THE NEW DC-280 CYCLOTRON. STATUS AND PERSPECTIVES

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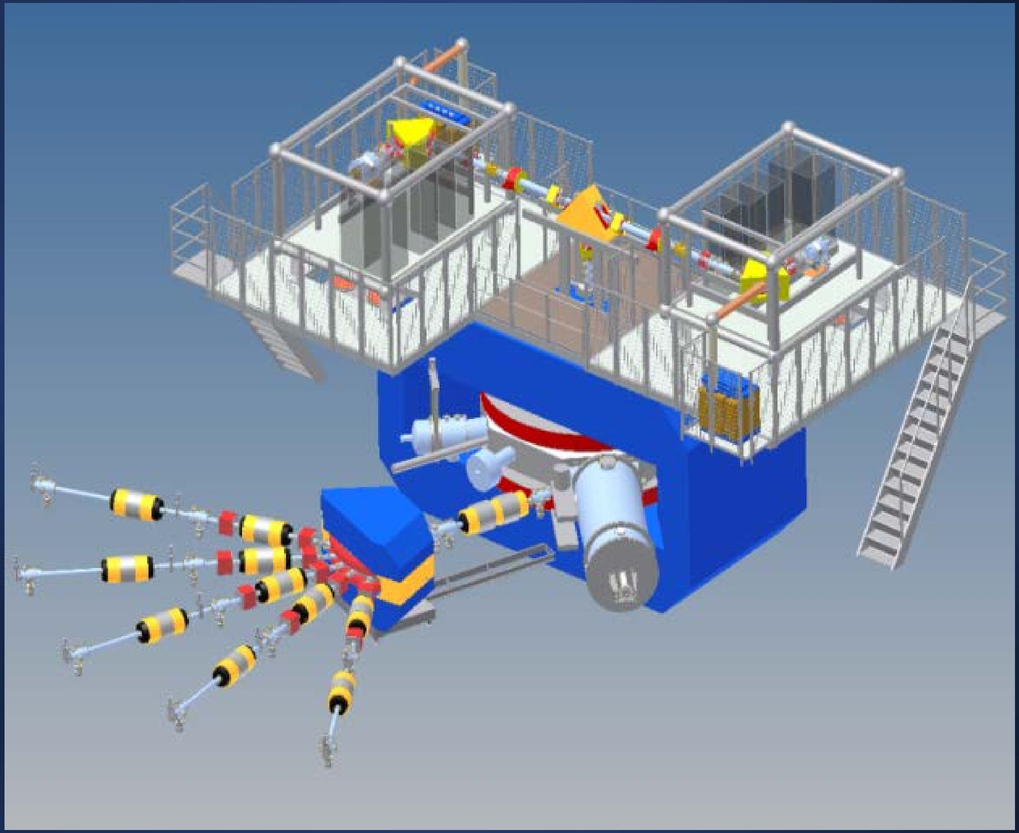


Igor Kalagin

FLEROV LABORATORY of NUCLEAR REACTIONS

JOINT INSTITUTE FOR NUCLEAR RESEARCH

ECPM, LEGNARO 2017

PLAN OF THE FLEROV LABORATORY OF NUCLEAR REACTIONS

The project of the SHEF experimental building

The FLNR main building

Factory of Superheavy Elements – the main Goals

- **Synthesis of SHE and studying of their properties;**
- **Search for new reactions for SHE-synthesis;**
- **Study of chemical properties of SHE;**

Because of extremely low (σ<50 fb) cross sections of reactions the experiments require high intensities of primary beams for the best statistics.

The Factory will be based on the new DC-280 cyclotron. The cyclotron will produce high intensity ion beams. The cyclotron is being created in the new experimental building of the FLNR.

THE NEW FLNR ACCELERATOR – THE DC-280 CYCLOTRON

To satisfy the Goals, the DC-280 must have the following parameters of the ion beams:

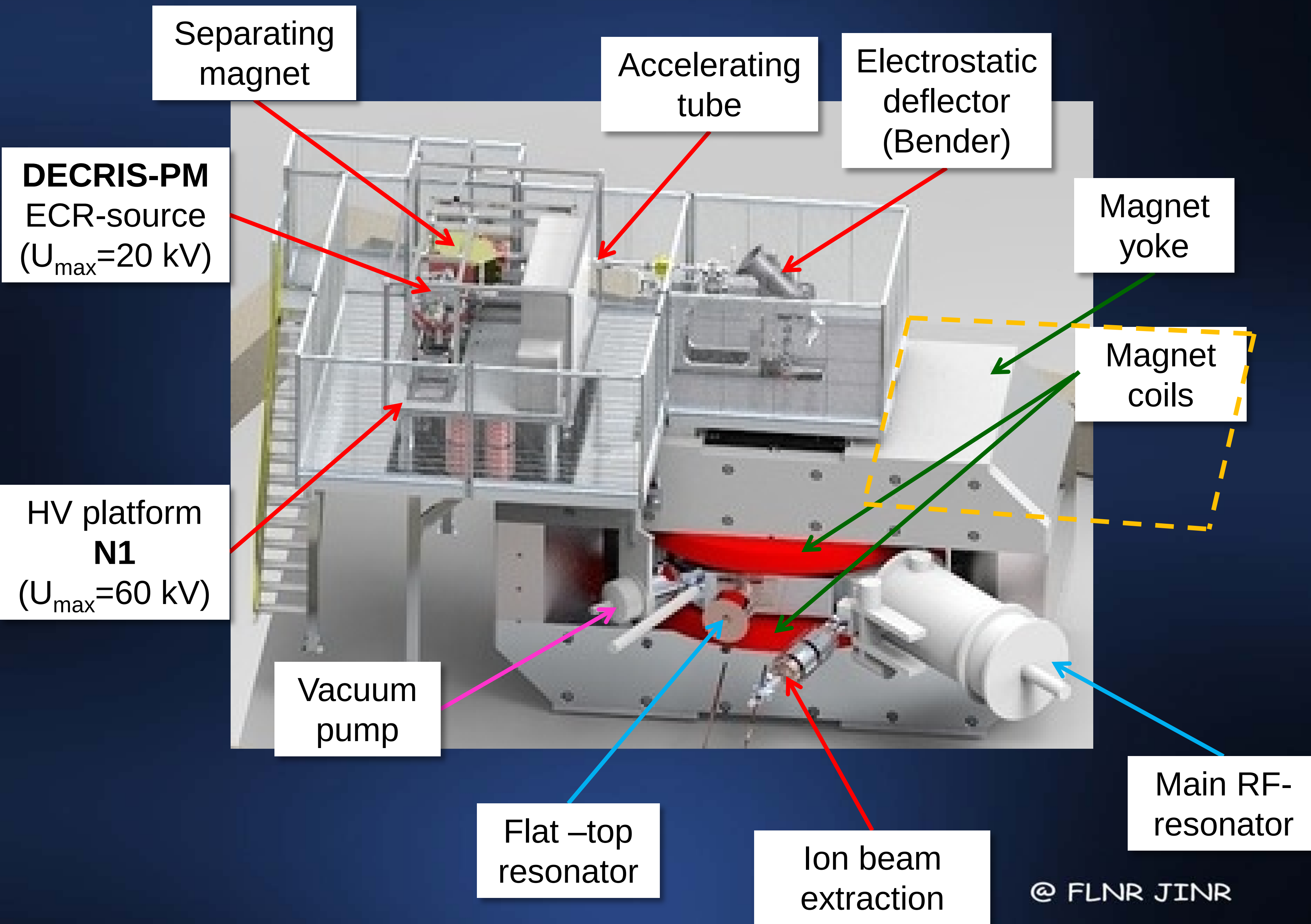
Ion energy	4÷8 MeV/n
Ion masses	4÷238
Intensities (A~50)	>10 pμA
Beam emittance	less than 30 π mm·mrad
Efficiency of beam transfer	>50%

