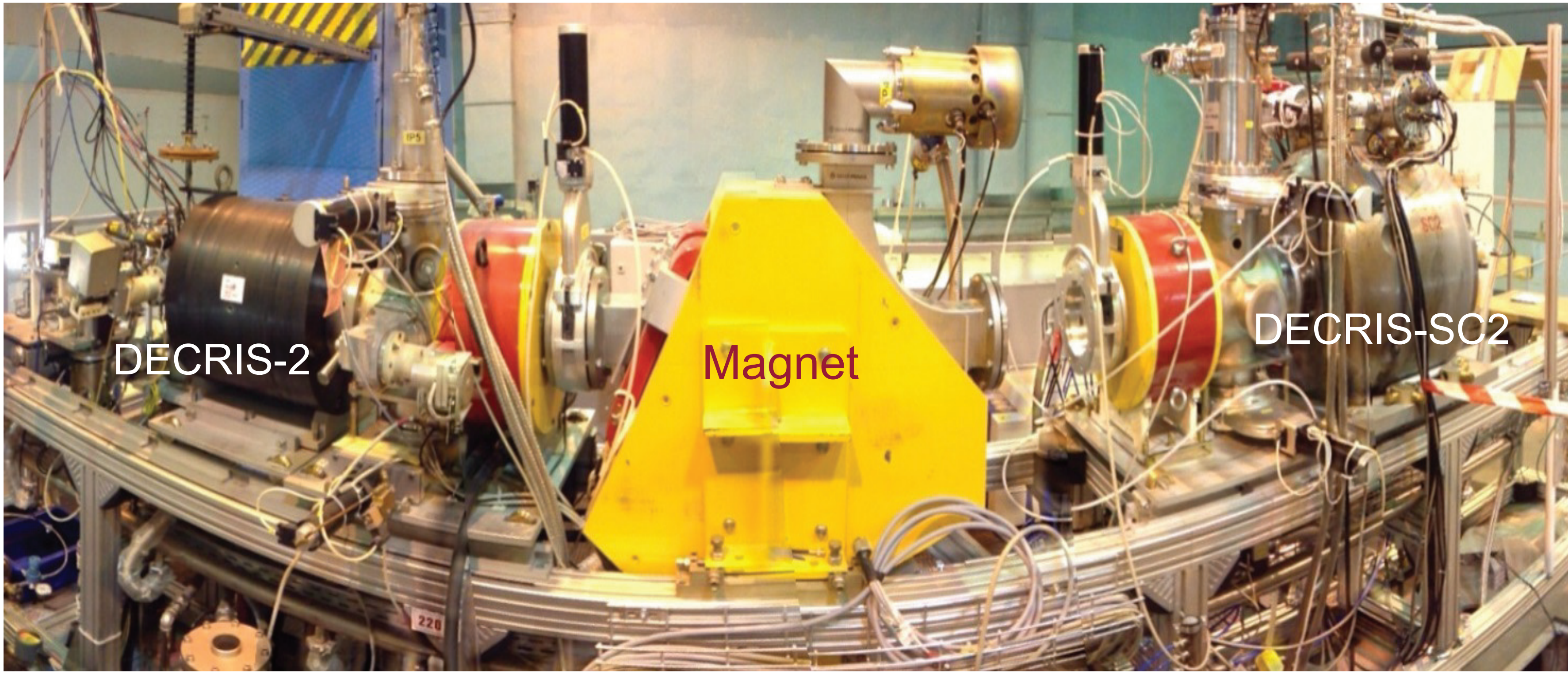
Beam intensity:

Kr^{15+} ~ 250 eμA,

Kr^{17+} ~ 150 eμA,

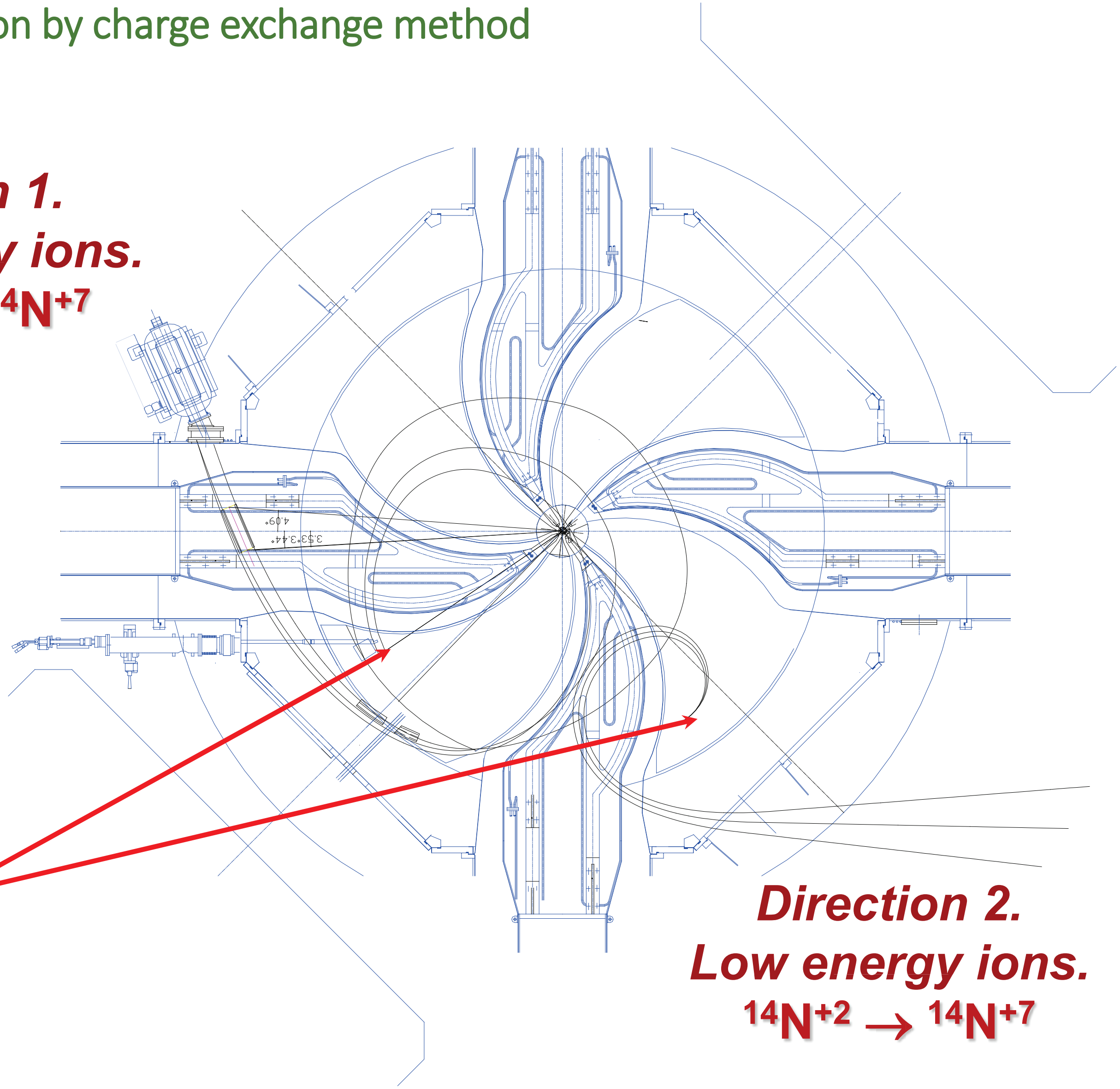
Xe^{30+} ~ 2 eμA

Ion sources of U-400M cyclotron DECRIS-2 (14 GHz) и DECRIS-SC2 (18 GHz)



U-400M. Ion beam extraction by charge exchange method

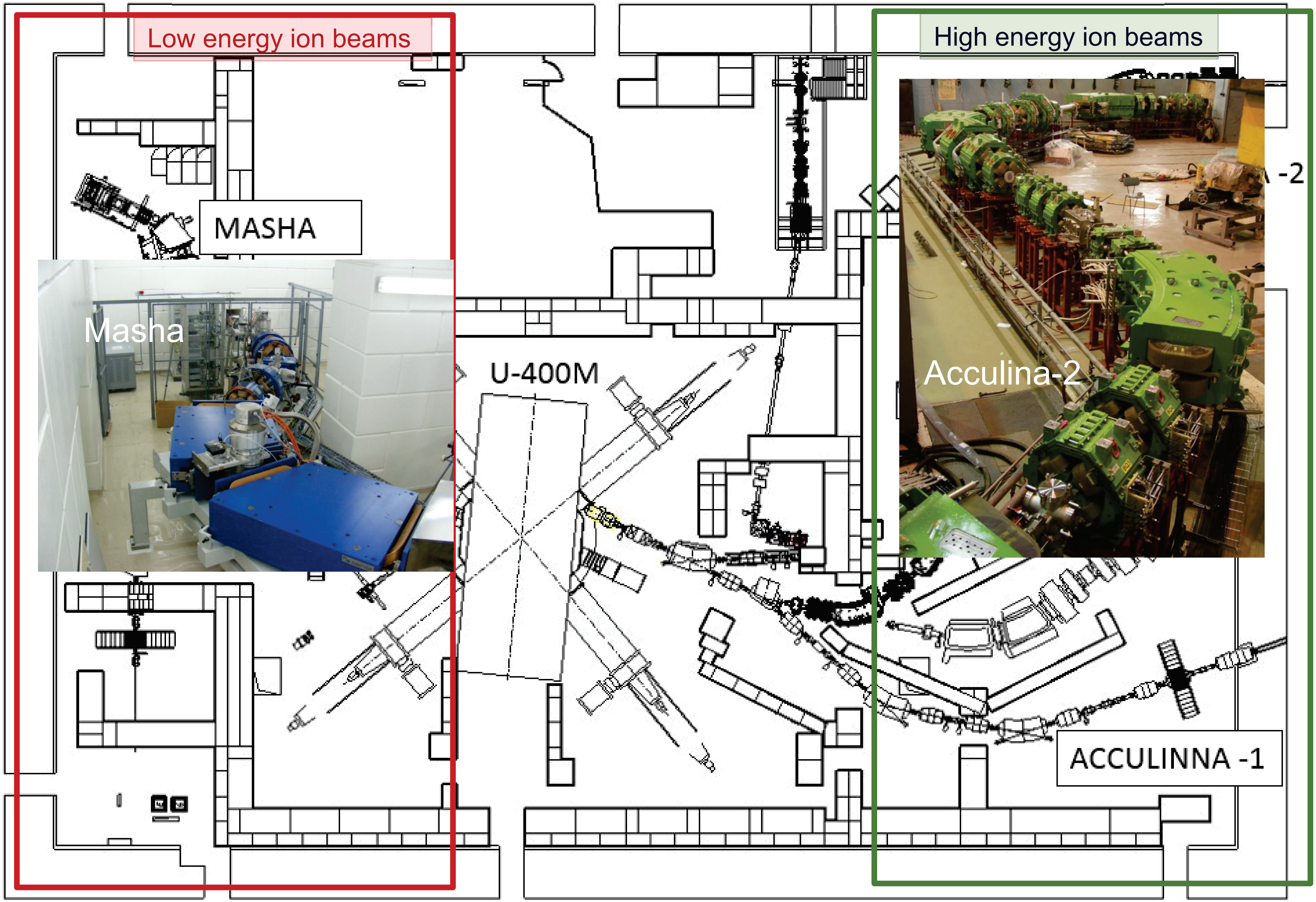
Direction 1.
High energy ions.
$^{14}N^{+5} \rightarrow {}^{14}N^{+7}$



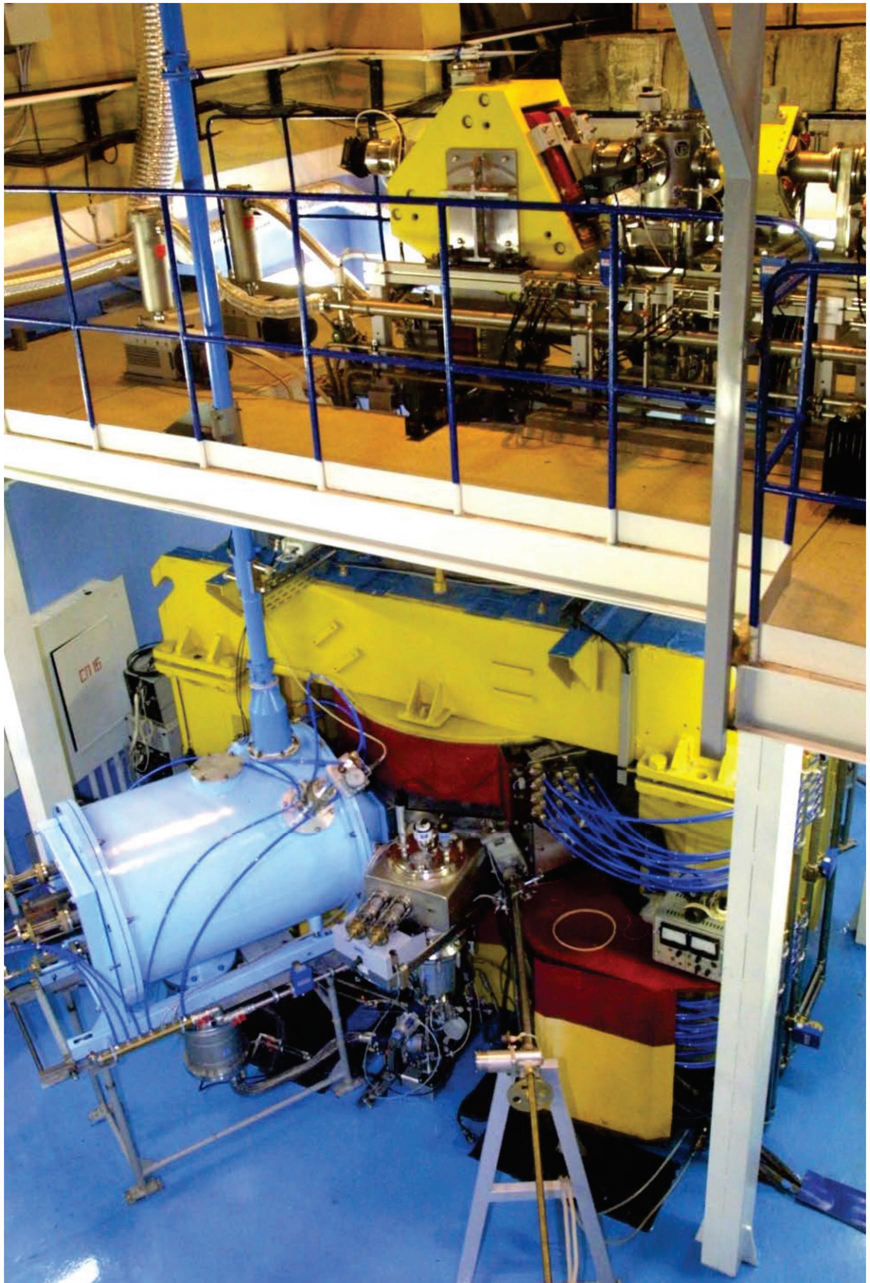
Thickness of stripping foils
20 ÷ 200 μg/cm²

