COMPACT AND CHEAP SYSTEMS FOR TRANSPORT PROTON AND ION BEAMS BETWEEN OF MEDICAL ACCELERATOR AND FIXATED HORIZONTALLY PATIENT AT MANY DIRECTIONS

M.M.Kats, Institute for theoretical and experimental physics,
25, B.Cheremushkinskaya, Moscow, Russia
Mark.Kats@ITEP.ru

Abstract

New versions of systems for optimal transport proton and ion beams are described: ex centric GANTRY, Planar systems (SPS(F) and NPS) and systems with super conductive magnets. Those systems can be useful at design of any new treatment facilities, especially,for transport of ions beam.

INTRODUCTION

There are a lot of new cancer patients in any countries in each year (in Russia like 200000). Therapy by proton and ion beams is very useful for them. Medical accelerator is the main part of equipment for such therapy. But any known systems of optimal transport beams to a few rooms (with GANTRY) are very large and expensive, or (without GANTRY) unable to optimal irradiation. They spend more then half of entrance into building and costs. Therefore design of small, simple and cheap transport systems is necessary for real introducing proton and ion beams in mass therapy.

MODERN TRANSPORT SYSTEMS

Scheme of main equipment of usual modern center of proton therapy together with its GANTRYs (NPTC, Boston, 2000) is shown on Fig.1. Similar centers were product and were designed in last years in many countries.

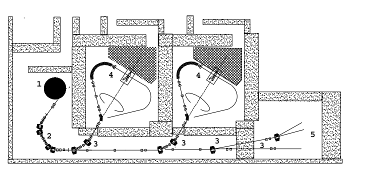

Figure 1. Scheme of NPTC layout.

GANTRY is a system for transport beam to center of the target into horizontally fixated patient from any (optimal) spatial directions. GANTRY includes a system for optimal distribution doses through volume of the target. GANTRY is universal and optimal system according of all medical requirements for each treatment rooms.

It is known that time of irradiation 5 times less then time of precision installation and fixation of patient at treatment coach. Therefore like 5 treatment rooms must be near each accelerator for its effective work. It is known that like 10% of the targets placed into patient head. Such targets can be irradiated successfully by horizontal beam. For optimal irradiation of next 90% of patients GANTRY is very useful in most of treatment rooms. Treatment center with proton beam MPTC was build in 2007 just according of those ideas (see Figure 2).

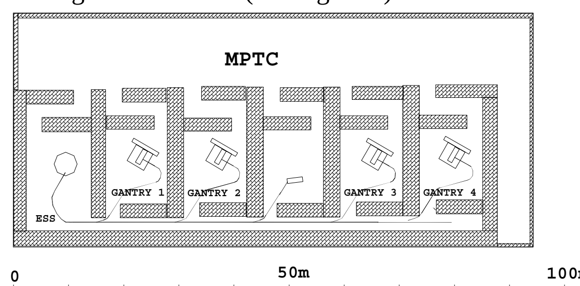

Figure 2. Scheme of MPTC layout.

For 30cm range of protons into body energy protons must be near 230MeV. They can be turned by usual magnetic field 1.6Tl with radius like 1.5m. Radius of ions movement at the same range and into the same field is like 4m. Therefore all equipment (accelerator and transport systems) for ion beams are bigger and much more expensive in comparison with systems for proton beam. But part of cancers can be treated only by ion beam. Therefore centers with ion beam are very useful.

TWO VERSIONS OF GANTRY

3.1. Spreading system is placed after the last bending magnet. For proton beam active (2 directional scanning) or passive (scattering and collimation) spreading system can be placed on total distance like 3m (see Fig.3). Therefore sizes of rotated GANTRY system are like $11m^3$, and they can not be decreased. Radius rotation of heavy magnet and its counter weight is like 4m. For its precision rotation heavy rigid frame is necessary and total rotated weight of proton GANTRY is like 100T. Spreading system for ion beam need more then 5m. Therefore similar design is not used for ion beam.