Ion energies correspond to total accelerating potential up to 40 MV

Basic principles of the DC-280 design

	Principles	Expected results
1.	**High injection energy of ions** (up to 80 keV/Z)	**Decreasing of ion beam emittance (typical injection energy of 15÷20 keV/Z). Effective transportation of ions through injection. Better efficiency of capture into acceleration.**
2.	**Low magnetic field** (up to 1.3 T)	**Larger beam starting radius. Lower power of the main magnet.**
3.	**High accelerating voltage** (up to 130 kV)	**Higher turns separation. Lower vacuum losses of ions.**
4.	**Beam extraction by the electrostatic deflector together with the flat-top system**	**Effective ion extraction. Better beam quality.**

Actual configuration of the DC-280



Main design parameters of the DC-280

Ion sources	1. DECRIS-PM - 14 GHz on the 1-st HV platform 2. Superconducting ECR on the 2-nd HV platform (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
Dee voltage	2x130 kV
RF power consumption	2x30 kW
Flat-top dee voltage	2x13 kV
Flat-top power consumption	2x2 kW

Expected beam parameters of the DC-280

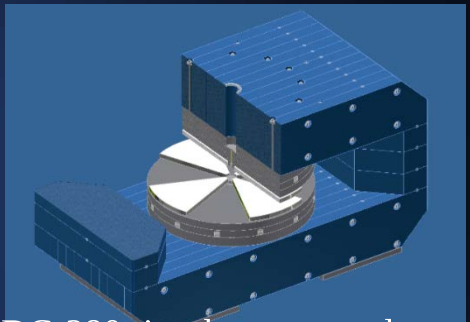
ION	Z	Beam Intensity from ECR		HV platform N	Efficiency of acceleration	Expected beam intensities of (4÷8) MeV/n ions on targets pps
		eμA	pps			
20Ne	3	150	3.10^{14}	1	50%	$1.5\cdot10^{14}$
40Ar	7	300	3.10^{14}	1	50%	$1.5\cdot10^{14}$
48Ca	7/8	160	$1.3.10^{14}$	1	50%	$6.2\cdot10^{13}$
^{50}Ti	8/9	80	$6.2.10^{13}$	1	50%	$3.1.10^{13}$
^{54}Cr	9	125	8.10^{13}	1	50%	4.10^{13}
58Fe	9/10	125	8.10^{13}	1	50%	$4\cdot10^{13}$
64Ni	10/11	125	8.10^{13}	1	50%	$4\cdot10^{13}$
70Zn	11/12	100	5.10^{13}	1	50%	$2,5.10^{13}$
136Xe	22/23	150	4.10^{13}	1	50%	$2\cdot10^{13}$
209Bi	34/35	15	$2,2.10^{12}$	2	60%	$1\cdot10^{12}$
238U	39/40	1	$1,5.10^{11}$	2	60%	1.10^{11}

Main systems of the DC-280

N	Item
1	Magnetic system
2	RF system
3	Beam injection system
4	Beam extraction system
5	Beam transport system
6	Diagnostic system
7	Vacuum system
8	Water cooling system
9	Control system

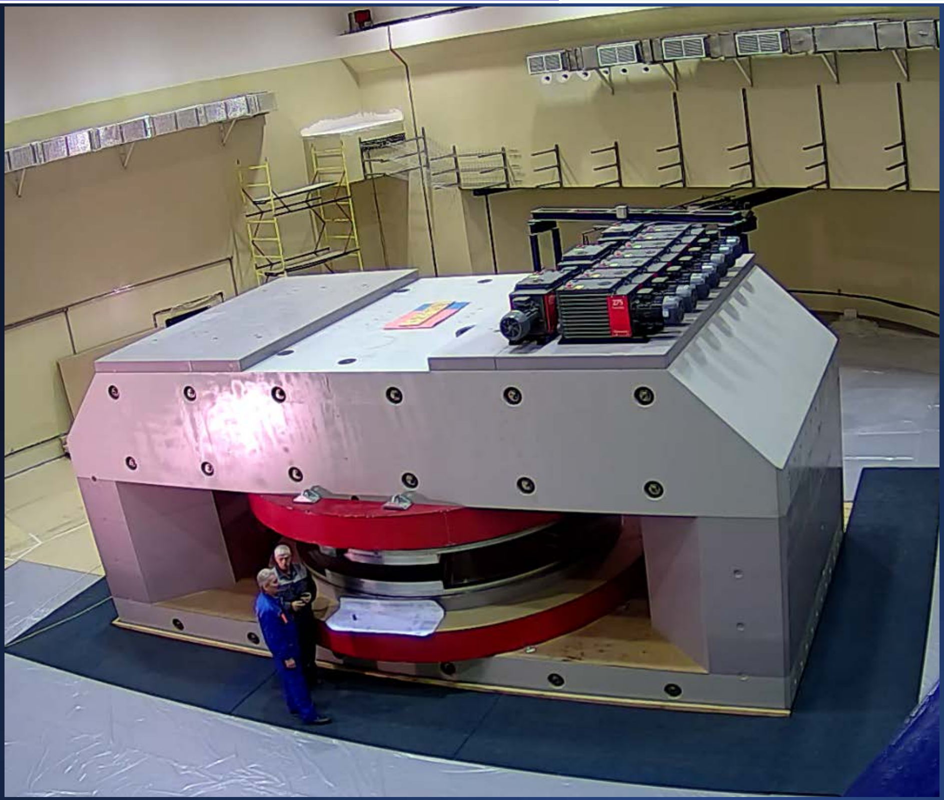
Magnetic system of ДЦ-280

Size of magnet yoke LxWxH	8.76x4.08x4.84 m^3
Pole diameter	4 m
Gap between central plugs	400 mm
Valley/hill gap	500/208 mm/mm
Magnet weight	1100 t
Magnet power	300 kW
Maximal current	1000 A
Magnetic field level	0.6÷1.3 T

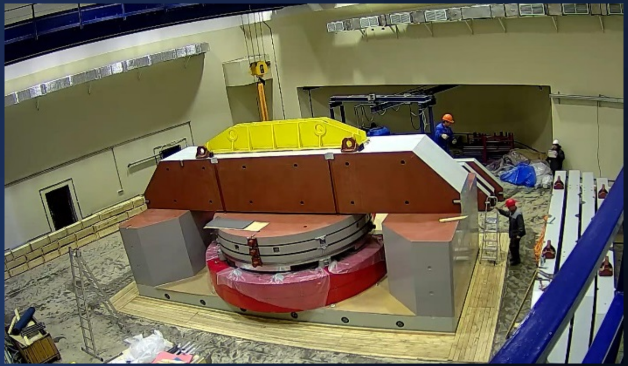


DC-280- isochronous cyclotron

Magnet at the NKMZ, Ukraine (2014)



DC-280 magnet at the FLNR, February 2017
Main coils made in N&V, Romania (2016)



Magnet assembling (November 2016)

