THE SECOND BEAM EXTRACTION CHANNEL FOR THE ACCELERATOR “EPOS”

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It is proposed to build a new beam extraction channel at the linear technological accelerator “EPOS”. A more effective exposure of materials to be processed can be reached by rotating the beam in a vertical plane through 90 deg. In the paper the schematic diagram of the channel is presented and the field value in the dipole magnet is estimated. Results of modeling the electron motion in the channel with taking into account real beam parameters are given. The density of electron stream onto the material being irradiated is calculated.

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INTRODUCTION

The linear accelerator “EPOS” [1] is one of several linear accelerators at the NSC KIPT being actively used in work aimed to investigations on the radiation resistance of different materials, development of new radiation technologies and radiation processing of large production lots. Naturally, that these problems impose some demands upon the electron beam which should be fulfilled to reach successfully the planned tasks. So, two year ago at the accelerator an energy filter system has been started [2] permitting to improve the beam parameter stability at the direct exit. During that time the system has worked for more than 9 thousand hours under conditions of high irradiation doses and demonstrated that its parameters meet the requirements.

At present a program of accelerator upgrading is under consideration. It consists in the replacement of the accelerating structure by the structure of 2856 MHz frequency with the use of klystrons VKS-8262F, as high-power sources, and thyratrons CX1525a in the modulators. At the pulse repetition rate of 600 GHz for the energy of 23 MeV the mean beam power should be 40 kW. It is expected that in the modernized accelerator the beam parameter stability will be significantly increased. In this connection we consider a possibility of building at the accelerator exit of a second channel to expose the beam onto the objects to be processed.

A purpose of the present study is to devise a design of the channel with beam rotation through 90 degrees.

1. CHANNEL GEOMETRY

A main function of the new channel is the mass radiation processing of products and materials using a 23 MeV electron beam with a beam consumption of about 4000 hours per year and irradiation session duration to 360 hours. The new channel design supposes that the possibility of object irradiation at the accelerator direct exit should be remained (Fig. 1). This condition is to be fulfilled making replacement of the existing energy filter magnet [3] by the magnet, which provides beam rotating through 90 degrees, and, respectively, changing the vacuum chamber. The beam at the direst exit can be obtained after the magnet removal upward. The beam rotation through the angle of 90 degrees at the techno-logical accelerator exit practically is not used. First of all it is because of a large (about several percents) beam energy spread in such accelerators. For example, by estimating the beam energy spread at the accelerator “EPOS” for the beam with energy of 31 MeV and cur-rent of 460 mA [2] we obtained the value equal to (25±0.6) MeV at a level of 0.6 from the maximum current value. For comparison, at the accelerator RHODOTRON [4], where the beam is rotating towards the target through 90 degrees, the energy spread is estimated from 100 to 300 keV with maximum energy of 10 MeV.

The space between the beam axis and the accelerator frame is 300 mm, therefore it is necessary to chose a minimum beam rotation radius in the magnet. The beam power will reach 40 kW and the vacuum chamber can be damaged by the beam in the case of sudden electron energy change. Taking into account this fact it is necessary to prevent this situation and to install the chamber closer, as soon as possible, to the collimator magnet, which is capable to absorb the beam during several seconds before the instant of cutoff. In connection with this requirement the magnet should be compact and the rotation radius should not exceed 160 mm that is equivalent to the field not less than 0.48 T. A variant has been considered for designing such a magnet on the base of constant magnets made of Nd-Fe-B alloy permitting to obtain the field up to 1 T if an estimated value of the gap is 25 mm. As a result of parameter optimization by the Mermaid program [5] the magnet design was obtained (Fig. 2). The magnet is cut in the beam trajectory plane. The magnet poles of 50 mm width have the shims of 1mm at their edges. In this model the field source is an assembly of Nd-Fe-B constant magnets (150×150×60 mm) made by the firm-manufacturer “Polyus-N” [6]. A normal field component calculated for this model is presented in Fig. 3. The radius of trajectory in this field is 0.14957 m, effective magnet length is 0.23494 m, maximum field value in the magnet gap is 0.516485 T.

