Summer Student Program
at Joint Institute for Nuclear Research

Veksler and Baldin Laboratory of High Energy Physics

Superconducting gantry systems in modern hadron therapy

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Summer Student Program at Joint Institute for Nuclear Research took place in Veksler and Baldin Laboratory of High Energy Physics (VBLHEP). The aim of this practice was to compare three types of gantries: conventional gantry, superconducting gantry for proton therapy and superconducting gantry for ion therapy. Besides this, a thermal power and heat transfer between magnetic structures (magnetic shields and windings) for 6 T supergantry was calculated and compared with calculations for 3 T superconducting gantry. All calculations were done first of all to see a difference between gantry setups and secondly to show advantages and disadvantages of gantry systems.

Introduction

Nowadays, cancer is the second highest cause of death in developed countries (heart diseases are on the first place) and it is a real challenge for doctors to treat it well.

In modern oncology, radiotherapy methods are widely used. The most common equipment for that are gamma-sets and in some cases - electron accelerators and gamma-ray therapy devices. However, its use in cancer treatment has significant limitations: a high amount of the dose is concentrated on the skin and adjacent healthy tissue, whereas the tumor in most cases is localized deeper. To reduce the effect of radiation on healthy tissue, radiation from different directions and fields with complex configuration should be used. Unfortunately, it is always possible to damage the surrounding tissue while getting the required therapeutic dose for tumor.

Proton and ion therapies

Along with the use of proton beams, a heavy ion (helium, carbon, oxygen, argon, neon) beam method is developed and applied too. It is called Hadron Therapy.

There are several disadvantages of conventional radiotherapy:

1. It cannot be used when the tumor is located close to critical organs that may be affected by irradiation;
2. In a case of radio resistive tumors it requires much larger doses which can cause complications;
3. It is impossible to take a radical dose to deep-seated tumors through post radiation complications in surrounding tissues.

In such cases, it is recommended to use a hadron therapy (proton or even a heavier ion). Proton and ion therapies, also like in other types of radiotherapy, are based on accelerating effect of ionizing particles on irradiated tumor. These particles damage the DNA cells ultimately causing their death.

Due to their relatively larger masses, protons and ions undergo small lateral scattering in a tissue and a spread of their path length is very small; a beam can be focused on the tumor without causing an unacceptable damage to surrounding healthy tissue. Moreover, almost all the radiation dose is released into tissue in the last path part of the particles. This maximum dose is called Bragg peak. It plots the energy loss while ionizing beam travels through matter.

Protons produce considerably less side effects of radiation than conventional radiation therapy because of reduced dose to healthy tissue. The most advanced technology is carbon-12 beams radiation. In comparison with protons, carbon ions have a big advantage: the biological effectiveness of radiation is 1,5 - 3 times higher. Although there is a drawback: the Bragg peak dose is reduced to zero, since nuclear reactions between ions and carbon atoms in the tissue lead to the formation of lighter ions. [6]

Gantry – what is it?

A device which transports an ionizing beam is called Gantry. It is the last part of transport channel. Widely used for installation of horizontal and vertical radiation exposure at a predetermined angle. The rotating gantries have been started to be used recently. They can deliver proton-ion beams almost everywhere in the body of the patient. Gantry is a rigid 3-dimensional frame, with a fixed transporting magnetic channel on it. The frame can be rotated around a horizontal axis passing through the center of the target and aligned with the direction of the beam held to treatment rooms. [5, 6]

Conventional gantry

Despite the obvious advantages, proton-ion beams gantry do not have widespread application yet because of very serious problems. First and foremost is the need for large financial costs of installation and at the stage of its operation, along with technological complexity, weight and setting of dimensional parameters. Such a construction can weigh around 600 t with a length of 25 m and diameter of 14 m (as an example Heidelberg Ion-Beam Therapy Center's Heavy Ion Treatment facility, figure 1). Therefore it is necessary to do a research and analysis of the data to reduce these parameters. [6]

