DEVELOPMENT OF THE BEAM DIAGNOSTIC SYSTEM FOR THE RADIOBIOLOGICAL RESEARCH AT THE PROTON LINEAR ACCELERATOR I-2*

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Abstract

At the present time at ITEP there is a possibility to investigate the biological mechanisms of the low energy protons on living systems on linear accelerator I2. The unique high current linear accelerator allows to obtain 20 MeV intense proton beams. They could be used for the radiobiological research in a wide range of absorbed doses and for different cell types. Currently some preliminary experiments were made to specify diagnostic equipment required for further investigations. This work presents the main results on the proton beam parameters measurements such as beam current, beam cross section dimension as well as the measurements of the absorbed dose and depth dose distribution using different types of detectors.

INTRODUCTION

For the last few years the distant radiation therapy with 70-230 MeV proton beam are on the rise in the world. According to PTCOG report 13 centers for proton radiation therapy are put into operation for last two years. Besides the general number of centers where the patients are irradiated, do not exceed 60 [1]. Though the amount of information has been collected for more than a half-century' history of the radiation therapy there are a set of questions needed further radiobiological investigations [2]. Now besides medical application the radiobiological research with low energy proton and ion beam of micron and submicron size develop worldwide (so-called microbeam) [3]. The main goal of this research is the biological effect investigation of charged particles on the level of single cell. It allows developing a deeper understanding of the ionizing radiation biological effect. Now at ITEP it is possible to provide the above-mentioned radiobiological research on proton linear accelerator I-2. The accelerator parameters allow to obtain high intensity proton beam with the energy approximately 20 MeV thus radiobiological investigations in the wide range of absorbed doses for different types of cells could be carried out. In this article, the made experimental setup for further radiobiological research and diagnostics system is described. Also the main results on the proton beam parameters measurements such as beam current, beam cross section dimension using different types of detectors and the measurements of the absorbed dose and depth dose distribution.

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EXPERIMENTAL SETUP

For the experiment the proton beam with the energy of 24.6 MeV was used. Figure 1 gives the overview of the experimental scheme.

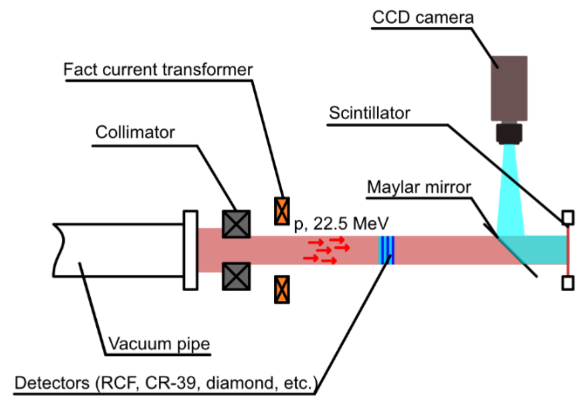

Figure 1. The view of the experimental setup.

The lateral size of the beam field in the area of measuring equipment is given by collimating system consisting of different sizes of brass collimator. The fast current transformer FCT-082 (Bergoz, France) was used as the main monitor to measure the number of particles. This detector is a broadband transformer of AC current with bandwidth of 700 MHz. The signal of current transformer is read off by oscilloscope DPO-3034 Tektronix (USA). The view is shown in Fig.2. The digitized signal send to software PTEK and the number of particles was calculated [4].

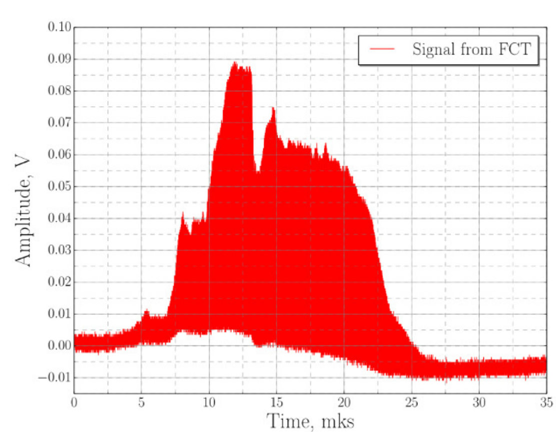

Figure 2. The output signal of FCT.