It is planned to manufacture a magnetoconductor of the ST 3 steel.

As the field value in the Nd-Fe-B magnet is temperature-sensitive provision is made for the magnet temperature stabilization by the water cooling of the magnetoconductor.

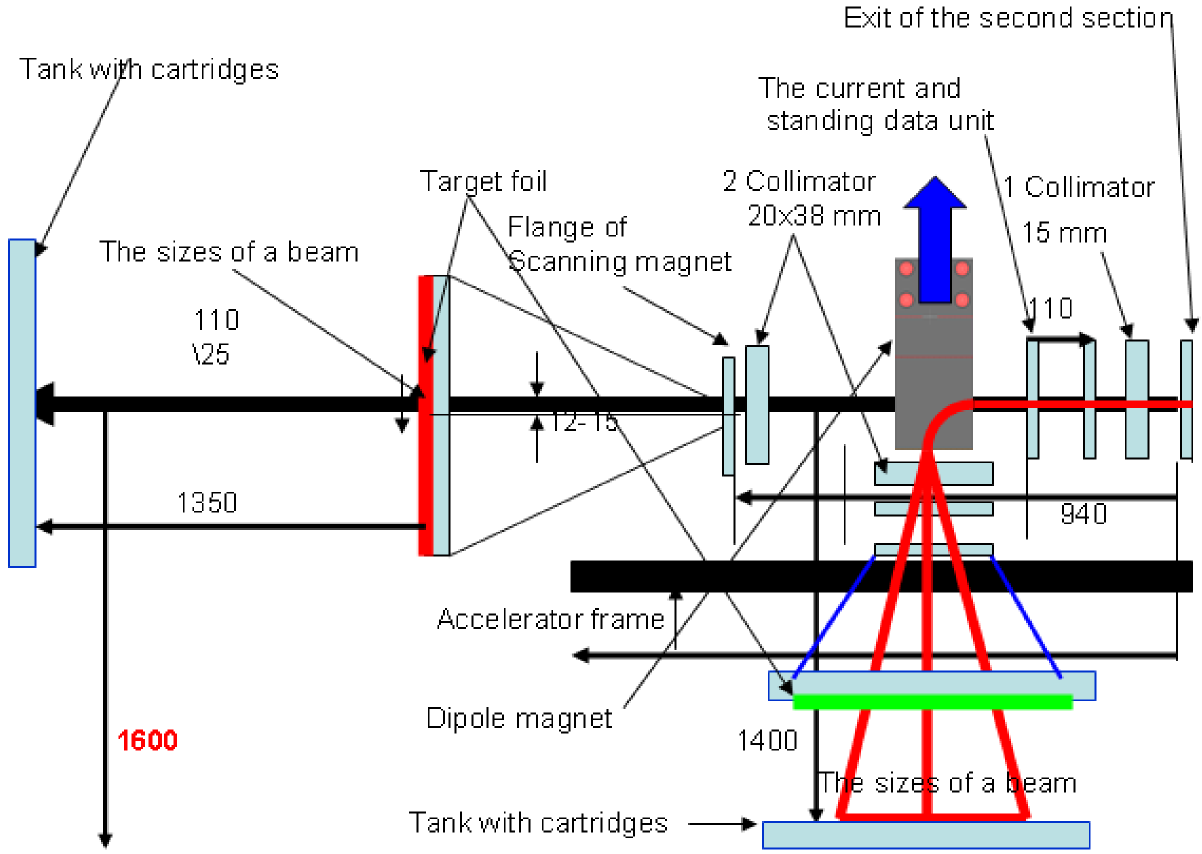

Fig. 1. Layout of equipment at the accelerator exit

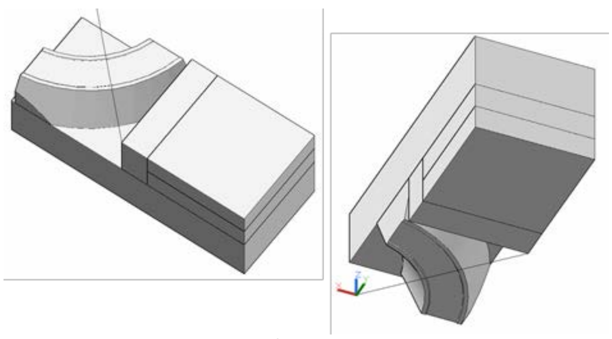

Fig. 2. Model of the magnet in section

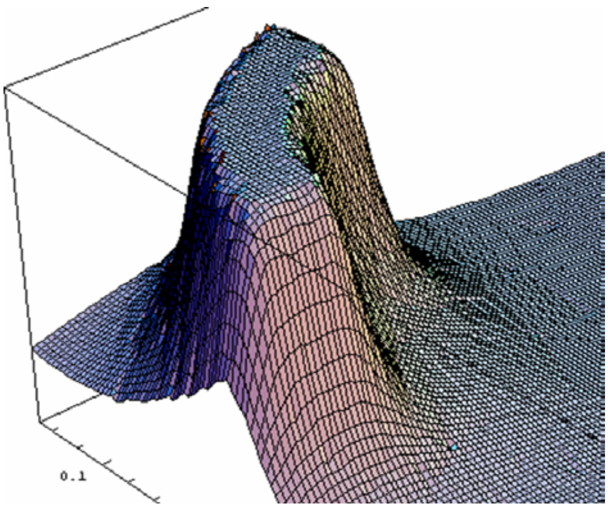

Fig. 3. Field distribution in the magnet gap

After passing the magnet the beam will be rotated in the median plane a result of energy spread. After passing the output foil the electrons, at a distance of 1.4 m from the accelerator beam axis, will get into the tank with cartridges containing materials being irradiated. The space between the bunker floor and the beam axis in the accelerator is 1.6 m.

2. BEAM SIZE

The program MAD X [7] was applied to simulate the beam passage through the extraction channel with electron density fixation at the magnet input and magnet output, on the output foil placed at a distance 0.3 m from the magnet output, as well as at the input into the tank with specimens. Simulation has been carried out by the method of tracking of 3000 particles through the channel.