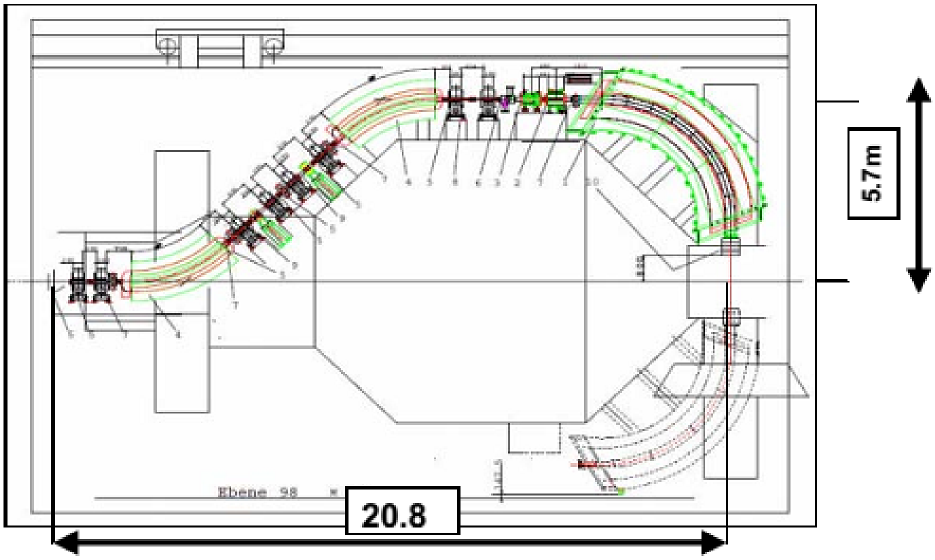

Figure 1 ***Heidelberg carbon ion facility gantry beam line and mechanical structure [1]***

Superconducting gantry for proton therapy

Promising way to develop new designs of gantry settings is to use superconducting magnets. Usually superconductivity is used in those cases where it is necessary to create a more compact thermal installation. Another advantage of superconducting magnets is the ability to create homogeneous fields with a high magnetic field. This can be achieved by creating special windings with optimized form using superconducting wires or cables of small cross section. In the long-term, using superconducting magnets would lead to economic benefits by lowering costs for electricity, cooling water and other exploitation costs specific to conventional magnetic systems. Therefore, a mechanism of rotating gantry is simplified, size and cost of power and water supply as well as the cost of their operation are reduced.

Table 1 Basic requirements of rotating gantry [6]

Parameter	Value
Type of particles	p, ^{12}C
Maximum energy of protons	250 MeV
Minimum energy of protons	60 MeV
Maximum energy of carbon ions	430 MeV
Minimum energy of carbon ions	250 MeV
Diameter of ion beam	3÷10 mm
Maximum magnetic field	4 T
Magnetic field heterogeneity	10^{-3}
Maximum scanning size	20x20 cm^2
Patient's position	horizontal, stationary
Angle of rotation	360°

In cooperation with the Institute of Physics of the Slovak Academy of Sciences a rotating gantry project was made. The basis of the magnetic system is shown in figure 2. It consists of three 90° bending magnets (with additional quadrupole and sextupole windings) BM1-3 and three scanning magnets SM1-3.

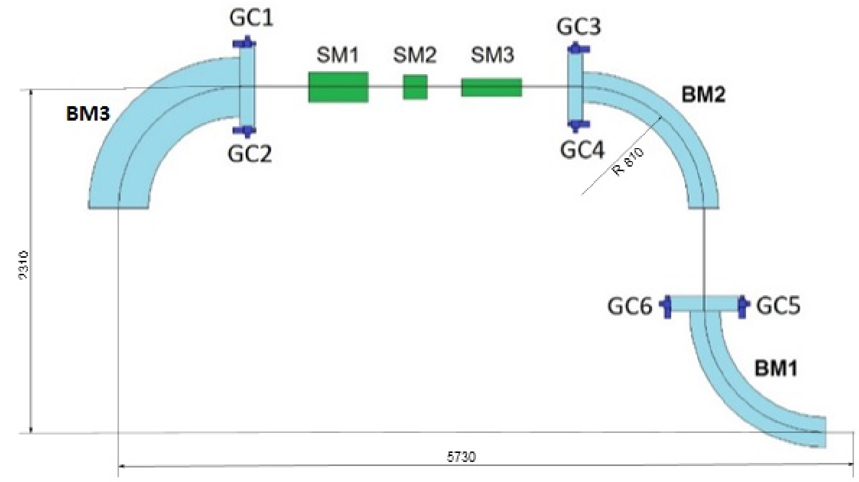

Figure 2 ***Magnetic structure of superconducting gantry (3 T),***
BM – bending magnets, SM – scanning magnets, GC – Gifford's cryocoolers [3]

In JINR VBLHEP a research about beam dynamics and magnetic structure is being conducted using special modelling software. Beam dynamics become a big problem because it has to be controlled precisely at a large weight of a gantry setup. Moreover, derived beam has to be in good quality, without any pulse - hit at one point and obtain homogeneity in time (the space-time beam homogeneity).

