MEDICAL APPLICATIONS OF INR PROTON LINAC

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Abstract

The main parameters of INR proton linac in Troitsk near Moscow are suitable for several medical applications. The isotope laboratory of INR is intensively producing Sr-82 for PET diagnostics in cardiology and the first proton therapy treatment room is now being tested. This treatment room was designed for the therapy of tumors of different sizes and localizations, the patient position can be either sitting or lying. The combination of two scatterers and of a couple of collimators makes the formed beam profile at the isocenter insensitive to the initial beam profile in the transport channel. During the last linac run for medicine the proton beams with energies from 120 MeV up to 209 MeV have been shown to fulfilled the basic medical requirements.

Due to high maximal intensity of the proton beam, the medical isotope production, the brachytherapy (HDR) source activation and the neutron therapy (and neutron-capture therapy) are other possible medical applications of this facility.

PROTON THERAPY

Synchrotrons and cyclotrons are now often used for the hadron therapy of malignant tumors. The recent studies, carried out in the Institute for nuclear research (INR) of Russian academy of sciences, have shown that linear proton accelerators have perspectives in the field of medical applications as well. The actual proton energy range of our linac is 70- 220 Mev, the mean intensity of the beam can be varied from zero up to 100 µA, the pulse ratio and frequency can be selected in a wide range. These main parameters of linac are suitable for the proton therapy. Actually, the INR proton accelerator is now the only proton accelerator in Russia with both energy range and pulse duration and frequency optimal for the radiotherapy. Of course, the high intensity of the beam is not needed for the proton therapy. However, the second beam,. the H^- -beam, will allow to simultaneously split the beams for several consumers: the low intensity beam for proton therapy and the high intensity one for isotope production or for neutron physics researches.

The first proton therapy treatment room (see Fig. 1) was designed for the therapy of tumors of different sizes, from few millimeters up to 10 cm, and localized at any depth up to 25 cm. The patient position can be either sitting or lying, according to an individual treatment plan. The medical beam formation is carried out using passive scattering scheme. The combination of two scatterers and of a couple of collimators makes the formed beam profile in the isocenter insensitive to the initial beam profile in the transport channel. Individual boluses, brash filters and collimators provide the prescribed 3D dose distribution in the tumor.

Figure 1: The first proton therapy treatment room (the entrance collimator is the circle at the right wall).

During the last linac run for medicine the proton beams with energies from 120 MeV up to 209 MeV have been studied. The registered basic medical beams have fulfilled the requirements of their homogeneity within medium size targets. In Fig.2 profiles of the basic beam for the energy of 160 MeV at different depths in water are presented. As it follows from this figure, the formed beam is enough homogeneous for the treatment of tumors up to sizes of 9 cm.

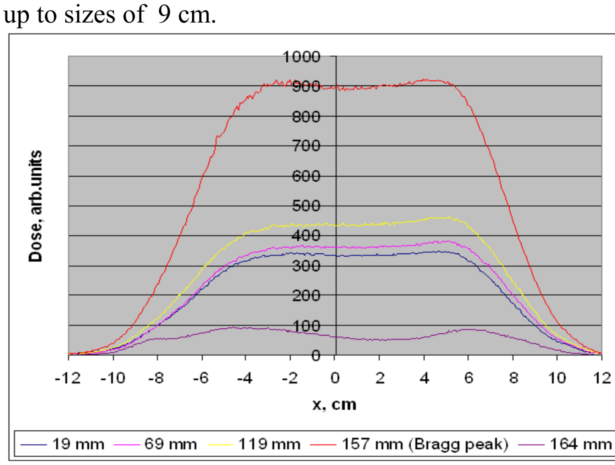

Figure 2: Profiles of the proton beam with E=160 MeV at different depths in water phantom.

The Fig.3 illustrates the penetration of proton beams of several energies into the tissue-equivalent plastic. The images have been obtained using the films Gafchromic MD-55. From this figure it also follows that the maximal dose (or the Bragg peak region, the clear region on photos) is enough narrow for each energy. The spread out of the Bragg peak will be further obtained with the help of individual boluses.

