Beam Dynamics Design of the PEFP 60MeV DTL

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Abstract. The low energy part of Proton Engineering Frontier Project (PEFP) accelerators consists of a 3MeV RFQ and a 20MeV DTL. The following accelerator is a 60MeV DTL. This work is related with the beam dynamics design of the new accelerating structure. After optimizing the DTL cell geometry in order to get the large effective shunt impedance per unit length, we have studied the behavior of the proton beam in the designed structure. The final design will be determined after optimizing the linac and considering the MEBT system positioned before the new accelerator for the beam matching.

Keywords: PEFP, linac, proton accelerator, beam dynamics

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INTRODUCTION

One of the important goals of PEFP[1] launched in 2002 is the construction of the 100MeV, 20mA proton linac. In the first phase completed in the next year, a 20MeV linac including an injector, a 3MeV RFQ, and 20MeV DTL(DTL1) will be installed and tested. The injector has been installed and used for the beam test of the following accelerators. The RFQ has been also installed and begun to beam test after tuning. The first tank of DTL will be delivered at the end of this year.

The next accelerating structure is the DTL up to 60MeV. After this energy we are considering two options. One is extending the DTL and the other is using the superconducting structure. Now the design study of the accelerator is under progress. Since PEFP has a plan to supply proton beams of 20MeV to the user group, a beam extraction system has to be installed after the 20MeV DTL. As a part of the system, two quadrupole magnets and a 45 degree bending magnet will be installed on the beam path between the accelerating structures. Since the beam properties become worse after going through the system, a medium energy beam transport (MEBT) system is an essential element to match the output beam of the 20MeV DTL into the new structure.

This work is related with the beam dynamics study of the 60MeV DTL(DTL2). At the first stage we have used the ideal input beam generated by the rms matching process using TRACE3D[2]. We have also studied the beam dynamics using the MEBT output beam whose input beam is the simulated output beam of the 20MeV DTL. The preliminary design of the MEBT is also included in this report. We have compared the beam dynamics results through the DTL2 depending on the matching schemes between the RFQ and DTL1.

BASIC DESIGN

The RF frequency remains to be 350MHz. The length of each tank is less than 5m. The tank geometry for DTL2 is same as for DTL1 except the bore radius and face angle. The bore radius is changed to be 12mm from 7mm for DTL1. The face angle is optimized to give as large effective shunt impedance per unit length(ZTT) as possible under the constraints to give the sufficient space for the focusing magnet in the drift tubes. Figure 1 shows the resulting ZTT as a function

Figure 1. ZTT for PEFP DTL2.
Table 1. Tank summary of PEFP DTL2.

<table>
<thead>
<tr>
<th>Tank</th>
<th>Cell #</th>
<th>Energy (MeV)</th>
<th>Length (cm)</th>
<th>Beam power (kW)</th>
<th>Cu Power (kW)</th>
<th>Total power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26</td>
<td>24.6</td>
<td>476.6</td>
<td>92.4</td>
<td>127.8</td>
<td>220.2</td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td>29.2</td>
<td>481.6</td>
<td>91.7</td>
<td>129.3</td>
<td>221.0</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>33.6</td>
<td>475.6</td>
<td>88.8</td>
<td>137.9</td>
<td>216.7</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>38.1</td>
<td>483.3</td>
<td>88.5</td>
<td>130.3</td>
<td>218.8</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>42.4</td>
<td>486.1</td>
<td>87.3</td>
<td>131.4</td>
<td>218.7</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
<td>46.7</td>
<td>484.4</td>
<td>85.4</td>
<td>131.4</td>
<td>216.8</td>
</tr>
<tr>
<td>7</td>
<td>18</td>
<td>50.8</td>
<td>478.6</td>
<td>82.3</td>
<td>130.2</td>
<td>212.5</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
<td>55.1</td>
<td>497.1</td>
<td>84.5</td>
<td>135.7</td>
<td>220.2</td>
</tr>
</tbody>
</table>

Table 2. MEBT parameters.

<table>
<thead>
<tr>
<th>Q01 (kG/cm)</th>
<th>Q02</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>B1 (MV)</th>
<th>B2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>-0.8</td>
<td>1.1</td>
<td>-2.2</td>
<td>2.3</td>
<td>-3.3</td>
<td>0.55</td>
<td>0.42</td>
</tr>
</tbody>
</table>

For the transverse beam matching between the RFQ and DTL1, we will use the first four quadrupole magnets in the first DTL1 tank as the transverse matching equipment. We have considered the two options for the longitudinal matching. One is using a buncher cavity and the other is no matching. Figure 4 shows the emittance behavior under the two options in the transverse and longitudinal directions. The longitudinal emittances are increased about 10% and 50% for with and without longitudinal matching.

Figure 2. Schematic plot of PEFP MEBT.

Figure 3. TRACE3D Result for PEFP MEBT.

Figure 4. Transverse and Longitudinal emittances in DTL1.
conditions, respectively. At present the latter option is adopted for the PEFP linac operation and the results in this report are based on the condition. For the beam dynamics simulation we have used the PARMILA code[3]. Figure 5 represents the output beam of the DTL1 which will be directly used for the following simulation. The particle number is 9832 reflecting the fact that the transmission rate of the RFQ is 98.3% with the input particle number of 10000.

![Figure 5. The Output Beam of PEFP DTL1.](image1)

Figure 5. The Output Beam of PEFP DTL1.

Figure 6 Full and RMS Beam size in PEFP DTL2.

![Figure 6. Full and RMS Beam size in PEFP DTL2.](image2)

The maximum and rms beam sizes in the DTL2 are given in Figure 6 where the large initial beam is in the MEBT system. It shows the matching is not perfect. Figure 7 shows the output beam of the DTL2. There are some tails in the longitudinal phase plot. The longitudinal and transverse emittance behaviors in the DTL2 are given in Figure 8. The transverse emittance increases in the first tank and become stabilized. The emittances grow about 10% in both directions.

Figure 7. The Output Beam of DTL2.

![Figure 7. The Output Beam of DTL2.](image3)

SUMMARY

We have studied the beam dynamics in order to design PEFP DTL2 which accelerate proton beam of 20mA from 20MeV to 60MeV. In order to match the beam into the new structure we will install a MEBT system consisting of two buncher cavities and four quadrupole magnets. This work is a preliminary result for the beam dynamics design and we have to optimize the design parameters.

ACKNOWLEDGMENTS

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REFERENCES