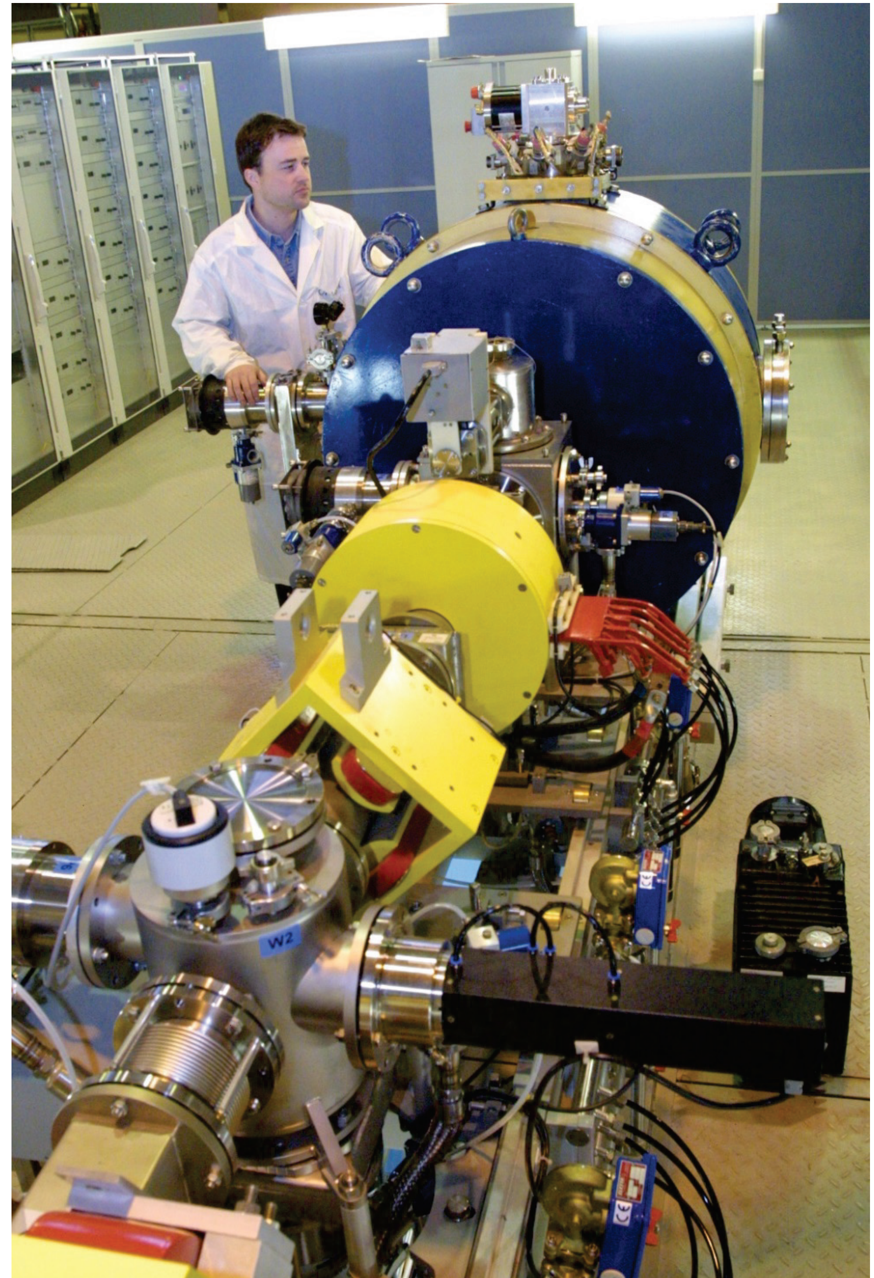
Direction 2.
Low energy ions.
$^{14}N^{+2} \rightarrow {}^{14}N^{+7}$

Experimental setups at U-400M



IC-100 cyclotron after reconstruction (2001-2002)





Parameters of the IC-100 cyclotron

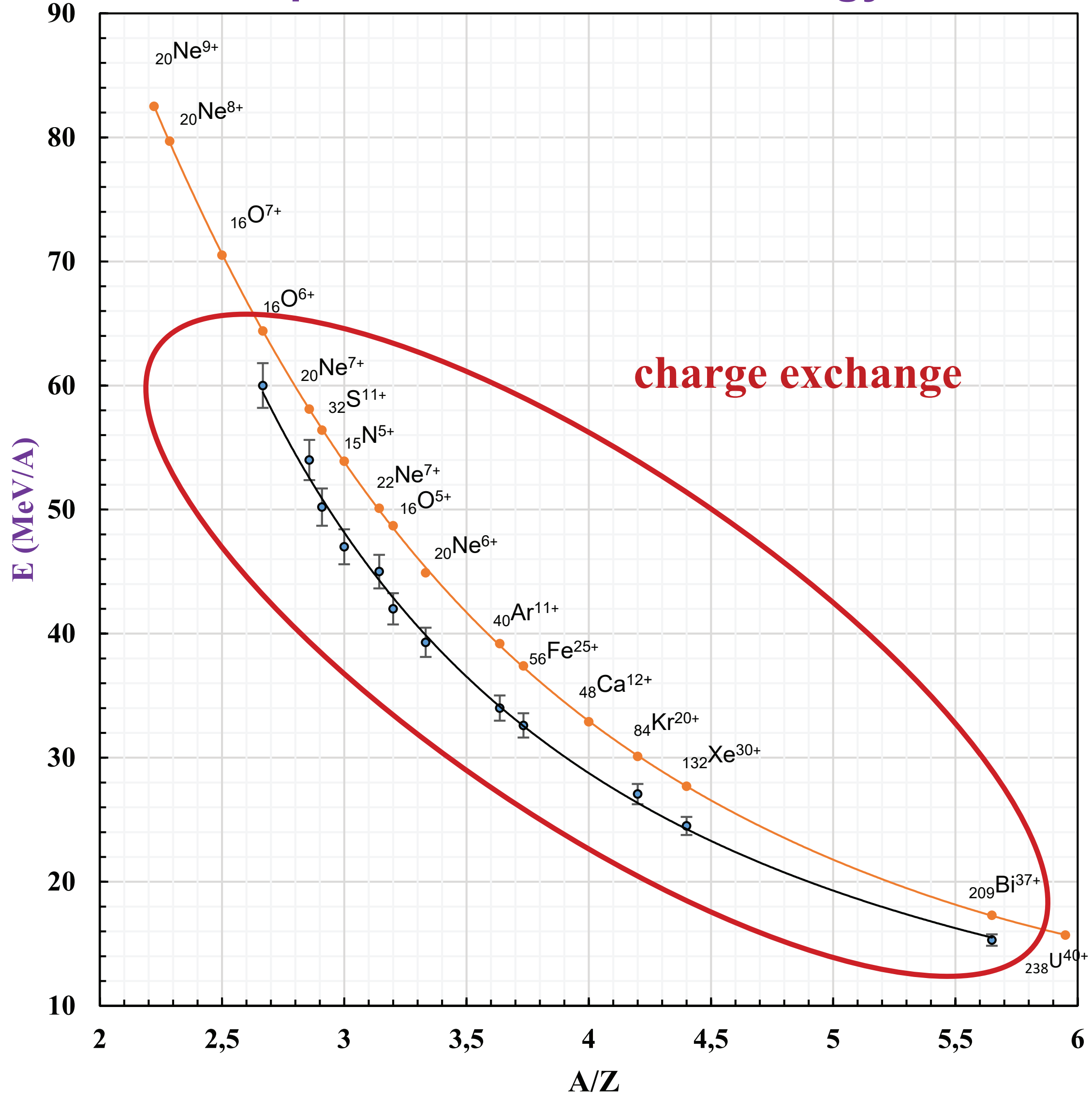
1	Ion source	**DECRIS-SC**
2	Accelerated ions	$^{22}Ne^{+4}$ $^{40}Ar^{+7}$ $^{56}Fe^{+10}$ $^{86}Kr^{+15}$ $^{127}I^{+22}$ $^{132}Xe^{+23}$ $^{132}Xe^{+24}$ $^{182}W^{+32}$ $^{184}W^{+31}$ $^{184}W^{+32}$
3	Mass-to-charge ratio of accelerated ions	$A/Z = 5.5 \div 5.95$
4	Ion energy	**0.9 ÷ 1.2 MeV/A**
5	Diameter of the magnet pole	1 m
6	Average magnetic field	1.78 ÷1.93 T
7	Frequency of the RF system	19.8 ÷ 20.6 MHz
8	Injection energy	14÷15 kV
9	Working vacuum in cyclotron	$5 \cdot 10^{-8}$ Torr
10	Voltage on the dees	45÷55 kV
11	Intensity of the accelerated and extracted beam of $^{86}Kr^{15+}$	$1.4 \cdot 10^{12}$ pps (3.5 μA)
12	Intensity of the accelerated and extracted beam of $^{132}Xe^{23+}$	~ 10^{12} pps (3.7 μA)

The main tasks of the FLNR for 2018–2023 are:

1. **Commissioning of "SHE Factory" based on the DC-280** cyclotron (design parameters and energies of beams; attaining maximum beam intensity up to 10 pμA for nuclei with A~50; development of infrastructure; first experiments); (2018-2019)
2. **Modernization of the U-400M** cyclotron (replacement of the main coils of the cyclotron magnet; correction of the first harmonic of magnetic field; replacement of vacuum pumping diffusion pumps to cryopumps; modernization of RF- resonators; modernization of RF control system- analog to digital LLRF; increasing intensities and energies of ion beams); (2019-2020)
3. **Reconstruction of the U-400** cyclotron (extension of the range of accelerated ions from helium to uranium with energies smoothly varying within a wide range 0.8–25 MeV·A; improve of the quality and intensity of stable and radioactive beams (^{48}Ca – 2.5 pμA); decreasing the total cyclotron power consumption from 1 to 0.25 MW) and building of a new experimental hall ; (2020-2023)
4. **Development of long-running experimental set-ups.**

Modernization of the U400-M cyclotron

Prospects of increase in energy and intensity of extracted ions



Dependence of energy of extracted ions on A/Z

Estimation

Ион	A/Z	Current from DECRIS-2M DECRIS-SC2 (18 GHz) μA	Extracted current μA (10% of injected current)	Extracted current pμA
$_{20}Ne^{9+}$	2.222	10	1	0.11
$_{16}O^{7+}$	2.2857	20	2	0.28
$_{20}Ne^{8+}$	2.5	70	7	0.875
$_{16}O^{6+}$	2.667	200	20	3.3
$_{20}Ne^{7+}$	2.857	100	10	1.43
$_{32}S^{11+}$	2.909	12	1.2	0.11
$_{40}Ar^{11+}$	3.636	65	6.5	0.59
$_{11}B^{3+}$	3.6667	180	18	6
$_{84}Kr^{20+}$	4.2	~ 10	1	0.05
$_{22}Ne^{5+}$	4.4	~ 200	20	4
$_{132}Xe^{30+}$	4.4	~ 1	0.1	0.003
$_{132}Xe^{24+}$	5.5	~ 50	5	0.21
$_{56}Fe^{10+}$	5.6	~ 40	4	0.4
$_{209}Bi^{37+}$	5.649	~ 4	0.4	0.011
$_{40}Ar^{7+}$	5.7143	~ 150	15	2.14
$_{132}Xe^{23+}$	5.7391	~ 50	5	0.22

