BALKAN PHYSICS LETTERS

1 October 2006
BPL, **14** (4), pp. 135 - 143 (2006)

100 MeV ENERGY DTL DESIGN FOR TAC LINEAR PROTON ACCELERATOR

A. ÇALIŞKAN , M. YILMAZ,
Gazi University, Arts and Sciences Faculty, 06500 Beşevler, Ankara, TURKEY

Abstract

Conceptual Design Report of the Turkic Accelerator Center (TAC) proposal was recently completed. It is planned that the Tecnical Design Report of the TAC will have been written in the next three years. 1-5 GeV proton accelerator part of the Turkic Accelerator Center (TAC) project will be constructed in the next stage. The proton linac as a preaccelerator consists of radio-frequency quadrupole linac (RFQ), drift tube linac (DTL) and coupled-cavity drift tube linac (CCDTL). In this study, a DTL accelelator was designed by using simulation codes. It is shown that the energy of the DTL can be extended up to 100 MeV.

1. INTRODUCTION

A few GeV linear proton accelerator will form an important part of Turkic Accelerator Complex (TAC) [1]-[3]. The purpose of this proton accelerator is to provide high-intensity proton beam and to produce secondary muon and neutron beams. Muon and Neutron area which include a lot of experimental stations will be formed by using muon and neutron beams respectively. In these stations, a wide spectrum of applied research is planned that comprise muon spin resonance (μSR) technique, muon catalysed fusion (μCF), muonium-antimuonium oscilations etc. for muon area [4] and investigations in different fields of applied physics, fundamental physics, molecular biology, engineering et cetera for neutron area [5], [6].

Low and medium energy part of linear accelerator comprises normal conduction linac consists of a few keV ion source (IS), 3-5 MeV radio-frequency quadrupole linac (RFQ), a 50-100 MeV drift tube linac (DTL) and a 100-300 MeV coupled-cavity drift tube linac (CCDTL) [7]. It will be decided in next years that whether superconducting cavities are used. The schematic block diagram of proton accelerator is given in Fig. 1.

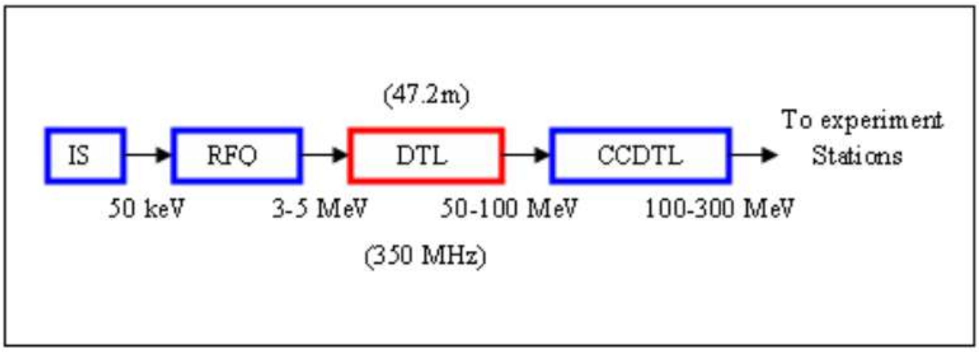

Figure 1: Block diagram of TAC proton linac.

2. RFQ STRUCTURE

In the linear accelerators, RFQ structure is generally chosen for low energy section. RFQ section of TAC proton linac accelerates protons from 50 keV to 3-5 MeV. RFQ and other structures realize three fundamental tasks. These are bunching, focusing and accelerating of beams. The focusing of beam is made with quadrupol magnets. Acceleration, basic task of an accelerator, is realized by using rf fields on charged particles.

3. DESIGN OF THE DTL

DTL structure, known as Alvarez accelerator, accelerates 3-5 MeV beam from RFQ to 50-100 MeV. In this study, 100 MeV proton linear accelerator has been designed by using SUPERFISH code [8]. The beam-dynamics simulation was studied using PARMILA code [9]. The geometrical shape of DTL accelerator is presented in Fig. 2.

The DTL consists of several resonant cavities or tanks and each tank contains a series of symmetrical cells. Quadrupol magnets are in the cavities and after the electric field voltage was applied, beam was focused by this magnets.