The magnetic optical system of gantry consists of six quadrupole magnet windings. It should help to transport beam with minimum values of the beta functions and obtain the required beam parameters in isocentre. Beam dynamics is linear because the sextupole windings of bending magnets allow to disturb the sextupolar nonlinearity in the distribution of magnetic fields. [6]

Construction of the rotating mechanism

An original version of the gantry frame has been designed and proposed, the total mass of which (with magnets) does not exceed 5 tons, which allows us to quickly change the angle of radiation and reduce the time of the session. A pair of four concentric rings rigidly connected radially and longitudinally in the cylinder create large and small diameters. This solution has obvious advantages as it allows to reduce the overall weight of the structure. A fixed cabin is inside a small cylinder. The patient is on a movable table in a horizontal position. A magnetic system mounted on the rotating mechanism beam can be lead to the fixed cabin. It is possible to rotate the beam at 360°. A counterweight is in diametrical plane of design. The estimated resulting mass of superconducting gantry (3 T) is 100 - 120 tons.

Superconducting gantry for ion therapy

In VBLHEP a conceptual design of superconducting gantry for cancer treatment by a beam of multiple charged carbon ions (C^{12}) with energy of 460 MeV is developed. Gantry contains three superconducting dipole magnets, a superconducting focusing magnet and a conventional scanning magnet (figure 3).

All superconducting magnets are dry (without dipping into helium) and cooled by cryocoolers with a power to 1 W at the temperature 4,2 K. It is assumed that this option of superconducting gantry would be the best solution of installations of irradiation with protons and ions. [2]

Table 2 Main parameters of the dipole magnets and initial data [2]

Parameter	Value
Energy of ion beam, MeV/nucleon	460
Type of ions	Carbon $^{12}C^{+6}$
Ion beam diameter, mm	3-10
Magnetic field, T	6
Inner diameter of the winding, mm	80
Outer diameter of the winding, mm	156
Bending radius of magnet, m	1
Beam rotation angle, deg	90
Magnetic field heterogeneity in a diameter of 40 mm	less than 10^{-4}
Diameter of ion-guide aperture, m	50
Position of the patient	horizontal, stationary
Gantry rotation angle, deg	360

Comparing magnets cooled by liquid helium, the above advantages are expressed more weakly. However, if conventional ion accelerator is used then an expensive refrigerator will be needed (and it will be used only for the gantry). In addition, these refrigerators are more difficult to operate than cryocoolers.

Superconducting magnetic system of a gantry

The magnetic system of the gantry contains (figure 3):

- 3 identical dipolar magnets (1, 2, and 3 along the beam), each of which rotates the beam is 90°;
- focusing solenoid or quadrupole (located between the dipoles 1 and 2);
- conventional scanning magnet;
- helium circulation between stationary compressors and heads of cryocoolers through hermetic connections along rotation axis. Pipeline connections and sliding contacts of power supply and cryocoolers;
- Water and power supply for the scanner.

The magnetic system is fixed on a rotating frame made in the form of 2 rolling wheels on ball bearings of support. [2]