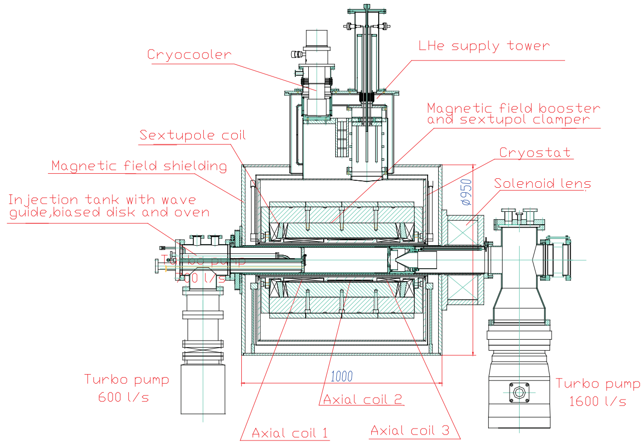
Extraction by electrostatic deflector

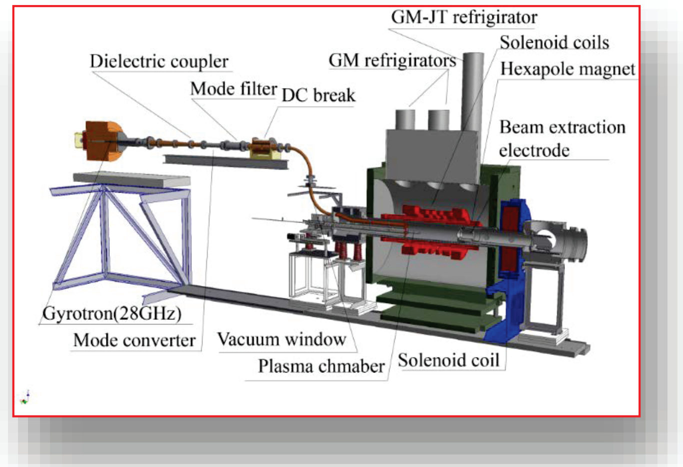
- **Extraction by charge exchange (existing U-400M)**
- **Extraction by electrostatic deflector (R_{out}=1.78 m), after magnetic field correction**

Intensities of accelerated ions are determined by cyclotron transmission factor and ion source currents (I^q). As $I^q \propto \omega^2_{ECR}$ (*1987* R. Geller) the new ECR ion source with ω_{ECR}=24÷28 GHz could be used for the U-400M.

28 GHZ ECR sources in the world:

SUSI – **Michigan State University (MSU), USA**; VENUS – **Lawrence Berkeley National Laboratory (LBNL), USA**; SC-ECRIS– **RIKEN, Japan**; SECRAL – **Institute of Modern Physics (IMP), Lanzhou, China**;





Ion	O^{6+}	O^{7+}	Ar^{12+}	Ar^{16+}	Ar^{17+}	Ca^{12+}	Ca^{14+}	Xe^{30+}	Bi^{30+}	Bi^{41+}	U^{36+}	U^{40+}
I, eμA	3000	1400	1400	350	50	670	270	320	710	100	150	20

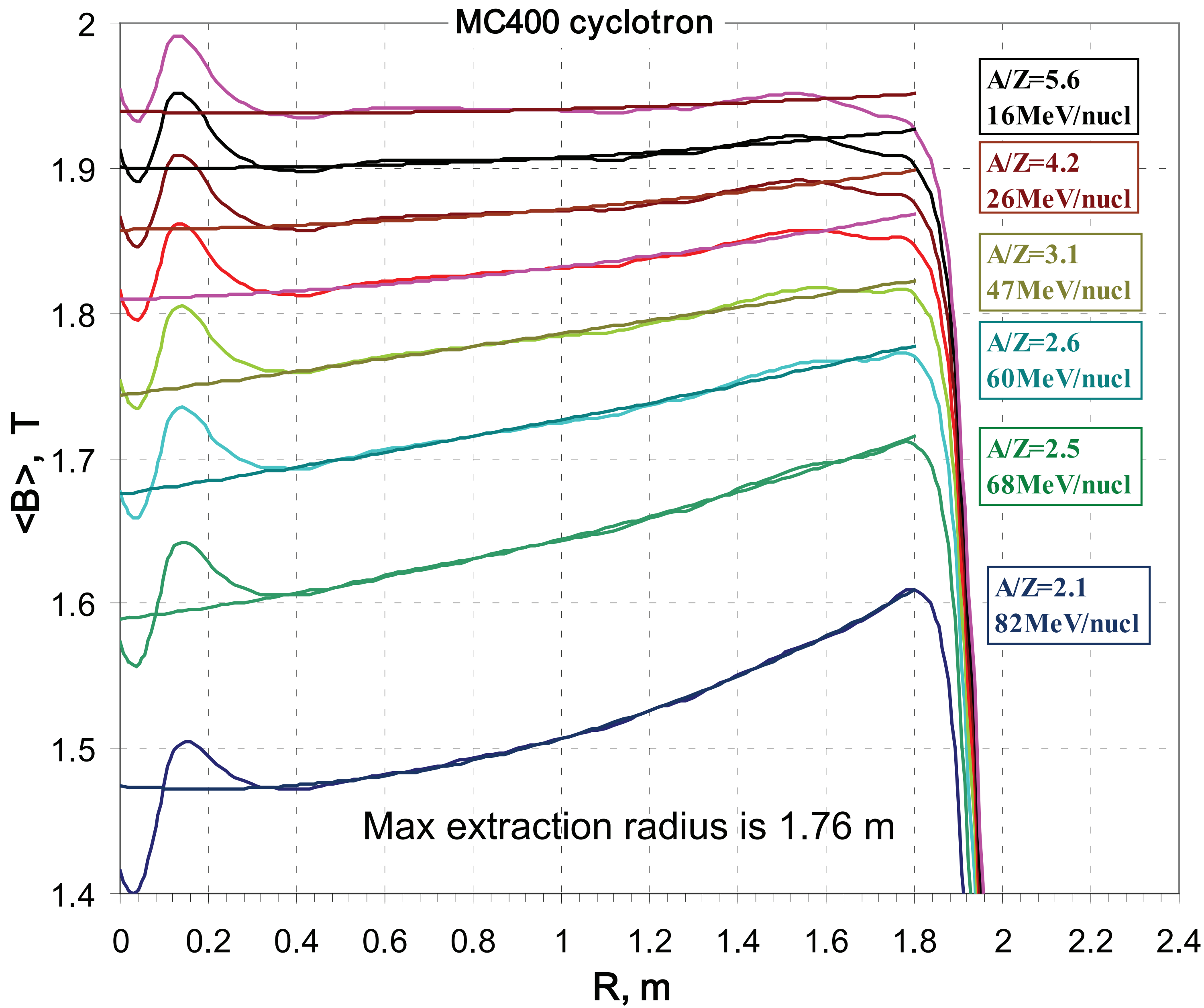
P_{UHF} = 5 ÷ 10 kW (28 GHz or 28 + 18 GHz)

The 3rd generation ECRIS development demonstrates :

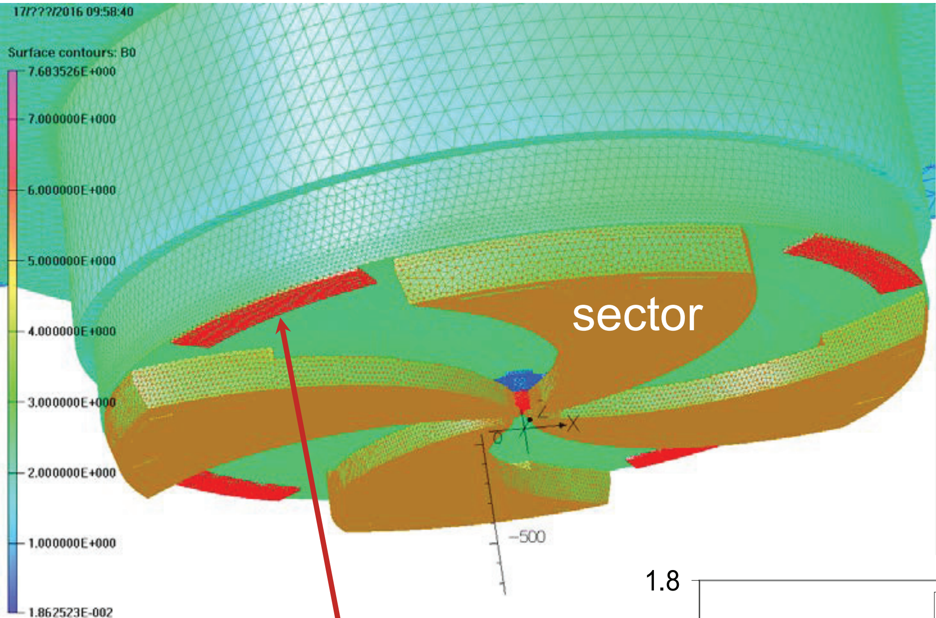
- **Big technical challenge**
- **High cost (5-6 M$)**
- **Very long time for R&D (10 years from R&D to High performance)**
- **Big risk (Could fail completely)**
- **But amazing performance and exciting results**

L. T. Sun, ECRIS2014,

Distribution of average magnetic field along the U-400M radius



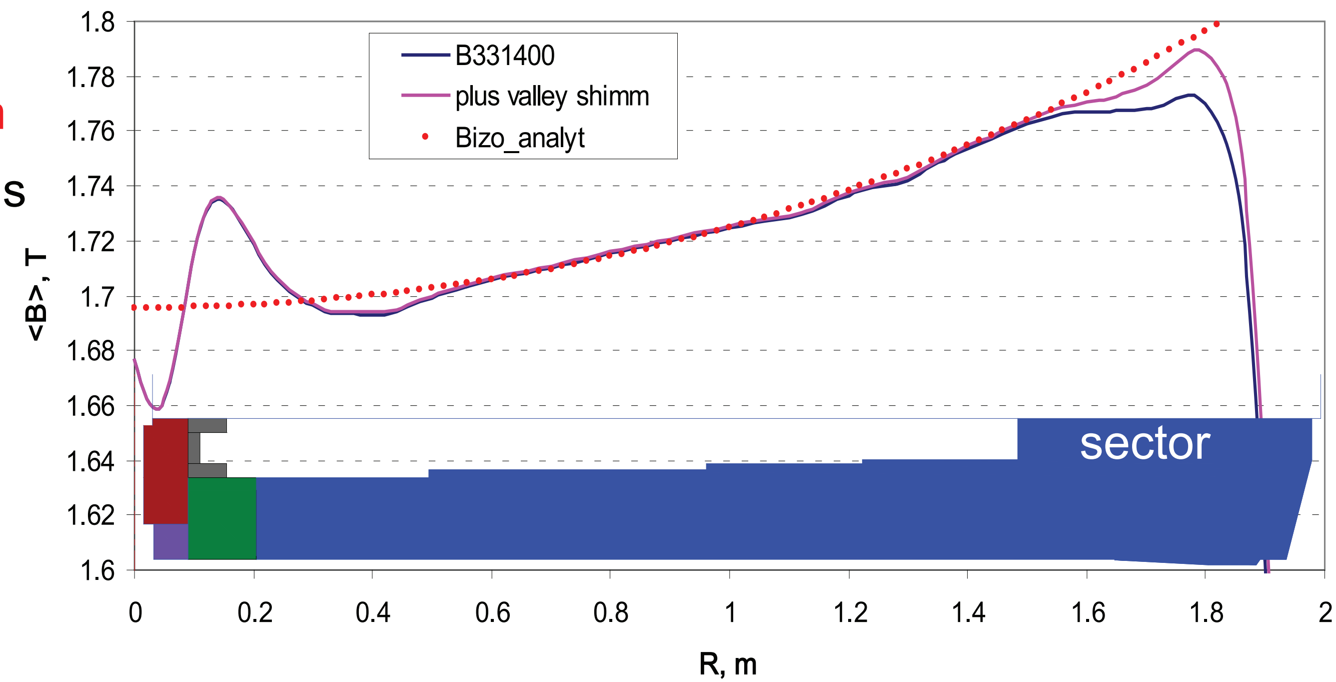
Cyclotron magnetic structure with additional shimming



