BEAM TRANSPORT SYSTEM SELECTION ON THE ACCELERATOR LU-10

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Presently at the NSC KIPT the upgrading of the linear accelerator LU-10, designed for radiation processing of materials and products within the range of about 10 MeV, is started. For the accelerator operation time be used more efficiently it is supposed to design the second beam output onto the target. Possible variants of the second channel have been considered. The beam characteristics and beam losses are calculated with taking into account the desired parameters of the beam at the accelerating section output. Analysis of some channel variants by various criteria has been performed. The most effective version is chosen.

PACS: 29.20.-c

INTRODUCTION

Linear accelerators, operating now at the NSC KIPT, are used, for the most part, for solving the problems on radiation processing of materials and for developing medical isotope sources [1, 2]. As far as, the component parts – klystrons and thyratrons for these accelerators are not commercially available it has been decided to reconstruct the accelerators for the operation at the frequency of 2856 MHz with the use of a klystron VKS-8262F and thyratrons CX1525a in the modulators. It is planned that first the accelerator LU-10 [3] will be upgraded for operation at the energy of 10 MeV. After making the decision to upgrade the existing accelerator LU-10 using a new klystron, the work on the choice and optimization of the accelerating structure has been carried out and the main characteristics of the beam at the accelerator output were calculated [4] (see Table). It is planned to increase the mean beam power at the accelerator output up to 20 kW.

Principal beam parameters of the accelerator LU-10

Parameter	
Beam current, A	0.389
Maximum energy, MeV	9.44
Energy spectrum (99 % part.), %	51
Energy spectrum at the half-height, %	0.48
Diameter (99 % part.), mm	6.8
Mean-square radius, mm	1.5
Meansquare normalized emittance, mm·mrad	13

A major task of our work is to choice a new system for beam transport onto the object being irradiated in the accelerator LU-10. In so doing it is necessary to hold an existing beam position at the output from the scanning magnet and to create the second irradiation channel. The beam extraction system, being in operation now, satisfies, by its characteristics, the main users’ requirements to the beam in the accelerator. It is necessary to perform a reconstruction only to decrease the electron beam path in the air.

1. PROBLEM GEOMETRY

Discussions on possible schemes of material processing using the accelerator have shown that the new accelerator parameters can not be used in full because of a low capacity of the available transporter. However, the parallel operation of two channels with the use of pulsed distribution of the beam into the second channel is improbable too. The reason is that the requirements to the beam for main planned tasks at the updated accelerator are not consistent with permissible beam losses at the stage of beam forming into the second channel.

The layout of the main forming units and output devices in the accelerator LU-10 after upgrading is presented in Fig. 1. Behind the output foil of the scanning magnet chamber, installed is a moving transporter with boxes containing materials to be irradiated. The system for forming and controlling the beam at the accelerator output should be placed between the output flange of the accelerating section and the output foil, and should contain, in the initial part, the elements having the size and locations indicated in Fig. 2. The first is a valve, separating the accelerator vacuum volume from output devices, then a collimator permitting to cut a halo around the main electron beam. Next situated are two quadrupole lenses and a system of correctors designed for beam forming in the direct output channel and in the deflected rotated channel. для формирования пучка на прямом выходе и на повёрнутом пучке. To turn the beam into the second channel the authors of [5] have propose to use a dipole magnet developed for the accelerator “EPOS”. This device was operating during three years and demonstrated the reliability and resistance to radiation damage of its construction.

At the direct channel output one can see the chamber of the existing pulsed magnet rotating the beam in the vertical plane.

The transport channel diameter is specified by the aperture of quadrupole lenses.

Using the data obtained we determined the placement of the future electromagnetic system at the accelerator output with coordinate binding to the bunker, accelerating structure and support systems.

The second output should be at a distance no less than 1 m from the direct output, taking into account the assembly technique and equipment maintenance (see Fig. 2).

