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THE RESULTS OBTAINED ON "RADIOBIOLOGICAL STAND" FACILITY, WORKING WITH THE EXTRACTED CARBON ION BEAM OF THE U-70 ACCELERATOR

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Abstract

This report provides an information of present status of the «Radiobiological stand» facility at the extracted carbon ions beam of the U-70 accelerator. The results of the development of the RBS facility are presented. A plans for development an experimental medical center for carbon ion therapy on the basis of the U-70 accelerator complex are also reported.

INTRODUCTION

The experimental facility «Radiobiological Stand» (RBS) is in operation on the extracted from the U-70 accelerator complex beam of carbon nuclei since 2014 [1]. The installation is to conduct physics and radiobiological experiments at the ion energies up to 450 MeV/u. Development of the oncology treatment technology and training of domestic experts are the main goals of these radiobiological studies. The first cancer treatments with the beam of carbon nuclei can be the another primary goal of these studies. The RBS installation has been certified as a Center of Collective Use [2] in 2017 under the number 507813 with the following reference: http://www.ihep.ru/pages/main/6580/8769/index.shtml. The RBS installation [3] is in the continuous process of run-to-run development: beam parameters and beam control systems are being improved, systems of active and passive modification of the carbon beam are being developed. This report presents today's RBS and describes its nearest perspectives.

RBS STATUS

The slow extraction of the carbon beam from U-70 into the channel No. 25 is being done with use of the scheme proposed by O. Piccioni and B.T. Wright in 1954–1955 [4]. The scheme is based on the beam energy moderation passing through a solid target. Currently 6 fixed energies are available for RBS: 450, 400, 350, 300, 250 and 200MeV/u. The channel No. 25 consists of septum magnet SM34, three dipoles BM1-BM3, two sets of quadrupoles: Q1-Q4 with the aperture of 75 mm and Q5-Q7 with the aperture of 100 mm, horizontal corrector and the beam stop. It is instrumented by three TV-boxes with remotely operated scintillation screens. The channel vacuum of 10^{-2} bar (not worse) starts from SM34 and ends up after Q7. The target station (see Fig. 1) consists of two target blocks with four Beryllium targets each.

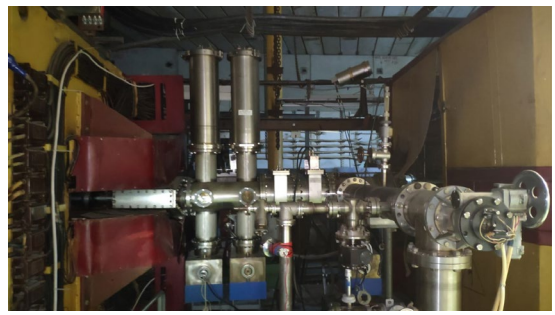

Figure 1: Target station of the channel No. 25.

Figure 2 presents the measured by RBS Bragg peaks in water.

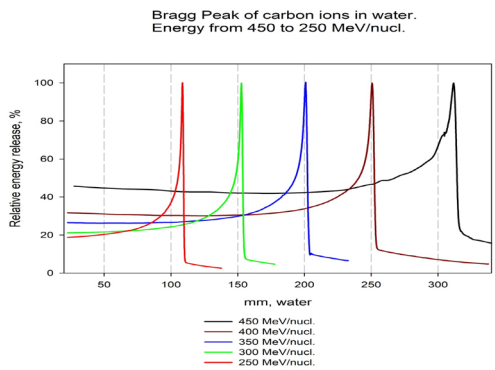

Figure 2: Bragg peaks for different energies of extracted carbon beam.

The shielded area of RBS consists of two zones: experimental and medical, as it can be seen in Fig. 3, with the common system of access control. These zones are separated from each other by a concrete wall with the intermediate collimator. The collimator aperture can be varied manually from 50x50 to 150x150 mm with use of special inserts.

