THE MAGNETIC FIELD COMPUTATION AND MAGNET SHIMMING SIMULATION OF 70MEV CYCLOTRON CYCIAE-70

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Abstract

In order to design a 70 MeV, 200 μA cyclotron, the magnetic field computation and magnet shimming simulation have been carried out. The primary dimensions of the magnet were determined by a computer aided engineering code, CYCCAE. Based on the geometry, the field distribution of the magnet is estimated by 2D and 3D program POISSON and DE3D. The particle dynamic behaves such as frequency of betatron oscillation, phase shift, ion extraction radius and orbit were computed. The profile of magnet sectors was modified based on the computed results of phase shift. With few iterations of the field computation, phase shift was improved. Finally, the magnet shimming simulation results show the total phase shift less than ±45°.

1 INTRODUCTION

70 MeV High Intensity Proton Cyclotron is a basic part of BRNBF (Beijing Radioactive Nuclear Beam Facility) proposed by CIAE. Radioactive nuclei produced by the cyclotron beam will be separated by an on-line mass separator. In order to obtain high intensity and low power consumption, the magnet of the cyclotron is designed meticulously.

The magnet design combines the advantages of solid pole cyclotron and separated sector cyclotron. The magnetic field could be adjusted during the manufacture by azimuthal shimming of the pole edges, providing a small first harmonic field and accurate isochronous field. Simultaneously high flutter larger than 0.8 keeps strong focusing.

2 THE MAGNET DIMENSIONS

The magnet consists of 4 sectors, return yokes and bases. The geometry of the magnet is shown in fig. 1. 54° sector and 40 mm hill gap are assumed that made field 1.6 T in hill and 0.16 T in valley. With these assumptions the conceptional dimensions of the magnet were determined by a computer aided engineering code, CYCCAE[1] . The relative parameters of the coils and RF system were found simultaneously. The results from CYCCAE are given in table 1.

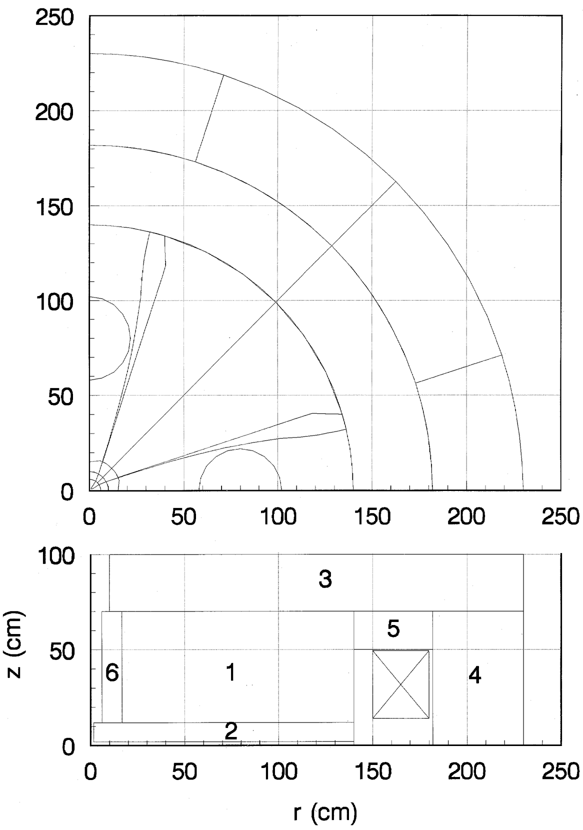


Fig. 1 The Geometry of CYCIAE-70 Magnet

Table 1 Parameters of Cyclotron CYCIAE-70

MAGNETIC STRUCTURE	
Number of Sectors	4
Sector Angle	54°
Field in Hill	1.6 T
Field in Valley	0.16 T
Average Field	1.02 T
Relative Magnetic Permeability	700.0
Radius of the Pole	1.40 m
Inner Radius of the Yoke	1.83 m
Outer Radius of the Yoke	2.30 m
Distance between Symmetry Plane and Up Base Side	1.21 m
Distance between Symmetry Plane and Down Base Side	0.81 m
Gap Between the Hills	0.04 m

High of Ring	0.30 m
Total Weight of Iron	230.6 t
Weight of Poles	46.11 t
COIL	
Current Density of Coil	0.50A/mm^2
D. C Power in the Coils	10. kW
Ampere-Turn Number of Coils	65.8 kAT
Copper Weight	13.72 t
R.F. SYSTEM	
Number of Dees	2
Dee Angle	30°
Harmonic Mode	4
Frequency(Fixed)	58.11 MHz

