# SYSTEM OF PRELIMINARY FORMATION OF THE BEAM FOR THE CHANNEL OF PROTON THERAPY

M.I.Grachev, E.V.Ponomareva, Kravchuk L.V., Gorbunov V.K., Skorkin V.M., INR, Moscow, Zapolsky V.N. # IHEP, Protvino, Russia

*Abstract*

The system of preliminary formation of the proton beam is introduced for the complex of proton therapy at Experimental Complex. The new scheme of the channel allows attaining a parallel beam on an output. Energy of a beam is adjusted in the channel in a range from 209 up to 70 MeV without change of energy of a beam in the accelerator.

The proton beam channel of the first stage of the complex of proton therapy was created for an irradiation of tumors of the small size, such as a tumor of an eye [1]. Later there was a decision made to expand a range of the tumor sizes, exposed to an irradiation on this channel. As a result, new requirements to the beam have been established, in particular an attaining a beam with sizes of ∅10 cm and uniform intensity distribution. Available uniformity of the beam density for old optical scheme was no more than 20%.

The search of a solution, that would enable us to attain a uniformly distributed parallel beam, has lead to creation of a new channel with a system of preliminary beam formation.

The system of preliminary beam formation for the channel of proton therapy is intended for creation a uniformly distributed dose field with sharp boundaries by means of the elements of magnetic optics.

The system consists of the channel for transportation and forming a proton beam with the vacuum system, the power-supply system for the magnetic elements of the channel, collimating and braking devices.

Fig.1 shows new optical scheme of the channel. In contrast to the previously developed scheme here we have included 8 additional lenses in the initial section and the collimating and braking devices. The special feature of the channel is the possibility of tuning the channel without introducing the scattering and dissipative elements into the beam. Hence the decrease of equipment activation is achieved down to the values, appropriate for the usual maintenance of channels.

## FORMATION OF AN INITIAL BEAM

The process of formation of an initial beam contains following stages:

### *Forming of the size of the beam*

The remotely controlled tantalum collimator the length along the beam of 2 cm is positioned in front of the magnet BM1 in order to determine and set up the initial size of the beam from ∅4 mm. The collimator is introduced into the vacuum system with the accuracy of the repetition of ± of 0,1 mm. The maximum power, produced in the collimator, does not exceed 200 W. For the beam diameter of ∅4 mm the angular divergence of the beam is not more than $1{\cdot}10^{-2}$ deg.

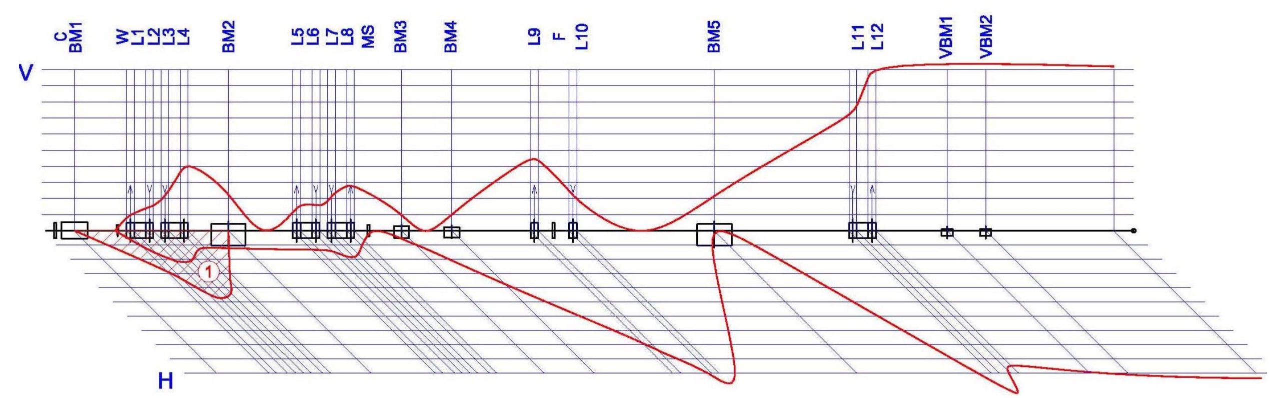


Figure 1: Optical scheme of the channel for proton therapy. C- collimator, BM – bending magnets, W – absorber of energy (wedge), L- lenses, VBM – vertical bending magnets, 1 – area of displacement of a beam.