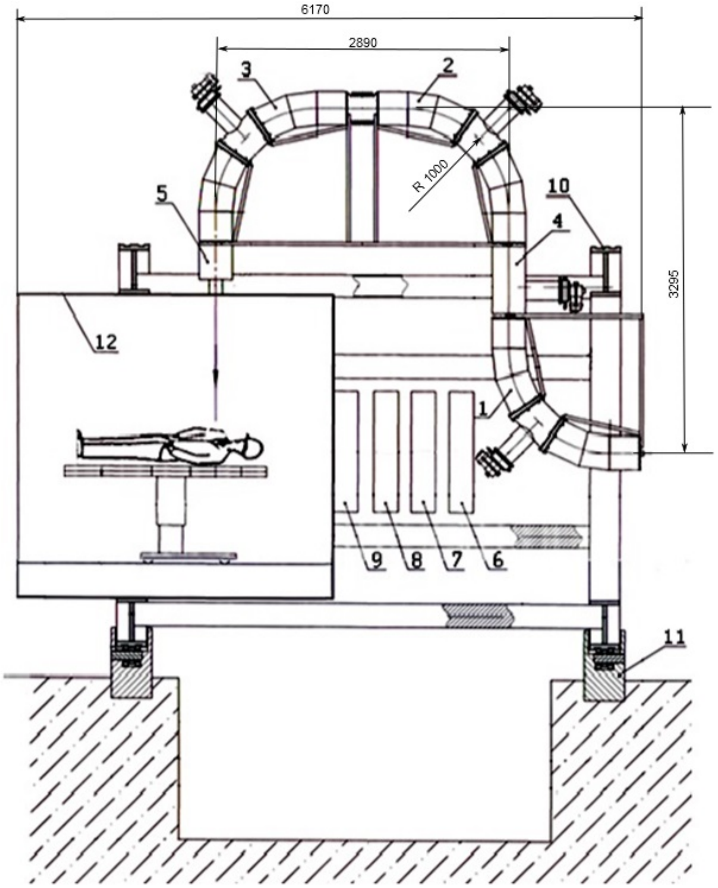

Figure 3 ***Side view of superconducting gantry (6 T)*** *(1-3 dipolar magnets,4 - focusing magnet, 5 – conventional scanning magnet, 6 – sealing of helium tubes, 7 – sealing of vacuum tube, 8 – electric sliding connection, 9 - cryocoolers' wires, 10 – rotating frame, 11 – support of frame wheels, 12 – screen of a treatment room) [2]*

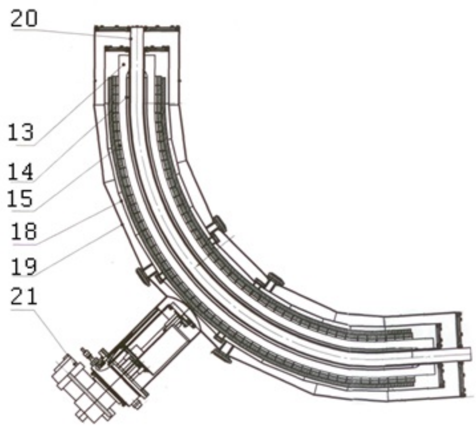

Figure 4 ***Cross section of a bending magnet*** *(13 – winding of dipolar magnet, 14 – resistive tube of magnetic system, 15 - bandages, 16 – copper pads, 18 – conventional shield, 19 – vacuum enclosure, 20 – ion-guide, 21 – cryocooler's head) [2]*

Dipolar magnet construction

Winding of a dipolar magnet with approximately cosine distribution of current density is done by a wire with a diameter of 0,65 mm. Flat winding layers are shifted with fiberglass material impregnated with epoxy compound. Windings are glued through the insulating gaskets to the support tube of stainless steel and reaped with bandages. Electrical insulation pad is installed between the bandage and winding. Two copper onlays are screwed to the tube and fixed to the coil. Onlays are connected with 2nd stage of cryocooler by heat conductors made of copper foils. Bandage consists of sections held together by stainless steel plates. These plates give additional rigidity for a winding.

Heat from the bands is led using strips made of copper and pure aluminium bolted to them, attached to the 2nd cryocooler's stage. Thus, heat conductors provide a stable winding temperature (about 4,5 K). The conventional shield is made of polished copper sheets and connected with 1st cryocooler's stage. Multilayer insulation is placed on top of the shield.

Vacuum enclosure consists of a central and boundary parts, caps and ion-guide's tube. It is made of aluminium alloy. Set of winding and bandage is placed in the central part of the enclosure by fiberglass rods. The head of cryocooler with combined current leads is attached to the central part of enclosure. Pre-evacuation is carried out by turbomolecular and fore-vacuum pump which is installed outside the rotating frame. [2]

Calculations

One of the major problems for superconducting magnetic systems in a gantry setup is the cooling process for superconducting electromagnets. Cooling this system by liquid helium is very complicated. Therefore, cryocoolers are used (figure 5). Their drawback is a small thermal power value at a temperature of 4.2 K. That is why while performing the calculations of gantry setup, a lot of attention should be paid on the thermal balance of all magnetic system.

