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THE DC130 PROJECT: NEW MULTIPURPOSE APPLIED SCIENCE FACILITY FOR FLNR

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Abstract

The main activities of Flerov Laboratory of Nuclear Reactions, following its name - are related to fundamental science, but, in parallel, plenty of efforts are paid for practical applications. Certain amount of beam time every year is spent for applied science experiments on FLNR accelerator complex. For the moment, the main directions are: the production of the heterogeneous micro - and nano-structured materials; testing of electronic components (avionics and space electronics) for radiation hardness; ion-implantation nanotechnology and radiation materials science. Basing on FLNR long term experience in these fields and aiming to improve the instrumentation, the accelerator department start the Design Study for new cyclotron DC130 which will be dedicated machine for applied researches in FLNR. Following the user's requirements DC130 should accelerate the heavy ions with mass-to-charge ratio A/Z of the range from 5 to 8 up to fixed energies 2 and 4.5 MeV per unit mass. The first outlook of DC130 parameters, its features, layout of its casemate and general overview of the new FLNR facility for applied science is presented.

INTRODUCTION

The main point is that for applied science people use powerful machines which were created and developed to solve the wide range of fundamental research. The usage of 'science' accelerators for such activities is connected which high cost of beam time and difficulty to meet quick changes of user's requirements. There is a "time lack" problem when application begin to demand the beam time more than laboratory could provide to it in parallel with its scientific plan's realization. Usually, it means that all technical "bugs" and methodological questions were successfully fixed and answered, and users requesting the time as much as they could. That's why Flerov Laboratory of Nuclear Reaction of Joint Institute for Nuclear Research starts the Design Study of the dedicated applied science facility based on the new DC130 cyclotron. The irradiation facility will be used mainly for the following applications: creation and development of track membranes (nuclear filters) and the heavy ion induced modification of materials; activation analysis, applied radiochemistry and production of high purity isotopes; ion-implantation nanotechnology and radiation materials science; testing of electronic components (avionics and space electronics) for radiation hardness. From the common user's requirements, operation simplicity and cost reasons the main parameters of future machine were chosen. The facility will be based on new DC130 isochronous cyclotron: multiparticle, double - energy machine, capable with light and heavy ions up to bismuth (2 and 4.5 MeV/nucleon).

The research works on radiation physics, radiation resistance of materials and the production of track membranes will be carrying out by using the ion beams with energy of about 2 MeV per unit mass and A/Z ratio in the range from 7.58 to 8.0. Besides these, testing of avionics and space electronics by using of ion beams (^{20}Ne, ^{40}Ar, ^{84,86}Kr, ^{132}Xe, ^{197}Au or ^{209}Bi) with energy of 4.5 MeV per nucleon and with mass-to-charge ratio A/Z in the range from 5.0 to 5.5, will be proceeded. One of the significant requirements for this application is the "ion cocktail" means mixed of highly charged heavy ions with the same or very close mass/charge ratios produced and injected in the same time. Once the ions will be accelerated, the different species will be separated by the fine tuning of the cyclotron magnetic field. This issue allows to switch the type of ions quick and will reduce the time which user should spent for full scale testing of its samples.

The idea is to effectively use existing stuff to modernize and totally upgrade the old U200 machine which was decommissioned in 2013, because of being outdated physically and technologically. The design will be based on existing systems of IC100 (Fig.1) and U200 (Fig.2) cyclotrons [1].

The working diagram of DC130 cyclotron is shown in Fig.3. The acceleration of ion beam in the cyclotron will be performed at constant frequency f = 10.622 MHz of the RF-accelerating system for two different harmonic numbers h. The harmonic number h = 2 corresponds to the ion beam energy W = 4.5 MeV/u and value h = 3 corresponds to W = 1.993 Mev/nucleon. The intensity of the accelerated ions will be about 1 pμA for lighter ions ($A \leq 86$) and about 0.1 pμA for heavier ions ($A \geq 132$).