3 THE FIELD COMPUTATION

Before three dimensional field computation, two dimensional field estimation are carried out to choose a set of primary size of the magnet. The fields in the symmetry plane both in the hill and in the valley are approximated by 2D field computation. The field distribution is shown in fig. 2. DE3D[2] is used to check whether the field distribution is acceptable. The 3D mesh is generated based on the geometry from the 2D results. The magnet structure is decomposed by 1 sector, 2 shimming bar, 3 base, 4 return yoke, 5 magnet ring and 6 central plug (see fig. 1). Only the field in the first octant is computed since the symmetry of the magnet structure. The hexahedral isoparametric element is used for the field computation. The 3D mesh is shown in fig. 3. The dimensions of the coil are: high 355 mm, inner diameter 3000 mm, and outer diameter 3600 mm. The distance between two coils is 280 mm. The exciting current is 34500 AT/coil. The results of 3D field computation are shown in fig. 4 with Fourier analysis.

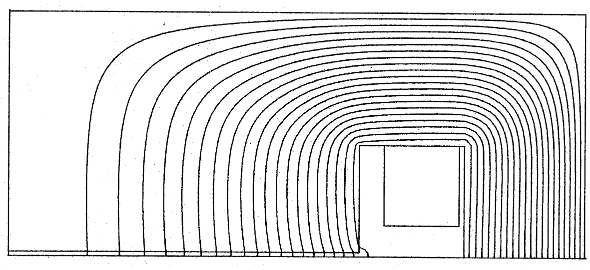


Fig. 2 Field Distribution on the symmetry plane in the hill

4 PARTICLE DYNAMICS ANALYSIS

The particle dynamic analysis has been done after the 3D field computation. Frequency of betatron oscillation, phase shift, equilibrium orbit and ion extraction position are calculated. The aim of dynamics analysis is to modify the edge shape of the sectors and let the field meet the requirement from isochronous filed and make the cyclotron work stable. The theoretical phase shift based on the data from DE3D is shown in fig. 5. According to results of dynamics analysis the sector edges are modified and a new the 3D mesh generated. With few iterations of such processes, phase shift is improved (also in fig. 5).

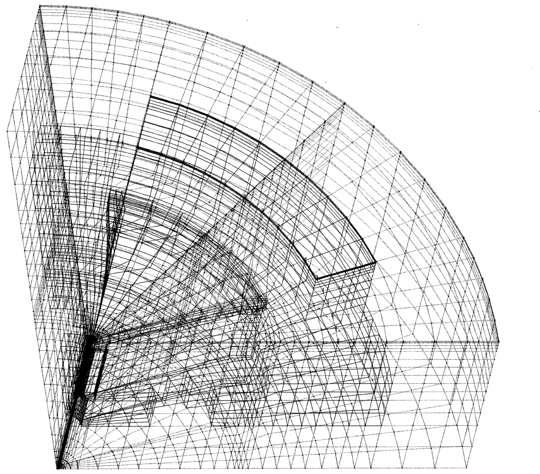


Fig.3 3D Mesh of the Magnet (1/8)

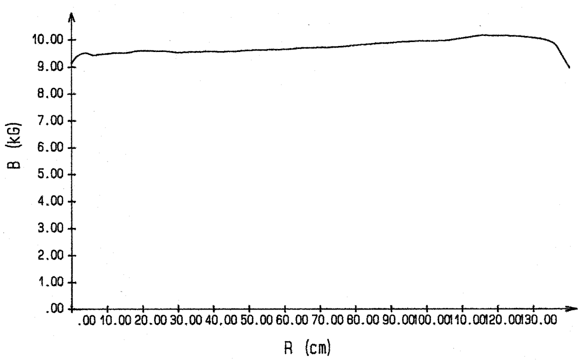


Fig. 4 (a) The Average Field

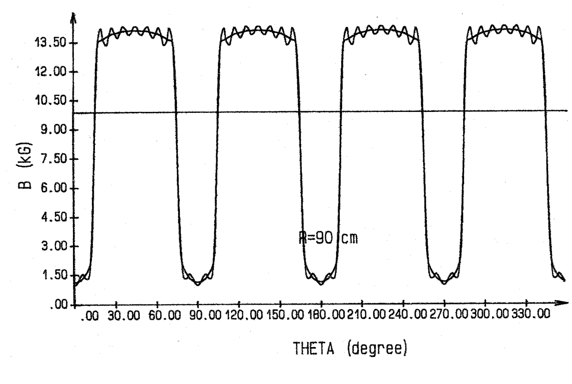


Fig.4 (b) The Field at R=90 cm

The magnet shimming simulation has been proved a great help during manufacture of our 30 MeV cyclotron CYCIAE 30. The shimming simulations make the phase shift improving and shorten the process of magnet manufacture. The total phase shift after the shimming simulation is shown in fig. 6. Then the ion extraction positions are determined by equilibrium orbit calculation and shown in fig. 7. Fig. 8 gives the frequency of betatron oscillation.