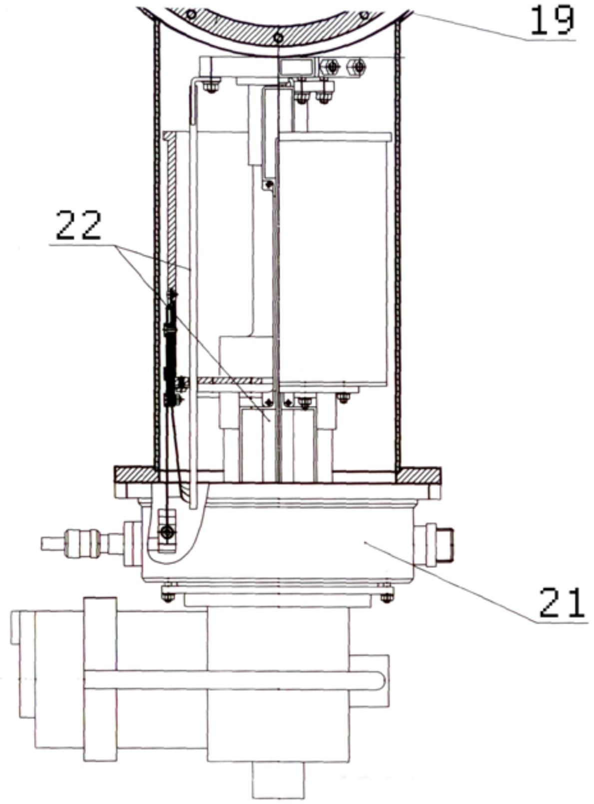

Figure 5 Cryocooler's cross-section (21 – cryocooler's head, 22 – combined current lead) [2]

An analysis of thermal losses in the gantry systems was done. Two superconducting systems were taken to compare - gantry for proton beam and gantry for ion beam.

Uncooled combined current leads (which consist of a copper conductor and high-temperature superconductor (HTS)) are used in superconducting magnetic systems with cryocoolers. Heat in the conductor is led by the first stage of cryocooler which cools the shield; in HTS – by the second stage, which cools the electromagnet.

Cryocooler's parameters from internal elaboration:

Nominal power P = 6.5 kW → power supply for 6 cryocoolers **P = 39 kW**
Heat transfer on a 1st stage (40 K) **Q_{c1} = 30 W**
Heat transfer on a 2nd stage (4.2 K) **Q_{c2} = 1,5 W**
Heat transfer by one current lead (enclosure-shield; 300 K – 40 K) **Q = 9 W** (for I_{max})
Heat transfer by one current lead (shield-electromagnet; 40 K – 4.2 K) **Q = 0,05 W** (for I_{max})
6 electromagnets = 12 current leads →
Q_{cl} (300 ÷ 40) = 9 W · 12 = **108 W**
Q_{cl} (40 ÷ 4,2) = 0,05 W · 12 = **0,6 W**

Heat transfer by radiation

To reduce heat transfer by radiation a surface has to be polished and made from materials with low thermal radiation. Shields are used to reduce heat transfer much more.

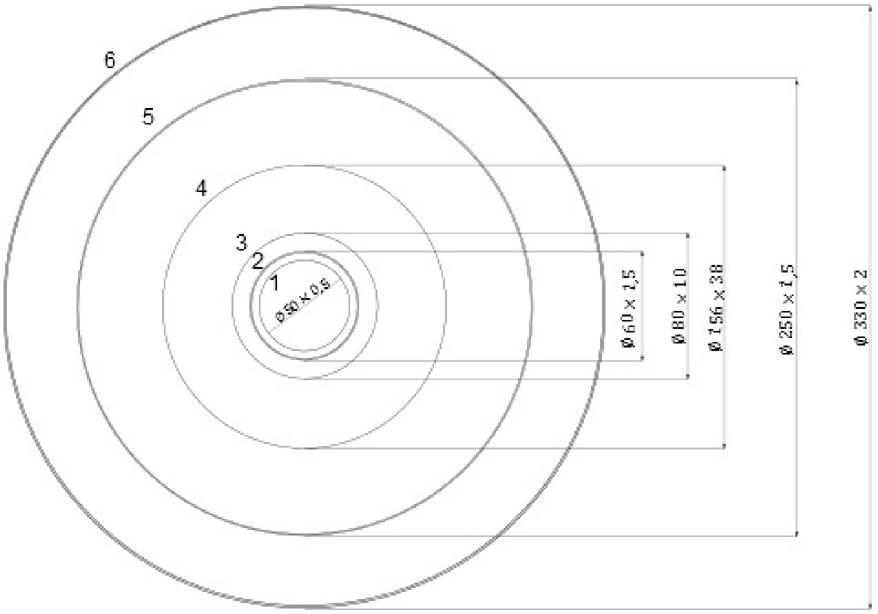

Figure 6 Structure of a gantry setup (cross section)