Additional valley shim

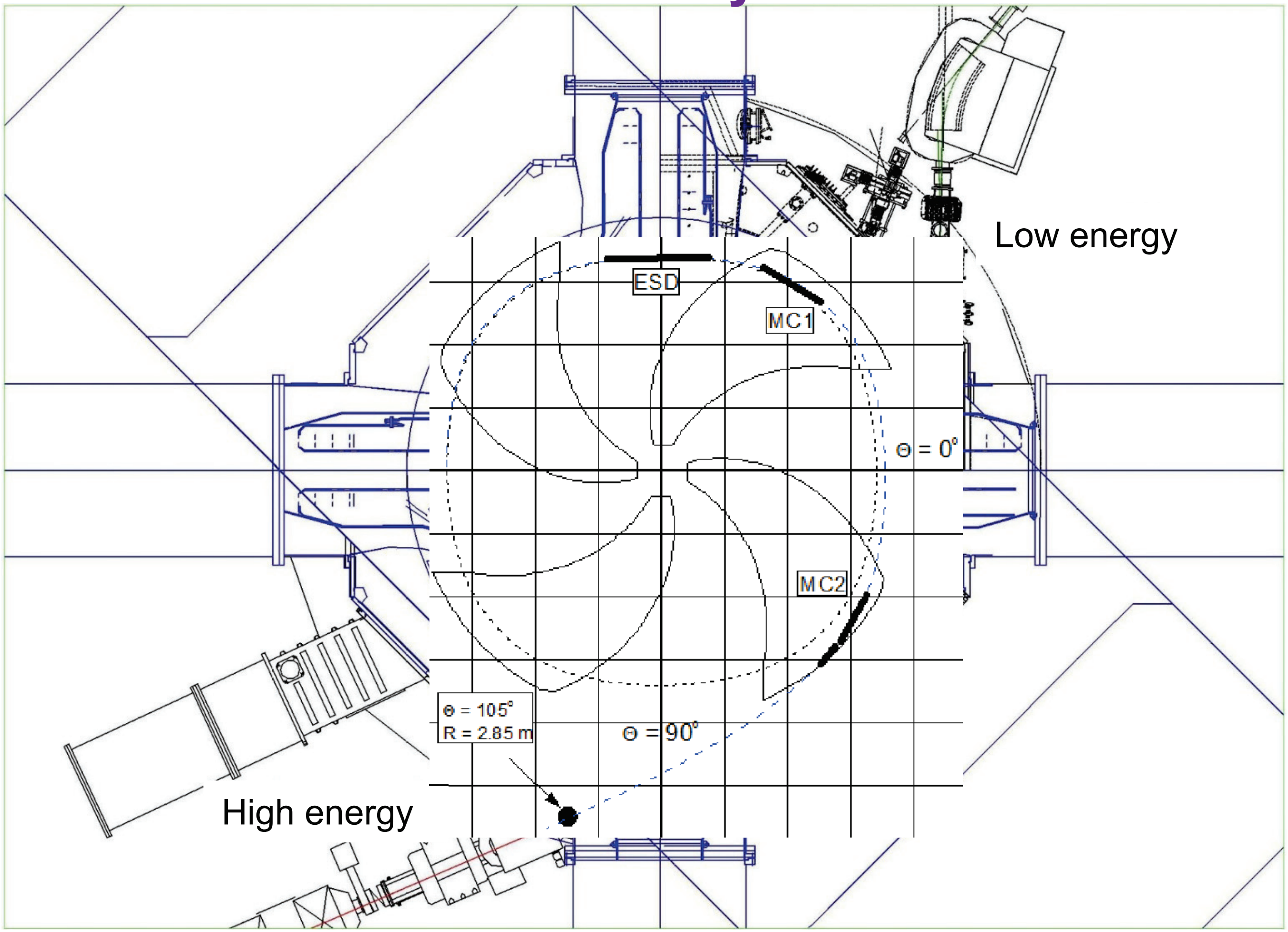
Tosca model with 4 shims arranged in valley

Using valley shims for magnetic field correction allows to increase the average extraction radius on about 2 cm (from 1.76 m to 1.78 m)



Estimation of valley shims influence at measured magnetic field (magenta). Dots- isochronous field. Red line- resulting field after shimming.

Extraction system



Deflector parameters:

L≈80 cм, aperture ΔX=0.8 cm

U_{max}=59 kV (E=74 kV/cm)

Modernization of the U-400 cyclotron (U-400R project)

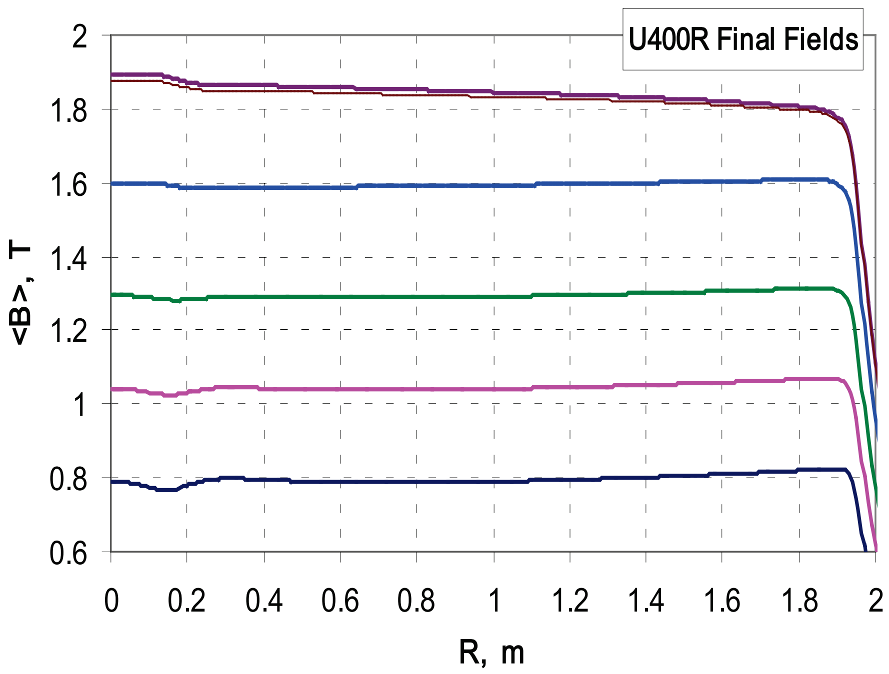
The project of the U-400 cyclotron modernization was developed.
The upgrade will be performed after the DC-280 cyclotron commission

MAIN PURPOSE

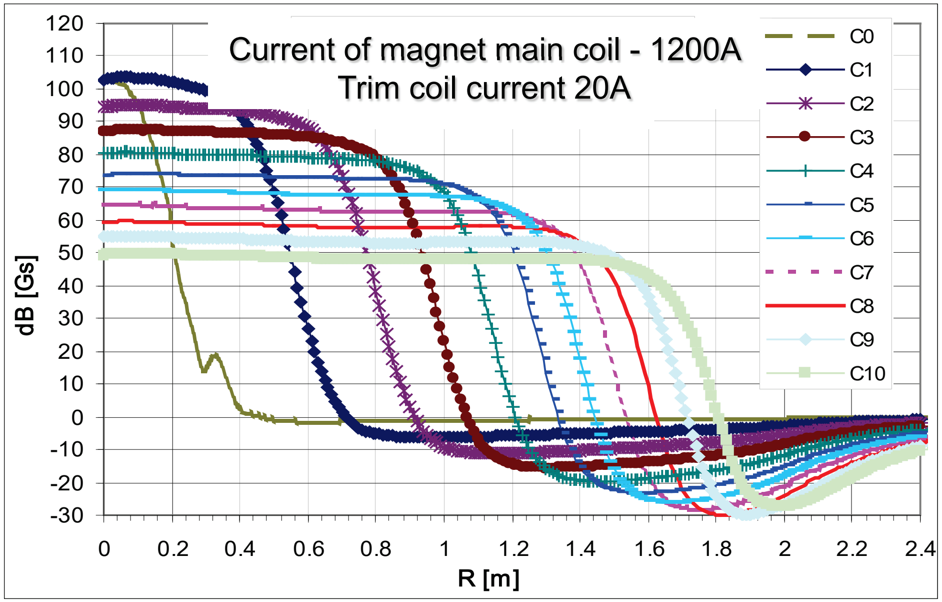
- **Improvement of the quality and intensity of stable and radioactive beams (^{48}Ca – 2.5÷3 pμA),**
- **Providing a smooth variation of ion energy in the range of 0.8 – 27 MeV/A,**
- **Decrease the consumption of rare isotopes,**
- **Decrease the total cyclotron power consumption from 1 to 0.25 MW.**

TABLE 1	U400	U400R
Parameters	Value/Name	
Electrical power of magnet power supply system	850 kW	200 kW
The magnetic field level in the magnet center	1.93÷2.1 T	0.8÷1.8 T
The hill angular width at the external radius	42°	43.7°
The hill gap at the external radius	42 mm	56 mm
The valley gap	300 mm	300 mm
The number of trim coils	8, radial 1, azimutal	14, radial 4, azimutal
The number of dees	2	2
The dee voltage (amplitude)	80 kV	80 kV
The A/Z range	5÷12	4÷12
The frequency range	5.42÷12.2 MHz	5.42÷12.2 MHz
Harmonic modes	2	2÷6
The ultimate extraction radius	1.72 m	1.8 m
K- factor	305÷625	100÷506
Vacuum level	$(1\div5)\cdot10^{-7}$ Torr	$(1\div2)\cdot10^{-7}$ Torr
Ion injection method	Axial with spiral inflector	Axial with spiral inflector
Ion extraction method	Stripping foil	Stripping foil Deflector
Number of directions for ion extraction	2	2

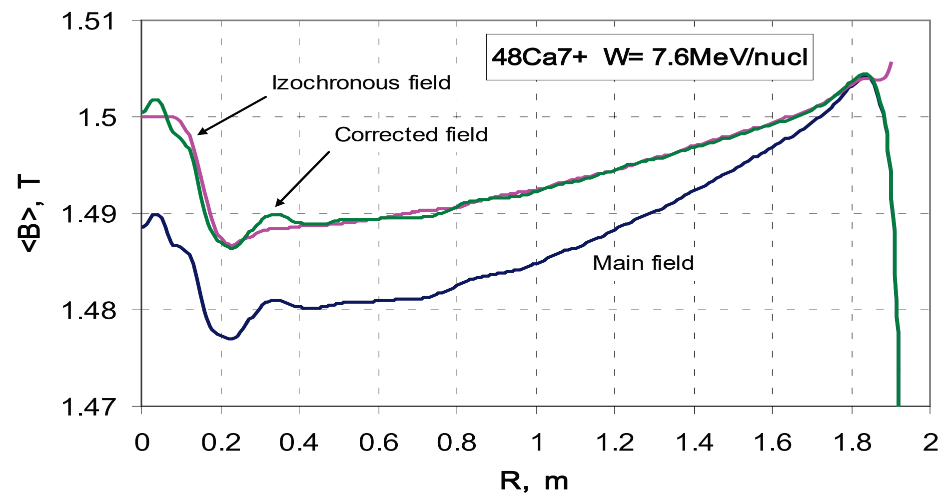
U400 → U400R



Radial Distribution of Average Magnetic Field without Trim Coil's Shimming



Radial Distribution of Magnetic Field of Trim Coils



Formation of Isochronous Magnetic Field

Parameters of U400 and U400R typical ions

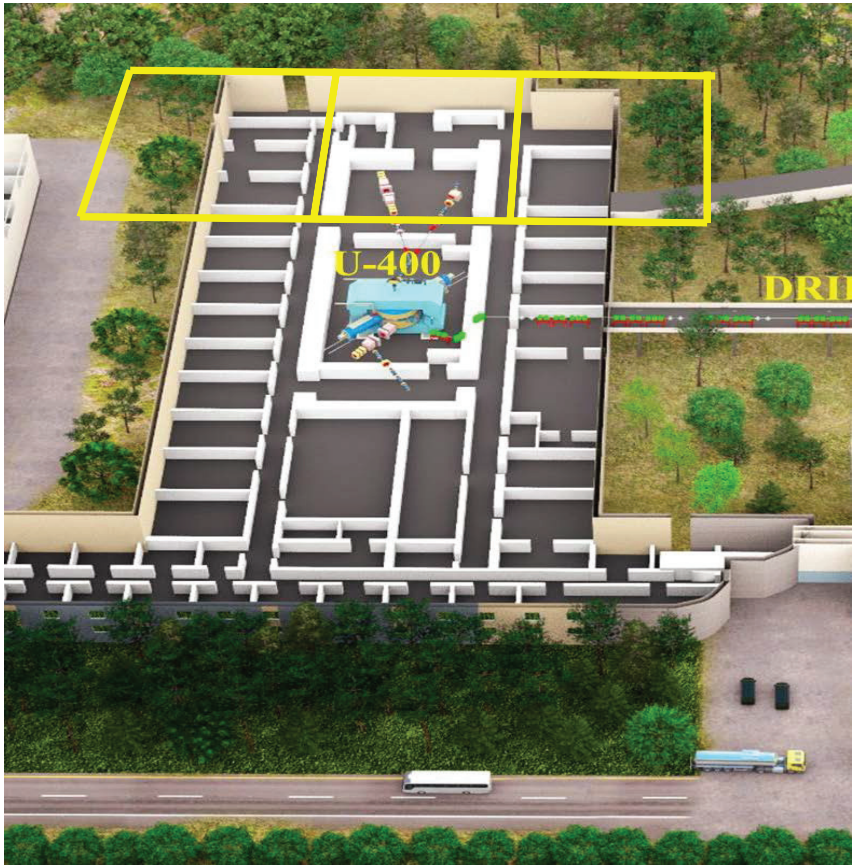
U400		
Ion	Ion energy [MeV/u]	Output intensity
$^{4}He^{1+}$	-	-
$^{6}He^{1+}$	11	$3 \cdot 10^{7}$ pps
$^{8}He^{1+}$	7.9	-
$^{16}O^{2+}$	5.7; 7.9	5 pμA
$^{18}O^{3+}$	7.8; 10.5; 15.8	4.4 pμA
$^{40}Ar^{4+}$	3.8; 5.1 *	1.7 pμA
$^{48}Ca^{5+}$	3.7; 5.3 *	1.2 pμA
$^{48}Ca^{9+}$	8.9; 11; 17.7 *	1 pμA
$^{50}Ti^{5+}$	3.6; 5.1 *	0.4 pμA
$^{58}Fe^{6+}$	3.8; 5.4 *	0.7 pμA
$^{84}Kr^{8+}$	3.1; 4.4 *	0.3 pμA
$^{136}Xe^{14+}$	3.3; 4.6; 6.9 *	0.08 pμA