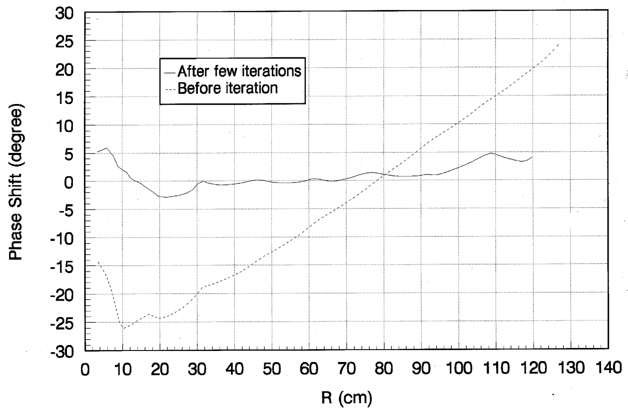


Fig. 5 Comparison of Phase Shift with before and after iteration

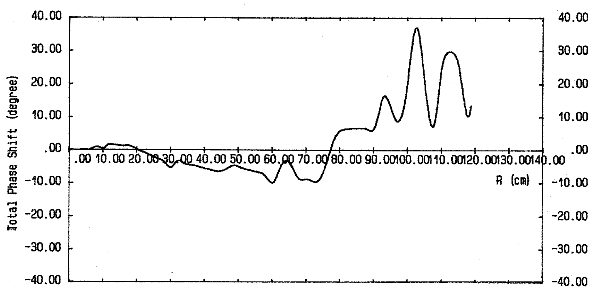


Fig. 6 The Total Phase Shift

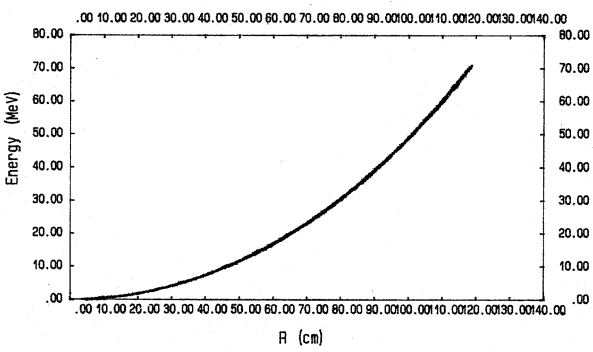


Fig. 7 The Extraction Position of Different Energy

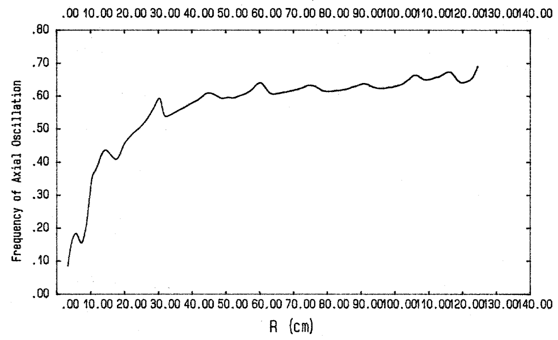
5 CONCLUSION

Due to simulation works well, the shimming becomes easier and manufacture price becomes lower. Of course, the manufacture period would be shortened and magnet quality is ensured.

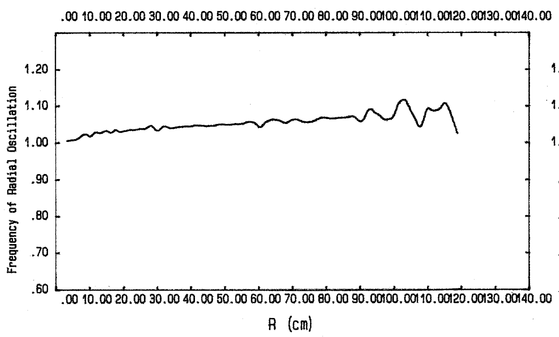
6 REFERENCES

[1] T.ZHANG, Y.CHEN and M.FAN, Proc. of Third European Particle Accelerator Conference, Berlin, 1992, pp1364-1366.

[2] M.FAN, T.ZHANG and W.YAN, China Nuclear Science & Technology Report, CNIC-00647.



Fit. 8 (a) The Frequency of Betatron Oscillation (axial oscillation)



Fit.8 (b) The Frequency of Betatron Oscillation (radial oscillation)