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

Status of FLNR JINR Cyclotrons

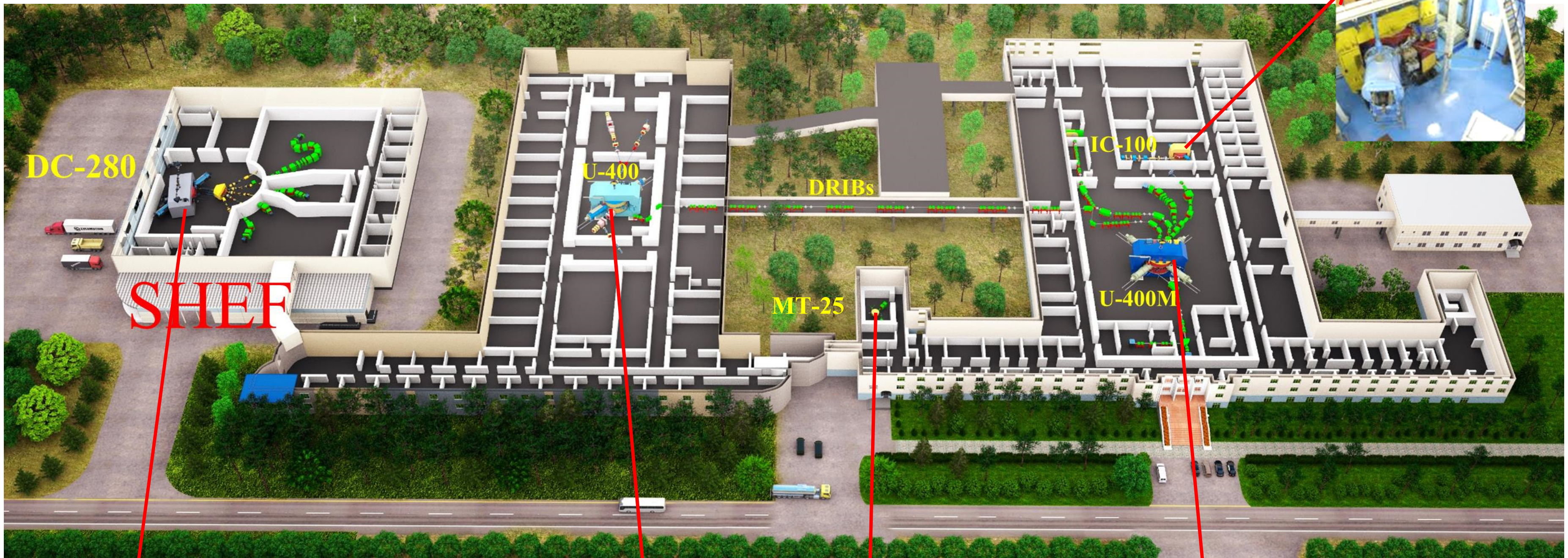
Igor Kalagin

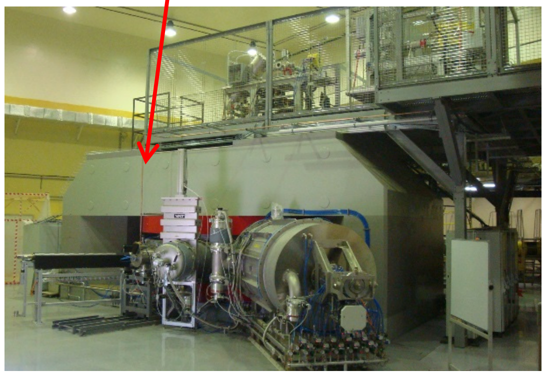
Flerov Laboratory of Nuclear Reactions
Joint Institute for Nuclear Research

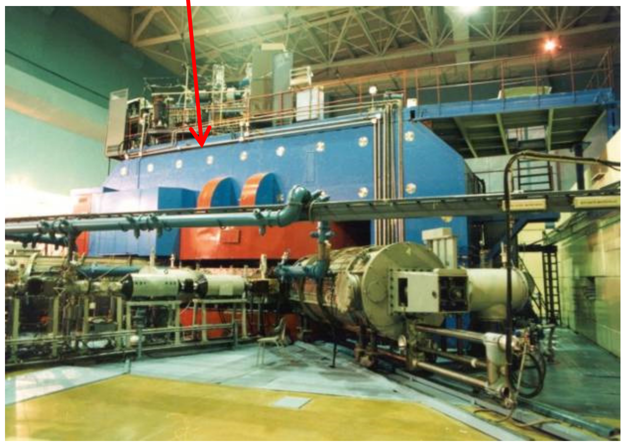
HIAT 2018

FLNR JINR Accelerator Complex

IC-100







DC-280

U-400

MT-25

U-400M

BASIC DIRECTIONS of RESEARCH at FLNR

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

- Heavy and superheavy nuclei:

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

U-400M cyclotron (ions 30 ÷ 50 MeV/n)

- Light exotic nuclei:

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

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

- Radiation effects and physical groundwork of nanotechnology.

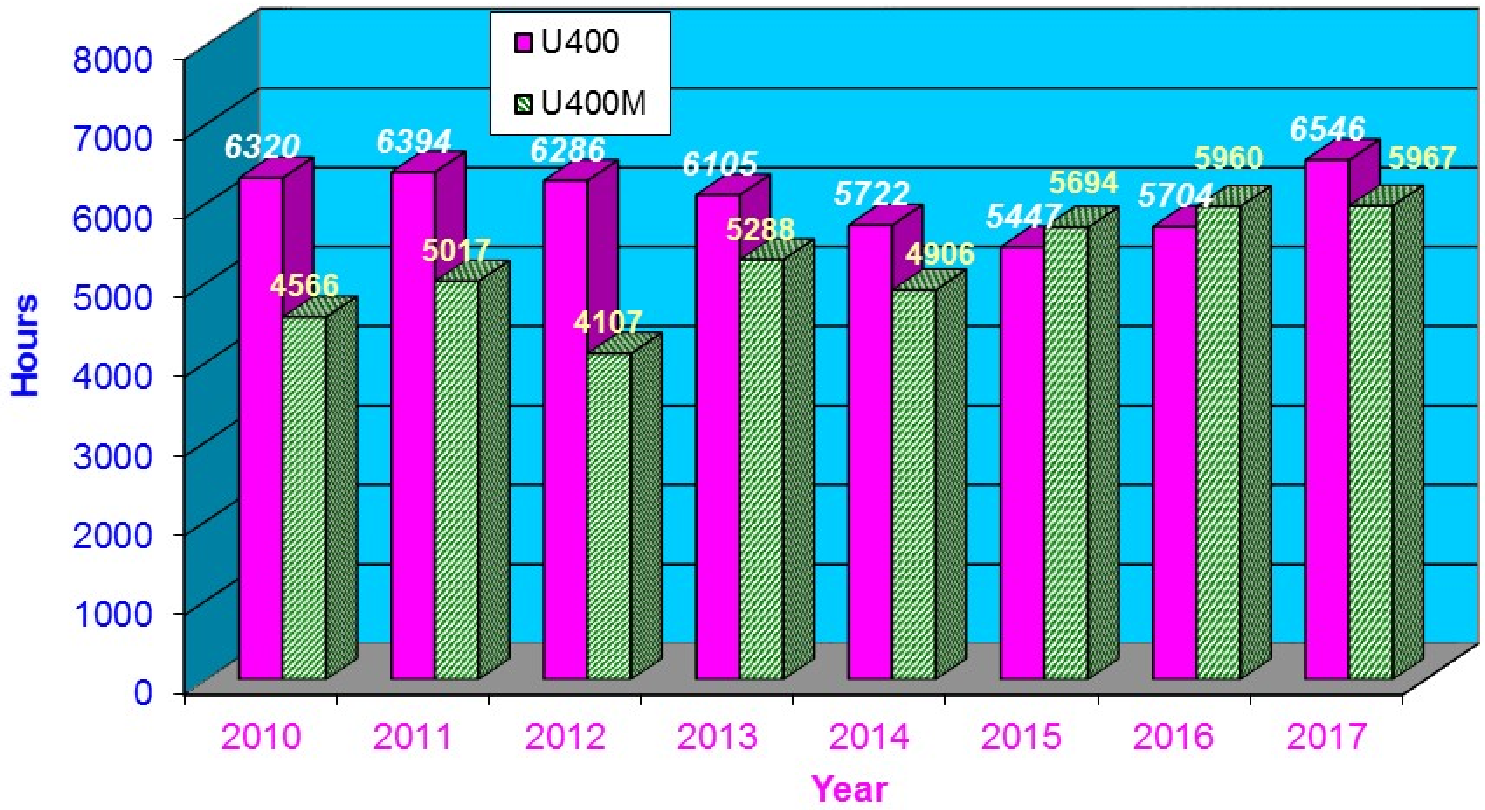
U-400 & U-400M (O ÷ Bi 3 ÷ 5 MeV/n) and
U-400M (O ÷ Bi 15 ÷ 60 MeV/n)

- 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

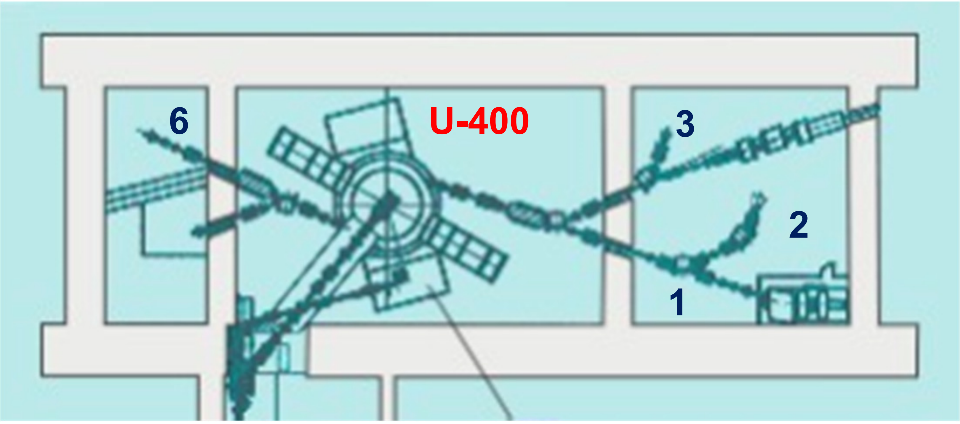


U400 CYCLOTRON (1978)

Parameters	Value/Name
Magnet weight	2100 t
Electrical power of magnet	850 kW
Magnetic field level in center	1.93÷2.1 T
A/Z range	5÷12
RF frequency range	5.42÷12.2 MHz
Sectors angular width	42°
The number of dees	2
Harmonic mode	2
K- factor	625
Vacuum level	$2\cdot10^{-7}$ Torr

