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Design of an epithermal column for BNCT based on D–D fusion neutron facility

E. Durisi[a,b,c,*], A. Zanini[c], C. Manfredotti[b,c], F. Palamara[a], M. Sarotto[d], L. Visca[b,c], U. Nastasi[a]

[a] *S. Giovanni Battista Hospital, Via Cavour 31, 10123 Turin, Italy*
[b] *Experimental Physics Department, University of Turin, Via P. Giuria 1, 10125 Turin, Italy*
[c] *INFN, Section of Turin, Via P. Giuria 1, 10125 Turin, Italy*
[d] *ENEA, Via Martiri di Monte Sole 4, 40129 Bologna, Italy*

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Abstract

Boron Neutron Capture Therapy (BNCT) is currently performed on patients at nuclear reactors. At the same time the international BNCT community is engaged in the development of alternative facilities for in-hospital treatments. This paper investigates the potential of a novel high-output D–D neutron generator, developed at Lawrence Berkeley National Laboratory (CA, USA), for BNCT. The simulation code MCNP-4C is used to realize an accurate study of the epithermal column in view of the treatment of deep tumours. Different materials and Beam Shaping Assemblies (BSA) are investigated and an optimized configuration is proposed. The neutron beam quality is defined by the standard free beam parameters, calculated averaging over the collimator aperture. The results are discussed and compared with the performances of other facilities.

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Keywords: Neutron source; D–D fusion reaction; MCNP; BNCT; Epithermal column

1. Introduction

Boron Neutron Capture Therapy (BNCT) is a binary radiation therapeutic modality for cancer treatment. It exploits the selective deposition in tumour cells of boron carriers, BPA (boronophenylalanine) and BSH (sulfhydryl borane) [1], enriched with ^{10}B isotope, and the high thermal neutron capture cross-section of ^{10}B (~3838 barn). When a high boron concentration ratio between tumour and healthy tissue is reached, the patient is irradiated with low energy neutrons (thermal/epithermal). Thermal neutrons are captured by ^{10}B and the excited nucleus breaks into two high LET (Linear Energy Transfer) particles: α and ^{7}Li recoil nucleus. The emitted particles have a short range in tissue ($<10\,\mu$m) and allow localized energy release in the tumour.

At present, BNCT is performed only at nuclear reactors, the unique facilities able to provide an intense epithermal ($0.4\,\mathrm{eV}<E_{\mathrm{epith\,n}}<10\,\mathrm{keV}$) and/or thermal ($E_{\mathrm{thermal\,n}}<0.4\,\mathrm{eV}$) fluence rate to treat deep and/or shallow tumours. The treated pathologies are malignant brain tumours (glioblastoma multiforme), head and neck cancer [2], malignant (cutaneous and cerebral) melanoma and recently liver cancer [3]. The promising results increased the interest in BNCT and encouraged the development of alternative neutron sources more suitable for in-hospital installation and of higher social acceptability than reactors. These sources could be operated in clinical environment, satisfy the clinical requests and increase the number of treated patients.

*Corresponding author. Experimental Physics Department, University of Turin, Via P. Giuria 1, 10125 Turin, Italy. Tel.: +39 0116707371; fax: +39 0116707378.
E-mail address: durisi@to.infn.it (E. Durisi).

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