PLANAR SYSTEM REPLACING GANTRY FOR PROTONS AND CARBON IONS BEAMS TRANSPORTATION.

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AbstractT

Two versions of planar magnet optic systems for transportation to the patient of proton or carbon ions beam from various directions are described. The charged particles beam is bent and focused in one of magnetic channels fixed immovably on the vertical wall. Patient is placed perpendicular to this wall. Two additional magnets are used to choose irradiation direction. They can be movable or immovable. According to calculations, these system have some advantages by comparison with usual rotated GANTRY.

1 INTRODUCTION.

As a rule size and price of each GANTRY is comparable to size and price of the main accelerator. Therefore it seems useful to consider various (even compromise) versions. That can make GANTRY smaller and cheaper.

Patient in GANTRY is traditionaly placed along the beam axis. Magnets, quadrupoles and scanning magnets are fixed on the rotated frame with a counterweight. To choose the irradiation direction this frame is rotated in the necessary direction.

In 1993 the new version of the patient irradiation from various directions was proposed [1]. In this version the patient is placed perpendicularly to the beam direction and the beam is bent and focused in the vertical plane only. Thus it was suggested that magnetic system of the beam transportation will use narrow premises with notable economy of volume.

For active scanning of the target surface fast beam movement in bending plane is proposed. After the irradiation in full depth the coach with patient is moved slowly (up to 2 cm/sec)

Different versions of PLANAR GANTRYs were discussed in the papers [2,3]. It was in particular shown that planar system can be realized without patient movement for any irradiation direction (from one hemisphere) using several magnetic channels fixed immovably on the vertical wall and several magnetic elements rotated on the special frame. The subject is discussed in this paper.

2 DESCRIPTION OF THE PLANAR SYSTEM

Magnet optic scheme of the barrel-type GANTRY for proton and carbon ion beams with one-direction scanning that was described in the previous paper [4] is used as a basic version of rotated GANTRY.

Sheme of the planar GANTRY with partially rotated equipment is shown on Fig.1. It is proposed to place seven particle transportation channels with directions of 30 degrees one with respect to another.

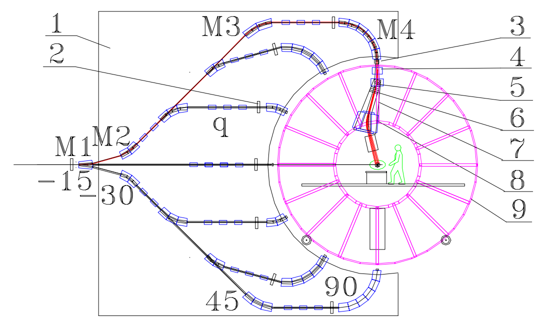

Fig. 1 Magnetic elements position for proton transportation in the planar GANTRY with partially movable equipment.

1. vertical wall (11m*12m) with seven immovable channels.
2. vacuum seal.
3. vacuum connection.
4. sweep magnet (swx).
5. magnet M5 +B(M5)*L(M5).
6. bellows.
7. swivel (±15degrees) platform.
8. magnet M6 -B(M6)*L(M6).
9. rotated frame D=7m, total weight 3t.

Magnetic optics of each channel is similar to the optics described in the paper [4] but M4 magnet does not have increased cross-section and weight because scanning magnet is placed after it. After M4 the beam is then bent in another two magnets in the opposite directions, first in M5 magnet by the angle less than 15 degrees then in M6 magnet placed twice nearer to the target and bending the beam by the angle twice greater than in M5. Magnets M5 and M6 placed in such a way do not have much influence on beam focusing. Scanning magnet is at the distance of 3.5 m from the target and maximal beam angle with respect to irradiation direction does not exceed 2 degrees. Two last magnets and devices placed in front of the patient are fixed on the platform connected with rotated frame. Magnets weight is of about 1 ton, their center of gravity is at the distance of about 2 m from the system axis. The counterweight is placed correspondingly. The frame has a diameter of about 7m and simple, almost planar construction. The total weight of the rotated part does not exceed 3 tons.The magnet optic scheme of the proton beam transportation for the irradiation direction of

76 degrees (90 + 14 - 28) with the initial phase volume of 1mm *3mrad is shown in the Fig. 2.

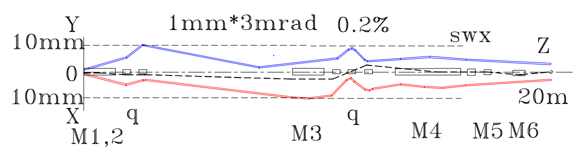

Figure 2 Scheme of the beam envelopes used for transportation of the proton beam with irradiation direction of 76 degrees.

From the Figures 1 and 2 it can be seen that all magnetic elements cross-sections (and their weight) are relatively small.The cross-section of the last magnet M6 gap is 300mm*20mm. It depends on beam bend in it and on beam scanning zone. Planar system size depends largely on the distance from the system axis to the last magnet M6, magnetic field limit and particles momentum. The system shown in the Fig. 1 takes up 11m* 12 m on the vertical wall. The total weight of magnets fixed on the wall does not exceed 10 tons.