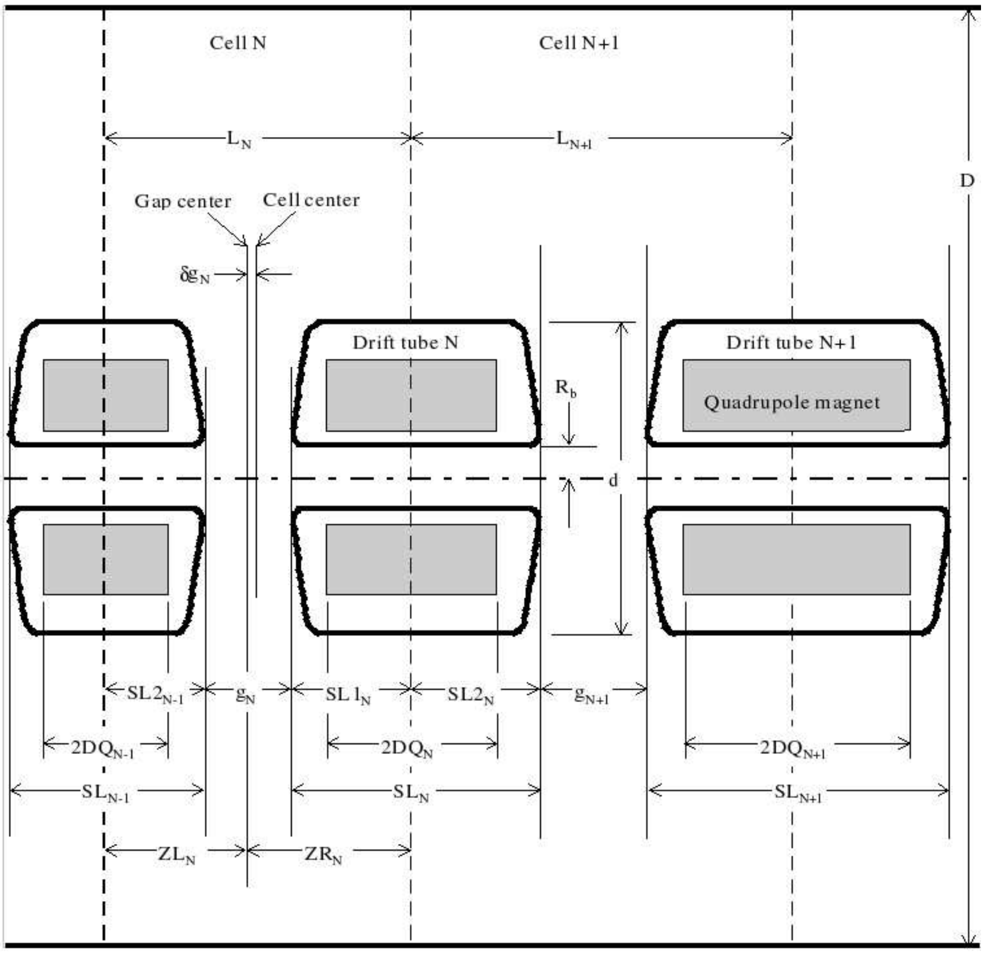

Figure 2: Drift-tube linac (DTL) cell geometry.

3.1 Cavity design with SUPERFISH code

SUPERFISH codes developed in the Los Alamos National Laboratory sets up half the symmetrical cell. The symmetry plane is in the gap center between the two drift-tube noses. The SUPERFISH code distribution includes several programs for automatically tuning accelerating cavities. The programs include DTLfish, CCLfish, RFQfish, SCCfish etc. Fig. 3 shows The DTL half cell set up by the code DTLfish and some parameters used.