3.2. After scanning magnets particles pass through gap of the last magnet [2,3] (see Figure 3). Directions of the beam after magnet are near to parallel to channel axis (scanning at large distance). It is the best conditions for scanning. But by such way sizes of the gap are the same, as sizes of maximal target (like

200mm*200mm). Therefore last magnet has very large weight and cost. It used a lot of power. Total sizes, weight of rotated equipment for proton and ion beam are (L=11m, D=8m, 100T) and (L=19m, D=15m, 600T). Properties of similar GANTRY depend mainly on the last magnet. They depend on phase volume of the beam slowly. It is impossible to decrease its sizes, weight and cost. According of medical requirements and opinion similar GANTRY is the best. It was build in HIT, Heildelberg, 2008 (see Figure 4).

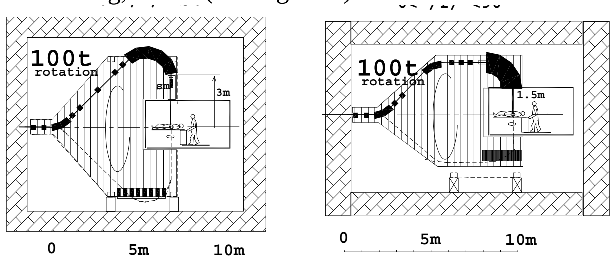

Figure 3. Schemes of two versions of modern GANTRYs for proton beam.

Cost and sizes of similar GANTRY for ions are so high, that only one treatment room in HIT was equipped with GANTRY (see Figure 4).

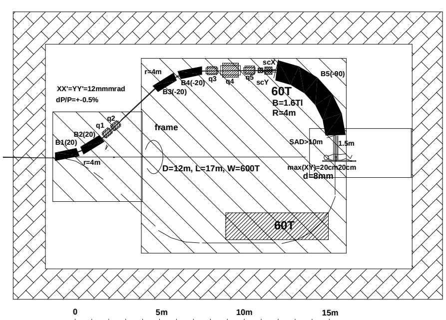

Figure 4. GANTRY for ion beam.

Therefore today a few last projects centers of treatment by ion beam in Germany and in Japan searched versions without GANTRY, with a few rooms with horizontal beams only and with one room with vertically bended beam. It is evident, it is not optimal system, but it is much simple, cheaper, smaller.

Take in account significance of both accelerator, diagnostic system, planning soft, systems of patient fixation and so, it is necessary to search possibility of new systems for transport proton and ion beams, more small, simple, and cheap, without loosing properties of irradiations.

COMPROMISE REQUIREMENTS TO TREATMENT EQUIPMENT

1. In order to use optimal directions of irradiation many spatial directions must be accessible, but ALL spatial directions (like in GANTRY) are NOT necessary. Probably optimal quantity of directions for each fraction is 2 or 3, but they must be optimal.
2. Directions of irradiation in different fractions can be different.
3. For minimal irradiation of healthy parts of the body doses distribution through the target volume must be done by active scanning at significant distance between scanning magnets and the target with take into account movement of the body parts.
4. For most effective using of complex and expensive equipment, for decreasing time, when patient is placed into treatment room, it is useful to fixated patient on plate with precision tomography into additional room. Plate can be fixated on treatment coach with high precision. By such way irradiation of patient into each fraction can be possible in a few rooms without additional measurement.

New solutions are possible by three ways.

EX - CENTRIC GANTRY

With aim of simplification of precision rotation of heavy system around of horizontal axes it was suggested systems with magnets rotation around of horizontal axis which pass through center mass of all magnetic channel. In such design no counter weight, diameter of rotated heavy equipment is near to radius of particles bend into magnetic field. Fixated horizontally patient is moved on beam direction around of the same horizontal axis, around of magnets (see Figures.5, 6).

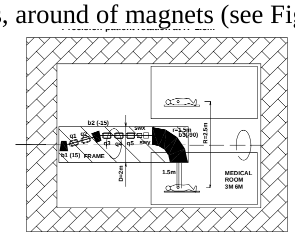

Figure 5. Ex - centric GANTRY for proton beam.

