BEAM OPTICS OF THE PEFP MODIFIED BEAM LINES*

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Abstract

The 100 MeV linac of the proton engineering frontier Project (PEFP) is designed to supply 20-MeV and 100-MeV proton beams to user groups. In order to extract 20-MeV proton beams, a 45-degree bending magnet is installed after 20-MeV DTL tank. The extracted proton beams are separated into five beam lines via a 90-degree dipole and an AC bending magnets. For 100 MeV beams, we use the same distribution scheme. Recently, the layout of the beam lines are modified to be short and compact. The work summaries the beam optics calculation of the modified beam lines.

INTRODUCTION

The main purpose of the proton engineering frontier project (PEFP)[1] is developing an 100-MeV proton linear accelerator and supplying 20 and 100-MeV proton beams to the user group. The linac consists of a 50 keV ion source, a low energy beam transport (LEBT) for beam matching, a 3 MeV radio frequency quadrupole (RFQ), an 100 MeV drift tube linac (DTL). The DTL is separated into two parts by a medium energy beam transport (MEBT) system. The MEBT includes a 45-degree bending magnet for 20-MeV proton beam extraction and two MEBT tanks for beam matching into the second part of the DTL. A MEBT tank is realized as a small DTL tank with 3 cells. The quadrupole magnets in drift tubes and the RF field in the tanks are used to control proton beams in the transverse and longitudinal directions, respectively. The 100 MeV proton beams are extracted by a 45-degree bending magnet which is located after the 100 MeV linac. This work includes the beam optics results of the PEFP 20 MeV and 100 MeV beam lines.

PEFP BEAM LINES

The PEFP has a plane to supply proton beams into 5 beam lines at the proton energy of 20 MeV and 5 beam lines at 100 MeV [2]. The main characteristics of the modified beam lines is the compact design which saves the space for beam lines and reduces the number of quadrupole magnets.

Beam Line Layout

The 100 MeV proton beams extracted by a 45-degree bending magnet are directed into the beam experimental hall by an additional 45-degree dipole magnet. The beams are divided into two directions via a 90-degree bending magnet. One goes into the first 100 MeV beam line (BL101) and the other into an AC magnet. The AC magnet separates the proton beams into three beam lines (BL102~BL104). The space for an additional beam line (BL105) is reserved in the opposite side of the 90-degree bending magnet. The 20-MeV beam lines (BL21 ~ BL25) adopts the similar scheme for beam distribution. The schematic plot for the PEFP linac and bema lines are given in Figure 1.

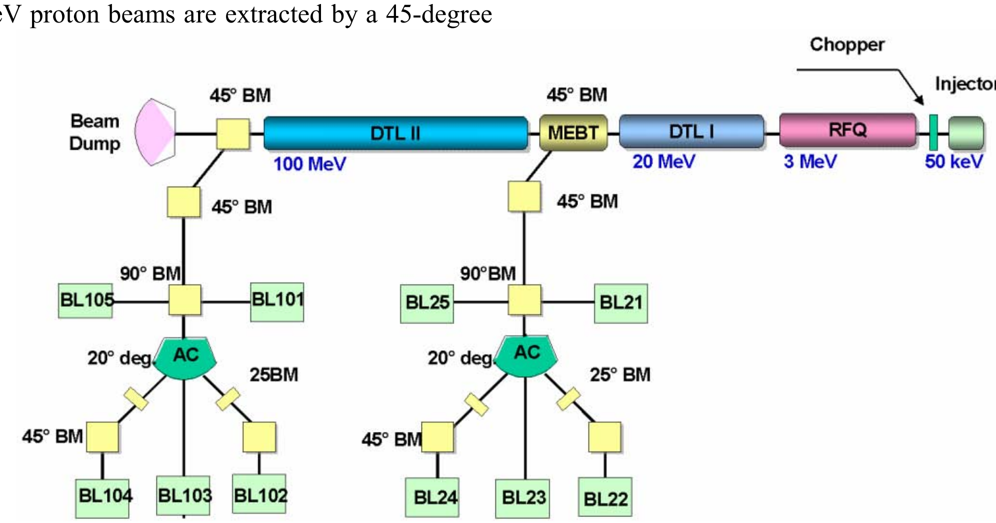

Figure 1: Schematic plot of the PEFP linac and beam lines. 20 MeV proton beams are extracted by a 45-degree bending magnet located in the MEBT and 100 MeV beam lines begin from a 45-degree bending magnet after the linac. The bending angles are explicitly given for the dipole magnets.

