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55 MeV ENERGY DTL DESIGN AND OPTIMIZATION FOR TAC LINEAR PROTON ACCELERATOR

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Abstract. - The Turkish Accelerator Center (TAC) proposal is a national project and it's conceptual design report (CDR) was recently completed. It is planned that the Tecnical Design Report (TDR) of the TAC will have been written in the next three years. 1 GeV energy linear proton accelerator part of the TAC Project will be constructed before 2020. The proton linac consists of radio-frequency quadrupole linac (RFQ), drift tube linac (DTL) and coupled-cavity drift tube linac (CCDTL). In this study, 55 MeV energy DTL accelerator was designed and main parameters of the DTL accelerator was optimized by using simulation codes.

1. INTRODUCTION

For the low energy part of TAC proton accelerator, after an ion source, 3 MeV energy radio-frequency quadrupole linac (RFQ) and 55 MeV energy drift-tube linac (DTL) structures will be used [1,2]. In the RFQ structure, fundamentally three jobs are performed. These are acceleration, bunching and focusing of the ion beam simultaneously. The RFQ accelerator is followed by a medium energy beam transport (MEBT) line containing beam chopper system and some diagnostic elements [3]. In this transport line, bunch structure of the beam is changed and beam bunchs are chopped to microbunchs [4,5].

After the 55 MeV energy DTL accelerator, coupled-cavity drfit-tube linac (CCDTL) structure will be used. Rf frequency of the RFQ, DTL and CCDTL structures is 350 MHz. For high energy section of accelerator that contains coupled-cavity linac (CCL) or super conducting linac (SC), rf frequency will be chosen as 700 MHz.

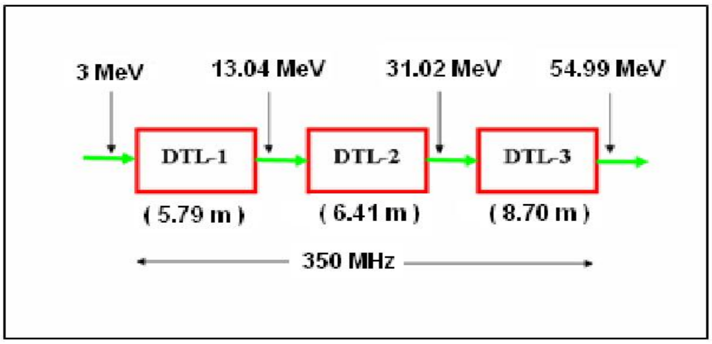

Figure 1: Block diagram of DTL accelerator

2. DTL structure and cavity design

DTL accelerator is an Alvarez type structure and is standard in medium–β structure [6]. The DTL structure operates in zero mode in which there is zero phase shift from cell to cell. For the cavity design, we used DTLfish code from SUPERFISH computer code group developed in the Los Alamos National Laboratory (LANL) [7]. The design of the DTL was started with 3 MeV of input energy and using three tanks, 55 MeV output energy was achieved (see Fig.1). The most fundamental parameters of a rf cavity are effective shunt impedance (ZTT) that measures the amount of accelerating field per unit power expended in the walls of cavity, transit time factor and quality factor of cavity. In the cavity design, maximum values of these parameters should be gotten. So, in the constant energy of 3 MeV that is starting energy of DTL, we optimized the geometrical parameters of cavity.

Firstly, frequency values between 300 MHz and 420 MHz were searched to determine resonant frequency of cavity. Figure 2 shows that effective shunt impedance (ZTT) and transit time factor (T) exhibit same behaviour. But for the ZTT curve, there is a maximum point at 350 MHz. Therefore, the 350 MHz value corresponding the peak value of effective shunt impedance was chosen as resonant frequency of cavity.

After rf resonant frequency, cavity diameter should be determined secondly. Sweeping diameter values between 40 and 60 cm, a peak point for effective shunt impedance was looked for. As seen than figure 3 the peak value of ZTT is achieved 54 cm cavity diameter. At this value, quality factor of cavity is quite high and power losses dissipated in the cavity walls have almost minimum.

Other geometrical parameters of the DTL cavity were similarly optimized at the input energy of 3 MeV. Table 1 lists these optimized parameters. After the input parameters were optimized, β–factor of beam was increased taking into account effective shunt impedance. The only parameter which change with β is drift tube face

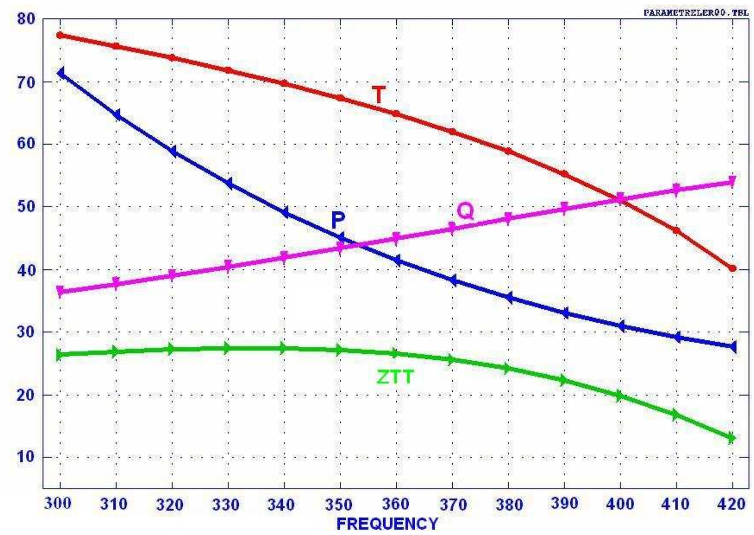

Figure 2: Effective shunt impedance (ZTT), quality factor (Q), transit-time factor and power losses in the cavity walls (P) versus resonant frequency for 3 MeV input energy