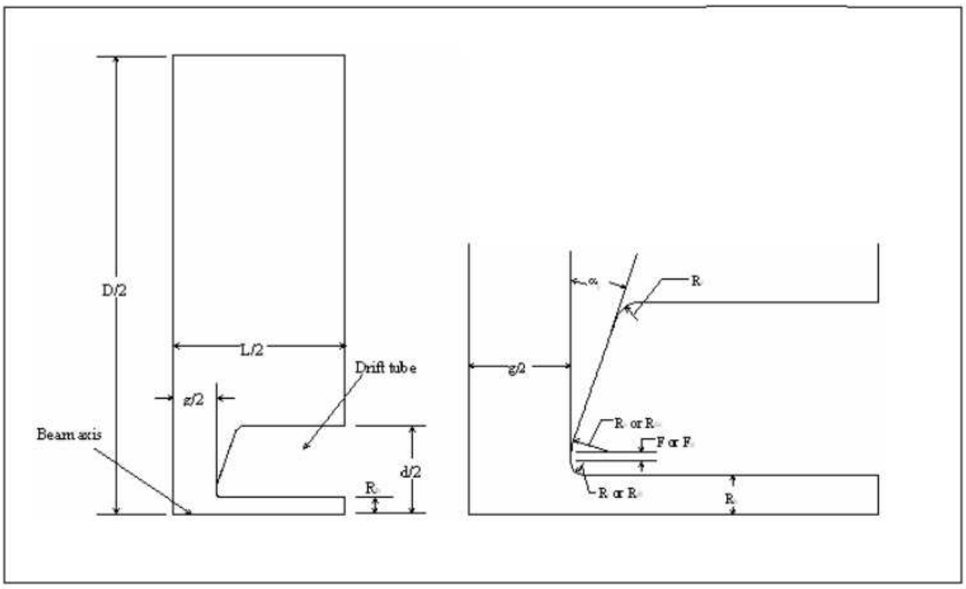

Figure 3: The DTL half cell (left) and detail near the drift-tube nose (right).

For our simulation study, proposed parameters are given in Table 1. The rf field distribution has been computed for 44 cells at different energies. Fig. 4 shows the half cell shape at the $\beta = 0.24$ from the DTLfish code.

Table 1: DTL design parameters for DTLfish code.

Parameter	Value
Frequency (MHz)	350
Cavity diameter (cm)	50
Drift-tube diameter (cm)	12
Corner radius (cm)	0.55
Inner nose radius (cm)	0.2
Outer nose radius (cm)	0.46
Bore radius (cm)	1
Drift-tube face angle	3
Drift-tube flat length (cm)	0.04

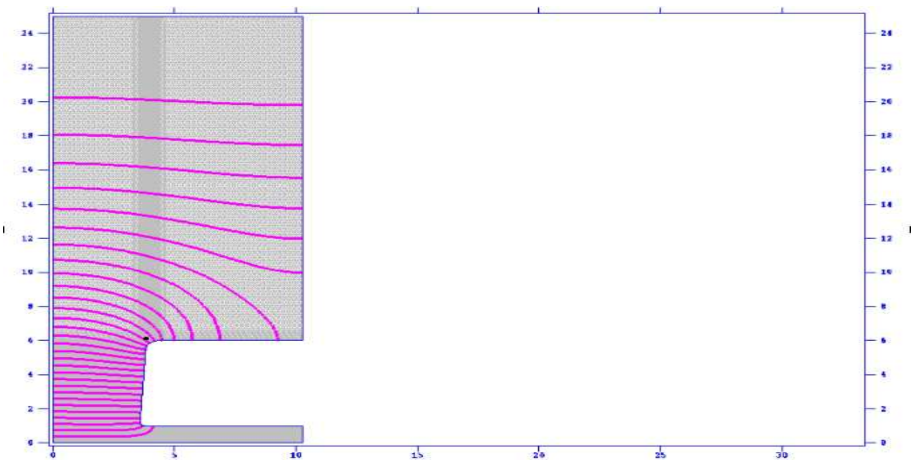

Figure 4: DTL cell geometry and electric field lines for $\beta = 0.2$.

3.2 Beam dynamics simulation with PARMILA code

The beam dynamics of the beam line was studied using PARMILA is an ion-linac particle-dynamics code and the name comes from the phrase, Phase and Radial Motion in Ion Linear Accelerators. It perfoms two tasks in general. First, it generates a linac by means of the SUPERFISH code and it transports particles through the linac secondly.

Recently, 75 MeV DTL accelerator was designed and simulated for TAC proton linac [10]. This study includes 100 MeV DTL design. The design frequency has been chosen 350 MHz and beam current is 30 mA. The details of design are shown in Table 2.

