CONSIDERATIONS ON THE DESIGN OF THE BENDING MAGNET FOR BEAM EXTRACTION SYSTEM OF PEFP*

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Abstract

The PEFP(Proton Engineering Frontier Project) is designed to have two beam extraction lines at the 20 MeV end and 100MeV end for beam utilization. In the 20MeV beam extraction system, a bending dipole have to be located in the small space between two buncher cavities of the MEBT. So, the design of the compact and optimized dipole is the key issue in the design of the whole beam extraction system. We designed a compact 90° bending magnet and using that magnet, we composed a most simple beam extraction system.

INTRODUCTION

The PEFP(Proton Engineering Frontier Project) is designed to have two beam extraction lines at the 20 MeV end and 100MeV end for beam utilization.

As shown in figure 1, the MEBT and 20MeV proton beam extraction system of the PEFP is composed of two buncher cavities, beam extraction magnet and quadrupole doublet[1]. A bending magnet to extract the beam from the beam line is located between two buncher cavities which will match the 20MeV proton beam to DTL II which accelerates the proton beam to 100MeV. This implies that there is a long drift space between the focusing structures, while, from the beam dynamics study, it is recommended to make the drift space shorter. Actually, the distance between the buncher cavities was limited under 750mm by the beam dynamics study.

In this study, we design the bending magnet to satisfy the beam dynamics requirements.

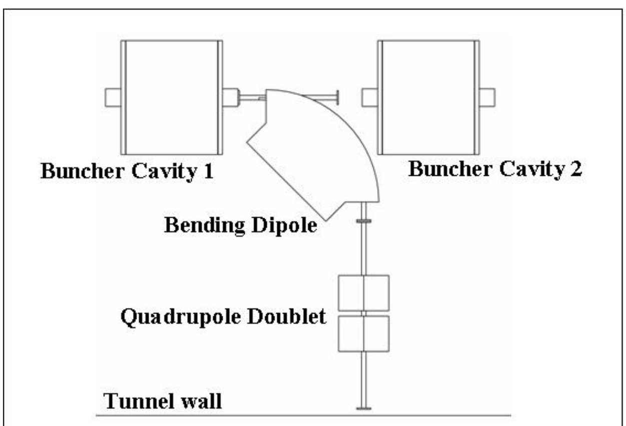

Figure 1: MEBT & Beam extraction system of the PEFP

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STEP BY STEP CONSIDERATION

First, Considering that there are two beam ways through the magnet, we chose the C-magnet as the type of bending magnet although this kind of magnet has the disadvantage that it is not symmetry around the center of the magnet[2] because if we select H magnet or window frame magnet, we have to design a relatively larger magnet and it would be not so easy to mount that magnet in such a small space.

Second, we defined the last bending angle from the accelerator axis as 90° to minimize the drift space through the accelerator tunnel wall.

Third, we consider several magnet compositions as follows.

1) 1 90° bending magnet
2) 1 30° bending magnet + 1 60° bending magnet
3) 2 45° bending magnets
4) 3 30° bending magnets

Naturally, the magnet which has smaller bending angle would be smaller and lighter, so will be easier to mount, handle, and align than the magnet which has larger bending angle. But to bend 90 degree, the system which uses magnets with smaller bending angle will need many magnets, so the total system containing power feeding and cooling will be much more complicated. Especially, we thought that case 1 and 2 were better systems. The case 1 which uses only a 90° bending magnet is the simplest system to fabricate, establish, and operate. And the case 2 which uses a 30° bending magnet and a 60° bending magnet could have some advantages. We could put a relatively small magnet into MEBT system and design the other magnet which could have the optimized edge focusing and the wedge focusing. We concluded that case 1 was better for our 20MeV proton beam extraction system. So we determined that first we tried to verify whether case 1 could be adaptable, and then to adapt the case 2 if case 1 could not be adapted to our system.

MAGNET DESIGN

Design constraints from beam dynamics study were shown in table 1

Table 1: Dipole Magnet Design Constraints

Beam energy	20 MeV
Pole gap distance	30 mm
Good field region width	30 mm
Field uniformity in good field region	0.1 %
Bending angle	90

2-D Design

We established a preliminary 2D design as shown in figure 2. Initially, we set the pole width as three times as the pole gap distance and yoke width as twice as the pole width. And we let the target field be 1.2T at which the bending radius of the 20MeV proton beam was 541mm. And there was no shim.

