PROTON CHANNEL THAT PROVIDES SIMULTANEOUS INDEPENDENT OPERATION OF A TREATMENT ROOM OF PROTON THERAPY AND NEUTRON SOURCES OF THE EXPERIMENTAL COMPLEX INR RAS

M.I. Grachev, E.V. Ponomareva, S.V. Akulinichev, L.V. Kravchuk, INR RAS, Moscow, Russia
V.N. Zapolsky, IHEP, Protvino, Russia

Abstract

During 2012 we have developed the system for beams separation, based on the splitter magnet, for simultaneous work of neutron source RADEX and a treatment room of the complex of proton therapy (CPT).

This set up also allows for an independent change of protons energy in the channel of proton therapy in a wide range from 209 MeV to 70 MeV.

The system is an extension of the main channel of the proton and H^- beams, previously described in [1]. Main channel carries out the simultaneous transportation and elevation of the beams H^- and protons in the experimental hall of INR RAS.

BEAMS SEPARATION AND UPGRADE OF THE CHANNEL TO RADEX

Figure 1 depicts the layout of the beams separation the beams line. After magnet 4MC the main beams line (protons and H^-) from Linac distributes to three beam lines as shown in Fig.1. Magnet 2MC2 [1] has been replaced by a pair of magnets 4MC and 4M.

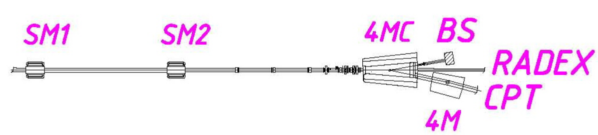

Figure 1: Layout of the beams separation: SM1, SM2 – steering magnets, 4MC – Lambertson magnet, 4M – bending magnet, BS – beam stopper, RADEX – neutron source, CPT – complex proton therapy.

A pair of magnets of this scheme provides a correction in the position of the deflected beam at its axial passage through the hole without the field of magnet 4MC.

The poles of magnet 4MC were developed by NIIEFA as part of the design Lambertson Septum Magnet for the proton storage ring. Coil of the magnet 4MC have been manufactured from the radiation-resistant water-cooled cable of PYROTENAX type.

The block of water-cooled poles is placed in the thin walled vacuum stainless steel chamber. There are the apertures in the upper and lower poles.

Wall thickness between the aperture and the gap is about 1 mm. Fig.2 and Fig.3 represent the photos of magnet 4MC (downstream and upstream respectively).

Detailed description of this magnet will be presented in the next paper.

Figure 2: 4MC magnet assembly view downstream.

Figure 3: 4MC magnet assembly view looking upstream.

Wall thickness between the hole and the pole is about 1 mm. Detailed description of the magnet will be presented in the next paper.

In front of the magnet 4MC a thin foil is installed, with aperture of different diameters, to control the intensity of the beam H^-. The thickness of the foil is sufficient for a recharge H^- in protons. Protons from distribution tails are deflected after recharging in the BS - beam stopper.

Due to the fringe fields, especially at the exit of the magnet, the direct beam experiences a deflection on some mrad. The set of doublet lenses L31-L32 is installed in order to fix the position of the beam on the target of the neutron source RADEX. These lenses focus the centre of magnet 4MC on the target centre (Fig.4).

ISBN 978-3-95450-125-0

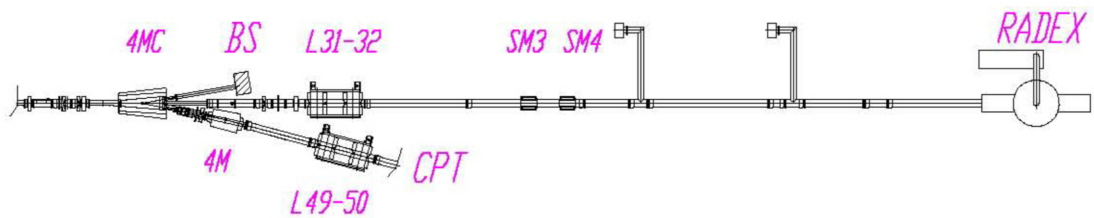

Figure 4: Part of the channel to RADEX : 4MC – Lambertson magnet, SM3,SM4 – steering magnets, doublet L31-L32, BS – beam stopper for recharged protons from H^- , RADEX – neutron source.

Calculations showed that the coefficient of magnification in x and y at the target is 3 and 7 respectively, depending on the type of focus, eliminating the beam focus to critically small size.

Beams H^- and protons are displaced vertically relative to each other by 4 cm by steering magnets SM1 and SM2 (see on Fig.1), that have opposite polarity. Further inside the magnet 4MC, one beam passes through the aperture in the pole (bottom pole on Fig.3); the other is deflected by an angle of 11.5^0.

The water-cooled magnetic screen is placed at the entrance of the magnet to reduce local fringe magnetic field, and to protect the iron plate septum from high intensive beam. Table 1 shows the results of the measurements of magnetic fields in the septum magnet.

Table 1: Septum Magnet 4MC (209 MeV).

Magnetic field in the gap	0.4 T
Integral fringing field at the beam entrance of magnet with magnetic screen	0.002 T x m
Integral fringing field at exit of magnet	0.01 T x m

CHANNEL TO COMPLEX OF PROTON THERAPY

The deflected beam is directed into the channels on the installation CPT or other neutron sources. Here we present the work of the channel for the CPT, whose optical scheme is changed for independent adjustment of the energy of the protons in the beam.