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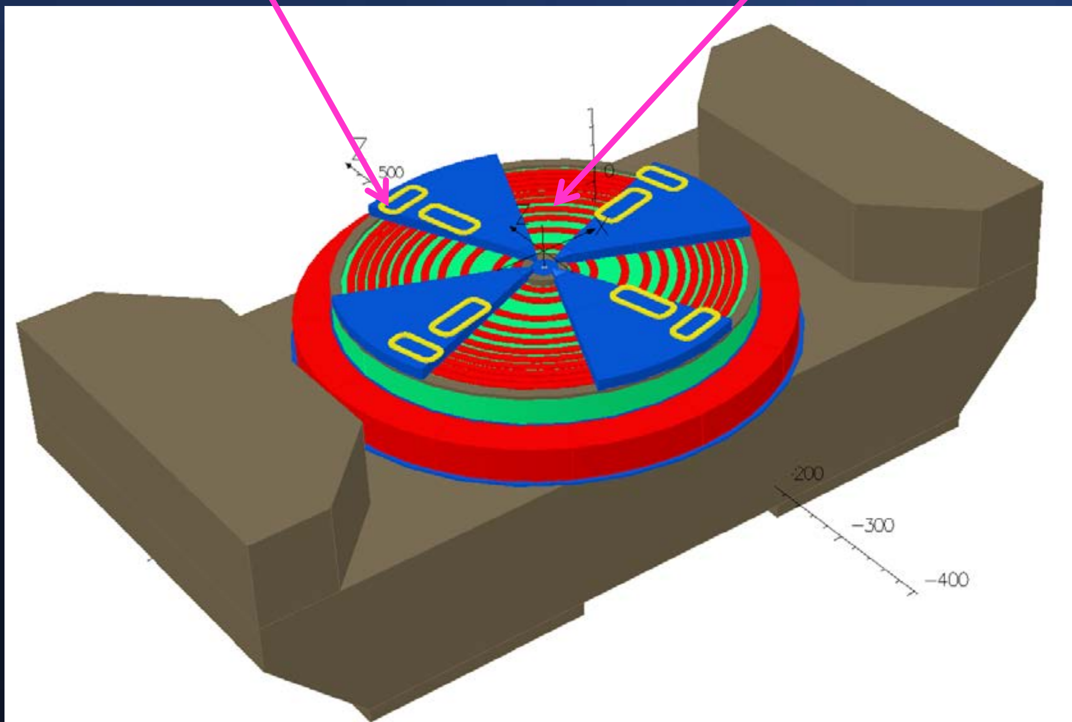
Magnet trimming coils



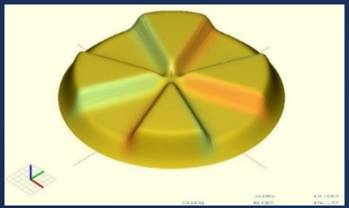
Number of radial trimming coils	11
Number of azimuthal trimming coils	8

Block of radial trimming coils (EVPU, Slovakia)

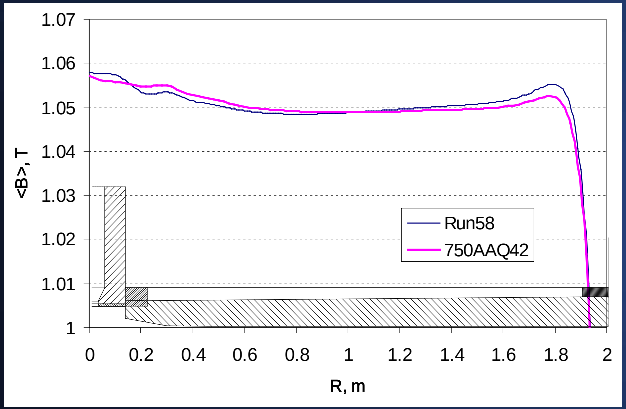
Blocks of azimuthal trimming coils (GKMP, Bryansk, Russia)

The radial trimming coils have been installed in the main magnet and are being used in magnetic measurements. The azimuthal trimming coils will be installed on magnet sectors after installation of the vacuum chamber.

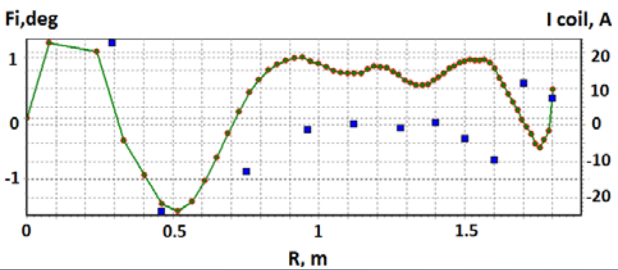
Magnetic field measurements



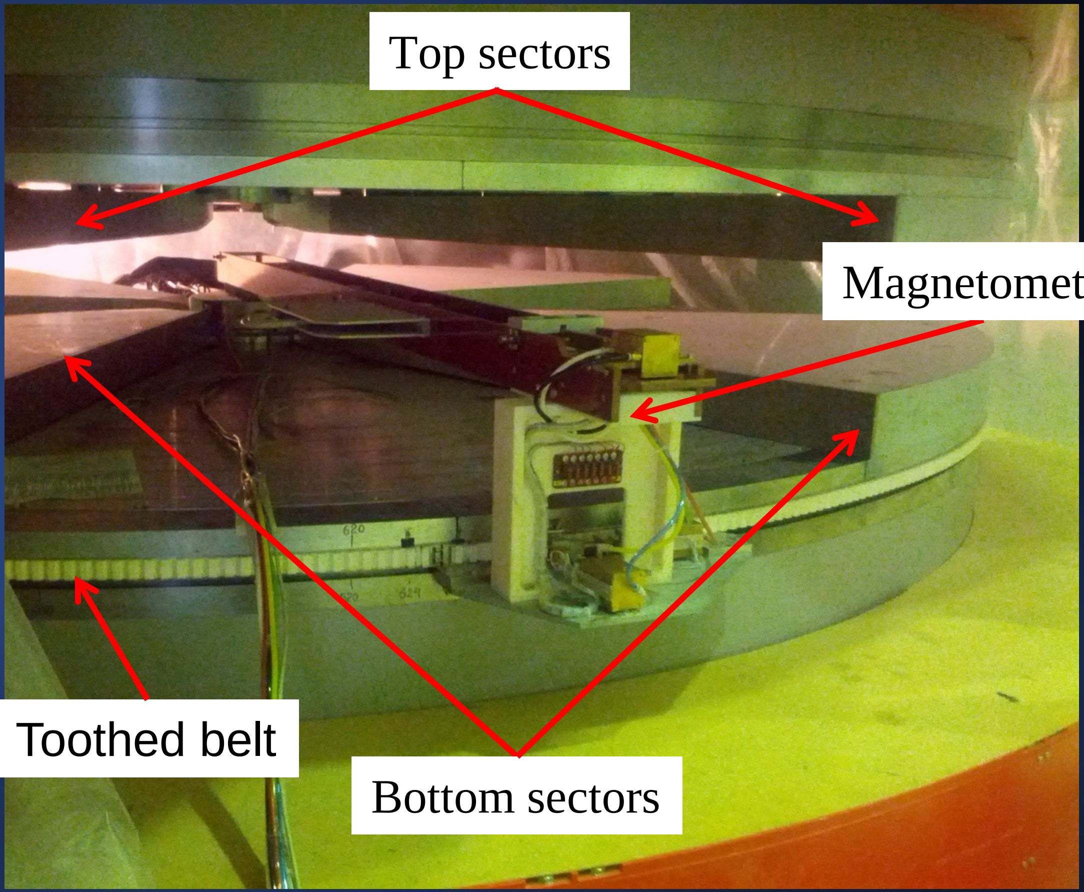
3D field map of the DC-280, coil current of 750 A, average magnetic field induction of 1.05 T



Comparative radial distributions of calculated and measured average magnetic field at the main coil current of 750A



Calculated behavior of beam phase (Fi) for ions with A/Z=6 at acceleration with using trimming coils (I coil)



The magnetometer with 14 Hall probes has been developed at the FLNR and was manufactured at the SPA “ATOM”, Dubna. Radial and azimuthal motions are carried by thepneumatic engines with using toothed belt for azimuthal stepping. Measuring accuracy of 10^{-4}. At present, magnetic field measurements finished and results are being processed.