Table 1: Parameters of the 100 MeV TAC-DTL .

Tank number	1	2	3	4	5
Injection energy (MeV)	2.5	12.37	36.81	61.07	80.70
Output energy (MeV)	12.37	36.81	61.07	80.70	100.70
Length (m)	7.06	11.08	10.83	9.12	9.12
Number of cell	78	60	41	29	26
Total rf power (MW)	0.91	2.6	2.7	2.3	2.6
Accel. field (MV/m)	1-3	3-3.6	3.6	3.6	3.8
Transit-time factor	0.7-0.8	0.8-0.7	0.7	0.7-0.6	0.6
Quad.gradient (kG/cm)	3.5	3.5	3.5	3.5	3.5
Quad. length (cm)	3.5	3.5	3.5	3.5	3.5

In the beam dynamics, emittance is an important quantity that is area of the phase-space elipse such as x-x′ and y-y′. According to the Liouville's theorem this area is preserved. The scattering of beam particles by interactions with the residual gas in the vacuum chamber will lead to emittance growth and beam loss. Also, space-charge effect among charged particles causes emittance growth. Because of the these reasons, it is important to control emittance growth of beam along accelerator.

The results of simulation for DTL are shown in Fig. 6. In the figure, emittances in the space of x-x′ and y-y′, real beam distribution on x-y plane and energy-phase diagram are shown at entrance and exit of 100 MeV DTL. Besides, Fig. 5 shows x, y and phase beam profiles and Fig. 7 shows x′, y′ beam profiles and energy spread.

4. CONCLUSION

A 350 MHz and 100 MeV DTL has been designed for TAC proton linear accelerator. It is shown that proton beam can be accelerated from 2.5 MeV to 100 MeV. Simulation results show that there is no extreme emittance growth. On the contrary, particle distribution at the end of DTL is quite acceptable (see Fig. 6).

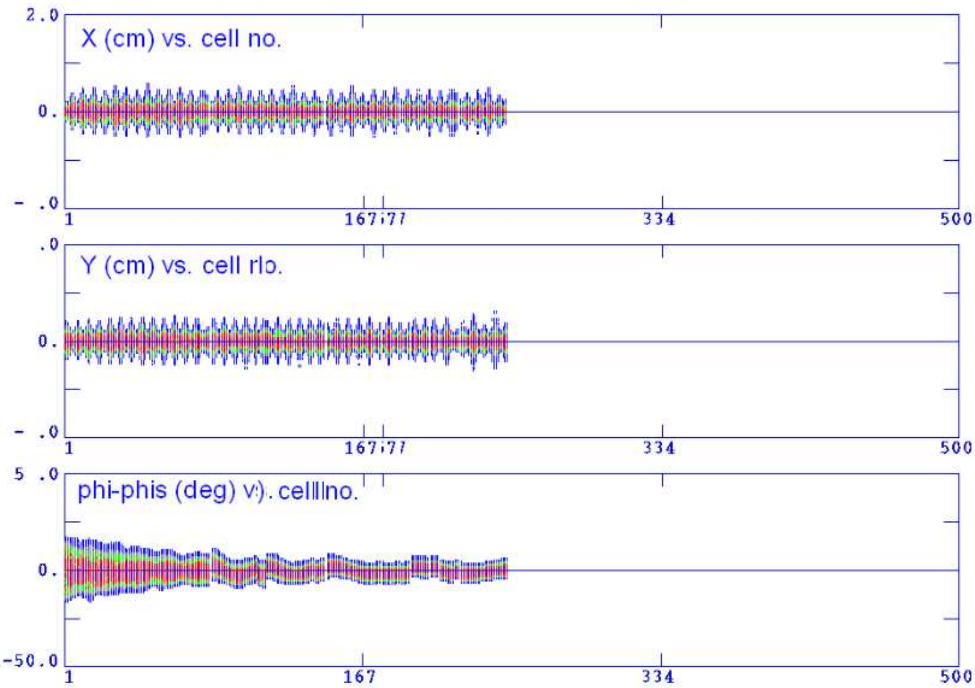

Figure 5: X (upper) and Y (middle) beam profiles for DTL and phase profile (lower) along accelerator.