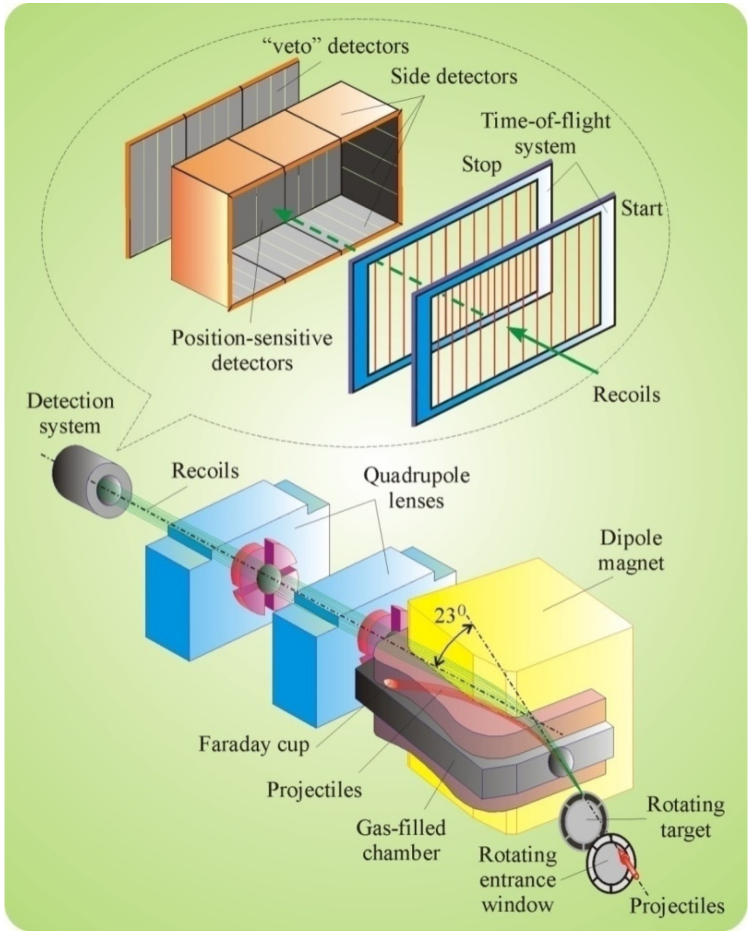
Ion	Ion energy [MeV/A]	Output intensity
$^{6}He^{1+}$	11	$3\cdot10^{7}$ pps
$^{16}O^{2+}$	5.7; 7.9	5 pμA
$^{18}O^{3+}$	7.8; 10.5; 15.8	4.4 pμA
$^{40}Ar^{4+}$	3.8; 5.1 *	1.7 pμA
$^{48}Ca^{5+}$	3.7; 5.3 *	1.2 pμA
$^{48}Ca^{9+}$	8.9; 11; 17.7 *	1 pμA
$^{50}Ti^{5+}$	3.6; 5.1 *	0.5 pμA
$^{58}Fe^{6+}$	3.8; 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

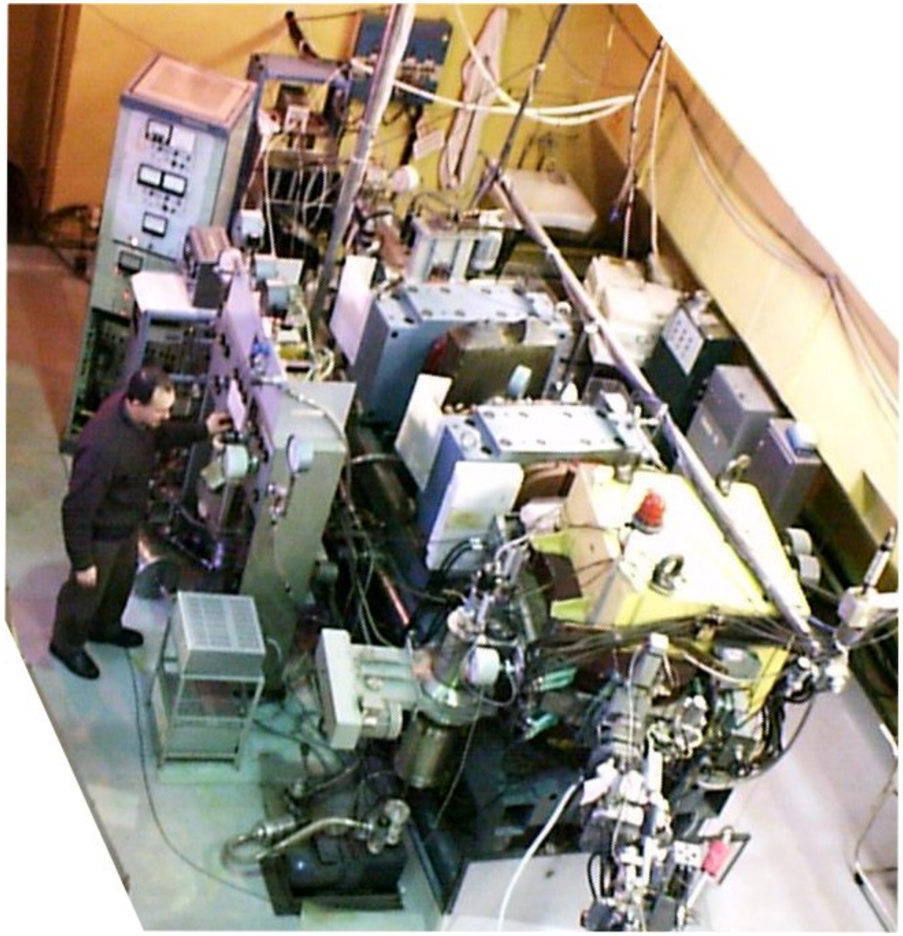
Experimental setups at U400 :



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





JINR

114 Flerovium

FLNR

Dubna

Периодическая таблица элементов Д.И. Менделеева

D.I. Mendeleev's Periodic Table of Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Водород 1 H 1,008 Hydrogen																	Гелий 2 He 4,0026 Helium
Литий 3 Li 6,94 Lithium	Бериллий 4 Be 9,0122 Beryllium											Бор 5 B 10,81 Boron	Углерод 6 C 12,011 Carbon	Азот 7 N 14,007 Nitrogen	Кислород 8 O 15,999 Oxygen	Фтор 9 F 18,998 Fluorine	Неон 10 Ne 20,18 Neon
Натрий 11 Na 22,99 Sodium	Магний 12 Mg 24,305 Magnesium											Алюминий 13 Al 26,982 Aluminum	Кремний 14 Si 28,085 Silicon	Фосфор 15 P 30,974 Phosphorus	Сера 16 S 32,06 Sulfur	Хлор 17 Cl 35,45 Chlorine	Аргон 18 Ar 39,948 Argon
Калий 19 K 39,098 Potassium	Кальций 20 Ca 40,078(4) Calcium	Скандий 21 Sc 44,956 Scandium	Титан 22 Ti 47,867 Titanium	Ванадий 23 V 50,942 Vanadium	Хром 24 Cr 51,996 Chromium	Марганец 25 Mn 54,938 Manganese	Железо 26 Fe 55,845(2) Iron	Кобальт 27 Co 58,933 Cobalt	Никель 28 Ni 58,693 Nickel	Медь 29 Cu 63,546(3) Copper	Цинк 30 Zn 65,38(2) Zinc	Галлий 31 Ga 69,723 Gallium	Германий 32 Ge 72,630(8) Germanium	Мышьяк 33 As 74,922 Arsenic	Селен 34 Se 78,971(8) Selenium	Бром 35 Br 79,904 Bromine	Криптон 36 Kr 83,798(2) Krypton
Рубидий 37 Rb 85,468 Rubidium	Стронций 38 Sr 87,62 Strontium	Иттрий 39 Y 88,906 Yttrium	Цирконий 40 Zr 91,224(2) Zirkonium	Ниобий 41 Nb 92,906 Niobium	Молибден 42 Mo 95,95 Molybdenum	Технеций 43 Tc [98] Technetium	Рутений 44 Ru 101,07(2) Ruthenium	Родий 45 Rh 102,91 Rhodium	Палладий 46 Pd 106,42 Palladium	Серебро 47 Ag 107,87 Silver	Кадмий 48 Cd 112,41 Cadmium	Индий 49 In 114,82 Indium	Олово 50 Sn 118,71 Tin	Сурьма 51 Sb 121,76 Antimony	Теллур 52 Te 127,60(3) Tellurium	Иод 53 I 126,90 Iodine	Ксенон 54 Xe 131,29 Xenon
Цезий 55 Cs 132,91 Cesium	Барий 56 Ba 137,33 Barium	Лантан 57 La 138,91 Lanthanum	Гафний 72 Hf 178,49(2) Hafnium	Тантал 73 Ta 180,95 Tantalum	Вольфрам 74 W 183,84 Tungsten	Рений 75 Re 186,21 Rhenium	Осмий 76 Os 190,23(3) Osmium	Иридий 77 Ir 192,22 Iridium	Платина 78 Pt 195,08 Platinum	Золото 79 Au 196,97 Gold	Ртуть 80 Hg 200,59 Mercury	Таллий 81 Tl 204,38 Thallium	Свинец 82 Pb 207,2 Lead	Висмут 83 Bi 208,98 Bismuth	Полоний 84 Po [209] Polonium	Астат 85 At [210] Astatine	Радон 86 Rn [222] Radon
Франций 87 Fr [223] Francium	Радий 88 Ra [226] Radium	Актиний 89 Ac [227] Actinium	Резерфордий 104 Rf [267] Rutherfordium	Дубний 105 Db [268] Dubnium	Сиборгий 106 Sg [271] Seaborgium	Борий 107 Bh [270] Bohrium	Хассий 108 Hs [269] Hassium	Мейтнерий 109 Mt [278] Meitnerium	Дармштадтий 110 Ds [281] Darmstadtium	Рентгений 111 Rg [282] Roentgenium	Коперниций 112 Cn [285] Copernicium	Нихоний 113 Nh [286] 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

Лантаноиды Lanthanoides

Церий 58 Ce 140,12 Cerium	Празеодим 59 Pr 140,91 Praseodymium	Неодим 60 Nd 144,24 Neodymium	Прометий 61 Pm [145] Promethium	Самарий 62 Sm 150,36(2) Samarium	Европий 63 Eu 151,96 Europium	Гадолиний 64 Gd 157,25(3) Gadolinium	Тербий 65 Tb 158,93 Terbium	Диспрозий 66 Dy 162,50 Dysprosium	Гольмий 67 Ho 164,93 Holmium	Эрбий 68 Er 167,26 Erbium	Тулий 69 Tm 168,93 Thulium	Иттербий 70 Yb 173,05 Ytterbium	Лютеций 71 Lu 174,97 Lutetium

Актиноиды Actinoides

Торий 90 Th 232,04 Thorium	Протактиний 91 Pa 231,04 Protactinium	Уран 92 U 238,03 Uranium	Нептуний 93 Np [237] Neptunium	Плутоний 94 Pu [244] Plutonium	Америций 95 Am [243] Americium	Кюрий 96 Cm [247] Curium	Берклий 97 Bk [247] Berkelium	Калифорний 98 Cf [251] Californium	Эйнштейний 99 Es [252] Einsteinium	Фермий 100 Fm [257] Fermium	Менделевий 101 Md [258] Mendelevium	Нобелий 102 No [259] Nobelium	Лоуренсий 103 Lr [266] Lawrencium