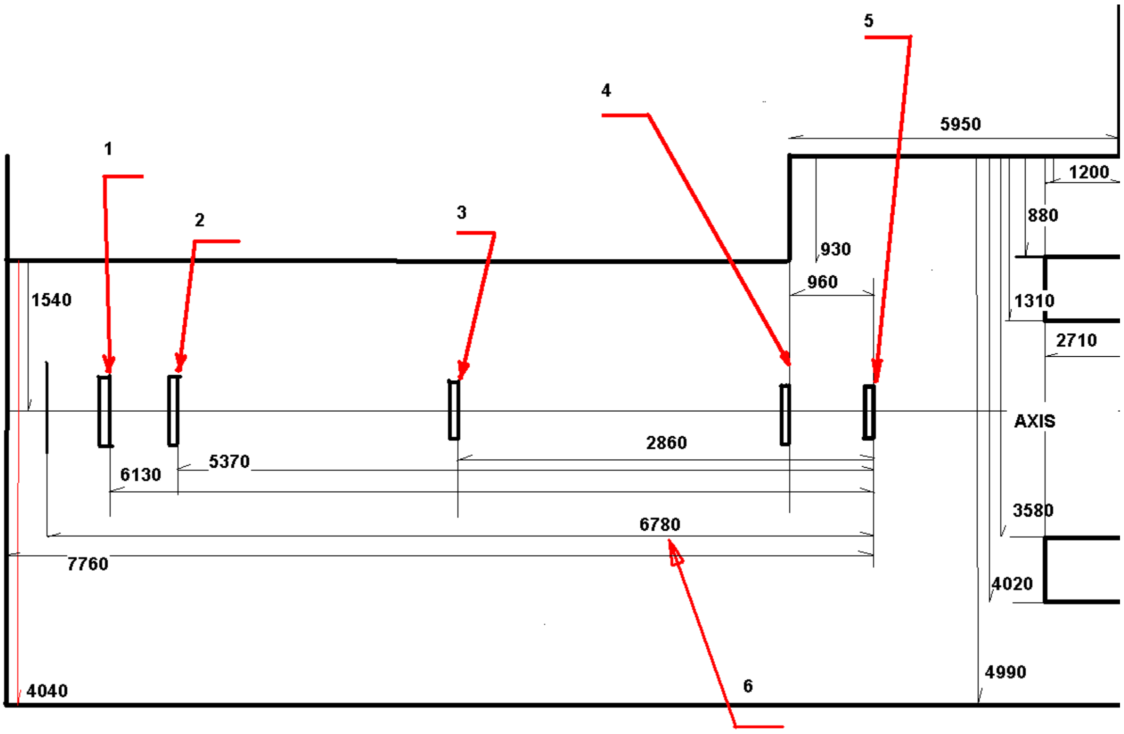

Fig. 1. Layout of the main accelerator units in the bunker.
1 – source flange; 2 – section input flange; 3 – section output flange; 4 – magnet chamber flange;
5 – scanner output flange; 6 – accelerator length + transport system length