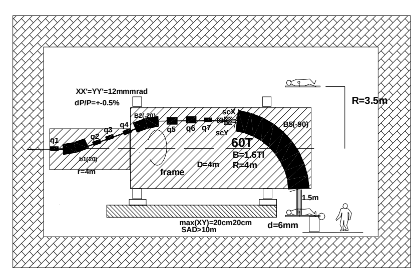

Figure 6. Ex - centric GANTRY for ion beam.

PLANAR SYSTEMS

In any “planar systems” beams are bended by immovable magnets in vertical plane only. Fixated horizontally patient is moved with precision by treatment coach on beam direction [5, 6].

Simple Planar System - SPS(F)

Immovable magnet is placed additionally just before of the patient instead of GANTRY into treatment room with usual horizontal beam. This magnet has large gap (like 200mm) and it can turn beam only in vertical plane at any angles to horizontal plane which less F (-F < f < F). Patient is fixated horizontally by usual devices. At change direction of the beam patient is moved by treatment coach slowly with precision in vertical plane on beam direction (see Fig.7). Angle F is a subject of compromise. As bigger F as close possibilities of SPS(F) to possibilities of GANTRY, but as heavy magnet, and as higher its power, and as bigger displacements of patient [5]. Similar system is able to improve significantly abilities of usual treatment rooms with horizontal beam even at small F.

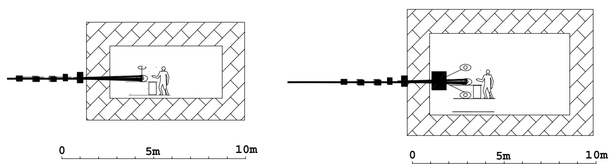

Figure 7. Schemes of treatment rooms with horizontal beam and with SPS(F).

SPS(F) has two physical defects: linear dispersion in vertical plane at the target is not zero, and it is impossible to use for irradiation directions from the top and bottom cones. But it evident, this system in comparison with any GANTRY is very simple, very small, and very cheap. Comparisons of abilities of different system are shown schematically on Figure 8. It can see, that abilities of SPS(60) are similar to abilities of GANTRY, and they are much better in comparison with horizontal beam or equipment with two direction.

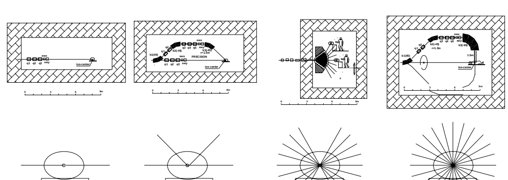

Figure 8. Horizontal Two dir. SPS(60) GANTRY

Properties of SPS can be improved by preliminary bend of the beam in vertical plane (see Figure 9). It is possible to choose optimal spread of directions for irradiation (F+A>f>F-A) and to decrease linear dispersion [4].

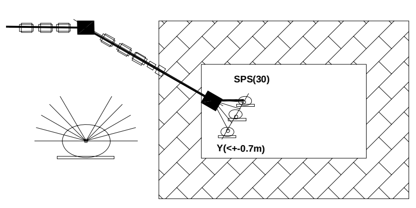

Figure 9. Scheme of SPS(F) with preliminary turn off the beam.

New Planar System (NPS)

New Planar System can work both instead of system of transport beam to a few treatment rooms, and instead of GANTRY into each room. Treatment rooms are placed on a few vertical levels. System of preliminary bend of the beam can transport beam to any one room. SPSs with small F are placed into each room. Each SPS is oriented on initial direction of the beam for this room. Therefore each room has its own spread of directions for irradiation. But any spatial directions can be used for treatment in many fractions at using abilities of all.

Preliminary versions of NPS at hot magnets for proton and ion beams with 5 rooms, which placed on 3 levels, are shown on Figures 10, 11. Both systems are very compact and any spatial directions can be used for irradiation. No rotation or displacement of heavy equipment. Magnets for preliminary bends of the beam have small gaps. At F=30 degrees gaps of magnets for SPS are not so big. Displacements of patients are less ±1.5m.