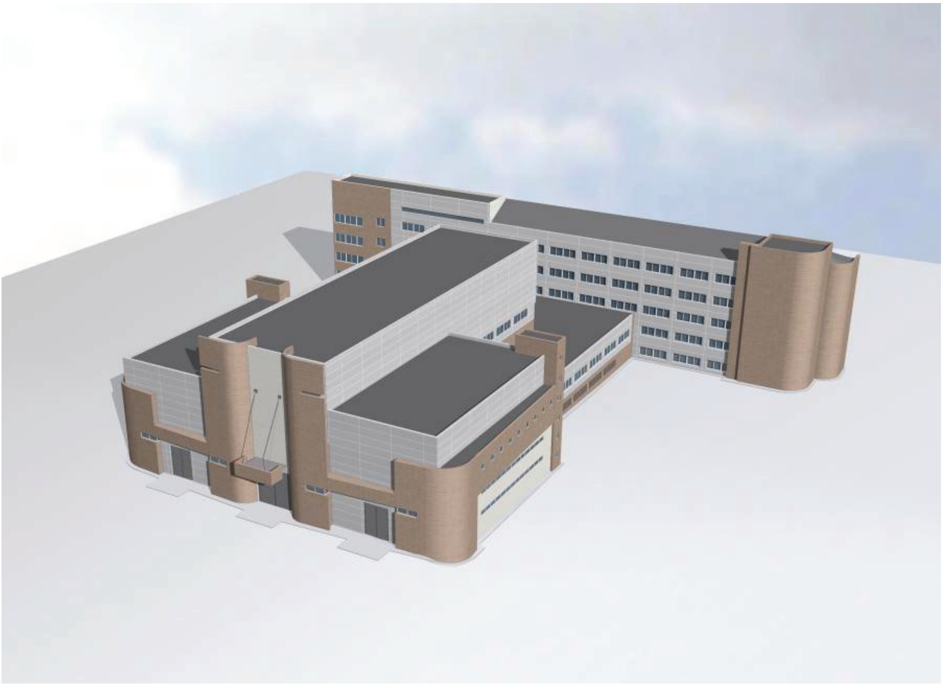
* Fixed ion energy of extracted beam

U400R (expected)		
Ion	Ion energy [MeV/u]	Output intensity
$^{4}He^{1+}$	6.4 ÷ 27	23 pμA
$^{6}He^{1+}$	2.8 ÷ 14.4	10^{8} pps
$^{8}He^{1+}$	1.6 ÷ 8	10^{5} pps
$^{16}O^{2+}$	1.6 ÷ 8	19.5 pμA
$^{16}O^{4+}$	6.4 ÷ 27	5.8 pμA
$^{40}Ar^{4+}$	1 ÷ 5.1	4 pμA
$^{48}Ca^{6+}$	1.6 ÷ 8	2.5 pμA
$^{48}Ca^{7+}$	2.1 ÷ 11	2.1 pμA
$^{50}Ti^{10+}$	4.1 ÷ 21	1 pμA
$^{58}Fe^{7+}$	1.2 ÷ 7.5	1 pμA
$^{84}Kr^{7+}$	0.8 ÷ 3.5	1.4 pμA
$^{132}Xe^{11+}$	0.8 ÷ 3.5	0.9 pμA

* Smooth variation ion energy of extracted beam

Reconstruction of the U-400 cyclotron experimental hall



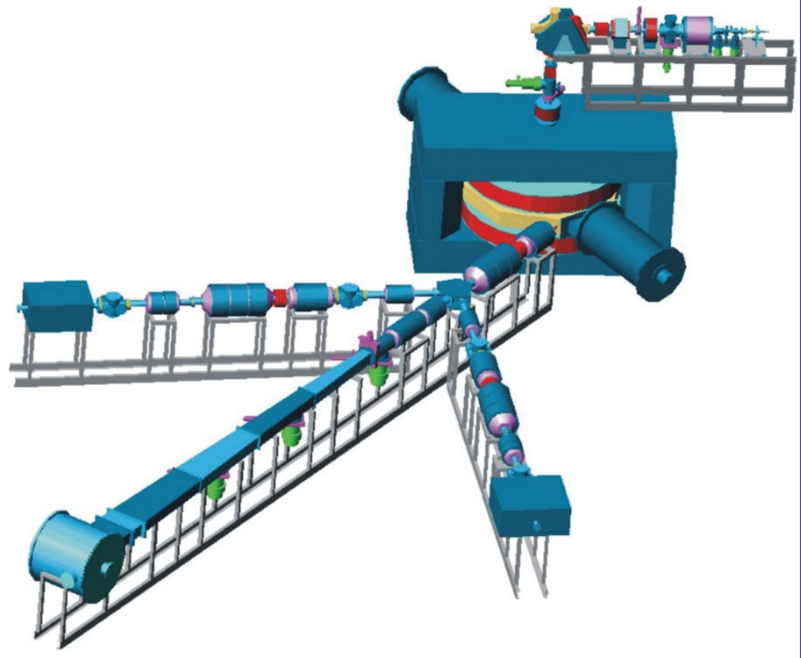


U-200 Cyclotron

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

The programme of applied research that is performed at the FLNR cyclotron IC-100, U-400, U-400M takes approximately 6000 hours of accelerator operation.

Main tasks for DC-130:
- research in the field of solid state physics,
- production of track membranes,
- See testing of electronic components,

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.

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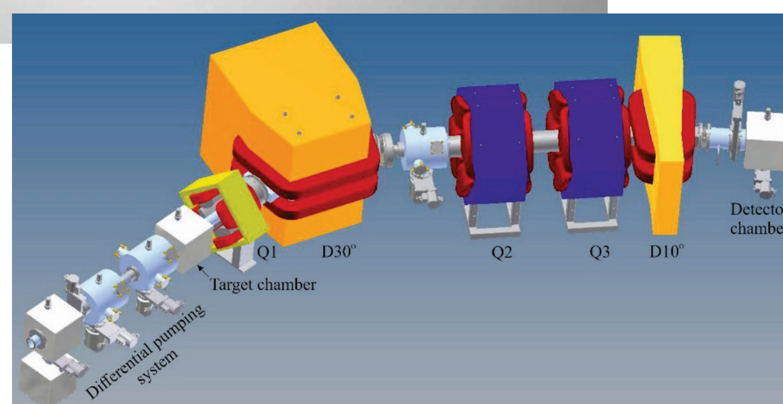
Factory of Super Heavy Elements (SHE)

SHE Factory Building

High-current cyclotron DC-280



New facilities:
- New gas-filled separator
- Preseparator
- SHELS
- Etc.

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.**

DC-280 CYCLOTRON- THE NEW FLNR ACCELERATOR

To satisfy the Goals, the DC-280 has to provide the following parameters of ion beams:

Ion energies (smooth variation)	4÷8 MeV/n
Ion masses	10÷238
Intensities (A~50)	>10 pμA
Efficiency of beam transfer	>50%

Stand-alone SHE factory with DC-280 cyclotron

SHE factory building 2012

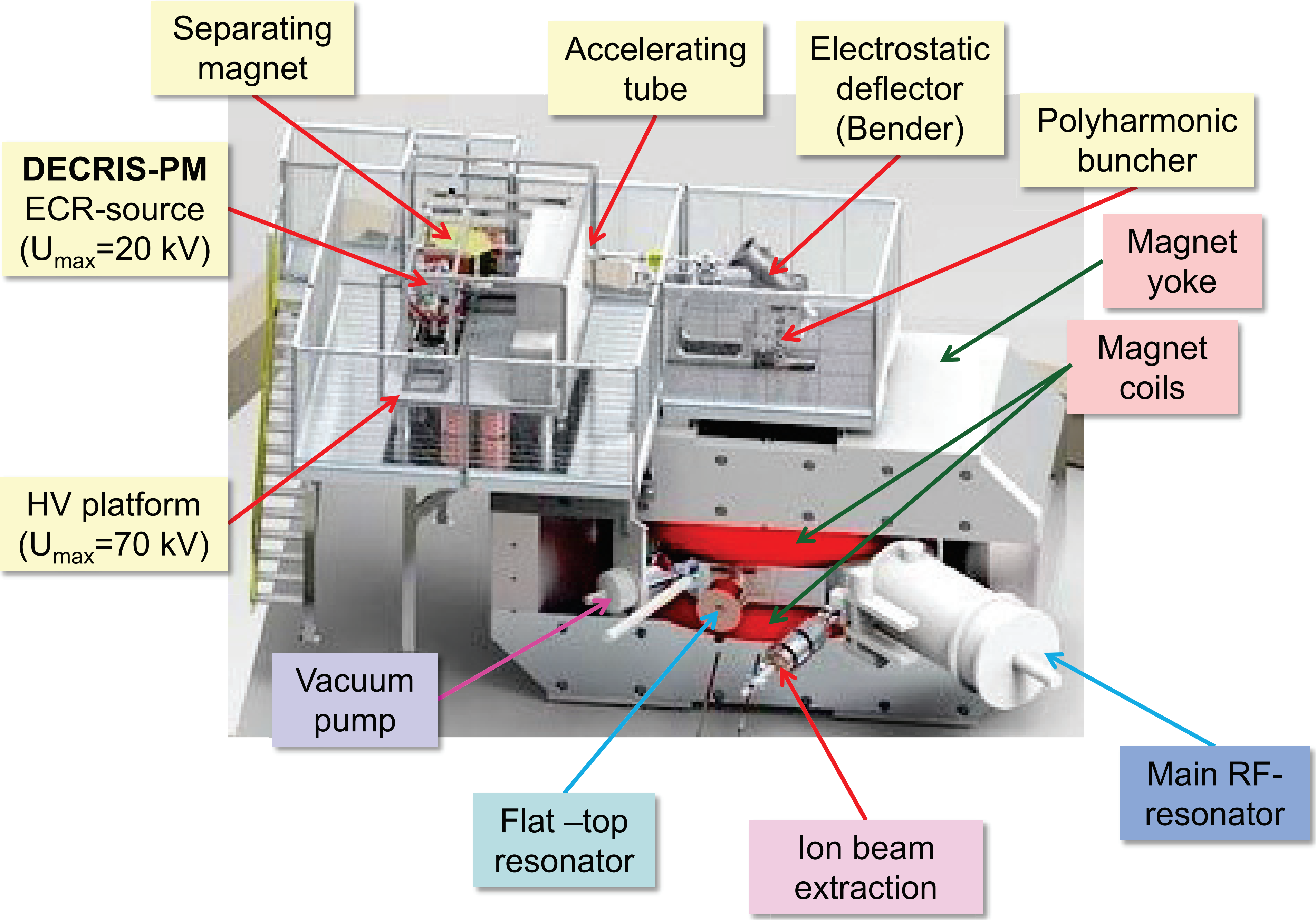
SHE factory building 2018

DC280 (expected) E=4÷8 MeV/A		
Ion	Ion energy [MeV/A]	Output intensity
^{7}Li	4	1×10^{14}
^{18}O	8	1×10^{14}
^{40}Ar	5	6×10^{13}
^{48}Ca	5	$6{,}2\times10^{13}$
^{54}Cr	5	2×10^{13}
^{58}Fe	5	1×10^{13}
^{124}Sn	5	2×10^{12}
^{136}Xe	5	1×10^{14}
^{238}U	7	5×10^{10}

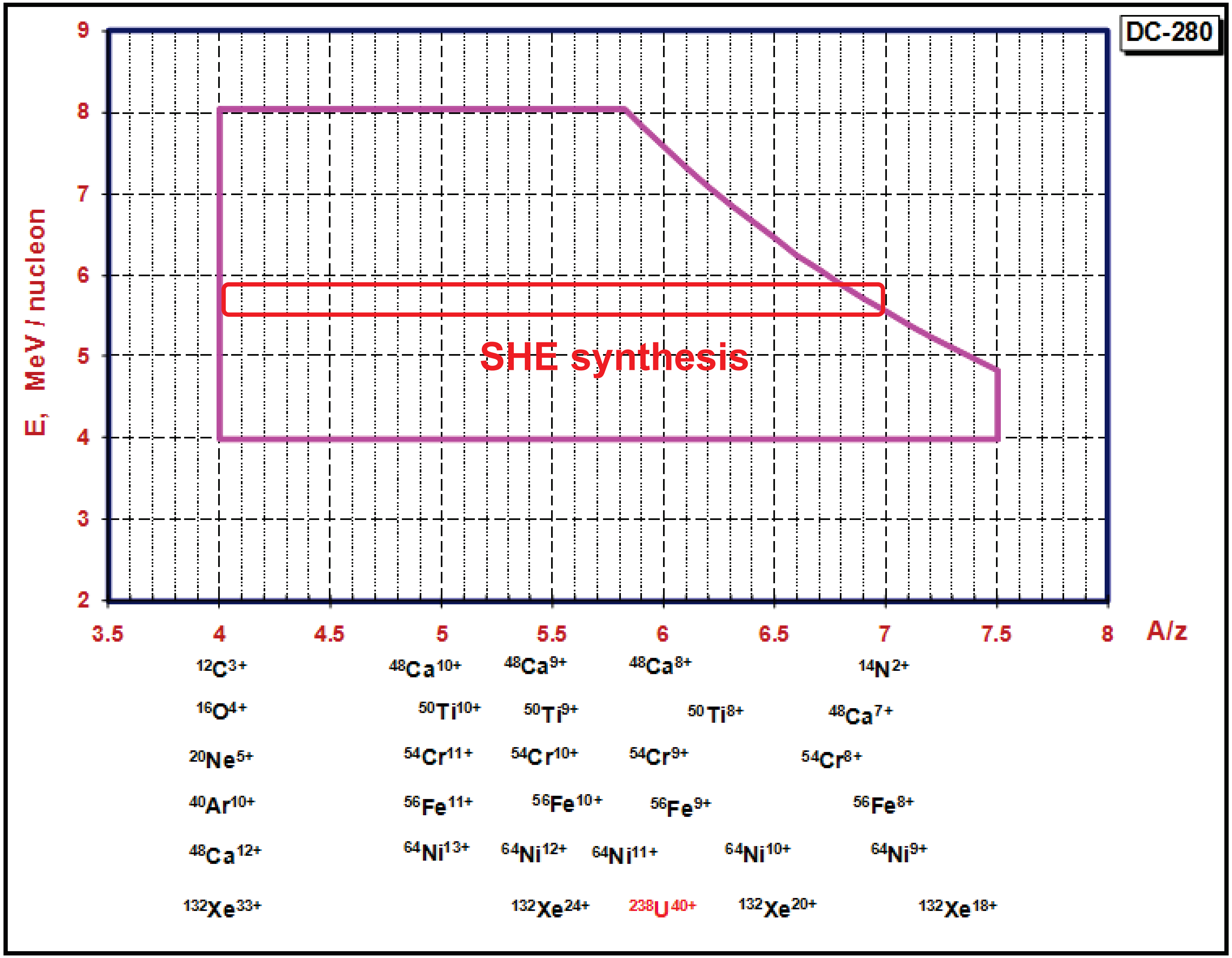
DC-280
Main Parameters

Ion sources	DECRIS-PM - 14 GHz Superconducting ECR (developing stage)
Injection energy	Up to 80 keV/Z
A/Z range	4÷7.5
Energy	4÷8 MeV/n
Magnetic field level	0.6÷1.3 T
K factor	280
Magnet weight	1000 t
Magnet power	300 kW
Dee voltage	2x130 kV
RF power consumption	2x30 kW
Flat-top dee voltage	2x14 kV
Deflector voltage	90 kV

