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Beam Dynamics Design of the PEFP 60 MeV DTL

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1. Introduction

The accelerating structure after PEFP 20 MeV accelerator has been designed to be another DTL(drift tube linac). It will be able to accelerate 20 mA proton beams from 20 MeV to 60 MeV. The structures of the linac can be independent of the previous DTL since the MEBT(medium energy beam transport)[1] can be used to match the 20 MeV output beam into the new DTL tanks. This brief report summarizes the beam dynamics design of the new linac.

2. Geometric parameters

The accelerating efficiency of a DTL cavity is determined by a lot of parameters such as tank diameter, DT(drift tube) diameter, gap distance, bore radius, corner radius, inner and outer corner radii, flat length, stem diameter, and face angle(Fig. 1).

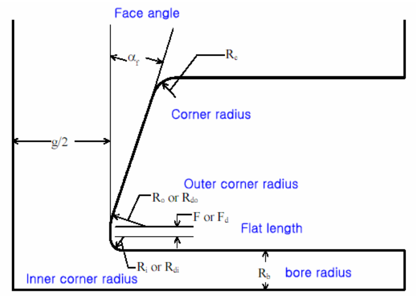

Figure 1. DT geometry determining the accelerating efficiency.

The effective shunt impedance per unit length representing the accelerating efficiency is given by

$$ZTT = \frac{V_0 T^2}{P}$$

where parameters V_0, T, and P are the accelerating voltage, transit time factor, and power loss in the cavity, respectively. The parameters are determined by the conditions to increase ZTT values, to minimize beam loss and to have sufficient space in order to install sub-components. For example, Figure 2 shows the variation of ZTT as a function of the beam energy under the various values of face angles. As the angle increases, the capacitance between the drift tubes becomes smaller and the resonant frequency of the cell reduced. In order to get the frequency of 350 MHz , the gap has to shrink and it results in the larger value of the transit time factor. Since the shunt impedance is proportional to the factor squared, the accelerating efficiency is enhanced. However the focusing magnets have to be installed in the drift tubes and the values of the face angle should be limited by the space for the magnets. We have chosen the face angle as 40 degrees. With similar considerations, we have obtained the optimized values of the basic parameters of the accelerator which are listed in Table 1. The lattice structure is selected to be FFDD and the integrated magnetic field is 1.75 T where the effective length is 75 mm. The tank diameter is determined to compensate the frequency shift by the stems, post-couplers, and slug tuners for the initial 4 tanks.

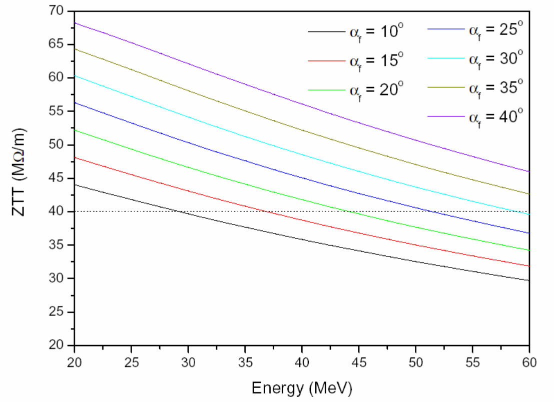

Figure 2. Face angle and ZTT as a function of beam energy.

Table 1. Basic parameters of the PEFP 60 MeV DTL.

Parameters	Values	
Tank diameter	547.73	mm
Drift tube diameter	135	mm
Bore radius	10	mm
Face angle	40	degrees
Stem diameter	38	mm
Corner radius	5	mm
Inner corner radius	2	mm
Outer corner radius	2	mm
Flat length	3	mm
Lattice	FFDD	
Integrated magnetic field	1.75	T

3. PEFP 60 MeV DTL

3.1 DTL tank geometry

After obtaining the basic geometry and the resulting effective shunt impedance per unit length, we have generated the geometrical structure of the DTL tanks using the PARMILA code developed at LANL[2]. We have also found that the number of klystrons is minimized if one klystron excites four DTL tanks under the condition that the length of each DTL tank is less than 5 m. In order to obtain the 60 MeV proton beam, we need 10 DTL tanks and 2.5 klystrons of 1MW. In practical operations, three klystrons will be used to excite 12 tanks. The characteristics of 60 MeV DTL tanks are summarized in Table 2.