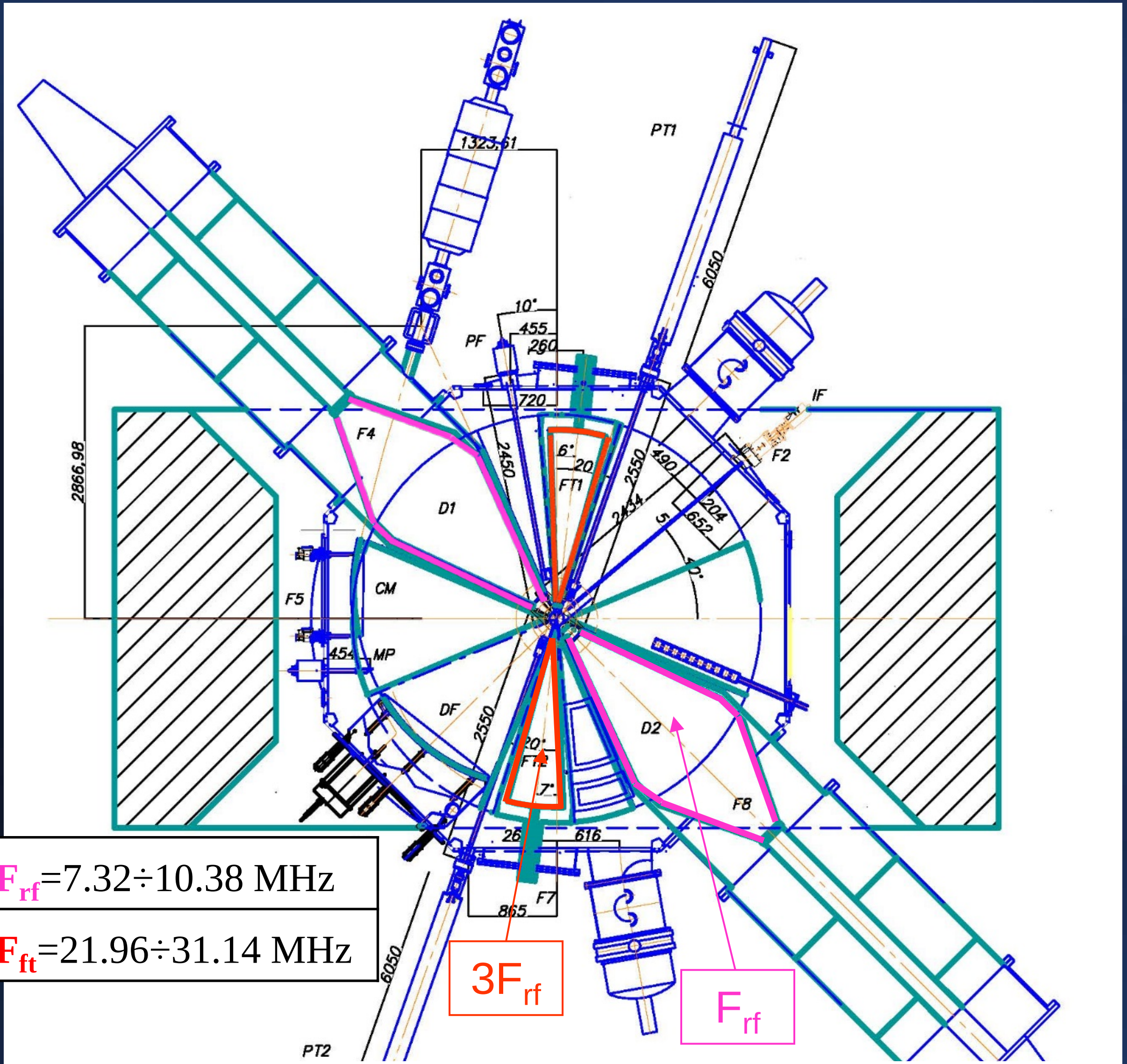
Vacuum chamber of the DC-280 magnet

Vacuum chamber has been manufactured at the NKMZ plant.
Vacuum tests have been made at the FLNR (2016)
The chamber is being installed now.

Working vacuum is 10^{-7} mBar

RF system

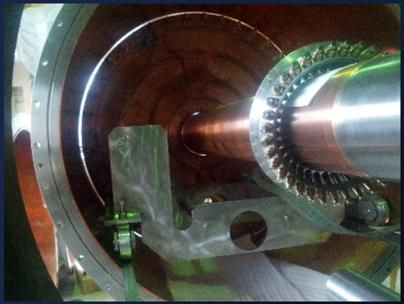
Configuration of the DC-280



In June 2017, resonance frequencies of the N1 resonator have been measured at minimal RF power. The experimental frequency range is 7.17÷10.8 MHz, which covers the designed one.

The main dee (EVPU, Slovakia)

The RF resonator at the FLNR



Details of the resonator (ZAVKOM, Tambov, Russia)

RF generators

Dee voltage	2x130 kV
RF Power consumption	2x30 kW
Generator RF Power	2x50 kW

Flat-top dee voltage	2x13 kV
RF Power consumption	2x2 kW
Generator RF Power	2x3 kW