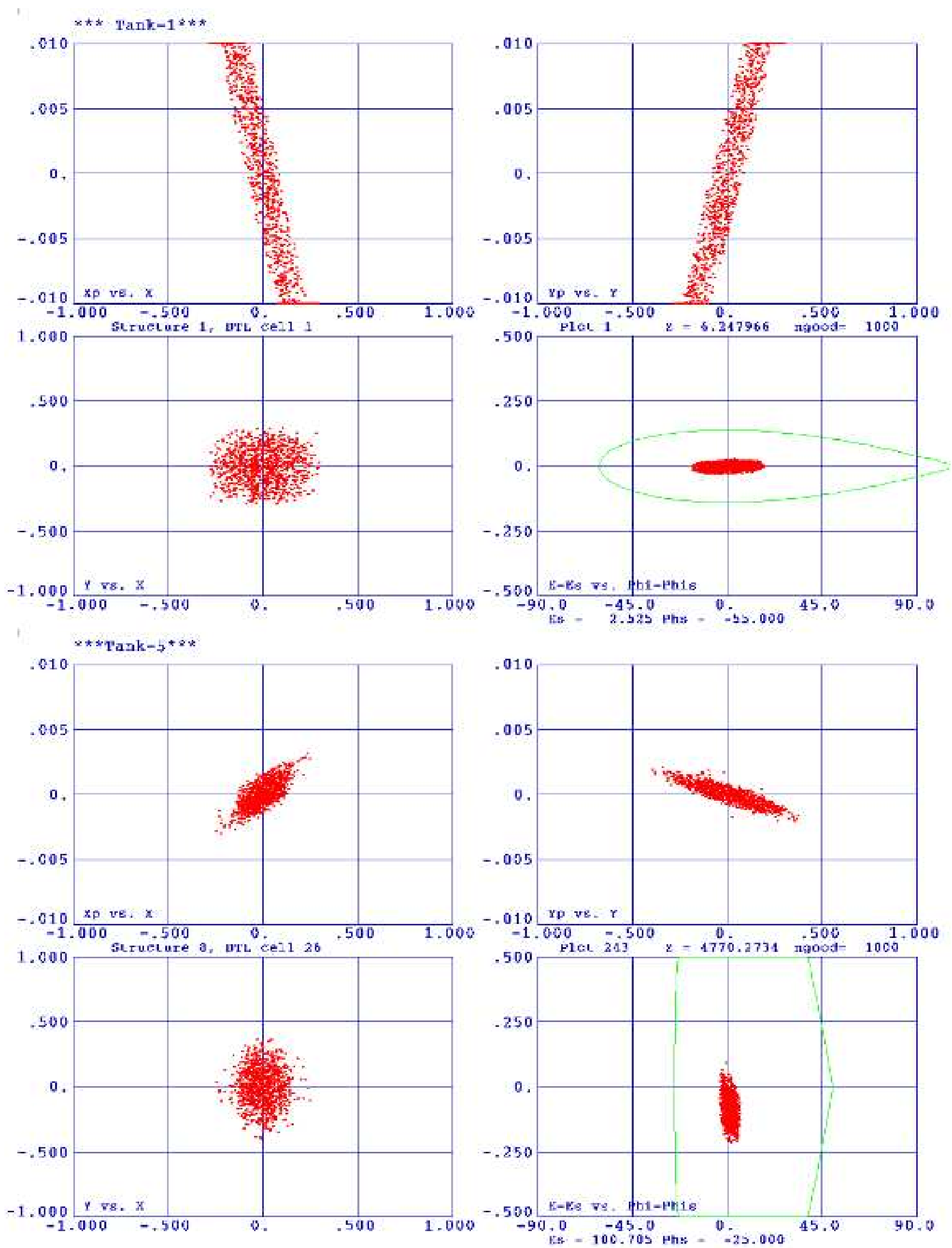

Figure 6: Phase space of the beam at the entrance (first four) and exit (last four) of 100 DTL.