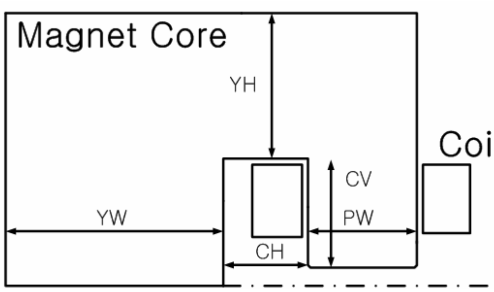

Figure 2: 2D design of the Magnet

And then we calculated the magnetic field variation according to pole geometry variation. As shown in figure 3, the minimum pole width was 90 mm within the limitation of 30mm good field width.

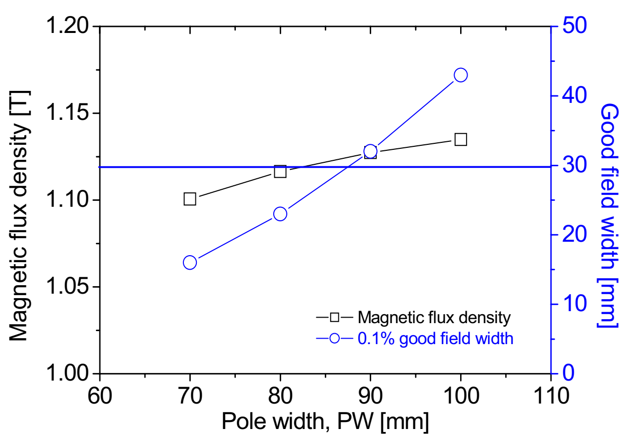

Figure 3: Magnetic field variation via pole width variation

And then we calculated the magnetic field variation according to yoke geometry variation. We defined optimum yoke geometry as the value where magnetic field started to decrease abruptly as shown in figure 4 and figure 5.

For the final 2D design, we calculated the magnetic field variation according to the coil current increase as shown in figure 6. Considering the field variation and the bending radius of the 20MeV proton beam, we determined the operating field as 1.1T at the operating current of 13600A-turn.

3-D Design

On the basis of the result of 2D analysis, we designed the bending magnet using 3D analysis. We established two kinds of magnet model.