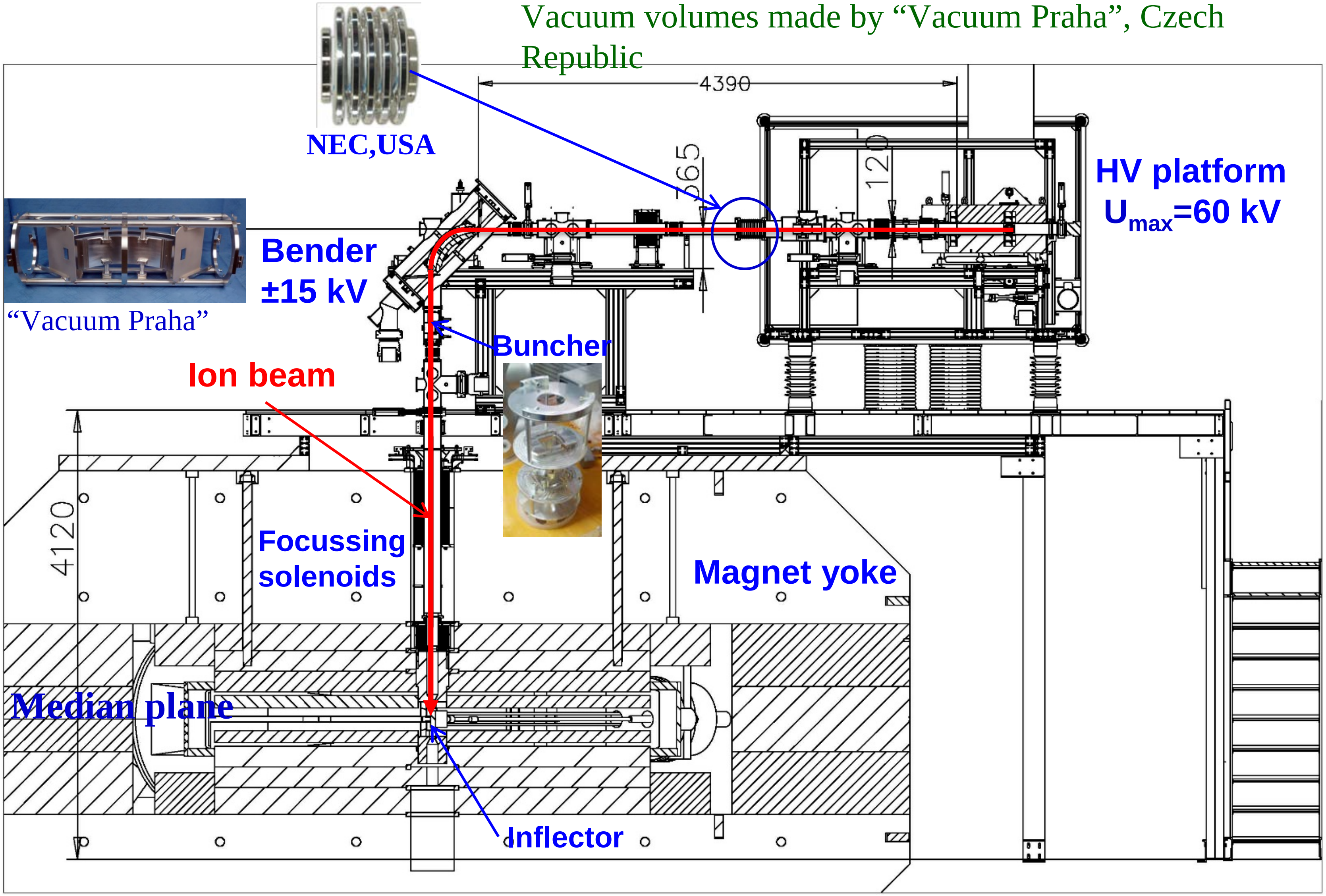
F_{rf}=7.32÷10.38 MHz

F_{ft}=21.96÷31.14 MHz

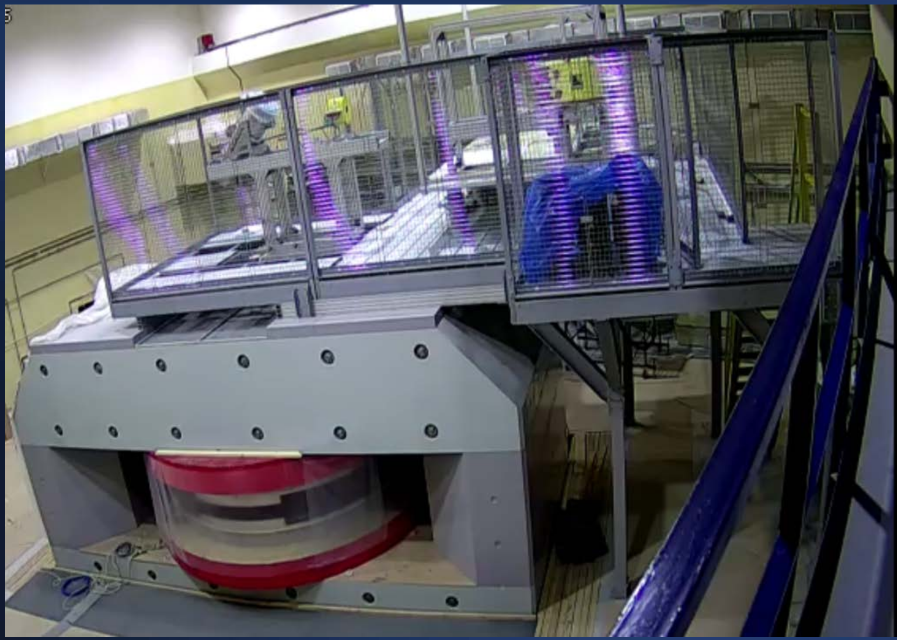
The RF generators made in the QEI Corporation, NJ, USA

Beam injection system

Working vacuum in injection is 5·10^{-8} mBar
Vacuum volumes made by "Vacuum Praha", Czech Republic



Beam injection system



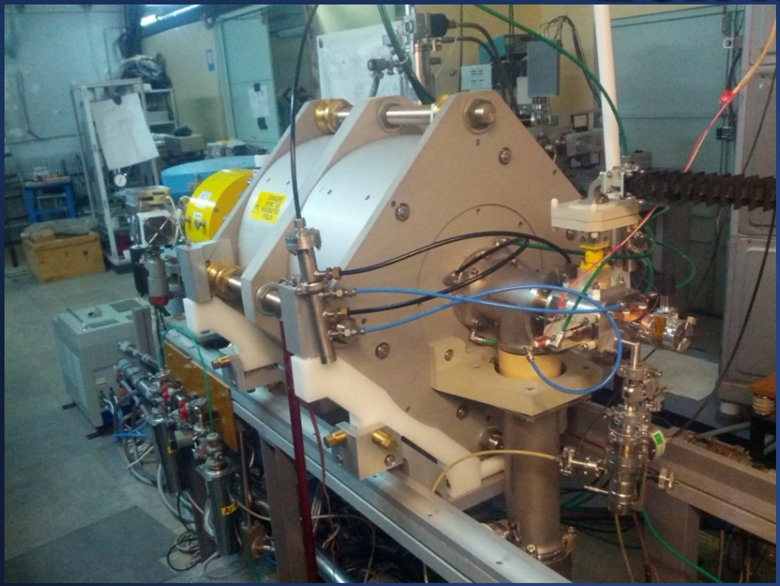
The magnet with the base platform for injection

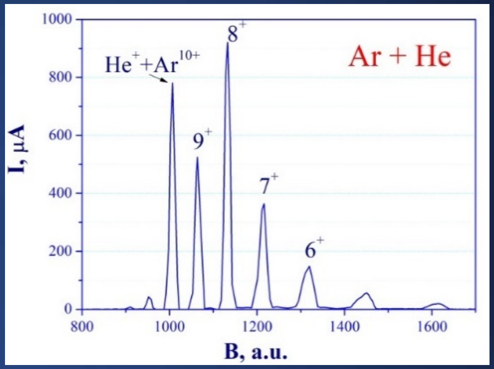
The HV platform **N1** (August 2017)

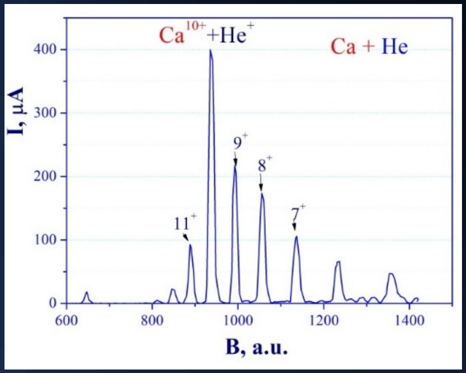
Internal focusing solenoids have been installed to the cyclotron center (May 2017)