Beam parameters at the accelerator exit were the following: maximum beam energy E_{max}=23 MeV, beam size along the vertical and horizontal is equal to 2 mm (2σ), beam emittance along the vertical and horizontal is $6 \cdot 10^{-3}$ mm rad, electron density transverse distribution and divergence is Gaussian. As a real electron energy distribution in the beam of the reconstructed accelerator is unknown we assumed it to be a Gaussian with the energy spread of 3 MeV (2σ), that is near the values measured in the accelerator. These parameters will be operating ones until reactor reconstruction completion.

The beam cross-section at the magnet input calculated for the above-mentioned parameters is represented in Fig. 4.

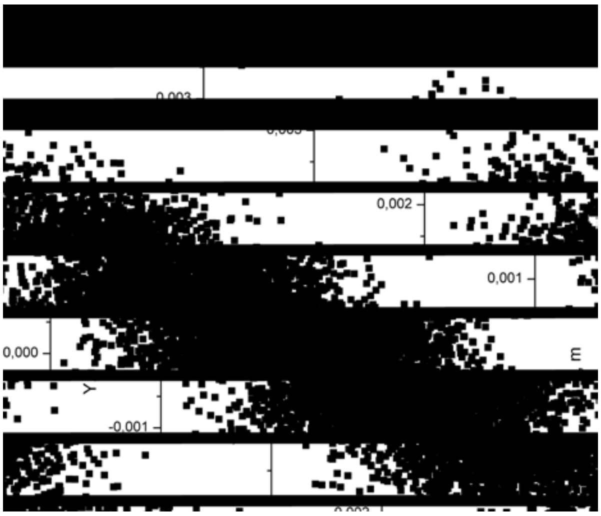

Fig. 4. Beam at the magnet input

After passing the magnet the beam cross-section becomes elliptic. As is shown in Fig. 5, the beam electron density distribution across the electron motion in the accelerator changes insignificantly after passing the magnet (on the magnet end section) and in the magnet dispersion plane the change becomes significant (Fig. 6).