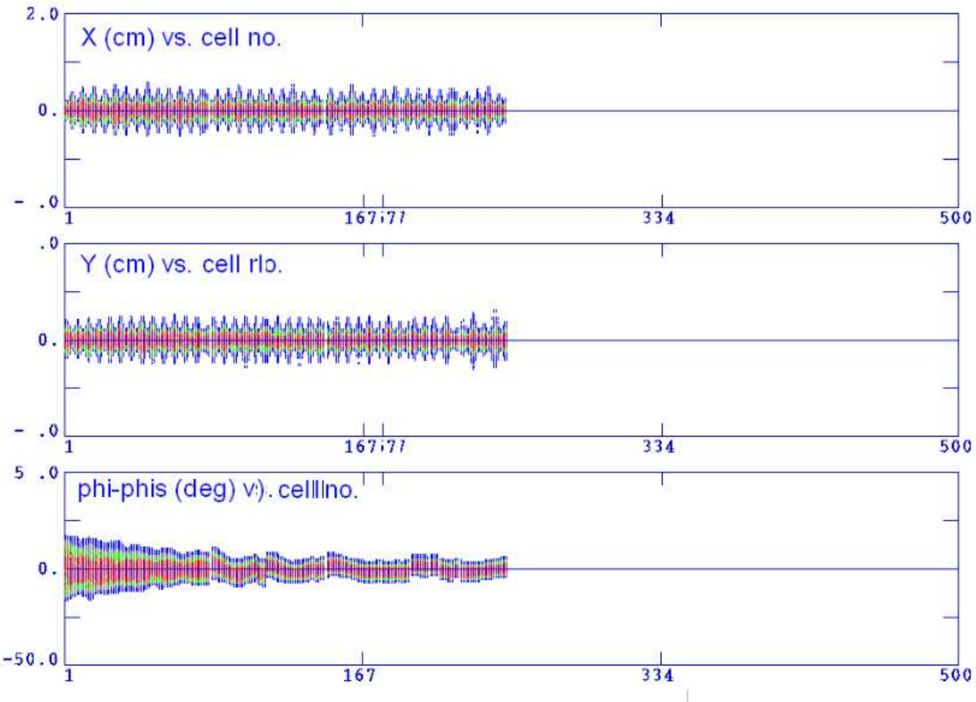

Figure 7: X′, Y′ beam profiles (up) and energy spread (bottom).

Acknowledgement. - This work is supported by Turkish State Planning Organization(DPT) under the Grants No DPT-2006K120470. Besides, we wish to thank Prof.Dr. Saleh SULTANSOY for valuable contributions.

REFERENCES

[1] Sultansoy, S., Yılmaz, M., Çakır, O., Çiftçi, A.K., Recepoğlu, E., Yavaş, Ö., The Status of Turkic Accelerator Complex Proposal, Proceedings of the Particle Accelerator Conference (PAC05), pp.449-551, Knoxville, Tennessee, USA, 2005.

[2] Sultansoy, S., Regional Project for Elementary Particle Physics: Linac-Ring Type c-τ-factory, Turkish Journal of Physics, **17**, 591, 1993.

[3] http://bilge.science.ankara.edu.tr

[4] Çalışkan, A., Proton Synchrotron and muon region applications, M.Sc.Thesis, Gazi Univ. Sci. and Tech. Inst., Ankara, Turkey, 2005.

[5] Eker, N., Proton Synchrotron and neutron region applications, M.Sc.Thesis, Gazi Univ. Sci. and Tech. Inst., Ankara, Turkey, 2005.

[6] Çiftçi, A.K., Gürkan, O., Olgar, T., Recepoğlu, E., Sultansoy, S., Yavaş, Ö., Yılmaz, M., Turkish Journal of Physics, **24**, 747, 2000.

[7] Akkuş, B., Bilgin, P.S., Çalışkan, A., Sultansoy, S, Yılmaz, M., Present Status of the TAC Proton Accelerator Proposal, 6. Int. Conf. of the Balkan Physics Union (BPU-06), Book of Abstracts, p.689, 22-26 August, İstanbul, Turkey, 2006.

[8] Bilen, J.H., Young, L.M., Poisson Superfish, Los Alamos National Laboratory document, LA-UR-96-1834, Rev. June 28, 2005.

[9] Takeda, H., Parmila, Los Alamos National Laboratory document, LA-UR-98-4478, Rev. July 26, 2005.

[10] Çalışkan, A, Yılmaz, M., DTL simulation for LINAC Alternative of TAC Proton Accelerator, unpublished.