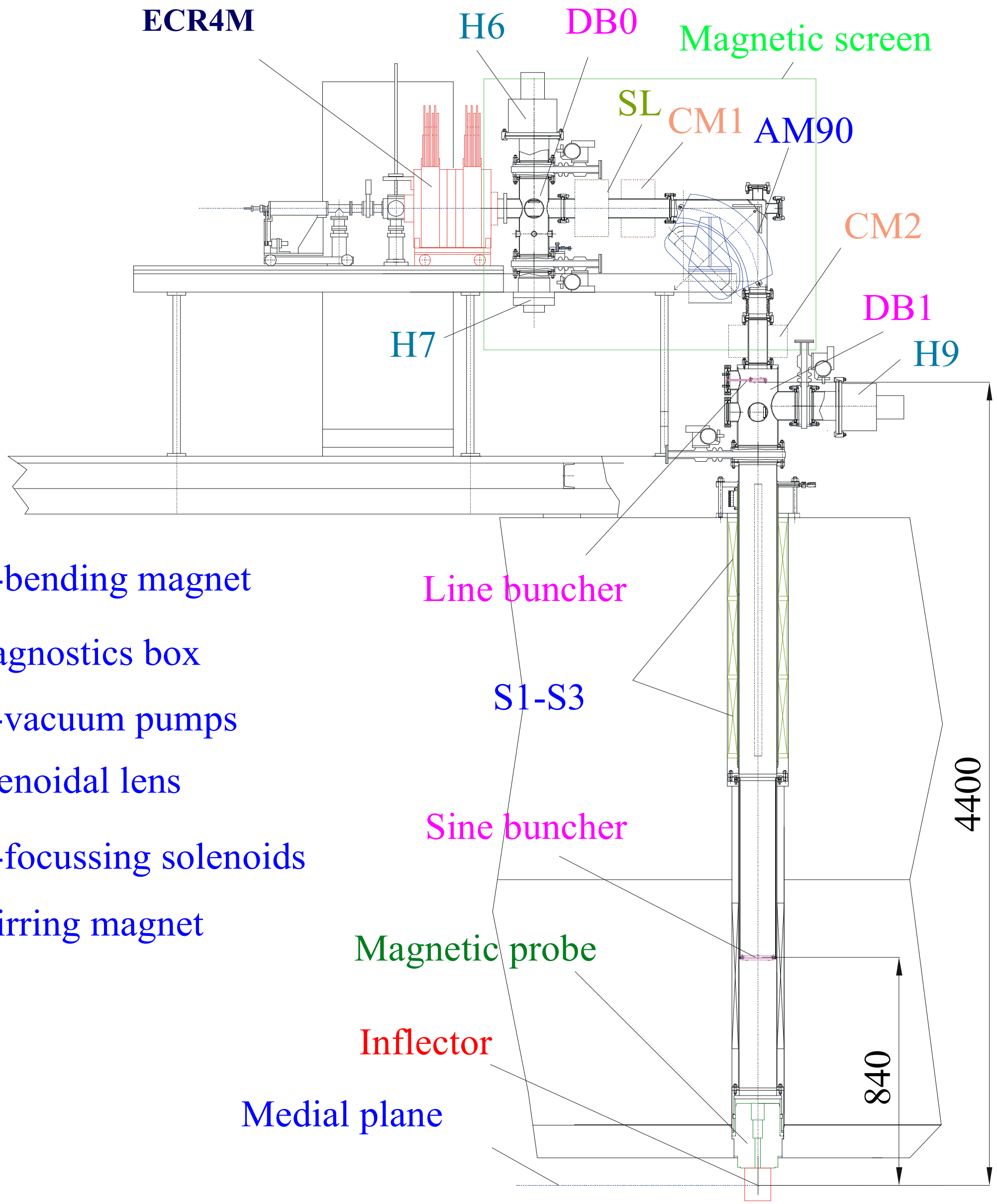
Водород 1 1s H 13,59844 0,0899 1,00794 -259,34 Hydrogen -252,87

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,°С / melting temperature, °C
-252,87 - температура кипения,°С / boiling temperature, °C

Axial injection system of U-400 Cyclotron

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

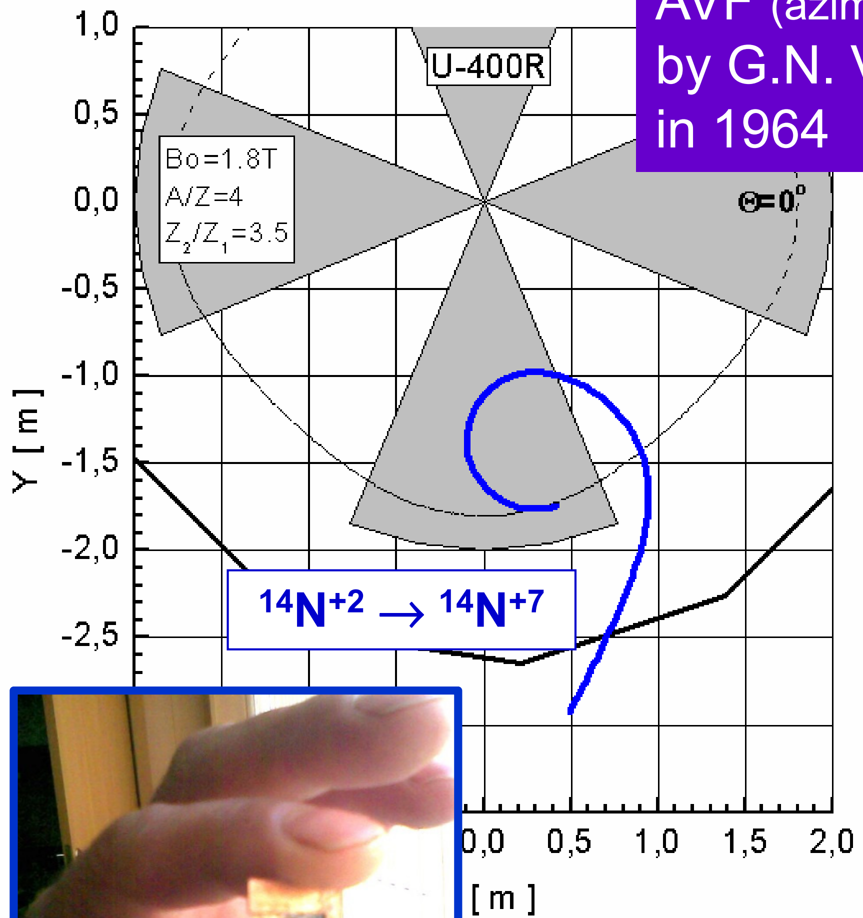
$^{48}Ca^{5+}$ - 100 eμA
$^{132}Xe^{12+}$ - 50 eμA
$^{209}Bi^{19+}$ - 20 eμA



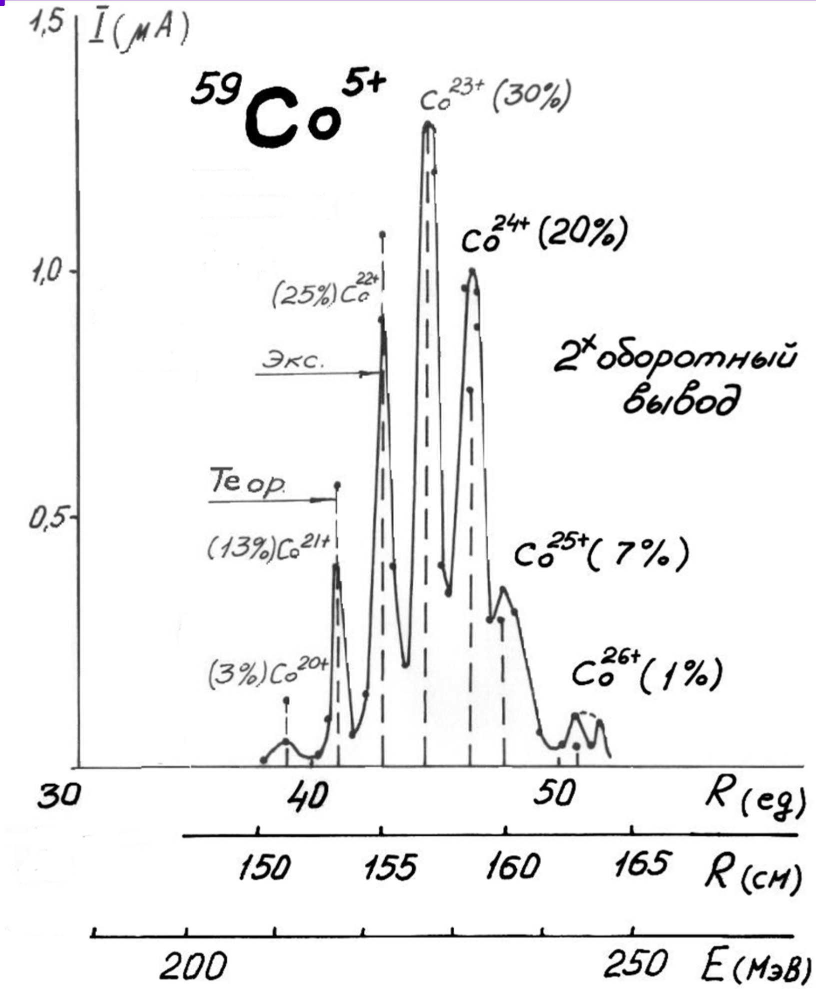
AM90-bending magnet
DB-diagnostics box
H6-H9-vacuum pumps
SL-solenoidal lens
S1-S3-focussing solenoids
CM-stirring magnet

