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DEVELOPMENT OF BEAM LINE FOR MEDICAL APPLICATION AT ITEP-TWAC COMPLEX

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Abstract

Possibilities of beam lines improvement for medical application at ITEP Accelerator Complex were observed. Existing beam lines were constructed for transport of the fast extracted proton beam with energy <230MeV from the synchrotron U10 to three treatment rooms with fixed horizontal direction of the target irradiation. Scattering and collimation were used to distribute irradiation dose to the target volume. New beam lines have been designed to transport of the slow extraction of the proton (E<230MeV) or carbon (E<400MeV/n) beams from synchrotron UK to the same three treatment rooms in the medical building and to building “120”. They will be equipped with scanning magnets. The fixed horizontal directions will be used in two rooms for treatment of the special locations in eye or head. The compact “planar system” supposed to facilitate treatment of any targets from different directions covering irradiation directions of ±45 degrees to horizontal plane. Planar system can be used in two rooms. Main features of proposed beam lines are compared with existing and planned proton and ion beams therapy centers.

INTRODUCTION

All possibilities of beam lines improvement for medical application at ITEP Accelerator Complex (TWAC) were observed [1]. Those possibilities are based on the synchrotron UK (13T*m) reconstruction, on the working conditions of proton linear accelerator I2 (20MeV), on the working conditions of laser ion source, the ions preliminary accelerator I3 (12MeV/z), and the magnetic canal for transport ion beam to UK, on existing building with three treatment rooms with devices for treatment and on significant experience of ITEP's medical team (4260 patients were treated by proton beam in 1969-2011).

Existing beam lines (see Fig.1) were originally designed for transport of the fast extracted proton beam with energy <230MeV (P/z < 0.7GeV/c) from synchrotron U10 (34T*m) to the three patient treatment rooms with fixed horizontal direction of targets irradiation [2]. Scattering and collimation were used to distribute irradiation dose to the target volume according of quick extraction (less 1 μs).

New magnet canal has been designed for transport of the proton beam from I2 to UK. Then UK will be able for the acceleration of both proton and ion beams for medical and scientific purposes.

New magnet canals (with P<3GeV/c) have been designed [3] for transport of the slow (like 1s) extracted proton (E<230MeV) or ion (E<400MeV/n) beams from synchrotron UK to the experimental building "120" in two directions: for the medico-biological experiments and for the tests of new devices (see Fig.2). Part of new magnetic elements have been manufactured. More correct measurements of the beam properties and more precision 3D scanning systems to distribute irradiation dose to the target volume shell enable the slow extraction. Two new holes in concrete walls are necessary for those canals.

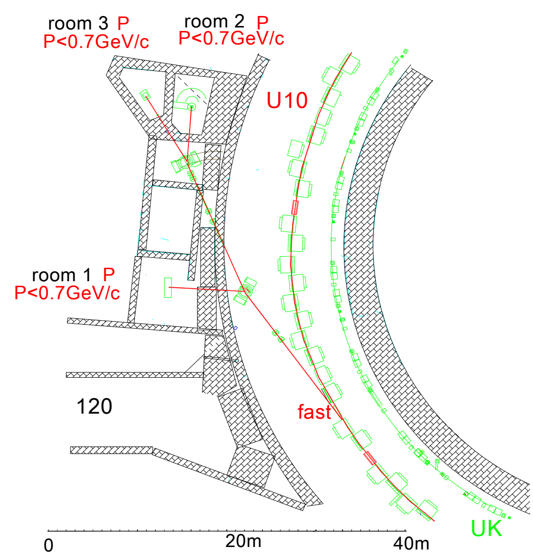

Figure 1: Layout of old magnet canals in ITEP for treatment by proton beam (1969-2011).

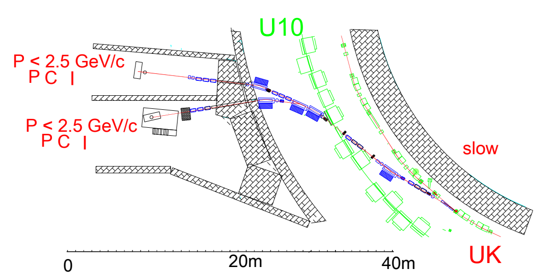

Figure 2: Layout of designed magnet canals in direction of 120 building after slow extraction proton or ion beams from UK.