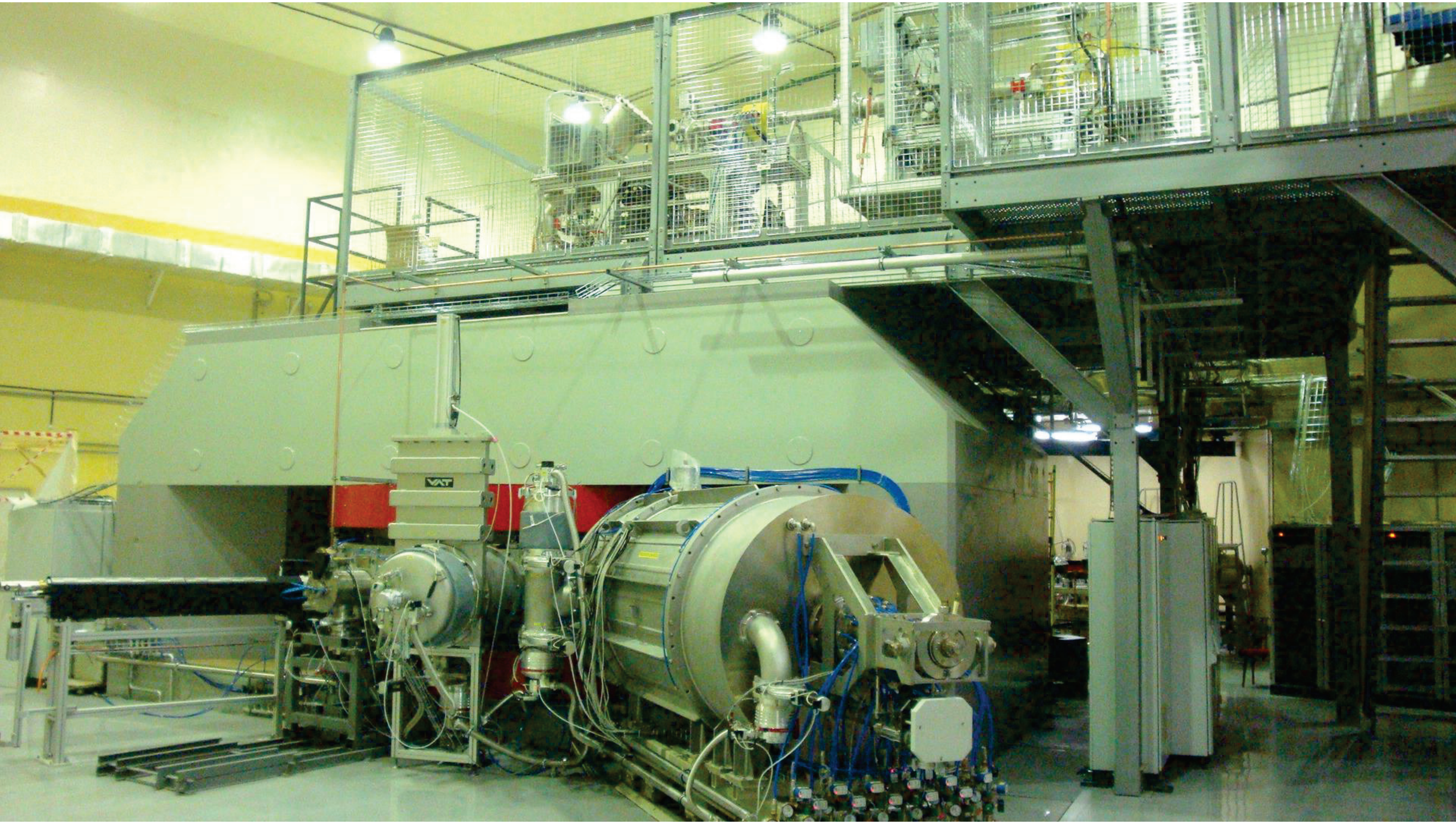
Configuration of the DC-280



Working diagram of the DC-280



DC-280 cyclotron



Main magnet was assembled in November 2016

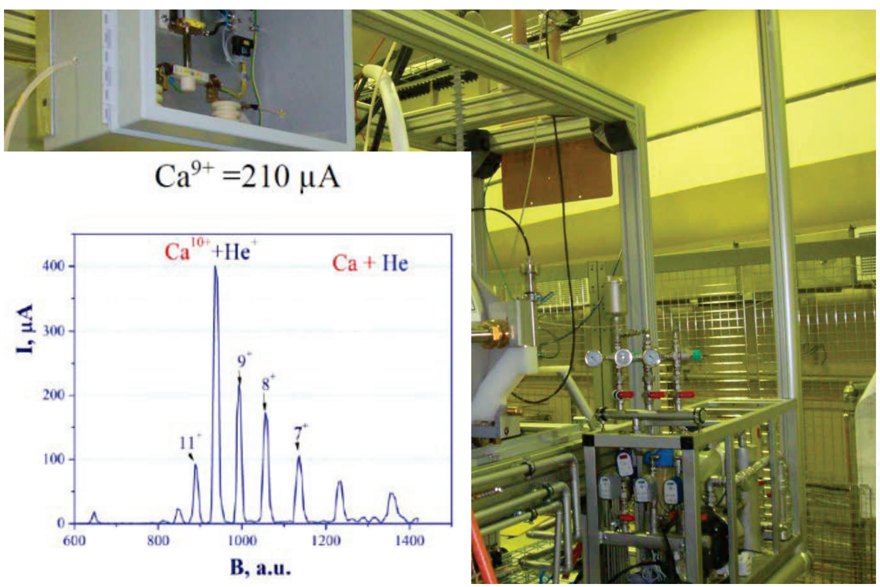
Magnetic field measurements were carried out in June-September 2017

Cyclotron systems were assembled and now they are being tested

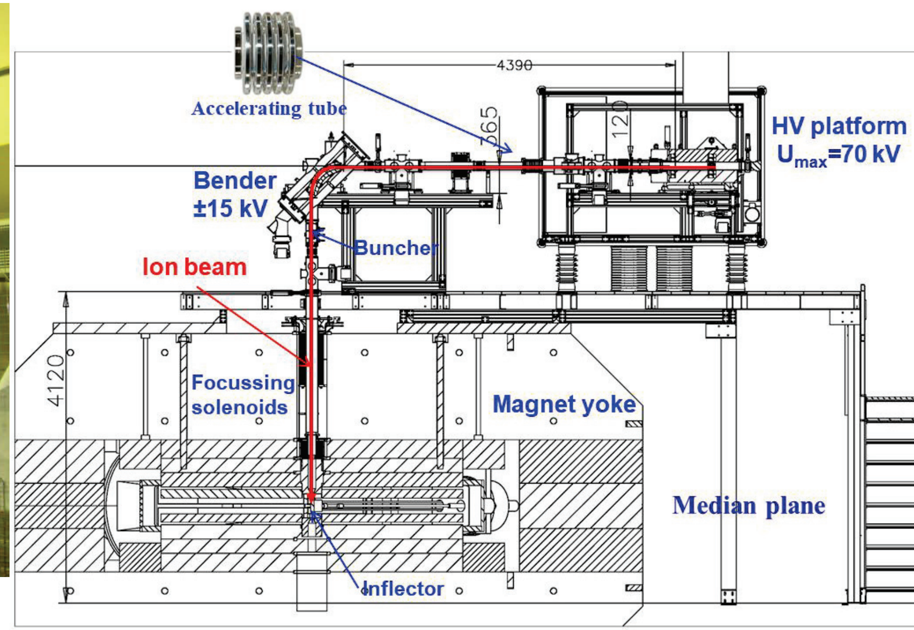
Beam injection system

The HV platform

Area of the electrostatic deflector (Bender)

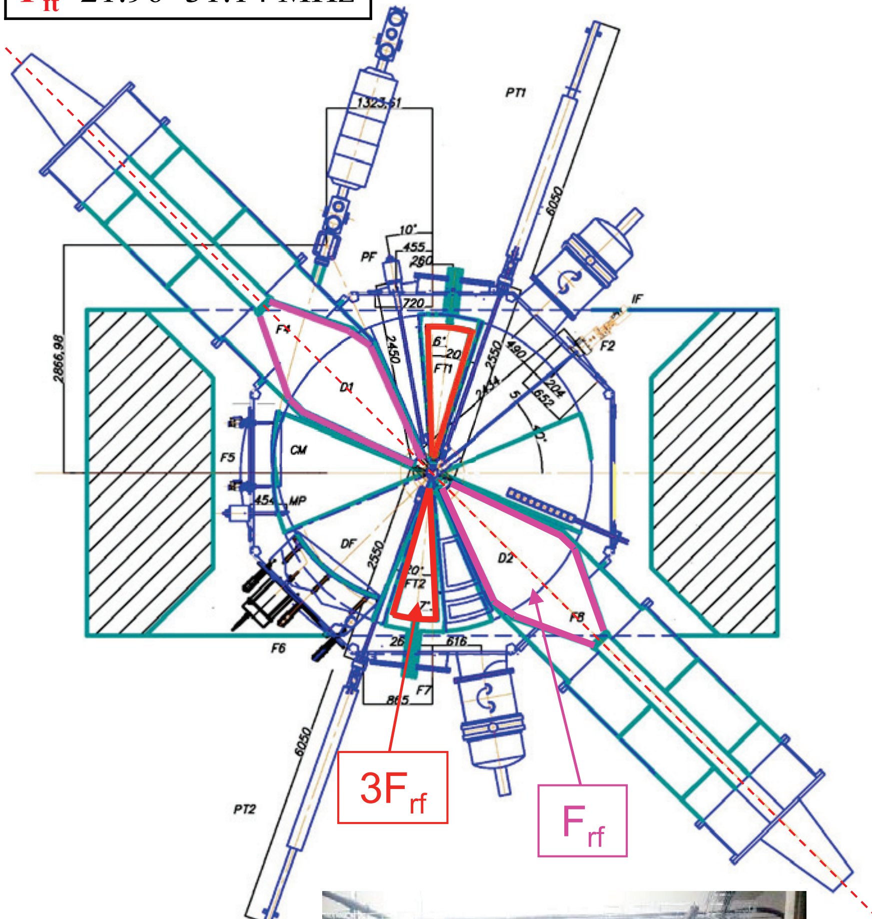


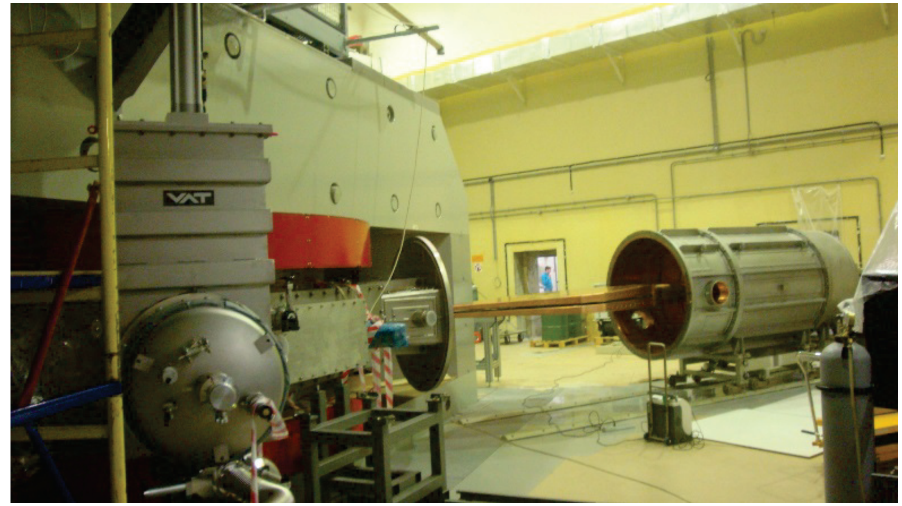
The DECRIS-PM ion source on the platform