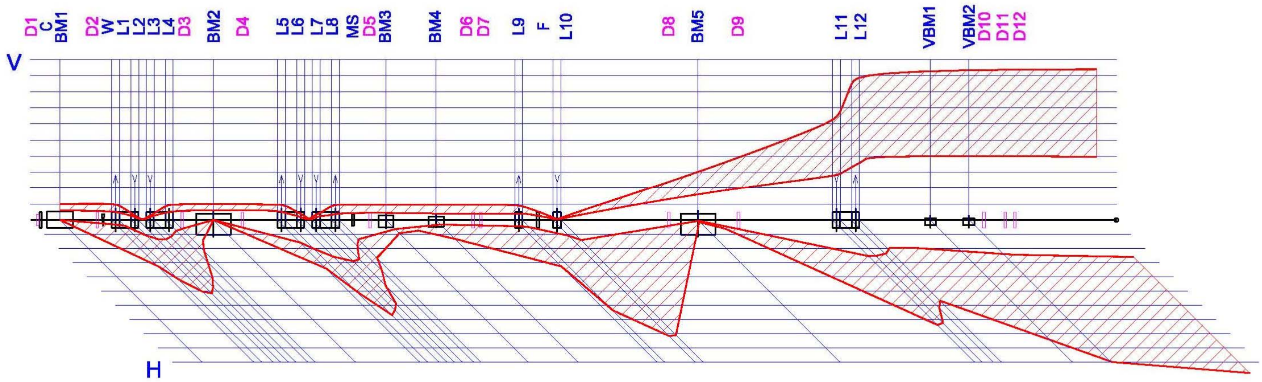


Figure 2: Optical scheme of the channel for proton therapy (mode of beam tuning operation). D – detectors, L- lenses, BM – bending magnets, VBM – vertical bending magnets.

## *Changing the energy of the beam*

Tantalum wedge-shaped energy absorber is introduced in the channel before the lens L1. Absorber positioned in the vacuum system and it is introduced remotely to the axis of a beam with the accuracy of ± 2mm on a vertical. The maximum heat output on the energy absorber is 20 W. The “spot” of a beam on the wedge is a source of a parallel beam in the end of the channel.

Due to the multiple-scattering of protons in the tantalum wedge the phase volume of the beam increases substantially which makes it possible to form the parallel beam of large cross-section area from practically only a point source, as shown in Fig.2. We attain almost a uniform apex of the beam by cutting out its middle section.

Material and dimensions of the wedge are selected in such a way that for with two values of energy of protons from accelerator of 209 and 160 MeV it overlaps the operating range of energies for irradiating the tumours of 209-70 MeV.
Reduction in the intensity of the beam due to the forming is estimated by two orders, which enables us to use a proton therapy on the high-current accelerator.

Fig. 3 shows the calculated profiles of the beam at the end of the channel at the distance of 5 m from each other.

## *Monochromatization of the beam*

To monochromatize the beam into the place of the horizontal focus of the beam after lens L8, vertical slit pulse collimator is introduced with the length of 30mm along the beam. The collimator is made from tantalum and with the dimensions of the slot of 4x150mm$^2$ (horizontal x vertical). Power, generated on the collimator

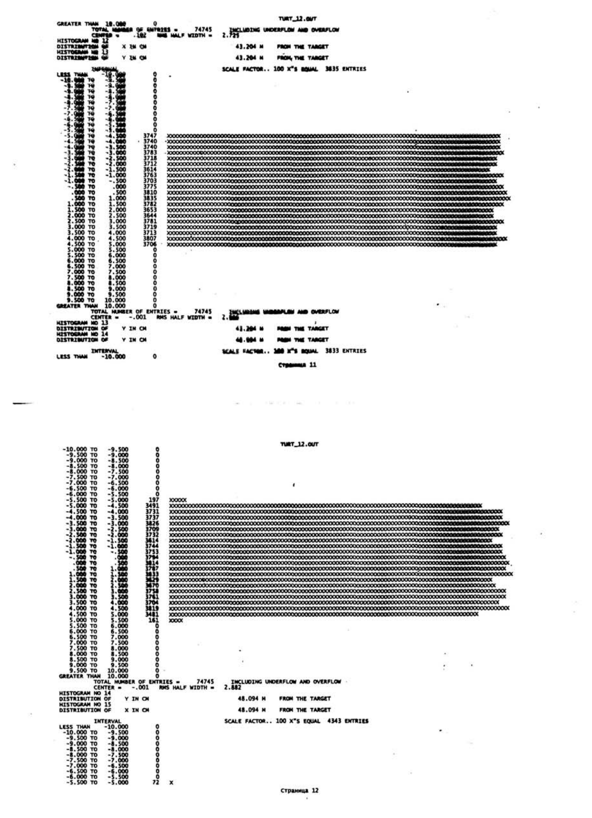

Figure 3: Profiles of the beam after collimator at the end of the channel (up) and at the distance 5 m.