NEW LAYOUT of MEDICAL BEAMS

New beam lines was developed for transport of the slow (like 1s) extracted proton (E<230MeV) or carbon (E<400MeV/n) beams from synchrotron UK to the same three treatment rooms (see Fig.3). Both of them will be equipped with 3D (or 4D) scanning systems. Both of them supposed to be equipped with new magnets and quadrupoles.

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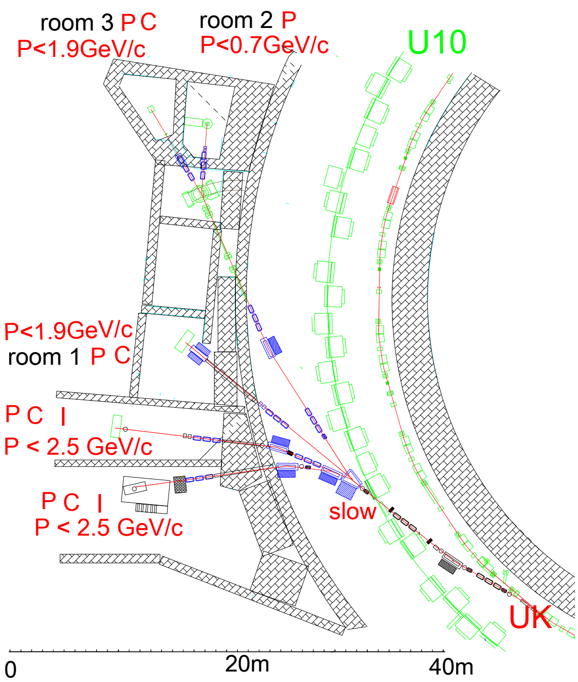

Figure 3: Layout of new magnet canals for transport proton or ion beam after slow extraction from UK to three old treatment rooms and to 120 building.

The fixed horizontal directions will be used in two rooms for treatment of special localizations in eye or head. Only proton beam can be transport in room 2 by reason of large bend of beam in the last magnet. Both proton and ion beams can be transport to room 3.

ROOM 1 WITH PLANAR SYSTEM

It was suggested new hole in concrete wall for transport both ion and proton beams in room 1. For treat any targets from different directions into small room 1 it was suggested to use compact "planar system" [4,5] instead of usual Gantry. Any proton Gantry has sizes like 11m^3 [6], it is much large then sizes of room 1. Suggested planar system is covering irradiation directions of ±45 degrees to horizontal plane and has sizes like 6m^3. Spatial scheme of planar system is shown on Fig.4.

The input beam at horizontal direction is focused by quadrupoles, and scanning is available in two directions by scanning magnets. Immovable magnet with increased gap placed just in front of the treatment table to bend the beam in the vertical plane.

Patient is fixed horizontally. To change irradiation direction it is necessary to turn off the beam, to change position of treatment table in vertical direction, to change direction of the beam in vertical plane by the magnet. The medical staff has to have a quick excess to the patient at any position of the treatment table.

The magnet with field B<1.6T and with a gap of 0.15m at diameter like 1.2m is necessary to bend of proton beam up to 45 degrees. The maximum field in the magnet shell reaches up to 4T for the ion planar system with the same requirements for the angle coverage.

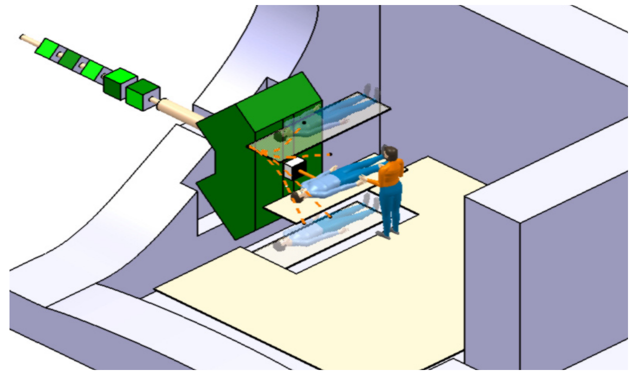

Figure 4: Spatial scheme of planar system.

The suggested magnets can facilitate necessary targeting because of the mobility of the whole system vs. heavy magnets are immovable: in Gantry more than 100T must be rotate with high precision in volume like 11m^3.

Beam's optic of planar system is simple vs. Gantry optic with 2-3 magnets and 5-9 quadrupoles, which is quite complicated.

Electricity power is minimal because of the limited bend of the beam is necessary (less than 45 degrees), and just in one plane. In Gantry total bend of the beam is up to 180 degrees at any direction of irradiation.

