Abstract

We highlight some of the results of an ongoing program at the National Atomic Energy Commission (CNEA) in Argentina to develop low energy (0.2 to 2.5 MeV), high current (30-100 mA) proton and deuteron electrostatic accelerators for nuclear and medical applications. This activity aims at developing: 1) Low-energy (200 keV) high-current (100 mA) deuteron accelerators for D(d,n) and T(d,n) for neutron production for various nuclear applications, among them the injection of a subcritical reactor. 2) The development of a 700 kV folded tandem for neutron production using the 9Be(d,n) reaction. 3) The development of a folded 1.2-1.4 MV tandem for epithermal neutron production through the 7Li(p, n) reaction. At the same time this machine can be operated as single-ended with a positive ion source at the terminal to produce 1.4 MeV deuteron beams for the 9Be(d, n) reaction. Development and progress have been made in the areas of mechanical, electromechanical and electronics components (structures, alternators, HV supplies, control systems, etc), ion sources, accelerator tubes, 3D electrostatic and selfconsistent beam transport simulations, high power neutron production targets.

Keywords: Electrostatic accelerators; Volume plasma sources; Neutron production, BNCT.

© 2014 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).

Peer-review under responsibility of the Organizing Committee of UCANS III and UCANS IV

Keywords: Electrostatic accelerators; Volume plasma sources; Neutron production, BNCT.

* Corresponding author.
E-mail address: kreiner@tandar.cnea.gov.ar
1. Introduction

We highlight some of the results of an ongoing program at the National Atomic Energy Commission (CNEA) in Argentina to develop low energy (0.2 to 2.8 MeV), high current (30-100 mA) proton and deuteron electrostatic accelerators for nuclear and medical purposes. Argentina has had, since the 1950s, a rather consistent policy regarding the development of an autonomous capacity in the field of nuclear power and reactor technology. As a logical consequence, in the last few years it was decided to follow a similar path as far as accelerator technology is concerned, given the possible future implications for the nuclear sector of accelerator-driven systems (ADS). A natural route is to start in the field of ADSs by developing an accelerator-based neutron source to eventually inject a subcritical assembly [1]. In addition, CNEA is heavily involved in Boron Neutron Capture Therapy (BNCT) and the presenting group has under its responsibility the development of accelerator technology for Accelerator-Based BNCT (AB-BNCT) and other applications [2]. This activity aims at developing: 1) Low-energy (200 keV) high-current (100 mA) deuteron accelerators for D(d,n) and T(d,n) for neutron production for various nuclear applications, among them the injection of a subcritical reactor. 2) The development of a 700 kV folded tandem for neutron production using the $^9$Be(d,n) reaction. 3) The development of a folded 1.2-1.4 MV tandem for epithermal neutron production through the $^7$Li(p, n) reaction. At the same time this machine can be operated as single-ended with a positive ion source at the terminal to produce 1.4 MeV deuteron beams for the $^9$Be(d, n) reaction. Development and progress have been made in the areas of mechanical, electromechanical and electronics components (structures, alternators, HV supplies, control systems, etc), ion sources, accelerator tubes, 3D electrostatic and selfconsistent beam transport simulations, high power neutron production targets.

2. 200 kV accelerator

The 200 keV deuteron accelerator is a single-ended electrostatic machine. Fig. 1 shows a picture of the assembled accelerator. It has a positive ion source at ground potential, a pre acceleration stage, two glass and metal tubes with electrostatic quadrupoles inside to guide the intense beam, and a high voltage dome at 200 kV. This accelerator is intended as a test bench for all components like electrostatic and mechanical structures, vacuum chambers, tubes, high voltage power supplies, cooled targets, etc., but also has a meaning in itself. This machine, using the Ti-D(d,n)$^3$He or Ti-T(d,n)$^4$He reactions, can be used as an intense neutron source (producing $1 \cdot 10^{13}$ and $10^{13}$ neutrons per sec and per 100 mA, respectively[2]). These significant fluxes, particularly those associated with 14 MeV neutrons form the T(d,n) reaction, can be used for different applications like injecting a subcritical assembly, or inducing radiation damage. Also the development of the Ti hydride targets is under way. Fig. 2 shows a closer view to the two glass-metal tubes developed in-house.

3. Ion source development

The ion source being developed is a volume plasma discharge and filament driven proton source. Fig. 3 shows a new test stand to develop and test the different ion sources being constructed. It comprises the plasma generator chamber, extraction electrodes, a short focusing and acceleration tube, and a Faraday cup. The test stand can operate up to 40 kV.

Fig. 4 shows an image of the proton beam (approximately 10 mA) taken through a vacuum window, visible due to the fluorescence induced in the residual hydrogen gas.
4. The higher energy accelerators

Fig. 5 shows two different versions of a folded Tandem (700 kV and 1.4 MV terminal voltage respectively). The primary power is generated by an electric motor installed at ground potential which drives a chain of insulating and rotating shafts which in turn drive alternators located at the different high-voltage levels. These alternators feed floated high-voltage power supplies connected in series which finally generate the total voltage of the dome and of the different levels. Within the dome there is in both cases a bending magnet and a charge exchange cell (gas stripper). These Tandems are designed to work in combination with negative ion sources installed at ground level. In this way the 700 kV Tandem may produce 1.4 MeV proton or deuteron beams and the 1.4 MV Tandem will be able to produce
2.8 MeV proton or deuteron beams. We may also envisage a single-ended version of these accelerators working with positive ion sources installed at the respective terminals. For instance the 1.4 MV- terminal machine may produce 1.4 MeV deuteron beams.

This last option may be used as a neutron producing machine in conjunction with the $^{9}$Be(d, n) reaction leading to a neutron production of $3 \cdot 10^{13}$ neutrons/s for a 100 mA beam. This may be a very attractive option for accelerator-based BNCT. On the other hand the 1.4 MV Tandem can be used in conjunction with the $^{7}$Li(p, n) reaction leading to a total yield of $10^{14}$ neutrons/s for a 100 mA beam [3]. This intensity is more than enough to carry out a single session high-quality BNCT treatment.

Fig. 6 shows a view of part of the mechanical structure of the 600 kV terminal machine. One sees the electric driving motor at the bottom of the machine. An alternator is mounted at the approximately 200 kV level. The different high voltage levels are separated by insulating posts. 100 kV, 60 mA high-voltage power supplies have been
Fig. 5. Two different versions of a folded Tandem (700 kV and 1.4 MV in the terminal respectively).

Fig. 6. Mechanical structure of the 600 kV terminal machine. An alternator is mounted at the 200 kV level.

developed in-house and are almost ready.
5. Summary and conclusions

A program to develop low energy (0.2 to 2.8 MeV), high current (30-100 mA) proton and deuteron electrostatic accelerators is under way at the Argentine Atomic Energy Commission. The aim is to develop technology to fabricate intense accelerator-based neutron sources, based on the D(d,n), T(d,n), $^9$Be(d,n) and $^7$Li(p,n) reactions, to promote all kinds of applications, both in the nuclear as well as in the medical sector. The main medical application is accelerator-based BNCT.

References


V.N. Kononov et al., 2006, Accelerator-based fast neutron sources for neutron therapy, Nuclear Instruments and methods A 525-531