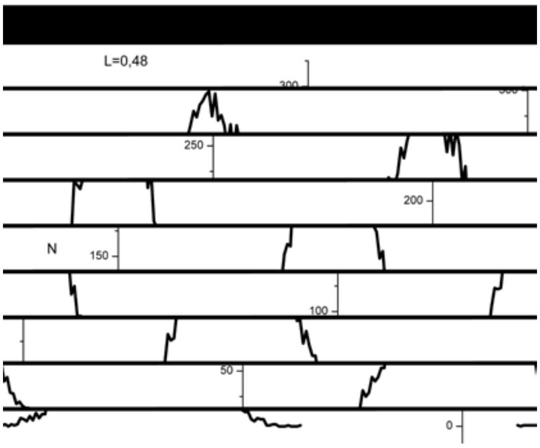

Fig. 5. Particle density distribution along the X axis

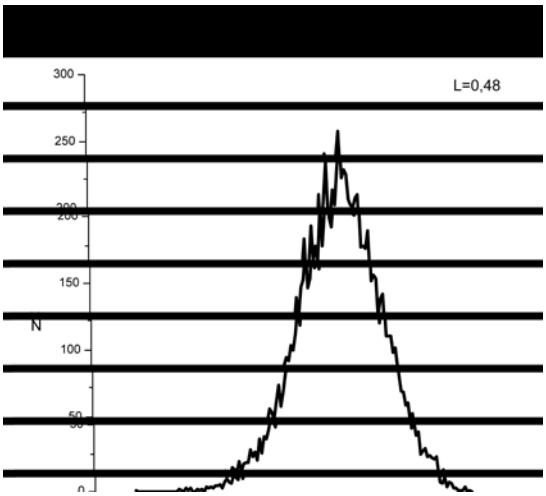

Fig. 6. Particle density distribution along the Y axis

After coming into the atmosphere the beam parameters will change according to Figs. 7, 8.

In all figures the parameter L denotes the distance along the beam trajectory counted (in meters) from the collimator at the accelerator exit (see Fig. 1).

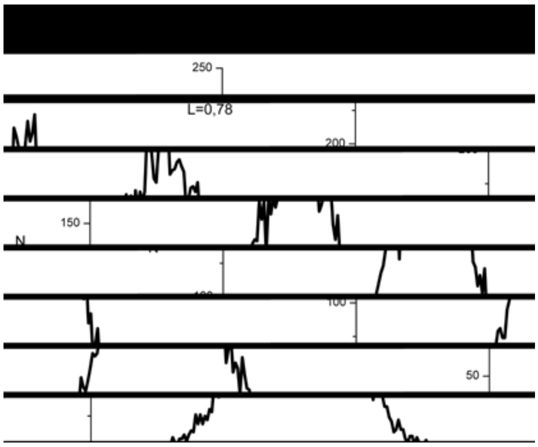

Fig. 7. Particle density distribution along the X axis after passing the output foil

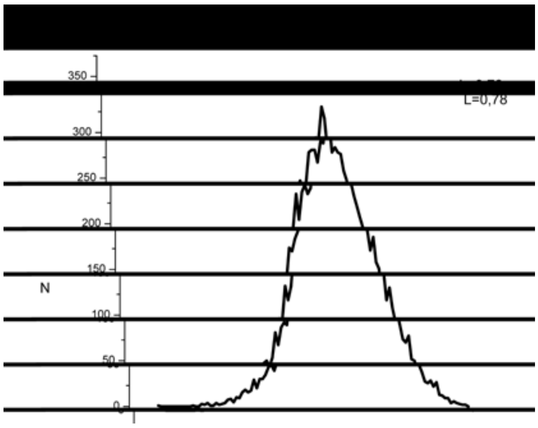

Fig. 8. Particle density distribution along the Y axis after passing the output foil

On the surface of the tank with cartridges the beam density distribution along the X and Y axes takes the form shown in Fig. 9 and Fig. 10.