Magnetic elements for the injection made in EVPU, Slovakia

ECR-ion sources

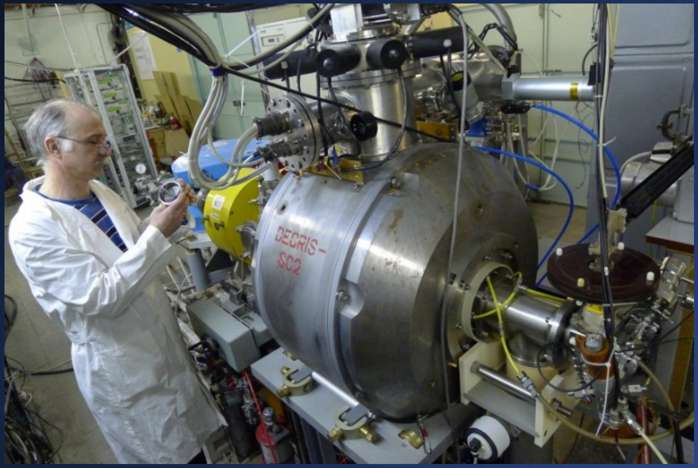






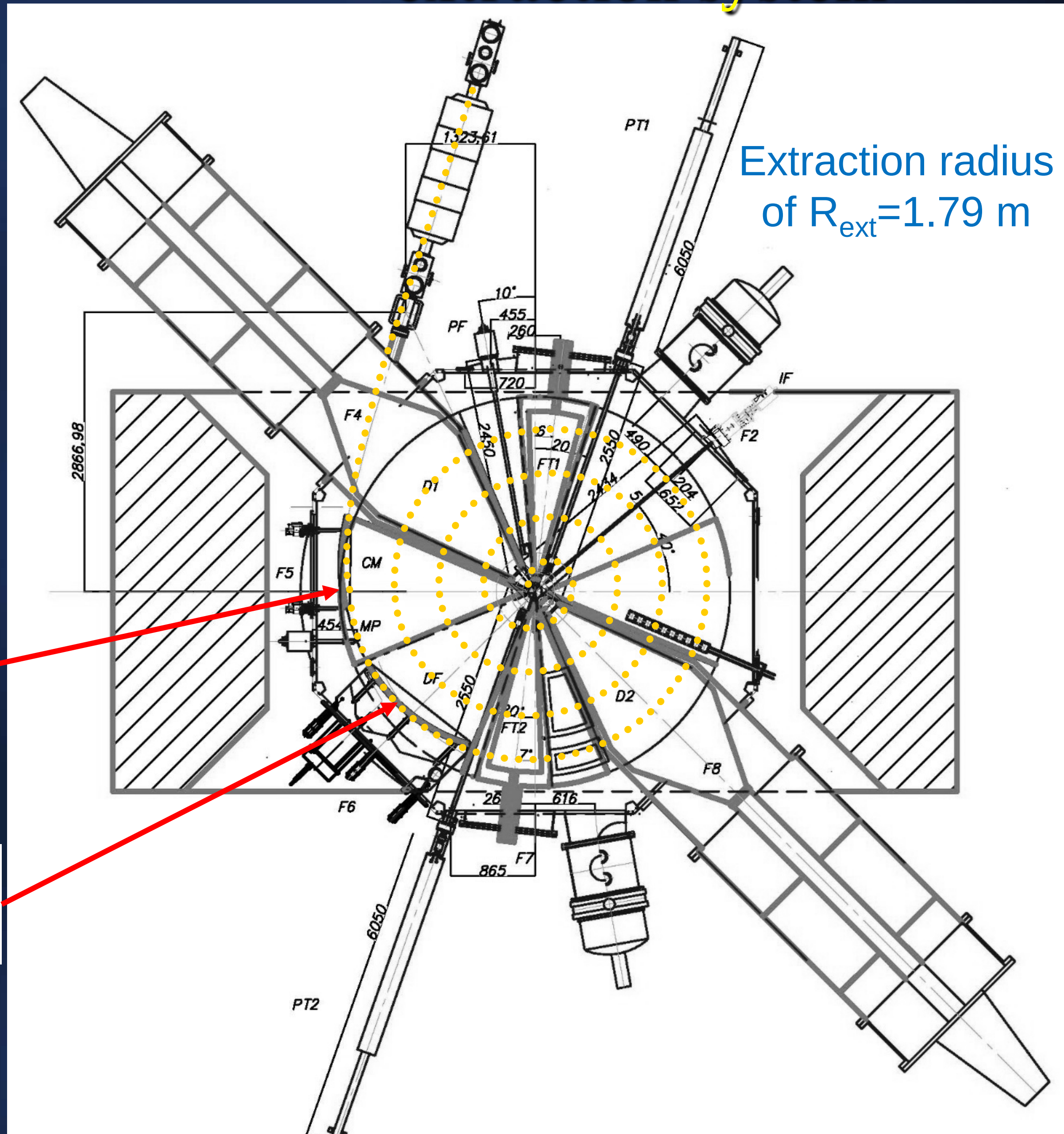
Experimental spectrums of Ar and Ca ions extracted from the DECRIS-PM

The new ECR-ion source DECRIS-PM (14 GHz) for the 1-st HV platform .
(FLNR and “ITT-Group”, Moscow).

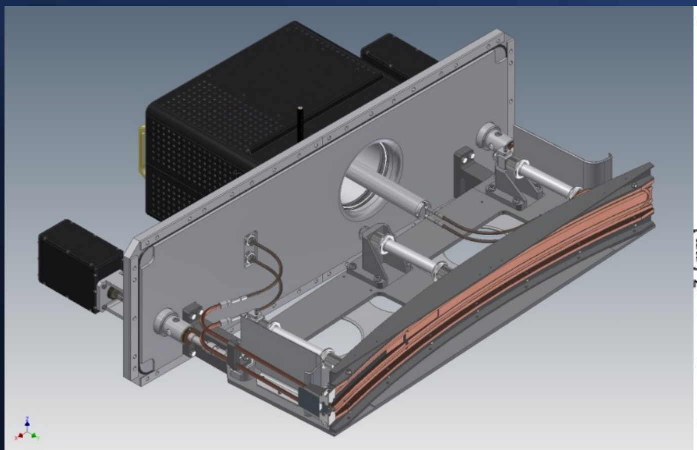


The FLNR has experience in developing and creation of DECRIS-SC and DECRIS-SC2 (18 GHz). The experience will be used for developing the new superconducting ECR for the 2-nd HV platform.

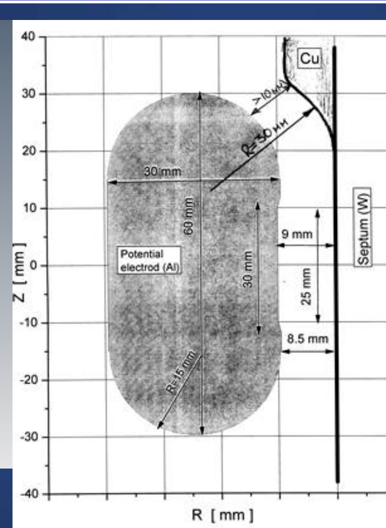
Beam extraction system

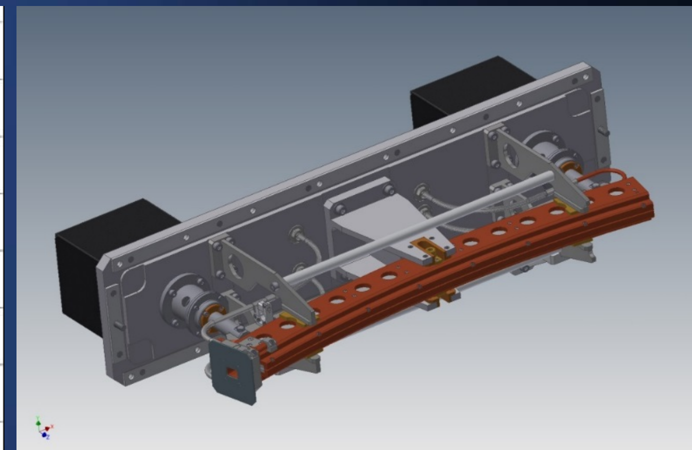


Length of electrostatic deflector	1.3 m
Deflector voltage	80 kV
Length of the magnetic channel	0.9 m
Gradient of the magnetic channel	4.6÷8.4 T/m