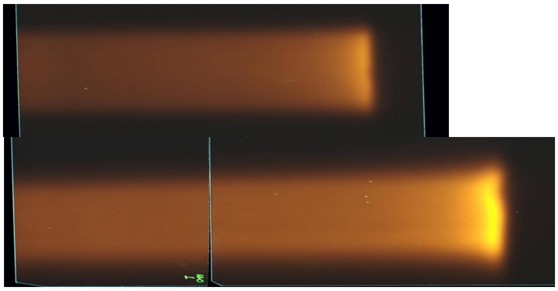

Figure 3: Medical proton beam visualization in the tissue equivalent plastic for E=120 MeV (upper picture) and E=160 MeV. The beam diameter is always about 5 cm.

The shortage of the linac run time for the medical needs has significantly postponed the beginning of patient cure. However, with the simultaneous second beam the proton treatment of patients looks more promising.

At the second stage of the INR radiological center we will have the new treatment room with two beam directions: a horizontal and a non-horizontal one (a simpler and a much chipper analog of gantry). The possible design of the new treatment room is presented on Fig.4.

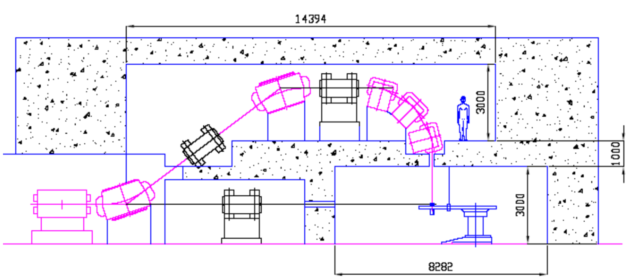

Figure 4: Possible design of the new treatment room with two proton beams of horizontal and vertical directions.

The layout of the medical facilities in the Experimental complex of INR is presented on Fig. 5.

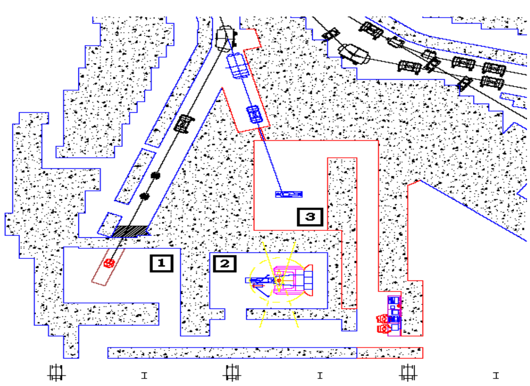

Figure 5: Layout of medical facilities of INR.

1- existing proton therapy tr. room (from Fig. 1),
2- medical electron accelerator SL-75,
3- future proton therapy tr. room (from Fig. 4).

OTHER MEDICAL APPLICATIONS OF LINAC

The energy and intensity of linac proton beams can provide the production of several medical isotopes. In particular, the PET isotope Sr-82 for cardiologic diagnostics is now intensively produced by means of proton irradiation of rubidium targets. The main installation the INR isotope complex is presented on Fig.6.

Figure 6: Isotope production installation (the proton beam magnets are at right hand).

Further medical applications of the INR high intensity proton beam will exploit secondary neutron fluxes in the vicinity of irradiated targets at the Experimental complex.

Recently, scientists from several collaborating Russian research organizations have developed the laser-based technology of production of Yb-168, the starting isotope for the new promising HDR (high dose rate) brachytherapy with ytterbium. This kind of HDR brachytherapy does not require any heavy shielding of the treatment room and of the patient. Normally, the sources with Yb-168 have been activated on nuclear reactors in order to become hot sources with Yb-169. It is possible to use the parasitic neutrons, arising at some installations of the INR experimental complex, for the irradiation of medical sources. Our estimations have shown that the typical source activity of the order of 6 Ci can be achieved after about 10 days of exposure of a source.

On the other hand, the beam intensity of the order of 10^{15} *protons/s*, available at the INR experimental complex, is sufficient for the neutron therapy and even for the gadolinium neutron-capture therapy of radio-resistant tumors. For these purposes we have investigated the radiobiological effectiveness of a radiation after a thermal neutron capture by liquid- crystalline nanoparticles, containing the (DNA-Gd) complex. Measurements with an irradiated cell suspension demonstrated the tumor cell killing possibility in case of 10^3 nanoparticles per cell and for the thermal neutron fluence of $5{\cdot}10^{11}$ n·см$^{-2}$. Such neutron fluence can be achieved after only few minutes of target irradiation at the Neutron complex of INR.