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

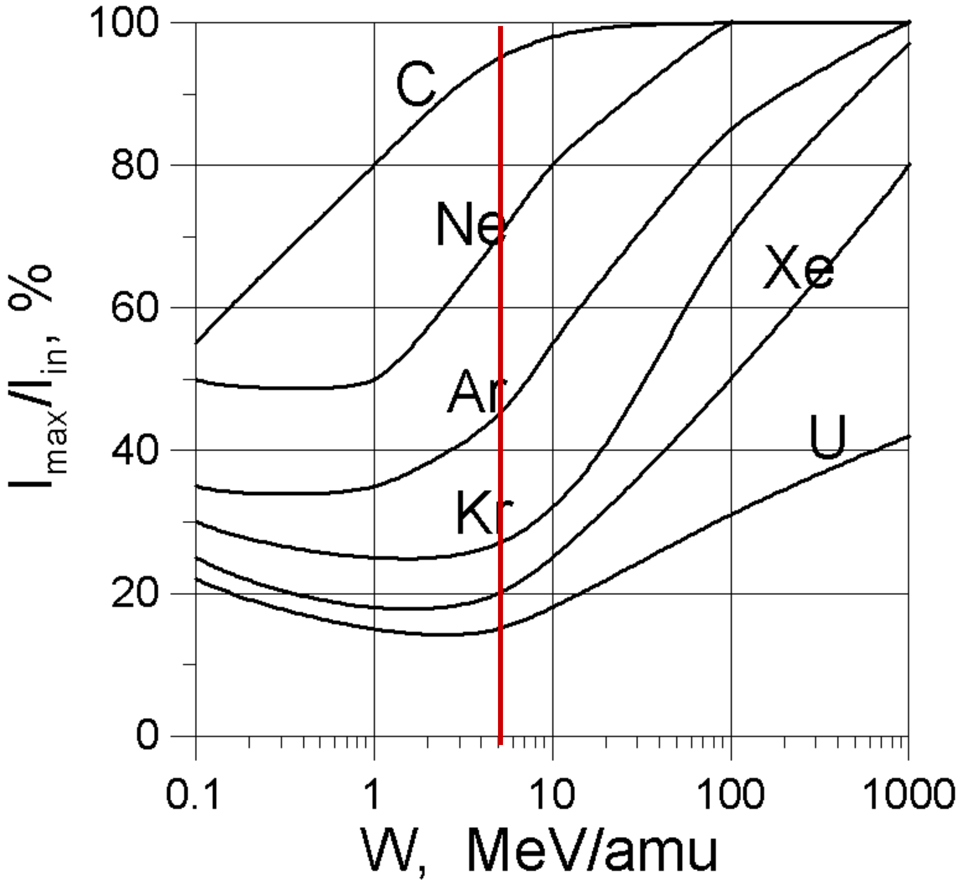


Thickness of stripping foil – 20 -200 μg/cm²



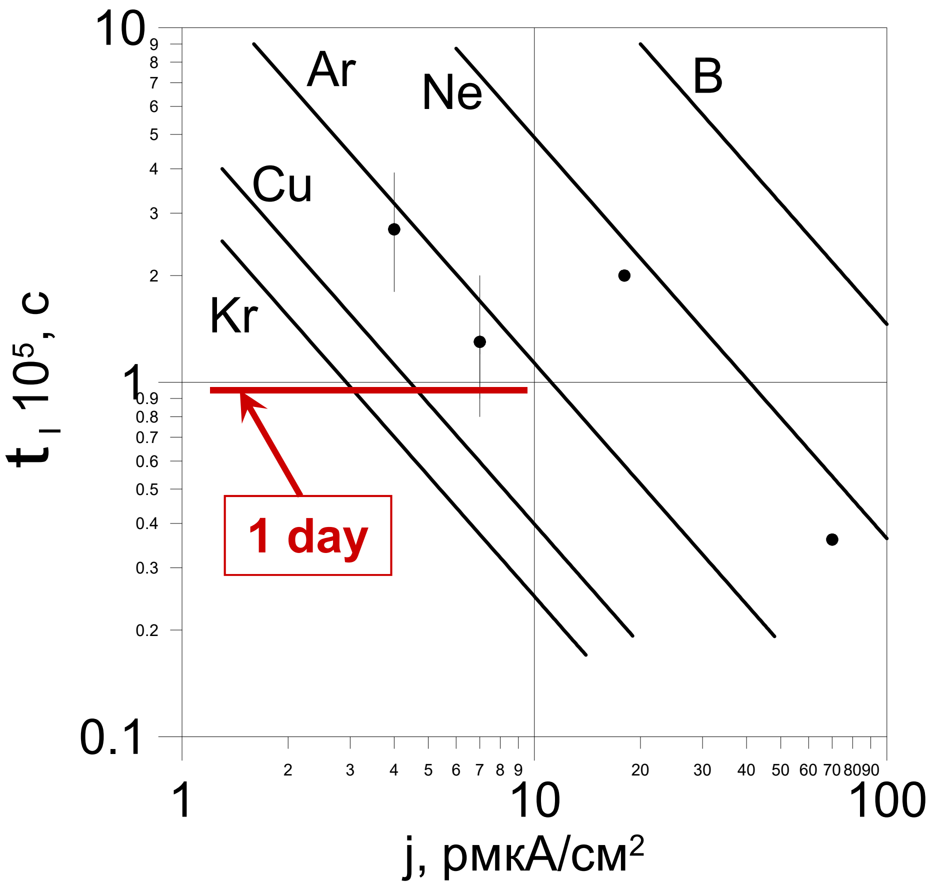
Heavy Ion Beam Extraction by Stripping Foil

1. Charge spread



Dependence of the maximum efficiency of a single charge extraction by stripping versus the ion energy

2. Life time of stripping foil



Dependence of life time of carbon stripping foil versus beam current density at 5 MeV/amu

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%

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

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<tr><td>Target</td><td>$8 \cdot 10^{12}$ pps</td><td>23 μAe</td><td>$^{48}Ca^{18+}$</td><td colspan="3">~1.2 pμA</td></tr>
</table>

Ionization efficiency of ^{48}Ca (neutral) to $^{48}Ca^{5+}$ - about 10%

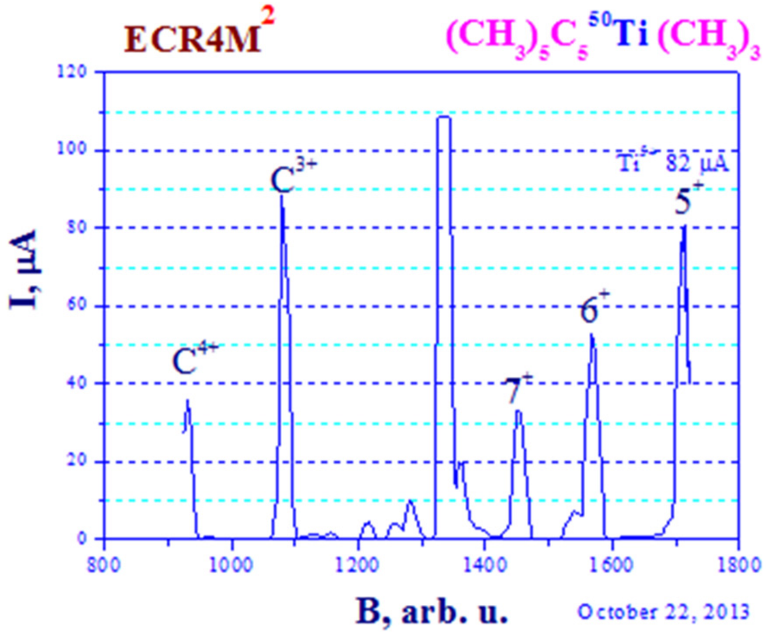
Development of ^{50}Ti beam using MIVOC method

(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)

Modernization of the U-400 cyclotron (U-400R project) (2020-2023)

1. **Beam intensity of masses A ≈ 50 and energy 5÷6 MeV/n up to 2.5 ρμa.**

2. **Smooth ion energy variation on the target with factor 5.**

3. **Decreasing the cyclotron average magnetic field level from 2.1 to 1.8 T**
 (Decreasing the total cyclotron power consumption from 1 to 0.25 MW**).**

4. **New equipment (**new magnetic system, new RF- resonators; replacement of vacuum pumping system- diffusion pumps to cryopumps and turbopumps; modernization of RF control system- analog to digital LLRF**).**

5. **Building of a new experimental hall**

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

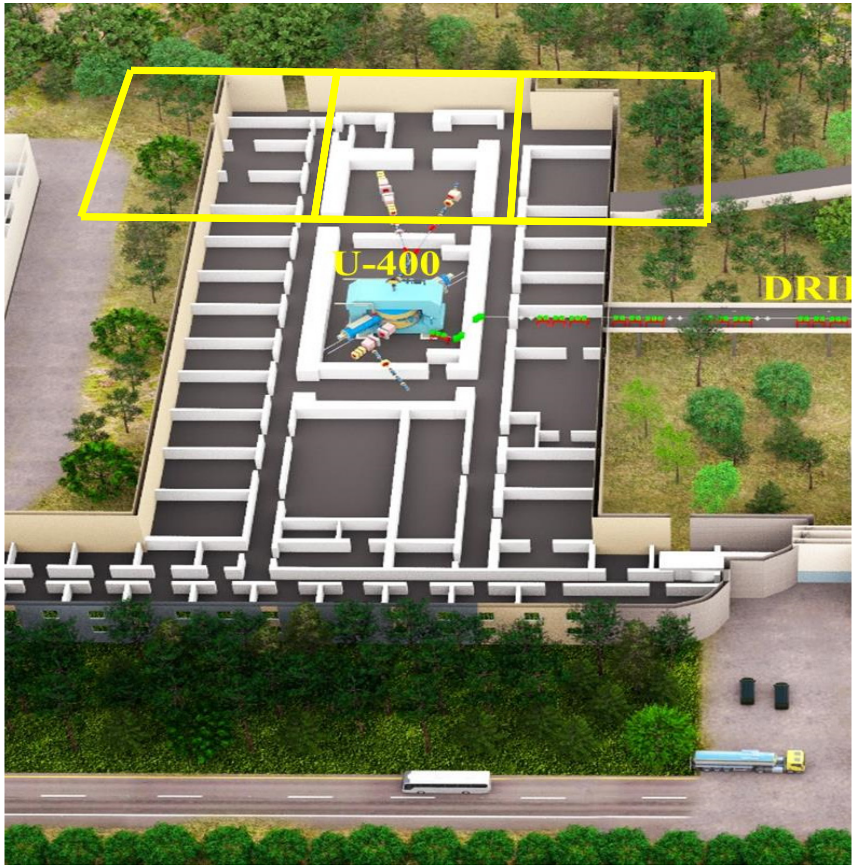
* Fixed ion energy of extracted beam

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

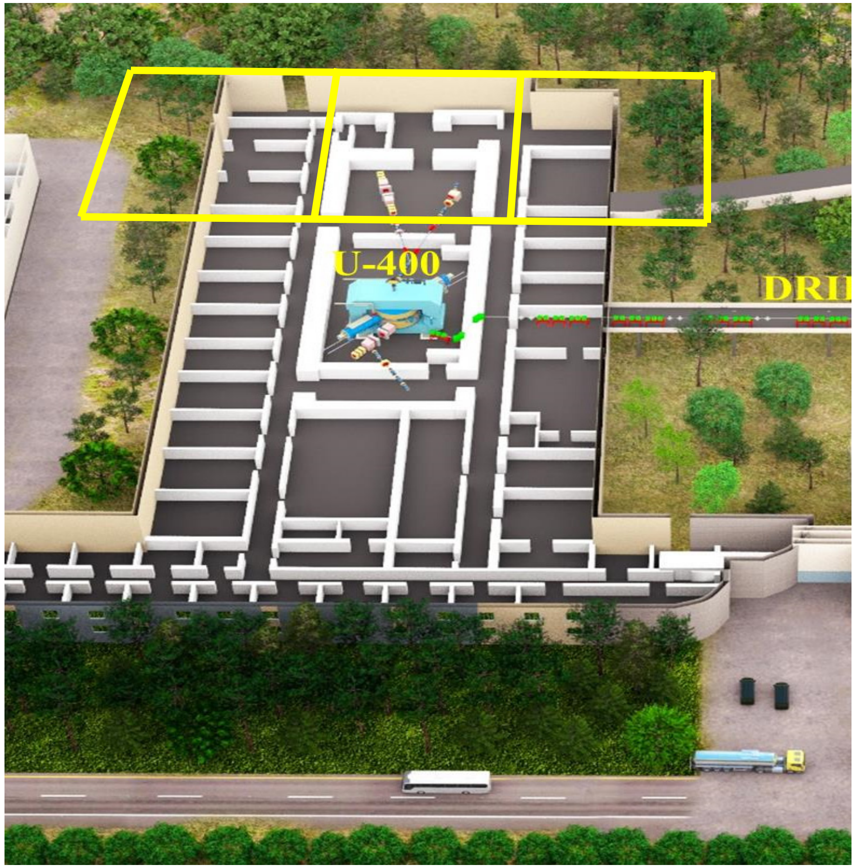
* Smooth variation ion energy of extracted beam

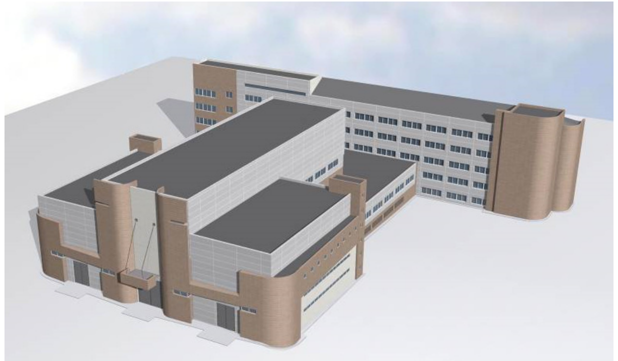
Reconstruction of the U-400 experimental hall