Channel functionally consists of two parts:

- Head channel, focusing the beam on a wedge-shaped absorber.
- Main medical channel, shaping of the beam for the treatment room of CPT.

One of the features of the main part optical scheme is the availability of considerable coefficient of the magnification at the end of the channel. This allows us to increase the number of protons after the wedge-shaped absorber by reducing the angular divergence of the particles in the channel and thus reduce the losses.

Compared to the previous scheme of the channel [4] the following changes have been implemented:

- Beam H^- is the basic beam of the channel.
- Control of the intensity of particles in the beam is done by recharging the beam in front of the magnet 4MC to protons, which are deflected in the opposite direction and are absorbed in a beam stopper outside the channel (Fig.1, Fig.2).
- Lenses L49-L50 and L51-L54 are included.
- Wedge-shaped beryllium degrader and tantalum collimator with diameter 4mm, have been installed;
- The tantalum aperture collimator has been installed.
- The momentum collimator has been installed.
- The second aperture collimator for halo beam absorption has been installed.

Fig.5 shows the optical scheme of the main channel onto the installation CPT and the beam envelope.

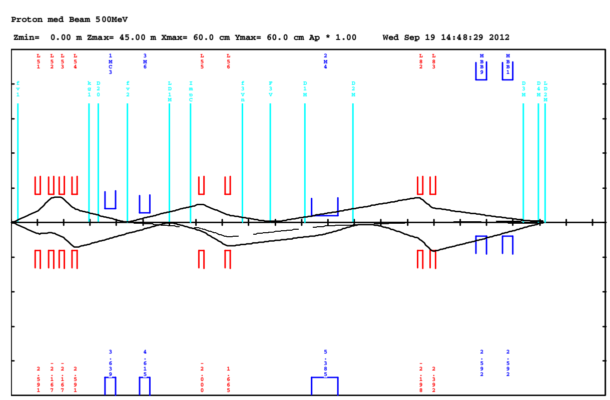

Figure 5: Optical scheme of the channel for CPT calculated by Transport [3].

Results of calculations show that a modernised channel scheme makes it possible to obtain the necessary intensity of the beam under working energies of the accelerator of 209, 160 and 127 MeV [2]. Using the movement of the degrader allows changing the beam energy continuously with acceptable losses. However any significant insertion of the degrader and a simultaneous decrease in the proton energy from 209 MeV to 70 MeV leads to the fact that beam intensity of the protons, reaching the end of the medical channel, is greatly reduced. Calculation results are given in Tables 2 and 3 (calculations are done using TURTLE program [5]). Part of number of particles at the end of the

ISBN 978-3-95450-125-0

channel (Table 2) and the main parameters of the beam in Table 3 are shown for three value of energy.

Table 2: Calculation results for the beam's intensity in the channel onto CPT, using beryllium degrader and tantalum aperture collimator with diameter 40 mm

The change in energy of the protons in the channel, MeV	**Part of number of particles that reached the end of the channel, %**
209 → 160	2.74
160 → 120	2.45
120 → 70	0.64

Table 3: Parameters of the beam (RMS half width) in the channel onto CPT, using beryllium degrader and tantalum aperture collimator with diameter 40 mm

The energy of the protons in the beam after the degrader, MeV	**X, mm**	**X′, mrad**	**Y, mm**	**Y′, mrad**	**ΔE, MeV**
160	4.83	2.70	0.72	1.62	0.717
120	4.89	2.80	0.82	1.60	0.650
70	5.03	3.22	1.20	1.61	0.569

Currently the assembly and installation of the equipment is carried out in the experimental hall at INR RAS. Testing of the new channel is expected to take place in the early 2013.

ACKNOWLEDGMENT

Authors are grateful to the fund RFFI for the support of the project.

REFERENCES

[1] M.I. Grachev, E.V. Ponomareva, "Optical Design of the Proton Beam Lines for the Neutron Complex INR RAS and Medical Application," IPAC'11, San-Sebastian, September 2011, WEPCO21, p. 2049-2051, (2011); http://www.JACoW.org

[2] S.V. Akulinichev, V.N.Vasiliev, Yu.K. Gavrilov, M.I.Grachev, E.V. Ponomareva, V.N.Zapolsky, "Tuning of the INR Therapeutic Proton Beam," RuPAC-2010, Protvino, Russia, p.396-398, (2010).

[3] U. Rohrer, Graphic Transport, downloadable code with some online documentation via the web, http://people.web.psi.ch/rohrer_u/trans.htm.

[4] M.I. Grachev, E.V. Ponomareva, L.V. Kravchuk, V.K. Gorbunov, V.M. Skorkin, INR, Moscow, Zapolsky V.N.# IHEP, Protvino, "System of preliminary formation of the beam for the channel of proton therapy", proceedings of XXI RuPAC 2008, Zvenigorod, Russia, p.352-354, (2008).

[5] U. Rohrer, Graphic TURTLE, downloadable code with some online documentation via the web, http://aea.web.psi.ch/Urs_Rohrer/MyWeb/turtle.htm

ISBN 978-3-95450-125-0