The axial injection system and its beam line for new accelerator will be adapted from the existing IC100 cyclotron systems.

In the frame of reconstruction of U200 to DC130 it is planned to upgrade the cyclotron magnetic structure, replace the magnet main coil and renovate RF system. Other systems: beam extraction, vacuum, cooling, control electronics and radiation safety will be new.

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Figure 1: Layout of IC100 cyclotron.

Figure 2: Layout of U200 cyclotron.

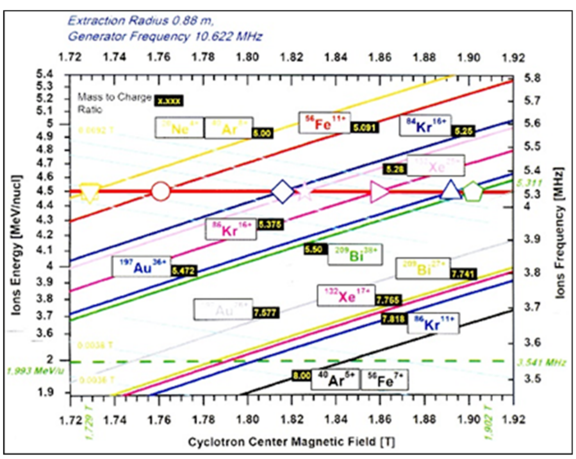

Figure 3: Working diagram of DC130 cyclotron.

The main parameters of DC130 cyclotron are contained in Table.1.

Table 1: DC130 Cyclotron Main Parameters

Pole (extraction) radius, m	1(0.88)	
Magnetic field, T	1.729÷1.902	
Number of sectors	4	
RF frequency, MHz	10.622	
Harmonic number	2	3
Energy, MeV/u	4.5	1.993
A/Z range	5.0÷5.5	7.577÷8.0
RF voltage, kV	50	
Number of Dees	2	
Ion extraction method	electrostatic deflector	
Deflector voltage, kV	60	

ECR SOURCE AND AXIAL INJECTION SYSTEM

The axial injection system [2] of DC130 cyclotron will be adapted from the existing IC100 cyclotron one consisted of the 18 GHz DECRIS-5 ion source which was developed based on sources of the DECRIS-4 (14 GHz) series with copper windings created at FLNR (JINR, Dubna) by intensifying the magnetic structure and changing to a new type of microwave oscillator. The DECRIS-5 ion source was created for industrial application and characterized by increased reliability. It was already successfully commissioned in the framework of DC110 project (mass production of the track membrane) [3]. Also transport beam line will be based on DC110 experience [4].

DC130 MAGNETIC SYSTEM

The magnetic system of DC130 cyclotron will be based on the existing U200 cyclotron one. The magnetic field distribution in the median plane of the DC130 cyclotron magnet has been found by means of computer simulation with 3D OPERA program code [5]. The main parameters of the magnet are contained in Table 2.

Table 2: DC130 Cyclotron Magnet Main Parameters

Size of the magnet, mm	5000×2100×3600
Diameter of the pole, mm	2000
Distance between the poles, mm	160
Number of the sectors pairs	4
Sector angular extent (spirality)	43° (0°)
Sector height, mm	45
Distance between the sectors (magnet aperture), mm	30
Distance between the sector and pole (for correcting coils), mm	20
Number of radial coils	6
Maximal power, kW	≈ 300

The operation mode change will be implemented only by variation the level of the magnetic field in the range from 1.729T to 1.902T and its isochronous distribution will be formed operationally by means of six radial correcting coils. The detail information about magnetic system of DC130 cyclotron contains in report [6].

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RF SYSTEM

The working frequency of RF system is constant and equal to 10.622 MHz. The scheme of RF-resonator is shown in Fig.4. The dashed line designates the placement of the ground plate. Two generators are used for independent feed of two RF resonators.