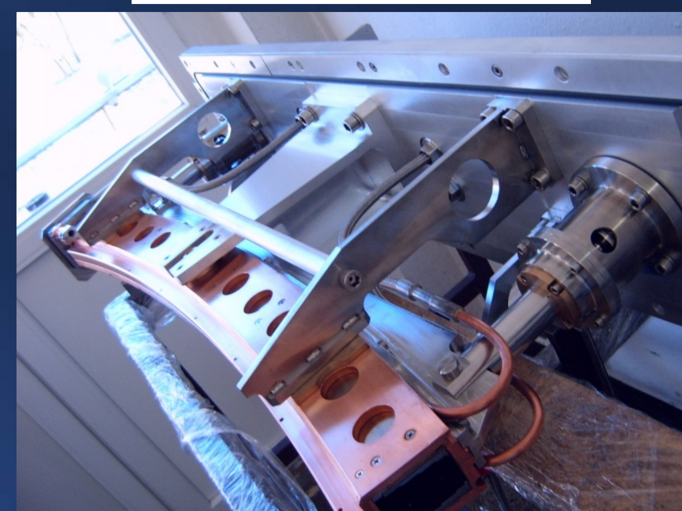


Electrostatic deflector





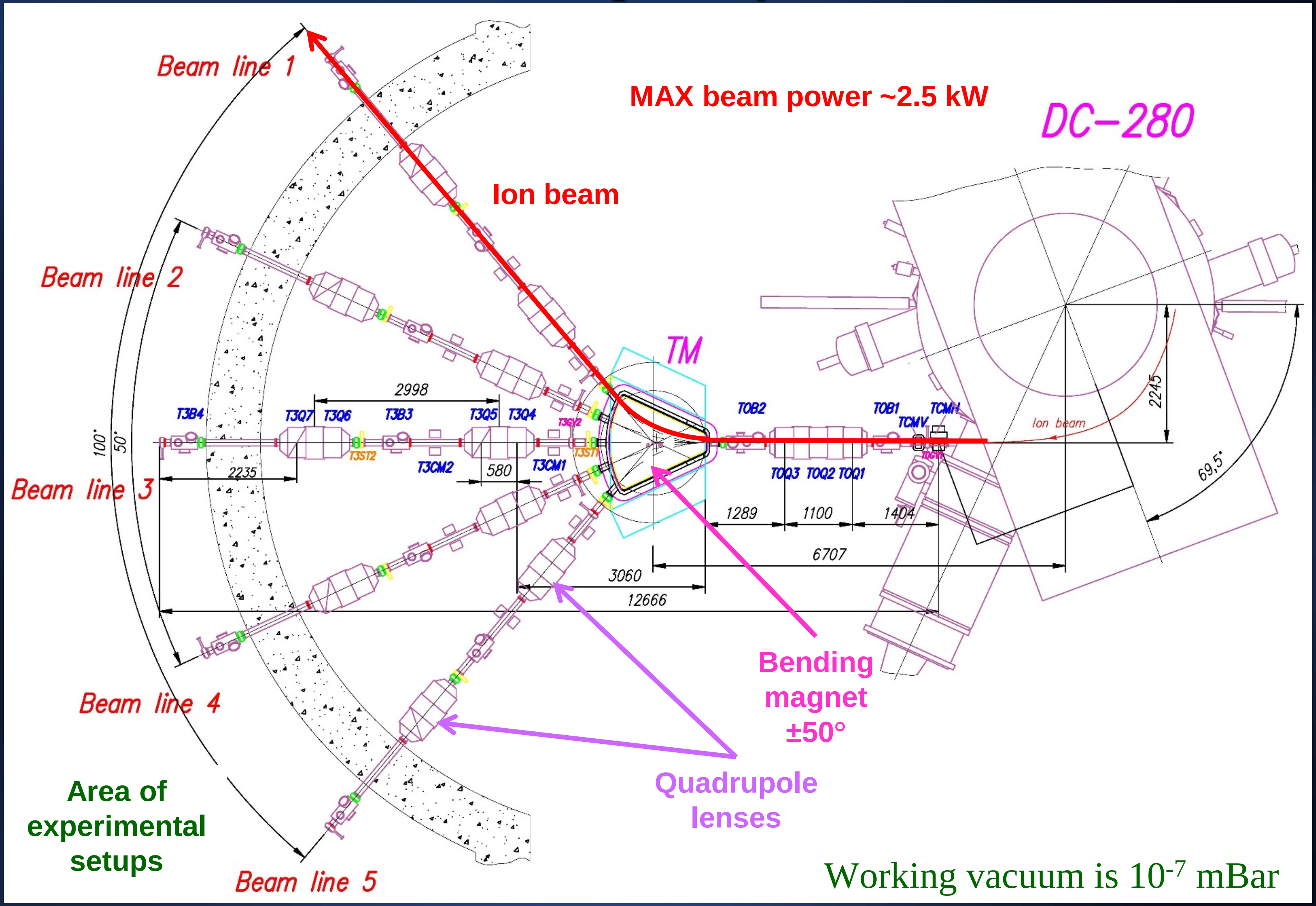
Magnetic channel



The magnetic channel has been produced at the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Science.

Electrostatic deflector is being produced in the INR&NE too.

Beam transport system



Vacuum volumes of channels: “Vacuum Praha”, Czech Republic

Beam diagnostics: INR&NE of the Bulgarian Academy of Science

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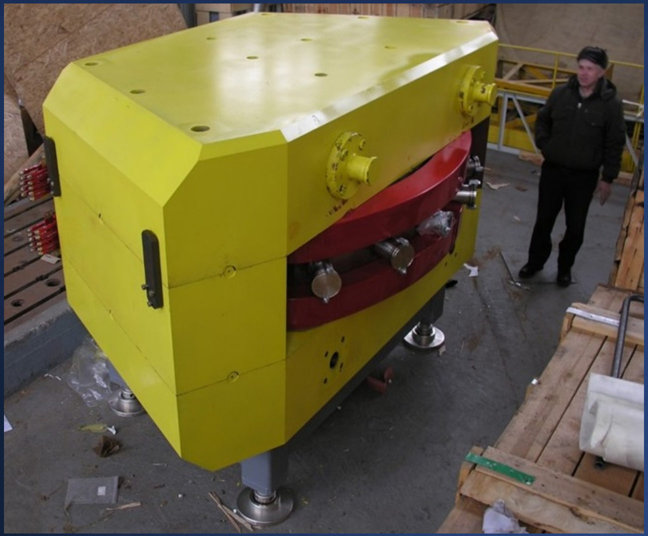
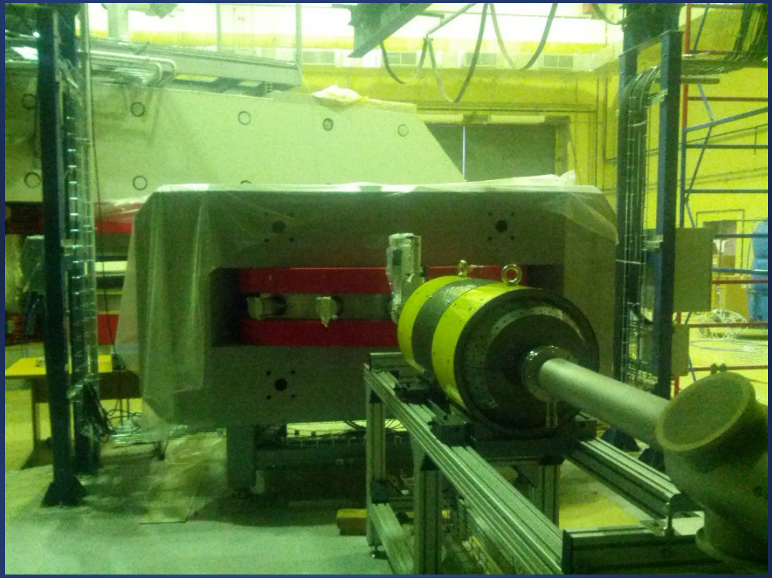
Magnetic optics



TM±50 bending magnet
(NKMZ, Ukraine)

The triplet of quadrupole lenses 11K30-700
(N&V, Romania)



