

TAC PROTON ACCELERATOR FACILITY: NORMAL CONDUCTING PART*

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Abstract

The Turkish Accelerator Center Proton Accelerator Facility (TAC PAF) is based on a 1 MW and 2-GeV proton linac that will include both normal conducting and superconducting accelerator structures. The normal conducting part of the TAC PAF will consist of an ion source, a low energy beam transport line, a radio frequency quadrupole, a medium energy beam transport line, and two drift tube linac structures in order to accelerate the beam up to 65 MeV. Acceleration from 65 MeV up to 2-GeV energy will be provided by a SC-spoke cavity and two SC-elliptical cavities. In the long term, TAC PAF will be used as a neutron source. We report the current status of the project including accelerator structures, ion source studies, and possible experimental stations.

INTRODUCTION

Turkish Accelerator Center (TAC) project is supported by Ministry of Development of Turkey and coordinated by Ankara University [1]. After feasibility and conceptual design studies, third phase of the project started in 2006 as an inter-universities project. The main scientific goal was to establish an Infrared Free Electron Laser (IR FEL) facility, named as Turkish Accelerator and Radiation Laboratory at Ankara (TARLA) as a first step [2]. At the same time four other facility plans had started during this phase. One of which is TAC Proton Accelerator Facility (TAC PAF) project.

The purpose of TAC PAF is to build a MW-class proton accelerator with 2-GeV final energy. Several experimental stations along the proton linac are planned to make use of the proton beam in various applications including condensed-matter, material, medicine, biology, geology, irradiation, radiography, space, etc. At the final energy the proton beam could serve as a neutron source.

Turkey suffers from lack of neutrons in the context of research and development. Therefore, this project is expected to establish a neutron community and to provide a multidisciplinary platform for national institutions, universities, and industries.

Project team is formed of 40 people, half of which being graduate students. Presently, the project team is responsible for the design of the normal conducting components, R&D of accelerator, and environmental protection. Due to limited budget, some of the

accelerating components will be built in-house. This procedure will also provide experience. Students have been trained at various laboratories on different accelerator components including ion source, linac and cavity design, and beam dynamics studies.

FACILITY LAYOUT AND DESIGN

The TAC-PAF parameters and layout of experimental stations have been modified in order to simplify the LINAC design, to meet the demand from users and to increase reliability by comparing the originally proposed design (1 MW, 1 GeV, 30-40 mA) [3]. A revised layout for the linear proton accelerator is shown in Figure 1. Its main features if compared to the present TAC-PAF design are: The negative hydrogen ion source considered earlier was replaced by a proton source. This would simplify the source design and avoid beam loss. Linear proton accelerator with low energy as a front end is comprised of an ion source with 45 keV energy and 30-40 mA average current, low energy beam transport line (LEBT), 3-MeV radio-frequency quadrupole linac (RFQ). The RFQ accelerator is followed by a medium energy beam transport (MEBT) line and some diagnostic elements. The proton beam of 3 MeV will be accelerated to 65-MeV energy by two drift-tubes (DTL). The first superconducting section contains spoke cavities that take the 65 MeV beam to 150 MeV. Beyond this, the first superconducting elliptical cavities will take the beam to 250 MeV and the second to the full energy of 2 GeV.

The project is divided into phases, and it is proposed to define two construction stages – a Low Energy (PAF-LE) stage to 65 MeV and a second stage to the full energy (PAF-HE). Low energy stage (65 MeV) of the project has higher priority in the sense of feasibility. Therefore, all efforts have been concentrated on this part. A project proposal for Ministry of Development has recently been considered only for this normal conducting linac, excluding the overall target of the project, i.e. a final 2-GeV proton accelerator.

The ion source of TAC PAF will be a microwave discharge ion source. The project team has started an experimental program on microwave ion source that has no external magnetic field ($B=0$). This ion source was already studied elsewhere [4]. Here, the extraction electrode design is changed from the previous study [4].

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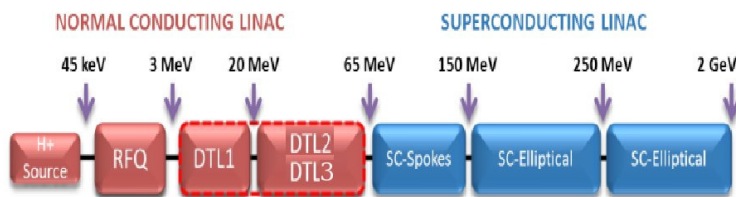


Figure 1: A general layout of the TAC-PAF.