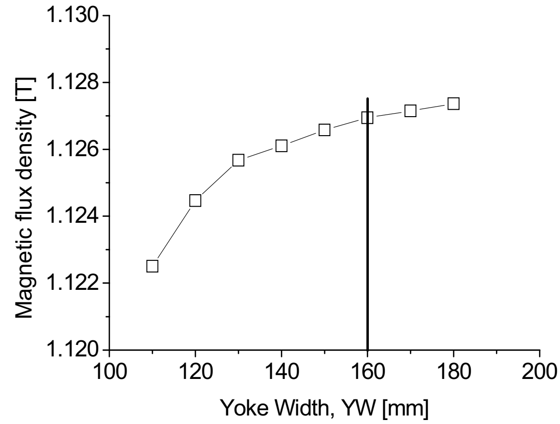

Figure 4: Magnetic field variation via yoke width variation

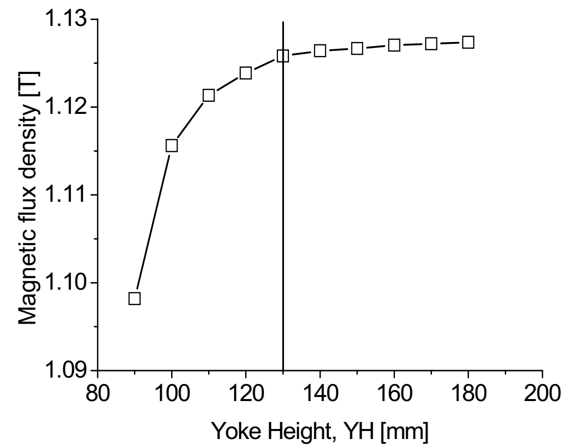

Figure 5: Magnetic field variation via yoke height variation

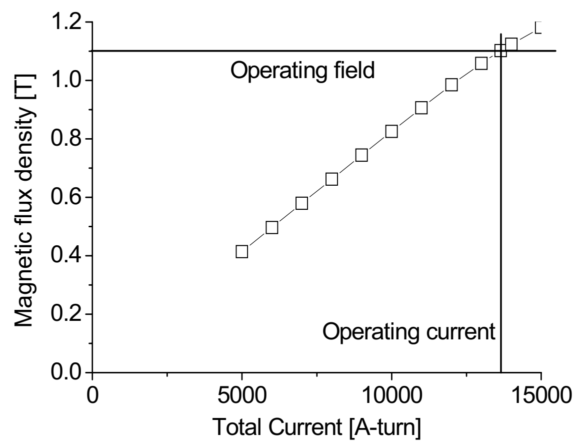

Figure 6. Magnetic field variation via coil current variation

As shown in figure 7, the one was a general type which was the expansion of 2D model and the other was a modified type to make the winding easy. As shown in figure 8, in the case of general type, we could get 1.1T at the current of 13800A-turn. In that case, we could confirm that 0.1% good field width was over 30mm, figure 9. In the case of modified type, magnetic field was about 5 % less than general type. Besides, as shown in figure 8, we could not acquire the target field of 1.1T within the reasonable operation current range.

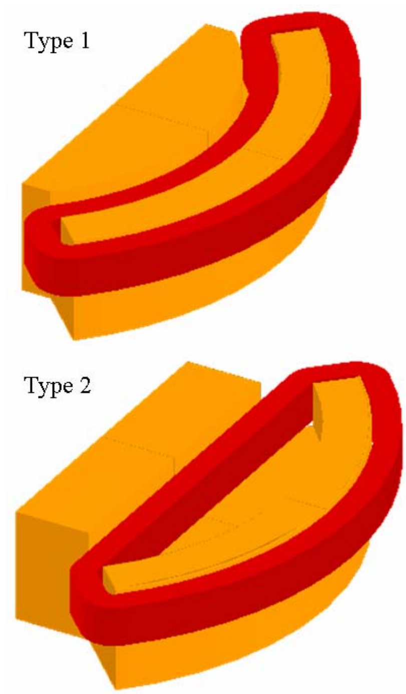

Figure 7: 3D magnetic analysis model. (a) general type, (b) modified type

We determined that we made the 20MeV beam extraction system with a general type 90° bending dipole magnet.

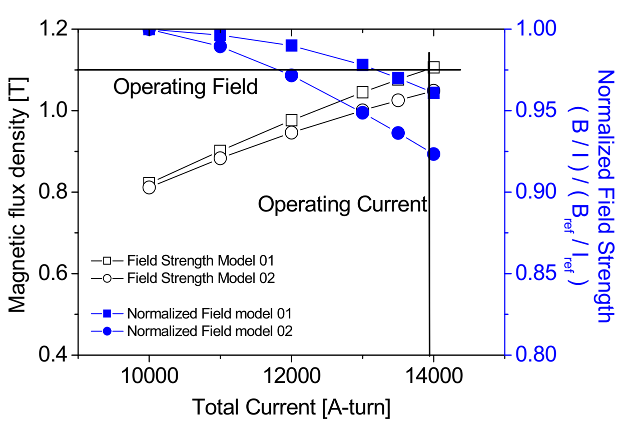

Figure 8: Magnetic field variation via coil current variation

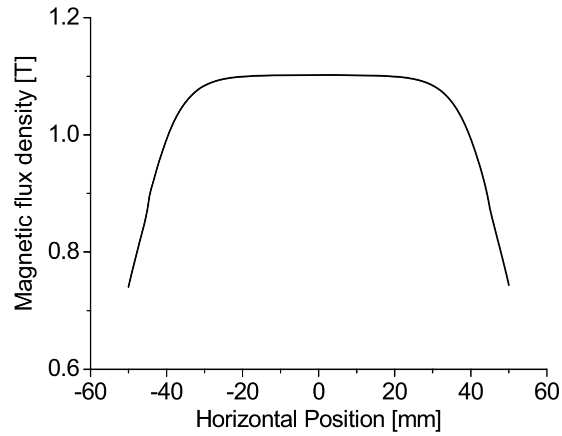

Figure 9: Magnetic field on the mid-plane.

SUMMARY

- We designed a simple beam extraction system using just 1 90° bending magnet.
- The designed magnet satisfied the constraints given from the beam dynamics study. Besides, that magnet was designed as compact as possible to be installed in the small space between two buncher cavities of the PEFP MEBT. The designed field strength is 1.1T and bending radius is 591mm

REFERENCES

[1] J.H. Jang, et al, DESIGN OF THE PEFP MEBT, Proceedings of the 2005 Particle Accelerator Conference, p2881
[2] G. Parzen, Magnetic Fields for Transporting Charged Beams, Brookhaven National Laboratory, 1976