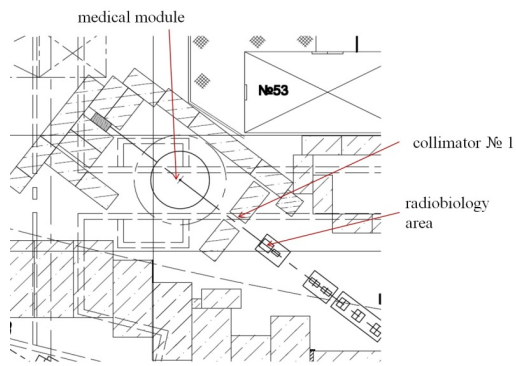

Figure 3: The schematic top view of the RBS installation.

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For the future patients there is a 6-axis table in the medical zone, see Fig. 4. The table was designed and manufactured at IHEP. The deck is made of carbon plastic. Accuracy of the table positioning in Cartesian coordinates is not worse than 0.5 mm.

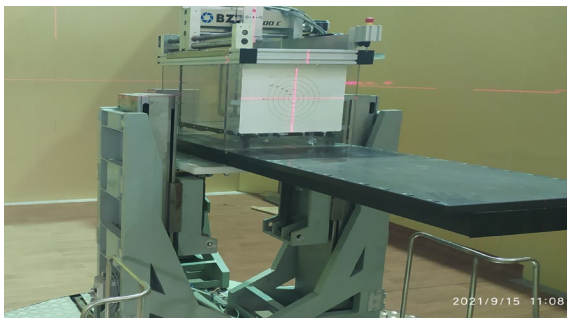

Figure 4: The 6-axis table in the medical module.

Recently developed and manufactured electromagnetic system of beam leveling is shown in Fig. 5. This system replaces the previous one with permanent magnets [5]. The system consists of the vertical and horizontal dipole magnets and their power supplies (Fig. 5).

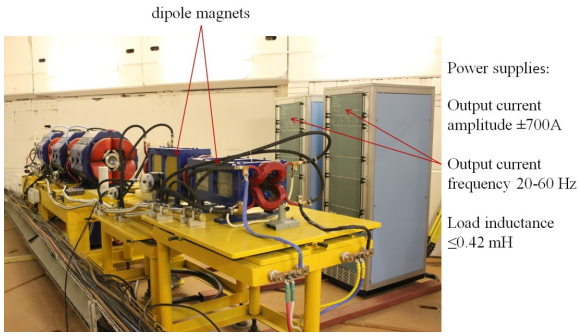

Figure 5: Electromagnetic scanning system.

The shapes of the dipole currents and the transverse distributions of the dose are shown in Fig. 6 and Fig. 7.

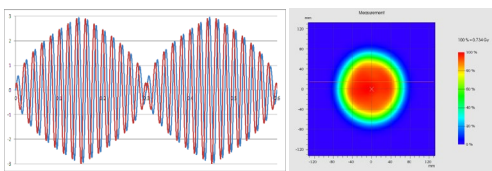

Figure 6: Currents and doses at helical scan.

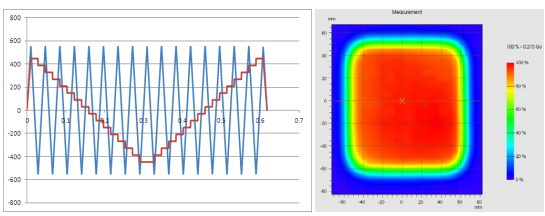

Figure 7: Currents and doses at Cartesian scan.

The automatic energy degrader inserts PMMA plates with thickness from 1 to 63 mm to moderate the beam energy smoothly. Ripple filters [6] are used to modify the Braggs peak. One of these filters is shown in Fig. 8 along with the corresponding Braggs peak in water.

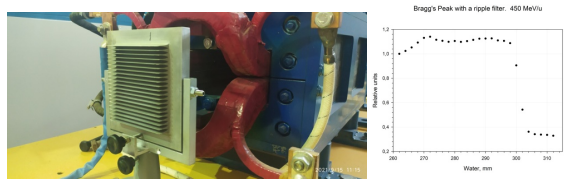

Figure 8: Aluminium ripple filter 16 mm on the left and Bragg's Peak on the right.

A certain work is done for the instrumentation of irradiation. A beam-content-meter is made to measure the beam composition wherever measured. The results of such a measurement are shown in Fig. 9.