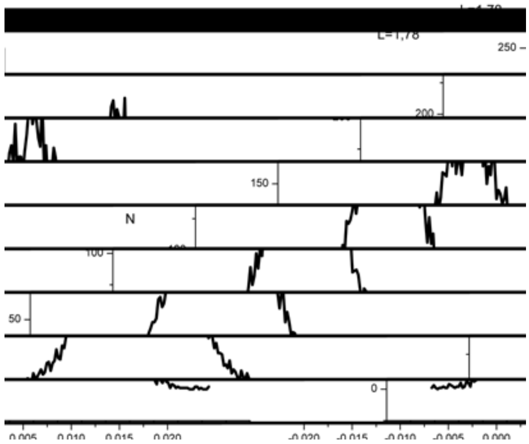

Fig. 9. Particle density distribution on the tank (X axis)

As is seen from these figures the irradiation field looks as an ellipse with rather small (about 15 mm) sizes along the X axis and to reach a uniform irradiation the cartridges with materials should be moved uniformly along the X axis. To obtain a uniform dose in the transverse direction it is necessary to use two cartridges placed symmetrically relatively to the maximum beam density. After the first passage of cartridges along the X axis one should interchange their places relatively to the maximum density and carry out irradiation at the same rate by moving cartridges in the backward direction.

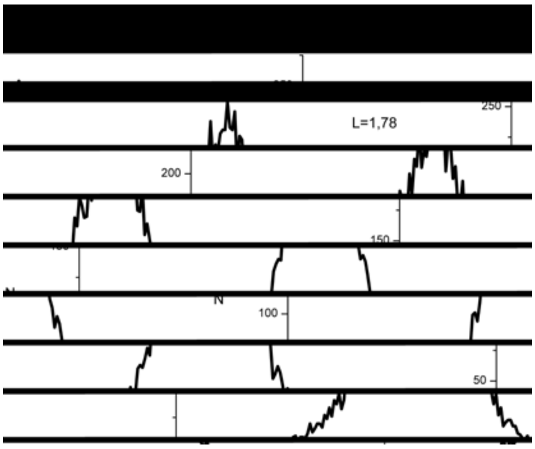

Fig. 10. Particle density distribution on the tank (Y axis)

Addition of doses obtained is demonstrated in Fig. 11 for the cartridges of 225 mm width.

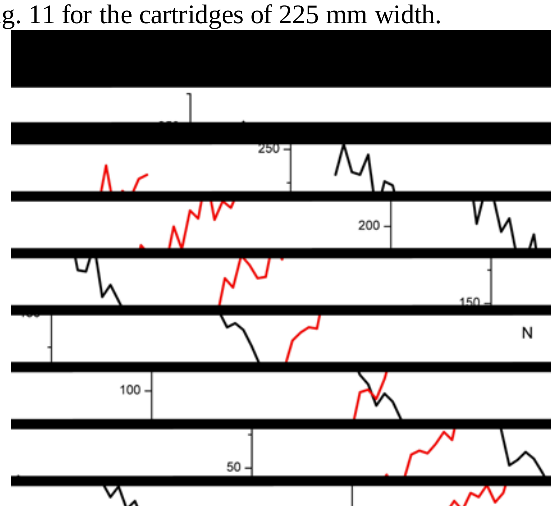

Fig. 11. Dose densities obtained after rearrangement of cartridges

As a result of addition the dose nonuniformity across the cartridge moving does not exceed 10% (Fig. 12).

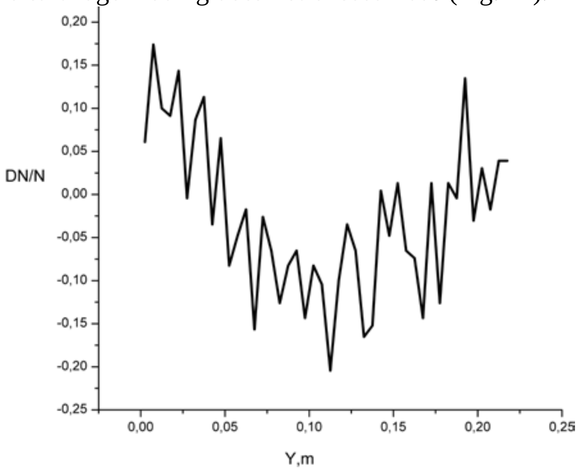

Fig. 12. Dose nonuniformity across the cartridge

In the vertical axis of the figure the dose fluctuations are plotted relatively to the averaged (for the cartridge) value obtained by addition. In the case of a high irradiation dose one can use an additional electron scattering by applying aluminum plates, which are introduced into the beam behind the output foil. In Fig. 13 and Fig. 14 presented are the electron density distributions on the tank with cartridges using the plates of 0.05 cm and 0.1 cm.