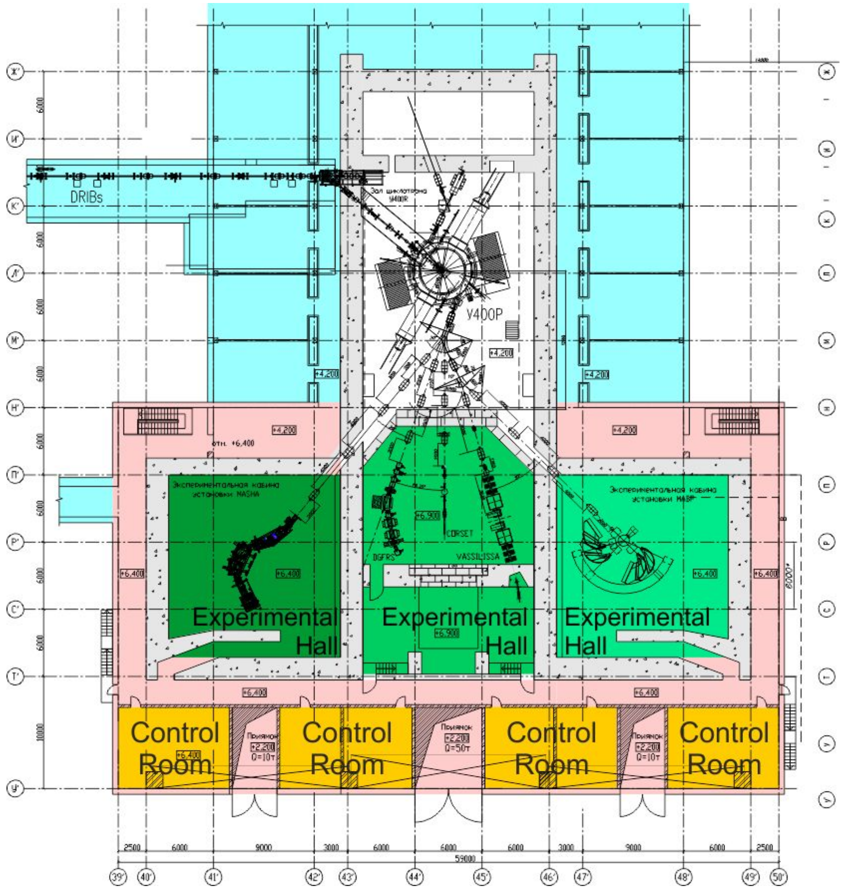
Reconstruction of the U-400 experimental hall



Reconstruction of the U-400 experimental hall

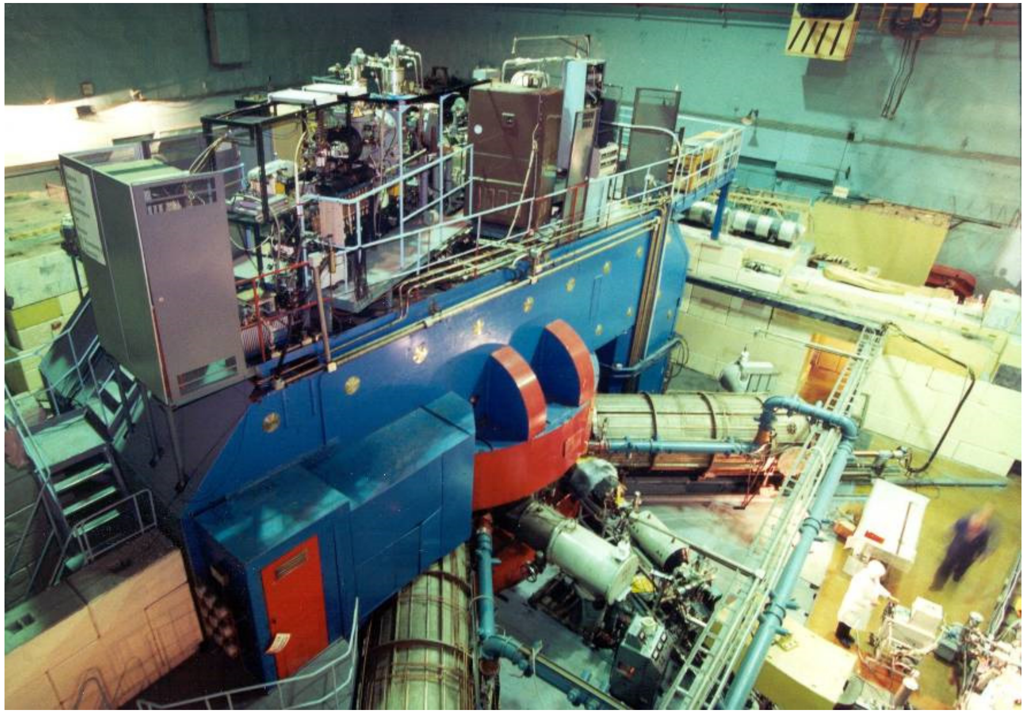






Experimental area ~1500 m^2 (2 floors)

U400M CYCLOTRON (1991)

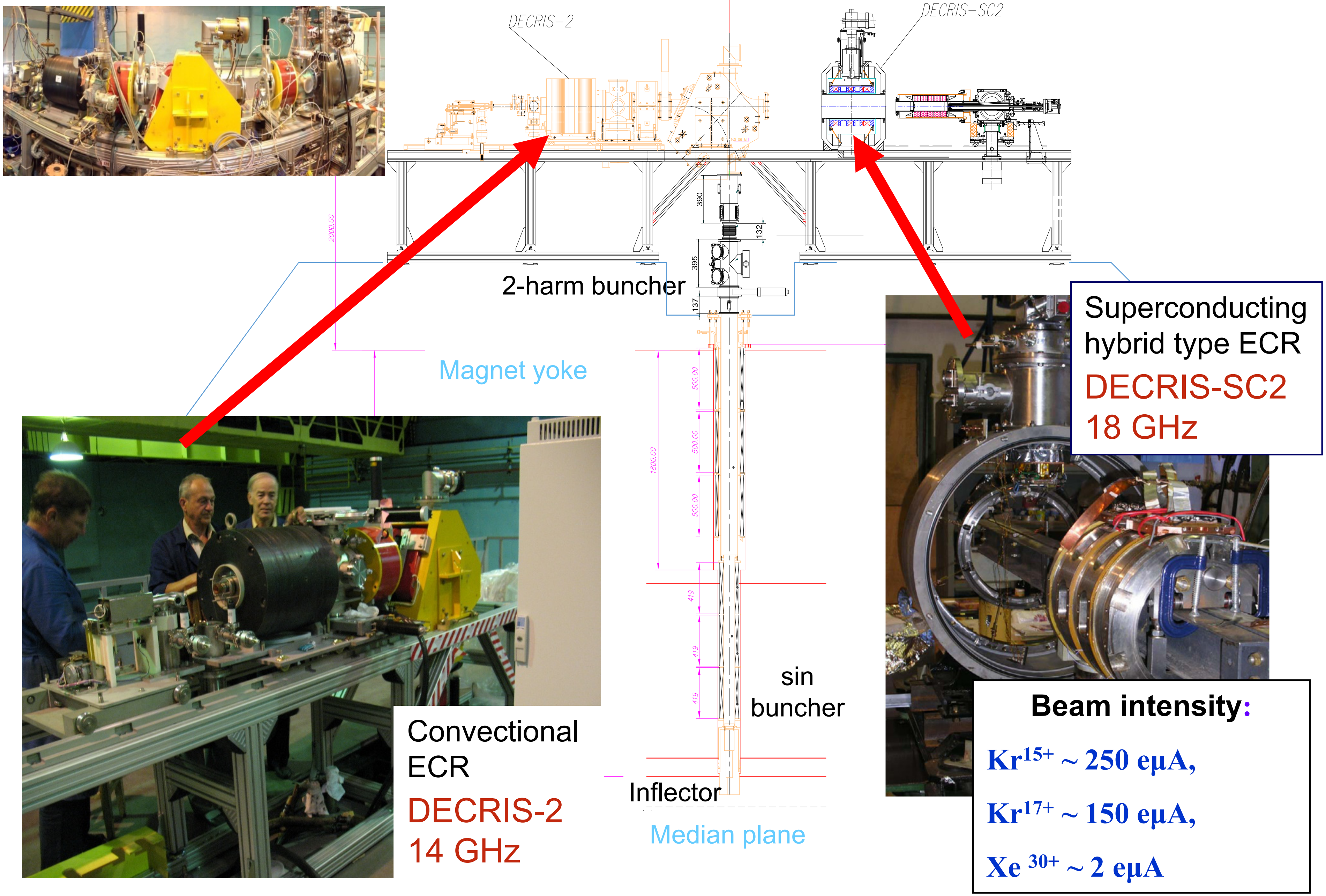


U400M E=15 ÷ 60 MeV/A E=4.5 ÷ 9 MeV/A		
Ion	**Ion energy [MeV/A]**	**Output intensity [pps]**
^{7}Li	35	6×10^{13}
^{18}O	33	1×10^{13}
^{40}Ar	40	1×10^{12}
^{48}Ca	5	3×10^{12}
^{58}Fe	5	1×10^{12}
^{124}Sn	5	2×10^{11}
^{136}Xe	5	4×10^{11}
^{132}Xe	25	3×10^{5}
^{238}Bi	5	3×10^{8}
^{238}Bi	15	1×10^{5}

Main tasks:

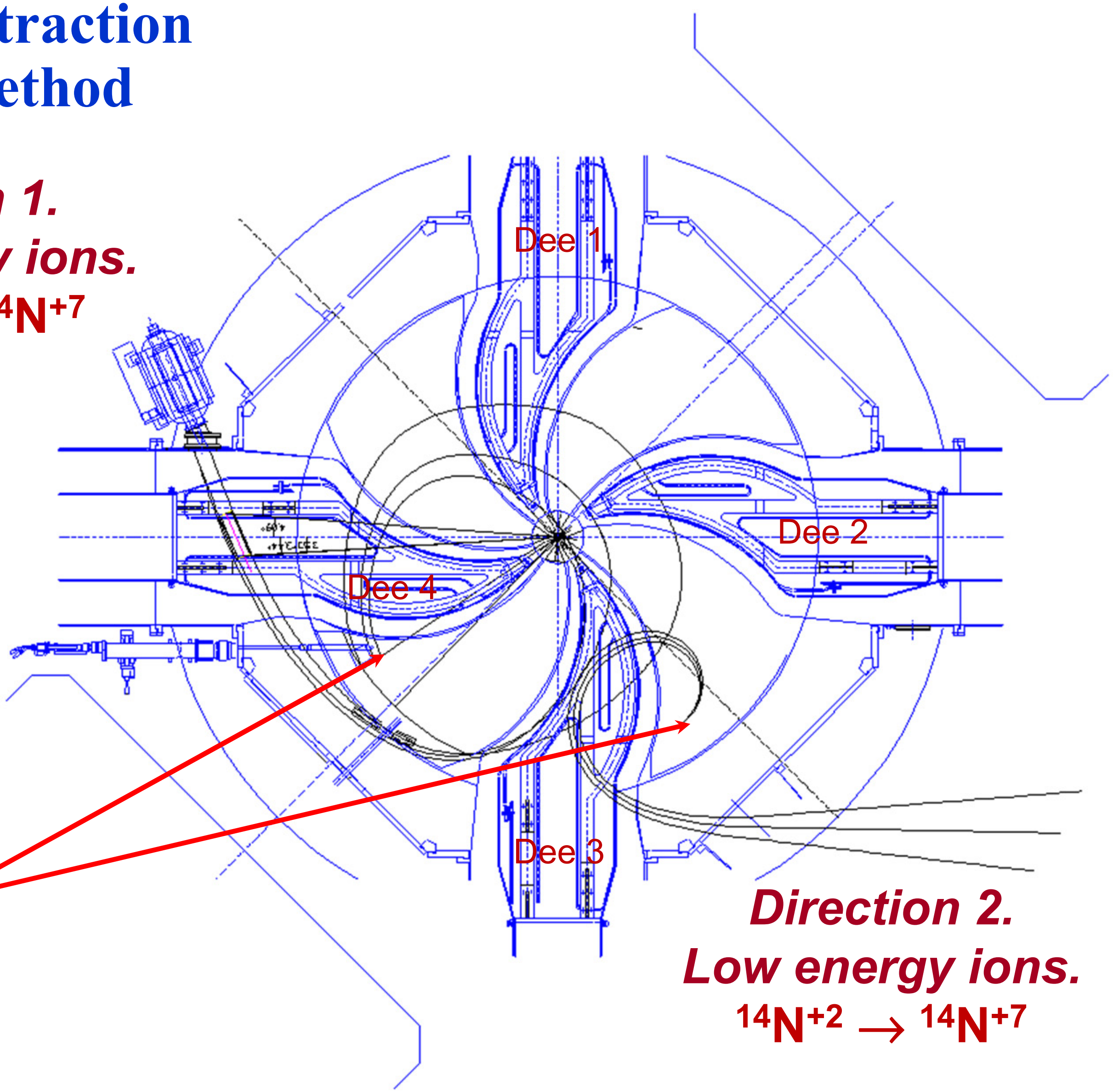
- *Producing of RIBs.*
- *Reactions with exotic nuclei;*
- *Properties and structure of light exotic nuclei.*