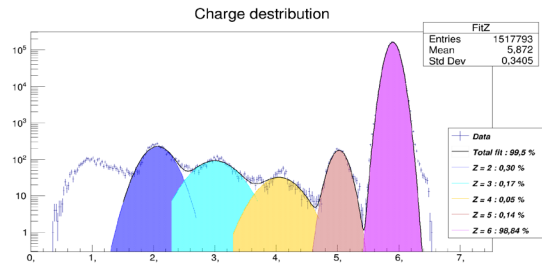

Figure 9: Carbon ion beam composition. 300 MeV/u.

To measure the 2D dose distributions the special mosaic ionization chamber was developed and manufactured. Schematic plot of the chamber and the screen shot of the measurement results are shown in Fig.10.

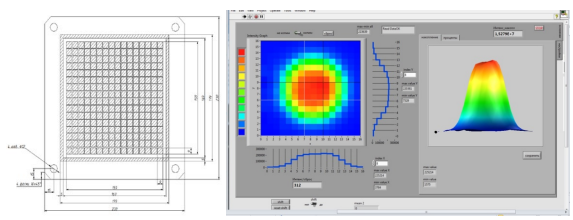

Figure 10: Mosaic 256-cell plane-parallel ionization chamber.

PLANS

The closest plans assume the new center of ion therapy on the base of U-70. Currently the new channel No. 26 is the candidate. Preliminary view of this new channel is shown in Fig. 11. The magnetic elements of this new channel have been designed and the prototypes are under the test program.

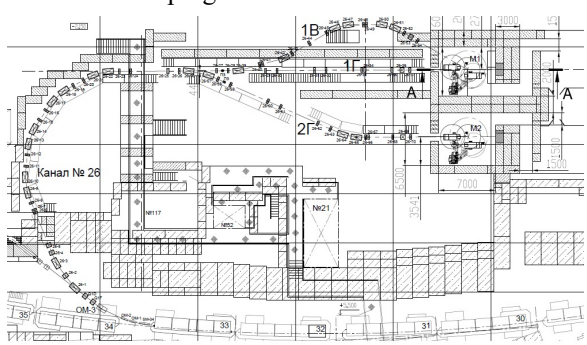

Figure 11: Schematic view of the channel No.26.

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CONCLUSION

The Radiobiological Stand Facility :

- works in continuous mode;
- according to the results obtained, 21 articles were published over the last 3 years;
- developed and implemented an electromagnetic beam leveling system (wobbler system);
- beam diagnostics tools were developed and manufactured;
- now has slow extraction of 200, 250, 300, 350, 400, 455 MeV per nucleon of $^{12}C^{6+}$ beam for radiobiology and future prior-to-therapy studies.

On the basis of the government decree No. 287 of 04.16.2020, work is underway to design the Ion Radiation Therapy Complex.

REFERENCES

[1] G. Britvich *et al.,* "First Results of Experiments with the Extracted Carbon Beam at the U-70 Accelerator", *in Proc. RuPAC2014,* Obninsk, Kaluga Region, Russia, 2014, pp. 197-199, WEPSB19.

[2] V.A. Pikalov and Y.M. Antipov, "Experimental Facility "Radiobiological Test Setup on Accelerator U-70" as Centers for Collective Use (CCU)", in *Proc. RUPAC'18,* Protvino, Russia, Oct 2018, pp. 253-255. doi:10.18429/JACoW-RUPAC2018-TUPSA50.

[3] Y. Antipov, V.A. Pikalov, "Carbon Beam from U-70 for Radiobiology", presented at the 25th Russian Particle Accelerator Conf. (RuPAC'16), St. Petersburg, Russia, Nov. 2016, paper THYMH01, unpublished.

[4] M. Antipov *et al., Instr. and Exp. Techn.,* v.64, n.3, pp. 343-351, 2021. DOI: 10.1134/S00204412210201 OX.

[5] Y.M. Antipov *et al., Instr. and Exp. Techn.,* v.58, n.4, pp. 552-561, 2015. DOI:10.1134/s0020441215040016.

[6] A. Solovev *et al.,* "3D-printed beam modifiers for radiobiological experiments in monoenergetic carbon ion beam." *Int. J CARS* Vol. 11, Suppl. 1, 2016, P. 58-59.