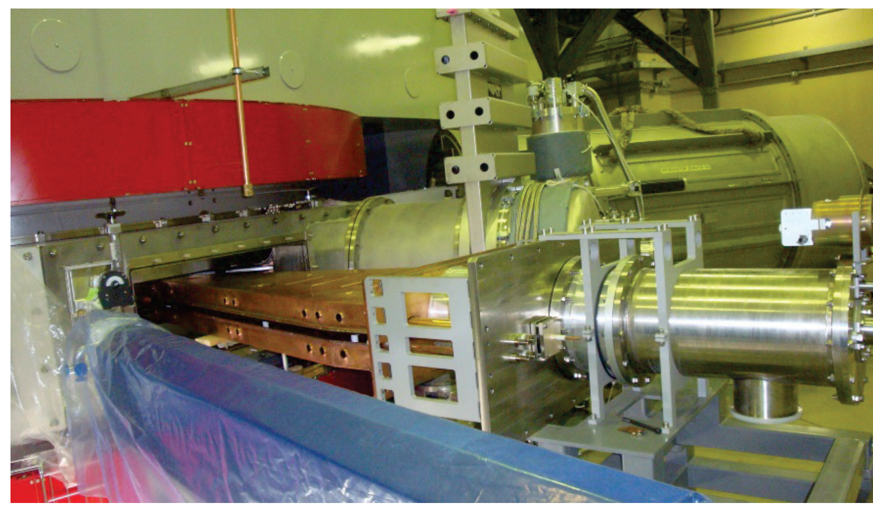
RF system

F_{rf}=7.32÷10.38 MHz	
F_{ft}=21.96÷31.14 MHz	





RF resonator with dee

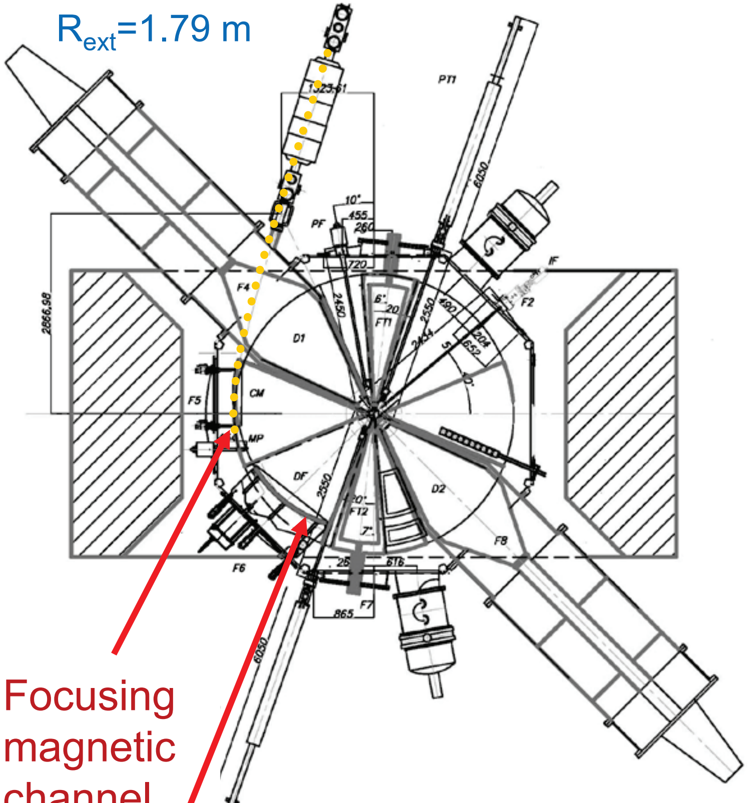


Flat-top resonator

RF generators

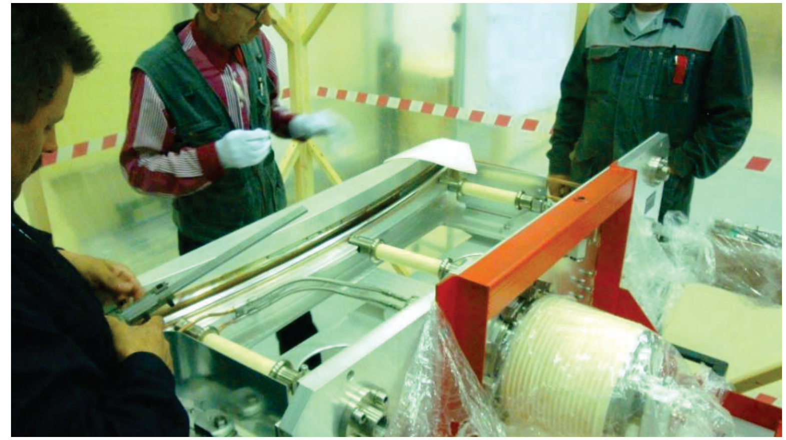
Beam extraction system

Extraction radius of R_{ext}=1.79 m

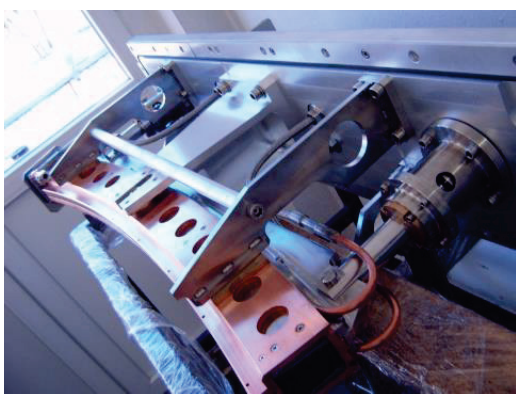


Focusing magnetic channel

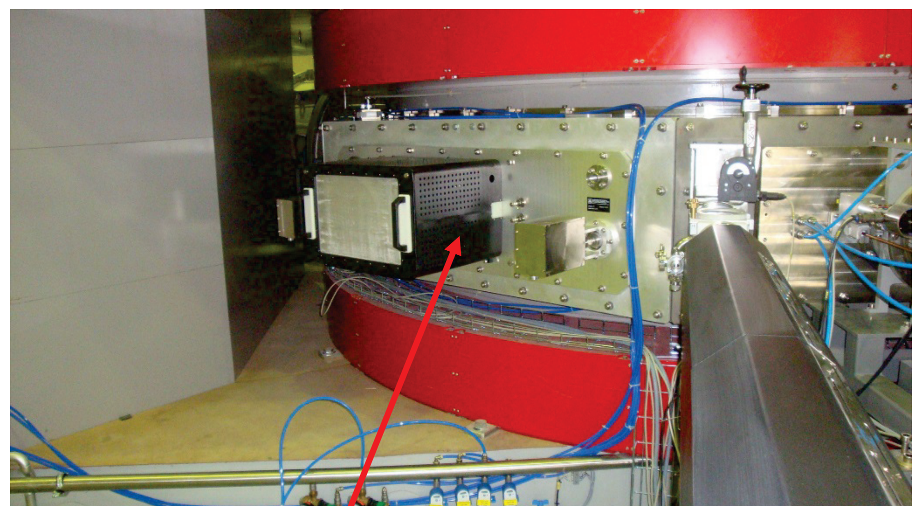
Electrostatic deflector



Assembling of the deflector
L=1.8 m, E=90 кВ/cm

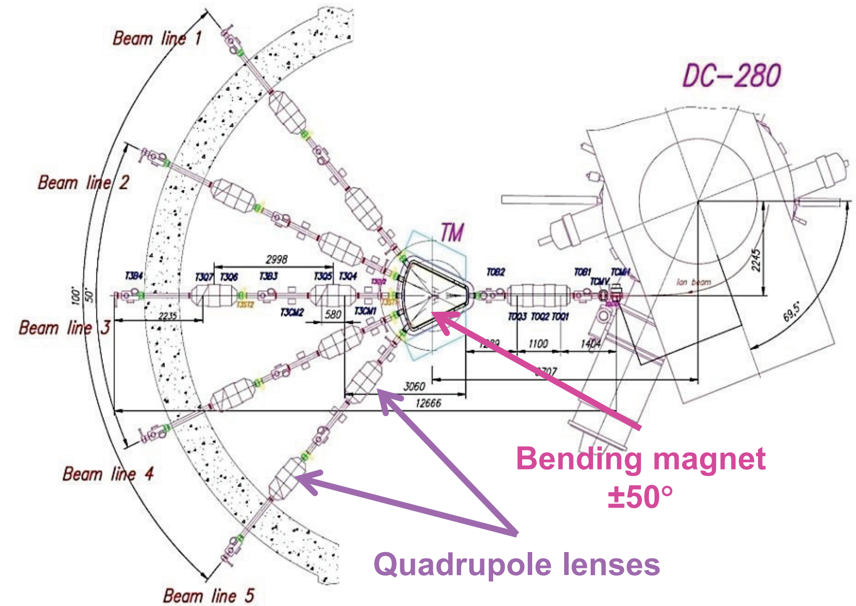


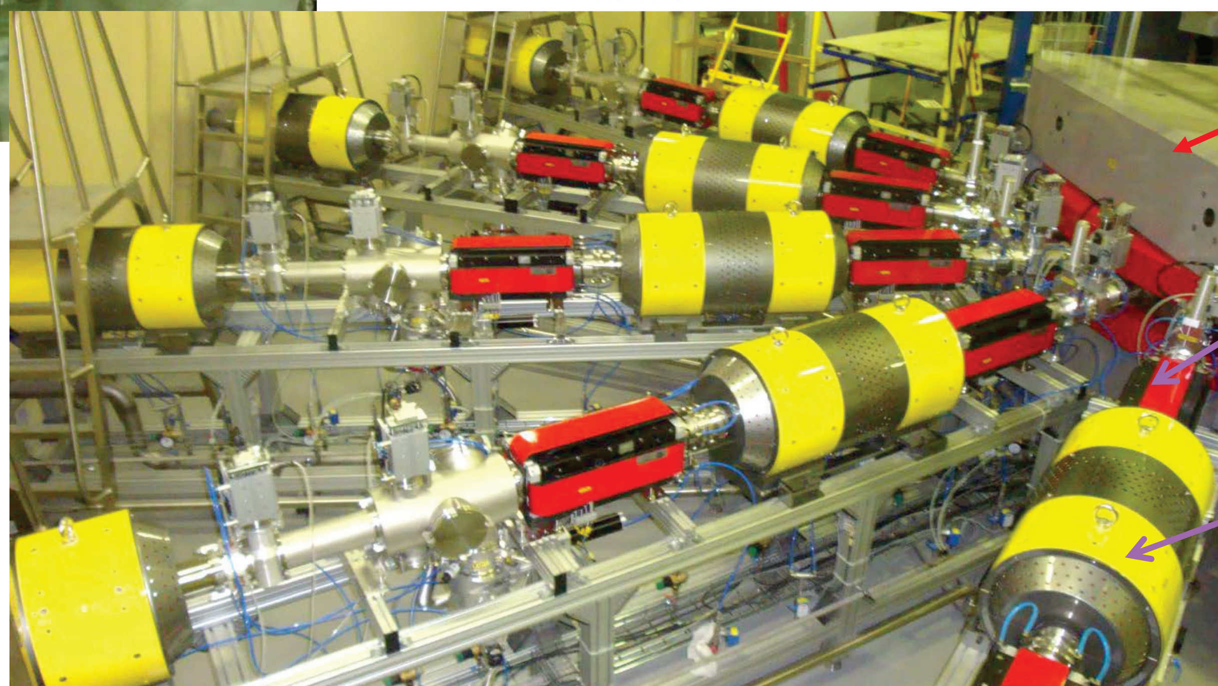
Magnetic channel
L=0.9 m, G=4.6÷8.4 T/m



Electrostatic deflector on vacuum chamber

Beam transport channels





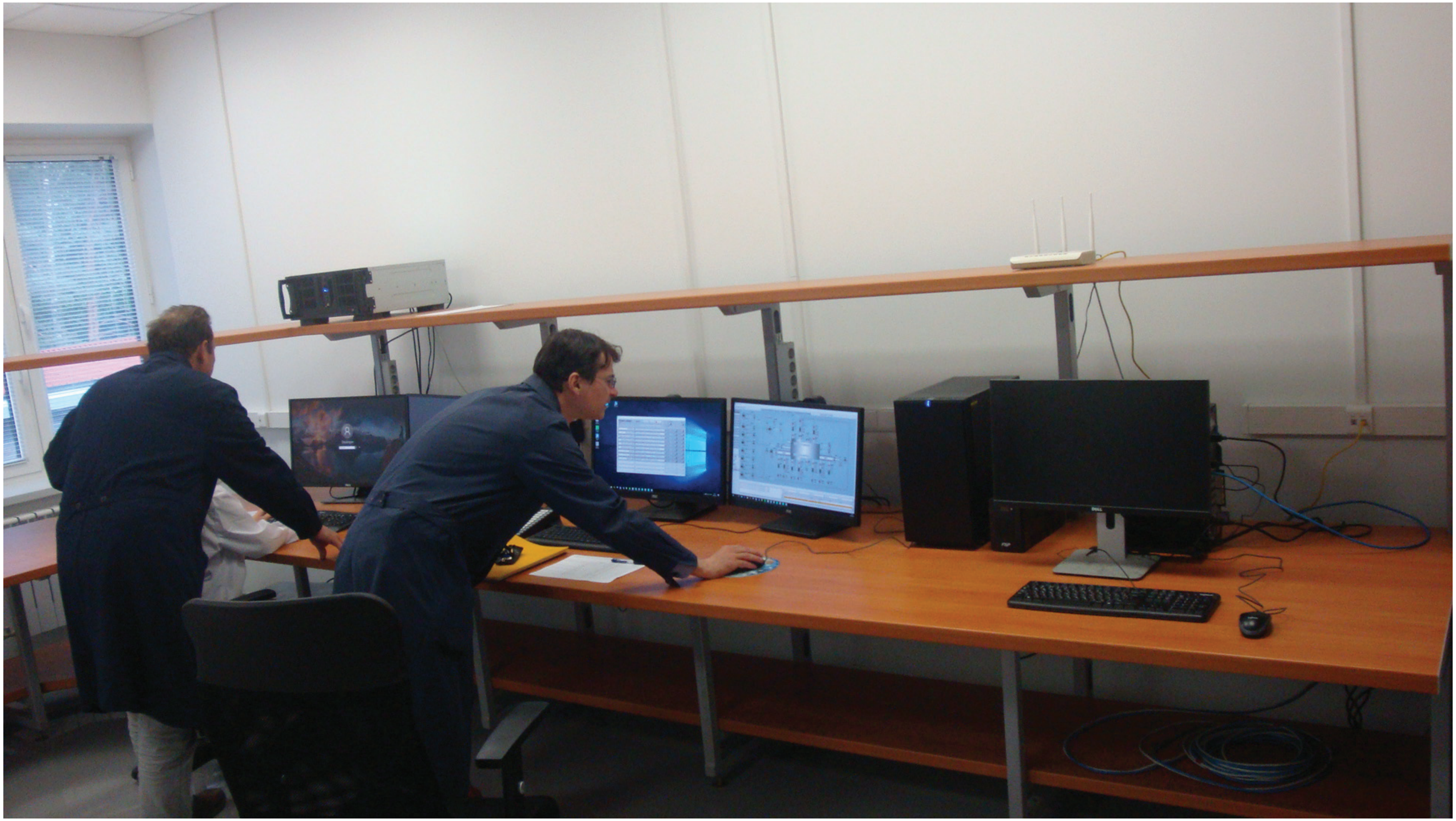
Control and power supply systems

Power supplies of cyclotron

Power supplies of injection

Water cooling system

DC-280 control room

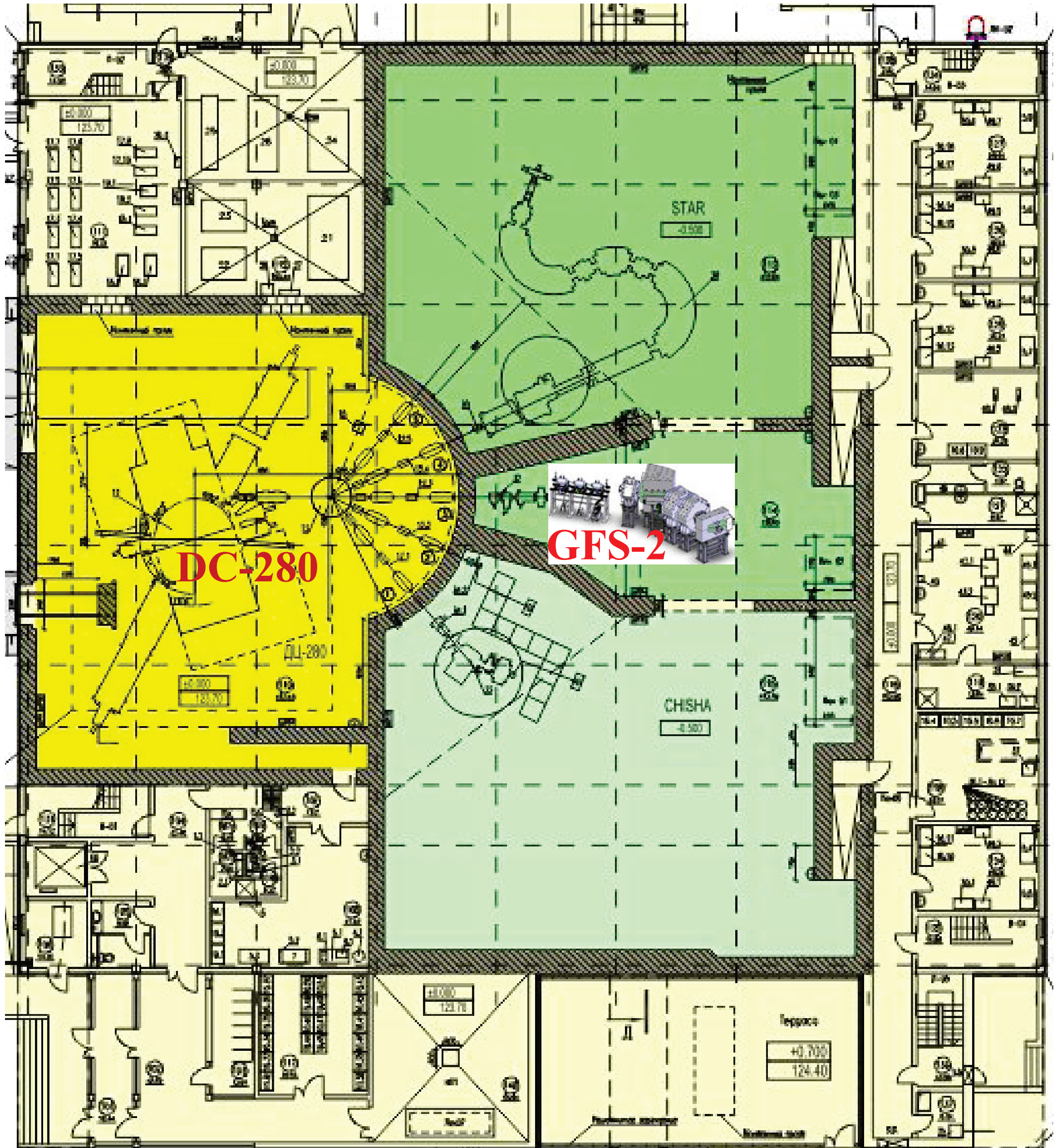


Launching and Tuning Works on the DC-280 systems without beam:
June – Oct. 2018

Obtaining licenses and permits : Nov. 2018

