61st ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams

HB2018

2018, June 18~22

WEP2PO028

CONCEPTUAL DESIGN OF FLNR JINR RADIATION FACILITY BASED ON DC130 CYCLOTRON

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INTRODUCTION

The irradiation facility will be used for Single Event Effect testing of microchips by means of ion beams (^{16}O, ^{20}Ne, ^{40}Ar, ^{56}Fe, $^{84,86}Kr$, ^{132}Xe, ^{197}Au and ^{209}Bi) with energy of 4.5 MeV per unit mass and having mass-to-charge ratio A/Z in the range from 5.0 to 5.5. Besides 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. The facility is based on DC130 isochronous cyclotron. The working diagram of DC130 cyclotron is shown in Fig.1.

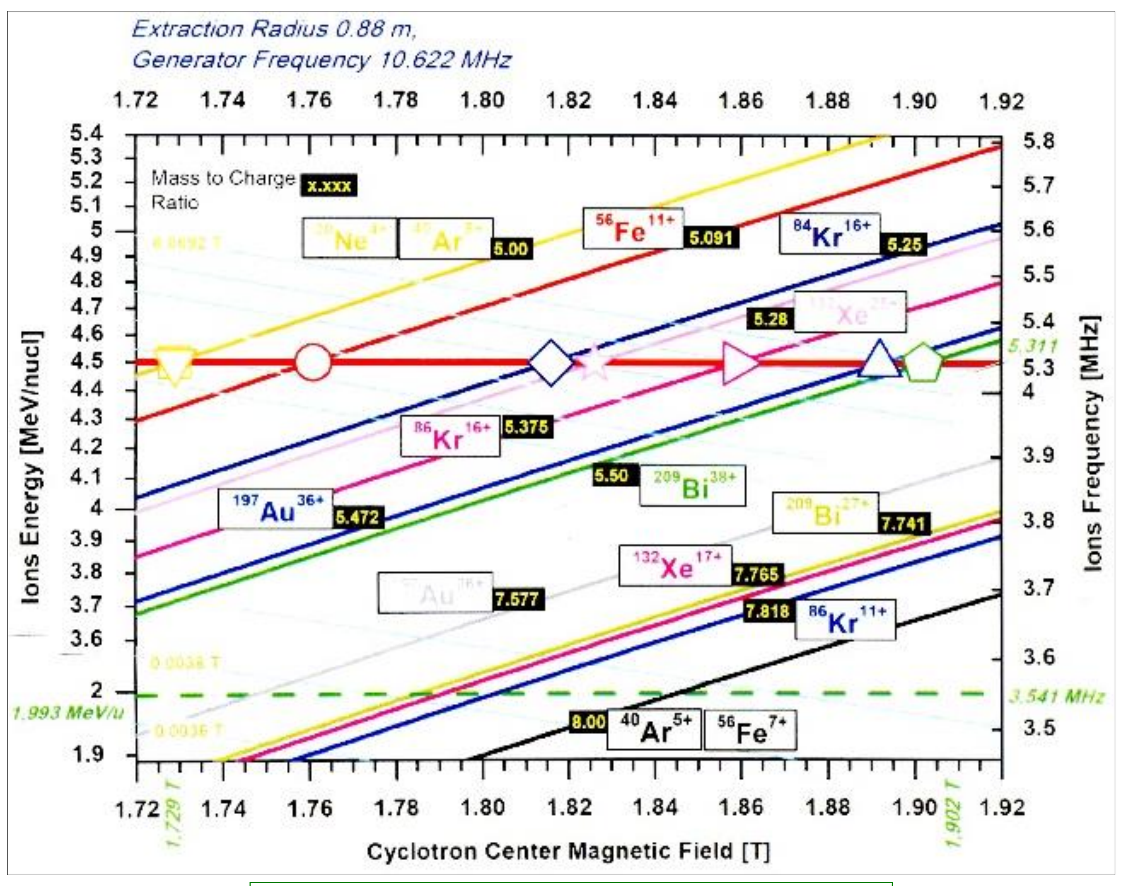

Figure 1: Working diagram of DC130 cyclotron

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 num-bers 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/u. The intensity of the accelerated ions will be about 1 pμA for lighter ions (A < 86) and about 0.1 pμA for heavier ions (A > 132).

