MAGNETIC SYSTEM OF ISOCHRONOUS CYCLOTRON F250 FOR PROTON THERAPY APPLICATIONS

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Abstract

Possibility of the isochronous cyclotron F250 creation with protons energy ~250 MeV on the basis of magnet with pole diameter 6 m, which is used for the synchrocyclotron (Phasotron), is examined in the JINR Laboratory of Nuclear Problems (LNP). The proposed cyclotron F250 will make it possible to strongly decrease the electric power of magnet and to avoid the need of beam degradation from 680 MeV to 250 MeV.

For creating the required magnetic field of the cyclotron F250 it is necessary to change the form of steel spiral shims and disks, located inside a vacuum chamber of synchro-cyclotron. The basic parameters of the magnetic system of the cyclotron F250 with the condition of retaining the vacuum chamber and the magnet yoke of synchrocyclotron are given.

INTRODUCTION

The basis of the experimental base for JINR Laboratory of Nuclear Problems (LNP) until 1979 served the first accelerator of Dubna - synchrocyclotron. As a result of a number of improvements this accelerator for a long time remained one of the most powerful installations of this type [1].

In (1967 -1970) the project [2] of reconstruction the synchrocyclotron into a small meson factory with the energy of protons 680 MeV was developed. In (1979 - 1984) this project was realized with the maximum intensity of the internal beam of protons 7 mkA and with the efficiency of extraction ~50%. The obtained parameters of accelerator made it possible to substantially enlarge the program of physical and applied works on the accelerator [3].

At present a medico - biological complex operates in LNP for treating the oncologic sick with the use of protons at energies 160-250 MeV. For determining the required energy of protons the information about the mean free path of protons in the correspondence for the position of Bragg's peak in each case is used. Necessary energy of protons is obtained by means of degrader system providing a retarding the extracted beam of protons with 680 MeV to 250 MeV and less. In this case the utilized for medical purposes intensity of beam does not exceed 50 nA.

The successes achieved in the last decade in the proton therapy led to development and creation of the specialized accelerators for this purpose. The considerable progress in this direction is achieved in the creation of isochronous cyclotrons [4, 5].

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The considerable progress in this direction is achieved in the creation of isochronous cyclotrons [4, 5]. However, the cost of construction as well as the operating costs of such cyclotrons comprises the rather great values.

In connection with the foregoing it looks appropriate to develop a project with a partial use of magnetic, high-frequency and other systems of working accelerator for creation on their basis an isochronous cyclotron for proton therapy.

The decommissioning of the JINR Phasotron will allow in the shortest possible time with minimal capital expenditure to create an isochronous cyclotron for protons up to 250 MeV with an intensity of the extracted beam about 50 mkA.

CALCULATION OF MAGNETIC FIELD

General view of F250 magnetic system, including the magnet of the working JINR Phasotron and the lids of vacuum chamber with the system of spiral shims of new configuration is shown in Figure 1. Position of the main elements of the magnetic system in the gap between poles of the electromagnet (Ø=6000 mm, d =1540 mm), that provide the desired field in the mid-plane is shown in Fig. 2.

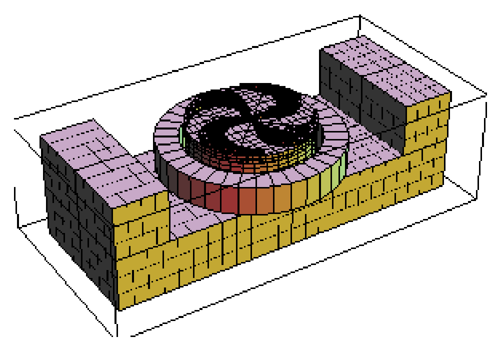

Figure 1: General view of FC250 magnetic system.

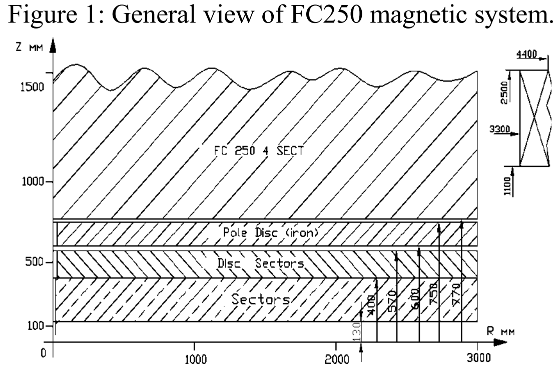

Figure 2: Scheme of the main elements location on vertical cross section.

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Pole disk and disk with sectors form the lids of the vacuum chamber of cyclotron.

Geometry of the steel disks and spiral shims has been chosen by the help of code Radia [6] which computes 3D magnetic fields in the system of Mathematica [7].

The calculations were carried out at a current in the magnet coil IW=165 kA, which corresponds to the power consumed by the magnet P= 100 kWt.