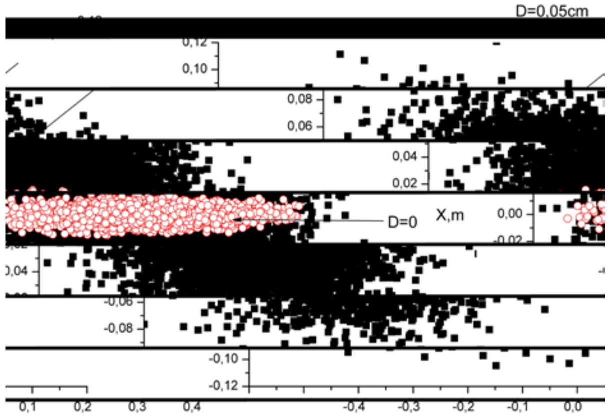

Fig. 13. Particle density distribution on the tank with introduced 0.05 cm plates

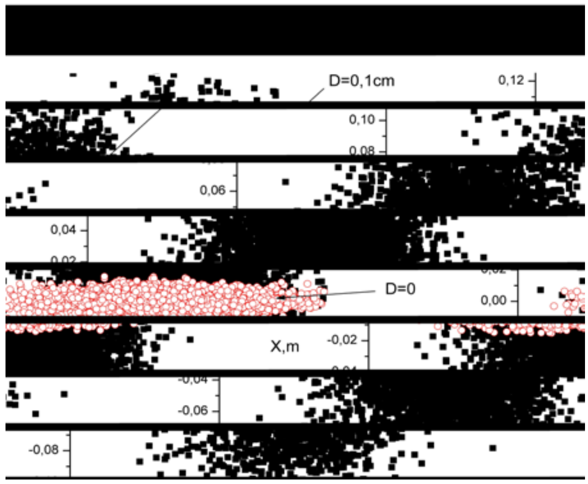

Fig. 14. Particle density distribution on the tank with introduced 0.1 cm plates

Energy losses by electrons passing through these plates are 0.476 MeV and 0.957 MeV corespectively. The scattering angles and energy losses by electrons passing through the plates were calculated with the use of known data [8 - 10].

The particle density distribution in the case without plates is shown in the figures by circles and after introduction of plates – by small squares.

CONCLUSIONS

The simulation of electron motion in the channel taking into account the real beam parameters allows one to optimize the parameters of the magnet and other elements of the transport channel and irradiation complex at the accelerator "EPOS" for the purpose of operation using the existing equipment and after upgrading it.

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ВТОРОЙ КАНАЛ ВЫВОДА ПУЧКА НА УСКОРИТЕЛЕ "EPOS"

А.Н. Довбня, И.С. Гук, С.Г. Кононенко, Г.Г. Ковалёв, А.О. Мыцыков

Рассматривается возможность создания на линейном технологическом ускорителе “EPOS” нового канала вывода пучка с углом поворота 90 градусов. Приводится схема канала, оценивается величина поля в поворотном магните. Приводятся результаты моделирования движения электронов в канале с учётом реальных параметров пучка. Рассчитана плотность потока электронов на облучаемых материалах.

ДРУГИЙ КАНАЛ ВИВОДУ ПУЧКА НА ПРИСКОРЮВАЧІ "EPOS"

А.М. Довбня, І.С. Гук, С.Г. Кононенко, Г.Г. Ковальов, А.О. Мициков

Розглядається можливість створення на лінійному технологічному прискорювачі “EPOS” нового каналу виводу пучка з кутом повороту 90 градусів. Представлена схема каналу, проведена оцінка величини поля в поворотному магніті. Проведено моделювання руху електронів у каналі з урахуванням реальних параметрів пучка. Розраховано густину потоку електронів на матеріалах, що опромінюються.