The design is based on existing systems of IC100 (Fig.2) and U200 (Fig.3) cyclotrons [1].

The axial injection system and beam line for track membranes production 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 will be new.

The experience of working at U400, U400M cyclotrons [2] will be used during developing the experimental channels for SEE testing of microchips. The main parameters of DC130 cyclotron are contained in Table.1.

Figure 2: Layout of IC100 cyclotron

Figure 3: Layout of U200 cyclotron

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	

AXIAL INJECTION SYSTEM

The axial injection system of DC130 cyclotron will be adapted from the existing IC100 cyclotron one consisted of superconducting ECR ion source – DECRIS-SC [3] and transport beam line [4].

DECRIS-SC ion source

DECRIS-SC is 18 GHz superconducting ion source designed in Flerov Lab. It is able to produce the beams of ion from ^{22}Ne to ^{209}Bi. In adaptation, the distance between extraction hole of the ion source and first focusing solenoid of transport beam line will be significantly reduced to avoid the losses of the ion beam.

Axial injection beam line

The axial injection system of DC130 cyclotron allows transporting with of 100% efficiency all declared ion beams for all working regimes of the facility. The detail information about axial injection beam line contains in report WEP2PO027 [5] at this conference.

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 simula-tion with 3D OPERA program code [6]. The computer model of the magnet is shown in Fig.6.

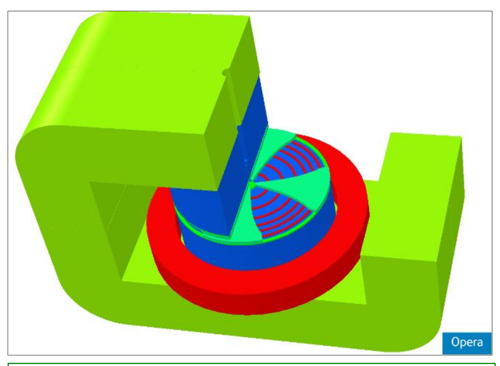

Figure 4: Computational model of cyclotron magnet

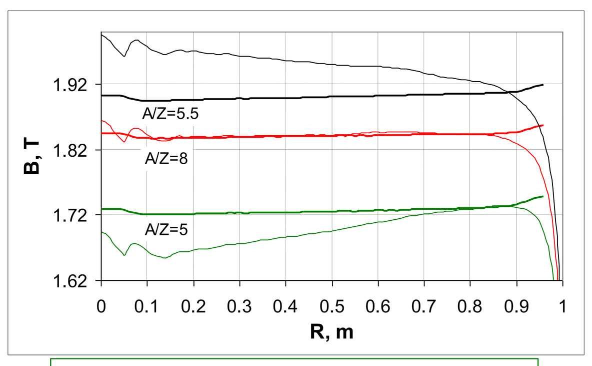

Figure 5: Magnetic field radial distributions

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 real magnetic field and isochronous ones radial distributions for three operation modes are shown in Fig.5. At the middle level (red lines) the formation of the magnetic field has been made by shaping of the sector height from the pole side. In accordance with magnetic field distribution, each radial coils should be capable to produce 600Gs of correction magnetic field. The esti-mated current of the coil is equal to 15000 At. We con-sider the possibility of reducing the range of the magnetic field of the cyclotron and, as a consequence, the magni-tude of the coil current.

The detail information about magnetic system of DC130 cyclotron contains in report THPWWC03 [7] at this conference.

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.6. The dashed line designates the placement of the ground plate. Two generators are used for independent feed of two RF resonators. 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.