The selected configuration of sectors (Figure 3) provides the required radial dependencies of average magnetic field (Figure 4) and both spiral angle and flutter (Figure 5).

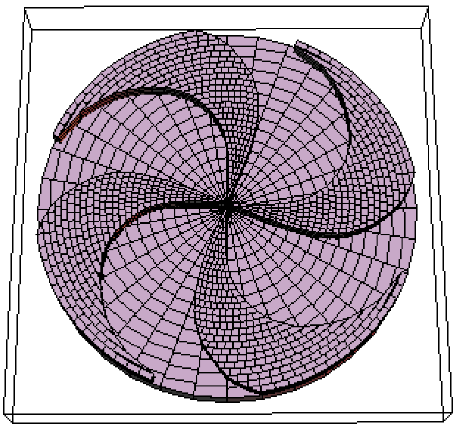

Figure 3: Configuration of the magnetic sectors.

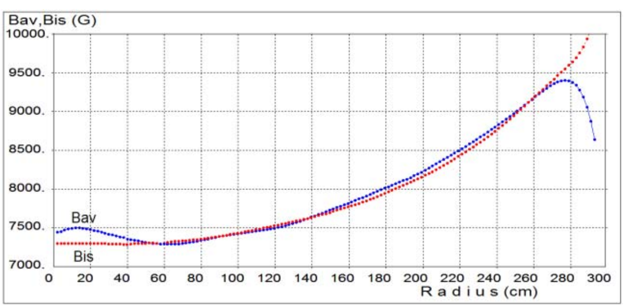

Figure 4: Average magnetic field Bav and isochronous one Bis versus radius.

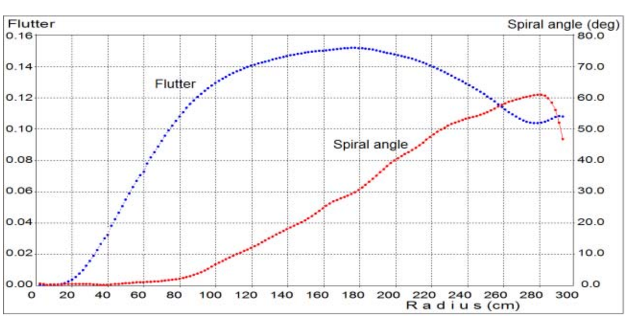

Figure 5: Flutter and spiral angle of the field versus radius

As can be seen from Figure 4 the deviation of the average magnetic field from the isochronous one in central region of the accelerator (r < 40 cm) is not larger than 250 G, and in the interval r =(40-270) cm does not exceed 50 Gauss. Off course, tight trimming of the average field in a main acceleration region is needed up to a level ±2-3 Gs deviation from the isochronous one. This can be provided by changing azimuthal width of the sectors.

Betatron tunes Qr and Qz are shown in Figure 6 versus orbital radius. Axial focusing by means of magnetic field begins from radius 15 cm. To provide focusing at radii less than 15 cm a corresponding change of the field bump in this place is needed. Some increase of the axial focusing due to electric field should also be taken into account in the very center of cyclotron

It is seen that the frequency of axial oscillations decreases from Qz=0.35 at radius r =230 cm to Qz=0.0 at radius r= 268 cm, which corresponds to maximal attainable proton energy W=260 MeV in this cyclotron (see Figure 7).

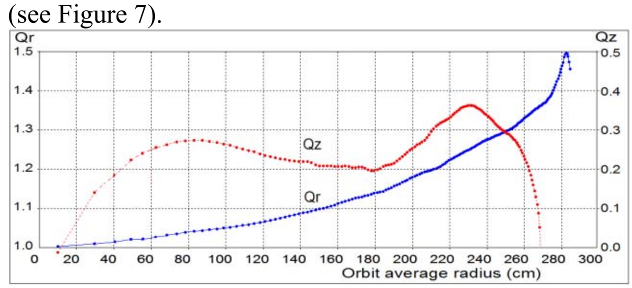

Figure 6: Frequencies of axial Qz and radial Qr oscillations versus orbit average radius.

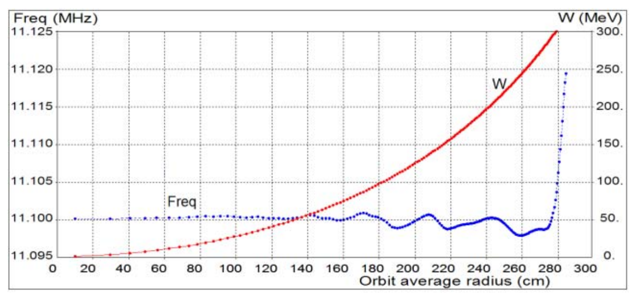

Figure 7: Orbital frequency Freq and energy of central proton W in isochronous field versus orbit average radius.

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