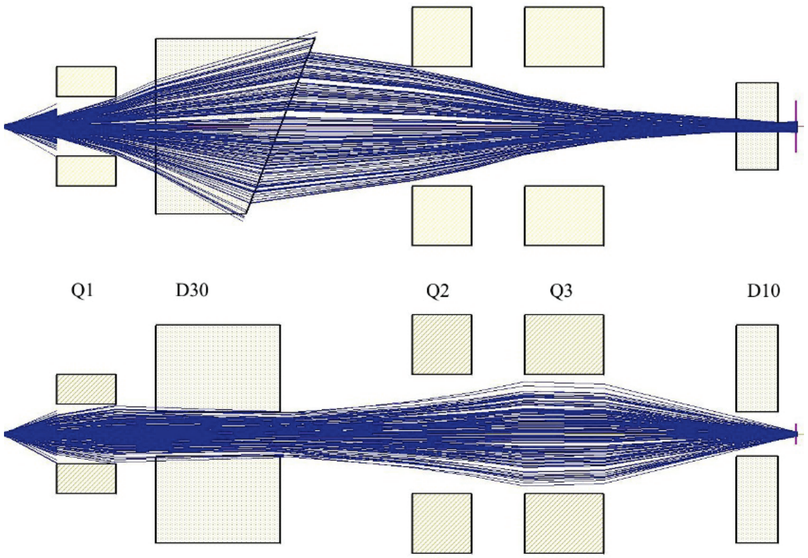
Commissioning: Nov. – Dec. 2018

Plan of the 1-st floor of the SHE Factory

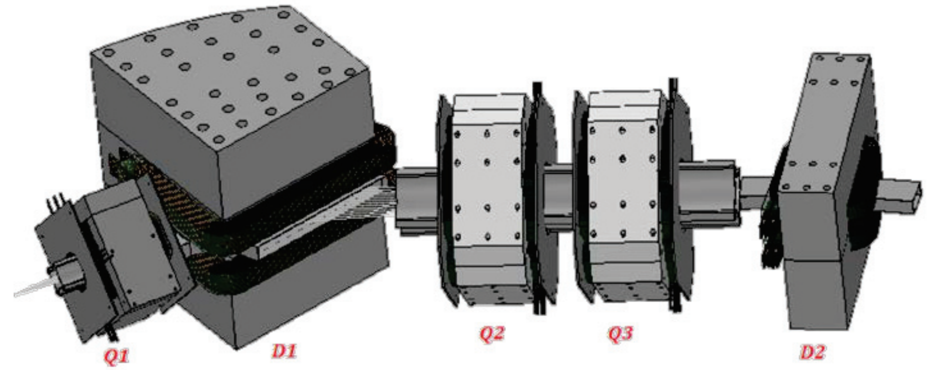


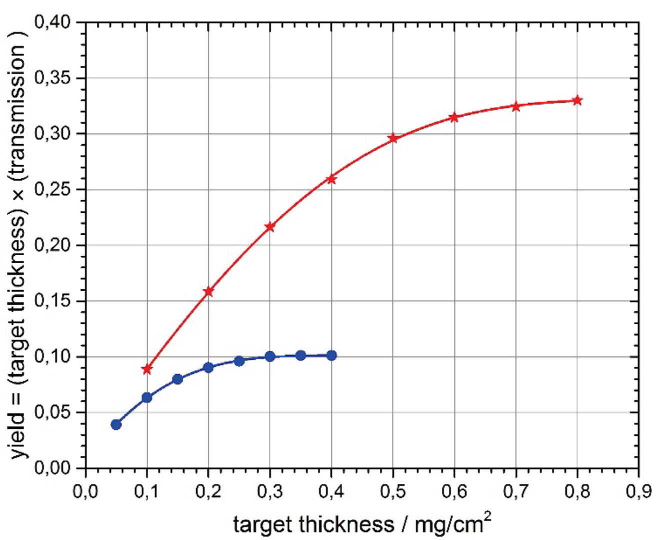
Experimental area ~1000 m^2 (3 halls)

New FLNR gas-filled separator (contracted)



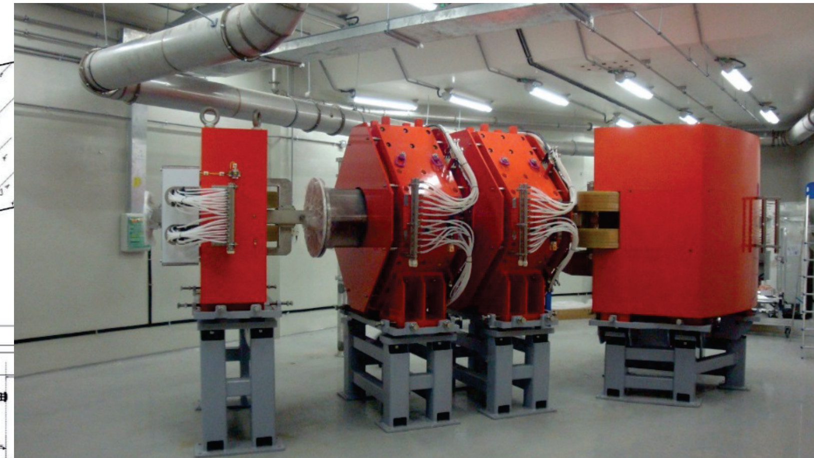
Technical Design
Report No 412923

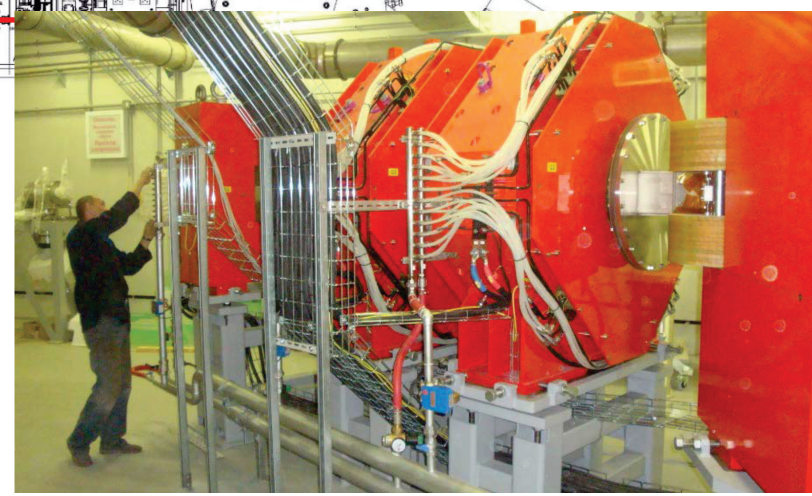




Reaction	Transmission
$^{244}Pu(^{48}Ca,3n)^{289}114$	60 %
$^{244}Pu(^{58}Fe,4n)^{298}120$	75 %

Arrangement of GFS-2 at the beam line No3





Installation of magnets: June 2018

Commissioning: Nov. – Dec. 2018

Obtaining licenses and permits : Nov. 2018

Conclusion

- FLNR JINR Accelerator Complex is being developed
- Expected commissioning of the DC-280 together with the new GFS-2 separator: Nov.–Dec. 2018. First experiments at the SHE Factory: 2019
- We expect to have essential results of the Accelerator Complex modernization to 2023


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