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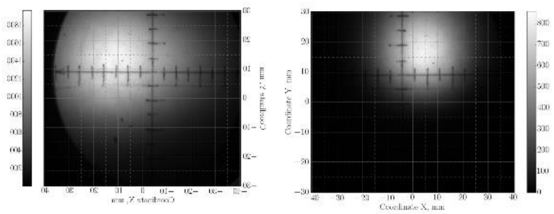
The particles spatial distribution in the beam cross-section was registered by optical system consists of the ceramic scintillator and CCD camera (SDU-285). The mirror made of thin metallized Mylar was used for image projection. Figures 3a and 3b give an image of the beam on scintillator with 12 mm collimator in diameter and without accordingly.



(a) (b)

Figure 3: The images of a beam on scintillator without (a) and with (b) 12 mm collimator.

The two types of radiochromic films (MD-55-2 and HD-810, GafChromic, USA) were used to measure dose depth distribution curve. This films change their color caused by irradiation. The color depth depends of absorbed dose value which is proportional to particle energy deposit. The homogenous field was formed with 12 mm diameter collimator. Two different assemblies consist of MD-55-2 and HD-810 films were irradiated. The assemblies were positioned each after each (the first one was MD-55-2).

RESULTS

Figure 4 gives a fragment of oscillograph image of output signal from FCT. The peaks locations allow determining the pulse period of micro bunches and it is 6.7 ns. The frequency of 148 MHz corresponds to this period value. This frequency is in good agreement with one of the cavity accelerating field.

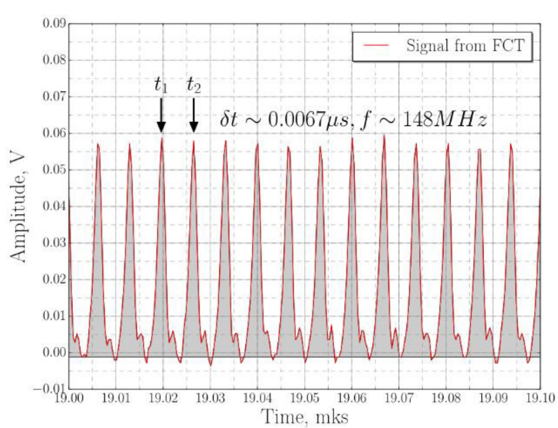


Figure 4: The image of output FCT signal.

Also the correlation between the integral value of scintillator light output and the intensity of the incoming beam were defined (Fig. 5). The beam intensity has been changing by adjusting the beam current in magnet elements of the beampipe [5].

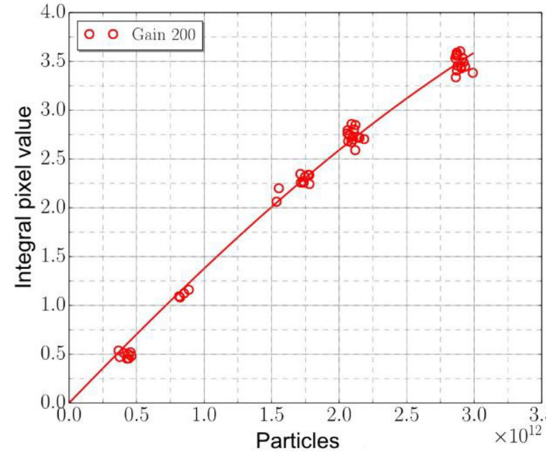
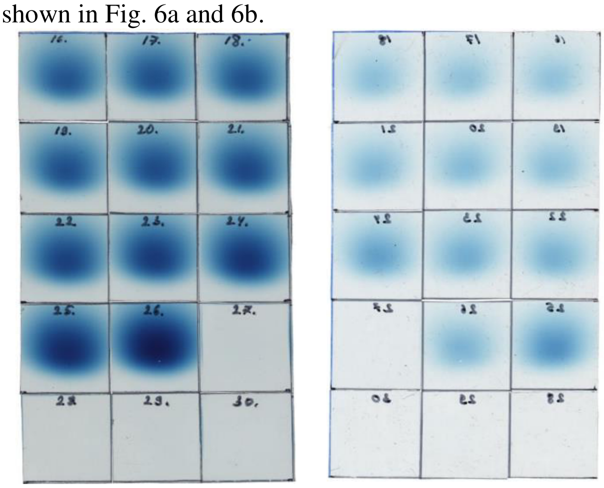