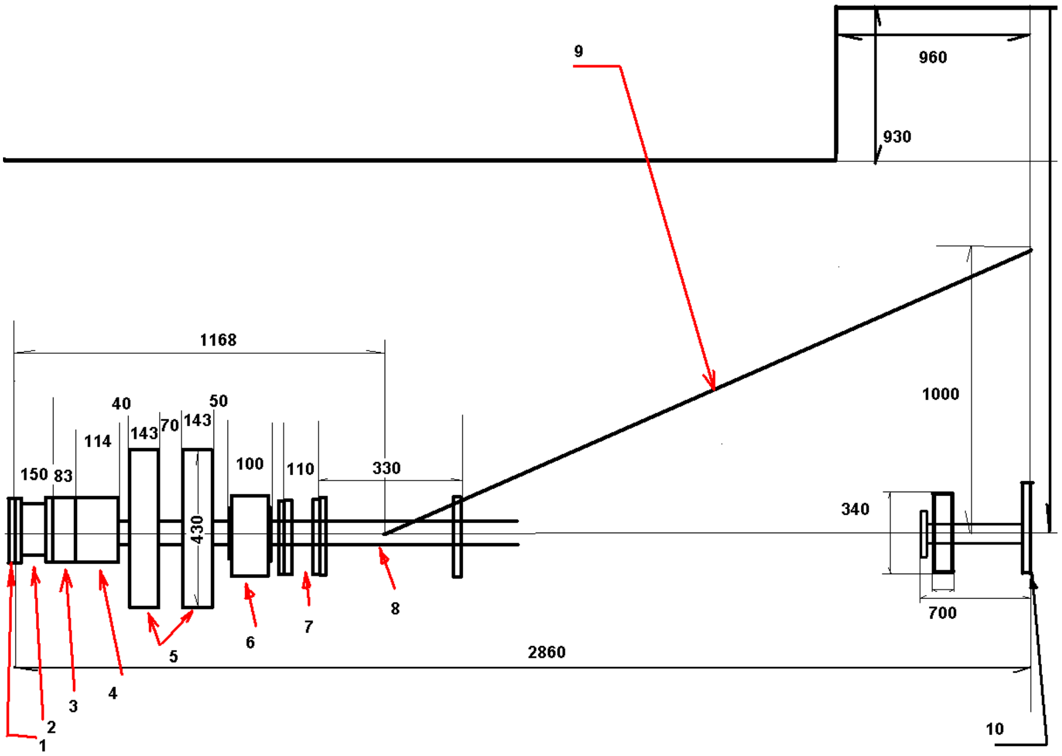

Fig. 2. Space for arrangement of output devices.
1 – section output flange; 2 – valve; 3 – collimator; 4 – position sensor; 5 – quadrupoles; 6 – corrector;
7 – bellow; 8 – magnet chamber; 9 – inner pipe diameter no more than 50 mm; 10 – output foil

The above-given data were used as a basis for simulation of the beam motion in the accelerator output devices.

2. SIMULATION RESULTS

The beam motion simulation/modeling has been carried out by the electron tracking method with the use of the MAD X program [6]. The beam dynamics simulation results of [4] were used as the initial beam data. The particle density distribution at the accelerator output (the section output flange) obtained as a result of simulation is shown in Fig. 3.

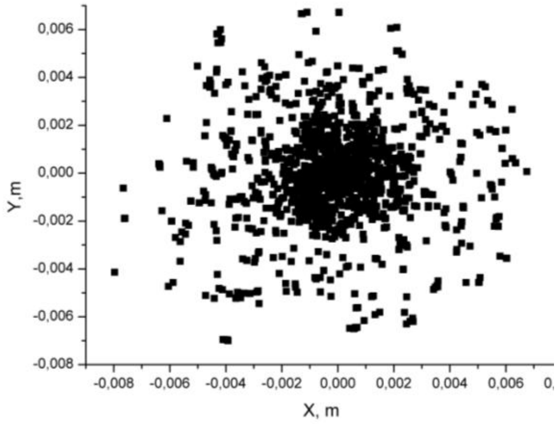

Fig. 3. Beam at the accelerator output

The energy spectrum of the electron beam at the accelerator output is represented in Fig. 4.

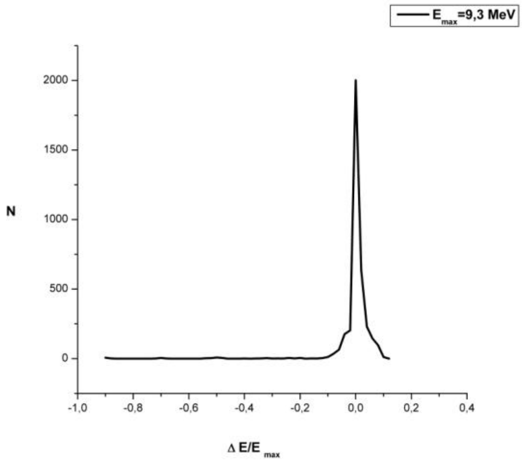

Fig. 4. Electron distribution as a function of their energy

From the very beginning of the problem consideration it was clear that the use of achromatic systems for beam extraction with such a large angular and energy spread has no advantage over the systems comprising a minimum number of elements because the monochromatic systems, by definition, operate only for small energy spreads in the beam [7]. Nevertheless, these variants were calculated too. The transport system has been positioned with taking into account that at the outputs of both channels a vertical beam scanning system (scanner) should be installed, provided that it was placed successfully in the predetermined place.

The simplest system presented in Fig. 5, has a minimum number of magnetic elements: a constant dipole magnet and a quadrupole. All elements, designed for preliminary direct beam forming, are located before these elements (see the figure). Before the vertical beam scanning system (V) a position sensor and a current sensor are located (such as at the accelerator output).

The beam losses along the transport track for chosen magnet apertures and lenses are given in Fig. 6, and the beam sizes at the channel output – in Fig. 7.

A gradient value in the quadrupole magnet was chosen taking into account the requirement of obtaining a minimum horizontal beam size.