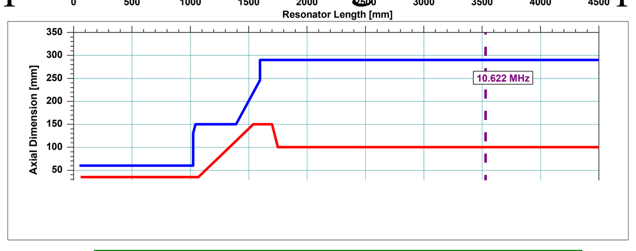

Figure 6: Scheme of RF resonator

EXTRACTION SYSTEM

The scheme of beam extraction system of DC130 cyclotron is shown in Fig. 7.

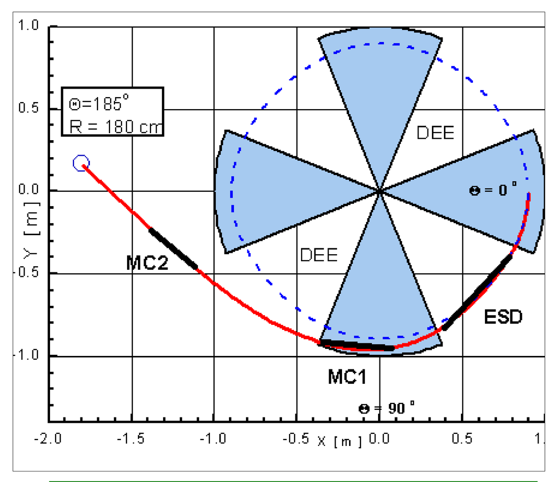

Figure 7: DC130 extraction system

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 magnetostatic 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 20 T/m and 9 T/m correspondingly.

VACUUM AND OTHER SYSTEMS

In the axial injection beam line, the allowable average pressure of the residual gas is $1.5 \cdot 10^{-7}$ Torr. Such pressure can be provided using two turbomolecular and two cryopumps with a total pumping speed of 1600 l/s. The ion losses due to charge exchange process in the beam line is less than 15%.

The vacuum system of the DC130 cyclotron should provide the average residual gas pressure in the vacuum chamber at the level $7 \cdot 10^{-8}$ Torr. This level of pressure will be achieved with the help of turbomolecular and cryopumps with a total pumping speed of 15000 l/s.

The water-cooling and control systems will be upgraded.

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.8. The common part of the channel consists of extraction bending magnet, the quadrupole lens triplet and commutating magnet. The center of the extraction bending magnet is an object point for all beam line.

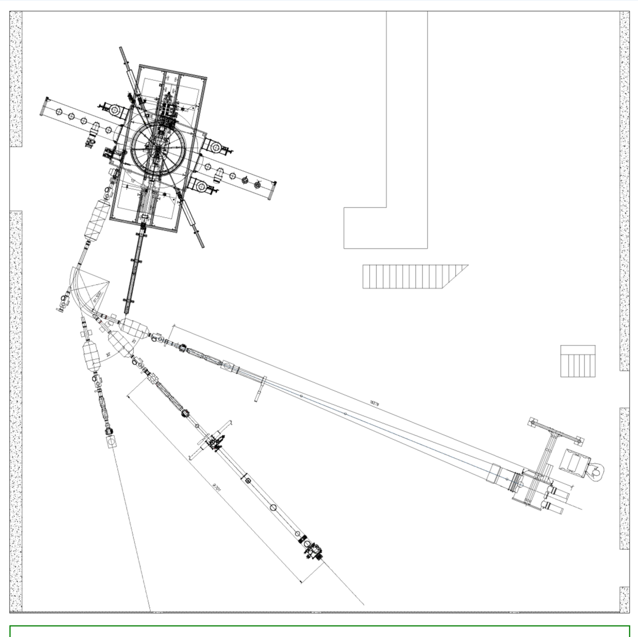

Figure 8: Scheme of experimental beam lines. From left to right: RP line; SEE testing line; TM line

SEE testing beam line

During developing the experimental channels for SEE testing of microchips, we will use the experience of working at U400, U400M cyclotrons [2]. The lower energy SEE testing beam line of U400M cyclotron will be adapted to ion beam parameters of irradiation facility. This beam line contains: ion beam transport system, beam monitoring system, energy measurement system and user vacuum test chamber with a mounting and positioning assembly to hold the sample in the irradiation field. The layout of the experimental set up is given in Fig. 9.