*Work supported by Ministry of Education, Science and Technology of the Korean Government
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BEAM OPTICS

In the beam optics calculation, we achieved a dispersion-free condition in a pair of bending magnets by inserting quadrupole magnets as follows,

- A quadrupole magnet between two 45-degree bending magnets in the extraction part of the 100 MeV beam lines.
- A quadrupole magnet between the AC magnet and the 25-degree bending magnets in 100 MeV beam lines.
- Two quadrupole magnets between two 45-degree bending magnets in the extraction part of the 100 MeV beam lines: one magnet to control the beam size in vertical direction and the other magnet to obtain the dispersion-free condition.
- A quadrupole magnet between the AC magnet and the 25-degree bending magnets in 100 MeV beam lines.

The other quadrupole magnets in the beam lines are used to control the beam size in the bending magnets whose gap size are given in Table 1. The aperture diameter and maximum field gradient of the quadrupole magnet are 110 mm and 5 T/m, respectively. This information is used to estimate the proper size of the beams in the beam line. The design and fabrication of the AC and 45-degree bending magnets, and quadrupole magnets are under progress by IHEP China. The 45-degree dipole magnets are a conventional C-type with parallel ends. We assumed the 25-degree bending magnets are also C-type with parallel end. Hence we included the edge effects of the bending magnets in the beam optics calculation. We also set the gap size of the 90-degree dipole to be 90 mm.

Table 1: Gap size of PEFP bending magnets: the values of the 90-degree and 25-degree dipole magnet are used the same values as the 45-degree bending magnet.

Type	Bending angle	Pole gap
AC	20 degrees	75 mm
BM type1	90 degrees	90 mm
BM type2	45 degrees	90 mm
BM type3	25 degrees	90 mm

Table 2: Input beam parameters of PEFP 20-MeV and 100-MeV proton beams with the normalized rms unit. The values of emttiance, α and β are ordered in the horizontal, vertical and longitudinal directions.

parameters	20-MeV BL	100-MeV BL
Energy (MeV)	20 MeV	102.6 MeV
Emittance (π mm-mrad, degree-MeV)	0.23/ 0.24/ 0.14	0.23/ 0.24/ 0.15
α	-1.68/ 2.80/ 0.56	-0.79/ -1.31/ -0.31
β (mm/mrad, deg/MeV)	0.55/ 1.19/ 136.8	4.12/ 2.42/ 39.9

The input beam parameters of the beam lines are summarized in Table 2. We use the TRACE-3D [3] code for the simulation. Figure 2 and Figure 3 show the dispersion free condition of the two parts of the 20-MeV and 100-MeV beam lines, respectively. The requirement of the quadrupole magnet is summarized in Table 3

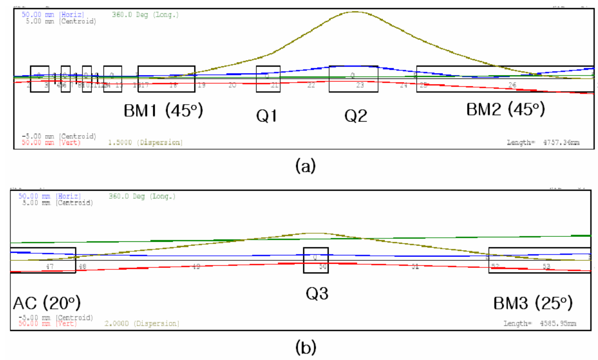

Figure 2: Dispersion free condition in 20-MeV beam lines: (a) between two 45- degree bending magnet and (b) between AC and 25-dgeree dipole magnets. The boundary of figure represents the dispersion value of 1.5 m.

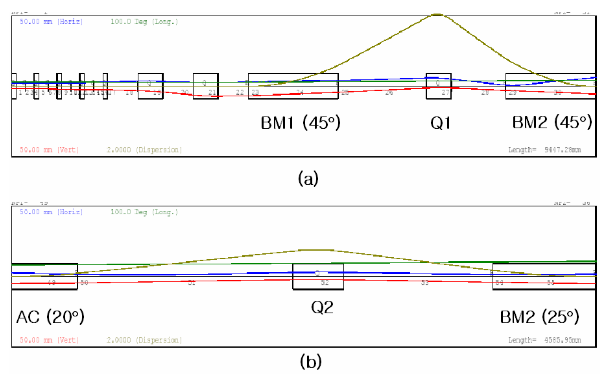

Figure3: Dispersion free condition in 100-MeV beam lines: (a) between two 45- degree bending magnet and (b) between AC and 25-dgeree dipole magnets. The boundary of figure represents the dispersion value of 2 m.