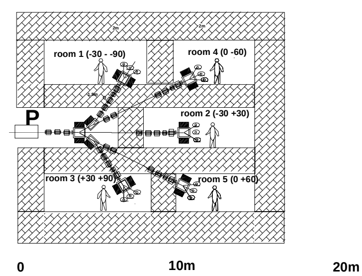

Figure 10. Vertical cross sections of NPS for protons and for ions.

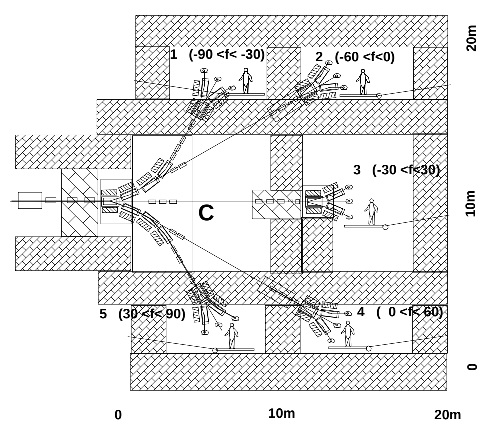

Figure 11. Vertical cross sections of NPS for ions.

SYSTEMS WITH SUPER CONDUCTED MAGNETS

Super conducted magnets can be used in any systems (for transport beam to treatment rooms, for usual GANTRY, for ex centric GANTRY, for planar systems), but really they can be useful for decreasing sizes, weight and power only at transport ions beams (see Figures 12 - 15).

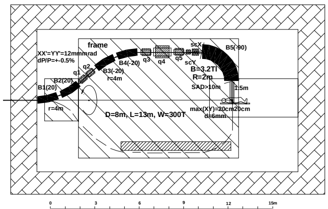

Figure 12. Usual GANTRY with 3Tl magnet

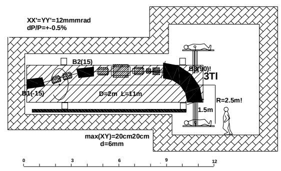

Figure 13. Ex centric GANTRY with 3Tl magnet

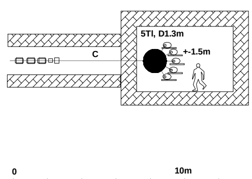

Figure 14. SPS(60) for ion beam with 5Tl magnet.

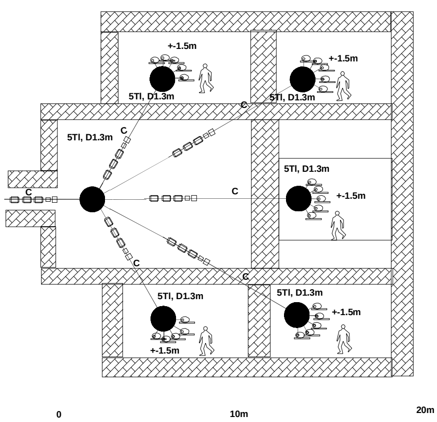

Figure 13. New planar systems with 6 similar 5Tl magnets.

All shown schemes can to use active scanning systems for doses 3 dimensional distribution. They are especially useful at transport of ion beam. All of them can be designed without any significant mechanical or magnets difficulties. All schemes were supported by optical calculations with TRANSPRT. Beams with phase volume up to 15mm*mrad (like after cyclotron with ESS system) can be transport through those systems successfully.

CONCLUSIONS

Today equipment for transport beam between accelerator and patients have so large sizes, weight, cost, that it is significant brake for introduce proton and ion beams in mass treatment. But equipment for transport medical beams can be designed according of new ideas with much less sizes, weights, costs without defects in its properties. It is a way for increasing year productivity of each medical accelerator.

Each existing treatment room with horizontal beam can be improved by installation of additional magnet (SPS).

It is necessary to use new solutions of proton and ion beam transport at design of all future centers for beam therapy independent on accelerator.

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