Therefore the overall investment per treatment room with planar system can be 3 times less of the usual Gantry room.

There are limits in irradiation directions. But at directions interval of $-45 \le f \le +45$ degrees to horizontal plane there is possibility to choose optimum directions in any fraction as in usual GANTRY.

There is linear dispersion. But after extraction from synchrotron at useful energy and at dP/P<±0.2% influence of linear dispersion is negligible.

An unwanted displacement of the table has to be taken into account. But such a displacement with patient less then 200kg in vertical plane in the interval of ±1m can be minimized to a reasonable ±0.2mm without difficulties.

It is necessary to use two radiograph equipments (in vertical direction and in beam direction) for the precise installation of the patient on treatment table. Similar equipment used in usual Gantry.

Beam monitors and other devises in treatment room with planar system are the same, as in room with usual Gantry.

Usual system to plan irradiation by Gantry can be used for Planar System with limits of directions.

Planar systems can work with scanning systems, with any accelerators in many versions. Planar systems are especially useful for the ion beam transport.

Additional treatment room with planar system can be placed in 120 building on place for the medical research.

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OPTIC CALCULATIONS

Magnetic optic of all suggested canals was calculated by TRANSPORT [7] in second order. At calculations properties of extracted beam were X*X' =2mm*3mr, Y*Y' =2mm*5mr, dP/P=±0.1%. Schemes of beam envelopes for all new canals are shown at figs 5-7. (Magnets – blue, quadrupoles green, envelopes -red and crimson, linear dispersion – lite blue).

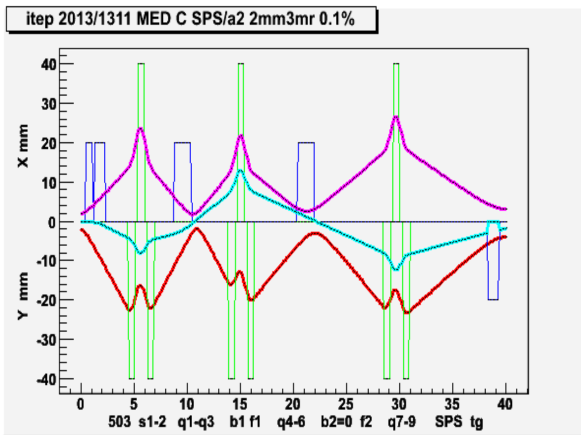

Figure 5: Schemes of beam envelopes of beam at transport to room 1 with planar system.

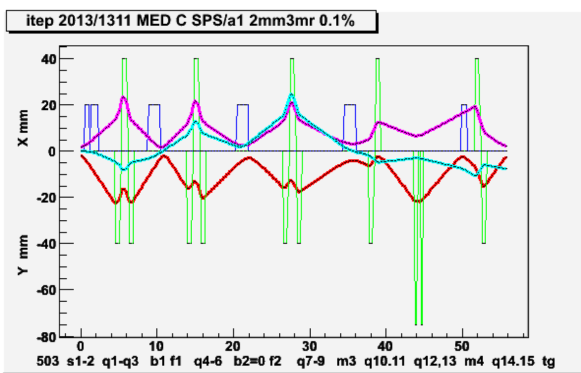

Figure 6: Schemes of beam envelopes of beam at transport to room 2 for eye treatment.

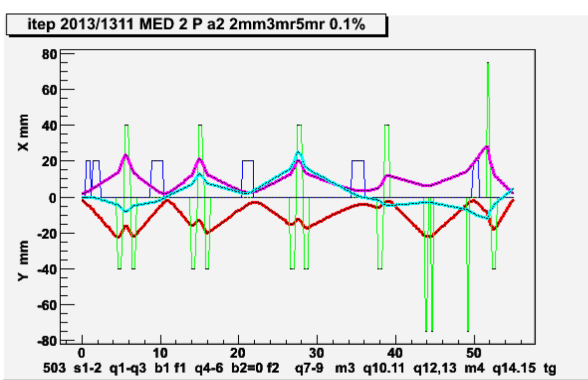

Figure 7: Schemes of beam envelopes at it transport to room 3 for treatment targets into head.

CONCLUSION

According of possibilities of using both proton and ion beams suggested complex of canals (4 rooms, both proton and ions in 3 rooms, 2 rooms with planar systems) would be in 2018 one of the best in the world [8].

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