1.	Ion-guide	50×0,5 [mm]
2.	Resistive tube	60×1,5 [mm]
3.	Vacuum	80×10 [mm]
4.	Winding	156×38 [mm]
5.	Magnetic shield	250×1,5 [mm]
6.	Vacuum enclosure	330×2 [mm]

Bending diameter of magnet D = 2 m, bending angle α = 90°

Length of the central line of the magnet L = π·D·α/360° = 1,571 m

$$F_j = \pi^2 \cdot D \cdot D_j \cdot \frac{\alpha}{360°}$$

F_{1i} = 0,242 m^2 F_{1o} = 0,247 m^2	D_{1i} = 49 mm = 0, 049 m D_{1o} = 50 mm = 0, 05 m	F_{4i} = 0,395 m^2 F_{4o} = 0,770 m^2	D_{4i} = 80 mm = 0, 08 m D_{4o} = 156 mm = 0, 156 m
F_{2i} = 0,281 m^2 F_{2o} = 0,296 m^2	D_{2i} = 57 mm = 0, 057 m D_{2o} = 60 mm = 0, 06 m	F_{5i} = 1,219 m^2 F_{5o} = 1,234 m^2	D_{5i} = 247 mm = 0, 247 m D_{5o} = 250 mm = 0, 25 m
F_{3i} = 0,296 m^2 F_{3o} = 0,395 m^2	D_{3i} = 60 mm = 0, 06 m D_{3o} = 80 mm = 0, 08 m	F_{6i} = 1,609 m^2 F_{6o} = 1,628 m^2	D_{6i} = 326 mm = 0, 326 m D_{6o} = 330 mm = 0, 33 m

$$F_{300} = \left(\pi^2 \cdot D_{6i} \cdot D \cdot \frac{\alpha}{360°} + 2\pi \cdot D_{6i} \cdot H_6\right) + \left(\pi^2 \cdot D_{1o} \cdot D \cdot \frac{\alpha}{360°}° + 2\pi \cdot D_{1o} \cdot H_6\right) + 2\pi \cdot \left[\left(\frac{D_{6i}}{2}\right)^2 - \left(\frac{D_{1o}}{2}\right)^2\right] =$$

$$(F_{6i} + 2\pi \cdot D_{6i} \cdot H_6) + (F_{1o} + 2\pi \cdot D_{1o} \cdot H_6) + 2\pi \cdot \left[\left(\frac{D_{6i}}{2}\right)^2 - \left(\frac{D_{1o}}{2}\right)^2\right] = \mathbf{2{,}22\ m^2}$$

$$H_6 = \frac{D_{6i} - D_{5o}}{2} + \frac{D_{5o} - D_{4o}}{2} - \frac{S_6}{1000} = 0{,}084998 \text{ m}$$

S_6 = 0, 002 m – thickness of vacuum enclosure’s wall

$$F_{40o} = \left(\pi^2 \cdot D_{5o} \cdot D \cdot \frac{\alpha}{360°} + 2\pi \cdot D_{5o} \cdot H_5\right) + \left(\pi^2 \cdot D_{3i} \cdot D \cdot \frac{\alpha}{360°} + 2\pi \cdot D_{3i} \cdot H_5\right) + 2\pi \cdot \left[\left(\frac{D_{5o}}{2}\right)^2 - \left(\frac{D_{3i}}{2}\right)^2\right] =$$
$$(F_{5o} + 2\pi \cdot D_{5o} \cdot H_5) + (F_{3i} + 2\pi \cdot D_{3i} \cdot H_5) + 2\pi \cdot \left[\left(\frac{D_{5o}}{2}\right)^2 - \left(\frac{D_{3i}}{2}\right)^2\right] = \mathbf{1{,}71\ m^2}$$
$$H_5 = \frac{D_{5o} - D_{4o}}{2} = 0{,}047 \text{ m}$$