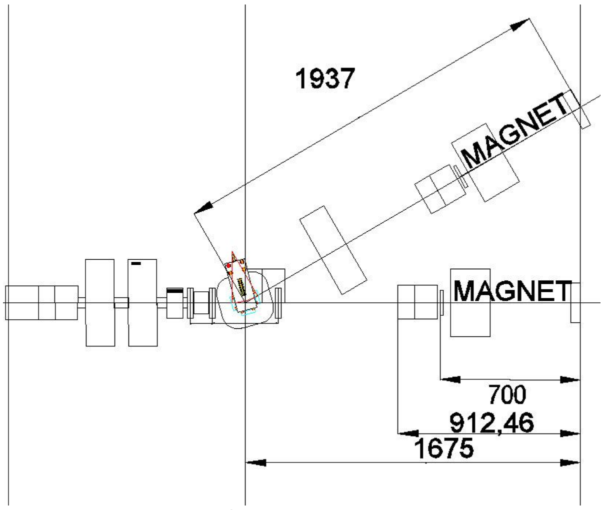

Fig. 5. Diagram of the channel with a single dipole

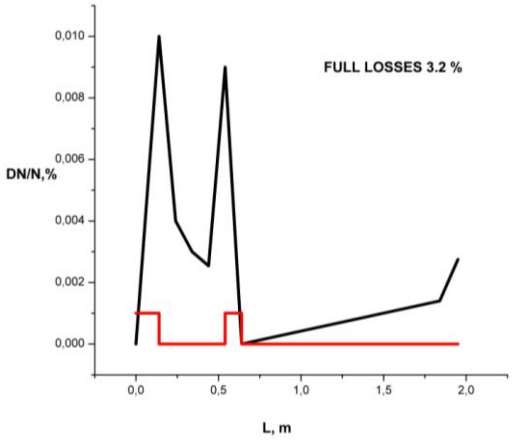

Fig. 6. Beam losses along the channel

Simulation has been carried out on a variant with the use of a pulsed magnet on the direct beam and a constant magnet for the beam output into the given point (Fig. 8). The beam distribution at the channel output does not differ appreciably from that shown in Fig. 7. The beam losses along the track for this variant are 3.7%.

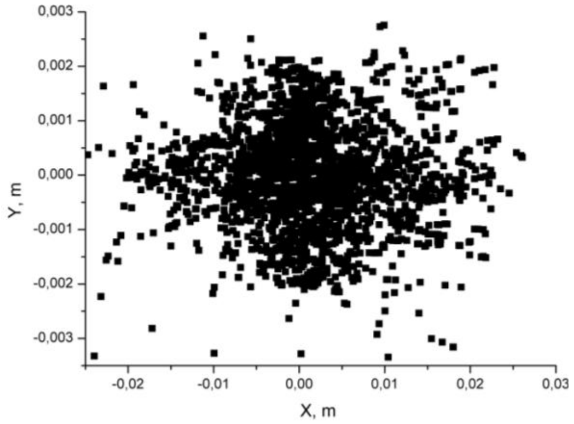

Fig. 7. Particle distribution channel output

Simulation has been made on the beam motion through the classic [7], specially selected achromatic system comprising two magnets and five lenses (Fig. 9) and the system with four magnets (Fig. 10). It is impossible physically to install five lenses in the channel with indicated sizes because of the overhung magnet winding, but it has been made with idealized lenses.