Table 3: Field gradient of the quadrupole magnet to achieve the dispersion-free conditions.

	Quadrupole	Field gradient
20-MeV BL	Q1	-5.00 T/m
	Q2	3.51 T/m
	Q3	3.68 T/m
100-MeV BL	Q1	4.32 T/m
	Q2	4.29 T/m

Figure 4 and Figure 5 show beam optics results and the rms beam size of the 20-MeV beam lines which are obtained by the TRACE-3D simulation. The corresponding results of the 100-MeV beam lines are given in Figure 6 and Figure 7. We found that the largest beam size occurs at the position before the 90-degree bending magnet. The beam size after the last bending magnet is not a problem because we have to expand the beam by using the beam-optical equipment at that region.

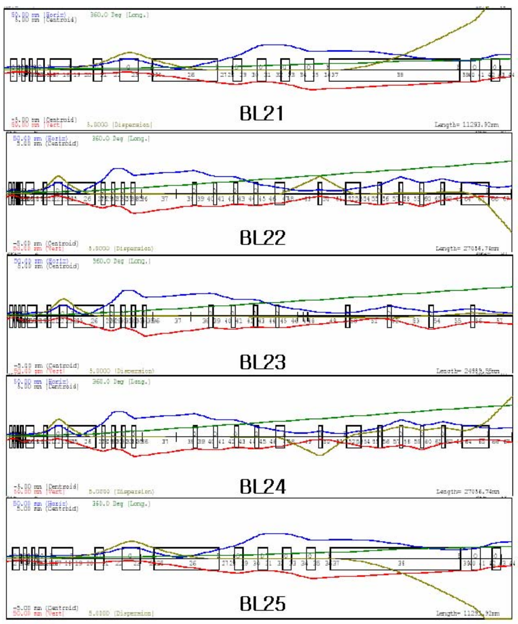

Figure 4: Beam optics results of PEFP 20-MeV beam lines.

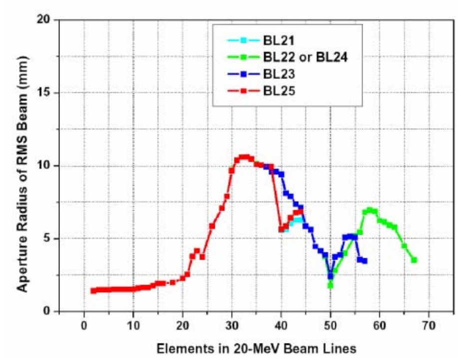

Figure 5: rms beam size in each element of PEFP 20-MeV beam lines.

CONCLUSIONS

We studied beam optics of the modified compact beam lines for the PEFP user facilities. We used the dispersion – free condition between pairs of the bending magnets. The resulting rms beam sizes are less than 12 mm in the 20-MeV beam lines and 8 mm in the 100-MeV beam lines.

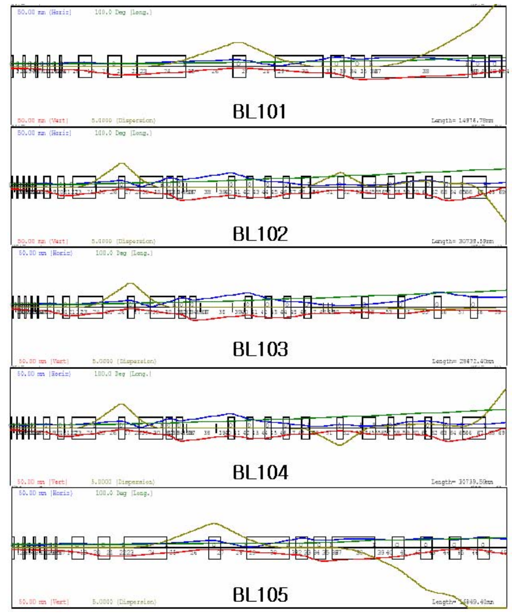

Figure6: Beam optics results of PEFP 100-MeV beam lines.

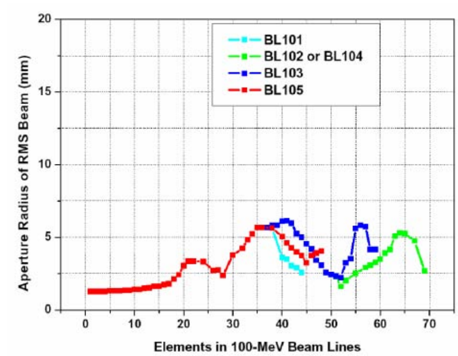

Figure 7: rms beam size in each element of PEFP 100 MeV beam lines.

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