

ISOCHRONOUS CYCLOTRON C250 FOR PROTON THERAPY APPLICATION

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Abstract

Dubna scientific medicine center is under development since 1967 on the base of the proton beam of LNP JINR Phazotron. Proton beam with energy $E_p \sim 170$ MeV and intensity $I \sim 0.1$ mA is used for patients irradiation. Proposal of the cyclotron with the same beam characteristics was reported earlier at the RUPAC04[1], ICAA05[2], RUPAC06[3] and printed in magazine[4].

New project of C250 – cyclotron for proton therapy is considered in this paper. Energy of the extracted beam increased according to last medical requirements up to 250 MeV. 4-fold and compact types of magnet yoke were studied by 3D computer magnetic field calculations. The ability of optimal combination of the magnet yoke, HF and extraction systems of the cyclotron taking into account the dynamics of the proton beam in calculated magnetic and accelerating field is under discussion.

INTRODUCTION

A number of cyclotrons C-235 (energy of the extracted proton beam is ~ 235 MeV) has been made and installed by IBA (Belgium). ACCEL Instruments GmbH [5] developed a superconducting proton cyclotron on energy of 250 MeV for the medical program PROSCAN PSI. Proposal of the investigation and production of C250p cyclotron for fixed energy of protons $E_p \sim 250$ MeV are given in this paper. This increased value of protons energy (due to previously discussed one) concerned to suggestion of the use anti-gantry system where the patient is irradiated in special fixed capsule. And the proton beam loses a part its energy passing through the capsule.

Some parameters proton cyclotrons C - 235 (IBA) , C-250 (ACCEL) , and C250p are given in the Table 1.

CYCLOTRON MAGNETIC SYSTEM

In [3] the various types of yoke are considered, it is shown, that the magnet with four by opposites yoke is more convenient for service, such design is accepted in the present project.

Isochronous cyclotron for proton therapy offered to create on the basis of a magnet with a diameter of poles $\varnothing = 3$ m. The computation of the cyclotron magnetic system was carried out by means of the program Radia ver. 4.098 [6], which works in the Mathematica environment and calculates a magnetic field of a three-dimensional magnetic systems by a method of the integrated equations. As a material of a magnet it is supposed to use steel - 10.

Table 1. Some parameters proton cyclotrons C - 235 (IBA) , C-250 (ACCEL) , and C250p.

PARAMETER	C – 235 IBA	C-250 ACCEL	C-250p JINR LNP
Energy of protons (MeV)	235	250	~ 250
Average mag. field (T)			
In center	1.739	~ 4	1.41
In extraction radii	2.165	~ 4	1.79
Extraction radius (m)	1.08	~ 0.9	1.4
Magnetic field at extraction radius (T)			
hill	3.09	4.0	2.80
valley	0.985	1.6	1.10
Gap (sm)			
valley	60	-	40
hill	9.6-0.9		4
Number of sectors	4	4	4
Main coil ampere turn (kA)	525	-	330
power consumption (kWt)	190	40(cooling)	170
weight of magnet (T)	210	90	300

The magnetic system consists of sectors, poles, horizontal and vertical yokes, current coils. Magnet scheme is shown on Figure 1. In opposite valleys through 90° the high-frequency resonators are located.

The variation of a magnetic field creates four pairs flat sectors located symmetrically on poles (see Fig. 1) from above and below. A gap between sectors is a constant size of 40mm. The average magnetic field is growing with radius and created by the increase of the azimuth extent of the sectors. The vertical stability is reached by deep variation of the magnetic field and the spirality of the sectors.

For the customer the important characteristics of installation are both: the size of the machine details and the technology of manufacturing; and both operational conditions - consumed energy and cost of service. We propose on the base of our results, that the offered project C250p with four symmetry return yoke (see Fig. 1) is optimum and that such installation can be created as a pilot project in of our institute.

The complete angular width of one sector is 55° , thus in valleys there is possible to place 42° rectilinear resonators.