Table 2. Summary of the PEFP 60 MeV DTL tanks

Tank	Cell number	Length (m)	Energy (MeV)	Power (KW)
1	26	4.77	24.74	227
2	24	4.83	29.45	228
3	22	4.78	34.01	223
4	21	4.86	38.56	225
5	20	4.89	43.04	225
6	19	4.88	47.41	223
7	18	4.82	51.66	219
8	18	5.01	55.98	227
9	17	4.90	60.28	218
10	16	4.82	64.38	211

3.2 Beam dynamics study

Because of a MEBT to be located between the 20 MeV DTL and new accelerating structure, it's possible to match the 20 MeV proton beam into the new DTL. Hence we have generated the matched input beams and used them in the following analysis. We have used the PARMILA code in this work.

Figure 3 shows the matched input beam in the trace space. Two upper plots represent the beam in the x-x' and y-y' spaces and the lower right one is the beam in the ΔW-$\Delta\phi$ space. The configuration plot of the beam in the x-y plane is given in lower left side of Figure 3. The propagation of the beam in the new DTL tanks is given in Figure 4 where the upper, middle, and lower plots are the behavior in x, y, $\Delta\phi$ directions as a function of the cell number. Figure 5 gives the emittances in the transverse and longitudinal directions.

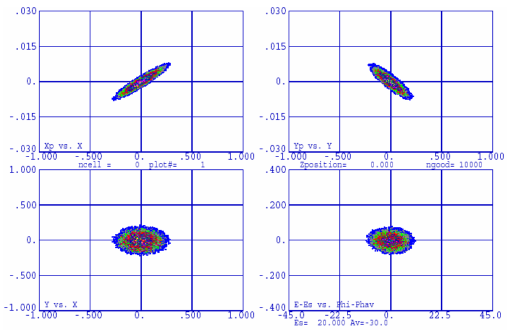

Figure 3. Matched input beam in the trace space

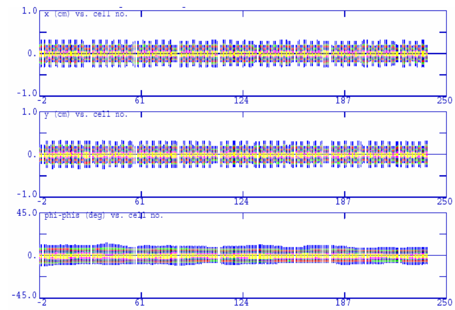

Figure 4. Configuration plot of the beam in the 60 MeV DTL.

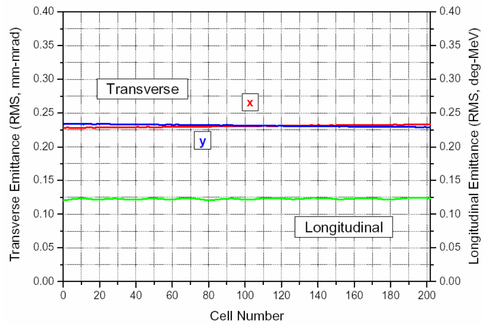

Figure 5. Emittances of the beam in the transverse and longitudinal directions.

4. Conclusion

In the second phase of the Proton Engineering Frontier Project, the 60 MeV DTL tank will be constructed. This work is related to the beam dynamics design of the tanks. After obtaining the optimized geometry of drift tubes, we have designed the DTL tanks and studied the beam dynamics in the new accelerating structures. Based on this work, we have completed the engineering design of the tanks and the first tank is under construction.

5. Acknowledgement

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REFERENCES

[1] J. H. Jang, Y. S. Cho, H. J. Kwon, and Y. H. Kim, "Design of the PEFP MEBT", PAC2005, Knoxville, Tennessee, USA.

[2] H. Takeda and J.H. Billen. "Parmila", LA-UR-98-4478, Revised August 13, 2002.