$$F_{40i} = \left(\pi^2 \cdot D_{5i} \cdot D \cdot \frac{\alpha}{360°} + 2\pi \cdot D_{5i} \cdot H_4\right) + \left(\pi^2 \cdot D_{3o} \cdot D \cdot \frac{\alpha}{360°} + 2\pi \cdot D_{3o} \cdot H_4\right) + 2\pi \cdot \left[\left(\frac{D_{5i}}{2}\right)^2 - \left(\frac{D_{3o}}{2}\right)^2\right] =$$
$$(F_{5i} + 2\pi \cdot D_{5i} \cdot H_4) + (F_{3o} + 2\pi \cdot D_{3o} \cdot H_4) + 2\pi \cdot \left[\left(\frac{D_{5i}}{2}\right)^2 - \left(\frac{D_{3o}}{2}\right)^2\right] = \mathbf{1{,}796\ m^2}$$
$$H_4 = \frac{D_{5o} - D_{4o}}{2} - \frac{S_5}{1000} = 0.0469985 \text{ m}$$

S_5 = 0, 0015 m – thickness of magnetic shield's wall

$$F_{4,2} = \left(\pi^2 \cdot D_{4o} \cdot D \cdot \frac{\alpha}{360°}\right) + \left(\pi^2 \cdot D_{2i} \cdot D \cdot \frac{\alpha}{360°}\right) + 2\pi \cdot \left[\left(\frac{D_{4o}}{2}\right)^2 - \left(\frac{D_{2i}}{2}\right)^2\right] = F_{4o} + F_{2i} + 2\pi \cdot \left[\left(\frac{D_{4o}}{2}\right)^2 - \left(\frac{D_{2i}}{2}\right)^2\right] = \mathbf{1,\ 08\ m^2}$$

$$Q_r = \mathrm{C} \cdot \epsilon \cdot \left({T_2}^4 - {T_1}^4\right) \cdot F_1$$

Where:
C – Stefan-Boltzmann constant = $5.67 \cdot 10^{-8}$ [W/($m^2 \cdot K^4$)]
T_1, T_2 – temperature of inner and outer surfaces [K]
F_1, F_2 – area of inner and outer surfaces [m^2]
ε – Emissivity

$$\epsilon = \frac{\varepsilon_1 \cdot \varepsilon_2}{\varepsilon_2 + \frac{F_1}{F_2} \cdot (1 - \varepsilon_2) \cdot \varepsilon_1}$$

ε (300) = 0,03 - polished stainless steel, covered with aluminium foil (tape)
ε (40) = 0,019 – copper mechanically polished with abrasive
ε (4,2) = 0,011 – cover with aluminium tape

T (range), K	**Q_r, W (1 magnet)**	**Q_{rt}, W**
300 ÷ 40	10,1255	30,3765
40 ÷ 4,2	0,0013	0,0039

Heat transfer by suspensions

Heat transfer by the material of suspension is determined by Fourier's law for 1D heat flow:

$$Q_s = \frac{\lambda \cdot (T_2 - T_1) \cdot F}{L}$$

Where:
λ – Thermal conductivity [W/(m·K)]
T_1, T_2 – temperature [K]
F – Suspension's cross section [m^2]
L – Suspension's length [m] (material – textolite)

12 suspensions (data taken from the internal elaboration)
D = 5 mm, F = $1{,}96 \cdot 10^{-5}$ m^2

$L_1 = 0{,}05$ m, $L_2 = 0{,}1$ m

$\lambda\ (300) = 0{,}7$ W/(m·K) $\lambda\ (40) = 0{,}2$ W/(m·K) $\lambda\ (4{,}2) = 0{,}09$ W/(m·K)

$\bar{\lambda}\ (300 \div 40) = 0{,}45$ W/(m·K)
$\bar{\lambda}\ (40 \div 4{,}2) = 0{,}145$ W/(m·K)

For <u>one</u> electromagnet:
$\mathbf{Q_s\ (300 \div 40)} = 0{,}45 \cdot (300 - 40) \cdot 1{,}96 \cdot 10^{-5} / 0{,}05 = 0{,}045\ \text{W} \cdot 12 = 0{,}551\ \text{W} \cdot 3 = \mathbf{1{,}653\ W}$
$\mathbf{Q_s\ (40 \div 4{,}2)} = 0{,}145 \cdot (40 - 4{,}2) \cdot 1{,}96 \cdot 10^{-5} / 0{,}1 = 0{,}001\ \text{W} \cdot 12 = 0{,}012\ \text{W} \cdot 3 = \mathbf{0{,}036\ W}$