U-400M. Ion sources and axial injection system



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

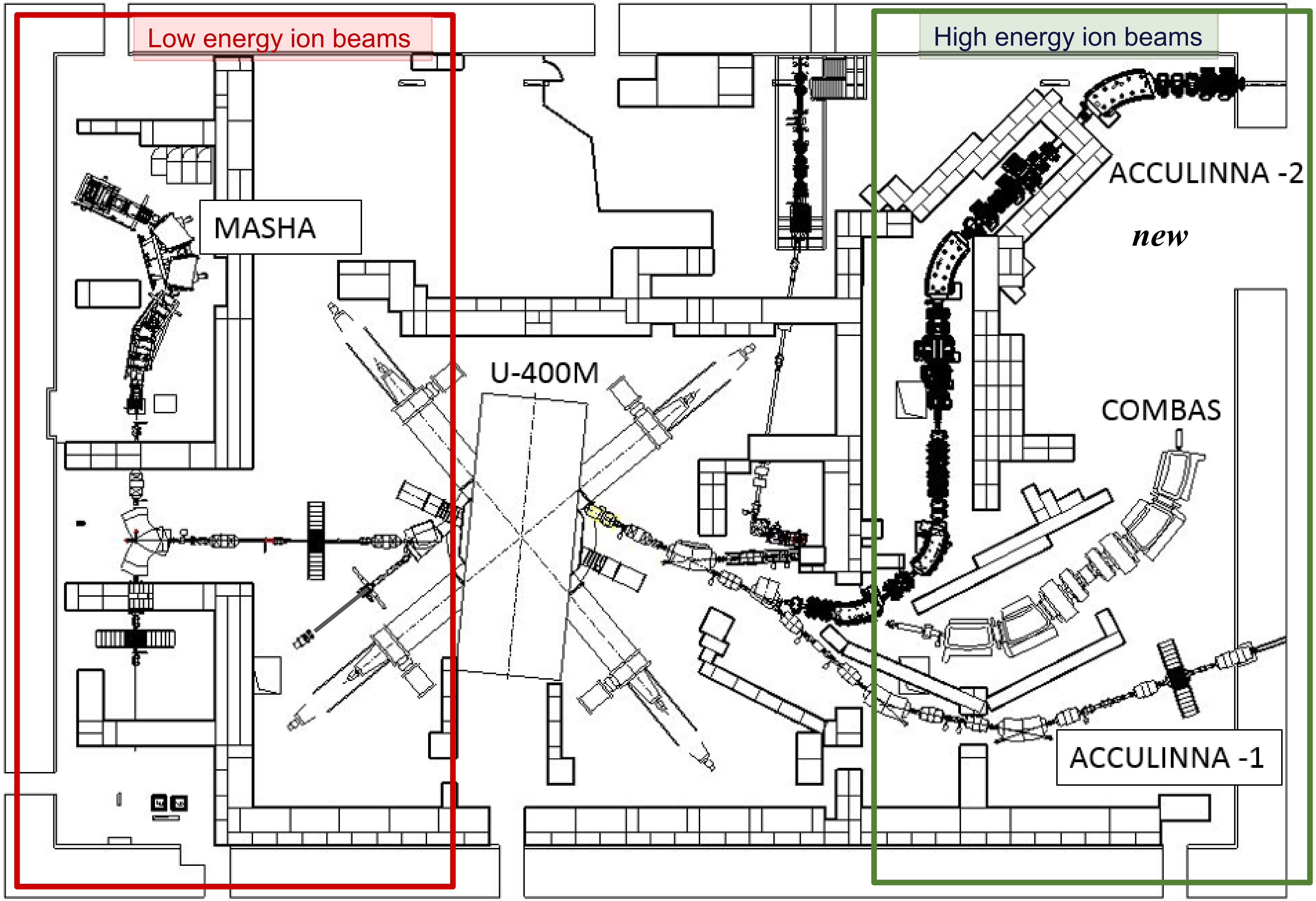
Direction 1.
High energy ions.
$^{14}N^{+5} \rightarrow {}^{14}N^{+7}$



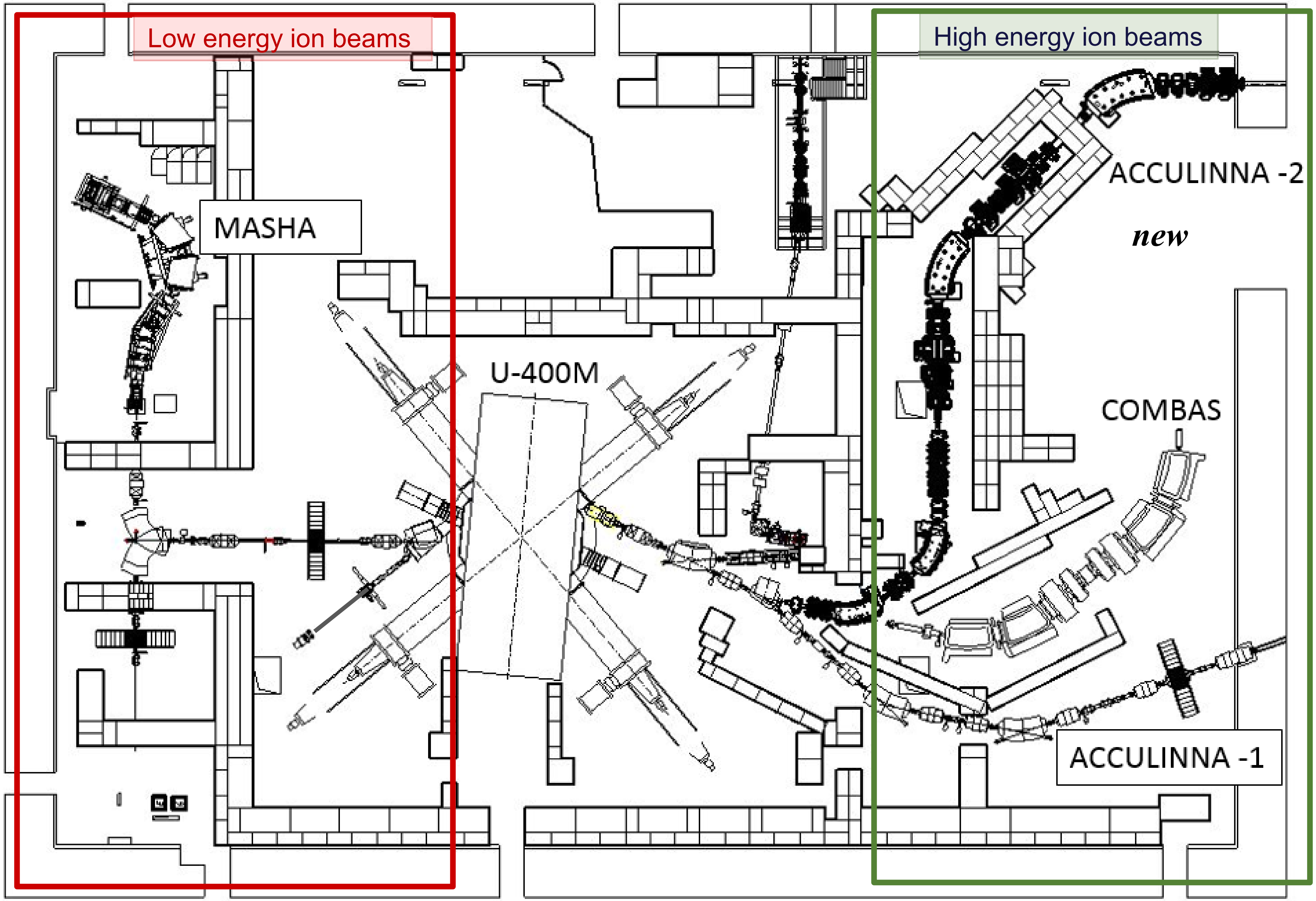
Direction 2.
Low energy ions.
$^{14}N^{+2} \rightarrow {}^{14}N^{+7}$