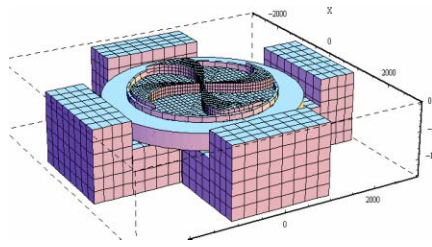


Fig.1. Computing model: lower part of magnet.

BEAM DYNAMICS

In the Fig. 2 the dynamic characteristics of a beam in the magnetic field calculated for magnet with yoke (Fig. 1) are shown. The frequencies of axial and radial motion are in allowable limits.

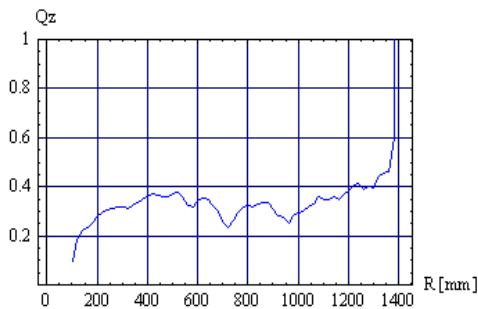


Fig.2. Dependence of frequency of axial fluctuations on radius.

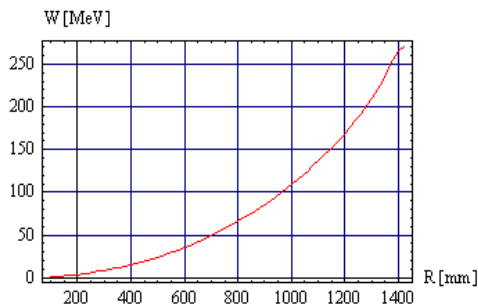


Fig.3. Dependence of energy of protons on radius.

RADIOFREQUENCY SYSTEM

Rectilinear on radius the accelerating resonators which have angular extent 42° and 30° dee are used. They are located in valleys, where the gap between poles is 400 mm. The adjustment and excitation of resonators is carried out through the coaxial lines. The central rod located from above and from below is used for the dee support. Parts of the lines, which leave for the size of 400 mm are placed in the channels of poles of the magnet. The basic parameters of high-frequency system were obtained making use a three-dimensional code. For excitation of the accelerating system it is proposed to use the standard high-frequency generator on the suitable capacity and frequency 81.8 MHz working on linkage feeder (see Fig. 4).

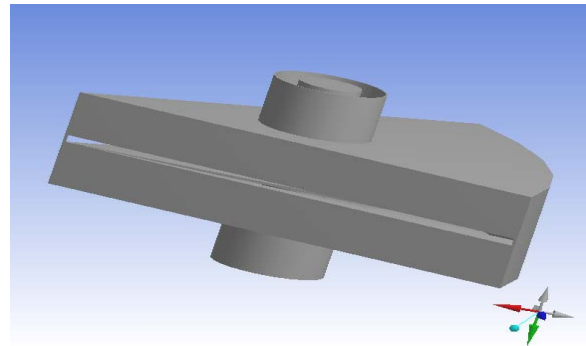


Figure 4: General view of the calculating model for accelerating system

EXTRACTION SYSTEM

The extraction system consists of the beam radial enhancement system, electrostatic sections, bending and focusing magnetic elements. At the moment only central ion extraction has been calculated. To study the beam acceleration at final radii and the efficiency of the extraction it is necessary to fulfill some additional calculations.

OTHER CYCLOTRON SYSTEMS

The design of the cyclotron vacuum chamber depends on the form of the return yoke. In our opinion the magnet with four return yokes is more convenient to make technological service of the cyclotron.

Diagnostics of the parameters of accelerated beam is carried out by three probes, one of them is on the entrance of extraction channel. On the exit of electrostatic section of the channel the fourth short probe is arranged.

In connection with a rather low required intensity of the beam in this cyclotron, it is possible to use a Penning ion source, which is moved from above in the centre of cyclotron. Acceleration and the formation of the beam during the first turns were carried out with the help of special central optics.

CONCLUSIONS

The physical consideration of proton cyclotron on the energy of about $E_p \sim 200$ MeV was given. This cyclotron will provide all scientific and medical programs on the medical beam of Dzhelepov Laboratory of Nuclear Problem, Joint Institute for Nuclear Research.

References

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