angle. The face angle was varied from 3 degree to 26 degrees to increase the effective shunt impedance in the tank 2.

3. DTL layout and beam dynamics

In the design of the DTL accelerator, cavity design is followed by beam dynamics simulations which determine other parameters and form the DTL layout. We used PARMILA code for beam dynamics simulations [8]. PARMILA uses data generated by the SUPERFISH computer code. DTL accelerator has three tanks with 131 accelerating gaps totally. The contour plots in figure 4 show electric fields in the half cells of the DTL cavity at 4.7 MeV, 24.7 MeV and 55.7 MeV respectively. Focusing lattice of quadrupol magnets is Focus-Focus-Empty-Defocus-Defocus-Empty (FFODDO). Transverse focusing period is $6\beta\lambda$ (cells are of length $\beta\lambda$). We have to allow enough room to install a quadrupole magnet inside the drift tube.

We chosen 8 cm as drift tube diameter which seemed to be adequate. Inside the drift tube, either electromagnet quadrupole (EMQ) or permanent magnet quadrupole (PMQ) will be used. For the electromagnet quadrupole, internal structure of drift tube is more complicated than the case of using a permanent magnet quadrupole. The synchronous phase changes from - 40^0 to - 25^0 through tank 1 and it is stable as - 25^0 in the tank 2 and tank 3. The Kilpatrick field is 18.39 MV/m at 350 MHz . As seen than table 2, all values are below 1.5 kilpatrick which shows that this is a quite conservative design.

Table 1: DTL design parameters

Parameters	Value	Unit
Frequency	350	MHz
Tank diameter	54	cm
Aperture radius	10	mm
Stem diameter	26	mm
Drift-tube diameter	80	mm
Corner radius	60	mm
Inner nose radius	1.5	mm
Outer nose radius	1.5	mm
Drift-tube face angle	3	degree

Table 2: DTL parameters for each tank

Parameters	Tank 1	Tank 2	Tank 3
Energy range[MeV]	3–13.04	13.04–31.02	31.02–54.99
Frequency[MHz]	350	350	350
Gradient E_0[MV/m]	1.13–3.61	3.6	3.8
Synchronous phase[deg]	–40/–25	–25	–25
Lattice	FFODDO	FFODDO	FFODDO
Number of cells	60	36	35
Aperture radius[mm]	10	10	10
Diameter[cm]	54	54	54
Drift tube diameter[mm]	80	80	80
Inter-tank spacing[mm]	41	47.6	–
Tank length[m]	5.79	6.41	8.7
Max.surface field[kilp.]	1.01/1.39	1.00/1.38	1.38/1.29
Peak rf power[MW]	0.72	1.45	2.11
Copper rf power[MW]	0.41	0.91	1.40
Quadrupole length[mm]	35	35	35
Quadrupole gradient[kG/cm]	3.6	3.6	3.6
Transit time factor	0.76–0.84	0.84	0.84–0.75

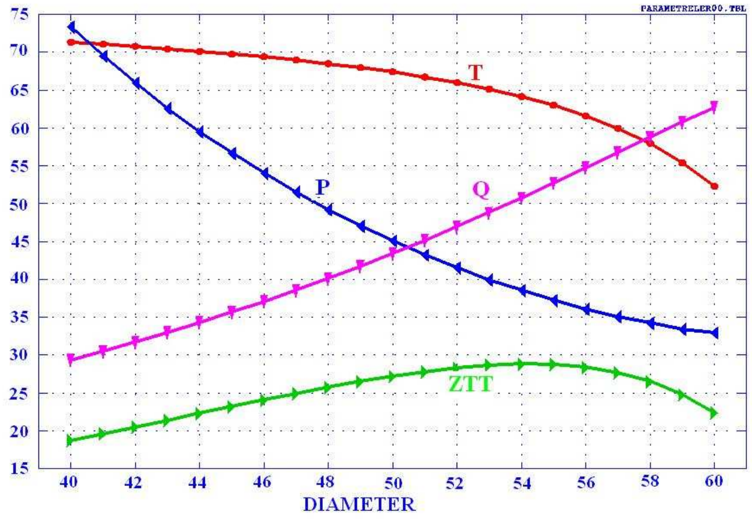

Figure 3: Effective shunt impedance (ZTT), quality factor (Q), transit-time factor and power losses in the cavity walls (P), versus cavity diameter for 3 MeV input energy