is 10 W. Momentum slit collimator is positioned into the vacuum system and is manipulated remotely. Control of insertion and extraction of collimators and energy absorber is accomplished remotely from the control panel in the additional building 25 of Experimental Complex [2].

## CONTROL OF THE ENERGY OF PROTONS IN THE BEAM

The possibility of changing the energy of the protons of the beam to the assigned parameters is one of the most important requirements, presented to the system of preliminary beam formation for the channel of proton therapy. The procedure of control of energy of protons in the beam is achieved in two stages:

Stage 1: Change of the energy of protons in the accelerator in the range from 209 to 160 MeV.

Stage 2: Change of the energy of protons in the channel by means of the wedge-shaped absorber. By varying the current in magnet BM1 with a step of 0.5 A we can accomplish the shift of the position of the beam on the wedge-shaped absorber and the corresponding change in the energy of protons. The deflected beam is focused towards the centre of magnet BM2 and only changing the current in magnet BM2 attains the compensation for beam displacement in the channel.

The limitation of energy (pulse) range to 0.3 (0.15 $\Delta p/p$) is accomplished with the help of the slit pulse collimator, which is positioned in the focus of the beam after lens L8 and has dimensions of slot of ±2 mm on a horizontal and of ±75 mm on a vertical.

The power-supply system of the magnetic elements of the channel supports the relative stability of currents at a level of 0.1% and it can provide the automatic programmed change in the currents in the range of 30% of the initial regime. Initial regime corresponds to the maximum energy of the beam for irradiating a particular tumour. The range of time for changing the currents - 1 min., the step of change - 2 sec.

## CHANNEL TUNING

Generally, especially at the beginning of an operation, tuning of channel [3] takes a significant amount of time, while irradiation continues for several minutes. The presence of the absorbing and scattering elements makes standard tuning is impossible because of the excess activation of the equipment. Therefore the optical scheme of channel is developed in such a way so that tuning of the beam is conducted without the use of the braking and collimating elements. Fig. 2 shows an optical scheme equivalent to medical channel with the system of preliminary beam formation. Here the regimes of the elements are equal to the regimes of the medical channel, which are needed to be selected because of the insufficiently precise correspondence of the computed value of the current strengths.

Calculated focal coefficients [3], which indicate by how much should the gradients be changed in a particular lens in order to displace the position of the focus in one of the transverse planes, without changing the position in another, are used for correction of gradients of fields in the lenses. We achieve tuning of “parallel” beam by focusing into a given point with further correction of regimes by focal coefficients for obtaining “parallel” beam.

Beam displacement by the angle X on a horizontal is accomplished by a magnet BM1, parallel displacement on a vertical Y - with pair of the corrective magnets in front of BM1. On Fig. 2 we can see a beam displacement for two values of initial displacement along X’ and Y. The profilometers detect a difference in the beam displacement (shaded region), which excludes the influence of the accuracy of the installation of detectors on the results of tuning.

At the moment the equipment of the channel of proton therapy with the system of preliminary beam formation is being developed and installed. The equipment has passed the tests of working with the beam. In the future there are plans to tune the system of preliminary beam formation according to the program of medical physics.

## RESUME

The new system of preliminary formation of the proton beam for the complex of proton therapy is developed and installed at present. The system is intended for creation a uniformly distributed dose field with sharp boundaries by means of the elements of magnetic optics. The special feature of the system is the possibility of tuning the channel before introducing the scattering and dissipative elements into the beam. Hence the decrease of equipment activation is achieved.

## REFERENCES

[1] Requirements specification on working out TES of the Complex of Proton Therapy on base of linear accelerator MMF INR RAS 44.453-032-T31. M., 1999. (in Russian)

[2] M.Grachev et al. Transportation of the proton beam at the Experimental complex of linear accelerator INR of the RAS, at this Conference.

[3] F.Bernard et al. The methods of tuning RF-beams, IHEP BD 73-9, Serpukhov, 1973 (in Russian).