Thickness of stripping foil – 20 -200 $\mu g/cm^2$

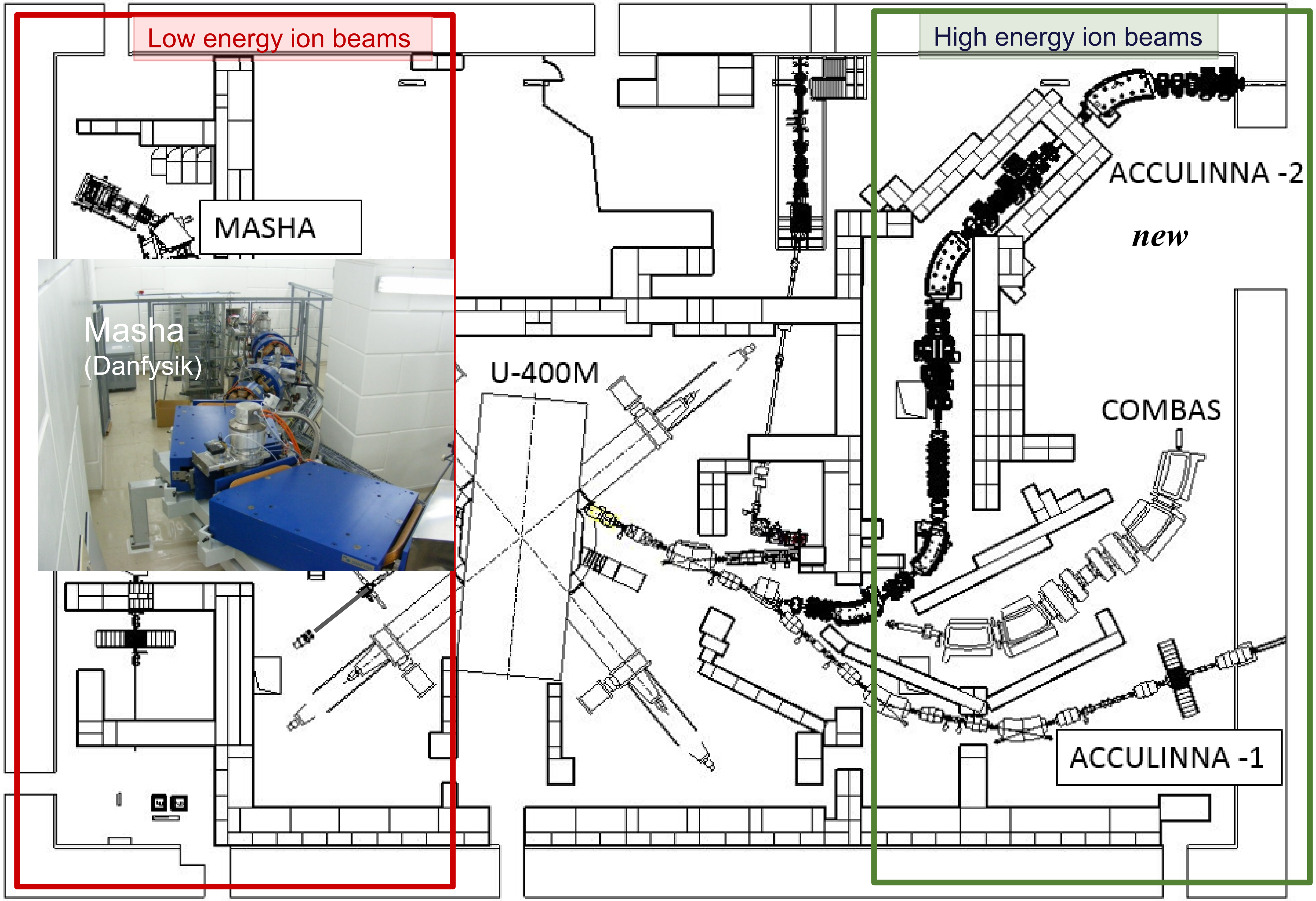
Experimental setups at U-400M



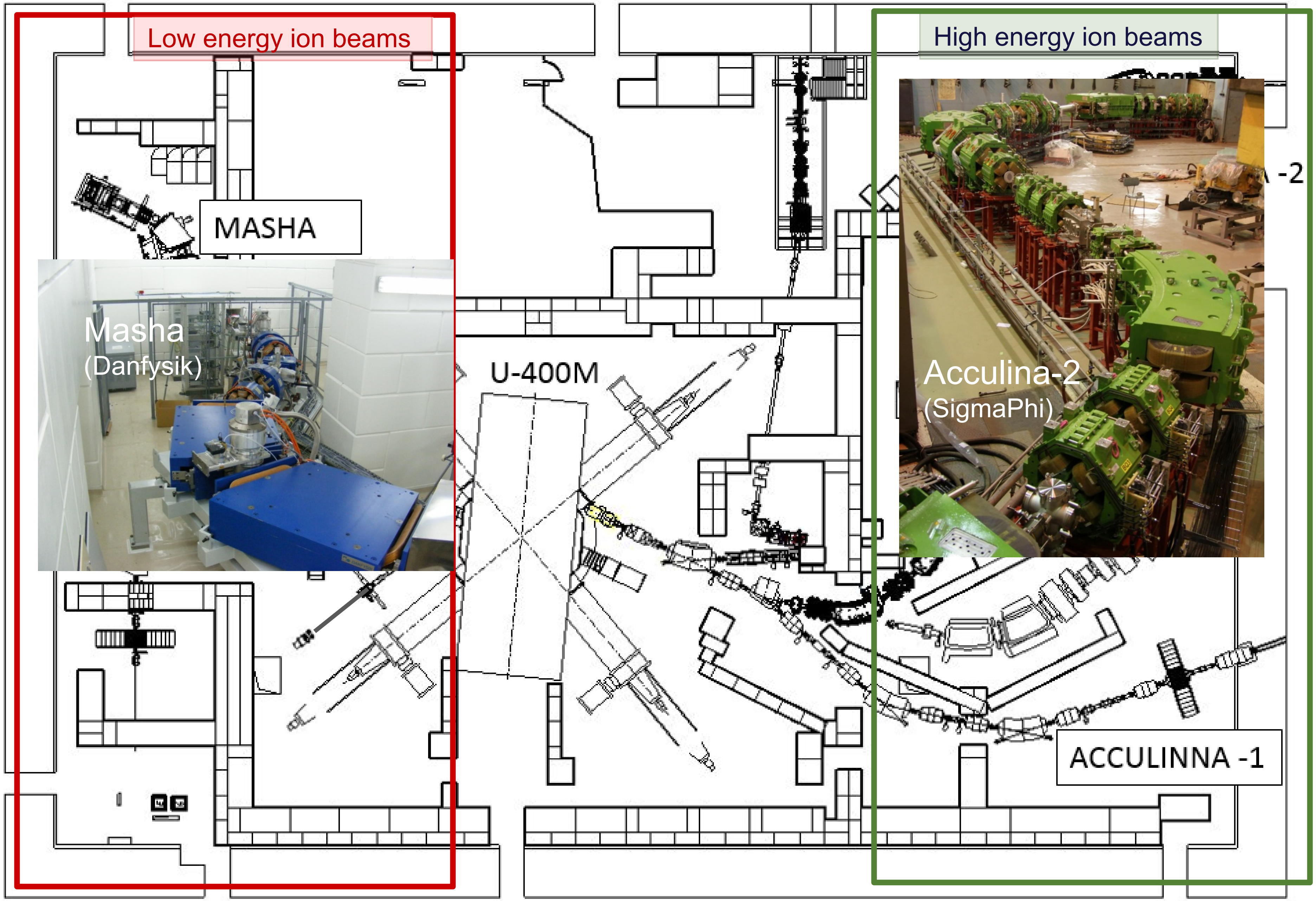
Experimental setups at U-400M



Experimental setups at U-400M



Experimental setups at U-400M

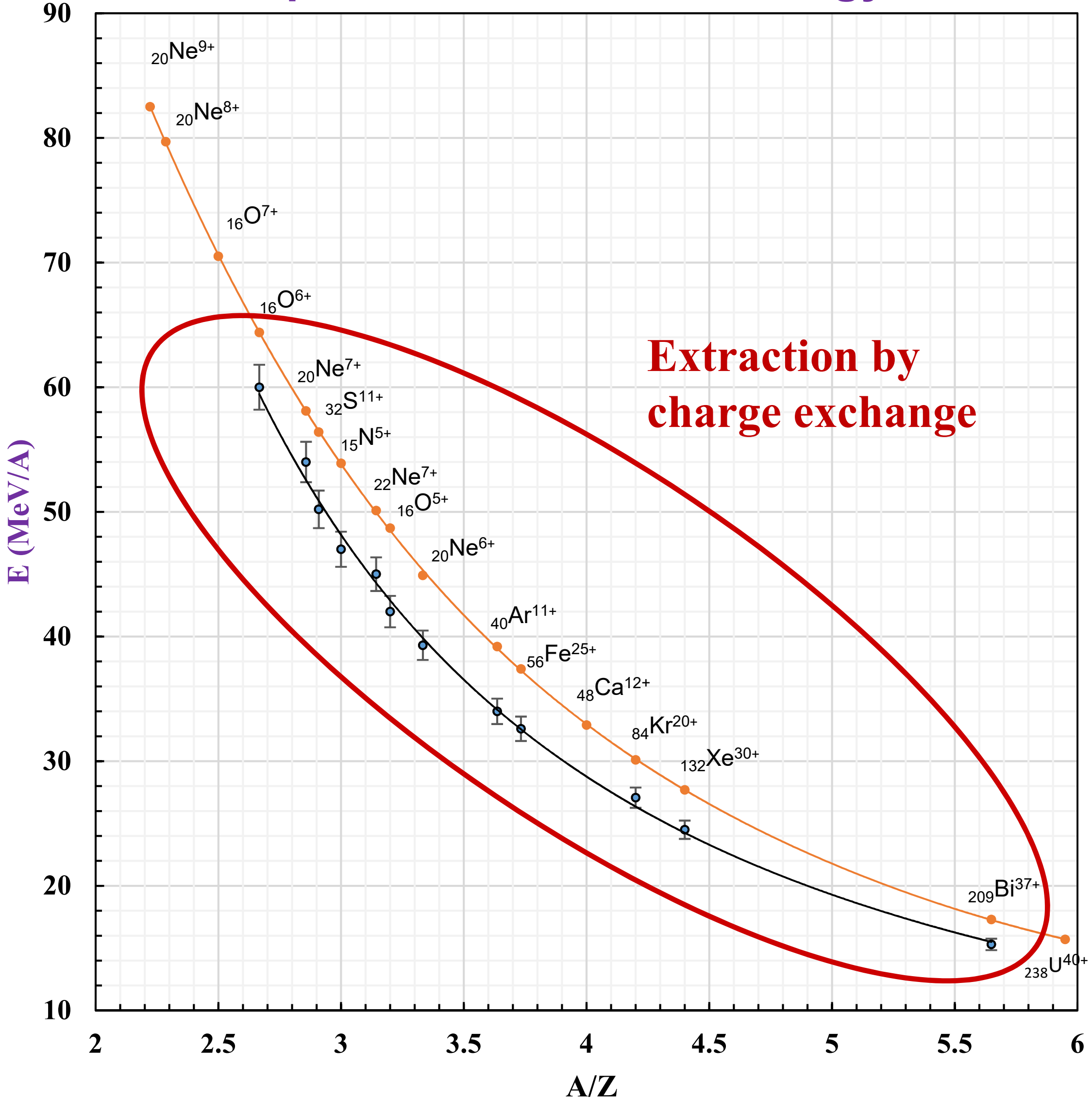


Modernization of the U400-M cyclotron (2019-2020):

1. Replacement of the main coils of the cyclotron main magnet; correction of the first harmonic of magnetic field;
2. Replacement of vacuum pumping system- diffusion pumps to cryopumps and turbopumps;
3. Modernization of RF- resonators; modernization of RF control system- analog to digital LLRF;
4. Increasing intensities and energies of ion beams.

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

Ион	A/Z	Current from DECRIS-2M DECRIS-SC2 μA	Estimation: Extracted current μA (10% of injected current)	Estimation: 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;** SECRAL – **Institute of Modern Physics (IMP), Lanzhou, China**; SC-ECRIS– **RIKEN, Japan;**

Benefits:

Higher intensities for high charged ions (factor 10 at least)

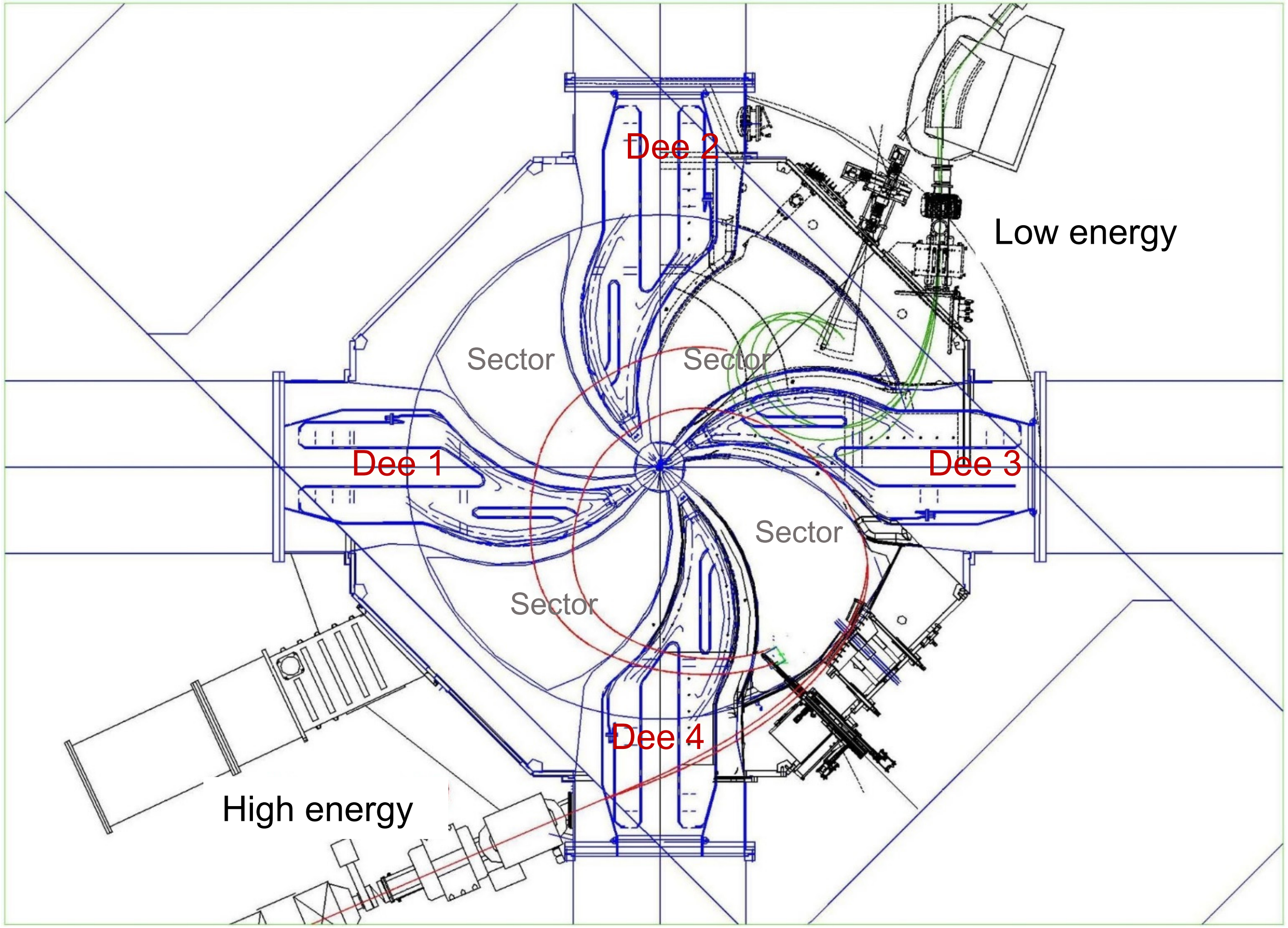
Problems:

Technical difficulties, high cost, big risks

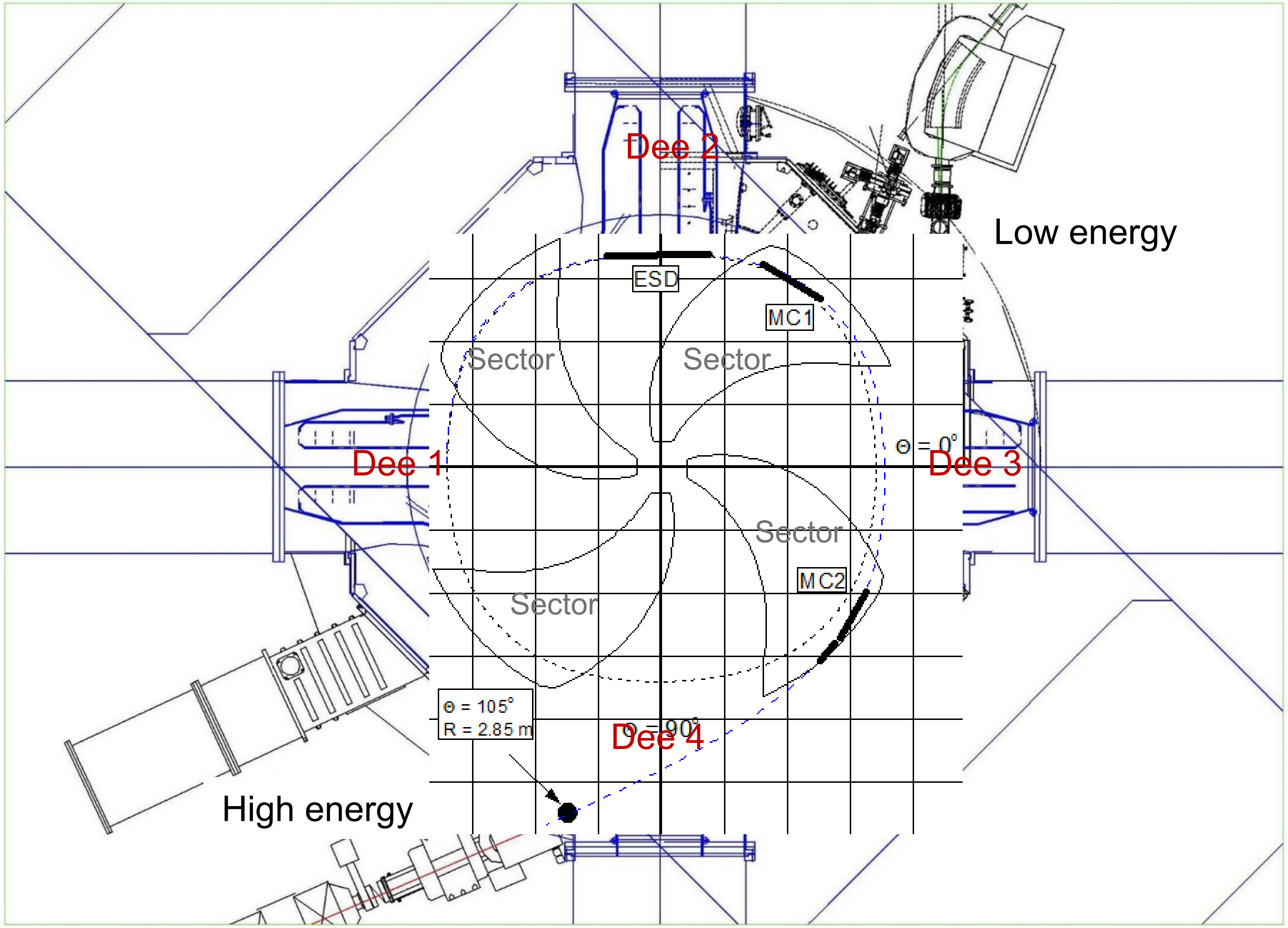
Possible decision:

Scientific collaboration, involvement of skilled manufacturers

Extraction by electrostatic deflector



Extraction by electrostatic deflector



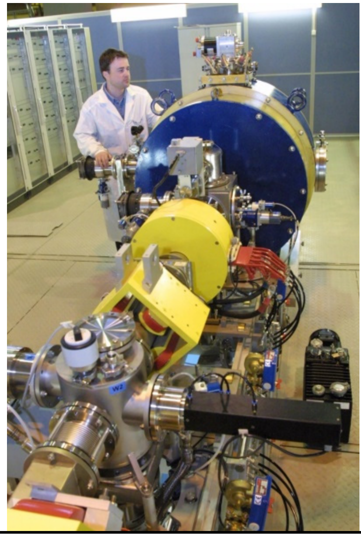
Deflector parameters:

L≈80 см, aperture ΔX=0.8 cm

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

Applied research

IC-100 cyclotron after reconstruction (2001-2002)



- **Production of track membranes**
- **Testing of reactor components with Kr and Xe ions**
- **Works on nanotechnology**

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 ions	A/Z = 5.5 ÷ 5.95
4	Ion energy	**0.9 ÷ 1.2 MeV/A**
5	Average magnetic field	1.78 ÷1.93 T
6	Frequency of the RF system	19.8 ÷ 20.6 MHz
7	Intensity of the accelerated and extracted beam of $^{86}Kr^{15+}$	$1.4 \cdot 10^{12}$ pps (3.5 μA)
8	Intensity of the accelerated and extracted beam of $^{132}Xe^{23+}$	~ 10^{12} pps (3.7 μA)

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.

Semen Mitrofanov: **WEOXA01** 14:40

U-200 Cyclotron

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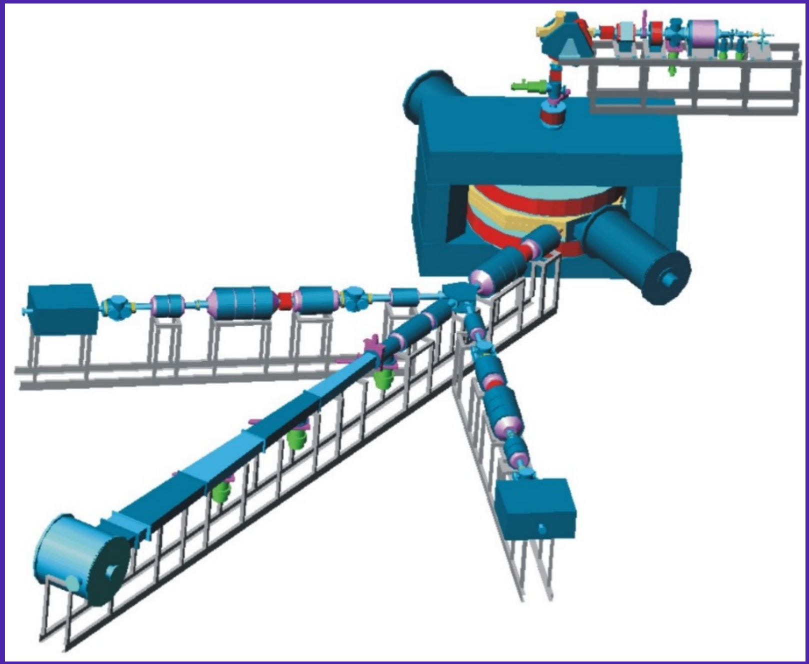

The project of DC-130 cyclotron

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.

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- production of track membranes,
- See testing of electronic components,

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Semen Mitrofanov: **WEOXA01** 14:40

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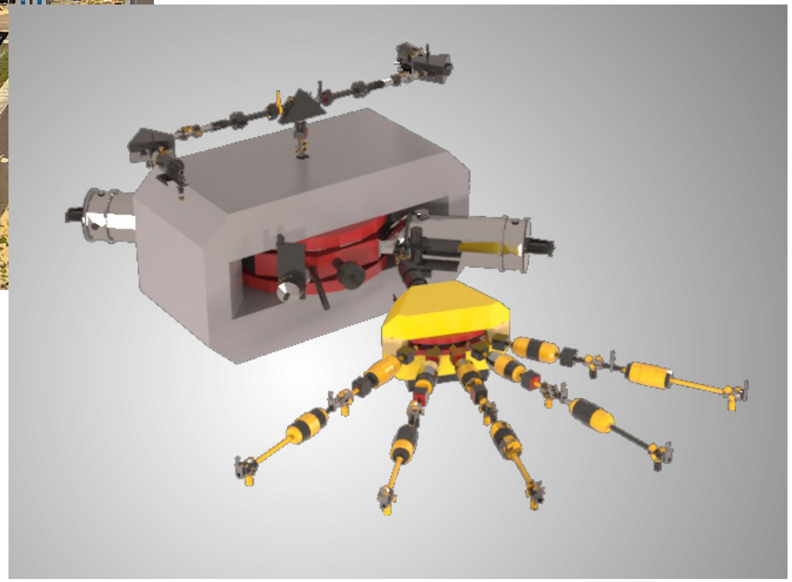
Factory of Super Heavy Elements (SHE)

SHE Factory Building

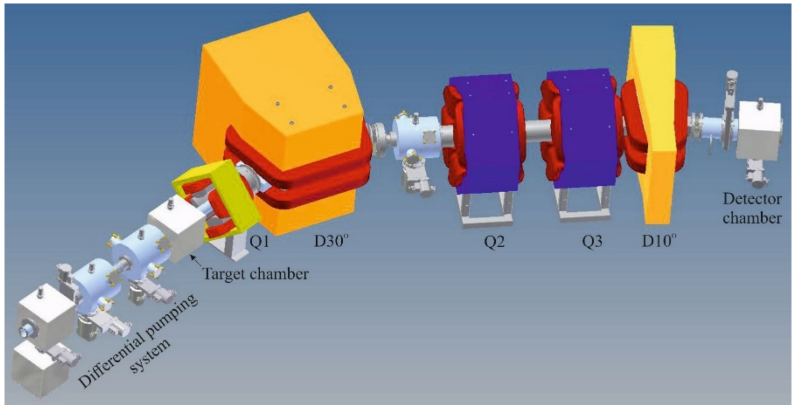
Reports:
Igor Kalagin (SHE-Factory): **Tuesday** 9:30
Andrey Efremov (ECR): **Tuesday** 15:10



High-current cyclotron DC-280

New facilities:

- New gas-filled separator
  (William Beeckman: **WEOAA01** 9:40)
- Preseparator
- SHELS
- Etc.



Conclusion

- FLNR JINR Accelerator Complex is being developed
- We expect to have essential results of the Accelerator Complex modernization to 2023


THANK YOU
FOR YOUR
ATTENTION !
Flerov Laboratory of Nuclear Reactions , JINR