Total heat transfer

$$Q_t = Q_{cl} + Q_r + Q_s$$

<u>Superconducting gantry with magnets of B = 3 T</u>

$\mathbf{Q_t\ (300 \div 40)} = \mathbf{132{,}76\ W}$
$\mathbf{Q_t\ (40 \div 4{,}2)} = \mathbf{0{,}868\ W}$

Gantry setup has 6 cryocoolers, so for one cryocooler:

$Q_t\ (300 \div 40)/6 = 132{,}76\ \text{W} / 6 \approx \mathbf{22{,}12\ W}$
$Q_t\ (40 \div 4{,}2)/6 = 0{,}868\ \text{W} / 6 \approx \mathbf{0{,}14\ W}$

<u>Superconducting gantry with magnets of B = 6 T</u>

$\mathbf{Q_t\ (300 \div 40)} = 108\ \text{W} + 30{,}3765\ \text{W} + 1{,}653\ \text{W} \approx \mathbf{140\ W}$
$\mathbf{Q_t\ (40 \div 4{,}2)} = 0{,}6\ \text{W} + 0{,}0039\ \text{W} + 0{,}036\ \text{W} \approx \mathbf{0{,}64\ W}$

For one cryocooler:

$Q_t\ (300 \div 40)/6 = 140\ \text{W} / 6 \approx \mathbf{23{,}3\ W}$
$Q_t\ (40 \div 4{,}2)/6 = 0{,}64\ \text{W} / 6 \approx \mathbf{0{,}11\ W}$

Estimated calculations of the thermal power of cryocoolers are:
SC gantry (3 T (300 ÷ 40)): $22{,}12 \cdot 100\% / 30 = \mathbf{73{,}7\ \%}$
SC gantry (6 T (300 ÷ 40)): $23{,}3 \cdot 100\% / 30 = \mathbf{77{,}6\ \%}$

SC gantry (3 T (40 ÷ 4,2)): $0{,}14 \cdot 100\% / 1{,}5 = \mathbf{9{,}3\ \%}$
SC gantry (6 T (40 ÷ 4,2)): $0{,}11 \cdot 100\% / 1{,}5 = \mathbf{7{,}3\ \%}$

Calculations were made discounting the additional power loss of quadrupole electromagnets for which losses will be less about 1 W (300 K – 30 K) and 0,1 W (40 K - 4,2 K).

According to data from internal elaboration loss for the suspension system of a single electromagnet is less than 1W (300 K – 40 K) and less than 25mW (40 K - 4,2 K).

Conclusions

- During the Summer Student Program at Joint Institute for Nuclear Research, three models of different gantries were analyzed: HIT carbon ion facility with conventional magnets, a model made in collaboration with Slovak Academy of Science with 3T superconducting magnets and gantry with 6T superconducting magnets (table 3).
- Gantries with conventional magnets are enormous and need to be reduced in its weight. It can be achieved by replacing magnetic shields made of steel by superconducting magnetic shields.
- The interaction between the particles is so strong, that it needs a special mechanical construction. In a gantry setup with a superconducting magnet of 6T, the magnetic field induction is much bigger and that is why shielding setup requires bigger magnetic shields to be applied so that overall mass of the setup will become bigger. Moreover, a heat transfer between windings and shields in a gantry with 6T SC magnets was calculated considering most optimal conditions (emissivity and thermal conductivity coefficients may change over time).
- Superconducting magnetic system requires a power supply of less than 40 kW, while the conventional system needs to be operated under the order of a few hundred kW. Assuming that gantry systems run continuously, operating costs of a conventional system will be much higher than the cost of operating superconducting gantry system.
- Analysis showed that the best solution for the future radiotherapy methods is superconducting gantry for ion therapy.

Table 3 Comparison of main parameters of different types of gantry [1, 2, 4, 5]

	Conventional gantry	**SC gantry for proton therapy**	**SC gantry for ion therapy**
Dimensions, m	L = 21 D = 6	L = 12 D = 9	L = 14 D = 4
Magnetic field, T	~ 1	2 - 4	4 - 8
Weight, t	670	< 150	150
Range of energyof the beam, MeV	50 - 430	60 – 250	110 - 460
Cooling	water	He cryocoolers	He cryocoolers
Angle of rotation, deg	360	360	± 180

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