Estimations of magnets parametrs were made with the same method as in previous paper [4,5].

For beam transportation inside the vacuum volume up to the beam exit from the last magnet each of the immobile channel is provided with remote control vacuum seal. Vacuum line of the bending channel part is provided with the means of remote conrol vacuum connection to the vacuum line of the immobile channel. To diminish pumping time during the change of irradiation direction it is suggested to use large auxilliary vacuum volume together with the vacuum pump. It is supposed that time of the vacuum system switching from one direction to another does not exceed the time of irradiation from the one direction (approximately 3 minutes). Irradiation time from four directions in one cycle will not therefore exceed 30 minutes.

In the second version of the planar system shown in the Figure 3 it is suggested to use immovable elements only. Instead of movable magnets M5 and M6 for the similar beam bends it is supposed to use semi-circular magnet with two gaps. This magnet is large, heavy (about 80 tons) and powerful. It is supposed to make it as seven 30-degrees sector magnets (See the lower part of Figure 3). In this case M5 and M6 can be designed as two independent magnets, and their weight can be essentially smaller. Size and other parameters of such system will be similar to ones of the planar system with partially movable equipment but it will lack problems with vacuum line connection and equipment rotation.

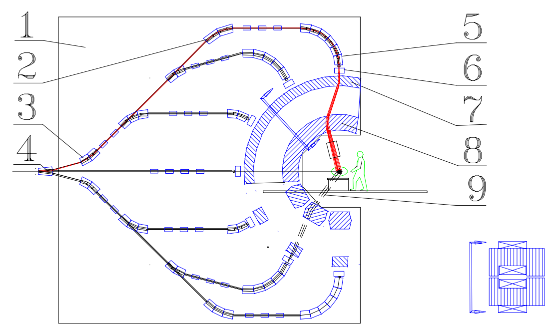

Figure 3. Scheme of the planar GANTRY with immovable magnetic elements for proton beam transportation.

1. vertical wall (11m*12m) with seven immovable channels (total weight about 10t).
2. magnet M3 (45).
3. magnet M2 (-30).
4. magnet M1 (-15).
5. magnet M4 (90).
6. sweep magnet.
7. magnet M5 (<15).
8. magnet m6 (<30).
9. beam transport with scanning from the direction of -50 degrees.

Similar planar systems can be used for carbon ion transportation. In this case for B < 1.8Tl vertical wall size is of about 18m*18m , total immovable equipment weight is of about 30 tons, rotated frame diameter is 11 m, total rotated equipment weight is 8 tons. It is important to note that superconducting magnets can be effectively used in the planar system with immovable elements. If magnetic field will be of about 5 Tl (instead of 1.7 Tl for protons) the size of the planar system for carbon ions will be similar to the size of the planar system for protons (See Figure 3).

To compare the size and volume of the planar systems with ordinary rotated ones [4] it is useful to have in mind that each system must be isolated with respect to radiation by a concrete wall with a width of about 2 m. Besides that for magnets operation and maintainance on the vertical wall with a height of 12 m it must have specific equipment and the room width must be not less than 2 m. Additionally the room for the patient coach and medical equipment must be not less than 3m*3m.

Thus one must expect economy of area twice for proton beams and three times for the carbon ion beams as compared with barrel-type rotated GANTRY but no economy of volume is expected.

3 CONCLUSION

Planar systems of charged particles transportation from the various directions to the immobile patient are technically possible and competitive with respect to ordinary rotated GANTRY type systems.

They can be realized in various versions including systems with totally immovable magnetic elements. In the version with partially movable magnets rotated part weight is seven times smaller than for ordinary GANTRY.

Planar systems take up less area but not less volume by comparison with ordinary GANTRYs.

For irradiation from second hemisphere the treatment coach with patient must be rotated 180 degrees, but usually this procedure is not useful in one irradiation process.

Essential drawback of the planar systems is their unusual design (especially from the medical point of view).

We can nevetheless draw a conclusion that both rotated and planar GANTRYs must be simultaneously taken into account when one designs new centers for charged particles therapy.

4 ACKNOWLEDGMENTS

The author is strongly grateful to V.M. Breev for his useful advices.

5 REFERENCES

[1] M.M.Kats, K.K.Onosovskii, The Planar Version of Flexible System for Proton Beam Transport to the Patient from any Directions., IET, 1993, 6, 164-169

[2] M.M.Kats, K.K.Onosovskii, Two Versions of a Plane Flexible System for Irradiation of a Prone Patient by a Proton Beam from Different Directions, IET, v.37, n 4, P.2, p.489-493.

[3] M.Kats, K.K.Onosovskii, A Planar Magnetooptical System for the Irradiation of a Lying Patient with Proton Beam from Various Directions IET, 39, 1, 127-134, 1996.

[4] Study of GANTRY Optics for Proton and Carbon Beams., PTCOG workshop, Loma linda, USA, 4.1998.

[5] A.Kalimov, H.Wolnik, Wide Aperture Magnets for Isocentric GANTRY for Lifgt Ion Cancer Therapy Facility, Report GSI 98-10, 1998.