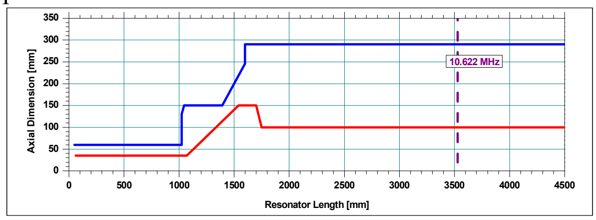

Figure 4: Scheme of RF resonator.

The feedback system ensures precise tuning of RF phase and amplitude at both dees independently. The evaluated power of each RF generator is equal to 11.5 kW.

BEAM EXTRACTION SYSTEM

The scheme of beam extraction system of DC130 cyclotron is shown in Fig. 5. The dashed line is the cyclotron orbit corresponding to average radius of 88 cm. The red line is extraction orbit ending in the object point of the experimental beam lines. The beam extraction system includes the electrostatic deflector ESD and two magnetic static channel MC1,2. In accordance with results of simulation, the maximum voltage at the deflector ESD is equal to 60 kV. The magnetic field gradients in MC1,2 channels are equals to 25 T/m and 8 T/m correspondingly.

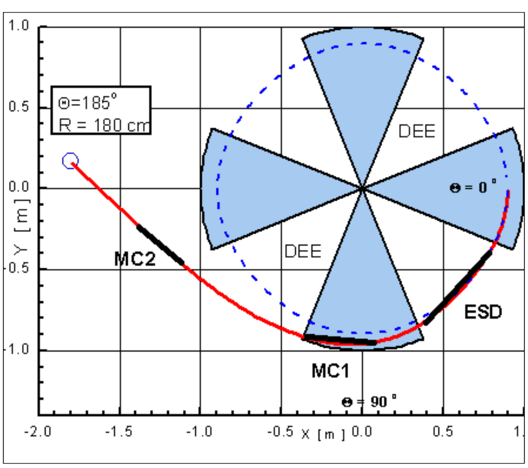

Figure 5: Scheme of DC130 extraction system.

EXPERIMENTAL BEAM LINES

The set of the experimental beam lines includes track membrane line, SEE testing line and radiation physics line. The scheme of the experimental beam lines is shown in Fig.6. The common part of the channel consists of extraction bending magnet, the quadrupole lens triplet and commutating magnet. The centre of the extraction bending magnet is an object point for all beam line. The experience of working at U400, U400M cyclotrons will be used during developing the experimental channels for these applications.

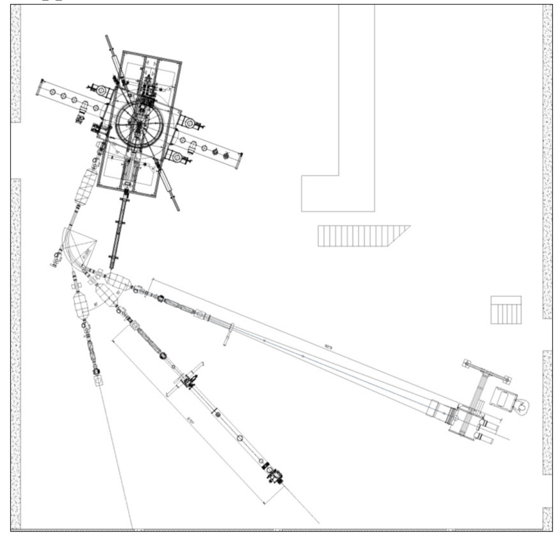

Figure 6: Scheme of experimental beam lines. From left to right: RP line; SEE testing line; TM line

CONCLUSION

Flerov Laboratory of Nuclear Reaction begins the works under the conceptual design of the dedicated applied science facility based on the new DC130 cyclotron. The main characteristics of it are defined and fit main user requirements well. The detailed project will be ready in December'2018.

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