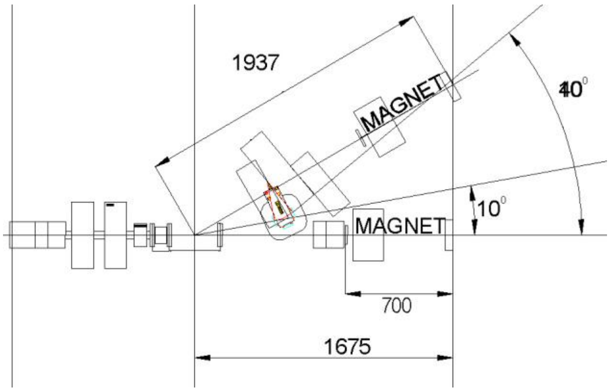

Fig. 8. Variant of a channel with a pulsed magnet

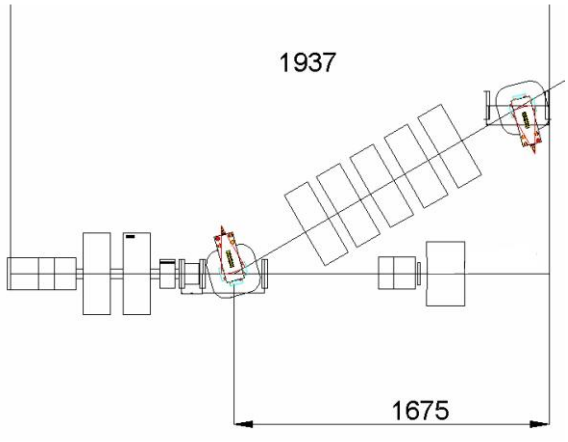

Fig. 9. System with 5 lenses

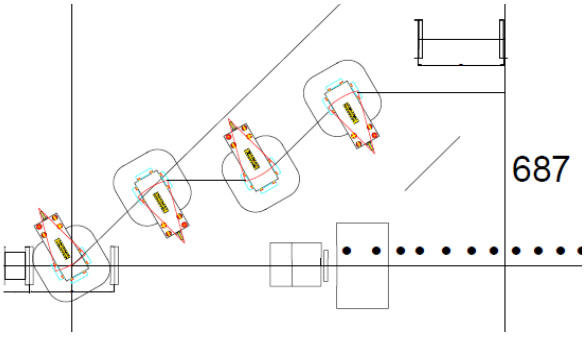

Fig. 10. System with 4 magnets

For this case the beam density distribution at the channel output is shown in Fig. 11. The beam density distribution for four magnets is shown in Fig. 12. The beam losses along these channels are close to the values given below for simpler systems.

The percentage of particles which have passed through the channel cross-section at the output, because of the central energy shift at the input with conservation of the relative energy spread, is presented in Fig. 13 for three systems under consideration. It is seen that in this case too the complex systems have no advantage.

The results of investigations strongly evidence that to realize a second channel it is necessary to use the simplest magnetic system being most inexpensive and reliable. However, as in the case of more complex systems, one should expect rather high particle losses along the channel that can lead to a short life time of equipment because of radiation damages.

The situation can became worse because of significant exceeding of the real energy distribution at the accelerator output in comparison with the designed value. For example, in the LU-10, being operating now, the spread value is 1.7 MeV at a level 0.5 [3], that is higher by a factor of 30 than the spread used in the course of simulation.

