Accelerator based Neutron Source VITA for BNCT and other applications

Sergey TASKAEV
Budker Institute of Nuclear Physics, Novosibirsk State University
Novosibirsk, Russian Federation
Email: taskaev@inp.nsk.su

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*.

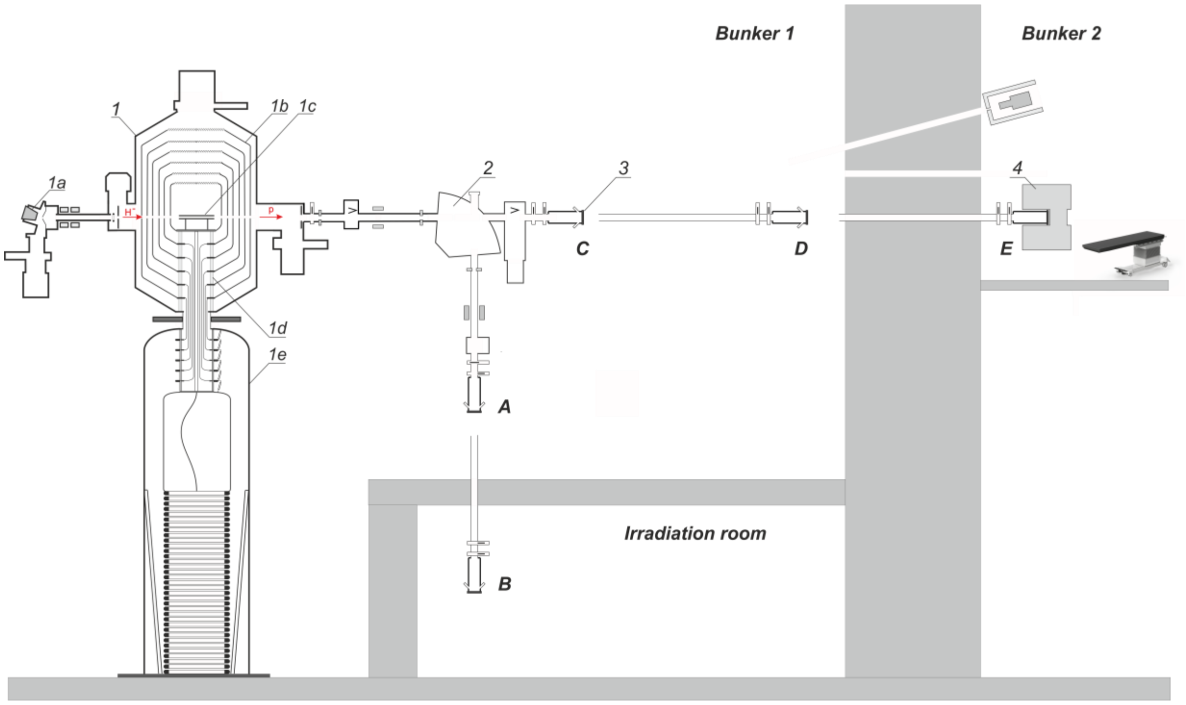

FIG. 1. Layout of the experimental facility: 1 – vacuum-insulated tandem accelerator (1a – negative ion source, 1b – intermediate- and high-voltage electrodes, 1c – gas stripper, 1d – feedthrough insulator, 1e – high-voltage power supply), 2 – bending magnet, 3 – lithium target, 4 – beam-shaping assembly. 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. 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. At present, the facility provides the production of protons or deuterons, the formation of neutron fluxes of almost any energy range: cold, thermal, epithermal, over-epithermal, monoenergetic or fast, as well as the generation of 478 keV, 511 keV or 9.17 MeV photons, α-particles and positrons.

The facility is used for the development of the boron neutron capture therapy (BNCT) technique [1-4] up to treat large pets with spontaneous tumors [5], for *in situ* observations of blistering of a metal irradiated with protons [6, 7], for measuring the cross section of nuclear reactions [8-10], for measuring hazardous impurities in ITER materials [11], for radiation testing of promising materials for ITER and CERN [12], for testing new boron delivery drugs [13-17], for developing new techniques [18, 19], and for other applications.

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.

The report presents and discusses the design of the facility, its features and parameters, and the results of studies carried out using the facility.

This research was supported by Russian Science Foundation, grant No. 19-72-30005.

References

[1] TASKAEV, S., *et al*. Biology 10 (2021) 350.
[2] SATO, E., *et al.* J. Rad. Res. 50 (2018) 101.
[3] ZAVJALOV, E., *et al.* Int. J. Radiat. Biology 96 (2020) 868.
[4] KANYGIN, V., *et al.* Biology. 2021. V. 10. 1124.
[5] KANYGIN, V., *et al.* Biology 11 (2022) 138.
[6] BADRUTDINOV, A. *et al*. Metals 7 (2017) 558.
[7] BYKOV, T., *et al*. NIM B 481 (2020) 62-81.
[8] TASKAEV, S., *et al*. NIM B 502 (2021) 85-94.
[9] TASKAEV, S. *et al*. NIM B 525 (2022) 55-61.
[10] BIKCHURINA, M., *et al.* Biology 10 (2021) 824.
[11] SHOSHIN, A., *et al.* Fusion Eng. Des. 178 (2022) 113114.
[12] KASATOV, D., *et al*. Instrum. Exp. Tech. 63 (2020) 611–615.
[13] ZABORONOK, A., *et al*. Pharmaceutics 13 (2021) 1490.
[14] AIYYZHY, K., *et al.* Laser Physics Letters 19 (2022) 066002.
[15] ZABORONOK, A., *et al*. Pharmaceutics 14 (2022) 761.
[16] POPOVA, T., *et al*. Molecules 26 (2021) 6537.
[17] VOROBYEVA, M., *et al.* Intern. J. Molecular Sciences 22 (2021) 7326.
[18] KASATOV, D., *et al*. JINST 15 (2020) P10006.
[19] DYMOVA, M., *et al*. Radiat. Res. 196 (2021) 192-196.