ACCELERATOR FOR PROTON THERAPY

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Abstract

Proton radiation therapy nowadays has aquired considerable experimental experience. There are several medicine centers in the world, and the total amount of the cancer and endocrinological patients exeeds 10.000. With protons, radiation lesions can be confined in a well defined volume with sharp boundaries what can be achieved because protons have defined range in tissues (depending on their energy) and have only small side scattering. So, the possibility arises to work near the vitally significant organs, that is, to treat intraocular, intraskull and some other targets which can not be irradiated by usual methods.

Nowadays, transition begins from proton treatments at the accelerators built (and, mostly, used) for physics to the treatments at specially designed medical accelarators. The first of such accelerators has been constructed in Loma Linda (US). A project of such an accelerator in USSR is considered by ITEP and MRTI (Moscow). The accelerator under discussion , after approval, is to be followed by several similar ones.

Medical accelerators have to meet some specific requirements. They must be cheap, very relyable and exeptionelly simple in control and maintenance.

We describe here some features of the accelerator we are considering.

General features

The energy of the proton beams produced by medical accelerator is to be regulated between ≃70 and 220-250 Mev. As experience has shown, it is not good to start with high energy protons and to disgrade them after ejection to the energy required. Such a procedure leads to rather big background due to scattered protons, newtrons and other particles and to bad proton energy spectra. So, the protons are to be ejected from the accelerator with energy values individually chosen for each patient. 70 Mev energy is proper for superficial tumors whereas 250 Mev is enough to pass through the human body. Such an energy is required for very narrow beams, that is, in the case when beam broadening is more dangerous than tissue morbidity behind the target. It is impossible, certainly, to exclude irradiation of tissues in the front of the target. But one has to notice that ionization rise to the end of the range (Bragg peak) leads for proton irradiation to smaller front tissue damage than that for gamma- or electron treatments.

Accelerator intensity is to be enough to treat 100 patients a day what, as it seems, is needed for a big city. The construction of the accelerator must facilitate beam transportation to several treatment rooms adapted for different patients. Clinical facility is much more effective if it includes several treatment rooms working simultaneously.

Several problems of beam ejection and transportation are simpler if H^--ions are used for acceleration [1]. These ions are ejected from the accelerator after recharging in a target. With H^- acceleration, the magnetic field induction in dipoles is to be significantly deminished as compared to proton synchrotrons, and the accelerator circumference , subsequently, rises, what turns out to be rather an advantage than a drowback for a facility of a round lay out (see Fig.1).

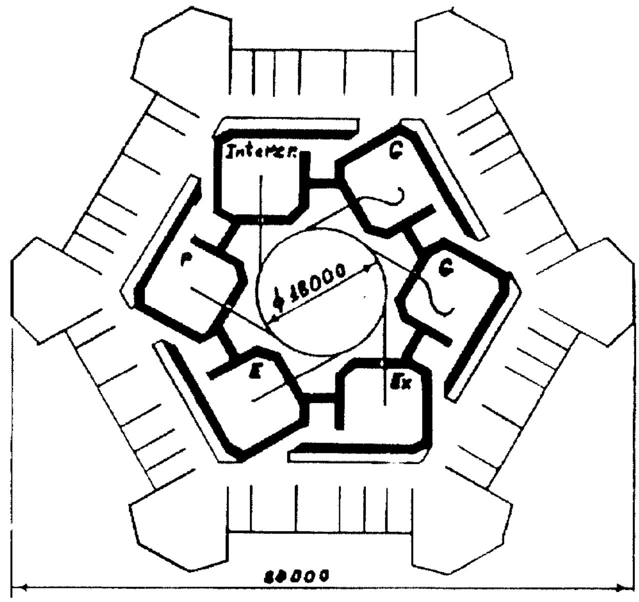

Fig. 1 Proton therapy facility
Inter. cr.- intracraniel unit
P - pelvis unit
E - eye unit
G - gantry unit
E_x - experimental (investigation) room

It is significant also to design the accelerator in such a way, that patient treatment in every procedure room does not depend on what is being done in other rooms. The 5 Hz frequency allows to send the beam in each room every second even if all 5 rooms are working simultaneously. Such a regime is inevitable if the beam is scanned over the target during treatment.

We are going to scan the beam throught the area as well as by range. The scanning is done at field flat tops which are of 30 ms duration. To make complicated dose fields one needs a chopper which kicks the beam out when the intensity is big enough or when the beam with the given energy is not required in the target part scanned.

Accelerator structure

Particles are accelerated in the following way. H^--ions of ≃12Mev energy are injected into the synchrotron, accelerated up to energy needed, guided to one of the inner targets by means of a local orbit distortion (a bump), then recharged and led out of the accelerator by the leading magnetic field.

Edge fields of bending magnets are used for beam focusing (edge focusing). Such a structure has a number of advantages compared to strong focusing: space-charge forces are smaller, the dispersion function (ψ-function) increases, and the whole design is simpler (there are no quadrupoles). The synchrotron has six long straight sections what is enough to place injection-ejection devices, acceleration stations and beam correction systems.

Basic accelerator parameters are given in the Table 1. The transverse orbit functions for structure period are presented in Fig 2.

Table 1. Main synchrotron parameters

Intensity..........................10^{11} p/s
Particle type.......................H^-
Injection energy....................12 Mev
Ejection energy.....................70-250 Mev
Repetition rate.....................5 Hz
Flat top duration...................30 ms
Orbit circumference.................49.9 m
Number of superperiods..............6
Superperiod structure
$B_1 BBBBB_1 O_1 B_1 BBBBB_1 O_1 B_1 BBBBB_1 O_2$
B are sector bending magnets,
B_1 - edge focusing bending magnets,
$O_{1,2}$ - straight sections;
O_2 length...........................3.32 m
O_1 length...........................0.4 m
Horizontal tune, Q_r.................0.705
Vertical tune, Q_z...................1.206
Transition energy...................absent
Vacuum..............................10^{-10} Torr

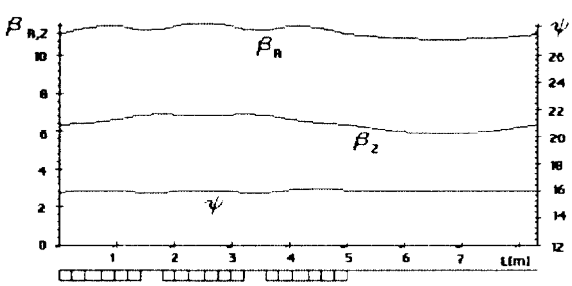

Fig. 2 Main orbit functions

The succeeding magnetic blocks $B_1 BBBBB_1$ are mounted on the same frame (their total number is 18) and are energized by a common main winding.

Acceleration is described in detail in [2].

References

1. Martin R.L. Modular design of H^- synchrotrons for radian therapy. Nuclear Instruments and Methods in Physics Research B40/41 (1989) 1331-1334.

2. A.E. Bolshakov, S.L. Lomize, K.K. Onosovsky Main parameters and correction systems of medical accelerator. Paper presented to II European Conference on Particle Accelerator.