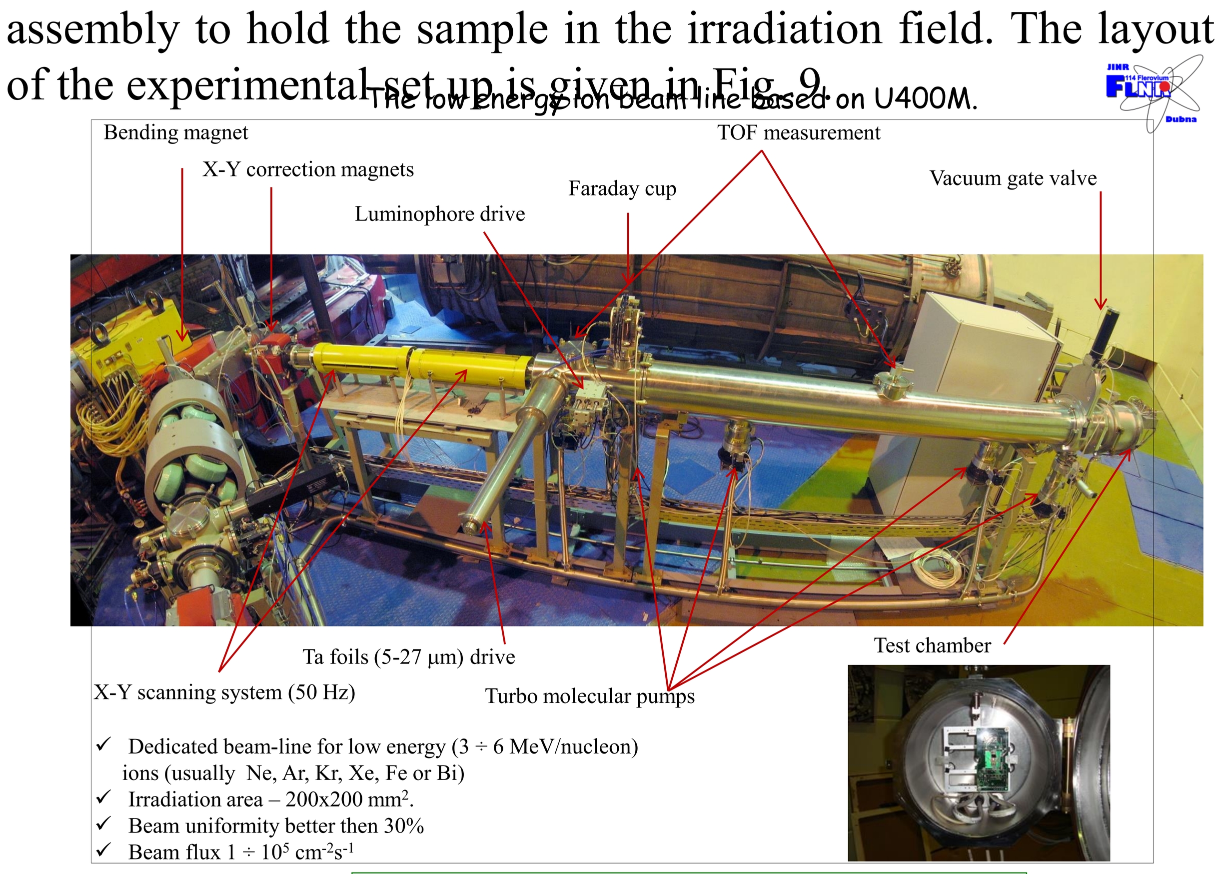

Figure 9: Layout of U400M SEE testing set up [2]

Track Membrane beam line

The beam line for track membranes production will be adapted from the existing IC100 cyclotron one [4]. The experience of creating TM beam line for DC110 cyclotron [8] will be used also. The TM beam line of IC100 and DC110 cyclotrons are shown in Fig.10,11. The optical system of the channel consists of a triplet of quadrupole lenses, correcting magnets, and a scanning system for the ion beam.