Custom made rectangular waveguide is manufactured from iron and covered with aluminum to prevent sparks. Its dimensions are 45 mm width and 93 mm height with a 1.7 GHz cut off frequency for TE₁₀ mode. A magnetron with 2.45 GHz frequency and 700 watt output power is taken from a commercial microwave oven and used for this study. Plasma chamber is made from Pyrex glass to endure heat. Plasma chamber is placed a distance of $n\lambda_g/4$ from the magnetron part of waveguide as shown in Fig. 2. We used two-electrode extraction system. Schematic view of extraction part is shown in Fig. 3. Experimental setup is given in Fig. 4. The diameter of the plasma electrode is 5 mm and ground electrode is 7 mm [5]. Electrodes are made from duraluminum due to its easy manufacture. In future experiments, electrode material will be replaced with other materials. Two vacuum pumps are connected in series at extraction region. The first pump is connected between the plasma electrode and ground electrode, and the second pump is connected between ground electrode and the faraday cup to prevent dc discharge (Fig. 3.). If dc discharge is formed between ground electrode and faraday cup, beam current measurements becomes too high and we need to prevent it for an accurate measurement. An 8.5 μ A of beam current is measured after 8 cm distance from plasma chamber at approximately 1 kV extraction potential under 0.8 – 1 mbar vacuum. The current is measured at the copper faraday cup that has no suppressor for electrons. Our ordered faraday cup has not arrived yet; therefore we infer that the beam current is measured more than its actual value. Additionally maximum extractable current is calculated by using Child-Langmuir Law and found as 59 μ A. Theoretical values is higher than our measurement results. System optimization studies related with electrode design and current measurement will continue in the following days.

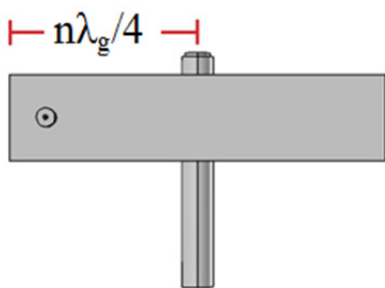


Figure 2: Plasma chamber location.

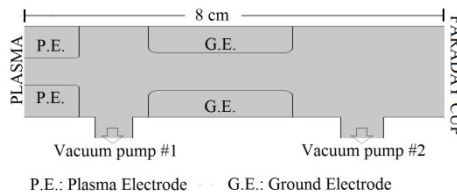


Figure 3: Extraction part schematic view.

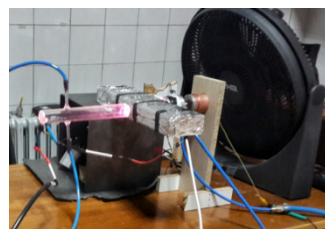


Figure 4: Experimental setup.

The protons from the ion source are then transported through a Low Energy Beam Transport (LEBT) section to the Radio Frequency Quadrupole (RFQ) where the protons are bunched and accelerated up to 3 MeV. The RFQ operates at 352.2 MHz, is 3.454 m long.

The preliminary design of DTL structure to operate at 352.21 MHz for TAC PAF has been studied. Following RFQ, three Alvarez DTL tanks at 352.2 MHz accelerate the beam up to 65 MeV. The DTL is predominately comprised of a series of 3 DTL tanks. The codes SUPERFISH and PARMILA were used for the electromagnetic and the tank design, respectively. During the electromagnetic design, geometry of the DTL cells were optimized to maximize the cavity figure of merits such as shunt impedance (Z), effective shunt impedance (ZTT), and transit time factor (T). The design parameters of DTL structure was given elsewhere [6]. The main parameters for RFQ and DTL are shown in Table 1.

