ACCELERATOR BASED NEUTRON SOURCE FOR BORON NEUTRON CAPTURE THERAPY AND OTHER APPLICATIONS

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A neutron source comprises an original design tandem accelerator, solid lithium target, a neutron beam shaping assembly, and is placed in two bunkers as shown in Fig. 1. The facility has the ability to place a lithium neutron producing target in 5 positions; in Fig. 1, they are marked as positions *A*, *B*, *C*, *D*, *E*.

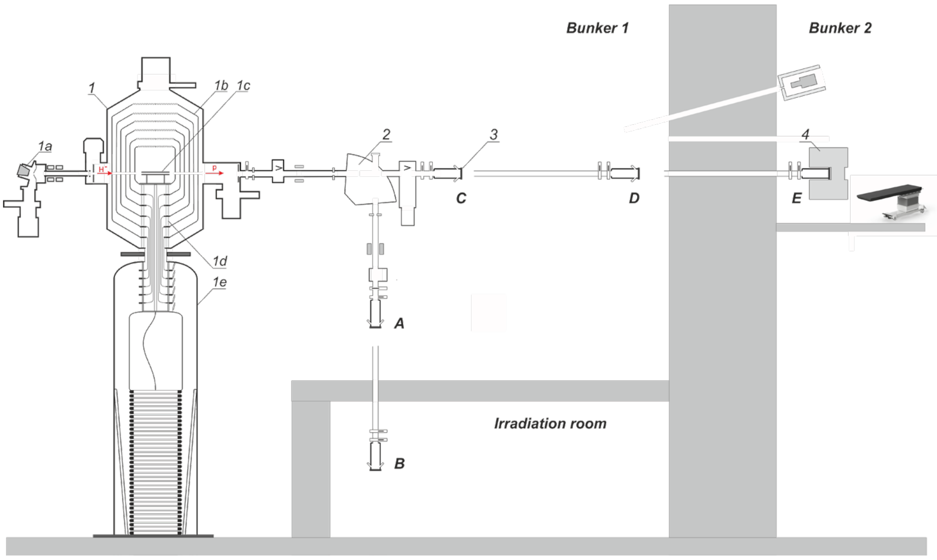

FIG. 1. Layout of the experimental facility: 1 – vacuum-insulated tandem accelerator (1a – negative ion source, 1b – intermediate- and high-voltage electrodes, 1c – gas stripper, 1d – feedthrough insulator, 1e – high-voltage power supply), 2 – bending magnet, 3 – lithium target, 4 – beam-shaping assembly. A, B, C, D, E – lithium target placement positions.

In order to generate a high-current, low-energy proton beam, a DC tandem accelerator is used. The BINP tandem accelerator, which was named as Vacuum-Insulated Tandem Accelerator (VITA), has a specific design that does not involve accelerating tubes, unlike conventional tandem accelerators. Instead of those, the nested intermediate electrodes (*1b*) fixed at a feedthrough insulator (*1d*) is used, as shown in Fig. 1. The advantage of such an arrangement is moving ceramic parts of the feedthrough insulator far enough from the ion beam, thus increasing the high-voltage strength of the accelerating gaps given high ion beam current. A consequence of this design was also a fast rate of ion acceleration – up to 25 keV/cm. The proton beam energy can be varied within a range of 0.6–2.3 MeV, keeping a high-energy stability of 0.1%. The beam current can also be varied in a wide range (from 1 pA to 10 mA) with high current stability (0.4%). The tandem accelerator is also capable of generating a deuteron beam with similar characteristics. The proton beam was used to study the radiation blistering of metals [1], to study the effect of blistering on the neutron yield from a lithium layer deposited on a metal [2], and is planned to be used for in-depth investigation of the promising $^{11}B(p,\alpha)\alpha\alpha$ neutronless fusion reaction.

Lithium target 10 cm in diameter has three layers: a thin layer of pure lithium to generate neutrons in $^{7}Li(p,n)^{7}Be$ or $^{7}Li(d,n)$ reactions; a thin layer of material totally resistant to radiation blistering; and a thin copper substrate for efficient heat removal. This target provides a stable neutron yield for a long time with an acceptably low level of contamination of the beam transport path by the inevitably formed radioactive isotope beryllium-7.

The facility is capable of producing:

— epithermal neutrons for boron neutron capture therapy (BNCT) [3] using magnesium fluoride moderator
— cold neutrons for neutron diffraction using heavy water ice;
— thermal neutrons for BNCT developing [4] and for measuring hazardous impurities in ITER materials [5] using plexiglas moderator
— monoenergetic neutrons for calibrating a dark matter detector and for boron imaging by prompt γ-ray spectroscopy using kinematic collimation
— fast neutrons in $^{7}Li(d,n)$ reaction [6] for radiation testing of materials developed for ITER and CERN
— 478 keV photons in $^{7}Li(p,p'\gamma)^{7}Li$ reaction [7] and 511 keV photons in $^{19}F(p,\alpha e^{+}e^{-})^{16}O$ reaction for *in situ* measuring the lithium layer thickness [8] and for determining the doses of high-LET radiation [9]
— α-particles in $^{7}Li(p,\alpha)\alpha$ and $^{11}B(p,\alpha)\alpha\alpha$ reactions
— positrons in $^{19}F(p,\alpha e^{+}e^{-})^{16}O$ reaction.

This neutron source is considered as one of the most attractive sources of neutrons for BNCT in an oncological clinic. The first facility was installed in a clinic in Xiamen (China), in one of the first six BNCT clinics in the world. The manufacture of two more neutron sources began this year: for National Oncological Hadron Therapy Center (CNAO) in Pavia, Italy, and for National Medical Research Center of Oncology in Moscow, Russia.

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