Figure 10:TM channel of IC100 cyclotron [4]

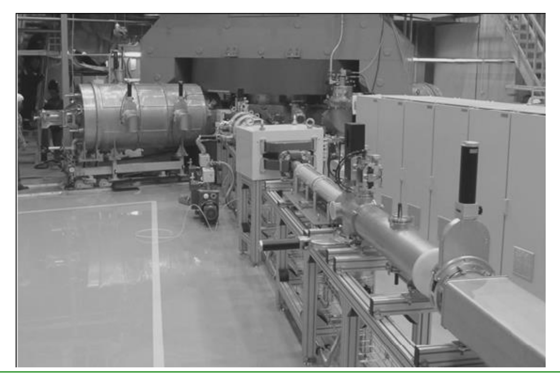

Figure 11:TM channel of DC110 cyclotron [4]

Radiation Physics beam line

RP line has a focusing quadrupole triplet and electro-magnetic two-coordinate beam scanning system provides the homogeneous ion distribution at the irradiated surface.

REFERENCES

[1] G. Gulbekyan, B. Gikal, I. Kalagin, N. Kazarinov, “Status Report and Future Development FLNR JINR Heavy Ions Accelerators Complex”, Proc. of 11-th Int. Conf. on Heavy Ion Acc. Tech., HIAT09, 8-12 June 2009, Venezia, Italy, p.59-63, http://www.jacow.org

[2] S. Mitrofanov, B. Gikal, G.G. Gulbekyan, I.V. Kalagin, N.F. Osipov, S.V. Paschenko, V.A. Skuratov, Yu.G. Teterev, V.S. Anashin, “Testing of Electronic Com-ponents at FLNR JINR Accelerator Complex: Current Status and the 7-Year Roadmap”, Proc. of XXV Russian Part. Acc. Conf., RuPAC2016, 21-25 November 2016, St. Pe-tersburg, Russia, http://www.jacow.org

[3] A.A. Efremov, V.V. Bekhterev, S.L. Bogomolov et al., “Status of the ion source DECRIS-SC”, Review of Scien-tific Instruments, V. 77, P.235-239, No.03A320,2006

[4] B. Gikal, S. Dmitriev, G. Gulbekian, N. Kazarinov et al., “Cyclotron Based Complex IC-100 for Scientific and Applied Research”, Proc. 18-th Int. Conf. on Cyc. and their App., CYC07, 1-5 October, 2007, Giardini Naxos, Italy, http://www.jacow.org

[5] N. Kazarinov, J. Franko, G. Gulbekian, I. Ivanenko, I. Kalagin, “Simulation of the Axial Injection Beam Line of the Reconstructed U200 Cyclotron of FLNR JINR”, pre-sented at HB2018, Daejeon, Korea, June 18-22, 2018, paper WEP2PO027, this conference.

[6] “OPERA-3D Reference Manual”, Oxford OX5 1JE, Eng-land, October 2012.

[7] G. Gulbekian, I. Kalgin, N. Kazarinov, I. Ivanenko, J. Franko, “The Choosing of Magnetic Structure of Iso-cronous Cyclotron DC-130 for Applied Application”, presented at HB2018, Daejeon, Korea, June 18-22, 2018, paper THPWWC03, this conference.

[8] B.N. Gikal et al. “Development, Creation, and Startup of the DC110 Heavy Ion Cyclotron Complex for Industrial Pro-duction of Track Membranes”, ISSN 1547-4771, Physics of Particles and Nuclei Letters, 2014, Vol. 11, No. 2, pp. 137–150. © Pleiades Publishing, Ltd., 2014.