Figure 5: The relation the integral value of scintillator light and number of particles.

As it says above the radiochromic films were used to get the proton depth dose distribution. The flatbed scanner (Epson Perfection V700 Photo) was used for films digitization. The following mode was chosen: 48 bit color mode (by 16 bit for red, green, blue components), the resolution of 300 PPI, no image correction adjustment. The images are saved in TIFF (Tagged Image File Format). The irradiated scanned films of MD-55-2 and HD-810 are shown in Fig. 6a and 6b.



(a) (b)

Figure 6: The digitized images of MD-55-2 (a) and HD-810 (b) films.

The relation between the films optical density and the proton penetration depth is shown in Fig. 7. The width of films was recalculated to tissue equivalent one. The obtaining results were brought into comparison with calculating ones by Monte Carlo method in SRIM. At first, the proton energy at the diagnostics equipment point was determined (after 30 cm of air) as 21.5 MeV. Then using this value the relation between proton energy loss and penetration depth were obtained.

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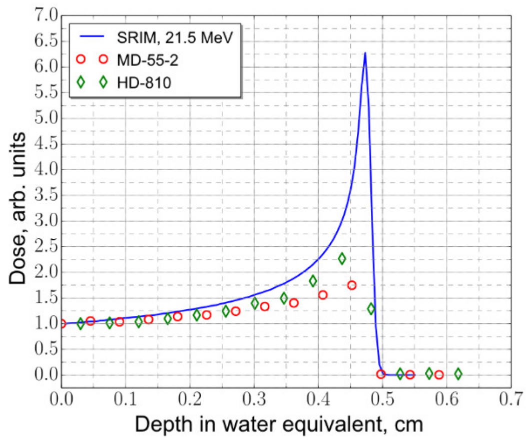

Figure 7: The energy deposition curve in water equivalent matter.

The presented results show that the Bragg Peak height is 2.25 for HD-810 and 1.75 for MD-55-22. These values differs because of films positioning in scanner and different films sensitivity. The difference is due to location of the films and sensitivity of these types of films. Though even the maximum values of the Bragg peak height obtained from HD-810 is more than double undervalue with the calculated results of the energy loss for 21.5 MeV proton in the water. The difference between experiment and calculation is due to a sensitivity reduction of the radiochromic films by increasing the proton energy deposit – Bragg peak range. The similar effect was obtained by several other experiments [6]. However, the presented results show that the location of the Bragg curve back for the calculation and experiment matches with good accuracy. Thus, we can say the beam energy defined correctly.

CONCLUSION

The obtaining experimental results show the possibility in principle of using the proton linear accelerator I-2 for radiobiological research. The design and creation of the facility with diagnostic system for further investigation has started. The homogeneous field of proton beam for different sizes was formed with the collimating system. The optical registration system based on scintillator and CCD camera was developed. The curve of energy depth distribution was measured with radiochromic films in tissue equivalent material. Also we used track detectors (CR-39) to measure the particles distribution in the beam cross section. But in view of the necessity of irradiated detectors chemical etching, the analysis of the results will be presented later.

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