Beam channel N3 at the DC-280 hall

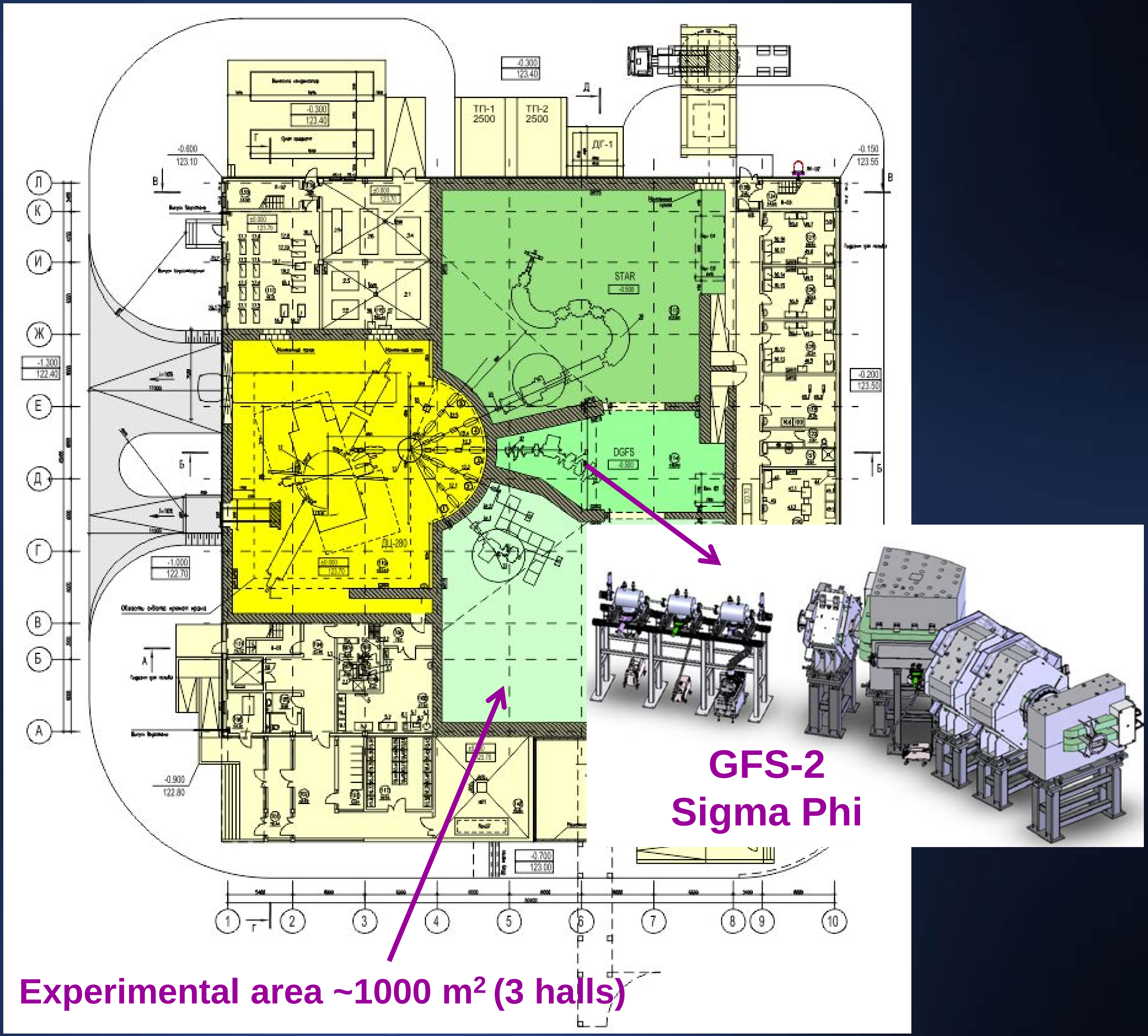
Water cooling system

The water cooling system was developed at the FLNR (equipment suppliers: Russia, Italy, Germany)

Control system

The control system based on FLNR developments and LabVIEW

Plan of the 1-st floor of the SHEF



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Schedule

Schedule of creation and launching of the DC-280 cyclotron.

N	Work content	2016												2017												2018											
	Months	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
1.	Construction of the building																																				
2.	Assembly and tuning of the DC-280																																				
3.	Launching of the DC-280 and acceleration of the first ion beam																																				

THANKS FOR YOUR ATTENTION!

The building of the SHEF

August 2017

The outline sketch of the building (2012)

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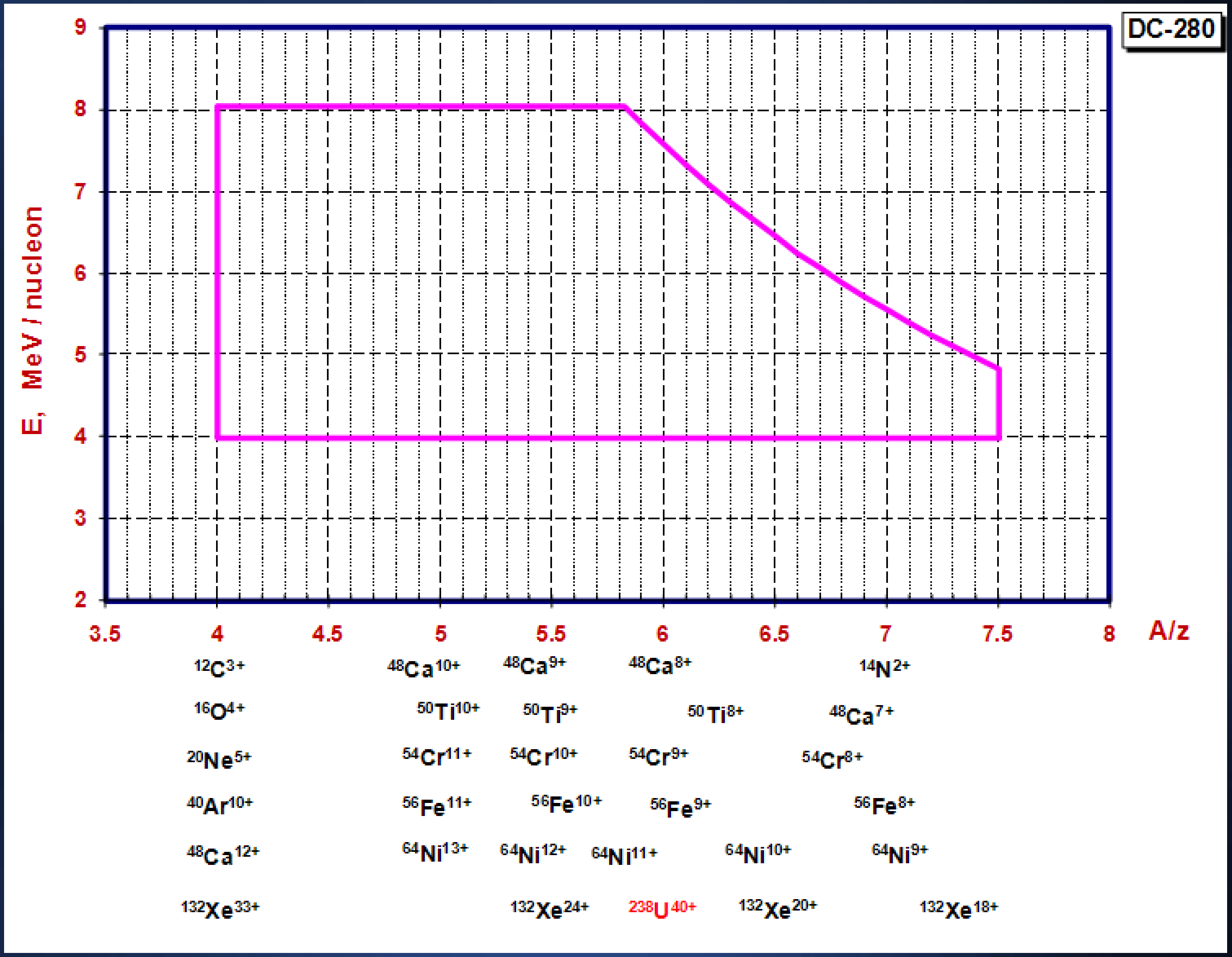
Working diagram of the DC-280



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