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Magnet Design for PEFP 20MeV Proton Beam Extraction System

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1. Introduction

The PEFP is designed to have two beam extraction lines at the 20 MeV end and 100MeV end for beam utilization. From the point of view of the beam dynamics study, it is recommended to make the drift space shorter. So it is needed to make the bending and focusing magnet compact, that is to say as possible as small. In this study, we reports the design results of magnets for PEFP 20MeV Proton Beam Extraction System

2. Quadrupole Magnet Design

2.1 Design constraints

Some parameters of the Magnets for PEFP 20MeV Proton Beam Extraction System were given from the beam physics calculation as follows

- Inner radius of the beam pipe : 10 mm
  → Magnet bore radius : 15 mm
- Required Integrated field : 1T
- Harmonic field strength : under 0.1% relative to the quadrupole mode

2.2 Core shape design using 2-D magnetic analysis.

First, we calculated the field gradient as the pole width varied using Poisson code[1]. We just calculated 1/8 model with the symmetry boundary conditions as shown in figure 1. We assumed the shape of pole tip was parabola and yoke width was the 1/2 of the pole width.

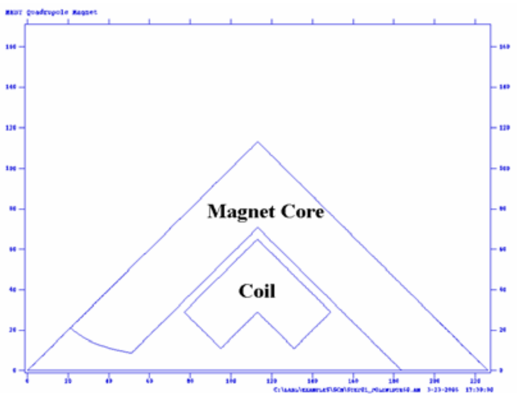

Figure 1. 2D Magnetic Analysis Model

As the results shown in figure 2, the optimum pole width was 60mm. And, we determined the operating current as the 6000 A-turns which was the current level just before magnetic saturation. At this case, field gradient was 1600 gauss/cm. So, the required effective length of the quadrupole magnet for the integrated field of 1 T was 62.5mm. As a result, the length of the core was determined to 60mm.

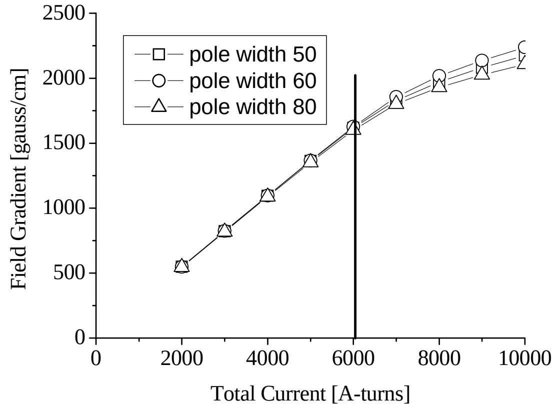

Figure 2. Field gradient as the total current variation in various pole widths

The harmonic field strength satisfied the required condition as shown in figure 3

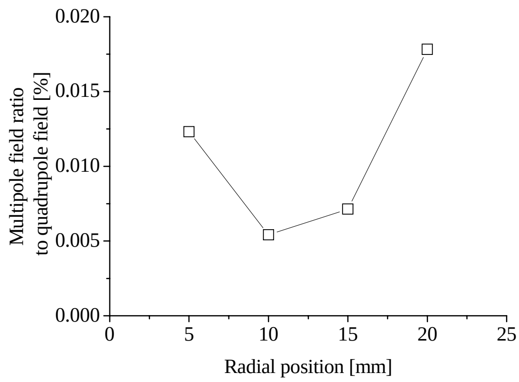

Figure 3. Field strength of the 12-pole-component relative to the quadrupole mode

2.3 Coil design.

We considered the two kinds of hollow conductors which have the dimensions of 4.62*4.62 and 5.6*5.6 mm. First, we set the limit of the current density to 5 A/mm^2 which is the general value in coil engineering design. In those cases, the numbers of turns of the coil were 72 turns for 4.62*4.62 conductor and 58 turns for 5.6*5.6 conductor, respectively. Considering the difficulty in winding and coil dimension, we chose the 5.6*5.6 conductor. In figure 4, We show the expected coil X-section which has the number of turns of 60 turns in figure 4 and magnet X-section in figure 5. The longitudinal space occupied by the quadrupole magnet was just 180mm.

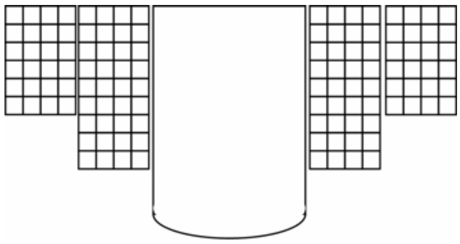

Figure 4. Expected coil X-section

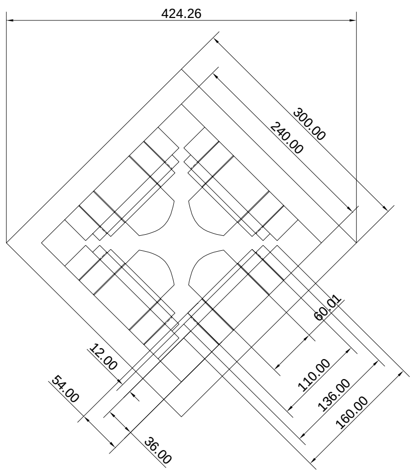

Figure 5. Quadrupole magnet X-section

2.4 Utilization of the Quadrupole Magnet as Steerer

With the additional dipole winding, Quadrupole magnet can be a steering dipole. We calculated the field profile and required current. Field profile was as figure 6 and the uniformity was 8% in the range from x=-10 to x=10. And average dipole field was 48gauss per 100A. In that case, we can bend the beam 0.44 mrad with 100A.

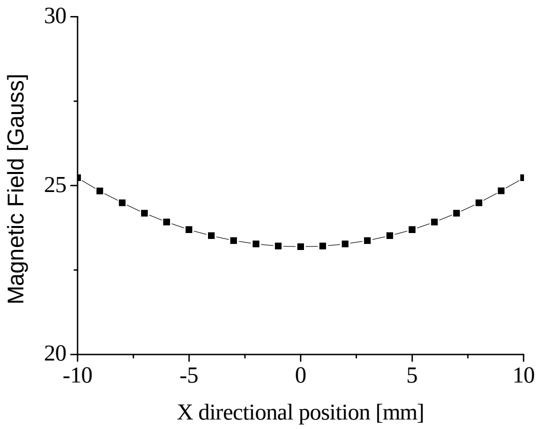

Figure 6. Field profile of the dipole component

3. Summary

We designed the magnet for PEFP 20MeV Proton Beam Extraction System as compact as possible and verified that magnet satisfied the operating condition.

4. Acknowledgements

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Reference

[1] Poisson/Superfish Manual, Los Alamos National Laboratory