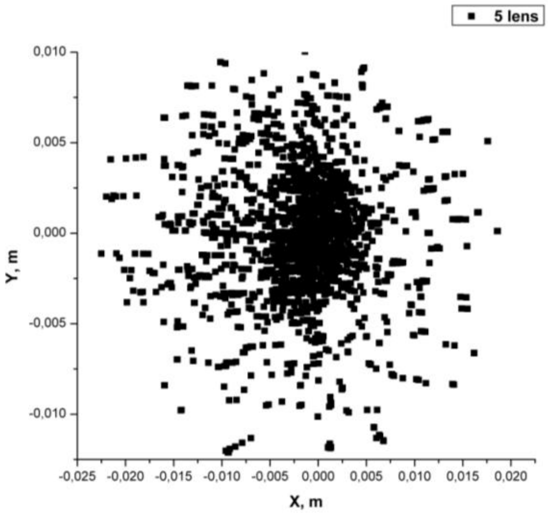

Fig. 11. Particle distribution at the system output

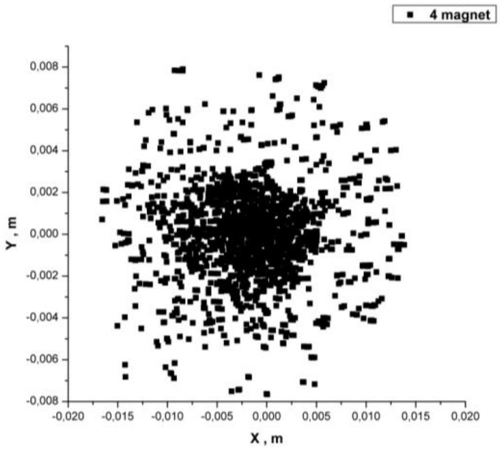

Fig. 12. Electron distribution after passing the channel with 4 magnets

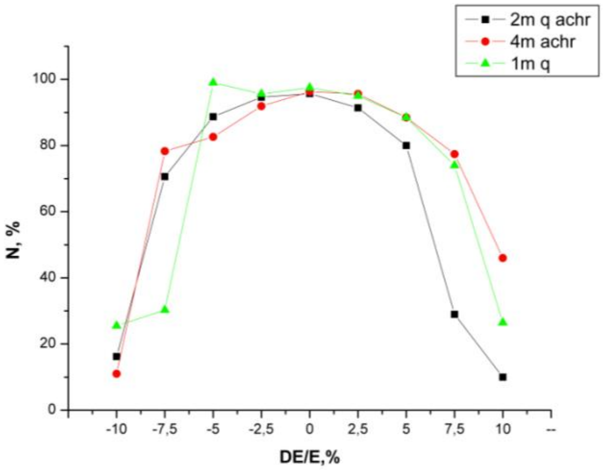

Fig. 13. Beam losses in the case of energy shift

In the system comprising a magnet and a quadrupole with such a spread the beam density distribution at the channel output will take the appearance shown in Fig. 14. And along the channel 15.5% of all the particles will be lost that is inadmissible at the beam power of 20 kW.

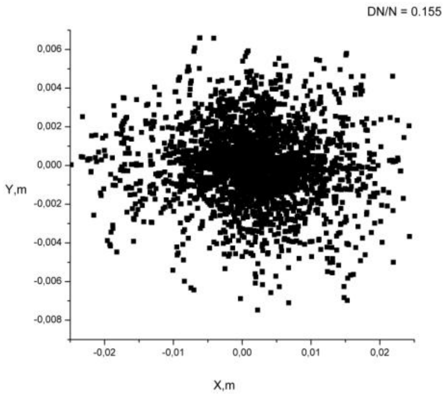

Fig. 14. Beam at the channel output in the case of a maximum energy spread

The beam losses in the channel as a function of the energy spread is shown in Fig. 15.

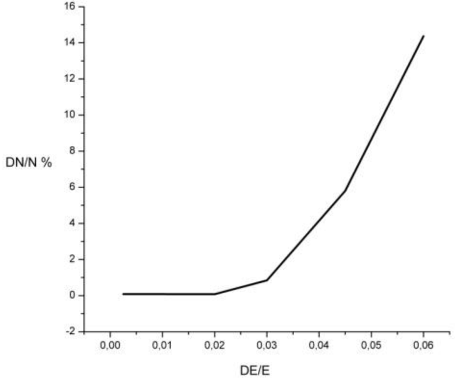

Fig. 15. Beam losses in the channel as a function of the energy spread

Analysis of the data obtained enables to conclude that it is possible to build the second channel at the output of the modernized Lu-10 with the energy spread no more than 4%.

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Article received 08.10.2013

ВЫБОР СИСТЕМЫ ТРАНСПОРТИРОВКИ ПУЧКА НА УСКОРИТЕЛЕ ЛУ-10

А.Н. Довбня, И.С. Гук, С.Г. Кононенко, А.С. Тарасенко

В ННЦ ХФТИ в настоящее время начата модернизация линейного ускорителя ЛУ-10, используемого для радиационной обработки материалов и изделий в диапазоне до 10 МэВ. В связи с этим для более рационального использования времени работы ускорителя предполагается создание второго вывода пучка на мишени. Рассмотрены возможные варианты создания канала, рассчитаны характеристики пучка и потери его с учётом предполагаемых параметров пучка на выходе ускоряющей секции. Проведен анализ по различным критериям и выбран наиболее эффективный вариант.

ВИБІР СИСТЕМИ ТРАНСПОРТУВАННЯ ПУЧКА НА ПРИСКОРЮВАЧІ ЛП-10

А.М. Довбня, І.С. Гук, С.Г. Кононенко, О.С. Тарасенко

У ННЦ ХФТІ розпочата модернізація лінійного прискорювача ЛП-10, що використовується для радіаційної обробки матеріалів і виробів у діапазоні до 10 МеВ. У зв'язку з цим для більш раціонального використання часу роботи прискорювача передбачається створення другого каналу виводу пучка на мішені. Розглянуто можливі варіанти створення каналу, розраховано характеристики пучка і втрати його з урахуванням передбачуваних параметрів пучка на виході прискорювальної секції. Проведено аналіз за різними критеріями й обраний найбільш ефективний варіант.