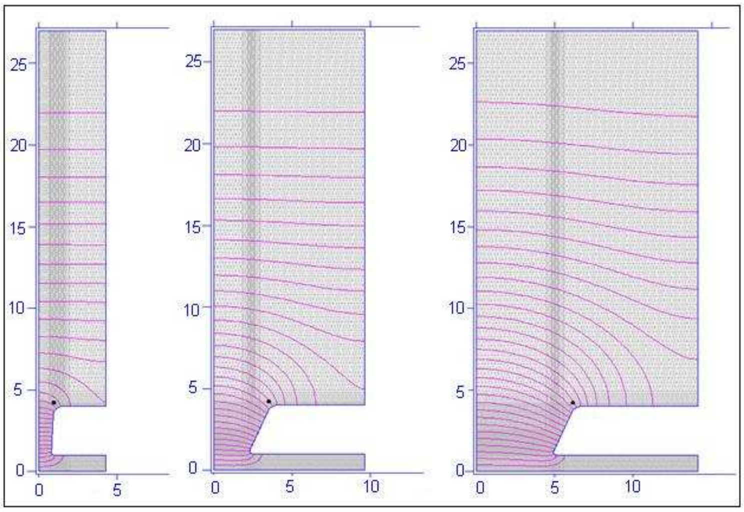

Figure 4: Half cell of DTL and electric field lines at 4.7 MeV, 24.7 MeV and 55.7 MeV respectively

Beam dynamics simulations are done with 10000 particles. Results from the simulations indicated that low emittance growth and good beam quality can be achieved

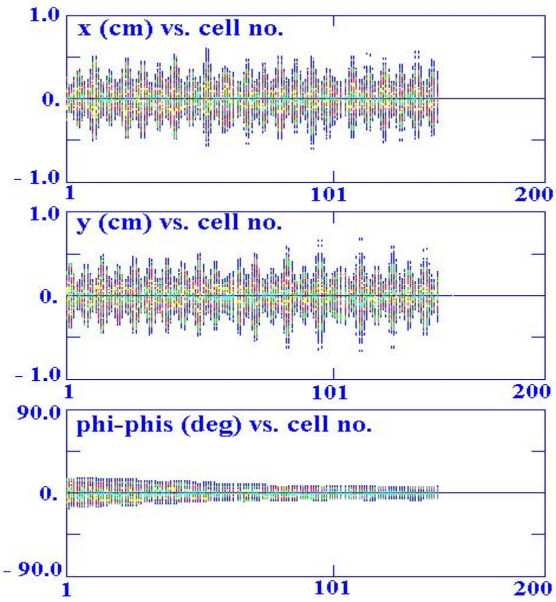

Figure 5: X and Y beam profile and phase profile along accelerator

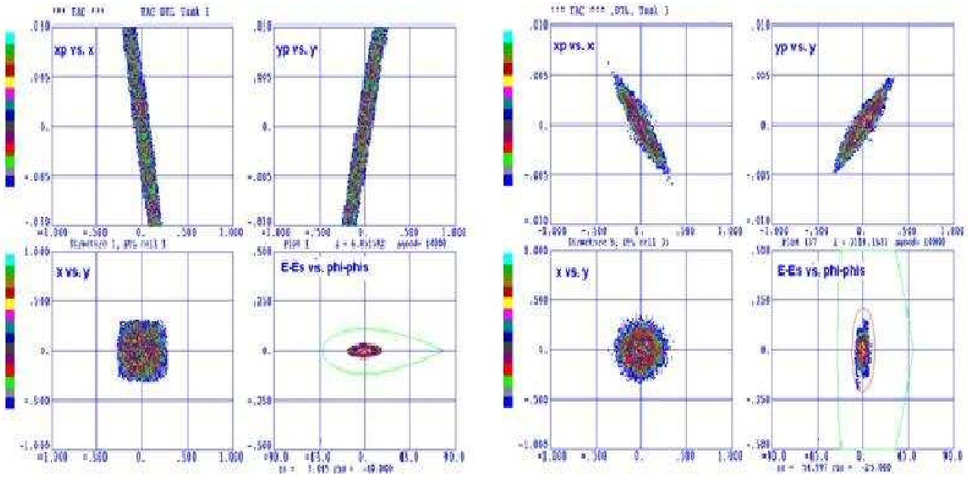

Figure 6: Input (left) and output (right) beam distributions of DTL accelerator with 10000 particles

with these parameters. Figure 5 shows x , y beam profile and phase profile through accelerator. Figure 6 shows input and output beam distributions of designed DTL accelerator. These distributions consist of x-x' and y-y'phase space, named transverse emittances, x-y real space and energy-phase space named longitudinal emittance.

4. Conclusions

We studied a 55 MeV energy DTL as the preaccelerator for TAC proton accelerator. It is shown that there is not extreme deviation in x and y directions and that deviation in the phase space is gradually decreased. The beam dynamics results are acceptable because low emittance growth was achieved. Our future works are to achieve 100 MeV energy using CCDTL structure for the TAC-PA test facility. We will have achieved 1 GeV enery using additional structures consist of CCL or SC and optimized parameters of these new accelerator structures in the next stage.

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