Table 1: Parameters of the 65 MeV Linac

Parameters	RFQ	DTL
Output energy (MeV)	3	65.2
Frequency (MHz)	352.2	352.2
Total length (m)	3.45	27.9
Number of tanks	1	3
Number of cells		149
Beam power (MW)	0.086	
Total power dissipation (MW)	0.44	3.21

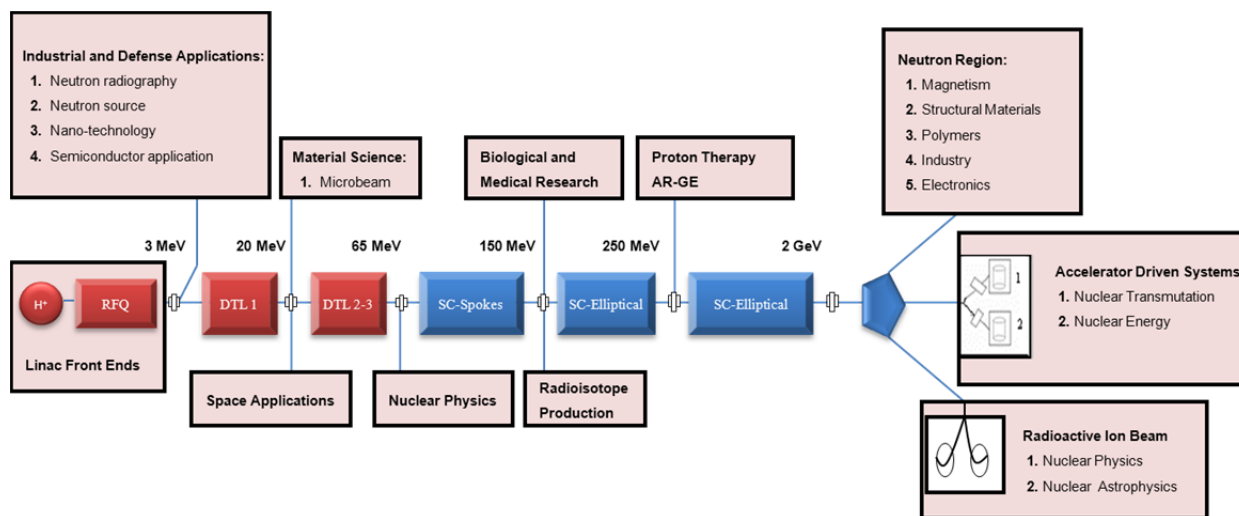


Figure 5: A revised layout of TAC-PAF experimental stations.

R&D

The first demand survey for proton user facilities had been fulfilled during the period from March 28th to May 6th, 2012. After this demand survey, a workshop named “Workshop on Turkish Accelerator Center Proton Accelerator Facility - Machine and Research Potential” was performed between May 7th and May 8th, 2012. A new linac and experimental stations of TAC PAF were introduced after this user workshop as shown in Figure 5.

In Turkey, one low current proton beam accelerator (cyclotron) has recently been started operating by Turkish Atomic Energy Authority (TAEA). A National Proton Accelerator Workshop was then organized by Ankara University and TAEA on April 18–19, 2013 in SANAEM (Ankara) with the objectives of defining a road map for potential usage of TAEA PAF and TAC PAF for R&D applications. The number of participants was about 80. In this workshop, material science and space applications had come to the forefront. In this workshop, we have also taken the decision of collaborating with TAEA Proton Accelerator facility team on the design and engineering of the accelerator.

Major beam utilization areas are nanotechnology, material science, semiconductor applications, space applications, medical research. In addition, there are several small research projects concerned with basic science and nuclear physics. In the long term, 2-GeV proton beam will be used as a neutron source. That will also make possible research studies on waste transmutation and accelerator driven systems.

An international network of collaborations is crucial to provide expertise for TAC PAF. Two research collaboration agreements have recently been established with ESS and INFN-LNS. These include accelerator technologies, beam transport and beam dynamics calculations, research and development relating to ion source and LEPT studies.

CONCLUSIONS

Demand survey and two workshops for user facilities have been carried out, and on the basis of its result, a layout on user facilities has been established. At the current phase of the project, only normal conducting part is considered; efforts are directed to produce a prototype of a microwave discharge ion source. Along with the ion source studies, technical design simulations on LEPT, RFQ, and DTL have been under development. In addition, radiation protection is also considered as a work package.

Once completed, TAC PAF will provide significant new opportunities in many areas for science, technology, and industry.

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